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: Dawn-Marie M. Roberts	
16. Submission Date and Time Stamp: 04/29/2021	17. Reporting Period End Date: 03/31/2021
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 support 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; 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) and working with NESDIS/STAR, other federal agencies, industry partners, and other NOAA CIs to refine the instrument specifications for future NOAA weather applications from low-earth orbiting and geostationary platforms;
• Supporting 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;
• Supporting NOAA's GOES-R program post-launch test and validation activities;
• Raising awareness of NOAA's Geo and Leo satellite assets and data within the educational community;
• Raising awareness of satellite remote sensing resources and advancing weather and climate literacy while working to ensure that CIMSS research products provide maximum benefits to society;
• Identifying the educational needs of students and professionals seeking to make better use of satellite observations and expand our training portfolio to cover new sensors, analysis techniques, and products associated with the next generation of satellite sensors;
• Engaging STEM students at all levels from K-12 to PhD through scholarships, fellowships, awards, and research opportunities; and

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, 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-17 products and generated sounder products at greatly enhanced spatial resolution using novel data fusion techniques. We also developed innovative satellite retrieval approaches including new applications of machine learning 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 Center 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. We also worked directly with the Storm Prediction Center and the National Severe Storms Laboratory (NSSL) in Norman, OK to implement severe weather forecasting tools.
Satellite Meteorology Research and Applications: CIMSS researchers developed new approaches for analyzing geostationary and polar orbiting satellite observations and worked with appropriate NOAA offices to transition new and improved products from research to operations. For example, we developed operational algorithms for tracking convective initiation, increasing lead times for severe weather threats, and identifying aviation hazards from GOES observations. CIMSS developed well documented visualization software and integrated several data products into AWIPS II allowing them 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 JPSS-1 and GOES-17. 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 is also contributing to the conceptual design of the NOAA Earth Prediction Innovation Center (EPIC) community modeling framework that seeks to engage the broad community of weather and climate modeling scientists to improve NWP.
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 short courses at multiple major international meteorological conferences. CIMSS also actively engages in K-12 education and public outreach to encourage students to pursue STEM careers

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

ACCOMPLISHMENTS *(cont'd)*

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

CIMSS location at the UW, 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. CIMSS' collocation with the Department of Atmospheric and Oceanic Sciences at UW-Madison affords CIMSS the potential 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 debuted the GOES-16/17 Virtual Science Fair in the spring of 2019 and offered it in 2020 and 2021. Students, grades 6-14, with guidance from a teacher-coach, apply data from GOES-16 or GOES-17 to investigate weather and natural hazards. Winning teams in 2021 will receive invitations to view the GOES-T launch at Kennedy Space Center.

• A NOAA scientist at CIMSS hosted the institute's first NOAA Experiential Research and Training Opportunity (NERTO) intern.

• CIMSS offers a rich selection of on-line satellite education resources and activities for all segments of society and users.

• 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 investigators advised 21 graduate students conducting research on a range of NOAA-related topics such as imager-sounder fusion, assimilation of atmospheric ozone data into air-quality models, machine learning-based cloud retrievals, and modeling tornadogenesis in severe thunderstorms.

• CIMSS' first William Smith Graduate Fellowship awardee Nuo Chen continued her PhD research to improve tropical cyclone forecasts within the CIMSS tropical cyclone group. She has completed the second year of her research.

• Wrote and published more than 160 case studies and training-related posts on the CIMSS Satellite Blog and developed comprehensive satellite training for new NWS forecaster hires. Note: VISIT nominally supports the development of training-related blog posts.

• Created a new VISIT Tele-training module: GOES-R Detection of Blowing Snow;

• Updated these training modules: NOAA/CIMSS ProbSevere (April 2020), NUCAPS Profiles tele-training (April 2020), and Mesoscale Convective Vortex (May 2020)

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, and training programs (See Q29).

