The Megalopolitan Snow Storm of 5-7 December 2003

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1. Introduction

The first major winter storm of the winter of 2003-2004 struck the eastern United States on 4-6 December 2003. The storm came on the heels of the first significant cold wave, which moved into the eastern United States on 1 December. The air mass had 850 hPa temperatures on the order of 1-2 standard deviations below normal and above normal surface pressure. The pre-storm environment included a cold dry air mass.

The low-level cold air and the anomalous surface pressure associated with the anticyclone played a significant role in the development of the winter storm. The antecedent cold conditions contributed to the maintenance of snow in the cities in the coastal plain comprising the megalopolitan corridor from Washington, DC to Boston, MA. Early season snowstorms from Washington to New York are not very common and this is one of the largest early season storms to affect the major eastern cities in many years. The more recent 24-26 December 2002 “Christmas Storm” did not produce heavy snow in the Washington and Baltimore areas. The 18-20 December 1995 storm was the last significant snowstorm to produce heavy snow in major cities in the Mid-Atlantic and northeastern United States. The last big and anomalous early December storm, which produced mainly rain in the coastal plain, was the 10-12 December 1992 storm.

This storm shared many of the common characteristics of major winter storms as identified by Kocin and Uccellini (1990) including the cold anticyclone over eastern Canada. The storm was a classic Miller Type B system (Gurka et al 1995) with the primary cyclone remaining west of the Appalachian Mountains and a secondary coastal low development. The latter surface system is often associated with the heavy snows in the northeastern United States.

As shown by Grumm and Hart (2001), with the overall departure from normal of many of the well-documented East Coast snowstorms, surface pressure and height anomalies are typically within a few standard deviations of normal. The more exceptional storms, such as the “Superstorm” of March 1993 (Kocin et al, 1995; Bosart et al. 1996; Dickinson et al 1997) and the East Coast snowstorm of 6-7 January 1996 (Nicosia and Grumm 1999) had significantly larger anomalies associated with them.

The big picture of the snowfall is shown in Figure 1a. These data show the snowfall extended from Illinois to the Atlantic Seaboard and from the mountains of North Carolina to Maine. An extensive area of snow and heavy snow for early December.

The snowfall closed airports or caused flight delays from Washington, Baltimore, and Philadelphia to New York and Boston, stranding thousands of travelers. The storm caused a wide range of travel delays on the highways and railroads from New Jersey to Maine. At least 12 deaths were attributed to the snowstorm.
In Pennsylvania snowfall totals of up to 14 inches were observed, New Jersey received up to 15 inches, on Long Island there were reports of 18 inches of snow and over 20 inches Westchester County, New York. Further south, Philadelphia and Baltimore had 11 and 5 inches respectively. In New York City 16 inches of snow was reported in the Bronx and 13 inches in Central Park. The Central Park snowfall was the largest early December snowfall, but was significantly less than the record 26 inch snowfall of December of 26-27 December 1947. This is the largest 24 hour snowfall event in New York City.

Hardest hit areas included northern New Hampshire, mainly in Coos County where many sites reported over 36 inches of snow and one lone site reported 52 inches of snow (Fig. 1b). Clearly this storm produced a large area of 12 inch or greater snowfall and some impressive maximums in New York and New England.

This paper will examine the conditions associated the 4-6 December 2003 winter storm. The focus is on the conditions and climatic anomalies associated with this early season snowstorm along the megalopolitan corridor of the United States.

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1 New York Times website 7 December 2003. December 1947 was reported by Todd Miner.
between the anticyclone to the north and the surface cyclone to the south.

2. Methods and data

All data were retrieved off websites. Some data was replicated after the fact. The National Centers for Environment Predications (NCEP) output from the Rapid Update Cycle (RUC) data was used to compute most derived model fields and show climatic anomalies.

The climatic data is from the National Climatic Data Centers (NCDC) Global reanalysis data set. The period of record for the 20-day centered mean values of heights, U and V winds, precipitable water (PWAT) and mean sea-level pressure (MSLP) spans 1960 through 1990. The standard deviations were computed from the same dataset (Hart and Grumm 2001).

