Hazardous Weather Testbed – Final Evaluation

Project Title: 2011 Fire Weather Experiment

Organization: NOAA's Hazardous Weather Testbed (HWT)

Evaluator(s): National Weather Service (NWS) Forecasters, Storm Prediction Center (SPC), National Severe Storms Laboratory (NSSL)

Duration of Evaluation: 22 August 2011 – 2 September 2011

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Overview:

In cooperation with the SPC and NSSL, the GOES-R Proving Ground organized a short Fire Weather Experiment from August 22 through September 2, 2011. This year's experiment was intended as a starting point for more in-depth experiments in the future, which will include inviting outside visiting scientists and forecasters. A mixture of 6 SPC and Norman, OK WFO forecasters, as well as NSSL and SPC scientists participated in generating experimental short-term fire weather outlooks during a 3-hour period within the HWT each day (see Fig. 1). Participants were asked to provide a 24-hour probabilistic forecast of burnable fuel and dry lightning threat (see Fig. 11). Forecast discussions and associated experimental product feedback were captured via online survey during the forecast period (see Fig. 2).

The experiment included testing the SPC and NSSL Hazardous Weather Testbed (HWT) facilities and developing an effective demonstration technique, using only a few experimental GOES-R and NWP products towards a fire weather focus. Satellite-derived Normalized Difference Vegetation Index (NDVI) and NDVI change composites, in addition to GOES observed surface dryness and associated dryness anomalies were demonstrated in combination with operationally available products to determine dry fuel availability (see Figs. 6 and 9). Experimental NWP output such as simulated total lightning threat from the NSSL-WRF (see Fig. 10) and simulated GOES-R ABI imagery (see Fig. 12) were also demonstrated to assist in the forecast of dry lightning. The GOES-R proxy fire / hotspot detection and characterization product was used primarily during verification exercises (see Fig. 3).

Figure 1 – SPC and NWS Norman WFO forecasters, as well as NSSL and SPC scientists participating in the 2011 Fire Weather Experiment within the HWT.

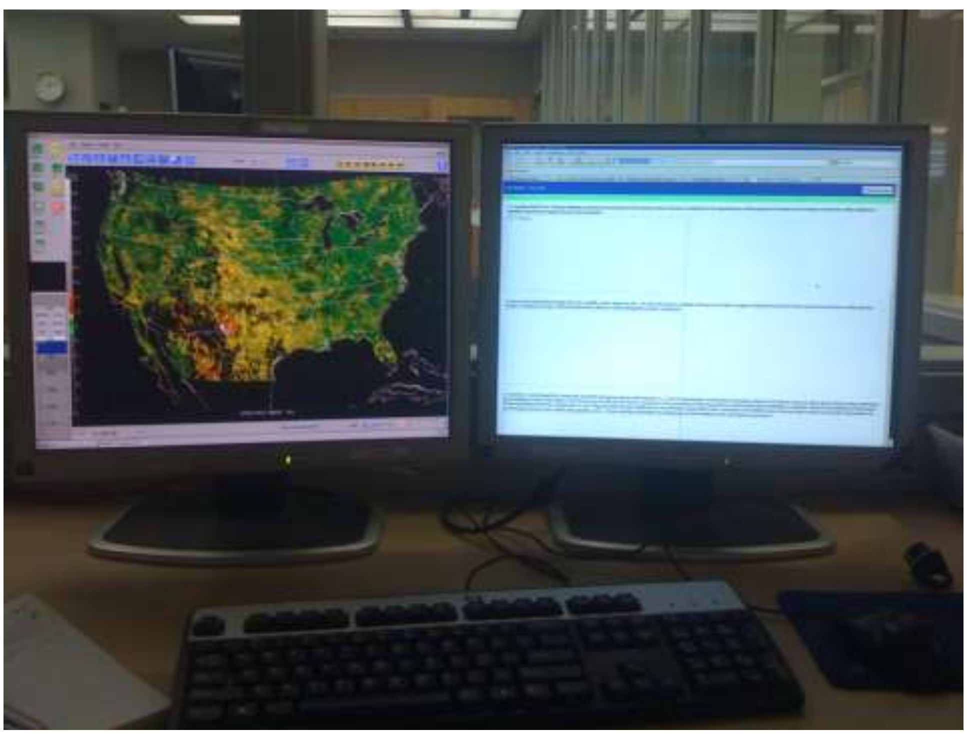

Figure 2 – HWT N-AWIPS workstation with experimental GOES surface dryness (left panel) and online forecast discussion / feedback form (right panel) used during the 2011 Fire Weather Experiment.

Products Evaluated:

1. **Fire / Hotspot Detection and Characterization** – University of Wisconsin – Cooperative Institute for Meteorological Satellite Studies (UW-CIMSS)

   The Fire Radiative Power (FRP) product provided within the 2011 Fire Weather Experiment assigns intensity values for fire pixels based on the UW-CIMSS GOES WildFire Automated Biomass Burning Algorithm (WF_ABBA). The product arrived within the HWT N-AWIPS workstations via UW-CIMSS ADDE server for every 15-minute GOES scan. For certain fire categories (saturated, cloudy, and low possibility) assigned FRP values are used in place of the WF-ABBA fire/hotspot detections. FRP values reveal how intense a fire is burning and estimates the radiant heat of the detected fires as a means to characterize fuel consumption. Processed, High, and Medium Possibility fires are assigned an estimated FRP value by the WF_ABBA. Saturated fires are assigned FRP values of 2000 MW. Cloudy and Low Possibility fires are assigned an FRP of 0 MW but still show up as fire pixels.

