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The GOES-R Proving Ground 2012 Summer Experiment at the Aviation Weather Center

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1. INTRODUCTION[1]

The National Oceanic and Atmospheric Administration (NOAA) Aviation Weather Center (AWC) Summer Experiment, run on 4 – 15 June 2012, provided the GOES-R Proving Ground with a pre-operational environment in which to demonstrate and evaluate algorithms associated with summer season aviation hazards and the next generation satellite systems.

Unlike the previous year, the 2012 Summer Experiment at the AWC included a desk dedicated to the demonstration and evaluation of a number of GOES-R products. This data was supplied by various research institutes including the Cooperative Institute for Meteorological Satellite Studies (CIMSS), the Cooperative Institute for Research in the Atmosphere (CIRA), NASA's Short-term Prediction Research and Transition Center (SPoRT), University of Alabama – Huntsville (UAH), and NASA's Langley Research Center (LaRC).

The participants involved in the experiment were widely varied, including those in aviation operations such as traffic flow managers from the Federal Aviation Administration (FAA), operations managers from various airlines, and forecasters from Central Weather Service Units (CWSUs) and the AWC, as well as those in aviation research, including a number of developers and scientists from our research partners listed above.

2. EXPERIMENT OVERVIEW

The structure of the 2012 Summer Experiment was built around the issuance of the experimental Aviation Weather Statement (AWS), a text and graphic based tool used to update traffic flow management planners to aviation weather hazards expected to impact air traffic or centers within the 0 – 4 hour time period. To accommodate the large amount of participants as well as the abundant amount of new datasets, the experiment was broken down into four desks, two focused on traffic flow management (TFM) and the exploration of the AWS, while the remaining two were dedicated to high resolution model verification and next generation GOES-R satellite tools.

The purpose of the dedicated GOES-R desk was twofold: (1) participants were able to use the new satellite tools to provide support to those responsible for the experimental issuance of the AWS, and at the same time (2) were able to explore the uses of each new satellite tool in the day to day forecasting of summer season aviation hazards, particularly convective initiation (CI) and lightning. Both of these things not only provided a first glance into next generation satellite technology, but also allowed for AWC and other forecasters to provide vital evaluation and feedback to product developers.

2.1 DAILY WORKFLOW

Each day the workflow at the GOES-R desk was split into two separate sections: (1) the morning weather outlook, and (2) afternoon nowcasting. After roughly thirty minutes of training, during which time the forecasters were provided with a brief overview of the GOES-R products to be demonstrated, the remaining hours of the morning were spent on a weather outlook. Participants were instructed to 'drive' the desk; using the tools they normally would in operations, as well as the GOES-R products, to forecast areas in which CI was likely to occur over the U.S. Given the nature of the experiment, they were asked to key in on events which had the potential to cause constraints to more significant flight routes and centers.

Later in afternoon (or earlier depending on the weather anticipated for the day), the desk transitioned into a nowcasting or 'weather watch' mode. During this time a number of GOES-R

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products, such as the CI and PGLM, were utilized in an effort to nowcast developing convection in the pre-determined areas of interest outlined from the morning outlook. Additionally, much collaboration was done with the TFM desks in an effort to aid in updating or issuing an AWS based on the impending weather.

3. GOES-R PRODUCT DEMOS IN N-AWIPS

The GOES-R satellite products used for the 2012 Summer Experiment were those deemed useful in forecasting for summer season aviation hazards and consisted of both GOES-R Baseline and Future Capabilities products. The GOES-R Baseline products are those that are funded for operational implementation as part of the ground segment base contract of the GOES-R program, whereas Future Capabilities products refer to a new capability made possible by ABI as optional in the ground segment contract of the GOES-R program. Table 1 below lists the GOES-R Baseline and Future Capabilities products.

Table 1. GOES-R Baseline and Future Capabilities products.

