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In 2020, NASA celebrated the 30th anniversary of the Hubble Space Telescope, which has provided unprecedented views of the universe and spectacular images. Paul Morris edited and produced an hour-long documentary about HST, which aired on NASA TV on April 24th, the date of its initial launch. The video is available to view on hulu and is available here: “NASA’s Incredible Discovery Machine: The Story of the Hubble Space Telescope” [https://www.youtube.com/watch?v=Lo43Gq_Xe1M](https://www.youtube.com/watch?v=Lo43Gq_Xe1M) (Provided by P. Morris.)
Joy Ng was a video producer of “Why NASA is sending rockets into Earth’s leaky atmosphere,” which discusses the phenomenon that occurs in the Arctic:

“In the tiny Arctic town of Ny-Ålesund, where polar bears outnumber people, winter means three months without sunlight. The unending darkness is ideal for those who seek a strange breed of northern lights, normally obscured by daylight. When these unusual auroras shine, Earth’s atmosphere leaks into space. NASA scientists traveled to Ny-Ålesund to launch rockets through these auroras and witness oxygen particles right in the middle of their escape. Piercing these fleeting auroras, some 300 miles high, would require strategy, patience — and a fair bit of luck. This was NASA’s VISIONS-2 mission, and this is their story. VISIONS-2 was just the first of many. Over the coming months, rocket teams from all over the world will launch rockets into this region as part of the Grand Challenge Initiative—Cusp, an international collaboration to study the mysteries of the polar atmosphere.”

The Goddard YouTube version of this video, “Launching Rockets Through the Leak in Earth’s Atmosphere” at https://youtu.be/bSt5peltUBo, was announced as a finalist in the Professional Documentary category at the Raw Science Film Festival.

Image from “Why NASA is sending rockets into Earth’s leaky atmosphere.” (Provided by J. Ng.)
This report is the ninth NASA Goddard Earth Sciences, Technology and Research (GESTAR) cooperative agreement annual Report, encompassing the period 11 May 2019 - 10 May 2020. GESTAR continues to be led by the Universities Space Research Association (USRA), with Morgan State University (MSU), the Global Science and Technology (GST), the I.M. Systems Group (IMSG), and The Johns Hopkins University (JHU) as current partners. All members of the team continue to contribute very effectively to the success of the NASA mission.

This report summarizes the accomplishments and activities of GESTAR Earth and Planetary scientists, model and algorithm developers, engineers, media specialists, video producers, science data visualizers, conceptual animators. Contributions by students, visitors and staff are also included. The research by GESTAR scientists spans a very broad range of fields, predominantly within the Earth Sciences Division, encompassing global modeling and data assimilation, mesoscale meteorology, climate and radiation, atmospheric chemistry and dynamics, cryospheric sciences, ocean ecology, hydrology and land surface processes, biosphere sciences and ecological modeling, geodesy and geophysics. Several GESTAR scientists also contribute to the Solar System Exploration Division, particularly in the fields of planetary atmospheres modeling and Mars exploration. The centrality of remotely sensed NASA data in all these fields of research, and the focus on the success of NASA’s mission, is a crucial aspect of all GESTAR activities. In addition, part of the GESTAR effort focuses on the dissemination of NASA achievements through high-level videos, documentaries, and social media content.

Aside from the research and communication accomplishments, this report contains sections pertaining to educational activities, awards, and public outreach. A separate Appendices report contains publications, presentations, proposals and grants.

This year, as in previous years, and in spite of the hardship caused by the pandemic, GESTAR has continued to strive for excellence, has kept producing outstanding achievements, and has dedicated itself to NASA’s goal of expanding the horizons of human knowledge.

Oreste Reale

Director
Founded in 1969, Universities Space Research Association (USRA) is an independent nonprofit research corporation that conducts basic and applied research and operates programs and national facilities for government and industry, many of which are in support of NASA. USRA currently manages 20 programs and facilities that employ more than 400 scientific, technical, and professional staff. With 105 university members, USRA provides a unique and special value that other research organizations do not. Only PhD-granting universities in Earth and space sciences with demonstrated outstanding research abilities are eligible for membership in USRA. USRA’s mission is to advance Earth and space sciences and exploration through innovative research, technology, and educational programs, and to develop and operate premier facilities and programs by involving universities, the private sector, and governments.

Morgan State University (MSU), founded in 1867, is one of the nation’s premier Historically Black Colleges and Universities (HBCUs). The University offers a comprehensive program of studies at both the undergraduate and graduate levels. Morgan State has continuously served the community with distinction while meeting the educational needs of an increasingly diverse society. Designated as Maryland’s Public Urban University, MSU will continue its prominence in Maryland’s educational future. In many fields, particularly in engineering and the sciences, MSU accounts for large percentages of degrees received by African Americans from Maryland institutions. At the graduate level, it awards doctoral and master’s degrees in several selected fields. The University has made a major commitment to academic excellence, investing substantial resources to enhance its research infrastructure, and stimulate research development in a broad range of disciplines, especially STEM.

I.M. Systems Group (IMSG) has over 15 years of providing environmental, scientific, technical support to the US government, as well as environmental services to government agencies in Africa and Asia. Over 60% of its workforce has advanced degrees with over 100 PhD researchers. IMSG is NOAA’s largest support service, with its largest concentration of researchers and support scientists in the Satellite Applications Research Center and the NWS Environmental Modeling Center.

Global Science & Technology, Inc. (GST) was founded by three business associates; two of the founders remain with the company today. They believed that hiring the right people into a nurturing, collaborative environment would produce a cutting-edge, innovative, and profitable company. GST provides superior service in the fields of science, engineering, Information Technology (IT), and technical support to worldwide government, industry, and academic clients. GST has built a highly specified workforce that includes experts in these key domains. From projects such as instrument engineering for the Hubble Space Telescope program, to meteorology, software engineering, and satellite communications—GST is committed to technical excellence and customer satisfaction.

Founded in 1876 as the first research university in the United States, The Johns Hopkins University (JHU) is one of the leading research institutions in the nation. JHU is the home of the prestigious Department of Earth and Planetary Sciences. A major focus within this department is global change science, with active research groups in atmospheric, oceanic, and hydrospheric sciences as well as planetary geodynamics. The department maintains state-of-the-art design and engineering facilities, as well as laboratories for high performance computing and large-scale data analysis that are also being used for Earth system science.
CODE 555: MICROWAVE INSTRUMENT TECHNOLOGY BRANCH

NASA’s Soil Moisture Active and Passive (SMAP) Mission is the first of a series of Earth Science Decadal Survey missions which was launched January 31, 2015. The mission is providing global measurements of soil moisture and freeze/thaw state using L-band radiometry.

Dr. Priscilla Mohammed (sponsor: J. Piepmeier) has worked with a collaborative team at GSFC to develop the L1B TB algorithm which converts radiometer data into calibrated estimates of brightness temperature. Work includes research and development of radio frequency (RFI) detection and removal algorithms and prototype instrument algorithm code for the L1B TB algorithm, which is part of ground processing.

Over the past year, radiometer data monitoring occurred by processing and observing instrument data from L1A radiometer and L1B_TB products. Automated reports were generated weekly and monitored to ensure normal instrument performance. Instrument performance was also reported at the annual SMAP engineering review held by the Jet Propulsion Laboratory on February 11, 2020. The SMAP microwave radiometer was shown to be stable with good performance and no concerns were reported over the remaining extended mission.

While the SMAP radiometer ground processing algorithm includes RFI detection and mitigation, high-level RFI sources cause the algorithm to flag and remove significant portions of the spectrum, thus increasing the noise equivalent delta temperature (or standard deviation of the measurement of interest). RFI reports were created using SMAP data and submitted to the NASA spectrum office; in turn, the spectrum office submits these reports to the necessary administrations with the hope that the offending countries will help eliminate illegal transmitters at L-band. This will help to improve the electromagnetic environment within the protected Earth Exploration Satellite Service passive frequency allocation (1400-1427 MHz). Over the past year, reports have been submitted for the following countries: Croatia, Syria, Albania, Indonesia, South Korea, Sudan, Pakistan, United Arab Emirates and Poland, and a report was completed for sources within the U.S. and provided to the FCC for further investigation.

Last summer, Dr. Mohammed attended the International Geoscience and Remote Sensing Symposium (IGARSS) in Yokohama, Japan and presented a poster on SMAP RFI Change Detection. The radiometer was designed to provide detection and filtering of RFI in order to meet error budget requirements. A time-series algorithm was developed to monitor, detect and report the changing environment with the objective of detecting new RFI sources as well as existing persistent sources. The algorithm uses information from the SMAP L1B_TB quality flag, which indicates the quality of brightness temperatures based on various conditions. This information was used to detect and track high-level RFI sources over time. The results of the algorithm showed a downward trend of RFI over China (see Fig. 2). Global results indicate transient RFI sources occur over the world while persistent, high level sources are mostly concentrated in Europe and Asia.

In the coming year, radiometer data monitoring will continue, and automated reports will be generated and monitored to ensure normal instrument performance. Note that even though the current RFI detection and mitigation algorithms do a good job of reducing the impact of RFI on SMAP radiometer data, residual RFI remains in the data over some parts of the globe even after the quality flags have been applied. A deep learning algorithm will be investigated to be used as an RFI detector with...
the intention that it will detect RFI not detected by the current detectors implemented in the ground processing software.

Dr. Jinzheng Peng (sponsor: J. Piepmeier) is part of the collaborative team on NASA’s Soil Moisture Active/Passive (SMAP) mission. In addition to researching and developing pre-launch and post-launch calibration theoretical bases, plans and activities, he is responsible for developing the SMAP L1B correction algorithms, instrument calibration, calibration/validation tools, the antenna temperature (TA) forward modeling for the Correlator Array-Fed Microwave Radiometer (CAFR) Component Technologies, and data processing of the EXRAD/CRS/HiWRAP radars for the IMPACTS campaign.

The SMAP L1B correction algorithms obtain the Earth surface brightness temperature (TB) from the calibrated and RFI-free antenna temperature. Unwanted emissions in the antenna sidelobe from the Sun, the Moon, the galaxy, the atmosphere, and Earth need to be removed from the radiometer measurements, and the effects of the atmospheric attenuation and Faraday rotations to the radiometer measurement need to be characterized and corrected. The correction algorithm has been successfully implemented into the SMAP L1B production code by the SMAP Science Data System (SDS) team for the radiometer L1B_TB data product. The calibration for a microwave remote sensing instrument after launch is to calibrate instrument parameter(s) using external known targets; thus, the bias in the instrument measurement could be reduced or eliminated over the required dynamic range. The latest L1B_TB data product (version 4) and its assessment report were released to public in June 2018. The radiometer data have been used by science activities not only on the Earth’s surface soil moisture and freeze/thaw status (SMAP’s primary mission) but also on the sea surface salinity (SSS) retrieval. In the past year, Dr. Peng upgraded the calibration algorithm for the SMAP radiometer in order to reduce uncertainty during eclipse seasons for ocean science activities and to support soil moisture data product to reduce bias in the SMAP Cal/Val sites. Multiple calibration approaches with different external calibration targets used had been tested and compared. These test results were presented at the SMAP Science Team Meeting in November 2019. The radiometer L1B data product has been evaluated by the soil moisture science teams and is planned to be released to the public in August 2020. In addition, the upgraded calibration activities were presented at the 2019 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) in summer 2019; the final calibration algorithms and their performance will be presented at IGARSS 2020 in July.

As a co-author, Dr. Peng had two SMAP-related peer-reviewed journal papers published in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (JSTARS) in November 2019 and in Remote Sensing of Environment in March 2020, respectively. As a Co-I, Dr. Peng contributes to the calibration portion of the proposal titled “SMAP Radiometer Calibration and Radio Frequency Interference Mitigation” in response to the NASA ROSES 2019 call “The Soil Moisture Active-Passive Mission Science Team” solicitation, which was submitted in July 2019. He also co-authored a peer-reviewed journal paper published in 2020 for the CubeRRT radiometer he had worked on.

The CAFR is an awarded NASA ACT (Advanced Component Technology) project that began in 2017. The goal is to provide multiband passive microwave imagery in X to W band with adequate spatial resolution by using a multi-band correlator array feeding a large reflector antenna. The key development is a broadband line array covering 10-90 GHz appropriate for illuminating a large deployable reflector. Its performance trade-study and design will be evaluated by the TA forward simulator. Dr. Peng has used the CAFR’s TA forward simulator that he developed to evaluate the CAFR performance with the 2-m

Figure 2: This plot shows the time series of the average percentage of footprints flagged by the quality flag for the RFI sources that were reported in China, and shows a decreasing trend. Of note is the cyclic pattern of RFI with respect to time of year. The reasons for the trends have not been identified. (Provided by P. Mohammed.)
diameter reflector (see Figure 1). The simulated result has been presented in the CAFR Year 2 final review.

The Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) campaign aims to improve remote sensing and forecasting of snowfall. In the first quarter of 2020, a field campaign flew a complementary suite of remote sensing and in-situ instruments for three 6-week deployments on the ER-2 and P-3 aircraft. The instruments include three of GSFC’s radars: HIWRAP (High Altitude Imaging Wind and Rain Airborne Profiler); CRS (Cloud Radar System); and EXRAD (ER-2 Doppler Radar). The radar data process will generate three data products (level 0, level 1A and level 1B). The radar data process software is under development to improve data quality for current and future campaigns. In 2019, Dr. Peng participated in the IMPACTS field campaign in Savannah, GA. He has completed the development of Level 0 data processing software for all of the three radar and generated level 0 data. He also completed the modification of the L1A data processing software for CRS radar and the nadir-looking portion of EXRAD radar, and he generated the corresponding L1A data products for the IMPACTS field campaign.

The SMAP radiometer is in its six-year extension mission. In the coming year, Dr. Peng’s responsibilities will include the SMAP radiometer calibration/validation for monitoring data quality and instrument calibration drift, and research on improving the radiometer performance. He plans to submit for publication a manuscript that describes the latest SMAP radiometer calibration approaches/performance. Work will continue with CAFR TA forward simulation, EXRAD/CRS/HIWRAP radars’ data analysis, processing, and software development. In addition, he will begin work on the COWVR (Compact Ocean Wind Vector Radiometer) pre-launch calibration/research activities.

**CODE 610: EARTH SCIENCES DIVISION**

At the U.S. Global Change Research Program’s National Coordinating Office Dr. Fredric Lipschultz (sponsor: J. Irons) broadly coordinates federal climate activities, especially sustained climate assessment activities, that support decision making. At USGCRP, he reports directly to the USGCRP director and interacts with other USGCRP leadership to meet broader goals of the program. In addition, with his expertise, he advises on international and domestic assessments and adaptation activities, ensuring that NASA’s capabilities, activities and interests are represented.

Dr. Lipschultz continued to broadly coordinate federal activities supporting national and regional climate science needs and activities, specifically those that guided the development of USGCRP’s Sustained Assessment process (including both the quadrennial National Climate Assessment report required by statute and any intermediate products) and especially those emphasizing regional issues, impacts, and responses. He is now the coordinator for USGCRP’s Coastal focus area, one of three priority areas over the next year, that brings together a broad swath of federal interests and activities in the coastal zone.

Starting in the fall of 2019, assessment activities at USGCRP shifted towards preparing for the 5th National Climate Assessment, which is due in 2023. Dr. Lipschultz has updated many of the NCA guidance documents that he previously authored for NCA3 and NCA4, and has created new ones based on feedback from NCA authors. After review by OSTP and the USGCRP agencies, these documents will form the basis for the author onboarding process in late 2020. As part of this process, he participates in the deliberations of the NCA5 Federal Steering Committee that guides the core NCA functions.

Dr. Lipschultz continued working to foster the federal provision of climate data and improve coordination among federal agency efforts, especially in areas such as climate adaptation and scenario development. As leader of the interagency team...
Dr. Lipschultz continues to serve as the only non-Canadian member of the advisory committee for the Canadian Climate Assessment, bringing his deep understanding of climate assessment to this role as they work to develop reports and websites based on the U.S. experience. The first elements of this report are due in summer 2020. He also is engaged with a Department of State effort, the Caribbean Resilience Partnership, which is charged by Congress to develop partnerships in the region to support increased resilience to climate-related impacts. The original two-day meeting was redesigned as a full virtual series of two-hour meetings over April 28-30 and May 6.

Over the next year, Dr. Lipschultz will continue to focus on National Climate Assessment activities as USGCRP’s efforts ramp up with author selection and a suite of regional engagement workshops across the country. For sustained assessment, he will continue his ongoing outreach efforts by fostering state and international assessments, and working to enhance provision of climate data with the release of the CMIP6 data archive. He will continue to lead the Climate Explorer task team for the CRT and lead strategic development of USGCRP’s efforts to promote adaptation and resilience. He will continue his engagement with the Canadian government and will be working with a nation-wide team to coordinate state climate assessments and identify best practices.

Ms. Abigail Seadler (sponsor: S. Platnick) supports Jack Kaye and the NASA Earth Science Research & Analysis Program in developing the Climate Explorer tool, a central component of NOAA’s Climate Resilience Toolkit (CRT), he has continued to play a crucial role that led to a major update in the fall of 2019. Dr. Lipschultz was first author on a paper in BAMS describing this release (see https://doi.org/10.1175/BAMS-D-18-0298.1). Further, he actively participated in the planning committee with colleagues from NOAA and several civil society groups that planned the 2nd Resilience Ecosystem Workshop. This nationwide effort seeks to build an open and inclusive community of public and private entities that are working individually and collectively to sustain and evolve science-based tools, information, and expertise to proactively build resilience to climate-related impacts. The original two-day meeting was redesigned as a full virtual series of two-hour meetings over April 28-30 and May 6.

One of her projects from this last year was leading three separate beta testing phases of the Earth Science Research Results Portal from August 2019 through April 2020 (Aug 1 – Sept 5; Oct 21 – Nov 22; and Feb 10 – Apr 3). These beta testing phases provided opportunities to obtain valuable user feedback and achieve buy-in from different user groups, including scientists, program managers, and communicators, for the Portal. Ms. Seadler is now working to create protocols and best practices based on feedback from all three phases of beta testing, which will provide reporting guidelines for the final site. In the coming year, she will work with stakeholders to improve the Portal and move it from beta to a final website.

Apart from the portal beta testing, Ms. Seadler also created new relationships and began pursuing strategic partnerships to strengthen the Portal with colleagues from NASA’s Science and Technical Information (STI) Program, the Earth Science Communications Content Registry (ESCCOR), and a Marshall Space Flight Center (MSFC) Deep Learning group led by Dr. Tsengdar Lee (NASA HQ). The STI partnership could aid in removing duplication of reporting efforts from NASA Earth scientists; the ESCCOR partnership could help draw connections between NASA’s external communications and research collected within the Portal; and, the Deep Learning partnership could improve the collection of information from existing publications databases, as well as with the recording of new information within the Portal, using the group’s algorithms for inputting keywords and other information fields. Her next step to more effectively collect and disseminate research results is to focus on streamlining the cataloging of research awards. She has begun contacting counterparts throughout the Science Mission Directorate (SMD) to benchmark best practices, and is investigating how information from awards is currently stored within NSPIRES, NSSC, and Raptor. Compiling this information in a more integrated and accessible way will allow NASA’s Earth Science Division (ESD) to tell more integrated stories.
Ms. Seadler was tasked with identifying and coordinating content for the 2020 Earth Science Week Toolkit. Earth Science Week is an annual event targeting K-12 students and educators during the second week in October. For 2020, the theme is “Earth Materials in Our Lives.” She worked with colleagues from EO Kids and Space Place to identify three pieces of water-related content to contribute to the toolkits. She will work with these groups to secure 10,000 copies of each and provide them to the American Geosciences Institute for distribution.

In 2020, ESD Acting Division Director Sandra Cauffman asked Ms. Seadler to coordinate ESD’s communications response to COVID-19. This involves maintaining the master list for internal awareness on all new research, data, activities, and events within ESD related to COVID-19; keeping ESD leadership aware of all these activities; and coordinating with existing ESD communicators to ensure proper up-and-out external communication of these activities. She provides daily updates on ESD’s COVID-19-related activities to ESD leadership and communicators, and she holds weekly communications meetings to determine which content to feature and to coordinate with the Office of Communication. She also leads the internal ESD review of all NASA features and communication related to COVID-19.

CODE 610.1: GLOBAL MODELING AND ASSIMILATION OFFICE (GMAO)

Dr. Niama Boukachaba (sponsor: M. Bosilovich) works on the evaluation of gridded MERRA-2 data assimilation innovations (Gridded Innovations and Observations or GIO), and associated datasets such as OmF and OmA, for weather and climate case studies. This year, Dr. Boukachaba has been exploring the MERRA-2 GIO radiance data, especially for the hyperspectral infrared sounders (e.g., AIRS, IASI and CrIS). The analyses include assessing key statistics derived from the data assimilation, including the innovations (OmB), the analysis increments (OmA), the forecast departure (OmF), as well as the bias corrections. She generated statistics tables, scatterplots and geographically distributed performance maps for several actively assimilated sensor (AIRS, CrIs and IASI) channels in MERRA-2 (based on McCarty et al. (2016)).

Dr. Boukachaba is currently working on a first author manuscript titled “Development of Gridded Innovations and Observations Data for Reanalysis Diagnostics,” which describes the concept of a gridded data collection based on the observations assimilated during the MERRA-2 reanalysis. This data, called the MERRA-2 GIO, will evaluate, validate and deliver the assimilated observations along the key statistics delivered from the data assimilation, including the forecast departure, RMS of the forecast departure, number of data counts as well as bias correction for satellites radiances. The GIO data will be binned to a grid similar as MERRA-2 and saved in NetCDF format. Dr. Boukachaba is also closely working with Robert A. Lucchesi to adapt the MERRA-2 GIO metadata to the NASA’s Goddard Earth Sciences Data and Information Services Center (GES DISC) requirements. The MERRA-2 GIO is providing long-time series of DA statistics and QC metrics allowing to the users to evaluate and validate the MERRA-2 reanalysis data. This particular data will be openly available to the users in near future at the NASA GES DISC. In April 2020, she presented this research at the GMAO Science Team. In the future, she plans to include other statistics to the MERRA-2 GIO data such as the Contextual Bias and the Effective Gain.

Dr. Niama Boukachaba, Dr. Manisha Ganeshan, and Dr. Erica McGrath-Spangler all work on and are supported by the NASA grant, “Using AIRS and CrIS data to understand processes affecting Tropical Cyclone structure in a global data assimilation and forecasting framework” (program manager: Dr. T. Lee; PI: Dr. Oreste Reale).

The work performed by Dr. Niama Boukachaba is focused on defining an optimal comprehensive cloud-clearing strategy for AIRS, CrIS and IASI with the ultimate goal of assimilating adaptively thinned cloud-cleared hyperspectral data into the NASA GEOS system. As a part of her research, Dr. Boukachaba worked on an efficient implementation of a standalone cloud-clearing algorithm. This was made completely independent from external dependencies and was then parallelized into the NASA Center for Climate Simulation (NCCS) to increase computational efficiency, decreasing the processing time from several days to few hours. The algorithm was designed to be a standalone tool in order to facilitate its porting to operational systems such as those of NOAA, ECMWF, etc. Dr. Boukachaba used two tools offered by the NCCS that enable users to execute a collection of independent tasks in parallel on multi-cores nodes called GNU Parallel and Portable Distributed Scripts (PoDS). By using those tools, she manipulated several AIRS granule files in few hours and without any interference between the files.

Dr. Boukachaba successfully ran several new GEOS test experiments to be more familiar with the GEOS modeling and data assimilation system, and she is currently running two
adaptive thinning experiments in the GEOS hybrid 4DEnVar data assimilation framework (5.17 version). Those experiments, CLD3 and CLD7, assimilate AIRS cloud-cleared radiances at a homogeneous thinning density of 300 km and 280 km, respectively. She is also testing a new configuration for the assimilation of CrIS CCR data downloaded from NASA Distributed Active Archive Centers (DAACs). The goal of those experiments is to investigate the optimal data density for the assimilation of AIRS and CrIS cloud-cleared radiances in the 4DEnVar framework. Dr. Boukachaba will also move all GEOS hybrid 4DEnVar experiments to advanced compute nodes as required by the NCCS. This year, Dr. Boukachaba was involved in three presentations, as a co-author, at the NASA Sounder Science Team Meeting, held in College Park, MD in September 2019.

In the coming year, Dr. Boukachaba plans to submit a first author manuscript, in which the cloud-clearing algorithm, as described in (Susskind et al. 2006), was implemented into the NASA GEOS system and made completely independent from external inputs and then parallelized for computational efficiency purposes and implemented in the NCCS. This paper provides examples of the assimilation of AIRS CCRs into the GEOS system in order to improve the representation of the global forecast skill and the simulation of tropical cyclones. Dr. Boukachaba also will work with others in preparing the Spring 2020 Virtual AIRS Science Team Sessions presentation “Advances towards an efficient multi-instrument assimilation of cloud-clear radiances in a global data assimilation and forecast framework.”

The work performed by Dr. Manisha Ganeshan is focused on carrying out numerical experiments and their analysis, investigating the impact of different strategies for assimilating hyperspectral infrared data on the analysis and forecast of Tropical Cyclones (TCs) and high-latitude convective systems in the NASA GEOS system. Dr. Ganeshan ran an adaptive thinning experiment using the GEOS 3DVAR (5.13 version) to investigate the impact of assimilating AIRS cloud-cleared radiances on the representation of a polar low (PL) that was observed in the Sea of Okhotsk to the north of Japan on 10th October 2014. The system is visible in MODIS and AMSU-B satellite imagery, and the 0600 UTC surface weather chart produced by the Japan Meteorological Agency (JMA). The new experiment, assimilating adaptively thinned AIRS cloud-cleared radiances with greater density in the vicinity of the polar low and lower density globally, produced a more intense storm with stronger low-level vorticity and wind speeds, lower sea-level pressure, greater vertical extent, and better alignment with upper level forcing, as well as a more compact warm core compared to the control experiment (RAD) that assimilated AIRS clear-sky radiances at homogenous density. The representation of the PL in the adaptive thinning experiment was also found to be superior when compared to the experiment assimilating AIRS cloud-cleared radiances at uniform density (CLD3). A paper detailing the results of this experiment and two other similar storms will be submitted this year.

Dr. Ganeshan also set up two new experiments for determining the optimum thinning density for assimilation of AIRS cloud-cleared radiances (CCRs) in the GEOS hybrid 4DEnVar modeling and data assimilation system (version 5.17). Both experiments are part of a set of Observing System Experiments (OSEs) to evaluate the impact of assimilating hyperspectral infrared CCRs on the global forecast skill and the representation of tropical cyclones in a 4DenVar framework. The first experiment, assimilating AIRS CCRs globally at 300 km x 300km density, was successfully completed, and Dr. Ganeshan has computed forecast statistics including global forecast skill, score cards, and the analyzed representation of hurricanes in this experiment. She is currently running another experiment assimilating AIRS CCRs at 240 km x 240 km global density. As part of this research, Dr. Ganeshan also helped Dr. Boukachaba run two similar experiments in the GEOS hybrid 4DEnVar framework. Dr. Ganeshan is running a third experiment in the GEOS hybrid 4DEnVar system assimilating CrIS CCRs obtained from NOAA Comprehensive Large Array-data Stewardship System (CLASS) at 300km x 300km global density in addition to assimilating AIRS CCRs at the same density. This is the first experiment assimilating hyperspectral infrared CCRs from multiple instruments, and the impact on global forecast skill and that of tropical cyclones will be evaluated as part of this research.

Dr. Ganeshan performed spectral decomposition using the parallelized 2D Hilbert Huang Transform (HHT) on output from the latest GEOS versions (GEOS x36 and x37). Specifically, HHT was used to compare horizontal winds and temperature fields at various atmospheric levels in the extratropics and tropics, with particular focus over the equatorial Pacific, Atlantic Ocean, and Indian Ocean. Dr. Ganeshan and Dr. McGrath-Spangler assisted Dr. Reale in the analysis and interpretation of the results. The differences between the spectra are found to be significant over the tropical oceans, with stronger diurnal convective activity observed in x36 compared to x37 version of the model. Dr. Ganeshan additionally used HHT for comparing the output of various model analyses produced from assimilating different types and configuration of AIRS data in the GEOS hybrid 4DEnVar system.
Dr. Ganeshan presented a talk titled “Continued research on the impact of assimilating AIRS cloud-cleared radiances on mesoscale warm-core cyclones outside the tropics” at the NASA Sounder Science Team Meeting (NSSTM) on in College Park, MD in September 2019. She also completed a related paper, which will be submitted this year. She was a co-author of two other talks at the NSSTM, one led by Dr. Reale and one led by Dr. McGrath-Spangler. Dr. Ganeshan is co-author on two additional manuscripts that are being finalized prior to submission: one led by Dr. McGrath-Spangler titled “Sensitivity of mid-latitude waves to Arctic temperature variations” and another led by Dr. Boukachaba titled “Implementation of a Cloud Clearing Algorithm into the NASA GEOS system: Application to the Atmospheric Infrared Sounder (AIRS).”

In the coming year, Dr. Ganeshan will complete running current ongoing experiments in the GEOS hybrid 4D-EnVar system. She is working on migrating all GEOS hybrid 4D-EnVar experiments to advanced compute nodes (SLES 12 SP3) available on the NCES platform. She will proceed to analyze the skill of the experiment assimilating multi-instrument (AIRS and CrIS) hyperspectral infrared CCRs, and design the set-up of new experiment utilizing guidance from the machine learning model output to prescribe the amount of hyperspectral infrared data for assimilation in the GEOS Hybrid 4D-EnVar system. Dr. Ganeshan will continue using the 2D HHT tool for performing model diagnostics and comparing the spectra associated with winds and temperature output from various GEOS Hybrid 4D-EnVar experiments.

The work performed by Dr. Erica McGrath-Spangler is focused on contributing to designing, conducting, and investigating numerical experiments focused on the impact of different hyperspectral infrared data types and assimilation strategies on the analysis and forecast of TCs in the NASA GEOS system. Dr. McGrath-Spangler developed the capability to assimilate locally generated and customized AIRS cloud-cleared radiances into the GEOS system. She generated AIRS cloud-cleared radiances from the level 1B radiances available from the Goddard Earth Sciences Data and Information Services Center (GES DISC). This was performed using code ported to NCES high end computing resources by former members of Dr. Joel Susskind’s (NASA GSFC) team and used results from the GEOS as the background for the computation. These radiances were assimilated in a GEOS experiment to assess the feasibility of using cloud-cleared radiances that have been locally generated and customized to model requirements. Preliminary results show an improved forecast skill and representation of tropical cyclones when compared to cloud-cleared AIRS radiances available from the GES DISC and to clear-sky radiances. Additionally, she worked with Drs. Karpowicz, Boukachaba, and Ganeshan to test the assimilation of CrIS cloud-cleared radiances that a NOAA team converted to the buf format, for ingestion into the GSI. As part of this effort, she hosted a meeting between members of this team, Drs Chris Barnet and Rebekah Esmaili from STC and Dr. Murty Divakarla from IMSG/NOAA.

Dr. McGrath-Spangler also developed the capability to adaptively assimilate hyperspectral infrared radiances in the hybrid 4-dimension Ensemble Variational (hybrid 4D-EnVar) data assimilation methodology in the GEOS DAS, similar to what she did previously in the 3-D variational methodology. She created a methodology to assimilate higher density hyperspectral infrared radiances according to a gridded mask and at a high temporal frequency. This mask can be determined by an artificial intelligence algorithm to automatically detect tropical cyclones from geostationary satellite images developed by a team at USRA RIACS. This allows a near real time ability to assimilate high-density hyperspectral IR radiances in areas of interest, identified by the AI algorithm, and lower density radiances in regions subject to a greater incidence of error correlation in violation of the assumptions of data assimilation. In the coming year, she will work with Drs. Akbari Asanjan (RIACS) and Drs. Ganeshan and Boukachaba to assimilate AIRS cloud-cleared radiances using adaptive thinning according to a mask, produced using artificial intelligence and geostationary data to identify the location and spatiotemporal extent of tropical cyclones.

Dr. McGrath-Spangler adapted the GEOS DAS to properly assimilate cloud-cleared hyperspectral infrared radiances from the Cross-track Infrared Sounder (CrIS) instrument. This involved adjusting the quality control employed by the system to evaluate the suitability of radiances for assimilation. She expects that the assimilation of cloud-cleared CrIS radiances will provide similar impressive results to the assimilation of cloud-cleared AIRS radiances, namely, an improved tropical cyclone representation with minimal global forecast skill impact or even a possible improvement, if assimilated at the appropriate density for a given environment.

Currently, Dr. McGrath-Spangler has two hybrid 4D-EnVar GEOS experiments running to test various assimilation strategies of AIRS data. The first assimilates the CCRs computed locally using GEOS as the background field in an effort to reduce issues of latency and external dependencies that have prohibited their use in an operational DAS previously. The results from this first attempt are promising, showing the potential to improve tropical
cyclone representation without significantly affecting forecast skill. The second assimilates AIRS CCRs using a thinning density of 340 km. This experiment, in conjunction with experiments previously run by her and Drs. Ganeshan and Boukachaba, is part of an effort to identify an optimal thinning density of AIRS CCRs in the hybrid 4DenVar context in preparation for experiments that will be run using adaptive thinning. These runs will include 80-day GEOS analyses, along with their associated forecasts and forecast statistics. In the coming year, she will complete several GEOS experiments, examining various thinning levels for the assimilation of AIRS cloud-cleared radiances in the GEOS hybrid 4DenVar system. After an optimal thinning level is identified, an experiment testing adaptive thinning will be performed to test the theory that AIRS cloud-cleared radiances, if assimilated at the proper density, can improve TC representation and global forecast skill.

This year, Dr. McGrath-Spangler presented at the 17th Joint Center for Satellite Data Assimilation (JCSDA) Technical Review Meeting held at NASA Headquarters, Washington, DC, in May 2019. As a result of this presentation, discussions to implement the adaptive thinning methodology into the new Joint Effort for Data assimilation Integration (JEDI) framework are underway. This will enable a seamless continuation of forward progress once the GEOS system transitions to JEDI. As lead author and co-author, she was involved with presentations at the NASA Sounder Science Team Meeting (NSSTM), held in College Park, MD in September 2019. She is also part of a team working on a paper that shows the assimilation of aggressively thinned cloud-cleared AIRS radiances results in a decrease in the lower-tropospheric Arctic temperature, which translates into a lowering of the mid to upper tropospheric geopotential heights. These alterations produce an increase in the latitudinal height gradient that propagates to mid-latitude waves and results in an improvement in global forecast skill. She also co-authored two other articles, one led by Dr. Ganeshan and the other led by Dr. Boukachaba.

Of note: Dr. Niama Boukachaba, Dr. Manisha Ganeshan, Dr. Erica McGrath-Spangler, and Dr. Oreste Reale are all part of a NASA ROSES proposal (PI: Dr. Ata Akbari Asanjan, RIACS), which describes a new TC detection and tracking methodology based on machine learning techniques applied to satellite data. They will collaborate with scientists from Research Institute for Advance Computer Science (RIACS/USRA) on developing satellite-based near-real time tracking of Tropical Cyclones using machine learning methods, and adopting data from the machine learning model output to the assimilation of hyperspectral radiances into the GEOS system. Also, the team contributed to an abstract titled “Fine-Delineated Tropical Cyclone Detection from Geostationary Satellites and IBTrACS data using Advanced Neural Networks” (lead author: Dr. Ata Akbari Asanjan), submitted to the 2nd NOAA workshop on Leveraging AI in Environmental Science (this meeting is currently postponed due to the COVID-19 pandemic).

Dr. Virginie Buchard (sponsor: A. da Silva) has been working on the upgrade of the aerosol assimilation system in the GEOS model to a variational ensemble type of scheme. With the recent progress made in the Joint Center for Satellite Data Assimilation (JCSDA)/Joint Effort for Data assimilation Integration (JEDI) framework, Dr. Buchard has been working on developing a prototype including GEOS aerosols as a component of the JEDI framework. The goal is to leverage and evaluate what JEDI has to offer in terms of assimilation methods but also in terms of infrastructure, in order to consider an adapted version of this system as the future system for the aerosol data assimilation in GEOS. An observation operator has been added to the JEDI Unified Forward Operator (UFO) to support the assimilation of Aerosol Optical Depth (AOD) observations at one or multiple wavelengths. An aerosol variational analysis was performed on a low-resolution model grid, with a background error derived from an ensemble of aerosol concentrations produced by the GEOS model. In terms of aerosol mass mixing ratio, first increments were produced after analyzing single but also multiple wavelengths of AOD observations. She presented these preliminary results at the AMS Joint Satellite Conference in Boston in October 2019; Dr. Buchard also chaired two sessions on Air Quality and Atmospheric Composition.

Dr. Buchard participated in a live chat session at EGU on “Coupled modelling and data assimilation of dynamics and chemistry of the atmosphere”. Related to her participation in an AEROCOM phase III experiment, she co-authored a paper titled “A global model-measurement evaluation of particle light scattering coefficients at elevated relative humidity” published in ACPD. Also, Dr. Buchard received a certification on Machine Learning for big data and text processing: Foundations from MIT.

Dr. Yehui Chang (sponsor: R. Koster) contributes to the overall evaluation of climate variability and predictability at sub-seasonal-to-decadal timescales and the role of initialization in improving prediction skill. He also works on climate simulations and attribution studies, and conduct climate diagnostic studies using the GMAO’s GEOS-5 model suite.
The excessive tropical precipitation, double ITCZ and very dry summer Indian monsoon are long-standing problems that exist in GMAO’s S2S system. In this study, Dr. Chang carries out global and regional TBC experiments in the Tropics (i.e., Tropical Indian, Tropical Pacific, Tropical Atlantic, Tropical North Pacific, Tropical South Pacific, SH extra-tropics and NH extra-tropics) to identify the regions to lead to improvements in the Indian Monsoon rainfall. The study also examines the link between the anomalous Walker circulation and precipitation over the Indian continent. His assessments of improvements in the SH extra-tropics contributes to improvements in the double ITCZ, the SH branch of the split in the tropical Pacific, as some studies suggest. He also studies the link (from feedback) between precipitation, cloudiness and SST biases in the coupled model. He completed hundreds of years of coupled model simulations.

In other research, Dr. Chang turned to the extreme dry conditions that occurred throughout much of the Southeastern U.S. during September 2019. The drought developed rapidly from the beginning to the end of the month, with the area going from abnormally dry to exceptional drought conditions. This study investigated the underlying causes of the drought, with a key focus on the atmospheric circulation changes (in particular the large-scale Rossby waves) that appeared to be an integral part of both the development and demise of the drought conditions. Dr. Chang completed a large number of regional AGCM replay ensemble simulations to assess the roles of Sea Surface Temperature (SST) anomalies, soil moisture anomalies, and atmospheric internal variability in driving the relevant circulation anomalies over the SE U.S.

In other work, one important variable that has yet to be exploited within coupled forecast systems is accurate estimation of near-surface ocean salinity. Satellite sea surface salinity (SSS), combined with temperature, could help to improve the estimates of ocean density changes and associated near-surface mixing. Dr. Chang has assimilated all available sea level and in situ temperature and salinity observations. Separate observing system experiments assimilate Aquarius, SMAP, SMOS, as well as a combination of these data sets. The assimilated ocean states are used to assess the impact of satellite SSS observations for improving near-surface dynamics within ocean reanalyses and how these initializations impact dynamical ENSO reanalyses and how these initializations impact dynamical ENSO forecasts using NASA’s coupled forecast system (GEOS-S2S-3). Moving forward, the assimilated ocean states will be used to assess the impact of satellite SSS observations for improving near-surface dynamics within ocean reanalyses and how these initializations impact dynamical ENSO forecasts using NASA’s coupled forecast system (GEOS-S2S-3).

Dr. Abhishek Chatterjee (sponsor: S. Pawson) contributes to the development of GMAO’s carbon cycle assimilation and predictive modeling capabilities, focusing on atmospheric carbon dioxide and methane distributions. He uses satellite observations to constrain present-day carbon cycle via data assimilation, and uses predictive models to estimate atmospheric carbon growth rates over the next decades, which will help define criteria for planning carbon-relevant observations from space. This year, Dr. Chatterjee developed and implemented a new compact module to simulate atmospheric CH4. The previous CH4 module was reliant on outdated emission files, which have been completely overhauled and rewritten. Alongside a new sector for CH4, emissions from biofuels have been added to make the model simulations more realistic. These model simulations have been tested against available atmospheric observations, and the results are encouraging. Manuscripts are being prepared and new visualizations for methane were generated by the Scientific Visualization Studio to capture this new capability in the GEOS model (see https://svs.gsfc.nasa.gov/4789 and https://svs.gsfc.nasa.gov/4798). The visualization “Earth Day 2020: Global Atmospheric Methane” is also highlighted in the introduction to the Delivering the Message section within this report. Dr. Chatterjee and other scientists worked with members of the SVS and Office of Communication to create this and other related visualizations.

Dr. Chatterjee has assumed a key role in NASA’s new Carbon Cycle OSSE initiative, led by Dr. Lesley Ott (NASA GSFC). The goal of this activity is to inform future space-based observing strategies through advanced modeling and data assimilation. He has assisted in creating realistic, model-based synthetic CO2 and CH4 datasets for use in inversion and signal detection experiments. In collaboration with the team, Dr. Chatterjee is making these datasets publicly available for use by the international carbon modeling community and in mission planning activities. Additionally, he successfully tested and released a carbon configuration of the GEOS GCM that can be run on the NCCS’s new SLES12 environment.
Dr. Abhishek Chatterjee (program manager: Dr. K. Jucks) performed research under the grant “Operations and data products for carbon-climate feedbacks using OCO-2” (PI: Dr. D. Schimel, JPL/Caltech). He used OCO-2 data to constrain carbon flux estimates at high spatial and temporal resolution, and tested current hypotheses about how increasing CO2 and climate variability affect carbon flux patterns in time and space. Using a suite of model simulations of air-sea fluxes and atmospheric transport, in situ observations of pCO2 from NOAA’s Tropical Atmosphere Ocean (TAO) project and auxiliary information from other remote-sensing missions, Dr. Chatterjee and collaborators attempted to better understand how the ocean carbon cycle responded during the 2015-2016 El Nino event. A manuscript on this work is in preparation and currently being reviewed by co-authors. Additionally, Dr. Chatterjee is leading a paper quantifying the information in OCO-2 retrievals and benchmarking them against a suite of model simulations. The goal of this study is to evaluate the extent to which the atmospheric CO signal present in OCO-2 retrievals is robust, characterizes the information content of the retrievals and has the ability to resolve patterns in CO2 surface fluxes that cannot be resolved by the existing network of in situ sites. A manuscript on this work is in preparation and will be submitted by Summer 2020. (Note, this grant will end in August 2020.)

Dr. Abhishek Chatterjee (program manager: Dr. H. Margolis) also works on a NASA grant titled “GEOS-5 Forecasting and Modeling in Support of ABoVE Airborne Research.” As part of this research, Dr. Chatterjee and his team work on delivering a fully integrated modeling framework that will use the multi-scale data streams from the 2017 field campaign to inform and improve process-based representation of permafrost-carbon dynamics within NASA’s GEOS-5 system.

This year, Dr. Chatterjee integrated the methane and CO2 fluxes generated from the LPJ model into the high-resolution atmospheric transport model (GEOS-GCM). The simulations have been completed from 2009-2017, with the critical period being the year 2017 when the ABoVE airborne campaign took place. He worked with collaborators at NOAA (Dr. Colm Sweeney) and JPL (Dr. Charles Miller) to benchmark these GEOS GCM-LPJ simulations against aircraft profiles that were taken during the 2017 ABoVE airborne campaign. A manuscript based on the findings has been submitted to ERL.

Dr. Chatterjee is working with Dr. Mathias Gockede (Max Planck Institute, Jena, Germany) to investigate changes in the pan-Arctic carbon cycle, and explore the next generation of missions that will be needed to observe and detect those changes. A new set of model simulations have been identified that will test new hypotheses, and consequently forge a stronger science partnership between NASA’s ABoVE campaign (focused on Alaska and Northwest Territories) and international partners (focused on high-latitude regions in Europe and Asia). Dr. Gockede’s student is working as a research assistant with Dr. Chatterjee on these new model simulations.

His additional work with the ABoVE campaign involved his work with the GMAO weather operations team to set up a dedicated website to support the ABoVE Aircraft Campaign that occurred in Summer 2019. He also worked with the ABoVE science team to coordinate flight plans and provide guidance on science acquisitions. Dr. Chatterjee was one of the conveners of multiple sessions at the Science Team Meeting in La Jolla, CA and the 2019 AGU Fall meeting that focused on ABoVE and other high-latitude carbon dynamics.

Upcoming plans include work with researchers from the MPI on the new research theme to study the pan-Arctic carbon cycle, and test new hypotheses about potential changes to the high-latitude carbon cycle in a changing climate. Dr. Chatterjee plans to participate in the upcoming 2020 ABoVE Science Team meeting and present results from his ABoVE-funded project using GEOS-LPJ simulations. Additionally, he is leading a team of researchers from the ABoVE Science Team to complete a carbon synthesis activity for the ABoVE domain. This activity is mandated by NASA HQ and aims to set up Phase 3, which focuses on modeling and synthesis.

Dr. Allison Collow (sponsor: M. Bosilovich) aims to make NASA’s reanalyses and data assimilation systems more usable for the National Climate Assessment (NCA) by calculating climate indicators and specialized products from MERRA-2, evaluating GEOS systems advancements in the context of NCA, and interacting with the NCA on various issues, which includes reanalyses that would contribute to decision-making and resource management. She is also providing support to the CAMP2Ex field campaign. This year, Dr. Collow began working with Dr. Arlindo da Silva to produce a mini-reanalysis for NASA’s CAMP2Ex field campaign. Thus far, she has been comparing the observations that were collected to the version of GEOS forward processing that was available during the field campaign.

A set of over two dozen indices that represent the frequency and intensity of extreme weather events based on daily surface air temperature and precipitation data has been recommended
by World Climate Research Program’s Expert Team on Climate Change Detection and Indices to assist with the assessment of such events and how they may change in the future in large datasets. Multiple members of the NCA group in the GMAO have developed codes to compute these indices, including Dr. Collow. Since MERRA-2 is an ongoing product, it became clear that this effort needed to become more coordinated. As a result, Dr. Collow homogenized the codes developed by her colleagues to produce a single monthly file containing all of the indices calculated using MERRA-2 data. She also configured the plots for these indices that can be created on the fly by users who visit the GMAO’s FLUID webpage, now available to the public (https://fluid.nccs.nasa.gov/reanalysis/extreme_merra2/).

There is considerable uncertainty in the time series of 2 m temperature over the Arctic Ocean in reanalysis products, despite the fact that observations indicate the climate of the region is changing more rapidly than anywhere else around the world. It is suspected that simplistic sea ice models along with a lack of assimilated observations and inconsistent boundary forcing all contribute to the uncertainty among reanalyses. Dr. Collow published a related manuscript in the Journal of Climate, which gives an overview of Arctic near-surface temperature in widely used reanalysis products and further explores MERRA-2 from the perspective of assimilated observations and sea ice concentration boundary conditions.

Extreme precipitation events in the United States can have a variety of attributions that have varying characteristics. In an effort to better define the causes behind regional extreme precipitation events and their interannual variability, Dr. Collow has been using the automated tracking algorithm, tempestExtremes, to detect atmospheric rivers. Along with her former intern, Haiden Mersiovsky (FSU), Dr. Collow analyzed the large-scale influences on atmospheric river-induced extreme precipitation events along the coast of Washington State, as well as the teleconnection patterns associated with these events. Dr. Collow presented the results at the 100th AMS Annual Meeting. Additionally, she has taken a lead role in the Atmospheric River Tracking Method Intercomparison Project’s (ARTMIP) reanalysis intercomparison. Related efforts included participating in the 3rd ARTMIP Workshop and coordinating the input data to be used for the study. In addition to a first author paper related to atmospheric rivers, Dr. Collow also co-authored a two papers published in Climate Dynamics and in Journal of Geophysical Research – Atmospheres.

Over the next year, Dr. Collow will work on evaluating the precipitation in experimental runs with GEOS that incorporate all-sky microwave radiances from instruments in addition to the GPM microwave imager, as well as continuing her work on extreme precipitation events in the United States. She also plans to further evaluate experimental versions of GEOS using observations from the CAMP2Ex field campaign.

Dr. Saulo Freitas (sponsor: W. Putman) conducts work to implement, further develop, and evaluate a new convection parameterization in the NASA GEOS-5 modeling system. This past year, the NASA Goddard Earth Observing System (GEOS) global model was evaluated through a cascade of simulations with increasing horizontal resolution. The GEOS employs a non-hydrostatic dynamical core and includes a scale-aware, deep convection parameterization (DPCP). He produced 40-day simulations at six resolutions from 100 km to 3 km with unvarying model formulations. At the highest resolution, two additional extreme experiments were run: one without DPCP and one with scale-awareness eliminated. Simulated precipitation, the radiative balance, and atmospheric thermodynamic and dynamical variables are well reproduced with respect to observational and reanalysis data. The convective precipitation smoothly transitions from mostly produced by sub-grid to grid-scale model formulations (cloud microphysics). The results were described in his lead author paper titled “Assessing the Goddard Earth Observing System GCM in non-resolved to convection-permitting regimes: Impacts of a deep convection parameterization,” which is under review with Geophysical Research Letters. (See Figure 1.)

Along with colleagues of the ESRL/NOAA, Dr. Freitas detailed and reported recent developments in the GF (Grell and Freitas, 2014, Freitas et al., 2018) convection parameterization and applications. The parameterization has been extended to a trimodal spectral size to simulate the interaction and transition from shallow, congestus and deep convection regimes. Another main new feature is the inclusion of a closure for non-equilibrium convection that resulted in a substantial gain of realism in the simulation of the diurnal cycle of convection, mainly associated with boundary layer forcing over the land. Additional changes include the transport of momentum, the use of three Probability Density Functions (PDF’s) to describe the normalized vertical mass flux profiles from deep, congestus, and shallow plumes (respectively) in the grid box, and the option of using temporal and spatial correlations to stochastically perturb PDF’s, momentum transport and the closures. Cloud water detrainment is proportional to mass detrainment and in-cloud hydrometeor
mixing ratio, and transport of chemical constituents (including wet deposition) can be treated inside the GF scheme. Transport is handled in flux form and is mass conserving. Finally, the cloud microphysics were extended to include the ice phase to simulate the conversion from liquid water to ice in updrafts with resulting additional heating release, and the melting from snow to rain within a user-specified melting vertical layer. This lead author paper “The GF Convection Parameterization: recent developments, extensions, and applications report” is under review with Geosci. Model Dev. Discuss.

After a comprehensive process of evaluating the performance of the mid-range weather forecasts of the GEOS-5 system with the GF-CP, the Grell-Freitas convection parameterization (GF-CP) is now the official convection parameterization for the “Forward Process” operational weather forecasts at GMAO. As explained in this announcement from January 17, 2020, it replaced the original formulation: “This GEOS FP model update replaces the Relaxed Arakawa Schubert (RAS) deep convective parameterization with a combination of the Grell and Freitas scale-aware deep and congestus parameterization combined with the Park and Bretherton shallow convection scheme. The boundary layer scheme has been retuned to work well with the updated convection parameterizations. This combination of convection parameterizations enables a smooth transition from largely parameterized to partially resolved convection across resolutions and produces significantly improved forecast skill and reduces biases in moisture, temperature and winds.”

Dr. Bryan Karpowicz (sponsor: W. McCarty) studies thermal infrared radiance assimilation within the Goddard Earth Observing System (GEOS) data assimilation system (DAS). A key objective is to extend the use of hyperspectral radiance measurements in parts of the thermal infrared spectrum that are presently underutilized in the GEOS DAS. He develops improved radiation transfer codes and methodologies to effectively assimilate these data; develops and refines assimilation methodologies to constrain ozone using hyperspectral radiances in the 9.6 um absorption continuum; and, quantifies the impact of these observations alongside others used in GEOS DAS.

Figure 1: August 2016 precipitation mean (mm day-1) as estimated by GPCP and GPM (panels A1 and A2). The remaining panels show the GEOS GCM simulated total precipitation (left column) and by its convection parameterization only (right column). From top to bottom (panels B to G), model resolution increases from C0090 (~100 km) to C2880 (~3 km). The global areal mean of each precipitation case appears on the left bottom of each panel. (Provided by S. Freitas.)
Recently, Dr. Karpowicz added a capability regarding ozone representation in the GEOS Atmospheric Data Assimilation System (GEOS-ADAS). This is an advanced system used to combine conventional (e.g., weather balloon measurements) and satellite observations along with a global atmospheric model to provide the best global estimate of the atmospheric state as a function of space and time. The improvements came from the addition of satellite data measured from hyperspectral spectrometers, which measure thousands of channels in the thermal, mid, and shortwave infrared portions of the electromagnetic spectrum. Many of these channels are sensitive to the presence of ozone in the stratosphere and troposphere, and are used to improve the concentration of ozone in the output of the GEOS-ADAS. These improvements are highlighted in comparison against in-situ profiles of ozone measured by balloon-borne instruments called ozonesondes. The improvement in ozone analysis is most clearly seen in so-called tropical wave-1 region (more ozone over the tropical Atlantic, less over the tropical Pacific – see Figure 1). Improvements can be seen in both the tropical Atlantic and tropical Pacific; thus, by including the ozone sensitive radiances, there is a better representation of the ozone wave-1 in the GEOS-ADAS analysis. The changes necessary were committed to the GEOS-ADAS code repository, and are currently undergoing testing (called x-runs) for the next GEOS-ADAS upgrade. Preliminary results from the x-run are positive, showing similar improvements for the summer of 2019. If the tests provide benefits in the x-run, then they will be added to the GMAO operational systems, and could provide a greatly improved ozone representation in the next reanalysis product. A related paper is in development.

This year, Dr. Karpowicz gave several presentations both domestically and internationally related to inclusion of ozone sensitive radiances in the GEOS-ADAS: at the 17th JCSDA Technical Review Meeting and Science Workshop in May 2019; at the NASA Sounder Science Team Meeting in September 2019; at the 22nd International TOVS Study Conference (ITSC) in Saint-Sauveur Quebec, Canada; and, at the 2019 AGU Fall Meeting in December 2019.

In January of 2020, Dr. Karpowicz provided expertise at the first CRTM Coefficient generation code sprint. The CRTM (Community Radiative Transfer Model) is a fast model used in several data assimilation systems including operational systems at NASA, NOAA, and the US Navy. The ability to generate coefficients prior to the code sprint had been lost mostly due to personnel changes at NOAA. During the two-week code sprint, Dr. Karpowicz contributed code and scripts to generate coefficients for microwave instruments (specifically AMSU and ATMS). While the goal of the code sprint was to generate both microwave and infrared instrument coefficients, a framework was established during the code sprint, which is currently being built upon to add infrared instruments into this framework. This work is critical to both maintaining the GEOS-ADAS when future instruments become available, and for Observing System Simulation Experiments (OSSEs) to evaluate future satellite mission concepts.

![Figure 1: An example of ozone analysis from August 2018: the top panel shows the percent difference in monthly averaged ozone at 300 hPa altitude for a case using the ozone sensitive radiances versus a control, and the bottom panel shows the reduction in bias against SHADOZ ozonesondes (blue indicates an improvement). (Provided by B. Karpowicz.)](image-url)

Dr. Karpowicz also is involved in a proposal supporting a potential new satellite constellation known as Midwave Infrared Sounding of Temperature and humidity in a Constellation (MISTiC), which was previously evaluated at GMAO using an OSSE. To supplement this work, simulation of Atmospheric Motion Vectors (AMVs) based upon simulations of brightness
temperature is being investigated by a team at the University of Wisconsin. Dr. Karpowicz provided simulated observations of brightness temperatures from MISTIC. Several simulations of brightness temperature from high-resolution WRF Model (Weather Research and Forecasting) forecasts were generated using a newly developed python interface to CRTM (Community Radiative Transfer Model) developed by Dr. Karpowicz. The simulations of high impact weather events (Hurricanes and Atmospheric Rivers) will highlight the importance of a hyperspectral sounder constellation of cubesats in answering key scientific questions regarding the development of such high impact weather events. In addition to high impact weather events, Dr. Karpowicz, along with sponsor Dr. McCarty, will be providing input on the importance of such instruments in global numerical weather prediction.

This coming year, Dr. Karpowicz will provide feedback to the GMAO monitoring team regarding the final implementation of ozone sensitive hyperspectral radiances, and he will be part of the MISTIC cubesat mission proposal, which will be submitted in 2020. His involvement will continue with the Joint Effort in Data Integration (JEDI), a multi-agency effort to modernize data assimilation systems to build upon a common framework, developing ozone sensitive radiances in the new JEDI framework and incorporating other ozone observations. He plans to incorporate shortwave infrared measurements from CrIS in both the current GEOS-ADAS based on the GSI (GridPoint Statistical Interpolation), and to implement CrIS shortwave infrared into the future JEDI version of the GEOS-ADAS. Finally, Dr. Karpowicz will remain connected to the CRTM coefficient generation community to provide feedback and support to develop a new coefficient generation package.

Dr. Christoph Keller (sponsor: S. Pawson) works on the Goddard Earth Observing System (GEOS) Earth System modeling, focusing on global atmospheric composition simulations at ultra-high resolution. He contributes to model development, and works on the assimilation of reactive trace gases, to constrain emissions using satellite observations from EOS and other platforms.

This past year, Dr. Keller continued the development of the NASA GEOS composition forecast model (GEOS-CF), a modeling system that produces global forecasts of atmospheric composition in near real-time. In September 2019, the GEOS-CF model output that produces global forecasts of atmospheric composition in near real-time, and, as discussed in a related video, “... the GEOS Composition Forecasting (GEOS-CF) computer model incorporates 240 chemical species and how they interact with each other and the weather through 700 chemical reactions. All of these chemical reactions directly or indirectly impact the formation of ozone.”

Dr. Knowland created a new data collection of the five most requested air quality pollutants – ozone (O\(_3\)), fine particulate matter (PM\(_{2.5}\)), nitrogen dioxide (NO\(_2\)), carbon monoxide (CO) and sulfur dioxide (SO\(_2\)) – in response to requests received by end-users, with the intention that the forecasts of this collection will never be removed from the public data portal. This collection was added to the GEOS-CF near-real-time (NRT) system on December 19, 2019 by Mr. Lucchesi (GMAO Operational Software Team Lead); Dr. Knowland coordinated with Mr. Lucchesi to back-fill the GEOS-CF dataset for the period prior to implementation in the GEOS-CF forecast system and to make the new data collection available to the public. Dr. Knowland updated the “File Specification for GEOS-CF Product” in April 2020 with the release this new file.

The GEOS-CF system required involvement from others as well. A team of scientists from GMAO and Code 614, led by Dr. Sarah Strode (USRA) and co-led by Dr. Knowland, met twice a month to fully evaluate the 2018-2019 GEOS-CF product. Drs. Knowland and Keller met weekly with Dr. Pamela Wales (USRA/NPP/GMAO) to discuss her monitoring of the GEOS-CF stratospheric composition, and met weekly with Dr. Emily Saunders (SSAI/GMAO), who monitored the GEOS-CF near-real time system and current events. Finally, Drs. Keller and Knowland met monthly with Mr. E. Brent Smith and Mr. Callum Wayman (both SSAI/GMAO) to discuss their work developing new dynamic capabilities in FLUID for the GEOS-CF.

As mentioned in their individual reports, Drs. Keller and Knowland worked with NASA’s Scientific Visualization Studio (SVS) on two visualizations of GEOS-CF composition: “Simulation of Surface Ozone” (https://svs.gsfc.nasa.gov/4764) and “The Complex Chemistry of Surface Ozone” (https://svs.gsfc.nasa.gov/4764)
As a member of the GEOS-Chem Steering Committee, Dr. Keller is heavily involved in the development and maintenance of the GEOS-Chem chemistry model. In May 2019, he attended the 9th international GEOS-Chem meeting in Boston, MA, where he chaired a session, led a working group clinic, and organized a half-day breakout session about machine learning applications in GEOS-Chem. He also contributed to model updates that facilitate the integration of GEOS-Chem into Earth System Models and that facilitate collaboration between NASA scientists and outside partners. As part of a NASA Advanced Information Systems Technology (AIST) project led by Prof. Randall Martin (Washington University of St. Louis), Dr. Keller has been working with GEOS-Chem support team members to further improve the interaction of the GEOS-Chem model with other components of the GEOS Earth System Model. This work is a collaborative effort that involves members of the NASA GMAO, the NASA Atmospheric Chemistry Dynamics Division, Harvard University, Washington University of St. Louis, and MIT.