   Within the 2011 Fire Weather Experiment, the FRP product was mainly used for verification of previous day's forecasts since the experiment mainly focused on forecasting the threat for fire weather based on dry thunder and burnable fuels over the next 24 hours. On occasion we would examine significant individual fires post event to evaluate the ability of the FRP product to properly characterize fire intensity (see Fig. 3). One of the early observations from the participants indicated that the color table provided for the FRP product was not properly displaying hotspot intensity changes. Detected hotspots would either be labeled as the weakest intensity or completely saturated, with little visible variability in between. The original color table, that was a smooth spectrum ranging from yellow to red, was difficult to see intensity changes (see Fig. 3). This was eventually changed to include the entire color spectrum, which added shades of blue and green and made the transitions more obvious. While this helped break intensity ratings into a few groups, it was still difficult to see minute changes in intensity, especially because of the relatively small pixel size area covered by the detected hotspots. This change was only intended as a quick fix and should be examined further for future demonstrations.

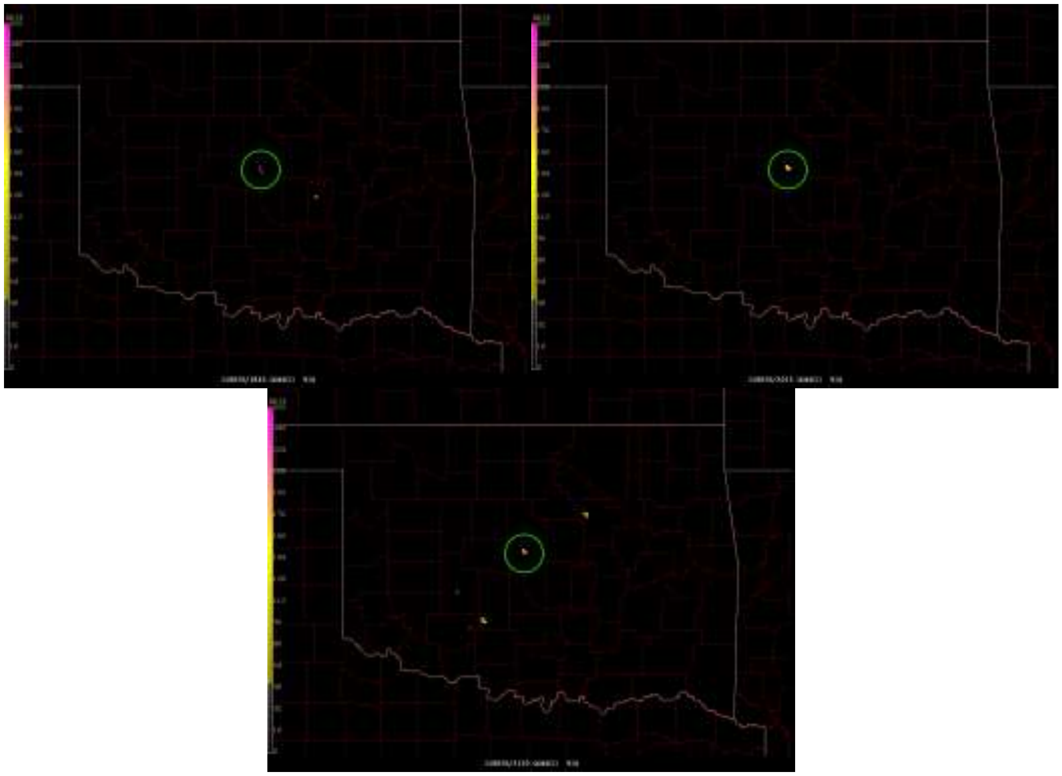

Figure 3 – FRP fire/hotspot characterizations from the 30 August 2011 Oklahoma City, OK fire at 1845 UTC (top left), 2015 UTC (top right) and 2130 UTC (bottom).

While examining individual fires classified by the FRP, participants focused on the continuity of the product in detecting the hotspots throughout scans, as well as intensity transitions that make sense (ie – increasing followed by decreasing intensity). For the majority of the detected hotspots by the WF-ABBA and classified by the FRP, the continuity throughout scans was good and the intensity changes conceptually made sense (see Fig. 3). On occasion participants expressed some frustration with the 'flickering' of the product, or detected hotspots turning on and off. This is most likely a factor of the spatial resolution of the current GOES imager and not of the algorithm itself.

The FRP product continues to flow into the HWT and SPC N-AWIPS workstations.

2. **Normalized Difference Vegetation Index (NDVI) / NDVI Change** – UW-CIMSS and NSSL

NDVI images were provided within the 2011 Fire Weather Experiment (see Fig. 4) and are derived from daytime measured reflectance in the visible (VIS, 0.4-0.7 microns) and the near-IR (NIR, 0.7-1.1 microns) bands of the NOAA AVHRR instrument (currently NOAA-18) for clear sky regions:

$$NDVI = (NIR-VIS)/(NIR+VIS)$$

The values of NDVI range from 0-1, providing a relative index of green vegetation cover (where photosynthesis is taking place). NDVI is based on the principle that plant leaves strongly absorb visible light for photosynthesis (chlorophyll) but reflect in the NIR portion of the spectrum. Low values of NDVI can mean relatively bare ground, or dry vegetation cover.