In all images of standardized anomalies, the departures are shown in standard deviations (SDs) from normal. Thus these are standardized anomalies. Assuming a normal distribution, any value between −1 and +1 SDs from normal should be expected about 66% of the time. Values greater than 2SDs from normal are rare events. Most meteorological data do not follow a standard normal distribution and tend to be slightly skewed. But the normal distribution rules are a close approximation. For more information see Grumm and Hart (2001). A quick overview can found at http://eyewall.met.psu.edu/ranking/ranking.html.

Radar data was retrieved from the NCAR/RAP NEXRAD data archive viewer site. This site allows radar data to be displayed in regional views. In this case, the Mid-Atlantic, eastern Great Lakes, and northeastern United States views were used to follow the progression of the storm.

3. Overview

i) General precipitation shield and snow

The storm produced snow from the Midwest to the east coast. The focus will be on the event along the East Coast. Snow and ice were observed in the mountains of western North Carolina late on the 4th and the precipitation shield moved to the north and east. Snowfall in the 30 cm range was observed in the western suburbs of Washington, DC by the morning of the 5th. The radar image valid at 0000 UTC 5 December shows the precipitation shield over the region. Several east-west bands are present in the image, two of them well to the north in Maryland and northern Virginia. Intense echoes indicating bright banding were observed over the Washington Metropolitan area around 0300 UTC on the 5th. Around 1200 UTC, the precipitation shield was moving northward out of the Washington metropolitan area (Fig. 2).

The precipitation shield continued to move northward spreading snow into the Pennsylvania and New York during on the 5th (Fig. 2). During the early phases of the event, snow and rain extended westward into the Midwestern United States. The precipitation shield continued to move northward with time finally moving into northern New England late on the sixth and seventh (Fig. 4).

iii) Climatic anomalies

One of the more significant climatic anomalies associated with this event was associated with the intense low-level easterly jet (Fig. 5). The low-level jet’s
(LLJ) origin began on the 5th with a northern stream short wave (Fig. 6) and its attendant surface (Fig. 7) and 850 hPa cyclone (not shown).

A LLJ was present over Illinois and Wisconsin and another LLJ on the cold side of the low-level boundary in the Carolinas early on the 5th. As the wave along the baroclinic zone developed and moved northward, in response to the upper level short wave (Fig. 6a), the two LLJ’s intensified and began to merge. This led to the elongated double structured LLJ as depicted by the RUC analysis at 1700 UTC 5 December 2003. North of the 850 hPa low in Indiana, the easterly jet was –3.5 to –4SDs below normal. At the surface, the primary surface cyclone was over western Ohio and a well-established surface cyclone was present off the coast of Virginia.

The LLJ ahead of the secondary wave was of equal magnitude across southern New Jersey, the Delmarva, Maryland, and northern Virginia by 1700 UTC on the 5th. Radar imagery showed a snow band over southern Michigan at this time and another band of snow and sleet associated with the eastern LLJ. There were some strong bands, with bright banding, east of the 850 hPa and surface lows in Ohio.

The surface situation on the 5th (Fig. 7a and 7b) captured the evolution of the Miller Type B cyclone with the secondary low becoming stronger as the primary low weakens west of the Appalachian mountains. This transition often leads to enhanced snow bands in the deformation zone between the two systems. As shown in Figure 7c, by 0600 UTC 6 December there was a strong surface cyclone off the New Jersey coast and no hint of the primary cyclone to the west. The central pressure of the cyclone along the coast was about 1SD below normal.

By 0600 UTC 6 December 2003, at 850 hPa there was still a hint of the remnants of the primary low over West Virginia, west of the now more pronounced secondary low. The strongest LLJ was focused north and west of the secondary low from Long Island to southeastern Pennsylvania. The jet was on the order of –4 to –4.5SDs below normal at 0600 UTC 6 December 2003.

The 0600 UTC radar image showed a broad band of snow from central Pennsylvania across New York and into New England (Fig. 2c). This band grew from the bands that moved northward head of the developing low as shown by the precipitation bands at 2155 UTC 5 December 2003. The band south of Long Island moved over Long Island and into Connecticut with time. The enhanced band in central Pennsylvania pivoted from east-west to more southwest to northeast leading to the heavy snow area in central Pennsylvania overnight 5 December (Friday) into early 6 December (Saturday).

