



# Center for Western Weather and Water Extremes

SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UNIVERSITY OF CALIFORNIA SAN DIEGO

PRECIPITATION SCIENCE AND PREDICTION GROUP

Contact:

Jay Cordeira

[jcordeira@ucsd.edu](mailto:jcordeira@ucsd.edu)

<http://cw3e.ucsd.edu>

## Summary of the 9–10 January 2024 East Coast Atmospheric River Event

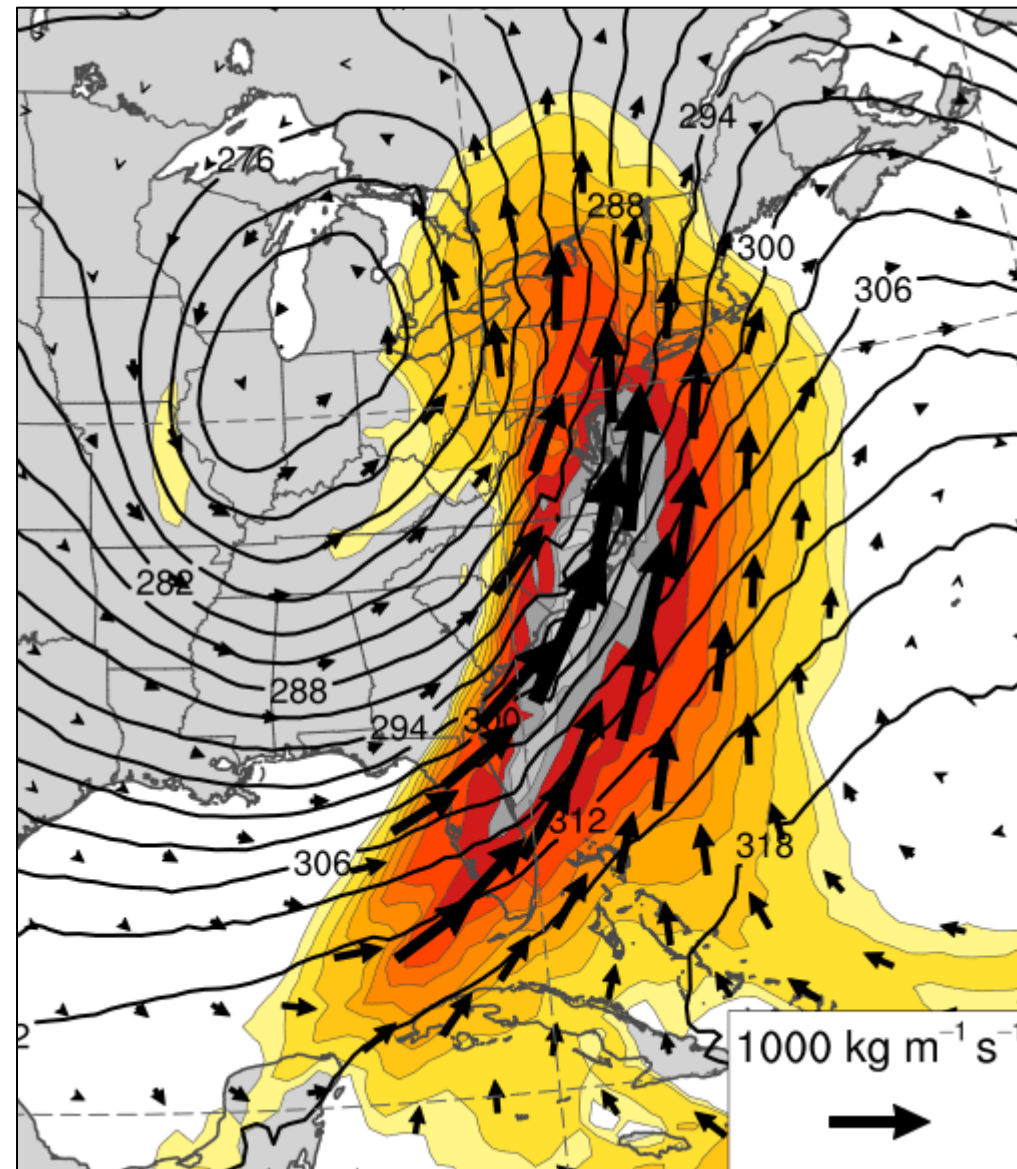
With a focus on impacts in the Northeast U.S.

Jay Cordeira, PhD

Center for Western Weather and Water Extremes

Scripps Institution of Oceanography

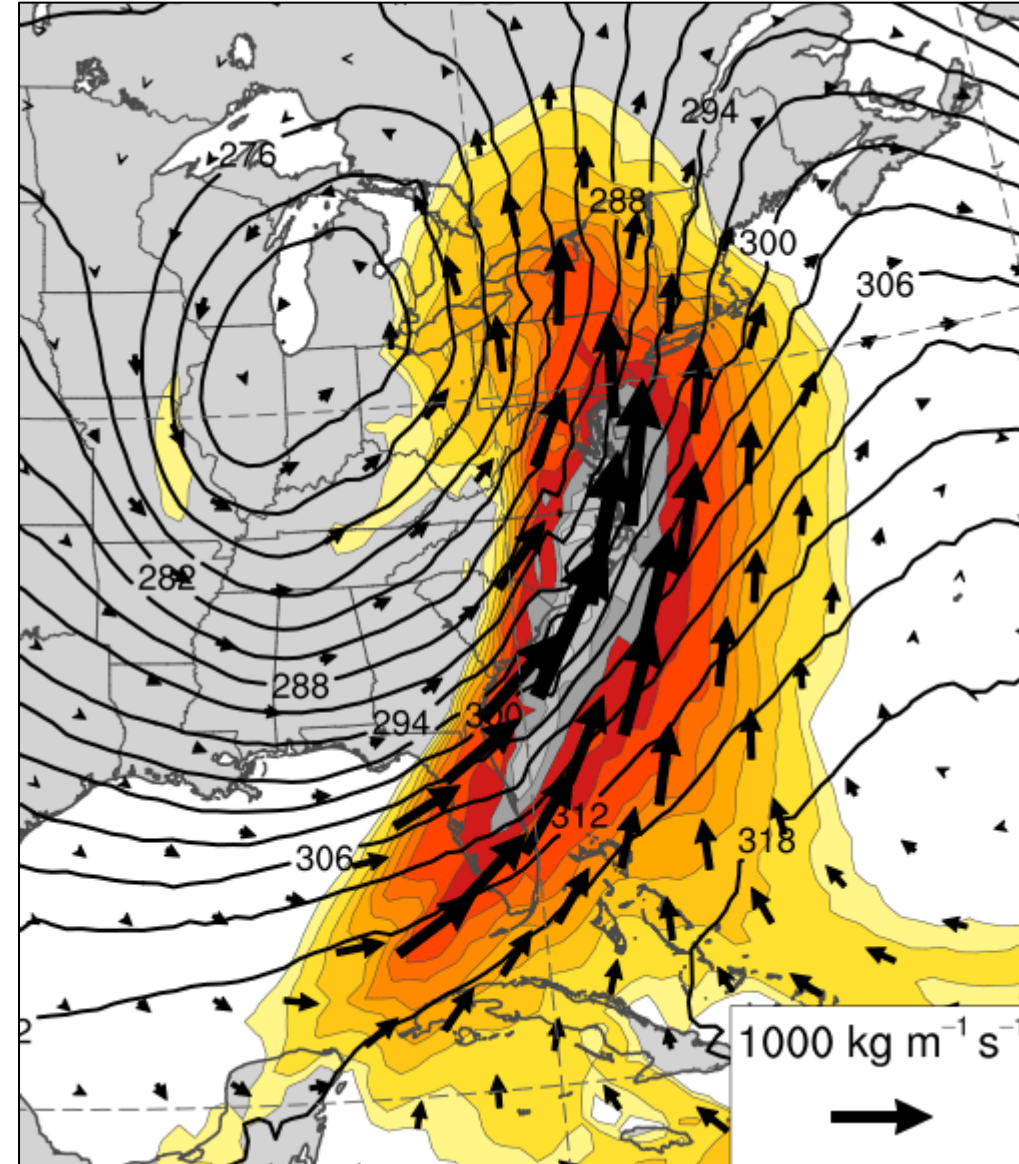
University of California San Diego





## Summary

- An intense cyclone moving through Central Plains and Great Lakes region contained a strong atmospheric river along the East Coast on 9–10 January 2024.
- The well-forecast storm and AR produced widespread hazards including winter weather, strong winds, severe weather, heavy rainfall and river flooding, and coastal surge-induced flooding.
- Flooding across the Mid-Atlantic and southern New England was exacerbated by antecedent snowfalls that melted with rainfall totals >4 inches.
- The storm followed on the heels of an active period with record seasonal rainfall; several locations in Connecticut have seen major or moderate floods now 3 times since 1 Dec 2023





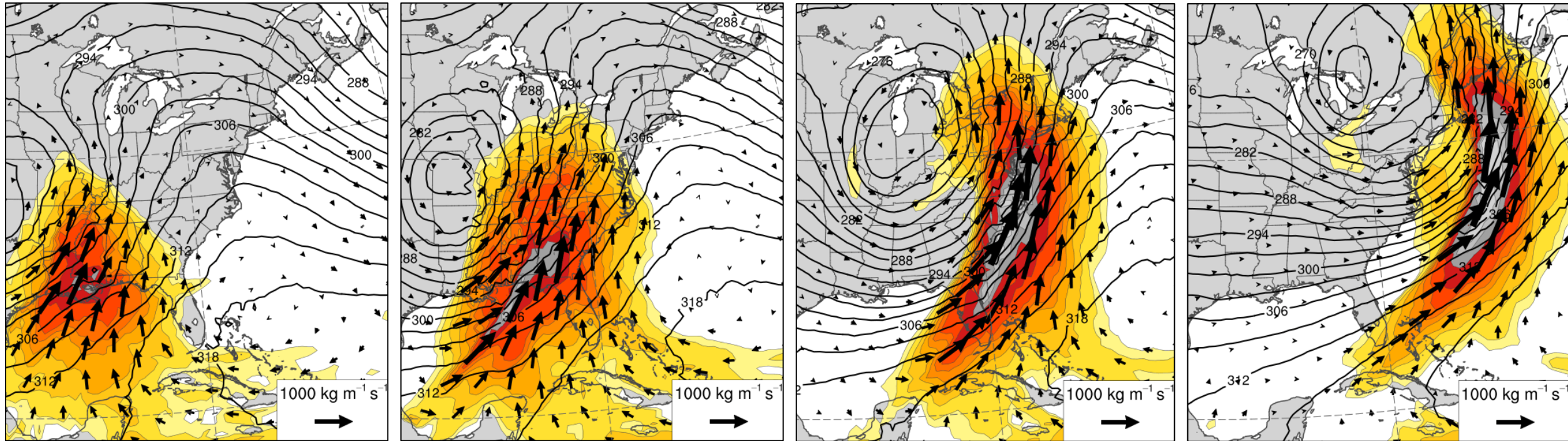


0000 UTC 09 January 2024

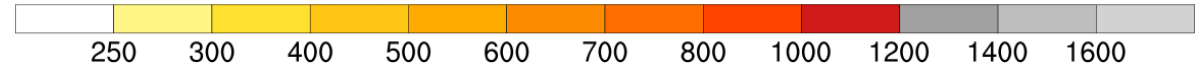
1200 UTC 09 January 2024

0000 UTC 10 January 2024

1200 UTC 10 January 2024



Select GFS Model Analyses of 700-hPa Geopotential Height, IVT magnitude, and IVT Direction  
(adapted from imagery provided by Dr. Alicia Bentley).



## Storm contained an “AR4” or “AR5” event depending on where you look

- Atmospheric river (AR) contained integrated vapor transport magnitudes  $>1600$  kg/ms in its core that extended south to north into New England.
- AR conditions persisted for  $>24$  hours over Mid-Atlantic/East Coast, making this an **exceptional AR5 event** according to Ralph et al. (2019), but  $<24$  hours over New England, making this an **extreme AR4 event locally**.



