Evaluating the Fundamental Components of a Warn-on-Forecast System In a Collaborative Real-time Environment

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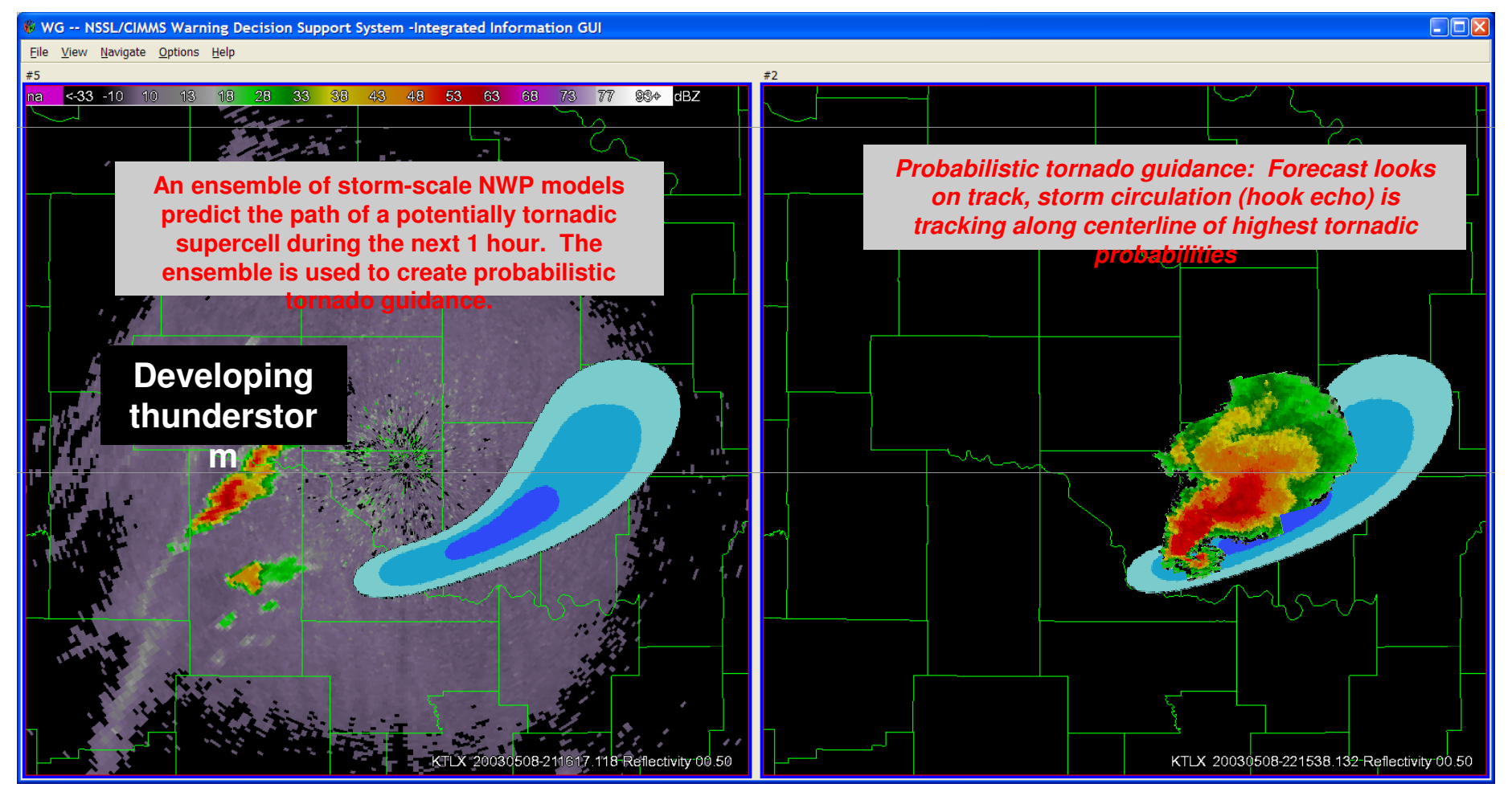
What is Warn-On-Forecast?

The Warn-on-Forecast paradigm (WoF) envisions probabilistic prediction of severe convective phenomena based on ensemble forecasts using high-resolution models. One of many scientific challenges facing WoF is how to construct reliable probabilistic information regarding severe convective phenomena when these phenomena will not be explicitly resolvable for many years to come.



