P1.11 HIGH IMPACT GRIDDED WEATHER FORECASTS

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1. INTRODUCTION

Forecasting high impact weather presents significant issues for the National Weather Service (NWS). There is no doubt these forecasts can be prepared and issued, but at what cost to NWS labor resources? In order to serve all customers, the NWS needs to become increasingly efficient in its production of the various high impact weather forecasts required by its customers. For this reason, the Weather Forecast Office in Tulsa, OK, (WFO TSA) has adopted a philosophy of forecasting the basic weather parameters (with a few additions) and allowing internal software to compute and produce the high impact forecasts and forecast graphics, as well as detailed observed fields.

Forecasters at WFO TSA produce their forecasts, as do all other NWS WFOs, using the Gridded Forecast Editor or GFE (Global Systems Division, 2006). Within GFE, WFO TSA has added numerous components and tools to create additional gridded forecasts and observed fields which can provide important decision-making information to the user community. High impact elements such as probability grids for severe thunderstorm and tornado threats have proven to be very valuable to users. Other hazard grids such as maximum wind gust, maximum heat index, flood and fire spread potential, allow users to easily locate areas of concern in the seven-day forecast.

2. GRIDDED FORECAST PHILOSOPHY

With the advent of gridded forecast databases, the mission of the NWS has added significant responsibilities at the WFO level.In the early 1990s, the public forecast function was easily completed by grouping a handful of counties into a zone, then typing a three or four period forecast for those four, five, or maybe as many as eight zone groups. The area forecast, which replaced the “state forecast,” was also a relatively short product that took little time to type.

However, the desire to provide more detailed forecasts for longer time frames has resulted in significant changes at WFOs. To accomplish these changes, the NWS employed gridded forecast fields and software to produce computer worded forecasts. This change in operations has provided the NWS with new methods and opportunities to provide an unprecedented level of service to our user community. This change in operations and the new technology has allowed the local forecast office to address as many customer needs and concerns as possible. The only way to do this is to use automation, where practical, in combination with “current” grid-based analyses and forecasts of the set of basic weather parameters.

At WFO TSA, the primary use and purpose of the GFE is to provide this set of analyses and forecasts of meteorological parameters as accurately as possible. From this set, parameters can be combined in numerous ways to produce a wide variety of high impact gridded analyses and forecasts. These can then be provided to the user community on a broad scale through the internet and through the Hazardous Weather Outlook (HWO) text product.

3. ANALYSIS AND SHORT RANGE FORECAST GRIDS

Analysis grids play an important role in keeping weather forecasts current and also in keeping forecasters situationally aware. At WFO TSA, the basic set of weather parameters are updated each hour, and include T, Td, Wind, Wind Gust, and Sky (cloud cover). From those basic parameters, other fields are updated, including Max T, Min T, RH, Heat Index, and Wind Chill. PoP (probability of precipitation) and Weather grids are updated at the discretion of the forecaster as required. All these parameters are then blended into the existing forecast through an interpolation technique. Max T and Min T are either adjusted manually or are allowed to adjust automatically as necessary to ensure the most accurate forecast possible.

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This interactive process within GFE helps forecasters identify significant changes in the atmosphere that may have a high or significant impact on customers.

The surface analysis grids are also combined with the latest model forecasts aloft to provide the latest and most accurate volumetric analysis of the atmosphere each hour (McGavock, 2004). A forecaster may choose to use data aloft from either the RUC or NAM models in combination with the latest hour's surface fields. The internal parameters of choice for WFO TSA generally tend toward convection or the previously mentioned parameters, including the following grid fields:

Storm Motion
CAPE
Cin (local cap index)
Lifted Index
Lifted Condensation Level
Level of Free Convection
0-6 km shear
0-1 km shear
0-3 km helicity
0-1 km helicity
Moisture Convergence
Energy Helicity Index
Max forecast hail size (local index)
Max wind gust potential (local index)
CAPE to 500mb
CAPE to 700mb
Windex
WIIB (local summary index)
Conditional probability of Severe Weather

("Local" grids are primarily generated based on local studies and may not apply to other parts of the CONUS.)

In addition to basic analysis grids, forecasters can provide special analyses in a more interactive process within GFE. This will generally occur when some portion of the county warning and forecast area (CWFA) has significantly different values than even a standard mesoscale analysis can provide. Forecasters can use GFE tools to make assessments of how the environment will affect individual storms. Storm scale analyses for helicity are prime examples. A forecaster can adjust the storm motion for a cell with a deviant motion (Figure 1) to see how that may affect the helicity for that thunderstorm. After running the

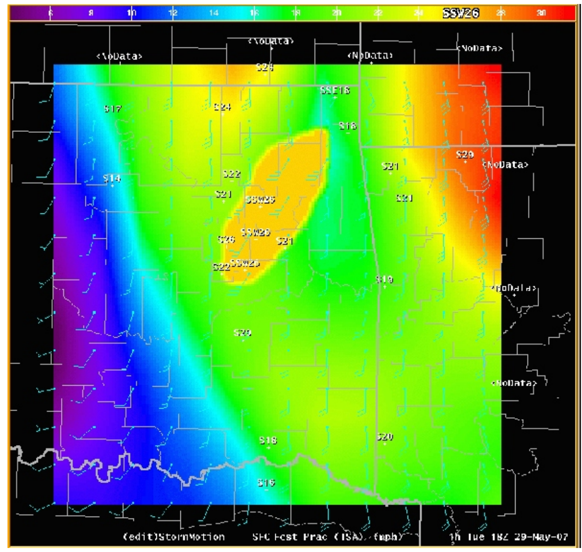

Figure 1. Manually updated storm motion field.

