10.3 MESOSCALE ASPECTS OF THE 2007 ST. PATRICK'S DAY STORM

Michael Fitzsimmons and Todd P. Lericos *
National Weather Service, Caribou, Maine

1. INTRODUCTION

This paper will focus on analyzing the meteorological characteristics of the 17 March 2007 - St. Patrick's Day Storm. The St. Patrick's Day storm was dissimilar from some historical late winter season storms affecting northern New England [e.g. April 1982 and March 1993 (Kocin and Uccellini 2004)]. However, the St. Patrick's Day storm produced qualitative precipitation amounts and snowfall that rival some of the more noteworthy late winter season storms to affect the northeast United States (U.S.).

Storm total snowfall amounts for this event were 20.0 - 35.0 cm in the western mountains of Maine. Liquid precipitation amounts over coastal and central Maine measured 3.8 - 7.6 cm. In addition to precipitation, wind gusts of up to 28.7 m s^{-1} affected coastal areas. The effects of this storm included fallen trees and power lines due to heavy wet snow and wind. In addition, localized flooding due to a combination of excessive rainfall and snow melt also occurred. The 17 March 2007- St. Patrick's Day Storm was a significant, snow, rain and wind event that affected all of northern and eastern Maine.

The primary objective of this case study is to highlight the relationship between synoptic and mesoscale forcing and the heaviest precipitation rates during this storm. Specifically, we will show that the mesoscale forcing was the largest contributor to vertical motion in the region of greatest precipitation rates. Section 2 describes the data used in this case study. In Section 3, we will describe the synoptic scale characteristics of this storm and their evolution. This will be followed by a detailed analysis of the mesoscale forcing mechanisms responsible for producing a significant widespread precipitation event in Section 4. A summary of results along with conclusions will be provided in Section 5 and 6.

2. DATA AND METHODOLOGY

Data used in this study were archived from the operational Advanced Weather Information Processing System (AWIPS). The archived data included observational data (e.g. radar, satellite and surface observations) and operational numerical weather prediction models from the standard National Center for Environment Prediction suite (NCEP). The goal of this study was to investigate the evolution and characteristics synoptic and mesoscale aspects of the St Patrick's Day storm, not to evaluate numerical model guidance performance prior to the event. Therefore, most model data presented here are from the analysis (0 h) or first six hours of the model forecast. The NCEP Rapid Update Cycle model (RUC) was used in most analyses. One noteworthy exception was the analysis of Q-vectors. The NCEP Global Forecast Model (GFS) was used instead since the RUC domain is not large enough to cover the area of interest for this field. In all analyses, great care was taken to be sure that model data matched the observational data and accurately reflected the evolution or characteristics of the parameter being analyzed.

3. SYNOPTIC SCALE FEATURES

A strong arctic cold front moved south from southern Canada through much of the eastern one third of the United States (U.S.) on 16 March 2007. This cold front then became stationary along a line from eastern Nova Scotia to the North Carolina coast, then to the eastern Gulf of Mexico. In the wake of the arctic frontal passage was a surface high pressure center (~1035 hPa) centered over the southern Ontario and Quebec border in Canada.

Upper air analysis at 1500 UTC 17 March reveals a broad trough in the 500-mb geopotential height pattern extending from the upper Midwest to the east coast of the U.S., and a ridge over the Atlantic Ocean just downstream from the trough (Fig. 1a). Confluent flow associated with the upstream ridging over Quebec and eastern Canada is associated with a jet streak over that same area (Fig. 1a,c). A second jet streak was located further south over New Jersey (Fig. 1c). Both jet streaks were associated with two distinct short waves imbedded in the long wave pattern.

Short waves were identified by examining layer Q-vector convergence between 700-mb and 500-mb. The first short wave was associated with the northern stream jet streak and was located just north Maine at 1500 UTC (Fig. 1a). The second shortwave was located further south over the Mid-Atlantic region. The second short wave had particular importance since it initiated cyclogenesis along the baroclinic zone over southern portion of the stalled arctic front that developed into the winter storm described here. This method of surface low development best resembles type-A cyclogenesis classification first described by Miller (1946).

It should be noted that synoptic scale forcing was not as prevalent over Maine as one might expect during the time period of heaviest precipitation rates (~1500-2000 UTC 17 March). In fact, a majority of the area where precipitation rates were largest existed

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* *Corresponding author address*: Todd P. Lericos, National Weather Service, Caribou, ME 04736;
e-mail: todd.lericos@noaa.gov

between the two afore mentioned short waves in an area of very weak synoptic scale forcing. Examination of other vertical levels also reveals weak to moderate synoptic lift (not shown). The lack of synoptic scale forcing during this period will be address further in Section 5.