An ensemble of storm-scale NWP models predict the path of a potentially tornadic supercell during the next 1 hour. The ensemble is used to create probabilistic tornado guidance.

Probabilistic tornado guidance: Forecast looks on track, storm circulation (hook echo) is tracking along centerline of highest tornadic probabilities

A conceptual illustration of a convective-scale WoF system is shown above. Developing thunderstorms are observed by radar (left) and assimilated into a convection-resolving numerical weather prediction model ensemble forecast system. Probabilistic predictions of the future evolution of these storms are produced, yielding a tornado probability field valid over the following 90 min (blue color fill). If the WoF system is accurate, then the observed storm 45 min later (right) produces a mesocyclone and hook echo that are along the axis of highest tornado probability. This type of predicted probabilistic hazard information would be updated frequently, perhaps with each volume scan of radar observations, and used to make warning decisions. Longer warning lead times are provided than are possible based upon observations alone (Figure and text taken from Stensrud et al. 2008).

One scientific challenge facing WoF is how to construct reliable probabilistic information regarding severe convective phenomena when these phenomena will not be explicitly resolvable in larger domain model configurations for many years to come (e.g., explicit prediction of tornadoes will require grid spacing on the order of a few tens of meters). It may be possible to overcome this problem by identifying "extreme" model-generated features that have strong correlations with observed severe convective phenomena, and then using the former as surrogates for the severe phenomena in question. This "surrogate-severe" (SS) approach is fundamentally different from traditional applications of NWP for severe weather because it is phenomenon based. In particular, it relies on identification of explicit convective phenomena rather than environmental conditions that might support such phenomena.

References

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Stensrud, D. J. , M. Xue, L. J. Wicker, K. E. Kelleher, M. P. Foster, J. T. Schaefer, R. S. Schneider, S. G. Benjamin, S. S. Weygandt, J. T. Ferree, and J. P. Tuell, 2009: Convective-Scale Warn-on-Forecast System. *Bull. Amer. Meteor. Soc.*, 90, 1487–1499.

Acknowledgements

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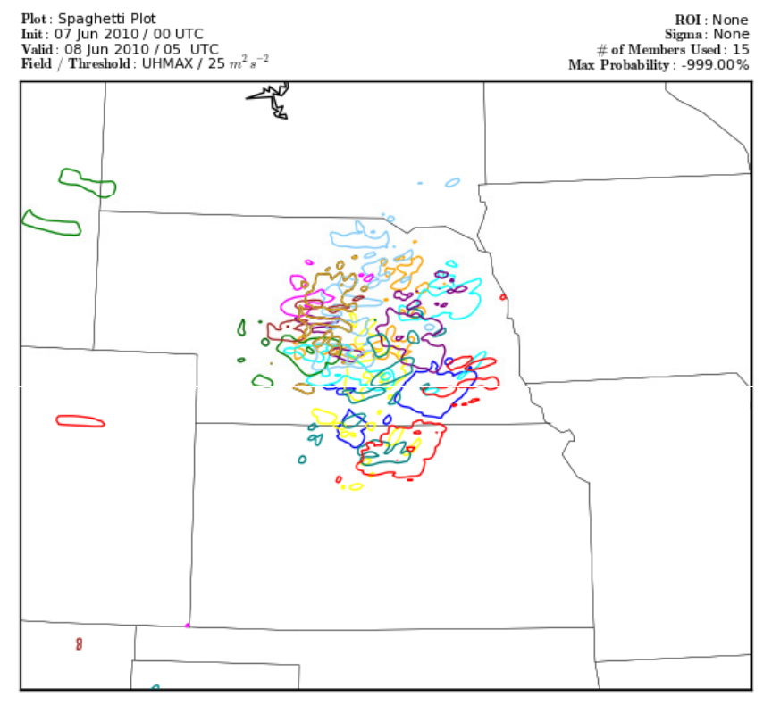
How Do We Get There?