Category	Instrument	Product
Baseline Products	Advanced Baseline Imager (ABI)	Aerosol Detection (Including Smoke and Dust)
		Aerosol Optical Depth (AOD)
		Clear Sky Masks
		Cloud and Moisture Imagery
		Cloud Optical Depth
		Cloud Particle Size Distribution
		Cloud Top Height
		Cloud Top Phase
		Cloud Top Pressure
		Cloud Top Temperature
		Derived Motion Winds
		Derived Stability Indices
		Downward Shortwave Radiation: Surface
		Fire/Hot Spot Characterization
		Hurricane Intensity Estimation
		Land Surface Temperature (Skin)
		Legacy Vertical Moisture Profile
		Legacy Vertical Temperature Profile
		Radiances
		Rainfall Rate/QPE
		Reflected Shortwave Radiation: TOA
		Sea Surface Temperature (Skin)
		Snow Cover
		Total Precipitable Water
		Volcanic Ash: Detection and Height
	Geostationary Lightning Mapper (GLM)	Lightning Detection: Events, Groups & Flashes
	Space Environment In-Situ Suite (SEISS)	Energetic Heavy Ions
		Magnetospheric Electrons & Protons: Low Energy
		Magnetospheric Electrons: Med & High Energy
		Magnetospheric Protons: Med & High Energy
		Solar and Galactic Protons
	Magnetometer (MAG)	Geomagnetic Field
	Extreme Ultraviolet and X-ray Irradiance Suite (EXIS)	Solar Flux: EUV
		Solar Flux: X-ray Irradiance
	Solar Ultraviolet Imager (SUVI)	Solar EUV Imagery
Future Capabilities	Advanced Baseline Imager (ABI)	Absorbed Shortwave Radiation: Surface
		Aerosol Particle Size
		Aircraft Icing Threat
		Cloud Ice Water Path
		Cloud Layers/Heights
		Cloud Liquid Water
		Cloud Type
		Convective Initiation
		Currents
		Currents: Offshore
		Downward Longwave Radiation: Surface
		Enhanced "V"/Overshooting Top Detection
		Flood/Standing Water
		Ice Cover
		Low Cloud and Fog
		Ozone Total
		Probability of Rainfall
		Rainfall Potential
		Sea and Lake Ice: Age
		Sea and Lake Ice: Concentration
		Sea and Lake Ice: Motion
		Snow Depth (Over Plains)
		SO_2 Detection
		Surface Albedo
		Surface Emissivity
		Tropopause Folding Turbulence Prediction
		Upward Longwave Radiation: Surface
		Upward Longwave Radiation: TOA
		Vegetation Fraction: Green
		Vegetation Index
		Visibility

Of these products, eight were demonstrated via N-AWIPS at the 2012 Summer Experiment including WRF synthetic satellite imagery, a number of convective initiation products, several lightning threat forecasts, and also a low cloud and fog probability tool. A brief description of each is detailed in the following sections.

3.2 SIMULATED CLOUD AND MOISTURE IMAGERY

Using several variables, synthetic satellite imagery is generated from the 0000 UTC NSSL WRF-ARW run and is available daily starting at 1200 UTC. While this is only model data, it allows the user to become familiar with the future satellite imagery of GOES-R. For the 2012 Summer Experiment, bands 8-16 were available, with a specific focus on bands 8-10 (high, mid, and low-level water vapor), and band 14 (traditional IR). Additionally, CIRA provided several band differences including a fog product, which discriminates low-level clouds from high-level clouds, and a low-level water vapor convergence band, which identifies areas of moisture convergence and/or pooling.

3.3 PSUEDO GEOSTATIONARY LIGHTNING MAPPER (PGLM)

Current lightning analysis products within AWC operations consist of Cloud to Ground (CG) strike threats. The PGLM uses the Lightning Mapper Array (LMA) to collect raw observations of total lightning, i.e. CG, Cloud to Cloud (CC), etc. to demonstrate another GOES-R baseline product. While this product is not a true proxy for the GLM, it was pulled into the experiment to expose the forecasters to GLM-type data in preparation for the real product, slated for launch with GOES-R.

3.4 WRF/HRRR LIGHTNING THREAT FORECAST

The Lightning Threat Forecast uses output, both dynamical and microphysical, from the high resolution convection runs of the HRRR and WRF models, and generates three quantitative forecast fields of lightning threats. Threat field 1 focuses the flux of graupel in the layer near -15°C, i.e. the lightning threat within a convective core, and threat field 2is based on vertically integrated ice content within simulated storms. A composite threat, threat field three, is created by blending field 1 (95%) and field 2 (5%), and was the focus for this year's experiment.