GFE tool, a newly calculated helicity grid is available (Figure 2). In this particular case, the forecaster's situational awareness is improved, allowing him to anticipate mesocyclone or even tornadic development from the thunderstorm.

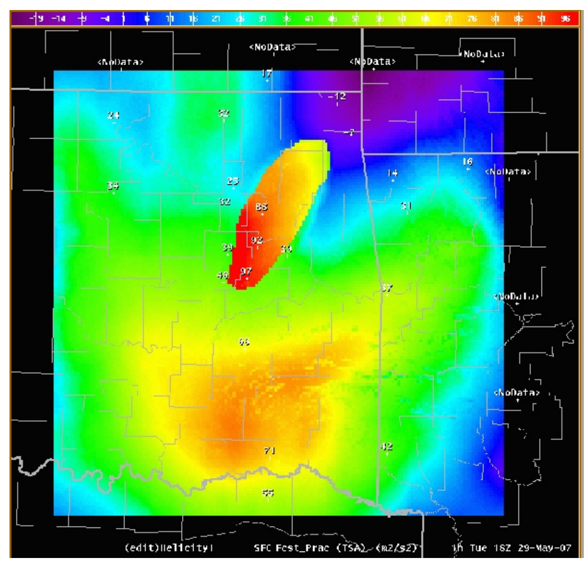

Figure 2. Updated helicity field from GFE tool.

Figure 3 shows a comparison of the GFE mesoscale analysis and the Storm Prediction Center (SPC) RUC analysis for the same area. The two images on the left show zero to 1km helicity output from the WFO TSA GFE tool, one hour apart. The image on the right is the SPC

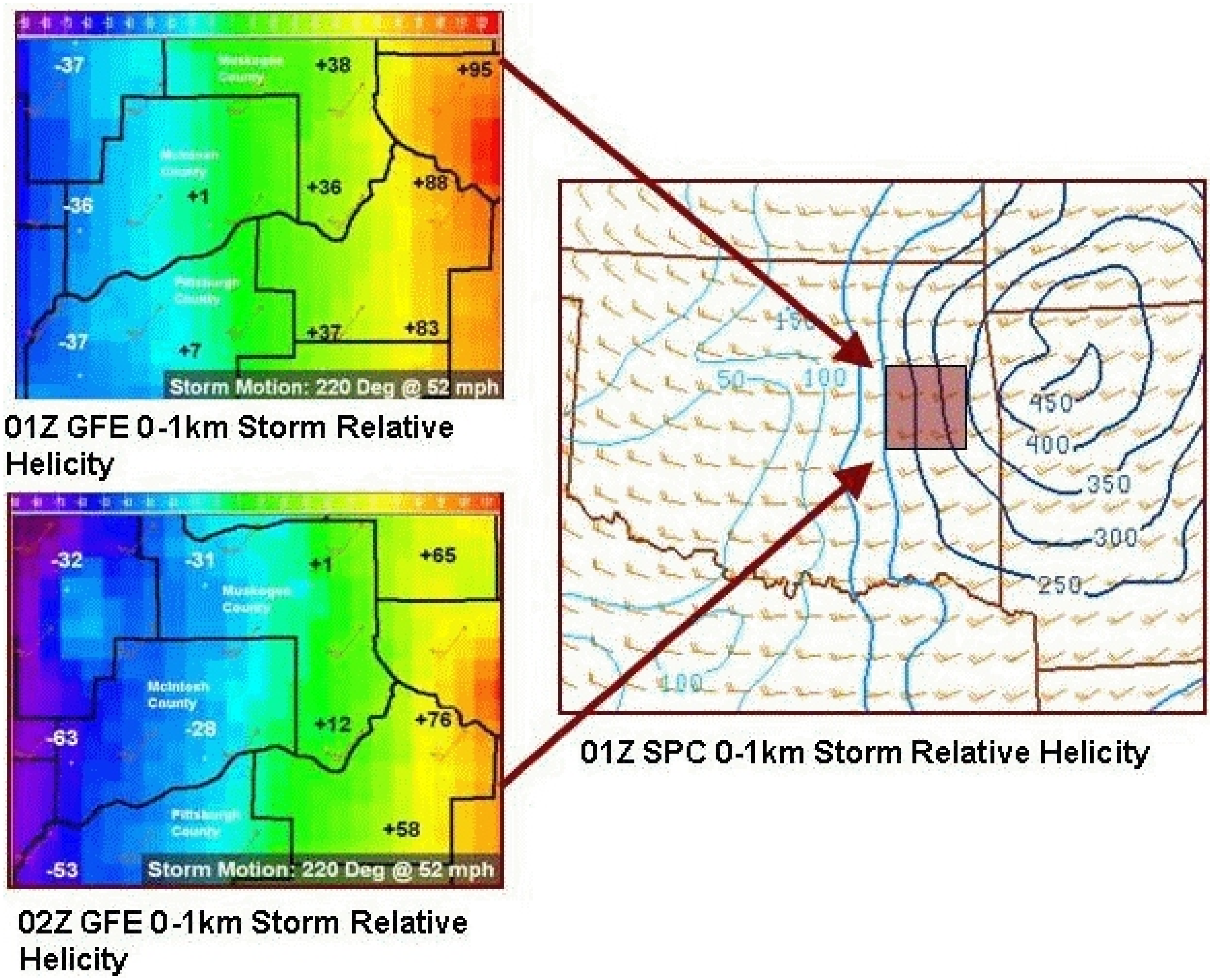

Figure 3. Comparison of WFO GFE analyzed helicity and SPC mesoscale helicity.

analysis. The hourly updated surface grids and the resolution of GFE paint a considerably different picture than the more synoptic scale analysis to the right. Note the rather large positive values in the SPC analysis while the GFE values showed a transition from negative to positive values from west to east. In fact, a supercell thunderstorm moving east across the area exhibited an anticylonic circulation on its north side, then transitioned to a cyclonic circulation on the south side as it moved to the east side of the boxed area. The detail in GFE helped warning forecasters understand the storm evolution and helped forecasters position spotters around the storm.

