37 THE UTILITY OF STORM-SCALE ENSEMBLE FORECASTS OF COOL SEASON SEVERE WEATHER EVENTS FROM THE SPC PERSPECTIVE

Jared L. Guyer* and Israel L. Jirak
NOAA/NWS Storm Prediction Center, Norman, Oklahoma

1. INTRODUCTION

The majority of recent peer-reviewed and conference examinations of deterministic convection-allowing models (CAMs) and convection-allowing ensemble forecasts have focused on warm season severe weather events, particularly those events coincident with the yearly NOAA Hazardous Weather Testbed (HWT) Experimental Forecast Program in Norman, Oklahoma (Kain et al. 2008; Clark et al. 2012a). The number of convection-allowing models (CAMs) available to forecasters at the Storm Prediction Center (SPC) has increased considerably over the past few years. Even in cool season environments characterized by lower instability regimes, forecasters at the SPC have found that CAM ensemble forecasts of storm-attribute hourly maximum fields (HMFs; Kain et al. 2010) to be helpful in forecasting the intensity, spatial locations, and convective modes of severe convective storms. Real-time, year-round convection-allowing ensemble forecast output guidance from the SPC Storm-Scale Ensemble of Opportunity (SSEO) and the Air Force Weather Agency (AFWA) 4-km Ensemble Prediction System are highlighted for three significant cool season severe weather events.

2. BACKGROUND

With horizontal model grid spacing around 4 km, CAMs provide explicit convective storm forecasts. These models serve as the base members in first-generation experimental CAM ensembles, such as the SPC Storm Scale Ensemble of Opportunity (SSEO) and Air Force Weather Agency 4-km Ensemble Prediction System (hereafter AFWA).

The SSEO is a multi-model, multi-physics ensemble comprised of seven deterministic CAM runs that are generally available to SPC forecasters on a year-round basis (Jirak et al. 2012). The SSEO includes the NSSL WRF-ARW, High-Resolution Window (HRW) WRF-ARW, HRW NMMB, CONUS WRF-NMM (sometimes referred to as the “SPC Run” by EMC and NWS forecast offices), and the NAM CONUS Nest. Two 12-h time-lagged HRW runs (one ARW and one NMM) are added for initial condition diversity to arrive at a total of seven members. 00 UTC and 12 UTC SSEO runs are available (a 12 UTC-based SSEO run was added in late 2013 subsequent to Jirak et al. 2012).

In contrast to the variety of model cores (i.e., three – WRF-ARW, WRF-NMM, and NMMB) within the SSEO, the AFWA is a 10-member single-model (i.e., WRF-ARW) ensemble. The AFWA uses a multi-physics approach with initial condition diversity derived by using downscaled global forecasts for initial conditions/lateral boundary conditions (Kuchera 2014).

Researchers and operational forecasters have found that ensemble HMFs can provide considerable forecast utility (Jirak et al. 2010). This includes HMFs related to 1-km AGL simulated reflectivity for diagnosing convective mode and intensity, updraft helicity (UH; Kain et al. 2008) for representing a rotating updraft in a simulated storm, updraft speed as a measure of convective overturning, and 10-m AGL wind speed for identifying convectively generated wind gusts. Although dominated by warm season cases, Clark et al. (2012b) and Clark et al. (2013) examined the relationship of strong UH values to tornadoes and tornado path length.

3. CASE EXAMPLES

The role of CAM ensembles are subsequently highlighted for three significant cool season severe weather cases. HMFs accumulated over 24-hr periods (valid 12-12 UTC) for the SSEO and AFWA are shown for each case.

