

**December 23-27, 2022 Buffalo Blizzard and  
Northeast Coastal Flood Event  
After-Action Review**

**April 2023**

*NOAA/NWS ERH Headquarters, Bohemia, NY 11716*



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## After Action Review Team

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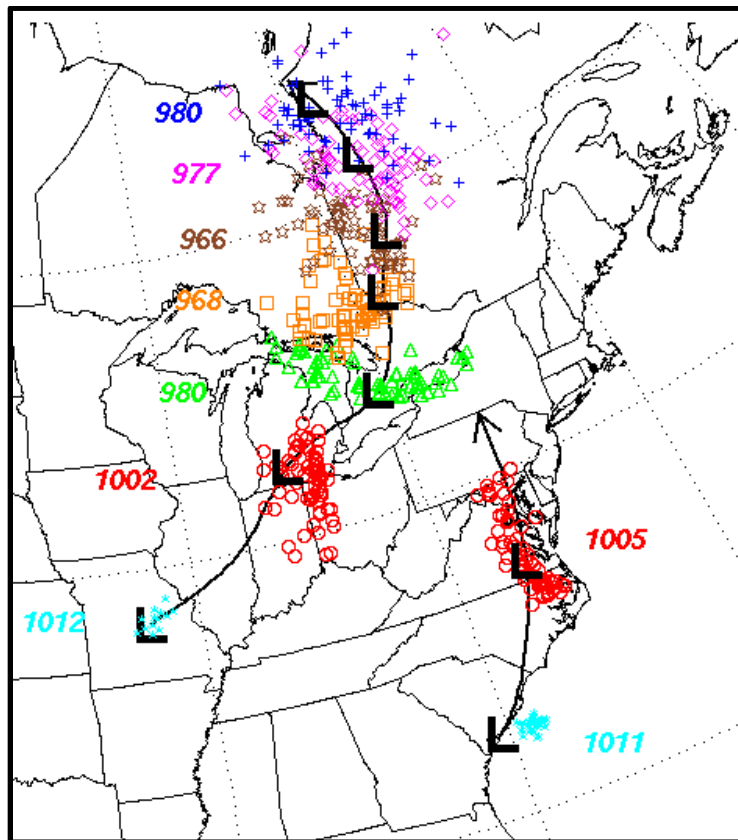
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## 1. Event Overview

### a. Western New York Blizzard

A historic blizzard and lake effect snow storm occurred northeast of Lake Erie and Lake Ontario during the 2022 Christmas holiday weekend. A powerful low pressure system moved through the Great Lakes into eastern Canada during this period setting both December and all time sea level pressure records in Ontario and Quebec (Fig. 1). The combination of very strong winds and heavy lake effect snow produced over 35 consecutive hours of blizzard conditions, resulting in devastating impacts across Buffalo and Watertown. Blizzard conditions began at Buffalo Niagara International Airport Friday morning, December 23, and continued into the evening on Saturday, December 24. At Watertown International Airport, blizzard conditions began early Friday afternoon and continued into the early morning hours on Sunday, December 25. Following the end of blizzard conditions, heavy lake effect snow continued from Sunday, December 25 to Tuesday, December 27, for portions of the Buffalo and Watertown areas.



**Figure 1:** Weather Prediction Center (WPC) Low Tracks Forecast issued 3:06 pm December 22, through 7am Sunday, December 25, showing forecast low position and strength every 12 hours.

The event began as rain during the early morning hours on Friday, December 23 before an arctic cold front passage changed the rain to snow during the mid-morning hours. The rapidly cooling airmass created a flash freeze on area roads making travel difficult as snow and blowing snow increased. Lake effect snow quickly followed the changeover on Friday, forming in the morning

northeast of Lake Erie and late morning northeast of Lake Ontario. The heavy snow and strong winds created a rapid onset of blizzard conditions across the Niagara Frontier and Northtowns northeast of Lake Erie and across Jefferson County northeast of Lake Ontario. This led to near-zero visibility and treacherous driving conditions beginning early Friday afternoon. On Friday morning, the highest wind gusts were recorded northeast of Lake Erie (79 mph) while the highest wind gust was reported Friday afternoon northeast of Lake Ontario (59 mph) - see Table 1. The wind caused downed trees and power lines resulting in widespread power outages northeast of Lake Erie and Lake Ontario including the cities of Buffalo and Watertown.

The lake effect snow bands shifted slightly to the north Friday night, which compounded the impacts across the Buffalo and Watertown Metro areas. The falling temperatures led to wind chills reaching  $-10^{\circ}\text{F}$  to  $-20^{\circ}\text{F}$  for many locations across western and north central NY Friday night. Snow accumulated quickly northeast of the Lakes with snowfall totals of 1-2 feet across northern Erie, southern Niagara and northern Jefferson counties by Saturday morning, December 24. A daily snowfall record of 22.3 inches at Buffalo Airport was reached on Friday, December 23. Snowfall rates were very hard to quantify due to the strong winds. The lake bands shifted slightly north across Niagara, Orleans, and northern Erie counties Saturday. Southwest winds continued to blow 50 to 60 mph Saturday. Blizzard conditions persisted Saturday, even for locations just outside of the bands due to blowing and drifting snow. Snowfall totals were approaching three feet at the Buffalo Airport by Saturday evening.

A notable wind shift occurred Sunday morning, December 25, and the winds weakened as they became more westerly. This wind shift led to a greater fetch off of Lake Ontario, which allowed for lake effect snow to intensify across Jefferson County. The drop in wind speeds would end the blizzard northeast of Lake Erie and Lake Ontario Saturday night. Lake effect bands moved south and settled across the Southtowns east of Lake Erie by late Saturday night and across the Tug Hill region by Sunday afternoon. Snowfall rates of 2-3" per hour were persistent east of Lake Erie Saturday night through Sunday. Snowfall rates of 3-4" per hour were estimated across the Tug Hill by Sunday. As the sun rose on Christmas morning, the impact of the historic blizzard across the Northtowns area was revealed, with high drifts of snow, ongoing power outages, untouched roads, closed interstates, and hundreds of stranded cars.

As the wind backed to west-southwest across Lake Erie late Sunday night, the lake band, in a weakened state, moved back north through the City of Buffalo through Monday, December 26. An intense lake band persisted east of Lake Ontario with 3-4" per hour rates across southern Jefferson and Lewis counties Sunday night into Monday. A wind shift to the south-southwest moved the lake band as it started to weaken into northern Jefferson County by Monday afternoon. The final snowfall totals exceeded 3 feet in numerous locations with some spots reaching 4 feet (Fig. 2 & Table 2).

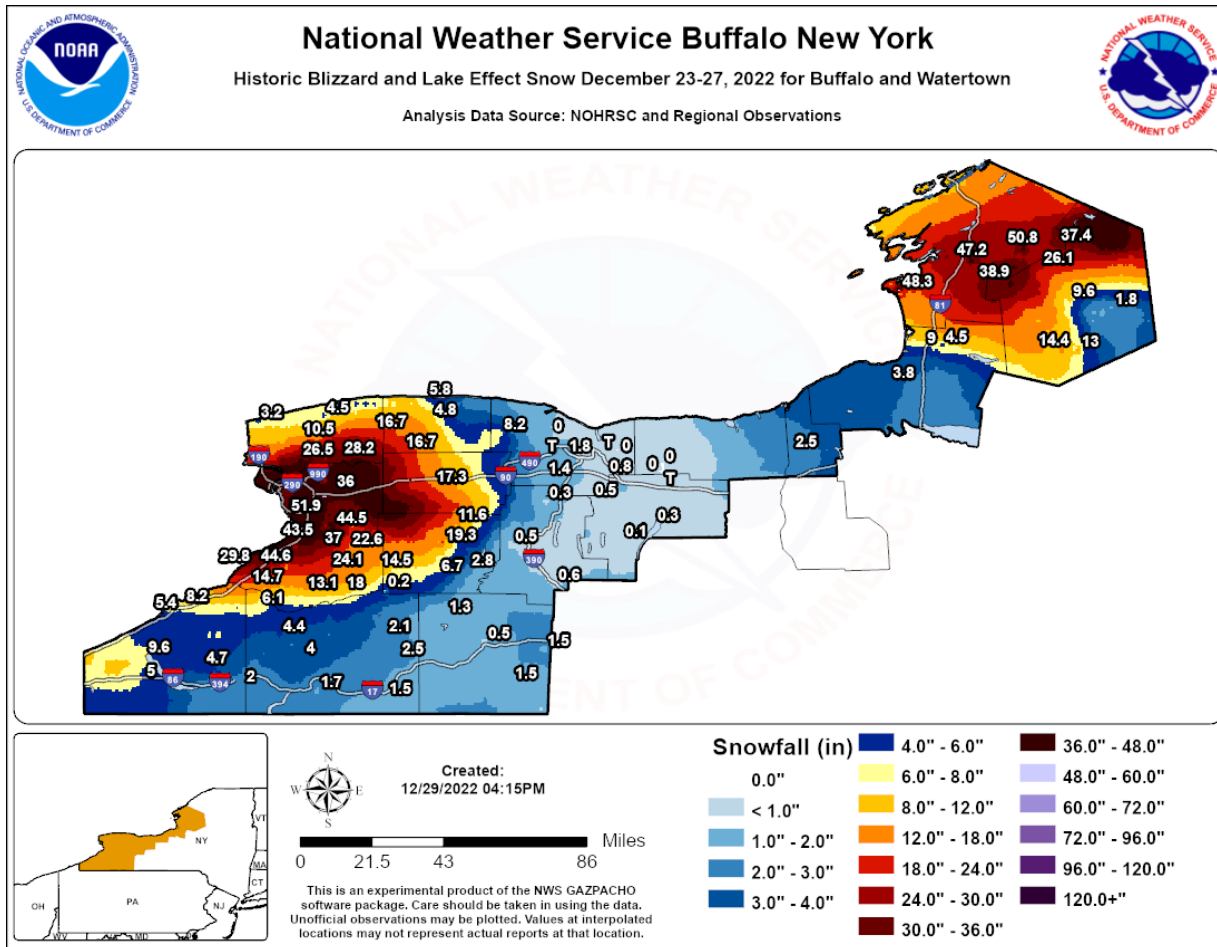


Figure 2: Snowfall totals from December 23-27, 2022.

Location	County	Peak Wind Gusts
3 NW Lackawanna	Erie	79 mph
Buffalo Airport	Erie	72 mph
Niagara Falls International Airport	Niagara	71 mph
Buffalo	Erie	65 mph
1 S Hamburg	Erie	64 mph
Batavia	Genesee	66 mph
Watertown Airport	Jefferson	59 mph

Table 1: Peak Wind Gusts from December 23-27, 2022.

Location	County	Source	5-day Snowfall Reports
Buffalo Airport	Erie	Co-op	51.9"
Deferiet (1 SSW)	Jefferson	Trained Spotter	50.8"
Elma Center 0.7SE	Erie	CoCoRaHS	20.0"
Watertown	Jefferson	Co-op	49.0
Henderson Harbor (2 SW)	Jefferson	Trained Spotter	48.3"
Lake View (1 NE)	Erie	Co-op	44.6"
Elma (2.7 SW)	Erie	CoCoRaHS	44.5"
Hamburg (2.0 N)	Erie	CoCoRaHS	43.5"
Copenhagen (4 NW)	Jefferson	Trained Spotter	38.9"
Natural Bridge (3 SW)	Jefferson	Trained Spotter	37.4"
Williamsville (3.8 E)	Erie	CoCoRaHS	37.6"
Orchard Park	Erie	Trained Spotter	37.0"

**Table 2:** Highest 5-day snowfall reports from WFO Buffalo Public Information Statement Issued on Wednesday, December 28, 2022 at 11:46 am.

b. Northeast Coastal Flooding

The same synoptic system that produced the dramatic change of airmass, strong winds, and blizzard conditions/heavy lake effect snow to the Great Lakes region was also responsible for a long period of southerly winds along the Atlantic seaboard (Fig. 3). While these winds were responsible for numerous land and marine-based wind advisories and warnings along the East Coast, the primary focus for this After Action Review is the impact that these winds had on building seas and storm surge along the Mid-Atlantic and Northeastern coast of the United States. This was a particularly noteworthy aspect of this event because tides were at astronomically high values for both the month and the year. Coastal inundation of 2 to 3 feet, with local values of up to 4 feet in some of the back bay areas, combined with the astronomically high tides to produce widespread moderate to major coastal flooding that extended from the coast of New Jersey to Maine (Fig. 4). During the course of this review, numerous other hazards were also noted throughout the northeastern United States, including river flooding, severe thunderstorms, accumulating snow, as well as a well-advertised rapid drop of temperatures (a “flash freeze”) that occurred during the day of December 23.

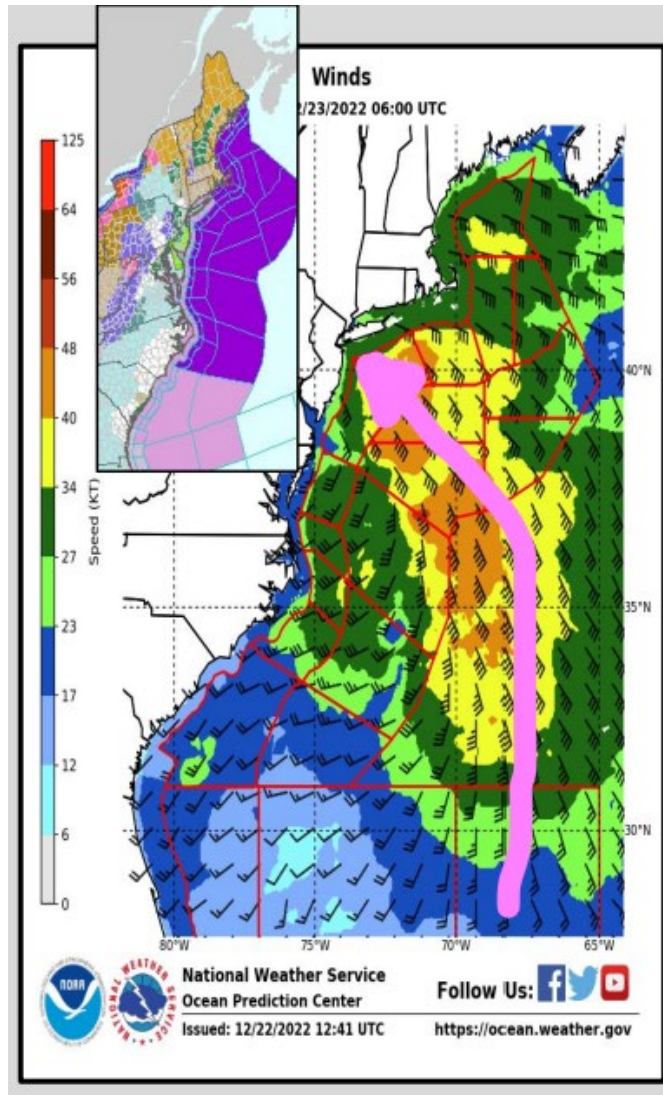
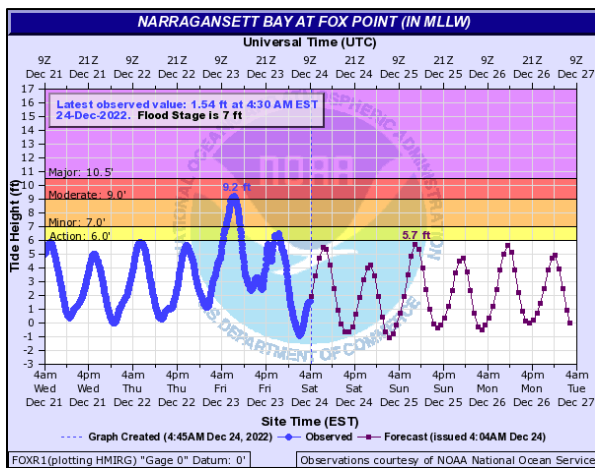
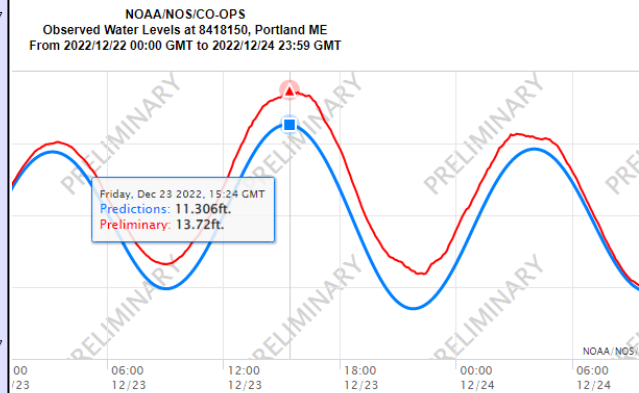


Figure 3: OPC-produced image of fetch and oceanic winds (with NWS headlines inset) valid 06Z December 23, 2022.

