THE EXPERIMENTAL WARNING PROGRAM'S 2011 AND 2012 SPRING EXPERIMENTS AT THE NOAA HAZARDOUS WEATHER TESTBED

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1. INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) Hazardous Weather Testbed's (HWT) Experimental Warning Program's (EWP) purpose is to integrate National Weather Service (NWS) operational meteorologists, and researchers from the National Severe Storms Laboratory (NSSL) and other institutions to test new science, technologies, products, and services designed to improve short-term (0-2 hour) warnings and nowcasts of severe convective weather threats wherever they occur in the U.S. (Stumpf et al. 2005, Stumpf et al. 2008, Stumpf et al. 2010). The HWT provides a conceptual framework and a physical space to foster collaboration between research and operations to test and evaluate emerging technologies and science for NWS hazardous weather warning operations.

The objective of the EWP testbed activities is to evaluate the accuracy and the operational utility of new science, technology, products, and concepts in a quasioperational setting to gain feedback for improvements prior to their potential implementation into NWS severe convective weather warning operations. The testbed provides forecasters with direct access to the latest developments in meteorological research. The testbed also helps researchers and developers to better understand operational forecast and warning requirements.

The 2011 and 2012 experiments (EWP2011 and EWP2012) were the fifth and sixth years for EWP pseudo-operational (real-time) activities in the testbed. EWP2011 and EWP2012 were conducted over fourand five-week periods, respectively, in May and June to capitalize on climatological peak of severe weather for the U.S.

EWP2011 and EWP2012 were designed to test and evaluate new applications, techniques, and products to

support Weather Forecast Office (WFO) and Center Weather Service Units (CWSU) severe convective weather nowcast and warning operations. There were three primary projects geared toward warning applications during these two springs: 1) evaluation of 3dimensional variational (3DVAR, Gao et al. 2009, 2012) multi-radar real-time data assimilation fields being developed for the Warn-On-Forecast initiative, 2) evaluation of multiple Geostationary Operational Environmental Satellite - R Series (GOES-R) convective applications, including pseudo-geostationary lightning mapper products when operations were expected within the Lightning Mapping Array domains (OK-TX, AL, DC, FL), and 3) evaluation of performance and forecast utility of the OUN Weather Research and Forecasting (WRF) model when operations were expected in the Southern Plains.

Several dozen NWS forecasters from WFOs and CWSUs, as well as some non-NWS and foreign operational meteorologists, participated in the experiments, along with personnel from the NWS Warning Decision Training Branch (WDTB), several universities, and other federal and academic agencies.

Operational activities took place during the week Monday through Thursday, with an end-of-week summary debriefing taking place on Friday. The visiting NWS forecasters used experimental data and products to issue warnings during real-time weather events while providing feedback to project scientists. Feedback was obtained from the forecasters during operations through the use of live blogging, online surveys, and post-event discussions. The NWS feedback is most important for future development for the NWS and eventual implementation of new application, display, and product concepts into NWS operational technologies.

Feedback from the visiting forecasters during EWP2011 was used to help refine the products tested in EWP2012. In addition, for EWP2012, we added an extra training shift that was taken at the forecaster's office prior to their arrival to Norman. With the goal of communicating the research to operations activities within NOAA, the HWT meteorologists added an end-ofweek national "Tales from the Testbed" Webinar hosted

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by the WDTB. 2012 was also the first year of operations in the HWT using the Advanced Weather Interactive Processing System -2 (AWIPS2).

2. EXPERIMENT ASPECTS

2.1 3DVAR Radar Data Assimilation Products

A real-time dynamically-adaptive three-dimensional variational data assimilation (3DVAR, Gao et al. 2004, 2009) system as part of the Advanced Regional Prediction System's (ARPS) has the ability to automatically detect and analyze severe local hazardous weather by identifying mesocyclones at high spatial resolution (1km horizontal resolution) and high time frequency (every 5 minutes) using data primarily from the national WSR-88D radar network, and NCEP's North American Mesoscale (NAM) model product (Stensrud et al. 2010). It is a first step in the long-term "Warn-on-Forecast" research project (Stensrud et al. 2009) to enhance tornado warning lead times by assimilating multiple data sources into a dynamically consistent analysis that provides the initial conditions for storm-scale numerical model forecasts.

NSSL's real-time 3DVAR analysis runs concurrently on 4 domains from 1pm to 9pm Central Daylight Time each day during the EWP real-time experiments. These domains are user-selectable. Each domain has the following properties:

- 1 km horizontal resolution
- 31 vertical levels
- 200x200 horizontal grid points
- 5-minute updates
- 3-4 minute latency

The NCEP 12 km NAM forecast valid at the analysis time is used as a first-guess background field. The analysis is not cycled – that is, it does not use the previous analysis as a first-guess field.

