P2.49 ENSEMBLE PREDICTIONS OF THE 2007 VALENTINE'S DAY WINTER STORM

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1. INTRODUCTION

A major winter storm affected the eastern United States (U.S.) from 13 to 14 February 2007, producing heavy snow from Nebraska to Maine. The greatest impact from snow was in upstate New York (NY) and northern New England (Fig. 1), where over 40 inches (100 cm) of snow was measured. Areas from Pennsylvania (PA), through New Jersey, southern NY, and southern New England received freezing rain and sleet, contributing to high profile adverse societal impacts, including multiple car accidents closing a PA interstate, and airplanes stranded on airport runways for many hours in New York City, NY.

The potential for a storm was relatively well forecast 3-7 days in advance. However, the exact track and extent of the precipitation shield implied considerable uncertainty with the event, especially 4 to 7 days in advance of the event. While there was confidence in snow as the predominant precipitation type over upstate NY and northern New England, there was considerable uncertainty with the precipitation type over the Mid- Atlantic region 24 to 36 hours prior to the onset. The strengths of the numerous sources of guidance will be presented, illustrating how an unusual consensus between over 20 sources of forecast guidance resulted in nearly unprecedented lead time in warning users of the impending hazards.

2. METHODS

The National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Predictions (NCEP) global ensemble forecast system [GEFS; also known as the Medium Range Ensemble Forecast (MREF); Toth and Kalnay 1997; Toth et al. 1997], and the NCEP short-range ensemble forecast system (SREF; Du and Tracton 2001)were examined.

Snowfall reports were obtained in near-real time from spotters and the National Weather Service Cooperative observing program. All snowfall amounts were plotted using Geographical Information System software. Model and Ensemble Prediction System (EPS) data were retrieved in near real-time from NCEP and archived for re-display using GrADS. A mix of traditional ensemble displays (Sivillo et al. 1997) and anomaly displays (Grumm and Hart 2001) were used. The latter method displayed the ensemble mean relative to the departure of the field in standard deviations (SDs) from normal (Hart and Grumm; 2001). In addition to plan view images of ensemble displays, time series ("plume" diagrams) of precipitation by precipitation type and temperature forecasts are presented.

The precipitation type is determined by each EPS members forecast of precipitation type which is a binary 0 or 1. The current EPS systems use 4 types including rain, snow, ice pellets, and freezing rain. The dominant type is set to 1 all others are set to zero at each grid point. The precipitation type from each member is set using the dominant type at each point and this type is then used to accumulate the precipitation for that member over the past 3 hours in the SREF and 6 hours in the GEFS. Interpolating the data to a point often necessitates using non-binary operations. In these cases, the precipitation type is determined by the highest residual value of the 4 precipitation types. More details on the EPS precipitation type can be found in Manakin 2005.

Forecasts at ranges of 3 to 7 days are limited to using GEFS data. For brevity times are displayed as day and cycle such as 13/1200 UTC for 13 February 2007 at 1200 UTC. The displays and approach is focused on the impact on the mid-Atlantic and northeast region.

3. RESULTS

This storm shared many characteristics associated with major East Coast storms (Kocin and Uccellini; 1990). A large surface anticyclone and cold air were present to the north, with negative sea-level pressure anomalies (compared to climatology) present. A strong upper-level jet streak was present and there was a strong low-level easterly jet, characteristic of major east coast storms (Grumm and Hart 2001; Stuart and Grumm 2006). Due to an extensive quasi east-west baroclinic zone, the event of 13-14 February had a large area affected by the anomalous easterly jet. Finally, a strong surface cyclone was forecast to affect the region, with a

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secondary cyclone forecasted to develop along the coastal plain.

3.1 *Long range GEFS forecasts*

The 06/1200 UTC through 10/1200 UTC GEFS ensemble means and spreads depicted a strong surface anticyclone over eastern Canada and a surface cyclone over the southeastern U.S. The ensemble mean pressure pattern implied a Miller Type-B (Miller 1946) system with a potential for a secondary redevelopment along the coast. The spaghetti plots (not shown) implied considerable uncertainty and a large spread in the MSLP field in the strong pressure gradient between the cyclone and anticyclone.

An 850 hPa low-level jet with U-wind anomalies on the order of 1 to 2 SDs below normal was indicated from Pennsylvania westward to the Midwest with the strongest low-level easterly winds over Illinois and Iowa. These strong winds were in an elongated east-west baroclinic zone which was defined in the 850 hPa temperature fields (Fig. 2) and the precipitable water (PW) fields (not shown). Note the large dome of arctic air with thermal anomalies around 1 to 2 SDs below normal and near 1 SD above normal on the warm side of the boundary which extended from the western Atlantic back to the southern plains. The strong low-level jet, often associated with historic snowstorms (Stuart and Grumm, 2006), was a consistent and persistent feature in all the forecasts.

