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AN OVERVIEW OF THE GOES-R PROVING GROUND: CURRENT FORECASTER INTERACTIONS AND FUTURE PLANS

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1. INTRODUCTION

The Geostationary Operational Environmental Satellite (GOES)-R is the first member of a next generation series of satellites that will replace the current GOES-I/M and GOES-N/O/P series. Scheduled for launch in 2015, its Advanced Baseline Imager (ABI) radiometer will provide marked improvements over the current GOES imager in terms of its spectral, radiometric, spatial, and temporal resolution. A description of GOES-R can be found online at http://www.goes-r.gov/. In addition, GOES-R will carry the first Geostationary Lightning Mapper (GLM) to detect all lightning continuously day and night over the western hemisphere. The National Oceanic and Atmospheric Administration (NOAA) conceived the GOES-R Proving Ground as a means to providing day-1 readiness to this new satellite era that will allow operational forecasters to achieve the maximum utility from the new data and products that will be provided.

The concept of the GOES-R Proving Ground was developed in part because of lessons learned from the success of a similar effort in the development of the National Weather Service (NWS) NEXRAD Program. An important goal of the GOES-R Proving Ground is to establish an early and sustained two-way dialog between forecasters who will use the GOES-R products and those who are developing new products and applications. It is important to establish this dialog early to allow time for development of useful products for operations, based on GOES-R simulated and proxy datasets.

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Proving Ground efforts are spread across NOAA/NESDIS/GPO, NOAA/NWS, NOAA/OSD, NOAA/OSDPD, NOAA/NESDIS/STAR, and three NOAA Cooperative Institutes: CIMSS with the University of Wisconsin, CIRA with the Colorado State University, and the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) with the University of Oklahoma. Complementary Proving Ground activities are also conducted at the NASA Short-term Prediction Research and Transition (SPoRT) Program, in Huntsville, Alabama. The Proving Ground plans to provide simulated GOES-R products for operational testing, using a variety of means including combining current GOES channels with other satellite channels, making use of analogous MODIS satellite imagery, and using synthetic, model-generated imagery to simulate GOES-R products.

The purpose of this paper is to provide an overview of the GOES-R Proving Ground activities that are currently ongoing with the operational forecasting community, as well as those planned for the future. A brief look at some of the specific activities being undertaken by CIMSS and SPoRT are presented. More detail on the CIMSS activities can be found in the paper by Gerth et al. (2009, this conference). The activities of the CIRA group and their initial interactions with two local NWS Weather Forecast Offices (WFOs) are presented. We will also discuss the plans of the GOES-R Proving Ground to organize these activities into a cohesive program that will best provide the type of feedback needed to yield the most effective set of operational products and training when GOES-R is launched.

2. WHAT IS THE GOES-R PROVING GROUND?

The concept of the GOES-R Proving Ground project engages the NWS forecast and warning community in pre-operational demonstrations of selected capabilities anticipated from the next generation of NOAA geostationary earth observing systems.

The Proving Ground project objective is to bridge the gap between research to operations by:

- Utilizing current systems (satellite, terrestrial, or model/synthetic) to emulate various aspects of future GOES-R capabilities
- Infusing GOES-R products and techniques into the NWS operational environment, with emphasis on the Advanced Weather Information Processing System (AWIPS) and transitioning from AWIPS-I ("AWIPS Legacy") to AWIPS-II ("AWIPS Migration").
- Engaging in a two-way dialogue to provide feedback to the developers from the users.

A key element of this activity is a sustained interaction between the developers and end users for the purposes of training, product evaluation, and solicitation of user feedback. The Proving Ground relies on close coordination with the GOES-R Algorithm Working Group (AWG) and Risk Reduction programs as sources of demonstration products, and will enhance the operational transition pathway for those programs.

The intended outcomes of this project are Day-1 readiness and maximum utilization for both developers and users of the GOES-R observing system, and an effective transition of GOES-R research products to the operational weather community. Details on the GOES-R Proving Ground can be found online at http://cimss.ssec.wisc.edu/goes_r/proving-ground.html.