Reaching beyond the academic research communities, 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:

• Student research: Contributions to climate solutions
CIMSS provides experiential research opportunities to undergraduate and graduate students – in this instance, research related to clouds and their role in weather and climate variability.
• Monitoring global flooding from direct broadcast flood products
Meeting the growing challenge of monitoring floods, researchers at CIMSS are taking advantage of high-resolution satellite imagery to detect where they may occur and how people, cities and rural areas might be affected.
• Natural disaster risks – Resilience research in a changing climate
Our research extends beyond Wisconsin -- with applications worldwide -- and is helping cities better prepare for future floods.

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

• Through the Atmosphere: Biannual magazine featuring research and education news of CIMSS and SSEC, with print and online distribution to stakeholders and public audiences.
• 2018-2019 Biennial Report: Covers research, collaborations and scholarly products of SSEC and CIMSS with federal and UW-Madison partners.
• CIMSS Satellite Blog: With a 30-plus year history, and nearly 4,000 visits per month, 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 public audiences.
• UW-Madison Featured Experts: In the last year, experts from CIMSS have been available to speak with local and national media on breaking news and trends in areas of expertise, such as tropical cyclones, drought, flooding in Wisconsin, volcanic ash, and atmospheric aerosols.
• Media Mentions: With over 900 media mentions in the last year, CIMSS and SSEC stories and imagery have been further amplified by news media across the country including UW News, The New York Times, The Washington Post, CNN, National Geographic, Popular Science, Wisconsin Public Radio, NASA, Milwaukee Journal Sentinel among many others. For example:
o Hurricane Intensification
NOAA NCEI scientists James Kossin and Kenneth Knapp and CIMSS collaborators, Christopher Velden and Timothy Olander, published research results in the Proceedings of the National Academy of Sciences that hurricanes are getting stronger–which has been featured in 735 stories published by 404 outlets.
• Social Media: CIMSS and SSEC Twitter and Facebook have garnered more than 36.2K total followers. These numbers continue to

ACCOMPLISHMENTS *(cont'd)*

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

CIMSS' newly awarded cooperative agreement began on 1 July 2020 at UW-Madison. CIMSS' goal is to continue its strong heritage as a center of excellence in satellite meteorology serving NOAA's mission to serve society's needs for accurate, timely weather and climate information. This is accomplished through several interrelated research tasks approved by different project sponsors. Researchers regularly present results from these tasks at scientific conferences, workshops, and project meetings and document the results through peer-reviewed publications, conference papers, and required progress reports. They directly engage with NOAA line offices and, especially, collocated NESDIS ASPB researchers to ensure that the products from this research align with NOAA's needs and goals. CIMSS conducts project reviews as appropriate and convenes a Science Advisory Council to review the CI as a whole annually.
An abbreviated but representative list of the complementary activities planned for the coming year include:
• Maintain routine operational Cryosphere products and improve the Cryosphere product retrieval algorithms as needed;
• Incorporate the RAP model instead of the GFS in the U.S. domain, obtain initial results for modeling mountain wave turbulence, further improve dissemination of product;
• Continue developing methodologies to allow assimilation of water vapor radiance tendencies;
• Continue developing nowcasting tools, which will allow evaluation of future GeoXO instruments;
• Confirm the sub-optimal performance of the current GOES-R Snow Cover and Grain Size algorithm and highlight the capabilities of the adjusted VIIRS single-channel algorithm;
• Successfully complete the GOES-17 Fog Low Stratus Operational Readiness Review and finalize the transition to operations;
• Continue to develop quantitative precipitation estimates and near-surface visibility products in CLAVR-x;
• 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;
• Hold a teacher workshop at the GOES-T launch;
• Continue to develop and release software packages, including new products and upgrades to existing products and capabilities;
• Continue VIIRS on-orbit radiance performance monitoring;
• Continue to support preparation for JPSS-2 launch readiness and advance preparation for JPSS-3 launch readiness;
• Continue to work with users at the Alaska Sea Ice Program to enhance product usability, timeliness, and capabilities;
• Improve ICEFLOES, a short-term sea ice motion forecasting product that predicts future ice configuration based on current ice motion;
• Develop NOAA Fire Website;
• Finish the Polar2Grid software refactoring and add support for more CSPP direct broadcast products;
• Generation of performance estimates of the NOAA Enterprise Cloud Algorithms applied to the METImage simulated data;
• Use synthetic statistic databases and results from the Evaluation Metrics Workshop to develop prototype scorecards for the Short-Range Weather (SRW) and Medium-Range Weather (MRW) applications;
• Continue with the verification and validation of the new infrared sea surface emissivity model and help NCEP with implementation

