National Aeronautics and Space Administration

NASA Short-Term Prediction Research and Transition Center

2014 SPoRT Annual Report

Preface

Calendar Year 2014 has seen new beginnings as project leadership has shifted to a set of rising young scientists in the organization. At the end of the year, PI Gary Jedlovec stepped into a senior scientist position in the Earth Science Office at Marshall Space Flight Center and is now acting in a strategy and advisory role for the project. Mr. Jason Burks, Dr. Andrew Molthan, and Mr. Bradley Zavodsky have assumed co-lead responsibilities for SPoRT. This past year has been a very successful for SPoRT as measured by the number of successful transitions of research products to operational end users, the large number of peer-reviewed publications being accepted for publication, and a broader community recognition of SPoRT as a "go-to place" in the community for transitioning experimental satellite products and capabilities to operations. While the number of new end users collaborating with SPoRT has grown over the past year, SPoRT continues to have very strong interactions with existing partners at both Weather Service Forecast Offices and NOAA National Centers. We look forward to continuing the strong legacy of the SPoRT Project.

This 2014 Annual Report provides a comprehensive update on the many of the SPoRT accomplishments over the last year. We are very appreciative of the efforts of Mr. Jonathan Case who exhibited strong leadership in guiding the development of the report and acted as the technical editor for all the articles. This report is as much a reflection of the SPoRT team's individual professional accomplishments as it is those of the SPoRT project in general.

Jason Burks

Gary Jedlovec

Andrew Molthan

Bradley Zavodsky

SPoRT Project Leads

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Executive Summary

The National Aeronautics and Space Administration (NASA) Short-term Prediction Research and Transition (SPoRT) program at the Marshall Space Flight Center is an end-to-end research-to-operations activity focused on improving short-term weather forecasts and disaster monitoring through the use of unique high-resolution, multi-spectral observations from NASA and National Oceanic and Atmospheric Administration (NOAA) satellites, nowcasting tools, and advanced modeling and data assimilation techniques. SPoRT partners with universities and other government agencies to develop new products, which are transitioned to applicable end-user Decision Support Systems (DSS). In August 2014, SPoRT held its biennial Science Advisory Committee (SAC) meeting in Huntsville, AL, in which an external advisory board consisting of both operational and managerial expertise at NASA and NOAA met with SPoRT staff to discuss progress on current projects and provide recommendations and vision for future direction. The SAC members provided feedback on how SPoRT should strengthen their relationships with NASA and NOAA/National Weather Service (NWS) headquarters to maintain a clearly defined role in transitioning satellite data into NWS operations, seek opportunities to proactively share knowledge to NWS for improving the use of satellite data operationally, expand its collaborations to new National Centers (e.g., National Water Center) and build a stronger link with NWS national programs. The full committee recommendations and feedback is available in the 2014 SAC meeting final report on the SPoRT web page at http://weather.msfc.nasa.gov/sport/sac_reports/.

Numerous advances and new collaborations were made in Remote Sensing and Lightning products used by operational partners. A near real-time aerosol optical depth product was developed for the northern Pacific region to monitor transport of east Asia aerosols to the western U.S., providing investigators with critical information for the CalWater 2 field campaign in early 2015 for assessing the impact of aerosols on atmospheric rivers and precipitation production on the U.S. West Coast. The National Centers for Environmental Prediction (NCEP) Weather Prediction Center (WPC) and Ocean Prediction Center (OPC) evaluated SPoRT's Atmospheric InfraRed Sounder (AIRS) total column ozone and ozone anomaly products during a Geostationary Operational Environmental Satellite-R series (GOES-R)/ Joint Polar Satellite System (JPSS) Proving Ground winter 2014 demonstration, with the product expanded to include JPSS Cross-track Infrared Sounder (CrIS) retrievals based on forecaster feedback. Nighttime and 24-h microphysics Red-Green-Blue (RGB) Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) products were expanded to Alaska to help distinguish low clouds and fog. SPoRT-provided RGB products, including dust and smoke, have been applied in local, National Center, and aviation operations during 2014, including a public "Graphicast" by NOAA/NWS forecast office in Albuquerque, NM for a major dust event. One of the SPoRT-sponsored graduate students developed a limb-correction technique to improve the fidelity of RGB products to the edge of the polar-orbiting swaths, set for implementation in spring 2015 into the RGB product suite. SPoRT continues to be a leader in promoting total lightning data for situational awareness, expanding its footprint in 2014 to include additional Lightning Mapping Array (LMA) networks and new partners, particularly for applying total lightning data to aviation operations within NOAA/NWS as part of the GOES-R Proving Ground visiting scientist program.

SPoRT pursued several applied research projects in modeling and data assimilation, with a focus on improving forecaster situational awareness and short-term numerical weather prediction accuracy. To place real-time NASA Land Information System (LIS) modeled soil moisture into proper historical context, a 30+ year LIS run of the Noah land surface model was made to develop soil moisture histograms for each county in the Conterminous U.S. (CONUS). This climatology will provide the foundation for real-time, high-resolution (~3 km) soil moisture percentiles to identify anomalously dry or wet regions. The NOAA National Environmental Satellite, Data, and Information Service (NESDIS) new daily, 4-km global VIIRS green vegetation fraction product was successfully tested and incorporated into the LIS and Weather Research and Forecasting (WRF) modeling frameworks to improve representation of vegetation over climatological datasets currently used in operational models. As a recognized Early Adopter for the Soil Moisture Active Passive (SMAP) mission, SPoRT conducted soil moisture DA experiments using retrievals from the European Space Agency's Soil Moisture Ocean Salinity (SMOS) satellite. Since the SMOS instrument has similar characteristics to the SMAP passive microwave radiometer, SPoRT's DA efforts will apply to future experiments and transition activities for SMAP soil moisture retrievals. On the atmospheric side, activities included continued assimilation experiments of hyperspectral infrared (IR) temperature and moisture profiles into the WRF model using the NCEP Environmental Modeling Center's operational Gridpoint Statistical Interpolation (GSI) system, in order to improve the simulation of a strong oceanic wind event and accompanying tropopause fold associated with a deep mid-latitude cyclone. A method was developed to assimilate the NOAA Unique CrIS/ Advanced Technology Microwave Sounder (ATMS) Process System (NUCAPS) dataset in GSI with improved observation error characteristics. Other research projects include aerosol assimilation for simulating atmospheric rivers on the U.S. West Coast, and the development of a technique to assimilate Global Precipitation Measurement (GPM) Level 2 precipitation products into GSI/WRF.

SPoRT continued development of capabilities for ingesting real-time data and model output into the NOAA/NWS Advanced Weather Interactive Processing System (AWIPS) DSS. With the ongoing upgrade to the next generation AWIPS II, SPoRT maintained products for both legacy AWIPS and AWIPS II and helped eight NWS partner forecast offices smoothly transition SPoRT products to AWIPS II. SPoRT's lightning expertise combined with its community leadership in AWIPS II development activities led to the transition of an LMA plug-in into the AWIPS II baseline, as well as a tracking meteogram tool for monitoring cell trends in total lightning, which have been found to correlate strongly with severe weather occurrence. The SPoRT leadership in AWIPS II development is exemplified by the Experimental Products Development Team (EPDT). During 2014, SPoRT hosted a new group of 15 participants in the EPDT program, which involved a hands-on learning session in the spring followed by a "code-sprint" in a fall session, in which participants developed their own plug-ins for products such as EUMETSAT RGB recipes or GOES-R data decoding and display.

Several formal product assessments occurred during 2014 to determine the utility of specific SPoRT products and receive feedback from forecasters for future product improvements. An assessment of nighttime and 24-h microphysics RGBs was conducted at high-latitude NWS forecast offices to apply RGB imagery in operations as a demonstration for products that will be available from GOES-R Advanced Baseline Imager (ABI), and to more effectively analyze low clouds/fog hazards to aviation. Forecasters overwhelmingly preferred the nighttime microphysics RGB over any other product to analyze low clouds and fog. An assessment of selected soil moisture output of SPoRT's real-time LIS was conducted to determine its utility in drought monitoring and estimating areal/river flooding potential. Forecasters had high overall confidence in applying the LIS soil moisture to drought monitoring, including recommended adjustments to drought categories in the weekly U.S. Drought Monitor product. A total lightning assessment was conducted with Center Weather Service Units (CWSUs) focused on lightning safety and decision support topics, representing the first lightning assessment for aviation applications. Forecasters found benefit from the total lightning data for making decisions regarding closing airspace over airports where convection was present. Additional assessments during 2014 are highlighted in this report, including the NESDIS snowfall rate product to provide supplemental information in data void areas with radar gaps, and a large suite of products delivered to numerous NCEP National Centers for the Satellite Proving Ground demonstration.

SPoRT continued integration of NASA, NOAA, and commercial Earth remote sensing imagery within the NOAA/NWS Damage Assessment Toolkit (DAT) application, following a successful feasibility demonstration and enthusiastic partner involvement. Following severe weather and tornado events, the DAT is used by NWS field meteorologists to acquire geotagged information that documents tornado damage according to the Enhanced Fujita (EF)-scale. Case studies of Earth remote sensing imagery were incorporated to demonstrate to forecasters how these products could also be used to improve or refine the characterization of the damage track. In addition to tornado applications, imagery has been used by a SPoRT-sponsored graduate student to help identify short-term, sudden decreases in vegetation health that result from hail damage to crops during the growing season. These case study efforts moved SPoRT closer to sustained inclusion and full transition of NASA Earth Science remote sensing imagery into the DAT application.

SPoRT continues to pursue its vision of being a "go-to place" within NASA for transition of emerging satellite datasets and capabilities. Through sustained collaborations with current partners at NOAA, universities, and other government agencies, SPoRT will continue to support the operational weather community by providing a means and a process for effectively transitioning Earth Science observations and research capabilities into operations. 2015 promises to be an exciting year for the SPoRT Team as new satellites are scheduled for launch and new partnerships are established.

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Introduction

Major Project Accomplishments during 2014

The National Aeronautics and Space Administration (NASA) Short-term Prediction Research and Transition (SPoRT) program is an end-to-end research-to-operations activity focused on improving short-term weather forecasts and disaster monitoring through the use of unique high-resolution, multi-spectral observations from NASA and National Oceanic and Atmospheric Administration (NOAA) satellites, nowcasting tools, and advanced modeling and data assimilation techniques. SPoRT partners with universities and other government agencies to develop new products, which are transitioned to applicable end user decision support systems. Recent advancements in product development and data dissemination, modeling and data assimilation, product applications in various decision support systems, and transition, training and assessment activities have significantly helped to improve operational weather forecasts and led to more efficient detection, monitoring, and community response to natural disasters. The following is a summary of select, major project accomplishments during 2014. More details of progress and accomplishments can be found throughout the rest of the report.

- SPoRT transitioned high-resolution imagery and a suite of derived products from instruments on the Suomi-National Polar-orbiting Partnership (S-NPP) satellite. Numerous weather forecast offices around the country and national weather forecast centers now use the data to address a variety of forecast challenges. The Visible Infrared Imaging Radiometer Suite (VIIRS) Red-Green-Blue (RGB) composite imagery combines information from several spectral channels to help diagnose restrictions in surface visibility that affect aviation across the country and in Alaska. An RGB composite derived from the Day-Night Band (DNB) on VIIRS provides significantly improved feature detection at night in these regions for monitoring low clouds and fog when infrared data alone is quite difficult. These product have been used as both forecasting tools and as demonstration capabilities for future instruments, such as the Geostationary Operational Environmental Satellite-R series (GOES-R).
- SPoRT has transitioned near-real time imagery from the microwave instruments on the recently launched Global Precipitation Measurement (GPM) mission to forecasters at the National Hurricane Center and other national forecast centers to better identify storm cores and monitor precipitation inside the clouds with unprecedented spatial resolution and radiometric accuracy. Additional precipitation estimates from the sensor suite allows forecasters to monitor storm structure and intensity leading to improved short-term forecasts.
- SPoRT has developed a "black-out" product from night-time before-and-after VIIRS DNB imagery in order to detect power loss in areas affected by extreme weather around the world. The product has been used by a number of national and international disaster monitoring and relief agencies (FEMA, USGS, DoD, DHS, among others) to understand the widespread effects of storm damage and to monitor recovery efforts. Additionally, high resolution NASA and private sector imagery has been integrated into the National Weather Service's Damage Assessment Toolkit (DAT) to help with damage surveys from devastating tornadoes and to provide better detection capabilities of agricultural damage from hail and winds in severe storms.
- SPoRT has integrated VIIRS Green Vegetation Fraction (GVF) data into the NASA Land Information System (LIS) which provides more comprehensive and timely surface information for initializing local and regional Numerical Weather Prediction (NWP) models. The enhanced surface analyses alone have been used to improve the monitoring of regional drought extent and in enhancing situational awareness associated with localized flooding events. Improved sensible and latent heat fluxes resulting from the satellite-influenced LIS fields lead to better evolution of temperature, moisture, and precipitation features in NWP modeling applications.

August 2014 Science Advisory Committee Meeting

SPoRT's Science Advisory Committee (SAC) met on 26-28 August 2014 in the newly developed Visualization and Collaboration Laboratory (VCL) at the National Space Science and Technology Center in Huntsville, AL to review the project's progress and provide recommendations for its future direction. The VCL is an open-space conference room with a state-of-the-art visualization and collaboration system composed of a 4 x 3 panel video wall (14 ft x 6 ft dimension) driven by the collaborative Scalable Adaptive Graphic Environment software. The multi-user collaboration facility was invoked to host presentations, demonstrate enhanced scientific analysis capabilities, and visualize shared displays from other hosted workstations such as the Advanced Weather Interactive Processing System (AWIPS) and next generation AWIPS II environments.

The current SAC members are Tom Bradshaw, Dave Radell, and Andy Edman (NOAA/National Weather Service [NWS] field offices), Dr. Ming Ji (NWS Office of Science and Technology), Greg Mandt and Dr. Mitch Goldberg (NOAA GOES-R and Joint Polar Satellite System [JPSS] Program Offices, respectively), Kim Runk (Director of the NWS Operations Proving Ground), Dr. Christa Peters-Lidard (Deputy Director for Hydrospheric and Biospheric Sciences at NASA Goddard Space Flight Center), Lawrence Friedl (NASA Applied Science Program Manager), and Dr. Tsengdar Lee (NASA HQ Weather Focus Area lead). Dr. Sujay Kumar (SAIC) attended on behave of Dr. Peters-Lidard who could only participate remotely. Bill Sjoberg (support contractor to NOAA) attended for Dr. Goldberg and assumed the SAC Chair position.

The SAC provided strong praise for SPoRT's execution of its transition to operations activities as indicated by the following select comments:

- Outstanding effort to form a SAC and respond to its recommendations. SPoRT is a stronger program because of it.
- SPoRT has been able to maintain remarkable fidelity to its core operating paradigm, with strong relationships with end-users being at its heart. They are consistently able to quickly integrate their products into NWS systems.
- Outstanding work broadening user-base to ensure SPoRT viability for years to come.
- SPoRT has done a great job of building a team of young and enthusiastic technical experts, which will ensure future success.

The committee's overall recommendations included the following actionable items:

- The NOAA and NASA satellite programs (S-NPP, GOES-R, JPSS) recognize the value of SPoRT in finding ways to improve the use of satellite data in NWS operations. SPoRT should look for ways to strengthen their strategic relationships with NASA headquarters (HQ), National Environmental Satellite Data and Information Service (NESDIS) HQ and NWS HQ to maintain a clearly defined role in transitioning satellite data into NWS operations.
- SPoRT has excelled in responding to user requests and requirements (reactive). They need to seek opportunities to proactively share knowledge and provide "suggestions" to their users (NWS) as to what is needed to improve use of satellite data operationally.
- SPoRT has developed a close working relationship with the NOAA/NWS Weather Forecast Offices (WFOs) and National Centers. This has resulted in a program that has been effective in exposing the field offices to new science and satellite technology, while incorporating forecaster feedback into improved satellite service. This is the core of your success and we strongly encourage SPoRT to continue this approach.
- SPoRT should seek opportunities for closer interactions with NWS National Centers and other modeling centers. For example in soil moisture modeling, SPoRT should work with the National Water Center, Weather Prediction Center (WPC), NWS River Forecast Centers (RFCs), Soil Moisture Active Passive (SMAP) mission and other programs, to determine how SPoRT work can be used in flood guidance.
- SPoRT should build on the excellent relationship with NWS WFOs by building a stronger link with NWS national programs (e.g., AWIPS, Training, Dissemination, NOAA Testbeds and affiliated Proving Grounds).
- Focus efforts at WFOs applying a defined time frame "demonstration period" for an explicit purpose (e.g. gain feedback on research, transition product into the WFO, gain feedback in order to help NWS implement product nationwide).
- SPoRT should define their vision for satellite assimilation into their land product models. Current strategy is focused only on soil moisture assimilation. There are many other sources of hydrological remote sensing data including soil moisture, snow, terrestrial water storage, land surface temperature. SPoRT should coordinate with land data assimilation efforts happening at other agencies.

The SAC also had specific comments and recommendations for SPoRT activities in its various expertise areas and are highlighted below.

Products, Training, and Assessment: The SAC noted that SPoRT has made excellent use of multiple ways of training and cited numerous examples of this with the following comments.

Some of the best satellite training available at WFOs is from SPoRT. SPoRT has successfully adapted many of the best practices of WDTB, COMET and training centers in terms of developing and delivering efficient training to NWS field staff. SPoRT has extensive experience in satellite training for (NWS) users. NWS should include SPoRT in the NWS training development team for Satellites (both GOES and Polar Orbiting Environmental Satellites [POES]).

- The one-pagers (Quick Guides) are very popular with NWS forecast staff. These are perhaps good models for other Cooperative Institutes.

- SPoRT may want to consider centralized training material outlet with an automatic notification service. SPoRT has a lot of experience communicating using multiple channels. SPoRT may expand these channels to include notification service.
- The SAC noted that the SPoRT product assessment program is a huge success. It should continue with the rigorous product assessment paradigm that has been developed, which could perhaps be used as a model for other Cooperative Institutes. The SAC highlighted a few specific examples of this.
- Good interaction with users during periods of evaluation of RGB capabilities. Extensive surveys capture very focused feedback. An example of interaction: Snowfall Rate was evaluated by three offices in Eastern Region. SPoRT helped STAR organize this evaluation.
- Ozone RGB overlaid with potential vorticity makes a visually appealing display that is easy to interpret when diagnosing possible stratospheric intrusion associated with a tropopause fold.
- Although not presented at this session about the multi-media communications, SPoRT should continue to use blogs, Facebook, Twitter, web pages, and email to communicate with the users. This approach would supply success stories to be used as part of the training and outreach program.

GOES-R/JPSS Proving Ground Activities:

- SPoRT has good ties to WFOs through Proving Grounds and the leveraging of existing testbed capabilities. It is very positive that SPoRT works with Algorithm Working Group developers to transition new/updated products.
- SPoRT's responsiveness to Outside the Conterminous U.S. (OCONUS) challenges and willingness to work with Alaska, the Pacific Region, and Puerto Rico in person has yielded great results.
- SPoRT should look for opportunities to integrate data from multiple systems to identify solutions to NWS forecast problems, as opposed to focusing on individual products. The AK fused product (GOES and Polar) is a very interesting example of this data fusion of two disparate data sets. We would encourage SPoRT to explore more concepts like this.

Decision Support System

- The SPoRT Experimental Products Development Team (EPDT) is a success story and should be considered as a model for how a collaborative developmental community should operate. This approach could have significant influence on projects like Virtual Lab.
- SPoRT's participation in AWIPS governance activities is very important and commendable.

Modeling and Data Assimilation

- While SPoRT has provided nice examples of modeling and data assimilation impacts on weather forecasts, it is recommend that SPoRT focus on collaborating with WFOs in conducting "local studies" using operational model guidance to address science issues/improving forecasts. Note: the notion of "local studies" excludes running local model for operational use. Collaboration with the National Water Center could produce some important advances for hydrologic forecasting, enhanced stream flow and routing prediction, flood and flash flood potential, etc.
- Good examples of practical, effective use of radiance assimilation to improve regional weather modeling (refinement of atmospheric rivers, improved depiction of stratospheric intrusions and influence on cyclogenesis, non-convective winds, cloud top representation). These activities highlight the value of a comprehensive, two-way iterative research-to-operations, and operations-to-research processes. Using the Gridpoint Statistical Interpolation (GSI) package for assimilation of hyperspectral infrared (IR) data is a good example of the operations to research approach.
- SPoRT has done a great job with the transition of Moderate Resolution Imaging Spectroradiometer (MODIS) GVF data into LIS modeling efforts. It will be great to see the full range of MODIS/VIIRS data products being used (leaf area index/albedo/emissivity). The switch to some of these datasets will be warranted due to significant changes in model versions that are expected soon.
- LIS work should be high priority. Drought and flooding potential products should be the near-term opportunity.

Disaster detection and response applications

- SPoRT's applied science exploratory projects are outstanding examples of the potential for high resolution, satellite-based products to inform disaster response and recovery operations for resource positioning or risk management decisions (pre- vs. post-event power outage, storm damage scars, hail damage swaths, etc.). This will clearly be a growth area. Success in this area will strengthen NASA and NOAA partnerships with FEMA and will contribute in a meaningful way to the National Response Framework.
- The work with the experimental DNB RGB imagery for use in disaster response is very impressive. Demand is almost certain to increase. Commendable innovation

and initiative shown by the SPoRT team to provide the data, and react promptly to modify the data on the fly to make it easier for users to interpret. The SAC would like to engage NASA SPoRT in integrating DNB RGB imagery for disaster response into NWS DSS Boot Camp. It's important for meteorologists who go on-site to an EOC to become familiar with experimental tools and data sets that might be available on an incident and to understand how to properly interpret them for EM decisions.

Report Structure

This annual progress report highlights the most significant accomplishments and developments in SPoRT during 2014. The report structure follows that of the SPoRT core functions. Highlights are presented in the areas of remote sensing products and research (section 2), lightning products and research (section 3), modeling and data assimilation activities (section 4), decision support systems (section 5), transition training and assessments (section 6), and disaster response efforts (section 7), followed by references. SPoRT continued its presence in satellite Proving Ground (PG) programs, including the GOES-R PG, GOES-R visiting scientists proposals, and JPSS PG activities. Highlights in each of these areas are presented within the upcoming sections in the appropriate context. The Appendices provide summaries of SPoRT products and partnerships, publications and conference presentations during 2014, and acronym definitions.

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Remote Sensing Products and Research

Aerosol Optical Depth Product for CalWater 2 Field Campaign

In early 2014, SPoRT began development of a near-real time (NRT) aerosol optical depth (AOD) composite product in an effort to monitor the long-range transport of aerosols across the Pacific Ocean to the western United States. The NRT AOD products currently available over the Pacific Ocean are generated using observations from only single satellite sensors, such as MODIS onboard the NASA Aqua and Terra satellites. It can be difficult to monitor and track the transport of aerosols using a single satellite sensor due to frequent cloud cover and sunglint regions over the Pacific Ocean that can completely mask the aerosol signal. As a result, AOD retrievals are highly uncertain in regions of cloud cover and sunglint and are generally removed from a quality-assured product. Thus, the spatial distribution of AOD is often poorly represented in the quality-assured products from single satellite sensors as shown for Aqua MODIS sensor in Figure 1a.

In order to better understand the spatial distribution of AOD across the Pacific, the SPoRT NRT AOD composite product combines information from the Aqua and Terra MODIS, S-NPP VIIRS, NOAA GOES, and Japan Meteorological Agency Multi-functional Transport Satellite (MTSAT). The initial step for generating the SPoRT AOD product was to develop AOD retrieval algorithms for the GOES and MTSAT since easily accessible NRT products are not available for these satellites. After developing and validating the AOD retrieval algorithms, the GOES and MTSAT retrievals were combined with already available MODIS and VIIRS NRT AOD products onto a 0.5° grid domain extending from Asia to North America. Six-hourly and daily AOD composite products were being generated in NRT after the final development stages were completed in December 2014. An example of the SPoRT daily AOD composite product for a long-range aerosol transport event on 23 March 2014 is shown in Figure 1b. The SPoRT AOD product provides a much better understanding of the spatial distribution of aerosols across the Pacific compared to only analyzing Aqua MODIS AOD in panel (a). A moderately thick aerosol plume associated with AOD of approximately 0.5 (red oval in Figure 1b) can be seen approaching western North America according to the SPoRT AOD product.

SPoRT NRT AOD composite products are set to be disseminated to science investigators involved with the NOAA CalWater 2 field campaign that will take place between January and March 2015 in northern California, with the objective of developing a better understanding of the aerosol interaction with Atmospheric Rivers (ARs) and the impact on precipitation (Spackman et al. 2014). An important component of the CalWater 2 field campaign is aircraft missions that will gather essential in situ measurements of aerosols interacting the ARs over northern California and the eastern Pacific Ocean. The SPoRT AOD NRT composite products will be used during the CalWater 2 field investigators with their aircraft flight activities, such as planning departure times and flight tracks, by providing critical information on the concentration and spatial variability of aerosols across the Pacific Ocean (Naeger et al. 2015).