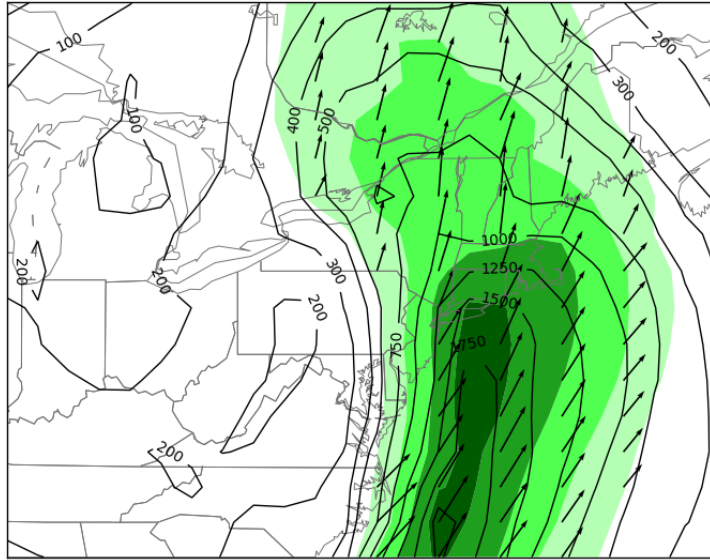
**ENSEMBLE SITUATIONAL AWARENESS TABLE**

NOAA / NATIONAL WEATHER SERVICE

NAEFS Mean Integrated WV Transport ( $\text{kgm}^{-1} \text{s}^{-1}$ ) and Standardized Anomaly  
 HOUR 006 - VALID 06:00 UTC Wed Jan 10 2024

NAEFS Mean Integrated WV Transport ( $\text{kgm}^{-1} \text{s}^{-1}$ ) and Climatological Percentile  
 HOUR 006 - VALID 06:00 UTC Wed Jan 10 2024

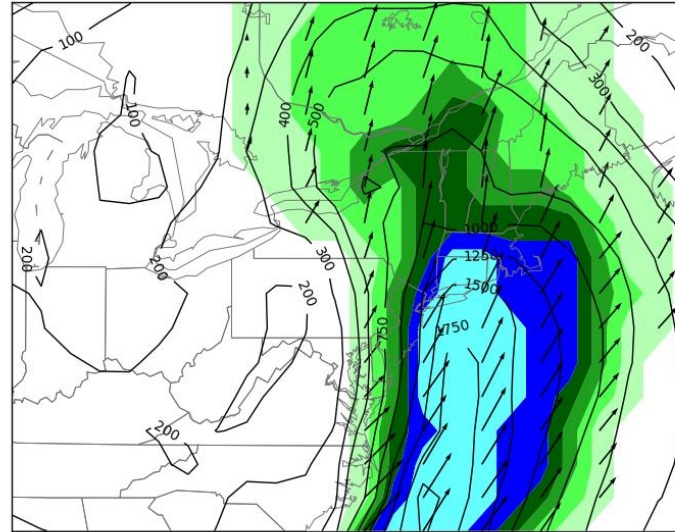
NAEFS Mean Integrated WV Transport ( $\text{kgm}^{-1} \text{s}^{-1}$ ) and Return Interval  
 HOUR 006 - VALID 06:00 UTC Wed Jan 10 2024



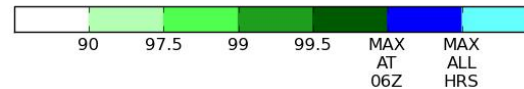
Relative to the 30-Dec to 20-Jan 1979-2009 CFSR climatology



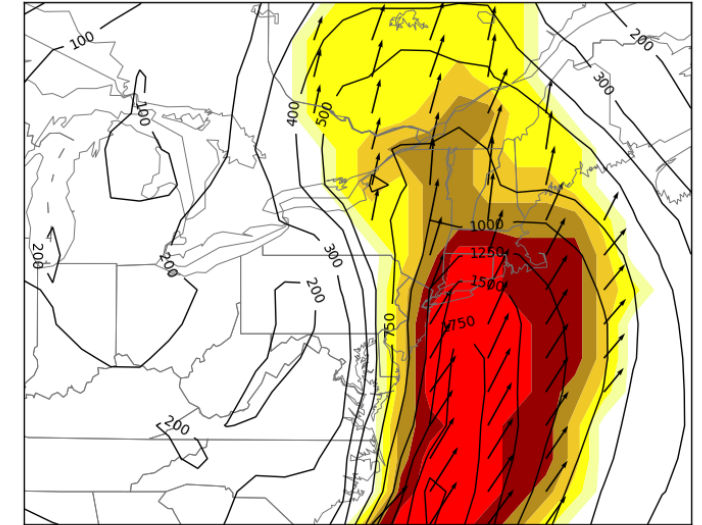
Ensemble mean 6-h IVT and Standardized Anomaly



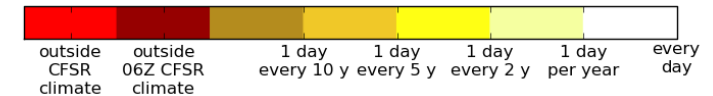
Relative to the 30-Dec to 20-Jan 1979-2009 CFSR climatology



Ensemble mean 6-h IVT and Climate Percentile



Approximate frequency of occurrence in the 30-Dec to 20-Jan CFSR climatology (1979-2009)



Ensemble mean 6-h IVT and Return Interval

**A >30-year event for a January Atmospheric River**

- IVT magnitudes within core of AR were ~8–10 standard deviations above normal for 30 Dec–20 Jan climate
- ~8–10 standard deviations is meaningless: it means values were **outside the 30-year climate period**
- **Corresponding return intervals were therefore also >30 years**





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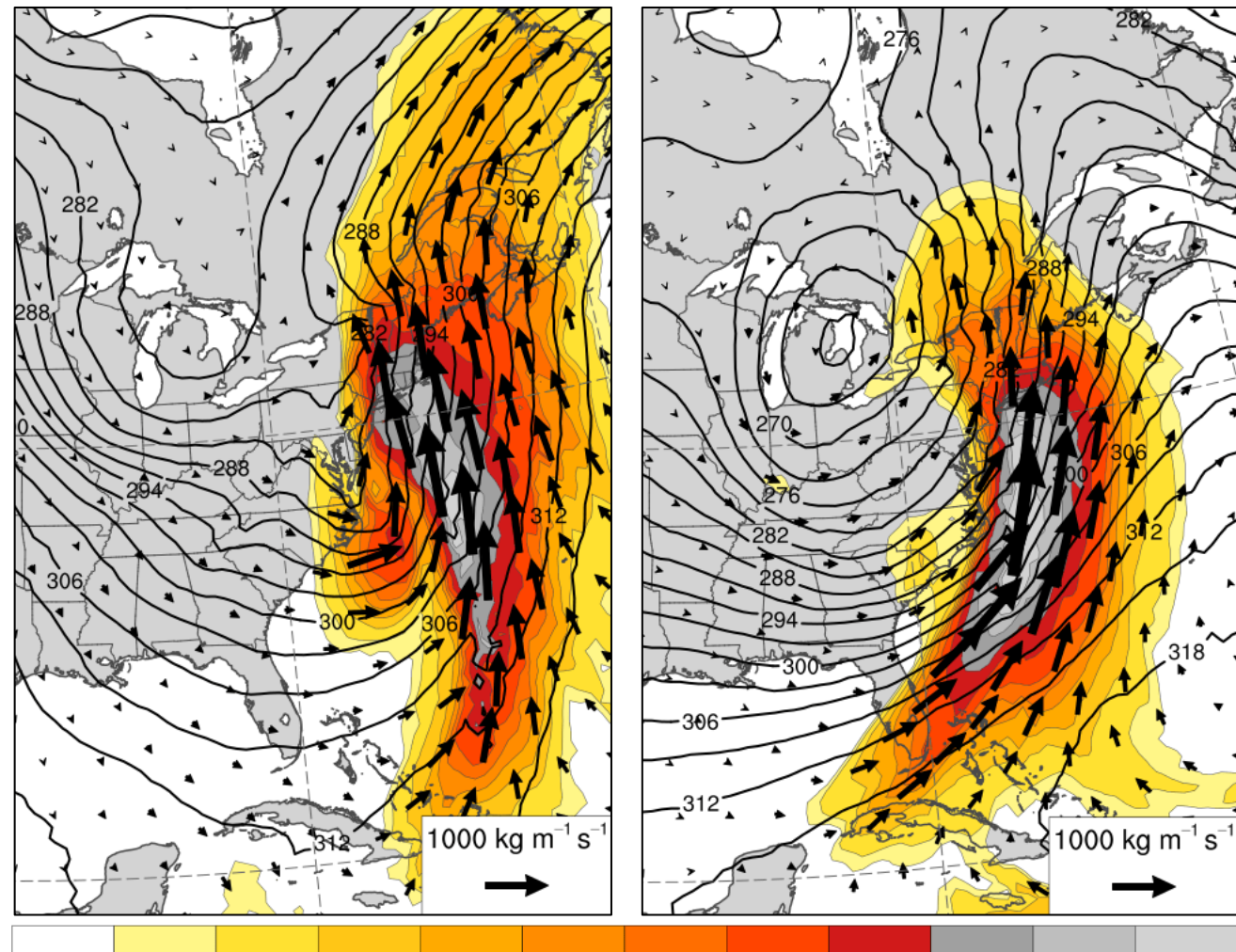
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jcordeira@ucsd.edu  
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a. 1200 UTC 18 Dec 2023

b. 0600 UTC 10 Jan 2024



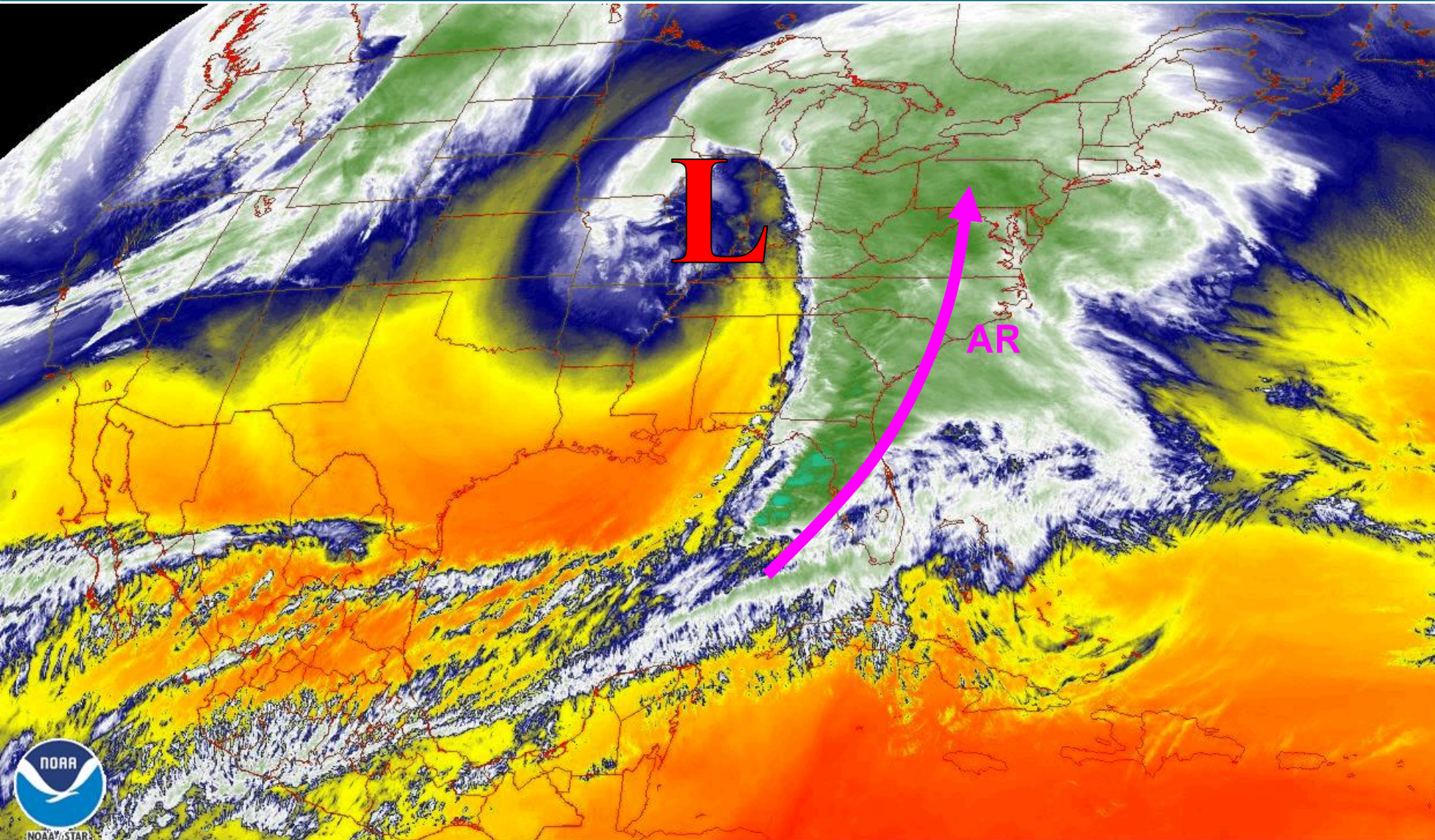
## Déjà vu

- East Coast AR shared many similarities to event on 18 Dec 2023.
- Jan 2024 event was shorter in duration and oriented more south-southwest to north-northeast as compared to Dec 2023 event.
- Dec 2023 event contained higher IVT magnitudes extending inland over southern and central New England
- Dec 2023 event occurred with a cyclone that tracked along coast and north through New England, whereas Jan 2024 event cyclone tracked through eastern Great Lakes
- Dec 2023 did not produce snow and primarily produced rain-on-snow over northern Appalachians in New Hampshire and Maine
- Jan 2024 event produced snow across central and northern England with rain-on-snow across New York and southwest New England.

250 300 400 500 600 700 800 1000 1200 1400 1600

Select GFS Model Analyses of 700-hPa Geopotential Height, IVT magnitude, and IVT Direction (adapted from imagery provided by Dr. Alicia Bentley).





