#### The historic 8-9 February 2013 Nor'easter and Blizzard

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#### **ABSTRACT:**

A high impact winter storm brought rain, wind, and record heavy snow to the eastern United States on 8-9 February 2013. The heavy snow from southeastern New York and Long Island, across Connecticut and into Maine was the result of a strong cyclone which tracked up the East Coast on 8 February before interacting with a northern stream wave. The two systems merged during the evening hours of 8 February 2013. During this merger period intense snowfall affect central Long Island and Connecticut producing areas of 30 to 40 inches of snowfall. From a historic perspective this storm was compared to the February 1978 Storm. This was a top 5 snowfall event in many locations across southern and eastern New England and for many sites in Long Island and Connecticut is the new snowfall of record.

The storm was relatively well predicted 1 to 3 days in advance and the European Centers high resolution model provide some insight into storm potential about 6 days in advance. As the storm approached and the forecast length decreased the models and ensemble prediction systems produced a deep cyclone with an anchoring intense anticyclone to the north, resulting in forecasts of 850 hPa winds -5 to  $6\sigma$  below normal, implying a near record if not historic event.

With the strong frontal forcing implied by the strong winds, both model and ensemble forecast system quantitative precipitation forecasts were on the order of 25 to 50 mm in areas where the predicted precipitation type was forecast to fall mainly as snow. Forecasts of 18 to 38 inches were common in SREF forecasts at least 48 hour prior to the onset of precipitation.

This paper documents the event of 8-9 February 2013 providing reanalysis of the event using standardized anomalies to but the event in a climatological context. Supporting data on the predictability of the event is provided focused on the European Centers longer range deterministic model forecasts and the National Centers for Environmental Prediction Centers forecasts of the event.

#### 1. INTRODUCTION

A high impact winter storm brought heavy snow (<u>Table 1</u>) and strong winds (<u>Table 2</u>) to coastal regions of the northeastern United States on 8-9 February 2013. Many locations from southeastern New York into eastern Maine had snowfall that either set a record snow event or was in a top-5 snowfall event. Many locations compared this event the historic blizzard of 5-6 February 1978 (Wagner 1978). The blizzard of 1978 brought 27.1 inches to Boston and 27.6 inches of snow to Providence, RI. The 1978 storms brought heavy snow to a larger portion to the East than the storm of 8-9 February 2013 (Kocin and Uccellini (2004,1990).

The nor'easter of 8-9 February 2013 involved a northern stream wave and a southern stream wave. The southern wave came across California and the Gulf Coast then up the East Coast. It will be shown that the circulations and the precipitation shields of the two systems did not merge until the storm was south of Long Island, NY (Fig. 1). The storm had all the characteristics associated with major East Coast Winter Storms (ECWS:Hirsch et al. 2000;Stuart and Grumm 2006). Historically, significant ECWS have a large anticyclone to the north and east, a deep cyclone moving up the coast, strong jet entrance region and potentially a coupled jet (Kocin and Uccellini 1990 & 2004). Additional work has shown the importance of strong low-level easterly flow (Stuart and Grumm 2006) with the historically more significant storms having -4 to  $-5\sigma$  850 hPa u-wind anomalies. It will be shown that at its peak, this storm had  $-6\sigma$  850 hPa u-wind anomalies.

Many historic storms (Kocin and Uccellini 2004; Novak and Colle 2012; Novak et al. 2004) have persistent mesoscale snow bands which develop in the region of heavy snowfall. Novak and Colle (2012) showed that ensembles often contain information suggesting the potential for mesoscale snow bands to develop and may aid in predicting the region where locally heavy snow may occur. Novak et al. (2004) showed a climatology of snow bands which produced heavy snow in the northeastern United States. There results implied that most, at least 85%, of large ECWS have mesoscale snow bands, which is not surprising as these bands were all associated with strong frontogenesis (see their Fig. 16). The snow bands of 8-9 February 2013 exhibited the pattern shown Figure 16 (Novak et al 2004).

The intense band that developed over Connecticut and Long Island was related to the merger of the northern stream wave with the southern stream wave. This band likely lead to the record snowfall at Brookhaven, NY (30.9) inches and some of the records snow fall amounts in the 30 to 40 inch range over central Connecticut (Table 1).