In 2019, Dr. Keller continued to work on a machine learning application that simulates atmospheric chemistry with almost the same accuracy as a reference model, but at a fraction of the computational cost. By further refining the methodology presented in Keller and Evans (2019), Dr. Keller was able to seamlessly incorporate the machine learning model into the NASA GEOS model, achieving a model speedup of more than a factor of 5. This algorithm is now being tested for new applications, such as probabilistic air quality forecasts. He presented this work at the NVIDIA GPU Technology Conference in Washington, DC in November 2019. The presentation was also summarized in a blog post on the NVIDIA homepage (https://blogs.nvidia.com/blog/2019/11/07/nasa-rapids-air-quality-forecasts/).

Work will continue on upgrading the GEOS-CF system, which will include the integration of real-time information of emission activities, an updated chemical mechanism, and updated model diagnostics. He also will work with end users on developing tailored air quality forecasts at a city level through a combination of model information and atmospheric observations.
Dr. Min-Jeong Kim’s (sponsor: R. Gelaro) research focuses on the GEOS Atmospheric Data Assimilation System (ADAS), in particular, the development and implementation of all-sky satellite data assimilation. This year, Dr. Kim successfully extended the GEOS all-sky GPM Microwave Imager (GMI) data assimilation system to utilize all-sky Microwave Humidity Sounder (MHS) data from NOAA and European satellites. To examine the impacts on GEOS forecasts, Dr. Kim ran numerical weather prediction (NWP) experiments with and without assimilating cloud- and precipitation-affected MHS data. The results demonstrated the positive impacts from all-sky MHS data on GEOS, and this extended all-sky system is being prepared to merge with the next GEOS upgrade.

Dr. Kim has been working to extend this all-sky GMI radiance DAS to assimilate all-sky MW radiance data from the Advanced Technology Microwave Sounder (ATMS), the Special Sensor Microwave Imager/Sounder (SSMIS), and the Sounding for Atmospheric Profiling of Humidity in the Intertropics by Radiometry (SAPHIR). This extended all-sky system will increase the benefit from cloud- and precipitation-affected MW radiances with much larger spatial and temporal coverages compared to the all-sky system assimilating GMI or MHS data only. It will produce better quality analyses, and the improved analyses will lead to improved GEOS forecasts. Further, Dr. Kim worked on merging NCEP GSI codes and GMAO GSI codes for all-sky radiance data assimilation. She debugged and fixed various codes to make the GSI work for both NCEP and GMAO in assimilating all-sky microwave radiance data from various sensors.

In a 2019 NASA PMM Science Team meeting, Dr. Kim gave a report on her team’s efforts on developing Level 4 precipitation data products to support the GPM mission (see figure). Subsequently, collaborations were formed between GMAO scientists and other branches’ scientists to examine the possibility of GEOS Level 4 precipitation data products to support the GPM mission. This collaboration includes comparisons of GEOS precipitation analyses products with IMERG data and ground validation data sets.

In the coming months, Dr. Kim will submit a journal paper describing the impacts of all-sky GMI data. She also plans to tune up the quality control procedures of all satellite radiance data using the methodology she developed, which demonstrated improvements in GEOS analyses and forecast skills. A related journal paper will be prepared, as well as a journal paper describing all-sky MHS data assimilation methodology and impact results. Other work will include the completion of building the all-sky SAPHIR, SSMIS, and ATMS data assimilation components in GEOS ADAS, and starting NWP experiments to examine the impacts of these extended all-sky radiance data on GEOS analyses and forecasts.

Dr. Emma Knowland (sponsor: L. Ott) works on improving the representation of atmospheric constituents in the GEOS-5 models and data assimilation systems. She focuses on transport uncertainty in the models, including its dependence on spatial resolution. Ensemble assimilation methods are being developed, and research contributes to the implementation of suitable ensembles that span the range of constituent uncertainty in GEOS-5, followed by the construction of state-dependent background error covariances that contain information about transport and source-sink uncertainties.

Dr. Knowland, in collaboration with Dr. Christoph Keller (USRA) and other members of the GMAO and the Atmospheric Chemistry and Dynamics Lab (Code 614), continues to validate and further develop the GEOS Composition Forecast (CF) system; in particular, Dr. Knowland updated the GEOS-CF system to run on the new Discover compute nodes upgraded to SLES12 Linux-based operating system.

Dr. Knowland, Dr. Keller, and Mr. Robert Luchessi (SSAI/GMAO) wrote the GMAO Office Note titled “File Specification for GEOS-CF Product,” released on the GMAO website with the public release of the GEOS-CF data in September 2019. She will maintain the GEOS-CF File Specification document. Dr. Knowland completed the 5-day reforecasts for the end of GEOS-CF hindcast period.
Drs. Knowland, Keller and Steven Pawson (GMAO) worked with members of NASA’s Scientific Visualization Studio (SVS) on two visualizations on GEOS-CF composition. The first, a simulation of surface ozone, was released on November 7, 2019, and the second, released on December 9, 2019, marches through 95 different chemical species simulated by the GEOS-CF system that play an integral part in ozone chemistry. A narrated version of the second visualization was part of the NASA Earth Day 2020 Countdown (https://svs.gsfc.nasa.gov/13580). See also the report from Katie Jepson (130/USRA) within the “Delivering the Message” section of this annual report.

Dr. Knowland co-authored two manuscripts that will be published in peer-reviewed journals: “Evaluation of NASA’s high-resolution global composition simulations: Understanding a pollution event in the Chesapeake Bay during the summer 2017 OWLETS campaign” and “Using networked Pandora observations to capture spatiotemporal changes in total column ozone associated with stratosphere-to-troposphere transport.” She also gave 12 presentations to NASA GSFC, national, and international audiences on the near real time air quality forecasting capabilities of the NASA GEOS model and the representation of stratospheric intrusion events in NASA GEOS forecasting and reanalysis products.

As a Co-I on Dr. Fei Liu’s (USRA) funded Atmospheric Composition: Modeling and Analysis (ACMAP) proposal titled “Development of Satellite-constrained Pollution Emissions for Improved Simulation of Global Tropospheric Composition,” Dr. Knowland will run experiments using the GEOS-CF framework with the Community Emissions Data System (CEDS) for Historical Emissions inventory. She also will use the combined CEDS and satellite-based emission inventory to simulate the response of tropospheric composition to the emission changes. She has downloaded the CEDS anthropogenic emission files and is preparing the files to run with GEOS-Chem and making necessary updates to the GEOS-CF input files to use this alternative anthropogenic emission inventory. Additionally, in April 2020, Dr. Knowland was nominated and selected to the World Meteorological Organization’s Global Air Quality Forecasting and Information System (GAFIS) Steering Committee.

In the coming year, Dr. Knowland along with Dr. Keller will be monitoring the GEOS-CF system. They also will monitor and continue to improve the GEOS-CF model. Drs. Knowland and Keller, along with contributing scientists from the GMAO and Code 614, will present to national and international audiences as well as write peer-reviewed paper(s) documenting the GEOS-CF system. Dr. Knowland is coordinating the benchmarking of the stratospheric constituents in the GEOS-CF.

Dr. Knowland will continue to contribute to the evaluation of tropospheric and lower stratospheric transport of reactive gases in the different products using the GEOS model products. In particular, she will focus on the GEOS-CF model, the GEOS-FP model, and the MERRA-2 reanalysis representation of stratospheric intrusions linked with surface ozone air quality exceedances in the western US during the spring stratospheric intrusion seasons.

Dr. Jana Kolassa (sponsor: R. Reichle) contributes to research and science development on land data assimilation within the Goddard Earth Observing System (GEOS) model and its associated Land Data Assimilation System (LDAS). She develops and implements LDAS components for the water and carbon cycles, and supports the maintenance and improvement of the science algorithm for the SMAP Level 4 data products.

Dr. Kolassa has extended the calibration of Catchment-CN vegetation parameters from the local to the global scale. She has generated a new version of the Catchment-CN land model that reflects the findings from her parameter calibration study, using the new GEOSladas framework (as opposed to the LDASsa framework, which was used during the calibration exercise). The new version of Catchment-CN features an increased number of vegetation types, a vegetation-type-dependent parameterization of model processes that were previously independent of type, and new parameter values resulting in modeled vegetation activity estimates that are in better agreement with observations. She used the new Catchment-CN to generate a global model simulation of photosynthetic activity to test the performance of new vegetation parameters that were calibrated against satellite observations from MODIS. Compared to a model simulation using the default parameters, the new vegetation parameters were able to reduce the RMSE and bias with respect to MODIS observations globally. The reductions in bias and RMSE were found to be proportional to the error magnitude of the uncalibrated model.

Dr. Kolassa also evaluated photosynthetic activity using the calibrated Catchment-CN model against observations from MODIS. Over the global, multi-year validation period, the new
vegetation parameters resulted in a consistent reduction of the root-mean squared error (RMSE), which is mostly driven by a reduction of the model bias. The global average error reduction is ~10%, with substantially larger error reductions locally. In addition to evaluating the effect on the modeled vegetation activity, Dr. Kolassa also investigated how the new vegetation parameters impact the overall modeled ecohydrology. The dominant effect of the parameter calibration is a reduction in the modeled vegetation activity that counteracts the overestimation of photosynthesis of the uncalibrated model; in turn, this leads to a reduced plant transpiration, which results in a higher soil moisture content. Similarly, the reduced vegetation activity is reflected in smaller carbon fluxes at the land surface.

Dr. Kolassa submitted a manuscript summarizing the results of her Catchment-CN vegetation parameter calibration study. This paper presents the Particle Swarm Optimization approach and the generation of vegetation sub-types, evaluates the performance of the calibrated model and assesses the impact of the new parameters on the model's ecohydrology. Dr. Kolassa led several proposals, specifically one NASA ROSES-19 proposal in which the team aims to demonstrate the value of assimilating SMAP observations into an operational weather forecast system to improve the forecast of tropical cyclone (TC) evolution surrounding landfall. They propose to better constrain soil moisture conditions in operational weather forecast models through the assimilation of SMAP observations, thereby improving the forecast of TC evolution before and after landfall. Dr. Kolassa also prepared a proposal for the Surface Water and Ocean Topography (SWOT) mission science team, which would use a combination of two land models to assimilate observed wetland and inundation extent and better constrain simulated methane emissions. From this work, they plan to expand the land data assimilation capabilities within the GMAO to accommodate the new observation type provided by SWOT, while concurrently strengthening collaborations with other GSFC groups. She was Co-I of an IRAD proposal to implement an urban process representation in the GMAO’s Catchment land model, and Co-I on a proposal to the NOAA MAPP program aimed at investigating the impact of drought-wildfire-hydrology connections.

In the coming year, Dr. Kolassa will begin to develop a vegetation data assimilation framework for GEOSSdas. Her initial work will include adding the ability to ingest MODIS observations of vegetation activity within the model, as well as the ability to simulate equivalent vegetation activity observations from the model states. From various experiments, she will determine the optimal assimilation strategy for the MODIS vegetation observations. The final step of this project will be to combine the MODIS vegetation data assimilation with the already existing SMAP soil moisture assimilation framework to assess the potential joint use of these two observation types.

Dr. Eunjee Lee (sponsor: R. Koster) works to advance the research of the carbon cycle feedback between the land, the atmosphere, and the carbon forecast with the GEOS model. She continued to advance the assessment of the carbon forecast skill in response to the GMAO retrospective forecast, in collaboration on a NASA Interdisciplinary (IDS) project led by Dr. Lesley Ott (GMAO). Dr. Lee’s analysis demonstrates the isolated contribution of the land initialization to the carbon forecast skill, from the meteorological variability in the retrospective forecast. The analysis utilized the outputs of the offline Catchment-CN simulations driven by the bias-corrected GMAO hindcast. The bias-correction was done by Dr. Fan-Wei Zeng (SSAI/GMAO), with assistance from colleagues in Code 617; Dr. Zeng and Dr. Lee conducted the 120 offline simulations. In the analysis of the simulation results, Dr. Lee found that a majority of the carbon forecast skill is attributable to the land initialization, which suggests the importance of utilizing satellite data in setting a good initial condition for the seasonal-to-subseasonal (S2S) forecast. Her analysis also highlights that the status of soil moisture in land initialization affects the skill considerably at the initial months (1-2 months) of the carbon forecast, while other initial conditions (e.g., vegetation status and carbon reservoir) become relatively more dominating in later months. Dr. Lee has prepared a related manuscript.

Dr. Lee continued to quantify the contributions of land carbon flux and atmospheric transport in atmospheric CO2 variability. This work is a more comprehensive study of a discussion point in her paper (under revision) in which the role of atmospheric transport (e.g., wind) in the atmospheric CO2 variability was addressed qualitatively. She performed a pair of supplementary offline AGCM simulations driven by net land carbon fluxes from the offline Catchment-CN, with the 3-hourly land carbon flux inputs being revised by removing the longer term trend in the 15-year time series, and with the fossil fuel emission and ocean carbon flux inputs set to zero. This pair of simulations with the reduced land flux variability was conducted to provide the baseline variability by land flux vs. atmospheric transport. In the preliminary results, several regional and seasonal hot spots were identified, where the atmospheric CO2 variability is strongly correlated with the atmospheric transport, such as the spring greening season in the boreal region.
Dr. Lim showed that the relatively poor simulation of the observed tropical Pacific El Niño heating anomalies in January. Further, Dr. Lim suggested that placing the January El Niño response to the west of the northeast Pacific is due to biases in the January climatology, characterized by a strengthened North Pacific jet and enhanced ridge over western North America, can be traced back to biases in the January climatology heating over the Tibet region and the tropical western Pacific.

In other work, Dr. Lim examined the capability of the GEOS subseasonal forecast model, version 2, developed by GMAO in predicting the MJO, the major intra-seasonal time scale variation of the large-scale convective activity across the tropics. He found that the prediction skill, in terms of the Real-time Multivariate MJO (RMM) bivariate correlations, is remarkably greater than the skill from the old version 1. For example, the bivariate correlation values fall below 0.5 at 20-25 forecast lead days in v.1, but the correlations in v.2 remain greater than 0.5 even at a 30-day forecast lead. Dr. Lim found a seasonal difference exists in the MJO prediction skill in the version 2 model. The correlation is still greater than 0.5 at ~40 day forecast lead in summer, while the correlation is slightly lower than 0.5 at ~30 day forecast lead in winter. Also, that eastward MJO propagation is getting slower than observation with an increase in forecast lead days in winter, yet the propagation speed is comparable to the observation in summer. To identify if the seasonal difference in prediction skill can be attributed to this seasonal difference in the MJO propagation speed relative to observation, he identified that bias of the mean state of the moisture and temperature, and their advective process simulated by GEOS S2S model, are not significantly different between the two seasons. He also investigated the 3-D tropical moist static energy distribution and Kelvin wave responses for two seasons as those factors are crucial for determining the MJO propagation speed. This research is ongoing.

As part of the GMAO’s subseasonal to seasonal (S2S) prediction model development and verification project, Dr. Lim primarily worked on verifying the forecast system, focusing on the prediction of major extra-tropical teleconnections, decadal-scale climate modes, MJO, and tropical cyclone activity. He found the model version 2 can predict the MJO with a correlation greater than 0.5 at ~30 day lead, which is comparable to or better than the other models in different institutions. He found that decadal-scale climate modes, such as the Pacific Decadal Oscillation (PDO) and the Atlantic Multidecadal Oscillation (AMO), are predicted reasonably, up to a 6-month lead. The spatial pattern of the PDO realized by the model is very realistic, while the pattern of the AMO needs improvement. Regarding the S2S time-scale climate modes, he demonstrated that the prediction skills of the North Atlantic Oscillation (NAO), the Arctic Oscillation (AO), and the Pacific North America (PNA) teleconnections in

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**Dr. Young-Woon Lim** (sponsor: S. Pawson) supports scientific research on climate variability, change, prediction, and weather extremes using modeling and assimilation tools developed by the GMAO. Among his research this year, Dr. Lim conducted a study on the monthly variation of the boreal winter El Niño precipitation response over North America (NA) using atmosphere-ocean coupled and uncoupled NASA GEOS-5 models and MERRA-2 reanalysis product. He decided to conduct this research when he saw the significantly poor prediction skill of the El Niño precipitation response in January but very high in February. The skill in January was found to be the result of the model placing the main circulation anomaly over the northeast Pacific, slightly to the west of the observed, causing precipitation anomalies that lie off the NA west coast instead of over land as observed. However, in February, the observed circulation anomaly over the northeast Pacific shifts westward, lining up with the predicted anomaly, which is essentially unchanged from January, resulting in both the observed and predicted precipitation anomalies remaining off the coast. Furthermore, the largest precipitation anomalies occur along the southern tier of states associated with an eastward extended jet – something that the models capture reasonably well. His simulations with a stationary wave model suggest that placing the January El Niño response to the west of the observed over the northeast Pacific is due to biases in the January climatological stationary waves, rather than errors in the tropical Pacific El Niño heating anomalies in January. Further, Dr. Lim showed that the relatively poor simulation of the observed January climatology, characterized by a strengthened North Pacific jet and enhanced ridge over western North America, can be traced back to biases in the January climatology heating over the Tibet region and the tropical western Pacific.
Dr. Lim investigated the diurnal variation of the warm season precipitation simulated by the GEOS-5 atmospheric general circulation model (AGCM) for 2005-2006 in 10-km horizontal resolution, in collaboration with the scientists outside NASA/GSFC. The simulation was validated with the satellite-derived Tropical Rainfall Measuring Mission (TRMM) 3B42 precipitation data and MERRA-2 for atmospheric winds and moisture; the simulation was compared with the coarse-resolution run in 50-km to examine the impacts driven by resolution change. Results showed that the model tends to reproduce the important features of the observed diurnal variation (e.g., amplitude and phase) that the precipitation peaks in evening over land and in morning over ocean, respectively, despite an excessive amplitude bias in the land. The model also shows the realistic propagation patterns of precipitation in the vicinity of coastal ocean and major mountains. Regional characteristics of the diurnal precipitation over two regions, the Bay of Bengal and the Great Plains in the US, were examined in detail, where the observed diurnal cycle exhibited a systematic transition in the peak phase due to the development and propagation of regional-scale convective systems. The model can reproduce this pattern and the diurnal variation of low-level wind and moisture convergence, but has difficulty representing the nocturnal peak in precipitation over the Great Plains. Results suggest that the increase in horizontal resolution of the model up to 10 km improves the representation of the diurnal cycle of precipitation substantially, but intrinsic model deficiencies still exist in topographical precipitation and the representation of mesoscale convective systems.

Additional research involved the possible linkage between the Arctic sea ice variability and large-scale atmospheric circulation in boreal summer (June-August). In order to understand that linkage, Dr. Lim and collaborators analyzed the three leading modes in the sea level pressure (SLP) variability in the Arctic (70° - 90°N) – the AO, the Arctic Dipole (AD), and the third mode called A3. His research team compared the decadal changes of the modes between the early (1982-1997) and the recent (1998-2017) periods and their influences on the Arctic sea ice extent (SIE). Only the AD mode showed a significant correlation increase with SIE from -0.05 in the early period to 0.57 in the recent period. The AO and the A3 modes showed a less significant relationship with SIE for the two periods. The AD was characterized by a dipole pattern of SLP, which modulates the strength of meridional surface winds and the transpolar drift stream (TDS). The major circulation change in the late 1990s was that the direction of the wind has been changed more meridionally over the exit region of the Fram Strait, which causes sea ice drift and discharge through that region. They also found that the zonal shift of the centers of SLP anomalies and associated circulation change affects a significant reduction in sea ice concentration over the Pacific sector of the Arctic Ocean. In response to the growing interest in the topic of how the Arctic and sub-polar region interacts in terms of climate variability, Dr. Lim plans to study how the radiative fluxes, along with Arctic sea ice and their variations, impact the climate variability over sub-polar region, by analyzing the satellite-based observations and reanalysis, and carrying out model experiments.

In the year ahead, Dr. Lim will continue to study the prediction of the MJO by the GEOS S2S prediction model. In particular, he will focus on the gradient of moisture and temperature, moist static energy and Kelvin wave response that are known to play a crucial role in determining the MJO propagation speed. He also will continue to verify the new GEOS S2S prediction model system (version 3) that is under development. This verification will include the prediction skill of the large-scale teleconnections (e.g., NAO, AO, and PNA), ENSO, decadal-scale climate modes (PDO and AMO) and MJO. Finally, Dr. Lim is involved in a proposal that aims to assess the capability of the new GEOS S2S system (V.3) in predicting the track/intensity of the tropical cyclones and further improving the TC prediction skill.

Dr. Karla Longo de Freitas (sponsor: A. da Silva) focuses on the use of data from NASA's field missions to assess the quality of aerosol and trace gas distributions in GEOS systems. She uses historical observations to evaluate reanalyses and to develop model transport algorithms to improve the representation of constituents, especially in the planetary boundary layer.

This year, Dr. Longo de Freitas led the implementation of the aerosol-cloud interaction in the Single Moment microphysics scheme in GEOS-5. She implemented the calculation of the effective radius of cloud liquid water as a function of the aerosol number concentration. The scheme follows the
diffusiophoresis, thermophoresis, and electrostatic collection.

Also, the aerosol particle activation as cloud condensation nuclei (CCN) follows the approach of Abdul-Razzak and Ghan (1998, 2002). This implementation was included in the current version of the Forward Processing at NASA/GMAO. Also, Dr. Longo has participated in the development of a new physics-based parameterization for the wet removal in GEOS-5, and she contributed to the analysis of the results of the most recent GEOS-S2S results, especially for the aerosol component. As such, Dr. Longo was a co-author on two articles, one published in JGR-Atmospheres and one submitted to Geophysical Research Letters.

Dr. Longo de Freitas also participated in NASA airborne missions. First, as part of CAMP2EX pre-mission activities, she designed and contributed to the implementation of a customized CAMP2EX portal for the GEOS-5 products to support the virtual CAMP2EX mission (available at https://fluid.nccs.nasa.gov/missions/mission_CAMP2EX/). The custom products included a set of vertical transects and interactive aerograms were thought to support the mission scientists to plan the flight tracks and to identified the optimal flight levels when aerosols were targeted. Second, as part of the ORACLES and ACEPOL missions, Dr. Longo contributed as a co-author to two scientific publications, one in review with Earth Syst. Sci. Data Discuss. and one submitted to Atmos. Chem. Phys.

Dr. Longo de Freitas will continue to develop the new parameterization for wet removal of aerosols in the GEOS system. This is a novel approach, which deals with both in- and below-cloud removal for the convective and large-scale clouds. In this new approach, for the convective clouds, there is an assumption of cloud droplets size distribution based on the variables available. In-cloud removal includes the heterogenous activation of aerosols into cloud condensation nuclei (CCN) and ice nuclei (IN) to estimate the nucleation scavenging (i.e., a fraction of the aerosols are activated and become cloud droplets or ice, while the rest remain interstitial particles). Inside the cloud, the interaction between interstitial aerosols and cloud droplets and ice crystals occurs through several collision processes. Below cloud, the same collision processes act for the raindrops and below cloud aerosols. In both cases, the formulation will account for Brownian diffusion, inertial impaction, interception, diffusiophoresis, thermophoresis, and electrostatic collection.

Dr. Peter Norris (sponsor: W. Putman) works on the atmospheric radiative transfer (RT) development and validation in GEOS-5. This involves improving the quality of solar and terrestrial radiative transfer in the GMAO’s GEOS-5 global model by integrating state-of-the-art radiation codes (e.g., RRTMG and RRTMG-P), and conducting tests and validations against observations. He also conducts the diagnosis and correction of RT problems, and improves the coupling between RT and other model Gridded Components.

This year, Dr. Norris was involved in updating the Earth Orbit Model in GEOS-5. Drs. Richard Cullather and Gary Partyka (GMAO) noted that GMAO’s GEOS-5 simulations and MERRA-2 reanalysis were missing a drift in the seasonal insolation seen in CERES EBAF and other global modeling center’s models. This was because GEOS-5’s existing orbital model was a repeating 4-year Julian cycle and therefore did not explicitly model the century-scale drift in the date of the equinoxes nor the even longer-term precession of the equinoxes. In response, Dr. Norris researched and implemented a new higher accuracy orbital model that includes the slow (century-scale) secular changes in not only the longitude of the perihelion, but also in the eccentricity of the orbit and in the obliquity (tilt of the Earth’s rotational axis). The new model vastly reduces the previous GEOS-5 bias in incoming solar radiation with respect to CERES EBAF. The new orbital system also now includes the so-called Equation of Time correction, for a more precise sun position, that was previously missing in GEOS-5. The need for this correction, which makes small adjustments to solar timing (e.g. sunrise/sunset times) had been pointed out earlier by Dr. Mike Bosilovich (GMAO) in response to communications he received via the CERES science team. This correction is important for precise diurnal timing, like the interpretation of measurements made near the Earth’s terminator line.

In other research, the GMAO’s release of the new forward processing system f525_fp was the first to use the RRTMG shortwave radiation code. The release initially suffered from a negative bias in solar heating at the stratopause that caused a significant bias in temperature at that level. Dr. Norris was assigned to examine this issue and worked with Drs. William Putman, Lawrence Takacs, and Lawrence Coy (GMAO) and Drs. Eli Mlawer and Michael Iacono (AER, Inc.) to address the bias. This led to a revision of the RRTMG shortwave code by AER that largely fixed the GEOS-5 bias, and the new forward processing system f525_fp was promptly updated with this revision. Dr. Norris was lead author on a research brief on this investigation.
Dr. Norris upgraded the GEOS-5 implementation of the RRTMGP radiation code (RRRTM - GCM Parallel version, from Dr. Rob Pincus of U. Colorado and Dr. Eli Mlawer of AER Inc.) to include the recently added long-wave surface temperature Jacobians and the NRLSSI2 solar variability model. The RRTMGP code is now near the capability of the existing RRTMG radiation codes, but with a much improved, maintainable, and extensible software structure. In the coming year, the RRTMGP implementation will be further updated to an additional new release, and the focus will then shift to improving its speed to compete with existing RRTMG codes. Also, the new GEOS-5 orbital system will undergo additional integrated testing within the GMAO.

This past year, Dr. Tomohiro (Tom) Oda (sponsor: S. Pawson) worked on the updates and improvements of his global high-resolution fossil fuel carbon dioxide emission (FFCO2) model (Open-source Data Inventory for Anthropogenic CO2, ODIAC). In 2019, Dr. Oda produced an updated version (ODIAC2019) of the ODIAC FFCO2 emission data set, in collaboration with researchers at Japanese National Institute for Environmental Studies (NIES) and the Carbon Dioxide Information Analysis Center (CDIAC) at the Appalachian State University. The year 2019 version of ODIAC data set is based on the most up-to-date FFCO2 estimates made by the CDIAC as well as emission estimates locally made by Dr. Oda using the latest global fuel use data. The updated emission data product was used for the CO2 simulations implemented at the Global Modeling and Assimilation Office mainly for the data analysis of CO2 data collected by NASA's Orbiting Carbon Observatory 2 (OCO-2).

Being the only one regularly-updated FFCO2 data product in the world and now a global standard FFCO2 data product in the carbon cycle research community, ODIAC has been frequently used in the research field. The total download data size of the ODIAC data product had been increased by more than a factor of 10 from the previous year (13TB in 2018 and 166TB as of August 2019). Dr. Oda’s ODIAC product served as a key dataset for the atmospheric inversion intercomparison under the OCO-2 project. The results were published in Atmospheric Chemistry and Physics (Crowell et al. 2019). Dr. Oda and French scientists used ODIAC to design the space-based urban carbon observations. The global emission hot spots were analyzed using the ODIAC product and the results were published in the journal Earth System Science Data as Wang et al. (2019). He also produced the 1x1 degree FFCO2 uncertainty estimates using an ensemble of different FFCO2 data products with a focus on the structural uncertainties among different products. The uncertainty estimates were examined by the simulation system developed at Pennsylvania State University. Feng et al. (2019) reported a part of the results in Geophysical Research Letters and suggested the FFCO2 is one of the largest uncertainties in regional carbon flux estimation. Dr. Oda was a co-author on all of the papers mentioned here, with significant contribution to the study and manuscript development. Dr. Oda also made significant progress on the use of new nighttime light (NTL) data retrieved from data collected by the Visible Infrared Imaging Radiometer Suite (VIIRS) on Suomi-National Polar-orbiting Partnership (NPP) satellite (“Black Marble” product) in his ODIAC emission modeling system. Dr. Oda, the Black Marble team at Goddard, and his collaborator at PSU further improved a model-based analysis of emission representation errors, and then found that the errors could be smaller than the single-shot uncertainty of current spaced-based carbon observations. He is working with the Black Marble team on a related manuscript.

In related research, Dr. Oda along with his program manager Dr. Richard Eckman worked on the evaluation of the developed emission data product. Dr. Oda and his collaborators implemented a detailed emission data comparison using a country level multi-resolution emission over the domain of Poland. The comparison revealed that the emission uncertainty over the cities are approximately 30-40% and the urban-urban-rural transitioning area are the largest source of errors. Dr. Oda applied the same approach to East Asia and conceived a study that assessed the impact of advanced population-based emission proxy for East Asia. This work was published in the Environmental Research Communications (Gaughan et al. 2019). The performance of the developed emissions were also examined by high-resolution transport model simulations in the Baltimore-Washington area in collaboration with the research team led by the University of Maryland. These simulations studied assess the utility of the ODIAC emissions for studies at policy relevant scales. The results were published in two journals, and the developed emissions were also used in the first urban CO2 analysis implemented by Japanese CONTRAIL project; a related manuscript has been accepted by Scientific Reports.

Dr. Oda also worked with program manager Dr. Ken Jucks and an international team on the OOC-3 project (USRA, Goddard, JPL, Penn State, and French LSCE). He examined the first CO2 data collected from the OCO-3 Sampling Area Map (SAM) mode observations, which is the new targeting function to be used for special observations for cities and other research targets. Dr. Oda’s team, led by Penn State, examined the early SAM data using high-resolution CO2 model results and NO2 data from the OMI team at Goddard in order to evaluate and assess the utility
of early data for urban carbon emission studies. Dr. Oda gave a related talk at the 2019 AGU Fall Meeting.

He also worked on a project with Professor Eric Kort at the University of Michigan along with program manager Dr. Ken Jucks. The project team (USRA, U. of Michigan, U. of Utah, Penn State, and French LSCE) examined the OCO-2 data over the urban domains and published three several key findings. The team first implemented a set of Observing Simulation System Experiments (OSSEs) to assess the number of OCO-2 observations to constrain emissions from cities. Second, the team found that the observed CO2 enhancement over Middle East cities were ~2.0 times higher than the inventory estimates. Both of these research items were published in JGR. Lastly, the team combined 100+ urban OCO-2 observations with the population maps to estimate per-capita CO2 emissions, and these first observational evidence-based estimates suggest that large cities are greener. This work was published in the Environmental Research Letters, and was highlighted by online media outlets.

Going forward, in collaboration with the Black Marble team at Goddard, Dr. Oda will work on the high-resolution global analysis of CO2 emissions using NASA's Black Marble NTL data. He plans to complete and submit a manuscript that documents the recent development and findings with the VIIRS-based ODIAC emissions. Work will continue on updating and improving his ODIAC model and producing an updated version of the ODIAC emission data product with minimal time latency; also, he will continue work on the fossil fuel emission error/uncertainty quantification.

Dr. Nikki Privé (sponsor: R. Gelaro) supports projects in atmospheric data assimilation, especially regarding the use of current and future space-based observations. This includes diagnostic studies to evaluate and improve the use of observational data as well as running and interpreting observing system simulation experiments (OSSE). This year, Dr. Prive conducted OSSE experiments to explore the impact of GPS radio occultation observations at different levels of saturation using the 4DEnVar GEOS-5/GSI. She performed experiments using 100,000 daily GPS-RO (GPS Radio Occultation) soundings and 10,000 daily GPS-RO soundings. Detrimental GPS-RO impacts on forecast skill at 300 hPa were noted in the results, and were identified to be a two-step interpolation of temperature profiles causing an error in tropopause temperatures and incorrect bending angles. These results were shared with developers working on the GPS-RO observation operators so that the operator methodology can be corrected.

Dr. Prive ran a series of experiments using the GMAO OSSE framework to explore the performance of the adjoint tool for estimating observation impacts on forecast skill for forecasts of various lengths. A manuscript describing these results was submitted to QJRMS and is currently under revision. Additionally, she analyzed the results of an OSSE that examined how correlated and uncorrelated observation errors are handled by the GSI data assimilation system. Preparation of a manuscript that discusses the effects of simulated error correlations in an OSSE framework is underway.

Dr. Prive completed OSSE runs and analysis for a proposed global network of geostationary hyperspectral infrared (GEO-IR) satellite instruments. Multiple scenarios were tested, including different observation thinning, subsets of selected satellites, and the use of shortwave thinning. Also, she began preliminary efforts in support of a potential new instrument for observing surface pressure over the ocean. Dr. Prive examined the current use and availability of marine surface pressure data in both the real operational setting and the GMAO OSSE.

She was lead author on a publication in Monthly Weather Review titled “Uncertainty of observation impact estimation in an adjoint model investigated with an Observing System Simulation Experiment.” In January, she gave a presentation titled “Robustness and Behavior of Adjoint Calculations of Observation Impacts in Numerical Weather Prediction” at the AMS Annual Meeting in Boston, MA.

In the coming months, once the GPS-RO operator in the GSI is modified to remove the problematic vertical interpolation step, Dr. Prive will redo the complete set of verification, baseline, and saturation runs with varying amount of GPS-RO observations up to 100,000 soundings per day. In this run, the temperature profile in the stratosphere will be partially smoothed to alleviate the issue with temperature remapping in the Nature Run.

Dr. Cecile Rousseaux (sponsor: L. Ott) performs research on ocean phytoplankton populations using the GMAO NASA Ocean Biogeochemical Model (NOBM). She has continued to serve the community and as the principal liaison for the Ocean Biogeochemical Modeling work at NASA GSFC. Her proposal on “Phytoplankton Algorithms and Data Assimilation: Preparing a Pre-launch Path to Exploit PACE Spectral Data” submitted to the second PACE Science Team was selected for funding. During the last year, she gave an invited talk on “Understanding the effects of climate on ocean carbon pools” for the Symposium on Earth Science and Applications from Space at the National Academy
of Sciences, Washington D.C. She also participated and gave a presentation at the Rapid Review of the GSFC Carbon Cycle Capabilities organized by Dr. Lee. Dr. Rousseaux was co-author on several publications, including the 2020 IOCCG Report on “Synergy between Ocean Color and Biogeochemical/Ecosystem Models” led by Stephanie Dutkiewicz, a paper published in Environmental Research Letters titled “Global ocean primary production trends in the Modern Ocean Color Satellite Record (1998-2015)” and a publication on “Space-based observations for understanding changes in the arctic-boreal zone” led by Bryan Duncan, recently published in Reviews of Geophysics. Dr. Rousseaux attended several meetings for the Surface Biology and Geology working group, a group established in response to the last Decadal Survey, which will recruit, coordinate and integrate input on applications needs, data product requirements and training/education. Finally, Dr. Rousseaux led several collaborations, including with other NASA, national and international universities, and other agencies that rely on information/data from the NASA Ocean Biogeochemical Model.

In the upcoming year, Dr. Rousseaux will continue to act as the lead of the ocean biogeochemistry model at NASA GSFC, and will continue to work toward the integration of the NOBM in the GEOS model. She will also continue to provide support to the scientific community through publication and proposal review, support in using the NOBM data and code, and contribute to community efforts such as the IOCCG.

Dr. Cecile Rousseaux (program manager: Dr. D. Considine) worked her NASA grant “Seasonal Forecast of Ocean Biogeochemistry using GEOS-5” funded by the Modeling, Analysis and Projection Program. She ran various forecasts to assess the skills of the system at both regional and global scales. During the second year of this project, she and her team refined and fine-tuned the forecast by assessing the biases, uncertainties and drifts in the forecast using retrospective forecasts in areas other than the Equatorial Pacific. Their analysis started with the North Pacific, since it had direct applications for the NASA Ocean Biogeochemical Model to assess the interannual variability in the North Pacific Ocean in the vicinity of the Station PAPA for various biogeochemical parameters involved in the export of carbon in the ocean. During the third, and final, year of this project, she and her team have worked on quantifying the seasonal variability in biogeochemical cycles in the Northeast Pacific Ocean. One of the major findings is the existence of a bimodal pattern in the primary production and export production (calculated at 200 m) that was related to a change in phytoplankton composition from a diatom-dominated ecosystem (in May) to a phytoplankton community dominated by coccolithophores (in August). This bimodal pattern was not observed using chlorophyll alone. Chlorophyll concentration varied little throughout the year and an increase of ~0.1 g chl L⁻¹ occurred in September. This work highlights the complex interactions between the production of chlorophyll in the surface water, the change in phytoplankton composition, and the export of this production to deeper waters. A manuscript presenting these results titled “A data assimilation approach to setting the spatial and temporal context for the EXPORT field campaign” is in preparation.

Dr. Rousseaux and team also worked directly with the EXPORTS Science Team in providing data on the spatial and temporal variability of various biogeochemical variables in the North Atlantic to prepare for the upcoming field campaign. The EXPORTS Science Team identified six potential stations and Dr. Rousseaux’s team provided information on the seasonal and interannual variability of various biogeochemical variables, including phytoplankton composition and nutrient concentration at those stations, to help them narrow down the best sampling strategies to effectively tackle their Science Questions.

Dr. Cecile Rousseaux (program manager: Dr. P. Bontempi) concluded work on her NASA grant “Phytoplankton Composition
algorithms for PACE.” As part of this project, the Ocean-Atmosphere Spectral Irradiance Model (OASIM) was reformulated from a 25nm to a 1nm resolution for the spectral range 250-800 nm at the global scale. The NOBM was used to produce a one-year simulation to provide the input of phytoplankton composition needed for OASIM as well as study the effects of various components on water leaving radiances in the oceans (Gregg and Rousseaux, 2017). During the last year of this project, several collaborations were developed with the PACE Project Team as well as others to use this dataset for various applications, including instrument design (e.g., band selection, atmospheric correction, and algorithm development). Some of the work accomplished as part of this project was published in Environmental Research Letters in 2019 in a paper titled “Global ocean primary production trends in the modern ocean color satellite record (1998–2015)”. Dr. Rousseaux was a co-author on a related paper published in Earth System Science Data; also, the dataset associated with this publication was published in Pangaea. These two publications arose from a PACE working group that Dr. Rousseaux led during the first PACE Science Team.

**Dr. Natalie Thomas** (sponsor: M. Bosilovich) investigates extreme weather and climate events over the United States using the MERRA-2 reanalysis in support of the National Climate Assessment (NCA) project. The focus of her work has been on heatwaves over the United States. Specifically, she examined the differences between heatwaves occurring primarily during the daytime versus nighttime in different regions of the US. The main goals of the project were to characterize heatwave days of different types over the United States, to determine local and remote climate phenomena associated with them, and to assess if there have been changes in a particular type of heatwave over recent decades. Over 1980-2018, trends in the number of heatwave days per summer were generally stronger for nighttime heatwave days than daytime heatwave days. Dr. Thomas used a composite analysis on a variety of variables from MERRA-2 to identify local and remote mechanisms associated with these two types of heatwave days. In general, daytime heatwave days are associated with negative anomalies in soil moisture and cloud cover and positive anomalies in sensible heating. Nighttime heatwave days are linked with increased cloud cover and humidity, and in some regions low-level temperature advection as well. Dr. Thomas attended the American Meteorological Society annual meeting in January 2020 and gave a talk titled “Mechanisms associated with Daytime and Nighttime Heat Waves over the United States,” and she submitted a related manuscript with several GMAO co-authors to the Journal of Applied Meteorology and Climatology in March 2020.

Dr. Thomas plans to continue with this heatwave research, and investigate connections between various climate teleconnections and heatwaves over the US. Specific research questions will include whether there is regional variability in the influence of remote processes on heatwaves in the US and whether teleconnections have different effects on the distinct heatwave types. She plans to apply the results to better understand the subseasonal predictability of heatwaves, and intends to expand on these topics to investigate the large-scale weather associated with other extreme events relevant to the NCA.

**Dr. Brad Weir** (sponsor: L. Ott) works on assimilating atmospheric CO2 observations into the GEOS-5 data assimilation system and developments to GEOS-5. He also participates in research studies aimed at evaluating observations from AIRS, GOSAT, and OCO-2 data using GEOS-5, and applying these to understanding the carbon cycle. This year, Dr. Weir submitted a paper on estimating carbon fluxes to Environmental Research Letters; this work represents a significant improvement over previous carbon fluxes used in GEOS and will be a vital part of an upcoming reanalysis of CO2 derived from space-based measurements.

Dr. Weir is PI as part of the science team of NASA’s Atmospheric Carbon and Transport – America (ACT-America) Earth Venture Suborbital 2 (EV-2) program, which received funding for its proposal. This work will build two-dimensional transects of CO2 by assimilating in situ aircraft measurements into the GEOS model. Known as “curtains”, these 2D transects will be, and have been, used to evaluate retrievals of column CO2 from the Orbiting Carbon Observatory 2 (OCO-2) mission and diagnose GEOS boundary layer heights and frontal genesis properties. Also, as part of work on constituent data assimilation, Dr. Weir submitted a project proposal where participants would work on using artificial intelligence and machine learning methods to accelerate the next generation of ensemble based assimilation techniques. This proposal is for a project at the Frontier Development Laboratory, which is a public-private partnership of NASA and several companies leading in technology innovation (e.g., Google, IBM, etc.).
prevent divergence of the HB procedure, that mechanism cannot operational algorithm does have a Nw-adjust mechanism to (2011), and even divergence of the HB procedure. Although the to result in an excessive growth of the S(r) integral (Grecu et al. This systematic behavior, unless properly accounted for, tends freezing level due to evaporation and coalescence processes. Size Distribution (DSD) tends to significantly decrease below the simulations suggest that the normalized intercept in the Drop Nw parameterizations. Specifically, cloud resolving model rates was, among other factors, a consequence of suboptimal parameterizations. It was also found that the Hitschfeld Bordan (HB) retrievals (Grecu et al. 2016) tend to exhibit a bimodal distribution consisting of either retrievals with very large systematic errors in convective precipitation retrievals revealed that deep convective reflectivity profiles are the most difficult ones to explain, given the current combined algorithm parameterizations. It was also found that the Hitschfeld Bordan (HB) retrievals (Grecu et al. 2016) tend to exhibit a bimodal distribution consisting of either retrievals with very large precipitation rates on the ground or very low precipitation rates. They hypothesized that the bimodal distribution and the inability of the algorithm to produce intermediate precipitation rain rates was, among other factors, a consequence of suboptimal Nw parameterizations. Specifically, cloud resolving model simulations suggest that the normalized intercept in the Drop Size Distribution (DSD) tends to significantly decrease below the freezing level due to evaporation and coalescence processes. This systematic behavior, unless properly accounted for, tends to result in an excessive growth of the S(r) integral (Grecu et al. 2011), and even divergence of the HB procedure. Although the operational algorithm does have a Nw-adjust mechanism to prevent divergence of the HB procedure, that mechanism cannot prevent the derivation of a large number of less likely solutions that exhibit large increases in retrieved rain rates toward the ground. A better solution is to adjust Nw not only through rescaling, but also by changing the slope of the Nw profiles as suggested by cloud resolving simulation. Such a procedure, not implemented in the operational algorithm yet, was developed and extensively tested using a large set of cloud resolving simulations. The plan is to implement this procedure into the official algorithm under current GPM funding.

Dr. Mei Han (sponsor: S. Braun) applies satellite-based observations from NASA satellites (GPM and TRMM), numerical models (WRF), and reanalysis data (MERRA) to study precipitation associated with extratropical cyclones over ocean and land, and evaluates the performances of cloud and precipitation models and retrieval algorithms in the middle latitudes. This year, Dr. Han was a Co-investigator on the NASA IMPACTS (Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms) project. This Earth Venture Suborbital-3 project is a collaboration program between universities, NASA centers, and NOAA. The purpose of the project is to improve snowfall remote sensing interpretation and model prediction abilities. During year 2019-2020, the project went through a preparation phase and conducted its first year field campaign.

In the preparation phase, Dr. Han participated in the dry runs as a forecaster from October -November. The primary field operation took place at NASA Wallops Flight Facility, VA, from Jan 15 - Feb 29, 2020; ten science flights were successfully carried out. Two research aircrafts, ER-2 and P-3, carried in-situ and remote sensing instruments to measure microphysical properties and thermodynamic environment of snowstorms. From Feb 4 – 21, Dr. Han worked at the campaign operation center, when five of the ten science flights occurred. Working with a group of forecasters, Dr. Han prepared and presented daily briefings and monitored the real time change of the weather and forecast. She worked with the mission scientists to facilitate the flight plans. During the science flights, she monitored the weather and flights, and supported the data exchange between the ground and flight scientists. The first year of IMPACTS campaign collected valuable data sets that will benefit the research to improve the understanding of the snowstorm and its remote sensing. For example, both the P-3 and ER-2 were deployed on Feb 7, 2020, when a bomb cyclone dumped 12 inches of snowfall in parts of New York.
As PI, Dr. Han submitted a proposal titled “A Study of Winter Precipitation over Bering Sea Using GPM, CloudSat, and Numerical Simulations,” in which Dr. Han evaluated multiple satellite precipitation products and found apparent discrepancies over the Bering Sea region. In order to understand the discrepancy and validate retrieved precipitation patterns, she proposed to conduct regional climate analysis and numerical simulations of individual cases. She also planned to apply multiple-level satellite data, including gridded and orbital data, the WRF model, and the Goddard Satellite Data Simulator Unit.

In June 2019, Dr. Han attended and presented at the 12th International Precipitation Conference in Irvine, CA, and participated in four short courses offered by the meeting. This meeting focuses on precipitation remote sensing, water cycle dynamics, and hydrological applications. She learned the multifaceted aspects of precipitation in addition to the cloud and precipitation microphysics and storm dynamics of her expertise. In November, Dr. Han attended the NASA PMM Science Team meeting in Indianapolis, IN, where gave a presentation on a study in which she investigated the precipitation particle sizes in individual cases and globally with 5 years of GPM data. Her comparison highlighted that the two datasets agree qualitatively in terms of the contrast between ocean vs. land, and geolocations; however, the particle sizes in DPR is generally 0.1 – 0.2 mm larger than those in CMB. The differences vary according to latitudes, ocean vs. land, and stratiform vs. convective. The zonal mean and seasonal variation of particles sizes also bear large contrasts between the datasets at multiple vertical levels. Differences between the two datasets may lay deep in the JAXA DPR algorithm and NASA combined algorithm. During the PMM Science Team meeting, working group meetings by the algorithm teams and the particle size working group have highlighted inconsistencies in the algorithm designs that may lack scientific evidence and understanding.

After the November PMM science team meeting, when the limitation of the current DPR retrieved particle size parameters was discussed, Dr. Han switched the research topic to focus on the NASA combined algorithm (CMB) only. She studied individual case represent 5 different climate regions and examined the global climatology analysis of precipitation particle sizes with 5 years of CMB data. She is currently preparing a manuscript to summarize this study. Dr. Han continued conducting research and writing the manuscript of a study focusing on the global precipitation particle sizes and their climatology. She used products generated by two types of algorithms by the GPM team. This research analyzes the global patterns of the geolocation of precipitation particle sizes, which is largely related to precipitation rate and regional climate. With the unique capability of the GPM satellite, it shows the vertical variation of the particle sizes and contrasts between stratiform and convective precipitation, which provides insights to storm dynamics and microphysics. She also compares the latitudinal and seasonal variations of the precipitation particle size and differences between the JAXA DPR and NASA combined algorithms. In the first half year, she focused on comparing theory and formulations of the two algorithms.

In other work, Dr. Han participated in NASA Center for Climate Simulation (NCCS) Python courses since November 2019. As a well-supported open source computer language, NCCS strongly suggests scientists to adopt using Python in their research. Since working from home during the COVID-19 pandemic, she has regularly attended these courses, and has successfully conducted research analysis for her current project using Python.

Dr. Xiaowen Li (sponsor: S. Munchak) uses the Goddard Cumulus Ensemble (GCE) model and satellite/field campaign observations to study cloud microphysics and dynamics using high-frequency passive microwave instruments. This year, the Weather Research and Forecasting (WRF) model has been used to simulate a Mesoscale Convective System case during the Mid-latitude Continental Convective Clouds Experiment (MC3E). The model can largely reproduce the storm evolution over a 24-hour time period with realistic surface rainfall amount. The convective/stratiform ratio remains too high compared with the observations. The hypothesis Dr. Li and team are exploring is the coalescence coefficients and terminal fall velocity of ice-phase hydrometeors (ice crystals, snow, and graupel). They also added sensitivity tests with near-surface wind shear through nudging of the domain-mean wind profiles. Figure 1 shows comparisons of evolution of the surface rainfall for observations (upper row), two sensitivity tests using SBM scheme (middle two rows), and Morrison bulk two-moment scheme (bottom row). The model results are used as input to a GPM satellite simulator for dual-frequency radar and microwave imager. The simulated satellite observables are been compared statistically with GPM observations described in the next item. In addition, selected results from MC3E case simulations have been provided to their collaborator, Dr. Ian Adams, for 3D radiative transfer calculations using the Atmosphere Radiative Transfer Simulator (ARTS). This will be used for evaluating future satellite instrument designs, and studying impacts of ice crystal shapes on polarized microwave observations.
The Mesoscale Convective Systems (MCSs) contribute to the large amount of surface rainfall during the warm seasons in both the continental US and western Africa; they are also associated with tornadoes, hail, flash floods, and dust storms. Five-year GPM observations were analyzed with MCSs identified and categorized using the combination of radar and microwave imager. The unique capability of the dual-frequency radar onboard GPM satellite allows for searching for signals of microphysical processes. Dr. Li and team have found clear indication of ice-phase particle density changing with height, as well as different characteristics of dual-frequency differences in the convective and stratiform regions. Furthermore, some preliminary indications of a transition zone between the convective and stratiform region also have been identified.

In the coming year, given that there are concerns of using attenuation-corrected radar reflectivity to study ice-phase microphysical processes due to the large uncertainty introduced during data processing, Dr. Li and team plan to redo all analyses using un-corrected radar signal, as well as individually processed GPM products.

**Figure 1. (Provided by X. Li.)**

![Surface Rainfall Validation: The first row is the observed rainfall in mm/day, increasing in time from left to right. The third row is model simulated surface rainfall, where SBM_control (second row) is the controlled skin scheme simulation. SBM_storm snow (third row) represents the best result by simultaneously modifying various processes; Morrison (fourth row) is the Morrison two-moment bulk scheme simulation.](image)

Dr. Liang Liao (sponsor: R. Meneghini) conducts research on a variety of topics associated with airborne and spaceborne weather radar analysis generally and the TRMM Precipitation Radar (PR) and GPM Dual-Wavelength Precipitation Radar specifically. This year, the uncertainties in the estimates of snow parameters associated with assumed particle size distribution (PSD) were examined through measured PSD data, the goal being to select the appropriate PSD model for the snow parameters of interest. For the gamma PSD model, Dr. Liao found that the best agreement between the estimated and PSD-derived (or truth) snow parameters is achieved if the shape factor of the gamma distribution is fixed at a value of zero.

To explore the capability of dual- and multi-frequency radar for the identification of snow, rain and mixed-phase hydrometeors, Dr. Liao and team conducted theoretical model simulations of dual-wavelength radar and multi-frequency radar. The preliminary results show a very promising means that could be potentially developed to distinguish hydrometeors’ phases. In another study, she and her team simulated the attenuation of V-band radar signal due to oxygen while propagating through atmosphere, the goal being to develop a V-band radar system comprising three slightly different frequencies, with one frequency chosen within oxygen band and the other two just outside the band. The use of the triple frequencies that separate with equal frequency differences is to mitigate influences of water vapor, cloud and precipitation on estimation of oxygen attenuation, since attenuation caused by oxygen is closely related to the surface air pressure. Several combinations of the triple-frequency systems have been tested through historical sounding data and general circular model products. Their results reveal that the triple-frequency V-band radar, if the frequencies are properly chosen, is not only capable of precisely measuring the surface air pressure in clear sky but also works fairly well in the presence of cloud and precipitation.

With use of ∼215,000 one-minute measurement data of droplet size distribution (DSD) of rain collected during several NASA-sponsored field campaigns, the relationships between rainfall rate, mass-weighted diameter and normalized intercept parameter of the gamma DSD were studied. Based on the simulations of the gamma DSD model, results showed that these parameters are closely inter-related, and that the ratio of rain rate to intercept parameter is solely a function of Dm, independent of the shape factor of the gamma distribution. Furthermore, the model-produced ratio agrees well with those from the DSD data. An analysis of two-parameter relationships reveals that rain rate and mass-weighted diameter are moderately correlated, while normalized intercept parameter and mass-weighted diameter are negatively correlated; however, normalized intercept and rain rate are uncorrelated. For the application of the Ku- and Ka-band dual-frequency radar for the retrieval of the DSD bulk parameters as well as the specific radar attenuations, the study was conducted in relating the dual-frequency radar reflectivity factors to the DSD and attenuation parameters. In the coming year, current studies will continue and...
new fields will be explored where the GPM radar algorithms can be improved and enhanced.

**Dr. Jaiin Jong (Roger) Shi** (sponsor: S. Braun) analyzes the representation of the vertical structure of the Saharan Air Layer (SAL) over northern Africa and the eastern Atlantic using MERRA-2 and NU-WRF. The Saharan Air Layer (SAL) is a warm, dry, and often dusty isentropic layer that results from intense surface heating and dry convection over the Saharan Desert. The SAL is critical to the formation of both the African easterly jet and African easterly waves, which directly impact the weather of northern Africa and downstream tropical cyclogenesis. Dr. Shi's investigation characterizes the structure of the SAL as represented in the NASA Modern Era Retrospective-analysis for Research and Applications (MERRA-2) global analyses with the Goddard Chemistry Aerosol Radiation and Transport (GOCART) at 0.5°x0.625° grid resolution and in the NASA Unified WRF (NU-WRF) model, including real-time aerosol-cloud-radiation coupling with a 3x3 km grid resolution. Using these model data sets, he investigated how the vertical structure (of dust and thermodynamic properties) of the SAL evolves during its transit from northern Africa to the eastern Atlantic. Dr. Shi and his team aim 1) to understand the capabilities of MERRA-2 and NU-WRF to reproduce observed thermodynamic and aerosol structures, and 2) to reveal the diurnal and seasonal variation of the WML/SAL and the Saharan dust distribution.

Following the detection algorithm of Nicholls and Mohr (2019) to analyze the MERRA-2 data for a 7-year (2011-2017) period, Fig. 1 shows Hovmöller diagrams that depict the seasonal and diurnal variations of SAL. The SAL is deeper and with more dust in summertime than in wintertime (Fig. 1a). Total dust loading and depth of SAL in summertime (JJA) are roughly twice as those in wintertime (DJF). Figs. 1c and 1d show the strong diurnal variation on both SAL top and base during wintertime but only on SAL base during summertime. This results in the largest SAL depth between 9-hr and 18-hour local time during the summertime and between 0-hour and 9-hour local time during the wintertime (Fig. 1b). (Reference: Nicholls, S.D. and K. A. Mohr, 2019: An Automated Detection Methodology for Dry Well-Mixed Layers. Journal of Atmospheric and Oceanic Technology, 36, 761-779.)

In related research, NU-WRF with real-time aerosol coupling was integrated from 00UTC 19 Aug. 2013 for 13 days. Results from the NU-WRF simulation were then compared to MERRA-2 global retrospective-analysis. Fig. 2 shows the time series of area-averaged (50 by 50 box) profiles of dust, potential temperature, and dust over land (50-100W and 200-250N) and over ocean (300-350W and 200-250N). Over land (Figs. 2a and 2b), the potential temperature field was characterized by stable stratification near the surface at night and in early morning hours, but showed a rapid transition to a deep well-mixed boundary layer just after noon as well as an equally rapid transition back to a low-level stable layer around 2100 Local Standard Time for the area between 5-10 deg west. Surface warming and dust emission appeared to be stronger with the top of SAL reaching higher altitude in MERRA-2 than in NU-WRF, especially during the last three days of NU-WRF simulations. Over ocean (Fig. 2c and 2d), both NU-WRF and MERRA-2 produced a stronger capping inversion above the marine boundary layer and somewhat lower stability within the SAL (greater spacing of isentropes).
In the coming year, Dr. Shi will continue to work on the statistical analysis of the representation of the vertical structure of the SAL over northern Africa and the eastern Atlantic using MERRA-2 and NU-WRF with real-time aerosol coupling.

**Figure 2: Data analysis comparison between NU-WRF and MERRA-2.** (Provided by J. J. Shi.)

In the coming year, Dr. Shi will continue to work on the statistical analysis of the representation of the vertical structure of the SAL over northern Africa and the eastern Atlantic using MERRA-2 and NU-WRF with real-time aerosol coupling.

**CODE 613: CLIMATE AND RADIATION LABORATORY**

Dr. Nayeong Cho (sponsor: L. Oreopoulos) creates updated versions of the International Satellite Cloud Climatology Project (ISCCP), Moderate Resolution Imaging Spectroradiometer (MODIS), and CloudSat/CALIPSO dataset, and then leverages on the simultaneous availability of the ISCCP and MODIS retrievals over the last fifteen years to create a Unified Weather State dataset. This year, Dr. Cho has studied to improve characterization of horizontal hydrometeor variability and its vertical overlap as inferred form the latest 2C-ICE, 2B-CWC-RVOD products. She and her collaborators focused on evaluating existing hydrometeor generators. She completed the COSP input dataset for its accessibility to users, which can be accomplished by comparing the statistical properties of two sets of simulated CPR and CALIOP fields.

Dr. Cho is also part of the MEaSUREs project to produce a dataset of MODIS cloud regimes. She has been collaborating with Dr. Jackson Tan (USRA), who had processed a MODIS L3 equal area dataset for the entire MODIS record and had started to analyze k-mean clustering runs. To determine the Global MODIS Cloud regime, a K-mean clustering algorithm was used, representing Global Cloud types based on joint cloud top pressure (CTP) and cloud optical thickness (COT) histogram at 1-degree. She has conducted many experiments to find the best global cloud regimes by varying the number of regime numbers or sampled dataset. Criteria for choosing the best set of centroids is also important, so she is determining the criteria to have global Cloud regime. She also completed the MODIS cloud regime dataset for its accessibility to users. These datasets were recorded in HDF5 format, the data period is 2003 – 2018, and the grid resolution is both Equal-area and Equal-angle.

This year, Dr. Cho co-authored two papers, one published in Journal of Geoscientific Model Development and the other published in Journal of Geophysical Research-Atmosphere. At the 2019 AeroCom/AeroSat annual meeting in BSC Barcelona, Spain, in September, she presented her research. In November, she attended the MEASURES project meeting. This project aims to create global satellite datasets to examine synoptic and mesoscale variability using ISCCP and MODIS joint cloud histograms. In December, she attended the 2019 AGU Fall meeting in San Francisco, CA, where she presented on her research, and was a co-author on two other presentations, led by Dr. Dongmin Lee and by Dr. Lazaros Oreopoulos. She attended the CloudSat/CALIPSO Science Team meeting in Boulder, CO in March 2020, where she learned about the updated version of products and increased her knowledge on the parameters of generator’s subcolumns with regard to the overlap of cloud and the variability of hydrometeor amounts from the CC data.