To evaluate the operational utility of Warn-on-Forecast 3DVAR Real-time Data Assimilation technology, the goals were to:

- Create real-time weather-adaptive 3DVAR analyses at high horizontal resolution and high time frequency with all operationally available radar data from the WSR-88D network.
- Compare 3DVAR data to other radar products, including multiple-radar / multiple-sensor (MRMS) products (see Section 2.4).
- Determine the potential operational impacts of these data on the WFO nowcast and warning decision process?

The following is a list of research questions that were sought regarding 3DVAR:

- How do 3DVAR diagnostic products affect the warning decision-making process?
- How do the depiction of storm structure and morphology in the 3DVAR products, which are derived from integration of multiple data streams, compare to how one would analyze the traditional radar and other data during typical nowcast and warning operations?
- Does 3DVAR produce realistic values of vertical vorticity and updraft intensity?
- Looking beyond 3DVAR diagnostic products, how will future storm-scale ensemble very short-term prediction products affect warning decision-making and communication of warning information?

The products that were of interest in the evaluation included:

3D Wind vectors: The three-dimensional wind field is the primary output of the 3DVAR analysis, from which other output fields are derived. If the three-dimensional wind field domain is sliced horizontally at constant altitude, one can diagnose the estimate two-dimensional wind field at those heights, which can be useful for identifying strength and trends in mesocyclones. The vertical component of the 3D wind field is used to create an updraft intensity field. An example of horizontal wind vectors and updraft strength for a severe hail storm on 16 May 2010 near Oklahoma City, OK, are shown in the example in Figure 1.



Figure 1: Maximum vertical velocity (left) and twodimensional wind vectors with mosaic reflectivity at 1.5 km MSL (right) for the May 16, 2010 hail storm in Oklahoma City.

Mosaic Reflectivity: A 3D reflectivity field (see also Fig. 1) is synthesized from nearby multiple radars using the method similar to Zhang et al. (2005). The synthesized field typically has weaker gradients and smaller peak values than the original WSR-88D data. The reflectivity field can be compared to the original WSR-88D data field as a "sanity check" to determine the assimilation's accuracy.

Updraft Track: The maximum updraft intensity can be time-accumulated to provide an "updraft track" product. This track product is one way to diagnose the history of storm severity, as the previous locations of the strongest

updraft in the storm, as well as the magnitude of the updraft strength in time, can be determined from the product. Figure 2 shows an example of a severe hail storm which impacted Oklahoma City, OK, on 16 May 2010. The updraft track is compared to an MRMS Maximum Expected Size of Hail product (MESH; Ortega et al. 2010). Strong pulses of high vertical velocity values are followed, as would be expected, by observations of larger hail sizes. Even though large hail is not detected directly by the assimilation, positive changes in vertical velocity (updraft "pulses") may be correlated to increases in hail size.



Figure 2: The 4-hour track of MRMS Maximum Expected Size of Hail (MESH; upper left) compared to the maximum updraft intensity (upper right) over the same time period for the 16 May 2010 Oklahoma City, OK, hailstorm. The graph on the lower right shows a time trend of updraft strength. The pictures on the lower left show damage photographs from the hail storm.

Vertical Vorticity: Vertical vorticity (Fig. 3) is also calculated from the horizontal wind field. Near-surface vorticity values are usually not accurate due to radar sampling limitations, but will be improved in future years. Therefore, we asked the forecasters to pay most attention to the vorticity values in the 3-7 km layer, which correlate to mid-level mesocyclones.



Figure 3: A vertical vorticity field (left) and a corresponding horizontal wind field (right).

Vorticity Tracks: As with updraft intensity, the maximum vertical vorticity can also be accumulated over time to produce "vorticity tracks". This track product is another way to diagnose the history of storm severity, but this time for storms containing mesocyclones. The previous locations of the strongest rotation in the storm, as well as the magnitude of that rotation in time, can be determined from the product. Figure 4 shows the

3DVAR vorticity track compared to a Linear Least Squares Derivative azimuthal shear track field (LLSD; Smith and Elmore 2004) derived directly from Doppler velocity from the KTLX radar. Both fields show the maximum values over a 1.5-hour time period. Figure 4 also shows reported tornado tracks and intensities for this event.



Figure 4: A 3DVAR vorticity track (upper left) and maximum Azimuthal Shear derived from KTLX Doppler Velocity (upper right) accumulated over the period from 2130 UTC to 2300 UTC during a tornado outbreak on May 10, 2010 in Central Oklahoma. Tracks of the tornadoes are shown on the lower left. A picture of one of the tornadoes is on the lower right.

