WFO Taunton Storm Series Report
#2007-1
The “Patriot’s Day” Coastal Storm of
April 15 – 17, 2007

Coastal Flood Damage in Salisbury, MA
(Nicole Belk, WFO Taunton Photo)

Foreword

The objective of the National Weather Service Forecast Office (WFO) Taunton Storm Report Series is to provide a concise summary of a significant meteorological event that impacted the WFO Taunton County Warning Area (CWA). The WFO Taunton CWA includes all of Massachusetts except for Berkshire County; all of Rhode Island; Cheshire and Hillsborough Counties in southwest New Hampshire; and Hartford, Tolland and Windham Counties in northern Connecticut.

Use of the series is intended for training and WFO Taunton historical documentation only. Official storm reports can be found in Storm Data, published by the National Oceanic and Atmospheric Administration, National Climatic Data Center.

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Taunton, MA
August, 2007

1. Introduction

An unusually strong and slow moving coastal storm for mid April tracked to western Long Island Sound on Monday, April 16th before weakening slowly and drifting offshore by Wednesday, April 18th. This storm brought a variety of impacts in southern New England, including heavy snow to the higher elevations of western Massachusetts and southwest New Hampshire, damaging winds in excess of 60 mph, widespread river and stream flooding, and significant coastal flooding through several high tide cycles.

Numerical Weather Prediction models (NWP) performed well and allowed forecasters to identify the potential for a significant coastal storm as much as 3 days in advance. Watches and warnings provided adequate lead time for each type of hazard.

WFO Taunton products and services were excellent throughout the event, highlighting the potential several days before, and then correctly predicting the significant impact of the river flooding, high winds, and coastal flooding. Conference calls with state and federal officials were deemed to be extremely useful, and reduced the phone workload on the operational staff.

2. Synoptic Overview and Performance of NCEP Model Guidance

Forecasters were alerted to the potential for a significant and highly anomalous East Coast storm several days in advance by the Global Ensemble Forecast System (GEFS). Grumm (2007) outlined the performance of GEFS leading up to this event, noting that while the forecast of a deep cyclone was correct, track and intensity forecast errors were significant enough as to have a great effect on sensible weather elements.

Initially, the heaviest rains were forecast to remain offshore. Only when the low track shifted westward did the heavy

rain forecast become more focused along the coastal plain from New York City to Boston. Strong southerly winds and high precipitable water values also reinforced the concept of heavy rainfall. Similarly, the models correctly forecast the strong low level winds which indicated the potential for high winds near the coast. Forecasters also recognized the potential for significant coastal flooding over several high tide cycles, due to the combination of persistent onshore winds and high astronomical tides that week.

As the event approached, short range model guidance was split into two camps – one which took the deepening low into southern New Hampshire (GFS) and the other which took the low into coastal Connecticut (NAM), before slowly filling the storm and taking it offshore. While it is not unusual to see these differences persist in the shorter ranges with such an anomalous system, the use of Short Range Ensemble Forecast (SREF) data added more weight to the latter camp, which turned out to be correct.

Figures 1 through 4 show the evolution of features at 500 mb and at the surface. A strong upper ridge was present over the central portion of the country, while a negatively-tilted trough closed off south of Long Island. At the surface, a 983 mb low east of the Delmarva deepened rapidly to 969 mb as it tracked south of Long Island, and became captured by the upper low.

