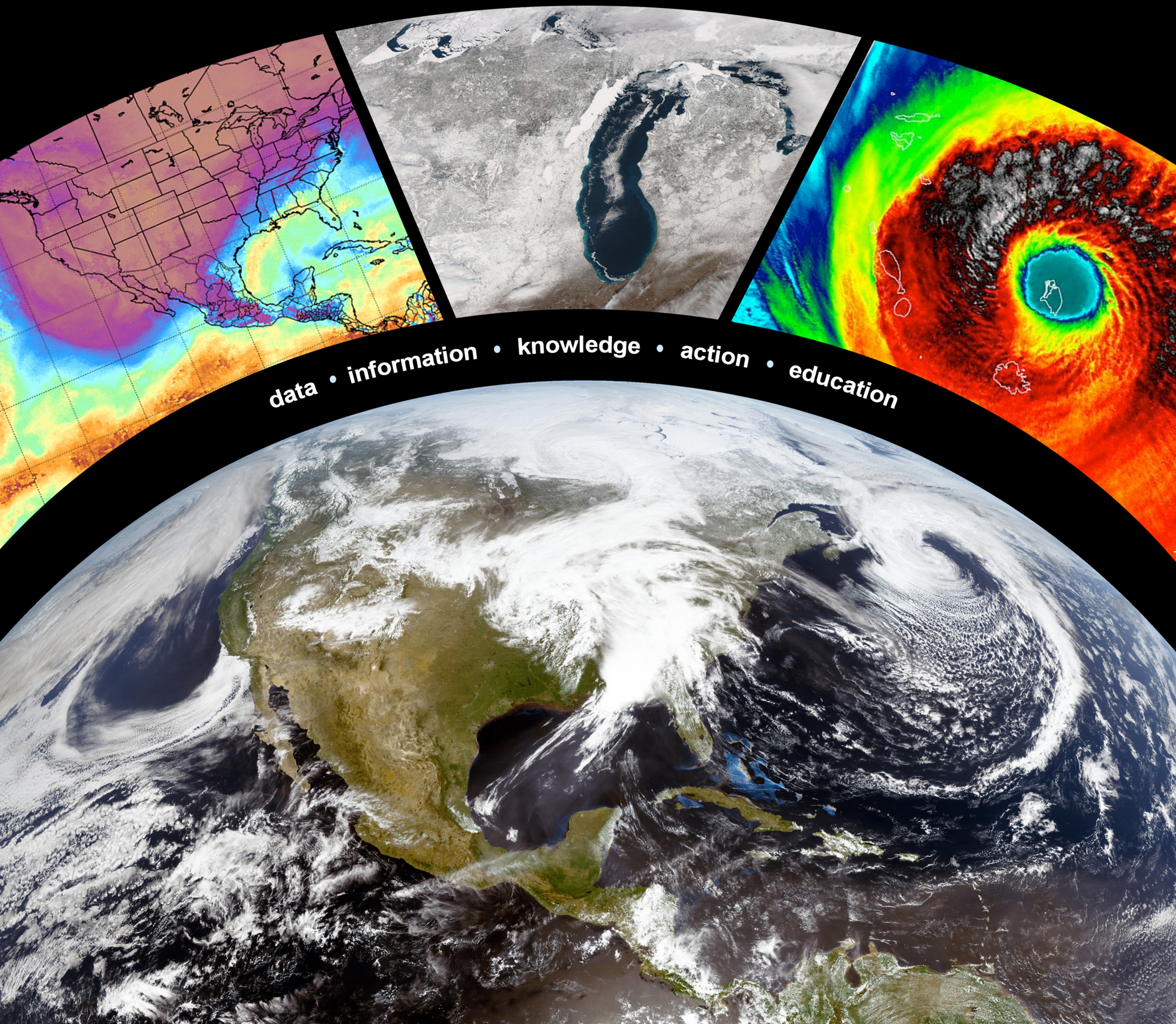
Proposal for the continuation of The Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin–Madison

Principal Investigator: Dr. Tristan L'Ecuyer

Total Proposed Cost: $150,000,000

For the Period: 1 July 2020 to 30 June 2025



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Abstract

The University of Wisconsin–Madison (UW) proposes to build on four decades of excellence in environmental satellite remote sensing and applications to host a NOAA Cooperative Institute (CI) for satellite studies to support NOAA's mission to "understand and predict changes in climate, weather, oceans, and coasts" and "share that knowledge and information with others." This CI will conduct research in four theme areas: (1) *Satellite Research and Applications*, to support weather analysis and forecasting by developing, evaluating, and analyzing new and innovative satellite products and guiding their transition into NOAA operations, (2) *Satellite Sensors and Techniques*, to characterize sensor performance, provide long-term calibration, specify instrument characteristics for future satellite imagers and sounders, derive data products that support situational awareness and meteorological applications using cloud computing and machine learning approaches, (3) *Environmental Models and Satellite Data Assimilation*, to increase the utilization of satellite data in nowcasting, operational weather analysis and prediction, and atmospheric chemistry models through advanced assimilation techniques, and (4) *Outreach and Education*, to engage the workforce of the future in understanding and using environmental satellite observations for the benefit of an informed society.

This proposal outlines a set of complementary activities that build upon the established practices and procedures of the current Cooperative Institute for Meteorological Satellite Studies (CIMSS) to support NOAA throughout the life-cycle of satellite meteorology from concept and design to applications and public engagement. Our overarching philosophy is to provide a single center that integrates end-to-end support of meteorological satellite applications that includes instrument design and demonstration, sensor calibration, data product development, validation, archival, and dissemination, research-to-operations (R2O), data assimilation, training, and outreach as well as 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. Housed within the Space Science and Engineering Center (SSEC) and collocated with the NOAA/NESDIS Advanced Satellite Products Branch (ASPB) and the UW Department of Atmospheric and Oceanic Sciences (AOS), the UWCIMSS has access to state-of-the-art computing facilities, data infrastructure, computational and engineering expertise, instrumentation, project management support, outstanding education, outreach, and communications programs, and graduate students at a world-class, degree granting education program in atmospheric and oceanic sciences. With these assets and its strong partnerships with other domestic and international institutions and agencies, UWCIMSS is an established center of excellence in satellite remote sensing that will continue to enable NOAA to meet the nation's weather and climate needs of today and tomorrow.

Proposal for the continuation of The Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin–Madison

Executive Summary

This proposal builds on four decades of successful partnership between the National Oceanic and Atmospheric Administration (NOAA) and the University of Wisconsin–Madison (UW) to continue a Cooperative Institute (CI) focusing on satellite studies related to weather and environmental analysis. The UW-Cooperative Institute for Meteorological Satellite Studies (UW–CIMSS) will conduct end-to-end satellite research and processing in support of NOAA's mission to meet the nation's weather needs. The effort is organized around four central themes: (1) Satellite Research and Applications, (2) Satellite Sensors and Techniques, (3) Environmental Models and Data Assimilation, and (4) Outreach and Education. Building upon strong existing collaborations with the National Environmental Satellite, Data, and Information Service's (NESDIS's) Center for Satellite Applications and Research (STAR) and its Advanced Satellite Products Branch (ASPB) UW–CIMSS will address the component topics within these broad themes by 1) serving as a hub to foster collaborative research between the university, NOAA, other agencies, and non-governmental and international partners; 2) bringing extensive scientific, education, and outreach expertise to bear on satellite research of relevance to NOAA; and 3) engaging and training the future NOAA workforce in weather and satellite remote sensing.

As a CI within the Space Science and Engineering Center (SSEC), an interdisciplinary research center within the UW graduate school, UWCIMSS has access to unique resources including powerful on-site computing facilities, a satellite data ingest and archival center, instrumentation and engineering expertise, an experienced Outreach and Education team, and a dedicated Communications team. This infrastructure will help the ASPB and other NOAA offices meet their objectives to provide satellite products to support situational awareness, accurate weather forecasting, and transitioning research findings to operational centers. In addition, the close association between UW–CIMSS and the UW Department of Atmospheric and Oceanic Sciences (AOS), a strong atmospheric science education program offering undergraduate and graduate degrees, provides a conduit for engaging students and postdoctoral scientists in NOAA-funded research. UW–CIMSS will leverage these resources to support the following broad activities under its four guiding themes:

Theme 1: Satellite Research and Applications

- Develop and test new retrieval algorithms for application to significant weather events;
- Provide operational upgrades for JPSS and GOES-R series atmospheric motion vector (AMV) products;
- Develop and optimize objective schemes incorporating data from multiple satellite platforms to more accurately analyze tropical cyclone intensity and structure;
- Support aviation applications with advanced satellite-based volcanic ash and turbulence products;
- Implement a global geostationary fire monitoring system, based on the GOES-R ABI fire algorithm for improved fire detection and characterization;
- Evaluate and enhance satellite-based estimates of cryosphere properties;
- Improve methods for detecting clouds and estimating their properties from satellite;
- Develop multi-platform fused climate data records for clouds, fires and sea/lake ice;
- Transition ProbSevere to operations;
- Evaluate the accuracy of probabilistic wind, hail, and extreme precipitation forecasts, and improve their performance;
- Continue to demonstrate product applications with partners at AWC, NHC, and others;
- Better characterize retrieval uncertainties to increase the use of satellite data in models;
- Increase the societal benefits of satellite and weather information through social science, public engagement, and collaboration with other agencies.

Theme 2: Satellite Sensors and Measurement Techniques

- Utilize UW–CIMSS/SSEC's extensive suite of sub-orbital instruments to assess the performance and calibrate satellite sensors and inform the design of next-generation low-earth orbiting and geostationary satellite sensors;
- Sustain ground-based measurements at long-term climatological validation sites and participate in targeted field campaigns to validate satellite retrieval products;
- Advance and expand the use data fusion techniques to increase the temporal and spatial resolution of satellite soundings and test their impact in forecast models;
- Continue efforts to mitigate the effects of the GOES-17 Loop Heat Pipe (LHP) anomaly;
- Apply revolutionary AI/ML approaches to maximize the benefits of NOAA environmental satellites for characterizing the physical environment.

Theme 3: Environmental Models and Data Assimilation

- Enhance approaches for assimilating thermodynamic and dynamic information provided by hyperspectral sensors and geostationary imagers;
- Increase the use of all-sky infrared brightness temperatures in a range of data assimilation systems and environmental modeling configurations by developing new bias correction methods, improving observation error characterization, and advancing QC methods;
- Improve radiance assimilation over land surfaces by separating surface and atmospheric contributions;
- Explore the assimilation of satellite observations sensitive to soil moisture and vegetation properties in NWP and land surface models;
- Extend the RAQMS Aura Reanalysis beyond 2016 using the next generation of operational trace gas retrievals;
- Advance innovative model verification methods to support operational model development;
- Conduct regional OSSE/OSE experiments to assess the impacts of advanced infrared sounders and imagers onboard geostationary and Cubesat satellite platforms.

Theme 4: Education, Training, and Outreach

- Refine and improve educational activities that facilitate the use of satellite observations from all NOAA missions in K-12 Earth science education;
- Expand access and usage of the community Climate Digest;
- Engaging and nurturing a diverse pool of prospective STEM students by expanding the highly-successful satellite virtual science fair to include all NOAA and NASA missions;
- Maintain the CIMSS website and continue the CIMSS Satellite Blog;
- Conduct in-person training visits to NWS forecast offices and run remote sensing schools;
- Continue joint education activities with STAR's CREST;
- Expand the number of distance learning modules aimed at helping to prepare tomorrow's forecasters for the next generation of meteorological satellites.

These activities, conducted in collaboration with NOAA scientists, contribute to NOAA's mission by supporting the product research and development needs for the nation's operational satellites. Upon successful selection for continuation, UW–CIMSS will work closely with NESDIS to refine and adapt specific research projects to maximize our contribution to NOAA's. Thus, this CI proposal describes activities in broad terms, which will be refined collaboratively with STAR and ASPB upon selection for continuation.

1. Introduction

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) embodies four decades of successful collaboration in environmental satellite research between the National Oceanic and Atmospheric Administration (NOAA) and the University of Wisconsin–Madison (UW). Located at the birthplace of satellite meteorology, CIMSS was formed through a Memorandum of Understanding between NOAA and UW in 1980. UW–CIMSS has continuously served the common interests of NOAA and the UW to meet societal needs for timely, accurate, and reliable satellite data in order to support short term weather forecasting, identify atmospheric hazards, and monitor the Earth-atmosphere system ever since.

The collaborative relationship between NOAA and UW upon which CIMSS is built has provided outstanding benefits to the atmospheric science community and to the nation by advancing the use of satellite, aircraft, and ground-based remote sensing measurements in research and applications. It has also furnished a framework for developing a robust education and outreach program to train students, professionals, and other stakeholders in the use of environmental satellite data. Through close interactions with the UW Department of Atmospheric and Oceanic Sciences (AOS) and the NOAA NESDIS Center for Satellite Applications and Research (STAR) Advanced Satellite Products Branch (ASPB), CIMSS:

- *Fosters collaborative research among NOAA, NASA, the University and the Private Sector in those aspects of atmospheric and earth system science which exploit the use of satellite technology;*
- *Serves as a center at which scientists and engineers working on problems of mutual interest can focus on satellite-related research in atmospheric and earth system science; and*
- *Stimulates the training of the next generation of scientists and engineers in the disciplines involved in atmospheric and earth sciences.*

UW–CIMSS achieves these objectives by conducting an integrated program of research and education activities that center on maximizing the information gleaned from environmental satellite data through innovative computational methods, value-added data interpretation, and effective communication to users and stakeholders, including the general public. Our research increases the quality and understanding of satellite remote sensing datasets and supports their application to numerical weather and air quality predication, analysis of the cryosphere, volcanic, tropical cyclone, wildfire, and severe weather detection, and environmental analyses. This research is organized under four themes:

1. *Satellite Research and Applications*
2. *Satellite Sensors and Measurement Techniques*
3. *Environmental Models and Data Assimilation*
4. *Outreach and Education*

Working directly with ASPB scientists stationed in Madison, Wisconsin, and in collaboration with NOAA line offices, UW–CIMSS has developed and improved satellite retrievals of atmospheric humidity and temperature structure, surface properties, including snow and ice cover, clouds, atmospheric motion, radiation, fire characteristics, volcanic ash, tropical cyclone track/intensity, and severe weather probabilities. We work with National Weather Service Forecast Offices (NWSFOs) to provide situational awareness and the National Centers for Environmental Prediction (NCEP) Environmental Prediction Center (EMC) to assimilate this information into Numerical Weather Prediction (NWP) models with the goal of improving short-range forecasting applications and to support rapid and accurate decision-making. Our tropical cyclone research team collaborates regularly on new product development with the Tropical Prediction Center (NCEP/TPC) in Miami. We also work directly with the Storm Prediction Center (NCEP/SPC) and the National Severe Storms Laboratory (NSSL) in Norman, OK on satellite applications to severe weather forecasting and collaborates with the Aviation Weather Center (NCEP/AWC) in Kansas City on aviation safety projects that utilize weather satellite data.

To demonstrate the potential of new observing systems, UW–CIMSS works with partners within the UW Space Science and Engineering Center (SSEC) to design and test advanced instrumentation to pave the way for future advances in satellite technology. Our research played a pivotal role in establishing specifications for the Advanced Baseline Imager (ABI) aboard the GOES-16 and GOES-17 satellites, and we are actively contributing to the design of the next-generation geostationary and polar orbiting platforms through engineering studies, participation in sub-orbital field campaigns, and observing system simulation experiments (OSSEs). UW–CIMSS is also pioneering novel applications of machine learning (ML) and artificial intelligence (AI) to extract actionable information from vast satellite datasets generated by contemporary satellite platforms.

At the core of our mission is education: educating students, training professionals, and engaging the public. UW–CIMSS provides hands-on experiences for high school and undergraduate students that increase exposure to NOAA research. Through active participation in the NOAA Pathway and Hollings Scholar programs, we serve as a conduit for these students to pursue career paths that align with NOAA. UW–CIMSS and ASPB scientists also mentor AOS graduate students on research projects that address NOAA needs while satisfying UW–Madison degree requirements. Based on this positive experience, many such students go on to join the NOAA workforce and supporting contractors. Finally, UW–CIMSS increases satellite literacy by conducting extensive training programs for users at NWS, NCEP, external agencies, and international satellite organizations as well as supporting an active outreach program to engage the general public assuring that our satellite products will be used to full advantage.

UW–CIMSS plays a unique role to NOAA as an academic partner, advisor, and link to UW–Madison students and researchers. As a long-term partner of NOAA, CIMSS helps serve as part of the NESDIS 'corporate memory'. For example, original UW–CIMSS staff associated with GOES VAS (the first geostationary sounding instrument) and GOES-8/14 design, testing, and checkout are now assisting with similar activities for GOES-16/17/T/U. On the polar orbiting satellite side, our decades long work with the TOVS and ATOVS sounders and the aircraft HIS (High spectral resolution Interferometer Sounder) and scanning-HIS are aiding in the development of applications for the CrIS (Cross-track Infrared Sounder) hyperspectral sounder on Joint Polar Satellite System (JPSS) and the Suomi National Polar-orbiting Partnership (NPP). In addition to bringing irreplaceable institutional knowledge to these new GOES and JPSS programs, our staff mentor the next generation of early career scientists who will support future partnerships between UW–CIMSS and NOAA.

2. Results from Prior Research

UW–CIMSS is an internationally-recognized center of leadership and innovation in the field of satellite remote sensing. From fundamental research in remote sensing techniques, to sensor innovation, to applications in NWP, to educating and informing users and the public, UW–CIMSS has a long history of transformative contributions to NOAA's environmental satellite programs that have directly benefited society. The most recent award associated with this work is titled "The Continuation of the Cooperative Institute for Meteorological Satellite Studies (CIMSS)," funded by NOAA, award number NA15NES4320001, under Principal Investigators Steven Ackerman and Tristan L'Ecuyer, for the period of July 1, 2015 through June 30, 2020, at an award ceiling value of $63,000,000.00.

2.1 Research

UW–CIMSS has a long legacy of advancing the science and applications of satellite remote sensing. Our research covers all aspects of satellite meteorology including: end-to-end demonstration of new observing system capabilities, sensor calibration, algorithm development, retrieval validation, data visualization, archival and dissemination, and applications, including model verification and data assimilation. We have played a key role in defining instrument requirements for past, current, and future geostationary and polar-orbiting satellite systems, including pioneering advanced hyperspectral infrared sounder technology and applications. In addition, UW–CIMSS scientists have developed an extensive suite of algorithms for extracting information from raw satellite data including geophysical variables such as surface emissivity, sea ice, tropospheric humidity/temperature profiles and stability, winds, cloud properties, and atmospheric constituents (e.g., total column ozone and sulfur dioxide from volcanic eruptions). UW–CIMSS produced the first 30+ year archive of all GOES data, developed the first sea surface temperature and biomass burning monitoring products, created the longest existing satellite cloud climatology from High Resolution Infrared Radiation Sounder (HIRS), and established new paradigms for identifying severe weather (e.g., tropical cyclones and thunderstorms) from geostationary and polar orbiting satellite data. Our researchers have also contributed to the assimilation of these products in NWP models leading to documented improvements in forecast skill.

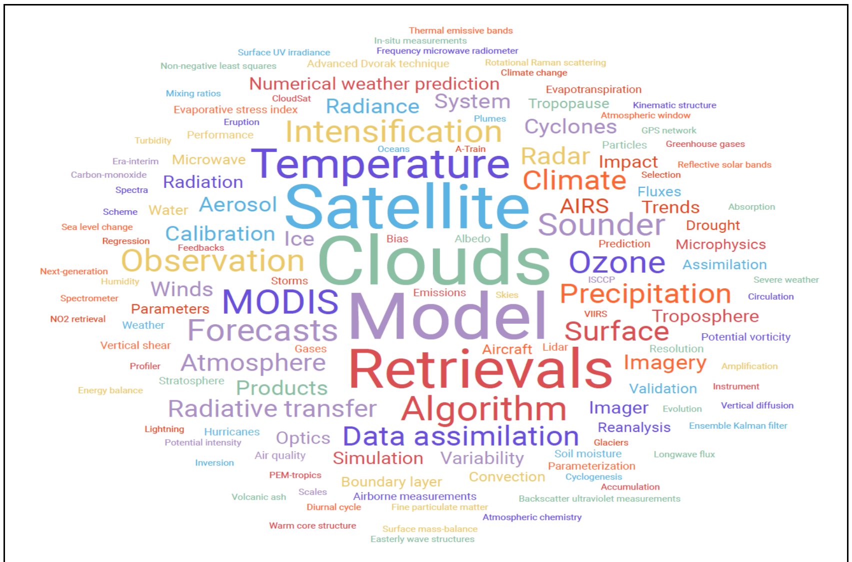

FIGURE 2.1.1: Word cloud of Web-of-Science (WoS) keywords from all CIMSS articles published in 2017 indicating areas of emphasis in published work. Word size indicates the frequency with which terms occur. WoS keywords were simplified to remove redundancies, improve clarity and focus, and minimize unimportant words.

The many research themes actively pursued within UW–CIMSS are depicted as a word cloud of keywords and subjects from all our publications in 2017 in Figure 2.1.1. These keywords reflect the CI's institutional mission and demonstrate our extensive record of contributions to the body of scientific knowledge in these themes. UW–CIMSS researchers have authored more than 720 peer-reviewed papers and thousands of conference papers between 2009-2019. A list of current projects at UW–CIMSS is provided in Appendix E.

2.2 Collaborative Activities with NOAA

UW–CIMSS has extensive collaborations with NOAA and NWS offices as well as collocated NESDIS ASPB researchers. ASPB and UW–CIMSS scientists have played a key role in the checkout of the new GOES-16/17 and JPSS instruments and products, developed and delivered software for processing and visualizing NOAA satellite data and products, and worked with NCEP to assimilate radiances, commercial aviation soundings, and satellite-derived atmospheric motion vectors into operational forecast models. We also collaborate with ASPB on numerous research projects such as assessing changes in Arctic climate and global cloud cover over the past two decades using satellite observations. In addition, our researchers work with both ASPB and NOAA line offices to transition results from research applications to operations. Examples include implementing new probabilistic metrics for severe weather (ProbSevere) and for identifying aviation hazards due to volcanic ash (VolAsh) and Fog and Low Cloud (FLC). In fact, one measure of our strong relationship with NESDIS is that more than two dozen UW–CIMSS research products have become operational within NOAA. In addition, more than 30% of CIMSS peer-reviewed publications are co-authored with a NOAA scientist, a further testimony to the strength of the NOAA/CIMSS collaboration.

2.3 Education

UW–CIMSS has developed training materials covering the spectrum of satellite data users from middle-school students through professionals (Section 3.3). Through this life-cycle of user-engagement, we have created a pipeline for young scientists to pursue careers in NOAA. Starting with the CIMSS GOES-R Virtual Science Fair, middle school students are exposed to the exciting field of satellite meteorology. High school students are engaged again via our STEM summer camps, the new Tech Camp, and the Suomi Scholarship awarded to graduating high school students interested in meteorology or related fields. The pipeline continues through our strong relationship with the AOS graduate and undergraduate programs as well as hosting NOAA Pathway and Hollings Scholars in AOS. Through these programs and opportunities, we are better able to recruit top students to be advised by CIMSS researchers creating a pipeline into the NOAA workforce including the opportunity to intern at local NWS WFOs. To date, UW–CIMSS scientists have directly supervised 102 Master's and 45 Ph.D. students and, in the past two years, three UW AOS graduates were hired into NOAA civil servant positions.

Our efforts to extend our educational reach beyond the UW–Madison have also benefitted countless students and colleagues worldwide. Examples include classes taught at the Department of Applied Physics at Curtin University of Technology in Perth, Australia, a cooperation with Nanjing Information and Technology University in China, and guest teaching at NOAA CESSRST (the NOAA Center for Earth System Sciences and Remote Sensing Technologies, a minority serving institution) in New York City; as well as mentoring visiting scholars. UW–CIMSS has partnered with NOAA and another CI at Colorado State University to develop and implement an extensive suite of online training materials including Massive Open On-line Courses (MOOCs, https://www.ssec.wisc.edu/news/articles/7129) and led in-person workshops for professional users including NWS personnel through the VISIT and SHyMet programs.

2.4 International Coordination

UW–CIMSS is an internationally-recognized leader in environmental satellite research and applications as demonstrated in the letters of support in Appendix B. We actively support the use of NOAA satellite data by international satellite agencies and weather prediction centers across the world including but not limited to the European Space Agency, the Japan Aerospace Exploration Agency (JAXA), the European Centre for Medium-Range Weather Forecasts (ECMWF), the UK Met Office, and the Taiwan Central Weather Bureau (TCWB). UW–CIMSS has developed and distributed direct broadcast processing packages for TOVS (ITPP), ATOVS (IAPP), and MODIS/AIRS (IMAPP); provided free online access to textbooks and other training materials; and led several international efforts to coordinate meteorological satellite data across platforms including active participation in the International TOVS Working Group, the World Meteorological Organization's (WMO) Expert Team on Observational Data Requirements and Redesign of the Global Observing System (GOS), the Global Space-based Inter-calibration System (GSICS), and the next-generation International Satellite Cloud Climatology Project (ISCCP). Scientists at UW–CIMSS serve on a number of international committees including the Coordination Group for Meteorological Satellites (CGMS) and the Committee on Earth Observing Systems (CEOS). The partnerships, data access, and knowledge exchange afforded by these activities have direct benefits to NOAA's mission to serve society's needs for weather and water information, understand climate variability, and provide critical support for NOAA's mission.

3. Project Description

The unique research setting at UW–CIMSS within SSEC and collocated with NESDIS/STAR personnel and AOS faculty and students has proven extremely effective in advancing research and operational applications of meteorological satellite data. The following section outlines a series of overarching goals to guide a Cooperative Institute (CI) that focuses on satellite studies related to weather and environmental analysis. Subsequent sections detail our technical approach for achieving these goals and the relevant experience and expertise at UW–CIMSS that demonstrates our ability to meet NOAA's needs for environmental satellite data to support short term weather forecasting and environmental monitoring.

3.1 Goals

We propose the continuation of a Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin–Madison (UW–CIMSS) to address four overarching goals centered on realizing the maximum 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.*

As articulated in NOAA's Strategic Plan, these goals can only be achieved through partnerships between NOAA, other government agencies, academic institutions, and the private sector and engaging the expertise of the international satellite community. Enabling these partnerships is the primary role of the CI. UW–CIMSS will build upon four decades of successfully integrating government, academic, and international expertise in satellite research and applications to address each of the research themes identified in the Notice of Federal Funding. The proposed research emphasizes CIMSS' extensive our experience in basic and applied satellite research to maximize the societal benefit of current and future instruments on national and international geostationary and polar orbiting satellites.

Satellite Research and Applications: UW–CIMSS has unique expertise in deriving geophysical variables, such as moisture, temperature, clouds, snow and ice cover, and winds, from weather satellites to support NOAA's goal "to understand and predict changes in climate, weather, oceans, and coasts". In collaboration with STAR and ASPB, UW–CIMSS scientists have developed new approaches for analyzing current GOES observations and worked with appropriate NOAA offices to transition new and improved products from research to operations. For example, UW–CIMSS and ASPB scientists have developed operational approaches for tracking convective initiation, increasing lead times for severe weather threats, and identifying aviation hazards from GOES observations. UW–CIMSS and ASPB scientists have also developed methods to derive polar winds from the MODIS measurements, which are used by NCEP, European Centre for Medium-range Weather Forecasts (ECMWF) and other NWP centers. **One of the primary goals of UW–CIMSS will be to continue to transfer these important advances in satellite data interpretation to the operational setting where they can be of direct benefit to society.**

Collaborations between UW–CIMSS and NASA scientists also vastly expand the utilization of NOAA environmental satellite data in the research community. The 2017 National Acadamies Decadal Survey for Earth Science and Applications from Space strongly recommends that NASA leverage the wealth of information from existing and planned weather satellites to serve as the program of record (PoR) for future Earth science missions. **The continuation of UW–CIMSS will enable its scientists to help ensure that JPSS and GOES provide a substantial fraction of the PoR for future earth system studies.**

Ensuring these satellite products meet societal needs also requires extensive visualization tools and user-engagement. UW–CIMSS has worked with NOAA and other agencies to develop well documented science and visualization code for measurements and products from numerous satellite platforms. We also develop and freely provide well documented software for use with NASA Direct Broadcast facilities. Through the GOES-R Proving Ground, JPSS Proving Ground and Risk Reduction, VISIT and SHyMet programs, UW–CIMSS has developed working relationships with various National Weather Service regional offices. A key part of the success of these relationships is the ability of UW–CIMSS scientists to develop, test, and integrate satellite analysis tools and products into the Advanced Weather Interactive Processing System II (AWIPS II) that is used by the NOAA NWS, NHC, SPC, OPC, WPC, and AWC National centers. **UW–CIMSS will continue to support the needs of NWS forecast offices, NOAA centers, and other users by incorporating their feedback to develop new satellite analysis tools that fuse distinct satellite outputs into value-added combined products to facilitate real-time decision making**.

Satellite Sensors and Measurement Techniques: The launches of Suomi NPP, JPSS-1, and GOES-16/17 mark a new era of meteorological satellite observations with increased spatial and temporal resolution and greater spectral diversity than ever before. UW–CIMSS played an integral role in developing several instruments aboard these satellites through field campaigns, instrument trade studies, observing system simulation experiments (OSSEs), independent radiance cross-calibration, validation of geophysical parameter retrievals, and informing new algorithm development. As NOAA designs the next generation of geostationary and polar orbiting satellite observations, continuing CIMSS at UW will enable ongoing support of instrument innovations. Our relationship with SSEC provides direct access to world class engineering expertise and state-of-the-art ground-based and airborne instrument facilities that can be deployed in targeted field experiments to refine instrument requirements for NOAA's future weather satellite sensors. UW–CIMSS has led Hyperspectral Environmental Suite (HES) trade studies to demonstrate the value of geostationary hyperspectral infrared sounding. These studies laid the foundation for the CrIS on the NOAA satellites and the Geostationary Interferometric InfraRed Sounder (GIIRS) on the Chinese FY4A satellite and the InfraRed Sounder (IRS) that will soon be launched on the European Metosat Third Generation - Sounder (MTG-S) satellite. **UW–CIMSS will continue to collaborate with NESDIS/STAR, other federal agencies, and industry partners, and other NOAA CIs to refine the instrument specifications to improve these capabilities for future NOAA weather applications from low-earth orbiting constellation platforms and to introduce them from geostationary platforms.**

NOAA's new satellite systems provide an unprecedented wealth of information for improving NWP and operational forecasting, identifying atmospheric hazards, and monitoring the changing environment. However, these new capabilities have increased satellite data volumes by two orders of magnitude in recent years posing the substantial unmet challenge of converting this "big data" to useable information. While the continued evolution of existing geophysical parameter retrievals is essential for supporting today's weather and climate needs, a new paradigm is required to fully realize the benefits of these new assets in NWP, operational forecasting, and data assimilation. **A primary goal of UW–CIMSS will be to develop, test, and implement revolutionary artificial intelligence and machine learning approaches to more effectively extract actionable information from current and future environmental satellites.** Locating CIMSS within SSEC at the UW–Madison provides access to the data science expertise, cyberinfrastructure (including cloud computing), and technical support critical to achieving this objective.

Environmental Models and Data Assimilation: The other essential element in realizing the benefits of environmental satellite observations is assimilating them into forecast models. **UW–CIMSS will continue to support NCEP's operational NWP modeling and assimilation efforts by increasing data usage, advancing data assimilation methods, developing radiative transfer models, and observational operators, and through model verification.** UW–CIMSS maintains the latest development versions of the global forecast system (FV3-GFS), stand alone regional (SAR-FV3) and hurricane (HWRF) modeling workflows on in-house computing facilities. Therefore, UW–CIMSS in a unique position to play a key role in the R2O/O2R process within 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. **Our goal is to provide the expertise in software development, data management, and innovative science applications to facilitate transitioning broad-based community weather modeling and data assimilation research efforts to NCEP operations within the EPIC framework.**

Outreach and Education: To maximize the benefits of these research efforts, UW–CIMSS has a long-standing commitment to training and education. Working closely with collocated AOS and ASPB scientists, UW–CIMSS eagerly embraces its mission to increase understanding of meteorological satellite data and its uses. **UW–CIMSS will support the historically strong curriculum in satellite meteorology and remote sensing at UW–Madison, provide appropriate training to students and professionals seeking to make better use of satellite observations and expand its portfolio to cover new sensors, analysis techniques, and products associated with the next generation of satellite sensors.**

Diversity and Inclusion: Incorporating experience, ideas, and opinions from a team with diverse backgrounds has profound benefits for advancing research. UW–CIMSS is committed to increasing diversity within the CI, within the campus community, across NOAA, and in STEM fields in general. **Our goal is to continue to build an inclusive environment, bring new perspectives on mentoring and educating students from diverse backgrounds, and incorporate diverse perspectives into our research.** UW–CIMSS has an existing memorandum of understanding with Hampton University to engage students from diverse backgrounds through joint mentoring and internship opportunities. **We will establish**

additional partnerships with other Minority Serving Institutions across the country, expand scholarship and internship opportunities for students from under-represented groups, and continue to build on our historical strengths in outreach and community engagement.

3.2 Research Themes

Throughout its 40-year history, UW–CIMSS has worked closely with NESDIS to improve our nation's meteorological satellite remote sensing capabilities. Our research spans the full end-to-end process of designing, assessing, and applying satellite remote sensing to weather and climate problems. UW–CIMSS is recognized nationally and internationally recognized for its satellite-based research in broad-ranging weather-related applications (e.g., see letters of support in Appendix B). Two of NOAA's key Weather and Water Mission Goals are to improve the lead time of weather-related warnings and extend accurate predictions out to 10 days. Meeting these goals requires a significant investment in refining existing retrieval algorithms (evolutionary algorithm development), developing novel and innovative approaches to analyzing the ever-increasing data volumes from satellites (revolutionary algorithm development), quantitatively assessing sensor performance and retrieval accuracy, and developing innovative data assimilation methods to increase the amount of satellite information ingested into NWP models. UW–CIMSS expertise will benefit NOAA as it strives to achieve these objectives.

3.2.1 Satellite Research and Applications

In recent years, UW–CIMSS scientists have provided strong support to the NOAA/NESDIS GOES-R and JPSS programs as part of associated satellite system risk reduction and algorithm working group initiatives. These initiatives assure the continuity of derived products, improve current products, introduce new products through basic and applied research, and ensure the results are integrated into NESDIS, NCEP and NWS operations. Discussed below are several examples of successful algorithms or products that were transitioned to NOAA operations through the Product Systems Development and Implementation (PSDI) program (see Appendix I for a list of recent CIMSS research-to-operations accomplishments). UW–CIMSS scientists continue to create, test and validate new algorithms and data products that will soon be ready for implementation. In the following subsections we discuss UW–CIMSS capabilities and areas of research expertise in satellite-based remote sensing, and what we propose to do in the next five years as a NESDIS CI to help NOAA meet its strategic goals of transferring research to operations.

3.2.1a Global Atmospheric and Surface Characteristics

To meet its future service delivery objectives under the Weather and Water Mission Goal, NOAA is committed to improving the accuracy and capabilities of its Earth monitoring and observing systems (NOAA Strategic Plan). Satellites constitute a unique component of the global observing system. The suite of GEO and LEO remote sensors not only captures images and animations of global-scale weather events, but it can also probe the properties of the troposphere and define characteristics of the land/sea surface. UW–CIMSS has a strong legacy in extracting information from these sensors to analyze geophysical variables such as surface emissivity, sea ice and algal blooms, and tropospheric humidity/temperature profiles, winds, cloud properties, aerosols, atmospheric constituents (e.g., total column ozone, and ash and sulfur dioxide from volcanic eruptions), and the occurrence of severe weather (e.g., tropical cyclones and thunderstorms). We will build on this heritage by continuing to develop novel methods of integrating satellite observations to characterize the Earth system. In particular, we propose to adopt emerging computing and analytic technologies and put them towards developing advanced data interrogation methods to improve atmospheric profiling, wind and trace gas retrievals, as well as cloud and surface properties. In partnership with our NESDIS STAR and ASPB colleagues, we will ensure these observations are used to improve situational awareness and short-term to medium-range weather forecasts.

Cloud Properties: UW–CIMSS scientists, working with ASPB scientists, have developed cloud products in the Clouds from Advanced Very High Resolution Radiometer (AVHRR) Extended (CLAVR-x) processing system. Products developed in CLAVR-x and delivered to the NOAA Office of Satellite and

Product Operations (OSPO) includes cloud height, temperature, pressure, optical depth, effective radius, fraction, and emissivity. Cloud retrievals from CLAVR-x were originally developed for polar orbiting satellites but have expanded to include GOES observations (Heidinger et al. 2014a, b). Most recently these products have become operational for GOES-16, GOES-17, Suomi NPP, and NOAA-20. In the case of GOES-17, UW–CIMSS scientists developed procedures to address the Loop Heat Pipe (LHP) issue to produce high quality cloud products.

Working with NASA scientists, UW–CIMSS researchers are using Terra and Aqua MODIS to improve upon cloud remote sensing methods. We developed cloud detection, cloud top pressure, and cloud phase algorithms for MODIS (Menzel et al., 2008) that are run routinely at MODAPS (MODIS Adaptive Processing System). In addition, the MODIS-VIIRS Cloud Mask (MVCM) has been adapted from our MODIS cloud mask to operate on VIIRS radiance data from the SNPP and NOAA-20 platforms. The MVCM is designed to be used on both MODIS and VIIRS data in order to obtain a consistent cloud record. The MVCM has also been adapted to the Medium Resolution Spectral Imager-2 (MERSI-2) on the Chinese polar orbiting platform FY-3D, and to the Japanese geostationary Advanced Himawari Imager (AHI). UW–CIMSS can now produce cloud products from MSG/SEVIRI, COMS, and MTSAT data as well as data from FY3D and FY4A. UW–CIMSS closely monitors the quality of these cloud products. Imagery from VIIRS, ABI, and AHI sensors at daily, weekly, monthly, and seasonal time periods are routinely published on the website https://www.ssec.wisc.edu/clavrx/ with the goal of identifying any quality issues either with the cloud mask or cloud properties.

Clouds are a crucial component in all weather and climate studies. UW–CIMSS has developed several initiatives to take advantage of the capabilities of the newer JPSS and GOES-R series of satellites, as well as those from previous missions. One current project is the development of a machine learning (gradient boosting machine) based cloud masking product that substantially increases the accuracy of polar cloud detection on VIIRS. Another is investigating the feasibility of producing 250m or 125m channel-2 reflectances from ABI/AHI by training a generative adversarial network to derive plausible high-resolution scenes using high-resolution Sentinel-2 images. Our goal is to study variability of small clouds at high temporal resolution, or produce sub-pixel cloud products.

UW–CIMSS participates in several collaborative projects related to broader applications of cloud products including the International Satellite Cloud Climatology Project - Next Generation (ISCCP-NG) initiative that seeks to create a homogenous global cloud dataset from the global constellation of geostationary satellites with 10 common spectral channels. We are also working with the National Renewable Energy Laboratory (NREL) to use CLAVR-x cloud products to create a National Solar Radiation Database (NSRDB). The NSRDB provides an historical record of surface insolation and other weather fields over the United States for use by solar energy providers and others. Future work with NREL includes expanding the database over East Asia and the Indian Ocean Data Coverage (IODC) areas. UW–CIMSS is also engaged in a collaboration with the Central Weather Bureau of Taiwan (CWB) to help generate Himawari-8 cloud products in the CWB forecast offices for decision support.

We propose to continue our strong legacy in satellite-derived cloud product development, working together with ASPB and STAR to transition promising advances into NOAA operational processing. As new sensors emerge, we will continue to collaborate with NASA and other agencies, international partners, and the research communities to improve cloud products.

Atmospheric Moisture and Temperature Profiles: Calibrated infrared and microwave radiances from geostationary and polar-orbiting satellites and atmospheric moisture and temperature profiles derived from them provide valuable information for climate research, severe weather situational awareness, and sensor inter-calibration. Moisture, in particular, is central to many atmospheric hazards. The UW–CIMSS profiling team are leaders in deriving tropospheric moisture and temperature profiles and atmospheric stability from measured infrared radiances from satellite, aircraft, and ground-based platforms. We have developed and validated algorithms for sensors aboard polar orbiting satellites, including TOVS, ATOVS, MODIS, AIRS, IASI, CrIS, and ATMS (Li et al., 2000, Seemann et al., 2003). These polar orbiting retrieval algorithms have been widely distributed to users around the globe through the International ATOVS Processing Package (IAPP), International MODIS – AIRS Processing Package (IMAPP), and now Community

Satellite Processing Package (CSPP) (http://cimss.ssec.wisc.edu/cspp). The sounding products from those packages serve wide-ranging uses. For example, a near real-time surface-based CAPE derived from a fusion of hyperspectral IR sounding data from Suomi-NPP ATMS/CrIS and surface observations has been successfully demonstrated (Bloch et al. 2019).

The GOES-R series ABI provides high temporal and spatial resolution legacy atmospheric profiles (LAP) and derived total precipitable water, layered precipitable water and stability indices for severe storm warning and nowcasting. UW–CIMSS algorithms (Schmit et al. 2019) provide operational GOES-R series LAP products whose value has been demonstrated during the Hazardous Weather Testbed (HWT) and when assimilated into regional Numerical Weather Prediction (NWP) models (Wang et al. 2019).

In the absence of a GEO-sounder with high spectral resolution IR measurements over CONUS, UW–CIMSS scientists have used temporal and spatial fusion to transfer LEO-based CrIS information content to GEO-based ABI time and space resolution (Weisz and Menzel 2019). Imager/sounder product fusion extends the value of either instrument. Specifically, it has been shown that the vertical resolution of hyperspectral sounding products and the horizontal and temporal resolution of ABI radiances can be blended for use in, for example, severe weather monitoring and prediction systems (e.g. Fig. 3.2.1.1).

We propose to continue to develop new and improved algorithms for current and future GOES, POES, as well as CubeSat IR/MW sounders. JPSS series ATMS/CrIS boundary layer sounding retrievals will be improved by making better use of surface emissivity information developed at UW–CIMSS, combining surface temperature and moisture observations/analysis, and combining clear sky time-sequenced ABI IR radiances with the ATMS/CrIS radiances to estimate boundary layer changes in time. In addition, IR and MW sounder data will be combined with high spatial resolution imager cloud products (cloud mask, cloud-top height etc.) to derive humidity and temperature profiles in all-sky conditions. Finally, global geostationary advanced imager water vapor band radiances from the GOES-R series, Himawari-8/-9, GK-2, and later MTG series will be homogenized using the GEO 6.5 μm imager homogenization of Li et al. (2019) and used to derive a high spatial and temporal resolution moisture profile climate data record (CDR) for climate studies.

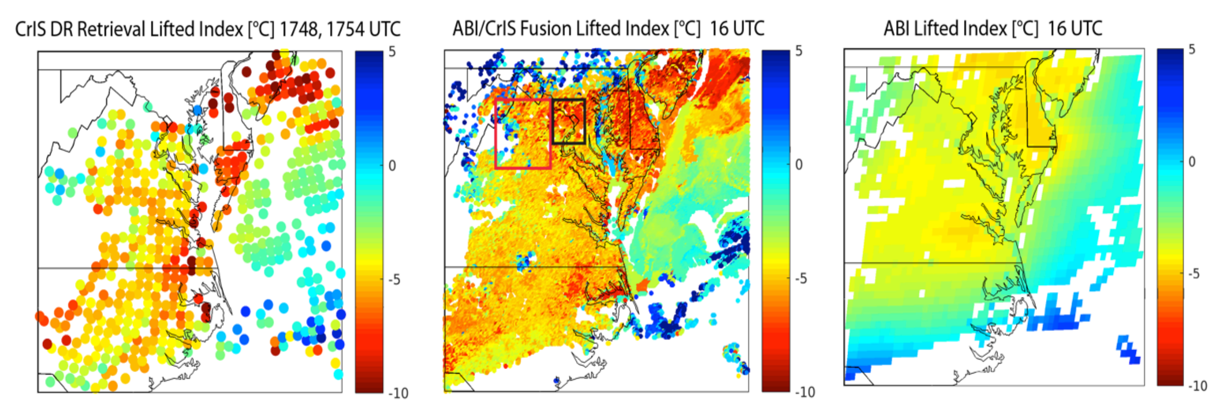

FIGURE 3.2.1.1: Left: CrIS DR Lifted Index (deg C) retrievals on 19 May 2017. Middle: ABI/CrIS fusion Lifted Index (deg C), red and black boxes delineate more stable and less stable atmospheres validated by subsequent weather (not shown). Right: ABI only Lifted Index (deg C).

Atmospheric Motion Vectors: Deriving tropospheric wind estimates is a prime example of both evolutionary and revolutionary research in the field of satellite meteorology. What started as a novel concept of UW Prof. Verner Suomi in the late 1970s has been transformed into an important contribution to NOAA and meteorology communities across the globe (Menzel 2001). We expect further scientific advances in the AMV product from the current GOES-R and JPSS systems, as well as from novel approaches to extracting the wind information from other emerging sensor technologies including Cubesats. Improving the accuracy of the AMV measurements is paramount to advancing the nation's numerical weather prediction capabilities.

Since automating AMV estimation algorithms in the late 1980s, numerous refinements and advances to the technique have been made in close collaboration with NESDIS/STAR colleagues (Velden et al. 2005). For example, determining the appropriate height assignment for a particular wind vector has improved considerably by using multispectral information to better deduce cloud properties. Identifying and tracking "features" has been successfully expanded beyond visible and IR window wavelengths to include water vapor bands, helping to significantly increase coverage both horizontally in cloud-free regions as well as vertically in middle levels of the troposphere. The AMV product is now run operationally by NESDIS to support data assimilation into NCEP and other agencies' numerical weather prediction models. UW–CIMSS has also provided global, near real-time AMV datasets from multiple GEOs to the U.S. Navy to support the Department of Defense, and to the research community for process studies, weather-event case studies, and reanalysis efforts. Our research on AMV algorithm improvements continues at UW–CIMSS by exploring cutting-edge methods and innovative applications.

In addition to AMVs produced from GEOs, UW–CIMSS, in partnership with ASPB, has developed methodologies for generating wind vectors in the high latitudes (polar regions) using LEO imagery (Key et al. 2003). The impact in both the NASA DAO (now GMAO) and ECMWF systems was statistically significant, resulting in our developing a near real-time product that was transitioned to NESDIS operations. Throughout the 2000s and 2010s, data from additional polar satellite platforms were added from the AVHRR on NOAA and Metop satellites, and the VIIRS on SNPP and NOAA-20. The polar winds product is currently in use by over a dozen global NWP centers.

Embracing NOAA's desire to unify LEO and GEO products for NWP, a combined LEO/GEO AMV product was also developed at UW–CIMSS (Lazzara et al. 2014) to cover the gap between the GEO AMV extent (equatorward of 60 degrees latitude) and LEO AMVs (poleward of 70 deg. latitude). This product is used by several NWP centers with many demonstrating a positive impact of both geostationary and polar satellite AMVs on forecasts (see Section 3.2.3). We propose to continue to improve the polar winds and LEO/GEO products to expand on the single-satellite winds product to using mixed satellites (e.g., alternating passes of SNPP and JPSS) and to work closely with NESDIS/STAR to help transition these improvements into the NOAA/NESDIS operational production code. The team is an integral member of the GOES-R Algorithm Working Group (AWG), and a primary focus over the next few years will be to continue advancing the operational utilization of GOES-R for AMV production.

In the future, we also propose to apply revolutionary innovations for automated wind derivation such as Optical Flow to optimize the applications of the AMV data. UW–CIMSS, in collaboration with NESDIS/STAR, will devote significant efforts to optimizing, demonstrating and assessing the wind measurement capabilities of the ABI on GOES-R to observing mesoscale phenomena. The high spatial and temporal resolution of ABI mesoscale-sector imaging provides unprecedented observational capabilities to view severe weather events and hurricanes, and the UW–CIMSS AMV team will conduct research to increase the impact of this important satellite-derived product.

Total Column Ozone: UW–CIMSS began developing total column ozone (TCO) estimates from the GOES sounder in the late 1990s (Li et al., 2001). GEO-based IR ozone detection retrieval methods have better spatial and temporal resolution than those from polar orbiting instruments such as the Total Ozone Mapping Spectrometer (TOMS) and Ozone Monitoring Instrument (OMI), which use backscattered UV light to measure ozone quantities. However, the GEO IR retrieval methods tend to have lower precision due to clouds, water vapor, and surface emissivity.

Building upon its experience with the GOES Sounder, UW–CIMSS developed a TCO algorithm for the GOES-R series adapted to use the ABI, and producing generally good results despite the limitations of the input data (Schmidt and Hoffman, 2011). Visual inspection of image loops shows that there is still work to do over land to make the performance and consistency comparable to that over the ocean. Scientists at NOAA have expressed interest in the TCO product for use in air quality work. UW–CIMSS proposes to improve the existing algorithm and work toward operational implementation of the ABI TCO algorithm. Improving performance over challenging land surfaces and adding processing over low clouds will benefit users in the aerosol modeling community and aid in tracking mesoscale and smaller tropopause features that could indicate turbulence. Further work on the TCO product for ABI would apply retrospectively to the GOES Sounder data to allow generation of long TCO time series for climate studies. In addition, ozone profile retrieval methodologies (Jin et al. 2008; Li et al. 2007) will be developed for future geostationary advanced IR sounders such as the InfraRed Sounder (IRS) onboard the MTG series.

Cryosphere Monitoring and Research: Correct characterizations of snow and ice, including ice sheets, glaciers, sea ice, and seasonally frozen ground are critical for accurate weather forecasts and climate studies. Changing snow and ice conditions can have profound socio-economic impacts making them a high priority focus area of several national agencies, including NOAA. Satellites provide a means to routinely monitor sea/lake/river ice and snow cover with unprecedented temporal and spatial resolutions (e.g., GOES-R and JPSS). UW–CIMSS has pioneered many snow and ice retrieval algorithms, including ice and snow identification, ice concentration, ice thickness and age, ice motion, and snow cover. The current operational ice products from JPSS and GOES satellites (Figure 3.2.1.2) are generated by the algorithms developed by the team, which closely collaborates with NOAA/NESDIS/STAR scientists stationed at UW–CIMSS. Validation of these products suggests they meet the requirements for the applications of climate, weather, and water studies, as well as for data assimilation into NWP and climate models.

We propose to continue the evolution and validation of the NOAA operational cryosphere products. In addition to providing technical and science support to current ice and snow products from JPSS and GOES for algorithm maintenance and product validation, we will further leverage international satellites (e.g. Himawari and MTG) to extend the coverage and implementation of ice and snow algorithms. Furthermore, we will develop new cryosphere products, and expand the near real-time system generating ice and snow products for demonstrations. Finally, we will produce and archive long-term ice and snow data records for cryosphere studies including trends, feedback mechanisms, data integration and assimilation.

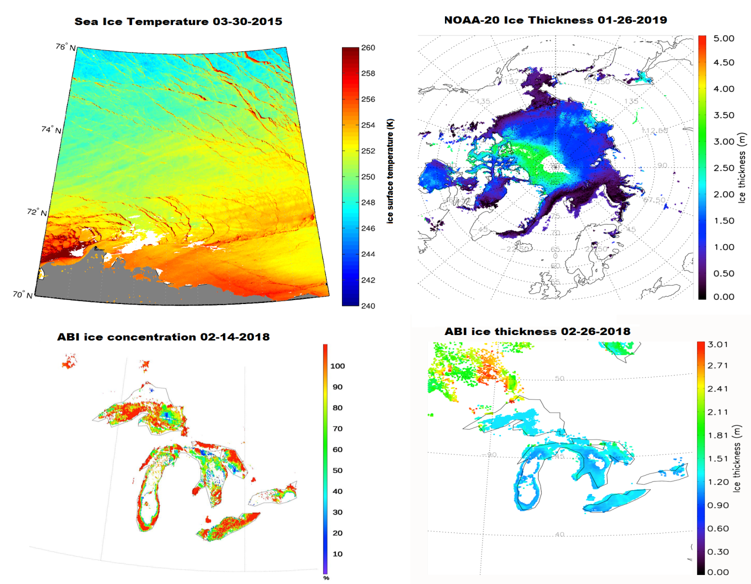

FIGURE 3.2.1.2: Ice surface temperature (top-left) and thickness (top-right) from NOAA-20, GOES-R ice concentration (bottom-left) and thickness (bottom-right) all generated with UW–CIMSS algorithms.

Land Surface IR Emissivity: Any application that requires an IR radiance calculation such as atmospheric retrievals, NWP data assimilation, observing system simulations, or satellite Cal/Val needs a good estimate of the underlying surface emissivity. UW–CIMSS has developed the Combined ASTER MODIS Emissivity over Land (CAMEL) high spatial resolution monthly mean database (https://lpdaac.usgs.gov/products/cam5k30emv002/). CAMEL has been implemented into the Radiative Transfer for TOVS (RTTOV) forward model and continues to evolve. This database, developed under NASA MEASURES support, provides a valuable resource for NOAA applications. UW–CIMSS proposes to implement the CAMEL database into the JCSDA CRTM forward model and investigate diurnal and angular dependence of the IR surface emissivity. We also propose to extend spectral coverage of CAMEL into the far infrared region to support future sensors. This work will benefit many retrieval applications and data assimilation efforts, and provide more accurate surface characteristics for Cal/Val activities. Using IR channels over land which were previously excluded, will benefit NWS NCEP, while also supporting NESDIS derived product imagery that relies on knowledge of the infrared land surface.

3.2.1b Application to Severe Weather

The wealth of geophysical parameter information provided by these retrievals has substantial benefits for numerous applications. As part of our end-to-end strategy for maximizing the societal benefits of NOAA's environmental satellite program, UW–CIMSS conducts research into new ways of applying satellite products to improve identification of severe weather and aviation hazards, monitor drought and assess fire danger, improve tropical cyclone forecasts, and project the economic impacts of severe weather.

Severe weather hazards, including large hail, strong wind gusts, and tornadoes, are a substantial threat to life and property in the U.S. One of the most important tasks for NWS forecasters is issuing accurate and timely watches and warnings for these rapidly evolving hazards. Geostationary satellites are key to monitoring the convective environments that can spawn severe storms. Collaborating with the local NOAA/ASPB group, UW–CIMSS has been a leader in developing satellite-based products fused with other meteorological data (e.g., radar, lightning, NWP output) to improve severe weather warning timing, confidence and accuracy. Two such products include the NOAA/CIMSS ProbSevere system and the UW–CIMSS convective development 'NearCasting' model. The success and promise of these products have earned multiple research awards from the NOAA GIMPAP, GOES-R Risk Reduction, JPSS Risk Reduction, WMO, and OAR-OWAQ programs.

The NOAA/CIMSS ProbSevere system (ProbSevere; Cintineo et al. 2018) is an exemplary example in the fusion of multiple data sources. ProbSevere predicts the probability of any severe weather (hail, wind, and tornado) for every thunderstorm throughout the CONUS in real-time, leveraging GOES satellite trends (cloud growth) prior to the presence of robust radar echoes to give an earlier indication of imminent severe weather to forecasters. The ProbSevere model uses GOES along with Multi-Radar Multi-System (MRMS) radar, Earth Networks Inc. (ENI) lightning, and Rapid Refresh (RAP) model environmental data in a statistical framework to generate the probabilities. It has demonstrated increased lead time to the initialization of severe hazards in the Hazardous Weather Testbed (HWT) and Operations Proving Ground (OPG) and is now widely used by NWS warning offices.

ProbSevere software has been smoothly transitioned to preliminary operations at NOAA/OAR/NSSL, and will be fully operational at NCEP Central Operations (NCO) in 2020 as a subsystem of MRMS. Furthermore, a specialized AWIPSII plug-in was developed at UW–CIMSS in support of ProbSevere (see Figure 3.2.1.3), which uses lightweight shapefile to render storm objects and a scroll-over readout of predictor values, all of which facilitates ease of use and understanding. A new warning paradigm is emerging in the NWS, called Forecasting A Continuum of Environmental ThreatS (FACETS), seeks to make continuously and rapidly updating probabilistic hazard grids; it has been using ProbSevere output as a prototype. UW–CIMSS is poised to lead in this new paradigm with respect to probabilistic severe weather guidance.

The UW–CIMSS NearCasting system expands the utility of GEO and LEO products from observations to short-range projections that help identify areas of convective destabilization 1-9 hours in advance of storm development. It constructs vertical profiles of θ_e and layered precipitable water and uses Lagrangian trajectories to preserve and transport sharp gradients, maxima and minima in the data, as well as incorporating new data to revise previous projections in a continuously updating manner. Vertical trends in the profiles (e.g., low level moisture moving under upper level dry air) may indicate destabilization to forecasters during the 1-6-hour time gap that lies in between longer-range NWP guidance updates. NearCasting has been evaluated at the HWT with forecasters noting how the observation-based guidance helps determine the location of stable and unstable air. UW–CIMSS is currently developing methods to integrate LEO observations to fill gaps left in GOES IR products and is also preparing to deploy NearCasting over west-central Africa to meet WMO needs and for the Meteosat Third Generation satellite series.

More recently, UW–CIMSS has adapted machine learning and deep learning methods to accelerate the process of identifying the onset of intense convection using satellite only predictors (Cintineo et al. 2019). As outlined in Section 3.2.2f, this revolutionary algorithm development activity is anticipated to increase over the next decade as data, software, and compute resources become more capable.

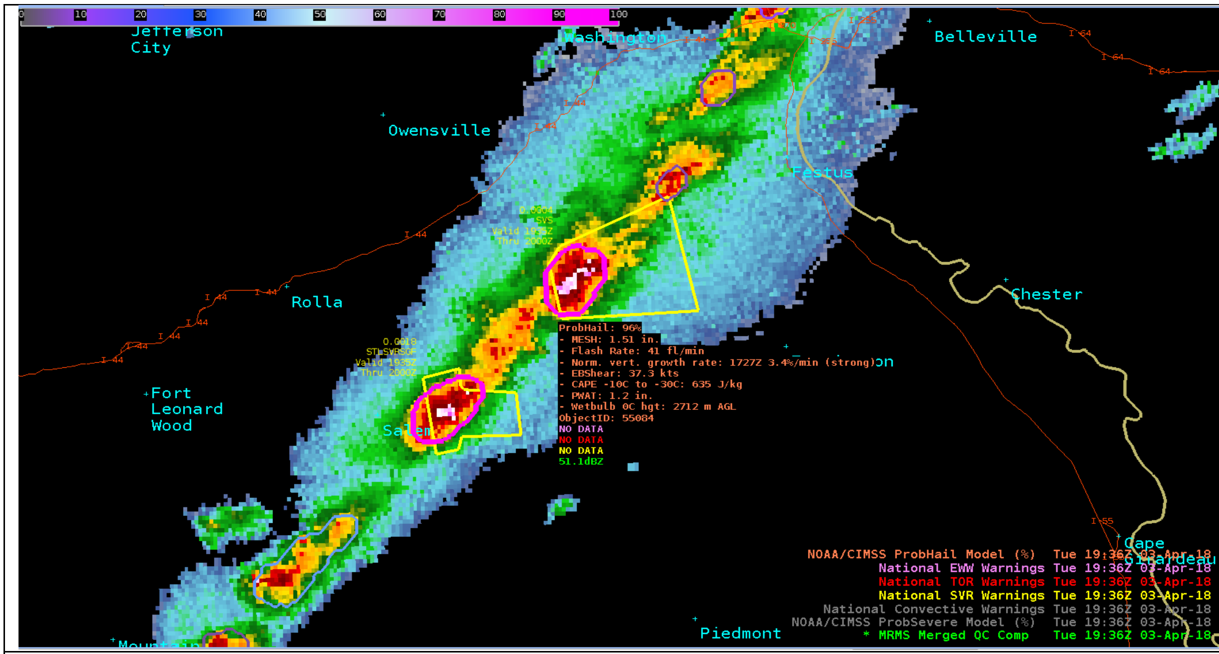

FIGURE 3.2.1.3: ProbSevere output (storm contours) in AWIPSII, with MRMS radar reflectivity and NWS severe weather warnings (yellow polygons). Inset shows the probability and predictor readout for ProbHail when a user hovers over a storm cell. The targeted storm shows a strong satellite growth rate two hours prior to the radar time.

3.2.1c Aviation Hazards

Often related to severe weather, turbulence and other aviation hazards pose significant risks to commercial aviation. The FAA predicts the number of passengers on U.S. commercial carriers will increase almost 40% in the next 20 years, therefore increasing the importance for focused research to mitigate weather's impact on aviation. Geostationary and polar satellites provide a means to monitor aviation weather conditions, providing information for nowcasting and forecasting in-flight hazards such as convective and clear-air turbulence as well as operational hazards such as cloud cover and cloud properties. In response, NOAA, in partnership with the FAA, is conducting research to mitigate the impacts of weather on the air transportation system. UW–CIMSS will continue to work with NOAA (and leverage our NASA, FAA and private sector collaborations) to improve the detection of aviation hazards using satellite observations.

In the last decade UW–CIMSS has significantly expanded its research in the area of satellite applications for aviation. In collaboration with NOAA/ASPB we have developed new aviation applications using satellite sounders and imagers, including the detection of clear-air turbulence (Wimmers et al. 2018), the identification of cloud properties, including cloud-top height and pressure, cloud ice and water content, and cloud geometrical thickness (Heidinger and Pavolonis 2009), the detection of cold air pockets aloft and a process for validating cloud cover forecasts over airports. These products are currently being demonstrated in real-time to both public and private partners and have been used in multiple field campaigns for aircraft safety. The outstanding success in this applied research area has also been acknowledged by outside agencies including NASA who awarded UW–CIMSS a Group Achievement Award in 2014 for supporting Global Hawk navigation during the Hurricane and Severe Storm Sentinel (HS3) experiment.

UW–CIMSS proposes to continue leading-edge efforts to develop future GOES-R series aviation requirement science algorithms to detect clear-air turbulence (CAT). Turbulence accounts for the highest percentage of aviation accidents. Therefore, knowledge of when and where turbulence is likely to occur can greatly benefit the aviation industry through improvements in safety and also flight path efficiency. Figure 3.2.1.4 shows an example of a product developed at UW–CIMSS that combines aircraft measurements of turbulence with GEO satellite imagery to explore the relationship between turbulence and gravity waves. This relationship is being used to predict possible higher risk regions of CAT.

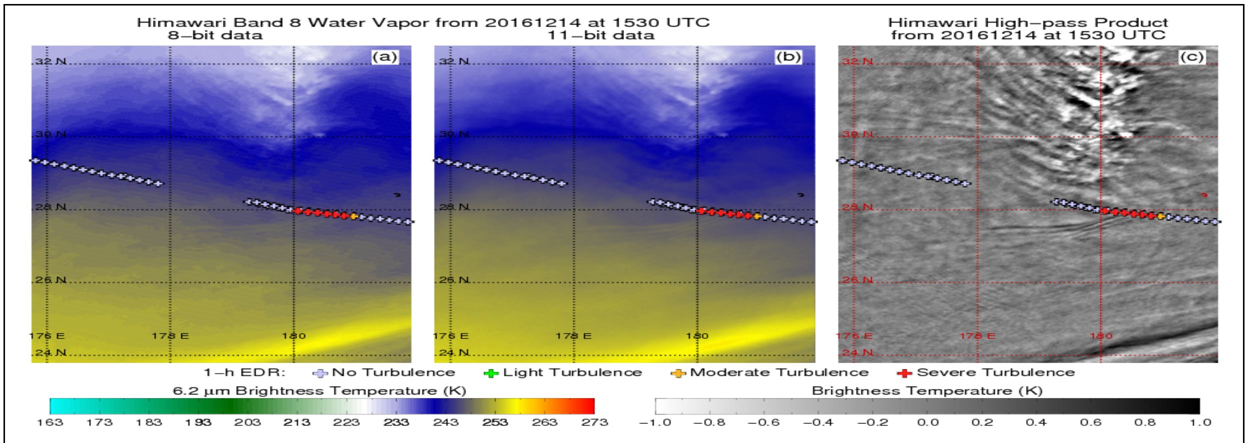

FIGURE 3.2.1.4: Example of the difference in gravity wave visualizations between (a) traditional 8-bit rendering of brightness temperature in the upper-level water vapor band, (b) full 11-bit rendering, and (c) a high-pass product. Cross-shaped symbols along the flight track are automated EDRs (turbulence) peaking at 0.620 m^2s^{-3} (severe turbulence). Turbulence reports fall within 0–1 h before the image time.

From better satellite observations we also are working to improve the prediction of turbulence. The probability of turbulence is calculated using automated reports of turbulence and satellite observations in a deep learning framework. The deep learning model can be trained to make direct predictions of the probability of significant turbulence, and then can be implemented in the form of a complete two-dimensional probability map over the domain of the imagery.

UW–CIMSS will continue the development and automation of identifying aviation hazards using satellite observations from imagers and sounders. This work includes a continued collaboration with the NOAA/ASPB team on satellite-based volcanic ash detection, which is an important aviation hazard during eruptions. We propose to continue to work with NOAA and other partners to produce new products that integrate measurements from GEO and LEO satellites with aircraft and ground-based observations to better detect aviation weather hazards.

3.2.1d Tropical Cyclones

Tropical cyclones (TCs) constitute a subset of extreme weather events with particularly high societal impacts. Accurate forecasts of the strength and motion of TCs are essential to public safety and minimizing the economic costs associated with preparation and evacuations. Though our understanding of and ability to predict TCs has considerably advanced over the past century, these storms continue to challenge researchers and forecasters alike. Most TCs occur over the ocean well removed from dense *in situ* surface and upper-air observing networks. Aircraft reconnaissance can provide valuable intensity and structure information; however, these measurements are infrequent and expensive. The constellation of LEO satellites can provide observations over the tropical latitudes in which TCs occur while 24-hour imagery from GEO platforms provides continuous surveillance of active TCs in all tropical basins.

The AMS award-winning CIMSS Tropical Cyclone group (Figure 3.2.1.5) is both nationally and internationally recognized as a leader in TC research using satellite data. Our work involves both basic research on fundamental understanding of TC behavior and applied research leading to operational transition of novel algorithms and data products. Our work leads to improved analyses of storm conditions, and the transition of algorithms based on this research ultimately leads to more accurate TC warnings from forecasters at the National Hurricane Center and other agencies.

As new generation instruments are becoming available (GOES-R series, JPSS), we aim to develop novel ways to exploit and extract this information with the goal of improving tropical cyclone understanding, analysis and ultimately predictions. The CIMSS TC group is well-positioned to perform such satellite data interrogations given the "treasure chest" of meteorological satellite data that resides in the co-located SSEC Data Center. With over 25 years conducting satellite-based TC research, much of which has transitioned to operational applications, the group has gained the knowledge to perform future studies with a high probability of benefit to NOAA.

