Service Assessment

The Historic Nor'easter of January 2016

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, Maryland

Cover Photograph:

Left Image: Bill Goodman, General Forecaster, WFO, and New York City providing an IDSS briefing to NYC OEM staff. Photo from the Twitter feed of Joe Esposito, NYC OEM Commissioner.

Upper Right: Coastal flooding in Wildwood NJ. Photo courtesy of Carrie Ensle via NBC Philadelphia.

Lower Right: Snow removal activity at Dulles International Airport in Virginia. Photo from Dulles International Airport's Twitter feed.

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November 2016

National Weather Service
Louis W. Uccellini
Assistant Administrator for Weather Services

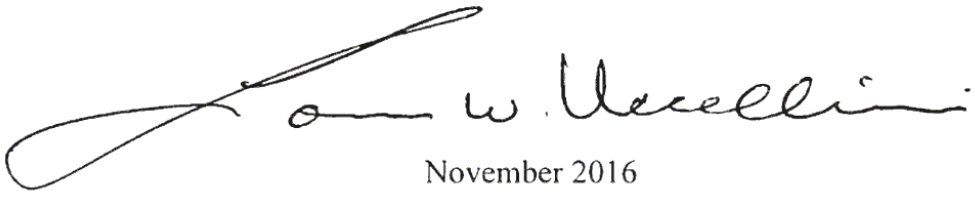
Preface

A historic blizzard affected much of the Northeast and Mid-Atlantic states from January 22–24, 2016. Over 100 million people were affected by the historic Nor'easter that dumped widespread 2–3 foot snowfall accumulations across the region. The snow was accompanied by winds in excess of 35 mph creating blizzard conditions over much of the area. The combination of wind and very heavy snow created major impacts to travel, closed many major airports, and stranded hundreds of motorists on roads.

The historic Nor'easter also led to significant coastal flooding along portions of the Mid-Atlantic and northeast seaboard. Numerous roads, homes, and businesses along the New Jersey and Delaware coasts were flooded and emergency personnel conducted numerous water rescues. The coastal flooding along the southern portion of the Jersey shore exceeded that experienced in the area during Hurricane Sandy in October 2012.

Because of the significant impacts of the event, the National Weather Service formed a service assessment team to evaluate its performance before and during the historic Nor'easter. The National Weather Service Mission Delivery Council will review and consider the findings and recommendations from this assessment. As appropriate, new requirements will then be integrated into the Annual Operating Plan to improve the quality of operational products and services and enhance the National Weather Service's ability to provide an increase in public education and awareness materials related to winter weather and coastal flooding. The ultimate goal of this report is to help the National Weather Service meet its mission to protect life and property and enhance the national economy.

Louis W. Uccellini
Assistant Administrator
for Weather Services



November 2016

Table of Contents

Appendices

List of Figures

Page

List of Tables

Service Assessment Team

The following people participated as members of the Service Assessment Team:

Kevin Barjenbruch	Warning Coordination Meteorologist, Weather Forecast Office (WFO) Salt Lake City, UT
Alan Gerard	Deputy Chief, Warning Research and Development Division National Severe Storms Laboratory
Tom Johnstone	Team Leader: Meteorologist in Charge, WFO Corpus Christi, TX
Cedar League	Social Scientist, Helena, MT
Andy Nash	Meteorologist in Charge, WFO Burlington, VT
Bruce Smith	Meteorologist in Charge, WFO Gaylord, MI

Subject-Matter Experts/Consultants:

Paul Pisano	Federal Highway Administration

Other Valuable Contributors:

Cindy Woods	Chief, Operations Division, Silver Spring, MD
Douglas Young	Chief, Performance and Evaluation Branch, Silver Spring, MD
Salvatore Romano	Evaluation Meteorologist, Performance and Evaluation Branch**,** Silver Spring, MD
Melody Magnus	Technical Editor, Innovim, Inc., NWS Analyze, Forecast, and Support Office, Silver Spring, MD

Executive Summary

From January 22–24, 2016, a historic snowstorm affected areas from the mid-South to southern New England. The Mid-Atlantic region was hardest hit with widespread 2–3 foot snowfall accumulations. Winds in excess of 35 mph created blizzard conditions across the area and travel and commerce was severely impacted with most airports and highways closed. Along the Pennsylvania Turnpike, more than 500 motorists were stranded overnight by the heavy snow. In all, the storm affected over 100 million people, including the major metropolitan areas of New York, Philadelphia, and Washington, D.C. The storm was later rated as a Category 4, or "Crippling," on National Oceanic and Atmospheric Administration's Northeast Snowfall Impact Scale.

Hurricane force winds and record coastal flooding also accompanied the Nor'easter along parts of the Mid-Atlantic and northeast seaboard. Numerous roads, homes, and businesses along the New Jersey and Delaware coast were flooded and emergency personnel conducted numerous water rescues. The coastal flooding along the southern portion of the Jersey shore exceeded that experienced in the area during Hurricane Sandy.

The blizzard's meteorological evolution was classic. A strong upper-level disturbance dropped from the Pacific Northwest across the Southern Plains from January 19–21. Low pressure at the surface formed over the Deep South and moved across the Gulf Coast states on January 22, 2016. Late on Friday, January 22 into the morning of Saturday, January 23, the low pressure center reformed off the Carolina coast and the storm rapidly strengthened as it moved off the Mid-Atlantic and New England coasts. Heavy snow overspread the region from south to north on January 22 and continued through the day on January 23. The snow gradually tapered from west to east as the storm moved out to sea on Sunday, January 24, 2016.

National Weather Service (NWS) forecasts highlighted the potential for a significant winter storm in the region, nearly a week in advance. The National Centers for Environmental Prediction individual medium range model runs, as well as ensemble solutions, were excellent and showed remarkable consistency with the synoptic scale handling of the system. Finer scale details of the forecast, especially related to a sharp northern gradient to the heavy snowfall, were not handled as well. Model runs Friday into Saturday steadily trended north with the axis of heavy snow resulting in significant upward adjustments to snowfall forecasts as the event unfolded from Pennsylvania into southern New England. The snow also overspread parts of the area faster than forecasted resulting in significant travel impacts, sometimes beginning before NWS warnings had gone into effect.

Across parts of the Mid-Atlantic, especially around Washington D.C. where preparations were ongoing for the impending blizzard, a light snowfall event on the evening of January 20 also created significant travel impacts. Despite receiving around an inch or less of snow accumulation, a combination of cold road surfaces, inadequate road treatment, and the rush-hour timing of the snow resulted in gridlock across the region. Many motorists were stranded on the road for hours. The looming blizzard expected on January 22–23 overshadowed the light snowfall event and many residents were unprepared for the severity of the impacts related to the light snowfall.

NWS provided impact-based decision support services (IDSS) before and during the historic event. Staff disseminated briefing packages early in the week highlighting the threat for a major storm and expressing weather forecasters' unusually high confidence. As the event drew closer, NWS provided dozens of phone, webinar, and in-person briefings to partners in the affected areas. The Aviation Weather Center's National Aviation Meteorologists and Center Weather Service Units in the Northeast United States provided their users with consistently high quality information to reduce impacts to the Nation's aviation system. As the event unfolded, NWS meteorologists were embedded with key partners in state and local EOCs supporting decisions makers. Comments from key partners about NWS services associated with this event were almost unanimously positive.

Local and national media coverage of the event was extensive. A national news conference led by NWS Director Dr. Louis Uccellini was widely praised for helping to raise awareness of the impending blizzard. Local Weather Forecast Offices (WFO) worked with media partners to inform the public and maintain consistent messaging. NWS also used social media to get the word out about the storm. Social media efforts were aided by the NWS's coordinated efforts to develop and promote a hashtag for the event: ***#winterstorm***.

NWS staff across the affected region were pushed to their limits by the storm. Many staff members were stranded at their duty stations for 24 hours or more. In some cases, staff members required National Guard assistance to reach their offices.

The NWS formed a Service Assessment Team to evaluate Agency performance as it relates to IDSS and internal coordination before and during the blizzard. The team focused its efforts on the hardest hit areas across the Mid-Atlantic including the NWS offices in Upton, NY; Mt. Holly, NJ; Sterling, VA; and State College, PA. Also included were these National Centers for Environmental Prediction offices: Weather Prediction Center, Aviation Weather Center, Climate Prediction Center, and National Hurricane Center. Additionally, the National Weather Service Operations Center (NWSOC) and the Eastern Region Regional Operations Center (ROC) performed active roles, often around the clock.

Overall, the assessment team determined exceptional performance across the board by the Agency. The team identified 10 Best Practices in the report, 28 Findings, and 33 Recommendations addressing Agency performance. The findings focus on IDSS, internal coordination, and coastal flood messaging/communication. Key findings and recommendations were related to the following:

- NWS IDSS efforts are inconsistent with improved support needed at the state level. Targeted training and increased staff engagement are key when providing IDSS. Other improvements should include incorporating on-site deployments into office staffing plans.
- Around-the-clock NWSOC/ROC support is critical leading up to major weather events. NWSOC and ROC roles need clear definition.
- Consistent with the Hurricane Irene and Hurricane/Post-Tropical Cyclone Sandy service assessments, NWS needs an impacts-based approach for tropical and non-tropical coastal inundation.

- Coastal flooding and inundation information is critical for tropical and non-tropical systems. The National Hurricane Center provided inundation graphics during the January storm, but it requires the necessary resources for providing such services on a routine basis.
- Winter storm products were not updated to address the earlier than expected arrival of heavy snow in parts of the Mid-Atlantic.
- Social media is a powerful tool, but consistent IDSS messages from official sources are needed.
- While experimental NWS snowfall graphics were useful IDSS tools, more scientific vetting and testing will be needed as well as situational training for forecasters.

Service Assessment Report

1. Introduction

1.1. National Weather Service (NWS) Mission

The mission of National Oceanic and Atmospheric Administration's (NOAA) NWS is to protect life and property by providing weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas. The NWS disseminates centrally produced data, weather products, and guidance to 135 regional and local Weather Forecast Offices (WFO) and River Forecast Centers (RFC). The forecasters at the WFOs and RFCs issue all local forecasts and warnings to the public and interface with local emergency managers (EM) and state and local governments to promote community awareness and understanding of local climates, forecasts, and weather events.

The NWS is organized into six regional headquarters and one National Headquarters, which provide policy and guidance to the WFOs and RFCs. The National Centers for Environmental Prediction (NCEP), consisting of nine prediction centers, provide central guidance, outlooks, and hazardous weather watches and warnings to the NWS organization and the public. A National Water Center operationally supports and delivers science-based, integrated, water resources monitoring, prediction, and diagnostic information.

1.2. Purpose of Assessment Report

The NWS may conduct service assessments of significant weather-related events that result in one or more of the following: multiple fatalities, numerous injuries requiring hospitalization, significant impact on the economy of a large area or population, extensive national public interest or media coverage, or an unusual level of attention to NWS operations (performance of systems or adequacy of warnings, watches, and forecasts) by media, the EM community, or elected officials. Service assessments evaluate the NWS performance and ensure the effectiveness of NWS products and services in meeting its mission. The goal of service assessments is to better protect life and property by implementing recommendations and best practices that improve NWS products and services. This document presents findings and recommendations resulting from the evaluation of NWS performance during the historic blizzard and major coastal flood event of January 22–24, 2016.

1.3. Methodology

The NWS formed an assessment team on February 28, 2016, consisting of employees from NWS field offices, the National Severe Storms Laboratory, and a social scientist. The team completed the following:

- Performed an on-scene evaluation from February 29–March 3, 2016, conducted interviews with staff from WFO Philadelphia PA/Mount Holly, NJ ; WFO Baltimore, MD/Washington, DC (Sterling); WFO New York, NY (New York City); and Eastern

Region Headquarters (ERH). These NWS offices had primary responsibility for providing services to the affected area.

- Interviewed EMs, transportation officials, the media, and other key partners in the impacted areas
- Conducted remote interviews with staff from Center Weather Service Unit (CWSU) offices in Leesburg, VA, and Ronkonkoma, NY, as well as WFO State College, PA
- Evaluated products and services issued by WFOs, CWSUs, and NCEP, including the Weather Prediction Center (WPC), the National Hurricane Center (NHC), and the Aviation Weather Center (AWC)
- Developed a list of significant findings and recommendations to improve the effectiveness of NWS products and services

After a series of internal reviews, the service assessment was approved and signed by the NOAA Assistant Administrator for Weather Services and issued to the American public.

2. Meteorological Overview and Impacts Summary

On January 22–24, 2016, a large portion of the eastern United States was struck by a historic Nor'easter. All the major metropolitan areas on the Eastern Seaboard were affected, including Washington D. C., Baltimore, Philadelphia, New York City, and Boston. The storm brought heavy snow, gale force winds, and blizzard conditions to many areas, while near hurricane-force winds resulted in extreme coastal flooding. Commerce and travel were severely impacted for several days. The storm's total snow accumulations (**Figure 1**) exceeded 2 feet across parts of West Virginia, Virginia, Maryland, Pennsylvania, New Jersey, and New York, with snow accumulations reaching up to 3 feet in some areas. Snowfall records were established at many locations. The storm was later rated as a Category 4, or "Crippling," on NOAA's Northeast Snowfall Impact Scale. Some select snowfall reports and records from official observing locations are included in **Table 1**:

Table 1: Select snowfall amounts

Location	**Storm Total Amount** ***** denotes all-time record***
Somerset, PA	35.8"
Allentown, PA	31.9" ** (also 30.2" for calendar day record)
JFK/Kennedy International Airport, NY	30.6" (also 30.3" for a calendar day record)
Harrisburg, PA	30.2" (also 26.4" for a calendar day record)
IAD/Dulles International Airport, VA	29.3"
BWI/Baltimore-Washington Airport, MD	29.2" (also 25.5" for a calendar day record)
LGA/LaGuardia Airport, NY	28.2"** (also 27.9" for a calendar day record
NYC/Central Park, NYC, NY	27.5"** (also 26.6" for a calendar day record)
EWR/Newark International Airport, NJ	24.5"
Philadelphia, PA	22.4" (also 19.4" for a calendar day record)
DCA/Washington-Reagan Airport, DC	17.8"

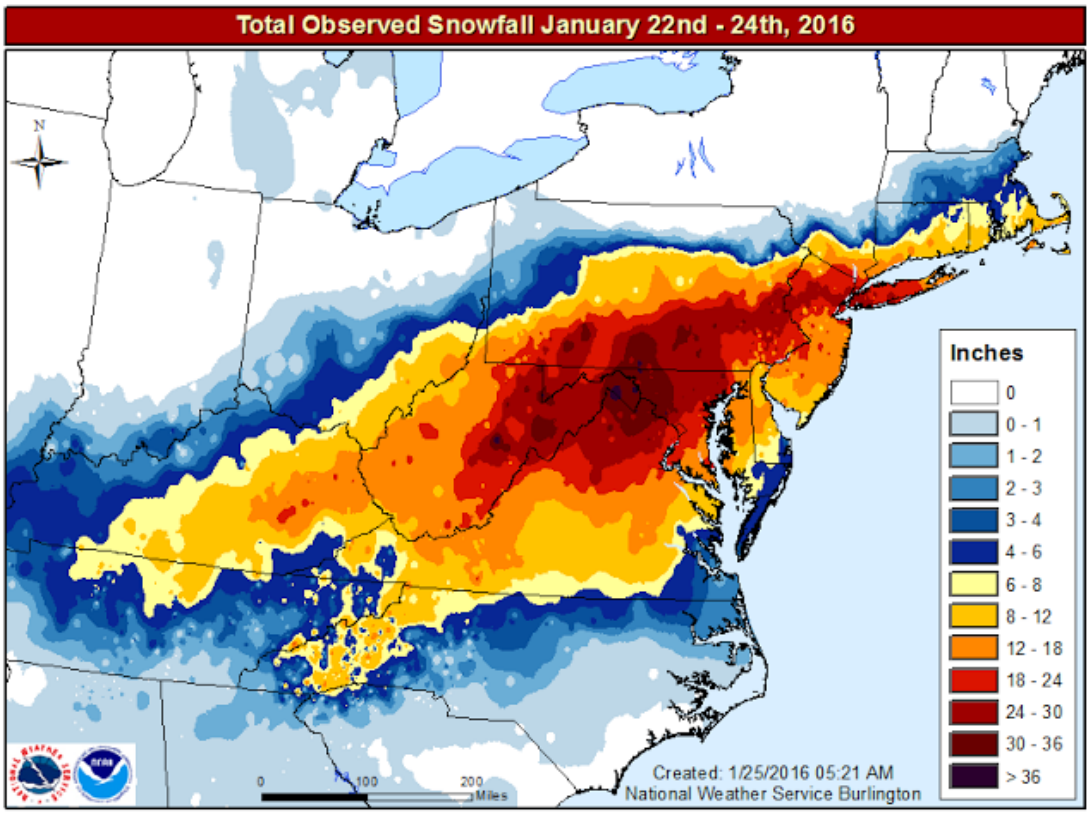


Figure 1: Observed storm total snowfall January 22–24, 2016. *Source: NWS, Burlington, VT.*

The synoptic evolution of this winter storm was classic. A strong upper disturbance crossed the Pacific Northwest on Tuesday, January 19 (3 days before the storm impacted the East Coast) and dropped southeast into the Southern Plains by Thursday, January 21. The resultant upper trough deepened significantly over the southeastern United States by Friday, January 22, before moving east-northeast into the Atlantic and becoming a closed upper low by late Saturday. An associated surface low developed along the Texas Gulf Coast on Thursday, January 21. The surface low subsequently underwent strong cyclogenesis as it moved northeast. By 1200 UTC Saturday, January 23, it was located just off the Virginia coast over the Atlantic. See radar (**Figure 2**) and satellite (**Figure 3**) images of the storm, late on January 22, 2016.

Light snow fell across portions of the Plains Wednesday into Thursday as the storm slowly organized. By late Thursday, snow expanded into parts of the mid-Mississippi River Valley and became heavier, especially as the storm reached the Ohio River Valley. Also on Thursday, thunderstorms in the Deep South produced large hail, damaging winds, and tornadoes over parts of Texas, Louisiana, Mississippi, Alabama, and Florida. On Friday, heavy snow gradually expanded into the Mid-Atlantic region, including West Virginia, Virginia, Maryland, Pennsylvania, and New Jersey. Eventually, the snow reached southern New York, Rhode Island, parts of Massachusetts, and Connecticut. As the low continued to deepen, strong east to northeast winds developed late Friday into Saturday across the Mid-Atlantic region. This low produced blizzard conditions as well as significant coastal and back bay flooding.

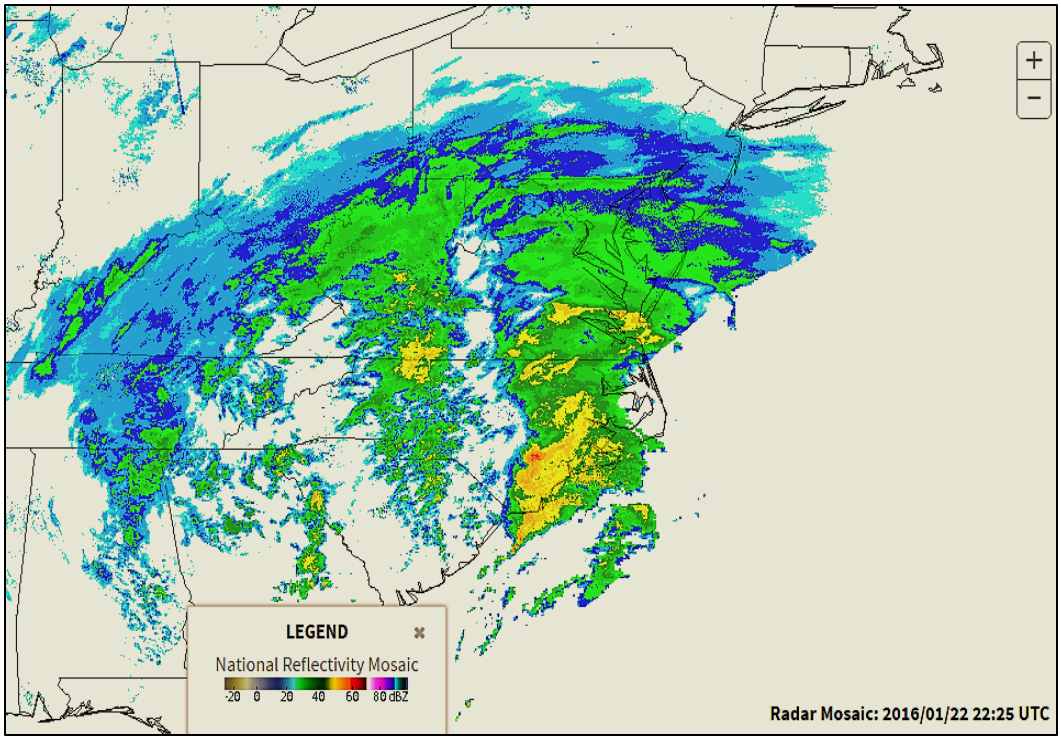


Figure 2: Radar composite valid 2225 UTC January 22, 2016. *Source: NCEP.*

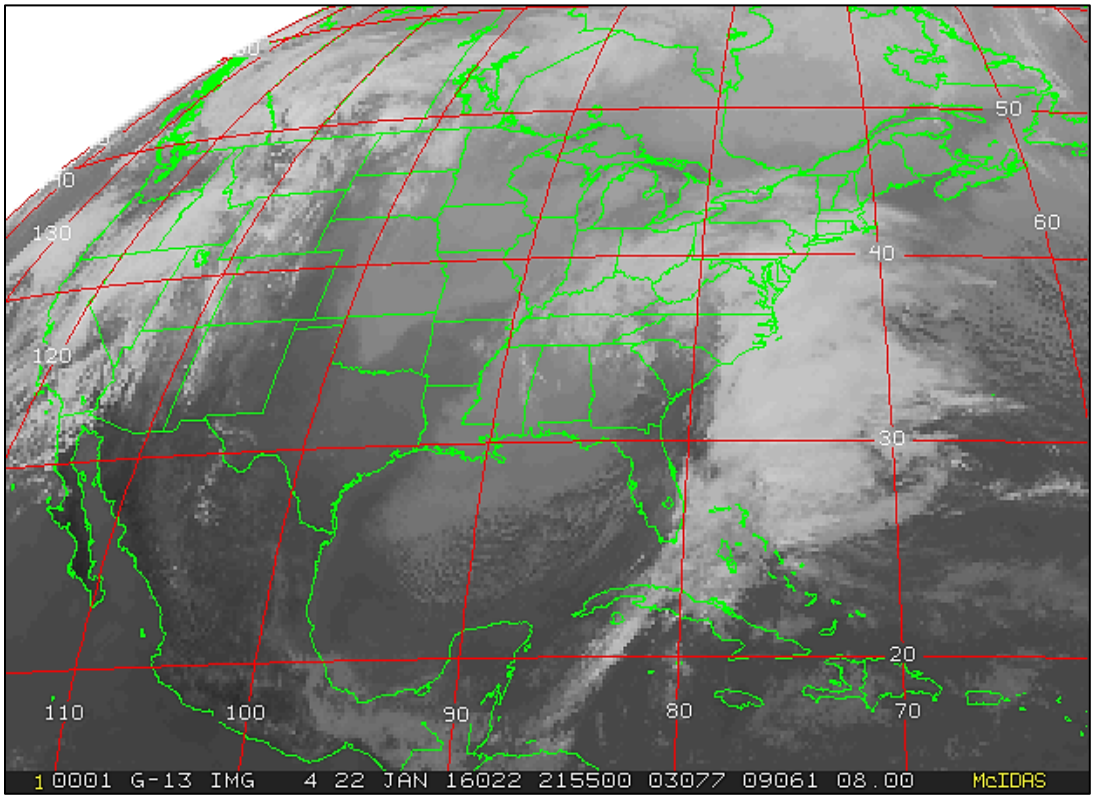


Figure 3: Infrared satellite image from 2155 UTC January 22, 2016. *Source: NCEP.*

This winter storm illustrated two important aspects of how NWS services have evolved in recent years. First, NWS offices provided their local partners with extensive Impact-based Decision Support Services (IDSS) well in advance of the storm. These offices effectively leveraged a variety of communication platforms such as webinars, conference calls, and social media to provide partners with timely and potentially lifesaving impact and information related to forecaster confidence before and during the storm. Second, this event highlighted strides NWS has made in Numerical Weather Prediction (NWP). Not only was the storm accurately forecasted nearly a week in advance, but run-to-run variations in storm location were relatively small. This consistency allowed forecasters to have greater confidence than usual as they communicated expected storm impacts, magnitude, and timing to core partners. The expanded messaging to core partners, the performance of numerical models, and the confidence in an extended forecast of this magnitude were rarely attainable just a decade or two ago.

To illustrate, **Figure 4** is the 132 hour forecast for mean sea level pressure (valid 1200 UTC January 23, 2016) from the 0000 UTC January 18, 2016 run of the Global Forecast System (GFS). Also shown is the verifying analysis for the same time. The GFS performed exceptionally well 5.5 days in advance, placing the surface low just off the Virginia coast, with a very accurate intensity forecast. Similarly, the Day 3–7 U.S. Hazards Outlook produced by the Climate Prediction Center on Monday, January 18 (not shown) accurately depicted heavy snow for parts of the Mid-Atlantic and Northeast for January 22 and 23.

