2026 HURREVAC Training Webinar Series

Day 3 – Storm Surge and Flooding Hazards

June 17, 2026

FEMA NATIONAL HURRICANE PROGRAM

HURREVAC
HURRICANE DECISION SUPPORT TOOL

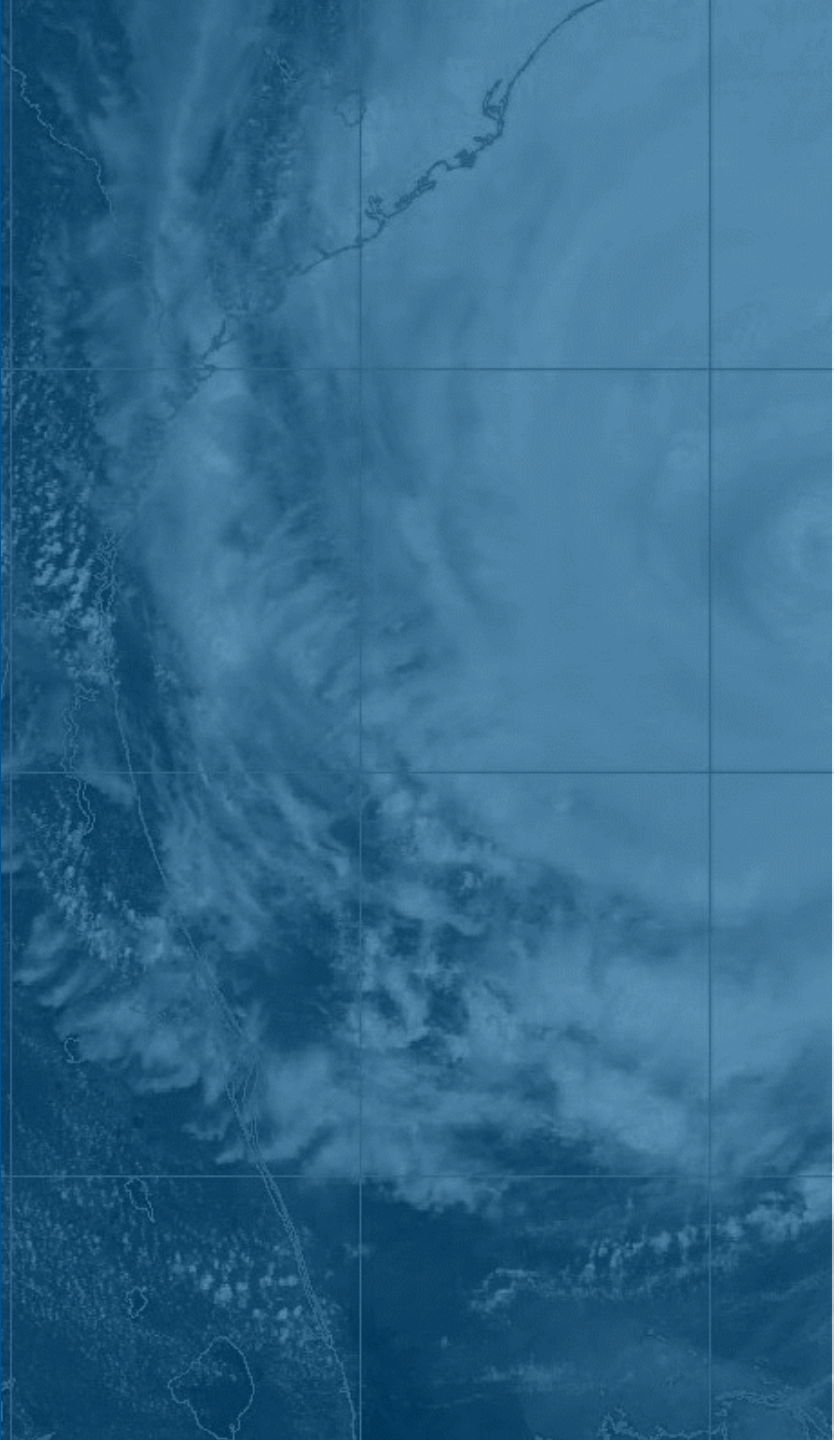
THIS WEEK'S AGENDA

MON. JUNE 15: Intro to HURREVAC *(on YouTube)*

TUES. JUNE 16: Wind Forecast Features *(on YouTube)*

WED. JUNE 17: Storm Surge and Flooding Hazards

THURS. JUNE 18: Evacuation Timing Features



Today's Presenters

Cassandra Mora
Storm Surge Specialist
NOAA National Hurricane Center

Owen Shieh, Ph.D.
Warning Coordination Meteorologist
NOAA / NWS Weather Prediction Center

Jason Elliott
Service Coordination Hydrologist
NOAA National Water Center

John Boyer
Sea Island Software

2026 Hurrevac Webinar – Storm Surge

Storm Surge Specialists:
Cassandra Mora, Laura Alaka, Heather Nepaul
Cody Fritz – SSU Team Lead

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service

Objectives

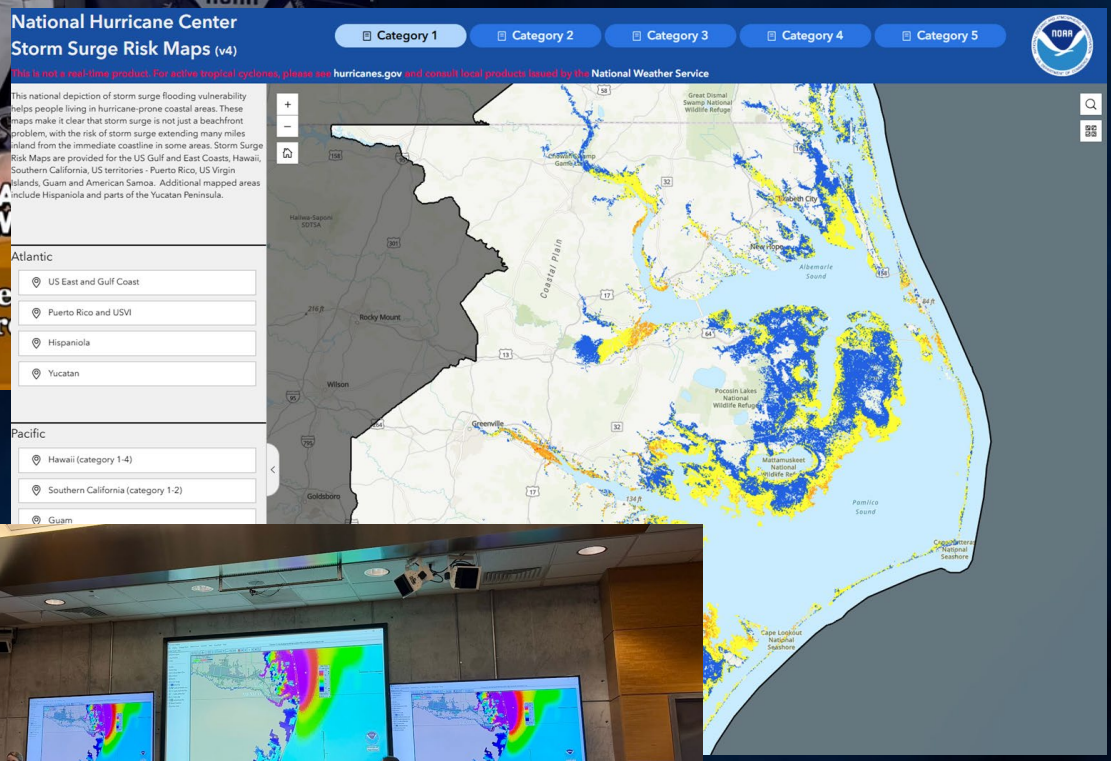
Hurrevac Webinar – Storm Surge 2026

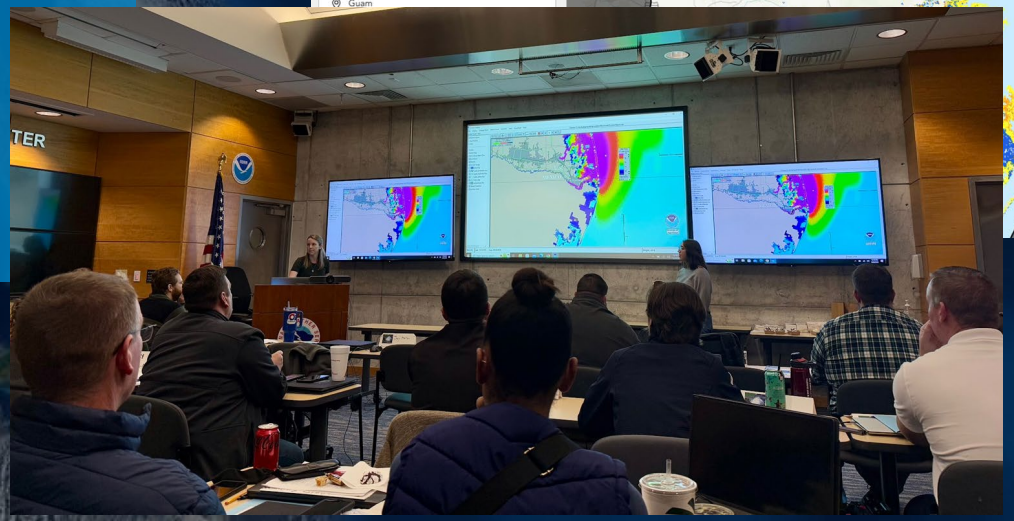
- **Communicate the danger of storm surge caused by tropical cyclones**
- **Demonstrate how probabilistic storm surge forecasting provides a more complete picture of risk and impacts.**
- **Highlight the products available for planning and response to storm surge within Hurrevac**

NHC Storm Surge Unit

Mission

To serve the Nation's growing need for storm surge information by providing accurate real-time surge forecasts during tropical cyclone events, supporting coastal community preparedness and resiliency through storm surge vulnerability mapping, and increasing awareness through outreach and education.



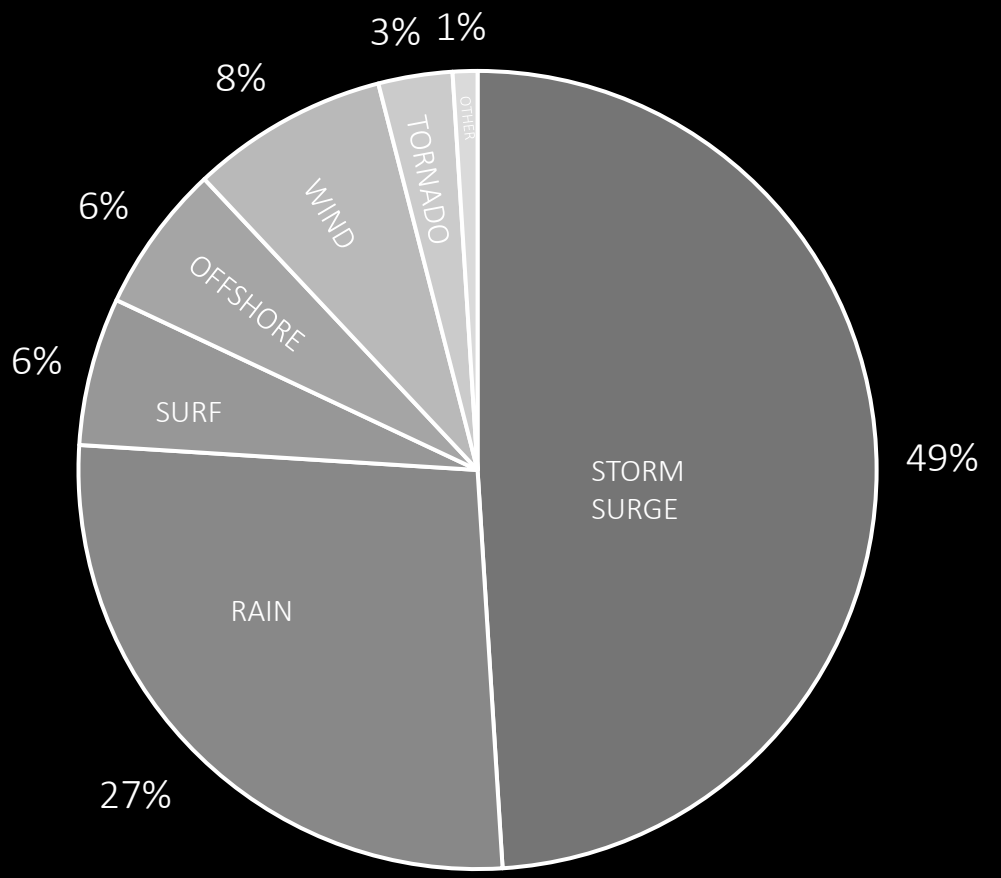


Cause of death in the United States directly attributed to Atlantic tropical cyclones (1963-2012)

[Rappaport 2014]

- Almost 50% the deaths are due to storm surge
- More than 80% of deaths are due to water
- Wind causes less than 10% of deaths

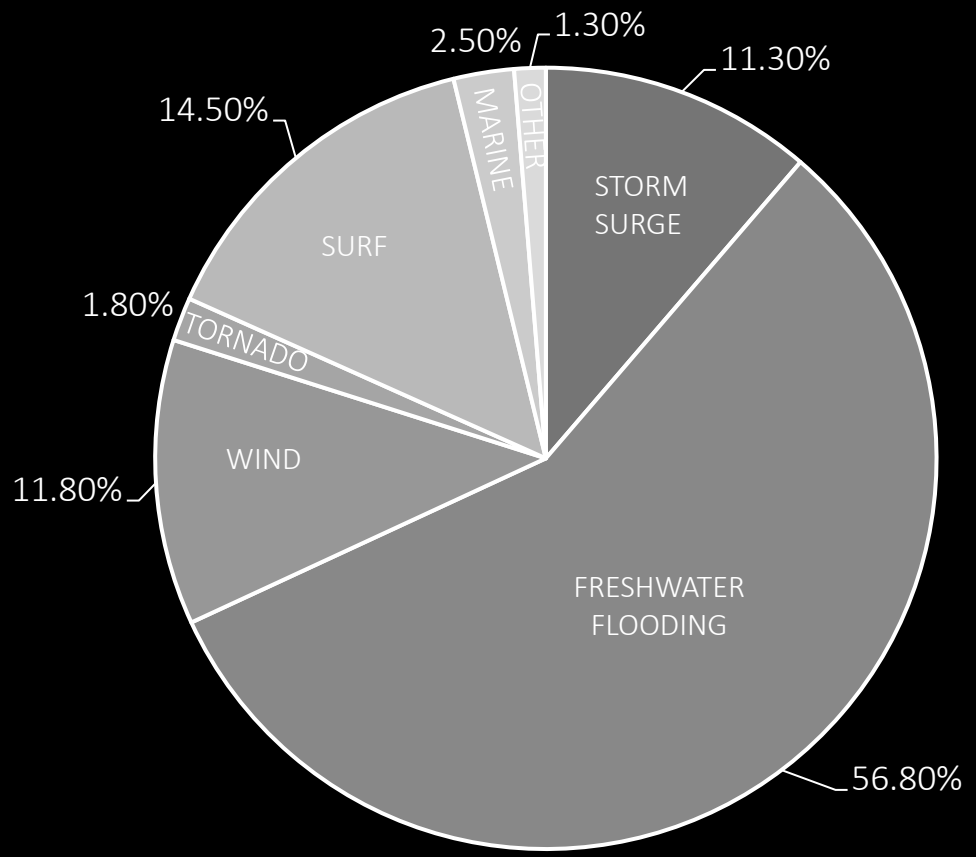
2,544 Fatalities From 1963–2012



Edward N. Rappaport, 2014: Fatalities in the United States from Atlantic Tropical Cyclones: New Data and Interpretation. Bull. Amer. Meteor. Soc., 95, 341–346.

Cause of death in the United States directly attributed to Atlantic tropical cyclones (2013-2022)

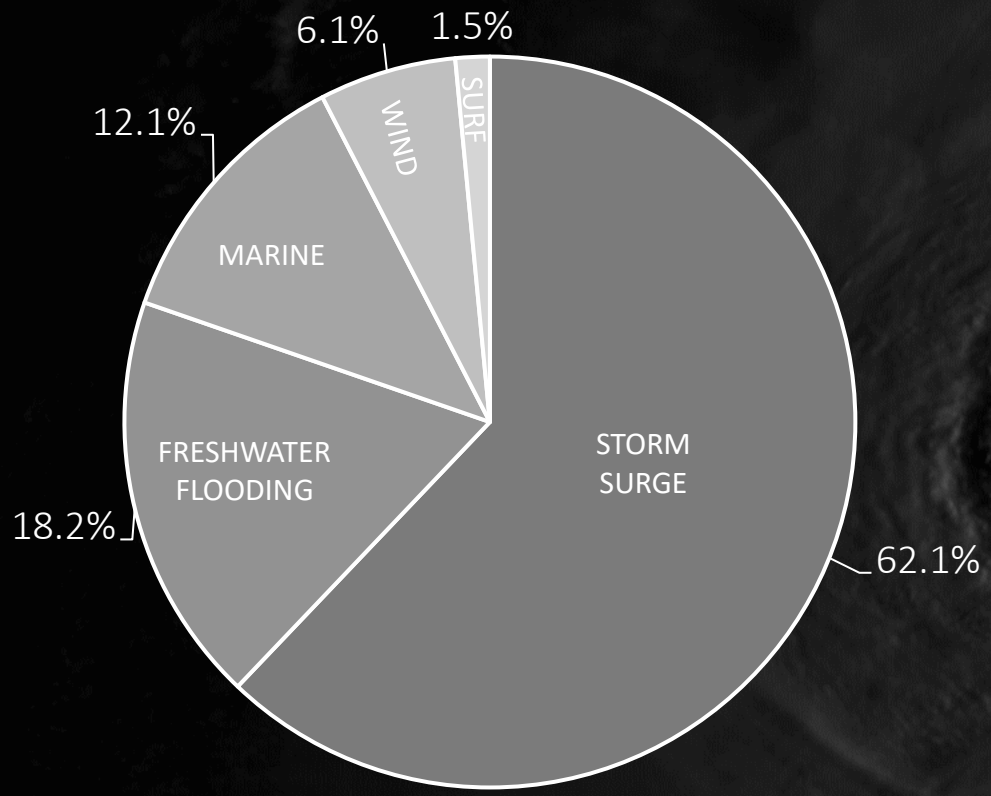
- Storm surge accounts for only 11.3% of direct deaths
- Freshwater now leads tropical hazards with 56.8% of storm related direct deaths
- Wind still a small percentage of storm related deaths with 11.8%



BRENNAN ET AL. 2022

442 – direct fatalities 415 – indirect fatalities

…and then there was Hurricane Ian (2022)



- 41 lives were lost to storm surge, whereby 36 lives were directly lost in Lee County alone
- 15 feet of storm surge [above ground level] inundated Fort Myers Beach, Florida

Storm Surge

Storm Surge vs Storm Tide vs Inundation

STORM SURGE

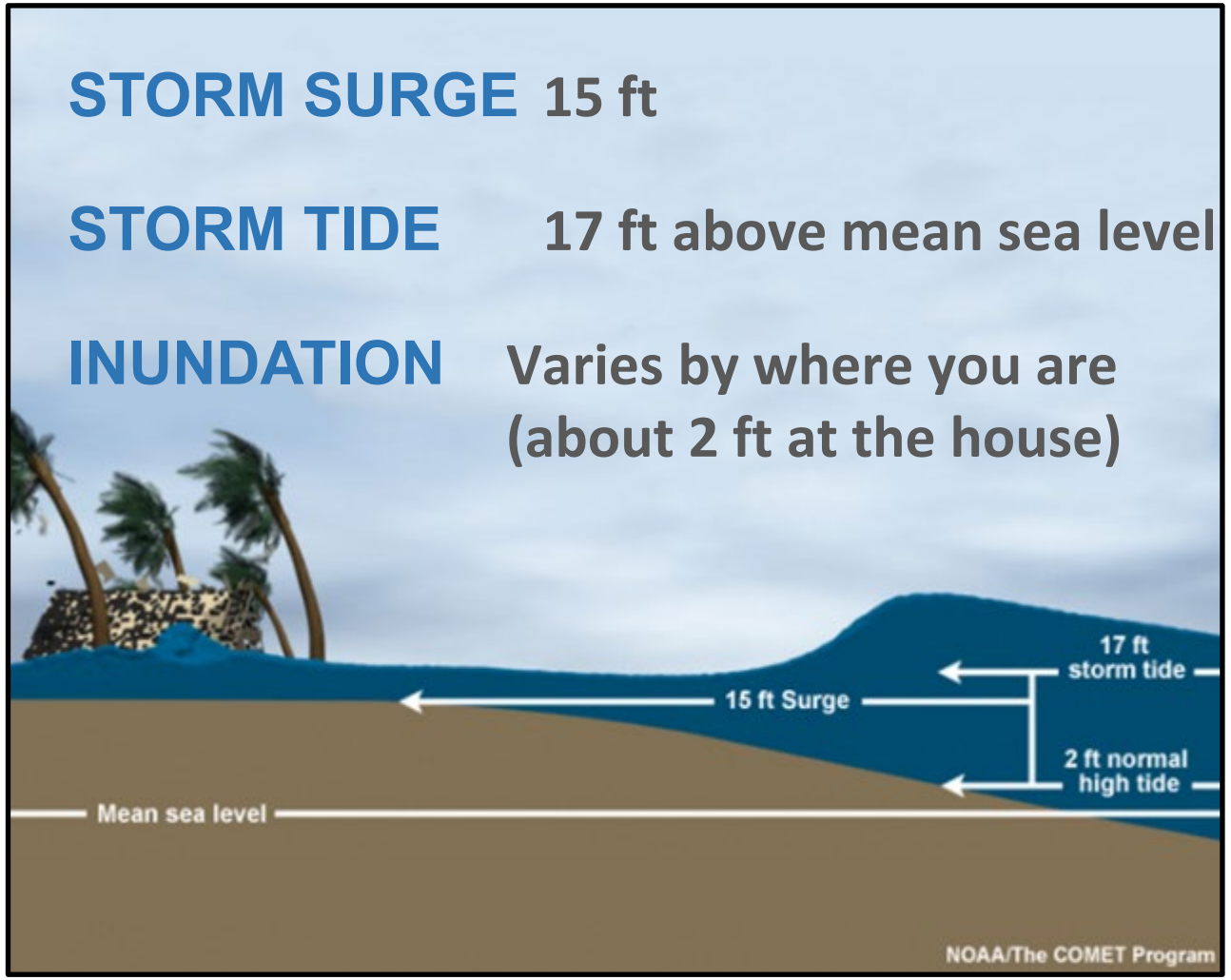
An abnormal rise of water generated by a storm, over and above the predicted astronomical tide.

