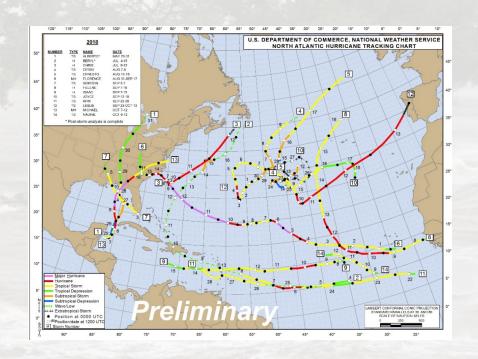# Water Impacts from Recent U.S. Landfalling Tropical Cyclones
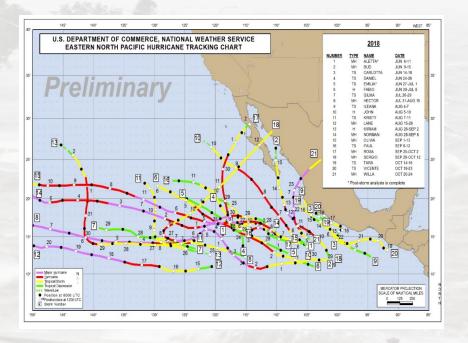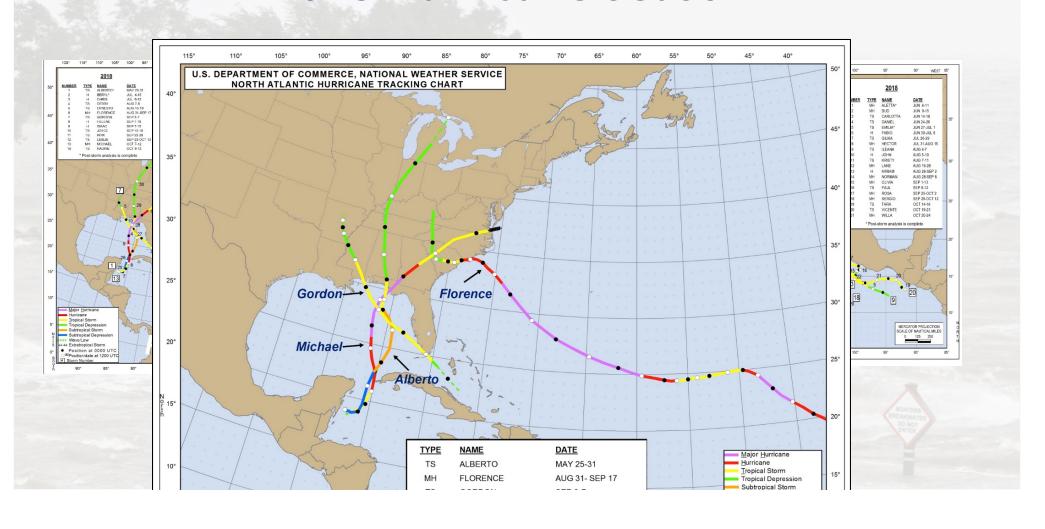
Ken Graham
National Hurricane Center
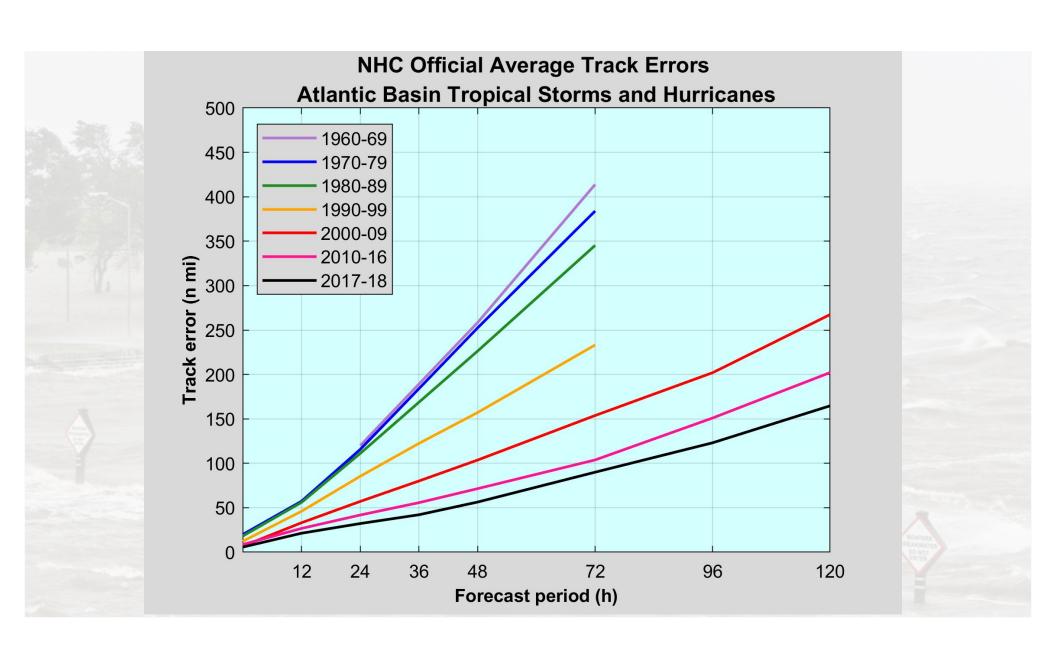
2018 Hurricane Season

