1.3 **Implementation of the WFO Tulsa Vision for Local Impact-Based Decision Support Services**

Karen A. Hatfield*, Edward J. Calianese, Steven F. Piltz,
James M. Frederick, J. Brad McGavock, Mark E. Plate
NOAA/National Weather Service Tulsa, Oklahoma

1. Introduction

With the National Weather Service's (NWS) increased focus on providing Impact-Based Decision Support Services (IDSS; NWS, 2013) to core partner groups, discussion and planning has occurred across the agency concerning how best to accommodate the increased workload within the existing staffing framework while still producing accurate, consistent forecast information. Much of the dialogue has focused on streamlining the daily forecast process to afford extra time for or the ability to reconfigure office forecast operations to devote a full staffing position to IDSS duties.

Since at least the mid-2000's, meteorologists at the NWS Weather Forecast Office (WFO) in Tulsa, Oklahoma, have undertaken efforts to also simplify the IDSS process by connecting it directly to the forecast process. By creating a direct connection between the gridded forecast database and IDSS, forecasters routinely distribute hazardous weather information in multiple non-traditional formats while also placing a more traditional focus on the forecast itself. This also ensures consistency among a variety of communication methods, including dynamic web pages, briefing packages, video recordings, and text products. With this vision, effort placed into crafting a good forecast naturally and efficiently results in good IDSS.

To accomplish the vision, WFO Tulsa meteorologists developed numerous in-house tools that allow forecasters to provide a suite of IDSS, ranging from venue-specific to broader-scale needs, by leveraging information contained in the gridded human forecast data and various observational and model forecast datasets. These tools include the Decision Support Page (DSP; Sondag, et al., 2005) and Outdoor Hazards Monitor and Response System (OHMARS) webpages; both webpages require little additional non-routine forecaster intervention to produce updated output, as information updates when the gridded forecast, observational, or model data change. Other tools, including an advanced Hazardous Weather Outlook (HWO) text formatter, a briefing package generator, and graphics templates, offer a reasonable head start toward complete information delivery, allowing more effort to be expended toward the addition of information supplemental to the gridded forecast, such as impact-specific timing and messaging.

This paper will provide an overview of the WFO Tulsa IDSS toolset, including details on the individual tools, a discussion of the importance of accurate forecast data to the tools' success, and an examination of the WFO Tulsa IDSS philosophy's operational success during the 13-14 January 2017 ice storm.

* *Corresponding author address:* Karen A. Hatfield, 10159 E. 11th St. Suite 300, Tulsa, OK, 74128; e-mail: Karen.Hatfield@noaa.gov

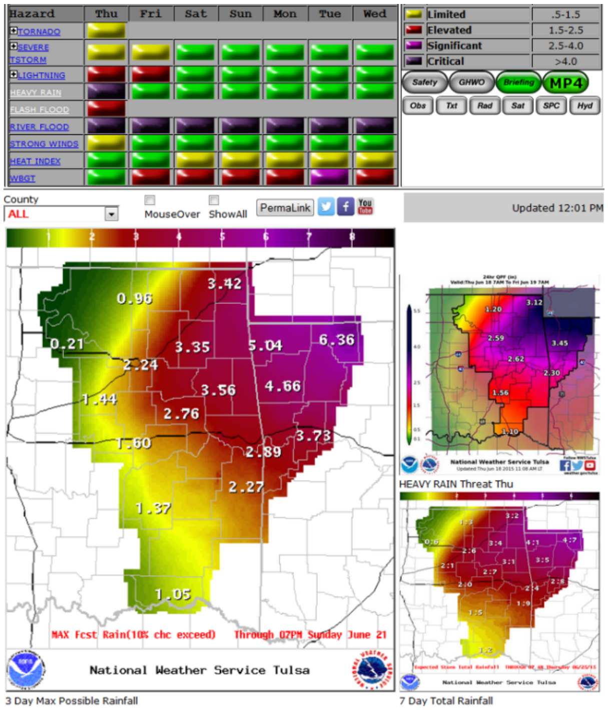

Figure 1. Example of the DSP.

2. DSP

The DSP (Figure 1), initially developed and implemented in 2004-2005 and redesigned in 2009, is a dynamic webpage created to quickly and efficiently convey daily threat levels of specific weather hazards to core partners by directly sourcing gridded forecast information contained in the Official database within the Graphical Forecast Editor (GFE) on AWIPS-II. Besides being a standalone communication tool, the DSP also serves as the backbone for much of the off-site IDSS provided by WFO Tulsa, including web and social media graphics, briefing packages, and even the more traditional HWO text product.

a. Functionality

The DSP is located at http://www.weather.gov/tsa/dsp, and in its present format, is divided into two main content areas: the Hazard Table and the Main Graphics Area.

The Hazard Table highlights seven days of weather threats by day and hazard via color coded buttons corresponding to one of five threat levels: Nil (Green), Limited (Yellow), Elevated (Red), Significant (Pink), and Critical (Purple). Table 1 lists the thresholds assigned to each threat level by hazard, as well as the weather element(s) used to gauge the overall threat. Many of the thresholds are based on Watch/Warning/Advisory criteria for the WFO Tulsa County Warning Area (CWA) and known local impact points. A single day on the Hazard Table encompasses the 24 hours bounded by 1200 UTC on the day listed and 1200 UTC on the subsequent day, consistent with the definition common to national outlook products and guidance.

