3A.2 FORECASTING THE SUPER TUESDAY TORNADO OUTBREAK AT THE SPC: WHY FORECAST UNCERTAINTY DOES NOT NECESSARILY DECREASE AS YOU GET CLOSER TO A HIGH IMPACT WEATHER EVENT

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1. INTRODUCTION

The 5 February 2008 (Super Tuesday) tornado outbreak ranks as the deadliest tornado outbreak in 23 years for the United States, and the deadliest since 3-4 April 1974 in the Ohio and Tennessee Valleys (Fig. 1). Eighty-four tornadoes occurred during the course of the outbreak, killing 57 people directly in Arkansas, Kentucky, Tennessee and Alabama (Fig. 2) and injuring hundreds of others within these and surrounding states. The outbreak also produced widespread wind damage along with large hail up to the size of softballs (4.5 inches in diameter).

Synoptically, this event was evident up to a week in advance as large scale features favored a potential outbreak of severe thunderstorms and tornadoes. A deepening middle and upper level trough of low pressure was forecast consistently by medium-range numerical models (e.g. GFS, GFS Ensemble, ECMWF) over the central United States around 5 February. Ahead of this system, several days of southerly low level flow out of the Gulf of Mexico was expected to support unseasonable moisture (i.e. surface dew points in excess of 60 ° F) over the lower Mississippi river valley, the Mid South, and lower Ohio and Tennessee river valleys. Low level moisture of this quality is a common feature for cool season tornado outbreaks across the Southern and Southeastern U.S. (Guyer et al. 2006). Winds aloft and associated shear profiles were forecast to be anomalously strong at all levels with this system.

These "synoptically evident" (Doswell et al. 1993) events are quite rare with only a few such occurrences as clearly apparent in medium range model guidance each year. More typically, differing model solutions lead to inherently higher forecast uncertainty several days in advance of a severe weather event. Even if model guidance is in general agreement, the coarser resolution of these data sets limit the assessment of any sub-synoptic scale processes that could significantly impact event evolution. Consequently, tools such as climatology and large scale pattern recognition play an important role at this point in the forecast process.

Tornado Outbreaks by Number of Fatalities (since 1950)

Rank	12z-12z	# Fatal	Mid-Mid (CST)	# Fatal	Rank
1	04/03/74	310	04/03/74	308	1
2	04/11/65	260	04/11/65	260	2
3	03/21/52	205	03/21/52	202	3
4	06/08/53	142	06/08/53	142	4
5	05/11/53	127	05/11/53	127	5
6	02/21/71	121	02/21/71	121	6
7	05/25/55	102	05/25/55	102	7
8	06/09/53	90	06/09/53	90	8
9	05/31/85	76	05/31/85	76	9
10	05/15/68	72	05/15/68	71	10
11	03/03/66	58	03/03/66	58	11
11	04/21/67	58	04/21/67	58	11
13	04/10/79	57	04/10/79	57	13
13	03/28/84	57	03/28/84	57	13
13	02/05/08	57	02/05/08	47	15

Fig 1. Ranking of deadliest tornado outbreaks since 1950 based on direct fatalities. Two time-frame criteria are used; one based on UTC (12z-12z), and another on midnight CST. (From www.spc.noaa.gov)

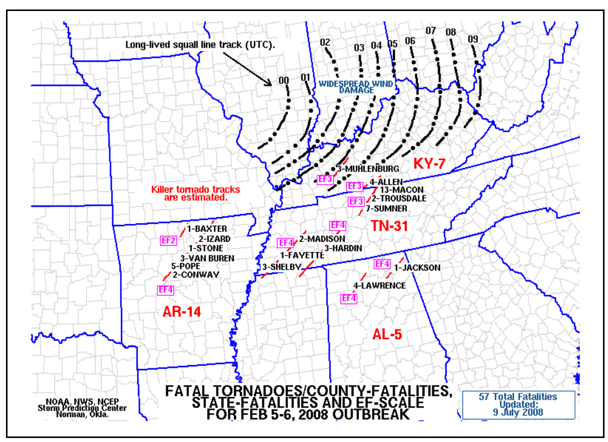

Fig 2. Tornado tracks and fatality locations for the February 5-6 tornado outbreak. (From www.spc.noaa.gov/wcm)

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As the forecast valid time nears 12-24 hours in advance, forecasters are able to examine finer scale details of the atmosphere through the use of mesoscale models and observational data. Typically, this additional information provides insight into meso and perhaps even storm scale processes that may have a profound impact on how a severe weather event evolves. When these data are consistent with previous forecast expectations, then the confidence in the forecast increases with the approach of the event. However, when the short term data either conflict with the earlier forecasts or support differing solutions, then forecast confidence can actually *decrease* as one nears the valid time.

