9.2 EVALUATING POTENTIAL IMPACT OF SIGNIFICANT EAST COAST WINTER STORMS BY ANALYSIS OF UPPER AND LOW-LEVEL WIND ANOMALIES

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1. Introduction

The predictability of east coast winter storms (ECWS) has greatly improved during the past several decades, due to a combination of improved Numerical Weather Prediction (NWP) guidance, and improved forecaster interpretation of data and NWP guidance (Vislocky and Fritsch 1995). However, recent ECWS such as 25 January 2000 (Bosart 2003), 4-6 March 2001 (Grumm 2001; D'Aleo 2001) and 6-7 January 2002 (Grumm 2002), illustrated that NWP guidance and forecasters can still miss important atmospheric features that have a large impact on how ECWS evolve. Small changes in forecasted and observed snowfall (amounts and areal extent) can result in a considerable difference in how businesses, local government and the general public prepare for the storm, and how they are impacted.

Forecasting major winter storms is a critical function for all weather services. Conventional pressure levels, geopotential heights and temperature analyses from NWP models, do not provide information on whether a winter storm represents a large departure from normal. A method will be presented, using normalized departures from climatology, to assist forecasters in identifying long duration and potentially historical winter storms.

2. Data and Methodology

This method focuses on anomalous low-level and upper-level wind anomalies associated with winter storms along the US east coast. Climatological anomalies are calculated as standard deviations from normal, based on a 30-year climatology from 1961 through 1990, and are calculated on a 2.5° by 2.5° grid (Hart and Grumm 2001). For this study, low-level and upper- level wind anomalies were calculated at 850 hPa and 300 hPa, respectively. Figures depicting the anomalies from the reanalysis data were created with the GRADS software package.

The proposed method for evaluating U wind anomalies, will be shown to assist in identifying potentially slow-moving storms with extended periods of enhanced precipitation. To illustrate this method, upper and low-level wind anomalies from past ECWS will be presented. ECWS from 1948 to 2002 were analyzed (85 storms with >12 cm of snow), and a subset of historical snowstorms was created. Based on a comparison of wind anomalies and snowfall distribution for all the snowstorms in the data set, historical snowstorms will be defined as ECWS with widespread observed snowfalls ≥45 cm from Virginia through the northeastern U.S., and ≥30 cm from the Carolinas through the southeastern U.S. The four following cases, one storm each that affected the southeast U.S., the mid-Atlantic U.S., the northeastern U.S., and one that affected the entire eastern U.S., illustrate representative upper and lower wind anomalies in historical snowstorms.

3. Case 1: December 1989 storm

On 23-24 December 1989, a historic snowstorm occurred in the eastern Carolinas, where 30 to 60 cm of snow fell. This event was extremely unusual, occurring in an area that normally sees <15 cm of snow in an entire season. Significantly below normal temperature anomalies over the Carolinas [2 to 4 Standard Deviation (SD) below normal, not shown], were consistent with temperatures at or below freezing from the surface through 850 hPa, which supported snow as the predominant precipitation type.

On 24 December, U wind anomalies at 850 hPa and 300 hPa peaked at –4 SD (4 SD from normal in a –U direction, Figure 1) and –3 SD (Figure 2), respectively. The –4 SD U wind anomaly at 850 hPa represented an easterly wind maximum around 25 m sec^{-1}. Easterly winds at 850 hPa can be correlated with moisture

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advection off the Atlantic Ocean, low-level convergence, and enhancement of low-level frontogenesis, resulting in increased precipitation production. The –3 SD U wind anomaly at 300 hPa represented winds of 10 m sec^{-1} north of the center of the upper low, which signaled that the storm was nearly cut off from the predominant westerlies, resulting in slower movement of the system and a prolonged precipitation event.

Note the nose of the 850 hPa anomaly area extending into the Carolinas and Virginia. The greatest potential for historical snowfall amounts, typically occur within the nose of the –3 SD anomaly contour, and adjacent areas. The areas where potentially historical snowfall amounts are expected, also depends on local effects such as orography, and temperature profiles supportive of snow as the predominant precipitation type.

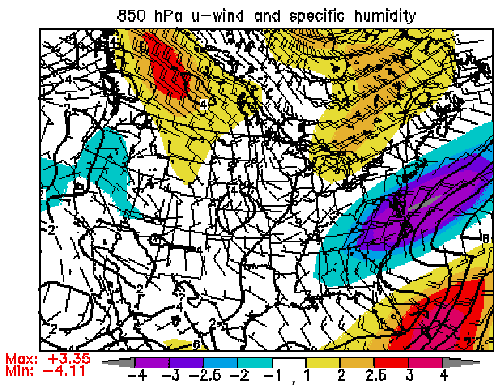

Figure 1. U wind (m sec^{-1}) and specific humidity at 850 hPa (solid lines) 24 December 1989. Wind barb values are as follows: half= 5 m sec^{-1} and full=10 m sec^{-1}. Anomalies (Standard Deviations from normal) are colored, with maximum and minimum anomalies in the lower left in red text.