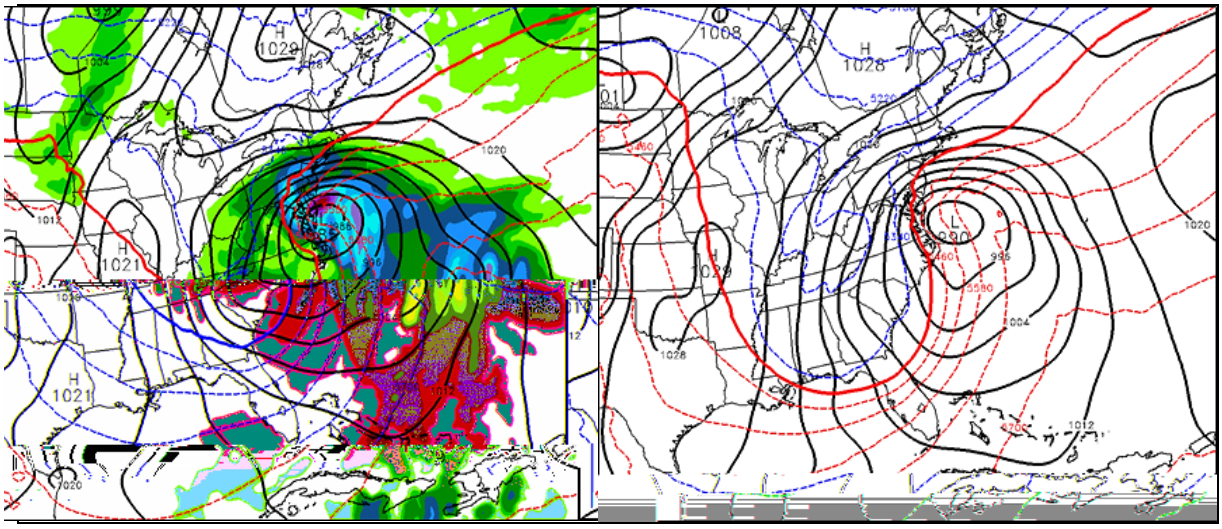


Figure 4: 0000 UTC 18 January 2016 GFS 132 hour forecast Mean Sea Level Pressure valid at 1200 UTC 23 January 2016 (left), and corresponding verifying analysis (right). *Source: NCEP.*

From a synoptic perspective, this winter storm was accurately forecast many days in advance; however, a subtle shift in the northward extent of the heavy snow late Friday, January 22, and on Saturday, January 23, created an extremely challenging forecast and communication issue for parts of Pennsylvania, northern New Jersey, southern New York, and New England. This shift was problematic given the sharp gradient in snowfall intensity that existed along the northern periphery of the precipitation. Extremely heavy snow ultimately fell approximately 40 to 60 miles farther north than many earlier forecasts had indicated. This shift, though relatively

small, produced significant impacts to travel in areas originally not expected to be the path of this storm and represented another unique aspect of this winter storm.

2.1. January 20 Light Snow Event in Metro D.C.

A relatively light, but high-impact, winter weather event occurred within a smaller portion of the Mid-Atlantic states prior to the January 22–23 winter storm. This event is included in this Service Assessment because of the disproportionately large impact it had in the Washington, D.C. metropolitan area and the possible connection it had to the winter storm that would occur later that week.

In the days leading up to the January 22–23 winter storm, surface high pressure brought cold air with significantly below-normal temperatures to the eastern United States. Maximum temperatures in the Washington, D.C. metropolitan area were subfreezing starting on January 18, with morning minimum temperatures in the teens. With this cold air in place, a strong upper disturbance moved out of the Great Lakes region across the Mid-Atlantic and Northeast states late on January 20. This system produced light accumulating snow across parts of the Ohio Valley and Great Lakes region, but NWP guidance indicated this area of snow would diminish as the system moved east into the surface high and encountered drier air. Most NWP guidance showed very light or no measurable precipitation across the immediate Washington, D.C. metropolitan area associated with this weather system (**Figure 5**).

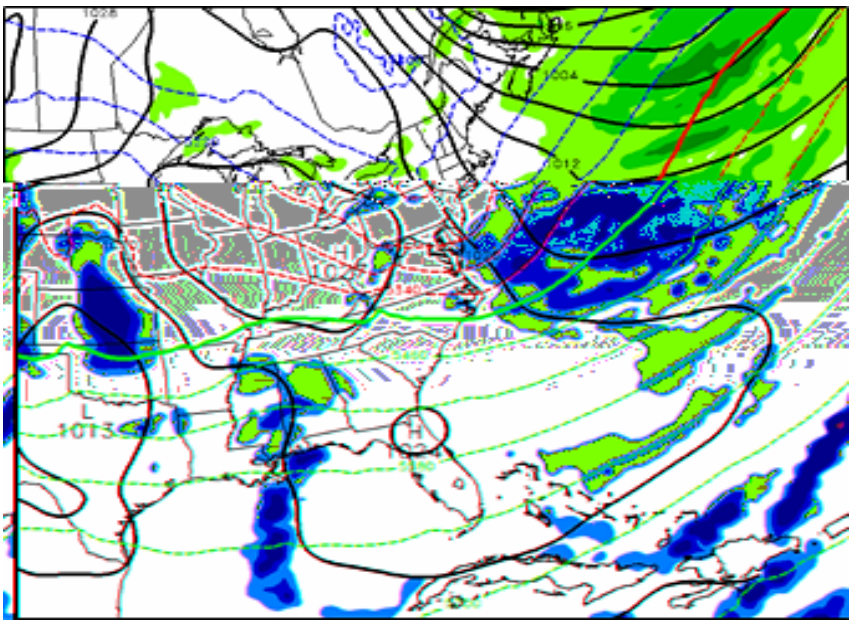


Figure 5: 1200 UTC January 19, 2016 GFS 42-hour forecast Mean Sea Level Pressure and 6-hour quantitative precipitation valid at 0600 UTC January 21, 2016. *Source: National Centers for Environmental Prediction.*

In reality, strong forcing associated with the upper disturbance was sufficient to produce widespread, light snow across the National Capital District region. The maximum amount of snow reported in the D.C. metro area was 1.6" measured by a trained spotter 1 mile west-

southwest of the National Zoo in the District of Columbia. Most locations reported an inch or less of snow (**Figure 6**).

Though snow amounts were light, the snowfall combined with the very cold temperatures and snow event timing during the evening commute resulted in significant impacts to transportation in the area.

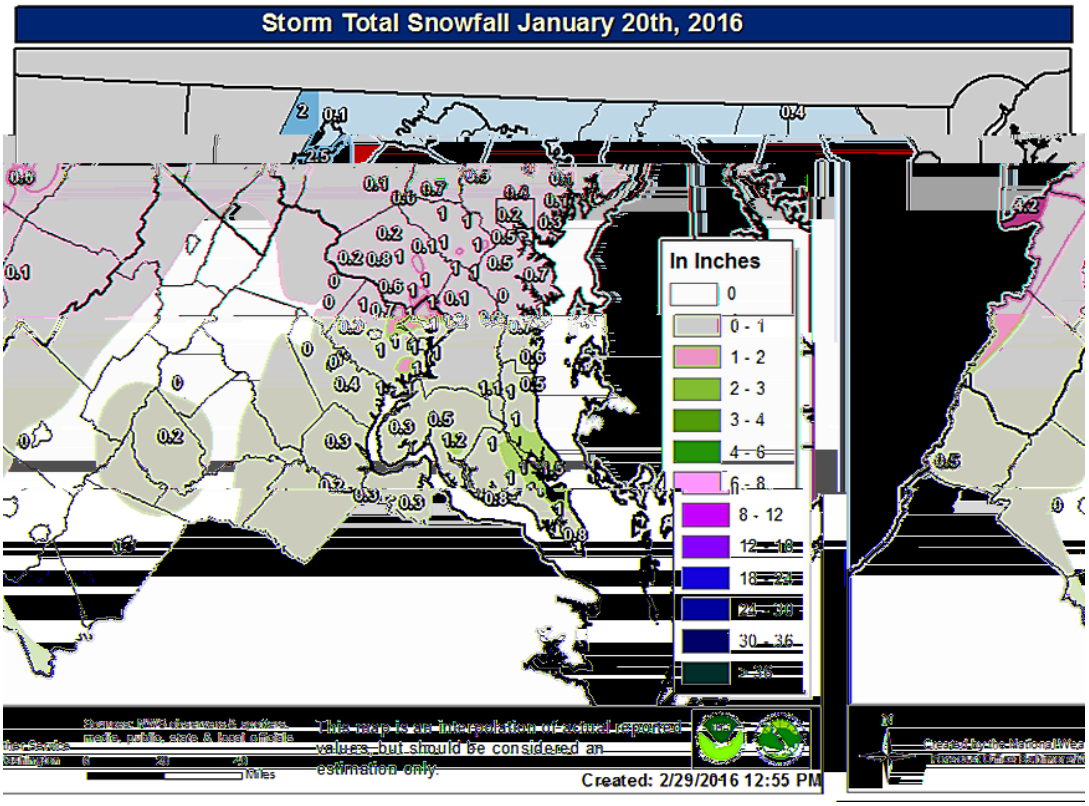


Figure 6: Observed snowfall 20 January 2016. *Source: NWS Baltimore/Washington.*

2.2. Blizzard/Coastal Flooding/Light Snow Impacts

2.2.1. Impacts within WFO Baltimore/Washington County Warning Area (CWA)

2.2.1.1. Light Snow Impacts

A period of light snow during the evening hours of January 20, in combination with sub-freezing road surface temperatures, led to significant impacts on the surface transportation system of the Washington, D.C. metropolitan area. Given less than adequate time for transportation officials to mobilize resources, roadways quickly became snow covered and slick with the onset of the snow. Commuters were mired in traffic across major arteries; some drivers were stuck for more than 6 hours, well past midnight. On the Capital Beltway, Travel Time Index values, a measure of the increase in travel time associated with congestion, were up to 10, translated to mean a typical commute took 10 times as long as would normally be expected.

Even President Obama's motorcade was slowed as it made its way from Joint Base Andrews to the White House. Unofficially, more than 1,000 motor vehicle accidents were reported.

2.2.1.2. Blizzard Impacts

The blizzard impacts became more wide-ranging as heavy snow coupled with strong winds and associated blowing snow affected the region. Governors declared the following States of Emergency:

- DC mayor Muriel Bowser declared a State of Emergency early Thursday afternoon.
- MD governor Larry Hogan declared a State of Emergency early Thursday afternoon.
- VA governor Terry McAuliffe declared a State of Emergency Thursday morning.
- WV governor Earl Ray Tomblin declared a State of Emergency Friday morning.

Interstate 270 and Interstate 70 between Frederick and Baltimore were closed for 12 hours during the height of the storm. Virginia Governor, Terry McAuliffe, said there were more than 1,200 vehicle accidents attributed to the storm.

Although all three Washington, D.C. international airports (Ronald Reagan, Dulles, and Baltimore-Washington Thurgood Marshall) officially remained open, all flights were cancelled during the height of the blizzard. Flight service was gradually restored on Monday, January 25, with Ronald Reagan and Dulles opening one runway during the morning. A total of 2398 flights combined from the three airports were cancelled, from Friday, January 22 through Monday, January 25. The Washington Metropolitan Area Transit Authority shut down bus and rail service Friday evening. Very limited rail service resumed on Monday.

While there were over 10,000 power outages in Maryland alone during the peak of the storm on Saturday, power was restored quickly. By early Sunday, there were only about 238 outages in Maryland; 103 outages in Washington, D.C.; and 416 outages in northern Virginia.

Structural damage from the weight of the snow included the collapse of three roofs in Page County, VA, a shopping center roof in Stafford County, VA, and the roof of a bowling alley in Waynesboro, VA. Calvert Cliffs Nuclear Plant in Lusby, MD, was forced to shut down Unit 1 for maintenance due to the high winds and heavy snow accumulation.

The Federal Government was closed beginning noon on Friday and re-opened on Wednesday, January 27.

2.2.2. Impacts within WFO Philadelphia/Mount Holly CWA

The blizzard of January 22–23, 2016, had a tremendous impact on the Mid-Atlantic region, including the entire area served by WFO Philadelphia/Mount Holly. Heavy snow, strong winds, and reduced visibility created exceedingly hazardous travel conditions. Major airports including Philadelphia International were shut down for the duration of the storm and many roads and highways were closed. Additionally, strong onshore flow created extreme coastal flooding along the Delaware and New Jersey coasts.

In general, 20–30 inches of snow fell across the northwest two-thirds of the WFO Philadelphia/Mount Holly forecast area during the 72-hour period ending 1200 UTC January 24. It was a historic snowfall with daily snowfall records established at Allentown and Philadelphia, PA (**Table 1**).

Even before the snow began to fall late Friday, January 22, States of Emergency were declared in all four states served by WFO Philadelphia/Mount Holly, including Pennsylvania, New Jersey, Delaware, and Maryland. The Philadelphia International Airport was closed Saturday. Area schools were closed on Monday and Tuesday following the storm. Power outages were minimal. Fewer than 250,000 people lost power, and those outages were mainly along the coast where winds were strongest. There were eight known fatalities in the WFO Philadelphia/Mount Holly forecast area resulting from this storm.

2.2.3. Impacts within WFO New York, NY CWA

On January 23–24, 2016, heavy snow and strong winds created blizzard conditions along the coast with near blizzard conditions elsewhere across the WFO New York, NY area of responsibility. In general, 20–30 inches was measured across a large portion of the forecast area. Unofficial totals of 34 inches were reported in Queens, NY. Impacts to travel and mass transit were widespread, with a complete transportation shutdown across New York City (NYC) by Saturday afternoon. Recovery was gradual on Sunday and Monday, with near normal conditions returning area wide by Tuesday.

This winter storm also caused widespread coastal sand dune erosion with isolated over washes and minor to locally moderate coastal flooding, mainly around high tide cycles January 23–24. Across Long Island's inland bays, residual tidal flooding continued through January 25. Widespread beach erosion across the Atlantic Ocean shores caused significant impacts to local area beaches and parks.

In NYC, at least three indirect deaths occurred when people suffered heart attacks while shoveling snow. The number of injuries is unknown; many traffic accidents were reported. Property damage, including at least one roof collapse, was caused by heavy snow, strong winds, and coastal flooding. Damage estimates exceeded $50 Million in NYC alone. Extensive property damage occurred to the exposed Atlantic Ocean shores, impacting dunes, beaches, parks, and homes. This damage was partially caused by high surf driven by high winds and coastal flooding. Winds gusts of up to 59 mph were recorded in Suffolk County, NY.

Emergency declarations were ordered by state officials in New Jersey and New York, and by city officials in NYC and at the county and town levels. A selected list of significant emergency declarations included:

- Friday January 22 4 p.m.: NJ Governor Christie declared a State of Emergency
- Saturday January 23 7:49 a.m.: NY Governor Cuomo declared a State of Emergency
- Saturday January 23 8:00 a.m.: NYC Mayor De Blasio declared a Winter Weather Emergency advising people to stay off the roads except for an emergency

- Saturday January 23 9:00 a.m.: Eleven NY counties declared States of Emergency: Bronx, Kings, New York, Queens, Richmond, Nassau, Suffolk, Westchester, Orange, Putnam, and Rockland.
- Saturday January 23 12:40 p.m.: NY Governor Cuomo ordered the shutdown of NYC in response to the worsening winter storm

Aviation impacts to the major airports in the immediate NYC metro area were severe. Although JFK Airport technically stayed open throughout the storm, based on Federal Aviation Administration (FAA) data, airlines had cancelled over 4,800 flights in and out of the NYC area airports between late Friday, January 22 and Sunday January 24. That equates to an overall cancellation rate of 65 percent, including 98 percent during the height of the storm on Saturday. Cancellation rates rapidly diminished Monday (32 percent) and Tuesday (16 percent), with residual runway-clearing activities causing most of the delays, especially at Newark Liberty International Airport where 42 percent of flights were still cancelled on Tuesday. By Wednesday, flight activities had returned to normal with all three major New York City area airports reporting more than 98 percent of scheduled flights operating.

2.2.4. Pennsylvania Turnpike Impacts

Snow overspread south central Pennsylvania during the afternoon hours of Friday, January 22. The snow was light initially but picked up in intensity steadily. By late afternoon, moderate to heavy snowfall was occurring over the area. With temperatures in the 20s, the snow quickly began to accumulate and impact travel conditions. Travel impacts were most intense along the Pennsylvania Turnpike in Bedford and Somerset counties. The first significant roadway incident occurred sometime before 5:21 pm when a tractor-trailer slid off the turnpike near mile marker 155.5W in Bedford County (**Figure 7**). This resulted in a nearly 6-mile backup before the accident was cleared. Additional accidents involving trucks continued to occur through the evening hours and by 10 p.m., westbound traffic was stopped completely.

Figure 7: Tractor-trailer crash at MM 155.5 Westbound on the PA Turnpike.
Source: PA Turnpike Commission After Action Review.

Figure 8 depicts when and where the most significant traffic incidents occurred. More than 500 vehicles, including buses carrying college athletes and church groups, were stranded for more than 24 hours on the turnpike when the road became impassible. The response and

recovery operations involved approximately 300 personnel from more than 30 state, county and local agencies. The incident on the turnpike garnered significant national media coverage. Eventually all motorists were rescued and no deaths or serious injuries occurred.

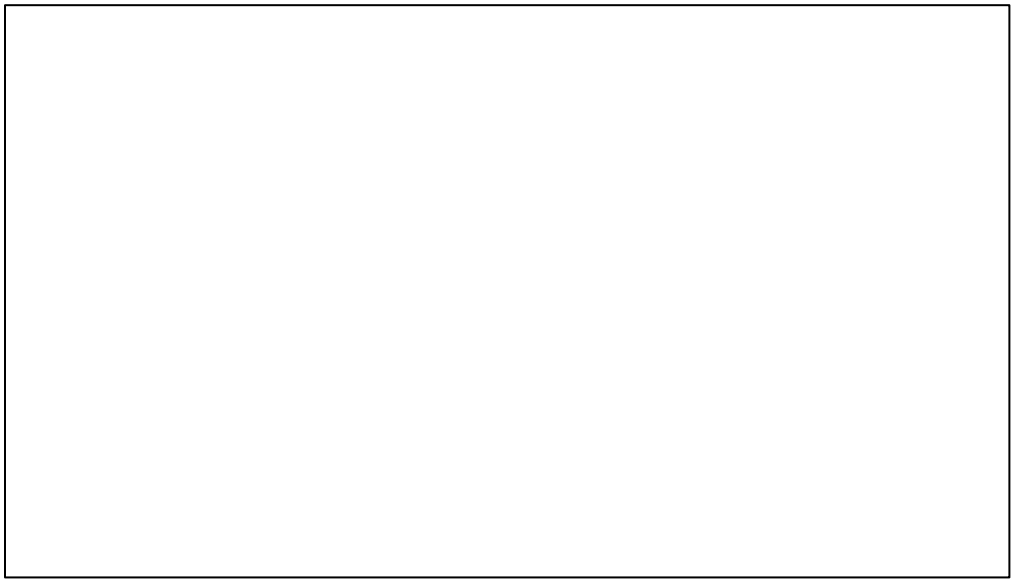


Figure 8: Traffic incident timeline on the PA Turnpike. *Source: PA Turnpike Commission After Action Review.*

3. Facts, Findings, Recommendations, and Best Practices

3.1 NCEP Products and Decision Support Services

Several NCEP centers provided products and services for this blizzard:

- Climate Prediction Center: Day 3–7 U. S. Hazards Outlook
- WPC: Collaboration with Regions; New Experimental Day 4-7 Winter Weather Outlook; QPF/Snowfall/Ice; Storm Track; Media
- Storm Prediction Center (SPC): Severe Weather Outlooks for Gulf Coast State Areas; Mesoscale Discussions for Severe Thunderstorm Potential, Winter Mixed Precipitation, Heavy Snow and Blizzard Conditions
- AWC: National Aviation Meteorologists Support at FAA Command Center and Overall Aviation Support
- Ocean Prediction Center/NHC: Extratropical Storm Surge Support
- Environmental Modeling Center (EMC): Model Evaluation
- NCEP Central Operations: Supplemental Sounding Strategy (with EMC/WPC); Monitoring of Model Guidance on the Weather and Climate Operational Supercomputing System

Nearly 25 operational forecasters (WPC, Ocean Prediction Center, NCO, and NESDIS SAB) sheltered at NCEP College Park to maintain continuity of operations during the storm, a majority of which sheltered for more than 48 hours. The sheltering was among the most extensive in NCEP history.

Management made a concerted effort to emphasize employee safety (best practice). By all accounts, the sheltering went extremely well—a testament to successful preparations for accommodations and the dedication and professionalism of the staff. AWC's Joey Carr voluntary sheltering in place for two consecutive days at the FAA Command Center resulted in the reopening the National Air Space in a much more effective manner than would have occurred otherwise and should be commended.

3.1.1. Environmental Modeling Center

EMC provided numerical weather model guidance to all NWS entities and the weather community at large. Overall, NWP guidance for the blizzard was outstanding, providing a consistent forecast of a high-impact winter storm for the Mid-Atlantic and parts of the Northeast. Discussions with NWS and media meteorologists indicated a high level of satisfaction with EMC guidance. The primary area of concern related to the evolution of the northern edge of the large precipitation shield over the eastern United States. Most NWP guidance, including the GFS model, forecast the northern edge of the precipitation too far south, resulting in lower snowfall forecast amounts for areas along this northern gradient, such as the New York City metropolitan area. The North American Model (NAM) more accurately depicted the precipitation shield progressing farther north than the GFS or other global models (e.g., UKMO and ECMWF). A post-event evaluation completed by EMC and presented to the Model Evaluation Group indicated that the NAM's success was likely because of a better depiction of

upper-level diffluence between the northern and southern branches of the Jetstream. The GFS also appears to have incorrectly over-developed convection over the Atlantic Ocean, resulting in an unrealistic reduction of moisture inflow into the area around New York City and southern New England.

One issue relating to EMC's NWP guidance was the methodology and requirement for extra radiosonde releases from NWS upper air sites for input into the numerical models. The NCEP After Action Review (AAR) for the blizzard noted NCEP did not have a well-defined protocol for determining where and when extra radiosonde releases might be needed. The determination was made on the fly in collaboration between WPC, EMC, NCEP Central Operations and the Regional Operations Centers (ROC), resulting in extra balloon releases at 1800 UTC and 0600 UTC at most continental United State (CONUS) sites east of the Rockies starting on January 20. These balloon releases were in addition to the dropsonde data obtained by Hurricane Hunter flight operations off the Mid-Atlantic and Southeast coastline beginning with the 0000 UTC model cycle on January 22.

The NCEP AAR noted it was not clear whether the extra soundings made a substantial improvement to the modeling, and requested a sensitivity study to examine the benefit for the blizzard. The sensitivity study team worked with NCEP to request model runs with and without the extra radiosonde data; EMC provided such runs of the NAM during the time extra soundings were provided. A preliminary subjective and objective analysis conducted by the team showed minimal improvement in the model runs that used extra rawinsonde and dropsonde data versus those that did not. Results of this analysis indicated minimal to no impact on the forecast. A cursory objective verification of model snowfall for a variety of locations around the impacted region showed a slight improvement in total snowfall forecasts, but this result varied by location. For example, snowfall forecasts for Washington-Dulles, Philadelphia and Harrisburg showed some improvement with the added data, while forecasts for Boston and Scranton/Wilkes-Barre were somewhat degraded.

Fact: NCEP does not have a well-established protocol to determine when and how supplemental soundings should be obtained during winter storms in support of EMC NWP operations. For this blizzard, such operational decisions were made by NCEP in collaboration with ROCs, resulting in extra soundings from most central and eastern CONUS sites beginning on January 20, 2016.

Finding 1: A preliminary subjective and cursory objective analysis of NAM runs both with and without supplemental upper air data provided by EMC showed minimal impacts from the extra data. Snowfall forecasts showed some small improvements for some sites, but other sites actually showed degradation. On average, snowfall forecasts based on verification for several cities showed a very small improvement with model runs that included supplemental upper air data.

Recommendation 1: NCEP should work to undertake a more scientifically-rigorous analysis of the impact of extra sounding data on NWP guidance for synoptic systems such as the January 2016 blizzard and other significant storms. Such analyses should provide requirements for supplemental sounding data and drive development of a supplemental sounding protocol if such data are shown to be beneficial.

3.1.2. Weather Prediction Center

WPC provides guidance and forecasts to NWS offices and the broader weather community for winter weather, Quantitative Precipitation Forecast (QPF), and medium-range weather elements. WPC produces an experimental medium-range probabilistic winter precipitation forecast that provides probability values for exceeding 0.25" of melted snow/sleet. This product **(Figure 9**) verified well for this event, and showed a high likelihood of impactful winter precipitation for the Mid-Atlantic and Northeast several days in advance; however, given that this product only has one threshold for amounts (0.25"), it was not able to convey the potential for historic crippling impacts.

