Anomalous Low and its weather impacts 10-12 May 2008

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1. INTRODUCTION

An unusually deep and cold upper-level low moved across the eastern United States from 10 to 12 May 2008. This anomalous system produced severe weather and heavy rainfall over the eastern United States as it moved through the region. Over the higher terrain of central Pennsylvania, the storm produced a period of wet snow which covered the ground in some locations. It was one of the latest accumulating snow in several locations in central Pennsylvania.

May 2008. Overall, there were 466 and 211 severe weather reports on the 10 and 11th respectively for a total of 677 reports over the two days. The number, 466 reports is an unusually high number of reports suggesting this was a significant severe weather outbreak. Tragically, several of the tornadoes produced fatalities on the 10th. There were approximately 21 tornado related deaths including 8 in Oklahoma and 13 in Missouri on the 10th of May. Ten deaths were reported near Racine, Missouri.

In addition to the severe weather, the system produced locally heavy rainfall

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Heavy rains were observed in Illinois and there were bands of moderate rain with the upper-level low as it tracked eastward. The heaviest rain was observed late on the 11 and 12 over the Mid-Atlantic region. Heavy rain was also observed in the lines of severe thunderstorms which produced the severe weather as indicated in Figure 2. The heavy rain with the severe weather had the same general northwest to southeast alignment as indicated by the severe weather reports in Figure 1.

This paper will document the event of 10-12 May 2008. The focus will be on the large scale pattern and anomalies associated with the hazardous weather observed. Forecasts for the NCEP Ensemble Prediction systems will be presented to demonstrate how these systems alerted forecasters to the potential for a significant weather event.

2. Methods

Data for this study include re-analysis climatological data from the NCEP/NCAR global re-analysis project (GR: Kalnay et al 1996). The means and standard deviations were used to compute standardized anomalies, displayed in standard deviations from normal (SDs).

The 00-hour forecasts from the NCEP NAM are used to provide an overview of the large scale pattern and the evolution of this weather system.

Ensemble data shown here were primarily limited to the NCEP GEFS and SREF. Displays focus on the storm system and the precipitation patterns.
The climatological data used to compute Figure 4. As in Figure 3 except valid 0000 UTC 11 May 2008.

Figure 3. NAM 00-hour analysis valid 1200 UTC 10 May 2008 showing a) 500 hPa heights (m) and anomalies, b) 850 hPa temperatures (°C) and anomalies, c) precipitable water (mm) and anomalies and d) mean sea level pressure and anomalies.

Figure 4. As in Figure 3 except valid 0000 UTC 11 May 2008.

The climatological data used to compute
anomalies was restricted to those produced by the NCEP/NCAR GR data set (Hart and Grumm 2001). They will be presented in relation to the NAM output. All data was displayed using GrADS. Anomalies were computed as described Hart and Grumm (2001) and Grumm and Hart (2001). Shaded values show the standardized anomalies computed as:

\[ SD = \frac{F - M}{\sigma} \]  

Where \( F \) is the value from the reanalysis data at each grid point, \( M \) is the mean for the specified date and time at each grid point, and \( \sigma \) is the value of 1 standard deviation at each grid point.

Anomaly data were applied NAM output to produce a sense of the meteorological setting in which the event occurred.

For brevity times are presented in the format of 11/0000 UTC which signifies 11 May April 2008 at 0000 UTC.

The 4km precipitation data was obtained from the multi-sensor State-IV data (Seo 1998 and Seo et al. 1999). An example of the hourly summed data valid for the 48 hours ending 12/1200 UTC is shown in Figure 2.

3. Overview

i. pattern overview

Figures 3-6 show the evolution of the large scale pattern over the eastern United States from 10/1200 UTC to 12/1200 UTC. The rapid evolution of a deep 500 hPa trough

![Image of weather maps]

Figure 5. As in Figure 3 except valid 1200 UTC 11 May 2008.
and strong surface cyclone are clearly illustrated in the images. In the span of 24 hours the 500 hPa heights over Illinois go from near normal to -3.5 standard deviations below normal (Figs. 3a & 4a). This intense 500 hPa low then tracks...
rapidly eastward and the anomalies fall to -4 to -4.5SDs below normal along the Virginia coast by 12/1200 UTC.