STORM TIDE

Water level due to the combination of storm surge and the astronomical tide.

INUNDATION

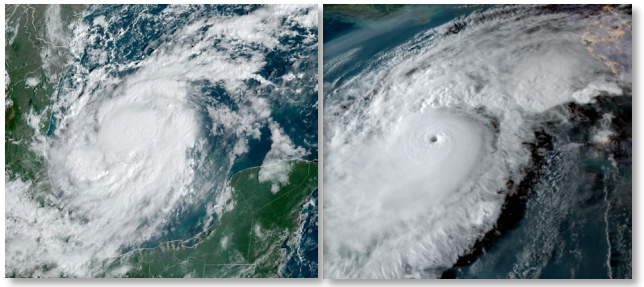
The flooding of normally dry land, resulting from storm tide and possibly other factors.



Factors Affecting Storm Surge

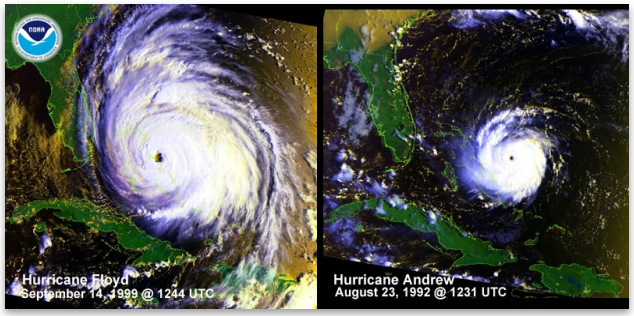
Intensity

Stronger storm = More storm surge



Size (Radius of Maximum Winds)

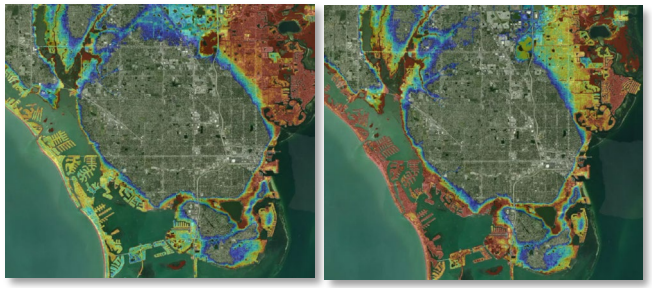
Larger = More storm surge



Forward Speed

Slower storm = Surge farther inland

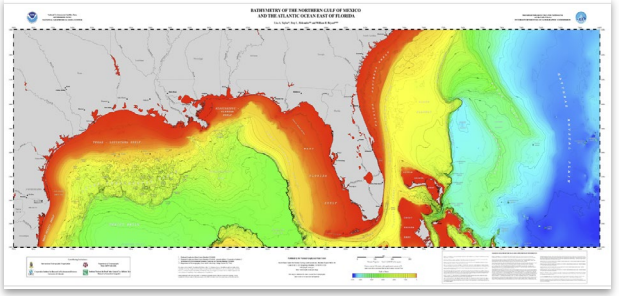
Faster storm = higher peak at coast



Slower Faster

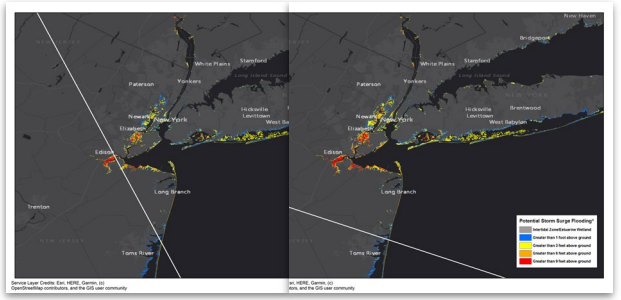
Width and Slope of Shelf (Bathymetry)

Gradual sloping shelf = More storm surge



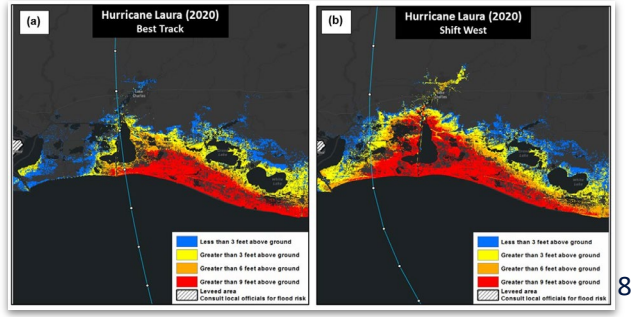
Angle of Approach

Alters focus of storm surge



Landfall Location

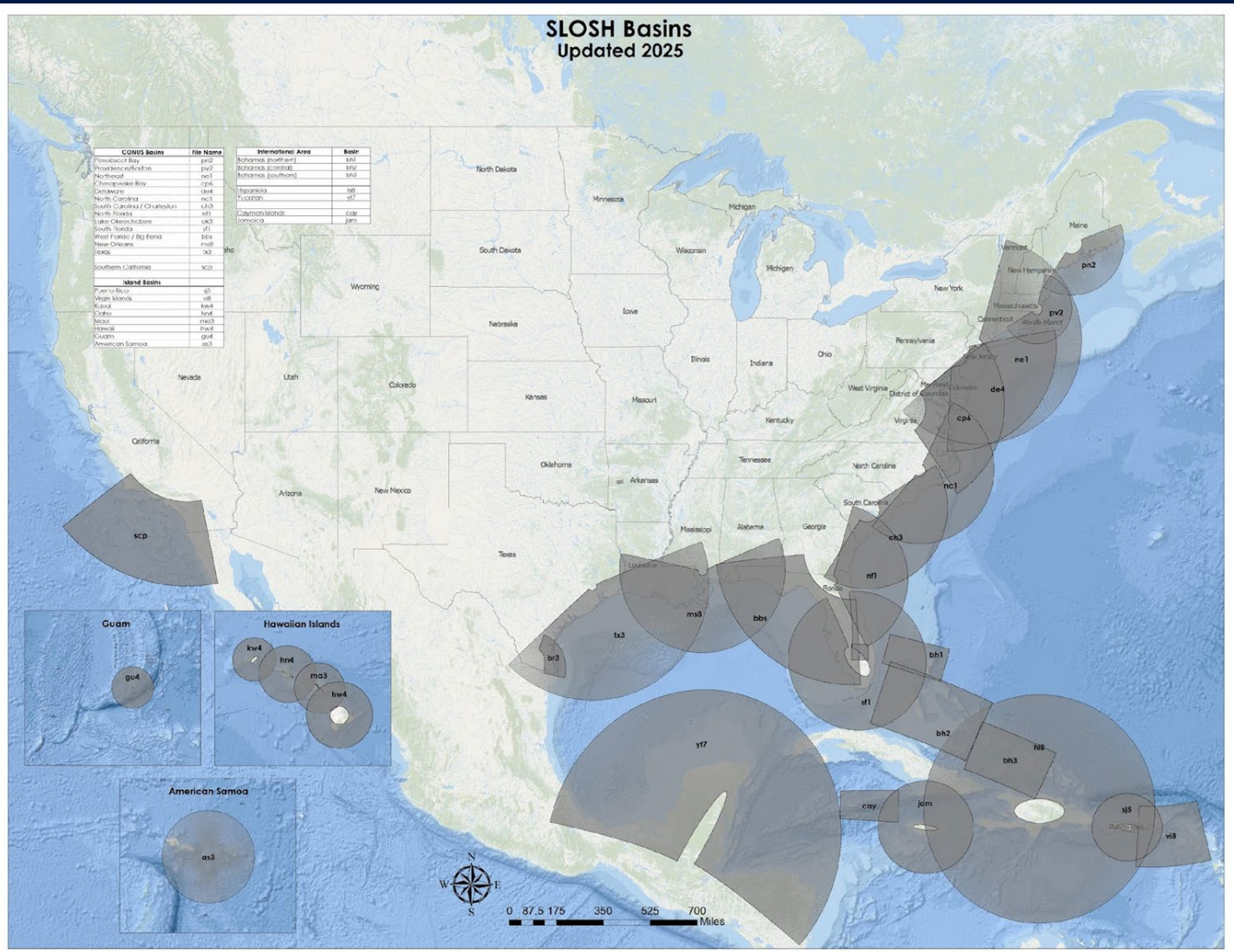
Depends of the exact track of storm



SLOSH Model

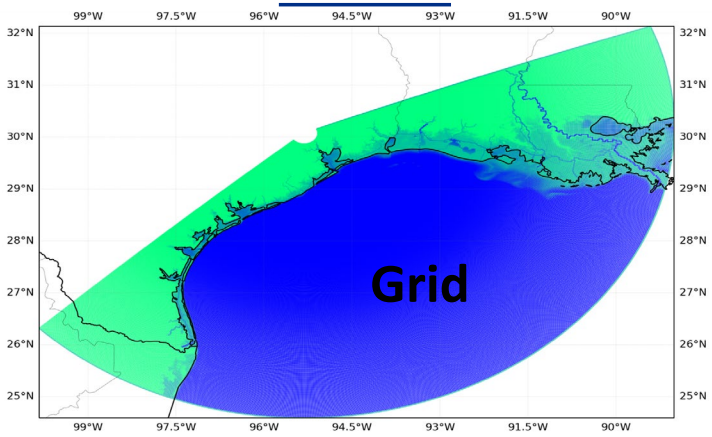
Sea,
Lake, and
Overland
Surges from
Hurricanes

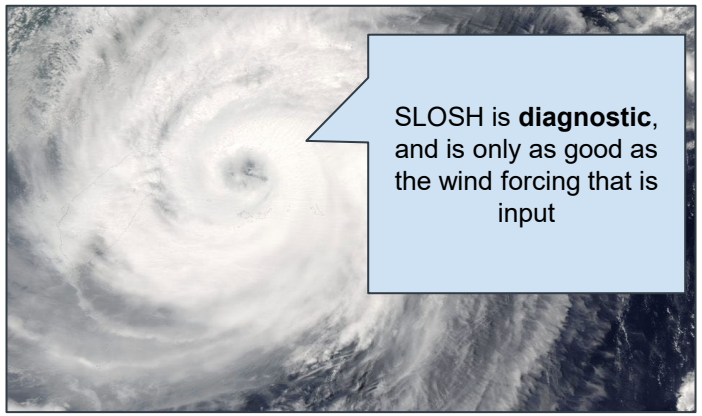
A numerical model used to estimate storm surge heights for historical, hypothetical, or predicted hurricanes



Running the SLOSH Model

INPUTS

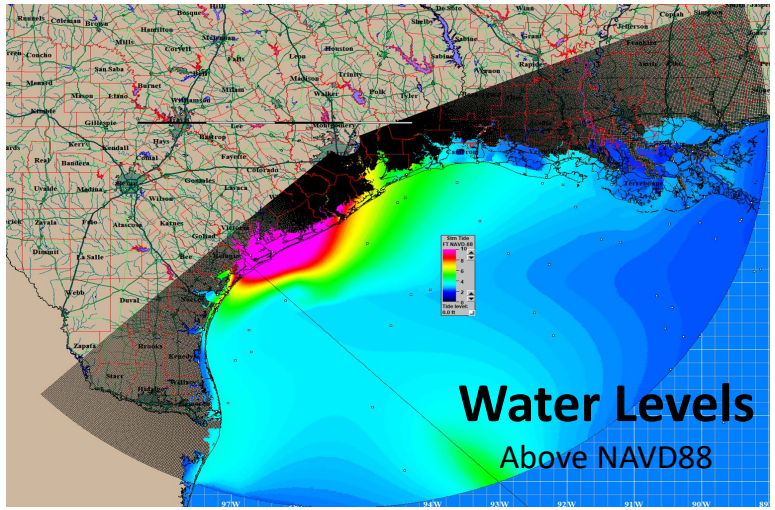




SLOSH MODEL

Sea, Lake, and Overland Surges from Hurricanes

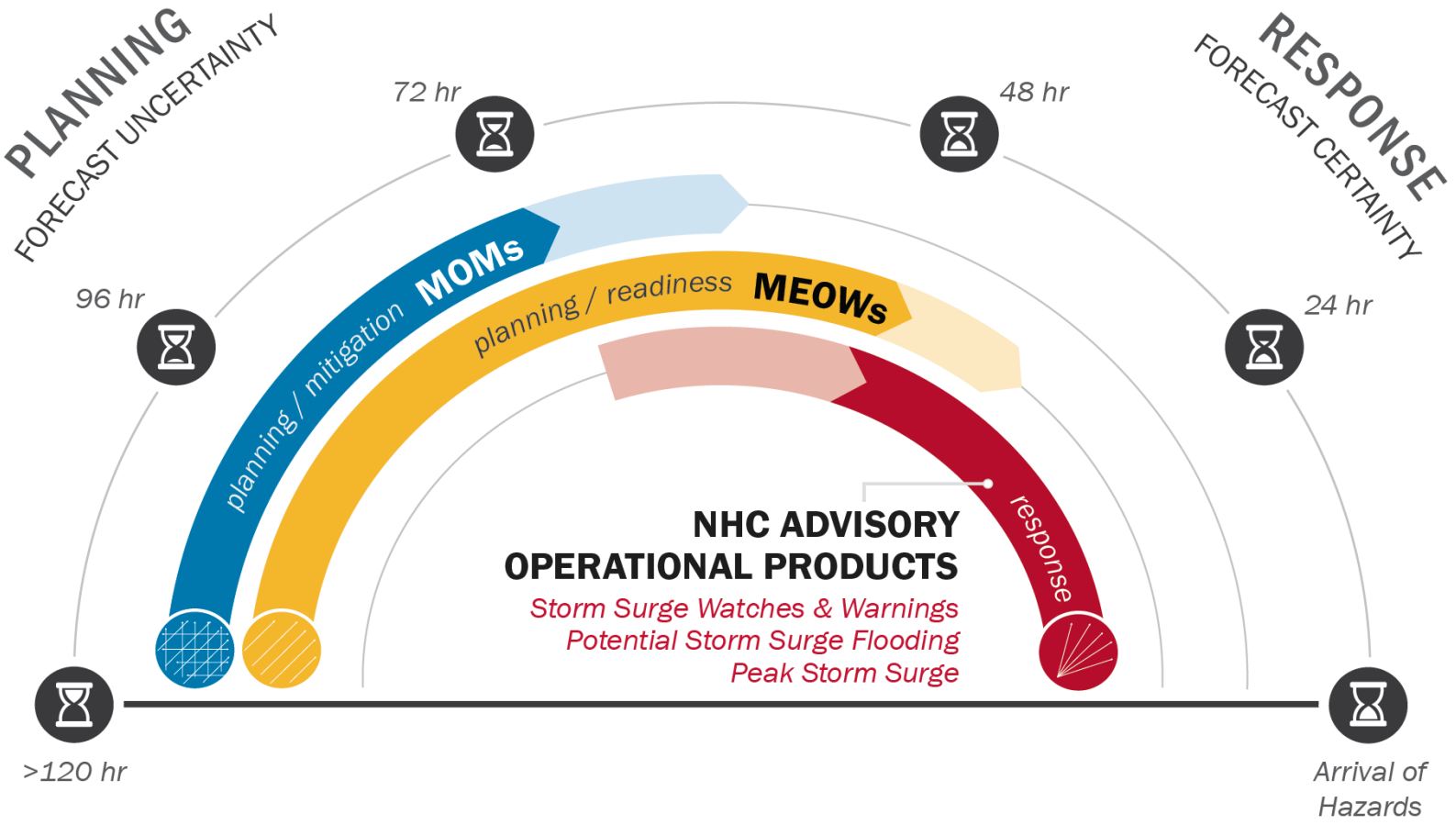
OUTPUT



* Above ground inundation via GIS post-processing

Storm Surge Planning and Response

Storm Surge Risk Tools

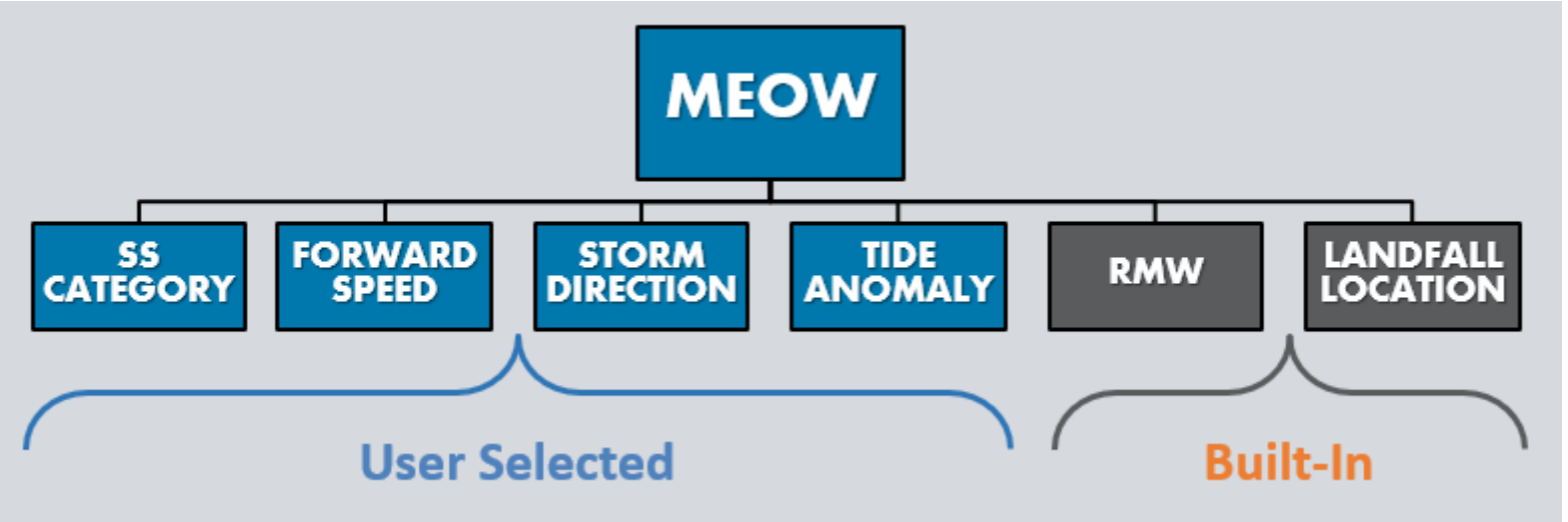


MEOW: Maximum Envelope of Water

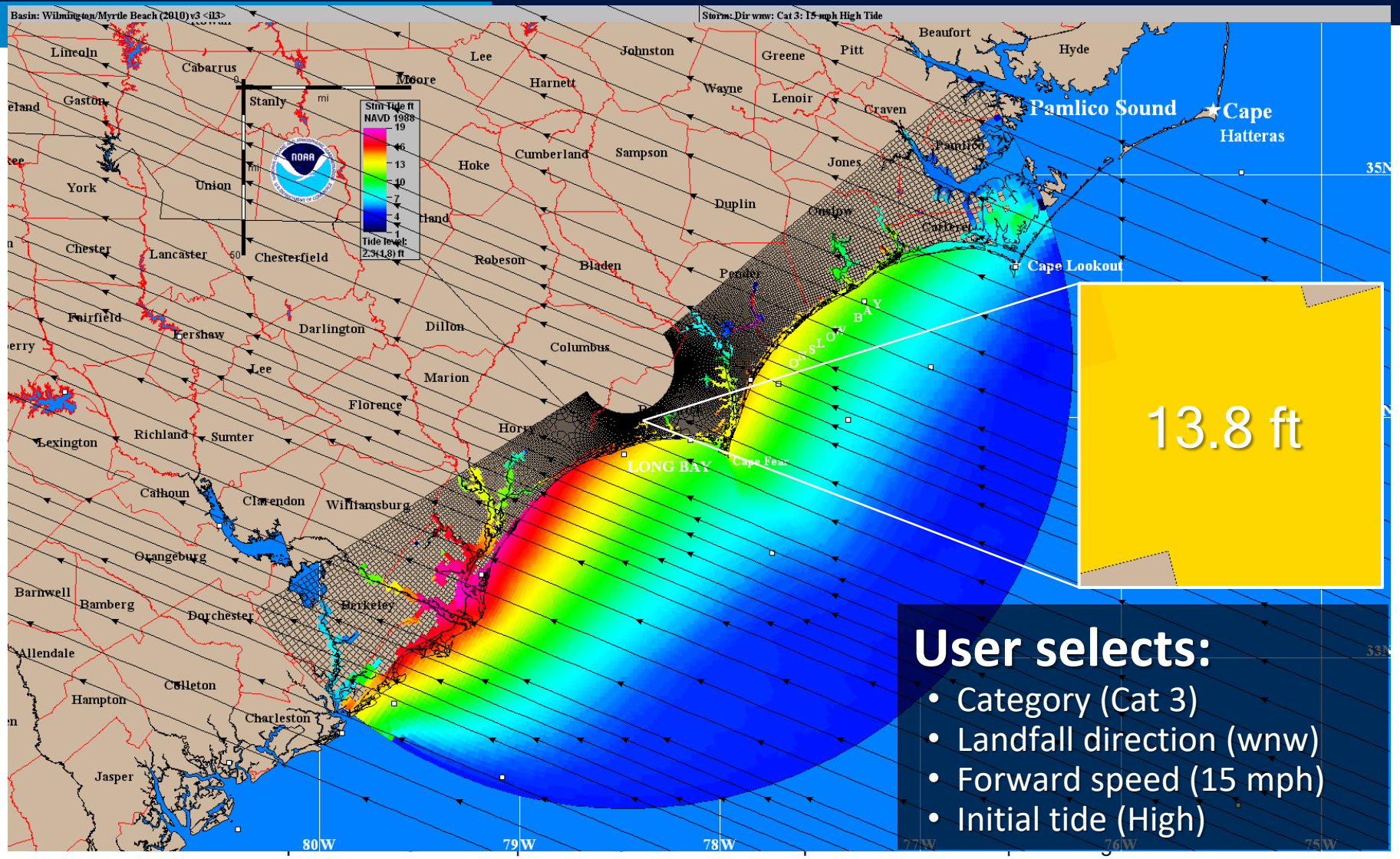
Generated by running 1000's of hypothetical storms through SLOSH

Composite of maximum storm surge for specific storm scenarios given a set of parameters the *user chooses* (by basin)

Used as guidance for planning and operations (before real-time guidance is available)