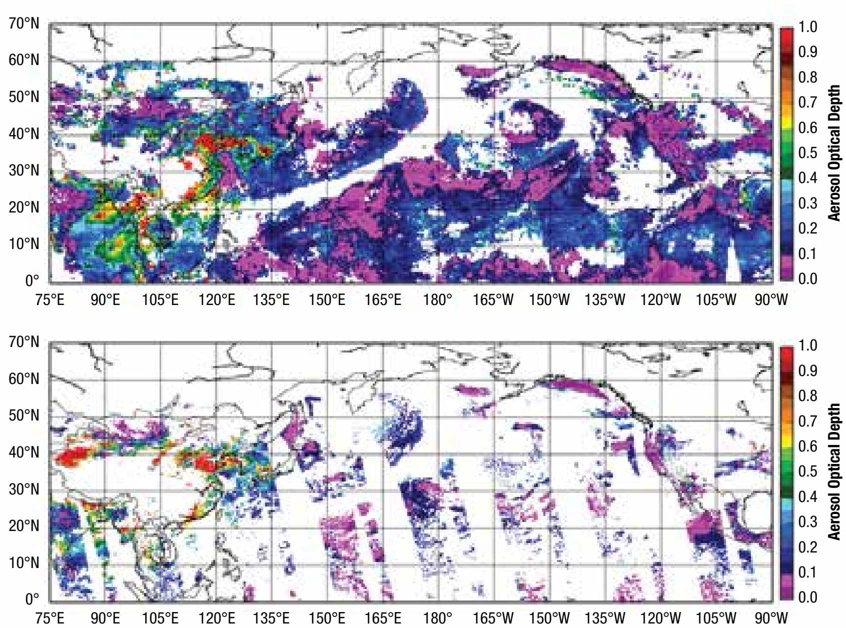

Figure 1. a) Aqua MODIS AOD product for all available overpasses across the Pacific Ocean during a 24-h period centered on 23 March 2014 at 0000 UTC, and b) SPoRT daily AOD composite product for the same time period.

NUCAPS Efforts with AIRS/CrIS/IASI Activities

SPoRT has worked closely with the GOES-R and JPSS Proving Grounds (PGs) to develop and transition ozone products into the National Centers-AWIPS (N-AWIPS) format to the National Centers for Environmental Prediction (NCEP) Ocean Prediction Center (OPC) and WPC for identification of stratospheric air and tropopause folds that lead to cyclogenesis and high wind events. These National Centers have used the Air Mass RGB product, derived from instruments such as MODIS, the Spinning Enhanced Visible and IR Imager (SEVIRI), and GOES Sounder, as proxy products to prepare for GOES-R Advanced Baseline Imager (ABI) capabilities. Because RGB products are qualitative in nature, total ozone retrievals, such as those from the Atmospheric InfraRed Sounder (AIRS), can be used to enhance interpretation and increase forecaster confidence in the Air Mass RGB before the GOES-R launch. SPoRT worked with the GOES-R/JPSS PG Satellite Liaison in 2012 and 2013 to develop ozone products, total column ozone, and ozone anomaly (Van Haver et al. 1996; Ziemke et al. 2011) to complement the Air Mass RGB. During 2014, forecaster feedback led to further product development and expansion to other instruments.

The SPoRT AIRS ozone products, Total Column Ozone and Ozone Anomaly, were evaluated at the National Centers during the GOES-R/JPSS PG Satellite Liaison's 2014 winter product demonstration. Forecaster feedback was valuable and suggested that forecasters found the product useful, but desired more overpasses. One forecaster stated that the product "reinforced the evidence from the RGB of the descent of stratospheric air with tropopause folding". This statement shows the ozone products enhanced the Air Mass RGB for the particular forecast challenge. Another forecaster provided two-fold feedback that the product "was helpful in reaffirming my suspicions on whether stratospheric air was present", but expressed the need for lower latency and more frequent overpasses in the second half of his comment: "if there was greater coverage of passes and not as much of a lag, it would certainly be useful."

Figure 2 demonstrates the increased temporal and spatial coverage over the North Atlantic domain. With the addition of retrievals from the JPSS Cross-track Infrared Sounder (CrIS), forecasters have additional overpasses to provide hourly coverage from 1400-1700 UTC in this case. Initial CrIS products were developed from retrievals processed with the NASA Cross-Track Infrared and Microwave Sounding Suite (CrIMSS) algorithm, which differs from the AIRS algorithm and resulted in some inconsistencies between the AIRS and CrIS products. The NOAA Unique CrIS/Advanced Technology Microwave Sounder (ATMS) Process System (NUCAPS; Gambacorta and Barnet 2013) is developed from the legacy AIRS algorithm. Therefore, ozone products developed from NUCAPS more closely match SPoRT ozone products derived from AIRS retrievals. Future product development in 2015 will focus on replacing CrIMSS ozone products with CrIS NUCAPS and then expanding product development to the European Infrared Atmospheric Sounding Interferometer (IASI). Deriving ozone products from three instruments, with similar processing algorithms, will provide additional temporal and spatial coverage for the vast National Centers' domain. Additionally, product development is planned for early 2015, so the additional ozone products can be available for the GOES-R Satellite Liaison's 2015-2016 winter demonstration.

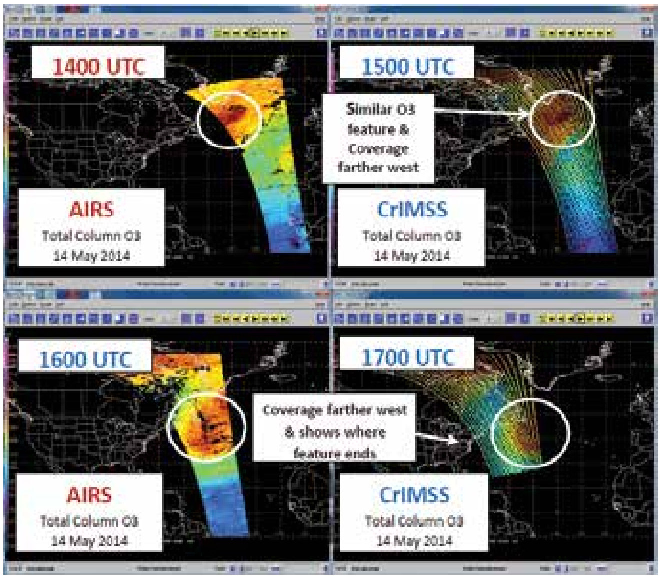

Figure 2. AIRS and CrIMSS total column ozone products from 1400-1700 UTC on 14 May 2014.

Passive Microwave Activities with Pacific Region

The transition of a passive microwave suite of products to the NCEP National Hurricane Center (NHC) continued in 2014. Additional instruments and data processing improvements were made to take advantage of the launch of the GPM satellite, allowing SPoRT to engage with more users of the data. The full passive microwave product suite is listed in Appendix A and is highlighted by multi-channel, false-color (i.e., RGB) composites of both the 89- and 37-GHz channels. The RGB image products are created by combining the horizontal and vertical polarization observations as well as the difference between the horizontal and vertically polarized brightness temperatures, referred to as the polarization corrected temperature, or PCT product. These products have proven valuable to forecasters at NHC, particularly in better determining the center location of a tropical system. Viewing a storm in microwave wavelengths versus infrared allows forecasters to diagnose storm structure that may be obscured by high clouds. The resulting color combination of the 37-GHz RGB helps to discriminate areas of deep cloudiness from more active convection and areas of open water or land. The 89-GHz RGB composite is similar to the 37-GHz RGB, but it does an even better job of identifying areas of strong convection due to the characteristics of scattering of the 89-GHz by large ice particles. Areas of thunderstorms or deep cloud cover often show up as bright red. While NHC users had already been examining these data via the Naval Research Laboratory (NRL) webpage displays, SPoRT's previous work had developed data-processing methods that accessed the data from NRL, as well as new display capabilities within N-AWIPS, in order to facilitate the use of tools and other data sets with the passive microwave products.

With the launch of the GPM satellite in early 2014, efforts by the GPM Science team at NASA Goddard Space Flight Center (GSFC) led to the development of a new passive microwave dataset that was inter-calibrated using the GPM Microwave Imager (GMI) as the base instrument. This provided greater consistency between different instruments and enabled inter-comparison of passive microwave imagery from multiple satellites. Included in the suite were the Advanced Microwave Scanning Radiometer-2 (AMSR-2) instrument, Tropical Rainfall Measuring Mission, three SSMI/S (F16, F17, F18) instruments on the Defense Meteorological Space Program (DMSP) satellites, and two MHS instruments. Even though these are single-swath low-Earth orbiting instruments, they provide multiple overpasses across a given region each day and they are global in near-realtime. The GSFC data included additional instruments beyond the NRL dataset such as GMI and the ATMS (from S-NPP).

After release of the GMI data in May, one of the first notable impacts occurred with an 89-GHz RGB image of Hurricane Iselle in the eastern Pacific (Figure 3) that was used by the NHC to examine the storm center and structure in operations. This image was take several days before Iselle struck the big island of Hawaii. Other instruments also passed over Iselle to provide observations, and interest in the passive microwave eventually spread to other National Centers, including the Central Pacific Hurricane Center (CPHC). SPoRT began work to transition the passive microwave suite to CPHC within AWIPS II and this work will be completed in 2015 (see Transition Training and Assessments section). Future work is to provide passive microwave rain rates to both Conterminous U.S. (CONUS) and Outside the CONUS (OCONUS) WFO forecasters in AWIPS II for analysis of precipitation in data void regions, particularly over oceans, but also in areas of poor radar coverage. This work will also include evaluation of the Integrated Multi-Satellite Retrievals for GPM (IMERG) rain rate "early", "late", and "final" runs and their associated accumulation values.

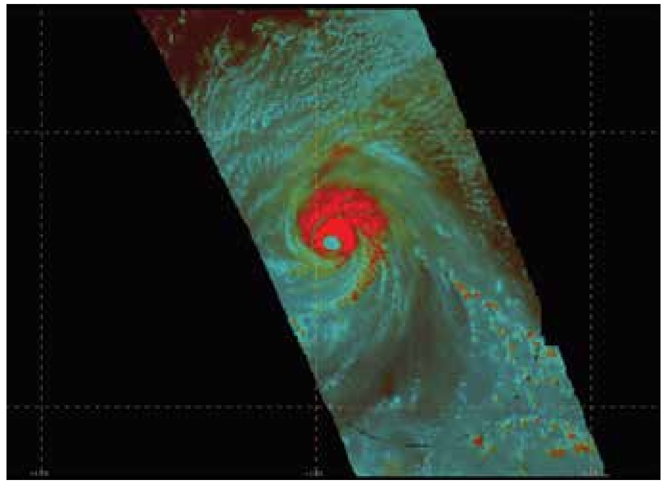

Figure 3. Hurricane Iselle over the eastern Pacific Ocean as observed by the Global Precipitation Measurement Microwave Imager (GMI) with the 89-GHz RGB composite, valid 1515 UTC 5 August 2014.

Microphysics RGB Composite Products

Since 2004, SPoRT has created multi-spectral RGB imagery from MODIS to support NWS WFO analysis of wild fire smoke plumes, land/water surface changes, and snow cover. SPoRT has supported the Satellite PG and its partners via additional near real-time RGB imagery since 2011. The use of MODIS and VIIRS from S-NPP has provided the opportunity to create a suite of "best practices" RGB imagery developed by EUMETSAT through their work with the SEVIRI instrument on the Meteosat Second Generation (MSG) satellite (EUMETSAT User Services 2009).

One of the RGBs in the suite is the Nighttime Microphysics RGB (NtMicro), which provides efficient cloud analysis and is often used to diagnose low cloud and fog features that pose a hazard to public and aviation transportation communities. The NtMicro uses the traditional "fog" product, or 11-3.9 mm channel difference, and adds information regarding cloud thickness and temperature via a 12-11 mm channel difference and 11 mm channel, respectively. This provides a composite image that describes the cloud thickness, phase, and temperature which can be inferred by users to categorize cloud types. The data for this product were obtained via Direct Broadcast capabilities from the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin and UAF/Geographic Information Network of Alaska (GINA) for CONUS and OCONUS users, respectively. The SPoRT Remote Sensing group developed code to process the data for use in NWS decision support systems (AWIPS I/II, N-AWIPS) and recently began to limb and bias correct the imagery (see Bias and Limb Correction section below).

Forecasters in Alaska especially benefit from the MODIS and VIIRS passes due to the greater frequency of these data and the more optimal viewing angle (compared to GOES centered over the equator). Alaska forecasters assessed the value of this imagery to help differentiate low clouds from fog (see Transition Training and Assessments section below). As a result of the assessment, forecasters indicated that some cases resulted in low clouds and fog in the RGB imagery appearing the same color. The 3.9 mm channel at cold temperatures can become noisy and falsely cold with decreasing temperature. In addition, the NtMicro product has limited value during Alaska summer where nighttime duration is very short. The NtMicro RGB is unusable during the day because the 3.9 mm channel is sensitive to the visible spectrum and the 11-3.9 mm relationship changes from night to day. Hence, it was suggested by EUMETSAT colleagues that a 24-h Microphysics RGB be developed for high-latitude applications. The 24-h Microphysics RGB is a very similar recipe to the NtMicro except the 3.9 mm channel is replaced by the 8.7 mm and the "green" component of the RGB uses a more narrow range for the 11-8.7 mm channel difference in order to emphasize the particle phase, since the 8.7 mm channel is less sensitive to water versus ice compared to the 3.9 mm channel. The 24-h Microphysics RGB began to be processed at SPoRT in 2014 and tested by Alaska users in late 2014 into early 2015. It was compared to the more well-known NtMicro RGB in order to determine if the value is similar and to help users understand the new product based on what they know from the previous evaluation of the NtMicro RGB (Figure 4).

The initial RGB suite via MODIS and VIIRS imagery has provided utility to public and aviation forecasts for NWS WFO forecasters, but the National Centers have also benefited from these same products via the MSG/SEVIRI instrument over the eastern Atlantic Ocean region. While SPoRT has created many of the EUMETSAT "best practices" RGBs, there are others still be transitioned from MODIS and VIIRS that require additional channel processing to be developed. These will include RGBs focused more on microphysical properties and their relationship to developing convection. Some of this work has already been done for the SEVIRI-based RGBs and SPoRT will look to continue this work for application by WFO forecasters in 2015.

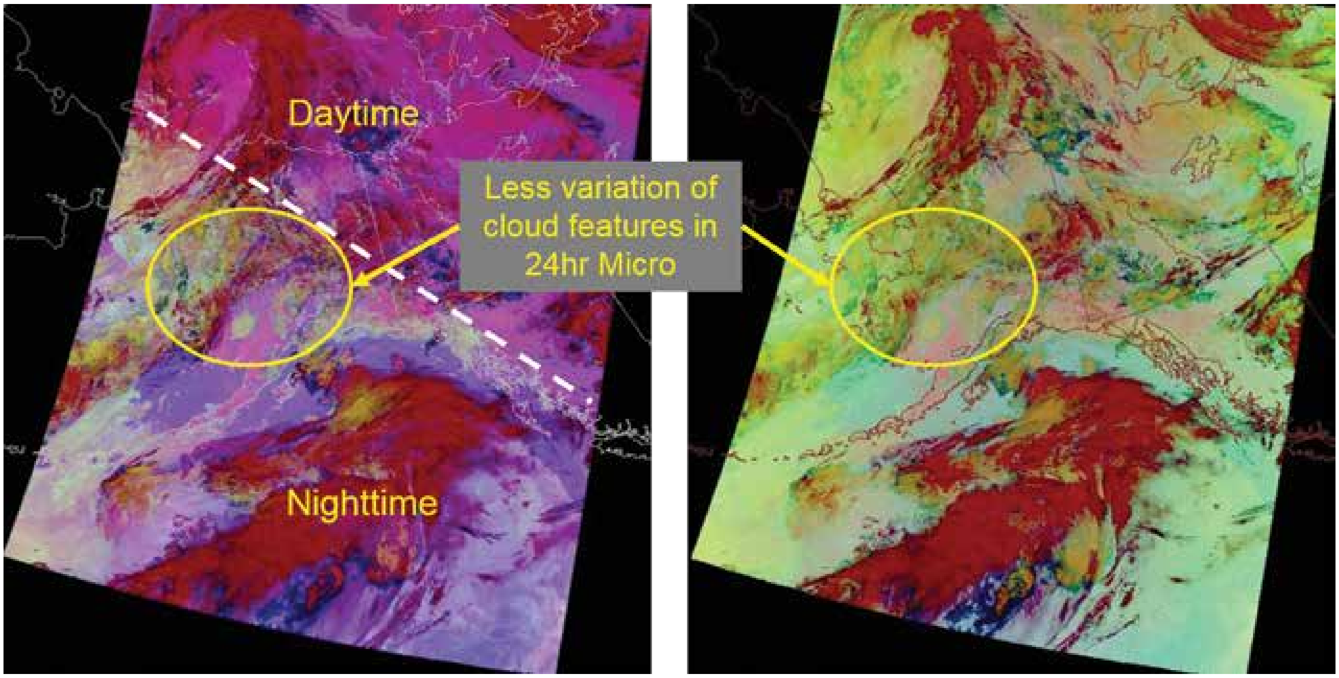

Figure 4. Nighttime Microphysics (left) and 24-h Microphysics product (right) from VIIRS, valid at 1217 UTC 17 July 2014 (4:17 A.M. local time). Note the yellow circled areas with less color variation in the 24-h RGB for the same scene. For the NtMicro, low clouds (bright aqua to light green tones) and fog (gray to dull aqua) can be differentiated from mid (tans, oranges) and high (dark red, dark blue, purple) clouds. The 24-h Micro RGB used in the 2014/15 winter assessment shows low clouds (light green to yellow/green shades) and fog (light to olive green) but colors are similar. Similar colors in the NtMicro RGB for mid to high clouds are seen in the 24-h RGB.

Bias and Limb Correction Technique for Polar Orbiting RGB Products

A technique was developed to correct for limb effects (Goldberg et al. 2001) in the SPoRT CONUS-based MODIS Air Mass, Dust, and Night Microphysics RGBs. The limb effect is a result of an increased optical path length of the absorbing atmosphere as scan angle increases to the edge of a polar-orbiting swath (or geostationary scene). The limb effect creates cooler brightness temperatures than reality and interferes with the qualitative interpretation of RGB composites at the edge of the MODIS swath. The technique corrects for limb effects as a function of latitude and season to account for variability in airmass characteristics, such as temperature and water vapor content. In the corrected imagery, anomalous cooling due to limb effects is removed, enabling the RGB product to more accurately depict atmospheric conditions out to the limb. The correction also normalizes the MODIS channels to match MSG/SEVIRI channels, which are similar to the ABI channels that will be available on GOES-R. This normalization accounts for channel differences between sensors, ensuring that the colors in the RGB products are consistent from sensor to sensor.

Figure 5 demonstrates the improved utility of the limb-corrected Air Mass RGB. In the SPoRT Air Mass RGB product, warm tropical air masses have a large green contribution while dry air masses have a large red component. The blue component often correlates with high moisture content. The feature bounded by the red box in the uncorrected Terra MODIS Air Mass RGB appears to be cold, dry air as a result of the limb effect. However, the same feature, when observed at nadir in the Aqua MODIS Air Mass RGB, is correctly depicted as warm, tropical air. After limb correction, both the Terra and Aqua MODIS Air Mass RGBs correctly depict the feature as a warm, tropical air mass. Note also that the RGB coloring between the corrected Terra and Aqua MODIS Air Mass RGBs are very similar, allowing for these products to be used jointly for analysis. Implementation of this bias correction technique into SPoRT's operational product suite is planned for Spring 2015.

Future Direction of SPoRT Remote Sensing Products

Future activities include refining and adding new RGBs to the current suite of products. Specifically, SPoRT plans to implement into its operations the limb correction technique to MODIS and VIIRS RGBs and continue to improve RGBs for high-latitude regions. Refining the RGBs to handle atypical seasonal characteristics at high-latitude regions include adjusting RGB recipes to enhance low cloud and fog features in cold regions, or incorporating cloud properties to add quantitative information to the RGB. SPoRT also plans to begin producing the NtMicro RGB with Metop and the NOAA Advanced Very High Resolution Radiometer (AVHRR). With additional overpasses offered by these satellites, the product will be available to high latitude end-users with a greater temporal resolution. Additional RGBs include products such as the convection and day-time microphysics RGBs that require additional calculations for 3.9 um reflectance are planned for development. As the community moves toward GOES-R and the ABI instrument for RGB imagery, the Japanese Space Agency has a nearly identical imager that has been launched on the Himawari satellite (Advanced Himawari Imager [AHI]). SPoRT plans to acquire Himawari data in 2015 to demonstrate proxy ABI RGB imagery within the Satellite PG. SPoRT will continue expanding the suite of passive microwave products to include GPM and transition additional quantitative precipitation estimates using the IMERG product.

During 2014, SPoRT purchased six new servers and a large 38 TB RAID to support its expanding suite of remote sensing products. Two of the servers will replace aging GOES ground station ingestors and one will replace the SPoRT web server. The remaining servers will allow SPoRT to further increase research and product-generation capabilities, including activities involving additional satellites (AVHRR, Himawari, GOES-R) and domains (Pacific Region). These new assets will be implemented and deployed into operations throughout 2015.

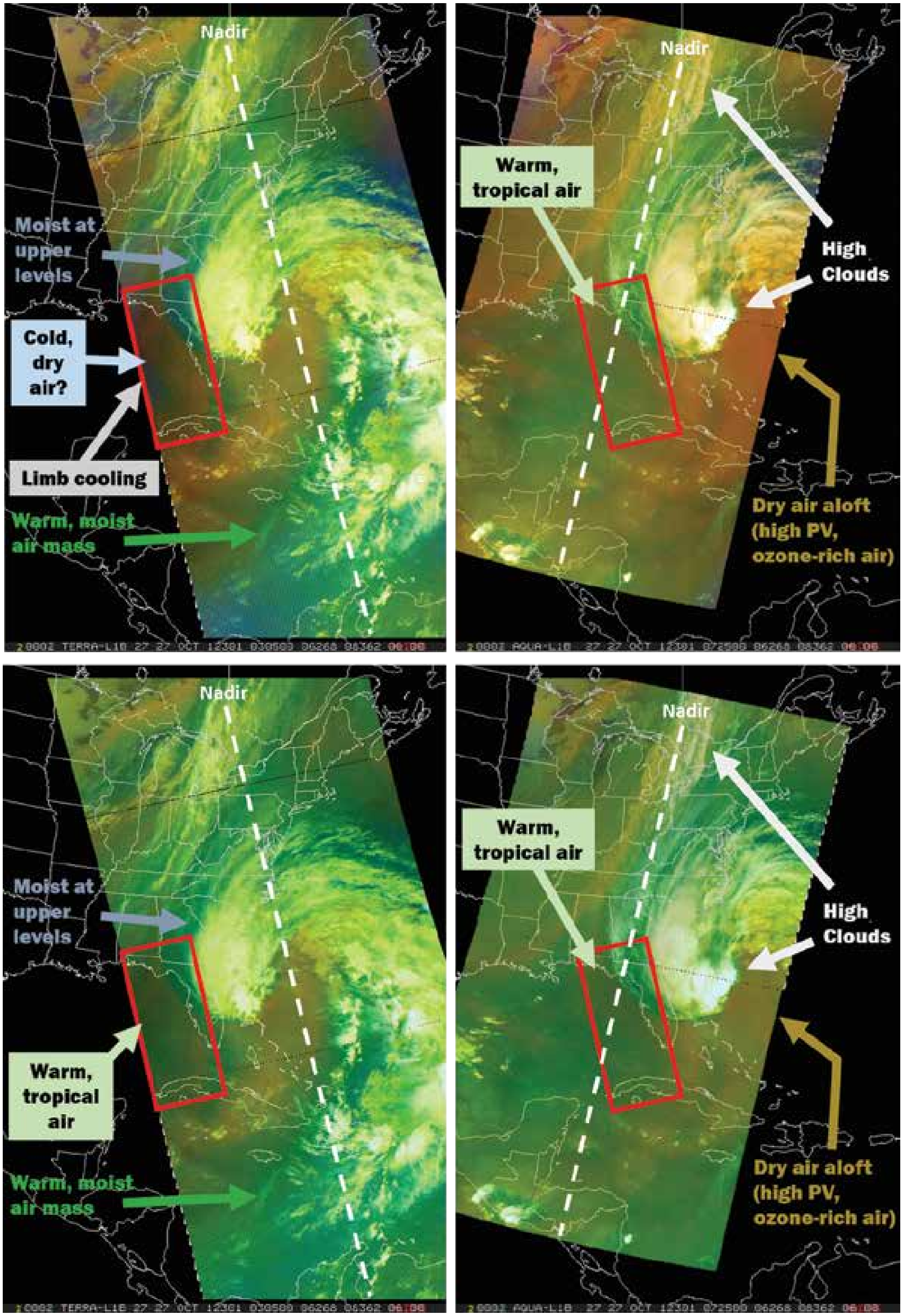

Figure 5. MODIS swaths with and without limb correction of developing Hurricane Sandy from 27 October 2012: (top-left) uncorrected Terra MODIS Air Mass RGB valid 0305 UTC; (top-right) uncorrected Aqua MODIS Air Mass RGB valid 0725 UTC; (bottom-left) corresponding limb-corrected Terra MODIS Air Mass RGB, and (bottom-right) corresponding limb-corrected Aqua MODIS Air Mass RGB.