The GEFS plume diagram of precipitation and precipitation type for State College, PA from the 10/1200 UTC GEFS is shown in Fig. 3. Due to the tendency for the precipitation shield to be farther south, all the members supported snow and many members showed little or no significant precipitation for State College, PA. The large differences in these precipitation accumulation forecasts suggested a high degree of uncertainty with this event.

3.2 *Short range forecasts*

After 10/1200 UTC the storm began to fall into the range of the NCEP SREF and more detailed forecast information became available. Although the consensus from the GEFS and SREF regarding 850 hPa wind anomalies increased forecast confidence of a major storm in the mid-Atlantic and northeast U.S., uncertainty in precipitation type and amount actually increased as the event drew nearer.

The plume diagrams for State College, PA from the 11/0300 UTC SREF and 11/0600 UTC GEFS are shown in Fig. 4. Both EPSs showed an all snow event, with accumulations (assuming a 10:1 ratio) of 8 to 20 inches (15 to 50 cm). However, the 11/1500 UTC SREF and 11/1800 UTC MREF (not shown) depicted half or more of the ensemble members with mixed precipitation, which was not indicated in the GEFS forecasts early on 11 or 10 February.

Critical to both EPS was the redevelopment of the coastal cyclone and the strong easterly jet associated with this system. The coastal low was trending farther north with each successive model/ensemble run, and trended closer to the coast with a stronger 850 hPa (and 925 hPa) jet. The GEFS forecasts valid at 11/0000 were similar to the 11/0300 UTC SREF, capturing the secondary redevelopment and the strong easterly jet north of the original cyclone.

The forecasts from the SREF and GEFS for precipitation type over central Pennsylvania initialized at 11/1500 and 11/1800 UTC trended toward more mixed precipitation continued. Though not shown heavy snow was forecast into NY with the Binghamton and Albany plumes showing high amounts of QPF falling as snow.

The consensus from the SREF, GEFS and single deterministic models became so strong, that Winter Storm Watches for 6 or more inches (15 or more cm) of snow and more than ¼ inch (6 mm) of freezing rain were issued from many National Weather Service offices in the northeastern U.S. during the early morning hours of 12 February, more than 48 hours prior to the onset of precipitation.

3.3 *Near term forecasts*

Forecasts on the 12th continued to show significant precipitation type uncertainty over PA, southern NY and southern New England with a stronger cyclone and anomalous easterly low-level jet. The 12/1200 GEFS emphasis on ice pellets was clear, though the 12/0900 SREF focused on a significant wintry mix of snow, ice pellets and freezing rain. The stronger and more northerly tracking low produced extremely heavy snow in the GEFS and the precipitation plume diagram for Albany, NY (not shown) exhibited an ensemble mean of 2 inches (5 cm) of liquid, with a maximum of 2.5 inches (6 cm) falling as snow on the 14th.

The 12/1500 UTC SREF (Fig. 5) and 12/1200 UTC GEFS (not shown) probability of 1 inch (2.5 cm) of QPF for the 36 hour period ending at 15/0600 UTC captured the same general area of heavy QPF and the potential for heavy snow inland, and rain along the coast (not shown).

Despite the uncertainty in precipitation type over portions of the northeast, the continued consensus from the GEFS, SREF and operational deterministic models provided enough confidence for Winter Storm Watches to be upgraded to Winter Storm Warnings during the early morning hours of 13 February, more than 24 hours prior to the onset of precipitation.

3.4 *Observations*

A wintry mix occurred over most of central and southern sections of PA, through southern NY and southern New England, which limited snowfall in those areas to 3 to 12 inches (8 to 30 cm). A strong low-level easterly jet north of the developing secondary cyclone produced a band of extremely heavy snow which impacted northeastern PA and east-central NY (Fig. 6). The highly reflective band was producing snow from PA into NY.

The heaviest snows were observed in east-central NY where snowfall exceeded 40 inches (100 cm). Most of these extreme reports were in the Adirondack region. Other areas of central NY and interior sections of New England saw widespread 6-20 inch (15-40 cm) snowfall amounts mainly on the 14th to early on the 15th in northeastern sections of New England.