Another example where local GFE mesoscale analyses are helpful are the Cin (Cap index, Figure 3), which is also a WFO TSA created tool for GFE. This tool is very helpful in identifying the potential for convective

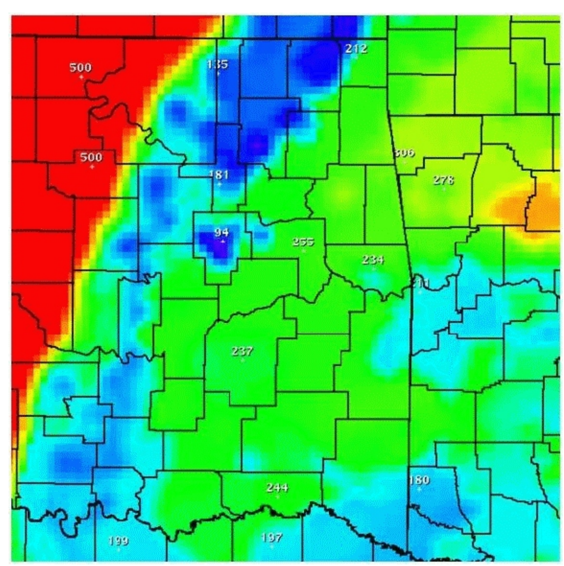

Figure 4. WFO detailed Cap index.

development. These grids also seem to provide better information than a generic RUC analysis. Strong capping is shown in red, while blue areas indicate very little cap.

Another helpful tool used in storm-scale analyses is the GFE hodograph tool (Figure 5),

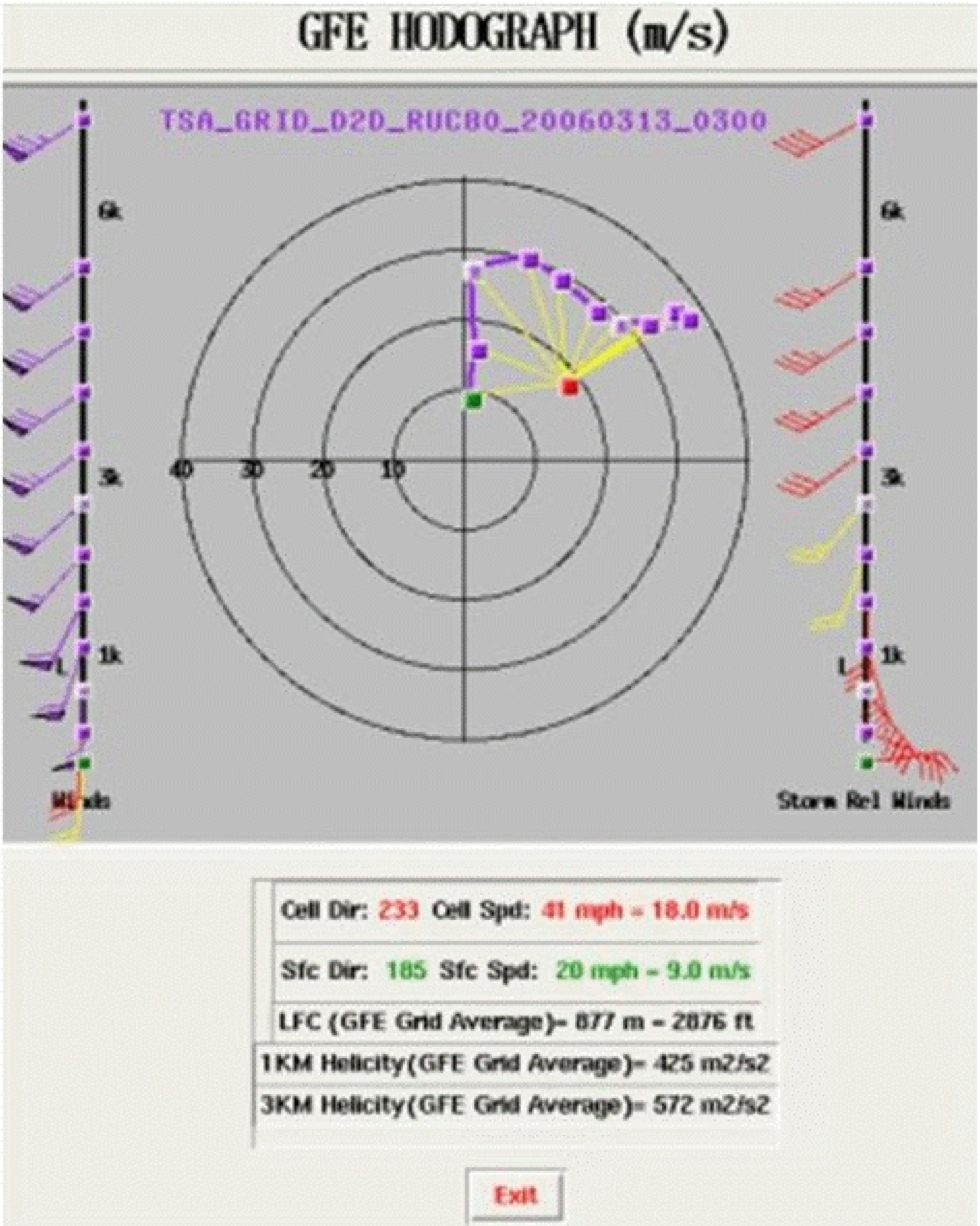

Figure 5. Locally developed GFE point hodograph tool output, valid for near storm analysis.

developed at WFO TSA. This tool allows forecasters to generate hodographs “on-the-fly” in proximity to specific thunderstorms. With hourly updated surface grids and manually or automated storm motions, this hodograph output provides warning forecasters with the information necessary to anticipate thunderstorm evolution.