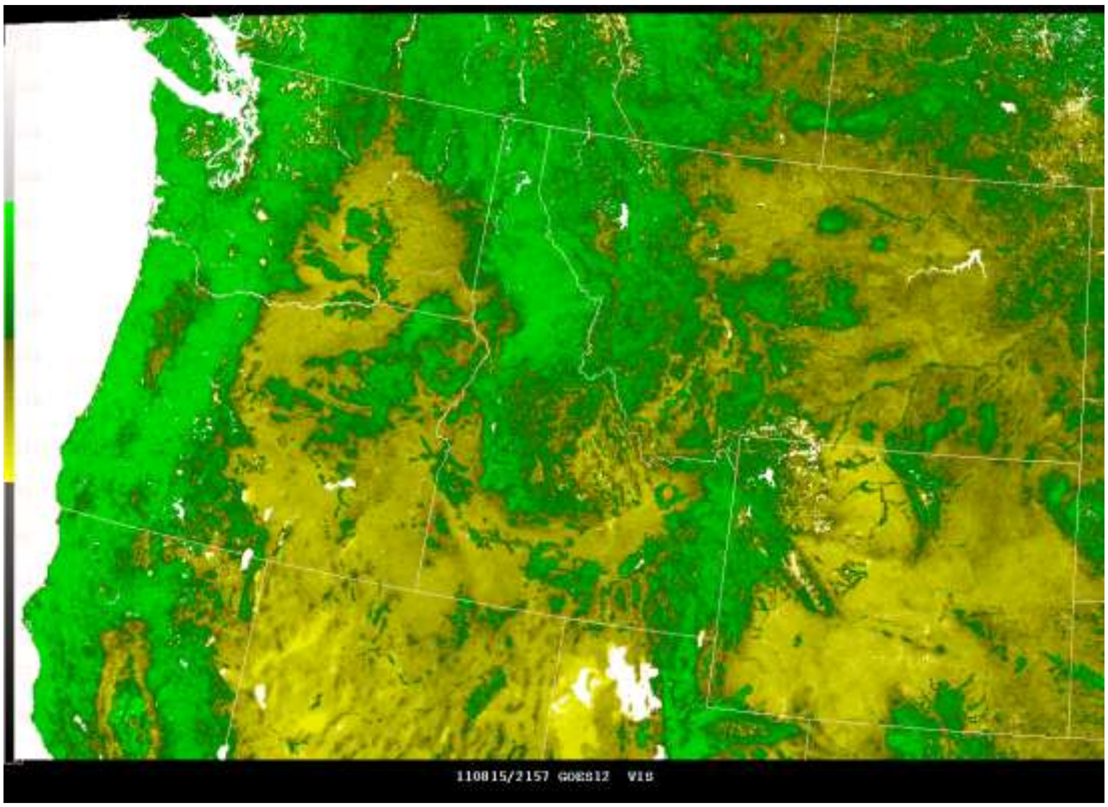

Figure 4 – Example 14-day NDVI composite displayed within HWT N-AWIPS workstations. Areas of green indicate green vegetation, whereas areas of yellow indicate regions of dead, dry or no vegetation. Areas of white indicate regions indicate missing data due to areas of water or cloud cover.

A time change in NDVI (current minus 4 weeks ago) was also provided within the 2011 Fire Weather Experiment to identify regions of increasing and decreasing vegetation coverage (see Fig. 5). Decreasing coverage may be indicative of reduced green biomass (i.e., harvested crops) or increased amounts of dry biomass (uncut, dry grasses; dry leaves below dormant trees, etc.).

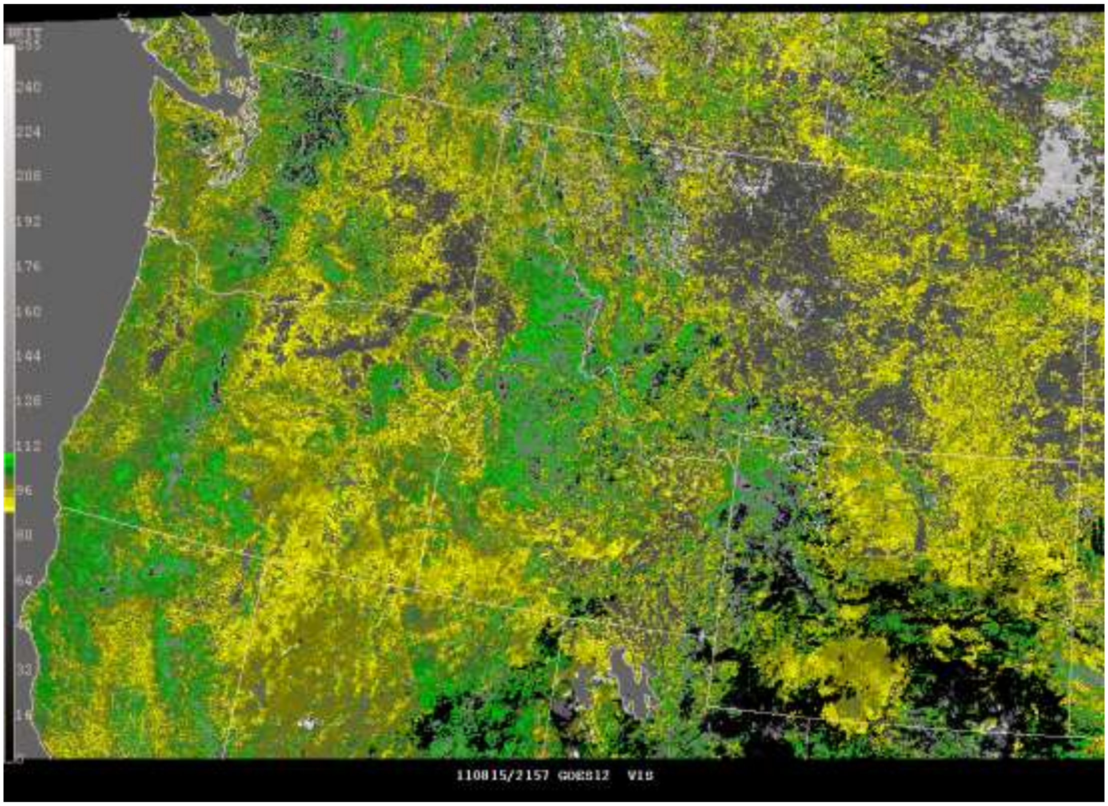

Figure 5 – Example 4-week NDVI change based on the 14-day NDVI composite displayed within HWT N-AWIPS workstations. Areas of green indicate increased green vegetation, whereas areas of yellow indicate regions of decreased green vegetation. Areas of gray indicate little to no change in green vegetation, and areas of black indicate regions indicate missing data.

