July 9-12, 2023
Northeast Flash Flood and River Flood
After-Action Review

November 2023
NOAA/NWS ERH Headquarters, Bohemia, NY 11716

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1.0 Introduction

Rounds of intense rainfall from July 9th through the 11th caused flash flooding and river flooding in Vermont, New York, New Hampshire, Connecticut, and Massachusetts. Figure 1 shows the rainfall totals for this event. The National Weather Service issued guidance, forecasts, and warnings ahead of this event from five weather forecast offices (WFOs), Northeast River Forecast Center (NERFC), and the Weather Prediction Center (WPC). The flooding caused significant property damage and lives lost. As part of the NWS efforts to assess its services and performance in this event, the NWS Eastern Region Director initiated this after action review (AAR).

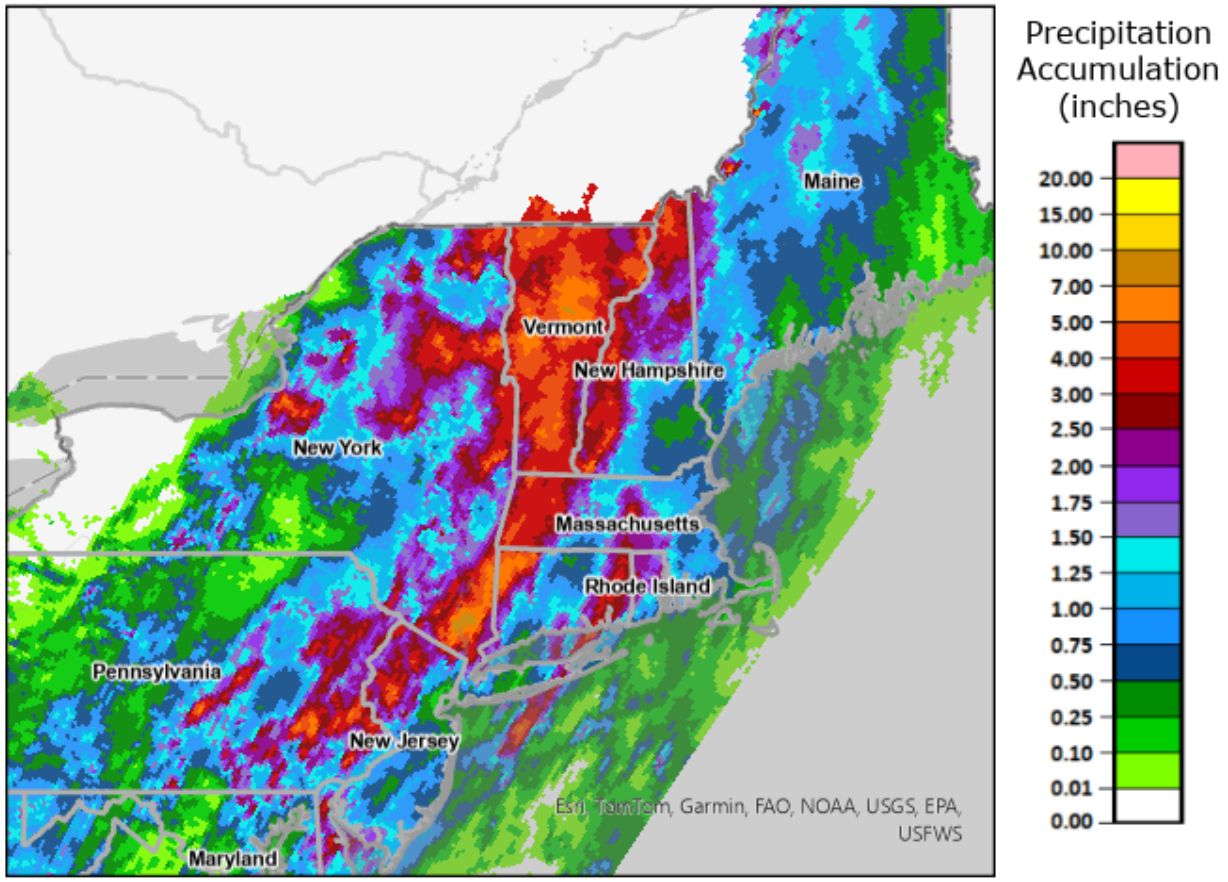


Figure 1. Rainfall totals from July 9 to July 11, 2024

2.0 Methodology

To conduct a comprehensive AAR for the intense rainfall and subsequent flooding in the northeast, our approach identified and engaged NWS Offices,

identified and interviewed partners, collected data, and compiled and verified information.

2.1 Identification and Engagement with NWS Offices

We began by identifying NWS offices that played a role in providing services and support during this event. This list includes:

- Five Weather Forecast Offices (WFO)
    - Burlington, Vermont (BTV)
    - Albany, New York (ALY)
    - Upton, New York (OKX)
    - Gray, Maine (GYX)
    - Norton, Massachusetts (BOX)
- The Eastern Region Operations Center (ROC).
- The Northeast River Forecast Center (NERFC).
- The Water Prediction Center (WPC).
- The Water Prediction Operations Division (WPOD).

We conducted interviews with both the management teams and staff from these offices. During these sessions, we asked a series of questions, focusing on the preparation for, and response to, the weather events in question.

2.2 Partner Identification and Interviews

Each NWS office recommended partners for us to interview. Based on their suggestions, we interviewed:

- The State of Vermont Emergency Operations Center (VTEOC).
- The Orange County New York Emergency Operations Center (NYEOC).
- The New York State Department of Homeland Security (NYDHS).
- Officials from the State of Vermont.
- Local media.

In these interactions, our questions were geared towards understanding their perception of interactions with the NWS during the event.

2.3 Data Collection

We collected a wealth of data from the NWS offices. This included:

- Office logs detailing the sequence of events.
- Briefings provided to partner entities.
- Collected weather data pertinent to the event.
- Post-event verification data.
- Various graphs and figures related to the weather patterns and impact.

2.4 Compilation and Verification

From the gathered data and insights, we crafted a detailed narrative of how the entire event unfolded. During this process, we identified certain inconsistencies. These were then clarified through a series of follow-up emails to ensure accuracy and completeness. Sections 3 through 10 summarize what we learned from this review.

3.0 Culture and Planning

Culture in a WFO represents those shared values, behaviors, and attitudes that guide practices and decisions. Planning ahead of an event includes how an office organizes teams, trains individuals, flexes shifts, and requests assistance. Evidence from the pre-event planning and post-event staffing decisions at the WFOs indicate that teamwork and cooperation are valued at those offices.

3.1 Pre-event Planning

Several of the affected WFOs have an active hydrology team, ensuring policy/software expertise and established relationships with partners is spread among several WFO team members. WFOs Burlington, Albany, and Boston all worked to ensure staffing included hydrology expertise on different shifts throughout the flood event.

WFO Burlington's hydro team shares responsibility for hydro program management. The Senior Service Hydrologist oversees the team and ensures hydrologic training for all staff including specialized training for the hydro team members to serve as experts in software, practices, partner engagement, and post-event surveys. WFO Burlington hydro team members nurture relationships with federal partners such as the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), and state teams such as the Vermont and New York Silver Jackets. A member of the hydro team was among those providing onsite IDSS to the VTEOC.

Best Practice 1: WFO Burlington maintains a broad group on their hydro team. This ensures expertise/experience can cover multiple shifts during high impact events.

Best Practice 2: The WFO Burlington hydro team invests in relationships with core partners. This ensures familiarity with those partners and their IDSS needs.

3.2 Post-event Staffing

Following the high-impact flooding, WFO Burlington coordinated with NWS ERH on the need for staff relief from the intense operational cadence. NWS ERH supplied assistance from the ER ROC and ERH staff members, experienced staff from unaffected WFOs, as well as NERFC and NWS Pathway (SUNY Albany) student assistance. That support allowed WFO Burlington staff to conduct post-flood surveys and extended onsite IDSS to VTEOC.

Best Practice 3: ER WFOs should contact the ER ROC in a timely manner for assistance during and immediately after high impact events to allow for continued IDSS, operations, and surveys following a high impact event.

4.0 Meteorological Overview

4.1 Soil Moisture Conditions

Soil moisture conditions were wet before the rain began on July 9th, and those conditions contributed to the hydrologic response. June rainfall had been 1-2 inches above average for the northeastern US. Then, in the early part of July, the region had several rounds of localized rainfall that led to

flash flooding and left the ground near saturation by the time an additional 5 to 10 inches of rain entered the forecast for the July 9th-11th period.

Flash Flood Guidance (FFG) is one indicator forecasters can review to gauge the likelihood of flash flooding. It is the amount of rain that is forecast to result in flash flooding. FFG is inversely related to past recent rainfall. FFG lowers as rain saturates the soil, and FFG increases as soils dry out. Due to the recent rainfall and the weeks of above average rainfall, FFG on July 9 were low with one-hour duration FFG between 1 and 1.5 inches, three-hour duration FFG between 1.5 and 3 inches, and six-hour duration FFG between 2 and 3.5 inches.

4.2 Weather Pattern

A strong, blocking upper high over the North Atlantic, with a resultant slow-moving upper low over Central Canada created a synoptic pattern that changed little from July 7-10. It continually brought moisture into the New England area. Periodic shortwaves rotated around the upper low, crossing the flooding region and creating numerous periods of heavy rain. Analysis of the rainfall pattern shows persistently high levels of precipitable water over New England and a persistent upper low over Canada and the Northern Plains.

On July 10th, strong dynamical forcing combined with a 250mb shortwave crossing New England led to winds aloft above 125 knots which is strong for July in this region. A blocking high over the Atlantic caused the shortwave to slow its progress over New England. This extended the period of dynamical support over an area of elevated precipitable water.

4.3 Hydrologic Response

The rainfall produced two hazards: Flash flooding and river flooding. The July 9th-11th intense rainfall produced flash floods at several areas in Vermont and New York, major river flooding at six NWS forecast points in central and northern Vermont, and moderate river flooding at eight NWS forecast points in Vermont, Connecticut, and Massachusetts. All of those forecast points are in the NERFC area of responsibility. The most severe river flooding was within the WFO Burlington warning area. Less severe river flooding occurred within the warning areas of WFOs Albany and Boston.

The intense rainfall on July 9th-10th caused a rapid rise on many area rivers–particularly in Vermont. Some locations along the Winooski, Williams, Lamoille and Otter Creek reached major flood stage within 12 hours after the initial rise above flood stage.

5.0 Impacts

Two of Vermont's rivers, the Winooski and the Lamoille, reached crest levels 2nd only to the flood of record in November 1927. A few locations exceeded flood crests associated with Hurricane Irene in 2011. Unlike Hurricane Irene, river flooding impacted a smaller number of forecast points. Crests above major flood stage occured in central and northern Vermont, whereas during Hurricane Irene, crests exceeding major flood stage occurred through areas of eastern New York and Massachusetts.

The severe flooding prompted hundreds of evacuations and shut down major roads and highways. Flooded roads along the Winooski River cut off access to the Vermont State EOC. The State EOC had to be evacuated and relocated to an alternate location during the height of the flooding. Interstate 89 near the state capital of Montpelier also flooded.

NWS preliminary flood fatalities identified three potential cases of flood- or flash flood-related fatalities in Vermont, and one individual in Orange County, New York died as a direct result of the flash flooding.

6.0 Flash Flooding

This section details how each office delivered services in response to the flash flood hazard. The flash flood warning (FFW) verification subsection describes the metrics NWS uses as an objective evaluation of WFO performance. The IDSS subsection describes the communications between NWS offices and core partners. The Collaboration subsection describes the communications between NWS offices, and the Public Messaging section describes mechanisms the NWS offices used to communicate with the general public.

6.1 FFW Verification

Four WFOs (Burlington, Gray, Albany, and Upton) issued 64 FFWs from July 9th to July 11th. FFWs are verified against official NCDC Storm Data reports.

Government Performance and Results Act (GPRA) goals for FFWs are a lead time of 65 minutes and an accuracy (POD) of 76%. For GPRA purposes, POD is calculated as the percentage of flash flood areas that were warned for. Lead time is simply calculated as the difference between the time of issuance of the warning and the first incidence of reported flooding. Table 1 shows the verification statistics for these 4 offices.