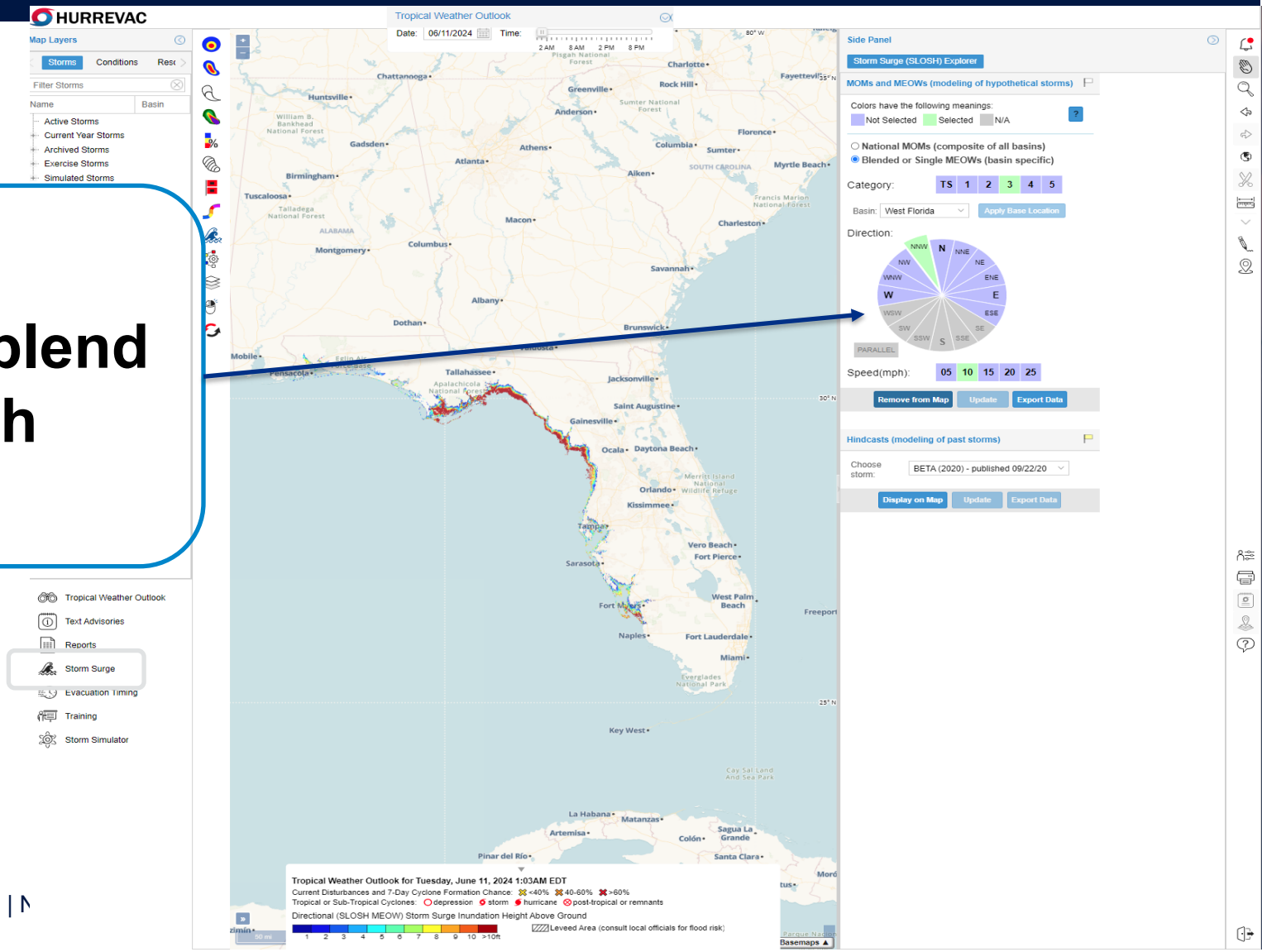


How a MEOW is Made



SURGE EXPLORER IN HURREVAC: MEOW

Viewing MEOWS in HURREVAC, which can blend directions or look at each direction independently

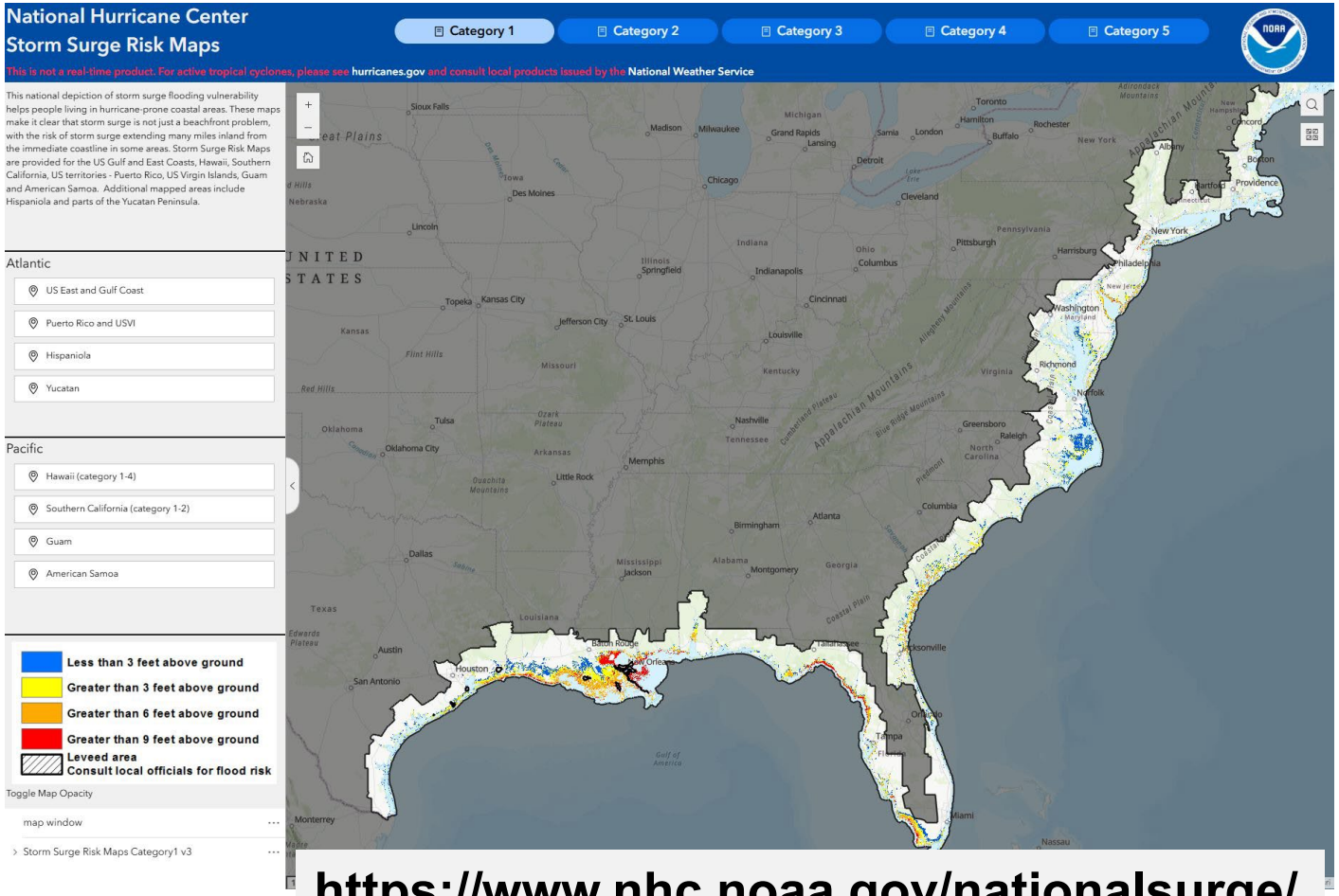


MOMs: Maximum of the Maximums

Worst-case scenario for storm surge at any location for any particular storm of a single category.

Composite of data from hypothetical storms varying in forward speed, angle of approach, size, initial tide, and landfall location.

Used to create Storm Surge Risk Maps: High-resolution inundation maps for effective risk communication and analysis. Used as planning and mitigation tool to evaluate risk to critical facilities



https://www.nhc.noaa.gov/nationalsurge/

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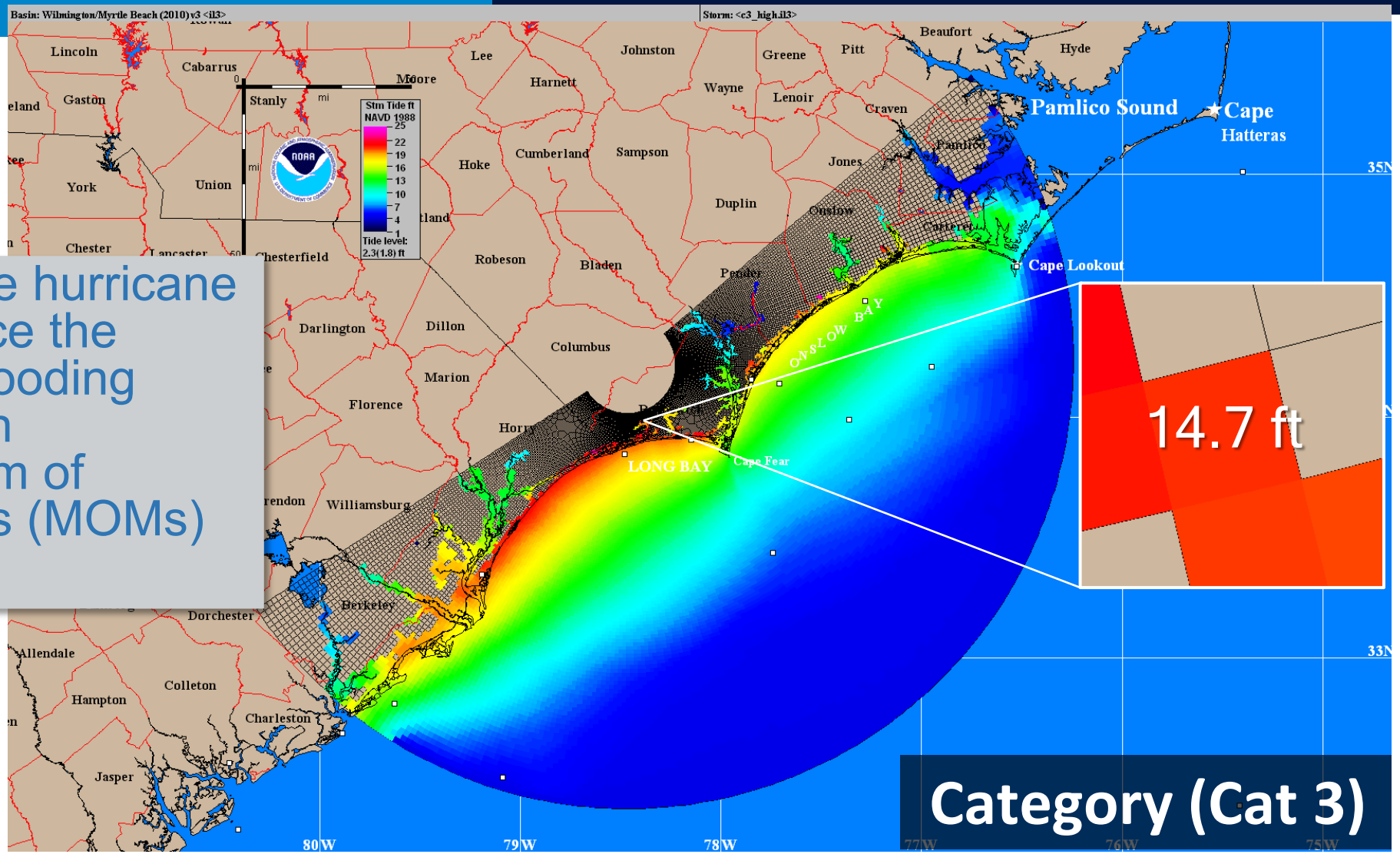
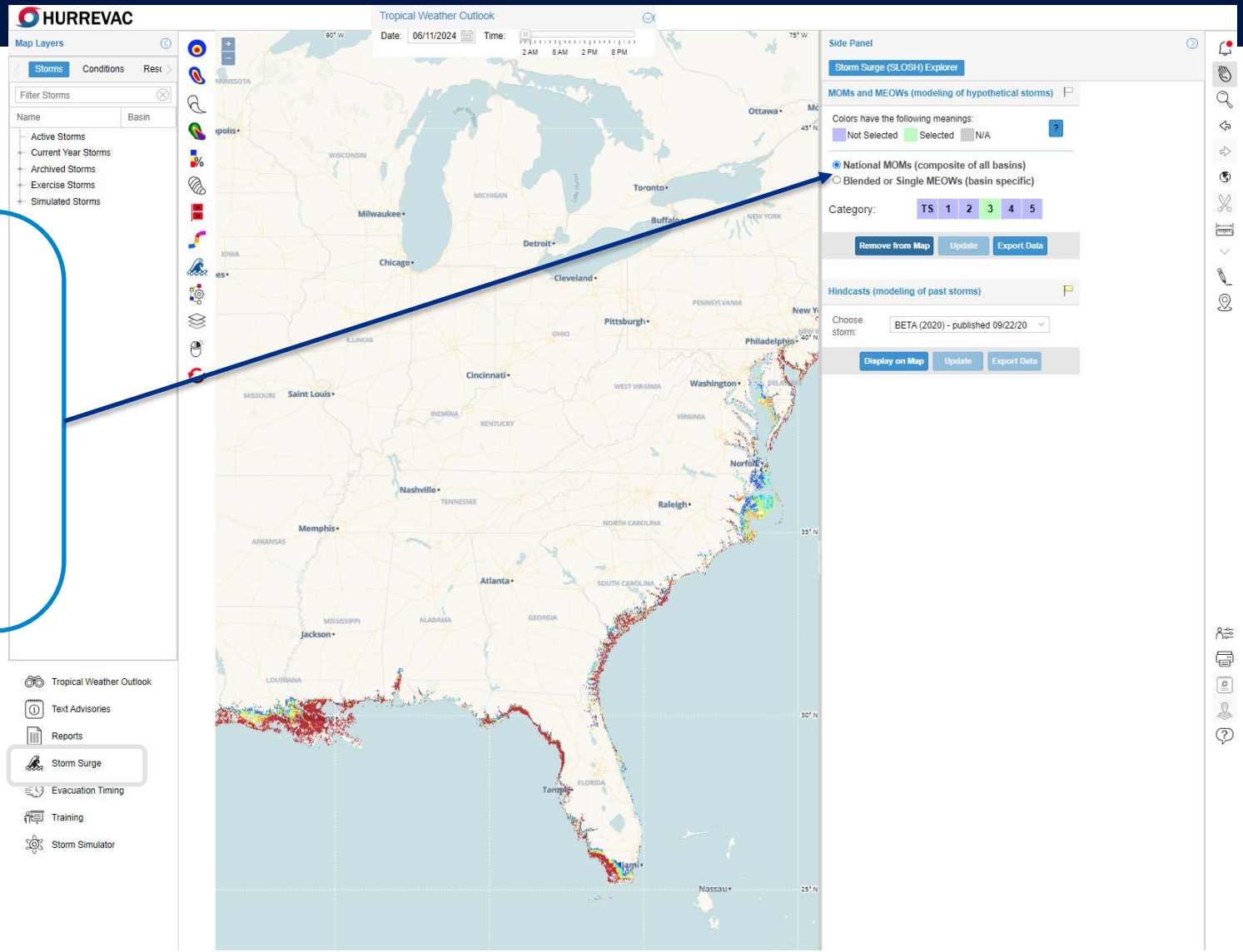


**No single hurricane will produce the regional flooding depicted in a Maximum of Maximums (MOMs)

Category (Cat 3)

SURGE EXPLORER IN HURREVAC: MOM

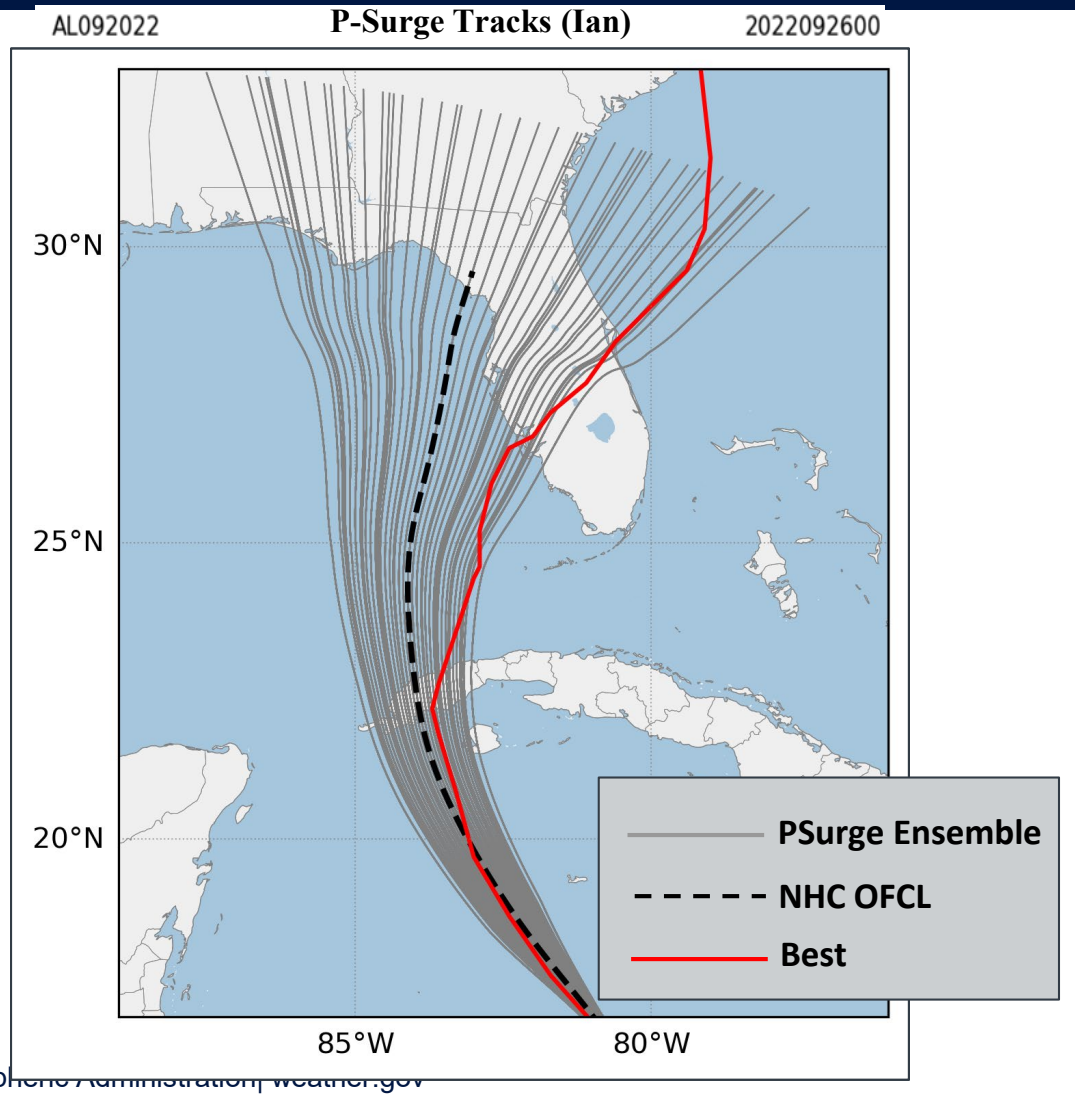
Viewing the National MOM in HURREVAC, where you select the category of storm you want to view



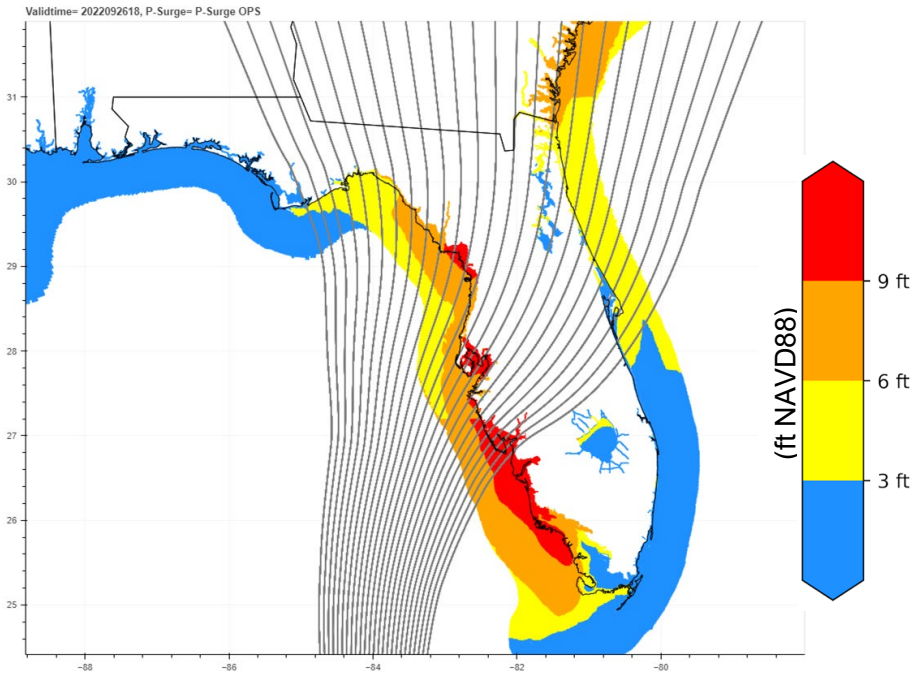
Introduction to P-Surge

Probabilistic Storm Surge (P-Surge)

- Statistical-dynamic forecast system using SLOSH
- **Probabilities** based on the **NHC official Forecast** & 5 year errors in official forecast
- **Accounts for uncertainty in:**
  - **Storm Size (3 member RMW)**
  - **Cross Track (landfall location)**
  - **Along Track (forward speed)**
  - **Intensity (stronger and weaker)**



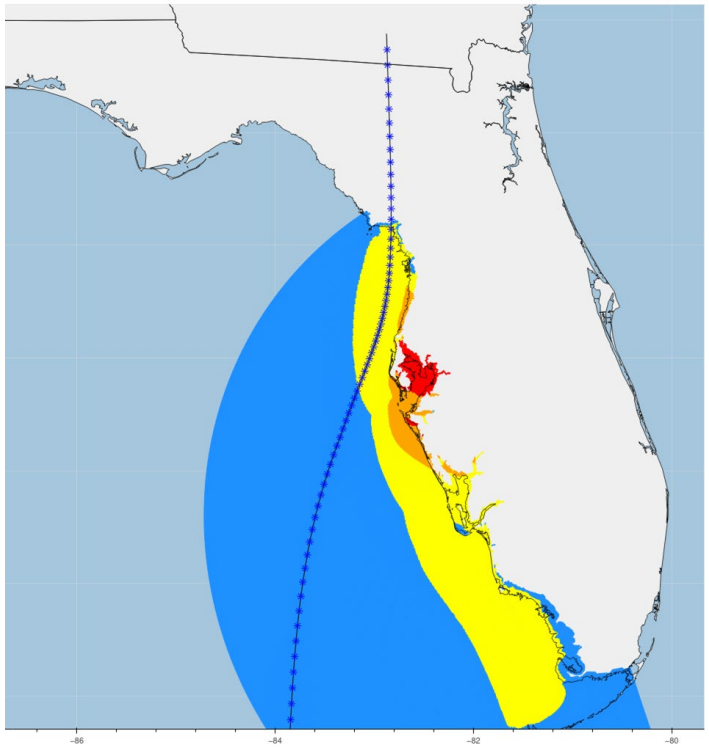
Probabilistic vs Deterministic



Probabilistic

P-Surge, 10% exceedance

'Reasonable Worst Case Scenario'