Upper-Level Divergence: Divergence at specific levels was available in AWIPS2 during the spring 2012 experiment. However, during the first week of operations, forecasters suggested that a single storm-top divergence field would help them assess storm intensity without the need for loading in multiple panes of divergence data at different vertical levels. This change was implemented for the second week of EWP2012 as a product that shows the maximum divergence values in the vertical column above 8km MSL. This product is show in the upper-left panel of Figure 5).

Updraft Helicity: During EWP2011, several forecasters suggested that the instantaneous updraft helicity product available in the OUN WRF product suite (described below) would also be a useful addition to the 3DVAR products. This product (Fig. 5, upper left) was added for EWP2012, along with an "Updraft Helicity Tracks" product (not shown) that uses the same technique as the Vorticity Tracks product shown in Figure 4.

These products represent the first step in a decade-long project directed at providing reliable storm-scale ensemble model guidance as part of the warning decision-making and dissemination process for severe convective weather events. The initial real-time experiment showed that real-time assimilation of high space-and-time resolution data is possible using a 3DVAR analysis scheme by Gao et al. (2009). Future experiments may test other assimilation techniques such as 4DVAR and Ensemble Kalman Filter, as well as storm-scale numerical weather prediction.



Figure 5: Instantaneous Updraft Helicity (top-left), Maximum Divergence above 8 km AGL (top-right), MESH (bottom-left) and Maximum Updraft (bottom-right) for an event on June 14, 2012.

2.2 OUN Weather Research & Forecasting model

The WFO in Norman (OUN) operates a large computational cluster dedicated to running a local version of the WRF model (Version 3.2). The cluster features 10 nodes composed of 80 Intel E5620 processors running at 2.8 GHz. Communication between nodes is achieved using the scalable, high-speed, and low latency InfiniBand communication link. Collectively, this system is referred to as the "OUN WRF".

The domain of the model covers the Southern Plains and is centered on Norman, Oklahoma. In order to resolve the storms that produce the majority of severe weather (i.e., squall lines and supercells), 3-km gridspacing is used: this allows features of spatial extent greater than 15 km to be resolved. Since severe weather is produced on relatively short time scales, the OUN WRF runs every hour, out to 8 hours, with 15minute output. The model uses the NAM model forecasts (12-km grid-spacing) initialized at 00, 06, 12, and 18 UTC to supply the lateral boundary conditions. In order to generate initial conditions, the OUN WRF uses the ARPS 3DVAR (see Section 2.1).

The OUN WRF is highly-suited to explore the operational impacts associated with the Warn-on-Forecast paradigm. In Warn-on-Forecast, it is envisioned that, as a result of increasingly sophisticated data assimilation techniques and bourgeoning computer technologies, ensemble predictions of storm-scale phenomena (e.g., tornadoes, hail, etc.) will become possible. Since the OUN WRF is an experimental model, it is a good candidate to test the operational impact of high-resolution modeling. Unlike operational models, the OUN WRF can be adapted immediately to examine specific attributes of modeling, with a view toward Warn-on-Forecast. Specifically, the grid-spacing

of the model, the domain, initialization package, model physics, and model parameterizations can be adjusted with impunity. This allows the principal investigators, along with the Experimental Warning Program (EWP) participants, to take an active role in forging the role of high-resolution modeling in warning operations.

Some research questions related to these topics include:

- Do severe storm proxies add skill to a convective forecast?
- Does the OUN WRF forecast of relevant, largescale processes (e.g., evolution of storm mode) increase situational awareness (SA) during warning operations?
- Does the high frequency of OUN WRF output increase forecaster SA?
- How does the introduction of high-resolution model data impact forecaster workload?
- What new, high-resolution model products might increase forecaster SA?
- How can high-resolution model data be streamlined into warning operations?

In order to begin to answer these questions, participants were asked to produce the following during each Intensive Operations Period (IOP).

Here is a detailed description of each product:

Composite Reflectivity: The maximum reflectivity in the vertical column over each grid point. This derived product serves as a proxy for storm intensity. Generally, this product is useful for determining the timing and location of convective initiation, and the intensity of storms. The usual threshold values for interpreting radar apply to this product, though the maximum simulated reflectivity values tend to be 5 - 10 dBZ less than the legacy reflectivity values from just radar data.

1-km Reflectivity: Same as for composite reflectivity, except the value at the level which is 1 km above the ground.