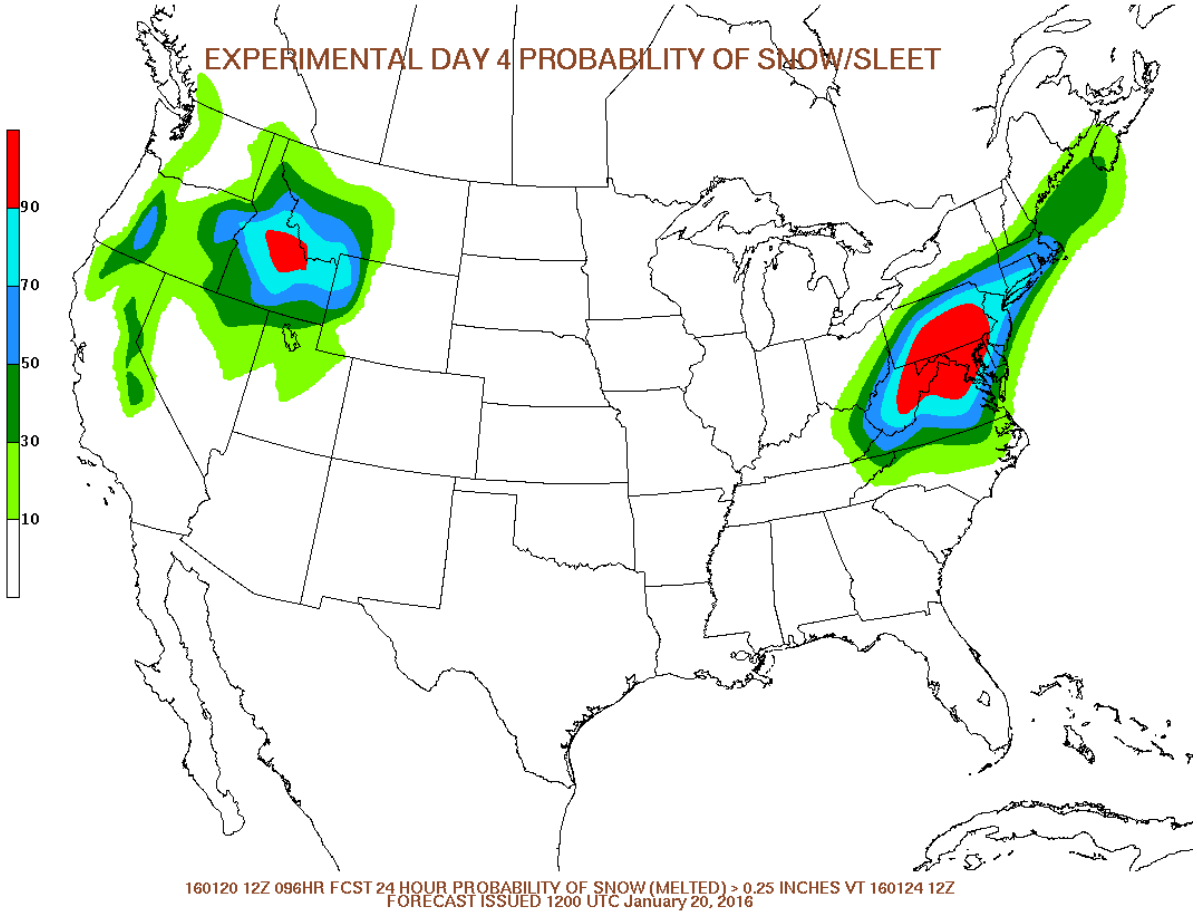


Figure 9: Day 4 Snow Probability Graphic. *Source: NCEP.*

As the event moved closer in time, WPC's Days 1–3 QPF and probabilistic winter weather guidance provided excellent forecasts and guidance yielding high confidence in a historic event for the Mid-Atlantic and part of the Northeast (**Figure 10**). WPC organized and led conference calls with those WFOs that had the greatest potential for high impacts to collaborate on forecast issues. WPC produces probabilistic forecasts of QPF and winter precipitation accumulations; these WPC products feed into the experimental ER probabilistic snowfall forecasts discussed above; however, it should be stressed that WPC products are only part of the ER probabilistic

snowfall methodology, and WFO forecasters can make manual adjustments that affect the ultimate output.

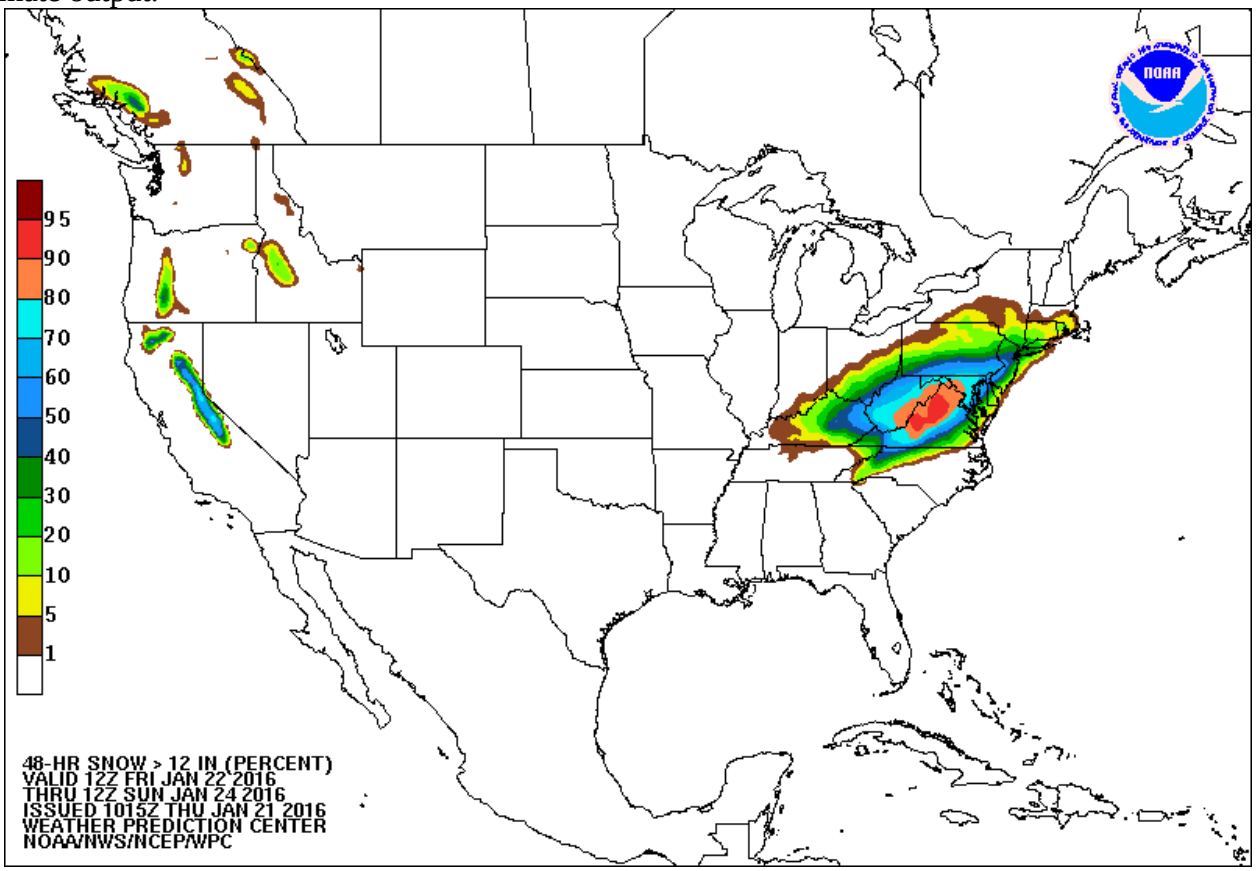


Figure 10: Day 3 12-Inch Snow Probability Graphic. *Source: NCEP.*

WPC also dealt with a significant workload related to media requests, accommodating over 100 interviews before and during the blizzard. Unlike other national service centers such as NHC and SPC, WPC does not have onsite NOAA Public and Constituent Affairs (PCA) support. Coordination and collaboration between NCEP and NOAA PCA seemed somewhat ad hoc and minimally effective; for example, NCEP/WPC developed a talking points document relating to the blizzard without being aware that NOAA PCA was also developing talking points. One positive outcome however, was a press conference hosted by NWS Director Dr. Louis Uccellini on Thursday, January 21. Several partners that the Service Assessment Team spoke with felt this press conference reinforced the significance of the upcoming winter storm.

Fact: WPC had a heavy workload relating to media requests, accommodating more than 100 media interviews before and during the blizzard.

Finding 2: WPC does not have an onsite NOAA PCA staffer, unlike centers with similar missions such as SPC and NHC. Additionally, collaboration between WPC and NOAA PCA for the blizzard was ad hoc and minimally effective.

Recommendation 2: National Weather Service Headquarters should work with WPC management to perform a workload analysis for current and future public affairs needs at WPC and develop a plan to provide public affairs support to WPC as necessary.

Best Practice: On Thursday, January 21, a press conference was given by NWS Director Dr. Louis Uccellini. A member of the Long Island print media noted the Director's press conference was useful in providing a big picture understanding of what was happening, especially in identifying the sharp northern edge of snowfall in the region.

3.1.3. Aviation Weather Center

AWC National Aviation Meteorologists (NAM) embedded in the FAA Air Traffic Control Systems Command Center (ATCSCC) in Warrenton, VA provided extensive IDSS to the national aviation system related to the blizzard. On Monday, January 18, AWC produced special medium-range aviation impact graphics (**Figure 11**) out through Day 7 (the following Sunday, January 24), an extension beyond their standard practice, to issue graphics through Day 4. AWC continued issuing graphics beyond its standard Day 4 period through the week to ensure the entire period of the blizzard's impact on the East Coast was covered by medium-range impact graphics.

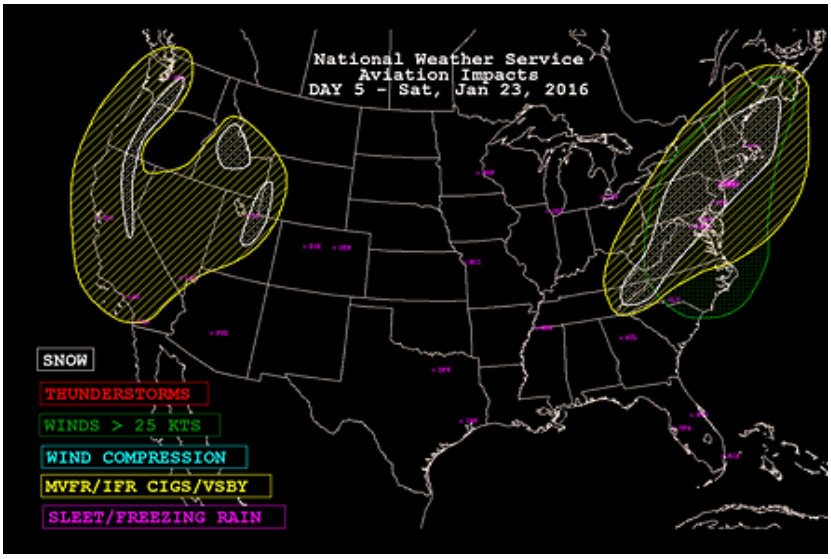


Figure 11: Day 5 Aviation Impact Graphic. *Source: AWC.*

The NAMs stationed at the ATCSCC provided hundreds of scheduled and ad-hoc winter storm briefings and updates to ATCSCC management and operational staff, in addition to FAA senior leadership, from January 18–24 regarding the blizzard's anticipated and observed impact on the National Airspace System (NAS). These efforts by AWC NAMs, in addition to aviation products from AWC in Kansas City, undoubtedly contributed to the rapid recovery of the NAS discussed earlier in the report.

Fact: AWC's decision to create special Day 5–7 impact outlook maps benefitted the ATCSCC.

Finding 3: The routinely produced Day 2–4 impact outlook maps, and the specially-created Day 5–7 impact outlook maps for this event were created specifically for FAA Command Center daily conference call briefings. These briefings may have remote participation from CWSU staff, FAA Air Route Traffic Control Centers (ARTCC) Traffic Management Unit, and Terminal Radar Approach Control Facility (TRACON) staff. The maps are not otherwise available to or coordinated with CWSU staff, though they could help CWSU staff create briefings for ARTCC.

Recommendation 3: AWC should make all impact graphic outlook maps available to CWSUs and WFOs to ensure consistent messaging is provided by all NWS entities (AWC, CWSUs, and WFOs) interfacing with FAA offices: ATCSCC, ARTCCs, TRACONs.

3.2. WFO Operations and Decision Support Services

3.2.1. WFO Baltimore/Washington D.C. (Sterling, VA)

From Monday, January 18, through the duration of the Blizzard the evening of Saturday, January 23, WFO Baltimore/Washington was deeply engaged in providing IDSS to its core partners, including EMs, surface transportation and aviation officials, media, and the general public. WFO Baltimore/Washington disseminated email briefings, took part in nearly 100 conference calls including EMs and transportation officials, maintained daily contact with Office of Personnel Management officials for a 9-day period, and took part in 75 media interviews and briefings. The WFO was also actively engaged in social media messaging, reaching thousands of people via shares and retweets.

In the numerous interviews with WFO Baltimore/Washington core partners, all described having a strong relationship with the WFO staff and an associated high level of trust in the information the office provides. In every case, partners referred to the WFO as their primary source for weather information, although they also used broadcast media and private sector weather providers. Among the partners interviewed, each highlighted conference calls and webinars as one of the primary NWS mediums through which they received weather information.

WFO Baltimore/Washington has historically been an active supporter of local and state agencies by providing an on-site meteorologist. This support has included, but is not limited to, previous significant weather and political events as well high profile Emergency Operations Center (EOC) exercises. WFO Baltimore/Washington deployed an on-site meteorologist to the Maryland Emergency Management Agency (MEMA) for approximately 36 hours during the peak of the blizzard. High-level MEMA personnel commented the onsite IDSS was crucial because the refined information led to better decisions relating to plowing and other operations, "*Sometimes when smaller changes occur leading up to and during event, we don't hear about it. Having IDSS onsite really helps.*"

Fact: WFO Baltimore/Washington deployed an on-site meteorologist to the MEMA Operations Center during the blizzard.

Finding 4: Senior MEMA personnel strongly indicated that onsite IDSS was crucial to their success.

Recommendation 4: Ensure NWS National IDSS Training Plan addresses all components necessary for the consistent provision of on-site support, leveraging the IDSS Professional Development Series training.

WFO Baltimore/Washington serves as the State Liaison Office (SLO) for Maryland, and as such coordinates statewide briefings. High-level Maryland Department of Transportation (MDOT) and MEMA officials stated they needed to source information from WFO Pittsburgh, PA, WFO Philadelphia/Mount Holly, and WFO Wakefield, VA, in addition to WFO Baltimore/Washington. Officials stated a need for statewide services because sourcing information from multiple offices is time consuming. In fact, these partners stated they would prefer having a single statewide forecast office, although local jurisdictions preferred local WFOs – "*They do an excellent job of providing state liaison. Really rely on them for statewide support. All of the areas of the state like their individual WFOs. Really like the format and content of the statewide briefings they do. MEMA would really prefer to have all of the forecast responsibility under* Baltimore/Washington - *but local jurisdictions prefer having their local offices. Big issue with inconsistency of Web pages over the years between the four offices.*" The state level partners expressed that WFO Baltimore/Washington has utilized their feedback and are performing excellent statewide support and services to Maryland.

Finding 5: As SLO for Maryland, WFO Baltimore/Washington coordinates statewide briefings and graphics utilizing forecast products and services from the other WFOs serving the state. Maryland officials stated a strong need for statewide services, including graphics and products.

Recommendation 5: NWS Directives should provide policy and procedural guidance to ensure a consistent level of basic statewide decision support, including briefings, web services, and graphics for state officials.

In an effort to convey confidence information, WFO Baltimore/Washington provides several experimental winter weather services via web services and briefing packages. One of these experimental services is probabilistic snowfall information: minimum, most likely, and maximum snowfall graphics; probability that snow accumulation will be greater than various snowfall thresholds; and a table providing probabilities of various snowfall accumulations for a variety of specific locations. Another experimental winter weather product WFO Baltimore/Washington produces is the Day 4–7 winter storm threat, which combines confidence and potential impact to define a threat level.

Partners consistently commented that these products were valuable. In particular, decision makers expressed a strong need for probabilistic information. Several partners also stated they found the winter storm threat extremely useful. Some partners, however, also expressed concerns about the readiness of these products for use, citing occasional issues such as inconsistency between forecasts and unrealistically large spreads between minimum and maximum snowfall accumulations. Several users also expressed skepticism about the public's ability to understand the experimental products.

WFO Baltimore/Washington personnel also raised concerns about the technical readiness of the experimental products, pointing out the need to make on-the-fly manual adjustments to the production methodology for the day 4–7 winter storm threat product to achieve the "desired" outcome for the product. Concerns about the current probabilistic snowfall methodologies, specifically with respect to range of forecast values, were also expressed. One employee expressed frustration that a couple of days before the blizzard the minimum snowfall for most areas was around 8 inches, when all NWP models were showing well in excess of 1 inch of liquid precipitation (typically a ratio of ten to one means that every 10 inches of snowfall equals 1 inch of liquid water). Another member of the WFO team stated they felt the experimental products should undergo evaluation in a testbed or proving ground environment before operational implementation.

Fact: WFO Baltimore/Washington provides several experimental winter weather services related to winter weather on its website.

Finding 6: While WFOs (including WFO Baltimore/Washington) correctly followed the experimental product process outlined in NWSI 10-102, *New or Enhanced Products and Services*, the comments of partners and NWS forecasters raised concerns about the physical and social science robustness of these products. Many experimental techniques and services in other NWS service programs are vetted via a testbed or proving ground experiment prior to implementation; however, no mechanism currently exists for such testing of WFO winter weather products. WFO personnel specifically emphasized that a testbed/proving ground for these winter weather services could have reduced operational problems that were noted with these services during the blizzard.

Recommendation 6: NWS Headquarters should review and potentially amend NWSI 10-102 to take advantage of NOAA testbeds and proving grounds for robust vetting and testing of experimental products and services, particularly those that involve significant physical and/or social science advances. This review should include examining the potential involvement of partners (e.g., EMs, transportation officials) in testbed/proving ground experiments related to new services.

Following the intense January 26, 2011, snow event in the Washington, D.C. metropolitan area, extensive coordination efforts have taken place between the Metropolitan Washington Council of Governments' Metropolitan Area Transportation Operations Coordination (MATOC) Program, which includes the Departments of Transportation (DOT), Office of Personnel Management, and the Washington Metropolitan Area Transit Authority. WFO Baltimore/Washington takes part in the monthly MATOC meetings during the fall and winter. These meetings serve as opportunities to educate members on NWS decision support services, establish policies, procedures, and predetermined messages, and build relationships.

MATOC members unanimously stated WFO Baltimore/Washington participation in these meetings had built strong relationships and instilled trust between group members and the WFO, which they believed has dramatically improved understanding of key decision points and partner needs. All group members felt surface transportation decision making for winter weather events had dramatically improved since the 2011 event due to this collaboration. Of note, during the

blizzard event, MEMA collaborated with WFO Baltimore/Washington, getting the message out about when people should be completely off the roads. While predetermined messaging is of some value, an opportunity exists to develop an approach for dynamic message creation leading into and during events, to enhance message consistency, and potentially improve partner and public response.

Fact: WFO Baltimore/Washington participates in the MATOC Program, designed to enhance collaborative efforts.

MATOC members unanimously stated the participation of WFO Baltimore/Washington in its meetings built strong relationships and trust with the WFO and dramatically improved the WFO's understanding of its member's needs. MEMA collaborated with WFO Baltimore/ Washington on blizzard event messaging. The Service Assessment Team suggests that WFOs review *Collaboration Across the Road Weather Enterprise, The Pathfinder Project*, which provides guidance for decision support operations (see **Appendix C)**.

For several days in advance of, and throughout the event, WFO Baltimore/Washington was active in social media, reaching thousands of people via Facebook and Twitter. The most popular posts were focused on impacts, accumulations, timing, and information via watches and warnings. During the week, WFO Baltimore/Washington added nearly 2,000 Twitter followers, for a total of around 15,000. Retweets from entities with a national reach, such as *The Washington Post* and CNN, were integral to reaching a wide audience. WFO Baltimore/ Washington gained roughly 2,000 page likes on Facebook, bringing the WFO's total followers to around 50,000. Social media sites also were useful in driving traffic to WFO websites; approximately 6 percent of the visits were via social media referrals, compared with long term averages around 2.5 percent.

Best Practice: WFO Baltimore/Washington promoted the blizzard 5 days in advance via Facebook and Twitter, maintaining a consistent message with other outlook services.

When users and partners were asked if the weather community should use a collaborated social media hashtag for large winter storms, the general consensus was "yes," with some noting that such a hashtag should originate from the NWS. With respect to naming storms, opinions were mixed, though some *did* indicate their public information officers were using storm names designated by The Weather Channel. One WFO Baltimore/Washington official who took part in an after action review at one of the major Washington, D.C. area airports noted hearing feedback in support of providing winter storm names. The rationale was that a widely accepted moniker would make it easier to track costs and tasks related to a given weather event.

3.2.1.1. Wednesday, January 20 Event – Impacts on Blizzard Response

In the midst of preparing for the blizzard, the Washington, D.C. metropolitan area experienced a light, yet highly impactful, snow event. The assessment team tried to determine what effect, if any, the impending blizzard had on WFO Baltimore/Washington operational decisions and actions for the January 20 event, and equally important, the decisions and actions of core partners.

While messaging for the blizzard originated up to 7 days in advance of the event, messaging for the light precipitation/high-impact event during the evening of Wednesday, January 20, was somewhat limited until late that morning. On January 19, and even into the early morning hours of January 20, the forecast included a chance of snow, with little or no accumulation expected. Hazardous Weather Outlook (HWO) products issued on January 18–19 indicated the potential for snow showers "POSSIBLE DURING THE EVENING COMMUTE ON WEDNESDAY." On the morning of January 20, however, the 520 a.m. HWO did not mention any potential for impacts from the event as a result of an internal miscommunication. A message posted in NWSChat during the afternoon of January 19 stated, *"Good afternoon everyone. I'm sure everyone's eyes are focused on the major weekend system. The latest guidance continues to have incredible agreement and we will continue to highlight the potential for significant impacts. Mixing could still be problematic near and southeast of I-95. It is important to note that preliminary snowfall forecast coming out from the NWS (in NDFD and from WPC) will still not encompass the entire system. It is also important not to totally overlook the clipper passing through Wednesday afternoon and evening. East of the Appalachians there may only be flurries, but in a worst case scenario, there could be a light coating of snow in spots during the evening rush hour."*

A message posted in NWSChat on the morning of January 20 continued to indicate some potential snowfall stating, *"Good morning! A disturbance will cross the region later today and tonight. Snow showers are expected to begin across the western slopes of the Allegheny Front late this morning. 1-2 inches of accumulation is expected. Snow showers and flurries are possible farther east this afternoon and evening. Snow showers and flurries may impact I-95 towards sunset, however little to no accumulation is expected."* While both of these messages indicated some potential for an event, confidence was low.

During the morning hours of January 20, WFO forecasters became increasingly concerned about impacts to roadways during the evening rush hour, and as a result, issued a Winter Weather Advisory for the metropolitan area at 11:14 a.m. WFO Baltimore/Washington also posted information about the event on social media platforms and through partner briefings. The Winter Weather Advisory for the January 20 event was issued about an hour after the 10:13 a.m. issuance of the Blizzard Watch and Winter Storm Watch, and thus was embedded within the same winter weather message used to highlight the impending blizzard event. As a consequence, the Winter Weather Advisory information was somewhat "buried" or "lost" in the winter weather text bulletin. Additionally, WFO Baltimore/Washington did not issue a follow-up statement until 6:34 p.m. With the ongoing preparation for the blizzard, the WFO did not make contact with the DOTs about the advisory issuance until around 1 p.m., although all interviewed partners stated they were aware of the advisory very soon after it was issued.

With respect to the Winter Weather Advisory, NWP guidance leading up to the event indicated minimal precipitation amounts. Interviews with WFO personnel indicated the very light precipitation being forecast was the primary reason WFO Baltimore/Washington anticipated little in the way of impacts for this event. Temperatures were expected to be very cold during the evening rush hour on January 20, hinting at some potential for an impact event. Operational staff indicated they were focused on the potential historic blizzard later in the

forecast period, and this focus likely detracted from more in-depth forecast analysis that might have recognized the potential for greater impacts due to the cold antecedent road conditions.

With the issuance of the Winter Weather Advisory only 3–4 hours before the start of the afternoon and evening commute, DOT officials did not have enough time to mobilize resources for the event. A Virginia DOT official stated that it relies solely on contract services and thus needs 24 hours to fully mobilize resources. Personnel from the D.C. DOT and MDOT stated they required 12 to 18 hours of lead time. Even with sufficient notice, DOT officials have compressed windows between peak commute periods to pretreat and/or treat road surfaces.

Fact: Because of the complexities and strained capacity of the transportation system in the Washington, D.C. metropolitan area, DOT officials need 12 to 24 hours of lead time to prepare any significant road treatment.

Finding 7: The Winter Weather Advisory issued a few hours before rush hour on January 20, 2016 provided insufficient lead time for Washington, D.C. area transportation officials to pre-treat roads and mobilize resources.

Recommendation 7: All WFOs should work closely with DOT officials to ensure adequate understanding of unique decision points, lead time thresholds, and communication strategies, with information documented via the Impacts Catalog within the Integrated Real-time Impact Services or other impacts catalog systems. Low probability/high-impact winter weather scenarios need to be included in Impacts Catalogs.

One forecaster interviewed relayed that the Senior Forecaster on the day shift January 20 recognized messaging was telling people to get out and prepare for the blizzard although there was a potential impact event that evening. It was noted that while the potential for snow during the evening commute was discussed on a MEMA call, with all the preparation for the blizzard, the WFO did not contact the DOTs until around 1:00 p.m. It was also noted by members of the WFO management team that there is a need to continue incorporating societal impacts into operations and associated messaging, as "*people don't always associate accumulations with impacts.*" As stated earlier, given the complexities of the surface transportation system in the region including a transportation system at near capacity and the need to work with multiple government entities, sufficient lead time is critical.

With respect to the decision making and actions of core partners for the light snow event that affected the evening commute, a majority of partners interviewed stated that in retrospect, messaging and preparing for the blizzard influenced preparation, decision making, and/or response for the light snow event of January 20. Some partners noted that a preoccupation with the blizzard by DOT and EMs, as well as those in the weather enterprise, including private sector weather providers and the media, led to the event being overlooked. One DOT official said, "*When the update came out at 11:00 a.m., we were in a press conference talking about the blizzard.*" Another DOT official commented, "*It feels like if the blizzard wasn't in a couple of days, [there] would have been more focus both on the NWS side and the DOT side . . .might have enabled a better forecast and response.*"

An unintended consequence of the messaging for the blizzard event was that it led to an extended evening commute, in part because some people were out gathering supplies in preparation for the blizzard.

3.2.1.2. Media Response

The Washington/Baltimore region is one of the largest media markets in the country. The Washington TV Designated Market Area (DMA) is the 9th largest in the country, and is served by more than a dozen stations. These stations include all major broadcast networks, including Telemundo. In addition to the Washington DMA, Baltimore has its own DMA, the 27th largest in the United States. Baltimore also has broadcast TV stations serving all major networks. Along with weather information being provided through broadcast media, the Washington, D.C. metropolitan area also is served by *The Washington Post's* Capital Weather Gang (CWG), a team of meteorologists who provide weather news, forecasts, and information via website, social media, and blogging platforms. To provide some perspective of CWG's reach, they have 231,000 Twitter followers and 90,000 Facebook likes.