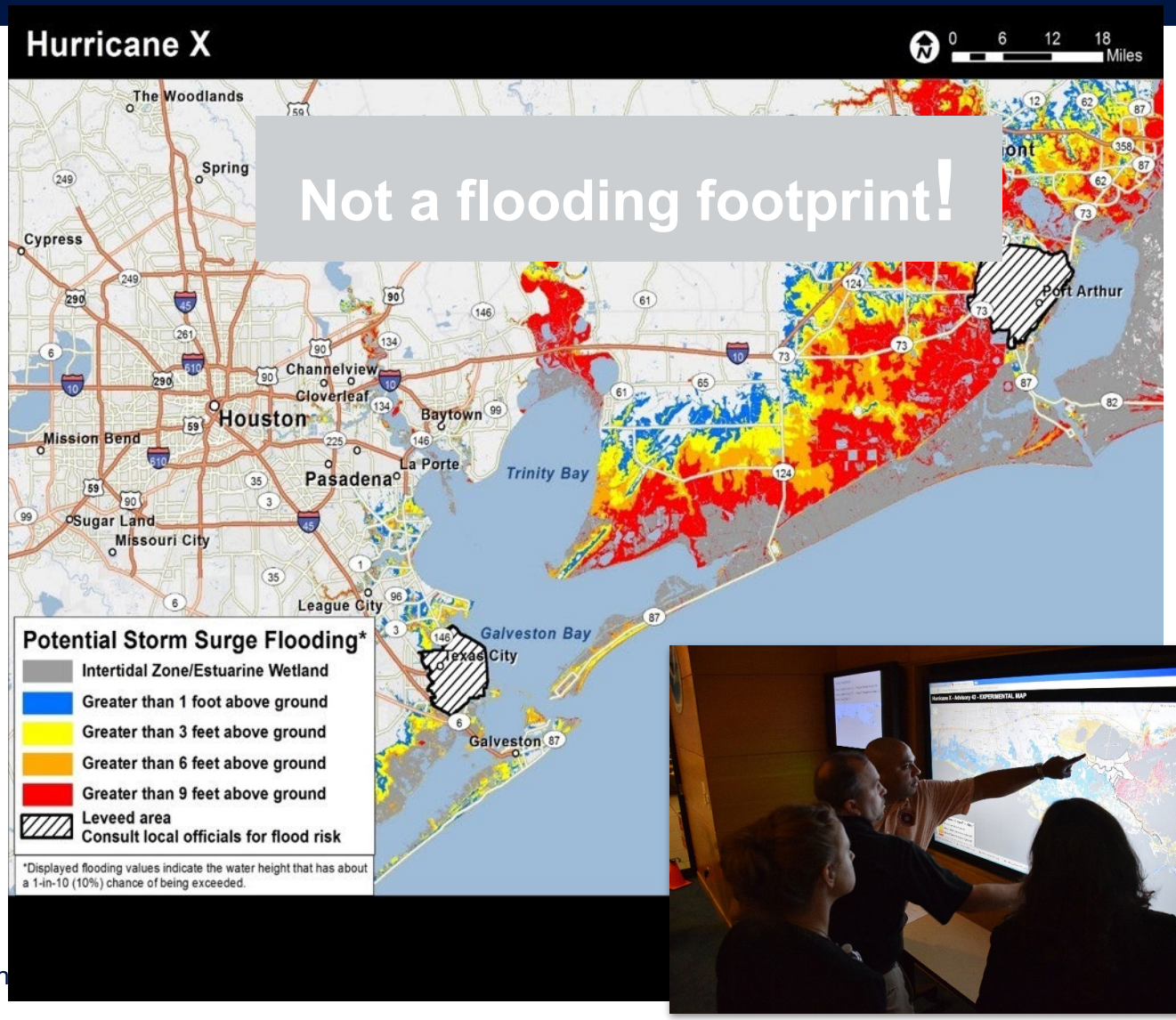
Deterministic

Single-Track Simulations

Potential Storm Surge Flooding Map

INUNDATION MAP

- **Height above ground that the water could reach**
  - Reasonable worst-case scenario for any individual location
  - Values have a 10% chance of being exceeded
- **Issued up to ~72 hours prior to the onset of the hazard**
- **Available ~60-90 minutes after the advisory release**



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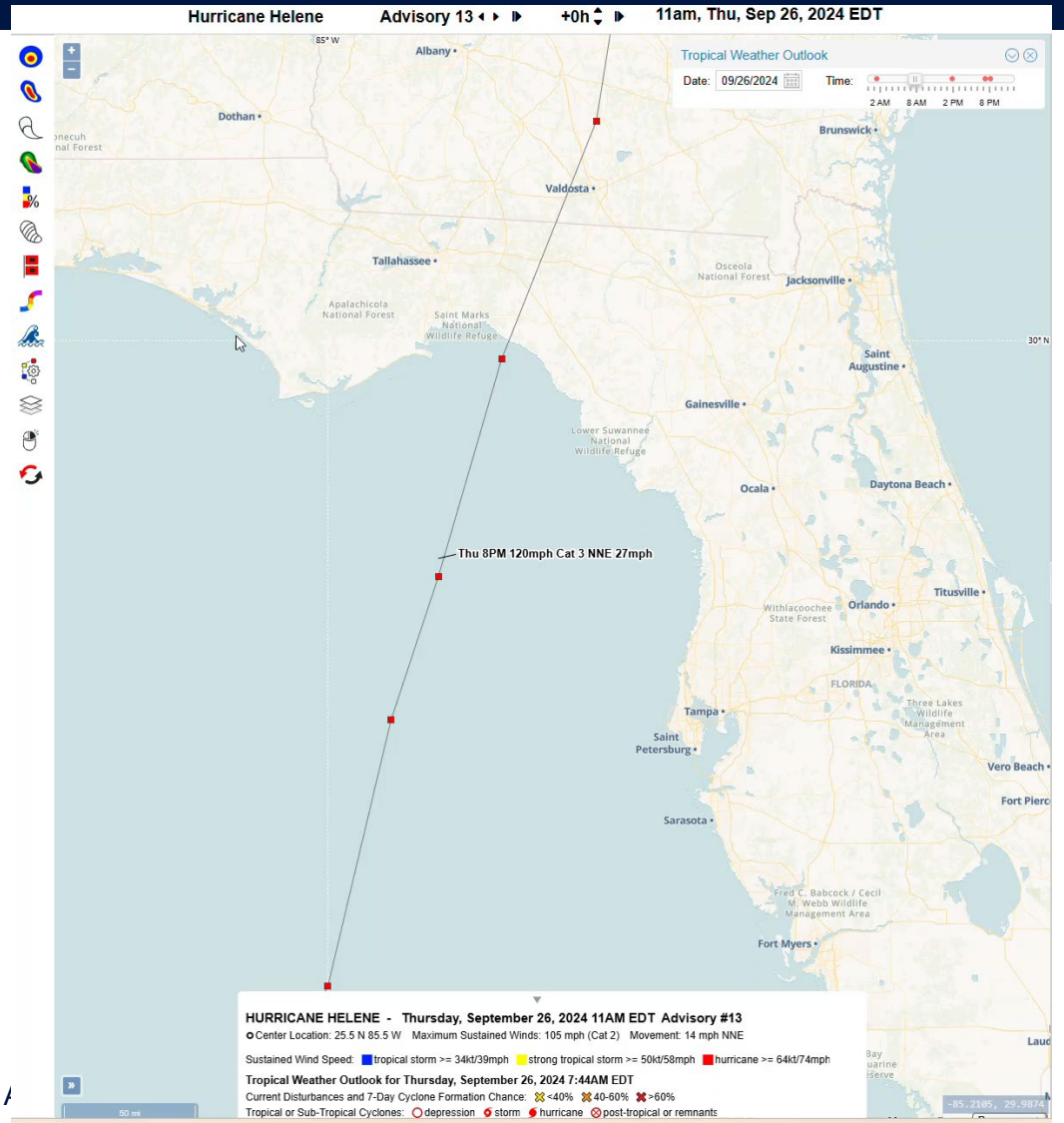


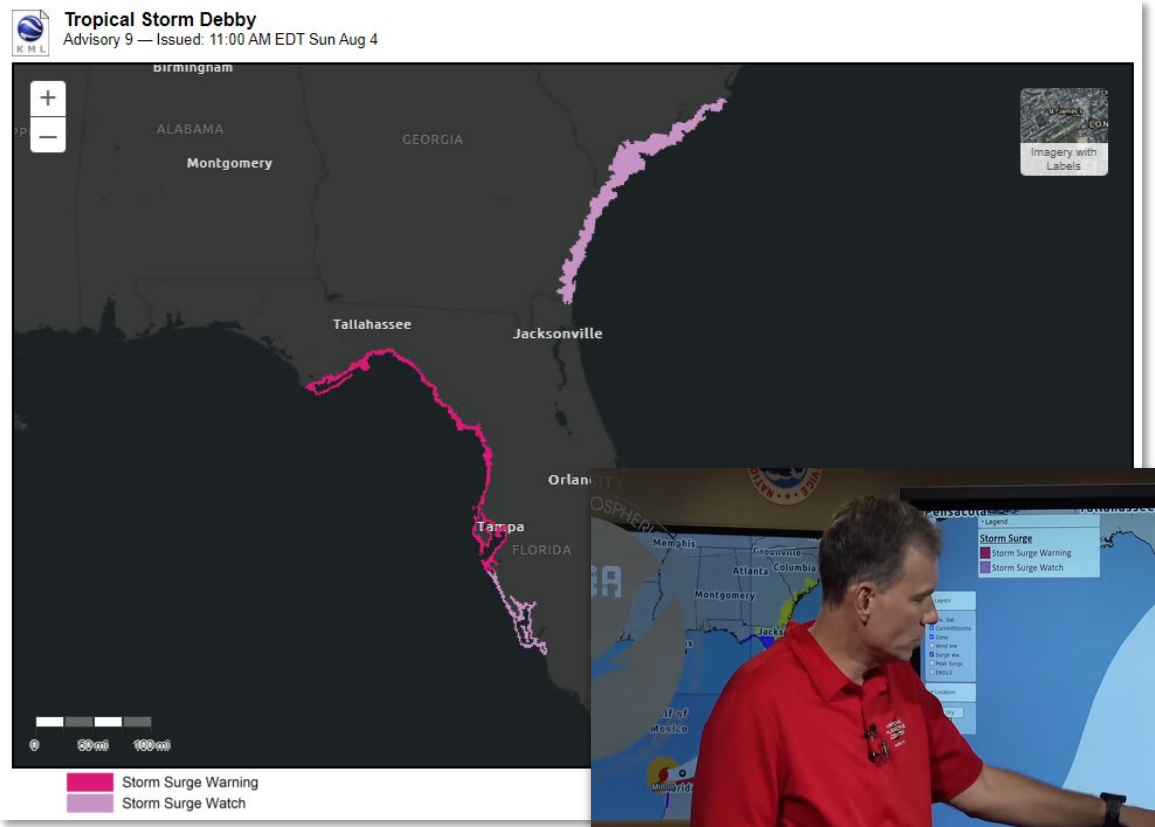
Storm Surge Watch and Warning

Watch vs Warning:

- **Watch**: The POSSIBILITY of life-threatening inundation within 48-hours
- **Warning**: The DANGER of life-threatening inundation generally within 36-hours
  - WEA Phone Alerts sent for **Warning**

Purpose:

- Shows areas at risk for life-threatening storm surge
- For the general public & decision makers to aid evacuation decisions.
  - Example: highlighting coastline vulnerable to life-threatening storm surge during live stream



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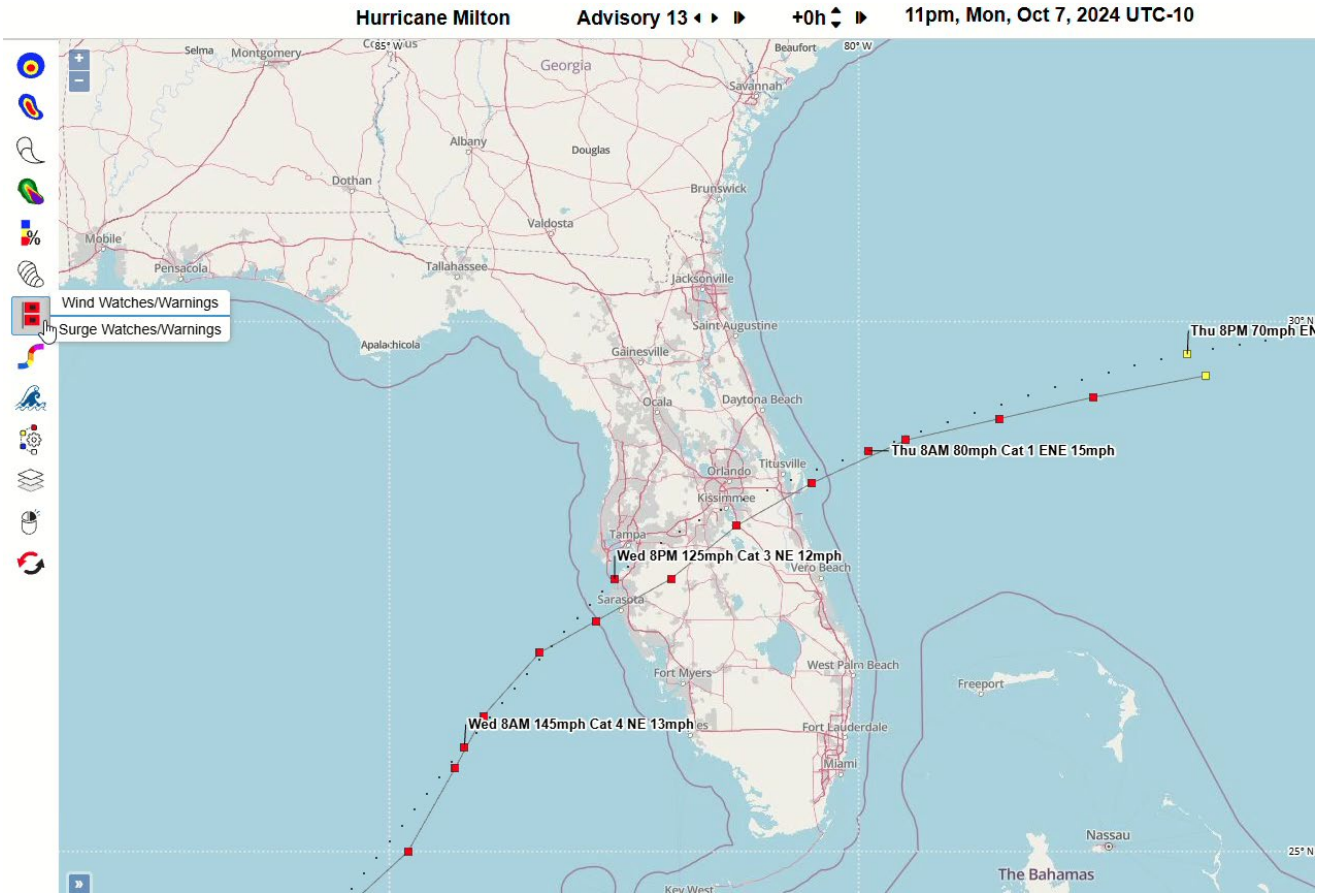
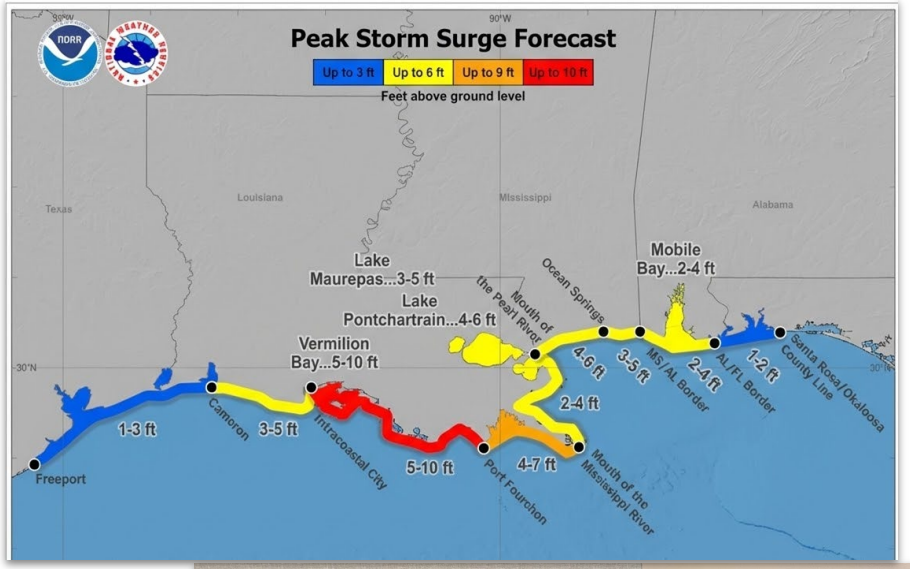
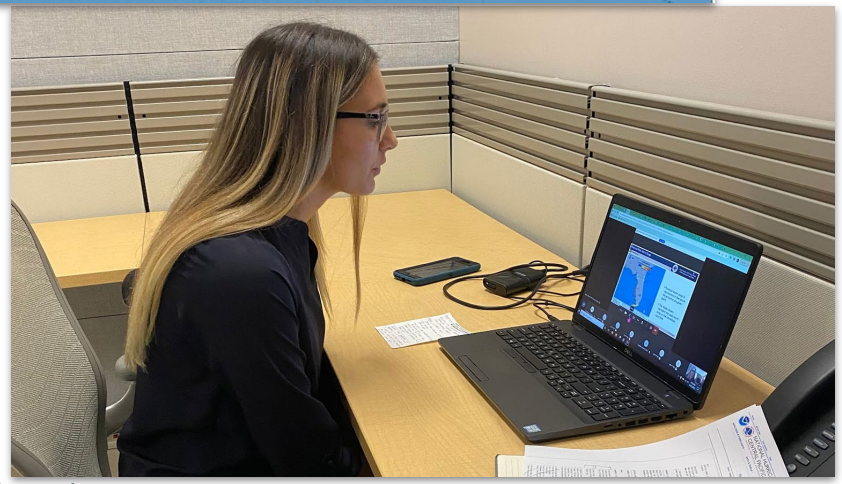


Peak Storm Surge Forecast Graphic

Peak Surge Forecast

- **Forecast for peak inundation along the immediate coast from storm surge and tides within the next 48 hours**
  - Height water could reach above normally dry ground, occurring somewhere between 2 points
  - Not location specific
- **Introduced when Watch/Warning is in effect**
- **May differ from potential storm surge flooding map**





