Improving the Transition of Earth Satellite Observations from Research to Operations

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There are significant gaps in the transitioning of new research observations into models and the decision support tools that make use of new data. At the Short-term Prediction Research and Transition (SPoRT) Center in Huntsville, Alabama, a NASA-NOAA-University collaboration has been developed to accelerate the infusion of NASA Earth science observations, data assimilation and modeling research into NWS forecast operations and decision-making. The SPoRT Center research focus is to improve regional 0-1 day short-term forecasts with emphasis on high impact weather, ranging from convective initiation and evolution to 24-hr quantitative precipitation forecasting. The near real-time availability of high-resolution experimental products of the atmosphere, land, and ocean from the Moderate Resolution Imaging Spectroradiometer (MODIS), the Advanced Infrared Spectroradiometer (AIRS), and lightning mapping systems provide an opportunity for science and algorithm risk reduction, and for application assessment prior to planned observations from the next generation of operational low Earth orbiting and geostationary Earth orbiting satellites. This paper describes the process for the transition of experimental products into forecast operations, current products undergoing assessment by forecasters, and plans for the future.

I. Introduction

The NASA Short-term Prediction Research and Transition (SPoRT) Center was established in the fall of 2001 to accelerate the infusion of NASA earth science observations, data assimilation and modeling research into the Nation's forecast operations and decision-making procedures. The activity conducts both discovery and product-driven research associated with advanced algorithm development, land/atmosphere interactions, satellite data assimilation, convective initiation and evolution, lightning/severe storm kinematics, and quantitative precipitation estimation and forecasting. A Collaborative Research Area (CRA) at the Huntsville, AL (HUN) National Weather Service Forecast Office (NWSFO) and physically collocated within a building shared by NASA researchers, students, and forecasters was created to facilitate technology transfer. The CRA provides the opportunity for the community of researchers, students, and forecasters to work side-by-side in the analysis and evaluation of NASA experimental products. The Observations from a number of NASA satellite missions and state-of-the-art community-based mesoscale prediction/assimilation systems are used. Specific examples include 1) land surface information from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Terra and Aqua satellites; 2) radiance data and retrieved profiles from the Atmospheric Infrared Sounder (AIRS) on AQUA, total lightning data from the Lightning Imaging Sensor (LIS) aboard the Tropical Rainfall Measurement Mission (TRMM) and the north Alabama Lightning Mapping Array (LMA); and 3) the Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model version 5 (MM5) and the next generation Weather Research and Forecast (WRF) System and associated data assimilation systems including the Forecast System Laboratory (FSL) Local Analysis and Prediction System (LAPS) and the MM5 4-dimensional variational (4D-VAR) system. The principal focus of experimental products is on the regional scale with an emphasis on forecast improvements on a time scale of 0-24 hours. This paper describes the process for the transition of experimental products into forecast operations, current products undergoing assessment by forecasters, and plans for the future. The SPoRT Web page is (http://www.ghcc.msfc.nasa.gov/sport).

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II. Derived Products from NASA Earth Science Observing Systems

Advanced NASA ESE instruments on the TRMM, Terra, and Aqua low earth orbiting satellites such as the TRMM Precipitation Radar (PR), TRMM Microwave Imager (TMI), TRMM Lightning Imaging Sensor (LIS), MODIS, AIRS, and AMSR-E provide measurements of surface, atmospheric, cloud, precipitation, and lightning signatures with excellent spatial resolution and spectral capabilities to augment the current observations of clouds and surface features, and the related higher order atmospheric and surface parameters important for weather analysis, nowcasting, and short-term prediction. In the future, instruments on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) platforms will also provide "pathfinder" like capabilities for GOES-R in 2012. In advance of the 2009 launch of NPOESS a limited suite of instruments on the NPOESS Preparatory Project (NPP) will provide a bridge between the NASA Earth Observing System (EOS) and NPOESS instruments.