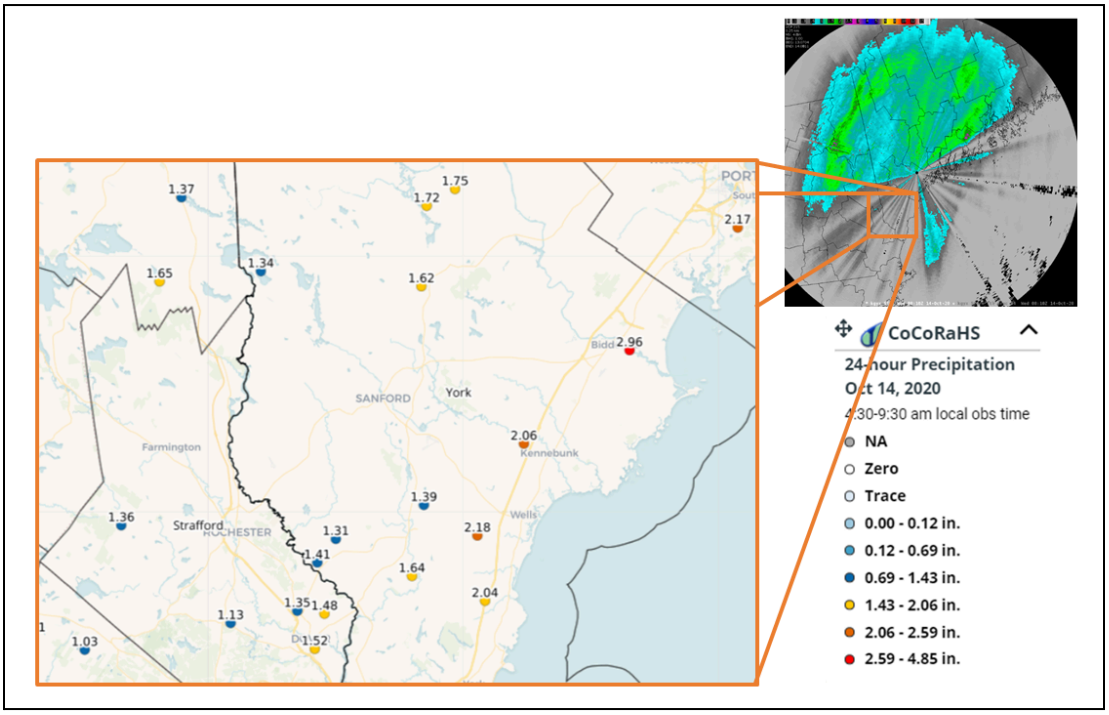
Table 1. Flash Flood Verification Statistics, July 9th to 11th, 2023.

WFO	Warnings	Verified	Not Verified	Missed Events	POD, %	Lead Time, Minutes
ALY	12	11	1	0	95	48
BTV	22	18	4	1	89	108
GYX	6	5	1	7	50	32
OKX	24	20	4	3	92	81
Total	64	54	10	11	86	72
GPRA					76	65

The total POD and Lead Time calculated are aggregated by combining all of the data for all 4 offices. These results overall exceed the GPRA goals (POD of 86% versus GPRA 76%; and a Lead Time of 72 minutes versus GPRA 65 minutes). It is common for high impact events to show good verification statistics because, for large on-going and strongly forecast events, there is a lowered surprise factor. There were office-to-office differences; however, most notably in Lead Time.

WFO Gray (GYX) is an outlier in the FFW statistics largely due to beam blockage by trees in proximity to the radar. The beam blockage limits the information available to forecasters about intense rainfall--leading to the challenging flash-flood warning process for WFO Gray. Figure 2 shows the differences between the radar rainfall estimates and the rain gauges for two counties immediately southwest of the radar. The FFW performance at Gray

has potential impacts to life and safety as well as degradation of NWS services to that population. Raising the tower to a full 30 meters will reduce



the beam blockage; that solution awaits funding.

Figure 2. Comparison of the GYX radar rainfall estimates with CoCoRaHS rain gauge network for October 14, 2020 around Sanford County, ME and Strafford County, NH.

Finding 1: The GYX radar's beam blockage caused significant underestimation of rainfall across Sanford County, ME and Strafford County, NH.

Recommendation 1: NWS should fund raising the GYX radar tower to 30 meters.

6.2 IDSS

This subsection describes IDSS delivered as briefings and onsite support.

6.2.1 Briefings

NWS offices provided core partners with relevant information and interpretive services that helped them make decisions. Albany, Burlington,

Gray, Upton, and NERFC produced email briefings and conducted conference calls. In addition, WFO Burlington deployed staff to VTEOC where the NWS staff conducted in-person briefings to the Governor. Their briefings supported the decision of the Governor of Vermont to order a rare "State of Emergency Declaration'' on July 9th.

The most impactful flash flooding started on Sunday evening July 9th and continued through Monday July 10th. This was followed by river flooding that continued into Wednesday, July 12th. Most offices started their email briefings on Friday July 7th, continued briefings through the weekend, then stopped briefings as the threat dissipated in their area.

Best Practice 4: WFO Burlington's practice is to email a briefing on Friday before the end of the work day when significant weather is expected during the weekend. This gives sufficient lead time to partners who may not access email during the weekend.

Eastern Region socialized and trained forecast staff to prepare One-Pagers using a standard format to send to partners ahead of an event. One-Pagers are geared toward situations in which there is a single hazard or early notification for an expected multi-faceted significant event in which the full briefing slide deck will eventually be used. The regional guidance for One-Pagers describes the Hazards and Impacts section content.

> *List which describes the weather hazard(s) and related impacts associated with the expected event. An NWS watch/warning or advisory is neither a hazard nor an impact. Location information is included either here or in the Timing section.*

Best Practice 5: Well ahead of this event, the WFOs and NERFC sent One-Pagers to partners.

Finding 2: Some ER One-Pagers did not list detailed impacts from the expected event, rather they included generic 'flash flooding' wording.

Table 2 highlights examples from this event that show excellent impact descriptions and examples that lacked impact descriptions.

Recommendation 2a: Review and update as appropriate the ER One-Pager guidance regarding the description of impacts for partners.

Recommendation 2b: The IDSS Briefing Builder should allow for a list of pre-scripted impacts to be inserted into the the Hazards & Impacts section of the briefing.

Table 2. Examples from Hazard and Impact sections

Clear impacts
Flash Flooding: Widespread rainfall of 1-3 inches with localized higher amounts will likely lead to widespread flash flooding. Expect washed out roads and culverts. Persistent excessive rains may cause flooding of streets, urban and poor drainage areas. Flooding of structures and road closures are possible.
Missing Impacts
Additional 1 to 3 inches of rainfall on already saturated ground could increase the potential for flooding and isolated to scattered flash flooding.

As confidence in the forecast increased, WFO Burlington changed the language in their briefings to include the term “catastrophic” to describe the potential impacts. Figure 3 shows a portion of a briefing that they sent to partners via email on the evening of July 9. VTEOC recognized this change, and during post-event interviews they said to the WFO Burlington management that “this term caught everyone’s attention”. At the VTEOC and in NWSChat 1.0, WFO Burlington stated that this event could be the “Most significant event since Irene, perhaps localized comparable damage”. According to the VTSECO, this analogy “Woke everyone up to another level.” The decision to use this comparison was carefully considered by management and staff at WFO Burlington. Additionally, at least one member of management reviewed NWSI chapters to determine if comparisons to past events could be used in briefings.

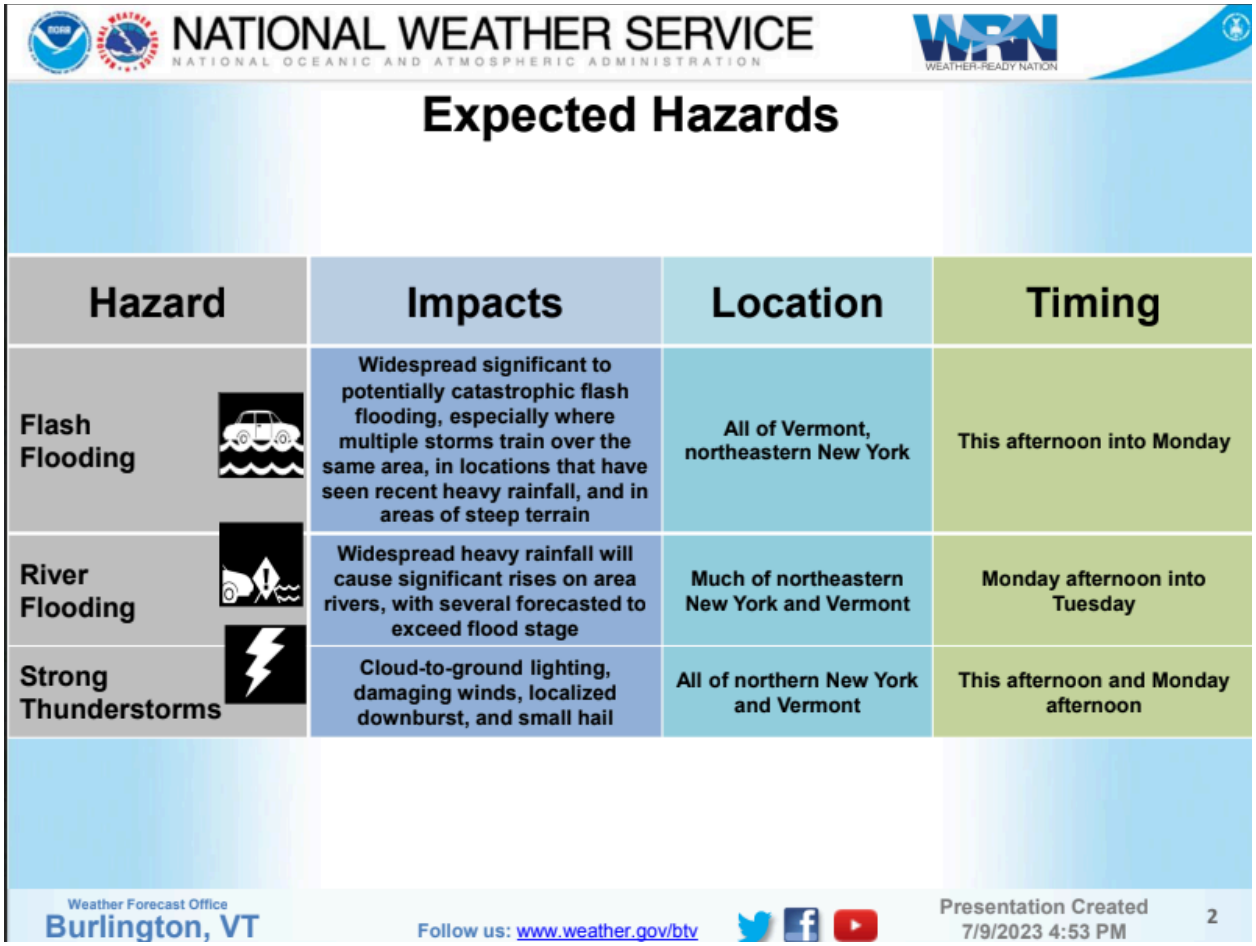


Figure 3. WFO Burlington IDSS briefing emailed the evening of 7/9/2023

Hurricane Irene had a devastating impact on Vermont and other parts of the Burlington forecast area. It was recent enough that it was relevant to many of the people still involved in government. For example, the current governor was a state-wide elected official during Hurricane Irene.

WFO Burlington attributes the Hurricane Irene analog as a primary reason that VTEOC made an emergency declaration and activated resources well ahead of the event. The rescue teams distributed across Vermont were busy. The WFO notes over 200 rescues occurred in a short period of time once the flooding started.

In August 2011, Hurricane Irene caused damage from North Carolina to Maine. Much of the damage in the south was due to high winds, and as the storm came north the damage was due to flooding. The impacts included 40 deaths and $6.5 billion in damages. NWS conducted a Service Assessment.

https://www.weather.gov/media/publications/assessments/Irene2012.pdf

Best Practice 6: The WFO Burlington office conveyed high confidence of catastrophic impacts using terms not normally used in briefings (i.e. "catastrophic") and references to a recent past catastrophic event–Hurricane Irene. This raised a clear, unambiguous alert to state partners and motivated them to take action.

Using Hurricane Irene as an analog, WFO Burlington caused confusion for other local forecast offices–and possibly partners. Appendix 1 compares and contrasts the two events. The extent of the most serious flooding was more limited than the extent of the impacts from Hurricane Irene. Since one office's messaging can expand beyond the borders of the CWA, populations surrounding the Burlington CWAs also heard the messaging about impacts severity referencing Hurricane Irene.

Finding 3: WFO Burlington did not coordinate the Hurricane Irene (2011) analogy with neighboring offices or ER ROC.

Recommendation 3: ER WFOs need to coordinate in advance the key messages and references to historical events with surrounding WFOs, RFCs, and ER ROC prior to sending this wording to partners or to the media/social media.

Once this comparison was shared in NWSChat 1.0, it resulted in several inquiries to WFO Albany, WFO Boston, the State of New York, and local media. WFO Albany described allocating resources away from the event to respond to these inquiries.

Finding 4: The way that the Hurricane Irene analog was messaged was ambiguous in time and space. It caused additional workload for surrounding offices because partners interpreted it too broadly.

Recommendation 4: ER WFOs should use historical event language in well-coordinated messages that are unambiguous in the time and location where it applies.

Finding 5: WFO Burlington did not use the comparison to Hurricane Irene (2011) in their IDSS email briefings.

