

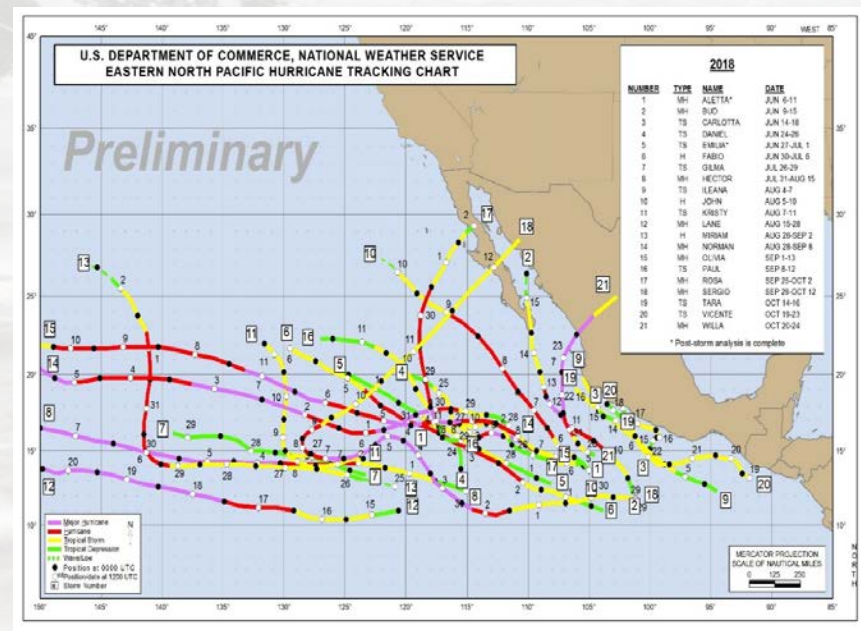
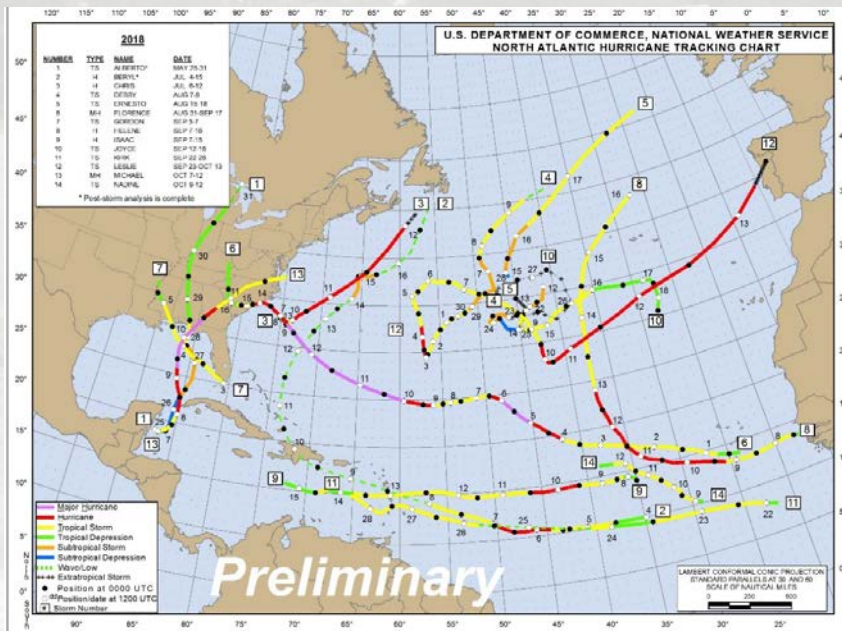
Water Impacts from Recent U.S. Landfalling Tropical Cyclones



