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THE EXPERIMENTAL WARNING PROGRAM 2008 SPRING EXPERIMENT 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 National Severe Storms Laboratory (NSSL) researchers to test new science, technologies, products, and services designed to improve short-term (0-2 hour) warnings and nowcasts of severe convective weather threats (Stumpf et al. 2005). 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. Although the EWP is physically located in Norman, OK, it is intended to be a national testbed, with planned capabilities to simulate the technological environment of any WFO nationwide[1].

The EWP conducted its second formal Spring Experiment during a six week period in 2008 at the National Weather Center in Norman, OK. There were three primary projects geared toward WFO severe weather warning operations, 1) an evaluation of the rapidly-updating phased array radar in Norman, 2) an evaluation of a high-density network of 3-cm radars in Central Oklahoma, and 3) an evaluation of experimental high temporal and spatial resolution gridded probabilistic hazard information.

The NSSL has played a key role in the development and evaluation of applications and technology to improve NWS severe convective weather warning operations. The development process at NSSL begins with basic and applied research including field experiments, theoretical studies, and case studies designed to better understand storms and relate weather to remotely sensed signatures. This research leads to the development of technological applications, including computer algorithms employing sophisticated image processing and artificial intelligence, and innovative display systems [e.g., the Four-dimensional Stormcell Investigator (FSI; Stumpf et al. 2006)], and NSSL leads the path in new Doppler radar technologies.

The spring experiment was designed to gather feedback from visiting operational meteorologists. Evaluations were conducted using archived case studies as well as real-time proof-of-concept tests at the HWT facility during actual severe weather warning operations. User comments were collected during shifts, short surveys were given at the end of shifts, and discussions occurred during post-mortem de-briefings. Input from NWS operational meteorologists is considered vital to the improvement of the NWS warning process, which ultimately saves public lives and property. The interaction between scientists and operational meteorologists will provide a synergy that will lead to improvements in future products. The NWS feedback on this test is most important for future development for the NWS and eventual implementation of new application, display, and product concepts into AWIPS2 and other operational systems.

The primary objectives of the 2008 EWP Spring Program can be summarized as follows:

- To evaluate the accuracy and the operational utility of new science, technology, products, and concepts in a testbed setting in order to gain feedback for improvements prior to their potential implementation into NWS severe convective weather warning operations.
- To provide forecasters with direct access to the latest developments in meteorological research while imparting scientists with the knowledge to formulate research strategies that will have practical benefits for operations. The Hazardous Weather Testbed serves as a primary vehicle for transitioning new research, knowledge, and concepts into NWS operations.
- To help researchers and developers to understand operational forecast and warning requirements, and to improve warning accuracy and services.

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[1] Note that the HWT also includes an Experimental Forecast Program (EFP), which is concentrated on transitioning new research into operations in the Storm Prediction Center (SPC). More information about the EFP 2008 spring experiment is at http://hwt.nssl.noaa.gov/Spring_2008/index.html

This manuscript will provide information about the three specific experiments conducted in 2008, a description of the experiment logistics, and a discussion about future EWP activities.

2. SPECIFIC EXPERIMENT DETAILS

2.1 National Weather Radar Testbed Phased Array Radar (NWRT PAR)

The Weather Surveillance Radar – 1988 Doppler (WSR-88D) network is approaching its operational 20-year lifespan. A number of possible replacements to the existing radar network are currently under development and testing. The NWRT supports an experimental single-face phased-array radar that was originally part of a Navy ship aircraft tracking system. The single-face antenna can scan a 90° sector, and is on a rotating platform which can be steered and parked to sample high-interest areas. This S-band PAR is located in Norman, Oklahoma, and has an operational range covering a large portion of Central Oklahoma (Heinselman 2008). Figure 1 shows sample PAR data collected during one of the 2008 events.