As noted earlier, three main groups are involved in the GOES-R Proving Ground. The interactions with the NWS as of late May 2009 are summarized in Fig. 1. Just the principal interactions are shown in Fig. 1. As will be discussed later, there are a number of additional WFOs that currently receive GOES-R Proving Ground products, particularly from the CIMSS and SPoRT groups.

The GOES-R Proving Ground will facilitate the testing and validation of new ideas, technologies

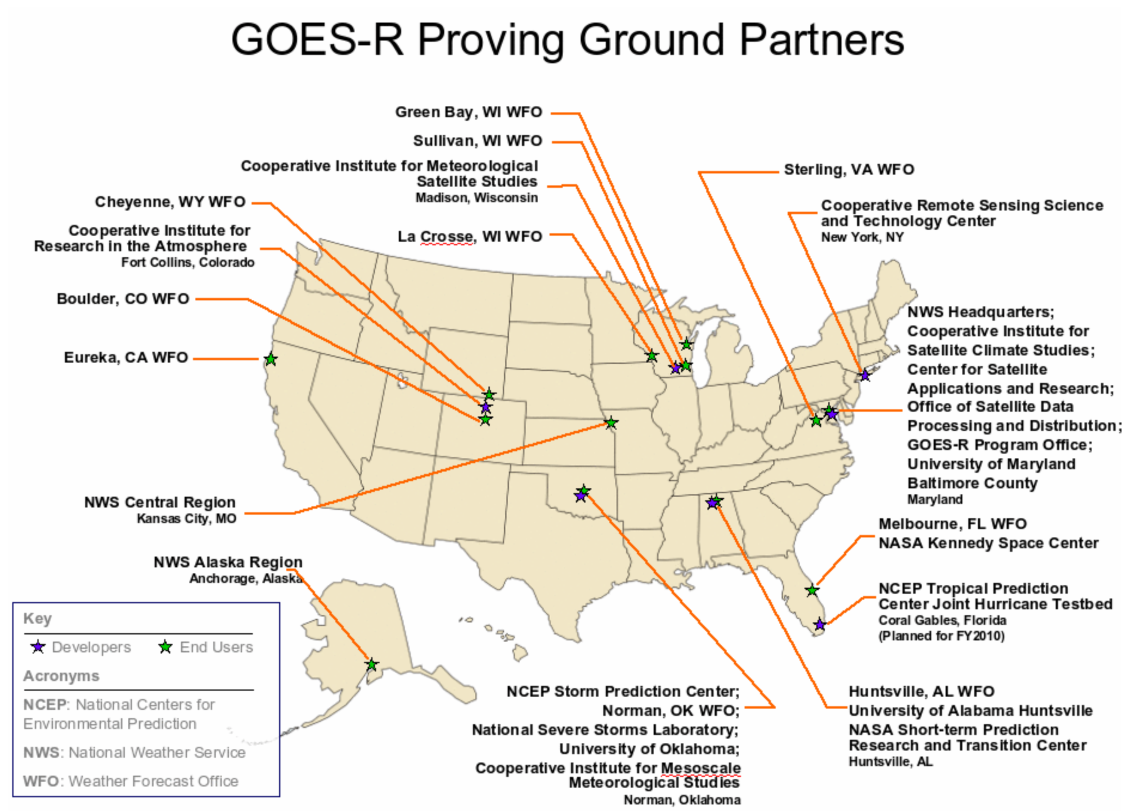

Fig. 1. Overview of the current (May 2009) interactions between the principal GOES-R product developers and main end users. As noted, this figure shows the main interactions taking place; other WFOs also receive GOES-R Proving Ground products, as discussed in the text.

and products before they become integrated into operational use. This proving ground is an essential component of GOES-R risk reduction, which will help to ensure that users are ready for the new types of satellite imagery and products that will be available in the upcoming GOES-R era.

The potential for a number of new products and types of imagery in the GOES-R era is possible in part because of the increased number of bands that will be available in the Advanced Baseline Imager (ABI) on GOES-R. As seen in Table 1, 16 bands will be available, compared to five usable bands in the current operational GOES. In addition to the greater number of channels, there will be an increase in both time and spatial resolution of products over the current GOES. IR image resolution will be 2 km, compared to the current 4 km with GOES, and for visible imagery will be 0.5 to 1 km (depending on the band), compared to the current 1 km. The time resolution will increase to a full-disk image every 5 min, versus 15 min today, with rapid scan at 1-min resolution.