The Hazard Table is organized such that a decision maker can answer the critical questions of What?, When?, and How Bad? regarding upcoming weather, simply by scanning the table. The table defaults to showing only those hazards meeting at least the Limited threshold anywhere in the WFO Tulsa CWA on at least one day; however, a user can downscale the area of interest by selecting a single county from a dropdown menu immediately below the table, thereby helping to narrow down the other critical question of Where? All "Nil" hazards can also be displayed by clicking a radio button.

Besides providing a quick look at potential weather and hydrologic impacts, the Hazard Table also controls the three graphics displayed in the Main Graphics Area, which is found below the table. The default graphics include a hand-drawn graphical HWO (gHWO) and a forecast image corresponding to each of the hazards containing the two

Hazard	Weather Element(s)	Thresholds				
		Nil	Limited	Elevated	Significant	Critical
Tornado*	Probability of a Tornado Warning	< 2%	2%-10%	11%-40%	41%-80%	> 80%
Severe Thunderstorm	Probability of a Severe Thunderstorm Warning	< 5%	5%-20%	21%-40%	41%-70%	> 70%
Lightning	Probability of Lightning	< 15%	15%-30%	31%-60%	61%-90%	> 90%
Heavy Rain	24-Hour Rainfall	< 0.50”	0.50”-1.50”	1.50”-2.50”	2.50”-4.00”	> 4.00”
Flash Flood*	Probability of a Flash Flood Warning	< 5%	5%-25%	26%-60%	61%-80%	> 80%
River Flood	24-Hour Rainfall, River Stage Forecasts	None	>2.00” rain, Action Stage	Minor Flood Stage	Moderate Flood Stage	Major Flood Stage
Strong Winds	24-Hour Maximum Wind Gust	< 25 mph	25-39 mph	40-58 mph	59-70 mph	> 70 mph
Fire Danger	Spread Index	< 30	30-43	44-63	64-80	> 80
Snow	24-Hour Snowfall	< 0.1”	0.1”-1.0”	1.1”-4.0”	4.1”-8.0”	> 8.0”
Ice	24-Hour Ice Accumulation	< 0.01”	0.01”-0.25”	0.26”-0.75”	0.76”-1.50”	> 1.50”
Wind Chill	24-Hour Minimum Wind Chill	> 10°F	0°F - 10°F	-5°F - -1°F	-10°F - -6°F	< -10°F
Visibility	Fog	None	Patchy	Patchy Dense	Areas Dense	Widespread Dense
Heat Index	24-Hour Maximum Heat Index	< 100°F	100°F-104°F	105°F-109°F	110°F-115°F	> 115°F
Wet Bulb Globe Temperature	24-Hour Maximum Wet Bulb Globe Temperature	< 83°F	83°F-86°F	87°F-90°F	91°F-93°F	> 93°F
Air Quality*	Ozone Alert	None	N/A	Ozone Alert in effect	N/A	N/A

Table 1. Hazard-specific threat level thresholds. (* Indicates threat level only assigned for Day 1.)

highest threat levels over the next seven days. Clicking the color coded buttons in the table changes the visible graphics to images pertinent to that specific hazard and day, thereby providing additional detail. For example, clicking Monday’s Severe Thunderstorm button will display forecast maps of the 24-Hour Probability of a Severe

Thunderstorm Warning, the Maximum Expected Hail Size, and the Maximum Surface Wind Gust, all forecast between 1200 UTC Monday and 1200 UTC Tuesday.

In addition to the display controls offered by the Hazard Table, other dropdown menus located to the right of the table populate the large frame of the Main Graphics Area with Storm Prediction Center outlooks, radar and satellite data, and current surface observations, as well as locally-produced convective mesoanalysis data (McGavock, et al., 2006b) and short-term (one to two-hour) lightning and severe thunderstorm forecasts (Frederick, et al., 2015).

b. Determining the Threat Levels and the Forecaster's Role

The hazard threat information results from a combination of observational, model, and human-generated weather information. The threat levels can change anytime a forecaster makes an update to the gridded forecast, new model data are available, or observational data are incorporated into the near-term gridded forecast. DSP updates are automatically forced via a cron job once an hour for all hazards except the convective ones, which update every 10 minutes.

Many of the hazards' threat levels, such as those for Lightning, Wind Chill, and Strong Winds, are controlled by weather elements already contained in the official human-generated gridded forecast produced by every WFO. Others, such as those for Wet Bulb Globe Temperature (Dimiceli, et al., 2011) and Fire Danger, are calculated by combining official human-generated gridded forecast fields to populate locally-added non-standard weather elements (Amburn, et al., 2006). The obvious hazards that do not fall into either of these cases are the Tornado and Severe Thunderstorm hazards.