Instantaneous Updraft Helicity: Updraft helicity is used as a surrogate for supercell thunderstorms. As the name implies, updraft-helicity is defined by the product of the updraft speed and vertical vorticity integrated over some depth. As it turns out, the depth of this layer is important. During the fall, winter, and early spring months (when supercells tend to be smaller due to small convective instability), a layer starting near 1 km and ending near 4 km may be sufficient to serve as proxy for mesocyclones. Later in the spring and into the summer, however, convective instability tends to increase, leading to taller storms and mesocyclones. During this time, the best integration layer is generally from 2 to 5 km. The deeper the layer, the more likely that mesocyclones will be found (Hitchcock et al. 2010). However, increasing the depth of the updraft helicity

layer also increases product noise. For this experiment, the 2 to 5 km layer was used.

The threshold value of updraft helicity for which one can imply a rotating updraft varies with season, location, and model resolution. As model grid-spacing increases, the model is able to resolve higher velocities, due to a better representation of turbulence. Consequently, the wind field tends to increase with higher model resolution. As a result, the vertical velocities increase and vertical vorticity increases (as the wind gradients increase), leading to higher values of updraft helicity. For the OUN WRF, which has a grid-spacing of 3-km, 50 m² s⁻² is a good threshold value for which one can imply a rotating updraft (during the months of May and June). A moderately strong mesocyclone is implied by values between 100 and 200 m² s⁻².

Maximum Updraft Helicity: Similar to the instantaneous updraft helicity, except hourly maxima are plotted. Continuous swaths of this path may imply longer-lived supercells. See Figure 6 for an example.



Figure 6: An updraft helicity field from the OUN WRF.

Maximum Hourly Column Hail: Maximum hourly column hail has been used as a proxy for thunderstorm electrification (since charge separation is implied in its vertical integration), but it may also be useful for the prediction of severe hail. Values of maximum hourly column hail greater than 40 kg m⁻² may imply the presence of severe hail.

10-m Wind Speed: The 10-m wind speed can be used as a proxy for severe wind gusts. As explained in the updraft-helicity description, the magnitude of the wind in a model depends on model resolution. At 3-km gridspacing, the OUN WRF is not able to resolve processes with a characteristic length less than 15 km; thus, the processes that produce severe gusts are not fully resolved. However, this product may still imply the presence of severe gusts in a forecast, albeit with lower severe thresholds than in reality. For a baseline threshold, 10-m wind speed values around 20 m s⁻¹ may correspond to severe wind gusts.

2.3 GOES-R proxy satellite products

Pre-operational demonstrations of these GOES-R Proving Ground (PG) products provide National Weather Service (NWS) operational forecasters an opportunity to critique and improve the products relatively early in their development (Goodman et al. 2012a). The demonstration included training and evaluations on baseline and future capabilities products generated from current satellite-based, land-based and numerical model-based datasets and used as proxies to help demonstrate GOES-R products for use in severe convective weather nowcast and warning operations.

Objectives of the demonstration included:

- Identify best practices for using the GOES-R products in nowcast and warning decision making, as input into future operational training.
- Assess various satellite-based applications, including convective initiation and nowcast applications for the pre-storm environment.
- Evaluate GOES-R pseudo-GLM products including the flash rate of storms and their tracks for use in storm interrogation and warning decision making.
- Identify appropriate display strategies within AWIPS2 for GOES-R products.

The products that were demonstrated include:

Convective Initiation: The University of Alabama in Huntsville (UAH) has developed a proxy product called AnalysiS SATellite Convection and Tracking (SATCAST; Berendes et al. 2008). 0-1 hour nowcasts of CI for tracked cloud objects are provided. The SATCAST algorithm uses a daytime statistically-based convective cloud mask, performs multiple spectral differencing tests of IR fields (so-called "interest fields"), and applies atmospheric motion vector (AMV) cloud tracking. SATCAST integrates radar observations, numerical weather prediction (NWP) wind and stability fields, and other data to assist in developing convective initiation nowcasts.

For EWP2011, the UAH SATCAST algorithm produced only "binary" yes/no forecast output regarding the potential of CI for tracked cloud objects. As a result of forecaster user feedback during that year, the algorithm underwent an enhancement that instead provides forecasters with a "Strength of Signal" (SS) probabilistic forecast output (Fig. 7). This method applies a linear regression approach to combine information from all available GOES IR channels into a single numerical value on a scale from 0 to 100, giving a sense for how strong the satellite-retrieved signal is for the development of cloud objects between the previous two GOES satellite scans.



Figure 7. UAH SATCAST output from EWP2011 (left; binary output) and EWP2012 (right; probabilistic output).

