OMB Number: 0690-0032
Expiration Date: 08/31/2021

DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

For instructions, please visit
http://www.osec.doc.gov/oam/grants_management/policy/documents/RPPR%20Instructions%20and%20Privacy%20Statement.pdf

AWARD INFORMATION	
1. Federal Agency: Department of Commerce / NOAA	2. Federal Award Number: NA20NES4320003
3. Project Title: Proposal for the continuation of The Cooperative Institute for Meteorological Satellite Studies at the Univers	
4. Award Period of Performance Start Date: 07/01/2020	5. Award Period of Performance End Date: 06/30/2025
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	
6. Last Name and Suffix: Wu , null	7. First and Middle Name: Wenhua ,
8. Title: Senior Admin Program Specialist	
9. Email: wenhua.wu@ssec.wisc.edu	10. Phone Number: 608-263-8890
AUTHORIZING OFFICIAL	
11. Last Name and Suffix: Roberts , null	12. First and Middle Name: Dawn-Marie , M.
13. Title:	
14. Email: drobert4@rsp.wisc.edu	15. Phone Number: 608-262-0152
REPORTING INFORMATION	
Signature of Submitting Official: Brenda Egan	
16. Submission Date and Time Stamp: 04/28/2023	17. Reporting Period End Date: 03/31/2023
18. Reporting Frequency: (●) Annual ( ) Semi-Annual ( ) Quarterly	19. Report Type: (●) Not Final ( ) Final
RECIPIENT ORGANIZATION	
20. Recipient Name: UNIVERSITY OF WISCONSIN SYSTEM	
21. Recipient Address: 21 N PARK ST STE 6301, MADISON, WI 53715-1218 USA	
22. Recipient UEI: LCLSJAGTNZQ7	23. Recipient EIN: 396006492

ACCOMPLISHMENTS

24. What were the major goals and objectives of this project?

CIMSS addresses four research goals that are central to maximizing the benefit of satellite observations to NOAA's mission:
• Improve and increase the use of satellite data in numerical weather prediction at all scales;
• Advance satellite remote sensing, machine learning/artificial intelligence, and data assimilation techniques for environmental satellite applications;
• Help NOAA and other stakeholders, both public and private, effectively exploit satellite observations to make society more resilient to environmental change; and
• Develop a workforce knowledgeable in satellite meteorology and remote sensing.
These objectives are addressed through an integrated program of research and education activities using innovative computational methods, value-added data interpretation, and effective communication to users and stakeholders, including the general public.
By addressing these goals, CIMSS provides end-to-end development of meteorological satellite applications including instrument design and demonstration; sensor calibration; data product development, validation, data archiving and dissemination; research-to-operations (R2O); data assimilation; and training and outreach. CIMSS is supporting new initiatives in artificial intelligence and machine learning, impact assessment and social sciences, community modeling, including the Earth Prediction Innovation Center (EPIC), and defining next-generation environmental satellites. Our approach includes the following specific elements:
• Fostering inter-disciplinary relationships to accelerate the development of revolutionary approaches for effectively extracting actionable information from current and future environmental satellites, including artificial intelligence and machine learning;
• Transferring important advances in satellite data interpretation to the operational setting where they can be of direct benefit to society;
• Engaging communities throughout the US and world to develop strategies for utilizing NOAA datasets to model risks and vulnerabilities;
• Soliciting and implementing feedback from users including NWS forecast offices and other NOAA centers to develop new satellite analysis tools that fuse distinct satellite outputs into value-added combined products to facilitate real-time decision making;
• Providing subject matter expertise (SME) to refine the instrument specifications for future NOAA weather applications from low-earth orbiting and geostationary platforms;
• Applying scientific computing methodologies for the integration, testing, and support of satellite algorithms, data stewardship, and data delivery;
• Distributing software allowing direct broadcast users to process data received from geostationary satellites in near real-time with low latency;
• Advancing application of satellite data in nowcasting;
• Curating multi-satellite, multi-sensor products to produce long term climate data records (CDRs);
• Contributing to NCEP's operational NWP modeling and assimilation efforts by increasing data usage, advancing data assimilation methods, developing radiative transfer models and observational operators, and verifying models;
• Performing GOES-R program post-launch test and validation activities;
• Advancing weather, water, and climate literacy in the educational and user communities while working to ensure that CIMSS