Both the Tornado and Severe Thunderstorm hazard threat levels are evaluated by calculating the Probabilities of a Tornado or Severe Thunderstorm Warning issuance in the 24-hour period of interest (McGavock, et al., 2006a). The warning probabilities result from the product of a gridded forecast of Lightning probability and a separate gridded forecast of Conditional Tornado or Severe Thunderstorm probabilities. While the Lightning probability can be easily extracted from the already available "Wx" gridded forecast, the Conditional Severe Thunderstorm probability is a locally-added non-standard field populated through a combination of human-generated gridded forecast elements (namely temperature, dew point, and wind) and computer model upper level data. Forecasters have some control over the conditional probability output, and thus, the total warning probability, through hand edits (primarily during the Day 1 period) and tools that govern which model(s) supply the upper level information. The procedure for determining the Conditional Tornado probability is less advanced, requiring forecaster hand edits to populate the grid; however, the conditional probability is initialized with percentages based on those in the Storm Prediction Center's Day 1 Tornado Outlook, if any nonzero values are present.

For the DSP to function in its present state, added workload for the forecast staff is largely limited to the Conditional Tornado and Severe Thunderstorm probabilities and thus, the Tornado and Severe Thunderstorm threat levels. Given the abundance of mesoanalysis and storm-scale model data available, keeping these grids fresh leading up to and during a

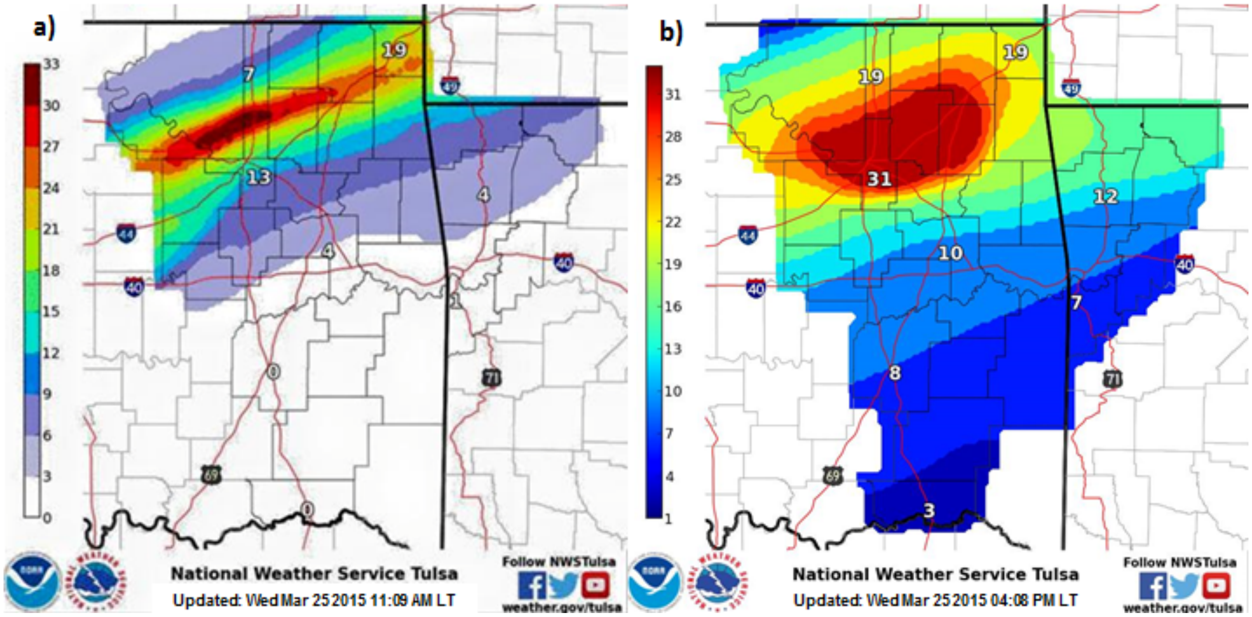

Figure 2. Probability of a Tornado Warning forecasts from 25 March 2015 preceding the Sand Springs, Oklahoma, EF2 tornado, produced at a) 11:09 am LT and b) 4:08 pm LT. The tornado initially developed at 5:21 pm LT.

convective event can admittedly become a more time-consuming task than the small number of forecast grids would indicate. However, the extra effort has produced notable successes; for example, on 25 March 2015, forecasters increased the Tornado threat level near the I-44 corridor several hours in advance of an EF2 tornado that struck Sand Springs, Oklahoma, giving local emergency management time to prepare for the potential well ahead of the tornado (Figure 2).

c. Utilization in Alternate Forms of IDSS

The vast amount of data accumulated on the DSP can aid forecasters in supporting core partners via communication methods beyond the web interface. Additional locally-developed tools allow forecasters to more efficiently produce HWOs, briefing slide packages, and gHWOs by exploiting the information from the DSP.

i. HWO. The HWO text product, routinely issued by many NWS WFOs, outlines the expected weather hazards through the upcoming 7-day forecast period. It is disseminated to core partners via several methods, including NOAA Weather Radio, text message, and e-mail.