Although the end user for transitioning NASA research to operations through SPoRT has been focused on the local NWS offices, the information derived from the data has links to a number of vital application areas, e.g., aviation safety and efficiency, agricultural efficiency, air quality, water, disaster, energy, and coastal management. Better short-term analysis and prediction of lightning assists decision makers in Air Quality, as lightning is one of the greatest natural sources of NOx production and in Aviation as it aids Air Traffic routing and maximizes system capacity. Initialization of models using NASA satellite data has the potential through improved forecasts or data for use within the decision support systems that benefit these regional scale applications. A framework for the transition from research to decision support is shown in Figure 1. SPoRT provides a testbed for working with agencies on infusing these data to assess its utility and capabilities in their decision support tools in advance of these operational systems. Leveraging the short-term weather research ongoing within SPoRT and that proposed here have the potential to affect many of the key areas of national importance through existing and future datasets.

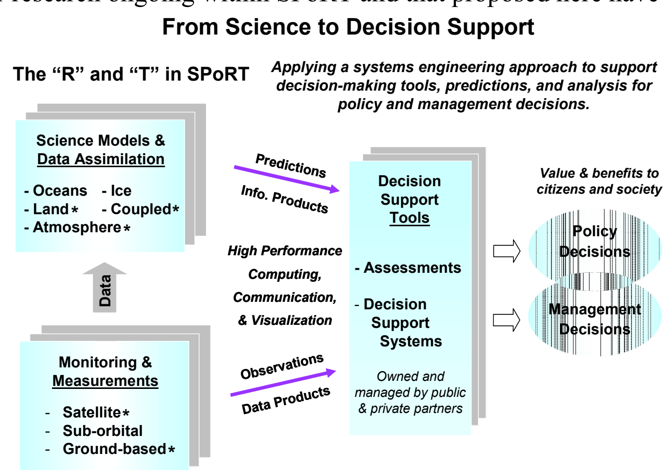


Figure 1. Framework to transfer new earth observations from research to operations.

The key to use of these data in forecast operations is the availability of these data and products to the forecaster in near real-time and in a way which quickly enhances situational awareness, is straightforward to interpret, and easy to use. SPoRT obtains real time MODIS and AIRS data from several external sites, which ingest the data via direct broadcast systems. The data are available minutes after collection, processed by SPoRT and disseminated to selected National Weather Service Forecast Offices (NWSFO) for ingest into the NWS Advanced Weather Information and Processing System (AWIPS), used for operational decision support. AWIPS provides a key display and integration platform where the NASA and NOAA data and products can be viewed and synthesized with other meteorological data to make this task more formidable. In February of 2003, SPORT provided the first real time MODIS imagery available to a NWS office via AWIPS within 70 minutes of data collection. Current latency is down to around 30 minutes. Not all GOES data and derived products are readily available or accessible in AWIPS. Super rapid scan data, and other products not mainstream to AWIPS, and unique or timely observations from MODIS and AIRS can provide valuable information for the forecaster. New visualization and display techniques not part of the current AWIPS can make interpretation and use of the satellite data and products more efficient in the operational environment. Additionally, not all forecasters have the latest insight to interpret the data and derived products, and how they can be used in the operational environment. Training must go hand-in-hand with the new data and products or they may quickly fall into disuse.

III. Results

Two new data sources were introduced during 2003 into three WFOs located in the NWS Southern Region (Huntsville, HUN; Birmingham, BMX; and Nashville, OHX). The MODIS on board the NASA low Earth orbiting Terra and Aqua satellites, and total lightning discharge mapping from a ground-based 3-D VHF lightning mapping sensor array are providing early opportunities for forecasters to develop operational experience with measurements similar to those that may be provided by the next generation of Geostationary satellites. The Advanced Weather Information Processing System (AWIPS) forecaster workstation ingests, displays, and integrates these experimental data sets in addition to the standard data products and model output, allowing the forecaster to readily issue the forecasts and warnings. Early on in the development of the joint collaboration between NASA and NWS, it was clear that product assessment would be most effective if the products were available in near real-time to the forecasters with minimum latency within AWIPS. Within this operational environment the researchers and forecasters are jointly able to assess the utility of the new experimental products.