Dr. Verity Flower (sponsor: R. Kahn) is a volcanologist and atmospheric scientist who uses satellite-based remote sensing data to monitor and investigate global volcanic eruptions occurring in the NASA EOS era (2000-present). Dr. Flower’s volcanic assessment technique (Volcanology from Space) incorporates plume particle property assessments from the Multiangle Imaging SpectroRadiometer (MISR), lava flow intensity and extent from the MODerate resolution Imaging Spectrometer (MODIS) and sulfur dioxide (SO2) emissions using the Ozone Monitoring Instrument (OMI). By tracking variations in these volcanic processes, the underlying geological dynamics can be inferred. In 2019, Dr. Flower authored papers exploring the dynamics of volcanic eruptions in Kamchatka (Flower & Kahn, 2020) and Iceland (Flower & Kahn, in review). She presented her work at the NASA Solid Earth Science Team Meeting held in San Diego, CA in November 2019.
In other research, Dr. Flower was involved in response efforts to multiple volcanic eruptions, including Raikoke (Kuril Islands) (https://disasters.nasa.gov/raikoke-eruption-2019/misr-plume-heights-and-aerosol-characteristics-2019-raikoke-eruption) and Ulawun (Papua New Guinea) volcanoes in July 2019. She also applied techniques, developed for the assessment of volcanic plumes, to smoke from forest fires throughout eastern Australia from November 2019 through early 2020. An example of the MISR fire plume height retrievals, which she performed for December 16th, were incorporated into an advanced 3D visualization map, and made accessible to the public in collaboration with the NASA Disasters Portal (https://disasters.nasa.gov/australia-fires-2020/nasa-terra-satellite-maps-australia-smoke-plumes-in-3d).

In the coming year, Dr. Flower will be extending her ‘Volcanology from Space’ technique to other active volcanoes around the globe; initially, she plans to investigate the recent eruptive history of Kilauea (Hawaii) and the multiple island volcanoes of Vanuatu (South Pacific). She also will be collaborating on a paper, with her NASA sponsor and colleagues, on the observation and analysis of the 2020 Australian Fire event. She will continue to respond to emergent volcanic events and participate in disaster response efforts with the NASA Disasters Working Group and Applied Science Division.

Dr. Manisha Ganeshan (sponsor: Y. Yang) works collaboratively to improve knowledge on the Antarctic radiation budget. This year, at the 2019 AGU Fall Meeting, Dr. Ganeshan presented new research laying the foundation for a multi-year, comprehensive study geared toward investigating Antarctic surface-cloud-boundary layer interactions at Dome C, Antarctica. She described the effective use of multiple datasets, combining in-situ (e.g., daily radiosondes, hourly surface meteorological observations, surface longwave and solar radiation from Baseline Surface Radiation Network) and satellite (e.g., CALIPSO Lidar Level 2 Blowing Snow product, and Combined CloudSat and CALIPSO 2B-GEOPROF-LIDAR products) observations to explore the impact of sky condition (cloudy, blowing snow, clear) on the atmospheric boundary layer structure and surface radiation at Dome C, Antarctica. Part of this work was presented by Dr. Yuekui Yang in another talk at the CloudSat/CALIPSO Science Team Meeting in Boulder, CO in March 2020; Dr. Ganeshan was a co-author on this presentation.

The article titled, “Evaluation of the Antarctic Boundary Layer Thermodynamic Structure in MERRA2 Using Dropsonde Observations from the Concordiasi Campaign” was published in Earth and Space Science in November 2019. Dr. Ganeshan was lead author in this work, and Dr. Yuekui Yang was co-author. This study highlights the skillful representation of the Antarctic boundary layer thermodynamic structure in MERRA-2. When compared against dropsonde observations from the austral spring 2010 Concordiasi campaign, MERRA-2 has a good representation of the frequency of surface-based inversions (SBIs). However, there is an underprediction of mixed layers and layers without surface-based inversions (No SBIs), particularly over elevated regions of the East Antarctic plateau during conditions of increased lower tropospheric stability. Over West Antarctica, despite an evident cool and dry bias in the lowest atmospheric levels (below 1500m), MERRA-2 performs better in capturing mixed and No SBI layers. With improvements in the parameterization of very stable boundary layers and advances in data assimilation, Dr. Ganeshan and team expect that model biases in the representation of the Antarctic atmospheric boundary layer will be further reduced.

Dr. Ganeshan will continue investigating the impact of sky condition on the surface radiation and boundary layer thermodynamic structure at Dome C, Antarctica, using multi-instrument in-situ and remote sensing observations. She plans to perform a comparative study of observations against model-based reanalysis, with the end goal of improving the representation of Antarctic surface-cloud-boundary layer interactions in models and publishing the research results. Additionally, Dr. Ganeshan will participate as co-I in NASA ROSES MAP proposal, led by Dr. Yuekui Yang, to investigate and improve the representation of blowing snow and Antarctic boundary layer properties in the Goddard Earth Observing System (GEOS) model.

Dr. Charles Gatebe (sponsor: D. Wu) works to advance the knowledge of clouds, aerosols, ecosystem structure and function, snow and ice, albedo, ocean, and feedbacks to climate. Research involves building a well-calibrated and feature-rich airborne dataset on surface bidirectional reflectance distribution function (BRDF), and conducting elaborate experiments and developing new methods to define surface and atmosphere radiative transfer functions. He also works to improve remote sensing retrievals using laboratory, ground-based, airborne and satellite remote sensing.

This year, Dr. Gatebe was a co-author on a Code 613 Monthly Science Highlight “Aircraft data helps satellites estimate the radiative effects of wildfire smoke,” based on his work with the ARCTAS campaign. Additionally, the Cloud Absorption Radiometer (CAR) Science Team and the NASA Goddard Earth Sciences Data

Dr. Gatebe is part of the Snow Albedo Working Group that has developed a draft implementation plan for the SnowEx-Tundra/Boreal Field Campaign in 2021 and beyond. The WG has placed a high priority on acquiring new ground-based, airborne, and spaceborne measurements in Alaska and Northwestern Canada. To date, the ongoing NASA SnowEx project lacks datasets to inform and validate land surface and climate models, especially for simulating snow cover trends, snow albedo feedbacks, and snow-dependent ecosystem processes.

Dr. Gatebe is working on a new paper that demonstrates the simultaneous retrieval of aerosol and cloud optical depth from airborne measurements. He and his co-authors are using CAR measurements, which permit the retrieval of aerosol optical properties above clouds separated into above and below aircraft, plus the cloud optical properties, allowing the quantification of aerosol and cloud properties and aerosol-induced changes to clouds. Also, as mentioned, the coming year will involve work with the Snow Albedo Working Group in developing an implementation plan for the SnowEx-Tundra/Boreal Field Campaign in 2021 and beyond.

Dr. Jie Gong (sponsor: D. Wu) works on developing retrieval techniques and delivery of retrieval products (such as cloud ice water path, cloud top height, ice particle size) of AMSUB/MHS onboard NOAA satellite series. This year, Dr. Gong self-taught on how to run a new radiative transfer model called ARTS, and wrote a proposal to the Rapid Response call using her ARTS simulations and preliminary IceCube observations. She won this proposal and has been working on correcting IceCube Level 0 photon count measurements to eventually deliver the Level 1 calibrated IceCube radiance data to the public in Fall 2020. She is also helping her sponsor, Dr. Dong Wu, conduct some sensitivity tests using ARTS for his SWIRP project. She presented on some of this work at the 2019 AGU Fall meeting; also, a related manuscript should be completed by the end of this Rapid Response project.

Dr. Gong also co-authored a published JGR paper titled “Tropopause laminar cirrus and its role in the lower stratosphere total water budget.” Another co-author was one of her former summer interns who worked with Dr. Gong on her

Figure 1: Release of CAR BRDF Version-2 Data. (Provided by C. Gatebe.)

Figure 1: This figure shows the sensitivity range of ice cloud optical thickness (i.e., IWP) with different measurement techniques demonstrated by collocated passive and active observations (color contours) and model simulations (lines). One can clearly see the observational gap between infrared (IR) and microwave (MM) can be filled by the sub-millimeter (sub-mm) technique. IceCube is the first spaceborne radiometer that takes radiance measurement at 874 GHz, the highest frequency at the sub-mm regime. (Provided by J. Gong)
In the coming year, Dr. Gong plans to publish the IceCube Level 1 data along with user manual documentation and scientific data. At the 2020 AGU Fall meeting, Dr. Gong plans to convene a sub-millimeter technology and science session to encourage communications and expansion of the sub-millimeter community. She also will continue to explore the capability of polarized sub-millimeter techniques for better retrievals of ice microphysical properties using both sub-mm observations (e.g., IceCube) and simulations.

Future plans include the validation of the GMI-retrieved IWP diurnal cycle against ARM ground observations along with the comparison against GEOS-5 output. Dr. Gong will write a paper to report the results. She is preparing a NASA MAP proposal, which is due at the end of June 2020; this proposal will be closely relevant to her current CCST project.

Dr. Daeho Jin (sponsor: L. Oreopoulos) investigates the relationship between precipitation and clouds as well as climate phenomena using the concept of “cloud regime”. Dr. Jin downloaded the newly updated precipitation dataset, IMERG version 06B, and transformed data to the “easy-to-use” format. With this precipitation data, he performed joint analyses of cloud regime and precipitation to reveal further details of tropical convective systems. For example, he performed clustering analyses of clouds by the condition of precipitation rates in order to examine the possibility of improved cloud classification. Dr. Jin also developed a methodology of classifying the aggregates of tropical convective systems by their precipitation characteristics (i.e., by the precipitation amount before and after the MODIS observation, and by the characteristics of aggregate shape. With these results, Dr. Jin attended the PMM science team meeting held at Indianapolis, IN, and the AGU Fall meeting held at San Francisco, CA, where he presented posters at both conferences. Another approach to develop the cloud study using the cloud regime and precipitation data was to investigate the intra-seasonal variability. Dr. Jin performed time-filtering and composite of cloud regimes to investigate how the cloud regimes respond to the Madden-Julian Oscillation. As first author, Dr. Jin published a paper titled “Large-scale characteristics of tropical convective systems through the prism of cloud regimes” in the Journal of Geophysical Research: Atmosphere. This paper showed that, at 1-deg resolution, large synoptic convective systems tend to have about 30% of the convection core area and 50% of anvils in terms of occupying area.

Dr. Jin implemented the methodology of providing the most optimized initial condition, k-means++, which effectively...
shortened the number of iterations to be converged. In addition, he also implemented new criteria (Calinski-Harabasz Criterion and Davies-Bouldin Criterion) to help the most optimized selection of clustered results among several trials.

Additionally, Dr. Jin is developing an idea how to utilize the cloud observation of geostationary satellites, and submitted a proposal as PI in response to the call from Earth Science Research from Operational Geostationary Satellite Systems.

Upcoming plans include searching for the possibility of a combined regime of cloud and precipitation, the objective being to investigate the coupling of specific cloud and precipitation patterns. Dr. Jin also will examine the seasonal and interannual variation of cloud occurrence using the concept of cloud regime, and the indices of measuring the level of organization of tropical convective systems.

Dr. Sergey Korkin (sponsor: A. Lyapustin) develops and supports scientific software for numerical simulation of light scattering and absorption in the Earth atmosphere for remote sensing applications. This year, Dr. Korkin has refactored Dr. Lyapistin’s code for atmospheric transmission. Refactoring includes complete revision of the code, adding the most recent HITRAN database and newer MODTRAN data. Due to the increase in number of points in atmospheric profiles, the height integration was simplified without the loss of accuracy. Also, for the convenience of practical use, transmission of the gas cell was created as a separate tool; this tool is intended to be used for the new NASA digital aircraft gas (ch4) registrator (DAGR).

Additionally, the completely new C/C++ code has been uploaded to GitHub (see https://github.com/korkins/atmospec). By creating his own code from scratch in contrast to using software developed by others, Dr. Korkin has significantly deepened his knowledge in atmospheric spectroscopy. This skill is unique among GESTAR science. The new code was tested against the original one for different atmospheric gases and a methane gas cell transmittance that was provided by the DAGR team. A perfect agreement was reached; however, it was noticed that fine line structure of the oxygen A-band in the new code differ from those reported in literature. Active investigation of this phenomenon is currently underway.

As an expert in atmospheric radiative transfer (multiple scattering with polarization), Dr. Korkin supported two ROSES proposals as a Co-I, both led by Dr. A. Lyapustin: “MAIAC Processing of OCI over Land: High Resolution Aerosol Retrievals and Atmospheric Correction” and “Development of MAIAC processing for Geostationary Observations.” This past year, he also gave presentations at the 18th Electromagnetic and Light Scattering Conference, in Hangzhou, China in June 2019 as well as the SPIE Remote Sensing, in Strasbourg, France in September 2019, the APOLO-2019, in Lille, France in November 2019, and the 2019 AGU Fall Meeting, San Francisco, CA in December 2019. Dr. Korkin was first author on a published conference paper, and a co-author on four other papers, in various stages of publication.

Dr. Korkin continues to improve his skills as a scientific software developer by taking the Python classes offered by the NCCS. He also received USRA’s Learn & Development support to attend the 2019 International Workshop on Software Engineering for Science, Montreal, Canada, May 25-28. At this workshop, Dr. Korkin learned about best practices for software development and modern trends in the scientific software engineering.

Work will continue on studying the surface polarized reflectance using space (CATS) and airborne lidars as well as POLDER data. He plans to publish a paper as a first author. He also hopes to report results at conferences in 2020 and 2021. Dr. Korkin will further broaden his scientific software developer skills and focus on object-oriented programming in scientific applications (SATERN and NCCS classes in Python & C/C++). Further, using his experience in numerical simulation of light scattering, Dr. Korkin plans to support the NASA MAIAC, AERONET, and ozone-monitoring teams as needed (e.g., generating look-up tables, providing software support, serving as co-author or co-investigator).

Dr. Benjamin Marchant (sponsor: S. Platnick) works on the development of MODIS and VIIRS cloud optical products. This past year, his research was focused on the study of multilayer clouds which are important sources of uncertainties in passive satellite sensor cloud retrievals. Since MODIS MYD06 cloud optical products include a multilayer cloud detection flag, he developed a methodology to evaluate this product through comparisons with CALIOP and CloudSat products. His results and conclusions have been summarized in a research paper published in the Atmospheric Measurement Techniques (AMT) journal titled “Evaluation of the Aqua MODIS Collection 6.1 multilayer cloud detection algorithm through comparisons with CloudSat CPR and CALIPSO CALIOP products,” and he presented at the MODIS/VIIRS science team meeting, held in November...
2019. In 2020, he pursued a post-graduate degree in Machine Learning and Artificial Intelligence. He then started to develop a common machine learning-based algorithm to detect cloud thermodynamic phase and multilayer clouds. His main interests lie in Bayesian approaches, in particular Gaussian processes for classification and regressions problems.

Since Dr. Marchant has developed the MODIS MYD06 Collection 6 cloud thermodynamic phase detection algorithm, he also has contributed to the development of VIIRS cloud thermodynamic phase algorithm and to the data record continuity products between MODIS MYD06 and VIIRS CLDPROP. These are described in the user guide released in 2019 titled “EOS MODIS and SNPP VIIRS Cloud Properties: User Guide for the Climate Data Record Continuity Level-2 Cloud Top and Optical Properties Product (CLDPROP).”

The research of Dr. Jackson Tan (sponsor: G. Huffman) comprises three components. First, with the release of the Integrated Multi-satellite Retrievals for GPM (IMERG) V06 algorithm, IMERG V07 will require continued development. Second, an approach to create a unified set of Weather States dataset from MODIS and International Satellite Cloud Climatology Project (ISCCP) observations will be devised, creating a long-term (> 30 years) record for scientific analysis. Third, a combined analysis of precipitation will be conducted, leveraging the detailed insights gained during the creation of each product to achieve an informed understanding of the connections between clouds and precipitation.

The IMERG product is the global gridded precipitation dataset from the Global Precipitation Measurement (GPM) mission. Following the completion of IMERG V06 reprocessing in mid-2019, Dr. Tan wrote two papers with algorithm developers George Huffman (GSFC), David Bolvin (SSAI), and Eric Nelkin (SSAI). One detailed the major change in a component within IMERG V06, published in the Journal of Atmospheric and Oceanic Technology, and the other was on the application of IMERG to study diurnal cycles, published in Geophysical Research Letters. He also co-authored a paper published in the Journal of Hydrometeorology on a potential improvement to how various satellites can be combined. Concurrently, he gave presentations on these subjects in the AOGS Annual Meeting (Singapore), AMS Annual Meeting (Boston), PMM Science Team Meeting (Indianapolis), and a departmental seminar at the University of Maryland. Development work has begun for V07, and Dr. Tan introduced changes to address known issues on the algorithm near orography and to correct for distortion in distributing precipitation values.

Working toward the ultimate goal of producing a dataset of Unified Weather States from the ISCCP and MODIS cloud observations, Dr. Tan collaborated with Dr. Nayeong Cho (USRA) and Dr. Lazaros Oreopoulous (GSFC) to produce and release the latest MODIS Cloud Regimes product. He also began preliminary investigations into the comparison of MODIS Cloud Regimes with its ISCCP counterpart, highlighting inconsistencies that will need to be resolved when unifying them. These inconsistencies were discussed during a meeting at GISS, which led to several action items, some of which have been completed by Drs. Tan and Cho. Concurrently, Dr. Tan has begun investigating the use of the MODIS Cloud Regimes to categorize the evaluation of passive microwave satellite precipitation in order to better understand the underlying processes that caused retrieval inaccuracies.

In investigating the relationship between clouds and precipitation, Dr. Tan examined the viability of developing an IR-based (or cloud-based) precipitation algorithm using machine learning. He tested a multitude of deep learning models and focused on a set of models that appeared to be optimal for this purpose. Thus far, evaluation of this IR precipitation algorithm suggests it is superior to the existing scheme implemented in IMERG, which is due to be replaced in IMERG V07.

In the coming year, Dr. Tan will finalize and optimize the improvement to the algorithm near orography and the correction for the distribution of precipitation rates. Furthermore, numerous pressing issues need attention for V07; Dr. Tan will address them in coordination with the IMERG algorithm team. Simultaneously, an internal analysis of IMERG V06 results with collaborators is ongoing. Dr. Tan also will continue to work with Drs. Cho and Oreopoulous to address the remaining action items resulting from the joint meeting at GISS. Dr. Tan will revisit the investigation into unifying the cloud information with renewed understanding of the differences between MODIS and ISCCP, thereby revealing potential approaches to overcoming the inconsistencies. He also will continue to investigate the use of MODIS Cloud Regimes to interrogate the conditions surrounding passive microwave retrieval deficiencies, potentially leading to algorithmic improvements. Additionally, he will pursue the various deep learning models to build an optimal IR-based precipitation scheme; he also plans to improve his understanding of various deep learning models and learn the various cutting-edge techniques for interpreting and optimizing the outputs.
Dr. Guoyong Wen (sponsor: A. Marshak) works on the radiative transfer of solar radiation in the atmosphere, specifically aerosol in the vicinity of clouds and cloud edge properties. This year, Dr. Wen and his sponsor performed a detailed analysis of Earth Polychromatic Imaging Camera (EPIC) spectral data. They found that the vector composed of blue and near-infrared (NIR) reflectance follows a counterclockwise closed-loop trajectory from 0 to 24 UTC as Earth rotates. This nonlinear relationship was not observed by any other satellites, due to limited spatial or temporal coverage of either low Earth orbit or geostationary satellites. They found that clouds play an important role in determining the nonlinear relationship in addition to the well-known cloud-free land-ocean reflectance contrast in the two bands. The nonlinear relationship is the result of three factors: (1) a much larger cloud-free land-ocean contrast in the NIR band compared to the blue band, (2) a significantly larger difference between cloudy land and cloudy ocean reflectance in the NIR band compared to the blue band, and (3) the periodic variation of fractions of clear land, clear ocean, cloudy land, and cloudy ocean in the sunlit hemisphere as Earth rotates. They also found that the green vegetation contributes significantly to the NIR global average reflectance when the South and North Americas appear and disappear in EPIC’s field of view. The blue and NIR relationship can be useful for exoplanet research. Clouds impose a strong impact on global spectral reflectance, and the reflectance response to a change in cloud cover depends on whether the change is over land or over the ocean. Dr. Wen was first author on a related paper published in Earth and Space Science.

In other research, Dr. Wen and team used the spectrally invariant method to study the variability of cloud optical thickness and droplet effective radius (reff) in transition zones between the cloudy and clear-sky columns observed by Shortwave Array Spectroradiometer Zenith at the Southern Great Plains Central Facility site (SGP C1) and during the Marine ARM GPCI Investigation of Clouds (MAGIC) field campaign. The spectrally invariant method approximates the spectra in the transition zone as a linear combination of definitely clear and definitely cloudy spectra. Their research included the analyses of 22 cloud edge cases from the SGP and MAGIC. The research results were published in a paper Dr. Wen co-authored titled “Cloud Edge Properties Measured by the ARM Shortwave Spectrometer Over Ocean and Land” in Journal of Geophysical Research - Atmospheres.

At the 2019 AGU Fall Meeting, Dr. Wen and team presented results of their research from a detailed analysis of EPIC spectral data, and he co-authored another presentation, which presented an overview of their efforts to characterize and better understand cloud-related changes in aerosol properties as well as cloud properties in transition zones between cloudy and clear skies. These efforts primarily involved the statistical analysis of global datasets of satellite observations and ground-based measurements of shortwave spectrometers. More than half of all aerosol measurements by passive satellite instruments come from near-cloud areas, where clouds and cloud-related processes may significantly modify AOD and particle size. Aerosol optical depth increases systematically with a regional cloud amount throughout the Earth. In contrast, effective particle size can increase or decrease with increasing cloud cover. They also discussed the variability of cloud optical depth and droplet effective radius approaching clear skies.

Plans for the coming year include applying the correction algorithm to both MODIS and VIIRS data for correcting cloud 3D effects and compare the differences. Dr. Wen will continue to analyze spectroradiometer observations from ARM sites and radiative transfer modeling for understanding cloud and aerosol properties in clear-cloud transition zones.

CODE 614: ATMOSPHERIC CHEMISTRY AND DYNAMICS LABORATORY

This past year, Dr. Daniel Anderson (sponsor: B. Duncan) worked on three primary tasks: understanding the impact of oil and natural gas production on air quality on the Gulf Coast, determining the relationship between modes of climate variability and the spatiotemporal variability of atmospheric hydroxyl (OH), and evaluating the GEOS-CF chemical forecast using TROPOMI retrievals.

In support of an interagency agreement between NASA and the Bureau of Ocean Energy Management (BOEM), Dr. Anderson developed multiple case studies to show the capabilities of NASA satellite products and chemical forecasting in estimating the impacts of oil and natural gas production in the Gulf of Mexico on coastal communities. He also used a combination of observations from the Satellite Coastal and Oceanic Atmospheric Pollution Experiment (SCOAPE) field campaign and Lagrangian modeling to show that, during the field campaign, pollution transport from oil & natural gas activities in the Gulf did not worsen air quality in coastal Louisiana. Instead, pollution over the Gulf was primarily due to long-range transport of biomass.
burning emissions from the Yucatan Peninsula and advection of continental pollution from the US.

In close collaboration with NASA sponsor Bryan Duncan, Dr. Melanie Follette-Cook and researchers for Columbia University, Dr. Anderson began investigating the relationship among internal modes of climate variability (e.g., the El Nino Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO)), and the spatiotemporal variability of OH, the primary atmospheric oxidant and methane sink. Using the NASA GMI model, as well as output from models involved in the Chemistry Climate Modeling Initiative (CCMI), Dr. Anderson has shown that ENSO strongly modulates concentrations of OH and some of its precursors over large areas of the tropical Pacific, while Northern Hemispheric modes of climate variability and monsoons have more localized but still strong effects. They also analyzed satellite retrievals of CO from MOPITT and water vapor from AIRS, confirming the relationship between these OH sources and sinks and ENSO. A paper based on these results is being written and will be submitted to Atmospheric Chemistry and Physics.

As part of a team evaluating the GEOS chemical forecast (GEOS-CF), Dr. Anderson has evaluated the model’s ability to accurately capture the NO\textsubscript{2} distribution in the model using retrievals from the TROPOMI instrument. He has shown that, in the model, tropospheric NO\textsubscript{2} is within 10% for all seasons in the United States, low by 30-40% over Europe during the winter and spring but within 10% during the other seasons, and high by 30-40% over eastern China throughout the year. In addition, he has shown that NO\textsubscript{2} is overestimated in the model over biomass burning regions, suggesting that emissions are too high and/or there are deficiencies in the model chemistry.

Going forward, Dr. Anderson will work toward understanding the relationship between OH, its drivers, and large-scale dynamical features through publication of his current research, and eventually attempting to develop a satellite-based proxy for OH involving these dynamical drivers. Additionally, he will expand his evaluation of the GEOS-CF model to include formaldehyde and proxies for ozone production. Finally, he is seeking funding to help train countries in Sub-Saharan Africa on the use of the GEOS-CF model and other NASA resources to improve their understanding of the drivers of local air quality.

**Dr. Melanie Follette-Cook** (sponsor: S. Uz) works on two tasks. For her first one, she develops webinars and conducts training sessions on use of satellite data for air quality applications under the NASA Applied Sciences ARSET project. The goal of ARSET is to increase utilization of NASA remote sensing data sets among air quality scientists at universities, other federal agencies, state agencies, non-governmental organizations, and foreign entities. Course content is based on collaborative research on tropospheric chemistry observations from satellites to be conducted between Dr. Follette-Cook and civil servant scientists in the Code 614 at Goddard.

In late May 2019, Dr. Follette-Cook and colleague Dr. Pawan Gupta (MSFC/USRA) organized and instructed a NASA Applied Remote Sensing Training (ARSET) three-session advanced webinar series entitled “High Resolution NO\textsubscript{2} Monitoring from Space with TROPOMI.” Preliminary estimates indicate there were 553 participants representing over 400 organizations and 76 countries. This course was supported by Brock Blevins (614/UMBC), Elizabeth Hook (613/SSAI), and Selwyn Hudson-Odoi (614/UMBC). In this advanced webinar, attendees learned about current applications using OMI NO\textsubscript{2} data, and how to access and analyze OMI and TROPOMI data. In June 2019, Dr. Follette-Cook presented a poster titled “Capacity Building with NASA’s Applied Remote Sensing Training Program” at the TEMPO Science Team Meeting in Madison, WI.

Drs. Follette-Cook and Gupta organized and conducted a NASA ARSET two-day in-person training entitled, “Application of Satellite Observations for Air Quality and Health Exposure” in October 2019. This training was held before and after the TEMPO Health Applications Conference, and was in partnership with University of Alabama - Huntsville, and NASA MSFC. Additionally, Drs. Follette-Cook and Gupta were prepared to conduct a NASA ARSET three-day in-person training in March 2020; however, this was postponed due to travel restrictions imposed due to the COVID-19 pandemic. They plan to reschedule this training when restrictions are lifted.

In the coming year, Dr. Follette-Cook hopes to conduct a three-day in-person training at the EPA, Research Triangle Park, Durham, NC. She will also conduct and assist in two upcoming webinars. The first is an introductory webinar on observing changes in air quality using remote sensing observations. This webinar is in response to media and other stakeholder interest in recent observed changes in air quality coinciding with decreases in economic activity as a result of the COVID-19 pandemic; this is planned for May 2020. The second is a two-hour webinar on how end-users can make the transition from air quality relevant products from MODIS to those from VIIRS. This webinar is tentatively scheduled for August 2020. She will also assist in future ARSET trainings.
**Dr. Melanie Follette-Cook** (sponsor: B. Duncan) works on a second task in which she oversees the performance and evaluation of meteorological and chemical simulations of the four DISCOVER-AQ campaigns. She uses model output, along with observations made during DISCOVER-AQ, to diagnose and characterize the relationship between column quantities and surface concentrations during the four DISCOVER-AQ deployments. She also assists with evaluating suborbital and satellite retrievals of NO2, as well as derived global surface products.

Dr. Follette-Cook continued work on the Aura/ACMAP-funded project titled “Deriving Surface NO2 from Orbital and Suborbital Observations: Maximizing the Use of Current and Future NASA Data for Tropospheric Composition and Air Quality Studies” (PI: Lok Lamsal, 614/USRA). She also worked on evaluating high-resolution model output for three of the four DISCOVER-AQ deployments (Maryland, California, and Colorado) and managed the design, development, and evaluation of a simulation for the Texas deployment. These model simulations are being evaluated with respect to chemistry (e.g., NO2), and meteorology (e.g., surface temperature, winds, boundary layer height) for use in both retrieval algorithms and for the estimation of surface NO2 from airborne column observations.

In addition to model evaluation, Dr. Follette-Cook is evaluating NO2 vertical column densities (VCDs) from the GeoTASO (flown during the KORUS-AQ campaign), GCAS (flown during the Texas and Colorado DISCOVER-AQ deployments), and ACAM instruments (flown during the Maryland and California DISCOVER-AQ deployments). VCDs from these remote sensing instruments are being evaluated against surface column observations by Pandora instruments, and in-situ aircraft observations. Results from this work were presented by co-investigators at the AMS 2019 Joint Satellite Conference in Boston, MA (Sep 28 - Oct 4, 2019), the Community Modeling and Analysis System (CMAS) meeting in Chapel Hill, NC (Oct 26-28 2019), the AGU Fall Meeting in San Francisco, CA (Dec 9-13, 2019), and the AMS 2020 Annual Meeting in Boston, MA (Jan 12 - Jan 16, 2020). In the coming year, Dr. Follette-Cook will continue work on this project and will contribute to several manuscripts currently in development.

**Dr. Hiren Jethva** (sponsor: O. Torres) performed a variety of tasks throughout this year. He worked on the aerosol correction in ozone-sensing algorithms, developed software related to aerosol layer height, performed data analyses, and prepared a proposal. Dr. Jethva was given a task to simulate satellite radiances at the UV wavelengths for the joint Ozone-Aerosol atmosphere. The goal was to develop an empirical aerosol correction method, based on the simulation results, for use in the ozone remote-sensing algorithms of OMI, OMPS, and TOMS. He carried out extensive radiative transfer simulations of satellite radiances for a wide variety of ozone columnar amounts and aerosol parameters, which required a great deal of organizing radiative transfer runs, producing output, and subsequently reading/analyzing the results. These simulations were intended to analyze the effect of absorbing aerosols (e.g., carbonaceous smoke and mineral dust) on the satellite-measured UV radiance in the presence of ozone. In the process, a linearized model was derived to correct the spectral radiance for the aerosol effects. The empirical method for aerosol correction derived, based on Dr. Jethva’s work, will be implemented into the next processing of the OMI ozone data product. At present, he is drafting a manuscript describing these results.

Dr. Jethva took on a significant task of developing modules for aerosol retrievals from the TropOMI sensor onboard Sentinel5-P platform. He prepared and thoroughly tested a new application that delivered retrievals of aerosol layer height retrievals from the Oxygen-B band observations taken from the TropOMI sensor. He created aerosol look-up tables for smoke and dust models, a new Level 1B reader, and a retrievals subroutine, which was integrated into the original near-UV aerosol algorithm application. Additionally, he created the above-cloud aerosol algorithm/app for TropOMI and later upgraded it by including pixel-level uncertainty fields. Both modules are now ready and have been delivered to the team members for their integration into the mainstream algorithm, TropOMAER (NASA’s TropOMI aerosol algorithm).

Other work involved an analysis of the Aug 2017 British Columbia and Jan 2020 Australian Wildfire PyroCb events. PyroCb, or pyrocumulonimbus, is a fire-augmented thunderstorm that can introduce biomass-burning emissions into the lower stratosphere. Dr. Jethva conducted detailed analyses of the two unprecedented PyroCb events on record using satellite observations. In Aug 2017, a wildfire-generated PyroCb smoke cloud ascended into the atmosphere and eventually injected into the lower stratosphere. Using satellite observations from the DISCOVR-EPIC sensor along with radiative transfer simulations, he estimated the mass of aerosols injected into the stratosphere. The research results were used in a first-author manuscript by Dr. Torres, which has been accepted for publication in Journal of Geophysical Research-Atmospheres.
During the last (first) week of Dec (Jan) of 2019 (2020), many wildfire events in the New South Wales, Australia, resulted in several PyroCb events lifting the smoke particles to much higher levels of the atmosphere. Using satellite observations from CALIOP and TropOMI, Dr. Jethva calculated aerosol mass reaching stratosphere for the multi-day, multiple PyroCb events. For this work, he developed a special aerosol algorithm for both cloud-free and cloudy skies, and subsequently retrieved aerosol loading in both conditions followed by the estimation of aerosol mass in the stratosphere. Additionally, he calculated the aerosol index using visible-near-IR observations from the Japanese geostationary platform Himawari-8, and created maps and animation of the PyroCb events for multiple days (see Figure 1).

Work in the coming year will focus on his 2019 Aura Science Team grant, in particular applying the de-polarization method to CALIOP lidar measurements to deduce a global dataset of above-cloud aerosol optical depth followed by its validation against airborne measurements. Also, Dr. Jethva will assist Dr. Torres and team with completing some unfinished work related to the developments of the OMI, OMPS, TropOMI, and EPIC aerosol algorithms. These tasks will include refinements in the algorithms, look-up table calculations, developing new modules, testing, processing, and data analysis.

Dr. Dongchul Kim (sponsor: M. Chin) investigates aerosol using the NASA GEOS-5/GOCART model and multiple observations from space and ground-based remote sensing technique. He leads the high-resolution dynamic dust source function development effort in the NU-WRF modeling system.

Mineral dust is one of the dominant aerosols in the atmosphere that exerts multi-faceted effects on the earth system, including absorbing and scattering sunlight, providing nutrients to ocean and land ecosystems, determining cloud formation, and affecting human health; all of them critically depend on the dust mineral composition, nutrients content, and particle size. The current GEOS model system only includes a single mineral type, whereas the existing studies show a wide range of mineral in soil. In this project, Dr. Kim aims to introduce multiple mineral types to the GEOS modeling system to explore the role of minerals to earth climate and ecosystem.

Dr. Kim is participating in the Anthropogenic dust experiment of AeroCom III project. In this experiment, GEOS model simulation results have been submitted to the AeroCom database. He is also leading a new dust source attribution study (DUSA). The official proposal and diagnostics tables are uploaded to the AeroCom wiki-page for participating modelers.

The DEAD dust emission scheme has been implemented into the NU-WRF model. Dr. Kim conducted the long-term simulations to study the inter-annual variation of dust over the North America domain for April 2005, 2008, and 2009. They analyzed controlling factors for the large variation of dust over West America. These research results were presented at the 2019 AGU Fall meeting.

Dr. Kim will continue investigating aerosols using NASA models and various observations. The mineralogy data has been
implemented to GEOS system, and early results show that the model can successfully handle the new mineral components. He will continue to study the impact of the local and long-range transported dust on the West America dust. Work also will continue on improving NU-WRF model and validating with available observations.

**Mr. Tom Kucsera** (sponsor: M. Chin) supports global and regional modeling and analysis of atmospheric aerosols and trace gases and support NASA-sponsored observational programs. Mr. Kucsera post-processed NASA GEOS5 modeling results for the AEROCOM 3 model inter-comparison project. The control base case results, labeled by the project as AP3-CTRL, are being processed into the strict and required structure that was mandated by the organizing committee and in which all participating researchers must follow to aid in the inter-comparison of the results. This standardized format will eliminate the requirement of dealing with different and model-dependent output data structures and formats. The committee selected 2010 as the control year, which requires that detailed and comprehensive results must be generated. In addition to the control experiment base, the multi-year modeling results from 1980-2018 were post-processed. These 39 years of analyses are being generated and post-processed for the history (i.e., “HIST”) portion of the AEROCOM 3 multi-model inter-comparison.

Mr. Kucsera also processed fire emission products. He generated global daily emission products for a number of chemical species assumed to be emitted and derived from biomass burning data products, in which small-scale-sized fires were included in the analysis. Products were divided by biome type and quantified by the satellite-based and derived GFED 1.4s amounts of area burnt for the years 2016-2018. Simulations were later made with the GMAO GEOS model using these comprehensive biomass burning emissions. Additionally, Mr. Kucsera generated emission products for use in the GEOS5 global simulation model consisting of the emissions of NMVOC and CO2, which were generated from aircraft emission data. The emissions were re-gridded to the GEOS5 model vertical levels using MERRA2 data to determine the time-dependent heights of the GEOS5 model layers. These computed emissions were directly incorporated into the NASA GEOS5 model simulations.

Throughout the year, Mr. Kucsera was a co-author on three research papers published in Atmos. Chem. Phys.: “Observationally constrained analysis of sea salt aerosol in the marine atmosphere,” “Six global biomass burning emission datasets: intercomparison and application in one global aerosol model,” and “Evaluation of NU-WRF model performance on air quality simulation under various model resolutions – an investigation within the framework of MICS-Asia Phase III.” Other work that Mr. Kucsera is responsible for included maintaining the hardware and computer equipment and Linux servers. He and some of his group members met with the super computer management staff from the NASA Center for Climate Simulation (NCCS) to discuss space requirements needed by all members on super computers in order to meet current and upcoming scheduled workload project requirements.

In the coming year, Mr. Kucsera will continue the work on processing multi-year and long-term AEROCOM historical model results as well as generating analyses for the AEROCOM project, which will include the ANTHRODUST analyses. He also will work on acquiring and processing satellite and in situ atmospheric data products.

**Dr. Lok Lamsal** (sponsor: N. Krotkov) manages the operational processing of the operational standard OMI NO2 (OMNO2) product, maintains NO₂ algorithms, implements improvements in the algorithms, conducts test retrievals, and evaluates the product. He has completed the processing, assessment, and distribution of a new version (Version 4.0) of the OMI NO2 product. The processing applies to daily Level-2 (OMNO2) and high-level products, namely gridded global Level 2 (OMNO2G) and Level-3 (OMNO2d) products. These data are publicly available from the NASA’s Goddard Earth Sciences Data and Information Services Center (GES-DISC) and Aura Validation Data Center (AVDC) websites. This new version represents significant advances from the previous version (Version 3.1) that was released a year ago. The major V4.0 updates include: 1) use of a new daily and OMI field of view specific geometry-dependent surface Lambertian Equivalent Reflectivity (GLER) product in both NO2 and cloud retrievals; 2) use of improved cloud parameters (reflective cloud fraction and cloud optical centroid pressure) from a new cloud algorithm (OMCDO2N), which are retrieved consistently with NO2 using a new algorithm for O2-02 slant column data and the GLER product for terrain reflectivity; 3) use of a more accurate terrain pressure calculated by using OMI ground pixel-averaged terrain height and monthly mean GMI (Global Modeling Initiative) terrain pressure; and 4) improved treatment over snow/ice surfaces by using the concept of scene LER and scene pressure. Dr. Lamsal and his colleagues have thoroughly evaluated the product by comparing with previous versions and many other independent measurements. He has prepared a README document and a manuscript describing the product and its validation.
As PI of MEaSUREs NO\textsubscript{2} project, Dr. Lamsal manages the MEaSUREs (Making Earth System Data Records for Use in Research Environments) NO\textsubscript{2} project titled “Multi-Decadal Nitrogen Dioxide and Derived Products from Satellites (MINDS).” The goal is to develop consistent long-term (1995-present) global trend-quality data records of tropospheric NO\textsubscript{2} columns and value-added surface NO\textsubscript{2} concentrations and NO\textsubscript{x} emissions. Dr. Lamsal and his team are applying the approach and algorithms currently deployed for the Version 4.0 OMI NO\textsubscript{2} products, which are based on cloud parameters from a newly developed oxygen dimer (O\textsubscript{2}-O\textsubscript{2}) cloud algorithm. These new NO\textsubscript{2} and cloud algorithms are self-consistent and take advantage of high-resolution information from MODIS-derived BRDF data that accurately describe surface angular reflection. For this, his team is currently adapting OMI NO\textsubscript{2}, cloud, and geometry-dependent surface reflectivity retrieval algorithms to Global Ozone Monitoring Experiment (GOME, 1996-2011) and TROPOsphere Monitoring Instrument (TROPOMI, 2017-present). The follow-up instruments for the algorithm adaptation include SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY (2002-2012)) and GOME-2 instruments on Meteorological operational (METOP) satellites – A (2007-present) and – B (2012-present). Under a separate activity, he is also developing an NO\textsubscript{2} algorithm for Ozone Mapping and Profiler Suite (OMPS) instruments on the Suomi National Polar-orbiting Partnership NPP (2011-present) and the next-generation Joint Polar Satellite System (JPSS-series) (2017-present).

Dr. Lamsal leads an effort to develop an NO\textsubscript{2} product from airborne sensors that participated in NASA’s DISCOVER-AQ campaign in the U.S. and the joint NASA and National Institute of Environmental Research (NIER) Korea-U.S. Air Quality study (KORUS-AQ) in South Korea. Those instruments include ACAM (Airborne Compact Atmospheric Mapper), GCAS (Geostationary Coastal and Air Pollution Events (GEO-CAPE) Airborne Simulator), and Geo-TASO (Geostationary Trace gas and Aerosol Sensor Optimization). A retrieval algorithm for airborne sensors differs from that for satellite sensor in multiple ways; for example, airborne sensors cannot provide solar irradiance measurements that are needed for the Differential Optical Absorption Spectroscopy (DOAS) spectral fitting procedure. To address this issue, the algorithm requires creating reference spectra over a ground site as well as their application results in differential slant column densities (DSCDs). This process requires accounting for NO\textsubscript{2} from the reference site. Other features of the algorithm include air mass factor (AMF) using the VLIDORT model with MODIS BRDF for surface reflectivity and diurnally varying NO\textsubscript{2} profiles from the high-resolution regional model (WRF/CMAQ) for troposphere and from GMI for upper troposphere and stratosphere. The computation of DSCDs has been completed for all the campaigns, and Dr. Lamsal has developed an NO\textsubscript{2} product from these sensors for most of these campaigns. Evaluation of the product and preparation of a related manuscript are ongoing.

Additionally, Dr. Lamsal is the PI of the Aura Science Team/ACMAP grant, “Deriving Surface nitrogen dioxide (NO\textsubscript{2}) from Orbital and Suborbital Observations: Maximizing the Use of Current and Future NASA Data for Tropospheric Composition and Air Quality Studies”. A method to infer surface concentration consists of NO\textsubscript{2} retrievals from OMI requires surface-to-column relationship simulated with a chemical transport model (CTM) to infer surface concentrations. Therefore, he has been heavily involved in modeling work using both the global and regional models. His team’s work with the DISCOVER-AQ observations revealed that several factors complicate the relationship between satellite-observed columns and surface data. For instance, there is a need to characterize the PBL heights to improve the column-to-surface relationship on a day-to-day basis and certainly for an hour-to-hour basis for the geosynchronous TEMPO satellite. Dr. Lamsal also serves as a science and algorithm lead for a recently funded NASA Instrument Incubator Program (IIP) proposal that will develop a new high (spatial) resolution hyperspectral instrument, named Compact Hyperspectral Air Pollution Sensor-Demonstrator (CHAPS-D) (PI: William Swartz, JHU-APL). The CHAPS-D is the airborne demonstration of a space-borne CHAPS prototype instrument. As part of his activity as ESA’s Sentinel-5 Precursor validation team member for the TROPOMI NO\textsubscript{2} product, Dr. Lamsal uses the operational OMI NO\textsubscript{2} Standard Product to assess TROPOMI operational NO\textsubscript{2} product. He has adapted the OMI NO\textsubscript{2} algorithm to TROPOMI data to identify any deficiencies in the operational TROPOMI NO\textsubscript{2} algorithm. Finally, Dr. Lamsal was heavily involved in multiple NASA ROSES proposals, particularly those responding to the Aura call. He contributed to seven different proposals (three as co-investigator and four as collaborator).

Dr. Feng Li (sponsor: P. Newman) works on a task focusing on chemistry-climate interactions, stratosphere-troposphere coupling, and atmosphere-ocean interactions. Using the GEOS-5 model with coupled ocean and interactive stratospheric chemistry as the main tool, Dr. Li investigates how atmospheric processes, particularly stratospheric ozone depletion and recovery, affect the ocean circulation and sea ice, and how oceanic processes influence the atmosphere.
Dr. Li submitted a first-author manuscript titled "Response of Southern Ocean surface temperature to stratospheric ozone recovery" to Geophysical Research Letters. This study investigated the response of the Southern Ocean sea surface temperature to the projected stratospheric ozone recovery in 2080-2099 using the coupled atmosphere-ocean GEOS Chemistry Climate Model (CCM). The model results show that ozone recovery causes warming of the Southern Ocean surface during austral summer and cooling in other seasons. He and his team investigated in detail what causes these Southern Ocean surface temperature changes, and they found that ozone recovery causes a decrease of the Southern Ocean mixed layer depth in austral summer. Thus, heat entering the Southern Ocean is absorbed in a shallower surface layer, leading to warming. Stratospheric ozone recovery also causes a slowdown of the Southern Ocean circulation; as a result, colder deep ocean water is transported to the surface and causes surface cooling outside of summer season. This manuscript will be revised and resubmitted.

This year, Dr. Li presented a talk titled “The coupled atmosphere-ocean Goddard Earth Observing System Chemistry-Climate Model” at the Department of Earth and Space Sciences, Johns Hopkins University. His talk was an overview of his research on atmosphere-ocean-chemistry coupling, and covered four topics: 1) Impacts of interactive chemistry on Southern Hemisphere climate change; 2) Effects of greenhouse gas increase and stratospheric ozone depletion on the Brewer-Dobson circulation; 3) Response of Southern Ocean surface temperature to stratospheric ozone recovery; and 4) Climate impact of stratospheric water vapor feedback. Dr. Li discussed collaborations with Johns Hopkins researchers on climate modeling. For his upcoming work, Dr. Li will conduct and analyze coupled atmosphere-ocean replay simulations to investigate Antarctic sea ice variability.

Dr. Feng Li's (program manager: K. Jucks) second grant is titled "Understanding Stratospheric Water Vapor and Ozone Feedbacks and Their Impacts on Global Warming" (P.O.P.: 3/01/17-02/28/21). For this project, Dr. Li quantifies and constrains the stratospheric water vapor and ozone responses and feedbacks to global warming using the coupled GEOS-5 atmosphere-ocean model and NASA satellite observations.

Dr. Li submitted a first-author paper titled “Stratospheric Water Vapor and its Climate Impact in the Coupled Atmosphere-Ocean Goddard Earth Observing System Chemistry-Climate Model” to Climate Dynamics. This paper investigates the stratospheric water vapor feedback on climate for abrupt CO2 quadrupling with the coupled atmosphere-ocean GEOS Chemistry-Climate Model.
model. A feedback suppression method is used to quantify the stratospheric water vapor climate feedback parameter and the impacts of stratospheric water vapor increases on temperature and circulation. Dr. Li found that increases in stratospheric water vapor change the model’s net climate feedback parameter by 0.11 Wm-2K-1, contributing to 0.5 K (10%), of the global-mean surface warming under abrupt CO2 quadrupling. Further, stratospheric water vapor increases lead to significant impacts on stratospheric temperature and dynamics. The increases induce stratospheric dynamical changes that strongly modify stratospheric cooling patterns. About 30% of the acceleration of the stratospheric Brewer-Dobson circulation under CO2 quadrupling is attributed to the stratospheric water vapor increases. In the troposphere, the stratospheric water vapor feedback plays a role in Arctic amplification and is responsible for 14% of the Arctic warming. It also affects tropospheric circulation, causing a greater poleward shift of the northern hemisphere tropospheric midlatitude jet. His plans going forward include revising the paper on stratospheric water vapor feedback and submitting a manuscript on stratospheric chemical feedback.

**Dr. Jin Liao** (sponsor: T. Hanisco) participated in the FIREX-AQ field campaign, analyzed the data, and supported other projects. She participated in the FIREX-AQ field campaign in Boise, ID and in Salina, AK to study the impacts of wild fires and agricultural fires. She was responsible for the ISAF HCHO, ROZE O3, and CANOE NOx measurements onboard the NASA DC8 during August 8-23, 2019. She helped to examine the comparison of HCHO (i.e., formaldehyde) measurements in the field, and performed a flow calibration, compared HCHO measurements and responded to colleagues’ questions. After the FIREX-AQ field campaign, Dr. Liao carried out lab work by checking calibration deck flow with PICARRO. She checked the HCHO calibration system flows by feeding zero air and CO2 into this calibration system and comparing the calculated concentrations to PICARRO readings. A series of combinations of HCHO meter and air meter flows were tested, and the CO2 concentrations in CO2 cylinder and zero air cylinder were recorded. The results confirmed that the calibration system flow mixing is proper. After the FIREX-AQ field campaign, Dr. Liao began analyzing the FIREX-AQ data to study the evolution of formaldehyde in wild fire plumes, including reviewing the factors that affected the different trends of HCHO enhancement ratios in the wild fire plumes. She found that photolysis is a dominant factor in determining the observed trends of HCHO enhancement ratios. Dr. Liao also calculated the secondary production rates of HCHO and found they have a good correlation with the OH concentrations estimated from the VOC ratios. Dr. Liao continued to support HCHO measurements onboard the UMD Cessna; she calculated the impact of HCHO a priori profiles from different global transport models on retrieving vertical HCHO column over Southeast U.S.; and, she generated L3 TROPOMI HCHO 0.125 deg data for July 2019 for a colleague. Additionally, Dr. Liao participated in the HCHO measurements using the Aeris Technology instrument at the Beltsville-HU site from July to early August 2019.

This year, Dr. Liao gave presentations about her research at these meetings: the 2019 Middle Atlantic Regional Meeting of ACS in late May 2019; the Aura Science Team meeting in Los Angeles, CA, in late August 2019; and, the in-situ measurement group meeting at Goddard (due to the COVID-19 virus, the FIREX-AQ Science Team Meeting (NASA Langley, March 2019) was cancelled). Dr. Liao was a co-author on a paper published in PNAS as well as a paper submitted to Atmos. Chem. Phys.

**Dr. Fei Liu** (sponsor: B. Duncan) works on estimating emissions and trends of SO2 and NOx inferred from Aura OMI satellite data. The new emission estimates will help to improve the performances of climate and air quality models. Dr. Liu plans to continue to develop and augment the anthropogenic SO2 and NOx emission database as well as augment the satellite capability for estimating CO2 emissions based on satellite-based NOx emissions. This past year, Dr. Liu investigated the abrupt declines in tropospheric nitrogen dioxide over China after the outbreak of COVID-19, and her work was reported by NASA Earth Observatory, BBC and other media.

Dr. Liu published a paper titled “Inferring Carbon Dioxide Emissions from Coal-fired Power Plants Using Nitrogen Dioxide Observations from the Space-borne Ozone Monitoring Instrument” in Atmos. Chem. Phys. Coal-fired power plants contribute significantly to global energy-related CO2 emissions, though their emissions at plant level are typically poorly known in much of the world. Dr. Liu developed a novel method to quantify CO2 emissions from individual power plants based on satellite observations of co-emitted NO2. She inferred nitrogen oxides fluxes from individual power plants using Ozone Monitoring Instrument (OMI) NO2 tropospheric vertical column densities by a well-established method. Dr. Liu determined the relationship between NOx and CO2 emissions for US power plants based on the emissions data reported by the Continuous Emissions Monitoring System. This method may be applicable to thermal power plants worldwide, which potentially contribute to an independent verification of
reported CO2 emissions and an estimation of CO2 emissions in countries that do not report emissions.

In August 2019, Dr. Liu attended the 2019 AURA science meeting; in December, she attended the 2019 AGU Fall meeting; and in January 2020, she attended the 2020 AMS meeting. She presented at each of these meetings. Dr. Liu also submitted a NASA ROSES ACMAP proposal that was selected for funding. She proposed to develop merging inventories by combining satellite-derived and bottom-up emission estimates. This proposal was based on her previous work on developing SO2 emission database by combining satellite-based emission estimates and the conventional bottom-up inventory.

Dr. Liu’s upcoming plans include quantifying the satellite-derived NOx emissions from high-resolution CTM model and OMI/TROPOMI NO2 observations. She plans to attend the 2021 AMS annual meeting held in January 2021, and will submit the manuscript about the abrupt declines in tropospheric nitrogen dioxide over China after the outbreak of COVID-19.

**Dr. Junhua Liu** (sponsor: B. Duncan) conducts research to understand the processes affecting atmospheric composition in the troposphere and lower stratosphere, specifically the sources, chemical evolution and transport pathways. She studies the quantifying contributions of stratospheric intrusion, surface biomass emissions and lightning to the observed interannual variations (IAV) as well as trends in tropospheric O3 and precursors over the tropics and mid-latitude, and investigates their interaction with the Earth’s climate.

Dr. Liu is working on her ACMAP project of using a high-resolution model and its various tracer diagnostics to quantify the spatial distribution and vertical extent of impacts of stratosphere – troposphere exchange (STE) on tropospheric ozone interannual variability and trends, radiative forcing, and air quality. Throughout the past year, Dr. Liu conducted a series of diagnostic tests to examine the variations of chemistry and transport processes over the past 25 years in the model including using a stratospheric ozone tracer. The model results indicate the role of the dynamical variations (e.g., Arctic Oscillation) in modulating the IAV of stratosphere-troposphere exchange and in regulating the tropospheric ozone IAV. She submitted a related manuscript “Stratospheric impact on the Northern Hemisphere winter and spring ozone interannual variability in the troposphere” to Atmos. Chem. Phys. in September 2019; she has submitted the revised manuscript. Dr. Liu also worked with Co-I Mark Olsen on examining the ENSO and QBO impact on ozone variability and stratosphere troposphere exchange (STE) relative to the subtropical jets. These results were published in J. Geophys. Res. – Atmospheres in June 2019.

Dr. Liu conducted sensitivity runs for tropospheric O3 LW and SW Radiative Effect (RE) by feeding the ozone fields simulated from MERRA2-GMI run into the offline RRTM. To isolate and compare the effects of temporal changes in IAV of stratospheric input, compared to those resulting from emissions, she ran the radiative transfer module with four different ozone fields: StratO3, emissO3, O3 and 0 ppb. The offline module is set up so that all input fields except ozone remained fixed; thus, differences between two runs of the radiation code with different ozone yield the changes of radiation due to ozone change alone. The results show that RE from tropospheric O3 with stratospheric origin accounts for 40% and 36% of the global tropospheric O3 RE in January and August 2005. The RE from tropospheric O3 with stratospheric origin exceeds even that from emissions and shows dominant contributions to tropospheric O3 RE over regions including subtropical jets, terrain area of Antarctica, and southern ocean in January, and SH subtropical jet regions, the eastern Mediterranean in August.

Dr. Liu also provided support to work on an atmospheric model. She set up a chemistry and aerosol evaluation package for new runs of CCM/CTM. This uses satellite measurement, in-situ observation to generate an evaluation package for major chemical species (including NOx, O3, SO2, CH4, CO) and aerosol (AOD) of CCM/CTM simulations. The chemistry and aerosol evaluation package has been implemented into the CCM model. For the CCM tropospheric chemistry evaluation work, Dr. Liu compared the CCM CO, O3 and NO2 simulations with the latest version of MOPITT CO, OMI/MLS O3 and OMI NO2; she then presented the comparisons during bi-weekly meetings. In other work, she also participated in evaluating the GEOS-CF model. She compared the GEOS-CF O3 analysis with available ozonesonde measurements for year 2018, and performed the GEOS-CF CO analysis with the latest MOPITT CO product.

This year, Dr. Liu was a lead author on one paper currently in review with Atmos. Chem. Phys. Discuss., and was a co-author on a paper published in the Journal of Geophysical Research. In August 2019, she gave a presentation at the Aura meeting in Pasadena, CA, titled “The ENSO and QBO impact on ozone variability and stratosphere-troposphere exchange relative to the subtropical jets.” In January 2020, she gave a presentation “Quantifying the stratospheric contribution to tropospheric ozone radiative forcing” at the AMS meeting in Boston, MA.
Dr. Edward Nowottnick (sponsor: P. Colarco) evaluates Ozone Monitoring Instrument (OMI) aerosol products in the context of the NASA GEOS-5 model and provide Observing System Simulation Support (OSSE) and data analysis for spaceborne and aircraft lidar systems.

This past year, Dr. Nowottnick supported operations of the Cloud Physics Lidar (CPL) for two NASA field campaigns: FIREX-AQ out of Palmdale, CA and IMPACTS out of Hunter Army Airfield in Savannah, GA. He supported the missions by operating the CPL instrument and then processing initial and final CPL level 1 and level 2 data products. Additionally, in late October, the NASA GSFC lidar group had the NASA ER-2 aircraft in Palmdale, CA to fly the well-known CPL coincident with newer lidar instruments from the group that have not yet flown. Dr. Nowottnick served as the lead flight planner for the lidar group and coordinated two ER-2 underpasses of ICESAT2 underpasses using CPL and the new lidar instruments.

In fall 2019, Dr. Nowottnick served as the Operations Officer and Composition Forecast Lead in support of the NASA CAMP2Ex Field Campaign that took place in the Philippines. He led composition forecast training of roughly 10 graduate students from the Manila Observatory. Additionally, as Operations Officer, Dr. Nowottnick assisted with hangar operations, including organizing and managing daily forecasts, flight planning, media day, and maintenance of the NASA P-3 aircraft.

Dr. Nowottnick continued to participate in the NASA Aerosols and Clouds, Convection, and Precipitation (ACCP) pre-formulation study by simulating the performance of candidate lidars that are being considered as part of ACCP architectures. He has developed a simulator code that simulates lidar signals for aerosol layers provided by the NASA GEOS high-resolution nature run, and has performed simulations of cirrus cloud signals for various cloud types.

Dr. Nowottnick was involved with two NASA ROSES proposals that were selected for funding. He is PI on his proposal “Untangling Interactions Between Tropical North Atlantic Dynamics and Saharan Dust Using Observations from the Joint NASA-ESA Aeolus Validation Campaign,” which will utilize observations from the 2021 Convective Processes Experiment - Aerosols & Winds (CPEX-AW) to better determine dynamical controls that enable the long transport of Saharan dust to the Caribbean. Dr. Nowottnick will serve as Co-I on an Instrument Incubator Program (IIP-ICD) proposal “Metasurfaces for Compact, Next-Generation Polarimetric Remote Sensing of Aerosols and Clouds” (PI: Federico Capasso, Harvard University). Dr. Nowottnick will assist with aerosol forward modeling to determine the suitability of the instrument for Earth Science applications.

In the upcoming year, Dr. Nowottnick will continue to perform lidar simulations in support of the ACCP pre-formulation study and will extend his simulator code to include additional new lidars that are being considered as part of the ACCP study. Results from these simulations will be used as input to the Generalized Retrievals of Atmosphere and Surface Properties (GRASP) joint lidar-plus-polarimeter retrievals of aerosols properties. He also will support the Cloud Physics Lidar (CPL) Team by operating the instrument and processing data for the second deployment of the Earth Venture Suborbital (EVS) IMPACTS field campaign slated to commence operations in January 2021.

Dr. Nowottnick will begin supporting his Weather and Dynamics proposal by helping to develop flight modules and participate in forecasting exercises for the CPEX-AW field campaign (note, this is now postponed until 2021 due to COVID-19). Also, he will work with Dr. Federico Capasso to develop aerosol forward modeling capabilities for testing the performance of the compact metasurface polarimeter concept for Earth Science applications.

Dr. Edward Nowottnick (program manager: A. Leidner, NASA HQ) was PI for NASA grant #NNX16AI08G. By utilizing NASA lidar data, assumed aerosol optical properties used in the NASA
GEOS-5 model were evaluated extensively and corrected for biases. New optical properties were used to perform a series of Observing System Experiments (OSE), which will be used to determine optical wavelength and depolarization measurement combinations for use in future NASA spaceborne lidar systems.

Dr. Nowottnick’s 1-D Ensemble Based Variational (1-D EnsVar) aerosol extinction retrieval approach was applied to one year’s worth of Cloud Aerosol Transport System (CATS) data. The results are currently being evaluated using surface Aerosol Robotic Network (AERONET) sunphotometers and aircraft observations of aerosol extinction from the High Spectral Resolution Lidar (HSRL-2). In December, Dr. Nowottnick provided an evaluation of the 1-D EnsVar CATS/GEOS aerosol extinction approach at the 2019 AGU Fall meeting in his presentation “Evaluation of 1-D EnsVar Retrievals of Aerosol Extinction using the NASA CATS Lidar and the GEOS AGCM.” A related manuscript is in progress that details the 1-D EnsVar approach, and it will provide an evaluation of the methodology using ongoing independent observations. After the manuscript is submitted, Dr. Nowottnick will have finalized his work on this grant, as funds expired as of April 2020.