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 that were published during the reporting period are provided as an appendix. Some noteworthy examples include:

• Liu, Y; Key, J.R.; Wang, X, and Tschudi, M., 2020: Multidecadal Arctic sea ice thickness and volume derived from ice age. The Cryosphere, 14(4), 1325-1345, 2020, https://doi.org/10.5194/tc-14-1325-2020.
Presents a new record of Arctic sea ice thickness and volume from 1984 to 2018 based on an existing satellite-derived ice age product.

• Hyman, D.M.R.; Pavolonis, M.J.; Sieglaff, J. 2021: A novel approach to estimating time-averaged volcanic SO2 fluxes from infrared satellite measurements. Remote Sens.,13, 966. https://doi.org/10.3390/rs13050966
Time-averaged volcanic SO2 flux and lifetime estimation techniques can be successfully modified to accept newly-available hyperspectral IR SO2 data, enabling robust gas monitoring at high-latitude volcanoes in all illumination conditions, including low- or no sunlight conditions. This has the potential to fill a key observational gap in traditionally UV-based monitoring.

• Cintineo, J. L., M. J. Pavolonis, J. M. Sieglaff, A. Wimmers, and J. Brunner, 2020: A deep-learning model for automated detection of intense mid-latitude convection using geostationary satellite images.Wea. Forecasting., 35, 2567-2588, https://doi-org.ezproxy.library.wisc.edu/10.1175/WAF-D-20-0028.1
Research uses deep learning to incorporate the detection of all satellite-based features of intense thunderstorms, mimicking human pattern recognition. The model presented can provide forecasters rapid guidance on evolving severe weather threats day or night, even in the absence of precipitation-sensing weather radar.

• Dzambo Andrew, Mooney M., Handlos Z., Lindstrom S., Hang, A.,Ackerman, S., 2020: An interactive online course in climate and climate change: Advancing climate literacy for non-atmospheric science majors. Bull. Amer. Meteor. Soc., 101, 10, 1–33, https://doi.org/10.1175/BAMS-D-19-0271.1
Presents a course structured to actively engage students in learning about the science of climate change based on a variety of learning techniques.

CIMSS researchers regularly present the results of their research at conferences, workshops, meetings and symposia. During the reporting period, CIMSS researchers gave more than 40 presentations at international conferences. Many meetings were delayed or cancelled due to the pandemic, thus the number of presentations is less than in previous years. A complete list of CIMSS presentations is provided as an appendix. Some noteworthy examples include:

• Lindstrom, S. S., T. J. Schmit, J. J. Gerth, E. Lau, N. Eckstein, 2020: Tailoring National Weather Service Training to Serve the

PRODUCTS *(cont'd)*

30. Technologies or techniques

• New technique for assimilating multi-spectral ozone retrievals was developed and their impact assessed;
• Methodology for combining Arctic satellite composite imagery;
• Advanced processing strategies for enhanced atmospheric motion vectors (AMVs) around hurricanes;
• Parallax correction training webapp: http://cimss.ssec.wisc.edu/goes/webapps/parallax/overview.html
• ABI data quality monitoring pages: http://cimss.ssec.wisc.edu/goes-r/abi-/16band_mainmenu.html
• ABI data quality statistics monitoring page for GEO-GEO comparisons: http://cimss.ssec.wisc.edu/goes-r/abi-/band_statistics_imagery.html
• VIIRS, ABI, AHI, joint ABI/VIIRS, joint AHI/VIIRS, and composite VIIRS flood products;
• New short-term forecast model employing strictly satellite retrievals for quick predictions of near-term significant weather environments using real observations;
• New assimilation techniques to exploit more information from infrared sensors in weather forecast models;
• New global-scale water quality products for coastal and inland waters. This work will be leveraged through potential grants from UW SSEC, World Bank and Google Earth Engine.

