



# **Unit 3: Understanding Forecast Uncertainty**

# Unit 3 Objectives



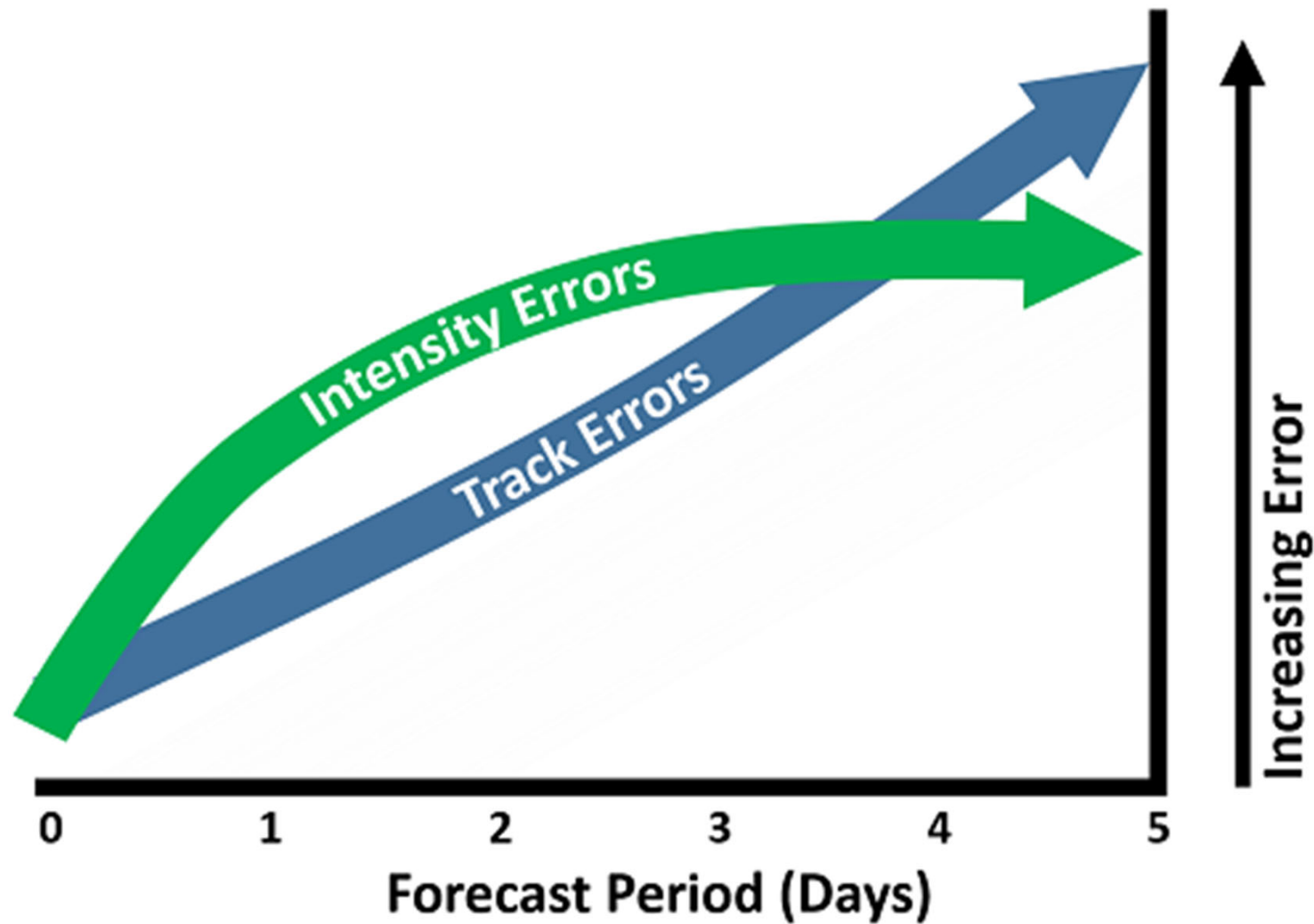
At the end of this unit, you should be able to:

1. Explain the meaning of “uncertainty” as it relates to NWS forecasts.
2. Explain what “59% chance of TS-force winds” (or similar probability) means.
3. Discuss the challenges inherent to rainfall and inland flooding forecasting.