3

Lightning Products and Research

2014 has been an active year for SPoRT's total lightning activities with new efforts including GOES-R visiting scientist proposal trips, expanded collaborations, a total lightning evaluation, the arrival of a new graduate student, testing of a real-time flash extent density product (Carcione et al. 2015), and a publication on the use of total lightning data for the 2013 Moore, OK tornado (Stano et al. 2014). By the end of the year, SPoRT's total lightning collaborations included eight lightning mapping arrays (LMAs), nine NWS WFOs, three Center Weather Service Units (CWSUs), the Spaceflight Meteorology Group, and two National Centers (Aviation Weather Center [AWC] and Storm Prediction Center [SPC]; Figure 6). The work with the CWSUs is the first-ever use of LMA data with these offices, and marks the first time that these offices participated in the evaluation of these data for both SPoRT activities and with the GOES-R PG (Stano et al. 2015a). SPoRT also continued to provide its expertise in the operational use of total lightning with participation in the Hazardous Weather Testbed (HWT) and AWC Summer experiment. SPoRT personnel are also serving on the American Meteorological Society's Committee on Atmospheric Electricity through 2018.

SPoRT conducted a substantial total lightning assessment in 2014 (Stano et al. 2015a), with the details listed in the following sub-section. Part of the assessment resulted in recommendations by forecasters for a variant of the existing SPoRT total lightning data. The forecasters noted that the one-minute data available from the new LMAs (Colorado, Houston, and Langmuir) were difficult to use as the time bins tended to "chop up" the available data. This made total lightning trends far more difficult to monitor and observe. Participating WFOs at Cheyenne, WY and Melbourne, FL recommended a running two-minute summation that updates every minute (Figure 7). This product modification takes advantage of the specific LMA's temporal resolution while generating a larger binning time. This revision was transitioned in late 2014 and will be available to all forecast offices with LMAs that update every minute in 2015. SPoRT has used this feedback to investigate potential Geostationary Lightning Mapper (GLM) visualization methods given the instrument's 20-second temporal frequency (Stano et al. 2015b). This methodology will also be adopted for the 2015 HWT for use with the Pseudo-GLM (PGLM) product.

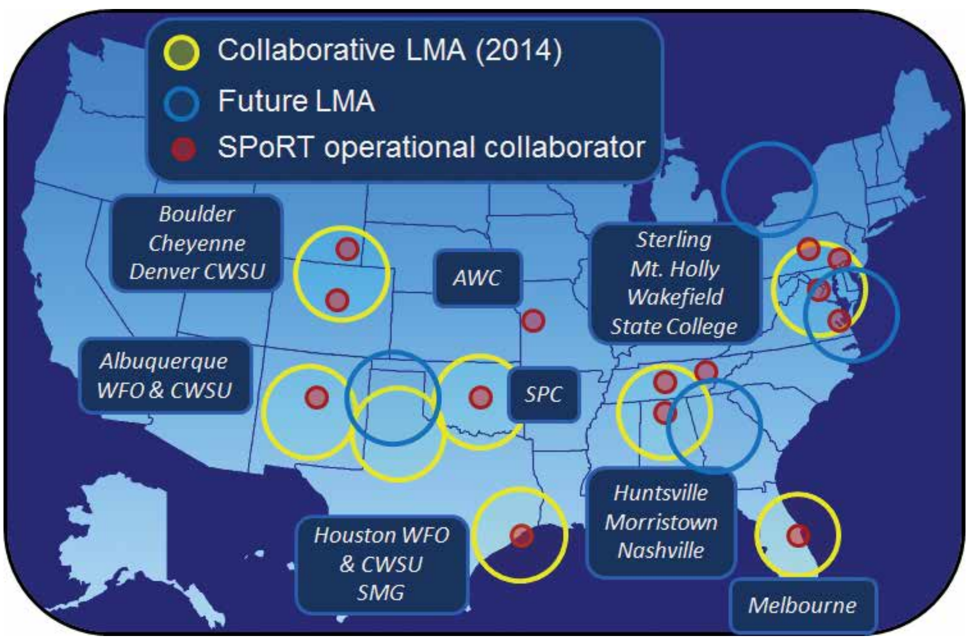

Figure 6. Locations and coverage of current collaborating lightning mapping arrays (yellow), potential new collaborative networks (blue), and operational partners using these data (red dots).

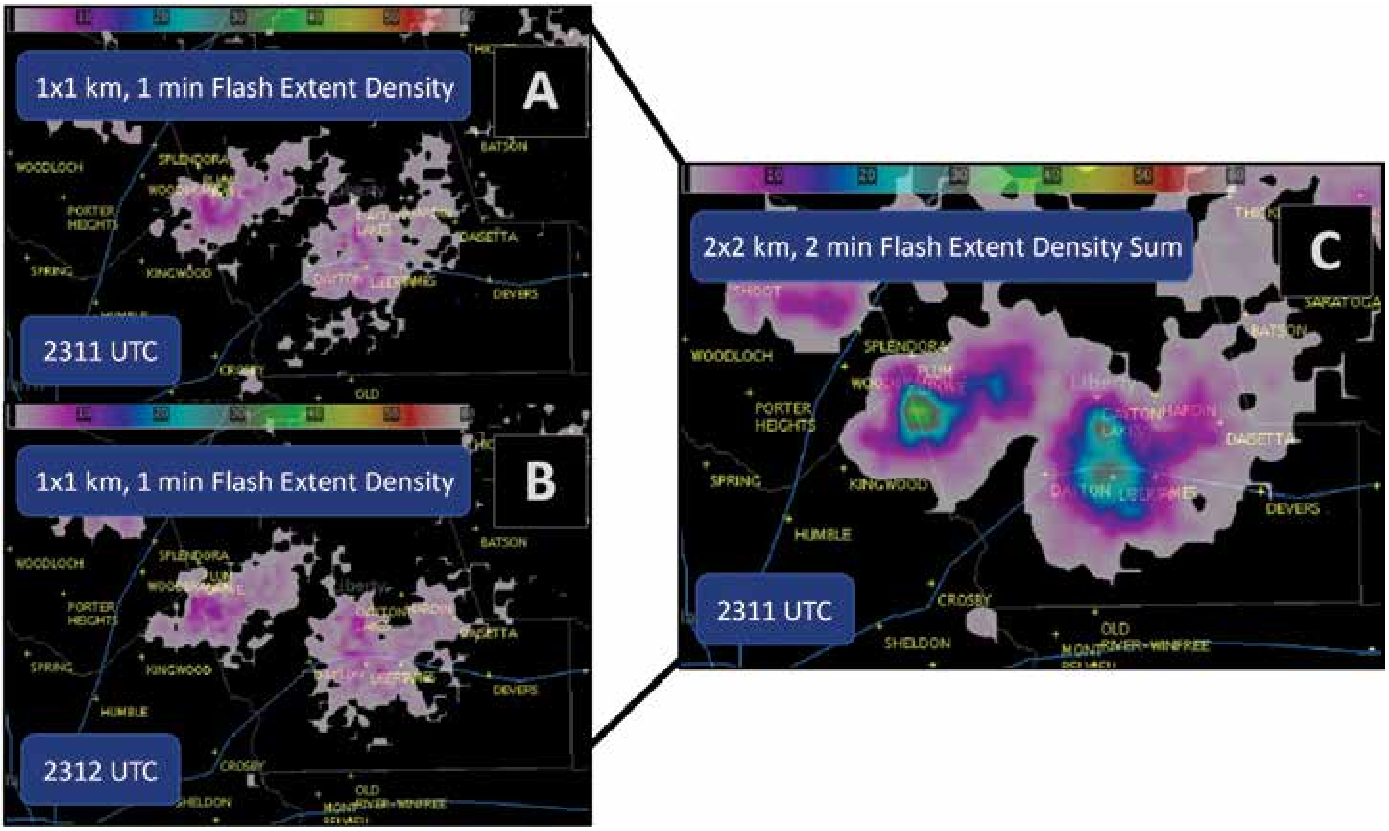

Figure 7. Original 1x1 km and 1-minute flash extent density from the Houston Lightning Mapping Array valid on 6 June 2013 at (a) 2311 UTC, and (b) 2312 UTC; (c) two-minute summation valid at 2311 UTC, which uses the 2x2 km resolution chosen by WFOs Huntsville, AL and Sterling, VA. Note how no significant features stand out in (a) and (b), while (c) shows the advantage of binning the total lightning data an extra minute with a slightly larger grid box, such that storm cores stand out far more readily and enable better monitoring of trends in storm activity.

Total Lightning for Short-term Aviation Forecasts

SPoRT was awarded a GOES-R Visiting Scientist Proposal (VSP) to work with new WFOs at Albuquerque, Boulder, Cheyenne, and Houston, as well as focus on the aviation weather issues of CWSUs at Albuquerque, Denver, and Houston. SPoRT met with each of the offices listed, but also included visits to Spaceflight Meteorology Group and the New Mexico Institute of Mines and Technology in Socorro, NM, who are the developers of LMA technology. The New Mexico meeting resulted in four sensors in the Langmuir, NM LMA being moved north to Albuquerque to better support forecast operations in this major population center. It was also an opportunity to shadow forecasters at each location.

An important take-away from the CWSU visits is how their operations focus exclusively on supporting the Federal Aviation Administration's Traffic Management Unit (TMU) at Air Route Traffic Control Centers. Unlike a local WFO, the CWSUs are tasked to provide incident support to the TMU to monitor convection and other aviation threats for air traffic flying through CWSU airspace and approaching the major airports in their jurisdiction. Another difference from local WFOs is that the CWSUs are not specifically concerned with "severe convection" but rather any convection occurring within their airspace. The concern is for the timing and location of convection, as this affects air routes, ground safety, and the rate of aircraft arrivals and departures at airports. Convection also affects organizing aircraft at "gates" 50 nautical miles out from airports on precise arrival and departure corridors within the Terminal Radar Approach Control (TRACON) airspace. Total lightning was likely to have the greatest impact on short-term forecasts as convection develops, and for monitoring the strength of convection. Total lightning can help provide greater confidence to the CWSU forecasters on convective activity, leading to improved recommendations to the TMU manager.

The 2014 assessment spanned mid-May through August and was the first total lightning assessment that included CWSUs. Beyond introducing new collaborators to total lightning, the assessment sought to expand the use of total lightning beyond lightning jumps and severe weather. Thus, training in support of the assessment expanded to include lightning safety, situational awareness, and decision support. SPoRT was able to provide on-site training at each location, supplemented with two science sharing telecons as well as the release of a three-part module titled, "Total Lightning: Operational Examples." This module was made available on SPoRT's web page as well as in the NWS learning management system. SPoRT provided the traditional source density product and a newer flash extent density product to each collaborator in their native display system (AWIPS or AWIPS II). The temporal resolution was at the refresh rate of the local LMA, which was one minute for all but the North Alabama LMA. Aside from WFO Huntsville, the other participants used the more "traditional" source density product.

Based on the feedback, total lightning observations were determined to have an impact of "High" to "Very High" in 43% of the surveys and this expanded to 79% when users rated the perceived impact to be "Medium" to "Very High". Figure 8 shows the breakdown of the types of events that were dealt with for each rated impact level. Discussions with the forecasters noted that in several of the Medium impact cases, the assessed impact was not due to a limitation of the total lightning observations, but due to the event not warranting a higher impact. The 39 surveys submitted showed that 44 separate actions were taken by forecasters in response to total lightning observations. Of these 44 actions, these covered 13 unique types of actions/products, as summarized in Figure 8, indicating the wide-range of uses of total lightning data outside of traditional severe weather applications. The responses from the forecasters were exceptionally useful for the variety and detail of the feedback.

An example, high-impact case from 21 June 2014 occurred at the Denver CWSU, which highlighted the utility of total lightning information to support air route traffic management. Figure 9a shows the total lightning source densities and radar reflectivity at 2100 UTC for storms southeast of the Denver International Airport. The circled region shows a wide gap in the storms' coverage, which allowed for continued air traffic through this particular gate in the Denver TRACON. By 2121 UTC (panel b), the CWSU is noting total lightning observations in the previously clear airspace. Additionally, the LMA observations show a small core of lightning activity (circled) in a region not observing strong radar reflectivity. The CWSU forecasters alerted the TMU that the southeast gates will need to close as convective activity is imminent. By 2147 UTC (panel c), the radar observes an unbroken line of storms across this TRACON gate verifying the need for this gate to be closed.

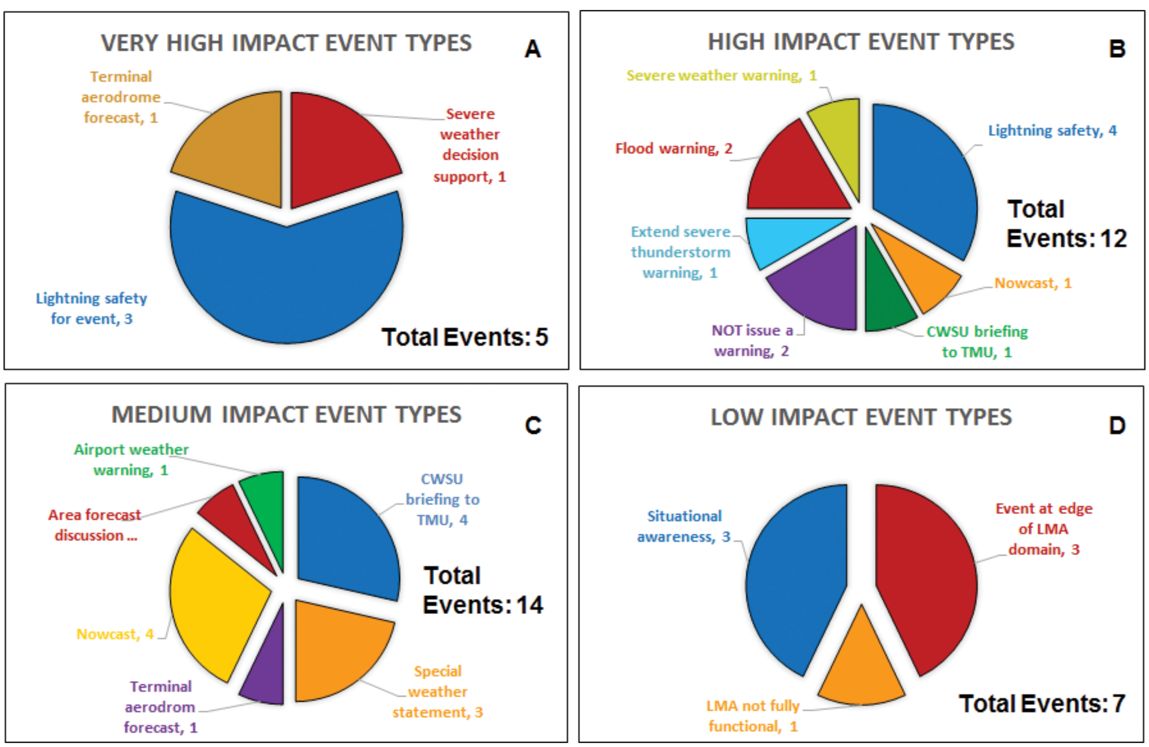

Figure 8. Breakdown of the types of actions taken based on the ranked impact of total lightning from 39 surveys during the 2014 total lightning assessment. Not shown is a single "Very Low" impact event, which was ranked as such due to the storm being at the extreme range limit of the LMA network used.

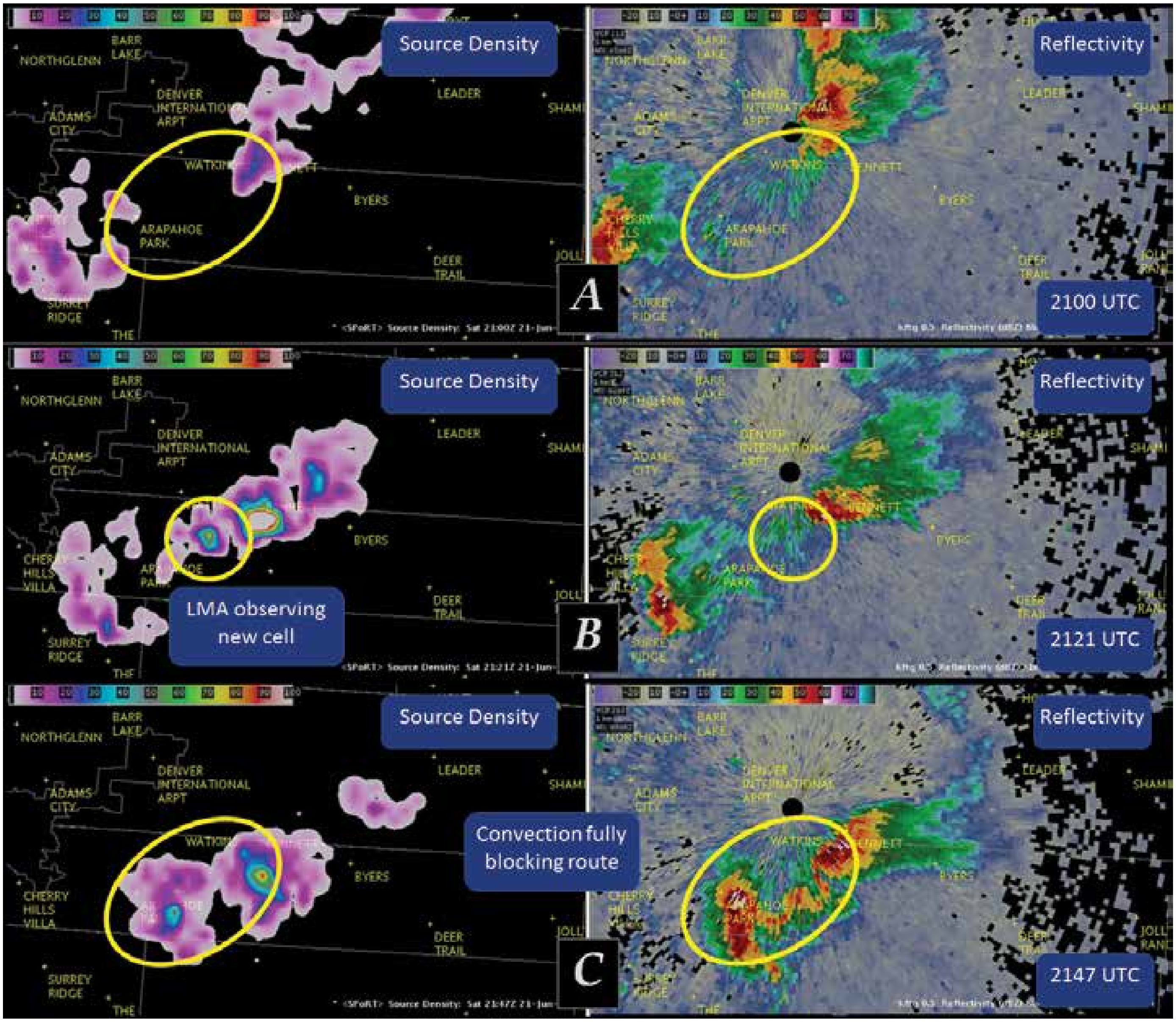

Figure 9. Example from the Denver CWSU on 21 June 2014, showing the Colorado LMA source density product (left column) and Denver radar reflectivity (right column) valid at (a) 2100 UTC, (b) 2121 UTC, and (c) 2147 UTC. The circled region shows a developing thunderstorm that eventually closed down the southeast gate to the TRACON airspace of the Denver International Airport.

Future Direction of Lightning Activities

SPoRT will build on the collaborations established in 2014. In the near-term, based on user feedback, SPoRT is developing a new format for the PGLM mosaic product for use by AWC for the 2015 summer evaluation. Additionally, SPoRT is updating the web display of total lightning data to better facilitate collaborations with WFO Morristown, TN and the Chattanooga/Hamilton County, TN emergency managers for expanded lightning safety capabilities. The effort will facilitate potential collaborations with other non-NWS partners in the future and expand SPoRT's collaborations with emergency managers. SPoRT's expertise in total lightning transitions continues to be recognized as we will support three new networks (Toronto, Atlanta, and Wallops Island) as they become available in late 2015 and early 2016. Finally, the GLM instrument is scheduled to launch on GOES-R in 2016 and SPoRT will be shifting its role to be prepared for this new capability. This includes investigating new collaborations to develop specific GLM tools (e.g., aviation needs at AWC and CWSUs), and expanding to international collaborations with NOAA and NASA partners. Furthermore, SPoRT's expertise in the use and training of total lightning data, as well as preparations for GLM, presents an opportunity to collaborate with EUMETSAT as they prepare for the launch of their own Lightning Imager, currently scheduled for 2019.

4

Modeling and Data Assimilation

Land Surface Modeling with LIS

Brief Overview of SPoRT-LIS

SPoRT continued running a real-time, high spatial resolution configuration of the Noah land surface model (LSM) within the NASA LIS (Kumar et al. 2006; Peters-Lidard et al. 2007) framework (hereafter referred to as the "SPoRT-LIS"). Output from the real-time SPoRT-LIS is used for (1) initializing land surface variables for local modeling applications, and (2) displaying in decision support systems for enhanced situational awareness and drought monitoring at select NWS partner WFOs. The SPoRT-LIS continued to run over a domain covering the southeastern half of the CONUS, with an additional experimental real-time run over the entire CONUS and surrounding portions of southern Canada and northern Mexico (Case 2014), both of which incorporate SPoRT's real-time green vegetation fraction (GVF) derived from MODIS (Case et al. 2014). The experimental CONUS run incorporates hourly Quantitative Precipitation Estimate (QPE) from the Multi-Radar Multi-Sensor product (Zhang et al. 2011, 2014), which was transitioned into operations at the NCEP Environmental Modeling Center in fall 2014. Efforts are underway to update to version 7 of the LIS software, bringing consistency between the software maintained at GSFC and that used in near real time by SPoRT.

An assessment of selected SPoRT-LIS soil moisture output variables was conducted from August to October 2014 at three partner NWS WFOs to identify the operational utility for drought monitoring and evaluate the risk for areal/river flooding (White and Case 2015). The SPoRT-LIS soil moisture data were transitioned into the NWS native decision support system (AWIPS II) to enable optimal use of the data in conjunction with other operational datasets. While the SPoRT-LIS output was found to exhibit a favorable utility for contributing to drought monitoring (and to a lesser extent areal flooding potential) on finer sub-county scales than current national drought products, a limitation is that the soil moisture data by themselves cannot provide the proper historical context of the soil state in terms of anomalies or departures from a "normal" condition. Additional details of the SPoRT-LIS assessment are provided in the Transition Training and Assessments section of this report.

Soil moisture climatology and anomaly product

To address key feedback from the LIS assessment, a 30+ year soil moisture climatology was developed at ~3-km grid spacing, county-by-county, over the entire CONUS. LIS-Noah fields were output once per day from the restarted run spanning 1 January 1981 to 31 December 2010. For initial development of soil moisture anomalies, the total column relative soil moisture variable ($RSM_{0\text{-}2m}$; Eq. [1]) was used to construct the soil moisture distribution by county,

$$RSM_{0-2m} = \frac{\theta - \theta_{wilt}}{\theta_{sat} - \theta_{wilt}} \quad (1),$$

where θ is the volumetric soil moisture, θ_{sat} is the field capacity, and θ_{wilt} is the wilting point of the soil classification at a given grid point. The value of $RSM_{0\text{-}2m}$ at grid points for each county were grouped together over the 30-year spin-up run to develop a climatology, from which ranked histograms were generated to determine the climatological context of any given time period. A sample histogram on 21 August for Madison County, AL is shown in Figure 10, along with the daily mean $RSM_{0\text{-}2m}$ from 21 August 2007 during the peak of a severe drought. The county-averaged $RSM_{0\text{-}2m}$ from 21 August 2007 (22.64%) falls between the 5th and 2nd percentiles of the 21 August 30-year distribution for Madison county, AL; the 5th and 2nd percentiles are used as proxies for D3 and D4 drought following Xia et al. (2014a, b), as subsequently described.

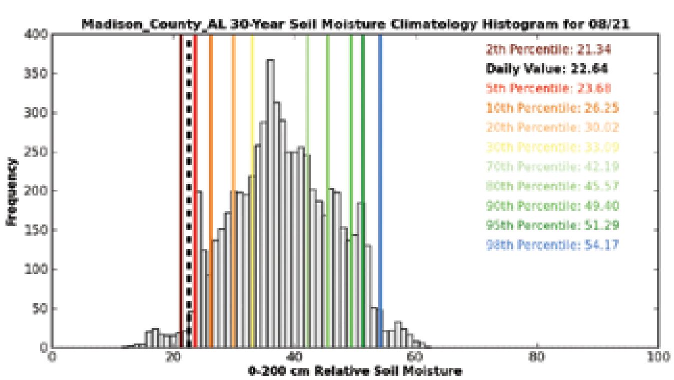

Figure 10. Sample daily histogram of 0-2 m relative soil moisture ($RSM_{0\text{-}2m}$; in %) on 21 August from the 30-year LIS soil moisture climatology run spanning 1981-2010, using all grid points residing within Madison county, AL. The colored vertical lines represent the values of $RSM_{0\text{-}2m}$ corresponding to the proxy percentile thresholds for D4 (2nd percentile), D3 (5th percentile), D2 (10th percentile), D1 (20th percentile), and D0 (30th percentile), along with their mirror analogs on the moist side of the histogram. The bold dashed vertical line represents the county-averaged $RSM_{0\text{-}2m}$ for 21 August 2007 during the severe drought in the Southeastern U.S.

Daily maps of these point-by-point percentiles can be displayed on a map to provide an objective analysis of drought similar to the U.S. Drought Monitor (USDM) drought classification product. A proxy soil moisture percentile threshold was applied to correspond to the individual USDM categories (i.e., D0 through D4), following the method used by Xia et al. (2014a,b). Plotting the soil moisture thresholds in the same colors as the USDM classifications for quick visual comparison reveals good qualitative agreement, especially over the eastern half of the U.S. (Figure 11) for the 21 August 2007 case. The severe and exceptional drought classifications (D3 and D4) over the southeastern U.S. and western Great Lakes regions (right panel) are represented well by the proxy percentiles of $RSM_{0\text{-}2m}$. Dry soil moisture anomalies appear to be strongly correlated to drought occurrence in the eastern U.S. (at least for this date) and thus are represented well by the $RSM_{0\text{-}2m}$ proxy percentiles.