Recommendation 5: For a significant event involving multiple offices, ER offices should share documents that include all talking points and key

messages that should be used throughout the suite of forecast, social media and IDSS briefings to make sure the message is consistent.

WFO Gray maintained an internal "message of the day" Google slide. Figure 4 shows an example of the slide which includes key messages to use in briefings and social media posts.

Best Practice 7: WFO Gray coordinated messages using their "message of the day" tool. This slide ensured that all staff presented a consistent message throughout the event.

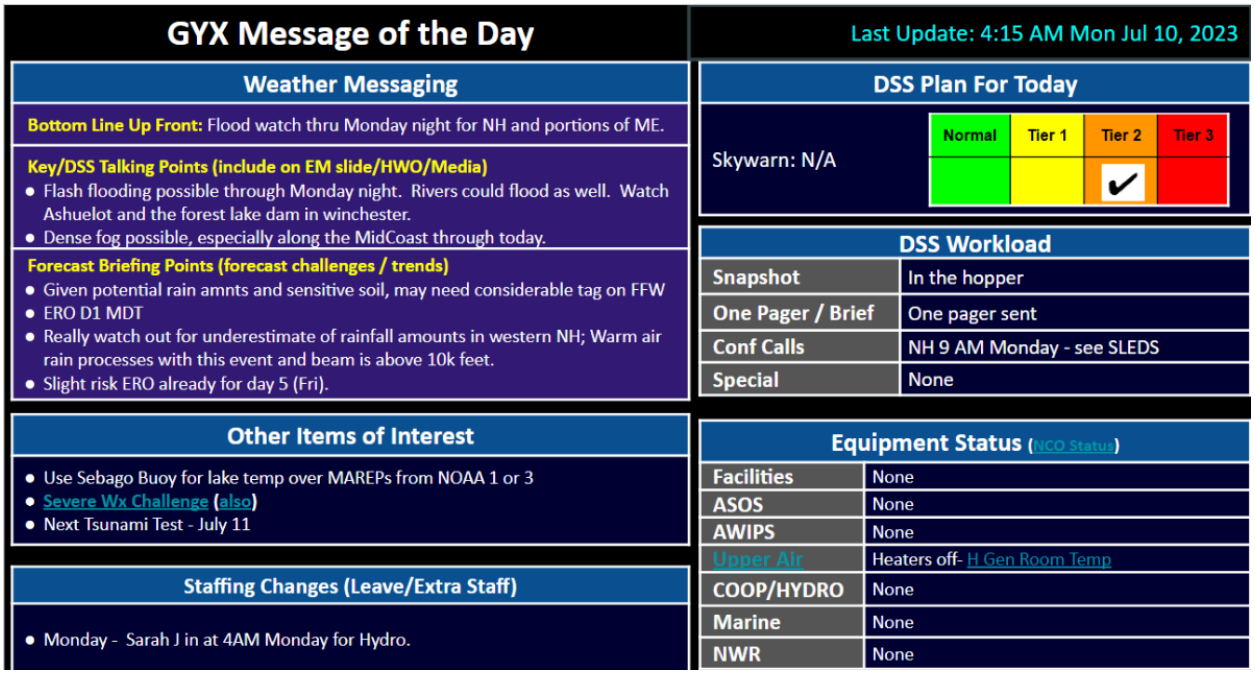


Figure 4. Message of the Day slide from WFO Gray on July 10th.

The "potentially catastrophic" wording in the IDSS email briefings raised awareness about the potential impacts from this event. In many cases, this phrase was added after the title slide, to where partners would have to scroll to find this information. The appearance of the title slide did not change as the confidence in significant impacts increased. A social media post from WFO Burlington used a red font to heighten awareness of the potentially significant impacts.

Finding 6: On some briefing slides sent to partners, the appearance of the title page remained unchanged as confidence in significant impacts increased.

Recommendation 6: It is recommended that red text should be used in the title slide of briefings to draw attention to the potential for an extreme weather event, as recommended in the EM_Core_Briefing Content Template document.

Figure 5 shows an example of the use of red text to highlight a key message.

Figure 5. WFO Burlington Social Media Post

Many IDSS email briefings included quantitative precipitation forecast (QPF) maps to message expected rainfall amounts. Some partners reported confusion or surprise with rainfall totals significantly different from what was shown on the QPF maps. Appendix 2 is a critical review of some attempts by forecasters in this event to convey a range of QPF values, and it recommends probabilistic approaches to these maps.

Finding 7: Single deterministic QPF values do not effectively convey rainfall and potential impact uncertainties, and can adversely impact user decision making.

Recommendation 7: WFOs should utilize probabilistic information to convey uncertainties in QPF. Particular emphasis should be on exceedance of critical/impactful rainfall thresholds that are identified through interactions with partners.

IDSS briefings from one office stated the next briefing would be made available "If/When a flood watch was issued or expanded". Starting July 10th, a specific date and time was given for the next briefing. Tying the next briefing issuance to when an unscheduled product was issued likely made it difficult for partners to know when they would receive the next briefing.

Finding 8: Briefings from one office lacked consistency regarding when the next briefing would be available, with several using an unscheduled product as a trigger for the next briefing.

Recommendation 8: ER WFOs should use specific times, not headline issuances, for the next briefing, so partners can know exactly when this information will be received.

The Graphical Hazardous Weather Outlook (GHWO) provides risk levels for several hazards including excessive rainfall which is generated from the Weather Prediction Center (WPC) excessive rainfall outlook (ERO). WFO Gray used the GHWO excessive rainfall risk graphic to communicate the location and risk level for excessive rain. Figure 6 shows an example of this graphic, and Figure 7 shows the ERO issued by WPC.

Finding 9: The threat risk levels for excessive rainfall on the GHWO (Limited, Elevated, Significant, and Extreme) are different from the threat risk levels used by WPC (Marginal, Slight, Moderate, and High). This resulted in inconsistent messages for the risk of excessive rainfall.

Recommendation 9: NWS/AFS should review and implement consistent threat/risk thresholds for both national center and field office products and related messaging.

All local forecast offices interviewed for this event sent IDSS slide-decks with a regular and consistent cadence, with a morning briefing followed by a late afternoon briefing. A large majority of these briefings included a specific time when the next briefing would be issued, with most offices sending these between 4 and 6 PM.

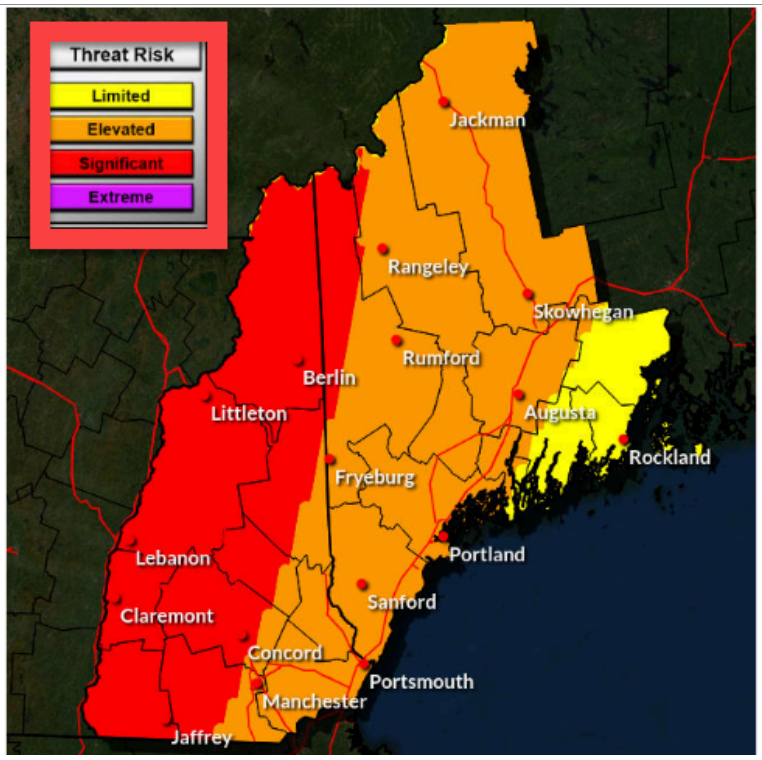


Figure 6. Example GHWO Excessive Rainfall Risk used in WFO Gray.

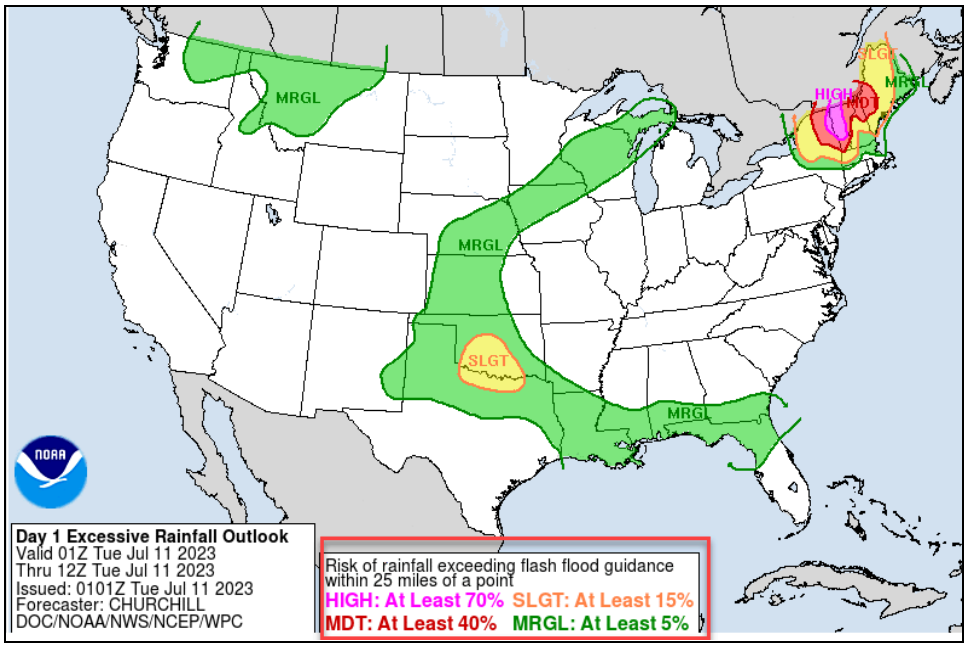
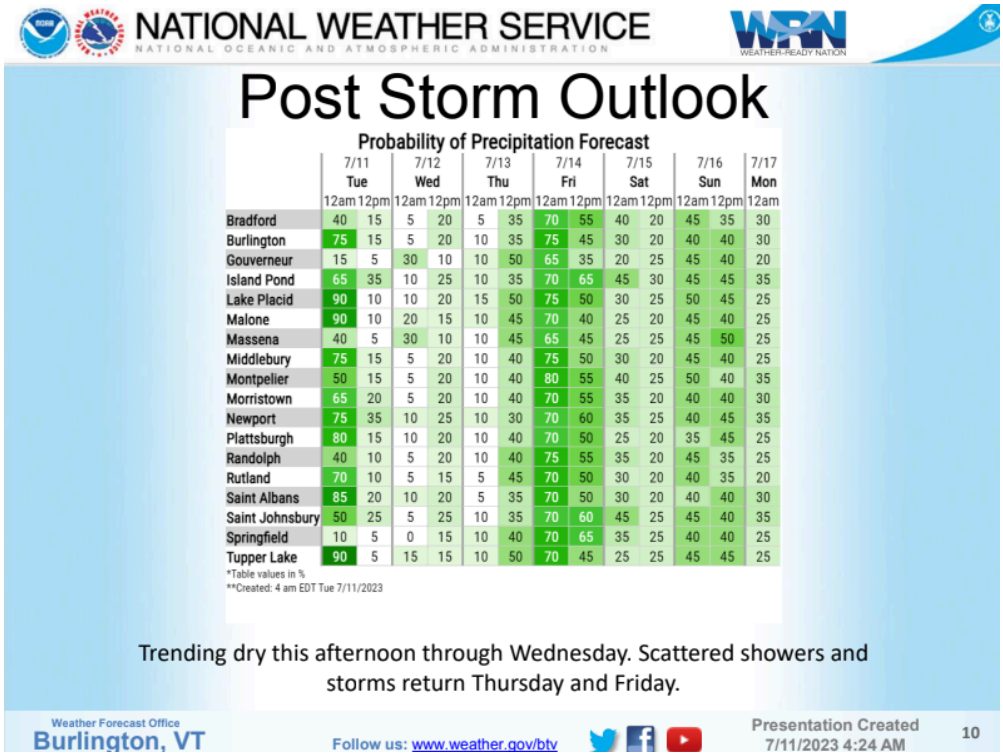


Figure 7. WPC ERO.

Best Practice 8: WFO Upton provides clear triggers on when to start and escalate IDSS. This supports consistency in delivering IDSS to our partners.