4. CONCLUSIONS

A major east coast winter storm with many of the synoptic characteristics defined by Kocin and Uccellini (1990) evolved on the 14th of February 2007. For New England and eastern NY, the storm was associated with a rapidly developing secondary cyclone along the coast. The MREF and SREF forecasts for the low to mid-level features were good, showing relatively little spread in the ensemble members, though the forecasted surface cyclone tracks showed significant spread, and the resultant mean track was too far south and east of the observed track. The concept of a secondary cyclone development along the coast was well forecasted.

The key anomaly patterns (Grumm and Hart; 2001, and Stuart and Grumm; 2006) were well forecasted by the deterministic models. Most of the snow and ice fell in the regions impacted by the strong and highly anomalous low-level easterly jet and presence of a strong 850 hPa baroclinic zone. These features were well forecasted by the GEFS at long ranges and the SREF at shorter ranges. The QPF and baroclinic zone position were initially not as well forecasted.

As the event approached, the precipitation shield in the eastern U.S. shifted northward. While regions where precipitation types of all snow and all rain were well resolved in the MREF and SREF, the northward shift of the strong baroclinic zone contributed to uncertainty in the precipitation type within the precipitation transition zone. The GEFS focused on a mix of snow and ice pellets about 2 to 2.5 days prior to the event which proved to be quite accurate. The SREF showed more uncertainty with regard to precipitation type over PA, southern NY and New England.

This case demonstrated that even when there is high confidence in a high impact east coast winter storm (in this case upstate NY and northern New England where mostly snow was forecasted and observed), there is still considerable uncertainty in forecasting precipitation types, amounts and locations within the precipitation transition zone, which during winter is often proximate to the strong 850 hPa baroclinic zone. Though the EPS can predict the large scale pattern weather quite well, the mesoscale details, especially proximate to the precipitation transition zone, still remain unresolved.

However, as stated earlier, the patterns associated with potentially significant weather events were well forecasted by current operational EPSs. Considering the long lead time EPSs provided in anticipating the impacts of the 2007 Valentine's Day Storm, adverse societal impacts may be reduced, or even averted in similar future situations by utilizing EPS information.

REFERENCES

Doty, B.E., and J.L. Kinter III, 1995: Geophysical data and visualization using GrADS. Visualization Techniques Space and Atmospheric Sciences, E.P. Szuszczewicz and Bredekamp, Eds., NASA, 209-219.

Du, J., and M. S. Tracton, 2001: Implementation of a real-time short-range ensemble forecasting system at NCEP: An update. Preprints, Ninth Conf. on Mesoscale Processes, Fort Lauderdale, FL, Amer. Meteor. Soc., 355–356.

Grumm, R.H. and R. Hart, 2001: Standardized Anomalies Applied to Significant Cold Season Weather Events: Preliminary Findings. *Wea. and Forecasting*,**16**,736-754.

Hart, R.E. and R.H. Grumm, 2001: Using Normalized Climatological Anomalies to Rank Synoptic-Scale Events Objectively. *Mon. Wea. Rev*.,**129**,2426-2442.

Kocin P.J. and L.W. Uccellini, 1990: Snowstorms along the Northeastern Coast of the United States: 1955–1985. Meteor. Monogr., No. 44, Amer. Meteor. Soc., 280.

Manikin, G. S., 2005: An overview of precipitation type forecasting using NAM and SREF data. Preprints. *21st Weather Analysis and Forecasting Conference/17th Numerical Weather Prediction Conference*. Amer. Met. Soc., Washington, D.C., 8A.6.

Miller J. E., 1946: Cyclogenesis in the Atlantic coastal region of the United States. *J. Meteor.*, **3**, 31–44

Sivillo, S.K,J.E. Ahlquist, and Z. Toth,1997: An ensemble forecasting primer. *Wea. Forecasting*.,**12**, 809-818.

Stuart, N.A and R.H. Grumm 2006: Using Wind Anomalies to Forecast East Coast Winter Storms. *Wea. and Forecasting,***21**,952-968.

Toth, Z., and Kalnay, E., 1997: Ensemble forecasting at NCEP and the breeding method. Mon. Wea. Rev., **125**, 3297-3319.

Toth, Z., E. Kalnay, S. M. Tracton, R. Wobus and J. Irwin, 1997: A synoptic evaluation of the NCEP ensemble. *Weather and Forecasting*, **12**, 140-153.