Meteorologists from CWG and TV stations in both the Baltimore and Washington markets were interviewed by the Service Assessment Team. All of those interviewed stated they had a good relationship with WFO Baltimore/Washington and felt it was a strong office. The meteorologists praised the WFO for having an annual winter weather workshop for the media in which they had all participated. These media partners said the workshop helped prepare them for the winter by providing updates about new products and services as well as information about new science and forecast techniques.

Best Practice: WFO Baltimore/Washington annually hosts a Winter NWS/Media Workshop, which helps the NWS share updates about new products and services as well as information about new science and forecast techniques to the media meteorologists. The workshop also helps develop collaborative relationships that can be leveraged during high-impact weather events.

Overall, the media felt WFO Baltimore/Washington performed very well for the blizzard event. A WJLA meteorologist stated the WFO's performance was "*one of the best I've ever seen*" by an NWS office.

The media overall felt the WFO's experimental products, including probabilistic snowfall and the days 4 through 7 winter storm threat, were effective and provided useful information they could incorporate to provide impact and uncertainty information to the public. A CWG meteorologist expressed concern that the winter storm threat product was difficult for the public to understand and that only their "*wonkier*" readers seemed to really know how to use it. Personally, he felt the product did a good job highlighting a high-end event several days in advance. The media meteorologists also indicated they used comparisons to past events to provide their viewers and readers with context on the potential impact of this blizzard and that they felt that this is an effective methodology. A CWG meteorologist said they used the Saint Louis University Cooperative Institute for Precipitation Systems Analog System to help identify past events to use for their comparisons. A WJLA meteorologist appreciated that WFO

Baltimore/Washington listed snowfall amounts for previous events in an easy-to-find location on their WFO website.

The media meteorologists unanimously stated NWSChat and social media are vital communication channels they use extensively. They also echoed comments heard from other partners that they need higher fidelity information regarding synoptic and mesoscale evolution once the event has begun.

With regard to the high-impact light snowfall event that occurred on January 20, the media meteorologists indicated their focus leading up to that event was on the blizzard, and that what limited attention they gave to the event was enhanced by Baltimore/Washington issuing an advisory on the morning of January 20. CWG meteorologists stated they had spent little time looking at the January 20 event, and the advisory surprised them and "*put it on (their) radar screen.*" A CWG meteorologist strongly felt the media in the Washington, D.C. metropolitan area similarly had little awareness the January 20 event had potential to be a high-impact event, and that the NWS' advisory kept the event impacts from becoming even worse.

3.2.1.3. Internal Operations

In anticipation of the high visibility, high workload event, WFO Baltimore/Washington developed a surge staffing plan to bolster each operational shift by at least one person. This plan included a member of the WFO management team for every shift from the time the office issued the Winter Storm Watch through the duration of the event. The plan also resulted in Saturday operational staff being called in early to the WFO. The office used the authority delegated in NWSI 1-208, *Delegation of Authority for Food/Lodging Expenditures in Advance of or during Major Weather Emergencies or Disasters*, to procure lodging at a nearby hotel for employees and to purchase emergency food supplies." The office also used emergency supplies such as blankets, pillows, and cots.

Finding 8: Emergency employee lodging and food was critical in sustaining operations.

Recommendation 8: NWS WFOs Severe Weather and Winter Weather Operations Plans should detail procurement procedures for employee lodging and food as specified within NWSI 1-208, *Delegation of Authority for Food/Lodging Expenditures in Advance of or during Major Weather Emergencies or Disasters.*

A couple of issues were found with respect to WFO Baltimore/Washington equipment and technical support. It was noted that Electronic Technician (ET) coverage was not optimal for the impact of event. WFO Baltimore/Washington had listed an ET vacancy since August 2014. The vacancy meant two ETs ran back-to-back 12-hour shifts. It was also noted that the Information Technology Officer (ITO) and Electronic Systems Analysts were unable to remotely access WFO systems because they were denied VPN access by ERH due to IT security concerns. This capability would have allowed remote troubleshooting of network issues as well as the ability to reset servers and application software.

Finding 9: The WFO Baltimore/Washington ITO and Electronic Systems Analysts requested VPN access and were denied by ERH due to IT security concerns. Thus, they did not have the ability to access critical WFO systems remotely.

Recommendation 9: ERH leadership should allocate sufficient resources to ensure infrastructure supports VPN access to the regional WAN/LAN (NOAA8882) and develop a policy that supports VPN functionality after the requirements are defined.

As a result of snow and blowing snow, facility roads leading to WFO Baltimore/Washington became impassable. Snow was up to 20 inches deep on the access roadways to the office. WFO leadership indicated the contract for WFO snow removal was not finalized until the day before the blizzard started due to administrative issues with NOAA contract officials. As a result, the contractor employed had no experience performing the work for the facility as described in the contract's Statement of Work. WFO Baltimore/Washington used a Polaris vehicle already on station to transport employees. In addition, the WFO leveraged relationships with the Virginia National Guard (VNG), Washington Dulles International Airport, and local EMs to facilitate emergency transportation (**Figure 12**). During the event, the VNG Humvee became stuck on WFO property, stranding WFO employees onboard one-half mile from the WFO for 45 minutes. The end result was that while employees were effectively transported, WFO management and staff felt an unsafe working environment was created.

Figure 12: A Virginia National Guard soldier digs out a stuck Humvee on the access road to WFO Baltimore/Washington. The Humvee was being used to transport WFO personnel during the Blizzard. Source: WFO Baltimore/Washington.

Fact: Approximately 30 inches of snow fell at WFO Baltimore/Washington during the blizzard, causing access roads to the WFO to become impassible.

Finding 10: The contract for snow removal at WFO Baltimore/Washington was not finalized until the day before the blizzard and, likely because of unfamiliarity with the facility, the contractor did not perform the required work to expectations. As a result, the WFO had to take extraordinary measures to transport staff members to and from the facility. A VNG vehicle became stuck, stranding WFO staff in the vehicle for 45 minutes; both management and staff members stated they felt potentially unsafe conditions resulted.

Recommendation 10: Field offices that manage local contracts, such as snow removal, should work with their Regional Administrative Division to ensure contracts are submitted to NOAA Acquisition and Grants Office (AGO) within the prescribed lead time per AGO/CAMS Section 1307.1, Appendix C.

3.2.2 WFO Philadelphia (Mt. Holly, NJ)

With few exceptions, this major winter storm was forecast with excellent lead time and accuracy by WFO Philadelphia/Mount Holly. Good model consensus and run-to-run consistency allowed forecasters to communicate well in advance, and with reasonably high confidence, that a major winter storm could impact the region. The office first communicated this potential 5 days prior to the storm's arrival via the HWO and Area Forecast Discussion (AFD). The HWO issued at 12:58 p.m., Sunday, January 17, stated, *"A winter storm with associated snow and rain as well as strong gusty winds is possible later Friday into Saturday."* The AFD issued at 4:20 a.m. Sunday, January 17, stated *"The GFS, ECMWF, and CMC with the track of the closed low expected to lift out of the southeastern U.S. towards the mid-Atlantic late in the week" . . . "with the latest tracks, many locations could see mostly snow if they have precip through this period."*

WFO Philadelphia/Mount Holly's IDSS program delivered critical weather information to core partners within its service area. Partner engagement leading up to and during this event included multi-page briefing packages and numerous conference calls and webinars. WFO Philadelphia/Mount Holly took part in 47 conference calls and webinars over the 6-day period from Tuesday, January 19, through Sunday, January 24. WFO Philadelphia/Mount Holly did not initiate these webinars and conference calls. Thanks in large part to the solid relationships that had been established by WFO Philadelphia/Mount Holly, governmental and EM partners contacted WFO Philadelphia/Mount Holly to request its participation in calls and webinars. The governors of New Jersey, Delaware, and Pennsylvania took part in several of these briefings.

WFO Philadelphia/Mount Holly also did an excellent job preparing comprehensive and informative multi-page IDSS briefing packages before the winter storm. These packages were prepared beginning Monday, January 18, roughly 4 days before the onset of the winter storm. Single briefing packages were provided daily Monday, Tuesday, and Wednesday (January 1820) and two daily briefing packages were created as the storm drew closer on Thursday, Friday, and Saturday (January 21–23). These briefing packages included vital information on expected hazards and impacts, headlines, uncertainty, wind speeds, snow accumulations, and coastal flooding. In several of these briefings, WFO Philadelphia/Mount Holly effectively summarized changes from the previous briefing package to its partners.

Best Practice: When providing IDSS briefing packages multiple times leading into a high-impact event, explicitly referencing "changes from the previous briefing" is an effective way to highlight subtle but potentially important changes in the forecast to core partners.

At WFO Philadelphia/Mount Holly, IDSS briefing packages are routinely posted to the office web page. Core partners know where to look for these briefing packages; however, since these briefing packages reside on the office web page, the public can also view them. It is likely the public will find them because WFO Philadelphia/Mount Holly posts an explicit message to social media whenever staff posts a new briefing package.

Personnel from the Philadelphia Office of Emergency Management (OEM), while expressing their strong support for the technical briefings, stated the briefing packages, *"should not be geared toward the general public,"* and that *"briefing packages should be more internal in nature and contain more speculative information such as caveats and uncertainty."*

Finding 11: Briefing packages prepared by WFO Philadelphia/Mount Holly are posted to the office web page. On the final page of each briefing package, WFO Philadelphia/Mount Holly explicitly includes the statement, "*if you wish to be notified when a briefing package is issued, you can follow us on social media where we post the notice*." Therefore, briefing packages can be viewed by both core partners and the public.

Recommendation 11: The NWS should decide whether high-level IDSS briefing packages containing detailed impact, mitigation, confidence, and probabilistic information (such as probabilistic storm total snowfall graphics) should be exclusively designed for core partners or whether this information should also be shared with the general public.

Similar to other WFOs impacted by this event, several of the briefing packages WFO Philadelphia/Mount Holly provided contained maps showing the minimum, most likely, and maximum snowfall expected. This representation is part of an experimental probabilistic storm total snowfall graphic initiative many NWS offices are conducting. Statistically, these probabilistic maps strive to communicate the reasonable low end of possible snowfall (10th percentile), the most likely snowfall (50th percentile or median), and the reasonable high end of possible snowfall (90th percentile, or the so-called "reasonable worst case scenario"). These statistical maps are based on model guidance, the ensemble spread, but are effectively adjusted to the official deterministic WFO snowfall forecast (**Figure 13**).

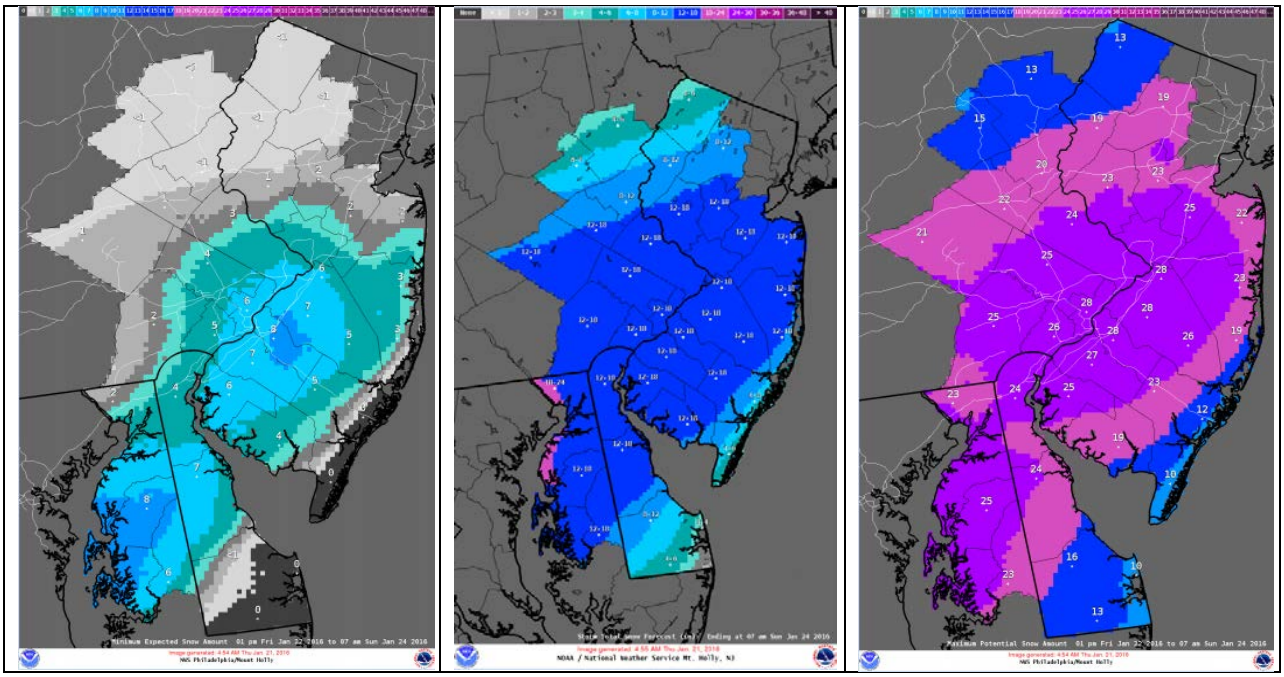


Figure 13: Minimum Snow Forecast, Most Likely Snow Forecast, and Maximum Snow Forecast (respectively) from the briefing package issued by WFO Philadelphia/Mount Holly at 9:00 a.m., January 21, 2016.

When asked about the utility of these probabilistic snowfall maps, several forecasters said they believed the public was confused by the wide spread of snowfall forecasts and perhaps too fixated on the high-end snowfall amount. One forecaster, envisioning how someone might use the information for this event stated, *"So you're forecasting 0 to 20 inches… really?"* This forecaster went on to say we need to do a better job of educating our partners on how to use this information. Similarly, some EMs and media partners indicated they found the probabilistic snowfall maps somewhat confusing and of questionable utility. Officials from the Delaware EMA stated, *"As event drew near, the 50 percent mode shifted toward the reasonable worst case scenario 90 percent. Hard to work with the public on these graphics because the public tends to focus on the high end 90 percent. Considerable education is needed for this probabilistic information to be used properly. Questionable whether this information will ever be used properly by the general public."* This is consistent with Recommendation 6 referenced earlier in this assessment related to experimental winter weather products.

It was also discovered that forecasters at WFO Philadelphia/Mount Holly employ a variety of techniques to maintain their official QPF, snow ratio, and snowfall grids in the National Digital Forecast Database. One forecaster noted rather than using QPF and Snow Ratio to derive Snowfall, some forecasters *"start with snowfall and work backwards."* The forecaster additionally noted this occasionally results in inaccurate and unrealistic snow ratio grids and that the office is *"trying to promote a more science-based approach so that grids are more internally consistent."*

WFO Philadelphia/Mount Holly has, for the most part, developed a strong working relationship with its local and state EM partners. The Service Assessment Team received

positive feedback regarding WFO Philadelphia/Mount Holly from the New Jersey State EOC, the Philadelphia OEM and the Delaware State EOC. One EM indicated Philadelphia/Mount Holly staff was well prepared for the storm stating, *"We knew the storm was coming about Monday of that week."*

The Director of the Sussex County EOC stated, *"We are very comfortable reaching out to (WFO Mt. Holly)."*

Another official with the New Jersey State EOC enthusiastically stated, *"(We have a) great relationship with Mt. Holly. You will not hear me say anything negative about the NWS. We call them so often, and we feel terrible and guilty about contacting them so much. They are patient with us. Would be impossible for us to do our jobs without them."*

The New Jersey State EOC indicated it was extremely satisfied with the services provided by WFO Philadelphia/Mount Holly; however, the EOC did note they manually create state-level maps for constituents since NWS does not provide any for New Jersey. This finding is consistent with Recommendation 5 referenced earlier in this assessment related to state-level support and State Liaison Office roles and responsibilities.

Officials with Cape May County and Atlantic County OEM expressed confusion regarding forecasts for coastal flooding during this event. They noted inconsistencies and inaccuracies. The service assessment team believes there were several contributing factors. First, since Superstorm Sandy affected northern New Jersey more than southern New Jersey and this Nor'easter did just the opposite, residents in these areas perceived impacts were under forecast in the south and over forecast in the north, when, in fact, forecasts were reasonably accurate. Residents were, in effect, anticipating impacts to be similar to Superstorm Sandy. Second, the various types of flood forecast guidance available to EM officials: (coastal flood warning [CFW], extratropical storm surge [ETSS] guidance, and official NWS IDSS briefing packages) created confusion since they were issued at different time intervals and weren't always consistent with one another. Lastly, confusion resulted when one NWS briefing package (issued at 10 a.m., Friday, January 22) changed the water level reference from what had been used in previous briefing packages. MSL datum was inadvertently used in this briefing package, but the official forecast in the CFW referenced Mean Lower Low Water (MLLW) datum. In the words of the Atlantic County OEM, *"this resulted in a small panic."* Still, the Cape May County OEM expressed general satisfaction with IDSS briefing packages from WFO Philadelphia/Mount Holly, stating, *"We routinely forward them to our 16 municipalities within the county."*

3.2.2.1 WFO Philadelphia Media Response

Overall, the media in the Philadelphia and Allentown DMAs were positive about WFO Philadelphia/Mount Holly's performance before and through the event. Media partners praised the office's AFDs and briefing packages, which expressed growing confidence that significant impacts were going to occur and that uncertainty remained where a tight northern gradient of snowfall was expected across Pennsylvania and New Jersey. The likelihood of significant coastal flooding, a major concern after the devastation of Superstorm Sandy, was also well-handled. TV media was able to communicate this threat to its viewers. As the event drew

closer, TV media noted, *"The NWS was quick to respond to the northward shift, [of the snow band]"* said one Philadelphia TV meteorologist. *"Why is the NWS doing an assessment for a storm where nothing went wrong?"* noted another TV meteorologist.

While WFO Philadelphia/Mount Holly's products and briefing packages were heavily used before and during the event, the WFO had little direct interaction with media partners. WFO Philadelphia/Mount Holly had minimal interaction via social media and only a few phone calls. NWSChat has proven to be an invaluable resource at many NWS offices across the country to coordinate consistent messaging, maintain communication, and promote situational awareness among key partners. Unfortunately, NWSChat gets relatively little usage in WFO Philadelphia/Mount Holly's service area. In fact, several TV meteorologists the service assessment team spoke with had no experience with this product. During the heavy snowfall and most significant coastal flooding, there was no communication via chat between the NWS and media. The service assessment team thinks that WFO Philadelphia/Mount Holly and its key partners would benefit greatly from increased NWSchat usage, especially during major weather events such as this one.

Beyond the scope of this weather event, there was a consensus among media partners and WFO Philadelphia/Mount Holly employees the service assessment team interviewed that the relationship between the NWS and media could be improved. NWS employees noted media partners rarely share real time reports and viewed many of the local TV meteorologists as celebrities with little time for interaction. Local media the service assessment team interviewed noted it had been years since any formal interaction had taken place with the WFO. *"It would be nice if Mt. Holly would reach out to us every year or two to share what works and to learn,"* said one TV meteorologist. *"I struggle to get real time information from the Mt. Holly office,"* said another.

Finding 12: WFO Philadelphia/Mount Holly does not fully use or promote NWSChat with its media partners, and there was almost no communication between the media and the NWS in NWSChat during the event. Additionally, the service assessment team found that the relationship between WFO Philadelphia/Mount Holly and local TV media needs to be improved.

Recommendation 12: WFOs should strengthen relationships with local media and EM partners by developing an Integrated Warning Team (IWT). IWT meetings can be in person, virtual, or a combination of both based on local needs and partner availability. NWSChat should be featured as a prime tool for communication and collaboration within the IWT. WFO Philadelphia/Mount Holly should hold an IWT meeting before the start of the 2017/2018 winter season.

3.2.2.2 WFO Philadelphia Internal Operations

An issue discovered by the assessment team relates to the evolution of social media usage and engagement at WFO Philadelphia/Mount Holly. It is reasonably well known that the Meteorologist In Charge (MIC) at WFO Philadelphia/Mount Holly at the time of this assessment had maintained an active and popular Twitter presence, and that he posted weather information to his personal account before and following recent high-impact weather events (see Hurricane/Post-Tropical Cyclone Sandy assessment). Several partners the service assessment

team spoke with indicated they actually relied more heavily on the MIC's Twitter feed than on the official WFO Philadelphia/Mount Holly feed. The assessment team strongly feels any social media posts intended to enhance the Agency's IDSS should only come through official channels.

It was also discovered that leading up to this event, the MIC or WCM represented the WFO on virtually all core partner webinars and conference calls. While this level of management support and teamwork is commendable, and may be viewed positively by forecasters from a workload standpoint, the assessment team is concerned that other staff members may not be preparing adequately for future NWS IDSS functions, including direct core partner interactions. When asked, "*Do you feel your WFO has the tools and training necessary to provide high quality Decision Support Services?*" one WFO Philadelphia/Mount Holly forecaster stated, *"No, I don't think we have the vision from management to push it,"* and that *"we need to promote more on-site IDSS."* These findings, collectively, suggest local management may not be empowering or trusting the local staff to fully engage and communicate with core partners during high-impact events.

WFO Philadelphia/Mount Holly issues a myriad of winter weather and marine headlines in the days leading up to the event. Philadelphia/Mount Holly issued storm watches and coastal flood watches late in the afternoon Wednesday, January 20, and upgraded to storm warnings and CFWs January 21 and January 22. Winter storm watches issued late in the afternoon on Wednesday, January 20, initially did not include all of the WFO Philadelphia/ Mount Holly forecast area, but were expanded north early Thursday morning to include all of the northern counties in the WFO Philadelphia/Mount Holly forecast area.

Winter weather headlines across the densely populated I-95 corridor (including Washington, D.C., Philadelphia, and New York City) were not well coordinated and appeared somewhat disjointed **(Figure 14**). Concurrent with the Winter Storm Watch in the WFO Philadelphia/Mount Holly forecast area, to the north, WFO New York, NY had a Blizzard Watch in effect across parts of the forecast area. To the south, WFO Baltimore/Washington had a Blizzard Watch in effect for much of its CWA.

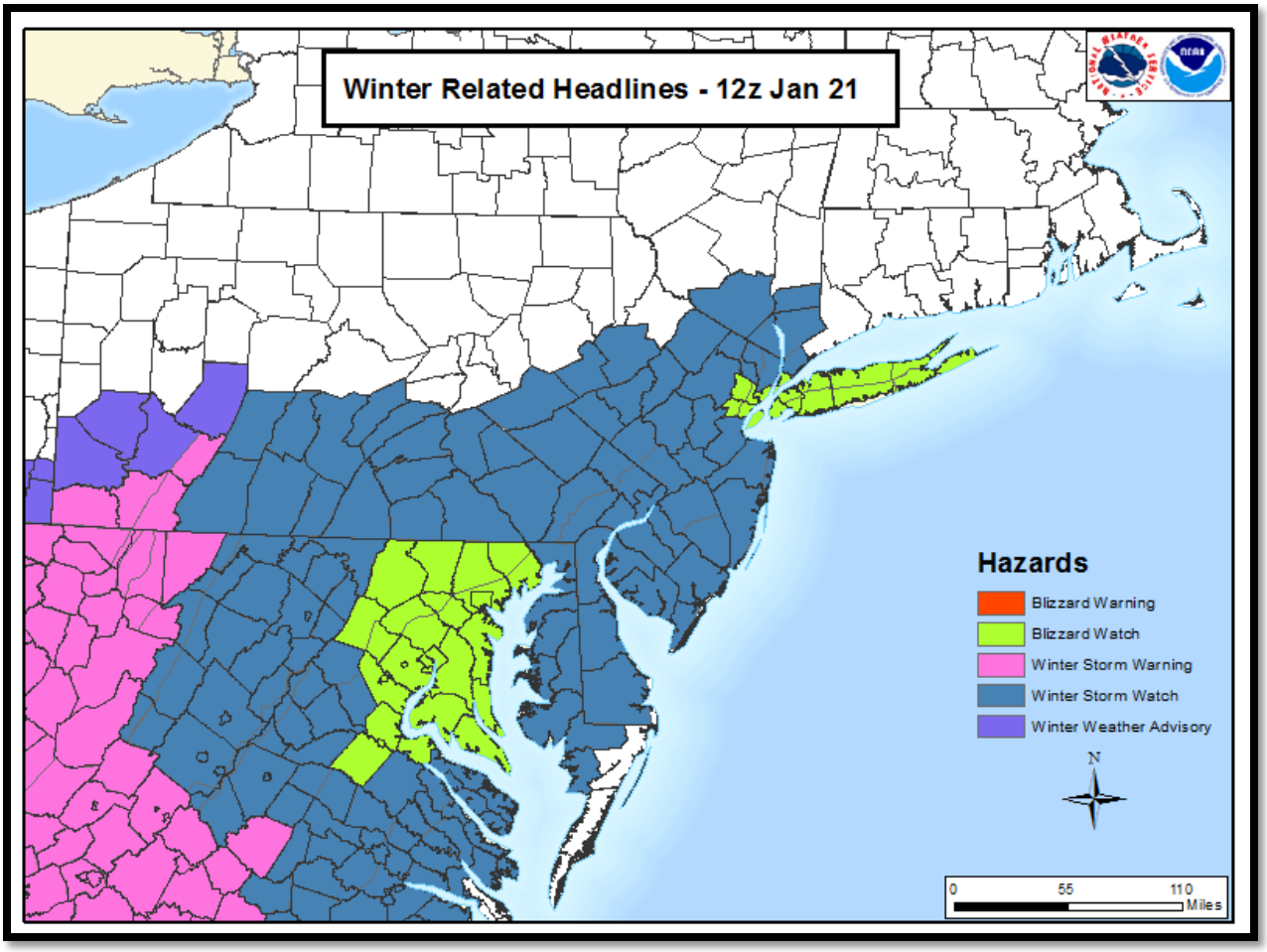


Figure 14: Valid Winter Weather headlines at 1200 UTC January 21, 2016. *Source: NOAA.*

WFO Philadelphia/Mount Holly forecasters were apprehensive about upgrading to blizzard headlines early Thursday morning for several reasons. They cited as contributing factors less-than-optimal coordination with other WFOs, low confidence that true blizzard conditions would be observed, and confusion regarding the impact of blizzard headlines versus winter storm headlines on office verification statistics. Additionally, forecasters indicated they were unclear regarding the roles that the Eastern Region (ER) ROC and the National Weather Service Operations Center (NWSOC) should play to help facilitate overall messaging and consistency during an event of this magnitude.