4. SHORT RANGE FORECAST GRIDS/WEB IMAGES

However, hourly updated parameters are also used to generate products, mostly graphical, for more specific weather related risks. In addition to convective threats, other risk analyses are displayed on the WFO TSA web page for hazardous weather. Specific analysis and forecasts on the hazardous weather page show risk analysis information for tornadoes, severe thunderstorms, flash flood, heavy rain, lightning, dense fog, strong winds, fire danger and heat index or wind chill. These are all produced from the GFE basic set of forecast grids. However, elements such as the conditional probability of severe thunderstorms can be manually overridden by the forecaster. The graphics are automatically generated, allowing forecasters to monitor and forecast the weather, and not be consumed in graphics generation.

The risk analysis graphics are generated either directly from the forecast grids, or by combining grids and algorithms. Work is being tested to use GFE grids to create warning probabilities for the WFO TSA web page (McGavock, 2006). The current list of risk fields in the WFO TSA hazardous weather Decision Support Page are discussed below and provide decision makers with an easily viewable set of significant weather parameters for a variety of purposes.

4.1 Tornado

The Tornado threat level (Figure 6) is based on the probability of being in a Tornado Warning in an area. The probability of a Tornado Warning in an area is forecast based on:

- The Probability of Thunderstorms (local grid derived from the Weather and PoP grid)
- The Probability of a Thunderstorm becoming Severe once it has developed (local grid of Conditional Probability)
- The Probability of a Thunderstorm becoming Tornadic once it has become Severe (local grid of Conditional Probability)

A “local” grid is one which has been created at WFO TSA for the WFO TSA GFE and is not part of the national GFE basic set of grids.

4.2 Severe Thunderstorm

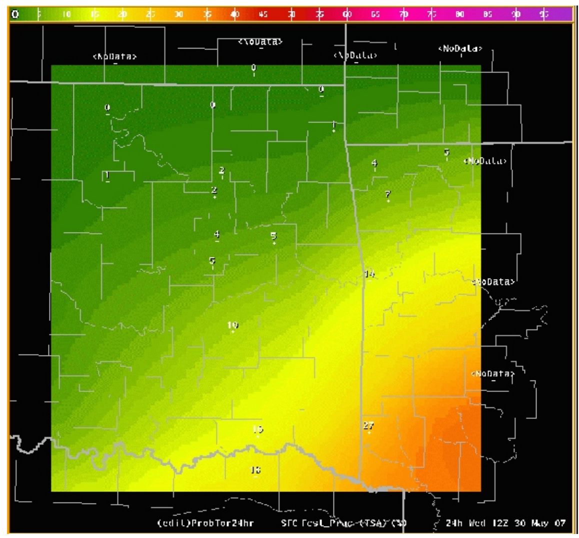

Figure 6. The 24-hour probability of being in a tornado warning.

The severe thunderstorm threat level (similar to Figure 6) is the probability of being in a severe thunderstorm warning sometime during the remaining portion of the hazard outlook. The probability of a Severe Thunderstorm Warning in an area is forecast based on:

- The Probability of Thunderstorms (local grid)
- The Probability of a Thunderstorm becoming Severe once it has developed (local grid of Conditional Probability)

4.3 Flash Flood

The flash flood threat analysis is a combination of parameters consistent with the following bulleted list. The final grid is based on the probability that the flash flood guidance will be exceeded in a three hour period. The probability of exceedance (POE) is computed from the QPF (the mean of the expected distribution of rainfall amounts) and the probability density function of the exponential equation. Details on the calculation of POE can be found in Amburn (2006).

- The Flash Flood threat level is based on Flash Flood guidance from the River Forecast Centers and the WFO QPF.
- The QPF is based on expected coverage, intensity and duration of Thunderstorms.

4.4 Heavy Rain

The threat for heavy rain is measured as the probability to exceed 1 inch of rainfall in a six-hour period (Figure 9). Again, this is based on the probability of exceedance computed from the QPF (the mean of the expected distribution of rainfall amounts) and the probability density function of the exponential equation.

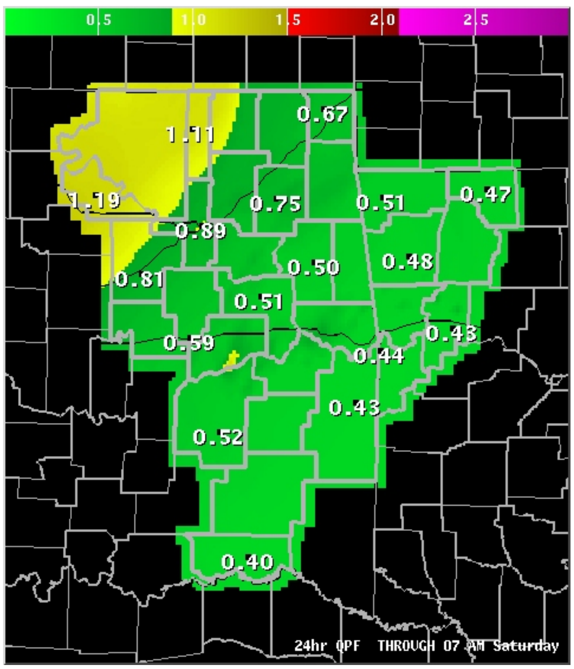

Figure 7. Heavy rain potential graphic, shown as the 24-hour QPF total.