**Dr. Henry Selkirk** (sponsor: N. Krotkov) utilizes observations of atmospheric trace constituents, such as water vapor, ozone and sulfur dioxide, to better characterize their vertical structure and the processes through which they influence the earth’s climate. He manages the ongoing NASA balloon sonde observations program in Costa Rica known as Ticosonde, and supports the NASA OMI science team in validating satellite measurements of SO₂ on a variety of platforms. He also works on validating satellite measurements of water vapor and ozone.

For the period May 2019 through April 2020, the GasLab team at the Universidad de Costa Rica (UCR) acquired 12 Cryogenic Frostpoint Hygrometer (CFH) water vapor profiles and 29 ozone profiles from a total of 29 launches. The team also was able to make 5 CFH flights coinciding with solar occultations by the SAGE-III instrument on board the International Space Station (ISS). These are extremely valuable data for validation of both ozone and water vapor by SAGE-III ISS. In March 2020, travel restrictions due to COVID-19 forced the cancellation of the annual site visit to the Universidad de Costa Rica. Nevertheless, Dr. Jorge Andres Diaz and his team at the UCR GasLab have been able to continue Ticosonde launches without interruption.

Dr. Selkirk gave several presentations related to Ticosonde water vapor findings. The first was a poster presentation titled “Near-Saturation Conditions at the Tropical Tropopause: Results from Ticosonde” at the Aura Science Team Meeting, Pasadena, CA, in late August 2019. He also presented to the SAGE-III ISS Science Team Meeting, NASA Langley Research Center, Hampton, VA, in late October 2019, and at the Annual Meeting of the AMS, Boston, MA, in January 2020. He presented a poster titled “The Vertical Structure and Long-Term Variability of Moisture in the Upper Troposphere and Lower Stratosphere at Costa Rica Using Observations from Satellites, Radiosondes, and Frostpoint Hygrometers and Comparisons with Large-scale Model Simulations.” He also presented on SO₂ findings from Ticosonde at the Sentinel-5 Precursor (TROPOMI) meeting at the European Space Agency’s ESRIN facility in Frascati, Italy, in November 2019. In his talk, “Profiling Volcanic SO2 with Balloonsondes in Costa Rica for TROPOMI Validation- An update,” Dr. Selkirk reported on results from the 66 soundings at Costa Rica made since TROPOMI First Light on November 10, 2017 up through the end of September 2019. Nearly half (30) of the soundings had identifiable notches associated with balloon-sonde passage through volcanic SO₂; the notches began at 2.4 km and were 1.7 km deep. The latter result should prove useful for remote-plumes, and on average sensing retrievals of SO₂ vertical column density (VCD) by TROPOMI researchers.

**Dr. Henry Selkirk** (sponsor: D. Barahona) works on a second task where the goal is to improve the moist physics components in GEOS-5 by analyzing suborbital water vapor and related tracer data, and using these observations to inform improvements to GEOS-5. He works in collaboration with Dr. Donifan Barahona (NASA/GMAO) and Dr. Mark Schoeberl (Science and Technology Corporation). Over the past year, Dr. Selkirk has analyzed the structure of the UT/LS with respect to the tropopause. Results showed that the episodic supersaturation events, which ultimately determine the water vapor content of the stratosphere, occur in the Tropical Tropopause Layer (TTL) generally, but only in the final km below the tropopause. The uppermost layer of the TTL can be referred to as the Tropopause Saturation Layer and can be defined using frostpoint measurements of relative humidity.

Future plans include comparing measurements of moisture in the upper troposphere and lower stratosphere from Ticosonde CFH measurements to values from the MERRA2 reanalysis and GEOS-5 simulations using Dr. Barahona’s two-moment moisture physics. They also will perform a similar analysis but with moisture observations derived from the Vaisala RS41 radiosondes launched at Costa Rica since 2012.
Mr. Stephen Steenrod (sponsor: L. Oman) supports the Global Modeling Initiative (GMI) investigations of chemical and dynamical aspects of the middle and lower atmosphere. He is involved in the development, optimization, multiprocessing, execution, and evaluation of atmospheric modeling codes; the development of diagnostic software for analysis of model output and satellite data; and, the development of general user software to allow simple access to large central databases of model output.

This year, Mr. Steenrod accomplished several milestones related to the GEOS CCM model, including a few major enhancements to the CCM model’s capabilities. The most significant was completing and testing the implementation of the latest version of the FastJX photolysis rate calculation code into the GEOSCCM GMI mechanism, often referred to as CloudJ. This is a major update to the GEOSCCM since the new photolysis rate code calculates the chemical photolysis rates with a much more sophisticated handling of cloud and aerosol optical depths. This new code takes a more statistical approach to calculating the rate by calculating multiple photon pathways through the atmosphere to more accurately represent the effects of sub-grid scale cloud effects. The new rates change the chemical composition enough in places to significantly affect the oxidation properties of the troposphere. Mr. Steenrod is now running simulations of the two different modeling approaches and will be comparing the two methods to the chemical composition data measured during the ATom aircraft campaign.

Mr. Steenrod also modified the GMI chemical mechanism in the GEOSCCM to add in short-lived bromine species and HFC chemistry. Bromine is a very powerful ozone-depleting substance (ODS), much more powerful than chlorine. As such, this mechanism update has important implications for the lower stratospheric ozone profile. The original mechanism accounted for the bromine that is present in the atmosphere from HFCs, bromoform and dibromomethane by adding an extra 5-ppb to bromomethane (CH3Br). This gives the proper amount of bromine present in the atmosphere, but the lifetime of CH3Br is different than the HFCs; thus, the bromine available for ozone depletion is at a lower altitude than when modeling the HFCs and short-lived species individually.

Mr. Steenrod continued to support the offline GMI CTM, which continues to be used for several projects, mainly for a long-running application of keeping the GMI CTM simulation near real-time. Several groups use this model run for various projects, including its use as first-guess fields for satellite retrieval work for NO₂. Mr. Steenrod also helped rerun the multi-decadal GMI CTM simulation, which included many updates to boundary conditions and patches to the code, which patched several minor bugs through the intervening years. This rerun version will now assume the duties of the near real-time simulation. Additionally, Mr. Steenrod used the GMI CTM for a collaboration with the ATom project scientist. This unique configuration of the offline model uses many of the aircraft-measured constituents as initial conditions. The model is then run for one day with no transport or emissions. The goal is to identify shortcomings in the CTM mechanism and ultimately improve the representation of atmospheric oxidation in the model. They hope to identify missing or misrepresented processes, especially in the troposphere.

In other responsibilities, Mr. Steenrod continued his support of the computer system administration of the Atmospheric Chemistry and Dynamics Laboratory Linux computer cluster. The most important task is updating and securing the operating system regularly. He also updated and maintained the hardware for 20 computers in the cluster, in a timely and unobtrusive manner. This year, work included installing new Fortran compilers and replacement computers as well as fixing or replacing failed hard-drives, graphics cards, monitors, UPS batteries and printers, in addition to the OS updates.

In the coming months, Mr. Steenrod will continue work on improving the GEOS CCM GMI chemical mechanism and fix issues as they are discovered. The completion and testing of a new reduced chemical mechanism is anticipated this year, significantly reducing the complexity of the species and reactions necessary to simulate the troposphere. Mr. Steenrod also anticipates completion of the photolysis rate comparison project with the GEOS CCM.

Dr. Susan Strahan (sponsor: P. Newman) uses models and observations to determine how stratospheric composition and chemistry are changing. Analyses examine stratospheric transport processes, their variability and trends, and their effects on the chemistry of trace gases, especially ozone. A secondary focus is her involvement in chemical model development and supervising new model integrations.

As ozone-depleting substances (ODSs) banned by the Montreal Protocol decline and greenhouse gases (GHGs) emissions increase, the stratospheric circulation is likely to change. Many chemistry climate models predict that the circulation will speed up everywhere, making the air younger and increasing the
rate of ODS removal from the atmosphere. But some models predict that Antarctic ozone hole recovery in the 21st century will slow down the circulation and make the air older - but only in the southern hemisphere. All the predicted changes are small compared to the large natural variability of the stratosphere – how will we detect change? Dr. Strahan analyzed 25-year-long data records of column HNO$_3$ and HCl from 9 ground-based stations of the Network for the Detection of Atmospheric Composition Change (NDACC). This analysis gave observational evidence that air in the southern hemisphere lower stratosphere has been getting younger relative to the northern hemisphere at a rate of 1 month/decade from 1994-2018. Models did not predict this behavior for reasons unknown. The analyses also revealed extratropical variability with a 5-7-year period driven by interactions between the circulation and tropical winds. This previously unrecognized, low frequency variability is much larger than hemispheric transport trends. Long records like the 25-year NDACC datasets are essential for distinguishing small trends from variability. Understanding and quantifying changes in the transport circulation matters to our ability to model how our protective O$_3$ layer will evolve in the future.

The effects of stratospheric circulation change on ozone chemistry were investigated using satellite trace gas measurements from the Aura Microwave Limb Sounder (MLS), 2004-present, along with simulations from the GMI chemical transport model (CTM). The MLS observations and model agree that changes in the transport circulation have increased reactive nitrogen in the upper stratosphere since 2004. Model calculations show quantitatively how and where this increases loss from the nitrogen-ozone loss cycle and how this competes with decreased ozone loss driven by declining ODSs. The model and data analyses together explain much about the observed ozone trends of the last two decades. A new simulation using repeating stratospheric meteorology from 2005-2007 is revealing how ozone today would be different if the stratospheric circulation was not changing.

In a collaboration with NDACC LIDAR O3 scientists, Dr. Strahan is using the GMI CTM to understand why O3 trends from nearby measurement sites do not always agree. LIDAR measurements are typically made about twice a week and only at night. The model is used to investigate whether 1) nighttime sampling represents the daily average ozone, 2) 8 profiles per month provide an accurate estimate of the true monthly mean, and 3) profile differences between nearby stations represent geophysical variations or measurement errors. Model comparisons show that nighttime profiles measured 8-10 times per month are representative of true monthly means at altitudes from 20-40 km. Below 20 km there are true geophysical variations, while above 40 km the issue may be measurement uncertainties. Dr. Strahan presented these results at the 2019 annual NDACC Steering Committee meeting, where she is Co-Chair of the Theory and Analysis group. She continues to support the NDACC by providing customized model output files for more than 70 individual NDACC station instruments.

Throughout the year, Dr. Strahan participated in press releases, interviews and video projects on the topic of stratospheric ozone and ozone hole recovery. She worked with her NASA and NOAA colleagues to write the annual Antarctic ozone press release as well as a special press release on unusual Arctic ozone loss in 2020. She was interviewed and filmed by the Canadian Global News and for a NASA Earth Science video project that was shown at the AGU Fall Meeting (https://www.youtube.com/watch?v=opjQOmxqiWdl).

Dr. Strahan continues to work with the GEOS model development group, providing expertise on transport diagnostics, model evaluation, and benchmarking. She co-leads the Stratospheric Working Group for the Harvard GEOS-Chemistry model. The main tasks of this group are 1) to evaluate the fidelity of the model’s stratospheric composition, and 2) to monitor stratospheric impacts of changes in the model’s chemical mechanism, emissions, and tropospheric processes. Dr. Strahan also continues to collaborate with and provide model simulations for many different groups, including the NOAA Aeronomy Lab, the Johns Hopkins University, Georgia Tech, the New Zealand National Institute of Water and Atmospheric Research (NIWA), as well as groups in the Atmospheric Chemistry and Dynamics Lab at GSFC.

In the year ahead, Dr. Strahan will continue an investigation using models and observations to understand how stratospheric transport changes drive composition changes and the impacts on ozone chemistry. This study will use GMI MERRA2-driven CTM simulations to understand and explain observed O$_3$ trends. She will continue to collaborate with and provide model support for NDACC instrument teams. She will continue to work with Code 614 scientists to monitor polar ozone depletion and to communicate new findings to the public through press releases, videos, and publications. Dr. Strahan will continue to participate in CTM development and evaluation at Goddard and for the Harvard GEOS-Chem model.
**Dr. Sarah Strode** (sponsor: B. Duncan) contributes to the three-dimensional modeling efforts in Code 614, both for Chemical Transport Models and Chemistry Climate Models. In particular, she conducts simulations for the Atmospheric Chemistry-Climate Model Intercomparison (ACCM), and provides emission scenarios for simulations. One of her research studies involved quantifying the impact of chlorine on the isotopic composition of methane. The concentration and geographic distribution of tropospheric chlorine is uncertain, and atmospheric chemistry models produce a broad range of results for the average value and distribution of chlorine. Since methane oxidation by chlorine alters the ratio of $^{13}$C to $^{12}$C isotopologues of methane, which is often used to infer methane sources, understanding the effects of chlorine on methane’s isotopic composition is important for constraining the methane budget. This year, Dr. Strode conducted modeling studies to show how the different chlorine fields produced by state-of-the-art models impact the isotopic composition of methane. She presented her findings at the NOAA ESRL Monitoring Meeting, and submitted a related paper that is currently in review.

In other work, Dr. Strode joins scientists from the GMAO and Code 614 in evaluating the GEOS Composition Forecasting (GEOS-CF) system. She compared GEOS-CF surface ozone concentrations to observations from the Tropospheric Ozone Assessment Report database to identify daytime versus nighttime biases. She also evaluated the GEOS-CF surface concentrations of carbon monoxide against observations from remote locations. Dr. Strode also is contributing to evaluating the representation of tropospheric chemistry in the GEOS chemistry climate model (GEOSCCM). She compared the annual cycle and multi-year trend in simulated CO to surface observations, and is helping develop comparisons against aircraft data. In the coming year, she will continue to evaluate tropospheric chemistry in the GEOSCCM, focusing on ozone and hydrocarbon species.

Dr. Strode processed new emissions and other input files for the GEOS model and the GMI chemical transport model (CTM). She processed CMIP6 emissions for the GMI CTM’S’s new hindcast simulation, and prepared the pre-industrial emissions and other forcings recommended by CMIP6 for the GEOS model’s simulation of 1850. She also used satellite observations of formaldehyde to evaluate updated biogenic emissions of isoprene. For other research, Dr. Strode has been investigating how land use/land cover change impact atmospheric composition through biogenic emissions of trace gases (e.g., isoprene). She used output from a dynamic vegetation model to account for changes in the type of plants growing in particular regions over time, and used the GEOS model to simulate how these changes impact isoprene emissions and trace gas concentrations in the atmosphere. Dr. Strode presented this work at the 2019 AGU Fall meeting.

**Mr. Andrew Swanson** (sponsor: T. Hanisco) is responsible for providing engineering support for the In Situ Observation Laboratory at GSFC’s Code 614/Atmospheric Chemistry and Dynamics Branch. He works on the development of prototypical in situ and remote sensing atmospheric instruments, with a primary focus on the optomechanical design of innovative spectroscopy cells, mechanical chassis engineering, electrical design, and aircraft integration of novel instruments into tropospheric and stratospheric research aircraft.

Mr. Swanson finalized the development and assembly of the NASA GSFC In Situ Observation Laboratory’s newest instrument, the Rapid OZone Experiment (ROZE). ROZE utilizes broadband cavity enhanced absorption spectroscopy to detect ozone concentrations to a 1-sigma precision of 80 pptv (0.1 s) and 31 pptv (1 s). ROZE is designed to be capable of semi-autonomous operation and can achieve sample throughput of 20 slm with a 1/e response time of 50 ms, substantiating its utility for tropospheric flux measurements. Mr. Swanson completed the assembly and preparation of ROZE in time for it to be part of the NASA/NOAA Fire Influence on Regional to Global Environments Experiment - Air Quality (FIREX-AQ) campaign in summer 2019. In addition to ROZE, Mr. Swanson also was responsible for preparing two other Code 614 instruments for the campaign – the In Situ Airborne Formaldehyde (ISAF) instrument, and the Compact Airborne Nitrogen dioxide Experiment (CANOE) – as well as the instrument’s shared aircraft sampling inlet and coordinating the experimenter rack layout with fellow researchers from NOAA. Participation in the campaign provided the opportunity for ROZE to be validated against a well-established chemiluminescence NOAA ozone instrument. Data demonstrates increased precision and responsivity in a lighter more compact package to accepted measurement standards. Mr. Swanson continued work on ROZE, performing several refinements and modifications to enhance its measurements, and improving instrument robustness and versatility. This included creating a finalized version of the small volume optical cell with rigid optical mirror fixtures that allows routine cleaning maintenance to be performed during a field campaign while the capturing mechanism provides highly repeatable precise centricity alignment. Measurement sensitivity is improved by the final cell components, including an inert nickel-plating components reduced ozone reactivity. Mr. Swanson also helped refine
various electrical systems to improve the instrument’s reliability, which involved helping to redesign several of the instrument’s custom PCBs and upgrading some of the thermal management subsystems.

Later in the year, Mr. Swanson prepared the instrument for its involvement in 2020 campaigns and future high-altitude field campaigns, particularly for NASA’s EVS-3 Dynamic and Chemistry of the Summer Stratosphere (DCOTSS) mission, which was scheduled for test flights to begin in summer 2020. This involved assisting with laboratory experiments in a thermal vacuum chamber and detailed mechanical/electrical planning for the instrument’s integration into the NASA ER-2 high-altitude research aircraft. Plans involved making custom provisions for an air sampling probe to be mounted adjacent to the instrument’s aircraft location. Due to the COVID-19 pandemic, the DCOTSS field campaign has been delayed.

A second major accomplishment for Mr. Swanson this past year was the final completion of the lab’s Compact Airborne Formaldehyde Experiment (CAFE) Deux. CAFE Deux is a complete instrument spare (i.e., a duplicate) for the lab’s existing Compact Airborne Formaldehyde Experiment. CAFE has been involved in various NASA missions, and a complete instrument spare was desired in the event that the original experienced catastrophic technical problems during the middle of a mission, or so that identical instrument measurements can be deployed simultaneously to various locations around the globe. Mr. Swanson has worked on creating a duplicate for CAFE for several years, since the custom parts of the originally intended duplicate were abruptly consumed and utilized in a different project in early 2018 – the creation of a new unique laser-induced fluorescence nitrogen dioxide high-altitude instrument, the CompAct Nitrogen diOxide Experiment (CANOE). Subsequent to that, Mr. Swanson was working on ROZE and assisting with various field missions; at the end of 2019, Mr. Swanson could finalize the assembly of CAFE Deux, partially because the duplicate would be required for 2020 and 2021 fieldwork when the lab is scheduled to participate in several campaigns and local air quality measurements simultaneously. Throughout this past year, Mr. Swanson worked on procuring parts for CAFE Deux and then assembled the instrument, putting together all of electrical components and wiring the instrument. Once the instrument was fully assembled, he assisted with initial laboratory testing and verification. Subsequently, he assisted with laboratory experiments in a thermal vacuum chamber. Several modifications and improvements were included in CAFE Deux, which were simultaneously made to CAFE and CANOE. These included improving the instruments’ thermal management systems and modifying their sample pressure monitoring methodology.

Thermal management changes were essential based on the instruments’ performance in the thermal vacuum testing. To improve stability, Mr. Swanson designed and incorporated new optical plate risers that facilitated the new intake cooling fans with increased air displacement. He also upgraded exhaust cooling and added new cooling systems to the instruments’ lasers power supplies. Sample pressure monitoring also was enhanced with the integration of higher precision pressure sensors. In previous versions of CAFE’s spectroscopy cell pressure values were borrowed from an upstream pressure controller. However, this measurement method has inherent errors where the signal occasionally drops out. To increase accuracy and precision, and for a redundant measurement, a new micro-machined piezoresistive pressure transducer was incorporated into the instruments.

This year, Mr. Swanson assisted his colleagues Dr. Jason St. Clair and Dr. Reem Hannun on instrument papers for CAFE and ROZE, respectively. He provided mechanical and electrical engineering of both instruments, as well as overseeing their construction. He also assisted with laboratory testing and their field campaign involvement. The CAFÉ paper, “CAFE: a new, improved nonresonant laser-induced fluorescence instrument for

Photo of NASA GSFC’s In Situ Observation Laboratory’s newest instrument, the Rapid Ozone Experiment (ROZE).
(Provided by A. Swanson.)
Mr. Swanson spent significant time preparing multiple Code 614 In Situ Observation Laboratory instruments for upcoming field campaigns in 2020 and beyond. He prepared ROZE and CANOE for their involvement in the DCOTSS campaign as well as ISAF for its involvement in the NASA/NSF collaborative Asian Summer Monsoon Chemical and Climate Impact Project (ACCLIP). He prepared CAFE for its planned fieldwork, collaborating with the European Space Agency (ESA) in Romania in 2021, performing formaldehyde validation there for TROPOspheric Monitoring Instrument (TROPOMI) measurements. He also collaborated with various researchers and engineers from NASA Ames, NASA JSC, his colleagues at NASA GSFC, and researchers from Denmark and Romania for ESA. In preparation for DCOTSS, Mr. Swanson was responsible for a structural analysis of the lab’s involved instruments and aircraft air sampling probes. Since multiple Code 614 instruments were flying aboard the NASA ER-2 at different configurations simultaneously, Mr. Swanson was responsible for overseeing the production and assembly of new identical aircraft air sampling probes for the campaign. All of the probes are replicas to the one that Mr. Swanson had designed and made in fall 2016 for the ER-2 high-altitude flight test. He helped to procure parts for the probes, oversaw the custom machine work, aluminum dip brazing, and mechanical assembly. Mr. Swanson made detailed structural failure analyses for all of his lab’s involved components; these analyses are critical to instrument and sample probe flight involvement. He was responsible for documenting the instrument package integration configurations and verifying their integrity under combined worst-case loading conditions of various failure mechanisms; finally, he received approval from Armstrong ER-2 aeronautical structural and flight integration engineers.

Throughout the year ahead, Mr. Swanson is scheduled to participate in several NASA Airborne Field Campaigns, as well as a TROPOMI validation flights that will utilize CAFE for HCHO (formaldehyde). He will be responsible for the structural engineering, planning, preparation, and integration of the lab’s instruments into various airborne research platforms on these field campaigns.

Dr. Ghassan Taha (sponsor: G. Jaross) supports the development and validation of the SNPP OMPS Limb aerosol product. His goal is to understand the underlying sensitivities for retrieval errors and to optimize the external inputs needed for improved product performance. He also compares the OMPS aerosol product with correlative measurements to understand sources of error. This past year, Dr. Taha developed OMPS LP V2.0 aerosol maps to track the smoke plume from the Australian fires in the stratosphere as the smoke plume circumnavigates the globe, and he analyzed the unusual diabetic rise of this plume from 15 to 35 km over 3 months. Preliminary analyses suggest that the Australian fires have injected more smoke aerosol into the stratosphere than any other fire measured on record. Also, Dr. Taha developed a straylight algorithm to correct SAGE III limb radiance measurements. The corrected radiances were used to retrieve ozone and aerosol profiles and showed good agreement with OMPS LP measurements. He modified the newly developed V2.0 aerosol algorithm as well to retrieve SAGE III LS multi-wavelength aerosol products.

In June 2019, Dr. Taha attended the 10th International Limb Workshop in Greifswald, Germany and presented a talk titled “Overview of OMPS LP Aerosol Extinction Measurements,” and he co-authored three other presentations. Dr. Taha attended the 2019 AGU Fall meeting in San Francisco, CA, and presented a talk titled “Development of the OMPS LP Version 2.0 Multi-wavelength Aerosol Extinction Coefficient Retrieval Algorithm” and co-authored four other presentations. He also attended the SAGE III/ISS science team meeting in Hampton, VA, and the 27th IUGG general assembly in Montreal, Canada. This past year, Dr. Taha was a Co-I on a NASA ROSES AST proposal selected for funding titled “Effects of the Asian summer monsoon dynamics on aerosol composition and interannual variability in the upper troposphere/lower stratosphere” (PI: Mian Chin). He also was a co-author on four articles, one each with Earth and Space Science Open Archive and AMTD (in review), and one each in JGR-Atmospheres and Atmos. Chem. Phys. (published).

In the coming year, Dr. Taha plans to write a paper describing the OMPS LP V2.0 multi-wavelength algorithm and products validation. Additional work will involve refining the SAGE-III limb scattering ozone and aerosol retrievals and providing a detailed assessment of the algorithm performance.

Dr. Zhining Tao (sponsor: M. Chin) focuses on development of the regional chemistry-transport model (NASA Unified WRF, NUCAN) examination of biosphere-atmosphere interactions, and investigation of the role of aerosols and trace gases (e.g., CO2 and ozone) in climate change and air quality through global/regional modeling studies and data analysis.
Dr. Tao gave several presentations related to his research this past year. In late June 2019, he gave a presentation at the 4th Atmospheric Composition and the Asian Monsoon (ACAM) Workshop at the Universiti Kebangsaan Malaysia, Malaysia. In July, he gave a presentation “Development of a framework to improve chemical lateral boundary conditions in support of National Air Quality Forecast Capability (NAQFC)” at the 8th COAA International Conference on Atmosphere, Ocean, and Climate Change (ICAOCC) in Nanjing, China. In December, he presented a poster at the 2019 AGU Fall meeting in San Francisco, CA, and was the co-author of other two presentations. At the 100th AMS Annual Meeting in Boston, MA, in January 2020, Dr. Tao gave a presentation “Application of Satellite-constrained Chemical Lateral Boundary Conditions to NOAA’s Air Quality Forecast Capability – A Case Study in Support of FIREX-AQ.”

Dr. Tao led a proposal of using satellite data and NU-WRF modeling to investigate the source attribution of air quality changes over East Asia in the Aura Era (2005 - present) and submitted this to the NASA ROSES 2019 call of Aura Science Team (declined funding). As a co-I, Dr. Tao participated in a proposal titled “Toward conceptualization and predictability: A multi-scalar analysis of urban-influenced hydrometeorological processes.” This proposal has been submitted to the Interdisciplinary Research in Earth Science (IDS) program of NASA (decision pending).

Dr. Tao also was involved with several papers throughout this year. He was lead author of a paper titled “Evaluation of NU-WRF model performance on air quality simulation under various model resolutions – an investigation within the framework of MICS-Asia Phase III” published in Atmos. Chem. Phys. This study used NASA Unified WRF to quantify the impact of model resolution on air quality simulation over the North China Plain, and to explore the underlying reasons that led to the inter-resolution modeling discrepancy. It also provided suggestions to the MICS-Asia community as to how to move on to future air quality model investigation. He also led a paper titled “Impact of Fire Emissions on U.S. Air Quality from 1997 to 2016–A Modeling Study in the Satellite Era” published in Remote Sens. This paper quantified the impact of fire emissions on U.S. air quality based on the 20-yr satellite observation and simulations with the SMOKE-CWRF-CMAQ modeling system. The results showed that fire emissions can lead to 10% more surface ozone exceedances (as compared to the NAAQS) and 33% more PM_{2.5} exceedances over the contiguous U.S. He also co-authored four papers published in Atmos. Chem. Phys.

Future plans include working on the funded MAP project, including analyzing the representation of the vertical structure of Saharan Air Layer over northern Africa and eastern Atlantic using NU-WRF. Dr. Tao also will conduct high-resolution (4-km) simulations of atmospheric composition over the contiguous U.S. in support of satellite retrieval activity.

Dr. Jerald Ziemke (sponsor: R. McPeters) conducts research to accomplish the following: to develop a long-record (1979-current) of tropospheric and stratospheric ozone by combining TOMS, SBUV, OMI, and OMPS measurements; to improve the new V9 algorithm; to derive OMI/MLS tropospheric ozone; to derive tropospheric ozone product from DSCOVR EPIC measurements; and, to produce a tropospheric ozone product from NPP OMPS nadir mapper and limb profiler.


Dr. Ziemke will continue his science research and producing ozone data products from various sources including OMI/MLS, OMPS, and the new DSCOVR EPIC instrument. Plans also include attending conferences and science team meetings, writing/contributing to proposals, and writing/co-authoring journal papers.

**CODE 615: CRYOSPHERIC SCIENCES LABORATORY**

Dr. Ludovic Brucker (sponsor: S. Nowicki) conducts research to advance and validate satellite-derived properties of snow and ice on Earth using surface-, air-, and space-based microwave sensors. In May 2019, Dr. Brucker conducted fieldwork in Cambridge Bay, Nunavut for monitoring snow properties in the watershed surrounding the Canadian High Arctic Research Station. This activity was possible thanks to a close collaboration with University of Sherbrooke, Québec, Canada. University of Sherbrooke has granted Dr. Brucker the ability to formally co-advice its graduate students. Snow properties were measured in pits dug in the field of view of surface-based microwave

radiometers operating at 19 and 37 GHz. In addition to snow properties, information on soil roughness was also collected. Together, these measurements will allow the researchers to evaluate radiative transfer models.

NASA’s Terrestrial Hydrology Program supports the SnowEx mission, which is a coordinated multi-year airborne and ground experiment. Dr. Brucker contributed to the SnowEx 2020 experiment plan, especially for the activities that took place at Grand Mesa, CO. This site was used as 1) a time-series site with repeated airborne L-band SAR acquisitions and some LiDAR acquisitions throughout the winter; and 2) an intensive observation site for a campaign in mid-February. The primary objectives of the Grand Mesa campaigns were to test and validate SWE retrieval from active and passive microwave sensors. In addition to contributing to the development and writing of some elements in the SnowEx 2020 Experiment Plan, Dr. Brucker developed specific sampling plans for soil moisture and snow that were executed in the fall 2019 campaign at Grand Mesa, CO; he presented the overall plan at the ESA Living Planet Symposium held in Milan, Italy. He participated in the planning, preparation, and execution of the November campaign at Grand Mesa. The fall campaign’s objective was to collect airborne acquisition for characterizing soil scattering with GSFC’s SWESARR airborne instrument, and to measure relevant snow and soil properties. He then worked on data quality assessment and quality control.

Dr. Brucker’s work over the past year resulted in five published journal articles, and more than ten presentations. Some of these articles were published in Nature Communication, and Reviews of Geophysics, which are high-impact factor journals (>10). Also, for the third consecutive year, he co-chaired a session at the AGU Fall Meeting on sea ice remote sensing. Additionally, for an initial one-year term, Dr. Brucker became responsible for the GSFC Snow and Ice Research Facility, which has a walk-in freezer used by the GSFC community to store ice cores and to analyze ice and ocean samples at low temperature.

During the next year, Dr. Brucker will focus his activities on the polar regions. In particular, he will carry out activities using microwave radiometer observations with the NASA team’s sea ice concentration algorithm. He will also participate in a brief effort to create satellite composite products of the Greenland ice sheet melt during the summer months.

Dr. Paolo de Matthaeis (sponsor: D. Le Vine) works on continuing the estimation of sea surface salinity from space, for the study of large-scale ocean processes and climate change, using measurements from the SMAP radiometer and the Aquarius instruments. He aims to minimize the various errors in the brightness temperature measurements acquired over the ocean to perform a reliable retrieval of sea surface salinity (SSS).

This past year, Dr. de Matthaeis has worked on several topics related to sea surface salinity retrieval using SMAP radiometer measurements. He investigated Aquarius RFI filter capabilities on SMAP data and identified the cause of the seasonal/latitudinal bias between expected and measured salinity and brightness temperature. Further, Dr. de Matthaeis continued his analysis of the error produced by the reflected galactic radiation on SMAP measurements with regards to sea surface salinity retrieval. Work in the coming year will involve continued calibration/validation analyses of the SMAP radiometer data for sea surface salinity retrieval.

At IGARSS 2019, held in Yokohama, Japan in summer 2019, Dr. de Matthaeis was involved as a co-organizer and lecturer for the tutorial “Spectrum Management and Radio Frequency Interference (RFI) in Microwave Remote Sensing,” as a lead author and co-author of three presentations, as a co-organizer of an oral and a poster session on Radio Frequency Interference (RFI) in Microwave Remote Sensing, and as the chair of the Annual Meeting of the IEEE GRSS Frequency Allocations in Remote Sensing Technical Committee.

Dr. de Matthaeis was part of the organization of the RFI 2019 Workshop as its General Chair. This small conference was held in Toulouse, France in late September to discuss the effect of Radio Frequency Interference (RFI) on remote sensing and radio astronomy observations. At this workshop, he gave an oral presentation of which he was first author and he co-authored another oral presentation, led by Dr. Yan Soldo.

Dr. Yan Soldo (sponsor: D. Le Vine) supports the Aquarius/SAC-D and the SMAP missions to map ocean salinity and soil moisture worldwide. His research aims at improving the quality of salinity retrievals from raw satellite data. This past year, he found that unexpected signals were observed in the measurements of the 4th Stokes parameter made by SMAP. His team’s investigation of these signals led to a published paper; a second paper is in preparation.

They also analyzed different potential approaches to compute match-ups between in-situ and satellite measurements of salinity. This is in the context of collaboration with ESA for
developing a web-based tool to assess satellite salinity products. Further, he and his team have developed tools to extract the characteristics of RFI signal in the protected frequency band 1400-1427 MHz. The results of these tools will help develop RFI-robust hardware and software and it will have enforced international spectrum regulations.

CODE 616: OCEAN ECOLOGY LABORATORY

Dr. Andrea Andrew (sponsor: C. Del Castillo) works on capturing colored dissolved organic matter (CDOM) dynamics in the mangrove forest of Southwest Florida coastline, via the analysis of absorption and fluorescence measurements as well as other parameters including dissolved organic carbon (DOC), salinity, tidal patterns and location. She then determines the quantum photoproduction efficiency of dissolved inorganic carbon (DIC – measured as CO2) via photodegradation of CDOM in the study area. She also investigates the relationship between fluorescence EEMs and other optical properties of CDOM from different coastal environments to discern the relative proportion of marine/terrestrial and photo oxidized / microbial reworked DOM.

Dr. Andrew completed the fluorescence EEMS analysis for a large group of CDOM samples from several field efforts in very diverse environments. In support of the other Ocean Ecology lab efforts, Dr. Andrew processed fluorescence emission data for several CDOM samples, including recent field cruises to Alaska in 2018 and 2019 and samples from earlier cruises to the Gulf of Mexico in 2013, totaling approximately 310 samples. She further exported the data, including EEMS (3D emission spectra), absorbance and xyz data for contour plots, and summarized into a master spreadsheet along with other samples details and experimental parameters. In the long term, Dr. Andrew intends to use this data, after completing the data analysis of one more set of CDOM samples, as part of a manuscript relating CDOM absorption and EEMS linking optics to discern relative proportions of different types of DOM from the different areas.

Dr. Andrew made significant progress towards completing a manuscript. The initial focus was to investigate the distribution and dynamics of CDOM in the Everglades, but this was modified. After much discussion, Dr. Andrew and co-authors changed it to be a descriptive piece, which also examines the export and fate of the mangrove carbon and whether remote sensing can be used to measure the organic carbon export.

During the processing and analysis of fluorescence data acquired by other users of the Horiba Aqualog instrument, Dr. Andrew discovered some very important aspects of the data acquisition process that were either omitted or done incorrectly, and therefore resulted in poor data. She realized the need for some guidance on using the instrument, and subsequently prepared a written protocol that is posted in the lab and available in a shared folder for any users of the instrument.

In the coming year, Dr. Andrew will analyze the fluorescence EEMS collected for the KORUS 2016 field event, and compile it in a spreadsheet. Further analysis will be performed to include all three sets of CDOM samples processed (ECOA 2018, GEOCAPE 2013 and KORUS 2016). Initial figures will be produced for data comparison and a related manuscript. Work also continue with irradiating more samples from the study region, including samples from the Shark River, Tarpon bay, Harney River and the Creeks further north of the Shark River source. The focus would be to provide data for two future manuscripts, one examining DIC yields upon photo-irradiation of CDOM and another for a methods development manuscript. Finally, in support of other Ocean Ecology lab efforts, Dr. Andrew plans to perform POC (particulate organic carbon) measurements for samples collected from several field events, and provide data to colleagues to use for publication or data banks.

Dr. Dirk Aurin (sponsor: A. Mannino) developed the HYPERsCpectral IN Situ Support for the PACE (HyperInSPACE) mission’s software package from the original, partial framework at the beginning of the cycle to a completed and externally released and reviewed product. The software is capable of ingesting raw binary data from automated, hyperspectral radiometer suites deployed in the field (mainly on ships at sea), applying factory calibrations, filtering the data for solar/sensor geometry and ship attitude, deglitching and dark shutter correction, and cross-instrument time and wavelength interpolation. HyperInSPACE also applies a comprehensive collection of quality controls based on the current state of the science and produces Level 2 reflectances and other ocean color products using various approaches informed by recently published papers, protocols and the latest research in the field of polarization, hyperspectral glint removal, and other radiometric corrections. This software was designed to be highly flexible, adaptable, and accommodating of a wide variety of environmental conditions and ocean color water types. This enables the processing and quality control of long time series automated data collections in challenging conditions that historically had precluded its use in ocean color research or
orbital instrument validation. HyperInSPACE is open source, platform independent, and modularized to allow for future developments.

Due to his level of involvement at NASA in hyperspectral above-water radiometry data processing, analysis, and protocols, Dr. Aurin was invited to participate in the Future of Above Water Radiometry workshop (FAR-1) in Belgium in October 2019 to meet with international colleagues focused on the collection of similar data in support of satellite ocean color sensor calibration/validation. As development of the PACE mission ocean color instrument (OCI) proceeds at Goddard toward the 2023 launch, work continues with identifying and developing robust hyperspectral radiometric measurements at the ocean surface for post-launch cal/val of OCI. While HyperInSPACE represents one strategy to reach this goal, the development and emergence of a new global network of radiometric towers being coordinated by European and international colleagues presents another opportunity. Dr. Aurin presented HyperInSPACE at the meeting, with considerable interest from attendees eager to take advantage of a flexible, comprehensive processing suite. New developments and publications related to radiometry processing and protocols were discussed, as well as knowledge gaps where further study is required. Several attendees at the FAR-1 meeting expressed interest in participating in the early 2020 beta release of HyperInSPACE.

Internal alpha-testing (version 1.0.α) of HyperInSPACE was launched in late 2019 when Dr. Aurin hosted a meeting at Goddard with the principal stakeholders in the PACE ocean color mission. He presented the outcomes of the FAR-1 meeting and upgrades identified for HyperInSPACE in the following categories: processing standardization and compatibility, uncertainty estimation, improved sky/sunglint correction, and inclusion of a bidirectional reflectance distribution function (BRDF) correction. In early 2020, development focused on three main areas: 1) incorporating the updates to HyperInSPACE from alpha testing to establish a stable version for processing Field Support Group (FSG) above-water radiometry; 2) presenting the software and processing results, including a demonstration of the software, at a talk given at the Ocean Sciences Meeting in San Diego in February 2020, and, 3) upgrading the software to prepare for the March external beta release.

Following these software upgrades, Dr. Aurin performed a sensitivity analysis on various permutations of data reduction and processing highlighting the strengths of HyperInSPACE over conventional methodologies for retrieving high-quality normalized water-leaving radiances and remote sensing reflectances. All underway above-water radiometry from the 2016 KORUS cruise around the Korean peninsula were processed using 12 different permutations, each time adding another element/improvement introduced in HyperInSPACE. Dr. Aurin presented analysis results and demonstrated the software at the Hyperspectral Sensing of Coastal Aquatic Environments session of the Ocean Sciences Meeting. Several more individuals offered to volunteer beta testing assistance, additional software enhancements, and future collaboration. At the time of this writing, Dr. Aurin was collaborating with 17 external beta (version 1.0.ß) reviewers in several countries working in academia, institutional research, and the private sector. While beta testing feedback was somewhat delayed by the COVID-19 pandemic, reviewers are now beginning to provide helpful feedback and suggestions, some of which have already been incorporated in the external release in April 2020 of another software version (1.0.0).

Dr. Aurin also participated in a one-year pilot program to evaluate the utility of commercial satellite imagery for doing research in ocean color. Working with satellite imagery obtained from DigitalGlobe (DG; now Maxar), he developed an automated process for converting WorldView-2, WorldView-3, and CAVIS images to a convenient data format for ocean color imagery, from which images were subset to a number of areas of interest, including the ocean color calibration site MOBY in Hawaii, the LISCO site in western Long Island Sound, the MVCO site off Martha’s Vineyard, and various cruise locations in the Arctic and North Atlantic Bight. He developed a scheme to correct the low-level imagery using the vicarious gains and offsets obtained from DG, and processed them to top-of-atmosphere radiances and reflectances using earth-sun distance, view and solar geometry, and Thuillier and spectral response functions (RSRs) for exoatmospheric irradiance. Imagery was matched to legacy ocean color sensors MODIS Aqua and Terra, which showed reasonable radiometric agreement. This result is promising for the potential use of this very high spatial resolution data collected at wavelengths useful for ocean color research, although further vicarious sensor calibration and atmospheric correction over the ocean is clearly needed. The final report on the project was presented to NASA headquarters in October 2019.

This coming year, Dr. Aurin will continue the external beta test of HyperInSPACE to identify bugs and other issues, will continue processing FSG cruise data for submission to the NASA SeaBASS database, and will begin to explore the resultant ocean color products more deeply. He plans to develop the improved glint corrections, BRDF corrections, and uncertainty
estimates, and continue collaboration with the community to identify improvements and enhancements that would make HyperInSPACE more robust and applicable to a larger number of instrumentation suites. He plans to compare reflectances retrieved from above-water instrumentation using HyperInSPACE and those retrieved from in-water profiling and buoyed platforms for some recent NASA oceanographic cruises around the world. In turn, these comparisons will highlight improvements in the HyperInSPACE approach and areas where research is needed to obtain high quality radiometry for use in hyperspectral algorithm development and orbital sensor validation.

Dr. Ivona Cetinić (sponsor: P. J. Werdell) serves as the Project Scientist for the EXPORTS program and as a Project Science Lead for Biogeochemistry for the PACE mission. The former involves interacting with the HQ EXPORTS Program Manager and Science Team Lead and collaborating with the Principal Investigators that participate in the field campaigns. The latter involves supporting the PACE Project Scientist in data product development and validation, documentation, science team collaboration. Among her work duties, she also will develop and validate ocean color algorithms to estimate marine biogeochemical variables from satellites, and give presentations and produce peer-reviewed literature.

As part of her PACE responsibilities, Dr. Cetinic continued supporting the PACE mission. She continues to oversee two postdoctoral researchers, and work on the studies to support algorithm development and preparation for the PACE launch. She also has been contributing to PACE-associated science trade studies and communication efforts. See PACE: [https://pace.gsfc.nasa.gov/](https://pace.gsfc.nasa.gov/).

With EXPORTS, she continued to serve as a Project Scientist, overseeing the project office, conducting science, and supporting the funded scientists. Due to the COVID-19 pandemic, she oversaw the postponement of the EXPORTS campaign for next year, and responded to related consequences of this. See EXPORTS: [http://oceanexports.org/](http://oceanexports.org/).

Dr. Cetinic continues to work on data analysis from her Sea2Space cruise, and to collaborate with scientists from her other projects (OSSEs in support of EXPORTS, and MINIONS). She continued work on data analysis, dissemination and presentation of the results from last year’s “Sea to Space particle Investigation” cruise, of which she was the lead. She has started work on her newest projects, Minions (miniature lagrangian floats). She continues to actively contribute to Phytoplankton Taxonomy workgroup (funded under OCB), and Particulate Organic Carbon protocol group (funded under NASA). Additionally, she has been contributing to an OSSE project led by Dr. Cecile Rousseaux (USRA).

Throughout the past year, Dr. Cetinic participated in many national, international, and project meetings, presenting highlights of her work on EXPORTS, PACE and associated sciences. In May, she organized and participated in the NASA- and NSF-funded EXPORTS science meeting in Williamsburg, VA. In June, she gave an update on PACE mission during the summer OCB workshop, held at the Woods Hole Oceanographic Institute. In July, she traveled to the UK to participate in the BIARRITZ workshop, which brings together projects focusing on the fate of carbon in oceanic twilight zone, and in late August, she presented updates from PACE at the 7th European Phycological Congress in Zagreb, Croatia. In September, at the OceanObs19 Conference, she presented updates from the PACE mission and gave two hyperwall presentations, one on PACE and one on EXPORTS. In November, Dr. Cetinic organized and was part of the EXPORTS planning meeting in Seattle, WA, working on finalizing the 2020 North Atlantic Field campaign. She also participated in meeting of National Academy of Science Committee for Earth Observations and Application from Space meeting in December. In February, Dr. Cetinic attended the Ocean Science Meeting in San Diego, CA, where she chaired two large sessions, presented a first author poster, and was co-author of many oral and poster presentations. She also gave a NASA Hyperwall presentation, co-organized a town hall, and worked at the NASA booth. She organized and chaired a full day meeting for EXPORTS planning, on the Sunday before the meeting.

Dr. Cetinic was selected to be part of JAXA’s GCOM-C Science Team, and she submitted a proposal to NSF. She co-authored five papers in various stages of publication, she is helping postdocs finalize several more papers, and she is working on two more technical memos to be finalized, part of the support for PACE and EXPORTS.

Work will continue with PACE and EXPORTS scientific studies. As EXPORTS continues onto its second field campaign (North Atlantic 2020), Dr. Cetinic will continue to support preparations and organization of the project, and oversee the project office (including the organization of the science meetings). She will participate in several meetings, OCB summer workshop, BIARRITZ carbon workshop, OceanObs 19 and Ocean Sciences 2020, presenting her work, organizing sessions and town halls.
During the past year, Dr. Violeta Sanjuan Calzado (sponsor: B. Frank), as lead of NOMAD (NASA bio-Optical Marine Algorithm Dataset) validation dataset for the PACE mission, has been doing extensive work on establishing guidelines for the submission of datasets into the SeaBASS (SeaWIFS Bio-optical Archive and Storage System) database. Following community guidelines and protocols, a series of documents on submission requirements for every validation product have been generated for PI’s contributing to SeaBASS, to ensure data quality from the instrument calibration to the acquisition methodologies as well as data processing and quality control. This effort also provides further information to assess uncertainties as a fundamental goal for PACE mission. These documents are live on SeaBASS website and are the primarily guideline for new submissions. These new requirements were presented during the past OCRT (Ocean Color Research Team) meeting in November 2019 and will be presented to the whole community during the upcoming Ocean Optics meeting this fall.

Special efforts were dedicated to the radiometry product as a primarily validation product on algorithm development. A specific goal was to address acquisition of radiometry for different instruments and platforms and to develop a coherent processing for radiometry, following community requirements and recommendations from lead experts in radiometry. Software was developed to process radiometry from different profiling radiometers. This software includes uncertainty calculations associated with the measurement moving toward PACE requirements of uncertainty estimates for radiometry products; in the future, the software will be used to provide water-leaving radiances for satellite validation within the Ocean Biology Processing Group. This effort is framed within the PACE mission requirements to provide an uncertainty estimate of the satellite measurements and its validation activities supporting algorithm development.

Dr. Sanjuan Calzado is also contributing to the definition of the PACE validation plan, which defines mission requirements for validation activities as well as setting guidelines for contributing science teams into PACE. She has provided standard operation procedure documents for some of the validation products of the PACE mission, providing guidelines on data acquisition, processing and quality control.

Dr. Sanjuan Calzado has also established a working group of experts on optical measurements, who are all leads on different ocean color validation products. The role of this group is to perform quality checkups on SEABASS submissions following quality standards on data acquisitions and data submissions from the ocean optics community. These experts will provide feedback on submission guidelines for SeaBASS and on data submissions by PI’s to SeaBASS, and will provide QA/QC on current and past SeaBASS submissions. This working group is an important function of SeaBASS to ensure high data quality control of the database. Further, as NOMAD lead, Dr Sanjuan Calzado continues working on submitted datasets to the SeaBASS database, building a NOMAD validation dataset and associated software. This updated version of NOMAD provides uncertainty estimates on each validation product, as required by PACE mission goals.

Dr. Andrew Sayer (sponsor: P. J. Werdell) supports the NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission and related Ocean Ecology Laboratory activities as Project Science Lead for Atmospheres (https://pace.gsfc.nasa.gov), expected to launch in 2022-2023, working under Dr. P. J. Werdell. The bulk of his effort has been toward achieving mission success by ensuring that required atmospheric (aerosol and cloud) data products will be able to be produced and validated at the NASA Ocean Ecology Laboratory.

Several important milestones have been achieved over the past year. Dr. Sayer has contributed to the implementation and refinement of heritage aerosol and cloud property retrieval algorithms to create a proxy data processing chain for future PACE Ocean Color Imager (OCI) measurements. He has written algorithm theoretical basis documents (ATBDs) describing these implementations, and he has developed a cloud top pressure retrieval algorithm (for which there is no heritage NASA approach suitable for OCI) and applied this successfully to simulated OCI measurements. Beyond retrieval algorithms, Dr. Sayer also led a study into the underlying distributions of aerosol loading in space and time. These distributions have an implication on the way data should be aggregated to provide the most appropriate summary of the Earth system. This is important because many applications of aerosol data sets, such as climate and trend studies, use monthly-aggregated products (known as level 3) rather than instantaneous orbit-level (level 2) data. These results will allow PACE (and other missions) to provide more meaningful level 3 data products.

Dr. Sayer has been part of new developments to advance the state of aerosol remote sensing, relevant both to PACE and other future missions such as might be proposed in response to the recent Decadal Survey in Earth Sciences. As part of the AeroSat group, he has been leading an initiative to develop a framework
to assess uncertainty estimates provided in satellite aerosol data sets. These are key to making the best use out of the satellite data, especially for applications such as data assimilation for weather and hazard forecasting. A paper summarizing this effort was published this year. He co-authored another AeroSat study on strategies to merge satellite aerosol data sets. This past year, he also became one of the vice-chairs of the AeroSat group, taking a leading role in coordinating these international efforts to improve aerosol remote sensing. Dr. Sayer also contributed to developing the widely-used VLIDORT radiative transfer code, improving the treatment of surface reflectance and polarization, which are necessary for modeling satellite signals with high accuracy. This code is being used in research by many groups at NASA GSFC (including within the PACE mission), at other NASA centers, and elsewhere internationally.

In response to the release of the recent Decadal Survey in Earth Sciences, Dr. Sayer is part of a team (led by P. Colarco) funded by NASA GSFC’s Internal Research And Development (IRAD) program. This group seeks to assess the possibilities and necessary characteristics for improved quantification of the Earth’s aerosol system through a constellation of cubesats carrying multiangle polarimeters. The work involves the use of and improvement to the GRASP retrieval code using simulated data for characteristics similar to the HARP instrument, which is expected to fly both on the PACE mission and as a stand-alone cubesat within the next several years. He is also a collaborator on a funded NASA Instrument Incubator Program (IIP), led by F. Capasso (Harvard University), to develop meta-surface-based polarimeters, with potential remote sensing applications. His role is to provide advice to guide the development of the instruments such that its measurements will be useful for remote sensing of atmospheric aerosol properties.

Much of Dr. Sayer’s efforts in the coming year will remain on the PACE mission. He will continue to refine prototype algorithms for PACE aerosol and cloud data processing, and contribute to other mission development and outreach activities as necessary. One key area will be the validation, refinement, and implementation of his cloud top pressure algorithm into the broader PACE proxy data processing system. Now that NASA HQ has selected a Science and Applications team, he will interface and coordinate with them on atmospheric topics. Dr. Sayer also will continue participating in activities relating to the funded GSFC IRAD on cubesat polarimeter developments for aerosol studies. The current IRAD ends at the end of FY2020, although an extension may be proposed, to further develop the work. He will also continue providing advice to the Harvard team on the NASA IIP polarimeter development work.

Dr. Bridget Seegers (sponsor: P. J. Werdell) leads the Cyanobacteria Assessment Network (CyAN) Project, a multi-agency (EPA, USGS, NOAA, and NASA) effort to demonstrate that satellite data can be used to identify and monitor cyanobacteria blooms in U.S. inland lakes and water bodies. As the lead, she continued to collaborate and coordinate efforts with interagency partners at EPA, USGS, and NOAA. Dr. Seegers attended and presented at a two-day CyAN interagency meeting with project collaborators from the EPA, NOAA, and USGS. At the meeting, they discussed project updates, achievements, and next steps. This project had initially focused on developing the cyanobacteria index (CI) remote sensing capabilities for the lower 48 states. Dr. Seegers worked with interagency partners and programmers in the NASA Ocean Ecology Lab (OEL) to implement improvements in the CyAN processing code and perform a full reprocessing that resulted in an improved final product.

Dr. Seegers attended and presented at several workshops and conferences. At the American Chemical Society National Meeting in San Diego, CA, she gave a series of presentations, and gave an invited session talk titled “NASA water quality monitoring within the current era of the Cyanobacteria Assessment Network (CyAN) & the future era of the Plankton, Aerosol, Clouds, ocean Ecosystem (PACE) mission.” At the Ocean Obs ’19 conference, she was an invited ambassador at the “Breaking Waves, Breaking Barriers: Celebrating Women’s Instrumental Role in Ocean Science, Leadership, and Mentorship,” event. In November, she presented at the US HABS symposium in Orange Beach, AL on the CyAN monitoring app, to educate and excite people about the Cyanobacteria Index. In January, Dr. Seegers attended the National Council for Science and the Environment conference focused on science in environmental decision making in Washington D.C. In February, Dr. Seegers gave an oral presentation at the Ocean Sciences Meeting in San Diego, CA titled “Satellite remote sensing of Cyanobacteria: Success stories of management taking action and the CyAN data sharing app.” Dr. Seegers gave invited CyAN-related hyperwall presentations in the exhibitor’s hall at the majority of these meetings.

In the coming year, Dr. Seegers will complete work on a full continental U.S. analysis of chlorophyll MERIS products for inland lakes. This type of analysis has never been done before for US lakes. This analysis will be submitted to a peer-reviewed journal. She also will lead a SeaDAS software training for Cyanobacteria Assessment Network (CyAN) project collaborators.
and stakeholders with a focus on the cyanobacteria satellite products. This is a unique SeaDAS course that Dr. Seegers developed and is lake-centered designed particularly for the CyAN project.

Dr. Seegers was invited to co-teach a Statistical Analysis Workshop at the international Ocean Optics meeting in October 2020. The request is a follow-on to the workshop Dr. Seegers co-created and co-led focused on better statistical methods for data analysis at the 2018 international Ocean Optics Conference. This popular workshop was titled "Better Metrics for Algorithm Assessment." The course reached capacity and had a waitlist. The course was designed to address the need for more robust algorithm analysis as the number of ocean color algorithms available to the community has increased in recent years, along with the need for these algorithms to inform models, decision support, and management.

**Dr. Inia Soto Ramos** (sponsor: P. J. Werdell) is actively engaged and collaborating with EXPORTS researchers, project office members, and working with SeaBASS team members. Her work has led to the archival of over 70% of the data collected during the first EXPORTS field campaign. The diversity of the EXPORTS data presented a challenge for the SeaBASS long-term data repository. Dr. Soto Ramos worked alongside the SeaBASS team to develop standardize terminology and submission requirements for ingesting different types of data that were not previously accepted. In addition to data submission requirements, she assisted with the development of data collection and submission protocols. EXPORTS PI’s received individualized attention and assistance while preparing their data for submission and to guarantee the data was archived. Her work with each researcher has helped EXPORTS scientists comply with their data submission requirements and has strengthened the collaboration with SeaBASS. Additionally, she keeps records and tracks data submission status, follows up with the PI’s, and informs the Project Office and Program Managers of potential delays or compliance issues. Dr. Soto Ramos has begun a transition to the SeaBASS team, where she interacts with SeaBASS users, receives and archives the data, and helps with data submission protocols.

Dr. Soto Ramos also was involved in planning the EXPORTS second field campaign. For this, she developed a code that would allow researchers to see in real-time the location of all the assets using Google Earth with minimal data usage so it can be easily shared with team members onboard the different vessels. The code relies on a series of codes that Dr. Ivona Cetinic (USRA) developed to harvest the data from all the assets. This is crucial for communication, preventing accidents and losses, and coordinating and executing a successful field campaign.

This year, Dr. Soto Ramos presented a poster at Ocean Sciences (San Diego 2020), presented and participated in the EXPORTS all-hand meetings (Williamsburg, VA and Seattle, WA), and was invited as a seminar speaker for the GLOBE project.

Dr. Soto Ramos will continue to support EXPORTS and SeaBASS as their data manager, and make sure all EXPORTS data is archived and in compliance with NASA’s requirements. Dr. Soto Ramos will work with Dr. Cetinic and Dr. Siegel in preparing an overview manuscript, a NASA Technical Memoranda that will contain all the EXPORTS protocols, and an EXPORTS data management manuscript.

**CODE 617: HYDROLOGICAL SCIENCES LABORATORY**

**Dr. Pukar Amatya** (sponsor: D. Kirschbaum) develops open source landslide detection algorithms for production of landslides inventories, which can be used for susceptibility, hazard, risk studies and rapid response efforts. He also oversee the CEOS Landslide Pilot.

Dr. Amatya finished the development of the Semi-Automatic Landslide Detection (SALaD) system and submitted required information to NASA Technology Transfer Program for code release. A related manuscript highlighting this system was submitted to Landslides journal. The SALaD system was utilized extensively for rapid response efforts mapping landslides in Burundi, Kenya and Vanuatu.

Dr. Amatya participated in NISAR Landslides Application Workshop in Seattle, WA and NASA CSDAP Pilot Project Meeting in Rockville, MD. At the 2019 AGU Fall Meeting, Dr. Kirschbaum gave a presentation titled "Characterizing landslide changes across High Mountain Asia with remote sensing data" on his behalf. Dr. Amatya also prepared materials and participated online in the CEOS WG Disasters meeting on behalf of the CEOS landslide pilot.

Dr. Amatya participated in NISAR Landslides Application Workshop in Seattle, WA and NASA CSDAP Pilot Project Meeting in Rockville, MD. At the 2019 AGU Fall Meeting, Dr. Kirschbaum gave a presentation titled “Characterizing landslide changes across High Mountain Asia with remote sensing data” on his behalf. Dr. Amatya also prepared materials and participated online in the CEOS WG Disasters meeting on behalf of the CEOS landslide pilot.

This year, Dr. Amatya published two papers. He was lead author on one published in Remote Sensing, highlighting landslides and susceptibility along the Karnali Highway, Nepal, and he...
was co-author on one published in Frontiers in Earth Sciences, reviewing the state of remote sensing capabilities for studying cascading hazard in High Mountain Asia (HMA). Additionally, he was a Co-I on three submitted proposals; of these, the proposals for SERVIR and for Understanding Changes in High Mountain Asia (HMA) were funded, but the proposal for AIST was not. An augmentation to the team’s previous HMA project was also funded through the NASA Commercial SmallSat Data Acquisition Program (CSDAP). A report highlighting feasibility of the high-resolution imagery of landslide studies was prepared and submitted as part of this grant.

In the year ahead, Dr Amatya will continue to expand the SALaD system’s ability by introducing a change detection module to the existing framework. He also will continue to support the CEOS landslide pilot and rapid response efforts mapping landslides.

**Dr. Andrew Badger** (sponsor: D. Kirschbaum) conducts research to advance ground validation activities for the Global Precipitation Measurement (GPM) in three ways: characterizing uncertainties in satellite and ground-based (radar, dense gauge networks) rainfall estimates over a broad range of space/time scales; using data from synergistic missions/sensors (e.g., SMOS, SMAP, GRACE, MODIS) to characterize correct detection or false alarms in GPM products; and characterizing uncertainties in hydrologic models and understanding propagation of input uncertainties into model forecasts. The research involves work on retrospective regional analysis, retrospective global analysis, and real-time global analysis. He utilizes existing open source modeling platforms, including NASA’s Land Information System (LIS), to conduct these analyses.

For his work on developing ground validation methods for the Integrated Multi-satellite Retrievals for GPM (IMERG) products, he developed a variety of validation techniques, in concert with Soil Moisture Active Passive (SMAP) observations as a proxy for precipitation detection. Dr. Badger developed multivariate frequency distributions for a set of SMAP overpass-to-overpass change thresholds to quantify the uncertainty in SMAP volumetric soil moistures estimates and to assess the skill of using SMAP as method of precipitation detection. Regarding the SMAP drying rate, in an effort to reduce the frequency of false alarms, Dr. Badger generated two estimates of soil drying rates from SMAP to quantify the anticipated rate of soil drying for times when light precipitation occurs between SMAP overpasses. He calculated a temporally dynamic drying rate for up to 30-days and applied these idealized drying rates such that varying overpass-to-overpass times have respective drying estimates for such timeframes.