The satellite community needs to facilitate efficient transitions of promising research initiatives to operations. Over the next 5-10 years we will build on our recent successes in supporting NOAA's strategic goals to address the priorities of the TC forecasting community identified through workshops and conference interactions, and site visits to prominent TC entities such as the National Hurricane Center and Joint Typhoon Warning Center. One emerging research area for TC applications is Deep Learning. Members of the TC group are investigating how AI could open new avenues of TC analysis. With a very large dataset available through SSEC's satellite data archive, we are eager to apply DL methods to tease out new signals in the satellite data.

Operational TC analysts and forecasters are the primary beneficiaries of our efforts, and this influence extends internationally. One highlight is our online product archive tailored to TCs. Moving forward, we will engage the community to request feedback, a main driver of current leading-edge research. As we communicate promising/emerging satellite data and applications, we'll assess research priorities based on feedback from our users. With that information in mind, we will partner with STAR and other CI scientists to plan research projects centered on those user priorities. We will also work with NOAA to transition promising results or algorithms into operational environments.

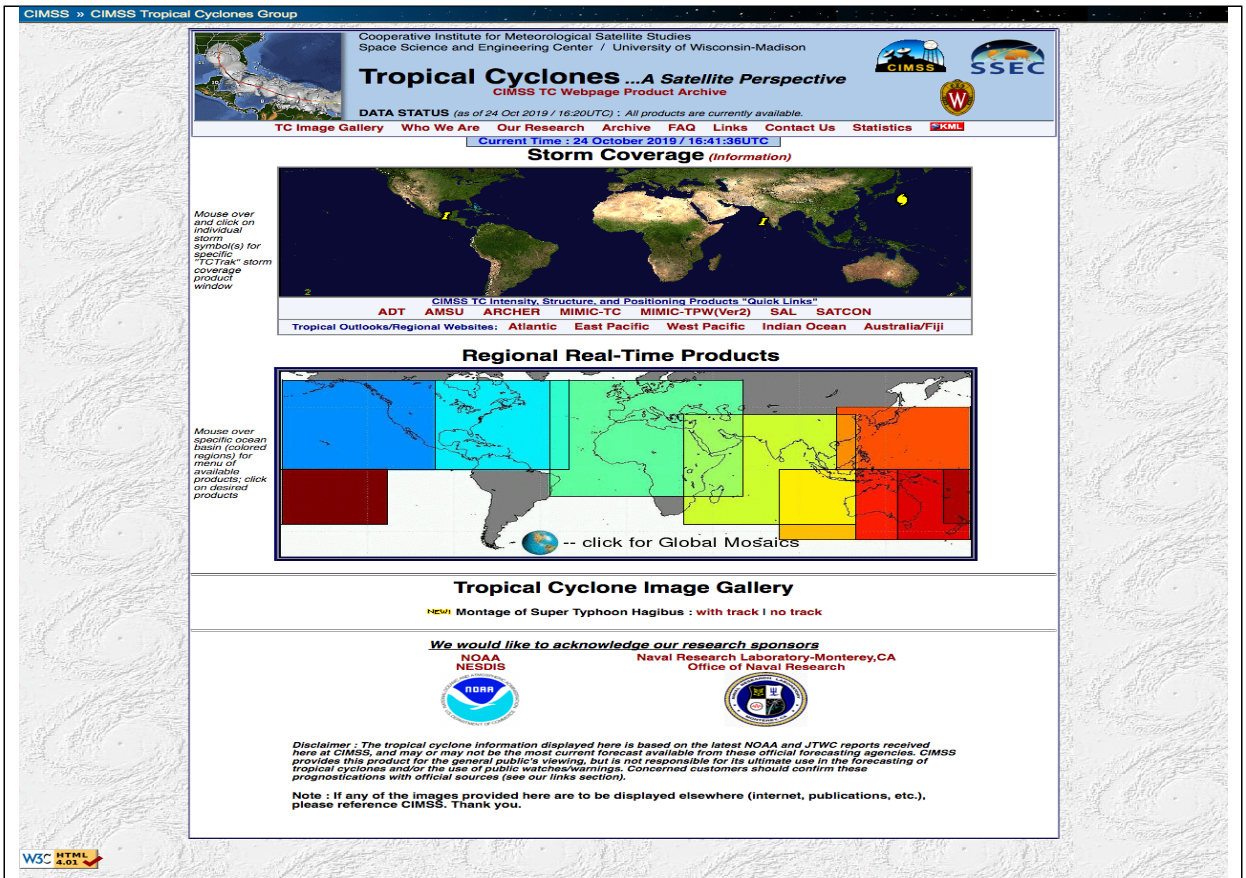

FIGURE 3.2.1.5: The CIMSS Tropical Cyclone web site contains a unique repository of satellite-derived products related to TCs, and is an important public outreach portal for the TC community. The popularity of the site is evidenced by the fact that it is not uncommon to get millions of hits/day during significant hurricane events.

3.2.1e Drought Monitoring

Unlike other forms of severe weather, including TCs, drought has traditionally been viewed as a slowly developing climate phenomenon that takes many months or even years to reach its full intensity; however, recent events across the U.S. and elsewhere around the world have shown that severe drought conditions can develop very quickly (known as "flash drought") during climatologically sensitive parts of the year. Satellite-derived surface characteristics such as the Evaporative Stress Index (ESI) that depicts anomalies in evapotranspiration (ET) provide insights into the salient characteristics of flash droughts and may yield a pathway for predicting their occurrence (Otkin et al, 2013). Rapid increases in moisture stress over a several week period are often accompanied not only by below normal rainfall, but also by intense heat, reduced cloud cover, large vapor pressure deficits, and strong winds – all of which hasten the depletion of soil moisture through increased evaporation. These features are illustrated in Fig. 3.2.1.6, which shows the evolution of a flash drought that occurred across Oklahoma. The rapidly increasing moisture stress inferred from rapid decreases in the ESI starting in mid-August coincided with increasing precipitation deficits, hot temperatures, sunny skies, and large dew point depressions. Subsequent studies by Otkin et al. (2014, 2015a) showed that flash drought is far more likely to develop when large moisture stress increases persist for multiple weeks and that hybrid statistical methods can provide early warning of their development (Lorenz et al. 2017a,b, 2018).

We plan to improve our understanding of the physical mechanisms driving flash drought evolution, developing improved monitoring and forecasting capabilities, and working with stakeholders to ensure timely access to drought early warning data. Given that flash droughts have been shown to strongly reduce crop yields and livestock production, and the health and functioning of natural ecosystems (Otkin et al. 2015b, 2016, 2018), it is vital to rigorously evaluate their characteristics across the U.S. and to assess potential changes in their occurrence and intensity. Additional research is required to develop objective indicators of flash drought and tools that can be used to forecast their onset, intensification, and demise over sub-seasonal time scales. We will seek to improve the ability of weather and climate models to simulate their driving mechanisms and develop hybrid-statistical or machine learning methods that can predict their onset and evolution. The outcomes are anticipated to directly benefit a wide-range of stakeholders including: farmers and ranchers through improved drought early warning tools; government and non-governmental organizations that could use early warning information to mitigate the impacts of flash droughts; and climatologists who require a more detailed understanding of flash drought characteristics.

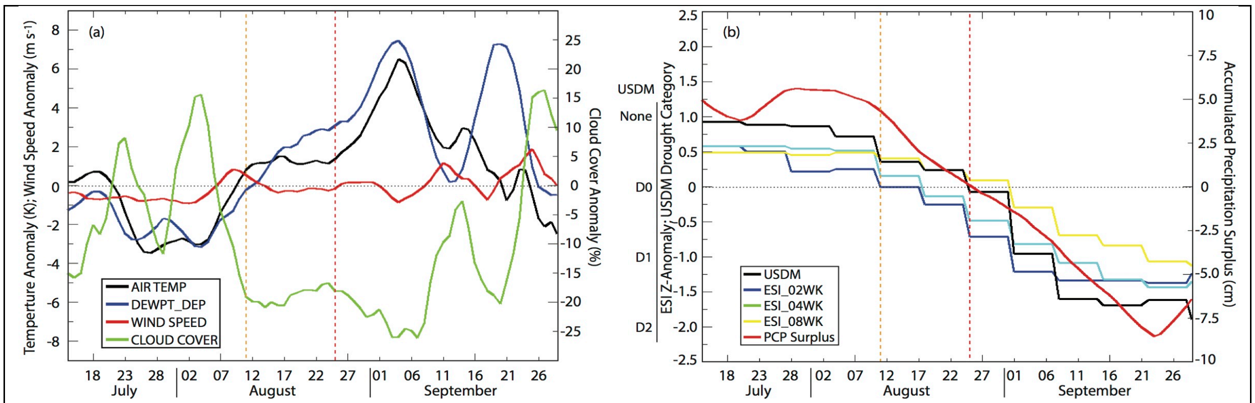

FIGURE 3.2.1.6: (a) Time series of 2-m air temp. (K), dew point depression (K), surface wind speed (m s^{-1}), and cloud cover (%) anomalies over eastern Oklahoma during 2000. (b) Time series of U.S. Drought Monitor (USDM) drought severity category, ESI anomalies computed over 2, 4, and 8-week time periods, and accumulated precipitation surplus (cm) starting on 16 June 2000.

3.2.1f Detecting and Monitoring Fires and Smoke

Prolonged dry periods also enhance the probability of fires and their rapid intensification posing another significant risk to life and property. NOAA GEOs have had a spectral band sensitive to fires for over 30 years. In the 1990s, the Automated Biomass Burning Algorithm (ABBA) was developed at UW–CIMSS using GOES-7 and GOES-8 data, and it saw extensive use monitoring the burning in South America (Prins et al., 1998). Its successor, the Wildfire ABBA (WFABBA), designed to run over the entire hemisphere, became an operational product in 2002. It was made a baseline product for the GOES-R Series, and rechristened as the Fire Detection and Characterization Algorithm [FDCA]. UW–CIMSS also adapted the

WFABBA to Europe's MSG, Japan's MTSAT, and Korea's COMS series. The WFABBA is the first and only fire detection algorithm to be consistently applied to the global constellation of geostationary satellites. The Fires team at UW–CIMSS has been home to the top experts on geostationary fire detection and is one of only two teams internationally with substantial experience in the field. It is the only team to field a real-time fire detection algorithm. The team develops and refines the WFABBA/FDCA, as well as participates in training and outreach to new users both within NOAA, such as NWS forecasters, and beyond to other Federal agencies and the private sector.

We propose to develop an updated WFABBA that provides for early detection that rivals the ability of an analyst examining satellite imagery, with a low false alarm rate, and with improved characterization of the detected fires. Specifically, the UW–CIMSS Fires team plans to:

- Utilize additional spectral information to improve detection, characterization, false alarm rejection; e.g. high resolution shortwave bands to refine fire locations;
- Utilize the temporal dimension of GEO data as a primary component of diagnostic algorithms;
- Redefine fires as "fire events" rather than individual fire pixels, creating data records that include the estimated perimeter, characteristics, and history of a given fire; and
- Develop a comprehensive training dataset for an AI-based fire detection system.

The Fires team will pursue two approaches to fire detection in order to determine which best achieves the goals of fast, accurate detection, or whether the two approaches should be brought together into a hybrid algorithm. The two approaches are: 1) extending the existing diagnostic approach of the WFABBA to include upgrading the temporal domain and additional bands, and 2) applying artificial intelligence. Achieving the former requires overcoming programming challenges and revisiting how fire detection is performed. The AI approach requires an extensive training dataset that, in order to assure success, would have to be created by experts examining tens of thousands of images, or more. The UW–CIMSS team will also continue to collaborate on instrument concepts for future fire detection missions. Early wildfire detection means fewer fires grow to a size that threatens lives and property, and better characterization of the fires will lead to improved modeling of their smoke production and other effects. To measure success, we'll examine quantitative true and false positive rates, solicit feedback from fire chiefs and forecasters about the real-world utility of early detections, and monitor major fire events from satellites.

Timely mapping of wildfire burn scars after major events is also critical for assessing subsequent flood and mudslide hazards. Satellites such as Landsat create high-quality BARC (Burned Area Reflectance Classification) maps. However, the information from the OLI sensor on Landsat 8 is only collected once every 16-days and is subject to cloud cover interference. Therefore, the BARC maps are often not available in time to assist real-time mudslide forecasting. To address this issue, UW–CIMSS scientists are bringing S-NPP and NOAA-20 VIIRS imagery into the workflow to cut latency. This project includes designing, building, and testing a prototype web-based dashboard for rapidly producing satellite-derived post-fire Burn Intensity Delta Greenness Estimation (BRIDGE) maps to support mudslide and debris flow warnings issued by the National Weather Service. This is currently being tested at the NWS-WFO in Spokane, WA. The BRIDGE maps are intended to provide an early actionable quick look to the more detailed BARC maps produced via Landsat.

A BRIDGE map is quickly made by subtracting before-fire Normalized Difference Vegetation Index (NDVI) from after-fire NDVI over a burn scar area following a wildland fire (Fig. 3.2.1.7). NDVI is an Environmental Data Record routinely produced through the CSPP Direct Broadcast processing package. The resulting raster is converted to GIS-compatible vector polygons with four levels of estimated intensity applied. This procedure trades accuracy and resolution for reduced latency, greater coverage, and greater availability.

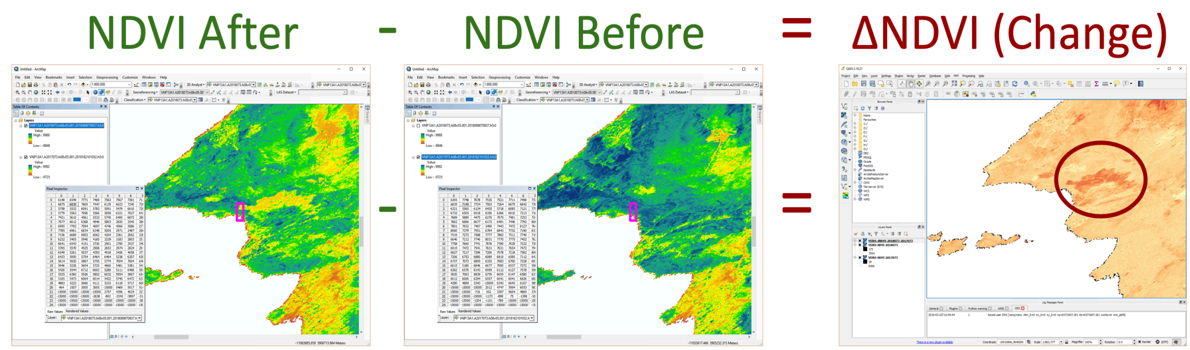

FIGURE 3.2.1.7: This series shows a Burn Intensity Delta Greenness Estimation (BRIDGE) map made from taking the difference between before-fire and after-fire VIIRS-derived NDVI from standard EDRs that highlights the burn scar left by the Thomas fire in Southern California of 2017-18.

UW–CIMSS researchers propose to improve the situational awareness of NWS post-fire hazard forecasts by providing timely burn intensity maps based on an expanded array of satellite observations. Our vision over the next 5-10 year period is to produce a set of near-operational decision support maps of estimated burn intensity derived from multiplatform satellite imagery.

3.2.1g Great Lakes-Specific Applications

NOAA strategic plans document the need to facilitate a stronger understanding of coastal, Great Lakes, and associated weather sciences. As a NESDIS CI located in the upper Midwest, UW–CIMSS applies satellite-derived atmosphere and surface properties to support operational forecasting and research in the Great Lakes region.

The Great Lakes have a huge impact on the surrounding regional weather and climate. For example, cold air outbreaks are a common during the winter in this area and often lead to lake-effect snow (LeS) events, which significantly impact the leeward shores of the Great Lakes. LeS forecasting is challenging due to high variability in the intensity and locations of the snow bands, further exacerbated by NEXRAD observational deficiencies due to the shallow precipitation profile. Additionally, LeS events are difficult for NWP models to forecast as the snow to liquid ratios have high variance and accumulation estimates rely on accurate representations of the boundary layer thermodynamics and microphysical assumptions.

UW–CIMSS researchers work closely with ASPB scientist Dr. Mark Kulie to improve snowfall estimates from spaceborne instrumentation and understand LeS processes. In coordination with Dr. Kulie and the Marquette NWS office (MQT), UW–CIMSS is developing a LeS nowcasting product that derives snowfall accumulation from an empirical relationship between GOES-based cloud liquid water path and NEXRAD-derived snow rates. Looking forward, UW–CIMSS LeS scientists propose to fuse satellite-retrieved cloud properties with ground-based radar and microphysical observations to generate an improved near real-time product for LeS nowcasting of quantitative snowfall estimation. This project will leverage our long-term (6+ years) ground-based instrument suite at the MQT NWS office to further enhance these studies (Pettersen et al., 2019). A similar analysis is proposed for the lower Great Lakes to develop additional regional parameterizations that account for assumed microphysical and snowfall intensity differences associated with intense single-band LeS events. This effort will lead to a GOES16-based nowcasting product for the entire Great Lakes region that can be used by NWS offices in the region.

UW–CIMSS also participated in an experiment to understand elevated spring and summertime ozone levels that pose an air quality challenge along the western coast of Lake Michigan. Production of ozone over the lake combined with onshore daytime lake breezes increases ozone concentrations preferentially at inland locations within a few kilometers of the shore. The 2017 Lake Michigan Ozone Study (LMOS 2017) was a collaborative, multi-institutional field study of ozone chemistry and meteorology along the

Wisconsin-Illinois Lake Michigan shoreline using a combination of aircraft, ground- based and ship-based measurements.

UW–CIMSS deployed the SSEC Portable Atmospheric Research Center (SPARC, Wagner et al. 2019) at the Sheboygan, WI supersite to provide continuous ground-based temperature and water vapor profiles from the SSEC Atmospheric Emitted Radiance Interferometer (AERI) (Knuteson et al. 2004a, b), aerosol backscatter measurements from the SSEC High Spectral Resolution LIDAR (HSRL) (Shipley et al, 1983), and Doppler Lidar wind measurements. Meteorological characteristics of lake-breeze penetration were captured in detail, including during multiple ozone exceedance events. We are currently collaborating with the Wisconsin Department of Natural Resources (WDNR) and the Lake Michigan Air Directors Consortium (LADCO) on using lake breeze observations from the 2017 Lake Michigan Ozone Experiment (LMOS) to develop improved meteorological modeling platforms for federally mandated State Implementation Plan (SIP) activities. The LADCO SIP activities are used to determine the best emission control strategies to mitigate ozone exceedances along the shore of Lake Michigan.

Future Lake Michigan campaigns are being planned to include the deployment of instrumented drones and ultra-light piloted aircraft to better sample the lowest 100m of the marine and terrestrial boundary layer to understand the role of ozone precursors such as nitrogen oxides (NOx) and volatile organic compounds (VOCs) to better understand ozone formation mechanisms in this region (Vermeuel et al., 2019).

3.2.1h Climate Data Records

Leveraging this extensive expertise in satellite remote sensing, UW–CIMSS researchers also perform the intense inter-calibration and sampling analyses necessary to generate long-term satellite climate data records (CDRs) for tracking long term changes in variables such as clouds, moisture, fires, and sea/lake ice concentrations at local to global scales. These efforts address NOAA's goal to employ satellite observations to advance the national climate mission, including the monitoring and understanding of climate variability.

One of the longest CDRs developed by UW–CIMSS scientists is a HIRS dataset that offers a unique record of satellite-based IR measurements in the 4.3- and 15-µm CO2 absorbing bands and in the 6.7-µm H2O absorbing band beginning in 1975 with Nimbus 6 and has been continuous since TIROS-N in 1978. Counting periods when multiple sensors were flying in each orbit, this HIRS data record amounts to over 80 satellite years. Using inter-comparisons with high spectral resolution IASI (Infrared Atmospheric Sounder Interferometer) measurements and simultaneous nadir overpasses, HIRS infrared data have been recalibrated through adjustment of spectral response functions from 1981 onwards.

Analysis of this recalibrated dataset shows that 75% of the annual HIRS observations are influenced by cloud, a trend which has remained steady in the forty years recorded (Menzel et al., 2016). High cloud frequencies have a seasonal cycle with the NH and SH oscillating out of phase and NH maxima that are ~5% larger than those of the SH (see Figure 3.2.1.8). Subsequent integration of the existing HIRS cloud dataset and the MODIS collections (Frey and Menzel, 2019) has revealed that there are differences in the percentage of high cloud determinations, but the global patterns through the seasons and hemispheres are very similar.

In parallel, working in collaboration with ASPB scientists, UW–CIMSS has developed a long-term CDR of clear sky total precipitable water (TPW) using AVHRR and HIRS observations. HIRS-derived products have been analyzed to determine global moisture changes over seasons and decades, and it is has been found that the seasonal TPW cycle is strongest in northern mid-latitudes, weakest in the tropics and decreases in tropical TPW during La Ninas are causing a modest 35 year drying trend. The absence of a split window in earlier HIRS sensors has prompted a merging with AVHRR data, and reprocessing is underway.

AVHRR data from 1981 to the present have also been collected in the Pathfinder Atmospheres-Extended (PATMOS-x) record which consists of twice daily fields from all sensors mapped to an equal-angle global grid (Heidinger et al., 2014). Developing cloud climatologies that are physically consistent with those from EOS and JPSS is crucial so that the 30 years of LEO data contribute to the climate missions of more advanced sensors. Recently, water vapor and CO2 channels from the HIRS instrument have been added to the AVHRR GAC data record (Weisz et al., 2017). The goal is to address known shortcomings of the AVHRR-only record, such as polar cloud detection and vertical placement of thin cirrus, and to make the spectral content of the PATMOS-x record more consistent with that of the EOS and JPSS missions.

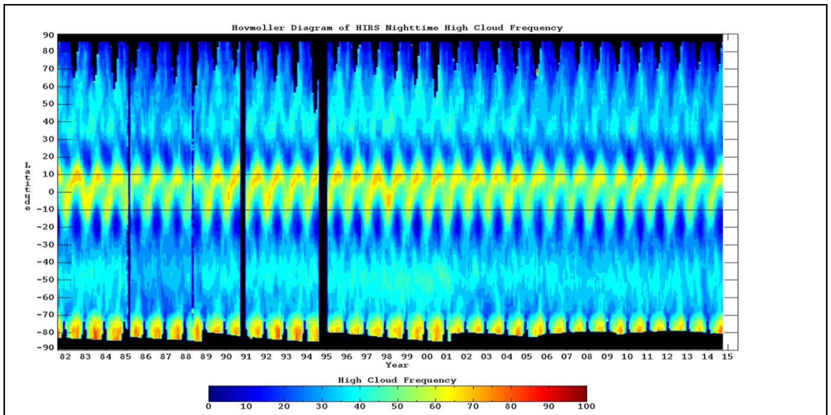

FIGURE 3.2.1.8: Hovmoller plot of HIRS nighttime high cloud frequency from 1982 - 2015.

The long-term AVHRR dataset has also been used to study climate change in the Arctic. Current surface temperature, surface albedo, and cloud forcing tendencies imply that without changes in seasonal cloud amounts, surface warming would be even greater than that observed. The influence of trends in cloud cover and sea ice concentration on trends in Arctic Ocean surface temperature was investigated analytically and evaluated empirically with the AVHRR data and other satellite products (Liu et al., 2008). It was demonstrated that changes in ice concentration and cloud cover played major roles in the magnitude of Arctic surface temperature trends. Significant surface warming associated with sea ice loss accounted for most of the observed warming trend in autumn. In winter, cloud cover trends explain most of the surface temperature cooling. In spring, half of the warming is attributed to the trend in cloud cover.

In an effort to extend the AVHRR/HIRS data and products to more than 50 years, AVHRR/IASI and VIIRS/CrIS data can provide continuity for the TPW and high cloud determination CDRs. The high spectral resolution CrIS and IASI measurements can be averaged over a selected HIRS spectral response function to create HIRS-like measurements. The AVHRR cloud mask co-located within IASI measurements can identify the presence of cloud; the VIIRS cloud mask developed with an AVHRR approach (Heidinger et al., 2016) can be used to identify cloudy CrIS measurements. The CO2 slicing approach can then be used in a consistent manner on all three data records to identify cloud properties.

Challenges remain, but the combined AVHRR/HIRS, AVHRR/IASI, and VIIRS/CrIS records offer unique insights in the long term cloud and moisture trends observed through several sun cycles and major volcanic eruptions. UW–CIMSS proposes to continue work with NOAA/STAR/ASPB in developing satellite-based CDRs for applications to trends in variables such as clouds, moisture, fires, and sea/lake ice. Because CDRs require carefully calibrated radiances, UW–CIMSS will continue to monitor the calibration of the GEO/LEO constellations and develop stronger ties with other NESDIS CIs as we pursue these activities.

3.2.1i Operational Demonstrations of Satellite Product Applications

The value of these applications of satellite products is only fully realized when they are adopted at forecast offices and by other stakeholders. UW–CIMSS researchers have partnered with NWS Forecast Offices and NOAA National Centers to provide data products, train forecasters in their applications, and evaluate their utility. This two-way interaction with professional users through the annual NOAA Testbed demonstrations (https://www.testbeds.noaa.gov/) and 'Proving Grounds' has helped to ensure the usefulness of satellite-based data and derived products by streamlining the research-to-operations process. For example, UW–CIMSS played a major role in support of GOES-16/17 Proving Ground demonstrations by evaluating the Algorithm Working Group demonstration algorithms and baseline products, testing enhancements and

advanced products (from the Risk Reduction Program), and getting user assessments and feedback to the product developers. Partnerships were expanded to NWS Forecast Offices with direct visits to help train additional forecasters in product applications and to get feedback on their utility.
Over the past 10 years, potential decision support products developed at UW–CIMSS have been demonstrated with operational forecasters to obtain feedback within NOAA Research Testbeds or National Centers (reports can be found at https://www.goes-r.gov/users/pg-activities-01.html). A complete summary can be found in Table 3.2.1.1. Examples include:

- Annual Hazardous Weather Testbed (HWT) -- Spring Experiment
- National Hurricane Center (NHC) -- Tropical Cyclone satellite-based product demonstrations. Participants include NHC forecasters.
- Annual Aviation Weather Center (AWC) -- Summer Experiment. Participants include AWC forecasters and FAA representatives.
- HPC/ OPC/ TAFB/ and SAB demonstrations (ongoing: focus on precipitation and ocean applications).
- High Latitude and Arctic Testbed (ongoing: focus on snow, cloud, volcanic ash, and aviation applications). Participants include NWS Alaska Region.
- Pacific Region OCONUS Demonstration (ongoing: focus on tropical cyclones, heavy rainfall, and aviation applications). Participants include NWS forecasters and University of Hawaii scientists.

UW–CIMSS also participated in the NOAA Sensing Hazards with Operational Unmanned Technology (SHOUT) campaigns. This program ran from 2015 through 2017 and was designed to demonstrate the real-time tropical cyclone observing capabilities of a NASA Global Hawk aircraft for potential eventual operations support to NOAA. UW–CIMSS provided the Global Hawk team with flight path decision support data in real time from multiple satellite platforms, tailored specifically to the SHOUT region of interest.

TABLE 3.2.1.1: Summary of selected CIMSS developed or supported satellite-based products and decision support aids for the GOES-R Series/JPSS Series programs, their designated categories (Baseline/NOAT/Future Capability), and the supporting operational Testbed leads during 2010-2020.

GOES-R/JPSS Demonstrated Products 2010-2019	Testbed	Category
Aircraft Flight Icing Threat	AWC/Alaska	Future Capability
ACHA Cloud Height/Phase Algorithms	AWC/Pacific Region	Baseline
Fog and Low Stratus	AWC/Alaska	Future Capability
NearCasting Model	HWT/Alaska	Risk Reduction
GOES Super Rapid Scan – Mesoscale Sector imagery	HWT	Baseline
Probability of Severe Model	HWT/OPC	Risk Reduction
Overshooting Top Detection	HWT/AWC/OPC	Future Capability
Thermodynamic profile stability and total precipitable water	HWT/AWC	Baseline
Simulated Cloud and Moisture imagery	HWT/AWC	Baseline
ADT and SATCON TC Intensity	NHC	Baseline
Turbulence Inference	AWC/Pacific Region (Hawaii)	NOAT Priority
Simulated Satellite Imagery using NWP	AWC/HWT/ Pacific Region	Baseline
Baseline Products: products designated for initial operational implementation **NOAT/Future Capabilities Products:** Promising new capability products **Risk Reduction:** Advanced current products through enhanced research		

3.2.1j Impact Assessment, Community Engagement, and Social Sciences

To further address our objective of supporting end-to-end utilization of meteorological information and address NWS mission to "*protect life and property*", UW–CIMSS also leverages its data, products, and expertise in geospatial modeling to engage communities throughout the US and world to develop strategies for modeling their risks and vulnerabilities to natural disasters. This research and outreach is becoming a central focus of NOAA and other agencies as changes to our climate influences the impacts to people, infrastructure, and local economies. Communities are struggling to find answers to the new challenges that climate change is bringing. In 1980 the United States averaged three disasters per year that exceeded one billion dollars (CPI-adjusted), but in 2019 that number has increased to 13 per year. Building strategies that make communities more resilient to these disasters is a priority many federal agencies have developed into their future strategies.

To strengthen the pathway for CIMSS data to impact local communities, Dr. Shane Hubbard works with states and local governments to identify hazard risks before, during and after storm events and then collaborates to design strategies that mitigate against those risk. These agencies work together leveraging mitigation grant programs that are offered by the Federal Emergency Management Agency (FEMA). Recently, Hubbard and his team modeled the potential impacts from Hurricane Dorian as it was forecasted to make landfall. They relayed information regarding the potential damages and dollar losses from Dorian to South Carolina Emergency Management Division and Florida's Division of Emergency Management. These analyses are critical in determining affected populations and understanding the spatiotemporal evolution of the areas that will require the most assistance after a hurricane's landfall. In January 2017, Hubbard worked with a collaboration of private sector, public sector, and academic institutions in San Juan, Puerto Rico modeling the potential impacts from a major hurricane. This work was used by the communities to lobby the municipal government to make changes to their stormwater system. This data was also instrumental in guiding the evacuations of 100 families just prior to Maria's landfall.

Recently, CIMSS 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 those locations in the Toledo, Ohio area that will have longer recovery times after being impacted by a flooding event. This work is being used by planners to understand the spatial patterns that of risk for increased resilience building activities.

CIMSS continues to grow its capabilities for modeling the impacts to natural disasters. In a continuing partnership with the Georgia Department of Natural Resources we have modeled the impacts of flooding and hurricane winds along the 11 coastal counties. In early 2019 we completed a project that examined the potential impacts in the late 21st century when climate change and sea level rise are included in the hazard development (Figure 3.2.1.9). For the coastline, we found the dollar losses could increase from three times higher to as much as eight times higher than today's expected dollar losses from a hurricane. Stream and Riverine flooding could see losses in some communities that are double the losses than we see today.

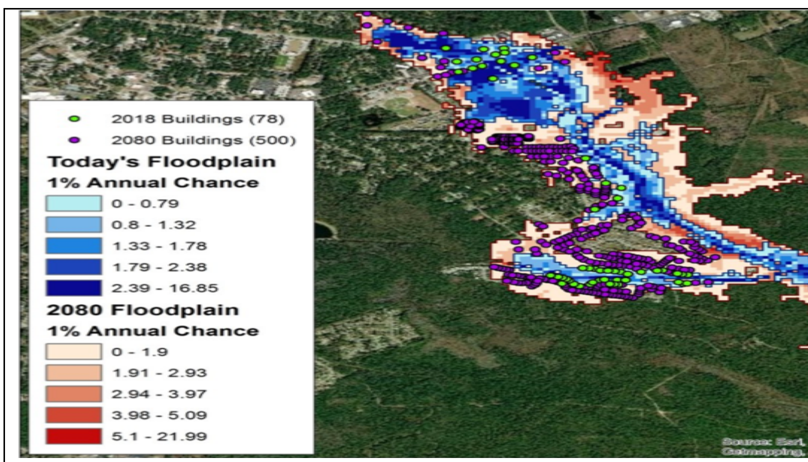

FIGURE 3.2.1.9: Changes to future floodplains in coastal Georgia and the potential impacts to future citizens.

The collaborations with government, academic, private sector, and non-profit groups has been a relationship that continues to grow. Each engagement serves a unique purpose within the collaboration. 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.

3.2.1k Summary of Proposed Activities

In summary, the continuation of CIMSS at the UW will enable improved methods of characterizing the earth-atmosphere system using satellite observations. Many of the projects are developing algorithms for delivery to respective Algorithm Working Groups at STAR. Successful algorithms will be transferred to NOAA operations. Specific examples of our proposed research plan include:

- Work with STAR and ASPB JPSS and GOES-R series teams to develop and test new retrieval algorithms for application to significant weather events;
- Continue research to provide operational upgrades for JPSS and GOES-R series AMV production;
- Further develop and optimize objective schemes incorporating data from multiple satellite platforms to more accurately analyze tropical cyclone intensity and structure;
- Continue our aviation applications work to produce new and advanced satellite-based analysis tools including volcanic ash and turbulence detection;
- Work with NOAA and international working groups on further development and implementation of the global GEO fire monitoring system, including the GOES-R ABI fire algorithm for improved fire detection and characterization;
- Enhance cryosphere research methods, continuing our collaboration with ASPB in AWG algorithm development to evaluate, improve, and provide satellite-based retrieval algorithms to estimate ice and snow properties;
- Continue to develop improved methods for monitoring clouds and their properties from satellite observations and conduct studies to better characterize the errors in cloud retrievals;
- Work with NOAA and ASPB in developing multi-platform fused climate data records for clouds, fires and sea/lake ice;
- Continue to support the transition of ProbSevere to operations, evaluate the accuracy of probabilistic wind, hail, and extreme precipitation forecasts, and improve their performance.
- Continue to demonstrate product applications with our partners at AWC, NHC, and others;
- Advance social science applications to increase the impact of satellite and weather information on public safety through collaborations with experts on the UW campus and other government agencies such as FEMA and the Department of Agriculture.

All of these activities will contribute directly to NOAA's Strategic Plan and the NWS mission by supporting the product research and development needs for the nation's operational satellites.

3.2.2 Satellite Sensors and Techniques

The successful transition of Suomi NPP, JPSS-1, and GOES-16/17 to operations has significantly advanced the capabilities of NOAA's meteorological satellite suite providing increased spatial and temporal resolution and greater spectral resolution than ever before. These satellites provide an excellent example of the unique capacity of UW–CIMSS to support the end-to-end process of realizing the benefit of satellite observations for weather and environmental analyses from designing the mission concept to developing the tools to extract information from the data they collect. This section describes how UW–CIMSS will utilize its experience in instrument design and optimization, sensor calibration and performance analysis, product validation, and state-of-the-art analysis techniques to maximize the societal benefit of current and future satellite observations.

3.2.2a Satellite Sensor Calibration

NOAA continues efforts to increase the accuracy of on-orbit calibration of its satellite instruments, to assure system specified requirements are met, and to validate satellite derived products. UW–CIMSS has assisted NOAA in these pursuits, and major examples over the past years are described here.

A major undertaking by NOAA and CIMSS in the past decade is ensuring and improving the calibration of the VIIRS and CrIS sensors on the SNPP and JPSS series satellites. Efforts regarding both sensors have included participating in the sensor design and trade-off studies, documenting performance reviews, collecting and analyzing pre-launch test data at the sensor vendor and spacecraft level testing, developing and improving the calibration algorithm, and performing a range of in-orbit evaluations. For VIIRS UW–CIMSS has provided wide-ranging input but with a primary focus on the spectral response function testing and characterization. For CrIS UW–CIMSS has focused on the radiometric and spectral calibration along with efforts to characterize the radiometric noise. Figure 3.2.2.1, for example, shows a long time series of daily mean differences between SNPP VIIRS and CrIS; the mean biases are 0.1K or less and the long-term trends are less than 2mK per year.

Developing calibration and validation (Cal/Val) procedures contributes directly to improved forecasts through more accurate model initialization. As climate studies using IR satellite measurements mature, intercalibration of satellite measurements that span beyond the life of a single satellite will become increasingly important. To this end, UW–CIMSS has played a major role in GSICS efforts to intercalibrate LEO-GEO, LEO-aircraft, LEO-LEO, and RO-LEO. Recent LEO-LEO work features inter-comparing IR sensors including CrIS, IASI, and AIRS, as well as assessing more recent LEO sensors GOSAT and HIRAS. LEO-GEO comparison are also contributing to FY4A GIIRS calibration. GSICS also leverages our efforts to develop an on-orbit absolute radiometric standard through the CLARREO program. UW–CIMSS/SSEC built and demonstrated the Absolute Radiance Interferometer (ARI) capable of 0.1K 3-sigma radiometric calibration accuracy. Along with this high accuracy for climate benchmarking, ARI provides on-orbit verification systems to prove the accuracy on-orbit, making it an ideal reference sensor for GSICS. Simulation experiments have also been performed to characterize the ability to transfer the ARI/CLARREO calibration to concurrent LEO sensors such as IASI and CrIS.

Comparisons of radio occultation (RO) and hyperspectral infrared (IR) sounder data also have useful applications for Cal/Val purposes. Our initial work in this area helped pioneer the validation of hyperspectral infrared sounder temperature retrievals using RO dry temperature products, which have high vertical resolution and high accuracy in the upper-troposphere, lower-stratosphere (UTLS) region (Feltz 2014). Following this initial work, comparisons of RO and hyperspectral IR sounders were then performed in radiance space – that is, simulated IR radiances were computed using the RO temperature profiles and compared to the direct IR radiance measurements. This method was first applied to AIRS and COMSIC data over a 6-year time period, but more recently was applied to CrIS/IASI and ROM SAF GRAS RO data through a visiting scientist position with the EUMETSAT ROM SAF (Feltz 2017). A primary objective for future work on this topic is to provide Cal/Val support for both NOAA's operational hyperspectral infrared products and the COSMIC-2 operational profile products by creating and making use of profile-to-profile comparisons between the two datasets.

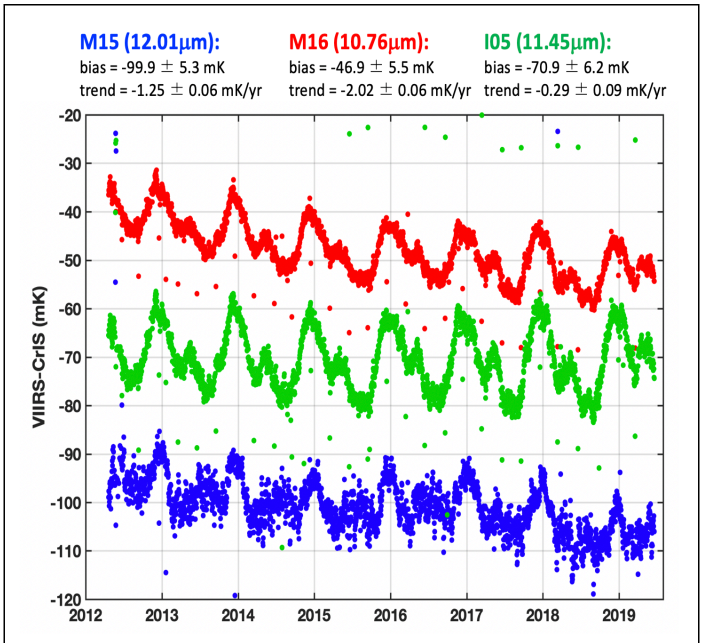

FIGURE 3.2.2.1: Long term differences between SNPP CrIS and SNPP VIIRS for VIIRS spectral bands M15, M16, and I05.

UW–CIMSS has been an active participant in the GOES-R Calibration Working Group (CWG), supporting ABI calibration and validation activities pre-launch and post-launch. Experience with the previous and new generation GOES-series on science checkouts and radiance quality assurance have been valuable to the CWG, as well as involvement on the GOES-R AWG to develop a system for analyzing ABI product output. UW–CIMSS continues to report to the CWG on issues affecting GOES radiance and navigation quality on operational GOES. This includes supporting GOES-R Program and CWG efforts to mitigate the effects of the GOES-17 LHP anomaly by generating a web page that presents GOES-17 Focal Plane Module (FPM) temperatures along with mean brightness temperature differences for GOES-16 and GOES-17 in near-realtime (http://cimss.ssec.wisc.edu/goes-r/abi-/band_statistics_imagery.html). Through analysis of this data, our researchers found a periodic calibration anomaly (later named PICA) was affecting ABI data calibration and helped validate when a correction was implemented. We also studied the ABI instrument vendor's LHP mitigation strategy called Predictive Calibration (PCal), and showed that it greatly improves the quality of GOES-17 ABI data during diurnal heating periods. In addition, UW–CIMSS first notified the GOES-R Program of the Cold Pixels Around Fires (CPAF) phenomenon; artificially cold pixels appear near especially hot (fire) pixels in the 3.9um band due to remapping and validated the results from the new remapping algorithm.

UW–CIMSS will continue to support ABI calibration and validation. Currently the team is assessing GOES-17 ABI Spectral Response Functions (SRFs) updated for inflight internal FPM temperature of approximately 81K instead of the pre-launch anticipated 60K. In first quarter 2020 the GOES-17 L1b radiance and L2 Imagery products will undergo Full Maturity Status reviews, with CIMSS assisting the CWG on the L1b review and leading the Imagery portion of the review. GOES-17 LHP issue support is expected to continue. There will be two more Post Launch Tests for ABI on GOES-T and GOES-U during which UW–CIMSS anticipates providing the same support that was provided during GOES-16 and GOES-17 PLTs.

3.2.2b Sensor Performance Analysis

Recognizing the importance of observational systems to weather and climate applications, NOAA research seeks to ensure that new observations meet the demands of both applications through close coordination of observing system requirements. To support this NOAA goal UW–CIMSS collaborates with NESDIS and other CIs in the sensor performance characterization and post-launch check-out of GOES and JPSS satellites.

CIMSS has been involved in the post-launch science checkout of every GOES satellite, examining the quality of the Imager and Sounder instrument data and derived products. CIMSS continues to play a critical role in the success of the Advanced Baseline Imager on the GOES-R mission from the initial band selection studies in 1999 through to today's post-launch validation, GOES-17 loop heat pipe mitigation efforts, and transition to Enterprise algorithms. UW–CIMSS GOES-R checkout activities include collection and archival of the data, an assessment of the radiometric accuracy of the instruments, and validation of various products. For example, UW–CIMSS assessed post launch radiometric performance of the GOES-16 and GOES-17 Advanced Baseline Imager (ABI) in three ways. First, the data from ABI is collocated and compared to polar-orbiting instrument data using the UW–CIMSS GEO-LEO intercalibration methods. Second, the noise in each band is estimated from special space views. Third, quantitative products and derived imagery are generated and compared to other GOES operationally generated products.

UW–CIMSS also played a key role in the sensor performance analysis and pre- and post-launch checkout of the VIIRS and CrIS instruments on the SNPP and JPSS-1 (NOAA20) satellites. These efforts included participation in the sensor design and trade-off studies, performance reviews, pre-launch test data collection and analysis at the sensor vendor and spacecraft level testing, calibration algorithm development and improvements, and a range of in-orbit performance evaluations. For example, VIIRS performance assessment has included relative spectral response (RSR) testing and characterization; daily VIIRS-CrIS radiance comparisons over the mission lifetimes for the VIIRS TEB bands M13, M15, M16, and I5; the investigation of a temperature and scan angle dependence in NOAA-20 VIIRS bands M15 and I5; and the evaluation of M13 detector striping.

For CrIS, UW–CIMSS efforts have focused on radiometric uncertainty assessment, noise characterization, radiometric accuracy and stability, detector nonlinearity characterization and refinement of the nonlinearity correction algorithm, characterization of the degraded SNPP internal calibration target (ICT) emissivity and evaluation of the impact on radiometric uncertainty, polarization characterization and development of a correction algorithm, and instrument spectral response (line-shape) characterization and calibration.

The CrIS polarization characterization and correction work is a prime example of leveraging the unique capabilities at UW–CIMSS for sensor performance analysis. The impact of sensor polarization on radiometric calibration was expected to be negligible for CrIS. However, the CIMSS team determined that when the very small levels of polarized emission from the scene mirror were considered, the impact on calibrated brightness temperature is significant for cold scenes. Our team developed a model of the polarization induced calibration bias and determined the model parameters using on-orbit pitch maneuver data for both the SNPP and NOAA20 CrIS sensors. The UW–CIMSS CrIS team then collaborated with NOAA NESDIS to integrate the polarization calibration bias correction into a near-operational version of the Algorithm Development Library (ADL) as a new module and three months of SDR and corresponding BUFR data with and without the polarization correction applied were generated at UW–CIMSS for both SNPP and NOAA-20. These large datasets were used for EDR and Data Assimilation assessments and the results were presented at a NOAA Technical Interchange Meeting (TIM), and the Algorithm Engineering Review Board (AERB) approved implementation of the CrIS polarization correction in the operational processing after reviewing this material.

3.2.2c Optimizing Instrument Characteristics for Future Satellite Imagers and Sounders

Developing the next generation operational satellites is a critical NOAA function led by NESDIS with assistance from cooperative institutes. Given its decades of experience, UW–CIMSS is uniquely qualified to provide expertise in evaluating proposed satellite sensors, including specifying instrument characteristics and applications for future satellite imagers and sounders. UW–CIMSS has supported the spectral channel selection for the VISSR Atmospheric Sounder (VAS), the subsequent operational GOES Sounder, and the current generation GOES-R Imager (ABI) (Schmit et al., 2005). For the polar orbiting instruments UW–CIMSS has strongly advocated the addition of a water vapor absorption channel to later versions of the VIIRS. UW–CIMSS scientists also played a key role specifying instrument characteristics for the NPP CrIS instrument (the original design concept for CrIS was developed at SSEC/CIMSS).

UW–CIMSS' experience in satellite remote sensing of clouds, snow, land and sea ice, volcanic ash, atmospheric and sea surface temperature, atmospheric moisture, precipitation (including snowfall), fires, coastal and Great Lakes, drought monitoring and prediction, and conditions that lead to severe weather will be key assets for specifying instrument characteristics for future satellite imagers, as was the case with the ABI. There is an opportunity to add bands to the imager that will help air quality and coastal waters monitoring (ocean color). Additionally, technical improvements that increase spatial resolution and other potential enhancements offer the opportunity for a new set of algorithms.

Accurate proxy datasets are critical for specifying and simulating instrument characteristics for future sensors. UW–CIMSS pre-launch activities for the GOES-R mission included development of real-time ABI proxy data by utilizing CIMSS expertise in numerical weather prediction (NWP) and radiative transfer. All algorithm development teams, the GRB simulator, and AWIPS pre-launch training efforts used those proxy data to help prepare the nation for GOES-R (Greenwald et al, 2016). CIMSS also used these proxy data in assisting the government in the prelaunch analysis of 18 instrument waivers for the ABI during instrument fabrication and integration on the spacecraft. Figure 3.2.2.2 shows the 16 spectral bands of a GOES-R ABI proxy dataset generated at UW/CIMSS.

In the future, NOAA's geosynchronous orbit program may also include instruments in a Tundra orbit. CIMSS has developed a Tundra orbit simulator and generated imagery from an ABI-like instrument in Tundra orbit with realistic view angle and spatial resolution considerations. CIMSS is currently working with NOAA's Office of Projects, Planning, and Analysis (OPPA) under their Technology Maturation Program (TMP) to assess the utility of placing instruments in Tundra orbit to support future high-latitude satellite meteorology applications.

In conjunction with SSEC, UW–CIMSS also has established expertise supporting the specification of high spectral resolution imaging infrared sounder measurement requirements. Our first detailed design of what we now refer to as a GEO Hyperspectral Imaging Infrared Sounder (HIIS) is given in the report of a University of Wisconsin-led NOAA contract that began in 1980, the year in which CIMSS was founded, driven by the recognition that atmospheric sounding needed higher vertical resolution. This began a long series of interferometer-based sensor designs and industry partnerships that significantly advanced this field of research and provided visions of new opportunities for NOAA operational observing.

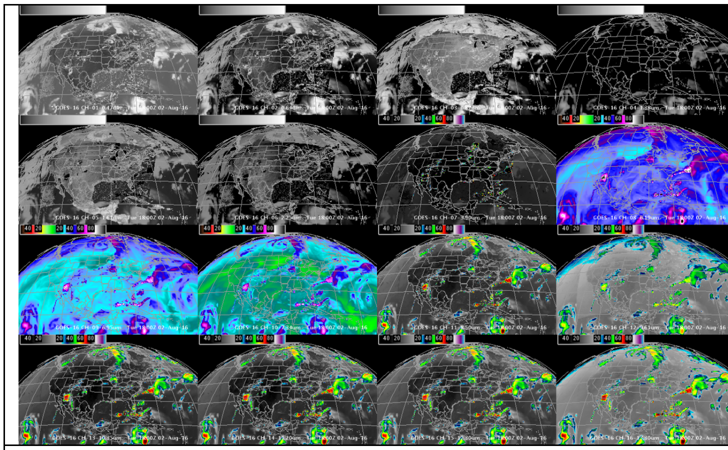

FIGURE 3.2.2.2: The 16 spectral bands of GOES-R ABI simulated at UW/CIMSS, processed via the GOES-R Ground System, acquired via NOAAPort, and shown in AWIPS-II for August 02, 2016 (3 months before launch) for DOE-4.

Instrument specification and design research at UW–CIMSS has greatly benefited from accompanying airborne and ground-based instrument development at SSEC. The hyperspectral IR sensor (HIS), for example, flew on many research campaigns aboard the NASA high altitude U2 and ER2 aircraft between 1985 and 1998. HIS spectra were used to thest the premise that higher spectral resolution would result in atmospheric soundings with 2.5-3 times higher vertical resolution. SSEC also designed and built the Atmospheric Emitted Radiance Interferometer (AERI) system for the DOE Atmospheric Radiation Measurement (ARM) program, a new Scanning HIS high-altitude aircraft system, and performed a Phase A design for EUMETSAT that led the way for what became the CrIS IR sounder on Suomi NPP/JPSS. The AERI is a ground-based sensor that has been used extensively to further improve radiative transfer models and for sounding the critical planetary boundary layer region of the atmosphere. The Scanning HIS took over for the HIS, flying in many NASA, NOAA and DOE campaigns and became a very effective tool for validating the accuracy of spacecraft instruments, first demonstrating this important capability with very detailed evaluations of the AIRS sounder on the NASA Aqua mission soon after launch in 2002.

The great success of CrIS in the PM operational orbit is well known. CrIS together with IASI in the AM orbit have demonstrated the high level of importance of hyperspectral IR sounders to global NWP. All of these hyperspectral instruments have set a new standard for accuracy, demonstrating that a major limitation of the accuracy of infrared instruments has been the uncertainty of their spectral properties, which are extremely well defined for these spectrometers.

Since 2000, the primary focus on new observing capabilities at UW–CIMSS has been on the GEO HIIS, which began with the Geostationary Imaging Fourier Transform Spectrometer (GIFTS). By 2006, GIFTS had proven the feasibility of implementing an operational imaging IR hyperspectral sounder in geostationary orbit. Unfortunately, GOES-R did not include such a sounder, but the value was recognized in Europe leading to the MTG-IRS sounding instrument now scheduled for launch in 2022. Following the launch of a similar version by China in 2016, we are currently engaged in detailed evaluation of GIIRS data under NOAA funding.

This 40-year history of sounder development and related applications has allowed us to support NOAA’s need for operational sounding expertise and information on future systems. At this critical time for defining the next NOAA observing system capabilities, UW–CIMSS proposes to remain actively involved in helping to define the justify new sounding capabilities, to define potential future GEO and LEO observing systems, and to delineate approaches for handling the data streams, processing, and applications. Specific mechanisms include involvement in interactions organized under GOES-R, contributing to responses to recent Broad Agency Announcements (BAAs), and participation on the Systems performance Assessment Team (SAT).

Given our role in the success of the GOES-R and JPSS programs, UW–CIMSS is uniquely qualified to provide critical mission support to NESDIS in all phases of the next generation satellites, for imager and sounder, to ensure the United States remains a world leader in Geostationary, Tundra, and low-Earth orbit remote sensing science.

3.2.2d Satellite Product Validation

One of NOAA's Weather and Water Program Objectives is to reduce the uncertainty associated with weather and water decision tools and assessments, including uncertainties associated with satellite observations. Meeting this objective requires field observations to validate satellite derived products. UW–CIMSS and SSEC are actively involved in field campaigns (Appendix J) whose objectives include the validation of satellite radiances and derived products. The observations from aircraft and ground-based measurements systems continue to be important for assessing the performance of satellite algorithms in retrieving given physical parameters. Many of these validation exercises leverage collaborative activities with NASA, DoE and NSF.

Examples of CIMSS Cal/Val work include the evaluation of the first- and second-generation airborne Water Vapor Sensing System (WVSS), recent collaborations with EUMETSAT to investigate the role that routine aircraft observations can have in satellite product validation, and satellite Cal/Val via ground-based and high-altitude airborne observations that utilize infrared hyperspectral instruments developed at CIMSS/SSEC.

Recent collaborations between CIMSS and EUMETSAT have investigated the role of routine aircraft observations in satellite product evaluation. The Airborne Meteorological Data Relay (AMDAR) enables observations taken by commercial aircraft to be transmitted to the surface and disseminated to weather services worldwide with low latency. While these data have traditionally been used for NWP (and have been shown to have significant positive impacts on forecast skill) they are also a valuable tool for evaluating satellite observations, especially during ascent and descent where they create in situ profiles of temperature and winds (and in some cases, water vapor). In the past year, the collaboration has focused on developing an operational framework for using AMDAR observations to evaluate the Level 2 profiles from IASI. Results showed that AMDAR observations exhibit similar performance relative to IASI as operational radiosondes, with many more regions being evaluated as radiosonde launches only occasionally align with LEO overpass times while aircraft are flying constantly. This work was also an integral part of the operational certification of IASI on METOP-C. We propose undertaking similar research in coordination with NOAA Unique Combined Atmospheric Processing System (NUCAPS) for the evaluation of the current generation of LEO sounders and to prepare for future deployments of GEO hyperspectral instruments.

The UW–CIMSS/SSEC designed, built, and operated S-HIS is recognized as an infrared calibration reference standard for airborne satellite calibration validation. The high accuracy and established traceability of the S-HIS combined with pre- and post-campaign calibration tests conducted by CIMSS/SSEC scientists and engineers make the S-HIS uniquely capable of assessing current and future infrared satellite observations. The S-HIS has proven to be a key capability and asset for NOAA over its lifetime, and has been critical to highly accurate and traceable Cal/Val of satellite infrared sensors. In addition, it has been equally valuable for the development and improvement of many avenues of research including temperature and water vapor sounding, radiative transfer algorithm improvements, numerical weather prediction, and trace gas detection. In recent years, the S-HIS has been deployed for SDR and EDR calibration validation of the CrIS sensor during the 2013 and 2015 Suomi-NPP Cal/Val campaigns, Cal/Val of the Advanced Baseline Imager (ABI) during the 2017 GOES-PLT airborne campaign, and as a critical component of the ER-2 payload for the 2019 FIREX-AQ (Fire Influence on Regional to Global Environments and Air Quality) NOAA and NASA joint venture. Our hyperspectral infrared remote sensing team provides a unique combination of scientists and engineers with many decades of experience in hyperspectral infrared instrument design, calibration, and product development.

The AERI also provides a valuable resource for validating satellite sounding products. Through statistical or physical retrievals, high-temporal resolution thermodynamic profiles of the boundary layer can be obtained from AERI radiances. As a ground-based instrument, AERI has notable advantages for observing the boundary layer as compared to satellites: the proximity of the boundary layer to the instrument means that information content is concentrated precisely in the layer of the atmosphere where changes in the thermodynamic structure are the greatest, while the simple background of an upward looking observation means that profile retrievals are not as complicated as satellite-based measurements that have the earth's heterogeneous surface as the background. Permanent AERI installations exist in dozens of locations, and during field projects AERIs have been deployed to every continent and nearly every climate regime. We plan to reach out to all AERI operators worldwide and arrange a Memorandum of Understanding whereby the AERI operators gain access to the suite of tools and expertise developed by SSEC for the AERI (e.g. knowledge base, real-time monitoring, quality control, thermodynamic profiling, troubleshooting) in exchange for data sharing with SSEC. This arrangement will furnish SSEC with access to AERI observations at broad range of field sites in addition to the data publicly available through the ARM archive. We also plan to participate and support field campaigns with our partners for atmospheric process studies, resulting in additional satellite Cal/Val datasets. These partnerships will lead to overall better scientific cooperation between research groups with the goal of creating a users' group for all AERI operators, with regular meetings and data and information exchange.

AERIs can also be used to augment satellite observations. To advance this concept in the coming decade, CIMSS plans to evaluate how the fusion of AERI radiance observations with hyperspectral observations from geostationary orbit will enhance thermodynamic profiling, especially when characterizing instability in the preconvective environment. We propose to use a combination of observing system simulations and observations from current polar orbiting satellites (CrIS, IASI) and current and future geostationary hyperspectral instruments (GIIRS, MTG IRS) to develop a combined retrieval in anticipation of the future deployment of a geostationary hyperspectral sounder capable of observing CONUS.

3.2.2e Advanced Data Fusion

The fusion of ground-based and satellite-based hyperspectral radiances to improve humidity and temperature profiling capabilities represents just one example of revolutionary algorithm development at CIMSS. Another example is temporal/spectral fusion (TSF) that seeks to increase the temporal and spectral coverage of satellite sounders through autocorrelation and covariance between channels. UW–CIMSS researchers developed a strategy for mitigating the GOES-17 ABI detector cooling issues that occur at certain times on days before and after the equinox compromising the continuity of infrared image. The approach uses the GOES-17 ABI longwave infrared window (IRW) band 13 (B13) at 10.3 µm, which remains mostly unaffected, to map the other spectral bands, which exhibit data artifacts, including saturation. Beginning with the last full set of infrared radiances, TSF links subsequent IRW B13 measurements to the five best matching initial IRW B13 measurements (Weisz et al., 2017). Emulated measurements at affected spectral bands are then generated from these five matches to restore the missing ABI IR spectral bands at times when cooling issues are apparent. In this way, the fusion of data from one time to another is accomplished while maintaining spatial coherence with the unaffected channel.

The TSF approach has proven powerful for mitigating the LHP data outages in GOES-17 imagery but additional work is required to gain the full benefit of the fusion-based radiances. First, while window channels and band 16 (13.3 µm) are highly correlated with B13 images and the TSF products have been shown to exhibit few artifacts, the information contained in these products has not yet been used in any quantitative way to derive atmospheric state parameters or infer atmospheric hazard potential. Additional research is required to apply relevant geophysical parameter algorithms and evaluate the quality of the retrieved products.

In addition, water vapor sensitive images represent a big challenge for this fusion approach because they are the least correlated with B13 infrared window images. Over oceanic clear sky regions where the B13 temperatures do not change appreciably over time, the water vapor features remain stationary in the TSF restoration images. This produces a misleading sense of the atmospheric motion away from clouds (which are accurately tracked in the B13 measurements). In the coming years, two pathways can be explored to improve the water vapor image restoration:

1. Use GFS winds and reverse-domain-filling trajectory mapping (Pierce et al., 1997) to re-map the water vapor images during the data outage. IRW band 13 would locate the clouds at each time and the model inferred motion field, either vertically averaged using the WV band weighting functions or at a specific pressure level (e.g., 400 hPa) would move the clear sky water vapor gradients.

2. Use GFS forecasted temperature and water vapor, calculate the clear sky water vapor radiances (Greenwald et al., 2016) during the data outage using the Community Radiative Transfer Model (CRTM). Synthetic WV band radiances for a given pixel at times t0 and t would be generated at full ABI resolution. The TSF approach would be applied using the synthetic WV bands as predictors.

For both approaches a radiance bias (i.e., difference between model and observed radiances) will be evaluated at time t0, and an appropriate bias correction scheme will be applied to the radiance calculations at subsequent time steps. We anticipate that a thorough proof-of-concept investigation of the two avenues stated above will lead to an improved mitigation solution, which enables qualitative utility of the final fusion estimates in a variety of applications but in particular for forecasting operations. We will demonstrate the efficacy of these two approaches for specific use cases identified by the NWS.

3.2.2f Machine Learning, Artificial Intelligence, and Cloud Computing

More generally, machine learning and artificial intelligence are likely to feature prominently in the advancement of revolutionary algorithm techniques in the next decade. While machine learning has been an area of active research for decades, the discipline has rapidly increased in popularity in the past several years due to the advancements in GPU-accelerated computing, cloud computing, and associated software development. Furthermore, advancements in deep learning, a type of neural network framework with the capability of complex, non-linear pattern detection, has become a revolutionary tool for model development with image data and other very large, tabular datasets. CIMSS is exploring the potential of these new methods to more fully exploit the temporal and spatial information in LEO and GEO satellite observations. The university setting of UW–CIMSS facilitates the interdisciplinary collaborations required to pioneer creative new approaches to applying ML to modeling many aspects of the weather. In addition, CIMSS is in a unique position to explore cost-effective hardware infrastructures and cloud computing solutions to the Big Data challenge posed by applying ML to satellite applications.

Researchers at CIMSS have been investigating the possibilities of applying statistical image processing, machine learning and deep learning feature detection problems for several years. For example, Cintineo et al. (2019) describe a deep learning approach to detecting severe weather with lead times of up to 10 minutes longer than that of ProbSevere. Given the inherently non-linear nature of weather phenomena, however, it is important to link the results of such approaches to the underlying physics that connects the observations to the predictions. To these ends, Cintineo et al. (2019) present several relevant diagnostics (Figure 3.2.2.3) that identify the specific features in the imagery from which the associated severe weather predictions derive.

UW–CIMSS is uniquely positioned to advance the use of machine learning in satellite meteorology through multiple pathways:

1. *Improving algorithm performance*. ML techniques can improve upon many empirically-derived satellite-based detection methods, such as fire detection, severe weather detection, tropical cyclone diagnostics, AMVs, and aircraft hazards. They can also enhance physically-based methods for retrieving cloud and aerosol properties, moisture profiles, snow cover, and precipitation by adding ancillary information such as expected error (uncertainty) and probabilistic estimates. CIMSS' specific aims include:
    a. Improving deep learning models to infer aircraft turbulence potential from multichannel geostationary imagery.
    b. Use convolutional neural networks to identify scenes that pose a challenge for cloud height retrievals and atmospheric motion vector tracking.
    c. Apply convolutional neural network methods to hyperspectral sounding retrievals (e.g. from CrIS) to improve the process of data thinning (dimensionality reduction) for easier incorporation into NWP.
2. *Adapting data science techniques*. Computationally intensive ML techniques are vastly enhanced by new data science analysis tools. CIMSS will explore the use of dimensionality reduction through unsupervised learning, t-distributed stochastic neighbor embedding ("t-SNE", a form of data

clustering), and various model interpretation and visualization techniques (McGovern et al., 2019) to advance the use of ML in satellite meteorology.

3. *Use of LEO and GEO imagery to train and deploy machine learning models.* The complementary aspects of polar-orbiter imagery (high resolution, low sampling rate) and geostationary imagery (lower resolution, high sampling rate) have commonly enabled innovation in which imagery from geostationary platforms are calibrated to the higher spatial and spectral detail of the polar platforms. We will develop methods to accelerate this process through generalized training procedures and techniques of "transfer learning" (Pan and Yang 2009) that apply one robustly-trained data source to a new data source.
4. *Exploiting large data repositories to improve model skill*. CIMSS has direct access to the SSEC's satellite data archive, which is the largest satellite archive of any university in the world. This is an advantage in training deep learning models, which normally require at least tens of thousands of training samples, and whose final performance scales logarithmically with the training sample size (Sun et al. 2017). Another advantage of such a large archive is that it possesses a large sample size of even very rare events. This is of particular relevance to weather applications to ensure that rare extreme events of greatest societal relevance are present when training automated detection systems. Such "edge cases" usually present the biggest challenges to model skill.
5. *Joint modeling with satellite imagery and NWP fields*. The SSEC also maintains a repository of global GFS forecast fields, for the simulation of real-time joint satellite/NWP products, such as cloud height retrievals. We will configure the repository for direct access with large deep learning models that combine satellite imagery with NWP fields.

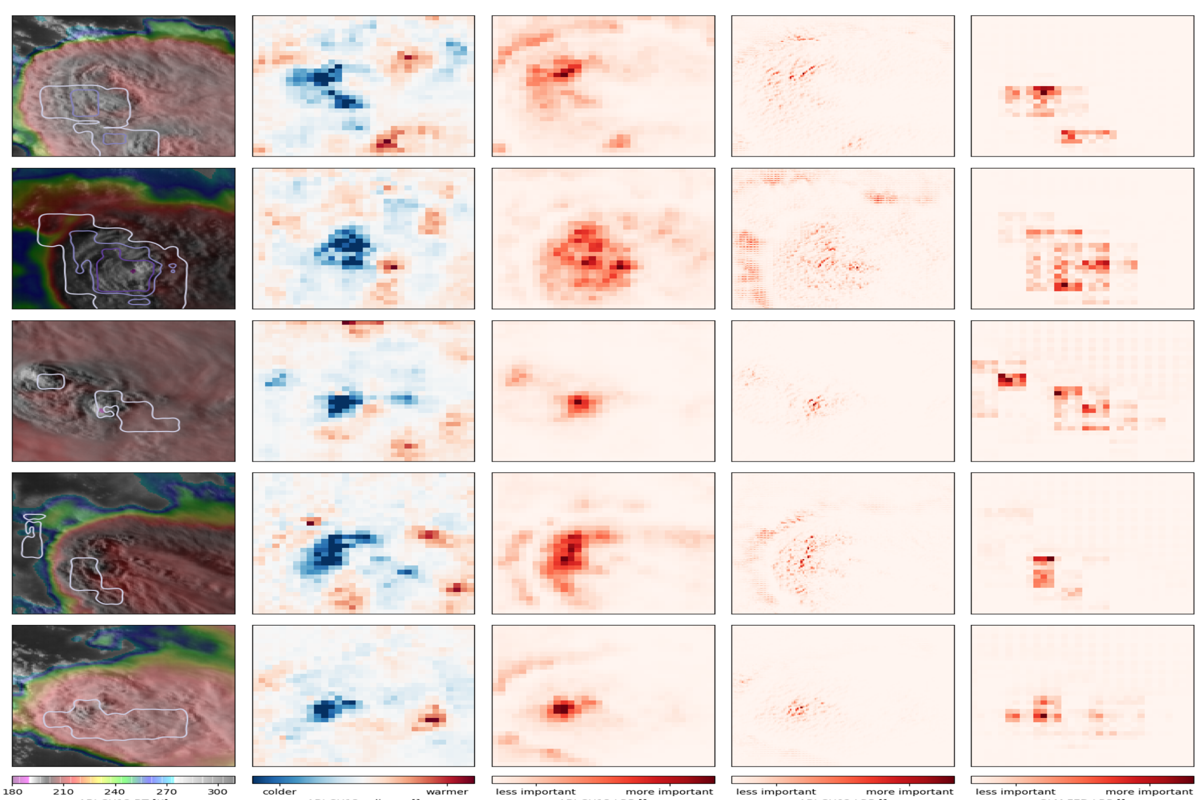

FIGURE 3.2.2.3: Deep learning visualization diagnostics from Cintineo et al. (2019) demonstrating the relative contribution of various features in the image to the predictand (severe weather) over five examples. Contours on the satellite image are the computed probability of severe weather at the surface.