Finding 13: The ER ROC was not operating 24/7 in the days leading up to this event. This decision, coupled with a collaboration misunderstanding between WFO Philadelphia/Mount Holly and WFO New York, NY early Thursday morning, January 21, contributed to inconsistent winter weather headlines.

Recommendation 13: All ROCs need to have the capability for 24/7 operations leading into and during high-impact events. This capability would permit ROCs to facilitate coordination calls on all shifts, as necessary, to ensure consistent IDSS, messaging, and headlines.

WFO Philadelphia/Mount Holly recognized, as one forecaster stated, that its Winter Storm Watch was effectively "boxed in" between blizzard headlines to the north and south. It was also noted that feedback received by the office through social media during this time was "harsh," with many wondering why there were no blizzard headlines. WFO Philadelphia/Mount Holly subsequently upgraded the Winter Storm Watch to a Blizzard Watch at 10:30 a.m., Thursday morning, and eventually to a Blizzard Warning at 4:16 a.m. early Friday morning, January 22. These actions resulted in more coherent and less confusing headline messaging across the region.

WFO Philadelphia/Mount Holly repeatedly highlighted the impact of its "chronic" staff shortage on this event. At the time of this event, the office was short one lead forecaster, one journeyman forecaster, and one meteorologist intern. To ensure all shifts were filled, forecasters had to rearrange work schedules and personal lives, and some forecasters camped out at the office for up to 48 hours. The WFO Philadelphia/Mount Holly staff made significant sacrifices to support winter storm operations. One forecaster noted, *"quite a bit of advanced planning took place"* in preparation for the storm.

During this event, Philadelphia/Mount Holly occasionally used less experienced staff to develop and issue IDSS briefing packages. The staff attributed these decisions to the staff shortage. In one instance noted earlier in this section a briefing package was issued that contained inconsistent coastal flooding information. This package resulted in confusion among core partners. In general, forecasters noted inadequate staffing made it extremely difficult to keep up with the workload. The assessment team found these comments in conflict with the fact that one WFO Philadelphia/Mount Holly forecaster, who was available to work during the event, indicated he was never contacted. This forecaster specifically stated, *"I expected to be called in, but wasn't."*

3.2.3. WFO New York, NY

WFO New York, NY's area of responsibility encompasses 20 counties within the states of Connecticut, New York, and New Jersey, covering a population of 18.7 million people. Thus, its IDSS responsibilities are large and varied. WFO New York, NY was proactive in its IDSS before and during the event. The office conducts routine daily conference calls with New York City OEM as well as its aviation partners (FAA New York TRACON and New York CWSU). A week before the storm, New York City staff was already messaging the potential for a significant winter storm on these routine briefings.

During the week leading up to the storm, IDSS activities ramped up significantly for WFO New York, NY. The office disseminated 16 email briefings, took part in 28 scheduled conference calls and 31 ad-hoc phone briefings, hosted 2 webinars with EMs, media and other partners (several hundred in attendance on each call), and conducted 36 media interviews, including 3 radio interviews. Staff took part in three executive-level conference calls where elected officials (NY Governor, NJ Governor, and NYC Mayor) were on the call. Six separate briefing emails were disseminated to coastal partners, providing specific localized surge information and potential impacts. WFO New York, NY also coordinated with U.S. Geological Survey staff on wave and tide sensor deployment.

In addition, WFO New York, NY provided on-site support at the NYC OEM EOC on Friday, January 22, through Saturday night January 23. Because of WFO staffing requirements, the MIC had previously arranged for one member of ERH staff to assist in the on-site support. WFO New York, NY provided two staff members and ERH an additional staff member for the three on-site support shifts over the course of 2 days. WFO New York, NY management coordinated with its EM core partners for on-site needs and relayed that information to the ER ROC so it could coordinate with non-affected WFOs concerning the need for additional on-site staff needs. Two days prior to the storm, ER ROC identified no "outside" resources needed, so it suspended the effort because of the administrative requirements needed to bring additional staff in on temporary duty assignments before the storm. Less than 24 hours prior to the storm, the Nassau County EMA changed its mind and requested on-site support. WFO New York, NY management had to decline this request because of the coordinated scheduling process that had already occurred.

Fact: WFO New York, NY and ERH combined to provide on-site staff at NYC OEM for Friday, Saturday, and Saturday Night.

Best Practice: The ER ROC meteorologist who provided on-site support to NYC OEM beginning 7 a.m., Saturday, January 23, pre-positioned the evening before in hotel accommodations near the NYC OEM to ensure there would be no interruption in on-site support due to anticipated travel difficulties.

Fact: The Nassau County EMA initially declined an offer for on-site NWS support, and then changed its mind about 1 day prior to the storm. By that time, scheduling had been finalized and no NWS staff was available.

Finding 14: ER ROC was working with WFO New York, NY to identify resources from surrounding WFOs based on on-site IDSS support needs; however, due to limited staffing and pre-existing travel they needed 2 days to complete travel plans and have additional staffing arrive at the location.

Recommendation 14: Office staffing plans need to anticipate off-site deployment and ensure deployed staff is positioned well ahead of anticipated impacts, using additional personnel from regional deployment pools, as needed.

Partners all praised WFO New York, NY for its IDSS activities. In particular, the initial emails and phone calls to alert core partners well ahead of time were singled out as best practices by the partners. Several EMs alluded to the belief that because of the strong personal relationship they had built with WFO staff, when [NWS] says something bad is going to happen "we" (EMs) listen and, in turn, pass that same message along to constituents. This was best expressed by the Suffolk County NY EM who said, "*We are not weather people. We put out what the NWS gives us, plain and simple.*" WFO New York, NY also made it a practice to begin its briefings with a summary of changes from previous briefings, to help users track changing weather information (**Figure 15**).

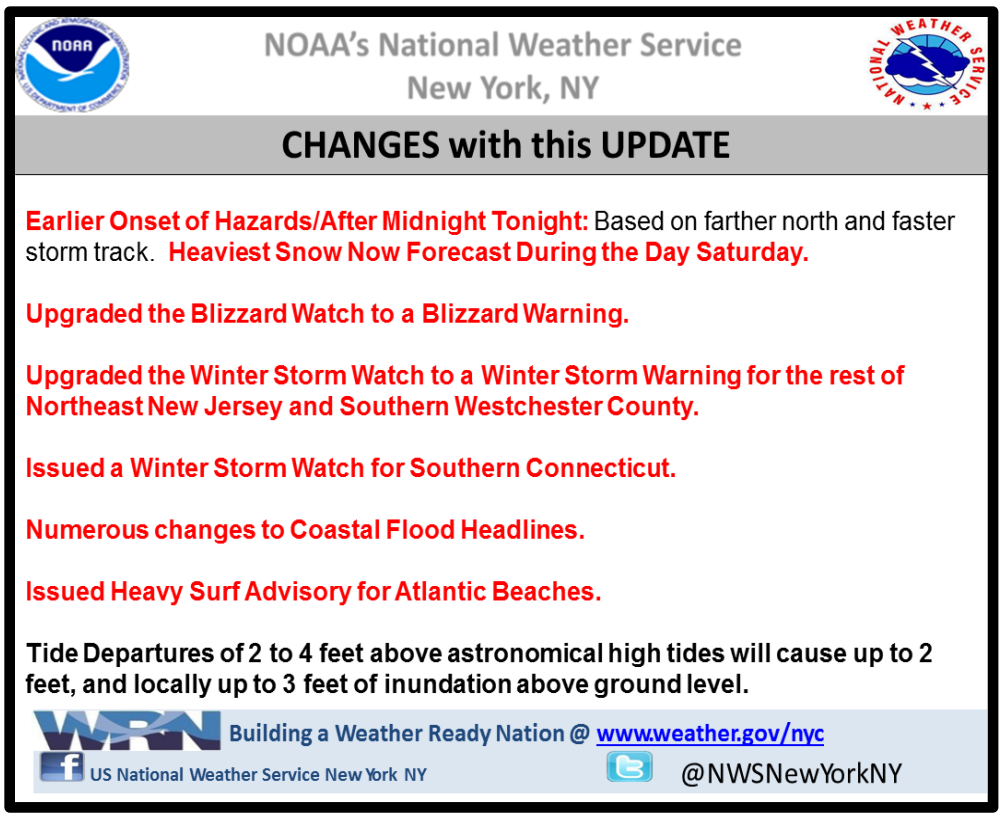


Figure 15: Example of the updated information slide included with the 12:30 p.m., January 22, briefing package from WFO New York, NY.

Best Practice: WFO New York, NY streamlined its IDSS briefings based on results and recommendations from the social science research, "*They Had the Facts, Why Didn't They Act?*" (Nurture Nature Center and RMC Research Corp., 2015) conducted after Hurricane Sandy.

All partners interviewed indicated they fully understood the messages from WFO New York, NY, especially the uncertainty with the snowfall forecasts and the northern gradient cutoff.

3.2.3.1 Media Response

The office has a strong relationship with the various television, print, and online media across its area of responsibility and made an effort to visit each group once a year. Media for the most part praised the office regarding the services received. There were a few minor comments about the desire to have a more seamless suite of maps depicting snowfall totals that were not restricted to office CWAs. The NYC television meteorologists are in a difficult situation because their media market cuts across at least three CWAs. Typically, the NYC media rely heavily on information from WFO New York, NY and WFO Philadelphia/Mount Holly. These partners noted a difference in the coastal flood information provided between the two offices and the frequency of real-time snowfall observations. One NYC TV meteorologist noted she would benefit from more communication and interaction between offices for clearer messaging, including boundaries of minor/major coastal flooding as well as merged projected snowfall maps between WFOs.

Fact: One member of the media mentioned how interesting it was to be on an informational webinar that included media and EMs. Questions asked by EMs provided the media with a new appreciation for issues on which EMs focus.

WFO New York, NY successfully leveraged social media to convey critical storm information to its followers. The office opened social media accounts in 2012. During this event, WFO New York, NY saw its largest amount of engagement to date on the social media platforms. From January 18–25, total Facebook reach was 1,214,127, with 6,016 new page followers, bringing the total to 63,170 followers. The WFO New York, NY Twitter page gained 3.3 million impressions, compared to 273,000 the previous week, with 6,600 retweets and 31,600 followers. EM briefings were shared via a link on social media posts; however, knowing few people click on links on social media, the office also included images of key slides such as its summary. During the peak of the storm, social media posting decreased as this duty is typically handled solely by the "public service" desk. That person was also responsible for upper air balloon launches and logging storm reports. Additional balloon launches and the large volume of snowfall reports pushed social media duties to a lower priority.

WFO New York, NY's usage of the NWSChat system was minimal leading up to the storm; however, during the event the office reported its highest number of NWSChat registered users. In particular, a considerable number of useful snowfall reports were relayed to the office via NWSChat. Staff recognized that NWSChat could be better used. When interviewing the media and EM community about NWSChat usage, the responses indicated that a small minority (10–15 percent) had used NWSChat before and during the event and at least one New Jersey EM had never even heard of it. Overall, NWSChat usage by WFO New York, NY is among the lowest in the East (**Figure 16**).

Fact: Just 15 percent (3 out of 20) of all EM partners interviewed indicated they used NWSChat leading up to the event, and 11 percent (2 out of 19) said they used NWSChat during the event.

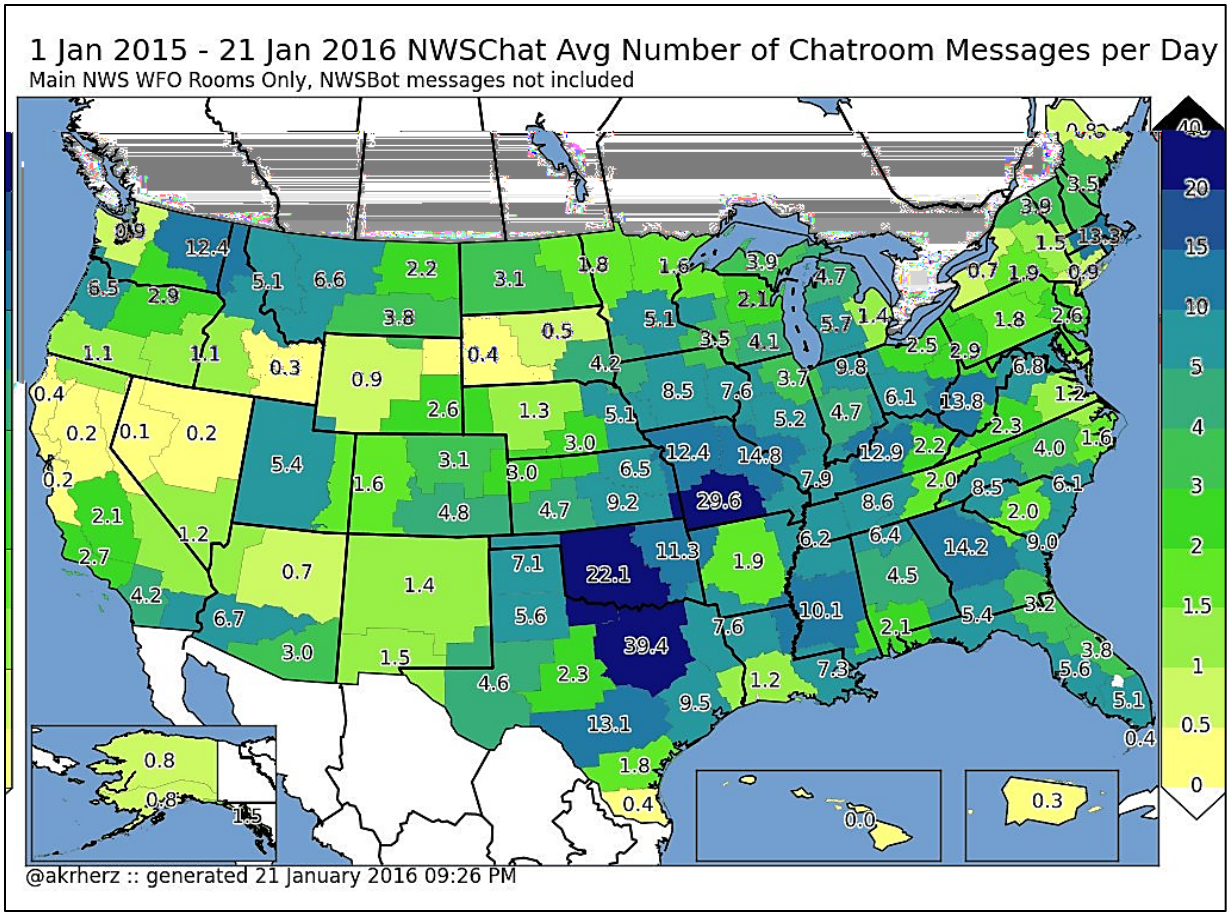


Figure 16: Average activity per primary WFO NWSChat room. *Source: Daryl Herzmann, Iowa State University.*

Finding 15: Social media duties tended to fall lower on the priority list when workload increased during the event at WFO New York, NY.

Recommendation 15: To maintain high situational awareness and ensure the office provides timely information, WFOs should include monitoring NWSChat and social media when preparing their staffing plan for high-impact events

3.2.3.2 WFO Internal Operations

Forecasters at WFO New York, NY in an effort to maintain consistent messages, purposefully were not quick to greatly increase or decrease snowfall total forecasts even though the models varied run to run. Uncertainties in the mesoscale banding and exact placement of the tight snowfall gradient on the northern edge, caused forecasters to refrain from making significant increases in forecast snowfall amounts until just before the event. This internal process was based on experience with the February 2015 winter storm. During that event, forecasters incorporated similar model run-to-run changes into the official forecasts. The resulting flip-flopping of expected snowfall confused messaging to partners and the public. The more steady approach appeared to work well. One media partner mentioned specifically the

steady rise and ramping up of snow totals helps its viewers gain confidence in the overall forecast **(Figure 17**).

Regarding uncertainty, WFO New York, NY also acted on lessons learned from the February 2015 winter storm with regard to the experimental Probabilistic Snowfall Forecasts. During that event, staff realized EM partners and the public tend to focus on only the maximum potential (90th percentile) amount when presented with snow probability maps. While WFO New York, NY posted snowfall probabilities on its website for this event, its EM partner briefings steered the discussion to the overall range and uncertainty, with an emphasis on reasonable best and worst cases. This approach provided the essential narrative to put the maximum potential snowfall into a proper context. WFO New York, NY did not post the maximum potential values on social media because that communication forum favors short messages rather than a full narrative.

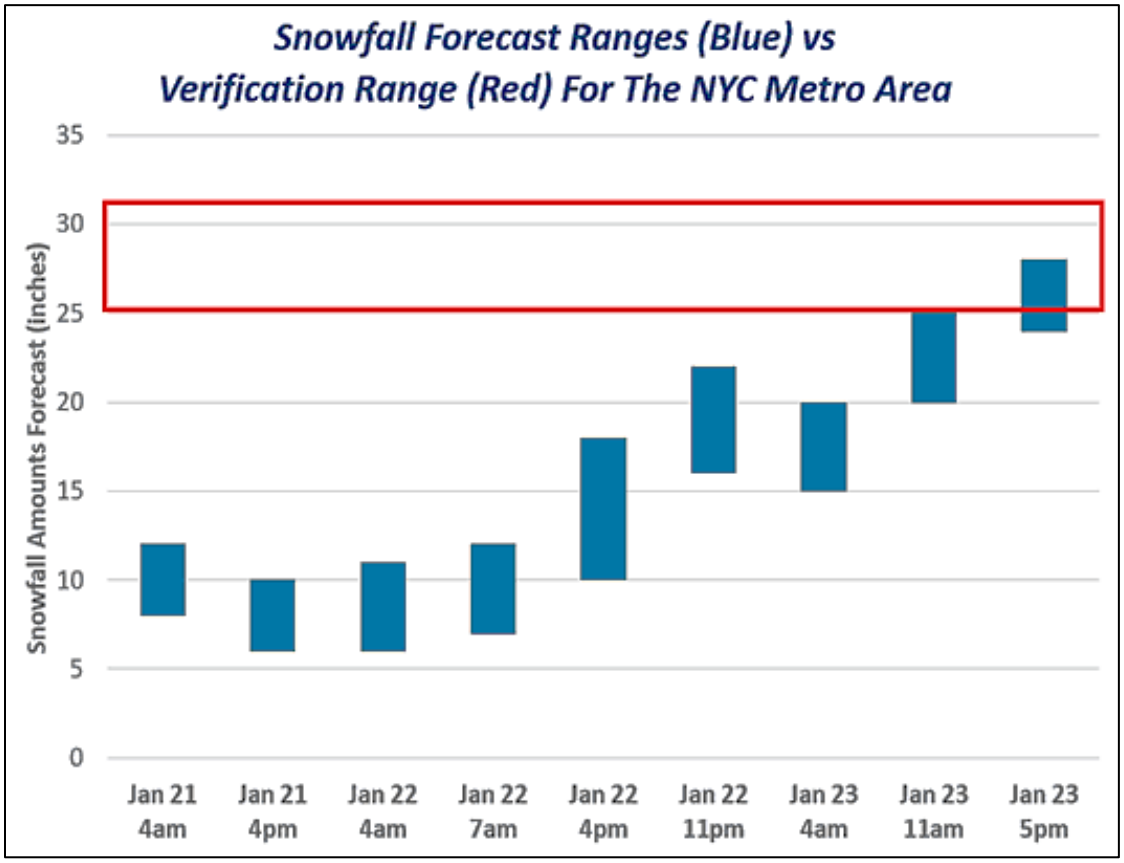


Figure 17: Snow accumulation forecasts for the NYC metro area as highlighted in the various watch/warning messages compared to the observed range of snowfall in the NYC metro area.

EM and media partners interviewed indicated forecast confidence and uncertainty was well communicated to them by WFO New York, NY. Out of 19 partner responses conducted for this assessment, 89 percent (17/19) said they used the probabilistic snowfall forecast product (**Figure 18**), while 11 percent (2/19) said they did not use this product, but were familiar with it. When pressed for feedback, the majority said they used the product internally and found it useful for their decision-making. While many just focused on the most likely snowfall amounts, they liked

being aware of maximum amounts for worst case scenario planning. Those who found the product less useful indicated they preferred a simpler product or that "*sometimes you end up with range of 2"–20", so everything is in play, so it is less useful.*" For example, NYC OEM needed to know if there would be more than 20" or less than 20". The Streets Department can handle 20", but if it's more than 20", additional resources would be required. At the end of the day, the decisions made by EM partners are deterministic in nature. For Friday afternoon and just prior to the start of the storm, the probabilistic snow maps indicated a range of <1" to 25" for the immediate NYC metro area.

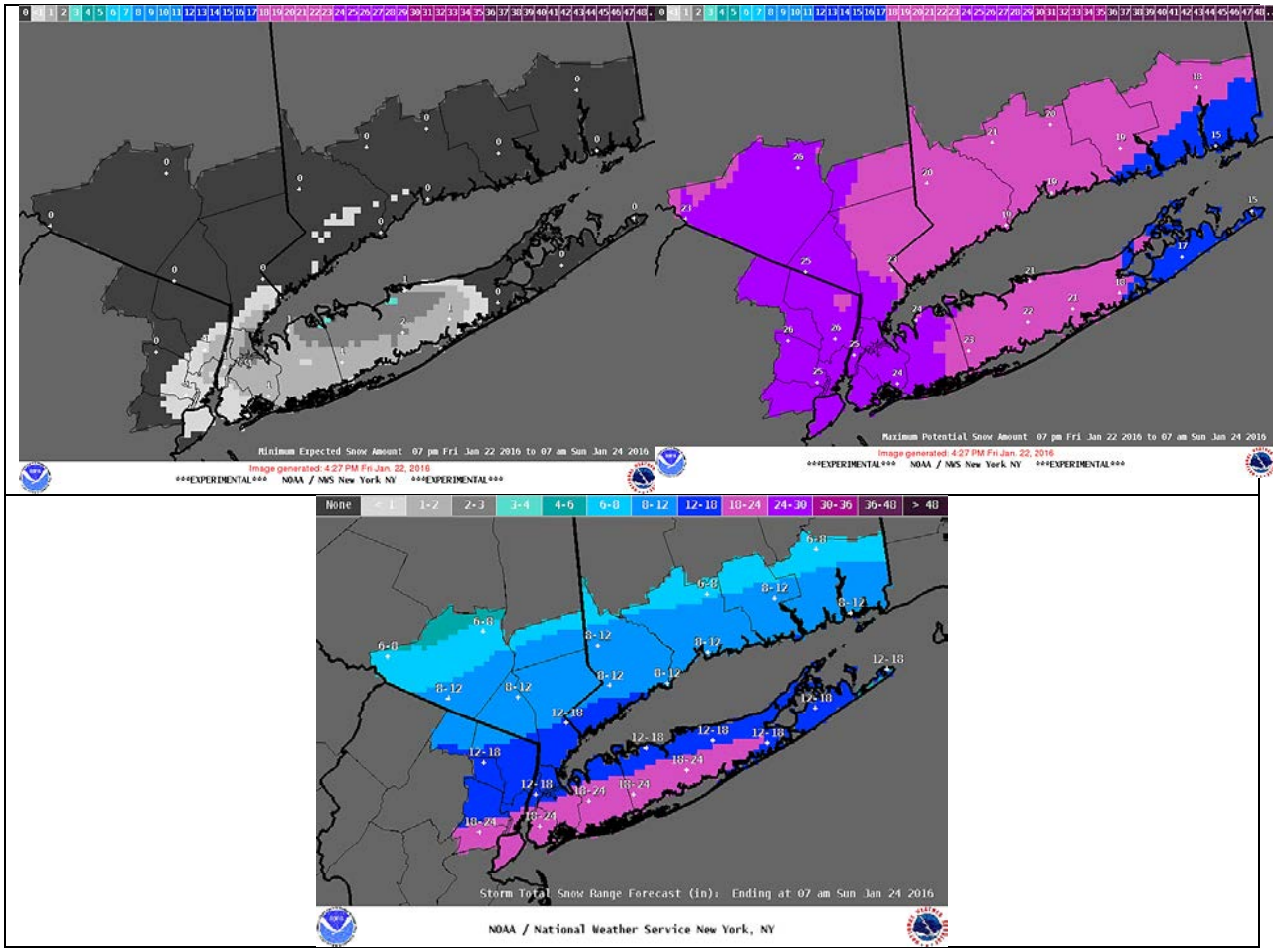


Figure 18: Minimum Snow Forecast, Most Likely Snow Forecast, and Maximum Snow Forecast (respectively) from briefing package issued by WFO New York, NY at 5:00 p.m., January 23, 2016.

Recent social science research has found the public is receptive to receiving uncertainty forecasts, though when asked to interpret a probability of precipitation forecast, the majority of the U.S. public did not know the meteorological interpretation of probability of precipitation (PoP) (Morss et al. 2008). Weather forecasts including numerical uncertainty estimates have led end users to make more optimal decisions, compared to deterministic forecasts (Joslyn and LeClerk 2012). Ramos et al. (2013) stress it is important to understand how decision makers use uncertainty information in real time, as well as to consider developing training tools for decision-making under uncertainty to increase effectiveness of probabilistic predictions to support

decisions. Thus, research shows benefits and interest in receiving probabilistic information by end users. To improve the user's understanding of probabilistic forecasts, Peachey et al. (2015) proposed that when probabilistic forecasts are presented to a new audience, there is a need to clarify the meaning of these new formats using innovative, yet simple means to communicate.

Fact: Uncertainty in snow amount forecasts was communicated via mixed use of deterministic forecast, snowfall probability maps (typically only the maximum potential and/or chance of accumulation above a certain amount), and verbalizing the uncertainty issues during briefings.