# Forecast Errors



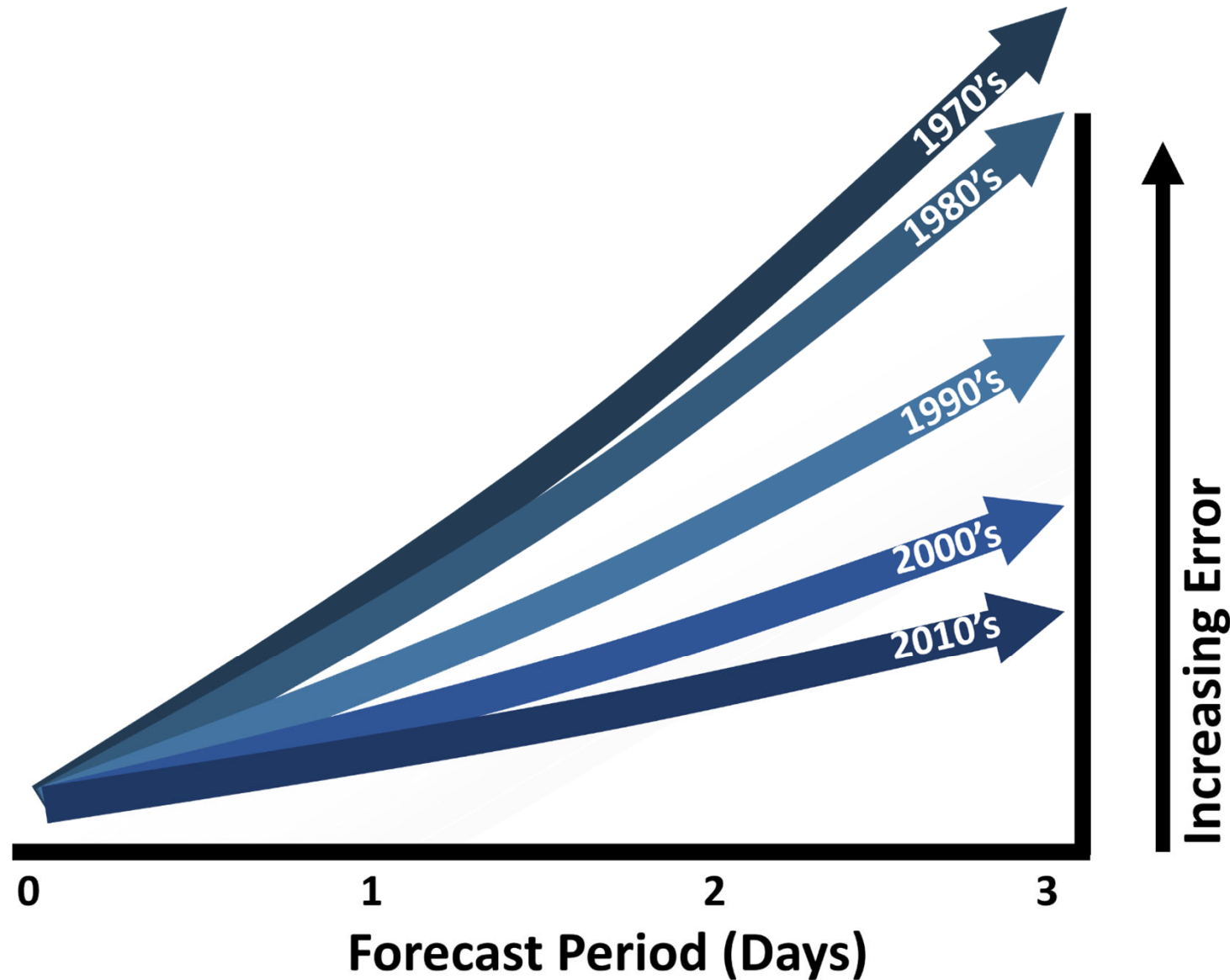
FEMA



# Forecasts are Improving, But Not Perfect



FEMA



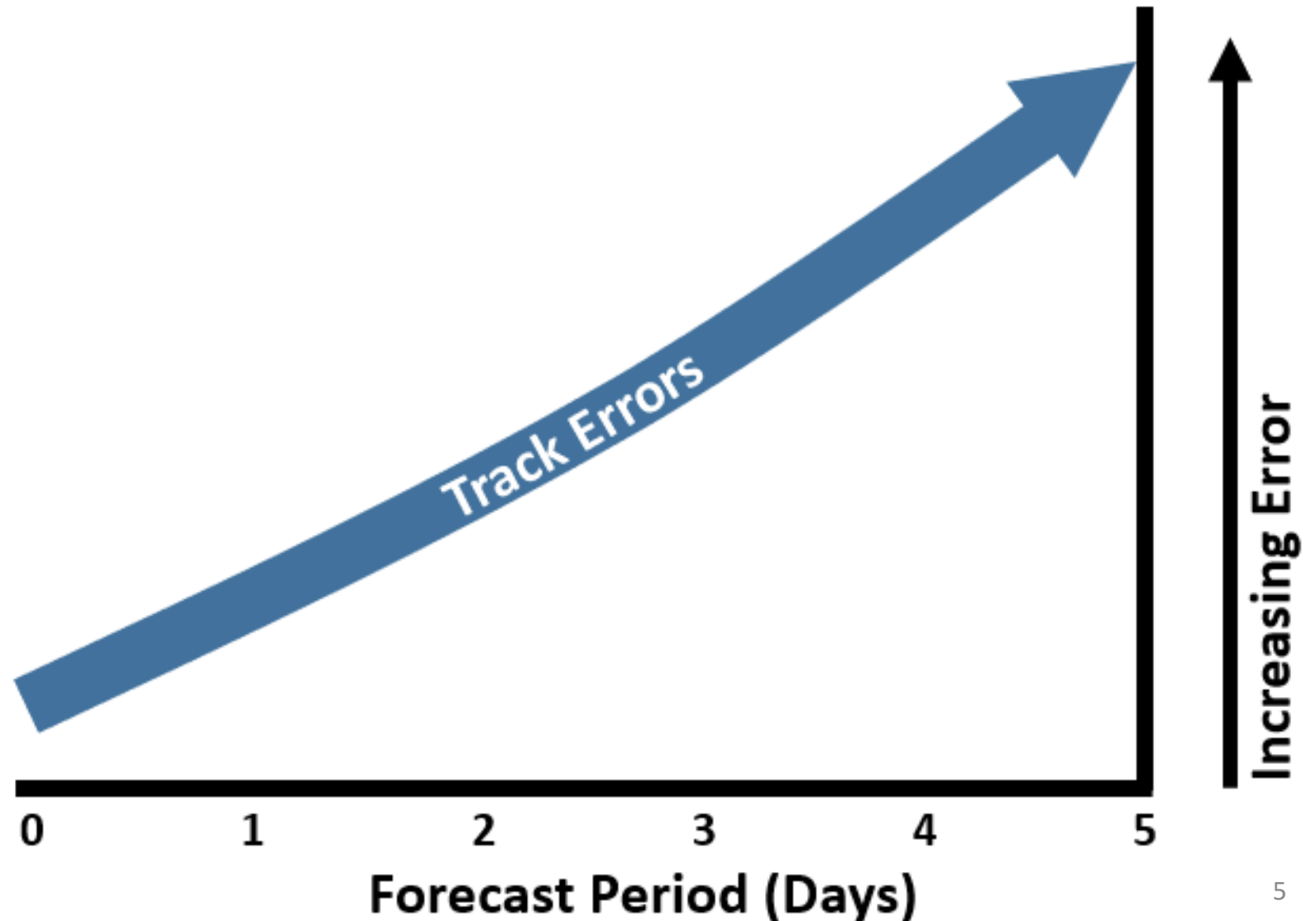
# NHC 5-Year Averages: Track Errors



FEMA

## Track Errors

- Increase 40 miles (35 nautical miles (nm)) per day

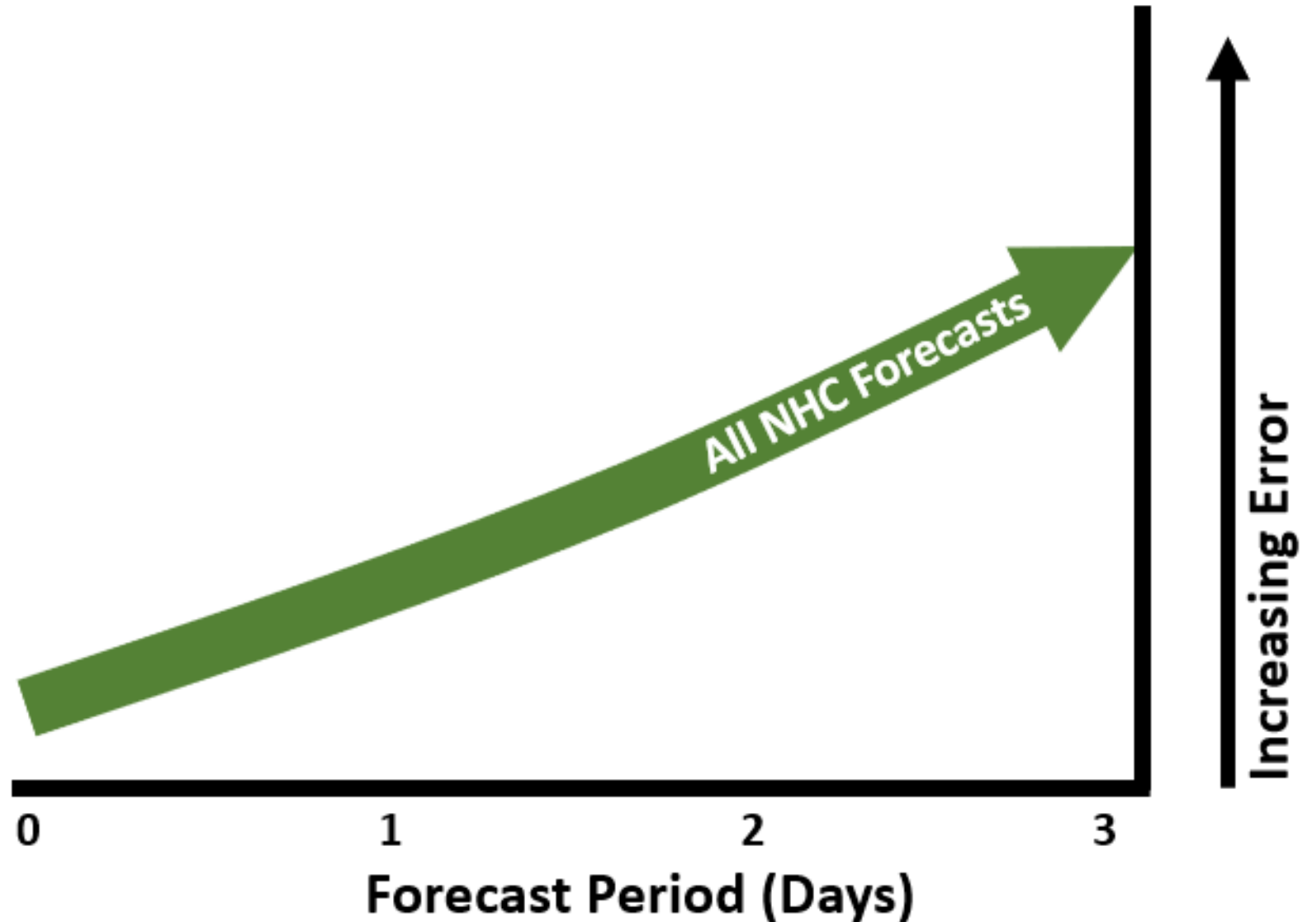


# Track Errors – All NHC Forecasts



## All NHC Forecasts

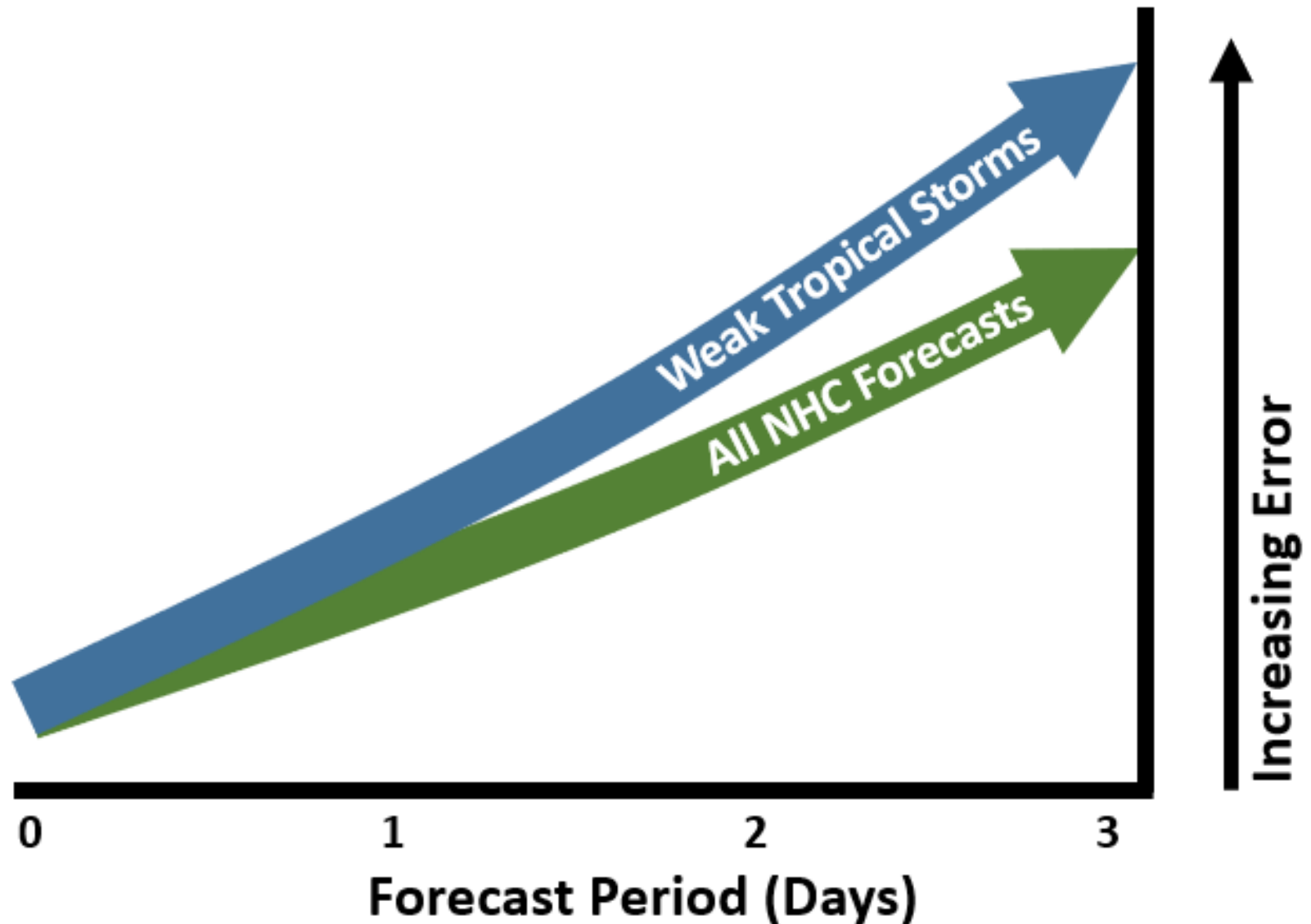
- Track errors increase about 35–40 miles per day