2018 Hurricane Season

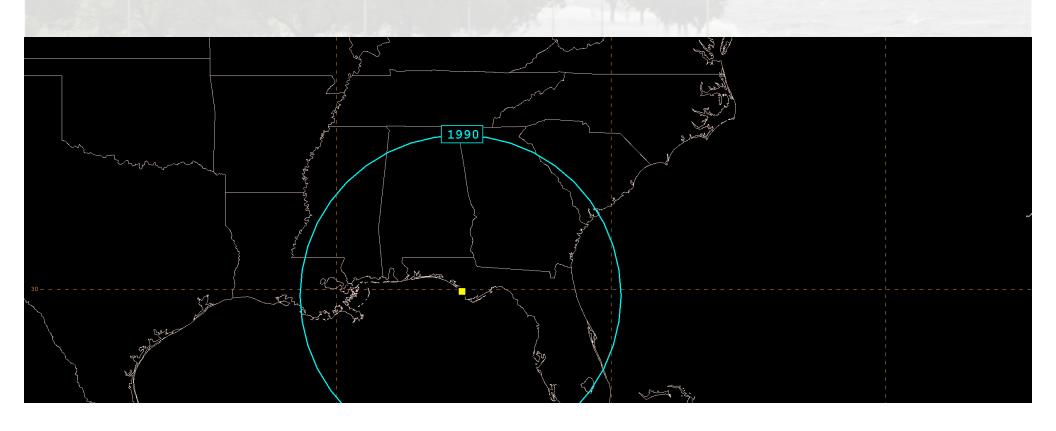NHC Official Average Track Errors
Atlantic Basin Tropical Storms and Hurricanes