Table 1: ABI bands on GOES-R.

Table 1. Summary of the wavelengths, resolution, and sample use and heritage instrument(s) of the ABI bands. The minimum and maximum wavelength range represent the full width at half maximum (FWHM or 50%) points. [The Instantaneous Geometric Field Of View (IGFOV).]

Future GOES imager (ABI) band	Wavelength range (μm)	Central wavelength (μm)	Nominal subsatellite IGFOV (km)	Sample use	Heritage instrument(s)
1	0.45–0.49	0.47	1	Daytime aerosol over land, coastal water mapping	MODIS
2	0.59–0.69	0.64	0.5	Daytime clouds fog, insolation, winds	Current GOES imager/ sounder
3	0.846–0.885	0.865	1	Daytime vegetation/burn scar and aerosol over water, winds	VIIRS, spectrally modified AVHRR
4	1.371–1.386	1.378	2	Daytime cirrus cloud	VIIRS, MODIS
5	1.58–1.64	1.61	1	Daytime cloud-top phase and particle size, snow	VIIRS, spectrally modified AVHRR
6	2.225–2.275	2.25	2	Daytime land/cloud properties, particle size, vegetation, snow	VIIRS, similar to MODIS
7	3.80–4.00	3.90	2	Surface and cloud, fog at night, fire, winds	Current GOES imager
8	5.77–6.6	6.19	2	High-level atmospheric water vapor, winds, rainfall	Current GOES imager
9	6.75–7.15	6.95	2	Midlevel atmospheric water vapor, winds, rainfall	Current GOES sounder
10	7.24–7.44	7.34	2	Lower-level water vapor, winds, and SO_2	Spectrally modified current GOES sounder
11	8.3–8.7	8.5	2	Total water for stability, cloud phase, dust, SO_2 rainfall	MAS
12	9.42–9.8	9.61	2	Total ozone, turbulence, and winds	Spectrally modified current sounder
13	10.1–10.6	10.35	2	Surface and cloud	MAS
14	10.8–11.6	11.2	2	Imagery, SST, clouds, rainfall	Current GOES sounder
15	11.8–12.8	12.3	2	Total water, ash, and SST	Current GOES sounder
16	13.0–13.6	13.3	2	Air temperature, cloud heights and amounts	Current GOES sounder/ *GOES-12+* imager

There are a number of ways in which test products representative of GOES-R era products can be demonstrated to forecasters now in order to get feedback that will greatly help to improve the operational utility of satellite products available to forecasters once GOES-R is launched. One method involves using the Terra and Aqua polar orbiting satellites that have 36 bands from the Moderate Resolution Imaging Spectroradiometer (MODIS), as well as higher spatial resolution than the current GOES. Test products can be created by either sending some of the MODIS satellite images directly, making new products from the MODIS channels, or combining some of the imagery with current GOES imagery, as will be demonstrated later for a product developed by the CIRA group. A major downside to using the MODIS imagery directly is its poor time resolution, generally yielding only one or two usable images per day at a given location, since the Aqua and Terra are polar orbiting satellites.

Using "synthetic" imagery is one way to overcome the time resolution issue and still demonstrate some of the new bands. This method employed by CIMSS uses an advanced numerical model to generate output resembling the images that could be displayed from the GOES-R satellite.

In addition to the improved ABI imager, another GOES-R instrument, the Geostationary Lightning Mapper (GLM), will provide continuous coverage of total lightning flash rates over land and water. The SPoRT group has been heavily involved in this aspect of the GOES-R development, as will be discussed in the next section.

3. SPECIFIC GOES-R PROVING GROUND ACTIVITIES

In this section we will exemplify the scope of interaction activities underway within the three main groups.

3.1 *CIMSS activities.*

CIMSS of course has had a long history of satellite research and training activities, and has established an extensive network of interactions for potential GOES-R products. A separate presentation of their GOES-R Proving Ground activities is given at this conference (Gerth et al 2009), so we will provide only a brief overview here.