# Track Errors – Weak TS

## Weak Tropical Storms

- Track errors increase about 40–45 miles per day



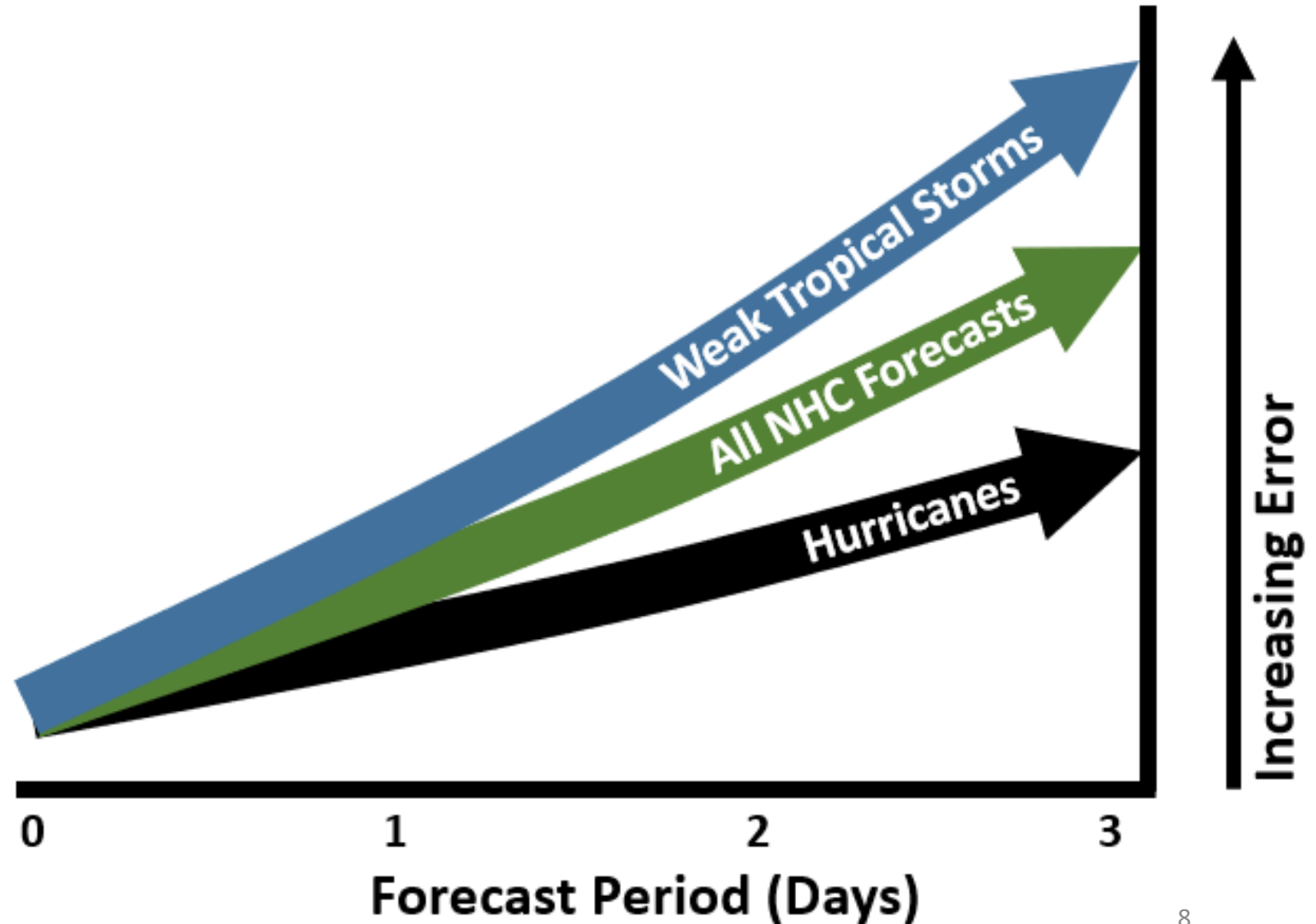
# Track Errors – Hurricane



FEMA

## Hurricanes

- Track errors increase about 25–30 miles per day





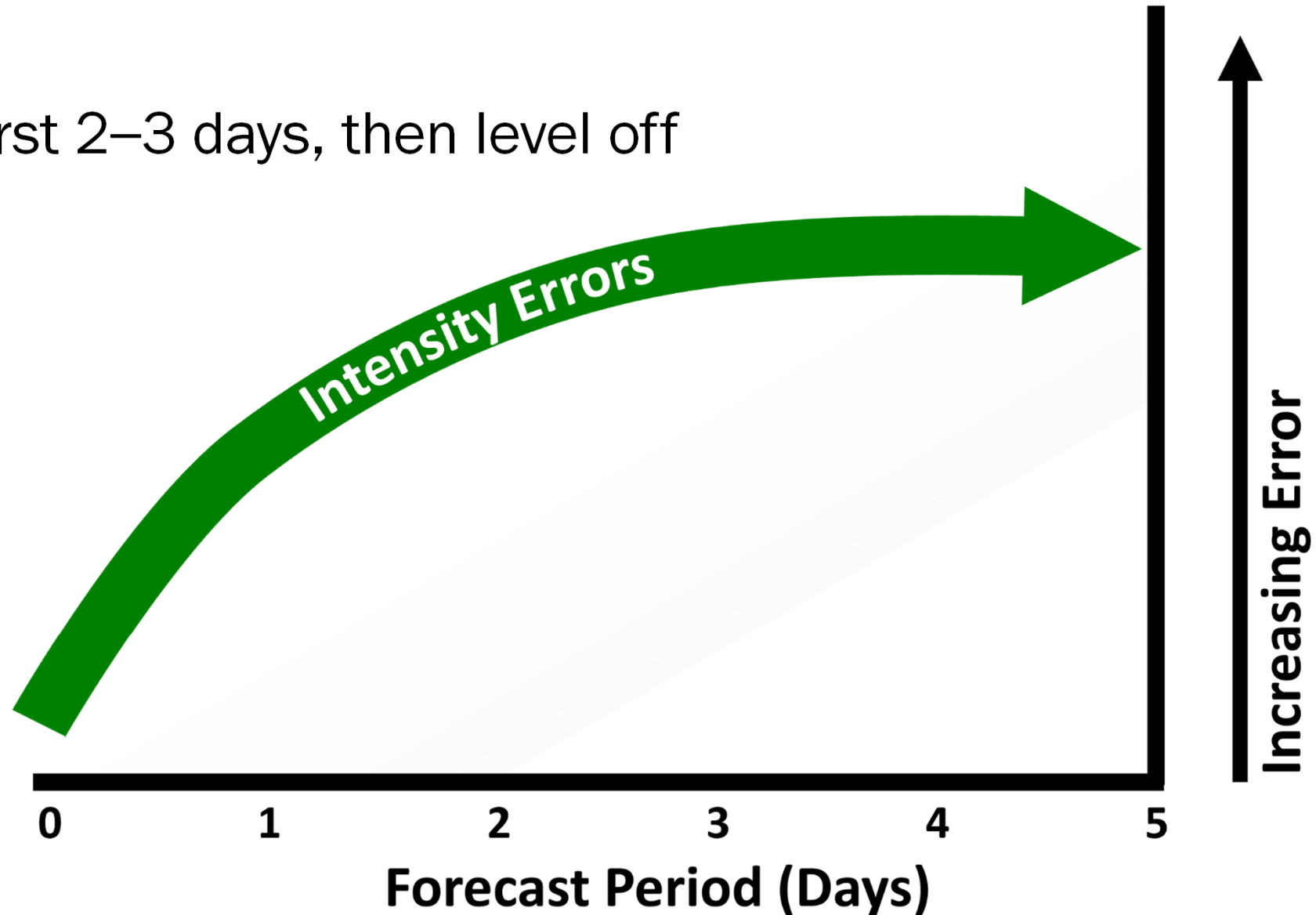
# NHC 5-Year Averages: Intensity Errors



FEMA

## Intensity Errors

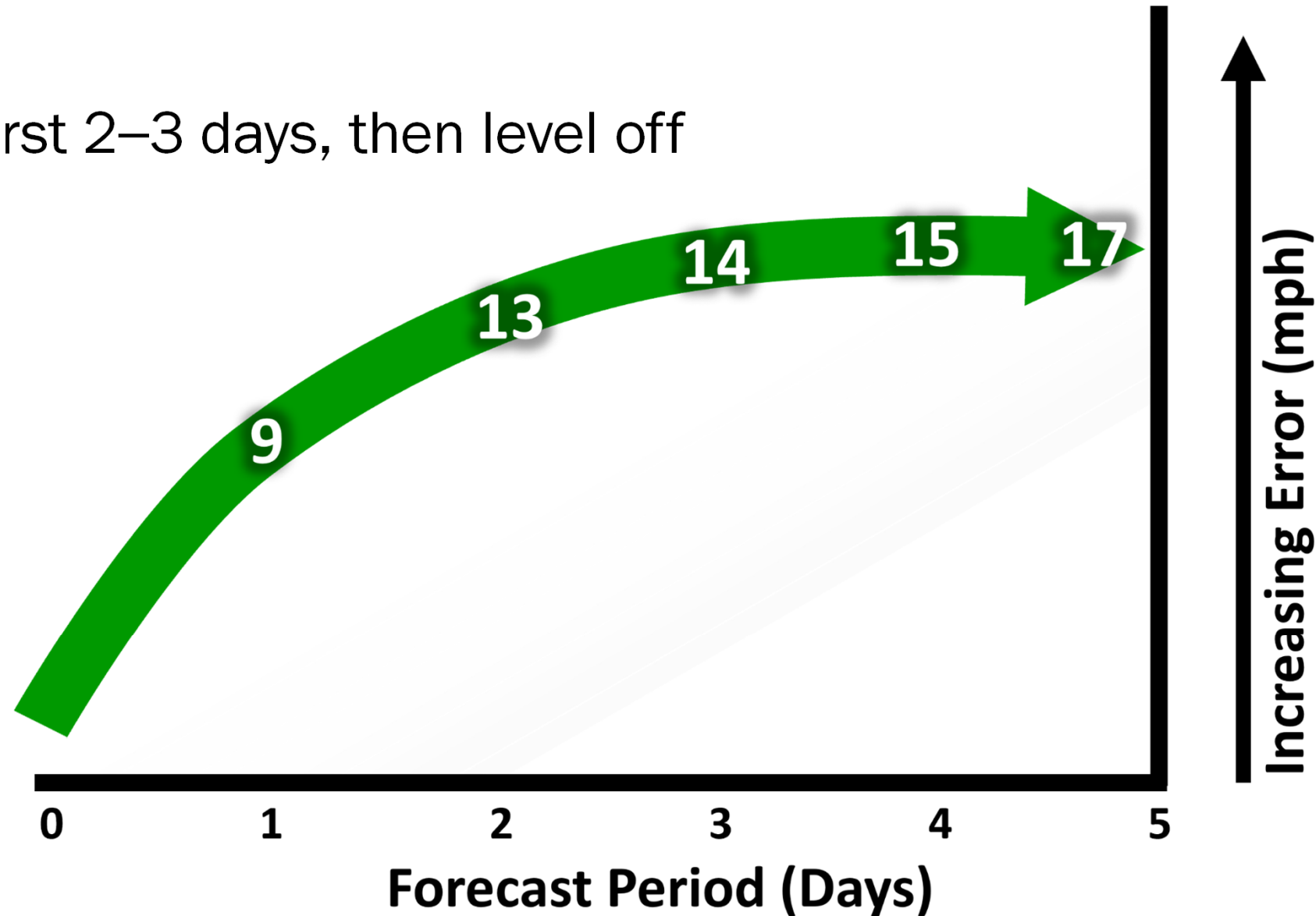
- Increase the first 2–3 days, then level off



# Intensity Errors Over 5 Days

## Intensity Errors

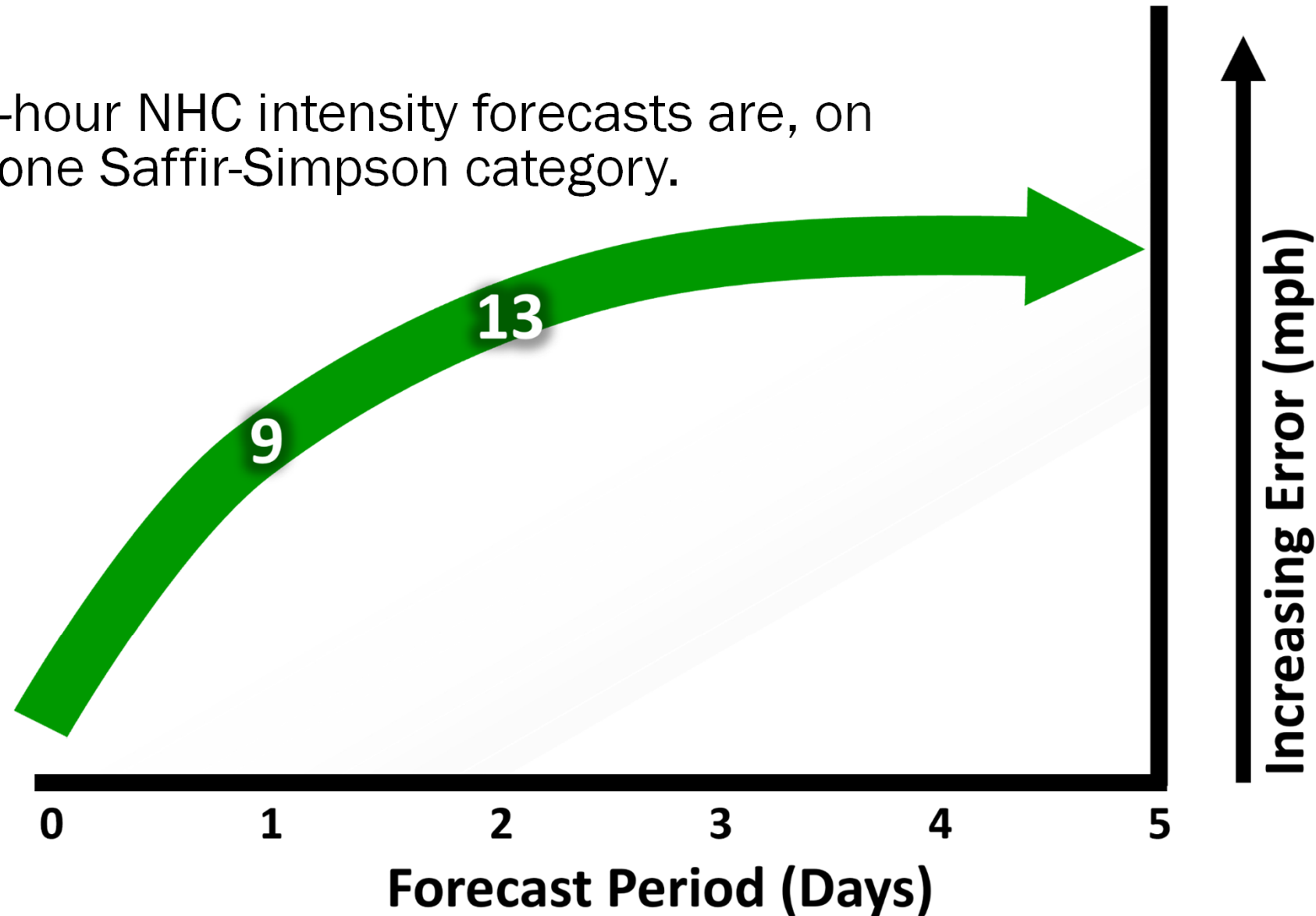
- Increase the first 2–3 days, then level off



# Intensity Error Over 48 Hours

## Intensity Errors

- The 24- and 48-hour NHC intensity forecasts are, on average, off by one Saffir-Simpson category.