2. MEDIUM-RANGE FORECAST

By as early as 31 January 2008, the consistency between, and run-to-run continuity of, the medium-range models provided increased confidence of an impending significant, severe weather event. As such, the Storm Prediction Center (SPC) highlighted the potential threat in their Day 4-8 convective outlook, 6 days in advance (Fig. 3). Subsequent SPC outlooks increased both the potential area of severe thunderstorms and the significance of the expected event. Forecaster confidence supported a “Moderate Risk” in the initial Day 2 outlook issued at 1 am CST 4 February, which included a ≥10% probability forecast of significant severe thunderstorms (defined as those producing 2" or larger hail, 65 knot or stronger winds, and EF2+ tornadoes). The Moderate Risk was expanded westward into more of Arkansas in the subsequent Day 2 outlook (Fig 4) issued at 1230 pm CST on the 4th, which included mention of “long-lived supercells and possible strong tornadoes.”

3. SHORT-RANGE FORECAST

Late on 4 February, however, an assessment of observational data and higher resolution numerical model output resulted in SPC forecasters becoming more uncertain in how the event would unfold. The presence of a lead, low latitude short wave trough over the lower Rio Grande valley in advance of the primary upper-level trough presented added complexity to the forecast. One plausible scenario was that this lead shortwave trough would initiate storms early in the day over eastern Texas into western Louisiana, eventually overturning much of the air mass prior to the peak of the diurnal heating cycle. Another possible scenario was that the presence

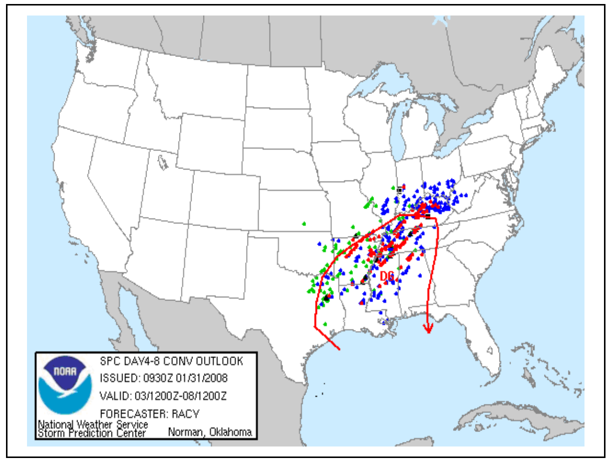

Fig 3. Day 6 outlook issued by the SPC on Jan 31st valid from 12z Feb 5 - 12z Feb 6. overlaid on severe reports valid during that time. Tornadoes are red dots, wind damage blue and hail green.