GOES-East  
Band 10  
9 January 2024

East Coast AR was embedded within warm sector of a broad and strong cyclone moving over Ohio River Valley and into Great Lakes region

Image: NOAA





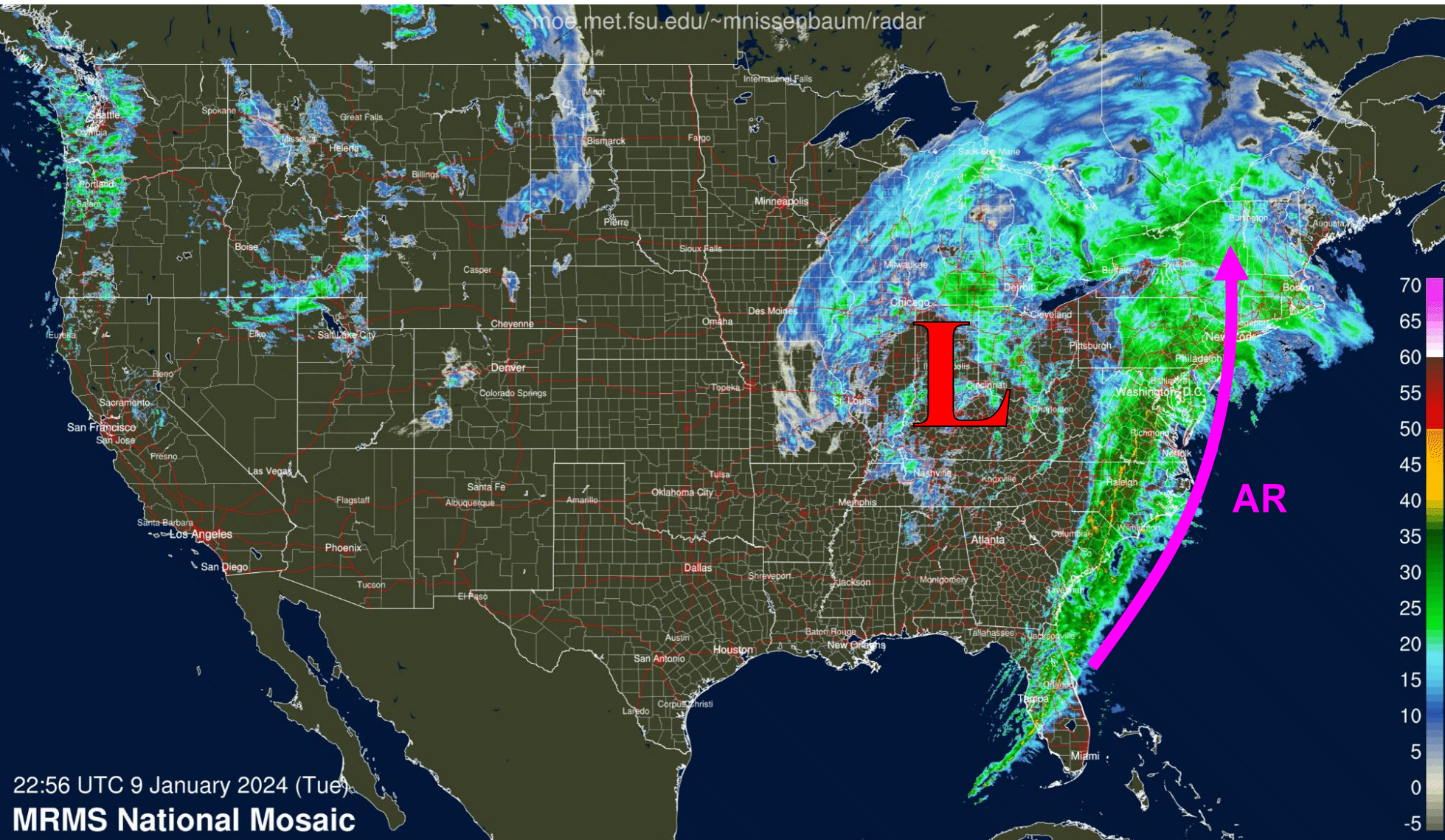


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MRMS  
National Mosaic  
9 January 2024

East Coast AR was embedded within warm sector of a broad and strong cyclone moving over Ohio River Valley and into Great Lakes region

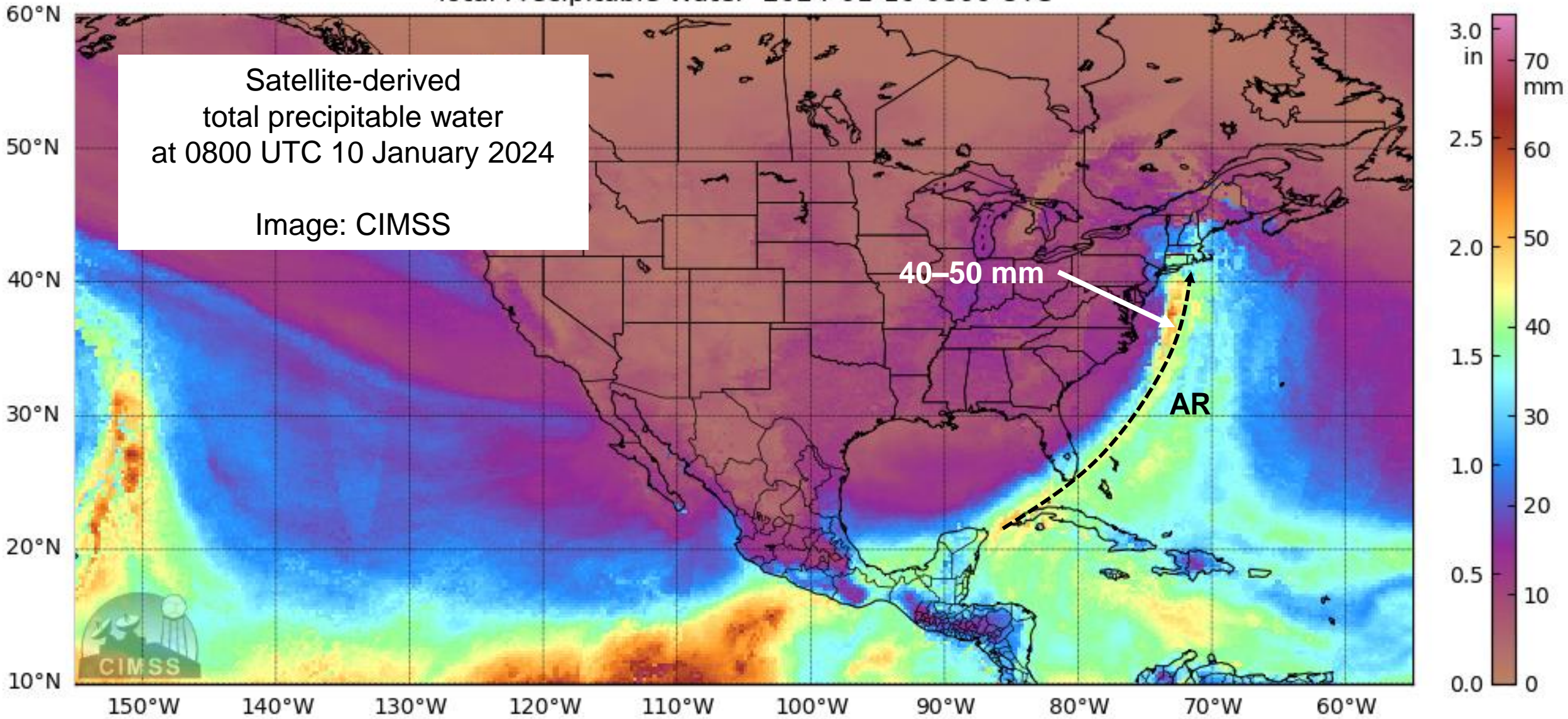
Image: M. Nissenbaum

22:56 UTC 9 January 2024 (Tue)  
MRMS National Mosaic





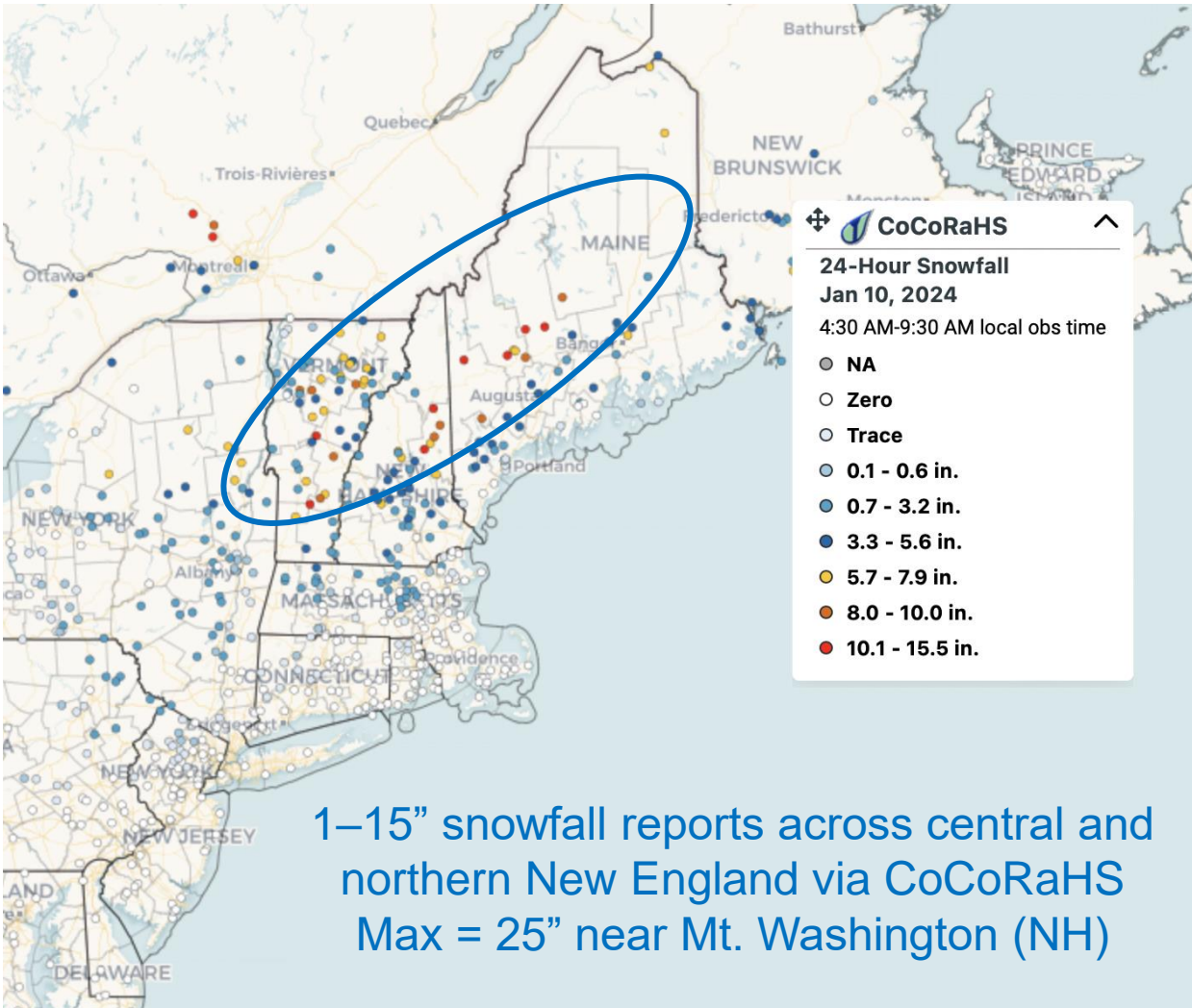
Total Precipitable Water 2024-01-10 0800 UTC