3.5 UNIVERSITY OF WISCONSIN CIMSS NEARCASTING MODEL

The NearCasting model uses observations from the GOES-13 sounder water vapor channels in an effort to define areas most susceptible to convective initiation via areas of mid-level destabilization. It is a 9 hour forecast, using Rapid Update Cycle (RUC) winds to advect the sounder information forward in time. There are several outputs from this model including a vertical precipitable water difference, a vertical theta-e difference, and mid-level CAPE. For the 2012 experiment, the focus was on the mid-level CAPE.

3.6 UNIVERSITY OF WISCONSIN CIMSS CLOUD-TOP COOLING (CTC)

The UWCI CTC algorithm is used to examine vertical growth of immature convective clouds via GOES imagery. Specifically, it looks for rapid cooling of pixels within the infrared imagery, and also utilizes cloud phase information to identify the stage of growth of a cooling cloud (immature water cloud to completely glaciated cloud). Additionally, cloud optical depth was utilized recently to allow for detection of rapidly cooling pixels below a thin cirrus deck

3.7 UAH CONVECTIVE INITIATION SATCAST

The SATellite Convection Analysis and Tracking (SATCAST) algorithm is similar to the CTC produced by UW CIMSS as it does examine rapidly cooling pixels within infrared imagery. However, the SATCAST also utilizes information from the other available IR channels through a number of additional spectral tests that describe the convective environment. In the first stages of development this algorithm used a simple "yes/no" classification scheme. However, recently it has been upgraded to output a "Strength of Signal" (SOS), giving a score of 1-100 to each detected cloud object.

3.8 UNIVERSITY OF WISCONSIN ENHANCED-V/OVERSHOOTING TOPS

As with the CTC algorithm, the Overshooting Top (OT) detection utilizes infrared imagery, but in this case it searches for small clusters of pixels that are significantly colder than those in the surrounding anvil cloud (with a diameter consistent with commonly observed OTs). The Enhanced-V, or Thermal Couple (TC), detection uses the OT detection and looks for clusters of anomalously warmer pixels that are adjacent to the identified OT, i.e. a thermal couplet. While a turbulence and lightning probability associated with these two algorithms are provided, the summer experiment focused only on the OT and TC detections.

3.9 FOG AND LOW STRATUS

The GOES-R fog and low stratus (FLS) detection products use satellite and NWP model data, as well as ceilometer observations, to produce quantitative probabilities of Instrument Flight Rules (IFR) for each cloud pixel. Unlike the current legacy products, the low cloud/fog detection is available both during the day and night, and contains Cloud Thickness and Cloud Phase algorithms, along with IFR and LIFR probabilities. Given the focus on convection for this year's experiment, this product wasn't frequently viewed; however, the forecasters were able to utilize it a number of times, particularly for West Coast fog situations.

4. GOES-R PRODUCT EXAMPLES IN N-AWIPS

Throughout the two weeks of the experiment various records were kept and cases collected via personal notes, screen captures, and blog posts. Additionally, much forecaster feedback was compiled through both verbal discussion as well as a series of survey questions. Highlights of each of the GOES-R products utilized are summarized in the following sections.

4.1 SIMULATED CLOUD AND MOISTURE IMAGERY

On the morning of 15 June 2012, the water vapor imagery showed a broad area of transverse wave activity along the eastern edge of the cirrus shield associated with a dissipating Mesoscale Convective System (MCS) in the Central U.S. These wave clouds caused a fairly significant number of moderate turbulence reports at cruising altitude (~FL300 – FL350) from various large commercial aircraft, including several 737s, an A320, and a DC10.

The forecast runs of the WRF simulated water vapor (band 8) for the same time period, while advancing the convection slightly too far east, did indicate this wave activity (Figure 1). Also notable was the similarity of the synthetic imagery to the real time imagery, and subsequently the utilization of this data as a proxy for the Advanced Baseline Imagery (ABI) bands on GOES-R.