a. 17 November 2013

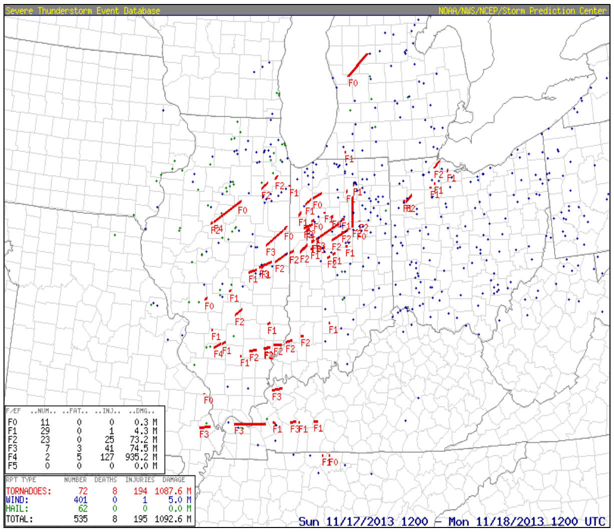
A significant cool-season tornado outbreak occurred in the Midwest on 17 November 2013. This included a total of 74 tornadoes, with 32 (43%) of them rated EF2 or greater. There were eight tornado-related fatalities and 440 severe wind/wind damage reports across the region (Fig. 1). The event was generally well forecast with a SPC High Risk centered on Illinois and Indiana on the 1300 UTC Day 1 Convective outlook (Fig. 2). As common for the cool season, the severe weather outbreak was generally characterized by a combination of high vertical shear and relatively modest buoyancy (Guyer and Dean 2012). For example, mixed-layer (ML) CAPE generally did not exceed 1000-1500 Jkg^{-1} at the time of peak tornado occurrence (Fig. 3), although a special 1400 UTC KDVN observed sounding did feature a ~1600 Jkg^{-1} MLCAPE (not shown).

Figures 4-6 highlight UH forecasts from the 12 UTC 17 November 2013 SSEO, including 24-hr spaghetti plot of UH (Fig. 4), 24-hr ensemble maximum of UH (Fig. 5), and a 24-hr smoothed neighborhood probability of UH exceeding 25 m^{2}s^{-2}(Fig. 6). Figures 7-

---

* *Corresponding author address*: Jared L. Guyer NOAA/NWS Storm Prediction Center, National Weather Center, 120 David L. Boren Blvd, Suite 2300, Norman, OK 73072; e-mail: Jared.Guyer@noaa.gov

9 highlight similar UH forecast fields from the 12 UTC 17 November 2013 AFWA. When compared to storm reports (Fig. 1), these forecasts coincide with the majority of observed supercells and tornadoes across the region on 17 November 2013. Of note, peak values (≥100 m^2s^{-2}) of 24-hr ensemble maximum UH from the 12 UTC SSEO (Fig. 5) and especially the AFWA (Fig. 8) generally coincided with strong long-tracked tornadoes that occurred initially across parts of north-central Illinois (including a late-morning 46-mile track EF4 tornado near the Peoria, Illinois area) and subsequently across parts of northeast/east-central Illinois into northern Indiana. However, it is also important to note that many of the reported tornadoes occurred in areas where the forecast UH values from the 12 UTC SSEO and AFWA were around 25 m^2s^{-2} (c.f., Figs. 5,8 and Fig. 1). As commonly seen during the cool season, the relatively modest amounts of buoyancy were likely a factor in muting the magnitude of ensemble forecast UH.



F/EF	..NUM..	..FAT..	..INJ..	..DMG..
F0	11	0	0	0.3 M
F1	29	0	1	4.3 M
F2	23	0	25	73.2 M
F3	7	3	41	74.5 M
F4	2	5	127	935.2 M
F5	0	0	0	0.0 M

RPT TYPE	NUMBER	DEATHS	INJURIES	DAMAGE
TORNADOES:	72	8	194	1087.6 M
WIND:	401	0	1	5.0 M
HAIL:	62	0	0	0.0 M
TOTAL:	535	8	195	1092.6 M

Figure 1. Storm reports for 17 November 2013 (24-hour period ending 12 UTC 18 November 2013) including tornado tracks (red), damaging winds (blue dots), and severe hail (green dots).

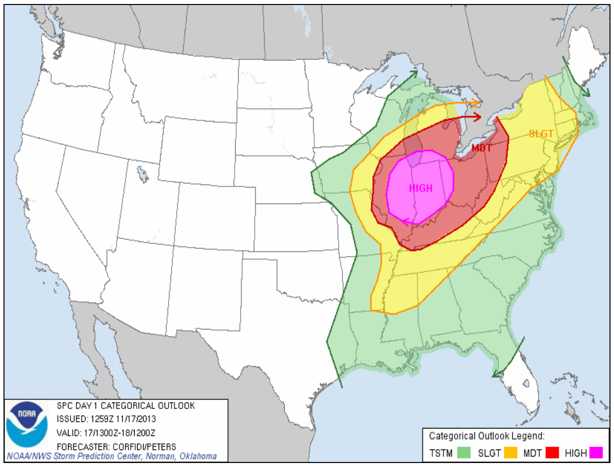


Figure 2. Storm Prediction Center (SPC) Day 1 Convective Outlook from 13 UTC 17 November 2013.