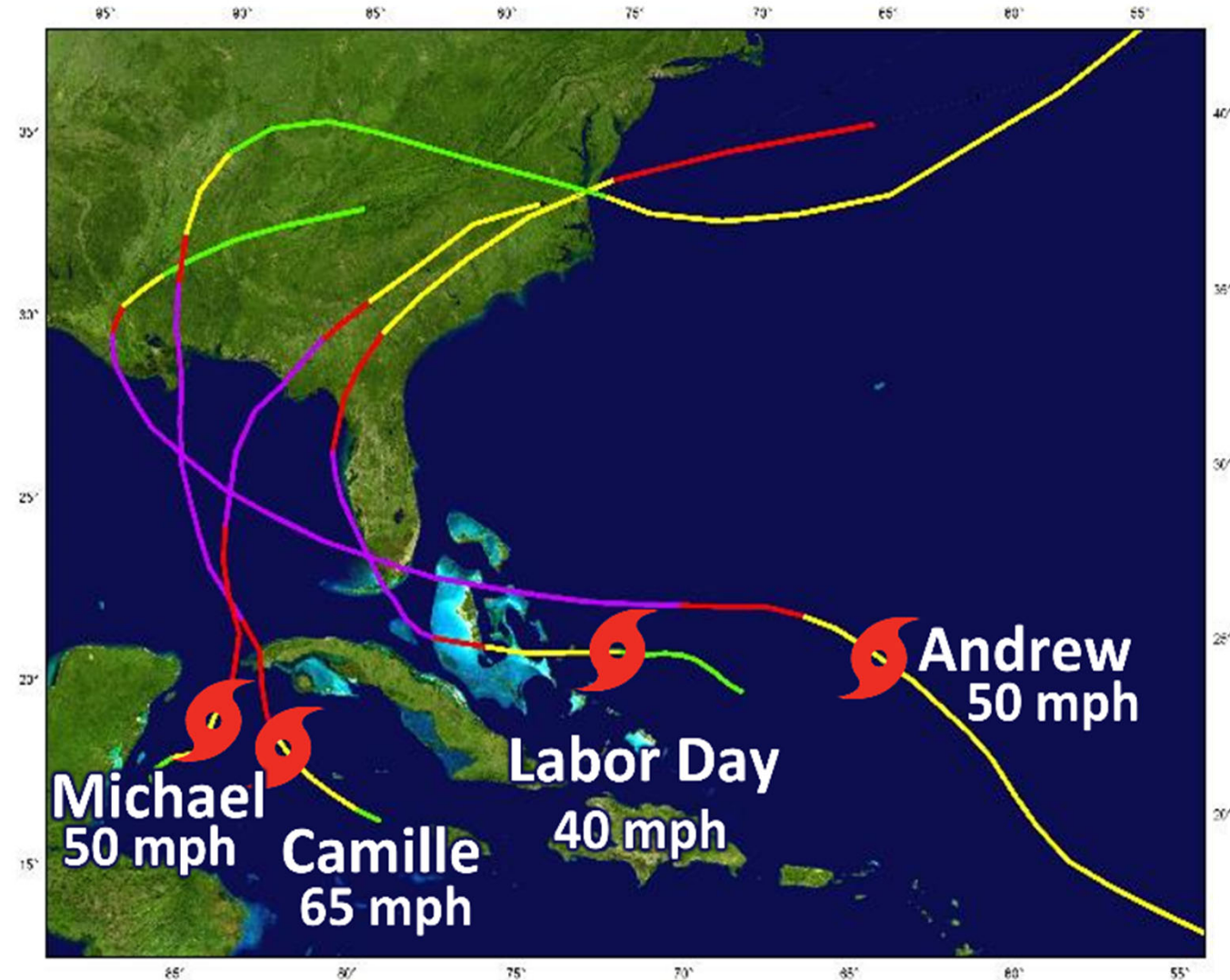


# Rapid Intensification

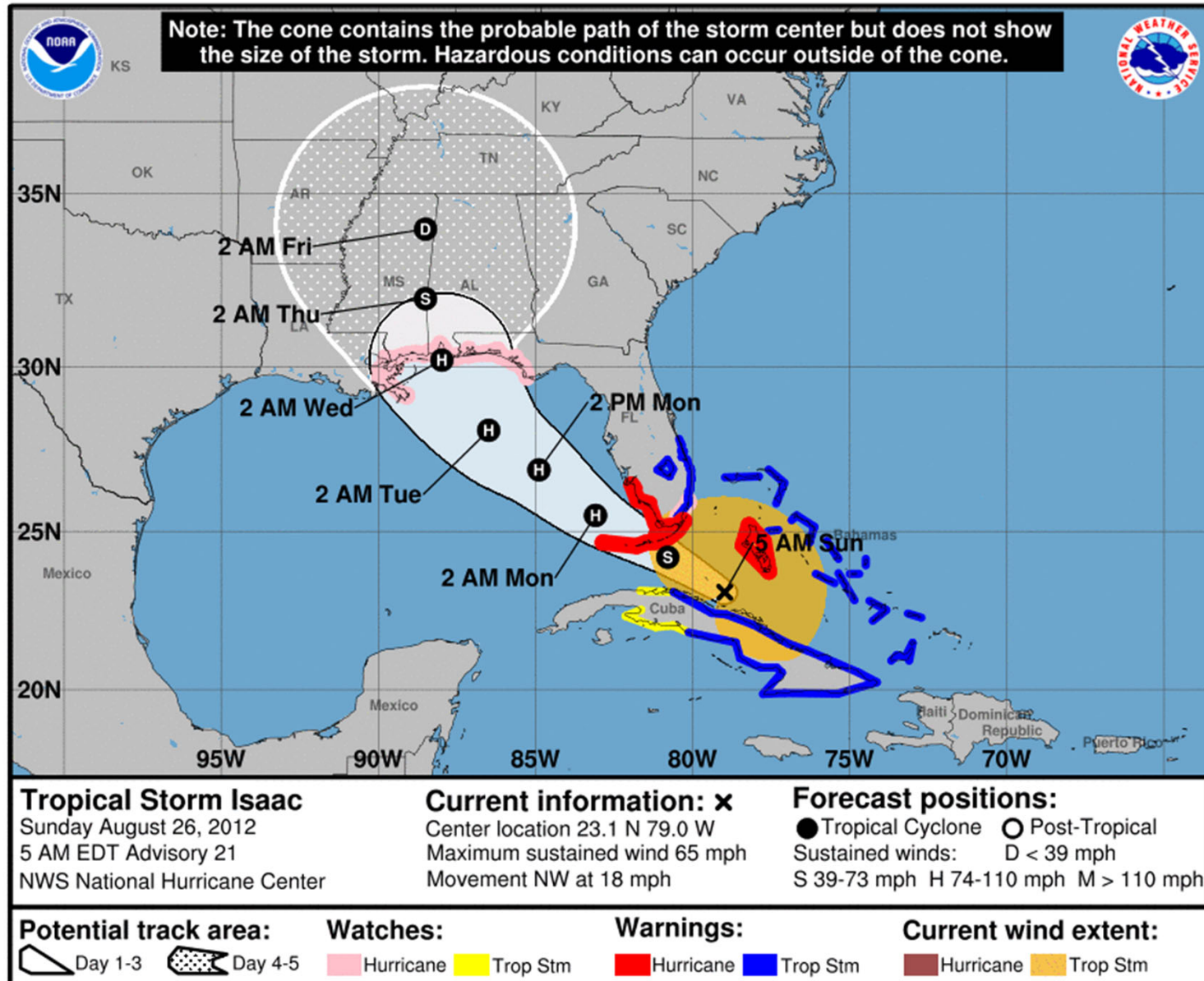
- Increase in the maximum sustained winds of at least 30 kts (35 mph) in a 24-hour period

Where were these Category 5 hurricanes 3 days before landfall?

- Labor Day (1935)
- Camille (1969)
- Andrew (1992)
- Michael (2018)



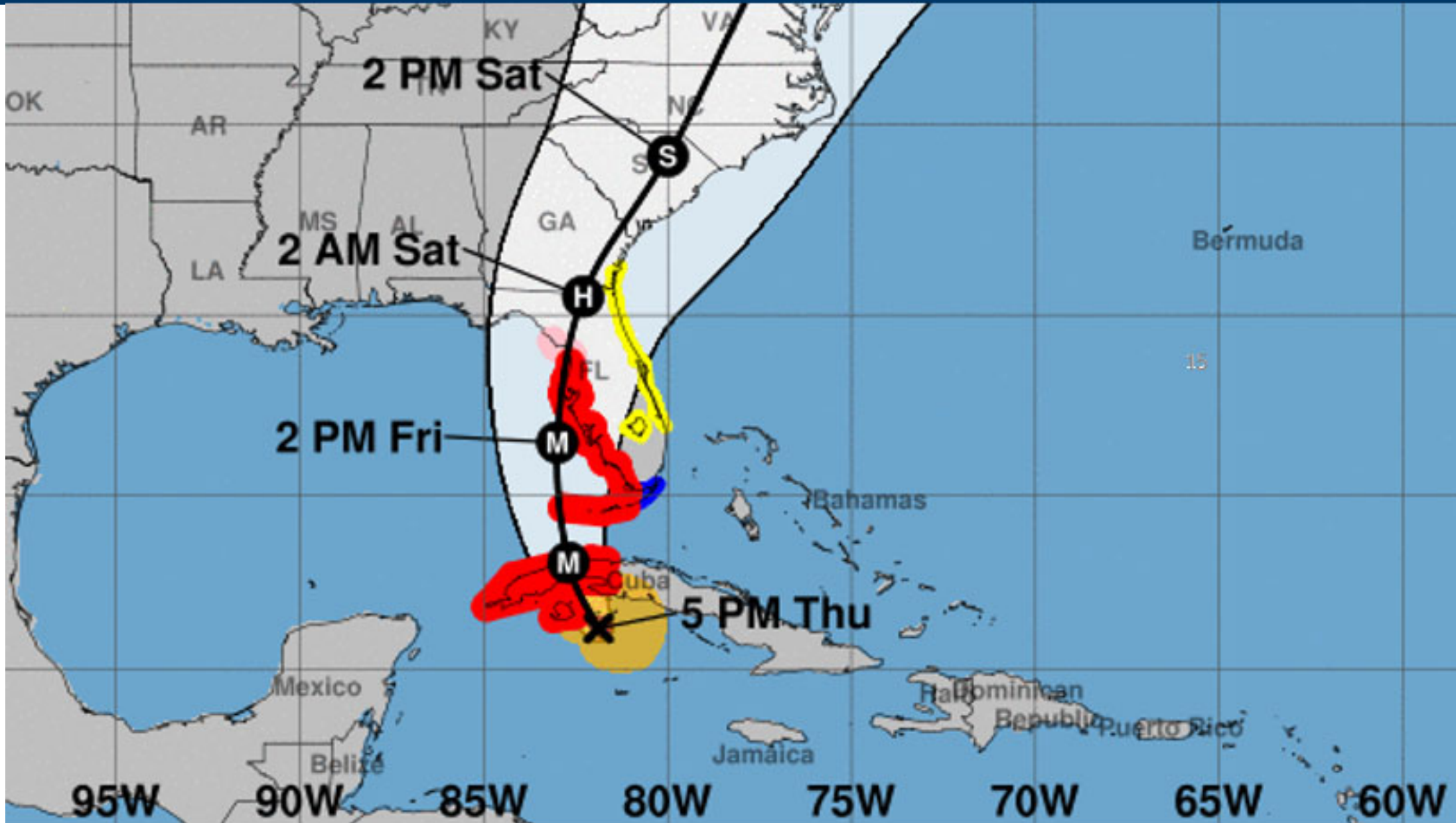
# Forecast Error Cone – Probable Track, Watches, Warnings