The potential for strong winds and heavy snow was generally well predicted along the coastal plain from New Jersey into New England. There were forecast issues related to how far west heavy snow would fall. The NCEP global ensemble forecast systems (GEFS) and short-range ensemble forecast systems are examined to show how this event was predicted.

This paper will document the historic East Coast winter storm and southern New England blizzard of 8-9 February 2013. The focus is on the pattern and standardized anomalies to show how strong the storm was and which features in the may have played a role in the record event. The paper also serves to document the storm and provide some insights into predictability of this storm and perhaps aid in better prediction of similar storms in the future.

# 2. METHODS

The large scale pattern was reconstructed using the Climate Forecasts System (CFS) as the 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 precipitation was estimated using the Stage-IV precipitation data in 6-hour increments to produce estimates of precipitation during the 60 hour period centered on 1200 UTC 9 February 2013. Snow fall and maximum wind gust data was retrieved from NWS public information statements. These data were put into a database for plotting and producing tables (Table 1 & 2).

The NCEP GEFS and SREF data were used to show the larger scale forecasts of the pattern, the QPF, precipitation types, and the probabilities of a high anomalies cyclone with anomalous easterly winds.

# 3. OVERVIEW

The 500 hPa heights in 12-hour periods (Fig. 2) from 07/0000 through 09/1200 UTC show the evolution of the short-waves moving across the United States. The southern stream wave could be made out over the southwest at 07/0000 UTC (Fig. 2a). The distinct wave can be seen at 08/1200 UTC with the southern wave over the Carolinas and the north wave over the Midwest (Fig. 2e) and then the merger and the appearance of a deep 500 hPa trough over the East Coast by 09/1200 UTC.

The evolution of the precipitation over the United States from 7-9 February showed an area of rain moving out of Texas then eastward along the Gulf Coast before turning northward up the coast (not shown). As late as 1800 UTC on 8 February the precipitation shields with the two waves remained distinct and separate, the 24-hour accumulated precipitation valid 1200 UTC on 6-9 February (Fig. 3) clearly show the evolution of the 2 distinct precipitation shields from the 2 distinct waves. It will be shown that most forecast models were able to distinguish between these two distinct areas of precipitation and close to where the merged is where the heaviest snowfall was observed.

The total QPE (Fig. 4) over the eastern United States showed the light precipitation over Ohio, Pennsylvania and western New York relative to the higher amounts of precipitation along the coast from Maryland into southern Maine. Some of the higher amounts over Long Island and Connecticut are in close proximity to where the two waves merged after 0000 UTC 9 February 2013. These data show that southward along the coast heavy precipitation was observed with the southern stream wave, most of which occurred before the merger.

The heavy precipitation along the coast and the heavy snow over Long Island and eastern New England lined up well with the strong low-level 850 hPa jet (Fig. 5). As the southern stream storm moved up the coast, the u-winds ranged from -3 to -6 $\sigma$  below normal. The easterly winds increased to -5 to -6 $\sigma$  above normal as the storm moved northward (Fig. 5c-d) with -6 $\sigma$  winds near eastern Long Island and eastern Massachusetts at 09/0000 and 09/0600 UTC respectively. These anomalous winds occurred upwind of the heavier QPF and heavy snow areas. The bands of heavy snow developed near and west of these intense low-level winds, commonly defined feature of significant ECWS (Stuart and Grumm 2006) and a

common feature associated with heavy snow bands in general (Novak et al. 2004). The strong easterly winds created surface wind gusts (Fig. 8) and blizzard conditions in some locations.

The strong low-level 850 hPa jet (Fig. 5) was associated with a plume of deep moisture (Fig. 6) which had precipitable water (PW) anomalies on the order of 2 to 3s above normal. Though not shown, the moisture flux with this system exceeds  $6\sigma$  above normal. The deep plume of moisture was an essential ingredient in producing the high end precipitation amounts, which over southern New York and New England was mainly in the form of snow (Fig. 7). The deep plume of high PW air ingested into the storm circulation (Fig 1) was relatively short-lived along the Mid-Atlantic and north with high PW values present from about 1200 UTC 8 February through about 0600 UTC 9 February 2013.

The evolution of the precipitation shield based on radar (Fig. 9) indicated that two distinct separate precipitation shields were present with each wave. The southern stream wave (Fig. 3) with deeper moisture, higher PW values and strong low-level easterly flow produced greater precipitation rates. However as the northern stream wave interacted with the southern stream wave, there was an increase in the reflectivity as the east-west bands became oriented more south-to-north over Long Island and Connecticut. After 0200 UTC the two waves had merged and shortly afterwards the reflectivity in the snow bands decreased. By 0400 UTC the band extended from northern Long Island across Connecticut, Massachusetts, southeastern New Hampshire and into southern Maine.