4. MESOSCALE FEATURES

A thermally direct transverse circulation associated the entrance region of the northern jet streak can be seen in a cross-section oriented over Maine (Fig. 1f). One should note the cross sections in Figure 1e,f were drawn perpendicular to the Maine coast along a line labeled A to A' in Figure 1a. Thermally direct transverse circulations with an upper-level ridge-trough system are known to extend through the depth of the troposphere in strong storms (Uccellini and Kocin 1987). The ageostrophic circulation streamlines here reveal enhancement of the southward transport of low-level cold air between the western mountains of Maine and the coastline in the lower-level of the atmosphere (Fig.1f). The divergence pattern associated with this circulation can be seen in Fig. 1e. Divergence values over +4.0 x 10^{-5} s^{-1} and +8.0 x 10^{-5} s^{-1} (light red and dark red, respectively) and -4.0 x 10^{-5} s^{-1} and -8.0 x 10^{-5} s^{-1} (light blue and dark blue, respectively) outline a typical divergence convergence pattern for upward vertical motion. In addition to the upper-level jet induced circulation, a strong low-level jet (~ 38.5 m s^{-1}) moved into the Gulf of Maine after 1200 UTC (Fig. 1d). The low level jet was enhanced in strength due to the deepening surface low pressure as it moved northward along the coast (Fig 1b). This strong low level jet advected large amounts of tropical moisture and warmer air northward toward the Maine coast. The combination of this northward transport of warm air and southward moving cold air enhanced from the upper-level jet circulation were largely responsible for strong low level frontogenesis along the Maine coastal front.

The cross section in Figure 1e reveals strong coastal frontogenesis through 500-mb as evidenced by both the strong theta-e gradient and 2-D frontogenesis. Plan view and cross sections further illustrate the low-level jet's perpendicular orientation to the surface front resulting in low-level convergence along and inland from the Maine coast (Fig. 1d,e). This strong convergence was further enhanced by diabatic processes from latent heat release (not shown). This mesoscale forcing served to produce intense vertical ascent within the lower and middle troposphere. Figure 1f illustrates the calculated omega field for areas less than –10.0 x 10^{-6} hPa (dark red) and less then -20.0 x 10^{-6} hPa (light red).

It should be noted that both upper and lower-level mesoscale features were collocated over the area of greatest precipitation during this event. This can be seen by comparing the panels in Figure 1b,c,d. The area of heaviest precipitation was likely induced by strong upward vertical motion enhanced in the region of interest by the mesoscale circulations. This is consistent with earlier research found with several other significant winter storms (e.g Uccellini and Kocin 1987).

5. SUMMARY

The 17 March 2007 winter storm had several unique factors. The heaviest precipitation occurred between two distinct short waves lifting through the long wave pattern, which is inconsistent with other similar winter storms where synoptic scale forcing plays a major role in producing precipitation. The forcing that did occur was largely a result of both upper and lower-level mesoscale circulations. The linking of these two mesoscale circulations produced enhanced coastal frontogenesis and strong vertical ascent through the lower and mid troposphere.

It is clear that the mesoscale forcing resulting from the upper and lower-level circulations and their dominance over the synoptic features of the storm, resulted in significant precipitation amounts over a relatively short time frame which made this storm noteworthy.

6 . CONCLUSIONS

The 17 March 2007 St. Patrick's Day Storm was a significant, snow, rain and wind event that affected all of northern and eastern Maine. We have shown that robust precipitation amounts can accompany late season winter storms while the presence of strong mesoscale forcing remains separate from synoptic scale forcing contributions. This case study provides an appreciation for the mesoscale fields available in detecting and enhancing vertical motion in producing a widespread significant precipitation event in the absence of any appreciable synoptic forcing, which is uncharacteristic of most late season winter storms.