After the catastrophic flash flooding subsided on Tuesday July 11th, localized heavy rain continued to bring pockets of flash flooding that caused landslides and debris flows to some of the impacted areas. VTEOC noted "landslides were something we were not used to dealing with". Many local forecast offices included forecast information beyond the peak of the event to assist partners with recovery efforts. Figure 8 shows the format of the outlook product.

Best Practice 9: WFO Burlington delivered a post-storm outlook in their IDSS briefing. This assisted partners with recovery efforts.



	7/11 Tue		7/12 Wed		7/13 Thu		7/14 Fri		7/15 Sat		7/16 Sun		7/17 Mon
	12am	12pm	12am	12pm	12am	12pm	12am	12pm	12am	12pm	12am	12pm	12am
Bradford	40	15	5	20	5	35	70	55	40	20	45	35	30
Burlington	75	15	5	20	10	35	75	45	30	20	40	40	30
Gouverneur	15	5	30	10	10	50	65	35	20	25	45	40	20
Island Pond	65	35	10	25	10	35	70	65	45	30	45	45	35
Lake Placid	90	10	10	20	15	50	75	50	30	25	50	45	25
Malone	90	10	20	15	10	45	70	40	25	20	45	40	25
Massena	40	5	30	10	10	45	65	45	25	25	45	50	25
Middlebury	75	15	5	20	10	40	75	50	30	20	45	40	25
Montpelier	50	15	5	20	10	40	80	55	40	25	50	40	35
Morristown	65	20	5	20	10	40	70	55	35	20	40	40	30
Newport	75	35	10	25	10	30	70	60	35	25	40	45	35
Plattsburgh	80	15	10	20	10	40	70	50	25	20	35	45	25
Randolph	40	10	5	20	10	40	75	55	35	20	45	35	25
Rutland	70	10	5	15	5	45	70	50	30	20	40	35	20
Saint Albans	85	20	10	20	5	35	70	50	30	20	40	40	30
Saint Johnsbury	50	25	5	25	10	35	70	60	45	25	45	40	35
Springfield	10	5	0	15	10	40	70	65	35	25	40	40	25
Tupper Lake	90	5	15	15	10	50	70	45	25	25	45	45	25

*Table values in %
**Created: 4 am EDT Tue 7/11/2023

Figure 8. Post-Storm outlook briefing sent by WFO Burlington on July 11th, 2023.

Finding10: The VTEOC was not accustomed to responding to landslides and debris flows, and the IDSS Briefing Builder lacks icons for this hazard in the 'Main Points' template to assist and remind forecasters to include it in briefings.

Recommendation 10: ER offices should coordinate with partners-to make sure briefing templates include landslides and debris flows hazards in the partner's area.

6.2.2 Onsite Support

WFO Burlington provided onsite support at the VTEOC from July 10 through July 21 with remote support continuing through September 1st. Due to flooding at the primary VTEOC site, Vermont moved the VTEOC to their designated backup location. WFO Burlington participated in three to four daily briefings, including briefing the governor for the duration of the onsite and remote support. VTEOC found this onsite support "invaluable", and stated anytime they needed weather information or an impromptu briefing, WFO Burlington was "Johnny on the spot".

ER and other NWS offices assisted WFO Burlington to enable onsite IDSS during and after the event. From July 7th through July 20th, a meteorologist from the Eastern Region ROC, Eastern Region Headquarters, MSD, or an MIC from another office, worked operational shifts which allowed staff from NWS Burlington to provide onsite support, as well as alleviate stress after this long-duration event.

Best Practice 10: WFO Burlington contacted ER ROC for help with operations during and shortly after the event. This allowed the office staff to focus on IDSS and to gather information to verify the office's forecasts.

VTEOC officials praised WFO Burlington for quickly tailoring their briefings to the audience. Because WFO Burlington was embedded with the VTEOC, deployed meteorologists knew what critical weather information the Governor needed compared to what county and local officials required.

One deployed meteorologist from WFO Burlington overheard Vermont Emergency Management officials discuss overtopping dams and how they should respond. This meteorologist immediately informed these officials that the NWS can run dam-break flood modeling and mapping, which Emergency Management officials hailed as a tremendous service.

Best Practice 11: WFO Burlington deployed meteorologists who listened to feedback from their partners during and following briefings. This allowed them to customize future briefings for a similar audience.

The long duration of the onsite IDSS at the VTEOC required several meteorologists from WFO Burlington to participate, including meteorologists who were just returning to work after several days off. To ensure critical information was not lost during shift transitions, deployed meteorologists from WFO Burlington arrived at least one hour before the outgoing deployed meteorologist departed. At intense times, WFO Burlington extended the duration of this overlap.

6.3 Collaboration

Interviews with affected WFOs, WPC, and the ROC revealed that there was frequent collaboration between WFOs and national centers, as well as the ROC, regarding the ERO and high-level messaging.

While NWS offices frequently collaborated, WFOs Burlington and Albany did not coordinate key messages and references to Hurricane Irene as an analog for this event before WFO Burlington released this comparison to the media.

After the high risk outlook for excessive rain was issued on Sunday July 9, WPC proactively contacted FEMA to schedule a briefing Monday morning July 10 with the FEMA administrator. This inter-agency collaboration resulted in FEMA moving resources to locations where the greatest impacts were expected.

Best Practice 12: When a moderate or high-risk ERO is issued, WPC contacts FEMA to schedule a briefing. Similarly at a regional level, ER ROC worked with FEMA region 1 to conduct a briefing. This ensures that FEMA has awareness as early as possible.

7.0 Public Messaging

The WPC ERO increased from a slight risk on Saturday morning July to an extremely rare high risk across extreme northeast New York and most of Vermont by Sunday morning July 9th. Figure 9 shows the progression of the ERO product over two days.

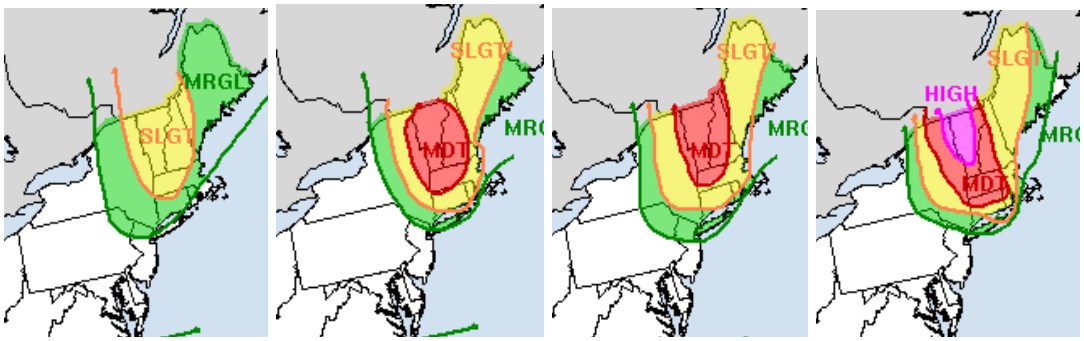


Figure 9. WPC EROs issued at 07:45Z July 8; 19:53Z July 8; 07:35Z July 9; and 20:27Z July 9.

WPC has never issued a high risk for excessive rain in this region, and it increased awareness about the potential severity of flash flooding. WFO Burlington and WFO Upton amplified this message through social media posts. Figure 10 shows a facebook post from WFO Burlington on July 9th referring to the anticipated flash flooding as “a very rare event” and “catastrophic”.

Once the moderate and high-risk areas were issued by WPC, at least one local TV station modified staffing in anticipation of the significant flooding. WPTZ-TV supplemented their messaging about the expected significant flash flooding and river flooding by using the ERO graphic in their broadcast–something they had never done.

Best Practice 13: By noting the frequency of the ERO risk level, WFO Burlington helped communicate the rarity and expected impacts from the impending flooding and flash flooding. This alerted the local news and public of the seriousness of the potential flooding.

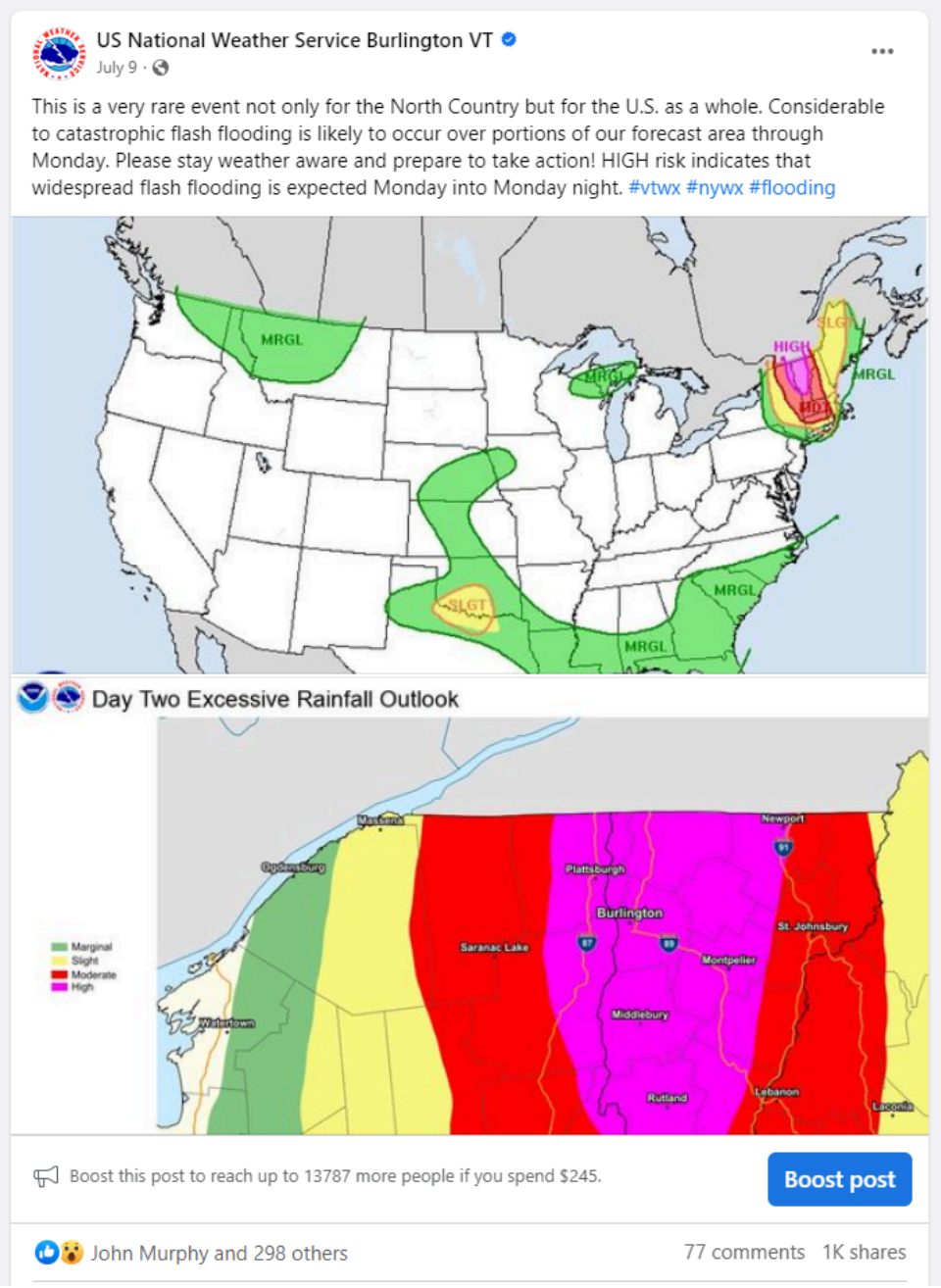


Figure 10. A facebook post from WFO Burlington on July 9th referring to the anticipated flash flooding as "a very rare event" and "catastrophic".

WFOs Albany, Burlington, Gray, Boston, and Upton all issued Flood Watches well in advance of the significant flooding and flash flooding with long lead times. WFOs Gray and Burlington included language about the potential for heavy rain in their Hazardous Weather Outlook (HWO) as early as Wednesday July 5th, 2023.

WFO Burlington issued their first FFW for this event at 3:13 PM July 9th. It included a “Considerable” tag which triggered Wireless Emergency Alerts (WEA). Through Tuesday morning July 11th, WFO Burlington issued 22 FFWs. Ten contained a “Considerable” tag, so each of those triggered a WEA. WFO Burlington upgraded one of these FFWs with a “Considerable” to a Flash Flood Emergency using a Flash Flood Statement. During the afternoon of July 10th, WFO Burlington transitioned from issuing FFWs to Flood Warning (FLWs), with nine FLWs issued between 2:25 PM EDT and 11:49 PM EDT on July 10th. This transition from FFWs to FLWs made it difficult for media partners to communicate the impacts due to this change. According to WPTZ Chief Meteorologist Tyler Jankoski, “We were looking for flash flood warnings considering there was still flowing water. Areal flood warnings stuck around for central Vermont too long and should have gone to {a} more severe {level}.” Jankoski went on to note that most viewers did not understand the term “areal”.