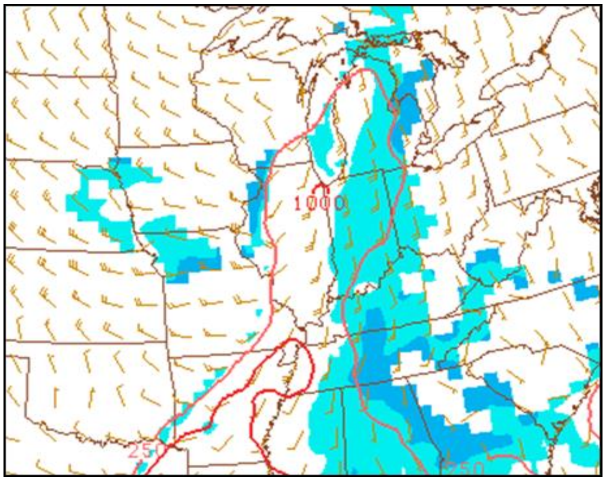


Figure 3. SPC Mesoanalysis (Bothwell et al. 2002) MLCAPE (Jkg^{-1}) valid 18 UTC 17 November 2013.

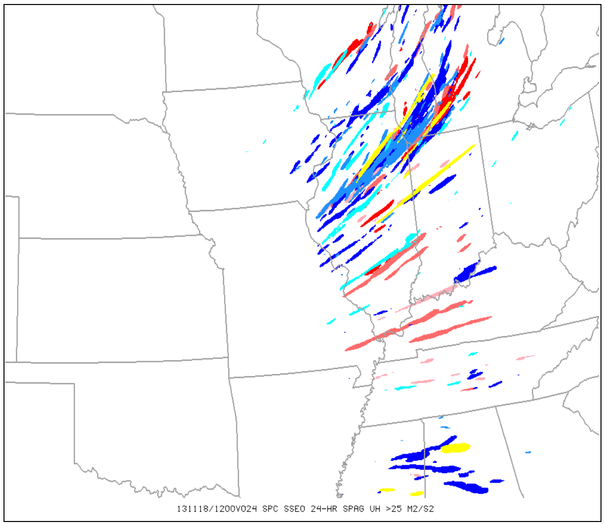


Figure 4. 12 UTC 17 November 2013 SSEO 24-hr spaghetti plot of UH ≥25 m^2s^{-2}.

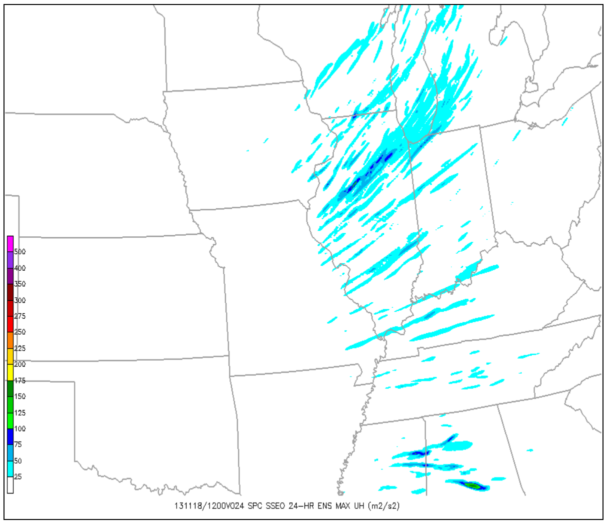


Figure 5. 12 UTC 17 November 2013 SSEO 24-hr ensemble maximum of UH (m^2s^{-2}).