The pattern similarities tend to break down over the western U.S. and High Plains, possibly because of the predominantly arid climatic regimes. Small changes in soil moisture from a rain event could yield substantial changes to the percentile within a given county's probability density function. There is still a tendency for more arid soil moisture anomalies in the western U.S. where the USDM product indicates D2 and D3 drought categories. However, other factors such as reservoir levels, baseflow, streamflow and snowpack/snowmelt likely contribute more strongly to drought severity in the western U.S., and thus should be examined for a better correlation to drought.

NESDIS/VIIRS GVF Implementation in LIS

NOAA/NESDIS produces a daily real-time, global GVF product at 4-km resolution and a regional 1-km GVF product over CONUS derived from VIIRS enhanced vegetation index composites (Vargas et al. 2013). The GVF product suite will be promoted to operational status at NESDIS in early 2015, and SPoRT plans to incorporate these real-time VIIRS GVF into the upgraded CONUS-LIS run described above.

NESDIS provided a sample year of VIIRS GVF data, which SPoRT successfully incorporated into both LIS and the Weather Research and Forecasting (WRF) model frameworks, in a similar fashion as how the current real-time SPoRT-MODIS regional GVF is used. A preliminary analysis of the VIIRS GVF data and output from LIS incorporating the VIIRS GVF showed that the NESDIS product responded reasonably to weather/climate anomalies. An example difference plot between the static GVF climatology and the real-time VIIRS GVF during May 2013 is shown in Figure 12. Spring 2013 experienced a delayed green-up of deciduous vegetation (panel b) relative to the climatological depiction (panel a) due to substantially colder than normal temperatures across much of the Continental U.S. (panel d). Fractional differences of up to 40% or more are seen across portions of the Upper Midwest and Appalachians during May 2013 (panel c). These large differences in input GVF resulted in discernible modeled differences in the surface energy fluxes and soil moisture distribution during May 2013 (Figure 13). The continued use of real-time GVF in current and upgraded versions of the SPoRT-LIS running the Noah land surface model are expected to have positive benefits on modeled soil moisture for applications by SPoRT end-users.

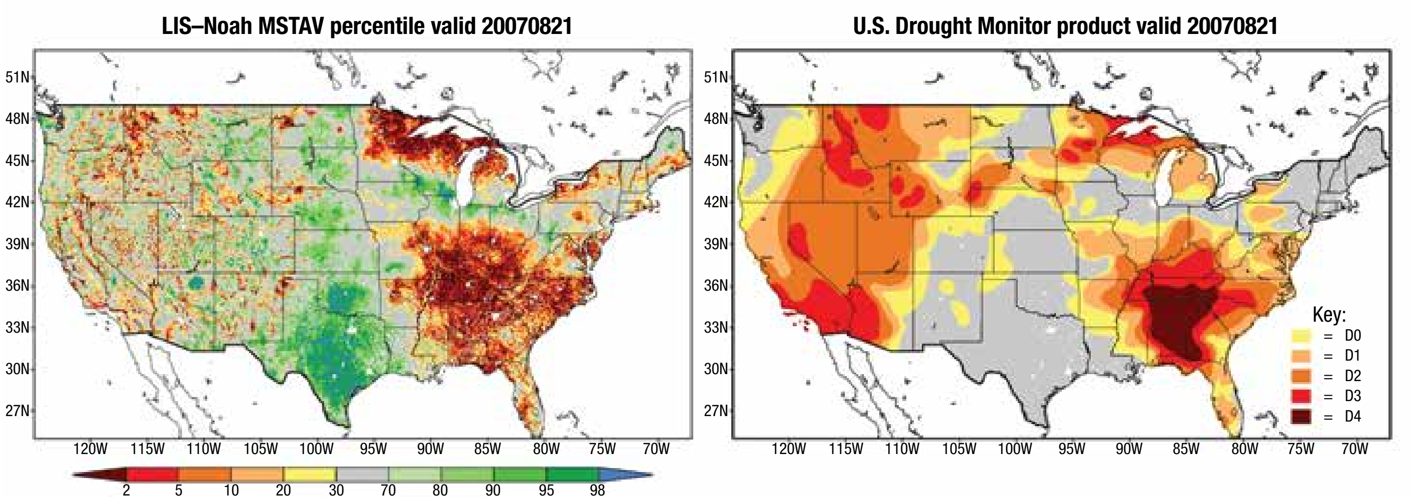

Figure 11. LIS-Noah $RSM_{0\text{-}2m}$ percentiles on 21 Aug 2007 colorized by the proxy USDM drought class and moist analogs (left), and corresponding USDM drought classification map from 21 August 2007 (right).

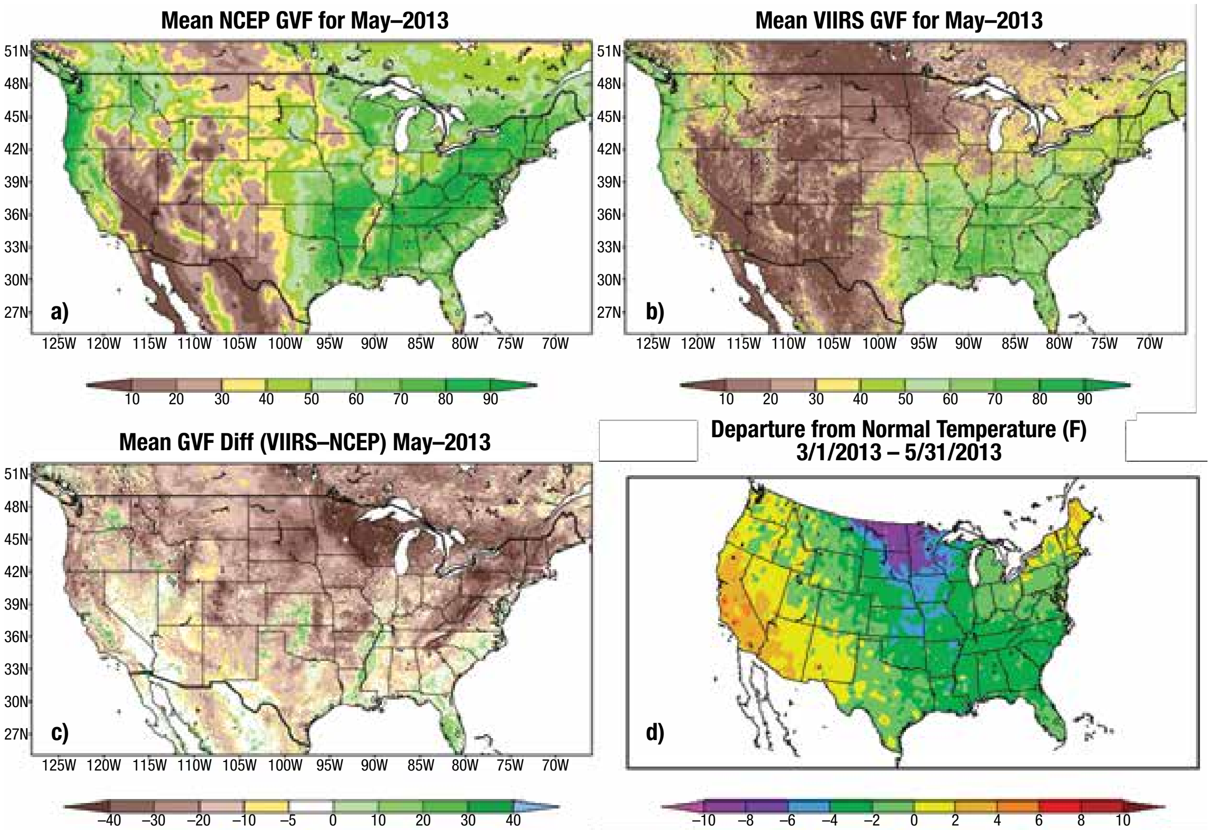

Figure 12. Comparison of GVF (%) during the delayed green-up of May 2013: (a) NCEP climatology GVF during May, (b) mean VIIRS GVF during May 2013, (c) difference in means (VIIRS–NCEP), and (d) departure from normal temperatures (deg F) from March to May 2013.

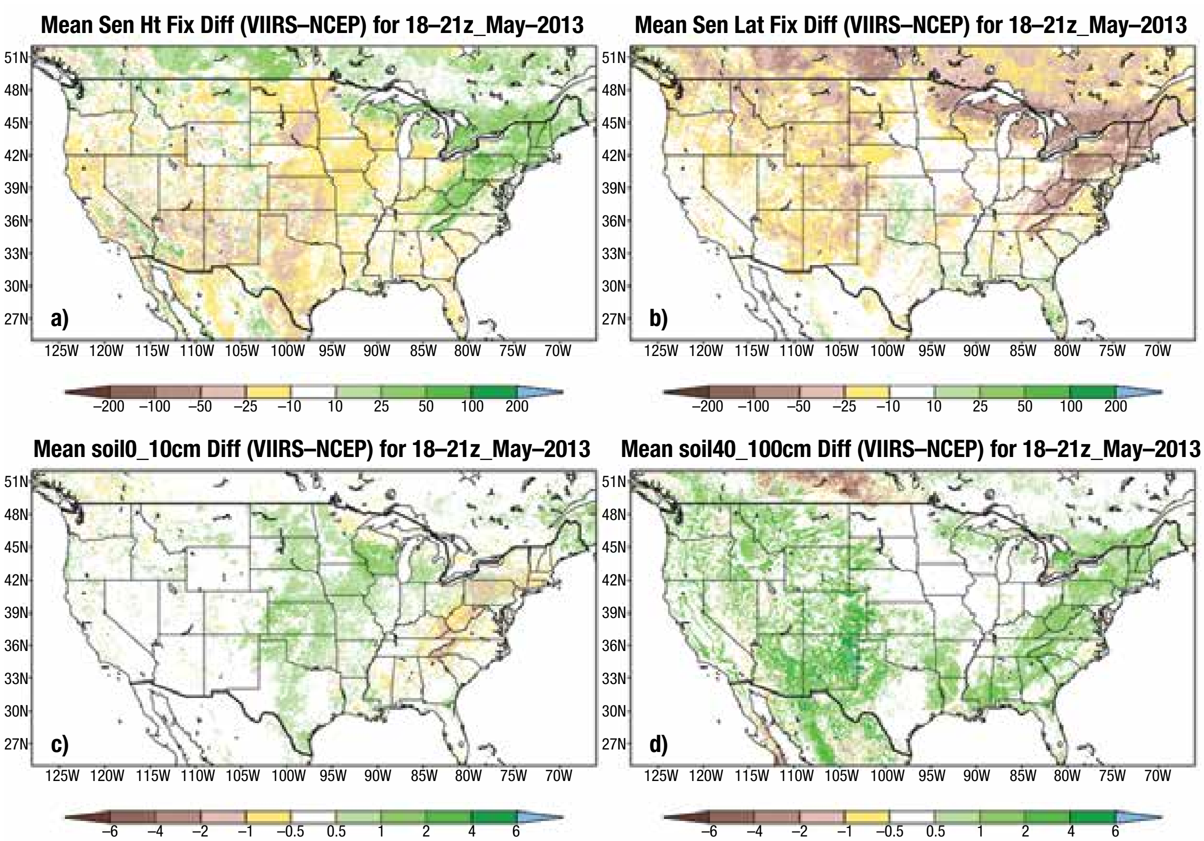

Figure 13. Mean monthly differences in heat fluxes (W m-2) and volumetric soil moisture (m^3 m^{-3}) in LIS-Noah from the 1800-2100 UTC time frame (~peak heating) during May 2013 for (a) sensible heat flux, (b) latent heat flux, (c) 0-10 cm soil moisture, and (d) 40-100 cm soil moisture.

Soil Moisture Data Assimilation

In the lead up to the SMAP launch in January 2015, SPoRT implemented the assimilation of soil moisture retrievals from the Soil Moisture and Ocean Salinity (SMOS) satellite into the Noah LSM within LIS in order to improve model depiction of soil moisture. SMOS is a polar-orbiting satellite launched by the European Space Agency in 2009 (European Space Agency 2002) which is used to retrieve near-surface soil moisture with a resolution of 35-50 km and an accuracy of 4% (volumetric). SMOS has a similar accuracy and resolution to the SMAP satellite products (Entekhabi et al. 2012; Kim et al. 2012) for which SPoRT is an Early Adopter. Through assimilation of SMOS measurements, SPoRT is preparing for use of SMAP data when the retrieval product is made available later this year.

Within LIS, satellite retrievals of soil moisture are combined with previous model fields (backgrounds) by an Ensemble Kalman Filter algorithm to produce updated analyses of soil moisture. This process is illustrated in Figure 14 for a test case from 1 April 2013. The LIS background soil moisture (panel a, before any assimilation) is combined with the SMOS retrieved soil moisture (panel b) to produce the updated analysis (panel c). The SMOS data includes elevated soil moisture values in the lower Mississippi Valley in a large area that is equipped for irrigation for rice agriculture (shown in panel d). The model forcing data does not include irrigation, so this feature is absent in the background field. However, the assimilation incorporates these data so the final analysis reflects the observed areas of high soil moisture. While the impact of the SMOS data is much smaller in most cases, this illustrates clearly the ability of the assimilation algorithm to adjust the model soil moisture fields to more closely match the satellite observations.

A data assimilation experiment was conducted for a 7-month period over the summer of 2011, with validation against 193 surface soil moisture probes over the central and eastern US. Correlations between model and directly measured soil moisture increased from 0.48 to 0.61 for the 0-10 cm layer, and from 0.67 to 0.72 for the root zone (10-100 cm) layer due to the use of SMOS data. Assimilation of SMOS and SMAP soil moisture retrievals will help to improve modeled soil moisture for situational awareness of flood risk and drought assessment. Through coupling of LIS with the WRF atmospheric model, it is anticipated that short-term weather forecasts may also be improved.

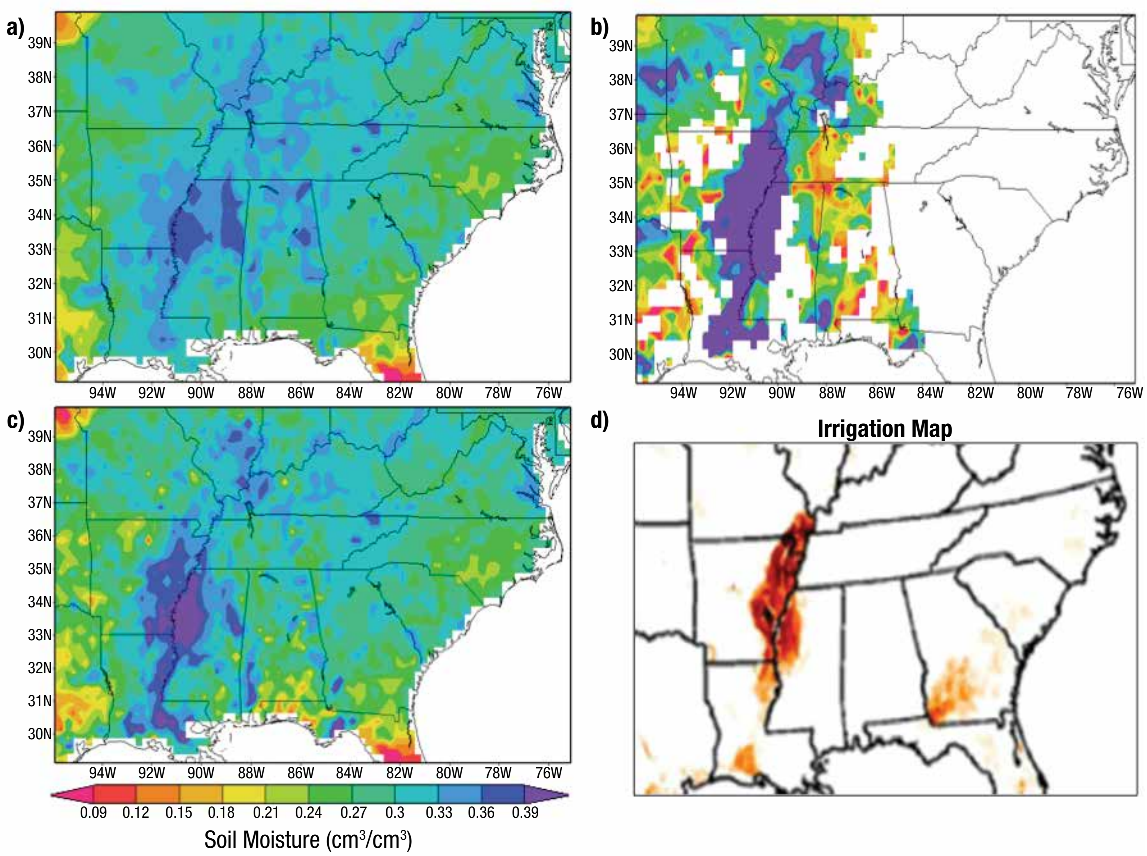

Figure 14. Soil moisture data assimilation case from 1 April 2013: a) Model background 0-10 cm volumetric soil moisture (cm^3 cm^{-3}); b) SMOS near-surface soil moisture retrieval (cm^3 cm^{-3}); c) 0-10 cm soil moisture analysis (cm^3 cm^{-3}); d) Food and Agriculture Organization of the United Nations map of irrigated areas.

Hyperspectral IR Data Assimilation

Impact of Hyperspectral IR on Modeling Strong Non-Convective Wind Events

SPoRT has a long history of assimilating retrieved profiles from hyperspectral IR sounders into NWP models. Work was performed to demonstrate the impact of assimilating hyperspectral IR profiles on forecasting stratospheric air, tropopause folds, and associated non-convective winds. Hyperspectral infrared profiles from AIRS, IASI, and CrIMSS were assimilated into the Advanced Research Weather Research and Forecasting NWP model using the Developmental Testbed Center's GSI System. The modeling system was configured with forecast cycling mimicking the operational NAM model; therefore, observations were assimilated at 3-h intervals, starting 12 h before initialization time. The model was configured with a 12-km domain, 35 vertical levels, and initialized with NCEP Global Forecast System model data. A control simulation was completed with conventional data assimilation and an experiment simulation was completed with conventional data assimilation plus hyperspectral IR temperature and moisture profiles from AIRS, IASI, and CrIMSS. Both the control and experiment excluded AIRS radiance assimilation so the impact of the satellite profiles could be assessed independent of the radiances. The control and experiment simulations were then compared to 32-km North American Regional Reanalysis (NARR) interpolated to a 12-km domain that matched the model simulations.

Both the control and experiment simulated strong non-convective winds south of the low pressure center in a case study from 9 February 2013 (Figure 15); however, the control over-forecasted the magnitude of the winds, while the experiment that assimilated satellite profiles forecasted winds closer in magnitude to the reanalysis data. Vertical cross sections of potential vorticity were analyzed to identify the tropopause fold. Results showed the experiment simulated a tropopause fold with a similar shape as the reanalysis, but with a greater magnitude of potential vorticity. Vertical profiles were plotted to reveal a connection between the shape and magnitude of the tropopause folds and the near-surface winds (Figure 16). Inspection of the profiles revealed the experiment simulated the magnitude of the winds closer to the reanalysis data because of the presence of a lower, deeper inversion layer (red dot, dash line) which limited the vertical transport of momentum and resulted in weaker near-surface winds. The same inversion layer was not present in the control; however, the strong inversion layer was not present in the reanalysis data either. Even though the experiment near-surface wind forecast was closer to the reanalysis data, the forecasted vertical profiles were less representative. These results indicate that representing near-surface stability appears more important to simulating the near-surface wind field than accurately representing the tropopause shape and magnitude.

The preliminary results led to questions about the technique used to assimilate the satellite profiles in GSI as radiosondes with radiosonde error characteristics. Satellite profiles typically have larger error characteristics than radiosonde observations, especially in the lower levels. There is thus a need to expand this work to assimilate the profiles with appropriate error characteristics to better represent the near-surface environment.

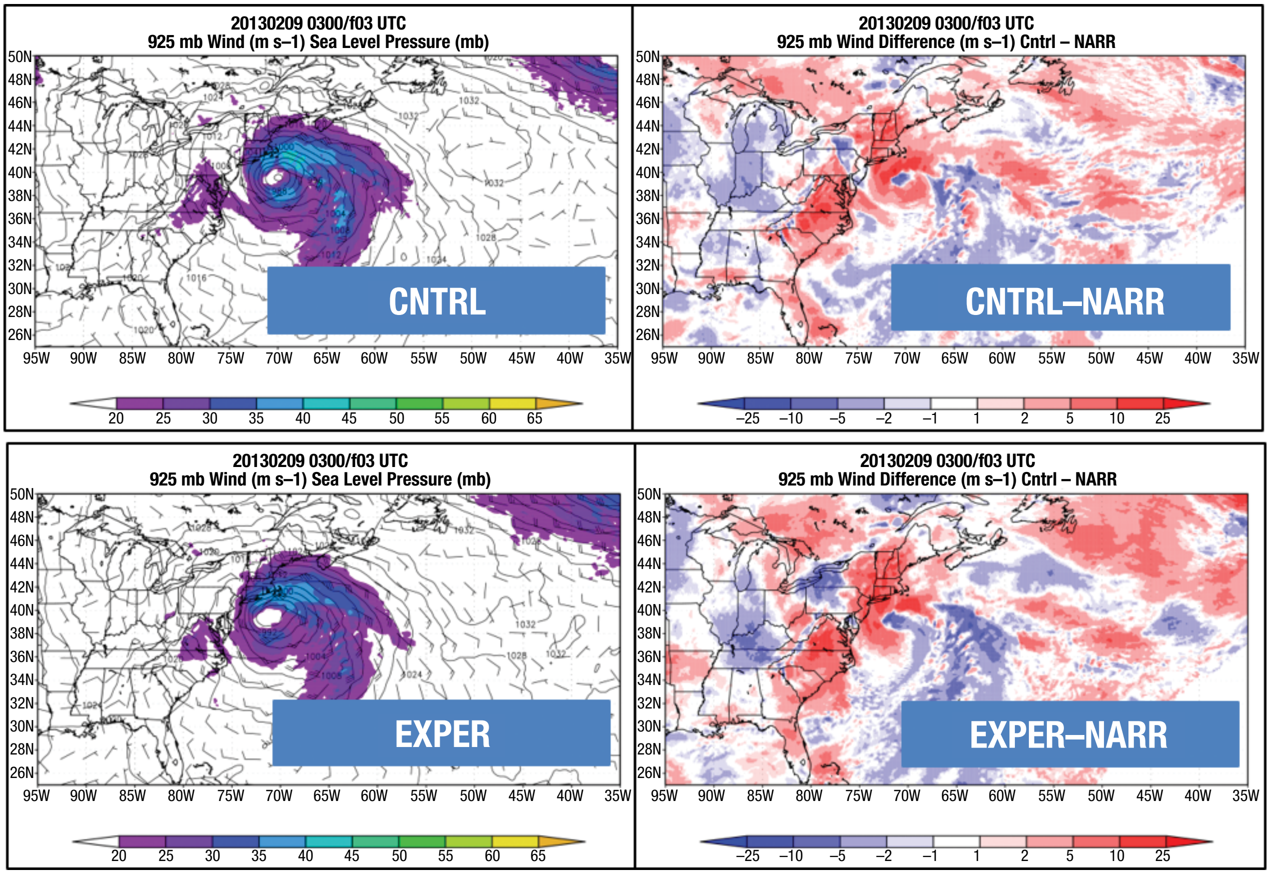

Figure 15. (Top left): Model 3-h forecast 925-hPa wind (shaded and barbs) and mean sea level pressure (black solid lines) initialized at 0000 UTC 9 February 2013 for a control simulation that only assimilated conventional observations. (Top right): Difference between 925-hPa wind from the control simulation and 925-hPa wind from the NARR analysis valid 0300 UTC 9 February 2013. (Bottom left): Same as top left but for experiment simulation that assimilated conventional observations plus AIRS, IASI, and CrIMSS retrieved temperature and moisture profiles. (Bottom right): Difference between 925-hPa wind from the experiment simulation and 925-hPa wind from the NARR analysis valid 0300 UTC 9 February 2013.

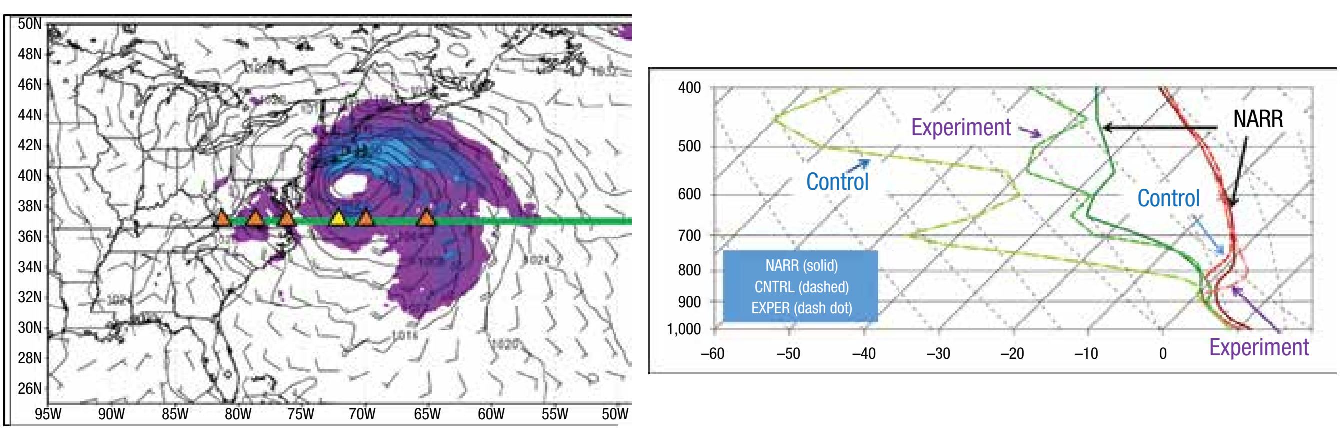

Figure 16. (top-left) Triangles show locations where model profiles were analyzed, with yellow triangle being the location of the model profile shown at bottom. (top-right) Model profiles for the 3-h forecast initialized at 0000 UTC on 9 February 2013 compared to the NARR reanalysis at 0300 UTC on the same date: NARR temperature (red solid) and dew point (green solid), Control temperature (red dashed) and dew point (green dashed), and Experiment temperature (light red dot-dash) and dew point (light green dot-dash).