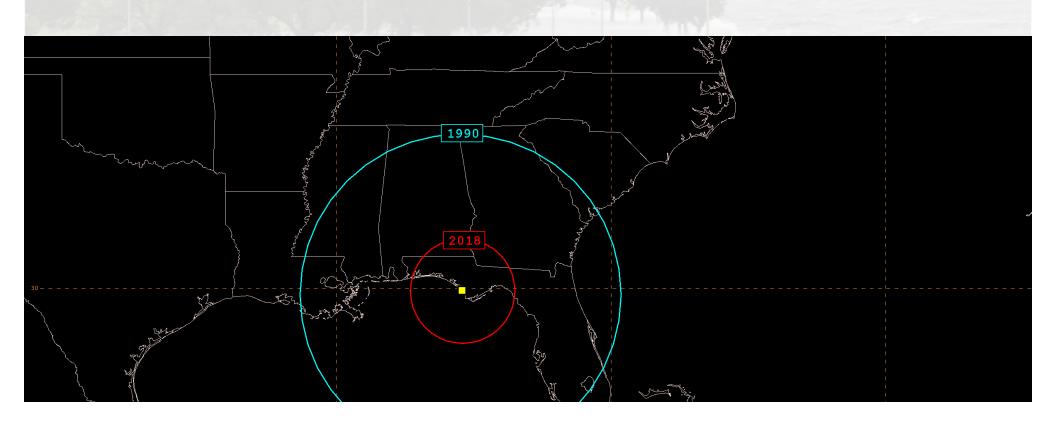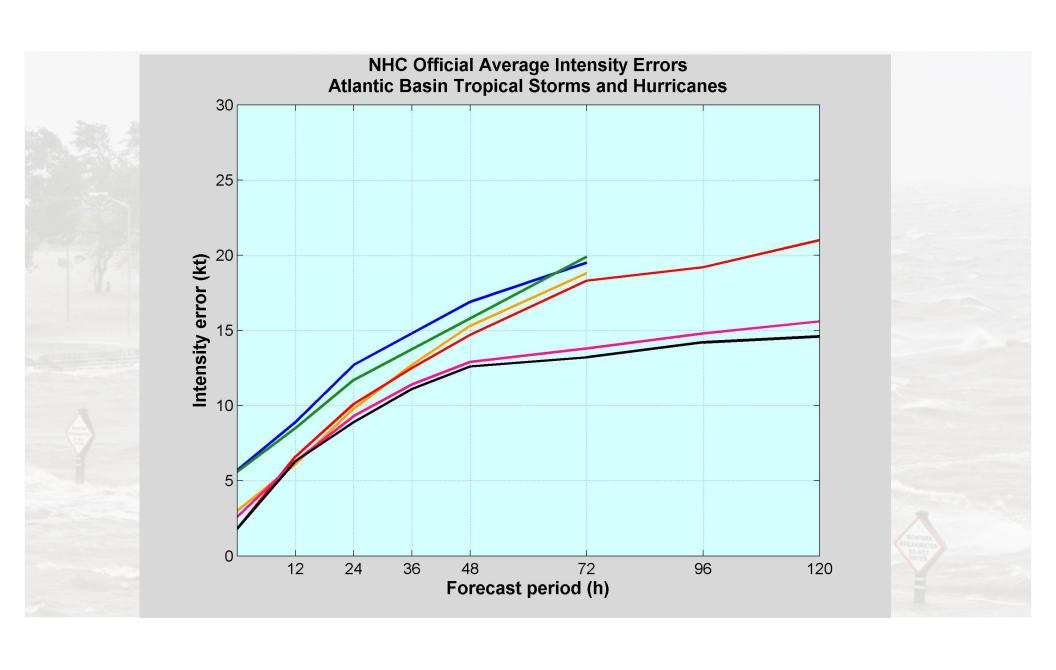# Improvements in Track Forecasting
3-day Forecasts in 1990

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**
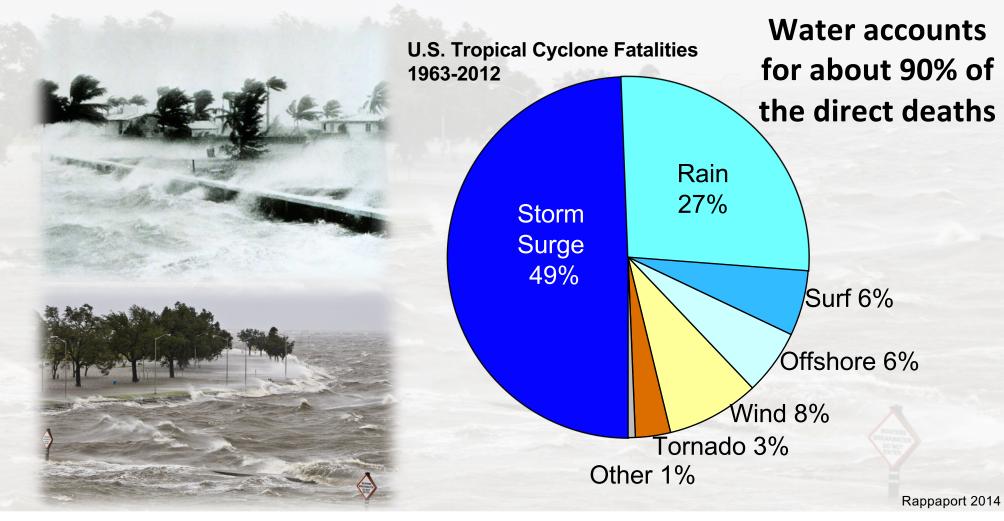
**Florence (2018) – 35.93/26.63 inches
North Carolina/South Carolina Record**
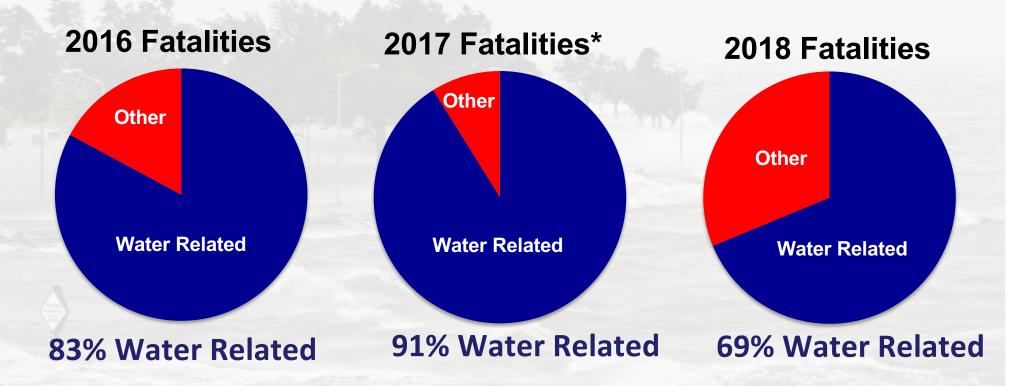
**Lane (2018) – 52.02 inches
Hawaii Record**