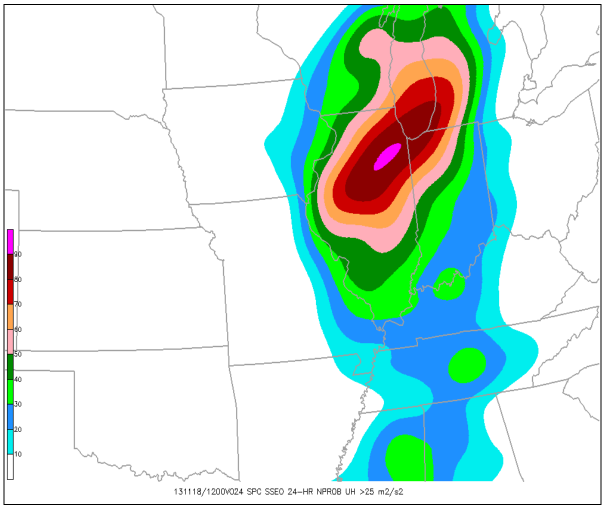


Figure 6. 12 UTC 17 November 2013 SSEO 24-hr smoothed neighborhood probability (%) of UH ≥25 m^2s^{-2}.

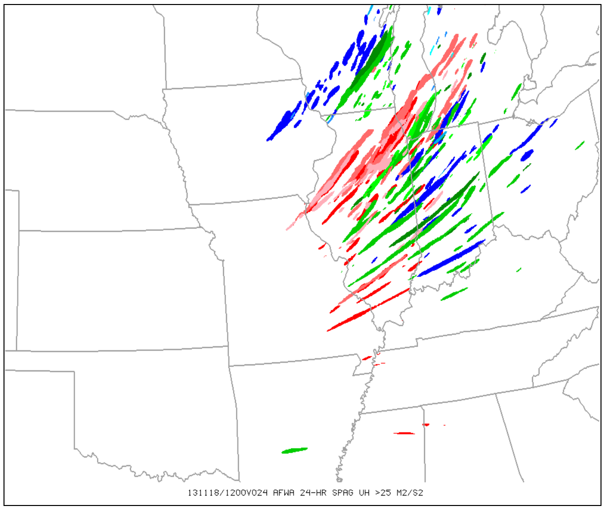


Figure 7. 12 UTC 17 November 2013 AFWA 24-hr spaghetti plot of UH ≥25 m^2s^{-2}.

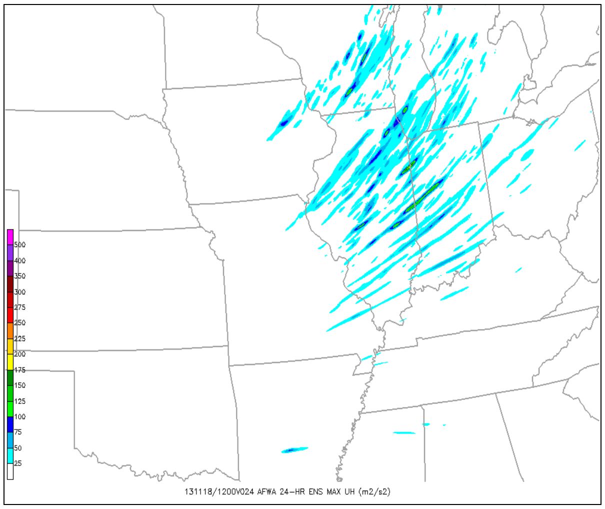


Figure 8. 12 UTC 17 November 2013 AFWA 24-hr ensemble maximum of UH (m^2s^{-2}).

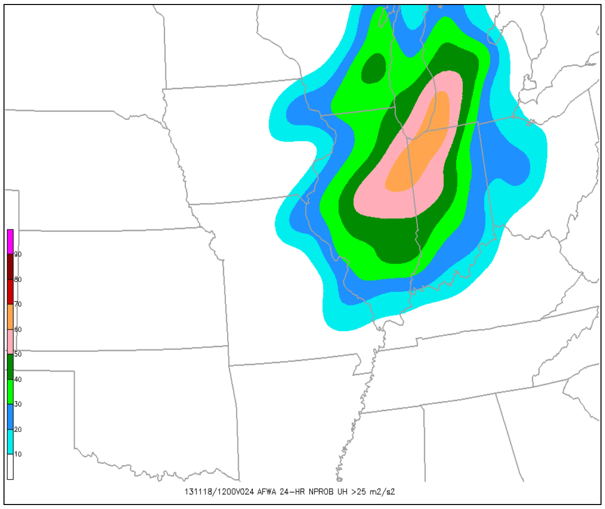
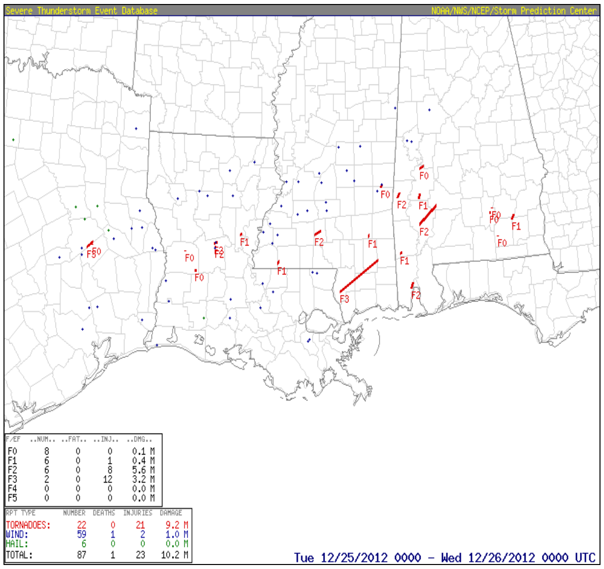