# 4. FORECASTS

The deterministic EC and EC EFS were the first systems to predicted a cyclone along the East Coast on 8-9 February 2013. Six EC forecasts valid at 0000 UTC 09 February 2013 (Fig. 10) show the cyclone potential along the East Coast. A relatively weak cyclone was forecast by the 02/0000 UTC and 02/1200 UTC EC. These early forecasts did not produce a storm which tracked up the coast. The forecasts from 03/0000 UTC onward began to predict a storm moving up the coast and began to show two distinct waves. Despite the ECs' prescient forecast of a surface cyclone, there was considerable uncertainty in all the single EC forecasts to include cyclone location, intensity, track, and timing. There was considerable run-to-run variation.

The GFS comparative forecasts, missing the 02/1200 UTC GFS run, shows (Fig. 11) that the operational GFS did not produce a significant surface cyclone affecting southern New England until the forecasts initialized after 0000 UTC 4 February 2013. Earlier forecasts had a cyclone developing farther east and affecting northern Maine and the Canadian Maritimes.

The GEFS, showing 9 forecasts, had some hints of a cyclone as a low probability forecast by 04/1200 TUC (Fig. 12d) however the high probability evolution of strong surface cyclone did not emerge from these forecasts until forecasts initialized on and after 05/1200 UTC (Fig. 12f) from which point a higher confidence convergent forecast toward a major ECWS evolved. The ensemble mean forecasts with the standardized anomalies clearly showed a) a good forecast for the strong anticyclone over eastern New England and Canada and b) a trough or cyclone offshore from forecasts initialized after 03/0000 UTC (Fig. 12c). But a strong cyclone forecast did not begin to emerge until forecasts issued at 05/1200 UTC (Fig. 12f).

The variable forecasts of the cyclone evolution and track produced variable QPFs. The mean QPF and the 50mm contour are shown in Figure 13 and the probability of 25mm or more QPF is shown in Figure 14. These data show a retrogression of the precipitation shield toward the coast though hints of QPF existed over Long Island from forecasts issued at 04/0000 UTC (Fig. 13a). The 50 mm contour reached the coastal regions in some members by forecasts issued at 05/1200 UTC (Fig. 13d) and a closed 50mm contour appeared by forecasts issued at 07/0000 UTC (Fig. 13h). The 25 mm or great QPF probability forecast showed this same progression and kept a high probability of heavy QPF focused over New Jersey and points east. Much of New York, Pennsylvania and western New Jersey were on the edge of the heavier precipitation shield.

SREF QPS (Fig. 16 & 17) showed the same sharp gradient and QPF drop off to the east. The high probability of 25mm or more QPF remained mainly in the coastal zone and only in shorter range forecasts did the 25mm QPF probabilities push into eastern Pennsylvania. The SREF mean QPF and each 50mm contour showed the same general pattern with very light QPF amounts over most of Pennsylvania, thought the 25mm contour did push into New York State.

The NCEP SREF plume diagrams (Fig. 18) showing precipitation accumulations and precipitation types for 3 cycles from 0300 and 1500 UTC 6 February and 1500 UTC on 7 February 2013 show that most of the members predicted snow as the dominant precipitation type; using a 10:1 ratio snowfall amounts of 12 to 38 inches were well within the range of possibilities. Planview maps (Fig. 19) of snowfall showed a similar pattern for heavy snow. Though not shown, locations such as Islip, NY had precipitation type issues but even at Islip the potential for snowfall 1 inch to as high as 30 inches (using a 10:1 ratio). Islip was a difficult forecast as most forecast cycles showed rain and snow as nearly equal probabilities.

The planview "threats" image (Fig. 19) showed the intense area of snowfall over southern New York and New England. Forecasts from various times showed maximum values in the mean of over 28 inches (not shown). These data highlight the potential for snowfall and for heavy snow quickly and show different accumulation times all valid at the same time. In this case, the period of heavy snow was over as only 2-3 inches was forecast over eastern New England while 6, 12 and 24 hour totals were well over 6, 10 and 20 inches respectively.