To ensure that efforts to enhance the use of ML techniques in satellite meteorology yield value, we propose to investigate the robustness and interpretability of different approaches with a particular focus on assessing their reliability and reproducibility, central questions facing NOAA STAR as noted by Boukabara et al. (2019). Specifically we will seek to address:

1. Will the ML model be reliable, or will it be prone to be less accurate or even fail for rare or unusual cases? ML models can only learn what is in their training data sets.
2. How can AI overcome the trust barrier, i.e., the reluctance of some to accept ML model output if they can't understand what it is doing in its hidden layers?
3. Can ML development be disciplined enough to produce reproducible results?

To investigate the first two questions, we will identify and apply methods for combining physical models can be combined with neural network (NN) architectures to make them more interpretable, more reliable, and less sensitive to rare events absent from training datasets. Recent studies have shown that combining a NN architecture with a linear physical model decreases the required volume of training data (Gilton et al. 2019). We will build on this work to address the reliability and interpretability of ML methods (Gagne et al. 2019; Brenowitz et al. 2018; Karpatne et al. 2017).

Ensuring reproducibility from ML algorithms also remains an open challenge for meteorological applications (Roelofs 2019). For example, Recht et al. (2019) point out that the performance of NNs is very sensitive to minute changes in the dataset used to assess empirical error performance. It is, therefore, unclear how robust ML results may be given the potential for small perturbations in, for example, instrument calibration or noise (Engstrom et al. 2019; Recht et al. 2019). As an integrated center with expertise in sensor calibration, access to vast archives of LEO and GEO data, and high-end computing resources, CIMSS is well-positioned to rigorously assess the reproducibility of ML results in a variety of atmospheric remote sensing applications.

Supporting next-generation satellite observing systems: ML and AI also offer significant potential for defining instrument requirements for the next-generation of environmental satellites. For example, the NOAA NESDIS vision for the future of meteorological satellite observing systems includes utilizing distributed constellations of smaller and lower-cost satellites. To support instrument development for future distributed weather satellite networks, UW–CIMSS researchers will explore the potential benefits of ML methods for mitigating increased instrument noise due to the decreased optical aperture size relative to conventional sensors (Taylor et al. 2015; Pagano et al. 2003). Increased noise may impact the performance of current retrieval methodologies since temperature and water vapor retrievals from sounder observations is an ill-posed inversion problem (Huang et al. 2002). Machine learning methods may offer a solution for recovering some of the lost accuracy. They have proven useful for addressing the noisy ill-posed atmospheric lidar inversion problem (Hayman et al. 2017; Marais et al. 2016). The hyperspectral research team at UW–CIMSS will investigate how current statistical and machine learning techniques can be employed to improve current sounder retrievals.

Collaboration, Education, and Partnerships: Achieving these goals for advancing the use of ML for satellite meteorology applications requires the close interactions between atmospheric scientists, machine learning theoreticians (including statisticians, computer scientists, and mathematicians), and NOAA personnel that UW–CIMSS can provide. UW–CIMSS researchers collaborate with the UW department of Computer Sciences to address both the challenges of developing use cases for satellite data modeling and optimizing the hardware infrastructure to support these analyses. UW–CIMSS also engages several other departments with a shared interest ML applications including the School of Engineering, the Medical School, and the Department of Geosciences. These collaborations provide a conduit for sharing expertise enabling UW–CIMSS to keep pace with rapid scientific developments in the areas of AI and ML. They also growing common hardware infrastructure into a highly leveraged system with more processing capability than any one department or institute can build. These interactions have also provided an opportunity to explore the relative value of campus-based cluster computing and commercial cloud computing, for future development of ML approaches. Likewise, UW–CIMSS has cultivated collaborations with researchers at other institutions and within NOAA. For example, ongoing collaborations with Dr.

Rebecca Willett at the University of Chicago, an internationally-recognized expert in developing state-of-the-art AI and ML techniques, have led to the development of new methodologies for cloud and aerosol identification from radiometer images. We will leverage these strong connections to AI and ML expertise both within UW and from external partners to further the strategic goal of NOAA of maximizing the benefit of current satellite observations for weather applications. In addition, we will work with faculty members in other UW departments like CS and engineering to help develop the future NOAA workforce by encouraging students with ML-related skillsets to apply them to meteorological applications.

3.2.2g Summary of Proposed Activities

The effective use of satellite observations is essential to fulfilling NOAA's objectives of providing timely, accurate forecasts to stakeholders. Maximizing the societal benefits of new satellite measurements in the coming decade will require rigorous assessment of sensor calibration and performance, characterization of the information content of new technologies, and new advances in data analysis. Leveraging our extensive expertise and recognized leadership in satellite remote sensing, calibration, and validation, UW–CIMSS will:

- Maintain its strong legacy of using sub-orbital instruments such as S-HIS, AERI , and SPARC for calibrating and assessing the performance of satellite sensors such as CrIS, ABI, and VIIRS and informing the design of sensors in support of the next-generation of NOAA GEO and LEO satellites.
- Sustain ground-based measurements at long-term climatological validation sites and participate in targeted field campaigns to validate satellite retrieval products.
- Advance and expand the use data fusion techniques to increase the temporal and spatial resolution of satellite soundings and test their impact in forecast models.
- Continue to lead efforts to mitigate the effects of the GOES-17 Loop Heat Pipe (LHP) anomaly.
- Apply AI/ML approaches to develop revolutionary new algorithms that realize the full benefit of NOAA environmental satellites for characterizing the physical environment including but not limited to: winds, cloud properties, fire detection, severe weather, tropical cyclones, and aviation hazards (turbulence and volcanic ash).

3.2.3 Environmental Models and Data Assimilation

UW–CIMSS environmental modeling and data assimilation (DA) research during the next decade will focus on supporting NOAA's goal to "advance numerical guidance skill, reclaim and maintain international leadership in NWP, and improve the research to operations transition process" as outlined in the 2017 Weather Research and Forecast Innovation Act. These efforts will build upon our ongoing activities that support NCEP's operational global and regional NWP models in areas such as improved observation usage, DA system enhancement, model verification, and forward radiative transfer modeling. UW–CIMSS scientists have advanced operational DA capabilities and are recognized as leading experts in the use of satellite observations for model verification.

The foundation for our DA R2O efforts is expert knowledge of the operational Gridpoint Statistical Interpolation (GSI) analysis system. This expertise includes developing new datasets and forward operators, managing data formats, developing quality control (QC) procedures, determining observation error settings, and impact assessment. R2O relies on a strong Operations-to-Research (O2R) foundation, which is augmented by our easy access to the Supercomputer for Satellite Simulations and Data Assimilation Studies (S4) located in the Atmospheric and Oceanic and Space Sciences (AOSS) building that houses UW–CIMSS (Boukabara et al., 2016). As NOAA operational NWP models have rapidly evolved in recent years, we have continuously updated model software and requirements for documenting software contributions for NOAA code repositories (e.g., svn, git, github). This effort continues with the porting of the operational versions of the global FV3-GFS, regional SAR-FV3, and HWRF modeling workflows to S4. A key focus of our future DA efforts is aligning and transitioning from supporting GSI-based development towards more generalized and scalable architectures currentlybeing developed under the Joint Effort for Data assimilation Integration (JEDI).

As the NOAA operational modeling and DA frameworks continue to evolve to include more community input, UW–CIMSS will play a critical role in developing a community weather research modeling and DA system, and in particular within the new EPIC, a NOAA effort to engage the broad community of weather and climate modeling scientists to improve NWP. EPIC will provide the software, data, and user support so that researchers within the broader community, at the NOAA CIs, and operational centers are using common NWP systems. UW–CIMSS is in a unique position to play a vital role in the R2O/O2R process within the EPIC community modeling framework by continuing to support "mission-oriented research and development to improve NOAA's operational and information services" (Fig. 3.2.3.1). The modeling expertise at UW–CIMSS allows it to serve as a conduit between NOAA's community-based research partners and operational development and implementation through rigorous testing and evaluation of the innovative approaches from the broader NWP community within the NOAA Test Beds. Ultimately, the most useful approaches can be transitioned to NOAA Operations for further testing.

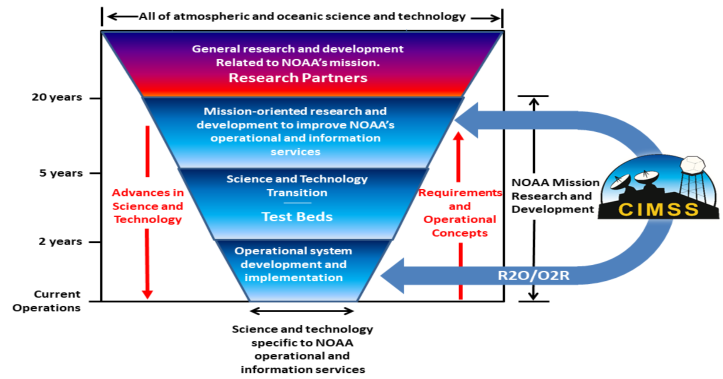

FIGURE 3.2.3.1: Schematic illustration of the community global weather research modeling and data assimilation system within the proposed Earth Prediction Innovation Center (EPIC) (Adapted from "The Earth Prediction Innovation Center (EPIC) Overview Presentation", Bill Lapenta, EPIC Community Workshop, 6 August 2019, Boulder CO). Our vision for CIMSS's role in EPIC R2O/O2R is indicated on the right side of the schematic.

3.2.3a Developing Satellite Data Assimilation Methods for NWP

Observations from the new generation of environmental sensors onboard the JPSS series and GOES-16/17 provide critical information for NWP. In particular, radiances sensitive to atmospheric temperature and moisture provide thermodynamic information that contributes significantly towards the prediction of high impact weather events such as tropical cyclones (TCs) and local severe storms (LSS). UW–CIMSS has improved the assimilation of sounding information in NOAA operational regional (e.g., HWRF) and global (e.g., GFS) NWP models, especially in cloudy skies, by adding collocated high spatial resolution VIIRS cloud information and IR band radiances (Wang et al. 2017; 2019). Figure 3.2.3.2 highlights results from the CIMSS Satellite Data Assimilation for Tropical storm (SDAT, https://cimss.ssec.wisc.edu/sdat/) development platform that assimilates both conventional and satellite observations. SDAT experiments showed that using collocated high spatial resolution VIIRS cloud mask and IR band radiances for cloud-clearing the CrIS radiances (CrIS cld-clr) leads to significant improvements in 120 h track forecast skill compared to using conventional (GTS), microwave (AMSUA+ATMS), and the original CrIS radiances for Hurricane Joaquin in 2015 (Wang et al, 2017). The operational NWP models incorrectly predicted landfall on 29 and 30 Sep, but then gradually corrected the forecast path starting 01 Oct. The SDAT experiments showed similar results with the original GSI scheme for CrIS (red line in Fig. 3.2.3.2). However, with the VIIRS-based CrIS cloud-cleared radiances (CCRs) assimilated, the track forecasts are much improved (green line in Fig. 3.2.3.2) due to the assimilation of more CrIS radiances, especially in cloudy skies. UW–CIMSS has also contributed to improving the operational geostationary AMVs assimilation in the GFS and HWRF models, including utilizing new information such as vortex scale AMVs from rapid scan ABI based AMVs within the NOAA operational HWRF and GSI assimilation system. These vortex scale AMV's are now ready for operational transition (Li et al. 2019). We also developed technical approaches and important quality control (QC) schemes for improving the water vapor absorption band radiance assimilation over land (Lee et al. 2019).

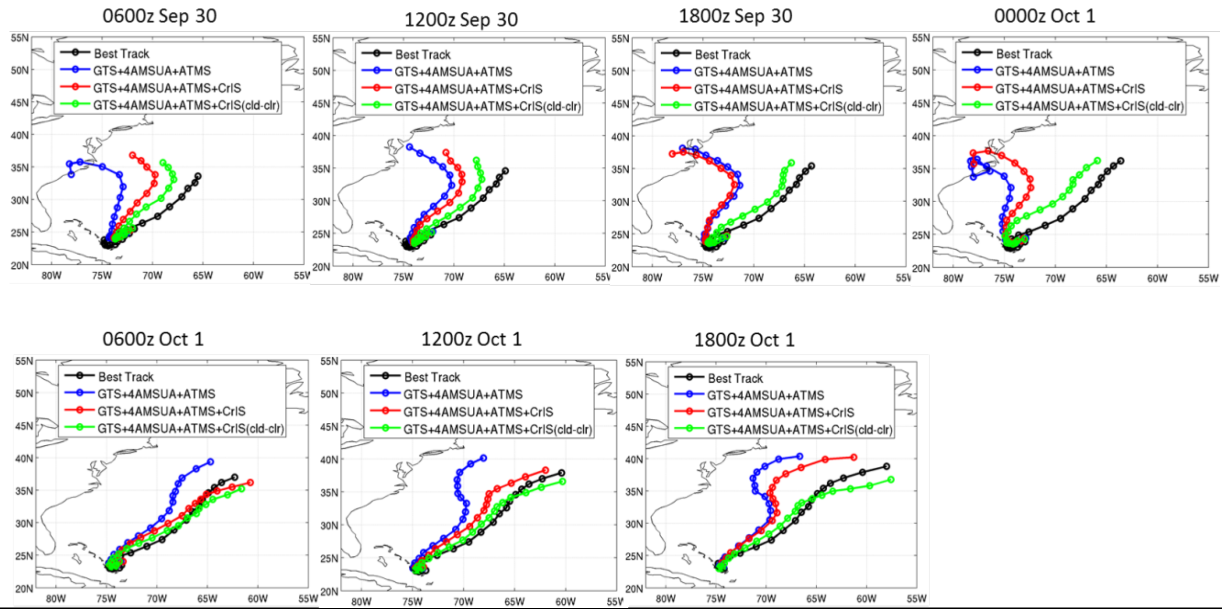

FIGURE 3.2.3.2: The 120-h track forecast from the Best Track (black), CTNL (blue), original CrIS (red) and cloud-cleared CrIS radiances (green) for Hurricane Joaquin from 0600 UTC 30 Sep to 1800 UTC 1 Oct. 2015. Note that most operational NWP forecasts have similar performance to the control run.

During the past decade, we have been at the leading edge of efforts to improve all-sky infrared brightness temperature assimilation in regional-scale DA systems. Several OSSEs were used to explore their impact in a controlled manner (Otkin 2010, 2012a, b, Jones et al. 2013, 2014) before transitioning to DA experiments where the all-sky observations were actively assimilated (Otkin et al. 2019). Our recent work has focused on developing a nonlinear bias correction method that can be used to remove complex biases from all-sky infrared brightness temperatures prior to their assimilation (Otkin et al. 2018). Results have shown that all-sky observations from water vapor sensitive bands provide critical information about the cloud and water vapor fields that is not available using other observation types. In addition, CIMSS has helped improve the RAP and High-Resolution Rapid Refresh (HRRR) models by using the low latency Regional ATOVS Retransmission Service (RARS), EUMETSAT ATOVS Retransmission Service (EARS) and Direct Broadcast Network (DBNet) data from various satellites. UW–CIMSS is currently collaborating with NESDIS/STAR in validating GOES-16/17 Clear-Sky Radiance/All-Sky Radiance products and adding CrIS polarization corrections to better assimilate CrIS observations.

CRTM is a vital component of the NOAA operational DA system. CRTM includes the forward modeling, tangent linear, and Jacobian components of the system. During the past 5 years, we have accelerated microwave and infrared scattering calculations in the CRTM by optimizing the current solvers and exploiting fast solvers. We conducted experiments using the NASA GMAO global Hybrid 4D EnVar system and all-sky observations from the Global Precipitation Measurements (GPM) Microwave Imager (GMI) to show that the optimized CRTM was much faster (19%) than the most recent release of the CRTM (v2.3.1). Recently, we began developing a fully polarized (i.e., the I, Q, U, V Stokes parameters) radiative transfer model, which is an urgent priority of the JCSDA for the purposes of improving the accuracy of radiances for clouds, aerosols and polarized surfaces, as well as exploiting satellite sensors that measure all polarization parameters. A semi-polarized (I, Q) extension of the Successive-Order-of-Interaction (SOI) solver, one of two solvers in CRTM v2.3.1 developed by UW–CIMSS in a previous JCSDA project (Heidinger et al. 2006), has been built and is undergoing testing. These new solvers will be included in the v3.0 release of the CRTM in 2020. We propose to work closely with the JCSDA to conduct 4D EnVar data assimilation experiments using the updated CRTM within the JEDI framework as well as participating in JCSDA code sprints because the CRTM is one of the observation operators in the Unified Forward Operator (UFO) component of JEDI.

NOAA operational environmental modeling systems are undergoing rapid changes with the transition to a new model dynamical core (FV3). These changes include implementing advanced parameterization schemes that are able to more accurately represent cloud properties, development of more accurate radiative transfer models, and the development of new DA systems that are better able to use information about clouds and other atmospheric variables provided by all-sky satellite observations. During the next decade, UW–CIMSS will leverage our extensive expertise in CRTM development, regional-scale OSSEs, SDAT, and ensemble DA to promote the use of all-sky satellite observations in NOAA operational models.

Because all-sky infrared data assimilation is a relatively new topic, many open questions will need to be addressed before these observations can be effectively assimilated into NOAA operational models. DA systems will need to be optimized to ensure that information gleaned from the all-sky infrared brightness temperatures can be used effectively given constraints in the DA systems and the ability of the NWP and radiative transfer models to properly simulate the characteristics and evolution of cloud and water vapor features. Proposed all-sky DA activities include the development of all-sky cloudy radiative transfer model and associated Jacobians, sophisticated bias correction methods, better observation error characterization, channel selection, and enhanced QC methods that build upon machine learning techniques that are currently being introduced to the community. An additional line of research will be the improved use of radiances over land by better separating the atmospheric and surface contributions. This will support the greater use of information about surface emissivity, albedo, vegetation, snow, soil moisture, aerosols, and chemistry provided by different infrared, visible, and microwave sensors. This in turn leads toward the need to explore methods that can efficiently merge information from multiple satellite sensors and bands in order to limit computational cost. It will also be necessary to develop the infrastructure to support the assimilation of observations from CubeSats and other non-traditional observing platforms that contain complex viewing geometries. Finally, sophisticated observation error models will need to be developed. Together, these tasks will lead to improved use of all-sky satellite observations in operational DA systems.

3.2.3b Assimilation of Satellite Derived Atmospheric Composition Products in Atmospheric Chemistry Models

NOAA's Next Generation Global Prediction System (NGGPS) will include online prediction of atmospheric aerosols and composition within a single, multi-scale dynamical core. This development supports NOAA through improved predictions of ozone radiative heating in the upper troposphere and lower stratosphere, operational NWP DA through better use of infrared radiances, implementation of aerosol forecasting by providing oxidation rates, and improved estimates of background concentrations of ozone and its precursors for NWS regional air quality predictions. To achieve these goals, accurate and computationally efficient unified chemical mechanisms that account for stratospheric and tropospheric chemistry are required. Under support from the NOAA Research Transition Acceleration Program (RTAP), CIMSS has implemented the Real-time Air Quality Modeling System (RAQMS, Pierce et al., 2007, 2009) unified chemistry into the NGGPS dynamical core (FV3-RAQMSCHEM) and ported this composition forecasting system onto S4. We are currently collaborating with NOAA/NESDIS/STAR to develop capabilities to use the GSI to assimilate CrIS and TROPOMI carbon monoxide (CO) and TROPOMI tropospheric nitrogen dioxide (NO2) retrievals within FV3-RAQMSCHEM to provide constraints on boundary layer CO and global NOx emission inventories within NGGPS.

As part of CIMSS participation in the NASA Aura Science Team, we have conducted the first Aura Chemical Reanalysis in support of NASA Air Quality Applications. This project utilized RAQMS in conjunction with GSI to conduct a multi-year (2006-2016) global chemical and aerosol reanalysis using NASA Aura and A-Train measurements. We propose to extend this RAQMS Aura reanalysis by conducting a FV3-RAQMSCHEM SNPP/JPSS chemical reanalysis beyond 2016. The SNPP-JPSS chemical reanalysis would begin in January 2015 so that we can use the full spectral resolution CrIS radiances which are necessary for retrieving CO from the CrIS radiances. This will also provide a 2 year overlap for assessing the impact of the assimilation of the new sensors. Atmospheric composition prediction and DA capabilities are explicitly called for in the NGGPS Strategic Implementation Plan (SIP) (https://www.weather.gov/media/sti/nggps/SIP-FY18-20-v4.pdf). The FV3-RAQMSCHEM SNPP-JPSS reanalysis will support NOAA R2O because it would provide a basis for evaluation of the NGGPS atmospheric composition and aerosol forecasting capabilities. The SNPP-JPSS chemical reanalysis would also be used to assess trends in tropospheric ozone, which has important implications for climate change (https://www.ipcc.ch/assessment-report/ar5/). The current generation satellite ozone instruments such as the Ozone Monitoring Instrument (OMI) and Microwave Limb Sounder (MLS) that were used in the RAQMS-Aura reanalysis are being replaced by next generation instrumentation such as the Ozone Mapping Profiler Suite (OMPS). The impact of assimilation of OMPS column and Limb Profiler ozone retrievals (which do not provide nighttime stratospheric ozone retrievals like MLS) could impact trends in analyzed tropospheric ozone and will be assessed.

3.2.3c Model Verification

In the past decade, UW–CIMSS scientists have been involved in numerous NOAA-funded projects using satellite observations to assess the accuracy of cloud and water vapor forecasts in a variety of models, including the HRRR, HWRF, GFS, and WRF models (Otkin and Greenwald 2008; Otkin et al. 2009; Bikos et al. 2012; Cintineo et al. 2014; Lee et al. 2014; Thompson et al. 2016; Griffin et al. 2017a, b; Otkin et al. 2017). We have also used GOES-16 ABI brightness temperatures to examine how adding stochastic perturbations to several parameters in the operational Thompson microphysics scheme impacts cloud and precipitation forecasts (Griffin et al. 2019). Together, these model verification studies have provided valuable guidance to developers of parameterization schemes and have also been used to identify which parameterization schemes perform best in different situations. Modifications to the Unified Post Processor (UPP) have been delivered to NCEP and the Development Testbed Center (DTC) to allow operational models to output simulated brightness temperatures for the GOES-13/15 Imager, GOES-16/17 ABI, and SEVIRI sensors for use in model verification and for visualization of model forecasts by NWS forecasters. These projects have used various methods to assess the forecast accuracy, ranging from traditional grid point metrics to neighborhood-based methods (Fractions Skill Score, probability distributions) to innovative object-based verification techniques that provide useful information about object attributes that is not available using traditional methods. CIMSS also developed a near real-time satellite-based verification system for the HRRR model that provides operational forecasters tools to assess the accuracy of HRRR model forecasts (http://cimss.ssec.wisc.edu/hrrrval/).

Our prior research has shown that all-sky infrared brightness temperatures and retrievals from geostationary satellite sensors provide critical information for verifying cloud and water vapor forecasts in both global and regional NWP models. We are currently in the midst of rapid changes in the global satellite observing system due to the advent of meteorological CubeSats with complex viewing geometries and the launch of advanced geostationary imager and hyperspectral sounding sensors that observe the earth system with unprecedented spatial, temporal, and spectral resolutions. These enhancements to the satellite observing system are occurring in tandem with equally rapid changes in our environmental modeling capabilities. These changes will require robust verification methods that are able to assess the accuracy of all aspects of the environment (atmosphere, land surface, ocean, cryosphere, etc.). The advent of fully coupled models may also require development of coupled verification metrics that treat the model as a unified whole rather than as separate components. Identifying systematic errors in each model component will provide useful guidance to the developers of parameterization schemes that in turn will promote improved accuracy of the model forecasts. Efficient use of the new satellite observations may also require developing new verification methods that seamlessly merge information from multiple sensors, as well as new visualization techniques that can distill the wealth of verification results down to a more manageable level for model developers and decision-makers. With this in mind, we will leverage our extensive model verification expertise to develop innovative machine learning and spatial verification methods, while also promoting the routine use of satellite observations using existing verification techniques.

3.2.3d Impact Studies and Observing System Simulation Experiments

An Observing System Experiment (OSE) is used to assess the impact of a new sensor in an existing DA system, whereas an OSSE is used to assess the value of a proposed sensor or observing system. Since the "truth" is known in OSSEs, they can be used to provide quantitative evaluations on observing system impacts from proposed instruments, an alternative mix of current instruments, and DA system diagnosis and improvement. The information gained from OSSEs can lead to better planning and decisions. NOAA and NASA have developed global and regional OSSE systems for assessing the current and future observing systems. UW–CIMSS scientists have developed regional OSSE (rOSSE) capabilities focusing on local severe storm impact studies from geostationary hyperspectral IR sounder and Cubesat infrared and microwave sounders that are supplemental to the NOAA and NASA OSSE activities. The CIMSS rOSSE system includes an orbit simulator, navigation simulator and all-sky radiance simulator for the current and future sensors. Impact studies have been conducted on a geostationary hyperspectral IR sounder, Cubesat infrared and microwave sounders, and Tundra orbit based imager [Li et al. 2018; 2019].

While OSSEs are an effective and efficient tool to understand the impact of current and future observing systems, calibration is critical and often very difficult. To address this issue, we propose to conduct hybrid OSSE/OSE studies for observing system assessment activities. In a hybrid study, most of the data are real observations (with real errors), but the proposed sensors are simulated (with realistic noise added) from high temporal and spatial resolution re-analysis and forward models. This arrangement allows for possibly the best of both worlds, using what is already available (today's observations) while simulating what you plan to have in the future, such as a hyperspectral IR with high temporal resolution. We also propose to extend the NWP DA based OSSE/OSE to a nowcasting OSSE/OSE. The nowcasting OSSE/OSE is important for decisions on high temporal and spatial sounding observing systems which critical for nowcasting local severe storms. The nowcasting OSSE/OSE can be conducted using existing UW–CIMSS real-time nowcasting systems such as ProbSevere and the newly developed statistical warning and prediction model (SWIPE).

3.2.3e Summary of Proposed Activities

The UW–CIMSS DA and modeling groups will continue to work with NOAA operations, laboratories, and CIs to achieve optimal use of satellite-based measurements of the environment. Specifically, we will:

- Enhance our ability to assimilate the high vertical resolution thermodynamic information provided by hyperspectral sensors and the high temporal and spatial resolution dynamic and hydrometeor information provided by geostationary imagers;
- Advance ongoing efforts to assimilate all-sky infrared brightness temperatures through the development of new bias correction methods, improved observation error characterization in cloudy skies, optimized channel selection, and QC methods suitable for use with a wide range of DA systems and environmental modeling configurations;
- Improve radiance assimilation over land surfaces by separating surface and atmospheric contributions in DA. In addition, explore the assimilation of satellite observations sensitive to soil moisture and vegetation properties in NWP and land surface models;
- Extend the RAQMS Aura Reanalysis beyond 2016 by using FV3-RAQMSCHEM to assimilate the next generation of operational trace gas retrievals for climate change and global air quality studies;
- Develop innovative model verification methods, with the aim of supporting both operational and research model development efforts;
- Conduct regional OSSE/OSE experiments to provide an assessment of the potential impacts of new sensors such as advanced infrared sounders and imagers onboard geostationary and cubesat satellite platforms.

3.3 CIMSS Education and Outreach

Maintaining CIMSS 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. We propose to continue formal education, informal education and professional training activities at the UW to support and advance NOAA's education and outreach goals. CIMSS infrastructure enables multi-tiered activities, trainings, and collaborations that support and advance NOAA's mission as well as NOAA's Education Strategic Plan.

3.3.1 Higher Education

Educating undergraduate and graduate students is a cornerstone of the CIMSS mission. The strong relationship between UW–CIMSS and AOS provides a direct conduit for undergraduate and graduate education in NOAA-related fields. This relationship is cemented by a requirement that the CIMSS Director also serves on the AOS faculty, starting with CIMSS founder, Professor Verner Suomi and continuing through present director, Professor Tristan L'Ecuyer.

3.3.1a Graduate Education

UW–CIMSS strives to support a skilled workforce to meet NOAA and our nation's needs and will continue to foster collaborative research activities with other NESDIS STAR cooperative institutes. In collaboration with the faculty in AOS, our researchers have mentored 133 M.S. and 53 Ph.D. graduate students since 1980, the majority through collaborative research efforts and financial support from NOAA; the AOS Ph.D. is the terminal degree most directly relevant to NOAA. All our graduate students have an academic advisor in AOS and a science advisor in UW–CIMSS or NOAA ASPB fostering tight collaboration between researchers and faculty. By working directly with UW–CIMSS and ASPB research teams, students receive valuable real-world experience for their future careers as well as exposure to NOAA.

Through continued collaboration with NOAA's Cooperative Research Program (CoRP) and its institutes, UW–CIMSS will enhance and advance research in support of STAR's science and education missions. The annual STAR-CoRP Symposium is key to these collaborations. This symposium, with rotating themes and location, provides an opportunity for the NESDIS CIs and CREST (the Center for Earth System Sciences & Remote Sensing Technologies) to share their research and showcase the work of students, post-docs, and early career scientists. We will remain active in this symposium, sending students and early career scientists to participate and supporting follow-up research exchanges after symposiums. We will also continue its positive collaborations with CREST, a multidisciplinary center led by the City College of the City University of New York (CUNY). UW–CIMSS has a formal collaboration through a Memorandum of Understanding (MOU) with two CREST members, CUNY and Hampton University, a Minority Serving Institution. Under a new cooperative agreement, UW–CIMSS will build on this foundation to develop new educational relationships.

3.3.1b William L. Smith Graduate Scholarship

The William L. Smith Graduate Scholarship at UW–CIMSS was established in partnership with NOAA to support graduate studies to improve public safety through more accurate weather prediction. William Smith, for whom the scholarship is named, is an emeritus AOS professor and former CIMSS director known worldwide for his leadership in pioneering satellite sounding capabilities. The award provides up to three years of financial support toward the completion of an advanced degree and an additional travel stipend to attend a relevant professional meeting, conference, or workshop. CIMSS selected and awarded Nuo Chen as the first recipient of the Smith Graduate Scholarship in the spring of 2019. Chen is working to combine NOAA's satellite observations and weather models to improve hurricane forecasts and provide more accurate information to the public and emergency managers, towards minimizing damage and saving lives.

3.3.1c Undergraduate Education

Each year UW–CIMSS bestows a Verner E. Suomi Scholarship award to one or two graduating high school seniors each year who have demonstrated excellent achievements in the physical sciences. This scholarship is a one-year, one-time opportunity to be used during their first year at any University of

Wisconsin system school. Very often, our Suomi scholars choose to study atmospheric science at the UW–Madison and working at CIMSS. One recent example is Britta Gjermo who was awarded the Suomi Scholarship in 2010 attended the UW–Madison and then interned at UW–CIMSS. While at the CI, Gjermo applied and received an Air Force scholarship, as profiled in SciJinks careers at https://scijinks.gov/air-force/. Gjermo recently won the 2018 Flight Commander of the Year for the 9th Reconnaissance Wing at Beale AFB, CA.

UW–CIMSS typically employs three to five undergraduate students majoring in atmospheric science or a related field interested in pursuing advanced degrees. Participation in a CIMSS research project helps prepare an undergraduate to conduct future independent research and to experience collaborative thinking while engaged with other scientists.

We also contribute to the AOS curriculum to support training undergraduate students in all aspects of satellite meteorology and remote sensing. Our research forms the backbone of the AOS undergraduate major course "AOS 441: Radar and Satellite Meteorology" and the advanced graduate course "AOS 745: Meteorological Satellite Applications." Furthermore, in 2013, we worked with AOS to co-develop a 100-level course on "Climate and Climate Change" which is offered on-line each summer. In addition, UW–CIMSS hosts NOAA Hollings undergraduate scholars to conduct summer research projects on-site.

3.3.1d International Collaborations, Conferences, Workshops, and Summer Schools

To foster broader collaborations world-wide, UW–CIMSS hosts and supports visiting scientists from around the world and has strong ties with research and operational centers in China, Australia, and Europe. Over the years we have maintained scientist exchange programs with many research partners (Figure 3.3.1.1). These connections have strengthened through the development of several international scientific organizations. UW–CIMSS and NOAA fostered the creation and growth of the International TOVS Working Group (ITWG) after the inception of the NOAA series of operational polar orbiting satellites. ITWG continues to organize International TOVS (TIROS Operational Vertical Sounder) Study Conferences which have met every 18-24 months since 1983. The Group also has an important education and training role, primarily through the Vlab (Virtual Laboratory for Training and Education in Satellite Meteorology) utilized by a global network of specialized training centers and meteorological satellite operators. UW–CIMSS and NOAA also organized the International Winds Working Group together with EUMETSAT and JMA; this group has been meeting since 1991 in order to achieve uniformity of atmospheric motion vectors derived from geostationary satellite image loops along with the associated quality flags and reports to the Coordination Group for Meteorological Satellites (CGMS). More recently we assisted in the formation of the International Cloud Working Group that also reports to the CGMS.

Between 2001 and 2013, our scientists taught remote sensing summer schools on "Applications with the Newest Multi-spectral Meteorological Satellites" in Italy, Brazil, Poland, Australia, Turkey, Norway, South Africa, and the USA, attracting participants from three dozen different countries. An online textbook was written (and continues to be updated) to assist students (ftp://ftp.ssec.wisc.edu/pub/menzel/AppMetSat19.pdf). While not directly funded by NOAA, these schools engaged a large community interested in using remote sensing assets of the Global Observing System and helped to establish a dialogue between scientists in a diverse collection of countries and foster international collaboration. These lines of communication and collaborations will be vital as we work together to tackle 21st century global challenges.

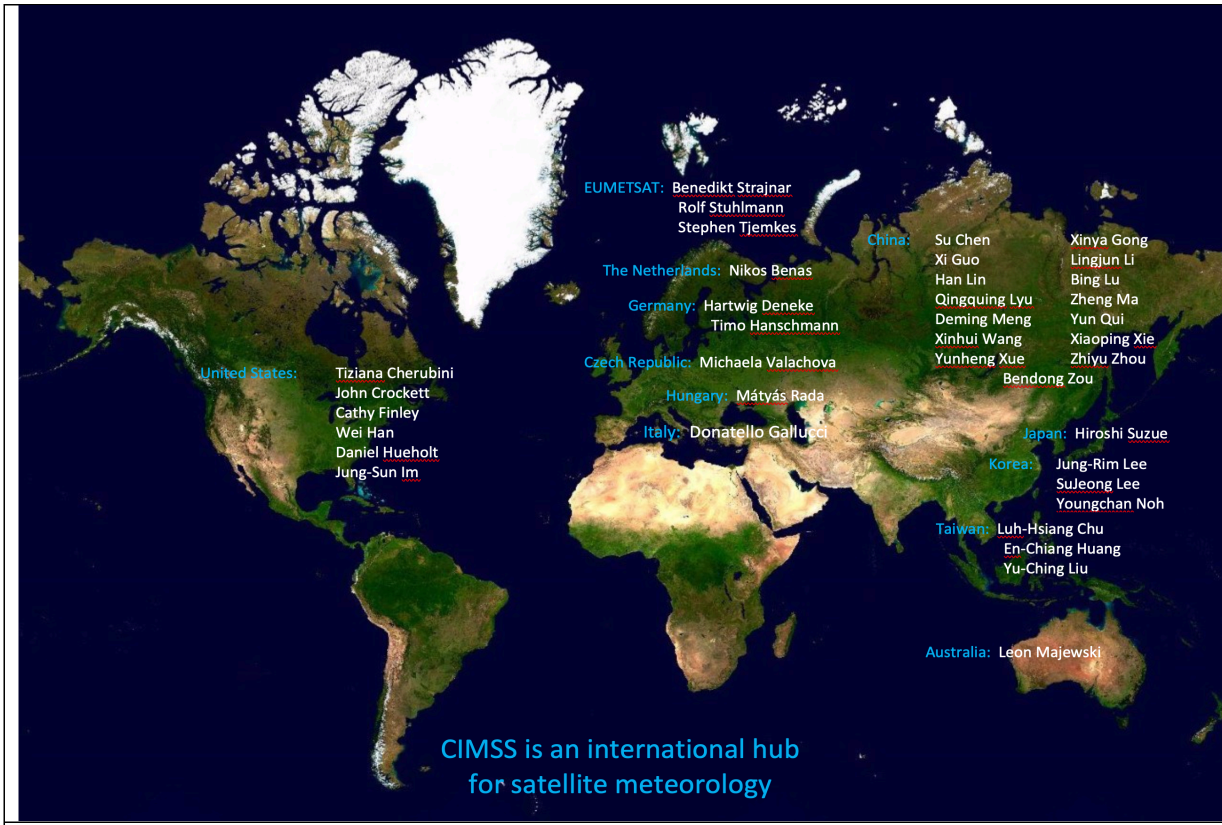

FIGURE 3.3.1.1: Scientists (by country of origin) visiting CIMSS for to conduct research for longer than a month since 2010.

3.3.2 K-12 Education

UW–CIMSS has engaged hundreds of science teachers and thousands of middle and high school students around the GOES-R satellite series, which included a workshop at the historic 2016 GOES-R launch. We also conduct annual teacher workshops in collaboration with ESIP (Earth Science Information Partners). Other national partners include NOAA's Science On a Sphere (SOS) community, NOAA Planet Stewards, and the American Meteorological Society. CIMSS has been a leader in educational software design for decades, pioneering distance learning software and computer-based education tools like the popular HTML5 web apps that allow users to explore physical processes like tornadoes, thunderstorms, rainbows, snowflakes and more recently, imagery from the GOES-R Advanced Baseline Imager. CIMSS has developed and maintains an on-line course for students titled "Satellite Meteorology for Grades 7-12" and an on-line course for middle and high school teachers titled "Global and Regional Climate Change" Examples of these courses and more can be found on-line at http://cimss.ssec.wisc.edu/education/.

In spring 2019, UW–CIMSS debuted a Virtual Science Fair (VSF) as part of its GOES-R Education Proving Ground activities. It is likely that the GOES-16/17 VSF will continue throughout the entirety of the GOES-R series. Ideally, the VSF will expand to include all meteorological and environmental satellite missions in three main categories: Geostationary, Polar orbiting, and Nano-satellites.

Our flagship formal education program is the resident STEM science camp that UW–CIMSS has offered to high school students each summer since 1991. Participating students experience science education, research, and modern technology firsthand. Students work with data via activities that further their interest in careers in the physical sciences. They also take multiple field trips on and off campus, including a visit to a near-by National Weather Service office.

3.3.3 Public Outreach

Located in Madison Wisconsin, the birthplace of satellite meteorology, CIMSS embraces the "Wisconsin Idea" that education should influence and benefit lives beyond the boundaries of the University. This "Idea" has become a guiding philosophy for CIMSS outreach. The global nature of satellite data combined with 21st century communication capabilities enables successful local, national and international outreach.

For example, in 2015, former UW–CIMSS Director Steve Ackerman and UW–CIMSS EPO lead Margaret Mooney co-taught a Massive Open On-line Course (MOOC) on "The Changing Weather and Climate in the Great Lakes Region" featuring NOAA data and Great Lakes imagery to over 7000 participants from 25 countries and 34 different U.S. states. The 4-week course suggested one behavioral change each week to lower personal carbon footprint, which could provide significant impacts if enacted. In a post-course survey with over 600 responses, 87% indicated that they felt better prepared to discuss climate change with family and friends.

Also in the climate realm, UW–CIMSS produces a quarterly Climate Digest to feature highlights from NOAA's National Centers for Environmental Information (NCEI) global analysis. Along with creating Climate Digest for SOS exhibits, we produce similar YouTube videos for online viewing; viewers get a comprehensive global climate brief in mere minutes. SOS began tracking digest plays in July 2018 and usage statistics indicate over 12,140 plays on SOS exhibits (as of 11/20/19) since tracking began.

In addition, UW–CIMSS staff conduct school tours, give public lectures, and participate in campus open-house activities. For example, we lead the UW–Madison "Meteorology Major" each summer where alumni and their grandchildren attend a 2-day workshop learning everything weather – especially satellite meteorology. They also learn about NOAA and NOAA satellites directly from NOAA ASPB scientists co-located at UW–CIMSS.

A popular informal education component is the CIMSS Satellite Blog (https://cimss.ssec.wisc.edu/goes/blog) that started in 2005 and averages nearly 100,000 visits a month and is frequently referenced in news stories. UW- also operates a JPSS-centered blog that shows how Satellite Data can help define extreme weather events (https://www.ssec.wisc.edu/jpss-sdoc/posts/). UW–CIMSS is active in social media with two Twitter feeds and a Facebook page. Our Facebook page has over 15,000 fans and @UWCIMSS over 10K Twitter followers reaching over 8 million people annually. The UW–CIMSS Satellite Blog (@CIMSS_Satellite) Twitter feed has over 41K followers.

Recognizing our effective and successful outreach program, the UW awarded UW–CIMSS EPO Director Margaret Mooney the Robert and Carroll Heideman Award for Excellence in Public Service and Outreach in April 2018. In 2019, SSEC enlisted UW–CIMSS expertise to help debut a Tech Camp for underrepresented students. In all outreach activities, we promote NOAA, the value of NOAA CIs, and NOAA's many contributions to our nation and the world.

3.3.4 Professional Training

Training atmospheric scientists is a cornerstone of the UW–CIMSS mission, and aspects of training touch many CIMSS-developed products and programs. These activities include: targeted on-site training for Direct Broadcast data users; training material as requested by the Office of the Chief Learning Officer (OCLO) Forecast Decision Training Division (FDTD); in-person training (GEO and LEO data, visible, infrared, and microwave) as requested; and satellite-related training modules developed for the VISIT and SHyMet programs for National Weather Service forecasters. We have developed training for our products as well, including MIMIC TPW, NOAA/CIMSS ProbSevere, GOES-R IFR Probability, and GOES-R Baseline Products. This training is available online and has been made available to SPC's Hazardous Weather Testbed (HWT).

In addition, UW–CIMSS has developed multiple display systems that are useful for both Geostationary (GOES-R, Himawari, GEOKOMPSAT-2) and for JPSS Data. Software Display systems include HYDRA, SIFT, McIDAS-V, Polar2Grid and Geo2Grid (the latter two being shell scripts that manipulate Satpy software). Some of these training materials are in the CIMSS Satellite blog (https://cimss.ssec.wisc.edu/goes/blog) or on the SIFT-specific blog (https://sift.ssec.wisc.edu); other training material is incorporated into on-site training visits to direct broadcast sites. A partial list of these is at the CIMSS Direct Broadcast Workshop page (https://cimss.ssec.wisc.edu/dbs/).

UW–CIMSS works in support of the global satellite direct broadcast community includes distributing software that allows users to create calibrated and geolocated science products from locally received data in real-time. NOAA has funded the Community Satellite Processing Package (CSPP) for Low Earth Orbiter (LEO) satellites since 2012; included in this funding is support for educating environmental decision-makers on the utility of the software and products. Over a span of 15 years, we have taught more than 15 global direct broadcast applications workshops with students from more than 60 countries and 5 continents participating. Most recently, the CSPP team has taught workshops for US National Weather Service forecasters in Miami, Puerto Rico, Hawaii and Guam Offices. We manage a deployment of direct-broadcast antennas at each of these locations; each workshop was tuned to focus on training forecasters how they might use the direct broadcast products to assist in local forecast challenges. The CSPP team plans to continue to promote the use of real-time locally received satellite data as well as foster the next generation of scientists through these workshops.

UW–CIMSS routinely participates in Satellite-related Short Courses that occur at Scientific Meetings, such as the AMS Annual Meetings, CMOS Annual Assemblies, AMS Broadcaster Meetings and NWA meetings, and at Servicio Meteorologico Nacional (SMN) and Laboratoire Nacional de Observacion de la Terra (LANOT) in Mexico City. These short courses are increasingly more hands-on and less lecture/PowerPoint-driven. In addition, we help develop numerous webapps as well as case studies, that can be used to help participants understand Satellite data and how it is useful.

UW–CIMSS will continue to develop timely and operationally-relevant satellite training materials that assist end users (NWS, broadcast media, academia) in their use and understanding of satellite data in the GOES-R and JPSS era. This training allows these new science products (or advances in satellite technology) to be used to maximum benefit as soon as the products become available in the WFOs.

3.3.5 Summary of Proposed Education and Outreach Activities

Under a new CI agreement with NOAA, UW–CIMSS proposes to embed our education and outreach activities within the larger context of NOAA's education and outreach goals. Specific activities include:

- Developing new and innovative methods of online training in support of professional development of weather forecasters and K-12 teachers;
- Refining and improving educational activities that facilitate the use of satellite observations from all NOAA missions in K-12 Earth science education;
- Expanding access and usage of the community Climate Digest by increasing its scope and endorsement from NOAA and other entities;
- Engaging and nurturing a diverse pool of prospective STEM students by expanding the highly-successful satellite virtual science fair to include all NOAA and NASA missions;
- Continuing the CIMSS Satellite Blog, a valuable "just-in-time" training resource that highlights examples of new satellite products for a variety of current weather events;
- Maintaining the CIMSS website and continuing to distribute data products on tropical cyclones, volcanic eruptions and other topics;
- Continuing in-person training visits to NWS forecast offices as requested;
- Continuing joint education activities with STAR's CREST;
- Offering remote sensing schools to the international community annually;
- Continuing our active outreach program, building upon a diversity of past successes;
- Expanding the number of distance learning modules aimed at helping to prepare tomorrow's forecasters for the next generation of meteorological satellites including modifying/updating existing training modules with guidance from Science and Operations Officers (SOOs) at NWS WFOs.

3.4 Unique Capabilities

Embedded within SSEC, UW–CIMSS has access to unique end-to-end satellite data processing capabilities that include all aspects of data analysis from downlink and ingest to processing and visualization to applications and assimilation into NWP models. The on-site presence of STAR/ASPB scientists further allows UW–CIMSS to collaborate directly with NOAA offices to transition research to operations and fully realize the benefits of these satellite products. Finally, collocation with AOS, a highly regarded, M.S. and Ph.D. granting atmospheric science department at UW–Madison, affords CIMSS the additional potential to engage students in NOAA research and to develop tools for training professionals and the public. Together, these capabilities enable CIMSS to fulfil its mission to provide timely, accurate, and reliable satellite data in to support the nation's weather needs. Each of the unique capabilities that are realized from locating CIMSS at UW–Madison are described in greater detail in the sections that follow.

3.4.1 Downlink, Ingest, Processing, Archival, and Distribution of NOAA Satellite Observations

The first step in fulfilling the role of a CI for satellite studies related to weather and environmental analyses is the capability to routinely acquire and ingest the large volume of data collected by NOAA's environmental satellites with minimal interruption. SSEC's data reception and processing facility is housed in the sixteen-story AOSS building. The facility consists of two dedicated climate controlled computer server rooms, a rooftop antenna farm, and a system monitoring room. The facility is supported by 5 x 65 kW UPS and 65 kW of non-UPS power for a total capacity of 325 kW. Temperatures of the cooler output air, rack outlets and inlets, as well as room temperature and humidity are monitored to ensure a proper operating environment for the computer systems. The facility is locked at all times and has electronic door locks for secured access. Additional data center facilities are available at a commercial offsite facility provided under agreement with UW–Madison, providing additional capacity and increased redundancy.

Downlink Capabilities: The SSEC Data Center has both local and remote antennas that are owned and operated by SSEC. In Madison, SSEC has four geostationary L-Band antennas, one of which can automatically track high inclination geostationary satellites. Two of the antennas are configured to ingest GOES-R class satellites from the East, West or Central locations. The remaining two L-Band antennas are configured to ingest GVAR, from any satellite transmission location between 60ºW and 135ºW. The four antennas give SSEC the ability to ingest and archive data from four GOES satellites simultaneously. SSEC also has four C-Band Antennas situated on and next to its building. Two of the C-band antennas receive polar orbiting satellite data relayed through Wallops Island and Fairbanks Alaska. The other two C-Band antennas receive NOAAport and GEONETCast Americas (GNC-A) data via geostationary domestic communication satellites. In addition, SSEC has two rooftop tracking antennas capable of receiving Low Earth Orbiting (LEO) satellites. A 4.4 m X-Band antenna on the SSEC rooftop receives EOS satellite data. A 2.4 m X/L band antenna on a neighboring building, receives data from Suomi NPP, NOAA-20, Met-op and other LEO satellites.

In addition to the local antennas, SSEC owns and operates four X/L band antennas at remote locations that cover most of North America, and portions of the Pacific. Three of the antennas are 2.4 meter in diameter and are located in Miami, Puerto Rico, and Hawaii. A fourth 3 m antenna is located in Guam. The four remote antennas, in combination with the 2.4 m X/L band antenna in Madison, all contribute data to the DBNet network.

Ingest Capabilities: SSEC routinely receives satellite data from 11 different geostationary satellites and 14 polar orbiting satellites. In addition to satellite data, SSEC also ingests non-satellite data via its antennas, the full NOAAport feed which includes the US Nexrad radar data, global in situ observations, and model output. SSEC also receives and contributes to the GNC-A data broadcast. SSEC makes use of locally developed ingest software and hardware (SDI-104) which are also utilized at NOAA for GOES-15 ingest. More recent GOES data are ingested using the locally-developed CSPP-GEO, while polar data are ingested using CSPP-LEO. The volume of data from all sources (antenna and internet) is greater than 8 TBs each day. Approximately 2 TBs of the data are archived daily, primarily from geostationary satellites. GRB data ingested locally at SSEC are continuously compared against data ingested at NOAA PDA. These comparisons are shared via an automated monitor to NOAA personnel at the Environmental Satellite Processing Center (ESPC) and other NOAA locations.

Compute, Processing, and Storage Infrastructure: Processing this enormous volume of data to generate useful data products for NWS and other end users requires substantial cyberinfrastructure. SSEC maintains several large High-Performance Computing Clusters (HPCCs) and High performance Lustre File Systems for the purpose of executing geophysical parameter retrievals and archiving the resulting products. These compute and storage resources are paid for in part by many projects funded by NOAA, and SSEC. This shared resource allows several groups to take advantage of idle processing cycles and maximize the use of their project funds. A shared lustre storage system allows different projects to access datasets curated by other projects. Some of these curated datasets available include 40 years of Polar AVHRR data, and over 40 years of Geostationary GOES satellite data. In addition, over 20 years of international geostationary satellite data are available on these shared systems.

The largest HPCC at SSEC is called The Supercomputer for Satellite Simulations and Data Assimilation Studies (S4). S4 is the third iteration of a HPCC that was first funded by NOAA in 2012 to allow more streamlined access to compute infrastructure intended to be used for data assimilation experiments with the latest available NOAA NWP models. The latest iteration was installed in 2018 and brought into service in 2019. The 2019 S4 update consists of 2,560 processing cores, 15 TBs of memory and 4 PB of storage. Combined with the second generation system installed in 2014, the number of processing cores available is 4,160. S4 allows data assimilation experiments as well as Observing System Simulation Experiments (OSSEs) in a research environment using U.S. operational data assimilation and forecast models, at both global and regional scales (Boukabara et al. 2016). This system, intended to be an R&D capability open to NOAA scientists and their collaborators, is part of the Operational-To-Research (O2R) environment that is a critical component of the R2O process, which aims at maximizing the return on investment of NOAA projects related to satellite data assimilation.

Geostationary Weather Satellite Archive: SSEC currently maintains the world's largest online archive of geostationary weather satellite data. SSEC has a 40+ year continuous record of GOES satellite data that begins in 1978 and extends to the present. SSEC also maintains an archive of international geostationary satellite data for which routine outine archiving began in 1998 and extends to the present. The archive also contains GOES data that was not archived by the NOAA Comprehensive Large Array-data Stewardship System (CLASS). These unique datasets were usually created during satellite checkout or during periods where non-operational GOES satellites were taken out of storage for short periods. SSEC has often provided data to NOAA NCEI when real-time was not archived by CLASS. The current SSEC archive of all satellite data is greater than 1.8 PBs. Archive satellite data are made available locally for machine learning investigations. Data are also made freely available to external users using McFETCH.

Distribution Capabilities: SSEC/CIMSS distributes more than 3.5 PetaBytes of satellite observations and derived geophysical data products per year via several mechanisms. Data are provided to UW–CIMSS scientists using direct filesystem access, McIDAS Abstract Data Distribution Environment (ADDE), file transfer protocol (ftp), ftps, http(s), Local Data Manager (LDM), and GRB fanout. Many ingested datasets utilize advanced message queue protocol (amqp), to provide events to data users to minimize latency and efficiently initiate data transfers. Data are not only distributed to SSEC scientists, but also to the University community. Satellite and NOAAport data are relayed via the Internet Data Distribution (IDD) service which is managed by Unidata. GRB data are also relayed to Unidata using GRB fanout and made available via ADDE, and LDM. SSEC also manages the North America and Pacific portions of the DBNet network of antennas relaying data from those antennas to NOAA NCEP and Eumetsat.

3.4.2 Software Design for Data Analysis, Operational Implementation, and Visualization

Much of the research conducted at UW–CIMSS involves the design and development of software for processing, analyzing, and visualizing meteorological satellite data. Our scientists and programmers calibrate sensors, develop products, maintain algorithm testbeds, assist NOAA with operationalization of algorithms, create software tools for training, and develop publicly available software for processing and visualization of satellite data. Software and science staff at UW–CIMSS and SSEC maintain proficiency in programming languages and methods, evaluate new technologies, and apply cutting edge techniques in areas such as artificial intelligence and cloud computing.

R2O support: UW–CIMSS contributes to the GEOCAT and CLAVR-X algorithm testbeds, which provide a means to quickly prototype and test new meteorological analysis products. These testbeds were used to develop many of the GOES-R product algorithms, and continue to be used to refine and improve them, as well as adapt them for use with other instruments such as AVHRR, and the VIIRS polar-orbiting imager. The theoretical basis for the GOES-R Ground System was derived, in part, from research done using these testbeds under AWG. As part of an ongoing collaboration with the JPSS Algorithm Scientific Software Integration and System Transition Team (ASSISTT) group at NOAA STAR, a technique has been developed that allows validated science code developed in GEOCAT and CLAVR-X to be run directly in the NOAA STAR Algorithm Integration Team (AIT) Framework and the GOES-R Ground System, thereby facilitating integration of science improvements to the ground system and reducing the cost of R2O. Throughout the R2O efforts, UW–CIMSS has provided tools and expertise for integration, verification, and validation of the algorithm software. Through the remainder of the GOES-R series and into the GOES-XO era, we will continue to improve algorithm testbeds, adding new sensors and enhancing existing "enterprise" capabilities. During the GOES-XO planning phase, CIMSS will offer technical solutions and approaches geared toward rapid development of new capabilities and efficient operationalization of research algorithms.

CSPP: UW–CIMSS has a long history of developing and distributing software allowing users to process data received directly from weather satellites, beginning with the International TOVS Processing Package in 1984, and extending to the Community Satellite Processing Package (CSPP) in present day. The CSPP LEO and GEO projects are funded by NOAA to provide software allowing ground stations capable of receiving data from Low Earth Orbiting and Geostationary satellites to generate products in real-time. The software has been widely adopted in the U.S and abroad by users of JPSS and GOES-R series data in the public and private sectors. Products are used in data assimilation for NWP, operational forecasting, real-time hazard detection, environmental modeling, and research.

CSPP software can ingest raw data feeds, generate Level 2 geophysical products including fires, floods, severe weather, air quality, volcanic ash, cloud properties, atmospheric profiles, stability indices, and surface properties, visualize data, and convert data to formats useful in downstream applications such as AWIPS-II. Users include NWP centers, NOAA, NASA, military, foreign meteorological and space agencies, disaster response agencies, receiving station vendors, weather services providers, aerospace contractors, the aviation industry, the electric power industry, space weather monitoring groups, and the research community.

In 2019, the National Weather Service selected CSPP Geo software to run on their 20 GOES-R series and 4 Himawari-8 direct broadcast processing systems, located at sites throughout the United States and Pacific Region. SSEC was contracted to provide operational software support. The generated products are considered a critical input to NWS weather models as well as providing low-latency real-time data to forecasters, allowing prediction of severe weather events in a timely manner. As of late 2019, all systems have been successfully transitioned to CSPP Geo software.

The benefits of CSPP to NOAA and program stakeholders are far-reaching and have included encouraging early use of data from new sensors, providing a means to release NOAA-developed algorithms to a broader audience, providing a pipeline for identification and evaluation of candidate operational algorithms originating in the research community, and direct participation in instrument checkout and reporting of data and distribution issues to the operational satellite programs.

In the near term, CIMSS plans to release additional NOAA algorithms to users, release upgrades to existing algorithms and add support for new sensors. New capabilities considered high value for users will be emphasized, including multi-sensor "enterprise" algorithms which leverage the increasingly global coverage of the international constellation, "fusion" approaches that exploit properties of co-located sensors to add value, and novel products originating in the user community. CIMSS plans to leverage previous work done at SSEC to containerize and demonstrate cloud-compatibility of CSPP software, in order to explore alternative models of processing, data distribution and software distribution. In addition, as more direct broadcast sites come online and as products are added to the CSPP suite, we anticipate an increasing need for software and products training worldwide.

McIDAS: UW–CIMSS scientists have also developed a substantial archive of shared data analysis and visualization software tools to assist them in their research. For over 45 years, McIDAS (Man computer Interactive Data Access System) has been a cornerstone for imaging and analyzing satellite data, comparing numerous data types within a single display, and evaluating satellite derived products. The software is used worldwide in research institutes, international weather services, universities, the private sector, and government agencies, such as NASA and NOAA. Within NOAA, McIDAS is used by NESDIS/STAR, NESDIS/OSPO, NESDIS/ESPC, NESDIS/NCEI (CLASS), OAR/NSSL, NWS/AWC, NWS/NCO, NWS/NHC, NWS/SPC, and NWS-Pacific Region, to support both research and operations. The ABI and VIIRS imagery and visualization teams at CIMSS and CIRA and in NESDIS operations use McIDAS to generate the satellite data in GOES Ingest and NOAAPort Interface (GINI) format for use in AWIPS.

To address the challenge of accessing ever evolving data formats, the McIDAS team at SSEC continually adapts new technologies and methods to facilitate the import of new data. For example, McIDAS can read a variety of data in netCDF or HDF format that is CF-compliant, which is a standard that continues to gain acceptance in the remote sensing community. McIDAS is also being enhanced to interface to Python scripts and libraries, which will enable access to data from additional satellites, improve analysis functions, and enable the use of more sophisticated scripting using Python.

RealEarth: is a data discovery and visualization platform developed at SSEC to allow quick, continuous visualization and sharing of real-time Earth observation imagery and data in a common and familiar map-based interface. The system is built with geographic information system (GIS) awareness (WMS/WMTS/GeoJSON) coupled with the needs of meteorological and atmospheric scientists for real-time data and animations. A wide variety of land, oceanic, and atmospheric remote sensing imagery and related data are available to be layered, compared, and animated in time-series loops. With over 450 active data products, close to 1,700 registered users, and over one million unique IP addresses served since 2016, RealEarth has proven value with a solid and expanding user-base.

SatPy: UW–CIMSS staff actively contribute to SatPy, an open source Python package for earth-observing satellite data processing. Developing new capabilities in SatPy ensures that they are available to the worldwide satellite data user community, and in turn allows for improvements and refinements from the user community.

Glance: is a program developed and maintained at SSEC that allows comparison of data products, including automated generation of plots and statistical information. It is useful for interrogating data, troubleshooting software and data problems, and verification of products. Glance was widely used during GOES-R algorithm development and integration, and continues to be used in software development and routine product monitoring at UW–CIMSS and at NOAA STAR.

3.4.3 New Technologies for Processing Big Data: Machine Learning and Artificial Intelligence

Meteorology is often called "the original Big Data science." Until recently, numerical weather prediction and climate modeling were consistently at the forefront of innovations in supercomputing and hardware solutions to maximize data throughput. Now with recent breakthroughs in machine learning/artificial intelligence (ML/AI), UW–CIMSS has embraced a new Big Data focus that seeks to adapt new machine learning methods from outside our field, both in ways that operate on a desktop computer at the scale of less than a terabyte, and on multi-server systems at the scale of several petabytes.

Our researchers have gained significant experience in applications of machine learning (and the subset of deep learning) to satellite image data sets in the past several years. In each of these cases, we have addressed topics that can expand into more powerful applications by using scaled-up training data sets. The tropical cyclone deep learning application of Wimmers et al. (2019a) was designed as a first step toward deep learning model development using multichannel satellite archives of LEO and GEO imagery spanning decades. Deep learning revealed the relative importance of various microwave imagery channels on inferring TC intensity (maximum surface wind speed), and developed a model competitive with the state of the art.

Another application in which deep learning has been successful in realizing more of the potential of satellite observations is that of Cintineo et al. (2019) who use deep learning to train a model to predict severe weather using GOES-16 visible, infrared and GLM imagery. While the training system is currently limited by the production rate of the manual labeling tools designed for the application, additional methods such as semi-supervised learning (Xie and Luong 2019) may leverage the manual approach with an additional unlabeled data set that is 10-100 times the size of the original.

Machine learning also has applications to signal processing for extracting useful information from noisy data. Marais et al. (2019) present a statistical image processing methodology, that leverages fundamental machine learning techniques, to quantitatively and qualitatively improve the retrievals of optical properties of the atmosphere from noisy lidar observations. This pioneering work clearly demonstrates the advantage of exploiting spatial and temporal structures of *images*, and not individual pixels, to separate the optical properties of the atmosphere from noisy measurements. Finally, unsupervised deep learning methods such as improved cloud identification through clustering (Wimmers et al. 2019b) take advantage of many years of extratropical infrared imagery to automatically partition cloud types for a climate model.

Adapting these approaches to the terrabyte and petabyte scales of NOAA's new satellite observations, demands significant innovations in hardware utilization and networking. To support its cutting-edge ML/AI applications, UW–CIMSS is developing hardware and networking configurations that allow rapid access to SSEC's Satellite Data Services' 1.5 petabyte image archive, under internal funding. This effort will enable us to train far more powerful machine learning models with repeated access to large training images and avoid limiting a training data set to only what can be copied to a local drive.

3.4.4 Unique Expertise in Model Development and Data Assimilation

Beyond products and applications, CIMSS scientists conduct end-to-end research, that includes evaluating new instrument capabilities and developing data assimilation techniques for transition from research to operational use by NOAA and international weather agencies. S4 affords CIMSS and NOAA scientists the unique capability to work together to develop and test data assimilation capabilities and conduct OSSEs for new and future sensors using the current operational modeling and data assimilation systems. The capabilities of the S4 facility are updated frequently to assure that the current Operational NWP suite can be run effectively. The most recent upgrade supports data assimilation experiments with the FV3-GFS numerical weather prediction suite using the four-dimensional ensemble–variational data assimilation system (4DEnsVar).

Atmospheric Composition Modeling Expertise: Much of the recent model development at UW–CIMSS has focused on implementing chemical forecasting capabilities into NGGPS. The chemical mechanism is based on the RAQMS unified stratosphere/troposphere chemical module, which has been used for daily real-time global trace gas and aerosol assimilation and forecasting since 2012 (http://raqms-ops.ssec.wisc.edu/). Under support from the NOAA RTAP we have implemented RAQMS full tropospheric/stratospheric chemistry into the FiniteVolume Cubed-Sphere Dynamical Core (FV3) following the framework of the National Unified Operational Prediction Capability (NUOPC) coupler. This effort has been coordinated through Dr. R. Bradley Pierce's participation in the Aerosols and Atmospheric Composition Working Group supporting Annex 10 of the Strategic Implementation Plan (SIP) for the evolution of the NGGPS to a National Unified Forecasting System.

Data Assimilation Capabilities: CIMSS scientists have also developed a near-real-time regional Satellite Data Assimilation for Tropical storm forecast system (SDAT, http://cimss.ssec.wisc.edu/sdat) using S4. At SDAT's core is the NOAA community GSI assimilation system along with the advanced WRF and HWRF models. Real-time NCEP GFS (now FV3) outputs are used as SDAT background and initial/boundary input. The system runs a 6-hour cycling assimilation followed by 72-hour forecasts that could be extended to 120 hours if computer resources allow. In addition to conventional data and satellite radiances obtained from NCEP BUFR files which contain GOES, AMSU-A/-B, HIRS, MHS, ATMS, AIRS, CrIS and IASI, the system is also capable of assimilating satellite derived products such as cloud-cleared radiances (CCRs) (or cloud-removed radiances), soundings, AMVs, total precipitable water (TPW), and layered precipitable water (LPW) from real-time JPSS and GOES-R series data processing and CSPP. SDAT is flexible for assimilating JPSS and GOES-R series radiances and derived products. Using SDAT as a testbed, UW–CIMSS scientists have conducted studies to improve the assimilation of hyperspectral IR sounder radiances by using collocated high resolution imager data (e.g., cloud mask and IR band radiances) to better handle sub-footprint clouds, as well as improve the HWRF track and intensity forecasts by using GOES-R series rapid scan based mesoscale AMVs in the inner core region and the high resolution ABI moisture information in the environmental regions. The WRF/HWR-based SDAT system can be used to study the satellite data assimilation; especially JPSS and GOES-R series data assimilation for improve tropical cyclone and local severe storm forecasts, the model and assimilation systems from EPIC can be used in SDAT research testbed, and the research progress has the potential for operational transition.

Model Verification Expertise: Systematic approaches to routinely verify models are essential for objectively determining whether changes to the operational modeling system lead to more accurate forecasts. During the past decade, UW–CIMSS scientists have been involved in numerous projects using satellite observations to assess the accuracy of NWP model forecasts, with a primary emphasis on examining the ability of high-resolution models to accurately simulate the evolution of clouds and water vapor. We are recognized as leading experts on the use of satellite observations for model verification as demonstrated through our involvement in the NGGPS Verification and Validation Strategic Implementation Plan (V&V SIP) working group. For example, UW–CIMSS researchers are leading a NOAA-funded project that recently transitioned a new version of the Thompson microphysics scheme containing stochastically-perturbed parameters into the RAP and HRRR models. The team is now delivering spatial verification use-cases will be to operational collaborators to be conducted during regular updates to the operational METplus verification system. We also have a proven track record of using operational NWP models, and we maintain strong collaborations with the model developers. Together, these capabilities will allow us to continue to serve as leading experts on satellite-based verification, and to continue to develop innovative verification and visualization methods to support the development of the next generation of operational environmental models.