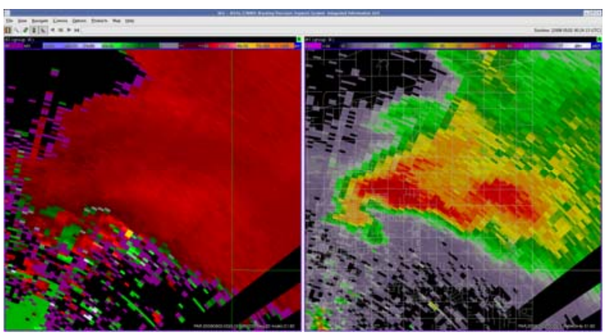

Figure 1. Phased-Array Radar (PAR) data (left: radial velocity, right: reflectivity) from a supercell on 7 May 2008 in Central Oklahoma

The advantages of PAR technology include:

- Rapid collection of volumetric data by the electronically-steered antenna (up to ten times faster than conventional WSR-88D).
- Custom adaptable scan strategies that can be used to sample high-interest areas with more repetition and denser coverage.
- Multi-purpose use besides weather surveillance (e.g., cooperating and non-cooperating aircraft tracking).
- A future four-face system will have no moving parts, meaning lower operation and maintenance costs.

The visiting forecasters evaluated the operational utility of PAR technology using archive cases and during real-time operational warning situations within central Oklahoma. The archive cases included weather events more common to regions outside the Southern Plains, including wet microbursts and tropical-cyclone min-supercells. Forecasters completed questionnaires intended to meet these objectives:

- Assess the strengths and limitations of PAR data (as compared to WSR-88D) in the analysis and understanding of severe storms.
- Determine how using PAR data to make warning decisions impacts warning decision-making.
- Comment on how PAR data may be of benefit to NWS operational responsibilities and to the public.

2.2 Collaborative Adaptive Sensing of the Atmosphere (CASA) radar network

Another possible replacement or augmentation to the existing WSR-88D radar network includes collaborating dense networks of low-cost, low-power, X-band radars with overlapping coverage that can observe the lower troposphere with high spatial and temporal resolution (Philips et al. 2009). The networked radars work together using algorithms which help steer the radars in order to provide coverage of high-interest regions from multiple viewing angles based on specific user requirements. The radars also can be used to fill in the unobserved altitudes below the WSR-88D viewing horizons to provide details of the boundary layer.

The CASA project deployed an experimental 4-node radar network in southwest Oklahoma situated between two operational WSR-88D radars at Twin Lakes and Frederick (Fig. 2).

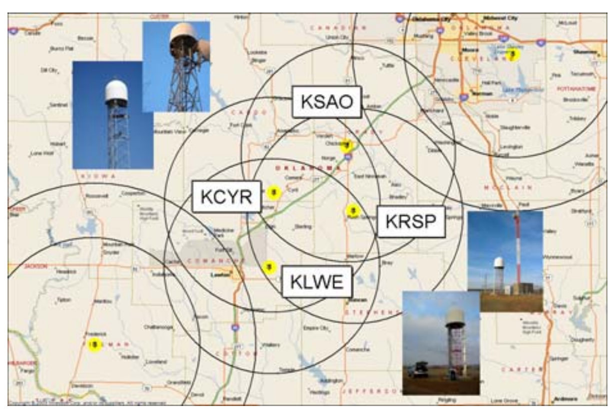

Figure 2. Map showing the location of the four CASA radars in southwest Oklahoma (KSAO: Chickasha, KCYR: Cyril, KRSP: Rush Springs, KLWE: Lawton East).

The visiting forecasters evaluated the operational utility of CASA technology within this operational network during real-time operational warning situations in southwest Oklahoma as well as through playback of archived cases. Forecasters completed questionnaires intended to meet these objectives:

- Evaluate how CASA reflectivity and velocity data may help the severe weather warning process.

- Evaluate the strengths and limitations of CASA's technical capabilities, including:

    - High resolution data
    - Lower troposphere coverage
    - Rapid volumetric refresh rate
    - Adaptive scanning strategies

- To evaluate the potential benefits of NWP forecasts that incorporate CASA data for warning operations.

- To assess how forecaster might incorporate real time 3DVAR-derived wind products into warning decision making (Fig. 3).