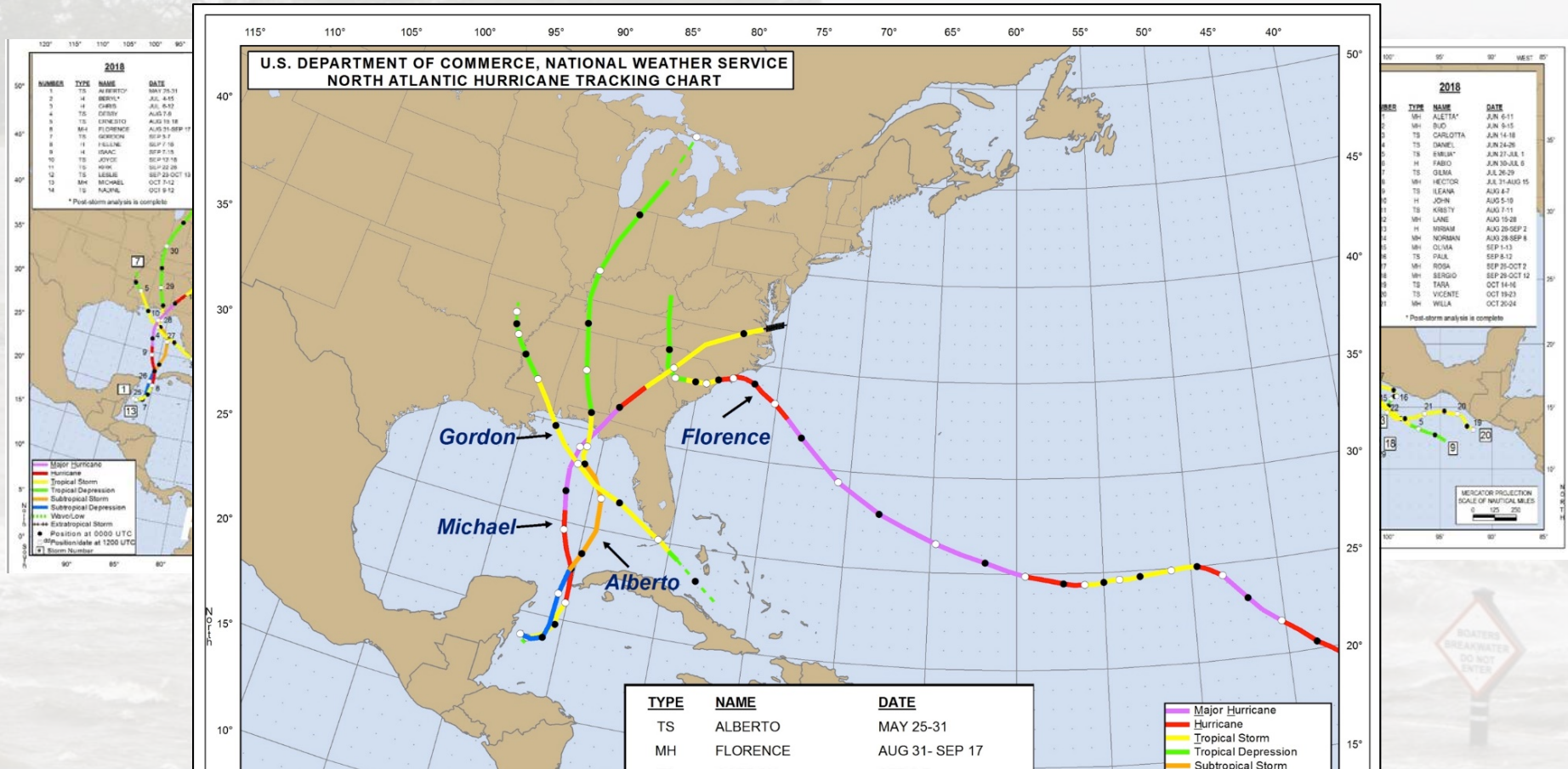
Ken Graham
National Hurricane Center



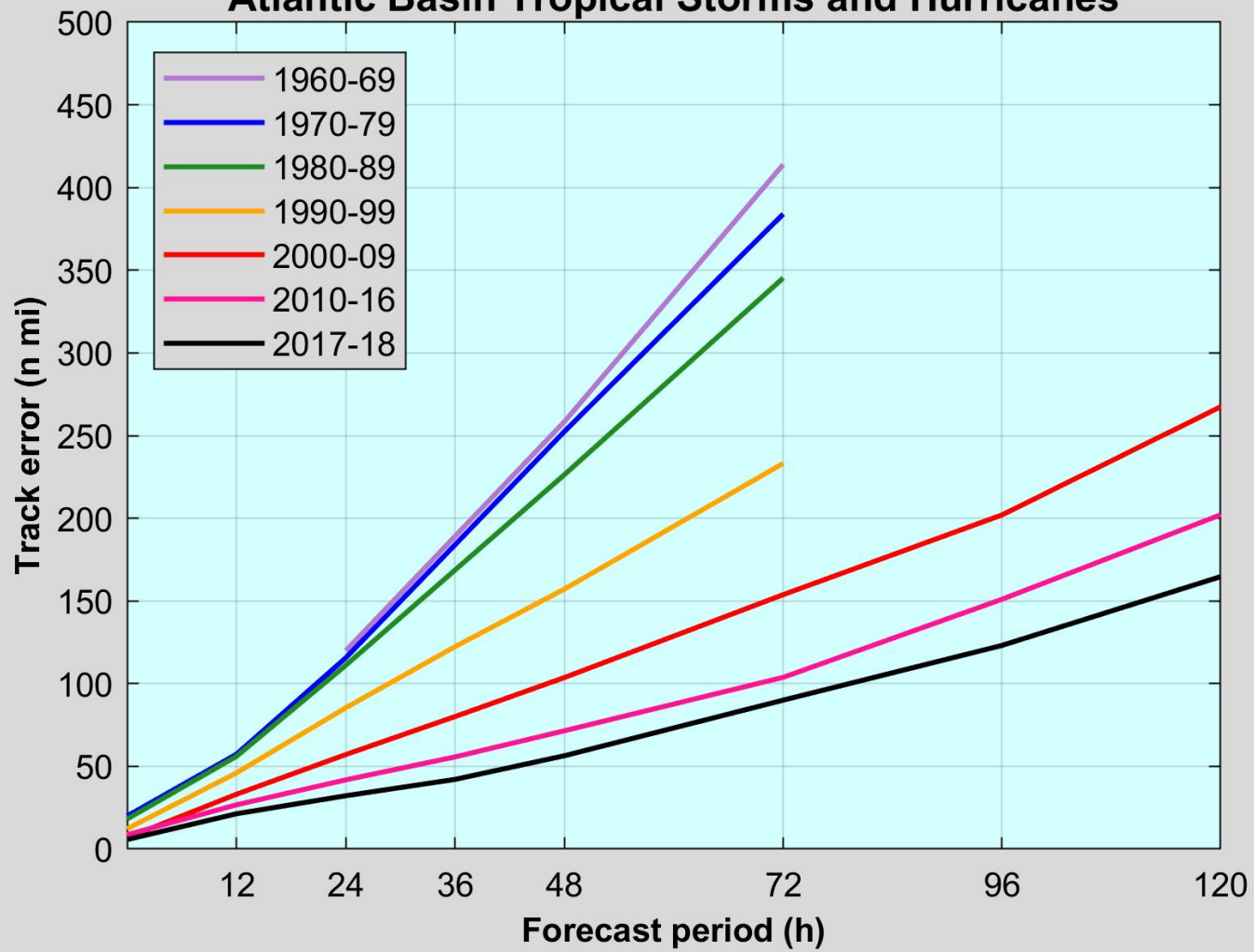
2018 Hurricane Season



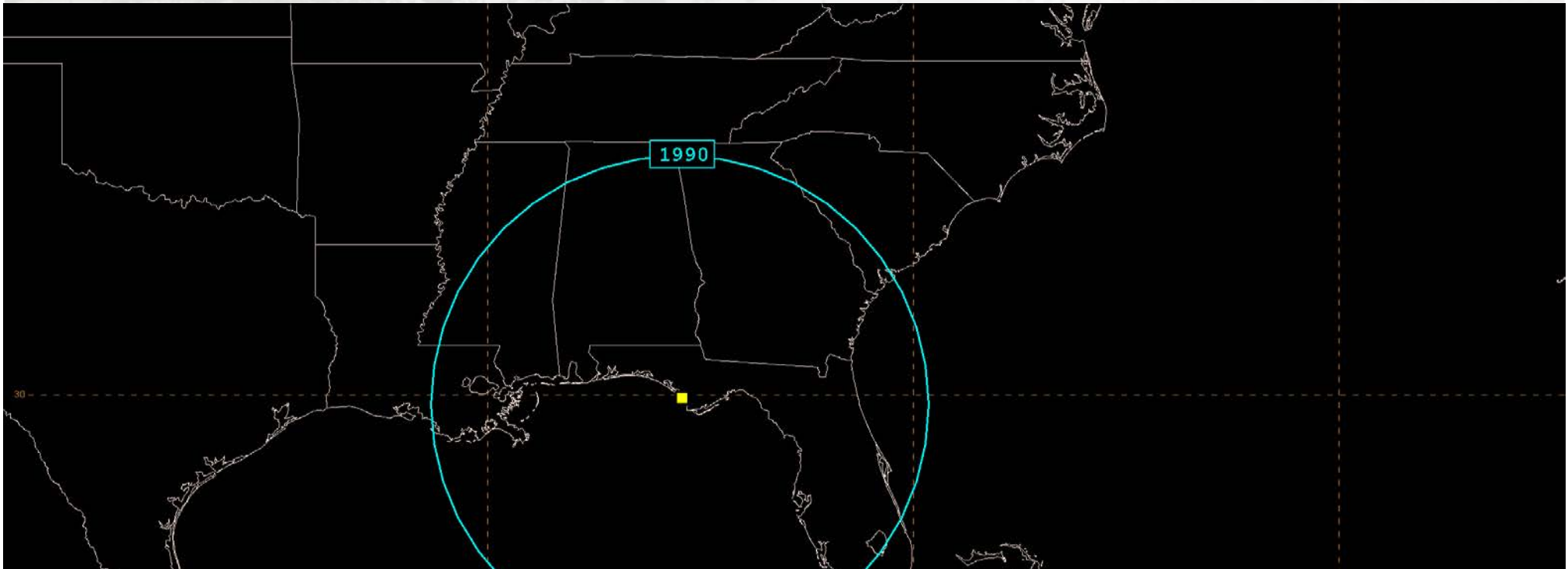
2018 Hurricane Season



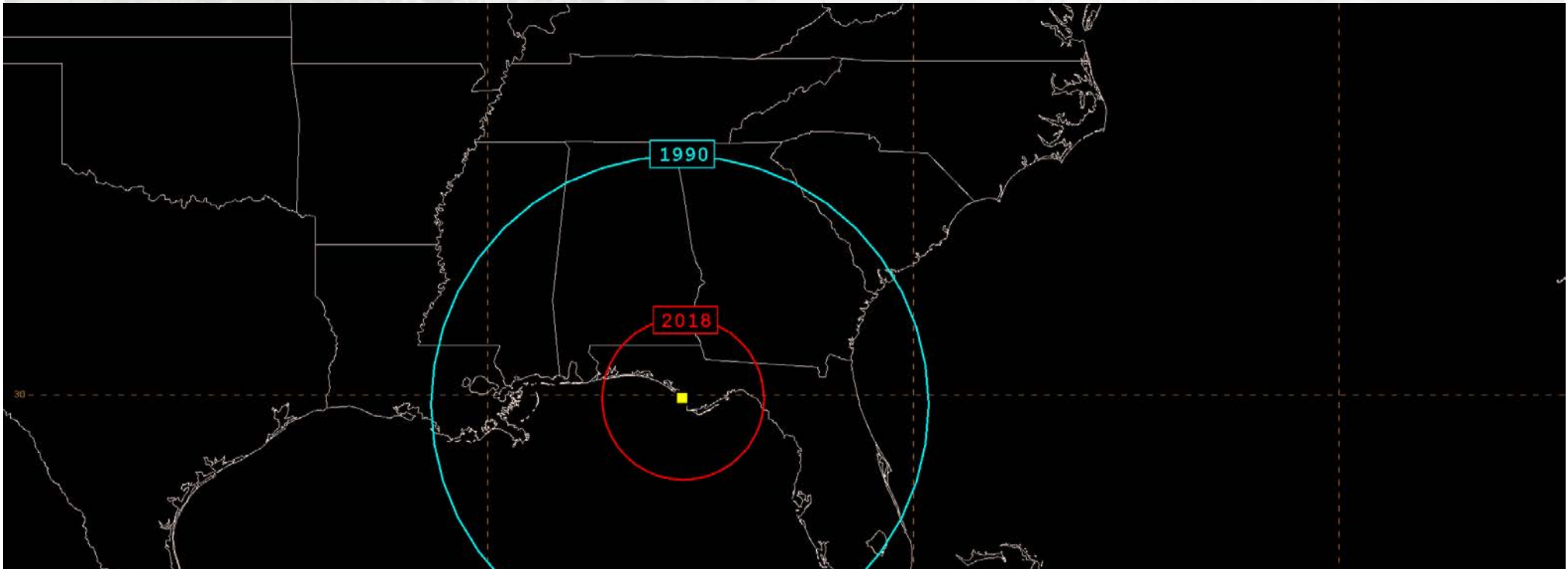
NHC Official Average Track Errors Atlantic Basin Tropical Storms and Hurricanes