Updated Assimilation Techniques using NUCAPS Data

Recently, NOAA has committed to the NUCAPS algorithm as the operational system for processing retrieved temperature, moisture, and trace gases from CrIS. NUCAPS is based off the legacy AIRS retrieval algorithm and is flexible enough to provide a singular retrieval algorithm to process CrIS, AIRS and IASI retrievals. This feature makes it an attractive dataset for assimilation activities. In order to demonstrate impacts of assimilating NUCAPS-CrIS temperature and moisture profiles into GSI, changes were made in processing the satellite data and within the GSI configuration tables. The results presented in the previous section highlight the need for assimilating hyperspectral IR sounders with more representative error characteristics, especially in the lower levels. These observations are traditionally assimilated as radiosonde observations and assigned radiosonde errors which are unrepresentative for satellite profiles. Thus, GSI error tables were configured to contain NUCAPS temperature and moisture root mean square errors from Nalli et al. (2013).

An initial experiment over a small test domain demonstrated that the assimilation of profiles does produce changes to analysis fields evidenced by innovations larger than +/- 2.0 K (Figure 17; left panel) and warmer analysis increments over portions of the domain (Figure 17; right panel). This preliminary work to assimilate hyperspectral IR profiles with distinct error characteristics from radiosondes in GSI and WRF system will lead to more experiments that show the impact of assimilating NUCAPS profiles on various forecast applications. The next steps include additional experiments with a model configuration that mimics the High Resolution Rapid Refresh (HRRR) and assessing the impact of assimilating hyperspectral IR profiles for summer-time prefrontal convection cases.

MODIS/AIRS Radiance and Cloud Top Pressure Comparisons

SPoRT continues to collaborate with the Global Modeling and Assimilation Office (GMAO) at Goddard Space Flight Center to investigate the cloud-top designation within GSI used for determining clear radiances from hyperspectral IR sounders. SPoRT has developed a technique within GSI to input observed cloud top pressures from MODIS for designating clear versus cloudy AIRS radiances. This technique has been implemented within an offline version of the GMAO GSI system and a set of 3-month experimental cases has been run. Analysis of the output will be evaluated in the coming year.

Cloud and Precipitation Modeling

Aerosol Assimilation with WRF-Chem Model

Pollution and dust aerosols suspended in the atmosphere over the western U.S. have been traced back to source regions in Asia, the Middle East, and North Africa (Creamean et al. 2013). These aerosols are carried by strong mid- to upper-level westerly winds across the Pacific to the western U.S. where they can influence cloud and precipitation processes (Ault et al. 2011). Local pollution aerosols from the highly urbanized cities of California have also been shown to impact cloud and precipitation processes over the region (Fan et al. 2014). Therefore, it is essential to fully understand the impact of these local and

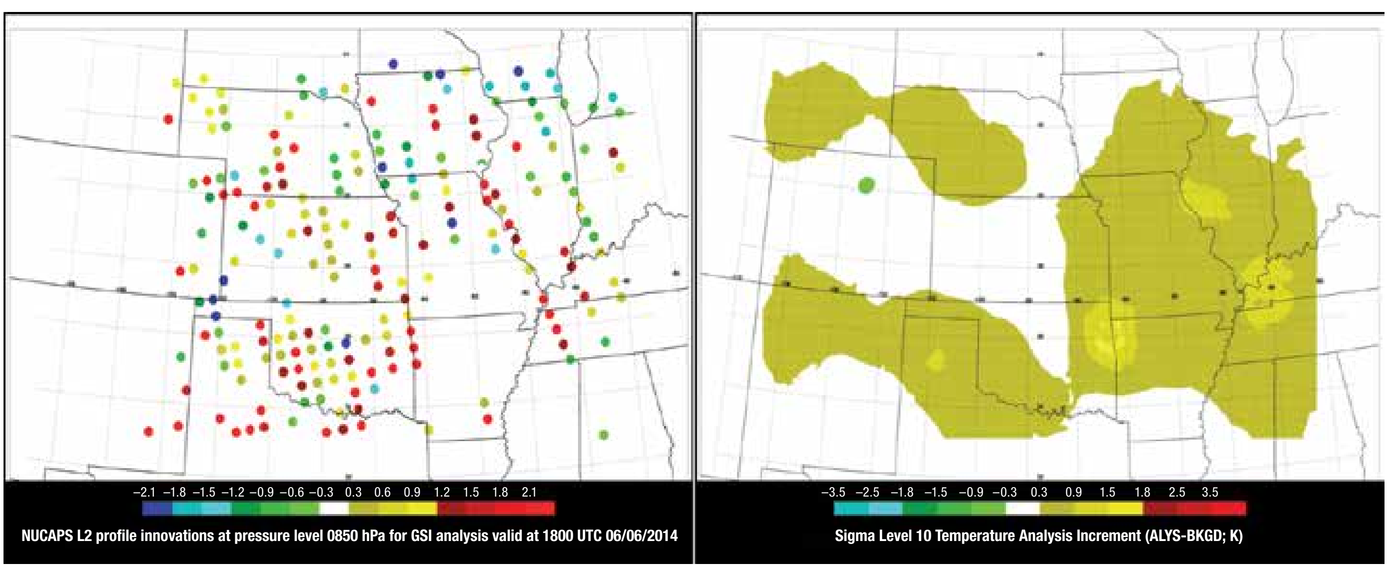

Figure 17. Temperature innovations at 850 hPa (K; observations – background; left) and temperature analysis increment (K; right).

long-range transported aerosols on clouds and precipitation production over the western U.S., especially during AR events, which account for up to half of California's annual precipitation and can lead to widespread flooding (Ralph et al. 2006). In an effort to improve the understanding of the impacts of aerosols on precipitation processes over this region, dedicated field campaigns (i.e., CalWater 1 and 2) were designed over northern California during the winters of 2011 and 2014 (Spackman et al. 2014). During these CalWater campaigns, detailed measurements of aerosol and cloud processes were gathered, which provide an excellent opportunity to fully understand and evaluate WRF-Chem simulations of the aerosol-cloud-precipitation interactions associated with AR events.

SPoRT began modeling simulations on two AR events that made landfall in California on 18-19 February and 5-7 March, 2011, which were distinctly different in terms of Integrated water Vapor Transport (IVT), cloud condensation nuclei and ice nuclei concentrations, and precipitation. The 5-7 March storm produced much less precipitation compared to the 18-19 February event, even though the March storm was associated with twice the upslope IVT along coastal California. At the same time, the March storm was associated with less ice nuclei (i.e., dust) and more cloud condensation nuclei (i.e., pollution and sea salt) than the February event. Through modeling simulations, the intent is to unravel whether the vastly different aerosol concentrations during these two storms were the primary cause of the atypical IVT and precipitation trends. Control runs utilized the Model for Ozone and Related chemical Tracers for providing the initial and lateral boundary conditions for aerosols. Future experimental runs will invoke the GSI data assimilation system for updating the initial and lateral boundary conditions with satellite retrievals of AOD, initially using MODIS Terra and Aqua AOD as GSI is already setup for these datasets.

Assimilation of GPM Data into GSI

SPoRT funds projects through the competitive Research Opportunities in Space and Earth Sciences (ROSES) proposal process. One of the projects funded in 2014 is titled "Data Assimilation and Evaluation of GPM Dual-Frequency Precipitation Radar and Microwave Imager Data with the GSI Data Assimilation System". SPoRT supports this work by providing technical expertise in the application of GSI data assimilation system and programmatic direction through collaborations with the Joint Center for Satellite Data Assimilation. This particular project focuses on developing techniques to assimilate GPM Level 2 precipitation products—including the Level 2 Dual Polarmetric Radar and Level 2 Goddard Profiling Algorithm products from GMI—into GSI. One of the main motivators for this work is that the WRF model tends to over-predict stratiform precipitation (Figure 18a, c), although the amount of over-prediction can be related to choice of microphysics and convection parameterization schemes. The hypothesis is that assimilation of the GPM rain rates (Figure 18b) will lead to more accurate representation of all precipitation output from the model (both convective and stratiform). The GPM precipitation rate data has been successfully read into the GSI system, but impacts of the data have been limited due to inconsistency and inaccuracy between the model variables from the WRF file and related GSI modules, and in the tangent linear and adjoint modules. Work is ongoing to update/modify the tangent linear and adjoint codes of the precipitation modules in GSI that compute convective precipitation, heating, and moistening; the gridscale condensation routine; grid-scale precipitation processes; and the driver for the precipitation forward and adjoint models.

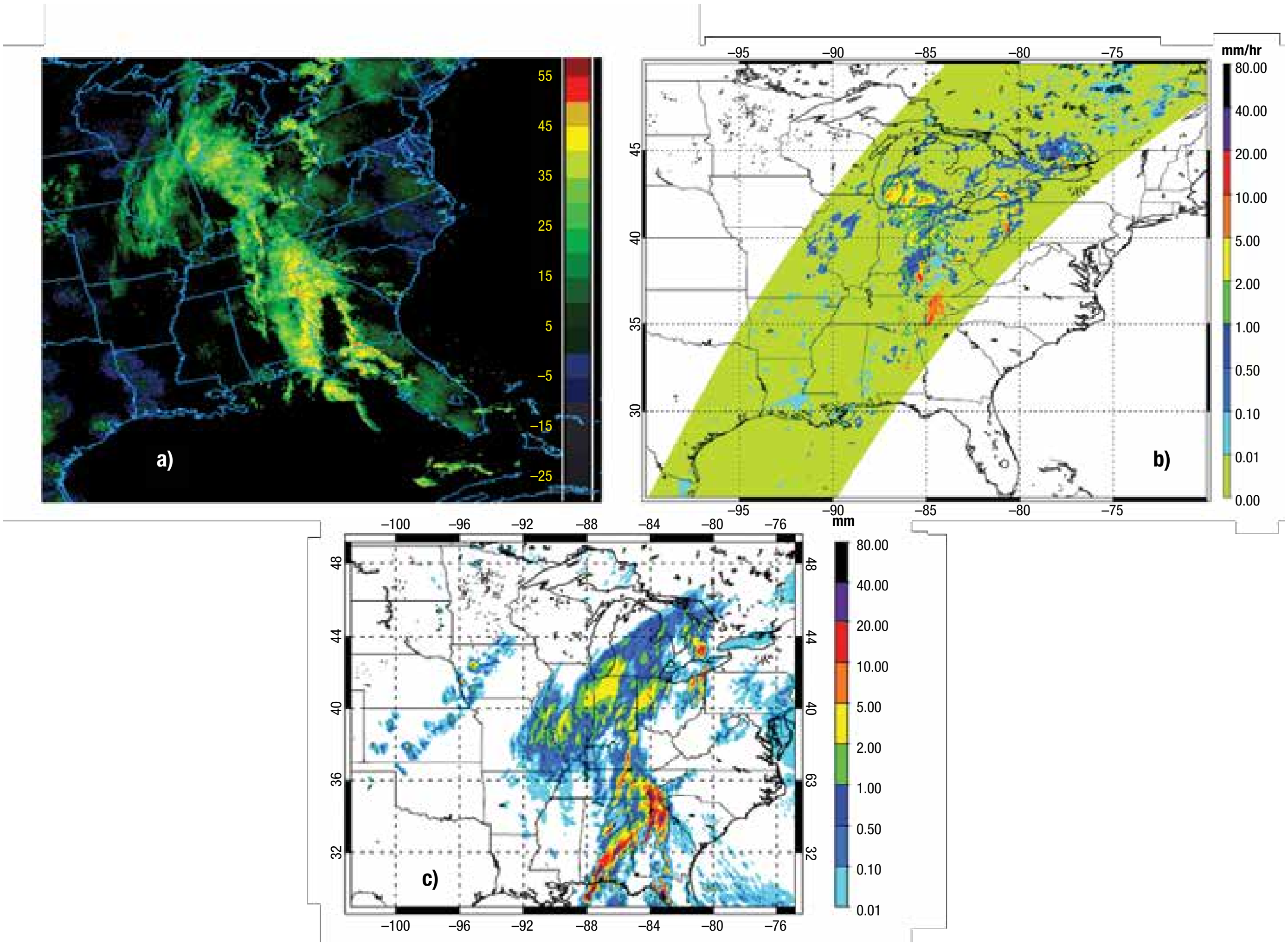

Figure 18. Radar reflectivity from (a) regional NEXRAD composite at 0155 UTC, (b) precipitation rate from GMI Goddard Profiling Algorithm at 0215 UTC, and (c) twenty-six hour forecast of hourly accumulated precipitation from the WRF model run initialized on 0000 UTC 14 May 2014 (valid 0200-0300 UTC on 15 May).

Future Activities

Future work in modeling and data assimilation will involve integration of new NASA datasets into existing modeling capabilities. As previously mentioned, SMAP retrievals will be assimilated into the SPoRT-LIS. Additionally, the GPM IMERG dataset will become the precipitation forcing dataset for international LIS domains, such as the real-time simulation over eastern Africa to support SERVIR collaborations with the Kenya Meteorological Service. The IMERG product can also offer model validation over oceanic and remote regions where high-quality radar/rain gauge QPE is unavailable.

With the migration to version 7 of LIS, SPoRT will be able to take advantage of new capabilities and data sets for inclusion into the real-time SPoRT-LIS. Ongoing collaborations with the Goddard LIS and NU-WRF teams will lead to the transitioning of capabilities developed by these research groups into the operational SPoRT-LIS, which will ultimately be evaluated by forecasters. SPoRT will also seek collaborations with the National Water Center in Tuscaloosa, AL as the facility matures and NOAA hydrological modeling services increase there.

Lastly, new computer resources are expected in the second half of 2015, which will enable a more robust, comprehensive coupled LIS/WRF "SPoRT WRF" system that combines all of the modeling and data assimilation research activities described above into a single modeling system that can be run in real time. Traditionally, SPoRT has supported NWS local modeling through distribution of datasets for individual offices to acquire and run using local WRF configurations. Local modeling within the NWS is undergoing a paradigm shift from individual offices running a local version of WRF to having WRF run in an "on-demand" capacity for regions where high impact weather is expected. SPoRT plans to learn more about these activities through discussions with NWS regional and national headquarters personnel to understand how to leverage SPoRT modeling expertise in regional modeling, cloud computing, and on-demand modeling to support NWS operations.

5

Decision Support Systems

AWIPS II Transitions

Product Preparation and Transition to AWIPS II

The NWS has been migrating its WFOs from the legacy AWIPS system to AWIPS II since 2011. During 2014, eight WFOs who collaborate with SPoRT were transitioned to AWIPS II. A package of configuration files (menu, color map, and style rules), tailored to the product needs of each WFO was provided, along with any needed technical support. SPoRT directly assisted WFOs and/or NWS Regional Headquarters personnel to ensure that our products would be displayable in AWIPS II. In order to streamline the process of transitioning data to support the wide-range of partners, SPoRT began to invoke the "Regionalsat" baseline AWIPS II plug-in to ingest most data products. This plug-in handles NetCDF files so that, with minor modifications, the same files being delivered to WFO partners using legacy AWIPS could also be delivered to newly-transitioned AWIPS II WFOs. This reduces local processing and network bandwidth required to provide products to NWS partners. As new products are designed for AWIPS II, the most important task is to ensure the configuration within AWIPS II has proper labelling and sampling within the Common AWIPS Visualization Environment. This can sometimes be complicated by changes within newer versions of AWIPS II.

AWIPS II LMA Plug-in for Lightning Mapping Arrays

As the NWS continues its upgrade to AWIPS II, SPoRT has promoted a seamless transition of its lightning products to this upgraded decision support system. SPoRT's total lightning efforts are different from satellite capabilities, since AWIPS II was not designed to initially support these non-standard data. SPoRT had the additional need of maintaining a data feed to NWS partners using both AWIPS II and the legacy AWIPS. The solution has been SPoRT's LMA plug-in to visualize ground-based LMAs within AWIPS II (Figure 19). This tool has been used in a test-bed mode with select, operational users via an AWIPS Test Authorization Note (ATAN). In 2014, the number of partners approved to use the ATAN had expanded to nearly every SPoRT NWS collaborator. Additionally, the plug-in was reviewed by NOAA's AWIPS II management team. Based on the successful review, the LMA plug-in was delivered to the AWIPS II baseline in December 2014 and included in AWIPS II version 14.4.1. This is an exciting milestone for SPoRT as the plug-in will no longer be considered a third-party product and represents the first ever non-NOAA effort to transition a plug-in through the ATAN process. Additionally, the plug-in has been demonstrated with other lightning data sets, opening possibilities for future collaborations.

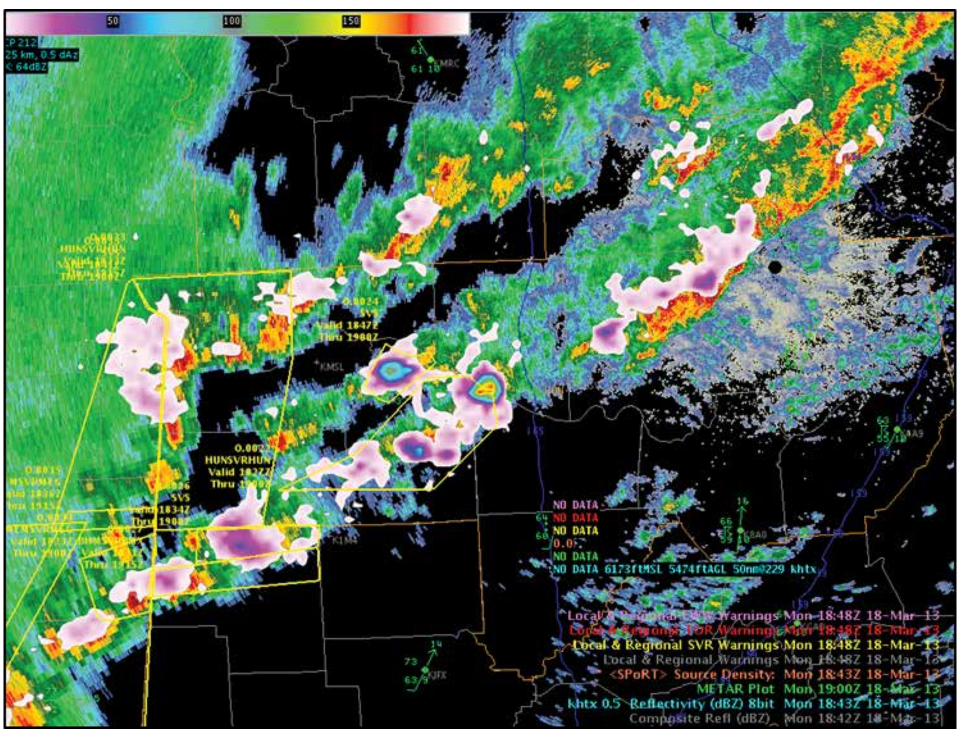

Figure 19. Sample display of total lightning in AWIPS II using the LMA plug-in developed by SPoRT. Total lightning data are overlaid with radar reflectivity data in this example.

Tracking Meteogram Tool for Total Lightning

SPoRT has been co-developing the tracking meteogram AWIPS II plug-in with the NWS Meteorological Development Laboratory (MDL; Burks and Sperow 2015). The tracking meteogram is a tool within AWIPS II that allows the end-user to manually track features and graph and monitor changes in meteorological variables through a graphical output. A proposal awarded to SPoRT by the NOAA/NWS Operations Proving Ground (OPG) enabled an expansion of the original SPoRT tracking meteogram tool to incorporate total lightning tracking into a similar MDL tool (Figure 20).

An evaluation took place at the OPG during May 2014, and was the first ever OPG assessment of this type that aimed to bring forecasters and developers to Kansas City for the assessment. The OPG evaluation allowed forecasters to test the tool in a simulated real-time environment with both archived and real-time events. With the tool, forecasters manually tracked observational fields of interest and displayed time-series trends in real time. This capability was particularly useful for monitoring lightning jumps, which can often precede severe weather events. The manual nature of the tool was emphasized given the trouble that automated cell trackers can sometimes have with merging and splitting cells. The tracking meteogram tool was well-received at OPG and SPoRT obtained feedback for improvements.

Although the tool was originally developed to track changes in total cloud lightning, the tool could also be used on numerical model, radar, and satellite data. The tool has applications in monitoring moving features such as velocity couplet strength in mesocyclones, cloud-top cooling rates, deepening of low pressure systems, and many other phenomena. Operational deployment of this tool is planned for mid-2015 within version 15.1.1 of the baseline code of AWIPS II.

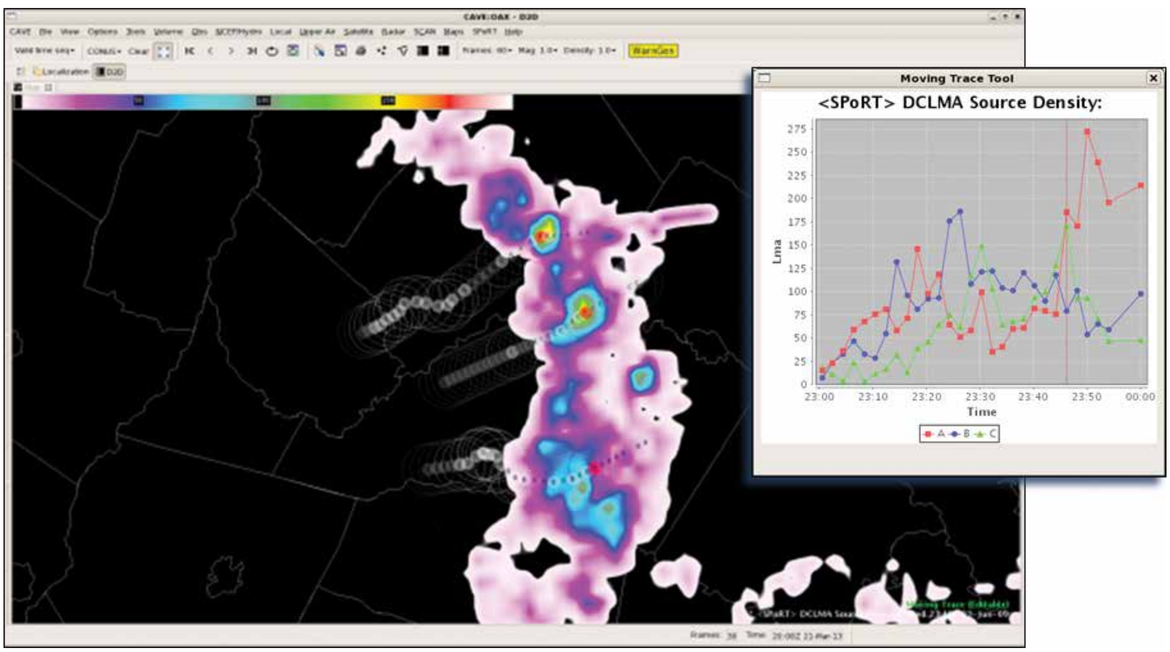

Figure 20. AWIPS II demonstration image of the tracking meteogram tool being used to track three separate cells observed by the Washington D.C. Lightning Mapping Array. The main image shows the traditional AWIPS display of the plane view source density product with the storm tracks overlaid. The inset shows the time series of the maximum source density observations for each cell being tracked.

Experimental Products Development Team

SPoRT continues to be a leader in AWIPS II development training by evolving the highly successful Experimental Products Development Team (EPDT). In 2012, SPoRT established the EPDT to create, provide, and collect training for AWIPS II development. A highly successful AWIPS II development training program has been established as part of EPDT. Since the creation of EPDT, over 45 participants have received AWIPS II development training through EPDT. The EPDT training program combines two types of training: instructor led classroom training and hands-on, real world development activities. Through the combination of these two types of training, participants learn skills and continue to refine them by solving problems that are beneficial to the meteorology community, while enabling new data and displays in AWIPS II.

In 2014, SPoRT hosted the second group of 15 participants ("group B"), in the EPDT program. The initial hands-on learning session was held in April 2014, and a development "code sprint" was held in August 2014. In addition to group B activities, members of the first EPDT group were brought in to perform a code sprint, which consists of writing plug-ins to ingest and display new datasets in AWIPS II. Part of the code-sprint group developed RGB capabilities within AWIPS II. These EPDT members devised the derived parameter Python code needed to implement all of the EUMETSAT RGB recipes for display by the Raytheon baseline-provided "Truecolor" plug-in. The "Truecolor" plug-in enables combining products into a 24-bit image by supplying separate products for the Red, Green and Blue components of the images. Once NWS sites receive AWIPS II version 14.3.1, they will be able to fully utilize the EUMETSAT recipes by using the EPDT-developed Python RGB derived parameters.