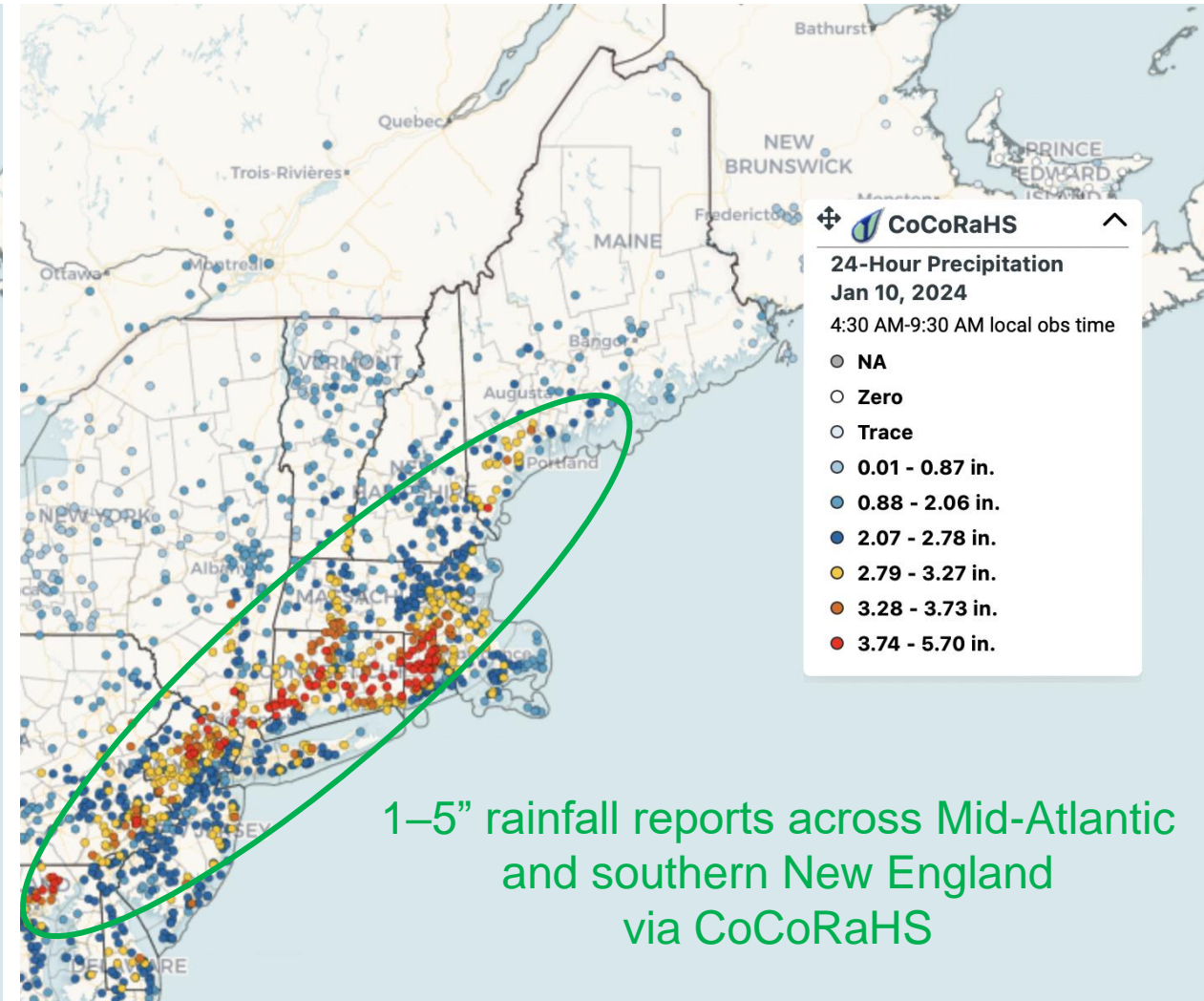




a. 24-h **snowfall** reports 4:30AM–9:30AM EST 10 Jan 2024



b. 24-h **precipitation** reports 4:30AM–9:30AM EST 10 Jan 2024







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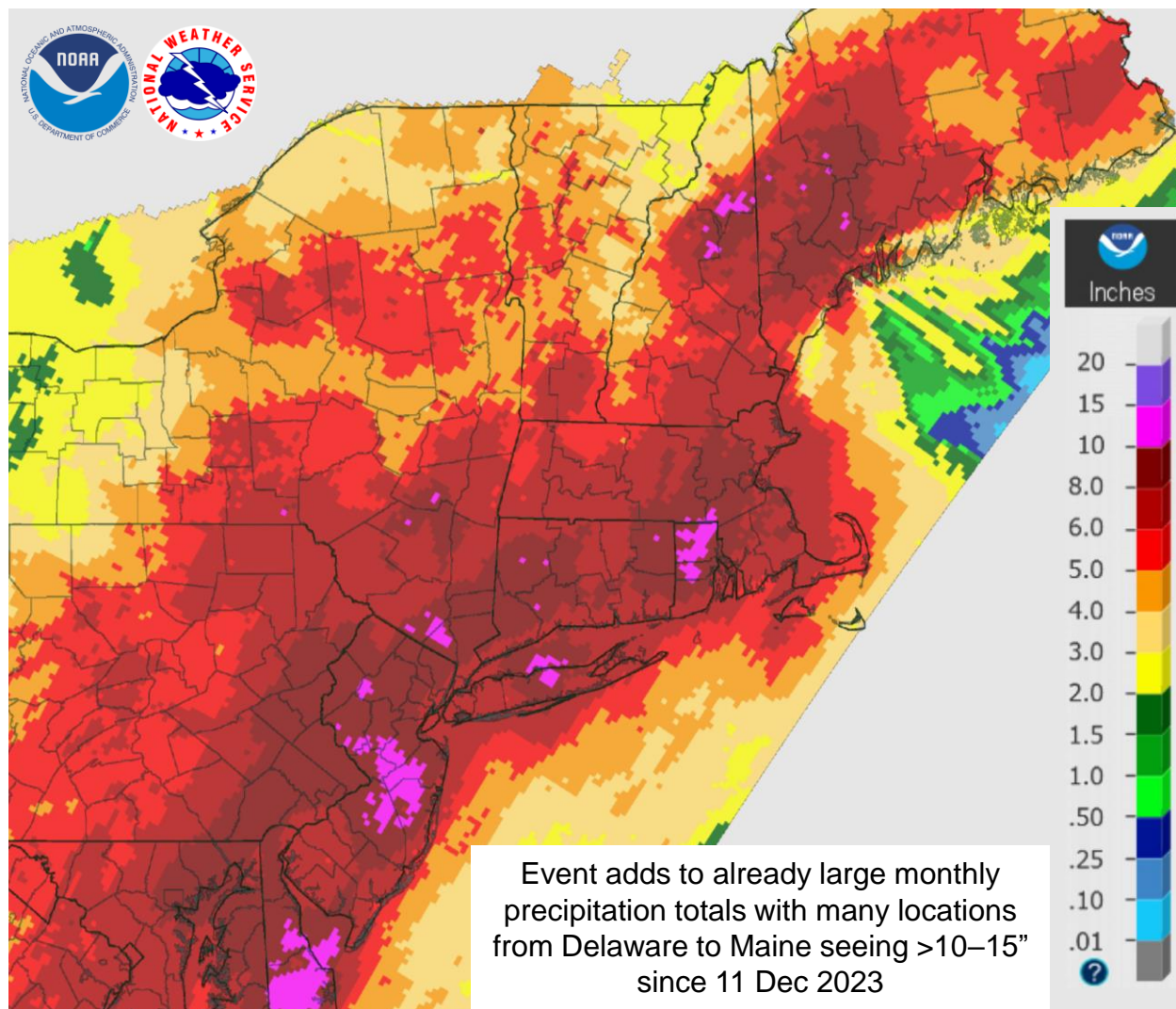
Contact:

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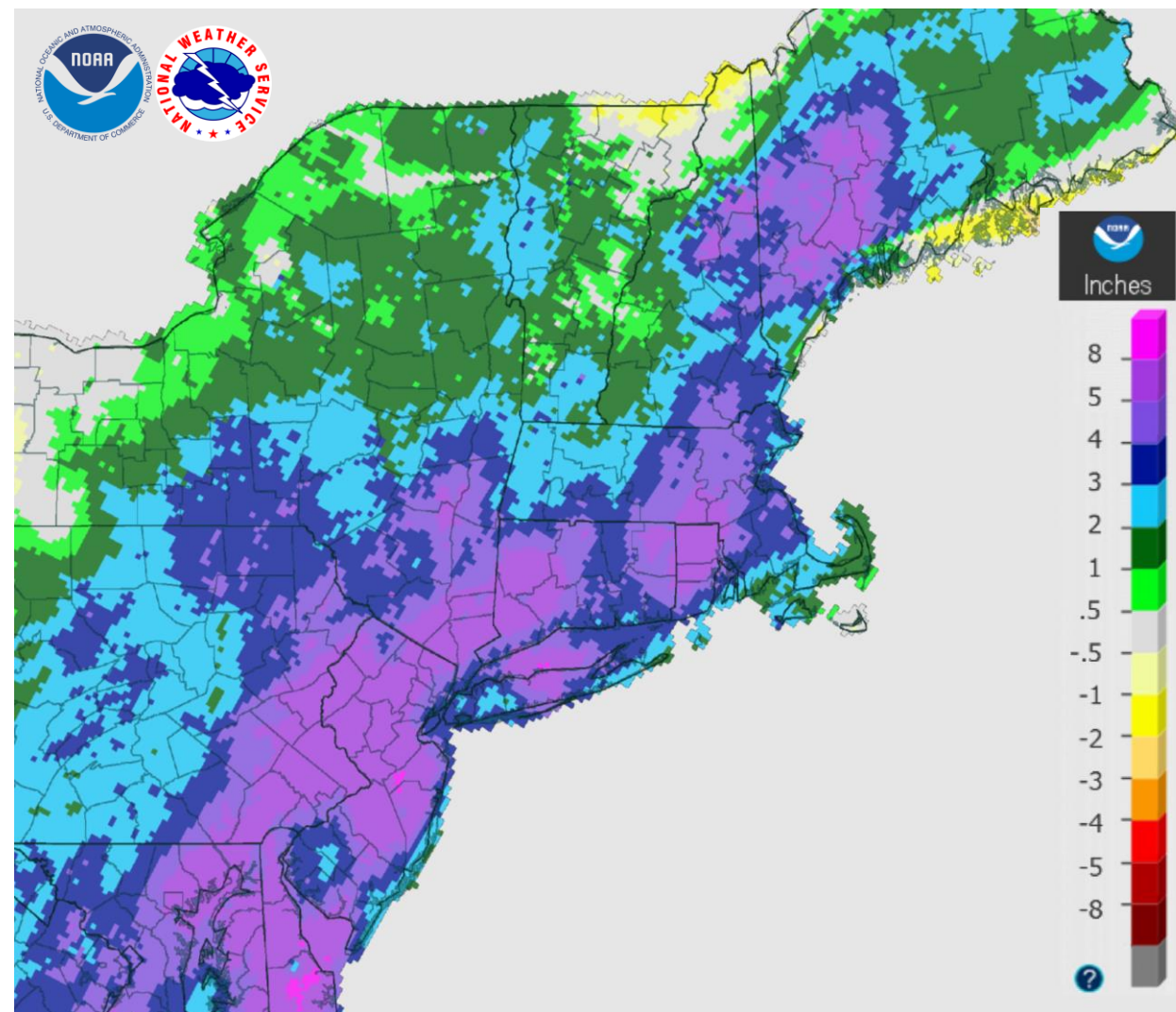
[jcordeira@ucsd.edu](mailto:jcordeira@ucsd.edu)

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a. 30-day Precipitation (11 Dec 2023 – 10 Jan 2024)



b. 30-day Precipitation Departure (11 Dec 2023 – 10 Jan 2024)





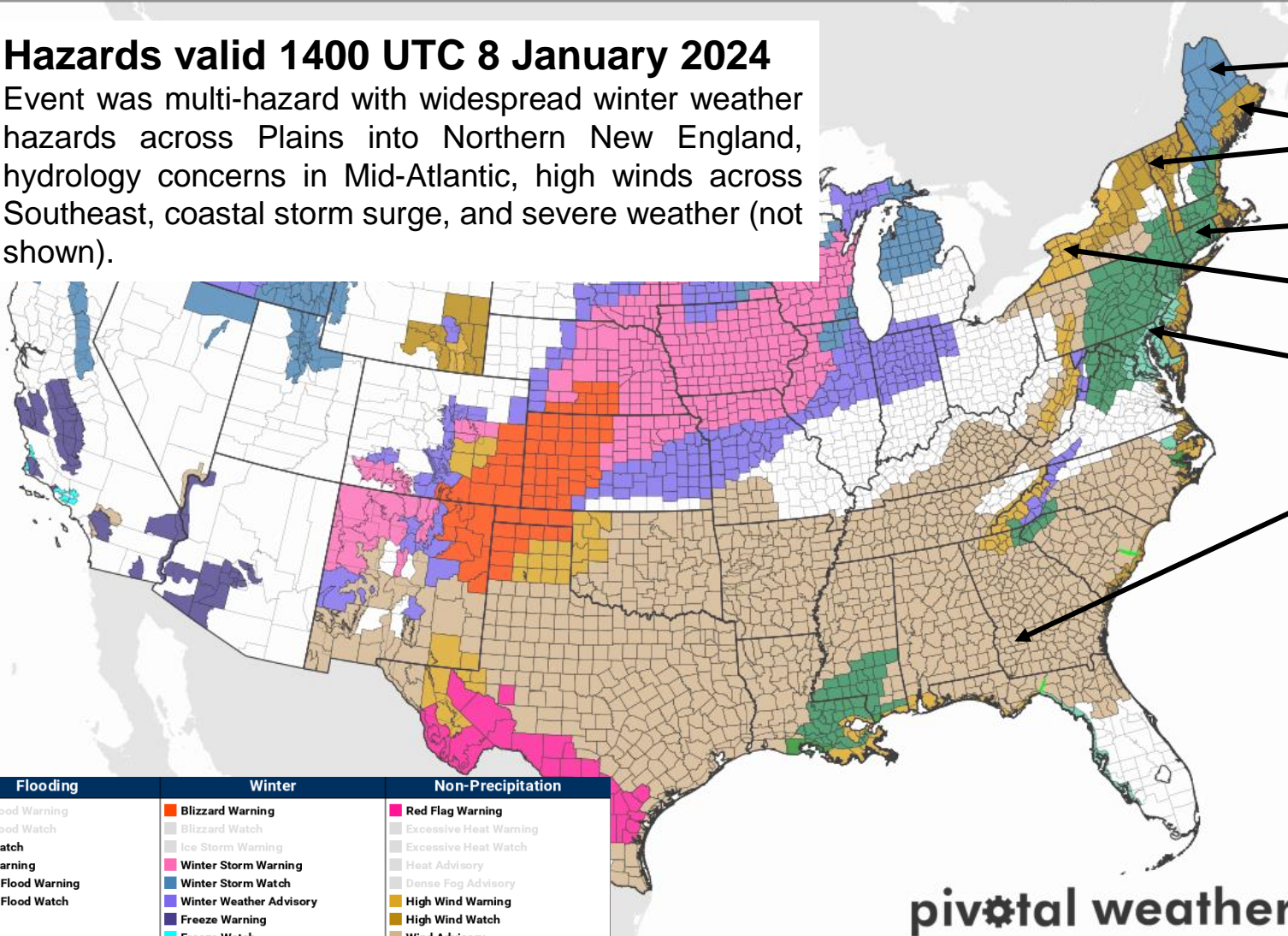


National Weather Service - Current Hazards

Valid: 01/08/2024 at 14:08:09 UTC

## Hazards valid 1400 UTC 8 January 2024

Event was multi-hazard with widespread winter weather hazards across Plains into Northern New England, hydrology concerns in Mid-Atlantic, high winds across Southeast, coastal storm surge, and severe weather (not shown).



Winter Storm Watch

High Wind Watch

Flood Watch

High Wind Warning

Coastal Flood Watch

Wind Advisory

Flood Watch  
 National Weather Service New York NY  
 357 AM EST Mon Jan 8 2024

...FLOOD WATCH REMAINS IN EFFECT FROM TUESDAY EVENING THROUGH WEDNESDAY AFTERNOON...

\* ADDITIONAL DETAILS... - A strong storm system will impact the area Tuesday night into Wednesday with the likelihood of heavy rainfall. Rainfall amounts of 2 to 3 inches with localized higher amounts are possible during this time. This combined with a snowpack across portions of the watch area along with saturated grounds will lead to rapid runoff into area rivers and streams. There will be potential for widespread flooding.