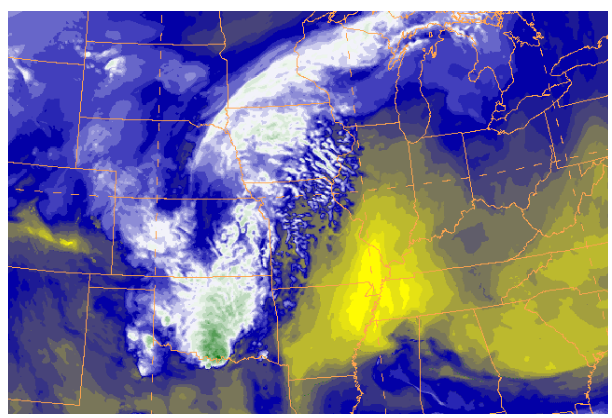

Figure 1. WRF-ABI Water Vapor imagery on the morning of 15 June 2012.

4.2 PGLM

Though a later addition to the experiment, the Pseudo Geostationary Lightning Mapper (PGLM) was a valuable tool in the evaluation of convection and the associated lightning threat. The PGLM was available in near-real time for the forecasters in a mosaic format, using all data from the Kennedy

Space Center, North Alabama, Oklahoma, and Washington D.C. networks.

One particularly good example of the PGLM was found on 14 June 2012. Typical scattered summertime convective developed over the Florida Peninsula and Gulf of Mexico in the early afternoon. At 1707 UTC one particular cluster of cells developed just north of Orlando Center. The current lightning threat, which detects Cloud to Ground (CG) strikes only, noted the highest occurrences of lightning strikes within the core of the convection. As such, air traffic was diverted on a route between these cells (Figure 2).

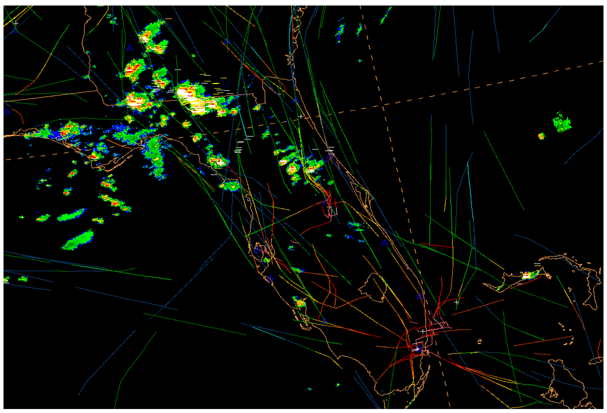

Figure 2. 120614 1707 UTC base reflectivity, GC lightning strikes, and ASDI flight routes.

At the same time, the PGLM, which detects total lightning (both CG and intra-cloud lightning), was actually showing the most electrical activity in the direct path of the divert routes (Figure 2). This example demonstrated the potential for dangerous electric activity in areas devoid of CG strikes and how the anticipated GLM can be utilized for traffic flow management and aviation operations safety.

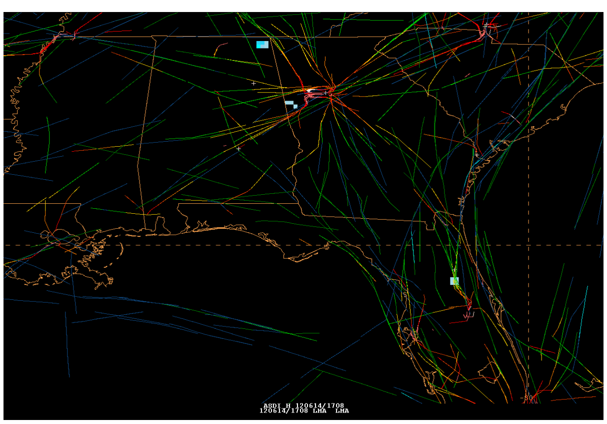

Figure 3. 120614 1708 UTC PGLM total lightning and ASDI flight routes

4.3 WRF/HRRR LIGHTNING THREAT FORECAST

The WRF and HRRR Lightning Threat Forecast is a model-based method of determining quantitative forecasts of lightning threats. For the experiment, the focus was on the composite threat, threat 3, and though a number bugs prevented an in-depth evaluation, it was shown to be a valuable situational tool, particularly in forecasting CI. It can be used to not only highlight areas of potential CI, but also areas for which the potential of lightning is the greatest.