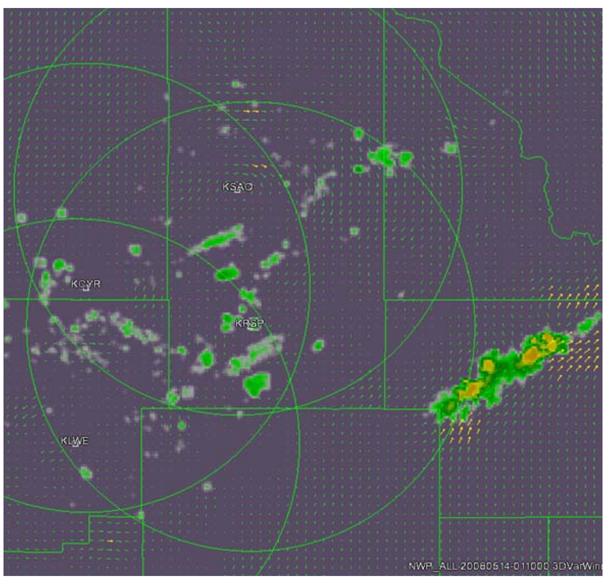

Figure 3. Output from the 3DVAR wind analysis incorporating CASA and WSR-88D radar data, from 14 May 2008 over southwest Oklahoma.

2.3 Probabilistic Hazard Information (PHI)

This experiment is designed to assess the concept of rapidly-refreshing high spatial and temporal resolution gridded probabilistic hazard information as the basis for next-generation severe weather warnings (Kuhlman et al. 2008). This concept is seen as the next step toward a future "Warn-On-Forecast" concept in which storm type and behavior statistics and numerical ensemble models will be used to help create probabilistic guidance about severe weather threats in time frames between today's typical NWS warning lead-times (approximately 10-15 minutes) and probabilistic convective weather watches and outlooks (4-6 hour lead-times). From these grids, it is envisioned that a variety of user-specific threat alerts could be derived across a variety of users' sophistications. These can range from high-resolution probabilistic point-warning trends which include times of arrival and departure for multiple threats, all the way down to the polygon- or county-based warnings similar to today. These hazard products could be customized to meet the needs of specific users to address their individual response times and exposure to the hazard, versus the current one-size-fits-all approach to severe weather warnings.

The PHI experiment is a multi-year project in its early stages, and forecasters are being tapped for their feedback in the early stages to help give direction. For the first stage of the project, forecasters were asked to provide their own values of probability within the hazard grids. Eventually, as the science matures, we envision that a combination of statistical and numerical probabilistic guidance will be available to provide more meaningful assistance to forecasters producing severe weather hazard information to users.

The EWP infrastructure allowed for the evaluation of the PHI concept anywhere within the Continental United States (CONUS). Therefore, real-time PHI exercises were conducted during periods of quiet weather in Oklahoma when PAR and CASA operations were not anticipated. The evaluators produced probabilistic grids for severe hail, thunderstorm winds, and tornadoes using real-time radar data, experimental CONUS multiple-radar/sensor algorithm output from the NSSL Warning Decision Support System – Integrated Information (WDSSII; Hondl et al. 2007, Lakshmanan et al. 2006), and state-of-the-art systems which can share spotter reports and live video images of ongoing severe weather. In addition, each forecaster individually participated in a two-hour exercise on a single archive case (a supercell event in North Dakota) so that statistics could be collected in order to analyze the distribution of warning decisions given the same event. Figure 4 shows sample PHI output from and operational event.

Forecasters provided feedback during shifts and during post-mortem discussion intended to meet these objectives:

- Provide feedback on the science of adding probabilistic information to warnings, how various probabilities might be determined by forecasters with the aid of statistical and numerical guidance, and how these probabilities might eventually blend with larger scale severe weather probability outlooks.

- Qualitatively evaluate the management of warning team workload in the issuance of rapidly-refreshing gridded hazard information.

- Assess the scientific and technological concepts as part of the requirements phase for the NWS Next-Generation Warning Tool (NGWT).

- Evaluate the concept of continuously-refreshing probabilistic hazard grids on warning time and space scales, and how these grids may be of benefit to the broad spectrum of users of severe convective weather hazard information.

