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INTERACTIVE MESOSCALE OBJECTIVE ANALYSIS IN THE NATIONAL WEATHER SERVICE'S GRAPHICAL FORECAST EDITOR

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1. INTRODUCTION

The National Weather Service's (NWS) Graphical Forecast Editor (GFE; Forecast Systems Laboratory 2001) is being utilized at the Weather Forecast Office (WFO) in Tulsa, Oklahoma not only to generate forecast products, but also as an interactive mesoscale objective analysis tool. The latter use involves the generation of environmental parameters classically associated with severe local storm forecasting, such as lifted index, helicity, and shear. These data are produced on a 5km x 5km grid, where the integrity of the observed values is maintained, whereas point specific output from the Mesoscale Analysis and Prediction System Surface Assimilation System (MSAS; FSL 2002) and the Local Analysis and Prediction System (LAPS; FSL 2004) often deviate from input observations. Variations on classic parameters can also be calculated and displayed, such as storm-relative helicity (SRH) computed to the lifting condensation level (LCL) instead of to an arbitrary height. The parameters are produced by a combination of editable surface data and forecast fields from numerical models. Thus a forecaster can produce either an analysis of the current hour (as is done by other schemes that mix observed surface data with model data from higher levels), or produce forecast fields, adjusting for biases in model surface data. WFO Tulsa meteorologists have perceived early work with this analysis technique as beneficial.

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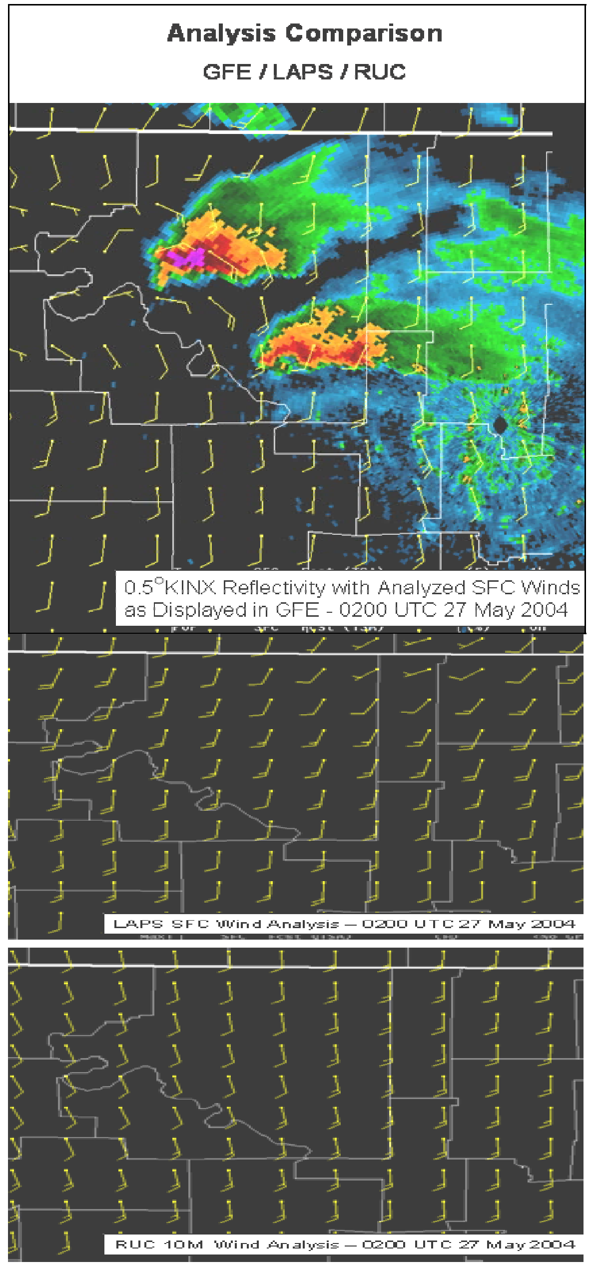

Figure 1: Surface Wind (mph) Analysis Comparison at 0200 UTC 27 May 2004. Note the smoothed RUC and LAPS fields in the vicinity of the convection as compared to the GFE-based analysis, which more accurately depicts the observed data.