Finding 11 The legacy term “areal” is still attributed to the FLW product.

Recommendation 11: ER offices should coordinate with partners to review the suite of flood-related products and clarify that we no longer use the term “areal” in FLW products.

At WFO Upton, 25 FFWs were issued from 12:11 PM on July 9th through 10:07 PM July 10th. Eight of these FFWs contained the “considerable” tag, and WFO Upton upgraded one FFW to a “Flash Flood Emergency'' with the “Catastrophic” tag for Southeast Orange, Western Putnam, Rockland and northern Westchester counties. One fatality in Orange county occurred within this warning.

Forecasters in more than one office noted that the how and what activities that triggered Wireless Emergency Alerts (WEA) seemed ill suited to the needs of partners and the public. Some forecasters were unclear about the difference between the “considerable” and “catastrophic” tags in FFWs. Adding to the confusion is that Severe Thunderstorm Warnings trigger WEA at the highest level (Destructive); Tornado Warnings trigger WEA at the lowest level (base); and Flash Flood Warnings trigger WEA at the second level of severity (Considerable).

Externally, high ranking leaders publicly stated during the event that all FFWs would activate WEA. The NY Division of Homeland Security and

Emergency Services found it difficult to ascertain which, of the dozens of FFWs issued during this event, triggered WEA.

Finding 12: Forecasters were unclear when they should use "considerable" versus "catastrophic" tags in FFWs.

Recommendation 12: ER offices should reference existing resources for IBW in flood products in seasonal drills so that IBW tags are used properly for different triggers.

The NWS does not provide a geographical discernment between base and considerable/catastrophic FFWs on its weather.gov web pages. This can hamper response efforts.

Finding 13: State partners coordinating response efforts found it difficult to track locations where FFWs contained "considerable" or "catastrophic" tags.

Recommendation 13: NWS/AFS should provide unique visual highlights to FFWs that have IBW tags of "considerable" and "catastrophic" (as well as other WWA products with IBW tags).

Finding 14 Elected officials and the public do not understand which IBW tags in FFWs trigger WEA.

Recommendation 14: NWS should develop one-pagers to support field office education/outreach efforts on WEA and IBW tags.

8.0 River Flooding

This section details how each office delivered services in response to the river flooding hazard.

8.1 River Model Performance

This section looks at the information provided mostly by NERFC to help indicate where and when the river flood hazard would have impacts. NERFC, like all ER RFCs, utilizes ensemble forecasting as well as deterministic forecasts. This section summarizes the performance for both of these tools, and it summarizes the verification for the river forecasts.

8.1.1 Ensembles Forecasts

NERFC produces ensemble river forecasts via both the Hydrologic Ensemble Forecast System (HEFS) and the Multi-Member Ensemble Forecast System (MMEFS). Both MMEFS and HEFS rely on an ensemble of coarse global weather forecast models which do not have the skill of convective allowing models in forecasting the type of deep convection/flash flooding that occurred on July 10 and 11.

The HEFS river level probabilities issued on July 8 and 9 indicated less than 5% probability of moderate/major flooding for river forecast points within the Winooski or Lamoille basins.

The MMEFS guidance indicated 30% potential for major flooding at one location within the Winooski basin beginning with the 00z run on July 9. The threat expanded later that day. Figure 11 shows the MMEFS guidance issued on 7/9/23 at 12Z. It shows several points within the Winooski and Lamoille basins with at least a 30% probability of major flooding.

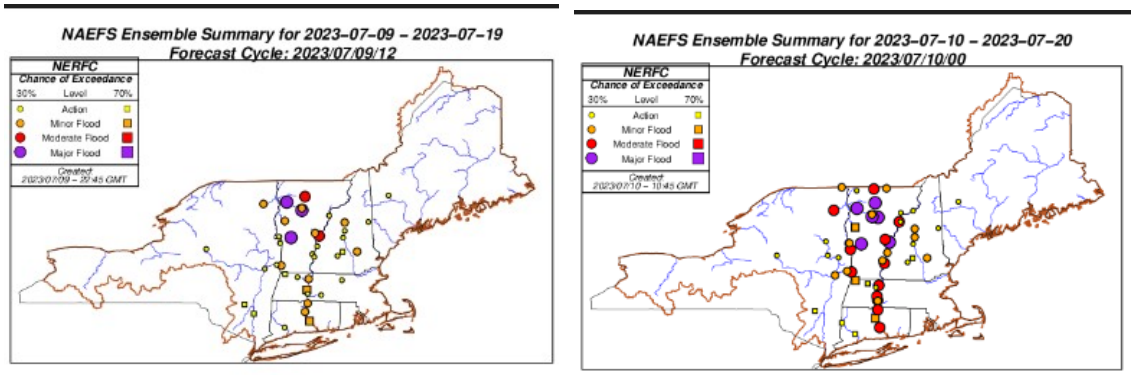


Figure 11. NERFC MMEFS guidance on 7/9/23 12Z (L) and 7/10/23 00Z (R)

While the 07/09/23 12z run of MMEFS indicated an increasing potential for major flooding at several forecast points in Vermont, QPF uncertainty was still high during the July 9 river forecast issuance. The 00z July 10 MMEFS run (indicated here), shows a more widespread 30% potential of major flooding.

8.1.2 River Forecasts

NERFC issued guidance at 14 locations that forecast river stages to exceed moderate or major flood category. The average lead time for these forecasts

was over 26 hours. The probability of detection for moderate or major river flood crests was 1.00, in other words all the forecasts were verified.

Coordination logs and interviews with staff from WPC, NERFC, and WFOs indicate the offices recognized the potential for flash flooding as early as July 7, with the potential for significant river flooding being recognized by July 9. Their confidence increased as the event approached. In the late afternoon/early evening of July 9, the offices saw the first indications that heavy rain would have a widespread pattern. By the early afternoon of July 9, forecasts described widespread minor river flooding with some locations forecast to exceed moderate flood stages.

During the evening of July 9, NERFC updated forecasts again with adjustments to QPF that indicated heavy and widespread rain. The river simulation modeling of this QPF indicated previous forecasts insufficiently described the risk for moderate and major flooding in portions of Vermont. NERFC coordinated with WFO Burlington that the 18z QPF indicated some potential for moderate and even major flooding. NERFC communicated their suspicion that the runoff was overdone in the river models. Both NERFC and WFO Burlington agreed to continue with the daytime river forecasts of minor to some moderate flooding, as uncertainty remained in the spatial extent and placement of the heavy rainfall. During the afternoon/evening of July 9, uncertainty was still high in the scattered vs. widespread nature of the heaviest rainfall, as well as the placement and which basins would be most affected.

Best Practice 14: NERFC coordinated closely with WFO Burlington on their uncertainty and concerns of how widespread the heaviest rain would be, and the potential for more river points to exceed moderate flood, some with the potential to exceed major flood.

8.1.3 Verification

This section examines the verification statistics for River Flood Warnings issued above moderate and major river stages. This includes WFOs Burlington, Albany, and Boston. Unlike flash flood warnings, NWS does not have GPRA goals for river flood warnings. They do maintain annual regional performance goals.

For WFO Burlington, their average lead time from initial flood warning to flood stage was just over 5 hours. The average lead time from the issuance

of the forecast to river crest was over 13 hours. The probability of detection for moderate or major river flood crests was 1.00.

For WFO Albany, one location exceeded the major flood stage-the Williams River near Rockingham. It is a fast-responding point for which the only forecast guidance is from the Site Specific Headwater Program (SSHP). NERFC does not produce river forecast guidance at this point. Lead time for SSHP points is typically short. They tend to be fast-responding points, and the complexity of the SSHP software tends to extend the production time for a forecast. An additional forecast point exceeded moderate flood stage in the WFO Albany area. For these locations, the average lead time from initial flood warning to flood stage was 27 minutes. The average lead time to the river crest was over 4 hours. The probability of detection for moderate or major river flood crests was 0.50.

For WFO Boston, four locations exceeded moderate flood levels during the July 9-13 timeframe. For these locations, the average lead time from initial flood warning to flood stage was just over 8 hours. The average lead time to river crests was just over 5 hours. The probability of detection for moderate or major river flood crests was 0.75.

8.2 IDSS

NERFC distributed one-pagers to partners on July 8 and 9, and they conducted a full briefing on the afternoon of July 10. The one-pagers highlighted the most significant flooding in a concise snapshot, but they also included some uncertainty/forecast challenges. With the extended briefing on July 10, specific details on timing/impacts were included, as well as some confidence issues with river forecasts, due to exact rainfall placement.

WFO Burlington included highlights of river flood impacts within their twice-daily partner briefings beginning the morning of July 9. While river forecasts were highlighted, at the time, no rivers were expected to exceed moderate flood levels. There was no mention of river forecast uncertainty and that some rivers may rise to moderate or major flood levels.

Finding 15: Public and partner feedback in the July 2023 floods indicated there was some lack of understanding of the potential of major river flooding.

Recommendation 15: ER offices should include probability/ potential information of instances where there is potential for flooding to be more severe than currently forecast.

8.3 Collaboration

This section focuses on the collaboration between NWS offices for QPF and dam failures. The ultimate value of our services is sensitive to both of these forecast activities.

8.3.1 QPF

WFOs, NERFC and WPC described positive and productive collaboration/coordination of QPF. On July 10, NERFC and the WFOs coordinated the QPF with WPC since this QPF cycle was driving critical river forecasts. While QPF incorporated into the river forecasts on July 9 largely matched WPC's (Fig. 13, top image), on the 10th NERFC and WFO BTV staff recognized that HREF probabilities and trends in convective allowing models put the placement of the heaviest rainfall in a different location than WPC's forecast. Figure 12 shows the adjustment that was collaborated on July 10. NERFC QPF on July 9 showed little deviation from WPC, whereas July 10 QPF shows the deviation from WPC QPF and the result. The resultant QPF was better able to focus the heaviest rainfall in the Winooski and Lamoille basins, resulting in higher forecast river crests, closer to what actually occurred.

Best Practice 15: NERFC HAS forecasters adjusted QPF in a way that provided greater lead time to river flooding than the WPC QPF forecast.

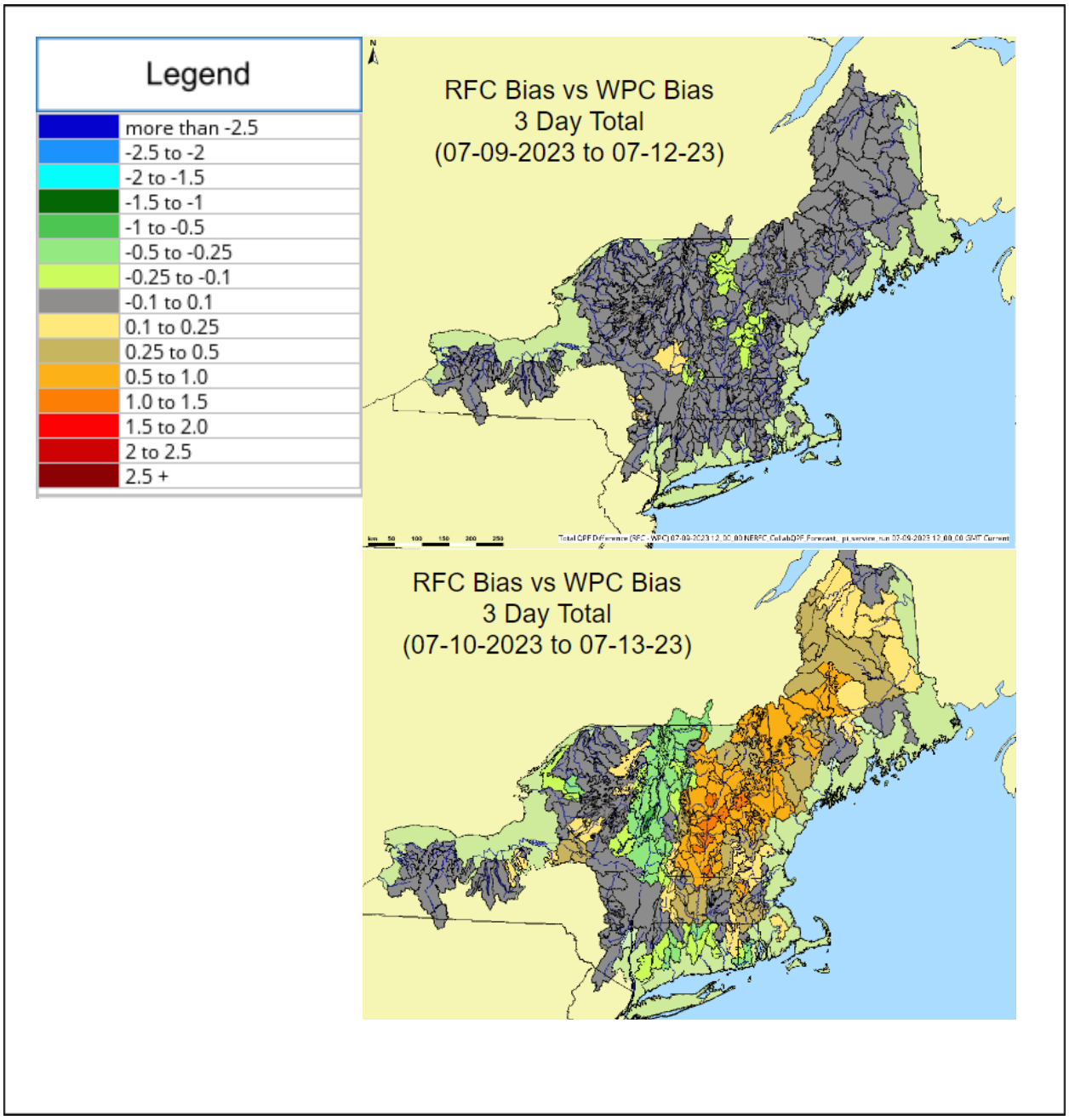


Figure 12. 3-day QPF difference between NERFC and WPC for the July 9 12z issuance (top) and July 10 12z issuance (bottom). Values between -0.1 to 0.1 indicate no deviation of NERFC QPF from WPC. Negative values indicate WPC QPF was greater than NERFC, with positive values indicating NERFC QPF was higher than WPC.