Flooding	Winter	Non-Precipitation
Flash Flood Warning	Blizzard Warning	Red Flag Warning
Flash Flood Watch	Blizzard Watch	Excessive Heat Warning
Flood Watch	Ice Storm Warning	Excessive Heat Watch
Flood Warning	Winter Storm Warning	Heat Advisory
Coastal Flood Warning	Winter Storm Watch	Dense Fog Advisory
Coastal Flood Watch	Winter Weather Advisory	High Wind Warning
	Freeze Warning	High Wind Watch
	Freeze Watch	Wind Advisory





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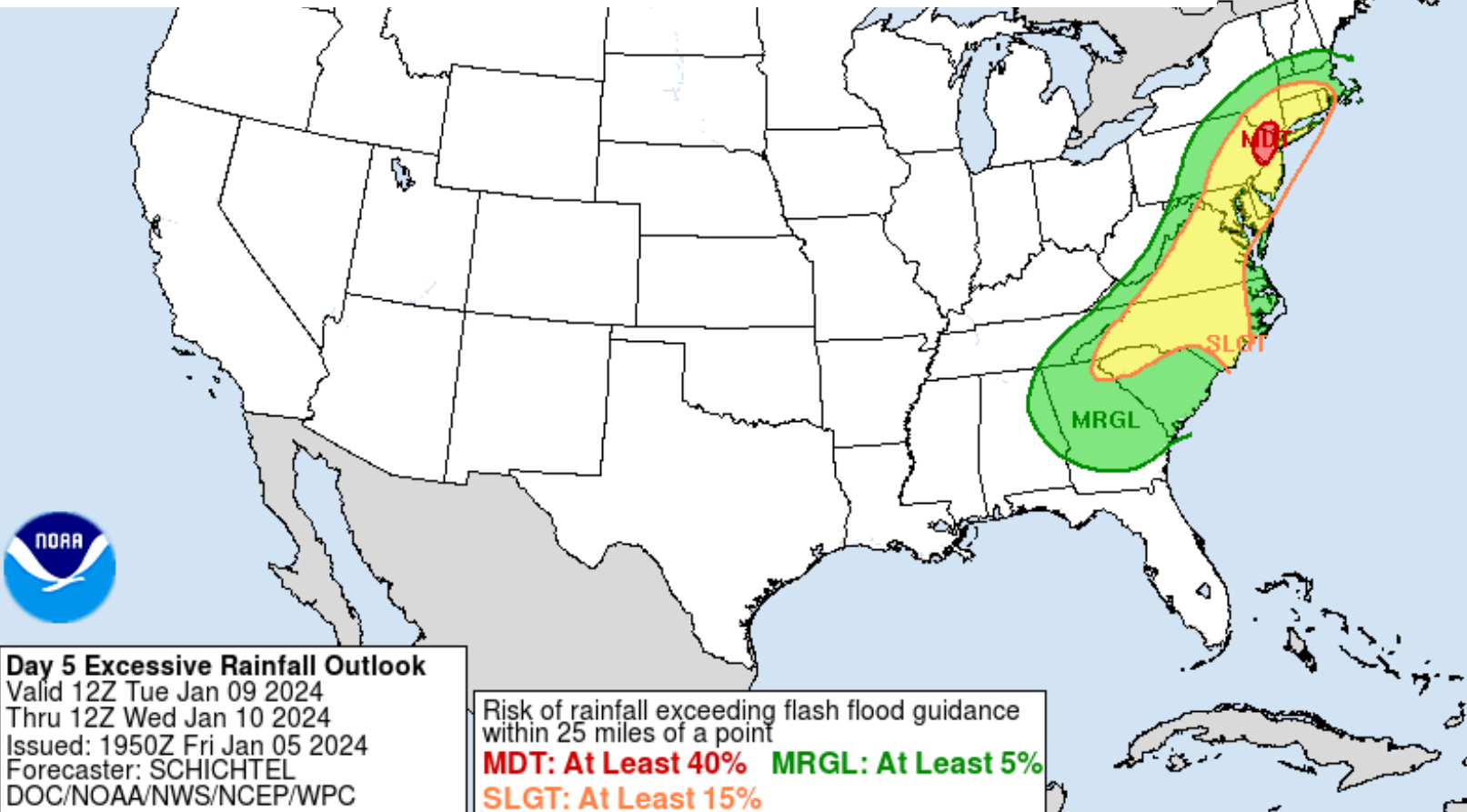
<http://cw3e.ucsd.edu>

## WPC Day-5 Excessive Rainfall Outlook

Sixth time a moderate risk at Day-5 issued

First time since day-5 EROs have been issued operationally

First time a day-5 moderate risk issued in Northeast

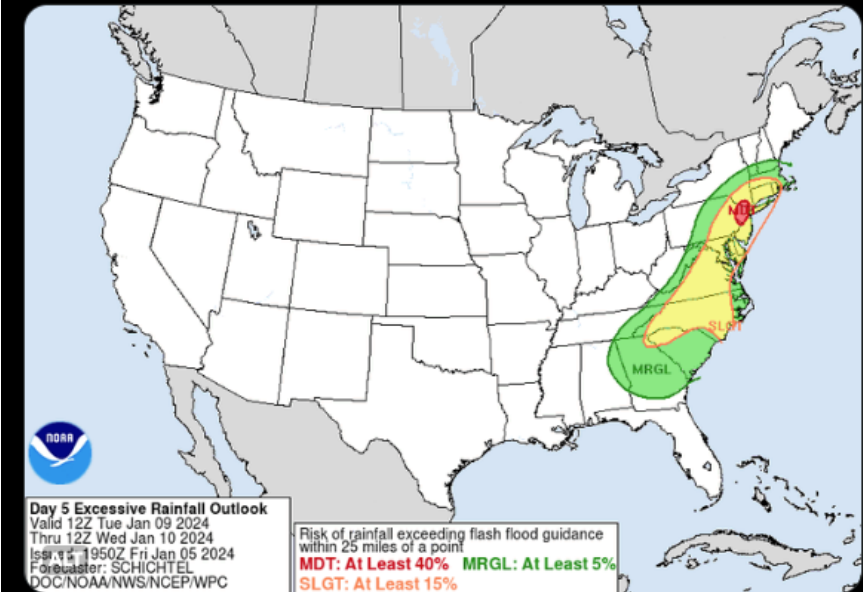


NWS Weather Prediction Center

@NWSWPC

With a Moderate Risk on the Day 5 Excessive Rainfall Outlook (for Tues. & Tues. Ngt) we've been asked whether this has happened this far in advance before.

The answer is yes: five times when it was in experimental status. This is the first time operationally (since 1 June 2023).



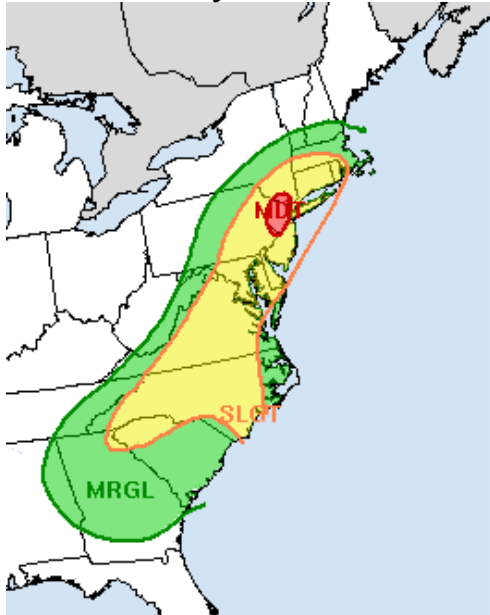
4:32 PM · Jan 5, 2024 · 4,020 Views



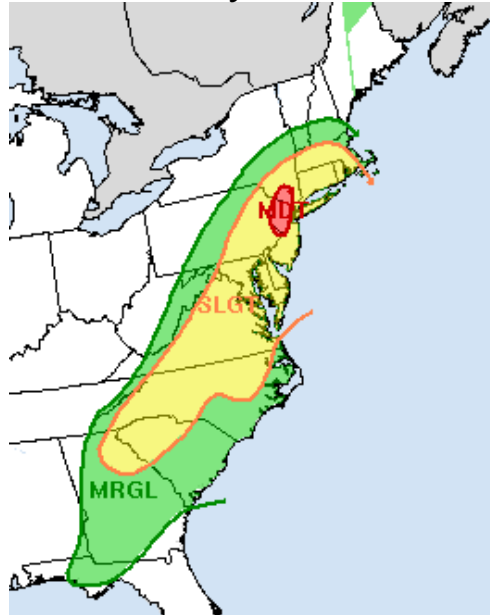


NOAA Weather Prediction Center Excessive Rainfall Outlooks all valid 1200 UTC 10 January 2024

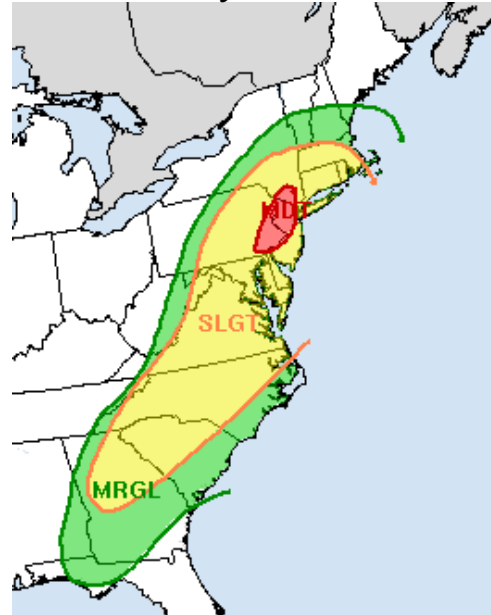
Day-5



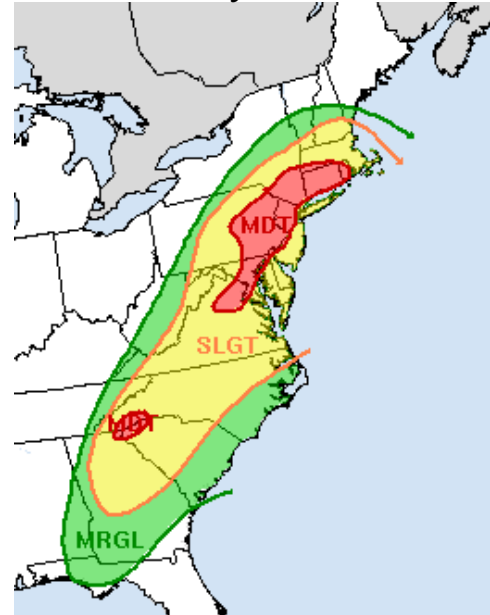
Day-4



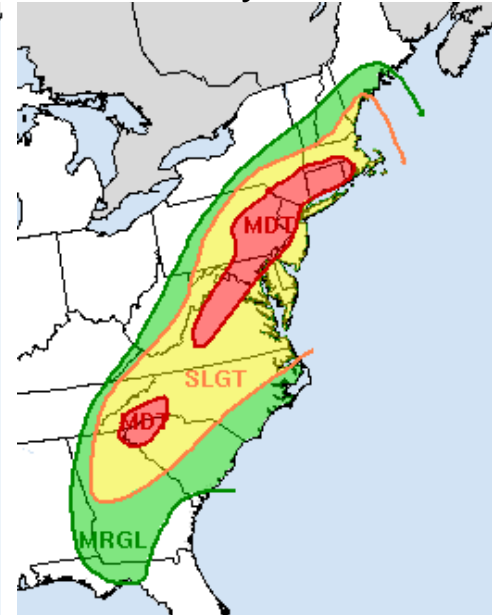
Day-3



Day-2



Day-1



Risk of rainfall exceeding flash flood guidance within 25 miles of a point  
**MDT: At Least 40%** **MRGL: At Least 5%**  
**SLGT: At Least 15%**

Issued 5 Jan

Issued 6 Jan

Issued 7 Jan

Issued 8 Jan

Issued 9 Jan

Storm and its impacts related to flash flood risk was well forecast at least 5 days in advance by forecasters at Weather Prediction Center