CIMSS interacts most directly with the three WFOs in Wisconsin, including the nearby WFO at Sullivan, and the other two WFOs at LaCrosse and Green Bay. In addition to MODIS imagery that replicates potential GOES-R imagery, these WFOs also receive synthetic imagery. Site visits are undertaken to improve interaction with forecasters, as well as on-site training on new products. Products began to be distributed to these WFOs in 2006 through the Local Data Manager (LDM), making them available on the forecaster's AWIPS workstations. A description of the CIMSS interactions and products can be found in the presentation by Bachmeier and Gerth (2009).

Besides the Wisconsin WFOs, CIMSS has made available various MODIS imagery via the LDM for display on AWIPS to a number of WFOs in the Central and Western Region of the NWS. A total of 26 WFOs, in addition to the three in Wisconsin, currently receive MODIS imagery in AWIPS. CIMSS maintains an active "satellite blog" at http://cimss.ssec.wisc.edu/goes/blog/cimss-satellite-proving-ground that gives monthly updates on interesting cases throughout the U.S.

3.2 *SPoRT activites.*

SPoRT is a NASA project established in 2001 to transition unique observations and research capabilities to the operational weather community to improve short-term forecasts on a regional scale. The SPoRT facility is collocated with NASA Huntsville and the WFO at Huntsville, putting it in an excellent position for a direct interaction with forecasters at the WFO. The SPoRT website is at http://weather.msfc.nasa.gov/sport/

For the GOES-R Proving Ground activities, one of the focuses of SPoRT has been to investigate the use of total lightning data in operations. Total lightning observations are available to SPoRT through the North Alabama Lightning Mapping Array (NALMA, Goodman et al, 2005), which was established as ground verification in 2001 for the Lightning Imaging Sensor aboard the Tropical Rainfall Measuring Mission (TRMM) satellite. By using this array, SPoRT can demonstrate the lightning data that will be available during the GOES-R era. The NALMA provides full lightning coverage to the forecast areas for the Huntsville and Nashville WFOs, and partial coverage for the WFOs at Birmingham and Knoxville. The data is transmitted to the AWIPS at these four WFOs through their Local Data Acquisition and Dissemination (LDAD) system. A number of different types of lightning displays are possible with the data. Forecasters typically combine the lightning data with conventional radar data when interrogating storms for potential severe weather, as shown in the AWIPS display in Fig. 2. Examples of the NWS operational use of this data can be found in Nadler et al (2009).

SPoRT is involved in a number of other projects with the Huntsville WFO. SPoRT has an ongoing Memorandum of Understanding (MOU) with the NWS Southern Region Headquarters for distribution of products. In addition, they also transmit MODIS imagery to a number of partner WFOs, as well as new products generated from this imagery. A total of 12 WFOs currently receive such products from SPoRT, most, but not all, within the Southern Region of the NWS.

SPoRT has progressed in their NWS interactions by establishing a means of obtaining feedback from forecasters as to the utility of the

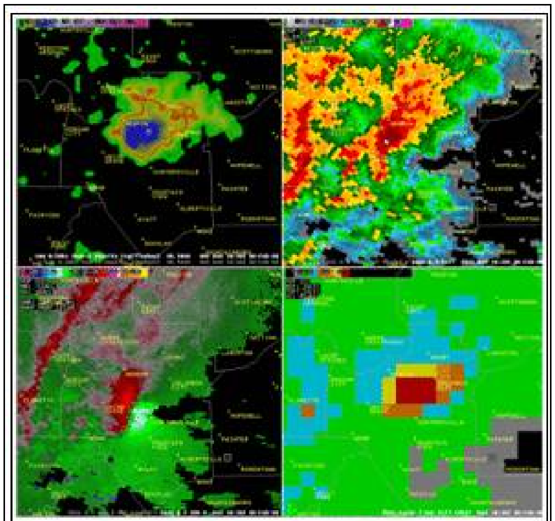

Fig. 2. Example of an AWIPS display combining a cumulative source lightning density map display (upper left) with radar displays of 0.5 degree base reflectivity (upper right), mid level layer reflectivity maximum (lower right), and 0.5 storm relative motion (lower left). This example is from 6 Feb 2008, at the time when an EF-4 tornado was within the Huntsville county warning area.

test products. This is a very important aspect of the GOES-R Proving Ground activities, and we are still determining the best manner to get feedback in general, but it will likely involve some of the methods currently used by SPoRT. They have compiled online evaluations specific to the different products, with the forecaster answering various directed questions by checking off boxes. This yields a more quantitative feedback, and provides space for more subjective, free-form commentary. Nadler et al (2009) indicates that the forms used by SPoRT were well received by the forecasters at the WFOs that SPoRT has surveyed, and uses the input to summarize forecaster reaction to the total lightning data. An example of one of the online forms for the total lightning product can be found at http://weather.msfc.nasa.gov/sport/survey/LMA_survey.html.