# Don't Focus on the Skinny Black Line



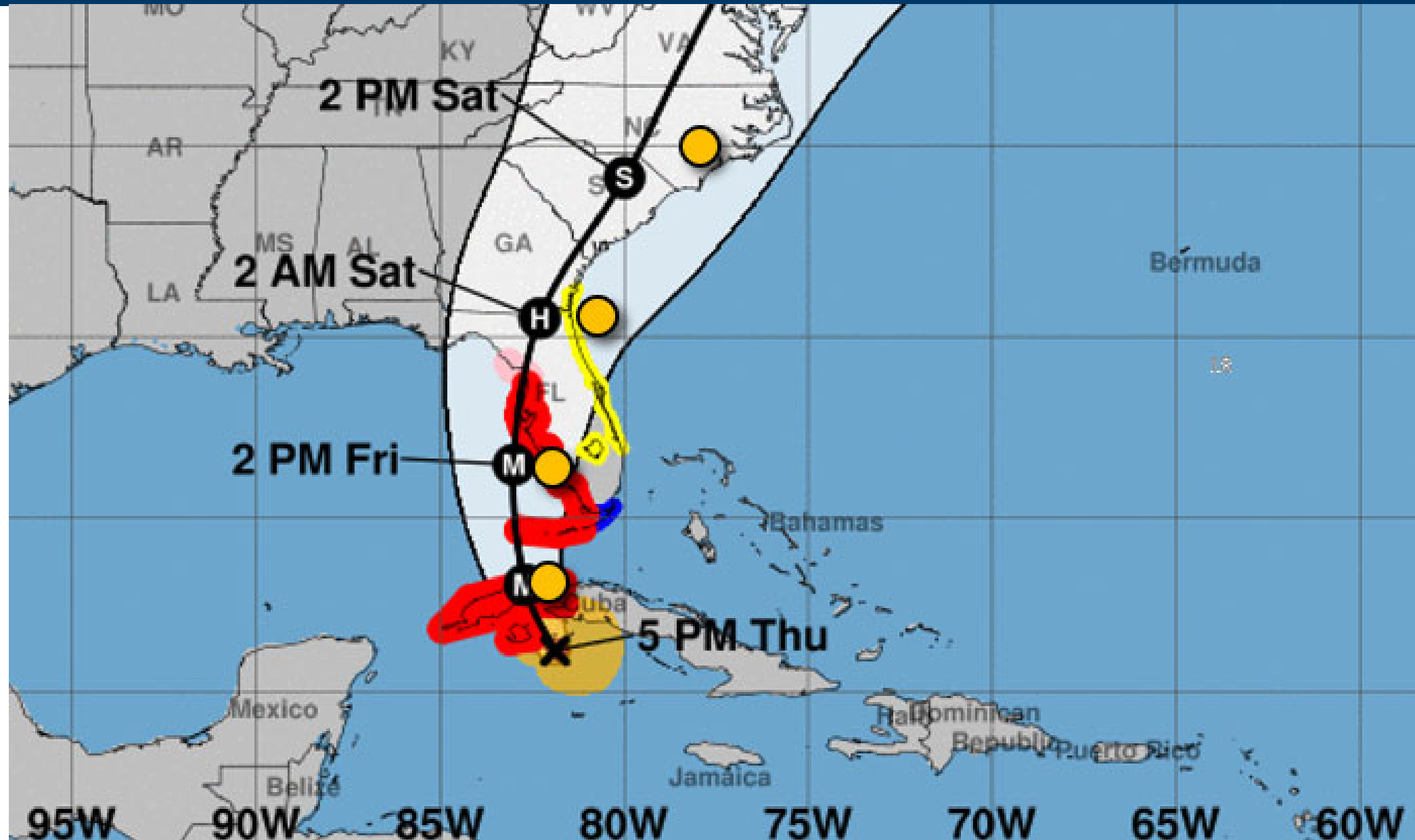
FEMA



# Forecast vs. Observed



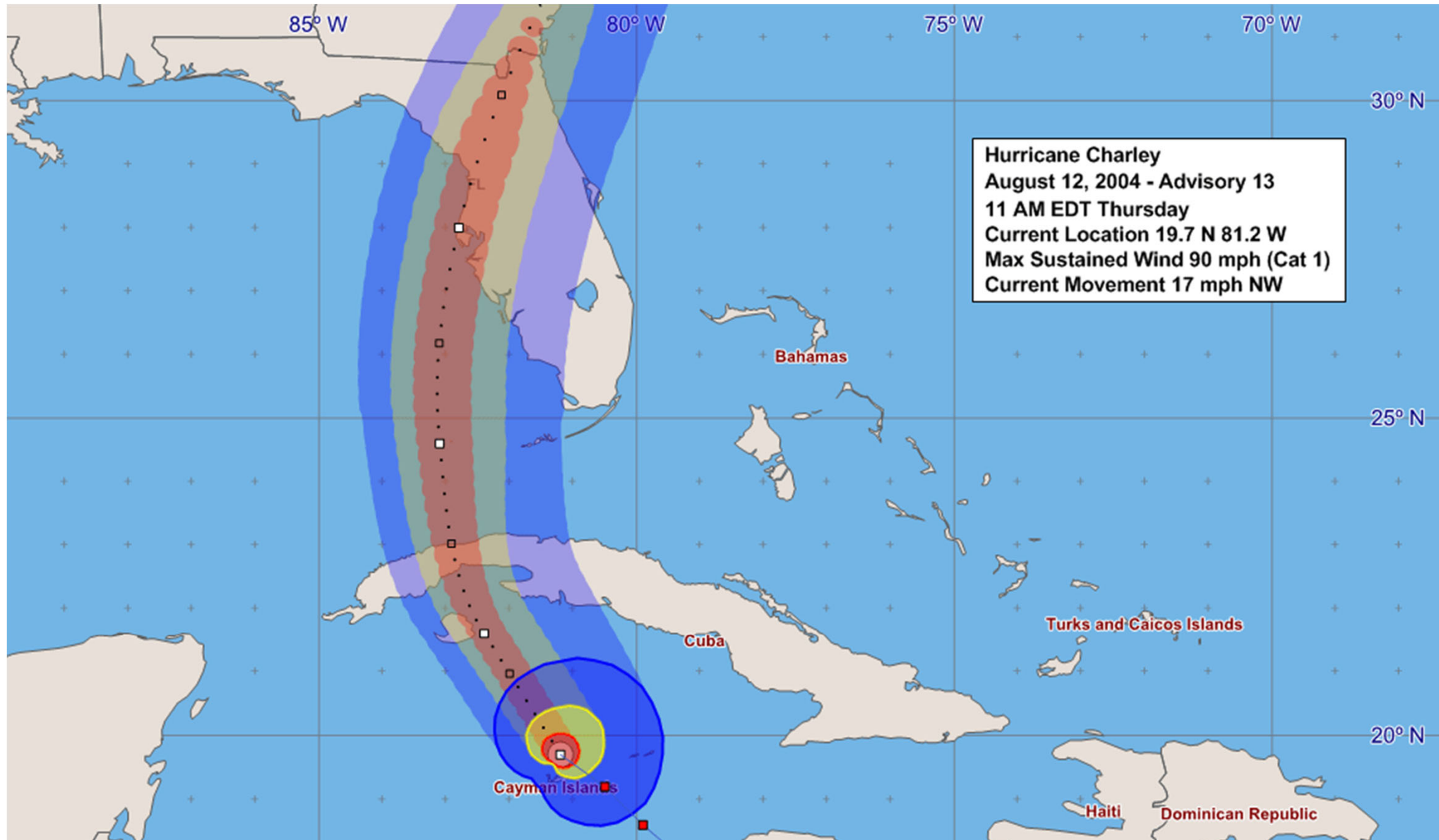
FEMA



# Hurricane Charley



FEMA





# Would Alternate Scenarios Help?



# What Does 59% Chance Mean?



FEMA



# How Are WSP Generated? (1 of 3)

More scenarios

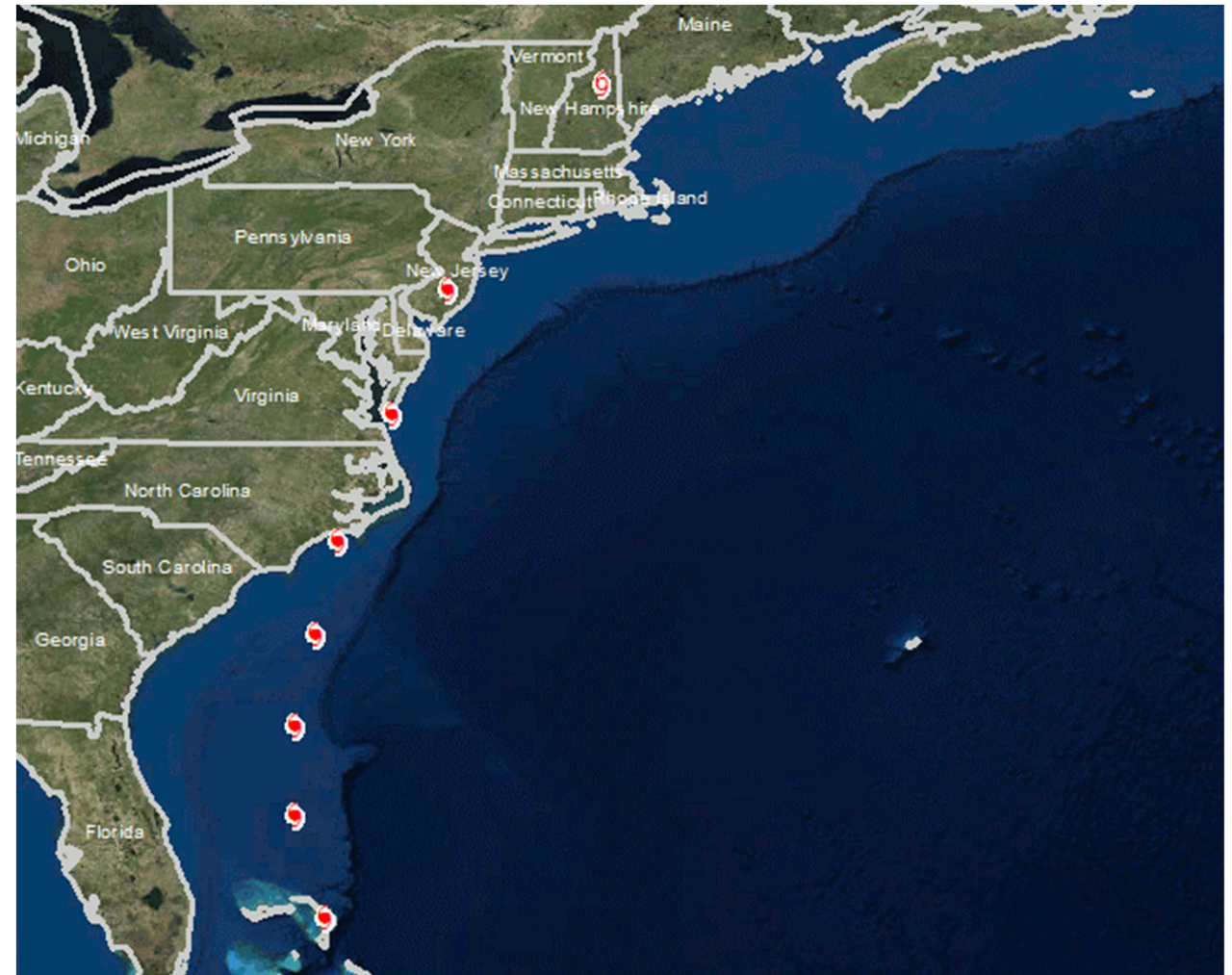
1,000 realistic alternative scenarios are generated

- Official NHC forecast
- Historical track and intensity forecast errors

Weakening over land

Track model spread

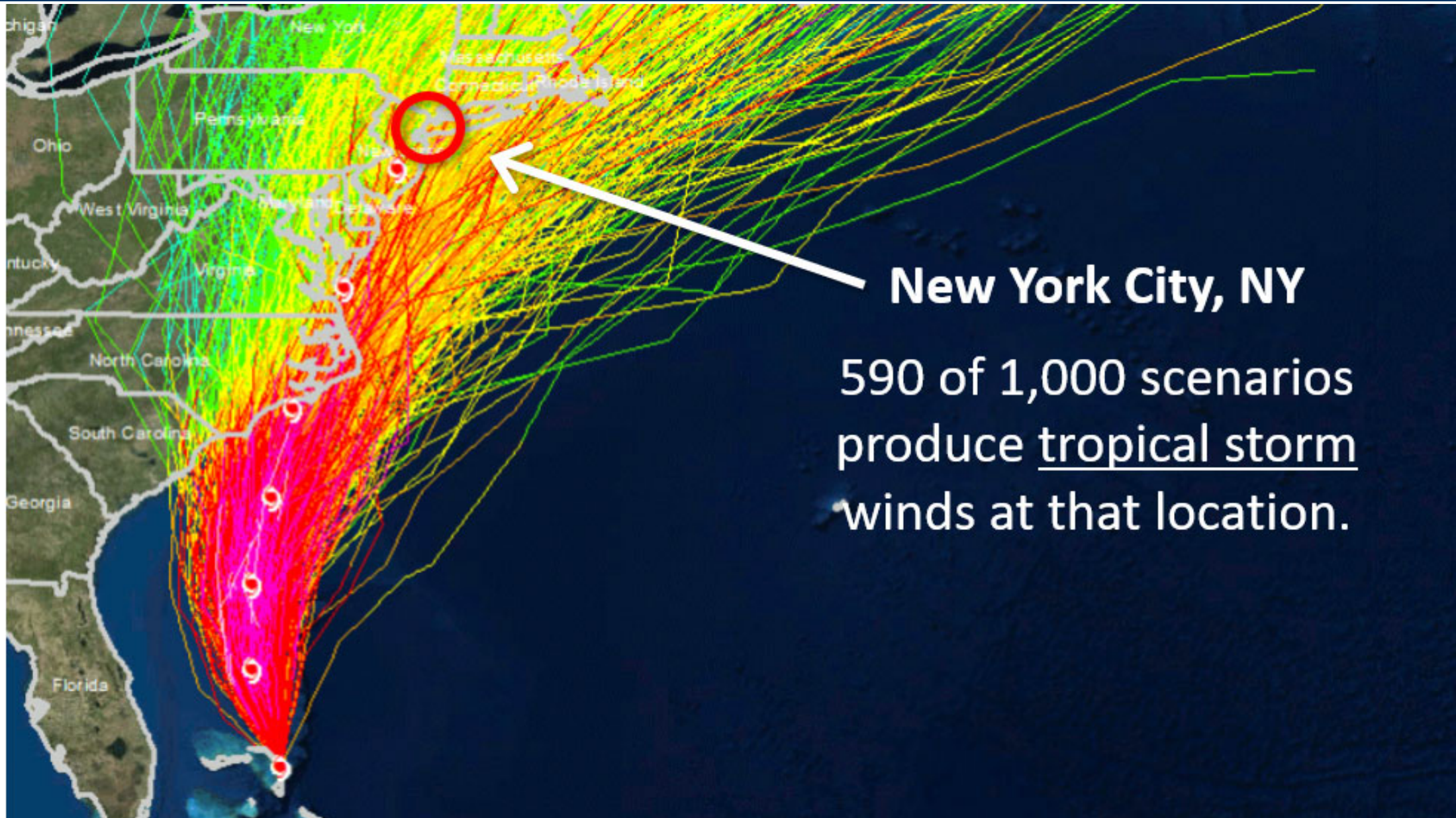
- Forecast track errors are correlated to the spread of model guidance