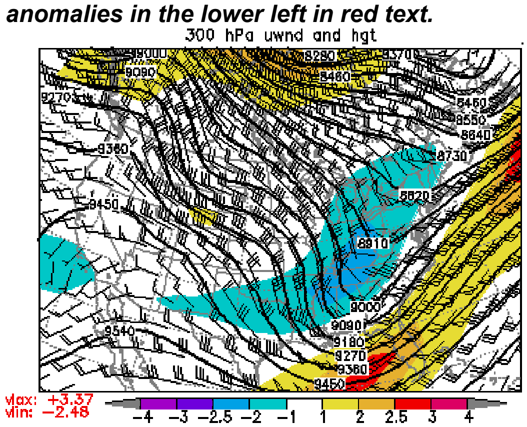

Figure 2. Same as Fig. 1 except with 300 hPa heights (decameters; solid lines) for 24 December 1989.

4. Case 2: Ash Wednesday storm of March 1962

On 6-8 March 1962, one of the most severe and prolonged coastal storms on record occurred in the mid-Atlantic U.S. The combination of heavy snow, strong winds, coastal flooding and erosion was unprecedented. The wind and coastal effects were so extreme, that substantial damage was observed, and new inlets were formed on the barrier islands from North Carolina through Maryland, to New Jersey and New York. Snowfall totals ranged between 30 and 60 cm over inland areas of the mid-Atlantic U.S, with up to 90 cm in the southern Appalachian Mountains.

On 7 March 1962, U wind anomalies at 850 hPa and 300 hPa peaked at –5.5 SD (Figure 3) and –4.5 SD (Figure 4), respectively. The –5.5 SD U wind anomaly at 850 hPa, represented easterly winds around 35 m sec^{-1}. The nose of the 850 hPa anomaly area extended through southern New England and the mid-Atlantic states, where the greatest snowfall amounts occurred.

The –4.5 SD U wind anomaly at 300 hPa represented easterly winds at around 30 m sec^{-1}, along the northern periphery of the upper low, suggesting this system was completely cut off from the predominant westerly steering flow. This storm represented one of the longest-duration storms in the entire study.

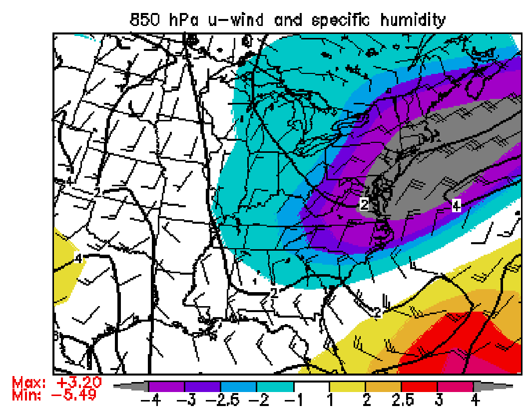

Figure 3. Same as Fig. 1 except 7 March 1962.

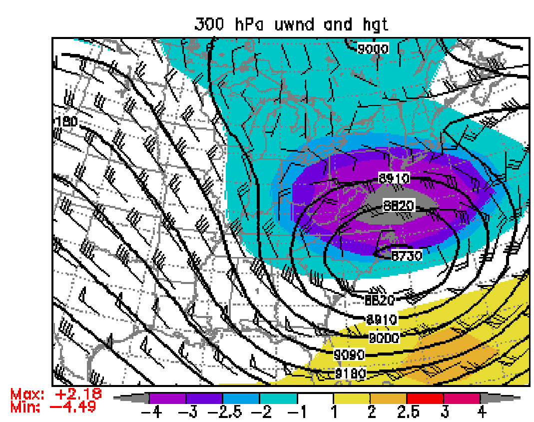

Figure 4. Same as Fig. 2 except 7 March 1962.

5. Case 3: Blizzard of February 1978

On 6-8 February 1978, a severe and prolonged snowstorm affected southeastern New England, producing 90 to 120 cm of snow in parts of Rhode Island and Massachusetts. Boston received over 60 cm of snow, and traffic on the interstate highways was stopped for over 24 hours. Extreme coastal flooding and erosion also occurred, with some homes along the Massachusetts coast being damaged or destroyed.

On 7 February 1978, U wind anomalies at 850 hPa and 300 hPa peaked at –5.4 SD (Figure 5) and –3.9 SD (Figure 6), respectively. Wind directions and wind speeds in this storm, at 850 hPa and 300 hPa, were comparable to the Ash Wednesday Storm of March 1962. Note the area bounded by the nose of the 850 hPa –3 SD anomaly, over much of New England and New York. The heaviest snow amounts occurred over this region.