The teamwork demonstrated by WFO New York, NY was described as phenomenal by all staff members interviewed. Preparations were made to provide overnight accommodations for staff on-site and in nearby facilities on campus and all operational shifts were fully staffed during the event. Arrangements were also made to have additional ET staffing; however, the severity of the storm and resulting travel bans made it impossible for the ET to make it to the office. During the height of the storm, WFO New York, NY staff was extremely busy providing as much real-time storm information as possible. This included documenting snowfall reports, providing ad-hoc interviews to media and updating the gridded forecasts every few hours. On Sunday, January 24, as the storm was quickly winding down, NWS Director Dr. Louis Uccellini called WFO New York, NY (and other WFOs and NCEP) personally to congratulate the staff on a great job. This was a cold call direct to operations and the staff was greatly appreciative.

Finding 16: WFO New York, NY electronics staff checked all equipment in the days before the storm to ensure everything was working properly. An ET was scheduled to come into the office on Saturday in case of system failures; however, due to road conditions, he was unable to make the drive. Fortunately, no system failures occurred.

Recommendation 16: Office staffing plans should include onsite electronic and IT staff during and well ahead of major weather events

Fact: WFO New York, NY operational staff received more than 900 snowfall reports during the storm.

Finding 17: Staff found it hard to provide real-time quality control of the reports prior to issuing the snowfall reports via ECLAIRS in the local storm report (LSR) or public information statement products.

Recommendation 17: Storm Report logging software needs to have a built-in quality control aspect to allow the NWS staff to validate the report meets spatial and temporal consistency prior to public issuance.

3.3. Aviation Decision Support at Center Weather Service Units

This major winter storm provided an excellent example of how the NWS provides IDSS to the FAA and aviation community. Services were provided by forecasters at the WFOs, within the FAA ARTCC in Ronkonkoma, NY, (CWSU ZNY) and in Leesburg, VA, (CWSU ZDC) and the FAA Command Center in Warrenton VA. Because of close coordination, these NWS offices

provided consistent messages to the aviation user community. That level of coordination was an outgrowth of the relationships and improved collaboration focus between NWS and FAA staff that were strengthened by the relatively recent (2012) addition of NWS meteorologists embedded within the FAA Command Center. The Golden Triangle Initiative, a multi-year project to enhance aviation safety in the busy airspace of the Northeastern United States, may have played a role.

As part of routine conference calls held by the FAA, CWSU, and AWC NAMs information regarding the expected impacts was briefed many days in advance. For example, CWSU ZNY provides a weekend outlook briefing each Wednesday to the ARTCC Traffic Management Unit. During this event, that briefing indicated increased confidence for a significant impact to airports within the New York City and Philadelphia areas. Expected impacts included gusts of more than 40 knots and an extended period of Instrument Flight Rules conditions. By Thursday, CWSU ZDC and ZNY staffs were involved in coordination calls led by the FAA, which included airlines, during which there was considerable discussion about pre-storm flight cancellations. Airline cancellations began late Thursday and continued on Friday, well before the storm reached the region. CWSU staff also reported taking calls directly from several major airline operations personnel with questions about the expected storm. Some of these airlines also employ their own meteorologists, so CWSU staff felt hearing the same "story" from the NWS as they were hearing from their own meteorologists greatly increased confidence regarding pre-storm cancellation decisions.

On Saturday, January 23, while the storm was still ongoing, the focus of the FAA-led coordination conference calls turned to recovery actions. AWC NAMs and CWSU staff were heavily involved in these calls, providing information concerning when the snow and wind would diminish. Decisions from these calls ranged from when to increase staff at the ARTCC (staffing was minimal during the storm since the only air traffic they had were the flights traversing the ARTCC airspace at high altitudes), airport snow removal operations, and timing for resuming flights. CWSU staff indicated this was the first time they had been included in such post-storm coordination calls. CWSU ZNY also reported taking calls from one airline that was trying to time its flights leaving from Asia to arrive as soon as airports were back in operation. Because of these coordination calls, airport operations were back to near normal by late Monday, January 25, only about 24 hours after the storm ended.

One other aviation IDSS success story involves Washington Dulles International Airport. WFO Baltimore/Washington staff briefed Washington Dulles International Airport operations staff early in the week about the potential for significant snowfall accumulation. Based on that information, airport operations procured a snowcat from out-of-state to keep the instrument landing system equipment from becoming snow covered (**Figure 19**). That equipment sits 18 inches above the ground, and if it becomes snow covered, there is a lengthy (at least one week) time in which recalibration has to be done. If the airport does not have instrument landing system equipment available, it impacts the airports ability to land aircraft, leading to further disruption within the NAS. Ultimately, the airport was able to keep snow cleared from the equipment for the duration of the storm and as a result, returned to normal operations on Monday.

Figure 19: Dulles Airport tweet on January 22 highlighting the temporary acquisition of a Snowcat to assist in snow removal. *Source: Dulles International Airport Twitter feed.*

Though the storm did cause significant impacts to the NAS, with more than 11,000 flights cancelled from January 22–24, the IDSS provided by the NWS resulted in a net positive for the aviation community. There were no reports of commercial aircraft that became stuck at any airports and minimal housing of stranded passengers at the airports. Most important, airports quickly recovered after the storm, allowing the NAS to return to normal. Though specific economic impacts were not available from the airline industry, estimates were calculated based upon flight cancellations at the major airports from Washington, D.C. to Boston. The Team estimated that the aviation sector had $100 to $120 million in losses January 22–24 that were unavoidable due to the severity of the storm. [1]Historically, major winter storms of this magnitude resulted in significant aviation impacts for the following 2 to 3 days. Had this occurred, it is estimated that the aviation industry would have incurred an additional $75 to $100 million in losses during the recovery phase. The IDSS provided by the NWS and the entire weather enterprise, largely contributed to the ability of major airports and airlines to resume near-normal operations by late Monday, January 25, 2016. The service assessment team estimates that the IDSS reduced expected post storm losses by $40 to $75 million.[2]

[1] Due to proprietary nature of the information, any release of economic loss data by airlines is typically delayed by 8-12 months. Estimates were modeled based on information obtained from http://airwaysnews.com/blog/2014/10/30/masflight-dissects-flight-cancellations-and-customer-disruption/

[2] Assumption for recovery without IDSS contribution was 100% cancellations for January 25-26, and 50% cancellation rate January 27. Actual cancellation rates were about 35% on January 25, 15% January 26 and 2% on January 27

Best Practice: The strong relationships and collaboration focus built as a result of adding NWS meteorologists to the FAA Command Center, as well as the Golden Triangle Initiative, led to the successes across the NAS.

3.4 Services Associated with Travel Impacts along the Pennsylvania Turnpike

The threat for heavy snow along the turnpike was well advertised by WFO State College, PA. A "one pager" email briefing WFO State College sent to key partners on Tuesday, January 19, stated, "*Snow expected to develop on Friday and continue into Saturday.*" The briefing goes on to state that "*Significant snowfall is possible. Right now, south-central and southeastern PA appears to have the highest probability of seeing heavy snow*." as well as "*Significant travel impacts are possible.*" WFO State College began coordinating the potential for heavy snow with the Pennsylvania EMA (PEMA) on January 19. At 3:42 p.m. on Wednesday, January 23, WFO State College issued a Winter Storm Watch for the entire stretch of turnpike where travel impacts **(Figure 20**) occurred.

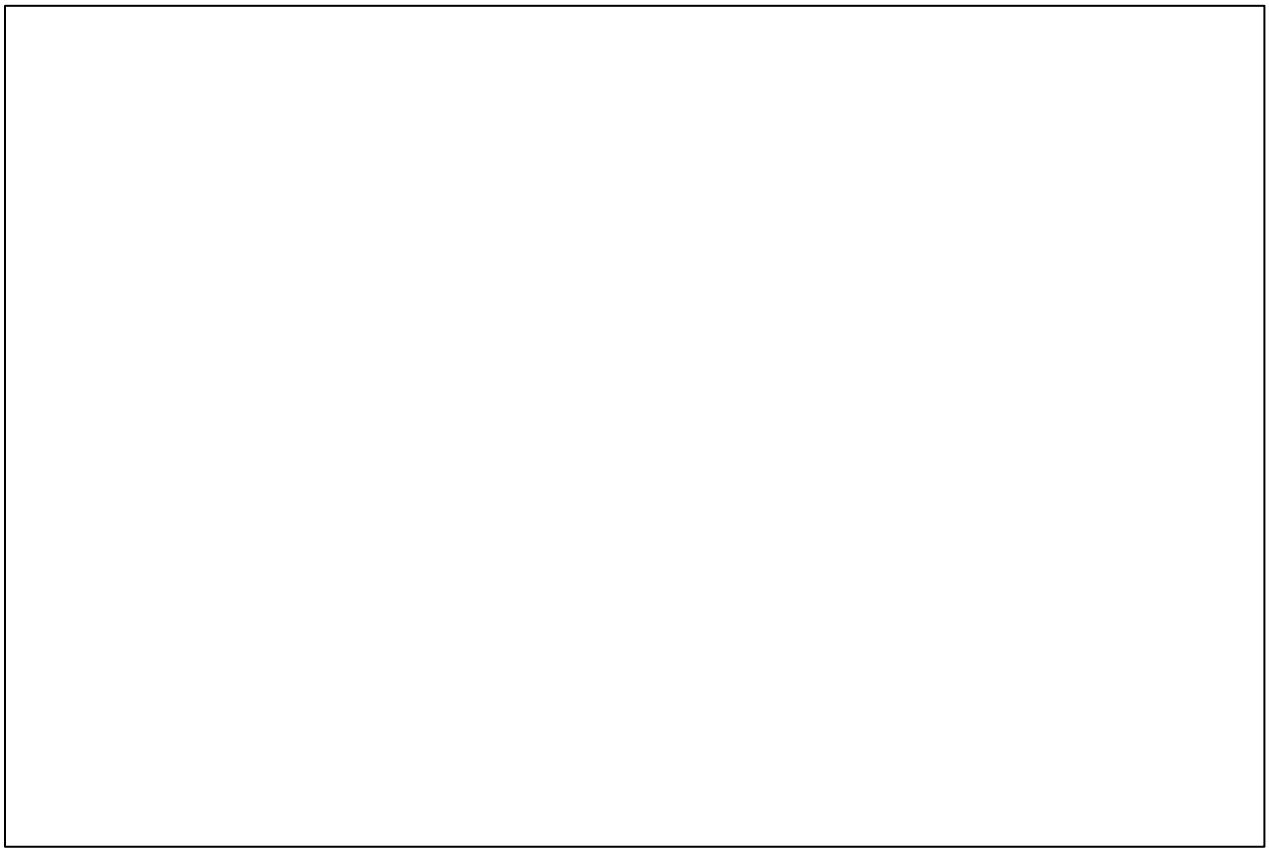


Figure 20: Motorists stranded on the Pennsylvania Turnpike on Saturday, January 23. *Source: PA Turnpike After Action Review.*

Email and conference calls continued throughout the week, each expressing greater and greater confidence that a high-impact snow event was likely. By early morning Thursday, January 21, WFO State College was forecasting 12–18 inches of snow along the turnpike **(Figure 21 left)**. WFO State College was also providing key decision makers with probabilistic

snowfall graphics indicating that up to 2 feet of snow was possible **(Figure 21 right)**. At 2:47 p.m. on January 21, the Winter Storm Watch was upgraded to a warning for the entire stretch of turnpike that was impacted. In all, WFO State College provided eight weather briefings to key federal, state and local partners. Additionally, WFO State College sent multiple email briefings and targeted text messages. PEMA described the NWS performance leading up to and through the event as "*spectacular*." The early message of a dangerous storm expected to last Friday into Saturday, affecting mainly south of the I-80 corridor with highest impacts from I-76 to PA/MD line, was "*loud and consistent*."

Fact: WFO State College forecasted heavy snow days in advance of the turnpike being impacted and provided consistent IDSS.

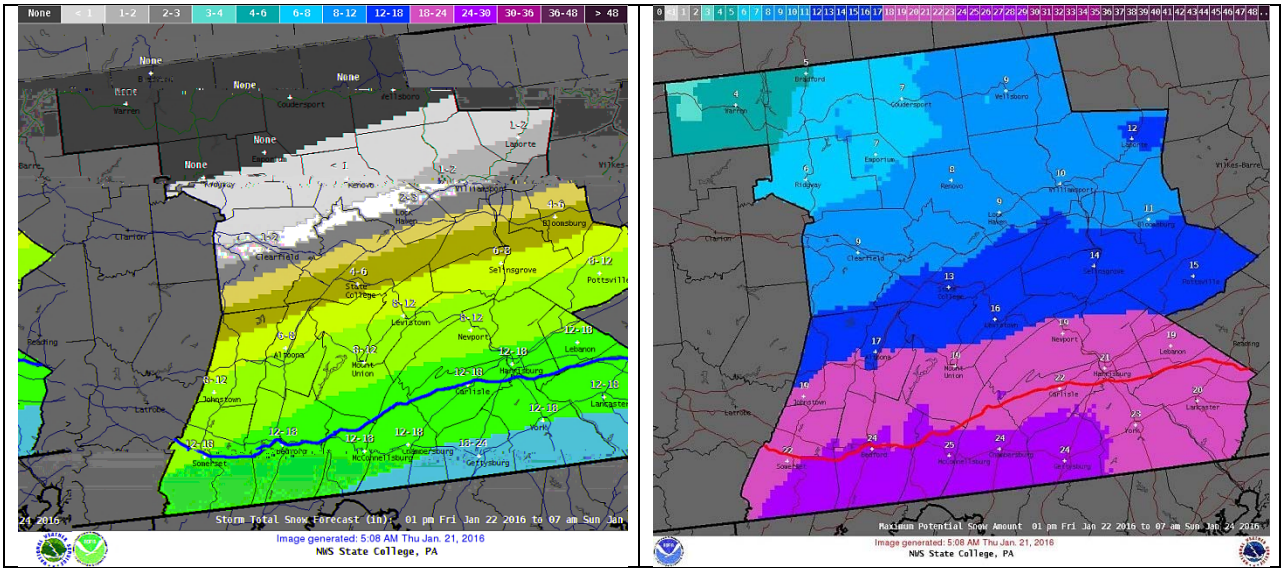


Figure 21: Deterministic (left) and 10 percent exceedance (right) snowfall guidance from WFO State College Thursday, January 21, 2016. Red line depicts approximate location of PA Turnpike. *Source: WFO State College.*

3.4.1 NWS IDSS for Transportation Agencies in Pennsylvania

On February 13–14, 2007, a major winter storm struck Pennsylvania with significant snow and ice impacts. After the storm, the Pennsylvania Governor commissioned an AAR of the state's preparedness for and response to the storm. One of the outcomes of the AAR was that Pennsylvania DOT contracted with a private weather company for weather support. This contract was in force during the January 2016 storm. The contract brought Pennsylvania DOT in line with the Pennsylvania Turnpike Commission (PTC), which has used the same private weather forecasting company for many years. PEMA, on the other hand, relies solely on the NWS for decision support related to weather.

Since August 2015, PEMA has employed a state meteorologist who, among other duties, coordinates statewide weather briefings and consolidates NWS information from the five offices that serve the state. NWS IDSS information leading up to the heavy snow was shared with all state agencies, including Pennsylvania DOT and the PTC. Both agencies took part in PEMA-led

conference calls. Pennsylvania DOT and the PTC used NWS forecasts in their decision-making process leading up to the incidents on the turnpike, but found it cumbersome to deal with information coming from five separate offices. A finding from the January 2016 PTC AAR states, "*Request that PEMA consolidate NWS reporting and provide one NWS/PEMA report*" (p. 26). This finding is in line with this team's Finding 5 in Section 3.2.1 that NWS needs consolidated state support.

Fact: The PTC was using NWS IDSS packages as part of its decision-making process leading up to the major winter storm.

3.4.2 Timing Issues associated with the Start of Snowfall Impacts

In testimony before the Pennsylvania Senate Transportation Committee and Veterans Affairs and Emergency Preparedness Committee, PTC Chairman Sean Logan stated that an earlier than expected arrival of the snowfall contributed to the significant travel impacts on the turnpike. WFO State College Winter Storm Warning for the turnpike did not go into effect until 7:00 p.m., Friday, January 22. As outlined above, snowfall impacts began earlier than 7:00 p.m. along the turnpike, which was not unexpected by WFO State College.

Beginning with IDSS briefings on the morning of Thursday, January 21, WFO State College forecasters felt heavy snow could begin in the afternoon over southern Pennsylvania. The 11:00 a.m., briefing has a bullet stating "*heavy snow likely after 5 p.m.*" referring to the far southern portion of the CWA along the turnpike. **Figure 22** is a map from that same briefing depicting the expected arrival time of heavy snow.

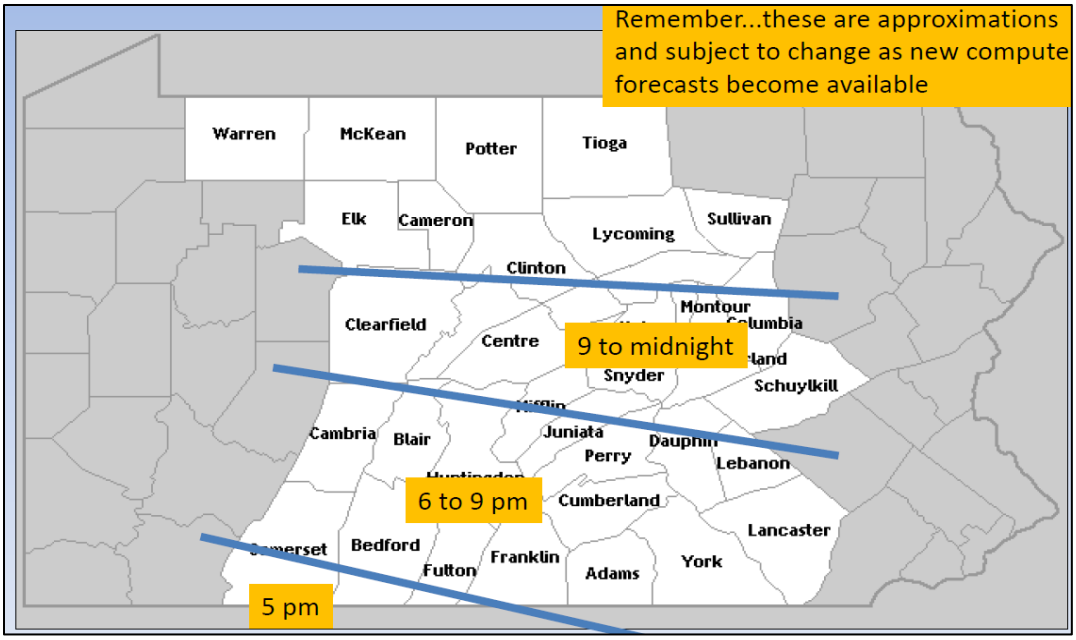


Figure 22: Heavy Snowfall Arrival Timing graphic. *Source: WFO State College Email Briefing Package.*

Fact: WFO did not begin its warning for its section of the PA Turnpike until 7 p.m., though its IDSS briefings on January 21 and 22 indicated an earlier start was possible.

As the event drew closer, WFO State College forecasters became more and more aware that the snowfall was coming in faster than expected. A short term forecast (i.e., nowcast) issued at 2:18 p.m., stated "SNOW WILL OVERSPREAD SOUTH CENTRAL PENNSYLVANIA FROM SOUTH TO NORTH THIS AFTERNOON" and "PERSONS TRAVELING THIS AFTERNOON SHOULD BE ALERT FOR A WIDE RANGE OF CONDITIONS AND ALLOW EXTRA TRAVEL TIME." In an AFD issued at 3:14 p.m., WFO State College stated "LATEST RADAR IMAGERY...SFC OBS...AND WEB CAMS SHOW LIGHT SNOW HAS MOVED INTO SRN PA...A BIT AHEAD OF SCHEDULE." Another AFD issued at 4:10 p.m., said "BANDS OF SNOW INTO SOUTHERN PA...NOWCAST OUT. SPS/S MAY BE ISSUED LATER AS NEEDED FOR THE HEAVIER BANDS." WFO State College did not move up the start time of the Winter Storm Warning to account for the expectation or the reality of impactful snow arriving before the start time of the warning.

Fact: NWSI 10-513, *WFO Winter Weather Products Specification,* Section 6.2.4 states that valid times for winter storm warning products will be the period "for which impacts will be experienced."

Finding 18: WFO State College used a beginning time of 7:00 p.m. for the Winter Storm Warning yet was consistently communicating the likelihood of heavy snow arriving earlier than 7:00 p.m. along the impacted section of PA Turnpike. After heavy snow had begun and travel was being impacted along the turnpike during the afternoon, WFO State College did not update its warning to reflect an earlier start time.

Recommendation 18a: WFOs should follow NWSI 10-513 and closely align warning valid times with the times of expected impacts.

Recommendation 18b: When credible reports of travel impacts due to weather are received before a warning has become valid the product should be re-issued to reflect current trends.

3.5 Internal Coordination/Collaboration

3.5.1 National Centers for Environmental Prediction

Of the various NCEP divisions, WPC was most heavily involved in various internal coordination and collaboration activities. In addition to the routine Winter Weather Desk duties and collaboration with field offices via the AWIPS Collaborate tool (formerly 12Planet) on expected snowfall amounts, WPC forecasters took part in conference calls with field offices and ER ROC beginning Tuesday, January 20. On the conference calls, the primary role of the WPC forecasters was to discuss their professional assessment on the overall synoptic pattern, model trends, QPF, and snowfall amounts. The conference calls also allowed WFO forecasters to discuss differing views and request modifications to the WPC snowfall forecast, thus resulting in a more collaborated end product.

3.5.2 National Weather Service Operations Center

The focus of the NWSOC before and during the event was to keep NWS and NOAA senior leadership and Congressional Affairs staff informed of internal activities and external impacts of the storm. The NWSOC has a staff of four Emergency Response Meteorologists and it is not a 24/7 operation. The small NWSOC staff was overwhelmed by the information flow, and as a result, added four volunteers from NWS HQ to assist NWSOC operations. The NWSOC was staffed roughly 16 hours a day immediately preceding and during the event.

For the light snow event on January 20, the NWSOC prepared a "Breaking News Report" to provide information on the winter weather advisory issued by WFO Baltimore/Washington along with the expected impacts to the evening commute.

For the winter storm, in addition to the regular 7:45 a.m. daily briefing for NWS leadership, the NWSOC provided supplemental briefings via webinar and conference calls throughout the week. NWSOC staff also took part in a conference call early in the week with WPC, ER ROC, and SR ROC to develop a talking-point document ensuring a consistent message on all levels of NWS (NWS HQ to WFO level) when conducting media interviews and posting social media and webpage headlines. The NOAA PCA also had been tasked to complete a similar set of talking points. Ultimately, NOAA PCA distributed a document late in the day Tuesday, January 19, 2016. However, as the forecasts evolved over the course of the week those talking points were never updated.

The NWSOC relied heavily on the ER ROC as its source of information. This information included such things as the status of watch/warning headlines, validation that WFOs were in touch with core partners, and updates on the latest snowfall totals (even though some of that information was readily available via officially transmitted products). ER ROC staff indicated that some of these requests for information already available created a burden on its ability to perform other responsibilities.

Additional overlap in duties between the NWSOC and NOAA PCA involved the weather.gov headline updates. The NOAA PCA staff handled updates during normal business hours, and the NWSOC, during the evening and weekends. During the event, several of the new NOAA PCA staff members did not have the correct permissions to update the headlines, so NWSOC staff handled the duty. NWSOC also provided backup duties to the NOAA PCA staff by posting NWS social media updates.

Finding 19: The activities of the NWSOC, ROC, and NOAA PCA did not appear to be well defined during the winter storm.

Recommendation 19: The roles and responsibilities of the NWSOC, ROCs, and PCA need to be defined clearly. This includes relating to internally coordinating consistent messaging for web headlines, social media posts, and talking points; maintaining web headlines and social media posts; and determining when and what type of information ROCs should supply to the NWSOC.

3.5.3 Eastern Region Regional Operations Center

The ER ROC operates by pulling staff from their primary positions in the Meteorological Services Division (MSD), Hydrological Services Division (HSD), Systems Operations Division (SOD), and Scientific Services Division (SSD). The ER ROC is then staffed Monday through Friday during normal operational hours at ERH. Additional coverage during evenings and weekends is handled remotely from employee's homes. This remote work means the ROC staff has no access to some of the internal collaboration systems, such as the AWIPS Collaborate tool, or the Hurricane Hotline. There is no scheduled ROC coverage during the overnight hours.

Beginning the Monday before the storm, the ER ROC created a list of possible additional staff from non-affected WFOs to bring in if IDSS on-site requests overwhelmed the combined resources of the affected WFOs and ERH. That activity ceased 2 days before the event because all known IDSS requests were covered and there was no longer time to bring in distant staff before the storm was expected to begin. The following day, Nassau County, NY EOC informed WFO New York, NY that they had changed their mind and did want on-site support. The request was rejected based on the inability to get additional staff with such short lead time. ER ROC staff expressed frustration that winter storms don't allow for such long-lead time in planning, compared to tropical systems, which often allow 5 or more days of "*knowing it's coming.*"

On Tuesday afternoon January 20, the ER ROC conducted the first coordination call with affected WFOs, WPC, and PCA. The primary purpose of this call was to coordinate talking points for use by PCA and the WFOs. This list included agreeing upon a standard social media hashtag (#winterstorm). The team held additional coordination calls the afternoons of January 21 and 22. The focus on the meteorology of the event, especially with regard to model trends and location of the heaviest snow axis, and ending with a brief coordination of watch/warning issuance decisions. Because the ROC is not staffed overnight, no coordination calls were conducted at night, and this was one factor in the less than optimal inter-office continuity with the Blizzard Watch issued January 21 (see Recommendation 13).

Throughout the event, the ER ROC staff also was responsible for keeping the NWSOC updated with the latest information on WFO actions involving core partners and storm impacts. ROC staff expressed frustration about some of the NWSOC information requests, such as the latest snowfall reports, which were already readily available via LSR and Public Information Statement products issued by affected WFOs. In addition to managing coordination calls with forecasters at affected offices and providing information to the NWOC, ROC staff had to deal with a complex flow of information with other internal and external partners. ER ROC provided DSS briefings to FEMA Regions 2 and 3, while also coordinating with the Southern Region ROC staff who were in turn briefing FEMA Region 4 (which covers North Carolina). ER ROC staff also indicated they would occasionally communicate with the NWS liaison at FEMA Headquarters. The ROC briefings to FEMA were provided on an established schedule, as were situational reports to the NWSOC. However, outside of the normal situational reports, occasional short-suspense NWSOC information requests had to be handled by the ER ROC staff causing disruptions to management of the information flow.