## 5. High resolution model forecast

The 13km RAP data was used to replicate the radar analysis in Figure 9 and show features from the banded snowfall conceptual from Novak et al. (2004:see their Figure 15a). The data include the RAP reflectivity, 500 hPa heights, and both the 850 hPa winds and temperatures. Figure 20 shows the "analysis" or 00-hour forecasts from 6 RAP cycles. Though the radar is similar to Figure 9 intensities are weaker as are the details. Similar to the radar, the RAP showed *the two distinct wave* and then the slow merger and the evolution of the "*single band event*" with the single band north and east of the 500 hPa close cyclone (Fig. 20b-f).

The forecasts from the 19Z 8 February RAP (Fig. 21) show the two distinct waves with a merger of the implied precipitation shields and the enhancing band to the east with the southern stream wave. By 0300 UTC 9 February the merger process is nearing completion. The evolution of the main band peaks in the 03-0400 UTC time period and fitting the conceptual model of Novak et al. (2004). It should be noted that the RAP band was slightly *east* of where the band as viewed on radar set up.

Forecasts from 6 cycles valid at 0000 through 1200 UTC were examined, only the 0400 UTC valid time is shown here (Fig. 22). These data show similar patterns in the simulated reflectivity with some run-to-run variations; they show the heavy snow band of Novak et al. (2004) quite well; and likely provided useful forecast guidance as to the potential for heavy precipitation. An examination of precipitation types is not presented here.

# 6. CONCLUSIONS

The late merger of northeastern Pennsylvania and New Jersey likely limited the snow fall to the east. The precipitation shield from the coastal storm did not penetrate too far inland over Pennsylvania and central New York. The precipitation shield became more north-south as the northern stream wave approached and the intensity of the precipitation and radar echoes peaked as the systems merged. As viewed on radar, after the systems merged, there was a dramatic decrease in the radar returns.

The GFS had a cyclone in Gulf of Maine 6 days in advance suggesting some East Coast Cyclone potential in the model. The EC had a potential major ECWS from forecasts issued at 02/0000 UTC but subsequent forecasts varied markedly as to the location, track and intensity of the cyclone. Predictability issues with this storm abounded.

The NCEP GEFS showed considerable uncertainty in the mean sea-level pressure field off the East Coast at least 5 days prior to the storm. However, the potential for a major cyclone along the coast in both the spaghetti plots and ensemble mean forecasts did not become evident with much more lead-time than that provided by the higher resolution model core, the GFS. This, and experience viewing other cases, implies some limitations of global ensemble forecast systems which use the same base initial conditions, which are then perturbed and systems which use the same model core. It is possible that in strongly forced systems there is not a enough variability in the EFS verse the higher resolution models.

This case has considerable research potential spanning phasing waves and the impacts on cyclone evolution and precipitation bands. In this event, the precipitation bands appeared to intensify as the distance between the two waves decreased, but diminished after the merger of the two systems. Other issues involve model and ensemble prediction system sensitivities to initial conditions in strongly forced situations and limit of single model core EFS.

The RAP data presented here show that in strongly forced situations, a) the RAP can do a good job representing radar data (Figs 9 vs Fig 20); b) the RAP can simulate band and wave mergers on a mesoscale quite realistically; c) in this strongly forced cases this band evolutions in the forecasts were relatively consistent and similar to the reality as viewed on radar. These RAP data provide great hope for storm scale ensembles providing detailed short-term forecasts for heavy precipitation and snowfall and suggest the RAP and likely the 3 km HRRR are ideally suited NOWCAST tools in strongly forced events.

## 7. Acknowledgements

## 8. References

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Wagner, J.A. 1978: Cold with Record Snowfall in the Midwest and Northeast, Mild and Wet in the West, Monthly Weather Review Volume 106,579-585.