4.5 Lightning

The lightning threat level is based strictly on the probability of thunderstorms in an area. The probability of rain (GFE PoP grid) and probability of thunderstorms (GFE Weather grid) are used to derive this high impact element in GFE. More detailed lightning information for ongoing thunderstorms is also available at the WFO TSA web site through GFE analysis tools.

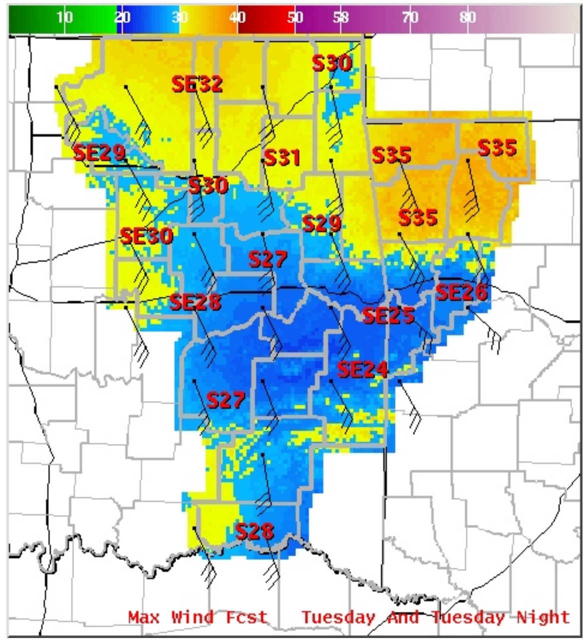

Figure 8. Max wind forecast for 24-hour period from sustained winds and gusts.

4.6 Dense Fog

The fog threat level is based on the forecast of fog (basic GFE Weather grid) and occurrence as predicted by the forecaster. The graphic depicts the weather type and time of beginning and ending of event. This graphic is “shipped” directly from GFE to the web page to provide graphical information to the users. Again, the forecasters only need to maintain accurate grids.

4.7 Strong Winds

This grid is the maximum wind speed and direction obtained from the hourly forecast wind grids or wind gust grids. These are also basic GFE grid fields available from any WFO (Figure 12). When these are highlighted in the Decision Support page, it provides a reminder to the forecasters to look for meeting possible watch or warning criteria.

4.8 Fire Danger

Deteriorating fire weather conditions mean that fires of any origin would have an increasing potential to spread (Figure 13). A fire “spread index” is used to assess the threat of fires burning out of control. This spread index uses a

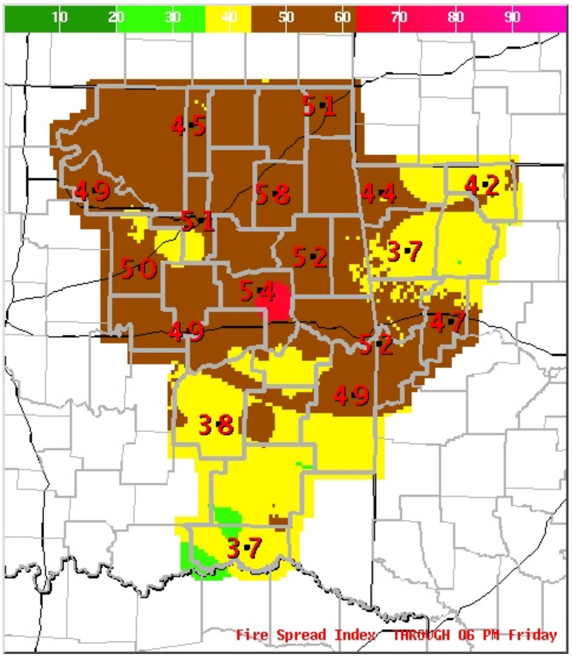

Figure 9. Wild fire spread index, available out 7 days.

combination of temperature, humidity, wind, and fine fuel state to calculate its value. All these inputs are basic GFE grids except fine fuel state which has been added to the WFO TSA GFE database for creation of this fire danger index.

Information seen in this graphic is most appropriately used for grass fire potential as the index is based on fuels that can dry within one hour (grasses). The fuel state is a seasonal input that is based on whether the grasses in the area are green, dormant and dry, or some state of transition in between. (Pharo, et. al.)

4.9 Heat Index / Wind Chill

The Heat Index or Wind Chill Index graphics are also shown on the Decision Support page. These are the extreme values from each hourly grid in the forecast area throughout the valid time of the forecast. These can be very useful to schools, coaches and other decision makers who are responsible for the health and welfare of people who may be working or playing outdoors.

4.10 Convective Watch Enhancement

The GFE convective analyses, tornado and severe thunderstorm probabilities are also being used to provide enhancements to SPC convective watches. This is a step toward probabilistic warnings. On a given day, the SPC outlook may indicate an increased risk for severe convection. When the watch is issued, that risk or probability has increased by some increment. At WFO TSA, mesoscale analyses through GFE are then used to indicate which areas within the watch are more favorable for severe convection than others.

Figure 16 shows the forecaster's GFE grid for tornado probability. Figure 17 shows a tornado watch covering much of the CWFA. However, within the SPC watch, the WFO TSA forecaster was able to identify and effectively downscale the watch to show areas which would have a higher probability of tornadoes. Red areas had the highest likelihood of tornadoes according to the GFE and forecaster analyses. This kind of refinement clearly provided an extra layer of information to the customers.