3.3 *CIRA activities.*

CIRA has a long history of satellite research and operational interaction with the NWS, but is relatively new to the GOES-R Proving Ground project. About a year ago it was decided that a good path for CIRA to follow would be to establish close interaction with the two nearest WFOs, in Cheyenne, Wyoming, and Boulder, Colorado. Initial discussions with the Meteorologist-In-Charge (MIC), Science Operations Officer (SOO), Information Technology Officer (ITO), and a few of the forecasters occurred in the late spring and early summer of 2008 with visits by CIRA personnel to the two WFOs. Besides giving an overview of the GOES-R Proving Ground and establishing mutual interest in proceeding, potential products were discussed. Input from the WFO staff helped determine an initial list of Proving Ground products to test.

Presentations were then made in October 2008 at the Winter Workshop at each WFO. This proved to be a very effective way to reach the entire staff, as each WFO held two workshops so that all the forecasters could attend. The talk at the workshops were planned around the first CIRA GOES-R Proving Ground products being available on the WFO AWIPS workstations soon after. However, it turned out that things did not move as quickly as anticipated. This was due, in part, because the decision was made to distribute GOES-R Proving Ground products through official channels at NWS Central Region and then distributing to the two WFOs through their LDAD system. This required reaching a formal agreement (MOU) with NWS Central Region. While this has taken extra time, now the mechanism is in place for distribution of GOES-R Proving Ground products to other WFOs that may be interested in receiving them.

Once the MOU was in place, site visits were made in the spring of 2009 to the Cheyenne and Boulder WFOs to make the changes (menu and otherwise) required to ingest the first product into AWIPS. The initial installation was made on a test AWIPS to insure that there was no degradation of AWIPS performance, or any other issues, and now the transition is being made to the operational AWIPS workstations.

The first product that is being tested at the Boulder and Cheyenne WFOs is called GeoColor Imagery. The product is a nice representation of the capabilities that will be available in the GOES-R era, and was initially developed several years ago for use by forecasters at the Naval Research Laboratory in Monterey, California. The GOES-R Proving Ground partners have agreed that each product developed for testing should have a standard product description that includes how the product is made, who developed it, and why it is a GOES-R Proving Ground product. While achieving such a product description for all the products is still under development, an example of the product description for the GeoColor Imagery can be found at http://rammb.cira.colostate.edu/goes_r_proving_ground/gci.asp. Next, we will use this product description to briefly discuss the GeoColor Image product.

An example of the GeoColor imagery is shown in Fig. 3. The image combines IR and visible imagery to make a single image that smoothly transitions from day to night, uses true color and city lights as background, and makes use of the difference between GOES channels 2 and 4 (3.9 and 11 microns) to distinguish low clouds and fog at night. In the example in Fig. 3 the nighttime

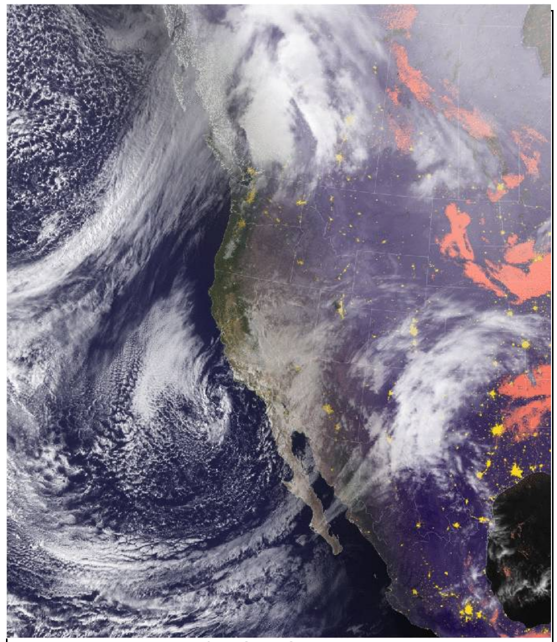

Fig. 3. Example of a GeoColor image.

image is on the right, while the daytime image is on the left. The coral color on the right side indicates the areas of low clouds and/or fog. The daytime image resembles the current GOES visible image except that a natural color background is used.