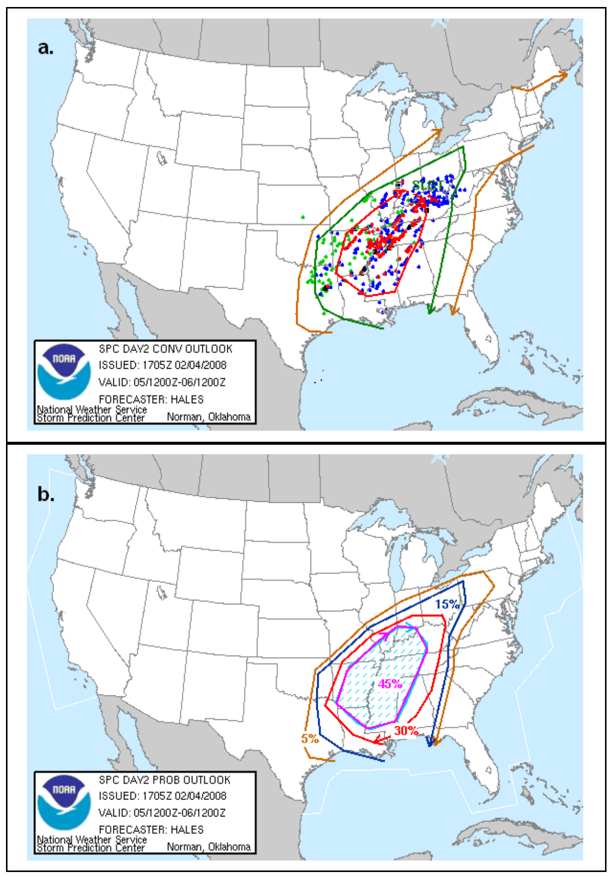

Fig 4. Same as Fig 3, except Day 2 outlook issued at 1230 pm Feb 4th. a) Categorical outlook, b) Probabilistic outlook

of the elevated mixed layer (Carlson et al. 1983) and resultant cap would delay any surface-based, deep moist convection in association with this feature until later in the afternoon within the warm sector. This latter scenario would increase the likelihood of a squall line being forced eastward by deep convergence along the surface front during the evening and overnight. This would limit potential to an isolated significant tornado threat, with a main threat of widespread damaging surface winds. Model forecast soundings from both the NAM and Eta-KF control member from the SREF supported this scenario, as surface heating was forecast to be inadequate to break the cap until arrival of a strong surface cold front late in the day (Fig. 5).

In addition, some of the simulated radar reflectivity products available with the higher resolution WRF data sets (Weiss et al. 2006), tended to suggest rather weak and disorganized convection over the lower Mississippi valley through the afternoon (Fig. 6). SPC forecasters are aware of the limitations with these explicit, convection-allowing models, particularly in low instability environments, due in part to the ~4 km grid length that is relatively coarse to resolve convective-scale updrafts. However, operational use of high-resolution WRF output has proven useful in similar situations by providing unique convective details (e.g. mode and evolution).

While it was felt that the environment was potentially supportive of a "High Risk", these complicating factors left enough uncertainty that a Moderate Risk was maintained in the initial Day 1 outlook issued at midnight CST 5 February.

These uncertainties persisted through the remainder of the night and into the next day. The weak, southern stream short wave trough increased deep moist convection in the form of elevated thunderstorms over north central Texas, which spread quickly into eastern Oklahoma and western Arkansas through the early morning hours of the 5th. However, by daybreak it became apparent the primary effects from this low latitude short wave trough would overspread the Ozark region, and likely not impact most of the warm sector during the day. Modified forecast soundings, using slightly warmer surface temperatures as predicted by local NWS forecast offices, indicated capping would therefore likely be broken across most of the warm sector by the mid afternoon. In addition, a comparison of the observed 12 UTC Little Rock, AR sounding the morning of the 5th with the 12 UTC 21 January 1999 sounding (another cool season tornado outbreak over the Mid South), indicated cap

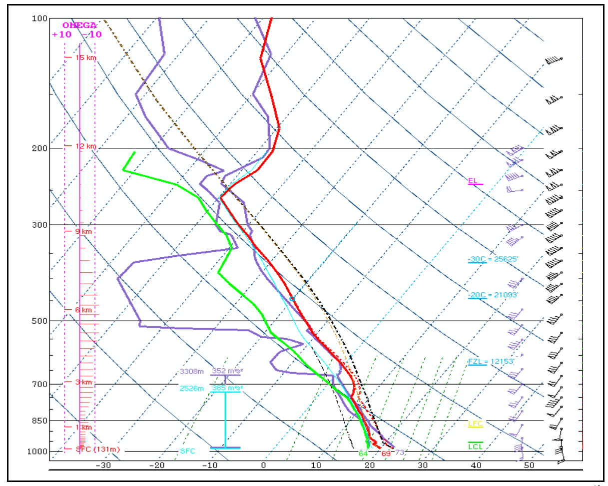

Fig 5. Eta-kf 21 hr forecast valid at 00z Feb. 6th overlaid with observed sounding valid the same time. Red- temperature and green- dew point for the forecast Eta-kf sounding. Obs. in purple.