31. Inventions, patent applications, and/or licenses

• RealEarth™: a data discovery and visualization platform developed by scientists at SSEC and CIMSS
• GEOSphere

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

PRODUCTS *(cont'd)*

32. Other products

• Real-time satellite-derived analyses for tropical cyclone monitoring via the CIMSS TC web site;
• ABI flood product available on dedicated RealEarth server at https://floods.ssec.wisc.edu/?products=River-Flood-ABI .
• ABI flood product available in geotiff, shapefile, and AWIPS format;
• Near-real-time ice motion products at an ice motion distribution server maintained by the Geographic Information Network of Alaska for analysts at the Alaskan Ice Program;
• Automatically-updating webpage of cryosphere products;
• Arctic satellite composite imagery;
• Contributions to the open source SatPy Python libraries.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

Please see attachment of full list of individuals that work on the new CIMSS Cooperative Agreement.

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?

Nothing to report.

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
- Chinese Meteorological Agency (CMA)/NSMC
- CSIRO
- DoD/JTWC
- ECMWF
- EMC
- EUMETSAT
- ESA
- FEMA
- Geographic Information Network of Alaska (GINA)
- Honolulu WFO
- JMA
- JAXA
- L3Harris
- Logistikos
- Michigan Tech University MTRI
- NASA
- NCAR
- National Hurricane Center
- National Weather Service
- NOAA Ocean Prediction Center (OPC)
- NOAA/STAR
- NOAA/OSPO
- NOAA/ASPB
- North Central River Forecast Center
- Office of Naval Research

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

36. Have other collaborators or contacts been involved?

• FAA
• MIT Lincoln Labs
• NASA/GMAO
• NOAA/NCEP/EMC
• NOAA/NESDIS/STAR/ASPB
• NOAA/NESDIS/STAR/JPSS
• CMA/NSMC
• ECMWF
• UKMO
• AquaWatch Secretariat, Dr. Merrie Beth Neely on programmatic issues
• Paul DiGiacomo and Emily Smail at NOAA

IMPACT

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

CIMSS provides end-to-end support 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 used in operational NWP models at more than 10 meteorology centers throughout the world to improve weather forecasting;
• Advancements in storm structure and strength have improved hurricane forecasting;
• Volcanic cloud detection, characterization, and tracking have been advanced through upgrades to Version 3 VOLCAT and real-time deployments of the VOLCAT Event Dashboard and Volcanic Radiative Power Time Series Monitoring Dashboard;
• Fusion methodologies for assimilating collocated imager and sounder data in NWP provide the scientific basis for optimally planning imagers and sounders together on the same platform for better utilization.
• Bias corrections to all-sky infrared brightness temperatures facilitate assimilation into numerical weather prediction models;
• 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 supported 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 developed and applied new 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;
• 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 advances 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;
• A new STAR ocean infrared emissivity model is aiding the assimilation of infrared sensors into NWP;
• Next-generation sensors (e.g., ICI) are improved through the development of realistic proxy global proxy datasets;
• CIMSS has advanced techniques for assimilating satellite chemical data within the Next Generation Global Prediction System;
• GOES-R trainings developed at CIMSS serve the community by providing hands-on activities that engage trainees in case studies geared toward their disciplines and geographical areas;
• The Arctic Composite satellite imagery from both polar-orbiting satellite and geostationary satellite imagery supports weather forecasting and monitoring activities across the Arctic Ocean and adjacent continents;