Another subset of the EPDT code sprint group developed ingest plug-ins to decode and display GOES-R data. The group started with Raytheon-developed GOES-R product plug-ins, initially testing the plug-ins with sample data. The group then identified GOES-R products that are currently missing from the AWIPS II baseline, thus requiring future plug-in development.

Future Work

SPoRT will continue its successful EPDT and AWIPS II plug-in development as well as deliver its core products in AWIPS II as partner offices upgrade. The tracking meteogram plug-in will also continue to be developed and refined for baseline delivery in version 15.1.1 of AWIPS II. Finally, the EUMETSAT RGB recipe code will be bundled for delivery to partner sites once they transition to AWIPS II version 14.3.1.

6

Transition Training and Assessments

Multi-spectral Composite Imagery for Aviation Forecasts and Cloud Analysis

Using current MODIS and VIIRS instruments, multi-spectral composite imagery (i.e., RGBs) can be created analogous to future-generation NOAA geostationary instruments (ABI on GOES-R/-S). These RGB products are both a demonstration of capabilities that forecasters will have from GOES platforms as well as a valuable tool in operations to increase situational awareness for many forecast issues. SPoRT transitioned the Nighttime Microphysics (NtMicro) and VIIRS DNB RGBs (Figure 21) to user groups at high-latitudes as well as in the coastal southeast CONUS for assessment in early 2014. The purpose was to (1) provide experience to forecasters applying RGB imagery in operations to ready them for day-1 operations of the ABI instrument on GOES-R and (2) more efficiently analyze cloud types and hazards to aviation (i.e., low clouds and fog). Operational users included the Alaska WFOs (Fairbanks, Anchorage, Juneau), WFO Medford, OR, and WFO Great Falls, MT as part of the "high-latitude" group, along with several existing WFO partners from the NWS Southern and Eastern Regions who are either on the Gulf or Atlantic coasts.

Training was provided to both groups in the form of recorded web modules. Because of the geographical differences between the participating groups, two modules were created. One 15-minute module used a fog example from McCarthy, AK while the other was a "micro-lesson" (about 8 minutes long) that demonstrated the ability of the NtMicro to differentiate fog from low cloud in the southeastern U.S. These materials were presented via teletraining sessions and made available online.

The assessment results indicated that 72% of users preferred the NtMicro RGB imagery over any other product to analyze low clouds and fog while the other 28% tended toward traditional satellite or surface observations. Between 40-50% of responses indicated that the NtMicro RGB imagery had "large" to "very large" perceived impact on general aviation and the differentiation of fog from other cloud features. This same impact from the VIIRS DNB RGB imagery was seen in roughly 20% of the user feedback. The DNB RGB imagery was not available as often due to a single satellite source (VIIRS only) and the dependency of the moon phase to provide adequate low-light conditions. These issues limited the effectiveness in the DNB RGB product in its current state.

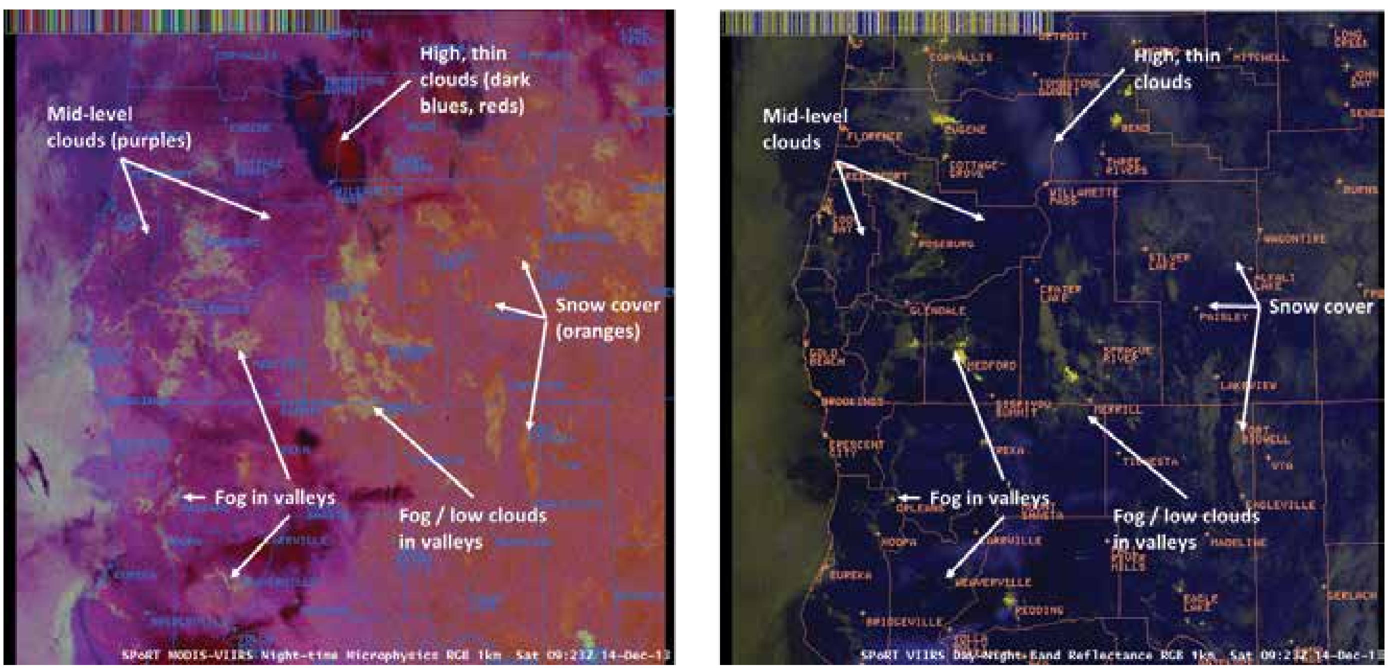

Figure 21. The NtMicro (left) and DNB Reflectance (right) RGBs for 14 December 2013 at 0923 UTC as displayed in AWIPS. The image is centered near the Oregon/California border and the city of Medford is in the left-center of image. Feedback for this event came from WFO Medford, OR in preparation for the assessment in early 2014.

While some users found the NtMicro RGB imagery to be a large advance in satellite imagery applications, others were unsure of the imagery interpretation and did not find the resulting colors intuitive to identify various features. The level of comfort with RGB imagery seemed to be a factor of the experience level of the user. While training was provided on these specific products, it was those users with prior training on the basics of RGB imagery and some experience who found large value in the NtMicro RGB imagery to analyze and differentiate cloud features. In some cases the extreme cold of high-latitude winter did limit the NtMicro RGB imagery effectiveness, but overall a notable impact was seen in operations, with several user feedback submissions indicating that decisions regarding aviation responsibilities were influenced by the RGB imagery. Further training on RGB applications are needed to ameliorate user's interpretation and operational application skills, and a greater number of existing instruments should be used in future activities to increase the product frequency. Future activities will include western U.S. users where a lack of in situ data increases the value of these RGB products from MODIS and VIIRS.

Within the southwestern CONUS, NtMicro RGB imagery had impact to aviation operations and WFO forecasters, but other RGB imagery was equally important. The Albuquerque WFO frequently used the Dust RGB imagery to diagnose dust plumes during both day and night. This RGB is again from the EUMETSAT "best practices" recipe and incorporates the same channels as the 24-h Microphysics; however, the thresholds and contrast-stretching per color component is adjusted to accentuate airborne dust in a bright magenta coloring. The channels needed for the product are available from both MODIS and VIIRS, and data are obtained from Direct Broadcast resources. The Albuquerque WFO had many opportunities to use the Dust RGB in Spring 2014 due to prevailing drought conditions in the region. Spring cyclones and northerly frontal passages were often accompanied by strong winds that lofted dust into the air, carrying it hundreds of miles. The Dust RGB was created and delivered with a typical latency of approximately 40 minutes. This enabled it to influence aviation and public forecasts. Figure 22 highlights how the Dust RGB product was used within the Albuquerque general public "Graphicast" via the NWS website and ultimately helped to change the aviation forecast operational policy defining ceilings from dust plumes.

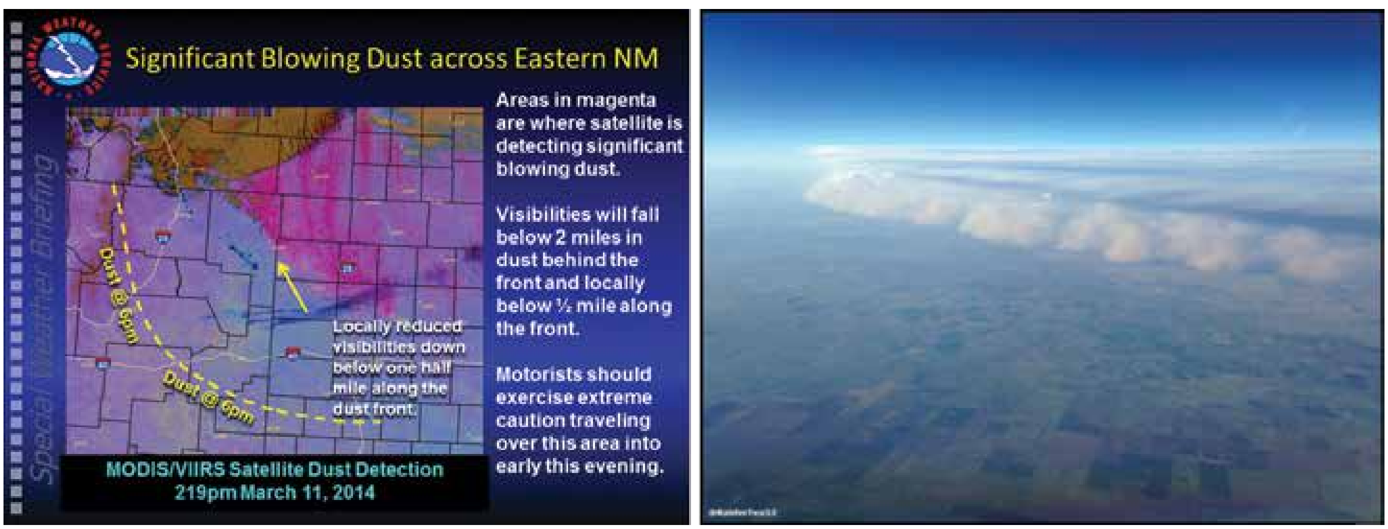

Figure 22. (left) "Graphicast" by the NWS WFO in Albuquerque with the Dust RGB from NASA/SPoRT inserted. Annotations point out a dust front (yellow arrow) associated with strong winds and the projected position of the dust leading edge at 6:00 P.M. local time. (right) Aerial photo of the 11 March 2014 dust "front" over northeastern New Mexico, corresponding to the WFO Albuquerque Dust RGB public Graphicast.

NASA LIS for Drought Monitoring and Situational Awareness for Flooding Forecasts

An assessment of selected soil moisture output of the SPoRT-LIS was conducted from August to October 2014 to determine its potential utility in the areas of drought monitoring and estimating the areal/river flooding potential from antecedent soil moisture conditions. The SPoRT-LIS has been evaluated in a testbed mode since 2011 by WFO Huntsville. Given the utility found at WFO Huntsville, this more formal assessment was conducted to broaden the applications of the SPoRT-LIS to drought and areal flood potential with the NWS WFO Houston, TX and Raleigh, NC. A subset of the SPoRT-LIS output variables were sent to each WFO consisting of the 0-10 cm volumetric, 0-10 cm and total column (0-200 cm) relative soil moisture (depicted in AWIPS II; Figure 23), and the weekly change in the total column relative soil moisture.

Prior to the kick-off of the August to October assessment, SPoRT developed two training modules (NASA Land Information System: A Primer, and NASA Land Information System: Applications Training; both available from the SPoRT web page at http://weather.msfc.nasa.gov/sport/training/) to help acquaint the participating NWS end-users with the SPoRT-LIS. The LIS Primer module serves as an introduction to the NASA LIS software framework, SPoRT's real-time configuration and transition of LIS, and how to view LIS output for various situational awareness applications. The LIS Applications training module focuses on the use of LIS soil moisture output variables to analyze sub-surface conditions associated with drought as well as to anticipate areal flooding potential given antecedent soil moisture conditions. Operational examples captured during initial testing by Huntsville forecasters were used within the training to demonstrate application impacts of LIS. Throughout the development of the modules, SPoRT personnel worked with NWS forecasters to ensure an appropriate presentation level.

Feedback from the NWS WFOs during the assessment was handled in several ways: (1) blog posts to the Wide World of SPoRT blog, (2) correspondence via email and/or the NWS chat forum, and (3) completion of short, online questionnaires. Two separate surveys for drought and flooding were developed using a Likert-type scale to determine the level of perceived utility of select SPoRT-LIS soil moisture variables on the forecaster's decision-making process. Ten blog posts were made during the course of the assessment along with 27 completed questionnaires (24 for drought and 3 for flooding).

Overall survey results indicated that forecasters had high confidence in applying the SPoRT-LIS soil moisture to drought monitoring and to a lesser extent, areal flooding potential. Survey participants noted that they were comfortable in applying the SPoRT-LIS data based on the training, indicating the success of the training modules developed in advance of the assessment. Of the LIS variables provided, forecasters identified the total column relative soil moisture and especially the weekly change in this variable as the most helpful fields in making decisions regarding drought classification. Based on analysis of the SPoRT-LIS in AWIPS II, the NWS Raleigh recommended adjustments to the USDM D0 areal coverage, which was accepted by USDM authors. This and other applications of LIS in operations were highlighted in cases and blog posts documented by the NWS Raleigh. Future recommendations for the LIS include an expansion to a full CONUS domain at the same resolution, and the development of a soil moisture climatology to place real-time soil moisture into an historical context for drought and flood applications.

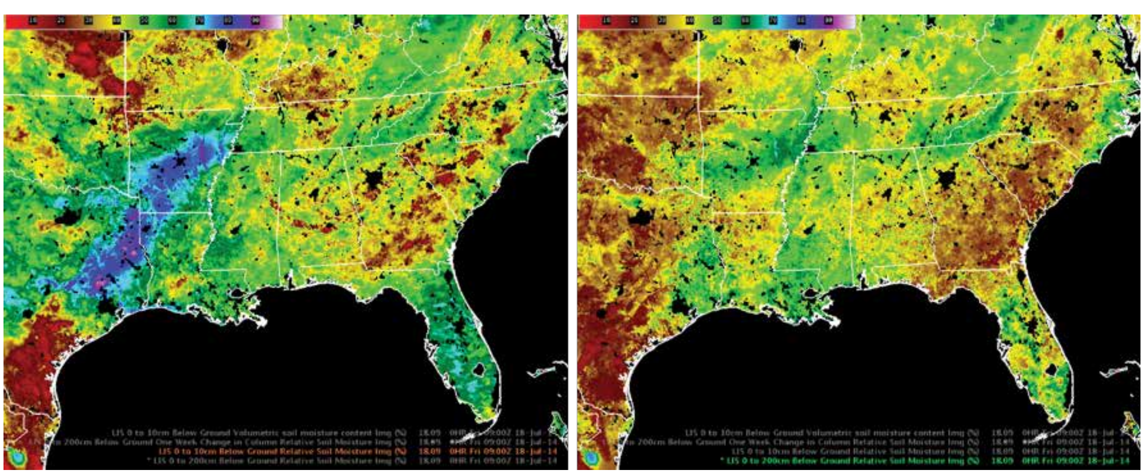

Figure 23. SPoRT-LIS 0-10 cm (left) and 0-200 cm (right) relative soil moisture as displayed in AWIPS II.

As SPoRT continued in 2014 to prepare a LIS domain for the entire CONUS, interactions with users in the western CONUS have indicated a need for land surface model products for similar issues of flooding and drought. In particular, interest in the southwest U.S. for LIS applications during the monsoon season has been expressed by several WFO users. Sparse observations of sub-surface moisture in the west reveal a need for modeled products forced by NWP and QPE analyses. Additional needs in the area of vegetation health are anticipated to influence decisions regarding drought classification and wildfire threat. SPoRT will look in the future to establish LIS-CONUS output, including GVF, to gauge the value to drought/flood and other applications. SPoRT also plans to engage NWS RFCs to explore the use of LIS within their operations, including the possible ingest of LIS within hydrologic modeling applications used by the RFC.

Snowfall Rate Assessment

An assessment of the NESDIS SnowFall Rate (SFR) product was conducted during winter 2014 to determine its operational utility in the forecaster environment as it relates to radar gaps, beam blockage and overshooting, and in combination with satellite imagery for tracking snowfall rate maxima. Forecasters from Albuquerque, NM, Burlington, VT, Charleston, WV, and Sterling, VA WFOs and the NOAA/NESDIS Satellite Analysis Branch (SAB) participated in the assessment. This evaluation was conducted from 6 January to 15 April 2014, which generally coincides with climatological peaks in North America snowfall events.

Training materials were developed jointly by SPoRT staff and the product developers describing the SFR product, discussing its strengths, weaknesses, and limitations and included specific case studies demonstrating how it was anticipated that forecasters would use the product. These materials were presented to users during a teletraining session that include the SFR product developers. In addition, a one-sheet Quick Guide was created as a reminder of the important aspects presented and to allow for users to easily reference the information in operations. A key component to SPoRT product assessments is the use of online surveys to quickly capture forecaster impressions of the product being evaluated following its use. While the surveys were completed only by forecasters participating in the evaluation process, valuable interaction occurred between forecasters, SPoRT, and the NESDIS product developers during the course of the assessment.

Winter 2014 provided an excellent opportunity to evaluate the SFR Product as a number of high-impact winter weather events occurred during the assessment period. While the product was limited at times by its latency, forecasters found the SFR product to be valuable operationally, and also to help validate snow reports. Overall feedback on the SFR product was positive with more than three-quarters of the responses indicating that the product was useful in operations for questions related to improving data coverage in areas with traditional radar gaps (e.g., mountainous areas and regions far from radar) and in combining the product with geostationary satellite observations to track snowfall maxima. Users noted several limitations regarding product latency, lack of light snow detection, and the absence of SFR analysis in temperatures below 21 deg F. NESDIS SFR developers addressed these by lowering the product latency through use of Direct Broadcast data, relaxing the minimum requirement for detection, and improving the retrievals for temperatures down to 7 deg F.

The NESDIS group responsible for developing the SFR product was funded through ROSES proposal in 2014 to investigate expansion of the SFR product to include ATMS observations. A re-assessment of the improved SFR product with a wider audience of forecast offices is planned for early 2015 with a focus on understanding the impacts of the algorithm changes and inclusion of additional data from ATMS.

National Centers and OCONUS Collaboration Transition Activities

SPoRT supplied a suite of unique NASA and NOAA products to many of the NWS National Centers (AWC, NHC, OPC, WPC) for use within the Satellite PG demonstration activities. Table 1 summarizes the products being disseminated to each National Center. The RGB imagery suite from MSG/SEVIRI was created at SPoRT via data supplied by NOAA/NESDIS. This includes products such as the Nighttime Microphysics, Airmass and Dust RGBs, similar to what can be made from MODIS and VIIRS. Additional products from SEVIRI included the Convective Storms and Daytime Microphysics RGBs to assist in the diagnosis of strong convection and cloud types. While the Dust and Airmass RGBs have helped forecasters analyze the environment surrounding tropical cyclones, the Convective Storms and Daytime Microphysics also helped to diagnose the storm itself through the highlighting of small ice particles indicative of strong convection.

These SEVIRI RGB products demonstrated the capabilities of the ABI instrument and their transition prepared National Center forecasters for future products in the GOES-R era. Additionally, quantitative information from AIRS was used to corroborate the colors of the Airmass RGB indicating stratospheric ozone intrusions. The 2014 winter demonstration at OPC/WPC/SAB focused on applications of the RGB Air Mass product with an emphasis on quantifying the product using AIRS ozone retrievals and associated ozone anomaly product. Analysts at SAB found the Air Mass product very useful in identifying stratospheric intrusions associated with rapidly-deepening extratropical cyclones that affected the U.S., namely in March 2014. They noted that identifying the red coloring (associated with dry, descending air from the stratosphere) gave the analysts more confidence in the evolution of the storms. The other National Centers are also utilizing the products regularly and the forecasters are becoming more confident in the interpretation when compared to traditional water vapor imagery to identify significant meteorological features.

Table 1. Products made available in N-AWIPS and AWIPS II to the Aviation Weather Center (AWC), National Hurricane Center (NHC), Ocean and Weather Prediction Centers (OPC/WPC), Satellite Analysis Branch (SAB), and Storm Prediction Center (SPC). Products ingested for a given Center are indicated by an "X".

	AWC	NHC	OPC/WPC/SAB	SPC
RGB SEVIRI suite		X	X	
RGB MODIS/VIIRS suite	X		X	
RGB GOES Sounder Airmass	X		X	
PGLM	X		X	X
Passive Microwave Suite		X	X	
GOES-R CI	X		X	X
SPoRT Hybrid Imagery Suite	X		X	
AIRS Ozone and Anomaly	X		X	
MODIS SST Composite		X	X	
NESDIS QPE & Snowfall Rate			X	

SPoRT staff traveled to Hawaii for both a VSP award and as part of the GOES-R PG OCONUS annual meeting in order to meet with several user groups to establish collaborations related to preparing users for upcoming NASA & NOAA satellite missions. With Himawari and GOES-R imagers becoming available in 2015 and 2016, respectively, SPoRT outlined a variety of products that could be transitioned to both National Centers and OCONUS WFOs to address forecaster needs, and SPoRT discussed these with users during visits in both May (VSP) and July (OCONUS meeting). These included QPE, the Cooperative Institute for Research in the Atmosphere (CIRA) Layered Precipitable Water (LPW), Sea Surface Temperature (SST), GOES-R Convective Initiation (GOES-R CI), SPoRT Hybrid imagery, multi-spectral RGB imagery, and training for use of total lightning data.

SPoRT made available the SPoRT SST composite product, CIRA LPW, as well as the NESDIS QPE. OCONUS priorities were heavily weighted to QPE given their need for monitoring vast areas uncovered by radar. The GOES-R QPE product had been evaluated by the San Juan, PR WFO and Alaska WFOs/RFC with mixed results, but the current proxy product from NESDIS is missing several key channels that will not be available until Himawari or GOES-R is operational. However, Pacific Region forecasters wanted to test the product in its current proxy state. Similar to evaluation by San Juan and Alaska forecasters, Pacific Region user feedback showed that QPE under performed in areas where verification data was available and users were less likely to find the current product valuable. OCONUS users did find the SST composite valuable for marine forecasts as well as impacts to tropical cyclone development. LPW had not been installed in Pacific Region at the time of SPoRT's visits, but the analysis of moisture across the region is of high interest based on other OCONUS (i.e., Alaska and San Juan) evaluations of LPW showing applications to the analysis of tropical wave and atmospheric river moisture structure vs. using only Total Precipitable Water (TPW).

The vast areas of responsibility covered by the National Centers means that forecasters heavily rely on remotely-sensed data from both geostationary and low-earth orbit satellites. The latter resource was provided to National Centers in the form of a suite of Passive Microwave products that are derived from a host of LEO satellites, which are then inter-calibrated by the NASA GPM microwave imager. Several single channel, multi-spectral, and rain-rate products from passive microwave imagers (AMRS2, SSMI/S, GMI, ATMS) were made available, and these were regularly applied to the analysis of tropical cyclone intensity and center position (e.g., Wide World of SPoRT blog post at: https://nasasport.wordpress.com/2014/09/17/nasa-next-generation-satellite-observations-of-hurricane-odile/). Users at NHC and OPC regularly applied the RGB and Passive Microwave suite of products in their daily operations and these products have been part of the seasonal demonstration periods conducted by local GOES-R satellite champions within the Satellite PG.

Interactions with CPHC users indicated that both microwave and multi-spectral imagery would also be of interest in their operations. SPoRT began work in 2014 to provide the same passive microwave suite for the CPHC forecasters as was transitioned for NHC applications, and this work would extend into 2015 before completion. Also, SPoRT plans to actively pursue Himawari near-real-time data in 2015 for development of RGB imagery from the geostationary AHI instrument, which is nearly the same as ABI on GOES-R. These products and associated training will be provided in 2015 to NOAA PG participants from the National Centers and OCONUS WFOs as a demonstration of future capabilities.

The GOES-R CI product was also used by multiple National Centers. The product was applied to identify the potential for new convective cells associated with heavy rain events and possible flash flooding. In most cases, the product performed well and provided the OPC/WPC forecasters with additional confidence when used in association with other forecast methods. AWC forecasters used the CI product in conjunction with pre-existing tools such as the Nearcasting Model in order to categorize the convection and anticipate related aviation hazards. At a more local level, WFO forecasters used GOES-R CI as part of their situational awareness displays related to short-term airport condition forecasts (i.e., TAFs); future plans are to incorporate NWS CWSUs to evaluate GOES-R CI as part of their support of airport TRACON arrival and departure routes.

In addition to satellite imagery products, several LMA ground-based networks throughout the CONUS are ingested and processed by SPoRT in a form analogous to products likely to be seen from GOES-R, which is referred to as the Pseudo-GLM (PGLM). The PGLM product is a gridded composite of all the LMA networks and it has been transitioned to National Center users to aid the diagnosis of severe convection and other aviation hazards such as turbulence. Because of its land-based networks in the CONUS, the PGLM is most relevant to the AWC responsibilities near major airways over the U.S. The PGLM was transitioned for use by AWC forecasters as part of their "Summer Demonstration" conducted within the GOES-R PG in 2014. Forecasters evaluated the application of the PGLM to provide greater lead-time for developing convection that may require rerouting of air traffic. AWC also incorporated the SPoRT Hybrid Imagery suite where MODIS or VIIRS data were inserted into a base image of analogous GOES data. This provides a "snap-shot" of what the ABI sensor will provide via MODIS/VIIRS as a proxy, while still allowing high-frequency imagery from current GOES to provide context on either side of the LEO swath imagery.