Figure 9. 12 UTC 17 November 2013 AFWA 24-hr smoothed neighborhood probability (%) of UH ≥25 m^2s^{-2}.

b. 25 December 2012

A regional outbreak of supercells and tornadoes occurred on Christmas Day 2012 across parts of the Gulf Coast states. There were 22 tornadoes, including six EF2 tornadoes and two EF3 tornadoes, in addition to 59 reports of wind damage from parts of east Texas to southern Alabama (Fig. 10). Peak values of 24-hr smoothed neighborhood probabilities of UH from the 00 UTC 25 December 2012 SSEO (i.e., f12-f36 valid 12-12 UTC; Fig. 11) were largely coincident with the main regional corridor of tornado occurrence. The forecast UH magnitudes from the 00 UTC SSEO were locally as high as 100-175 m^2s^2 across east-central Louisiana and southern Mississippi (not shown).



F/EF	..NUM..	..FAT..	..INJ..	..DMG..
F0	8	0	0	0.1 M
F1	6	0	1	0.4 M
F2	6	0	8	5.6 M
F3	2	0	12	3.2 M
F4	0	0	0	0.0 M
F5	0	0	0	0.0 M

RPT TYPE	NUMBER	DEATHS	INJURIES	DAMAGE
TORNADOES:	22	0	21	9.2 M
WIND:	59	1	2	1.0 M
HAIL:	6	0	0	0.0 M
TOTAL:	87	1	23	10.2 M

Tue 12/25/2012 0000 - Wed 12/26/2012 0000 UTC

Figure 10. As in Fig. 1, except 25 December 2012 (24-hour period ending 12 UTC 26 December 2012).

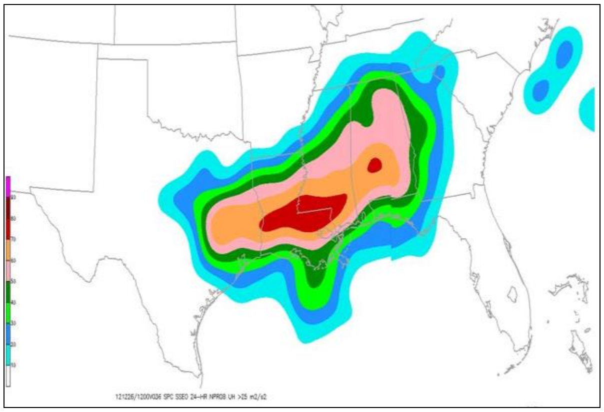
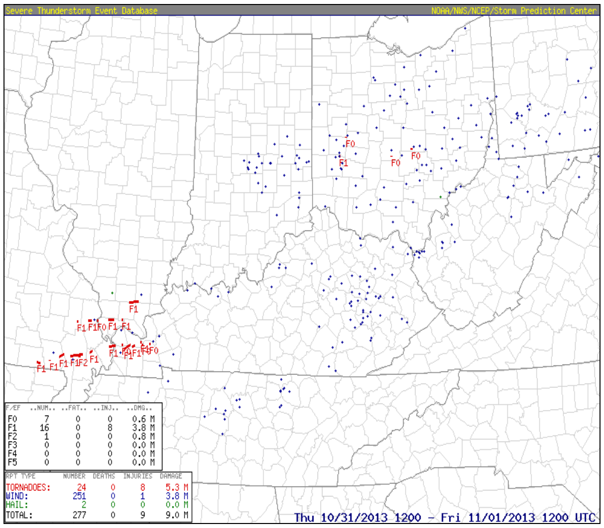


Figure 11. 00 UTC 25 December 2012 SSEO 24-hr smoothed neighborhood probability (%) of UH ≥ 25 m^2s^{-2} valid 12 UTC 25 December to 12 UTC 26 December (i.e., f12-f36).