One particular example was found on 7 June 2012 in association with an anticipated line of storms in the Northeast. The lightning threat forecast indicated the potential area of CI where a squall line did develop, and the highest noted lightning threats did correspond relatively well with the strongest radar echoes.

4.4 NEARCASTING MODEL

The NearCasting Model was developed in an effort to forecast for mid-level instability, as was seen in the case of a developing bow echo on 11 June 2012. A line of storms formed just west of the Kansas City, MO, and tracked eastward. Throughout the morning the NearCasting model forecasts consistently showed a significant area of mid-level instability ahead of this convection, and as the afternoon progressed, the squall line strengthened into an intense bow echo that resulted in significant air traffic constrains to centers such as St. Louis and Memphis (Figure 4).

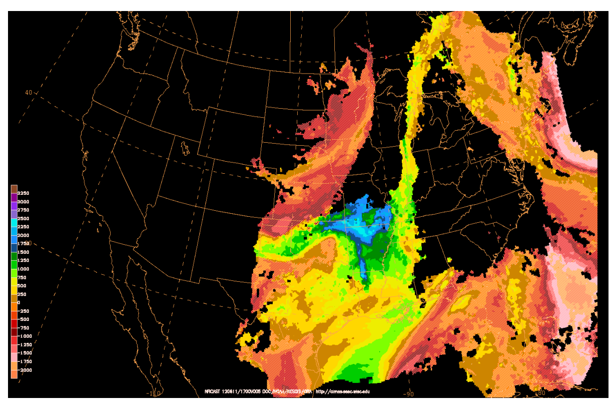

Figure 4. 120611 1700V002 NearCasting Model run

In some cases, however, the utility was actually found in the areas of mid-level stability, particularly in the development of convection in the Northeast. Due to mid-level stability, this convection was low-topped and short-lived. As convection is the single biggest cause of traffic constrains at the various centers, being able to predict developing or diminishing convection is key for efficient and safe traffic management.

4.5 UWCI CLOUD TOP COOLING

University of Wisconsin's Cloud Top Cooling algorithm was utilized a number of times throughout the experiment as a way to not only identify areas of potential convective development, but also provided extra lead time over radar echoes. One such case occurred on 6 June 2012 over Texas. A weakening Mesoscale Convective Vortex (MCV) located over Amarillo was forecast to slowly progress east towards Fort Worth Center, with convection expected in the "toes" of the chicken foot feature.

While the potential area of convection initiation was wide, the detections from the CTC algorithm significantly narrowed down the spatial extent, and in this case, correctly identified areas in which rapid convective development and significant air traffic constrains occurred (Figure 5).

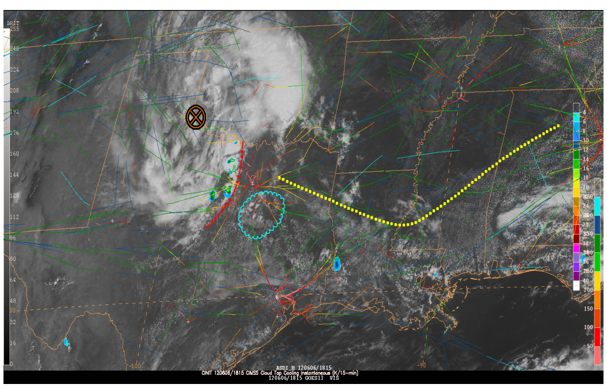

Figure 5. 120606 1815 UTC Cloud Top Cooling; with the 'X' marking the center of the MCV, the boundary of the cumulus cloud field in yellow, the 'toe' of the MCV in which CI was expected in red, and already agitated cumuls within the blue scalloped area.

4.6 UAH SATCAST

Similar to the UWCI algorithm, the UAH SATCAST identifies significant cooling of pixels in the IR imagery, while also using a number of IR spectral tests to analyze the environment in which CI is occurring, giving a Strength of Signal (SOS) of CI within a cumulus field.

The SATCAST showed a great amount of potential, as a situational awareness tool, particularly in identifying the occurrence of convective initiation within a cumulus field of large spatial extent, but also, as a relatively new product, showed room for further development. For example, given the relaxed constrains of the algorithm many forecasters noted a significant amount of 'noise'. However, with further improvement, this algorithm shows much utility for air traffic management and safety.