Future Direction

SPoRT's Transition, Training, and Assessment activities will continue efforts related to the NOAA Satellite PG, NASA capabilities and existing instruments, and new missions such as Tropospheric Emissions: Monitoring of Pollution (TEMPO), IceSat2, and SMAP. There is a continued need to use NASA resources to demonstrate upcoming NOAA capabilities with GOES-R and JPSS-1. The transition of multi-spectral imagery, total lightning, and unique satellite products (e.g., VIIRS Day-Night Band or AIRS ozone/anomaly) are still relatively limited to a select user group. Greater exposure of these products to a wide audience and the development of associated application training will be a goal. A training library for many of these products will be considered for development using a strategy of short, application-based modules (i.e., "micro-lesson") that can be utilized or referenced within the operational work environment.

SPoRT plans to conduct several assessments of products related to Satellite PG efforts in order to reach a wider audience and to gather case examples for future training. Assessments of NASA capabilities such as LIS and GPM are also planned. The NASA/LIS has many unexplored operational applications and future activities plan to test its use in the western U.S. for drought and flooding as well as for monitoring vegetation and soil conditions related to wild fire potential. In addition, the GPM mission will allow SPoRT to expand its user base to a larger community of international users who are looking to monitor precipitation in near real-time. New satellite launches will utilize SPoRT as an early adopter of data for transition to the user community in order to validate and test operational impacts. TEMPO's aerosol and public health applications and SMAP soil moisture retrievals will be unique opportunities for the operational weather community where SPoRT will assist in their infusion to improve short-term weather analysis and forecasting.

7

Disaster Response

Selection of ROSES Award for Continued Funding

In 2012 and 2013, members of the SPoRT team were awarded a grant in response to the NASA ROSES 2011 solicitation in the NASA Applied Sciences: Disasters focus area. The award was a feasibility study to explore the integration of NASA, NOAA, and commercial Earth remote sensing imagery within the NOAA/NWS Damage Assessment Toolkit (DAT) application. Following a successful feasibility demonstration and enthusiastic partner involvement, the team was awarded a three-year follow-on proposal in May 2014. This extended "Feasibility to Decisions" phase of the award focuses on the full transition of SPoRT-developed capabilities to the NWS, sustaining the inclusion of Earth remote sensing imagery within the DAT application.

Following severe weather and tornado events, the DAT is used by NWS field meteorologists to acquire geotagged information that documents damage of varying EF-scale categories. As a result of the feasibility study, case studies of Earth remote sensing imagery were incorporated to demonstrate to forecasters how these products could also be used to improve or refine the characterization of the damage track (Figure 24; Molthan et al. 2014). In addition to tornado applications, imagery can be used to help identify short-term, sudden decreases in vegetation health that result from hail damage to crops during the growing season (Molthan et al. 2013).

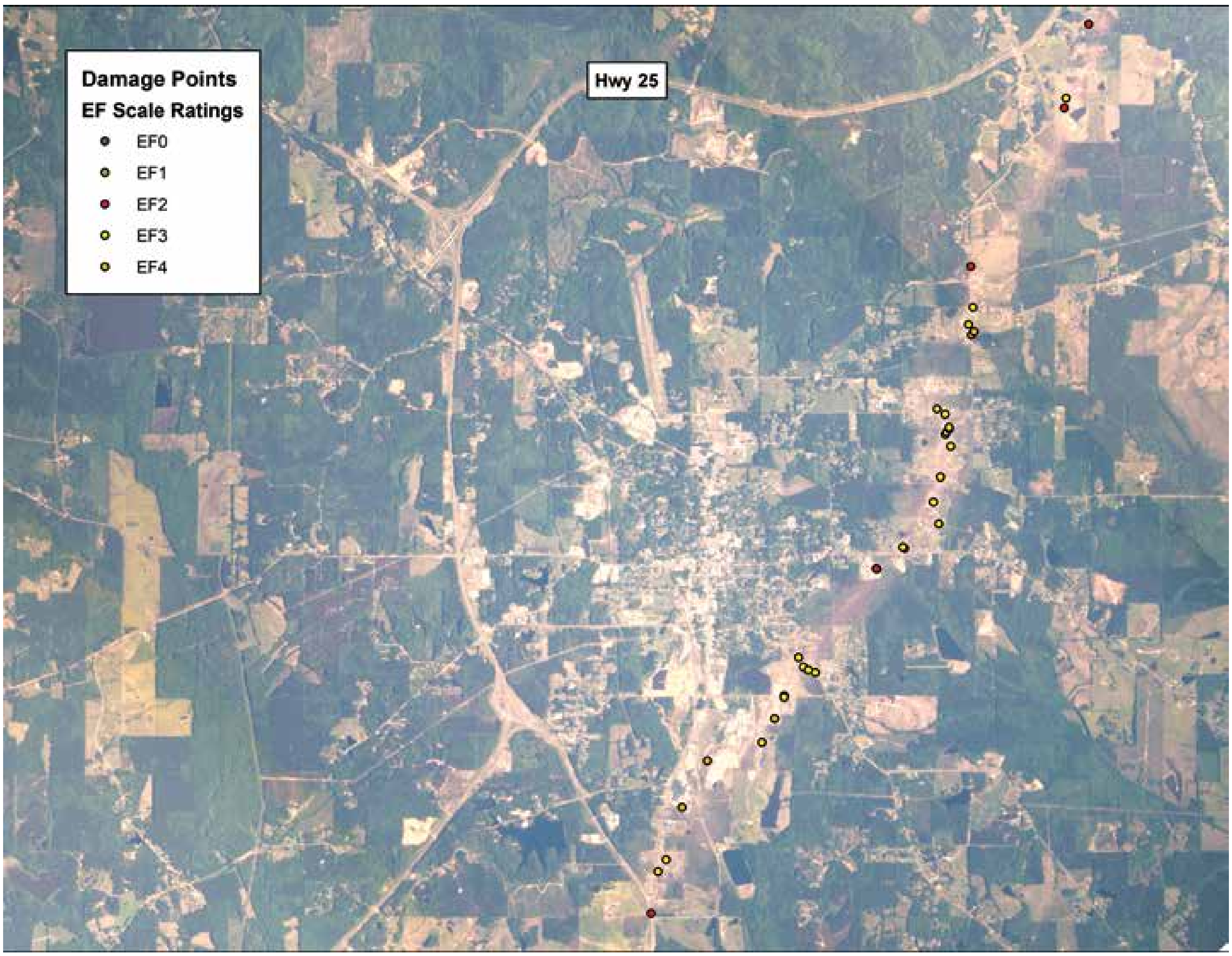

Figure 24. Image taken from the International Space Station (ISS) SERVIR Environmental Research and Visualization System (ISERV) on 4 May 2014 over the city of Louisville, Mississippi. The EF-4 tornado moved through southeast portions of the city on 28 April 2014. Various damage indicators from the official NWS ground survey are overlaid on the image.

Integration of Earth Remote Sensing Data in the NWS Damage Assessment Toolkit

The "Decisions" phase of the award began in June 2014, where the team focused on establishing automated means of disseminating Earth remote sensing products to the NOAA/NWS DAT. Efforts were kicked off through hosting of a technical interchange meeting in Huntsville, attended by partners in NOAA/NWS and USGS. After developing a roll-out strategy, the team has worked with NASA and USGS to automate the collection and dissemination of products from NASA's Terra and Aqua MODIS, the NASA/NOAA S-NPP VIIRS instrument, Landsat-7 and Landsat-8, the Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument, and the NASA EO-1 satellite. Continued efforts focus on the automation of higher-resolution commercial imagery and products from other sensors collected by USGS during their disaster response activities. The team also developed training on how to interpret various datasets and products in order to be ready for an assessment beginning in spring 2015.

Other Disaster-Related Activities

SPoRT continues to support development of new disaster-related applications of Earth remote sensing imagery. One application is using Aqua MODIS data for the objective identification of hail-damaged pixels during the growing season of the high plains. This work explores the identification of hail-damaged pixels through analysis of short-term decreases in Normalized Difference Vegetation Index (NDVI) and coincident increases in land surface temperature (Figure 25). Another application is exploring the use of the VIIRS DNB for identifying power outages and recovery following meteorological and other disaster events. As an example, Figure 26 shows a "percentage of normal light" product following an earthquake in Chile in 2014. In this scenario, cloud-free, pre-event light emissions are compared to post-event values, with post-event reported as a percentage of pre-event emissions. Future work will focus on understanding differences in light emissions on various spatial scales, and through use of improved NASA DNB products. Initial partnerships have been established with colleagues at NASA Goddard Space Flight Center to incorporate upcoming, new Level 2 composites of DNB and cloud masking information. Early efforts will focus on characterizing the degree of variability seen in DNB radiance for population centers of varying spatial scale: for example, comparing variability in emitted light among rural, suburban, and urban areas as a first step towards separating signal from noise when identifying decreases in emitted light.

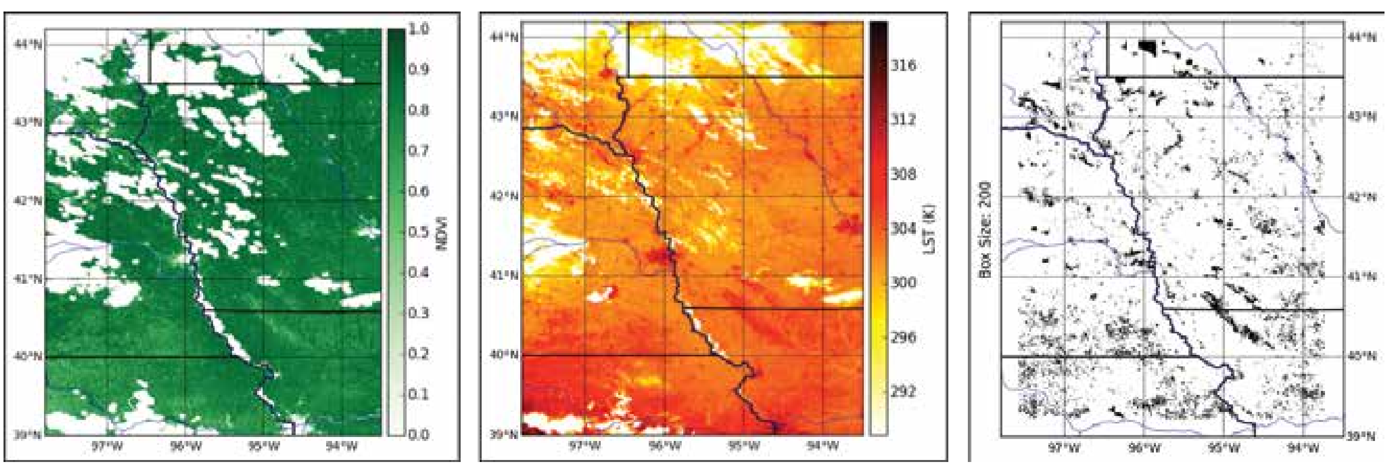

Figure 25. (left) NDVI observed by MODIS on 19 August 2011 following a severe hail event in northwestern Missouri, with lowered values identified as streaks across the region. (middle) Warmer land surface temperatures corresponding to areas of damaged vegetation apparent in the NDVI imagery. (right) An example of preliminary attempts to identify anomalies in both vegetation and land surface temperature corresponding to possible storm damage in northwestern Missouri.

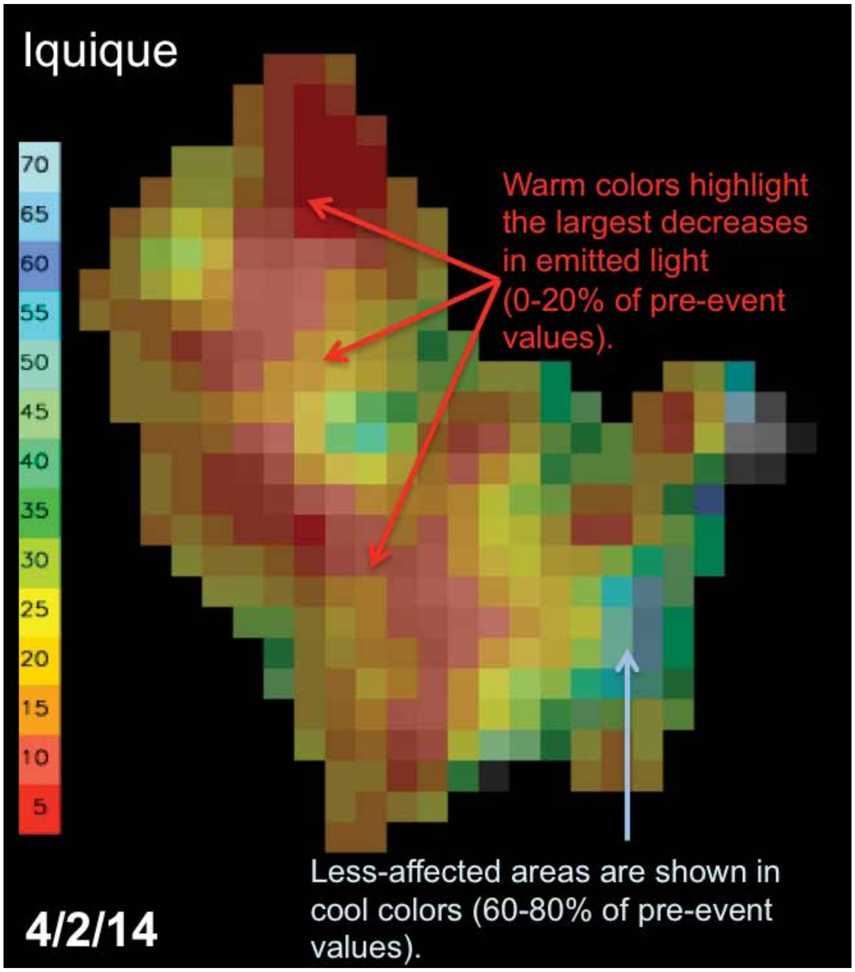

Figure 26. Example of a "percent of normal" light emission for Iquique, Chile on 2 April 2014 following the Chilean earthquake. Warm colors represent a large loss of emitted light versus comparable, cloud-free and pre-event imagery. Future products will use multiple years of cloud-free DNB imagery to improve characterization of typical pre-event lighting conditions to improve the quality and accuracy of the output.

Future Work

In 2015, the team will continue their disaster-response activities in collaboration with USGS and the NWS, providing training and support for the use of Earth remote sensing during the severe weather season. In late spring and early summer, the team will work with the NWS to assess the efficacy of the satellite products provided and develop a strategy to refine products and begin the transition of image processing capabilities to NWS partners. In addition, the team will continue working with NASA Headquarters to understand how they can best partner with other Centers to share capabilities supportive of severe weather and other disaster assessments.

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Appendix A. Complete List of SPoRT Products

Table A1 summarizes the suite of SPoRT products, details on the products, and the forecast challenge(s) that each product helps to address.

Table A1. SPoRT product suite provided to end-users.

Instrument/Product	Forecast Challenge (Domains)
MODIS (Terra and Aqua)	**(CONUS, Alaska)**
Imagery (visible, 3.9, 6.7, 11 µm)	Improved situational awareness
Suite of RGB products (true, false color snow, air mass, night & 24-hour microphysics, dust)	Cloud structure, visibility obstructions, snow-cover extent, atmospheric structure
Fog/low cloud (11-3.9 µm)	Improved situational awareness
NDVI/Green Vegetation Fraction (GVF)	Improved NWP model initialization and forecasts
AIRS (Aqua)	**(CONUS)**
Carbon monoxide, ozone imagery and anomaly	Fires, air quality, storm dynamics, stratospheric intrusions
Total Lightning Data (ground-based)	**(North AL, DC, Central FL, OK, West TX, CO, Langmuir)**
Source/flash density	Severe weather, ltg safety, impact-based decision support
Combined Instrument Products	**(Northern Hemisphere – Atlantic & Pacific basins)**
Multi-sensor SST/Great Lakes LST/ice mask composite	Coastal processes, lake-effect precipitation; Improved NWP model initialization and forecasts
CIRA Blended TPW/Layered PW	Moisture mapping, atmospheric rivers, precipitation
HMS/FIRMS fire/burn area	Smoke, reduced visibility, localized flooding
GOES	**(CONUS)**
Sounder air mass RGB	Storm dynamics, improved situational awareness
GOES-R Proxy Products	**(CONUS, Alaska)**
Pseudo GLM product suite	Severe weather, lightning safety, impact-based decision support **(total lightning nests)**
POES-GOES hybrid imagery (visible, 3.9, 6.7, 11 µm)	Improved situational awareness **(CONUS, Alaska)**
POES-GOES Hybrid RGB suite	Improved situational awareness **(CONUS, Alaska)**
NESDIS Quantitative Precipitation Estimates	Precipitation mapping **(CONUS, Alaska)**
GOES-R Convective Initiation (CI) algorithm	CI, precipitation mapping **(GOES-East & West)**
JPSS Proxy Products (S-NPP)	**(CONUS, Alaska)**
VIIRS imagery (visible, 3.9, 11 µm)	Improved situational awareness
Suite of VIIRS RGB products (true color, night & 24-hour microphysics, dust)	Cloud structure, visibility obstructions, storm dynamics
VIIRS DNB (low light) – radiance, reflectance, RGB	Improved situational awareness
SEVIRI	**(Atlantic basin)**
RGB products (air mass, dust, night- & day-time microphysics, natural color, convective storms, snow-fog, Saharan Air Layer)	Tropical storm forecasting, storm dynamics
Passive Microwave (TMI, SSMI/S, AMSR-2, GMI, ATMS, MHS, SAPHIR)	**(Atlantic & Pacific basins)**
37-GHz & 89-GHz (V/H)	Precipitation monitoring, storm dynamics
37-GHz & 89-GHz RGB Composites	Precipitation monitoring, storm dynamics
Rain Rate	Precipitation monitoring, storm dynamics
Miscellaneous	
Land Information System (LIS) – soil moisture	drought/flood monitoring; Improved NWP model initialization and forecasts **(SE CONUS/CONUS)**
WindSat – Ocean Surface Wind Vectors (OSWV)	Improved situational awareness over oceans **(global)**

Appendix B. Product Suites at SPoRT Collaborating Partners

The tables below summarize the SPoRT product suites that are developed and disseminated to the collaborating entities listed. The information pertains to the collaborating product development partners (Table B1), National Center evaluation partners (Table B2), and NWS Regional Headquarters (Table B3).

Table B1. List of Product Development Partners and the suite of products provided to SPoRT.

Product Development Partner	Product Suite Provided
CIRA – Cooperative Institute for Research in the Atmosphere	Blended TPW, Layered PW, GOES Sounder air mass
NOAA/NESDIS – National Environmental Satellite, Data, and Information Service	GOES data, MSG/SEVIRI NESDIS QPE, Snowfall rate
NRL – Naval Research Laboratory	Passive microwave, WindSat
UAF/GINA – University of Alaska - Fairbanks/Geographic Information Network of Alaska	MODIS and VIIRS data
UW/CIMSS – University of Wisconsin - Madison/Cooperative Institute for Meteorological Satellite Studies	MODIS and VIIRS data

Table B2. List of National Center Evaluation Partners and the suite of products obtained from SPoRT.

National Center Evaluation Partner	Product Suite Obtained
AWC – Aviation Weather Center	GOES-R CI, PGLM
HWT/SPC/NSSL – Hazardous Weather Testbed/Storm Prediction Center/National Severe Storms Laboratory	GOES Sounder air mass, GOES-R CI, PGLM
NHC – National Hurricane Center	Passive Microwave, RGBs
OPC/WPC/SAB – Ocean Prediction Center, Hydro-meteorological Prediction Center, Satellite Analysis Branch	AIRS Ozone, MODIS, Passive Microwave, RGBs, VIIRS

Table B3. List of NWS Evaluation Regions and the suite of products obtained from SPoRT.

NWS Evaluation Region	Product Suite Obtained
Alaska Region Headquarters	NESDIS QPE, SPoRT Hybrids, MODIS, RGBs, SPoRT SST, VIIRS, WindSat
Central Region Headquarters	RGBs, Total Lightning, SPoRT SST (Great Lakes)
Eastern Region Headquarters	MODIS, RGBs, SPoRT Hybrids, SPoRT SST, VIIRS data, Total Lightning
Pacific Region Headquarters	NESDIS QPE, SPoRT SST
Southern Region Headquarters	CIRA Blended TPW, GOES-R CI, LIS, MODIS, MODIS GVF, RGBs, SPoRT Hybrids, SPoRT SST, Total Lightning, VIIRS
Western Region Headquarters	CIRA Layered PW, MODIS, NESDIS QPE, RGBs, SPoRT SST, VIIRS, WindSat

Appendix C. SPoRT Publications and Presentations in 2014

2014 Peer-reviewed journal publications:

Case, J.L., F.J. LaFontaine, J.R. Bell, G.J. Jedlovec, S.V. Kumar, and C.D. Peters-Lidard, 2014: A real-time MODIS vegetation product for land surface and numerical weather prediction models. *IEEE Trans. Geosci. Remote Sens.,* **52(3),** 1772-1786. doi/web link: dx.doi.org/10.1109/TGRS.2013.2255059.

Molthan, A.L., J.R. Bell, T.A. Cole, and J.E. Burks, 2014: Satellite-based identification of tornado damage tracks from the 27 April 2011 severe weather outbreak. *J. Operational Meteor.,* **2 (16),** 191–208.

Molthan, A.L., J.L. Case, J. Venner, R. Schroeder, M.R. Checchi, B.T. Zavodsky, A. Limaye, and R.G. O'Brien, 2014: Clouds in the cloud: Weather forecasts and applications within cloud computing environments. *Bull. Amer. Meteor. Soc., In Press.*

Stano, G.T., C. J. Schultz, L.D. Carey, D.R. MacGorman, and K.M. Calhoun, 2014: Total lightning observations and tools for the 20 May 2013 Moore, Oklahoma, tornadic supercell. *J. Operational Meteor.,* **2 (7),** 71–88.

Conferences, Symposia, Workshops, Newsletters and Meetings:

Bell, J.R., 2014: Using Satellite Imagery to Identify Tornado Damage Tracks and Recovery from the April 27, 2011 Severe Weather Outbreak. NASA/UA Huntsville Brown Bag Seminar, 9 April 2014.

Bell, J.R., A.L. Molthan, J.E. Burks, and **K.M. McGrath,** 2014: Using ISERV and Commercial Satellite Imagery to Assess and Monitor Recovery Efforts in Urban Damaged Area. *18th Conf. on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 94th AMS Annual Meeting,* Atlanta, GA, P.629.

Berndt, E.B., B.T. Zavodsky, and **G.J. Jedlovec,** 2014: Development and Application of Hyperspectral Infrared Ozone Retrieval Products for Operational Meteorology. *Virtual Presentation, STAR/JPSS Annual Science Team Meeting,* May 14, 2014.

Berndt, E.B., B.T. Zavodsky, and **G.J. Jedlovec,** 2014: Applications using Satellite Sounder Products at the NASA SPoRT Center. *Virtual Presentation, STAR/JPSS Annual Science Team Meeting,* May 14, 2014.

Berndt, E.B., B. Zavodsky, G.J. Jedlovec, and **N.J. Elmer,** 2013: Impact of the assimilation of hyperspectral infrared retrieved profiles on Advanced Weather and Research model simulations of a non-convective wind event. *38th National Weather Association Annual Meeting,* Charleston, SC, P2.7. [Available online at http://www.nwas.org/meetings/abstracts/display.php?id=1862].

Berndt, E.B., B.T. Zavodsky, and **G.J. Jedlovec,** 2014: The Transition of Atmospheric Infrared Sounder Total Ozone Products to Operations. *Fourth Conf. Transition of Research to Operations, 94th AMS Annual Meeting,* Atlanta, GA. [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper232503.html].

Berndt, E.B., M.J. Folmer, and J. Dunion, 2014: A Comparison of the Red Green Blue Air Mass Imagery and Hyperspectral Infrared Retrieved Profiles and NOAA G-IV Dropsondes, *Tenth Annual Symp. New Generation Operational Environmental Satellite Systems, 94th AMS Annual Meeting,* Atlanta, GA. [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper236571.html].

Berndt, E.B., B.T. Zavodsky, and **G.J. Jedlovec,** 2014: Demonstration of AIRS Total Ozone Products in Operations to Enhance User Readiness, Virtual Presentation, GOES-R Virtual Science Seminar, 15 July 2014.

Berndt, E.B., B.T. Zavodsky, G.J. Jedlovec, 2014: The Transition of Atmospheric Infrared Sounder Total Ozone Products to Operations, Virtual Presentation, *NOAA Satellite Science Week Virtual Meeting* 2014.

Berndt, E.B., B. Zavodsky, G.J. Jedlovec, and **N.J. Elmer,** 2014: Impact of the assimilation of hyperspectral infrared retrieved profiles on Advanced Weather and Research model simulations of a non-convective wind event. *26th Conf. on Weather Analysis and Forecasting/22nd Conf. on Numerical Weather Prediction/18th Conf on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, 94th AMS Annual Meeting,* Atlanta, GA.