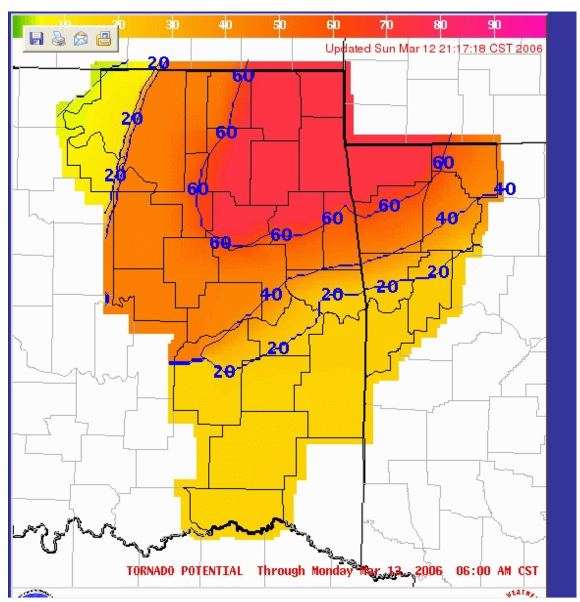

Figure 10. WFO TSA tornado warning probabilities from GFE grids.

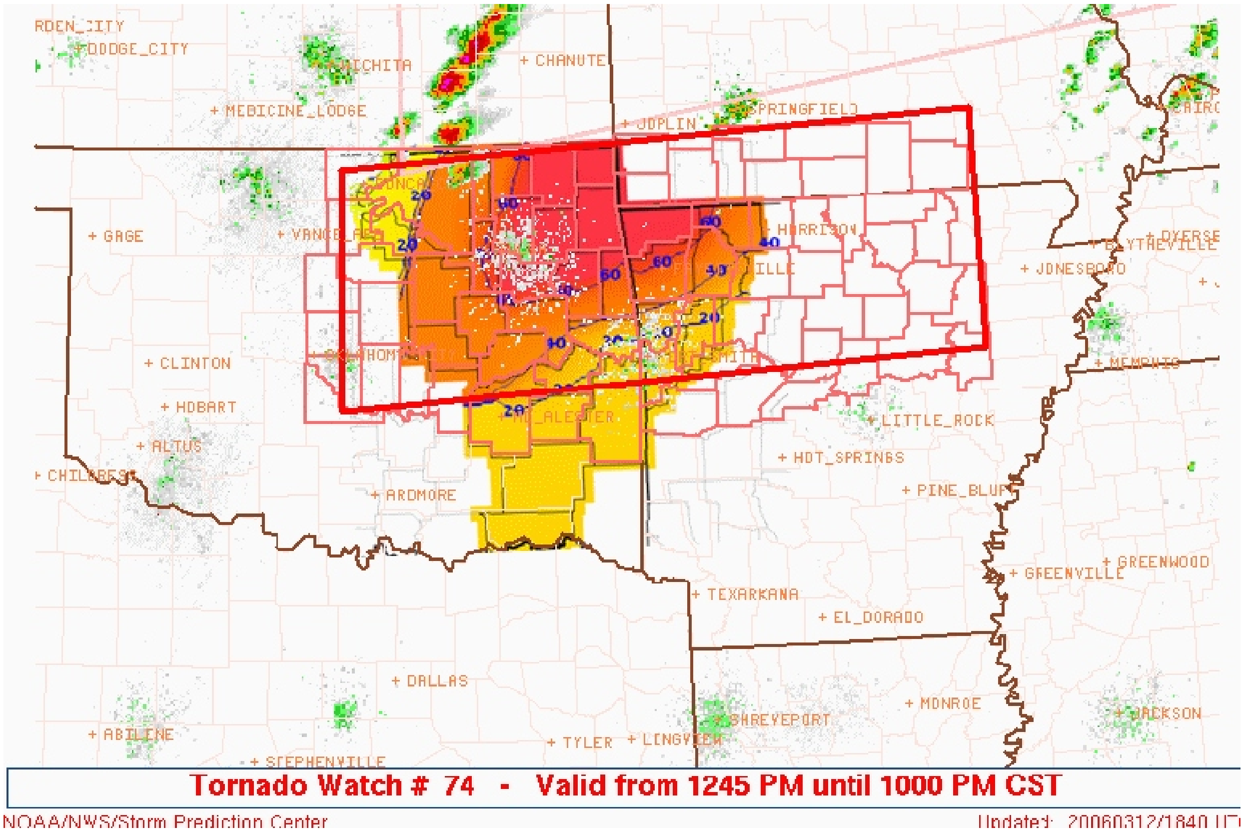

Figure 11. SPC tornado watch with WFO enhanced threat probabilities.

5. LONG RANGE FORECAST GRIDS

Longer range forecast grids also provide risk assessment graphics on the WFO TSA Hazardous Weather Outlook (HWO) web page and text product. Again, forecasters' efforts are on providing the best possible set of basic forecast grids. From those, forecasts of risk for select weather phenomena are produced within GFE for use in the HWO and on the web. There is no duplication of effort to draw the hazards. Neither is there any risk of having forecasts and hazards that do not match.

For severe weather risks, upper air features from the model of choice are combined with the forecasters' set of basic surface grids to generate forecast graphics of risk for the hazardous weather outlook for days two through seven. A set of parameters are checked automatically in GFE which determines the threat level and therefore identifies the possible high impact weather for our customers.

Similarly, QPFs are summed for each day of the hazardous weather outlook to derive the potential of heavy rain. Total seven-day rainfall and POEs are generated from the basic grids and sent to the web page for use in the HWO text to notify customers of possible high impact weather situations (Figure 18).