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

To further our objective of supporting end-to-end utilization of meteorological information and address the NWS mission to "protect life and property," 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. In addition, CIMSS recently collaborated with the Association of State Floodplain Managers (ASFPM) and The Polis Center at Indiana University, Purdue University – Indianapolis to develop a Flood Recovery Risk Index. This index identifies locations in the Toledo, Ohio area that will have longer recovery times after a flooding event and is being used by planners to understand the spatial patterns of risk for increased resilience building activities. In early 2019, we also completed a project with the Georgia Department of Natural Resources to model the impacts of flooding and hurricane winds along 11 coastal communities–finding that the dollar losses due to such events could be between three and eight times higher than they are for similar events today.
Each of CIMSS' external collaborations serves a unique purpose. Some other examples of impacts on other disciplines that have resulted from engaging these groups include:
• Improved methods for communicating warnings through community engagement (social science);
• NWS, other professionals, students, and the general public benefit directly from trainings and improvements made to imagery, especially GOES-17;
• General demonstrations of novel applications of deep learning;
• The freely available software provided by CIMSS has multi-disciplinary uses that extend beyond meteorology;
• CIMSS research has demonstrated blended advection (morphing) methodologies in an operational meteorological application;
• CIMSS data visualization tools have replaced some licensed graphics packages to expand their utility beyond the satellite community;
• CIMSS has researched and implemented improved data archival and search tools that have expanded the use of GOES and JPSS data beyond primary users and have applications to other 'Big Data' fields;
• CIMSS researchers have worked with water resource managers to better understand their needs and provide new tools for the monitoring and management of water quality;
o NOAA River Forecast Centers are using products to assess current floodwater conditions in areas not covered by river gauges;
o Using similar products, FEMA is able to assess floodwater conditions to estimate the scale of a flood;
• 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;

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. Here are a few examples from the reporting period:

Scholarships for Students
• Verner E. Suomi Scholarship
Three accomplished students awarded Suomi Scholarship
The scholarship is competitively awarded by CIMSS to students who exhibit strong aptitude for physical sciences.
• William L. Smith Graduate Scholarship
Nuo Chen to receive William L. Smith Graduate Scholarship
Offered through NOAA and CIMSS, the scholarship advances NOAA's research and education mission. Chen continued her research and studies in year two of the scholarship.
.
2020 Graduates
CIMSS investigators advise graduate students conducting research on a range of NOAA-related topics. During the reporting period, 3 students advised by CIMSS investigators received MS degrees and 4 received PhDs, all through the Department of Atmospheric and Oceanic Sciences. Some examples include:
• Alyson Douglas (now a post-doc at Oxford University): Analyzed satellite cloud and aerosol products to understand the impacts of aerosol-cloud interactions on climate.
• Andrew Dzambo (now a post-doc at OU-CIMMS): Developed cloud and precipitation products from airborne instrumentation during the ORACLES field campaign and used them to characterize warm cloud structures in the southeast Atlantic.

Scientist Exchange
• During the reporting period, CIMSS hosted 15 scholars from China, German, Japan, Korea, and Taiwan. Ranging from one month to two years in duration, these exchanges provide opportunities for scientists from international remote sensing organizations to collaborate with CIMSS researchers on projects of mutual interest.

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 satellite meteorological heritage at CIMSS 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 Students
During the reporting period, CIMSS researchers advised 21 graduate students and several undergraduate interns. Examples of CIMSS undergraduate and graduate student research projects include:
• Callyn Bloch: As a graduate student in Life Science Communications, Bloch began working with the communications team at SSEC to gain experience in the field. Her work has been funded by CIMSS.

• Anne Sledd and Chuck White: Student research: Contributions to climate solutions

CIMSS has also provided experiential research opportunities to undergraduate and graduate students – in this instance, research related to clouds and their role in weather and climate variability:

• R. Adomako, a student at New York City College, completed a 12-week NOAA Experiential Research and Training Opportunity (NERTO) internship with NOAA ASPB scientist Tim Schmit. The internship topic was "Using machine learning to identify GOES-17 ABI instrument imagery artifacts."