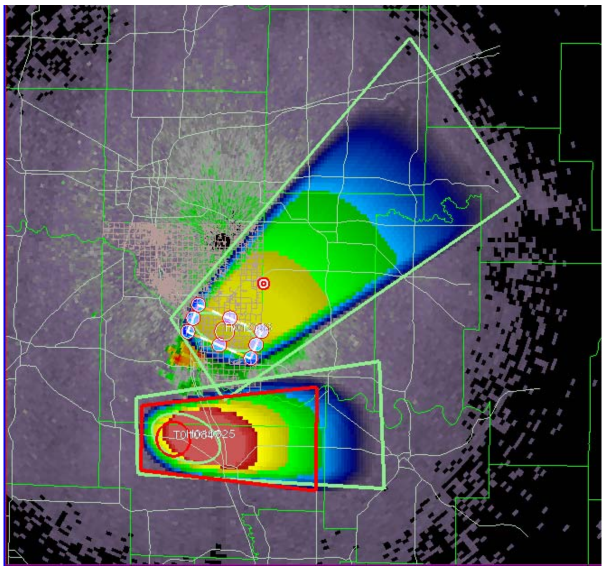

Figure 4. Probabilistic Hazard Information (PHI) hail grids (shaded rainbow colors), PHI hail and tornado polygons (mint green and red polygons), and KTLX reflectivity (green and grey background grid) for the 21 April 2008 operational event in central Oklahoma.

3. EXPERIMENT LOGISTICS

3.1 Participants

Twenty NWS forecasters representing five of the six NWS Regions participated in the experiment (Eastern, Central, Southern, Western, Alaska). In addition, six foreign meteorologists participated (Canada, Serbia). Figure 5 shows the geographic distribution of the participants' home locations. The visiting forecasters assumed the role of evaluators for each of the three experiments. Their operational expertise was tapped in order to provide constructive criticism of any aspect of the experiment. Figure 6 shows EWP participants evaluating CASA data.

The EWP management team consisted of an Operations Coordinator responsible for the 2008 spring experiment logistics, an Information Technology Coordinator, 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 responsible for the day-to-day scheduling of operations, and led the pre-shift weather briefings and post-shift discussions. Cognizant scientists for each of the three experiments (PAR, CASA, and PHI) were available during archive playback and real-time shifts 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 5. Home locations of the EWP forecaster participants, overlaid on Google Earth™.

Figure 6. Visiting forecasters evaluating CASA data during real-time operations in the EWP.

Besides the NWS WFOs and the NSSL, the organizations represented included the NWS Meteorological Development Laboratory, the NWS Warning Decision Training Branch, and several universities (University of Oklahoma, University of Massachusetts, University of Delaware, and University of Virginia), with these personnel participating in various roles.

3.2 Operations Statistics

The operational experiment was conducted across the six-week period from 28 April 2008 through 6 June 2008. A fresh set of forecaster participants was available for each one-week period. A one-week shakedown period in which in-house personnel played the roles of participants was conducted in the week prior to the official start of the experiment.

Operational activities took place during the week Monday through Thursday (Tuesday – Thursday during the Memorial Day week) within a fixed 1-9 pm shift. Each operations day began with a weather briefing which included a post-mortem discussion of the previous day operations, a discussion of the severe weather outlook for the current day, and the schedule for the current day operational shift (e.g., training periods, choice of experiments, archive and/or real-time cases, etc.). On the first experiment day of each week, several project orientation seminars were delivered, and WDSSII hands-on training was given. An end-of-week two-hour summary debriefing took place each Friday morning from 10am-12pm. This debriefing was instrumental in gathering and summarizing the overall feedback from the participants, and recorded in the "EWP Blog" (see section 3.4).

Most operational days included a 3-4 hour Intensive Operations Period (IOP) where the forecasters were immersed in evaluations of the three experiments on live data in a simulated severe weather warning environment. When severe weather was occurring within Central Oklahoma, the PAR and CASA experiments were the primary focus. When storms were elsewhere in the CONUS, the gridded probabilistic warning experiment was conducted. There were 23 IOPs conducted, 19 of which were conducted with live data (6 PAR events, 2 CASA events, and 15 PHI events). Figure 7 shows the geographic location of the 15 PHI operational events.