The NDVI and NDVI change products were provided within the HWT N-AWIPS workstations for comparison with products current available within SPC fire weather operations. In particular, NDVI and NDVI change products were compared directly against the operational land use and Predictive Service Area (PSA) dryness products (see Fig. 6), which SPC fire weather forecasters use to identify areas of increasing dry burnable fuels. Quite often, the NDVI and NDVI change products mirrored features seen in the operational PSA dryness product when it came to identifying regions of increasing burnable fuel threat. In addition, NDVI and NDVI change composites are not motivated by political boundaries, whereas the PSA dryness products are. PSA dryness threats will often be a single value for an entire Predictive Services Area and therefore have very low spatial resolution. Additionally, the PSA dryness product does not extend outside of CONUS, whereas the NDVI and NDVI change can be made available anywhere with satellite coverage. One caveat of the current NDVI and NDVI change products is that they rely on a composite of LEO-based observations, whereas the current operational PSA dryness product does not. Therefore, where we can currently get an update about once every week, the PSA dryness products update daily. Once GOES-R is available however, these updates can be done at a much higher frequency since the necessary channels will (for the first time) be available from a GEO platform.

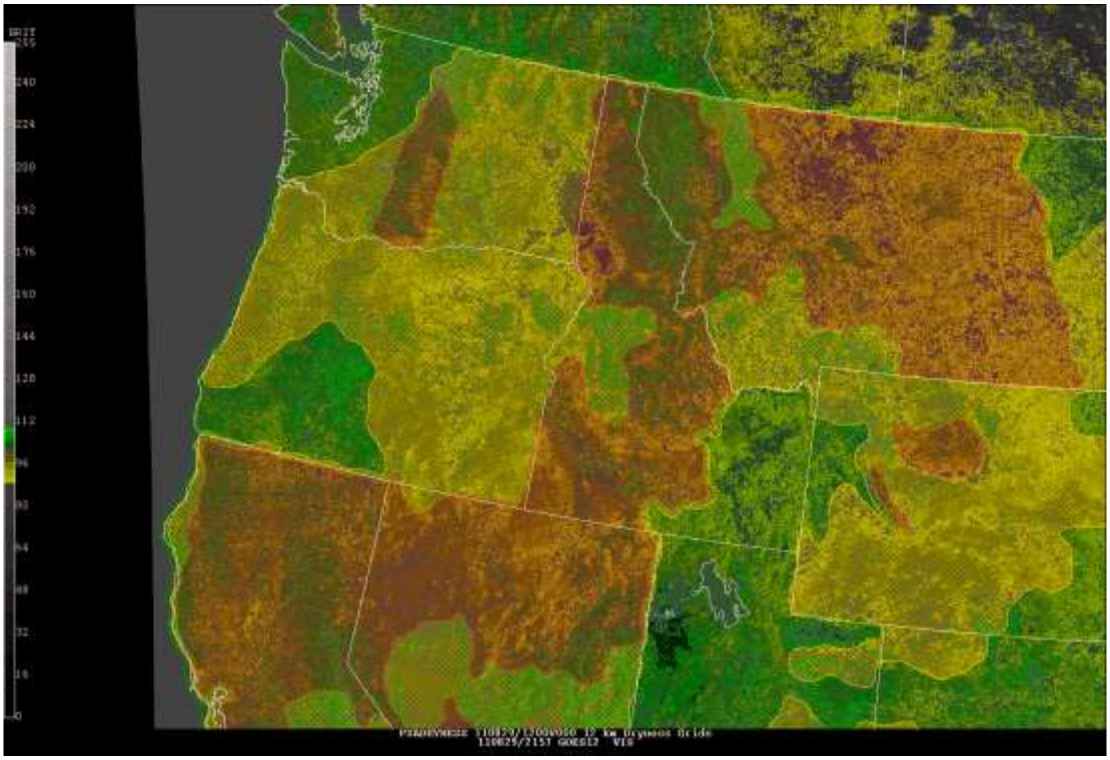

Figure 6 – 4-week NDVI change based on the 14-day NDVI composite with PSA dryness product overlaid within HWT N-AWIPS workstations on 29 April 2011. For the PSA dryness product, areas of green indicate low threat for burnable fuels, whereas yellow and red indicate elevated levels of burnable fuels. Overall, patterns within the NDVI change product mirror the PSA dryness threat levels (ie – decreases in green vegetation and elevated threat level areas).

NDVI composite images can also be directly compared to the land use maps, which are available and widely used within SPC fire weather operations. The operational land use maps do not change, or change very rarely. The NDVI composites therefore have an advantage for operational forecasters to identify changes in land use, or just to simply identify regions of specific land use interest with a dataset that provides current information.

The NDVI and NDVI change composites are currently provided within the HWT and SPC non-operations N-AWIPS workstations. A training session will occur during this year's fall SPC forecaster training to expose the remainder of the SPC fire weather forecasters to the NDVI and NDVI change composites. It is expected that the NDVI and NDVI change composites will be provided within SPC operations in the future.

3. **GOES Surface Dryness / Dryness Anomaly** – UW-CIMSS and NSSL

To augment information on vegetation cover, a dryness index was developed to provide information on the relative amount of moisture in the biomass (vegetation canopy) or the soil surface in the case of bare ground (or partially covered soil). This index is based on daytime heating rates of the land surface as observed from clear-sky GOES imagery IR measurements (see Rabin et al., 2006). Higher (lower) heating rates are associated with drier (wetter) surfaces and higher (lower) ratios of sensible to latent heat flux (Bowen ratio). In areas of moderate to high vegetation cover, the moisture index will be negatively correlated with NDVI. Both NDVI and the moisture index can be used together to help assess dryness. The moisture index may provide independent information on dryness where NDVI is relatively small (sparse vegetation cover).

The horizontal resolution of the GOES dryness index is dictated by that of the GSIP products (1/8th degree). The dryness index is only evaluated where sky conditions are deemed to be clear. Separate estimates are made from GOES-13 (east) and -11 (west) satellites. A bias adjustment is applied to the GOES-11 data. The choice of adjusting the GOES-11 index is arbitrary, but accounts for systematic differences from the GOES-13 heating rates. The dryness index is produced on a daily basis. Owing to limited coverage due to cloud cover (and to facilitate comparison with NDVI), 7- and 14-day averages are computed on a daily basis. These data are available within the HWT N-AWIPS workstations via McIDAS ADDE server (see Fig. 7).