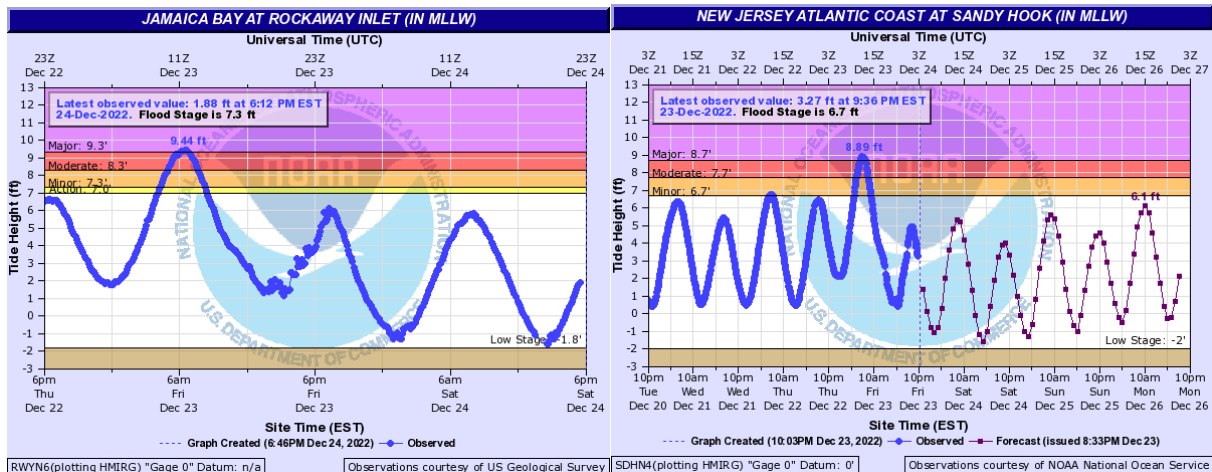


Hydrograph For Narragansett Bay at Fox Point (MA)



Hydrograph For Portland (ME)





Hydrograph For Jamaica Bay at Rockaway Inlet (NY)

Hydrograph For Atlantic Coast at Sandy Hook (NJ)

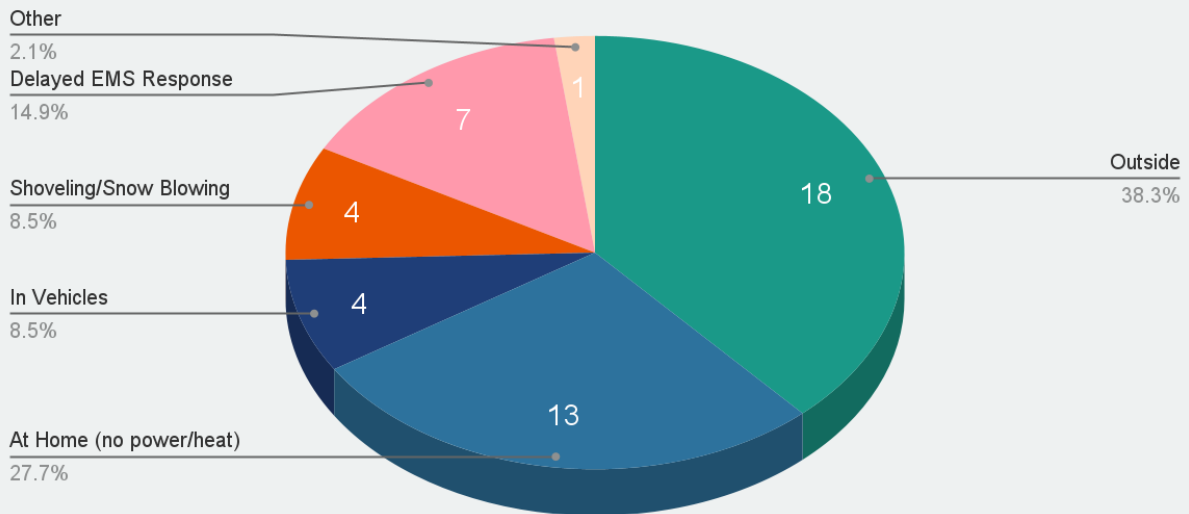
Figure 4: Example hydrographs from tidal forecast points that reached flood stage for the December 23, 2022 event.

## 2. Western New York Blizzard

### a. Impacts

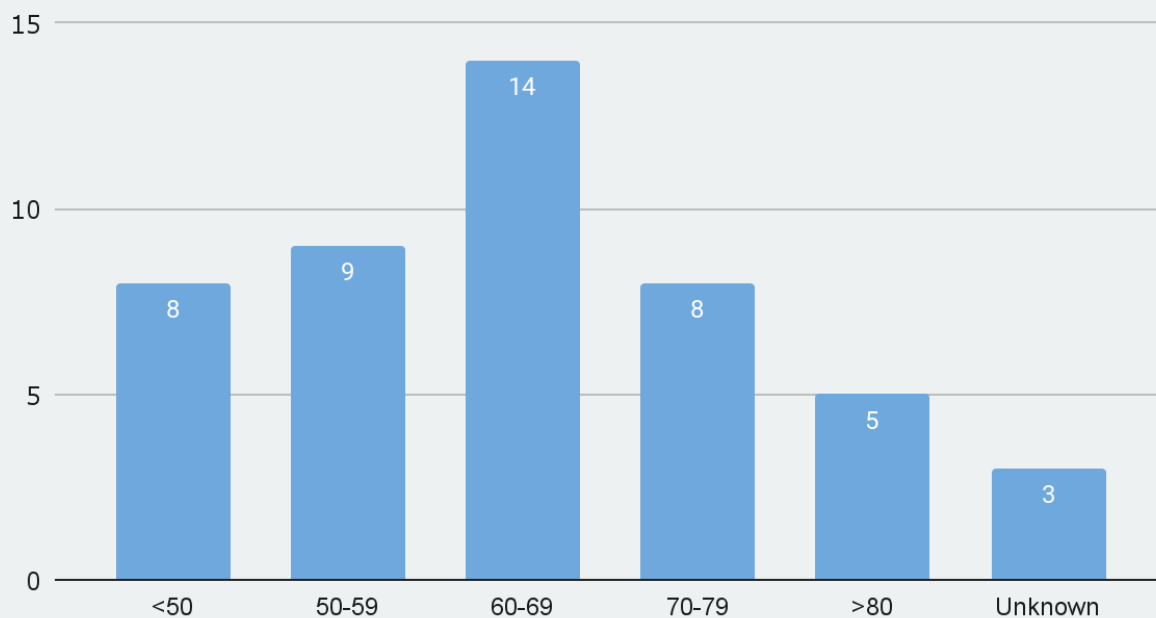
This historic blizzard and lake effect snow event spanned 5 days and included the Christmas Holiday. It was the most significant blizzard to affect western New York since the Blizzard of 1977. New York Governor Kathy Hochul, a native of Buffalo, described this as an “epic, once-in-a-lifetime storm”. This high impact event led to school and government closures on Friday, December 23, 2022, impossible travel conditions, widespread power outages, and the loss of life across the Buffalo and Watertown metro areas. In total, there were 47 reported fatalities (direct/indirect) that were attributed to the storm. Figures 5 through 8 show the breakdown of the fatalities attributed to the storm by circumstances (Fig. 5), age (Fig. 6), race (Fig. 7), and gender (Fig. 8) (data source: Kara Kane, Erie County Public Information Officer).

## Blizzard-Related Fatalities (47 Total)



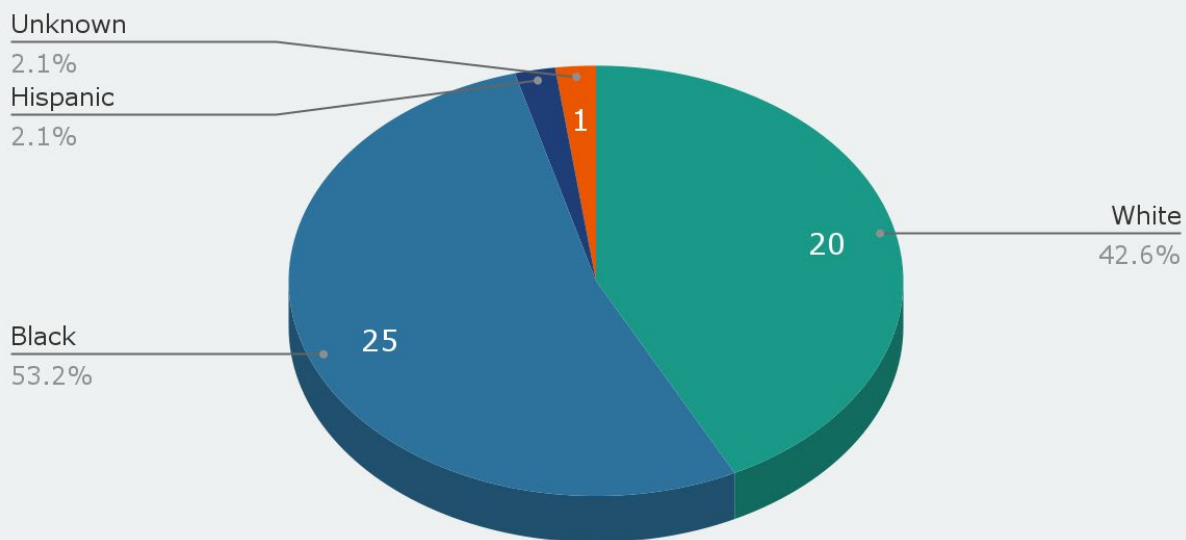
**Figure 5:** Blizzard-Related Fatalities in Erie and Niagara Counties.

## Blizzard-Related Fatalities by Age



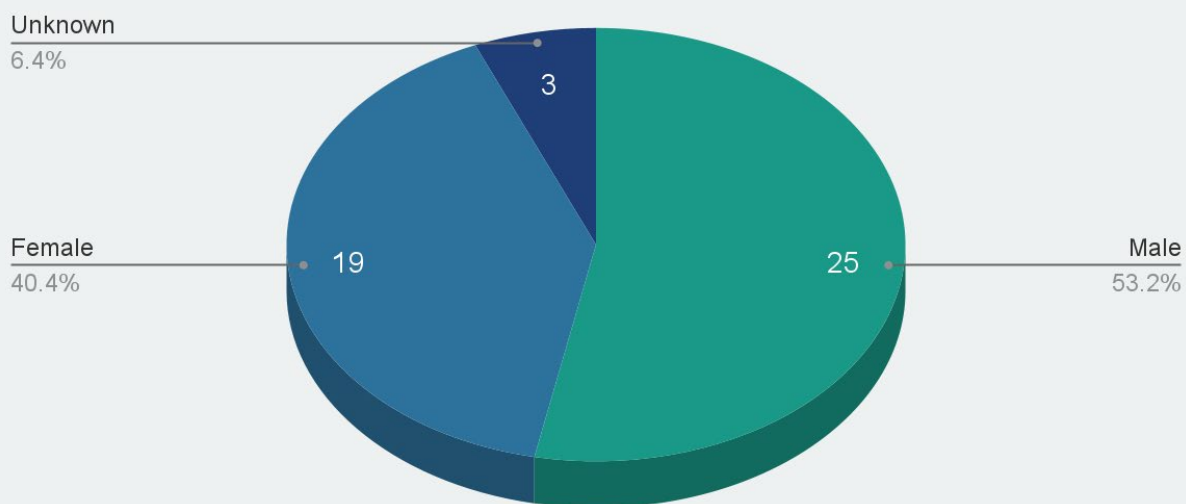
**Figure 6:** Blizzard-Related Fatalities by Age in Erie and Niagara Counties.

## Blizzard-Related Fatalities by Race



**Figure 7:** Blizzard-Related Fatalities by Race in Erie and Niagara Counties.

## Blizzard-Related Fatalities by Gender



**Figure 8:** Blizzard-Related Fatalities by Gender in Erie and Niagara Counties.

Road closures occurred on the New York State Thruway (I-90) from Rochester, NY to the Pennsylvania state line. Travel bans across Niagara and Erie counties that lasted 1-2 days after

blizzard conditions ended. The Buffalo and Watertown Airports were closed for multiple days during the holiday weekend. Emergency Services were unavailable across portions of Erie County, including Buffalo, Tonawanda, Cheektowaga, Clarence, Lancaster, Williamsville, and Kenmore during the worst of the blizzard. Erie County Executive Mark Poloncarz said that two-thirds of emergency vehicles in the worst affected areas became stranded (Fig. 9).

A county-wide travel ban for portions of western New York was instituted at 9:30 am, one hour after the first reported blizzard observation at Buffalo's airport. A heads up was given to the public about the coming ban at 8:49 am on Friday, December 23, 2022. Given the timing of this travel ban many people were already on the road or at work on this final weekday before the Christmas holiday weekend.



*Figure 9: Buffalo Fire Department truck stuck in snow (Image: WeatherNation).*

b. Numerical Model Performance

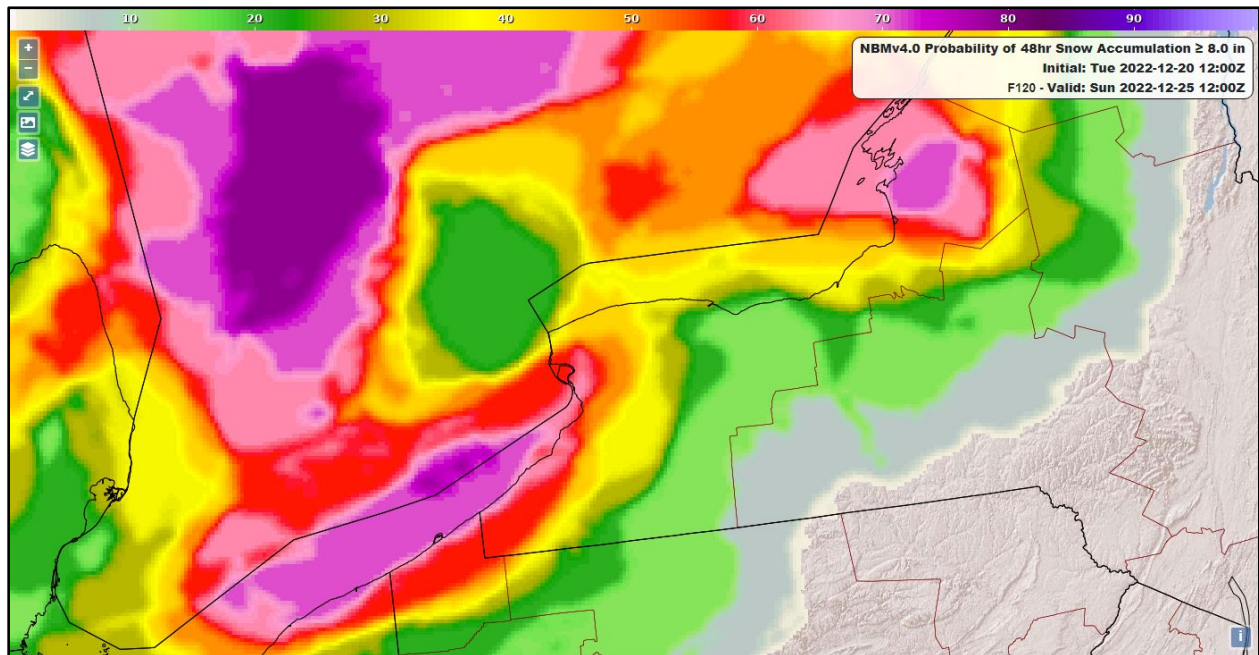
Synoptic scale model guidance accurately depicted a significant low pressure system in the northeastern United States one week in advance. This led WFO Buffalo to include the potential for a southwesterly flow lake effect snow event in their Area Forecast Discussion (AFD) on Saturday, December 17, 6 days before the event (Fig. 10).

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timing. The 00z guidance suite alone shows a possible envelope of solutions ranging from a strong low tracking northeastward along the Mid Atlantic and New England coasts (GFS) to an even stronger system lifting northeastward across the central Great Lakes (GEM/ECMWF). The former would bring a widespread synoptic/lake-enhanced snowfall to our area Thursday and Friday...while the latter scenario would bring a shot of widespread mixed precipitation Thursday...followed by a possible SW flow lake effect event and potentially strong winds on Friday. About the only thing that appears certain later next week is that the coldest airmass of the young winter season will begin to arrive on Friday and last at least through the Christmas weekend... other than that confidence in the forecast details for later next week remains rather low. Stay tuned...
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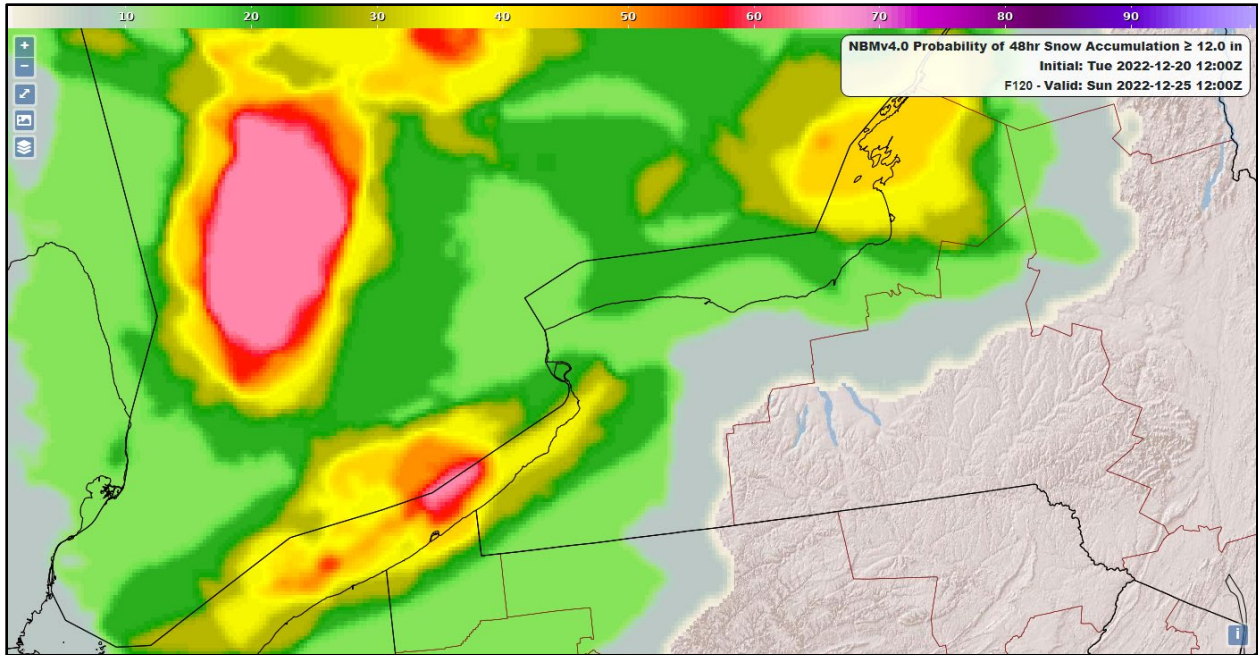
*Figure 10: AFD excerpt from WFO Buffalo originally sent at 4:34 am Saturday, December 17, 2022.*

By early Monday, December 19, (four days lead time) the AFD discussed increasing confidence for a widespread impactful event. By Tuesday morning, December 27, after the event, the terms “off the charts” and “once in a generation type event” were used to describe the combined impacts of plummeting temperatures, snow, wind, and lakeshore flooding.