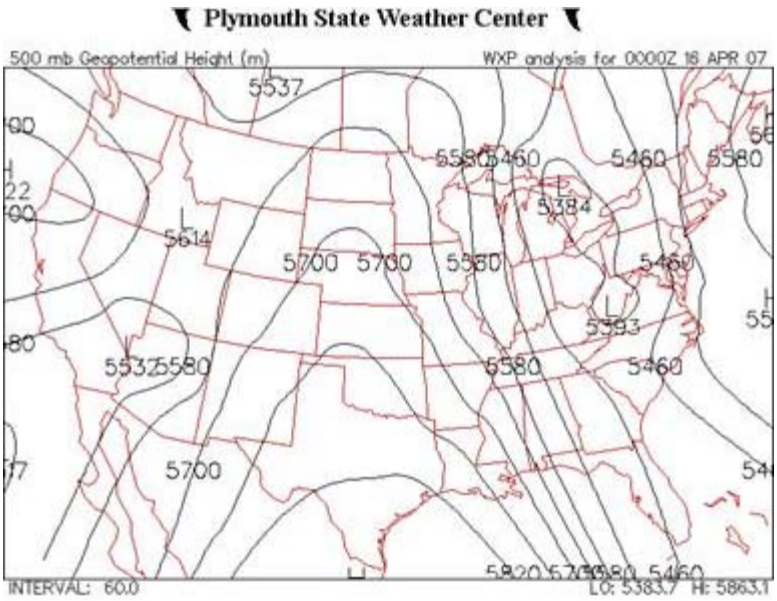

Figure 1. 500 mb analysis valid 00z April 16, 2007

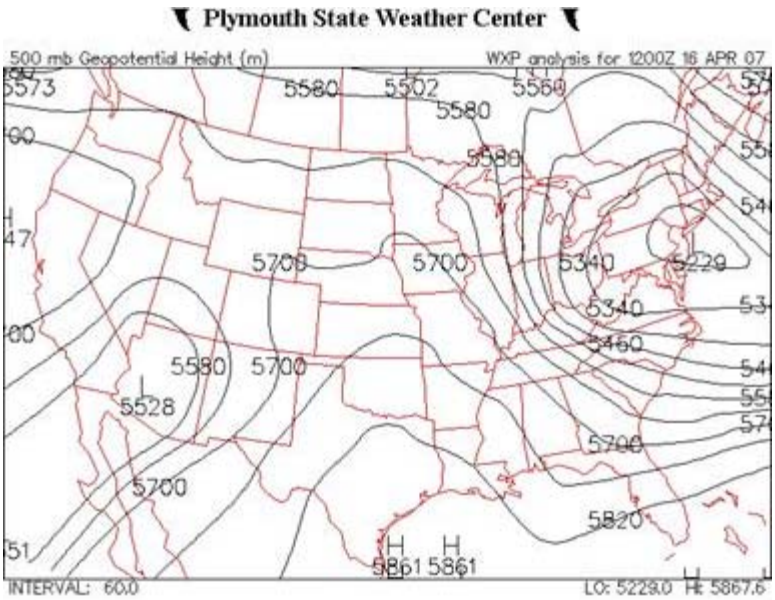

Figure 2. 500 mb analysis valid 12z April 16, 2007

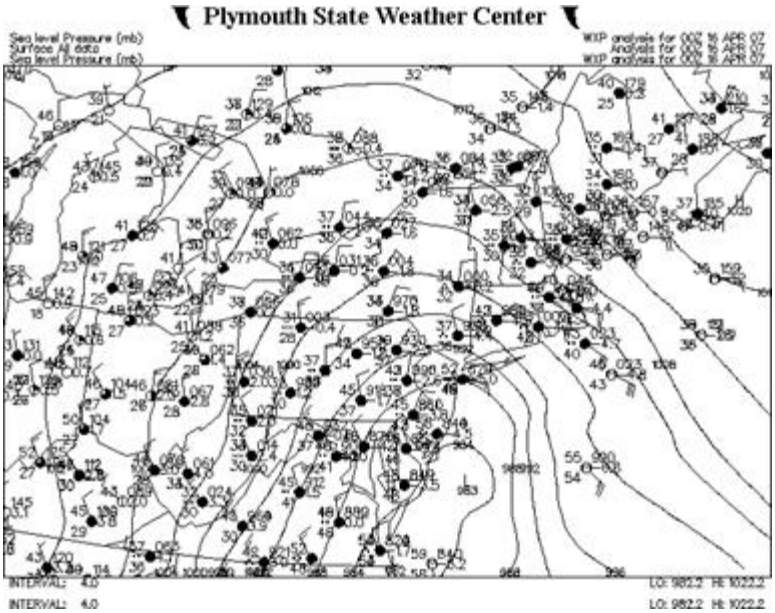

Figure 3. Surface analysis valid 00z April 16, 2007

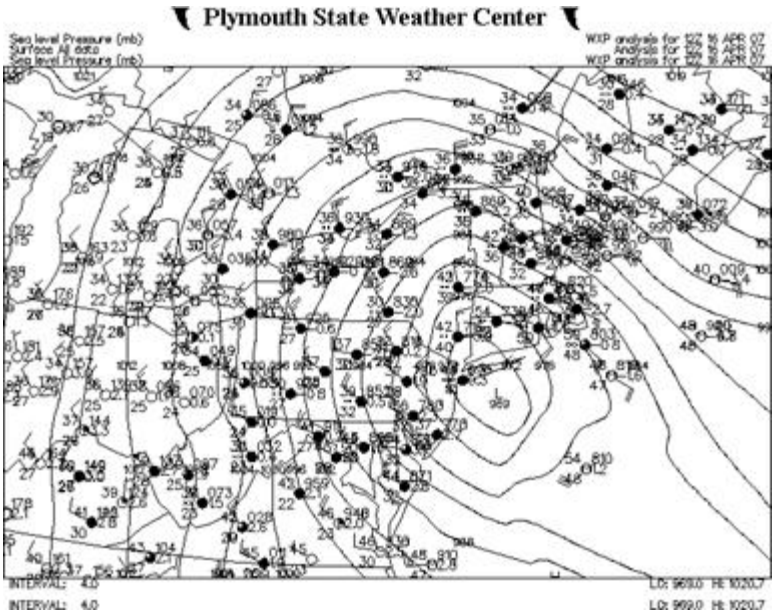

Figure 4. Surface analysis valid 12z April 16, 2007

3. Storm Impacts

a. Interior Snowfall

Accumulating wet snow was the first impact from this powerful storm across the higher terrain of western Massachusetts and southwest New Hampshire. The precipitation began mainly as rain during the morning of April 15th, before changing to heavy wet snow from the late morning into the afternoon. The heavy wet snow changed to back to heavy rain from south to north during the late afternoon and early evening hours.

Snowfall totals ranged from 3 to 7 inches at elevations over 1000 feet in Franklin, Hampshire, and Hampden Counties in Massachusetts as well as Cheshire and Hillsborough Counties in southern New Hampshire (Figure 5). There were numerous reports of downed trees and power lines in these areas from the weight of the heavy, wet snow. Although many locations received less than 6 inches of snow, warning criteria was met because of the significant impact. Across the lower elevations of these counties, accumulations were mainly between 1 and 3 inches. A few slushy inches of wet

snow were also reported in northern Worcester and northwest Middlesex Counties in Massachusetts.

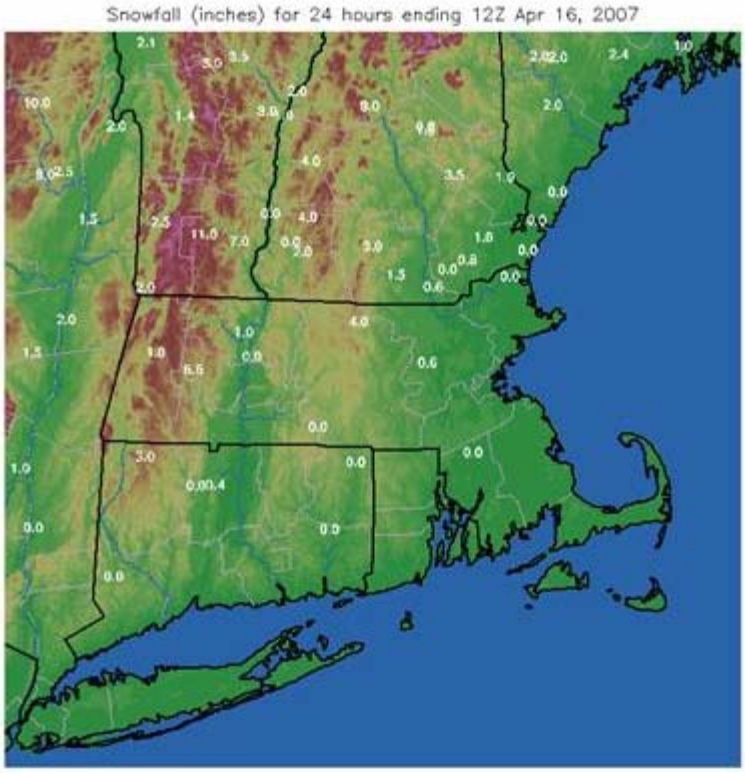

Figure 5. Observed 24 hour snowfall, ending 12z April 16, 2007

NCEP model guidance did an excellent job in advertising the potential for a period of accumulating heavy wet snow across the higher terrain of far western Massachusetts and southern New Hampshire. In response to this, a Winter Storm Watch was issued over 24 hours in advance. Forecasters specifically mentioned the potential for heavy wet snow to bring down tree limbs and cause power outages. The Watch was later converted to a Winter Weather Advisory, and forecasters continued to mention the potential for up to 6 inches of wet snow with the potential for downed tree limbs and power outages at higher elevations.

During the morning of Sunday, April 15th, a 993 mb low over western North Carolina was in the process of rapidly intensifying and moving slowly northeastward. Weak cold air damming was evident over southern New England, indicated by the bagginess of the surface pressure fields (Figure 6).

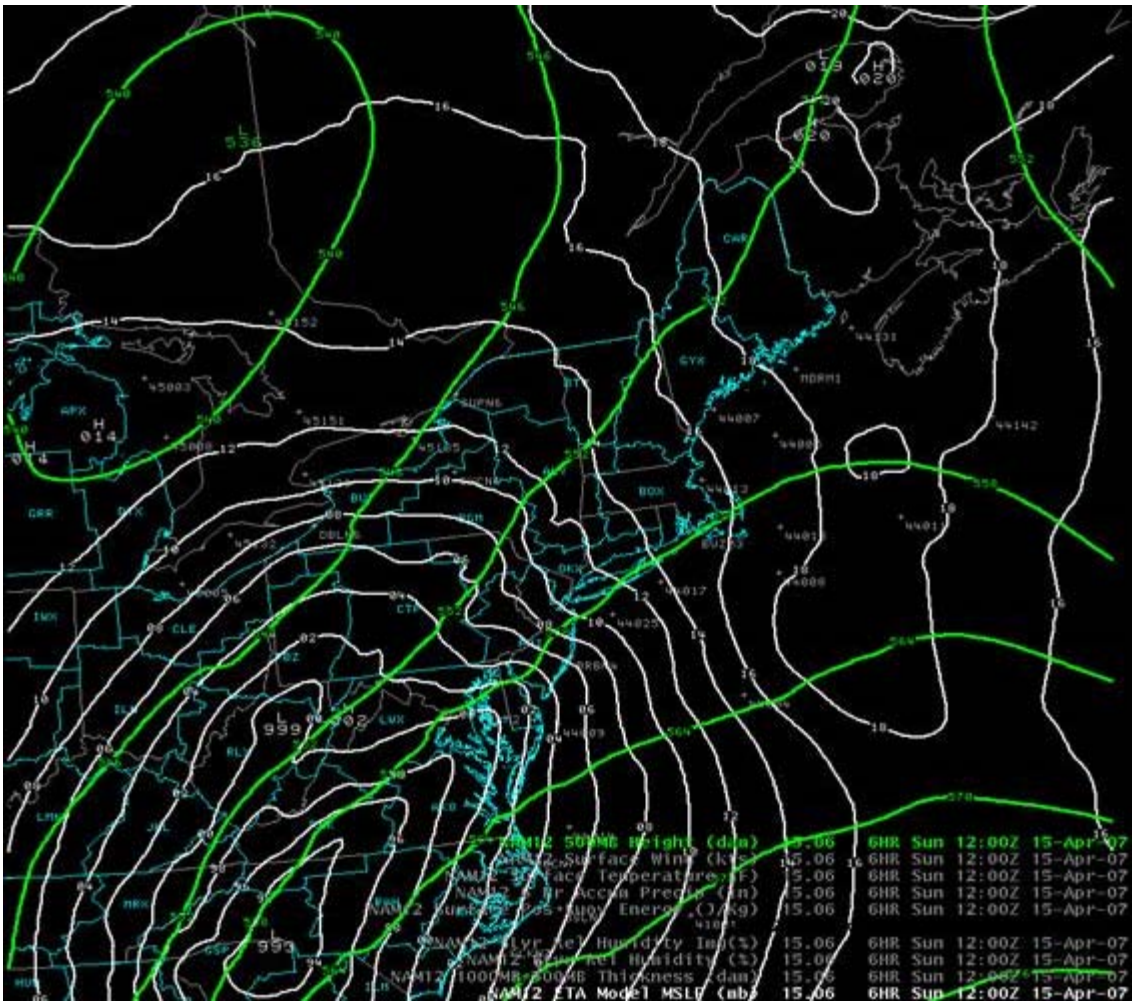

Figure 6. 6 hour NAM forecast of MSLP (white) and 500 mb height (green) valid 12z April 15th.