2. METHODOLOGY

NWS meteorologists utilize the GFE to produce and manipulate gridded data as part of the forecast process. Through the application of computer scripts within GFE, known as SmartTools, output from several numerical models (ETA, GFS, RUC) can be used independently or in combination with other fields to generate gridded forecast fields. These fields are often standard elements such as temperature, wind, and weather. However, the GFE allows the inclusion of user-defined elements as well. NWS Tulsa has focused on utilizing the capabilities of GFE as a forecasting tool, capitalizing on the benefits of melding adjusted surface fields with numerical model output. This capability is available using both observed and forecast fields, making it beneficial both in producing hourly analyses and in assisting the formulation of forecasts. The grid domain is a rectangle slightly larger than the WFO Tulsa County Forecast and Warning Area (CFWA).

The combination of Oklahoma Mesonet (Brock, et al. 1994) and Automated Surface Observing System (ASOS) observations provide the hourly surface information of temperature, dewpoint, wind speed and wind direction for ingest into the analysis routine. An initial condition grid is required for the objective analysis, which may consist of a previous forecast grid, MSAS or LAPS analysis, or raw numerical model output, as best determined by the forecaster. The difference between the observed surface data and initial field are used to produce a difference grid, which is then added back to the initial grid. The difference grid is calculated by fitting a surface of "serpentine curves" to differences between the initial grid values and the point specific hourly data (Colin and Barker 2003). The advantages of this routine include maintaining exact values at data points, while maintaining small-scale detail existing in the initial grid.

Once analyses are complete for surface temperature, dewpoint, and wind fields, the user executes a series of SmartTools that allow for the selection of model data and the configuration of the output. The GFE then interpolates the selected model data to the 5km grid, associating the model information with the previously analyzed surface data to create a profile of the atmosphere at native model vertical resolution. This allows the forecaster to create fields from thousands of synthesized vertical profiles at 5km resolution across the Tulsa CFWA, instead of attempting to infer the near-storm environment from individual model soundings. Computations are then made from these GFE-synthesized profiles that result in a high-resolution objective analysis of environmental parameters typically associated with severe local storm forecasting (Johns and Doswell 1992). At present, convective fields produced include lifted index, cap strength, LCL height, surface-1km and surface-6km shear, storm-relative helicity to 1km, 3km and LCL height, and moisture convergence. The storm-relative helicity calculations are unique in that a user-defined storm motion grid is utilized, instead of assuming a motion as is often done. Storm-relative helicity is highly variable in both time and space (Markowski, et al. 1998), making the ability to control the storm motion variable vital in attempting to diagnose the potential helicity fields. Additionally, working in the GFE environment allows computed parameters to be combined to produce other indices. An example is helicity calculated from the surface to the LCL, then normalized to the depth of the layer.

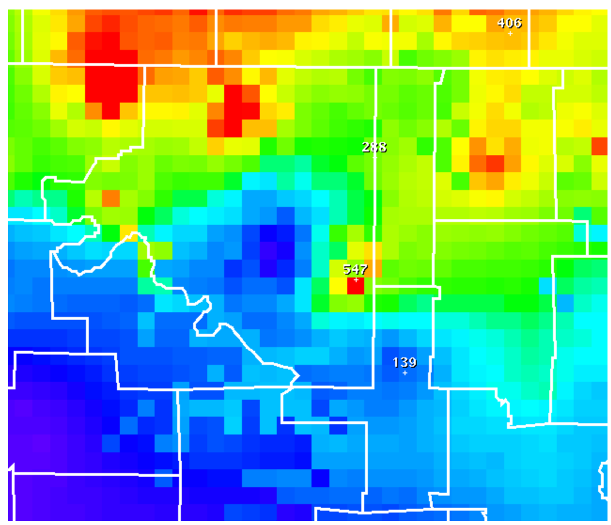

Figure 2: Storm-Relative Helicity from the surface to the LCL (m/s^2), normalized to the depth of the layer. The data are from 0200 UTC 27 May 2004.

