Late April Rains and Severe Weather  
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1. INTRODUCTION

A strong frontal system and upper-level wave produced rain and severe weather over the eastern United States on 28 April 2008. Behind the front, an unseasonably cold air moved into the eastern United States. As the cold air pushed through the coastal plain on the 28th it triggered a strong severe weather event in the Mid-Atlantic region to include an EF3 tornado.

Ahead of the cold front, there was a surge of above normal moisture and an extremely strong low-level jet. This and the implied instability produced a line of showers and thunderstorms from North Carolina into southern New Jersey. Severe weather was observed along this line (Fig. 1) with several tornadoes reported in Virginia and North Carolina.

The strongest reported tornado was an EF3 in coastal Virginia. Tornadoes ranging in strength from EF0 to EF3 were observed on the afternoon of 28 April 2008 (Fig. 2). A detailed map of the Virginia tornadoes is provided in Figure 2. The pattern of a below normal surface low pressure to the west, anomalously strong low-level southerly flow, and relatively high moisture were all in place during the event. Thus, this event exhibited a known pattern, often associated with severe

Figure 1 Storm reports color coded by type from the storm Prediction Center (SPC). Image courtesy of the SPC for 28 April 2008.
weather during the afternoon hours of 28 April 2008. This note will document the frontal system which produced the severe weather on 28 April 2008. The focus is on putting this event into a meteorological context often associated with Mid-Atlantic severe weather events.

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 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:

\[ SD = \frac{(F - M)}{\sigma} \quad (\text{j}) \]
Figure 3. NAM 00-hour forecasts valid at 1800 UTC 28 April 2008 showing a) 850 hPa winds (kts) and 850 hPa v-wind anomalies, b) 850 hPa winds and u-wind anomalies, c) precipitable water (mm) and precipitable water anomalies, and d) mean sea-level pressure.

Figure 4. NAM 00-hour forecasts valid at 0000 UTC 27 April 2008 showing a) 850 hPa heights (m) and 850 hPa height anomalies, b) 500 hPa heights (m) and 500 hPa height anomalies, c) 925 hPa temperatures (°C) and temperature anomalies, and d) 850 hPa temperatures (°C) and temperature anomalies.
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 27/0000 UTC which signifies 27 April 2008 at 0000 UTC.

Large scale rainfall estimates were derived from the unified precipitation data set (UPD: Higgins et al. 2000).

3. Overview
   i. The pattern

   Conditions over the eastern United States at 28/1800 UTC are shown in Figure 3.

   The surge of above normal precipitable water (PW) ahead of the frontal boundary is evident (Fig. 3c) along with a strong low-level jet (Fig. 3a) over the coastal plain. The strongest winds analyzed in the NAM 00-hour forecast were actually north of the affected region. Other features included the area of low pressure (Fig. 3d).

   The thermal pattern (Fig. 4) implied that the large scale frontal boundary at 850 and 925 hPa was still west of the coastal plain at 28/1800 UTC.

   By 29/0000 UTC the frontal system had shifted eastward and the low-level jet was offshore. The strong southerly winds and high PW values likely contributed to the rainfall in New England.

   ii. precipitation
The observed rainfall from the UPD data is shown in Figure 6. These data show that the heaviest rainfall was over New England with the strong low-level jet and surge of high PW air (Fig. 5) that impacted that region. Maximum rainfall in the UPD was 2-3 inches (50-75 mm).

Over the Mid-Atlantic region, lower rainfall amounts were observed. Most areas received 0.5 to 1 inch (12.5 to 25 mm). The line of showers and thunderstorms produced a narrow area, 1 to 2 inches of rainfall (25-50 mm) over portions of Virginia and southeastern Pennsylvania.

### iii. Forecasts

SREF forecasts of CAPE are shown in Figure 7 and the 850 hPa winds are shown in Figure 8. The data show that some CAPE was forecast over the region but only about 400 Jkg\(^{-1}\) was forecast over NC and VA with a range of up to about 800 Jkg\(^{-1}\). Not overly impressive CAPE, but for the time of year these values were higher than normal. The SREF did show the strong low-level jet in the region (Fig. 8).

The SREF did show helicity values over 200 and strong shear (Fig. 9). The strongest helicity was near the frontal boundary well north of Virginia and North Carolina. However, the combination of modestly high CAPE and helicity implied the potential for thunderstorms and perhaps rotating thunderstorms. The details of which are beyond the capabilities of the data presented here to detect.
Figure 7. SREF Convective available potential energy (CAPE: JKG-1) valid at 1800 UTC 28 April from forecasts initialized at 0300 UTC 28 April. Panels show a) CAPE every 200 JKG-1 and the spread of the CAPE (shaded) and b) the CAPE and the departure in standard deviations from normal.

Figure 8. As in Figure 7 except SREF 850 hPa winds (kts) showing a) winds and u-wind anomalies and b) winds and v-wind anomalies.

Figure 10 shows the SREF 24 hour QPF ending at 29/1200 UTC. These data, when compared to Figure 6 suggest that the SREF forecast the overall pattern and areas of heavy rainfall quite well. The arm of light rain over Ohio in Figure 10b and Figure 6 is eerily well forecast. Though hard to discern, the SREF had a 1.5 inch closed contour over New England from Connecticut into Vermont and New Hampshire.

4. Conclusions

A frontal system brought rain and severe weather to the eastern United States on 28 April 2008. The combination of the strong low-level winds and shear along with modest instability produced thunderstorms over the Mid-Atlantic region. These storms produce severe weather and
tornadoes over portions of North Carolina and eastern Virginia.

Though the SREF forecast the large scale conditions quite well, the signals for such a widespread tornadic event was not so clear. The guidance suggested CAPE in the 400-800 Jkg\(^{-1}\) range and high helicity. The potential for thunderstorms and possibly rotating thunderstorms were indicated in these forecasts. Clearly, some mesoscale features and local effects impacted this event as the SREF forecasts indicated convection but nothing to consider an EF3 tornado as a high probability forecast.

In the spring, modest CAPE with strong shear and helicity can produce rotating storms as observed in this event. Detailed mesoscale models might have revealed more instability over the region. Forecasters are often presented with cases that show some potential but ultimately
still have to rely on radar and observational data to predict these significant mesoscale severe weather events.

The large scale forecast of the front and winds being correct likely contributed to the relatively accurate QPFs shown in Figure 10b versus the verification in Figure 6.

6. Acknowledgements

National Weather Service Office in Wakefield for storm summaries and tornado maps and the Storm Prediction Center for the storm reports and plots.

Figure 10. As in Figure 7 except SREF QPFs valid at 1200 UTC 29 April 2008. Upper panel shows the probability of 1.00 inches of QPF (shaded) and the ensemble mean 1.0 inch contour. Lower panel shows the ensemble mean QPF and each member's 1.0 inch contour.