Water Continues to Kill

2016 Fatalities

2017 Fatalities*

2018 Fatalities

Other

Water Related

Other

Water Related

Other

Water Related

83% Water Related

91% Water Related

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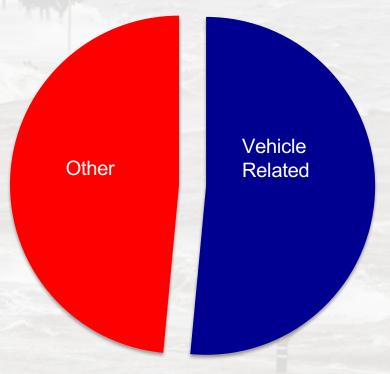
*excludes Maria due to uncertainty related to causes of direct deaths

Flood Related Vehicle Fatalities
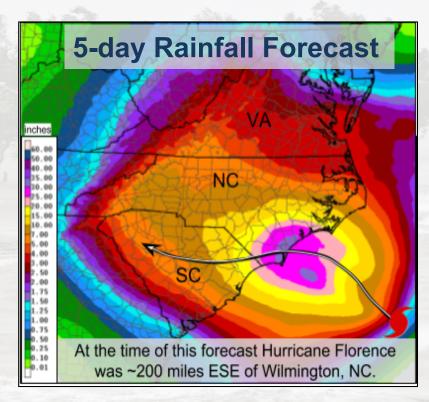
- During the past three seasons, *more than half* the U.S. tropical cyclone water-related fatalities were vehicle related!
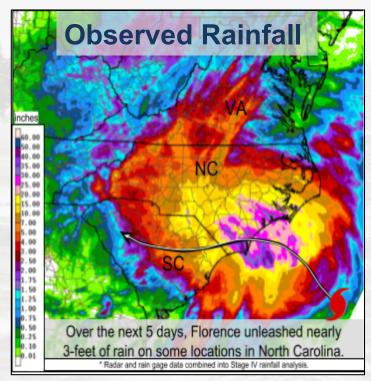
2016-18 U.S. Tropical Cyclone Water Related Fatalities
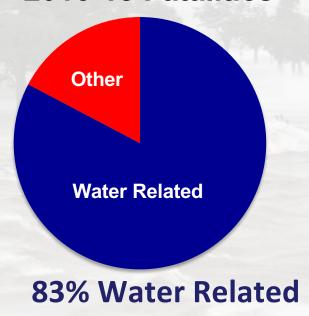
Other

Vehicle Related

ROAD CLOSED

Hurricane Florence

5-day Rainfall Forecast

At the time of this forecast Hurricane Florence was ~200 miles ESE of Wilmington, NC.