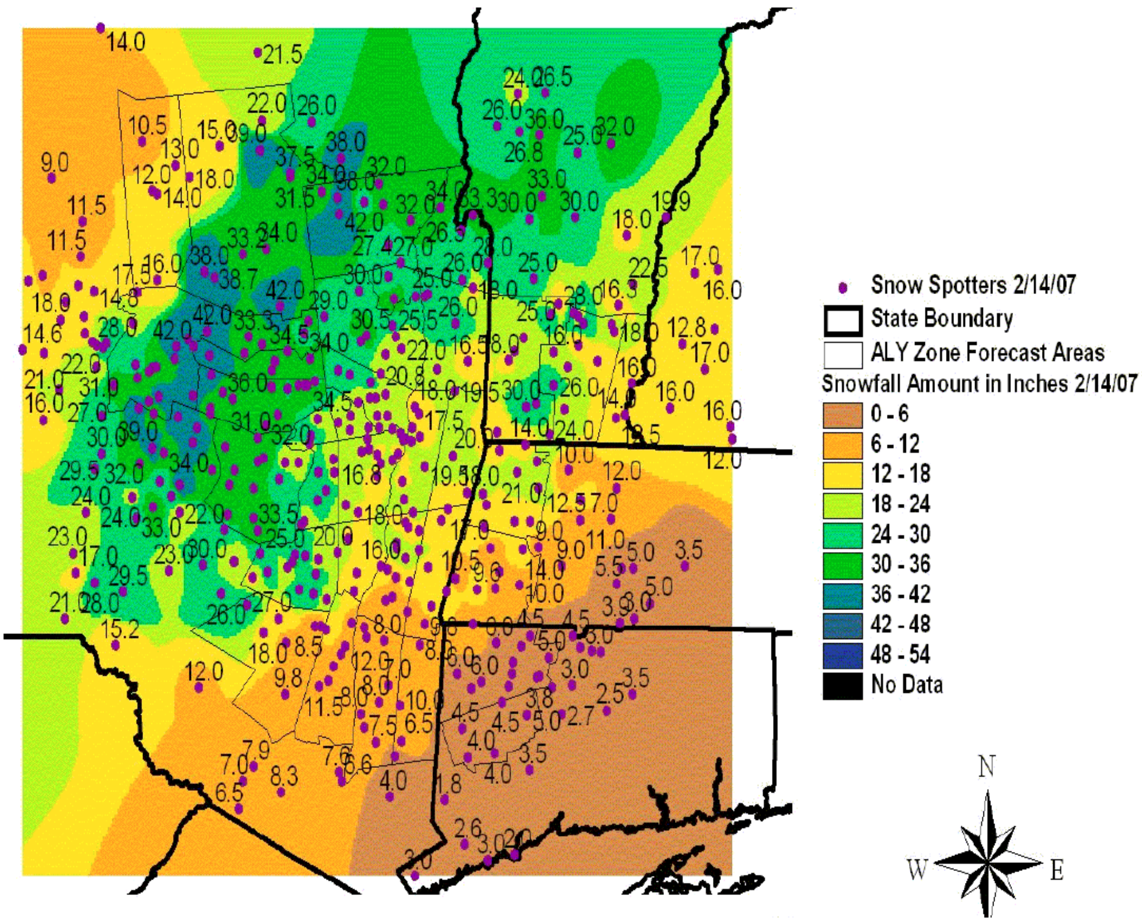


Fig. 1. Observed snowfall (inches) in New York and western New England during the Valentine's Day 2007 Snowstorm. (snowfall map courtesy of John Quinlan).