The product is segmented into sections containing discussions of Day 1 hazards and Days 2 through 7 hazards. By leveraging the data contained in the gridded weather elements used to determine hazard threat levels for the DSP, the product text formatter initializes some details in the HWO rather than relying on the forecaster alone to supply the information. Notably, the formatter automatically lists the threat levels of all non-Nil threat hazards in the Day 1 period and also, any hazards reaching a hazard-specific threat level in the Days 2 through 7 period (i.e., at least an Elevated Severe Thunderstorm threat level is mentioned, as is at least a Limited Snow threat level).

ii. Briefing Package. WFO Tulsa forecasters create a briefing slide package every weekday morning and as necessary on weekends detailing the hazardous weather through the next seven days. Distribution methods include routine posting to the office website, office-wide staff e-mail, and when conditions warrant, core partner e-mails. The basic slide package provides a foundation for consistent messaging of significant events, allowing others to tailor the slides according to the final audience and/or purpose (i.e., video conference calls and multimedia web briefings).

In the past, the DSP was utilized simply as a guide to assembling a briefing package; now, a locally-developed script is used to directly source the data contained in the DSP to provide a more efficient start to a total briefing package. The script builds a slide for every single-day non-Nil threat level hazard on the DSP, featuring a customized slide title and hazard appropriate graphics. In addition, the script scans the latest Zone Forecast Product and Fire Weather Forecast text products for any long-fused watches, warnings, or advisories in effect and creates additional slides as warranted.

The briefing package generator does not create a final product but makes the overall process quicker and more efficient. Information on multiple slides can often be manually consolidated on a single slide. Additional graphics and text descriptions to better focus the threat timing, for instance, frequently add value to the information automatically presented. Any ongoing river flooding must also be included manually, although work is currently in progress to automate this.

iii. gHWO. The gHWO, manually created each morning and updated through the day as needed, emphasizes the most hazardous expected weather event over the upcoming 7-day period. The graphic is prominently featured on the DSP by default, distributed via social media, and occasionally included in multimedia web briefings and briefing slide packages. Due to its location on the DSP, the information covered in the gHWO is intended to enhance, rather than replicate, DSP data; as a result, the intended audience is a more knowledgeable user than the general public. Graphics templates, organized by DSP hazard type and day, have been developed to keep the audience and added value goals in mind. The templates serve to increase the efficiency of the design process and reinforce the consistency of the overall office message.

3. OHMARS

OHMARS was developed in 2005 from a collaborative effort between WFO Tulsa and a county emergency management director responsible for ensuring the safety of large crowds at an outdoor venue in his jurisdiction. It was originally developed to make the DSP point-specific with an increased time-density and was used as a tool to help provide enhanced weather decision support to emergency management and first responders working large outdoor venues. OHMARS has since evolved to include the ability to display thunderstorm probability “petals”, HYSPLIT output, and short-term warning probability graphics from the WFO Tulsa gridded forecast database. It is a highly dynamic and interactive situational awareness display that can be easily modified for different venues.

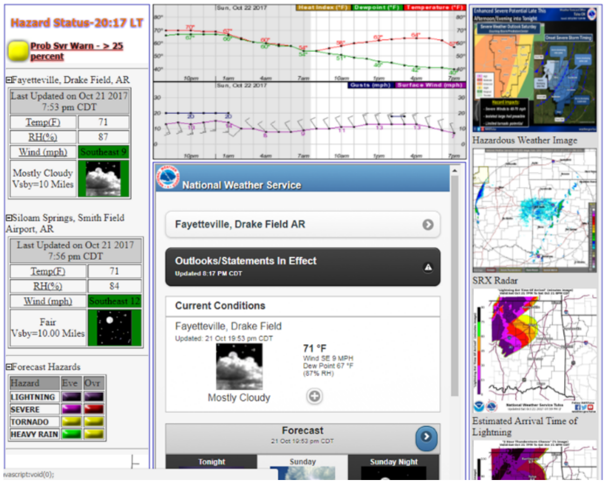

Figure 3. Example of OHMARS. Here, OHMARS is point-specific to Donald W. Reynolds Razorback Stadium in Fayetteville, Arkansas, in support of Washington County Emergency Management operations during University of Arkansas home football games.

OHMARS (Figure 3) fulfills the need to be able to effectively monitor and compare point-specific observed data (e.g. lightning data, heat index values, wind measurements from nearby observing systems, and NWS warning polygons), as well as forecast meteorological parameters (e.g. 2-hour thunderstorm probability and wind gust forecasts in the WFO Tulsa gridded forecast database), against predetermined action stages (thresholds) for a variety of hazardous weather. These critical impact thresholds are based on the venue's emergency operations plan (EOP). If these predetermined action stages are met with either observed or forecast weather data, OHMARS produces an audio and visual alert that indicates a threshold has been met and a predetermined action (based on the EOP) is required.

Alerts are triggered by OHMARS for near-term, imminent weather threats that may reflect an immediate need to shelter venue attendees, such as threats from lightning or damaging thunderstorm outflow wind. Alerts could be also triggered for longer term threats whose high probability of occurrence requires raising awareness for possible later sheltering, such as a severe thunderstorm or lightning threat developing an hour or two upstream from the venue. Some of these longer term alerts may be based on the WFO Tulsa short-term gridded forecasts, which for example, may indicate the probability of Tornado or Severe Thunderstorm Warning issuance that exceeds the predetermined threshold for the venue. These probability forecasts attempt to bridge the gap between a watch and a warning, and hourly adjustments of these probability grids by WFO Tulsa forecasters provide useful trend information regarding the overall threat to the venue. Longer term alerts could also be based on thunderstorm probability petals, which are produced by locally-derived algorithms that output a probability plume based on lightning data (where is the storm now) and the storm motion grid (where is the storm likely to move and how quickly).