Strong mid level lift developed across the region, in response to southwest flow aloft and the intensifying surface low pressure system. The GFS predicted over 20 microbars per second of lift at 700 mb across southern New England by 18z Sunday (Figure 7). In addition, the model showed QPF of 0.50 to 1.00 inch in just a 6 hour period from 12z to 18z. All of this indicated the potential for heavy precipitation, resulting in dynamic cooling. As it turned out, the dynamic cooling was the key to this winter weather event, since most locations initially had temperatures above freezing and began as rain.

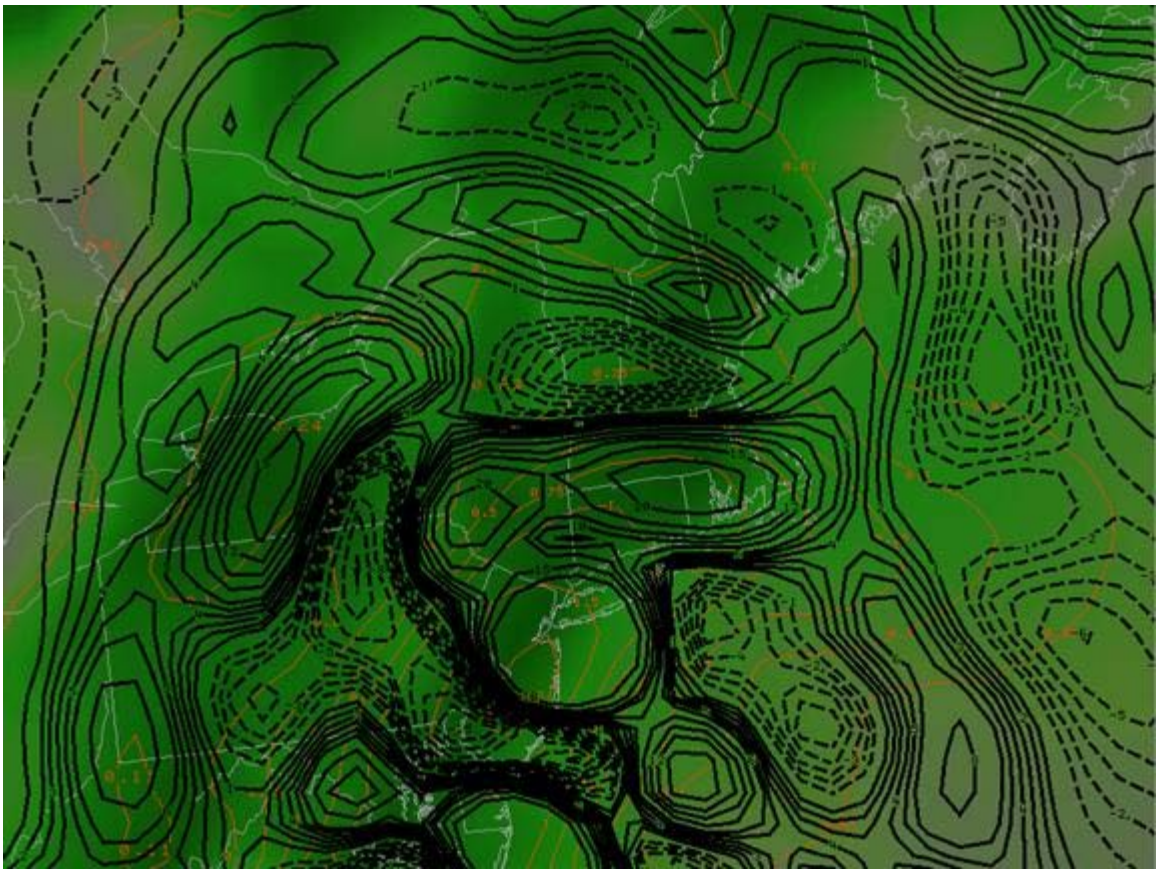

Figure 7. GFS 700 mb omega (black), past 6 hour QPF (red), and 850-700 mb RH (image) valid at 18z Sunday, April 15th. Note the strong omega in excess of 20 microbars per second.

The NAM forecast sounding at Orange, MA showed an area of above freezing air from the surface to around 2500 feet at 09z that morning (Figure 8).

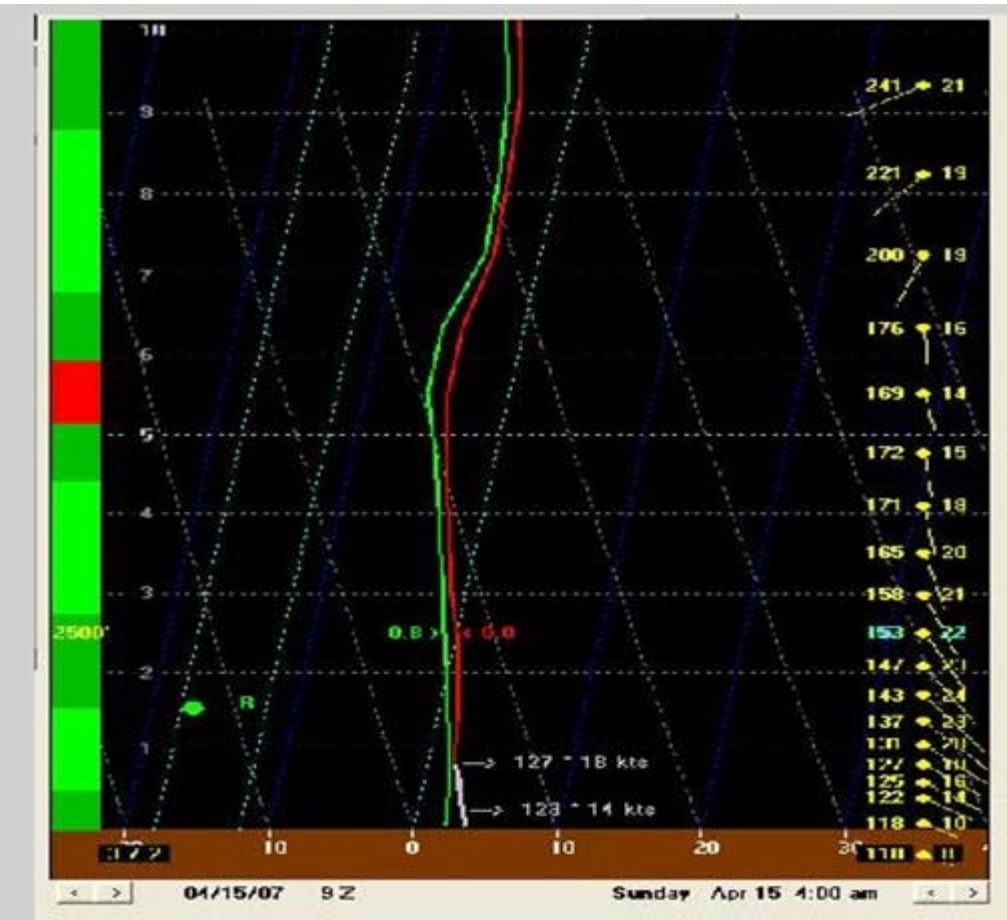

Figure 8. NAM forecast sounding valid at 09z on April 15th for Orange, MA.

Forecast soundings revealed that once above 2500 feet in elevation, temperatures were below freezing throughout the rest of the atmosphere. Forecasters needed to consider if the lowest levels would cool enough to result in a period of heavy wet snow. NAM forecasts depicted this scenario quite well in its highly detailed 2 meter temperature field. In Figures 9 and 10, respectfully, note how 2 meter temperatures were forecast to cool considerably between 09z and 18z on the 15th. This was the result of the model showing tremendous lift resulting in dynamic cooling. Also, note how the higher resolution of the NAM was able to show the coldest readings across the higher terrain of western Massachusetts and southern New Hampshire, which turned out to be where the heaviest snow fell. In addition, the forecast cross section at Orange, MA from the NAM (Figure 11) showed the strongest lift was expected to reside in the maximum dendritic snow growth region of -12C to -18C between 17z and 22z.