REFERENCES

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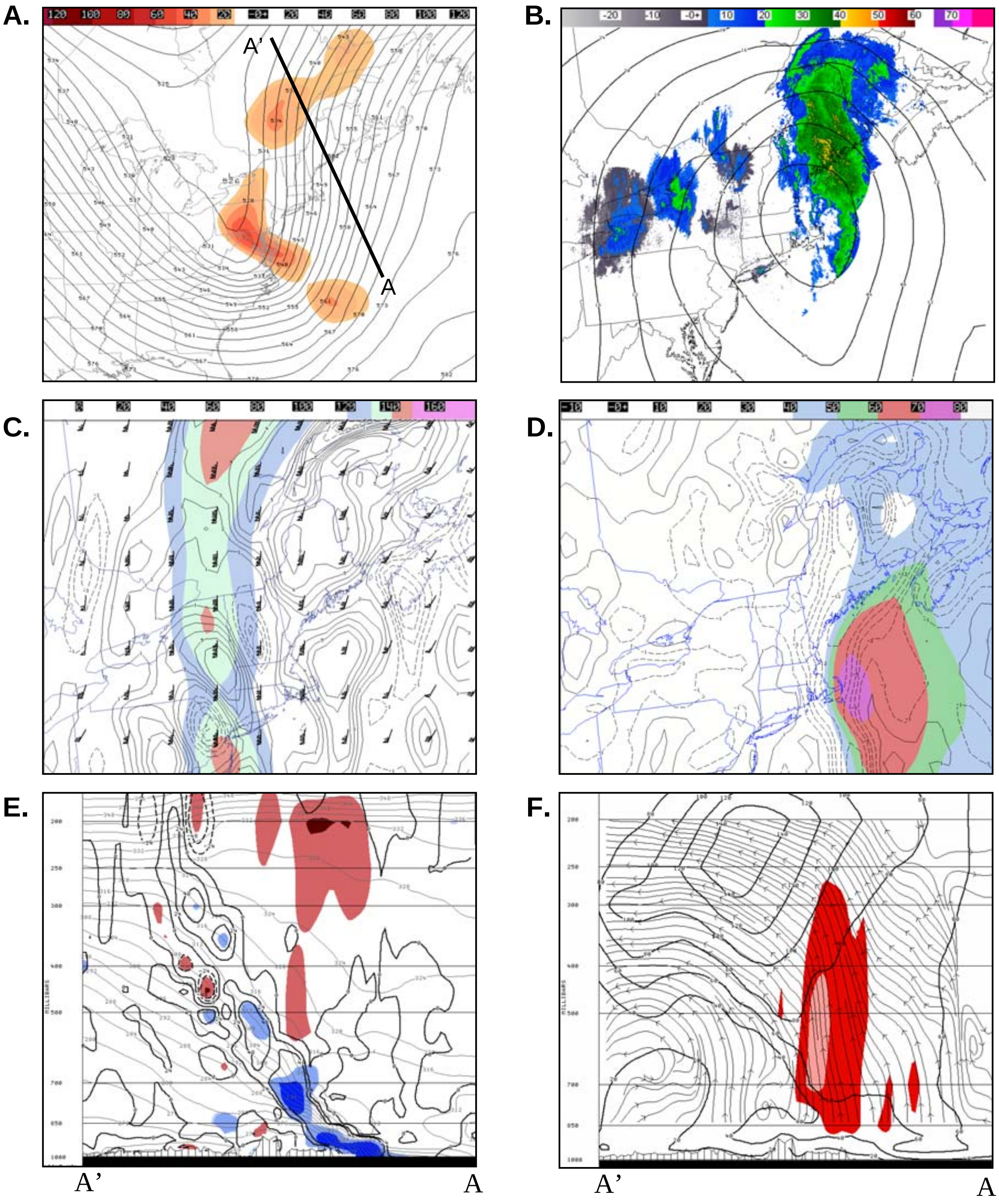

Fig. 1. Synoptic and Mesoscale depiction for 17 March 2007 at 1500 UTC for a) 500 mb geopotential heights (dm, black lines) and 700-500 mb Q-vector divergence (K m^{-2} s^{-16}, shaded as labeled), b) Mean sea level pressure (mb, black lines) and composite radar reflectivity (dBz, shaded as labeled), c) 250 mb isotacts (knots, shaded as labeled) and 250-200 mb Divergence ($x10^{-5}$ s^{-1}), d) 950 mb isotacts (knots, shaded as labeled) and 1000-950 mb Divergence (s^{-5}), e) Cross section of Divergence ($x10^{-5}$ s^{-1}, shaded – see text), Equivalent Potential Temperature (K, light gray contours) and 2-D Frontogenesis (K m^{-2} s^{-10}, black contours), e) Cross section of Omega ($x10^{-6}$ hPa, shaded - see text), Ageostrophic Vertical Circulation (light gray streamlines) and Isotachs (kts, black contours).