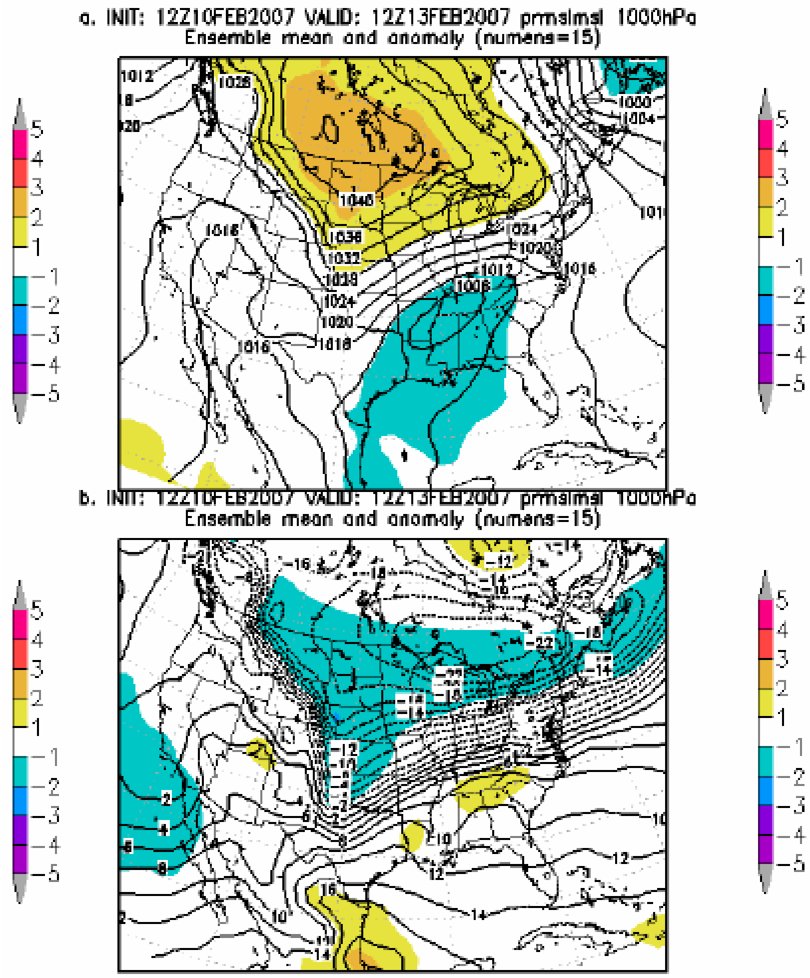


Fig. 2. NCEP GEFS 72-h forecasts initialized at 1200 UTC 10 February 2007 showing the ensemble mean and the departure from normal valid 1200 UTC 13 February 2007 of a) mean sea-level pressure (hPa) and b) 850 hPa temperatures (C). Isobars are every 4 hPa and isotherms are every 2˚C.