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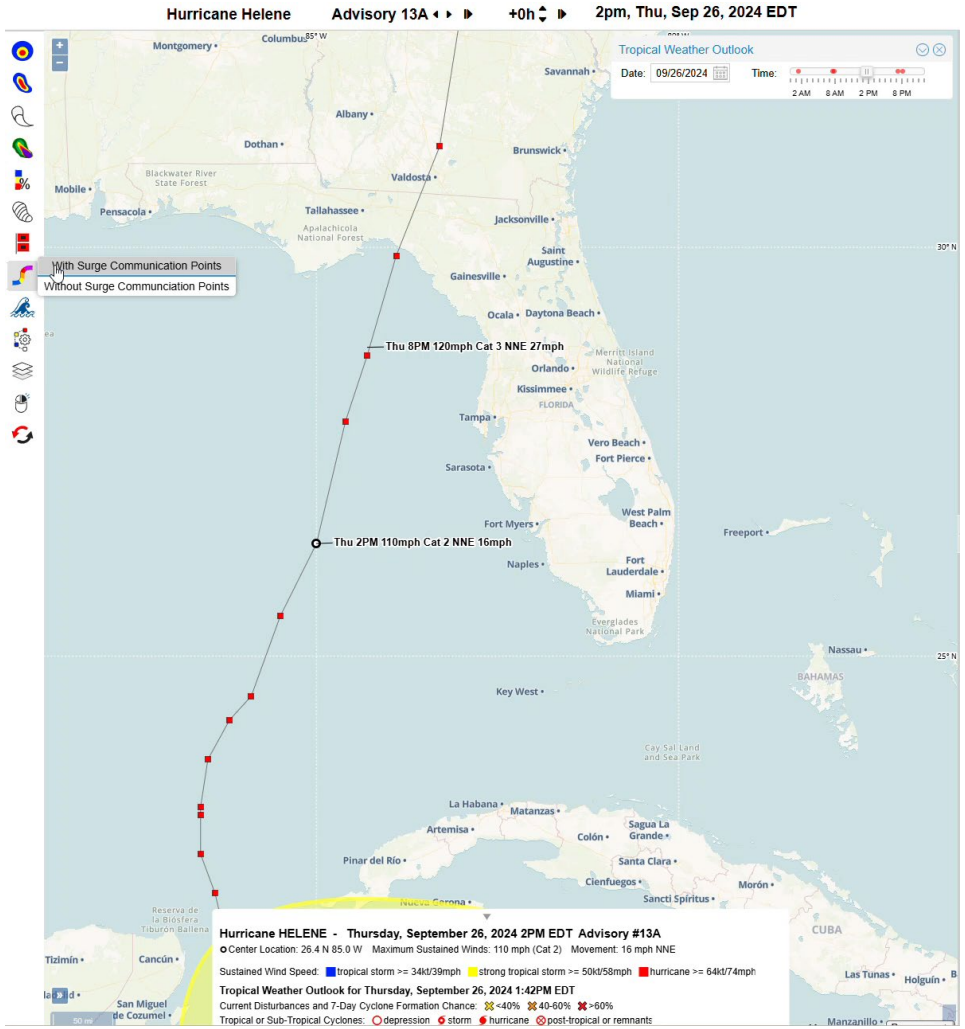
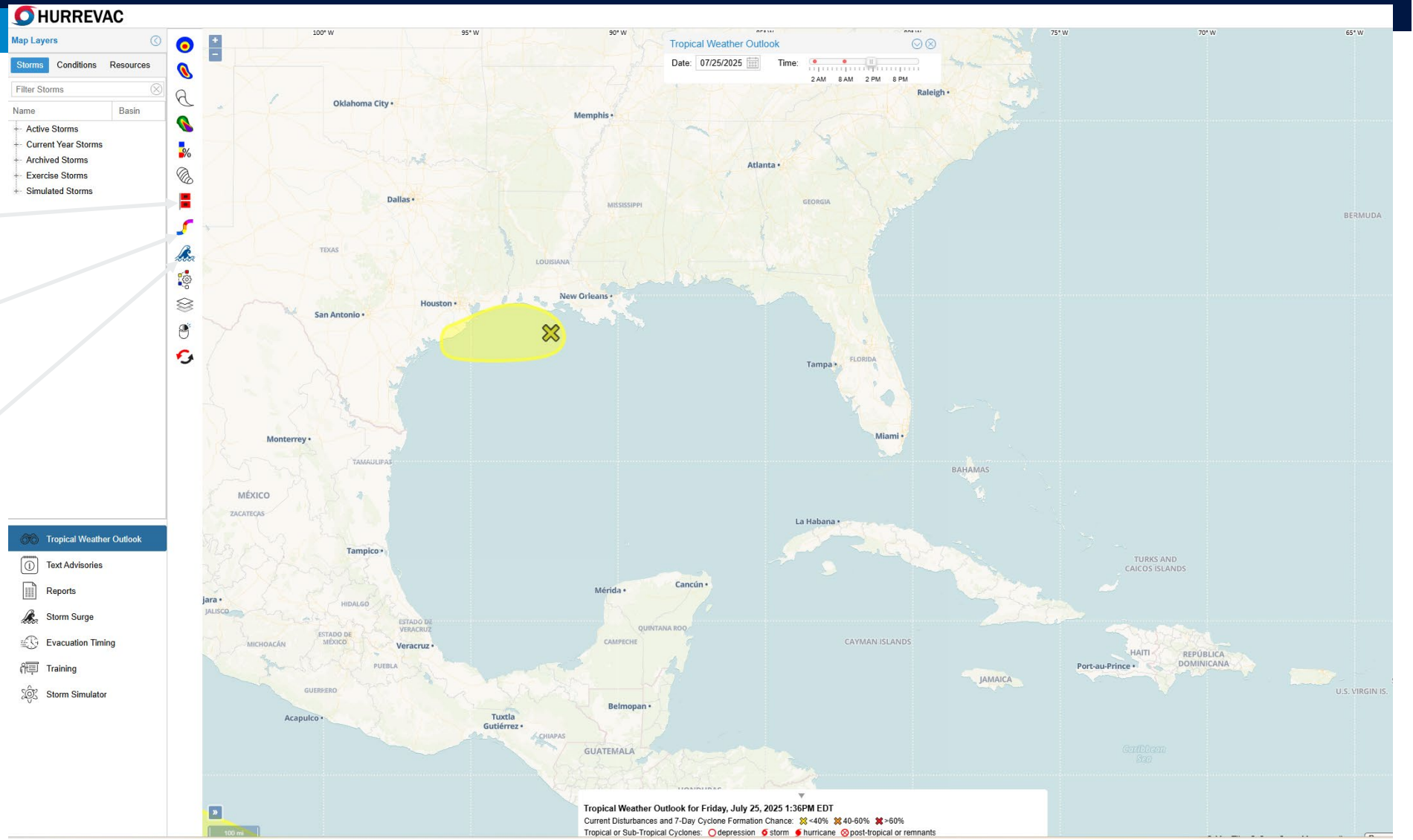


Real Time Products in Hurrevac

- Watches and Warnings
- Peak Storm Surge Graphic
- Potential Storm Surge Flooding Map



Questions?

Cassandra Mora

2026 Hurrevac webinar – Storm Surge

Storm Surge Unit - National Hurricane Center

Cassandra.mora@noaa.gov

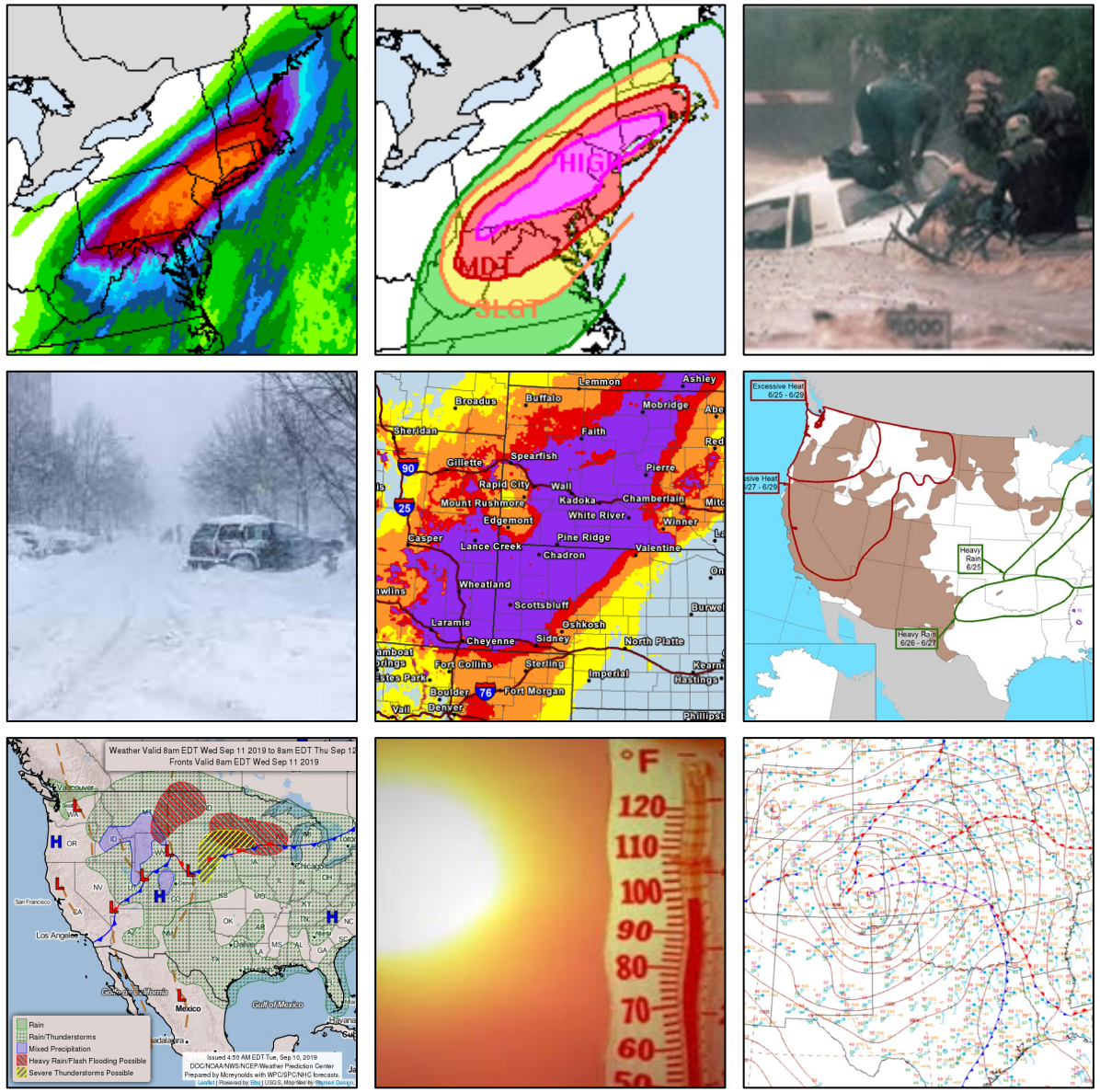
www.nhc.noaa.gov/surge/

NHC_Surge

Tropical Cyclone Rainfall

Owen Shieh, Ph.D.
Warning Coordination Meteorologist

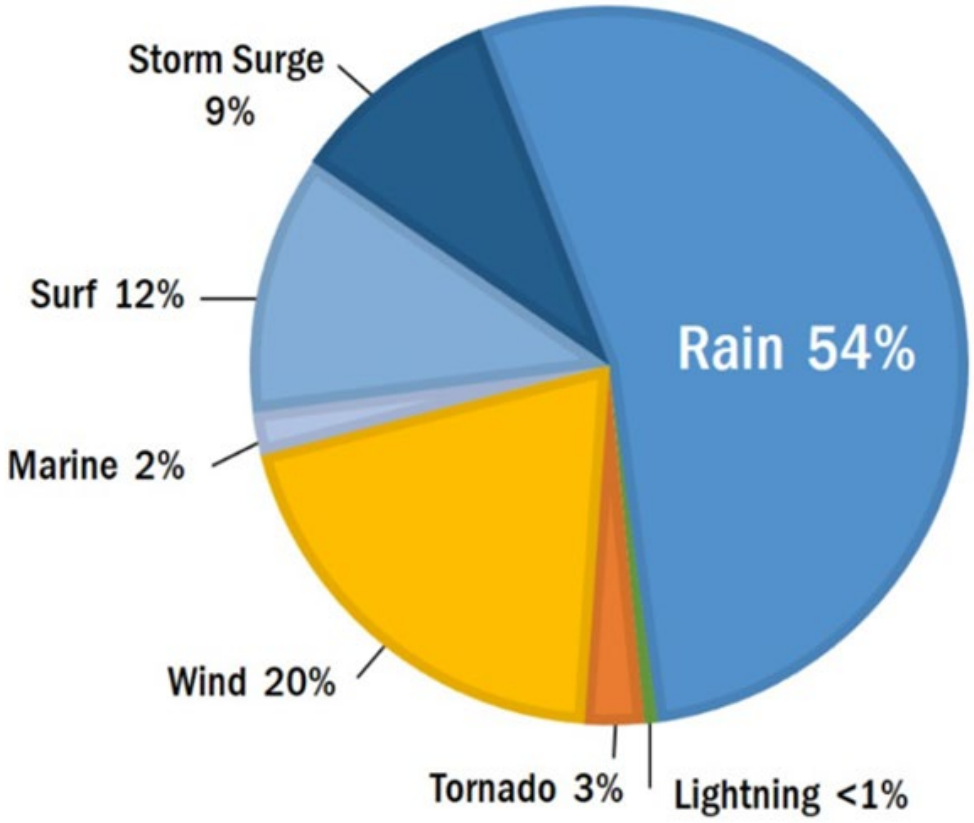
NWS Weather Prediction Center
College Park, MD



WPC: What do we do?

- **Short answer: a lot!**
- Precipitation forecasting expertise including rainfall and snow/ice
- Growing role in extreme temperatures, from heat to cold
- Foundation of the national weather story
- Continuing the 150+ year legacy of surface weather map analysis
- National Hurricane Center backup

U.S. Direct Tropical Cyclone Fatalities (2013-2024)



Since 2013, most fatalities have been due to **drowning due to freshwater flooding (rainfall).** Helene was the deadliest hurricane to affect the mainland U.S. since Katrina and a majority of those direct fatalities were due to freshwater flooding.

“An almost absurdly simple concept”

The heaviest rain falls where it rains hardest for the longest time.

(Paraphrase of Doswell, 1996)

Rainfall rate, or intensity

Related to the magnitude of…

- Forcing
- Moisture
- Instability

Rainfall duration

Related to the…

- Persistence of forcing
- Areal extent of rainfall
- Storm motions
- Backbuilding potential

The *duration aspect* makes this a tough forecasting challenge!

With most severe weather (tornadoes, hail, wind) the event is instantaneous. However with heavy rain, not only do we have to forecast the potential for instantaneous heavy rates, but also how long they will last. There’s a big difference between 3” per hour rates lasting fifteen minutes (0.75” total) or two hours (6” total)!

Key Factors that Affect TC Rainfall

1 **Movement**

Slow motion can lead to more rainfall. Storm track determines location of the rain footprint and heaviest rainfall.

2 **Storm Size**

Larger storm will lead to a greater area affected. For same forward motion, larger storm will produce more rainfall.

3 **Topography**

Enhances rainfall in upslope areas, decreases past the spine of mountains. Upslope depends on storm location.

4 **Moisture**

Increased moisture can increase rainfall. Entrainment of dry air can redistribute or reduce rainfall.

5 **Instability**

Greater instability will tend to support higher rainfall rates.

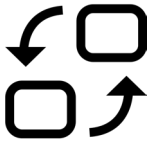
6 **Diurnal Cycle**

Heaviest rainfall will tend to occur near storm center overnight, and outer band rainfall favored during the daytime.

7 **Vertical Wind Shear**

In general, the heaviest rainfall will tend to be concentrated downshear of the storm center.

8 **Interactions**

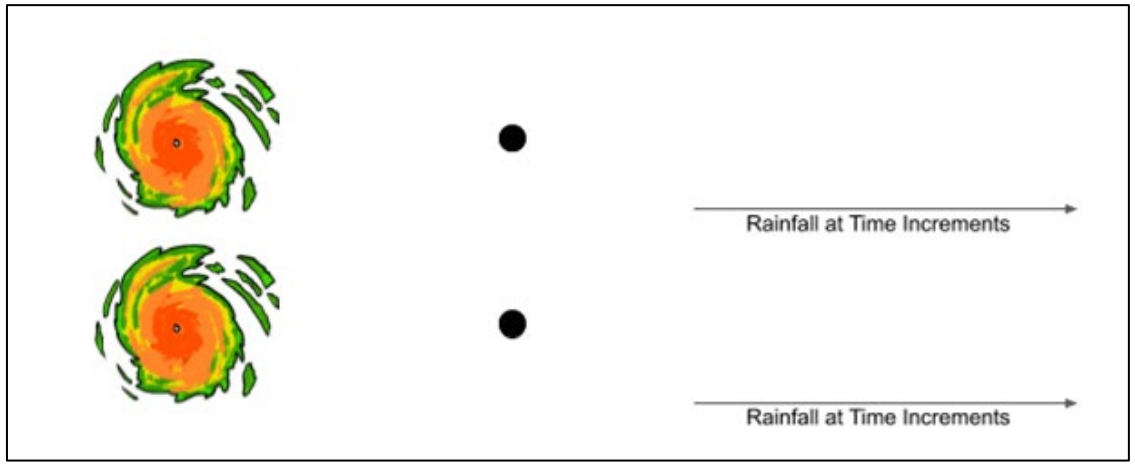


Interactions with troughs, fronts, and jets, and extratropical transition can greatly modify rainfall distribution

Key Factors that Affect TC Rainfall

The Speed Factor

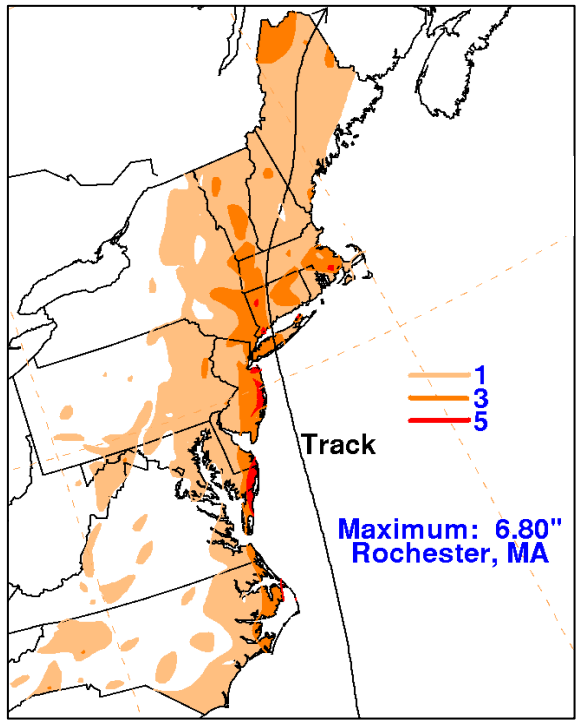
<u>Slow-moving tropical cyclones</u> that create longer duration opportunities for **repetitive, high-intensity rainfall**



Example for similar track

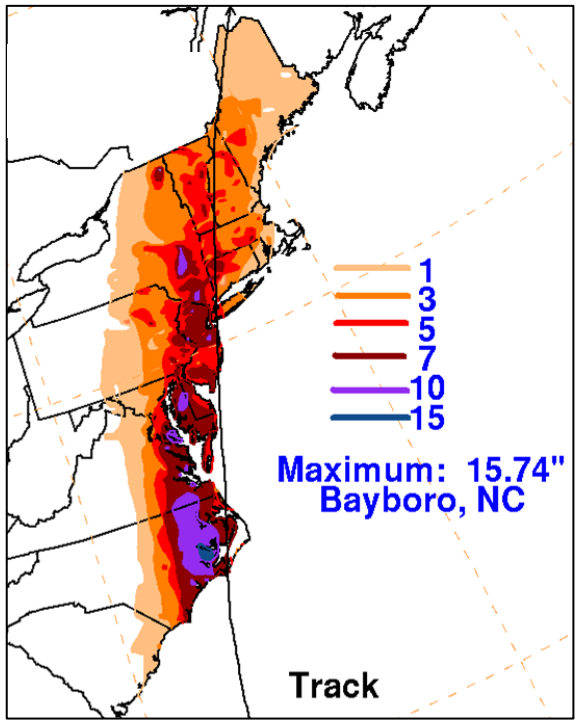
Belle (1976)

Forward speed near NJ:
26 MPH or ~70th percentile



Irene (2011)

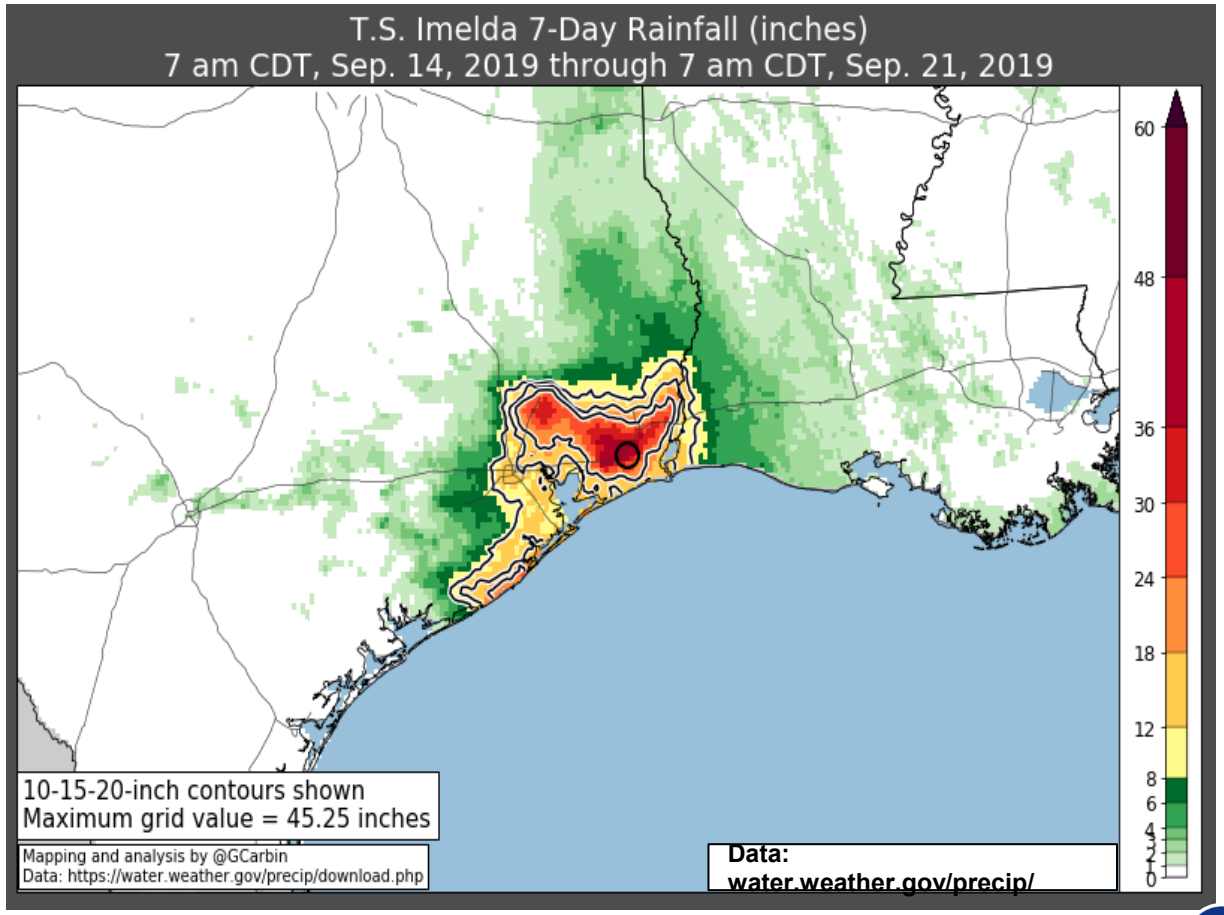
Forward speed near NJ:
18 MPH or ~20th percentile