In addition to validating IMERG, Dr. Badger applied the same validation method to the Multi-Radar/Multi-Sensor (MRMS) data to ascertain the potential level of skill when using SMAP as a proxy for precipitation detection. By validating both IMERG and MRMS with SMAP, this provides a level of confidence for expanding the analysis from the continental-scale to the global-scale.

Dr. Badger prepared material for discussion at the NASA GPM Cal/Val and Algorithm Symposium in Boulder, CO, in late March 2020. The goal of the material was to present the progress of the IMERG Hydro-GV with SMAP to a broader audience and to ascertain how these ground validation methods will be incorporated into current validation efforts.

In the upcoming year, Dr. Badger will continue to assess how the skill of the various validation methods. To maximize elements of skill associated with different regimes (e.g. landcover, soil type), a spatially dynamic validation product will be developed in hopes of capturing the best techniques for each region. Upon completion of potential refinements to the method, a global-scale analysis to assess IMERG skill will be conducted.

**Dr. Rhae Sung Kim** (sponsor: S. Kumar) works on developing, validating, and applying the land surface model and data assimilation for the Land Information System (LIS) team. This year, he worked with colleagues on the Snow Ensemble Uncertainty Project (SEUP) to characterize and estimate snow water equivalent (SWE) and its associated errors over the North America. Dr. Kim employed an ensemble-based modeling approach to examine the uncertainty (quantified as the ensemble spread) in simulated SWE estimation, using several currently operational models and three different modern forcing datasets (MERRA-2, GDAS, and ECMWF. During the 2009-2017 experimental period, SWE and total snow water storage (SWS (km3), SWE summed over all pixels) were assessed across regions with different topography, snow classes, and vegetation types to characterize uncertainties in space and time. The highest modeled SWE uncertainty was observed in mountain regions, in particular, the Pacific Coastal mountains, likely due to the relatively deep snow, forcing uncertainties, and process variability between the different models in resolving the snow processes over complex terrain. This highlights a need for high-resolution estimates in mountains to capture SWE variability. In tundra regions, even though the spatiotemporal variability in
modeled SWE is low, there is considerable uncertainty in the SWS estimates, due to the large areal extent over which those estimates are spread. This highlights the need for high accuracy in snow estimations across the tundra. In mid-latitude boreal forests, large uncertainties in both SWE and SWS indicate that vegetation-snow impacts are a critical area where focused improvements to modeled snow estimation efforts need to be made. Finally, the first-order control of SWE on runoff estimation (via snow melt contribution to runoff) is observed in the SEUP results over most of North America, pointing to the need for better SWE observations in order to improve runoff estimation. Overall, Dr. Kim’s study serves as a benchmark for employing macroscale, ensemble snow modeling to quantify spatial and temporal SWE uncertainty in conjunction with the direct impact of SWE ablation and runoff on hydrological processes, which may help inform observational needs for future snow missions.

In other research, Dr. Kim employed a snow Observing System Simulation Experiments (OSSE) to derive the utility from several observations by exploring the interaction between different observation types (e.g., how they add to or detract from the desired objective) and observation sampling methods (e.g., using different spatial and temporal resolutions). Snow is one of the most important freshwater storages on Earth, yet there is significant uncertainty in our understanding and quantification of terrestrial snow; while this has encouraged the development of remote sensing methods to estimate snow, no single sensor exists that currently provides global snow information with the required accuracy and resolution for climate studies and hydrologic applications. As new observing systems are designed for characterizing snow, systematic efforts to quantify their utility for scientific and end-user applications are needed. Dr. Kim simulated four different geophysical parameters (i.e., SWE, snow depth, snow cover, and snow albedo) from different observations, assimilations, and assessments for their efficacy in improving snow estimates using the NASA Land Information System (LIS) across a Colorado domain during the 2014-2017 period. Dr. Kim tried to achieve the following: 1) Quantify how combinations of assimilated remote sensing observations (snow cover, snow depth, SWE, etc.) can impact modeled SWE estimates, and 2) Quantify the observational characteristics (spatial and temporal resolution, revisit time) needed from remote sensing observations for reducing modeled SWE uncertainty. He will evaluate the results from the snow OSSE across a suite of metrics that capture the information of the observations and uncertainty. These results are expected to help in selecting and refining sensors for the accurate characterization of global, terrestrial snow mass.

SnowEx, a five-year program initiated and funded by NASA THP, addresses the most important gaps in snow remote sensing knowledge. It focuses on airborne campaigns and fieldwork, and on comparing the various sensing technologies, from the mature to the more experimental, in globally-representative types of snow. The goal is to address the most important gaps in our snow remote sensing knowledge, and thus lay the groundwork for a future snow satellite mission. To support SnowEx in the modeling aspect, Dr. Kim developed a near real time snow monitoring (depth and SWE) over SnowEx domain by simulating LIS land surface models (https://lis.gsfc.nasa.gov/projects/SNOWEX).

This past year, Dr. Kim gave lead author presentations at the 2019 AGU Fall meeting in December and at the 2020 AMS annual meeting in January, and he attended a SnowEx workshop in Baltimore, MD. Dr. Kim was a lead author on a 2019 paper titled “Estimating alpine snow depth by combining multifrequency passive radiance observations with ensemble snowpack modeling” published in Remote Sensing Environment. Another first author paper is under review with Water Resources Research. As a Co-I, Dr. Kim’s two proposals were awarded in a NASA AIST call: one titled “Towards the Next Generation of Land Surface Remote Sensing: A Comparative Analysis of Passive Optical, Passive Microwave, Active Microwave, and LiDAR Retrievals” and another titled “New Observing Strategies -Testbed (NOS-T) Pilot Study for A Hydrology Mission Design and Analysis System (H-MIDAS)”.

Upcoming work includes the implementation and validation of the LIS-DA to improve hydrological processes for both snow OSSE and NOS-T work. Dr. Kim also plans to use orbital trajectory data for different sensors within the Land Data Toolkit (LDT) observation simulator to evaluate the SWE or other variable resolution and timing requirements. He will continue his work with the snow OSSE and complete a draft of a manuscript that describes the follow-up questions of SEUP. He also plans to prepare an abstract for the 2020 AGU Fall meeting and the 2021 AMS annual meeting.

The development and coordination of water resource applications and water cycle activities within the Group on Earth Observations (GEO) and in the wider water community requires substantial coordination and nurturing both within and outside NASA and the US. Mr. Richard Lawford (sponsor: F. Policelli) maintains the coordination and synergies needed to advance the use of NASA hydrometeorological data products both in GEO and in the water community. The GEO Global Water Sustainability
GEOGLOWS, a GEO initiative focused on supporting global water sustainability through water services and products, features projects addressing flooding, drought, water supply and water resources. During 2019, NASA GEOGLOWS projects expanded the GEOGLOWS portfolio of projects. Mr. Lawford contributed a description of NASA activities to the 2020-2022 GEOGLOWS work plan update and contributed inputs on IGWCO and NASA GEOGLOWS projects to the newly launched GEOGLOWS Website. As part of GEOGLOWS outreach, he presented highlights from GEOGLOWS to the NASA Water Resource Program Team meeting in Portland, OR in July 2019. Subsequently, in collaboration with NASA GEOGLOWS PIs, he prepared a more comprehensive slide deck on NASA Contributions to GEOGLOWS for use by NASA and GEOGLOWS program managers.

As chair of the IGWCO CoP, Mr. Lawford initiated a review of the IGWCO CoP; this review, led by Dr. Wolfgang Grabs, resulted in a roadmap for IGWCO. The roadmap promotes the broadening of IGWCO CoP’s outreach for GEO and Earth Observations to organizations such as UN-Water and the development of a water interface with the GEO Knowledge Hub. Mr. Lawford organizes quarterly IGWCO teleconference calls of which the minutes are provided to the ~140 members. In addition to discussing the roadmap, participants discussed updates to GEO water-related Initiatives, Essential Water Variables (EWVs), evolving GEO expectations, and the GEO Knowledge Hub. Actions on Recommendations from the GEOSS Water Strategy continued to be tracked and new actions documented. Mr. Lawford completed a major review of the status of these actions in March 2020 and has prepared an update that is being distributed to the GEO Program Board, CEOS, and WCRP or WMO. The GEO Program Board recently adopted an “Earth Observations for the W-E-F Nexus (EO4WEF)” Community Activity for which Mr. Lawford prepared a 2020-2022 work plan and responded to questions from US GEO and other groups.

The Water-Energy-Food (W-E-F) Nexus provides a new approach to using Earth Observations for integrated resource planning and management. This past year, Mr. Lawford completed a synthesis report for this Future Earth W-E-F Nexus Cluster project. The report assessed the role of data, information systems and improved governance in increasing W-E-F Nexus Sustainability. It also outlines a strategy for developing regional information systems and pilot projects to encourage integrated planning among the three sectors. The report is available through Research Gate or directly from Mr. Lawford. Additionally, a Special Issue of the online journal Frontiers in Environmental Sciences dealing with the W-E-F Nexus has been completed by Mr. Lawford and two co-editors, Drs. Rabi Mohtar (Texas A&M) and Jill Engel-Cox (DOE). Details on this special collection are provided here: http://www.frontiersin.org/Freshwater_Science/researchtopics/Achieving_Water-Energy_Food_Nexus_Sustainability_a_Science_and_Data_Need_or_a_Need_for_Integrated_Public_Poli/6823. According to the site, papers in the special issue have received a cumulative total of 92,679 views (as of 5/1/2020). Among the 25 papers in this special issue, Mr. Lawford is the sole author for one paper on the design of information systems, and a co-author on a second paper on tradeoffs and co-benefits of the targets for SDG Goals 2 (food), 6 (water), and 7 (energy).

Together with Jennifer Daw (DOE), Mr. Lawford organized a W-E-F Nexus poster session at the 2019 AGU Fall meeting in San Francisco, CA; the session addressed the benefits of using Earth Observations in decision making for the WEF Nexus. Mr. Lawford presented a poster in this Session, along with an iPoster in a GEO session on ways in which the W-E-F Nexus could interface with GEO Knowledge Hub resources. He has helped to popularize the added value of Earth Observations in integrated planning for the W-E-F Nexus via several talks and poster presentations at various meetings and conferences: the Water Future Conference in Saskatoon, SK in May 2019; the 12th International Precipitation Conference and Soroosh Sorooshian Hydrometeorology Symposium in Irvine, CA in June 2019; and, the Canadian Meteorological and Oceanographic Society at the University of Manitoba in Winnipeg in February 2020. Also, in February 2020, Mr. Lawford and colleagues launched the GEO EO4WEF Community of Practice (CoP), and approximately 40 experts have joined. The first teleconference call focused on the GEO Knowledge Hub, developing an EO4WEF project inventory, follow-up to the Future Earth W-E-F Nexus report, opportunities for meetings and funding, and the CoP’s Terms of Reference.

Regarding Earth Observations and Water Sustainability, Mr. Lawford supported the development of the Sustainable Water Future Conference in Bengaluru, India, by organizing three sessions on the theme of “Sustainability in Water Space,” reviewing abstracts and chairing two sessions at the conference in September 2019. He gave two presentations in the W-E-F Nexus sessions as well as one on the role of data and Earth
Observations in Monitoring SDG6. He prepared a summary of the meeting, which was published in the February 2020 GEWEX Quarterly. Mr. Lawford also participated in the Red River Basin Commission’s (RRBBC) annual meeting in Fargo, ND in January 2020, where attendees discussed water management issues for the Red River of the North Basin. Discussions also are underway with the Goddard DAAC, Canada Water Futures, Agrifood Canada, and others about possible projects or activities in the Red River of the North Basin.

Mr. Lawford will continue to contribute to the development of GEOGLOWS and GEO water activities. He also will act on the recommendations for the IGWCO CoP Roadmap and develop actions and strategies for addressing the remaining recommendations in the GEOSS Water Strategy. These opportunities and others will be used to foster links with NASA water activities with GEO, especially in the GEO Knowledge Hub area. Additionally, Mr. Lawford will continue to develop the theme of Earth Observations and information systems for the W-E-F Nexus, drought risk monitoring and the Sustainable Development Goals. He will address appropriate recommendations in the Future Earth W-E-F Nexus report. He also will support the MPDI Sustainability issue with a paper on EO and the W-E-F Nexus, and possibly develop a paper of GEO water activities. He plans to participate in 2020 Fall AGU Meeting and others as appropriate.

Throughout this past year, Dr. Cheng-Hsuan (Joseph) Lyu (sponsor: E. Kim) has supported the National Polar-orbiting Partnership (Suomi-NPP)/ Advanced Technology Microwave Sounder (ATMS) & Visible Infrared Imager Radiometer Suite (VIIRS) pre-launch testing and post-launch sensor calibration and validation and algorithm development, and subsequent Joint Polar Satellite System (JPSS)/ATMS sensors testing, characterization and/or algorithm development.

Dr. Lyu requested, downloaded and processed ATMS raw data record (RDR) science data (both from S-NPP and NOAA-20) and generated ATMS monthly performance trending reports, which he provided to JPSS ATMS instrument managers, his sponsor, and other colleagues. This year, Dr. Lyu received reviewers’ comments from IEEE TGRS on his NOAA-20 ATMS active geolocation journal paper. In April 2020, Dr. Lyu revised and resubmitted it to IEEE TGRS.

He was also involved with several types of reviews. Dr. Lyu contributed some J2 Thermal Vacuum Testing (TVAC) analysis results for JPSS-2 (J2) ATMS Polarimetric Scanning Radiometer (PSR) Science Review slides/document, and he supported the NASA science, including MIT Lincoln Laboratory (MIT-LL), tag-up discussions and the J2 ATMS PSR review on Mar. 9 - 10, 2020. Dr. Lyu supported reviews of several Performance Review Documents and various calibration test reports. As a result of his efforts, Northrup Grumman (NG) has made changes and corrections to their dG/G (short-term gain stability evaluation) equation. Additionally, Dr. Lyu supported the J2 ATMS Thermal Vacuum (TVAC) on-site test from Nov. 22 - 29, 2019, and provided TVAC analysis reports to the NASA science team.

Dr. Lyu will continue supporting S-NPP and NOAA-20 (J1) ATMS on-orbit calibration and validation activities, and will continue monitoring ATMS science RDR, generating ATMS monthly trending reports and sending reports to JPSS ATMS instrument managers and NASA sponsor and colleagues. He will be coordinating with all NASA ATMS science team and ATMS SDR team members, including NOAA/STAR, MIT-LL, NG and Raytheon to support JPSS-2 and NOAA20/ATMS and NPP/ATMS as well as the subsequent sensors’ calibration and validation plan and/or activities. This includes the upcoming JPSS-2 Satellite Level integration review and Satellite Level TVAC testing activities.

He will continue supporting J2 ATMS post-launch working group planning and discussions, and he plans to review J2 ATMS test reports, CDRL, etc. documents and send reviewer’s report to his sponsor and other colleagues. Along with the NASA ATMS science team, MIT-LL, NOAA, and NG, Dr. Lyu will work on a paper on J1 to present analysis results about ATMS prelaunch characterization tests and post-launch on-orbit performance.

Mr. Thomas Stanley (sponsor: D. Kirschbaum) continues to develop, test, and expand a rainfall-triggered landslide model that provides real-time and forecasted estimates of potential landslide activity at a regional and ultimately global scale. One of the main goals of his research is to aid in evaluating model outputs and providing improving characterization of landslide hazard and triggering conditions. He is also involved with managing and updating a landslide database of events, and evaluating and improving landslide inventories.

Mr. Stanley developed a prototype of the version 2.0 global landslide nowcast. This nowcast incorporates soil moisture and other variables into a machine-learning model. Among other challenges, this project entailed merging diverse landslide databases from across the research community. The model outputs the probability that a landslide will occur at a resolution of one kilometer across the Earth’s tropical and temperate regions. This prototype doubles the accuracy of the
For the implementation of GEOSS, the GEO requested building information and data products that can meet users’ and stakeholders’ needs within various Societal Benefit Areas (SBAs). One strategic priority identified by GEO is that Members address EWVs that are particularly relevant to Water Cycle Extremes (WCEs) due their disproportionate impact on social, economic, and ecological systems. The impact of global climate change on WCEs is also of major concern; therefore, in response to the feedback to the White Paper, Dr. Unninayar has begun considering the incorporation (in the EWV review) of observations and product delivery requirements of high-impact water cycle-related events, such as floods, droughts, forest fires, landslides, and severe storms (hurricanes and tropical storms). This also would address objectives of the UN-SDGs and the Sendai Framework (disaster risk reduction), which calls for multi-hazard early warning systems (also emphasized by the WMO).

In the coming year, work will continue on further developing observational and modeling requirements for EWVs, especially requirements for observation of WCEs. A special sub-category of EWVs will be introduced to integrate EWVs and WCEs together in terms of observing and product delivery requirements for water-related, high impact, event-based extremes (mentioned above). This too will address the needs of the Sendai Framework, the Ramsar Convention on Wetlands, the Aichi Convention on Biological Diversity, and the UN Framework Convention on Climate Change.

NASA's global Earth observing systems and data assimilation modeling technologies are well positioned to serve a broad range of research and applications end users. It is critical to identify in a timely manner extreme events and their impacts on water resources management as well as social and economic systems and structures. Space-based systems are uniquely positioned to provide global and transboundary coverage but could lack sufficient space/time resolution for some variables to adequately characterize intense or localized extreme events. Identifying gaps in existing data systems is important to address global water sustainability issues. IGWCO and GEOGLOWS' activities support the observations required for monitoring indicators of the UN-SDGs and the Sendai Framework on disaster risk reduction. Deficiencies will be considered as part of the planning for the next generation of Earth observing systems, following the recommendations of the National Academy of Sciences (NAS) Decadal Survey. Thus, Dr. Unninayar submitted a White Paper titled “Requirements for Essential Water Variables” to the Surface Biology and Geology (SBG) Community Workshop in June 2019 on planning for a SBG mission (a priority mission that the Decadal Survey recommends NASA considers). Also, while the IGWCO and GEOGLOWS recommended holding an international...
EWV Workshop to assemble multi-sectoral experts to discuss various issues related to EWVs, due to the COVID-19 outbreak, alternate plans are being considered, including postponing the workshop to 2021.

Dr. Unninayar continued advising the collaboration between NASA and the United Nations Environment Programme (UNE), the custodial agency for Sustainable Development Goals (SDGs), with regard to NASA’s Earth Observations to monitor indicators for SDG 6, which deals broadly with water resources management, water availability, water stress, water quality, wastewater management, health and sanitation. In 2017, Dr. Unninayar initiated this pilot project as a collaborative project between NASA/GSFC-Applied Sciences and UNE to conduct a “Multiple-Scale Analysis” of fresh water systems in selected countries on a priority basis for UNE’s SDG reporting needs. The pilot continued in 2018 and was extended into December 2019, with an emphasis on monitoring water quality parameters and coastal wetlands ecosystems using Landsat/Sentinel satellites. He co-authored with Raha Hakimdavar (lead, USDA) and others at NASA/GSFC and UMD a paper submitted to the MDPI Journal of Remote Sensing special issue on “Remote Sensing Measurements for Monitoring Achievements of the Sustainable Development Goals (SDGs).” NASA has since initiated a new pilot to investigate the use of EO in monitoring “Urban” sustainability by quantifying Urban extent and changes in collaboration with Conservation International (note, this addresses SDG 11.3.1).

In June 2019, Dr. Unninayar initiated discussion with NASA on potentially applying EO to other SDG goals and monitoring indicators, such as SDG 6.4.2: Level of Water Stress, and SDG 6.4.1: Change in Water-Use Efficiency. The objective of the indicator SDG 6.4 is described in the UN SDG Target 6.4: “By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.” All the above are “complex” indicators that involve cross-cutting Water-Energy-Food-Ecosystem Nexus issues, among others. In late 2019, Dr. Unninayar prepared a comprehensive White Paper on all UN-SDGs cross-mapped against existing and potential client organizations/UN custodial agencies, and relevant EO observations, and NASA-related programs/projects. The paper was distributed at NASA/GSFC and NASA-HQ for the further development of potential pilot projects for 2020-2021. The WP included a ranking of the extent to which existing NASA EO/RS observations and existing NASA/GSFC programs/projects were almost ready for monitoring SDG indicators; the challenge for NASA is to develop the tools and protocols to demonstrate that remote sensing EO can be used to monitor indicators of sustainable development. Following prototype applications at target sites chosen by collaborating end-user partners, the goal is to standardize the EO applications’ protocols through in-situ cal/val and extend the analysis to regional and transboundary scales. Ultimately, a system would be built for global monitoring of SDG indicators using NASA satellite and model-derived products. The procedures developed in this manner could be applied to other programs.

Dr. Unninayar is an invited founding member and rapporteur of the WEF-Nexus Community of Practice (CoP). He is exploring the development of verifiable methodology for assessing and optimizing the balance between competing resources in the water-energy-food (W-E-F) nexus. In fall 2019, he developed a methodology to integrate water-related SDGs and WEF objectives by constructing a new SDG-WEF index. Water is at the center of the intersection of the observational and decision support needs for the operational and strategic management of water resources to ensure the availability of fresh water for human consumption, as well as providing water for agriculture, energy production, and ecosystem services. In this connection, work continued on developing frameworks for the applications interfaces for water cycle-related EO data/info systems that can be accessed by the multi-sectoral end user communities. An integrated approach to the W-E-F nexus is considered essential for achieving the effective governance of sustainable environmental and economic development. In this context, Dr. Unninayar continued to work on advancing conceptual models to improve the data and information flow from observing systems to end-users via “adaptive cognitive intelligence” cloud-based user interfaces that apply analytical tools to address user queries and needs. Such a system would provide a transparent and seamless conduit to expand exposure to, the effectiveness of, and the transfer of various NASA observational and modeling products; this would support integrated global water cycle research and client-driven water resources management applications. Plans for a related workshop (tentatively titled “AI Applications to the Water-Energy-Food Nexus”) are underway.

At present, the COVID-19 pandemic is causing an inordinately large, ongoing impact on the national and interconnected fabric of social, industrial and economic systems and the global environment. In May 2020, Dr. Unninayar responded to a call of ideas (NASA@WORK) from the NASA HQ Administrator with...
two proposals: one titled “Understanding, quantifying, and predicting the seasonality (or not) of COVID-19 using EO/RS and global earth system models” and another titled “Understanding and monitoring the impact of COVID-19 on UN Sustainable Development Goals with EO/RS and earth system models.” Along with Dr. Argyro Kavvada (NASA/HQ), Dr. Unninayar submitted a proposal to the NASA-Challenge program “The SDG impact of COVID-19”, inviting participants to develop creative solutions to help countries across the world fight the impact of the COVID-19 by assessing the impact on the UN SDGs and the global environment by using NASA and other earth observations, crowd-sourcing data, and in-situ measurements. In March 2020, he proposed that the WEF-Nexus CoP consider how EO/RS and models can be used to assess and track the impact of COVID-19 on the WEF Nexus.

This past year, Dr. Unninayar was a co-convener of a session at the 2019 AGU Fall meeting titled “Remote sensing applications for water management and extremes prediction.” These themes have been conveyed successfully over several successive years, and have attracted numerous papers, covering nearly all aspects of remote sensing and modeling of the global water cycle and the application of data and models for monitoring EWVs, identifying extremes, and predicting future changes to water systems. Elsevier has approached Dr. Unninayar with a renewed interest in publishing a reference book on the topic of EO/RS applications for WRM. For AGU2020, Dr. Unninayar plans to be the primary convener for two sessions and co-convener of one.

In the coming year, he will continue to work with NASA-HQ, NASA/GSFC, and other national and international organizations regarding the implementation of the GEOSS Water Strategy, the international IGWCO-CoP, the GEOGLOWS program, and regional GEOSS projects such as AmeriGEOSS. Particular emphasis will be placed on using Earth observations for the monitoring of indicators of the UN-SDGs, the Sendai Framework for disaster risk reduction (among others), and on developing ways to address the WEF Nexus and WCEs. Specific attention will be paid to developing projects and pilots that use EO/RS and environmental models to understand, quantify and predict the seasonality and spatial/temporal propagation rates and cycles of COVID-19, which is currently global in scale and with inordinately large impacts on the fabric of global society and the eco-environment. For the UN SDGs, work will continue toward developing plans that demonstrate the benefits of NASA remote sensing data and models for achieving the targets of SDGs (6-Fresh water and sanitation, 2-Food production and food security, 3-Health and well being, 7-Energy access and resilience, 11-Urban environments, 13-Climate change, 14- Life under water, 15-Life on land). Applying EO/RS to monitor other SDG indicators will involve a broader range of satellite data and modeling-derived information products and statistics. Work will continue on improving the use of Earth observations and data/information systems to support integrated approaches to the strategic management of water resources in the context of an integrated W-E-F Nexus. Conceptual models for “adaptive-cognitive-intelligence” systems will be examined to develop multi-sectoral capabilities for accessing and using NASA observations, modeling and analysis products in the integrated analysis required by end-user research and applications. These activities will showcase the use of remote sensing and modeling technologies available at NASA, which assist policy-level decision makers and water resources managers with achieving their objectives.

GEWEX: The Global Energy and Water Exchanges project

Dr. Peter van Oevelen and Ms. Fernande Vervoort (sponsor: F. Policelli) with support from USRA and Science and Technology Corporation (STC) cover the operation of IGPO, and facilitate and coordinate GEWEX research, activities, and products. This past year, USRA provided directly or through access to the necessary facilities and staffing the support required to meet the obligations and responsibilities of IGPO and its Director. Examples include supporting the GEWEX Scientific Steering Group (SSG) and its Co-Chairs; assisting with the coordination and implementation of the Third Phase of GEWEX through GEWEX Panels, Working Groups, Regional Hydroclimate Projects (RHP) and the SSG; coordinating the formation of new working groups, panels, and related activities in certain areas of GEWEX; reporting on GEWEX activities to international bodies and government agencies; implementing an outreach program for GEWEX; representing GEWEX at scientific conferences and other international forums; facilitating the development of cross-cutting issues and the linkages of GEWEX with other programs, such as Future Earth and the Intergovernmental Panel on Climate Change (IPCC); managing travel requests from scientists to attend GEWEX meetings and meetings where GEWEX attendance is required; reviewing plans from WCRP and other environmental programs, providing inputs to planning documents for WCRP and other programs, and responding to numerous requests for information about the GEWEX program and data sets; and representing WCRP in the International Global Water Cycle Observations Community of Practice (IGWCO-COP) theme and
Science Advisory Group through the provision of secretariat services and contributions to the Group on Earth Observations (GEO).

Support related to the GEWEX SSG included updating Terms of References for panel members, working groups and SSG members; assisting with organizing the SSG-32 meeting at the Cahill Center in Pasadena, CA in January 2020, where the discussion centered on the GEWEX strategy for the coming years, including the formation of new Process Evaluation Studies and its place within the structure of GEWEX; and, introducing new initiatives (e.g., GLASS Land Atmosphere Feedback Observatories (GLAFOs) and the GEWEX Integrated Product).

IGPO assisted the GEWEX SSG co-chairs with their inputs and responses to the WCRP Joint Scientific Committee (JSC), who are formulating a road map for the development of a new strategic plan for WCRP. Additionally, IGPO prepared presentations for the SSG co-chairs for the JSC-40 meeting held in Geneva, Switzerland (May 2019). With respect to the WCRP Grand Challenge (GC) “Challenge on Clouds, Circulation and Climate Sensitivity,” IGPO assisted the Cloud Feedback Model Intercomparison Project (CFMIP) committee in collaboration with the GEWEX Global Atmospheric System Studies (GASS) Panel and the Climate Dynamics Panel (CDP) of Climate and Ocean – Variability, Predictability, and Change (CLIVAR) project with the promotion of the 2019 CFMIP meeting in Mykonos, Greece in September. In support of the WCRP GC “Water for the food baskets in the World,” IGPO presented several posters at the 2019 AGU Fall Meeting in San Francisco, CA in December. On several occasions, the IGPO director and the GEWEX Co-Chairs met with Pavel Kabat, who is the new World Meteorology Organization (WMO) Chief Scientist and WCRP Director of Research in 2019. These meetings concerned the developments at WMO and WCRP and the impact it may have on GEWEX and other WCRP core programs. IGPO also represented WCRP in the IGWCO-COP theme and Science Advisory Group through the provision of secretariat services and contributions to the Group on Earth Observations (GEO), where appropriate.

For the GEWEX Panels’ annual meetings, IGPO tracked travel grants, assisted with logistics and planning, and created meeting websites with registration, venue, and other necessary and relevant information. Additionally, IGPO supported the Global Atmospheric System Studies (GASS) Panel with organizing and/or promoting the following meetings: the Regional Modeling & Aerosol in Snow Workshop in Nanjing, China (July 2019), the Aerosols Clouds Precipitation and Climate (ACPC) Workshop 2019, the International Workshop on Convection Parametrization in Exeter, UK (July 2019), and the LATSIS Symposium 2019, which was organized together with the 3rd GEWEX Workshop on Convection-Permitting Climate Modeling in Zurich, Switzerland (August 2019). IGPO attended several videoconferences with the GASS Panel members dealing with panel and projects progress and strategy, and assisted with the installment of two new panel members. IGPO also supported the GEWEX Water Vapor Assessment (G-VAP), one of the projects of the GEWEX Data and Analysis Panel (GDAP), with the promotion of their 8th G-VAP meeting in Madrid, Spain (June 2019). Assistance to GDAP also involved updating their Panel Webpages, installing a new panel member, organizing the 2020 GDAP meeting in Tucson, AZ (January 2020), and promoting the workshop on the GEWEX Integrated Product in Toledo, Spain (March 2020).

In support of the GEWEX Hydroclimatology Panel (GHP), IGPO assisted with organizing and coordinating the 2019 GHP Meeting and a GHP Workshop, held in Sydney, Australia (October 2019). Additionally, IGPO assisted with the promotion of the 2nd International Global Water Futures (GWF) Meeting in Saskatoon, Canada (May 2019) and the 12th HyMeX Workshop in Split, Croatia (May 2019), which are both RHP’s. IGPO assisted PannEx, an initiating RHP on the Pannonian Basin, with editing and publishing of their White Book, and organizing their 5th PannEx Workshop in Novi Sad, Serbia (June 2019). IGPO assisted GHP with a session for the Third Pole Environment (TPE) project at the AOGS in Singapore (August 2019) and The AsiaPEX Kick-off Conference in Sapporo, Japan (August 2019). Both projects are prospective RHP’s. IGPO collaborated with WCRP Coordination Office for Regional Activities and other relevant parties to increase its network and secure funding for a workshop in Central Asia in order to establish a future RHP in this region by visiting several relevant research institutes and funding organizations in Bishkek, Kirgystan (March 2020). Lastly, IGPO assisted GHP with the installment of four new members. IGPO also supported the GEWEX Global Land/Atmosphere System Study (GLASS) Panel with organizing their 2019 GLASS Panel Meeting in Toledo, Spain (August 2019) and with installing two new panel members.

The IGPO developed, published, and distributed GEWEX Quarterly, a quarterly published newsletter with a distribution of approximately 1600 copies. (As of August 2019, the GEWEX Newsletter has been renamed to GEWEX Quarterly to make a clear distinction from GEWEX E-News.) For every issue of the newsletter, IGPO determined the newsletter content; solicited articles; and collected, edited, and formatted these articles for
IGPO's director met with colleagues from University Utrecht and to be held in Versailles, France in November 2020. In addition, conference “Earth Observation for Water Cycle Science 2020” advisory board. In 2019, contact between IGPO/GEWEX and ESA member of the Digital Belt and Road Initiative: DBAR-Water to the Water Cycle Societal Benefit Area under GEO and is a Earth2Observe Project. Dr. Van Oevelen also provided input Observations (GEO), and on the Board of the FP7 Project (IGWCO) Community of Practice (COP) of the Group on Earth Committee for the Integrated Global Water Cycle Observations (IGPO) developed and maintains a Wiki page containing a list of information on upcoming and past GEWEX events. In addition, IGPO also hosts (including domain registration), maintains, and continually updates the GEWEX website (http://www.gewex.org), which provides recent GEWEX science results, overviews of the structure and organization of GEWEX and its projects, access to GEWEX reports and publications and GEWEX data sets, updates on recent and planned activities, and a calendar of project meetings and conferences. IGPO also hosts (including domain registration), maintains, and updates the GEWEX events website (http://www.gewexevents.org), which provides detailed information on upcoming and past GEWEX events. In addition, IGPO developed and maintains a Wiki page containing a list of most commonly known and used Abbreviations and Acronyms related to climate research (https://bit.ly/2CEE2NP).

To encourage the involvement of young scientists in GEWEX/WCRP activities, IGPO invited the Young Hydrologic Society (YHS), the AGU Hydrology Section Student Subcommittee (H3S), and the Young Earth System Scientists (YESS) Community to contribute one-half page in each issue of GEWEX Quarterly to advertise their activities. The IGPO assisted in planning cross-collaboration activities of GEWEX and the Integrated Land Ecosystem—Atmosphere Processes Study (iLEAPS). GEWEX and CLIVAR joint activities included the JSC-task group on extreme weather and climate and the WCRP Monsoon Panel. The latter has organized an advanced school and workshop in São Paulo, Brazil in August 2019 and has welcomed a few new panel members.

The IGPO director served on the Executive Board of the Science Committee for the Integrated Global Water Cycle Observations (IGWCO) Community of Practice (COP) of the Group on Earth Observations (GEO), and on the Board of the FP7 Project Earth2Observe Project. Dr. Van Oevelen also provided input to the Water Cycle Societal Benefit Area under GEO and is a member of the Digital Belt and Road Initiative: DBAR-Water advisory board. In 2019, contact between IGPO/GEWEX and ESA intensified, which resulted in the planning of a jointly organized conference “Earth Observation for Water Cycle Science 2020” to be held in Versailles, France in November 2020. In addition, IGPO’s director met with colleagues from University Utrecht and Technical University Delft, both in The Netherlands, regarding possible joint research opportunities.

Also in the past year, the IGPO director attended and gave oral and/or poster presentations at the following meetings: GEWEX SSG Meeting, Geneva, Switzerland; ESA/EC Meeting, Brussels, Belgium; UCP 2019 Understanding Clouds and Precipitation, Berlin, Germany; EGU General Assembly 2019, Vienna, Austria; ANDEX Writing Workshop, Quito, Ecuador; Aerosols Clouds Precipitation and Climate (ACPC) Workshop, Nanjing, China; JSC-40 meeting, Geneva, Switzerland; CM SAF User Workshop 2019, Mainz, Germany; International Precipitation Conference and the Soroosh Sorooshian Hydrometeorology Symposium, Nanjing, China; International GEWEX/GASS/LS4P and TPEMIP Regional Modeling & Aerosol in Snow Workshop, Nanjing China; AOGS 16th Annual Meeting, Singapore, Singapore; GLASS Panel Meeting, Boulder, CO; 1st Kick-off Conference of AsiaPEx, Sapporo, Japan; GHP CC Workshop: Determining Evapotranspiration, Sydney, Australia; GHP Meeting, Sydney, Australia; ICRC-Cordex 2019: International Conference on Regional Climate, Beijing, China; ISCCP-NG Meeting, Darmstadt, Germany; WMO High Mountains Summit, Geneva, Switzerland; USGCRP International Briefing, Washington, DC; USGCRP Meeting, Washington, DC; AGU Fall Meeting, San Francisco, CA; DBAR-Water Workshop, Shenzhen, China; DBAR Science Team Meeting, Shenzhen, China; and the 4th Digital Belt and Road Conference, Shenzhen, China. Due to COVID-19, participation at the GEWEX Integrated Product Workshop in Toledo, OH (March 2020), WCRP Elements Workshop in Washington, DC (March 2020), and EGU General Assembly 2020, Vienna, Austria (May 2020) was cancelled.

At the time of this writing, GEWEX meetings and workshops are postponed, cancelled, or moved to an online setting due to COVID-19 Pandemic until September 2020. These include the 3rd Global Water Futures Annual Open Science Meeting in Waterloo, Canada; the JpGU-AGU Joint Meeting 2020 in Chiba, Japan; the 10 Year HyMeX Workshop in Toulouse, France; the 3rd Baltic Earth Conference in Jastarnia, Poland; the 6th PannEx Workshop in Martonvásár, Hungary; the GASS side meeting at the Improvement and Calibration of Clouds in Models Workshop in Toulouse, France; the16th BSRN Scientific Review and Workshop in Bologna, Italy; The International Conference on Clouds and Precipitation in Pune, India (August 2020); The International Conference on Tibetan Plateau and High Mountains Energy and Water Exchanges in Yunnan, China; and, The International Workshop Convection-Permitting Modeling for Climate Research in Kyoto, Japan. IGPO is assisting with
organizing the UTCC-PROES Meeting 2020 in Paris, France (September 2020), the joint ESA-GEWEX conference “Earth Observation for Water Cycle Science 2020,” which will be followed by a Pan-GEWEX meeting, scheduled in Versailles, France (November 2020), the 2nd Evapotranspiration Workshop, Wageningen, The Netherlands (February 2021), and 3rd Pan-GASS Meeting, Monterey, CA (October 2021).

**CODE 618: BIOSPHERIC SCIENCES LABORATORY**

**Dr. Assaf Anyamba** (sponsor: C. Tucker) conducts research using time series satellite vegetation index measurements from various satellite instruments including MODIS, SPOT Vegetation, NOAA’s Advanced Very High Resolution Radiometer (AVHRR), Tropical Rainfall Measuring Mission (TRMM), and associated ground-based rain gauge measurements. Other research focuses on land surface response to interannual climate variability associated with El Niño/Southern Oscillation (ENSO) and drought pattern analysis; and, it infers long-term trends and dynamics of vegetation patterns, development of long-term data records (LTDRs) of the biosphere and links between climate variability and vector-borne disease outbreaks. Dr. Anyamba leads and develops research analysis and applications development for global agricultural and drought monitoring for the USDA/ Foreign Agricultural Service (USDA/FAS); climate variability and vector-borne disease prediction mapping in support of the DoD Global Emerging Infections Surveillance and Response System (DoD/GEIS) and USDA/Center for Medical, Agricultural & Veterinary Entomology (USDA/CMAVE); and global monitoring and risk assessment for Chikungunya outbreaks in support of Defense Threat Reduction Agency (DTRA).

Throughout this past year, Dr. Anyamba continued to maintain an active research and applications portfolio in both vector-borne disease monitoring and risk mapping and global agricultural monitoring. Together with his team, they successfully transitioned the Global Chikungunya Monitoring and Mapping System (CHIKRisk) ([https://vbd.usra.edu](https://vbd.usra.edu)) from a DTRA research and development effort into the operational realm supporting Armed Forces Health Surveillance Branch Global Emerging Infections Surveillance (GEIS). This application is now utilized on a monthly basis to support DoD Combatant Commands in risk assessment for pre- and post-deployment Force Health Protection (FHP) decision making. They also operationalized the updated version of Global Agricultural Monitoring System (GLAM, [https://glam1.gsfc.nasa.gov/](https://glam1.gsfc.nasa.gov/)), which supports USDA/FAS monthly agricultural commodity production estimates. Edwin Pak (SSAI) is lead engineer and developer of the GIMMS GLAM system.

Dr. Anyamba participated in Rift Valley fever fieldwork in Free State province, South Africa to evaluate interepizootic period mosquito larval succession during the rainfall season (January – May 2019). Dr. Damoah (618/MSU) provided daily climate data support during fieldwork. The conducted larval sampling at Meadow site (identified Aedes spp., Culex spp. and Anopheles spp.) for 30 days beginning on February 11, 2019 immediately after flooding of the dambo/pan habitat (see Figure 1); however, this period did not have continuous daily rainfall, and there was little or no rainfall from February 21 to March 10. The larval population succession shows that Aedes spp. peaked immediately after the early February rains and collapsed quickly within a period of about 15 days. The emergence of the Anopheles spp. was short-lived, and the number of specimens collected were very low ~ 3/dip during the entire sampling period. However, there was an explosion of Culex spp. after the collapse in the Aedes spp., peaking at ~80 specimens/dip on March 1 and then steadily declining to near 0 specimens/dip on March 11. This succession pattern mirrors the sampling results reported (Linthicum et al., 1985) from Kamiti dambo in Kenya. However, the number of specimens collected at Meadows dambo are very low, which may be partly attributed to unfavorable climate conditions over the last several seasons. Such a low number decreases the probability of virus in the mosquitoes and therefore diminishes the chance of an outbreak or even localized Rift Valley fever activity during the 2019 rainy season.

Over this past year, Dr. Anyamba was invited to present at several interagency meetings and international forums: in late May 2019, the Future Earth Health Knowledge-Action Network Symposium at The Center for Sustainability Science in Academia Sinica, Taipei, Taiwan; in June 2019, the Symposium on Geographic Perspectives on Infectious Diseases in Humans, Animals, and the Environment, Harvard University; in September 2019, the American Public Health Association (APHA): Climate Change & Health Session; in September 2019, the Pandemic Prediction and Forecasting Science and Technology (PPFST) Working Group; in September 2019, the DTRA Biological Threat Reduction Program (BTRP) Science Program Review (SPR) 2019, Warsaw, Poland; and in November 2019, the 2nd Asia Pacific Rickettsia Conference (APRC2) and DTRA Biological Threat Reduction Program (BTRP) Rickettsial Pathogens Threat Reduction Network Meeting in Chiang Rai, Thailand. Of note, in October 2019, Dr. Anyamba was invited to give a keynote presentation on “Rift Valley fever Risk Mapping and Prediction: Progress, Challenges
and Future Opportunities” at the GEOVet 2019 Conference, UC Davis, California. GEOVet is an international, interdisciplinary conference that specializes in spatial epidemiology, spatial statistics and the application of Geographical Information Systems (GIS) to animal health, public health and food safety.

Dr. Anyamba, Dr. Soebiyanto and Erin Glennie (618/SSAI) traveled to Vienna, Austria in October 2019 to conduct a training session on Remote Sensing Applications in Agriculture and Vector-borne diseases, where they demonstrated the use of the GIMMS Global Agricultural Monitoring System and Chikungunya Risk Mapping and Forecast system. Dr. Anyamba next attended a Salzburg Global Seminar held at Schloss Leopoldskron in Salzburg, Austria. This seminar brought together 32 multidisciplinary experts to address the following program objectives: define outbreak milestones relevant to the animal health, wildlife, and environmental sectors; identify key barriers to implementation at the national and transboundary levels and develop guidance to address these barriers; map concrete steps to align the One Health outbreak metrics framework with other efforts to improve disease surveillance capacity; and, identify key agencies and stakeholders for advancing the outbreak timeliness metrics in the One Health space. Among other meetings he attended were the World Organisation for Animal Health/ Organisation Mondiale de la santé animale (OIE) Meeting on Approaches to improving sustainable management of animal health emergencies in November, and an invited meeting of experts on Emerging Issues in Climate Change and Human Health by the U.S. National Academies of Sciences, Engineering, and Medicine (NASEM) held in Washington, DC, in December. The latter brought together scientific experts as well as environmental and health philanthropies to consider areas of climate and human health that would especially benefit from increased investment and research focus.

Dr. Amanda Armstrong (program manager: H. Margolis) works on grant #80NSSC19M0111 as PI, with Dr. Batuhan Osmanoglu as Institutional PI. The goal is to examine and quantify the likelihood of predicted changes in TTE forest structure patterns occurring within the ABoVE extended domain, using airborne imagery and lidar observations, site-scale (i.e., high resolution spatially-explicit individual-based) forest and tundra vegetation modeling and a Landsat-derived map of the extent and pattern of the TTE.

Work began on the ABoVE Phase II funded project in May 2019. During the first three quarters of this project, modeling work began, a graduate student was hired and began tenure at the University of Virginia (UVA), two team efforts to merge models began in tandem (one at UVA, the other based at NASA-GSFC but including PI Armstrong remotely), and Dr. Armstrong communicated the project aims and progress at numerous meetings and conferences. Project team members coded significant improvements to the SIBBORK model, initially focusing on the improvement of how the model simulates the below-ground processes that occur in boreal and tundra systems. This included the addition of a permafrost module, which tracks the monthly freeze and thaw depths through time, computes the active layer depth, resultant soil moisture availability, and includes soil depth, texture and thermal-dynamics. An unforeseen preceding code upgrade, moving
SIBBORK from python 2.7 to 3 and subsequent debugging, was completed prior the permafrost module integration and testing.

In early 2020, team members Drs. Armstrong and Osmanoglu and Dr. Paul Montesano (GSFC/SSAI) had weekly work sessions remotely to debug the permafrost module that was previously built and tested. The active layer depth in the module was artificially bottoming out due to a unit error with one of the soil depth variables that was being pulled directly from the soilgrids.org database. Once corrected, team members began to link the permafrost module into the SIBBORK model such that permafrost would drive the belowground freeze/thaw environment, which would in turn impact tree growth. In order for solar radiation and climate to influence permafrost dynamics, upgrades to SIBBORK had to be made to both topographic position and solar radiation. Previously, solar radiation impacted photosynthesis in the model by impacting the amount of light incident on individual trees based on sun angle, competition, and topography of the plot. To address this impact on both the soil and tree canopy, solar.py was written into SIBBORK in early 2020, and incident solar radiation now impacts photosynthesis in trees and warms soils to affect permafrost thaw and melt dynamics. Additionally, each plot’s topographic position previously was not variable, incident sunlight did not affect soil temperature and topography from one plot did not influence neighboring plots (e.g., water from an uphill plot would not flow into a downhill plot). They upgraded the topographic positional index to account for not only slope and elevation but also concavity and watershed shape at a sub-plot level. Concurrently with these improvements, the team made input dataset upgrades to continue the process of making SIBBORK a dynamically spatially explicit model. In order to correctly simulate freeze/thaw dynamics through time and at fine spatial scales, soil data parameters, cloudiness and climate data are incorporated by interacting directly with data repository APIs, meaning that when the model is initialized, it now connects with these APIs to download the required dataset for each site that is run.

During fall 2019 and spring 2020 (prior to the COVID-19 pandemic), Dr. Armstrong met weekly with E. Heffernan and H. Epstein at the University of Virginia. They would discuss presenting the SIBBORK Model and the ArcVeg Model for the purposes of familiarizing team members and affiliated UVA graduate and undergraduate students with the internal framework, processes and equations found within both models. In addition, E. Heffernan and Dr. Armstrong began building a shrub, tree and calibration/validation database. Tree and shrub demographic and allometric information were compiled for the ABoVE domain parameterization; Dr. Armstrong added to the validation dataset database downloading, cataloguing and characterizing permafrost, soil, shrub and tree-cover datasets, all essential for calibrating and validating model runs. Throughout the year, monthly team member meetings were conducted virtually to report on progress and brainstorm the important linkages between the variables and modules that are currently being upgraded within SIBBORK. In the coming year, she plans to upgrade soil nutrients, litter, moss and decomposition in SIBBORK to read the model for ArcVeg interfacing.

In May 2019, Drs. Armstrong, Montesano and Epstein traveled to La Jolla, CA to present at the ABoVE Science Team Meeting, where she presented a speed talk as a new Phase II investigator, and the team presented posters for ABoVE projects. In December 2019, at the 2019 AGU Fall Meeting, Drs. Armstrong and Osmanoglu gave a presentation titled “Vulnerability of the taiga-tundra ecotone: predicting the magnitude, variability, and rate of change at the intersection of Arctic and Boreal Ecosystems.” In early 2020, Dr. Armstrong was invited to speak at a European Modeling Roundtable at Helmholtz UFZ in Leipzig, Germany. The roundtable consisted of European Modeling scientists coming together to discuss the frontiers of Forest Modeling and present their work. Her invited talk was titled “Linking remote sensing with forest modeling: toward spatially explicit modeling across temperate and boreal
Mr. Bhaskar Bishnoi (sponsor: C. Tucker) works with Dr. Assaf Anyamba, Dr. Radina Soebiyanto, Dr. Richard Damoah, and Ms. Heidi Tubbs on the development and deployment of the CHIKRISK application currently hosted on USRA server (vbd.usra.edu). CHIKRISK (Global chikungunya risk mapping, monitoring and Forecasting) provides a platform for monitoring Chikungunya activity worldwide and climate-based risk maps for Chikungunya occurrence. In addition, he is working on developing the application, MEDINA, which will focus on vector-borne diseases like Dengue and Zika, including Chikungunya. Climate data used will include rainfall from Climate Prediction Center Unified (CPC-UNI), land surface temperature from NASA Moderate Resolution Imaging Spectroradiometer (MODIS), soil moisture and specific humidity from Global Land Data Assimilation (GLDAS).

Mr. Bishnoi revamped the CHIKRISK application by expanding the UI usability and responsiveness. A few significant improvements included implementation of less pixelated administrative boundaries, displaying locations of chikungunya mosquito vectors as scalable vector graphics (SVG) for faster rendering and reduced world file size for ProMED frequency maps. He generated and embedded into the application map tiles of land surface temperature and precipitation, climate forecasts anomalies as well as current risk and global forecast risk maps, and updated the Chikungunya outbreak and location data to display the incidents as a time series. Furthermore, he improved the landing page to show Chikungunya points as markers in interval of five years. He organized application functionality script into multiple smaller modules to increase modularity and readability, and updated the developer user guide and application documentation for CHIKRISK accordingly. On October 18, 2019, Mr. Bishnoi attended the CHIKRisk project closeout and hand-off at NASA Goddard hosted by Dr. Anyamba and Dr. Soebiyanto. He reviewed and updated the developer guide and application documentation frequently with Dr. Soebiyanto and Ms. Tubbs before finalizing the functionalities and usability. Mr. Bishnoi ensures the currency of the data on the CHIKRISK application, maintains the application dependencies, and optimizes the performance of the application as required.

Last year, in May, June and September, Mr. Bishnoi attended a workshop on Immersed in Data Analytics, a workshop on Using machine learning in the Astrophysical sciences, and a session on Data Visualization, respectively. In October 2019, Mr. Bishnoi began to work on developing the Rift Valley fever application with the creation of an initial application prototype. He led the front-end development of the application. The initial prototype development of the application is now complete, and revisions to the application will continue in order to make improvements as necessary. This will be embedded as an option in the MEDINA application prototype. Mr. Bishnoi began the development of the MEDINA application in November of 2019. This application has the capability to monitor and map globally the areas at risk of dengue, zika, chikungunya, and other vector-borne diseases. He performed analytics to produce suitability maps for dengue and zika. He continues to calibrate machine-learning models to create current risk maps for those diseases to be ingested in the application while translating the current scripts written in R to Python.

In the coming year, Mr. Bishnoi will continue to monitor and maintain the application dependencies, datasets and performance of the CHIKRISK application. He will continue his work on developing the MEDINA application. Mr. Bishnoi will work on integrating the Rift Valley fever application into the Medina prototype app. He will perform pre-processing, data-cleaning, visualization, analytics for CHIKRISK and MEDINA, and continue to implement various machine learning tasks for both CHIKRISK and MEDINA. He will also take Python courses, which will benefit the efficiency of his current and future deliverables.

Mr. Thomas Eck (sponsor: B. Holben) continues to investigate the optical properties of atmospheric aerosols within AERONET for application to studying the effects of aerosols on the atmospheric radiation balance and climate, and for validation of satellite retrievals of aerosol properties. He conducts analyses of measurements made by automatic sun-sky scanning radiometers that are globally distributed as a part of the NASA-managed Aerosol Robotic Network (AERONET; project leader: Brent Holben (GSFC)). They utilize the measurements of spectral direct sun intensity and sky radiance distributions to infer a complete description of the column integrated optical properties of the aerosols. These ground-based remote sensing retrievals of aerosol optical properties are analyzed to better understand the dynamics of aerosol properties as a function of source region, transport, aging processes, and interaction with clouds.

This past year, Mr. Eck participated in the Fire Influence on Regional to Global Environments Experiment - Air Quality (FIREX-AQ) field campaign, by working on an instrumented altitudinal transect in mountains of the River of No Return Wilderness, Idaho in August 2019. He also participated in the analysis of the new AERONET version 3 sky radiance scan retrievals and...
contributed to a publication on the topic, including hybrid scan retrievals and retrieval uncertainties.

In December, Mr. Eck gave a presentation at the 2019 AGU Fall Meeting titled “FIREX-AQ: Analysis of AERONET Measurements and Retrievals of Aerosol Optical Properties during the Field Campaign and Climatological Context Plus Analysis of Brown Carbon Absorption with Biomass Burning Cases Retrievals Extended to 380 nm”. He was first author on a paper that is in press with Atmospheric Environment titled “Influence of Cloud, Fog, and High Relative Humidity during Pollution Transport Events in South Korea: Aerosol Properties and PM2.5 Variability”. Additionally, Mr. Eck co-authored four other published articles, one in Atmospheric Environment, two in Atmos. Meas. Tech., and one in Quart. J. Royal Met. Soc.; he also co-authored two articles that are currently in review (Atmos. Meas. Tech. and Elementa: Science of the Anthropocene). He is currently participating in an AERONET project study on the impact of national shutdowns due to the COVID-19 pandemic on the measured fine mode aerosol optical depth (AOD) from AERONET, with a planned publication of these results.

Moving forward, Mr. Eck will continue to analyze the absorption properties of desert dust aerosols and biomass burning aerosols with the new 6-channel AERONET retrievals, including the 380 nm and 500 nm wavelengths. He had an abstract on this topic accepted for the International Radiation Symposium (IRS) that was originally scheduled for July 2020 in Thessaloniki, Greece, but due to COVID-19, this meeting has been postponed until 2021. He plans to present some preliminary results from these studies at the 2020 AGU Fall Meeting in December (either in person or virtually).

He will continue to participate in analyzing the time series of fine mode AOD at several AERONET sites with multi-year monitoring, comparing the 2020 data during the COVID-19 national lockdowns with the prior multi-year averages. He plans to contribute to a journal publication on this topic. Mr. Eck also will continue to participate in operational duties within AERONET, including direct sun calibration of reference and field instruments, plus contacting site managers of various sites in the network for troubleshooting of instrument problems.

Dr. Min-Jeong Jo (sponsor: B. Osmanoglu) works on flood monitoring with both synthetic aperture radar (SAR) imagery and optical imagery related to NASA disasters program. She has been developing an automatic flood mapping system based on the characteristic of backscattered signal power changes between pre- and post-event SAR images as well as the Normalized Difference Water Index (NDWI) estimated using high spatial resolution optical imagery. The goal is to develop a rapid and efficient monitoring system to respond flood events, which helps urgent decision-making.

Dr. Jo attended the 2019 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) and presented her research about flood map generation, titled “Rapid Generation of Flood Maps using Dual-polarimetric Synthetic Aperture Radar Imagery.” She demonstrated the initial results of complementary use of optical and radar imagery in flood response. Yet, although a significant improvement in flood monitoring has been achieved through the penetration capability of radar, it is unwise to map floods in urban areas due to the strong backscattered signals by manmade structures. Therefore, the approach of integrating SAR and very high-resolution optical imagery has been conducted to generate precise and accurate flood maps in urban areas. Upcoming plans include submitting a research paper regarding the combined method of SAR and optical imagery to detect flood extent over the urban areas, and it will include proposing a novel method, experiments in test sites, and cross-validation.

At the 2019 AGU Fall Meeting in December, Dr. Jo gave a poster presentation on the development of a flood monitoring system, and showed a new method of combining SAR and optical data for flood mapping. She presented that the joint probability function approach, based on Bayes theorem, has been adopted to combine two independent flood products, which were generated from dual-polarimetric Sentinel-1 SAR and high-resolution optical imagery in Planet Labs. The proposed combined method was applied to the flood event resulting from Hurricane Harvey, from August 2017 in Houston, TX. The results...
showed that water boundaries can be more clearly recognized on the combined probability map.

Dr. Jo has been developing a Python program, based on the Jupyter notebook on the server, to create Flood Depth (FD) products related to the project on the NASA Disasters Program. She anticipates that the prototype of this notebook program will be developed and applied to ongoing disasters in summer 2020. This will provide a useful flood depth product, and in turn help with urgent decision-making by end-users.

**Dr. Ian Paynter** (sponsor: D. Morton) conducts research to advance the understanding of forest recovery mechanics at the tree, stand, and forest scale through the monitoring of the post-hurricane recovery of Puerto Rico’s tropical forests. For the Puerto Rico Campaign 2020, Dr. Paynter, along with Dr. Doug Morton, took observations with a ground-based laser scanner at forest sites previously surveyed in 2019, 2018 and 2017. The field campaign was curtailed due to the COVID-19 pandemic, but all the previous sites within the El Yunque National Park, Puerto Rico, were successfully observed. Dr. Paynter implemented a new sampling approach and protocol to reduce the time per site in the field, and also to reduce the time and resources needed to process the data.

In the coming year, Dr. Paynter will continue to develop a time-series, voxelized product for forest change for the Puerto Rico post-hurricane data. He will work with potential end-users of the data to ensure the data product is useful and accessible. He also plans to develop metrics and tools to assess the mechanisms of canopy closure occurring as part of the post-hurricane recovery in Puerto Rico tropical forests. The aim is to distinguish between canopy regrowth and expansion of existing trees, and canopy closure resulting from new trees growing into canopy gaps. In other activities, Dr. Paynter will continue to improve his abilities and expand his knowledge in Python and Python libraries, in order to offer greater capability and efficiency in his tasks.

**Dr. Alka Singh** (sponsor: B. Poulter) works toward utilizing a suite of remote sensing and model-based datasets with a special focus on SMAP soil moisture to improve our understanding of the carbon and water cycle coupling. To this end, Dr. Singh works on two research projects.

The primary task of this first project is to improve the forest fire danger index. The existing McArthur Forest Fire Danger Index (FFDI) is based on MESOLAPS forecasts. In recent years, there has been an increasing availability of different global gridded observations by combining remote sensing and model products like soil moisture, temperature, precipitation, evapotranspiration, etc. SMAP products are available at very high spatial (9 km) and temporal (3 hours) resolution. The SMAP-based FFDI will have much higher spatial and temporal estimates than the existing indices. With the increasing number of recent fire events and active fire counts globally, better prediction of wildfire danger has now become paramount importance than ever before. Her second task is focused on flash droughts. Extreme events are intensifying in their character in recent years. Rapid drying of land systems driven by high temperature and low precipitation contributes to flash drought. Dr. Singh’s work is to first identify flash droughts and regular long-term droughts globally. She then examines how vegetation responds differently to flash drought compared to a regular drought. Dr. Singh analyzes different carbon variables, such as OCO-2 solar-induced chlorophyll fluorescence (SIF), SMAP gross primary productivity (GPP), SMAP respiration, and SMAP net ecosystem exchange (NEE) during drought events.

Dr. Singh has conducted extensive inter-comparisons of different soil moisture data products. She has downloaded, harmonized and inter-compared multiple soil moisture data products (e.g., SMAP L4, SMAP L3, ESA Climate Change initiative Soil Moisture (CCI), in-situ observations, LPJ model-based soil moisture estimates). She has done seasonal comparisons and Reccap-2 based regional comparisons of different datasets. She made temporal composites (7, 15, 30 days) of all datasets to analyze extreme events.

Dr. Singh calculated the McArthur FFDI using precipitation, temperature, specific humidity, and wind velocity obtained from SMAP L4 data product. She also generated a modified FFDI using SMAP soil moisture as a fuel load indicator. She examined different land use land cover masks suitable for the East Australian 2019 forest fire study. She compared GFED based on carbon emission and MODIS-based burned area estimates for the 2015-2020 period.

Dr. Singh calculated 40 years of flash drought (1980-2019) using MERRA-2 rootzone soil moisture and evapotranspiration in addition to SMAP/nature-run-based flash drought estimates (2015-2019). Her study extracted North American 2017 flash drought and shows that vegetation responded to the sudden change in weather. She used GRACE gravity field mission-based terrestrial storage anomalies to compute long-term/regular drought. She compared soil moisture (SMAP L3, SMAP L4, CCI, LPJ), Solar-Induced chlorophyll Fluorescence (OCO2
SIF), Net Ecosystem productivity (SMAP NEE), plant respiration (SMAP), and gross primary productivity (SMAP GPP) to the analyze the impact of flash drought and regular drought on plants in various biomes.

In December, Dr. Singh presented her work at the 2019 AGU Fall Meeting in San Francisco, CA. While there, she also attended a one-day workshop on Machine Learning and participated in the OCO-2/OCO-3/ECOSTRESS Data User Workshop.