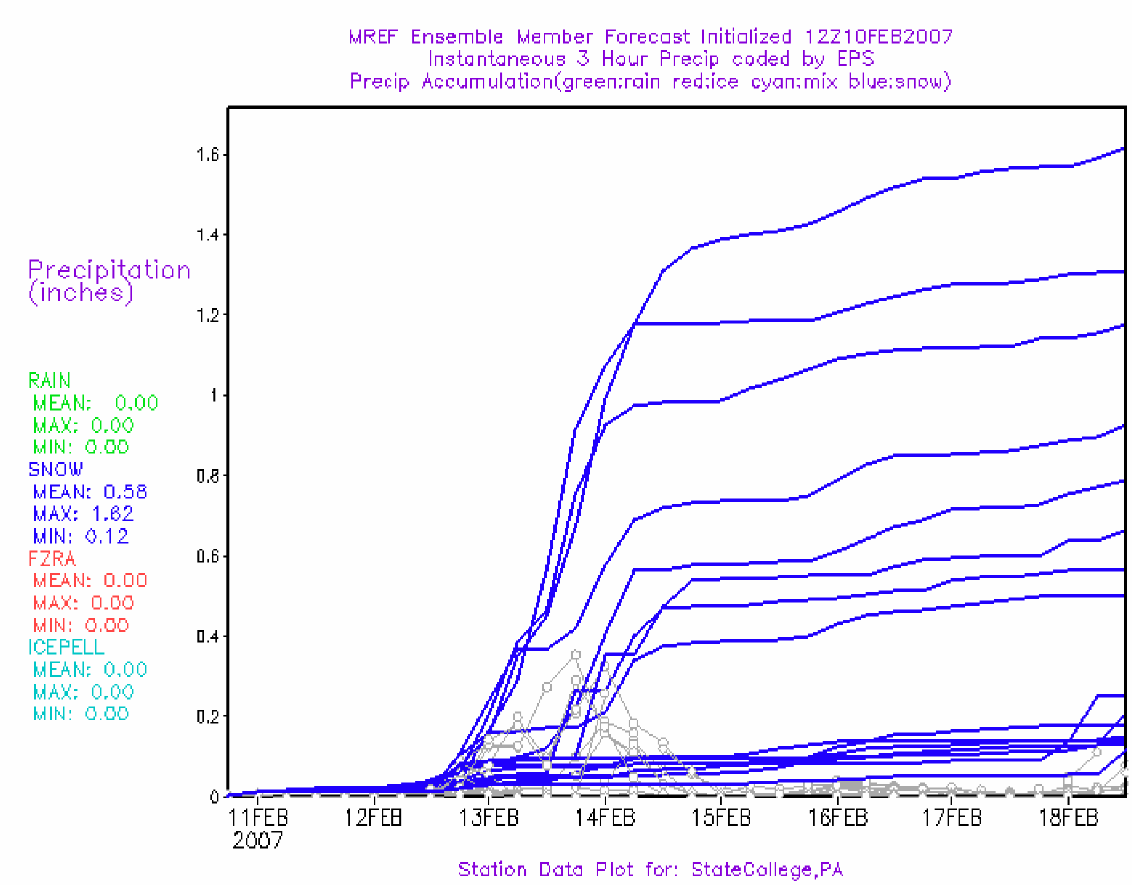
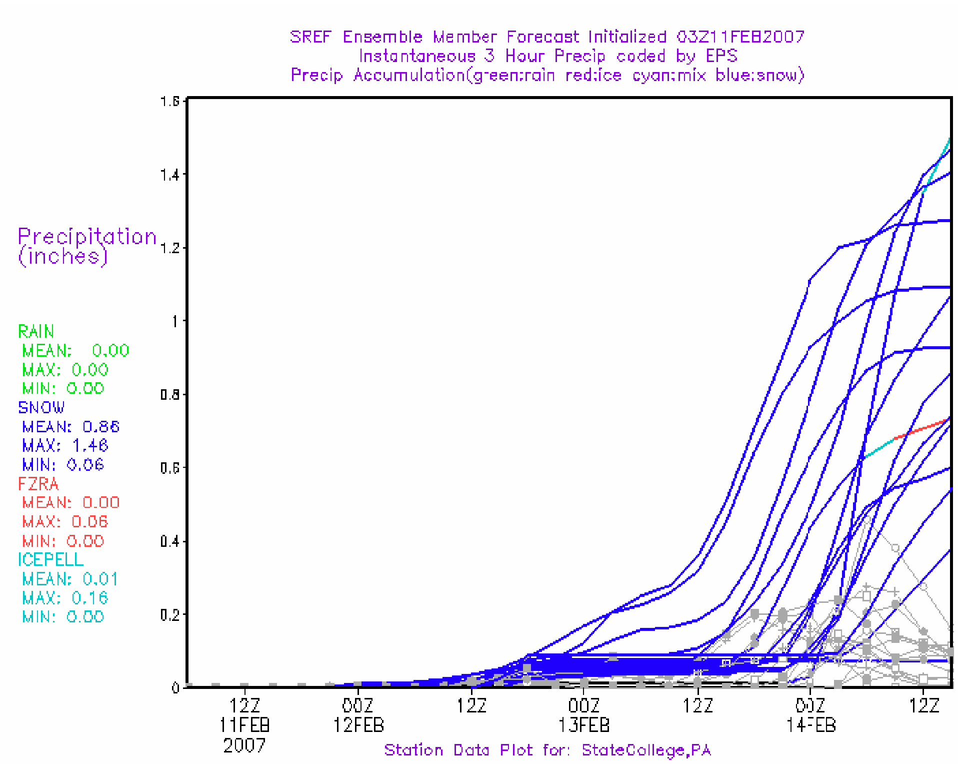
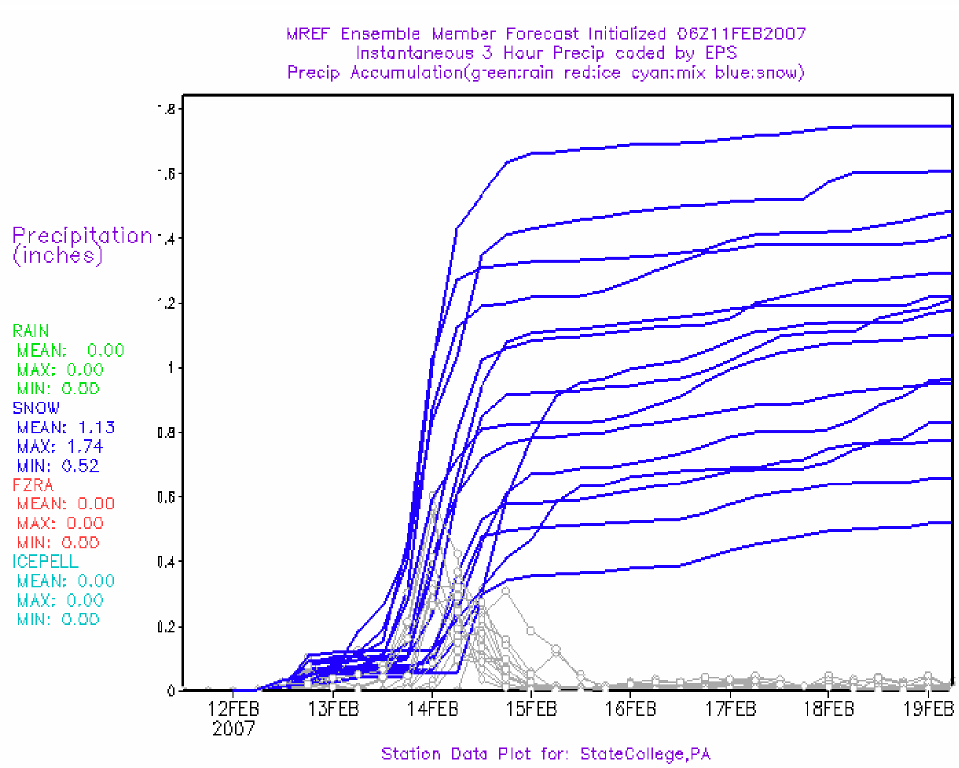