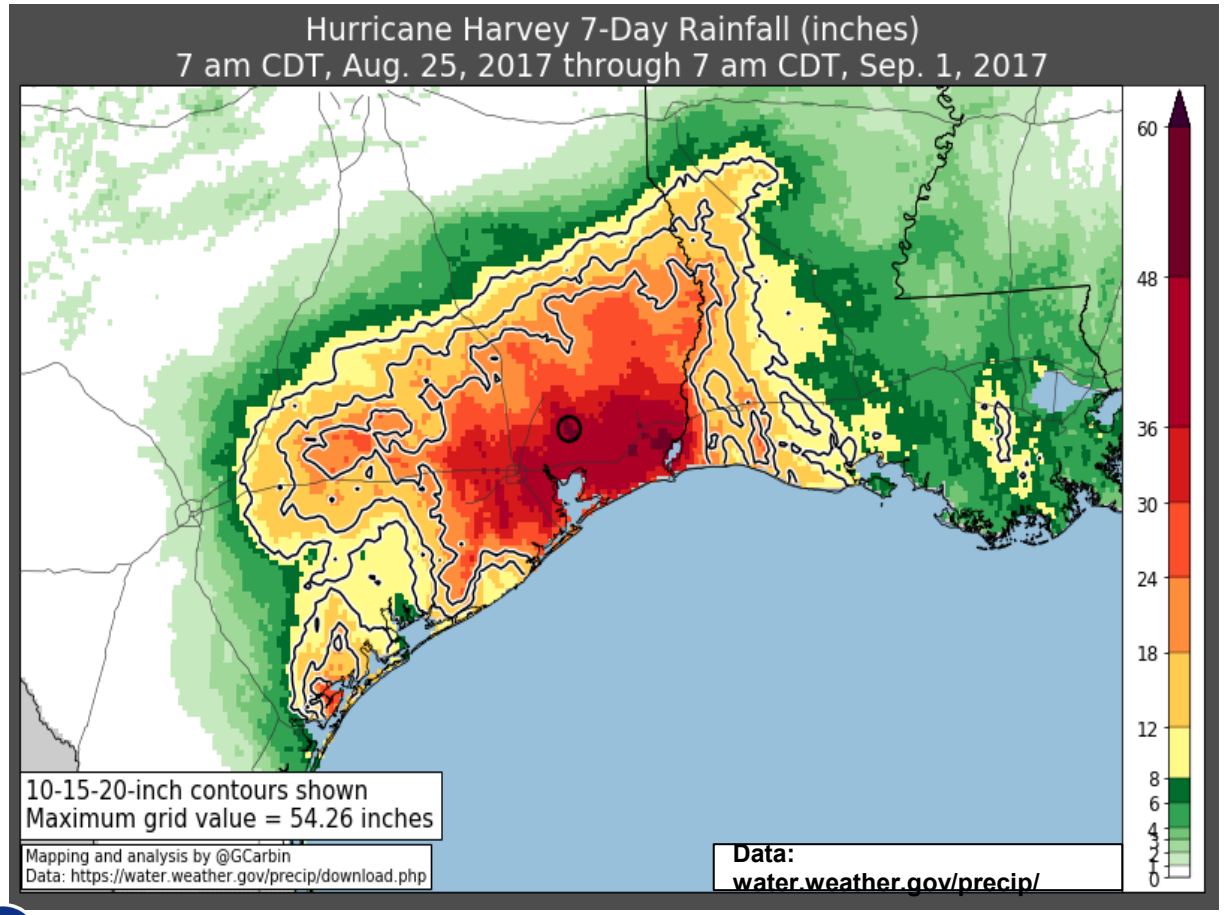


Key Factors that Affect TC Rainfall

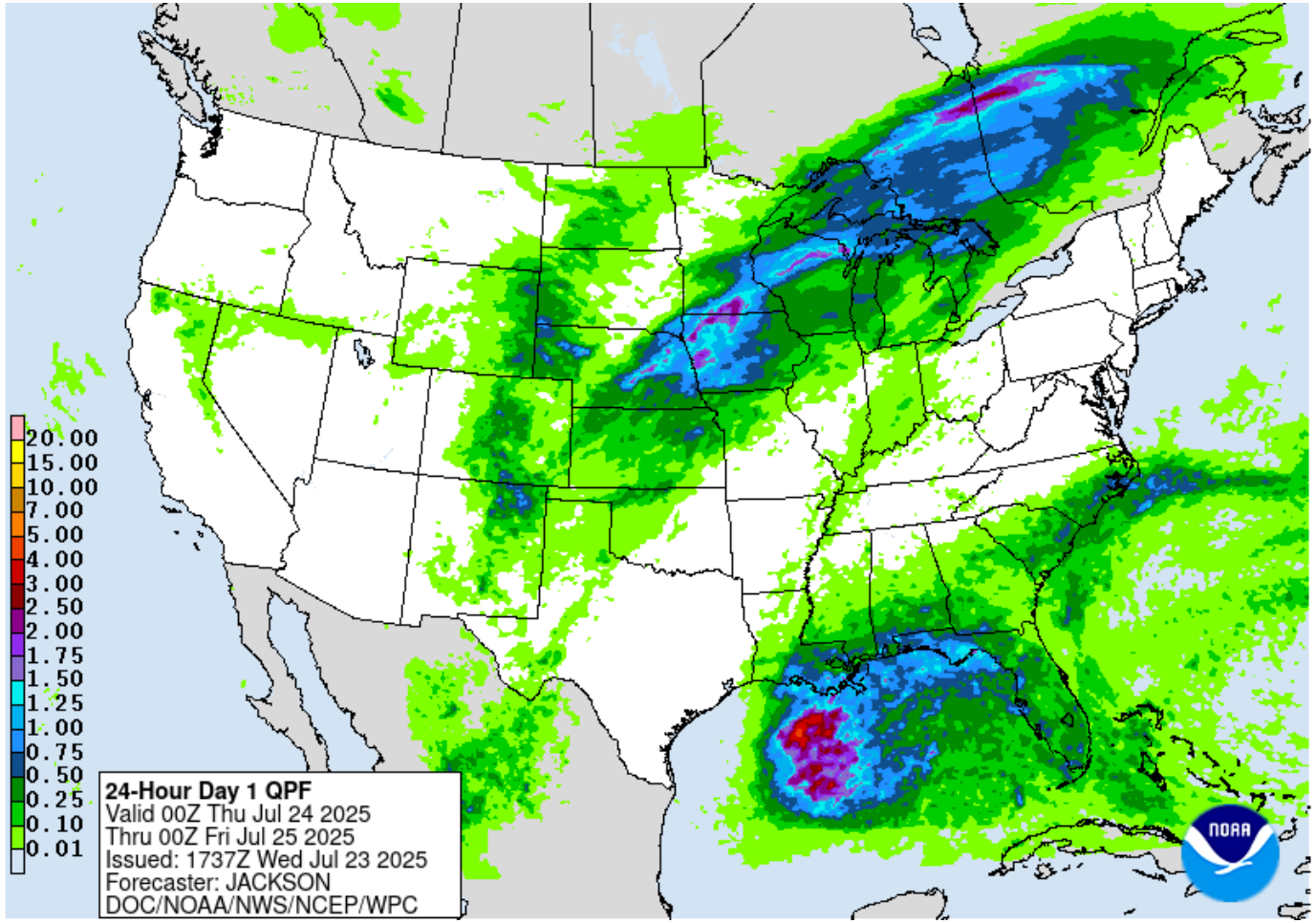
The Size Factor

Harvey and Imelda both moved at walking speeds in Texas, produced rainfall maxima of several feet, but Harvey was a ***MUCH bigger storm*** so extreme rainfall occurred at a much bigger scale.



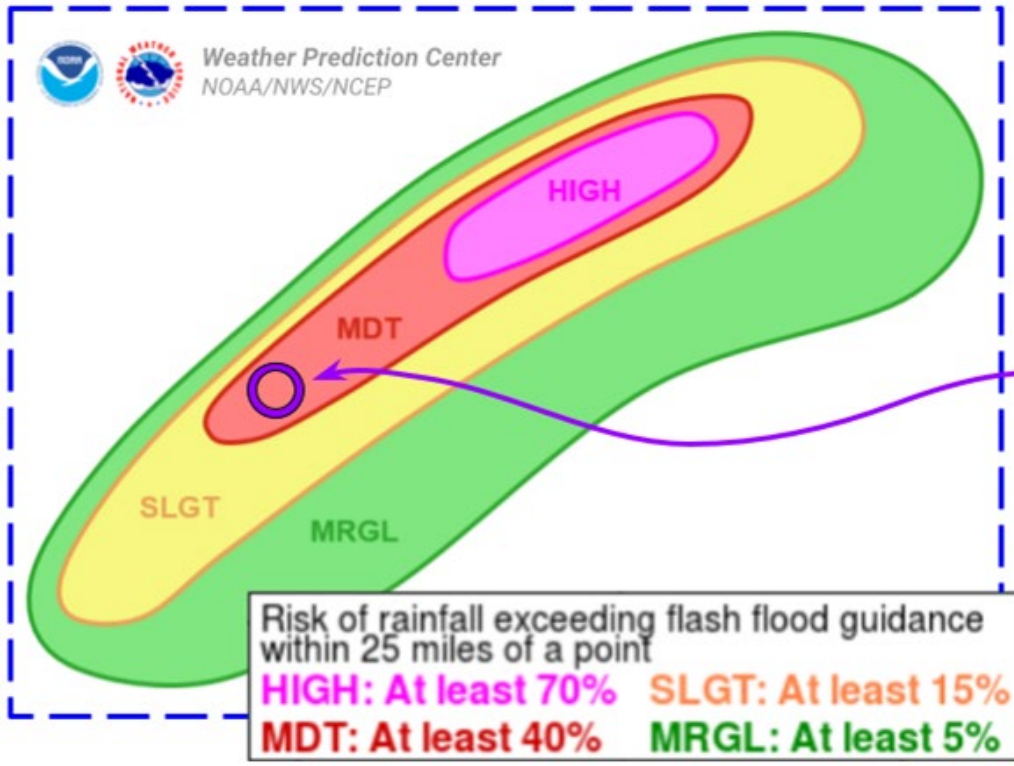


Quantitative Precipitation Forecast (QPF)



- Our “best guess” for rainfall totals
- Localized maxima will likely be higher
- Will correspond to the text rainfall statement in the official advisory
- 7 days of forecast precipitation always available on the WPC website
- QPFs are updated twice a day

Interpreting the Excessive Rainfall Outlook

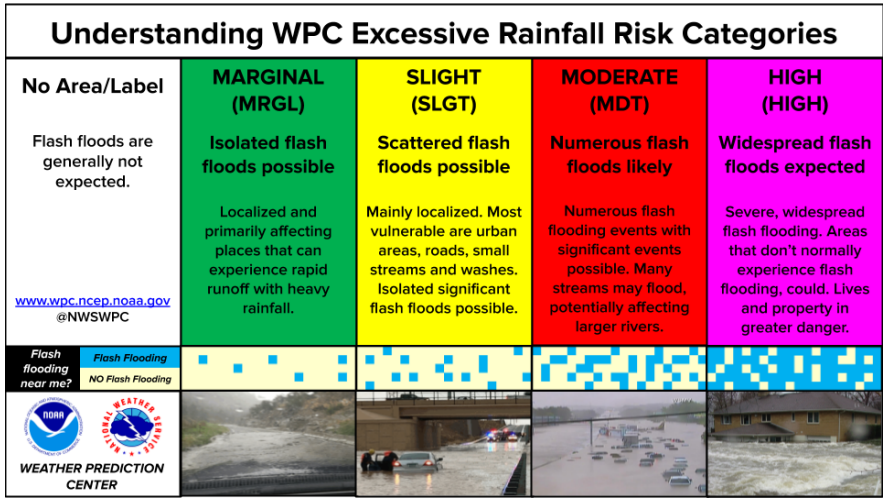


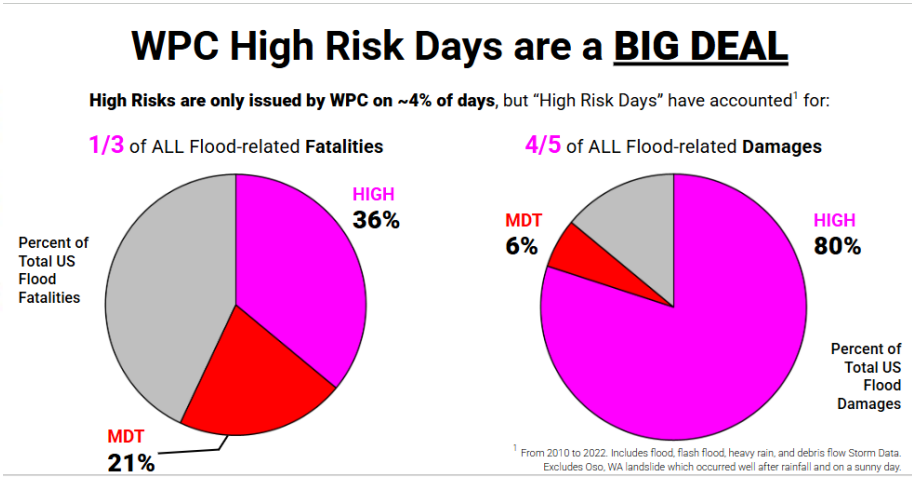
IN THE BIG PICTURE

- Orients you to potential problem spots for intense rainfall and resulting flash flooding
- Where is the risk relatively higher?

AT A LOCAL LEVEL

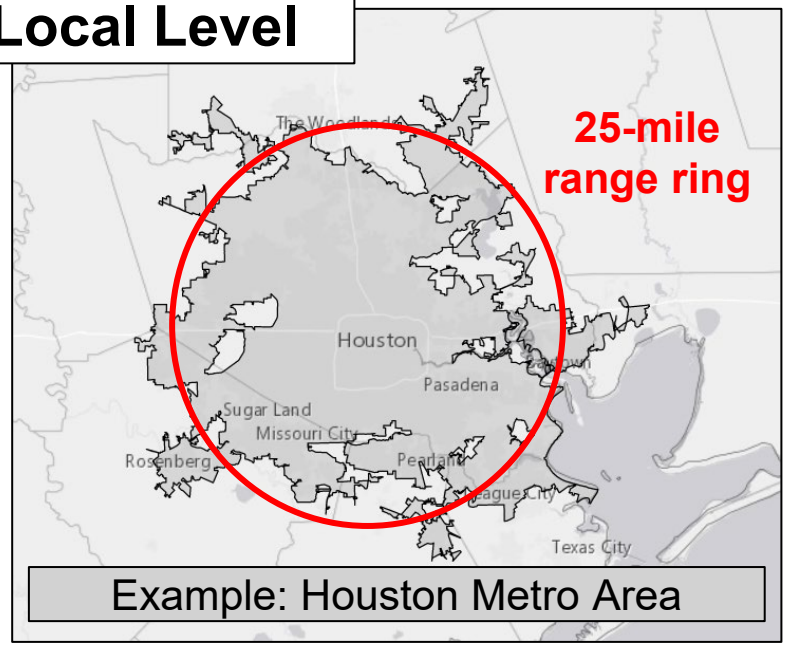
- Describes the probability (definition left) of intense rainfall leading to flash flooding within an area approximately the size of a large metro area or county/parish.
- "What are the chances I'll be dealing with flash flooding today?"





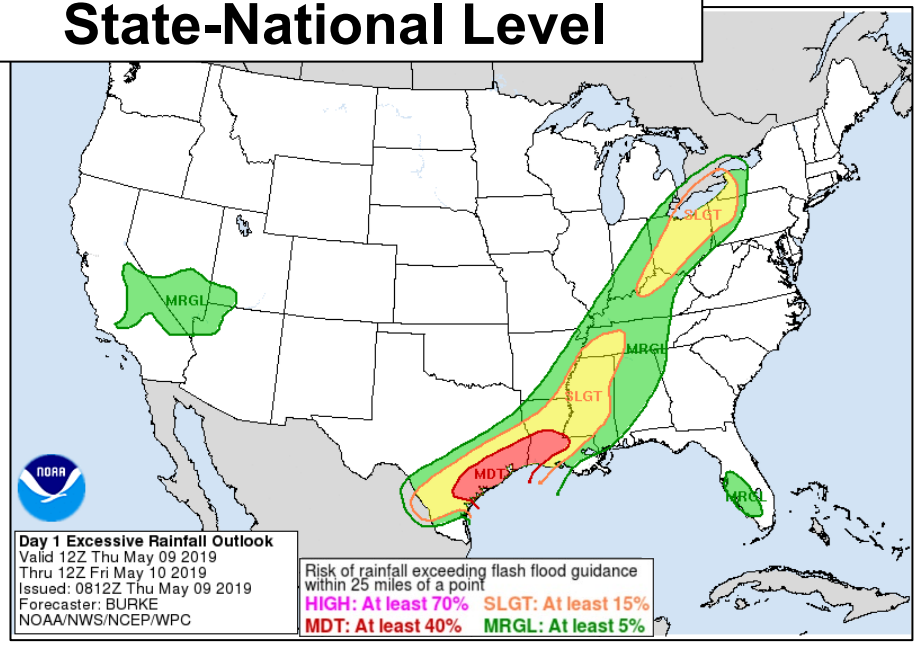
Interpretation of the ERO

Local Level



- Describes the probability of excessive rainfall leading to flash flooding within an area approximately the size of a large metro area or county/parish.
- "What are the chances I'll be dealing with flash flooding today?"

State-National Level



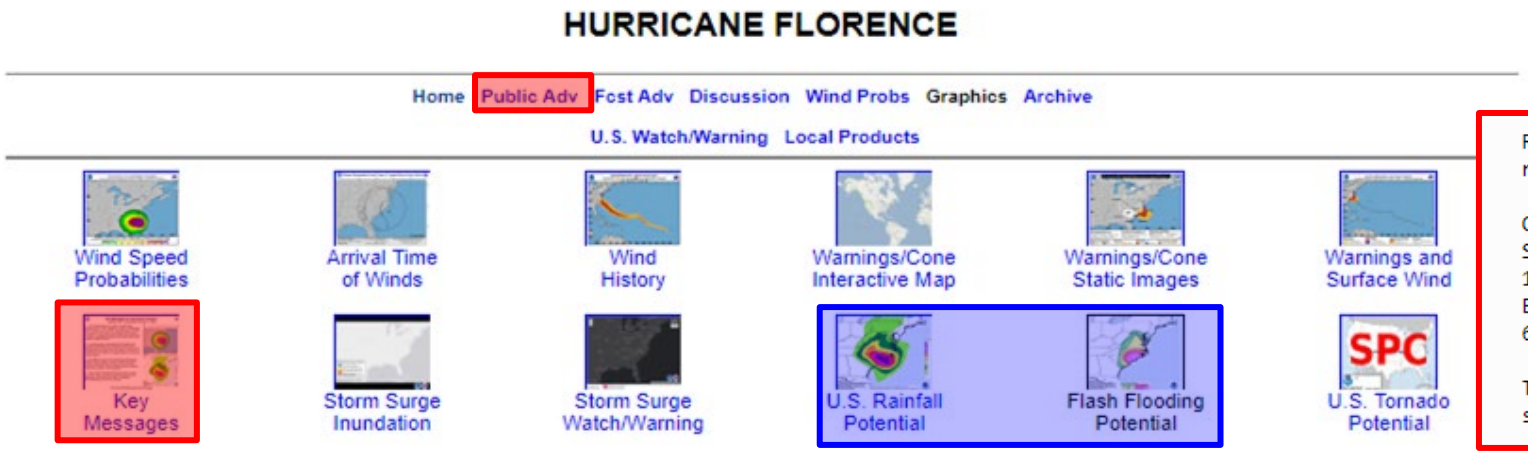
- Where are the potential problem spots for intense rainfall and resulting flash flooding, and where is the relative risk higher?
- Days with a much stronger signal, or higher risk levels, may generally require a greater response

IN THIS EXAMPLE

State Level: Texas
Flash flooding issues due to excessive rainfall are most likely in the southeast part of Texas. And the risk is at the second highest level, so overall confidence is higher than usual.

Local Level: Houston
The chances of excessive rainfall in Harris County and the Houston metro area would be about 40 to 70 percent on this day.

Integration with NHC Advisories

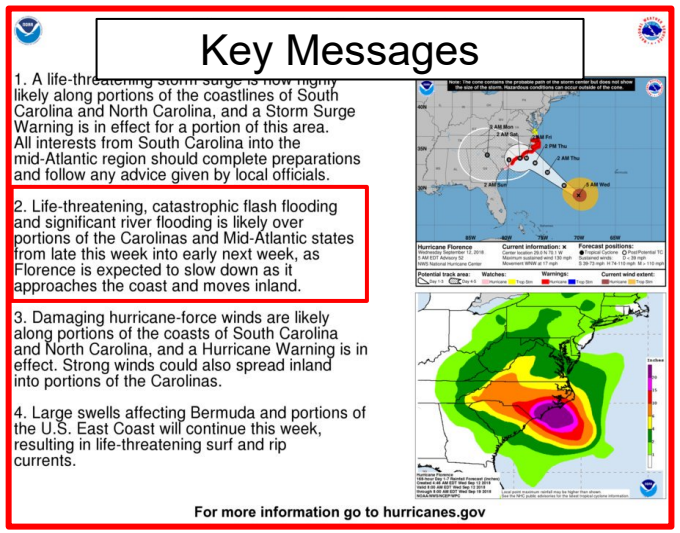


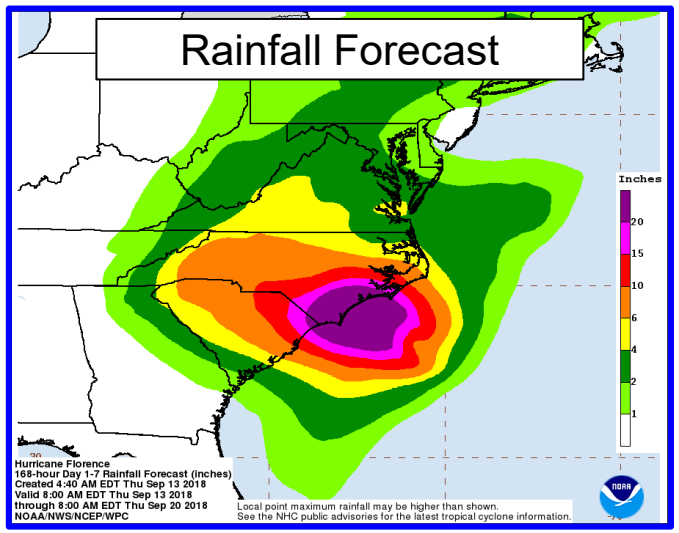
Public Advisory

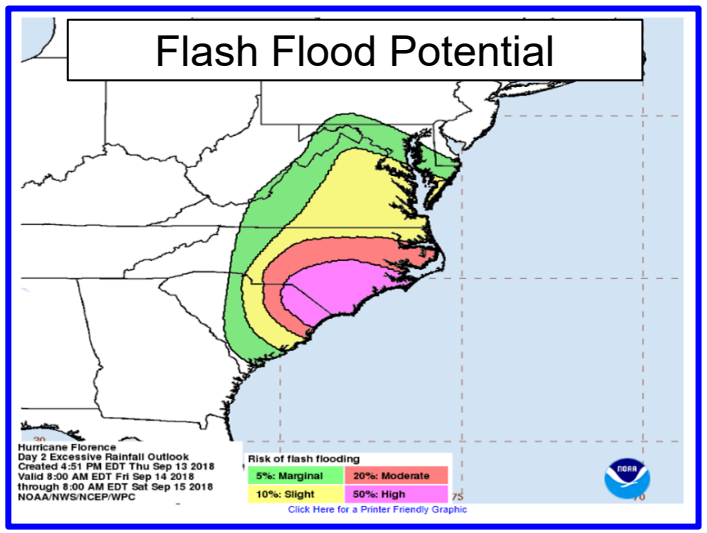
RAINFALL: Florence is expected to produce heavy and excessive rainfall in the following areas...

Coastal North Carolina...20 to 30 inches, isolated 40 inches
South Carolina, western and northern North Carolina...5 to 10 inches, isolated 20 inches
Elsewhere in the Appalachians and Mid-Atlantic states...3 to 6 inches, isolated 12 inches

This rainfall would produce catastrophic flash flooding and significant river flooding.