Going forward, Dr. Singh will complete the FFDI estimation and evaluate the improvement one can bring by introducing SMAP soil moisture and other model-derived variables like relative humidity, wind velocity, temperature, and precipitation. She will write a research article to publish in a high-impact factor journal. Dr. Singh also will complete the vegetation response analysis to flash drought and compare it to regular drought, and write an article to publish in a high-impact journal. In a second paper on flash drought, she will try to explore how different hydroclimate responds to the duration of flash drought, and, based on this, how one can redefine the definition of flash drought.

Ms. Heidi Tubbs (sponsor: C. Tucker) is a Software Engineer who works with Dr. Assaf Anyamba. She supports the Global Inventory Modeling and Mapping Studies Group (GIMMS) to develop web user interfaces and RESTful client/server applications. She develops and analyzes a variety of Earth science satellite data, and develops software applications for climate and environmental monitoring, agriculture, ecological-climate based modeling of vector-borne and food borne disease transmission and dynamics projects.

In supporting the work of Dr. Anyamba, Ms. Tubbs works on the development of global monitoring and risk assessment for global chikungunya outbreaks and global monitoring of agriculture. This year, Ms. Tubbs contributed to the development of the CHIKRisk: Global Monitoring and Mapping of Chikungunya Risk system (https://vbd.usra.edu). She enhanced the user experience of the webpage by improving many aspects of the user interface, including creating an updated logo and creating cleaner administrative boundaries for the maps. She contributed to the creation of new chikungunya report frequency maps, which reflected both imported and locally acquired cases of chikungunya. She also contributed to the development of both a PostgreSQL and MongoDB database for CHIKRisk.

In the transition from global monitoring and risk assessment for chikungunya outbreaks in support of DTRA to DoD/GEIS, Ms. Tubbs contributed to the design of monthly chikungunya risk reports for DoD/GEIS. She continues to support the delivery of monthly reports by gathering reports of chikungunya outbreaks, generating monthly chikungunya outbreak maps, and compiling the report. In the interest of global monitoring of disease outbreaks, Ms. Tubbs designed and prototyped an application that would facilitate the gathering of accurate and well-organized disease outbreak reports. The application consists of a web interface and an object database, and features strong error-checking. Ms. Tubbs also wrote scripts to s web pages for disease outbreak reports, and programmatically derive location data from written outbreak reports.

Ms. Tubbs also contributes to the development of global agricultural monitoring for the U.S. Department of Agriculture/Foreign Agricultural Service (USDA/FAS). She supports work for the GIMMS Global Agricultural Monitoring application (https://glam1.gsfc.nasa.gov) assisting Mr. Edwin Pak (SSAI), lead engineer and developer of GLAM (see report by Dr. Anyamba in this section). Ms. Tubbs compared dozens of image downsampling algorithms, and developed an algorithm to quickly generate web map tiles from binary NDVI data. This algorithm will allow for efficient integration of new datasets into the web application, and continuous updating of older maps to reflect new long-term means.

In addition, Ms. Tubbs is also contributing to the development of an integrated disease mapping and forecasting application,
MEDINA (Machine Learning, Climate Variability and Disease Dynamics), which will focus on vector-borne diseases. She is working to integrate rodent-borne diseases into MEDINA by analyzing and building machine learning frameworks for hantavirus and plague. She is also creating a data pipeline to ingest and analyze GPM data to be used in various disease risk forecasting and assessment applications.

This year, Ms. Tubbs attended several Python workshops on data analysis, data visualization, and machine learning. She also learned R programming from online lectures, and attended machine learning workshops hosted by the GSFC Machine Learning Academy.

Going forward, Ms. Tubbs plans to continue supporting global agricultural monitoring by analyzing and mapping the global reach of the GIMMS Global Agricultural Monitoring application. She also plans to build climate-based risk assessment models for hantavirus and plague in support of MEDINA development.

Additionally, Dr. Engelmann-Suissa participated in the discovery and modeling of TESS’ first Earth-sized planet in the habitable zone, TOI-700 d. She worked closely with the TESS team at Goddard, and co-authored two papers regarding both the discovery and confirmation of the system. She was first author of a paper titled “The First Habitable Zone Earth-sized Planet from TESS. III: Climate States and Characterization Prospects for TOI-700 d.” For this work, she used 3D General Circulation Models and radiative transfer tools to assess potential habitable climate states for the planet. Her work confirmed that TOI-700 d was a robust candidate for a habitable world, and determined that transmission spectroscopy and phase curve characterization for this planet would be exceedingly difficult. Dr. Engelmann-Suissa gave several talks on this research, and worked with NASA communications team to coordinate a press release; subsequently, she was interviewed by many journalists, and her research received worldwide media coverage. Dr. Engelmann-Suissa worked with Christopher Smith (GESTAR/130) to help him create an artistic illustration of the planet TOI-700 d that maintained scientific accuracy based on the models she and her team produced. This image has been circulated both by NASA Communications and media outlets around the world. She also worked with NASA’s Scientific Visualization Studio to design a new Hyperwall Presentation based partly on her work in modeling the atmospheres of habitable exoplanets. She gave a well-attended Hyperwall talk at the American Astronomical Society in Hawaii using her new animations.

Dr. Engelmann-Suissa is a co-investigator for two submitted TESS and Hubble Space Telescope proposals. If these proposals are funded, she will use her modeling skills to assess how the climates of habitable planets are impacted by photochemical reactions with the host star, by coupling the outputs of GCM runs to a photochemistry model. Also, she will continue a new effort to model the atmospheres of super-Earths and mini-Neptunes in the habitable zone of M stars. She is a Co-I on a newly awarded SEEC proposal intended to explore these bigger and potentially habitable exoplanets. She will use 3D GCM to run her own suite of climates for planets of various sizes and compositions around host stars of various effective temperatures, and then obtain their synthetic transmission spectra and phase curves to ascertain whether or not these atmospheres could be characterized by future space-based telescopes.

Dr. Thomas Fauchez (sponsor: R. Kopparapu) works on simulating exoplanet atmospheres with 3-D climate models and generating their corresponding observables (transmission spectra, thermal phase curves, etc.). She uses these synthesized observations based on 3-D climate simulations to assess which terrestrial exoplanets could be amenable to characterization by the JWST, ELT and OST missions. She also works with the TESS team at Goddard and with the TESS catalog to identify target systems to model.

This past year, Dr. Engelmann-Suissa led two major efforts in atmospheric modeling of Earth-sized exoplanets. The first resulted in a first-author publication titled “Dim Prospects for Transmission Spectra of Ocean Earths around M Stars”. This work used 3-D General Circulation Models (GCM) of ocean-covered Earth-sized planets in the habitable zone of M stars to synthesize transmission spectra and calculate exposure times needed for characterization by space telescopes JWST, LUVOIR, OST. This work confirmed that the detection of water vapor in the atmospheres of synchronously rotating Earth-sized planets would be infeasible using JWST, LUVOIR, OST, and other space-based mission concepts.
Earth-like exoplanets orbiting the Habitable Zone of M dwarf stars such as the TRAPPIST-1 system. He continued to lead a planetary Global Climate Model (GCM) intercomparison effort, to evaluate how the model differences impact the prediction of the habitability and observability of exoplanet’s atmospheres. He also identified an Oxygen absorption feature that was missing in previous exoplanet studies, which is now thought to be the strongest Oxygen absorption feature to be remotely detectable in transmission spectroscopy of exoplanet’s atmospheres.

This past year, Dr. Fauchez has presented his work at six international conferences. He has published seven papers, including three as first author. In one of his first author papers, “Sensitive probing of exoplanetary oxygen via mid-infrared collisional absorption,” published in Nature Astronomy, he discussed the possibility of detecting an O2 signature with the James Webb Space Telescope (JWST). He also reports on detecting oxygen from exoplanet analyses by examining collision-induced absorptions (CIAs). Dr. Fauchez was invited to present on this research during the NASA press panel at the American Astronomical Society conference in Honolulu, Hawaii in January 2020. Dr. Fauchez also was part of the team who discovered the new multi-planet system TOI-700 d, for which he co-authored two publications (one led by Dr. Engelmann-Suissa). These two works, highlighting the planetary science research, have received media coverage worldwide.

In the future, Dr. Fauchez will continue to lead the TRAPPIST-1 Habitable Atmosphere Intercomparison (THAI) and to use 3D climate models to determine the habitability of extrasolar planets. He is also organizing a remote workshop on these subjects, planned for September 2020.

Dr. Adrian Southard (sponsor: S. Getty) develops instrumentation for in situ detection of biosignatures and elemental composition on extraterrestrial bodies including ocean worlds (e.g., Europa, Enceladus and Titan) as well as airless bodies (e.g., asteroids and comets) and Mars. At the 2019 American Society of Mass Spectrometry conference, Dr. Southard presented a poster on recent progress on the Advanced Resolution Organic Molecular Analyzer (AROMA) instrument. The poster demonstrated the successful reintegration of a MOMA prototype linear ion trap (LIT) mass spectrometer into AROMA. He also discussed the successful detection of ions ejected from the LIT and detection of those ions by a channel electron multiplier (CEM). Detection of these ions by a CEM proves that AROMA is ready for its final end-to-end test, which involves replacing the CEM with an orbitrap mass spectrometer.

Dr. Southard’s modeling and lab work resulted in the CORALS (Characterization of Ocean REALms and Life Signatures) instrument team reaching important goals for an instrument designed to look for signs of life on Jupiter’s moon Europa. This included obtaining a mass resolving power of over 100,000 (FWHM at m/z=133) and mass accuracy of less than 5 ppm. These capabilities will vastly improve upon past efforts (e.g., MOMA-MS with mass resolving power of 500 and mass accuracy of 400 ppm) to identify molecules present. Improved identifications will inform whether life was once present on Europa.

This past year, Dr. Southard supported PI Lucy Lim’s efforts to continue development of the Miniature Electron Probe for Micro Analysis (Mini-EPMA) with proposals to the PICASSO and IRAD calls (not selected). He also teamed up with PI John Hagopian on his Small Business Innovation Research program proposal (results pending). Finally, he partnered with PI Mary Beth Wilhelm (NASA Ames) on an instrument for extraction and detection of lipids from lunar and Martian soil. Dr. Southard’s role on that project is to use laser desorption mass spectrometry to detect these extracts. This proposal, named ExCALIBR, was selected for funding.

Going forward, Dr. Southard will lead a team to qualify MEMS pirani pressure sensors for the DRAMS instrument on the Dragonfly spacecraft. These new sensors will function much like the MOMA-MS sensors that Dr. Southard’s team qualified but will have to survive the conditions of Titan instead of Mars, including higher pressures, different gas compositions, and higher levels of radiation. His work will continue on developing a fluidic trap designed to interface a liquid extract/analyte and a gas chromatograph mass spectrometer. This trap aims to derivatize non-volatile analytes for use in a gas chromatograph. He plans to present a poster at the virtual 2020 ASMS reboot conference on the CORALS prototype, and he expects to present at the Ocean Worlds workshop hosted at JPL (rescheduled date pending). Dr. Southard plans to submit a MatISSE proposal on AROMA to continue to mature this instrument for use on an Enceladus orbiter/lander or on Ceres.

Dr. Southard will continue to serve as the point of contact for two new labs being built for the Instrument Development Facility (Bldg. 37) at NASA Goddard Space Flight Center. He will be supporting the relocation of many instrument from Bldg. 33
to ensure that Code 699 can streamline its instrumentation development efforts.

**Dr. Samuel Teinturier** (sponsor: P. Mahaffy) is involved on several NASA Flight Missions. He works on the development and testing of experimental procedures for the Sample Analysis at Mars (SAM) instrument suite, and on Gas Chromatography Mass Spectrometry (GCMS) lab experiments in order to analyze and interpret the results from Mars. He is one of the key users of the SAM Testbed at Goddard and part of the MSL (Mars Science Laboratory) Science and Tactical team. He works as a GCMS specialist on future Missions to the Moon and to Titan.

Dr. Teinturier is searching for the presence of organic matter on Mars, with the SAM (Sample Analysis at Mars) team. The SAM instrument, onboard NASA Mars Science Laboratory (MSL) Curiosity rover, is an analytical laboratory that seeks to detect organic molecules and potential biomarkers in the Martian subsurface and in the atmosphere. Nine of SAM’s 74 sample cups contain “wet chemistry” reagents to aid in the extraction and analysis of less thermally stable polar molecules of abiotic, prebiotic or biotic relevance such as amino and carboxylic acids. Seven of these wet chemistry cups are using N-methyl-N-(tert-butyldimethylsilyl) trifluoroacetamide (MTBSTFA) as the derivatizing agent. SAM is one of the key instruments onboard the Curiosity Rover of the MSL mission and several drills and samples have been recently collected, especially in 2019, to be used in one of these MTBSTFA cups. Dr. Teinturier and the SAM team have chosen and optimized some parameters for these experiments. These data are analyzed for a few months, and he assists other SAM scientists in conducting laboratory experiments to gain a better understanding of the Martian results. Another way to understand the presence and evolution of organic matter on Mars, and one of the primary objectives of SAM, is the study of Methane in the atmosphere. Dr. Teinturier and some SAM team members have recently submitted interesting results to a highly ranked journal, from the last atmospheric measurements conducted with SAM, especially regarding the intriguing differences of methane concentration between night and daytimes at Gale Crater, where Curiosity landed eight years ago.

Some key experiments are still needed to fully understand some SAM results on Mars, onboard the Mars Science Laboratory rover. Several of these experiments are made in a regular GCMS instruments lab at Goddard, and important analog sample experiments were conducted on the SAM Testbed as well, after the refurbishment of the Testbed experiment. As one of the leads with the SAM Testbed experiments, Dr. Teinturier conducted many analog and science experiments during 2019.

Looking ahead, Dr. Teinturier and the SAM team are working on the best parameters to use with a possible new wet chemistry experiment in Gale Crater. Two other wet chemistry cups are filled with tetramethylammonium hydroxide (TMAH) in methanol for thermochemolysis/methylation. These cups are a key element of the analysis path with SAM, as many of the interesting compounds, such as carboxylic acids, nucleobases, and amino acids that might be diagnostic for sources, are too polar to be analyzed by pyrolysis-gas chromatography-mass spectrometry (GCMS) alone. If needed - and if the science potential of a sample is interesting enough - the team will analyze this soil material with the help of one of these TMAH cups. Dr. Teinturier will be a key member of the decision and preparation of the next runs. Additionally, he will work on other flight missions, especially related to the Moon and Titan. He will serve as a Gas Chromatography deputy PDL for the GC subsystem of the DraMS spectrometer onboard the Dragonfly drone, which will head to Titan in 2026.
Members of the Office of Communications (Code 130, sponsor W. Sisler), the Scientific Visualization Studio (Code 606.4, sponsor H. Mitchell), and the Science Support Office (POC: Winnie Humberson, GST; sponsor: S. Platnick) have provided support to a variety of events and missions, and have continued to generate products to convey the discoveries from NASA research. Products are distributed on a growing variety of social media platforms and are often picked up by high-profile news media outlets. The SVS website offers improved search capabilities and showcases work by its partners: the Conceptual Image Lab, Goddard Multimedia Studios, and Scientific Hyperwall Presentations. This past year, hyperwalls were featured at events such as the 2019 AGU Fall Meeting, the 2020 AMS Annual Meeting, the 2020 AAS Annual Meeting, and several domestic and international meetings and conferences. Ongoing collaborative efforts combining scientific research with technology, animation, visualization, and interviews will continue to engage and inform.

**CODE 130 (Sponsor: W. Sisler)**

Jefferson Beck completed his formal support of the polar airborne mission, Operation IceBridge, and helped to complete a major overhaul of the public-facing IceBridge media gallery. Jefferson started a new chapter in support of JPSS in the form of a major video on paradigm-shifting moments in weather forecasting. He interviewed five distinguished veterans in the field, including the Director of the National Weather Service, and commissioned a series of conceptual animation title cards. From this, he produced a 16-minute video - the longest of his USRA/NASA career - on the subject. From his five interviews, he has created five interview archive pieces, totaling three hours in all, to share with the public for posterity. He also has interviewed five additional experts specifically on improvements in hurricane forecasting for a future video. He also produced a 12-minute hyperwall show on weather forecasting, which was used at the 2019 AGU Fall meeting; after some revisions, it was shown again.
Jacquelyn DeMink, a Science Animation Fellow at Conceptual Image Labs (CILab), works closely with the producers and scientists to create animations of various missions and science results, by using a variety of programs (e.g., Adobe Creative Suite, After Effects, Photoshop, Premiere, and also Autodesk Maya). At the beginning of her fellowship, Jacquelyn was assigned to an animation project for a MAVEN spacecraft science result. This project was a very stylized animation, based off a style frame created by Art Director Michael Lentz who was inspired by the movie “Spiderman: Into the Spiderverse.” Jacquelyn assisted fellow animator Bailee DesRocher, by making necessary 2D assets in Photoshop and helping to replace old assets in After Effects.

Jacquelyn was the lead for an animation project for Earth Science called Earth Ventures, which included five different missions: S-MODE, DCOTSS, Delta-X, ACTIVATE, and IMPACTS. Working closely with the producers and scientists, Jacquelyn was in charge of the entire pipeline, from style frames to the finished animation. For the design of the animation, she was inspired by construction paper cutouts, stickers, and an After Effects stop-motion technique that she learned from animator Bailee DesRocher. In the end, Jacquelyn created five animations (one for each mission) and five transitions to make an altogether five-and-a-half-minute 2D animation. Jacquelyn also assisted Bailee DesRocher with Webb Elements, a series of live action videos that have 3D animations and effects layered over top of it. Jacquelyn made necessary 3D assets in Maya, including various atomic models of elements. Additionally, Jacquelyn was the lead for another animation project for the Earth Science team, focusing on the DeltaX mission. This 3D animation includes four different scenes that show the effects of rising sea levels on the soil of the delta. The animation was scheduled for release near Earth Day and for use in various presentations.

For JPSS, Jacquelyn’s project is to create title cards for various videos. She completed a total of five cards, a title card, and an extra simple card for any extra elements. The cards highlighted many different inventions, including the development of satellites that were able to accurately collect data of the weather in the southern hemisphere, the IBM machine, storm predictors and warnings, and more. Jacquelyn worked with Photoshop and After Effects to create an “old TV” look to the animation using real photographs.

Jacquelyn plans to finish all of the animations that she is currently working on including the LandSat light path Animations and texturing various LUCY instruments. She will continue to learn how to use the Maya rendering software, RenderMan.

Bailee DesRocher, a Science Animation Fellow, uses software such as Adobe Creative Suite, After Effects, and Maya to develop animation and motion graphics content. She creates animation assets, designs motion graphics, VFX design/compositing, and supervises some 2D animation workflow. She develops many projects from start to finish. This past year, Bailee served as VFX artist on several JWST projects, including the new Elements of Webb series and the upcoming “24 Days of Webb” mini-documentary.

Bailee worked on a variety of projects featuring title design, logo design, and graphics packaging, including the Hubble 30th anniversary logo, DAIVNCI+, NASA’s Curious Universe podcast, and NASA’s 5 Things. She worked closely with clients to create designs tailored to their programming needs, while maintaining agency standards. Her work was featured online in Forbes, the Apple Podcasts featured content page, and more.

Bailee introduced editable motion graphics templates to CILab. Since the same graphic elements will be used in multiple episodes of a show, the placement of text and graphics needs to be editable by producers. Premiere Mograph templates were created to suit a variety of social media platforms, and streamlined through multiple tests by both CILab and its clients.
The template design can be customized for each program, keeping sophisticated design, visual effects and animation intact, while providing flexibility for producers to edit certain properties per episode, making the templates a single purchase but multi-use element for Goddard media production teams. Templates can include custom-designed opening titles and self-resizing lower thirds, animated title cards, animated on-screen text, social media assets, and more.

Under the direction of Art Director Michael Lentz, Bailee designed an animated character based on the Lucy spacecraft for an upcoming series featuring Lucy’s adventures as she makes her way to the Trojan asteroids.

**Ryan Fitzgibbons** supports the GPM and ICESat-2 missions in all multimedia needs, including the documentation of mission milestones, production of web videos and live press events, and support for the Education/Public Outreach (E/PO) programs.

In support of the agency’s level-one priority for the 50th anniversary of Earth Day, Ryan produced a handful of videos. The most prominent product Ryan produced was a 2-minute video titled “NASA Looks Back at 50 Years of Earth Day,” which connected archival imagery and new data visualizations to illustrate how far NASA has come in its observation of Earth. The video was very well received both on social media platforms and from NASA leadership. As of this reporting, the video has been viewed over 71,000 times on YouTube and over 106,000 times on Instagram. It was embedded by NBC, CBS and Express UK. Many people within NASA GSFC, including Paula Bontempi, Deb Hernandez, Jim Irons and Horace Mitchell, expressed their enjoyment of the production. Additionally, the Spanish version of the video was viewed 247,000 times on the NASA en Espanol Twitter account. In addition to the main video, Ryan produced three other short videos for the lead up to Earth Day 2020. These videos included a SnowEx-themed Photon Phriday episode, a video about the isolating environment of the 88-South Antarctic Traverse campaign, and a video explaining the science behind a carbon cycle-themed ocean game featuring scientist Ivona Cetinić (616/USRA).
In February, Ryan traveled to Grand Mesa, Colorado, to document and produce videos for the SnowEx 2020 campaign, which is a ground and airborne campaign designed to study the variables of snow water equivalent in the western United States. Ryan collected footage and interviews from scientists and logistics personnel on the field campaign and produced four short social media videos while in Colorado. The videos ranged from a montage of snowmobiling across the mesa to a lighthearted look at getting properly dressed for the winter conditions to a short wrap-up of the fieldwork. The videos were well-received on the NASA Expeditions social media platforms as well as by the SnowEx science team.

Ryan worked with ICESat-2 writer Kate Ramsayer to produce a series of short videos that look at ICESat-2’s photon cloud passes over various features. These videos were designed to be produced quickly and inexpensively by using Skype as the main form of interviewing science team members from all over the U.S. To date, Ryan has produced nine episodes, along with three custom animated intro sequences, and the videos have covered topics such as Himalayan glaciers, Caribbean bathymetry, forests in Botswana and sea ice in the Arctic.

Ryan also worked with the greater ICESat-2 science team as well as SVS visualizer Kel Elkins (606.4/USRA) to produce two new visualizations and a web video on the mission’s findings regarding the loss of mass on both Antarctica and Greenland over 16 years. The study compares the elevation of the ice sheets from the ICESat era and the ICESat-2 era and found that, while there were gains in elevation in East Antarctica and parts of Greenland, the gains were outpaced by the losses in West Antarctica and the Greenland coasts. Ryan also coordinated the new visuals with the NASA Science Live team for an upcoming episode featuring the science team and their new findings. This science result marked a new milestone for the ICESat-2 mission and Ryan was integral in communicating the results to the public.

Along with producer Joy Ng, Ryan produced a large amount of production material to promote the analysis of nearly 20 years of global precipitation data. The IMERG analysis was a major milestone for the GPM mission and combined precipitation data from both the TRMM mission and GPM era. Ryan facilitated the production of several new data visualizations, which came from both the SVS and the GPM team. These visualizations included maps of daily climatology, diurnal cycles and accumulations and anomalies. Ryan produced a signature web video to highlight the IMERG analysis, as well as the material for the live shot campaign. He also produced customized regional visualizations to use for certain regional news markets.

During the upcoming year, Ryan will produce several products for both the GPM and ICESat-2 mission, as well as for the Earth Science News. Ryan will complete and publish a wrap-up video for the SnowEx 2020 campaign to complement writer Jessica Merzdorf’s feature. Also, he will produce a short video for the GPM mission looking at the use of precipitation data for microinsurance companies in El Salvador. Ryan will be producing a video treatment using the new Perpetual Ocean 2.0 visualization created for the Earth Day 2020 campaign with the SVS.

Dan Gallagher is a multimedia producer with Goddard Media Studios who creates videos that inform the public about missions and scientific research being conducted at NASA Goddard Space Flight Center.

As the lead video producer for Planetary Science at Goddard, Daniel provides video support for the MAVEN and OSIRIS-REx missions, as well as for general planetary research. He supports the Goddard Media Studio mission of bringing NASA science to the public in an entertaining and informative manner.

Dan released a “director’s cut” version of a shorter video focused on the discovery of a hydrated layer in the lunar soil. Scientists

Image from “Land Ice Height Change Between ICESat and ICESat-2.” (Provided by R. Fitzgibbons.)
have discovered that water is being released from the Moon during meteor showers. When a speck of comet debris strikes the Moon it vaporizes on impact, creating a shock wave in the lunar soil. For a sufficiently large impactor, this shock wave can breach the soil’s dry upper layer and release water molecules from a hydrated layer below. For the director’s cut, Dan incorporated longer portions of an interview with scientist Mehdi Benna, produced additional narration and graphics, and added an extended segment on the historical search for water on the moon. The video has been reposted by numerous science news outlets (https://www.youtube.com/watch?v=X8Zz14hOzgg&feature=youtu.be).

In October, Daniel released a movie teaser for the Lucy mission, the first mission to explore the Trojan asteroids, which will launch in 2021. The teaser includes spacecraft beauty shots and a flyby animation of Lucy’s binary asteroid target, created by CI Lab animator Jonathan North, along with mission trajectory animations created by Kel Elkins (SVS). Daniel produced, narrated, and edited the teaser (https://svs.gsfc.nasa.gov/13352).

In December, Daniel released a narrated video about the observation of upper atmosphere wind currents on Mars by NASA’s MAVEN mission. MAVEN used its mass spectrometer to measure wind speed and direction in the Mars upper atmosphere over the course of several years, building up the first map of thermospheric wind currents at the red planet. The map revealed that high-altitude winds on Mars are perturbed by gravity waves originating at the planet’s surface, as mountains and valleys alter the flow of surface winds. Daniel served as producer and narrator of the video, which features data visualizations and animations by the SVS and CI Lab studios at Goddard (https://svs.gsfc.nasa.gov/13485).

Dragonfly is a NASA mission to send an autonomous roto-craft to Saturn’s largest moon, Titan, and is the fourth mission in the New Frontiers line. In December, Daniel released a video about the science instruments and goals of Dragonfly. The objective is to study the chemistry and potential habitability of Titan. For this purpose, Dragonfly is equipped with a neutron spectrometer, a drill system, and a mass spectrometer. He produced and narrated the video, which features a suite of artist concept animations by Goddard’s CI Lab studio (https://svs.gsfc.nasa.gov/13562).
In February, Daniel produced and edited a video for the OSIRIS-REx mission about the selection of the Nightingale sample collection site on asteroid Bennu. Before OSIRIS-REx arrived at Bennu in December 2018, mission planners had anticipated that the asteroid’s surface would consist largely of loose material, similar to gravel, making it an ideal place to touch down and collect a sample. However, when OSIRIS-REx arrived, it was greeted by a rocky world littered with boulders. After a year of studying Bennu, the mission selected a spot in the northern hemisphere as the primary sample collection site, and named it Nightingale. For this video, Daniel worked with Kel Elkins (SVS) to produce new 3D flyover animations of Bennu, based on data and imagery from OSIRIS-REx (https://svs.gsfc.nasa.gov/13565).

Upcoming plans include work on an Ocean Worlds video. Daniel will work with NASA scientists Lucas Paganini and Avi Mandell to produce a video about their recent Europa observations, and about the habitability of Europa and other icy moons of the outer solar system, such as Titan and Enceladus. He also will continue working with MAVEN scientists Robin Ramstad and David Brain on their upcoming results concerning the Mars upper atmosphere and its interaction with the solar wind. Daniel will also work with SVS animator Cindy Starr to create data visualizations related to this result. For the OSIRIS-REx TAG (Touch-and-Go) event, Daniel will work with animators in CI Lab and SVS to produce a new suite of OSIRIS-REx animations for 2020. The focus will be to publicize the challenges and technologies around collecting a sample of asteroid Bennu during the TAG (touch and go) event in late summer. He also plans to produce new 3D flyover animations of Bennu’s topography, providing a virtual tour of the asteroid.

For the Transit of Mercury across the Sun, Michelle led an interdisciplinary satellite media tour. This unique campaign was particularly well suited to highlight science from across the astrophysics, heliophysics and planetary departments. She was able to blend into the campaign questions why scientists were excited for this transit in our solar system; how they use transits in other solar systems to find exoplanets; and, if astronauts on the moon as part of the Artemis program might ever get to see Earth transit in front of the Sun. She helped coordinate 51 interviews over a week on this topic, including 21 interviews in top 20 TV markets, seven interviews with radio/podcast outlets, eight with international and national networks, and six with Spanish language media. Highlights include interviews with the Associated Press in London; NBCNews.com; Bloomberg’s @TicToc, and NPR’s Morning Edition, which has a weekly listenership of 13 million. This campaign also was unique because interviews took place as the transit was happening that morning; it also was the most interdisciplinary campaign the team has done to date.

Michelle Handleman Seff is the lead producer for the live team, which includes the satellite media tour program that highlight the broad spectrum of science and technology being done at Goddard Space Flight Center. Satellite media tours, also known as live shots, are an important part of the Office of Communications’ media outreach strategy. These campaigns connect NASA scientists to local, network and international broadcast and online audiences though live and taped interviews centered around specific campaigns. Michelle works with the scientists and editorial producers to craft the story arc of the campaign and makes sure all the moving parts are in place. Michelle holds media training sessions with the scientists to prepare them for interviews, and mentors Office of Communications Pathways students and interns.
national media, 11 Spanish language interview, and 14 radio/podcast requests, and she supported six in-person interviews. Thirty-seven interviews were in top 20 TV markets nationwide. Some highlights include CNN-Washington DC, Bloomberg’s TicToc digital news outlet, Telemundo LA, CBS-New York, The Weather Channel, and KMAX-Sacramento’s “NASA Man.” This campaign had the second-highest interview requests, with one of the highest booked Spanish-language media bookings. These live shots blended beautifully the opportunity to discuss the 50th anniversary of Apollo, what we’re still learning about the moon with the LRO, and why we want to go forward to the moon with the Artemis mission.

Michelle led a very successful remote media campaign highlighting the impressive 30th anniversary of the Hubble Space Telescope. She had worked with the Hubble team for more than a year on anniversary media plans, which included live shots and outreach to major media outlets. As a result of COVID-19, plans needed to be adjusted, including how the live shots would be conducted. Michelle worked on alternative plans for the scientists from NASA HQ, NASA Goddard and the Space Telescope Science Institute (STSI) to do interviews remotely by using video chat platforms. She led ‘virtual’ rehearsals with the scientists and discussed how to do these interviews from home. She worked with the live shot team to ensure schedules were coordinated and that the scientists had all the logistical details. Together scientists did 51 interviews on the anniversary with six of them were in Spanish. Ten of the day’s interviews were in markets that include international, national, statewide or other categories, and 14 interviews were in top 20 TV markets, including Ft. Worth/Dallas, Washington, D.C., and New Orleans. Some highlights include The Weather Channel, CNN En Espanol, BBC radio, and an interview with the Schiele Museum of Natural History and Planetarium in Georgia. She also coordinated a few interviews associated with the live shot pitch that were done prior to the anniversary, including NPR’s Science Friday; CNN.com; Associated Press TV London, and PopularScience.com. NPR’s Science Friday airs on nearly 400 public radio stations throughout the U.S. and has 1.8 million public radio listeners each week. Michelle is still fielding some Hubble requests following the anniversary.

In April 2020, Michelle led the live news team in their first-ever satellite media tour done entirely remotely to mark this year’s ‘superest’ supermoon. With NASA centers closed and normal activities canceled due to COVID-19 precautions, Michelle brainstormed the idea of conducting a media campaign using video chat platforms such as Skype and Zoom. She polled media outlets to confirm their interest, and she worked with the scientists on whether they were interested as well. Michelle worked with the editorial team, video editor, and scientists to prepare them, including holding ‘virtual’ meetings and rehearsals. She worked with the team and media outlets to book the interviews and to ensure that the details of doing this remotely was clear. Together the scientists did a total of 41 interviews, including 15 in top 20 TV markets. Highlights included The Weather Channel, CNN En Espanol, Univision and Telemundo L.A, and stations in Chicago and Washington, D.C. This campaign had a total of 11 Spanish language interviews - the highest number of requests for a live shot.

This April, Michelle led a remote media campaign highlighting the 50th anniversary of Earth Day. This campaign was unique because it combined both NASA’s study of the Earth with its development of technology that benefits us on the ground. She worked with NASA’s Chief Technologist and Acting Director of Earth Sciences (both from NASA HQ), scientists from Goddard, and a scientist from NASA Jet Propulsion Laboratory. Michelle coordinated with the different talent on rehearsals, answering questions and building the story arc that would allow them to incorporate Earth science highlights and technology into the messaging. She helped coordinate 49 interviews for this campaign, including 10 Spanish language interviews, and this
campaign included 20 interviews in top 20 TV markets. Some highlights included The Weather Channel, CNN En Espanol, Univision, Bloomberg News, and stations in Chicago and Washington, D.C., as well as international station New Zealand, RNZ.

Looking ahead, Michelle is working on live shot plans for the upcoming NASA/SpaceX launch that will launch American astronauts to the International Space Station from U.S. soil. She is working on plans for how to continue to incorporate interviews done by video chat programs into regular use even after a return to Goddard is permitted, the idea being that allowing for interviews by video chat in addition to in the studio may allow for supporting more requests.

Katherine Jepson is a Multimedia Production Fellow who supports the Earth Science News Team and the NASA Goddard Office of Communications. As such, she distills emerging Earth science data and reports into informative and engaging multimedia products for wide distribution through NASA’s various communication channels. Since joining GESTAR in April 2019, Katie has served as the lead producer on 14 video products, in addition to working on numerous productions in an ancillary capacity. Over the last year, she has been involved in three distinct agency-wide communication campaigns: the conclusion of the 11-year Operation IceBridge campaign, the launch of the latest Earth Expedition suite of missions, and the Earth Day 50th celebration.

In June 2019, Katie worked on the agency-wide Freshwater communication campaign. She produced two videos for this campaign: “NASA Tracks the Future of Asia’s Glaciers” and “NASA Helps Warn of Harmful Algal Blooms.” Both videos were released on the SVS as well as on YouTube, Facebook, and Twitter, and accompanied features on the NASA.gov website. In August 2019, Katie produced a video to support the Fires communication campaign. The video, highlighting Arctic fires, featured the work of the ABoVE team and included an interview with Dr. Elizabeth Hoy. The video was shared across multiple distribution channels, including both the main NASA and NASA Earth Twitter accounts.

In June 2019, Katie worked with visualizer Cindy Starr and Andy Aschwanden, a researcher at the University of Alaska Fairbanks Geophysical Institute, to release a video highlighting simulations of the effects of outlet glacier flow under differing climate scenarios in order to estimate Greenland’s projected contribution to sea-level rise. The resulting video, “Modeling the Future of the Greenland Ice Sheet,” was featured on Business Insider, Science Alert, and NASA news portal and social channels. In September 2019, Katie produced a video covering the 2019 Arctic Sea Ice Minimum. The production involved close collaboration with writer Maria-José Viñas, visualizer Trent Schindler (SVS/USRA), as well as an interview with Dr. Nathan Kurtz, project scientist for the IceSat-2 satellite.

For the Earth Day 50th Celebration, Katie supported the level-1 agency-wide event with video content for both the 50-day countdown Earth social campaign and web feature highlighting NASA technology and air quality monitoring. Her 50-day countdown content included a short video highlighting increased data inputs into GMAO models. A Spanish version of the video also was released on NASA’s Ciencia page and NASA en Español social accounts. During this time, she also produced a video that accompanied a feature and new SVS visualization from Cindy Starr that depicted complex patterns of methane emissions produced around the globe. In April 2020, Katie released a video highlighting a SVS visualization of the complex chemistry of surface ozone, which drew from the work of Drs. Christoph Keller and Emma Knowland (both 610.1/USRA) and included an interview with Dr. Lesley Ott. (A related write-up can be found in the Code 610.1 section of this report.) In addition, Katie provided editing support for both #EarthDayatHome demonstration videos and Earth Day demonstration videos from EO Kids and GLOBE.
For her other projects, Katie worked alongside Jefferson Beck and Lauren Ward to create a suite of products celebrating the completion of the 11-year Operation IceBridge campaign. As part of the deliverables, she worked to update the mission’s footage gallery that consolidated 11 years of IceBridge operation. The resulting gallery contains over 46 new gallery pages, with each page supporting one or more new high-quality reels of IceBridge footage. This work represents the largest update of the IceBridge gallery since its original launch in 2011. Additionally, Katie worked with visualizer Trent Schindler to create an updated Operation IceBridge flight line visualization that was featured on the new gallery page. The resulting visualization provided viewers a comprehensive look at the scope of the multi-year polar mission. Katie used this visualization to produce a 5-minute video that highlighted 10 major milestones of the mission. The video served as a visual representation of the accomplishments of the mission and premiered at the final Operation IceBridge town hall meeting at the 2019 AGU Fall meeting in December 2019, which she attended. The video accompanied social efforts and a feature on the NASA.gov website.

In January 2020, Katie produced a kickoff video for NASA’s Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) campaign, NASA’s first comprehensive study of East Coast snowstorms in 30 years. The finished video included an interview with the mission PI, Dr. Lynn McMurdie (University of Washington), and was distributed through NASA social media and the NASA Earth web portal. As part of the campaign, Katie traveled to the Wallops Flight Facility to cover IMPACTS’ field operations, where she assisted with NASA Social Media Day, collected multimedia assets for Earth Expeditions blogs, filmed a Facebook live session with mission scientists, produced assets for an Instagram story on NASA’s main account, and produced content for NASA’s Earth Expedition Twitter account.

David Ladd is a Senior Multimedia Producer with Goddard Media Studios, working in the realm of planetary science communications. He produces and edits videos that highlight the latest planetary research and science results, while also creating videos for numerous NASA missions and programs, including the Lunar Reconnaissance Orbiter (LRO), Lucy, OSIRIS-REx, MAVEN, and the Goddard Instrument Field Team. This year, working with colleague Ernie Wright, David produced and edited the video “Apollo 13 Views of the Moon in 4K,” which was released in March 2020. This video used data gathered from the Lunar Reconnaissance Orbiter spacecraft to recreate some of the stunning views of the Moon that the Apollo 13 astronauts saw on their perilous journey around the farside in 1970. This video was a huge success online and went viral, amassing over 1 million views on the Goddard YouTube channel, and being picked up by numerous news outlets and local news stations across the country. The video was also picked up and reported on by numerous international news channels, including Skynews Australia. David also produced a Spanish-language version of this video. View the video here: https://www.youtube.com/watch?v=Ilifg26TZrI or https://svs.gsfc.nasa.gov/13537.

Working with the LRO Mission and the Boston Red Sox Major League Baseball team, David helped facilitate the NASA STEM Education Day at Fenway Park, which took place on September 19, 2019. This year, David was a featured speaker at the event, discussing NASA video production to an audience of over 4,000 students and teachers. This day also featured an exhibition of NASA missions and projects, demonstrations of space science concepts, and presentations on a wide array of NASA science.

David produced and edited the video “10 Years at the Moon,” which celebrated the 10-year anniversary of the Lunar
Reconnaissance Orbiter mission. This video highlighted some notable facts and accomplishments of the LRO mission over the past decade, establishing how LRO is paving the way forward for reestablishing a human presence on the Moon. Visit the Goddard YouTube channel at https://youtu.be/ctA97quYlig or view the SVS version: https://svs.gsfc.nasa.gov/13229

David produced and edited the video “Water Vapor Plumes on Europa,” which revealed how NASA scientists have obtained the first direct detection of water vapor on this moon of Jupiter. This video was released in November 2019 in conjunction with a science paper by NASA scientist Lucas Paganini (https://svs.gsfc.nasa.gov/13163). This research result and video was a huge success online, amassing more than 280,000 views on the Goddard YouTube page, and was picked up by numerous national and international news outlets, including CNN, Fox News, BBC, and space.com. David also produced and edited a Spanish-language version of the video.

For NASA’s annual National Air & Space Museum Event, which was titled “Small Worlds, Big Impacts” this year, David served as the lead technical producer. Held on September 25, 2019, the featured speakers were Goddard scientists Dr. Amy Simon and Dr. Barbara Cohen, as well as Dr. Lori Glaze, Director of NASA’s Science Mission Directorate’s Planetary Science Division. David was responsible for creating all visuals and videos for this event.

Michael Lentz is Art Director at NASA’s Conceptual Image Lab (CI Lab) and responsible for guidance and creation of art and animation in the lab, with a focus on quality and scientific accuracy. He encourages artistic creativity throughout production, while also ensuring that all lab products maintain a standard of excellence. Michael works agency-wide with scientists and producers to help bring their stories to life. Throughout the year, Michael provided art direction on dozens of high profile missions across the agency. Inspired by Sony’s “Into the Spider-Verse” animated film, Michael designed style frames and guided artists in creating animation to showcase new science findings for MAVEN’s discovery of Sporadic E layers in Mars’ atmosphere. The animation has been submitted to several film and animation festivals.

Michael also guided the art direction for the logo and graphic design for NASA’s Curious Universe podcast with Bailee DesRocher. In addition to these projects, he designed art and animation for PACE, WFIRST, GIFT, Juno, Dragonfly, and Hubble;
recently he worked again with Bailee to promote a new character animation series for the Lucy mission to explore Trojan asteroids.

Michael began to develop the idea of using VR/AR as a way to disseminate more information about various missions at NASA a few years ago. After developing an animation pipeline capable of this, the JWST will now be the first mission to use this idea and new pipeline. Colleague Jonathan North did a crash course to learn the ins and outs of developing an AR app to showcase Webb and its capabilities using this new workflow, while Michael guides the art direction. The goal is to release a 1.0 version of the Webb AR app over the summer. Michael is also creating and art directing the animations for the James Webb Space Telescope with a team of six artists. Some of the new animations are being created in a cinematic style inspired by high-end car photography.

Michael has been developing a creative brief to help producers bring new projects into CI Lab. This document has started to be utilized; as it is refined, it will become a requirement for all new work coming into the Lab. With the Lab’s ever-increasing workload, it has become more important to have a properly conceived creative brief that clarifies all details and an agreed-upon direction before the project begins. This provides a roadmap for all involved - producers, scientists, artists, and management – and allows for continuous review to guarantee a project is proceeding in a timely way and on-course with the initial goals and objectives. Michael plans to have this document ready in summer 2020.

In the year ahead, as new missions start up, Michael will continue to encourage those involved to consider how they want to brand the mission - from designing the logos to the overall look of the videos and animations being produced. In addition, he will continue working with producers to create graphic packages for video products so they have a unified look and feel to help further brand the mission. For the upcoming OSIRIS-REX sample collection in August, numerous animation products are being prepared; these include animations created in both realtime and traditional rendering. One product will be a one-hour animation running in realtime to roll in during live shots of the sample event. This will be created using Unreal Engine and rendered in realtime. Michael is creating animations and art directing the other artist assigned to this project. For JWST, Michael also is creating and art directing dozens of animations, working closely with the producers and artists assigned to the project. Michael has begun to reach out to other art directors at NASA with the idea of forming an art director’s working group where everyone can share ideas and best practices.
Adriana Manrique Gutierrez is an animator and multimedia artist for the Conceptual Image Lab (CILab), who creates a wide variety of audiovisual outreach materials for different NASA missions. This year, Parker Solar Probe’s first scientific results were released to the public on December 2019. In support of the Heliophysics team, Adriana’s work was part of the media package used by the communications Team for live shots, press conferences and scientific talks related to this milestone (https://svs.gsfc.nasa.gov/20299). For the Solar Orbiter’s launch in February 2020, the multimedia team at GSFC, with Joy Ng as a lead producer, was tasked with creating the mission’s Launch Briefing Video, which included 3 animated sequences created by Adriana (https://svs.gsfc.nasa.gov/20306).

In support of Astrophysics, the CILab has completed a number of multimedia products for JWST like videos, still images, and 3D models. In addition to being a lead animator, Adriana is also the technical director for the Webb Telescope 3D model, which will continue to be used in the production of other multimedia products. She also worked with the WFIRST mission with video producer, Scott Wiessinger, in developing a set of explainer animations for a WFIRST story on Microlensing (https://svs.gsfc.nasa.gov/20315).

The CILab team had the opportunity to attend SIGGRAPH, the premier conference for the fields of Data Viz and Visual Effects. New technology and techniques are showcased through panels, poster sessions, seminars, along as being explored through workshops. The team also had a chance to make direct connections with the software developers of the many packages used by CILab, which gives the lab a unique opportunity for collaboration and personalized support. Adriana plans to submit a poster on the importance of art and design in scientific communication to the 2020 AGU fall meeting.

Kathryn Mersmann supports the Earth science news team by producing videos and social media content highlighting news and announcements from around the agency. In addition to creating the content, Katy also posts to @NASAEarth on Twitter, Instagram and Facebook and creates content specifically for agency-wide platforms like Snapchat, Instagram and tumblr.

This year, for her work with Earth Expeditions, Katy traveled in July to Boise, ID with the Fire Influence on Regional to Global Environments and Air Quality Experiment (FIREX-AQ), along with Lauren Ward and Ellen Gray. Before they left, Katy produced a video about the campaign’s goals and work. Onsite, she assisted with a media day, helped conduct interviews for NASA Explorers and Earth Expeditions blogs, and produced a tumblr post, Snapchat story and Facebook Live. Katy managed the newly minted @NASAExpeditions accounts, using the week as a test case for how to use social media for firsthand, experiential storytelling. The FIREX-AQ experiment was extremely successful, gaining many new followers and creating a place for engagement with other agencies involved in the field campaign, as well as helping establish best practices for future missions to use the accounts. During the campaign, Katy, Lauren and Ellen embedded with several different research groups, including camping out overnight with a group collecting smoke in the Sawtooth Mountains.

In September, Katy traveled with Samson Reiny to the Philippines to support the Cloud, Aerosol and Monsoon Processes in the Philippines Experiment (CAMP2Ex). Before traveling, Katy produced a video about the field campaign’s goals and science platforms, which was posted to the usual social media and websites, and was used by the project scientist as part of an embassy presentation. While in the Philippines, Katy filmed footage and conducted interviews for the NASA Explorers episode about CAMP2Ex, as well as managed the @NASAExpeditions accounts for the week. She also created a tumblr post and

*Image from “Roman Space Telescope Microlensing Animations.” (Provided by A. Manrique Gutierrez.)*
Katy is now a co-lead on the @NASAExpeditions accounts, supporting Earth science missions. Katy worked with Lauren Ward and Molly Wasser to create and present an ePoster at the 2019 AGU fall meeting, showcasing experiments with NASA Explorers and NASA Expeditions to help communicate science and encourage viewers to see scientists as real people.

Katy worked on several Earth science campaigns. She was the lead producer for the ongoing Earth science campaign focusing on global freshwater availability, which kicked off in mid-June, with a video Katy produced. She oversaw the development of key scientific visualizations and conceptual animations to explain how NASA studies freshwater, as well as helped determine which stories to emphasize. Technically, she helped manage the creation of a Flickr gallery showcasing NASA applied sciences role in people’s lives, and developed and oversaw an agency-wide social media collaboration, emphasizing how freshwater research on Earth applies to other science areas, as well. The freshwater campaign is ongoing; Katy has one more video being released in July, and will continue to support the campaign on social media. For her work with NASA Science Live, Katy developed and helped produce the ninth episode about fires. She suggested the topic to coincide with the Earth science division’s communications campaign about fires and helped establish the focus of the episode. She identified and worked with scientists to appear on the show, helped edit the script, and assembled b-roll footage. During the show, she ran computer graphics and arranged to have questions answered from the #AskNASA. In late July 2019, Katy worked with Lauren Ward and Michelle Handler to produce live shots about fires around the globe and how NASA studies them. Katy also developed a new social media strategy for integrating the live shots audience with the #AskNASA. In late July 2019, Katy worked with Lauren Ward and Michelle Handler to produce live shots about fires around the globe and how NASA studies them. Katy also developed a new social media strategy for integrating the live shots audience with the #AskNASA. In late July 2019, Katy worked with Lauren Ward and Michelle Handler to produce live shots about fires around the globe and how NASA studies them. Katy also developed a new social media strategy for integrating the live shots audience with the #AskNASA. In late July 2019, Katy worked with Lauren Ward and Michelle Handler to produce live shots about fires around the globe and how NASA studies them.

Katy also worked with the audio team and Moon social media manager to craft a release strategy for the second season, which emphasizes its differences while still maintaining the established Explorers brand. The season ran from mid-June to early July, and Katy produced a number of behind-the-scenes Facebook Lives, as well as the majority of the season’s social media posts. For NASA Explorers Fires, she again worked with Lauren Ward on this third season of NASA Explorers, focused on how the agency studies fires. Katy was the sole social media producer on the show, uploading every episode, and coordinating and filming the behind-the-scenes Facebook Lives, as well as helping to develop a final wrap-up episode that ran longer and reflected on this year’s fire season. Katy also produced a full episode for the series, highlighting the work she documented traveling with CAMP2Ex. This episode helped bring in the international collaboration aspect of NASA’s research. Overall, at the time of this writing, this season of NASA Explorers had the highest views-per-episode on both YouTube and Facebook and engaged new audiences. To prepare for this season, Katy and Lauren worked with the NASA HQ social media team to ensure they were implementing the best practices for serialized content.

For the 50th anniversary of Earth Day, Katy created and coordinated content, including posting daily to a countdown blog (blogs.nasa.gov/earthdaycountdown) and sharing that content on @NASAEarth Twitter and Instagram and NASA Earth Facebook. She worked with communications teams for space technology, the International Space Station and more to consolidate, organize and repurpose existing content into a calendar of daily posts. She also worked on the agency’s digital strategy, helping consolidate key messages and develop content for sharing NASA’s Earth science in advance of Earth Day. After the COVID-19 pandemic shifted all Earth Day celebrations to virtual events, Katy helped develop, coordinate and post content for Earth Day at Home, including a series of 10 at-home science talks from Earth scientists, a partnership with Lego that invited families to build planets at home, a takeover of the @Instagram account by Jessica Mier, and a variety of other posts in the days leading up to Earth Day and on the day. This culminated with NASA’s hashtag #EarthDayAtHome trending up to fourth-highest in the U.S. and significant growth in followers on NASA Earth’s Instagram, Twitter and Facebook pages.

This year, Katy was involved in the production of three seasons of NASA Explorers – two as an executive producer and social media brand supervisor and one as a videographer, video editor and social media manager. For NASA Explorers: Apollo, Katy worked with Lauren Ward and Goddard’s audio production team on the second season of NASA Explorers, which focused on the scientists and engineers behind the Apollo era of lunar science. The season was primarily designed as a podcast, so Katy and Lauren worked together with the team to redesign each episode to be video-optimized for the traditional Explorers accounts. Katy also worked with the audio team and Moon social media manager to craft a release strategy for the second season, which emphasizes its differences while still maintaining the established Explorers brand.

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NASA Explorers social media strategy and worked with the ISS Research to modify it to this unique season, including replacing the standard behind-the-scenes Facebook Lives in situations where the explorers themselves were still in space and therefore unavailable for interviews. This season set some new records for viewership and continued to grow the NASA Explorers audience, reaching more than 90,000 followers on Facebook. In late April 2020, the NASA Explorers team learned that NASA Explorers: Cryosphere, the first season, was a finalist for a Webby in the Social Content Series & Campaigns – Education & Discovery category. The season is now up for public voting, as well as final judging.

In addition to campaigns and special products, Katy continued her support of NASA’s Earth science news team as a video producer and social media co-lead. She produced more than 1000 discrete social media posts, including Instagram stories, Facebook posts, Twitter threads and tumblrs posts. Some of these posts, especially during the 50th anniversary of Earth Day, garnered particularly high engagement and helped the NASA Earth accounts reach new high watermarks. On average, the number of monthly impressions on NASA Earth Twitter is several million higher than a year ago. In addition, the NASA Earth Instagram, which Katy began contributing to in January, has grown substantially in followers. She has continued working on the collaborative social media effort throughout the agency and has helped with NASA’s work to consolidate social media accounts, including presenting to other thematic account managers about how the NASA Earth team works together. Meanwhile, Katy produced many videos supporting the Earth Science News Team’s coverage of science results, producing the annual GISTEMP global temperature update video and social media effort, as well as the annual ozone hole update.

Going forward, Katy will continue her regular support of the Earth Science News Team as a video producer and social media co-lead. In summer 2020, she will help to share the story of COVID-19’s effects on the environment, as part of a NASA Earth science effort. Katy will continue participating in the #NASAatHome initiative, sharing existing and newly created content for audiences to use while in quarantine or stay-at-home directives.

Paul Morris is a Multimedia Producer Specialist and video producer for the Hubble Space Telescope. He coordinates with the Hubble multimedia team and communications officials to provide multimedia in support of mission goals and communication campaigns. Over the course of the year, Paul interviewed major NASA employees about the Hubble Space Telescope. Paul then edited and produced an hour-long documentary about the telescope. The documentary aired on NASA TV on Hubble’s 30th anniversary, and the video is available for streaming on HULU (https://www.youtube.com/watch?v=Lo43Gg_Xe1M). (A related image is posted in this report’s Table of Contents.)
While filming B-Roll at the NASM for the Servicing Mission 4 anniversary, it was noticed that the Hubble exhibit featured a video from 2003. Paul and the Hubble Outreach Team offered to create a new video featuring the history of Hubble and some of its more recent accomplishments. Paul’s updated Hubble video is now playing at NASM alongside the life-size Hubble model. In addition to assisting in this video’s production, Paul filmed and edited a video about how the visually impaired can experience Hubble images through touch. After this video had great success on Hubble and Goddard’s social media pages, Paul then worked with NASA HQ’s social media team to upload the video, which went on to gain over 4.2 million views. The video was selected as a Webby Honoree under the Science and Educational video category.

Paul also produced and edited a video sharing Hubble’s new discovery of an exoplanet with water vapor. The video “went viral” for a time, actually ending up on Twitter’s trending newsfeed. The Goddard YouTube video gained over 180,000 views, and when combined with Hubble’s and Goddard’s social media pages, managed to gain over 2.5 million views. In total, Paul edited and produced over 20 videos and/or graphics for the Hubble Outreach Team that have a combined total viewership across all social media channels of over 15 million views: historical videos featuring specific moments and missions in Hubble’s history; science news press release videos; AR videos for public outreach; and, GIFs for social media.

Paul also helped plan the video release strategy to celebrate Hubble’s 30th anniversary in space, culminating in a video featuring the anniversary image with Dr. Jennifer Wiseman providing the narration, explaining the image. This video “Hubble’s 30th Anniversary Image” gained a combined 800,000 views across Hubble’s social media channels. Hubble’s YouTube channel is available here: https://www.youtube.com/playlist?list=PL3E861DC9F9A8F2E9. For more information on HST’s 30th, visit https://www.nasa.gov/content/hubbles-30th-anniversary.

Plans for the coming year will involve ongoing work on breaking Hubble science release news stories, as well as working on a new explainer-style mini-series that will focus on frequently asked questions about Hubble (e.g., its gyroscopes, how Hubble images are made, and gravitational lensing). Paul plans to rearrange Hubble’s SVS page to ensure that the archives are arranged in an easy-to-understand and easy-to-navigate fashion for outside users. He will continue to discover, digitize, and add helpful metadata to old Hubble archive footage.

Joy Ng is a video producer for both NASA’s heliophysics division and NASA’s Global Precipitation Measurement (GPM) mission and provides all multimedia needs in support of mission goals, communication campaigns, and agency priorities.

Over the year, Joy has published 18 unique video products for NASA’s heliophysics division. For the field campaign focused on Earth’s leaky atmosphere, Joy produced a video that was a finalist for science film festival (see page 4). She produced an abridged Instagram TV version for NASA’s flagship Instagram account on the same field campaign, which achieved more than 4 million views making it the account’s fifth-most-played IGTV video of all time. Joy also produced video products aligned with the agency’s top priorities, such as Artemis and space exploration to Mars and beyond. Her video titled “How NASA Will Protect Astronauts from Space Radiation” (https://youtube.be/vpNa4u997xA) was shared by the flagship NASA accounts during an Artemis-focused month. She produced video products and helped direct new animations for the recent Solar Orbiter mission, a joint NASA-ESA mission to the Sun. These useful products were shared by many news outlets, including The New York Times, The Verge, CNN, The Guardian, and more.

As a one-woman film crew, Joy supported the BITSE balloon campaign at NASA Goddard and in the field in New Mexico. She produced a video titled “NASA’s BITSE Solar Scope Is Ready for Balloon Flight Over New Mexico”. She also managed two live streams during launch day: one featuring the inflating and

Image from “NASA’s New Solar Scope is Ready for Balloon Flight.” (Provided by J. Ng.)
launch of the balloon and another that highlighted the mission’s scientists and engineers. She worked with science writer Lina Tran on a digital campaign during the mission for the NASA Sun and NASA Expeditions social media accounts. Overall, they published around 150 posts, achieving 35,000 engagements. Posts included videos, photos, GIFs, blog posts, and text captions. In addition, Joy produced social stories for NASA’s flagship accounts on Snapchat, Instagram and Facebook in which 1.3 million viewers watched the entire social story.

This year, Joy was tasked with managing and directing live shows and launch shows associated with NASA’s Sounding Rockets Program and two NASA launches: the Ionospheric Connection Explorer (ICON) and Solar Orbiter. The show titled “Sounding Rockets: Cutting-Edge Science, 15 Minutes at a Time” (https://youtu.be/KKeCXgrjuY) aired on NASA TV, Facebook, and Periscope, and involved showcasing NASA’s broad repertoire of research in sounding rockets. She worked with project leads at NASA HQ and scientists from NASA Goddard, NASA Wallops, and Johns Hopkins University to devise key messages, diverse storylines, and accurate representation of the entire program. For both the ICON and Solar Orbiter launches, she was responsible for writing the script, generating imagery, coordinating with guest speakers from NASA HQ, the European Space Agency, and NASA Goddard, and working closely with NASA’s Kennedy Space Center TV team on the technical logistics. Her previously produced work was also featured in the live launch coverage.

For her work with Earth Science, Joy worked on videos related to GPM and hurricanes, among others. Joy and Ryan Fitzgibbons worked with the SVS and Jackson Tan (613/USRA) to produce unprecedented data visualizations of a 20-year record of rain and snow from NASA’s Global Precipitation Measurement mission. Using these new data visualizations, Joy produced a video titled “NASA’s New View of Daily Cycle of Rain” (https://youtu.be/AsE7CpYOrhc) and a tumblr blog post titled “What Does Two Decades of Rain and Snow Show Us?” She helped Ryan narrate the video titled “NASA Remasters Nearly 20 Years of Global Rain.” These new data visualizations were utilized for Live Shots (live TV interviews with scientists discussing the new imagery). For the NASA’s Earth Day 2020 that focused on societal benefits of NASA research, Joy produced a video titled “Guiding Farmers with NASA Satellites” that featured farmers from Pakistan using NASA satellite data to predict and estimate freshwater resources (https://youtu.be/T1NSkp0RI5E). Additionally, in early 2020, Joy produced content for the start of the Atlantic hurricane season. This included a video titled “NASA Has Eyes on the Atlantic Hurricane Season,” which achieved more than 74,000 views on YouTube, Facebook, and Twitter, and a NASA social story for Instagram, Snapchat, and Facebook, which achieved an average completion rate of 60.14% across those three platforms. In addition, she has contributed to the HQ-led NASA Science Live show on the production team, editorial team, and as an on-screen host.

Joy pitched and produced a panel session for the World Congress of Science and Factual Producers about scientific data visualizations and animations in documentaries, virtual reality, and live television shows. During the conference, she led the discussion as the moderator and a NASA representative, and spoke with guests from the BBC, NHK (Japan’s public broadcaster), and other independent production companies. Throughout the conference, she had meetings with other broadcast companies, producers/directors, and commissioners to discuss NASA-related capabilities, resources, and ideas.

In the next year, Joy will transition to being a full-time producer for the heliophysics division. She will continue supporting broader agency-wide communication campaigns around Artemis and space weather developments. She also will transition to being the heliophysics point of contact for Artemis-related external communications strategies. In addition, she will work on a solar cycle campaign as we enter into the new Solar Cycle 25.
Jonathan North is an Animator with the Office of Communications. This past year, he was involved with a variety of missions and projects. For the Lucy mission, Jonathan provided much content, including conceptual looks of the seven binary asteroids that Lucy would be visiting. Along with images and videos of the asteroids, Jonathan created digital renderings of the Lucy Spacecraft. These assets were used by scientist and producers to create essential mission content like the Lucy mission overview as outreach content. The video “Lucy Mission Overview: Journey to Explore the Trojan Asteroids” is available at https://svs.gsfc.nasa.gov/13482.