Advancement

• A series of recent gifts to CIMSS through the University of Wisconsin Foundation is providing funding for undergraduate research experiences and leading to research support for graduate students.
Other Examples of CIMSS Teaching and Education Impacts
• Undergraduate student interns at CIMSS have gained experience in data processing, analysis, and visualization;
• 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;

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

• Three members of our organization are now using GIS in daily activities;
• Improved weather forecasts relating to national safety and commerce;
• All AquaWatch objectives are directed towards the construction of a "Knowledge Hub." The Knowledge Hub will be 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 can be viewed as a compilation or 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;
• Storage was added to the Satellite Data Services archive to allow additional storage of L1 and L2 GOES data for use by CIMSS scientists

IMPACT *(cont'd)*

42. What was the impact on technology transfer?

• Wind algorithms and subsequent improvements developed at CIMSS are transferred to NOAA and vice versa;
• 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;
• Validation codebase is well established and will be used to validate future JPSS VIIRS instrument volcanic ash EDRs;
• NOAA-20 VIIRS volcanic ash EDR was granted Full Maturity status;
• We are transferring ProbSevere AWIPSII plug-in capabilities to NWS operations;
• New visualization capabilities were developed for the ProbSevere AWIPSII plug-in for NWS forecasters and are being transferred to NWS operations within a future release of AWIPSII;
• Applied research to improve NEXRAD QPE for lake-effect snow events and develop a GOES lake-effect snow QPE product 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;
• We deliver daily remote sensing data to OU CIMMS;
• We deliver additional information during severe weather events related to cloud-top signatures and their translation to surface features;
• Greater understanding on the best approaches for forecasting flash flooding;
• Software changes to CLAVRx will be migrated to NOAA's ASSISTT software framework;
• There may be opportunity to transfer knowledge learned in developing AI-ProbSevere models to international entities, as some of them rely only on geostationary satellite data.

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

• Improved hurricane forecasts lead to fewer casualties and lower economic losses;
• Improved accuracy for detection of Volcanic Ash for commercial aviation avoidance;
• Improved warning of aviation atmospheric turbulence hazards;
• Deployment of the turbulence model into rapid, global computation;
• Improving short-term forecasts and severe winter weather warnings for the general public;
• Enable use of satellite data in the public and private sectors for time-critical applications such as forecasting and modeling, severe weather monitoring and alerts, space weather;
• Provide timely JPSS satellite-derived burn intensity estimates to enable NWS-WFOs to craft accurate warnings and support their emergency management and response partners;
• The BRIDGE map has the potential to support emergency operations in fire-scarred areas by saving lives with earlier warnings;
• Improved air quality prediction;
• A demonstration of the commitment for the NWS to be effective stewards of federal resources that will help the NWS best allocate its resources to best serve all sectors of society;
• Short courses developed for the US Broadcast Meteorology community provided broadcasters a first introduction to GOES-R ABI and GLM. The broadcasters are the voice of meteorology for most Americans through TV news and social media;
• Through social media, NOAA reaches out to the public with frequent postings highlighting interesting GOES ABI images that were either generated at CIMSS or CIRA, or using tools generated at CIMSS;
• The public continues to show a high interest in ABI imagery, especially color imagery. This imagery is a great assistance to meteorologists (NWS, broadcasters) in getting the public to pay attention to hazardous weather events.

IMPACT *(cont'd)*

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

0 , NA

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

The past year resulted in a systematic change in the CIMSS approach to research and education due to the global pandemic. All research activities shifted from mostly occurring collocated within a building on campus to isolated, remote work. Education, advising, and outreach shifted from in person to virtual. Despite these changes in modality, CIMSS was able to accomplish the vast majority of its stated objectives.