UWCI-Cloud Top Cooling (CTC): The UWCI-CTC algorithm is an experimental satellite based product used to diagnose infrared brightness temperature cloud top cooling rate and nowcast convective initiation (Sieglaff et al, 2011). The UWCI-CTC algorithm uses GOES imager data to determine immature convective clouds that are growing vertically and hence cooling in infrared satellite imagery. Additionally, cloud phase information is utilized to deduce whether the cooling clouds are immature water clouds, mixed phase clouds or ice-topped (glaciating) clouds.

New for EWP2012, based on previous forecaster feedback from EWP2011, the UWCI-CTC algorithm has been improved to operate in areas of thin cirrus clouds during daytime hours by including GOES cloud optical depth retrievals (Fig. 8). Additionally, for EWP2012 the focus will be using the UWCI-CTC rates as a prognostic tool for future NEXRAD observations. The two NEXRAD fields of focus will be composite reflectivity and Maximum Expected Hail Size (MESH; Fig. 9). One major research question was to determine if the relationships of the NEXRAD-based validation of the UWCI-CTC rates performed by Hartung et al (2012) could potentially be used to increase severe thunderstorm warning lead-time ahead of NEXRAD-only guidance.

Pseudo Geostationary Lightning Mapper (PGLM): A proxy for the GOES-R Geostationary Lightning Mapper (GLM) takes the raw total lightning observations, or sources, from any of the ground-based Lightning Mapping Array (LMA) networks available to the EWP, and recombines them into a flash extent gridded field (Kuhlman et al. 2010). These data are mapped to a GLM resolution of 8 km and will be available at 1 or 2 min refresh rate, depending on the ground-based network being used. Those ground networks include Central Oklahoma, North Alabama, Kennedy Space Center, and Washington DC. A new ground network was added in 2012 to cover West Texas, and to connect to the Central Oklahoma network with additional sensor across southwest Oklahoma and northwest Texas. The LMA network data delivery takes place over an established LDM feed to NSSL every 2 minutes, with an average latency of 1 minute.



Figure 8. The UWCI-CTC output used in EWP2011 (top) and in EWP2012 (bottom). The red oval encircles an area where detections were masked in the former version of the algorithm (top), but visible in the new version due to the use of the cloud optical depth retrievals.



Figure 9. Relationship between cloud top cooling (CTC) rates and radar-based Maximum Estimate Size of Hail (MESH).

With the flash data, when a flash enters a grid box, the flash count will be increased by one. Also, no flash is counted more than once for a given grid box. The PGLM is not a true proxy data set for the GLM as it does not attempt to create a correlation between the VHF ground-based networks and the eventual optical-based GLM (individual events, groups, flashes at 20 second latency). However, the PGLM product will give forecasters the opportunity to use and critique a demonstration of GLM type data to help improve future visualizations of these data. Products include 8-km flash extent density (Fig. 10), flash initiation density, and 30-minute flash extent density track.



Figure 10. AWIPS display of the 8 km GOES-R Pseudo-GLM product.

The overall emphasis of the PGLM evaluation was to provide forecasters the opportunity to use real-time data that is representative of the future capabilities of the GOES-R Lightning Mapper and to provide feedback for visualization tools. The major research question was to determine if the GLM data will have operationally utility in severe weather warning decision making.

NearCasting Model: This model generates 1-9 hour forecasts (or "NearCasts") of atmospheric stability indices. Products generated by the NearCast model have shown skill at identifying rapidly developing, convective destabilization up to 6 hours in advance. The system fills the 1-9 hour information gap which exists between radar nowcasts and longer-range numerical forecasts. The NearCasting system uses a Lagrangian approach to optimize the impact and retention of information provided by GOES sounder. It also uses hourly, full resolution (10-12 km) multi-layer retrieved parameters from the GOES sounder. Results from the model enhance current operational NWP forecasts by successfully capturing and retaining details (maxima, minima and extreme gradients) critical to the development of convective instability several hours in advance, even after subsequent IR satellite observations become cloud contaminated.

NearCasting products using GOES data include Lowand Mid-altitude Total Precipitable Water (TPW), Lowand Mid-altitude Equivalent Potential Temperature (Theta-E), Convective Instability (the difference between Lower- and Mid-altitude Theta-E and a new parameter to diagnose the potential for sustained convection (the product of Convective Instability and Low-Level Theta-E and TPW (Fig. 11). The relevant research objective is for forecasters to determine if the NearCasting model products offer improved spatial and temporal convective initiation forecasts as well as additional warning lead time during severe weather situations.