LOCATION	STATE	SNOW (IN)	LOCATION2	STATE3	SNOW (IN)4
HAMDEN	CONNECTICUT	40.00	RICHMOND	MAINE	26.50
MILFORD	CONNECTICUT	38.00	GRAY NWS OFFICE	MAINE	26.40
CLINTONVILLE	CONNECTICUT	37.00	WRENTHAM	MASSACHUSETTS	26.00
OXFORD	CONNECTICUT	36.20	KENNEBUNK 2 NE	MAINE	26.00
EAST HADDAM	CONNECTICUT	35.50	EAST HAMPSTEAD 1 S	NEW HAMSPHIRE	26.00
GORHAM	MAINE	35.50	WEST GLOCESTER	RHODE ISLAND	25.70
FAIRFIELD	CONNECTICUT	35.00	WELLS	MAINE	25.60
TOLLAND	CONNECTICUT	35.00	LEWISTON 2 E	MAINE	25.50
NEW HAVEN	CONNECTICUT	34.30	NEW IPSWITCH	NEW HAMSPHIRE	25.00
GLASTONBURY	CONNECTICUT	33.50	BURRILLVILLE	RHODE ISLAND	25.00
NEW HARTFORD	CONNECTICUT	33.00	EAST WAKEFIELD 1.2 SE	NEW HAMSPHIRE	24.50
STRATFORD	CONNECTICUT	33.00	WOONSOCKET 1.3 ESE	RHODE ISLAND	24.40
COVENTRY	CONNECTICUT	32.50	BLANDFORD	MASSACHUSETTS	24.00
BERWICK	MAINE	32.00	FALL RIVER	MASSACHUSETTS	24.00
PORTLAND JETPORT	MAINE	31.90	NORTHAMPTON	MASSACHUSETTS	24.00
UPTON	NEW YORK	30.30	NORWOOD	MASSACHUSETTS	24.00
WESTBROOK	MAINE	30.00	OTISFIELD 1 W	MAINE	24.00
SEABROOK 5 W	NEW HAMSPHIRE	29.30	TURNER 4 S	MAINE	24.00
COMMACK	NEW YORK	29.10	HAMPTON 1 NNW	NEW HAMSPHIRE	24.00
EAST SETAUKET	NEW YORK	28.50	NASHUA	NEW HAMSPHIRE	24.00
SOUTHWICK	MASSACHUSETTS	28.30	SMITHFIELD	RHODE ISLAND	24.00
WORCESTER	MASSACHUSETTS	28.00	MANVILLE 0.2 NE	RHODE ISLAND	23.90
SOUTH WINDHAM 1 ENE	MAINE	28.00	LACONIA	NEW HAMSPHIRE	23.60
GOFFSTOWN	NEW HAMSPHIRE	28.00	DERRY 3 ENE	NEW HAMSPHIRE	22.00
ISLIP AIRPORT	NEW YORK	27.80	BOSTON LOGAN ARPT	MASSACHUSETTS	21.80
ST. JAMES	NEW YORK	27.50	BRONXVILLE	NEW YORK	21.30
STONY BROOK	NEW YORK	27.50	PAWTUCKET 1.4 SW	RHODE ISLAND	21.00
HARTFORD	CONNECTICUT	27.00	AMHERST	MASSACHUSETTS	20.60
BELMONT	MASSACHUSETTS	27.00	WASHINGTONVILLE	NEW YORK	20.50
SHREWSBURY	MASSACHUSETTS	27.00	CONCORD	NEW HAMSPHIRE	20.30
SACO 2 NNW	MAINE	27.00	SCARSDALE	NEW YORK	20.20
FARMINGTON 2 SSE	NEW HAMSPHIRE	27.00	SUMMIT	NEW YORK	20.00
MELROSE	MASSACHUSETTS	26.50	WASHINGTON 1 ESE	NEW HAMSPHIRE	19.00

Table 1. List of sites, States and snowfall (inches) for locations which received in excess of 19 inches of snowfall. Based on NWS snow reports. <u>Return to text.</u>