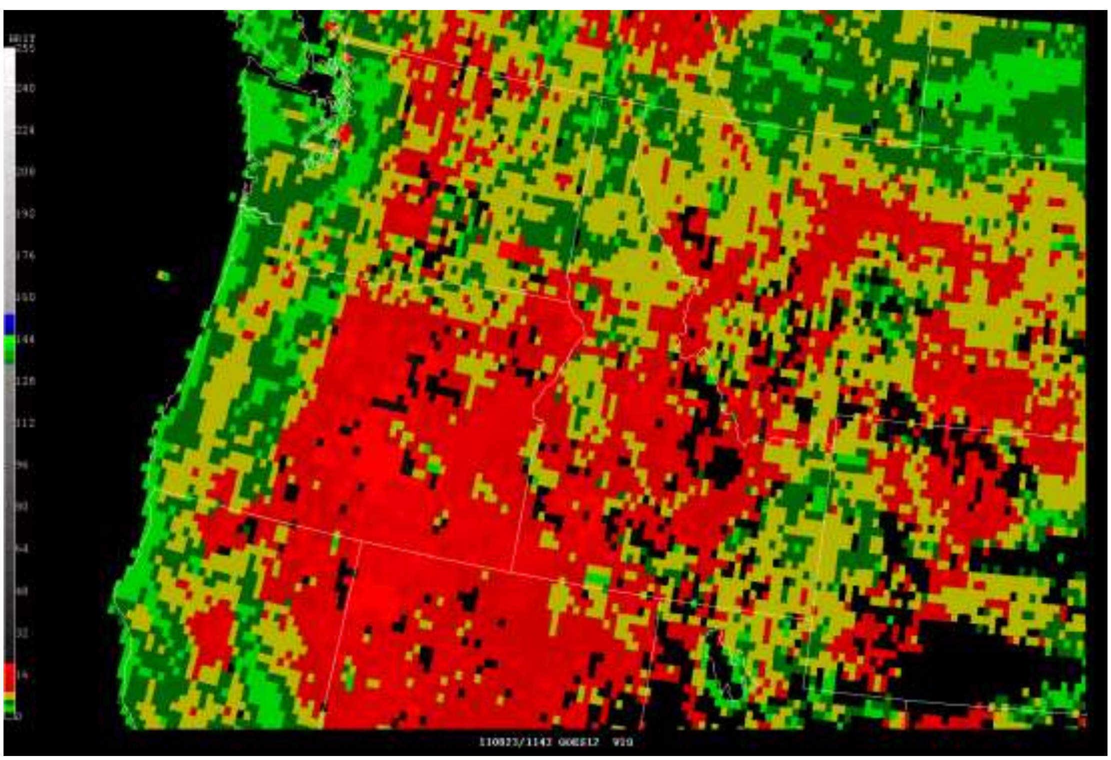

Figure 7 – GOES surface dryness product displayed within HWT N-AWIPS workstations on 23 August 2011. Areas of yellow and red indicate observed

significantly dry surface conditions. Areas of black indicate regions where no observation was made due to cloud cover.

The dryness product was provided from both the GOES-West and GOES-East satellites. Quite often the output from these two sources would have very different results. This is to be expected because of the viewing angle differences. Perhaps for future experiments, the dryness products could be stitched together into a single composite image so that forecasters do not have to choose which product to view based on the region of interest. The GOES-based dryness product also does provide a dryness 'anomaly' field in addition to the raw dryness observations (see Fig. 8). This was shown to be useful in identifying where regions are experiencing anomalous dry surface conditions and may be especially susceptible to dangerous fire weather conditions.