Finding 20: ROC staff provide information and briefings to internal and external partners within a complex framework that has not been fully defined.

Recommendation 20: Regional ROCs should work with the NWSOC and the NWS FEMA liaison to clarify roles and responsibilities of each group, identify the partner/customer groups involved, and develop a structured plan to ensure the required, yet consistent, information is provided at established time intervals that best meet the needs of all involved.

When WFO forecasters were asked about ER ROC support to their WFO, the responses were positive, but indicated that forecasters were only aware of the ROC's role in organizing conference calls. This is not surprising given the current practice of the ER ROC, which is activated only for significant events. WFO forecasters do not have many opportunities to interact with ER ROC staff. It is anticipated that this gap in understanding with WFO forecasters will be mitigated once the ROC becomes a dedicated function within ERH and ER ROC staff interact with WFOs on a routine basis.

3.5.4 Social Media

Fact: During the January 20, 2016, coordination call involving ROCs, NWSOC, PCA, and WFOs, the participants agreed on the hashtag **"#winterstorm**" for social media communications.

To date, limited social science research has been conducted on public perception of winter storm names, including use of hashtags. Lachlan et al. (2014) found that localized hashtags are more advantageous for users seeking information during a crisis, compared to non-localized or national hashtags, which are less targeted and lack actionable information. The researchers suggest government agencies "*work on providing relevant and useful information within the hashtags they promote.*" Furthermore, Rainear et al. (2016) investigated public perception of naming winter storms. Source trustworthiness, goodwill and competence was found to be greater when no winter storm name was used in an experiment, though perceived severity of a winter storm increased when a winter storm name was used. Rainear et al. (2016) calls for a need to better understand how winter storm names will be received by the public before implementing new initiatives.

When asked about using a coordinated and collaborative hashtag during winter storms, there was no strong consensus on whether the NWS should adopt the usage of a uniform hashtag strategy, and many opinions were mixed (see Appendix D). Many of the EMs, media, and NWS personnel interviewed recognized the value of using a uniform hashtag because it would allow all users to keep track of, and harvest information about the storm. Concerns were also raised as to determining what information is locally and temporally relevant when using a uniform hashtag (e.g., multiple WFOs sending messages, public from widespread area tweeting information), resulting in confusion and inconsistent messaging. Some of the interviewees noted they do not rely on social media, and do not use hashtags, but thought a uniform hashtag may better reach younger generations. One forecaster noted, "*I like the idea, but I don't agree with what they came up with. Often, if you want the greatest outreach, you have to find what's trending, and glop on to it.*" Though not specifically asked, many interviewees commented on the use of winter storm names. Some were receptive to using winter storm names and thought it could be

useful for messaging, as long as a consistent name was used to prevent public confusion. A media representative noted, "*Bottom line, if the NWS did it, it would have to be done engaged with the entire weather enterprise. Going out on their own would not be productive*."

Finding 21: Despite being coordinated, **"#winterstorm**" was used inconsistently across the WFOs interviewed leading up to and during the event.

Recommendation 21: NWS forecast offices should include targeted and actionable information within any hashtags they promote.

Finding 22: Feelings among those the team interviewed were mixed on the use of winter storm names. Those in favor thought a universally named winter storm may help the public remember the storm, and aid in consistent messaging. Those not in favor felt named winter storms were confusing, and worried they desensitize the public and take away from the effectiveness of named hurricanes. Many agreed the weather enterprise should meet together to discuss the naming of winter storms.

Recommendation 22: NWS should collaborate with representatives from the entire weather enterprise, including social scientists, the private sector, core partners, and the media to discuss how best to proceed regarding winter storm messaging.

3.6 Coastal Flooding Decision Support

In addition to the impacts from heavy snow, the pressure gradient between the low pressure center over the Atlantic and very high pressure to the north created northeasterly winds of 50 to 70 mph along the coastline. These persistent strong northeast winds resulted in a storm tide which impacted most of the East Coast from North Carolina to Massachusetts. Storm tide impacts were greatest over the lower Jersey shore and just south in the Delmarva Peninsula, which experienced 3–5 feet of surge inundation **(Figure 23**). Millions of dollars in damage occurred and dozens of water rescues were performed as a result of this storm tide.

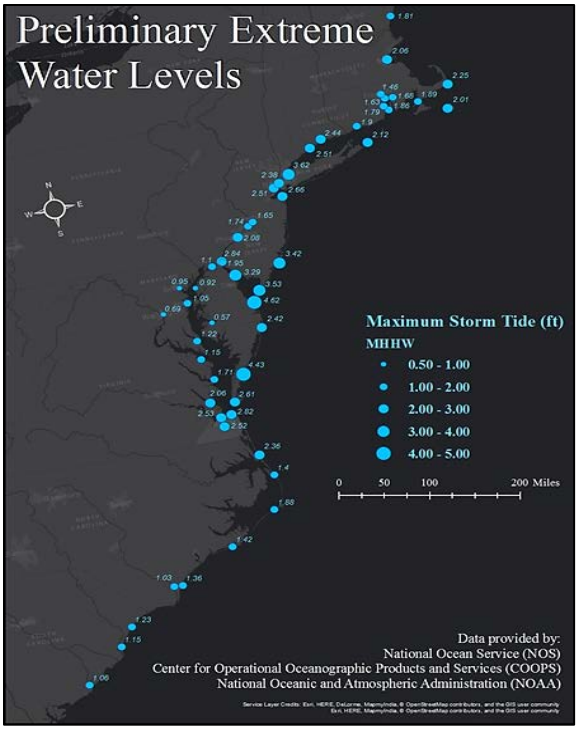


Figure 23: Maximum Storm Tide above Mean Higher High Water. *Source: NOAA COOPS.*

NWS offices in the affected area anticipated the storm surge early and clearly communicated its possibility to their partners and the public. On Monday afternoon January 18, WFO Philadelphia/Mount Holly distributed a briefing package to its core partners. The briefing highlighted the threat for moderate to major coastal flooding 6 days in advance, stating, "*With the strong onshore flow, and a full moon on Saturday, coastal flooding is currently likely, potentially moderate to major.*" WFO Baltimore/Washington and New York City followed suit Tuesday afternoon highlighting the possibility of coastal flooding over the weekend. Throughout the week all NWS offices in the affected area continued to stress the likelihood of impactful coastal flooding and expressed high confidence in its occurrence. Partners in state and local EMAs praised the advance notice and high forecast confidence as key factors in their favorable view of NWS services.

Finding 23: Core Partners appreciated the advanced notice and high degree of confidence that was communicated about coastal flood impacts.

Recommendation 23: Confidence information needs to be communicated to key partners in all hazardous weather briefings.

As the event drew closer, WFO New York, NY began sending separate briefing packages specific to the coastal flooding threat and targeted to users needing that information. WFO New York, NY also modified its staffing model to include a forecaster specifically dedicated to the coastal flooding threat. Like most coastal offices, only a few forecasters at WFO New York, NY have experience and familiarity with coastal flood forecasting. One forecaster at the office helps to train other staff on how to use the coastal forecasting and storm surge tools, as well as taking

calls to relay coastal flood impacts. Having the forecasters most familiar with storm surge forecasting dedicated to that threat allowed them to provide a consistently high level of service throughout the event.

Best Practice: WFO New York, NY distributed briefing packages to key partners specifically relating to the storm surge threat using a dedicated surge specialist.

Best Practice: WFO New York, NY has teamed up with Stevens Institute of Technology and SUNY Stony Brook to enhance surge forecast information.

Finding 24: The service assessment team found a wide range of skill and comfort among WFO forecasters with regard to handling significant coastal flooding.

Recommendation 24: WFOs in coastal areas should establish coastal flooding teams and ensure that forecasters have sufficient knowledge, skill, and ability to deliver coastal flood decision support services.

3.6.1 Challenges Communicating Risk of Storm Surge

While the likelihood of coastal flooding was well communicated leading up to the event, there were challenges in describing the likely impacts of the flooding. The first challenge relates to how the NWS warns for coastal flood inundation. The NWS has historically treated coastal flooding associated with extratropical systems differently than coastal flooding associated with tropical storms. For extratropical systems, the local WFO issues a CFW based on locally determined criteria. For tropical systems, coastal flooding/surge is part of the tropical storm or hurricane warning and is communicated through the hurricane local statements issued by the local WFO. Previous service assessments, including the Hurricane/Post-Tropical Cyclone Sandy report in released in May 2013, found this multi-tiered array of coastal flood products confusing and recommended letting coastal flood impacts, not the cause of those impacts, drive NWS forecast and warning services. In interviews, local users agreed that coastal flooding should be handled the same regardless of what's causing it. "*We would like to see NWS handle surge the same for tropical and extratropical systems*" said the Delaware State EMA.

Finding 25: Coastal flooding from tropical and non-tropical storms continues to be handled differently even though impacts are the same.

Recommendation 25: The NWS should provide a consistent, impacts-based service relating to coastal flooding.

3.6.2 Consistent, Impacts-Based Approach Needed For All Types of Surge

Beginning with the tropical season in 2015, NHC started producing storm surge watch/warning graphics for areas affected by land falling tropical systems. The storm surge watch/warning graphic is intended to highlight areas most at risk from life threatening surge flooding, currently defined as around 3 feet or more above ground level. The graphic is created

using P-Surge model output and a collaborative process between the NHC and WFOs affected by landfalling tropical systems.

As an internal prototype demonstration, and coordinated through ER and the affected WFOs, the NHC Storm Surge Unit created an ETSS Watch/Warning graphic on January 21 (**Figure 24**). Instead of using P-Surge data, the graphic was created using ETSS model guidance data from the Ocean Prediction Center. NHC and the affected WFOs then used the Graphical Forecast Editor in the same collaborative process as is used with tropical systems to create an ETSS Watch/Warning graphic. The Prototype Storm Surge Watch/Warning graphic is limited in geographic extent to areas expected to see potentially life-threatening surge, as opposed to the legacy zone-based coastal flooding products (**Figure 25**). During this event, inland areas such as Mt. Holly, NJ; Dover, DE; and large swaths of heavily populated Long Island were never under the threat for coastal flooding yet were placed in a warning because they were in a warned NWS zone.

Figure 24: Prototype ET Storm Surge Watch/Warning Graphic. *Source: NHC Storm Surge Unit.*

Finding 26: Coastal flood watches/warnings cover a much larger geographical area than will actually flood due to a reliance on NWS zone boundaries. Inland areas, such as Mt. Holly, NJ, and Dover, DE, as well as large swaths of heavily populated Long Island were never under the

threat for coastal flooding yet were placed in a warning because they were in a warned NWS zone.

Recommendation 26a: Coastal flood watches/warnings should be graphical and limited in geographic scope to the areas actually expected to experience life-threatening flooding.

Recommendation 26b: The NWS should work with FEMA on Wireless Emergency Alerts to ensure geo-targeted warnings are sent directly to mobile devices within warned areas.

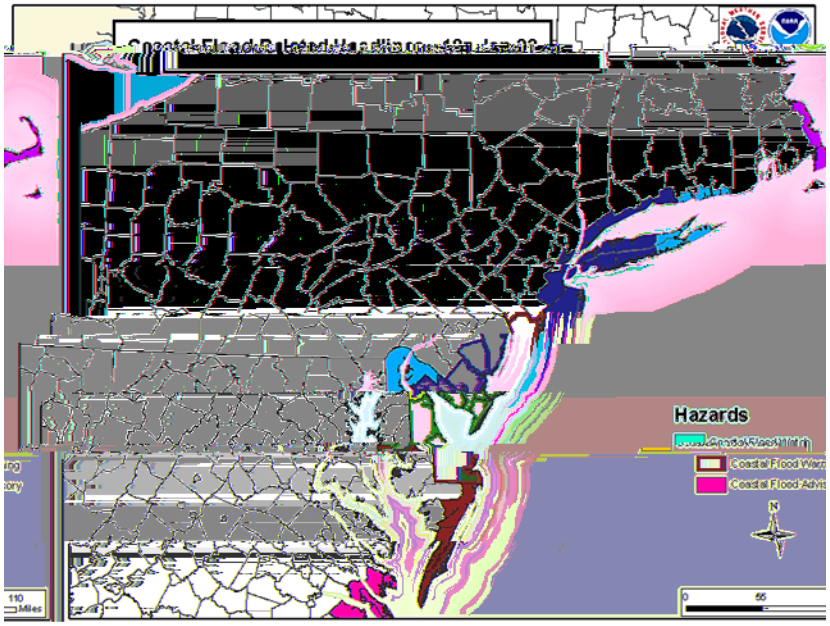


Figure 25: Valid Coastal Flooding Headlines at 1800 UTC January 23, 2016. *Source: National Weather Service.*

An even greater challenge related to coastal flood decision support, and one that was a consistent theme with core partners the team interviewed, is the critical need for flood inundation forecast information. Tremendous strides have been made since Hurricane Sandy relating to the availability of inundation graphics for IDSS ahead of and during tropical systems. Since 2014, NHC's Storm Surge Unit has been producing Experimental Potential Storm Surge Flooding maps (**see example Figure 26**). Beginning 48 hours before the expected onset of tropical storm force winds along the Atlantic or Gulf Coast, NHC produces maps detailing potential storm surge flooding. The maps are created by subtracting high-resolution elevation data from NOAA's Coastal Services Center from surge values derived from Probabilistic Hurricane Storm Surge or P-Surge ensemble model. The output represents a reasonable worst case scenario defined as a 1 in 10 chance value of being exceeded at a given location. The maps are color coded based on four levels of potential flooding above ground level:

- Up to 3 Feet
- Greater than 3 Feet
- Greater than 6 Feet
- Greater than 9 feet

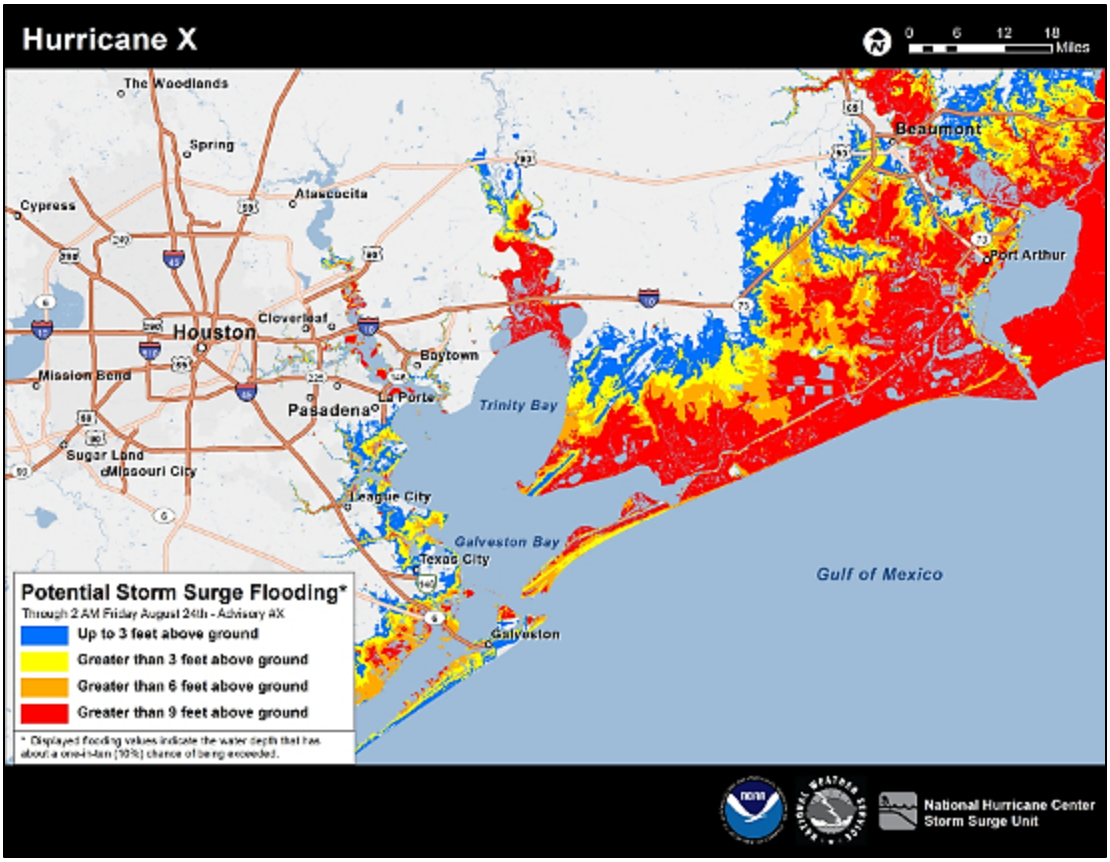


Figure 26: Potential Storm Surge Flooding map example. *Source: NHC Inundation webpage.*

For the January 2016 Storm, NHC demonstrated the capability to develop real-time extratropical inundation graphics and provide prototype ETSS watch/warning graphics. Using the same processes used to create potential storm surge flooding maps for tropical systems, but based on ETSS guidance instead of P-Surge, prototype ETSS inundation maps were created ahead of the worst of the coastal flooding associated with the storm. One limitation to this process is the deterministic nature of the ETSS guidance as opposed to the ensemble P-surge data, but for a proof of concept the process worked quite well. The ETSS inundation maps, examples of which can be seen in **Figure 27**, provided a realistic, useful depiction of the magnitude of inundation. Inundation information, including a reasonable worst case expectation, is critical for decision makers. NHC's Storm Surge Unit has demonstrated it can be made available for tropical and non-tropical storms along the Atlantic and Gulf Coast.

Best Practice: NHC produced accurate and useful maps of expected inundation ahead of the worst coastal flooding associated with the January storm. The maps were shared with the affected offices to enhance situational awareness and IDSS.

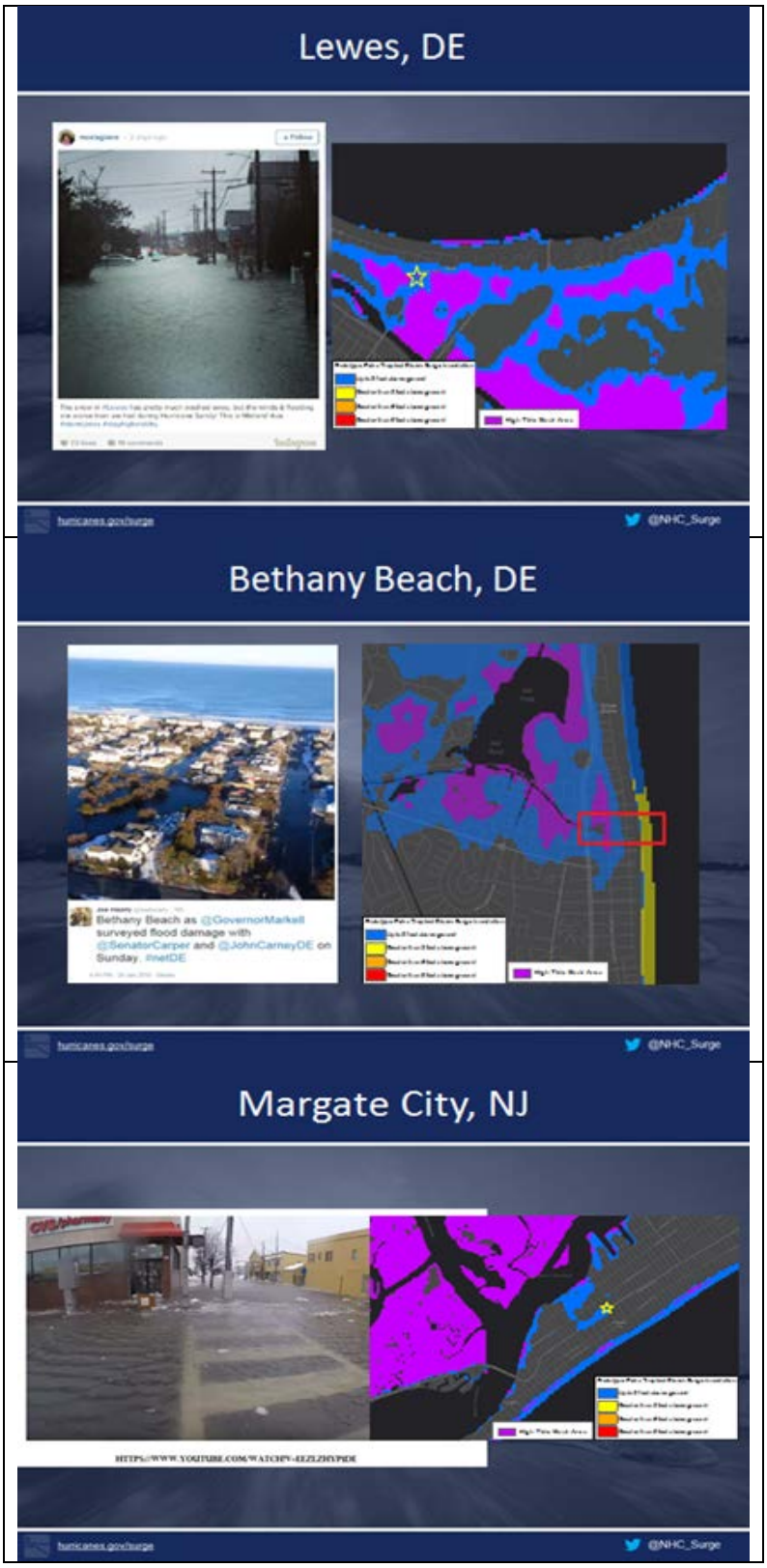


Figure 27: Prototype Storm Surge Graphics. Yellow star on graphic denotes location of corresponding photograph on left from various social media feeds. *Source: NHC Storm Surge Unit.*

Finding 27: NHC's Storm Surge Unit has delivered an effective proof of concept that Potential Storm Surge Flooding maps can be produced for extratropical systems. ETSS Inundation Maps are listed in the Storm Surge Roadmap Plan, but as an out year product awaiting a decision to proceed from the NWS.

Recommendation 27a: The NWS ETSS Team should make the decision to proceed with seeking an inundation map and recommend that this be incorporated into the NWS Annual Operating Plan.

Recommendation 27b: Funding should be made available to develop and provide extratropical surge products and services in the same manner as tropical products.

Recommendation 27c: Extratropical surge products and services should be incorporated into NOAA's Storm Surge Roadmap to reflect the decision to move forward producing extratropical operational products, along with an anticipated timeline and deliverables.

Recommendation 27d: Future ETSS Inundation maps should be made available in both graphic and GIS formats to best support decision makers along the coast.

A final issue with communicating coastal flood impacts, and one that has been addressed by recent service assessments of Sandy and Irene, is the issue of datums. Recommendation17 of the Hurricane/Post-Tropical Cyclone Sandy service assessment stated, "*The NWS should present storm surge forecasts in a single, consistent datum and adopt a unified format and language for products describing impacts from storm surge, regardless of (tropical or extratropical) origin.*" Unfortunately, for the January 2016 storm the Agency was still using different datums for inundation from tropical versus non-tropical storms.

A vertical datum is a level of reference for water levels. The NWS uses two primary vertical tidal datums for referencing coastal flooding, both of which are related to tidal cycles averaged over the 19-year tidal epoch from 1983 to 2001. Mean Lower Low Water (MLLW) is the average of the lowest low tide each day averaged over the aforementioned 19-year period. Mean Higher High Water (MHHW) is the average of the highest high tide each day over the same period. In many locations along the U.S. East Coast the difference between MLLW and MHHW is 5 feet or more with typically lower differences along the Gulf Coast.

Since the early days of the Weather Bureau providing navigational information for mariners, MLLW has been the datum of choice for referencing water levels as it is the depth datum for all nautical charts. Coastal flood and warning programs evolved using MLLW as a reference and have been doing so for decades to be consistent with navigational charts. These tidal datums are different the than the terrestrial elevation datum, the North American Vertical Datum of 1988 (NAVD88) and should not be confused. NHC, however, understanding that inundation of normally dry land is the biggest threat to life and property, uses MHHW as the reference for coastal flooding associated with tropical systems. Land above MHHW is normally above the tidal cycle, so coastal water levels exceeding MHHW is considered inundation. Referencing MHHW provides key decision makers and the public alike a much clearer picture of how much water will actually flood normally dry areas. Since the coastal flooding associated with the

January storm was non-tropical, MLLW was used as a reference in all flood forecasts, warnings and categories. As shown in the tide forecast **(Figure 28**), nearly 9 feet of coastal flooding was forecast at Lewes, DE, using MLLW. In reality, since MHHW is nearly 5 feet higher than MLLW at this point, only around 4 feet of inundation for areas above the tidal cycle was forecast. This disparity continues to provide unnecessary confusion to forecasters, partners, and the public and needs to be eliminated as soon as possible.

Finding 28: Coastal flooding associated with non-tropical storms continues to be forecast and referenced differently than flooding associated with tropical systems.

Recommendation 28: The NWS should reference all coastal flood forecasts and warnings to a single consistent datum by 2018. The assessment team strongly recommends the use of MHHW and the terrestrial elevation datum NAVD88, where necessary.