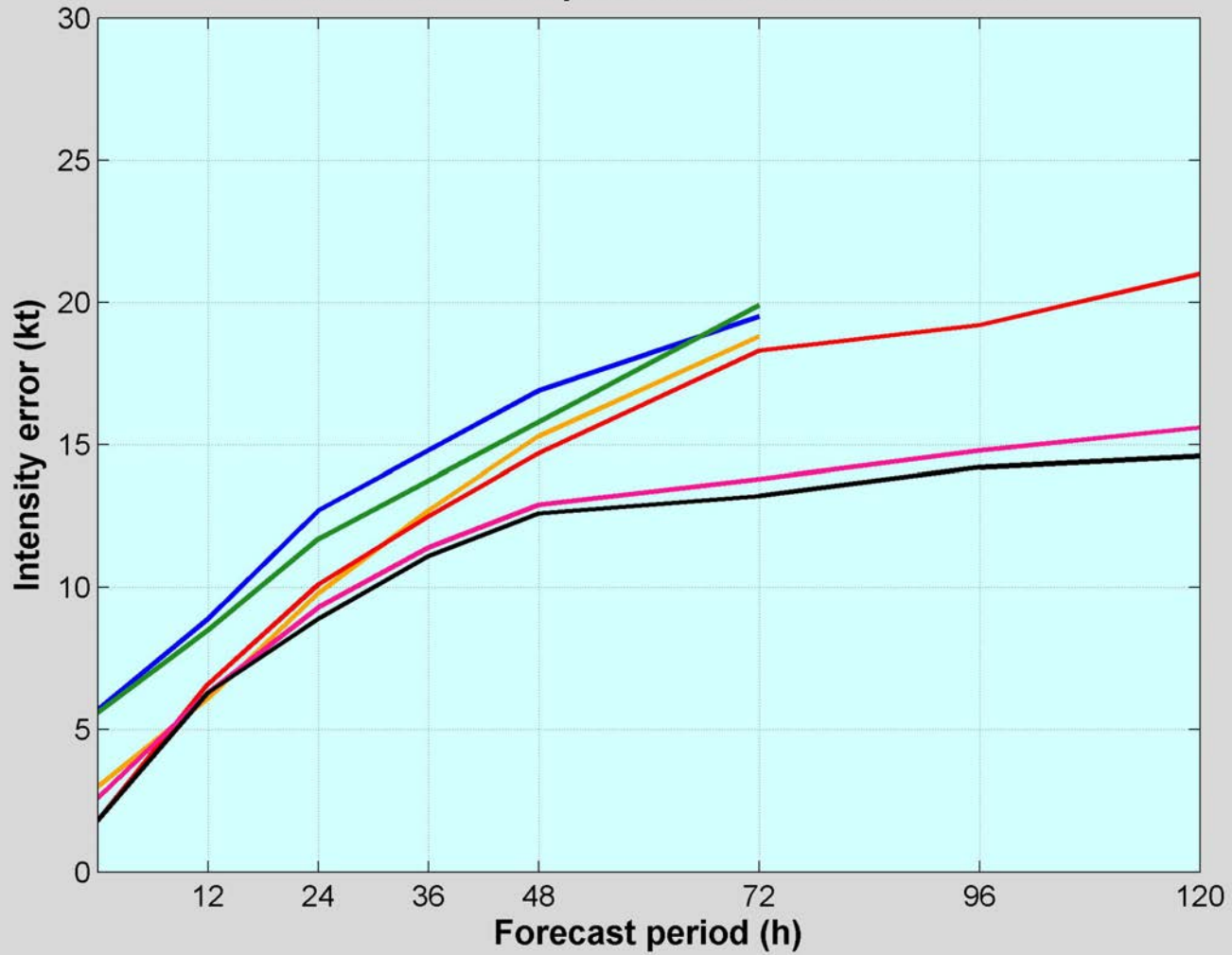
Improvements in Track Forecasting 3-day Forecasts in 1990




Improvements in Track Forecasting 3-day Forecasts in 1990



NHC Official Average Intensity Errors Atlantic Basin Tropical Storms and Hurricanes





When you close your eyes, what do you see when you think of a hurricane?

Record Setting Rainfall 2017-18

Hurricanes Harvey, Florence, and Lane have each set state records for tropical cyclone rainfall with Harvey's rainfall of 60+ inches setting the U.S. record



**Harvey (2017) - 60.58 inches
Texas & US Record**



**Florence (2018) – 35.93/26.63 inches
North Carolina/South Carolina Record**

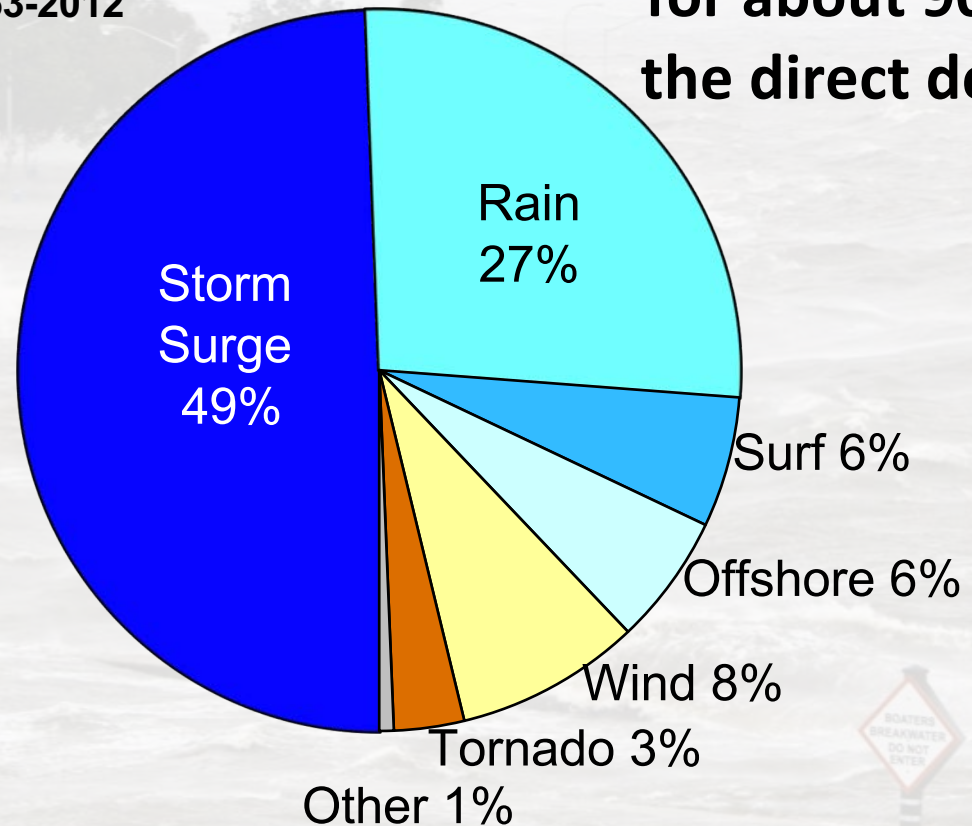


**Lane (2018) – 52.02 inches
Hawaii Record**

Water is What KILLS!!!

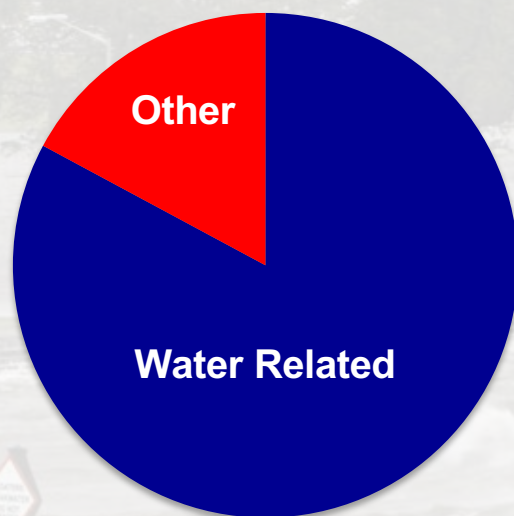
U.S. Tropical Cyclone Fatalities
1963-2012

Water accounts
for about 90% of
the direct deaths



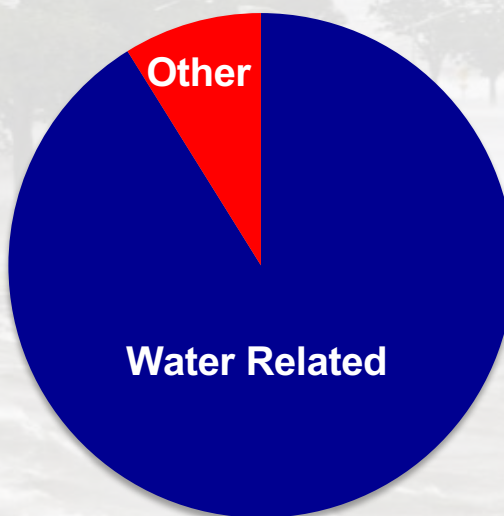
Water Continues to Kill

2016 Fatalities



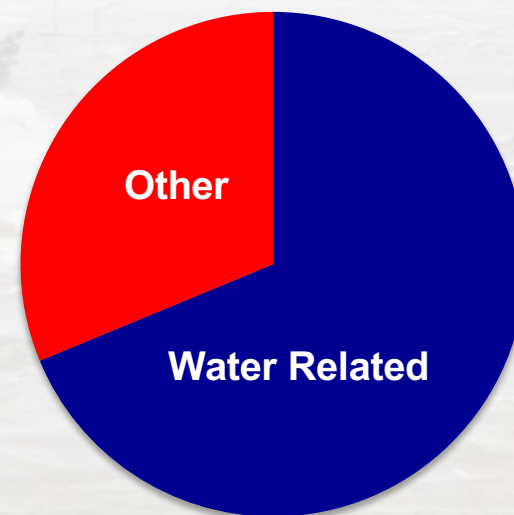
83% Water Related

2017 Fatalities*



91% Water Related

2018 Fatalities



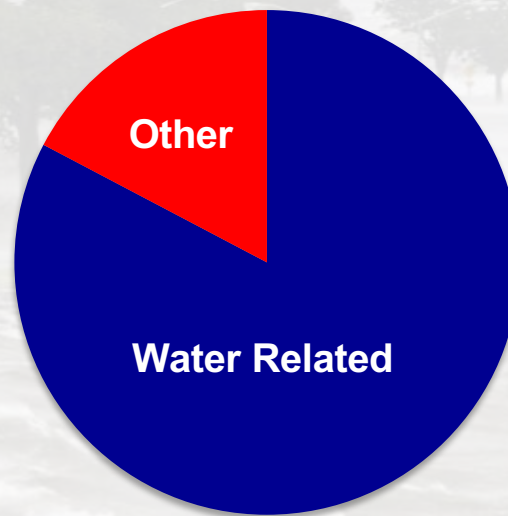
69% Water Related

Most Inland Flooding – Only 4% Storm Surge Related

*excludes Maria due to uncertainty related to causes of direct deaths

Water Continues to Kill

2016-18 Fatalities*



83% Water Related

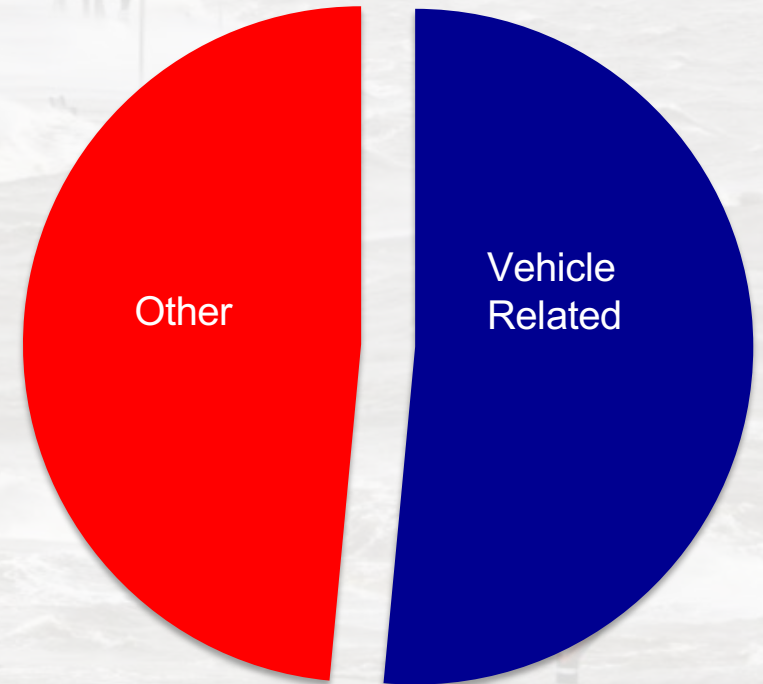
Most Inland Flooding – Only 4% Storm Surge Related