4.7 ENHANCED-V/OVERSHOOTING TOP DETECTION

The utility of the Enhanced-V/Thermal Couplet (TC) and Overshooting Top (OT) detections was a much-debated topic throughout the two weeks of the experiment. In particular, many explored how these algorithms compared to what is already seen in radar imagery, and how they could be used to aid in traffic flow management.

One answer was in radar sparse areas, both over land and also in offshore areas, where the sea stretches far beyond the range of coastal radar coverage. In cases like these, such as 5 June 2012, where several intense convective cells developed directly in the path of several flight routes over the Gulf of Mexico, the algorithms may assist where traffic flow diverts are needed but radar returns aren't available (Figure 6).

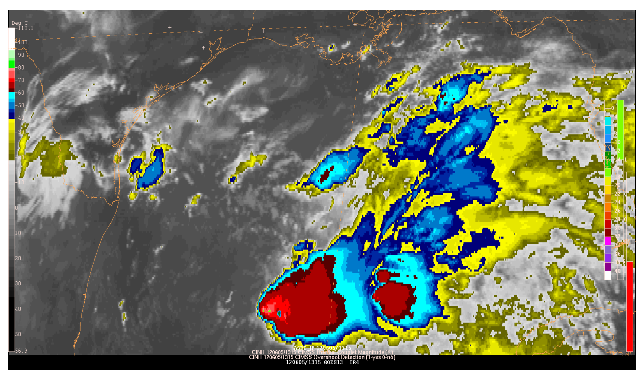

Figure 6. 120605 1315 UTC IR imagry, Overshooting Top (green), and Thermal Couplet (blue).

A second answer was turbulence. Traffic flow management is an elaborate and complicated test of efficiency; trying to keep a large number aircraft moving from place without compromising the safety of the pilots and flight crews, particularly in the face of impending weather. In the end, it is the operations managers giving their pilots the go or no go when it comes to both climbing over convection, as well as flying the gaps through it.

For this reason the OT algorithm may have further usefulness. Generally it can be assumed that there is a high likelihood of moderate or greater (MOG) turbulence associated with an OT given the intense updraft associated with its generation. As such, knowing which cell within a group of cells, or how far out turbulence would be expected, would give traffic flow managers a better idea of which areas in which to direct traffic around or over, especially in cases where radar returns don't look particularly intense.

4.8 FOG AND LOW STRATUS

As not every day of the experiment was convectively active, some exploration into the Low Cloud and Fog product was also done. While it was noted to have utility on both the East and West Coast, several forecasters from the FA desks at the AWC, which are responsible for issuing AIRMETs for low ceilings, expressed the usefulness of this product in West Coast fog situations.

An example of this utility was noted on 13 June 2012, particularly with the IFR probability portion of the algorithm. The IFR probabilities indicated low ceilings to remain in place until shortly after 1800 UTC, and in fact the fog did not dissipate until just before 1800 UTC.

5. CONCLUSION

As mentioned previously, the products evaluated during the summer experiment included both Baseline products and Future Capabilities (Table 1). The Research to Operations effort at each GOES-R Proving Ground, including the AWC, focuses first on the transition of the Baseline products into operations, while keeping the Future Capabilities in mind for further evaluation if a viable route into operations can be found.

Several Baseline products, the Low Cloud and Fog product and the Cloud Top Cooling algorithm, have already been transitioned into operations at the AWC, with more, such as the PGLM, anticipated to make the transition in the future. Additionally, while not the main focus of the Proving Ground at the AWC, there are also a number of Future Capabilities products likely to be further evaluated in coming experiments, including the Overshooting Top Detection and several icing and turbulence related tools.

Overall the 2012 Summer Experiment at the Aviation Weather Center was very much a positive experience, its success attributed not only to the hard work of the developers in generating innovative, aviation-related GOES-R products and associated training materials, but also the willingness of the participants to learn and explore.

The feedback collected from this experiment will allow for further development and improvement of satellite derived algorithms for futures experiments, and will also further the efforts of the GOES-R Proving Ground in familiarizing forecasters and other end users for the upcoming next generation satellite technology.

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