Three days before event onset, the National Blend of Models (NBM) showed high confidence of significant snowfall in the snow belt regions downwind of Lakes Erie and Ontario with 60+% probabilities of greater than 8” of snow in 48 hours (Fig. 11).

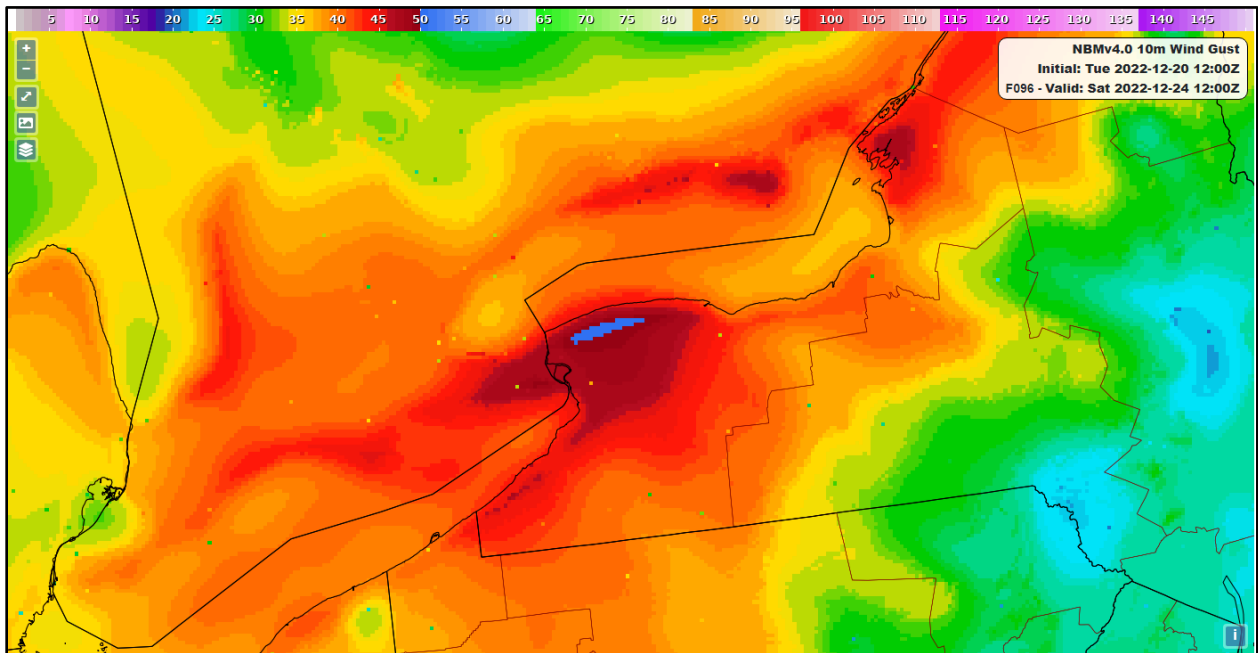


**Figure 11:** Probability of 2-day snowfall over 8” ending 12Z December 25, from the 12Z December 20, NBM. At the same time, probabilities for 2-day snowfall totals over 12” were significantly lower but located near the areas eventually impacted (Fig. 12).



**Figure 12:** Probability of 2-day snowfall over 12" ending 12Z December 25, from the 12Z December 20, NBM.

Combined with the heavy snowfall expectations, the NBM guidance showed wind gusts in excess of 50 knots (58 mph; Fig. 13).

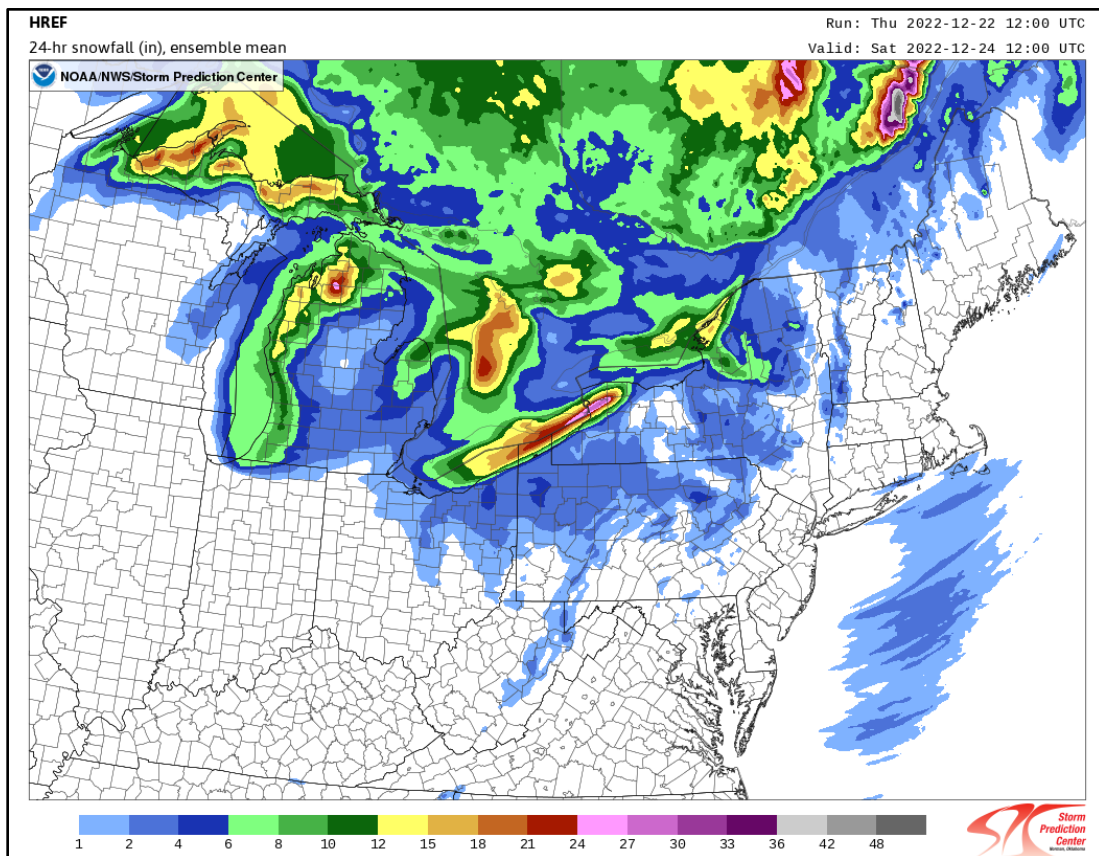


**Figure 13:** Wind gust forecast valid 12Z December 14, from the 12Z December 20, NBM.

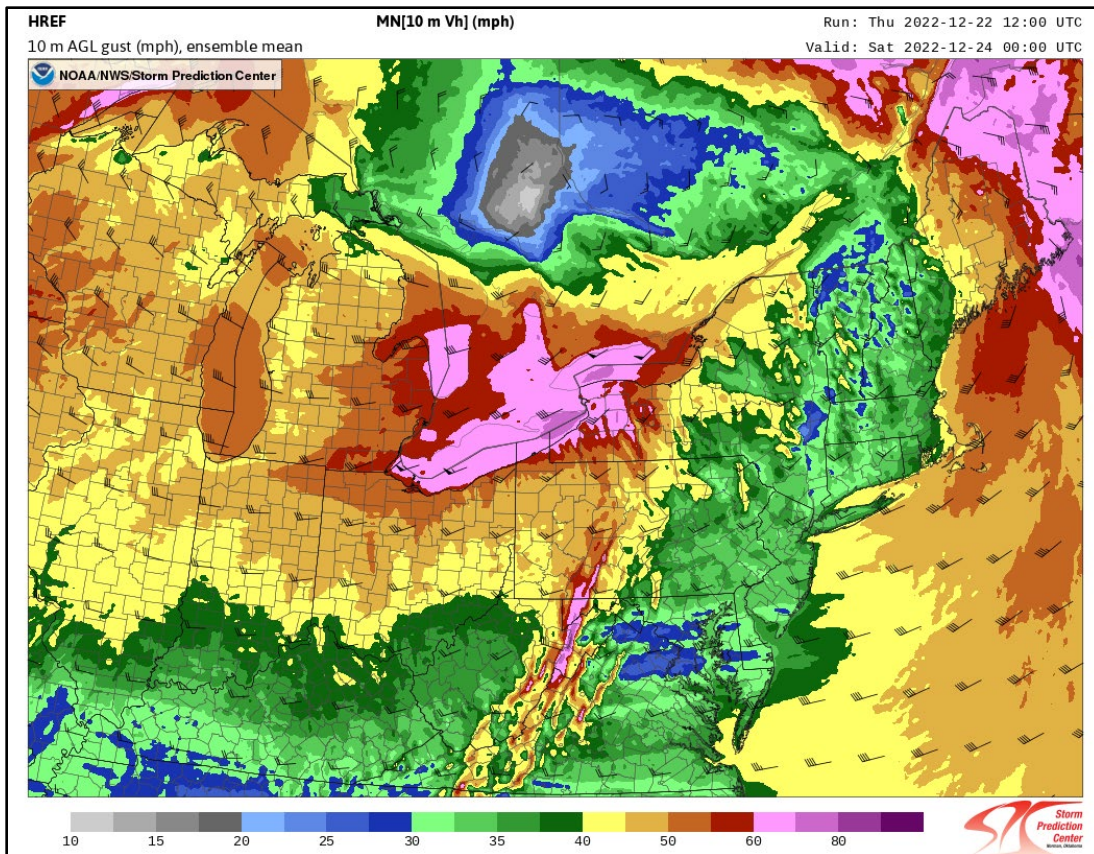
Although the NBM snowfall totals were under forecast, it did anticipate atmospheric conditions supportive of blizzard conditions more than 72 hours in advance. This resulted in greater than

usual confidence in the potential for a blizzard event. Looking further back, the NBM continued to correctly anticipate the arrival of an arctic airmass and the potential for lake effect snow 5-6 days prior to the event. However, the timing was roughly 24 hours later than what actually occurred.

As is typical for lake effect snowfall events, mesoscale guidance provided significantly more detail regarding lake effect band placement and gave clear signals that a blizzard event would occur. For example, 24 hours before event onset, the HREF anticipated 24 hour snowfall totals in excess of 2 feet very close to where the heaviest snowfall fell. The forecast snowfall was co-located with wind gusts exceeding 60 mph which are very similar to the conditions that were experienced (Fig. 14 and 15).



**Figure 14:** 24 hour snowfall forecast ending 12Z Saturday, December 24, from the HREF initialized at 12Z on Thursday, December 22.



**Figure 15:** HREF mean wind gusts forecast (in mph) valid at 00Z Saturday December 24, initialized at 12Z Thursday, December 22.

c. Office Preparation & Performance

i. Verification

A list of all hazard products related to the blizzard event issued by WFO Buffalo is provided in Appendix 1. The warning verification for the blizzard event can be found in Table 3 below. There were no missed events and a lead time of over two days for all winter headline products with over 40 hours of lead time for the lakeshore flood warnings. The historic longevity of the blizzard was well handled in the blizzard warnings with all blizzard conditions happening within the time bounds of the blizzard warning.

Office	# Events	POD	FAR	CSI	Lead Time
BUF-Winter	23	1.00	0.11*	0.90*	51.8 hrs
BUF-Flood	4	1.00	0.33	0.67	42.9 hrs

**Table 3:** Headline verification for the Buffalo blizzard event. \* indicates this number impacted by an error on the Performance Management Website.



The final blizzard warning issued for Erie County before the onset of blizzard conditions included a snowfall forecast of 2 to 3 feet with winds as high as 65 to 70 mph. This had been a consistent message since the first blizzard warning was issued early on the morning of December 22, 2022. As shown in Table 2, total snowfall exceeded 3 feet in many areas with over 4 feet at the Buffalo Airport. Numerous wind gusts in excess of 60 mph occurred. So, while snowfall exceeded initial expectations, the message of blizzard conditions, heavy snow, and high winds was well communicated in all hazard products well before the event occurred. Both for timing and storm impacts, WFO Buffalo provided an accurate forecast of this event.

The most difficult aspect of the forecast was timing the **onset** of blizzard conditions. In the morning AFD on Friday, December 23, the timing of blizzard conditions was anticipated to occur in the afternoon, despite the blizzard warning taking effect at 7:00 am (Fig. 16).

High confidence continues for expected BLIZZARD conditions downwind of both Lake Erie as well as for Jefferson County off Lake Ontario. These areas will experience the strongest southwest winds. The expectation is that the combination of heavy lake effect snow and very strong winds will produce blizzard conditions across the Niagara Frontier starting this afternoon and lasting into Saturday night, with these same blizzard conditions starting in Jefferson County by this afternoon and lasting into Sunday morning.

**Figure 16:** The 5:38 am Area Forecast Discussion from WFO Buffalo from Friday, December 23, 2022.

Blizzard conditions were first reported at the Buffalo airport at 8:39 am on Friday, December 23, 2022 (see observation below) with continuous blizzard conditions recorded for the following 37 hours.

```
KBUF 231339Z 22038G58KT 1/4SM R23/2400V3500FT +SN BLSN BKN007 OVC013 M02/M03 A2901
```

A well-timed SPS was issued as the front passed through the area at 7:57 am EST (Fig. 17). This product focused on the potential for a flash freeze. However, there was no mention in the product of developing blizzard conditions which occurred 42 minutes later at the airport in Buffalo.

```
NYZ001>003-010>013-020-021-085-231500-  
Niagara-Orleans-Monroe-Northern Erie-Genesee-Wyoming-Livingston-  
Cattaraugus-Allegany-Southern Erie-  
Including the cities of Niagara Falls, Medina, Rochester,  
Buffalo, Batavia, Warsaw, Geneseo, Olean, Wellsville,  
Orchard Park, and Springville  
757 AM EST Fri Dec 23 2022  
  
***ARCTIC COLD FRONT WILL BRING A RAPID CHANGE OVER TO SNOW WITH  
VERY GUSTY WINDS AND A RAPID DROP IN TEMPERATURES THIS  
MORNING***  
  
Arctic cold front will quickly work northeast across Western New  
York this morning. Rain will continue to change over to snow with  
temperatures quickly falling below freezing behind the front.  
This change over to snow has already occurred across Chautauqua  
County and will work northeast across the Niagara Frontier through  
10AM. Wind will also pick up, with wind gusts expected as high as  
65 to 70 mph today into tonight. With temperatures quickly  
falling below freezing, any wet surfaces that have not been  
treated will have the potential to flash freeze creating hazardous  
travel conditons.  
  
If traveling across the area expect conditions to rapidly change  
and deteriorate throughout the day today.
```

**Figure 17:** Special Weather Statement (SPS) issued by WFO Buffalo at 7:57 am Friday, December 23, 2022.

Subsequent SPSs were issued at 11:31 am and 1:18 pm describing heavy lake effect snow and strong winds. Blizzard wording was then added to the SPS at 3:31 pm, just under 7 hours after blizzard conditions had commenced at the Buffalo airport. Based on the wording in these products, blizzard conditions developed faster than the forecasters expected and this was consistent with interviews with the office and with some partners.

After the event, when entering the blizzard event into the Performance Management website for verification, it was determined that there are errors that occur when trying to verify multiple warnings with the same Event Tracking Number (ETN). This error occurred in forecast zones where a blizzard warning was later replaced by a winter storm warning as conditions slowly improved in portions of the warned area. This error has been identified by the Performance Management Branch and has impacted multiple WFOs across the country.

**Finding 1:** Performance Management Branch verification calculation is in error for multiple warnings that use the same ETN.

**Recommendation 1:** NWS ER should work with AFS/Performance Management Branch to fix the issue with the ETN.

## ii. IDSS

### 1. Briefings and Conference Calls

WFO Buffalo provided extensive IDSS through briefings, phone calls, webinars, and email slide packages. A summary of these IDSS activities is given in Appendix 2. A total of 33 conference calls were attended over a nine day period during, before, and after the blizzard. WFO Buffalo indicated that at times the number of conference calls became overwhelming. This is in part due to several state agencies who have overlapping jurisdictions requesting separate calls. WFO Albany noted the same issues and is working with state-level partners to find a solution.

*Finding 2:* Redundant conference call requests became overwhelming at times for WFO Buffalo.

*Recommendation 2:* Requests for briefings on partner-led calls should be coordinated well before a significant event occurs to reduce redundancy.

*Best Practice 1:* To maintain a consistent message throughout the dozens of conference calls WFO Buffalo participated in, a shared Google Document was created to track these IDSS events, and, more importantly, identify key talking points that could be used to describe events. Forecasters had access to these talking points which were then used to provide a consistent message during phone interviews, social media posts, etc. This promotes consistent messaging before, during, and after significant weather events.

In talking with WFO Buffalo and their media partners, it was noted that WFO Buffalo does not send its IDSS briefing packages to media partners. The office indicated that they believed only government partners could receive these briefings. From discussions with other offices for the coastal flood portion of this report, as well as within the assessment team itself, it became clear that some offices send IDSS briefing packages to media partners while others do not. In the [draft NWS Service Description Document for Impact Based Decision Support Services for NWS Core Partners](#), “members of the real-time media” are included as one of the four NWS Core Partner Groups.

*Finding 3:* Email lists from different WFOs contain different customer groups, leading to inconsistent IDSS from office to office.

*Recommendation 3:* NWS ER should clarify regional policy on what partners are allowed to receive briefing materials from local offices and then ensure consistency throughout the region.

In terms of how NWS products and services could be improved, one partner commented that emailed briefings did not communicate the same level of danger that the office Tweets and AFD did. This inconsistency may have had an impact on their preparedness. To understand this possible disconnect, it is important to discuss the messaging used in various products. Beginning with the AFD issued at 451 AM on December 20, the phrase “once in a generation” was used in

the next 11 consecutive AFDs (roughly 36 hours). In fact, much of this section of the AFD was copied verbatim from shift to shift during this period (Fig. 18 and 19).

meeting the definition of bombogenesis (24mb/24hrs). Such deepening is relatively rare in the Lower Great lakes...but more common across the Upper Great Lakes and certainly with Nor'easters along the coast. Some of the parameters of this intense storm are forecast to be climatologically 'off the charts'...such as MSLP and strength of both the low level and upper level jets. One could certainly describe this storm system as a once in a generation type of event.