Figure 11. NearCast image of the Long-Lived Convection Parameter, which is a product of Convective Instability, low-altitude θe , and low-altitude total precipitable water.

Other products: Several other GOES-R proxy products, designed primarily to assist the Experimental Forecast Program portion of the HWT, were also made available to the forecasters in EWP2012. These included a simulated infrared satellite forecast product that uses output from the NSSL WRF forecast model. The other was the Sounder RGB Airmass product. Details of these products are found in Goodman et al. (2012).

2.4 Other complimentary products (not evaluated alone)

In addition to the above three primary projects, there were additional experimental products that were used to compliment the above three datasets. All of these products have already been tested in the HWT in past experiments and feedback was not officially recorded for these products.

The NSSL multiple-radar / multiple-sensor (MRMS) severe weather algorithms integrate data from the entire CONUS WSR-88D radar network into rapidly-updating three-dimensional data cubes for reflectivity and velocity-derived azimuthal shear (Lakshmanan et al. 2006). From these data cubes, two-dimensional products are obtained, in many cases, when integrated with Near-Storm Environment (NSE) data from the Rapid Refresh model (RAP). These products include fields such as Isothermal Reflectivity (reflectivity at a constant temperature surface), Reflectivity Thickness

(height difference between an echo-top product and a thermodynamic surface), Maximum Estimated Size of Hail (MESH), Hail Swath (time accumulated MESH), and Rotation Tracks (time accumulated azimuthal shear). These products were also available in AWIPS to compare with the main experimental products.

While the PGLM data was meant to be evaluated as though it were the only source of total lightning data in the experiment, at times, the raw ground-based Lightning Mapping Array (LMA) total lightning data was occasionally visualized during operations.

3. EXPERIMENT LOGISTICS

3.1 Participants

The visiting NWS meteorologists who participated as evaluators in EWP2011 and EWP2012 represented four of the six NWS Regions (Eastern, Central, Southern, and Western). Participants were selected so that there was good diversity in warning experience (little, some, much), and in geographic location (locations throughout the U.S.). Positions from the Weather Forecast Offices (WFO) included general and lead forecasters, Science and Operations Officers (SOO), Warning Coordination Meteorologists (WCM), Meteorologists In Charge (MIC), and even a few interns. Three of the participants were drawn from the Decision Support Services "pilot project" WFO at Charleston, WV. Several participants were drawn from regional headquarters positions, one from the WSR-88D Radar Operations Center, and one from the U.S. Air Force Weather Agency. For EWP2012, we also included meteorologists from the CWSUs who deal primarily with aviation weather. A handful of our visitors were international meteorologists, from Austria, Canada, and Germany. Participants' operational expertise was tapped in order to provide constructive criticism of any aspect of the experiment. We had a total of 21 participants for EWP2011 (over four weeks), and 28 participants in EWP2012 (over 5 weeks). Figure 12 shows a group of EWP participants and project scientists during a real-time event in EWP2012 where forecasters were issuing severe weather warnings.

The EWP2011 and EWP2012 management team consisted of an Operations Coordinator responsible for the experiment logistics, an Information Technology Specialist, and the two EWP Team Leaders (from the NSSL and the NWS WFO Norman) responsible for the overall management of the EWP. Weekly Coordinators were in charge of the day-to-day scheduling of operations, and led the pre-shift weather briefings and post-shift discussions. Principle scientists for each of the experiments were available to assist the visiting participants and provide information and guidance on the particular experiments. They worked closely with the forecaster/evaluator participants during training, operations, and debriefings.



Figure 12. On-going real-time EWP2012 operations in the Hazardous Weather Testbed operations area. Photograph by Greg Stumpf.

3.2 Operations Periods

The 2011 spring experiment (hereafter, EWP2011) took place across four work-weeks (Monday – Friday) from 9 May through 10 June. The 2012 spring experiment (hereafter, EWP2012) took place across five workweeks from 7 May through 15 June. There were no operations during Memorial Day week either year.

3.3 Weekly Schedule

a. Training

From EWP2008 through EWP2011, the spring experiment would only conduct full-fledged real-time operations on Tuesday, Wednesday, and Thursday. Mondays were reserved as the orientation and training day. On rare occasions when there was a possible major severe weather event forecasted for a Monday, we would abbreviate training to work the event. However, based on forecaster feedback, neither of these was desired. In order to increase the amount of time forecasters could evaluate the products in realtime, they offered two suggestions. Either have the visitors spend two weeks at the testbed, or move the training back to the visitors' forecast offices to be taken prior to their arrival in Norman. We chose the latter for EWP2012, with great success.