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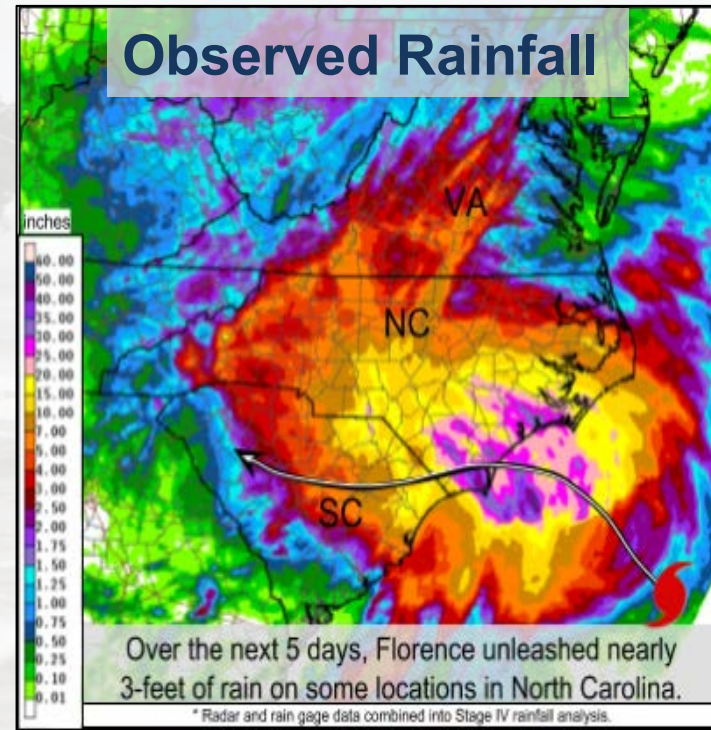
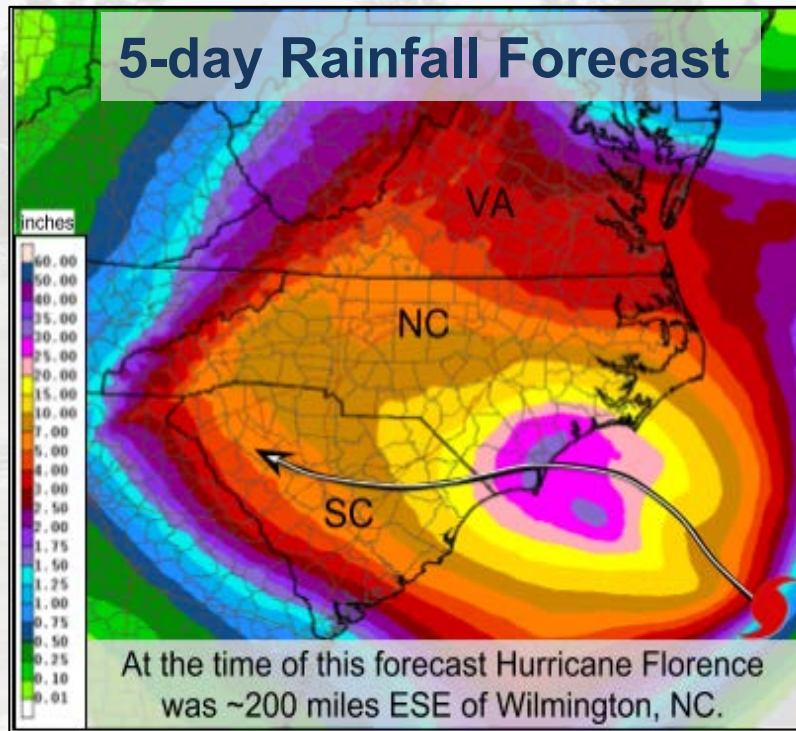
Flood Related Vehicle Fatalities

- During the past three seasons, more than half the U.S. tropical cyclone water-related fatalities were vehicle related!

2016-18 U.S. Tropical Cyclone
Water Related Fatalities



Hurricane Florence

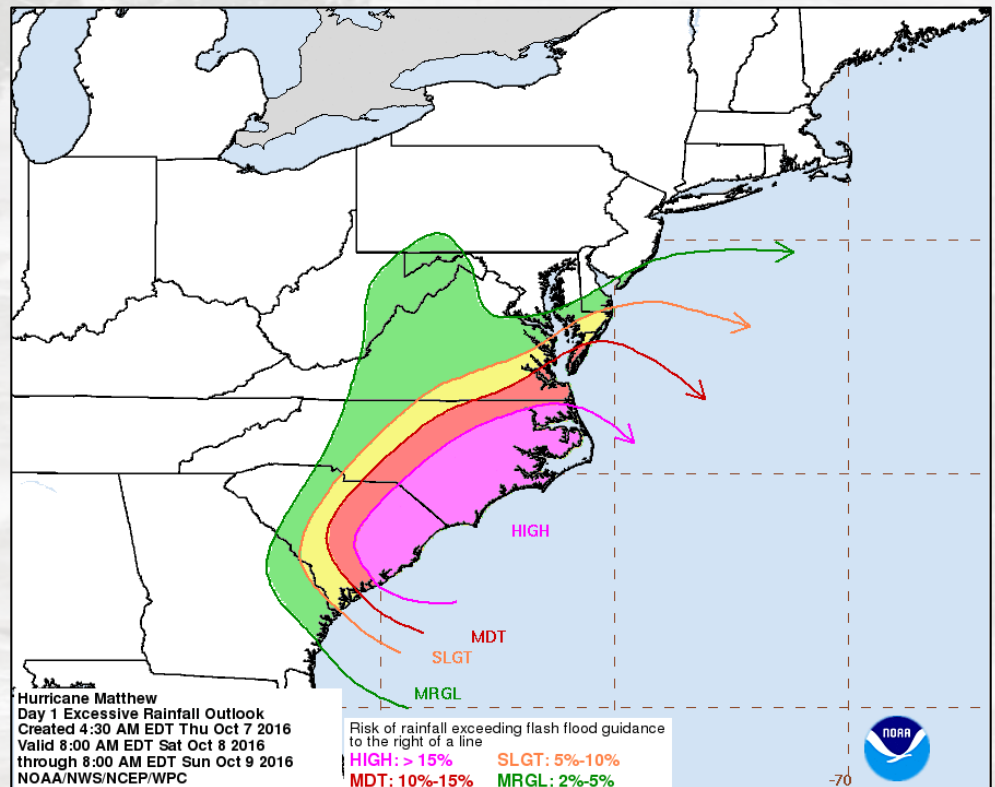


Excellent Forecasts – Yet 16 out of 17 flood related fatalities were in vehicles!