# How Are WSP Generated? (2 of 3)

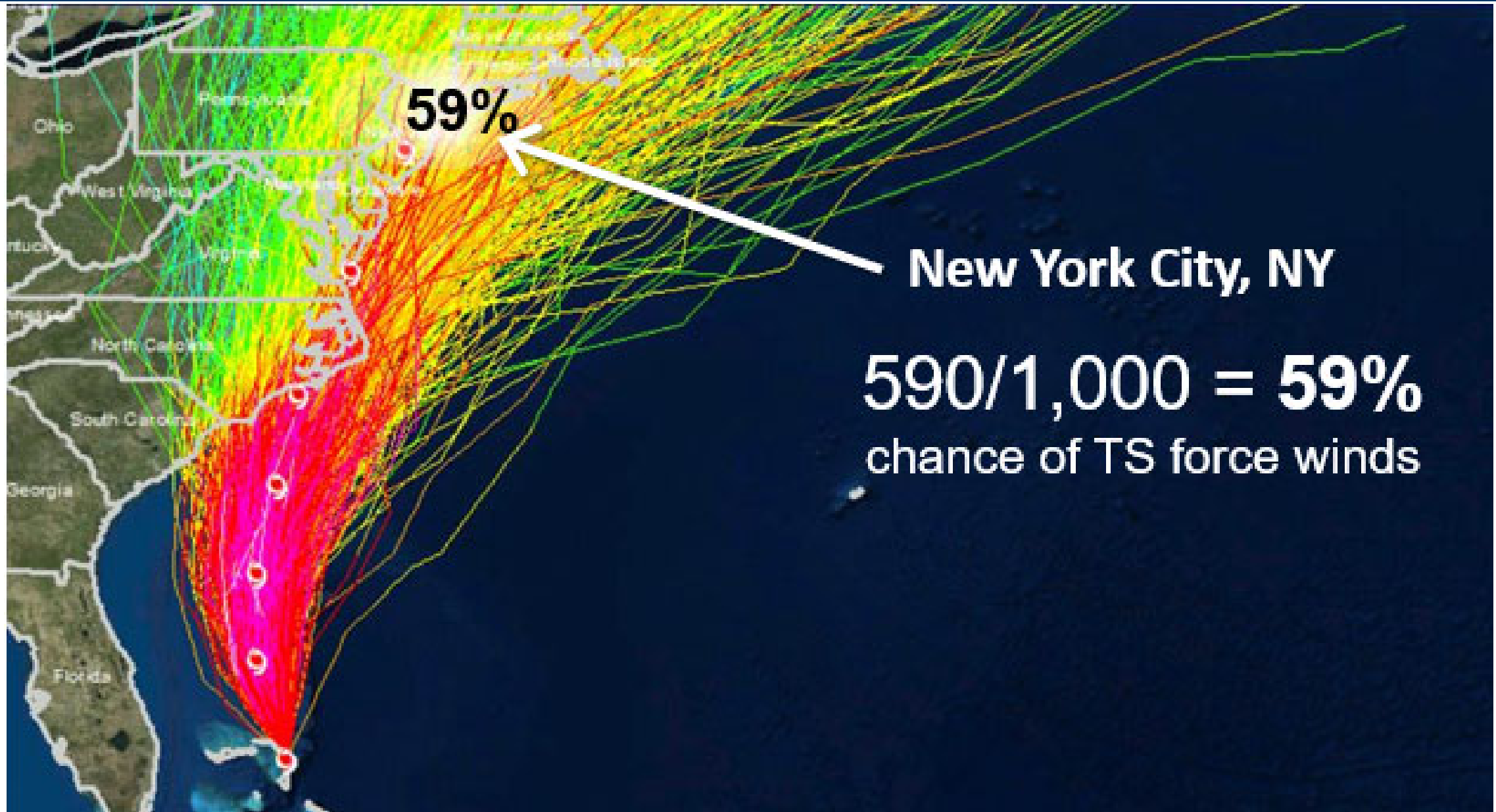


FEMA



**New York City, NY**  
590 of 1,000 scenarios  
produce tropical storm  
winds at that location.

# How Are WSP Generated? (3 of 3)



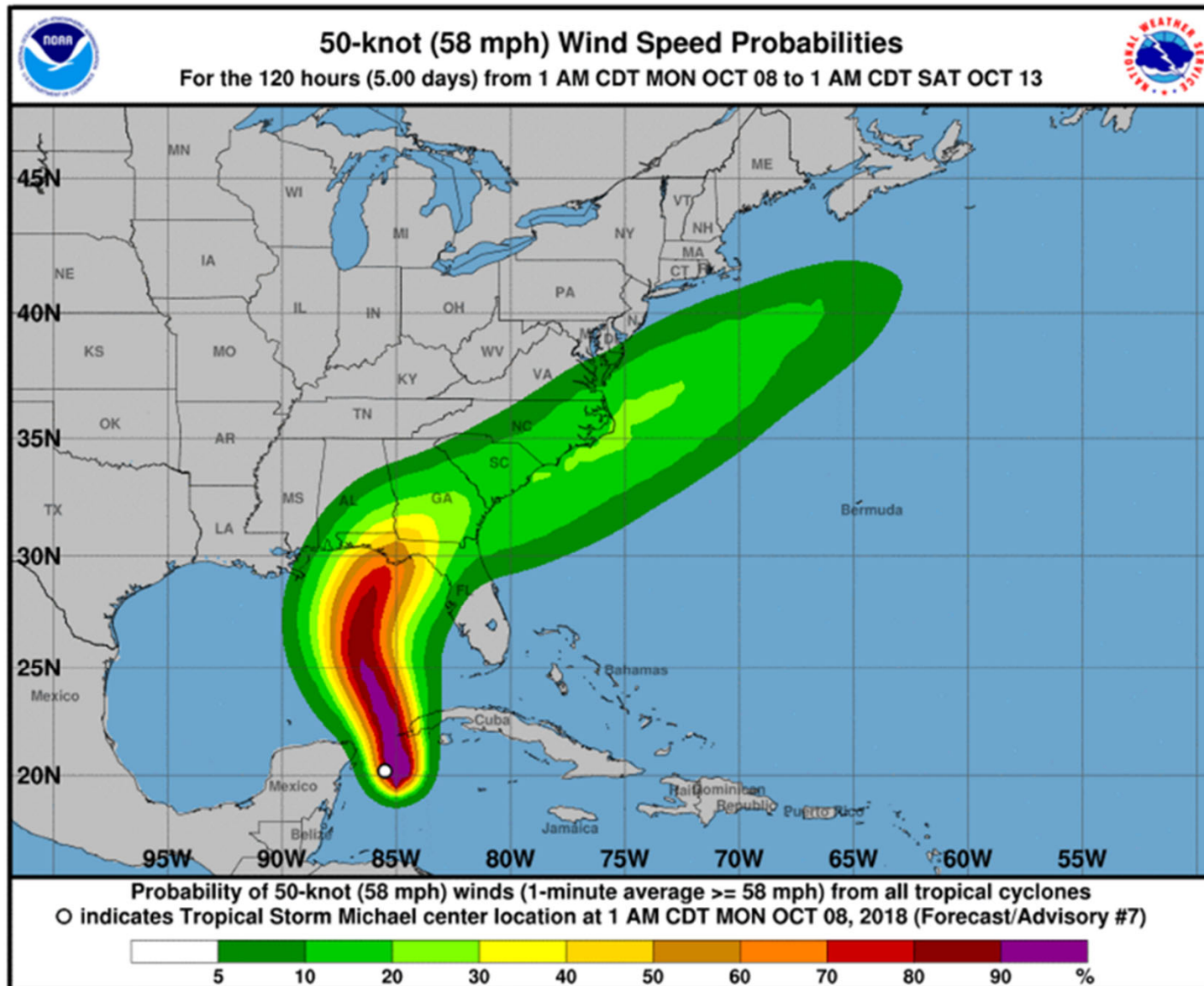
# 5-Day Cumulative Graphic: TS-Force



## Location-specific Probabilities

- Tropical Storm-Force
- 58 mph (“Strong” Tropical Storm)
- Hurricane-Force

# 5-Day Cumulative Graphic: 58 mph



## Location-specific Probabilities

- Tropical Storm-Force
- 58 mph (“Strong” Tropical Storm)
- Hurricane-Force

# 5-Day Cumulative Graphic: Hurricane-Force



## Location-specific Probabilities

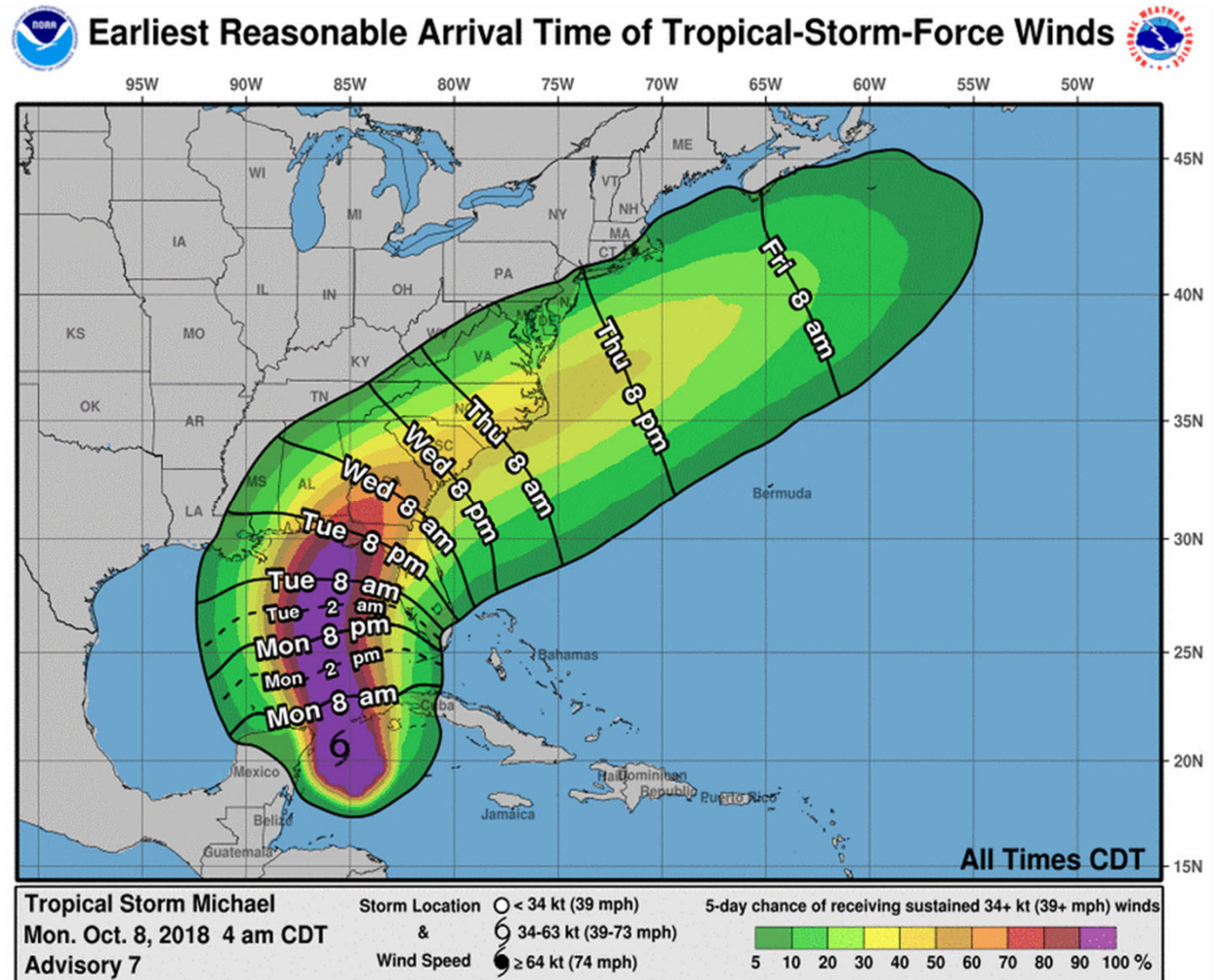
- Tropical Storm-Force
- 58 mph (“Strong” Tropical Storm)
- Hurricane-Force



# Earliest Reasonable Onset of TS Winds

## Earliest Reasonable

- 10% chance of onset (Most conservative timing)
- Black Contours: Arrival time of TS winds
- Color fill: 5-day cumulative TS probabilities