25. What was accomplished under these goals?

In the past year, CIMSS researchers developed and improved satellite retrievals of atmospheric humidity, surface properties, clouds, atmospheric motion, ice and snow cover and thickness, surface water and flooding, fire characteristics, volcanic ash, tropical cyclone track/intensity, and severe weather probabilities. We supported vicarious calibration of CrIS and VIIRS and validated associated data products. CIMSS played an integral role in validating GOES-18 products as the satellite was commissioned to replace GOES-17. CIMSS also led innovative applications of machine learning to satellite data to derive atmospheric motion vectors and identify severe weather.
To realize the benefits of these activities, CIMSS engaged stakeholders at NOAA to translate the products of our research to actionable information. CIMSS worked closely with NWS forecast offices to provide situational awareness and the National Centers for Environmental Prediction to assimilate this information into NWP models to improve short-range forecasts and to support rapid and accurate decision-making. Our tropical cyclone research team collaborated with the Tropical Prediction Center in Miami to develop new satellite-derived wind products.
Satellite Meteorology Research and Applications: CIMSS researchers developed new approaches for interrogating geostationary and polar orbiting satellite observations to extract information to improve weather analyses and supported their transition from research to operations (R2O). For example, we developed operational algorithms for identifying fires, increasing severe weather warning lead times, and identifying aviation hazards from GOES observations. CIMSS also developed a deep neural network (DNN) to retrieve soundings from partially cloudy CrIS FOVs with the help of clear sky ABI radiances with promising results. CIMSS pioneered the transition of satellite algorithms and products to the cloud and developed well documented visualization software allowing products to be easily accessed by the NOAA NWS, NHC, SPC, OPC, WPC, and AWC.
Satellite Sensors and Measurement Techniques: CIMSS contributed to the calibration and validation of radiances and geophysical data products from GOES-18 and continued to assist in the GOES-R program's efforts to mitigate the GOES-17 loop heat pipe issue. CIMSS assisted NOAA in conducting trade studies to demonstrate the value of geostationary hyperspectral infrared sounding and provided subject matter expertise to the System performance Assessment Team (SAT). CIMSS researchers have worked with experts on campus and at other universities to develop new artificial intelligence and machine learning-based approaches for converting "big data" to useable products such as turbulence and severe weather indicators.
Environmental Models and Data Assimilation: The other essential element in realizing the benefits of environmental satellite observations is assimilating them into forecast models. CIMSS scientists continued to develop approaches for improved cloud screening and cloudy-sky radiance assimilation. CIMSS also conducted TROPOMI data assimilation experiments and evaluated the impact on UFS-RAQMS CO analyses using FIREX-AQ airborne measurements.
Outreach and Education: Working closely with faculty in the collocated department of Atmospheric and Oceanic Sciences, CIMSS researchers advised several graduate students on research utilizing NOAA satellite observations and forecast systems. Embracing its mission to increase understanding of meteorological satellite data and its uses, CIMSS scientists developed new training modules that explain new products from GOES-R series satellites and conducted virtual short courses at multiple major international meteorological conferences. CIMSS maintained a significant presence on social media and actively engages in K-12 education and

ACCOMPLISHMENTS *(cont'd)*

26. What opportunities for training and professional development has the project provided?

CIMSS' location at the UW-Madison, the birthplace of satellite meteorology, maximizes NOAA's potential to engage a world class workforce in science, technology, engineering and mathematics (STEM). The UW is renowned for educational excellence and regularly ranks among the top ten in national research rankings for public and private universities. The institute's collocation with the Department of Atmospheric and Oceanic Sciences at UW-Madison affords opportunities to engage students in NOAA research and to develop tools for training professionals and the public. CIMSS has engaged in activities, trainings, and collaborations that support and advance NOAA's Education Strategic Plan:

• CIMSS offers a rich selection of on-line satellite education resources and activities for all segments of society and users.
• CIMSS researchers participated in, and created training videos for, the 2022 Hazardous Weather Testbed, demonstrating ProbSevere v3 and LightningCast (M. Pavolonis/J. Cintineo/J. Sieglaff) and PHSnMWnABI (W.L. Smith/Qi Zhang).
• CIMSS led a teacher workshop via the Earth Science Information Partners (ESIP) and conducted NWS trainings through the Virtual Institute for Satellite Integration Studies (VISIT).
• CIMSS holds weekly telecons with the National Weather Service of Pago Pago and bi-weekly telecons with the National Weather Service of Guam to instruct forecasters about satellite data and its support for Decision Support and Situational Awareness. In-person trainings were delivered at both locations.
• CIMSS participated in AMS/SATMOC/GOES-R/JPSS-sponsored Short Courses on heavy rain and flooding detection by satellite in February 2022 and on volcanoes in June 2022.
• CIMSS Weather Camp: NOAA's Cooperative Institute for Meteorological Satellite Studies (CIMSS) hosted 50 high school students from 32 states in a week-long virtual weather camp June 27th through July 1st. The agenda ranged from classic weather events and climate change to cutting-edge tools that incorporate artificial intelligence in forecasting. The full agenda is available online at https://cimss.ssec.wisc.edu/wxcamp/.
• CIMSS collaborated with the Department of Atmospheric and Oceanic Sciences at UW-Madison to design a course for non-atmospheric science majors to teach them about the essentials of climate change. See p.32-33: https://www.ssec.wisc.edu/wordpress/wp-content/uploads/2020/11/TtA_Summer_Fall_2020_s.pdf.
• CIMSS Outreach Director M. Mooney and other educators published a paper based on course data that investigated climate education and the connection between knowledge gains and behavior change.
• CIMSS investigators advised or currently advise 21 graduate students conducting research on a range of NOAA-related topics such as remotely sensing sea ice thickness, assimilation of atmospheric ozone data into air-quality models, machine learning-based cloud retrievals, and modeling tornadogenesis in severe thunderstorms. A complete list of current graduate student research projects is provided in Appendix A.
• CIMSS Satellite Blog contributors wrote and published more than 150 case studies and training-related posts for use by researchers, educators, trainers, the media, and others.

27. How were the results disseminated to communities of interest?

CIMSS shares a consistent message with internal and external audiences to broaden awareness and visibility of its research, as well as demonstrate its impact and value to NOAA, other funders, the citizens of Wisconsin and beyond. The results of research are initially shared with the scientific community through scholarly communications networks, peer-reviewed articles, conference presentations, seminars, websites and training programs (See Q29).