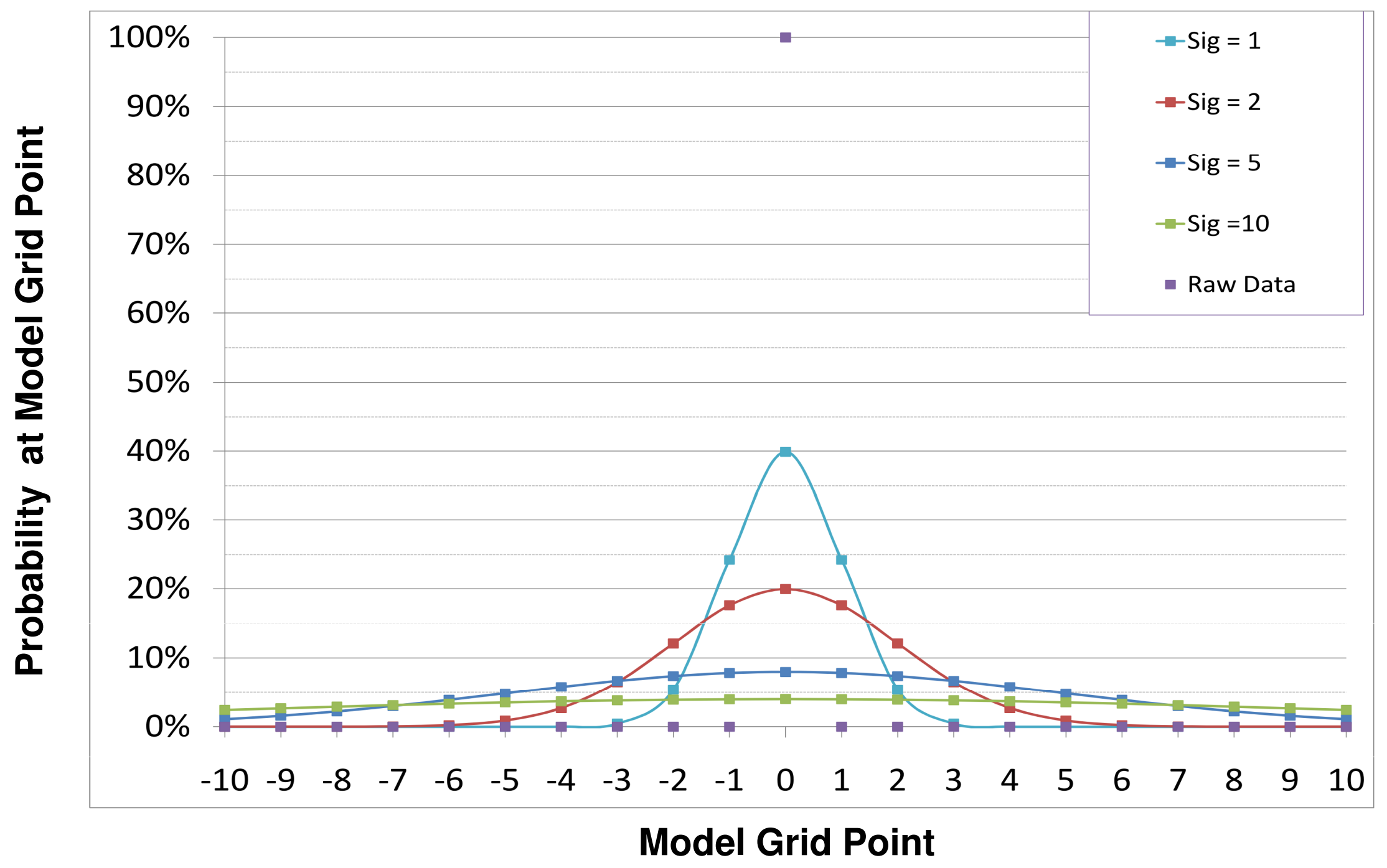


It is not readily apparent how to best synthesize and display ensemble guidance for extreme model-based phenomena. So, one question needing to be addressed is, "How do we move from the figure above, a spaghetti plot of direct model output, to the figure on the left, a reliably calibrated probability of occurrence?"

In an effort to address this issue, matrices of figures were constructed from the 2010 Center for Analysis and Prediction of Storms (CAPS) storm-scale ensemble that display different techniques for computing the probability of the hourly maximum updraft helicity (UH) exceeding a threshold of 25 m^2s^{-2} at each grid point. Empirical evidence suggests that this threshold is useful for identifying mid-level mesocyclones in 4-km WRF-ARW output. so the occurrence of UH greater than or equal to 25 m^2s^{-2} is considered an event. The matrices were designed to illustrate the sensitivity of the exceedence probability to: 1) search radius (SR), and 2) spatial uncertainty on the computation, and to solicit feedback from forecasters and research scientists during the Spring Experiment on optimal ways to display the probability information.