For the Mars Winds project, Jonathan worked with the Maven science team and producers to help create content for the Mars upper atmosphere reveal video. With Maven’s NGIMS instrument creating a map of the wind current on Mars, the team wanted to create a video showing what they discovered. Using a new pipeline tool called Unreal Engine in the CI Lab, Jonathan used the tool’s real-time rendering capabilities to create a conceptual look of Maven’s NGIMS instrument’s technology. The real-time rendering allowed Jonathan to work more efficiently with the scientist and producer to create a more accurate depiction of Mars’ wind current distribution. The video “Mars Wind Currents Reveal a Surprising Feature – Animations” can be found at https://svs.gsfc.nasa.gov/20302.

Dragonfly, a NASA mission, will explore Saturn’s moon Titan to test its chemical makeup and will be launched in 2026. For this mission, Jonathan was tasked with helping the Dragonfly team to create visuals to accompany their proposal. He created a variety of animated shots for the proposal, including three shots that showed the interior mechanism of how Dragonfly collects and tests samples from Titan. Four animated graphs showed the results of the collected samples, and he created four exterior shots, including one with Dragonfly drilling into Titan’s surface collecting samples and another that showed how two of the measuring instruments worked. Jonathan also created a shot that showed the samples flowing through the piping of Dragonfly that transferred into the collection chamber to be tested as well as a shot of the hovercraft on Titan’s surface. Dragonfly is equipped with a neutron spectrometer and a representation of that instrument’s results also was needed for the proposal video, so Jonathan created four 3D animated graphs that showed the results of the collected samples. The video can be found here: https://svs.gsfc.nasa.gov/20311.

For the James Webb Space Telescope (JWST) mission, Jonathan created lights and renders to existing shots as well as created other B-roll videos for the JWST overview. This project pushed the creativity and understanding of lights, camera movements, and presentation. The idea behind his shots were to create videos that show the spacecraft in a way that would further the public’s interest in the mission. Additionally, Jonathan was given the project of developing an Augmented Reality (AR) app for the JWST Team, which will be a useful tool for outreach purposes. It will be considered a “living” app, meaning that its content will evolve with the telescope. Wherever the Webb Telescope is in the process of launch and post-launch, the app will reflect content that will continuously keep the public updated. One of the more exciting features of the app is that a user can place the JWST model in the real world, scale it to its full size, and walk around and interact with it. Another exciting feature of the app is putting the telescope in space, which will give the users an idea of what it would be like after JWST has launched. The variety of this app’s uses will provide scientists, teachers, and parents with a tool to help educate students and the public about the evolution and possibilities of the James Webb Space Telescope.

Jonathan’s plans for the upcoming year include learning more about content creation, specifically the coding aspect for creating the vast variety of content the CI Lab are tasked with to better assist in the outreach for scientists and producers at NASA.

Christopher Smith is a multimedia producer and animator for astrophysics. His multimedia production work includes short videos, high-end animations, motion graphics, static illustrations for science journals, graphics for conferences and scientific talks, and content specifically designed for social platforms. Chris works collaboratively with a team of science writers and scientists to create accurate, accessible media for press releases, feature stories, partner institutions, and other announcements and presentations. Throughout this past year, Chris produced a wide range of products for NASA Astrophysics, ranging anywhere from cartoon aliens to realistic renders of faraway exoplanets.

One of Chris’s major accomplishments was “NASA’s Guide to Black Hole Safety,” an innovative video created for Black Hole Week, an agency-wide campaign to educate the public about black holes. Asked to create a “safety video” about black holes, Chris took the concept one step further, developing a video about an intrepid blue alien traveler and a black hole that would rather just be left alone. Chris also developed a visual brand package for the campaign that included graphics for social media, short vignettes featuring the characters, and Instagram story animations. Across the agency, the video was shared by
@NASAUniverse (NASA’s main Astrophysics account), NASA’s James Webb Space Telescope, the Hubble Space Telescope, and others. The YouTube version of the video (https://youtu.be/aMTwtb3TVik) has amassed over 560,000 views, and it was featured in articles by CNET, Mic, and educational websites. The official NASA Instagram and Snapchat accounts also shared vignettes featuring the alien traveler and black hole characters. NASA astronaut Chris Hadfield shared the video on his Facebook page, commenting that “the British accent is somehow perfect,” and NASA’s Astronomy Picture of the Day also featured the video. Finally, the video’s YouTube metrics showed that the vast majority of views came from audiences well outside our team’s traditional reach. The alien traveler continues to have a life well beyond the initial campaign. Chris performed a real-time “live” animated version of the character for the NASA Science Live television program (https://youtu.be/AmCT0ZOY1Hg?t=558), and the Goddard employee gift shop now sells t-shirts featuring the alien traveler and its black hole friend. Chris has already begun work on a second video.

This year, Chris also produced a large suite of animations and video products for NASA’s Transiting Exoplanet Survey Satellite (TESS). The content supported major TESS milestones and discoveries, including two planets located in their stars’ habitable zones, a world orbiting two stars, and the mission’s smallest detected planet to date. The videos produced to support these results (one example: https://youtu.be/6bWra2Wvudk) collectively received 1.7 million views on YouTube alone and were featured in articles in a wide range of publications, including the New York Times, CNN, CBS News, Fox News, BBC Worldwide, Telemundo, and the Los Angeles Times. As part of this process, Chris created new workflows for rendering exoplanets and their host stars. To ensure accuracy in his animations and increase overall efficiency, he created a template that enabled him to enter data directly from TESS scientific papers. This data would then be used to instantly render a system with correct planet and star sizes, planet distances, and relative orbit speeds. Chris also developed a method to create “photographic” renderings of what these exoplanets might look like. Using a mix of real solar system imagery, computer models developed by researchers, and physically accurate rendering, he was able to create planet illustrations that were inspiring but also faithful to the science.

Ultimately, when Chris worked with Dr. Gabrielle Engelmann-Suissa (699/USRA) and Dr. Geronimo Villanueva (NASA/GSFC) to develop conceptual animations of an Earth-size exoplanet in the habitable zone of its star (https://svs.gsfc.nasa.gov/13496), Chris saw an opportunity to present the project at SIGGRAPH, an international conference featuring work from the world’s best animators, data visualizers, and interactive developers. This unique team brought together the fields of climate modeling, data visualization, and animation, and Chris led an effort to submit a SIGGRAPH talk that showed how Gabrielle’s team’s models, Geronimo’s climate visualization tool, and Chris’s animation work contributed to possible renderings of the exoplanet. Their work also was promoted as a NASA Goddard feature: https://www.nasa.gov/feature/goddard/2020/nasa-planet-hunter-finds-its-1st-earth-size-habitable-zone-world.
In addition to Black Hole Week and TESS results, Chris produced video and animation products for many other Astrophysics discoveries and improved his animation capabilities. Results Chris supported included the NICER mission’s brightest X-ray burst to date and a zoom in to the black hole at the center of galaxy M87. He also supported NASA’s astrophysics presence at the January AAS conference, including the discovery of the farthest known galaxy group (https://youtu.be/ShHilot8icc) and a new study on a unique binary star (https://youtu.be/oynnkyDbOPM).

To improve his animation skillset, Chris spent the year learning and using a new type of 3D rendering software to create photoreal products in a fraction of the time it would traditionally take. He has since moved over permanently to this rendering software for NASA satellite animations, ground telescope renderings, and images of other spacecraft.

Plans for the coming year will involve continuing to support NASA Astrophysics results, initiatives, and campaigns while developing new styles and workflows. Specifically, Chris will be instrumental in developing a new video in the alien traveler series along with derivative products, and he will produce multiple new exoplanet videos and animations to support TESS discoveries as well as other astrophysics science results. He also will work to develop innovative ways to tell NASA Astrophysics stories using non-traditional visual styles and storytelling methods, drawing inspiration from media outside the science storytelling world.

Lauren Ward is the lead video producer for Goddard Earth Science stories. This year, she and her team continued to expand the digital series, NASA Explorers, a growing storytelling initiative that takes a look at people from around the agency who explore a unique aspect of our planet and solar system with each new season. Lauren’s primary mission continues to be to tell compelling Goddard stories that communicate the importance of our science and NASA’s unique role in the earth observation community.

Lauren wrote, produced, directed, edited and narrated three of five unique episodes of the new NASA Explorers digital series, Fires. This season took their team of storytellers all over the world, from the American West, to the Canadian Arctic, to the rainy Western Pacific islands. So far, the series has garnered over one million views. In addition, Lauren was executive producer of the fourth season of NASA Explorers, Microgravity, which was produced by the ISS Research Team at Johnson Space Center. NASA Explorers was also recently nominated for a prestigious Webby Award, the leading international award honoring excellence on the Internet. Watch the entire season of Fires and of Microgravity at these sites, respectively: https://www.youtube.com/watch?v=RN7fm1ZRK90&list=PL2aBZuCeDwlRis4U4PlP0e48GiD43dy and https://www.youtube.com/watch?v=U_GQ65c2irk&list=PL2aBZuCeDwlQDM6x6FpHE_XOIL7hvR6P. Along with producing episodic content for the NASA Explorers digital series, Lauren teamed up with the Earth social media team to create bonus content for each episode. She hosted five Facebook Live interviews with scientists featured in that week’s episode.

During the year, Lauren wrote, produced, and edited a feature video explaining how human-generated greenhouse gases and atmospheric particles were affecting global drought risk as far back as the early 20th century, according to a study from NASA’s Goddard Institute for Space Studies (GISS) in New York, NY. The video “Human Influence on Global Droughts Goes Back 100 Years” is available here: https://svs.gsfc.nasa.gov/13198. Additionally, Lauren and another producer created the Operation IceBridge campaign wrap-up videos for the end of its 11-year mission. Both videos were shown at the 2019 AGU Fall meeting in San Francisco in December as well as promoted on Earth social channels (https://svs.gsfc.nasa.gov/13501).

Lauren co-produced fire-themed Live Shots and NASA Science Live by supplying footage from the FIREX-AQ campaign in Boise, ID and ABoVE in the Canadian Arctic, and providing guidance on strategic talking points around NASA contribution to fire research. Along with Planetary and Astrophysics scientists and colleagues, Lauren produced, filmed, wrote, edited and narrated

*Image from “NICER Catches Milestone X-ray Burst” https://svs.gsfc.nasa.gov/13419. (Provided by C. Smith.)*

Lauren was part of a four-person content team producing stories about big ideas for the future as part of NASA's celebration of 50 years of Earth Day. She directed three scientists who filmed their videos at home, since the agency was on mandatory telework. These were added into a montage video that explored themes around how monitoring Earth from space can help us better manage and understand our planet 50 years from now (https://www.youtube.com/watch?v=wr5qS_3_jHE&feature=youtu.be).

Going forward, Lauren and her team will be creating the fifth season of NASA Explorers. She was asked to help create a standard production guide meant to instruct other departments within NASA on how to create their own season of NASA Explorers. Lauren will begin drafting a three-part, story-driven series about the upcoming launch of Landsat-9 along with producer, Matt Radcliff. She will continue to build relationships with other media teams at Goddard and across the agency to create a strong network of support and collaboration among science communicators.

Scott Wiessinger is Goddard’s senior multimedia producer for astrophysics and the WFIRST mission, as well as a producer for heliophysics. His multimedia production work includes short videos, static graphics, animated gifs, hyperwall content, 4k media, and digital art installations, directing the creation of animations and data visualizations, creating animations himself, providing materials to outside media and producers, collecting, creating additional social media content, and curating visuals online. Scott coordinates and collaborates with science writers, animators, visualizers and scientists to produce accurate and accessible materials timed to coincide with press releases, other announcements and presentations.

Throughout this past year, Scott produced, edited and/or animated over 30 videos and clips. These videos consisted of an extremely broad range of styles and formats, such as narrated videos, text-on-screen videos, data visualizations, animations, motion graphic cartoons, and animated gifs. This breadth is partly because Scott is now creating multimedia for an extremely large group. He is a senior producer for the Astrophysics Science Division at Goddard, and does work for every mission, except JWST and Hubble, although he has done work for both, including narration. He also supports groups such as the Sellers Exoplanet Environments Collaboration (SEEC) and continues to work on heliophysics projects for missions like SDO and Parker Solar Probe.

Scott has embraced the full breadth of products enabled by social media. He created two infographics during the year, and many still images and gifs. His infographic covering the TESS discovery of an exoplanet system – TOI 270 – had graphics appear in the New York Times, PBS, Time and Ars Technica. The New York Times also carried a heliophysics animation that Scott worked on. In addition to creating non-standard content, Scott preserved it with the SVS archival of many products destined for social media and guided it with editing advice for a series of social media videos. In March, work at Goddard shifted to mandatory telework. Scott continued to produce products and worked many new projects, including several that are due out in mid-May. He created a home audio booth and recorded narration for his own videos as well as others for heliophysics. Scott’s complete collection of work can be found here: http://svs.gsfc.nasa.gov/search/Person/WiessingerScott.html.

Astrophysics had a successful and productive year. In July, TESS celebrated its first anniversary. Scott made a highlights video and a tour of TESS’s view of the southern sky. The southern sky video was picked up by EarthSky, Science Times, and Slashgear; the sky image got ~800,000 views on NASA’s flagship Instagram account. September was a great month for astrophysics, anchored by Black Hole Week from September 23-27. The week was a major effort by the entire astrophysics communications team and included a large number of releases. Scott worked with astrophysicist Jeremy Schnittman to create a new visualization of a black hole’s accretion disk. He made several short clips and gifs from the visualization. The flagship NASA Instagram account posted one of these clips, which reached 4.4 million views, one
of the highest numbers for any video on that account. The SVS page for this material had over 800,000 hits in the first month, meaning many people went there to view and download it. The visualization made ripples throughout the internet, and even resulted in Dr. Schnittman being interviewed by NPR’s Morning Edition. Scott’s biggest release for black hole week was a video about TESS and Swift spotting a supermassive black hole’s “tidal disruption event”, where a star wanders too close and is torn apart into a stream of gas that orbits the black hole. Scott created the related animation and narrated video. The release of this news became the culmination of Black Hole Week and was massively successful. In less than two days, the video climbed to one million views on YouTube; at present, it is at 4.5 million, making it one of the most successful Goddard has released. Many major news outlets carried the story and animation, including CBS, USA Today, the Weather Channel, Bad Astronomy, and the NY Times. It is one of the most successful science result stories astrophysics has ever had.

In December and early January, Scott worked on several products for the American Astronomical Society meeting held in January 2020. He created one narrated video for TESS, another for WFIRST, other products for a TESS press panel, and assisted with colleague Chris Smith’s AAS products. Because AAS is in the first week of January, much of Scott’s work had to happen during peak holiday season. Scott worked during vacation time to confirm everything was ready. Additionally, throughout the year, Scott worked on two videos to commemorate XMM-Newton’s 20th anniversary. To create these, he interviewed many scientists currently using the spacecraft’s data and those involved in the satellite’s creation, including Steve Kahn and France Cordova.

Scott’s work for heliophysics was somewhat lighter than for astrophysics or WFIRST. He worked on creating or modifying several animations for a major announcement of Parker Solar Probe discoveries in December. One of these was picked up by the New York Times and featured prominently in its article. Scott also created two videos to mark SDO’s 10th launch anniversary. These videos were partially placeholders for a more ambitious ten-year anniversary project that he initiated. With June 2020 as the target release time, Scott is working with visualizer Tom Bridgman to create a full ten-year time lapse that will last for nearly an hour. This will be a first for Goddard, since such a large time-lapse will require over 87,000 4k frames. Some of Scott’s older projects continue to shine as well. His “jack o’ lantern sun” image from 2014 gets a bump every year around Halloween. This year the NASA Instagram account posted it and it quickly climbed to 1.5 million views. Finally, near the start of the quarantine period, Scott and his family created a video showing how to bake sunspot cookies. His daughter provided the on-camera hand and voice talent. They recorded using Scott’s own equipment, including a GoPro camera to suspend over the counter, and a recording booth made out of towels that he built in the basement. The main NASA Facebook account posted the video and it currently has 138,000 views.

For WFIRST, Scott’s production increased dramatically this year. He released five WFIRST videos, an infographic, and numerous stills and animated gifs. The most successful, a video touring a simulated WFIRST image, has 39,000 views on YouTube. The WFIRST group has added a new science writer and social media coordinator to the team. Scott has been working with both to produce content for them and help improve content that
they have been creating. He is currently working on a series of products for release in mid-May. There will be a major news event for WFIRST, and Scott is leading the production of content for it with three new videos that are helping to set the style and tone for the event.

In the coming year, again Scott will be involved in work on Astrophysics, Heliophysics, and WFIRST. He will continue working on conveying science results for astrophysics. For heliophysics, Scott will continue working on Solarium, breaking news, and special non-standard projects. In the long-term, Scott is developing content to accompany orchestra performances. For WFIRST, Scott will complete several videos for an upcoming release. Numerous releases are planned through the year, including several infographics.

Elizabeth Wilk is a multimedia visiting fellow at NASA’s Goddard Space Flight Center. Predominantly working with The GLOBE Program’s GLOBE Observer team, she also develops and produces video products for other groups. Her work includes short videos explaining how to use the GLOBE Observer citizen science app available for smartphones and why NASA scientists are interested in data collected by students and citizen scientists. Additional products include promotional videos for events and anniversaries such as the TERRA satellite’s 20th anniversary, animations for videos, and social products.

Throughout the year, Liz consistently worked on writing, shooting video, developing animations, editing and releasing videos to promote the GLOBE Observer app. GLOBE Observer is a citizen science app with different topics for users to take measurements on. To promote the app, Liz produced videos as part of a larger series focused on showing users how to navigate and use the app. Since May 2019, she has produced pieces explaining how to take observations on land cover and mosquito habitats. As of this writing, she is in the midst of producing an additional video on mosquito habitats, focusing on additional activities for observers to complete, such as identifying the mosquito larvae.

In addition to producing videos explaining how to use the GLOBE Observer app, Liz produced longer video products explaining why NASA scientists are asking citizen scientists and students for their help in observing clouds, land cover, tree height and more. The first in the “Why Observe?” series focused on land cover. Liz created graphics and animations to help further explain the science behind land cover and the challenges scientists face, and her work included interviews with Peder Nelson (Oregon State University), Dr. Amita Mehta (ARSET), and Dr. Eric Brown de Colstoun (618/GSFC). The video “Why Observe?: Land Cover” was recently accepted as a semi-finalist in the Vienna Science Film Festival, and she is waiting to hear from other festivals on the submission status of the video (https://svs.gsfc.nasa.gov/13286). At present, Liz is wrapping up the next video in the Why Observe? series about measuring tree height. Despite the challenges presented by the COVID-19 pandemic, her work on the video is progressing well, with a release date planned later this summer. The video touches on how satellites (e.g., ICESat-2) work, how to measure tree height and what is learned from tree height.
This past year, Liz continually supported Goddard’s Office of Communications in various ways. She volunteered and helped with supporting live shots for different events. Liz also participated in producing a video documenting the annual event “RockOn!” At the event, held at Wallops Flight Facility, high school and college students learn how to build a sounding rocket payload that is sent up at the end of the week. During the week, Liz and a small production crew documented the students’ activities, which resulted in a one-minute-long video promoting the sounding rocket launch and a four-minute video about the overall event. The videos can be viewed at https://svs.gsfc.nasa.gov/13252.

December 21, 2019 was the 20th anniversary of the launch of the Terra satellite. As part of the celebration and promotion of Terra, Liz had the opportunity to produce a video celebrating how the satellite changed Earth science and understanding of the planet. Working closely with the Terra outreach team, she completed the video to be released in time for the 2019 AGU Fall meeting and the anniversary of the launch. She also produced two videos that were released to public, each focusing on different aspects of the Terra satellite and what it has done to benefit the public. The videos were both released by NASA’s Goddard social media as well as the NASA Earth account on Facebook where they received positive responses from the public (https://svs.gsfc.nasa.gov/13493).

Liz has worked on additional projects while producing the Why Observe?: Tree Height video. To promote the GLOBE Observer tree height protocol in time for Earth Day, she completed a short video about trees and what scientists can learn from their height. However, due to the COVID-19 pandemic, the video has yet to be released, since it was part of a campaign promoting a tree height measurement challenge. In other work, Liz supported a fellow producer in locating archival images and b-roll for use. The images gathered are part of a longer video about the history of weather satellites in space. This video, sponsored by JPSS, celebrates 60 years of these satellites as a way to promote the mission as well as to convey how these satellites changed the lives of people on Earth.

Other activities this year included Liz’s participation in the American Conservation Filmmaker Workshop held in October, where filmmakers shared their experiences in creating engaging content for viewers. She also attended remote talks for the NASA working group, including discussions on the work other NASA centers are producing.

For the coming year, Liz will be completing the highly anticipated Why Observe?: Tree Height video for GLOBE Observer and continue with the Getting Started series, focusing on the mosquito habitat mapper protocol. In addition, Liz will be joining the JPSS team in producing videos as well as continuing support to the Goddard Office of Communications.

**CODE 606.4 (Sponsor: H. Mitchell)**

Tom Bridgman provides visualizations for the NASA GSFC Office of Communications. For the Solar Orbiter project, Tom generated several visualizations of the solar magnetic field, identifying regions of poor coverage for magnetograms from the existing spacecraft (https://svs.gsfc.nasa.gov/4788). Orbital trajectories for the mission were generated prior to launch; since the launch was delayed a few days, updated visuals were released under the same identifier.

Tom generated a visualization showing several days of GOLD ultraviolet imaging of Earth’s ionosphere, released with a comparison of similar UV imagery taken of Earth by Apollo 16 on the Moon back in 1972. A final product was generated and released in July 2019 (https://svs.gsfc.nasa.gov/4737). Tom used some of the code from this project to show the July 2019 South America solar eclipse made visible by the GOLD ultraviolet imager. Three different views were generated: visible light, oxygen emission, and nitrogen emission. Side-by-side composites were generated for easier comparison. The final products were...
For “A New Type of Reconnection Story,” Tom generated some SDO imagery to support this particular story release. Imagery was delivered to the producer and released at https://svs.gsfc.nasa.gov/4761 on December 12, 2019. For his work on the Transit of Mercury, Tom had to alter his data retrieval and rendering pipeline to use near real-time data employing SunPy. The product was delivered and released at https://svs.gsfc.nasa.gov/4763 on the day of the transit, November 11, 2019.

Heliophysics producers Genna Duberstein and Scott Wiessinger found a poster promoting very high-resolution solar imagery taken by the Swedish Solar Telescope and thought it would be very useful to have some of it available on the Hyperwall system. They and Tom made contact with the observatory’s director, Jorrit Leenaarts, who was enthusiastic about showcasing some of their data and provided a long data run. The data was provided in a custom and non-standard format, but Tom had enough information to convert the data to a file sufficient to process in the existing rendering framework. He also obtained some contemporaneous SDO/HMI imagery to provide context as well as a background reference for generating coordinate information for the dataset. The multi-wavelength data had other challenges, but Tom completed movies of the visible-light components and released them at https://svs.gsfc.nasa.gov/4715 on June 7, 2019. He expects to revisit the other imagery at a future time.

Another project under development is a visualization about how Solar Orbiter will be coordinated with Parker Solar Probe and other Sun-observing missions to more directly compare in situ measurements with remote observations using various orbit configurations of conjunctions, quadratures, and alignments along the solar magnetic field. Additionally, Tom continues to work on porting an aurora simulation to RenderMan 23 (the newest version). Pixar recently added Python 3 to their API support; with Tom recently converting his visualization modules to use Python 3, these updates will eventually be mapped into Tom’s regular rendering processing.

Leann Johnson provides the SVS with software to aid the functionality and productivity of the group. Software development is focused on but not limited to the website, database, and hyperwall systems. This year, Leann implemented and released a new, vastly improved, Django-powered SVS search page: https://svs.gsfc.nasa.gov/search. The new search has a median response time that is 92.5% faster than its predecessor; that is, the new search is over 12 times faster than the old search. Furthermore, the number of searches taking longer than 3 seconds has been reduced by 99.3%. Additionally, the server load for search requests has been decreased by 71% on average. To release the search, Leann was involved in completing the implementation, reviewing and implementing security standards, conducting full-scale testing on a test webserver, and performing the final release onto two production servers. She also wrote technical documentation for the code that drives the new search in order to aid future maintenance or any future developers on the project. Following this release, Leann implemented a search-based API for SVS material; this API can be used by other NASA groups or the general public to obtain queried SVS material programmatically.

The SVS has long hosted a web form on the SVS development site that allows internal users to request that various media products be created or handled by the Goddard Web and Social Media teams. In order to fulfill the many changed requirements from the initial form development, this form is being redeveloped in Django, the new website framework used by the SVS. Together with stakeholders, Leann constructed a set of requirements for the new Goddard Web application. She designed the Django database structure and application-flow and then implemented the new application, including all management processes. Finally, she implemented the application on the test webserver and began full-scale testing. Leann worked with Laurence Schuler (ADNET) to upgrade all three SVS databases from MariaDB 5.5 (a MySQL fork) to Oracle’s MySQL 8.0.17. This
upgrade provides enhanced security, support, and functionality; also, it was a prerequisite for the functionality of the new search.

On the SVS story detail pages, if applicable, the newest version of a page is now automatically listed at the top of the page in an attempt to direct public users to the newest SVS material. It had been reported that viewing the download lists of specific media was less than ideal on small devices, so Leann adjusted the styling of those download lists to be functional and appealing on all device sizes. She fixed a bug that was causing abstracts to arbitrarily appear above or below the first video on a webpage, regardless of what the user had selected for that particular page. Relatedly, the content management system (CMS) for the story detail pages enforces a few basic requirements for each page. Some confusion had arisen about how the system handles cases where the basic requirements are not met. Leann altered this code so that users do not have to re-release a page if they fix the missing requirements immediately; additionally, if they choose not to address the missing requirements immediately, they are sent an email notification for added transparency. Leann provided assistance and support to internal users using the CMS and hyperwall systems. She trained 12 new users on the SVS CMS, and provided support to dozens of users as they tested and began working remotely due to the teleworking mandate in response to COVID-19.

She ensured that the auto-updating IMERG visualization stayed up-to-date, fixing bugs as needed. In one case, the movie was broken due to extreme slowness that was temporarily experienced on the SVS internal file systems. Leann moved the code that updates this movie to a different server that was not experiencing the slowness in order to keep this visualization continuously updated. In other work, to support NASA Headquarters, Leann created an auto-updating Earth Science gallery page that showcases SVS visualizations pertaining to specific Earth Science research focus areas. She provided monthly Earth Science statistics for NASA HQ as well. She has kept closely informed of Goddard’s response to the “Web Modernization and Security Protocol Memo” issued by NASA in 2019 by attending several meetings, including those hosted by the Code 600 WebCIG, the Code 600 Web Council, and Code 600 IT Security, as well as agency-wide meetings on the topic. As a part of the center’s response to the memo, the Goddard Web Services group is auditing all of Goddard’s AART entries. Thus, Leann reviewed each SVS website/app entry in AART and updated each entry so that they are 100% documented. Security requirements mandated that the SVS set a Content-Security-Policy (CSP) in its website headers. Leann tested many CSP configurations on a test server and made several changes to the sites HTML/CSS/JS structure in order to reduce vulnerabilities. As needed, she investigated high webserver load to ensure the live site was not under any cyber-attacks at any time.

Leann responded to questions and inquiries from public users using the website. In particular, she communicated extensively with a WGBH group that is being funded, partially by NASA, to create Spanish-language versions of many pieces of content originally published on the SVS website. She served as a contact point between WGBH and individual producers and visualizers who provided the group with updated or raw materials to aid them in their translation work.

For her support of the hyperwall system, Leann fixed two major bugs in the hyperwall CMS. The first was causing image files presented in captions on the master screen to not be mirrored to the traveling hyperwalls. The second was preventing a user from creating a show directly when splitting frame sets. As part of an effort to get more SVS-generated content on the hyperwall for use by presenters at various conferences, Leann performed an audit of high-resolution SVS visualizations that were not yet formatted for the hyperwall. Three new Astrophysics hyperwall shows and corresponding webpages were created on behalf of Greg Bacon (Space Telescope Science Institute). She also answered many user questions about creating hyperwall shows and playlists, creating hyperwall HTML files, operating the hyperwall, and other various hyperwall-related questions.

Going forward, Leann will complete the testing and release of the new Goddard Web application. She will continue to transition other sections of the SVS internal and external websites into the Django web-framework. As always, Leann will continue to address the programming needs of the SVS and its partners.

Alex Kekesi had his NASA/SVS entry “NASA Surveys Hurricane Damage to Puerto Rico’s Forests” shown at ACM/SIGGRAPH’s 2019 Computer Animation Festival (CAF); this is detailed further in the Awards and Recognition section of this annual report. For his work with IMERG, Alex created two data visualizations showing IMERG rainfall measurements that cover January 2001 to December 2018 in support of the GPM project. Both of these were well accepted and have resulted in interest from the outside community (https://svs.gsfc.nasa.gov/4759 and https://svs.gsfc.nasa.gov/4760).

Working closely with Horace Mitchell, Alex created seven separate visualizations for the Proxima Centauri B Hyperwall.
Show to be shown at AAS. The science team was very grateful to have this as part of their presentation. Gabrielle Engelmann-Suissa (699/USRA) conveyed to Alex via email her appreciation for the work that went into creating the visualizations and organizing the slides for the successful Hyperwall talk she gave at AAS. These items are available at https://svs.gsfc.nasa.gov/4777, https://svs.gsfc.nasa.gov/4778, https://svs.gsfc.nasa.gov/4779, and https://svs.gsfc.nasa.gov/4780.

Alex created a data visualization of Hurricane Dorian as it was off the East Coast of the U.S. What made this pass unique is that not only did GPM get a perfectly centered overpass of Dorian’s eye, but also the eye seemed to be in a stalled eyewall replacement (https://svs.gsfc.nasa.gov/4753).

Alex plans to complete work on Landsat classification data sets both over Brazil as well as throughout the Northern Hemisphere, and he will continue to support GPM as needed.

Eric Sokolowsky’s main task over the last year was supporting the NASA hyperwall by developing software, updating operating system software, and maintaining hardware. Eric supports three permanent hyperwall installations at NASA Goddard Space Flight Center and supports three more installations that travel to different locations for conferences and public outreach events. Each individual installation involves either nine or 15 screens.

Eric added several major and useful features to the hyperwall during this year. The system is now able to be controlled by a remote control. While the show presentations previously could be controlled, he added the ability to pause and continue playing movies within a presentation using a remote control device. Users can jump to the beginning or the end of a movie, jump forward or backward about 5 seconds, single-step forward or backward, pause, play, and play backward. Eric also rewrote a program that generates preview images of hyperwall content to take better advantage of multiple cores and processors on a single machine, making this process much faster. Related to this effort, Eric continued to work on the program that generates preview web pages for hyperwall shows. These previews are often used by scientists before their hyperwall presentations to determine if the show has been set up correctly. He added the ability to more easily use multiple instances of the hyperwall control software with only one remote by making only one instance actively paired with the remote.

Eric added several features to the program called “hwtool” that splits images for display on the hyperwall. He implemented a new plugin architecture to allow splitting of images in different ways for different situations. Eric created two different plugins: one uses a program called “tractor” to create the images on the SVS computing cluster, and the other is used for testing and debugging to ensure correct operation. Eric also maintains the operating system software for the hyperwall systems. Most of the machines were upgraded from CentOS 7 and Fedora 27 to Fedora 30 Linux. In order to upgrade these systems, Eric prepared and debugged kickstart scripts, debugged hardware problems, and replaced faulty hardware. He also made sure that the desktop settings were correct, updated the scripts to perform this function, and updated the setup script to provide more options, such as disabling DHCP or DNS services, to more easily configure those hyperwall systems that do not need such features.

Eric obtained a new type of machine called a Jetson Nano to try on the hyperwall. After compiling the hyperwall software for this machine, he found that it performs quite well, even on
4K screens. This shows major promise that could dramatically reduce the price, power footprint, and size of a hyperwall system. Eric added support for a new serial protocol to control the hyperwall screens used for travel and in the Building 33 lobby at NASA Goddard Space Flight Center.

Again this year, Eric traveled to support the hyperwall at various conferences and meetings, such as the 70th International Astronautical Congress in Washington, DC; the 2019 American Public Health Association Annual Meeting in Philadelphia, PA; the Supercomputing (SC19) Conference in Denver, CO; the 2019 American Geophysical Union Fall Meeting in San Francisco, CA; the 235th American Astronomical Society Meeting in Honolulu, HI; and, the 2020 American Association for the Advancement of Science Annual Meeting in Seattle, WA. Eric was solely responsible for several hyperwall talks given at SC19, and he supported many other meetings by preparing presentations and copying presentations back to the permanent archive.

Eric will continue to develop and support the hyperwall hardware and software, and will continue to support local and remote presentations as required. He will continue to develop the facility to play big movies across all hyperwall screens to ensure consistent, error-free playback. Work will continue on improving the synchronization software to support animation playback using the Digital Earth PC software. Eric also intends to proceed in releasing the hyperwall software so it is available for wider use.

Cynthia Starr develops data visualizations to support the scientific community, as well as NASA education and public outreach efforts. A major project completed this year included a series of visualizations showing the projected melt of the Greenland ice Sheet from 2008 through 2300 under three different climate scenarios. Other visualizations on the cryosphere include one on the new Antarctic BedMachine topography and an update of the change in the Arctic sea ice age between 1984 and 2019. Atmospheric visualizations created include several showing atmospheric methane and another showing a combination of carbon dioxide, carbon monoxide, and methane. Finally, she made additional progress on a visualization of the idealized currents around Mars.

Andy Aschwanden (Univ. of Alaska Fairbanks Geophysical Institute) created simulations showing the effects of outlet glacier flow on Greenland’s ice sheet thickness under different possible climate scenarios in order to estimate its projected contribution to sea-level rise in monthly time steps from 2008 through 2300. With guidance from Greg Shirah (SVS), Cindy generated RenderMan rib archive datasets of the ice sheet for the elevation of each monthly dataset. She also extracted the velocity fields and worked with Horace Mitchell to represent the motion of the ice sheet using flow vectors. She provided matching visualizations for three climate scenarios: Representative Concentration Pathway (RCP) 2.6, RCP 4.5, and RCP 8.5. (https://svs.gsfc.nasa.gov/4721, https://svs.gsfc.nasa.gov/4722, and https://svs.gsfc.nasa.gov/4727). Cindy also continued work on the Greenland Melt visualizations, generating additional still-camera versions of three different climate scenarios for the Northeast, Northwest, and Jakobshavn regions. (https://svs.gsfc.nasa.gov/4738, https://svs.gsfc.nasa.gov/4739, and https://svs.gsfc.nasa.gov/4743). Cindy consulted with scientist Andy Aschwanden and producer Lauren Ward on plans for a short two-minute entry to SIGGRAPH 2020 based on the Greenland Ice Sheet climate scenario visualizations. Using new data provided, Cindy created charts to present the effects of each scenario on temperature change and on sea level rise. She submitted the final version produced by Lauren to the SIGGRAPH 2020 Electronic Theater.

Cindy collaborated with Kel Elkins to develop a volumetric visualization of atmospheric methane. She extracted and processed the methane data while Kel created the initial visualization project and generated several drafts of alternative visual styles that could be employed. After reviewing an initial draft, science advisors suggested revisions that would highlight the sources of methane. Cindy re-processed the data to create an eight-dataset running average, which provided smoother results. Cindy also collaborated with Greg Shirah to develop a
method to adjust the particle densities based on this change in the voxel size. She then reprocessed the data and included the volume size for each voxel, thereby providing a more accurate visual representation of the data. Also, Cindy created two volumetric visualizations of global atmospheric methane: 1) a global rotation showing a year of methane data and 2) focused on certain regions at time periods requested by the advising scientist (https://svs.gsfc.nasa.gov/4789). Cindy revised the second methane visualization to match the timing to a narrated audio track provided by producer Katie Jepson, and collaborated with her on submitting the video to the SIGGRAPH 2020 Electronic Theater. Additionally, Cindy created a revised version of the global rotation in order to incorporate the Earth Day globe created by Greg Shirah: “Earth Day 2020: Global Atmospheric Methane.”

In support of the Nature Geoscience paper “Deep Glacial Troughs and Stabilizing Ridges Unveiled Beneath the Margins of the Antarctic Ice Sheet” by Mathieu Morlighem, Cindy created a visualization revealing the topographic details at seven different locations around the continent by gradually removing the ice sheet from each location to emphasize the depth of different topographic troughs beneath glaciers and ice streams. This visualization was based on the BedMachine dataset that provides high-resolution topography of the surface and land beneath the Antarctic ice sheet (https://svs.gsfc.nasa.gov/4773).

Cindy developed a visualization of the weekly Arctic sea ice age between 1984 and 2019 that was similar to a visualization that she previously created in 2016. After inspection, Cindy found that the older version of the project was no longer compatible with the current visualization software, so she developed this project using new versions of the software. She also simplified the visualization’s design on a recommendation from the consulting scientist. This visualization was delivered for use in the sea ice live shots in September 2019 (https://svs.gsfc.nasa.gov/4750).

In support of the EPSC-DPS Joint Meeting 2019 paper “The Global Current Systems of the Martian Induced Magnetosphere” by Robin Ramstad and David Brain, Cindy had previously created several sample visualization sequences of the solar wind passing Mars, the induced currents measured by the Mars Atmosphere and Volatiles EvolutioN (MAVEN) orbiter, and the idealized current flow around the planet. Upon advice from the scientist, Tom Bridgman revised the structure of the idealized current flow lines used in this visualization, and Cindy recreated the visualization of the motion of these idealized currents (this work is ongoing).

Cindy prepared a series of 3-hour global volumetric datasets for each of carbon dioxide, carbon monoxide, and methane for use in a volumetric particle visualization. With each of the three co-located volumes of data, she worked to identify the ranges to show along with the appearance of each quantity. Both the methane data and the carbon monoxide data worked well due to the regional nature of their concentration levels, but the carbon dioxide data presents more of a challenge due to the seasonal change in concentration. In addition, the carbon dioxide required modifications of the particle code to support showing both the high and low values without displaying the intermediate values. Cindy created drafts of three different time periods for review. The July time period draft was selected to be shown at the Carbon Cycle Working Group during the 2020 ABoVE Science Team meeting in July 2020.

In the coming year, work will continue on several projects. Although she has generated many of the individual components needed for the MAVEN visualization, she will work to integrate those components at the request of producer Dan Gallagher. Cindy will continue to consult with SciAct partner WGBH on

![Image from BedMachine: A high-precision map of Antarctic ice sheet bed topography. (Provided by C. Starr.)](image-url)
visualizations to enhance their educational curriculum and will support this effort as needed. Also, Cindy will begin work on a dome format production on Antarctica in cooperation with the National Center for Supercomputing Applications.

**Kelly Elkins** provides data visualization support for NASA Earth and space science missions and research as part of the Scientific Visualization Studio. Over the past year, Kel has continued to support the OSIRIS-REx sample return mission by creating many visualizations depicting both the satellite mission trajectory and target asteroid, Bennu. One key aspect of Kel’s OSIRIS-REx visualization work has been to create a ‘virtual 3D Bennu model’ using the latest Bennu shape model, high-resolution imagery, and detailed surface elevation models. This virtual Bennu model has been used in several visualizations and is continuously updated as higher resolution data becomes available. Kel created a short visualization that was used to announce the four finalist candidate sample sites on the surface of the asteroid using preliminary surface images (https://svs.gsfc.nasa.gov/4744). Kel later updated this visualization to include detailed 3D flyovers for each site using data from the OSIRIS-REx Laser Altimeter (OLA) instrument, and this updated sample site visualization was used extensively during the final site announcement press, even at the 2019 AGU Fall meeting (https://svs.gsfc.nasa.gov/4771). He also has created Hyperwall visualizations (resolution: 5760x3240 pixels) showing both global views of the asteroid and detailed regional views (https://svs.gsfc.nasa.gov/4795). Kel used the detailed 3D Bennu model to create content that was used in an OSIRIS-REx video describing the satellite’s natural feature tracking (NFT) system.

Using data from the ICESat-2 mission, Kel created a number of visualizations. He published a visualization describing how ICESat-2 measures sea ice thickness, which combines views of ICESat-2 data tracks, a close-up representation of sea ice above and below the ocean surface, and a monthly sea ice thickness data product to explain how scientists study changes in sea ice over time (https://svs.gsfc.nasa.gov/4734). He also created visualizations that compare ICESat-1 and ICESat-2 measurements to depict ice height change over time (created versions for Antarctica and Greenland) (https://svs.gsfc.nasa.gov/4796).

In support of the upcoming Lucy mission, Kel created visualizations that show the satellite trajectory as it moves throughout the solar system. The mission will send a satellite to study six Jupiter Trojan asteroids and one Main Belt asteroid over the course of twelve years. The visualizations were created in multiple reference frames to help communicate the overall mission trajectory and showed how the Trojan asteroids are clustered around Lagrange points in Jupiter’s orbit around the Sun (https://svs.gsfc.nasa.gov/4719).

Kel published a series of visualizations describing how the Landsat-9 satellite (Launch: 2020) orbit and image data collection will fit into a larger constellation of Landsat and Sentinel satellites (https://svs.gsfc.nasa.gov/4745). To create this visualization, he developed new methods to display satellite data swaths building up over time to show global coverage.

In November 2019, Kel attended the SIGGRAPH Asia conference in Brisbane, Australia to present work that had been accepted.
to the conference; he had co-authored a technical brief (with SVS colleague Greg Shirah) and gave a presentation describing the work. The paper was published in the ACM (Association for Computing Machinery) Digital Library. He also spoke about NASA visualization during a course on Cinematic Scientific Visualization. Kel’s visualization on “Black Marble View of Puerto Rico After Hurricane Maria” accepted to the SIGGRAPH Asia CAF and screened during the meeting (see Awards and Recognition section of this report).

Work ahead includes a number of OSIRIS-REx visualizations leading up to the sample TAG (Touch-and-Go) in August 2020. These include updated detailed orbit visualizations showing the final TAG trajectory and additional detailed views of Bennu highlighting some preliminary science findings. Kel also is working on a visualization describing new science discoveries from the Juno mission.

Helen-Nicole Kostis is a science visualizer based at the SVS at NASA/GSFC. She develops and produces data-driven visualizations in the format of movies and still images to explain NASA’s Earth Science research findings to the public. The visualization-based products are developed closely with NASA scientists and members of the Science Storytelling Team. After approval from the scientists, the visualizations are released to the public via the SVS website (svs.gsfc.nasa.gov) and within NASA press releases at NASA.gov.

This past year, Helen-Nicole was very involved in promoting the science of Assaf Anyamba (618/USRA). On August 13, 2019, Dr. Anyamba was interviewed by Netflix for an upcoming documentary titled “Connected.” To support Dr. Anyamba in this effort, Helen-Nicole created two data-driven visualizations that showcase the relationship between NDVI (using MODIS data) and Rift Valley Fever (RVF) outbreaks in Africa. These visualizations were not released publicly, as they were considered early drafts and works in progress; refined versions were released during 2020. In addition, she developed a hyperwall presentation and playlist for Dr. Anyamba (Bldg. 28, Hyperwall Theater). This playlist included a series of visualizations that she had developed for him, such as the relationship of ENSO index and SST for the period 1982-2018 and visualizations of Dengue Outbreaks in Southeast Asia during 2015-2016.

On December 10, 2019, Helen-Nicole released the visualization titled “Sea Surface Temperature anomalies and patterns of Global Disease Outbreaks: 2009-2018,” created in support of Dr. Anyamba’s and Dr. Radina Soebiyanto’s 2019 AGU meeting presentation. In January 2020, she released updated versions of this visualization in 4K and HD; in these versions, 11 different infectious diseases have been mapped on the globe, including Zika virus. In February 2020, visualizations that she had created in support of Dr. Anyamba’s interview with Netflix were released: “Vegetation index anomalies and Rift Valley fever (RVF) outbreaks in Africa and Middle East during 2000-2018” and “Vegetation index anomalies and Rift Valley fever (RVF) outbreaks in South Africa during 2009-2011.” In support of his research, she released “ENSO Teleconnections and Rift Valley fever (RVF) Outbreaks,” “Precipitation Anomaly and Rift Valley fever (RVF) outbreaks in South Africa: 2008-2011,” and “Vegetation Index Anomalies and Rift Valley fever (RVF) outbreaks in South Africa region: 2008-2011.” These all have been developed for 4K resolution, and multiple versions of hyperwall shows have been created.

Helen-Nicole collaborated with ~30 international visualization researchers and practitioners from academia, industry and government to author the book titled: “Foundations of Data Visualization”, to be published by Springer in 2020. She was lead author and co-author of articles within Chapters 16, 18, 20 and 21. (See more information under the Products section of this report.) Helen-Nicole also co-authored and co-presented the 3-hour course at ACM SIGGRAPH 2019 titled “Cinematic Scientific Visualization: The Art of Communicating Science.” In her presentation on July 30, 2019, Helen-Nicole focused on specific sections of the course: 1) Introduction: Definitions of what Scientific Visualization is (and what is not), its narrative impact, 2) State of the art within the community, 3) Open challenges 4) Impact. The course was
Helen-Nicole serves on NASA’s Information Science and Technology (IS&T) Colloquium Committee. Under this role, she selects and hosts distinguished speakers from the fields of computer graphics and visualization to share their latest research with NASA employees. This year, she hosted Andy Johnson, Director of Research at the Electronic Visualization Laboratory & Professor of Computer Science at the University of Illinois at Chicago. On May 29, 2019, Dr. Johnson gave a talk titled “Immersed in Data Analytics” in the Goett Auditorium in NASA GSFC Building 3 (https://istcolloq.gsfc.nasa.gov/content/spring-2019-colloquium-series-dr-andy-johnson).

Throughout the year, Helen-Nicole assisted Editor Ellen Gray in visual storytelling efforts and released eight NASA Viz stories: “Arctic Bubbles,” “Predicting Landslides,” “Moon Craters a Window to Earth’s Past,” “Greenland on the move,” “Yellowstone Fire: Then and Now,” “Missing Dark Matter,” “From Interstellar Space,” and “Revisiting the Pale Blue Dot at 30.” These stories are available on the web (https://nasaviz.gsfc.nasa.gov/) and are pushed on the NASA Viz app for iOS and Android versions. (Read more about the NASA Viz in the Products section of this report.)

Upcoming plans include continued data-driven visualization support to SVS and the broader NASA Storytelling Efforts. Tasks will include data acquisition and processing, ad-hoc programming and scripting, scene and project development using Maya, Pixar’s Renderman, IDL, After Effects, collaborate with fellow visualizers to resolve technical issues and identify the best visualization technique, receive and apply feedback from scientists, producers and fellow visualizers, and release developed materials to the public using the SVS database.

She will continue to support the NASA Visualization Explorer project each month, assuming the project is supported for FY20/21; NASA Viz has been on editorial maintenance mode since FY17. A story is released usually every other Monday. Tasks include supervising the editorial workflow and scheduling, assisting with visual storytelling, releasing stories via SVS database, and exploring future directions for the NASA Viz.

Helen-Nicole plans to attend ACM SIGGRAPH 2020 (which will be held virtually, due to COVID-19) and the IEEE Vis 2020 Short Papers Program. She will attend meetings with SIGGRAPH 2020 and SIGGRAPH 2021 Committee members. She has been advising various committee members on how to support the visualization community. As a volunteer, she contributes to and supports the communities of Computer Graphics, Scientific Visualization and Media Arts. In addition, she has been advising ACM SIGGRAPH 2021 Art Papers Chair and serves as a Founding Board Member of the non-profit CapXLab. Additionally, she plans to expand her technical skills by learning a software package and/or language.

Trent Schindler supports the NASA SVS and creates visualizations for various missions and research. This year, in collaboration with scientist Lok Lamsal (614/USRA) and fellow scientists from Code 614, Trent created visualizations of the response of NO2 (a proxy species for air pollution) to the reduced consumption of fossil fuels resulting from COVID-19 social restrictions and mitigation efforts, using data from OMI/AURA. The visualizations include numerous regions within the United States and across the world. This is an ongoing effort that has attained significant media exposure.

Trent updated a visualization of global wildfire occurrence using the VNP14 dataset. The visualization “Active Fires as Observed by VIIRS, 2012-2018” runs for a full six years, and was used to support a live shot regarding the fires. He also worked on a visualization for the Operation IceBridge campaign, which was created from navigational data obtained from the flights. The visualization “Operation IceBridge Flight Lines 2009-2019” shows the flight lines of each yearly OIB campaign. Further, Trent supported the Global Freshwater Campaign, creating multiple visualizations that included SMAP soil moisture, IMERG precipitation, MODIS snow and ice, and GRACE groundwater datasets with local and global coverage.

Image from “Reductions in Pollution Associated with Decreased Fossil Fuel Use Resulting from COVID-19 Mitigation.” (Provided by T. Schindler.)
Trent delivered several visualizations demonstrating how Earth’s radiation budget is measured by the Clouds and the Earth’s Radiant Energy System (CERES) mission. The visualizations include animated graphs, as well as globally mapped satellite data. The visualizations were used to highlight the CERES Terra First Light 20th Anniversary.

Ernest Wright provides scientific visualization products in support of communications and public outreach for Lunar Reconnaissance Orbiter and other NASA efforts. This year marked the anniversaries of Apollo 11, 12, and 13. Ernie produced a visualization of the Apollo 12 landing site (https://svs.gsfc.nasa.gov/4767), highlighting the pinpoint landing only 500 feet from the robotic Surveyor 3 spacecraft that had landed two years before. For Apollo 13, he produced over 10 minutes of a visualization that recreated what the astronauts saw as they flew behind the Moon (https://svs.gsfc.nasa.gov/4793). This material was incorporated into apolloinrealtime.org and was used to create a video feature that has so far garnered 1.8 million views on the NASA and Goddard YouTube channels (https://www.youtube.com/watch?v=IlIfg26TZri). Ernie also created a visualization showing the location of the S-IVB (Saturn V third stage) impact on the Moon as revealed in Lunar Reconnaissance Orbiter imagery.

Ernie released the 2020 edition of the annual phase and libration visualization (north up, south up). This year’s animation adds labels for the Apollo landing sites and a number of albedo features. This continues to be the most popular feature on the SVS website and is used by amateur astronomy clubs, observatories, museums, and scientists. In conjunction with a Nature Geoscience paper by Tom Watters et al. about moonquakes, Ernie created a flyover (https://svs.gsfc.nasa.gov/4714) of the Lee-Lincoln Scarp in the Taurus-Littrow valley, site of the Apollo 17 Moon landing. For anyone who would like to visualize the Moon, Ernie released a “CGI Moon Kit” (https://svs.gsfc.nasa.gov/4720), a set of color and elevation maps of the Moon formatted for 3D artists, which is the same data he uses in his own visualizations. Ernie also visualized the path of Comet 2I/Borisov (https://svs.gsfc.nasa.gov/4758), the first confirmed interstellar comet, as part of the media campaign for the release of Hubble telescope images of the comet.

This past year, Ernie participated on a panel at the 2019 Escape Velocity convention and presented at the American Astronomical Society Eclipse Workshop in St. Louis, MO. He also engaged
in public outreach at NASA GSFC and worked with others in outreach, including Doug Duncan of Fiske Planetarium in Boulder, CO, and Carter Emmart of the Hayden Planetarium in New York.

**SCIENCE SUPPORT OFFICE**

The Science Support Office (SSO) (formerly the Science Communications Support Office) consists of Global Science & Technology, Inc. (GST) staff who lead and coordinate science community “in-reach” as well as outreach product development for NASA’s Earth Science Division (ESD), Science Mission Directorate (SMD), and Applied Sciences Program (ASP). Each NASA customer falls under a different task, and activity under each task for the most recent year is summarized below. The success of the SSO’s broad array of endeavors requires contributions from the entire team, which includes Winnie Humberson (lead), Steve Graham (deputy lead), Ryan Barker, Doug Bennett, Sally Bensusen (now retired), Kevin Durham, Heather Hanson, Marit Jentoft-Nilsen, Mark Malanoski, Debbi McLean, Kevin Miller, Amy Moran, Cindy Trapp, and Alan Ward.

Due to the global coronavirus (COVID-19) pandemic, numerous challenges emerged for SSO staff as several major conferences and meetings—originally scheduled for March–July 2020—were either postponed or cancelled altogether for the year. Many SSO staff began teleworking in March when NASA first encouraged on-site staff (whose positions and individual circumstances enabled them to do so) to work from home. At the time of this report, the NASA exhibit and Hyperwall have either been cancelled or postponed for the following 2020 meetings and conferences: Space Symposium; National Science Teaching Association Annual Meeting; Earth Day at Union Station; USA Science and Engineering Festival; European Geosciences Union General Assembly; Japan Geoscience Union–American Geophysical Union Joint Meeting; American Library Association Annual Meeting; and Asia Oceania Geosciences Society Annual Meeting. Additionally, the April SMD Science Activation meeting, which SSO staff help plan and support, was rescheduled as a virtual meeting.

During the period covered by this report (May 11, 2019–May 10, 2020)—and despite the postponement or cancellation of many planned meetings and events in 2020 due to the COVID-19 pandemic—SSO staff still organized and supported 20 professional society meetings sponsored by ESD, SMD, and ASP (including four international conferences), designed and produced five thematic exhibits and 35 custom graphics products, and helped prepare and facilitate the presentation of 462 NASA Science stories on the Hyperwall.

As NASA continues adapting to the changes triggered by the COVID-19 pandemic, demand for virtual engagement has skyrocketed. SSO staff are staying connected to the greater science community and promoting at-home learning, while also investigating participation in virtual exhibits. Previously recorded NASA Science stories presented on the Hyperwall are available on the NASA Scientific Visualization Studio (SVS) YouTube channel [https://www.youtube.com/channel/UCM2GOiWD xn1D7HP80lrBg](https://www.youtube.com/channel/UCM2GOiWD xn1D7HP80lrBg) or directly from the SVS website [https://svs.gsfc.nasa.gov](https://svs.gsfc.nasa.gov).

**EARTH SCIENCE DIVISION SUPPORT**

In May 2019, the SSO supported the Japan Geoscience Union (JpGU) Annual Meeting in Chiba, Japan. JpGU is an academic union that covers all disciplines of Earth and planetary sciences and related fields. Its annual meeting supports international discussion and exchange that contributes to driving the boundaries of science and understanding forward and helps invigorate the global Earth and planetary science community. The NASA exhibit prominently featured the Hyperwall, with presentations from NASA science leadership, Japan Aerospace Exploration Agency (JAXA) science leadership, and mission and program scientists from both NASA and JAXA. In addition, relevant publications and outreach materials were distributed from a variety of NASA Science programs and missions. The exhibit hosted 80 junior high school and 110 high school students for a series of special Hyperwall presentations and hands-on activities.

In July–August 2019, the SSO supported the Asia Oceania Geosciences Society (AOGS) meeting in Singapore. AOGS promotes geosciences and its application for the benefit of humanity, specifically in Asia and Oceania, and with an overarching approach to global issues. More than 2,300 individuals from 53 countries attended the meeting. The NASA exhibit featured the Hyperwall, which scientists used to deliver presentations covering a range of planetary and Earth science topics. In addition, relevant publications and outreach materials were distributed about a variety of NASA Science programs and
missions. The exhibit hosted 20 high school students for a series of special Hyperwall presentations.

In September 2019, SSO staff supported the OceanObs’19 conference in Honolulu, HI. The OceanObs conference is held once every 10 years for the scientific, technical, and operational communities involved in ocean observing systems. The NASA exhibit featured the Hyperwall, a virtual reality (VR) demo station, and tables for handing out informational material. In total, 22 Hyperwall presentations were delivered, covering several Earth science satellites and field campaigns. An estimated 1,200–1,500 attendees attended this 5-day event.

In October 2019, SSO staff supported the NASA exhibit and Hyperwall at the joint meeting of the 21st William T. Pecora Memorial Remote Sensing Symposium (Pecora 21) and the 38th International Symposium on Remote Sensing of the Environment (ISRSE 38) held in Baltimore, MD. The NASA exhibit was co-sponsored by the Applied Sciences Program (ASP) and ESD. The Hyperwall was the exhibit’s featured component, with presentations by NASA Earth Science leadership and program managers. SSO staff and other exhibit staffers distributed relevant publications and outreach materials from a variety of NASA Science programs and missions.

In November 2019, SSO staff organized and supported the NASA exhibit at the American Public Health Association (APHA) Annual Meeting in Philadelphia, PA. The NASA exhibit was co-sponsored by NASA’s ASP and ESD. Over 13,000 people participated in the APHA meeting, and the NASA Hyperwall was one of 300 exhibits featured. NASA scientists delivered Hyperwall presentations covering the various ways that NASA’s remote sensing data is being applied to address a range of public health challenges, including air quality and water borne diseases.

In early January 2020, SSO staff planned and supported the NASA exhibit and Hyperwall at the National Council for Science and the Environment (NCSE) Annual Conference, held in Washington, DC. Meeting attendees engaged with NASA Science experts, who presented captivating data visualizations on the Hyperwall to highlight NASA’s latest Earth science discoveries. Participants learned how NASA Science helps inform environmental policy- and decision-making around the world. Seven Hyperwall presentations were made by Earth Science program managers from NASA Headquarters (HQ) and Goddard Space Flight Center.

In mid-January 2020, SSO staff planned and staffed the NASA exhibit and Hyperwall at the 100th Annual Meeting of the American Meteorological Society (AMS) in Boston, MA. The AMS is the nation’s premier scientific and professional organization promoting and disseminating information about the atmospheric, oceanic, and hydrologic sciences. Its annual meeting is the world’s largest yearly gathering for the weather, water, and climate community, typically attracting over 4,000 scientists worldwide. Participation for this centennial meeting was estimated at 7,000 this year, the largest annual meeting in AMS history. The NASA Science exhibit prominently featured the Hyperwall and included participation by the Earth Science Technology Office (ESTO) and the NASA Postdoctoral Program. Altogether 22 Hyperwall presentations were delivered.

In February 2020, SSO staff organized and supported the NASA exhibit and Hyperwall at the 2020 Ocean Sciences Meeting in San Diego, CA. It was the 20th biennial meeting since the event began in 1982. More than 6,300 scientists, researchers, and students from 66 countries attended the conference, which
was co-sponsored by the American Geophysical Union, the Association for the Sciences of Limnology and Oceanography, and The Oceanography Society. Over 350 exhibitors participated. The NASA exhibit featured the Hyperwall and NASA’s Jet Propulsion Laboratory (JPL) SciVR installation—an immersive environment allowing visualization and exploration of ice sheet, hurricane, and sea level data. Program representatives were available to answer questions about the PACE Mission and the Physical Oceanography Distributed Active Archive Center (PO.DAAC) data holdings and access capabilities. NASA Science leadership gave overviews of NASA’s Earth Science missions, and other presentations covered the Ocean Biology and Biogeochemistry and Physical Oceanography programs. In total, 30 Hyperwall presentations were given over three days.

Although planning was already well underway, NASA’s eighth annual Earth Day at Union Station event was cancelled in March due to the COVID-19 pandemic. The event is organized by the SSO and was scheduled to occur April 21–22, 2020. This two-day event—free and open to the public—normally occurs inside Union Station’s historic Main Hall. This central transportation hub attracts some 25,000 to 30,000 people daily, allowing NASA to reach a larger group of citizens, in addition to the 200 middle- and high-school students from surrounding areas who attend each day (400+ total students) and are the primary target audience for the event. After NASA’s event was cancelled for this year, SSO staff redirected their attention to developing new concepts to provide engaging, enlightening, and fun hands-on NASA Science activities in support of SMD’s new “NASA @ Home” initiative: https://www.nasa.gov/specials/nasaathome/index.html.

When not on the road, SSO staff remained busy creating and updating content and products to support future activities. Products are often custom-designed to support the themes of individual conferences and events; at other times, products focus on more generic topics so they can be used in a variety of venues. Exhibit backdrops, posters, and accompanying signage, fliers, and other marketing products are developed as needed.