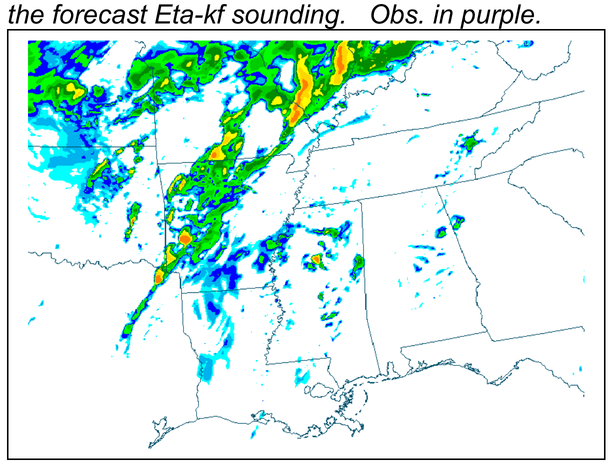

Fig 6. 21 hour forecast of the 1 km agl simulated reflectivity from the 00z Feb 6 run of the WRF-NMM4.

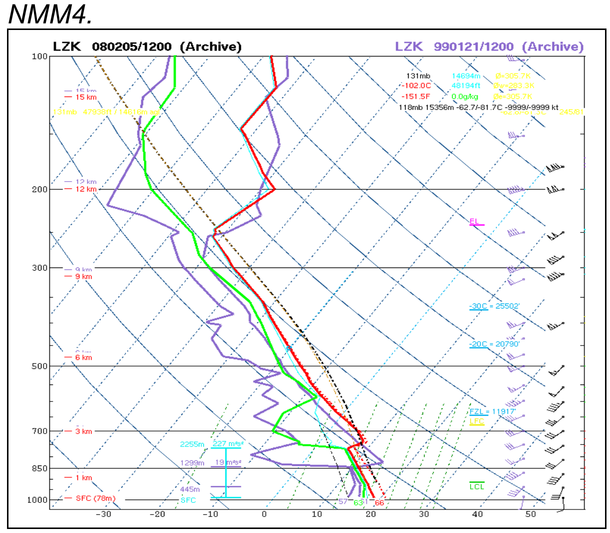

Fig 7. Observed sounding valid at 12z for Feb. 5th, 2008 (red and green) and Jan. 21st, 1999 (purple)

erosion was farther advanced with weaker capping in place on the morning of the 5th (Fig. 7). These factors increased confidence that the severe threat would evolve into a significant tornado outbreak, given the very favorable large scale environment and the likelihood of discrete thunderstorm development ahead of the main surface cold front. The subsequent Day 1 outlook issued at 7 am CST included a High Risk centered over the Mid South region (Fig. 8).

Even after the introduction of the High Risk area, uncertainty regarding the timing and location of the greatest threat lingered well into the early afternoon. Some 12 UTC numerical model guidance continued to suggest the development of widespread thunderstorms by late morning or early afternoon over the Arklatex region in association with the lead short wave trough lifting out of the lower Rio Grande Valley. However, as the morning progressed, observational data trends confirmed that the cap was holding across much of the warm sector and significant, discrete thunderstorm development would likely be delayed until peak heating that afternoon, but would still precede the main surface cold front. This allowed forecasters to discount the spurious numerical guidance and focus more intently on the observations and short term model solutions that still remained plausible. As a result, the mid-morning convective outlook (issued at 1030 am CST) expanded the High Risk and more accurately captured the ensuing event. The first two tornado watches for the outbreak were issued shortly after 2 pm CST and 3 pm CST for the area, and both included the "Particularly Dangerous Situation" wording that is reserved for significant tornado threats.

4. CONCLUSIONS

A commonly accepted scenario for high impact severe weather events is that forecasters gain confidence as model guidance and observed data gradually converge on a common solution that increases in accuracy as the event time nears. For example, it is assumed that the data will gradually indicate that an increasing threat exists for a high impact event, and forecasters begin to address the high end potential at an earlier point in the forecast timeline. As additional data become available, specific details of the convective scenario and better specification of the threat area are provided in subsequent forecast issuances.