Figure 18: AFD snippet from 4:51 am December 20, 2022.

.LONG TERM /FRIDAY THROUGH TUESDAY/...  
...Once in a Generation Winter Storm to Slam the Region Heading into and THROUGH the Christmas Weekend...

Figure 19: AFD snippet from 4:45 am December 21, 2022.

This verbiage was changed to “Multi-faceted and HIGH IMPACT winter storm” at 3:32 pm on December 21, with the phrase “DANGEROUS WINTER STORM” used beginning at 5:08 am on December 22.

A social media post made 48 hours before the onset of the event also messaged that the storm would be a “once in a generation event” (Fig. 20).



Figure 20: Tweet from WFO Buffalo issued at 7:37 am December 21, 2022.

During our discussions with WFO Buffalo media and EM partners, both mentioned noticing the “once in a generation” verbiage and believed that it was appropriate for the severity of the storm. However, this verbiage never appeared in a partner briefing products and likely led to the perception by some partners that there was a discrepancy between what was shared on social media and the AFD, compared to what they received in email briefings.

For example, on the same morning where the “once in a generation” language was used on social media and in the AFD, the title slide for the IDSS briefing included the headlines in effect, but no mention that this would likely be a highly unusual and impactful event (Fig. 21).

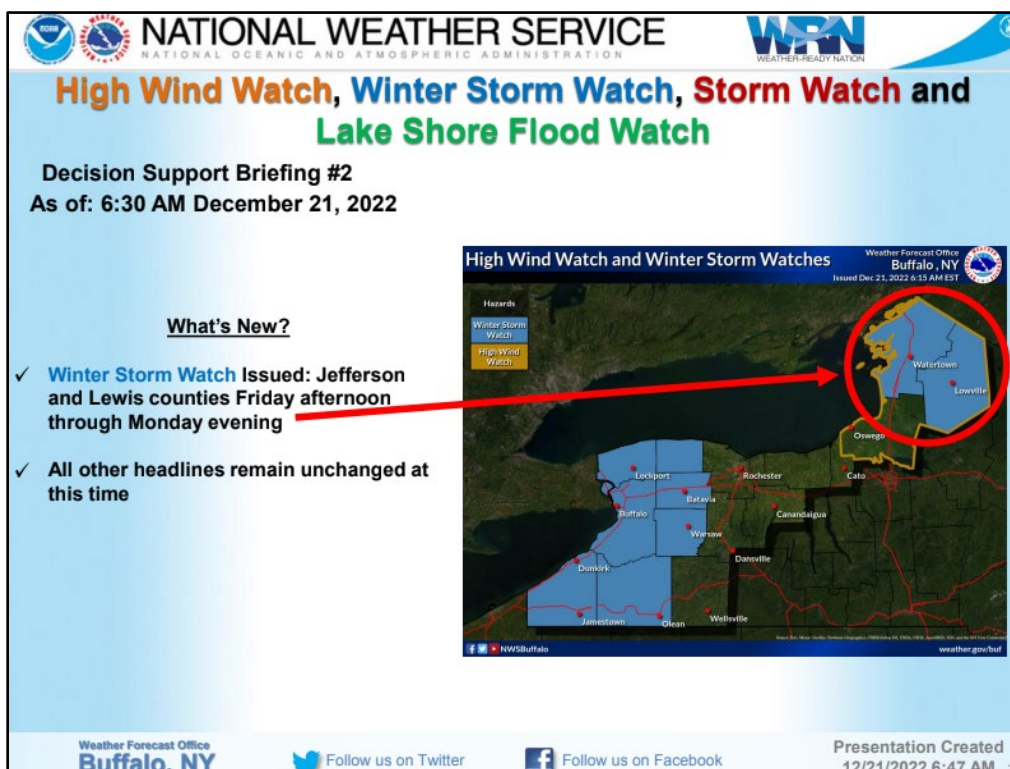


Figure 21: Title slide from WFO Buffalo Briefing from December 21, 2022 at 6:47 am.

Also, while the verbiage was well-received, by the day before the event, the phrase “once in a generation” no longer appeared in any forecast, social media, or briefing products. From the perspective of the briefing, it is possible that this type of information was not included in the briefing because the NWS Eastern Region IDSS briefing template does not include a Key Messages slide. Key messages are now commonly used by national centers (e.g. WPC, NHC) during high impact events and help promote message consistency both within and between offices depending on the scale of an event.

**Finding 4:** Inconsistent messaging between forecast, social media, and IDSS briefing products led to some partner confusion.

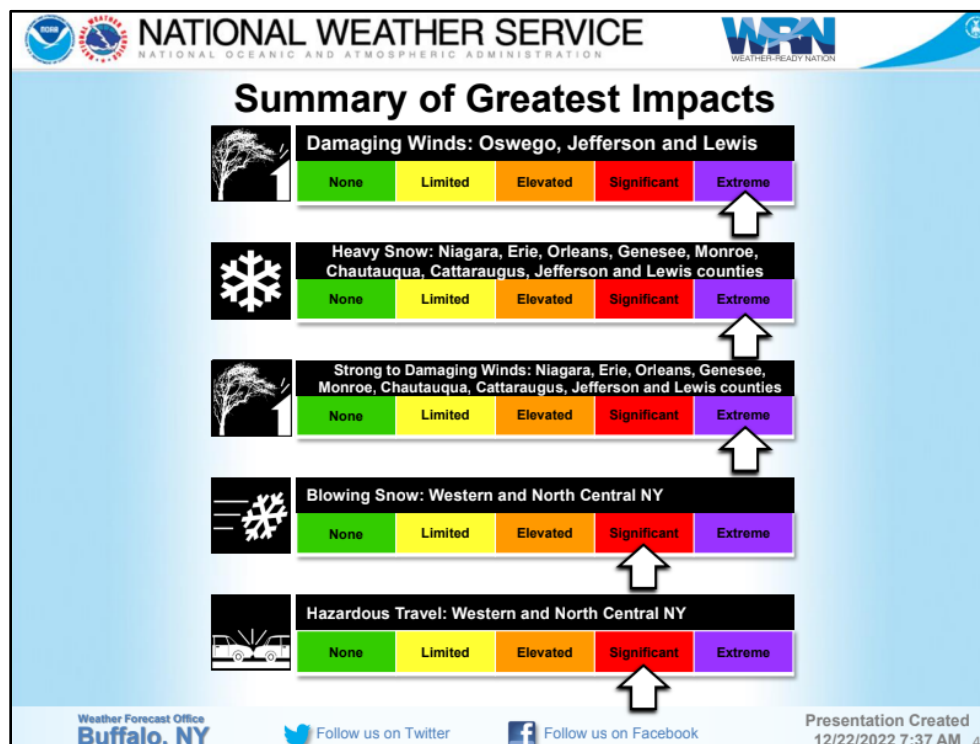
**Recommendation 4a:** The title slide of ER IDSS briefings should convey the severity level of the event to ensure impacted core partners do not misunderstand the potential impacts.

**Recommendation 4b:** Offices should have a document that includes “key messages” that will be used throughout the suite of forecast, social media, and IDSS briefing products to promote a consistent message to all partners.


**Finding 5:** The NWS Eastern Region IDSS briefing template does not have a slide to include these Key Messages for high impact events.

**Recommendation 5:** The standard IDSS briefing template should begin with a Key Messages slide.






Reviewing the IDSS briefings emailed by WFO Buffalo to their core partners, impact information was primarily confined to the format of the mandatory slides in the ERH Briefing template as shown in Figures 22 and 23 below. One partner noted that the use of the “Extreme” category was appropriate for this event and used this information in press conferences to describe to the people of Buffalo how extreme the event was going to be. Clearly given what occurred, this choice was completely justified for this event.



**Figure 22:** “Chicklet” Impacts slide from WFO Buffalo Briefing from December 22, 2022 at 7:37 am.



**Main Points**

Hazard	Impacts	Location	Timing
Damaging Winds 	Widespread downed trees and powerlines, along w/isolated structural damage expected.	Oswego, Jefferson and Lewis counties	7PM Tonight through 1PM Friday
Heavy Snow 	Heavy snow will cause reduced visibilities and hazardous driving conditions.	Niagara, Erie, Orleans, Genesee, Monroe, Chautauqua, Cattaraugus, Jefferson and Lewis counties	7AM Friday through 7AM Monday
Strong to Damaging Winds 	Widespread downed trees and powerlines, along w/isolated structural damage expected.	Niagara, Erie, Orleans, Genesee, Monroe, Chautauqua, Cattaraugus, Jefferson and Lewis counties	7AM Friday through 7PM Saturday
Blowing Snow 	Strong gusty winds will result in blowing snow that could cause whiteout conditions.	Western and North Central NY	7AM Friday through 7AM Monday
Hazardous Travel 	Heavy snow and blowing snow will create difficult to near impossible travel.	Western and North Central NY	7AM Friday through 7AM Monday



Weather Forecast Office Buffalo, NY  Follow us on Twitter  Follow us on Facebook Presentation Created 12/22/2022 7:37 AM 2

Figure 23: “Table” of Main Impacts slide from WFO Buffalo Briefing from December 22, 2022 at 7:37 am.

There were impacts experienced in this event, however, that were not clearly conveyed using this format. For example, while downed trees and power lines suggest the potential for widespread power outages, the **prolonged nature** of the strong winds during this event would indicate that power outages would also likely be extended in duration. This would have heightened the need for decision makers and the public to plan for alternative heat sources, warming shelters, etc. The example above also did not include blizzard conditions anywhere in the impacts column despite blizzard warnings being issued before this briefing. The format shown in Figure 23 also splits snow impacts into “Heavy Snow”, “Blowing Snow” and “Hazardous Travel” making it somewhat confusing what the greatest snow-related impacts were. In this case, having the flexibility of an additional slide that could describe what potential impacts were possible given the historic nature of the expected event would have been beneficial. For example, combining the extremely cold temperatures, whiteout conditions, and strong winds to indicate that stranded motorists or anyone caught outdoors would be in danger of death. Another example would be that whiteout conditions will make it difficult for emergency services to reach your location for an extended period of time.

**Finding 6:** The standard ER Briefing template does not have the flexibility to connect different weather impacts into a cohesive message to be received by core partners.

**Recommendation 6:** NWS ERH should examine the standard briefing template to include template slides for improved messaging of impacts.

In reviewing the IDSS briefing materials provided by WFO Buffalo, the slide format used for the office-held webinars was different from what was used in the briefing packages sent each

morning. This included a different slide background and some slides containing content formatted in different ways. After the webinars, the slides from these uniquely-formatted presentations were sent to the partners that attended the call.

*Finding 7:* Partner webinars and emailed briefings used different slide formats. While it is acknowledged that different **content** may be necessary to meet the needs of different partners, the overall **format** change may cause confusion among partners.

*Recommendation 7:* All ER field offices will adhere to the ER IDSS briefing template to ensure a consistent look and feel for all IDSS briefings to partners.

In their full IDSS briefings, WFO Buffalo included images generated from three different graphics packages. These included 1) GraphiDSS, 2) SacGridImageMaker, and 3) Graphics directly from the NDFD website.

*Finding 8:* Using multiple graphics types in IDSS briefings resulted in inconsistent labeling and a different look and feel for forecast information provided throughout the briefing. This has the potential to cause confusion for partners.

*Recommendation 8:* ER field offices should strive to streamline graphics into as few formats and styles as possible to reduce possible confusion. If there are graphic types that are not supported by a single graphics package, offices should work with NWS ERH to document these limitations and request improvements to currently used graphics creation software.

WFO Buffalo issues afternoon full IDSS briefing packages for high impact events only when there are substantial changes to the forecast (most likely headline changes). Some partners indicated that these afternoon briefings are frequently sent after the end of the traditional workday and therefore are less useful to their operations.

*Finding 9:* Sending full briefing packages to core partners after 4pm was found to be too late to be useful to core partners. They would have preferred briefing materials by the end of the traditional workday.

*Recommendation 9:* ER field offices should develop IDSS briefing delivery schedules that incorporate feedback from their core partners. In general afternoon briefing packages should be sent to partners at a time (window) as determined by partner input.

## 2. Integrated IDSS / Onsite Support

Integrated IDSS is part of a spectrum of IDSS delivery to Core Partners that constitutes the most direct one-on-one engagement and support, and is based on Core Partner needs and NWS operational unit resources. One aspect of Integrated IDSS is onsite deployments, which entail embedding NWS staff in partners' support operations, such as an emergency operations center (EOC). When deployed, NWS staff members are expected to focus entirely on Core Partner



needs by providing targeted information. It is expected that NWS staff will tailor briefings to Core Partners' needs, thresholds, and means of communication. Deployed NWS staff should coordinate all information with the NWS operational unit(s) to ensure a common operating picture.

Onsite support was not provided to any partner agency by WFO Buffalo, or to New York State Division of Homeland Security and Emergency Services (NYDHSES) by WFO Albany, the state-liaison office for New York. In the case of WFO Buffalo, onsite support was not offered, and partners were not aware that this level of support was available.

WFO Buffalo partners believe they get all of the weather support they need from the office through emails and phone calls with the MIC, WCM, and operational staff. However, it was clear that they do not have a good understanding of NWS IDSS, specifically Integrated IDSS and onsite support.

The NYDHSES used a contract meteorologist from the University of Albany to brief NWS forecast information at their watch center and help them understand NWS products for decision making. They were reluctant to have NWS staff onsite, as they had the understanding that onsite NWS Albany staff would only brief on what WFO Buffalo was already sending to the state, such as email briefings.

*Finding 10:* There was a clear misunderstanding from core partners at both the local and state level on the value-added IDSS information that NWS onsite staff could provide. More importantly, the ability of onsite staff to pass along critical thresholds and decisions being considered back to impacted WFOs will allow briefings and forecast products to be better tailored to partner needs.

*Recommendation 10:* NWS ER should work with local offices to develop best practices on accomplishing on site support as well as documenting success stories that can then be used by other offices when they approach their local partners with an offer of onsite support and its potential benefits.

*Finding 11:* There is concern from multiple staff members at WFO Buffalo that the NWS may become over-extended if they were to offer onsite IDSS.

*Recommendation 11:* WFO Buffalo should embrace the strategic plan as it relates to IDSS.

NWS recommends that any staff member providing virtual or onsite IDSS be recognized as Deployment-Ready. This ensures that required instructional components, including Professional Development Units (PCUs) 1-7, task book items, and in some cases hands-on training through IDSS Bootcamps/regional roadshows and local exercises/simulations, have been completed.

*Finding 12:* There was conflicting information from WFO Buffalo on the number of employees that were deployment ready, ranging from as few as 2 to as many as 5.

*Recommendation 12:* WFO Buffalo should increase the number of deployment ready personnel in accordance with IDSS policy. WFO Buffalo should maintain a roster of deployment-ready employees.

iii. Public Messaging

WFO Buffalo used a unique progression of headlines to help heighten the messaging for this event. First, Winter Storm Watches were issued on Tuesday, December 20, 2022. Given that blizzard conditions did not occur until Friday morning, December 23, this represented over 60 hours of lead time. In addition to the unusually long lead time, WFO Buffalo's choice to issue Winter Storm Watch headlines instead of Lake Effect Snow Watch headlines to help heighten the awareness of the potential for blizzard conditions given the added hazard of very strong winds. WFO Buffalo felt that a Winter Storm Watch headline would receive a larger response than a lake effect snow headline. Lake effect snow events are typically not accompanied with very strong winds which made the December 23-27, 2022 event especially unusual and impactful. On Saturday, December 24, 2022, when the heaviest lake effect snow bands moved out of Chautauqua County, Blizzard Warnings were transitioned to Winter Storm Warnings to signal to the county that snow removal was again possible, but to maintain public messaging that travel was dangerous.

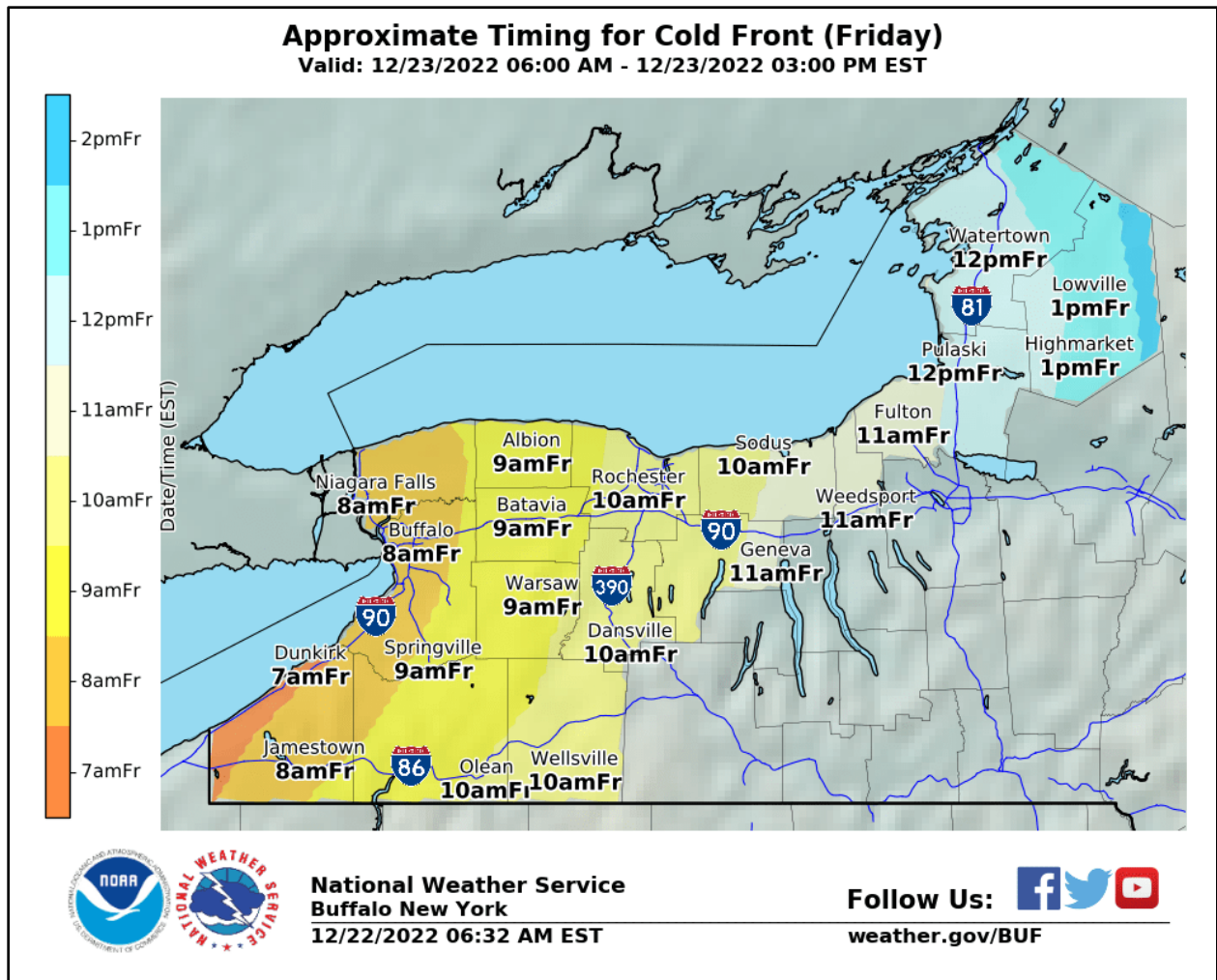
Despite the tremendously long lead time for both the Winter Storm Watches and subsequent Blizzard Warnings, many partners indicated that the blizzard conditions started earlier than expected. While the blizzard conditions were captured within the start/end times of the blizzard warning, the product was lacking in its ability to inform partners of specific timing information about when the hazardous conditions would begin.