F/EF	..NUM..	..FAT..	..INJ..	..DMG..
F0	7	0	0	0.6 M
F1	16	0	8	3.8 M
F2	1	0	0	0.8 M
F3	0	0	0	0.0 M
F4	0	0	0	0.0 M
F5	0	0	0	0.0 M

RPT TYPE	NUMBER	DEATHS	INJURIES	DAMAGE
TORNADOES:	24	0	8	5.3 M
WIND:	251	0	1	3.8 M
HAIL:	2	0	0	0.0 M
TOTAL:	277	0	9	9.0 M

Figure 12. As in Fig. 1, except 31 October 2013 (24-hour period ending 12 UTC 1 November 2013).

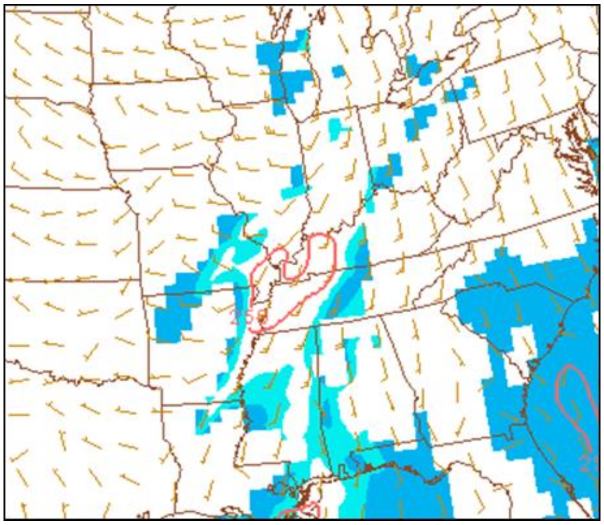


Figure 13. As in Fig. 3, except SPC Mesoanalysis MLCAPE (Jkg^{-1}) 00 UTC 1 November 2013.

c. 31 October 2013

Around two-dozen tornadoes (only one EF2+) occurred with supercells across the middle Mississippi Valley and lower Ohio Valley during the late afternoon and early evening of 31 October 2013. More than 250 reports of subsequent wind damage (Fig. 12) occurred during the evening and overnight hours of 31 October into 1 November 2013, as a fast-moving quasi-linear convective system became the dominant storm mode. In the presence of very strong vertical shear, the severe weather occurred with limited buoyancy, indicated by MLCAPE estimated at 250 Jkg^{-1} or less (Fig. 13; 00 UTC SPC Mesoanalysis represents the maximum estimated MLCAPE during the event). Figures 14 and 16 show 24-hr spaghetti plots of UH from the 12 UTC 31 October 2013 SSEO and AFWA, respectively. While spatial errors are evident in the UH forecasts, they still provide operationally useful guidance concerning storm character and intensity (related to tornado reports) given that each of the ensembles had multiple members that developed and sustained rotating updrafts. Furthermore, related to 250+ wind reports that evening/overnight, 24-hr plots of 10-m AGL ensemble maximum wind speeds appeared to have utility in indicating the potential for strong surface winds from the 12 UTC SSEO (Fig. 15) and AFWA (Fig. 17). In this particular event, the AFWA (Fig. 17) especially indicated very high (50+ kt) maximum wind speeds in a regionally (and temporally) coincident manner with the wind damage reports across the Ohio Valley.