SSO staff produced a 2019 update to NASA’s Earth Observing Missions posters, Hyperwall graphics to show the currently operating fleet and future planned satellites, and Hyperwall posters for the JpGU 2019 conference. SSO staff also developed the graphics layout for a Hyperwall enclosure at the 2019 European Geophysical Union (EGU) meeting. The layout was designed to complement the nine Hyperwall screens by showcasing NASA science images that are typically featured in Hyperwall presentations, while not distracting from the Hyperwall itself.

Even when enshrouded in darkness, our planet has dazzling stories to tell. For several years, significant effort was dedicated to producing the Earth at Night coffee table book and eBook—a compilation of preexisting material and published essays from The Earth Observatory and other NASA sources aimed at showcasing Earth’s night lights as seen from space. In concert with staff at NASA HQ, SSO staff completed the layout, finalized content, and conducted final science, editorial, and copy-editing reviews for the 200-page Earth at Night book and eBook. Earth at Night examines the science behind Earth’s lights at night as seen from space. The book covers the types of sensors that can “see” Earth at night, the role of astronaut photography from the International Space Station (ISS), natural phenomena visible at night, how human presence is visible at night from Earth orbit, and the next generation of sensors for observing Earth at night. In addition to preparing the book for print production, SSO staff formatted accessibility metadata in the print files to ready the book for ePub production. The SSO began distributing a limited number of print editions of the book at conferences and events.
The oldest continuous product produced by the SSO is The Earth Observer newsletter, which began in March 1989. Content is derived from a variety of sources, and several staff collaborate on editing and design to produce six issues each year. Each edition of the newsletter begins with an editorial from Earth Observing System (EOS) Senior Project Scientist Steve Platnick, and includes feature articles, national and international meeting and workshop summaries, and a “NASA Earth Science in the News” section. The bi-monthly publication is printed in black and white, but PDFs of color issues can be downloaded from http://eospso.nasa.gov/earth-observer-archive. SSO staff were either authors or co-authors on a number of articles throughout the year. Due to production delays caused by the federal government shutdown in early 2019, seven issues of The Earth Observer newsletter were published during the period covered by this report: March–April 2019, May–June 2019, July–August 2019, September–October 2019, November–December 2019, January–February 2020, and March–April 2020. The March–April 2019 issue is noteworthy because it marked the publication’s 30th anniversary. The issue contains a reflection article written by Executive Editor Alan Ward offering his perspective on the publication’s evolution over the time he has been involved—nearly two-thirds of The Earth Observer’s history. A modified version of the article is posted on The Earth Observer’s archive page—https://eospso.nasa.gov/sites/default/files/eo_pdfs/Mar_Apr_2019_color_508.pdf#page=4.

SSO staff are working with the Landsat 9 outreach and science teams to produce a pre-launch mission brochure. The eight-page brochure will cover the following topics: Landsat: Tracking Decades of Change; Landsat 9; Operational Land Imager 2; Thermal Infrared Sensor 2; Launch and Operations; An Invaluable Archive; and Landsat 9 Quick Facts. The mission is scheduled to launch in June 2021. SSO staff designed a preliminary layout and cover design options using an early text draft as a starting point. Design and layout will evolve as the text is finalized.

Building on designs previously used for NASA’s Apollo 50th anniversary event on the National Mall, SSO staff developed new tabletop quiz concepts to be used for Earth Day and other future events. The “Earth by Night. Earth by Day” theme includes multiple-choice quiz questions, with answer dials that can be turned and flaps that can be lifted to reveal nighttime and daytime satellite imagery of selected regions.

SSO staff produced NASA exhibit and Hyperwall posters and flyers for conferences sponsored by SMD and ESD, and also started developing concepts for a new eclipse/night lights poster requested by SMD leadership. In support of NASA’s PACE program, SSO staff developed paper model activity sheets, resized the PACE “What Color Is Your Ocean?” wheel to accommodate larger displays, and produced the Ocean Color Instrument & Polarimeters brochure (#5 in the PACE brochure series).

The NASA Hyperwall continues to serve as the centerpiece of many science exhibits, and the SSO continues to respond to
the corresponding high demand for the uniquely engaging science stories that can be told using the Hyperwall. This year, SSO staff updated the long-term warming trend visualization to include 2018 data (https://svs.gsfc.nasa.gov/31028) and created new data visualizations for Hyperwall versions of Earth Observatory stories about flooding in Nebraska and drought in Australia (https://svs.gsfc.nasa.gov/31032 and https://svs.gsfc.nasa.gov/31033). SSO staff created a Hyperwall visualization showing urban growth in Shanghai from a pair of ISS photos and created a time-lapse visualization of the Kilauea eruption using nighttime Landsat TIR data. SSO staff developed a technology “explainer” animation to describe the physics behind the GRACE-FO mission and produced the first draft of a GRACE-FO animation for the Hyperwall.

SSO staff updated the SMAP Soil Moisture and Salinity and IMERG precipitation visualizations to include data through spring 2019 (https://svs.gsfc.nasa.gov/31046) and created Hyperwall versions of Ocean Color Gallery images (https://oceancolor.gsfc.nasa.gov/gallery) for late summer 2019 (https://svs.gsfc.nasa.gov/31054). SSO staff also expanded a previous visualization of ice loss in glaciers in Peru’s Andes Mountains into a series on tropical glacier ice loss, based on new work by Dr. Christopher Shuman and Dr. Compton Tucker. New visualizations of changes in glaciers in South America and a landslide on Lamplugh Glacier in Glacier Bay National Park were completed: “Landsat View of a Disappearing Glacier in Iceland” (https://svs.gsfc.nasa.gov/31050) and “2016 Lamplugh Glacier Landslide in Glacier Bay National Park” (https://svs.gsfc.nasa.gov/31042).

SSO staff also adapted content from the Earth Observatory for the show “Eerie Blooms in Lake Erie” (https://svs.gsfc.nasa.gov/31051), and added graphics of NASA’s A-Train and C-Train to the Hyperwall Content Library (https://svs.gsfc.nasa.gov/31049).

SSO staff added Hyperwall captions, metadata, and preview movies to visualizations in the SVS database that had partial or insufficient database information. SSO staff also worked on an automatically-updating global clouds Hyperwall visualization; began developing an updated SSTA and NDVI anomaly visualization; corrected captions for existing CERES net radiation Hyperwall shows (https://svs.gsfc.nasa.gov/30369, https://svs.gsfc.nasa.gov/30604, and https://svs.gsfc.nasa.gov/31059); and designed new Earth System Science and Earth at Night graphics to be used in Hyperwall presentations delivered by SMD leadership at future meetings and events.

SSO staff will continue to support NASA's Hyperwall exhibit at upcoming conferences by developing fresh science story and visual content, as well as providing technical support for speakers who prepare and deliver Hyperwall presentations.

**SCIENCE MISSION DIRECTORATE SUPPORT**

In June 2019, SSO staff supported the NASA exhibit at the summer meeting of the American Astronomical Society (AAS) in St. Louis, MO. The Origins Space Telescope (OST) 3D Virtual Reality activity was the focal point of the exhibit. Backdrop graphics were provided by the SSO graphics team and complemented the booth very well. Five NASA programs participated in the booth, conducting hands-on activities and providing handouts to attendees.

Also in June, SSO staff supported the American Library Association (ALA) Annual Conference in Washington, DC. Ten NASA programs participated in the unified exhibit space, conducting hands-on activities and disseminating content to approximately 25,000 attendees. The mission of ALA is “to provide leadership for the development, promotion, and improvement of library and information services and the profession of librarianship in order to enhance learning and ensure access to information for all.” The NASA exhibit featured 44 Hyperwall presentations and 14 tables that shared science developments and information from across SMD. Over 900 exhibitors participated, making it one of the largest conferences for librarians in the world.

In July 2019, the Smithsonian’s National Air and Space Museum hosted a celebration on the National Mall in Washington, DC, of the 50th anniversary of the Apollo 11 Moon landing. NASA participated and had numerous tents set up featuring a variety of exhibits and hands-on activities. NASA’s SMD and SSO assisted the NASA HQ Office of Communications in planning and staffing the event. It was projected that 50,000 people would participate over the three days of the event; however, actual participation was somewhat lower due to extreme heat and humidity. Most of the activities focused on the Moon, where NASA plans to return by 2024; however, NASA's Earth and Planetary Science programs were also prominently featured. An inflatable tent with Earth imagery on its exterior was a big draw.

Inside the Earth tent were a series of hands-on activities highlighting NASA’s research in ice, land, water, and air/carbon; a Global Learning and Observation to Benefit the Environment (GLOBE) exhibit focused on citizen science; and a tabletop quiz—designed and fabricated by the SSO team—to test visitors’ knowledge of the Earth and Moon. The Earth Tent also featured a demonstration of NASA’s Eyes on the Earth interactive application, which enables users to monitor Earth’s vital signs, including sea level height, atmospheric carbon dioxide concentration, and Antarctic ozone. For a more detailed summary of the Apollo 50th anniversary event, please refer to [https://eospso.nasa.gov/sites/default/files/eo_pdfs/Sep_Oct_2019_color_508.pdf#page=16](https://eospso.nasa.gov/sites/default/files/eo_pdfs/Sep_Oct_2019_color_508.pdf#page=16).

In July–August 2019, SSO staff organized and supported the NASA exhibit at the 2019 International Geoscience and Remote Sensing Symposium (IGARSS) in Yokohama, Japan. IGARSS provides a forum for sharing NASA’s latest science results with the international geoscience and remote sensing community. NASA’s exhibit featured presentations by NASA Science experts on the Hyperwall, CubeSat models demonstrated by NASA ESTO, and informational materials about NASA Science programs. Hyperwall presentations were given on topics ranging from spacecraft integration to how NASA’s observations evolve into models and,
ultimately, applications. Special Hyperwall presentations were presented to two groups of Japanese students who are studying remote sensing. Both of the student presentations were translated from English to Japanese by a professional translator.

ESTO displayed models of three recently developed CubeSats: RainCube, HARP and RAVAN. These CubeSats advance key technologies for studying precipitation, cloud formation and Earth’s energy balance.

In August 2019, SSO staff supported the NASA exhibit at the American Institute of Aeronautics and Astronautics (AIAA) Conference on Small Satellites (a.k.a., “Small Sat”) at Utah State University in Logan, UT. Small Sat has become internationally recognized as the premier conference on small satellites, providing a forum for the best minds in the community to review recent successes, explore new directions, and introduce emerging technologies in small spacecraft development. Annual attendance is currently 2,500–3,000, with 234 exhibitors. The meeting’s theme was “Driving A Revolution,” with an objective to explore the technical issues, development considerations, and new opportunities that result from an ever-growing trend toward missions using tens, hundreds, or even thousands of small satellites to achieve revolutionary effects. The NASA exhibit featured a large video display showing a series of small satellite- and SMD-related video content. It was part of a larger “NASA village” consisting of eight booths with representation across the agency.

Also in August, SSO staff supported the NASA exhibit at the American Chemical Society national meeting in San Diego, CA. The Hyperwall was the center of the exhibit, with some 20 narrations scheduled during the opening reception and the “Caffeinate and Communicate” sessions. Narrations covered a range of topics in NASA Earth Science, Planetary Science, and Astrophysics. The theme of this year’s meeting was “Chemistry and Water,” and several of the Hyperwall narrations were related to this overall topic, including a new presentation on NASA’s Airborne Science program. Numerous SMD informational materials were shared with the attendees. NASA was one of 266 exhibitors, and overall attendance was approximately 12,400.

In September 2019, SSO staff organized and supported the NASA exhibit at the Geological Society of America (GSA) annual meeting in Phoenix, AZ. The exhibit featured the Hyperwall and had participation from NASA partners including the Johnson Space Center Astromaterials Group. The GSA, a global professional society, has a membership of 20,000+ individuals in over 100 countries. GSA provides access to elements essential to the professional growth of earth scientists at all levels of expertise and from all sectors: academic, government, business, and industry. The GSA unites thousands of Earth scientists from every corner of the globe to study the mysteries of our planet (and beyond) and share scientific findings. Relevant publications and outreach materials were distributed from a variety of NASA Science programs and missions. Overall meeting attendance was approximately 5,500.

In October 2019, SSO staff supported a robust NASA exhibit at the 70th International Astronautical Congress (IAC), held in Washington, DC. The NASA exhibit featured programs and materials specific to NASA’s Artemis Program. The Hyperwall was prominently featured and included presentations from NASA leadership across all mission directorates. The Hyperwall was also used for a press conference given by NASA Administrator
Jim Bridenstine. More than 6,500 people were registered for the event with representation from space agencies around the globe.

One of the SSO’s biggest annual events took place in December 2019. As they have done for more than 11 years—with significant assistance from the broader NASA Science outreach community—the SSO played a seminal role in organizing and supporting the NASA exhibit at the 2019 American Geophysical Union (AGU) Fall Meeting in San Francisco, CA. The conference, attended by nearly 30,000 registrants from around the world, returned to its familiar Moscone Convention Center setting after a two-year hiatus while the Moscone facility was being renovated. The NASA exhibit was by far the most popular one at the meeting and encompassed the full range of NASA’s science activities across four SMD divisions. The exhibit featured the Hyperwall, VR and technology demonstrations, interactive educational activities, and a variety of NASA satellite, aircraft, and balloon models on display. The 2019 NASA exhibit also included a new “NASA Lights the Way” global map (backlit with LED lights) to help promote NASA’s new Earth at Night book (described under ESD section), which was released to the general public at this meeting. Throughout the week, the NASA Hyperwall showcased 102 science stories and flash talks, including eight winners of the 2019 AGU Data Visualization and Storytelling Competition, a contest open to undergraduate and graduate students that focuses on innovation and creativity in presenting data to a larger audience in new, more easily accessible ways. (The competition is funded by a grant from NASA.) Presentations and demonstrations in the NASA exhibit continuously attracted large crowds, generating high levels of engagement with NASA Science among attendees. Several information tables where attendees could collect resources and talk one-on-one with NASA personnel about specific topics received a steady stream of visitors, and the 2020 NASA/SMD Planning Guide and Science Calendar was as popular as ever, with over 12,000 copies distributed. (More details about the 2020 NASA/SMD Planning Guide and Science Calendar appear later in this report.)

In January 2020, SSO staff planned and staffed the NASA exhibit and Hyperwall at the 235th Annual Meeting of the American Astronomical Society (AAS), held in Honolulu, Hawaii. The NASA exhibit featured 16 stations representing NASA’s planetary, heliophysics, and astrophysics divisions. The exhibit stations were very popular and featured both hands-on activities and virtual/augmented reality (VR/AR) demos. The Hyperwall served as the focal point of the exhibit space. A total of 50 NASA Science stories were presented on the Hyperwall by subject matter experts over the four-day conference. Many NASA STEM materials were disseminated, and the SMD calendar was extremely popular. Approximately 3,600 astronomers, educators, students, and journalists attended this largest gathering of the AAS to date.

In February 2020, SSO staff supported the 2020 Annual Meeting of the American Association for the Advancement of Science (AAAS) in Seattle, WA. Once again, the Hyperwall was the centerpiece of the NASA exhibit. Ten Hyperwall narrations were made with participation from NASA HQ, GSFC, the SocioEconomic Data and Applications Center (SEDAC), the European Commission, and academia. Presentations highlighted recent Earth Science field campaigns, planetary science, socioeconomic data mining, and NASA-supported research in academic institutions. SSO staff updated existing science outreach and engagement products and produced new ones for SMD events they support. A great deal of preparatory work was done for Earth Day, including developing schedules, floor plans, signs, brochures, displays, activity passports, and more. SSO staff also updated the Science Photo from the 2020 Annual Meeting of the AAAS. (Photo provided by D. Bennett.)
Resources Z-Card and Brochure and made it available online, as well as new Earth and Moon concepts for a new lenticular ruler.

The NASA 60th Anniversary History Quiz sheets were repurposed and redesigned for generic use at future conferences and meetings, with 500 copies printed on color paper and shared during the April 2019 Space Symposium. SSO staff developed the design and layout for signage and flyers for the 2019 NSTA Conference to help promote NASA Hyperwall Science Stories. For the 2019 AAS summer meeting in St. Louis, SSO staff developed a floorplan, table name signage, a NASA Science header showing the SMD fleet of missions, an Astrophysics fleet poster, and posters for the HabEx, LUVOIR, LYNX, and ORIGIN missions.

As described in the event description above, SSO staff developed a concept for a “low-tech” tabletop quiz activity used at the Apollo 50th Anniversary celebration on the National Mall in July 2019. Staff manufactured 15 separate quizzes in total. The design incorporated contour cut dials that rotated to select answers and hinged doors that lifted to reveal the answer key. The panels were designed with easy setup in mind and can be folded flat for shipping. The quiz boards were very popular during the event and held up well through numerous uses.

Also for the Apollo 50th anniversary event, SSO staff created a layout of a poster showcasing Apollo Moon Landing maps, reprinted a Moon to Mars footprint floor graphic, and produced the Earth tent signage and floor plan.

SSO staff helped SMD staff at NASA HQ convert InDesign files to a web-friendly format for the Research and Analysis Program landing pages on science.nasa.gov. SSO staff collaborated to ensure fresh content and provide a new look and feel to the SSO Annual Report (for the period September 1, 2018 to August 31, 2019). The booklet includes up-to-date listings of all team activities, including event support, Hyperwall stories, and communication products created, and can be viewed at: https://eospso.nasa.gov/sites/default/files/publications/AnnualReport2019_508.pdf.

In support of the Small Sat conference, SSO staff produced Hyperwall graphics and display posters for CubeSat, including an overview (“Big Discoveries, Small Missions”), a CubeSat roadmap, and a synopsis of the CubeSat fleet.

In preparation for the AGU Fall Meeting, SSO staff designed and produced a range of posters, signs, and flyers used to advertise and promote various activities in the NASA exhibit including the Earth at Night book release and signings, numerous Hyperwall and Flash Talk presentations, and the AGU Data Visualization and Storytelling Competition awards event. SSO staff also designed and produced a backlit LED display—based on this year’s “NASA Lights the Way” exhibit theme—to help promote the recent publication of NASA’s new Earth at Night book. In addition, a number of signs and posters were created to facilitate wayfinding to NASA events and splinter meetings held during the AGU Fall Meeting.

SSO staff produced a poster and brochure to highlight the AGU Centennial Narratives project, which featured personal science stories shared by NASA personnel; an LED light box for “NASA” and “EXPLORE” signage utilized in the NASA exhibit; a Hyperwall version of infographics for NASA’s Airborne Campaign; and an Earth at Night lenticular.

SSO staff collaborated again this year with NASA HQ personnel on the 2020 Explore NASA Science calendar, which was released to the general public during the December AGU Fall Meeting in San Francisco. SSO staff teamed with NASA HQ staff to design...
a new layout that showcases carefully selected NASA images and notable scientists. SSO staff also helped coordinate all aspects of production, from initial concepts through final printing.

During the review, Thomas Zurbuchen [Associate Administrator for NASA’s Science Mission Directorate] wrote, “#BestOneEver.” In November, Dr. Zurbuchen held a special assembly at NASA HQ to reveal the calendar. He also tweeted, “I love that this calendar highlights a few of the many ways that NASA Science is making discoveries that affect us all.” This year, for the first time, SSO staff worked with a bilingual writer, who translated the calendar text into Spanish. Together they produced 2020 Explora la Ciencia to bring NASA science to Spanish-language audiences. Both English- and Spanish-language versions of the calendar have been made available online as 508-compliant PDF files.

For the 2020 NCSE and AAS conferences, SSO staff updated four decadal mission posters (HabEx, ORIGINS, LUVOIR, and LYNX), posters depicting the SMD and Astrophysics instrument fleets, table signs for each mission, Hyperwall agenda posters, flyers, and other NASA promotional signage.

SSO staff produced a Hyperwall visualization featuring a selection of lunar datasets. The visualization will combine data collected by the Lunar Reconnaissance Observer (LRO) and other NASA missions—elevation, albedo, surface temperature, and evidence of water—in a style similar to the previous visualization “Earth: A System of Systems” (https://svs.gsfc.nasa.gov/30701). A whiteboard animation was also developed to explain the technology roadmap for Artemis—from the Space Launch System, to Orion, to Gateway, and then on to Mars.

SSO staff updated the “How to Put Together a Hyperwall Talk” whiteboard animation (https://svs.gsfc.nasa.gov/30993), added NASA’s SmallSat/CubeSat Fleet diagram and associated graphics to the Hyperwall Content Library (https://svs.gsfc.nasa.gov/31047), and updated the Astrophysics Fleet diagram to reflect recent changes (https://svs.gsfc.nasa.gov/30834). SSO staff also created a Hyperwall graphic of the Apollo Landing sites as viewed by the Lunar Reconnaissance Orbiter (https://svs.gsfc.nasa.gov/31052) and presented a poster at the Gordon Research conference on creating NASA visualizations.

SSO staff helped presenters prepare over 55 Hyperwall presentatations for the AAS Annual Meeting in January 2020 and updated the Astrophysics and Heliophysics Fleet diagrams.
SSO staff updated a series of global time-series animations featuring data from several instruments on NASA’s Terra mission, which celebrated its 20th anniversary in December. The updated datasets included the Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation index, cloud properties, fire radiative power, and land surface temperature; Clouds and the Earth’s Radiant Energy System (CERES) top-of-atmosphere radiative flux and net surface radiative flux; and Measurements of Pollution in the Troposphere (MOPITT) carbon monoxide. These visualizations were used in the Terra@20 presentations during the December 2019 AGU meeting.

**APPLIED SCIENCES PROGRAM SUPPORT**

In June 2019, the SSO continued its ASP support by staffing the Air & Waste Management Association (A&WMA) 112th Annual Conference & Exhibition in Quebec City, Quebec. A&WMA is a nonprofit, nonpartisan professional organization enhancing knowledge and expertise by providing a neutral forum for information exchange, professional development, networking opportunities, public education, and outreach to more than 5,000 environmental professionals in 65 countries. The NASA booth at A&WMA featured the NASA Hyperwall, where several scientists delivered presentations about remote sensing monitoring of air and water pollution and how NASA data is being integrated into monitoring pollution. A few tables were set up, where attendees could interact with NASA staffers or take informational brochures.

In October 2019, SSO staff supported the NASA exhibit and Hyperwall at the joint meeting of the 21st William T. Pecora Memorial Remote Sensing Symposium (Pecora 21) and the 38th International Symposium on Remote Sensing of the Environment (ISRSE 38) held in Baltimore, MD. And, in November, SSO staff organized and supported the NASA exhibit at the American Public Health Association (APHA) Annual Meeting in PA. The NASA exhibit was co-sponsored by ASP and ESD. (Please refer to the ESD section of this report for more details.)
Photos from the A&WMA 112th Annual Conference & Exhibition. (Provided by D. Bennett.)
USRA FUNDING OPPORTUNITIES

 Universities Space Research Association (USRA) is proud to offer its scientists the opportunity to submit proposals to seek additional internal sources of funds. Two types of support are offered: PI-Support funds and Internal Research and Development (IRAD) Funds. PI-Support funds are primarily awarded to cover the time in which a scientist is planning to work on a non-NASA proposal. These proposals for PI-Support funds may be submitted at any time during the year. Evaluation and award decisions are made by the GESTAR Director.

IRAD funds have a broader scope and are awarded to develop innovative ideas that are not currently funded through ordinary proposals. They are not restricted to proposal preparation (e.g., these funds could be used to develop an Earth-Venture idea, to prepare an unsolicited proposal, or to create large collaborative efforts with partners outside the usual range of a task, etc.). Interested individuals should submit their proposals directly to Dr. Anthony Thornton, using their USRA email. The IRAD funds are aligned with the fiscal years and the call for proposals will be in a company-wide announcement during the summer. The following reports are a few examples of GESTAR scientists who reported on, began working on, and/or concluded their USRA IRAD grants.

In September 2019, Dr. Amanda Armstrong (code 618) submitted a final report communicating the accomplishments of the USRA IRAD project, funded from January to August. The goal of her work was to initialize the permafrost improvements to the SIBBORK Model in advance of the ABoVE Project funding. The permafrost upgrades to SIBBORK using the model written by Bonan (1989b) were begun over the course of the IRAD funding period. The SIBBORK Model ingests daily temperature and precipitation data, which can be aggregated to monthly time-steps for temperatures above degree-day base (e.g., 5.5°C) in the growing season. In preparation for the permafrost improvements, the monthly time-step calculations were modified to inform the site conditions (e.g. solar radiation, PE, soil water, soil freezing and thawing). An annual calculation was also added to calculate water deficit and latitudinal variations. Finally, the environmental parameters related to soil conditions also were updated in advance of integrating in the permafrost subroutine.

Supported by USRA IRAD funds, Dr. Emma Knowland and Dr. Christoph Keller (both code 610.1) continued to work with potential end users on the dissemination of GEOS-CF model output for air quality applications. In 2019, they pursued further pilot projects with IBM and Swiss Re, and also started a partnership with the World Resources Institute (WRI) aiming at extending the reach of NASA air quality information. In June 2019, Drs. Keller and Knowland visited IBM Watson Research Center in Yorktown Heights, NY to discuss potential end-user applications using the GEOS-CF model. They identified potential pilot projects (e.g., ozone impacts on crop yields (IBM). This year, Drs. Knowland and Keller were awarded USRA IRAD FY2020 funding for their proposed “Third Party Solutions to Air Pollution” to continue the successful FY19 USRA IRAD project. They are continuing to work with IBM as well as the World Resource Institute (WRI), who were new contacts from the first IRAD project. As a result of this effort, part of the GEOS-CF output is now highlighted on the ResourceWatch platform (https://resourcewatch.org/). (See additional report on the GEOS-CF in the Code 610.1 section of this annual report.)

In last year’s report, Dr. Bridget Seegers (code 616) reported that she had received USRA IRAD funding; this year, Dr. Seegers completed a summer 2019 field season to validate the Cyanobacteria Index (CI) satellite remote sensing algorithm. She reports that this funded research resulted in nearly four weeks of successful in-situ lake sampling in Wisconsin and Minnesota. A total of 55 stations were sampled across nine lakes to gather data for the validation of the CI. Wisconsin and Minnesota were selected because of the high density of lakes that cover a range of conditions. The diverse set of lakes sampled had a range of conditions from no blooms to moderate blooms to extreme blooms and also ranged in turbidity, which is ideal for validation. The samples and data gathered included hyperspectral radiometry, turbidity via secchi disk, discrete water samples for surface chlorophyll concentration, high-performance liquid chromatography (HPLC), particle absorption, toxin concentrations, wind speed and community composition. The hyperspectral data gathered also makes the data set appropriate for algorithm development that could be applied to future NASA satellite missions including the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission. This IRAD also highlighted USRA collaborations across agencies including NASA, EPA, NOAA, USGA, and the Naval Research Laboratory.

Dr. Samuel Teinturier (Co-I) (code 699) was awarded FY20 USRA IRAD funding along with Dr. Thomas Fauchez (Co-I) (code 699) and Dr. Oreste Reale (PI) (code 610.1) for the study of an OSSE framework for Mars titled “A Roadmap to OSSE on Mars.” A large uncertainty still exists about varying atmospheric conditions on other planets, especially Mars. Enhanced knowledge of real-time wind conditions, density, temperatures, or dust distribution could provide a great advantage to future missions, either orbiting or landing on Mars. Therefore, a real-time operational weather forecasting capability for Mars would be a tremendous asset to help the success of these missions. This difficult task that cannot be accomplished without a large amount of observing systems. Dr. Teinturier and his colleagues
intend to provide NASA an extensive documentation to explain the benefits that an Observing System Simulation Experiments (OSSE) framework would have, in designing future observing systems for Mars. This effort, to document and provide a roadmap to reach this goal, is conceived as a “seed” to allow for future, larger developments. Drs. Teinturier, Reale and Fauchez will pursue their work in order to identify the different tools needed to establish an OSS on Mars, will write a white paper, and will submit a proposal to continue this work.
**MANIAC TALKS**

The GESTAR Maniac Talks are about “what inspired people to do what they are doing now in their career.” Since 2012, the Maniac Talks have “promoted scientific interaction between young and experienced scientists in order to learn/improve/review the knowledge of basics/fundamentals of science and scientific methods for research.” Charles Gatebe and Bill Hrybyk were consistently instrumental in hosting and maintaining this exciting series, which concluded as of December 2019.

Throughout the past year, speakers from NASA Goddard Space Flight Center included the following:

- Dorothy “Dot” Zukor
- Lucy McFadden
- Jennifer Wiseman

Speakers came from outside NASA GSFC as well:

- Dennis Dixon Butler (Founder & President, YLACES)
- Stamatios “Tom” Krimigis (Emeritus, Head of Space Exploration Sector of the Johns Hopkins Applied Physics Laboratory (APL))
- Stephen Jurczyk (Associate Administrator, NASA Headquarters)
- H. Jay Zwally (Sr. Researchch Scientist, Earth System Interdisciplinary Science Center (ESSIC), University of MD, College Park)


**NASA VIZ**

The NASA Visualization Explorer (NASA Viz) is a science storytelling project aimed to inform the general public about NASA's research. The project creates and releases visualization-based stories to highlight research findings from all four NASA science themes – Earth Science, Heliophysics, Planetary science and Astrophysics - and include technology and science mission accomplishments. The project comprises free iOS universal and Android apps and a responsive website featuring all the released stories including links to source material and related content.

Since the app's launch on July 26, 2011, the app has released 582 stories to date. GESTAR/USRA team member Helen-Nicole Kostis (NASA Viz project manager; code 606.4, sponsor: H. Mitchell) works with Ellen Gray (NASA Viz Editor) to plan the editorial storytelling efforts of NASA Viz. Through their ongoing efforts stories are packaged, edited and released through the iOS and Android apps, the NASA Viz responsive and mobile-friendly website and NASA's social media channels. The apps were actively developed and maintained until 2017, when the Android beta version was released to the public along with its three subsequent updates. Currently, the apps and the website are used as conduits to release the packaged and visualized science stories.

During the summer of 2019, NASA Viz and the NASA Office of Education continued their collaboration in the experiential learning initiative with University of Maryland at College Park. As part of this effort, undergraduate students from a technical writing course are getting hands-on experience in science storytelling. NASA Viz shared with the faculty and the participating students its editorial guidelines, story templates and a list of stories to consider for contributions. As part of this collaborative and educational effort, UMUC faculty and students from the technical writing course met with NASA Viz team members and discussed timelines and editorial workflow. NASA Viz team releases the stories that the students deliver after review and gives them credit for their contributions. Students not only obtain hands-on experience while working on real-life projects but also build their editorial portfolios on an official NASA project.

Helen-Nicole Kostis co-authored the article NASA Visualization Explorer: Adopting the Newspaper Model in the Classroom with former Einstein Fellows from the NASA Office of Education at Goddard: Paulo A. Oemig and Geraldine B. Robbins. The article is set to be published in the upcoming book M. Chen et al. (eds.), Foundations of Data Visualization, in Chapter 20 titled “Reaching Broad Audiences in an Educational Setting”. The article discusses the history of the project as well as the opportunities and challenges stemming from the NASA Visualization Explorer project, and presents how it was used by educators in the classroom. (See [https://www.springer.com/gp/book/9783030344436](https://www.springer.com/gp/book/9783030344436).)

Even though the project is not actively maintained, it continues to have a niche and active fan base on social media channels. During the last months, Rebecca Roth from the Office of Communications has been leveraging the NASA Viz social media channels (Facebook and Twitter) and their fan base to share data-driven visualizations and science stories to highlight the work at the Scientific Visualization Studio.

**Products**

- Dorothy “Dot” Zukor
- Lucy McFadden
- Jennifer Wiseman
- Dennis Dixon Butler (Founder & President, YLACES)
- Stamatios “Tom” Krimigis (Emeritus, Head of Space Exploration Sector of the Johns Hopkins Applied Physics Laboratory (APL))
- Stephen Jurczyk (Associate Administrator, NASA Headquarters)
- H. Jay Zwally (Sr. Researchch Scientist, Earth System Interdisciplinary Science Center (ESSIC), University of MD, College Park)
- Paulo A. Oemig
- Geraldine B. Robbins
- Helen-Nicole Kostis (NASA Viz project manager; code 606.4, sponsor: H. Mitchell)
- Ellen Gray (NASA Viz Editor)

**STUDENT ENGAGEMENT**

**Assaf Anyamba** hosted and supervised Destini Garrison, a student intern from Georgetown University, in 2019. They have a manuscript on “Cholera, Conflict, Climate Variability and Implications on the Yemen Public Health System” due to be published in a special issue of the journal of Global Health Governance on New Health Security Paradigm.

**Assaf Anyamba** is co-supervising Cameron Nosrat, a senior in the Department of Pediatrics (Infectious Diseases) at Stanford University. Cameron is utilizing NASA Earth Science data to evaluate the “Impact of Recent Weather Extremes on Mosquito-Borne Disease Transmission in Kenya.”

**Abhishek Chatterjee** is advising a student from the Max Planck Institute of Meteorology as part of the Carbon Cycle OSSE initiative.

**Thomas Fauchez** continued to mentor his post-baccalaureate student Daria Pidhorodetska, who has recently submitted two peer-reviewed papers. He also mentored a summer intern.

**Manisha Ganeshan** is assisting Dr. Yuekui Yang in mentoring intern Daniel Kiv, who arrived at Goddard in January 2020. In particular, she recommended scientific literature and helped with reading CALIPSO Lidar Level 2 Blowing Snow product files, among other things.

In 2019, **Jie Gong** worked with a summer intern who was a junior from the Dept. of Astrophysics at University of Maryland. Her intern worked on analyzing the interannual variability and long-term trend of stratospheric gravity waves observed by AIRS and MLS satellite observations. Presently they are writing a paper together to report the findings.

**Jin Liao** helped advise a high school student for maintaining the measurements and analyzing the data for preliminary scientific results. The analysis was included in a student intern poster presentation.

In summer 2019, **Adrian Southard** mentored Jessica Patel, a graduate student at Delaware State University, in support of calibration of the CORALS instrument. Jessica’s goal was to optimize transmission of ions from a commercial laser desorption ionization source through the ion optics designed by Dr. Southard and into an orbitrap mass spectrometer.

**Adrian Southard** also mentored Nolan Roth, a rising junior undergraduate student from High Point University, NC, during his testing of field emitters for the MiniEPMA instrument.

In summer 2019, **Liz Wilk** mentored an intern working in the Office of Communications. In this role, she guided and provided help to the intern when needed, which resulted in the intern successfully completing a series of videos for various social platforms.

**EDUCATION AND PUBLIC OUTREACH**

**Assaf Anyamba** had his work featured in summer/fall 2019 in the following portals: Climate.gov: “ENSO and your health: how the 2015-16 El Niño led to early warnings for global disease outbreaks”; Smithsonian Magazine: “How Scientists Use Climate Models to Predict Mosquito-Borne Disease Outbreaks”; and NIH - National Institute of Environmental Health Sciences (NIEHS): “Global Disease Outbreaks Enhanced by El Niño”.

**Assaf Anyamba** was the subject of a two-part Netflix filming of a forthcoming documentary series called “Connected.” The docuseries will be showcasing the connections and linkages between computing, NASA satellite observations, climate and weather and disease outbreaks patterns. Filming at Goddard was supported by SVS personnel (Helen-Nicole Kostis, Lori Perkins, Greg Shirah, Matthew Radcliff, and Britt Griswold) and coordinated by the Public Affairs Office (Isabelle Yan, Courtney Photo of Netflix crew members filming Dr. Anyamba at a Field Site in Free State, South Africa. (Provided by A. Anyamba.)
Lee) on August 13, 2019. This was followed up by filming at several Rift Valley fever field sites in Free State, South Africa, August 31-September 5, 2019. This episode will be released later in 2020. As part of this effort, he collaborated with Helen-Nicole Kostis (USRA/GESTAR) on developing several global and regional diseases outbreak visualizations (see Helen-Nicole’s report under Code 606.4 in this report.).

Assaf Anyamba gave a seminar presentation on “Climate Variability and Disease Outbreak Patterns” to graduate students at Department of Microbiology and Immunology, Georgetown University, School of Medicine in February 2020.

Jefferson Beck arranged a media visit from an up-and-coming Spanish language video series, Ciencia Sumersé, and arranged for them to shoot seven different interviews with various Goddard scientists and communication personnel.

Niama Boukachaba presented her research at the GMAO Science Team in April 2020 with the theme of ‘observations’, “Development of Gridded Innovations and Observations Data for Reanalysis Diagnostics,” which gave an update status of the MERRA-2 GIO data.

Virginie Buchard represented GMAO Early Career Scientists at the EMC2 working group initiated by the 610 leadership.

Virginie Buchard presented a summary on “The aerosol observing system - present and future” at a GMAO science theme meeting.


Ivona Cetinić participated in many outreach events for the PACE mission, including a webinar about PACE and an outreach video for NASA Earth Day 2020.

Gabrielle Engelmann-Suissa participated in and supported community efforts such as Goddard’s Seller’s Exoplanet Environments Collaboration (SEEC). She assisted Drs. Avi Mandell and Ravi Kopparapu (both NASA GSFC) in organizing the annual SEEC Symposium and SEEC Reports, in order to help sustain the SEEC initiative.

Verity Flower’s work on volcanic eruptions in Kamchatka work was included as a NASA Atmospheric Science Highlight in February 2020: https://science.gsfc.nasa.gov/sed/index.cfm?fuseAction=sci_highlight.view&iMonthId=2&srchYear=2020&navOrgCode=613&navTab=nay_about_us.


Manisha Ganeshan’s work appeared as a 610AT Monthly Science Highlight for the Climate and Radiation Laboratory from Code 613 in January 2020.


Hiren Jethva presented “Connecting Crop Productivity, Residue Fires, and Air Quality over Northern India” at a 614 branch lunch seminar on November 21, 2019.

Hiren Jethva participated in live TV panel discussions on NDTV (www.ndtv.com) about the 2019 post-monsoon crop stubble burning season and its impact on air quality in northern India. The videos of these conversations are available here:


NASA’s Earth Observatory cited Hiren Jethva’s research work on the post-monsoon haze event in Northern India:
Hiren Jethva contributed to a story highlighting changes in aerosol loading over India post-lockdown induced by the COVID-19 outbreak: https://earthobservatory.nasa.gov/images/145827/haze-smothers-northern-india.

Bryan Karpowicz gave a talk related to inclusion of ozone sensitive radiances in the GEOS-ADAS at NASA Goddard for the SED Directors Seminar Series.


Sergey Korkin’s research was a Code 613 Laboratory monthly highlight for December 2019: https://sciences.gsfc.nasa.gov/sed/images/science_highlight_slides/atmos/1058201912_1.jpg. He gave a related talk titled “Surface polarized reflection analysis using CATS system” at the NASA GSFC CATS group meeting on March 5, 2020.

Sergey Korkin was a visiting scientist at Laboratory for Optics of Atmosphere, Lille, France from October 28 to November 1, 2019. He shared his experience in numerical simulation of light scattering and learned the basics of the GRASP algorithm.

Helen-Nicole Kostis served as co-Presenter of Best in Show Award for the Computer Animation Festival (CAF) event at ACM SIGGRAPH 2019, Los Angeles, CA. The CAF is the premier venue of showcasing the best achievements (technical, artistic and storytelling) from all around the world, through a peer-review process. Animations and works that receive awards in the CAF are eligible for Oscars. Helen-Nicole was asked to co-present the Best in Show award, which was given to Pixar Animation Studios. Images are available here: https://www.flickr.com/photos/siggraphconferences/with/48434746626/.

Helen-Nicole Kostis was interviewed by SIGGRAPH 2019 as one of the co-authors of a course given at the event. The interview was featured at the SIGGRAPH blog and is available here: https://blog.siggraph.org/2019/07/why-cinematic-scientific-visualization-is-more-important-than-ever.html/.

Eunjee Lee co-organized a half-day review meeting titled “Rapid Review of the Goddard Carbon research,” where 21 rapid talks were presented. Other organizers included Drs. Benjamin Poulter (618), Lesley Ott (GMAO) and Randal Koster (GMAO). The goal was to connect carbon cycle researchers in different branches inside Goddard and seek out collaboration opportunities. The meeting was structured into three thematic areas of the carbon cycle research areas (land, ocean/river/lake and atmosphere).

Eunjee Lee presented “Forecasting land carbon fluxes at S2S time scales” at the GMAO theme meeting.

Michael Lentz continued to reach out to universities about the animation fellowship program sponsored by USRA for recent graduates in animation. This paid position runs for one year in the Conceptual Image Lab. He also has been active in professional groups, such as SIGGRAPH, AIGA, the Design leadership forum, the Art Director’s Club, and the Academy of Television Arts & Sciences.

Junhua Liu reported her work on examining the ENSO and QBO impact on ozone variability and stratosphere troposphere exchange (STE) relative to the subtropical jets at the Aura science team meeting in August 2019.

Junhua Liu gave a talk titled “Quantifying the stratospheric contribution to tropospheric ozone radiative forcing” during a monthly CCM meeting on January 8th and in a Code 614 branch lunch seminar on April 2nd.

Adriana Manrique Gutierrez attended two outreach events as part of the ICESat-2 EPO team. On July 19, 2019, Adriana volunteered at the Apollo 50th Anniversary at the National Mall event, and later that year she attended AGU for the first time. At both events, her tasks included running E/PO activities and engaging with the public in order to promote ICESat-2 and NASA’s role in the study of the cryosphere and beyond.

Erica McGrath-Spangler gave a GMAO presentation “Progress in the assimilation of cloud-cleared infrared radiances in the GEOS to improve tropical cyclone representation” at a GMAO Science Theme Meeting with the theme of all sky assimilation for tropical cyclones.
Katy Mersmann volunteered to travel to a local high school to talk with ninth grade students about jobs available at NASA while she was in the Philippines with the CAMP2EX campaign.

Edward Nowottnick continued to serve as an AeroCenter and Early Career Scientist Forum committee member. As an AeroCenter committee member, he helped host seminar speakers, including coordinating visits from speakers from outside GSFC. As an Early Career Scientist Forum committee member, he helped to organize and convene the NASA GSFC Code 600 Early Career Scientist Forum, held in October 2019.

Ian Paynter and Dr. Doug Morton ran a tutorial and demonstration session for the Riegl VZ400i ground-based laser scanner for GSFC 618 members. The session showed instrument setup, sampling considerations, data acquisition and processing.

Cecile Rousseaux presented on analysis results on the use of GEOS-5 for Seasonal Forecast of Ocean Biochemistry at the GMAO Research Theme Seminar in 2019.

Cecile Rousseaux presented “GMAO’s ocean biogeochemical model for planning NASA missions” at a NASA GMAO Research Theme meeting.

Bridget Seegers was invited by the California State Water Resources Control Board and Southern California Coastal Water Research Project (SCCWRP) to serve on the technical advisory committee (TAC) on a joint freshwater HABs project. The CA State Water Board and SCCWRP are working together to develop a framework for monitoring and assessment for freshwater HABs for the state of California.

Alka Singh presented her ongoing work for 618 group at the NASA GSFC site visit by Drs. Hank Margolis, Mike Falkowski, and Kathy Hibbard, all from NASA Headquarters.

Inia Soto Ramos discussed red tides when she was interviewed by Ciencia Café Pá Sumercé: https://cienciacistasunmercede.wordpress.com/.


Susan Strahan was interviewed for a podcast made by the American Chemical Society on the history of the Antarctic ozone hole: https://cen.acs.org/environment/atmospheric-chemistry/Podcast-solve-problem-like-ozone/97/web/2019/12.
In May 2019, Adriana Manrique (code 130, sponsor: W. Sisler) accepted the award in the Outreach Team category presented to the ICESat-2 Outreach Team at the Robert H. Goddard Honor Awards ceremony.

In June 2019, Alex Kekesi (code 606.4, sponsor: H. Mitchell) had his NASA/SVS entry “NASA Surveys Hurricane Damage to Puerto Rico’s Forests” shown at ACM/SIGGRAPH’s 2019 Computer Animation Festival (CAF), which is a prerequisite competition to the Academy Awards short animated film category. This highly competitive event draws applicants from academia to major Hollywood studios. A scientific data visualization accepted alongside giants in the computer graphics industry is a great honor. Others among the team included Matt Radcliff (code 130, sponsor: W. Sisler) and Kel Elkins (code 606.4, sponsor: H. Mitchell). See the video here: https://svs.gsfc.nasa.gov/4735.

In June 2019, as part of the 2019 Agency Honor Awards, Fei Liu (code 614, sponsor: B. Duncan) was the recipient of an Exceptional Scientific Achievement Medal.

Related to her previous work on the assessment of the quality of aerosol estimates from the MERRA-2 reanalysis, Virginie Buchard (code 610.1, sponsor: A. Da Silva) was part of the MERRA-2 science team who won a NASA 2019 Agency Honor Award this year.

In August 2019, Emma Knowland was part of the OWLETS team that was recognized by NASA with a Group Achievement Award: “For designing and executing an unprecedented scientific investigation in the upper and lower Chesapeake Bay to understand the ozone pollution at the land-water interface.”

Also in August 2019, the Office of the Director Peer Awards Ceremony was held at the NASA GSFC Recreation Center. Two GESTAR members were recognized for their achievements:

- Robert Garner (code 130, sponsor: W. Sisler): “In recognition of his excellence in customer service as Web Chief, as a Go-To Person, as a Team Lead for the Social Media Group, as Master of Ceremonies at various events, as a valued member of the Conversations with Goddard Team, and as one who encourages others.”
- Lauren Ward (code 130, sponsor: W. Sisler): “In recognition of her outstanding customer service for her work with the NASA Explorers storytelling digital series, which focuses on different divisions and areas of NASA’s work.” NASA Explorers: Season 1 is available on YouTube as well as episodes from Season 2 (https://www.youtube.com/watch?v=L2HvloywWTU&list=PL2aBZuCeDwl0qXzd_hXEX0OSi1yXp9Cj). In April 2020, NASA Explorers: Cryosphere was nominated for a Webby Award for 2020. The prestigious Webby Awards are the leading international award honoring excellence on the Internet.

In September 2019, the Hydrosphere, Biosphere and Geophysics (HBG) Peer Awards Ceremony was held at NASA Goddard, and three GESTAR members were recognized for their achievements:

- Pukar Amatya (code 617, sponsor: D. Kirschbaum) received an award for Scientific Achievement: “For excellent work in developing automatic change detection methods for landslide hazards.”
- Perry Oddo (code 617, sponsor: J. Bolten) also was recognized for Scientific Achievement: “For outstanding scientific achievement in leading the development of the operational flood inundation damage assessment system and value of information study in the Lower Mekong River Basin.”
- Bridget Seegers (code 616, sponsor: P. J. Werdell) received a Scientific Achievement award for her work as part of the CyAN Team: “For coast-to-coast detection of harmful algal blooms.”

Also in September 2019, at the Earth Sciences Division - Atmospheres (Code 610AT) Awards Ceremony, Xiaowen Li (code 612, sponsor: S. Munchak) was recognized for Outstanding Performance - Science: “For outstanding scientific research
using sophisticated microphysical processes to improve our understanding of interactive processes between cloud, precipitation and aerosols.”


In November 2019, Kel Elkins’ visualization “Black Marble View of Puerto Rico After Hurricane Maria” (https://svs.gsfc.nasa.gov/12616) was accepted to the SIGGRAPH Asia Computer Animation Festival, held in Brisbane, Australia. This visualization was shown during the conference at the Electronic Theatre.

USRA Management Awards were announced at the GESTAR Holiday Party in December 2019. These awards recognize managers who demonstrate excellence in leading a team, managing the work, and positively affecting staff, all while demonstrating USRA’s Core Values of Passion, Partnerships, and Professionalism. This year’s recipients were Ludovic Brucker (code 615, sponsor: S. Nowicki) and Robert Garner (code 130, sponsor: W. Sisler).

In January 2020, Peer Awards were distributed at the GMAO - Code 610.1 Ceremony, and Saulo Frietas (code 610.1, sponsor: W. Putman) was recognized for Scientific Achievement: “For your diligent GEOS work, updating the deep and shallow convective schemes, in conjunction with boundary layer and microphysics retuning. This has produced notable improvements at all levels and fields of the atmosphere in medium range weather prediction – possibly the most significant skill improvement from an AGCM update in FP in the history of GEOS systems.”

Also in January 2020, Goddard’s Climate and Radiation Laboratory (Code 613) held its awards ceremony. Henry Selkirk (USRA) and Dan Laughlin (MSU) represented GESTAR at the event.

• Boon-Sze (Jackson) Tan (code 613, sponsor: G. Huffman) received an award For Best First-Authored Paper: “For a paper that introduces novel ways to interpret coincident cloud and precipitation observations.”


• Guoyong Wen (code 613, sponsor: A. Marshak) received a Scientific Leadership Award: “For leading work of extraordinary breadth that interprets solar radiation signals in the Earth System.”

• Additionally, a fellow with the NASA Postdoctoral Program (NPP), which is administered by USRA, Alfonso Delgado-Bonal was recognized with a Code 613 award for Scientific Achievement. Ludovic Brucker (USRA) presented him with a certificate on behalf of the NPP administration: “For applying original concepts in the analysis of the complexity of the climate system.” (Dr. Delgado-Bonal joined GESTAR in February 2020 in code 613, sponsor: A. Marshak.)

This year, Thomas Fauchez (code 699, sponsor: R. Kopparapu) received a Group Achievement Award for his work as part of the Study Team on the Large UV/Optical/IR Surveyor (LUVOIR) mission, one of four Decadal Survey Mission Concept Studies that were initiated back in January 2016. “NASA presents the Group Achievement Award to Astrophysics Large Mission Study Team for the substantial and effective scientific, technical, and management work in developing the Large Mission Concept Studies for the 2020 Astrophysics Decadal Survey.”

Also, in May 2020, a video titled “MAVEN Explores Mars to Understand Radio Interference at Earth” submitted to SIGGRAPH 2020 was accepted into the Electronic Theatre, an ongoing show that runs during the conference featuring selected animated works from around the world. As mentioned in Alex Kekesi’s item from 2019, having a visualization accepted into the SIGGRAPH ET is an honor. Bailee DesRocher was Lead Animator, and Michael Lentz, Jonathan North, Krystofer Kim, Jacquelyn DeMink, and Adriana Manrique Gutierrez (all code 130, sponsor: W. Sisler) were among the team on this visualization. The video is available here: https://svs.gsfc.nasa.gov/13342.
Acronyms List

4DENVAR . . . . . . . . . . Four-Dimensional Ensemble Variation (data assimilation)
ABOVE . . . . . . . . . . . Arctic Boreal Vulnerability Experiment
ACAM . . . . . . . . . . . . Arctic Compact Atmospheric Mapper
ACCP . . . . . . . . . . . . Aerosols and Clouds, Convection and Precipitation
ACMAP . . . . . . . . . . . . Atmospheric Composition: Modeling and Analysis Program
ADAS . . . . . . . . . . . . Atmospheric Data Assimilation System
AERONET . . . . . . . . . . . . Aerosol Robotic Network
AERONET-OC . . . . . . . . . . Aerosol Robotic Network – Ocean Color
AGCM . . . . . . . . . . . . Atmospheric General Circulation Model
AGU . . . . . . . . . . . . American Geophysical Union
AIRS . . . . . . . . . . . . Atmospheric InfraRed Sounder
AMS . . . . . . . . . . . . American Meteorological Society
AOD . . . . . . . . . . . . Aerosol Optical Depth
AO . . . . . . . . . . . . Arctic Oscillation
AOT . . . . . . . . . . . . Aerosol Optical Thickness
AROMA . . . . . . . . . . . . Advanced Resolution Organic Molecule Analyzer
ARSET . . . . . . . . . . . . Applied Remote Sensing Training program
ATom . . . . . . . . . . . . Atmospheric Tomography Mission
ATMS . . . . . . . . . . . . Advanced Technology Microwave Sounder
AVHRR . . . . . . . . . . . . Advanced Very High Resolution Radiometer
BRDF . . . . . . . . . . . . Bidirectional Reflectance Distribution Function
CAFE . . . . . . . . . . . . Compact Airborne Formaldehyde Experiment
CAFIR . . . . . . . . . . . . Correlator Array-Fed microwave Radiometer
CALIOP . . . . . . . . . . . . Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO . . . . . . . . Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CAMP2Ex . . . . . . . Cloud, Aerosol and Monsoon Processes Philippines Experiment
CANOE . . . . . . . . . . . . Compact Airborne Nitrogen diOxide Experiment
CCMI . . . . . . . . . . . . Chemistry-Climate Model Initiative
CDC . . . . . . . . . . . . Center for Disease Control
CDOM . . . . . . . . . . . . Colored Dissolved Organic Matter
CEOS . . . . . . . . . . . . Committee on Earth Observation Satellites
CERES . . . . . . . . . . . . Clouds and Earth Radiant Energy System
CFH . . . . . . . . . . . . Cryogenic Frostpoint Hygrometer
CHAPS-D . . . . . . . . . Compact Hyperspectral Air Pollution Sensor-Demonstrator
CIL . . . . . . . . . . . . Conceptual Imaging Lab
CLIVAR . . . . . . . . . . Climate Variability and Predictability project
CMAVE . . . . . . . . . . . Center for Medical, Agricultural, and Veterinary Entomology
CMIP . . . . . . . . . . . . Coupled Model Intercomparison Project
CORALS . . . . . . . . . . Characterization of REalms and Life Signatures
COWVR . . . . . . . . . . . . Compact Ocean Wind Vector Radiometer
CPEX-AW . . . . . . . . . . Convective Processes Experiment – Aerosols & Winds
CtIS . . . . . . . . . . . . Cross-track Infrared Sounder
CRTM . . . . . . . . . . . . Community Radiative Transfer Model
CTM . . . . . . . . . . . . Chemistry Transport Modeling
CubeRRT . . . . . . . . . . CubeSat Radiometer Radio Frequency Interface Technology
CYAN . . . . . . . . . . . . Cyanobacteria Assessment Network
DAGR . . . . . . . . . . . . Digital Aircraft Gas (CH4) Registrator
DAS . . . . . . . . . . . . Data Assimilation System
DCOTSS . . . . . Dynamic and Chemistry of the Summer Stratosphere field campaign.
DFR . . . . . . . . . . . . Differential Frequency Ratio
DIC . . . . . . . . . . . . Dissolved Inorganic Carbon
DISCOVER-AQ . . . . . . . . Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality
DOD . . . . . . . . . . . . Department of Defense
DOE . . . . . . . . . . . . Department of Energy
DPR . . . . . . . . . . . . Dual-frequency Participation Radar
DSD . . . . . . . . . . . . rainDrop Size Distribution
DTRA . . . . . . . . . . . . Defense Threat Reduction Agency
ECMWF . . . . . . European Centre for Medium-Range Weather Forecast
EMAS . . . . . . . . . . . . Enhanced MODIS Airborne Simulator
ENSO . . . . . . . . . . . . El Niño/Southern Oscillation
EO4WEF . . . . . . . Earth Observations for the W-E-F Nexus
EPIC . . . . . . . . . . . . . Earth Polychromatic Imaging Camera
ESA . . . . . . . . . . . . . European Space Agency
EWV . . . . . . . . . . . . . Essential Water Variables
EXPORTS . . . Export Processes in the Ocean from RemoTe Sensing
FAS . . . . . . . . . . . . Foreign Agricultural Service
FDA . . . . . . . . . . . . Food and Drug Administration
FFCO2 . . . . . . . . . . . . Fossil Fuel CO2
FFDI . . . . . . . . . . . . Forest Fire Danger Index
FIREX-AQ . . . . . . . . . . Fire Influence in Regional to Global Environments and Air Quality Experiment
FLUID . . . . . . . . . . . . Framework for Live-User Invoked Data
GCAS . . . . . . . . . . . GEOCAPE Airborne Simulator
GCE . . . . . . . . . . . . . Goddard Cloud Ensemble
GCRP . . . . . . . . . . . . Global Change Research Program
GEDI . . . . . . . . . . . . Global Ecosystem Dynamics Investigation
GEIS . . . . . . . . . . . . Global Emerging Infections Surveillance
GEMS . . . . . . . . . . . . Geostationary Environmental Monitoring Satellite
GEO . . . . . . . . . . . . . Group of Earth Observations
NASA Viz .......... NASA Visualization Explorer app
NASM .......... National Air and Space Museum
NCA .......... National Climate Assessment
NCCS .......... NASA Center for Climate Simulation
NCEP .......... National Centers for Environmental Prediction
NDACC .......... Network for the Detection of Atmospheric Composition Change
NDVI .......... Normalized Difference Vegetation Index
NDWI .......... Normalized Difference Water Index
NEWS .......... NASA Energy and Water Cycle Studies
NGIMS .......... Neutral Gas and Ion Mass Spectrometer
NOAA .......... National Oceanic and Atmospheric Administration
NOBM .......... NASA Ocean Biogeochemical Model
NOMAD .......... NASA bio-Optical Marine Algorithm Dataset
NPP .......... NASA Post-Doctoral Program
NPP .......... National Polar-orbiting Partnership (Suomi)
NPP OMPS .......... NPP Ozone Mapping and Profiler Suite
NSIDC .......... National Snow and Ice Data Center
NU-WRF .......... NASA Unified Weather Research and Forecasting
OASIM .......... Ocean-Atmosphere Spectral Irradiance Model
OCO-2 .......... Orbiting Carbon Observatory-2
ODIAC .......... Open-source Data Inventory for Anthropogenic CO2
OIB .......... Operation IceBridge
OMI .......... Ozone Monitoring Instrument
OMPS .......... Ozone Mapping Profiler Suite
ORACLES .......... Observations of Aerosols above CClouds and their InterRacionS
OSIRIS-REx .......... Origins-Spectral Interpretation-Resource Identification Security Regolith Explorer
OSSE .......... Observing System Simulation Experiments
OWLETS .......... Ozone Water-Land Environmental Transition Study
PACE .......... Pre-Aerosol, Clouds, and ocean Ecosystem
PBL .......... Planetary Boundary Layer
PDO .......... Pacific Decadal Oscillation
PSD .......... Particle Size Distribution
PSP .......... Parker Solar Probe
RFI .......... Radio Frequency Interference
RIACS .......... Research institute for Advanced Computer Science
ROZE .......... Rapid OZone Experiment
RRTMG .......... Rapid Radiative Transfer Model for GCM applications
RT .......... Radiative Transfer
RVF .......... Rift Valley Fever
SAL .......... Saharan Air Layer
SALAD .......... Semi-Automatic Landslide Detection
SAM .......... Sample Analysis at Mars
SAPHIR .......... Sounder for Atmospheric Profiling of Humidity in the Intertropics by Radiometery
SCOAPE .......... Satellite Coastal and Oceanic Atmospheric Pollution Experiment
SDG .......... Sustainable Development Goals
SDO .......... Solar Dynamics Observatory
SeaBASS .......... SeaWiFS Bio-optical Archive and Storage System
SEAWIFS .......... Sea-Viewing Wide Field of View Sensor
SIGGRAPH .......... Special Interest Group on Computer GRAPHics and Interactive Techniques
SMAP .......... Soil Moisture Active/Passive
SMOS .......... Soil Moisture Ocean Salinity
SSG .......... Scientific Steering Group
SSO .......... Science Support Office
SST .......... Sea Surface Temperature
STE .......... Stratosphere-Troposphere Exchange
STEM .......... Science, Technology, Engineering and Mathematics
SVS .......... Scientific Visualization Studio
SWE .......... Snow Water Equivalent
SWSARR .......... SWE Synthetic Aperture Radar and Radiometer
TESS .......... Transiting Exoplanet Survey Satellite
THAI .......... TRAPPIST-1 Habitabte Atmosphere Intercomparison
TIRS .......... Thermal Infrared Sensor
TOAR .......... Tropospheric Ozone Assessment Report
TOMS .......... Total Ozone Mapping Spectrometer
TRMM .......... Tropical Rainfall Measuring Mission
TROPOMI .......... TROPOSphere Monitoring Instrument
UNEP .......... United Nations Environment Programme
USDA .......... U.S. Department of Agriculture
UT/LS .......... Upper Troposphere/Lower Stratosphere
VCD .......... Vertical Column Densities
VIIRS .......... Visible Infrared Imager Radiometer Suite
WCRP .......... World Climate Research Program
W-E-F .......... Water-Energy-Food
WFIRST .......... Wide-Field Infrared Survey Telescope
WRF .......... Weather Research and Forecasting