SSEC News and UW News published stories showcasing important research results from CIMSS, field campaigns, accomplishments of students, outreach activities, and more. Here are some stories of impact:

• A new focus on Arctic sea ice
Funded by NOAA, CIMSS researchers are improving the spatial resolution of Arctic sea ice imagery in order to paint a clearer picture of environmental change.
• Flash drought: A multivariable approach to understanding drought impacts
CIMSS research on flash drought is helping farmers, communities and policy makers develop resilience through improved planning and monitoring capabilities.
• Smith honored with IRC Gold Medal Award
Former CIMSS Director and UW-Madison Atmospheric Science Professor William L. Smith received the International Radiation Commission's Gold Medal Award, recognizing his contributions of lasting significance to the field of radiation research.

Research results are further disseminated to communities of interest through these outlets:

• Through the Atmosphere: The biannual magazine features research and education news of CIMSS and SSEC, with print and online distribution to stakeholders and public audiences. The latest issue highlights satellite technologies that are being employed to study environmental extremes exacerbated by a changing climate.
• 2020-2021 Biennial Report: Highlights research, field programs, collaborations and scholarly products of SSEC and CIMSS with federal, UW-Madison and other partners.
• UW-Madison Federal Relations: The UW-Madison Office of Federal Relations shares federally-funded research with stakeholders during state budget discussions as success stories of federal dollars at work for the state and the nation. Highlights this year include:
1. NASA-funded research: One minute data from UW helps NASA detect wildfires faster.
2. NOAA-funded research: Predicting lightning strikes and Better hurricane tracking.
• On Wisconsin, the university's magazine for alumni and friends, reaches more than 400,000 homes, broadening the audience reach of CIMSS research. The magazine editors picked up three CIMSS and SSEC stories in 2022:
1. A quicker way to stop wildfires
2. Making air travel safer
3. The news from Venus
• CIMSS Satellite Blog: With a 30-plus year history, nearly 4,000 visits per month, and over 290 posts for 2022, the blog presents case studies of weather events or phenomena using satellite imagery for training, as well as for use by other scientists, the media, and

ACCOMPLISHMENTS *(cont'd)*

28. What do you plan to do during the next reporting period to accomplish the goals and objectives?

During the next reporting period, CIMSS will leverage its strong heritage as a center of excellence in satellite meteorology to contribute to NOAA's mission to serve society's needs for accurate, timely weather and climate information. This will be accomplished through several interrelated research tasks approved by different project sponsors. An abbreviated but representative cross-section of the complementary activities planned for the coming year include:

• UW-Madison CIMSS will host the 2023 CoRP symposium during the week of July 24-28th, 2023 providing an opportunity for the NOAA Cooperative Institute student community to exchange science results along with networking interactions.
• Maintain routine operational Cryosphere products and improve ice and snow retrieval algorithms as needed;
• Continue to support evolving data production software needs and develop new tools and techniques to support current and future instrument systems;
• Transition promising research methods, algorithms and products to operational frameworks;
• Continue developing software to facilitate NOAA's migration of algorithms and products to the cloud;
• Utilize radiosonde launches from NOAA21 overpasses of the ENA, NSA, and SGP ARM sites to begin to validate and monitor NOAA21 retrievals of temperature and water vapor;
• Continue collaboration with NESDIS partners on the Enterprise Fire Algorithm and the Next Generation Fire System, work with researchers from NASA and NOAA on algorithm improvements that can be moved into Operations quickly. Implement terrain correction of fire locations in the operational FDCA;
• Develop the NESDIS NGFS (Next Generation Fire System) interface by providing web mapping services and GIS support as well as visualization of new fire and smoke products such as the terrain corrected GOES day fire and fire temp RGB along with near real-time detections;
• Participate on the GOES-18 ABI L1b and CMIP Full Maturity Review by providing analysis and feedback for the review board;
• Continue GOES-18 ABI radiance comparisons to GOES-16;
• Investigate the source and identify potential solutions to the GOES-18 "bar code anomaly";
• Develop, release, and provide user support for data ingest and visualization software with an emphasis on new products, science upgrades, and GOES-18;
• Analyze and verify mountain wave turbulence dataset;
• Continue developing the Himawari-8 cloud, QPE, near-surface visibility, and aircraft icing products and upgrade the typhoon intensity code previously delivered to the CWB;
• Assess NUCAPS v3 products for selected case studies;
• Implement CRTM NLTE bias correction scheme and quality control procedures in FV3GFS;
• Implement CEMS emissions in UFS-RAQMS and conduct full year (October 2019-November 2020) UFS-RAQMS Control and JPSS data assimilation experiments;
• Port UFS-RAQMS forecasting capability for real-time forecasts to ESRL/GSD;
• Continue to participate in GEO-XO planning and provide SME to the SAT to further plan the best configuration of NOAA's Leo and Geo capabilities;

PRODUCTS

29. Publications, conference papers, and presentations

CIMSS research was published and presented in numerous peer-reviewed papers, conference proceedings, and presentations throughout the reporting period. A complete list of CIMSS-authored publications from this reporting period are provided in Appendix B. Some noteworthy examples include:

• Cintineo, J. L., M. J. Pavolonis, and J. M. Sieglaff, 2022: ProbSevere LightningCast: A deep-learning model for satellite-based lightning nowcasting. Weather and Forecasting, 37, 1239-1257, https://doi.org/10.1175/WAF-D-22-0019.1
In this study, a satellite-based machine learning model was developed to provide objective, short-term, location-specific probabilistic guidance for next-hour lightning activity – especially important because lightning strikes are a hazard to human life and property and can be difficult to forecast in a timely manner.