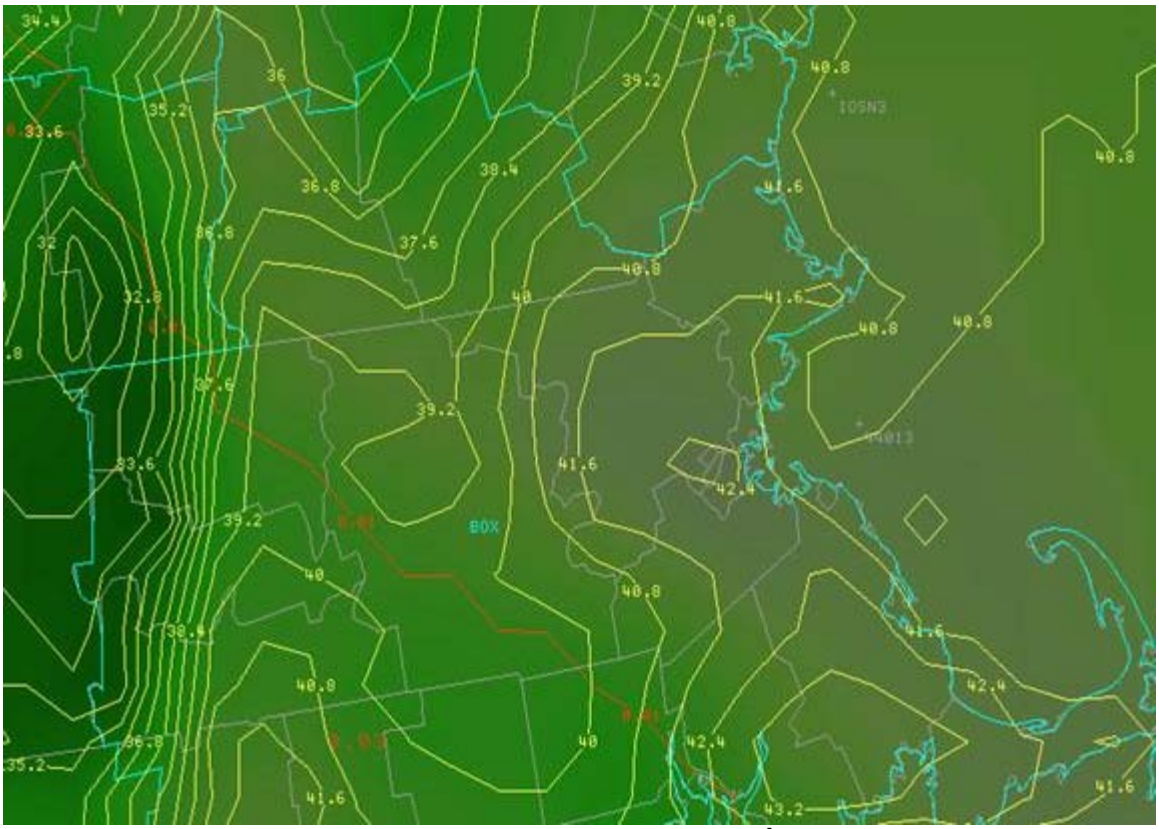

Figure 9. NAM 2M temperature forecast (yellow) valid 09z April 15th.

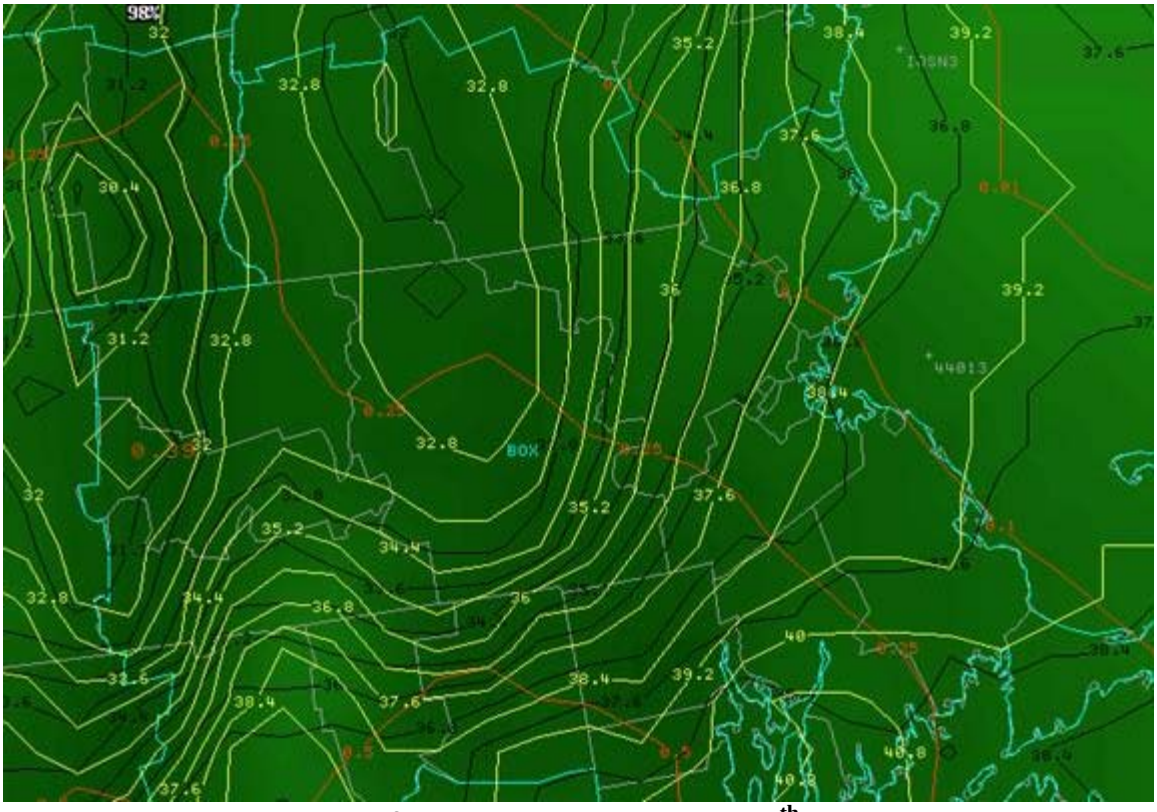

Figure 10. NAM 2M temperature forecast (yellow) valid 09z April 15th.

