Strong Synoptic System Type Severe and Tornadic Event
17 November 2013

value of anomalies for situational awareness

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1. Overview

A strong mid-tropospheric trough (Fig. 1) raced across the central and United States from 17 November through 18 November 2013. The fast moving short-wave was associated with a strong 250 hPa jet stream which had a nearly textbook severe pattern (Fig. 1 & Fig. 6a: Uccellini and Johnson 1979) over the Mid-Mississippi and Ohio Valley from 1200 UTC to 0000 UTC on 17 November 2013 (Figs. 2b-c). The flow between the deep trough and the strong ridge over the eastern Gulf of Mexico (Fig. 1) resulted in a surge of warm moisture rich air and strong low-level flow which produced over 580 reports of severe weather (Fig. 3) on 17 November and into early 18 November 2013.

Similar to the severe event of 1 November 2013, this case also illustrates the power of using standardized anomalies to identify potential high impact weather events (HIWE). Numerous studies over the past decade have shown the value of using standardized anomalies to predict HIWEs. Grumm and Hart (2001), Hart and Grumm (2001), Stuart and Grumm (2006), and Graham and Grumm (2010) have all shown the value of using standardized anomalies to identify a wide range of HIWEs. The method is effective at identifying when the pattern as predicted by a forecast system departs significantly from normal. Though the climate data used to compute the standardized anomalies approximate a normal distribution, the data are not normally distributed. This is a limitation in the data that requires additional information to identify some of the extreme weather events.
The success of the method of using standardized anomalies to identify HIWE lead to the concept of a situational awareness table (Graham et al. 2013). In the table, key anomalies by parameter, such as height (Z), temperature (T), moisture (q or PW), wind speed (V), and wind components (u- and v-) were displayed and color coded to draw the forecasters attention to the potential of extreme events. A complete list of the variables and levels the anomalies are computed at are listed in Table 1 (Graham et al. 2013). These data were then used to show how the historic western United States storm of January 2010 was predicted. In addition to providing visual alerts, these data provide good input to software to produce messages to alert users of HIWEs.

This paper will document the strong severe weather event of 17-18 November 2013. The focus on the impacts is related to the traditional use of standardized anomalies and some of the limitations in using these data to identify extremely anomalous stations. The concept of using return periods and percentiles to compliment standardized anomalies is introduces as a more advanced means to assess the potential of a HIWE. With over 580 reports of severe weather and over 400 events in the Midwest, this was by far one of the largest November severe events in recent history (Table 1).

2. Data and Methods

The large scale pattern was reconstructed using the 00-hour forecast of the NCEP Global Forecast System (GFS) as first guess at the verifying pattern. The standardized anomalies were computed in Hart and Grumm (2001). All data were displayed using GrADS (Doty and Kinter 1995). The standardized anomalies and the probability distribution functions are based on the re-analysis climate (R-Climate). Though not shown here, they could be produced from internal model system climatologies (M-Climate).

The traditional standardized anomalies were produced from the GFS 00-hour forecast using Climate Forecast System based means and standard deviations. The climatology spans a 30 year period. This 30-year period was used in the situational awareness (SA) tables to show the return period of the anomalies.

The forecasts in the SA tables were derived from the 42 member North American Ensemble Forecast System (NAEFS). These data are displayed using the NAEFS mean fields relative to the climate. In addition to standardized anomalies, the return period and interval of the anomalies are produced relative to the 21-day centered values. The return period is in years such that a 30-year return period represents the extreme in the climatological data set. The percentile data represent where along the climatological probability distribution the current NAEFS forecast lies. Extremes in the tails would be in the 97 to 100 percentile (MAX) or in the 3 to 0th percentile (MIN). In addition to finding the MAX and MIN relative to the time, the MAX and MIN are computed using the 4 climatological times of 00, 06, 12, and 18 UTC. This provides the ability
to estimate the MAX (MIN) at the specified time or for all 4 times in the same 21-day centered climatological window.

Storm reports were gathered from the Storm Prediction Center (SPC) and using the local archive at the National Weather Service Office in State College, PA. These latter data were used to produce Table 1. The data were filtered by date and region to compare this event focused over the Mid-Mississippi and Ohio Valleys (MMV and OHV) to previous events.

3. Pattern over the region

The large scale pattern as analyzed by the GFF 00-hour forecasts (Fig. 1) showed the deep 500 hPa trough which rapidly moved across the central United States from 16/0000 through 18/1200 UTC. The 500 hPa height anomalies were on the order of -1σ below normal. This trough combined with the positive height anomalies over the Gulf of Mexico produced a strong gradient between the two systems resulting in the strong 250 hPa jet with +1 to +2σ above normal winds in the jet as it swept through the MMV on 17 November 2013 (Fig. 2).