At other times, the data may begin to indicate that a more limited threat exists than was earlier anticipated. In these instances, however, some lower potential for a significant event typically remains, and the forecaster is faced with the decision of how best to downplay the threat contained in existing forecasts, while still acknowledging that a lower level of threat may exist. Typically, the use of probabilistic forecast products provide a vehicle to better reflect forecaster uncertainty (confidence), although interpretation of the probabilistic information by members of the user community requires additional communication and education efforts.

In both of these examples, a consistent signal amongst the various observational and model data sets increases forecaster confidence in modifying the prevailing forecasts.

However, it is not uncommon for the various data sets (e.g., model guidance, satellite imagery, observed soundings, etc.) to contain mixed signals regarding the likelihood of a high impact event, especially for smaller scale phenomena such as

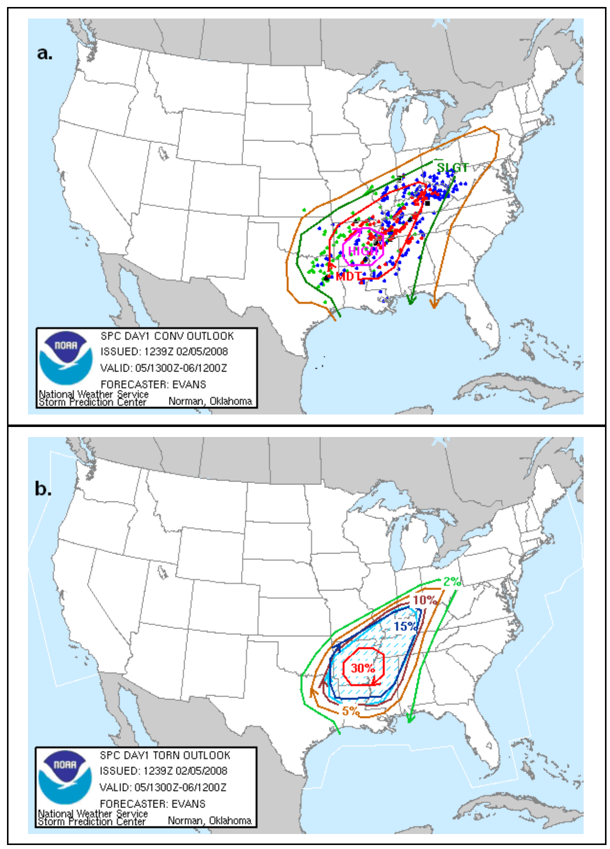

Fig 8. Same as Fig 3, except Day 1 outlook issued at 1300z Feb 4th. a) Categorical outlook, b) Tornado probabilities

severe thunderstorms and tornadoes where predictability on the storm scale is relatively low. In these instances, forecaster certainty may actually decrease with time as increasing volumes of newer and more detailed observational data and model guidance become available, often providing a variety of mesoscale and storm scale scenarios that were not resolved by the larger scale data. Given the limitations in our ability to sample and resolve in sufficient detail the four-dimensional structure of the atmospheric in real time (especially the distribution of water vapor), a number of the differing scenarios can all appear to be plausible, and it can be very challenging to determine which of the scenarios are most likely to occur. Thus, even in situations leading up to significant severe weather events, low predictability on the smaller scales is inherently present, and forecasters may become less confident in the impending threat as the event nears. This is consistent with previous studies (e.g. Heideman et al. 1993) that showed that more data by itself does not necessarily result in improved forecasts, and more data may actually contribute to a reduction in forecast quality unless better ways are found to incorporate the data into the decision-making process.

We have used the Super Tuesday case to illustrate the latter forecast scenario. Despite the very favorable large-scale environment, which was correctly predicted a week in advance, a high degree of uncertainty persisted into the morning of 5 February concerning the evolution of the mesoscale environment and subsequent convective response. This uncertainty stemmed from conflicting short term model solutions, disparities between the model guidance and observational data, and questions about how the environment would evolve in a very dynamic atmospheric pattern. But by “stepping back” and refocusing on the overall synoptic scale pattern, and utilizing observational data to identify important trends that provided insights into the timing and location of when and where the cap was likely to break across the region, forecasters were able to place a higher level of confidence in predicting a significant tornado outbreak.

5. REFERENCES

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