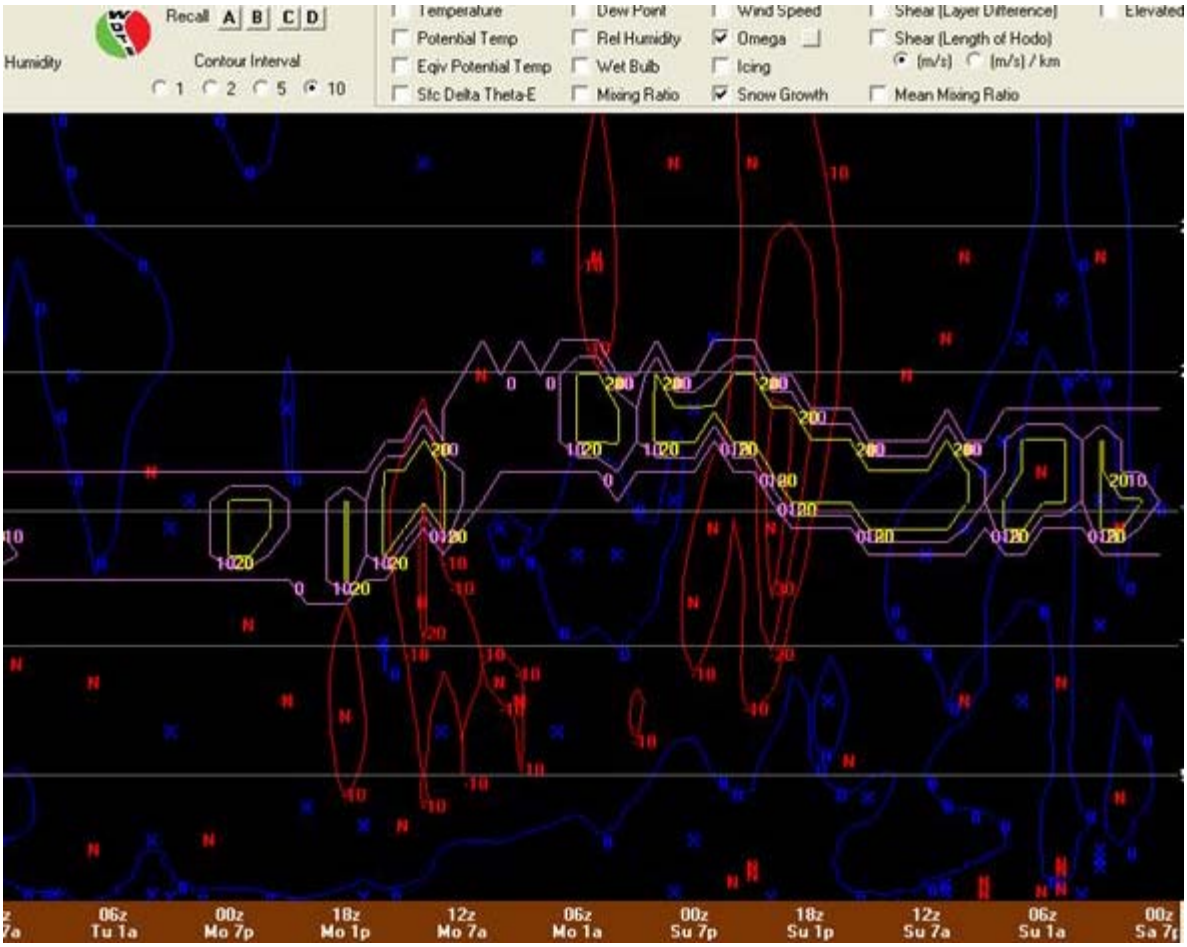

Figure 11. NAM cross section at Orange, MA showing strongest lift (red) in the maximum dendritic snow growth region (yellow) from 17z to 22z on April 15th.

By 18z on April 15th, dynamic cooling had reduced the warm layer to below 1000 feet. NAM forecast soundings for Orange, MA indicated only the lowest 600 feet of the atmosphere was expected to be just above freezing (Figure 12). This was cold enough to allow snow to reach down into the valleys. The heaviest snow and most significant problems occurred above 1000 feet, where snow fell for a longer period of time and temperatures were a few degrees colder.

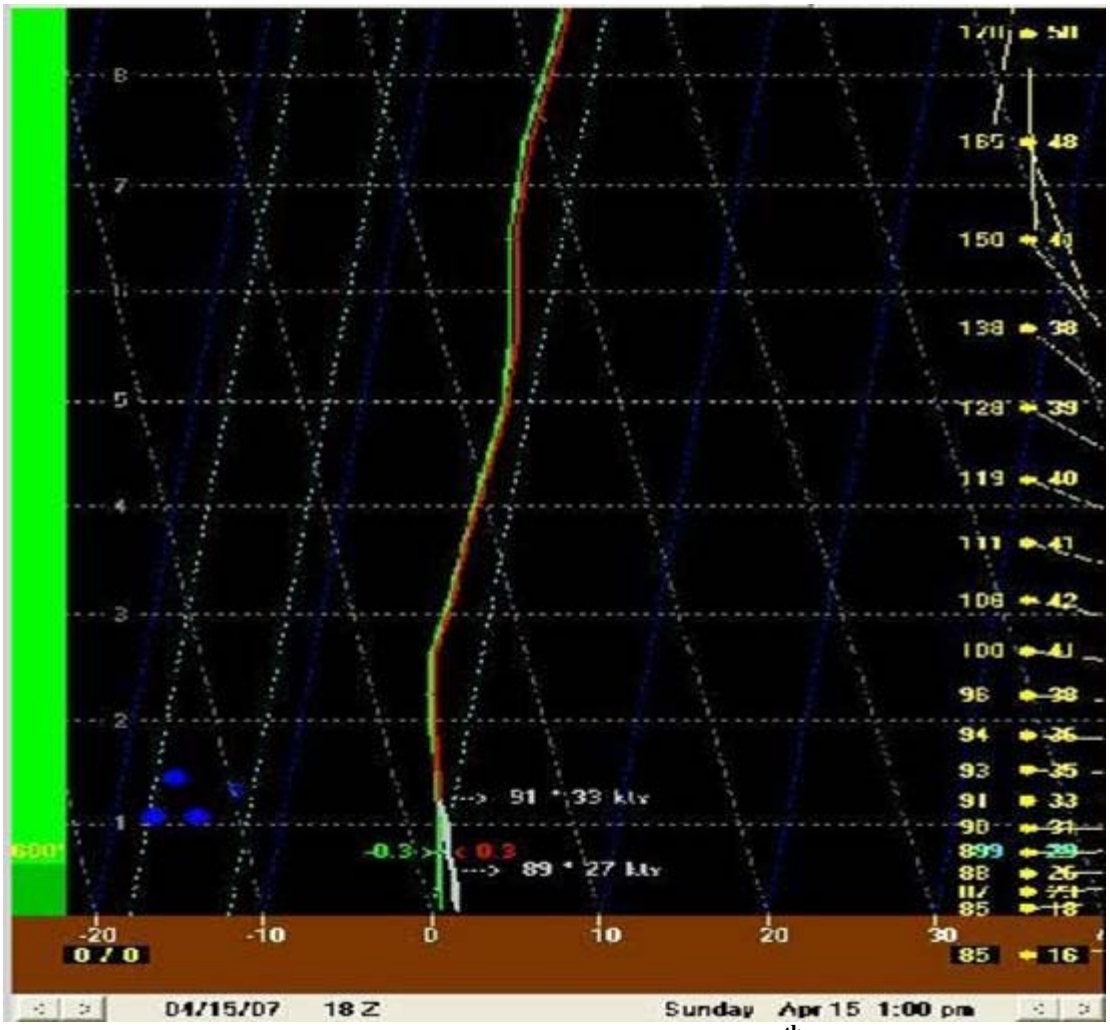

Figure 12. NAM forecast sounding for Orange, MA valid 18z April 15th. Freezing level dropped to 600 feet.

Another way to depict dynamic cooling was to look at NAM temperature and wind fields at 925 mb (Figures 13 and 14). Temperatures were forecast to cool several degrees between 09z and 18z Sunday, despite winds strengthening markedly from the southeast during that time. Normally, southeast winds bring in much warmer air, and that did eventually happen that night. However, 925 mb temperatures initially cooled despite increasing southeast winds, due to dynamic cooling.