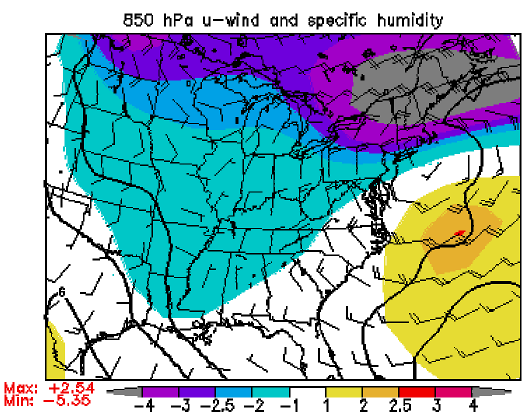

Figure 5. Same as fig. 1 except 7 February 1978.

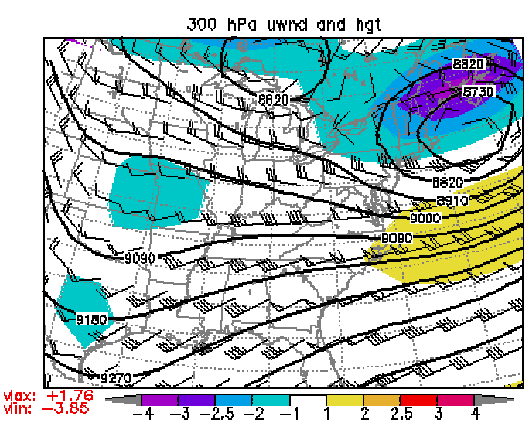

Figure 6. Same as Fig. 2 except 7 February 1978.

6. Case 4: January 2000 "Surprise storm"

On 25 January 2000, a snowstorm affected the entire eastern U.S. from Georgia and the Carolinas, through the mid-Atlantic and northeast U.S. This storm produced 30 to 60 cm of snow over its entire long track through the eastern U.S.

U wind anomalies at 850 hPa and 300 hPa peaked at –4.2 SD (Figure 7) and –3.2 SD (Figure 8), respectively. The area bounded by nose of the 850 hPa –3 SD anomaly is situated over the Carolinas at this time. The storm, and associated anomalies tracked northeast, along the entire U.S. east coast, where historical snowfall amounts were observed.

7. Conclusion

Anomalously strong 850 hPa easterly winds can be correlated with moisture advection off the Atlantic Ocean, low-level convergence, and enhancement of low-level frontogenesis, resulting in increased precipitation production. Below-normal upper wind anomalies signal a disruption of the typical westerly 300 hPa flow that usually contributes to the eastward progression of the storms.

Based on a comparison of wind anomalies for all the historical snowstorms in the reanalysis data set, thresholds for peak lower and upper U wind anomalies are –4 SD and –2 SD, respectively. The historical snowfall amounts typically occur within the nose of the area bounded by the 850 hPa –3 SD contour, and adjacent areas, depending on local effects.

Forecast anomalies that meet or exceed the threshold values for historical snowstorms can alert a forecaster to potentially significant weather that may not otherwise be resolved in NWP guidance and forecasts can be modified accordingly. However, forecasters must be aware that the finer-resolution NWP synoptic-

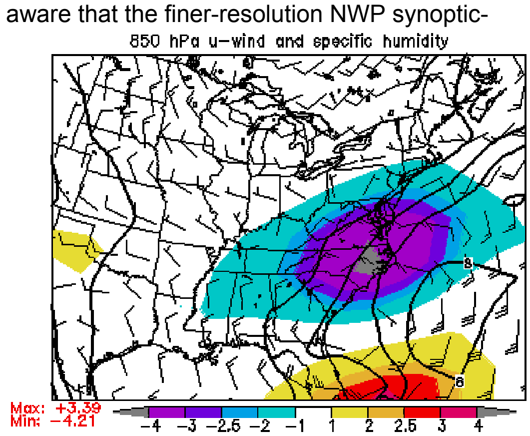

Figure 7. Same as fig. 1 except 25 January 2000.

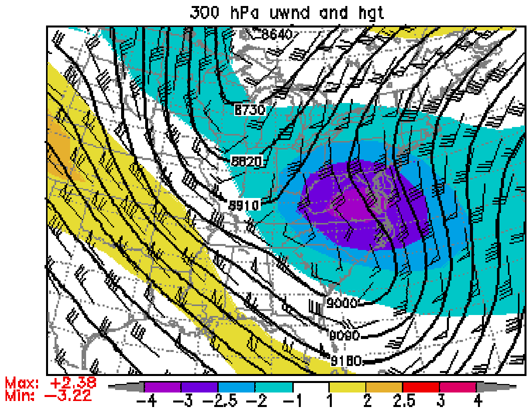

Figure 8. Same as fig. 2, except 25 January 2000.

scale and mesoscale model data produce larger departures from normal, compared to the coarser reanalysis data used to compute the climatological means and standard deviations (Hart and Grumm 2001). Additionally, the value of the forecasted anomalies is only as good as the model output itself. Errors in the forecasted wind fields produce unrepresentative forecast anomalies, and ensembles can dampen out extreme values, resulting in lower anomaly values.

The examination of climatological anomalies from model forecasts may assist forecasters in identifying significant winter storms in the short range (2–3 days) and potentially out to ranges as long as 7 days when applied to ensemble forecast guidance.

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