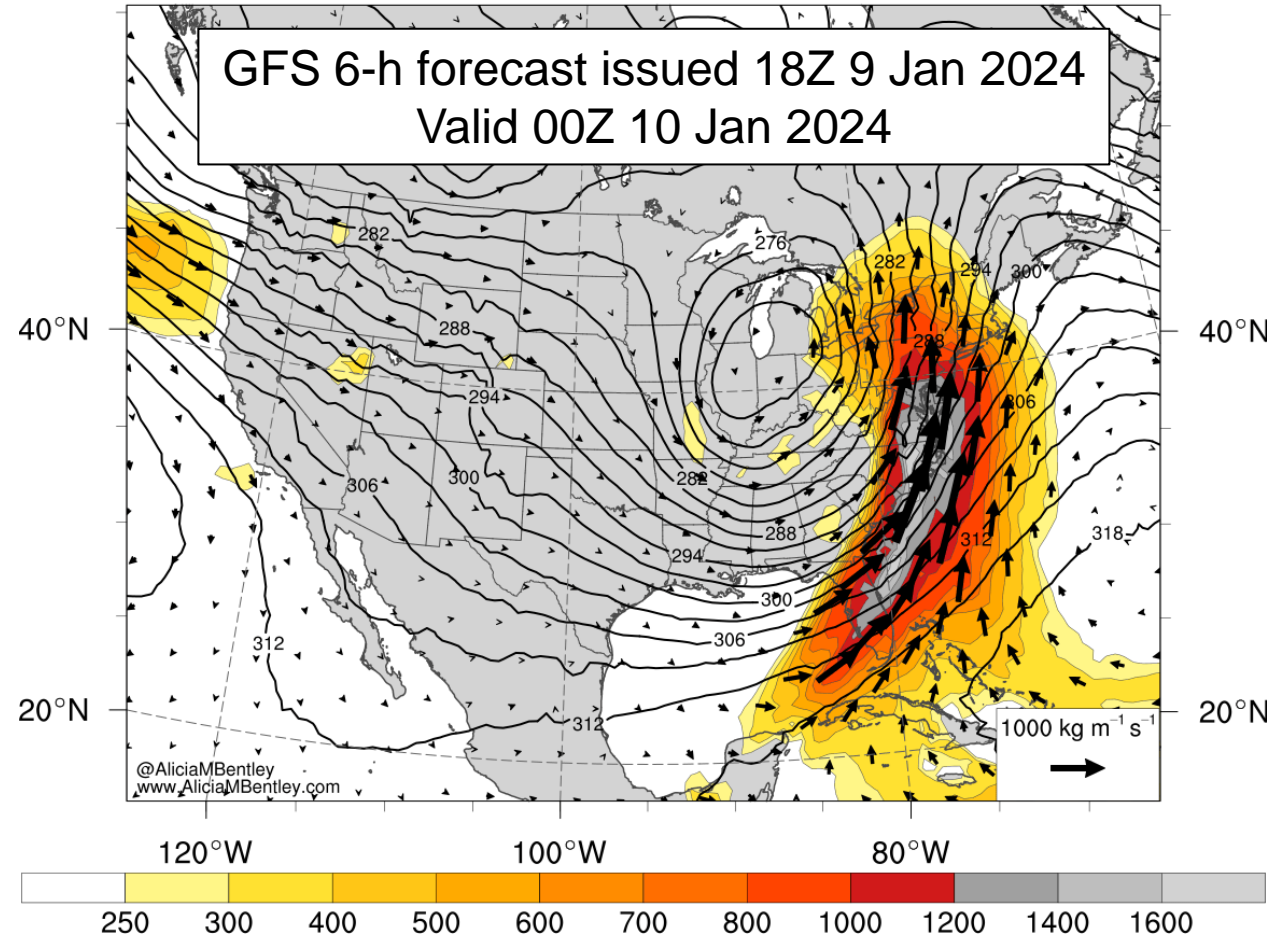
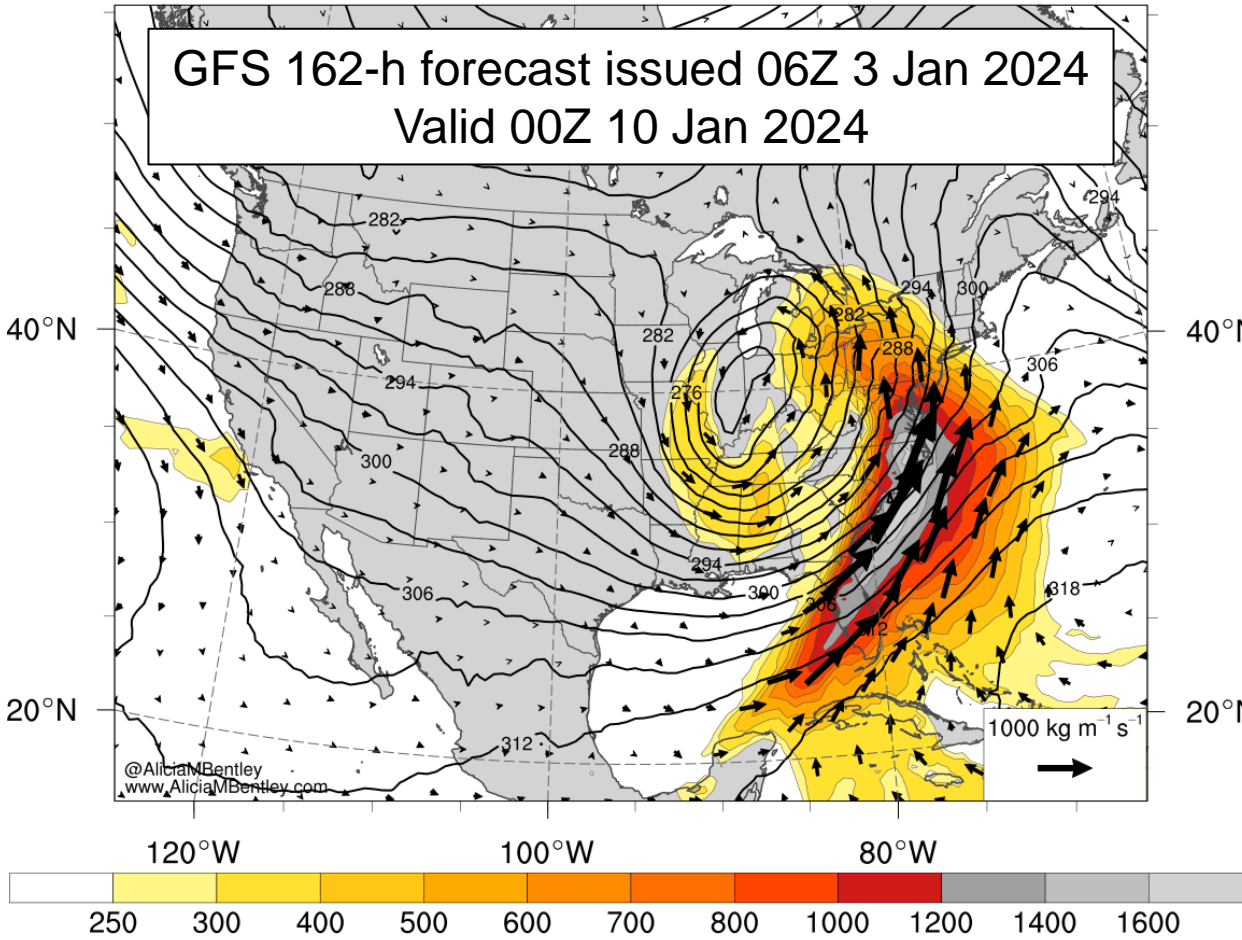


700-hPa geo. height (black, dam), Integrated water vapor transport [IVT] (shaded, kg/m/s) (vectors, kg/m/s)  
Initialized: 0600 UTC 3 Jan 2024 | Forecast hour: 162 | Valid: 0000 UTC 10 Jan 2024

700-hPa geo. height (black, dam), Integrated water vapor transport [IVT] (shaded, kg/m/s) (vectors, kg/m/s)  
Initialized: 1800 UTC 9 Jan 2024 | Forecast hour: 6 | Valid: 0000 UTC 10 Jan 2024

**GFS 162-h forecast issued 06Z 3 Jan 2024**  
Valid 00Z 10 Jan 2024

**GFS 6-h forecast issued 18Z 9 Jan 2024**  
Valid 00Z 10 Jan 2024



Forecasts by GFS model were remarkably accurate at lead times >7 days with relatively minor errors in structure, location, intensity of primary cyclone. East Coast AR forecasts were remarkably consistent.



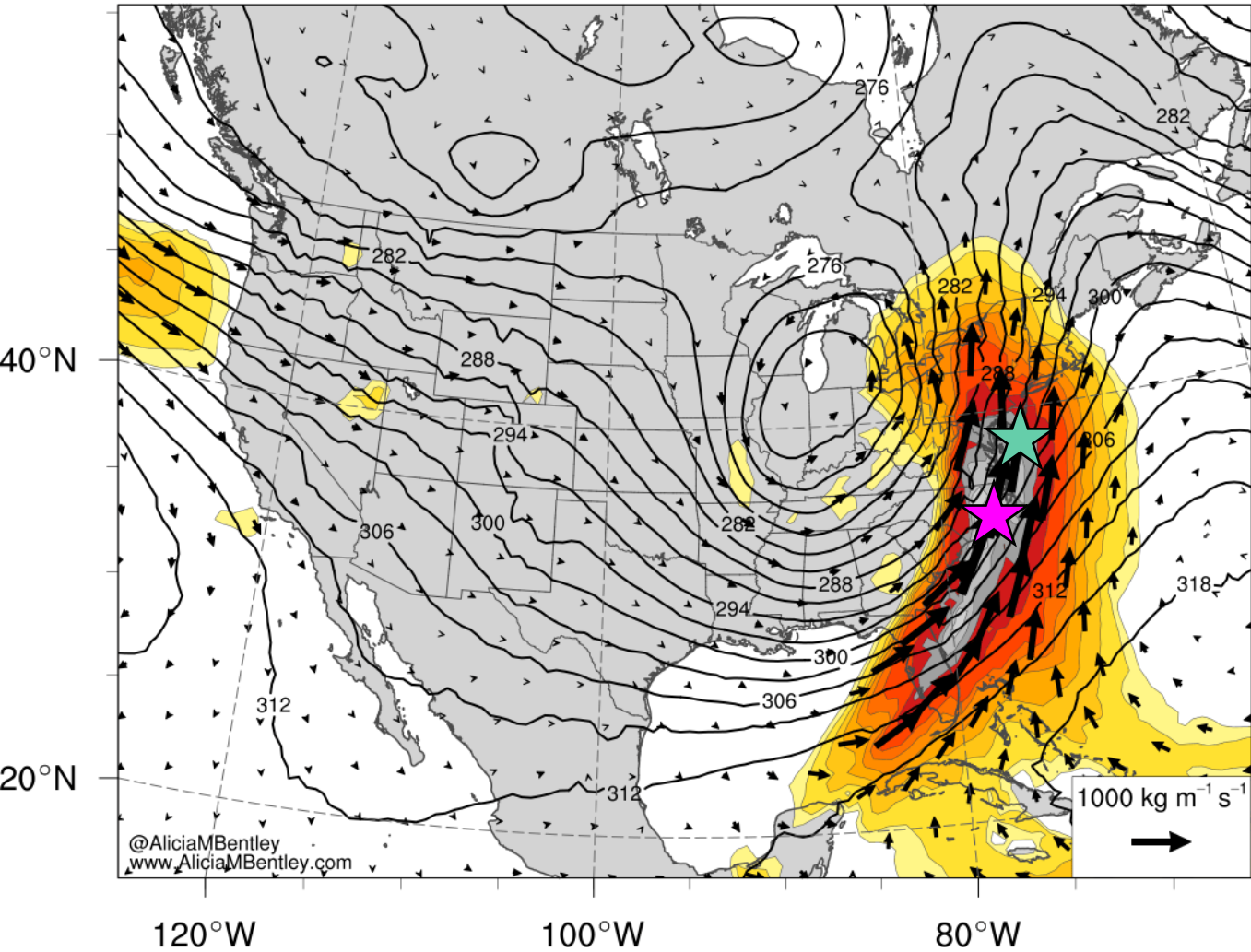


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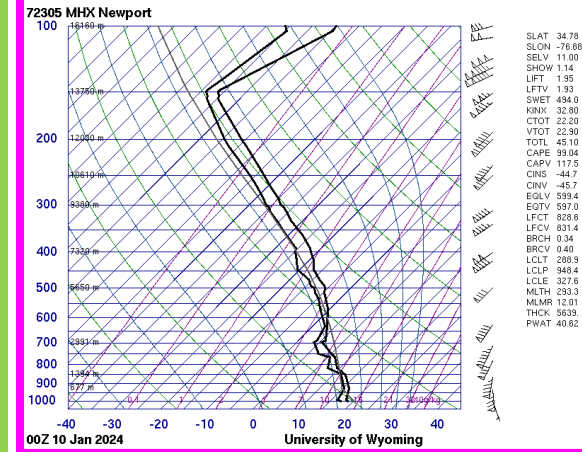
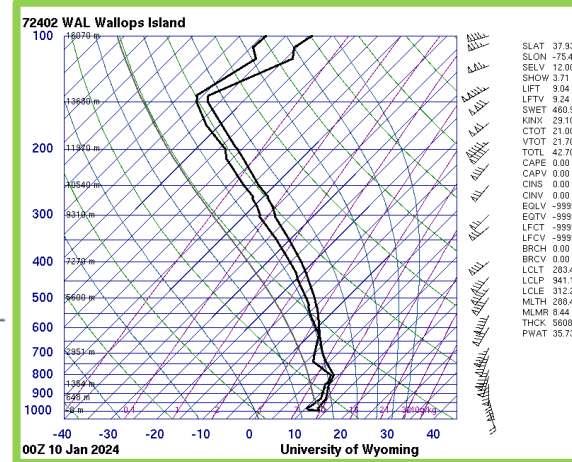
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700-hPa geo. height (black, dam), Integrated water vapor transport [IVT] (shaded, kg/m/s) (vectors, kg/m/s)  
Initialized: 1800 UTC 9 Jan 2024 | Forecast hour: 6 | Valid: 0000 UTC 10 Jan 2024



0000 UTC 10 January 2024



WAL/Wallops Island  
Observed IWV: 35.7 mm  
Observed IVT: 1388 kg/ms

MHX/Newport  
Observed IWV: 40.6 mm  
Observed IVT: 1528 kg/ms

Storm verified with IVT magnitudes >1500 kg/ms in coastal North Carolina and ~1400 kg/ms in the Mid-Atlantic