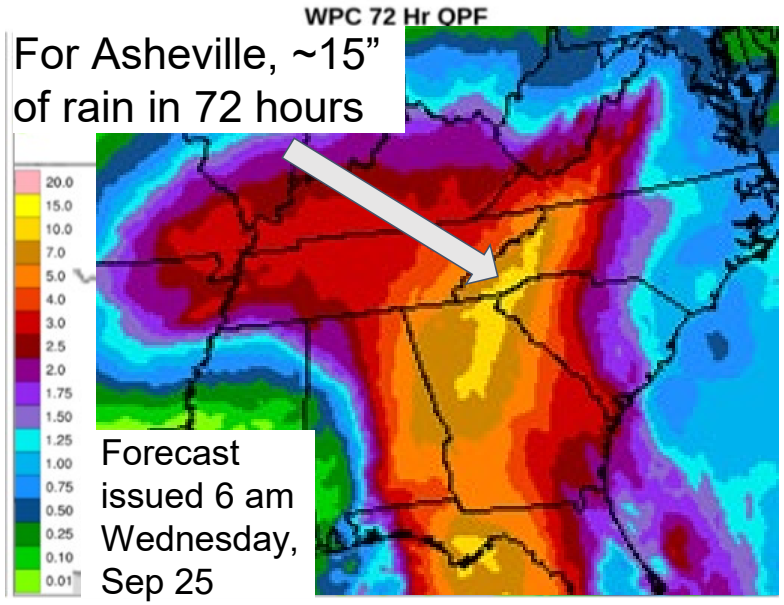
Zoomed graphics are produced for the CONUS. *(Rainfall only for Puerto Rico and USVI)*

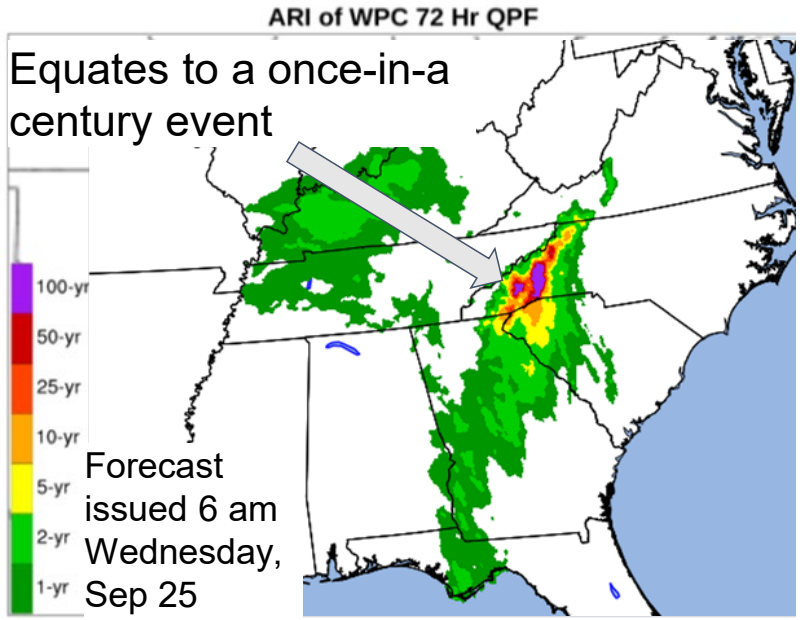
Extreme Precipitation Monitor

Annual Recurrence Interval (ARI)

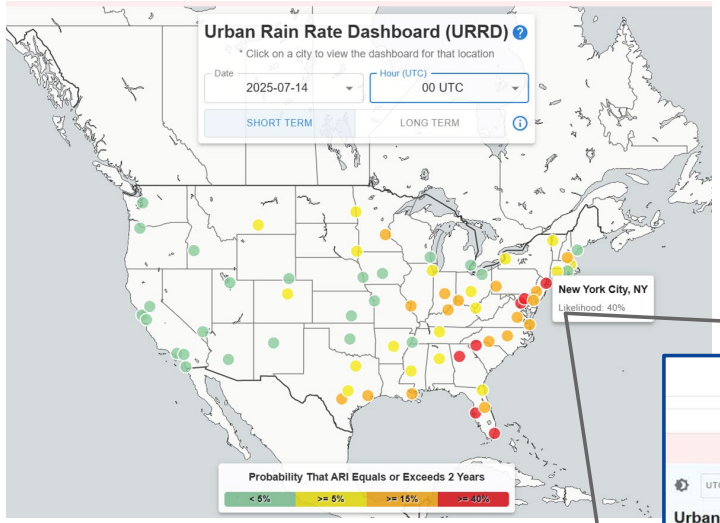
https://www.wpc.ncep.noaa.gov/qpf/epm/extreme_precip_monitor.php

- Answers the question: “How rare is that rainfall forecast?”
- Tool provides both the most likely and the reasonable-worst case
- Helps distinguish between a ‘bad event’ and a ‘REALLY bad event’





Urban Rain Rate Dashboard (*New!*)



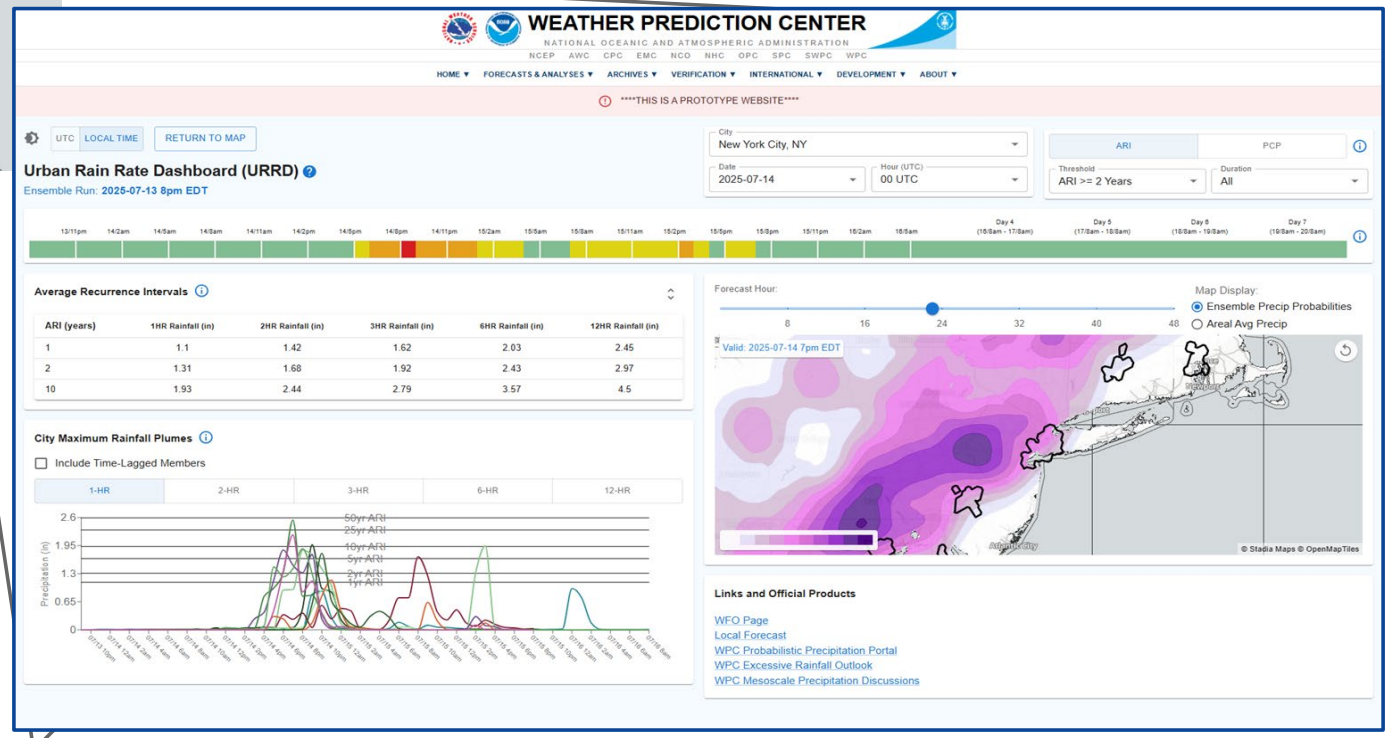
Provides a color-coded snapshot of the probability of high rain rates that may lead to urban flooding.

https://www.wpc.ncep.noaa.gov/urrd/

City-specific rain rate risk information
is available by clicking on the city from the national map landing page.

City-specific information includes:

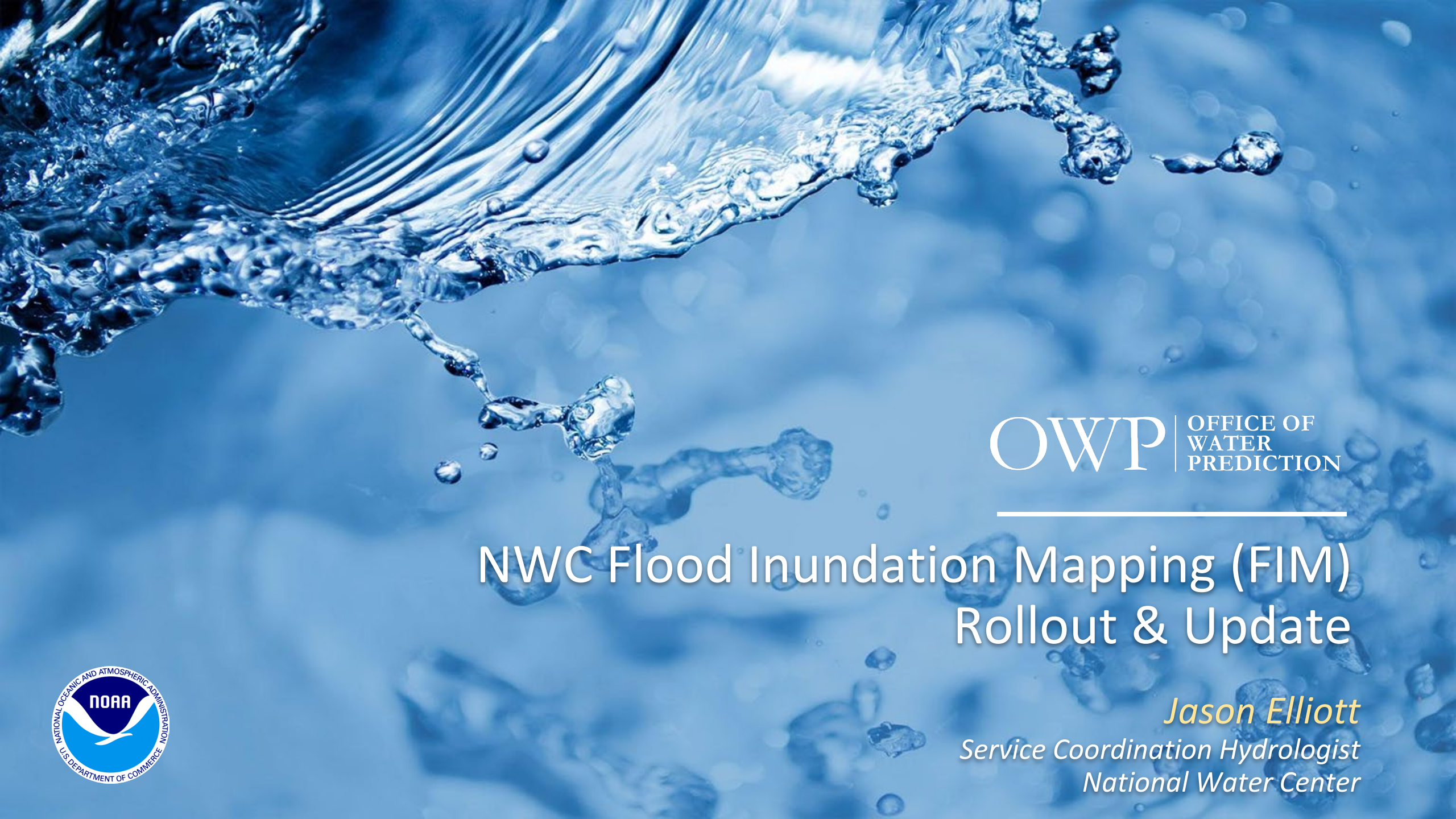
- Probability of exceedance
- Precipitation plumes
- Area average rainfall
- Local forecast



Thank You!

Owen Shieh, Ph.D.
Warning Coordination Meteorologist
Owen.Shieh@noaa.gov

NWS Weather Prediction Center
www.wpc.ncep.noaa.gov



OWP | OFFICE OF WATER PREDICTION

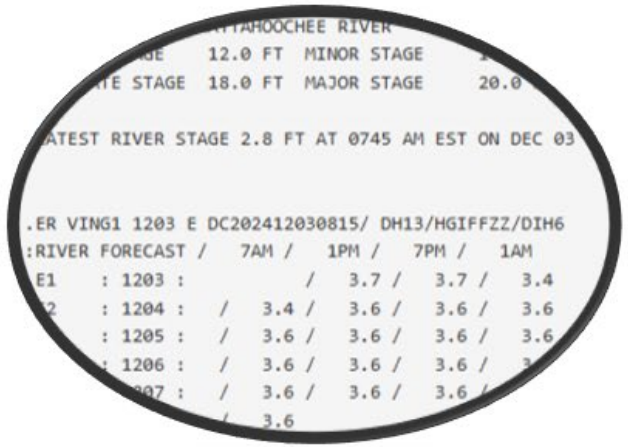
NWC Flood Inundation Mapping (FIM) Rollout & Update

Jason Elliott
Service Coordination Hydrologist
National Water Center

Where we have come from…

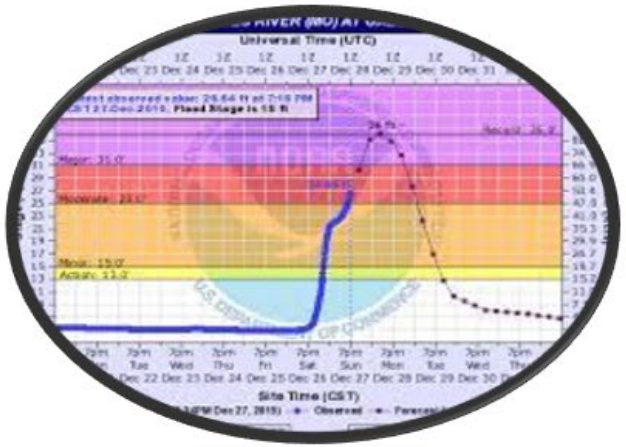
History of NWS Water Forecast Services

1980s -1990s



Text Forecasts

1990s – 2000s



Graphical Forecasts and Maps

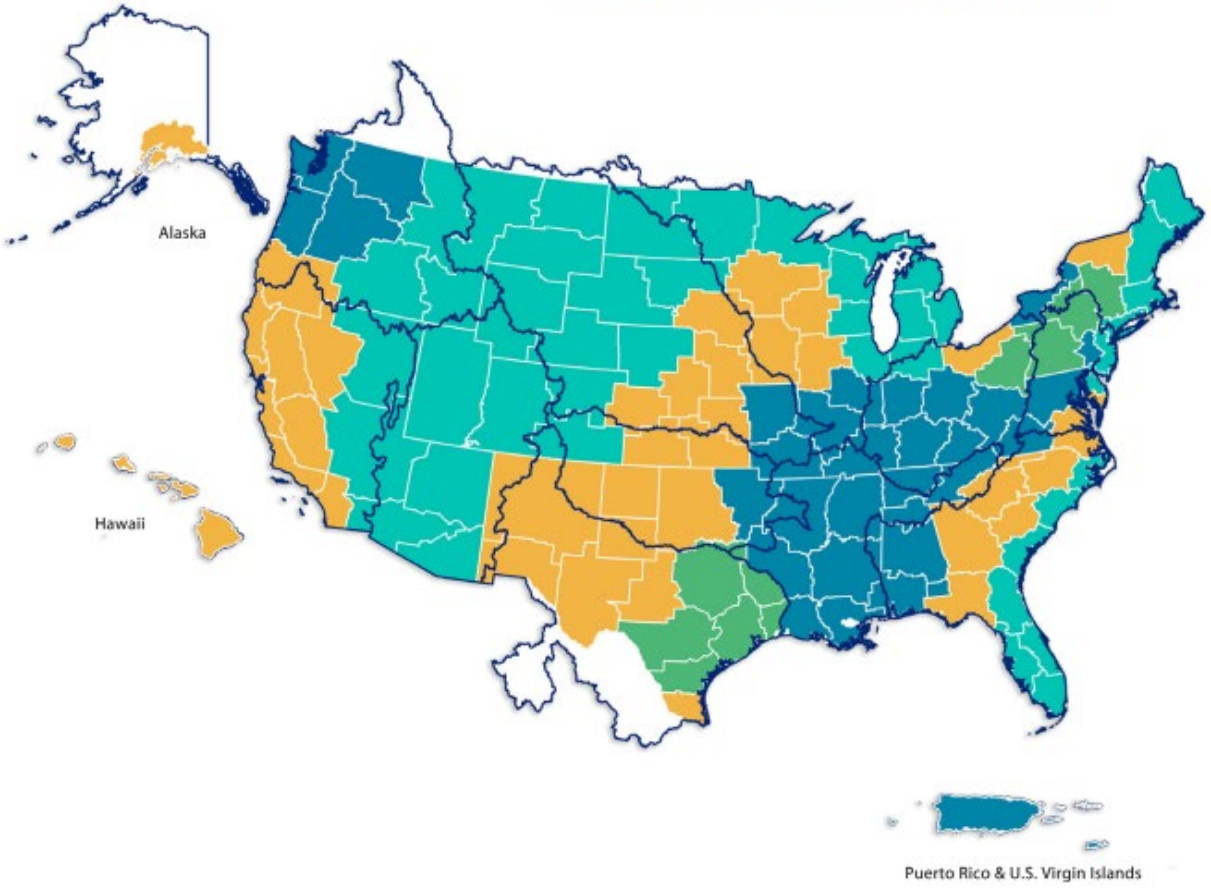
2000s-2010s

Flood Mapping

Limited

The rollout is nearly complete!

NWS Flood Inundation Mapping Services Implementation



Map Legend

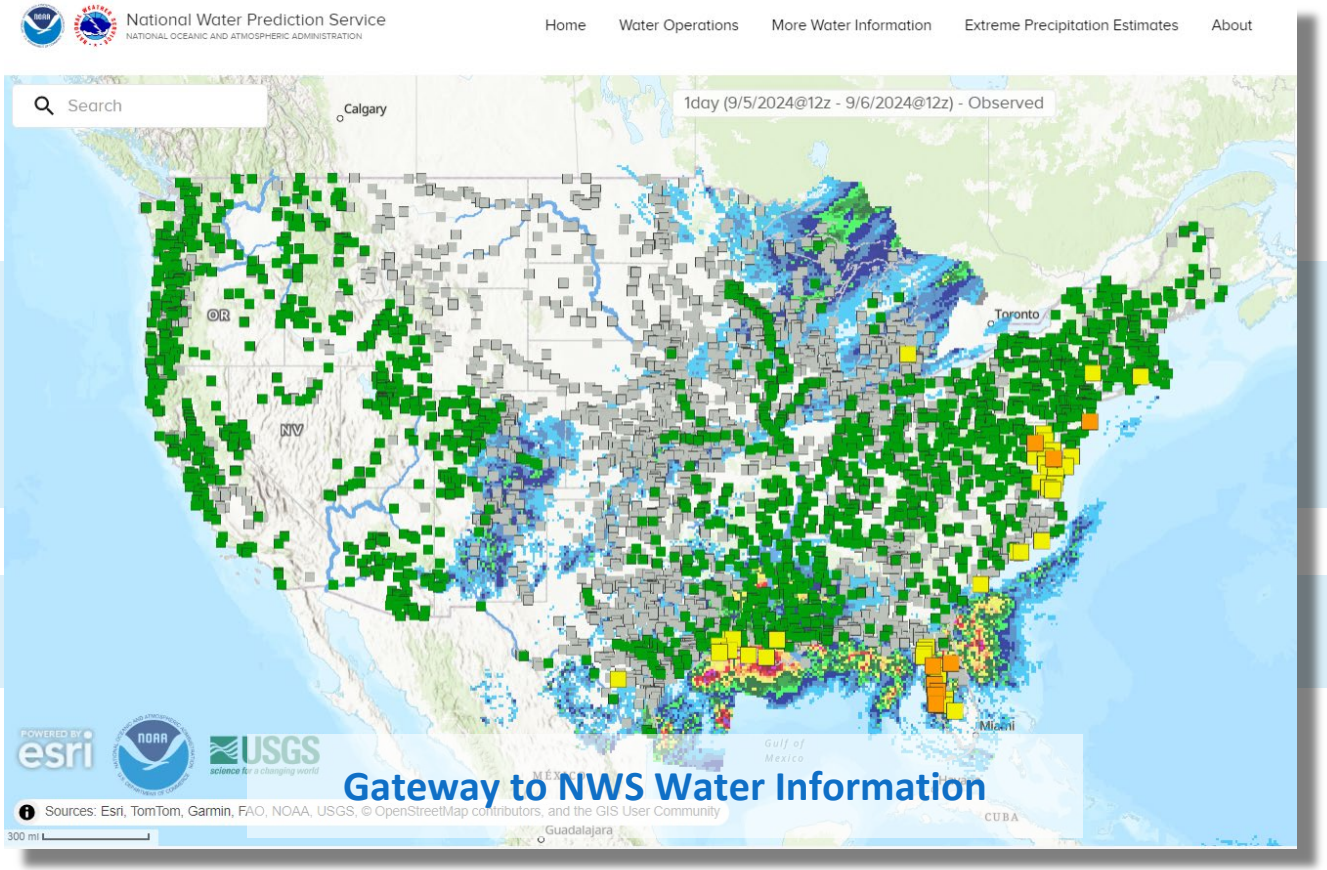
- 10% — Population served by **October 2023**.
- 30% — Population served by **October 2024**.
- 60% — Population served by **October 2025**.
- 100% — Population served by **October 2026**.
- NWS County Warning Areas
- NWS River Forecast Center Boundaries

*100% is approximate. Does not include all parts of Alaska, American Samoa, and Guam Implementation areas are subject to change

Where can I find NWS Flood Maps?