Outside of the IOPs, the forecasters worked with cognizant scientists to review archive cases, sometimes in a simulated displace real-time setting. Feedback was obtained from the forecasters during live and archive playback operations through the use of written surveys, voice recording, discussions during the shifts, and during post-mortem debriefings conducted daily and at the end of the week. Some of this feedback was recorded in the "EWP Blog".

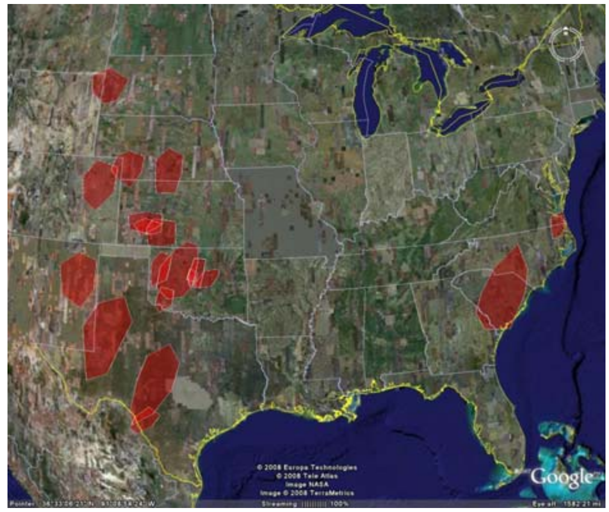

Figure 7. Geographic location of the 15 real-time PHI domains during the course of the EWP 2008 spring experiment (red), overlaid on Google Earth™.

3.3 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. This room is equipped with a variety of technology to support real-time experiments with visiting forecasters and researchers (Fig. 8). These included:

- *Experiment Stations:* There were three sets of two Linux workstations to support the three individual experiments (PAR, CASA, and PHI). When needed, however, any workstation could be used as secondary support to any of the other two experiments.

- *Situational Awareness Display (SAD):* A combination of plasma and LCD monitors that could display the output from any of the experiment workstations. In addition, 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. The SAD was visible to all three experiment stations (Fig. 9).

- *Advanced Weather Information Processing System (AWIPS):* Central to all of the three experiment stations was a NWS AWIPS workstation running the latest operational build (8.3) at the time. This workstation was assisted by an AWIPS server especially customized for the HWT to be able to process the live radar data streams for any Weather Forecast Office (WFO) in the CONUS. In addition, satellite, lightning, upper air, surface, and mesoscale model data were available.

- *Warning Decision Support System-Integrated Information (WDSSII):* Each workstation ran the NSSL WDSSII 3D display software (the basis for the Four-dimensional Stormcell Investigator), which was the primary software used to display the custom data sets being analyzed by the participants. The WDSSII display was also used by forecasters to create the probabilistic hazard information grids. Each workstation could also log onto the AWIPS workstation so that the AWIPS display could be remotely used side-by-side with the WDSSII display software. This was particularly useful as the NWS participants were more familiar with the AWIPS display for storm interrogation. In addition to the WDSSII display, experimental CONUS multiple-radar/sensor severe weather algorithms were available (Lakshmanan et al. 2006). These included the gridded hail diagnosis and "rotation tracks" algorithms (Manross et al. 2008).

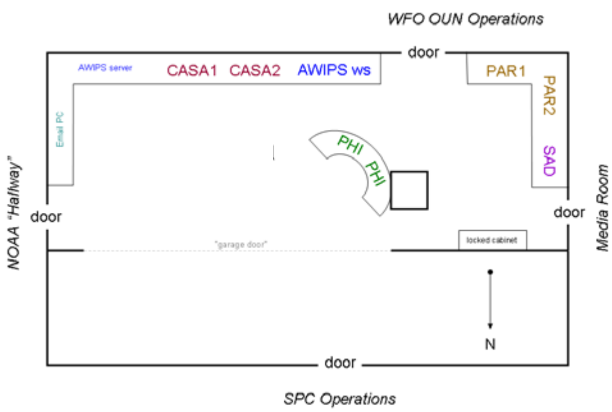

Figure 8. Diagram showing the layout of the Hazardous Weather Testbed Experimental Warning Program during the 2008 spring experiment.