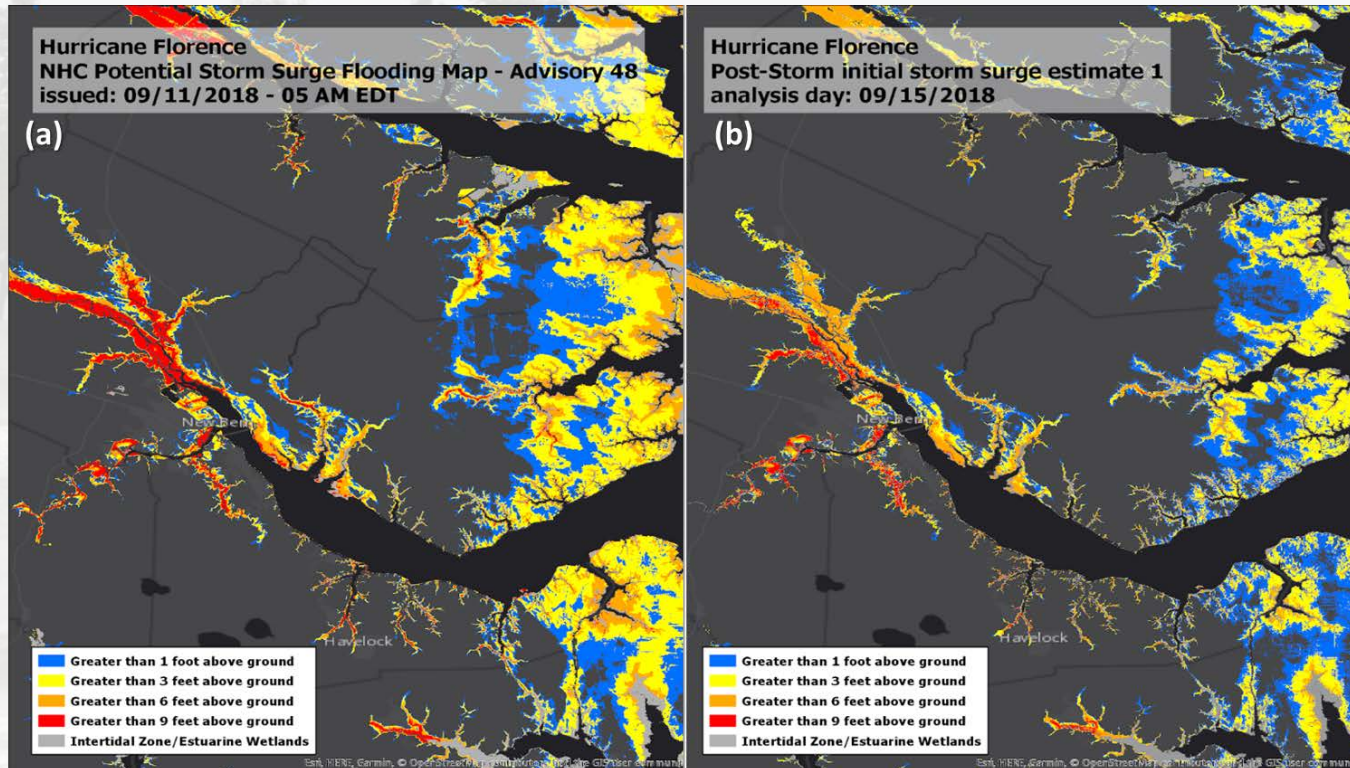
Excessive Rainfall Outlook

Highlights Risk of Flash Flooding

- 54% of High Risk Days have at least 1 fatality or injury
- 73% have at least \$1 million in damage
- High Risk Days account for 1/3 of flood fatalities and 4/5 of damage



Storm Surge Forecasting



Most Inland Flooding – Only 4% Storm Surge Related (2017-2018)

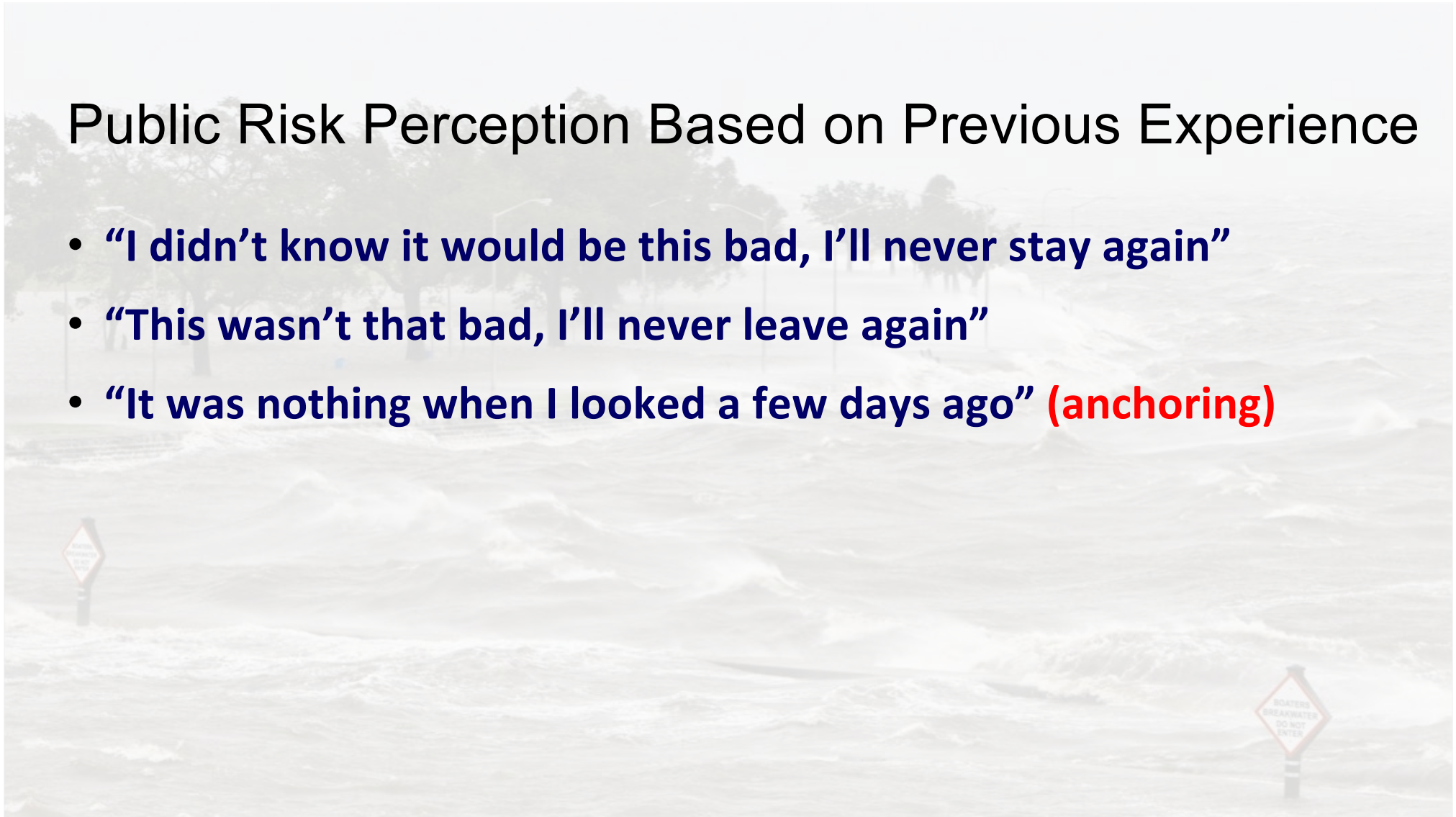
*excludes Maria due to uncertainty related to causes of direct deaths

Public Risk Perception Based on Previous Experience

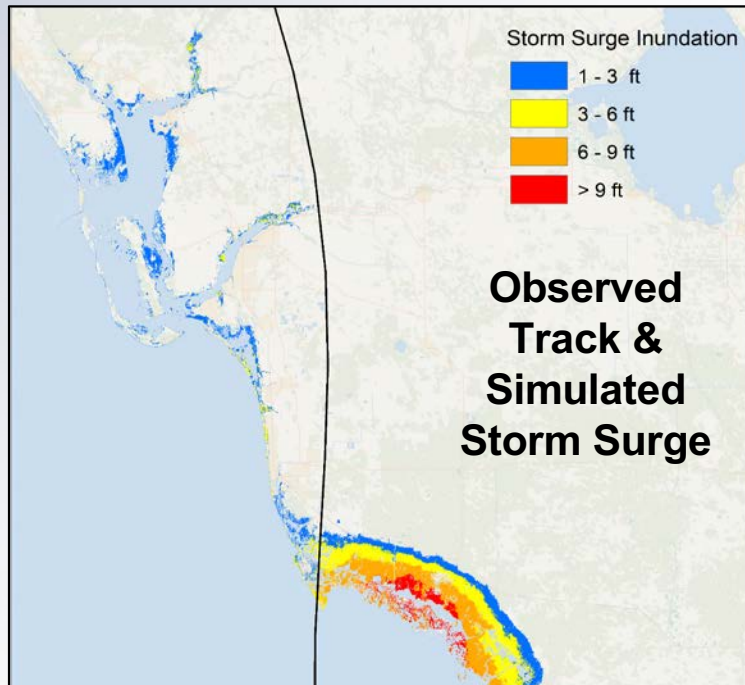
- **“My house is elevated, I thought we would be just fine”**
- **“It’s never flooded here before”**
- **“They always turn”**
- **“I thought these floods come once in a 100 years”**
- **“It’s just a tropical storm”**
- **“I live a hundred miles from the coast, I didn’t expect this”**
- **“This didn’t happen last time”**

Public Risk Perception Based on Previous Experience

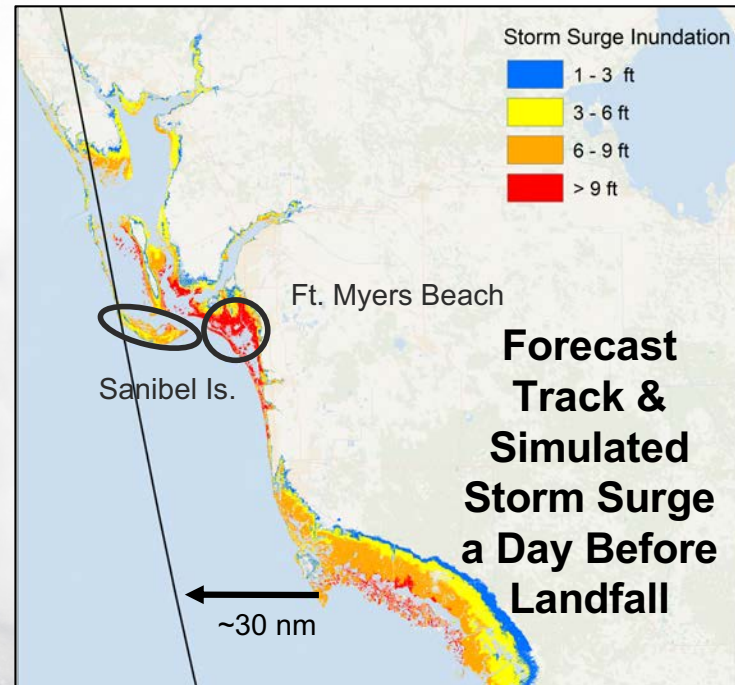
- “I didn’t know it would be this bad, I’ll never stay again”
- “This wasn’t that bad, I’ll never leave again”
- “It was nothing when I looked a few days ago” (anchoring)