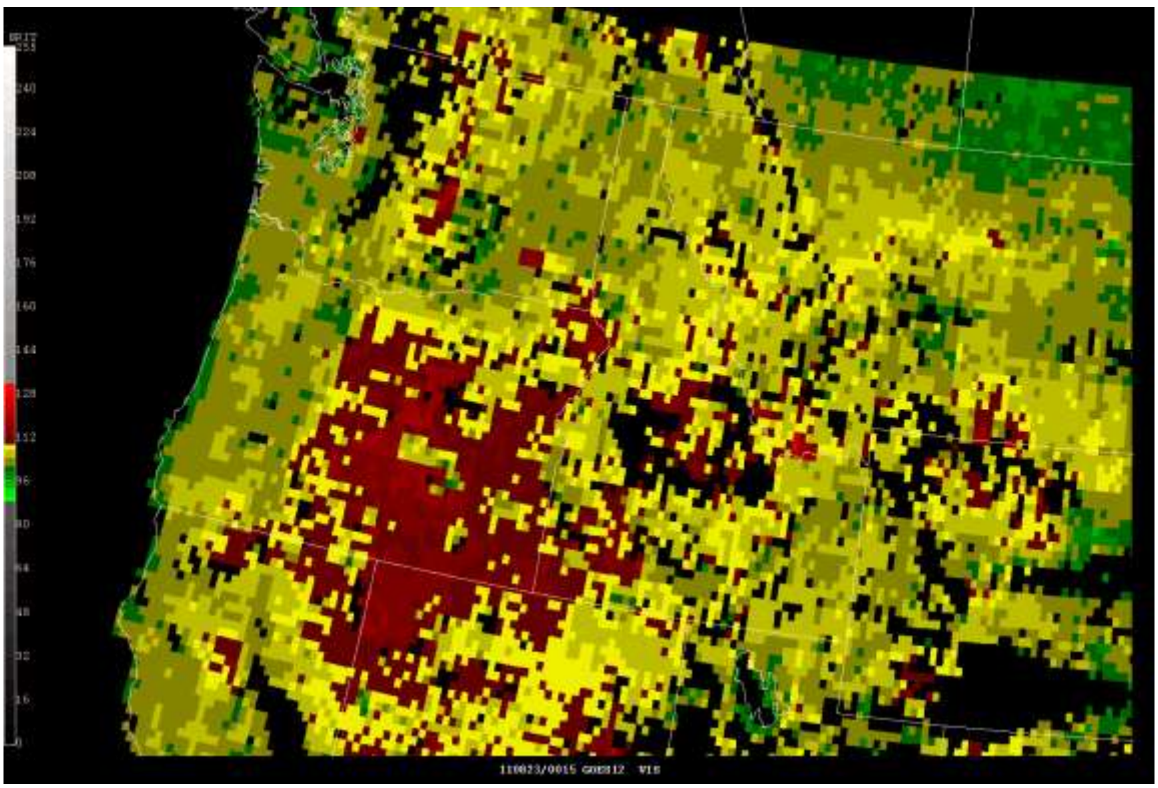

Figure 8 – GOES surface dryness anomaly product displayed within HWT N-AWIPS workstations on 23 August 2011. Areas of yellow and red indicate observed anomalously dry surface conditions. Areas of black indicate regions where no observation was made due to cloud cover.

The GOES dryness products were compared directly to the operational PSA dryness product since they both provide surface dryness observations on a daily basis to determine added benefit from using the GOES-based surface dryness observations (see Fig. 9). Generally, the PSA dryness and GOES observed dryness products have similar features; however, the GOES-based surface dryness observations are not dominated by political boundaries and generally tend to have higher resolution information that the PSA dryness cannot provide. This is similar to the findings stated in Section 2 regarding the NDVI products. Forecasters found that this would be useful as a compliment to what they use operationally; however, they would like the spatial resolution to be improved. In addition, the creation of a dryness 'anomaly' product was very intriguing to them since they do not have this information within their operational systems at this time.

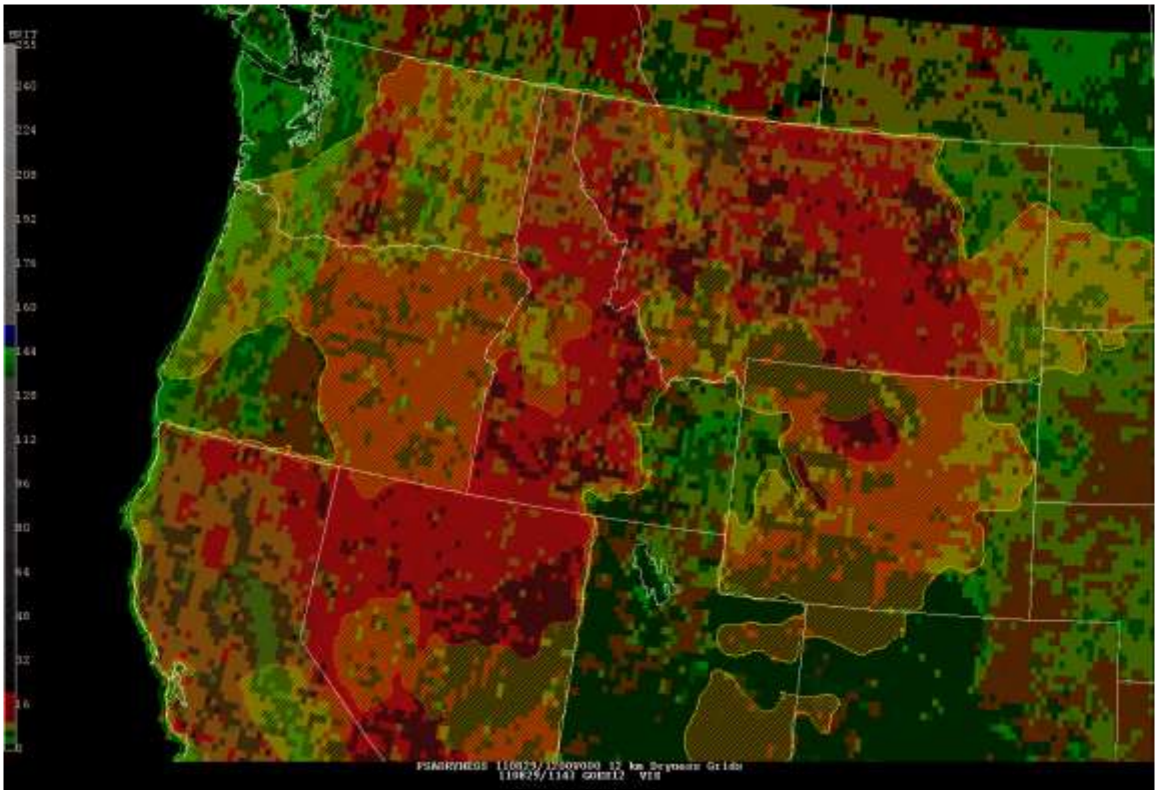

Figure 9 – GOES surface dryness anomaly product overlaid on the operational PSA dryness product within HWT N-AWIPS workstations on 29 August 2011. Areas of yellow and red indicate observed anomalously dry surface conditions.

The GOES-based surface dryness and dryness anomaly products continue to flow into the HWT and SPC non-operational N-AWIPS workstations. We hope to provide a stitched composite and evaluate further during future experiments. A training session will occur during this year's fall SPC forecaster training to expose the remainder of the SPC fire weather forecasters to the GOES surface dryness products.

4. **Simulated Lightning Threat** – NASA Short-term Prediction Research and Transition Center (SPoRT) and University of Alabama in Huntsville (UAH)

Prior to the 2010 HWT Spring Experiment, NASA SPoRT and UAH provided code to NSSL for generating experimental total lightning threats, following the technique described in McCaul et al. (2009, Wea. Forecasting). The lightning threats were included in the 4-km CONUS NSSL daily WRF runs and demonstrated within the 2011 Fire Weather Experiment (see Fig. 10). The lightning threat output was provided for the entire NSSL-WRF forecast time period.