Equally impressive to the 500 hPa cyclone was the evolution and rapid eastward progression of the surface cyclone. Though difficult to visualize, the pressure anomalies reach -5SD below normal in Illinois at 11/1200 UTC with a 990 hPa closed contour. This deep cyclone, with pressure anomalies in the -3.5 to -4.5 range then tracked to the east and was off the coast of New Jersey by 12/1200 UTC (Fig. 6d).

The pressure field indicated a strong cold front south of the cyclone. This front and strong southerly flow ahead of pulled some relatively warm moist air northward. The precipitable water (PW) surge ahead of the frontal system pulled in some +1SD above normal PW values into the region ahead of the surface cold front. The 850 hPa temperature anomalies also indicated the colder air behind this system.

The coldest air at 850 hPa, slightly below 0C (Fig. 6b) moved over Pennsylvania between 12/0600 and 12/1200 UTC. Combined with the anomalously low heights and precipitation, this cold air and upper-low produced the wet snow over central Pennsylvania. The upper-low and unseasonably cold air also maintained the clouds which in turn produced several record high-low temperatures in the Mid-Atlantic region. Baltimore-Washington airport set a record low-high of 49F on the 12th. Many locations in central Pennsylvania remained in the 40s, 20 to 25 degrees below normal for the date.

Figure 8. NAM 00-hour analysis showing a) 850 hPa winds and v-wind anomalies, b) 850 hPa winds and u-wind anomalies, c) 925 hPa temperatures and anomalies, and d) precipitable water and anomalies.
The NAM analysis showed the strong low-level southerly jet at 850 hPa over Missouri at 11/0000 UTC (Fig. 8a) in close proximity to the location of the tornadoes and severe weather at that time. To the north, the easterly jet over Illinois (Fig. 8b) was in close proximity to the heavy rain shown in Figure 2. There was a hint of a surge of higher moisture into southern Missouri as indicated by the PW field (Fig. 8d).

By 11/0600 UTC the strong southerly jet was over the Mississippi Valley (Fig. 9a) and had pulled in a narrow plume of 1 to 2SD above normal PW values (Fig. 9d). Strong shear and instability were present over the affected regions where severe weather was observed. (Fig. 9).

As the storm system moved eastward, a strong southeasterly jet developed and u-wind anomalies of 3 to 4 SDs below normal were observed in the Mid-Atlantic region. These anomalies peaked near - 5.5SDs below normal over Maryland and Delaware at 12/1200 UTC (Fig. 10). The strong and anomalous easterly winds aligned well with the generalized regions of heavy rainfall in the Mid-Atlantic region.

**ii. Forecasts Mississippi Valley convection**

The pattern forecasts for 11/0000 UTC from the SREF is shown in Figure 11. Forecasts from previous SREF and GEFS cycles indicate the fast evolving upper-level cyclone and anomalous height values associated with this feature. For brevity only a single SREF cycle is presented.
Figure 11 shows the SREF forecasts from 10/0900 UTC. These data indicate a strong southerly jet over the plains with a surge of high PW air into Arkansas and Missouri. Though not shown, earlier forecasts show the surge into Oklahoma. In addition to the high PW air the SREF indicated a strong southerly jet over Missouri with a modestly strong easterly jet over Illinois.

With the pattern relatively well forecast, the SREF indicated the potential for rainfall quite well. Only 30% of the members predicted over 2 inches of rainfall in a small area of Illinois and Iowa (not shown). A larger area was forecast to receive 1 inches (25 mm) or more QPF for the 24-hour period ending at 11/1200 UTC (Fig 12). These data compare well with the implied data in Figure 2. The 30-50% chance of 1 inch or more QPF across the Tennessee border suggests the SREF was able simulate a convective line that moved west to east across this region. This implies there was some significant larger scale forcing in the SREF system to predict these broad area of convective rainfall. The details were missing; the actual rainfall fell south of the forecast area and had more northwest to southeast orientation; but the larger scale concept was implied in these forecasts.