By 1800 UTC on the 6th, the surface and 850 hPa lows had moved north and the LLJ was more northeast to southwest but still had a very anomalous U-wind component (Fig. 3C). The surface pressure anomaly was on the order of –2SDs below normal. Similar to the Christmas 2002 storm, a north south snow band developed west of the surface cyclone and moved eastward with the system (Fig. 3a). This band produced additionally snow over southern New York, eastern New Jersey, Connecticut, and Long Island. The high snowfall amounts on Long Island and blizzard like conditions in southern New England were associated with this band. This second band behind the low
also contributed to the two-punch emphasis the media gave this storm system.

As the storm system lifted to the north and east, heavy snow bands moved into Maine. A large east-west band moved northward through Maine. Figure 3b shows the band across central Maine at 0600 UTC 7 December 2003. The surface pressure reached its lowest values and largest anomalies off the coast of Cape Cod (Fig. 7d)

j) Conclusions

The first major winter storm to strike the eastern United States produced heavy snow from Washington to Boston. Extremely heavy snows, in excess of 30 inches, were reported in New York State, New Hampshire, and Maine. Coos County, New Hampshire appeared to have snowfall in the 36 to 52 inch range for the event. The anomalous low-level jet clearly played a significant role in the heavy snow areas.

A strong upper level short wave, and attendant cyclone, interacted with a preexisting baroclinic zone along the coast. This produced a classic Miller Type B storm system. The secondary surface cyclone redevelopment along the coast caused this storm to be reported as a two-system event. Aloft, there was one significant upper level wave. The snow bands ahead of the developing low to the south and the wrap around bands when the cyclone matured contributed to the two-system theory. The snowfall maps and the low-level easterly wind anomalies clearly show how the interaction of the anticyclone to the north and the cyclones led to an elongated east-west snow area. This area extended from Illinois to the Atlantic coast.

This MTOTAL and anomalies by value are shown in Figure 8. These data showed that the MTOTAL, as analyzed by the fine scale Eta was on the order of 3.4. However the U-wind anomalies were on the order of 4.4 on the 6th and 7th of December. The overall values fall within the range associated with major East Coast snow storms. What set this storm apart from many storms was the anomalously strong low-level easterly jet. The strong low-level easterly is a common feature in the major eastern United States heavy rain and heavy snow storms. The extraordinarily strong 850 hPa jet with this storm likely was a significant factor in the area of heavy snow and some of the near historic snowfall maximums.

The area of heavy snow in central Pennsylvania was where the band that developed west of the secondary low pivoted form east west to north south. The snow rapidly diminished in Ohio and Michigan as the secondary low developed to the east. Central Pennsylvania was in the favorable deformation area between the primary and secondary low centers.

New bands developed ahead of the deepening coastal cyclone spreading snow farther northward into New England. These bands developed in the favorable strong low-level east-northeasterly flow associated with the intense baroclinic zone.

As the cyclone matured, well-developed north-south bands developed west of the surface cyclone. These bands gave additional snow and upped the storm total snowfall significantly in southern New York, northern New Jersey, Connecticut and Long Island.

k) Acknowledgements
John LaCorte, National Weather Service Office, State College provided the snowfall maps. The NCAR/RAP NEXRAD data archive viewer maintained by Peter P. Neilley.

l) References


Figure 2 NEXRAD reflectivity over the Mid-Atlantic Region valid at a) 0000 UTC and b) 1155 UTC 5 December 2003.
Figure 3 Composite radar images valid at a) 1700 UTC 05 December 2003, b) 2155 UTC 05 December 2003, and c) 0600 UTC 6 December 2003.
Figure 4 Composite radar imagery over the northeastern US valid at a) 1755 UTC 06 December 2003 and b) 0600 UTC 07 December 2003.
Figure 5 Rapid update cycle analysis of 850 hPa heights, winds, and U-wind anomalies valid at a) 1200 UTC 5 December, b) 0600 UTC 6 December and c) 1800 UTC 6 December 2003.
Figure 6 RUC 500 hPa analysis and anomalies valid at a) 1700 UTC 5 December and b) 1800 UTC 6 December 2003.
Figure 7 RUC surface analysis and anomalies valid clockwise from upper left a) 1700 UTC 5 December, b) 1900 UTC 5 December, c) 0600 UTC 6 December and d) 0600 UTC 7 December 2003.
Figure 8 Eta verifying and forecast anomalies from 06 and 07 December 2003.