Observed Rainfall

Over the next 5 days, Florence unleashed nearly 3-feet of rain on some locations in North Carolina.
* Radar and rain gage data combined into Stage IV rainfall analysis.
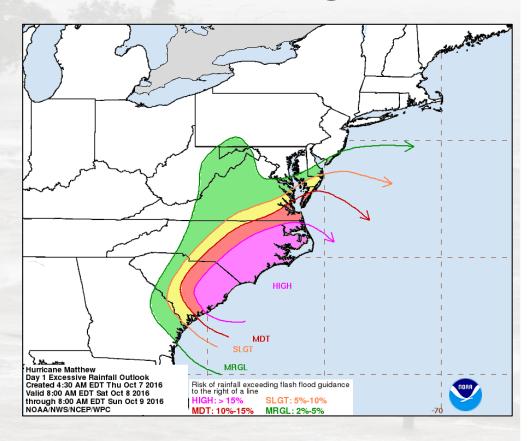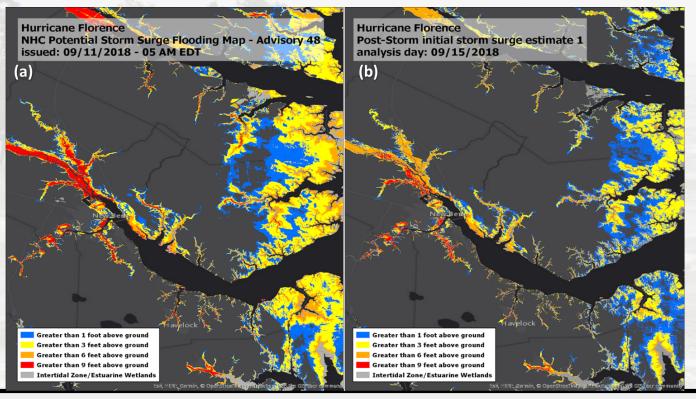
Excellent Forecasts – Yet 16 out of 17 flood related fatalities were in vehicles!

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**

Hurricane Matthew
Day 1 Excessive Rainfall Outlook
Created 4:30 AM EDT Thu Oct 7 2016
Valid 8:00 AM EDT Sat Oct 8 2016
through 8:00 AM EDT Sun Oct 9 2016
NOAA/NWS/NCEP/WPC

Risk of rainfall exceeding flash flood guidance
to the right of a line
HIGH: > 15%   SLGT: 5%-10%
MDT: 10%-15%   MRGL: 2%-5%

Storm Surge Forecasting

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

*excludes Maria due to uncertainty related to causes of direct deaths
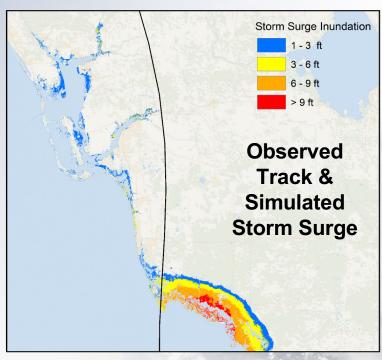
# Public Risk Perception Based on Previous Experience

- **"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"**
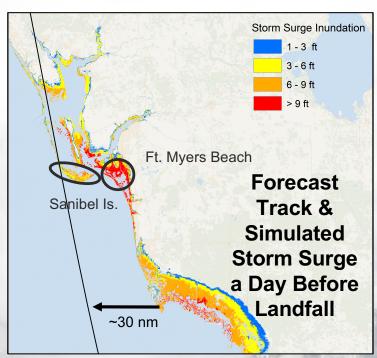
Public Risk Perception Based on Previous Experience

- **"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

Observed Track & Simulated Storm Surge

Storm Surge Inundation
- 1 - 3 ft
- 3 - 6 ft
- 6 - 9 ft
- > 9 ft

~50,000 people with 3+ foot surge

Forecast Track & Simulated Storm Surge a Day Before Landfall

Storm Surge Inundation
- 1 - 3 ft
- 3 - 6 ft
- 6 - 9 ft
- > 9 ft

Ft. Myers Beach

Sanibel Is.