The manner is which the GeoColor product can be created now is summarized in Fig. 4. Blending techniques in the vertical and horizontal are used to combine the images. The current GOES visible and IR images provide the basic satellite imagery for the product, with a horizontal blending at the day/night interface done by employing a solar zenith weighting factor, as shown in Fig. 4. The true color image used for the daytime comes from the NASA Blue Marble dataset, while the nighttime lights comes from an NGDC dataset. Both images are static images in the current product, but in the GOES-R era they will be frequently updated using imagery from the new polar orbiting NPOESS satellites. Vertical blending is used when compiling

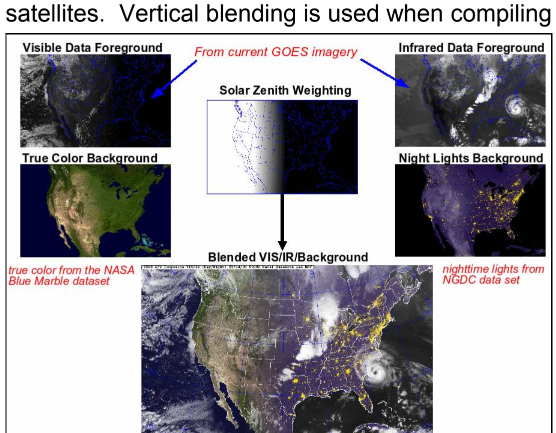

Fig. 4. Illustration of the five primary components contributing to the blended GeoColor imagery.

the imagery, with the GOES images scaled to define a transparency factor. This allows the background to penetrate through the cloud layer, depending on its thickness and properties.

An additional technique is employed to distinguish low clouds and fog at night from higher clouds and the background image. The difference between GOES channels 4 and 2 is used. The 11 – 3.9 micron imagery is a GOES product currently available on AWIPS. In this application the difference product is used to isolate the low cloud/fog layer and this is introduced as a separate layer in the vertical blending of the GeoColor imagery. In this way a special color table is applied to the low cloud/fog layer to make it distinct from the other clouds.

An example of the GeoColor image zoomed over Colorado and taken from the Boulder WFO AWIPS during an early morning fog and low cloud case in May 2009 is shown in Fig. 5. The large area of low clouds and fog extending from southeastern Colorado into Kansas and Nebraska is shown by the coral-colored area, distinct from the higher clouds that are white. The METAR observations also indicate that fog and low cloudiness extended back over the Denver area (shown as the concentration of city lights in the center of the image), but are not thick enough to obscure the city lights in this area. The transparency of the low cloud/fog layer to the background image is a scaling factor that can be adjusted. Initial forecaster reaction to this imagery during discussion at the Boulder WFO Spring Workshop was to question the value of the city lights background, wondering if it would obscure useful information and/or overlays. While we of course hope to see more forecaster feedback about the imagery after they have had the opportunity to work with it, this is the type of input that could go back to the developers and result in, say, a change to the transparency factor for the

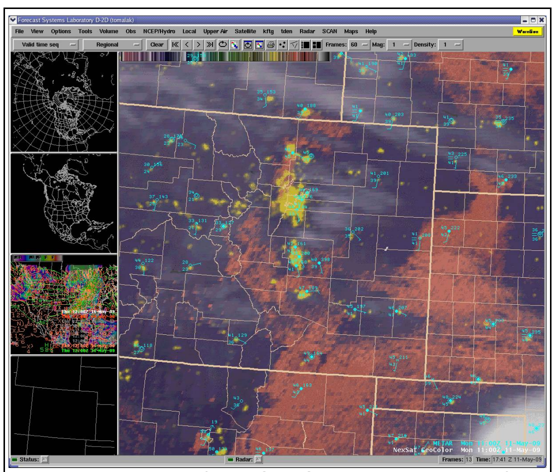

Fig. 5. Example of the GeoColor image taken from the Boulder WFO AWIPS, for 1100 UTC on 11 May 2009. METAR observations are overlaid.