• Taylor, Joe K., Henry E. Revercomb, David C. Tobin, Robert O. Knuteson, Michelle L. Loveless, Rebecca Malloy, Lawrence Suwinski, Flavio Iturbide-Sanchez, Yong Chen, Glen White, Joe Predina, and David G. Johnson. 2023: Assessment and Correction of View Angle Dependent Radiometric Modulation due to Polarization for the Cross-Track Infrared Sounder (CrIS), Remote Sensing, 15, 718, https://doi.org/10.3390/rs15030718
The potential for polarization errors contributing significantly to the radiometric uncertainty of infrared remote sounders has been well recognized and documented. The issue is equally applicable to FTS-based sensors like the Cross-track Infrared Sounder (CrIS). This paper presents a model for the polarization-induced calibration bias and the associated correction is presented for the CrIS instrument, along with details of the model parameter determination, and the impact of the correction on the calibrated radiances for a range of scene temperatures and types.

• Weisz, E., and W. P. Menzel, 2023: Monitoring the 2021 Cumbre Vieja Volcanic Eruption Using Satellite Multisensor Data Fusion. Journal of Geophysical Research-Atmospheres, 128, 2, https://doi.org https://doi.org/10.1029/2022jd037926
In this research, data from low Earth and geostationary orbits, such as the Joint Polar Satellite Systems and Geostationary Operational Environmental Satellites platforms, are integrated using spatial-temporal fusion to enhance the detection of trace gas emissions from volcanoes.

CIMSS researchers regularly present the results of their research at conferences, workshops, meetings, and symposia. During the reporting period, CIMSS researchers gave more than 60 presentations at international conferences. A list of CIMSS presentations is provided in the second tab of Appendix B. Some noteworthy examples include:

• Richard Dworak, Yinghui Liu, Jeffrey Key, Xuanji Wang, and Hong Zhang, Observing Sea and Lake Ice through JPSS VIIRS, 2022 AMS Collective Madison Meeting, 08-12 August, 2022, Madison, Wisconsin.

• Strabala, Kathleen I., and David J. Hoese. "Polar2Grid and Geo2Grid: Facilitating the Efficient Creation of High Quality Satellite

PRODUCTS *(cont'd)*

30. Technologies or techniques

CIMSS primary contributions to new technologies and techniques center on innovations in data visualization, increasing accessibility to imagery and products, and expanding the use of satellite data in models via data assimilation. Specific examples include:

• New method for generating combined Arctic satellite composite imagery;
• Web interface for monitoring ABI data quality using GOES-18 minus GOES-16 GEO-GEO difference statistics, 16 panel imagery, and time-difference imagery: http://cimss.ssec.wisc.edu/goes-r/abi-/16band_mainmenu.html;
• Including the latest web development to monitor GOES-R ABI CMIP file metadata statistics: https://cimss.ssec.wisc.edu/goes-r/abi-/cmip_stats;
• Interface for accessing GOES/ABI and VIIRS flood products in a variety of formats;
• New ECMWF Hybrid PCA approach for application to CrIS data;
• Software modifications and new data assimilation techniques for NOAA's National Centers for Environmental Prediction to improve weather forecasting;
• Advanced OGC Web mapping services (WMS, WMTS, GeoJSON API) dynamic web interface;
• Software modifications and assimilation techniques were transitioned to NOAA's National Centers for Environmental Prediction for implementation by their Central Operations.

31. Inventions, patent applications, and/or licenses

• RealEarth™: a data discovery and visualization platform developed by scientists at SSEC and CIMSS
• GEOSphere: a 4-D data discovery and visualization platform for displaying earth image layers

PRODUCTS *(cont'd)*

32. Other products

• Arctic satellite composite imagery (ACI);
• Data visualization software contributions to the open source SatPy Python library;
• Organized 56 products in 14 categories for NGFS Fire and Smoke Initiative "Collection"

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

Professor Tristan L'Ecuyer, Atmospheric and Oceanic Sciences, is the director of the Cooperative Institute for Meteorological Satellite Studies. Mr. Wayne Feltz is the Executive Director for Science. Ms. Margaret Mooney is the CIMSS Outreach Program Manager and Ms. Maria Vasys is an Outreach Specialist. Ms. Leanne Avila is the science technical editor. A complete list of all CIMSS Principal Investigators and Scientific and Programming Staff is provided in Appendix C.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

No significant changes other than the normal retirement and hiring cycle. A list of current CIMSS principal investigators is provided as Appendix C.