3.4 Communication and Outreach

There were several Web resources used to communicate information regarding the EWP. The EWP Main Web site:

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

contains links to general information about the EWP, results from the 2007 experiment, and when available, results from the 2008 experiment. This web site is publically available.

An internal EWP web page, accessible by experiment participants and NOAA employs (via their LDAP user accounts) is available at:

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

The internal page includes links to the operations manuals and orientation PowerPoint briefings (overall, PAR, CASA, and PHI), the daily shift schedules, 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 "live blogs" that were recorded during the actual operations.

Figure 9. The EWP Situational Awareness Display (background top), the PAR experiment stations (background bottom), and the PHI experiment station (foreground).

4. CONCLUSIONS

Some very useful feedback was obtained from the forecaster participants during the experiment. Some of this feedback is still being analyzed by the experiment cognizant scientists, and is or will be reported elsewhere (Heinselman 2008, Philips et al 2009, Kuhlman et al. 2008). A few highlights:

- Very high temporal resolution data from PAR and CASA will radically change the concept of real-time radar data analysis (volume scans can be up to 10 times faster than the WSR-88D).

- Participants saw the potential usefulness of the Probabilistic Hazard Information concept, but it requires a stronger scientific and statistical baseline from which to derive probabilities than was available in this initial demonstration. Additionally, sociological research will be required to turn scientifically-based probabilistic hazard information into NWS products that a wide variety of end-users can understand and use.

- Data sets should be made available in AWIPS (and soon, AWIPSII) as it is the standard NWS software platform whose user interface is familiar with most visiting forecasters.

- The experimental WDSSII CONUS Multi-radar/sensor severe weather products, such as the gridded hail and "rotation tracks", were very beneficial in providing warning decision guidance, and there was a strong consensus that they should become operational.

Following the spring experiment, the experiment scientists conducted an offsite retreat to review the outcome and to begin planning for 2009 activities. At the time of this publication, there still exists some uncertainty with the plans for 2009. All three experiments conducted in 2008 may be repeated in some fashion in 2009. We may include total lightning and hydrometeorological components to the EWP. We are also considering not limiting our experiment period to the spring season, in order spread out our resources year round. In addition, the Verification of the Origins of Rotation in Thunderstorms EXperiment II (VORTEX II) will be conducted during the springs of 2009 and 2010. That large experiment will consume some of our labor and facility resources, and may require us to "work around" their schedule.

We have also begun to explore collaboration with social scientists. The EWP hosted an Advanced Weather and Society Integrated Studies (WAS*IS) workshop in September 2008 (Gruntfest et al. 2009).

http://ewp.nssl.noaa.gov/wasis2008/

This workshop was designed to bring together research meteorologists at the EWP with a group of stakeholders representing a diverse user community, to integrate societal impact research at the beginning stages of the development of new gridded probabilistic hazardous weather information. The objectives of the workshop were to:

- Introduce new technologies/directions to a diverse spectrum of potential future collaborators,

- Define and address the needs of a broad spectrum of end-users,

- Clarify and suggest new ways to communicate uncertainty and storm information via emerging technologies,

- Define new measures of success to properly assess service, including changing concepts of storm verification including close calls and false alarms,

- Provide suggestions for the evolution of the Experimental Warning Program, designing spring experiments with stakeholders goals,

- Develop ideas for new ways to change the culture within all levels of the National Weather Service to facilitate operational implementation of these concepts, and

- Create visibility and consider possible future funding opportunities for Hazardous Weather Testbed activities and stakeholder interactions.

Future EWP activities may include non-meteorological evaluations of new technologies and operations concepts and products, in order to make the transition to operations even more socially relevant. We also envision that these evaluations will begin to cross the gap between the warning and forecast scales (WFO and SPC operations, respectively) as we move toward a future of seamless integration of weather hazard information across all time and space scales.

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