In the final blizzard warning issued by WFO Buffalo for the City of Buffalo before the onset of blizzard conditions (Fig. 24), the start time of the event was ambiguous. While the blizzard warning was technically in effect as of 7:00 am Friday, the WHAT bullet in the text product indicates a change from rain to snow with blizzard conditions **developing in the afternoon** and lasting into Saturday night. In fact, blizzard conditions began between 8:00 - 9:00 am Friday, December 23.

```
NYZ001-002-010-011-085-231600-  
/O.CON.KBUF.BZ.W.0001.221223T1200Z-221225T1200Z/  
Niagara-Orleans-Northern Erie-Genesee-Southern Erie-  
Including the cities of Niagara Falls, Medina, Buffalo, Batavia,  
Orchard Park, and Springville  
236 AM EST Fri Dec 23 2022  
  
...BLIZZARD WARNING REMAINS IN EFFECT FROM 7 AM THIS MORNING TO  
7 AM EST SUNDAY...  
  
* WHAT...Blizzard conditions expected. Total snow accumulations of  
2 to 3 feet with locally higher amounts possible. Winds gusting  
as high as 65 to 70 mph today and tonight. A rapid switch from  
rain to snow with sharply falling temperatures into the teens  
and single digits will result in a flash freeze today. Blizzard  
conditions will develop this afternoon lasting into Saturday  
night. Wind chills as cold as 10 to 20 below zero.  
  
* WHERE...Niagara, Orleans, Erie, and Genesee counties.  
  
* WHEN...From 7 AM this morning to 7 AM EST Sunday.  
  
* IMPACTS...Travel will be extremely difficult to impossible at  
times. Widespread blowing snow will significantly reduce  
visibility. Very strong winds could cause extensive tree  
damage and numerous power outages. The bitter wind chills as  
low as 10 to 20 below zero could cause frostbite on exposed  
skin in as little as 30 minutes.
```

**Figure 24:** Final Blizzard Warning issued by WFO Buffalo before the onset of blizzard conditions (2:36 am, Friday, December 23, 2022).

One day before the event, WFO Buffalo sent out the following image on social media given the approximate timing of the cold front (Fig. 25). While this timing was very accurate, it did not convey that blizzard conditions would follow the front in the areas under the blizzard warning. This reinforces the idea that the biggest forecast challenge for this event was the **onset** of lake effect snow and blizzard conditions.



**Figure 25:** Cold front arrival time graphic posted to social media by WFO Buffalo during the morning of December 22, 2022.

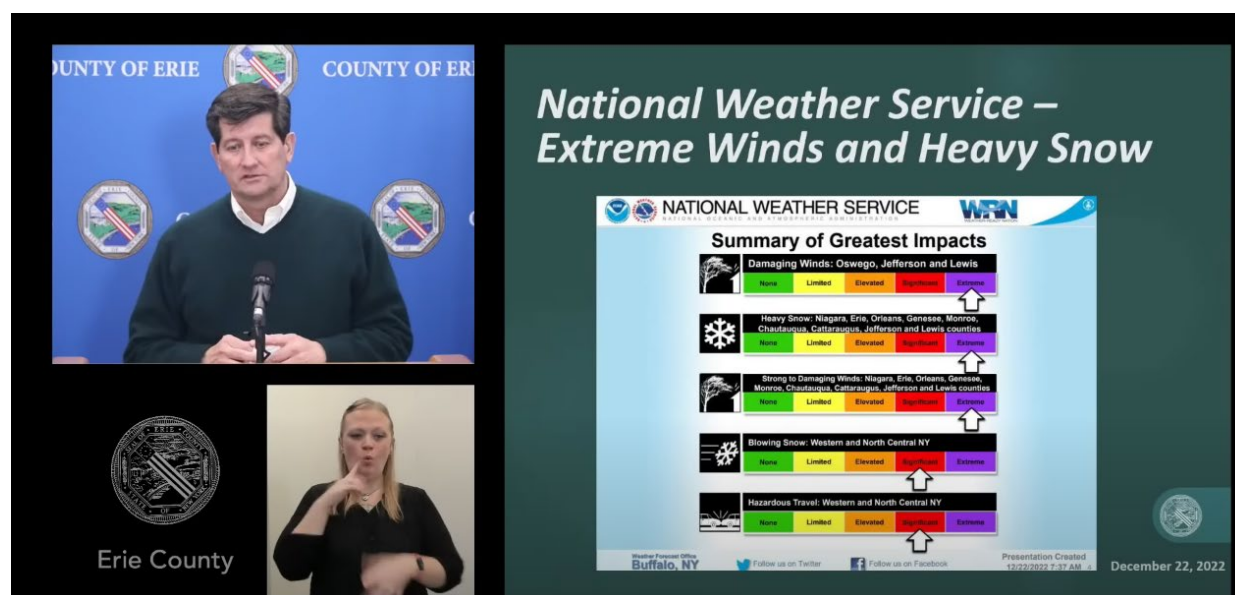
As the event unfolded, the office issued Special Weather Statements highlighting the arctic cold frontal passage, and then messaged the developing lake effect snow. While the Special Weather Statement is a popular product that is broadcast by the media, it does not have the same visibility as a product that activates the Emergency Alert System, etc. The weather event was a short-fused high impact transition from wet roads to subfreezing temperatures and blizzard conditions and in this case there was no NWS product that had high enough visibility to alert the public and partners about this drastic change in conditions in real time.

Impact-based warnings facilitate improved public response and decision making, and meet societal needs in the most life-threatening weather events. In fact, some partners as well as NWS Buffalo meteorologists suggested that if Wireless Emergency Alerts (WEA) had been available for blizzard warnings, it would have proven very useful in this event, potentially saving lives.

**Finding 13:** Long lead times for Winter Storm Warnings and Blizzard Warnings raised public awareness to this event; however, given the anticipated extreme impacts from the Blizzard, there was no way to effectively message the **onset** of the life-threatening conditions.

**Recommendation 13:** NWS should explore alerting capabilities (e.g. impact-based warning event tags) for Blizzard Warnings prior to, or at the onset of, blizzard conditions to provide heightened awareness to the public and decision makers.

Erie County, NY officials, including the county executive, conducted press conferences for the public leading up to the blizzard. These press conferences were meant to reassure the public and provide weather-related information to them straight from the NWS. County officials noted that they used the NWS information exclusively in these press briefings as they feel that NWS is the most accurate and trusted source (Fig. 26). In order to support these press conferences, WFO Buffalo sent one-pagers to provide the latest information to county officials just prior to each press conference.



**Figure 26:** Erie County Executive Mark Poloncarz briefing on December 22, 2022 including WFO Buffalo IDSS Briefing slides.

Erie County and the City of Buffalo held several press conferences leading up to and during the blizzard. A broadcast media partner in the Buffalo market noted that it would be good to have someone from the NWS that can communicate to the public at these press conferences. This would help with any miscommunication, and in the case of this event drive home that this is a once in a generation storm (and help define what that means).

**Finding 14:** WFO Buffalo staff did not participate directly in the press conferences, nor did they receive a request to have a representative at the press conferences. When one official was asked why a representative from the WFO Buffalo was not involved in the press conferences, they stated

they were unsure if the office had anyone to participate or if they were even allowed to do so. However, they were open to having a WFO Buffalo representative there.

*Recommendation 14:* WFO Buffalo should coordinate with partners and discuss their needs to support public messaging during significant weather events, including participation in press conferences as appropriate.

#### iv. Collaboration

Collaboration for the Buffalo blizzard event involved local, regional, and national NWS offices. This included two conference calls that were initiated by WPC with participation from WFO Buffalo as well as the Eastern Region Regional Operations Center (ER ROC). As discussed elsewhere, the Buffalo blizzard was only one aspect of the high impact weather occurring throughout the northeastern United States with the strong synoptic scale low pressure system. WPC indicated that collaboration on lake effect snow is difficult because of its localized nature and is frequently best left to the local office handling the event.

At the state level, NWS Albany, as the state liaison office collaborates with the other NWS offices in New York (Buffalo, Binghamton, Burlington, New York City) to lead statewide briefings at the New York State Emergency Operations Center. When discussing this event with NWS Albany, a challenge was described when trying to brief state-level partners when the different offices forecasting for portions of the state have different thresholds and timing for their IDSS briefings. While for some events these differences can be attributed to the weather (e.g. only one portion of a state being impacted by an event), differing internal IDSS policies exist for similar scale events which can make it difficult to coordinate state-level messaging.

*Finding 15:* Inconsistent policy for the types/timing of IDSS briefing materials provided by WFOs hampers the ability of the state liaison office to effectively brief state level core partners.

*Recommendation 15:* WFO Albany, as the New York state liaison office, should engage with each office serving the state of NY to define a consistent paradigm for issuing emails, one-pagers, and full briefing slide decks to their partners.

#### v. Facilities

The high-impact nature of the blizzard conditions resulted in nine NWS Buffalo employees being stuck at the WFO through much of the blizzard event. While employees sheltering in place at a WFO during high impact weather is not unprecedented, having this many employees stranded was particularly unusual. It became apparent through the event that the WFO was not designed to support staff being stranded at the office for an extended period. The office has no shower and there were only two cots. In addition, the HVAC system had been programmed not to heat/cool the administrative part of the building on weekends to conserve energy. This resulted in cold temperatures in this part of the facility that made sleeping conditions uncomfortable.

**Finding 16:** WFO Buffalo was not adequately prepared to handle multiple employees housed at the office for multiple days during an anomalously cold event on a weekend. This resulted in poor sleeping conditions and a lack of basic supplies (i.e. food, toiletries, cots/blankets, etc).

**Recommendation 16a:** ER WFOs should ensure employees have access to instructions for the HVAC system, to override programming during unusually cold or hot events.

**Recommendation 16b:** ER WFOs should evaluate and address needs to house personnel overnight during extended durations of high-impact and/or unusual events. Offices more prone to high impact events (e.g. hurricanes, blizzards, etc.) that would require multiple nights in the office should consider the installation of a shower. Any new office construction/renovation should include shower facilities.

#### vi. Planning & Response

Discussions with WFO Buffalo revealed that the office had no staffing plan in place for blizzard events. On Friday afternoon, when it became apparent that a number of employees were going to be stuck at the office, a schedule of shifts and duties was developed by the Lead Meteorologists on duty. While WFO Buffalo indicated they had sufficient staffing to handle the event, it is possible that prior to the event, a staffing plan may have provided coverage to assist in the conference calls which the office indicated became “overwhelming” at times. Staffing plans for high impact events are common throughout the NWS, particularly in the tropical program and also for warm season convection. They provide for sufficient staffing to handle all of the various needs for these complex events.

**Finding 17:** Given the lack of a staffing plan, the response to staffing was made in a reactive rather than proactive fashion.

**Recommendation 17:** WFOs should develop staffing plans for high impact winter storm events, including blizzards.

When discussing IDSS with WFO Buffalo, it was discovered that the office had never conducted an Integrated Warning Team (IWT) meeting. An IWT meeting is an opportunity for a diverse set of NWS stakeholders to meet together and not only learn more about the products and services of the NWS, but also for the WFO to learn more about partner needs. The resulting relationship building can help develop increased trust between the NWS and its partners and provides an environment where mutual needs can be expressed as well as brainstorming on how best to meet these needs.

NWS Headquarters has recently encouraged the use of Integrated Warning teams including the following verbiage in an all hand message from June 2020: *“The use of the Integrated Warning Team (IWT) concept is encouraged to build relationships with both Core Partners and other relevant stakeholders.”*

Based on discussions with the WFO Buffalo staff, there was a reluctance to host an IWT because of the political differences between some county and local government agencies in the Buffalo area, and competition between the different Buffalo Metro media markets.

**Finding 18:** WFO Buffalo has never hosted an IWT.

**Recommendation 18:** WFO Buffalo should host regular IWTs to help build trusting relationships with core partners which may lead to better mutual understanding during high impact weather events.

#### d. Partner Response

The feedback received for this event from state, county, local partners, and the media was positive. They noted that WFO Buffalo (and WFO Albany as the state liaison office for New York) provided timely and accurate products and services, and that the severity of the event was well-messaged. It was clear from partners that the briefings, warnings, and forecasts provided by the NWS saved lives and gave decision makers the ability to pre-position assets and use extraordinary means (e.g. county-wide travel bans) to respond to an historic event. In a word, the services provided by the NWS were recognized by partners to be invaluable (Fig. 27).



**Figure 27:** Example of partner feedback on Twitter provided by the Erie County, NY County Executive Mark Poloncarz.

Broadcast meteorologists commented that “everything the office said would happen did happen” and that WFO Buffalo “used the strongest wording I’ve seen from the weather service” and “took guts to use the language that was used”.

The long lead time on blizzard warnings was particularly noticed as setting this event apart from others. The trusted relationships WFO Buffalo developed with each of its core partners was very evident and it was clear that the partners recognized that a significant event would occur with a very long lead time. Partner feedback on NWS products and services during this event were unanimously positive at the county and city level. A WFO Buffalo poll of partners after the event rated their IDSS briefings and calls very highly.



e. Service Equity

The City of Buffalo, NY is culturally diverse with a number of new populations moving into the city. Per the city's website, [buffalony.gov](http://buffalony.gov), "Between 2006 and 2013, the foreign-born population in Buffalo increased by 95 percent". Not only is the City of Buffalo becoming increasingly diverse, there were particular vulnerable populations that existed during this event. For example, there were many Canadians in the area shopping before the Christmas holiday weekend. In addition, given the closure of Interstate 90 / New York State Thruway that occurred during the blizzard, numerous truck drivers and other motorists from out of the area were forced off the highway onto state roads. Thus, there are many different populations that are potentially vulnerable to high impact weather.

When asked how they identify and serve various diverse and underserved communities, WFO Buffalo identified some progress made in the city of Rochester with outreach on messaging heat events in collaboration with the University of Rochester.

From the discussion, it was clear that while WFO Buffalo was aware of the need to reach underserved communities in their forecast area, they had no systematic way to identify and understand underserved and vulnerable communities and determine whether NWS products and services were received and understood.

NWS leadership has expressed the desire to "enhance outreach to and engagement with vulnerable, marginalized, and underserved populations, as well as Minority-Serving Institutions (MSIs)" - NWS All Hands Email - March 23, 2023.

*Finding 19:* Without clear expectations and a systematic process for identifying and engaging underserved communities, NWS field offices are not yet prepared to fully understand and address how changes in messaging impacts these groups.

*Recommendation 19:* WSH and NWS Regional Headquarters need to provide guidance and tools to NWS field offices to help engage and better understand underserved and vulnerable communities.

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### 3. Northeast Coastal Flood

a. Impacts

This event produced a storm surge of 2 to 3 feet with local values of up to 4 feet in some back bay areas. The storm surge in combination with astronomically high tides produced widespread moderate to major coastal flooding on December 23, 2022, that extended from the New Jersey coast to Maine. Recorded water levels along portions of the coasts of New Jersey, New York, Connecticut, Massachusetts, and Rhode Island were at their highest levels since Post-Tropical Cyclone Sandy in 2012. Impacts along the northeast coast were significant, including widespread

flooding of vulnerable coastal roads and homes/businesses, water damaged vehicles, damage to vulnerable structures such as docks and piers, debris and large rocks washed onto coastal roads from breaking waves, and beach erosion. Below are examples of reports received following the event by WFO along with accompanying images in Figure 28.