35. What other organizations have been involved as partners?

- Australian Bureau of Meteorology (ABOM)
- Alaska Aviation Weather Unit
- Alaska-Pacific River Forecast Center
- AOML-HRD
- AquaWatch
- Aviation Weather Center
- Boeing Corporation
- CalFire
- CESSRST
- Chinese Meteorological Agency (CMA)/NSMC
- CIRA
- CSIRO
- DoD/JTWC
- DOE/ARM
- ECMWF
- EMC
- ESA
- EUMETSAT
- FEMA
- Geographic Information Network of Alaska (GINA)
- George Mason University
- Honolulu WFO
- JAXA
- JCSDA
- JMA
- L3Harris
- Logistikos
- Michigan Tech University MTRI
- NASA
- NCAR
- NCEI
- National Environmental Satellite, Data and Information Service
- National Hurricane Center

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

36. Have other collaborators or contacts been involved?

• CMA/NSMC
• ECMWF
• FAA
• MIT Lincoln Labs
• NASA/GMAO
• NOAA/NCEP/EMC
• NOAA/NESDIS/STAR/ASPB
• NOAA/NESDIS/STAR/JPSS
• NOAA/NESDIS/OSPO
• Paul DiGiacomo, Liqun Ma, Walter Wolf, Ivan Csiszar, Shoba Kondragunta, Jessica Matthews, Ken Knapp, and Emily Smail and other NOAA points of contact
• University of Colorado – Boulder
• University of Oklahoma Atmospheric Sciences
• Volcanic Ash Advisory Center (VAAC) – Anchorage/Washington DC

IMPACT

37. What was the impact on the development of the principal discipline(s) of the project?

CIMSS provides end-to-end development of meteorological satellite applications from concept to application and training. As a result, CIMSS research encompasses several sub-disciplines of satellite meteorology including: airborne and in situ observation, remote sensing, numerical modeling, weather forecasting, data assimilation, education and outreach, data visualization, and advanced computational techniques, including artificial intelligence and machine learning. Selected examples illustrating how CIMSS research has impacted the development of these disciplines include:
• Polar winds derived at CIMSS have substantially advanced the field of assimilating dynamical information into operational NWP models (currently used by 10 meteorology centers throughout the world);
• Advancements in storm structure and strength have improved hurricane forecasting;
• All-sky infrared brightness temperatures have a greater impact on forecasts with improved bias corrections;
• Innovative methods have been developed for using GOES Cloud Algorithm Working Group products to infer lake effect snowfall to augment the NEXRAD network in the Great Lakes region;
• CIMSS research has impacted the transition of several enterprise algorithms to NESDIS operations;
• CIMSS has improved data delivery mechanisms for remote sensing data (e.g., VIIRS Imagery EDRs);
• CIMSS has advanced vicarious calibration approaches to spaceborne hyperspectral sounders and imagers (CrIS and VIIRS);
• CIMSS research has improved weather and hydrodynamical forecasting potential by improving the fidelity of water vapor distribution in the atmosphere;
• CIMSS products have a positive impact on the flood monitoring discipline: NOAA River Forecast Centers use CIMSS products to assess current floodwater conditions in areas not covered by river gauges and FEMA is able to use products to assess floodwater conditions to estimate scales of flooding;
• By substantially improving the capability of GeoIPS, CIMSS has developed a multi-agency TC satellite image ingesting package;
• CIMSS is advancing new concepts for using satellite sounder products to improve ice cloud retrievals from imager observations;
• New developments in data visualization have advanced the state and availability of real-time satellite imagery used by the US polar orbiter meteorological and environmental decision makers;
• Advances in state-of-the-art volcanic cloud detection and tracking algorithm (VOLCAT) have impacted real-time forecasting of volcanic hazards and have utility in climate applications (e.g., significant volcanic sulfur dioxide releases);
• Improved sea ice observations advance cryosphere forecasting and associated climate change research;
• CIMSS imagery and training is advancing the broadcasting discipline that informs the public, private sector businesses to inform decision making;
• Rapid burn scar mapping with VIIRS NDVI offers the potential to reduce latency for input to debris hazard warning;
• GOES-R Series ABI data quality monitoring impacts all of the products that use GOES-R ABI data, positively impacting their accuracy;
• Improved sea ice observations for forecasting and higher resolution dataset for cryosphere and associated climate change research;

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

To further our objective of supporting end-to-end utilization of meteorological information, CIMSS has fostered collaborations with other government agencies, academic, private sector, and non-profit groups that expand our research into several other disciplines. Government agencies provide public policy and guidance, the academic sector provides new and innovative science, the private sector adds work resources and non-profit groups work to help bring communities, our team, and additional outside resources together. Through these interactions, CIMSS data, products, and expertise have had an impact on risk management, insurance, urban planning and management, and disaster relief. For example, CIMSS has engaged communities throughout the US and world to develop strategies to become more resilient to the risks and vulnerabilities to people, infrastructure, and local economies posed by natural disasters.
Each of CIMSS' external collaborations serves a unique purpose. Some specific examples of impacts on other disciplines that have resulted from engaging these groups include:
• Improved methods for communicating warnings through community engagement (social science);
• General demonstrations of novel applications of deep learning;
• Improved data archival and search tools have fostered advances in 'Big Data';
• CIMSS atmospheric composition studies and modeling contribute to improving NWS National Air Quality Forecasting Capability providing better air quality forecasts through better constraints on long-range pollution transport and timely updates of global NOx emission inventories;
• Cryosphere products are used to inform fisheries, fresh water supplies, polar region transportation, and polar animal habitation;
• Water quantity, quality, and extremes provide critical input for water resource and emergency managers;
• Assimilating JPSS composition measurements and predict global atmospheric composition may lead to improved seasonal to sub-seasonal forecasts and advance the field of radiance assimilation in general.