National Water Prediction Service

https://water.noaa.gov

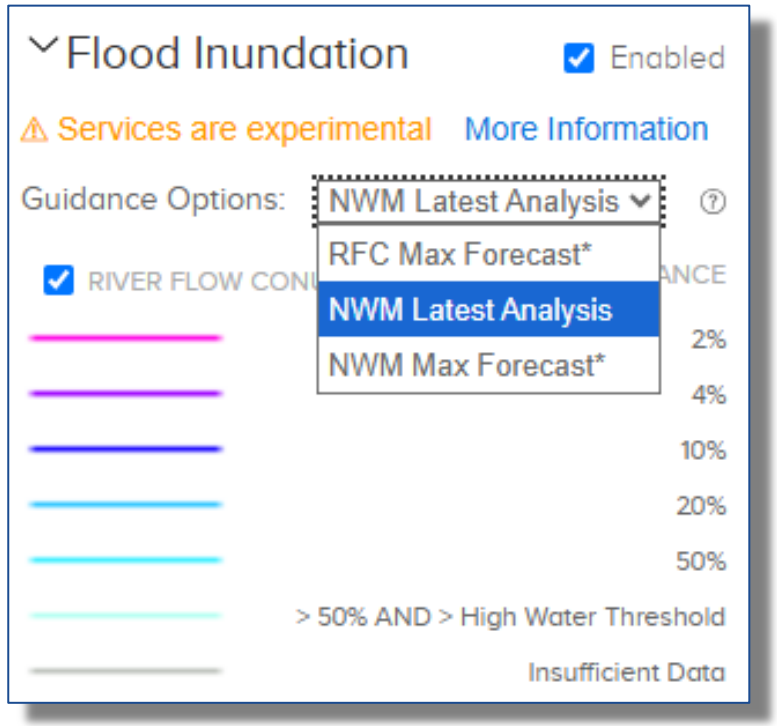


Flood Inundation Mapping

on the National Water Prediction Service (NWPS)

National Water Model Dynamic FIM Services

water.noaa.gov



NWM Latest Analysis FIM

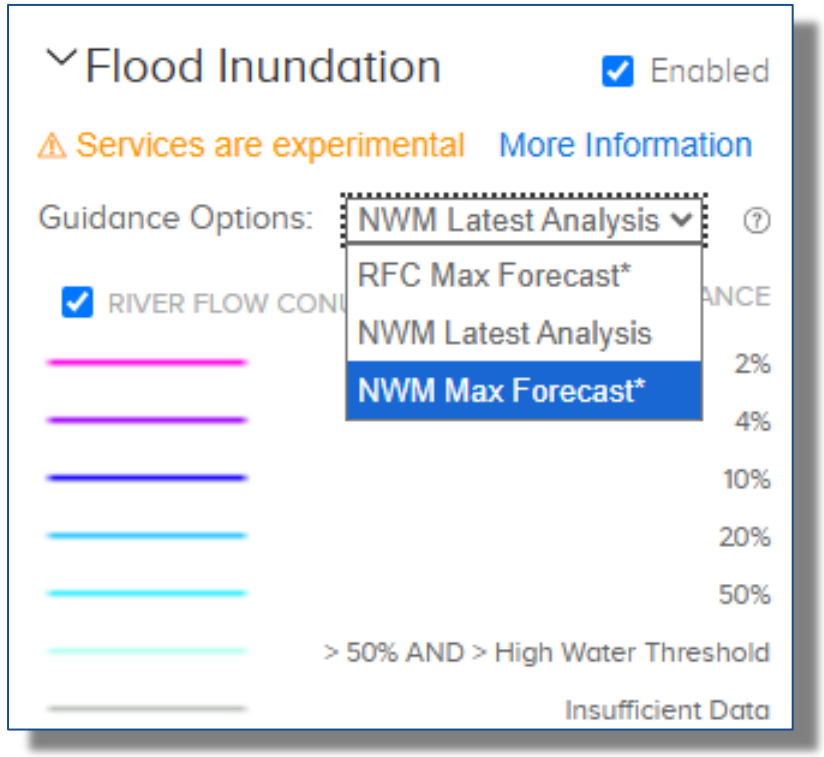
- FIM is generated when streamflow is above the high water threshold.
- Assimilates to USGS Gages and routes downstream where available
- Where no gage is available, assimilates using MRMS observed rainfall to generate flow from the NWM.
- No QPF or forecast flows
- Run every hour

Flood Inundation Mapping

on the National Water Prediction Service (NWPS)

National Water Model Dynamic FIM Services

water.noaa.gov



NWM Max Forecast FIM

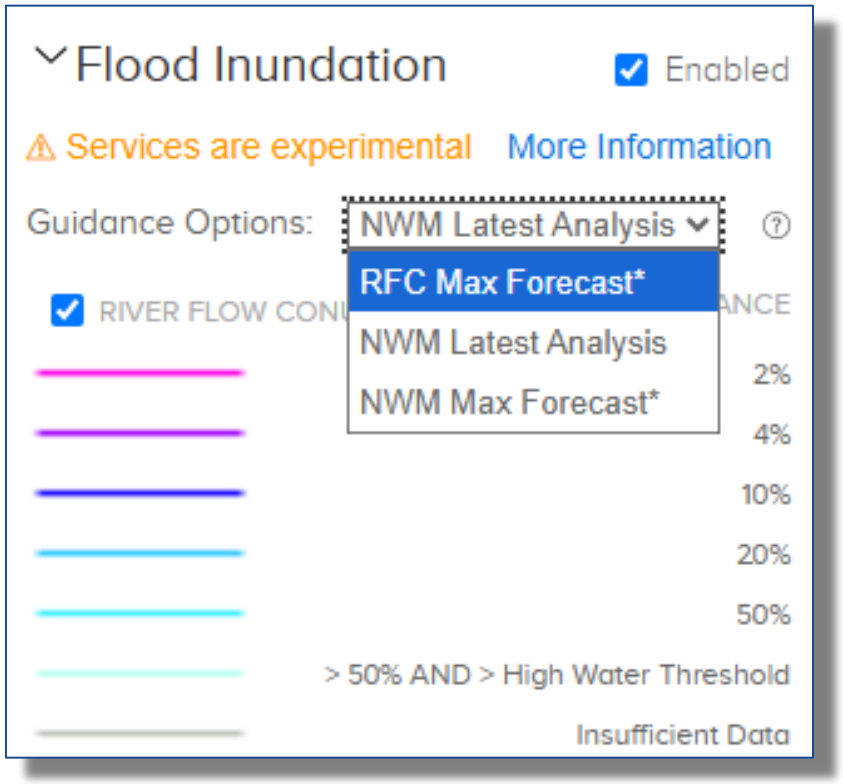
- FIM is generated when streamflow is above the high water threshold.
- Utilizes the National Water Model Forecast Flows
- Map represents the maximum flow over the next 5 days
- Produced using forecast rainfall from the National Blend of Models (NBM)
- Run every 6 hours - available about 6 ½ hours after model runtime

Flood Inundation Mapping

on the National Water Prediction Service (NWPS)

River Forecast Center Dynamic FIM Services

water.noaa.gov



RFC Max Forecast FIM

- FIM available if Action stage or greater at site
- Replaces the National Water Model Flow with RFC Forecast Flow
- Map represents the maximum extent over next 5 days
- Maximum Latency would be 45 minutes from RFC Forecast Issuance
- Shows FIM downstream of forecast gage

Services…

Flood Inundation Maps for NWS Flood Categories at Forecast Locations

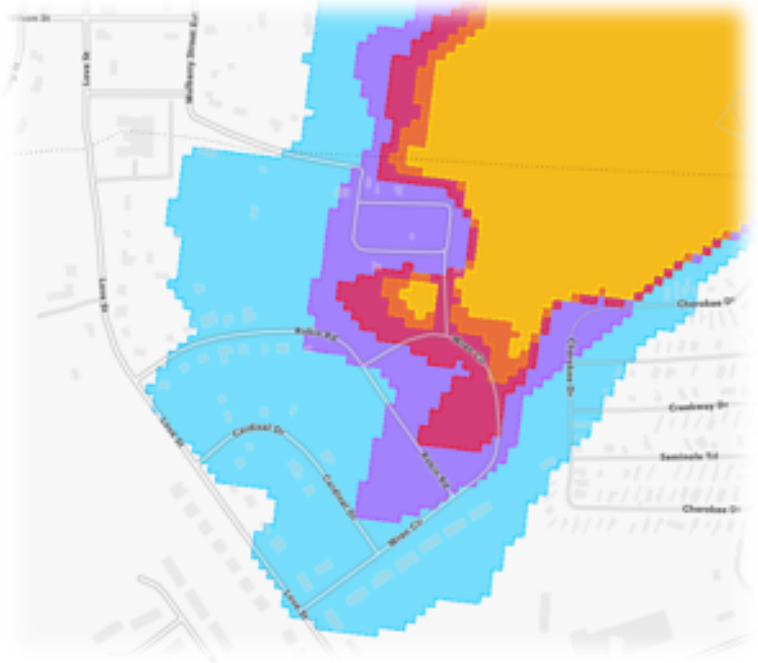
Action Stage

Minor Flood

Moderate Flood

Major Flood

Record Flood

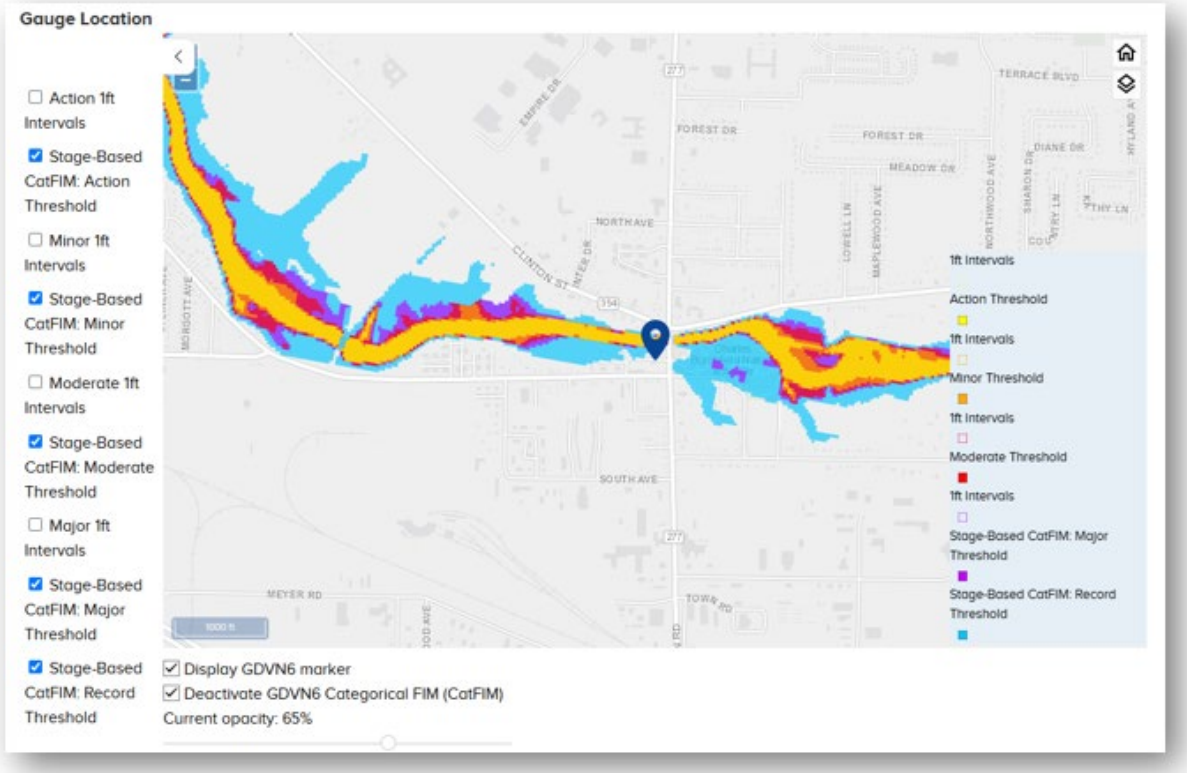


Static FIM Services

Flood Inundation Mapping

on the National Water Prediction Service (NWPS)

Static FIM Services



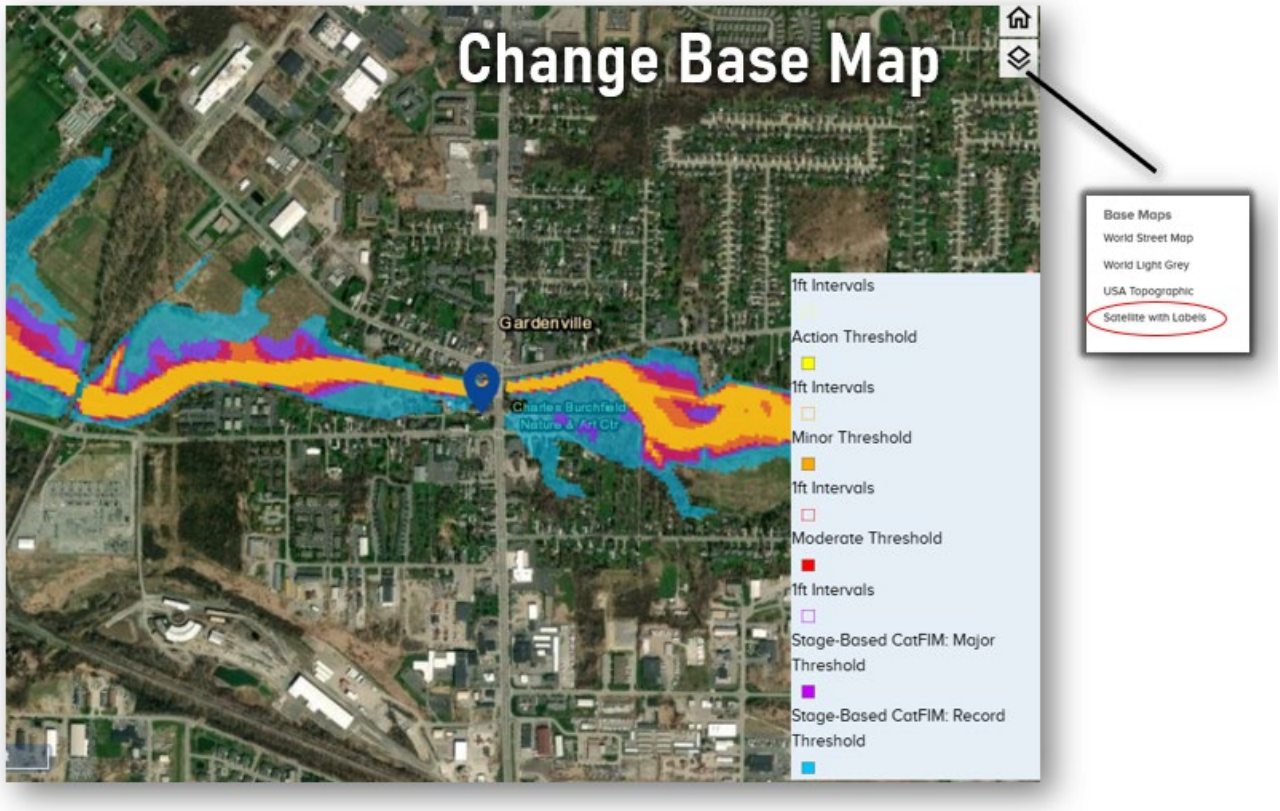
- Available at select River Forecast Center forecast locations
- Roughly extends 5 miles upstream and downstream from gage site

water.noaa.gov

Flood Inundation Mapping

on the National Water Prediction Service (NWPS)

Static FIM Services



- Available at select River Forecast Center forecast locations
- Roughly extends 5 miles upstream and downstream from gage site

water.noaa.gov

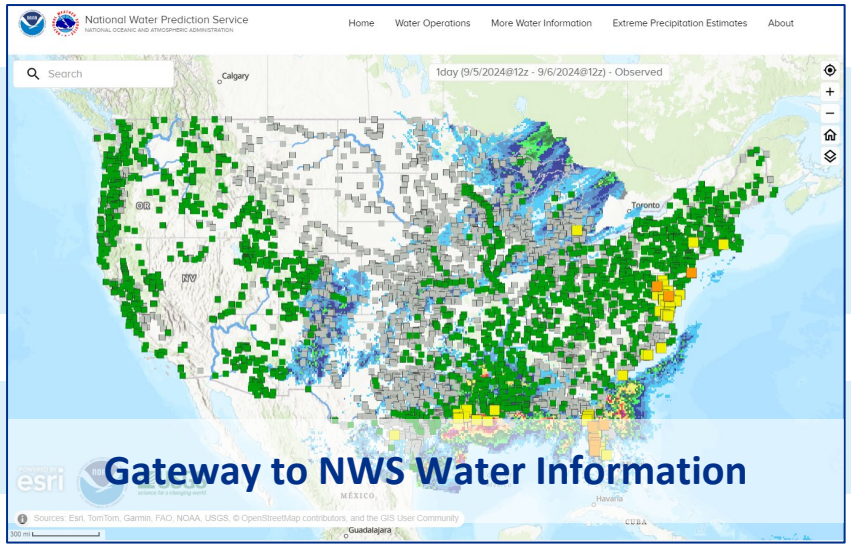
FIM Dissemination Endpoints

HydroVIS Enterprise GIS

https://maps.water.noaa.gov/server/rest/services

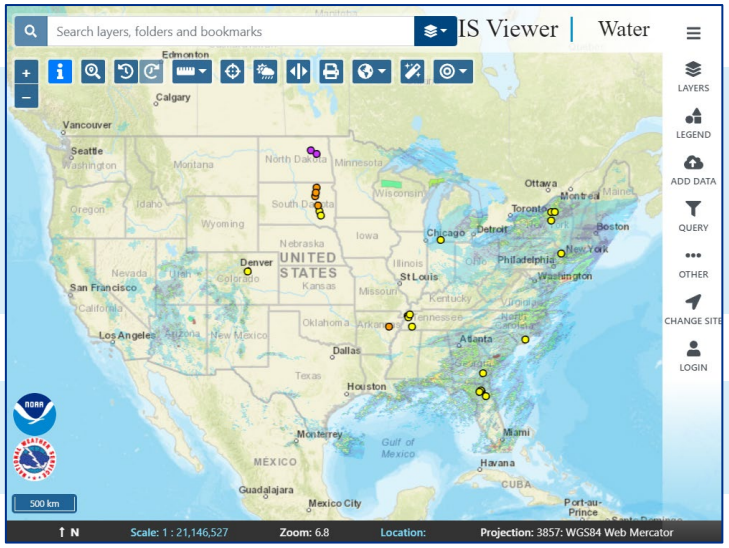
National Water Prediction Service

https://water.noaa.gov



NWS National GIS Viewer

https://viewer.weather.noaa.gov/water



Thank You!

Jason Elliott

jason.elliott@noaa.gov

https://water.noaa.gov

NOAA

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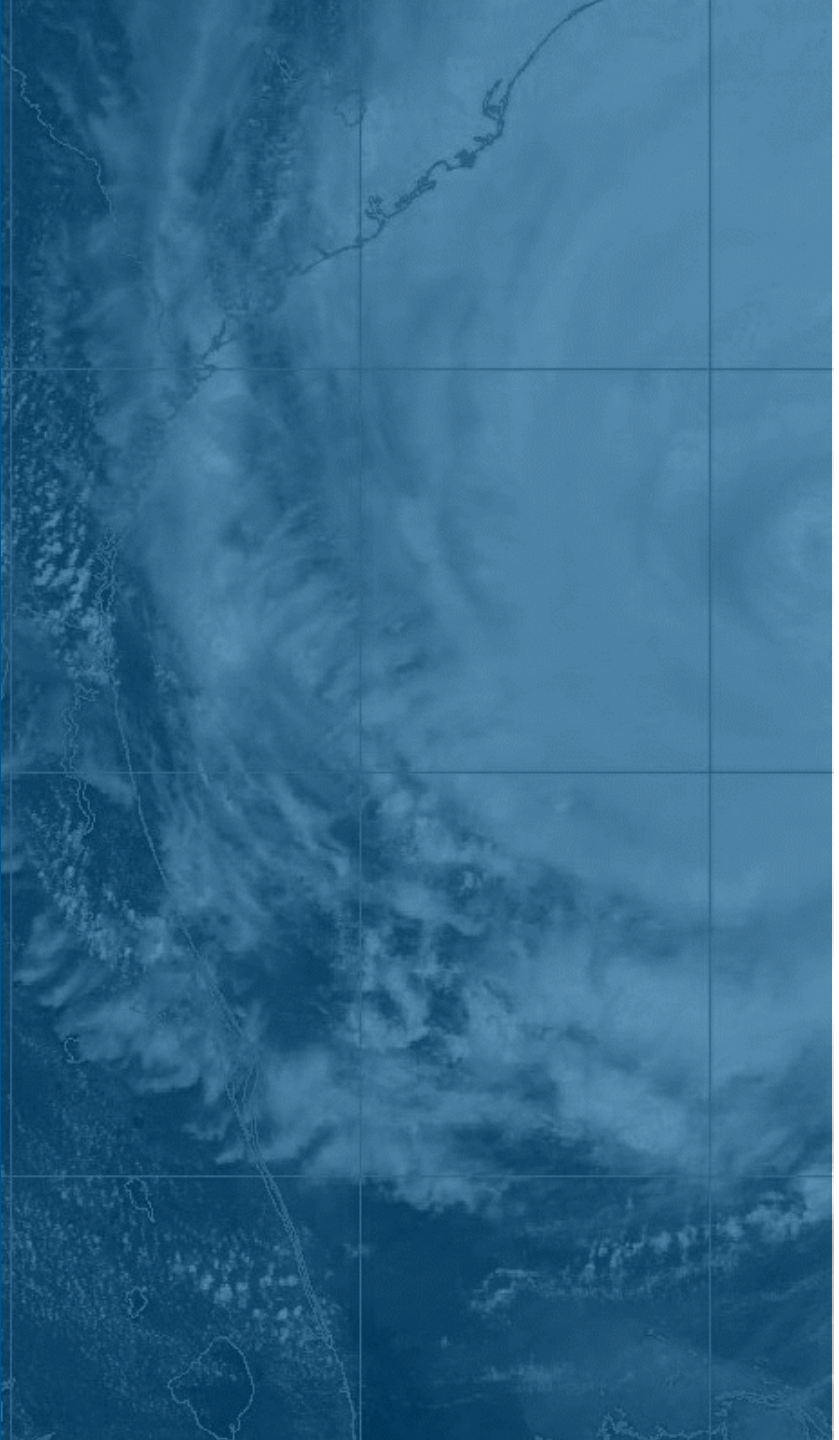
HURREVAC Demo



Goals for Today

1. Access current rainfall and flooding layers from NOAA/WPC
2. Map all NHC operational surge products
3. Use the SLOSH Explorer to map worst-case surge scenarios
4. Explore differences between MOM and MEOW products
5. Interact with surge data using flags and points of interest (POI)

Thank you!

HURREVAC Support Team

support@hurrevac.com

FEMA

NATIONAL HURRICANE PROGRAM

HURREVAC

HURRICANE DECISION SUPPORT TOOL