- **WFO Mount Holly:** Widespread moderate coastal flooding occurred, with major coastal flooding across Middlesex and Monmouth Counties and the back bays of the ocean. The West Atlantic City and Bargaintown, NJ, Fire Departments had to evacuate about 30 people from four motels along the Black Horse Pike using a raised military-grade vehicle due to the coastal flooding.
- **WFO New York:** Communities in and around Hempstead Bay and Great South Bay in southern Nassau County, NY, and Jamaica Bay in southern Queens County, NY, experienced widespread inundation of 2 ½ to 3 ½ feet, resulting in numerous impassable roads, basements of homes flooded, and water damaged cars. In addition, several coastal communities away from the immediate coast that do not typically observe coastal flooding were affected with 1 to 2 ½ feet of inundation, including low-lying areas along tidally influenced rivers such as the Hackensack, Passaic, and Hudson Rivers.
- **WFO Boston:** Minor to moderate coastal flooding affected both coasts (south and east-facing). In Boston, water overtopped the newly constructed Harborwalk and numerous roads were flooded and impassable. Numerous roads and parking lots were also flooded and impassable across many coastal communities, with flooding also occurring farther inland in places such as Dighton along the Taunton River. Rocks covered some roadways due to overwash in Bristol and Essex Counties. Several homes were flooded in Provincetown.
- **WFO Gray:** Fourth highest tide on record (since 1912) in the forecast area. Inundation of roads, businesses, parking areas in Portland Old Port. Substantial private residence inundation, with at least tens of millions of dollars in damage. Coastal roads inundated throughout the region requiring some water rescues. Significant beach erosion. Historic structures and forts were damaged, including: Portland headlight, Seawall Bug Light State Park, Portsmouth harbor Lighthouse Seawall destroyed, and Hampton NH.
- **WFO Caribou:** Piers in Hancock and Bar Harbor damaged from a combination of tides/waves. Multiple roads were closed due to coastal flooding and overwash, and in some cases debris covering the roadway. Some causeways were also badly eroded, with portions of the roadway collapsing.



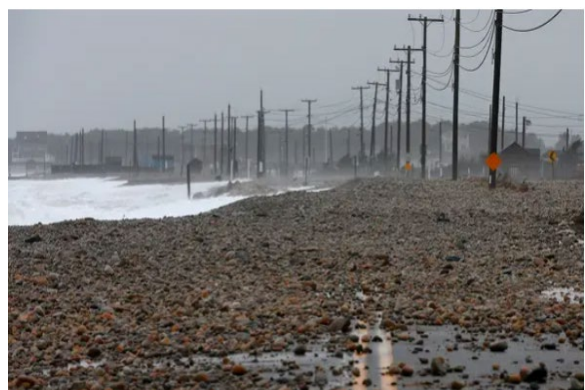
*Flooding in Hoboken, NJ (Image: NJ TRANSIT)*



*Flooding in East Rockaway, NY (Image: Stacey Sager, ABC 7 New York)*



*Flooding in Boston, MA (Image: Boston Globe)*



*Debris on Roadway in Westport, MA (Image: Standard Times)*



*Flooding in Winthrop, MA (Image: Mark Garfinkel, NBC Boston)*



*Flooding in Nantucket, MA (Image: Massachusetts Office of Coastal Zone Management)*



*Flooding/seafoam in Wells, ME (Image: Wells Police Department)*



*Flooding in Kennebunkport, ME (Image: Gregory Rec, Portland Press Herald )*

**Figure 28:** Example images of coastal flooding from the areas impacted during the December 23, 2022 coastal flood event.

#### b. Numerical Model Performance

In reviewing forecast products from the coastal offices in the northeast, it is clear that deterministic and ensemble guidance accurately predicted this event well before it occurred. In fact, the potential for a significant coastal storm in the northeastern United States was within the guidance envelope at a lead time of over one week. This led to significant lead time not only in coastal flood watches / warnings / advisories, but also in the provision of IDSS (discussed in the following section). The mention of a possible event began to be included in Area Forecast Discussions eight days before the event. In the figures below, a series of AFDs from each of the impacted offices all indicate a high degree of confidence in the storm event, with some of the early discussions recognizing a coastal flood threat with over one week lead time (Fig. 29-33).

Another storm system has the potential to impact the area by the end of next week. While still roughly seven days away, there is a higher than usual level of confidence that the system will affect New England sometime in the Thursday night to Saturday timeframe. There is strong agreement among the global models on this, and there has been a relatively high level of run to run consistency with the system as well. What remains to be seen, of course, is what the track of this system will be. Both rain and snow are possible with this system, with the development and track of a secondary coastal low the main driver of this. Models are showing anything between and wind driven rain to all snow, so at this point in time we will continue to monitor the trends over the next few days for a better picture of the impacts.

One factor with the storm late next week is that astronomical will be at their peak for the month, with any kind of onshore flow likely leading to impacts. These impacts will also be determined by the track and timing of the system.

**Figure 29:** Portion of WFO Gray AFD from the afternoon of December 15, 2022.

Friday: Potential exists for a very significant storm system on Friday into Friday night as an Arctic air mass over the north central U.S. contributes to extreme baroclinicity across the Northeast. Conditions are favorable for a strong surface low developing. Blocking across northeastern Canada generally favors a track over or just west of the area, which is now supported by nearly every deterministic model and ensemble mean. Damaging winds, coastal flooding from storm surge and wave run-up, and inland flooding are all possible threats. Tides will be near the

**Figure 30:** Portion of WFO Caribou AFD from the morning of December 17, 2022.

proverbial 'calm before the storm'. The bulk of model guidance, both deterministic and ensembles, are continuing to trend toward a storm track well west of our area, even west of the Appalachians. While we are still 5 days away from the storm, the overall pattern is becoming more conducive at least toward an inland storm track rather than coastal, and it is looking more likely that most of our area will see a minimal amount of wintry precipitation. Similar to the last storm, a still fairly cold

**Figure 31:** Portion of WFO Mount Holly AFD from the morning of December 18, 2022.

.LONG TERM /TUESDAY NIGHT THROUGH SUNDAY/...

Outside of small timing differences, the global models remain in good agreement in wrapping up low pressure across the Ohio Valley and Great Lakes Thursday night into Friday, sending a strong frontal system across the area. In addition, there is a strong signal of a

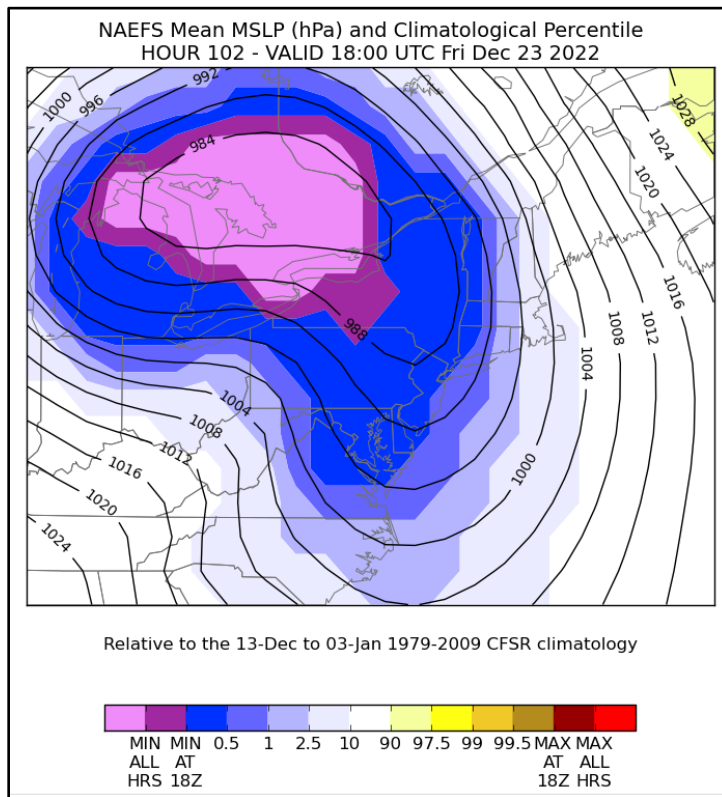
**Figure 32:** Portion of WFO New York AFD from the afternoon of December 18, 2022.

Potentially High Impact Storm late Thu and Fri...

The model guidance is in very good agreement in a highly anomalous and powerful storm that will impact the central and eastern U.S. this week. A very potent shortwave carves out a deep trough and low

**Figure 33:** Portion of WFO Boston AFD from the afternoon of December 19, 2022.

By the week of the event, there was strong enough ensemble guidance agreement for anomaly-based plots to identify the Great Lakes Low pressure system as exceeding a 30 year climatology (Fig. 34). Recall that this system broke December and all time pressure records for some stations in Ontario and Quebec. Not only does this speak to 1) the strength of the low pressure system but also 2) the agreement within the ensembles at significant lead times. Given the location of this anomalous low pressure system, and astronomically high tides, this increased the expected threat of coastal winds, surge, and coastal flooding.



**Figure 34:** NAEFS Mean 102 Hour MSLP forecast and climatological percentile compared to 1979-2009 CFSR reanalysis.

With regard to the storm surge guidance for this event, of particular note is that every office from WFO Gray to WFO Mount Holly commented on the utility of surge information from the Stevens Institute of Technology. In particular, the SNAP-Ex ensemble-based surge guidance provided valuable information in addition to NCEP-produced ETSS, PETSS, and ESTOFS guidance. Some specific office comments regarding the Stevens Institute of Technology guidance include:

**WFO Boston:** “Stevens Institute of Technology - Steven’s Flood Advisory System guidance provided a 4-day lead time with high level of accuracy”

**WFO Gray:** “Stevens Flood Advisory System was a great tool”

While multiple offices discussed the utility of the surge forecasts from the Steven’s Institute of Technology, most offices had no way to directly input these surge forecasts into their own Total Water Level (TWL) forecasts. As a result, they made adjustments based on what they saw on the web interface. Discussions with WFO New York indicated that given their relationship with the Steven’s Institute (located within their CWA), they had developed a means to bring some of the ensemble information within AWIPS.

*Finding 20:* Steven’s Institute of Technology ensemble-based surge guidance was an invaluable forecast tool for this event but was not accessible within AWIPS for most impacted offices.

*Recommendation 20:* ER WFOs with surge forecast points within the Steven’s Institute forecast domain should work with WFO New York to find a means to ingest the ensemble forecast information into AWIPS for direct use in TWL forecast production.

One model guidance concern that was documented during this event centered around appropriate modeling of storm surge impacts in riverine areas that have both fresh and saltwater influences on water level. Uncertainty due to surge impacts at WFO Caribou resulted in the relatively short lead time of 16 minutes for the river flood warning for the Penobscot River at Bangor, ME. WFO New York also indicated that riverine impacts were a particular challenge as they are not modeled sufficiently.

*Finding 21:* Extratropical storm surge impacts in riverine areas that have both fresh and saltwater influences on water level are poorly modeled resulting in less lead time on warning products.

*Recommendation 21:* Coastal offices and associated River Forecast Centers that have responsibility for river forecast points that are influenced by extratropical storm surge should work together to identify science and service gaps for these points and formulate a plan to improve services for these points.

c. Office Preparation & Performance

i. Verification

The overall forecast performance during this event was excellent. Table 4 below illustrates the Coastal Flood Warning verification for this event. High CSI and long lead times were consistent with forecasters messaging the high confidence of this event. This was a very well forecast event.

Office	# Events	POD	FAR	CSI	Lead Time
CAR	2	1.00	0.50	0.50	17.1 hrs
GYX	7	1.00	0.00	1.00	28.9 hrs
BOX	14	1.00	0.07	0.93	28.0 hrs
OKX	Not Avail	1.00	0.00	1.00	49.2 hrs
PHI	22	0.91	0.19	0.75	19.0 hrs

**Table 4:** Coastal flood warning verification information obtained from each local office and the Performance Management website.

ii. Impact-based Decision Support Services

Impact-Based Decision Support Services (IDSS) began well in advance of the onset of coastal flooding. Several WFOs began to indicate the potential for a storm with coastal flood impacts as early as Friday, December 16, 2022 in the form of routine EM briefing slides or social media posts. By Monday, December 19, 2022, all impacted coastal WFOs issued either email briefings or one-pagers highlighting an upcoming multi-faceted event, including the potential for coastal flooding on Friday, December 23, 2022 into Saturday, December 24, 2022. Impacted offices started to disseminate briefing packages and interacted with partners through webinars and/or partner-led briefings on Tuesday, December 20, 2022 or Wednesday, December 21, 2022.

**Best Practice 2:** Multiple impacted offices made personal, one-on-one phone calls to potentially impacted partners to help draw attention to the significance of this event. This provides awareness to partners that something important is happening, and also strengthens relationships.

In their IDSS briefings, WFO New York used pre-formatted coastal flood slides (Fig. 35). These slides included tabular information, visualizations (such as experimental potential coastal flood extent maps) and impact catalogs. They indicated that having an understanding of local vulnerabilities was critical to their successful delivery of local IDSS. In fact, they stated that their ability to communicate coastal flooding impacts has improved significantly since Post-Tropical Cyclone Sandy.



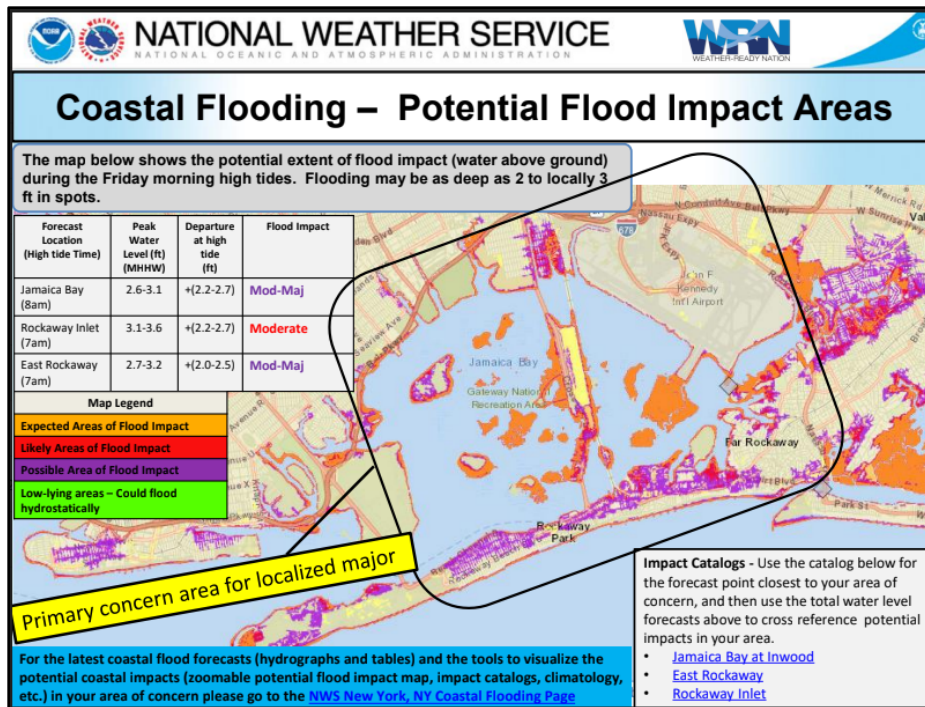


Figure 35: WFO New York briefing slide including an inset that includes impact catalogs for particular forecast points.

**Best Practice 3:** Coastal offices should develop or improve existing impact catalogs of coastal flooding to provide more detailed IDSS down to the local level to aid decision makers. Having those impacts readily accessible in pre-formatted IDSS slides allows for quicker creation of IDSS briefings and provides easy access to partners.

**Best Practice 4:** WFO Mount Holly and WFO New York maintained a collaboration document through the event which helped coordinate key messages and share forecasting challenges and tips. In the case of WFO New York, this document was shared with internal partners (WFO Albany as New York State Liaison Office, ERH ROC, etc.) to assist with state and regional-level messaging.

A review of IDSS briefings revealed that every office interviewed for this event used a different slide format to communicate coastal flooding impacts (Fig. 36). These slides ranged from map graphics, to AHPS Total Water Level plots to tables with one office (WFO New York) including inundation graphics. While all of the briefing slides highlighted appropriate forecast information and impacts, the diversity of slide styles would likely cause confusion for stakeholders who need coastal flood forecast information from multiple offices.

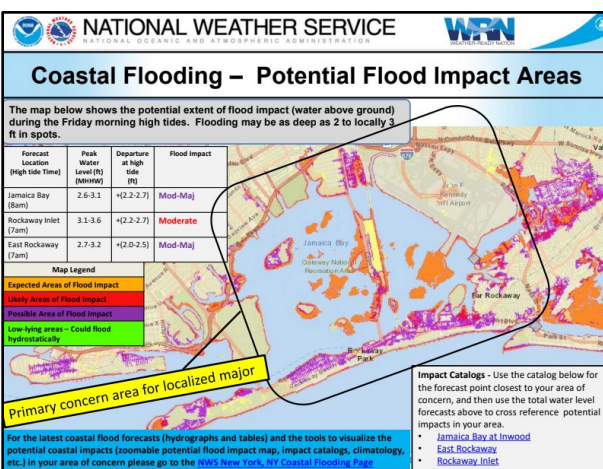
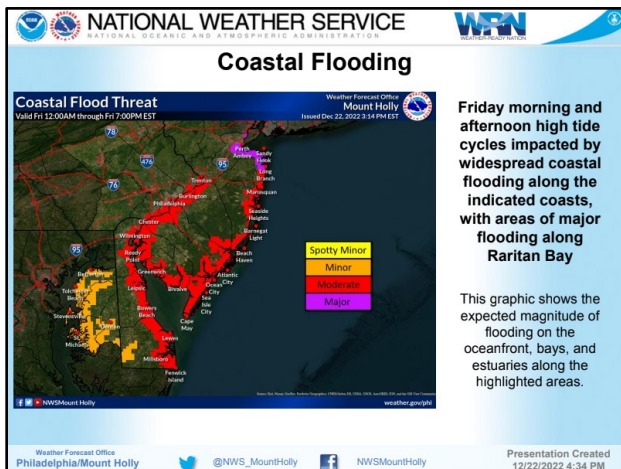
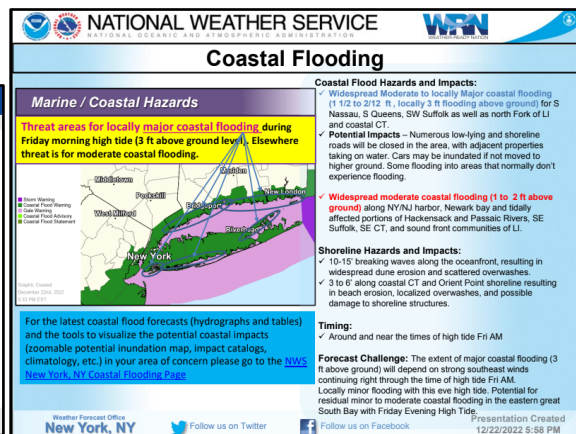
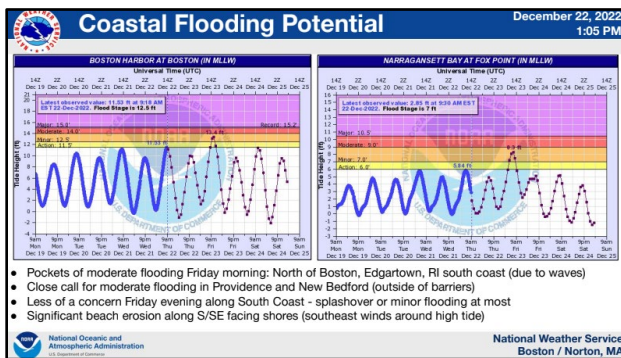
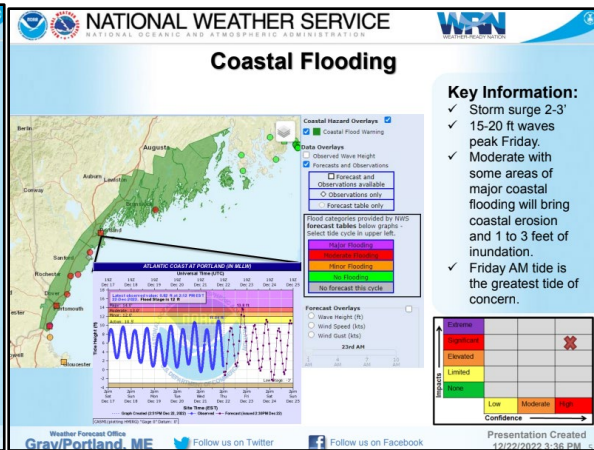
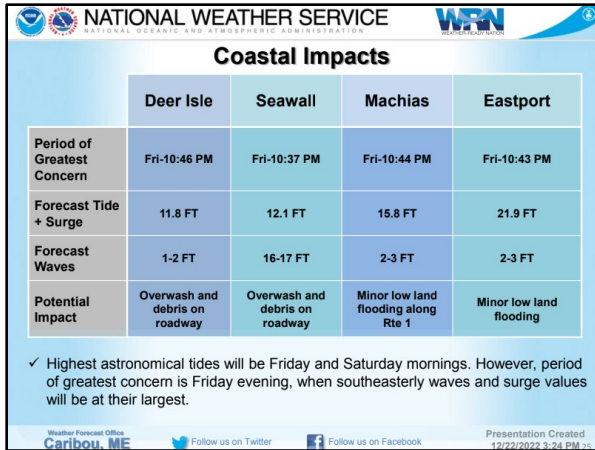


Figure 36: Example coastal flood slides from different coastal offices for the December 23, 2022 event.

