The Winter Storm of 12 March 2014

Leveraging uncertainty and short predictability horizons

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1. Introduction

A winter storm brought heavy snow and blizzard conditions across western New York State on 12 March 2014. South and east of the area of and despite earlier optimistic forecasts for heavy snow, rain was observed (Fig. 1) and only the northern edge of the precipitation was snow. The optimistic forecasts were likely related to early (Fig. 2) GEFS, EC, and GFS forecasts (GFS and EC not shown) tracking a cyclone over the Mid-Atlantic region and out over the coastal regions of New England. This track, combined with the observed trend in the 3 March 2014 storm, which tracked farther south and east of the forecast track (Grumm 2014) likely provided optimism that the storm would produce conditions supporting snow across most of interior New York and Pennsylvania.

Hamill (2003) showed that model trends are not always of value as trends often change. It is clear in Figure 2 that trend was relative persistent and the standardized anomalies produced a stronger signal at shorter forecast lengths due to the convergence of solutions. The spread about the mean GEFS mean sea-level pressure forecasts (Fig. 3) clearly shows the larger spread about the ensemble mean in the forecasts issued at 0000 UTC 7-9 March. As the spread about the mean decreased on 10-11 March the focus was on the cold side of the storm, related to both the position and the depth of the cyclone.

The changes in the track (Fig. 3) and the large spread should have been cause for pause and diminished optimism in the forecasts. The 850 hPa temperatures (Fig. 4) indicated a very tight 850 hPa gradient with a large spread about the mean. The spread about the mean was over 4C in and along the baroclinic zone where the precipitation type issues had the potential of being significant. Across Pennsylvania and southern New York the -4C contour was forecast in the mean with a spread of 4 to 8C. This implied the potential 850 hPa temperatures to be above 0C and implied that there was low confidence in the location of the baroclinic zone and thus where the heavy precipitation band would develop.

The strong baroclinic zone produced uncertainty in the quantitative precipitation forecasts (Fig. 5) produced by the GEFS (Fig. 5) and other operational models and ensemble forecast systems (not shown). Note the low probability of 25 mm of QPF from forecasts issued from 0000 UTC 7 to 10 March and the rapid convergence in the forecasts on and after 1200 UTC 10 March.
The uncertainty with this system could be visualized at 500 hPa using the mean and spread (Fig. 6). The cut-off cyclone over the southwestern United States was not forecast in the 0000 UTC 7 March GEFS (Fig. 6a) and the spread in the main trough and over the southwestern United States was well over 120 m. The 3 shorter range GEFS forecasts clearly showed a rapid decrease in spread in the 500 hPa forecasts and a convergence toward a higher confidence forecast.

This paper will examine the winter storm of 12 March 2014. The overall pattern is presented, with a focus on where the precipitation fell and the pattern in the context of standardized anomalies. Forecasts presented focus on the uncertainty associated with forecasts of this storm. The focus is on the NCEP GEFS and SREF forecast systems. The term forecast systems will be used in this paper to denote models and EFS-- all of which had difficulty with the forecast evolution of this event. This case implies that basic uncertainty information is not being leveraged in the forecast process.

2. Methods and Data

The large scale pattern was reconstructed using 00-hour forecasts from the NCEP Global Forecast System (GFS). Standardized anomalies were computed as in Hart and Grumm (2001) using the re-analysis (Climate Forecast System; CFS) climate (R-Climate). The climatology spans a 30 year period. All data were displayed using GrADS (Doty and Kinter 1995).

Ensemble forecasts were derived from the NCEP Global Ensemble Forecast System (GEFS) and the Short Range Ensemble Forecast System (SREF). The surface and 500 hPa patterns were used to show how the general forecasts of a significant storm were predicted at longer ranges.

Snowfall data was retrieved from the National Snow site in text format, decoded in Python, and plotted using GrADS. The QPE data was retrieved from the Stage-IV 6-hour data. These data too were plotted using GrADS.

The GEFS and SREF mean and spread was used to illustrate some of the uncertainty issues that were not well utilized in this event as forecasts (not presented) focused on snow too far south. These forecasts were too optimistic with too much snow too far south and east of the observed location. But the goal here is not to evaluate single human forecasts but to improve upon the use of EFS data and the uncertainty information within these systems.

3. Pattern

The large scale pattern during the critical period of the storms evolution showed the cut-off low over the southwestern United States (Fig. 7). The northern stream trough moving over the evolving ridge over the western United States deepened as it moved into the eastern United States (Figs. 6c-f). Heights in the trough ranged from -1 to -3σ below normal. The depth and tilt of the trough were difficult to predict in the GEFS at longer ranges relative to the verification (Fig. 2).
At 850 hPa a strong baroclinic zone developed over the eastern United States (Fig. 7) with +1σ temperature anomalies on the warm side of the baroclinic zone. As the cyclone developed (Fig. 8) rapidly after 1200 UTC 12 March, a surge of unseasonably cold air swept into the eastern United States behind the cyclone. The cyclone track was north and west of the initial GEFS forecasts from 7-10 March 2014 (Figs. 2 & 6). A deep cyclone did develop with pressure anomalies on the order of -2 to -3σ below normal.