Berndt, E.B., B. Zavodsky, A. Molthan, M. Folmer, and **G.J. Jedlovec,** 2014: The use of red green blue air mass imagery to investigate the role of stratospheric air in a non-convective wind event. *Advances in Understanding Atmospheric Processes Using Satellite Data, EUMETSAT Meteorological Satellite Conference* 22-26 Sep 2014. P2.8.

Beven J., M. Brennan, H. Cobb, M. DeMaria, J. Knaff, A.B. Schumacher, C. Velden, S.A. Monette, J.P. Dunion, **G. Jedlovec, K. Fuell,** and M. Folmer, 2014: The Satellite Proving Ground at the National Hurricane Center. *31st Conf. Hurricanes and Tropical Meteorology,* San Diego, CA, 30 March-4 April 2014.

Blackwell, W., A.B. Milstein, **B.T. Zavodsky,** and **C.B. Blankenship,** 2014: Neural Network Estimation of Atmospheric Thermodynamic State for Weather Forecasting Applications, *16th International Conf. Human-Computer Interaction,* Heraklion, Greece, 22-27 June 2014.

Blankenship, C.B., B.T. Zavodsky, and **J.L. Case,** 2014: Assimilation of SMOS Soil Moisture Retrievals in the Land Information System. *28th Conf. on Hydrology,* 94th AMS Annual Meeting, Atlanta, GA. [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper233646.html].

Blankenship, C.B., and **B.T. Zavodsky,** 2014: Soil Moisture in the Land Information System. Virtual Presentation, SMAP Early Adopters Teleconference, 23 May 2014.

Blankenship, C.B., B.T. Zavodsky, J.L. Case, and **G.J. Jedlovec,** 2014: Assimilation of SMOS Soil Moisture Retrievals in the Land Information System. *Satellite Data in Global and Regional Modeling, EUMETSAT Meteorological Satellite Conf.* 22-26 Sep 2014.

Burks, J.E., M, Smith, and **K. McGrath,** 2014: AWIPS II Application Development, a SPoRT Perspective. *94th AMS Annual Meeting,* Atlanta, GA. *30th Conf. Environmental Information Processing Technologies, 94th AMS Annual Meeting,* Atlanta, GA.

Burks, J.E., A.L. Molthan, and **K.M. McGrath,** 2014: Development of Web Mapping Service Capabilities to Support NASA Disasters Applications/App Development. *18th IOAS-AOLS Conference, 94th AMS Annual Meeting,* Atlanta, GA.

Burks, J.E., G.T. Stano, and K. Sperow, 2014: Lightning-Tracking Tool for Assessment of Total Cloud Lightning within AWIPS II., *26th Conf. Weather Analysis and Forecasting/22nd Conf. Numerical Weather Prediction 94th AMS Annual Meeting,* Atlanta, GA.

Burks, J.E. and A. Limaye, 2014: A Web Architecture to Geographically Interrogate CHIRPS Rainfall and eMODIS NDVI for Landuse Change. *Climate and Environmental Data, Info. And Knowledge for Societal Decision Making in the U.S. and International/SERVIR Region II posters, Global Environmental Change, 2014 AGU Annual Meeting,* 14-19 December 2014, San Francisco, CA.

Case, J.L., J. Mungai, V. Sakwa, E. Kabuchanga, **B.T. Zavodsky,** and A.S. Limaye, 2014: Toward improved land surface initialization in support of regional WRF forecasts at the Kenya Meteorological Service. *26th Conf. on Weather Analysis and Forecasting/22nd Conf. on Numerical Weather Prediction, 94th AMS Annual Meeting,* Atlanta, GA. [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper235263.html].

Case, J.L., and **K.D. White,** 2014: Expansion of the real-time SPoRT-Land Information System for NOAA/National Weather Service situational awareness and local modeling applications. *26th Conf. on Weather Analysis and Forecasting/22nd Conf. on Numerical Weather Prediction, 94th AMS Annual Meeting,* Atlanta, GA [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper235310.html].

Case, J.L., B.T. Zavodsky, C.B. Blankenship, and **K.D. White,** 2014: High Spatial and Temporal Resolution Satellite-Derived Land and Sea Surface Datasets for Local Operational Forecasting. *NOAA Satellite Science Week Virtual Meeting.*

Case, J.L., C.B. Blankenship, B.T. Zavodsky, J. Srikishen, and **E.B. Berndt,** 2014: NASA SPoRT Modeling and Data Assimilation Research and Transition Activities using WRF, LIS, and GSI, *15th Annual WRF Users' Workshop,* Boulder, CO, June 23-27, 2014. [Available online at: http://www2.mmm.ucar.edu/wrf/users/workshops/WS2014/WorkshopPapers.php].

Case, J.L., F.J. LaFontaine, S.V. Kumar, C.D. Peters-Lidard, **J.R. Bell,** and **B.T. Zavodsky,** 2014: Real-time Green Vegetation Fraction for Land Surface and Numerical Weather Prediction Models (poster), *JCSDA Workshop,* College Park MD, May 21-23, 2014.

Case, J.L., and **B.T. Zavodsky,** 2014: Real-time Green Vegetation Fraction for Land Surface and Numerical Weather Prediction Models. *NOAA Satellite Science Week Virtual Meeting.* 10-14 March 2014 [Available online at: http://www.goes-r.gov/downloads/ScienceWeek/2014/Thursday/03_Case.pdf].

Case, J.L., C.B. Blankenship, and **B.T. Zavodsky,** 2014: Soil Moisture Data Assimilation in the NASA Land Information System for Local Modeling Applications and Improved Situational Awareness. *39th National Weather Association Annual Meeting,* 18-23 Oct 2014, Salt Lake City, UT.

Chronis, T., C.J. Schultz, E.V. Schultz, L.D. Carey, K.M. Calhoun, D.M. Kingfield, K.L. Ortega, M.T. Filiaggi, G.J. Stumpf, and **G.T. Stano,** 2014: National Demonstration and Evaluation of a Real Time Lightning Jump Algorithm for Operational Use. *26th Conf. Weather Analysis and Forecasting/22nd Conf. Numerical Weather Prediction, 94th AMS Annual Meeting,* 2-6 February 14, Atlanta, GA.

Cole, T.A. , A.L. Molthan, J.E. Burks, and **J.R. Bell,** 2014: Using Satellite Imagery to Identify Tornado Damage Tracks and Recovery from the 27 April 2011 Severe Weather Outbreak. *18th Conf. Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 94th AMS Annual Meeting,* Atlanta, GA [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Handout/Paper232807/Cole_Poster_AMS.pdf].

Cole, T.A., 2014: Detection of Power Outages and Recovery following Natural Disasters: The Chilean Earthquake of April 1, 2014. *Seventh Annual Wernher Von Braun Symp.* 22 September 2014, Huntsville, AL.

Colle, B., **A.L. Molthan,** R. Yu, and S.W. Nesbitt, 2014: Evaluation of Model Microphysics Within Precipitation Bands of Extratropical Cyclones. *Precipitation Measurement Missions (PMM) Science Team Meeting,* 4-8 August 2014, Baltimore, MD.

Colle, B. **A.L. Molthan,** R. Yu, and S. Nesbitt, 2014: Evaluation of Mixed-Phase Microphysics Within Winter Storms Using Field Data and In Situ Observations. *Global Precipitation Measurement, Validation, and Applications III Posters, 2014 AGU Fall Meeting,* December 14-19, 2014, San Francisco, CA.

Dryden, R.L. , **A.L. Molthan, T.A. Cole,** and **J.R. Bell,** 2014: Identifying Hail Signatures in Satellite Imagery from the 9-10 August 2011 Severe Weather Event. *18th Conf. Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 94th AMS Annual Meeting,* Atlanta, GA. [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Handout/Paper232802/Dryden_AMS_Poster.pdf].

Elmer, N., E. Berndt, G.J. Jedlovec, F.J. LaFontaine, and **A. Naeger,** 2014: Limb Correction of RGB Composite Imagery for Improved Interpretation. *39th National Weather Association Annual Meeting,* 18-23 October 2014, Salt Lake City, UT, P3.41.

Elmer, N., 2014: Limb Correction of RGB Composite Imagery for Improved Interpretation. *NASA/UA Huntsville Brown Bag Seminar,* 12 Nov 2014, Huntsville, AL.

Folmer, M.J., **B.T. Zavodsky,** and **A.L. Molthan,** 2012: Operational use of the AIRS total column ozone retrievals along with the RGB air mass product as part of the GOES-R Proving Ground. *Session IN33C: Near Real Time Data Uses for Earth Science and Space Weather Applications IV Posters,* San Francisco, CA, Amer. Geophys. Union.

Folmer, M.J., J. Halverson, **E.B. Berndt,** J. Dunion, S. Goodman, M. Goldberg, and M. DeMaria, 2014: Improved Satellite Techniques for Monitoring and Forecasting the Transition of Hurricanes to Extratropical Storms. *Tropical Cyclones: Observations, Modeling, and Predictability V Posters, 2014 AGU Annual Meeting,* 15-19 December 2014, San Francisco, CA, A33L-3377.

Fuell, K., B. Guyer, and D. Kann, 2014: Integration of RGB "Dust" Imagery to Operations at the Albuquerque Forecast Office. *Fourth Conf. Transition of Research to Operations, 94th AMS Annual Meeting,* Atlanta, GA.

Gravelle, C.M., J.M. Mecikalski, R. Petersen, J. Sieglaff, and **G.T. Stano,** 2014: Using GOES-R Demonstration Products to Bridge the Gap Between Severe Weather Watches and Warnings for the 20 May 2013 Moore, OK Tornado Outbreak.

Greene, E., **B.T. Zavodsky,** R. Ramachandran, A. Kulkarni, X. Li, R. Bakare, S. Basyal, and H. Conover, 2014: Constructing Data Albums for Significant Severe Weather Events. *30th Conf. Environmental Information Processing Technologies, 94th Annual AMS Meeting,* Atlanta, GA.

Jedlovec, G.J. and **F.J. LaFontaine,** 2014: A Simplified Approach to Cloud Masking with VIIRS in the S-NPP/JPSS Era. Space-Based, Operational Global Earth Observations from S-NPP and JPSS II, 2014 AGU Fall Meeting, San Francisco, CA, Presentation IN12A-04.

Kidder, S.Q., J.M. Forsythe, and **K.K. Fuell,** 2014: Development and Testing of a Layer Precipitable Water Product to Aid Forecasting of Heavy Precipitation and Flooding. *26th Conf. Weather Analysis and Forecasting/22nd Conf. Numerical Weather Prediction, 94th AMS Annual Meeting,* 2-6 February 14, Atlanta, GA, P.163.

LeRoy, A., K.K. Fuell, and L. Rosa, 2014: NASA-SPoRT Methodology for JPSS and GOES-R Proving Ground Assessments. *26th Conf. Weather Analysis and Forecasting/22nd Conf. Numerical Weather Prediction, 94th AMS Annual Meeting,* 2-6 February 14, Atlanta, GA J13.2.

Li, X., J. Mecikalski, **B. Zavodsky,** and **J. Srikishen,** 2014: Assimilation of Dual-Polarimetric Radar and GPM Observations with GSI in Regional WRF (presentation), *JCSDA Workshop,* College Park, MD, May 21-23, 2014.

Li, X, J.M. Mecikalski, T. Fehnel, **B.T. Zavodsky,** and **J. Srikishen,** 2014: Assimilation of Dual-Polarimetric Radar and GPM Observations with GSI in Regional WRF. *26th Conf. Weather Analysis and Forecasting/22nd Conf. Numerical Weather Prediction, 94th AMS Annual Meeting,* Atlanta, GA.

McCaul, Jr., E.W., J.L. Case, B.T. Zavodsky, J. Srikishen, J.M. Medlin, and L. Wood, 2014: Impacts of Microphysics and Planetary Boundary Layer Physics on Model Simulations of U.S. Deep South Summer Convection. *26th Conf. on Weather Analysis and Forecasting/22nd Conf. on Numerical Weather Prediction, 94th AMS Annual Meeting,* Atlanta, GA. [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper235316.html].

McGrath, K.M., A.L. Molthan, and **J.E. Burks,** 2014: Use of NASA near Real-Time and Archived Satellite Data to Support Disaster Assessment. *18th Conf. Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 94th AMS Annual Meeting,* Atlanta, GA [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper235350.html].

Molthan, A.L., J.E. Burks, K.M. McGrath, J.P. Camp, D. Leonardo, and **J.R. Bell,** 2014: Applications of Satellite Remote Sensing for Response to and Recovery from Meteorological Disasters. *18th Conf. Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)/Satellite data and technology for forecasting and responding to natural disasters, 94th AMS Annual Meeting,* Atlanta, GA.

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Molthan, A.L., J. Case, B.T. Zavodsky, A. Naeger, F. LaFontaine, and **M. Smith,** 2014: Multi-Spectral Satellite Imagery and Land Surface Modeling Supporting Dust Detection and Forecasting. Integrating Airborne Dust Forecasting and Remote Sensing into Air Quality and Public Health Services, 2014 AGU Fall Meeting, San Francisco, CA, Poster A11D-3038.

Reynolds, D., W. Rasch, D. Kozlowski, **J. Burks, B.T. Zavodsky,** L. Bernardet, I. Jankov, and S. Albers, 2014: The Experimental Regional Ensemble Forecast System: Its Use in NWS Forecast Operations and Preliminary Verification. *94th AMS Annual Meeting,* Atlanta, GA.

Reynolds, D., W. Rasch, D. Kozlowski, J. Burks, B.T. Zavodsky, L. Bernardet, I. Jankov, and S. Albers, 2014: The Experimental Regional Ensemble Forecast System: Its Use in NWS Forecast Operations and Preliminary Verification. *Fifth NOAA Testbed Workshop,* 16-18 April 2014

Rogers, R. H., L. D. Carey, M. Bateman, **G. T. Stano,** S. A. Monette, W. F. Feltz, K. Bedka, and C. Fleeger, 2014: Total lightning as an indication of Convectively Induced Turbulence potential in and around thunderstorms. *Fourth Aviation, Range, and Aerospace Meteorology Special Symposium, 94th AMS Annual Meeting,* 2-6 Feb 14, Atlanta, GA, Presentation 3.2.

Schultz, C.J., L.D. Carey, E.V. Schultz, **G.T. Stano,** R.J. Blakesee, and S.J. Goodman, 2014: Integration of the total lightning jump algorithm into current operational warning environment conceptual models. *18th Conf. Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 94th AMS Annual Meeting,* 2-6 Feb 14, Atlanta, GA, Presentation J3.5.

Schultz, E.V., C.J. Schultz, L.D. Carey, D.J. Cecil, **G.T. Stano,** M. Bateman, and S.J. Goodman, 2014: Lightning Jump Algorithm for GOES-R Geostationary Lightning Mapper (GLM) Proxy Data. *Tenth Annual Symp. New Generation Operational Environmental Satellite Systems, 94th AMS Annual Meeting,* 2-6 Feb 14, Atlanta, GA, P.334.

Smith, M.R., K.K. Fuell, J.A. Nelson Jr., and M. Lawson, 2014: Using the SPoRT LEO/Geo Hybrid Product in OCONUS Forecasting. *Fourth Conf. Transition of Research to Operations, 94th AMS Annual Meeting,* Atlanta, GA. [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper234678.html].

Stano, G.T., 2014: Total Lightning: What is it, applications and comparisons to cloud-to-ground lightning observations. *Presentation, various WFOs, CWSUs, and the Spaceflight Meteorology Group,* February – April, 2014.

Stano, G.T., 2014: Total Lightning: What it is and operational impacts. *GOES-R Brown Bag Seminar Series,* 25 June 2014.

Stano, G.T., 2014: Using the Pseudo-GLM in Warning and Impact-based Decision Support in Preparation for GOES-R. *NOAA Satellite Science Week Virtual Meeting.*

Stano, G.T., 2014: NASA SPoRT OCONUS Collaborations. *OCONUS R2O Interchange Meeting,* Honolulu, Hawaii, 30 July 2014.

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Stano, G.T., E.J. Szoke, N. Rydell, R. Cox, and R. Mazur, 2014: Colorado Lightning Mapping Array Collaborations through the GOES-R Visiting Scientist Program. *Tenth Annual Symp. New Generation Operational Environmental Satellite Systems, 94th AMS Annual Meeting,* 2-6 Feb 14, Atlanta, GA, Presentation 8.3.

Stano, G.T., K.M. Calhoun, and A.M. Terborg, 2014: Assessment of the Pseudo Geostationary Lightning Mapper Products at the Spring Program and Summer Experiment. *Tenth Annual Symp. New Generation Operational Environmental Satellite Systems, 94th AMS Annual Meeting,* 2-6 Feb 14, Atlanta, GA, Poster 351.

Stano, G.T., K.K. Fuell, A. LeRoy, M. Smith, S.D. Miller, D. Kann, D. Bernhardt, N. Rydell, and R. Cox, 2014: SPoRT transition of JPSS VIIRS Imagery for Night-time Applications. *Testbed Activities in Numerical Weather Prediction, Observations, Analysis, and Forecasting IV/ 26th Conf. Weather Analysis and Forecasting/22nd Conf. Numerical Weather Prediction, 94th AMS Annual Meeting,* 2-6 Feb 14, Atlanta, GA, J13.3.

White, K.D., and **J.L. Case,** 2014: Assessing the Utility of 3-km Land Information System Soil Moisture Data for Drought Monitoring and Hydrologic Applications. *39th National Weather Association Annual Meeting,* 18-23 October 2014, Salt Lake City, UT, Poster P3.25.

Zavodsky, B.T., J.L. Case, J.H. Gotway, and **K.D. White,** J.M. Medlin, L. Wood, D.B. Radell, 2014: Development and implementation of dynamic scripts to support local model verification at NWS WFOs. *30th Conf. Environmental Information Processing Technologies, 94th AMS Annual Meeting,* Atlanta, GA [Available online at: https://ams.confex.com/ams/94Annual/webprogram/Paper232418.html].

Zavodsky, B.T., C. Blankenship, and **J.L. Case,** 2014: Data assimilation of SMAP observations, and impact on weather forecasts in a coupled simulation environment. *Third SMAP Applications Workshop,* Boulder, CO, April 9, 2014.

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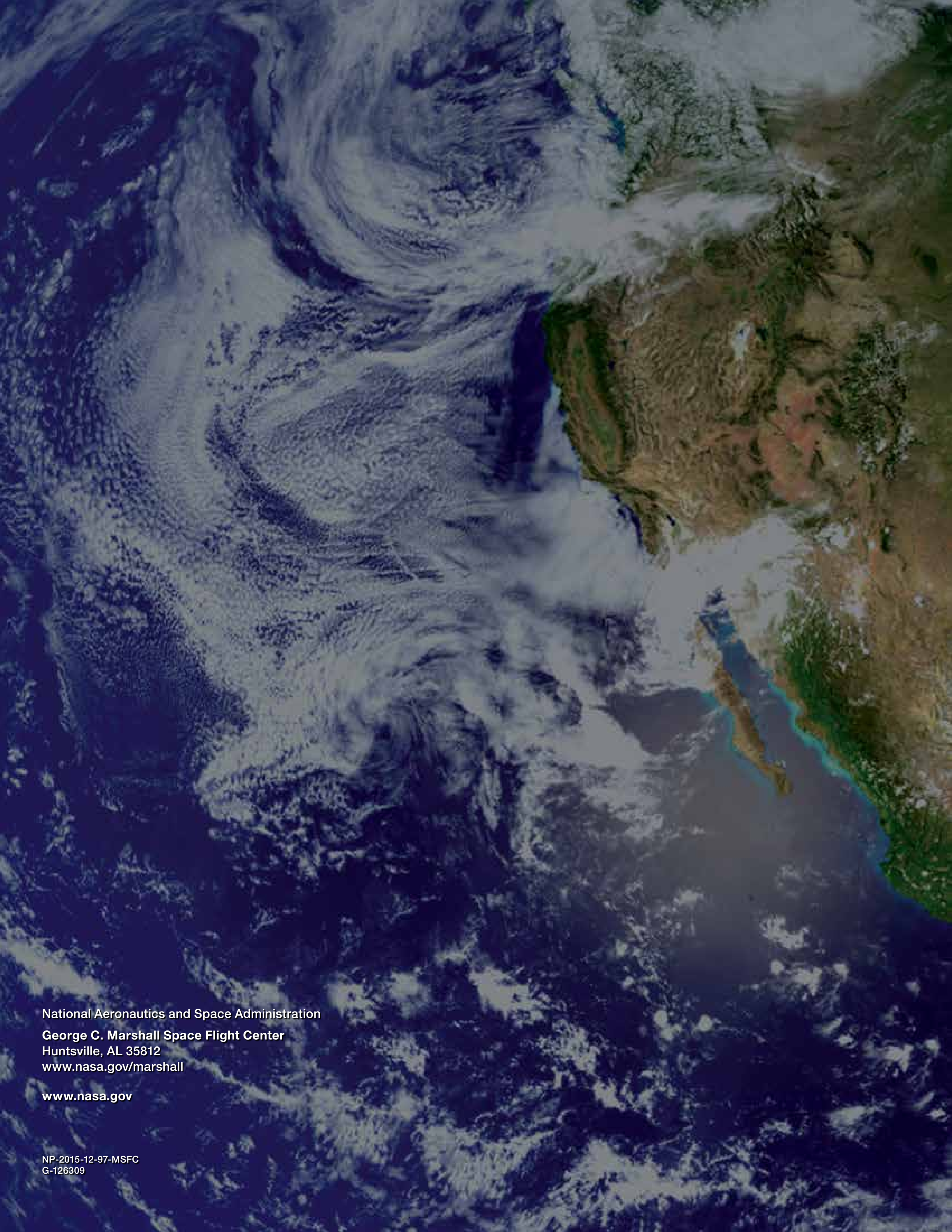
Appendix D. Acronyms and Abbreviations

ABI	Advanced Baseline Imager
AHI	Advanced Himawari Imager
AIRS	Atmospheric InfraRed Sounder
AMSR-2	Advanced Microwave Scanning Radiometer-2
AOD	Aerosol Optical Depth
AR	Atmospheric River
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATAN	AWIPS Test Authorization Note
ATMS	Advanced Technology Microwave Sounder
AVHRR	Advanced Very High Resolution Radiometer
AWC	NCEP Aviation Weather Center
AWIPS	Advanced Weather Interactive Processing System
AWIPS II	Next generation AWIPS
CI	Convective Initiation
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CONUS	Conterminous United States
CrIMSS	Cross-track Infrared and Microwave Sounding Suite
CrIS	Cross-track Infrared Sounder
CWSU	NWS Center Weather Service Unit
DAT	Damage Assessment Toolkit
DNB	Day-Night Band
DSS	Decision Support Systems
EF	Enhanced Fujita tornado scale
EPDT	Experiment Products Development Team
GINA	Geographic Information Network of Alaska
GLM	Geostationary Lightning Mapper
GMI	GPM Microwave Imager
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement
GSFC	NASA Goddard Space Flight Center
GSI	Gridpoint Statistical Interpolation
GVF	Green Vegetation Fraction
HWT	Hazardous Weather Testbed
IASI	Infrared Atmospheric Sounding Interferometer
IMERG	Integrated Multi-Satellite Retrievals for GPM
IR	Infrared
ISERV	ISS SERVIR Environmental Research and Visualization System
ISS	International Space Station
IVT	Integrated water Vapor Transport
JCSDA	Joint Center for Satellite Data Assimilation
JPSS	Joint Polar Satellite System
LIS	Land Information System
LMA	Lightning Mapping Array
LPW	Layered Precipitable Water
LSM	Land Surface Model
MDL	Meteorological Development Laboratory
MODIS	Moderate Resolution Imaging Spectroradiometer
MSFC	NASA Marshall Space Flight Center
MSG	Meteosat Second Generation
MTSAT	Multi-functional Transport Satellite
NASA	National Aeronautics and Space Administration
N-AWIPS	National Centers-AWIPS
NCEP	National Centers for Environmental Prediction
NDVI	Normalized Difference Vegetation Index
NESDIS	National Environmental Satellite Data and Information Service
NHC	NCEP National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NRT	Near-Real Time
NUCAPS	NOAA Unique CrIS/ATMS Process System
NWP	Numerical Weather Prediction
NWS	National Weather Service
OCONUS	Outside the CONUS
OPC	NCEP Ocean Prediction Center
OPG	Operations Proving Ground
PG	Proving Ground
PGLM	Pseudo Geostationary Lightning Mapper
POES	Polar Orbiting Environmental Satellite
PW	Precipitable Water
QPE	Quantitative Precipitation Estimate
RFC	River Forecast Center
RGB	Red-Green-Blue
ROSES	Research Opportunities in Space and Earth Sciences
SAB	Satellite Analysis Branch
SAC	Science Advisory Committee
SEVIRI	Spinning Enhanced Visible and IR Imager
SFR	SnowFall Rate
SMAP	Soil Moisture Active Passive
SMOS	Soil Moisture and Ocean Salinity
SPC	NCEP Storm Prediction Center
SPoRT	Short-term Prediction Research and Transition
SST	Sea Surface Temperature
S-NPP	Suomi-National Polar-orbiting Partnership
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TMU	Traffic Management Unit
TPW	Total Precipitable Water
TRACON	Terminal Radar Approach Control
UAH	University of Alabama in Huntsville
USDM	U.S. Drought Monitor
VCL	Visualization and Collaboration Laboratory
VIIRS	Visible Infrared Imaging Radiometer Suite
VSP	Visiting Scientist Proposal
WFO	Weather Forecast Office
WPC	Weather Prediction Center
WRF	Weather Research and Forecasting



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George C. Marshall Space Flight Center
Huntsville, AL 35812
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