A. MODIS

MODIS has a swath width of 2,330 km and images the entire surface of the Earth in 36 spectral bands between 0.405 and 14.385 µm. SPoRT started acquiring near real-time NASA Terra satellite MODIS (Level 1b) data via the Internet from the University of Wisconsin's (UW) Direct Broadcast system in the Fall 2002. This data stream originally included only Level 1 radiances, but now also includes selected EOS Atmospheric science team (Level 2) products, namely cloud products, atmospheric moisture and stability. Ingest, data processing, and storage scripts were written to automate data selection and dissemination. A Web-based display was generated to monitor the quality and latency of real-time data obtained from UW. Early in spring of 2003, Terra MODIS images and products were reformatted and made available to the HUN NWS office AWIPS system from a local NASA server. MODIS data from the NASA Aqua satellite were obtained beginning in early May and are routinely sent to AWIPS. In July, the staging of the final images and products were changed such that these products became available to multiple NWS offices directly from the Southern Region server (in Fort Worth) via their Local Data Acquisition and Dissemination (LDAD) system. Additional sources of products such as fire products, aerosols, and LST are being explored.

Use of MODIS data by the NWS required some additional configuration of enhancement and data lookup tables for display and data output in AWIPS. We have worked extensively on this to provide enhancements and capabilities consistent with standard AWIPS operations and with enhanced features to best display and use MODIS data. Efforts throughout the year have reduced the data latency by 50%. Most MODIS data and products are available in AWIPS within 45 minutes of data collection.

In addition to the MODIS products available from the EOS atmospheric science team through UW, several key in-house products have been developed that provide useful tools for the NWS. First, a 3-channel color composite (500m resolution) is made in real time and provided to the WFOs (Figs. 2,3).

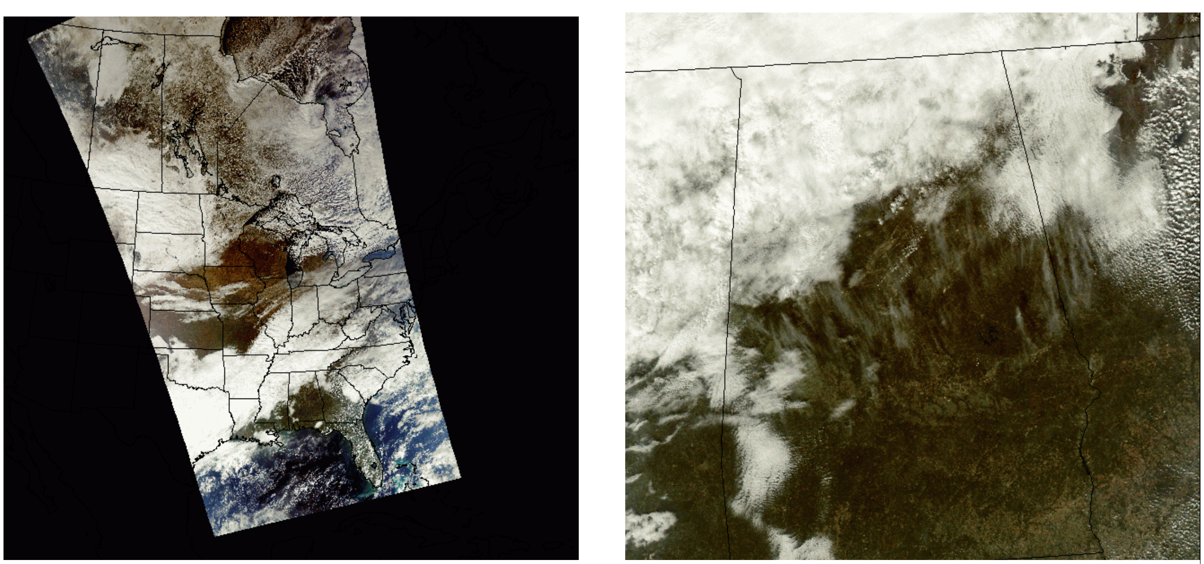


Figure 2. MODIS Aqua CONUS swath (left) and high-resolution regional (right) 3-band color composite image of the southeast US at 1853 UTC 7 November 2003.