8.3.2 Dam Failure Hazards

Pool levels rose sharply at several dams across the region. High pool elevations at Wrightsville Dam upstream of Montpelier on the North Fork of the Winooski River caused concern for Vermont officials. NERFC, in coordination with WFO Burlington, the ROC, and HSD, ran a dam breach scenario for Wrightsville Dam. This group initiated and maintained a Google chat room throughout the event to update information among those concerned. In July 2023, NERFC ran dam breach scenarios at six dams using DSS-WISE. They shared the results with the potentially impacted WFOs and the ROC. The NWS offices established clear internal coordination and communication as concerns for impacts to dam structures escalated.

Best Practice 16: NERFC produced quantitative dam breach scenarios out of an abundance of caution. This prepared the WFOs for the possibility of a dam breach.

8.4 Public Messaging

8.4.1 NERFC

NERFC maintained a frequent and escalating presence on social media as the river flood hazard increased. As NERFC's confidence that rainfall totals would exceed four inches increased, they produced graphics with messaging describing the forecast. The frequency of posts increased again as confidence rose that river floods would reach major flood levels. Figure 13 shows the dramatic change in NERFC's public messaging as their forecasts raised river flood crests forecast.

Finding 16 While the NERFC's Daily Briefing social media posts highlighted forecast rainfall and impacts on rivers, narratives sometimes strayed into forecast discussion verbiage (e.g, upper trough, surface front, etc). Other daily briefings contained more clear/public friendly verbiage which was more impact-focused.

Recommendation 16: Content shared on social media should always be in plain language and focus on impacts.

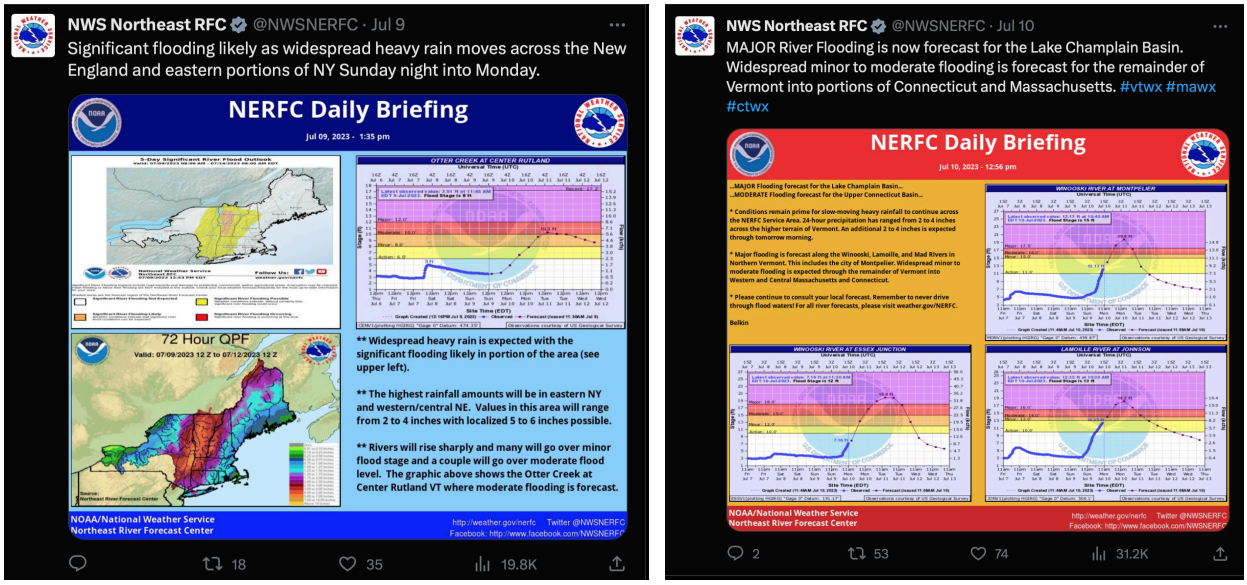


Figure 13. NERFC post on July 9, 2023 (left) and July 10, 2023 (right)

8.4.2 WFO Burlington

During the peak of the Vermont flash flooding, WFO Burlington actively communicated on social media. Besides the automated FFW, they highlighted the importance of safety measures and pinpointed the amplified risks associated with nighttime flooding, underlining the heightened danger to the public during such hours.

On July 10, as water levels in rivers surged, WFO Burlington made a dedicated social media post alerting the public about the anticipated major river flooding at the Winooski River in Montpelier. This post was distinct from other general updates, emphasizing the severity of the situation at that specific location. Furthermore, to aid residents in staying informed, they also provided a link directing users to a site offering river forecasts, as illustrated in Figure 14.

Both internal feedback from WFO Burlington staff and external input from the general public, gathered during WFO Burlington's post-flood high water surveys, highlighted a significant communication gap.

Finding 17: Public feedback indicated a lack of understanding of the severity of river flooding, and the rapid rises to major flood impacts.

Recommendation 17: ER WFOs should clearly message more detailed impacts during major river flooding. NWS AHPS river hydrographs indicate

flood categories, but they do not readily indicate what the categories mean (impacts).

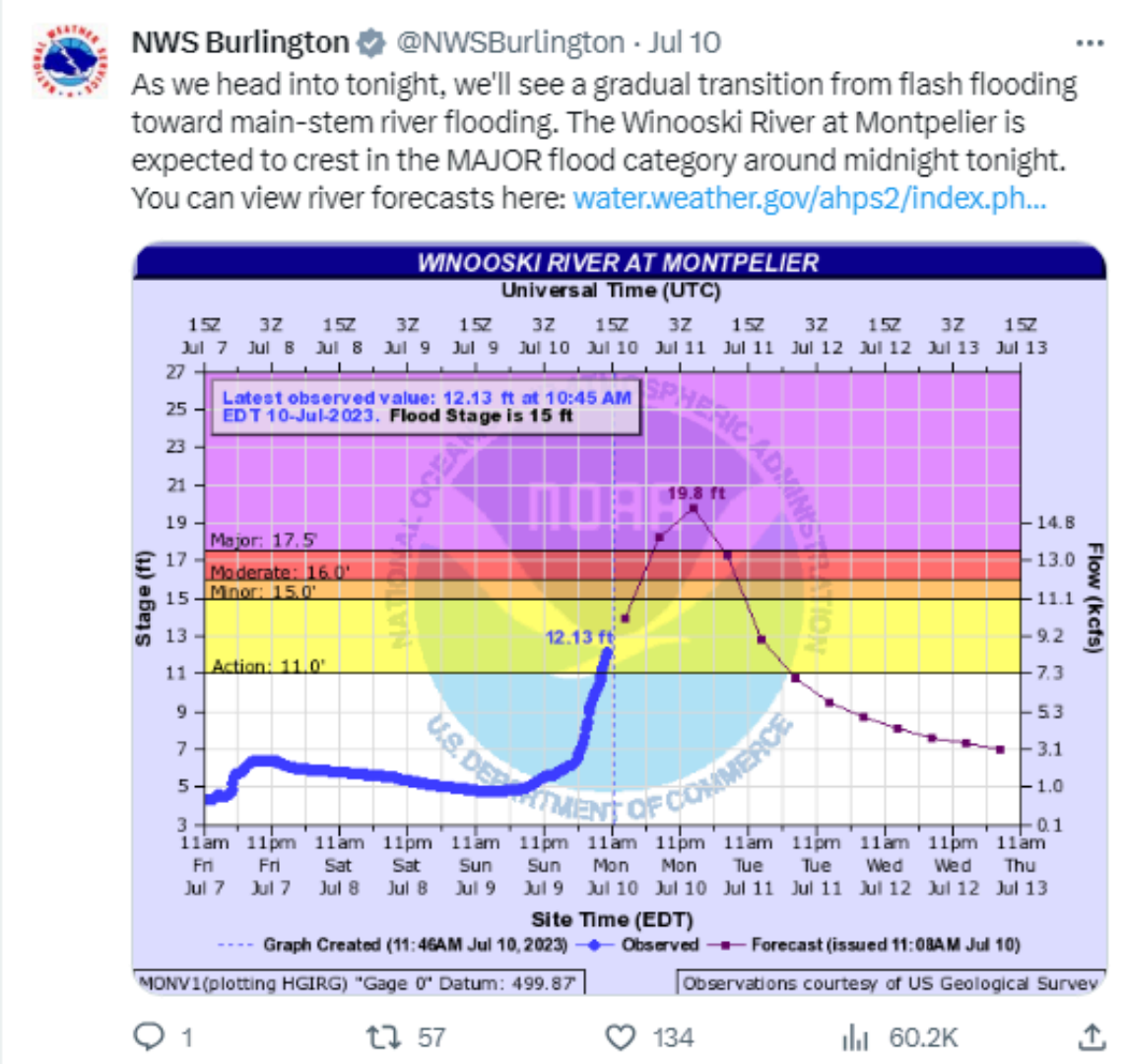


Figure 14. WFO Burlington Twitter/X post (also posted to Facebook) on July 10 depicting Winooski River at Montpelier forecast issued on July 10.

While the roll-out of NWS flood inundation mapping (FIM) will eventually help communicate flood impacts, short messages providing some detail of impacts should be communicated.

In addition to leveraging social media to clearly indicate what are the impacts of major river flooding, WFO Burlington staff suggested that some river flood warnings could perhaps be impact-based, prompting a Wireless Emergency Alert (WEA) message for forecasts of major flooding.

9.0 Service Equity

The NWS strategic plan calls for an agency that "remains indispensable and a global leader in equitable weather, water, and climate services." The partners interviewed talked mostly about their roles and responsibilities for reaching vulnerable populations.

The WFOs–without clear policies/goals of social equity topics–have performed the following activities:

WFO Albany planned spotter training sessions taking advantage of the ability to conduct virtual sessions. WFO Burlington stated they are working with a local university to determine how to identify vulnerable populations hardest hit by the flooding. The office worked with FEMA to find trailers. WFO Upton stated that emergency managers are vital to spreading the NWS' warning information.

WFO Albany stated that all warnings go out in English and Spanish on Twitter but not as often on Facebook. The French translations are conducted due to proximity to Canada. Information from the WFO also goes out in Spanish. The WFO Upton stated warnings do go out in Spanish and that they are in the process of getting products translated into other languages. That office also said they use automatic translations. ER WFOs can improve the reach of messages by translating them into languages that are widely used in their service areas. While individual offices with that capability should continue to utilize it, this is being addressed by NWS at a national level.

One of the state's Department of Homeland Security and Emergency Services coordinates across the entire state government. That office saw itself as the place that amplifies NWS messages across its networks. Another partner said a lot of planning happened in the last three months to use forecasts to match the needs of the most vulnerable people. In summary, discussions of service equity brought up general approaches to education and outreach.

Best practice 17: NWS partners identified themselves as collaborators who amplify the NWS' messages. This helps the NWS reach vulnerable populations.

10.0 Partner's Response

In addition to the interviews with WFO leadership and staff impacted by the July 9-11, 2023 floods, the AAR Eastern Region Team also spoke to several core partners, including a local broadcast meteorologist, the New York State Department of Homeland Security, the Orange County Emergency Manager (EM), and the Vermont State Emergency Operations Center (VTEOC) Manager.

During these conversations, all of the partners mentioned that they had a good relationship with the NWS, especially with their local WFOs. The frequency with which they met with NWS staff differed from quarterly meetings, to ad hoc meetings as needed, to just meeting once or twice a year at the local broadcast workshops. The Vermont State partner started his position in 2020, so he said that the relationship with the NWS had just started, and it was growing and positive. The understanding of the term IDSS also varied greatly among the partners. Some did not recognize the term at all. Others are familiar with the term, summarizing IDSS as the innovative and modern approach NWS is using to deepen relationships with Core Partners.