The ability to compute forecast parameters, based on manually adjusted fields, allows for additional high-resolution output that can be incorporated into the forecast process. The greatest advantage this technique offers is the ability to alter forecast surface elements while monitoring their associated effect on the convective parameters, thus producing ensemble solutions based on varying surface conditions.

3. APPLICATION

Local application of the GFE-based hourly analysis and forecast convective parameters has shown promise at WFO Tulsa in anticipating storm type and evolution. Additionally, as confidence in the output has grown, NWS Tulsa has begun to communicate portions of this decision process to external customers.

An example of this process occurred on the evening of 26 May 2004 when isolated supercell thunderstorms developed over north-central Oklahoma. The eastward extent in which these storms would survive was initially uncertain as strong surfaced-based cap strength was forecast in their advance. However, local analyses within the GFE diagnosed a relative minimum in cap strength over portions of north central and northeast Oklahoma. Additionally, computed storm relative helicity and LCL height values remained favorable for tornadic potential (Thompson, et al. 2003) ahead of the advancing storms. Hourly analyses of the surface-based cap strength began to reveal a tightening gradient across eastern Pawnee, eastern Osage, and western Tulsa counties. Given the absence of significant synoptic-scale forcing, the storms were forecast to rapidly decrease in intensity upon encountering this gradient.

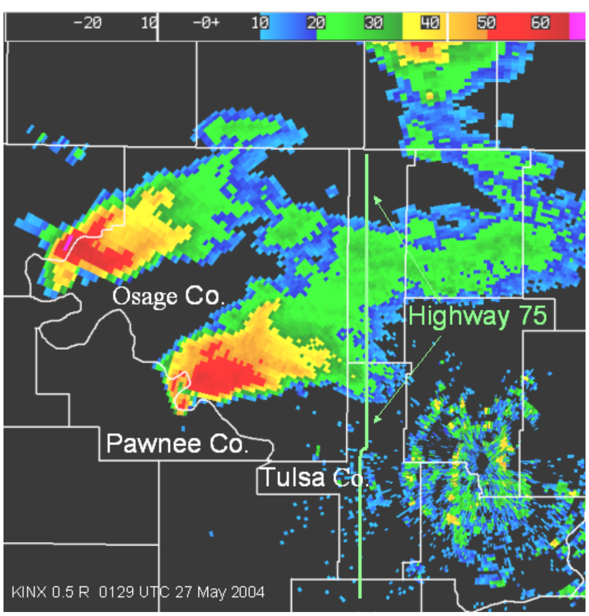

Figure 3: KINX WSR-88D 0.5 degree reflectivity (dBz) at 0129 UTC 27 May 2004. Highway 75 noted in green.

An updated forecast discussion issued at 0104 UTC 27 May 2004, as the storms were entering the WFO Tulsa CFWA, shared the following information:

> *"HIGH-RESOLUTION MESOCALE GRID ANALYSIS SHOWS THE CAP IS WEAKEST OVER OSAGE AND PAWNEE COUNTIES …ELSEWHERE THE CAP IS STRONG AND RAPID UPDATE CYCLE GRID POINT DATA SUGGESTS THAT THE CAP WILL NOT CHANGE MUCH FOR THE NEXT COUPLE OF HOURS. THEREFORE THE STORMS WILL LIKELY STRUGGLE PASSING THE HIGHWAY 75 CORRIDOR.*
>
> *UNTIL THEN DEEP LAYER SHEAR VALUES AND EXPERIMENTAL NORMALIZED STORM-RELATIVE HELICITY FROM THE SURFACE TO LCL ARE SUPPORTIVE OF A CONTINUED TORNADO THREAT IN OSAGE AND PAWNEE COUNTIES"*

The information in the discussion was relevant to the Tulsa area given that Highway 75 bisects Tulsa County north to south. This information was relayed to spotters and emergency managers through amateur radio.