250 300 400 500 600 700 800 1000 1200 1400 1600





# Center for Western Weather and Water Extremes

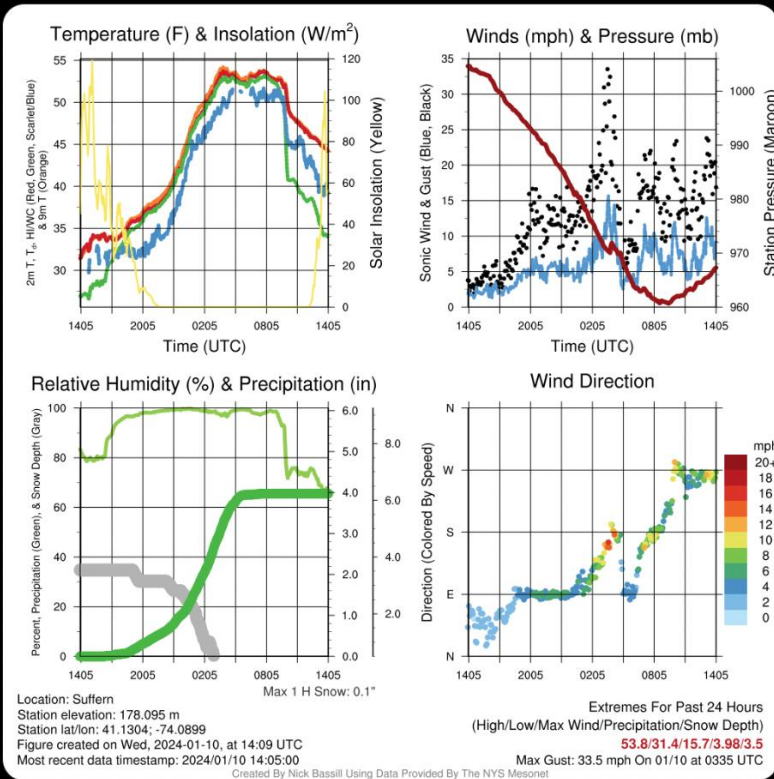
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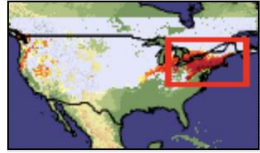
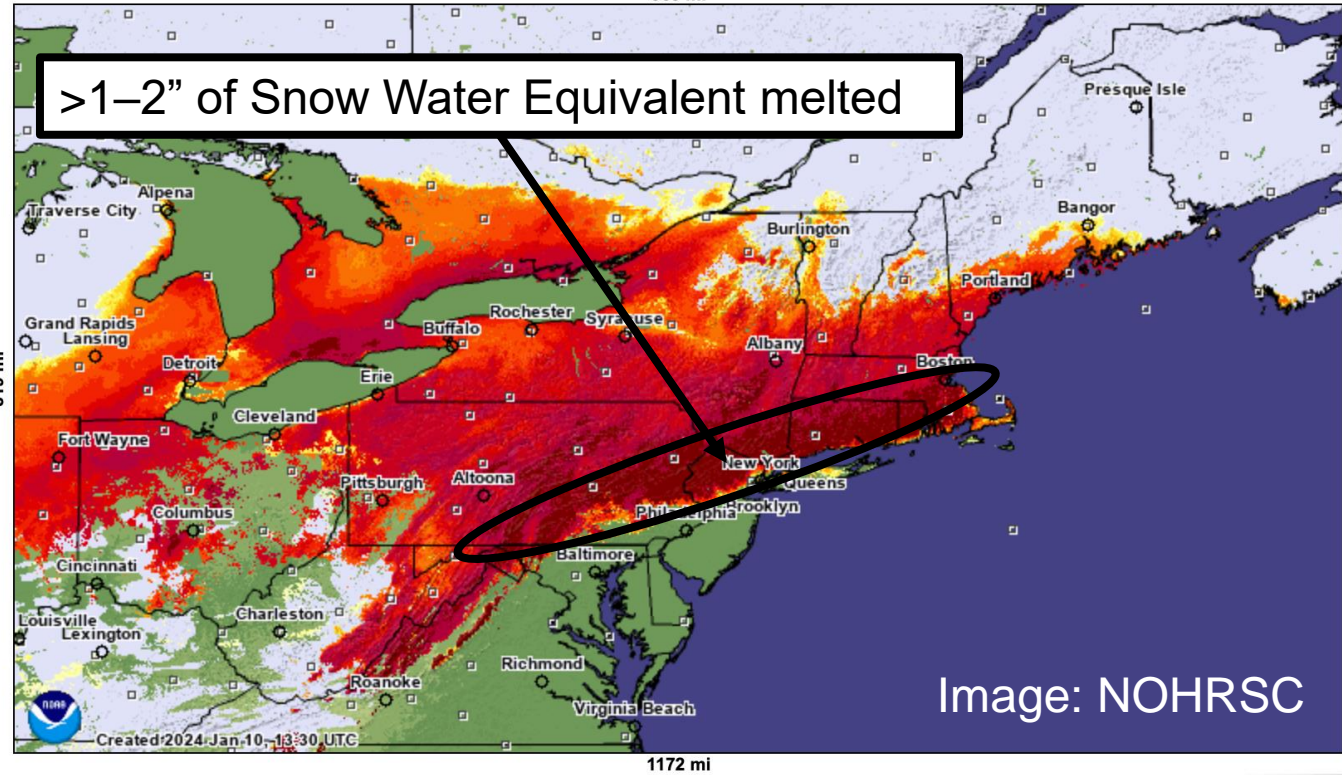
 Nick P Bassill  
@NickPBassill

Going to post some "fun" graphics from the storm yesterday over the course of the day.

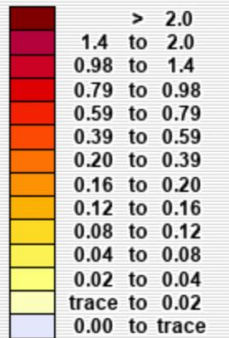
Here's the past 24 h weather trace from the @nysmesonet's Suffern site. Notice the bottom left panel: 4" of snow melted and 4" of rain fell! They've had an astonishing 14" of rain in ~31 days.



Total Modeled Snow Melt forecasted for 24h preceding 2024 January 10, 11:00 UTC



Inches of water equivalent



Elevation in feet



Flooding impacts were exacerbated by already above-normal rainfall totals, saturated soils, and recent snow from a snowstorm on 7-8 Jan. Rain on snow "melted off" an additional >1-2" of snow water, which added to rainfall totals of >2-4".





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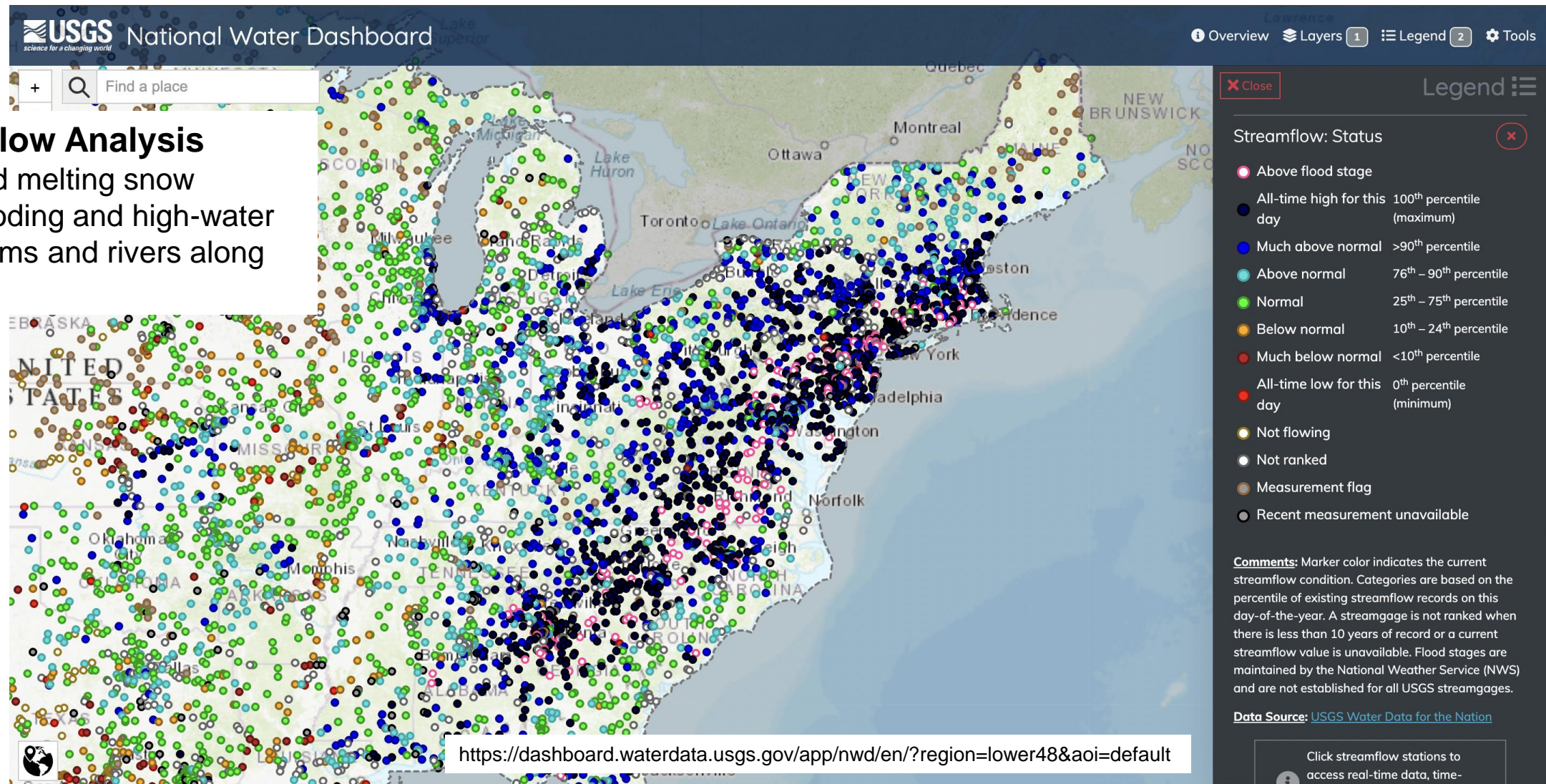
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## USGS Streamflow Analysis

Heavy rainfall and melting snow contributed to flooding and high-water along many streams and rivers along the East Coast



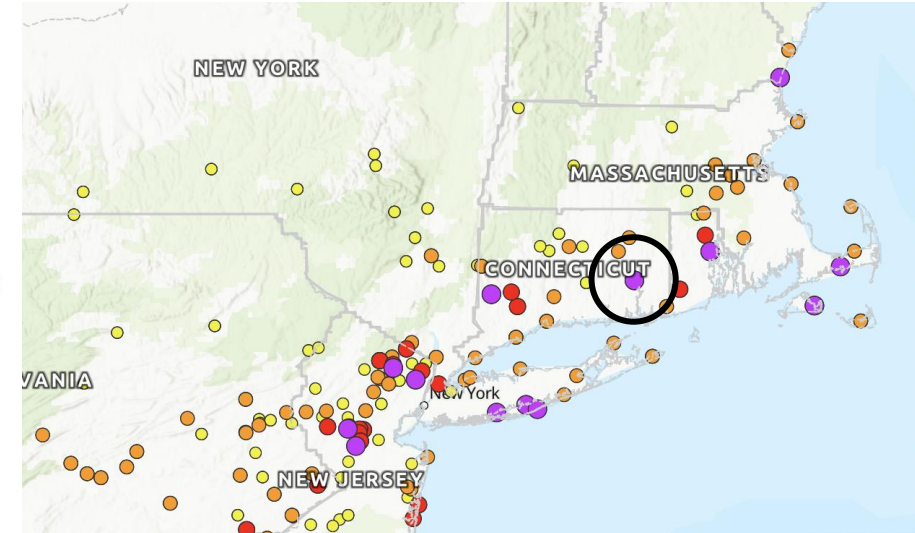
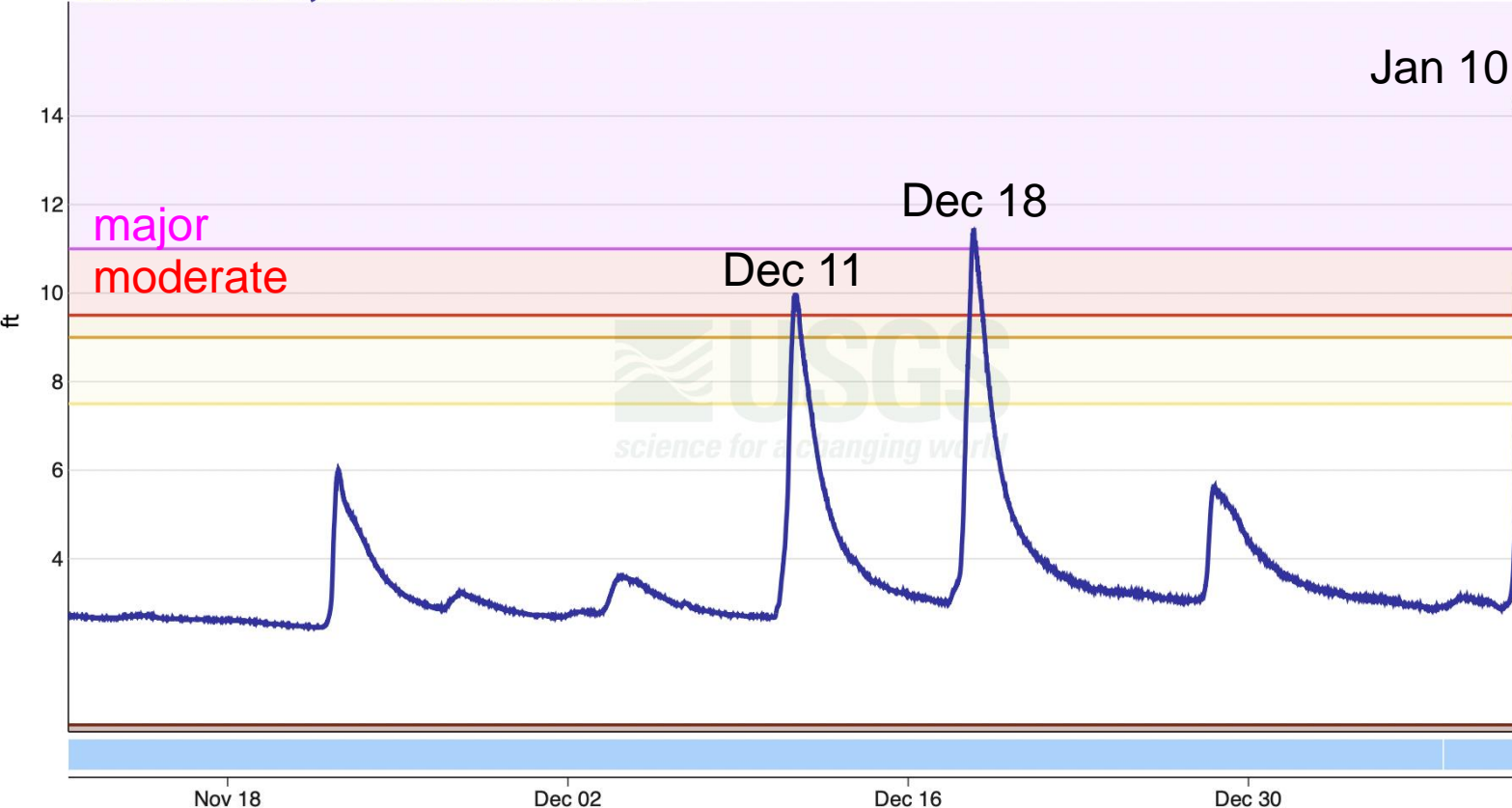