Capability to Perform OSSEs: UW–CIMSS has developed a quick regional OSSE (rOSSE) framework, including high resolution regional nature run (NR) generation, satellite orbit simulator, synthetic observation simulator, and NWP impact study. While OSSE studies are fully based on the simulated data, our scientists are also conducting hybrid OSSE/OSE. For example, in a UW–CIMSS hybrid OSSE/OSE for a geostationary advanced IR sounder study, all data are real observations from the current available observing systems (conventional, satellite, etc.), except that the GEO-IR sounder data are simulated from one of the world's most accurate reanalysis datasets (ERA5) with our quick rOSSE framework and package. UW–CIMSS has all the needed tools and capability necessary to conducting regional hybrid OSSE/OSEs.

3.4.5 Technical Computing

The backbone of the cyberinfrastructure at SSEC is the Technical Computing Group (TC) that provides a unique set of shared research computing services to meet the high performance computing and data storage needs of the UW–CIMSS research staff. Global weather forecast modeling, satellite algorithm development, and end user applications inherently involve the storage, efficient retrieval, and processing of very large volumes of data. This requires designing, constructing, and maintaining a high performance research computing environment ranging from a high performance data processing and storage facility to a customized science software application stack. The Technical Computing Group includes six full time staff who support:

- Project consulting, system design and planning, security planning, policy and implementation;
- Research systems management including complete lifecycle support for Linux physical and virtual systems, system and application monitoring, compiled and maintained bottom-to-top stacks of scientific software dependencies for a consistent research environment, and assistance compiling custom scientific software;
- High performance networking ranging from 10Gb ethernet to 100GB Infiniband interconnects, routinely upgraded;
- WAN connectivity to research networks such as Internet2 via UW–Madison;
- Data hosting and distribution - HTTP, HTTPS, SFTP, FTP, and Globus (grid FTP) services;
- Code Management / Continuous Integration services;
- Research Data Backup and Archive;
- High performance filesystems and expertise - supporting 14PB of Lustre storage; and
- HPC cluster resources and expertise (a shared cluster with more than 900 processing cores allowing projects to add dedicated nodes and share idle resources and infrastructure systems, infiniband networking, and software support provided by SSEC).

3.4.6 Field Campaigns and Satellite Calibration and Validation

UW–CIMSS and SSEC scientists, engineers, and students have supported a large number of field campaigns, contributing to the success of these efforts as members of instrument teams, product algorithm developers, calibration specialists, forecasters, and mission planning. A list of field campaigns is included in Appendix J. Many of our validation activities leverage CIMSS participation in field campaigns funded by agencies other than NOAA; UW–CIMSS and SSEC are committed to maintaining these collaborations and will continue to seek opportunities to validate satellite products. SSEC/CIMSS also has significant experience developing small and large-scale scientific research instruments for ground-based and airborne applications. Instruments such as the Atmospheric Emitted Radiance Interferometer (AERI), the Scanning High-resolution Interferometer Sounder (S-HIS), and the High Spectral Resolution Lidar (HSRL) provide a unique capability for field campaign support for the validation of satellite products.

The AERI is a ground-based infrared hyperspectral radiometer developed by engineers and scientists at UW–CIMSS/SSEC and made commercially available through a partnership with the private sector. To this day the manufacturer and members of the research community look to UW–CIMSS/SSEC to provide scientific leadership, data quality oversight, and instrument troubleshooting support for this instrument. AERI is automated, weather-hardened, and capable of long-term unattended operation; as such, it has been successfully deployed for extended periods of time in a variety of challenging environments, including polar ice caps, transoceanic cargo ships, and extreme elevations. The worldwide proliferation of AERIs provides research opportunities that we are uniquely qualified to capitalize on given our history of Cal/Val, as well as developing novel satellite observations and new applications for data assimilation.

The S-HIS is an airborne infrared hyperspectral sounder designed and built at the SSEC as an advanced version of the HIS instrument between 1996 and 1998 with support from several federal agencies. Since 1998, S-HIS has participated in 35 field campaigns around the world, on five different aircraft (ER-2, WB-57, DC-8, Proteus, and Global Hawk). It has proven to be a key capability and asset for NOAA, and has been critical to highly accurate and directly traceable Cal/Val of satellite infrared sensors. It has also been extremely valuable to the development and improvement of many avenues of research including temperature and water vapor sounding, radiative transfer algorithm improvements, surface emissivity, numerical weather prediction, and trace gas detection retrievals.

In addition to the hyperspectral infrared instruments, the SSEC has pioneered and built several HSRL instruments, including an airborne version. These systems provide vertical profiles of optical depth, backscatter cross-section, depolarization, and backscatter phase function. All HSRL measurements are absolutely calibrated by reference to molecular scattering, which is measured at each point in the lidar profile.

To aid in the deployment of these assets to support calibration, validation, and field projects, SSEC constructed and operates a ground-based instrument trailer that houses an AERI, a Doppler lidar, an HSRL, a radiosonde launching system, and standard surface meteorological observations. Instrumentation in the SSEC Portable Atmospheric Research Center, or SPARC, can capture the evolution of the thermodynamic, kinematic, and aerosol structure of the atmosphere in fine detail, showing how the atmosphere evolves in unprecedented detail. The SPARC has been deployed in multiple field campaigns across the United States, to support the UW–CIMSS mission. Examples include LMOS, in which high-temporal resolution thermodynamic profiles from AERI were used to evaluate GOES-16 products during its checkout period and a 2016 deployment to a tall tower (400+ m) in the Chequamegon National Forest in northern Wisconsin in which we used the in situ observations of ozone from the tower along with radiosonde launches timed with GOSAT overpasses to assist JAXA in the evaluation of that satellite's performance. The SPARC also has a sister facility, the SPARCLET, a shipping container version of the SPARC that has been designed to house an AERI and an HSRL instrument. The HSRL was recently deployed in the SPARCLET to the Philippine Sea for the Propagation of Intra-Seasonal Tropical Oscillations (PISTON) experiment.

3.4.7 Partners and Collaborations

NESDIS STAR ASPB: Since its inception, UW–CIMSS has hosted a NOAA research team in Madison. The group's original focus was to develop geostationary and polar orbiting temperature and moisture retrievals from the VAS and TOVS sounding instruments. Over the years, the diversity and research strength of the ASPB team has grown, as has the breadth of UW–CIMSS research. Our numerous collaborations with ASPB have significantly furthered the breadth of NOAA science, provided important products to NOAA operations, and demonstrated the positive outcomes from government and university scientists working together. Today ASPB's seven members stationed in Madison excel in a broad array of research, as evidenced by Table 3.4.7.1 below. UW–CIMSS PIs and support staff will continue to work with ASPB scientists on many projects related to this expertise. Combining the strengths of university and federal government researchers based at UW–Madison advances the transfer of scientific findings, tools and products to the operational users.

Table 3.4.7.1: ASPB and NCEI Team members and their research collaborations with CIMSS staff

Jeff Key	NOAA/STAR/NESDIS/ASPB, Branch Chief	Polar satellite observations; Arctic climate change; sea and lake ice; PDSI
Mark Kulie	NOAA/STAR/NESDIS/ASPB	GEO and LEO Weather Satellite Precipitation remote sensing studies
Andrew Heidinger	NOAA/STAR/NESDIS/ASPB	Cloud properties; cloud climatology
Mike Pavolonis	NOAA/STAR/NESDIS/ASPB	Cloud properties; aviation hazards; volcanic ash
Yinghui Liu	NOAA/STAR/NESDIS/ASPB	Cryospheric Meteorological Weather Satellite Decision Support Research
Tim Schmit	NOAA/STAR/NESDIS/ASPB	Geostationary sounder and imager applications; GIMPAP; PDSI; GOES-R AWG and proving ground
Jim Kossin	NOAA/STAR/NESDIS/NCEI	Tropical Cyclone and Climate Variability Studies

UW Department of Atmospheric and Oceanic Sciences: UW–CIMSS is housed in the same building as AOS and fostering strong collaborations between researchers, faculty, and students. These ties will increase in the coming years with recent hires within AOS with interests in engaging satellite observations. An academic department within the College of Letters and Sciences, AOS consists of 15 faculty and 29 affiliate/adjunct faculty. The department is committed to an excellent educational program and has approved several ASPB scientists to serve as adjunct faculty. Over the past decade AOS has averaged approximately 50 graduate students and 30 undergraduate majors at the junior and senior level and conferred 103 M.S. and 55 Ph.D. degrees since 2010.

Research by the AOS faculty covers a broad range of topics relating to the atmosphere and oceans with particular strength in the areas of climate dynamics, weather systems, and satellite remote sensing. All students supported by UW–CIMSS grants are co-advised by an academic advisor on the AOS faculty enabling strong collaborations with CIMSS PIs. Examples include:

- Jonathan Martin: Frontogenesis and on public outreach;
- Michael Morgan: Data assimilation through the JCSDA office;
- Grant Petty: Microwave observations from satellite platforms and the operation of an ultralight aircraft platform for instrument development and cal/val;
- Greg Tripoli: Satellite data assimilation on the mesoscale as well as satellite observations of thunderstorms and hurricanes to assess model performance;
- Dan Vimont: Statistical analysis of hurricane observations from satellites;
- Ankur Desai: Deployment of ground-based instrumentation, most recently for Midwest field campaign to understand spatial heterogeneity of turbulent heat fluxes.

Center for Climatic Research: Also housed within AOSS, the Center for Climatic Research (CCR) provides additional opportunities to partner with leading researchers in the area of environmental monitoring and prediction. CCR researchers are collaborating with CIMSS scientists to incorporate satellite observations of precipitation, land use, snow cover, and vegetation into analyses of variability in natural resources and hazards. UW–CIMSS director, L'Ecuyer, is a core member of CCR and is actively engaged in increasing visibility of NOAA satellite datasets and NCEP reanalysis at the center. CCR is part of the larger Gaylord Nelson Institute for Environmental Studies at UW providing additional pathways to expanding the use of NOAA satellite datasets across campus.

Collaborations with International Space Agencies: UW–CIMSS scientists serve on the mission planning teams of EUMETSAT for their future polar orbiting and geostationary sensors (Dr. Robert Knuteson has served on the IASI Science Team and Dr. David Tobin is serving on the MTG-IRS Mission Planning Team). Our scientists also provide input to the Coordinating Group for Meteorological Satellites (CGMS) through contributed reports in response to various action items. Collaborations with colleagues from international space agencies often are initiated at international working groups in which UW–CIMSS scientists have leadership roles. Dr. Allen Huang co-chairs the annual Asia Oceania Meteorological Satellite Users Conferences, Liam Gumley co-chairs the International ATOVS Working Group and Steven Wanzong co-chairs the International Winds Working Group. Dr. Dave Tobin is an active member of GSICS, often presenting CrIS and VIIRS calibration work. CIMSS is actively engaged in facilitating such connections and serves as an international hub for satellite meteorology as indicated, for example, by the large number of long-term international visitors we have hosted in the past decade (Figure 3.3.1.1).

3.4.8 Publications, Communications, and Library Services

As a science-based, research and development institute, UW–CIMSS scientists have consistently demonstrated a strong publication record that emphasizes their contributions to NOAA and UW–Madison mission and goals. Since 1995, our scientists have published 1333 articles in the peer-reviewed literature, with 729, or more than half, published since 2010, the period covering the last cooperative agreement (Figure 3.4.8.1). One out of 13 peer-reviewed papers published during the period 2010-2019 included an ASPB or other NOAA scientist as first author and over 30% of peer-reviewed papers published during the same period have included one or more NOAA co-authors. A listing of all papers that included a UW–CIMSS co-author in 2019 is included in Appendix K. For a more complete bibliography of UW–CIMSS publications dating to 1980, see: http://library.ssec.wisc.edu/research_Resources/bibliographies/cimss

Several additional metrics derived from our publications during the previous cooperative agreement can be found in Appendix L, "A Bibliometric Analysis of CIMSS Publishing for the period 2010-2019" including measures of productivity, impact, citations, and collaborations. These metrics show that CIMSS authors consistently publish in the top journals of atmospheric science and remote sensing and have co-authored highly cited papers resulting in new analyses and products, studies of satellite sensors and techniques, and studies of atmospheric properties and climate. In terms of collaboration, CIMSS scientists are partnering with researchers within NOAA, across the United States, and around the world to solve global environmental problems. And, an analysis of topics supports a consistent alignment with NOAA themes and important ongoing, as well as emerging, areas of research.

In addition to the Data Center, UW–CIMSS research is supported by strong Communications and Web Groups as well as top-tier library services through the Schwerdtfeger Library which is part of the UW–Madison system of libraries. The Communications Group supports the research and education missions of SSEC and UW–CIMSS by communicating research results across multiple platforms from print to social media with proactive, coordinated and consistent messaging to: 1) provide information about institute research, goals, plans and progress, including the importance and impact of research, 2) increase support and trust, 3) broaden and improve understanding and visibility of scientific endeavors, and 4) build internal and external relationships. The Web Group provides front- and back-end web development services in support of SSEC and UW–CIMSS research programs including: 1) designing, updating and maintaining websites, 2) coding and deploying new applications, and 3) incorporating best practices in content management, user interfaces, navigation, and security.

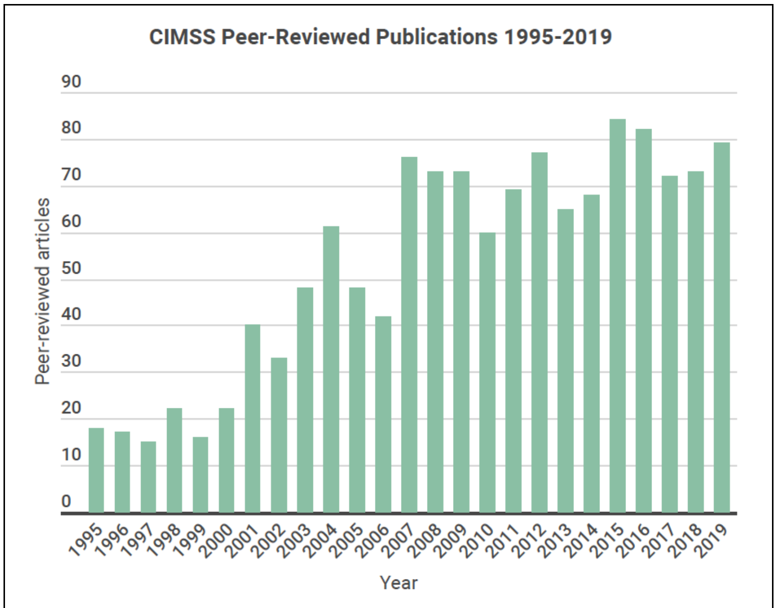

FIGURE 3.4.8.1: Peer-reviewed publications by UW–CIMSS authors from 1995-2019 during which we published 1333 articles.

Finally, the Scwerdtfeger Library supports and collaborates in the research, education, and outreach activities of SSEC, UW–CIMSS, and the Department of Atmospheric and Oceanic Sciences by providing services and systems to document and preserve knowledge and promote discovery. The library: 1) develops, preserves, and promotes access to collections necessary for research and teaching, 2) provides reference and research services to researchers, students, collaborators, administrators, and others, 3) provides access to, and instruction in, scholarly tools and resources such as library catalogs, databases, journals, interlibrary loan, research guides, and tutorials, and 4) supports public access compliance and the development of metrics. In addition, the library is undergoing renovation in 2020-2021, with support from SSEC to improve its teaching, collaboration, and study spaces.

3.4.9 Training Programs, Education, and Visiting Scientists from the U.S. and Abroad

Graduate students mentored by UW–CIMSS researchers have earned a total of 133 M.S. and 53 Ph.D. degrees working on projects that advanced NOAA's strategic vision since 1980 (Figure 3.4.9.1). These students benefited from the combined expertise of a UW–CIMSS or NOAA ASPB mentor and a faculty advisor in AOS providing them with both an education from a world-class atmospheric science department and valuable real-world experience contributing to elements of the NOAA enterprise. Appendix H provides a historical list of all graduate students who earned degrees while working on UW–CIMSS projects. In the past two years, three UW–CIMSS Ph.D. graduates have been hired into NOAA positions: Yinghui Liu and Mark Kulie were hired into NOAA's ASPB while Jordan Gerth recently joined the NWS Office of Observations.

UW–CIMSS is also actively engaged in undergraduate education through its collaborations with AOS. In addition to co-developing two courses in the AOS undergraduate curriculum, we have offered satellite bootcamps to expose AOS majors to satellite observations and their value for NWP. We also routinely employ undergraduate students majoring in atmospheric science or a related field interested in pursuing advanced degrees.

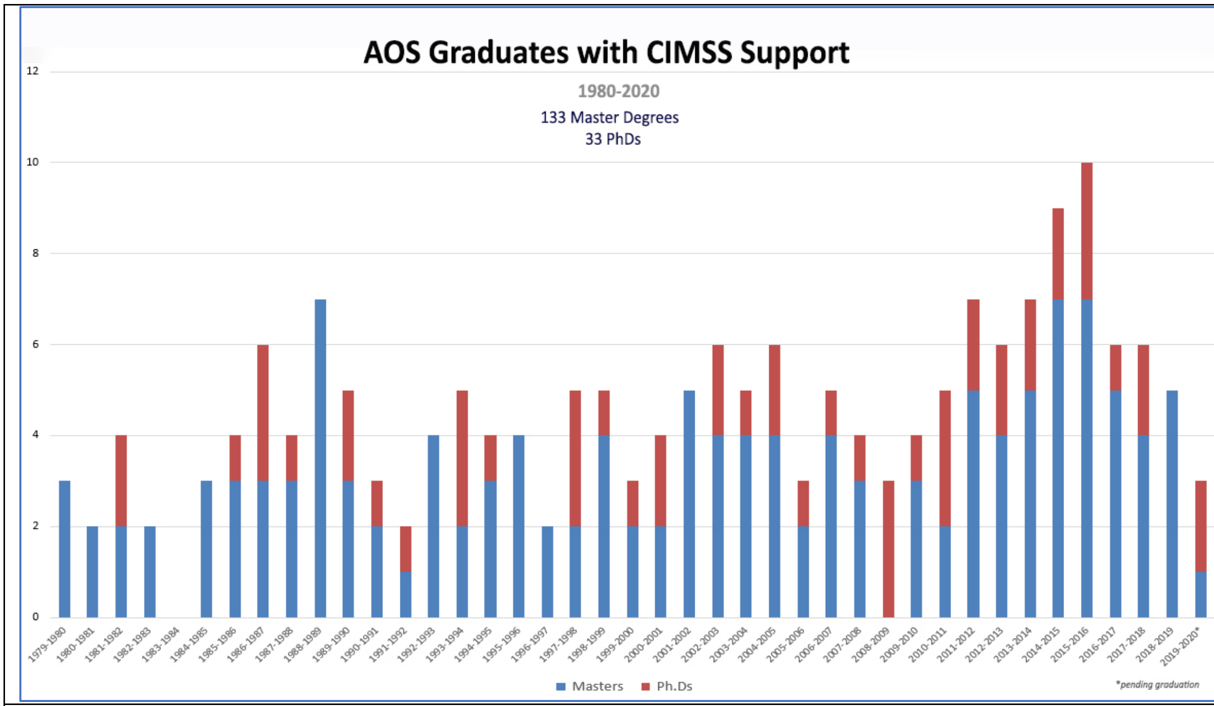

FIGURE 3.4.9.1: AOS Master and PhDs from 1980-2020 with CIMSS/NOAA support.

UW–CIMSS is also a primary source of professional training materials on the use of environmental satellite datasets to both professional and general users. We provide targeted on-site training for Direct Broadcast data users, in-person training on the use of GEO and LEO data, and has developed satellite-related training modules for the VISIT and SHyMet programs for National Weather Service forecasters.

UW–CIMSS has also developed a diverse and successful outreach program that includes targeted communications of major research findings, effectively engages the community through blogs and Twitter, contributes to educational tools such as online classes and Science on a Sphere, and leads school tours and displays to encourage STEM and advocate for NOAA interests.

Finally, UW–CIMSS has served as a hub for collaborations among the international satellite meteorology community. Over the past 10 years, UW–CIMSS has hosted dozens of international visitors, many of whom hold senior positions at major international organizations or satellite programs. The interactions enabled by these visits, as well as the numerous scientific workshops, conferences, and symposia hosted by UW–CIMSS over the years, have substantially expanded NOAA-related research capabilities and advanced satellite meteorology by tapping the collective knowledge of the international community.

3.4.10 Engineering

SSEC maintains a significant engineering research support capability that has a long and successful history working collaboratively with a diverse group of researchers and disciplines to help define, design, implement, test, and document cutting-edge hardware and software projects. SSEC's instrument development capability involves and integrates the disciplines of mechanical, thermal, optical, electro-optical, electrical software, and systems engineering, as well as program management and quality assurance. We have developed both small and large-scale scientific research instruments for terrestrial, aircraft, and space applications across a broad range of science disciplines.

Our instrument development group has extensive hands-on involvement with satellite, aircraft, laboratory, and field development of its instruments. These include the HIS, S-HIS, AERI, Planetary Imaging Fourier Transform Spectrometer, Volume Imaging Lidar, HSRLs, Hubble Space Telescope High Speed Photometer, Diffuse X-ray Spectrometer, the Galileo Net Flux Radiometer, and the IceCube Neutrino Observatory. SSEC was also selected by NASA to develop a highly accurate infrared spectrometer prototype for its climate benchmark mission called the Climate Absolute Radiance and Refractivity Observatory. SSEC successfully developed this instrument called the Absolute Radiance Interferometer, which included several novel technology advances, and demonstrated the required unprecedented level of performance (0.1 K) under the expected conditions of a space flight mission.

SSEC is recognized internationally as a leader in infrared hyperspectral instrument development and calibration and pioneered the application of using highly calibrated infrared Fourier Transform Spectrometry (FTS) for use in temperature, humidity, and trace gas remote sensing of the atmosphere. Coupled with our expertise in FTS technology, SSEC is a world leader in the development of highly accurate infrared calibration sources and the associated instrument calibration techniques.

Mechanical and Thermal. SSEC provides the full range of capabilities and facilities necessary for the mechanical and thermal detailed design, finite element analysis, fabrication, assembly, alignment, and test of instruments, including an extensive machine shop, precision mechanical assembly and test labs, temperature test chambers, thermal vacuum test chambers, and a Class 1000 clean room. SSEC mechanical expertise is featured in developments that range in size from a drilling system with multiple shipping containers to a penny. SSEC has design expertise with the harsh environments of space, the extreme conditions of the Antarctic, and cryogenic temperatures below 1 Kelvin.

Electro-optical. SSEC electro-optical capabilities include specification, detailed design, performance modeling, optimization, and fabrication of visible and infrared optical systems (reflective and refractive), infrared detectors and focal plane arrays (including, but not limited to, photovoltaic, photoconductive, and uncooled microbolometer detectors), and very high emissivity infrared blackbody calibration sources with very low radiometric uncertainty.

Electronics. Electronic development capabilities include comprehensive system design, signal processing electronics, interface electronics, precision measurement electronics, power electronics (including power supplies), servo control systems, high voltage electronics, electromagnetic compatibility, communications and radio frequency electronics, embedded controller systems, and high reliability electronics (including space qualified). SSEC employs sophisticated electronics modeling and layout design software, and has fully equipped electronics assembly and test laboratories on the premises. We also have used FPGA-based platforms for our instrument control and data handling.

Software Development. SSEC has considerable expertise in designing and implementing computing systems for scientific applications. High-performance data processing software, real-time meteorological instrument systems, cutting-edge visualization software, and interactive database and web application development are among active SSEC projects. Furthermore, SSEC has the capability to architect and manage software projects, whether it be by IEEE software processes, research-oriented prototyping, or open source.

Project Management and Systems Engineering. Since its founding, SSEC has a history of providing comprehensive project management approach to DOE, NASA, NSF, and NOAA projects from idea inception through proposal preparation, design, build, test, operations, data processing, and analysis. Project developments have ranged from a few months to several years in duration with budgets from $20,000 to over $250,000,000. SSEC has extensive experience and success developing and managing resource requirements, integrated development schedules, and detailed budget estimates for multidiscipline projects across departments and institutions. An integral part of SSEC's project success has been its approach to system engineering for incorporating a requirements-based design process, an emphasis on comprehensive interface definition and control, and maintaining a baseline design through a formal change review and approval process. The systems engineering approach has proved invaluable for communication between disciplines and among institutions or agencies.

3.4.11 Quality Assurance

SSEC/CIMSS has developed an advanced quality and safety program to address project needs. All SSEC processes are designed to be scalable to adjust to the size of the project as appropriate. The QA program includes procedures on document management, project development, training, project and employee safety, test equipment calibration, quality records and complaint handling. Developed to be compliant with ISO9001, this standardized set of processes is available to all SSEC/CIMSS projects, allowing managers and staff to work on different projects without having to learn or develop new procedures. SSEC Quality Assurance and Safety personnel have also developed QA resources such as the SSEC QAS SharePoint site with resources for project management and document libraries. The QA group also maintains a Deliverables Management database and reviews award documentation to identify and track project deliverables and reports. To track availability and ensure readiness of equipment for field deployments, the QA group maintains a scheduling tool for our mobile laboratories (SPARC and SPARCLET) and instruments (HSRL, AERI, Wind LIDAR, and Radiosondes). Another tool used for field deployments is the deployment safety risk assessment to identify and mitigate hazards that might be encountered in transit to and at the deployment site.

SSEC employs two full-time staff members who are responsible for creating, updating and maintaining quality system processes and documentation, evaluating project and staff safety, and training staff in areas of quality processes and safety.

3.4.12 Summary of Unique Capabilities

Its position in AOSS, collocated with AOS, CCR, other SSEC engineers and scientists, and several NOAA ASPB scientists, furnishes UW–CIMSS with a unique combination of facilities and capabilities that enable the CI to execute its mission effectively and exceed expectations. In addition, the fiscal support that UW–CIMSS receives from UW–Madison (outlined in Section 3.7) maintains these outstanding facilities that are the cornerstone of an internationally-recognized research institute.

UW–CIMSS researchers have expertise spanning the spectrum of satellite meteorology applications from sensor development and calibration, to evolutionary and revolutionary algorithm development in support of both GOES and JPSS, including extracting actionable information from satellite Big Data, to applications of this information for weather forecasting, including data assimilation. UW–CIMSS has played and continues to play a central role in defining new sensors to maximize the societal benefit of NOAA's next generation of environmental satellites. Working with ASPB scientists, our researchers are pioneering new approaches for using ML/AI to realize the full potential of these satellite products and working with NOAA offices to develop and implement data assimilation methods to incorporate these products into forecast models. UW–CIMSS supplies software tools for processing and visualizing satellite data and products to all types of users and provides training and education to increase understanding of these datasets and support the pipeline to the NOAA workforce.

Operating under the oversight of the skilled technical computing staff, UW–CIMSS state-of-the-art computing facilities, including S4, provide the cyber infrastructure critical for ingesting, reformatting, visualizing, processing, archiving, and disseminating all data collected by NOAA's geostationary and low-earth orbiting satellites as well as a broad array of complementary satellite and sub-orbital datasets. These facilities further offer the unique capability of running NCEP's operational global and regional NWP models at an off-site location to support research and development by users outside NOAA including universities. This will allow UW–CIMSS to play a key role in the new EPIC community modeling effort by providing software, data, and user support to researchers within the broader research community.

3.5 CIMSS Milestones

In 1966, the Principal Investigator of the spin-scan imaging camera system on the first U.S. geostationary weather satellite, Verner E. Suomi, made a simple, yet profound statement about the images: "the clouds move, not the earth." Dr. Suomi was instrumental in working with NOAA (called NESS in those days) to establish and advance the U.S. geostationary weather satellite program, work that was recognized in 2012 when NOAA honored Suomi by renaming the National Polar-orbiting Partnership (NPP) satellite, *Suomi*

NPP. Suomi went on to play a major role in the design of atmospheric sounders and turned his concept of digital analysis and visualization computer systems into McIDAS. In the late 1970s Dr. Suomi worked with the NOAA Director, David Johnson, to help create one of NOAA's earliest Cooperative Institutes. UW–CIMSS has continued the tradition of science innovation and excellence demonstrated by Dr. Suomi. This proposal has provided numerous examples of science contributions from UW–CIMSS scientists to our understanding of the earth / atmosphere system and their impact on people's lives. Studying the earth from space has truly given our generation a global perspective of weather and climate.

Figure 3.5.1 provides a sample of significant milestones over our 40 year history, demonstrating that the "Suomi tradition" lives on at Wisconsin. In addition, CIMSS' scientists have presented at numerous International/Domestic conferences/workshops, hosted many conferences, such as the National Weather Association Conference 2012, AMS Severe Storm Conference 2014, and the AMS Satellite Meteorology and Oceanography 2016 and led international workshops such as the 2nd Workshop of the International Cloud Working Group (ICWG).

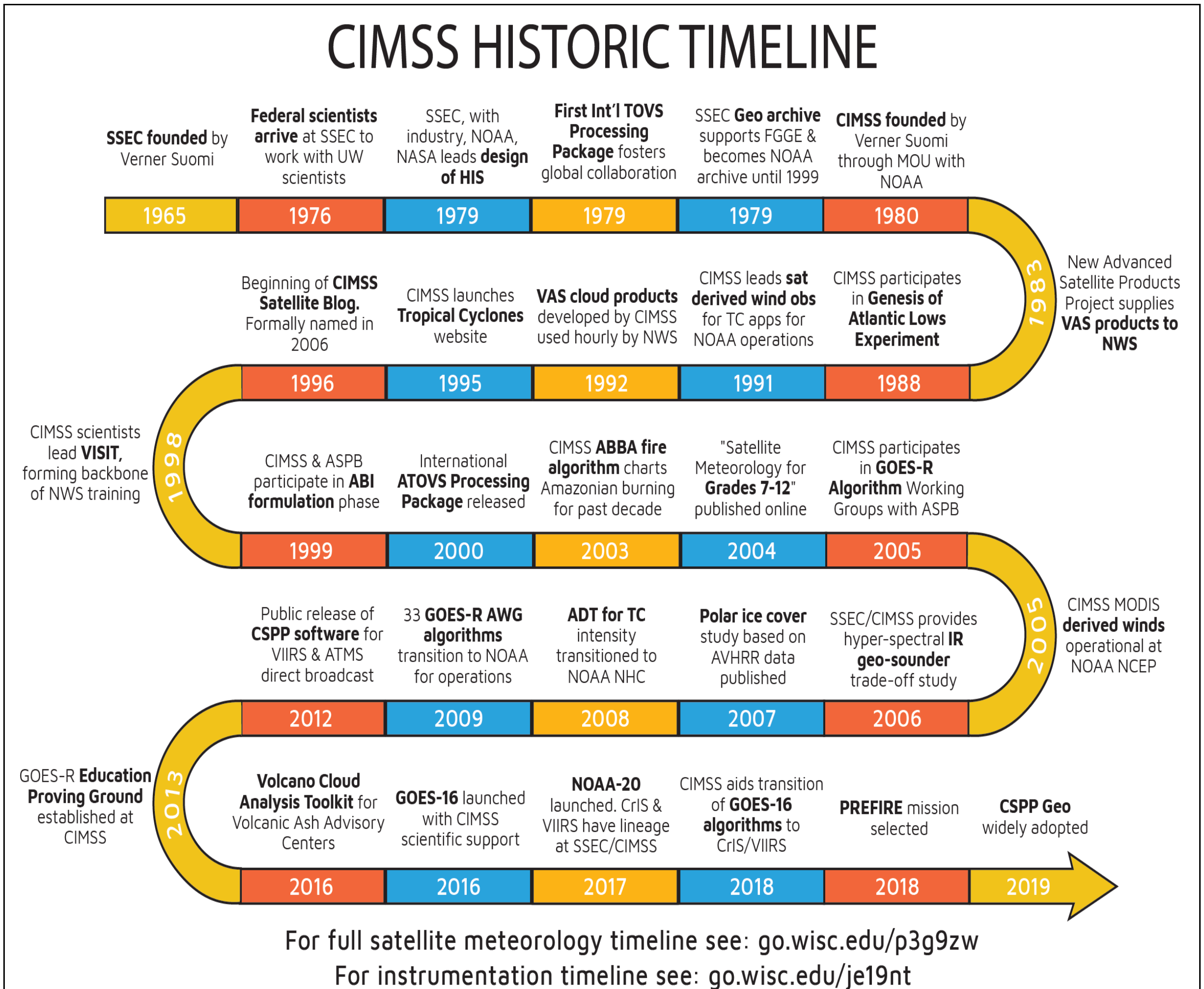

FIGURE 3.5.1: CIMSS past and present: examples of major highlights and achievements in the history of UW–CIMSS.

3.6 Business Plan

3.6.1 UW–CIMSS Organizational Structure

UW–CIMSS resides within SSEC at the UW. SSEC is part of the Office of the Vice Chancellor for Research and Graduate Education (OVCRGE), which oversees graduation education and a large sector of the campus research enterprise. Current UW–CIMSS activities (i.e., funding) comprise approximately 40% of SSEC projects.

Director: The UW–CIMSS Director, Tristan S. L'Ecuyer is a faculty member in AOS. Prof. L'Ecuyer's appointment within AOS is required by the Memorandum of Understanding between UW–Madison and NOAA.

Board and Council (Executive Council and Council of Fellows): UW–CIMSS is advised by a Board of Directors (akin to the Executive Council defined in the CI handbook) and a Science Advisory Council (e.g., the Council of Fellows in the CI handbook). The Board of Directors meets formally once a year to review the policies, research themes, and priorities of UW–CIMSS, including budget and scientific activities. The Board is also responsible for approving the appointment of members to the Science Advisory Council. The Science Advisory Council advises the UW–CIMSS Director in establishing the broad scientific content of its programs, promoting cooperation among the CI, NOAA, NASA and other agencies, maintaining high scientific and professional standards, and preparing reports of UW–CIMSS activities. The Science Council also meets formally, nominally once a year.

Staffing Structure: UW–CIMSS Executive Director, Wayne Feltz, oversees the day-to-day operations of CIMSS and provides management and coordination for the CIMSS research grants/contracts. As SSEC Executive Director for Science, Mr. Feltz represents CIMSS at the highest departmental administrative level.

The cornerstone of our research is its 31 Principal Investigators (PIs). UW–CIMSS encourages all of its staff to develop proposal ideas that support NOAA goals, in close coordination with the Director and Executive Director. The UW–CIMSS Director holds frequent PI meetings to discuss new or evolving NOAA priorities for research and operations, upcoming meetings, deadlines for product delivery, and agency announcements of opportunity. PI meetings are also a forum for sharing recent research results.

UW–CIMSS staff (over 130 individuals, including undergraduate and graduate students) provide the expertise that goes into its research activities. Most staff members work on multiple research projects, allowing the staff to expand their knowledge and skills. This arrangement provides a versatile core of talent and gives our institute the flexibility to apply it where and when it is needed to meet its research goals. A complete listing of UW–CIMSS PIs, supporting scientists, visitors and others is provided in Appendix C.

Communication and Collaboration with NOAA: UW–CIMSS recognizes the importance of communication as it pursues new research opportunities and collaborations with NOAA. These conversations are critical to developing a strong research program that meets the needs of NOAA. We will continue to attend and participate in the biannual CI director and administrator meetings, as well as side meetings at society annual meetings, and to host relevant programs to foster discussions and create connections. Through these activities, UW–CIMSS seeks to enhance communication and collaborations with NOAA to help fulfill its strategic mission goals.

3.6.2 UW–CIMSS/SSEC Operations within the University of Wisconsin Madison

SSEC's administrative philosophy is for "scientists to just do science." Dr. Bradley Pierce is the SSEC Director and an active PI in science and engineering programs. Supporting Dr. Pierce are one executive Director and three Associate Directors, Mark Mulligan is the executive director and Associate Director for Technology, Jennifer Hackel is Associate Director for Administration, and Wayne Feltz is Associate

Director for Science within SSEC. This team works closely with the CIMSS Director to define policy, establish goals and ensure sound research.

3.6.2a SSEC Administrative support

The SSEC administrative support team includes 14 full-time staff and several students providing services such as human resources, proposal processing, grant and contract management, accounting, financial programming, purchasing, travel, meeting logistics, and facilities management. A summary of key SSEC administrative support follows:

Human Resources and Payroll: Two personnel within the SSEC Office of Human Resources work directly with the UW–CIMSS Directors, OVCRGE Human Resources, and with the UW–Madison Office of Human Resources to create position openings, conduct application reviews, process employment adjustments and payroll, support medical leave, and address other employee issues. The SSEC HR office maintains employee records and ensures that annual employee review materials are collected.

Every employee of SSEC/UW–CIMSS is assigned a work supervisor, who reports through the staffing chart to one of the Directors. SSEC's professional development plan includes annual and interim reviews with work supervisors and/or Directors. SSEC also has an onboarding program for new employees to make sure that they understand the policies in the SSEC Employee Handbook and they learn how to use the resources in the building and on campus. In addition, SSEC has an equity, inclusion, and diversity committee which works with staff members and with the Directors to address recommendations made by staff. The chair of this SSEC committee participates in a similar group within OVCRGE.

Grant/Contract Management, Accounting, and Financial Programming: SSEC employs seven full-time accounting and financial programming experts. SSEC has developed its own accounting system that integrates directly into the campus-wide financial system to provide customizable, specific, and enhanced reporting capability for their projects. The SSEC system gives UW–CIMSS and SSEC Directors detailed cost information on programs and projects as well as a global view of the entire UW–CIMSS program. Principal Investigators and Program Managers receive monthly reports and have online access to years of accounting data, including project spending, labor, travel, and purchases. Additionally, these experts proactively examine financial data and award terms and conditions on a monthly basis to assist with routine project management to ensure that PI obligations are being met. The 2004 NOAA five-year review team evaluating UW–CIMSS noted "the outstanding (SSEC) accounting system as well as exceptional staff members."

Purchasing and Property Control: SSEC employs a full-time procurement specialist who is trained to make purchases in accordance with university, state and federal purchasing requirements. When UW–CIMSS projects require purchases or bids from vendors, the purchasing agent reviews the requirement(s) with the PI and the appropriate director(s), gathers the necessary information and undertakes the necessary purchasing actions. Additionally there is one supporting full-time staff person that assists in the procurements and serves as departmental property administrator for SSEC. This person oversees the purchase, tagging, and locations of equipment to ensure compliance with cooperative agreement and university equipment regulations.

Travel: SSEC employs a full-time travel specialist that assists UW–CIMSS staff in making travel arrangements and in reviewing and filing their travel reimbursement statements. The office also keeps up to date with university, state and federal travel regulations to ensure compliance.

Meetings and Facilities: Over the past five years, SSEC/UW–CIMSS administrative staff has planned numerous professional meetings for many groups varying in size and purpose. Taking into account the goals and needs of the group and the available funding, this support team coordinates appropriate venues in-house, on campus, or off-site.

Additionally, SSEC is committed to providing facilities support for UW–CIMSS, including the planning and execution of refurbishing projects on various floors and rooms occupied by UW–CIMSS. One such example is a recent remodeling effort to create a dedicated high-tech briefing room. This space, complete with several flat screen displays and other audio/video features includes seating for a small group (~24); the CAVE (CIMSS Audio–Visual Environment) has already proven very useful for the researchers to discuss and showcase their work. SSEC employs two full time individuals that are dedicated to monitor and ensure the smooth functioning of SSEC's facilities.

3.6.2b UW–Madison Provided Support

UW–Madison provides additional support to SSEC/UW–CIMSS via the OVCRGE, the Research and Sponsored Programs Office (RSP), and other campus administrative offices.

The OVCRGE office serves a supervisory role over SSEC, ensuring that SSEC is in compliance with UW, State of Wisconsin, and federal regulations. They provide further assistance by serving as an intermediary and voice for SSEC with the rest of campus, for example by addressing proposed policy updates that would impact SSEC's research and by supporting the UW fiscal contributions to SSEC's strong administrative infrastructure.

RSP is responsible for the final review, negotiation and submission of all UW–CIMSS grant and contract applications and for the negotiation of agreements. RSP staff provides financial and other administrative assistance by preparing financial reports, submitting invoices, and processing payments. Additionally, they provide valuable training on UW–Madison and Sponsor's policies/procedures for administrators and investigators.

Beyond RSP, several other administrative offices on campus contribute to the overall benefit of UW–CIMSS. One such example includes the central office of Property Control. They provide equipment information and financial data as required by University Administration for annual financial reporting, identify custodianship and holder of title to University equipment, maintain records required for calculating Federal overhead equipment use charges, provide control for proper use and disposition of University assets, ensure adequate insurance coverage and loss settlement, and provide required interim and final property reports for Federal and non-federal grants and contracts.

Compliance with University, State, and Federal Laws: Each year, UW–Madison is audited by the Legislative Audit Bureau for the State of Wisconsin for compliance with CFR 200 Uniform Administrative Requirements, Cost Principals, and Audit Requirements for Federal Awards (aka Uniform Guidance). The audit is posted online and copies of the audit are forwarded to the Federal clearinghouse as required. The most recent Single Audit results can be found at: https://legis.wisconsin.gov/lab/media/2833/19-3full.pdf

To ensure compliance with Uniform Guidance, RSP provides extensive training to department administrators and PIs identifying the basis whereupon charges are consistently treated, necessary, reasonable, allocable, and allowable against federal projects. The Cost Studies section of RSP is responsible for planning and developing facilities and administrative cost rates for the UW–Madison. The rate proposal is prepared using cost allocation and distribution methods as set forth in Uniform Guidance and other Federal Cost Principles. RSP personnel actively participate in rate negotiations with federal representatives and announce the agreed upon rates to faculty and appropriate campus representatives.

Additionally, UW–Madison complies with State of Wisconsin law, Research Terms and Conditions (RTC) terms, and agency specific terms as applicable.

3.6.2c Proposal Development, Review and Processing

UW–CIMSS encourages and provides support to its staff to develop proposals to support NOAA satellite meteorology needs. Concepts are discussed with the UW–CIMSS Director and/or the SSEC/UW–CIMSS Associate Director for Science (AD-S) and coordinated with NESDIS/ASPB scientists. The AD-S works with the PI and an SSEC budget specialist to address staffing, computing, and budgetary issues during the development stage. All UW–CIMSS proposals receive a final scientific review by the CIMSS Director and/or the AD-S. UW–CIMSS proposals are also reviewed by the SSEC Director and processed by SSEC administration. An SSEC budget specialist completes all required federal and university forms. An electronic proposal record is created on UW's proposal routing system WISPER that must be signed/approved by the PI, the SSEC Associate Director for Administration (AD-A), and OVCRGE prior to submission. After final review of the budget and other documents, RSP routes the proposal for signature by the authorized official and submitted to NOAA through Grants.gov.

UW–Madison – NOAA Interaction on Proposal Awards: After receiving the proposal through Grants.gov, the NOAA/NESDIS/STAR administrative office reviews it for compliance and prepares it for delivery to the NOAA Grants Management Division (GMD). The SSEC/UW–CIMSS administrative team has excellent communication with NESDIS/STAR administrators in the preparation/compliance process. When the NESDIS/STAR officer assures all requirements are met, the proposal is sent to GMD for review and approval. If approved for funding, RSP then reviews the award documents and negotiates any concerns or legal issues with NOAA. Once an agreement is met, NOAA then makes official notice of award to the PI. RSP accepts the award on behalf of the Board of Regents of the University of Wisconsin System, assigns a UW–Madison project number to it, and informs SSEC which sets up an corresponding account in its accounting system.

SSEC Management and Oversight of Funded Programs: Once a grant award is officially entered into the UW–Madison system, SSEC administration works with the UW–CIMSS PI to set up the administrative account for the project. For large programs, a Program Manager (PM) may be assigned to work with the PI and to be a point of contact for SSEC administration. An SSEC project number (or numbers if there is more than one specific task) is created and the budget is allocated to specific categories (e.g., labor, travel, publications). After the program begins, SSEC collects financial data and sends the PI / PM monthly financial statements that include all labor charges to the project, as well as other itemized charges. The PI / PM is responsible for reviewing all charges and notifying SSEC administration of any questions or issues. For larger projects, monthly program reviews are held with SSEC, the AD-S and the PI / PM. Any areas of concern are conveyed to the PI and the UW–CIMSS Director, with a statement of actions to be taken. The ED-S works with SSEC administration to ensure that quarterly, semi-annual or annual technical reports are submitted. The SSEC AD-A ensures that billing information is submitted to RSP and conveyed to NOAA. In addition, all this information is available on a restricted/secure area of the SSEC Web site. PI / PMs can access current and all historical labor and other financial information for their projects online. Many of the reports are in Excel spreadsheets so PI / PMs can easily move the information into personalized financial databases. SSEC employs two administrative programmers to create online accounting and other resources for PIs. They are also available to help design and create advanced financial information for individual programs.

At the end of each month, spending is billed to the UW account number via the SSEC accounting system. The UW–Madison bills NOAA for actual spending on a monthly basis. RSP prepares semi-annual financial reports and submits them to NOAA. As mentioned above, the UW–CIMSS PI and ED-S are responsible for the periodic technical reports that are submitted to NOAA.

3.7 Cost Sharing Plan

Building upon nearly four decades of collaboration, the UW–Madison recognizes the value and importance of institutional support for the CIMSS partnership with NOAA. UW–Madison is pleased to offer a combination of formal cost sharing and leveraged resources as outlined below.

3.7.1 Formal Cost Sharing

UW–Madison agrees to provide formal cost sharing with an estimated value of $821,739 through the following mechanisms:

1. Salary, Fringe, and F&A costs for the UW–CIMSS Director and Executive Director for Science. UW–Madison agrees to cost share 10% effort for each the UW–CIMSS Director and the Executive Director for Science. The estimated value of this contribution totals $321,739 and breaks down as follows:

Name/Role	Effort	Annual Rate*	Salary Amt	Fringe Rate	Fringe Cost	Total
PI – L'Ecuyer, Tristan	10%	143,263	$14,326	35%	$5,014	$19,340
ED-S – Feltz, Wayne	10%	152,198	$15,220	35%	$5,327	$20,547
SUBTOTAL			$29,546		$10,341	$39,887
Unrecovered Indirect Cost 55%						$21,938
Year 1 TOTAL						$61,825
Projected Year 2 (Same annual effort, 2% inflation assumed)						$63,061
Projected Year 3 (Same annual effort, 2% inflation assumed)						$64,323
Projected Year 4 (Same annual effort, 2% inflation assumed)						$65,609
Projected Year 5 (Same annual effort, 2% inflation assumed)						$66,921
FIVE YEAR PROJECT TOTAL						$321,739

*The basis of salary and effort for the UW–CIMSS Director is based on a 9 month faculty appointment. Salary and effort for the ED-S is a 12 month academic staff appointment.

2. The OVCRGE will provide flexible research support funds for direct costs in the amount of $100,000 per year over the five year award duration totaling $500,000. This funding is used to support undergraduate and graduate students, post-doctoral researchers and visiting scientists, outreach and communications, and research resources such as software or equipment.

3.7.2 Leveraged Resources

While the following is not "documented cost sharing," the services outlined below are of direct benefit to the federal government. This financial support brings significant additional capability and flexibility to the UW–CIMSS Director and the UW–CIMSS research teams.

In the discussion below, where possible, dollar amounts are provided for UW–CIMSS support services based on the most recent State of Wisconsin fiscal year (SFY) costs (1 July 2018 to 30 June 2019). This support has been and continues to be an ongoing contribution throughout the CIMSS partnership with NOAA. The most recent fiscal year data provides examples of the broad support that UW–Madison provides to the institute. The total UW–Madison contribution for SFY2019 is estimated to be $563,844 of support in additional to the formal cost-sharing outlined in Section 3.7.1. Specific components include:

1. **Physical space for ASPB/NCEI.** UW–Madison agrees to provide physical space for ASPB and NCEI federal researchers at UW–CIMSS to facilitate the transfer of scientific findings, tools and products to the operational users, to include office facilities, computing and other university services (e.g., access to facilities), details to be determined. The total square footage of NOAA employee occupied office space (7 persons) will be approximately 880 square feet not including the use of conference rooms, labs, and other facilities.
2. **Technical Computing** provides a unique set of shared research computing services to meet the high performance computing and data storage needs of the UW–CIMSS research staff. This includes the design, construction, and maintenance of a high performance data processing and storage facility to a customized science software application stack. These services provide the users with cost effective powerful tools they could not otherwise access while maximizing the available

resources (labor and equipment). As noted above, SSEC currently has one of the largest computing clusters on campus with 4,160 cores approximately 15 petabytes of total data storage.

3. **SSEC Satellite Data Services (SDS)** plays a key role in most UW–CIMSS science programs, providing scientists and collaborators with low latency, high quality global satellite and other data in near real time to support research and development. SDS works closely with NOAA/NESDIS/OSPO and /NCEI to support GOES ground station, product creation and archiving activities. Several times a year SDS provides data back-up support to OSPO when data is lost.
4. **The Schwerdtfeger Library** at SSEC/UW–CIMSS serves as an important resource for UW–CIMSS scientists and AOS students. The UW–Madison provides funds to support the SSEC Library activities. In SFY2019 this cost was $51,157.
5. **Quality Assurance and Program Management.** SSEC supports experts in Quality Control, Safety, and Employee Training. This group has developed specific quality and safety procedures for SSEC/UW–CIMSS including several documents (e.g., workplace emergencies). This team is also developing management training materials specific to SSEC/CIMSS project needs. The value to UW–CIMSS of this support in SFY20109 was approximately $30,695.
6. **SSEC Rooftop Instrument Suite and *SSEC Portable Atmospheric Research Center (SPARC)*.** SSEC supports an instrument validation site on the roof of its 15-story building. A UW–Madison grant funded the purchase and installation of high quality basic meteorological measurements (temperature, moisture, wind, pressure, solar radiation.) NSF, NASA and NOAA have funded the purchase and installation of remote sensing instruments. To bring all this information to scientists and other users, UW–Madison has funded the development of a data collection, management and Web-based delivery system for this instrument site. SSEC also maintains a mobile research facility called the SPARC (*SSEC Portable Atmospheric Research Center)* to study the atmosphere. Several instruments are integrated into a 36 foot trailer that is configured for remote operation either by using internal generators, or by connection to virtually any electrical power source found in the field. The current complement of instruments in the SPARC includes an Atmospheric Emitted Radiance Interferometer (AERI), High-Spectral Resolution Lidar (HSRL), a Halo Doppler Wind Lidar (DWL), a ceilometer, a meteorology surface station, a radiosonde launch receiver, and a GPS total precipitable water instrument. SSEC acquired the facility in 2013 and it has provided great benefit to UW–CIMSS to support field experiments and satellite Cal/Val activities. The SFY2019 support for the Rooftop Instrument Suite and SPARC was approximately $78,195.
7. **Start-up Funds for new ideas and projects:** The UW–Madison has provided considerable support for developing new research concepts that have a strong likelihood of leading to new proposals. These funds have supported several projects of significant benefit to both UW–CIMSS and NOAA. SFY19 approximate reinvestment of these programs totaled approximately $138,881. Examples include:
    a. **High spectral resolution IR interferometry:** The UW–Madison has provided important support to continuing efforts to build, operate, and demonstrate the capabilities of hyperspectral infrared sounders. While significant program funding has supported this work, gaps in funding were bridged by UW–Madison. SSEC's work in this area has been of great benefit to NOAA instrument design planning.
    b. **Application of satellite data for energy reserve capacity optimization system:** Renewable energy sources present challenges to the electrical power grid due to the volatility created by the spatially and temporally changing weather patterns. The UW Madison provided important seed funding support to utilize satellite data and numerical weather prediction models to address a key need for an optimized planning model for reserve capacity within a large region electrical power system.

c. **Data compression:** The very high data rates from advanced instrumentation require data compression. The UW–Madison has provided crucial support when UW–CIMSS has experienced gaps in funding in this area.

d. **Visualization tools:** When a new generation of data analysis and visualization tools were needed to work with the next generation of environmental satellite data, the UW–Madison funded a design study and proof of concept to develop the goals and requirements for the project. That funding has led to current NOAA and IPO support for building the open source, freely available McIDAS-V software.

8. **Support of Visiting Scientists.** The UW–Madison has provided partial support to foreign scientists visiting our institute for extended stays to help defray their living expenses (salaries and transit costs are usually borne by the home institution). In addition, UW–Madison supports UW–CIMSS scientists to visit foreign laboratories for extended stays fostering stronger collaborations. Examples include the Czech Republic Central Forecasting Office Prague, Japanese Meteorological Agency Satellite Division, EUMETSAT Met and Climate Division, the Taiwan Central Weather Bureau, the Australian Bureau of Meteorology, and the Chinese National Satellite Meteorological Center and many more international government and universities. These extended visits have cemented our strong international collaborations to the benefit of both UW–CIMSS and NOAA.

In summary, this section enumerates the many areas of **strong support the UW–Madison has provided to strengthen the partnership with NOAA in this Cooperative Institute.** NOAA benefits tremendously from the support the UW–Madison provides to NOAA/ASPB and SSEC/UW–CIMSS. This financial commitment furthers the goals of both NOAA and UW–CIMSS, supporting their science teams to provide the government with innovation and creativity in the research to operations process. This commitment from the UW–Madison further enhances NOAA's operational capability by linking with a strong university partner that can provide numerous programs and facilities that benefit NOAA as it seeks to fulfill its mission to the nation.

3.8 Performance Measures

Indicators of a successful research center include the number of publications in refereed journals, the success rate for submitted proposals, the number of graduating graduate students, awards of recognition, international scientist exchange programs, conference presentations and software distribution. We closely track these activities as noted in the examples below:

- A new bibliometric analysis of more than 720 peer-reviewed articles by UW–CIMSS authors documents our scholarly productivity for the period 2009-2019 presented in Appendix K. Highlights include: 1) UW–CIMSS averages 6.6 publications per million dollars across the decade; 2) UW–CIMSS authors publish in the top disciplinary journals with high impact factors; 3) article metadata show that our researchers collaborate with NOAA, domestic, and international agencies.
- Over 30% of UW–CIMSS papers published during the period 2010-2019 include one or more NOAA co-authors and many include an ASPB scientist as first author.
- UW–CIMSS monitors its research algorithms that have been successfully transferred to NOAA and other agencies with operational responsibilities. A list is provided in Appendix I. CIMSS scientists are currently delivering code to the GOES-R Algorithm Working Group. We will continue to monitor and report the timeliness of these deliveries.
- UW–CIMSS scientists and students have garnered numerous professional awards. These awards are listed in Appendix M. UW–CIMSS scientists have collaborated with ASPB and NOAA scientists who have received NOAA's gold, silver and bronze medals.
- UW–CIMSS tracks the graduation rate and employment location (as available) of graduate students who conducted research with CIMSS scientists. A history of graduate students is listed in Appendix H. We continue to track these graduation rates and which students go to work with NOAA.

- Performance reporting has been done through the CI annual report, containing synopses of all research projects attached to the CI (including Task II and other-agency activities that map to NOAA themes) and their relevance to NOAA mission goals. We also report on success stories from NOAA operations for CI-relevant transitions.
- CIMSS holds regular meetings of its Board of Directors receiving feedback from them and the CIMSS Science Council. Members are listed in Appendix G.

We will continue to work with NOAA on refining and detailing performance metrics that are relevant to NOAA. Pending the acceptance of this proposal, we will work with NOAA/STAR to ensure that any new performance metrics are adopted in our research plan.

3.9 UW–CIMSS Data Management Plan

UW–CIMSS fully supports, and enforces, NOAA and federal government policies to increase access to the results of federally funded scientific research, including both data and publications resulting from that research. UW–CIMSS/SSEC's pre-award and post-award processes align with these goals of ensuring openness and transparency in publicly funded research from NOAA and all federal agencies.

Our proposal development and review process, described in Section 3.6.2c, includes educating principal investigators on their responsibility to: meet all federal data management policies, manage data according to standards and best practices, and deposit manuscripts into the appropriate federal repository and data, into the appropriate archive, where warranted. All proposals submitted through the CIMSS Cooperative Agreement are also required to include a formal data sharing or management plan. Since UW–CIMSS research supports a number of different programs, each with specific data handling and sharing requirements, data management plans for individual submissions are tailored to address the specific requirements of each program or solicitation. An outline of a standard UW–CIMSS Data Management Plan that summarizes all of the information provided to the sponsor is provided below.

In short, UW–CIMSS data stewardship practices ensure that our research data is discoverable, accessible, and reusable in the longer term.

General Data Management Plan (Tailored to Meet Specific Program Requirements)

1. **Principal Investigator contact and descriptions of types of environmental data and information to be created or collected during the course of the project**
    a. PI contact information (name, institutional affiliation, email, phone).
    b. ***Type(s) (aircraft, ship, satellite, etc.) to be collected***
    c. Will all data have value to other researchers?
    d. What resources will you require to deliver this plan – either reflected in the budget or external to the project?

2. **Type of collection method**
    a. ***Type(s) (aircraft, ship, satellite, etc.) to be collected*** and anticipated volume/scope of data to be generated.
    b. Describe the method for documentation (including version control, directory structures, etc.) and for periodically checking the integrity of the data
    c. If there is pre-existing data, describe its provenance (lineage, how was it derived)

3. **Standards to be used for data/metadata format and content**
    a. Are there governing standards? If so, what are they?
    For example: NetCDF (https://www.nodc.noaa.gov/data/formats/netcdf/v2.0/), FGDC, HDF
    b. Include descriptions of file formats and names and their organization, parameter names and units, spatial and temporal resolution, metadata content, etc.

4. **Policies addressing data stewardship and preservation**
   a. Describe methods for preserving the data.
   b. What hardware and/or software resources are required to store the data?
   c. How will the data be stored and backed up (include frequency and who is responsible for this process)?

5. **Procedures for providing access, sharing, and security and prior experience in publishing such data**
   a. What access or security requirements does your sponsor have, if any (are there any embargo periods, for example)?
   b. Are there any privacy / confidentiality /export controls / intellectual property (copyright) requirements ?
   c. Who can access the data:
      i. During active data collection
      ii. When data are being analyzed and incorporated into publications
      iii. When data have been published
      iv. After the project ends
      v. Tentative date by which data will be publicly shared
   d. Are there any policies for re-use, redistribution or the production of derivatives?
   e. How should the data be cited and the data collectors acknowledged?

      Recommendation: An acceptable citation format for the dataset is:

      Authors, publication year. Dataset Title, Data Center. Download date. [Access path (URL or DOI)]

   f. What is the URL for public access to this Data Sharing Plan and the data? How long will they be available at that location?
   g. Briefly describe previous experience, if any
   h. Any peer-reviewed manuscripts produced with NOAA funding are to be submitted to the NOAA Institutional Respository to be made publicly available after an embargo of not more than one year: https://library.noaa.gov/Research-Tools/IR

6. **Optional: Plans for eventual transition of the data to an archive after the project ends**
   a. If appropriate, identify a suitable data center within your discipline (SSEC Data Center, NODC, NCEI, NGDC, NSIDC, CDIAC, NSSDC, UCAR, etc.)
   b. Consider establishing an agreement for archival storage.
   c. Understand the data center's requirements, including costs, for submission and incorporate into data sharing plan.

3.10 Complying with NEPA

To assist NOAA in complying with the National Environmental Policy Act (NEPA), UW–CIMSS will provide answers to the abbreviated set of questions from NOAA's Environmental Compliance Questionnaire for Federal Financial Assistance Applicants listed in the FFO for each project proposal submitted under the cooperative agreement. We will supply additional information concerning potential environmental impacts of UW–CIMSS research activities as requested by the agency. The current proposal for the continuation of UW–CIMSS does not describe specific research activities in sufficient detail to identify specific sites, data collection procedures, potential environmental impacts, or mitigation strategies here.

3.11 Proposal Summary

The University of Wisconsin–Madison proposes to build upon four decades of successful collaboration with NOAA to host a Cooperative Institute for Meteorological Satellite Studies (CIMSS) that will continue supporting NESDIS/STAR in meeting current and future challenges in satellite meteorology. This proposal builds upon the established practices and procedures of the current UW–CIMSS housed within the Space Science and Engineering Center, the birthplace of satellite meteorology, to meet these needs. UW–CIMSS and the UW have a history of successful partnerships with NOAA, NESDIS/STAR/ASPB, other government agencies and academic institutions, and international partners to advance all aspects of satellite meteorology from instrument design through assimilation into forecast models. In collaboration with on- and off-site NOAA colleagues, UW–CIMSS will conduct research in four theme areas: (1) Satellite Research and Applications to support weather analysis and forecasting through participation in NESDIS product assurance and risk reduction programs and the associated transitioning of research progress into NOAA operations; (2) Satellite Sensors and Techniques to assess instrument performance, conduct instrument trade studies in support of NOAA's future satellite platforms, validate remote sensing data and derived products, and advance the use of machine learning, artificial intelligence, and social sciences in converting satellite data to actionable information; (3) Environmental Models and Data Assimilation to increase the use of satellite data in operational weather forecast models and support community modeling efforts through EPIC; and (4) Outreach and Education to engage the current and future workforce in understanding and using environmental satellite observations for the benefit of an informed society. For 40 years UW–CIMSS has proven its excellence, service, and benefit to NOAA as a Cooperative Institute, a partnership we are eager and prepared to continue.