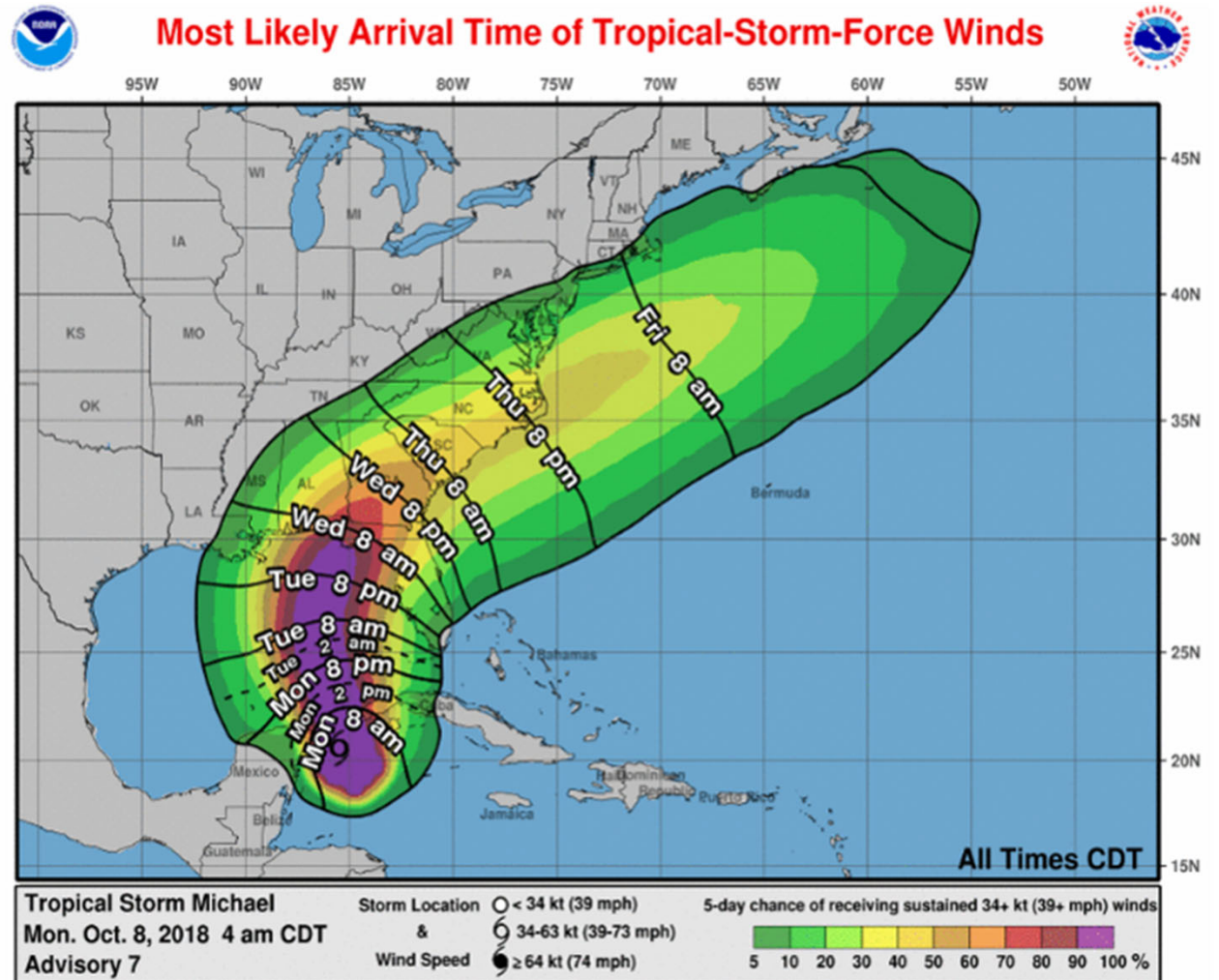
# Most Likely Onset of TS Winds



FEMA

## Most Likely

- 50% chance of onset (Equally likely to occur before as after)
- Black Contours: Arrival time of TS winds
- Color fill: 5-day cumulative TS probabilities

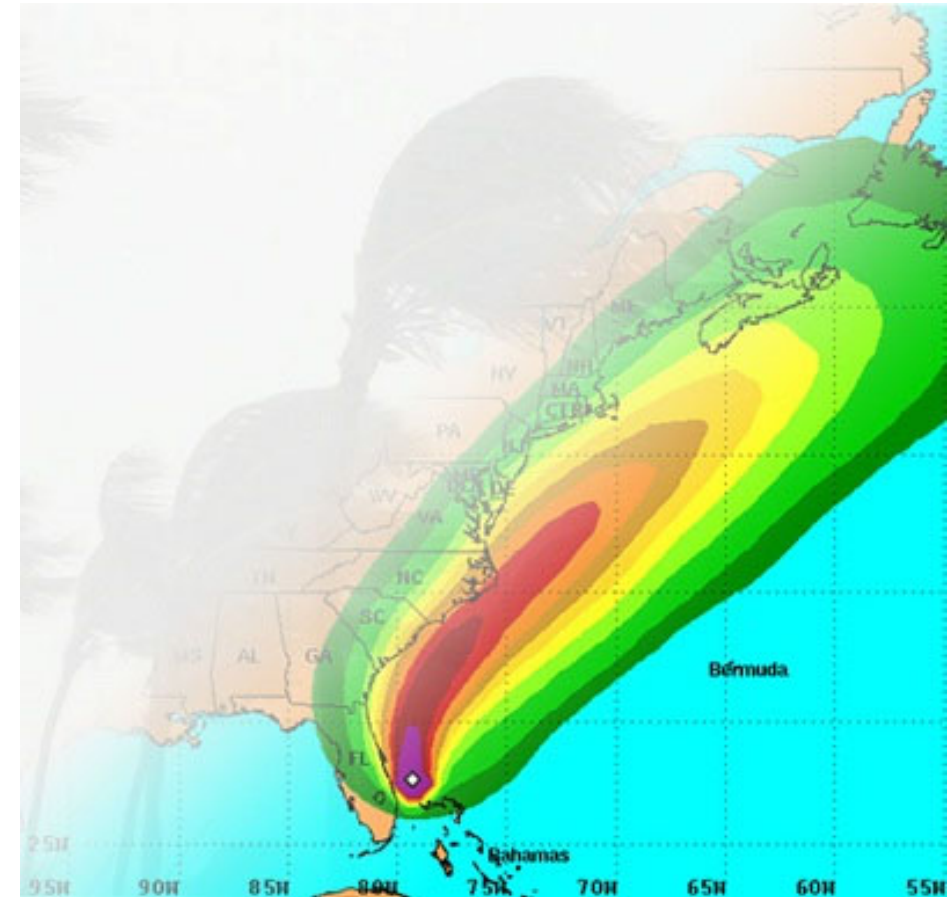


# Wind Speed Probabilities – Summary

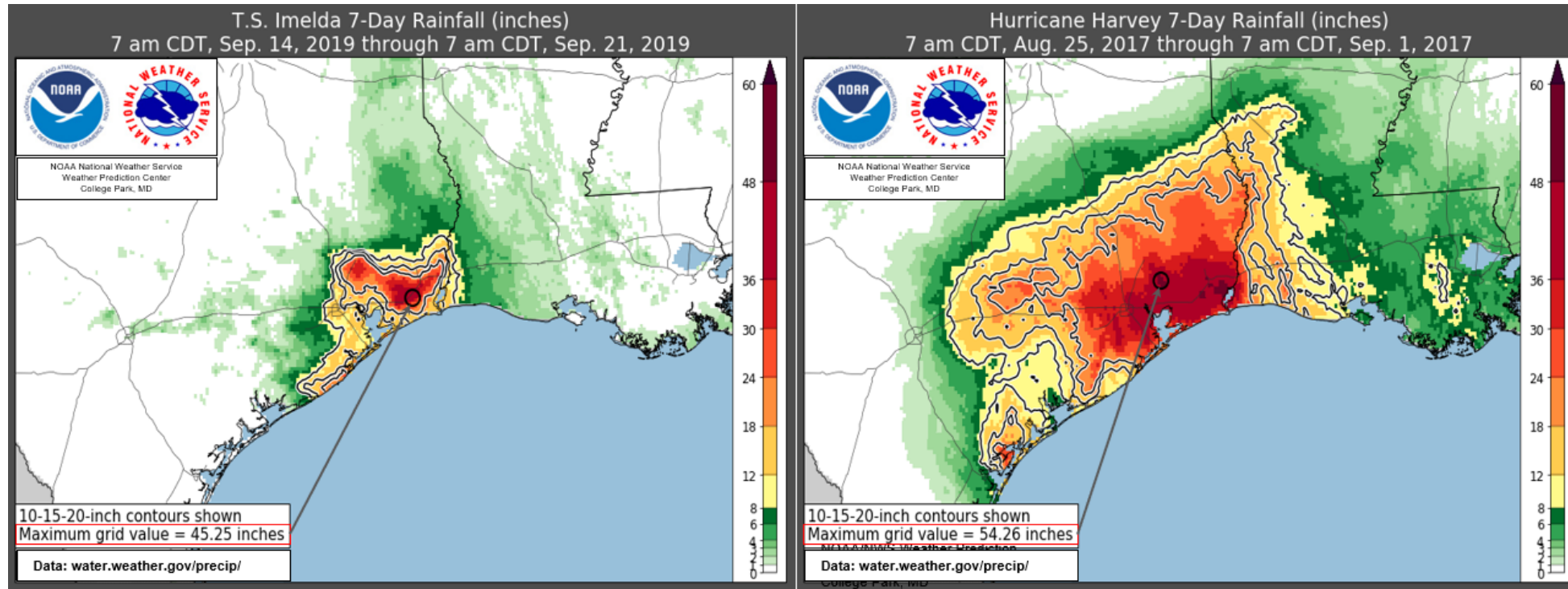


FEMA

- NHC's forecasts are improving, but errors remain
  - Error cone is not the cure for skinny black line
- Wind speed probabilities
  - Likelihood of tropical storm and hurricane winds
  - Onset timing of wind hazards
- Incorporates track, intensity, and size uncertainty
  - Includes weakening due to land
- Provides an assessment of wind timing and threat that accounts for NHC forecast errors