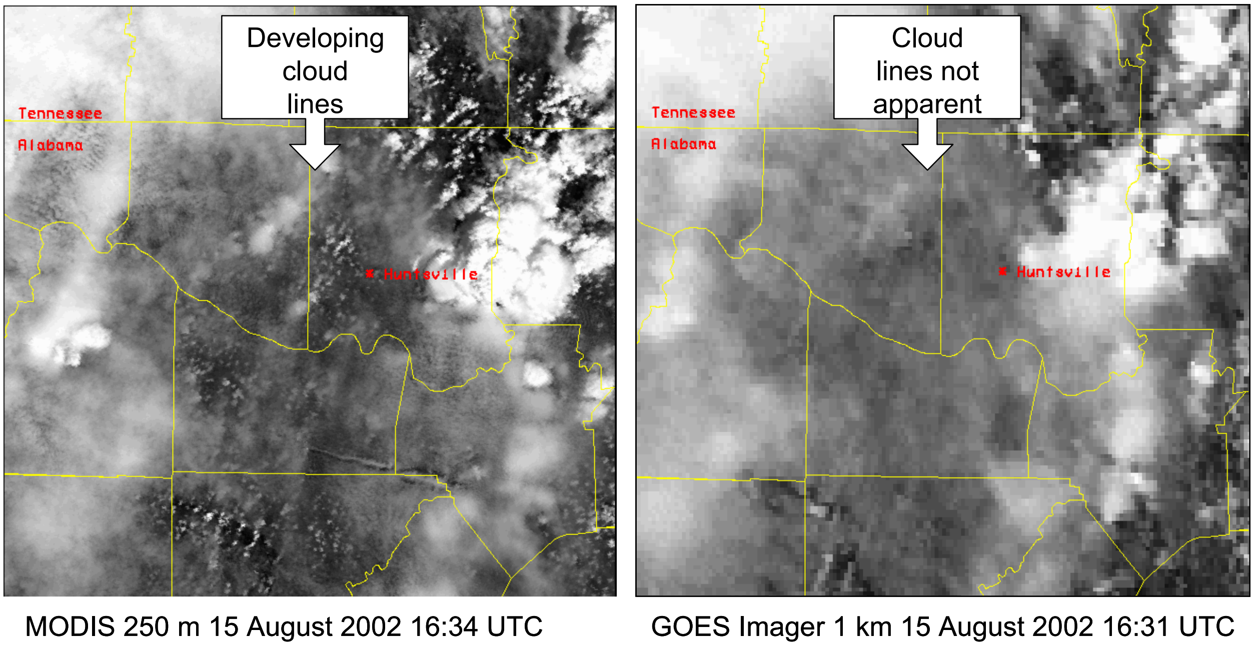
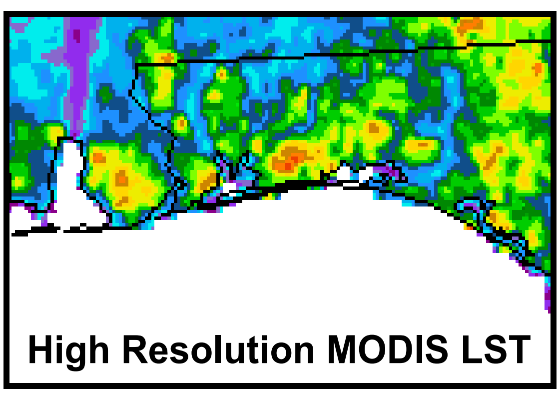


Figure 3. MODIS Terra 250 m, single visible image (left) shows greater cloud and surface detail than the concurrent GOES 1 km visible image (right).