Though not shown, SREF CAPE values were on the order of 600 to 1200JKg⁻¹ over the Mississippi Valley as the convection and rainfall moved eastward.

ii. Mid-Atlantic rainfall

Figure 13 shows the SREF forecasts of the pattern over the Mid-Atlantic region near the time the heavy rainfall was winding down. Key features include the deep 500 hPa low with -4.5SD anomalies over the Virginia Coast. The broad deep cut-off cyclone compared well with the analysis...
shown in Section 3. In addition to the strong 500 hPa cyclone there was an anomalous 850 hPa easterly jet over Pennsylvania with u-wind anomalies on the order of -5SDs below normal. The association of strong u-wind wind anomalies in heavy rainfall is a well-known pattern over the eastern United States. Though not shown, PW anomalies were not significantly above normal with this system over the Mid-Atlantic region.

Not surprisingly, the SREF forecast a 990 to 992 hPa cyclone along the East Coast (Fig. 15) with pressure anomalies on the order of -4 to -5 SDs below normal. The GEFS had similar forecasts and are not shown.

Figure 15 shows the SREF 10m winds and the probability of exceeding 35 KTS. In the strong easterly flow along the coast, the SREF showed areas with a 60 to 70 percent chance of winds exceeding 35 kts. With significant 925 and 850 hPa wind anomalies, the gust potential was likely higher than the winds forecast by the SREF 10 m winds.

Other SREF and GEFS cycles predicted the pattern well and are not shown.

Figure 16 shows the SREF QPF forecasts from forecasts initialized at 10/0900 and 11/0900 UTC. Both forecasts are valid at 12/1200 UTC. The probability of 2 inches...
or more of QPF was quite low, on the order of 20 to 30%. The 1.5 inch contour was in the ensemble mean of the forecasts initialized at 11/0900 and both forecasts showed a high probability of 1 inch or more QPF (not shown) as implied by the large 1 inch contour. The proper forecast of the pattern facilitated the precipitation forecast indicated moderate rainfall over the Mid-Atlantic region. However, these forecasts lacked the detail and amounts suggest in Figure 2.

The GEFS forecasts of the QPF and the probability of 2 or more inches of QPF from 10/1200 and 08/1800 UTC are shown in Figure 17. The rainfall pattern is quite similar to that produced by the SREF. This would be expected if the GEFS predicted the same general synoptic pattern as the SREF, which it did (not shown). The coarser resolution GEFS had some difficulty forecasting the higher end QPF amounts. The rainfall amounts shown by the forecasts initialized at 08/1800 UTC suggest this pattern was somewhat extraordinarily predictable.

Figure 18 is presented to show the 500 hPa pattern as forecast by the GEFS. These data indicated the 4 to 6 days in advance, the GEFS was forecasting a potentially deep and anomalous upper-level system over the Mid-Atlantic region. Overall, the concept of a period of cold and wet weather was well forecast by the GEFS, though the details are not presented herein.

iii. Coastal winds

In addition to the heavy rain and severe weather, there was a significant tidal flood event on the Delaware shore of Delaware Bay early on 12 May 2008. The flooding caused numerous emergency evacuations. In addition to the flood, there were reports and observations of hurricane force wind gusts along the New Jersey Shore. Ocean City, New Jersey had a wind gust to 70 mph, Sea Isle City peaked at 76 mph and Atlantic City peaked at 59 mph. Coastal areas of Delaware had winds of 60 to 68 mph with Lewes, Delaware reporting 68 mph. A summary of wind gust is provided in Table 1.

The deep low pressure, estimated at 986 hPa was considerably below normal. The SREF forecasts indicated 988 to 990 hPa over New Jersey at 12/1200 UTC (Fig. 19)
and 850 hPa winds in excess of 50kts which were -5SDs below normal.

4. Conclusions

An unusually deep and cold upper-level low moved across the eastern United States from 10 to 12 May 2008. This anomalous system produced severe weather and heavy rainfall over the eastern United States as it moved through the region. Over the higher terrain of central Pennsylvania, the storm produced a period of wet snow which covered the ground in some locations. It was one of the latest accumulating snow in several locations in central Pennsylvania.

This system was relatively well forecast at least 4 days in advance as indicated by the GEFS 500 hPa forecasts (Fig. 18) and the potential for heavy rainfall along the East Coast from forecasts initialized at least 4 days in advance (Fig. 17). These forecasts suggest something relatively predictable about the overall pattern the led to these relatively skillful 500 hPa and QPF’s.