The EWP2012 training was delivered online, designed to be taken in a single 8-hour supernumerary shift at the participants home office (WFO or CWSU) within two weeks prior to their arrival at the Hazardous Weather Testbed in Norman. The training materials consist of a mixture of self-paced PowerPoints, several Articulate and Visitview presentations, and a WES Virtual Machine training case with various job sheets. The WES case consisted of about 3 hours of data with many of the experimental products included. This new training format opened up Mondays as a fourth real-time operations day for each week.

b. Operational shifts

Operational days usually took place during a 1-9pm work shift, in order to capitalize on the peak convective period of the afternoon and evening. For EWP2011, we experimented with two overlapping shift schedules. The morning shift would work in conjunction with the Experimental Forecast Program's spring experiment (Kain et al. 2012) during 9am-1pm, and developing an Area Forecast Discussion (AFD) to inform the afternoon shift forecast decisions on where to operate. From 1-5pm, the morning shift team would join the evening shift team (on from 1-9pm) in issuing warnings using the experimental product. Feedback from the forecasters and the PI's own observations suggested that this split shift schedule wasn't working to our advantage.

For EWP2012, we returned to the single evening shift schedule, but with a "flexible" start time. By default, our usual shift would run from 1-9pm, as in pre-2011 experiments. However, based on a Day 2 outlook, the following day's shift could start either at 12pm, 1pm, 2pm, or 3pm, and ending 8 hours later (since we could do this on Mondays, the 1-9pm shift was fixed for that day). An earlier shift was advantageous when we were working east coast events which typically occur earlier in the day (and an hour difference due to the time zone). Later shifts were advantageous for Plains events that might start late due to a strong capping inversion, and might peak after sunset. Nevertheless, we worked shifts other than 1-9pm only a few times during EWP2012.

Each operations day began with a daily coordination briefing which included a post-mortem discussion of the previous day operations (unless on Monday), a discussion of the severe weather outlook for the current day, and a determination of which "virtual" WFOs we would emulate for real-time operations. On Mondays only, a short project orientation seminar was delivered. In addition on Monday, forecasters used a few hours to become familiar with using the new products on the AWIPS2 system and building procedures.

c. Feedback Acquisition

In order to obtain the feedback the project scientists needed, we employed a number of methods. The primary means was to place the forecasters in the "hot seat" using the experimental products to issue shortterm forecasts and warnings using live data. The idea was to have the forecasters think about how the new product could be used to help with warning decisions. There was no intent for the forecasters to "compete" for good warning statistics such as lead time (as in past experiments), only to place them in the mindset of warning operations.

Starting with EWP2012, we gave the forecasters an additional role during real-time operations. Our EWP Blog (see Section 3.5) was utilized as a communications means for the forecasters to provide their pre-warning and nowcast thoughts, via our "live blogs". They wrote short nowcasts, and included images captured from the display when appropriate. Their blog posts also allowed the forecasters to collect their thoughts and relevant images to be used for the Friday webinars.

Once storms became severe, forecasters issued actual warnings using the AWIPS2 Warning Generation (WarnGen) software. Forecasters were asked to provide some narrative in the warning text product that described which experimental products used to make that warning decision.

In addition to the above, at the end of each real-time shift, the forecasters filled out a 30-minute online survey questionnaire. Principal scientists also conducted dialog and took notes during operations. Finally, the next day and Friday de-briefings were used to capture more feedback (Fig. 13).



Figure 13: A EWP2012 daily coordination briefing in the NSSL Development Laboratory room. Photograph by Greg Stumpf.

d. Friday wrap-up and Webinar

We did not conduct real-time operations on Fridays. Instead, that time was used to conduct a two-hour morning end-of-week weekly summary debriefing. During this period, the project scientists listened to the forecaster participants one final time to hear about their thoughts on all the experimental products, and the overall experiment logistics as well.

Starting with EWP2012, we added a national "Tales From the Testbed" webinar to be delivered by the visiting forecasters. The goal of the weekly webinars was to provide the NWS listeners insights into the very latest tools and techniques under development and consideration for use for NWS operational warning operations. Preparation for the webinar took place throughout the week, as forecasters collected images and thoughts on their live blog posts. The final hour Thursday, and the first hour Friday was used to develop the presentation and do a "dry run". The two-hour endof-week debrief followed the dry run. At noon Central Time, the Webinar was delivered to a national NWS audience via telecon and gotoMeeting. The format varied throughout the five weeks of EWP2012, but eventually settled on the forecasters presenting two to four "takeaways" from their experience in the testbed. A WDTB meteorologist facilitated the discussion and put the final touches on the PowerPoint presentation, but the actual webinar was given by the visitors. After a 22minute presentation, 8 minutes was devoted to questions from the telecon audience. Questions were answered by the forecasters and the principle scientists that were present in the room.