Finding 22: Every office used a unique slide format to message the potential for coastal flooding in this event which may lead to confusion for partners that straddle more than one WFO.

**Recommendation 22:** NWS ERH should work with coastal offices to refine the ER IDSS briefing template to provide a consistent means for sharing coastal flooding information with core partners.

iii. Public Messaging

One of the challenges offices encountered in public messaging for this event centered around using social media to convey multiple different threats (heavy rain, strong winds, coastal flooding, flash freeze, etc.) and how these threats would evolve in time. With no consistent graphic available for a multi-hazard timeline, many of the offices developed novel approaches to conveying the timeline of the various hazards during this event (Fig. 37-39).

### WFO Mount Holly

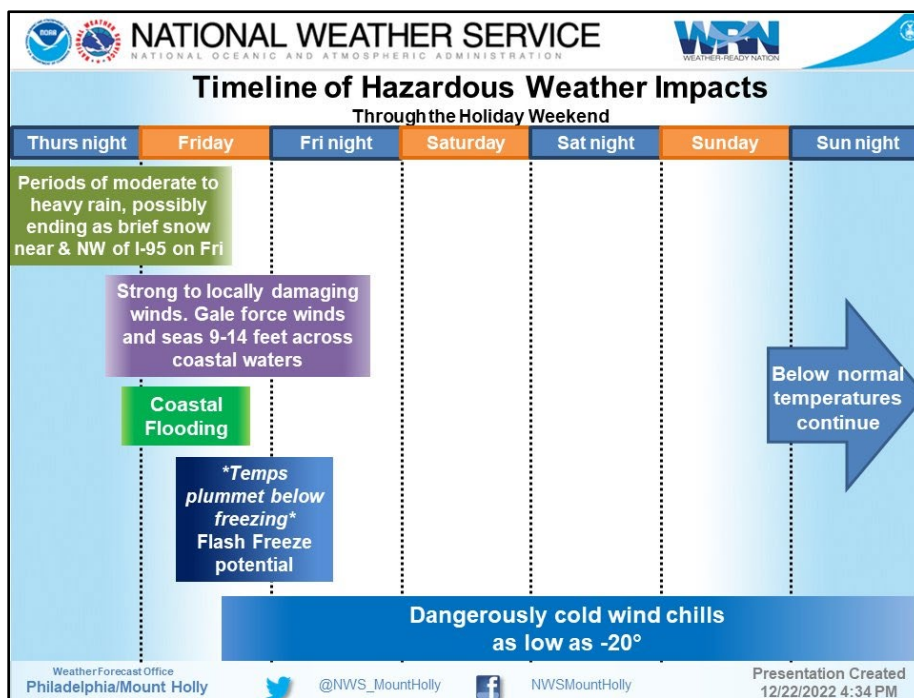


Figure 37: Example Multiple hazard timing slide from WFO Mount Holly.

WFO Boston

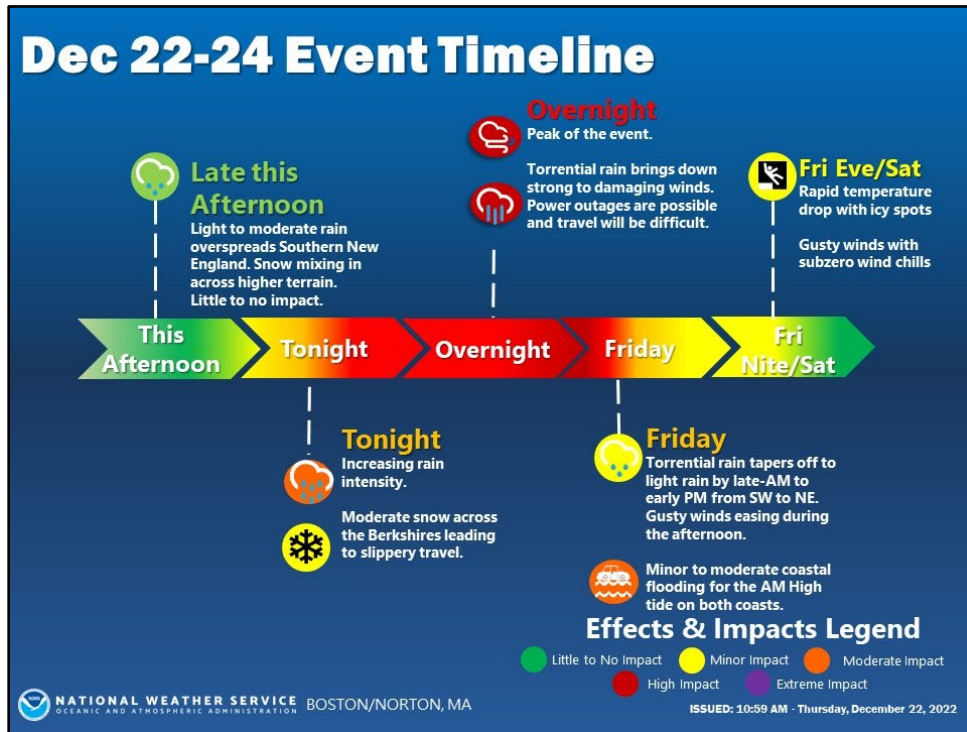


Figure 38: Example Multiple hazard timing slide from WFO Boston.

WFO Gray

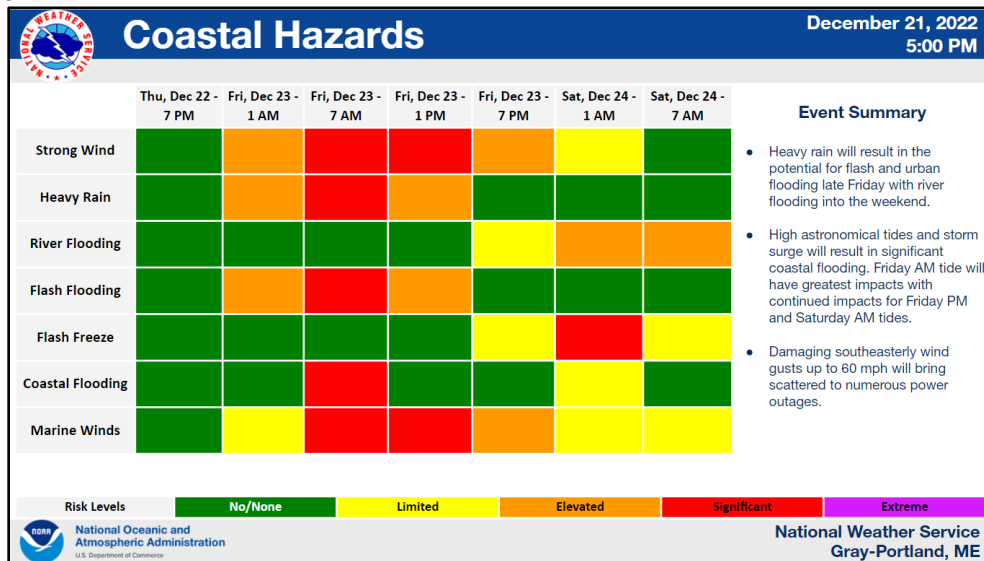


Figure 39: Example Multiple hazard timing slide from WFO Gray.

**Finding 23:** Offices highlighted a particular challenge trying to message a multiple hazard event graphically to the public and the result was numerous novel approaches from the different offices.

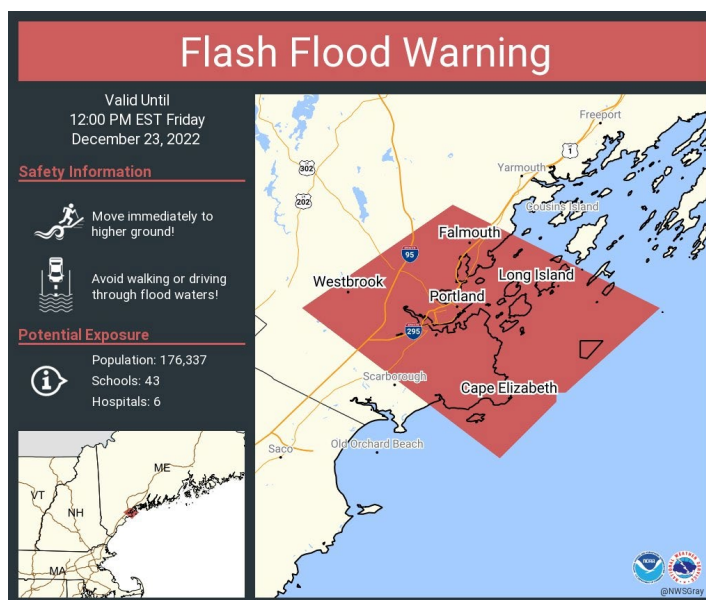
**Recommendation 23:** In coordination with the local offices, NWS ERH should develop a repository of best practice/recommended graphics for use during complex multi-hazard events.

WFO Boston discussed challenges both in the mapping and messaging of inundation. From a mapping perspective they noted that there is a lack of inundation mapping materials to share with partners. From a messaging perspective, they described a continuing challenge using the terms storm surge and inundation. Customer confusion persists regarding the difference in these terms for extratropical events which has been exacerbated at times with the terms inundation and storm surge being used interchangeably. Also, it may not be clear which of these two variables is being referred to in a graphic or briefing.

**Finding 24:** Partner confusion exists when using the terms inundation and storm surge for extratropical events.

**Recommendation 24:** NWS ER should work within and outside of the region to promote consistent messaging of the terms inundation vs. storm surge for extratropical events.

Another challenging messaging aspect of coastal flooding events occurs at the freshwater/saltwater interface. While not the primary focus of this review, there were flood watches and warnings issued for river and overland flooding throughout much of the northeastern United States for this event. Messaging flooding in areas where both freshwater and saltwater impacts were expected does not fit cleanly into the NWS Watch/Warning/Advisory suite. During this event, WFO Gray issued a flash flood warning at 9:19 am Friday, 86 minutes before flash flooding occurred in parts of downtown Portland, Maine (Fig. 40). The product was issued to cover the period of high tide (which occurred at 10:16 am Friday) when it was expected that the combination of heavy rainfall and significant overland flow would encounter a high astronomical tide with no outlet for the water, which is what occurred.



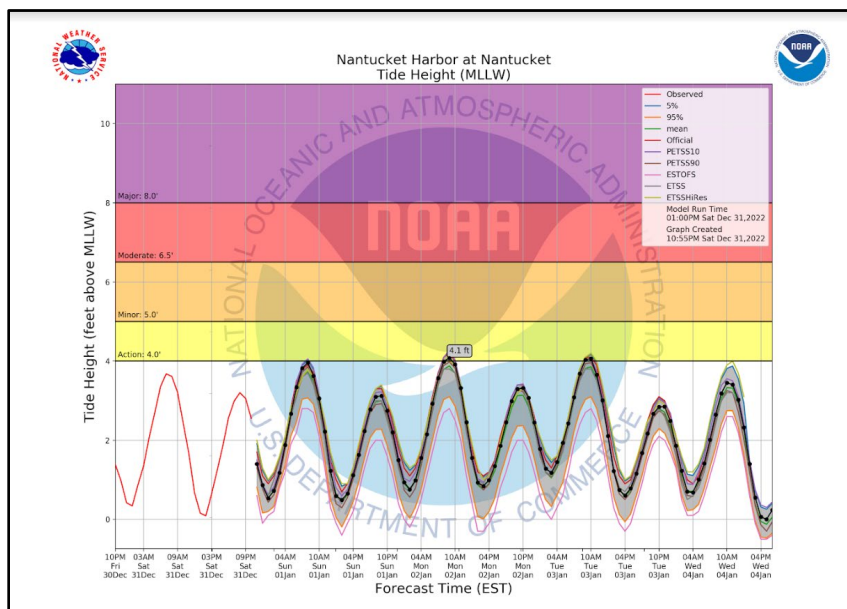
**Figure 40:** Auto-tweeted image of NWS GYX Flash Flood Warning issued on December 23, 2022.

**Finding 25:** Another challenge WFOs encountered was associated with the inability of partner briefings and coastal flood watches/warnings to reach areas vulnerable to coastal flooding in some cases. It was found that county emergency managers were not always passing along expected coastal flooding impacts to local coastal jurisdictions. Some media outlets also did not place much emphasis on the coastal flooding threat and focused on other impacts during this multifaceted event.

**Recommendation 25:** NWS should explore developing impact-based warnings for coastal flooding. The use of higher impact threat tags could allow for the activation of Wireless Emergency Alerts for those areas at risk of life-threatening coastal flooding.

**Finding 26:** WFOs Gray, Boston, and New York expressed a desire to leverage ensemble and probabilistic forecast information into coastal flood messaging. One emergency manager from Rhode Island expressed a desire to view the range of possible outcomes.

**Recommendation 26a:** Develop the capability to display an ensemble of storm surge forecasts showing the range of possible outcomes from all available surge guidance (ETSS, ESTOFS, P-surge, WFO surge, etc.). As an example, WFO Boston created an ensemble water level graphic, shown in Figure 41.



**Figure 41:** Example probabilistic hydrograph produced by WFO Boston.

**Recommendation 26b:** ER WFOs should utilize probabilistic output to determine the odds of reaching specified return intervals (5-yr., 10-yr., etc.) for coastal flooding.

#### iv. Collaboration

Coastal flood watches, warnings, and advisories were issued throughout the northeast for this event. Office to office collaboration on the timing of these headlines provided a consistent message from office to office. Of note was the early collaboration between offices (roughly 60 hour lead time) on issuing the initial coastal flood watches due to the high confidence in this event from both a meteorological and astronomical high tide standpoint. Offices indicated that some differences in headline type (warning vs advisory) from office to office is to be expected given the highly localized impacts coastal flooding presents.

Offices did not report any substantial collaboration with the ER ROC regarding the coastal flooding aspects of this event. Also, there is no national center collaboration with the WFOs for extratropical coastal flooding events.

#### d. Partner Response

IDSS provided to partners through briefings, webinars, one-on-one phone calls, and other methods appears to have been effective in providing partners ample notice of this significant coastal flood event based on feedback received through the impacted WFOs. Several notable partner responses/actions are noted below.

**WFO New York:** New York City deployed a response team to the targeted areas one-day in advance, using information provided to them in IDSS briefings provided by the WFO (which began 96-hours before the event). New York City has flood mitigation measures, such as temporary flood walls, that are used for life-threatening events with catastrophic damage, but based on briefings of expected impacts they did not need to utilize these measures.

**WFO New York:** The Mayor of the Village of Freeport, NY said in a news interview that “the NWS did notify us of extremely high winds and tides today in which we notified our residents of last night”.

**WFO Boston:** The Steamship Authority was very appreciative of targeted calls that began early on, and noted that this was one of the better predicted storms. They shut down operations for 2 days.

**WFO Gray:** The Southern Maine Volunteer Dune Surveying Teams were activated for additional beach surveys as well as Civic partners in Belfast and at the Gulf of Maine Research Institute.

**WFO Gray:** Authorities took mitigating actions prior to the arrival of the storm such as placing barricades and sandbags along coastal roads.

**WFO Gray:** A fire truck was pre-positioned in Biddeford where flood waters were known to cut off access to the region. The First Responders on this fire truck would later be activated in a life

threatening rescue, saving a person from drowning.