39. What was the impact on the development of human resources?

Central to the CIMSS mission is training the scientists and engineers of the future. Evidence of commitment to this mission includes awarding scholarships to promising students, providing research opportunities for students to work and learn alongside CIMSS researchers, educating graduate students who may become NOAA scientists, and participating in scientist exchange to enhance collaboration. Early to mid-career scientists at CIMSS also gain experience participating in and ultimately leading research tasks. Some examples from the reporting period include:

Scholarships for Students

• Verner E. Suomi Scholarship
Two future UW-Madison students awarded 2022 Suomi Scholarship
The scholarship is competitively awarded by CIMSS to students who exhibit strong aptitude for atmospheric and environmental sciences.
• William L. Smith Graduate Scholarship
The scholarship is offered through NOAA and CIMSS. The first recipient of the three-year scholarship, Ph.D. candidate Nuo Chen, completed her third year and continues her research on tropical cyclone forecasts.
• Hollings Scholar: Undergraduate research opportunity at CIMSS
NOAA Hollings Scholar Peyton Camden completed an internship at CIMSS that involved an examination of GOES cloud products and accompanying GLM data for specific storms.

2022 Graduates

CIMSS investigators advise graduate students conducting research on a range of NOAA-related topics. During the reporting period, CIMSS investigators advised five Ph.D. graduates and two M.S. graduates, all of whom are students in the Department of Atmospheric and Oceanic Sciences. Some examples include:

• James F. Anheuser, Ph.D.: Developed a retrieval method for estimating thermodynamic sea ice thickness growth from space by linking an algorithm for retrieving snow-ice interface temperature from passive microwave satellite data to a thermodynamic sea ice energy balance relation known as Stefan's Law.
https://minds.wisconsin.edu/handle/1793/83856

• Charles White, Ph.D.: Explores the use of a machine learning model for cloud detection and cloud-top pressure estimation from the Visible Infrared Imaging Radiometer Suite, Advanced Baseline Imager and Moderate Resolution Imaging Spectroradiometer as estimates of cloud properties are critical to understanding weather and climate variability.

IMPACT *(cont'd)*

40. What was the impact on teaching and educational experiences?

CIMSS maintains a robust education and outreach program to train students, professionals, and other stakeholders in the use of environmental satellite data. CIMSS educational impacts start at middle school where the CIMSS GOES-R Virtual Science Fair introduces students to the exciting field of satellite meteorology. High school students are engaged again via our STEM summer camps, including the new Tech Camp, and the Suomi Scholarship awarded to graduating high school students interested in meteorology or related fields. CIMSS researchers work with undergraduate interns and advise graduate students in the collocated AOS department to recruit top students into research fields aligned with NOAA's priorities. Through a strong commitment to mentoring, senior scientists with vast institutional knowledge of our satellite meteorological heritage provide guidance to early and mid-career scientists allowing them to gain experience managing projects, publishing results, reporting to NOAA, and overseeing undergraduate and graduate students. CIMSS also provides a wide range of satellite training materials and provides professional training to NOAA staff and a wide range of users at other agencies, the public, and other stakeholders.
Research Opportunities for Undergraduates
During the reporting period, CIMSS researchers advised several graduate students and undergraduate interns. Graduate student research projects are summarized in Appendix A. Examples of experiential research opportunities for undergraduate students include:
• Payten Camden: As a NOAA Hollings Scholar, she explored relationships between GOES cloud and lightning products working with NOAA scientists based at CIMSS.
• Several undergraduate summer student interns at CIMSS gained experience in data processing, analysis, and visualization.
Advancement

• A series of recent gifts to CIMSS through the University of Wisconsin Foundation is being used to fund undergraduate research experiences and leading to research support for graduate students.
Other Examples of CIMSS Teaching and Education Impacts
• CIMSS fosters close interaction between researchers developing cutting edge satellite imagery tools and those generating training materials providing the capability to generate captivating materials from case study images and animations to support bootcamps, short courses, and summer schools;
• CIMSS collaborated with SSEC visualization experts to co-produce a new movie for NOAA Science on a Sphere (SOS) showing the atmospheric impacts of the Hunga Tonga-Hunga Ha'apai Volcanic Eruption in 2022 through GOES and Himawari imagery;
• SSEC's McIDAS-V satellite visualization package is used in educational workshops internationally to educate users on the many uses of NOAA satellite observations;
• The GOES-R short courses at AMS Broadcast Meteorology meetings and AMS annual meetings, as well as at smaller venues such as IMET trainings and international trainings, have been very well-received;
• NWS benefits from hearing directly from GOES ABI scientists on how to use data, data quality, and anomalies;
• CIMSS trains NWS and other users using timely and regionally-applicable case study imagery generated in-house.