		PEAK WIND
LOCATION	STATE	(MPH)
CUTTYHUNK 6 WSW	MASSACHUSETTS	83
WESTPORT	CONNECTICUT	82
PORTLAND 1 S	CONNECTICUT	81
MOUNT WASHINGTON	NEW HAMPSHIRE	81
HYANNIS	MASSACHUSETTS	77
BOSTON LOGAN AIRPORT	MASSACHUSETTS	76
BEDFORD 2 WSW	MASSACHUSETTS	75
AIRPORT	MAINE	75
BROOKLIN 3 ESE	MAINE	75
PLUM ISLAND 4 ENE	NEW YORK	75
BUZZARDS BAY	MASSACHUSETTS	74
MARSTONS MILL	MASSACHUSETTS	74
NANTUCKET	MASSACHUSETTS	69
NANTUCKET 2 ESE	MASSACHUSETTS	69
JAMESTOWN	NEW HAMPSHIRE	68
JAMESTOWN	RHODE ISLAND	68
MILTON 3 SSW	MASSACHUSETTS	66
MILFORD	MASSACHUSETTS	65
EASTPORT	MAINE	65
EAST HAMPTON 20 SE	NEW YORK	65
PLYMOUTH	MASSACHUSETTS	63
WARWICK 2 NNW	RHODE ISLAND	63
SOUTH THOMASTON 1 E	MAINE	62
CHATHAM 2 NW	MASSACHUSETTS	61
SURRY 1 SW	MAINE	61
GROTON AIRPORT	CONNECTICUT	60
BROOKSVILLE 4 E	MAINE	60
NEW PORTLAND	MAINE	59
WINTERGREEN 4 NW	VIRGINIA	59
HITHER HILLS STA 3 W	NEW YORK	57
DULLES INTERNATIONAL ARPT	VIRGINIA	55
BATH	MAINE	54
BOONE 1 ESE	NORTH CAROLINA	53
MONTAUK HIGHWAY	NEW YORK	52
GLEN BURNIE 1 W	MARYLAND	51
PORT CHESTER 1 ENE	CONNECTICUT	50
FROSTBURG	MARYLAND	50
BAR HARBOR 3 W	MAINE	50

 Table 2. Wind gust of 50 mph or greater from observations on 8-9 February 2013. Date form National Weather Service Public information Statements. <u>Return to text.</u>

a. GFS 1000 hPa prmsImsI 12Z08FEB2013



b. GFS 1000 hPa prmslmsl 18Z08FEB2013



c. GFS 1000 hPa prmslmsl 00Z09FEB2013



-6-5-4-3-2-11 2 3 4 5 6

-6-5-4-3-2-1123456

123456 -6-5-4-3-2-1

- 1











-6-5-4-3-2-11 2 3 4 5 6

-6-5-4-3-2-11 2 3 4 5 6

Figure 1. Mean sea-level pressure in 6-hour increments and standardized anomalies valid every 6-hours from a) 1200 UTC 8 February through f) 1800 UTC 9 February 2013. <u>Return to text.</u>

-8-5-4-3-2-11 2 3 4 5 6

Figure 2. As in Figure 1 except for 500 hPa heights(m) and anomalies. Return to text.

( Par 3

-6-5-4-3-2-11 7 3 4 5 6



e. GFS 500 hPa hgtprs 00Z09FEB2013

-6-5-4-3-2-11 2 3 4 5 6

-6-5-4-3-2-11 2 3 4 5 6



c. GFS 500 hPa hgtprs 00Z08FEB2013



f. GFS 500 hPa hgtprs 12Z09FEB2013

-6-5-4-3-2-11 7 3 4 5 6

-6-5-4-3-2-11 2 3 4 5 6





d. GFS 500 hPa hgtprs 12Z08FEB2013

a. GFS 500 hPa hgtprs 00Z07FEB2013



Figure 3. Total accumulated precipitation (mm) from the Stage-IV data showing the accumulations ending at 1200 UTC on a) 6 February through d) 9 February 2012. Return to text.



a. Accumulated liquid equivalent precipitation (mm) from 00Z08FEB2013 to 18Z09FEB2013

Figure 4. As in Figure 3 except for total QPE 0000 UTC 8-1800 UTC 9 February 2013. Return to text.

-6-5-4-3-2-1123456

Figure 5. 850 hPa winds and u-wind anomalies. Return to text.

-6-5-4-3-2-1123456

-6-5-4-3-2-11 2 3 4 5 6

-6-5-4-3-2-11 2 3 4 5 6

c. GFS 850 hPa ugrdprs 00Z09FEB2013 ø



b. GFS 850 hPa ugrdprs 18Z08FEB2013



-6-5-4-3-2-11 2 3 4 5 6

a. GFS 850 hPa ugrdprs 12Z08FEB2013





-6-5-4-3-2-1123456



a. GFS 1000 hPa pwatclm 12Z08FEB2013





6 2C

-6-5-4-3-2-1123456

-6-5-4-3-2-11 2 3 4 5 6

e. GFS 1000 hPa pwatclm 12Z09FEB2013





Figure 6. Precipitable water mm. return to text.



-6-5-4-3-2-11 2 3 4 5 6

-6-5-4-3-2-1123456

















Figure 8. Wind guest and snow reports over 6 inches.