~30 nm
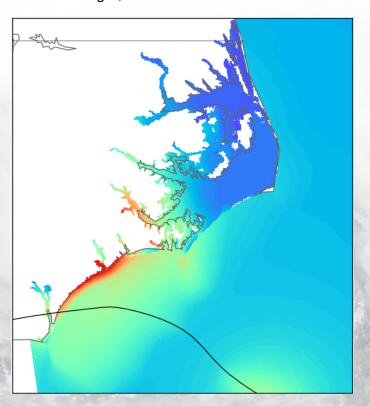
~200,000 people with 3+ foot surge
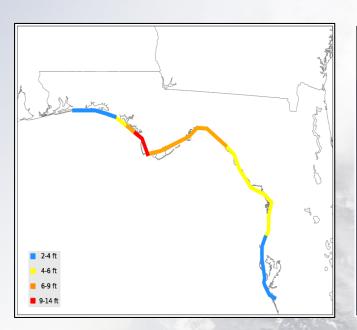
Florence: Structure Matters
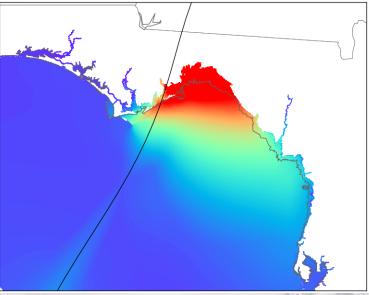
Best Track Deterministic

Stronger, Smaller Storm
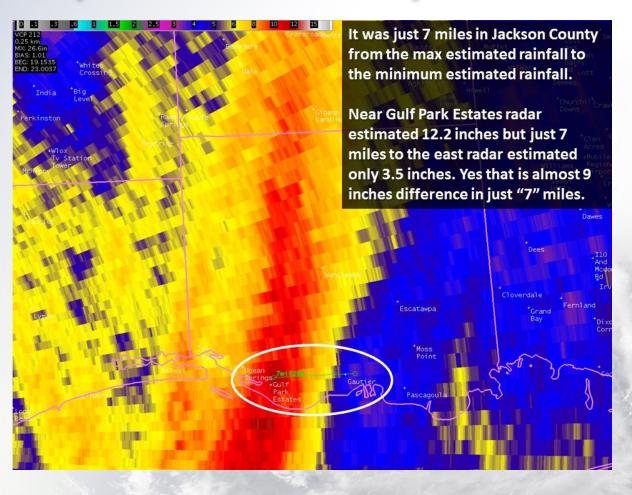
Michael: Just a Little East

2-4 ft
4-6 ft
6-9 ft
9-14 ft

Experience Based Perceptions of Risk

It was just 7 miles in Jackson County from the max estimated rainfall to the minimum estimated rainfall.

Near Gulf Park Estates radar estimated 12.2 inches but just 7 miles to the east radar estimated only 3.5 inches. Yes that is almost 9 inches difference in just "7" miles.
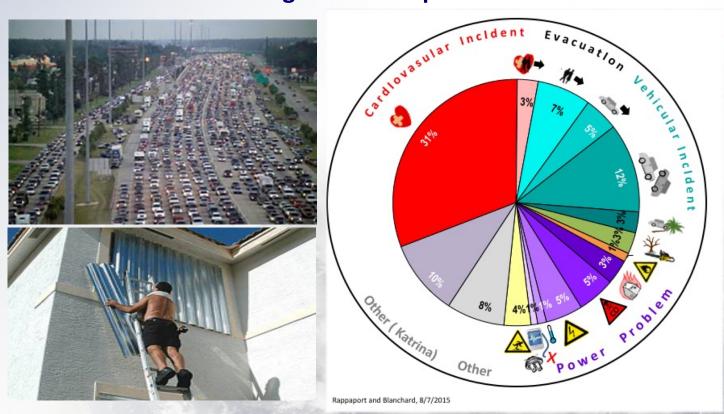
When you close your eyes, what do you see when you think of a hurricane?

"The storm is past me,
I'm safe now"