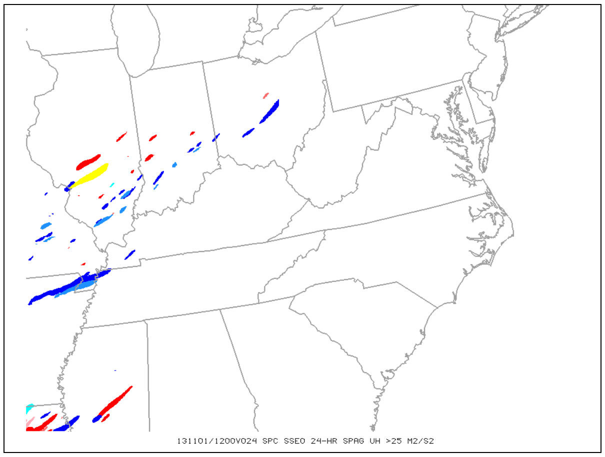


Figure 14. 12 UTC 31 October 2013 SSEO 24-hr spaghetti plot of UH ≥ 25 m^2s^{-2}.

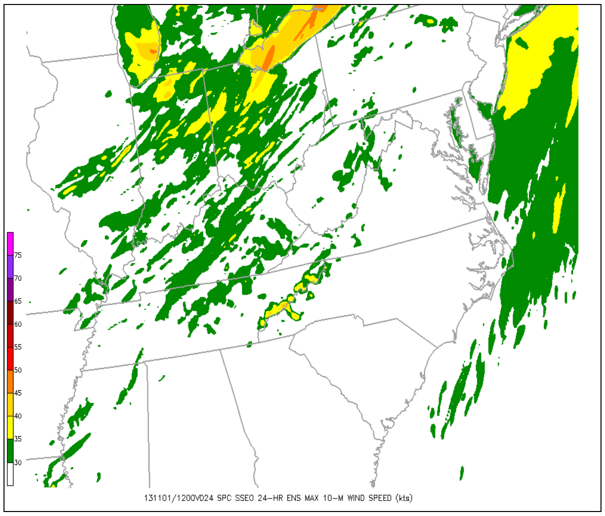


Figure 15. 12 UTC 31 October 2013 SSEO 24-hr ensemble maximum 10-m AGL wind speed (kt).

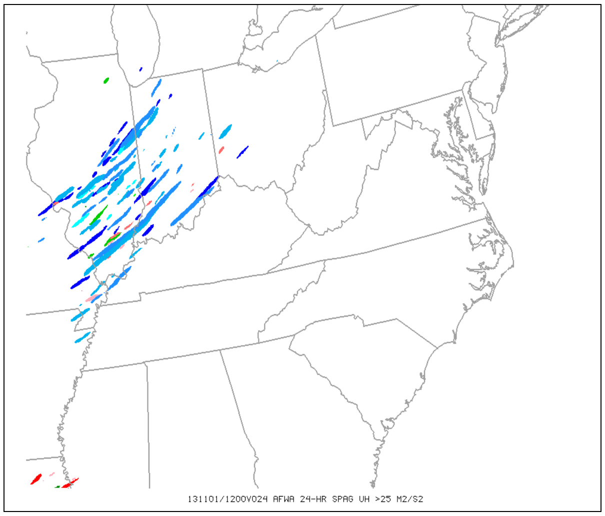


Figure 16. 1200 UTC 31 October 2013 AFWA 24-hr spaghetti plot of UH ≥25 m^2s^{-2}.

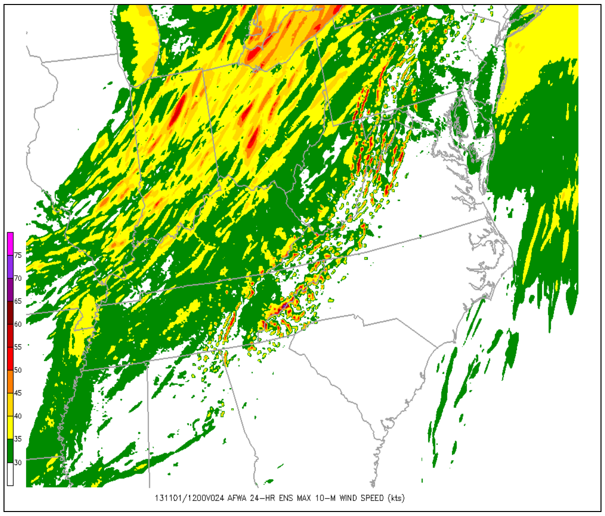


Figure 17. 1200 UTC 31 October 2013 AFWA 24-hr ensemble maximum 10-m AGL wind speed (kt).