**WFO Caribou:** The emergency manager in Hancock County, ME made an effort to reshare NWS social media posts, emphasizing the NWS as the one source for weather information. The EM later commented that “the forecast was accurate”.

e. Service Equity

WFO New York discussed some of the progress and challenges they face given such a large and diverse population they serve. Given the large population of their area, WFO New York does not have the staffing to develop relationships with all of the possible vulnerable communities directly. Their approach, over the past 10 years, has been to work with core partners to amplify their message to these groups. WFO New York discussed the need for translation services for their products to help reach these communities that might mimic NYC Notify, which is used by New York City to take key messaging and translate it automatically into 13 different languages for distribution. This model could be a best practice for other offices to follow, especially in urban areas. Recalling the service equity finding and recommendation from the Buffalo Blizzard, the same applies here with a need for clear expectations and resources aimed at making those expectations a reality.

Elsewhere, a varied approach to identifying and meeting the needs of vulnerable communities. Some of the efforts include:

**WFO Caribou:** Identified and contacted four Indian tribes in the forecast area.

**WFO Gray:** Oldest state in the country where reverse 911 has been used to reach vulnerable populations. Have devised prototype outreach graphics that minimize the use of words given language and reading barriers.

**WFO Boston:** Skywarn training for the deaf/hard of hearing, working together with Telemundo TV, making use of Spanish tweets.

**WFO Mount Holly:** Participated in HWT using the social vulnerability dashboard, making changes to allow for more access to those without computer literacy.

As mentioned in the public messaging section, there were concerns about coastal flood messaging reaching particularly vulnerable coastal communities. However, from the perspective of under-served populations, there were no specific efforts aimed at determining whether vulnerable populations received and understood the messages associated with coastal flooding.

A key common element was the need to work with local partners to identify these groups as well as to better communicate with them. A common theme was that the local WFO does not have the staffing to personally identify or reach out to all of the possible groups. It was clear through these interviews that while each office understands the NWSHQ goal of improved services to these traditionally underserved groups, there was, as of yet, little concrete guidance on the best means



to accomplish this task, nor training or resources to do so.

Given that the findings were very similar with WFO Buffalo, the finding and recommendation from that portion of this report is repeated below.

*Finding 27:* Without clear expectations and a systematic process for identifying and engaging underserved communities, NWS field offices are not yet prepared to fully understand and address how changes in messaging impacts these groups.

*Recommendation 27:* WSH and NWS Regional Headquarters need to provide guidance and tools to NWS field offices to help engage and better understand underserved and vulnerable communities.

#### 4. Findings/Recommendations/Best Practices

This section contains a catalog of all the findings, recommendations, and best practices throughout the review. For definitions on these terms, see Appendix 3.

##### Findings:

*Finding 1:* Performance Management Branch verification calculation is in error for multiple warnings that use the same ETN.

*Finding 2:* Redundant conference call requests became overwhelming at times for WFO Buffalo.

*Finding 3:* Email lists from different WFOs contain different customer groups, leading to inconsistent IDSS from office to office.

*Finding 4:* Inconsistent messaging between forecast, social media, and IDSS briefing products led to some partner confusion.

*Finding 5:* The NWS Eastern Region IDSS briefing template does not have a slide to include these Key Messages for high impact events.

*Finding 6:* The standard ER Briefing template does not have the flexibility to connect different weather impacts into a cohesive message to be received by core partners.

*Finding 7:* Partner webinars and emailed briefings used different slide formats. While it is acknowledged that different **content** may be necessary to meet the needs of different partners, the overall **format** change may cause confusion among partners.

*Finding 8:* Using multiple graphics types in IDSS briefings resulted in inconsistent labeling and a different look and feel for forecast information provided throughout the briefing. This has the potential to cause confusion for partners.

*Finding 9:* Sending full briefing packages to core partners after 4pm was found to be too late to be useful to core partners. They would have preferred briefing materials by the end of the traditional workday.

*Finding 10:* There was a clear misunderstanding from core partners at both the local and state level on the value-added IDSS information that NWS onsite staff could provide. More importantly, the ability of onsite staff to pass along critical thresholds and decisions being considered back to impacted WFOs will allow briefings and forecast products to be better tailored to partner needs.

*Finding 11:* There is concern from multiple staff members at WFO Buffalo that the NWS may become over-extended if they were to offer onsite IDSS.

*Finding 12:* There was conflicting information from WFO Buffalo on the number of employees that were deployment ready, ranging from as few as 2 to as many as 5.

*Finding 13:* Long lead times for Winter Storm Warnings and Blizzard Warnings raised public awareness to this event; however, given the anticipated extreme impacts from the Blizzard, there was no way to effectively message the onset of the life-threatening conditions.

*Finding 14:* WFO Buffalo staff did not participate directly in the press conferences, nor did they receive a request to have a representative at the press conferences. When one official was asked why a representative from the WFO Buffalo was not involved in the press conferences, they stated they were unsure if the office had anyone to participate or if they were even allowed to do so. However, they were open to having a WFO Buffalo representative there.

*Finding 15:* Inconsistent policy for the types/timing of IDSS briefing materials provided by WFOs hampers the ability of the state liaison office to effectively brief state level core partners.

*Finding 16:* WFO Buffalo was not adequately prepared to handle multiple employees housed at the office for multiple days during an anomalously cold event on a weekend. This resulted in poor sleeping conditions and a lack of basic supplies (i.e. food, toiletries, cots/blankets, etc).

*Finding 17:* Given the lack of a staffing plan, the response to staffing was made in a reactive rather than proactive fashion.

*Finding 18:* WFO Buffalo has never hosted an IWT.

*Finding 19:* Without clear expectations and a systematic process for identifying and engaging underserved communities, NWS field offices are not yet prepared to fully understand and address how changes in messaging impacts these groups.

*Finding 20:* Steven's Institute of Technology ensemble-based surge guidance was an invaluable forecast tool for this event but was not accessible within AWIPS for most impacted offices.

*Finding 21:* Extratropical storm surge impacts in riverine areas that have both fresh and saltwater influences on water level are poorly modeled resulting in less lead time on warning products.

*Finding 22:* Every office used a unique slide format to message the potential for coastal flooding in this event which may lead to confusion for partners that straddle more than one WFO.

*Finding 23:* Offices highlighted a particular challenge trying to message a multiple hazard event graphically to the public and the result was numerous novel approaches from the different offices.

*Finding 24:* Partner confusion exists when using the terms inundation and storm surge for extratropical events.

*Finding 25:* Another challenge WFOs encountered was associated with the inability of partner briefings and coastal flood watches/warnings to reach areas vulnerable to coastal flooding in some cases. It was found that county emergency managers were not always passing along expected coastal flooding impacts to local coastal jurisdictions. Some media outlets also did not place much emphasis on the coastal flooding threat and focused on other impacts during this multifaceted event.

*Finding 26:* WFOs Gray, Boston, and New York expressed a desire to leverage ensemble and probabilistic forecast information into coastal flood messaging. One emergency manager from Rhode Island expressed a desire to view the range of possible outcomes.

*Finding 27:* Without clear expectations and a systematic process for identifying and engaging underserved communities, NWS field offices are not yet prepared to fully understand and address how changes in messaging impacts these groups.

#### Recommendations:

*Recommendation 1:* NWS ER should work with AFS/Performance Management Branch to fix the issue with the ETN.

*Recommendation 2:* Requests for briefings on partner-led calls should be coordinated well before a significant event occurs to reduce redundancy.

*Recommendation 3:* NWS ER should clarify regional policy on what partners are allowed to receive briefing materials from local offices and then ensure consistency throughout the region.

*Recommendation 4a:* The title slide of ER IDSS briefings should convey the severity level of the event to ensure impacted core partners do not misunderstand the potential impacts.

*Recommendation 4b:* Offices should have a document that includes “key messages” that will be used throughout the suite of forecast, social media, and IDSS briefing products to promote a consistent message to all partners.

*Recommendation 5:* The standard IDSS briefing template should begin with a Key Messages slide.

*Recommendation 6:* NWS ERH should examine the standard briefing template to include template slides for improved messaging of impacts.

*Recommendation 7:* All ER field offices will adhere to the ER IDSS briefing template to ensure a consistent look and feel for all IDSS briefings to partners.

*Recommendation 8:* ER field offices should strive to streamline graphics into as few formats and styles as possible to reduce possible confusion. If there are graphic types that are not supported by a single graphics package, offices should work with NWS ERH to document these limitations and request improvements to currently used graphics creation software.

*Recommendation 9:* ER field offices should develop IDSS briefing delivery schedules that incorporate feedback from their core partners. In general afternoon briefing packages should be sent to partners at a time (window) as determined by partner input.

*Recommendation 10:* NWS ER should work with local offices to develop best practices on accomplishing on site support as well as documenting success stories that can then be used by other offices when they approach their local partners with an offer of onsite support and its potential benefits.

*Recommendation 11:* WFO Buffalo should embrace the strategic plan as it relates to IDSS.

*Recommendation 12:* WFO Buffalo should increase the number of deployment ready personnel in accordance with IDSS policy. WFO Buffalo should maintain a roster of deployment-ready employees.

*Recommendation 13:* NWS should explore alerting capabilities (e.g. impact-based warning event tags) for Blizzard Warnings prior to, or at the onset of, blizzard conditions to provide heightened awareness to the public and decision makers.

*Recommendation 14:* WFO Buffalo should coordinate with partners and discuss their needs to support public messaging during significant weather events, including participation in press conferences as appropriate.

*Recommendation 15:* WFO Albany, as the New York state liaison office, should engage with each office serving the state of NY to define a consistent paradigm for issuing emails, one-pagers, and full briefing slide decks to their partners.

*Recommendation 16a:* ER WFOs should ensure employees have access to instructions for the HVAC system, to override programming during unusually cold or hot events.

*Recommendation 16b:* ER WFOs should evaluate and address needs to house personnel overnight during extended durations of high-impact and/or unusual events. Offices more prone to high impact events (e.g. hurricanes, blizzards, etc.) that would require multiple nights in the office should consider the installation of a shower. Any new office construction/renovation should include shower facilities.

*Recommendation 17:* WFOs should develop staffing plans for high impact winter storm events, including blizzards.

*Recommendation 18:* WFO Buffalo should host regular IWTs to help build trusting relationships with core partners which may lead to better mutual understanding during high impact weather events.

*Recommendation 19:* WSH and NWS Regional Headquarters need to provide guidance and tools to NWS field offices to help engage and better understand underserved and vulnerable communities.

*Recommendation 20:* ER WFOs with surge forecast points within the Steven's Institute forecast domain should work with WFO New York to find a means to ingest the ensemble forecast information into AWIPS for direct use in TWL forecast production.

*Recommendation 21:* Coastal offices and associated River Forecast Centers that have responsibility for river forecast points that are influenced by extratropical storm surge should work together to identify science and service gaps for these points and formulate a plan to improve services for these points.

*Recommendation 22:* NWS ERH should work with coastal offices to refine the ER IDSS briefing template to provide a consistent means for sharing coastal flooding information with core partners.

*Recommendation 23:* In coordination with the local offices, NWS ERH should develop a repository of best practice/recommended graphics for use during complex multi-hazard events.

*Recommendation 24:* NWS ER should work within and outside of the region to promote consistent messaging of the terms inundation vs. storm surge for extratropical events.

*Recommendation 25:* NWS should explore developing impact-based warnings for coastal flooding. The use of higher impact threat tags could allow for the activation of Wireless Emergency Alerts for those areas at risk of life-threatening coastal flooding.

*Recommendation 26a:* Develop the capability to display an ensemble of storm surge forecasts showing the range of possible outcomes from all available surge guidance (ETSS, ESTOFS, P-surge, WFO surge, etc.). As an example, WFO Boston created an ensemble water level graphic, shown in Figure 41.

*Recommendation 26b:* ER WFOs should utilize probabilistic output to determine the odds of reaching specified return intervals (5-yr., 10-yr., etc.) for coastal flooding.

*Recommendation 27:* WSH and NWS Regional Headquarters need to provide guidance and tools to NWS field offices to help engage and better understand underserved and vulnerable communities.

#### Best Practices:

*Best Practice 1:* To maintain a consistent message throughout the dozens of conference calls WFO Buffalo participated in, a shared Google Document was created to track these IDSS events, and, more importantly, identify key talking points that could be used to describe events. Forecasters had access to these talking points which were then used to provide a consistent message during phone interviews, social media posts, etc. This promotes consistent messaging before, during, and after significant weather events.

*Best Practice 2:* Multiple impacted offices made personal, one-on-one phone calls to potentially impacted partners to help draw attention to the significance of this event. This provides awareness to partners that something important is happening, and also strengthens relationships.

*Best Practice 3:* Coastal offices should develop or improve existing impact catalogs of coastal flooding to provide more detailed IDSS down to the local level to aid decision makers. Having those impacts readily accessible in pre-formatted IDSS slides allows for quicker creation of IDSS briefings and provides easy access to partners.

*Best Practice 4:* WFO Mount Holly and WFO New York maintained a collaboration document through the event which helped coordinate key messages and share forecasting challenges and tips. In the case of WFO New York, this document was shared with internal partners (WFO Albany as New York State Liason Office, ERH ROC, etc.) to assist with state and regional-level messaging.

## Appendix 1: WFO Buffalo Key Product/Headline Timetable

Date	Time	Product/Headline	Description
Sun 12/18/22	438 AM	HWO	Contains potential for significant winter storm then significant lake effect snow Thursday through the weekend
Mon 12/19/22	529 AM	HWO	Contains potential for rain on Thursday/Thursday night, changing to snow on Friday with potentially significant lake effect snow and strong winds Friday Night and Saturday. Lakeshore flooding also mentioned.
Tue 12/20/22	451 AM	AFD	Describes the storm system as a once in a generation type event
	222 PM	WSW	Winter Storm Watch issued for eight western NY counties for Friday morning through Monday morning (Niagara, Orleans, N. Erie, S. Erie, Genesee, Wyoming, Chautauqua, Cattaraugus)
	332 PM	AFD	Describes the coverage of lake effect snow (widespread footprint) and mentions a more widespread impact of blowing and drifting snow.
Wed 12/21/22	400 AM	WSW	Winter Storm Watch issued for two counties east of Lake Ontario for Friday afternoon through Monday evening (Jefferson, Lewis)
	259 PM	WSW	Winter Storm Watch east of Lake Erie expanded to include one additional county (Monroe, including City of Rochester)
Thu 12/22/22	354 AM	WSW	Blizzard Warning Issued for five western NY counties from Friday morning to Sunday morning (Niagara, Orleans, N. Erie, S. Erie, Genesee)
		WSW	Winter Storm Warning issued for four western NY counties from Friday morning through Sunday (Wyoming, Chautauqua, Cattaraugus, Monroe), and for two counties east of Lake Ontario from Friday afternoon through Monday morning (Jefferson, Lewis)
	209 PM	WSW	Winter Storm Warning upgraded to Blizzard Warning for Jefferson County
Fri 12/23/22	956 AM	WSW	Winter Storm Warning upgraded to Blizzard Warning for Chautauqua County
Sat 12/24/22	156 AM	WSW	Blizzard Warning canceled and Winter Storm Warning issued for Chautauqua County
		WSW	Winter Storm Watch issued for Oswego County through Monday morning
Sun 12/25/22	235 AM	WSW	Blizzard Warning canceled and Winter Weather Advisory issued for Niagara, Orleans Counties through the afternoon

		WSW	Winter Storm Warning canceled and Winter Weather Advisory issued for Monroe County
	545 AM	WSW	Blizzard Warning canceled and Winter Storm Warning issued for N. Erie, S. Erie, Genesee Counties
	1244 PM	WSW	Blizzard Warning and Winter Storm Warning issued for Jefferson County
Mon 12/26/22	1232 AM	WSW	Winter Storm Warning canceled for Wyoming, Chautauqua, Cattaraugus Counties
	341 AM	WSW	Winter Storm Warning canceled and Winter Weather Advisory issued for N. Erie and S. Erie County
		WSW	Winter Storm Warning canceled for Genesee County
	635 AM	WSW	Winter Storm Warning canceled for Oswego County
Tue 12/27/22	103 PM	WSW	Winter Storm Warning expires and Winter Weather Advisory issued through the evening for Jefferson and Lewis Counties
		WSW	Winter Weather Advisory expires for N. Erie and S. Erie County
	900 PM	WSW	Winter Weather Advisory canceled for Jefferson and Lewis Counties

## Appendix 2: Timeline of WFO Buffalo Conference Calls and IDSS Briefings

### WFO Buffalo Conference Calls

	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	
NWS Partner	12/20	12/21	12/22	12/23	12/24	12/25	12/26	12/27	12/28	Total
NYS DOT - Statewide	X									1
Wrn District EM Briefing	X									1
NYS Thruway - Statewide		X	X	X	X	X				5
Lake District EM Briefing		X								1
NYS DOT - Region 4/5		X	X	X	X	X				5
WFO Webinar		X	X	X	X					4
NYS MAC - Statewide		X	X	X	X	X	X	X	X	8
NFTA - BUF Airport			X	XX	X	X	X	X	X	8
Total										33



## WFO Buffalo Email Briefings

Email / Slide Set	Time sent
#1	12/20 4:52 PM
#2	12/21 6:49 AM
Weekly Briefing	12/21 11:47 AM
Webinar #1 Slides	12/21 3:03 PM
#3	12/21 4:42 PM
#4	12/22 7:48 AM
Webinar #2 Slides	12/22 3:03 PM
#5	12/23 6:42 AM
Webinar #3 Slides	12/23 4:10 AM
#6	12/24 5:23 AM
Webinar #4 Slides	12/24 3:58 PM
#7	12/25 6:28 AM
#8	12/25 3:16 PM
#9	12/26 5:16 AM
#10	12/27 4:46 AM

## Appendix 3: Findings, Recommendations, and Best Practices

### Definitions

**Finding:** A statement that describes something important learned from the assessment for which an action may be necessary. Findings are numbered in ascending order and are associated with a specific recommendation or action.

**Recommendation:** A specific course of action, which should improve NWS operations and services, based on an associated finding. Not all recommendations may be achievable but they are important to document. Recommendations should be clear, specific, and measurable.

**Best Practice:** An activity or procedure that has produced outstanding results during a particular situation that could be used to improve effectiveness and/or efficiency throughout the organization in similar situations. No action is required.