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Transitioning Research Satellite Data to the Operational Weather Community: The SPoRT Paradigm

1. INTRODUCTION

Established in 2002 to demonstrate the weather forecasting application of real-time Earth Observing System (EOS) measurements, the Short-term Prediction Research and Transition (SPoRT) (http://weather.msfc.nasa.gov/sport) project (managed by the NASA/Marshall Space Flight Center Earth Science Office located at the National Space Science and Technology Center, NSSTC, in Huntsville, Alabama) has grown to be an end-to-end research to operations activity focused on the use of advanced modeling and data assimilation techniques, nowcasting tools, and unique high-resolution multispectral data from NASA, NOAA, DoD and international partner satellites to improve short-term weather forecasts on a regional and local scale. SPoRT partners with several universities and other government agencies for access to real-time data, and works collaboratively with them to develop new products, tools, and forecast methods, and infuses these capabilities into the operational weather environment. While the majority of the SPoRT end users are forecasters at various at NWS Weather Forecast Offices (WFOs) across the United States, the adaptation and use of SPoRT products in NOAA Testbeds (Ralph et al., 2013), at NOAA National Centers and Proving Grounds (Goodman et al. 2012), and for weather disaster applications (Molthan et al. 2011; Molthan and Jedlovec, 2013) shows the relevance of SPoRT's activities to a broader segment of the weather community. In this way, SPoRT is focal point and facilitator for the transfer of NASA and NOAA Earth science technologies to the operational weather community with an emphasis on short-term forecasting.

2. SPoRT PARADIGM

The transition of research and experimental data to the operational weather community for evaluation and use requires a committed partnership between data providers and end users. Without such a committed partnership, new data, tools, and enhanced forecast techniques, which are "thrown" to the operational users, "fall" to the bottom of the "valley of death" and never get successfully implemented. The phase "valley of death" is a metaphor for the barriers and obstacles separating research results and operational applications. NRC (2000) and NRC (2003) indicate that successful transitions require an understanding of the importance and risks of transition, the development of appropriate transition plans, adequate resources for the transitions, and continuous communication and feedback between the research and operational communities. SPoRT has developed and follows a conceptual transition of "research to operations," or R2O, model which involves close collaboration with the end user and provides a "footbridge" over the valley of death, as shown in Figure 1. Initial interactions with potential end users usually involve a site visit to end user facilities to learn about their operational constraints and forecast issues. The knowledge gained from such a visit allows developers to better match a particular research data or capability to the forecast problem. Potential approaches or solutions are typically discussed with end users in order to establish a baseline for collaboration. This close interaction with the end user from the start reassures the end user that SPoRT is focused on helping them do their job. Potential solutions are demonstrated and refined in a "test bed" environment which simulates operational constrains. The test bed environment includes end user decision support systems (for the NWS these are typically AWIPS, NAWIPS, or AWIPS II) along with the pertinent real-time data streams. To make the transition successful, it is important that the new capabilities be integrated into the end user decision support system so that they can be easily used with the rest of their data and capabilities.

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Solutions that seem viable (meet end user requirements for functionality, timeliness, display, etc.) are further demonstrated and ultimately evaluated in a broader collaborative arrangement that usually includes several offices with similar interests or needs.

The successful use of transitioned products requires that the test bed participants are knowledgeable of the capabilities, strengths, and weaknesses of the solution being tested. SPoRT develops and conducts several different types of training, all of them conveying the application of the new data or technique, its strength, weaknesses, and limitations, and includes end user examples of its application, taken directly from their decision support system. This training takes the form of short self-guided modules, user quick guides, distance learning with the product developer, and even face-to-face science sharing sessions. Examples of these training modules can be found on the SPoRT web site under "transitions" and "training." End users often participate in the development of these training aids.

It is important to understand the degree of impact the solution (the new product, tool, or forecast capability) may have in the operational environment. This assessment is usually done in the test bed environment with several end users or at different locations. Short surveys are used to ascertain the impact of the new product on operational decision making in the end user environment. The surveys must not be a burden on the end user but must allow for both quantitative and qualitative input on the utility of the product. The surveys used by SPoRT can be found on the web site under "surveys." The activities of the transition process and the outcome of numerous end user responses to the product surveys form an assessment study. These results guide either the broader product transition or a re-evaluation of the transition process.