Each of the partners have different duties and responsibilities. The state partners managed the EOC, coordinated multi-agency responses, and made pre-deployment decisions, while the local emergency manager and broadcast meteorologist focused exclusively on local weather conditions. The state/local distinction dictated the types of data they monitored to support their decision-making. At the local level, the partners used the local NWS webpages, relying heavily on the hourly weather graph and the ERO along with accounts on social media. They also relied on flood watches and warnings along with email blasts of briefings, AFDs, and the river forecast hydrographs to monitor the situation, especially as conditions rapidly changed over that particular weekend.

Unlike the local level, the state partners relied almost exclusively on the EM briefs. Their decisions are triggered by forecasts of potential heavy rainfall. The state partners also rely on mesonet and atmospheric scientists at local universities for additional support. One of the state partners also specifically mentioned that social media was not a primary source of data as they considered it unreliable. Instead, they relied on their contact on the ground to maintain situational awareness.

Overall, the partners appreciated the work and support provided by the NWS during this flooding event. Both state partners praised the email blasts, the real time communications over NWSChat, and the in-person presence of a NWS forecaster at the EOC. The partners also mentioned the river forecast hydrographs and all of the EM products provided by the NWS. They are really excited about the potential use of the Flood Inundation Mapping (FIMs) capabilities.

Best Practice 18: NWS offices delivered products and services to the EM community that were uniformly recognized for the value they provide.

In terms of possible improvements, all of the partners stated the need to simplify the water/flood alerts. They mentioned the alerts for flash flood emergencies needed improvement by possibly adding low to high risk terms with much better guidance. They mentioned receiving no information regarding the understanding of watches, warnings, and advisories which created some confusion. Both state and local partners also stated that they did not understand the timing of the WEA alerts, with the local broadcaster stating that he would have liked more WEA alert activations during this particular flooding event. The local EM also mentioned that no product or warning provided adequate notification of the severity of the storms, and they need more river gauges–especially for future storm events.

Communication processes differed based on the level of government. Most of the state partners coordinated through their EOC where on-site support from the NWS was critical for decision-making due to the changing nature of this event. Partners at the local level relied on vital information that was delivered through moderated conference calls. The local EM also stated that they use Trello to pass along information across villages and towns and that the NWS is invited to their Trello board. This local EM does not monitor Slack.

Finding 18: Partners may use different communications tools during active weather events.

Recommendation 18: ER WFOs should educate partners about the communications channels where they can see authoritative messages directly from NWS forecasters.

All of the partners said that it is a challenge for the general public to see NWS products and messages and that much of it is filtered through

broadcast media in the area. The local EM stated that he wished that during this event the local outlets had more regular coverage as he thought that the warning and advisories were less useful. This was particularly true for his county as internet and cell coverage were disrupted by the storms and flooding, with the folks in the valley being particularly difficult to reach. All of the partners also stated that they appreciate the use of elevated terms like "catastrophic" to grab people's attention and to create a sense of urgency. They also liked the use of past flood events, to create a frame of reference that they and the public could use to help them understand this flooding event.

Overall, the partners thought that the event was well forecast and that they had adequate support from the NWS. Partners noted a few surprises such as Champlain Valley in New York not being impacted as initially forecast and Addison County in Vermont received rainfall amounts significantly exceeding predictions. All of the partners were surprised by the speed with which this event became an emergency, and due to the changing nature of the storms, they were surprised by the amount of precipitation and the dense pattern of precipitation. All of the partners also mentioned the need for more data and continued communications with the NWS during recovery efforts. They all want to better understand the historical significance of this flooding event, and how they can continue to partner with the NWS to learn and improve their services and communications for future weather events.

Finding 19: Response efforts take considerable time and effort. Partners need to know the weather conditions during response and recovery.

Recommendation 19: ER WFOs should continue to engage with partners through the recovery phase of events.

11.0 Results and Summary

The AAR team encountered open, direct, and honest engagement with all of those that participated in the data collection. The set of 17 best practices are summarized in the following section. These represent a portion of the excellent practices that we heard about in our data collection. The 20 findings and recommendations, summarized in the final section, are the majority of the challenges we uncovered in our data collection.

11.1 Best Practices

Best Practice 1: WFO Burlington maintains a broad group on their hydro team. This ensures expertise/experience can cover multiple shifts during high impact events.

Best Practice 2: The WFO Burlington hydro team invests in relationships with core partners. This ensures familiarity with those partners and their IDSS needs.

Best Practice 3: ER WFOs should contact the ER ROC in a timely manner for assistance during and immediately after high impact events to allow for continued IDSS, operations, and surveys following a high impact event.

Best Practice 4: WFO Burlington's practice is to email a briefing on Friday before the end of the work day when significant weather is expected during the weekend. This gives sufficient lead time to partners who may not access email during the weekend.

Best Practice 5: Well ahead of this event, the WFOs and NERFC sent One-Pagers to partners.

Best Practice 6: The WFO Burlington office conveyed high confidence of catastrophic impacts using terms not normally used in briefings (i.e. "catastrophic") and references to a recent past catastrophic event–Hurricane Irene. This raised a clear, unambiguous alert to state partners and motivated them to take action.

Best Practice 7: WFO Gray coordinated messages using their "message of the day" tool. This slide ensured that all staff presented a consistent message throughout the event.

Best Practice 8: WFO Upton provides clear triggers on when to start and escalate IDSS. This supports consistency in delivering IDSS to our partners.

Best Practice 9: WFO Burlington delivered a post-storm outlook in their IDSS briefing. This assisted partners with recovery efforts.

Best Practice 10: WFO Burlington contacted ER ROC for help with operations during and shortly after the event. This allowed the office staff to focus on IDSS and to gather information to verify the office's forecasts.

Best Practice 11: WFO Burlington deployed meteorologists who listened to feedback from their partners during and following briefings. This allowed them to customize future briefings for a similar audience.

Best Practice 12: When a moderate or high-risk ERO is issued, WPC contacts FEMA to schedule a briefing. Similarly at a regional level, ER ROC worked with FEMA region 1 to conduct a briefing. This ensures that FEMA has awareness as early as possible.

Best Practice 13: By noting the frequency of the ERO risk level, WFO Burlington helped communicate the rarity and expected impacts from the impending flooding and flash flooding. This alerted the local news and public of the seriousness of the potential flooding.

Best Practice 14: NERFC coordinated closely with WFO Burlington on their uncertainty and concerns of how widespread the heaviest rain would be, and the potential for more river points to exceed moderate flood, some with the potential to exceed major flood.

Best Practice 15: NERFC HAS forecasters adjusted QPF in a way that provided greater lead time to river flooding than the WPC QPF forecast.

Best Practice 16: NERFC produced quantitative dam breach scenarios out of an abundance of caution. This prepared the WFOs for the possibility of a dam breach.

Best practice 17: NWS partners identified themselves as collaborators who amplify the NWS' messages. This helps the NWS reach vulnerable populations.

Best Practice 18: NWS offices delivered products and services to the EM community that were uniformly recognized for the value they provide.

11.2 Findings and Recommendations

In most cases the recommendations follow directly from a finding. Findings and recommendations are paired using the same index number when possible.

Finding 1: The GYX radar's beam blockage caused significant underestimation of rainfall across Sanford County, ME and Strafford County, NH.

Recommendation 1: NWS should fund raising the GYX radar tower to 30 meters.

Finding 2: Some ER One-Pagers did not list detailed impacts from the expected event, rather they included generic 'flash flooding' wording.

Recommendation 2a: Review and update as appropriate the ER One-Pager guidance regarding the description of impacts for partners.

Recommendation 2b: The IDSS Briefing Builder should allow for a list of pre-scripted impacts to be inserted into the the Hazards & Impacts section of the briefing.

Finding 3: WFO Burlington did not coordinate the Hurricane Irene (2011) analogy with neighboring offices or ER ROC.

Recommendation 3: ER WFOs need to coordinate in advance the key messages and references to historical events with surrounding WFOs, RFCs, and ER ROC prior to sending this wording to partners or to the media/social media.

Finding 4: The way that the Hurricane Irene analog was messaged was ambiguous in time and space. It caused additional workload for surrounding offices because partners interpreted it too broadly.

Recommendation 4: ER WFOs should use historical event language in well-coordinated messages that are unambiguous in the time and location where it applies.

Finding 5: WFO Burlington did not use the comparison to Hurricane Irene (2011) in their IDSS email briefings.

Recommendation 5: For a significant event involving multiple offices, ER offices should share documents that include all talking points and key messages that should be used throughout the suite of forecast, social media and IDSS briefings to make sure the message is consistent.

Finding 6: On some briefing slides sent to partners, the appearance of the title page remained unchanged as confidence in significant impacts increased.

Recommendation 6: It is recommended that red text should be used in the title slide of briefings to draw attention to the potential for an extreme weather event, as recommended in the EM_Core_Briefing Content Template document.

Finding 7: Single deterministic QPF values do not effectively convey rainfall and potential impact uncertainties, and can adversely impact user decision making.

Recommendation 7: WFOs should utilize probabilistic information to convey uncertainties in QPF. Particular emphasis should be on exceedance of critical/impactful rainfall thresholds that are identified through interactions with partners.

Finding 8: Briefings from one office lacked consistency regarding when the next briefing would be available, with several using an unscheduled product as a trigger for the next briefing.

Recommendation 8: ER WFOs should use specific times, not headline issuances, for the next briefing, so partners can know exactly when this information will be received.

Finding 9: The threat risk levels for excessive rainfall on the GHWO (Limited, Elevated, Significant, and Extreme) are different from the threat risk levels used by WPC (Marginal, Slight, Moderate, and High). This resulted in inconsistent messages for the risk of excessive rainfall.

Recommendation 9: NWS/AFS should review and implement consistent threat/risk thresholds for both national center and field office products and related messaging.

Finding 10: The VTEOC was not accustomed to responding to landslides and debris flows, and the IDSS Briefing Builder lacks icons for this hazard in the 'Main Points' template to assist and remind forecasters to include it in briefings.

Recommendation 10: ER offices should coordinate with partners to make sure briefing templates include landslides and debris flows hazards in the partner's area.

Finding 11: The legacy term "areal" is still attributed to the FLW product.

Recommendation 11: ER offices should coordinate with partners to review the suite of flood-related products and clarify that we no longer use the term "areal" in FLW products.

Finding 12: Forecasters were unclear when they should use "considerable" versus "catastrophic" tags in FFWs.

Recommendation 12: ER offices should reference existing resources for IBW in flood products in seasonal drills so that IBW tags are used properly for different triggers.

Finding 13: State partners coordinating response efforts found it difficult to track locations where FFWs contained "considerable" or "catastrophic" tags.

Recommendation 13: NWS/AFS should provide unique visual highlights to FFWs that have IBW tags of "considerable" and "catastrophic" (as well as other WWA products with IBW tags).

Finding 14: Elected officials and the public do not understand which tags in FFWs trigger WEA.

Recommendation 14: NWS should develop one-pagers to support field office education/outreach efforts on WEA and IBW tags.

Finding 15: Public and partner feedback in the July 2023 floods indicated there was some lack of understanding of the potential of major river flooding.

Recommendation 15: ER offices should include probability/potential information of instances where there is potential for flooding to be more severe than currently forecast.

Finding 16: While the NERFC's Daily Briefing social media posts highlighted forecast rainfall and impacts on rivers, narratives sometimes strayed into forecast discussion verbiage (e.g, upper trough, surface front, etc). Other daily briefings contained more clear/public friendly verbiage which was more impact-focused.

Recommendation 16: Content shared on social media should always be in plain language and focus on impacts.

Finding 17: Public feedback indicated a lack of understanding of the severity of river flooding, and the rapid rises to major flood impacts.

Recommendation 17: ER WFOs should clearly message more detailed impacts during major river flooding. NWS AHPS river hydrographs indicate flood categories, but they do not readily indicate what the categories mean (impacts).

Finding 18: Partners may use different communications tools during active weather events.

Recommendation 18: ER WFOs should educate partners about the communications channels where they can see authoritative messages directly from NWS forecasters.

Finding 19: Response efforts take considerable time and effort. Partners need to know the weather conditions during response and recovery.

Recommendation 19: ER WFOs should continue to engage with partners through the recovery phase of events.

12.0 Definitions and Concepts

Flash flooding occurs suddenly, typically within six hours of heavy rainfall or a dam break, affecting small areas like streets or valleys and can lead to rapid water rises. Flash flooding often presents an immediate, unexpected threat.

River flooding is a prolonged event that may develop more slowly, often taking days to build up and affecting larger areas alongside rivers after prolonged heavy rainfall or melting snow. River flooding can sometimes be predicted and monitored over a longer duration.