OHMARS also assists WFO Tulsa IDSS meteorologists in keeping up with a large amount of weather data, maintaining an awareness of specific alert thresholds, and determining distance and timing of hazardous weather to the venue. It allows for quick identification of weather hazard threats and assessment of the hazard risk through color-coded alerts. One quadrant of the OHMARS display is dedicated to showing the status of all hazard alerts that are currently being met for the venue. Other quadrants display current weather data from nearby surface observation sites. Real-time lightning data are continuously monitored and are plotted in one of the quadrants. Radar data from the nearest WSR-88D are animated in one quadrant,

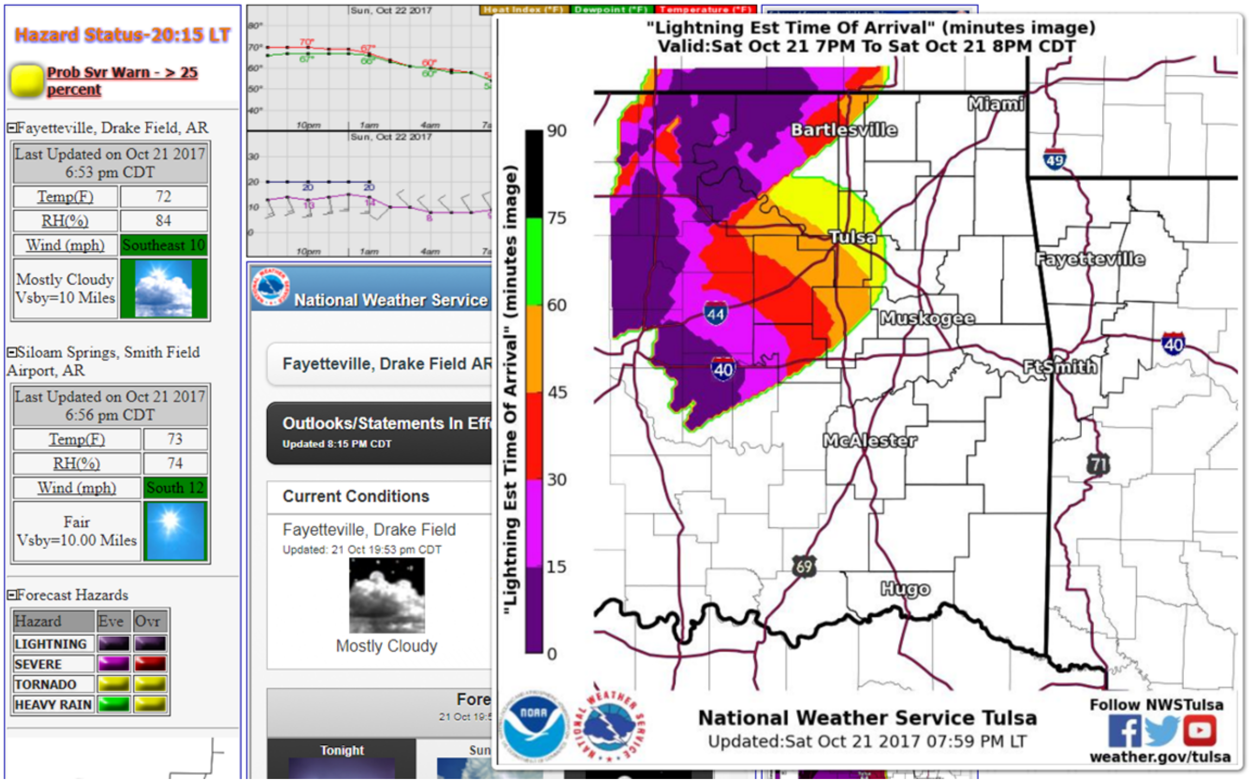

Figure 4. Example of OHMARS, showing the locally-produced Estimated Minutes Until Lightning Arrival graphic from 21 October 2017.

while the current gHWO is displayed in another. In one panel, forecast hazards are displayed in a form similar to the DSP, with each weather hazard broken into 6-hourly time steps through 24 hours. Two graphical products based on the locally-produced thunderstorm probability plumes are displayed: the 2-Hour Probability of Warning graphic and the Estimated Minutes Until Lightning Arrival graphic (Figure 4).

This situational awareness and decision-assisting tool has been updated several times since it was implemented in 2005, and it is currently used to support emergency management and other decision-makers for a number of large, outdoor venues across the WFO Tulsa CWA.

4. Producing Accurate Graphical Forecasts for Effective IDSS

All IDSS provided by OHMARS, the DSP, and the numerous information delivery methods based on the DSP ultimately depend on data contained in the routine seven day gridded forecasts produced daily by WFO Tulsa forecasters. As such, all gridded forecast weather elements play a direct and highly visible role in IDSS delivery. Dew points and winds in the extended forecast range control both Fire Danger and Severe Thunderstorm threat levels. Distinguishing between expected wintry precipitation types and resultant accumulations in the middle and latter forecast periods, as situationally feasible, is critical to assessment of the Ice and Snow threat levels. Even sky cover data are important as they are included in the WBGT calculations. Keeping the near-term gridded forecast elements updated according to observations and the latest expectations is also necessary to evaluation of the Day 1 threats.