3. STAKEHOLDERS, BENEFICIARIES, CUSTOMERS, AND PARTNERS

There are many individuals and groups who contribute to and benefit from the success of the SPoRT project. The primary stakeholders for SPoRT (those who invest in and gain from the success of the project) are the NASA research and applications program, the NOAA GOES-R and JPSS programs, the NWS Office of Science and Technology (OST) and the NWS WFOs. Managers of these organizations and projects provide funding and give guidance and direction to ongoing and future SPoRT research and transitional activities. The NWS and the collaborating WFOs are major stakeholders in the activity since they provide direct in-kind support through their allocation of forecasters, Science and Operations Officers (SOOs), and Information Technology Officers (ITOs) in the transition of SPoRT products into AWIPS, and the education, training, and assessment assistance they provide. SPoRT beneficiaries profit or benefit from the success of the project. The NASA and NOAA entities are direct beneficiaries of the success of the SPoRT program. In addition to the WFOs, who interact with and receive products / capabilities from SPoRT, other beneficiaries include collaborating private sector partners who also receive value-added products to improve their weather forecasts. The general public is an indirect beneficiary of SPoRT's success through improved forecasts provided by the WFOs.

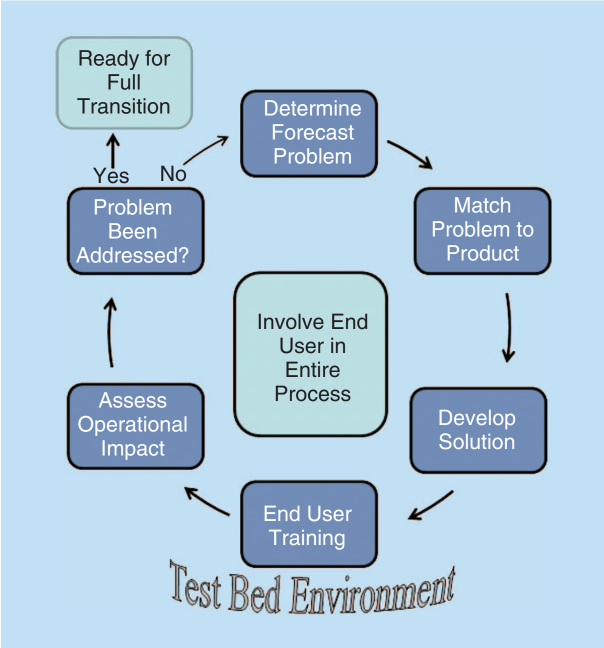

FIGURE 1. The SPoRT paradigm for successful transition of research data to the operational weather community.

Figure 2 indicates the locations of SPoRT's collaborative partners, both supporting and end users. Supporting partners help SPoRT conduct the research and transitional activities by providing capabilities such as technical expertise, computation resources, data, or other enabling capabilities. SPoRT end users include forecasters at the various collaborating NWS WFOs, and other operational weather entities such as some of NOAA's National Centers. The forecasters and environmental managers at these facilities have particular needs that can uniquely be met through the use of NASA and NOAA research capabilities. SPoRT currently works collaboratively with 23 WFOs (red dots) and several National Centers (open circles) including HPC, OPC, NHC, SPC, and AWC.

4. PRODUCTS

SPoRT provides a suite of products from various NASA, NOAA, DoD, and international community sensors to its end users for use in their decision-making process. A list of these data and products and the forecast challenges which they support are presented in Table 1. SPoRT initially transitioned basic Moderate-resolution Imaging Spectroradiometer (MODIS) imagery on NASA's Terra and Aqua satellites to several regional NWS forecast offices in February 2003. The data were displayed in AWIPS in a similar way as the more conventional NOAA operational GOES satellite imagery, but provided a factor of sixteen increase