Shorter term forecasts suggest that the SREF and GEFS both forecast the pattern over the eastern United States relatively accurately. This allowed the EPS’s to predict quite well the area of heavy rainfall.
in the Mid-West in close proximity and in relatively similar orientations to the observed patterns of rainfall (Fig. 2) and severe weather (Fig. 3). The mesoscale details were a bit elusive though the overall concept and area of the significant threat was well highlighted by the EPS’s.

Several key features were associated with the severe weather and rainfall on 10 May 2008. These included the strong southerly low-level jet ahead of the rapidly advancing cold front (Figs. 3-7) and the surge of warm moist air ahead of this.

Figure 14. As in Figure 12 except SREF forecasts of MSLP valid at 1200 UTC 12 May showing a) MSLP 992, 1008, and 1016 contours and spread and b) the ensemble mean MSLP field and the departure of these field in normal in standard deviations form normal.

Figure 15. As in Figure 13 except SREF forecasts of 10m winds (kts) showing a) the probability of 10m winds greater than 35 kts and b) the mean SREF 10m wind speed and the spread about the mean.

system. The strong shear and moisture are two significant ingredients in both heavy rain and severe convective events.

In the eastern United States, and more specially the Mid-Atlantic region, the strong surface cyclone, upper-level low and the intense easterly jet led to a region of heavy rainfall in the Mid-Atlantic region. Relative to observed guidance from the SREF and GEFS, it appears both systems placed the heaviest QPF threat too far north and under-estimated the potential for 4-7 inches of rainfall which fell over
the Washington, DC and Baltimore, MD regions. Our expectations for such forecasts to be more accurate may be unrealistically high as the details often remain elusive. This may suggest the need for higher resolution ensembles run at shorter time lengths to facilitate some improvement in the heavy rainfall amounts in localized regions.

In addition to the heavy rainfall, the anomalous low-level winds were a forecast issue. The SREF 10 m wind probabilities suggest the potential for winds in excessive of 35 KTS along the coast and offshore (Fig. 15). With 50 to 60 kts of wind in the 925 and 850 hPa layers, the wind gust potential was likely considerably higher.

This case demonstrates two contrasting points. First, both NCEP EPS’s were able to capture the large-scale pattern and features with remarkable skill. However, they both under forecast the heavy rainfall. Thus, despite great skill at features and pattern mesoscale details remain a difficult forecast issue.

The SREF indicated the potential for strong winds north of the surface cyclone. However, the SREF 10 m winds did not indicate the strength of the observed wind gusts. In this event, the SREF 925 and 850 hPa winds indicated the potential for 50-60 kt wind should the system mix down winds in that layer. Clearly, based on observations from Maryland to New Jersey, many coastal locations saw extreme wind speeds. SREF products

Figure 16. As in Figure 12 except SREF QPF showing 24 hour QPF ending at 1200 UTC 12 May probability of exceeding 2 inch and the ensemble mean 2 inch contour and the mean QPF and each member’s 1 inch contour. Right side initialized at 0900 UTC 10 May and left side initialized at 0900 UTC 11 May 2008.
using mixed layer winds could be produced to derive maximum wind gust potential.

5. References


Figure 17. As in Figure 15 except GEFS/MREF QPF showing 24 hour QPF ending at 1200 UTC 11 May from forecasts initialized at 18Z 10 May 2008 and 18Z 08 May 2008.
Figure 18. GEFS/MREF forecasts valid at 1200 UTC 12 May 2008 initialized at 1200 UTC 6 and 1200 UTC 8 May 2008. Upper panel’s show 5460 and 5760 m contours and spread. Lower panels show the mean 500 hPa field and the departure of this field in standard deviations from normal.
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Table 1. Locations by State of areas along the Mid-Atlantic coast which experienced wind gusts in excess of 49 mph. Gust, time, and date are provided from the Philadelphia public information statement. There were 59 sites that had winds in excess of 39 mph. [Return to text](#).
Figure 18 SREF forecasts initialized at 2100 UTC 11 May 2008 valid at 1200 UTC 12 May 2008 showing (left) a) MSLP 992, 1008, and 1016 contours and spread and b) the ensemble mean MSLP field and the departure of these field in normal in standard deviations form normal and (right) 850 hPa winds with a) u-wind anomalies and b) v-wind anomalies.