Fig. 3. NCEP GEFS 72-h forecasts initialized at 1200 UTC 10 February 2007 showing accumulated precipitation in inches (cm/2.5), color coded by type and the 6-hour instantaneous precipitation (gray) valid for the 7.5 day period.



a)



b)

Fig. 4. Plume diagrams of precipitation in inches by type similar to those shown in Fig. 3 except from a) the SREF initialized at 0300 UTC 11 February 2007 and b) the GEFS/MREF initialized at 0600 UTC 11 February 2007.

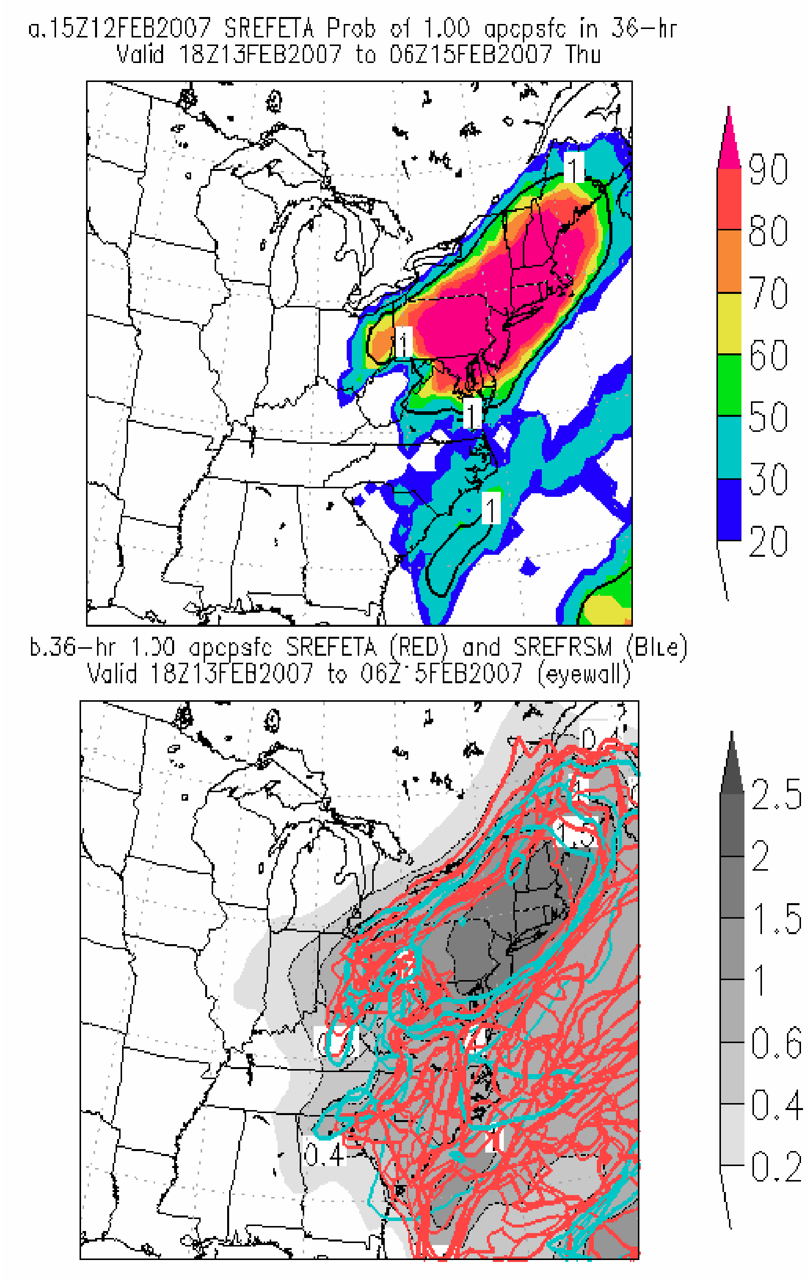


Fig. 5. Probability of precipitation forecasts of 1.00 inch (2.5 cm) or more in 36 hours from the SREF initialized at 1500 UTC 12 February 2007. Upper panel shows the probability of exceeding 1.00 inch (2.5 cm). Lower panel shows the ensemble mean and each member's 1.00 inch (2.5 cm) contour.