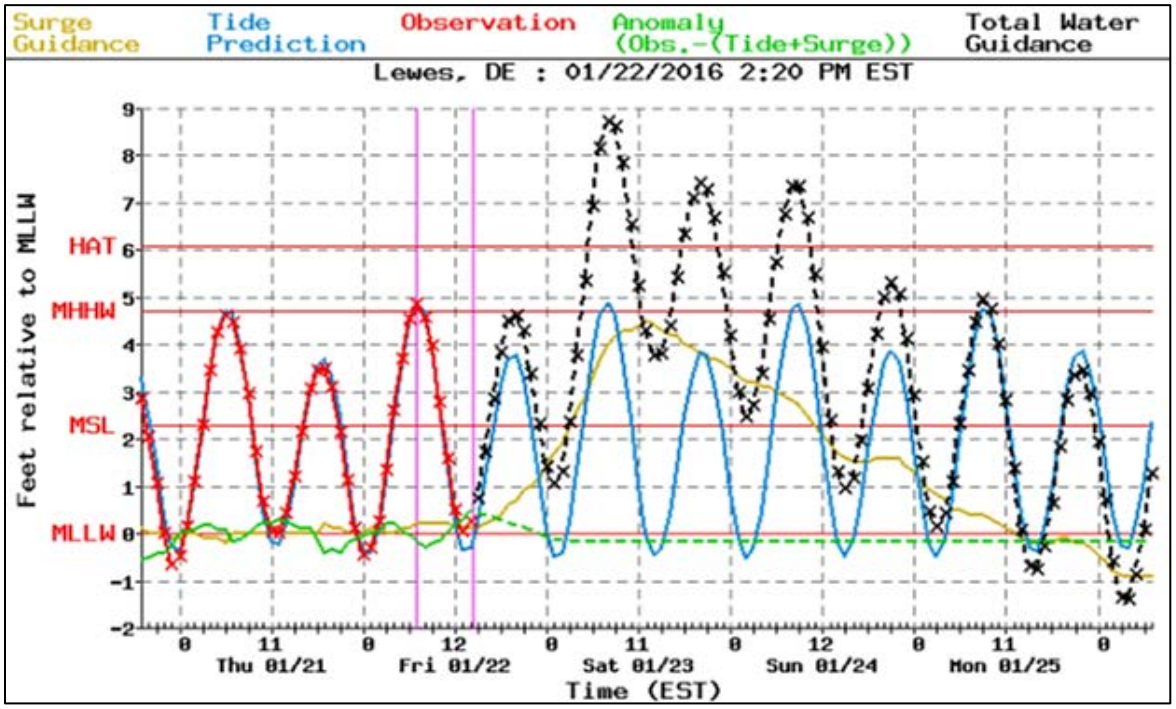


Figure 28: Tidal Forecast graph for Lewes, DE. *Source: National Weather Service.*

3.7 Snowfall Measurement Controversy

In the wake of the snowstorm, there was some controversy concerning the accuracy of snowfall measurements, particularly at the local climatological data stations at the Central Park Conservancy, Ronald Reagan Washington National Airport, and Newark Liberty International Airport. The Washington National measurement was the subject of significant local and national media interest since the total accumulation was much lower than surrounding measurements and involved observers losing the snow board. A separate assessment team evaluated the snowfall measurement issue. The report, *Evaluation of Reported Snowfall at Local Climatological Data Stations during the East Coast Blizzard of January 22–23, 2016,* is available at the following URL: http://www.nws.noaa.gov/os/assessments/pdfs/2016_blizzard_snowfall_evaluation.pdf.

Appendix A: Acronyms

AAR	After Action Review
AFD	Area Forecast Discussion
AGO	NOAA Acquisition and Grants Office
ARTCC	Air Route Traffic Control Center
ATCSCC	Air Traffic Control System Command Center
AWC	Aviation Weather Center
CFW	Coastal Flood Warning
CWA	County Warning Area
CWG	Capital Weather Gang
CWSU	Center Weather Service Unit
DMA	Designated Market Area
DOT	Department of Transportation
EOC	Emergency Operations Center
EM	Emergency Manager or Management
EMC	Environmental Modeling Center
ER	Eastern Region
ERH	Eastern Region Headquarters
ET	Electronic Technician
ETSS	Extratropical Storm Surge
FAA	Federal Aviation Administration
GFS	Global Forecast System
HWO	Hazardous Weather Outlook
IDSS	Impact-based Decision Support Services
ITO	Information Technology Officer
IWT	Integrated Warning Team
LSR	Local Storm Report
MATOC	Metropolitan Area Transportation Operations Coordination
MDOT	Maryland Department of Transportation
MEMA	Maryland Emergency Management Agency
MHHW	Mean Higher High Water
MIC	Meteorologist In Charge
MLLW	Mean Lower Low Water
NAS	National Airspace System
NCEP	National Centers for Environmental Prediction
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NWSOC	National Weather Service Operations Center
NWP	Numerical Weather Prediction
NWS	National Weather Service
OEM	Office of Emergency Management
PCA	Office of Public and Constituent Affairs
PEMA	Pennsylvania Emergency Management Agency
PTC	Pennsylvania Turnpike Commission

QPF	Quantitative Precipitation Forecast
RFC	River Forecast Center
ROC	Regional Operations Center
SPC	Storm Prediction Center
TRACON	Terminal Radar Approach Control Facility
VNG	Virginia National Guard
WFO	Weather Forecast Office
WPC	Weather Prediction Center
ZDC	CWSU Leesburg, VA
ZNY	CWSU Ronkonkoma, NY

Appendix B: Findings, Recommendations and Best Practices

Definitions

Best Practice: A best practice is an innovative, successful action taken to accomplish the NWS Mission that is worthy of use and can be used in other parts of the Agency. Best practices contain factual information and not opinions.

Fact: A fact is a discussion which flows from earlier narrative, usually immediately before the fact, that highlights and complements something important learned from the assessment and does not necessarily lead to a finding. A fact often reiterates significant ideas/points of previous narrative.

Finding: A finding is a statement that describes something important learned from the assessment. Findings are numbered in ascending order. They should be clear and concise with no opinions, repetition, or unrelated information and lead directly to a recommendation.

Recommendation: A recommendation is a specific course of action, directly related to a finding that will lead to improved NWS operations and/or services. Each recommendation is numbered with the same number as the associated finding. Recommendations should be written in terse, declarative sentences and be practical, specific, achievable, trackable, and closeable within a reasonable amount of time. All recommendations are vetted through the NWS Mission Delivery Council.

Findings, Recommendations

Finding 1: A preliminary subjective and cursory objective analysis of NAM runs both with and without supplemental upper air data provided by EMC showed minimal impacts from the extra data. Snowfall forecasts showed some small improvements for some sites, but other sites actually showed degradation. On average, snowfall forecasts based on verification for several cities showed a very small improvement with model runs that included supplemental upper air data.

Recommendation 1: NCEP should work to undertake a more scientifically-rigorous analysis of the impact of extra sounding data on NWP guidance for synoptic systems such as the January 2016 blizzard and other significant storms. Such analyses should provide requirements for supplemental sounding data and drive development of a supplemental sounding protocol if such data are shown to be beneficial.

Finding 2: WPC does not have an onsite NOAA PCA staffer, unlike centers with similar missions such as SPC and NHC. Additionally, collaboration between WPC and NOAA PCA for the blizzard was ad hoc and minimally effective.

Recommendation 2: National Weather Service Headquarters should work with WPC management to perform a workload analysis for current and future public affairs needs at WPC and develop a plan to provide public affairs support to WPC as necessary.

Finding 3: The routinely produced Day 2–4 impact outlook maps, and the specially-created Day 5–7 impact outlook maps for this event were created specifically for FAA Command Center daily conference call briefings. These briefings may have remote participation from CWSU staff, FAA Air Route Traffic Control Centers (ARTCC) Traffic Management Unit, and Terminal Radar Approach Control Facility (TRACON) staff. The maps are not otherwise available to or coordinated with CWSU staff, though they could help CWSU staff create briefings for ARTCC.

Recommendation 3: AWC should make all impact graphic outlook maps available to CWSUs and WFOs to ensure consistent messaging is provided by all NWS entities (AWC, CWSUs, and WFOs) interfacing with FAA offices: ATCSCC, ARTCCs, TRACONs.

Finding 4: Senior MEMA personnel strongly indicated that onsite IDSS was crucial to their success.

Recommendation 4: Ensure NWS National IDSS Training Plan addresses all components necessary for the consistent provision of on-site support, leveraging the IDSS Professional Development Series training.

Finding 5: As SLO for Maryland, WFO Baltimore/Washington coordinates statewide briefings and graphics utilizing forecast products and services from the other WFOs serving the state. Maryland officials stated a strong need for statewide services, including graphics and products.

Recommendation 5: NWS Directives should provide policy and procedural guidance to ensure a consistent level of basic statewide decision support, including briefings, web services, and graphics for state officials.

Finding 6: While WFOs (including WFO Baltimore/Washington) correctly followed the experimental product process outlined in NWSI 10-102, *New or Enhanced Products and Services*, the comments of partners and NWS forecasters raised concerns about the physical and social science robustness of these products. Many experimental techniques and services in other NWS service programs are vetted via a testbed or proving ground experiment prior to implementation; however, no mechanism currently exists for such testing of WFO winter weather products. WFO personnel specifically emphasized that a testbed/proving ground for these winter weather services could have reduced operational problems that were noted with these services during the blizzard.

Recommendation 6: NWS Headquarters should review and potentially amend NWSI 10-102 to take advantage of NOAA testbeds and proving grounds for robust vetting and testing of experimental products and services, particularly those that involve significant physical and/or social science advances. This review should include examining the potential involvement of

partners (e.g., EMs, transportation officials) in testbed/proving ground experiments related to new services.

Finding 7: The Winter Weather Advisory issued a few hours before rush hour on January 20, 2016 provided insufficient lead time for Washington, D.C. area transportation officials to pre-treat roads and mobilize resources.

Recommendation 7: All WFOs should work closely with DOT officials to ensure adequate understanding of unique decision points, lead time thresholds, and communication strategies, with information documented via the Impacts Catalog within the Integrated Real-time Impact Services or other impacts catalog systems. Low probability/high-impact winter weather scenarios need to be included in Impacts Catalogs.

Finding 8: Emergency employee lodging and food was critical in sustaining operations.

Recommendation 8: NWS WFOs Severe Weather and Winter Weather Operations Plans should detail procurement procedures for employee lodging and food as specified within NWSI 1-208, *Delegation of Authority for Food/Lodging Expenditures in Advance of or during Major Weather Emergencies or Disasters.*

Finding 9: The WFO Baltimore/Washington ITO and Electronic Systems Analysts requested VPN access and were denied by ERH due to IT security concerns. Thus, they did not have the ability to access critical WFO systems remotely.

Recommendation 9: ERH leadership should allocate sufficient resources to ensure infrastructure supports VPN access to the regional WAN/LAN (NOAA8882) and develop a policy that supports VPN functionality after the requirements are defined.

Finding 10: The contract for snow removal at WFO Baltimore/Washington was not finalized until the day before the blizzard and, likely because of unfamiliarity with the facility, the contractor did not perform the required work to expectations. As a result, the WFO had to take extraordinary measures to transport staff members to and from the facility. A VNG vehicle became stuck, stranding WFO staff in the vehicle for 45 minutes; both management and staff members stated they felt potentially unsafe conditions resulted.

Recommendation 10: Field offices that manage local contracts, such as snow removal, should work with their Regional Administrative Division to ensure contracts are submitted to NOAA Acquisition and Grants Office (AGO) within the prescribed lead time per AGO/CAMS Section 1307.1, Appendix C.

Finding 11: Briefing packages prepared by WFO Philadelphia/Mount Holly are posted to the office web page. On the final page of each briefing package, WFO Philadelphia/Mount Holly explicitly includes the statement, "*if you wish to be notified when a briefing package is issued, you can follow us on social media where we post the notice*." Therefore, briefing packages can be viewed by both core partners and the public.

Recommendation 11: The NWS should decide whether high-level IDSS briefing packages containing detailed impact, mitigation, confidence, and probabilistic information (such as probabilistic storm total snowfall graphics) should be exclusively designed for core partners or whether this information should also be shared with the general public.

Finding 12: WFO Philadelphia/Mount Holly does not fully use or promote NWSChat with its media partners, and there was almost no communication between the media and the NWS in NWSChat during the event. Additionally, the service assessment team found that the relationship between WFO Philadelphia/Mount Holly and local TV media needs to be improved.

Recommendation 12: WFOs should strengthen relationships with local media and EM partners by developing an Integrated Warning Team (IWT). IWT meetings can be in person, virtual, or a combination of both based on local needs and partner availability. NWSChat should be featured as a prime tool for communication and collaboration within the IWT. WFO Philadelphia/Mount Holly should hold an IWT meeting before the start of the 2017/2018 winter season.

Finding 13: The ER ROC was not operating 24/7 in the days leading up to this event. This decision, coupled with a collaboration misunderstanding between WFO Philadelphia/Mount Holly and WFO New York, NY early Thursday morning, January 21, contributed to inconsistent winter weather headlines.

Recommendation 13: All ROCs need to have the capability for 24/7 operations leading into and during high-impact events. This capability would permit ROCs to facilitate coordination calls on all shifts, as necessary, to ensure consistent IDSS, messaging, and headlines.

Finding 14: ER ROC was working with WFO New York, NY to identify resources from surrounding WFOs based on on-site IDSS support needs; however, due to limited staffing and pre-existing travel they needed 2 days to complete travel plans and have additional staffing arrive at the location.

Recommendation 14: Office staffing plans need to anticipate off-site deployment and ensure deployed staff is positioned well ahead of anticipated impacts, using additional personnel from regional deployment pools, as needed.

Finding 15: WFO New York, NY social media duties tended to fall lower on the priority list when workload increased during the event, at WFO New York, NY.

Recommendation 15: To maintain high situational awareness and ensure the office provides timely information, WFOs should include monitoring NWSChat and social media when preparing their staffing plan for high-impact events.

Finding 16: WFO New York, NY electronics staff checked all equipment in the days before the storm to ensure everything was working properly. An ET was scheduled to come into the office on Saturday in case of system failures; however, due to road conditions, he was unable to make the drive. Fortunately, no system failures occurred.

Recommendation 16: Office staffing plans should include onsite electronic and IT staff during and well ahead of major weather events

Finding 17: Staff found it hard to provide real-time quality control of the reports prior to issuing the snowfall reports via ECLAIRS in the local storm report (LSR) or public information statement products.

Recommendation 17: Storm Report logging software needs to have a built-in quality control aspect to allow the NWS staff to validate the report meets spatial and temporal consistency prior to public issuance.

Finding 18: WFO State College used a beginning time of 7:00 p.m. for the Winter Storm Warning yet was consistently communicating the likelihood of heavy snow arriving earlier than 7:00 p.m. along the impacted section of the Pennsylvania Turnpike. After heavy snow had begun and travel was being impacted along the turnpike during the afternoon, WFO State College did not update its warning to reflect an earlier start time.

Recommendation 18a: WFOs should follow NWSI 10-513 and closely align warning valid times with the times of expected impacts.

Recommendation 18b: When credible reports of travel impacts due to weather are received before a warning has become valid the product should be re-issued to reflect current trends.

Finding 19: The activities of the NWSOC, ROC, and NOAA PCA did not appear to be well defined during the winter storm.

Recommendation 19: The roles and responsibilities of the NWSOC, ROCs, and PCA need to be defined clearly. This includes relating to internally coordinating consistent messaging for web headlines, social media posts, and talking points; maintaining web headlines and social media posts; and determining when and what type of information ROCs should supply to the NWSOC.

Finding 20: ROC staff provide information and briefings to internal and external partners within a complex framework that has not been fully defined.

Recommendation 20: Regional ROCs should work with the NWSOC and the NWS FEMA liaison to clarify roles and responsibilities of each group, identify the partner/customer groups involved, and develop a structured plan to ensure the required, yet consistent, information is provided at established time intervals that best meet the needs of all involved.

Finding 21: Despite being coordinated, **"#winterstorm**" was used inconsistently across the WFOs interviewed leading up to and during the event.

Recommendation 21: NWS forecast offices should include targeted and actionable information within any hashtags they promote.

Finding 22: Feelings among those the team interviewed were mixed on the use of winter storm names. Those in favor thought a universally named winter storm may help the public remember the storm, and aid in consistent messaging. Those not in favor felt named winter storms were confusing, and worried they desensitize the public and take away from the effectiveness of named hurricanes. Many agreed the weather enterprise should meet together to discuss the naming of winter storms.

Recommendation 22: NWS should collaborate with representatives from the entire weather enterprise, including social scientists, the private sector, core partners, and the media to discuss how best to proceed regarding winter storm messaging.

Finding 23: Core Partners appreciated the advanced notice and high degree of confidence that was communicated about coastal flood impacts.

Recommendation 23: Confidence information needs to be communicated to key partners in all hazardous weather briefings.

Finding 24: The service assessment team found a wide range of skill and comfort among WFO forecasters with regard to handling significant coastal flooding.

Recommendation 24: WFOs in coastal areas should establish coastal flooding teams and ensure that forecasters have sufficient knowledge, skill, and ability to deliver coastal flood decision support services.

Finding 25: Coastal flooding from tropical and non-tropical storms continues to be handled differently even though impacts are the same.

Recommendation 25: The NWS should provide a consistent, impacts-based service relating to coastal flooding.

Finding 26: Coastal flood watches/warnings cover a much larger geographical area than will actually flood due to a reliance on NWS zone boundaries. Inland areas, such as Mt. Holly, NJ, and Dover, DE, as well as large swaths of heavily populated Long Island were never under the threat for coastal flooding yet were placed in a warning because they were in a warned NWS zone.

Recommendation 26a: Coastal flood watches/warnings should be graphical and limited in geographic scope to the areas actually expected to experience life-threatening flooding.

Recommendation 26b: The NWS should work with FEMA on Wireless Emergency Alerts to ensure geo-targeted warnings are sent directly to mobile devices within warned areas.

Finding 27: NHC's Storm Surge Unit has delivered an effective proof of concept that Potential Storm Surge Flooding maps can be produced for extratropical systems. ETSS Inundation Maps are listed in the Storm Surge Roadmap Plan, but as an out year product awaiting a decision to proceed from the NWS.

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Recommendation 28: The NWS should reference all coastal flood forecasts and warnings to a single consistent datum by 2018. The assessment team strongly recommends the use of MHHW and the terrestrial elevation datum NAVD88, where necessary.

Best Practices

Best Practice: On Thursday, January 21, a press conference was given by NWS Director Dr. Louis Uccellini. A member of the Long Island print media noted the Director's press conference was useful in providing a big picture understanding of what was happening, especially in identifying the sharp northern edge of snowfall in the region.

Best Practice: WFO Baltimore/Washington promoted the blizzard 5 days in advance via Facebook and Twitter, maintaining a consistent message with other outlook services.

Best Practice: WFO Baltimore/Washington annually hosts a Winter NWS/Media Workshop, which helps the NWS share updates about new products and services as well as information about new science and forecast techniques to the media meteorologists. The workshop also helps develop collaborative relationships that can be leveraged during high-impact weather events.

Best Practice: When providing IDSS briefing packages multiple times leading into a high-impact event, explicitly referencing "changes from the previous briefing" is an effective way to highlight subtle but potentially important changes in the forecast to core partners.

Best Practice: The ER ROC meteorologist who provided on-site support to NYC OEM beginning 7 a.m., Saturday, January 23, pre-positioned the evening before in hotel accommodations near the NYC OEM to ensure there would be no interruption in on-site support due to anticipated travel difficulties.

Best Practice: WFO New York, NY streamlined its IDSS briefings based on results and recommendations from the social science research, "*They Had the Facts, Why Didn't They Act?*" (Nurture Nature Center and RMC Research Corp., 2015) conducted after Hurricane Sandy.

Best Practice: The strong relationships and collaboration focus built as a result of adding NWS meteorologists to the FAA Command Center, as well as the Golden Triangle Initiative, led to the successes across the NAS.

Best Practice: WFO New York, NY distributed briefing packages to key partners specifically relating to the storm surge threat using a dedicated surge specialist.

Best Practice: WFO New York, NY has teamed up with Stevens Institute of Technology and SUNY Stony Brook to enhance surge forecast information.

Best Practice: NHC produced accurate and useful maps of expected inundation ahead of the worst coastal flooding associated with the January storm. The maps were shared with the affected offices to enhance situational awareness and IDSS.

Appendix C: References

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Appendix D: Survey results

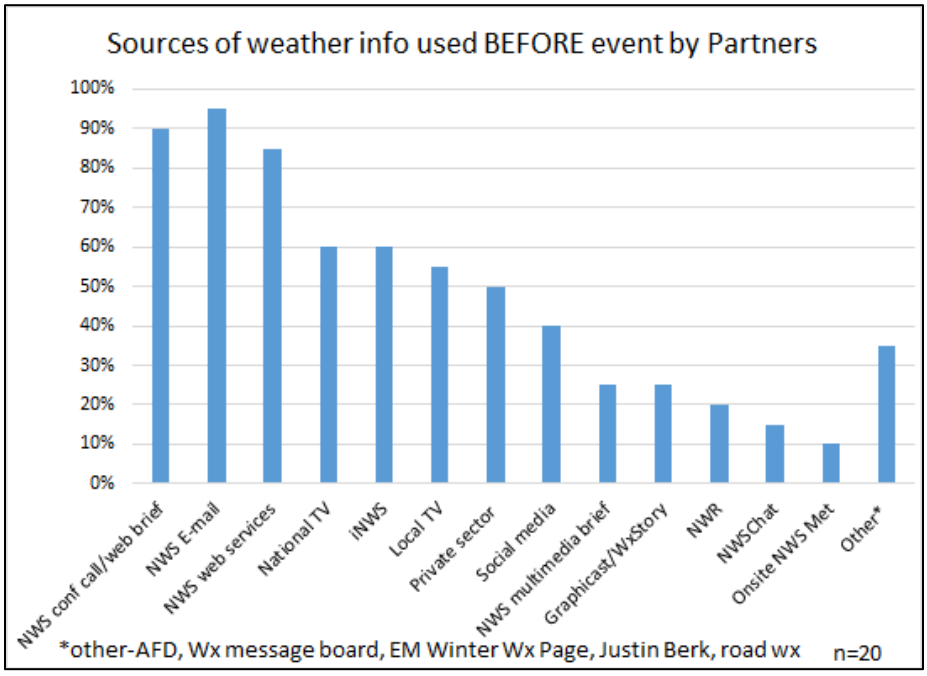

Figure 29: Partner responses to the question, "What sources for weather information were used leading up to the event?"

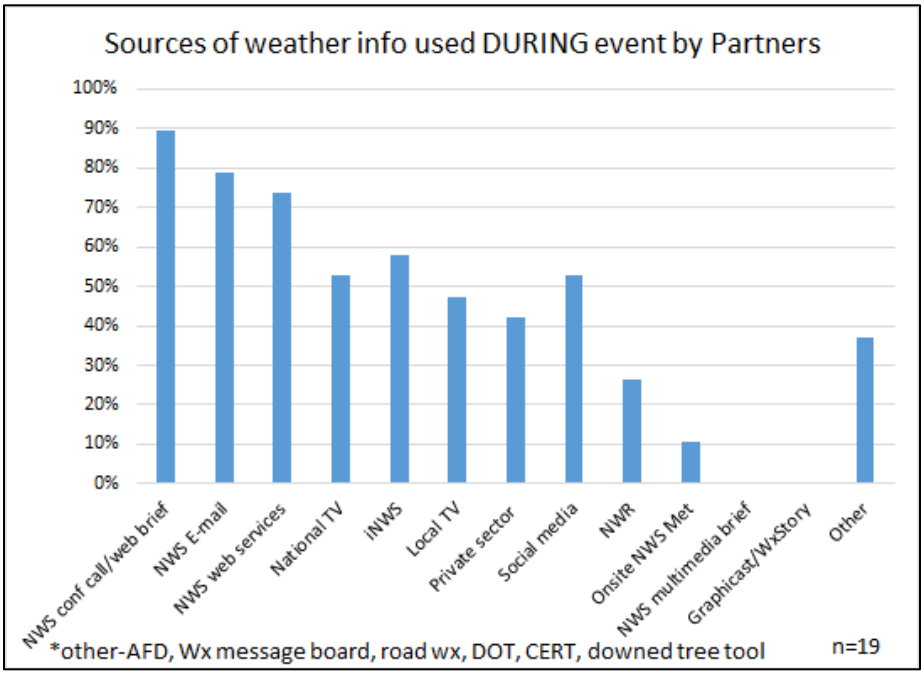

Figure 30: Partner responses to the question, "What sources for weather information were used during the event (when heavy snow and/or coastal flooding were occurring)?"

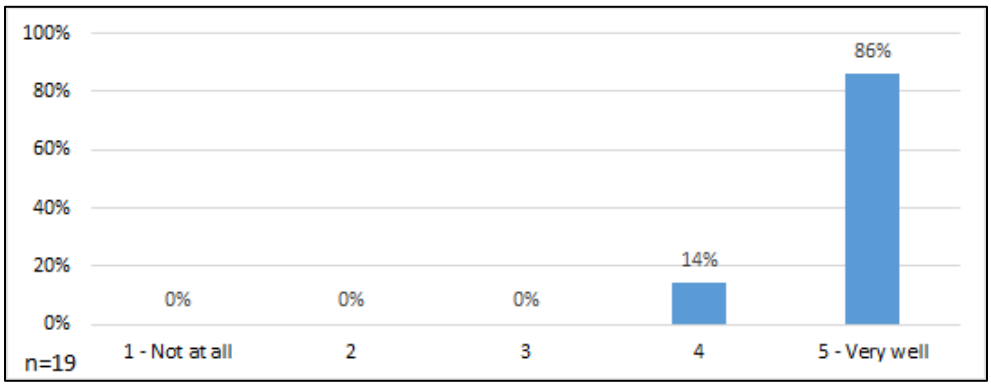

Figure 31: Partner responses to the question, "On a scale from 1 to 5, where 1 = not at all, and 5 = very well, overall, how well did you understand the information provided by the NWS?"

Table 2: Interview responses to the question: "Do you believe that the NWS utilizing a coordinated/collaborated social media hashtag for large winter storms would be beneficial?" Responses were classified into a yes, no or maybe category. While not specifically asked, some respondents also commented on the naming of winter storms.

	Partners (n=16)	**Media (n=8)**	**WFOs (n=17)**	**All (n=41)**
Hashtag YES	10	4	7	21
Hashtag NO	1	3	0	4
Hashtag MAYBE	5	1	10	16
	Partners (n=7)	**Media (n=8)**	**WFOs (n=4)**	**All (n=19)**
Winter Storm Name YES	1	2	0	3
Winter Storm Name NO	4	3	3	10
Winter Storm Name MAYBE	2	3	1	6