With these techniques, effective IDSS must start with placing effort into crafting the most accurate gridded forecast data for the given forecast scenario. To accomplish this, forecasters use a variety of single and blended model output, such as the National Blend of Models (Gilbert, et al., 2015) and the NWS Southern Region's SuperBlend, as a starting point, with encouragement to make any needed changes to model grid initializations. To keep the near-term forecast data on target, hourly surface observations from not only synoptic stations, but also the Oklahoma Mesonet (Brock, et al., 1995), are incorporated into the current hour forecast and then, merged with the succeeding few hours through interpolation with the existing forecast data or a choice of short-term model guidance.

On a typical forecast shift, routine duties are distributed among two forecasters in a short-term/aviation and long-term fashion. Long-term forecaster responsibilities center on the public forecast from the second period through Day 7; the short-term forecaster is concerned with the current period's public forecast, the HWO and its relevant short-term forecast elements, and all aviation forecasts. When available and/or when a weather event warrants, a third decision support forecaster is tasked with the less traditional IDSS duties, such as the briefing slide packages, gHWO, social media, and multimedia web briefings. During significant weather events with non-optimal staffing availability, the duties typically performed by three forecasters are often redistributed among the two in the base staffing model.

5. Application of the WFO Tulsa Vision to the 13-14 January 2017 Ice Storm

WFO Tulsa successfully applied its vision for effective IDSS in advance of and during the 13-14 January 2017 ice storm that affected portions of the Southern and Central Plains. The WFO Tulsa CWA was located on the southern edge of the significant ice accumulation, with 0.25 to 0.50 inch accumulations across northeast Oklahoma along and northwest of I-44 (Figure 5). The ice accumulation caused isolated short-lived power outages and travel impacts.

Considerable model uncertainty in the position of the freezing line provided a challenging forecast in the days preceding the event. Despite persistent model differences, WFO Tulsa forecasters first mentioned freezing rain potential in text products seven days in advance and pinpointed such details as the freezing line location, the area at greatest risk for significant ice accumulation, and the magnitude of ice accumulation five to six days prior to the event. Local experience in forecasting ice events proved critical to providing the best forecast and IDSS, through use of the local communication tools, to partners.

a. Forecast Verification

WFO Tulsa outperformed available model guidance, including blended model guidance, in placing the location of the freezing line near Interstate 44 several days in advance. Temperature verification statistics for Bartlesville Municipal Airport (KBVO) and Tulsa International Airport (KTUL) show the improvement of official NWS forecasts over the SuperBlend guidance and Model Output

Figure 5. Estimated Ice Accumulation in northeast Oklahoma and far northwest Arkansas 13-14 January 2017.

	KBVO		KTUL	
	Min	*Max*	*Min*	*Max*
13 January	29°F	30°F	30°F	33°F
14 January	28°F	32°F	30°F	33°F

Table 2. Overnight minimum and daytime maximum temperatures for KBVO and KTUL on 13 and 14 January 2017.

Statistics (MOS) from the Global Forecast System (GFS) and North American Model (NAM). Per automated ice accumulation measurements (Ryerson and Ramsay, 2007), a large portion of the accumulation at both KBVO and KTUL occurred during the daytime, placing particular importance on the maximum temperature forecasts at both sites.

A shallow, cold airmass and widespread clouds and precipitation resulted in a small diurnal temperature range at KBVO and KTUL both 13 and 14 January (Table 2). As is typical with shallow, cold air, synoptic-scale models and therefore, the corresponding MOS temperature guidance struggled to produce accurate maximum temperature forecasts, although minimum temperature guidance performed much better.

Figure 6 compares WFO Tulsa, GFS MOS, NAM MOS, and SuperBlend forecast errors. The GFS and NAM MOS were significantly too warm with daytime maximums. Despite the NAM MOS underperformance, the raw NAM surface temperatures did well, as they frequently do in shallow, cold air outbreaks. The SuperBlend performed better than both sets of MOS guidance but still exhibited a warm bias. WFO Tulsa outperformed the guidance; even in the extended periods (not shown), official forecast maximum temperatures 4°F to 6°F too warm were a 1°F to 2°F improvement over the SuperBlend. In general, forecast errors trended lower as the event approached.

b. Pre-Event IDSS

By simply identifying the freezing rain potential and including it in the official gridded forecast, WFO Tulsa IDSS for the ice storm began early morning on 7 January when the DSP reflected a non-Nil Ice threat level for Friday, 13 January (not shown). The non-Nil Ice threat level also triggered the automatic mention of “Winter Weather Potential” for Friday in the extended segment of the HWO issued at 4:07 AM CST on 7 January:

```
.DAYS TWO THROUGH SEVEN...SUNDAY THROUGH
FRIDAY.
SUNDAY...HIGH WIND AND DANGEROUS WIND
CHILL POTENTIAL.
MONDAY AND TUESDAY...HIGH WIND
POTENTIAL.
WEDNESDAY...NO HAZARDS.
THURSDAY...THUNDERSTORM POTENTIAL.
FRIDAY...WINTER WEATHER POTENTIAL.
```

Figure 6. Comparison of WFO Tulsa, GFS MOS, NAM MOS, and SuperBlend maximum temperature forecast errors at KBVO and KTUL for the afternoons of 13 and 14 January 2017.