While the thunderstorm's reflectivity pattern on radar began to suggest a slowly decreasing level of organization as they approached the Highway 75 corridor in Tulsa County, Doppler velocity data and spotter reports indicated continued low-level rotation. As the eastern most storm approached Tulsa County, hourly analyses continued to support the existence of an increasingly hostile environment ahead of the storm. An updated forecast discussion was issued at 0154 UTC 27 May 2004 addressing both potential warning decisions along with the anticipated outcome:

> *"TORNADIC SUPERCELL TRACKING ACROSS SOUTHERN OSAGE COUNTY IS APPROACHING THE END OF THE CORRIDOR OF THE BEST AVAILABLE SHEAR…CAP AND INSTABILITY PARAMETERS. EXTRAPOLATION OF THE CIRCULATION BRINGS IT TO THE TULSA COUNTY LINE AROUND 920 PM. THE COURSE OF LEAST REGRET MAY BE TO ISSUE A TORNADO WARNING FOR NORTHERN TULSA COUNTY…KNOWING THAT THE CELL COULD WEAKEN SIGNIFICANTLY AS IT APPROACHES THE COUNTY LINE.*
>
> *THE CELL IN WESTERN OSAGE COUNTY REMAINS IMPRESSIVE AND A TORNADO THREAT WILL CONTINUE WITH IT THROUGH 10PM."*

This information was briefed directly to the Tulsa Area Emergency Management Agency, allowing them to anticipate a tornado warning with the understanding that a rapid decrease in tornado potential was likely before the storm could traverse the entire county. The storm rapidly lost organization as it entered Tulsa County, with no severe weather occurring east of Highway 75. This case highlights a near textbook example of forecasting, incorporating, and relaying the appropriate information within a convective warning environment.

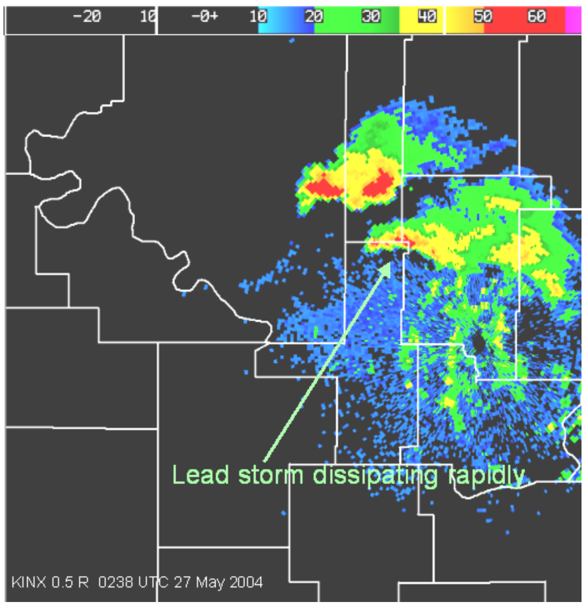

Figure 4: KINX WSR-88D 0.5 degree reflectivity (dBz) at 0238 UTC 27 May 2004. Eastern most storm rapidly dissipating.

While very few cases replicate this near perfect example, operationally significant data is often found within the GFE-produced analysis. The greatest strength of this approach, as perceived by WFO Tulsa forecasters, has been in diagnosing gradients in the near-storm environment, not just revealing a specific index number at a point. Appropriately combining the enhanced analysis and forecast data produced within GFE with other rapidly updating data such as radar, satellite, profiler, etc. has proven useful in enhancing warning and short term forecast decisions.

4. FUTURE WORKS

WFO Tulsa plans to continue developing forecast tools that capitalize on GFE's ability to incorporate forecast and observed fields with numerical model data. The severe storm SmartTool development will initially focus on producing and improving existing fields by incorporating Convective Available Potential Energy (CAPE) calculations, with additional fields focused on downburst potential associated with multi-cell storm structures. Later efforts will also refine existing SmartTools as dictated by observational findings and the latest near-storm environment research. The same approach has also begun toward creating SmartTools that assist in winter weather forecasting, with potential for the hourly analysis grids to be served to external customers during ongoing winter precipitation events.

Increasing computing and data storage capabilities will allow for a more automated analysis routine, and improve the availability of all analyses and forecast fields to both internal and external users. An additional advantage of this analysis approach within the GFE will be the capability of developing case studies and exercises that allow forecasters to re-create mesoscale analysis for research and training purposes.

5. ACKNOWLEDGEMENTS

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