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Appendices

Appendix A: Acronyms

ABBA Automated Biomass Burning Algorithm
ABI Advanced Baseline Imager
ADDE Abstract Data Distribution Environment
ADT Advance Dvorak Technique
AERB Algorithm Engineering Review Board
AERI Atmospheric Emitted Radiance Interferometer
AI – Artificial Intelligence
AIRS Atmospheric InfraRed Sounder
AIT Algorithm Integration Team
AMDAR Aircraft Meteorological Data Relay
AMS American Meteorological Society
AMSU Advanced Microwave Sounder Unit
AMV Atmospheric Motion Vectors
AniS AnimationS applet
AO Announcement of Opportunity
AOS Department of Atmospheric and Oceanic Sciences
AQ Air Quality
AHI Advanced Himawari Imager (Japan)
ARI Absolute Radiance Interferometer
ARM Atmospheric Radiation Measurement
ASPB Advanced Satellite Products Branch
ASTER Advanced Spaceborne Thermal Emission and Reflection radiometer
ATMS Advanced Technology Microwave Sounder
ATOVS Advanced TIROS Operational Vertical Sounder
AVHRR Advanced Very High Resolution Radiometer
AWG Algorithm Working Group
AWC Aviation Weather Center
AWIPS Advanced Weather Interactive Processing System
BAMS Bulletin of the American Meteorological Society
BARC Burned Area Reflectance Classification
BRIDGE Burn Intensity Delta Greenness Estimation
BUFR Binary Universal Form for the Representation
CA Cooperative Agreement
CAMEL Combined ASTER MODIS Emissivity over Land
CAPE Convective Available Potential Energy
CAT Clear Air Turbulence
CAVE CIMSS Audio-Visual Environment
CCR Cloud Cleared Radiance or Center for Climatic Research
CDR Climate Data Record
CEOS Committee for Earth Observation Satellites
CESSRST Center for Earth System Sciences and Remote Sensing Technologies
CGMS Coordination Group for Meteorological Satellites
CI Cooperative Institute
CICS Cooperative Institute for Climate Studies (University of Maryland and North Carolina State)
CIMSS Cooperative Institute for Meteorological Satellite Studies
CIRA Cooperative Institute for Research in the Atmosphere (Colorado State University)
CLARREO Climate Absolute Radiance and Refractivity Observatory
CLASS Comprehensive Large Array-data Stewardship System
CLAVR-x Clouds from AVHRR-Extended
CMOS Canadian Meteorological and Oceanographic Society
CO Carbon Monoxide
CO_2 Carbon Dioxide
COMS Communication, Ocean, Meteorological Satellite (South Korea)

CONUS CONtinental (or CONterminus) United States
CoRP Cooperative Research Program (STAR)
COSMIC Constellation Observing System for Meteorology, Ionosphere, and Climate
CPAF Cloud Pixels Around Fires
CREST Cooperative Remote Sensing Science and Technology Center (consortium of 8 universities)
CrIS Cross-track Infrared Sounder
CRTM Community Radiative Transfer Model
CSPP Community Satellite Processing Package
CUNY City University of New York
CWB Central Weather Bureau (Taiwan)
CWG Calibration Working Group or Cloud Working Group
DA Data Assimilation
DB Direct Broadcast
DBNet Direct Broadcast Network
DL Deep Learning
DOD Department of Defense
DOE Department of Energy
DWL Doppler Wind Lidar
EARS EUMETSAT ATOVS Retransmission Service
ECMWF European Centre for Medium-Range Weather Forecasts
ED-A Executive Director – Administration (SSEC)
ED-S Executive Director – Science (SSEC)
EDR Environmental Data Record
EMC Environmental Modeling Center
ENI Earth Networks Incorporated
EOS Earth Observing System
EPA Environmental Protection Agency
EPIC Earth Prediction Innovation Center
EPO Education and Public Outreach
ER-2 Earth Resources (airplane), #2
ESI Evaporative Stress Index
ESIP Earth Science Information Partners
ESPC Environmental Satellite Processing Center
ET Evapotranspiration
FAA Federal Aviation Administration
FACETS Forecasting A Continuum of Environmental ThreatS
FDCA Fire Detection and Characterization Algorithm
FEMA Federal Emergency Management Agency
FGGE First GARP Global Experiment
FIRE First ISCCP Regional Field Experiment
FIREX-AQ Fire Influence on Regional to Global Environments and Air Quality
FLC Fog and Low Cloud
FOV Field Of View
FPGA Field-Programmable Gate Array
FPM Focal Plan Module
FTP File Transfer Protocol
FTS Fourier Transform Spectrometers
FV3 Finite Volume Cubed-Sphere Dynamical Core
FY Fiscal Year
GAC Global Area Coverage
GB Gigabyte
GEO Geostationary
GOES-R Geostationary Operational Environmental Satellite – R(S,T,U) Series once operational GOES 16-19
GFS Global Forecast
GIFTS Geosynchronous Imaging Fourier Transform Spectrometer
GIIR Geostationary Interferometric Infrared Sounder
GIMPAP GOES Improved Measurements and Product Assurance Plan

GINI GOES Ingest and NOAAPORT Interface
GIS Geographic Information Systems
GLM GOES Lightning Mapper
GMAO Global Modeling and Assimilation Office
GMD Grants Management Division (NOAA)
GMI Global Microwave Imager
GMS Geostationary Meteorological Satellite
GNC-A GEONETCast-Americas
GOES Geostationary Operational Environmental Satellite
GOMS Geostationary Operational Meteorological Satellite (Russia)
GOS Global Observing System
GOSAT Greenhouse gases Observing SATellite
GPM Global Precipitation Measurements
GPS Global Positioning System
GPU Graphics Processing Unit
GS Graduate School
GSFC Goddard Space Flight Center
GSI Gridpoint Statistical Interpolation
GSICS Global Space-based Inter-Calibration System
GTS Global Telecommunications System
GVAR GOES VARiable data
GWINDEX-III Global Wind Experiment
HDF Hierarchical Data Format
HES Hyperspectral Environmental Suite
HIIS GEO Hyperspectral Imaging Infrared Sounder
HIRAS Hyperspectral Infrared Atmospheric Sounder
HIRS High-resolution Infrared Radiation Sounder
HIS High-spectral resolution Interferometer Sounder
HPCC High-Performance Computing Cluster
HRRR High Resolution Rapid Refresh
HSRL High Spectral Resolution Lidar
HS3 Hurricane and Severe Storm Sentinel experiment
HU Hampton University
HWRF Hurricane Weather Research and Forecast model
HWT Hazardous Weather Testbed (NOAA)
HYDRA Hyper-spectral Data Research Application
IAPP International ATOVS Processing Package
IASI Infrared Atmospheric Sounding Interferometer
ICT Internal Calibration Target
IDD Internet Data Distribution
IEEE Institute of Electrical and Electronics Engineers
IFR Instrument Flight Rules
IMAPP International MODIS/AIRS Processing Package
IMG Interferometric Monitor for Greenhouse gases
INR Image Navigation and Registration
IODC Indian Ocean Data Coverage
IPO Integrated Program Office
IPOPP International Polar Orbiter Processing Package
IR InfraRed
IRS InfraRed Sounder
IRW Infrared Window
ISCCP International Satellite Cloud Climatology Project
ISO International Organization for Standardization
ITPP International TOVS Processing Package
ITS Interferometer Thermal Sounder
ITWG International TOVS Working Group
JAXA Japan Aerospace Exploration Agency

JCSDA Joint Center for Satellite Data Assimilation
JEDI Joint Effort for Data assimilation Integration
JPSS Joint Polar Satellite System
JMA Japan Meteorological Agency
JPL Jet Propulsion Laboratory
JPSS Joint Polar Satellite System
K Kelvin
Km Kilometer
LADCO Lake michigan Air Directors COnsortium
LAP Legacy Atmospheric Profiles
LDM Local Data Manager
LEO Low Earth Orbit
LeS Lake Effect Snow
LHP Loop Heat Pipe
LMOS Lake Michigan Ozone Study
LPW Layered Precipitable Water
LSS Local Severe Storms
M.S. Master of Science
McIDAS Man computer Interactive Data Access System
MEASURES Making Earth Science Data Records for Use in Research Environments
MERSI Medium Resolution Spectral Imager
Meteosat METEOrological SATellite
METOP Series of polar orbiting meteorological satellites (EUMETSAT)
MHS Microwave Humidity Sounder
ML Machine Learning
MLS Microwave Limb Sounder
MODAPS MODIS Adaptive Processing
MODIS Moderate Resolution Imaging Spectroradiometer
MOOC Massive Open On-line Course
MOU Memorandum of Understanding
MRMS Multi-Radar/Multi-Sensor
MSG Meteosat Second Generation
MTG-IRS European Meteosat Third Generation – Infrared Sounder
MTSAT-1R Japan's geostationary imager
MURI Multidisciplinary University Research Initiative
MVCM MODIS-VIIRS Cloud Mask
MW Microwave
NASA National Aeronautics and Space Administration
NAST NPOESS Airborne Sounder Testbed
NCAR National Center for Atmospheric Research
NCEI National Centers for Environmental Information
NCEP National Centers for Environmental Prediction
NCO NOAA Central Operations
NDVI Normalized Difference Vegetation Index
NESDIS National Environmental Satellite, Data and Information Services
NGGPS Next Generation Global Prediction System
NH Northern Hemisphere
NHC National Hurricane Center
NOAA National Oceanic and Atmospheric Administration
NPOESS National Polar Orbiter Environmental Satellite System
NPP NPOESS Preparatory Project
NR Nature Run
NREL National Renewable Energy Laboratory
NSF National Science Foundation
NSMC National Satellite Meteorology Center (China)
NSRDB National Solar Radiation Database
NSSL National Severe Storms Laboratory

NUCAPS NOAA Unique Combined Atmospheric Processing System
NUOPC National Unified Operational Prediction Capability
NWA National Weather Association
NWP Numerical Weather Prediction
NWS National Weather Service
NWSFO NWS Forecast Office
O2R Operations To Research
OAR-OWAQ Oceanic and Atmospheric Research-Office of Weather and Air Quality
OCLC/FDTD Office of the Chief Learning Officer/Forecast Decision Training Division
ODT Objective Dvorak Technique
OMI Ozone Monitoring Instrument (Aura)
OMPS Ozone Mapping Profiler Suite
OPC Ocean Prediction Center
OPG Operations Proving Ground
OPPA Office of Projects, Planning, and Analysis
OSE Observing System Experiments
OSPO NOAA Office of Satellite Product Operations
OSSE Observing System Simulation Experiments
OT Overshooting top
OVCRGE Office of the Vice Chancellor for Research and Graduate Education
PATMOS-x Pathfinder Atmosphere
PB Petabytes
Ph.D. Doctor of Philosophy
PI Principal Investigator
PICA PerIodic Calibration Anomaly
PCal Predictive Calibration
PLT Post Launch Test
PM Program Manager
POES Polar Orbiting Environmental Satellite
PoR Program of Record
ProbSevere Probability of Severe Thunderstorm at earth surface
PSDI Product Systems Development and Implementation
QA Quality Assurance
QC Quality Control
RAMMB Regional and Mesoscale Meteorology Branch (CIRA)
RAQMS Regional Air Quality Modeling System
RARS Regional ATOVS Retransmission Service
R2O Research to Operations
RO Radio Occultation
rOSSE Regional Observing System Simulation Experiments
RSR Relative Spectral Response
RSP Research and Sponsored Programs
RT Radiative Transfer
RTAP Research Transition Acceleration Program
RTTOV Radiative Transfer for TOVS
S4 Supercomputer for Satellite Simulations and Data Assimilation Studies
SAB Satellite Analysis Branch (OSDPD)
SAFARI Southern African Regional Science Initiative
SAR-FV3 Volume Cubed Sphere -based stand-alone regional model
SAF Satellite Applications Facility
SAT System performance Assessment Team
SATCON Satellite Consensus
SDAT Satellite Data Assimilation for Tropical storm
SDI SSEC Desktop Ingestor
SDR Sensor Data Record
SEVIRI Spinning Enhanced Visible and InfraRed Imager
SFOV Single Field of View

SFY State Fiscal Year
SGP Southern Great Plains
SH Southern Hemisphere
SHOUT Sensing Hazards with Operational Unmanned Technology
S-HIS Scanning High resolution Interferometer Sounder
SHyMet Satellite Hydrology and Meteorology
SIP Strategic Implementation Plan or State Implementation Plan
SO_2 Sulfur dioxide
SOI Successive Order of Interaction
SOO Science and Operations Officer
SOS Science on a Sphere
SPARC SSEC Portable Atmospheric Research Center
SPC Storm Prediction Center
SRF Spectral Response Function
SSEC Space Science and Engineering Center
STAR Satellite Applications and Research
STEM Science, Technology, Engineering, Mathematics
SWIPE Statistical WarnIng and PEdiction Model
TAFB Tropical Analysis and Forecast Branch
TAP Technical Advisory Panel
TB Terabytes
TC Tropical Cyclones
TCO Total Column Ozone
TCWB Taiwan Central Weather Bureau
THORPEX The Observing system Research and Prediction Experiment
TIM Technical Interchange Meeting
TIROS Television InfraRed Observation Satellite
TMP Technology Maturation Program
TOMS Total Ozone Mapping Spectrometer
TOVS TIROS Operational Vertical Sounder
TPC Tropical Prediction Center
TPW Total Precipitable Water
TROPOMI Tropospheric Monitoring Instrument
TSF Temporal Spectral Fusion
UFO Unified Forward Operator
UPS Uninterruptible Power Supply
UTC Universal Coordinated Time or Universal Time Coordinated
UTLS Upper Troposphere – Lower Stratosphere instrument
UV UltraViolet
UW University of Wisconsin
VAS VISSR Atmospheric Sounder
VIIRS Visible/Infrared Imager and Radiometer Suite
VISIT Virtual Institute for Satellite Integration Training
VISSR Visible and Infrared Spin-Scan Radiometer
VOCs Volatile Organic Compounds
VSF Virtual Science Fair
WDNR Wisconsin DNR
WF_ABBA Wildfire Automated Biomass Burning Algorithm
WFO Weather Forecast Office (NWS)
WMO World Meteorological Organization
WPC Weather Prediction Center
WRF Weather Research and Forecasting model
WV Water Vapor
WVSS Water Vapor Sensing System

Appendix B: Letters of Support

Central Weather Bureau - Taiwan: Director CWB Satellite Center Dr. Chia-Rong Chen

CIRA: Dr. Christian Kummerow

CISESS: Dr. Ernesto Hugo Berbery

ECMWF: Dr. Florence Rabier

EUMETSAT: Chief Scientist Dr. Kenneth Holmlund

GSFC: Dr. Steven Platnick

JTWC – Hawaii: Commanding Officer R. C. Cherrett

NOAA/NWS/NCEP: Chief, Data Assimilation and Quality Control, Dr. Daryl Kleist

National Hurricane Center: Director Kenneth E. Graham

NRL - Monterey: Dr. James Hansen

NWS Milwaukee-Sullivan Office (MKX): Kevin Lynott (MIC) and John Gagan (SOO)

NRL – ICAP Consortium – Dr. Jeffery Reid

University of Chicago – Dr. Rebecca Willet

WMO: Assistant Secretary- General Dr. Wenjian Zhang

NSMC (Tristan ask Paul and cc Brad): Yang Jun

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November 27, 2019

To Whom It May Concern:

This letter is to acknowledge the contribution made by the University of Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS). The Central Weather Bureau (CWB) of Taiwan has greatly benefited from satellite processing packages developed at UW-CIMSS such as CLAvR-X, IMAPP, CSPP, Himawari-8 weather decision support products and AWIPS-2 satellite product visualization assistance.

UW-CIMSS has proven to be a leader in satellite data processing and educational software design. Over the last ten years our relationship has been strengthened by having CWB visiting scientists embedded with CIMSS scientists and researchers and establishing annual formal meetings.

This letter acknowledges the work done by CIMSS and dedication to supporting the CWB mission. We strongly endorses the continuation of CIMSS as a NOAA Cooperative Institute at the University of Wisconsin.

Sincerely yours,

Chia-Rong Chen
Director
Meteorological Satellite Center
Central Weather Bureau, Taiwan

2 November 2018

Cooperative Institute for
Research in the Atmosphere
Foothills Campus
1375 Campus Delivery
Fort Collins, Colorado 80523-1375
(970) 491-8448

Prof. Tristan L'Ecuyer
Director, CIMSS
Space Science and Engineering Center
University of Wisconsin—Madison
1225 West Dayton Street
Madison, Wisconsin 53706

Dear Prof. L'Ecuyer:

This letter expresses the support of the NOAA Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University for your application to continue your Cooperative Institute for Meteorological Satellite Studies with NOAA. CIRA has a long-standing and productive collaboration with CIMSS in both research and education and we look forward to continued collaborations. CIMSS, and its collaborations with CIRA, have been very successful and beneficial for NOAA, especially NESDIS. Our collaborative work on training programs leveraged the strengths of both institutes to develop the tools and the education modules to support training of NOAA forecasters. This training is now occurring in a variety of activities, including on-line courses (e.g. SHyMet), blogs and proving ground activities. Our research collaboration on tropical storms is a prime example of leveraging the expertise at our two organizations. This collaborative research has led to a better understanding for hurricanes and has helped NOAA improve hurricane predictions. In at least one occasion, the collaboration has even extended from CIMSS scientists to students at Colorado State University. More recently, our GOES-16 and GOES-17 collaborations are helping to assess capabilities and interpretation of these new weather imagers. For example, CIMSS and CIRA have collaborated both on the creation of new data products, as well as the visualization of the ABI (Advanced Baseline Imager) data that supports public awareness and addresses the needs of weather forecasters. Because of the great expertise that CIMMS has in creating cloud products, most of CIRA's new projects involving clouds have some level of collaboration with CIMSS.

I also look forward to strengthening collaborations that are just beginning to bloom, such as those involving potential new observations and the more complete utilization of data from existing satellites. With new capabilities in Data Assimilation, I feel collaborations can only get broader. We are very enthusiastic about these collaborations and look forward to their continuation and strengthening. The staff and scientists at CIMSS are well equipped to address the priorities of NOAA and CIRA looks forward to our continued collaborations as cooperative institutes.

Sincerely,

Christian Kummerow
Professor, Dept. of Atmospheric Science and
Director, Cooperative Institute for Research in the Atmosphere (CIRA)
Colorado State University

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College Park, 11 December 2019

Dr. Tristan L'Ecuyer
Director, CIMSS
University of Wisconsin-Madison
1225 West Dayton St
Madison WI 53706

Dear Dr. L'Ecuyer,

I am writing this letter to support your proposal from the University of Wisconsin-Madison to continue leading the Cooperative Institute for Meteorological Satellite Studies (CIMSS). Since its inception as a NOAA Cooperative Institute in 1980, CIMSS has successfully conducted research in the general area of satellite meteorology and applications with a wide variety of national and international partners, including CISESS (formerly CICS). The leadership of Steve Ackerman first, and yours now, has led to CIMSS becoming an essential entity to support NOAA's satellite based research and applications. Not least, CIMSS plays a significant role in the transition of research results to various operational agencies.

CIMSS is known world-wide for its strength in the development of cutting edge visualization and analysis tools, its meteorological satellite data center and associated end-to-end data processing capabilities, combined with the ability to evolve observing systems from the drawing board to space.

Our institute, CISESS, seeks to advance and refine the use of satellite information, apply best practices to data stewardship of large datasets, provide research and development services, as well as monitor changes in the Earth System. Our activities strongly complement your proposed extension of CIMSS. I am confident that we will continue to advance the collaborations between our Institutes. Particularly, your work on algorithm development and cal/val activities ties closely with our work of creating long term climate records and data for improving their assimilation in weather and climate models.

We look forward to working with your researchers over the next decade.

Sincerely,

Dr. Ernesto Hugo Berbery
Research Professor, Earth System Science Interdisciplinary Center
Deputy Director, Cooperative Institute for Satellite Earth System Studies

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Europäisches Zentrum für mittelfristige Wettervorhersage | Centre européen pour les prévisions météorologiques à moyen terme

Our ref: DG/19-259
Date: 12 December 2019

Direct line: +44 118 9499001
E-mail: florence.rabier@ecmwf.int

To the NOAA Re-compete Panel

Dear Panel Members

The purpose of this letter is to support renewal of the status of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) as a Cooperative Institute of the National Oceanic and Atmospheric Administration. ECMWF benefits from an excellent and long-standing collaboration with world leading scientists at CIMSS to enhance the impact of existing satellite observations and ensure the rapid validation and operational exploitation of new satellite data.

ECMWF assimilates two key satellite-based product types that have been developed by CIMSS in collaboration with NESDIS/STAR, namely Atmospheric Motion Vectors (AMV) derived from polar orbiting and geostationary spacecraft and Clear-Sky Radiances (CSR) obtained from geostationary (GOES) imagers. These provide critical real-time dynamical information to our atmospheric analyses and have a well-documented track record of improving the quality of operational NWP forecasts. CIMSS has also generated reprocessed historical time series of these data in support of our climate re-analysis activities.

ECMWF is currently developing an advanced assimilation system to exploit hyper-spectral infrared observations from the next generation of geostationary satellites. We believe these exciting new data will bring major advances to NWP forecast skill. Scientists here (and at our sister organization EUMETSAT) are currently working very closely with CIMSS experts to use data from the Chinese FY4 satellites as a prototype, ahead of the launch of the European Meteosat-Third-generation (MTG) operational mission.

In summary, we continue to regard CIMSS as a vital partner for the successful exploitation of satellite observations in our global forecasting systems – relying both on the data they produce and their world leading scientific expertise. A such we consider it very important that CIMSS receives the utmost support from NOAA established by its status as a Cooperating Institute.

Yours sincerely

Dr Florence Rabier
Director-General

Shinfield Park, Shinfield Road, Reading, RG2 9AX, UK

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EUMETSAT

EUMETSAT - Postfach 10 05 55 - 64205 Darmstadt - Germany

TO WHOM IT MAY CONCERN

Your reference / Votre référence	Your letter dated / Votre lettre du	Our reference / Notre référence	Darmstadt
		EUM/CS/LET/19/1146610	3 December 2019

Subject / Objet **Letter of Support for continuation of CIMSS at the University of Wisconsin**

This letter is to acknowledge the contribution made by the University of Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS) in advancing the evolution and utilization of the space-based Earth-observation system, in particular for environment, climatology and meteorology.

Since the 1980's CIMSS has played a leading role internationally and, in particular, been outstanding partner for EUMETSAT's scientific development activities. Specifically the collaboration has strongly supported the definition of new instruments for both the NOAA and EUMETSAT mandatory Programmes like the Joint Polar System, comprising today of the NOAA JPSS and the EUMETSAT EPS and future EPS-Second Generation satellites. Furthermore the collaboration has paved the way for a new generation of geostationary imagers, like ABI/GOES and FCI/NOAA with highly compatible capabilities enabling an efficient use of common algorithms and tools.

A particularly important aspect of the work at CIMSS is the capability to do state-of-the-art scientific research and turn it to operational applications. This ability will be key for the development of the next generation space-based capabilities stemming out of the ground-breaking approach used by NOAA in its space-based architecture studies in order to meet the future challenges as defined by the WMO WIGOS2040 Vision and to exploit the new opportunities provided by the advent of small-satellite capabilities.

In conclusion, this letter acknowledges the work done by CIMSS and continuous dedication to support the EUMETSAT meteorological satellite missions in all aspects including definition, engineering, design, calibration and exploitation. I therefore strongly endorse the continuation of CIMSS as a NOAA Cooperative Institute at the University of Wisconsin.

Sincerely,

Dr. Kenneth Holmlund

Chief Scientist EUMETSAT, Darmstadt, Germany

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National Aeronautics and Space Administration
Earth Science Division
Goddard Space Flight Center

December 17, 2019

Dr. Tristan L'Ecuyer
Director, Cooperative Institute for Meteorological Satellite Studies
Associate Professor, Department of Atmospheric and Oceanic Sciences
University of Wisconsin-Madison
1225 W. Dayton St, Madison, WI 53706

RE: CIMSS Letter of Support

Dr. L'Ecuyer:

I am very pleased to provide a letter of support for the CIMSS re-compete proposal.

As a NASA GSFC scientist, I have enjoyed a long productive and rewarding collaboration with a number of CIMSS researchers and students. These collaborations, largely funded through NASA competed projects, have primarily focused on the use of multispectral imagers for retrieving cloud properties to better understand cloud processes and the role of clouds in the climate system.

The close collaborations between CIMSS and NASA GSFC imager scientists began in the 1990s when CIMSS personnel were developing MODIS cloud mask and cloud-top property algorithms (S. Ackerman, P. Menzel), as well as helping lead algorithm evaluation activates using airborne simulators. The CIMSS algorithms were essential input to the cloud optical retrieval algorithm being developed at GSFC. The CIMSS team took a leading role in airborne simulator and on-orbit MODIS infrared radiometric characterizations, leveraging airborne imaging interferometers developed at SSEC/CIMSS, while GSFC focused on solar reflectance radiometry. A close working relationship was essential to the success of the NASA MODIS Science Team cloud product suite, which is quickly approaching a remarkable two-decade data record length.

While a number of graduate students were involved in these activities over the years, of special note was GSFC's support for three graduate students in the Department of Atmospheric and Oceanic Sciences (S. Nasiri, R. Holz, B. Maddux) through the *Suomi-Simpson Graduate Fellowship*, established in the early-2000s by Vince Salomonson who was then the Director of GSFC Earth Sciences. GSFC scientists (M. D. King, S. Platnick) served as science mentors to the fellows mentioned above in conjunction with their advisor S. Ackerman (AOS/CIMSS).

The team's MODIS cloud product and instrument characterization experience is now leveraged for algorithm continuity development that seeks to bridge the MODIS and VIIRS eras, despite significant differences in the imaging sensors. This continuity work is funded from a single competed proposal with both CIMMS and GSFC investigators, including a NOAA STAR member of CIMSS (A. Heidinger) who has been on several other NASA proposals with the same team (e.g., PACE Science Team). With the NASA Atmosphere SIPS being located at SSEC, the

CIMSS partnership has been particular useful in working with the SIPS. The collaborative team effort continues in pursuing opportunities for cloud products from the new generation of Geosynchronous imagers (ABI, etc.). Cloud data records from VIIRS and GEO, produced using common algorithms developed for MODIS, are components of the Program of Record discussed in NASA's 2017 Decadal Survey for the Aerosol Cloud Convection Precipitation (ACCP) Designated Observables.

In summary, CIMSS has been an essential partner with NASA in developing and evaluating cloud imager algorithms, assessing on-orbit imager radiometric performance, conducting scientific data analysis and fostering applications. The fruits of this long term collaboration will continue into the future as CIMSS helps to establish the Program of Record for future Decadal Survey missions.

Please feel free to contact me if I can provide additional information.

Regards,

Steven Platnick, Ph.D.
Deputy Director for Atmospheres, Earth Science Division (atmospheres.gsfc.nasa.gov)
Earth Observing System Sr. Project Scientist (eospso.nasa.gov/index.php)
MODIS Atmosphere Discipline lead (modis-atmosphere.gsfc.nasa.gov)
NASA Goddard Space Flight Center
Greenbelt, MD 20771
Email: steven.platnick@nasa.gov
URL: science.gsfc.nasa.gov/sed/bio/steven.e.platnick

DEPARTMENT OF THE NAVY
JOINT TYPHOON WARNING CENTER
425 LUAPELE ROAD
PEARL HARBOR, HI 96860-3103

Ser 00/ 191
03 Dec 2019

From: Commanding Officer, Joint Typhoon Warning Center
To: National Oceanographic and Atmospheric Administration

Subj: LETTER OF SUPPORT FOR CONTINUATION OF CIMSS AT THE UNIVERSITY OF WISCONSIN

1. The Joint Typhoon Warning Center (JOINT TYPHOON WRNCEN) is responsible for a region that spans 118-million square miles. Forecasters at the JOINT TYPHOON WRNCEN must rely heavily upon satellite data in order to carry out the mission of support for Department of Defense operations including safety of ships, aircraft and personnel. The task of providing quality support for the JOINT TYPHOON WRNCEN mission is enhanced through dedicated partnerships with cooperative institutes such as the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin. The high quality data and information provided by CIMSS is crucial to the JOINT TYPHOON WRNCEN continually providing timely, accurate, and relevant weather support for 89% of the world's tropical cyclones, while protecting billions of dollars in Department of Defense Assets across the Pacific and Indian Oceans.

2. JOINT TYPHOON WRNCEN recognizes CIMSS for providing world-class level satellite research, development of new satellite sensors, data processing, tropical cyclone intensity analysis algorithms and satellite-based analysis environmental fields. JOINT TYPHOON WRNCEN forecasters use products from CIMSS daily. Over the years, CIMSS has been committed to ensuring that JOINT TYPHOON WRNCEN personnel are updated on the latest changes to algorithms and tropical cyclone analysis tools. In return, JOINT TYPHOON WRNCEN often provides feedback on ways to improve the delivery of tropical cyclone products and vectors guidance regarding mission-essential priorities. This collaborative process is important for speeding the transition of research to operations and ensuring the highest quality of support to JOINT TYPHOON WRNCEN.

3. This letter acknowledges the work done by CIMSS and its dedication to supporting the JOINT TYPHOON WRNCEN mission for more than 35 years. JOINT TYPHOON WRNCEN strongly endorses the continuation of CIMSS as a NOAA Cooperative Institute at the University of Wisconsin.

R. C. CHERRETT

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

NOAA Center for Weather and Climate Prediction (NCWCP)
National Centers for Environmental Prediction (NCEP)
Environmental Modeling Center (EMC)
5830 University Research Court, College Park, MD 20740 USA

Date: 27 November 2019

To: Dr. Tristan L'Ecuyer, Director
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
University of Wisconsin – Madison
1225 W. Dayton St.
Madison, WI 53706

Dear Dr. L'Ecuyer,

This letter is in support of the renewal of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison as a Cooperative Institute of the National Oceanic and Atmospheric Administration.

As the operational numerical weather prediction (NWP) center within the National Weather Service, the Environmental Modeling Center (EMC) relies heavily on CIMSS to produce datasets and products for use in the data assimilation systems that provide initial conditions for a variety of numerical prediction systems. CIMSS has played a critical role in developing new products and providing expertise in support of optimizing the use of satellite based data in our operational data assimilation and verification systems for NWP. In particular, the development of atmospheric motion vectors from geostationary and polar orbiting satellites as well as geostationary radiance products has been key for realizing operational predictive skill, helping NWS to meet its mission. Furthermore, CIMSS scientists have been actively involved in a variety of activities within the multi-agency Joint Center for Satellite Data Assimilation (JCSDA). They have also provided support in effectively transitioning research to operations. Beyond operational NWP applications, CIMSS has supported the use of products by some of the operational forecast centers such as the National Hurricane Center and Storm Prediction Center.

This data is demonstrably important for operational NWP, and the exploitation of such information would not be possible without the basic research happening at CIMSS. The direct benefit from the work taking place at CIMSS that is being realized by NWS and our international NWP colleagues is significant.

I strongly endorse renewal of the cooperative institute agreement. I full endorse and expect EMC to continue (and grow) its relationship with CIMSS through the Cooperative Institute Program.

Sincerely,

Daryl T. Kleist

Dr. Daryl Kleist
Chief, Data Assimilation and Quality Control
Modeling and Data Assimilation Branch
NOAA/NWS/NCEP
Environmental Modeling Center
tel. +1.301.683.3942 (direct)
email: daryl.kleist@noaa.gov

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
National Hurricane Center
11691 SW 17th Street
Miami, Florida 33165-2149

November 26, 2019

To Whom It May Concern:

The NOAA National Hurricane Center (NHC) is responsible for providing tropical cyclone analyses and forecasts for the North Atlantic and eastern North Pacific ocean basins extending from the Equator to high latitudes. The success of this mission is greatly enhanced by the information and data provided by NOAA Cooperative Institutes that support NHC, including the Cooperative Institute for Satellite Studies (CIMSS) at the University of Wisconsin. NHC's analysis and forecast products are dependent on the availability of satellite data and guidance products derived from these data. In many cases, satellites are the only sources of information available to NHC. For example, about 70% of Atlantic and 95% of eastern North Pacific basin tropical cyclones are analyzed using satellite data alone. Many satellite-derived products that NHC relies upon have been provided by CIMSS, such as the Automated Dvorak Technique, which is used to help determine tropical cyclone intensity. Other products help diagnose the environmental conditions around tropical cyclones that affect changes in storm motion and intensity. CIMSS provides these products in near real-time to NHC via the CIMSS web page and through direct transmission to NHC for evaluation and testing. Over the years, the research team at CIMSS has been committed to updating existing algorithms and developing new tools that can be transitioned to NESDIS and National Weather Service operations for use by NHC forecasters. In addition, the CIMSS team has been valuable in supporting research efforts directly beneficial to NHC through field research campaigns. CIMSS personnel are committed to training and interacting with NHC forecasters on new satellite-based methods and have always been open to feedback on these techniques. This collaborative relationship has helped play a part in improvements in NHC tropical cyclone forecasts and products over the last ten years.

Because of the important impact of the CIMSS ongoing and future research efforts, NHC urges NOAA to support the renewal of CIMSS as a Cooperative Institute of NOAA.

Sincerely,

Kenneth E. Graham
Director, National Hurricane Center

U.S. NAVAL RESEARCH LABORATORY

9 December 2019

FROM: Superintendent, NRL Monterey CA
SUBJECT: Letter of Support for continuation of CIMSS at the University of Wisconsin

To whom it may concern,

The Naval Research Laboratory (NRL) in Monterey CA collaborates with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin to develop products for Naval Operations. The high quality data and information provided by CIMSS is crucial to the Navy continuing to providing timely, accurate, and relevant weather support for the entire globe, which in turn protects billions of dollars in Department of Defense assets worldwide.

CIMSS is a world-class satellite research institute, providing satellite data processing, tropical cyclone analysis and global analyses of satellite-based parameters. Products from CIMSS are used daily by Navy forecasters through forward deployed systems like the NRL Tropical Cyclone Page, the Automated Tropical Cyclone Forecast System (ATCF) and Navy numerical weather prediction. Over the years CIMSS has been committed to ensuring that the Navy is appraised of new algorithms and changes to existing tools. Exchanges between NRL and CIMSS include NRL funding both basic and advanced scientific efforts through grants, real-time use of CIMSS product (e.g., global shear products) and transitions of algorithms into operational products (e.g., transition of a CIMSS tropical cyclone tracking algorithm into the NRL Tropical Cyclone Page. This collaborative process is important for speeding the transition of research to operations and ensuring the highest quality of support to our Navy customers.

This letter acknowledges the work done by CIMSS and their dedication to supporting the Navy mission. The collaborations between CIMSS, its sister agency the Cooperative Institute for Research in the Atmosphere (CIRA), and NRL Monterey provide a formidable breadth and depth of scientific effort that has served the Navy through at least 30 years. NRL would greatly benefit from the continuation of CIMSS as a NOAA Cooperative Institute at the University of Wisconsin.

Sincerely,

Dr. James Hansen
Superintendent, NRL Monterey

Marine Meteorology Division – Code 7500
U.S. Naval Research Laboratory
7 Grace Hopper Ave. MS2, Monterey, CA 93943

www.nrl.navy.mil

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service - WFO Milwaukee/Sullivan
N3533 Hardscrabble Rd.
Dousman, WI 53118

10 December 2019

FROM: Kevin Lynott
Meteorologist in Charge

SUBJECT: Letter of Support for Continuation of CIMSS at University of Wisconsin

To Whom It May Concern:

This letter is to acknowledge the contribution made by the University of Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS).

It has been an immense pleasure to maintain the rich collaboration tradition between UW-Madison CIMSS and the National Weather Service (NWS) in Milwaukee-Sullivan. Research and development of the Probability of Severe program has improved severe weather warnings by operationally utilizing a robust set of intelligence developed and honed by CIMSS. Substantial support after the launch of the Geostationary Operational Environmental Satellite R-series satellites (GOES-16/17) has been invaluable to NWS operations here and nationwide. Numerous face-to-face training exercises have improved understanding and utilization of satellite information. This training has transitioned into testing usage of multiple satellite and forecast data sources to innovate NWS decision support services for hazardous weather across southern Wisconsin.

Office operations have benefitted from this valuable relationship. We look forward to additional tools, techniques and collaboration with the UW-Madison CIMSS on future projects.

Sincerely,

Kevin Lynott
Meteorologist in Charge
NOAA/NWS Milwaukee-Sullivan

John P. Gagan
Science and Operations Officer
NOAA/NWS Milwaukee-Sullivan

Monterey, CA USA   December 18, 2019

FROM: ICAP Consortium

RE: Letter of Support for continuation of CIMSS at the University of Wisconsin

Dear Evaluation Committee
We are writing today on behalf of members of the International Cooperative of Aerosol Prediction (ICAP) in support of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) with the Space Science and Engineering Center (SSEC) at the University of Wisconsin, Madison. ICAP is a grassroots style community/trade organization to advance global aerosol prediction and analysis through the open exchange of best practices between developers for global aerosol forecasting systems. All of the world's centers that generate a global aerosol forecast have representation in ICAP (e.g., BSC, Copernicus/ECMWF, FMI, JMA, MeteoFrance, NASA GMAO, NOAA NCEP, UKMO, US Navy NRL/FNMOC) as well as numerous agencies supporting satellite observations (JAXA, JMA, ESA, EUMETSAT, NASA). ICAP members are at the forefront of aerosol technology and are greatly concerned with the future of aerosol related systems, their application, and the supporting data that are used for initialization, assimilation and verification. While we do not officially speak for our respective agencies, we are writing today to present a consensus opinion of scientists and developers that CIMSS and SSEC provides a significant contribution from the US meteorological satellite community to this organization.

Developers for operational aerosol systems have been innovative in the use of satellite products for data assimilation provided three requirements are met: 1) the products are easily available and usable, bot rom a distribution and file format point of view 2) The products are generated in a timely manner with few outages; 3) Products are well characterized, including descriptions of error. CIMSS excels in all of these areas, and is considered a reliable partner across the globe. Indeed, CIMSS has and continues to provide foundational datasets for aerosol prediction. One of the aerosol communities most significant relationships with CIMSS originated with the development of the Wildfire Automated Biomass Burning Algorithm (ABBA), of the 1990s, resulting in the first global biomass burning emission product. Technology were quickly adopted by other centers with CIMSS cooperation. Second, product lines such as CLAVR-X find their way into the systems and best practices. Currently, CIMSS is in a global leadership position for the development of next generation aerosol products from AHI/ABI, including improved visualization. In all cases, CIMSS adheres to the best practices available for availability, expediency and quality.

In summary, the global aerosol community is grateful to CIMSS for their collaborative efforts and hope that will continue into the future. Indeed, with ever increasing numbers of satellite platforms and products each year, the community benefits greatly for their efforts.

THE UNIVERSITY OF CHICAGO

Dear Dr. Holz and Dr. Marais:

I am writing this letter of support for your CIMSS proposal. My career has focused on machine learning and signal processing methods that exploit not only training data but also physical models, and I am deeply interested in building substantially upon our prior work together to bring CIMSS scientists together with University of Chicago researchers to address NOAA's needs for revolutionary algorithm development and to realize the full potential of its new satellite assets.

Sincerely,

Rebecca M. Willett

Office of Professor Rebecca Willett
Statistics and Computer Science, University of Chicago
5747 S. Ellis Ave., Chicago, IL 60637
willett@uchicago.edu https://voices.uchicago.edu/willett/

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale
Organización Meteorológica Mundial
Всемирная метеорологическая организация
المنظمة العالمية للأرصاد الجوية
世界气象组织

Secrétariat
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CH 1211 Genève 2 – Suisse
Tél.: +41 (0) 22 730 81 11
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wmo@wmo.int – public.wmo.int

4 December 2019

TO WHOM IT MAY CONCERN

Subject: Letter of Support for continuation of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin

Dear Sir/Madam,

It is my great pleasure to write this letter to support the University of Wisconsin-Madison for the continuation of the NOAA Cooperative Institute for Meteorological Satellite Studies (CIMSS) located in Madison, Wisconsin, USA.

As you may be aware, the World Meteorological Organization (WMO) is a specialized agency of the United Nations. It is the UN system's authoritative voice on the state and behavior of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources and it is my great honor for me to serve the WMO currently as the Assistant Secretary-General the Organization. Before I joined WMO in 2008, I was the former Deputy Administrator of the China Meteorological Administration (CMA), former Director General of the Department of Observations and Telecommunication of CMA, and former Director General of the National Satellite Meteorological Center (NSMC) of China. It was also my great honor that I have been a visiting scientist of CIMSS during the years of 1998 to 1999.

In the past decade, the NOAA Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison has been well recognized in the international community for innovative and outstanding contributions to meteorological satellite remote sensing and applications. CIMSS has developed cutting-edge scientific methodologies, processing software, and visualization packages to enhance the application of global environmental satellite observations. The International TOVS Processing Package (ITPP), International ATOVS Processing Package (IAPP), International MODIS/AIRS/CrIS/VIIRS Processing Package (IMAPP), Man computer Interactive Data Assess System (McIDAS), and the Community Satellite Software Package (CSPP) developed by CIMSS have been widely used by WMO Members, WMO partner organizations and many international users for real-time use of satellite data for weather monitoring and forecasts. CIMSS is a world class leading center of excellence in remote sensing science, training young scientists, and helping with the international coordination of the global weather satellite observing system. CIMSS is a leader on the development of advanced methodologies for extracting key products such as atmospheric temperature, moisture, cloud properties, atmospheric motion vectors, and hurricane track and intensity from both polar and geostationary weather satellite observations. The methodologies are being used at several international operational weather centers. CIMSS is also a leading center for training the new generation of remote sensing scientists and leaders; after finishing Ph.Ds, training, or visiting scientist programmes at CIMSS, many of those young scientists have later become leaders and played critical roles in international academic institutes, operational organizations and universities.

- 2 -

The great success of CIMSS also has had a profound and positive impact on the WMO Space Programme through their achievements in scientific publications, hardware, and software development in the field of satellite meteorology. In more than the past 10 years, CIMSS senior scientists and experts made remarkable contributions to the WMO Expert Team on Observational Data Requirements and Redesign of the Global Observing System (GOS) with Dr Paul Menzel, the former science director for CIMSS as the chairman of the expert team. Moreover, CIMSS also contributed greatly to the leadership and development of The International TOVS Working Group (ITWG), as a sub-group of the Radiation Commission of the International Association of Meteorology and Atmospheric Sciences (IAMAS) with the CIMSS staff as co-chairs of the ITWG. In the past Dr Paul Menzel, the former science director for CIMSS, Mr Thomas Achtor, the former senior research program manager for CIMSS, Dr Allen Huang, Distinguished CIMSS scientist, and currently Mr Liam Gumley, CIMSS Senior Scientist have all co-chaired this conference. ITWG continues to organize the International TOVS Study Conferences (ITSCs) which have met every 18-24 months since 1983. Through this forum, operational and research users of atmospheric sounder data from NOAA series of polar orbiting satellites (TOVS, ATOVS, AIRS, CrIS, ATMS, etc.) and other international polar orbiting satellites (IASI, AMSU, HIRAS, MWTS, MWHS, etc.) have exchanged information on methods for extracting information from these data on atmospheric temperature and moisture fields and on the impact of these data in numerical weather prediction (NWP) and in climate studies. They have also prepared recommendations to guide the directions of future research and to influence relevant programmes of WMO, especially the WMO new Strategic Plan for the Earth System observations, modelling, prediction and services.

This letter acknowledges the work done by CIMSS and dedication to supporting the WMO meteorological satellite engineering and scientific missions. WMO strongly endorses the continuation of CIMSS as a NOAA Cooperative Institute at the University of Wisconsin-Madison.

Yours faithfully,

(W. Zhang)
Assistant Secretary-General

中国气象局国家卫星气象中心
NATIONAL SATELLITE METEOROLOGICAL CENTER
CHINA METEOROLOGICAL ADMINISTRATION
46 Zhongguancun South Avenue，Beijing 100081, China
Telephone: 86-10-62173894；Telefax: 86-10-62172724

NSMC

Dr. TRISTAN S L'ECUYER
Cooperative Institute for Meteorological Satellite Studies
Space Science and Engineering Center
University of Wisconsin-Madison
1225 West Dayton Street
Madison, WI 53706, USA

Dear Professor TRISTAN S L'ECUYER,

20 December 2019

It is my great pleasure to write this letter to support the University of Wisconsin-Madison for the continuation of the NOAA Cooperative Institute for Meteorological Satellite Studies (CIMSS) at Madison, Wisconsin. I have been Director General of National Satellite Meteorological Center (NSMC) of China Meteorological Administration (CMA) since 2004. During this time and well before, the NOAA CIMSS at the University of Wisconsin-Madison has collaborated and cooperated closely with NSMC on the development of improved weather satellite measurements and products that contribute to the space based Global Observing System (GOS), as well as improving weather monitoring and forecast. My experience has been that CIMSS has been and remains a very valuable resource for guiding and helping international satellite agencies.

CIMSS has played key role in validation and inter-comparison of measurements from international weather satellites for quality assurance, which is very important for quantitative use of those data in various applications especially in the global numerical weather prediction (NWP) models. Most recently they have been participating in evaluation and improvement efforts focused on our Geostationary Interferometric Infrared Sounder (GIIRS), which is helping the international community prepare for the advent of several planned geostationary hyperspectral infrared sounders. The state-of-art satellite data processing packages developed by CIMSS have been widely used by international users for real-time application of measurements from international weather satellites including Chinese FengYun series. In addition, CIMSS and NSMC have long history on exchanging visiting scientists, many of those NSMC young scientists who visited CIMSS have later become leaders and played key roles in promoting satellite data research and applications. This is a strong indication that CIMSS is a leading satellite research center for training the new generation of remote sensing scientists and leaders.

We at NSMC look forward to continued collaboration and joint efforts with CIMSS. I strongly endorse the continuation of NOAA CIMSS at the University of Wisconsin-Madison.

Sincerely yours,

Yang Jun
Director General
National Satellite Meteorological Center
China Meteorological Administration

Appendix C: UW–CIMSS Personnel Summary

December 2019

CIMSS ADMINISTRATION AND TECHNICAL SUPPORT:	Tristan L'Ecuyer	Director
	Wayne Feltz	Executive Director - Science
	Maria Vasys	Associate Outreach Specialist
	Leanne Avila	Editor/Webmaster

UNIVERSITY PRINCIPAL INVESTIGATORS:

(Tristan L'Ecuyer	Professor, AOS	Clouds / Aerosols)
(Wayne Feltz	Senior Scientist	Aviation Weather)
Sam Batzli	Senior Info Proc Conslt	GIS technologist
Eva Borbas	Associate Scientist	Retrieval Science
Mike Foster	Assistant Scientist	Cloud microphysical properties
Liam Gumley	Associate Scientist	Direct Broadcast and Data Analysis
Mathew Gunshor	Researcher	Calibration/Validation
Bob Holz	Associate Scientist	NPOESS / Lidar
Brett Hoover	Researcher	NWP/Data Assimilation
Allen Huang	Distinguished Scientist	Retrieval Science / Hyperspectral
Shane Hubbard	Associate Researcher	GIS Science
Jim Jung	Associate Scientist	Data Assimilation
Bob Knuteson	Senior Scientist	Hyperspectral Instruments
Allen Lenzen	Associate Instrument Innovator	Data Assimilation
Jun Li	Distinguished Scientist	Retrieval Science / Hyperspectral
Scott Lindstrom	Sr. Instrument Technician	Satellite Decision Support Training
Paul Menzel	Senior Scientist	Clouds and Climate / Instrumentation
Jason Otkin	Associate Scientist	Data Assimilation
Ralph Petersen	Senior Scientist	NWP / Nowcasting
Hank Revercomb	Senior Scientist	Hyperspectral Instruments
Dave Santek	Assistant Scientist	Polar Winds / Data Assimilation
Chris Schmidt	Researcher	Biomass Burning
Bill Smith Sr.	Senior Scientist	Hyperspectral Instruments
Kathy Strabala	Associate Scientist	Direct Broadcast and Data Analysis
Joe Taylor	Researcher	Instrumentation Science
Dave Tobin	Senior Scientist	Radiative Transfer
Christopher Velden	Senior Scientist	Satellite Winds / Tropical Cyclones
Andi Walther	Associate Reseacher	Clouds
Elizabeth Weisz	Associate Scientist	Hyperspectral Instruments
Anthony Wimmers	Assistant Scientist	Tropical Cyclones / Aviation Weather
Norman Wood	Researcher	Microwave/Rainfall

UNIVERSITY SCIENTIFIC AND PROGRAMMING STAFF

UNIVERSITY SCIENTIFIC AND PROGRAMMING STAFF

Scott Bachmeier	Researcher
Kaba Bah	Assistant Researcher
Lori Borg	Researcher
Denis Botambekov	Associate Researcher
Jason Brunner	Researcher
Corey Calvert	Researcher
John Cintineo	Associate Researcher
Lee Cronce	Associate Researcher
Geoff Cureton	Sr. Instrument Innovator
Jim Davies	Researcher
Russ Dengel	Sr. Instrumentation Tech
Dan DeSlover	Researcher
Rich Dworak	Researcher
Joleen Feltz	Researcher
Richard Frey	Researcher
Ray Garcia	Associate Researcher
Sarah Griffin	Associate Researcher
Pat Heck	Researcher
Derrick Herndon	Associate Researcher
Jay Hoffman	Researcher
Tommy Jasmin	Asso. Instrument Innovator
Jinlong Li	Assistant Scientist
Yue Li	Assistant Researcher
Zhenglong Li	Researcher
Agnes Lim	Associate Researcher
Yinghui Liu	Assistant Scientist
Graeme Martin	Associate Instrument Innovator
Scott Mindock	Associate Instrument Innovator
Szu-Chia Moeller	Researcher
Chris Moeller	Researcher
Margaret Mooney	Sr. Outreach Specialist
Fred Nagle	Researcher
Jim Nelson	Researcher
Sharon Nebuda	Researcher
Tim Olander	Associate Innov. Researcher
Erik Olson	Researcher
Min Oo	Researcher
Coda Phillips	Assistant Researcher
Greg Quinn	Associate Innov Researcher
Tom Rink	Assistant Innov Researcher
Eva Schiffer	Senior Instrument Technician
Justin Sieglaff	Researcher
Dave Stettner	Researcher
William Straka	Researcher
Xuanji Wang	Assistant Scientist
Steve Wanzong	Researcher
Pei Wang	Assistant Researcher
Tom Whittaker	Emeritus
Hong Zhang	Senior Intrument Tech
Yafang Zhong	Associate Researcher

Appendix D: Curricula Vitae and Current/Pending Support

Tristan L'Ecuyer, Principal Investigator
Curriculum Vitae
Current and Pending Support

Curricula Vitae for Co-Investigators (alphabetically):

Wayne Feltz

Michael Foster

Sarah Monette Griffin

Liam Gumley

Shane Hubbard

Jun Li

Robert Knuteson

Scott Lindstrom

Paul Menzel

Margaret Mooney

Scott Nolin

Jason Oktin

Claire Pettersen

Bradley Pierce

Jerrold Robaidek

Christopher Schmidt

Joseph Taylor

David Tobin

Christopher Velden

Timothy Wagner

Anthony Wimmers

Tristan S. L'Ecuyer
Associate Professor and R.I. Romnes Fellow
Director, Cooperative Institute for Meteorological Satellite Studies (CIMSS)
University of Wisconsin-Madison
1225 W. Dayton St., Madison, WI 53706

Education
Colorado State University, Ph.D. Atmospheric Science, 2001
Dalhousie University, B.S. Physics, 1995, M.S. Physics, 1997

Professional Experience

Aug. 2015 – present;	Associate Professor, University of Wisconsin-Madison
Aug. 2011 – present;	Assistant Professor, University of Wisconsin-Madison
Sep. 2001 – July 2011;	Research Scientist, Colorado State University
Aug. 1997– Aug. 2001;	Graduate Research Assistant, Colorado State University

Relevant Research Experience
Prof. L'Ecuyer is an expert in remote sensing, polar climate, and global energy and water cycles. L'Ecuyer's research centers on using satellite observations to improve estimates of Earth's energy balance and the factors that modulate it. L'Ecuyer is the principal investigator of NASA's Earth Venture Instrument (EVI-4) Polar Radiant Energy in the Far InfraRed Experiment (PREFIRE), a mission to ERBO dedicated to making spectrally-resolved measurements of mid and far infrared fluxes in the polar regions. L'Ecuyer is also director of the Cooperative Institute for Meteorological Satellite Studies (CIMSS). Prof. L'Ecuyer's other experience and positions of relevance to ERBO include:

- Chair WCRP GEWEX Data Analysis Panel (GDAP), 2016 – present
- Co-chair CLIVAR Concept-Heat Research Focus, 2017 – present
- Co-chair NEWS Energy and Water Cycle Climatology working group
- AMS Polar Meteorology and Oceanography Steering Committee 2016 – present
- Mission Scientist: Olympic mountains Experiment (OLYMPEx) 2015
- Mission Scientist: Integrated Precip and Hydrology Experiment (IPHEx) 2014
- Mission Scientist: Cold Season Precipitation Experiment (GCPEx) 2012
- Project Scientist: Light Precipitation Validation Experiment (LPVEx) 2010
- Lead developer CloudSat 2B-FLXHR-LIDAR radiative flux and heating rate product
- Co-lead developer CloudSat 2C-PRECIP-COLUMN, 2C-RAIN-PROFILE, and 2C-SNOW-PROFILE rainfall and snowfall detection and intensity products

Select Recent Publications Relevant to Proposed Research
(132 total publications; h-index = 38)

Sledd[s], A. and **T. L'Ecuyer**, 2019: How Much do Clouds Mask the Impacts of Arctic Sea Ice and Snow Cover Variations? Different Perspectives from Observations and Reanalyses, *Atmosphere* **10**, doi: 10.3390/atmos10010012

Hang[s], Y., **T. S. L'Ecuyer**, and A. V. Matus[s], 2019: Reassessing the effect of cloud type on Earth's energy balance after a decade of active spaceborne observations. Part I: Top of atmosphere and surface, *J. Climate*, in press.

Hang[s], Y. and **T. S. L'Ecuyer**, 2019: Reassessing the effect of cloud type on Earth's energy balance after a decade of active spaceborne observations. Part II: Atmospheric heating, *J. Climate*, in press.

Daloz, A.-S., E. Nelson[s], **T. L'Ecuyer**, A. D. Rapp, and L. Sun, 2018: Assessing the Coupled Influences of Clouds on the Atmospheric Energy and Water Cycles in Reanalyses with A-Train Observations, *J. Climate* **31**, 8241-8264.

Chang[s], K.-W., **T. S. L'Ecuyer**, B. H. Kahn, and V. Natraj, 2017: Information content in the visible and mid-infrared for retrieving tropical ice cloud properties, *J. Geophys. Res.* **122**, 4944-4966, doi: 10.1002/2016jd026357.

McIlhattan[s], E. A., **T. S. L'Ecuyer**, and N. B. Miller, 2017: Observational evidence linking Arctic supercooled liquid cloud biases in CESM to snowfall processes, *J. Climate* **30**, 4477-4495, doi: 10.1175/jcli-d-16-0666.1.

Matus[s], A. and **T. S. L'Ecuyer**, 2017: The role of cloud phase in Earth's radiation budget, *J. Geophys. Res.* **122**, doi:10.1002/2016JD025951.

L'Ecuyer, T. S. and co-authors, 2015. The Observed State of Global Energy Balance in the Early 21st Century, *J. Climate* **28**, 8319-8346.

Kay, J. and **T. S. L'Ecuyer**, 2013. Observational constraints on Arctic Ocean clouds and radiative fluxes during the early 21st century, *J. Geophys. Res.* **118**, doi:10.1002/jgrd50489.

Masunaga, H. and **T. S. L'Ecuyer**, 2014. A mechanism of tropical convection inferred from observed variability in the moist static energy, *J. Atmos. Sci.* **71**, 3747-3766.

Henderson, D. S., **T. L'Ecuyer**, G. Stephens, P. Partain, and M. Sekiguchi, 2013: A multi-sensor perspective on the radiative impacts of clouds and aerosols, *J. Appl. Meteor. and Climatol.* **52**, 853-871.

Haynes, J. M., T. H. Vonder Haar, **T. L'Ecuyer**, and D. Henderson, 2013. Radiative heating characteristics of Earth's cloudy atmosphere from vertically resolved active sensors, *Geophys. Res. Letters* **40**, doi:10.1002/grl.50145.

Waliser, D., J.-L. F. Li, **T. L'Ecuyer**, W.-T. Chen, and W.-L. Lee, 2011. Estimating the Radiative Impact of Ice Mass in Convective Clouds and Precipitation", *Geophys. Res. Letters* **38**, doi:10.1029/2010GL046478.

Masunaga, H. and **T. S. L'Ecuyer**, 2011. Equatorial Asymmetry of the East Pacific ITCZ: Observational Constraints on the Underlying Processes, *J. Climate* **24**, 1784-1800.

Elsaesser, G., C. Kummerow, **T. S. L'Ecuyer**, and S. Shige, 2010. Observed Self-Similarity of Precipitation Regimes Over the Tropical Oceans, *J. Climate* **23**, 2686-2698.

L'Ecuyer, T. S. and J. Jiang, 2010: Touring the Atmosphere Aboard the A-Train, *Physics Today* **63**, 36-41.

L'Ecuyer, T. S. and G. McGarragh, 2010: A ten year climatology of atmospheric radiative heating and its vertical structure from TRMM observations, *J. Climate* **23**, 519-541.

Berg, W., **T. L'Ecuyer**, and J. M. Haynes, 2010. The Distribution of Rainfall over Oceans from Spaceborne Radars, *J. Climate* **49**, 535-543.

Haynes, J. M., **T. L'Ecuyer**, G. L. Stephens, S. D. Miller, C. Mitrescu, N. B. Wood, and S. Tanelli, 2009. Rainfall retrievals over the ocean with spaceborne high-frequency cloud radar, *J. Geophys. Res.* **114**, doi: 10.1029/2008JD009973.

Ellis, T., **T. S. L'Ecuyer**, J. M. Haynes, and G. L. Stephens, 2009. How often does it rain over the global oceans? The perspective from CloudSat, *Geophys. Res. Letters* **36**, doi: 10.1029/2008GL036728.

Current & Pending Support
Investigator: L'Ecuyer, Tristan S

Current Awards

Title: CloudSat Science, CIRA Data Processing Center Support for the CloudSat Mission, CloudSat Education and Public Outreach
Agency: Colorado State University
Primary Sponsor: Nasa, Jet Propulsion Lab
Agency Reference Number: G-39690-1 Mod 27
Award PI: L'Ecuyer, Tristan S
Role: Principal Investigator
Commitment (months): N/A
Total Award Amount: $198,230.00
Period of Performance: 10/1/19 - 9/27/20

Title: Observations of Aerosols above Clouds and their Interactions
Agency: Nasa, Ames Research Center
Primary Sponsor: N/A
Agency Reference Number: NNX15AF99G
Award PI: L'Ecuyer, Tristan S
Role: Principal Investigator
Commitment (months): 0.50 Sumr.
Total Award Amount: $255,037.00
Period of Performance: 2/20/15 - 12/31/20

Title: The Continuation of the Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Agency: Comm, National Oceanic & Atmospheric Adm
Primary Sponsor: N/A
Agency Reference Number: NA15NES4320001
Award PI: L'Ecuyer, Tristan S
Role: Principal Investigator
Commitment (months): N/A
Total Award Amount: $62,051,335.81
Period of Performance: 7/1/15 - 6/30/20

Title: Advanced understanding and modeling of polar cloud processes and feedbacks using CloudSat, CALIPSO, and complementary datasets
Agency: University of Colorado - Boulder
Primary Sponsor: N/A
Agency Reference Number: 1554611
Award PI: L'Ecuyer, Tristan S
Role: Principal Investigator
Commitment (months): 0.75 Sumr.
Total Award Amount: No Cost Extension
Period of Performance: 8/2/16 - 7/31/20

Title: Data product development for cold cloud and precipitation process analyses
Agency: Doe, Chicago Operations Office
Primary Sponsor: N/A
Agency Reference Number: DE-SC0016045
Award PI: Wood, Norman
Role: Co-Investigator
Commitment (months): 1.00 Cal.
Total Award Amount: No Cost Extension
Period of Performance: 8/1/16 - 7/31/20

Title: Polar Radiant Energy in the Far InfraRed Experiment (PREFIRE)
Agency: Nasa, Langley Research Center
Primary Sponsor: N/A
Agency Reference Number: 80NSSC18K1485
Award PI: L'Ecuyer, Tristan S
Role: Principal Investigator
Commitment (months): N/A
Total Award Amount: $5,004,772.00
Period of Performance: 8/1/18 - 7/31/23

Title: The role of cirrus radiative heating in stratosphere-troposphere water vapor exchange
Agency: Nasa, Goddard Space Flight Center
Primary Sponsor: N/A
Agency Reference Number: 80NSSC17K0384
Award PI: L'Ecuyer, Tristan S
Role: Principal Investigator
Commitment (months): 0.10 Cal. Cal.
Total Award Amount: $44,931.00
Period of Performance: 9/1/17 - 8/31/20

Title: Leveraging GPM and ground-based measurements to examine high-latitude extreme precipitation
Agency: Nasa, Goddard Space Flight Center
Primary Sponsor: N/A
Agency Reference Number: 80NSSC19K0712
Award PI: Pettersen, Claire
Role: Co-Investigator
Commitment (months): N/A
Total Award Amount: $323,745.00
Period of Performance: 4/1/19 - 3/31/22

Pending Awards

Title: Global and Regional Water and Energy Variations Under a Changing Climate
Agency: Nasa, Headquarters (Hq)
Primary Sponsor: N/A
Agency Reference Number: 18-NEWS18-0009
Award PI: L'Ecuyer, Tristan S
Role: Principal Investigator
Commitment (months): N/A
Total Award Amount: $2,432,821.00
Period of Performance: 3/1/19 - 2/28/22

Title: Collaborative Research: Impact of Snowfall Regime Variability on High-Latitude Atmospheric Processes
Agency: National Science Foundation
Primary Sponsor: N/A
Agency Reference Number: 2001353
Award PI: L'Ecuyer, Tristan S
Role: Principal Investigator
Commitment (months): N/A
Total Award Amount: $584,757.00
Period of Performance: 6/1/20 - 5/31/23

Wayne F. Feltz

Associate Director of Science SSEC/CIMSS
Space Science and Engineering Center
Cooperative Institute for Meteorological Satellite Studies
Senior Scientist
University of Wisconsin–Madison
1225 West Dayton Street
Madison, WI 53706
Phone: (608) 265-6583
E-mail: wayne.feltz@ssec.wisc.edu

Curriculum Vitae
February 2019

RESEARCH INTERESTS

- Utilization of satellite-based observations to improve nowcasting/forecasting of aviation weather hazards such as turbulence, convection, winds, and volcanic ash
- Remote sensing of thermodynamic state using passive and active instrumentation
- Infrared hyperspectral resolution research toward improved weather observations
- Validation of remotely sensed atmospheric state variables
- Understand impact of future satellite observations through simulation
- Severe weather nowcasting using new atmospheric technologies

PROFESSIONAL EXPERIENCE

- American Meteorological Society – EUMETSAT Joint Meteorological Satellite Conference Organizational Planning Committee Representative, Boston, MA, USA September 2019
- European Geophysical Union session chair Aviation Meteorology Vienna, Austria 2017-2019
- European Convective Working Group member – Florence, Italy 2016
- European Geophysical Union session chair Vienna, Austria 2016
- European Meteorological Satellite session chair – Toulouse, France 2015
- NOAA GOES-R Aviation Algorithm Working Group Co-Chair 2007-present
- European/American Meteorological Society satellite conference organizational committee member – Vienna 2013 (United States representative)
- American Meteorological Society (AMS) Journal of Atmospheric and Oceanic Technology Editor 2009-2012
- European Meteorological Satellite conference organizational committee member – Poland 2012 (United States representative) – 2011-2012
- United States NOAA/FAA/DOD/DOE Joint Planning and Development Office (JPDO) air traffic improvement task force – weather observations – 2008-2011
- Member of AMS Satellite Committee 2006-2012
- UW–Madison Academic Staff Executive Committee representative 2009-2011
- AMS Committee on Radio Frequency Allocations 2009 -2010
- AMS Satellite Conference Session Chair, Phoenix, Arizona 2009
- American Meteorological Society NPOESS Satellite Conference Invited Speaker 2008
- EUMETSAT/AMS Satellite Conference Organizational Committee Member and Session Chair, Amsterdam, Netherlands, 2007
- University of Wisconsin Graduate School Committee on Academic Staff Issues (GS-CASI) Representative 2003-present

HONORS AND AWARDS

- *National Aeronautics and Space Administration (NASA) Group Achievement Award for Outstanding Achievement in the Success of GOES-R Satellite Launch and for the World's Highest Quality Weather Monitoring and Forecasting, June 15, 2017*
- *Certificate of Appreciation in Recognition as a member of the Committee on Academic Staff Issues 2008-2017*
- *Certificate of Appreciation for serving as Vice Chair of GS-CASI 2013*
- *Selected as a UW–Madison Kauffman Seminar series participant 2013-2014*

- *NOAA–CIMSS Collaboration Award 2011*
- *AMS Gold Star Editor Award 2010*
- *NASA LaRC Paul Holloway Technology Transition Award 2008*
- *NASA Honors Group Achievement Award (ASAP) 2006*
- *NASA Earth Sciences Application Team Group Award 2005*
- *NASA Aviation Safety and Security Program Award 2005*
- *University of Wisconsin–Madison Lettau Award for "Thesis of the Year" April 1995*

PUBLICATIONS

Authored or coauthored over 30 peer reviewed scientific publications and are available at http://www.ssec.wisc.edu/~waynef including:

Feltz, W. F., W.L. Smith, R.O. Knuteson, H.E. Revercomb, H.M. Woolf, and H.B. Howell, 1998: Meteorological applications of temperature and water vapor retrievals from the ground-based atmospheric emitted radiance interferometer (AERI). *J. Appl. Meteor.,* **37**, 857-875.

Feltz, W. F. and J. R. Mecikalski, 2002: Monitoring High Temporal Resolution Convective Stability Indices Using the Ground-based Atmospheric Emitted Radiance Interferometer (AERI) During the 3 May 1999 Oklahoma/Kansas Tornado Outbreak. *Wea. Forecasting,* **17**, 445-455.

Feltz, W. F., D. Posselt, J. Mecikalski, G. S. Wade, and T. J. Schmit, 2003: Rapid Boundary Layer Water Vapor Transitions. *Bull. Amer. Meteor. Soc*., **84**, 29-30.

Feltz, W. F., H. B. Howell, R. O. Knuteson, H. M. Woolf, and H E. Revercomb, 2003: Near Continuous Profiling of Temperature, Moisture, and Atmospheric Stability using the Atmospheric Emitted Radiance Interferometer (AERI). . *J. Appl. Meteor.,* **42**, 584-597.

Feltz, W. F., D.D. Turner, H.B. Howell, W.L. Smith, R.O. Knuteson, H.M. Woolf, R. Mahon, and T. Halter, 2005: Retrieving temperature and moisture profiles from AERI radiance observations: AERIPROF value added product technical description. DOE ARM Technical Report, TR-066, Available from http://www.arm.gov/publications/tech_reports/arm-tr-066.pdf

Feltz, W. F., K. M. Bedka, J. Otkin, and S. A. Ackerman, 2009: Understanding Satellite-Observed Mountain Wave Turbulence Signatures Using High-Resolution Numerical Model Data. Accepted for publication to J. of *Wea And Forecasting, **24**, No. 1.*

CURRENT RESEARCH

- **Principal Investigator:** GOES-R Proving Ground, funded by NOAA (2009–present)
- **Principal Investigator:** Boeing Company: Aviation Satellite Decision Support (2011 – present)
- **Program Manager:** Overall SSEC/CIMSS GOES-R/JPSS weather satellite activities (2007–present)
- More information at http://www.ssec.wisc.edu/~waynef/

FIELD EXPERIMENT PARTICIPATION

⇒ Participant in STORM-FEST experiment, NOAA Funded, Coffeeville, KS, 1992
⇒ Participant in Point Mugu Refractivity Experiment, DOE ARM Funded, Pt Mugu, CA, 1993
⇒ Participant in OTIS, Oceanic Temperature Interferometric Survey, NASA Funded, Gulf of Mexico, January 1995
⇒ Participant in CAMEX 2, 3, Convection and Atmospheric Moisture Experiment, Wallops Island, Andros Island, NASA Funded, September, 1995, September, 1998
⇒ Participant in numerous SGP CART field campaigns, Southern Great Plains Cloud And Radiation Testbed for Atmospheric Radiation Measurement (ARM) program, Lamont, Oklahoma1995-2000
⇒ Participant in WVSS Water Vapor Sensing System Validation Experiment, NOAA Funded, 1999

- ⇒ Participant in IHOP International H2O Experiment, Oklahoma Panhandle, DOE ARM funded, 2002
- ⇒ Co-I participant in WVSS-II Water Vapor Sensing System Validation Experiment, Louisville, KY, NOAA Funded, 2005, 2006
- ⇒ PI participant in TAVE TAMDAR Validation Experiment, NASA Funded, Memphis, TN, 2005
- ⇒ Participant in GIFTS EDU checkout experiment, NASA Funded, Logan, UT, 2006
- ⇒ Water Vapor Sensing System – II Validation Participation, NASA funded, 2009-2010

Michael J. Foster

Education

2006 – 2008	Ph.D., Atmospheric Sciences Rutgers University, New Brunswick, New Jersey
2003 – 2006	M.S., Environmental Sciences Rutgers University, New Brunswick, New Jersey
1994 – 1998	B.A., Mathematics and Political Science Boston College, Chestnut Hill, Massachusetts

Professional Experience

2010 – Present	Research Scientist – Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin – Madison. Promoted in 2012, 2014, 2017, and 2019.
2008 – 2010	Postdoctoral Researcher – Space Science and Engineering Center and Atmospheric and Oceanic Sciences department of the University of Wisconsin – Madison.
2003 – 2008	Graduate Research Assistant – Department of Environmental Sciences at Rutgers University
1998 – 2003	Co-founder – *NetTech Solutions*, a firm dedicated to the design and implementation of various local-area and wide-area network architectures.

Recent Professional Accomplishments

2010 – Present	Lead author of Global Cloudiness section for Bulletin of the American Meteorological Society annual 'State of the Climate' issue.
Fall 2018	Topical Group Lead: "Assessment of cloud parameter data records for climate studies" at the Second International Cloud Working Group (ICWG-2) held in Madison, Wisconsin
Fall 2018	Session Chair: "Monitoring Climate and the Oceans" at the EUMETSAT Meteorological Satellite Conference held in Tallinn, Estonia
Fall 2017	Keynote Presentation: EUMETSAT Meteorological Satellite Conference held in Rome, Italy
Spring 2017	Granted 'Permanent Principal Investigator' status by the University of Wisconsin - Madison
Summer 2016	Topical Group Lead: "Assessment of cloud parameter data records for climate studies" at the First International Cloud Working Group (ICWG-1) held in Lille, France. Recommendations from this group were included in a report submitted to the Coordination Group for Meteorological Satellites (CGMS).
Summer 2015	Keynote Presentation: EUMETSAT Meteorological Satellite Conference held in Toulouse, France

Active Projects (serving as Principal Investigator)

NCEI – *Generating 40-year cloud climate record from AVHRR and HIRS*.
NREL – *Producing GOES-R cloud mask and optical properties for the National Solar Radiation Database (nsrdb.nrel.gov)*
Taiwanese CWB - *Development of GOES-R decision support products for Himawari-8*
Curtin University – *PATMOS-x cloud climatological study over Australia*

Selected Peer-Reviewed Publications

Foster, M. J., L. Di Girolamo, R. A. Frey, A. K. Heidinger, S. Sun-Mack, C. Phillips, W. P. Menzel, M. Stengel, and G. Zhao, 2019: Cloudiness [in "State of the Climate in 2018*"]. Bull. Amer. Meteor. Soc*, **100** (9), S34-S35.