Storm Surge Highly Sensitive to Track! Irma 2017



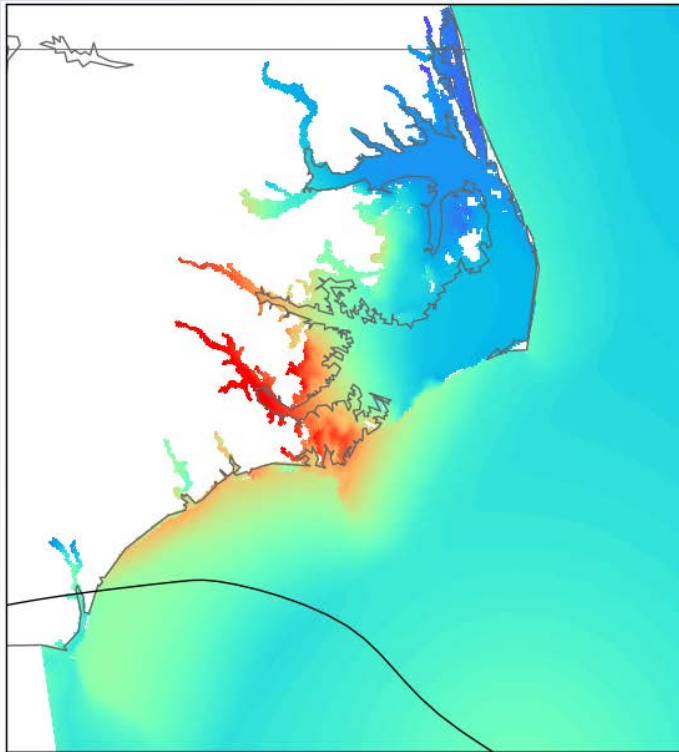
**~50,000 people
with 3+ foot surge**



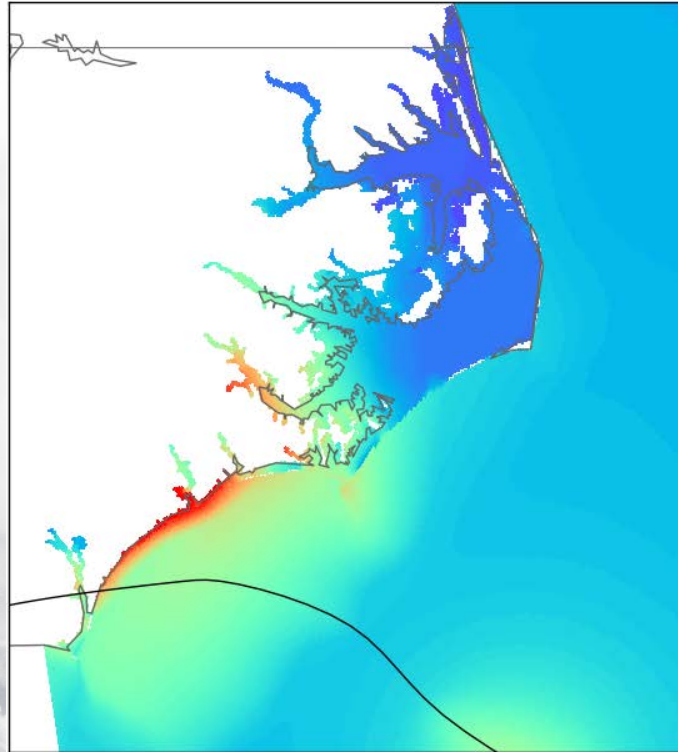
**~200,000 people
with 3+ foot surge**

Florence: Structure Matters

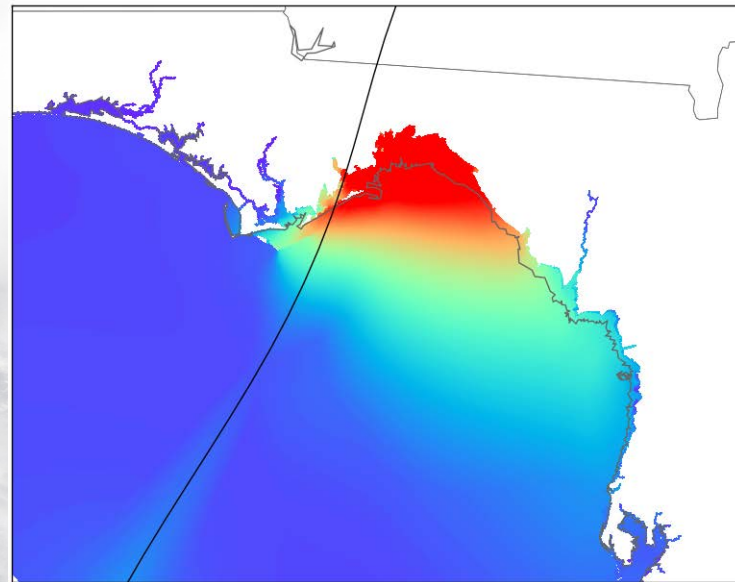
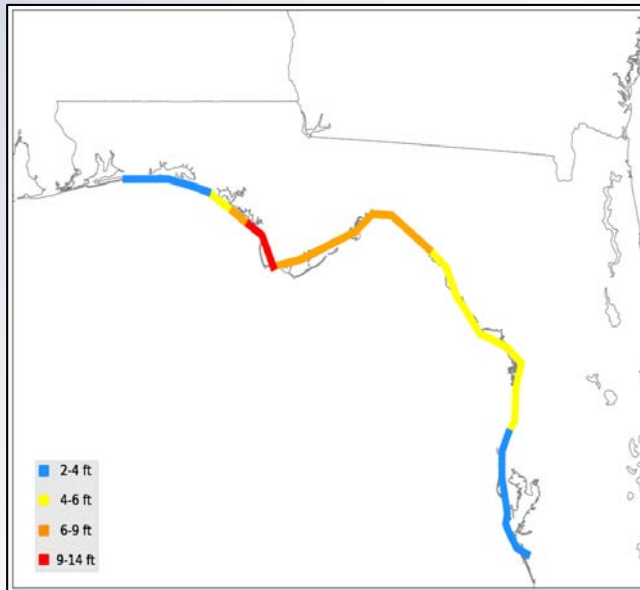
Best Track Deterministic