The DSP featured non-Nil Ice threat levels for both Friday and Saturday after the early morning forecast on 8 January, depicting a Limited to Elevated threat level for these days leading up to the event (Figure 7). In addition, the Strong Wind threat level for both days remained Nil, important to diagnosing the potential total impact of the forecast ice accumulation on power lines and trees (McManus, et al., 2008).

The gHWO published early morning on 8 January first provided a generic depiction of the possible freezing rain area (Figure 8a) in conjunction with an HWO that mentioned significant ice accumulation potential. A gHWO update early morning on 9 January

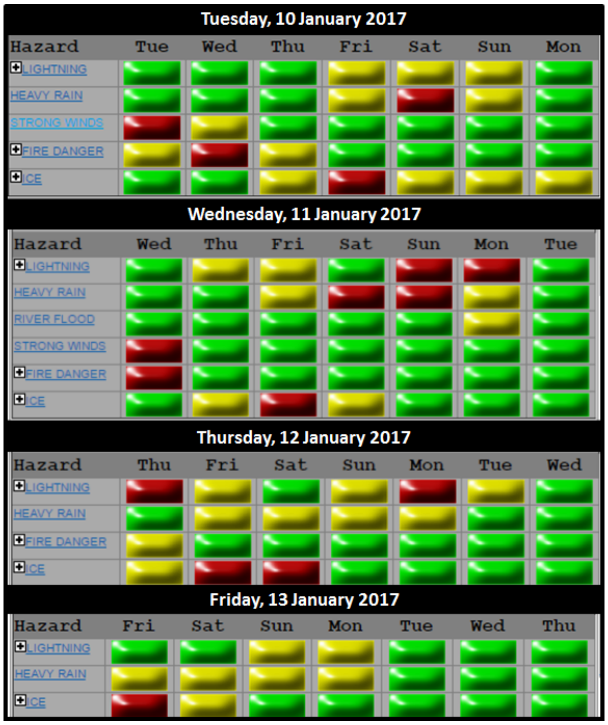

Figure 7. DSP Hazard Tables from 10-13 January 2017.

refined the original areal outline to along and northwest of Interstate 44 (Figure 8b), while an updated HWO early that afternoon read:

```
PARTS OF NORTHEAST OKLAHOMA TO THE
NORTHWEST OF INTERSTATE 44 CONTINUE TO
BE THE MOST LIKELY LOCATIONS TO SEE
SIGNIFICANT ICE ACCUMULATIONS THROUGH
SUNDAY MORNING...WITH ACCUMULATION
POTENTIAL JUST SOUTH AND EAST DEPENDENT
ON WHERE THE FREEZING LINE EVENTUALLY
SETS UP.
```

The information provided on 9 January reflected the eventual verification almost perfectly, and consistency continued in subsequent gHWO (Figure 8c) and HWO issuances.

Creation of the DSP-based briefing slide packages commenced mid-morning 9 January,