GeoColor imagery that would make it more effective.

Additional products are in the queue for the Boulder and Cheyenne WFOs, including a separate low-cloud/fog product and a “Dust Detection Product” (see the current list of products at http://rammb.cira.colostate.edu/goes_r_proving_ground/). Interest in the dust product peaked during the Spring of 2009 following a particularly intense blowing dust episode in early April, that was followed by a snowstorm that left a layer of “brown snow”, which has since become a factor in the melting of the snowpack. The WFOs at Grand Junction, in western Colorado, and Salt Lake City (Utah) have expressed interest in receiving the dust detection GOES-R Proving Ground product, and becoming part of the Proving Ground effort. It is likely that other WFOs will become interested in participating in the future as well. Interaction is also planned with WFOs in California, in part because of the association with the Naval Research Laboratory by one of the current CIRA staff (S. Miller).

At this time we are still determining the best way to get feedback from the forecasters at the Boulder and Cheyenne WFOs. At Boulder, for now we are making use of the electronic shift log, with a separate entry made for GOES-R Proving Ground products. The shift log is frequently used by most forecasters, and should allow for subjective free-form feedback. However, the larger issue remains as to the best way for the GOES-R Proving Ground to get forecaster feedback, as discussed in the next section.

4. FUTURE DIRECTIONS

Clearly, a significant number of WFO interactions have been established by the CIMSS, SPoRT and CIRA groups with the GOES-R Proving Ground. We have learned that the most effective interaction comes from relatively frequent personal interaction with the forecast staff (as reiterated in the assessment by Nadler et al (2009) in relation to SPoRT activities). This occurs for the three centers with their nearby WFOs; for CIMSS with the Sullivan, Wisconsin WFO, for SPoRT with the Huntsville WFO, and for CIRA with the Boulder WFO. Naturally, greater distances make it more difficult to sustain the same level of direct interaction with the other WFO partners. So one challenge for the GOES-R Proving Ground will be to determine the best ways to interact with forecasters at the more distant sites. It is difficult to reach all forecasters at any one time given the nature of shift work. One way to effectively reach the forecasters is through their internal workshops. In the case of Boulder and Cheyenne, workshops are held in October and April, generally each year, to update the staff on operational topics and hear occasional special presentations of interest. The workshop is repeated, usually within a week, so as to reach most if not all of the staff.

The GOES-R Proving Ground also plans to interact with national centers, such as the National Hurricane Center and the Aviation Weather Center. Site visits over periods of time may be a way to enhance the interaction with these groups. Already interaction has begun with the Storm Prediction Center (SPC), using their Spring Program as the impetus to get things started. A separate GOES-R Proving Ground point of contact has been assigned to the SPC to further enable the interactions there, and in May and June 2009 emphasis will be placed on evaluating a satellite-derived convective initiation product.

As noted earlier, another challenge for the GOES-R Proving Ground will be to determine the best way to get forecaster feedback. Similar to working towards consistent product descriptions for each GOES-R Proving Ground product, we hope to have a consistent method of obtaining feedback. The use of online forms, as is currently done by the SPoRT group, may become the best means to attain such feedback. Similar online forms have been used in the past for special field programs, such at the Development Testbed Center (DTC) Winter Weather Forecast Exercise (DWFE) in 2005 (Koch et al, 2005). The forms must be carefully designed for brevity yet should still maintain the ability to capture quantitative as well as free-form qualitative feedback from the forecasters.

The GOES-R Proving Ground efforts will continue to evolve over the coming months. Changes will be apparent on the main web page (at http://cimss.ssec.wisc.edu/goes_r/proving-ground.html) as we strive towards more consistency in how the test products are presented and organized. We hope that operational forecaster interest will continue to grow, with the end result being a better utilization of the potential products that will be available in the GOES-R era.

5. ACKNOWLEDGMENTS

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