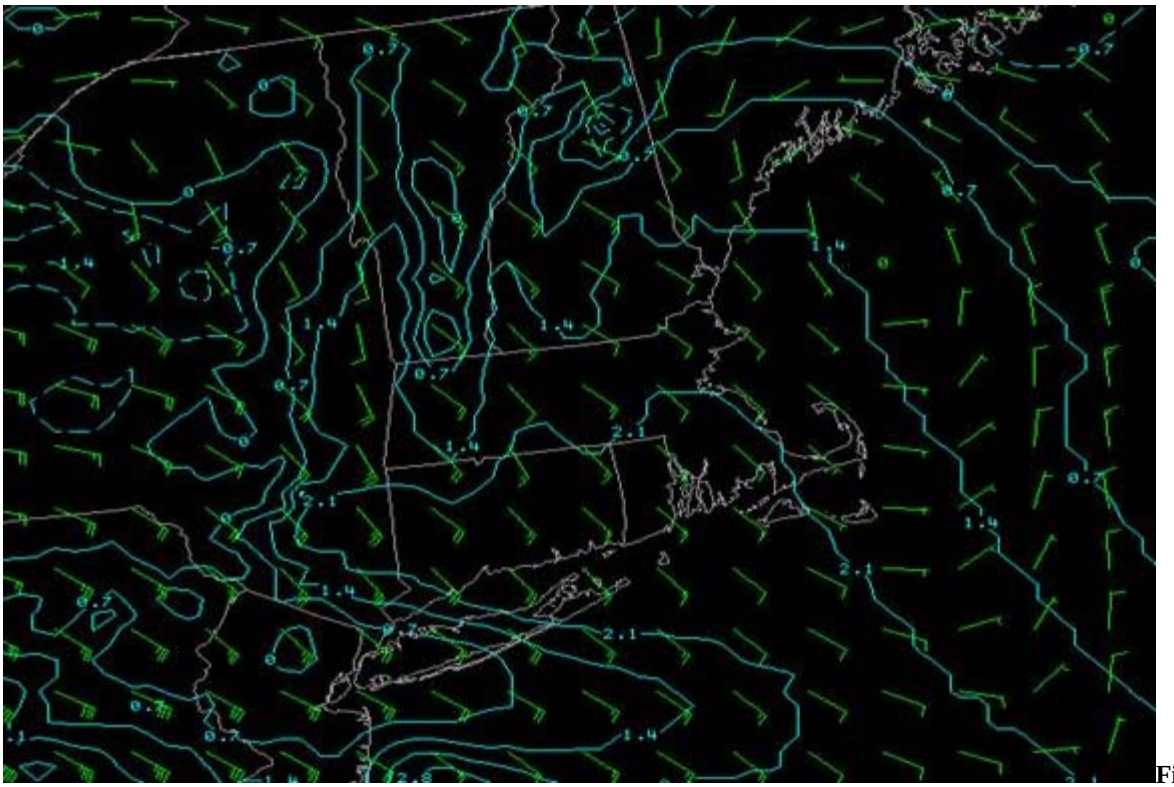

Figure 13. NAM forecast 925 mb temperature and wind, valid 09z April 15th . Note that temperatures are above freezing.

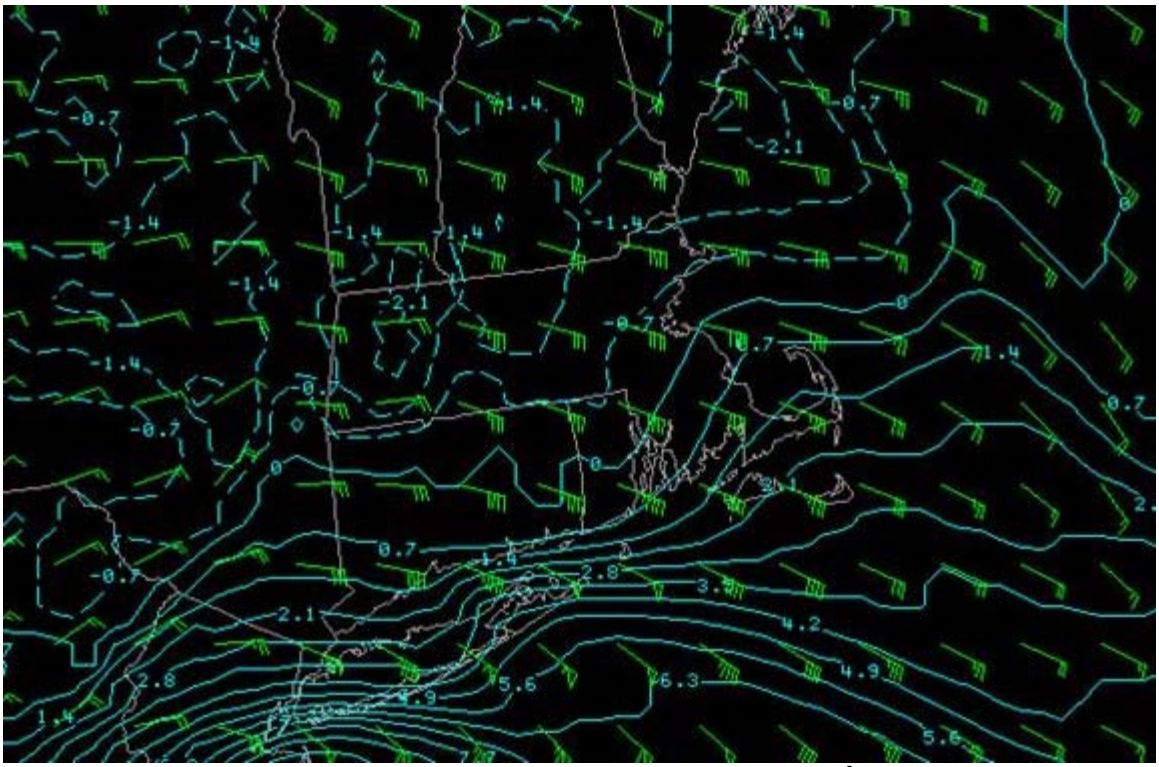

Figure 14. NAM forecast 925 mb temperature and wind, valid 18z April 15th . Note that temperatures have cooled below freezing across the region, despite increasing southeast winds.

As the low pressure system continued to intensify and tracked closer to southern New England, warmer air at mid levels and at the surface began to offset dynamic cooling (Figure 15). Wet snow across the higher elevations changed back to rain from south to north during the late afternoon. All the precipitation changed to rain by 00z Monday, and the attention then turned to high winds as well as river and coastal flooding.

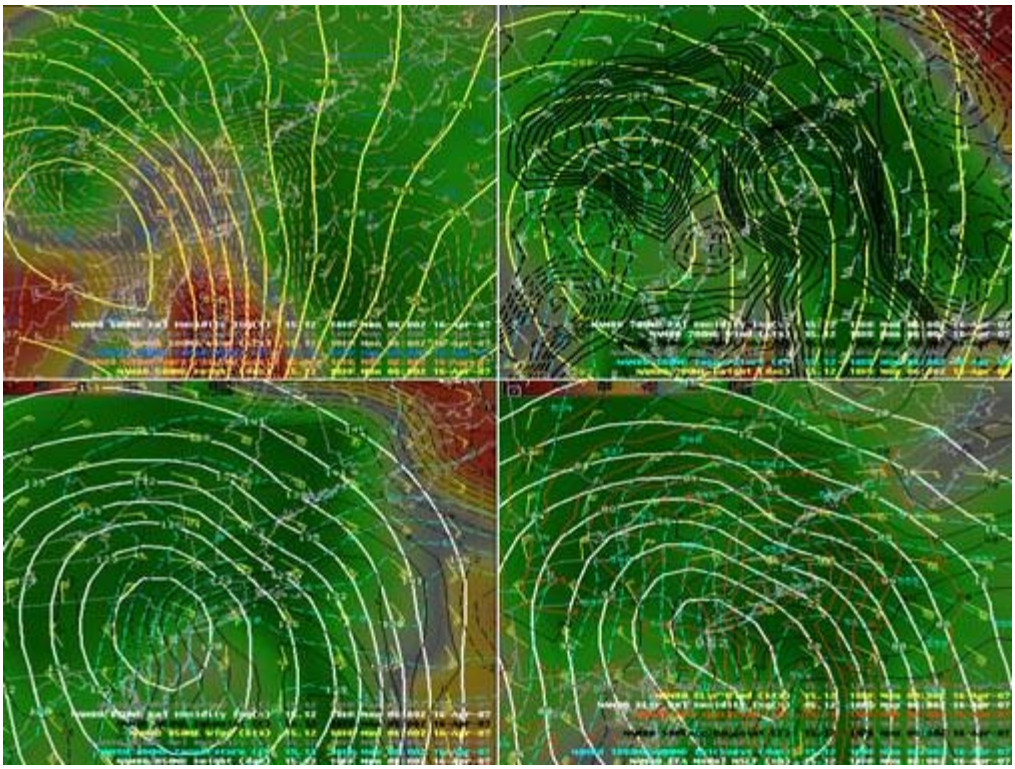

Figure 15. NAM forecast 4 Panel of 500 mb (top left), 700 mb (top right), 850 mb (bottom left), and boundary layer (bottom right) valid at 06z Monday April 16th. Mid level temperatures warmed well above freezing as the 700 mb and 850 mb low centers passed well to the west of New England.

b. High Winds

East to northeast winds gusted as high as 50 to 60 mph in eastern Massachusetts and Rhode Island Monday night into Tuesday morning. The highest gusts reported were in eastern Massachusetts and included 72 mph at the Blue Hill Observatory in Milton, 67 mph in East Falmouth, 64 mph on Nantucket, and 63 mph in Plymouth. There were widespread reports of downed trees, large branches, and power lines, especially in southern Rhode Island and eastern Massachusetts – as far inland as Providence, Taunton, Framingham, and Topsfield. Several roads were blocked by fallen trees in southeast Massachusetts. Wind damage was more sporadic across northern Connecticut and adjacent portions of western and central Massachusetts.

c. Heavy Rainfall and Flooding

Rainfall totals of 3 to 5 inches, combined with wet antecedent conditions, resulted in widespread river and stream flooding, as well as significant flooding of urban areas (Figure 16). The worst flooding affected the Merrimack Valley, where moderate to major flooding occurred on the Merrimack, Nashua, North Nashua, Piscataquog, and Souhegan Rivers. For many locations, this may have been the worst flooding since the May, 2006 or April, 1987 floods – but along the North Nashua, Piscataquog and Souhegan Rivers the preliminary crests recorded may have been the highest since the floods of September, 1938. Selected hydrographs are shown in Figure 17.