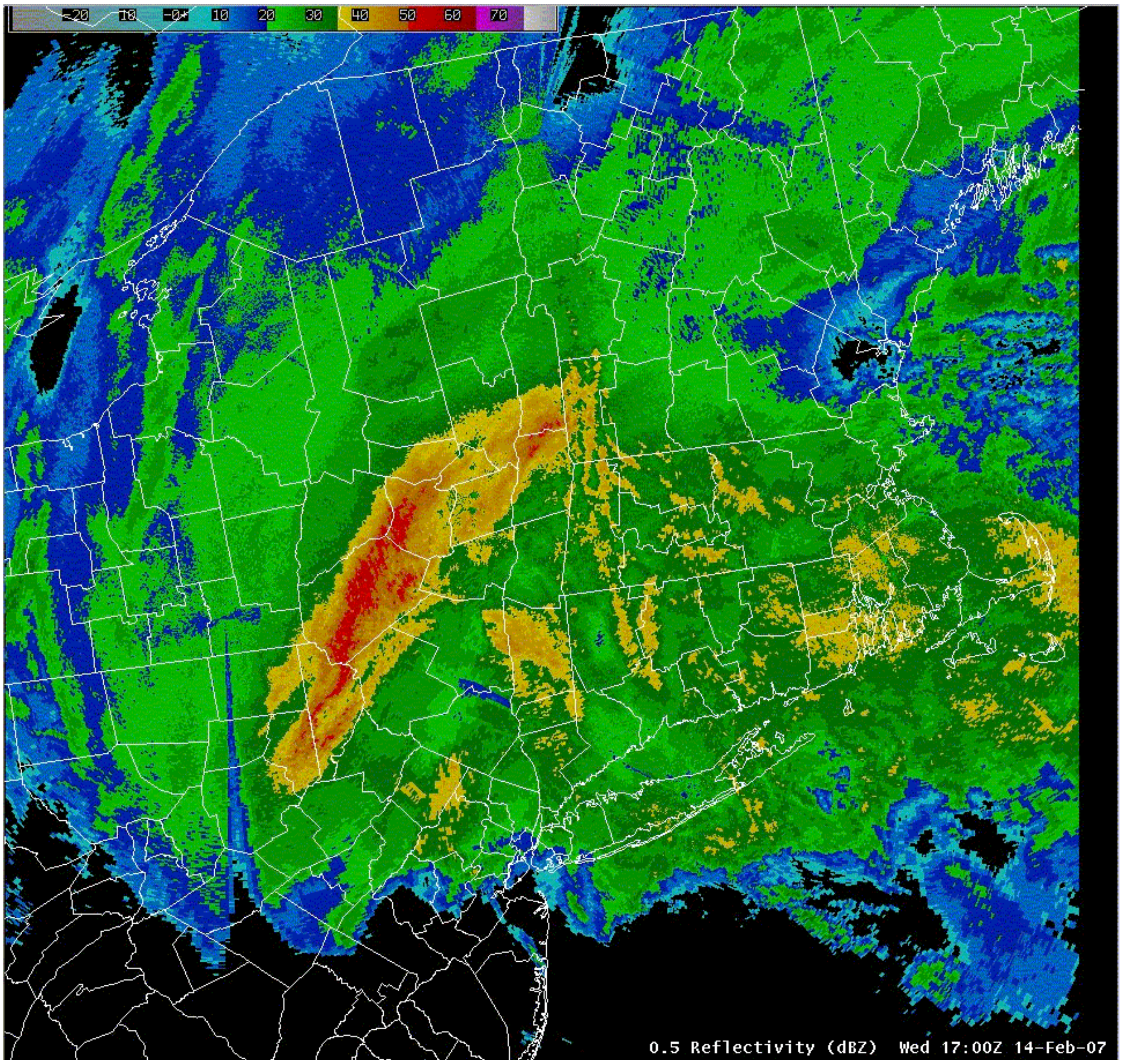


Fig. 6. Radar 0.5˚ base reflectivity mosaic image (dBZ) valid 1700 UTC 14 February 2007.