In New York State, blizzard conditions were observed and many roads were closed south of Lake Ontario as a state of emergency was declared on 12 March. These blizzard conditions were observed on the cold side of the frontal boundary (Fig. 7) and north of the surface cyclone track. This area was affected strong northeasterly winds which peaked at -3σ below normal (Fig. 10d-e). In this case previous work on standardized anomalies (Stuart and Grumm 2008) worked well identifying areas to be impacted by heavy snow and high impact winter weather.

4. Forecast Systems Predictions

i. Global Ensemble Forecast System 55 km (GEFS)

The GEFS data was presented in the introduction. These data showed that the GEFS mean cyclone track, precipitation shield and rain snow line (not shown) were initially predicted too far south and east of the verifying position.

The GEFS did provide signals, in terms of low probabilities of high QPF amounts, due to uncertainty between members and uncertainty with the evolution of the 500 hPa and surface cyclone tracks (Figs. 2-6).

ii. Short-Range Ensemble Forecast System (SREF)

Similar to the GEFS, the SREF forecasts tracked the cyclone too far south and east of the verifying track at longer ranges (Fig. 11). Similar to the GEFS, the SREF had large spread between members north and west of the cyclone track indicated depth and position errors. As the forecast converged, the SREF produced a deep cyclone with significant pressure anomalies (Fig. 12).

Similar to the GEFS, the SREF had significant uncertainty with the 850 hPa baroclinic zone (Fig. 13) and the in refining and converging on the region of high QPF (Fig. 14). The high confidence forecasts and a converged solution emerged on 10 March 2013 in terms of the QPF shield.

5. Summary

A winter storm brought heavy snow to western New York and northern-central New England on 12 March 2014. There was considerable uncertainty associated with this storm as indicated in the spread about the ensemble mean in both the GEFS and SREF. Despite the high spread about the mean in the 3-6 day forecast range, forecasts for a winter storm and the potential for heavy snow were made with considerable lead-time.
Successive forecasts, with short predictability horizons, the storm track and thus favoring snow shifted to the north and west. This implies that the uncertainty information in this case was either not examined or not correctly employed.

This case demonstrates the need to better use and understand forecast uncertainty. When there is high spread associated with the cyclone and the baroclinic zone, there is clearly uncertainty in where the precipitation will occur and where the heaviest precipitation will occur.

6. Science Issues

This case study reveals a number of science issues the must be addressed before more accurate forecasts of these types of events are possible.

- better use of basic mean and spread
- Better use of probabilities and the need for calibrated probabilities. Reliability is assumed here when a 90% chance of heavy snow is predicted at 72 hours, how often does it occur?
- Tools to define when predictability has increased.

7. Acknowledgements

The Pennsylvania State University Department of Meteorology for data access and discussions related to this storm. Edited by Elyse Colbert.

8. References


Irland L. C., 2000: Ice storm 1998 and the forests of the Northeast. J. For., 96, 32–40. Find this article online


Figure 1. Stage IV precipitation (mm) showing a) total QPE for the period of 0000 UTC 12-13 March 2014, b) 0000-1200 UTC 12 March, c) 1200 UTC 12 to 0000 UTC 13 March and d) to 0000 UTC 13 March through 1200 UTC 13 March 2014. Return to text.
Figure 2. NCEP GEFS ensemble mean forecasts of the surface pressure (hPa) and standardized anomalies valid at 1800 UTC 12 March 2014 from NCEP GEFS initialized at a) 0000 UTC 7 March, b) 0000 UTC 8 March, c) 0000 UTC 9 March, d) 0000 UTC 10 March, e) 1200 UTC 10 March and f) 0000 UTC 11 March 2014. Return to text.
Figure 3. As in Figure 2 except for the GEFS mean and the spread of the 21 GEFS members about the mean. Return to text.
Figure 4. As in Figure 3 except for 850 hPa temperatures (C) and the spread about the mean (C). Return to text.
Figure 5. As in Figure 4 except for the GEFS probability of 25mm or more QPF in the 24 hour period of 0000 UTC 12 to 0000 UTC 13 March 2014. Return to text.
Figure 6. GEFS 500 hPa mean and spread about the mean. Return to text.
Figure 7. GFS 00-hour forecasts of 500 hPa heights (m) and standardized anomalies (SD) in 12 hour increments from a) 0000 UTC 11 March through f) 1200 UTC 1 March 2014. Return to text.
Figure 6. As in Figure 6 except for 850 hPa temperatures (°C) and temperature anomalies for the 6-hour periods of a) 0000 UTC 12 March through f) 0600 UTC 13 March 2014. Return to text.
Figure 7. As in Figure 7 except for mean sea-level pressure (hPa) and pressure anomalies. Return to text.
Figure 8. As in Figure 7 except for 850 hPa winds (kts) and u-wind anomalies. Return to text.
Figure 11. As in Figure 3 except SREF initialized at a) 0900 UTC 9 March, b) 0300 UTC 10 March, c) 0900 UTC 10 March, d) 1500 UTC 10 March, e) 0900 UTC 11 March and f) 2100 UTC 11 March 2014. Return to text.
Figure 12. As in Figure 11 except for pressure and standardized anomalies. Return to text.
Figure 13. As in Figure 11 except 850 hPa temperatures (°C) and spread about the mean. Return to text.
Figure 14. As in Figure 13 except SREF probabilities of 25mm or more QPF for the 24 hour period ending at 0000 UTC 13 March 2014. Return to text.