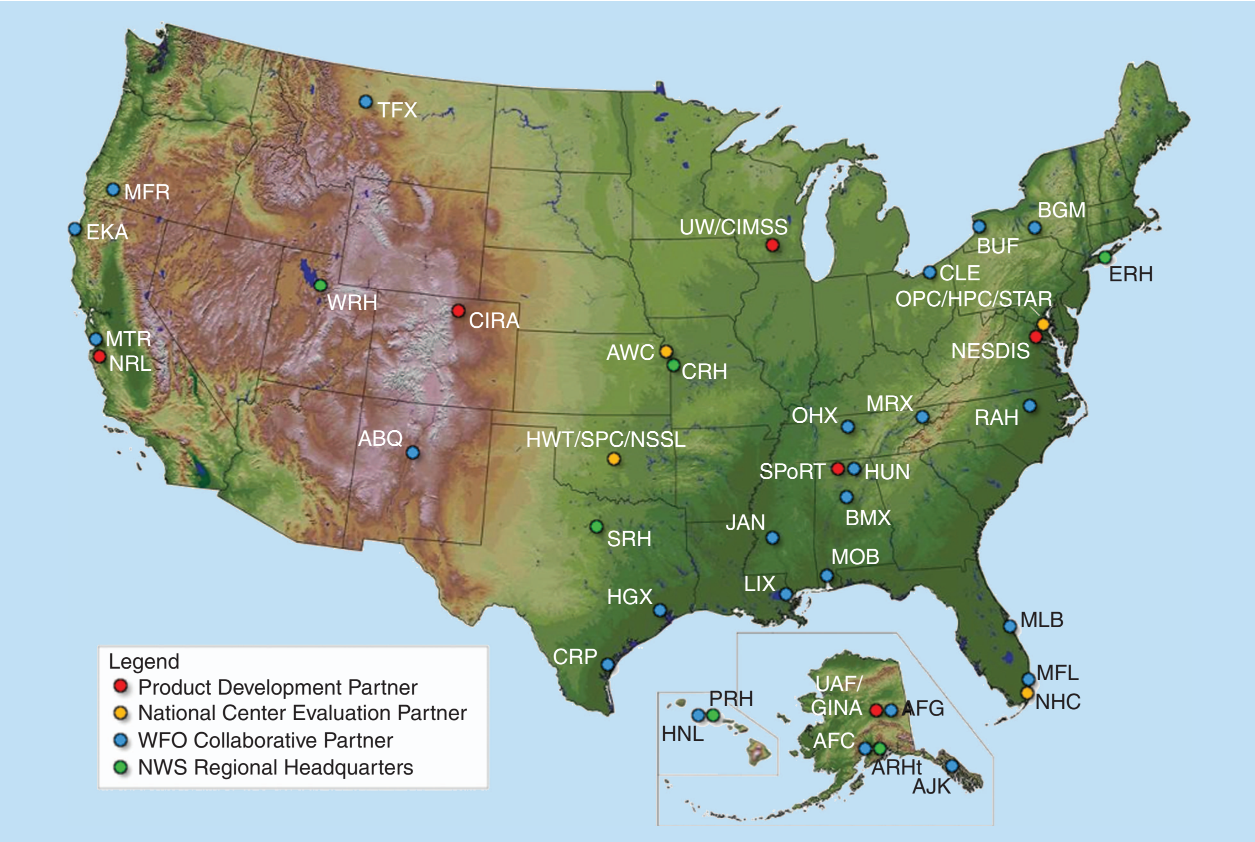

FIGURE 2. SPoRT collaborative partner map.

in spatial resolution over their existing GOES imagery. Although the polar orbit of the Terra and Aqua satellites limit data availability to 2–4 times daily, these image data are still regularly used to improve situational awareness (understanding current weather conditions to help support short-term forecasts and other weather decisions) at many SPoRT collaborative weather offices. SPoRT has also developed and transitioned additional MODIS products including a suite of red-green-blue (RGB) imagery to WFOs which replicate the observational capabilities of the EUMETSAT's Spinning Enhanced Visible and Infrared Imager (SEVIRI) data products. Many of these MODIS products were transitioned to address specific forecast issues like monitoring the change in surface visibility due to low clouds, fog, or smoke, changes in surface forcing leading to local temperature changes, cloud, and precipitation variations, or other particular issues associated with coastal weather (see listed forecast problems in the table). Several products from the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) instrument on the Aqua satellite were made available to coastal forecast offices as well to monitor precipitation associated with approaching storms and tropical weather systems outside the range of land-based radar systems. AMSR2 data from the Japanese Global Change Observation Mission (GCOM) satellite will soon be transitioned to replace the AMSR-E data stream which was lost due to its failure in 2011. In addition to products derived directly from swath data, SPoRT produces several multi-satellite / multi-time products such as the MODIS Normalized Difference Vegetation Index (NDVI) /Greenness Vegetation Fraction (GVF) product (Case et al., 2012) and the passive microwave/infrared cloud-free composite SST product (Haines, et al., 2007) to improve local situational awareness and to assimilate into weather models run by individual WFOs for local model applications (Case et al. 2011; Case et al. 2008; and LaCasse et al. 2008).