Many small streams throughout the region also rose out of their banks and flooded nearby areas, including roadways. Major flooding occurred along the Mill River in Northampton, Massachusetts which required the evacuation of nearby residents. Significant flooding also occurred along small streams in Hillsborough County New Hampshire, where a portion of Route 122 was closed in Hollis and a mudslide closed Route 101 in Wilton.

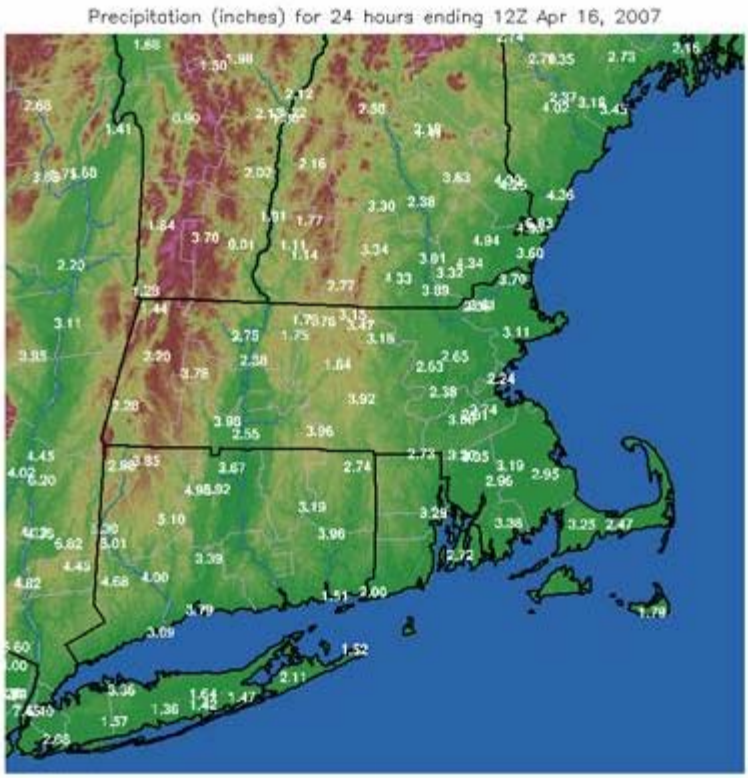

Figure 16. Observed 24 hour precipitation, ending 12z April 16, 2007

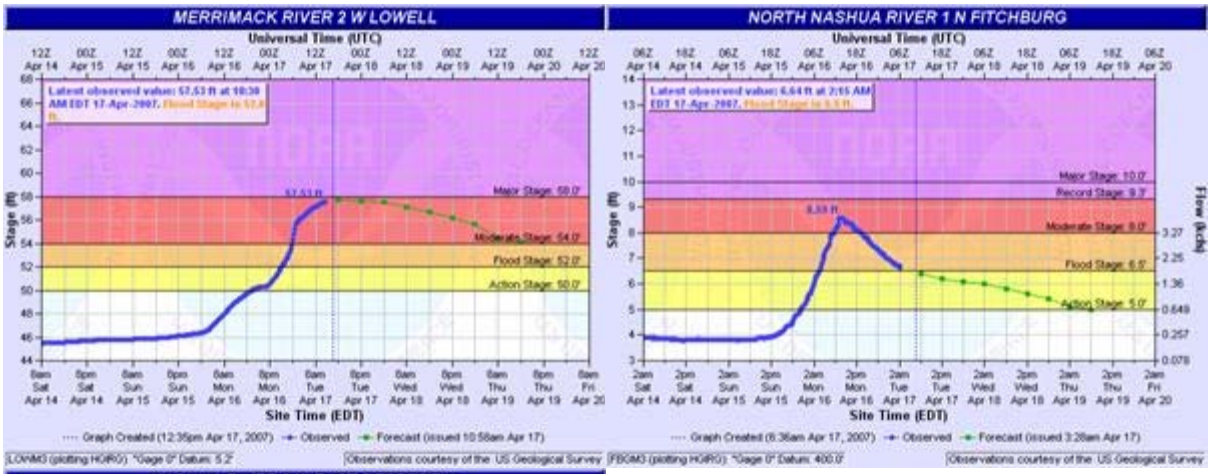

Figure 17. Selected hydrographs for some of the locations with significant flooding

d. Coastal Flooding

Minor to moderate coastal flooding occurred along the coastline of Rhode Island and Massachusetts through several high tide cycles, due to the combination of strong onshore winds, high seas, and astronomically high tides.

Along the South Coast, the worst coastal flooding occurred with the Monday morning high tide, where flood waters and debris closed several shore roads. Along the Rhode Island south coast, large boulders that washed ashore had to be removed with snow plows, according to media reports. Figure 18 shows the observed tides at Providence, RI on April 16th and 17th.

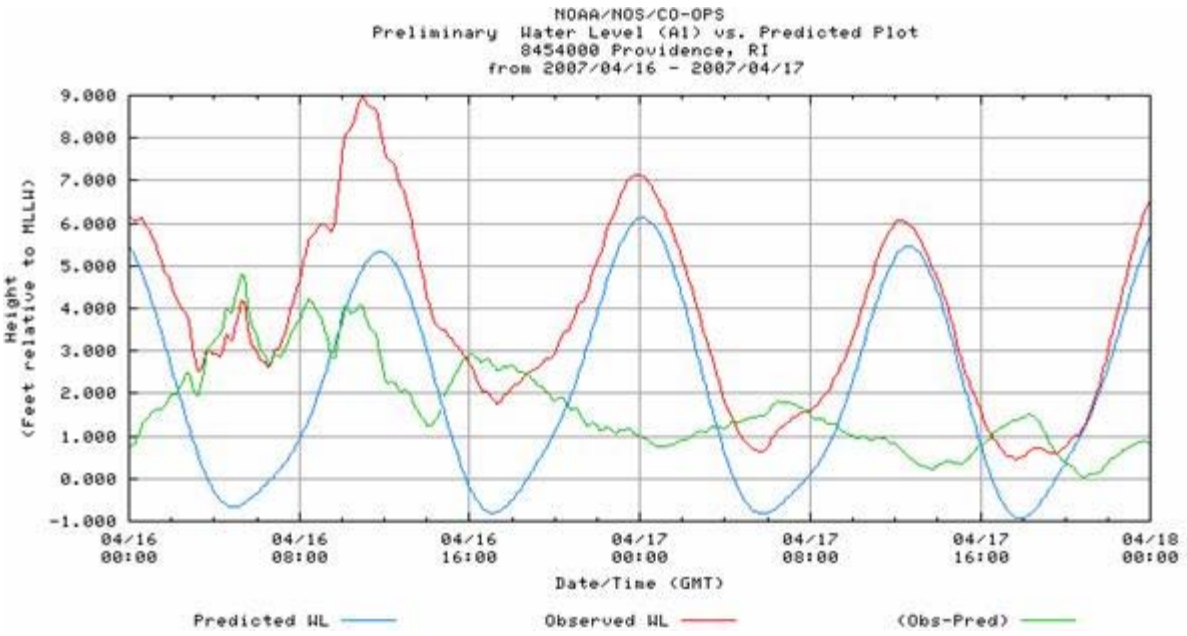

Figure 18. Observed tides at Providence, RI. Flood stage is 7.0 feet MLLW

In eastern Massachusetts, the worst coastal flooding occurred with the Tuesday night high tide. Moderate flooding forced the closure of many shore roads. There were reports of cars stranded in flood waters along the Plymouth County coast. Although no injuries or fatalities were reported, four people including two children needed to be rescued from vehicles – one of whom nearly drowned when her car was carried away by flood waters in the Green Harbor section of Marshfield. Farther north along the coast, flooding was especially severe in Salisbury, where significant beach erosion occurred and flood waters inundated portions of the boardwalk on Salisbury Beach.