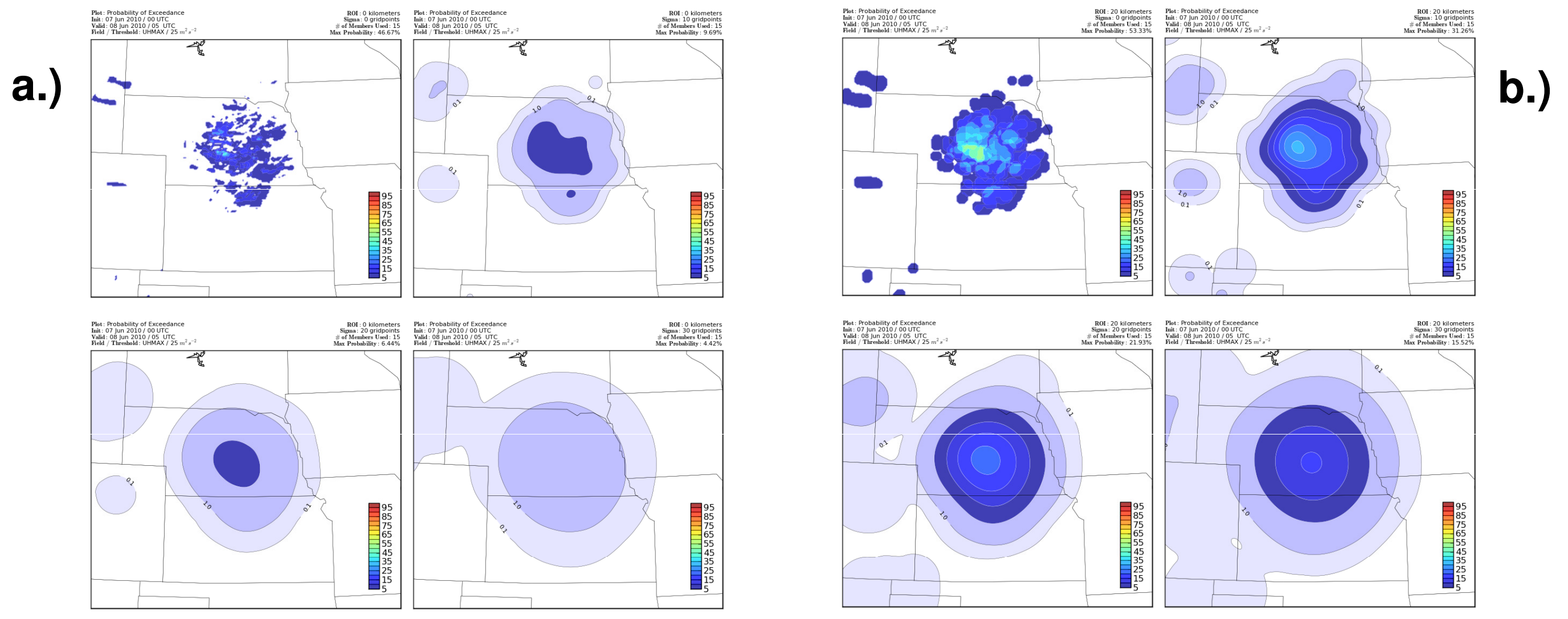
The infrequent nature of rare events makes it unlikely that two separate high resolution model forecasts would place extreme model-generated convective storm phenomena at the same grid point, even for generally similar mesoscale forecasts. One potential remedy to this problem is to examine all grid points within a specified SR for each occurrence of the designated event. As we would expect, a larger SR tends to yield higher probabilities.