Figure 9. Select composite reflectivity images from the NMQ-Q2 site showing the evolution of the precipitation shield over the eastern United States. Data valid upper left at 1900 UTC 8 February and 0000 UTC 9 February, second row 0200 and 0300 UTC 9 February and bottom row 0400 and 0500 UTC 9 February 2013. <u>Return to text.</u>

No File Missing

46.00N

Reflectivity [dBZ]

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75

46.00N

Reflectivity [dBZ]

10 15 20 25 30 35 40 45 50 55 60 65 70 75



Figure 10. EC forecasts of mean sea-level pressure (hPa) valid at 0000 UTC 9 February 2013 from EC forecasts initialized at a) 0000 UTC 5 February, b) 0000 UTC 4 February, c) 1200 UTC 3 February, d) 0000 UTC 3 February, e) 1200 UTC 2 February and f) 0000 UTC 3 February. Return to text.



-87-8-5-4-3-2-11 2 3 4 5 8 7 8

 a. EC INIT:00Z05FEB2013 Valid:00Z09FEB2013 preamal 100



-8-7-6-5-4-3-2-11 2 3 4 5 6 7 8

b. EC INIT:00Z04FEB2013 Valid:00Z09FEB2013 presmel 100

-8765432112345678

с. EC INIT:12Z03FEB2013 Valid:00Z09FEB2013 preemai 100



-8-7-6-5-4-3-2-11 2 3 4 5 6 7 8

-8-7-8-5-4-3-2-11 2 3 4 5 8 7 8

101

-8-7-6-5-4-3-2-11 2 3 4 5 6 7 8

024

Figure 11. As in Figure 10 except for GFS MSLP forecasts and anomalies from forecasts initialized at a) 0000 UTC 06 Feb, b) 0000 UTC 05 Feb, c) 0000 UTC 4 Feb, d) 1200 UTC 3 Feb, e) 0000 UTC 3 Feb, and 0000 UTC 02 Feb 2013. Return to text.

e. gfs INIT:00Z03FEB2013 Valid:00Z09FEB2013 prmslmsl 1000

-8-7-8-5-4-3-2-11 2 3 4 5 8 7 8

032 992 1008  $102^{4}$ 

-8765432112345678





b. gfs INIT:00Z05FEB2013 Valid:00Z09FEB2013 prmslmsl 1000



-8765432112345678

f. gfs INIT:00Z02FEB2013 Valid:00Z09FEB2013 prmslmsl 1000

c, gfs INIT:00Z04FE82013 Valid:00Z09FE82013 prmslmsl 1000



Figure 12. GEFS forecasts of mean sea-level pressure showing the 996, 1020, and 1032 contours for each member, the spread about the ensemble mean and the thick contours show the ensemble mean from 9 GEFS cycles from a) 0000 UTC 02 Feb to i) 0000 UTC 07 Feb 2013. Return to text. Return to text.







Figure 13. As in Figure 12 except for the GEFS ensemble mean and standardized anomalies. Return to text.



Figure 14. GEFS ensemble mean QPF (mm) and each members 50 mm contour valid for the 24 hour period of 1200 UTC 8-9 February from forecasts issued in 12 hour increments from a) 0000 UTC 4 February 2013 through i) 0000 UTC 8 February 2013. Return to text.



Figure 15. As in Figure 14 except for the probability of 25 mm or more QPF. Return to text.



Figure 16. As in Figure 15 except for SREF forecasts of QPF greater than 25mm. Return to text.



Figure 17. As in 16 except SREF mean QPF and each members 50mm contour. Return to text.

= 1 6.2512.5 25 50 100 125 150



Figure 18. NCEP SREF precipitation forecasts (gray) and accumulated precipitation color coded by precipitation type for a point near Boston, MA showing forecasts initialized at a)0300 UTC 6 February, b) 1500 UTC 6 February, and c) 1500 UTC 7 February 2013. Return to text.

a. 15Z06FEB2013 SREF Valid 21Z09FEB2013-00Z10FEB2013(Sun) sfc csnowsfc prob-amount in 3hrs



c. 15Z06FEB2D13 SREF Valid 12Z09FEB2013-D0Z10FEB2013(Sun) sfc csnowsfc prob-amount in 12hrs



- - d. 15Z06FEB2013 SREF Valid 00Z09FEB2013-00Z10FEB2013(Sun) sfc csnowsfc prob-amount in 24hrs