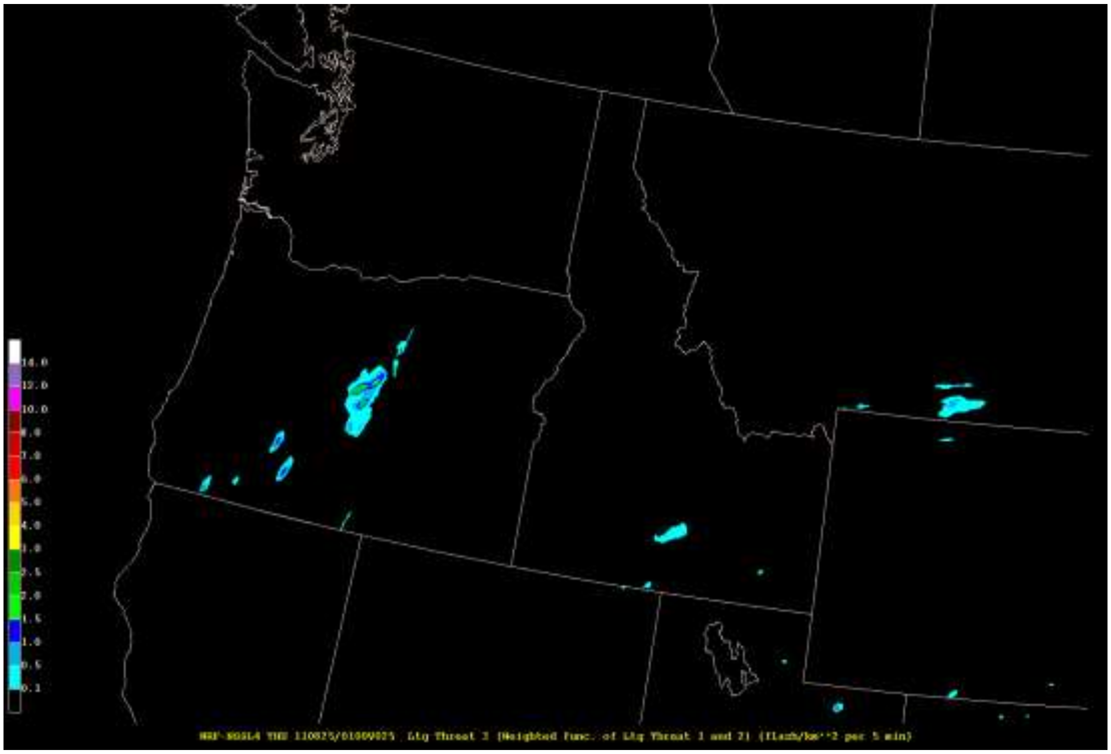

Figure 10 – Example NSSL-WRF simulated lightning threat forecast valid at 0100 UTC on 25 August 2011.

The lightning threat was mainly used as a proxy for dry thunder when combined with NSSL-WRF precipitation or radar reflectivity fields. Post-event validation was completed using observed NLDN lightning activity (see Fig. 11), as well as quality controlled precipitation totals. Because of the difficulties in modeling a complex atmosphere, very accurate forecasts of lightning activity were rare. However, the ability to forecast *total* lightning was useful in 'blurring' the areas of interest to where we could accurately provide a probabilistic forecast of dry thunder. Generally, areas where total lightning was forecast to occur from the NSSL-WRF would correspond to numerous NLDN detected CG flashes. It only takes one CG flash to start a fire that could become dangerous, so the NSSL-WRF total lightning threat was a valuable tool.

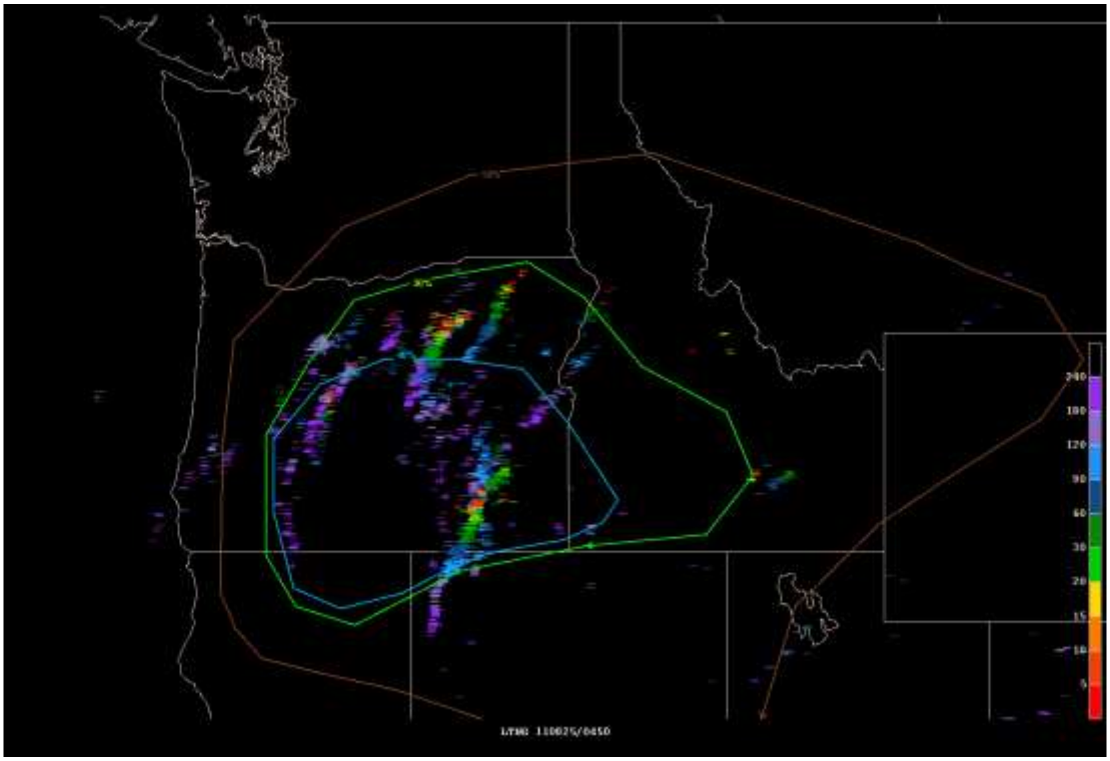

Figure 11 – Example 24-hour probabilistic forecast from 25 August 2011 for dry lightning and associated NDLN lightning flashes within the forecast period.