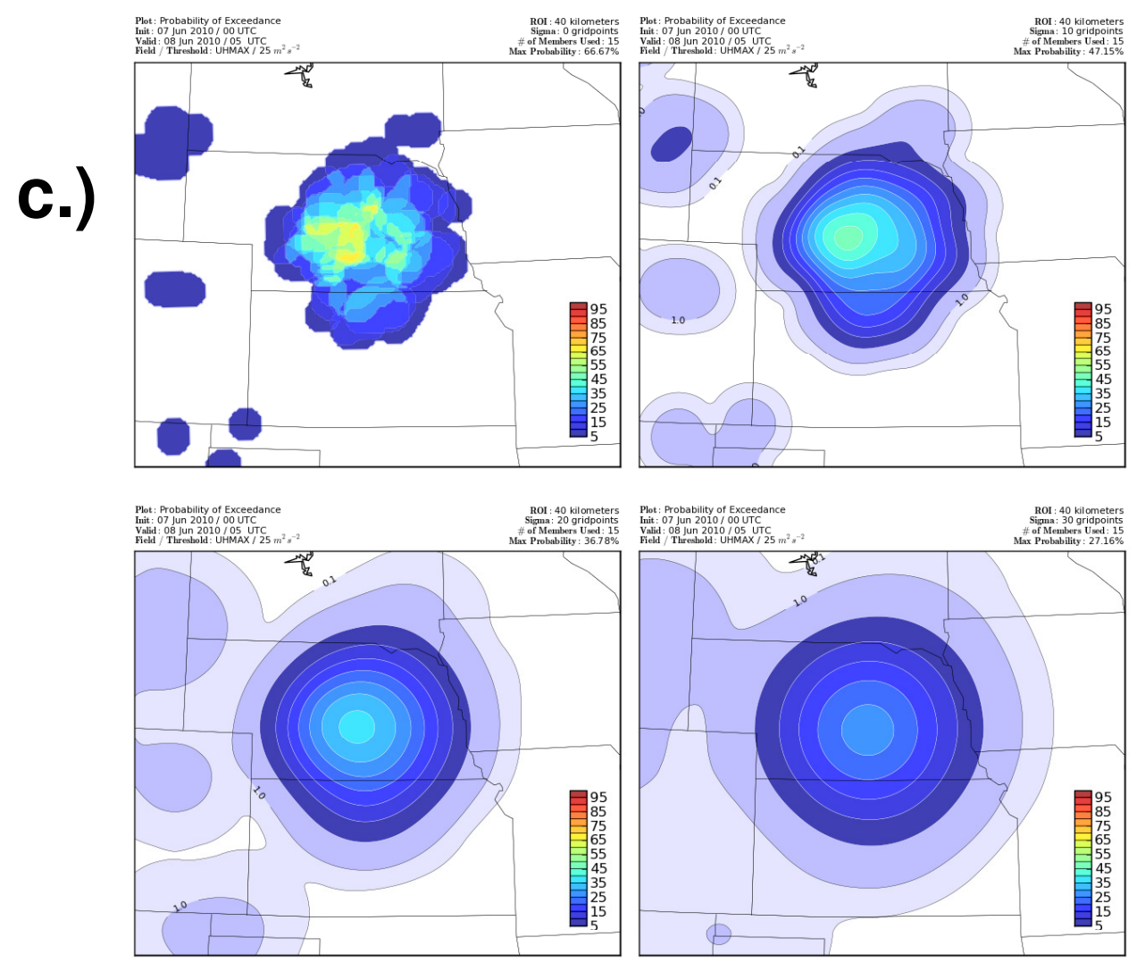
One post processing approach to add spatial uncertainty is to apply a Gaussian kernel density estimator to the ensemble forecast (Brooks et al. 1998 and Silverman 1986). In this approach, every identified model-based event is represented using a 2-D Gaussian PDF, allowing us to incorporate a measure of uncertainty in predicting the location of an event. By varying the standard deviation of the 2-D Gaussian distribution, the spatial uncertainty associated with each model-based event also varies. The figure below uses an idealized 1-D example to demonstrate this concept. The purple dots represent the raw probabilities generated by the model/ensemble (i.e., the event occurred at grid point 0, so there is a 100% probability there and a 0% probability elsewhere). By applying a Gaussian distribution to the raw probabilities and varying the standard deviation (sigma), probabilities are derived for neighboring grid points (represented by squares) from the underlying Gaussian distribution (represented by the thin, solid line).