This product is extremely useful for identifying thin cirrus, convergence lines and convective cloud structures, smoke from agricultural fires, land use and surface features. Second, a fog product, similar to that calculated with GOES, is made and displayed in AWIPS with specific enhancement curves to isolate regions of developing fog and low clouds. Third, a combined LST/SST product is produced with an in-house algorithm.



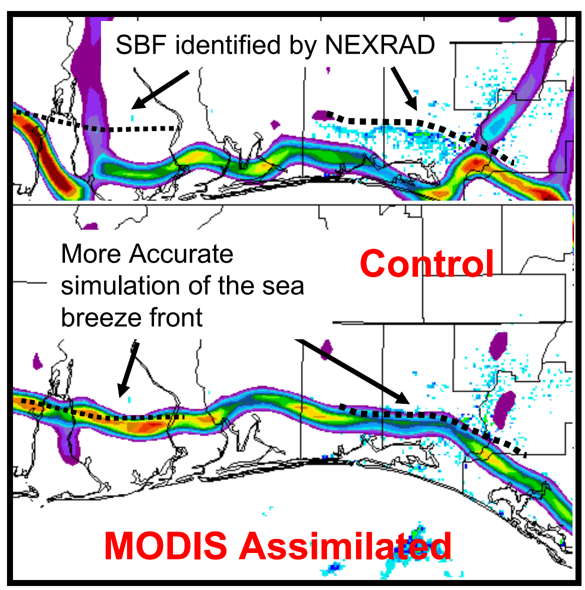


Figure 4. MM5 model assimilation of MODIS land surface temperature (bottom) produces an improved forecast of the sea breeze front (SBF) position compared to a Control run (top).

The LST product, along with hourly GOES data, will be used to develop a minimum temperature algorithm for use in the AWIPS Interactive Forecast Preparation System (IFPS). The real time products and L1B radiances are cloud-cleared and made available in real time to the in-house SPoRT modeling group for use in data assimilation studies. Since the evolution of mesoscale phenomena in the planetary boundary layer is sensitive to differential land surface forcing, high-resolution MODIS land and sea surface temperatures can be used to initialize models at scales below 10 km with the potential to fill information gaps such as the improved specification of the pre-storm environment. A technique to assimilate MODIS LST data into the land surface component of MM5 was found to have a positive impact on the formation and subsequent evolution of a non-precipitating sea breeze circulation observed along the Florida panhandle on 14 May 2001 (Figure 4). The experiment was conducted on a 4 km grid to exploit the high-resolution MODIS data. Assimilating the satellite data resulted in realistic representation of differential land surface forcing across and parallel to the coastline. Strength and inland penetration of the sea breeze front were validated with surface observations and NEXRAD clear-air returns.

Training on the use of the new EOS data and products was provided in several forms to the three regional NWS offices thus far receiving the data. Science sharing sessions and presentations were made on several occasions to the various offices on both MODIS data and product utilization. Based on requests from a couple of these offices, VISITview modules are being developed on "MODIS Polar Orbiting Data and Display" and "Night time Fog Detection with MODIS". The development of these modules is also being coordinated with NWS COMET program.

B. Lightning Mapping Array (LMA)

The North Alabama 3-D VHF regional lightning mapping array consists of ten VHF receivers deployed across northern Alabama and a base station located at the National Space Science and Technology Center (NSSTC), which is on the campus of the University of Alabama in Huntsville. The LMA system locates the sources of impulsive VHF radio signals from lightning by accurately measuring the time that the signals arrive at the different receiving stations Thomas et al[1]. Typically hundreds of sources per flash can be reconstructed, which in turn produces accurate 3-dimensional lightning density maps (nominally <50 m error within 150 km range).

Key objectives of our research investigations using LMA data are: a) Identification of intensifying and weakening storms using the time rate-of-change of total flash rate; b) Improve severe storm potential situational awareness; and c) Evaluation of the potential of total flash rate trend to improve severe storm probability of detection (POD) and lead time.