Regarding fire weather, the wild fire spread index (shown earlier) is computed out through day seven to provide concerned persons with information about possible weather impacts. Again, within GFE a combination of basic forecast elements of wind, humidity, temperature and vegetation state are used to generate the forecasts.

Other long range high impact forecasts include lightning, severe thunderstorm, fog, fire danger, strong winds, heavy rain, and heat index or wind chill. These are all derived from the basic set of forecast grids.

6. INTERNAL USES

High impact analyses and forecasts are used internally at WFO TSA to maintain forecaster situational awareness and also to assist in the forecast process. The tools available in GFE can generate grid fields to show forecasters when combinations of forecast parameters are nearing or passing critical thresholds for such risks as heavy rain, severe thunderstorms, fire danger and heat index. These tools can quickly and efficiently scan the entire grid database to determine if watches, long-fuse warnings or advisories should be issued. These tools also ensure forecast integrity.

Examples mentioned earlier include severe thunderstorm and fire weather grid fields. Other examples include checks for high wind events, heat index and wind chill thresholds, and Red Flag criteria. Tools developed within GFE are run and provide forecasters with information on when to issue or consider issuing watches for these high impact events.

7. HIGH IMPACT EXAMPLES

WFO TSA has had numerous occasions to provide high impact weather forecasts and analyses to its customers by making efficient use of the basic set of GFE grid elements. Emergency managers, fire weather respondents and others can readily obtain weather information that can be critical to their particular situation. Also, by maintaining accurate analysis and forecast grids, specialty products can be created "on-the-fly" to help provide briefings for weather-critical events. This has been done in the past for large wildfire events, heavy rain potential from the remnants of tropical systems, and numerous high probability severe weather days. In fact, a well maintained GFE grid database can provide an abundant set of weather information to the customer. This is being tested at WFO TSA now in the form of the Outdoor Hazard Monitoring and Response System (OHMARS).

7.1. Special Forecast for Fire Weather

In November 2005, conditions were warm, dry and windy. This followed a period of low rainfall and therefore resulted in extreme wildfire danger across much of Oklahoma. The state of Oklahoma required on-site briefings at their headquarters offices. Although this took our Warning Coordination Meteorologist out of the office, the high impact gridded analyses and forecast were automatically available on the WFO TSA web site and provided the needed information for briefing state officials. In addition, the fire spread index forecasts are available from our web site for the entire seven-day forecast period, allowing fire officials to start taking actions several days in advance.

7.2. Special Forecast for Heavy Rain

In the late summer of 2005, remnants of Hurricane Rita were forecast into central and eastern Oklahoma. Although winds were not expected to be a factor, 24-hour rainfall forecasts were expected to be over seven inches in some areas. Emergency managers were obviously concerned and needed frequent briefings on the potential. GFE grids allowed the continued production of rainfall exceedance probabilities (Amburn, 2006) for briefing purposes, instead of just the average QPF.

Standard exceedance probabilities (~probabilistic QPFs) are available for amounts of 0.10, 0.50, 1.00 and 2.00 inches. However, for very heavy rainfall forecasts typically associated with land falling or decaying tropical systems, rainfall POEs can be computed simply by changing a parameter in a GFE tool, then sending that image to the web to brief emergency managers and other officials. Figures 19 through 21 show an example of PoP, QPF and POEs for a decaying tropical event in the forecast area.

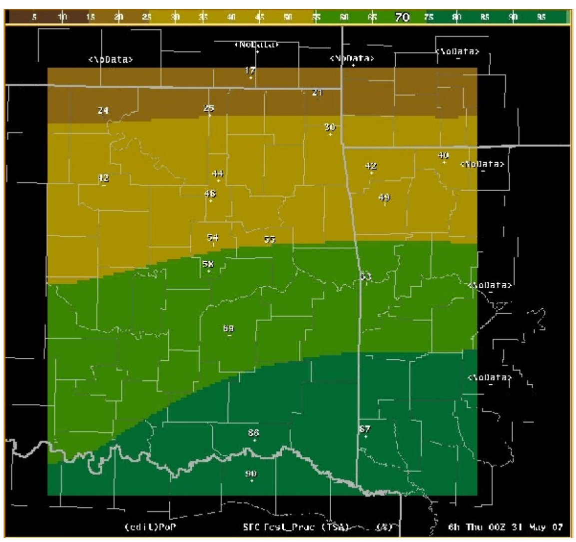

Figure 12. Probability of rain for decaying tropical system.

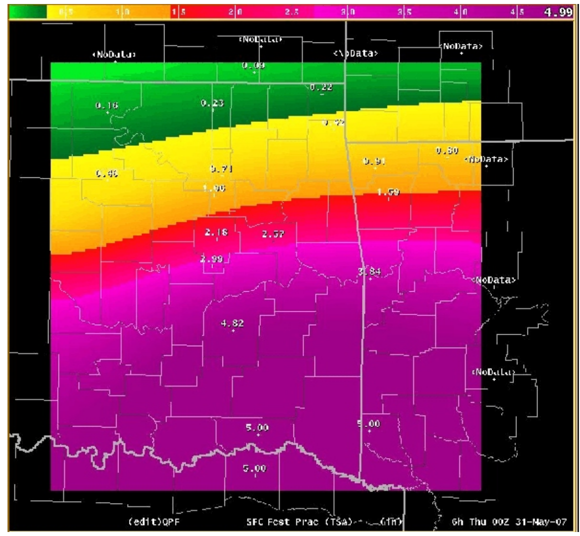

Figure 13. QPF for decaying tropical system.