# Yantic River at Yantic, CT - 01127500

November 11, 2023 - January 10, 2024  
Gage height, feet

14.23 ft - Jan 10, 2024 08:00:00 AM EST



Crested at 14.23 feet  
Third moderate flood in last 31 days  
Second major flood in last 23 days  
Highest crest since 1982  
Third highest crest on record behind:

- June 1982 – 14.88 feet
- September 1938 – 14.66 feet

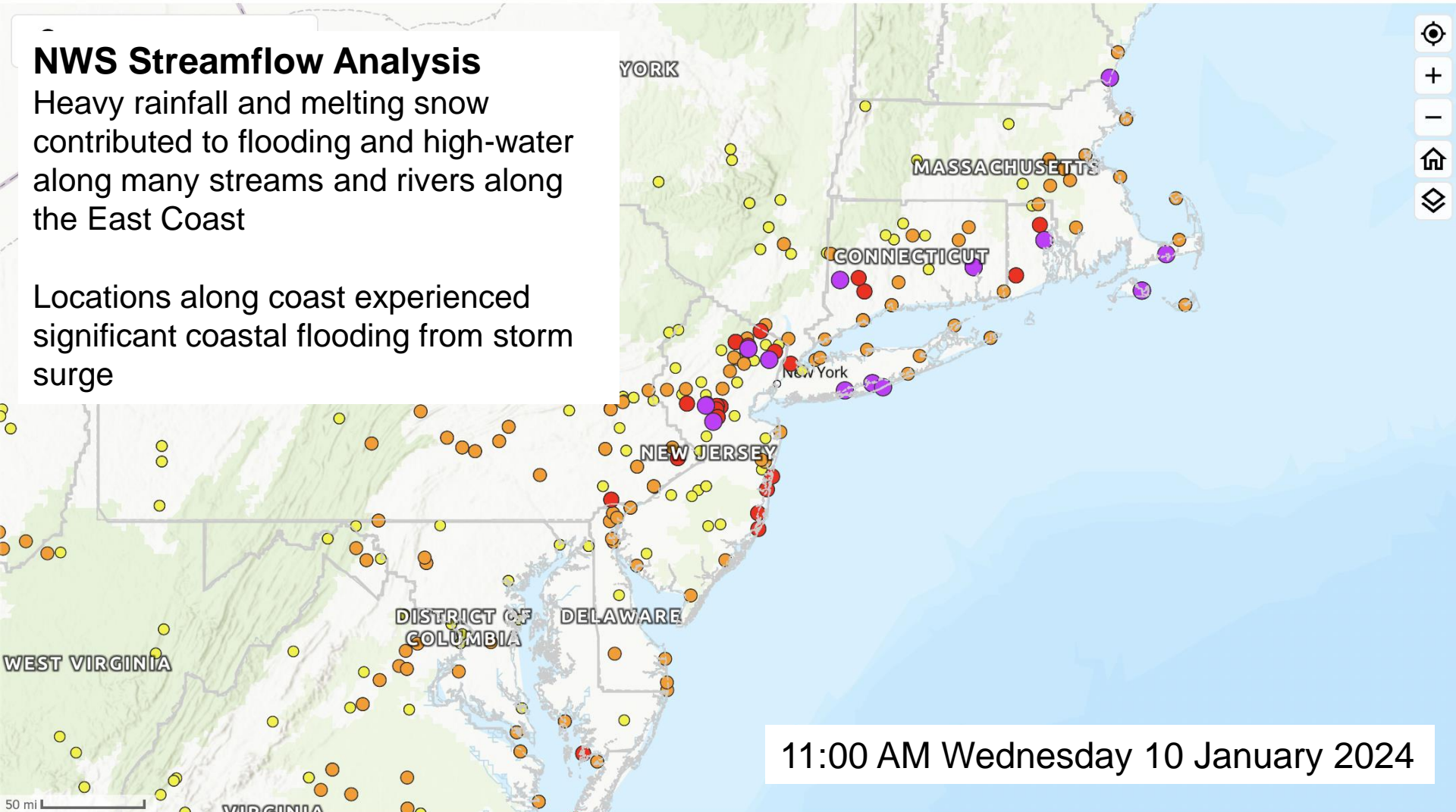
Highest January crest on record by +1.5 feet



## NWS Streamflow Analysis

Heavy rainfall and melting snow contributed to flooding and high-water along many streams and rivers along the East Coast

Locations along coast experienced significant coastal flooding from storm surge



- Observations & Forecasts
- Long Range Flood Outlook

CATEGORIES	OBSERVATION	FORECAST
Major Flood	21 <input checked="" type="checkbox"/>	0 <input type="checkbox"/>
Moderate Flood	42 <input checked="" type="checkbox"/>	0 <input type="checkbox"/>
Minor Flood	167 <input checked="" type="checkbox"/>	0 <input type="checkbox"/>
Action	189 <input checked="" type="checkbox"/>	0 <input type="checkbox"/>
No Flood	0 <input type="checkbox"/>	0 <input type="checkbox"/>
Flood Category Not Defined	0 <input type="checkbox"/>	0 <input type="checkbox"/>
Low Water Threshold	0 <input type="checkbox"/>	0 <input type="checkbox"/>
Data Not Current	0 <input type="checkbox"/>	0 <input type="checkbox"/>
Out of Service	0 <input type="checkbox"/>	0 <input type="checkbox"/>

- Limit by boundary
- Only display Partner FIM Gauges ⓘ

- > Hazards
- > Precipitation Estimate
  - Enabled
- > National Water Model

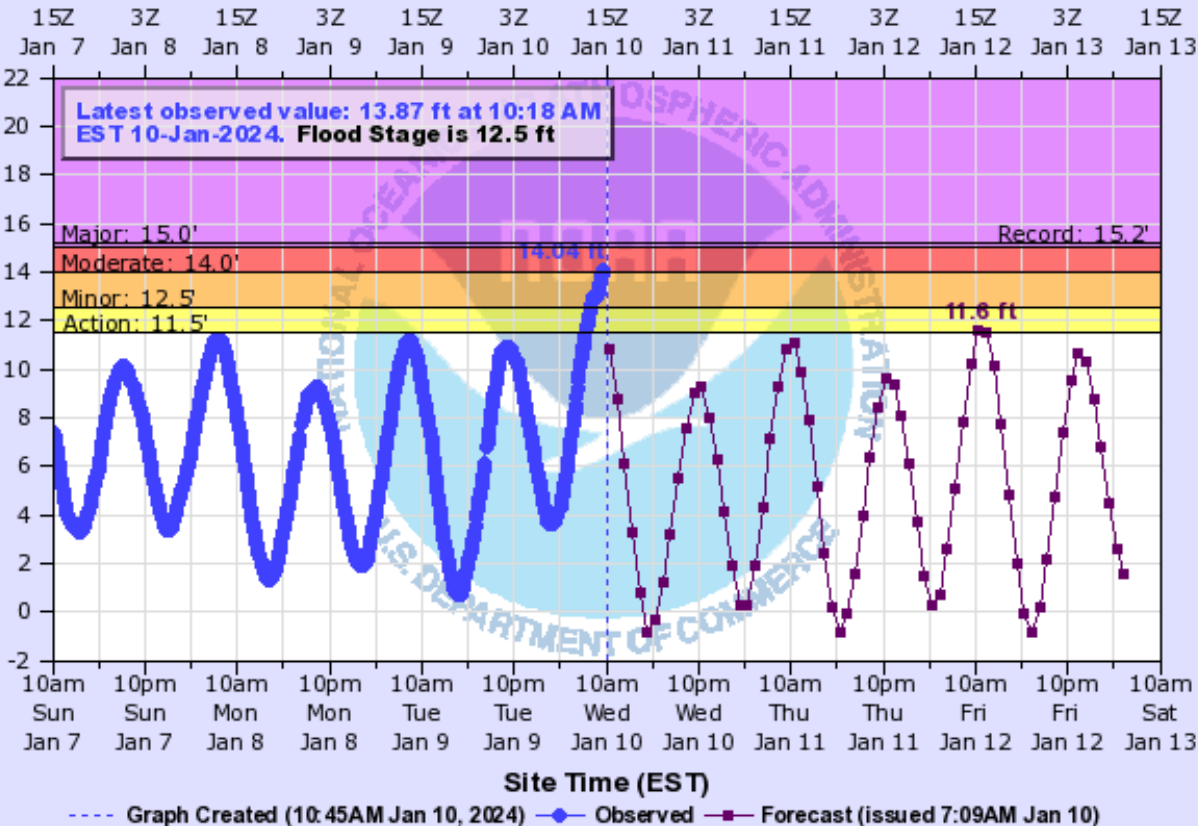




Coastal flooding in New England was **significant** with a 3-foot storm surge coinciding with high tide on 10 January

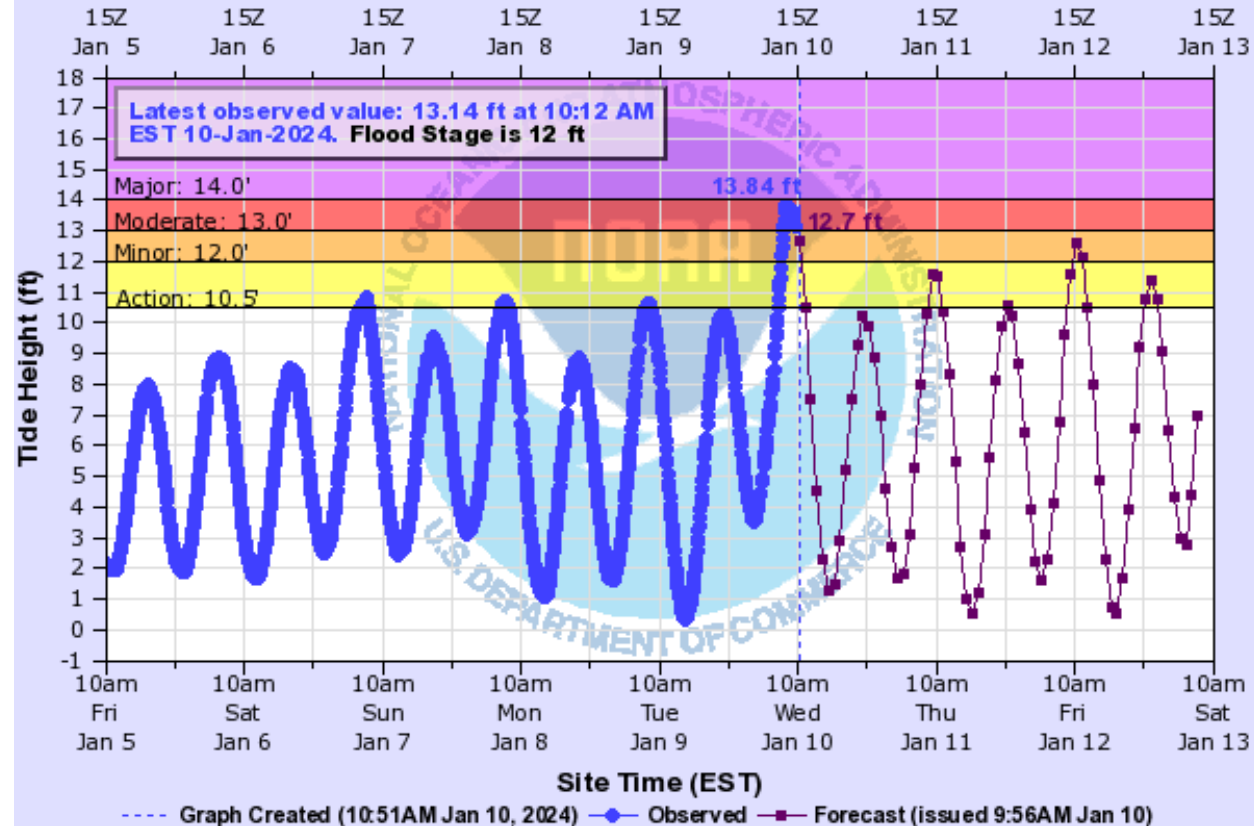
**BOSTON HARBOR AT BOSTON (IN MLLW)**

Universal Time (UTC)



**ATLANTIC COAST AT PORTLAND (IN MLLW)**

Universal Time (UTC)



14.04 feet is tied for sixth highest tide on record at Boston

13.84 feet is third highest tide on record at Portland behind pair of storms in early 1978 (e.g., Blizzard 1978)