Indirect Fatalities
Longer-Term Impacts

Rappaport and Blanchard, 8/7/2015

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

It's About the Impacts
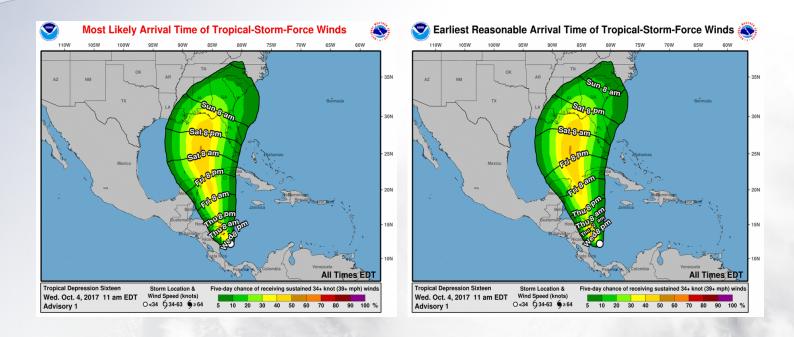
Since 2010 in the U.S., Category 1 hurricanes*
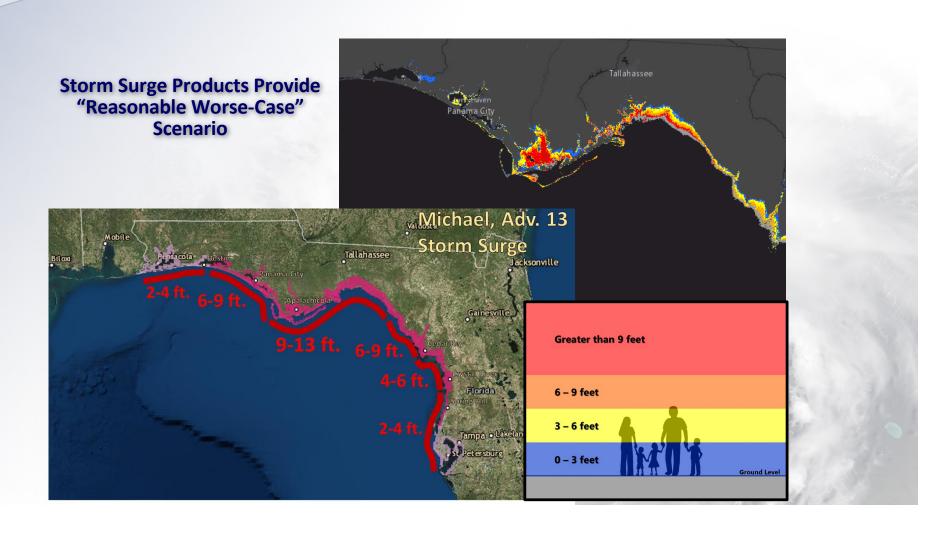
**175 direct deaths
$103 billion**
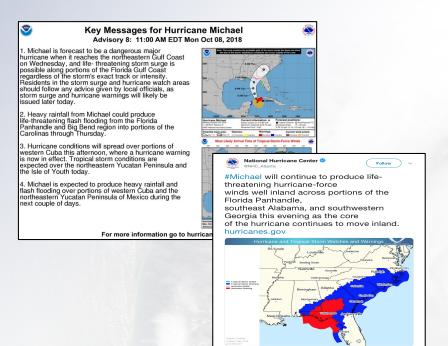
*Irene, Isaac, Sandy, Hermine, Matthew, Nate, Florence

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 Worse-Case" Scenario

Michael, Adv. 13 Storm Surge

2-4 ft.   6-9 ft.

9-13 ft.   6-9 ft.

4-6 ft.

2-4 ft.

Greater than 9 feet

6 – 9 feet

3 – 6 feet

0 – 3 feet

Ground Level

What are we doing about it?

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
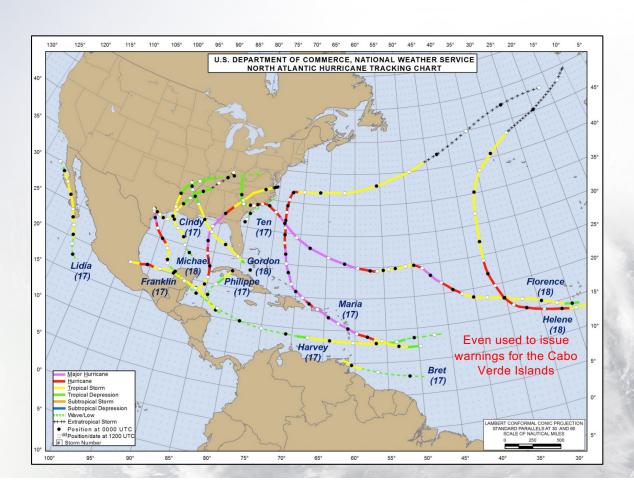
Live Internet Broadcasts in Florence and Michael: 1.5 million viewers

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)

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

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

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