"Areal" flooding is a deprecated term. In November 2019, NWS removed "areal" before Flood Watches, Warnings, and Advisories to eliminate any confusion about "areal" appearing anywhere within these products. The term was used to cover locations not quantified or indexed at specific locations such as river forecast points. NWS now issues these Watches, Warnings, and Advisories with a geographic area defined by a polygon.

Flood Categories are important indexes connected with river stages. NWS defines three categories of river flooding--minor, moderate, and major, and it applies those to specific locations referred to as forecast points.

> Minor - minimal or no property damage, but possibly some public threat, usually roads closed.
>
> Moderate - some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations.
>
> Major - extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations.

Appendix 1. Comparison with Hurricane Irene in 2011

Figure A1 shows the rainfall totals for the event side-by-side with Hurricane Irene rainfall totals. Large parts of the WFO Burlington area have similar rainfall totals. The July 2023 event was often compared with Hurricane Irene in 2011. Hurricane Irene had a strong impact on New England with 3 deaths in Vermont alone, and extensive flooding damage to buildings, roads, and bridges. Irene itself was compared with the 1938 New England Hurricane, a similar record-setting event. As Irene had such a strong impact, memory of it was still very strong 12 years later.

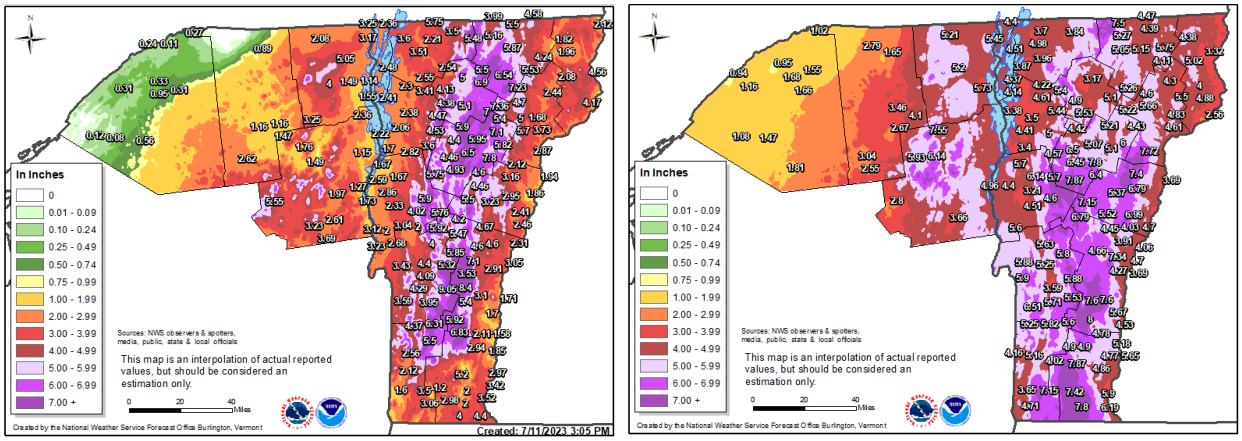


Figure A1. Rainfall totals for the July event (left) and Hurricane Irene (right)

Figure A2 shows the same data over a larger area. This highlights how similar the rainfall totals are for Vermont, and how different they are for the other surrounding states. Hurricane Irene is not a good analog for every other state. Irene, in fact, had severe impacts from South Carolina to Maine. In parts of Vermont, the rainfall totals from the July 2023 event were similar to Irene, but in many other areas they were less. Emergency managers in Vermont; however, would report that impacts from the July 2023 event were greater in some places than those from Irene.

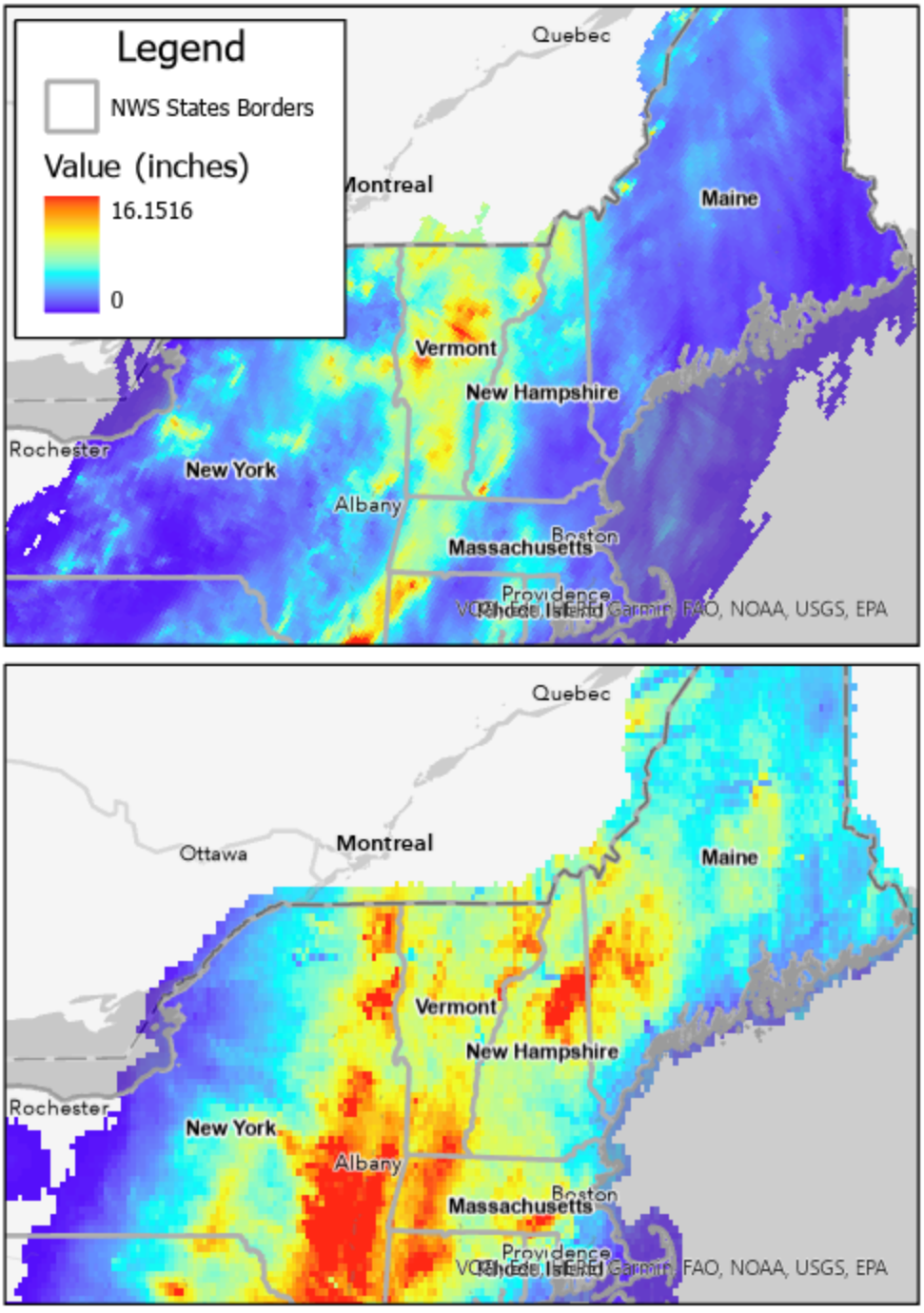


Figure A2. Two day rainfall totals for July 10-11, 2023 (top) and August 28-29, 2011 (bottom)

Appendix 2. Presentation of QPF Maps

Many IDSS email briefings included quantitative precipitation forecast (QPF) maps to message expected rainfall amounts. QPF maps convey the spatial distribution of the rainfall. Most of the QFP maps that offices shared with partners show a specific amount of rainfall–overlooking the uncertainty of the rainfall forecast. That implies certainty in the amount of precipitation and the placement of the precipitation, which can be reinforced when sample points with single deterministic values are used rather than just relying on the ranges implied by the color bar in the legend.

This implied certainty may cause partners to make decisions about mitigation and preparedness efforts–potentially staging resources outside of the areas with the highest amounts, but still within an area with a potentially high rainfall amount. For this event, partners described a few 'surprises' such as Champlain Valley in New York not being impacted as initially forecast and Addison County in Vermont received rainfall amounts significantly exceeding predictions.

Some offices switched from specific QPF sample point values on their maps to a range of values. Although this conveys some uncertainty in expected (e.g., most likely) rainfall amounts, and is an improvement over deterministic values, unless the ranges are directly linked to probabilities (for example, 25th and 75th percentile values) predefined ranges are arbitrary and do not have any scientific basis.

Incorporating probabilistic information based on the situation (e.g., lead time to impacts and degree of forecast confidence) are better ways to communicate forecast uncertainties and potential impacts. Possible approaches include using: exceedance probabilities, especially if critical impact thresholds are known; high (e.g. 90th percentile) and possibly low (e.g. 10th percentile) graphics along with expected/most likely amounts, probability-based categorical impact graphics (e.g., high/medium/low threat with probabilities of each indicated; or scenario-based messaging. Figure A3 depicts examples of probability of exceedance approach and the percentile range at a point approach.

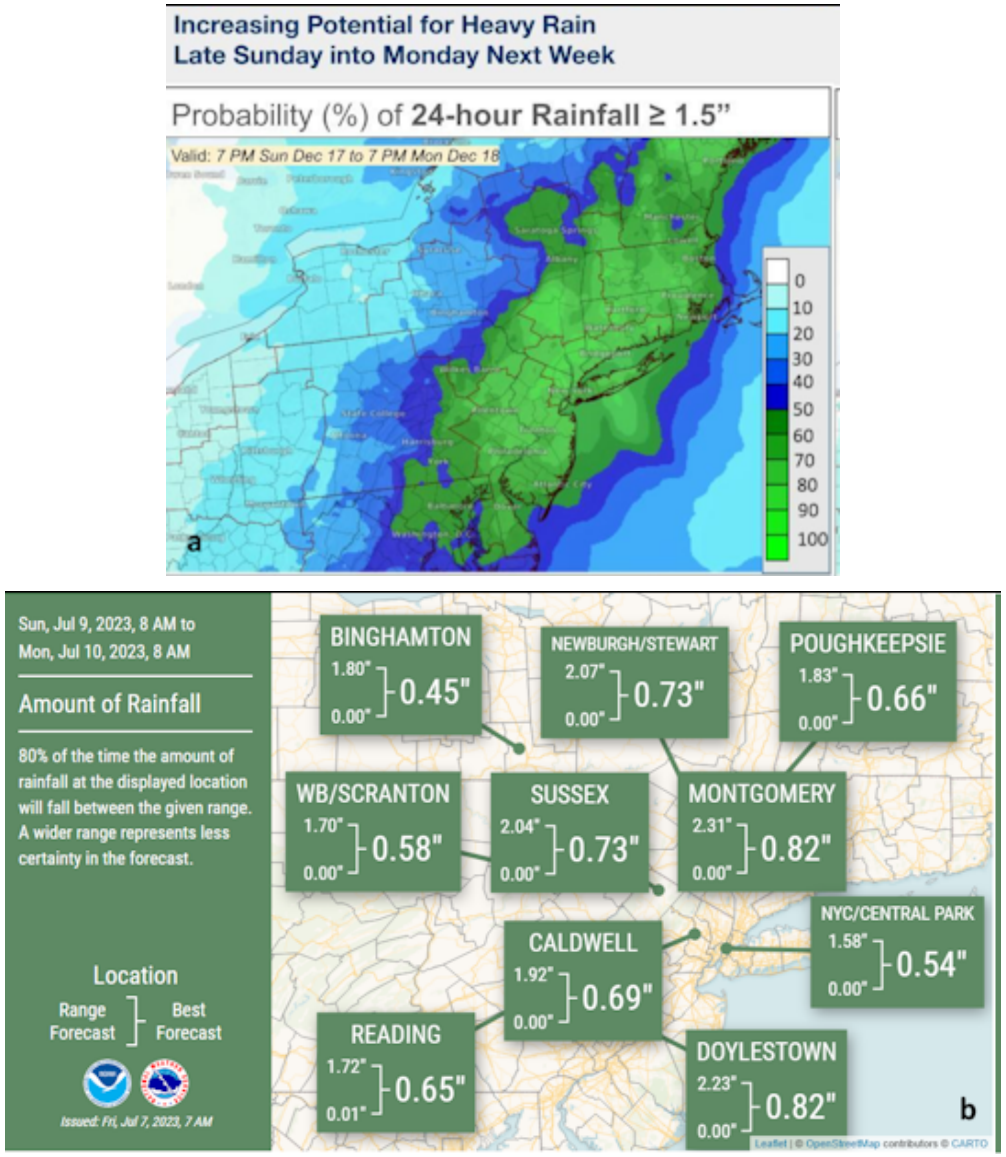


Figure A3. a) QPF probability of exceeding 1.5 inches. b) Probabilistic QPF graphic depicting the high end (90th percentile), most likely, and low end (10th percentile) forecasts.