NSSL continues to generate the total lightning threat forecasts and they are provided within SPC operations and HWT N-AWIPS workstations. It is expected that these data will provide a valuable tool within operations and future experiments.

5. Simulated Satellite Imagery - UW-CIMSS and Cooperative Institute for Research in the Atmosphere (CIRA)

Simulated GOES-R ABI imagery generated from the NSSL-WRF 00Z 4km model run was provided within the HWT N-AWIPS systems by UW-CIMSS and CIRA. UW-CIMSS provided simulated satellite data for all GOES-R ABI IR bands from the 12-36 hour forecast times (see Fig. 12). In addition, CIRA provided simulated satellite band differences for GOES-R unique channels, as well as providing a backup source of imagery for the standard mid-level WV and window IR simulated imagery for the same time periods. Most data from both UW-CIMSS and CIRA arrived locally at the SPC and HWT by 12 UTC, with a second ingest around 15 UTC to retrieve any additional or missing data.

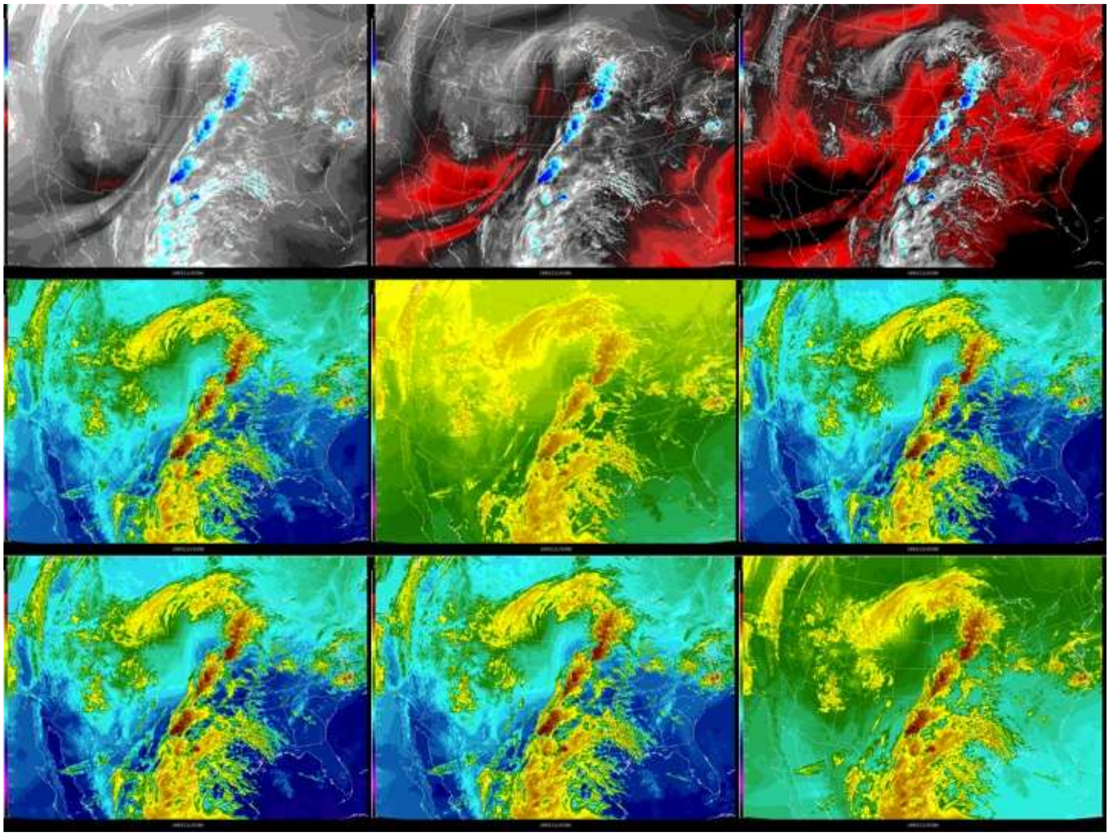

Figure 12 – UW-CIMSS NSSL-WRF simulated GOES-R ABI IR imagery. Al 9 non-solar bands can be produced from the NSSL-WRF.

The simulated satellite imagery was examined within the Fire Weather Experiment during a few daily forecasts, but was not the main focus on most occasions. For these few cases when the imagery was used during a forecast, participants examined the WV imagery to identify regions of significant dry air and associated disturbances that might trigger CI and lead to a dry lightning threat in the future. Much like the Spring Experiment, forecasters again found this data useful as a forecast tool for model diagnostics and a general quick look at what the atmosphere is doing, but for the Fire Weather Experiment this data was not always directly applicable to the dry thunder and burnable fuels forecasts.

The simulated satellite imagery from the NSSL-WRF continues to flow into SPC operations and within the HWT, and is expected to become an integral part of future demonstrations.

Conclusion

Overall, participant feedback was very positive. Interactions with SPC and Norman WFO forecasters, as well as SPC support and NSSL scientists were very fruitful, successful, and should be leveraged in future experiments. SPC and NWS forecasters were excited by the potential of the demonstrated capabilities that will be available on GOES-R once it launches with regards to lightning detection and surface moisture/vegetation measurements.

Much like the early years of the HWT Spring Experiment, the goal of the Fire Weather Experiment should be to build foundational relationships within the fire weather community and to help accelerate the transfer of research to operations for experimental products that are directly applicable to the fire weather forecast community. In addition, the interactions between researchers and the operational fire weather community are crucial in the development of future fire weather forecast decision aids.

Additional detailed feedback and case examples from the 2011 Fire Weather Experiment can be found on GOES-R Proving Ground HWT blog under the tag "Fire Weather Applications" at:
http://goesrhwt.blogspot.com

References

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