Heidinger, A., N. Bearson, M. J. Foster, Y. Li, S. Wanzong, S. Ackerman, R. E. Holz, S. Platnick, K. Meyer, 2019: Using Sounder Data to Improve Cirrus Cloud Height Estimation from Satellite Imagers. *J. Atmos. Ocean. Tech*. **36**. 10.1175/JTECH-D-18-0079.1.

Gumber, A. and M.J. Foster, 2017: A MODIS-Derived Value-Added Climatology of Maritime Cloud Liquid Water Path That Conserves Solar Reflectance. *J. Appl. Meteor. Climatol.,* **56**, 1767–1781, https://doi.org/10.1175/JAMC-D-16-0241.1

Wu, D.L., B.A. Baum, Y. Choi, M.J. Foster, K. Karlsson, A. Heidinger, C. Poulsen, M. Pavolonis, J. Riedi, R. Roebeling, S. Sherwood, A. Thoss, and P. Watts, 2017: Toward Global Harmonization of Derived Cloud Products. *Bull. Amer. Meteor. Soc.,* **98**, ES49–ES52, doi: 10.1175/BAMS-D-16-0234.1.

Foster, M.J.; Heidinger, A.; Hiley, M.; Wanzong, S.; Walther, A.; Botambekov, D., 2016: PATMOS-x Cloud Climate Record Trend Sensitivity to Reanalysis Products. *Remote Sens.*, *8*, 424.

Heidinger, A.; Foster, M.; Botambekov, D.; Hiley, M.; Walther, A.; Li, Y., 2016: Using the NASA EOS A-Train to Probe the Performance of the NOAA PATMOS-x Cloud Fraction CDR. *Remote Sens.*, **8**, 511.

Sun, B., M. Free, H. L. Yoo, M. J. Foster, A. Heidinger, K. G. Karlsson, 2015: Variability and trends in U.S. cloud cover: ISCCP, PATMOS-x, and CLARA-A1 compared to homogeneity-adjusted weather observations *J. Climate*, **28**, 4373-4389. doi: 10.1175/JCLI-D-14-00805.1

Foster, M. J. and A. K. Heidinger, 2014: Entering the Era of 30+ Year Satellite Cloud Climatologies: A North American Case Study. *J. Climate*, **27**, 6687–6697. doi: http://dx.doi.org/10.1175/JCLI-D-14-00068.1

Ackerman, S. A., A. Heidinger, M.J. Foster and B. Maddux, 2013: Satellite Regional Cloud Climatology over the Great Lakes, *Remote Sensing*, **5** (12), 6223-6240. doi 10.3390/Rs5126223.

Heidinger, A. K., M. J Foster, A. Walther and X. Zhao, 2014: The Pathfinder Atmospheres Extended (PATMOS-x) AVHRR Climate Data Set. *"]. Bull. Amer. Meteor. Soc*, doi: http://dx.doi.org/10.1175/BAMS-D-12-00246.1

Foster, M. J. and A. K. Heidinger, 2013: PATMOS-x: Results from a Diurnally Corrected Thirty-Year Satellite Cloud Climatology*. J. Climate*, **26**, 414–425. doi: http://dx.doi.org/10.1175/JCLI-D-11-00666.1

Heidinger, A. K., M. J. Foster and A. T. Evan, 2012: A CALIPSO derived Naïve Bayesian Cloud Detection Scheme for the Pathfinder Atmospheres Extended (PATMOS-x) data set. *J. App. Met. Clim*., **51**, 1129–1144.

Nielsen, J. K.; Foster, M. and Heidinger, A., 2011: Tropical stratospheric cloud climatology from the PATMOS-x dataset: An assessment of convective contributions to stratospheric water**.** *Geophysical Research Letters*, *38*, doi:10.1029/2011GL049329.

Foster, M. J., R. Bennartz, and A. K. Heidinger, 2011: Estimation of Liquid Cloud Properties that Conserve Total-scene Reflectance Using Satellite Measurements. *Journal of Applied Meteorology and Climatology*, *50*(1), 96-109.

Sarah Monette Griffin

CIMSS/SSEC, University of Wisconsin–Madison sarah.griffin@ssec.wisc.edu

Education

B.S. Atmospheric and Oceanic Sciences, 2009, University of Wisconsin–Madison
Distinctive Scholastic Achievement
Undergraduate Thesis: *Influence of the El Niño Southern Oscillation and Quasi-Biennial Oscillation on Seasonal Global Clouds*
via University of Wisconsin-Oshkosh from 9/2005 – 5/2007

M.S. Atmospheric and Oceanic Sciences, 2011, University of Wisconsin–Madison
Master Thesis: *Tropical Applications of a Satellite-Based Objective Overshooting Top Detection Algorithm*

Employment

2008 to 2009	Undergraduate Student Researcher	University of Wisconsin–Madison
2009 to 2011	Graduate Research Assistant	CIMSS/SSEC
2011 to 2012	Research Intern	CIMSS/SSEC
2012 to present	Assistant Research Scientist	CIMSS/SSEC

Awards and Honors

2008 University of Wisconsin–Madison Atmospheric and Oceanic Sciences Horn Award
2014 National Aeronautics and Space Administration Group Achievement Award
2015 American Meteorological Society Special Award

First-Author Peer-Reviewed Publications

Monette, S. A., C. S. Velden, K. S. Griffin, and C. M. Rozoff, 2012: Examining trends in satellite-detected tropical overshooting tops as a potential predictor of tropical cyclone rapid intensification. *J. Appl. Meteor. Climatol.*, **51**, 1917–1930.

Monette, S. A. and J. S. Sieglaff, 2014: Probability of Convectively Induced Turbulence Associated with Geostationary Satellite–Inferred Cloud-Top Cooling. J. Appl. Meteor. Climatol., 53, 429–436.

Griffin, S. M., K. M. Bedka, and C. S. Velden, 2016: A method for calculating the height of overshooting convective cloud tops using satellite-based IR imager and CloudSat cloud profiling radar observations. *J. Appl. Meteor. Climatol.*, **55**, 479–491.

Griffin, S. M., J. A. Otkin, C. M. Rozoff, J. M. Sieglaff, L. M. Cronce C. R. Alexander, 2017: Methods for Comparing Simulated and Observed Satellite Infrared Brightness Temperatures and What Do They Tell Us? *Wea. and Forecasting*, **32**, 5-25.

Griffin, S. M., 2017: Climatology of Tropical Overshooting Tops in North Atlantic Tropical Cyclones. *J. Appl. Meteor. Climatol*, **56**, 1783-1796.

Griffin, S. M., J. A. Otkin, C. M. Rozoff, J. M. Sieglaff, L. M. Cronce, C. Alexander, T. L. Jensen, and J. K. Wolff, 2017: Seasonal analysis of cloud objects in the High Resolution

Rapid Refresh (HRRR) model using object-based verification. *J. Appl. Meteor. Climatol.*, **56**, 2317–2334.

Griffin, S. M. and C. S. Velden, 2018: Hazard Avoidance Products for Convectively-Induced Turbulence in Support of High-Altitude Global Hawk Aircraft Missions. *Pure Appl. Geophys*. **1420-9136**, 1-11.

Griffin, S. M., J. A. Otkin, G. Thompson, M. Frediani, J. Berner, and F. Kong, 2019: Assessing the Impact of Stochastic Perturbations in Cloud Microphysics using GOES-16 Infrared Brightness Temperatures. *Mon. Wea. Review*. In Review.

Select Oral Presentations

2012 *Examining Trends in Satellite-Detected Overshooting Tops as a Potential Predictor of Tropical Cyclone Rapid Intensification*
S. A. Monette, C. S. Velden, K. S. Griffin, and C. M. Rozoff
30th Conference on Hurricanes and Tropical Meteorology
37th Annual National Weather Association Meeting

2014 Evidence of Strong Updrafts in Tropical Cyclones using Combined Satellite, Lightning, and High-Altitude Aircraft Observations
S. A. Monette, C. S. Velden, E. J. Zipser, D. J. Cecil, P. G. Black, S. A. Braun, G. M. Heymsfield
31th Conference on Hurricanes and Tropical Meteorology

2014 Supporting Unmanned Global Hawk Science Missions into Hurricanes with Tailored Satellite Products
S. A. Monette, C. S. Velden, E. J. Zipser, D. J. Cecil, P. S. A. Braun
27th Conference on *Severe Local Storms*

Relevant Field Experience

2010 *PRE-Depression Investigation of Cloud-systems in the Tropics*
Role: G-V aircraft nowcaster and provider of real-time tropical overshooting top locations for the G-V aircraft, Global Hawk, and DC-8

2**012-2014** *Hurricane and Severe Storm Sentinel*
Role: Forecaster and Provider of real-time cloud-top heights and tropical overshooting top locations for the Global Hawk

2014-2015 *Tropical Cyclone Intensity Experiment*
Role: Forecaster

2015-2016 *Sensing Hazards with Operational Unmanned Technology*
Role: Mission Scientist and Provider of real-time cloud-top heights and tropical overshooting top locations for the Global Hawk

2017 *East Pacific Origins and Characteristics of Hurricanes*
Role: Provider of real-time cloud-top heights and tropical overshooting top locations for the Global Hawk

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Waunakee WI 53597, USA
Liam.Gumley@ssec.wisc.edu

Education

M. S. (Meteorology), University of Wisconsin–Madison (1990)
B. App. Sc. (Applied Physics Major), Curtin University of Technology (1988)

Professional Experience

1994-Current: **Scientist**, Space Science and Engineering Center, University of Wisconsin–Madison. Current duties include the following:

- PI for NASA Science Investigator-Led Processing System.
- PI for NOAA JPSS Real-Time Data Network.
- PI for NOAA Community Satellite Processing Package GEO.
- Co-I and PM for NOAA JPSS Community Satellite Processing Package LEO.
- Co-I for NASA International MODIS/AIRS Processing Package.
- Manager of Polar Satellite Direct Reception Facilities at SSEC.
- Instructor for international workshops on polar meteorological satellite sensors, products, and applications.
- Former member of NASA MODIS Science Team.

1991-1994: **Senior Scientific Programmer**, Applied Research Corp., NASA Goddard Space Flight Center.

1988-1990: **Research Assistant**, Department of Meteorology, University of Wisconsin–Madison.

1986-1988: **Research Assistant**, Department of Applied Physics, Curtin University of Technology.

Liam E. Gumley has been associated with the NASA EOS program since 1991, when he developed the first Level 1 processing package for the MODIS Airborne Simulator. At SSEC he played a major role in developing the operational global MODIS cloud mask, atmospheric profiles, cloud properties, and destriping algorithms and associated software. He has been involved with the NASA EOS direct broadcast program since 1998, and played a leading role in distributing software for EOS direct broadcast processing to the global community via the International MODIS/AIRS Processing Package (IMAPP). He is the manager of the polar satellite direct reception and processing facility at SSEC. He was a member of the NASA MODIS Science Team where he led a successful effort to create real-time MODIS products over North America in real-time. He is the Principal Investigator for the NASA Science Investigator-led Processing System, under a $2.5M/year contract to NASA Goddard Space Flight Center. He is Co-Investigator and Project Manager for the Community Satellite Processing Package funded by the NOAA JPSS Project. He is Principal Investigator for the Algorithm Development Library (ADL) project funded by the JPSS Project. He has taught graduate level short courses in remote sensing in Australia, China, Norway, Taiwan, South Africa, and Italy. He is the developer of publicly released software packages for creating MODIS imagery in Google Earth KML format; destriping of MODIS Level 1B radiance data; and a Virtual Appliance for Terra and Aqua direct broadcast processing. He was the Principal Investigator for the installation and commissioning of a high performance computing system for numerical weather prediction at SSEC for NOAA. He has led the development of an iOS application for coordinated satellite and ground observations of cloud conditions (SatCam).

Awards

NASA Group Achievement Award (2012): Suomi NPP Mission Development Team
NASA Group Achievement Award (2005): Earth Sciences Applications Team
NASA Group Achievement Award (2005): Intercontinental Chemical Transport Experiment North America Science Team
NASA Certificate of Recognition (2003): Software Development for MODIS Science Team

Books Published

Gumley, Liam E. (2001). Practical IDL Programming: Creating Effective Data Analysis and Visualization Applications. Morgan Kaufmann Publishers, San Francisco.

Shane A Hubbard

Cooperative Institute for Meteorological Satellite Sciences
The University of Wisconsin - Madison
1225 W. Dayton Street
Madison, WI 53706
shane.hubbard@ssec.wisc.edu

Education

2013	Ph.D. Geography, The University of Iowa, Iowa City Dissertation: *Modeling Geospatial Events During Flood Disasters for Response Decision-Making* Appointments: Research Assistant, Teaching Assistant
2002 - 2005	M.S. Atmospheric and Oceanic Science, University of Wisconsin, Madison Thesis: *The explanation for cloud top temperatures using three mid-latitude cases from a 3-D cloud physics model simulation* Appointments: Research Assistant, Teaching Assistant

Relevant Professional Experience

2014 - Present	Research Scientist, Space Science and Engineering Center, University of Wisconsin,Madison
2013 – 2014	Post-doctoral Research Scientist, Space Science and Engineering Center, University of Wisconsin, Madison
2006 – 2008	Professional Staff, The Polis Center, Indiana University – Purdue University, Indianapolis
2004 - 2006	Hazard Mitigation Planner, Wisconsin Emergency Management, Madison
2004	Meteorologist, Wisc-TV 3, Madison

Professional Experience Highlights

Development of an Archival System for the Integration of High Resolution GOES-R, Radar, and Lightning Data for Improving Severe Weather Forecasting and Warning Capabilities, 07/17 – Present

- Predicting the development of mature storm evolution using high spatial and temporal resolution GOES 16 L2 products, GLM, and Radar
- Identifying flash flooding potential using multi-layered datasets

Spatially Derived Hazard Risk Layers for the Federal Emergency Management Agency's National Risk Index, 2016 - 2019

- Methodology research providing spatial layers of tornado, hail, thunderstorm wind risks for the United States based on a 30 year climatology
- The National Risk Index will be used by communities to understand the links between social vulnerabilities and hazard risk for better planning, response, and resilience.

Projecting the Future Potential Risks and Impacts from Hurricane Wind, Riverine and Coastal Flooding due to Climate Change and Population Changes in Coastal Georgia, 04/15 – Present

- Development of future flood depth grids in streams, rivers, and coastlines in 2080 due to predicted? rainfall and sea level rise changes.
- Modifying current wind hazard profiles from hurricanes to match projections of future intensities, sizes, and speeds of future landfalling hurricanes in the Atlantic Basin.
- Mentoring a Staff Scientist

Community-Based Support for Building Resilience to Hurricanes and Flooding in the Playita Neighborhood within San Juan, Puerto Rico, 12/16 – Present

- Modeling the drivers for flash flooding, storm surge, and hurricane winds in Playita.
- Community engagement leading to identifiable answers for resilience building to lessen the impacts to each disaster.

Curriculum Development for four Federal Emergency Management Agency Courses that are given through The Emergency Management Institute, 04/15 – 05/16

- Curriculum developed to teach students, educators, and professionals the use of geospatial modeling tools to identify risks, vulnerabilities, and impacts from natural disasters.

Geospatial Tornado Damage and Loss Simulation System Developed and then Integrated into the US Department of Homeland Security's Standard Unified Modeling, Mapping, and Integration Toolkit (SUMMIT), 07/14 – 03/15

- The modeling system is used by decision makers at State, Local, and Federal Emergency Management Agencies to model "What-IF" tornado scenarios for planning and exercises.

Publications and Presentations

Refereed Journals

Juran, L., MacDonald, M., Basu, N., **Hubbard, S**., Rajagopal, R., Rajagopalan, P., and Phillip., L. (2016). Development and application of a multi-scalar, participant-driven water poverty index in post-tsunami India. *International Journal of Water Resources Development* 33, 1-21.

Hubbard, S., Stewart, K., and Fan, J. (2014). Providing spatiotemporal decision support for building evacuations due to flooding. *Journal of Applied Geography* 52, 172-181*.*

Hubbard, S. and Stewart, K. (2011). Modeling Alternative Sequences of Events in Dynamic Geographic Domains. *Transactions in GIS.* 15(*5*), 557-575.

Refereed Conference Proceedings

Schlesinger, R. E., Hubbard, S. A., and Wang, P. K. (2008). Worldwide Microphysical Thunderstorm Variability in Different Climatic Regions: A Three-Dimensional Cloud Modeling Study. *24th Conference on Severe Local Storms.* Savannah, GA: American Meteorological Society.

Books

Hubbard, S. and Mickey, K. "Geospatial Technologies and Flood Risk Modeling". CRC Press. Abingdon, Oxfordshire, UK. Publication Forthcoming in 2020.

Other Publications

Mickey, K. and Hubbard, S. (2018). "The Impact of Overreliance on Static Floodplain Maps". *Journal of the National Institute of Building Sciences*. Washington, D.C. December 2018.

Hubbard, S., Pavolonis, M., Calvert, C. (2016). "Using Geographical Surface Characteristics to Detect Near Real-Time Valley Fog". 96th American Meteorological Society Annual Meeting, New Orleans, LA.

Roman, J. A., Knuteson, R., Hubbard, S., Ackerman, S., and Revercomb, H. (2016). "A Probabilistic Statistical Climatological Relationship between Precipitable Water Vapor and Precipitation for Near-Real Time Forecasting Applications". 96th American Meteorological Society Annual Meeting, New Orleans, LA.

Liebl, D. S., Hubbard, S., Hanson, A. (2016). "Targeting Flood Prone Manufacturing Facilities in Wisconsin". US Environmental Protection Agency, Region V.

Lulloff, A., Stone, J., Hubbard, S., Buechler, J., Danielson, L., Coulton, K., and Morlock, S. (2014). "Strategies to Establish Flood Frequencies Associated with Flood Event High Water Marks". The Association of State Floodplain Managers, Madison, WI.

Hubbard, S.A., Stewart, K., and Fan, J. (2011). **"**A spatiotemporal campus building evacuation model". Association of American Geographers Annual Meeting, Seattle, WA.

Hubbard, S.A. and Stewart, K. (2010). "A Branching Event Model for Spatiotemporal Decision Support". Association of American Geographers Annual Meeting, Washington D.C.

Hubbard, S. A., and MacLaughlin, K. (2006). "A Study of the GIS Tools Available During Tornado Events and Their Effectiveness for Meteorologists". *12th Conference on Cloud Physics.* Madison, WI: American Meteorological Society.

Schlesinger, R. E., Hubbard, S. A., and Wang, P. K. (2006). "A Three-Dimensional Cloud Modeling Study on the Dynamical and Microphysical Variability of Thunderstorms in Different Climatic Regimes". *12th Conference on Cloud Physics .* Madison, WI: American Meteorological Society.

Jun Li, Distinguished Scientist, CIMSS/UW-Madison (http://www.ssec.wisc.edu/~junl),
Jun.Li@ssec.wisc.edu, 608-262-3755

Education

Ph.D. in Atmospheric Physics, Chinese Academy of Sciences (CAS), May 1996.
M.S. in Satellite Meteorology, CAS, June 1990.
B.S. in Mathematics, Peking University, June 1987.

Research Experience

Dr. Jun Li has been working at CIMSS since 1997; he has developed algorithms for extracting geophysical parameters from both geostationary and polar-orbit environmental satellites; those algorithms have been used for deriving operational data products by NOAA, science data record by NASA, and real time nowcasting data products by direct broadcast users. He has developed methodologies for improving the applications of satellite observations in nowcasting and assimilation of data in numerical weather prediction (NWP) models for improving high impact weather forecast. He has also developed new concept and methodologies on future observing system simulation and impact assessment, with focus on geostationary hyperspectral infrared sounder, and CubeSat based microwave and infrared sounders. He has authored and co-authored more than 150 peer-reviewed articles in the international science journals.

Awards

2018 UW-Madison Permanent PI status by Univeristy of Wisconsin-Madison.
2015 UW-Madison Chancellor's Award for Excellence in Research as Independent Investigator.
2007 Certificate of Appreciation by NASA in grateful recognition of contributions to the success of the Atmospheric InfraRed Sounder (AIRS) Project.
2003 Certificate of Recognition by NASA for the creative development of technically significant software which has been accepted and approved by NASA, entitled "Moderate Resolution Imaging Spectroradiometer (MODIS) Production Software – Atmospheric Profiles."
2002 U.S. National Space Club and NOAA David Johnson Award for his exceptional and unique contributions to the development of sounding retrieval algorithms for the nation's civil operational geostationary and polar-orbiting environmental satellites and leadership in defining the high-spectral resolution sounders for the next generation of satellites.

Selected publications in recent three years

Schmit, T., **Jun Li**, et al., 2019: Legacy atmospheric profiles and derived products from GOES-16: validation and applications. Earth and Space Science, Vol. 6, 1730 – 1748.
Wang, Pei, **Jun Li**, et al., 2019: Impacts of observation errors on hurricane forecasts when assimilating hyperspectral infrared sounder radiances in partially cloudy skies. Journal of Geophysical Research - Atmospheres, Vol. 124, 10802 – 10813.
Lee, Jung-Rim, **Jun Li**, et al., 2019: ABI water vapor radiance assimilation in a regional NWP model by accounting for the surface impact. Earth and Space Science, Vol. 6, 1652 – 1666.
Li, Z., **Jun Li**, M. Gunshor. 2019: Homogenized water vapor absorption band radiances from international geostationary satellites, Geophysical Research Letters, 46, 10599 – 10608.
Gong, X., Z. Li, Jun Li, C. Moeller, 2019: Monitoring the VIIRS SDR reflective solar band calibrations using DCC with collocated CrIS measurements. JGR – Atmos., 124, 8688 – 8706.
Xue, Y., **Jun Li**, W. Menzel, E. Borbas, 2019: Characteristics of Satellite Sampling Errors in Total Precipitable Water from SSMIS, HIRS and COSMIC Observations, JGR - Atmospheres, 124, 6966 – 6981.
Di D., M. Min, **Jun Li**, and M. Gunshor, 2019: The Radiance Differences between Wavelength and Wavenumber Spaces in Convolving Hyperspectral Infrared Sounder Spectrum to Broadband for Intercomparison, Remote Sensing, 11, 1177, doi:10.3390/rs11101177.
Min et al., **Jun Li**, 2019: Estimating Summertime Precipitation from Himawari-8 and Global Forecast System Based on Machine Learning, IEEE Trans. Geosci. Remote Sens., 2557 – 2570.
Gao, L., L. Chen, **Jun Li**, A. Heidinger, 2019: A long-term historical aerosol optical depth data record (1982 - 2011) over China from AVHRR, IEEE Trans. Geosci. Remote Sens., 2467 – 2480.

Lu, J., T. Feng, **Jun L**i, 2019: Impact of assimilating Himawari-8 derived layered precipitable water with varying cumulus and microphysics parameterization schemes on the simulation of Typhoon Hato, JGR - Atmospheres, 124, 3050 – 3071.
Wang et al., **Jun Li**, 2019: Improving the calibration of Suomi NPP VIIRS thermal emissive bands during blackbody warm-up/cool-down, IEEE Trans. Geosci. Remote Sens., 1977–1994.
Liu, Z., M. Min, **Jun Li**, et al., 2019: Local Severe Storm Tracking and Warning in Pre-Convection Stage from the New Generation Geostationary Weather Satellite Measurements, Remote Sensing. 11(4), 383.
Li, Z., **Jun Li**, T. Schmit, 2019: The alternative of CubeSat based advanced infrared and microwave sounders for high impact weather forecasting, Atmos. Oceanic Sci. Letters, 1 - 11.
Di, D., **Jun Li**, W. Han, W. Bai, C. Wu, and W. Menzel, 2018: Enhancing the fast radiative transfer model for GIIRS by using local training profiles, JGR- Atmos., 123, 12583 - 12596.
Li, Z., **Jun Li**, P. Wang, A. Lim, J. Li, T. Schmit, R. Atlas, S. Boukabara, and R. Hoffman, 2018: Value-added Impact of Geostationary Hyperspectral Infrared Sounders on Local Severe Storm Forecasts—via a Quick Regional OSSE, Advances in Atmospheric Sciences, 35, 1217-1230.
Wang, P., **Jun Li**, B. Lu, T. Schmit, 2018: Impact of moisture information from Advanced Himawari Imager measurements on heavy precipitation forecasts in a regional NWP model, JGR - Atmospheres, 123, 6022 - 6038.
Gong X., Z. Li, **Jun Li**, C. Moeller, 2018:Inter-comparison between VIIRS and CrIS by taking into account the CrIS sub-pixel cloudiness and viewing geometry, JGR-Atmos., 123, 5335-5345.
Menzel, W., T. Schmit, P. Zhang, and **Jun Li**, 2018: Satellite based atmospheric infrared sounder development and applications, Bull. of American Meteorological Society. 99, 583 - 603.
Wang P., **Jun Li**, Z. Li, A. Lim, J. Li, T. Schmit, M. Goldberg, 2017: The Impact of Cross-track Infrared Sounder (CrIS) Cloud-Cleared Radiances on Hurricane Joaquin (2015) and Matthew (2016) Forecasts, JGR - Atmospheres, 122, DOI: 10.1002/2017JD027515.
Li, Jun, and Wei Han, 2017: A Step Forward toward Effectively Using Hyperspectral IR Sounding Information in NWP, Advances in Atmospheric Sciences, 34, 1263 - 1264.
Li, Jun, Z. Li, P. Wang, T. Schmit, W. Bai, R. Atlas, 2017: An efficient radiative transfer model for hyperspectral IR radiance simulation and applications under cloudy sky conditions, JGR - Atmospheres. 122, doi:10.1002/2016JD026273.
Zhu, L., Jun Li, et al., 2017: Retrieval of volcanic ash height from satellite-based infrared measurements, JGR - Atmospheres, 122, .DOI: 10.1002/2016JD026263.
Jang, H., B. Sohn, H. Chun, **Jun Li**, and E. Weisz, 2017: Improved AIRS temperature and moisture soundings with local a priori information for the 1DVAR, JTECH, 34, 1083 - 1095.
Lee, Y., **Jun Li**, Z. Li, and T. Schmit, 2017: Atmospheric temporal variations in the pre-landfall environment of Typhoon Nangka (2015) observed by the Himawari-8 AHI, Asia-Pacific Journal of Atmospheric Sciences. DOI:10.1007/s13143-017-0046-z.
Ai, Y., W. Shi, **Jun Li**, T. Schmit, 2017: Deep convective cloud characterizations from both broadband and hyperspectral infrared sounder measurements, JGR – Atmos., 122, 1700 – 1712.

Dr. Robert O. Knuteson

Senior Scientist
Space Science and Engineering Center, University of Wisconsin–Madison
1225 West Dayton St., Madison, WI 53706
Tel: (608) 263-7974, Fax: (608) 262-5974; Email: robert.knuteson@ssec.wisc.edu

Education: BS, MS, PhD UW–Madison Physics

Dr. Knuteson received his Ph.D. in theoretical High Energy Physics in 1987 from the University of Wisconsin – Madison. Dr. Knuteson joined the UW–Madison Space Science and Engineering Center in September 1987 working with Prof. William L. Smith, Sr. and Dr. Henry Revercomb (former SSEC Director) to exploit the advantages of spectral infrared remote sensing. Dr. Knuteson has been actively involved in several instrument projects including the high-altitude aircraft instrument High-resolution Interferometer Sounder (HIS and S-HIS), the ground-based Atmospheric Emitted Radiance Interferometer (AERI), the NASA climate observatory CLARREO, and JAXA's CO2/Methane GOSAT mission. His areas of expertise are in instrument calibration, satellite validation, and land/atmosphere remote sensing. He is actively involved with both the science and engineering of next-generation Earth orbiting satellites for the prediction of weather and climate. For the past decade, he has been on science working groups for the NASA AIRS science team, the EUMETSAT IASI Sounding Science Working Group, and the JPSS CrIS SDR Cal/Val team. Recent activities include supporting students in the use of GPS radio occultation for temperature validation, surface based GPS receiver networks for column water validation, and the use of OMPS ozone data for the interpretation of CrIS radiance trends. He is actively pursuing applications of spectrally resolved infrared observations for accurate climate monitoring and in near-real time estimates of atmospheric stability and heavy precipitation for weather nowcasting.

Selected Publications:

Bedka, S. et al. An assessment of the absolute accuracy of the Atmospheric Infrared Sounder v5 precipitable water vapor product at tropical, midlatitude, and arctic ground-truth sites: September 2002 through August 2008 *J. Geophys. Res.*, 115, 2010.

Bloch, C., Knuteson, R. O., Gambacorta, A., Nalli, N. R., Gartzke, J., & Zhou, L. (2019). Near-real time Surface-Based CAPE from Merged Hyperspectral IR Satellite Sounder and Surface Meteorological Station Data. *Journal of Applied Meteorology and Climatology*.

Divakarla, M., Barnet, C., Liu, X., Gu, D., Wilson, M., Kizer, S., Xiong, X., Maddy, E., Ferraro, R., Knuteson, R. and Hagan, D., 2014. The CrIMSS EDR algorithm: Characterization, optimization, and validation. *Journal of Geophysical Research: Atmospheres*, *119*(8), pp.4953-4977.

Feltz, M., Borbas, E., Knuteson, R., Hulley, G., & Hook, S. (2018). The Combined ASTER and MODIS Emissivity over Land (CAMEL) Global Broadband Infrared Emissivity Product. *Remote Sensing*, *10*(7), 1027.

Feltz, M. L., R. O. Knuteson, and H. E. Revercomb. "Assessment of COSMIC radio occultation and AIRS hyperspectral IR sounder temperature products in the stratosphere using observed radiances." *Journal of Geophysical Research: Atmospheres* 122.16 (2017).

Feltz, M.L., Knuteson, R.O., Revercomb, H.E. and Tobin, D.C., 2014. A methodology for the validation of temperature profiles from hyperspectral infrared sounders using GPS radio occultation: Experience with AIRS and COSMIC. *Journal of Geophysical Research: Atmospheres*, *119*(3), pp.1680-1691.

Feltz, M., Knuteson, R., Ackerman, S. and Revercomb, H., 2014. Application of GPS radio occultation to the assessment of temperature profile retrievals from microwave and infrared sounders. *Atmospheric Measurement Techniques*, *7*(11), pp.3751-3762.

Gartzke, J., Knuteson, R., Przybyl, G., Ackerman, S., & Revercomb, H. (2017). Comparison of satellite-, model-, and radiosonde-derived convective available potential energy in the Southern Great Plains Region. *Journal of Applied Meteorology and Climatology*, *56*(5), 1499-1513.

Kataoka, F.; Knuteson, R.O.; Kuze, A.; and coauthors, TIR Spectral Radiance Calibration of the GOSAT Satellite Borne TANSO-FTS With the Aircraft-Based S-HIS and the Ground-Based S-AERI at the Railroad Valley Desert Playa, *Geoscience and Remote Sensing*, IEEE Transactions on, vol.52, no.1, pp.89,105, Jan. 2014

Knuteson R. O., H. E. Revercomb, F. A. Best, N. C. Ciganovich, R. G. Dedecker, T. P. Dirkx, S. C. Ellington, W. F. Feltz, R. K. Garcia, H. B. Howell, W. L. Smith, J. F. Short, D. C. Tobin: Atmospheric Emitted Radiance Interferometer (AERI) Part I & II: Instrument Design, *Journal of Atmospheric and Oceanic Technology*, Volume 21 (2004), 1763-1789.

Knuteson, R. et al., 2004: Infrared land surface remote sensing using high spectral resolution aircraft observations, *Adv. Space Res.*, Vol. 33, (2004), pp 1114-1119.

Nikolla, Ester; Knuteson, R. O.; Feltz, M.; Revercomb, H. E. and DeSlover, D. H. Using IR brightness temperature spectra to disentangle the effects of ozone, carbon dioxide, and water vapor on global stratospheric temperature trends. Conference on Climate Variability and Change, 29th, Seattle, WA, 21-26 January 2017. American Meteorological Society, Boston, MA, 2017

Roman, J.A. et al. 2016: Estimating Minimum Detection Times For Satellite Remote Sensing of Trends in Mean and Extreme Precipitable Water Vapor. *J.Climate,* 29, 8211-8230, doi: 10.1175/JCLI-D-16-0303.1.

Roman, J., R. Knuteson, T. August, T. Hultberg, S. Ackerman, and H. Revercomb (2016), A global assessment of NASA AIRS v6 and EUMETSAT IASI v6 precipitable water vapor using ground-based GPS SuomiNet stations, *J. Geophys. Res. Atmos.*, 121, 8925–8948, doi:10.1002/2016JD024806.

Roman, J.A. et al. 2015: Future Change in Frequency of Extreme Precipitable Water Vapor Events. *J.Climate*, **28**, 7057-7070. doi: http://dx.doi.org/10.1175/JCLI-D-14-00679.1

Roman, J.A. et al. 2014: Time-To-Detect Trends in Precipitable Water Vapor with Varying Measurement Error. *J.Climate,* **27**, 8259-8275. doi: http://dx.doi.org/10.1175/JCLI-D-13-00736.1

Roman, J.A. et al. 2013: Using AIRS to Assess the Precipitable Water Vapor in Global Climate Models (GCMs) with Regional Validation from SuomiNet. *AIP Conf. Proc.,* **1531**, 480. doi: http://dx.doi.org/10.1063/1.4804811

Roman, J. A et al. 2012: Assessment of Regional Global Climate Model Water Vapor Bias and Trends Using Precipitable Water Vapor (PWV) Observations from a Network of Global Positioning Satellite (GPS) Receivers in the U.S. Great Plains and Midwest. *J.Climate*, **25**, 5471–5493. doi: http://dx.doi.org/10.1175/JCLI-D-11-00570.1

Seemann, S.W., Borbas, E.E., Knuteson, R.O., Stephenson, G.R. and Huang, H.L., 2008. Development of a global infrared land surface emissivity database for application to clear sky sounding retrievals from multispectral satellite radiance measurements. *Journal of Applied Meteorology and Climatology*, *47*(1), pp.108-123.

Tobin, D. et al., Suomi-NPP CrIS radiometric calibration uncertainty. *Journal of Geophysical Research-Atmospheres*, Volume 118, Issue 18, 2013.

Wielicki, B. et al., Achieving Climate Change Absolute Accuracy in Orbit. *Bulletin of the American Meteorological Society*, Volume 94, Issue 10, 2013, 1519–1539.

Scott Shipman Lindstrom

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Birthplace and date: Bellefonte, Pennsylvania, 8 October 1960

Education

Ph.D. (*Meteorology*), University of Wisconsin–Madison, Madison, WI, 1989. Advisor: D. Houghton
M.S. (*Meteorology*), University of Wisconsin–Madison, Madison, WI, 1984
B.S. (*Meteorology*), Pennsylvania State University, University Park, PA, 1982.
B.S. (*Computer Science*), Pennsylvania State University, University Park, PA, 1982.

Awards

2019 Larry R. Johnson Award (National Weather Association) "for outstanding efforts in educating operational meteorologists on the uses and benefits of the new GOES series of satellites" (With J. Gerth)
June 2017 NASA Group Achievement Award to the GOES-R Team
February 2014 NOAA–CIMSS Collaboration Award **For contributing to restore GOES-13 to operational service following a major anomaly**

Post-doctoral Research Experience

1995-present, Senior Information Technologist, Space Science and Engineering Center
Design and write McIDAS application, client, and server software. Create Training Modules for the National Weather Service. Program Manager for SHyMet and VISIT Training at SSEC/CIMSS.
1991-1996, Assistant Marine Scientist, University of Rhode Island
Developed dynamical analysis techniques for SYNOP dataset, focusing on vertical motions and eddy development, and using current meter, inverted echo sounder, and RAFOS float data.

Post-doctoral Teaching and Training Experience

2004-present, Instructor, Madison Area Technical College. Developed course material and presented weekly lectures for a 3-credit college credit course on Weather and Climate. Class presentation included face-to-face, *via* interactive television (ITV), and online. Develop and present Course Material for Climate and Climate Change class, as per NASA funding.
2002-present, Teletraining Instructor, Virtual Institute for Satellite Integration Training
Developed training modules for National Weather Service teletraining on topics related to Satellite Data.
2016-2017, Subject Matter Expert and Instructor, GOES-R/GOES-16 Science Operations Officer (SOO) Prep Course, National Weather Service Training Center, Kansas City.
2008, 2009 Instructor and Content Expert, Science Masters Institute, Madison Metropolitan School District – Develop and present content to 6th-grade Science teachers for Wind and Water classroom instruction.
1995, 1996-1997, Associate Instructor, Dept. of Geosciences, Univ. of Wisconsin-Milwaukee
Taught *Dynamic Meteorology* I and II, undergraduate core courses in dynamics. Topics included quasi-geostrophic theory, circulation and vorticity, shallow water equations, etc. Covered Chapters 1 through 9 in *Holton*.

Blogging

Principal blogger about Fog at http://fusedfog.ssec.wisc.edu; Frequent blogger at CIMSS Satellite Blog: http://cimss.ssec.wisc.edu/goes/blog/

Selected Refereed Publications

Schmit, T. J., S. S. Lindstrom, J. J. Gerth and M. M. Gunshor, 2018: **Operational Applications of the 16 Spectral Bands on the Advanced Baseline Imager (ABI)**. *J. Operational Meteor.* 6 (4), 33-46, doi: https://doi.org/10.15191/nwajom.2018.0604

Wimmers, A. J., S. Griffin, J. Gerth, S. Bachmeier and S. Lindstrom, 2018**: Observations of gravity waves with high-pass filtering in the new generation of geostationary imagers and their relation to aircraft turbulence**, *Wea. Forecasting*, 139-144, doi: https://journals.ametsoc.org/doi/10.1175/WAF-D-17-0080.1

Lindley, T. T., A. R. Anderson, V. N. Mahale, T. S. Curl, W. E. Line, S. S. Lindstrom and A. S. Bachmeier, 2016: **Wildfire Detection Notifications for Impact-based Decision Support Services**

in Oklahoma Using Geostationary Super Rapid Scan Satellite Imagery, *J. Operational Meteor.,* **4**(14), 182-191, doi: http://dx.doi.org/10.15191/nwajon.2016.0414

Schmit, T. J., S. J. Goodman, M. M. Gunshor, J. Sieglaff, A. K. Heidinger, A. S. Bachmeier, S. S. Lindstrom, A. Terborg, J. Feltz, K. Bah, S. Rudlosky, D. T. Lindsey, R. M. Rabin and C. C. Schmidt, 2014: **Rapid Refresh Information of Significant Events: Preparing users for the next generation of geostationary operational satellites**. Bulletin of the American Meteorological Society doi: 10.1175/BAMS-D-13-00210.

Lindstrom, S. S., X. Qian, and D. R. Watts, 1997: **Vertical motion and its relation to meanders in the Gulf Stream**. *J. Geophys. Res.*, **102**, 8485-8504.

Lindstrom, S. S. and D. R. Watts, 1994: **Vertical motion in the Gulf Stream near 68 W**. *J. Phys. Oceanogr.*, **24**, 2321-2333.

Lindstrom, S. S. and T. E. Nordeng, 1992: **Parameterized slantwise convection in a primitive equation model**. *Mon. Wea. Rev.*, **120**, 742-756.

Jascourt, S. D., S. S. Lindstrom, C. J. Seman, and D. D. Houghton, 1988: **An observation of banded convective development in the presence of weak symmetric stability**. *Mon. Wea. Rev.*, **116**, 175-191.

Selected Training Activities

Next-Generation GOES-R Weather Satellite Workshop. “RGB Composites”. Lunch talk given at Short Course offered at IUGG/CMOS 2019 Meeting in Montreal, 8 July 2019.

ABI On the GOES-R Series: Presentation/Hands-on Activity given at GOES-R Short Course at AMS Broadcasters’ Meeting, 11 June 2019, San Diego CA

Satellite Conversations about GOES-17. One-on-several training at NWS Forecast Offices in Anchorage, Juneau and Fairbanks AK. 18-27 March 2019.

Convective Applications for GOES-16. GOES-R Series Short Course: Forecast Applications. 6 January 2019, 99th Annual AMS Meeting, Phoenix AZ.

Investigating Weather and Natural Hazards with Next Generation Satellite Data (with Margaret Mooney and Tim Schmit). AGU-NESTA Geophysical Information For Teachers (GIFT) Workshop 2018 – Hot Topics in Earth and Space Science. AGU Fall Meeting, 11 December 2018, Washington DC

Workshop on Atmospheric Moisture, Total Precipitable Water and Atmospheric Stability. 14th AMS Symposium on the Urban Environment/10th International Conference on Urban Climate (ICUC), New York City, 6 August 2018.

Lectures on Geostationary Lightning Mapper (GLM); Advanced Baseline Imager (ABI); Fire Detection with ABI; Water Vapor and Sulfur Dioxide Monitoring with ABI; Data Sources for Polar Orbiting Satellites. GOES-16 Workshop at UNAM, Mexico City, Mexico, 23-25 July 2018

GOES-16 for Aviation. (With Paul Ford, ECC Canada). GOES-16 Workshop, CMOS 2018, Halifax, CA, 10 June 2018

Understanding and Using Satellite Data. CoRP Workshop, Madison WI, 7 June 2018.

ABI Overview and GLM Overview. GOES-16 Course, SMN, Mexico City, 2-3 May 2016.

WOLFGANG PAUL MENZEL

Education:
Ph.D 1974 University of Wisconsin - Madison (Theoretical Solid State Physics)
M.S 1968 University of Wisconsin - Madison
B.S. 1967 University of Maryland - College Park (with high honors, Omicron Delta Kappa, Phi Beta Kappa)

Experience:
* 2007 – present Senior Scientist at Space Science and Engineering Center (SSEC)
As Senior Scientist in SSEC, pursued research interests in remote sensing of atmospheric temperature and moisture profiles, ozone, carbon dioxide, cloud properties, and surface properties.
* 2007 – 2011 Verner Suomi Distinguished Professor at UW
As Professor in Atmospheric and Oceanic Sciences, taught classes and mentored students in remote sensing of land, ocean and atmospheric properties.
* 1999 – 2007 Chief Scientist for the Office of Research and Applications
As the Chief Scientist for the Office of Research and Applications, provided guidance on science issues and initiating major science programs for the Director of the Office.
* 1999 – 2005 International Expert Team Chairman
As the chairman of the World Meteorological Organization Expert Team on Observational Data Requirements and Redesign of the Global Observing System, lead 12 international experts in (a) reviewing observing system experiments indicating the relative contribution from various components, (b) recommending steps for the evolution of the surface and space-based components of the GOS and (c) reporting on how well the GOS is meeting user requirements in various applications areas and how the GOS performance can be improved.
* 1997 – 2000 Science Director of Cooperative Institute
As the Science Director of the Cooperative Institute for Meteorological Satellite Studies, was responsible for the day to day scientific direction of the activities of the CIMSS personnel. This involved coordinating university research principal investigator proposals in response to government funding opportunities, assuring science progress on grants and contracts, fostering peer review publications, and evaluating individual performance. At that time, CIMSS housed about 70 personnel and required about $4 to 5M annual budget.
* 1989 - 2007 Principal Investigator
As a member of the MODIS (Moderate resolution Imaging Spectrometer) science team, developed algorithms for the cloud mask, cloud properties, and atmospheric profiles. Early work included design, test, and application of the MODIS Airborne Simulator, a passive infrared radiometer flown on ER2 aircraft used to study cloud radiative properties (emissivity, height, temperature, phase) at 50 meter resolution. After launch of the EOS Terra and Aqua Platforms, the MAS experience was transferred to processing the MODIS 1 km resolution data routinely and studying the global cloud and moisture trends. To date the cloud top properties algorithm has been adjusted to account for calibration changes and cloud validation with CALIPSO. A continuous record of MODIS and HIRS (High resolution Infrared Sounder) cloud properties from 1978 onward is being established.
* 1986 - 2007 Adjunct Professor
At the University of Wisconsin, taught graduate level courses in satellite remote sensing of the earth-atmosphere system covering atmospheric processes (emphasizing radiative transfer) and satellite applications. A textbook has been written. As adjunct professor in the Atmospheric and Oceanic Sciences Department, I have been advisor to over forty Masters and PhD students.
* 1983 – 1999 Team Leader
As Leader of the Advanced Satellite Products Team in the Office of Research and Applications of NOAA/NESDIS, was responsible for developing, testing and evaluating procedures that show potential for derivation of new satellite products. This focused on transferring advances in the research laboratory to the operational weather forecast arena.

Selected Honors:

Haydn Williams Fellow at Curtin University, Perth, Australia in 1990
Transactions Prize Paper Award from the Geoscience and Remote Sensing Society in 1992 and 2017
Department of Commerce Bronze Medal in 1999 & 2001, Silver Medal in 1993, 1994, & 2007
American Meteorological Society Special Award in 1997, elected AMS Fellow in 2007
EUMETSAT Special Award in 2007 for exemplary leadership in international collaborations
Yuri Gagarin Medal from Russian Cosmonautics Federation for research and training excellence in 2019

Selected Publications since 2013 (from 162 peer review publications and 771 conference papers since 1974):

Frey, R.A. and W. P. Menzel, 2019: Observed HIRS and MODIS High-Cloud Frequencies in the 2000s, Jour. Appl. Meteor. Clim., 58, 2469-2478. doi: 10.1175/JAMC-D-19-0060.1.

Menzel, W. P., 2019: History of Geostationary Weather Satellites. Ch-2 of The GOES-R Series. ed. S Goodman et al. pub Elsevier. doi.org/10.1016/B978-0-12-814327-8.00002-0

Weisz, E., and W. P. Menzel, 2019: Imager and sounder data fusion to generate sounder retrieval products at an improved spatial and temporal resolution, J. Appl. Remote Sens. 13(3), 034506, doi: 10.1117/1.JRS.13.034506.

Yunheng Xue, Jun Li, W. Paul Menzel, Eva Borbas, Shu Zhenglong Li, and Jinlong Li, 2019: Characteristics of Satellite Sampling Errors in Total Precipitable Water from SSMIS, HIRS, and COSMIC Observations. J. Geophys. Res. Atmos., 129, Issue 10, doi: 10.1029/2018JD030045

Menzel, W.P., T. J. Schmit, P. Zhang, and J. Li, 2018: Satellite based atmospheric infrared sounder development and applications. Bull. Amer. Meteor. Soc., 99, 583-603. doi: 10.1175/BAMS-D-16-0293.1

Weisz, E., B. A. Baum, and W. P. Menzel, 2017: Fusion of satellite-based imager and sounder data to construct supplementary high spatial resolution narrowband IR radiances. J. Appl. Remote Sens. 11(3), 036022, doi: 10.1117/1.JRS.11.036022.

Plokhenko, Y., W. P. Menzel, R. Knuteson, and H. E. Revercomb, 2017: Mathematical aspects of the meteorological interpretation of satellite hyperspectral infrared measurements part II: Estimates of the cloud absorption vertical profile of Hurricane Ioke on 28 August 2006, Int. Jour. Rem. Sens., v.38, no.51, 2017, pp57-79.

Moeller, C. C., R. A. Frey, E. E.Borbas, W. P. Menzel, T. Wilson, A. Wu, and G. Xu, 2017: Improvements to Terra MODIS L1B, L2, and L3 science products through using crosstalk corrected L1B radiances. Proc. SPIE 10402, Earth Observing Systems XXII, 104020O (5 September 2017); doi: 10.1117/12.2274340

Menzel, W. P., R. A. Frey, E. E. Borbas, B. A. Baum, G. Cureton, and N. Bearson, 2016: Reprocessing of HIRS Satellite Measurements from 1980-2015: Development Towards a Consistent Decadal Cloud Record. Jour. Appl. Meteor. Clim. 55, 2397-2410. doi:10.1175/JAMC-D-16-0129.1

Rink, T, W. P. Menzel, L.Gumley, and K. Strabala; 2016: HYDRA2 – A Multispectral Data Analysis Toolkit for sensors on Suomi NPP and other current satellite platforms. Bull. Amer. Meteor. Soc., 97, 1283-1294. doi:10.1175/BAMS-D-14-00285.1

Menzel, W. P., D. C. Tobin, and H. E. Revercomb, 2016: Infrared Remote Sensing with Meteorological Satellites. Advances in Atomic, Molecular, and Optical Physics, Vol 65 (editors Ennio Arimondo, Chun C. Lin, Susanne F. Yelin): AAMOP, UK: Academic Press, 2016, pp. 193-264

Plokhenko, Y., W. P. Menzel, R. Knuteson, and H. E. Revercomb, 2016: Mathematical aspects of the meteorological interpretation of satellite hyperspectral infrared measurements part I: statement of the inverse problem for estimation of the cloud absorption vertical profile, Int. Jour. Rem. Sens., 37:7, 1601-1619, doi:10.1080/01431161.2016.1151570

Schmetz, J. and W. P Menzel, 2015: A Look at the Evolution of Meteorological Satellites - Advancing Capabilities and Meeting User Requirements. Weather, Climate, and Society. http://dx.doi.org/10.1175/WCAS-D-15-0017.1

Baldassarre, G., L. Pozzoli, C. C. Schmidt, A. Unal, T. Kindap, W. P. Menzel, S. Whitburn, P.-F. Coheur, A. Kavgaci, and J. W. Kaiser, 2015: Using SEVIRI fire observations to drive smoke plumes in the CMAQ air quality model: the case of Antalya in 2008. Atmospheric Chemistry and Physics 15, 8539-8558, doi:10.5194/acp-15-8539-2015, 2015.

Murino, L., U. Amato, M. F. Carfora, A. Antoniadis, B. Huang, W. P. Menzel, and C. Serio, 2014: Cloud Detection of MODIS multispectral images. J. Atmos. Oceanic Tech., 31, 347-365.

Gladkova, I., S. Fazlul, M. Grossberg, R. A. Frey, and W. P. Menzel, 2013: Impact of the Aqua MODIS Band 6 Restoration on Cloud/Snow Discrimination. J. Atmos. Oceanic Tech., 30, 2712-2719. doi: 10.1175/JTECH-D-13-00066.1

Cross, J., I. Gladkova, W. P. Menzel, A.Heidinger, and M. D. Grossberg, 2013: Statistical estimation of a 13.3 μm Visible Infrared Imaging Radiometer Suite channel using multisensor data fusion. J. Appl. Remote Sens. 7 (1), 073473. doi: 10.1117/1.JRS.7.073473

King, M. D., S. Platnick, W. P. Menzel, S. A. Ackerman, and P. A. Hubanks, 2013: Spatial and Temporal Distribution of Clouds Observed by MODIS onboard the Terra and Aqua Satellites. IEEE Trans. Geosci. Remote Sens., 51, No. 7, 3826-3852. doi:10.1109/TGRS.2012.2227333

Stubenrauch, C. J., W. B. Rossow, S. Kinne, S. Ackerman, G. Cesana, H. Chepfer, L. Di Girolamo, B. Getzewich, A. Guignard, A. Heidinger, B. C. Maddux, W. P. Menzel, P. Minnis, C. Pearl, S. Platnick, C. Poulsen, J. Riedi, S. Sun-Mack, A. Walther, D. Winker, S. Zeng, G. Zhao, 2013: Assessment of Global Cloud Datasets from Satellites: Project and Database initiated by the GEWEX Radiation Panel. Bull. Amer. Meteor. Soc., 94, 1031-1049. doi:10.1175/BAMS-D-12-00117.1

Margaret E. Mooney

Director, CIMSS Education and Public Engagement
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Space Science and Engineering Center (SSEC), University of Wisconsin-Madison
1225 West Dayton Street, Madison, WI 53706
margaret.mooney@ssec.wisc.edu

PROFESSIONAL PREPARATION

University of Wisconsin-Madison, Public Policy MPA, 2002
University of Michigan-Ann Arbor, Geology B.S., 1983

APPOINTMENTS

2012 - present: Director, CIMSS Education and Public Engagement
2002 - 2012: Earth Science Outreach Specialist
1985 - 2000: NOAA's National Weather Service, culminating as Meteorologist in Charge (MIC) of the Madison Weather Service Office (WSO MSN)

PUBLICATIONS

Grabow M, Bryan T, Checovich M, Converse A, Middlecamp C, Mooney M et al. Mindfulness and climate change action: A feasibility study. Sustainability 2018; 10(5).

Barrett, B., Grabow M., Middlecamp, C., Mooney, M., Checovich, M., Converse, A., Gillespie, B., and Yates, J. Mindful Climate Action: Health and Environmental CoBenefits from Mindfulness-Based Behavioral Training. Sustainability 2016: 8(10), 1040; NIHMS: 826863 PMC: in process

Ackerman, S., Mooney, M., Morrill, S., Morrill, J., Thompson, M., Balenovich, L.K., (2016) Libraries, massive open online courses and the importance of place: Partnering with libraries to explore change in the Great Lakes, New Library World, Vol. 117 Iss: 11/12, pp.688 – 701

Mooney, M. E., Ackerman, S., McKinley, G.A., Whittaker, T.W. & Jasmin, T. Lesson Plans and Classroom Activities from the Climate Literacy Ambassadors Community. The Earth Scientist Volume XXVIII, Issue 3, Fall 2012.

For a full list of publications and presentations, please see: http://go.wisc.edu/0x90n1

SYNERGISTICS ACTIVITIES

In 2015, Margaret Mooney co-taught a UW-Madison Massive Open Online Course (MOOC) titled, "Changing Weather and Climate in the Great Lakes Regions" to over 7000 participants, while simultaneously facilitating in-person weekly discussion groups at Wisconsin libraries. She mentors undergraduates on a one-to-one basis and serves as adjunct professor for AOS 102, an on-line course in climate and climate change. As director of CIMSS Education and Engagement programming, she has cultivated relationships with hundreds of Wisconsin teachers through workshops in satellite meteorology, climate change and GLOBE atmosphere protocols. She also orchestrates the annual CIMSS Student Workshop on

Atmospheric, Satellite, and Earth Sciences, which has successfully engaged high school students for over two decades.

Mooney has collaborated to develop educational tools and content for learners of all ages, including webapps (interactive training activities to explore atmospheric processes and phenomena), an on-line course in satellite meteorology for students in grades 7-12, an on-line course in climate and climate change for G6-12 science teachers, and content for the EarthNow blog which supports informal STEM education for NOAA's Science On a Sphere (SOS) exhibits in Wisconsin and beyond.

An advocate for STEM education, Mooney has guided thousands of Wisconsin K1-2 Students educational tours, participated in campus science events and open houses since the early 2000s, led the meteorology major for Grandparents University each summer for the last 12 years, and participated in legislative learning days at the State Capitol. She serves on the Wisconsin Initiative for Climate Change Impacts (WICCI) outreach team at the UW-Madison and in 2015 helped coordinate the StormReady designation for the UW-Madison conferred upon campus by the National Weather Service.

As Director for Education and Public Engagement at CIMSS, Mooney acts as a liaison with NOAA's 15 other cooperative institutes and manages CIMSS social media accounts. She is active on the Earth Science Information Partners (ESIP) Education committee, having served as Chair for two terms and Vice-Chair for multiple terms. Mooney also served on the White House Council on Environmental Quality (CEQ) Roundtable on Communicating Climate Change Adaptation in 2010. In 2011 she was Co-Investigator on NOAA award NA10OAR4170256, "Assessment and Evaluation of the NOAA Climate Services Portal" (www.climate.gov) and in 2013 participated in Climate Science Day on Capitol Hill. She is also a member of the Climate Literacy Network and the Union of Concerned Scientists.

In advance of the November 2016 launch of the GOES-R satellite, Mooney established the GOES-R Education Proving Ground, starting with six teachers from three states in 2013 and expanding to thirty-two teachers from fifteen states. This culminated in a workshop at Kennedy Space Center at the historic launch with twenty-three teachers traveling from ten different states and Puerto Rico. In 2017, 30 additional teachers joined the Proving Ground by attending a GOES-S Teacher Workshop at Lockheed Martin in Littleton Colorado. In 2019, CIMSS debuted a Virtual Science fair to engage student's nationwide using GOES-R data. Under Mooney's leadership, CIMSS will continue to promote the entire GOES-R satellite series to science teachers nationwide.

Recent testimonies to her contributions towards the transfer of knowledge include the 2018 Heideman Award for Excellence in Public Service and Outreach from the UW-Madison and the 2019 Catalyst Award in Education from the Earth Science Information Partners (ESIP).

COLLABORATORS

Steve Goodman – NOAA-NASA GOES-R Program Office
Steve Ackerman – UW-Madison Atmospheric and Oceanic Sciences
LuAnn Dahlman – NOAA Climate Program Office
Erin Robinson – Director, Earth Science Information Partners

Curriculum Vitae

Scott Nolin
Head of Technical Computing
Space Science and Engineering Center, University of Wisconsin-Madison

Work Experience

2018

Principal Investigator, S4. This 1.5 million dollar grant replaces and upgrades the S4 system to allow satellite data assimilation experiments with the FV3GFS numerical weather prediction (NWP) suite and continue other research activities.

2013-present

Technical Lead and Project Manager, SSEC High Performance Storage System (SHPS) .
This project provides a shared high performance storage system for the Center. The design of this system is unique in providing an expandable shared-use very high performance storage system given constraints of multiple separate funding sources. The system is in its third iteration in 2018.

2013-present

Technical Lead, High Performance Satellite Data Archive. This builds on the Lustre on ZFS Proof of Concept to provide an operational high performance data store of satellite data, including the entire geostationary satellite record over the continental United States and multiple other satellite records. The archive is uniquely beneficial for SSEC research in allowing cluster processing of large amounts of satellite data directly.

2013

Principal Investigator, Lustre on ZFS Proof of Concept project. This project is a proof of concept and design validation for ZFS as a backend to Lustre in production. Data integrity features in particular are important for the Center's large data archive. The project was funded with a $49,000 hardware grant from Dell.

2013

Co-Investigator, S4 Upgrade. This one million dollar upgrade allows the S4 system to run satellite data assimilation experiments with the GSI/GFS numerical weather prediction (NWP) suite at T1148 model resolution, a critical capability for the S4 research mission.

2011-present

Technical lead, Supercomputer for Satellite Simulations and data assimilation Studies (S4). The S4 system at SSEC supports NOAA NESDIS and JCSDA research, development, and system integration activities related to satellite data assimilation experiments an Observing System Simulation experiments for new sensors. The system also provides dedicated resources for UW SSEC use outside of NESDIS and JCSDA research. Duties include leading design, implementation, and ongoing support for the system. Provided critical in depth performance analysis to prove system met performance expectations running the GSI/GFS suite.

2006-present

Technical lead and Project Manager, SSEC Science Cluster. This project enables researchers and groups of any size to increase the value of their grant funding by participating in a shared use high performance compute cluster with access to large storage resources at SSEC.

2001-present

Head of SSEC Technical Computing group. Responsibilities include leading a team of 4 full time staff and 6 students providing support for all computing at SSEC. This includes understanding and providing solutions for varied systems such as desktops, infrastructure servers, networks, satellite data ingest and product publication, high performance data archives, and high performance computing clusters. Responsible for computing policies, technical planning, and implementation for SSEC and Center projects.

1997-2001

Joined University of Wisconsin Space Science and Engineering Center as system administrator for the Technical Computing group. Responsibilities included desktop and administrative computing systems. Planned and implemented long term strategy to unify SSEC Email infrastructure and move to standards based systems. Replaced administrative and desktop token ring network with Ethernet and unified Center network design. Responsible for management for student workers starting in 2000.

1994-1997

Technology Coordinator, Jefferson Davis Middle School. Technology planning, budgeting, purchasing, administration and grant writing for a school of approximately 1000 students and 90 staff. Responsible for installation and maintenance of multiple computer labs, networks, classroom, and administrative systems. Won and administered grants for classroom technology. Replaced and expanded the school telephone system to provide service to all classrooms while reducing the yearly cost.

Education

University of Florida, Gainesville, FL
Bachelor of Science in Computer Engineering, 1993

Publications and Conference Reports

Nolin, Scott; *Comprehensive Toolkit for Linux System Management*, Madison WI, 22 June, 2017. IT Professionals Conference 2017

Nolin, Scott and Barnet, Steve; *Protecting Systems with One Time Passwords*, Madison, WI, 22 June 2017. IT Professionals Conference 2017

Boukabara, S. A.; S. Lord; S. Goodman; T. Zhu; B. Pierce; R. Atlas; L. Cucurull; M. Zupanski; M. Zhang; I. Moradi; J. A. Otkin; D. Santek; B. Hoover; Z. Pu; X. Zhan; C. Hain; E. Kalnay; D. Hotta; S. Nolin; E. Bayler; A. Mehra; S. Casey; D. Lindsey; K. Kumar; A. Powell; J. Xu; T. Greenwald; J. Zajic; J. Li; J. Li; B. Li; J. Liu; L. Fang; and P. Wang; *S4: An O2R/R2O Infrastructure for Optimizing Satellite Data Utilization in NOAA Numerical Modeling Systems, A Step Toward Bridging the Gap Between Research and Operations.* Bull. Am. Meteorol. Soc. (December 2016)

Nolin, Scott and Wagner, Andrew; *Lustre Metrics: New Techniques for Monitoring Lustre*, Denver, CO, 13-15 April 2015. Lustre User Group Conference

Nolin, Scott; *SSEC Storage Systems*, 20 November 2013. SC13 Dell Panel: Solving the Data Deluge

Nolin, Scott; *Lustre on ZFS at SSEC* , Paris, France, 16-17 September 2013. Lustre Administrators and Developers Workshop

Boukabara, Sid Ahmed; Riishojgaard, L. P.; Yoe, J. G.; Devaliere, E. M.; Pratt, A.; Garrett, K. J.; Jung, J. A.; Nolin, S. and Sinno, S; *S4 and JIBB: Building the infrastructure for an effective O2R and a streamlined R2O. Special Symposium on the Joint Center for Satellite Data Assimilation,* Austin, TX, 6-10 January 2013. American Meteorological Society

Jason A. Otkin
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Space Science and Engineering Center (SSEC)
University of Wisconsin–Madison
1225 West Dayton St, Madison, WI 53706
Tel: (608) 265-2476; E-mail: jason.otkin@ssec.wisc.edu
Website: http://www.ssec.wisc.edu/~otkin/

Academic Education:
2015-2020: PhD, Mathematics, University of Reading, Reading, United Kingdom
2000-2003: M.S., Atmospheric Science, University of Wisconsin, Madison, WI
1996-2000: B.S., Meteorology, St. Cloud State University, St. Cloud, MN

Professional Experience:
Associate Scientist, SSEC/CIMSS, University of Wisconsin–Madison, October 2015-current
Researcher-Assistant Scientist, SSEC/CIMSS, University of Wisconsin–Madison, 2003-2015

Research Experience:
Mr. Otkin has been a scientist at SSEC/CIMSS for more than 16 years. He has extensive experience using satellite observations to evaluate the accuracy of numerical weather prediction model forecasts using innovative verification methods, has conducted ensemble data assimilation experiments that have examined the impact of remotely sensed observations on high-impact weather forecasts, and has developed new analysis tools that have increased our understanding of rapidly intensifying flash droughts and our ability to monitor their onset and evolution. He has authored or co-authored more than 60 peer-reviewed publications covering diverse topics.

Selected Publications (Data Assimilation):

Otkin, J. A., R. Potthast, and A. L. Lawless, 2019: Assimilation of all-sky SEVIRI infrared brightness temperatures in a regional-scale ensemble data assimilation system using nonlinear bias corrections. *Mon. Wea. Rev.*, **147**, 4481-4509.

Otkin, J. A., R. Potthast, and A. Lawless, 2018: Nonlinear bias correction for satellite data assimilation using Taylor series polynomials. *Mon. Wea. Rev.*, **146**, 263-285.

Cintineo, R., J. A. Otkin, T. Jones, S. Koch, and D. J. Stensrud, 2016: Assimilation of synthetic GOES-R ABI infrared brightness temperatures and WSR-88D radar observations in a high-resolution OSSE. *Mon. Wea. Rev.*, **144**, 3159-3180.

Jones, T. A., J. A. Otkin, D. J. Stensrud, and K. Knopfmeier, 2013: Assimilation of simulated GOES-R satellite radiances and WSR-88D Doppler radar reflectivity and velocity using an Observing System Simulation Experiment. *Mon. Wea. Rev.,* **141**, 3273-3299.

Otkin, J. A., 2012: Assimilation of water vapor sensitive infrared brightness temperature observations during a high impact weather event. *J. Geophys. Res.*, doi:10.1029/2012JD017568.

Otkin, J. A., 2010: Clear and cloudy-sky infrared brightness temperature assimilation using an ensemble Kalman filter. *J. Geophys Res.*, **115, D19207**, doi:10.1029/2009JD013759.

Selected Publications (Model Verification):

Griffin, S. M., J. A. Otkin, G. Thompson, M. Frediani, and J. Berner, 2019: Assessing the impact of stochastic cloud microphysics using GOES-16 infrared brightness temperatures. Conditionally accepted for publication in *Mon. Wea. Rev.*

Otkin, J. A, W. E. Lewis, A. J. Lenzen, B. McNoldy, and S. Majumdar, 2017: Assessing the accuracy of the cloud and water vapor fields in the Hurricane WRF (HWRF) model using infrared satellite observations. *Mon. Wea. Rev.*, **145**, 2027-2046.

Griffin, S., J. A. Otkin, J. Sieglaff, C. Rozoff, L. Cronce, and C. Alexander, 2017: Neighborhood and object-based methods for comparing simulated and observed brightness temperatures and what do they tell us. *Wea. Forecasting*, **32**, 5-25.

Griffin, S. M., J. A. Otkin, C. M. Rozoff, J. M. Sieglaff, L. M. Cronce, C. R. Alexander, T. L. Jensen, and J. K. Wolff, 2017: Seasonal analysis of cloud objects in the High Resolution Rapid Refresh (HRRR) model using object-based verification. *Mon. Wea. Rev.*, **56**, 2317-2334.

Thompson, G., M. Tewari, K. Ikeda, S. Tessendorf, C. Weeks, J. A. Otkin, and F. Kong, 2015: Explicitly-coupled cloud physics and radiation parameterizations and subsequent evaluation in WRF high-resolution convective forecasts. *Atmos. Res.*, **168**, 92-104.

Cintineo, R., J. A. Otkin, F. Kong, and M. Xue, 2014: Evaluating the accuracy of planetary boundary layer and cloud microphysical parameterization schemes in a convection-permitting ensemble using synthetic GOES-13 satellite observations. *Mon. Wea. Rev.*, **142**, 163-182.