4. SUMMARY

Building upon previously documented CAM-related warm season cases, these notable cool-season events illustrate how both the SSEO and AFWA can each provide valuable forecast guidance in significant cool season severe weather events, including regional tornado outbreaks. Likely related to weaker values of buoyancy in the (real-world and) model environment, operational forecasters should generally not expect magnitudes of CAM storm-attribute HMFs (particularly UH) in the cool season to necessarily be as high as those during the warm season. For example, it appears that tornado-related values of UH are commonly weaker in the cool season as compared to consequential warm season events in which UH may more commonly reach the 75-150 m^2s^{-2} thresholds utilized by Clark et al. (2012b) and Clark et al. (2013). Thus, even relatively modest values of forecast UH (e.g. 25 m^2s^{-2}) can serve as a reasonable proxy for the potential of sustained supercells and possible tornadoes during the cool season. When mindful of lower thresholds, these modest UH values from ensembles can provide valuable guidance to the operational forecaster in terms of general timing, convective mode, intensity, and spatial details and uncertainty in terms of the greatest severe weather and tornado potential on regional scales. Furthermore, the 31 October 2013 case illustrates the capabilities of CAMs to produce significant near-ground wind speeds even in the cool season when the boundary layer tends to be more stable.

Guidance from the Storm-Scale Ensemble of Opportunity (SSEO) is available online: http://www.spc.noaa.gov/exper/sseo

5. REFERENCES

Bothwell, P.D., J.A. Hart and R.L. Thompson, 2002: An integrated three-dimensional objective analysis scheme in use at the Storm Prediction Center. Preprints, *21st Conf. Severe Local Storms*, San Antonio, J117-J120.

Clark, A. J., and Co-authors, 2012a: An Overview of the 2010 Hazardous Weather Testbed Experimental Forecast Program Spring Experiment. *Bull. Amer. Meteor. Soc.*, **93**, 55–74.

Clark, A. J., J. S. Kain, P. T. Marsh, J. Correia, M. Xue, and F. Kong, 2012b: Forecasting tornado pathlengths using a three-dimensional object identification algorithm applied to convection-allowing forecasts. *Wea. Forecasting*, **27**, 1090–1113.

Clark, A. J., J. Gao, P. T. Marsh, T. Smith, J. S. Kain, J. Correia Jr., M. Xue, and F. Kong, 2013: Tornado pathlength forecasts from 2010 to 2011 using ensemble updraft helicity. *Wea. Forecasting*, **28**, 387–407.

Guyer, J.L., and A.R. Dean, 2010: Tornadoes within Weak CAPE Environments across the Continental United States. Preprints, *25th Conf. Severe Local Storms*, Denver CO, Amer. Meteor. Soc., 1.5 .

Jirak, I.L., S. J. Weiss, and C. J. Melick, 2012: The SPC Storm-scale Ensemble of Opportunity: Overview and Results from the 2012 Hazardous Weather Testbed Spring Forecasting Experiment. Preprints, *26th Conf. Severe Local Storms*, Nashville, TN, Amer. Meteor. Soc., P9.137.

Jirak, I.L., S.J. Weiss, C.J. Melick, P.T. Marsh, J.S. Kain, A.J. Clark, M. Xue, F. Kong, and K.W. Thomas, 2010: Evaluation of the Performance and Distribution of Hourly Maximum Fields from Storm-scale Ensemble Forecasts. Preprints, *25th Conf. Severe Local Storms*, Denver CO, Amer. Meteor. Soc., 13B3.

Kain, J. S., S. J. Weiss, D. R. Bright, M. E. Baldwin, J. J. Levit, G. W. Carbin, C. S. Schwartz, M. L. Weisman, K. K. Droegemeier, D. B. Weber, K. W. Thomas, 2008: Some practical considerations regarding horizontal resolution in the first generation of operational convection-allowing NWP. *Wea. Forecasting*, **23**, 931-952.

Kain, J. S., S. R. Dembek, S. J. Weiss, J. L. Case, J. J. Levit, and R. A. Sobash, 2010: Extracting unique information from high resolution forecast models: Monitoring selected fields and phenomena every time step. *Wea. Forecasting*, **25**, 1536–1542.

Kuchera, E., S.Rentschler, G. Creighton, and J. Hamilton, 2014: The Air Force weather ensemble prediction suite. 15th Annual WRF Users' Workshop, Boulder CO.
Website:http://www2.mmm.ucar.edu/wrf/users/workshops/WS2014/ppts/2.3.pdf