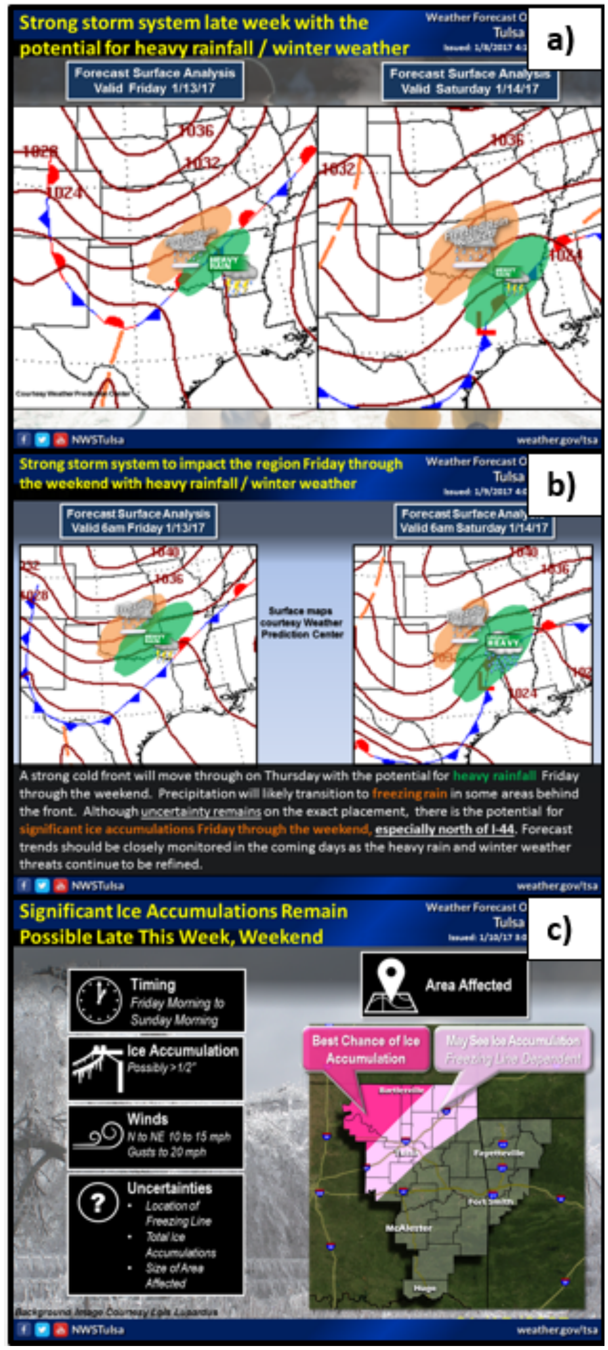

Figure 8. gHWO images created 8-10 January 2017.

with the initial multimedia web briefing, based off information in the briefing package, following that same afternoon. Daily briefing packages and multimedia recordings continued through the beginning of the event. Additionally, once-daily partner web conferences were conducted 10 January through 13 January, all containing information from the corresponding briefing package.

In summary, IDSS for the difficult but still well forecast ice storm began almost a week before the event because WFO Tulsa forecasters focused on making as accurate a gridded forecast as possible, knowing the data would be communicated consistently and automatically via the DSP and with increased efficiency through related tools.

6. Summary

Meteorologists at WFO Tulsa developed an in-house suite of tools designed to streamline the process of providing IDSS to core partners in multiple formats, including dynamic web pages, infographics, briefing packages, multimedia recordings, and text products. Since the tool output (hence, the IDSS) is dependent on the gridded forecast, forecasters must place a more traditional focus on the human-generated gridded forecast content, even in the extended forecast realm; the IDSS is only as good as the forecast that goes into it. The methodology of letting the forecast directly and automatically control the IDSS to core partner groups allows WFO Tulsa to provide consistent levels of service even in times of sub-optimal staffing and active weather. Work continues to improve the tools by incorporating both inter- and intra-office feedback, as well as new technologies, with a focused goal of providing the best service possible to partners without having to make procedural trade-offs as a forecast staff.

Acknowledgements. The authors would like to thank Steve Cobb for reviewing this manuscript and providing useful feedback. We would also like to thank all of our coworkers at WFO Tulsa; many minds and talents have contributed to the suite of IDSS tools that we have at our disposal, not to mention the daily efforts in making them work optimally.

7. References

Amburn, S.A., S.F. Piltz, J.B. McGavock, and J.M. Frederick, 2007: High Impact Gridded Weather Forecasts. 22nd Conference on Weather Analysis and Forecasting, Park City, UT, Amer. Meteor. Soc., P1.11.

Brock, F.V., K.C. Crawford, R. L. Elliott, G.W. Cuperus, S.J. Stadler, H.L. Johnson, and M.D. Eilts, 1995: The Oklahoma Mesonet: A Technical Overview. *J. Atmos. Oceanic Technol.,* **12**, 5-19.

Dimiceli, V.E., S.F. Piltz, S.A. Amburn, 2011: Estimation of Black Globe Temperature for Calculation of the Wet Bulb Globe Temperature Index. World Congress on Engineering and Computer Science, San Francisco, CA, International Association of Engineers.

Gilbert, K.K., J.P. Craven, D.R. Novak, T.M. Hamill, J. Sieveking, D.P. Ruth, and S.J. Lord, 2015: An Introduction to the National Blend of Global Models Project. Special Symposium on Model Postprocessing and Downscaling, Phoenix, AZ, Amer. Meteor. Soc., 3.1.

McManus, G.D., S.F. Piltz, S. Sperry, R.A. McPherson, A.D. Gartside, D. McClain, T. Meyer, C. Fetsch, and M.A. Shafer, 2008: Development and Testing of an Ice Accumulation Algorithm. 17th AMS Conference on Applied Climatology, New Orleans, LA, Amer. Meteor. Soc., 9.5.

McGavock, J.B., G.N. Mathews, and J.M. Frederck, 2006a: Utilizing Experimental Graphical Severe Weather Warning Probabilities to Supplement the Hazardous

Weather Outlook. Symposium on the Challenges of Severe Convective Storms, Atlanta, GA, Amer. Meteor. Soc., P.1.6.

McGavock, J.B., R.B. Darby, and S.F. Piltz, 2006b: Interactive Mesoscale Analysis Utilized in Assisting Local Decision Makers: A Review of the 24 March 2005 Supercell. Symposium on the Challenges of Severe Convective Storms, Atlanta, GA, Amer. Meteor. Soc., P1.9.

National Weather Service, 2013: Weather-Ready Nation Roadmap. http://www.weather.gov/media/wrn/nws_wrn_roadmap_final_april17.pdf.

Ryerson, C.C. and A.C. Ramsay, 2007: Quantitative Ice Accretion Information from the Automated Surface Observing System. *J. Appl. Meteor.*, **46**, 1423-1437.

Sondag, R.J., J.B. McGavock, J.M. Frederick, 2005: WFO Tulsa Decision Support Page. 30th Annual Meeting, St. Louis, MO, National Weather Association.