Selected Publications (Drought Monitoring):

Otkin, J. A., M. Svoboda, E. Hunt, T. Ford, M. Anderson, C. Hain, and J. Basara, 2018: Flash droughts: A review and assessment of the challenges imposed by rapid onset droughts in the United States. *Bull. Am. Meteorol. Soc.*, **99**, 911-919.

Otkin, J. A., T. Haigh, A. Mucia, M. C. Anderson, and C. R. Hain, 2018: Comparison of agricultural stakeholder survey results and drought monitoring datasets during the 2016 U.S. Northern Plains flash drought. *Weather, Climate, and Society*, in press.

Lorenz, D. J., **J. A. Otkin,** M. Svoboda, C. R. Hain, and Y. Zhong, 2018: Forecasting rapid drought intensification using the Climate Forecast System (CFS). *J. Geophys. Res*., **123**, 8365–8373.

Otkin, J. A., M. C. Anderson, C. Hain, M. Svoboda, D. Johnson, R. Mueller, T. Tadesse, B. Wardlow, and J. Brown, 2016: Assessing the evolution of soil moisture and vegetation conditions during the 2012 United States flash drought. *Agr. Forest Meteorol*., **218–219**, 230–242.

Otkin, J. A., M. Shafer, M. Svoboda, B. Wardlow, M. C. Anderson, C. Hain, and J. Basara, 2015b: Facilitating the use of drought early warning information through interactions with agricultural stakeholders. *Bull. Am. Meteorol. Soc*., **96**, 1073-1078.

Otkin, J. A., M. C. Anderson, C. Hain, and M. Svoboda, 2014: Examining the relationship between drought development and rapid changes in the Evaporative Stress Index. *J. Hydromet*., **15**, 938-956.

Otkin, J. A., M. C. Anderson, C. Hain, I. Mladenova, J. Basara, and M. Svoboda, 2013: Examining rapid onset drought development using the thermal infrared based Evaporative Stress Index. *J. Hydrometeor*., **14**, 1057-1074.

Synergistic Activities

1. Co-chair of the NOAA Next Generation Global Prediction System Strategic Implementation Plan Verification and Validation (NGGPS SIP V&V) working group that is tasked with compiling the verification metrics and techniques that will be used to assess the accuracy of the next generation of operational numerical weather prediction models in the U.S.

2. Publication referee for numerous journals, such as the Proceedings of the National Academy of Sciences, Bulletin of the American Meteorological Society, Quarterly Journal of the Royal Meteorological Society, Monthly Weather Review, Journal of Geophysical Research, Agriculture and Forest Meteorology, Journal of Applied Meteorology and Climatology, Journal of Atmospheric and Oceanic Technology, Geophysical Research Letters, International Journal of Climatology, Remote Sensing of Environment, Journal of Hydrology, National Hazards Earth System Science, Atmospheric Research, and Climate.

3. Member of PhD committee for Jordan Christian, University of Oklahoma.

Biographical Sketch
Claire Pettersen

a. Professional Preparation

Carleton College, Northfield, Minnesota	Physics and Astronomy	BA 2000
University of Wisconsin, Madison, Wisconsin	Materials Science	MS 2004
University of Wisconsin, Madison, Wisconsin	Atmospheric and Oceanic Sciences	MS 2014
University of Wisconsin, Madison, Wisconsin	Atmospheric and Oceanic Sciences	PhD 2017

b. Professional Appointments

Instrumentation Innovator, Space Science and Engineering Center, University of Wisconsin, Madison, Wisconsin**,** 2018 – Present

Associate Instrumentation Innovator, Space Science and Engineering Center, University of Wisconsin, Madison, Wisconsin**,** 2013 – 2018

Assistant Instrumentation Innovator, Space Science and Engineering Center, University of Wisconsin, Madison, Wisconsin**,** 2009 – 2013

Engineering Manager, Project IceCube, Department of Physics, University of Wisconsin, Madison, Wisconsin**,** 2007 – 2009

Winterover Experiments Researcher, Project IceCube, Department of Physics, University of Wisconsin, Madison, Wisconsin**,** 2006 – 2007

Digital Optical Module Engineer, Project IceCube, Department of Physics, University of Wisconsin, Madison, Wisconsin**,** 2004 – 2006

c. Products

Five publications and products most closely related to the proposed project:

Pettersen, C., Kulie, M.S., Bliven, L.F, Merrelli, A.J., Petersen, W.A., Wagner, T.J., Wolff, C.B., and Wood, N.B.: A composite analysis of snowfall modes from four winter seasons in Marquette, Michigan, JAMC, **2019**, doi: 10.1175/JAMC-D-19-0099.1.

Schirle, C.E., Cooper, S.J., Wolff, M.A., **Pettersen, C.**, Wood, N.B., L'Ecuyer, T.S., Ilmo, T., and Nygård, K.: Estimation of Snowfall Properties at a Mountainous Site in Norway using Combined Radar and In-situ Microphysical Observations, JAMC, **2019**, doi: 10.1175/JAMC-D-18-0281.1.

Pettersen, C., Bennartz, R., Merrelli, A.J., Shupe, M.D., Turner, D.D., and Walden, V.P.: Precipitation regimes over central Greenland inferred from 5 years of ICECAPS observations, ACP, **2018**, doi: 10.5194/acp-18-4715-2018.

Pettersen, C. and Merrelli, A.J.: Microwave radiometer snow categorization tool for Summit, Greenland, 2010 – 2015, Arctic Data Center, **2018**, doi: 10.18739/A2R28Q.

Pettersen, C. Bennartz, R., Kulie, M.S., Merrelli, A.J., Shupe, M.D., and Turner, D.D.: Microwave signatures of ice hydrometeors from ground-based observations above Summit, Greenland, ACP, **2016**, doi: 10.5194/acp-16-4743-2016.

Five other publications and products:

Bennartz, R., Fell, F., **Pettersen, C.**, Shupe, M.D., Schuettemeyer, D.: Spatial and temporal variability of snowfall over Greenland from CloudSat observations", ACP, **2019**, doi: 10.5194/acp-19-8101-2019.

Aartsen, M.G., Ackerman, M., Adams, J., Aguilar, J.A., Ahlers, M., Ahrens, M., Atlmann, D., and 184 coauthors: The IceCube Neutrino Observatory: Instrumentation and Online Systems, **2017**, J. Instr., doi: 10.1088/1748-0221/12/03/P03012.

Hudak, D., Kulie, M.S., and **Pettersen, C**.: GPM Ground Validation Environment Canada (EC) Micro Rain Radar (MRR) GCPEx V2, **2015**, **NASA**, doi: 10.5067/GPMGV/GCPEX/MRR/DATA203.

Petersen, W.A., **Pettersen, C.**, Kulie, M.S., Gatlin, P.N., and Wingo, M.T.: GPM Ground Validation NASA Micro Rain Radar (MRR) GCPEx V2, **2015**, **NASA**, doi: 10.5067/GPMGV/GCPEX/MRR/DATA204.

Bennartz, R., Shupe, M.D., Turner, D.D., Walden, V.P., Steffan, K., Cox, C.J., Kulie, M.S., Miller, N.B., and **Pettersen, C.**: July 2012 Greenland melt extent enhanced by low-level liquid clouds, **2013**, doi: 10.1038/nature12002.

d. Synergistic Activities

* Principal Investigator and member of the **NASA PMM** Science Team exploring snowfall modes in the mid- and high-latitudes (2018 – Present)
* Current Point of Contact and Principal Investigator of the Precipitation Imaging Package instrument for **NASA GPM-GV** (2018 – present)
* Principal Investigator of the **NASA GPM-GV** supported study to examine spatial distribution of snowfall accumulation within the GPM Microwave Imager footprint (2017 – present)
* Co-Investigator of the **CIMSS** Lake Effect Snow study for **NOAA GOES-16** with focus on connecting satellite-retrieved cloud liquid water path and radar-derived snow rates (2016 – present)
* Instrumentation lead and scientist for the **NASA**-sponsored ground-based instrument suite in Marquette, Michigan to study lake-effect snowfall in collaboration with the local **NWS** office (2014 – present)
* Research **cloud and precipitation processes** using radar and radiometer (ground-based, satellite), including significant involvement in instrumentation and science for **NSF ICECAPS** project in Greenland (2012 – present)
* Instrumentation lead for the **NSF** high-latitude snowfall study in Norway and Sweden (2015 – 2018)
* Co-Investigator on a **NASA PMM** Science Team to investigate precipitation structures aloft using wintertime ground validation campaign data (2015 – 2018)
* Field and science support for **NASA** and **NOAA** field campaign deployment of the Scanning High-Resolution Interferometer Sounder airborne instrument (2012 – 2017)
* Key member of science and instrument teams for ground-based and airborne validation field campaigns for **NSF** (2012/2016–2018), **NASA** (2013–2018), and **NOAA** (2016–2018), as well as **Antarctic Service** fieldwork, engineering, and science operations for **NSF** Project IceCube (2004/2005/2006-2007/2008/2009)
* Proposal Panel Reviewer: National Aeronautics and Space Administration
* Journal Manuscript Reviewer: American Geophysical Union, European Geophysical Union, American Meteorological Society, IEEE – Remote Sensing
* Service Committees: University of Wisconsin – Madison, Department of Atmospheric and Oceanic Sciences Hiring Committee (2019 – present), University of Wisconsin – Madison Space Science and Engineering Center Equity and Diversity Committee (2010 – 2019), University of Wisconsin – Madison Atmospheric, Oceanic, and Space Sciences Annual Poster Reception Director (2011 – 2019), University of Wisconsin – Madison, Department of Atmospheric and Oceanic Sciences Colloquium Committee (2013 – 2018)

Curriculum Vitae

R. Bradley Pierce
Space Science and Engineering Center
University of Wisconsin–Madison
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Email: rbpierce@wisc.edu
Phone: (608) 890-1892

Education:
PhD, Meteorology, University of Wisconsin–Madison, 1988
BS, Physics, University of Wisconsin-River Falls, 1982
BS, Mathematics, University of Wisconsin-River Falls, 1982

Work History

09/19-Present	Professor, Atmospheric and Oceanic Sciences, University of Wisconsin–Madison
10/18-Present	Academic Program Director, Space Science and Engineering Center, University of Wisconsin–Madison
05/07-09/18	Physical Scientist, Advanced Satellite Products Branch, NOAA/NESDIS Center for Satellite Applications and Research, Cooperative Institute for Meteorological Satellite Studies, Madison, WI
12/89-04/07	Research Scientist, Atmospheric Science Division, NASA Langley Research Center, Hampton VA

Honors & Awards

2003 NASA Exceptional Achievement Medal for outstanding contributions to the development of innovative techniques which enhance the scientific interpretation of airborne measurements of atmospheric constituents

2016 NOAA Administrator's Award for providing robust, real-time, simulated data of the next generation geostationary satellite imagers, reducing risk in post-launch operations.

Professional Experience

Dr. Pierce became the Director for the Space Science and Engineering Center (SSEC) at the University of Wisconsin–Madison in October 2018 and is responsible for providing scientific vision and leadership, including leadership of large-scale research programs involving instrument development, data analysis technique development, participation in field campaigns, and new technology definition and implementation. Prior to his SSEC Director appointment he was a physical scientist at the National Oceanic and Atmospheric Administration (NOAA) and a senior research scientist at NASA. Dr. Pierce's research focuses on the development of capabilities to utilize satellite, airborne and ground based measurements to improve our understanding and ability to predict the physical and chemical processes within the Earth's atmosphere. Dr. Pierce has more than 22 years of experience in the design, development and execution of global atmospheric models. Dr. Pierce has more than 20 years of experience in chemical modeling and forecasting support for NASA, NOAA, and NSF field campaigns. Dr. Pierce has been actively involved in the NASA Applied Sciences Program, which focuses on transitioning NASA satellite data sets to other agencies Decision Support Systems.

Selected Publications (103 refereed (h-index=35)

1. Vermeuel, M. P., G. A. Novak, H. D. Alwe, D. D. Hughes, R. Kaleel, A. F. Dickens, D. Kenski, A. C. Czarnetzki, E. A. Stone, C. O. Stanier, **R. B. Pierce**, D. B. Millet, T. H. Bertram, 2019,

Sensitivity of Ozone Production to NOx and VOC Along the Lake Michigan Coastline, Journal of Geophysical Research: Atmospheres,124, https://doi.org/10.1029/2019JD030842

2. Judd, L. M., J. A. Al-Saadi, S. J. Janz, M. G.Kowalewski, **R.B. Pierce**, J. J. Szykman, L. C.Valin, R. Swap, A. Cede, M. Mueller, M. Tiefengraber, N. Abuhassan, and D.Williams, 2019, Evaluating the impact of spatial resolution on tropospheric NO2 column comparisons within urban areas using high-resolution airborne data, *Atmos. Meas. Tech*., 12, 6091–6111, 2019 https://doi.org/10.5194/amt-12-6091-2019
3. Judd Laura M., Al-Saadi Jassim A., Valin Lukas C., **Pierce R. Bradley**, Yang Kai, Janz Scott J., Kowalewski Matthew G., Szykman James J., Tiefengraber Martin, Mueller Moritz, The Dawn of Geostationary Air Quality Monitoring: Case Studies From Seoul and Los Angeles, Frontiers in Environmental Science, Vol 6, 2018, DOI=10.3389/fenvs.2018.00085
4. Huang, M., Carmichael, G. R., **Pierce, R. B**., Jo, D. S., Park, R. J., Flemming, J., Emmons, L. K., Bowman, K. W., Henze, D. K., Davila, Y., Sudo, K., Jonson, J. E., Tronstad Lund, M., Janssens-Maenhout, G., Dentener, F. J., Keating, T. J., Oetjen, H., and Payne, V. H. (2017), Impact of intercontinental pollution transport on North American ozone air pollution: an HTAP phase 2 multi-model study, Atmos. Chem. Phys., 17, 5721-5750, https://doi.org/10.5194/acp-17-5721-2017, 2017.
5. Saide, P. E., S. N. Spak, **R. B. Pierce**, J. A. Otkin, T. K. Schaack, A K. Heidinger, A. M. da Silva, M. Kacenelenbogen, J. Redemann, G. R. Carmichaell (2015) , Central American biomass burning smoke can increase tornado severity in the U.S. Geophysical Research Letters, Volume 42, Issue 3, pages 956–965, 16 February 2015 DOI: 10.1002/2014GL062826
6. **Pierce, R. B.**, J. Al-Saadi, C. Kittaka, T. Schaack, A. Lenzen, K. Bowman, J. Szykman, A. Soja, T. Ryerson, A. M. Thompson, P. Bhartia, G. A. Morris, Impacts of background ozone production on Houston and Dallas, TX Air Quality during the TexAQS field mission, J. Geophys. Res., 114, D00F09, doi:10.1029/2008JD011337
7. Song, C.-K., D. W. Byun, **R. B. Pierce**, J. A. Alsaadi, T. K. Schaack, and F. Vukovich (2008), Downscale linkage of global model output for regional chemical transport modeling: Method and general performance, J. Geophys. Res., 113, D08308, doi:10.1029/ 2007JD008951.
8. **Pierce, R. B**., T. K. Schaack, J. Al-Saadi, T. D. Fairlie, C. Kittaka, G. Lingenfelser, M. Natarajan, J. Olson, A. Soja, T. H. Zapotocny, A. Lenzen, J. Stobie, D. R. Johnson, M. Avery, G. Sachse, A. Thompson, R. Cohen, J. Dibb, J. Crawford, D. Rault, R. Martin, J. Szykman, J. Fishman, (2007) Chemical Data Assimilation Estimates of Continental US Ozone and Nitrogen Budgets during INTEX-A, J. Geophys. Res., 112, D12S21, doi:10.1029/2006JD00772

Jerrold O. Robaidek

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Education

University of Maryland, College Park 1994
- M.S. Meteorology

University of Wisconsin, Platteville 1991
- B.S Physics

Employment Highlights

Satellite Data Services Data Center Project Manager 2009-Present
University of Wisconsin-SSEC

Information Processing Consultant 2005-2009
(Data Center Team Leader), University of Wisconsin-SSEC

Associate Information Processing Consultant 2001-2005
(Data Center Team Leader), University of Wisconsin-SSEC

Senior Research Specialist 2000-2001
(Data Center Team Leader), University of Wisconsin-SSEC

Research Specialist 1998-2000
(Data Center Team Leader), University of Wisconsin-SSEC

Associate Research Specialist 1995-1998
University of Wisconsin-SSEC

Memberships

- American Meteorological Society (AMS)
- AMS Data Stewardship Board 2014-2020

Awards

- NOAA-CIMSS Collaboration Award-2014, For contributing to restore GOES-13 to operational service following a major anomaly
- NOAA-CIMSS Collaboration Award-2011, For working with NOAA in revolutionizing NOAA Science Tests for geostationary satellites significantly reducing the likelihood of a single satellite configuration

Recent Publications and Presentations

- **Rescuing early geostationary weather satellite data: science, art, and serendipity!** Eumetsat Meteorological Satellite Conference, Rome Italy 2-6 October 2017. (Keynote)

- **Lost data is found: Rescuing geostationary weather satellite data from 1975-1979.** Conference on Environmental Information Processing Technologies, 33rd, Seattle, WA, 21-26 January 2017. (Invited Presentation)

- Robaidek, Jerrold O.; Santek, D. A.; Parker, D.; Bellon, W.; Suplinski, C. and Kohrs, R. A. **Multi-format client-agnostic file extraction through contextual HTTP (MCFETCH). Conference on Environmental Information Processing Technologies, 33rd, Seattle, WA, 21-26 January 2017.** American Meteorological Society, Boston, MA, 2017

- Kohrs, Richard A.; Robaidek, J. O. and Forrest, D. **GOES-R end-to-end readiness at the University of Wisconsin-Madison Space Science and Engineering Center Data Center. Conference on Satellite Meteorology, Oceanography and Climatology, 21st, Madison, WI, 15-19 August 2016.** American Meteorological Society, Boston, MA, 2016

- **Accessing McIDAS ADDE Satellite Data Servers in Python,** 2015 AMS 95th Annual Meeting in Phoenix, AZ, January 4-8, 2015.

- **Satellite Data Collaborations Between NOAA and the University of Wisconsin SSEC Data Center Past, Present, and Future,** NOAA 2013 Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, College Park, MD, April 8-12, 2013.

- **Kohrs, Richard A.; Robaidek, J. O.; Lazzara, M. A. and Santek, D. A..** Global satellite composites - 20 years of evolution**.** Conference on Environmental Information Processing Technologies, 29th, formerly IIPS, Austin, TX, 6-10 January 2013**. Boston, MA, American Meteorological Society, 2013**

- **University of Wisconsin SSEC Datacenter - Accessing Archive and Real-time datasets,** (invited workshop presentation), 2012 Unidata Users Workshop, “Navigating Earth System Science Data”, Boulder, CO, July 9-13, 2012.

- Genkova, I; Robaidek, J; Roebling, R; Sneep, M; and Veefkind, P. **Temporal co-registration for TROPOMI cloud clearing,** Atmospheric Measurement Techniques**,** 5, 595–602, 2012.

- **Interrogation and Reconciliation of Historical GOES Imagery From the Period 1978 to 1996,** 2012 AMS 92 Annual Meeting in New Orleans, LA, January 22-26, 2012.

- **Multi-satellite data ingest, archive, redistribution and product generation system,** Satellite Direct Readout Conference, Miami, FL, April 4 - 8, 2011.

- Gumley, Liam; Strabala, Kathy; Gerth, Jordan; Bachmeier, Scott; Dengel, Russ and Robaidek, Jerrold. **EOS direct broadcast real-time products for the US National Weather Service (Abstract only). International TOVS Study Conference, 16th, Angra dos Reis, Brazil, 7-13 May 2008 (proceedings).** University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies (CIMSS), Madison, WI, 2008, pp.5.

- Wimmers, Anthony; Bachmeier, A. Scott; Lindstrom, Scott; Robaidek, Jerrold; Bellon, William; Strabala, Kathleen and Kumar, Nikhil. **Analyzing aerosols over the U.S. in near real-time with MODIS. Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, 14th, Atlanta, GA, 29 January-2 February 2006 (preprints**). American Meteorological Society, Boston, MA, 2006, Paper P1.7. Reprint # 4843.

CHRISTOPHER CASEY SCHMIDT
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CIMSS/SSEC University of Wisconsin–Madison
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EDUCATION

1997-2000	University of Wisconsin – Madison; M.S. - Atmospheric and Oceanic Science Advisor: Dr. Steven Ackerman Thesis: "Hourly Ozone Estimates Utilizing the GOES I-M Sounders"
1993-1997	Lawrence University, Appleton, WI; B.A. – Physics

EXPERIENCE

2008-Present	Researcher; Cooperative Institute for Meteorological Satellite Studies Current Project Manager: ABI Fire Product
2003-2008	Associate Researcher; CIMSS
2001-2003	Assistant Researcher; CIMSS
2000-2001	Research Assistant; CIMSS
1997-2000	Graduate Research Assistant; University of Wisconsin - Madison

Mr. Schmidt manages the geostationary Biomass Burning projects at the Cooperative Institute for Meteorological Satellite Studies (CIMSS). His duties include program management, user outreach, and programming. Mr. Schmidt designed the realtime processing system for the GOES Wildfire Automated Biomass Burning Algorithm (WFABBA) and is responsible for the Fire Detection and Characterization Algorithm (FDCA) for the GOES-R series. He has performed numerous trainings on geostationary fire detection and presented the work at meetings and conferences. Those trainings have extended beyond the fire products to include the raw data and other products from the Advanced Baseline Imager (ABI), Also, Mr. Schmidt managed the adaptation of the GOES Sounder ozone detection algorithm to the GOES-R series. His expertise includes data analysis of satellite radiance measurements, programming in Perl, Fortran (77 and 90), IDL, and the bash shell on Linux systems as well as applications involving the Man computer Interactive Data Access System (McIDAS).

SELECTED PUBLICATIONS

Schmidt, Chris: Chapter 13 - Monitoring Fires with the GOES-R Series, Editor(s): Steven J. Goodman, Timothy J. Schmit, Jaime Daniels, Robert J. Redmon. The GOES-R Series, Elsevier, 2020, pp.145-163, ISBN 9780128143278, https://doi.org/10.1016/B978-0-12-814327-8.00013-5

Schmidt, Christopher C., Prins, E. M., Hyer, E., Hoffman, J. P., Brunner, J., Reid, J. S., 2012: The global geostationary Wildfire ABBA: Current implementation and future plans. Conference on Satellite Meteorology, Oceanography and Climatology, 18th, and Joint AMS-Asia Satellite Meteorology Conference, 1st, New Orleans, LA, 22-26 January 2012. Boston, MA, American Meteorological Society.

Miller, Steven D., Schmidt, Christopher C., Schmit, Timothy J., Hillger, Donald W., 2012: A case for natural colour imagery from geostationary satellites, and an approximation for the GOES-R ABI. International Journal of Remote Sensing, Volume 33, Issue 13, pp.3999-4028. Reprint #6636.

Schmidt, Christopher, Hoffman, J. P., Prins, E. M., 2011: Detection and characterization of biomass burning in the GOES-R era. Annual Symposium on Future Operational Environmental Satellite Systems, 7th, Seattle, WA, 23-27 January 2011. Boston, MA, American Meteorological Society.

Lindstrom, S., C. C. Schmidt, E. M. Prins, J. Hoffman, J. Brunner, T. J. Schmit, 2008: Proxy ABI datasets relevant for fire detection that are derived from MODIS data. GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. manuscript not available for publication. Boston, MA, American Meteorological Society.

Li, J., C. C. Schmidt, J. P. Nelson III, T. J. Schmit, W. P. Menzel, 2001: Estimation of total atmospheric ozone from GOES Sounder radiances with high temporal resolution. J. Atmos. Oceanic Tech., 18, 157-168.

Dr. Joe K. Taylor

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Education

2014	Ph.D., Electrical Engineering., University of Laval
2000	M.S. (Great Distinction), Engineering Physics, University of Saskatchewan
1994	B.S. (Great Distinction), Engineering Physics, University of Saskatchewan

Professional Background

2003 – present	Research Engineer, SSEC, University of Wisconsin–Madison
2000 – 2003	Instrument Scientist, Institute of Space and Atmospheric Studies (ISAS), University of Saskatchewan
1999 – 2000	Instrument Engineer, Institute of Space and Atmospheric Studies (ISAS), University of Saskatchewan
1994 – 1999	Graduate Assistant, Linear Accelerator Laboratory, University of Saskatchewan

Dr. Taylor is a key member of the Engineering Research and Development group at the Space Science and Engineering Center (SSEC) on the University of Wisconsin–Madison campus. His primary areas of expertise include design, optimization, analysis, application, and high accuracy calibration of infrared Fourier Transform Spectrometer (FTS) systems; infrared optical system design and analysis; and infrared detector performance evaluation, optimization and nonlinearity correction. He has considerable experience developing, testing, and calibrating infrared and far-infrared FTS-based hyperspectral remote sensing instruments, and has 20 years' experience supporting space missions in an engineering role.

Dr. Taylor is the Lead Instrument Engineer for the UW-SSEC Absolute Radiance Interferometer (ARI). The ARI is an FTS based sensor that achieves ultra-high calibration accuracy, and was developed as the IR demonstrator for NASA's CLARREO (Climate Absolute Radiance and Refractivity Observatory) climate benchmark measurement mission. As the Lead Instrument Engineer, Dr. Taylor led the instrument design, development, testing, and calibration. The ARI instrument has successfully demonstrated the ability to meet the CLARREO 0.1 K, k=3 measurement uncertainty requirement, and was assessed a Technology Readiness Level (TRL) of 6 by the NASA Earth Science Technology Office.

Dr. Taylor is the Principal Investigator for the NASA CrIS (Cross-track Infrared Sounder) L1b calibration software development project. This effort is funded by NASA with a goal of creating calibration software capable of generating a climate quality CrIS Level 1B mission data record. The calibration software supports reprocessing of the full mission datasets for all CrIS sensors, with a consistent calibration algorithm and consistent calibration coefficients and parameters, and a transparent and accessible code base. He is also a member of the NOAA led calibration validation team for the Suomi NPP (SNPP) and NOAA-20 CrIS instruments, and supported the thermal vacuum testing of these instruments.

Dr. Taylor is the Principal Investigator (PI) for the airborne UW-SSEC Scanning High-resolution Interferometer Sounder (S-HIS). The S-HIS is recognized as a highly accurate and extremely reliable airborne reference instrument for the measurement of hyperspectral infrared radiances and has been used for high-altitude airborne calibration validation of CrIS (Cross-track Infrared Sounder), IASI (Infrared Atmospheric Sounding Interferometer), ABI (Advanced Baseline Imager) on GOES-16, and AIRS (Atmospheric Infrared Sounder) sensors.

SELECT PRESENTATIONS AND PUBLICATIONS:

Taylor, Joe K., Henry E. Revercomb, Fred A. Best, Robert O. Knuteson, David C. Tobin, P. Jon Gero, Doug Adler, and Mark Mulligan. "An on-orbit infrared intercalibration reference standard for decadal climate trending of the Earth." In *Sensors, Systems, and Next-Generation Satellites XXIII*, vol. 11151, p. 1115116. International Society for Optics and Photonics, 2019.

Taylor, Joe K., David C. Tobin, Henry E. Revercomb, Fred A. Best, Ray K. Garcia, Bob Knuteson, Michelle Feltz, Frank Padula, and Steve Goodman. "Calibration Validation of the GOES-16 Advanced Baseline Imager (ABI) with the High-Altitude Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS)." In *Fourier Transform Spectroscopy*, pp. FTu2B-2. Optical Society of America, 2019.

Taylor, Joe K., Henry E. Revercomb, Fred A. Best, P. Jonathan Gero, David C. Tobin, Robert O. Knuteson, Doug Adler et al. "The Absolute Radiance Interferometer (ARI) for the CLARREO Pathfinder: Instrument Status and Demonstrated Performance." In *Fourier Transform Spectroscopy*, pp. FTu3C-4. Optical Society of America, 2016.

Taylor, Joe K., Henry E. Revercomb, and David C. Tobin. "An Analysis and Correction of Polarization Induced Calibration Errors for the Cross-track Infrared Sounder (CrIS) Sensor." *Fourier Transform Spectroscopy*. Optical Society of America, 2018.

Tobin, D. C. and Taylor, J. K., "CrIS Radiometric Uncertainty and Recent Aircraft Underflights to Establish its On-Orbit Traceability," GSICS Quarterly Newsletter, vol. 7, (2014).

Taylor, J. K., Tobin, D., Revercomb, H., Best, F., Garcia, R., Imbiriba, B., and Goldberg, M., "Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Calibration validation with the aircraft based Scanning High-resolution Interferometer Sounder (S-HIS)," Annual Symposium on Future Operational Environmental Satellite Systems, 10th,(2014).

Kataoka, F., Knuteson, R. O., Kuze, A., Suto, H., Shiomi, K., Harada, M., Garms, E. M., Roman, J. A., Tobin, D. C., and Taylor, J. K., "TIR spectral radiance calibration of the GOSAT satellite borne TANSO-FTS with the aircraft-based S-HIS and the ground-based AERI at the Railroad Valley desert playa," Geoscience and Remote Sensing, IEEE Transactions on, vol. 52, pp. 89-105 (2014).

Tobin, D. C., Revercomb, H. E., Knuteson, R. O., Taylor, J. K., Best, F. A., Borg, L., DeSlover, D., Martin, G., Buijs, H., and Esplin, M., "Suomi-NPP CrIS radiometric calibration uncertainty," Journal of Geophysical Research: Atmospheres, vol. 118, pp. 10,589-10,600 (2013).

Taylor, J. K., Revercomb, H. E., Buijs, H., Grandmont, F. J., Gero, P. J., Best, F. A., Tobin, D. C., and Knuteson, R. O., "The University of Wisconsin Space Science and Engineering Center Absolute Radiance Interferometer (ARI): instrument overview and radiometric performance," Proceedings of SPIE (8527),85270P-85270P-14 (2012).

Newman, S. M., Larar, A. M., Smith, W. L., Ptashnik, I. V., Jones, R. L., Mead, M. I., Revercomb, H., Tobin, D. C., Taylor, J. K., and Taylor, J. P., "The joint airborne IASI validation experiment: an evaluation of instrument and algorithms," Journal of Quantitative Spectroscopy and Radiative Transfer, vol. 113, pp. 1372-1390 (2012).

Gero, P. J., Taylor, J. K., Best, F. A., Garcia, R. K., and Revercomb, H. E., "On-orbit absolute blackbody emissivity determination using the heated halo method," Metrologia, vol. 49, p. S1 (2012).

Taylor, J. K., Revercomb, H. E., Buijs, H., Grandmont, F. J., Gero, P. J., Best, F. A., Tobin, D. C., Knuteson, R. O., LaPorte, D. D., and Cline, R., "The University of Wisconsin Space Science and Engineering Center Absolute Radiance Interferometer (ARI)," Proceedings of SPIE (7857),78570K-78570K-9 (2010).

Tobin, D. C., H. E. Revercomb, R. O. Knuteson, F. A. Best, W. L. Smith, N. N. Ciganovich, R. G. Dedecker, S. Dutcher, S. D. Ellington, R. K. Garcia,H. B. Howell, D. D. LaPorte, S. A. Mango, T. S. Pagano, J. K. Taylor, P. van Delst, K. H. Vinson, and M. W. Werner "Radiometric and spectral validation of Atmospheric Infrared Sounder observations with the aircraft-based Scanning High-Resolution Interferometer Sounder," J. Geophys. Res., vol. 111, 4/31/2006 (2006).

David C. Tobin
Space Science and Engineering Center, University of Wisconsin–Madison
1225 West Dayton St., Madison, WI 53706, (608) 265-6281, dave.tobin@ssec.wisc.edu

Dr. Tobin earned a Ph.D. in applied physics from the University of Maryland Baltimore County in 1996. His research focused on molecular spectroscopy, infrared radiative transfer, and remote sensing and his dissertation work dealt with laboratory and theoretical studies of the spectral lineshapes of water vapor and carbon dioxide. For the past twenty three years, he has worked as a research scientist at the University of Wisconsin–Madison Space Science and Engineering Center. He is involved with various projects involving infrared molecular spectroscopy and atmospheric radiative transfer, atmospheric water vapor, infrared spectro-radiometer calibration and validation, and infrared remote sensing. Past projects include Level 1 and 2 product validation as part of the AIRS science and Aura TES validation teams, infrared radiance and flux closure studies for the ARM program, investigations of the water vapor continuum, characterization studies of GIFTS and IASI, and development of the CLARREO climate mission. Current efforts include leading the center's efforts in the JPSS CrIS radiance and product development and validation, various other satellite calibration/validation and intercalibration efforts, and involvement in the center's aircraft based interferometer program.

Awards and Honors:

UW–Madison, Distinguished Scientist position, 2019
UW–Madison, Permanent Principal Investigator status, 2018
UW–Madison Chancellor's Award for Excellence in Research: Ind. Investigator, 2017
NASA Langley Henry J. E. Reid Award for Best Journal Paper, 2015
CLARREO Mission Concept Team, Group Achievement Award, 2012
Suomi NPP Mission Development Team Group Achievement Award, 2011
Young Scientist Award, International Radiation Commission, 2008
Group Achievement Award, Earth Observing System (EOS) Aqua Mission Team, 2003
Most outstanding graduating senior award, Physics Dept., UMBC, 1991
NIST cooperative fellowship award and appointment, 1988-1991

Committees, Working Groups, and Science Teams:

Chair, Advanced Sounder Working Group, International TOVS Working Group, 2019-
Member, Mission Advisory Group, Meteosat Third Generation InfraRed Sounder, 2017-
Member, International Radiation Commission, 2014-
Member, CLARREO Science Definition Team, 2011-2015
Member, NOAA GOES-R Algorithm Working Group, 2008-2010
Member, Global Space-based Inter-Calibration System Research Working Group, 2006-
Member, Integrated Program Office Sounder Operational Algorithm Team, 2005-2008
Member, AMS Atmospheric Radiation Committee, 2002
Member, NASA Atmospheric Infrared Sounder (AIRS) Science Team, 1998-2006
Member, Atmospheric Radiation Measurements (ARM) Science Team, 1998-2005

Selected Publications:

Serio, C.; Masiello, G. and **Tobin, D.**, 2019: *Characterization of the observational covariance matrix of hyper-spectral infrared satellite sensors directly from measured Earth views*, Sensors, special Issue "Advanced Hyper-Spectral Imaging, Sounding and Applications from Space", in press.

Serio, C.; Masiello, G.; Camy-Peyret, C.; Jacquette, E.; Vandermarcq, O.; Bermudo, F.; Coppens, D. and **Tobin, D.**, 2018: *PCA determination of the radiometric noise of high spectral resolution infrared observations from spectral residuals: Application to IASI.* Journal of Quantitative Spectroscopy and Radiative Transfer *206*, 2018, 8-21.

Tobin, D., Holz, R., Nagle, F., and Revercomb, H., 2016: *Characterization of the Climate Absolute Radiance and Refractivity Observatory (CLARREO) ability to serve as an infrared satellite intercalibration reference*, Journal of Geophysical Research-Atmospheres *121*, 4258-4271.

Menzel, W.P., **Tobin, D.C**., and Revercomb, H.E., 2016: *Infrared remote sensing with meteorological satellites*, Advances in Atomic, Molecular and Optical Physics *65*, 193-264

Tobin, D. et al., 2013: *Suomi-NPP CrIS radiometric calibration uncertainty*, Journal of Geophysical Research-Atmospheres *118*, doi:10.1002/jgrd.50809.

Mlawer, E.J., Payne, V.H., Moncet, J.-L., Delamere, J.S., Alvarado, M.J., and **Tobin, D.C.**, 2012: *Development and recent evaluation of the MT_CKD model of continuum absorption*, Philosophical Transactions of the Royal Society, A *370*, 2520-2556.

Tobin, D. et al., 2006: *Use of Atmospheric Infrared Sounder high-spectral resolution spectra to assess the calibration to Moderate resolution Imaging Spectroradiometer on EOS Aqua*, Journal of Geophysical Research-Atmospheres *111*, doi:10.1029/2005JD006095.

Tobin, D. et al., 2006: *Atmospheric Radiation Measurement site atmospheric state best estimates for Atmospheric Infrared Sounder temperature and water vapor retrieval validation*, Journal of Geophysical Research-Atmospheres *111*, doi:10.1029/2005JD006103.

Tobin, D. et al., 2006: *Radiometric and spectral validation of Atmospheric Infrared Sounder observations with the aircraft-based Scanning High-Resolution Interferometer Sounder*, Journal of Geophysical Research-Atmospheres *111*, doi:10.1029/2005JD006094.

Tobin, D. et al., 1999: *Downwelling spectral radiance observations at the SHEBA ice station: Water vapor continuum measurements from 17 to 26 microns* , Journal of Geophysical Research-Atmospheres *104*, 2081-2092.

Tobin, D. et al., 1996: *Experimental investigation of the self- and N2-broadened continuum within the v2 band of water vapor*, Applied Optics *35*, 4724-4734.

Brief Vitae

Christopher Velden

Current Position: University of Wisconsin – Space Science and Engineering Center
Physical Sciences: --Senior Scientist and Principal Investigator
--Chief Investigator for internationally-recognized UW-SSEC/CIMSS Tropical Cyclones Group and Satellite Winds Group

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University of Wisconsin–Madison
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Madison, Wisconsin 53706
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M.S. - Dept. of Meteorology, Univ. of Wisconsin–Madison, 1982.
Topic: Tropical Cyclone Warm Core Evolution: NOAA Satellite Microwave Views
B.S. - Univ. of Wisconsin-Stevens Point, 1979
Majors: Natural Sci., Geography (minor - physics)

Major Awards:
AMS Banner Miller Award, 2001 and 2018
AMS Special Award, 1998 and 2015
NASA Agency Honor Award, 2017
UWisc. Chancellors Research Excellence Award, 2012
AMS Fellow, 2008
OFCM Hagemeyer Award, 2003

Major Refereed Publications – Lead Author: 25+

Scientific Conference papers since 1985 - ~250

Major Field and Professional Experience

Co-Chair, WMO Workshops on Tropical Cyclone Satellite Applications (2011, 2016)
Co-Chair, WMO International Workshops on Tropical Cyclones (2010)
Co-Chair, AMS Annual Meeting (2008)
Chair, AMS Committee on Satellite Meteorology (2004-2007)
WMO/THORPEX International Science Team Working Group (2002-2012)
National Academy of Sciences NPOESS/GOES-R Study for NOAA/NASA (2007-2008)
National Academy of Sciences Decadal Study for NASA (2005-2007)
National Academy of Sciences TRMM/GPM Study for NASA/NOAA (2002-2004)
National Academy of Sciences CONNTRO Committee (2000-2003)
Bulletin of the AMS Journal Subject Editor (2002-2011)
Co-chair, WMO International Satellite Winds Working Group (1995-2008)
US Weather Research Project Science Steering Committee charter member (1996-1999)
Member AMS Committee on Satellite Meteorology (1997-2003)
Member AMS Committee on Tropical Meteor and Cyclones (1990-1993; 2010-2016)
Participant (PI or Co-I) in ~15 major atmospheric field programs since 1986

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Space Science and Engineering Center (SSEC) University of Wisconsin–Madison
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Education

Ph. D., Atmospheric and Oceanic Sciences, University of Wisconsin–Madison, Madison, WI, 2011.
Dissertation: *A method for retrieving the cumulus entrainment rate from ground-based observations*
Advisor: David D. Turner

M.S., Atmospheric and Oceanic Sciences, University of Wisconsin–Madison, Madison, WI, 2006.
Thesis: *Subhourly profiling of atmospheric stability during southern Great Plains severe weather events*
Advisors: Wayne F. Feltz, Steven A. Ackerman

B. S., Meteorology, University of Oklahoma, Norman, OK, 2003.

Professional Experience

May 2015 - present: Associate researcher (2018 – present) and assistant researcher (2015 – 2018), Cooperative Institute for Meteorological Satellite Studies (CIMSS), Space Science and Engineering Center (SSEC), University of Wisconsin–Madison, Madison, WI.

July 2011-May 2015: Assistant professor, Department of Atmospheric Sciences (2011-2014) and Department of Physics (2014-2015), Creighton University, Omaha, NE.

Peer-reviewed publications

Pettersen, C., M. S. Kulie, L. F. Bliven, A. J. Merrelli, W. A. Petersen, **T. J. Wagner**, D. B. Wolff, and N. B. Wood, 2019: A composite analysis of snowfall modes from four winter seasons in Marquette, Michigan. *J. Appl. Meteor. Climatol.*, in early online release.

Loveless, D., **T. J. Wagner**, D. D. Turner, S. A. Ackerman. And W. F. Feltz, 2019: A composite perspective on bore passages during the PECAN campaign. *Mon. Wea. Rev.*, **147**, 1395 – 1413.

Wagner, T. J., D. D. Turner, and P. M. Klein, 2019: A new generation of ground-based mobile platforms for active and passive profiling of the atmospheric boundary layer. *Bull. Amer. Meteor. Soc.* To appear in the January 2019 issue.

Wulfmeyer, V., and coauthors (including **T. Wagner**), A new research approach for observing and characterizing land-atmosphere feedback. *Bull. Amer. Meteor. Soc.*, **99**, 1639 – 1668.

Blumberg, W. G., **T. J. Wagner**, and J. Correia Jr., 2017: Quantifying the accuracy and uncertainty of diurnal thermodynamic profiles and convection indices derived from the Atmospheric Emitted Radiance Interferometer. *J. Appl. Meteor. Climatol.*, **56**, 2747-2766.

Wagner, T. J. and J. M. Kleiss, 2016: Error characteristics of ceilometer-based observations of cloud amount. *J. Atmos. Oceanic Technol.*, **33**, 1557 – 1567.

Wagner, T. J., Turner, D. D., Berg, L. K., Krueger, S. K., 2013. Ground-based remote retrievals of cumulus entrainment rates. *J. Atmos. Oceanic Technol*., **30**, 1460 – 1471.

Lu, C., Liu, Y., Niu, S., Krueger, S., **Wagner, T.**, 2013: Exploring parameterizations for turbulent entrainment-mixing processes in clouds. *J. Geophys. Res: Atmos*, **118**, 185 – 194.

Wagner, T. J., W. F. Feltz, and S. A. Ackerman, 2008: The temporal evolution of convective indices in storm-producing environments. *Wea. Forecasting*, **23**, 786 – 794.

Cady-Pereira, K. E., M. W. Shephard, D. D. Turner, E. J. Mlawer, S. A. Clough, and **T. J. Wagner**, 2008: Improved total column precipitable water vapor from Vaisala RS90 and RS92 humidity sensors. *J. Atmos. Oceanic Technol., 25, 873-883*.

Field Campaigns

Chequamegon Heterogeneous Ecosystem Energy-balance Study Enabled by a High-density Extensive Array of Detectors (CHEESEHEAD), 2019, Wisconsin

Land Atmosphere Feedback Experiment (LAFE), 2017, Oklahoma

Lake Michigan Ozone Experiment (LMOS), 2017, Wisconsin

Plains Elevated Convection At Night (PECAN), 2015, Great Plains

Radiative Heating in Unexplored Bands Campaign – II (RHUBC-II), 2009, Chile.

International H_2O Project, 2002

Anthony J. Wimmers – Curriculum Vitae

Updated December, 2019

Position: Associate Scientist, Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin – Madison
Contact: wimmers[---]ssec.wisc.edu

Education

B.S. Physics, 1996, University of Dayton, Summa Cum Laude, Honors Program
M.S. Environmental Science, 2000, University of Virginia
Master's Thesis: "Remotely-sensed extratropical specific humidity in the mid- to upper-troposphere"
Ph.D. Environmental Science, 2003, University of Virginia
Dissertation: "Satellite-based location of tropopause folding signatures along air mass boundaries"

Academic Positions

Postdoctoral Researcher, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison, 2003-2004
Assistant Researcher, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison, 2004-2007
Associate Researcher, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison, 2007-2011
Researcher, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison, 2011-2014
Assistant Scientist, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison, 2015-2017
Associate Scientist, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison, 2017-present

Selected Honors & Awards

NASA Group Achievement Award for Earth Sciences Applications, 2004
NASA Paul F. Holloway Technology Transfer Award, 2007
American Meteorological Society Special Award to the CIMSS Tropical Cyclone Group, 2014

Selected Publications

Wimmers, A. J., and J.L. Moody, A fixed-layer estimation of upper tropospheric specific humidity from the GOES water vapor channel: Parameterization and validation of the altered brightness temperature product, *Journal of Geophysical Research-Atmospheres*, *106* (D15), 17115-17132, 2001.
Wimmers, A. J., J.L. Moody, E.V. Browell, J.W. Hair, W.B. Grant, C.F. Butler, M.A. Fenn, C.C. Schmidt, J. Li, and B.A. Ridley, Signatures of tropopause folding in satellite imagery, *Journal of Geophysical Research - Atmospheres*, 109, art. no. 8360, 2003.
Mecikalski, J.R. W. F. Feltz, J. J. Murray, D. B. Johnson, K. M. Bedka, S. T. Bedka, M. J. Pavolonis, A. J. Wimmers, T. A. Berendes and E. R. Williams, Aviation applications for satellite-based observations of cloud properties, convection initiation, in-flight icing, turbulence, and volcanic ash, *Bulletin of the American Meteorological Society*, 88, 1589-1607, 2007.
Wimmers, A. J. and C. S. Velden, 'MIMIC': A new approach to visualizing satellite microwave imagery of tropical cyclones, *Bulletin of the American Meteorological Society*, 88, 1187-1196, 2007.
Hoff, R., H. Zhang, N. Jordan, A. Prados, J. Engle-Cox, A. Huff, Amy, S. Weber, E. Zell, S. Kondragunta, J. Szykmna, B. Johns, F. Dimmick, A. Wimmers, J. Al-Saadi and C. Kittaka.

Applications of the three-dimensional air quality system to western US air quality: IDEA, Smog Blog, Smog Stories, AirQuest, and the Remote Sensing Information Gateway*, Journal of the Air and Waste Management Association*, 59, 980-989, 2008.

Wimmers, A. J. and C. S. Velden, Objectively determining the rotational center of tropical cyclones in passive microwave satellite imagery, *J. Appl. Meteor.*, 49, 2013–2034, 2010.

Wimmers, A. J. and C. S. Velden, Seamless advective blending of total precipitable water retrievals from polar orbiting satellites, *J. Appl. Meteor.*, 50, 1024-1036, 2011.

Rozoff, C., C. S. Velden, J. Kaplan, J. Kossin, A. Wimmers, Improvements in the probabilistic prediction of tropical cyclone rapid intensification with passive microwave observations, *Wea. Forecast.*, 30, 1016-1038, 2015.

Wimmers, A. J. and C. S. Velden, Advancements in objective multisatellite tropical cyclone center-fixing, *J. Appl. Meteor.*, 55, 197-212, 2016.

Wimmers, A. J., S. Griffin, J. Gerth, S. Bachmeier and S. Lindstrom, Observation of gravity waves with high-pass filtering in the new generation of geostationary images and their relation to aircraft turbulence, *Wea. Forecast.*, 30, 1016-1038.

Mapes, B. E., E. S. Chung, W. M. Hannah, H. Masunaga, A. J. Wimmers, C. S. Velden, 2018: The Meandering margin of the meteorological moist tropics, *Geophys. Res. Lett.*, 45, 1177-1184.

Knapp, K. R., C. S. Velden, A. J. Wimmers, 2018: A global climatology of tropical cyclone eyes, *Mon. Wea. Rev.*, 146, 2089-2101.

Wimmers, A. J., C. S. Velden, J. H. Cossuth, 2019: Using deep learning to estimate tropical cyclone intensity from microwave satellite imagery, *Mon. Wea. Rev.*, 147, 2261-2282.

Cintineo, J. L., M. Pavolonis, J. Sieglaff, A. Wimmers, J. Brunner, Applying artificial intelligence to detect intense convection using geostationary satellite data, in preparation, 2019.

Appendix E: Project List

Project Name	PI/PM	Agency
GOES Series Calibration	Gunshor	NOAA
PSDI Polar/Geostationary R2O	Key/Velden/Santek	NOAA
HIRS Cloud Measurements	Menzel	NOAA
CIMSS Base Task I	Feltz	NOAA
GOES-R Algorithm Working Group	Huang	NOAA
GOES-R Proving Ground	Feltz	NOAA
GOES-R CIMSS-CIMMS Severe Wx	Hubbard	NOAA
GOES-R Series Risk Reduction	L'Ecuyer	NOAA
GOES-R Technical Support	Menzel	NOAA
GOES-R CSPP GEO Support	Martin	NOAA
GOES-R/JPSS ASSISTT Support	Garcia/Martin	NOAA
GOES-17 Program Support (Fusion)	Menzel	NOAA
GOES-R/JPSS S-HIS Cal/Val Field Support	Taylor	NOAA
Polar Orbiting FTS and CSPP Support	Gumley	NOAA
JPSS Proving Ground/Risk-Reduction	L'Ecuyer	NOAA
JPSS CrIS SDR Cal/Val	Tobin	NOAA
JPSS VIIRS SDR Cal/Val	Moeller	NOAA
JPSS Cloud/Cryosphere SDR	Heidinger, Wang, and Key	NOAA
JPSS VIIRS Derived Winds and VolAsh	Pavolonis/L'Ecuyer	NOAA
JPSS NUCAPS IR Emissivity Cal/Val	Knuteson	NOAA
JPSS Satellite Liaison Pacific Region	Lindstrom	NOAA
TMP Program – Tundra/TROPOMI/OSE	Pierce	NOAA
EPS-SG Cloud Imager Studies	Greenwald	NOAA
GOES/JPSS Enterprise System R2O	Garcia/Martin/L'Ecuyer	NOAA
NPP/JPSS Data Assimilation Studies	Jung	NOAA
Climate Hurricane Reanalysis	Kossin	NOAA
NWS Alaska QPE Improvement	Otkin	NOAA
Taiwan – CWB/ESRL H-8 Applications	Foster	NOAA
GOES-R Series ABI Short Courses	Gunshor	NOAA
GOES-R/JPSS Education/Outreach	Mooney	NOAA
VISIT	Lindstrom	NOAA
SHYMET	Lindstrom	NOAA
CrIS/OMPS and TES Ozone Retrievals	Pierce	NOAA
LEO/GEO High Impact Weather	Li/Velden/Pierce	NOAA
McIDAS Visualization GOES/JPSS	Rink	NOAA
RealEarth Visualization – GeoNetCast	Batzli/Huang	NOAA
Great Lakes/International – AquaWatch	Greb	NOAA
Commercial Aircraft NWP DA	Wagner	NOAA
Hurricane Supplemental – S4 computer	Nolin	NOAA
PECAN Weather Deployment	Feltz	NSF
PEATE Atmospheric SIPS	Gumley	NASA
TROPICS	Velden	NASA
Pre-FIRE	L'Ecuyer	NASA
JPL Cloudsat/Calipso	Holz	NASA
Navy Imagery Support	Holz	NRL
Pacific Tropical Cyclones	Velden	DOD
TC Intensity Forecasts	Velden	DOD
Naval Research Satellite Applications	Velden	DOD

Appendix F: Collaborations

CIMSS Scientist	Collaborating Scientist(s)	Institute	Project Title
Lori Borg	Tony Reale	NOAA/EMC/OBSPROC	CrIS DOE ARM Site Cal/Val
Brett Hoover	Eugene Petrescu	NOAA/NWS/Alaska Region	CIMSS Support for the Development of A High-Resolution Quantitative Precipitation Estimate Product over Alaska
	Matt Newman	Boulder/CIRES	Prediction, Sensitivity, and Dynamics of Subseasonal To Seasonal Phenomena Diagnosed Through Linear Inverse Models, Their Adjoints, and Numerical Weather Prediction Models
	Micheal Morgan	University of Wisconsin–Madison	1. Prediction, Sensitivity, and Dynamics of Subseasonal To Seasonal Phenomena Diagnosed Through Linear Inverse Models, Their Adjoints, and Numerical Weather Prediction Models 2. Diagnosis of the Sensitivity of Type B Cyclones to the Structure and Evolution of Their Upper-Tropospheric Precursors 3. Using Real-Time Numerical Weather Prediction for Statistical Modeling of Storm Losses
	Dan Vimont	University of Wisconsin–Madison	Prediction, Sensitivity, and Dynamics of Subseasonal To Seasonal Phenomena Diagnosed Through Linear Inverse Models, Their Adjoints, and Numerical Weather Prediction Models
	Jonathan Martin	University of Wisconsin–Madison	Diagnosis of the Sensitivity of Type B Cyclones to the Structure and Evolution of Their Upper-Tropospheric Precursors
	Rolf Langland	Naval Research Laboratory-Monterey Marine Meteorology Division	1. Satellite-Based Applications to Benefit Navy Meteorological Analysis and Numerical Model Forecasts 2. Importance of the Coupling of Tropical Cyclone Outflow Vents with the Environment: Observational and Model Sensitivity Studies
	Daniel Holdaway	NASA, Global Modeling and Assimilation Office	Dynamical Sensitivity Analysis of Weather Forecast Challenges Using the GEOS-5 Adjoint System
	Andrew Collard	NOAA/NCEP/EMC	Assimilation and Forecast Impact of High Temporal Resolution Leo/Geo AMVs in the High-Latitude Data- Gap Corridor
Agnes Lim	Jaime Daniels	NOAA/NESDIS/STAR	Development of Advanced Data Assimilation Techniques for Satellite-Derived Atmospheric Motion Vectors from GOES-16 and 17 in the Hurricane Weather Forecasting Model
Agnes Lim	Jaime Daniels	NOAA/NESDIS/STAR	Development of Advanced Data Assimilation Techniques for Satellite-Derived Atmospheric Motion Vectors from GOES-16

			and 17 in the Hurricane Weather Forecasting Model
	Sudhir Madiga	NOAA/EMC/OBSPROC	
	Shelley Melchior	NOAA/EMC/OBSPROC	
	Li Bi	NOAA/EMC/HWRF	
Agnes Lim	Joe Predina	Logistikos Engineering	Quantifying NCEP's GDAS/GFS Sensitivity to CrIS Detector Differences
Agnes Lim	John LeMarshall	Australian BOM	Development of Advanced Data Assimilation Techniques for Improved use of Satellite-Derived Atmospheric Motion Vectors in Hurricane Forecasting – GOES-R VSP
Jun Li	Andrew Collard	NOAA EMC	Improving CrIS assimilation in cloudy skies
Jun Li	Robert Atlas/Lidia Cucurull	NOAA AOML	OSSE studies on geostationary advanced IR sounder, cubesat infrared and microwave sounder
Jun Li	Zhiquan Liu	NCAR	Improving ABI water vapor information assimilation in regional NWP
Jun Li	Jason Sippel and Mark DeMaria	NOAA National Hurricane Center	Improving JPSS and GOES data assimilation in WRF/HWRF for TC forecast
Jun Li	Chian-Yi Liu	National Center Unversity in Taiwan	Satellite data assimilation in regional and IR/RO applications
Jun Li	Min Min, Di Di, Bo Li, Chunqiang Wu, Xinya Gon, Fenglin Sun	National Satellite Meteorological Center, Beijing, China	New generation of Geostationary Imager and Sounder applications in numerical weather prediction (NWP) and nowcasting
Jun Li	Jung-Rim Lee		Improving ABI radiance assimilation over land in NWP
Jun Li	Professor Byung-Ju Sohn	Korea Meteorological Administration, South Korea National Seoul University, South Korea	Advanced infrared sounder data assimilation, retrieval, and validation
Jun Li	Professor Myoung Hwan Ahn and Dr. Su Jeong Lee	Ewha Womans University South Korea	Legacy atmospheric profile - retrieval, validations, and applications
Jun Li	Yuanfu Xie	NOAA/ESRL	Assimilating cloud cleared CrIS radiances in RAP
Jun Li	Marco Matricardi	ECMWF	An alternative method to quantify the CrIS FSR Non-local Thermal Equilibrium Radiances
	Larrabee Strow	University of Maryland '	

	Sergio DeSouza-Machado	University of Maryland '	
	Manuel Lopez-Puertas	IAA	
Jun Li	Thomas Jones	University of Oklahoma	Assimilating synthetic hyperspectral sounder temperature and humidity retrievals to improve severe weather forecasts
	Steven Koch	Director of NOAA NSSL	
Jun Li	Zhiquan Liu	NCAR	Improving ABI water vapor information data assimilation in Regional NWP
Eva Borbas	Roger Saunders	Met Office, UK	Investigation into angular dependence of IR surface emissivity
Eva Borbas	Roger Saunders	Met Office, UK	Updating the CAMEL surface emissivity atlas for RTTOV
Eva Borbas	Glynn Hulley	NASA JPL	MEaSUREs Unified and Coherent Land Surface Temperature and Emissivity Earth System Data Record (ESDR)
Tristan L'Ecuyer	Brian Drouin, Brian Kahn, and Nicole Jeanne-Schlegel	NASA JPL	The Polar Radiant Energy in the Far-Infrared Experiment (PREFIRE) (NASA EVI-4)
	Jennifer Kay	University of Colorado	
	Xianglei Huang	University of Michigan	
Tristan L'Ecuyer	Margaret Turnbull	SETI	Colors of Planets in Designer Passbands (NASA WFIRST)
Tristan L'Ecuyer	Michael Steele	University of Washington	Advanced Understanding and Modeling of Polar Cloud and Precipitation Processes using CloudSat, CALIPSO, and complementary datasets (NASA CCST)
Tristan L'Ecuyer	Brian Soden	University of Miami	Earth Radiation Budget Observer (ERBO) (NASA EVC-1)
	Ping Yang	Texas A&M	
	Betsy Weatherhead	University of Colorado	
	Christine Chiu	Colorado State University	
Tristan L'Ecuyer	Matthew Rodell, Michael Bosilovich, Hiroko Beaudoing, and Mircea Grecu	NASA GSFC	Global and Regional Energy and Water Variations Under a Changing Climate (NASA NEWS)
	Robert Adler, William Olson, and Guojun Gu	UMBC	
	Seiji Kato	NASA LaRC	

	Ming Pan and Eric Wood	Princeton University	
	Anita Rapp	Texas A&M	
	Jason Roberts and Franklin Robertson	NASA MSFC	
	Sara Zhang	NASA GMAO	
Tristan L'Ecuyer	Steve Cooper	University of Utah	Collaborative Research: Variability in snowfall production and bulk microphysical processes for high-latitude snowfall regions
Xuanji Wang	Xiangdong Zhang	International Arctic Research Center (IARC) of the University of Alaska Fairbanks (UAF)	Impact of Storm Activity on Recent Changes in Arctic Sea Ice Mass Balance
Xuanji Wang	Dr. Ronald Kwok	NASA/JPL	Multisensor and multidecadal sea ice thickness records and their assimilation into Earth system model for understanding climate model biases and sea ice prediction
Xuanji Wang	Dr. Shu Wu	CCR/UW–Madison	Assimilating sea ice products from satellites into Energy Exascale Earth System Model
Jim Jung	Shelley Melchior	NOAA/NCEP/EMC	Support for NPP and JPSS Data Assimilation Improvements and Data Denial Experiments
	Andrew Collard	NOAA/NCEP/EMC	
	Daryl Kleist	NOAA/NCEP/EMC	
	Will McCarty	NASA GSFC	
	Mitch Goldberg	NOAA NESDIS	
	Walter Wolf	NOAA NESDIS	
	John LeMarshall	Australian BOM	
Jim Jung	Mingjing Tony	NCEP/EMC/HWRF	Development of Advanced Data Assimilation Techniques for Improved use of Satellite-Derived Atmospheric Motion Vector
	Jaime Daniels	NOAA/NESDIS/STAR	
	Wayne Bresky	NOAA/NESDIS/STAR	
	Iliana Genkova	NOAA/NCEP/EMC	
	Andrew Collard	NOAA/NCEP/EMC	
	Vijay Tallapragada	NOAA/NCEP/EMC	
Jim Jung	Walter Wolf	NOAA/NESDIS/STAR	Development of GOES-R IR Clear-Sky and All-Sky Radiance Products for NCEP
	Thomas King	NOAA/NESDIS/STAR	
	Haixia Liu	NOAA/NCEP/EMC	
	Chris Burrows	ECMWF	
	Ben Ruston	NRL	
	Haidao Lin	NOAA/ESRL	
Jim Jung	Andrew Collard	NOAA EMC	Compare and Investigate Potential Improvements to the Infrared Cloud Detection Algorithms used by NWP
	Andrew Heidinger	NOAA NESDIS	
	William McCarty	NASA/GMAO	
Micheal Foster	Tony Liao	NOAA/ESRL	CIMSS Support for Development of Himawari-8 Decision Support Products
	Dr. Chia Rong Chen	Taiwanese Central Weather Bureau	

Micheal Foster	Ken Knapp	NOAA/NESDIS/NCEI	Consistent Cloud Thematic Climate Data Records From Historical, Current, and Future +NOAA POES Sensors
Micheal Foster	Merv Lynch	Curtin University - Australia	Cloud Climatology - Curtin University
Micheal Foster	Manajit Sengupta	National Renewable Energy Laboratory	Delivery of Surface Radiation and Meteorological Datasets from Geostationary Satellites
Chris Moeller	Jack Xiong, et. al.	NASA MCST	MODIS Calibration Maintenance
Chris Moeller	Jack Xiong, et. al.	NASA VCST	VIIRS Calibration Maintenance
Chris Moeller	Jim McCarthy	NOAA JPSS DAWG	VIIRS Prelaunch Performance Evaluation
Chris Moeller	Changyong Cao	NOAA/STAR/VIIRS SDR Team	VIIRS SDR Performance
Dave Santek	Jaime Daniels	NOAA NESDIS	Development and Impact of Global Winds from Tandem S-NPP and NOAA-20 VIIRS
	Andrew Collard	NCEP/EMC	
	Regis Borde	EUMETSAT	
Dave Santek	Derek Posselt	NASA JPL	Assimilation of 3D Atmospheric Motion Vectors to Improve Subseasonal Numerical Weather Forecasts
	Will McCarty	NASA GMAO	
Mat Gunshor	Will McCarty	NASA GSFC	Re-calibrating water vapor absorption bands from international geostationary satellites for consistency with IASI
Mat Gunshor	Xiangqian Fred Wu	NESDIS/STAR/SMCD/SCDAB	CIMSS Support for Cal/Val Activities in the NOAA Calibration Working Group
Dave Tobin	Stephen Tjemkes	EUMETSAT	MTG IRS studies
Dave Tobin	Tim Hewison	EUMETSAT	GSICS studies
	Fred Wu	NOAA NESDIS	
Dave Tobin	Dan Mooney	MIT	CrIS studies
	Joe Predina	ITT	
	Farhang Sabet	NGST	
Dave Tobin	Denis Blumstein	CNES	IASI studies
Dave Tobin	Jim Anderson, John Dykema	Harvard University	CLARREO
	Dave Young	NASA Langley	
Scott Lindstrom	Dan Bikos, Bill Line, Jorel Torres, Bernie Connell	CIRA	NOAA VISIT, SHyMet, and other weather satellite training activities
	John Ogren, Brian Motta, Kevin Scharfenberg	NOAA FDTD/ OCLO	
	Bodo Zeschke	Australian BOM	
	Paul Ford, Matt Arkett, Hong Lin	ECCC Canada	
	Bill Ward, Eric Lau	NOAA NWS Pacific Region Headquarters	
	Jordan Gerth	NOAA NWS Observations Team/ NWS SOOs	

	Patrick Dills, Amy Stevemer	COMET	
Justin Sieglaff	Peter Webley	University of Alaska - Fairbanks	Volcanic Ash Detection and Physical Property Retrievals
	David Schneider	USGS/Alaska Volcano Observatory/University of Alaska - Anchorage	
	William Rose	Michigan Technological University	
	Tony Hall	National Weather Service/Alaska Aviation Weather Unit	
Wayne Feltz	Valliappa Lakshmanan	Google	Convective Initiation
Wayne Feltz	Lt Col Kurt Brueske	Raytheon/Retired from Air Force	NOAA GOES-R Proving Ground
	Dr. Marouane Temimi	UAE Masdar University	
	Dr. Russell Schneider	Director NOAA Storm Prediction Center (SPC)	
	Dr. Steven Koch	Director National Storm Prediction Center (NSSL)	Proving Ground
	Dr. David Turner	NOAA ESRL	AERI, NOAA
	Professor		
Chris Velden	Randall Pauley	FNMOC	Support for the operational NAVY satellite winds assimilation effort
Chris Velden	Robert Rabin	NSSL	Use of the CIMSS AMV algorithm for mesoscale winds and applications to severe weather
Chris Velden	Josh Cosseth	DOD NRL-MRY	Navy TC Satellite Support
Chris Velden	Andrew Burton	ABOM	Advanced Dvorak Technique use in the Australian TC region
Chris Velden	Russ Elseberry	Naval PostGrad School	TC case studies using satellite-derived products
Chris Velden	Dr. Chia Rong Chen	Taiwan Central Weather Bureau	ADT operational implementation into CWB
Chris Velden	Jack Beven	NOAA-NHC	Evaluation of operational Advanced Dvorak Technique and AMSU hurricanes intensity algorithms
Chris Velden		NRL-MRY Joint Typhoon Warning Center	Satellite Applications to Tropical Cyclones (NRL project)
Chris Velden	Jason Dunion	NOAA-HRD	Use of satellite products to deduce hurricane behavior
Chris Velden	Michael Turk	NESDIS-SAB	Implementation of the ADT into NESDIS operations (PSDI project)
Allen Huang	Wei Gao	East China Normal University	Research and Dvelopment of a Real-time Air Quality Monitoring and Forecasting System
Allen Huang	Roger Saunders	UK Met Office	Development of GPU based high performance RTTOV
Allen Huang	Peter Wang	Central Weather Bureau, Taiwan	DB CRAS
Allen Huang	Li-Mei Huang	Central Weather Bureau, Taiwan	Satellite Wind data Sets
Allen Huang	Tsengdar Lee	NASA HQ	IMAPP
Allen Huang	John Overton	NOAA IPO	IPOPP
Allen Huang	Mitch Goldberg	NOAA STAR	CIMSS Participation in the GOES-R Algorithm Working Group (AWG)

Allen Huang	Gary Jedlovec	NASA MSFC	UW Cooperative Agreement in Support of NASAS/MSFC Broad Area of Nowcasting and Other Related Activities
Allen Huang	Carl Schoeneberger	Orbital Systems	Dual-band Polar Orbit Satellite Data Receiving, Processing & Analyzing System
Allen Huang	Michael Ropp	Northern Plains Power Technology	Development of the use of satellite based data to predict cloud transients in photovoltaic (PV) systems
Norman Wood	Andy Heymsfield	NCAR	Ice Water Content and Snow rate retrieval research
Norman Wood	Flo Lemonnier	Sorbonne University	CloudSat snowfall rate research
Norman Wood	Lisa Milani	NASA GSFC	CloudSat snowfall rate research
Norman Wood	Mel Nicholls	U of Colorado	NWP Studies
Norman Wood	Lars Norin	Swedish Meteorological and Hydrological Institute	Intercomparison of Snowfall estimates with CloudSat
Norman Wood	Cyril Parlerme	Norwegian Meteorological Institute	Quantifying snowfall on the Antarctic ice sheet
Norman Wood	Gail Skofronick	NASA Goddard	Satellite estimation of falling snow: A Global Precipitation Measurement (GPM) Core Observatory perspectives
Norman Wood	Dave Wolff	NASA Wallops	UW support for NASA PMM GV activities
Chris Schmidt	Ivan Csiszar	NOAA NESDIS	Analysis of long-term fire dynamics and impacts in the Amazon using integrated multi-source fire observations
Chris Schmidt	Dana Sullivan	Sonoma Technology	Applications of WF_ABBA fire products in air quality monitoring and modeling
Chris Schmidt	Sundar Christopher	University of Alabama Huntsville	Applications of WF_ABBA fire products in the RAMS model for aerosol modeling
Chris Schmidt	Valerio Tramutoli	University of Basilicata, Potenza, Italy	Comparison of RST and WF_ABBA with SEVIRI data over Italy
Paul Menzel	Mervyn Lynch	Curtin University, Perth, Australia	Trending Australian cloud properties
Liam Gumley	Jim Gleason	NASA GSFC	NPOESS Preparatory Project Atmosphere PEATE
Liam Gumley	Rich Ullman	NOAA	International Polar Orbiter Processing Package
R. Bradley Pierce	Kevin Bowman	NASA JPL	CrIS/OMPS and TES ozone retrievals in support of the FIREX intensive Campaign (NOAA/NASA)
R. Bradley Pierce	Kelly Chance	Harvard/SAO	Tropospheric Emissions: Monitoring Pollution (TEMPO NASA EVI)
R. Bradley Pierce	Vijay Natraj	NASA JPL	Geostationary Coastal and Air Pollution Events (GEO-CAPE) Regional OSSE Working Group (NASA)
R. Bradley Pierce	Jassim Al-Saadi	NASA/LaRC	Lake Michigan Ozone Study (LMOS) and Long Island Sound Tropospheric Ozone Study (LISTOS)
	Laura Judd	NASA/LaRC	
	Jim Szykman	EPA/ORD	
	Luke Valin	EPA/ORD	
R. Bradley Pierce	Ivanka Stajner	NOAA/EMC	Next Generation Global Prediction System (NGGPS) Science Implementation Plan (SIP) Aerosol and Atmospheric

			Composition Working Group (NOAA)
	Georg Grell	NOAA/ESRL/GMD	
	Ravan Ahmadov	CIRES, University of Colorado	
R. Bradley Pierce	James Crawford	NASA/LaRC	Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER – AQ, NASA EVS)
	Jassim Al-Saadi		
R. Bradley Pierce	Andy Edman	NOAA/NWS	High Resolution Trajectory-Based Smoke Forecasts using VIIRS Aerosol Optical Depth and NUCAPS Carbon Monoxide Retrievals (NOAA/JPSS-PGRR)
	Shobha Kondragunta	NOAA/NESDIS/STAR	
Jason Oktin	Martha Anderson	U.S. Department of Agriculture	Drought Studies
	Chris Hain	NASA GSFC	
	Mark Svoboda	University of Nebraska-Lincoln	
	Eric Hunt	AER	
	Jeffrey Basara	University of Oklahoma	
	Tonya Haigh	University of Nebraska-Lincoln	
	Mark Shafer	University of Oklahoma	
	Jordan Christian	University of Oklahoma	
	Trent Ford	University of Illinois	
	Hanh Nguyen	Australia Bureau of Meteorology	
	Matthew Wheeler	Australia Bureau of Meteorology	
	Benjamin Zaitchik	Johns Hopkins University	
Jason Oktin	Roland Potthast	German DWD	NWP Data Assimilation
	Amos Lawless	University of Reading	
	Jacob Carley	NOAA EMC	
	Daryl Kleist	NOAA EMC	
	Xiaoyan Zhang	NOAA EMC	
	Brian Ancell	Texas Tech University	
	Thomas Jones	University of Oklahoma	
	Xuguang Wang	University of Oklahoma	
	Ralf Bennartz	Vanderbilt University	
	Tom Auligne	JCSDA	
	David Stensrud	Pennsylvania State University	
	Fuqing Zhang	Pennsylvania State University	
	Steve Koch	NSSL	
Jason Oktin	Tara Jensen	NCAR	Numerical Weather Model Verification
	Pat Skinner	University of Oklahoma	
	Greg Thompson	NCAR	
	Sharan Majumdar	University of Miami	
	Brian McNoldy	University of Miami	
	Curtis Alexander	NOAA ESRL	
Jason Oktin	Judith Berner	NCAR	Numerical Weather Model Development
	Fanyou Kong	University of Oklahoma	

Jason Oktin	Zac Adelman	LADCO	Numerical Weather Prediction Modelling
	Gail Good	Wisconsin DNR	
	David Bizot	Wisconsin DNR	
	John Mecikalski	University of Alabama-Huntsville	
	Gene Petrescu	NOAA NWS Alaska Region	
Yafang Zhong	Micheal Notaro	CCR UW–Madison	Evaluating and Advancing the Representation of Lake-Atmosphere Interactions and Resulting Heavy Lake-Effect Snowstorms Across the Laurentian Great Lakes Basin Within the NASA-Unified Weather Research and Forecasting Model. Collaborators
	Christa Peters-lidard	NASA GSFC	
	Micheal Notaro	CCR UW–Madison	Laying the Groundwork for High-Resolution Climate Projections for the Great Lakes Region Using a Convection-Permitting Regional Climate Model Interactively Coupled to a 3D Lake Model
	Jenna Jorns	GLISA, U of Michigan	
	Aslang Geirsdottir	University of Iceland	Integrating paleoclimate reconstructions with modeling to understand abrupt climate change in the northern North Atlantic region
Ralph Petersen	Patricia Pauley	NRL-MRY	Improving the Characterization and Evaluating the Impact of Assimilated Meteorological Observations from Commercial Aircraft
	Nancy Baker	NRL-MRY	
	John Mecikalski	U of Alabama-Huntsville	Fusing Multi-Platform NearCasts with Convective Initiation Products to Improve Nowcasts of Convective Storm Severity
	Thomas August	EUMETSAT	Improving very-short-range forecasts for the NWS Alaska Region using objective tools designed to optimize the retention of Hyperspectral Infrared and Microwave Moisture LEO Soundings - and - Improving the Characterization and Evaluating the Impact of Assimilated Meteorological Observations from Commercial Aircraft
		EUMETSAT NSAF	
	Dean Lockett	WMO Aviation Program	Improving the Characterization and Evaluating the Impact of Assimilated Meteorological Observations from Commercial Aircraft
	Caroline Baine	UK Met Office	Incorporate NearCast system for nowcasting into WMO HIGHWAY program

Appendix G: UW–CIMSS Board of Directors and Science Advisory Council

UW–CIMSS BOARD OF DIRECTORS

CIMSS Board of Directors (Board of Directors) **–** The Board of Directors will consist of senior employees from NOAA and UW–Madison. The Board of Directors shall review the policies, research themes, and priorities of CIMSS, including budget and scientific activities and will also provide for the periodic external review of the scientific activities of CIMSS. The Director of CIMSS or his/her designee shall serve as a non-voting member of the Board of Directors. The NESDIS Cooperative Research Program Director will serve as a special advisor to the Council in an ex officio status.