The strong southerly flow between the two upper-level systems opened the Gulf of Mexico allowing a flow of warm air and deep moisture (Fig. 4) into the region; the fuel for convection. The airmass was unseasonably warm and moist just ahead of the upper-level short-wave was accompanied by a strong 850 hPa jet (Fig. 5) and had a surge of CAPE with CAPE in the 600 to 1200 J Kg\(^{-1}\) range. CAPE is close to 0 during November so these numbers are quite impressive and most likely represent values well at the extreme tails of CAPE climatology for mid-November.

4. Forecasts and standardized anomalies to identify extreme events

Tabular data of the anomalies as forecast from the NAEFS showed the potential for a surge of strong winds from 850 to 250 hPa, high PW air, and a deep trough with several days lead-time (Figs. 7 & 8). Figure 7 shows the standardized anomalies for each variable while Figure 8 shows the return period of the anomalies in years, based on a 30-year base climatology. The wind and moisture anomalies for 17 November over the eastern United States were forecast to have return periods of 5-10 years from forecasts initialized at 14/0000 UTC. The return periods increased dramatically for the moisture field (Q) and wind fields (V) from forecasts issued at 15/0000 UTC.

The larger anomalies on 15 November (Fig. 8) relative to those on 14 November (Figs. 7 ) show the impact of averaging 42 forecasts and how the ensemble mean sharpens as the forecasts converge toward a solution. The NAEFS meridional winds from 15 November valid at 1800 UTC 16 November show the strong 250 hPa winds and the strong low-level jet over the central United States (Fig. 9).

5. Summary
Surges of deep warm moist air can produce conditions in November more similar to the warm season. When conditions with strong winds, strong shear, and relatively high CAPE are present they can and they do produce late season severe events. The conditions on 17 November in terms of the 250 hPa jet (Fig. 2), the 850 hPa jet (Fig. 5), the PW (Fig. 4) and the CAPE (Fig. 6) suggest this was an excellent set up for a late season severe weather event. The pattern was similar to the jet pattern and convergence of ingredients outlined by Uccellini and Johnson (1979), with the added benefit of knowledge related to how strong the forecast jet and moisture plume were relative to climatology. These additional climatological data can aid in anticipating high impact weather events (HIWE). Related to severe weather, this additional information may aid in identifying meteorologically and climatologically significant events.

The future of forecasting HIWE and automated procedures to produce alerts of such events will improve as the R-Climate and M-Climate probability distribution functions are employed. These data should improve identifying when the modeling system, relative to climate is producing a high end event. The use of M-Climate data may aid in identifying when the model is predicting an extreme event in the modeling system atmosphere, which is often indicative of the potential for a record event in the real (observed) atmosphere.

6. Acknowledgements

The Pennsylvania State University for gridded data access and the Mid-Atlantic River forecasts and Trevor Alcott for return period data and images.

7. References


Associated Press, 2013b: South Dakota: Cattle Loss from Blizzard Estimated above 10,000 and similar stories 6 to 14 October 2013.


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Uccellini LW and DR Johnson, 1979: The coupling of upper and lower tropospheric jet streaks and implications for the development of severe convective storms. MWR,107,682-703

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Table 1. List of severe events over the central US by event dates
NWS State College Case Examples
Figure 1. GFS 00-hour forecasts of 500 hPa heights (m) and and standardized anomalies (shaded) in 12 hour increments from a) 0000 UTC 16 November 2013 through f) 1200 UTC 18 November 2013. Return to text.
Figure 2. As in Figure 1 except for 250 hPa winds and total wind anomalies. Return to text.
Figure 4. As in Figure 1 except for GFS 00-hour forecasts of precipitable water (mm) and precipitable water anomalies from a) 0600 UTC 17 to f) 1200 UTC 18 November 2013. Return to text.
Figure 5. As in Figure 4 except for 850 hPa total wind and total wind anomalies. Return to text.
Figure 6. As in Figure 5 except for GFS 0-hour forecast of CAPE (J/kg) contours every 600 J/kg and shaded as in the color bar. Return to text.
Figure 7. The situational awareness tables from the NAEFS initialized at 0000 UTC 14 November 2013. For each time and variable the standardized anomalies are shown. The largest (by absolute value) anomaly is shown for each variable. Most variables include several pressure levels with the exception of sea-level pressure (SLP), precipitable water (PW) and integrated vertical water transport (IVT). Return to text.
Figure 8. As in Figure 7 except for the return interval in years for each variable. Return to text.
The image shows a series of charts demonstrating NAEFS mean meridional wind (kt) and return interval for different pressure levels: 200 hPa, 500 hPa, 700 hPa, 850 hPa, and 1000 hPa. The charts display wind return periods in days valid at 1800 UTC on November 17, 2013. Each chart indicates the departure of winds from normal in days.

Figure 9. NAEFS winds and wind return periods in days valid at 1800 UTC 17 November showing the winds at each pressure level and the departure of this winds from normal in days. Return to text.