Early in the collaborative process, SPoRT also transitioned some unique ground-based total lightning measurements to several WFOs. Lightning source and flash density products derived from the total lightning network data have been used along with Doppler radar by a number of WFOs to improve the lead time of severe weather producing tornadoes and damaging hail and for lightning safety (Darden et al. 2010). The current distribution of total lightning products includes data from four different networks that have been transitioned to eight WFOs and several National Centers.

While transitioning EOS satellite data and products demonstrates the utility of the NASA data for weather forecasting and other societal applications, the research data also serve as precursors or proxy data sets to future NOAA operational instruments such as those of the Joint Polar Satellite System (JPSS) and the Geostationary Operational Environmental Satellite (GOES)—R satellite

TABLE 1. PRODUCT SUITE PROVIDED TO END USERS.

INSTRUMENT/PRODUCT	FORECAST PROBLEM
MODIS (Terra and Aqua)	
Imagery (visible, 3.9, 6.7, 11 μm)	Improve situational awareness
Suite of RGB products (true, false color snow, air mass, night and day-time microphysics, dust)	Cloud structure, obstructions to visibility, extent of snow cover
Fog/low cloud (11–3.9 μm)	Improve situational awareness
Land and sea surface temperature (LST, SST)	Surface forcing for clouds and convection
SST and ice mask (Great Lakes and Arctic Ocean)	Coastal processes, lake effect precipitation
NDVI/green vegetation (GVF)	Model initiation/improved forecasts
AMSR-E (Aqua) / AMSR2 (GCOM)	
Rain rate, cloud water	Coastal weather, data in void regions
SST	Coastal weather
Total Lightning Data (Ground-Based)	
Source/flash density	Severe weather, lightning safety
Combined Instrument Products	
Multi-sensor SST composite	Short-term weather forecasts
Blended TPW	Moisture mapping, atmospheric rivers, precipitation
HMS/FIRMS fire/burn area	Smoke, reduced visibility, localized flooding
GOES	
NESDIS aviation products	Improve situational awareness
Sounder air mass RGB	Storm dynamics, improved situational awareness
GOES-R Proxy Products	
Pseudo GLM product suite	Severe weather, lightning safety
GOES-MODIS hybrid imagery (visible, 3.9, 6.7, 11 μm)	Improved situational awareness
Hybrid RGB suite	Improved situational awareness
Quantitative precipitation estimates (QPE)	Precipitation mapping
Convective initiation (CI) product	Convection, precipitation mapping
JPSS Proxy Products	
VIIRS imagery (visible, 3.9, 11 μm)	Improved situational awareness
Suite of VIIRS RGB products (true, air mass (w/CrIS), night and day-time microphysics, dust)	Cloud structure, obstructions to visibility, storm dynamics
VIIRS DNB (low light)—Radiance, reflectance, RGB	Improved situational awareness
SEVIRI	
RGB products (air mass, dust, Saharan air layer)	Tropical storm forecasting, storm dynamics
Passive Microwave	
TMI (TRMM) 37(V/H), 85(V/H), composite	Precipitation monitoring, storm dynamics
SSMI(S) 37(V/H), 85(V/H), 91(V)	Precipitation monitoring, storm dynamics
SSMI(S) RGBs—37/85, 37PCT	Precipitation monitoring, storm dynamics
MISCELLANEOUS	
Land information system (LIS)—Soil moisture	Convective initiation, drought monitoring, flooding
WindSat—Ocean surface wind vectors (OSWV)	Improved situational awareness over oceans
OMI	
NESDIS SO2	Volcanic ash monitoring
AIRS	
Carbon monoxide, Ozone imagery	Fires, air quality, storm dynamics