Steven Ackerman
Interim Associate Vice Chancellor for Research and Graduate Education

Tristan L'Ecuyer
Director, CIMSS

R. Bradley Pierce
Director, Space Science and Engineering Center, UW–Madison

Greg Tripoli
Chair, Department of Atmospheric and Oceanic Sciences, UW–Madison

Steven Volz
Assistant Administrator for Satellite and Information Services, NOAA/NESDIS

Harry Cikanek
Director, Center for Satellite Applications and Research, NOAA/NESDIS

Jeff Key
Chief, Advanced Satellite Products Branch, NOAA/NESDIS

Jack A. Kaye
Assoc. Director for Research, NASA Goddard Headquarters

Peter Hildebrand
Director, Earth-Sun Exploration Division of the Sciences and Exploration Directorate, NASA Goddard Space Flight Center

David F. Young
Director, Science Directorate, NASA Langley Research Center

UW–CIMSS SCIENTIFIC ADVISORY COUNCIL

Science Advisory Council (Science Council) -- The Science Council will advise the CIMSS Director in establishing the broad scientific content of CIMSS programs, promoting cooperation among CIMSS, NOAA, NASA and other agencies, maintaining high scientific and professional standards, and preparing reports of CIMSS activities. All Science Advisory Council members shall be recommended and selected by the Director of CIMSS, in consultation with the Board of Directors. In addition, the Executive Director of SSEC or designee shall be a Council member. Council members shall serve three-year terms. Reappointment is possible for additional three-year terms pending approval by the Board. The number of Council members shall be set by the Board, provided the number of University members equal the total number of agency members. The Director of CIMSS will serve as the Chairperson of the Council. The NESDIS Cooperative Research Program Director will serve as a special advisor to the Council in an ex officio status.

Tristan L'Ecuyer	Director, CIMSS, Professor, UW–Madison Atmospheric and Oceanic Sciences
Jun Li	Distinguished Scientist, CIMSS
Chris Velden	Senior Scientist, CIMSS
Trina McMahon	Professor, UW–Madison Engineering
Annemarie Schneider	Professor, UW–Madison, SAGE
Chris Kummerow	Professor, Department of Atmospheric Science, Colorado State Univ.
Mitch Goldberg	GOES-R Program Scientist, NOAA/NESDIS/ORA
Christopher Brown	Satellite Meteorology and Climate Chief, NOAA/NESDIS/STAR
Steve Platnick	Aqua Deputy Project Scientist, EOS Sr. Project Scientist (acting), NASA Goddard Space Flight Center

Appendix H: UW–CIMSS Graduate Students

1979-1980
Michael Kalb MS (NOAA/NESDIS)
Tony Siebers MS (NOAA/NWS)
Jim Block MS (Private Sector)

1980-1981
Jim Zandlo MS (Private Sector)
Roberta Marshment MS (Private Sector)

1981-1982
George Diak PhD (CIMSS emeritus)
Roy Spencer PhD (NASA/Marshall)
Chris Velden MS (CIMSS)
David Keller MS (U.S. Air Force)

1982-1983
John Bates MS (NOAA/NCDC)
Gin-Rong Liu MS (Taiwan National Univ)

1984-1985
David Donahue MS (NOAA/NESDIS)
Stacey Heikkinen MS (NRL)
Martin Mlynczak MS (NASA/LaRC)

1985-1986
John Bates PhD (NOAA/NCDC)
Allen Huang MS (CIMSS)
Chris Moeller MS (CIMSS)
Craig Burfeind MS (Private Sector)

1986-1987
Louis Garand PhD (Environment Canada)
Gin-Rong Liu PhD (Taiwan National Univ)
Gary Jedlovec PhD (NASA/Marshall)
Fred Wu MS (CIMSS, NOAA/NESDIS)
Maria Perrone MS (Rutgers University)
Tim Schmit MS (NOAA/ASPB)

1987-1988
Nelson Ferreira PhD (INPE, Brazil)
Richard Frey MS (CIMSS)
Arlindo Arriaga MS (EUMETSAT)
Grant Carlson MS (NASA/Marshall)

1988-1989
Hyosang Chung MS (Korea Met Agency)
Laurie Rokke MS (NOAA/GOES Program Office)
Liam Gumley MS (NASA/GSFC, SSEC/CIMSS)
Kurt Brueske MS (U.S. Air Force)
Murty Divakarla MS (Private Sector)
Elaine Prins MS (CIMSS, Private Sector)
Chris Scheuer MS (NASA/LaRC)

1989-1990
Allen Huang PhD (CIMSS)
Fred Wu PhD (CIMSS, NOAA/NESDIS)
Steve Nieman MS (CIMSS, Private Sector)
Walt McKeown MS (Navy)
Hai Yan Zhang MS (CSU)

1990-1991
Arlindo Arriaga PhD (EUMETSAT)
Peter Keehn MS (NASA/GSFC)
Yanni Qu MS (PhD Program)

1991-1992
Robert Purser PhD (NOAA/NCEP)
Kathy Strabala MS (CIMSS)

1992-1993
Daphne Zaras MS (NOAA/NSSL)
Chia Lee MS (CIMSS)
Rongrong Xie MS (NOAA/NESDIS)
Jason Li MS (NASA/GSFC)

1993-1994
Walt McKeown PhD (U. S. Navy)
Gilberto Vicente PhD (NASA, NOAA)
Xiaohua Wu PhD (Univ. of Chicago)
Wayne Feltz MS (CIMSS)
Tim Olander MS (CIMSS)

1994-1995
Yanni Qu PhD (NOAA/NESDIS, Private Sector)
Susan Faust MS (NOAA/NWS)
Lan Ge MS (NOAA/NESDIS)
Ben Ho MS (NASA/LaRC)

1995-1996
Jack Dostalek MS (CSU CIRA)
Nick Nalli MS (NOAA/NESDIS)
Brad Hoggatt MS (Private Sector)
Dan DeSlover MS (CIMSS)

1996-1997
Jay Heinzelman MS (SSEC)
Phil Politowicz MS (Private Sector)

1997-1998

Ben Ho PhD (NASA Langley)
Bormin Huang PhD (CIMSS)
Paul van Delst PhD (CIMSS, NOAA)
Gideon Kinyodah MS (Kenya Met Office)
Rose Shie MS (UW–Madison Computer Science)

1998-1999
Mike Friedman PhD (Oregon State, AMS Headquarters)
William Badini MS (Private Sector)
Jason Dunion MS (NOAA/AOML)
Rhett Grauman MS (NOAA/NWS)
Shaima Nasiri MS (CIMSS and TX A&M)

1999-2000
Erik Olson MS (CIMSS)
Chris Schmidt MS (CIMSS)
Nick Nalli PhD (CIMSS, NOAA)
Bormin Huang PhD (CIMSS)

2000-2001
Nick Bower PhD (from Curtin Univ)
Monica Harkey MS (UW, MATC)
Michael Pavlonis MS (CIMSS, NOAA/ASPB)
Kurt Brueske PhD (Air Force)
Paolo Antonelli PhD (CIMSS)

2001-2002
Howard Berger MS (CIMSS)
Brian Kabat MS (Air Force)
Hong Zhang MS (CIMSS)
Sarah Thomas Bedka MS (NASA/LaRC)

2002-2003
David Turner PhD (PNL, CIMSS, AOS, NOAA NSSL, NOAA GSD/ESRL)
Greg Gallina MS (CIMSS, NOAA/VAC)

2003-2004
Giulia Pannegrossi PhD (Italy)
Greg McGarragh MS (NASA/LaRC)
James Hawkinson MS (CIMSS)
Jason Otkin MS (CIMSS)
Xuanji Wang PhD (CIMSS)
Mark Gray MS (NASA/GSFC)
Xuanji Wang PhD (CIMSS)

2004-2005
Amato Evan MS (CIMSS, UVirginia, Scripps)
Robert Wacker PhD (Air Force)
Fang Wang MS (CIMSS)
Nathan Uhlenbrock MS (CIA)
Shaima Nasiri PhD (TX A&M, DOE)
Michael Mores MS (CIMSS)
Jason Brunner MS (CIMSS)

2005-2006
Robert Holz PhD CIMSS)
Jay Hoffman MS (CIMSS)
Michael Richards MS (FAA, Federal NTSB)

2006-2007
Justin Sieglaff MS (CIMSS)
Brent Maddux MS (CIMSS)
Jessica Staude MS (CIMSS/SSEC)
Richard Dvorak MS (CIMSS)
Yinghiu Lui PhD (NOAA/ASPB)

2007-2008
Alex Harrington MS (Private Sector)
David Santek PhD (CIMSS/SSEC)
Matthew Lazzara PhD (CIMSS/SSEC)

2008-2009
Li Bi PhD (NRL)
Amato Evan PhD (CIMSS, Univ. Virginia)
Zhenglong Li PhD (CIMSS/SSEC)
John Rausch MS (PhD Program)

2009-2010
Utkan Kolat MS (Private Sector)
Mark Kulie PhD (SSEC/NOAA/ASPB)
Chian-Yi Liu PhD (Taiwai Univ)
Chang Hwan Park MS (Korea Met Agency)
Ilya Razenkov MS (SSEC)

2010-2011
Sarah Monette MS (CIMSS/SSEC)
Kathryn Mozer MS (NOAA/OAR)
Mark Smalley MS (PhD Program)
Kenneth Vinson MS (Private Sector)
Timothy Wagner PhD (Creighton/CIMSS)

2011-2012
Jordan Gerth MS (PhD Program)
Michael Hiley MS (CIMSS/Private Sector)
Erik Janzon MS (Uppsala Univ, Sweden)
Nathaniel Miller MS (SSEC)
Kim Na-Young MS (private sector)
John Sears MS (Vermont Environmental Conservation)

Matt Sitkowski PhD (Weather Channel)

2012-2013
Caitlin Hart MS (Exelis/Harris)
Agnes Lim PhD (CIMSS/SSEC)
William Line MS (NOAA/NWS/CIRA)
Alexander Matus MS (PhD Program)
Aronne Merrelli PhD (CIMSS/SSEC)
Jacola Roman MS (PhD Program)

2013-2014
Tracey Dorian MS (UMBC/GSFC)
Jordan Gerth PhD (CIMSS, NOAA/NWS)
Erik Gould MS (Private Sector)
Kyle Nelson MS (FEMA)
Michael Pavolonis PhD (NOAA/ASPB)
Claire Pettersen MS (SSEC)
William Smith, Jr., PhD (NASA LaRC)
Elena Willmot MS (Private Sector)

2014-2015
Michelle Feltz MS (CIMSS/SSEC)
Ethan Nelson MS (PhD Program)
Aaron Letterly MS (CIMSS)
John Rausch PhD (Vanderbilt)
Alexa Ross MS (CIMSS/SSEC)

2015-2016
Amanda Gumber MS (CIMSS/SSEC)
Yun Hang MS (PhD Program)
Kyle Hosley MS NOAA/NESDIS
Xiaowei Jiang MS (NMIC/CMA)
Marian Mateling MS (AOS researcher)
Jacola Roman PhD (NASA JPL)
Mark Smalley PhD (NASA JPL)
Pei Wang PhD (CIMSS/SSEC)
Keiko Yamamoto MS (Kyoto University)

2016-2017
Alyson Douglas MS (PhD Program)
David Loveless MS (PhD Program)
Alex Matus PhD (Private Sector)
Kate Sauter MS (Denver Public Schools)
Skylar Williams MS (OU-CIMMS)
Brian Zimmerman MS (PhD Program)

2017-2018
Momodou Bah MS (CIMSS)
Ethan Nelson PhD (NASA JPL/CIMSS)
Claire Pettersen PhD (SSEC)
Anna Sienko MS
Anne Sledd MS (PhD Program)
Joshua Weber MS (CIRA)

2018-2019
Austin Dixon MS (Univ. of Oklahoma PhD Program)
Ashtin Massie MS
Coda Phillips MS (SSEC)
Julia Shates MS (PhD Program)
Charles White MS (PhD Program)

2019-2020
Kai-Wei Chang PhD (Texas A&M)
Elin McIlhattan PhD
Juliet Pilewskie MS (PhD Program

Appendix I: Research to Operation Contributions to GOES-R (16-17) and JPSS/Suomi NPP Series Meteorological Satellite Products within NOAA Operation Centers from UW–CIMSS

GOES/JPSS IR/Microwave Derived Products in NOAA/NESDIS Operations or Used Operationally within NWS from UW–CIMSS

Automated Dvorak Technique Hurricane Intensity Estimation
Clear Sky Masks
Cloud and Moisture Imagery
Cloud Cover Layers
Cloud Optical Depth
Cloud Particle Size Distribution
Cloud Top Height
Cloud Top Phase
Cloud Top Pressure
Cloud Top Temperature
Community Satellite Processing Package
- Geostationary (NWS and International)
- Low Earth Orbit (NESDIS/International)

Cryosphere Ice/Snow Detection
Derived Motion Winds
Derived Atmospheric Stability Indices
Fire/Hot Spot Intensity and Areal Characterization
Fog and Low Stratus (FLS) automatic detection
JPSS Environmental Data Products and Risk Reduction
- Active Fires
- Aerosols
- Burn Scar Detection
- Clouds
- Cryosphere (Ice/Snow)
- NUCAPS
- Polar Winds
- River Flood Detection
- Snowfall Rates

JPSS Sensor Data Record (SDR)
- Cross-track Infrared Sounder (CrIS)
- Visible Infrared Imaging Radiometer Suite (VIIRS)

Lake Effect Snow (Great Lake) Detection
Morphed Integrated Microwave Imagery (MIMIC) for Total Precipitable Water
Morphed Integrated Microwave Imagery (MIMIC) for Tropical Cyclones
ProbSevere – Automatic tracking of convective cell likely to produce severe weather at surface
Ozone
Total Precipitable Water
Turbulence – Automated commercial aircraft turbulence probability via GOES-R series satellites
Vertical Atmospheric Moisture Profiles
Vertical Atmospheric Temperature Profiles
Volcanic Ash Detection, Height and Loading

Appendix J: SSEC-CIMSS Participation in Field Programs

	Satellite Instrument Designs, Studies, Research, & Cal Val	Instrument & Subsystem Developments	Field Programs
1979	HIS for GOES Sounding		
1980			
1981			
1982			
1983		HIS ER-2 Instrument [1983-5]	
1984			
1985			
1986			Kitt Peak; COHMEX, SE US; FIRE 1, Wisconsin – HIS
1987	GHIS, GOES Mod –to replace filter wheel with FTS		
1988			GAPEX, Denver – Uplooking HIS
1989	GAP, Geo for EOS Trace Gas Sounding		
1990	ITS, Interferometer Sounder, EUMETSAT (led study effort, formed basis for)	AERI Groundbased system for DOE ARM Program [1990-6] Marine AERI [1995-7] Scanning HIS smaller aircraft instrument for UAW, ER2, DC8, WB-57 [1996-8] NAST-I Aircraft inst. For NPOESS Program [1997-8] GIFTS On-board Calibration Subsystem [2001-2005] SSEC Absolute Temperature Calibration Demonstration Using Miniature Phase Change Cells (IR&D Program)/NAST-I/S-HIS/AERI	
1991			CaPE/SERON, SE US; FIRE 2 Kansas – HIS, SPECTRE – AERI
1992			STORMFEST, SGP – HIS, AERI
1993			CAMEX 1, Atlantic Coast – HIS, AERI
1994	Small FTS for NASA New Millennium Program		ASHOE, New Zealand – HIS
1995			Gulf of Mexico – HIS, AERI; CAMEX 2 – HIS
1996			SUCCESS, SGP – HIS; CSP, TWP-AERI
1997	IMG Cal/Val Geo Imaging FTS Sounders, currently GIFTS (NASA LaRC lead, Utah State University sensor module) AIRS Cal/Val		WINCE, Wisconsin – HIS, AERI; FIRE 3, Alaska – HIS; SHEBA – AERI
1998			Wallops ’98 – NAST, HIS; CAMEX 3, Atlantic/Gulf – NAST (ER2) SHIS (DC8); NOAA K, Dryden – SHIS (ER2); AERI
1999			WINTEX, Wisc (ER2) – NAST, SHIS, AERI; KWAJEX, Kwajalein – SHIS DC8); Wallops ’99 – NAST, Intessa
2000			SAFARI, S Africa – SHIS (ER2); AFWEX, SGP – NAST (Proteus); SHIS (DC8); WISC-T2000, Wisconsin – SHIS (ER2)

2001	CrIS EDU Characterization		Texas-2001 – SHIS (ER2); Trace-P, Pacific Rim – NAST (Proteus) CLAMS, NASA Wallops – SHIS (ER2), NAST (Proteus)
2002	Atmospheric Water Vapor Distribution – Convection Research		International H2O Project Oklahoma / Kansas, US
2002	AIRS/MODIS Cal/Val		TX-2002 – San Antonio, TX/Lamont, OK
2002	TES Cal/Val GIFTS EDU Characterization		IHOP – SHIS (ER2); NAST (Proteus); CRYSTAL, NAST (Proteus)
2003			THORPEX – SHIS and NAST (ER2); MAINE - SHIS and NAST (ER2)
2004			MPACE – SHIS and NAST; Alaska TAMDAR – AERIbago; Memphis, TN
2005			TAMDAR – AERIbago; Memphis, TN WVSS-II – AERIbago Louisville, KY AVE – SHIS Oklahoma
2006	GIFTS/AERI Uplooking Cal Val	GIFTS Development	NASA CR-AVE SHIS Oklahoma
2006	GIFTS/AERI Uplooking Cal Val	GIFTS Development	GIFTS Engineering Design Unit Campaign, Logan, UT
2007	AIRS/IASI Cal/Val	S-HIS on NASA WB57	NPOESS JAIVEx Houston, TC4
2007-2015	NASA IIP CLARREO IR Instrument Design Support	CLARREO Advanced Technology Developments: On-orbit Absolute Radiance Source (OARS) & Calibrated FTS	Absolute Radiance Interferometer (ARI) Sensor development and Testing in Thermal Vacuum
2008	Air Quality Model forecast Support	RAQMS forecast support	NOAA ARCPAC - IPY
2008	Weather Satellite Aircraft Decision Support for Synoptic Data Need Decisions		THORPEX T-PARC
2009	Future GEOCAPE Cal/Val Activity	AERI Thermodynamic Retrievals	GEOCAPE Pre-Validation Deployment – AERIbago Virginia
2009	Validation of Aircraft Water Vapor Profiles Measured from Laser Diodes	Improvement in NWP Data Assimilation Quality Control	Water Vapor Sensing System-II - AERIbago Louisville, KY
2010	Satellite-based Tropical Forecast Support	GOES-R/JPSS Satellite Algorithms	PREDICT Atlantic Basin
2010	Air Quality Model Forecast Support	RAQMS Forecast Support	NOAA CalNex California

2011	GOSAT TIR Cal/Val	S-SHIS on NASA ER-2 Surface Scanning AERI	JAXA GOSAT Railroad Valley, Nevada CO2 from Space
2012	Satellite and Air Quality Model Forecast Support	RAQMS Forecast Support	NSF DC3 Alabama/Oklahoma
2012	Satellite and Air Quality Model Forecast Support	HSRL lidar within GV	NSF TORERO Costa Rica/Chile
2012-2014	NASA Hurricane Research	S-HIS on NASA Global Hawk UAV	NASA HS3 Atlantic Ocean
2013	Suomi NPP SDR Cal/Val for CrIS, ATMS and VIIRS	S-HIS on NASA ER-2 Surface-AERI in Arizona	Suomi SNPP CAL/Val Baja California/ Arizona/ Eastern Pacific Ocean
2013	GOES-R Cal/Val Demonstration	HSRL lidar at Huntsville, AL	NASA SEAC^{4}RS
2013	GOSAT TIR T, WV, CO2 Validation	Radiosonde at Park Falls, WI	GOSAT Cal/Val
2014	Air Quality Model Forecast Support	RAQMS Forecast Support	NSF CONTRAST Guam
2014	Satellite product support for WB-57 aircraft flight paths		ONR TCI Atlantic Ocean
2014	Air Quality Forecast Support and Research	AERI/HSRL/SPARC trailer	NSF FRAPPE and NASA DISCOVER AQ, Colorado
2014	Lake Snow Effect Experiment	Ground based Radar and in-situ frozen precipitation measurements	Marquette, Michigan Enhance Snow Observation Suite Field Campaign
2015	JPSS SDR/EDR Cal/Val for CrIS, ATMS, and VIIRS	S-HIS on NASA ER-2 and RAQMS forecast support	Greenland Suomi-NPP CAL/VAL
2015	MCC Convective Research in Great Plains	AERI/HSRL/Wind Lidar/SPARC trailer	PECAN Great Plains, USA
2015	Satellite product support for Global Hawk and WB-57 aircraft	SSEC/CIMSS Satellite Real-time Convective/Turbulence Decision Support	ONR TCI, NOAA SHOUT Atlantic Ocean
2015	Combined HSRL and Raman lidar Measurement Study (CHARMS)	AERI/HSRL/Wind Lidar/SPARC trailer	Southern Great Plains, DOE ARM, Lamont, OK
2016	GOES-16 PLT (Post Launch Test) Campaign ER-2	S-HIS Deployment on ER-2	Palmdale CA and Warner Robins AFB GA
2015-2016	Satellite product support for Global Hawk aircraft decision support flight routes		NOAA SHOUT Atlantic Ocean
2017			NOAA EPOCH Atlantic and Eastern Pacific Oceans
2017	NASA/EPA/NOAA/NSF/LADCO^2 Lake Michigan Ozone Study (LMOS)	AERI/HSRL/Wind Lidar/SPARC trailer ER-2 S-HIS Aircraft	Lake Michigan Ozone Experiment, Sheboygan, WI

2017	Land Atmosphere Feedback Experiment (LAFE), Land Surface Chemistry Flux Exchange Research	AERI/HSRL/Wind Lidar/SPARC trailer	Southern Great Plains, DOE ARM, Lamont, OK
2018	Satellite Based Ozone Weather Satellite Detection Decision Support	NOAA ASPB/CIMSS Aerosol and Weather Satellite Fire Detection Decision Support	NASA/EPA/NOAA/NESCAUM[1] Long Island Sound Tropospheric Ozone Study (LISTOS)
2018-19	Green Bay/Lake Michigan Ocean Color Satellite Cal/Val	CE-318 sun-photometer and water surface reflectance	AERONET-OC (AErosol RObotic NETwork Ocean Color)
2019	Ecosystem Energy-Balance Flux Study Research	AERI/HSRL/SPARC trailer	Chequamegon Heterogeneous Ecosystem Energy-balance Study Enabled by a High-density Extensive Array of Detectors (CHEESEHEAD) Park Falls, WI
2019	Fire Influence Research on Regional to Global Environments Experiments	CIMSS Aerosol and Weather Satellite Fire Detection Support	NASA/NOAA Fire Influence on Regional to Global Environments Experiment - Air Quality (FIREX-AQ)

Appendix K: CIMSS Publications in 2019

Books

Goodman, S. J., T. J. Schmit, J. M. Daniels, R. J. Redmon, 2019: *The GOES-R series: a new generation of geostationary environmental satellites*, Elsevier, 283 pp. *Chapter leads at CIMSS (in bold caps) and contributors below:

Aaron Letterly, Allen Huang, Andi Walther, **ANDREW HEIDINGER**, Bill Bellon, **CHRIS SCHMIDT**, **CHRISTOPHER VELDEN**, CIMSS, Corey Calvert, Dave Stettner, Denis Botambekov, Elaine Prins, GOES- Algorithm Working Group and GOES-Risk Reduction Programs and CIMSS, GOES-R Program Support at CIMSS, Graeme Martin, Hong Zhang, Jason Brunner, Jay Hoffman, Jean Phillips, **JEFFREY KEY**, Jim Nelson, John Cintineo, Joleen Feltz, Jordan Gerth, JUN LI, Justin Sieglaff, Kaba Bah, Mathew Gunshor, **MICHAEL PAVOLONIS**, Richard Dworak, Sarah Griffin, Scott Bachmeier, Scott Lindstrom, Sharon Nebuda, SSEC Data Center, Steve Wanzong, Tim Olander, **TIM SCHMIT**, **W. PAUL MENZEL**, William Straka, III, Xuanji Wang, Yinghui Liu, Yong-Keun Lee, Zhenglong Li, SSEC Data Center

Peer-Reviewed Papers

Anthes, R. A., M. W. Maier, S. Ackerman, R. Atlas, L. W. Callahan, G. Dittberner, R. Edwing, P. G. Emch, M. Ford, W. B. Gail, M. Goldberg, S. Goodman, C. Kummerow, T. Onsager, K. Schrab, C. Velden, T. Vonderhaar, and J. G. Yoe, 2019: Developing priority observational requirements from space using multi-attribute utility theory. *Bulletin of the American Meteorological Society*, **100,** 1753-1773, https://doi.org/10.1175/BAMS-D-18-0180.1.

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Walsh, K. J. E., S. J. Camargo, T. R. Knutson, J. Kossin, T.-C. Lee, H. Murakami, and C. Patricola, 2019: Tropical cyclones and climate change. *Tropical Cyclone Research Review*.

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Appendix L: CIMSS Bibliometric Analysis 2010-2019

About this Report
This report presents a bibliometric analysis of peer-reviewed publications by authors affiliated with the NOAA Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin–Madison. In the report we have analyzed and categorized scholarly publishing of CIMSS authors according to total productivity, quality (including impact factor and citations), national and international collaborations, and research topics.

Since 1995, the Schwerdtfeger Library Publications Database has served as the source for publications totals that are included in CIMSS annual reports to NOAA. Data are harvested from the Web of Science Core Collection (WoS), Science Citation Index Expanded through routine author searches. Institutional affiliation was not used as a search method in WoS as this method, for CIMSS, currently under-reports author productivity.

Please direct questions about this report to jean.phillips@ssec.wisc.edu.

Scholarly Productivity

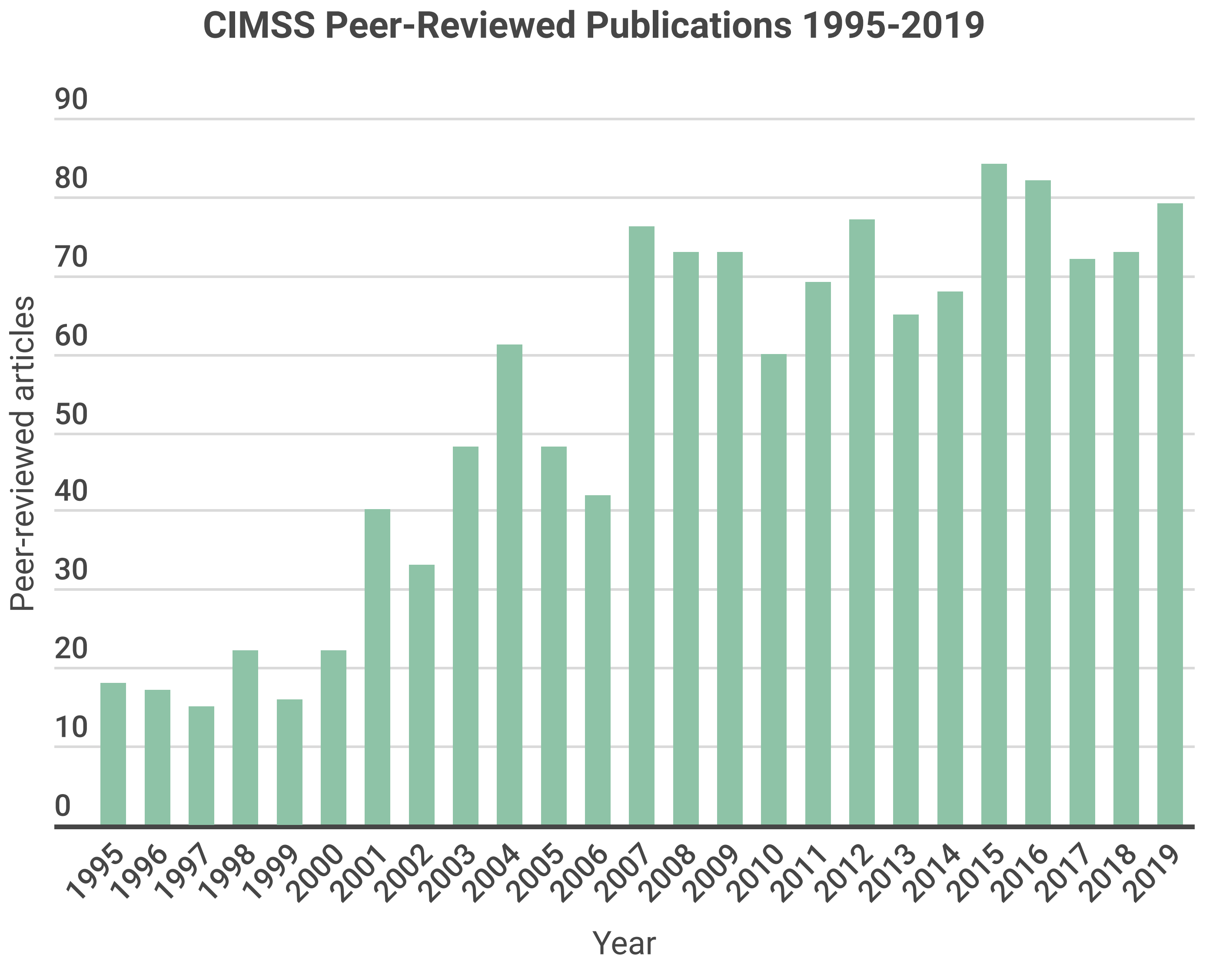

Figure 1 represents the number of peer-reviewed publications by CIMSS authors for the period 1995-2019 during which CIMSS authors published 1333 articles. For the period covering the last cooperative agreement, 2010-2019, CIMSS authors published 729 peer-reviewed papers.

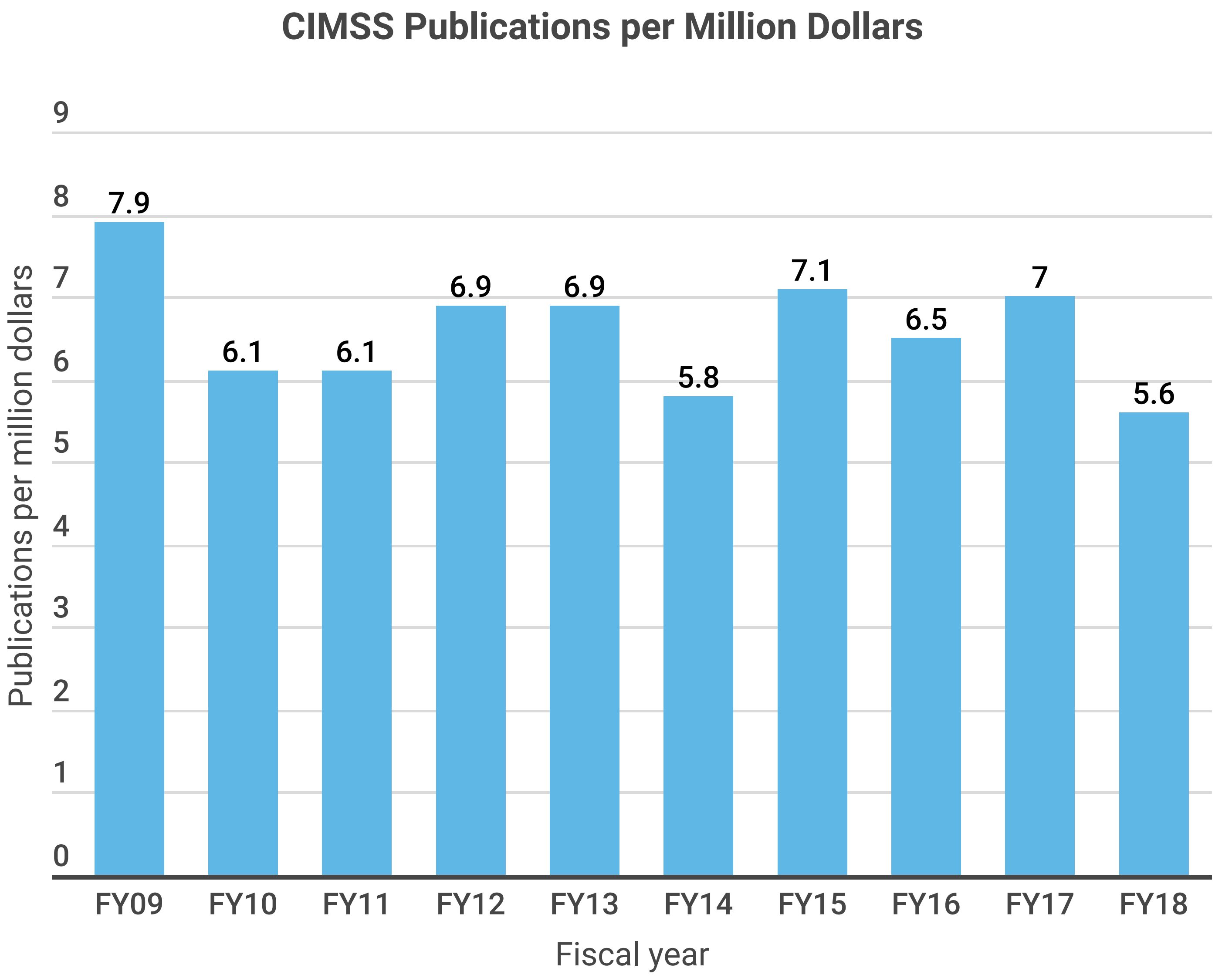

Figure 2 shows CIMSS scholarly output in terms of publications per million dollars for FY2009 through FY2018. Note: Publications are reported on a calendar year basis and budget information is presented for each fiscal year. Budget information for CIMSS was obtained from the Space Science and Engineering Grants Office. Publications with more than one CIMSS author are counted once.

Quality

Top CIMSS Journals by Impact Factor 2010-2019

Journal	Number of articles	Impact factor
Bulletin of the American Meteorological Society	76	8.166
Atmospheric Chemistry and Physics	31	5.668
Journal of Climate	26	4.805
Remote Sensing	30	4.118
Journal of Geophysical Research-Atmospheres	113	3.633
Atmospheric Measurement Techniques	23	3.4
IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	30	3.392
Monthly Weather Review	34	3.146
Journal of Applied Meteorology and Climatology	58	2.364
Weather and Forecasting	31	2.288

Figure 3 highlights the journals in which CIMSS authors published most frequently during the period 2010-2019, along with their respective impact factors based on 2018 data from InCites Journal Citation Reports, JCR (by Thomson Reuters). The Journal Impact Factor is defined as all citations to the journal in the current JCR year to items published in the previous two years, divided by the total number of scholarly items (these comprise articles, reviews, and proceedings papers) published in the journal in the previous two years. Though not a strict mathematical average, the Journal Impact Factor provides a functional approximation of the mean citation rate per citable item. A Journal Impact Factor of 1.0 means that, on average, the articles published one or two years ago have been cited one time. A Journal Impact Factor of 7.8 means that, on average, the articles published one or two years ago have been cited nearly eight times.

CIMSS Most Highly Cited Papers

Total citations	CIMSS Authors*	Title	Journal	Year
1108	Ackerman, S. A.; Menzel, W. P.; Baum, B. A.; Frey, R. A.	The MODIS cloud products: Algorithms and examples from Terra	IEEE Transactions on Geoscience and Remote Sensing	2003
880	Revercomb, H.; Smith, W. L.	AIRS/AMSU/HSB on the aqua mission: Design, science objectives, data products, and processing systems	IEEE Transactions on Geoscience and Remote Sensing	2003
792	Key, J. R.	Role of land-surface changes in Arctic summer warming	Science	2005
685	Ackerman, S. A.; Strabala, K. I.; Menzel, W. P.; Frey, R. A.; Moeller, C. C.; Gumley, L. E.	Discriminating clear sky from clouds with MODIS	Journal of Geophysical Research-Atmospheres	1998
638	Menzel, W. P.	Remote-sensing of cloud, aerosol, and water-vapor properties from the moderate resolution imaging spectrometer (MODIS)	IEEE Transactions on Geoscience and Remote Sensing	1992
636	Menzel, W. P.; Ackerman, S. A.	Cloud and aerosol properties, precipitable water, and profiles of temperature and water vapor from MODIS	IEEE Transactions on Geoscience and Remote Sensing	2003
463	Ackerman, S. A.	The CALIPSO mission: a global 3D view of aerosols and clouds	Bulletin of the American Meteorological Society	2010
408	Revercomb, H.; Smith, W. L.; Tobin, D.	Improving weather forecasting and providing new data on greenhouse gases	Bulletin of the American Meteorological Society	2006
354	Velden, C. S.	The impact of the Saharan air layer on Atlantic tropical cyclone activity	Bulletin of the American Meteorological Society	2004
345	Prins, E. M.; Menzel, W. P.	Potential global fire monitoring from EOS-MODIS	Journal of Geophysical Research-Atmospheres	1998
333	Smith, W. L.; Woolf, H. M.; Hayden, C. M.	TIROS-N operational vertical sounder	Bulletin of the American Meteorological Society	1979

Total citations	CIMSS Authors	Title	Journal	Year
319	L'Ecuyer, T.	CloudSat mission: Performance and early science after the first year of operation	Journal of Geophysical Research-Atmospheres	2008
311	Revercomb, H. E; Howell, H. B.; Smith, W. L.	Radiometric calibration of IR Fourier-transform spectrometers: solution to a problem with the high-resolution interferometer sounder	Applied Optics	1988
290	L'Ecuyer, T.	An update on Earth's energy balance in light of the latest global observations	Nature Geoscience	2012
283	L'Ecuyer, T.	Dreary state of precipitation in global models	Journal of Geophysical Research-Atmospheres	2010
279	Otkin, J. A.	A climatological study of evapotranspiration and moisture stress across the continental United States based on thermal remote sensing: 1. Model formulation	Journal of Geophysical Research-Atmospheres	2007
271	Menzel, W. P.	Introducing GOES-I: The first of a new generation of geostationary operational environmental satellites	Bulletin of the American Meteorological Society	1994
267	Schmit, T. J.; Gunshor, M. M.; Menzel, W. P.; Li, J.; Bachmeier, A. S.	Introducing the next-generation Advanced Baseline Imager on GOES-R	Bulletin of the American Meteorological Society	2005
250	Menzel, W. P.	Eight years of high cloud statistics using HIRS	Journal of Climate	1999
246	Ackerman, S. A.; Liu, Y.; Strabala, K. I.; Key, J. R.	Cloud detection with MODIS. Part I: Improvements in the MODIS cloud mask for collection 5	Journal of Atmospheric and Oceanic Technology	2008

Figure 4 shows the top 20 most highly cited, peer-reviewed papers by CIMSS authors. The total number of citations provides an indication of quality as evaluated by the author's and institution's scientific peers. Of note: Citation counts generally depend on time, that is, citation counts will increase with time, and there may be further differences by discipline, depending on volume of papers published. (See: NOAA Technical Memorandum OAR PPE-4: doi:10.7289/V5WM1BBC)
*CIMSS authors may be first author or co-author. External authors have been removed for clarity

Collaborations

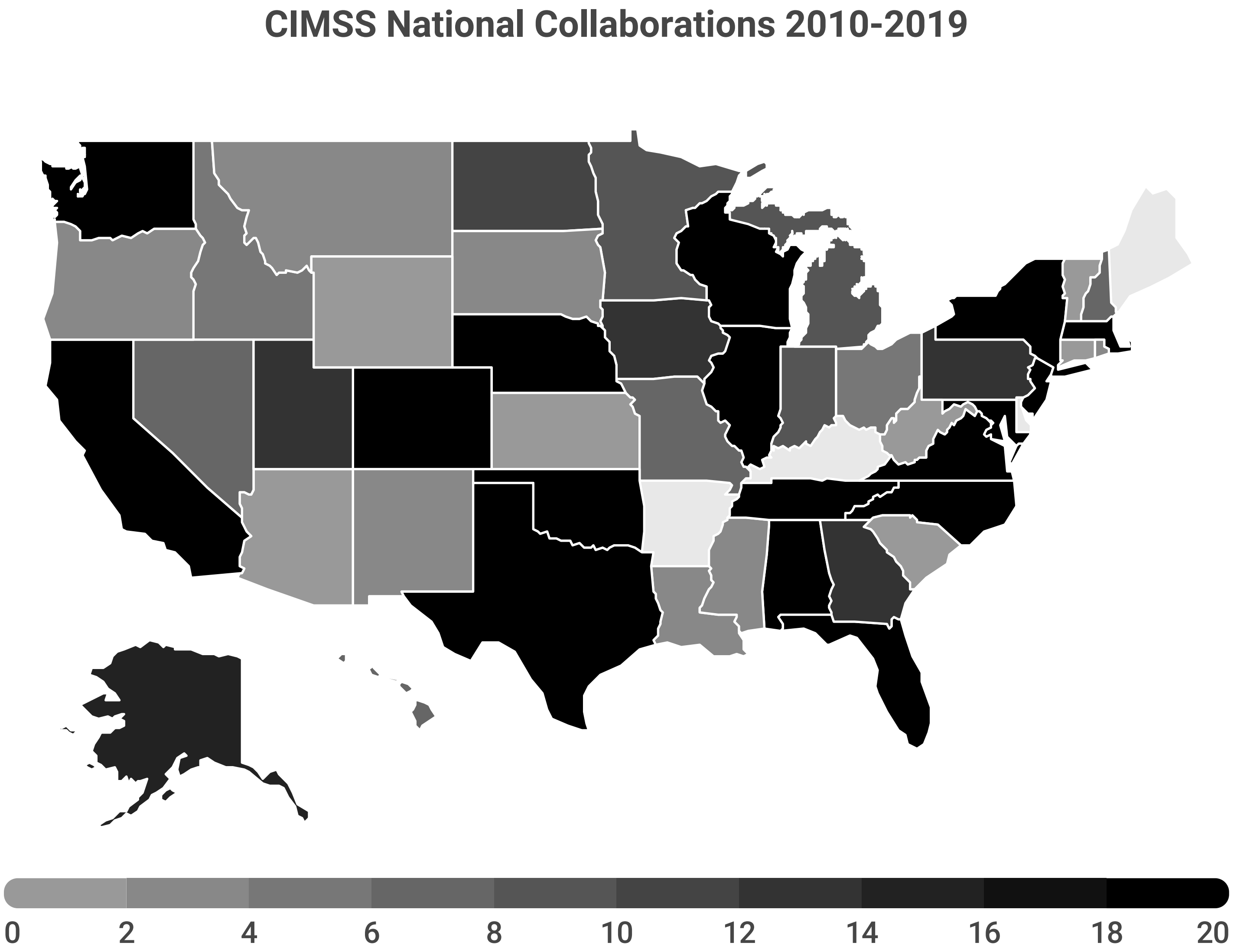

Figure 5 shows CIMSS collaborators across the United States for the period 2010-2019. Collaborator – or co-author -- data were extracted from WoS addresses and grouped by state. If more than one author shared the same address, they were counted once per the address listing in WoS. Grouping 20 includes 20 or more collaborations. The top collaborations are: California, 207; Wisconsin, 246; Colorado, 307; Maryland, 393.

CIMSS International Collaborations 2010-2019

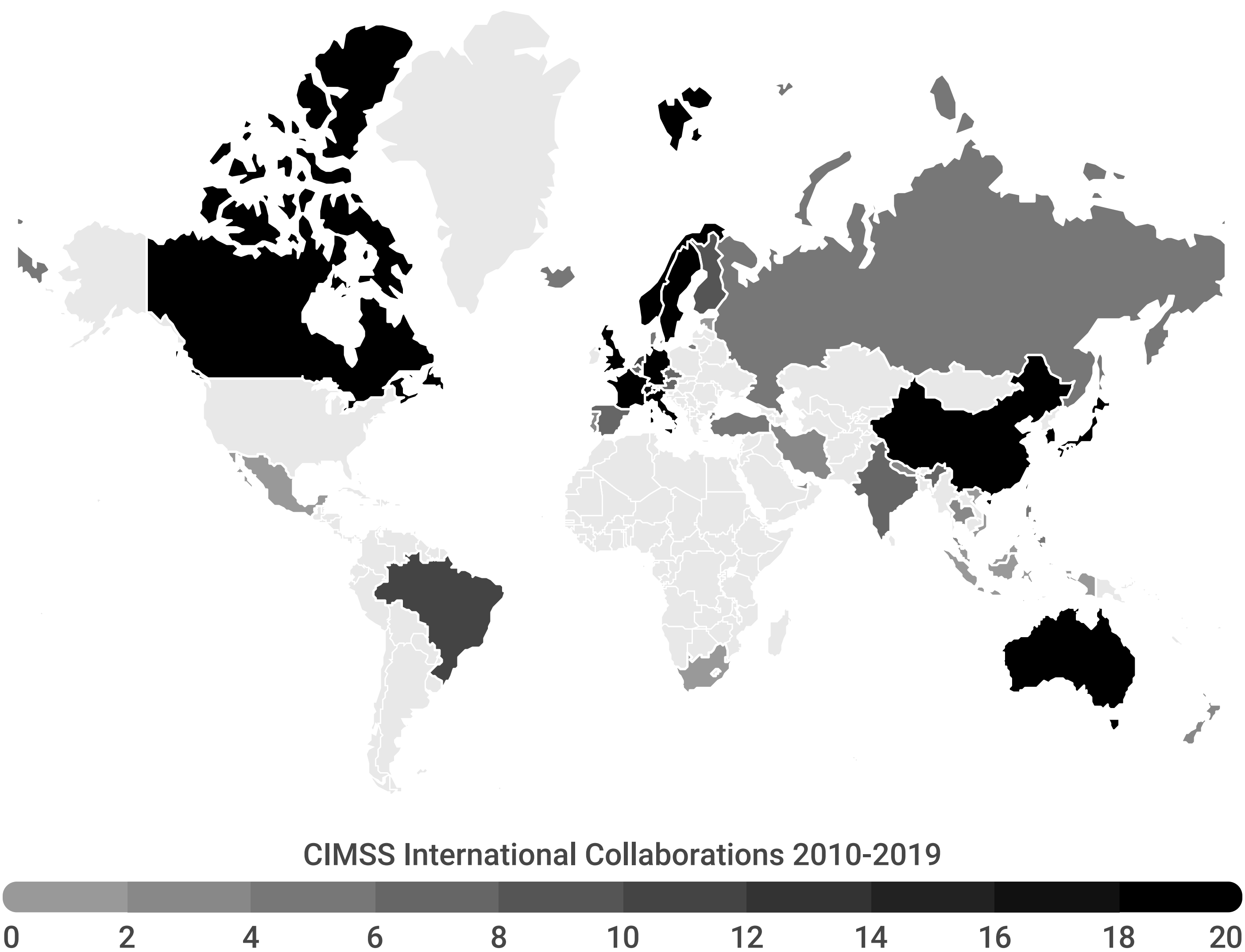

Figure 6 shows CIMSS international collaborations for the period 2010-2019. Collaborator – or co-author -- data were extracted from WoS addresses and grouped by country. If more than one author shared the same address, they were counted once per the address listing in WoS. The most collaborations occurred with: France, 69; United Kingdom, 74; Germany, 80; China, 137.

Appendix M: CIMSS Awards

2019

Jordan Gerth
National Weather Association's Larry R. Johnson Special Award

Shane Hubbard
Hurricane Dorian Achievement of Excellence

Jeff Key
NOAA Bronze Medal for Scientific/Engineering Achievement

Scott Lindstrom
National Weather Association's Larry R. Johnson Special Award

Paul Menzel
Yuri Gagarin Medal for contributions to environmental satellite applications, research and training

Margaret Mooney
Earth Science Information Partners (ESIP) 2019 Catalyst Award

Timothy Schmit
AMS Fellow

David Tobin
University of Wisconsin–Madison Distinguished Scientist

2018

Bob Holz
Permanent Principal Investigator, UW–Madison

Allen Huang
Chair, Asia-Oceania Meteorological Satellite Users Conference (AOMSUC)

Margaret Mooney
UW–Madison Robert and Carroll Heideman Award for Excellence in Public Service and Outreach

Tim Schmit
Finalist, Samuel J. Heyman Service to America Award

David Tobin
Permanent Principal Investigator, UW–Madison

Christopher Velden
American Meteorological Society Banner I. Miller Award

Tom Whittaker
STAC Distinguished Scientific/Technological Accomplishment and Outstanding Service Award

2017

SSEC/CIMSS
GOES-R Team Award
NASA 2017 Agency Honor Award
Group Achievement Award

Steven Ackerman
New Library World Highly Commended Award

Jim Kossin
NESDIS Award for Outstanding Science & Data Management

AMS Editor's Award

Margaret Mooney

New Library World Highly Commended Award

Hank Revercomb

Elected AMS Fellow

Tim Schmit

NOAA Administrator's and Technology Transfer Award

NOAA Administrator's Award

William Straka

JPSS Program Office Extra Mile Award

David Tobin

2017 Chancellor's Award for Excellence in Research

2016

Jim Kossin

NOAA NCEI Special Act Award

Allen Lenzen

NOAA-CIMSS Collaboration Award

Jun Li

Distinguished Scientist prefix

Leigh Orf

IDC High Performance Excellence Award

Michael Pavolonis

AAS Earth Science and Applications Award

Earth Science and Applications Award

Brad Pierce

NOAA Administrator's Award

William L. Smith

Losey Atmospheric Sciences Award

2015

Bob Aune

STAR Recognition for 25 Years of Government Service

Fred Best

NASA Langley 2015 H.J.E. Reid Award

Jessica Gartzke

Reid Bryson Undergraduate Scholarship

Sarah Griffin

AMS Special Award for CIMSS Tropical Cyclones website

NASA Group Achievement Award

Derrick Herndon

AMS Special Award for CIMSS Tropical Cyclones website

NASA Group Achievement Award

Bob Holz

NASA Langley 2015 H.J.E. Reid Award

Bob Knuteson

NASA Langley 2015 H.J.E. Reid Award

Jim Kossin

Department of Commerce Bronze Medal Award

Mark Kulie

NASA Group Achievement Award

NASA RHG Exceptional Achievement Awards for Science Teams

Jun Li

UW–Madison Chancellor's Award for Excellence in Research

Margaret Mooney

AMS Distinguished Educator Award

Tim Olander

AMS Special Award for CIMSS Tropical Cyclones website

Mike Pavolonis

NOAA David Johnson Award

Brad Pierce

STAR Recognition for 25 Years of Government Service

Hank Revercomb

NASA Langley 2015 H.J.E. Reid Award

John Sears

AMS Special Award for CIMSS Tropical Cyclones website

NASA Group Achievement Award

Walter Sessions

NASA Group Achievement Award

Bill Smith

NASA Langley 2015 H.J.E. Reid Award

Dave Stettner

AMS Special Award for CIMSS Tropical Cyclones website

Larry Stromovsky

Elsevier, Icarus Outstanding Reviewer Status

Dave Tobin

NASA Langley 2015 H.J.E. Reid Award

Chris Velden

AMS Special Award for CIMSS Tropical Cyclones website

NASA Group Achievement Award

AMS STAC Committee on Satellite Meteorology Award

Steve Wanzong

AMS Special Award for CIMSS Tropical Cyclones website

Tony Wimmers

AMS Special Award for CIMSS Tropical Cyclones website

2014

Steve Ackerman

Colorado State University's Atmospheric Science Outstanding Alumni Award

AMS Fellow

Wayne Feltz

University of Wisconsin Police Chief's Award

Committee on Academic Staff Issues Certificate of Appreciation

Jim Kossin

NOAA Administrator's Award

Tim Schmit
U.S. Department of Commerce Gold Medal
Chris Velden
WMO THORPEX Certificate of Appreciation

2013

Steve Ackerman
AMS Fellow
Wayne Feltz
Certificate of Appreciation from UW–Madison
Bormin Huang
SPIE Fellow
Tim Schmit
U.S. Department of Commerce Silver Medal
Dave Tobin
Appointed to International Radiation Commission

2012

Steve Ackerman
National Weather Service Spaceflight Meteorology Group Certificate
Bryan Baum
NASA/NOAA Certificate of Recognition
Rich Frey
NASA/NOAA Certificate of Recognition
Tommy Jasmin
NASA/NOAA Certificate of Recognition
Chair of the Earth Science Information Partners Geospatial Committee
Jun Li
Certificate of Recognition for Suomi NPP satellite system
Zhenglong Li
Certificate of Recognition for Suomi NPP satellite system
Christopher Moeller
NASA Group Achievement Award
Hank Revercomb
NASA/NOAA Certificate of Recognition
Tom Rink
NASA/NOAA Certificate of Recognition
Dave Tobin
NASA/NOAA Certificate of Recognition
Chris Velden
UW Chancellor's Award for Excellence in Research
Xuanji Wang
NASA/NOAA Certificate of Recognition
Tom Whittaker
Appreciation for Service as Co-chair of Committee on Environmental Information Processing Technology

2011

Steve Ackerman
Fellow of the Wisconsin Academy of Science Arts and Letters
Jordan Gerth
Wisconsin Space Grant Consortium Graduate Fellowship Award
Andrew Heidinger
NOAA Employee of the Month
James Kossin
NOAA Office of Oceanic and Atmospheric Research's Gold Medal
Mike Pavolonis
NOAA Employee of the Month
Tim Schmit
Department of Commerce Silver Medal
Theodore Fujita Research Achievement Award

2010

Thomas Achtor
UW–Madison Police Department Community Service Award
Steven Ackerman
NASA Exceptional Public Service Medal
Scott Bachmeier
NOAA Team Member of the Month
NESDIS Team Member of the Month
Wayne Feltz
UW–Madison Police Department Community Service Award
Jordan Gerth
Wisconsin Space Grant Fellowship Award
Andrew Heidinger
Department of Commerce Bronze Medal
Michael Pavolonis
Department of Commerce Bronze Medal

Appendix N: Data Center

N.1 Realtime Data Ingest

Geostationary	Sub-Point	Reception Method	Source	Latency	Daily Volume
GOES-16	75.2° West	L-Band	DB	<10 seconds	130-400 GB
GOES-13/14	141°/104º West	L-Band	DB	<2 minutes	23 GB
GOES-15	128.5° West	L-Band	DB	<2 minutes	23 GB
GOES-17	137ºWest	L-Band	DB	<10 seconds	130-400 GB
Meteosat-11	0° East	Network Relay	NOAA STAR	~30 minutes	24 GB
Meteosat-8	41.5° East	Network Relay	NOAA STAR	~30 minutes	24 GB
Himawari-8	140° East	Network Relay	NOAA STAR ABOM (backup)	~ 10 minutes	300 GB
Himawari-8	140° East	Himawari Cast Network Relay	Hawaii NWS	~ 10 minutes	62 GB
FY2H	79° East	Network Relay	ABOM	15-30 minutes	4.7 GB
FY2G	99.5° East	Network Relay	ABOM	15-30 minutes	4.7 GB

COMS	128° East	Network Relay	KMA	9-24 minutes	11 GB
FY-4A (GIIRS only)	105º East	Terrestrial Eumetcast	Eumetsat	10-15 minutes	~5 – 13 GB

Low-Earth Orbit	**Reception Method**	**Domain**	**ADDE Latency**	**Instruments**	**Access**
NOAA-15	C-Band relay, NOAA-STAR	DB CONUS Global	DB <1 minutes after pass	AVHRR, AMSU, DCS->level-1	**ADDE**
				All other instruments Level-0	NA
NOAA-18	DB L-Band, C-Band relay, NOAA STAR	DB CONUS Global	DB <1 minutes after pass	AVHRR->level-1	**ADDE**
				All other instruments Level-0	NA
NOAA-19	DB L-Band, C-Band relay, NOAA STAR	DB CONUS Global	DB <1 minutes after pass	AVHRR->level-1	**ADDE**
				All other instruments Level-0	NA
NOAA-20	DB XL-Band, NOAA STAR, CLASS	DB CONUS Global	DB <1 minutes after pass Global network relay ~45 min	VIIRS>level-1	**ADDE**
				VIIRS,ATMS, CrIS	DB ftp (sips)
Metop-A/B/C	DB L-Band, NOAA STAR Relay	DB CONUS Global	CONUS <15 minutes after pass	AVHRR ->level-1	**ADDE**
				AVHRR, IASI	DB ftp (sips)
Suomi-NPP				VIIRS	**ADDE**

	DB X/L Band, NOAA STAR, CLASS	DB CONUS Global	CONUS <15 minutes after pass Global network relay ~45 min	VIIRS,ATMS, CrIS	DB ftp (sips)
Aqua	DB X-Band, NASA Relay	DB CONUS Global	DB <15 minutes after pass	AIRS, MODIS -> Level-1	**ADDE**
				AIRS, MODIS	DB ftp (sips)
Terra	DB X-Band, NASA Relay	DB CONUS Global	DB <15 minutes after pass	MODIS -> Level-1	**ADDE**
				MODIS	DB ftp (sips)
Landsat-8	Network Relay (USGS)	CONUS	<24 hours	Level-1	WMS
Shizuku GCOM-W1	DB X-Band	CONUS	DB <1 min after pass	Level-0	SSEC ftp
FY-3B/C	DB X/L Band	CONUS	DB <1 min after pass	Level-0	SSEC ftp

N.2 Geostationary Satellite Archive

US Geostationary Satellites

- GOES-8 through GOES-17 (1994-Present) (East, West , South America and test)
- G16 and G17 L1 ABI and L2 GLM in Netcdf
- G16 and G17 CADUs (essential for SDS and CSPP-GEO debugging)
- GOES-1 through GOES-7 (1978-1996)
- SMS-1&2 (1978-1981)

International Geostationary Satellites

- GMS/MTSAT (1998-2015)
- Meteosat/Meteosat IODC (1998-Present)
- Meteosat-1 FGGE (1978-1979)
- FY2 (2004-Present)
- Kalpana (2005-2017)
- Insat-3D (June 2014-2017)
- COMS (June 2012 – Present)
- Himawari-8 (March 2015 – Present)

Appendix O: Antenna Infrastructure

On Site Antennas

C-Band

- 11 meter heated (101° West – SES-1, POES Fairbanks Relay)
- 6.3 meter heated (87° West – SES-2, POES Wallops Relay)
- 4.5 meter (101° West – SES-1, Noaaport)
- 3.7 meter GEONETcast (58º West INTELSAT 21)

L-Band

- 7.3 meter (75° West –GOES-East Primary/GOES-16)
- 7.3 meter (137° West –GOES-West Primary/GOES-17)
- 4.6 meter (128° West –GOES-15)
- 4.5 meter (60° West –GOES-13/GOES-14/GOES-15 backup)

X-Band

- 4.4 meter (Tracking – EOS)

X/L Band

- 2.4 meter (Tracking – Suomi NPP, EOS, Metop A&B, NOAA-18, 19, 20 and FY3)

Remotely Managed Antennas

X/L Band

- Honolulu Community College
- Atlantic Oceanographic & Met Lab , Miami, FL
- University of Puerto Rico
- Guam

All are 2.4 m except Guam which is 3 meters. They are used for Tracking – Aqua, Terra, Suomi NPP, EOS, Metop A,B&C, NOAA-18, 19, NOAA-20 and FY3 in support of NOAA NWS NCEP, Eumetcast, and GTS