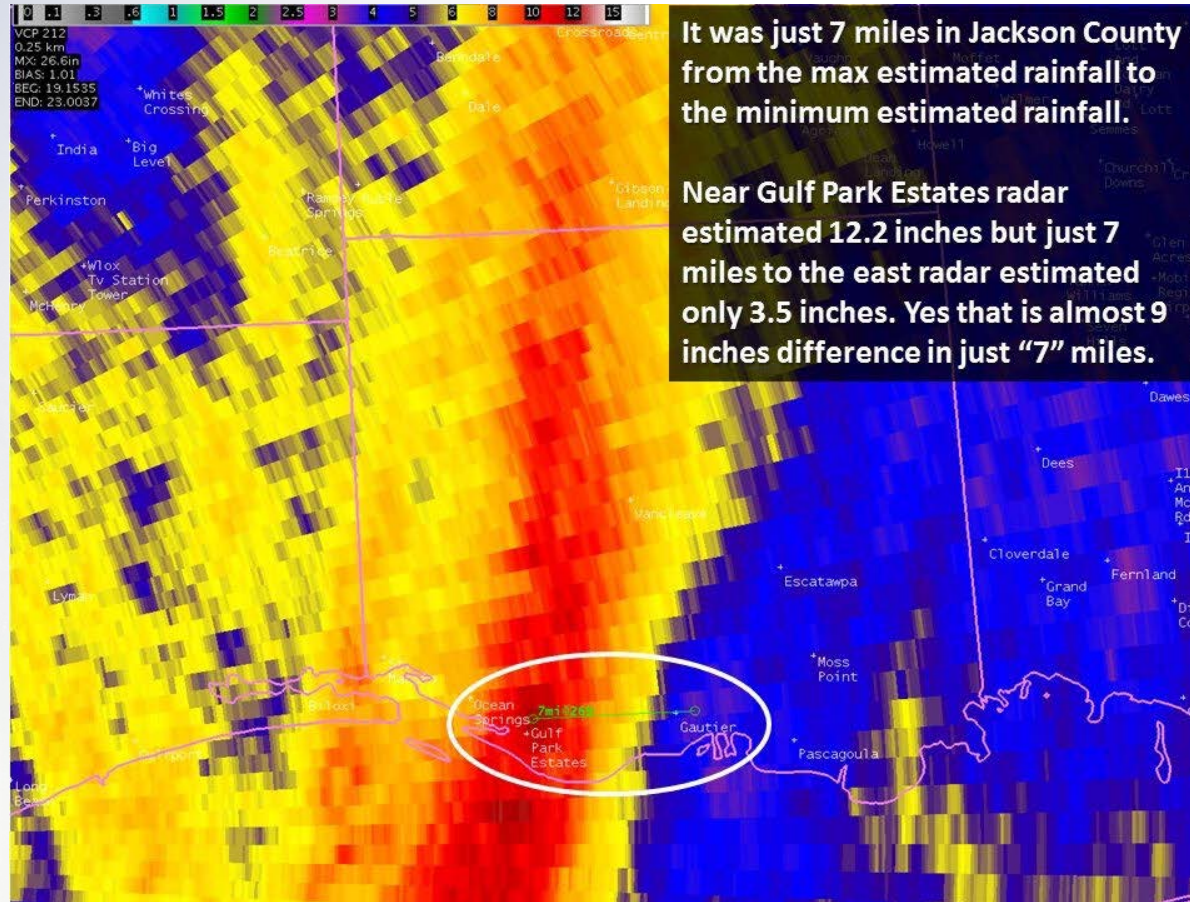
Stronger, Smaller Storm




Michael: Just a Little East



Experience Based Perceptions of Risk





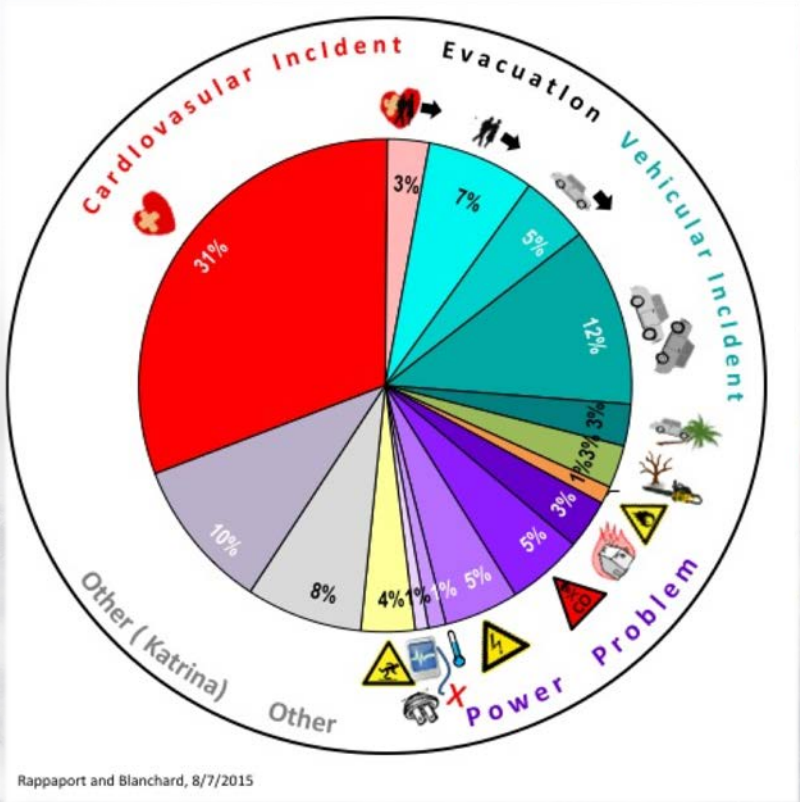
When you close your eyes, what do you see when you think of a hurricane?



**“The storm is past me,
I’m safe now”**

Indirect Fatalities

Longer-Term Impacts



Most frequent factors: cardiovascular, loss of electricity, vehicle accident, and evacuation

It's About the Impacts



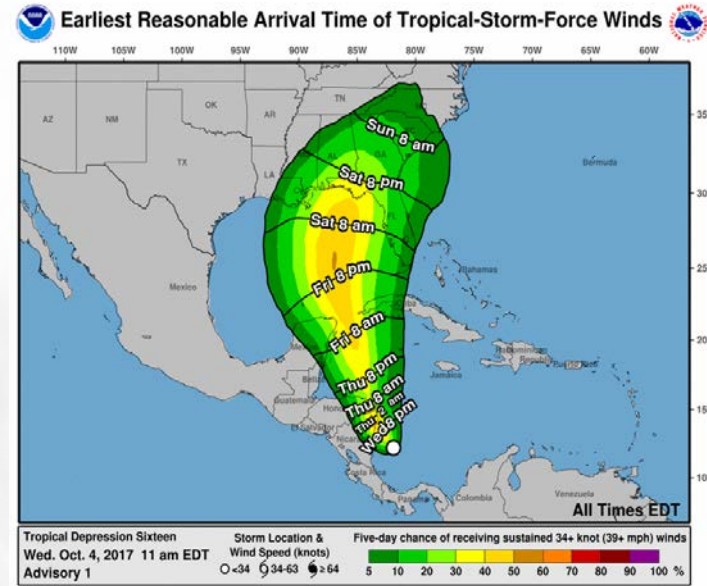
**Since 2010 in the U.S.,
Category 1 hurricanes***

**175 direct deaths
\$103 billion**

***Irene, Isaac, Sandy, Hermine, Matthew, Nate, Florence**



What are we doing about it?

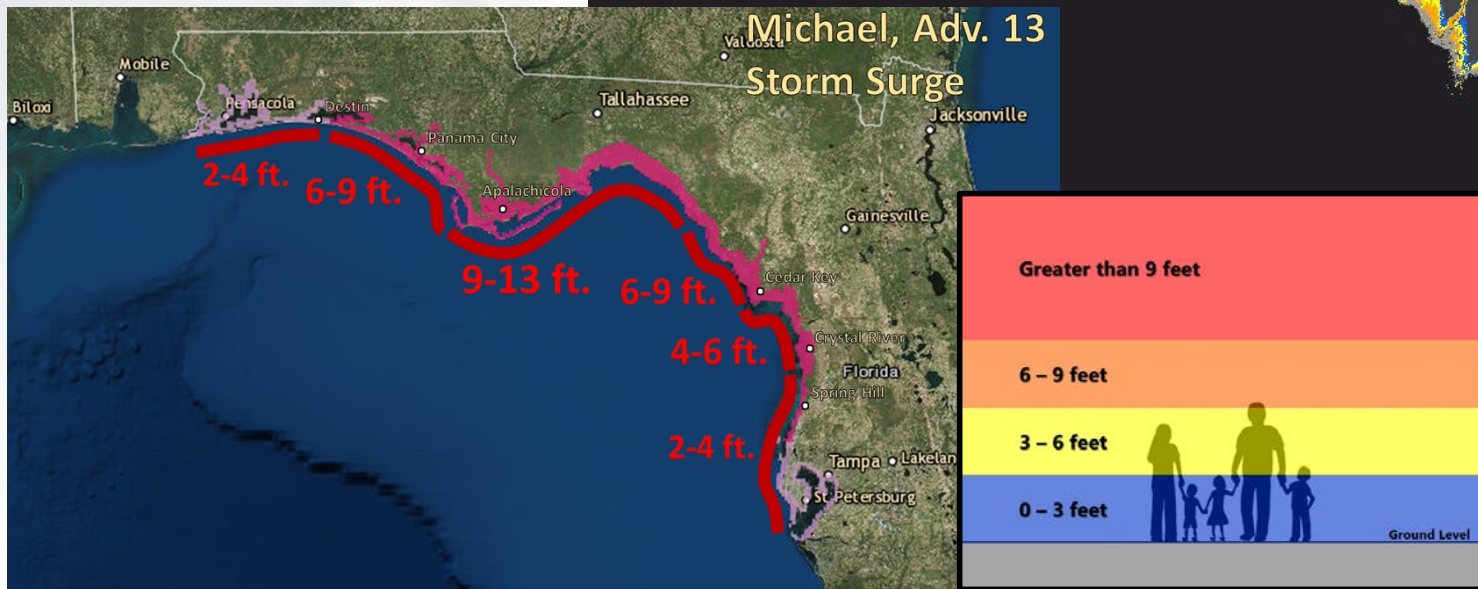
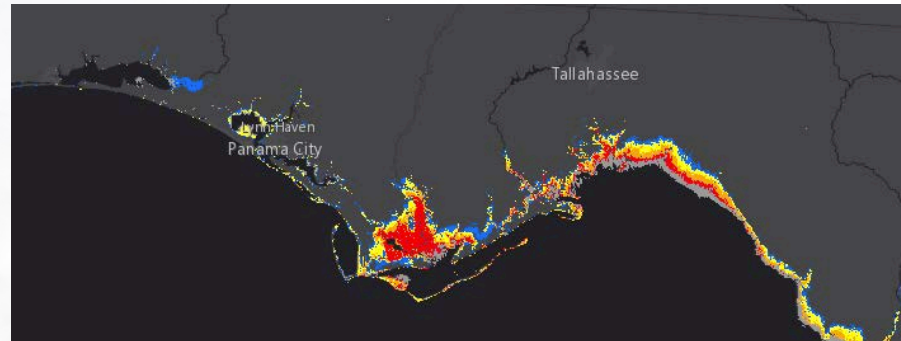


Mostly likely time somebody could see tropical storm force winds...

...but they could start as early as...

What are we doing about it?

Storm Surge Products Provide
"Reasonable Worst-Case"
Scenario




What are we doing about it?

Key Messages for Hurricane Michael
Advisory 8: 11:00 AM EDT Mon Oct 08, 2018

1. Michael is forecast to be a dangerous major hurricane when it reaches the northeastern Gulf Coast on Wednesday, and life-threatening storm surge is possible along portions of the Florida Gulf Coast regardless of the storm's exact track or intensity. Residents in the storm surge and hurricane watch areas should follow any advice given by local officials, as storm surge and hurricane warnings will likely be issued later today.
2. Heavy rainfall from Michael could produce life-threatening flash flooding from the Florida Panhandle and Big Bend region into portions of the Carolinas through Thursday.
3. Hurricane conditions will spread over portions of western Cuba this afternoon, where a hurricane warning is now in effect. Tropical storm conditions are expected over the northeastern Yucatan Peninsula and the Isle of Youth today.
4. Michael is expected to produce heavy rainfall and flash flooding over portions of western Cuba and the northeastern Yucatan Peninsula of Mexico during the next couple of days.