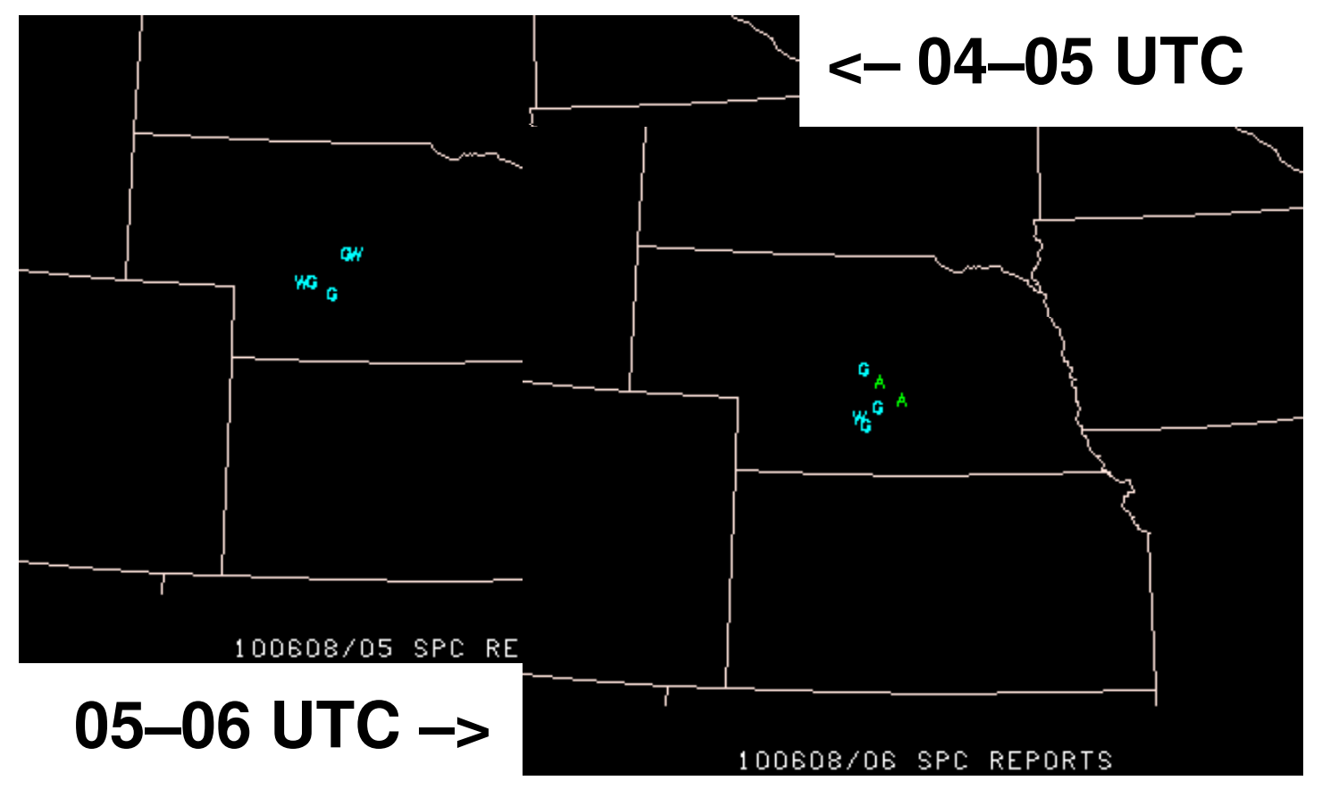
Example: F29 (05 UTC) from 07 June 2010

For the 2010 Hazardous Weather Testbed Spring Experiment, SR of 4-km (native model grid), 20-km (5 grid points), and 40-km (10 grid points) were examined. Additionally, standard deviations of 0 (no uncertainty), 5 grid points (not shown), 10 grid points (small spatial uncertainty), 20 grid points (moderate spatial uncertainty), and 30 grid points (large spatial uncertainty) were examined. Below, examples of these plots for hourly maximum updraft-helicity are shown, with observed severe weather reports in the bottom-left. Figures use a SR of a) 0-km, b) 20-km, and c) 40-km. In each of these groups, the top-left figure incorporates no spatial uncertainty, the top-right uses small spatial uncertainty, the bottom-left incorporates moderate spatial uncertainty, and the bottom-right incorporates large spatial uncertainty.





Observed Severe Weather Reports



Please visit http://hwt.nssl.noaa.gov/Spring_2010/modelcompare.php to view additional matrices for the entire 2010 HWT EFP.

Concluding Thoughts

A key challenge for the WoF paradigm is to produce probabilistic guidance that has a high degree of statistical reliability and resolution and is unambiguous for users to interpret. In this paper, it was shown that the character of event-based guidance products can vary substantially depending on the specific definition of an "event", the search radius for its occurrence, and the degree of spatial uncertainty associated with model predictions of it. It is anticipated that the WoF effort will require considerable research on each of these topics in order to optimize probabilistic forecasts of extreme and rare events such as tornadoes, large hail, and extreme wind gusts.