41. What was the impact on physical, institutional, and information resources that form infrastructure?

• The AquaWatch "Knowledge Hub" is useful to a wide range of stakeholders, from national experts needing to report on policy commitments, to non-profit end users seeking practical solutions to local water quality challenges. The hub is a synthesis of best practices from the community with long-term capacity development. The Knowledge Hub has six interlinked components: publications, code and models, remote sensing imagery, in situ data, results and products, and community discussion;
• New hardware and software in development provides CIMSS new incident-based training capability;
• Storage was added to the Satellite Data Services archive to allow direct access to L1 and L2 GOES data by CIMSS scientists;
• The composition data assimilation experiments are conducted on the NOAA/NESDIS Satellite Simulations and Data Assimilation Studies computer (S4) at the UW-Madison Space Science and Engineering Center (SSEC) that has been developed to align with NOAA forecasting and data assimilation frameworks.

IMPACT *(cont'd)*

42. What was the impact on technology transfer?

Transferring technological advances in retrieval code, assimilation approaches, analysis and visualization software, and numerical models is a high priority at CIMSS. CIMSS researchers have transferred code and products to both NOAA operations and distinct stakeholders requiring environmental satellite data for a wide range of applications. Examples include:
• The GOES-16/17 Fog, Low Stratus (FLS) products are integrated into the Satellite Processing Framework (SAPF) and NOAA Polar-Orbiting Partnership (NPP) Data Exploitation (NDE) for operational delivery;
• The GOES-R FLS algorithm was delivered to NESDIS operations and its products are in the NDE system and in the final stages of going into full operational status;
• CIMSS transitions new value-added products to operations (e.g., ProbSevere AWIPSII plug-in capabilities to NWS operations);
• NEXRAD QPE for lake-effect snow events and a GOES lake-effect snow QPE product are being developed for operational use by the National Weather Service and other stakeholders in the Great Lakes region;
• Taiwan CWB has new products for use in their forecasting and environmental monitoring;
• CIMSS delivers daily remote sensing data to OU CIMMS;
• Product algorithms developed by NOAA were released for public consumption, benefitting users of satellite data throughout the world;
• CIMSS research supports enhancements to NOAA global atmospheric composition forecasting and assimilation systems;
• Software changes to CLAVRx will be migrated to NOAA's ASSISTT software framework;
• New visualization capabilities were developed for the ProbSevere AWIPSII plug-in for NWS forecasters and are being transferred to NWS operations;
• CIMSS is exploring opportunities for transferring knowledge learned in developing AI-ProbSevere models to international entities, as some of them rely only on geostationary satellite data;
• Atmospheric composition products transferred to NOAA global atmospheric composition forecasting and assimilation system.

43. What was the impact on society beyond science and technology?

Satellite data play a critical role in providing actionable timely weather, water, air quality, and hazard information that directly benefits society. CIMSS research and data products have several tangible economic, health, and safety benefits that align with NOAA's mission to protect life and property. Some examples of the societal impacts of CIMSS research, products, and education include:
• GOES ABI products are extensively used in weather forecasting and disaster mitigation including wildfire detection and monitoring, volcanic eruption detection, and storm prediction, that are beneficial to saving lives and property;
• Cryosphere products are used to inform fisheries, fresh water supplies, polar region transportation, and polar animal habitation;
• Data assimilation leads to improved weather forecasts and, in turn, more accurate severe weather watches and warnings;
• Improved hurricane forecasts lead to fewer casualties and reduce economic losses;
• Aviation weather products, such as identification of smoke and ash, atmospheric turbulence hazards, and severe weather, improve public safety and limit disruptions to commerce;
• Timely JPSS satellite-derived burn intensity estimates are provided to enable NWS-WFOs to craft accurate warnings and support their emergency management and response partners;
• More rapid hot spot detection and new mapping software benefits emergency operations in fire-scarred areas by saving lives with earlier warnings;
• Water quantity and quality information are critical for human and ecosystem health in many regions of the world where such data are scarce – these data have far reaching implications that include education, women's rights, food insecurity and political instability;
• Improved air quality prediction through data assimilation helps mitigate exposure to air pollution and reduce associated health risks that include increased respiratory symptoms, hospitalization for heart or lung diseases, and even premature death;
• Short courses developed for the US Broadcast Meteorology community raise science literacy and broaden the impact of NOAA satellite data across many user communities;
• Through social media, NOAA frequently posts for the public interesting GOES ABI images that were generated at CIMSS or using CIMSS tools.

IMPACT *(cont'd)*

44. What percentage of the award's budget was spent in foreign country(ies)?

0 , None.

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

Unlike the previous year's report, most CIMSS staff have now returned to predominantly on-site work resulting in a transition back to more in person collaboration team meetings but taking advantage of virtual meetings when appropriate. There have been no substantial changes to the overall management of the CIMSS cooperative agreement. Any methodological changes that have occurred were on the level of individual tasks, often in response to stakeholder feedback, and include the following:

• Using an AI/ML-based approach to generate background temperature fields without fires for hot spot detection proved to be infeasible, so alternate options are being pursued;
• Changes were made to the monitoring web pages for data validation in response to GOES-18 becoming the operational GOES-West and GOES-17 being placed in storage;
• Neutral impact obtained from assimilating only water vapor bands from GOES-16;
• Limited computer resources have delayed the transition of infrared radiance assimilation developments to NOAA National Centers for Environmental Prediction and its implementation by their Central Operations and NESDIS providing some additional NOAA computing resources;
• Budget reductions resulted in the descope of OMPS NO2 assimilation development;
• Feedback from stakeholders led us to pivot towards supporting the NGFS interfaces for sharing fire information rather than develop separate stand-alone interfaces that would have been redundant and confusing for similar target end-users. Joining forces with NGFS brings the best of our technology to bear on fire information communication;
• The original project scope did not include geolocation. After feedback from NOAA stake holders, geolocation first guess application was added to tasks;
• FY-3D development has shifted to FY-3E now that the data stream is available.