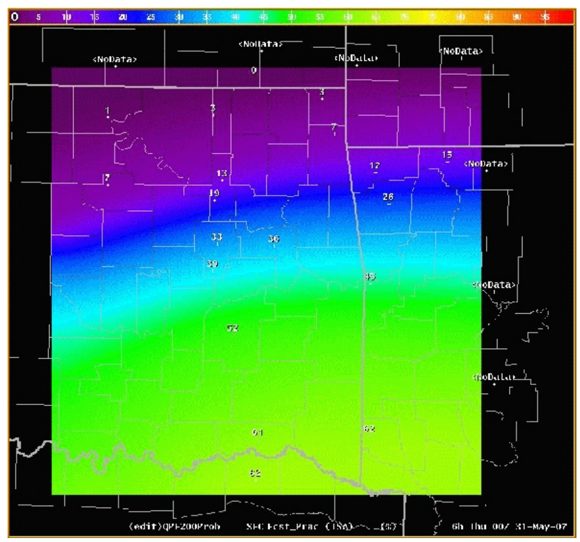

Figure 14. Probability to exceed (POE) 2 inches of rainfall, corresponding to figures 19 and 20.

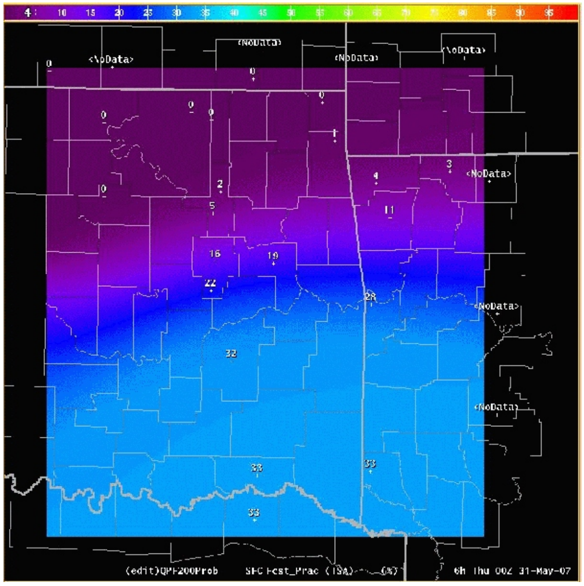

Figure 15. Probability to exceed (POE) 5 inches of rainfall, corresponding to figures 19 and 20.

7.3. OHMARS

The National Weather Service (NWS) in Tulsa is working with local emergency managers to develop a system named OHMARS, the Outdoor Hazard Monitoring And Response System. This is an application available on the web, generated fromGFE and other data at WFO TSA. The concept of OHMARS is currently under development and a working prototype has been in existence only a short time. The goal of the project is to tie all available NWS information together into one interface and support emergency management officials in dealing with weather threats at emergency response locations, e.g. hazardous response sites, and large outdoor public venues. At such locations, the response and evacuation times are often much larger than the lead time of an official NWS warning. Therefore decisions must come before the warning, and with less definite information. By tying all available information into a single interface, the decision support to emergency mangers is more efficient, and a more complete analysis of a situation can be accomplished.

In OHMARS, the emergency official sets the thresholds and actual response information in the system. At the heart of the system is the use of gridded forecasts from WFO Tulsa of tornadoes, severe thunderstorms, lightning, heat index, wind gusts, rainfall, and sky cover. NWS data are fed into the interface, and alarms in OHMARS are activated when thresholds are crossed. This results in bulleted text from the emergency manager's response plan to be displayed. OHMARS monitors observed data, digital forecast data, and NWS text products to trigger alarms.

Using an example of a tornado threat, the emergency manager is alerted to tornado potential for the public venue's location first thing in the morning by OHMARS after processing information from the nearest data point from the gridded tornado potential forecast issued by WFO Tulsa. As confidence grows in the threat, an update to the tornado potential is made and OHMARS, accessing the gridded forecast, updates and alerts for the change in potential. A Tornado Watch issued by the NWS Storm Prediction Center for the venue will alarm in the system. As upstream thunderstorm development is monitored and its evolution forecast, the tornado potential for the venue increases beyond the threshold, and OHMARS displays the emergency manager's own words that call for the evacuation of the venue, before a Tornado Warning is ever issued.

Additionally, OHMARS displays related graphics (some may be hand-drawn), along with current conditions, links to text products, hourly forecast information, and an audio briefing. It may be possible to include text messaging to cell phones from OHMARS when alarm thresholds have been exceeded. While OHMARS is currently a demonstration project, it is expected that various entities having access to NWS data sets will create applications with enhanced capabilities tailored for specific needs.

8. Summary

The National Weather Service Weather Forecast Office in Tulsa, Oklahoma, routinely uses the Gridded Forecast Editor to compute and otherwise produce a variety of high impact gridded forecast products for distribution to state and local decision makers. Emergency managers, city officials and the general public can obtain the information from the WFO TSA web site hazardous weather page and apply that information to their specific problem of the day.

The simplicity of providing high impact weather analyses and forecasts through the gridded forecast database is that forecasters need only maintain the “basic” GFE grids of meteorological parameters. Tools available in GFE help forecasters accomplish that, both for observed and forecast grid fields. This makes forecast and graphics production very efficient. Algorithms access those grids throughout the seven-day forecast to produce specific high impact weather forecasts and graphics with minimal additional input required of the forecaster. These high impact gridded observational and forecast fields also serve to enhance forecasters’ situational awareness of rapidly changing weather conditions, both on the short range mesoscale and also in the long range synoptic scale that may negatively impact our customers.

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