Other changes in proposed approaches include:

• The original proposal intended to purchase a Quorum demodulator. In the last year, more ground stations have begun to use a Novra S400 demodulator. A Novra S400 was acquired and is being tested. The demodulator will also be tested with CSPP-GEO.
• Primary microwave data source switched from NUCAPS to MiRS due to multi-platform support and better spatial resolution.
• Instead of near real-time subscription from CLASS used for data collection, a local, robust DB feed of MiRS data is used. Data availability latency was significantly decreased from 2-3 hours down to 10-30 minutes following MiRS swath processing.

CHANGES/PROBLEMS *(cont'd)*

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

• In rare cases, COVID-19 impacts slowed down research progress;
• COVID-19 significantly impacted communicating the results of CIMSS research activities over the past year but CIMSS scientists participated in virtual meetings to maintain channels to users and the research community;
• The ABI focal plane module temperature is monitored every second and stored in files generated once per hour and that cannot be obtained via GRB (direct broadcast). We frequently either get files late or in some cases, files never arrive. This data is important to users monitoring our web page for GOES-17 LHP problems so to mitigate this we added to the plots the FPM temperature that is stored in the L1b GRB files (this is less frequent but still useful);
• Testing of antenna components has been slower during the pandemic. Hardware should still be able to be purchased prior to launch of GOES-T;
• We have found it impossible to obtain large statistical databases from external model developers; therefore, we have decided to generate a synthetic database that contains a sufficiently large number of metrics and variables to explore the alternative scorecard methods.

47. Changes that had a significant impact on expenditures

• The ongoing pandemic severely curtailed travel during the past year;
• University mandated furloughs, changes in child care needs, and other impacts on individuals' schedules, reduced FTEs;
• The Novra S400 demodulator is less expensive, and would allow for additional storage to be purchased.

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

Nothing to report

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

Almost all CIMSS research activities shifted from the Atmospheric, Oceanic, and Space Sciences building at UW-Madison to telework from home during the pandemic.

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 provided end-to-end support of meteorological satellite applications from instrument calibration to data assimilation to training and outreach. CIMSS further supported new initiatives in community modeling, novel artificial intelligence and machine learning approaches for maximizing the information yielded by NOAA assets, impact assessment and social sciences, and defining next-generation environmental observing systems. Our efforts resulted in standardized, curated, and evaluated datasets of clouds, water vapor, cryosphere, atmospheric motion, and atmospheric composition that 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 contributed significantly to the calibration, validation, and independent verification of NOAA's geostationary and low-earth orbiting satellites (Suomi-NPP, NOAA-20, GOES-16, and GOES-17) and associated data products. A key 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. CIMSS also contributed to implementing and testing of several operational GOES-16 and GOES-17 algorithms and trained NWS forecasters and other GOES users how to use them. CIMSS developed prototype fusion methodology to generate high resolution sounder imagery. Another key outcome of CIMSS data processing and visualization research is the Geostationary Community Satellite Processing Package (CSPP Geo) that 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 research has also yielded a suite of advanced high-impact weather products that support the NWS mission to protect lives and property.

CIMSS scientists are dedicated to sharing their work and results with others. In addition to 18 peer-reviewed papers published in 2019-20, CIMSS and SSEC maintain several web sites for external audiences beyond the news stories sites noted earlier (in http://www.ssec.wisc.edu/news/articles), 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/ and http://www.ssec.wisc.edu/data/

CIMSS also continued its support of NOAA's education and outreach goals with involvement in K-12, undergraduate, graduate and professional training. CIMSS awarded three scholarships to incoming freshmen, supported undergraduate interns, awarded the first William Smith Graduate Scholarship, supported 21 graduate students working on NOAA research with CIMSS and ASPB scientists, and hosted post-doctoral researchers. While the outcomes of these efforts are realized over the course of several years to reinforce the pipeline of talent into the NOAA enterprise, they are 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 remote sensing applications enabling NOAA to meet the nation's weather and climate needs

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.