CHANGES/PROBLEMS *(cont'd)*

46. Actual or anticipated problems or delays and actions or plans to resolve them

• We continue to experience some delays in acquiring computer hardware as a result of global supply chain issues but the situation is improving;
• The unstable quality of GOES-17 radiances impacted delivery of some retrieval products – this will improve with the transition to GOES-18;
• NUCAPS science retrieval has not been implemented within operations. This will impact our proposed 1-year re-analysis. We intend to use NASA CLIMCAPS CO/O3 retrievals or TROPOMI CO retrievals instead.

47. Changes that had a significant impact on expenditures

Budget cuts to some GOES-R related activities limited the FTEs but the shortfall was largely accommodated for on new tasks.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

NA

49. Change of primary performance site location from that originally proposed

A majority of CIMSS researchers have returned to in-person work at the University of Wisconsin-Madison as of the time this report is submitted.

Attach a separate document if more space is needed for #6-10, or #24-50.

PROJECT OUTCOMES

50. What were the outcomes of the award?

The outcomes of the research conducted under the CIMSS cooperative agreement align with our four central themes: (1) Satellite Meteorology Research and Applications, (2) Satellite Sensors and Techniques, (3) Environmental Models and Data Assimilation, and (4) Outreach and Education. CIMSS' end-to-end research advanced meteorological satellite applications from instrument calibration to data assimilation to training and outreach. CIMSS supported new initiatives in community modeling, generated and dispersed operational climate data records (CDRs), introduced novel machine learning approaches for maximizing the information yielded by NOAA assets, led economic impact assessments, and helped define next-generation environmental observing systems. Our efforts resulted in standardized, curated, and validated datasets that include cloud properties, water vapor, water quantity and quality, cryosphere characteristics, atmospheric motion, and atmospheric composition. These products are widely used across NOAA line offices, weather forecasting offices, external government agencies, private sector partners, as well as foreign agencies and meteorological offices. CIMSS researchers also advanced techniques for identifying hazards including fires, floods, volcanic ash, turbulence, and severe storms that address public safety needs and delivered software to ensure users can access this information quickly and reliably. For example, the Geostationary Community Satellite Processing Package (CSPP Geo) developed at CIMSS has been widely adopted by U.S. government agencies, researchers, private industry, and other meteorological services to process GOES Rebroadcast (GRB) data from GOES-16 and GOES-17.

CIMSS contributed to calibrating and validating NOAA's geostationary and low-earth orbiting satellites, especially GOES-18, and associated data products. An important outcome of these efforts is calibrated radiances and intercalibrated water vapor, atmospheric motion, and trace gas datasets that can be assimilated to improve weather and pollution forecasts. For example, CIMSS researchers pioneered new methods for assimilating all-sky infrared radiances and significant improvements in quality control to facilitate their integration into NWP models. Finally, CIMSS researchers leverage multiple decades of subject matter expertise to provide guidance concerning instrument requirements for next-generation LEO and GEO platforms including leading efforts to demonstrate the potential of a Geostationary hyperspectral infrared sounder for determining moisture profiles, deriving 3D winds, and improving precipitation and severe weather forecasts.

CIMSS scientists are dedicated to sharing their work and results with others. In addition to 19 peer-reviewed papers published in 2022, CIMSS and SSEC maintain several web sites for external audiences beyond the news stories sites noted including:

- Educational resources for students and teachers: https://cimss.ssec.wisc.edu/education/
- The CIMSS Satellite Blog for case study discussion and analysis: http://cimss.ssec.wisc.edu/goes/blog/
- Data and imagery used by external media outlets, researchers, and many others: http://cimss.ssec.wisc.edu/data/

In 2022, CIMSS continued its support of NOAA's education and outreach goals with involvement in K-12, undergraduate, graduate, and professional training. CIMSS awarded two scholarships to incoming freshmen, supported several undergraduate interns, and advised several graduate students, including the William Smith Graduate Scholar, all working on NOAA research with CIMSS and ASPB scientists. These efforts reinforce the pipeline of talent into the NOAA enterprise as evidenced by recent hires into NOAA positions.

In summary, through successful completion of a diverse portfolio of activities, CIMSS has supported the full lifecycle of environmental satellite

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

Gender:

- ◯ Male
- ◯ Female
- ◯ Do not wish to provide

Ethnicity:

- ◯ Hispanic or Latina/o Not
- ◯ Hispanic or Latina/o Do not
- ◯ wish to provide

Race:

- ◯ American Indian or Alaska Native Asian
- ◯ Black or African American
- ◯ Native Hawaiian or other Pacific Islander
- ◯ White
- ◯ Do not wish to provide

Disability Status:

- ◯ Yes
  - [ ] Deaf or serious difficulty hearing
  - [ ] Blind or serious difficulty seeing even when wearing glasses
  - [ ] Serious difficulty walking or climbing stairs
  - [ ] Other serious disability related to a physical, mental, or emotional condition
- ◯ No
- ◯ Do not wish to provide

Attach a separate document if more space is needed for #6-10, or #24-50.