programs. Through the transition and use of data that simulate observing capabilities of instruments on these future observing systems, SPoRT is helping prepare and train forecasters for the use of these next generation capabilities. SPoRT has been participating in NOAA's JPSS and GOES-R Proving Ground activities for the last several years by working with its collaborative development partners (at the NOAA Cooperative Institute for Mesoscale Satellite Studies, CIMSS, and the Cooperative Institute for Research in the Atmosphere, CIRA) to transition these unique capabilities to operational end users. Eight of SPoRT's collaborative WFO and all five of the collaborating National Centers receive and evaluate the utility of proxy products in their forecast operations. These products are listed in Table 1 under the GOES-R and JPSS proxy products section. SPoRT uses high resolution MODIS and Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (NPP) satellite data to

About the National Space Science and Technology Center (NSSTC)

The SPoRT project is managed by NASA scientists located at the National Space Science and Technology Center (NSSTC) in Huntsville, Alabama. The NSSTC is a unique collaborative research and education facility that brings together creative people, new ideas, and world class facilities to enable advances in Earth, space, and material sciences, advanced optics, and information technology. It houses scientific staff from NASA's Marshall Space Flight Center, the University of Alabama Huntsville (UAH) Earth and Space Science research communities, the UAH Atmospheric Science academic program (which awards graduate degrees in Atmospheric Science), and the National Weather Service's Weather Forecast Office (WFO) serving northern Alabama and Southern Tennessee. The research environment encourages excellence and innovation and promotes interdisciplinary research by capitalizing on synergy among disciplines fostered by this collocation. Activities conducted by NSSTC scientists and engineers range from fundamental science investigations to early technology development to mission operations and data analysis. The NSSTC helps to educate the next generation of scientists and engineers through various educational and public outreach efforts at all levels from K-12 to graduate studies. The NSSTC hosts many summer intern programs, and offers many opportunities for undergraduate and graduate, and post doctorial research studies.

simulate the spatial and spectral capabilities of the future GOES-R Advanced Baseline Imager (ABI) by replacing the coarser resolution GOES data with polar orbit data with comparable spatial resolution to that of ABI. This "hybrid" image is then combined in an animated sequence with the current GOES data stream, replacing GOES data at observation times when the hybrid is available. The GOES-POES hybrid products are produced as proxies for ABI basic channel imagery and RGB products used by the weather forecast community. The total lightning data collected by the ground-based networks is also used to generate proxy data for the GOES-R Geostationary Lightning Mapper (GLM) by creating a suite of flash density products at the GLM 8 km spatial resolution. These pseudo GLM products are disseminated to the SPoRT collaborating National Centers for evaluation. Additionally, SPoRT works with the GOES-R Algorithm Working Group (AWG) teams to transition additional proxy products such as the ABI proxy Quantitative Precipitation Estimation (QPE) and Convective Initiation (CI) products to users who can best test and benefit from these additional tools.

5. FUTURE

Established in 2002 to demonstrate the weather forecasting application of real-time EOS measurements, the SPoRT project has grown to be an end-to-end research to operations activity focused on the use of advanced modeling and data assimilation techniques, nowcasting tools, and unique high-resolution multispectral observational data from NASA, NOAA, DoD, and international partner satellites to improve short-term weather forecasts on a regional and local scale. Through these efforts, SPoRT strives to be a focal point and facilitator for the transfer of unique Earth science technologies to the operational weather community with an emphasis on short-term forecasting. To achieve this vision, the SPoRT project will continue to address new data and technologies and develop and test solutions to critical forecast problems, and integrate solutions into end user decision support tools. SPoRT will draw on new instrumentation from satellites such as the Soil Moisture Active Passive (SMAP), which will provide high spatial resolution soil moisture data for diagnostic studies and data assimilation and weather forecasting, and the Global Precipitation Mapping (GPM) mission for more accurate measurements of precipitation at fine space and time scales.

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