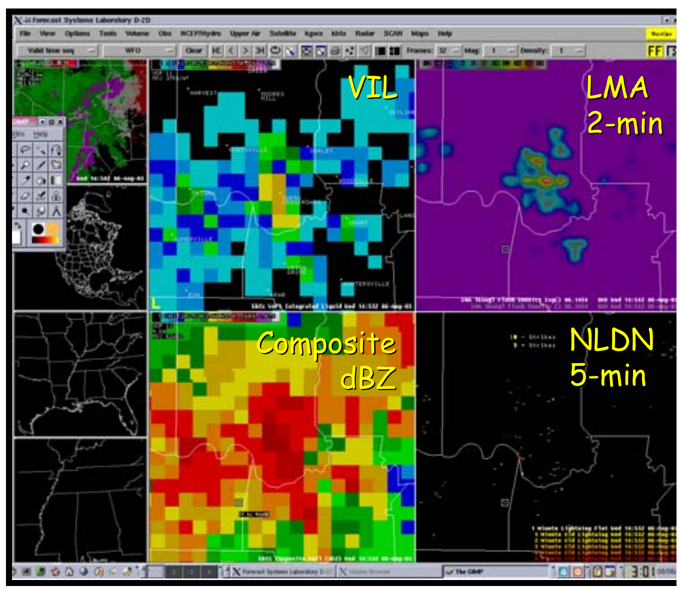


Figure 5. AWIPS 4-panel product display at 1453 UTC during tornadic storm event on 6 May 2003. The Lightning Mapping Array gridded 2-min VHF source density is shown in the upper right panel. Also shown is KHTX NEXRAD Vertically Integrated Liquid, VIL (upper left), composite reflectivity (lower left), and lightning ground strikes from the National Lightning Detection Network (lower right).

A 3-D gridded total lightning data set within a 460 km x 460 km domain, updated every 2 min, provides full coverage of the Huntsville, AL (HUN) and Nashville, TN county warning areas, as well as partial coverage of the warning areas of five other NWS office. Forecasters can interrogate the data on any of the 17 horizontal levels or examine the cumulative source density map that includes all levels. Forecasters can also readily dither between NEXRAD and LMA maps and loop multiple frames to enhance situational awareness during severe weather episodes. Real-time software and a wireless Ethernet network allow real-time data to be collected, products generated, and maps distributed, which are augmenting the standard WFO products used in the warning decision-making process. The LMA data are distributed via the NWS Southern Region for ingest and display in the regional WFO's AWIPS decision support system, and archived at each WFO for case studies, event playbacks, and assessments with NASA scientists using the NWS Warning Event Simulator. HUN has upgraded severe thunderstorm warnings to verified tornado warnings and avoided a false alarm on a severe storm through the added information on storm growth, intensification, and decay that can be deduced from the magnitude and temporal trend of total flash rates. The LMA products are automatically updated on the forecasters' workstation. In this way, the forecaster can optimally evaluate the added value of total lightning data within the forecast and warning decision-making process (Fig. 5).

IV. Conclusions

This paper describes a successful research and operational collaboration between NASA scientists and NWS forecasters. The first operational experimental products forecast products developed by SPoRT were delivered to the NWS forecast office in Huntsville, AL within their decision support system in February 2003. By September 2004 the SPoRT Center was providing a number of experimental products form MODIS, supplemental numerical guidance from the WRF and MM5 modeling systems, and total lighting data from the LMA to six forecast offices in the NWS Southern Region. All products are ingested and displayed in the NWS AWIPS decision support system. In addition, near real time MODIS imagery and experimental snow products are provided to the Great Falls, MT forecast office. Continued collaboration between researchers and forecasters will produce new opportunities to further evaluate the utility of experimental research data products. The focus of the SPoRT research and transition activities will be directed in the following areas: a) Explore the utility of new EOS data on specific NWS forecast problems; b) Determine how NASA EOS observations can enhance other sensor data (e.g., GOES products); c) Perform assessments of the utility of these new capabilities; and c) Exploit the SPoRT infrastructure for broader use of EOS data in applications outside the NWS, including International partners.

Acknowledgments

The SPoRT project is funded by the NASA Science Mission Directorate.

References

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