After the webinar, the participants gathered for a group photo before adjourning and returning home.

3.4 Technology

The operational experiments were conducted in the HWT Operations Area, which is a room located between the forecast operations areas of the Norman, OK NWS Weather Forecast Office and the NWS Storm Prediction Center (Fig. 14). This room is equipped with a variety of technology to support real-time experiments:

Central to EWP2011 operations was an Advanced Weather Information Processing System (AWIPS) server that processed live radar from any WSR-88D location, and national satellite, lightning, upper air, surface, and mesoscale model data. The server ingested the live experimental data sets making them displayable from the AWIPS Volume Browser. There were also six workstations that could run the D2D display. The AWIPS system could be "localized" to any CONUS WFO. WarnGen was used by the forecasters to issue their experimental severe weather warnings.

For EWP2012, we upgraded our system to the new AWIPS2 system, added four more workstations, and

moved all of the CPUs out of the room which made the room gujeter and cooler. The NWC 3rd floor computer room contains the AWIPS2 server and workstation CPUs. The experimental grids are provided for viewing within the AWIPS2 Common AWIPS Visualization Environment (CAVE), mainly via the Volume Browser. The forecasters utilized the experimental data along with traditional weather data to issue mock products and warnings on AWIPS2. As with our old AWIPS system, the new AWIPS2 system can be set up to provide "virtual" operations for any WFO in the CONUS. At many times, we would operate as multiple WFOs at workstation pairs, so that we could look at more than one active weather area at a time. Besides live WSR-88D data, the AWIPS2 system provided live satellite, surface, upper air, lightning, and numerical model data, among other data sources.



Figure 14. Diagram showing the layout of the Hazardous Weather Testbed during EWP2012.

The Open Radar Product Generator (ORPG) servers are also located on the 3rd floor of the NWC. The ORPG servers have the capability of running up to ten live radar feeds from any CONUS WSR-88D.

Our experimental data sets run with up to a two-minute update rate and 1-km or 500-m resolution depending on the product. Because of this, we are still unable to support a full CONUS domain at this resolution. Therefore, we used five smaller sub-domains (Fig. 15). Four of the domains are fixed and centered on the four Lightning Mapping Array domains covering central Oklahoma/west Texas, northern Alabama, east-central Florida, and the Washington DC area. A fifth domain will "float" anywhere in the CONUS and be positioned each day over an area where storms are expected. There are also four "floating" 3DVAR domains (Fig. 16), which are smaller than the domains shown below. The OUN WRF domain (not shown) is slightly larger than the Oklahoma domain.

The EWP Situational Awareness Display (SAD) consists of seven large flat-screen monitors that display the output from any of the experiment workstations. A video server was used to display local television broadcasts and live storm-chaser video feeds. Other output, such as Google Earth images with radar and spotter overlays, and near-storm environment maps, were displayed when needed.



Figure 15: The Domain Launcher for EWP2011 and EWP2012. The orange rectangle is the "floating" domain which can be moved to any location over the CONUS. The other four domains are fixed over the Lightning Mapping Arrays.



Figure 16: The four movable 3DVAR domains shown as the four smaller boxes within the Domain Launcher. The larger orange domain is our "floater" as seen on Figure 15 (but zoomed in).

3.5 Communication and Outreach

There are several Internet resources used to communicate EWP information. The EWP Main Web site:

http://ewp.nssl.noaa.gov/

contains links to general information about the EWP, and results from past spring experiments.

Internal EWP web pages for each experiment year, accessible by experiment participants and NOAA employees (via their LDAP user accounts) are available at:

https://secure.nssl.noaa.gov/projects/ewp2011/

https://secure.nssl.noaa.gov/projects/ewp2012/

The internal pages include links to the operations plans and orientation/training information for each experiment, the online feedback survey, logistics information, and the EWP Blog:

https://secure.nssl.noaa.gov/projects/ewp/blog/

The EWP Blog was used to communicate the daily activities during the experiment. This included the daily weather briefing outlooks, post-mortem summaries (daily and weekly), as well as the live blogs that were recorded during the actual operations.

4. **RESULTS**

Results of the specific experiments tested during EWP2011 and EWP2012 will not be covered in this paper. Instead, the reader is asked to consult companion papers in this and other conferences. Summaries of the 3DVAR product feedback are provided by Calhoun et al. (2012). Summaries of the GOES-R proxy product feedback are provided by Goodman et al. (2012b). Summaries of the OUN WRF feedback are yet to be published.

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