For more information go to [hurricanes.gov](#)



National Hurricane Center
@NHC_Atlantic

#Michael will continue to produce life-threatening hurricane-force winds well inland across portions of the Florida Panhandle, southeast Alabama, and southwestern Georgia this evening as the core of the hurricane continues to move inland. [hurricanes.gov](#)



Hurricanes and Tropical Storm Watches and Warnings

2:13 PM - 10 Oct 2018

NOAA NWS National Hurricane Center
October 10, 2018

NHC Director Ken Graham will provide a Facebook Live broadcast regarding Category 4 Hurricane Michael at 8:45 a.m. EDT (7:45 am CDT)



National Hurricane Center @NHC_Atlantic - 9 Oct 2018

#Michael is expected to produce a destructive & life-threatening storm surge along portions of the Florida Panhandle, Big Bend & Nature Coast on Wednesday & Wed night. The worst storm surge is expected to be between Mexico Beach & Keaton Beach with 9-13' of inundation possible.



Michael, Adv. 13
Storm Surge

Use of Twitter, Facebook, and Facebook Live to provide live storm updates

What are we doing about it?

2018 Season Web Hits: 9,632,372,000

2018 Max One Day Hits: Sept 12, 2 days before Florence landfall, 739,965,060

June 1 to November 30 unique devices: 32,155,492

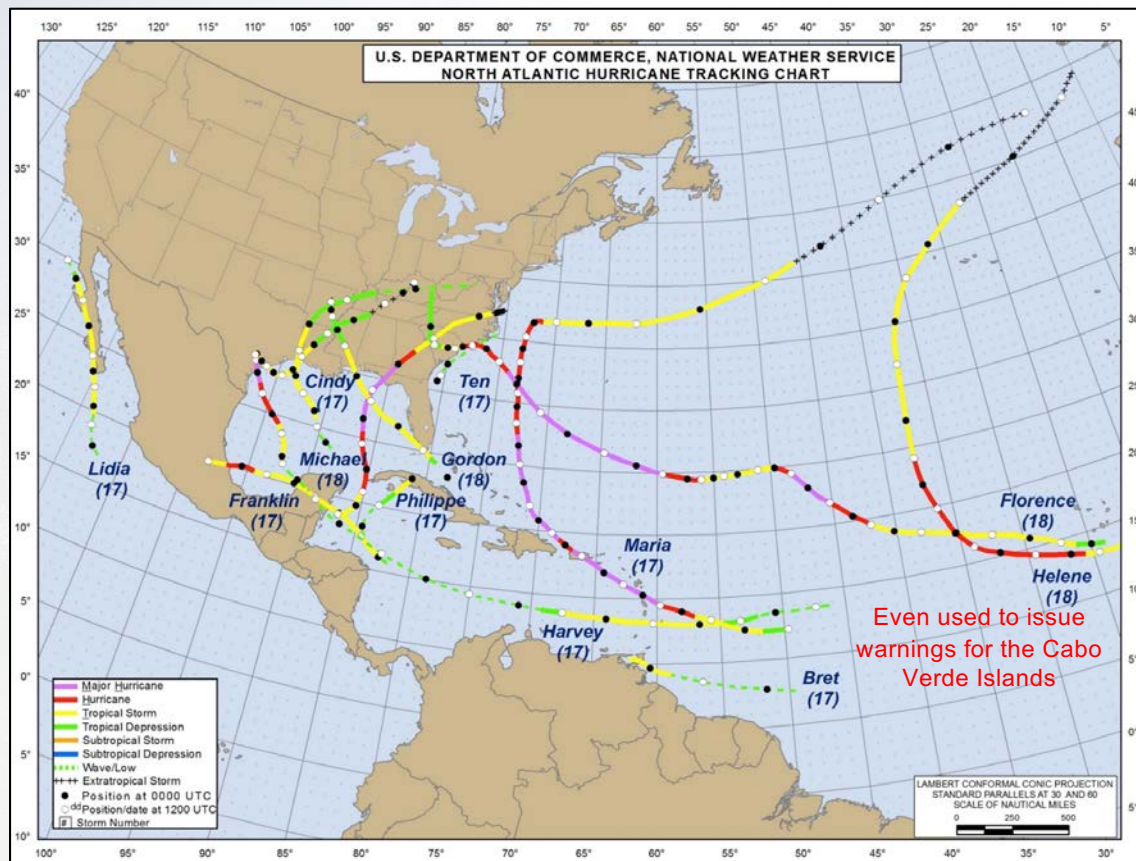
Live Internet Broadcasts in Florence and Michael: 1.5 million viewers

Use of Twitter, Facebook, and Facebook Live to provide live storm updates



What are we doing about it?

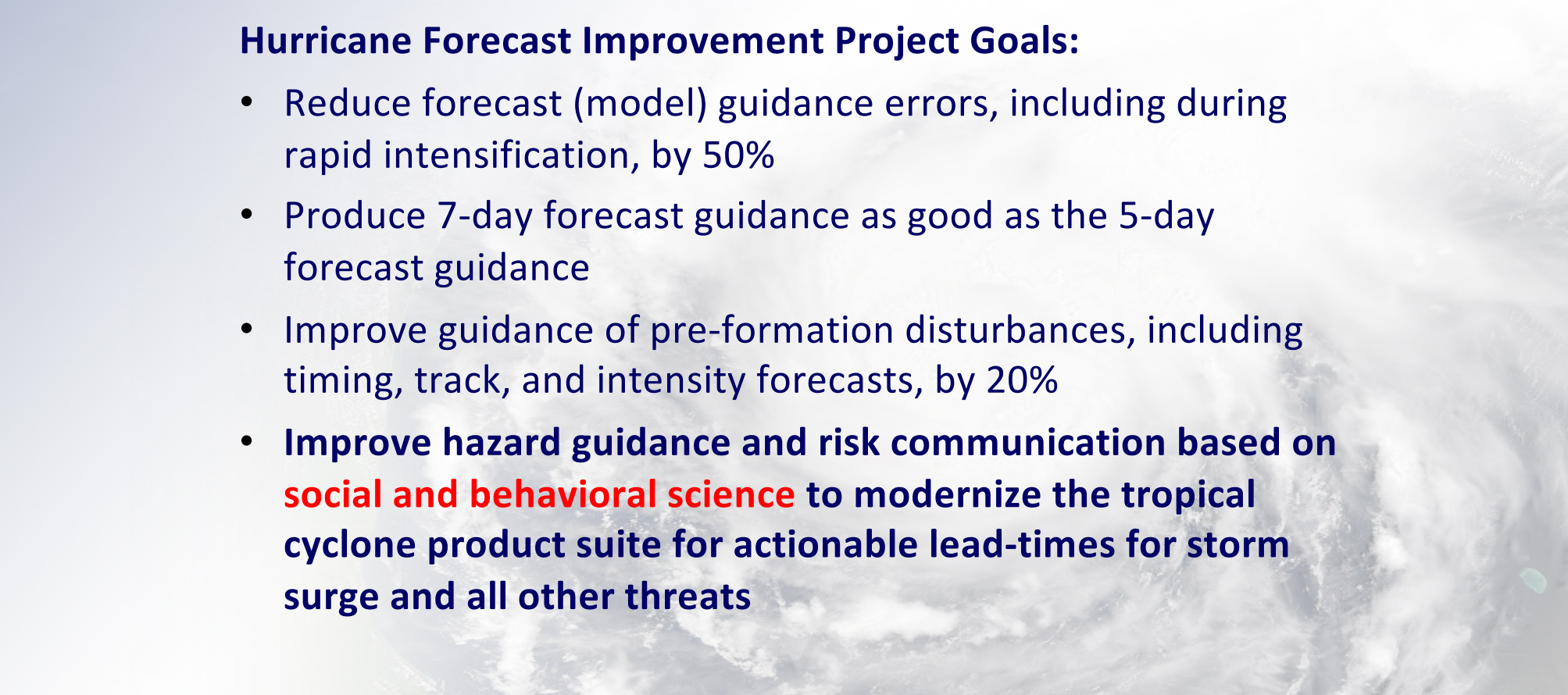
Potential Tropical Cyclone (PTC) 2017-2018





Where to Next

Hurricane Forecast Improvement Project Goals:

- Reduce forecast (model) guidance errors, including during rapid intensification, by 50%
 - Produce 7-day forecast guidance as good as the 5-day forecast guidance
 - Improve guidance of pre-formation disturbances, including timing, track, and intensity forecasts, by 20%
 - **Improve hazard guidance and risk communication based on social and behavioral science to modernize the tropical cyclone product suite for actionable lead-times for storm surge and all other threats**
- 



Where to Next

- **Storm Surge model improvements**
 - Southeast Superbasin (SC, NC, GA)
 - Southern California (waves too)
 - Florida, New York, and NE US Superbasin
 - **Work to implement SLOSH international locations as part of NHC's regional support to World Meteorological Organization**
 - **Incorporation of waves into the SLOSH model**
 - **Storm Surge real-time storm surge guidance from current 48 hours to 72 hours**
 - **Potential Tropical Cyclone products over marine only areas in addition to current land threat issuance**
- 



Where to Next

- **Hurricane Forecast Improvement Project**
 - Web-based survey on economic value of improved forecasts
 - Use study for the Cone of Uncertainty
- **Supplemental**
 - Wait, that forecast changed? – Assess consumption and processing of a changing forecast
 - NHC website – Optimizing tropical cyclone information
 - Minding the Gap – looking at the product suite by evaluating partner needs
 - There's a Chance of What? – numeracy analysis of forecasters, partners, and the public when it comes to uncertainty products