Figure 19. NCEP SREF snow probabilities and accumulations from the NCEP SREF initialized at 1500 UTC 6 February 2013 showing mean snowfall (inches) and the probability of snow for periods ending at 0000 UTC 10 February of the last a) 3hours, b) 6 hours, c) 12 hours, and d) past 24 hours. Return to text.

b. 15Z06FEB2013 SREF Valid 18Z09FEB2013—00Z10FEB2013(Sun) sfc csnowsfc prob—amount in 6hrs a. V:19Z08FEB2013 reflect hgt=500 850 T-winds init 19Z08FEB2013



d. V:03Z09FEB2013 reflect hgt-500 850 T-winds init 03Z09FEB2013

5 10 20 25 30 35 40 45 50 55 60 65 70

b. V:00Z09FEB2013 reflect hgt-500 850 T-winds init 00Z09FEB2013 762 5640 -8



- ः 5 10 20 25 30 35 40 45 50 55 60 65 70
- e. V:04Z09FEB2013 reflect hgt-500 850 T-winds init 04Z09FEB2013



5 10 20 25 30 35 40 45 50 55 60 65 70

c. V:02Z09FEB2013 reflect hgt-500 850 T-winds init 02Z09FEB2013

71552



5 10 20 25 30 35 40 45 50 55 60 65 70

Figure 20. RAP 00-hour forecasts of reflectivity (dBZ), 500 hPa heights (m), 850 hPa winds, and 850 hPa temperatures from RAP initialized at a) 1900 UTC 08 Feb, b) 0000 UTC 9 February, c) ) 0200 UTC 9 February, d) 0300 UTC 9 February, e) 0400 UTC 9 February, and f) 0500 UTC 9 February 2013. Reflectivity is as in the color bar, 500 heights black every 60m, winds kts skipping 4 of 3 grid points, and temperatures red every 4C. Return to text.

a. V:19Z08FEB2013 reflect hgt-500 850 T-winds init 19Z08FEB2013



5 10 20 25 30 35 40 45 50 55 60 65 70

d. V:03Z09FEB2013 reflect hgt-500 850 T-winds init 19Z08FEB2013

5 10 20 25 30 35 40 45 50 55 60 65 70

122

b. W00Z09FEB2013 reflect hgt-500 850 T-winds init 19Z0BFEB2013



5 10 20 25 30 35 40 45 50 55 60 65 70

e. \%04Z09FEB2013 reflect hgt=500 850 T-winds init 19Z08FEB2013



5 10 20 25 30 35 40 45 50 55 60 65 70

c. V:02Z09FEB2013 reflect hgt-500 850 T-winds init 19Z08FEB2013





f. V:05Z09FEB2013 reflect hgt-500 850 T-winds init 19Z08FEB2013





Figure 21. As in Figure 20 except for 19Z 08 February RAP forecasts valid at the same times as the radar in Figure 9. Return to text.

a. V:03Z09FEB2013 reflect hgt-500 850 T-winds init 18Z08FEB2013



5 10 20 25 30 35 40 45 50 55 60 65 70

d. V:03Z09FEB2013 reflect hgt-500 850 T-winds init 22Z08FEB2013

5 10 20 25 30 35 40 45 50 55 60 65 70

25

b. V:03Z09FEB2013 reflect hgt-500 650 T-winds init 19Z08FEB2013



- 5 10 20 25 30 35 40 45 50 55 60 65 70
- e. \%03Z09FEB2013 reflect hgt=500 850 T-winds init 00Z09FEB2013



5 10 20 25 30 35 40 45 50 55 60 65 70

c. V:03Z09FEB2013 reflect hgt=500 850 T-winds init 20Z08FEB2013





f. V:03Z09FEB2013 reflect hgt-500 850 T-winds init D2Z09FEB2013





Figure 22. As in Figure 20 except for forecasts from each cycle valid at 0400 UTC 9 February 2013. Return to text.

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FIG. 15. Conceptual model of the synoptic and mesoscale flow environment associated with (a) a single-banded event and (b) a nonbanded case highlighting the key features. Features shown include midlevel frontogenesis (red shading), midlevel deformation zone (encompassed by scalloped blue line) and associated primary dilatation axes [dashed lines in (a)], midlevel streamlines (black lines), and upper-level jet cores (wide dashed arrows).