On Nantucket, one home on Sheep Pond Road fell into the ocean after waves eroded the bluff underneath. Coastal flooding also affected Martha's Vineyard and Chatham. A breach was opened on Norton Point Beach on

Chappaquiddick Island, cutting off access to Edgartown, and also on Nauset Beach in Chatham where several cottages were cut off from the mainland. Figure 19 shows the observed tides at Boston, MA from April 16th through April 19th.

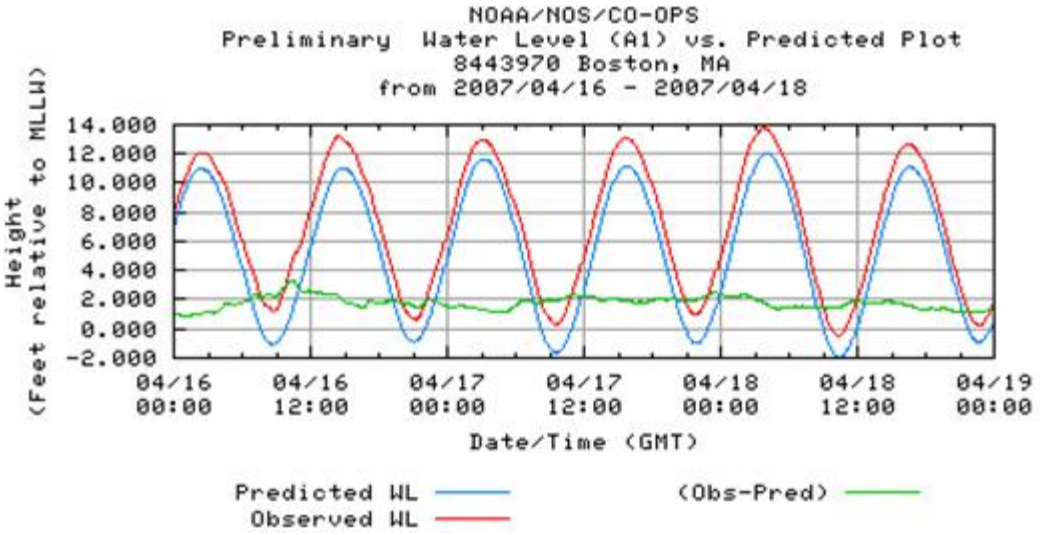

Figure 19. Observed tides at Boston, MA. Flood stage is 13.6 feet MLLW

4. Verification and Recommendations

Verification statistics for winter storm, wind, coastal flood, and flood events can be found in Figure 20. Forecasters were able to recognize the potential for a significant coastal storm several days in advance. Training and recent studies on flooding, coastal flooding and high winds were integrated into the forecast process, and led to outstanding lead times and detection of these events. Somewhat less skill was shown with winter storm events. This was primarily due to the fact that it was a marginal, late season event which was focused over higher elevations. While advisories were issued and verified, five forecast zones were classified as winter storm events either due to average snowfall or storm impact. Future training sessions will address interior high elevation snow events.

Type	POD	FAR	Avg Lead Time
Winter Storm Watch	0.80	0.20	34 hours
Winter Storm Warning	0	0	0 hours
Winter Weather Advisory	1.0	0.17	16 hours
High Wind Watch	0.77	0.30	46 hours
High Wind Warning	0.77	0.30	35 hours
Wind Advisory	1.0	0.11	17 hours
Coastal Flood Watch	0.81	0.03	32 hours
Coastal Flood Warning	1.0	0	21 hours
Areal Flood Warning	1.0	0	12 hours
River Flood Warning	0.90	0	9 hours

Figure 20. WFO Taunton verification statistics for April 15-17, 2007

A log of significant products issued up to and during the storm is in Figure 21. An informal query of partners and customers after the event indicated the staff performed exceptionally well, despite the various impacts of this late

season storm. The message was communicated clearly days in advance, and information from the office flowed smoothly during the event. Conference calls led by WFO Taunton were well received by state and federal agencies, and significantly cut down on the phone call load by operational staff, allowing them to focus on the storm. A follow up action to this storm was to draft a set of guidelines for holding such conference calls in the future.

Date/Time (EDT)	Product	Description
09/511 pm	HWO	Coastal flooding possible Sun along south coast
10/455 pm	HWO	Heavy rain/coastal flooding/gale force wind Sun
14/405 am	WSW	Winter Storm Watch interior high terrain for 4-8 inches
14/410 am	FFA	Flood Watch most of CWA
14/417 am	NPW	High Wind Watch south coast
14/512 am	CFW	Coastal Flood Watch east and south coast Sun night
14/1218 pm	FFA	Flood Watch all of CWA
14/1224 pm	NPW	High Wind Warning south coast; High Wind Watch east coast
14/313 pm	WSW	Winter Weather Advisory interior high terrain for 2-6 inches
14/501 pm	CFW	Coastal Flood Warning east and south coast Sun night
15/406 am	NPW	High Wind Warning east coast; Wind Advisory just inland
15/835 am	CFW	Coastal Flood Watch east and south coast Mon morning
15/1049 am	AWW	Airport Weather Warning for sleet at KBOS
15/155 pm	AWW	Airport Weather Warning for strong winds at RI airports
15/353 pm	FLW	Areal Flood Warning for CT and adjacent W MA
15/440 pm	CFW	Coastal Flood Warning east and south coast Mon morning
15/618 pm	FLW	Flood Warning for Pawtuxet River at Cranston
15/650 pm	AWW	Airport Weather Warning for strong winds at KBOS
15/744 pm	FLW	Areal Flood Warning for SE MA
15/800 pm	SPS	Heavy rain and strong winds arriving near coast
15/934 pm	FLW	Areal Flood Warning for NE MA
15/1051 pm	FLW	Flood Warning for Farmington and Blackstone Rivers
15/1152 pm	SPS	Heavy rain and strong winds RI and eastern MA
15/1158 pm	FLW	Areal Flood Warning for Hampshire County incl Mill River
16/346 am	FLW	Flood Warning for North Nashua River
16/513 am	SPS	Coastal flooding and high winds
16/700 am	SPS	Significant coastal flooding
16/705 am	FLW	Flood Warning for Sudbury and Shawsheen Rivers
16/727 am	FLW	Areal Flood Warning for Franklin County and SW NH
16/822 am	FLW	Flood Warning for Lower CT, Merrimack, Assabet, Nashua, Spicket, and Squannacook Rivers
16/941 am	FLW	Flood Warning for Contoocook River
16/1000 am	FLW	Flood Warning for Westfield River
16/1148 am	FLW	Flood Warning for Souhegan River
16/101 pm	CFW	Coastal Flood Warning east coast Mon night; Coastal Flood Watch east coast Tue morning and Tue night
16/453 pm	CFW	Coastal Flood Warning east coast Tue morning
16/453 pm	FLW	Flood Warning for Concord River
17/609 am	CFW	Coastal Flood Warning east coast Tue night
17/349 pm	CFW	Coastal Flood Warning east coast through Wed night

Figure 21. WFO Taunton significant product log for the April 15-17, 2007 Coastal Storm

5. Summary

An unusually strong and slow moving coastal storm brought a variety of impacts in southern New England, including heavy snow to the higher elevations of western Massachusetts and southwest New Hampshire, damaging winds in excess of 60 mph, widespread river and stream flooding, and significant coastal flooding through several high tide cycles.

WFO Taunton products and services were excellent throughout the event, highlighting the potential several days before, and then correctly predicting the significant impact of each hazard. Although there was disagreement among NWP models with the track of the surface low in the days leading up to the storm, forecasters identified the potential for a significant coastal storm as much as 3 days in advance. As the models came into agreement, Watches and Warnings were issued with adequate lead time.

6. Acknowledgements

This Storm Series Report was reviewed by the WFO Taunton Post-Event Analysis Team, and was written by Nicole Belk, Joseph DelliCarpini, Michael Ekster, Hayden Frank, and Frank Nocera.

7. References

Grumm, R.H., 2007: Forecasts of the Spring Storm of 13-16 April 2007. National Weather Service State College, PA