# Rainfall Predictability Challenges

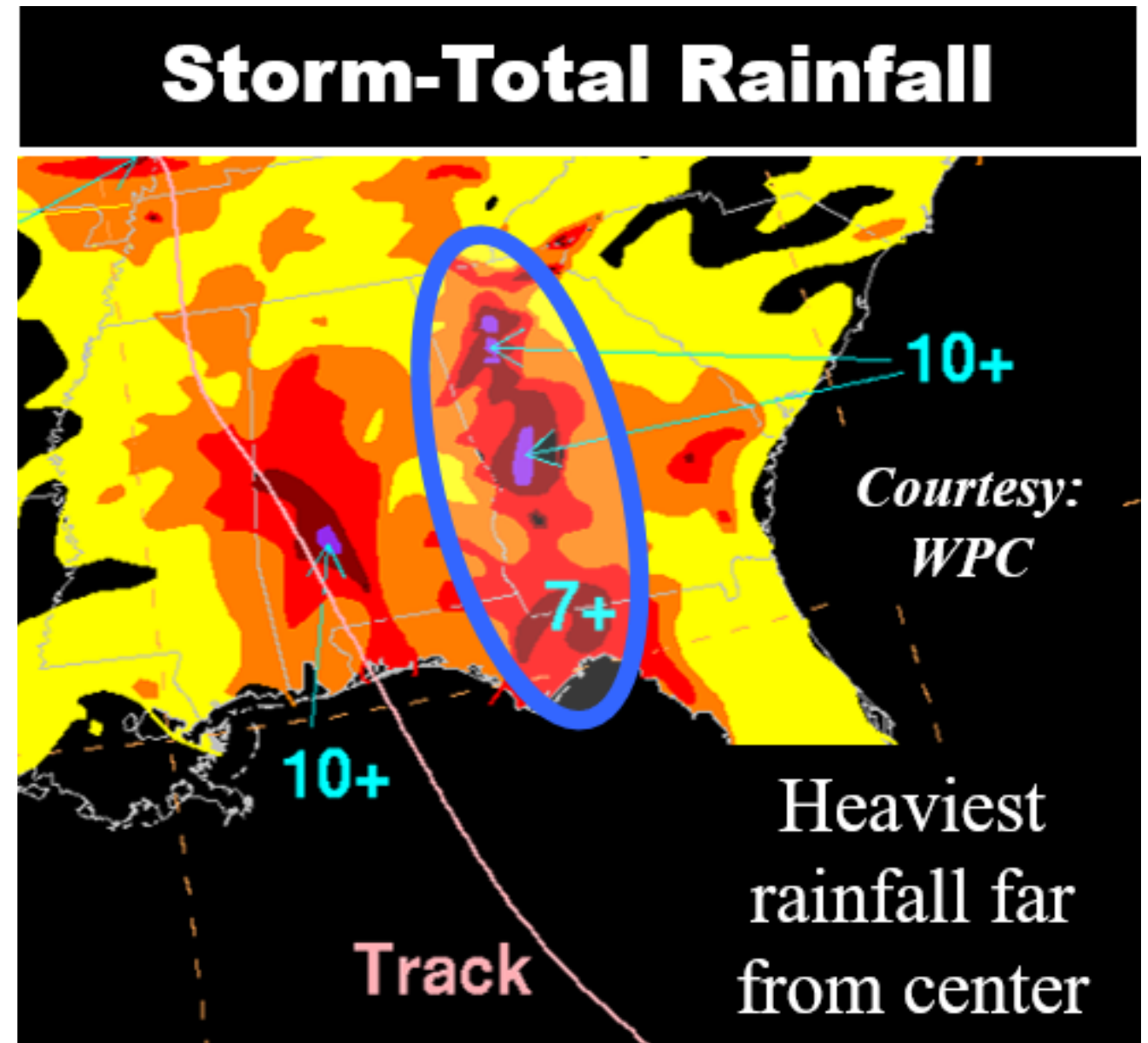
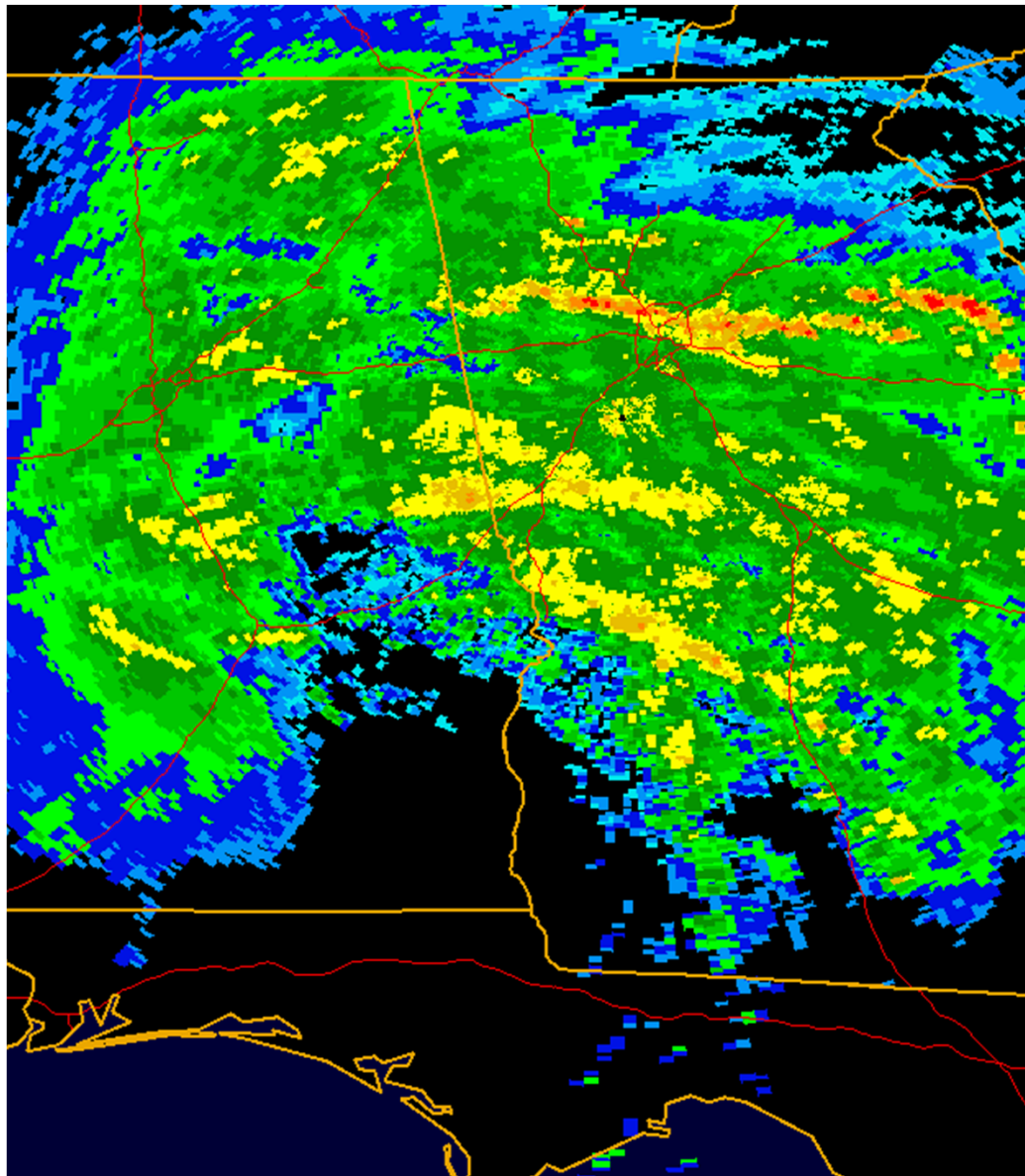


- Small, less organized storms can produce localized extreme rainfall maxima.
- Slow storm motion remains a factor.
- Less lead time and placement can make a big difference in impacts.
- Extreme events at this scale can be more obvious at longer lead times, but remember placement error.

# Placement of Persistent Rain Bands?



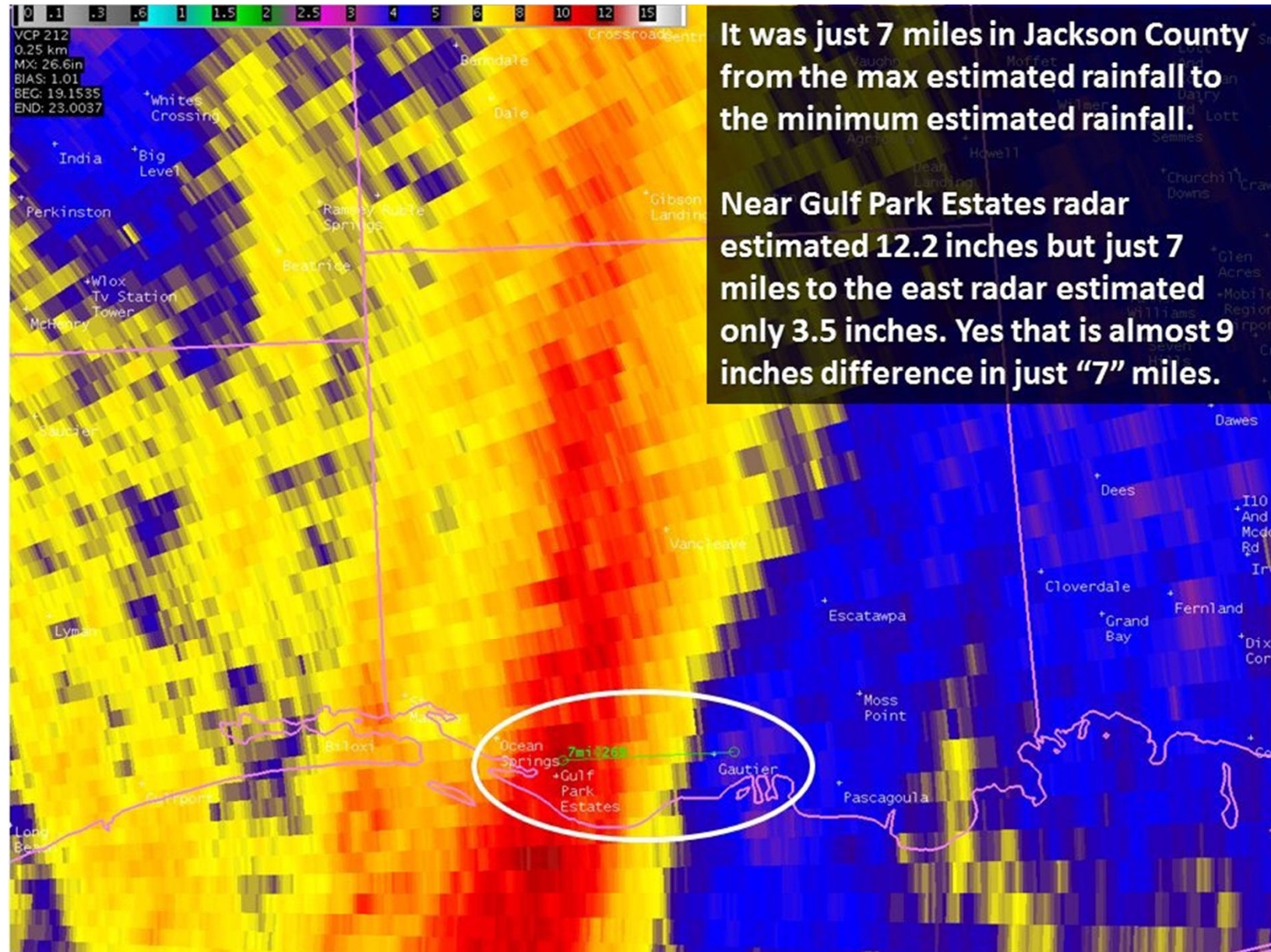
FEMA



# TS Cindy (2017) Forecast Challenge



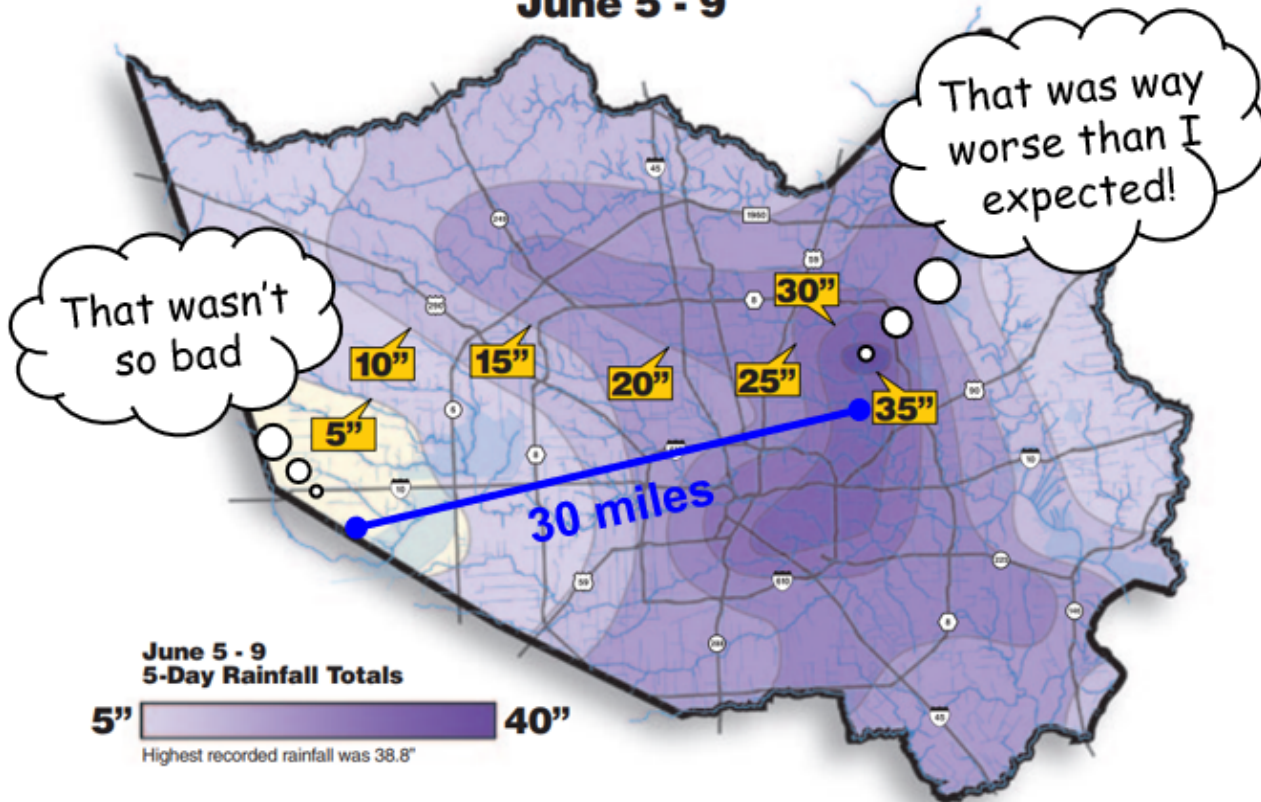
FEMA



# Messaging Issues

Extreme rain gradients in banding in slow-moving, disorganized storms present messaging issues.

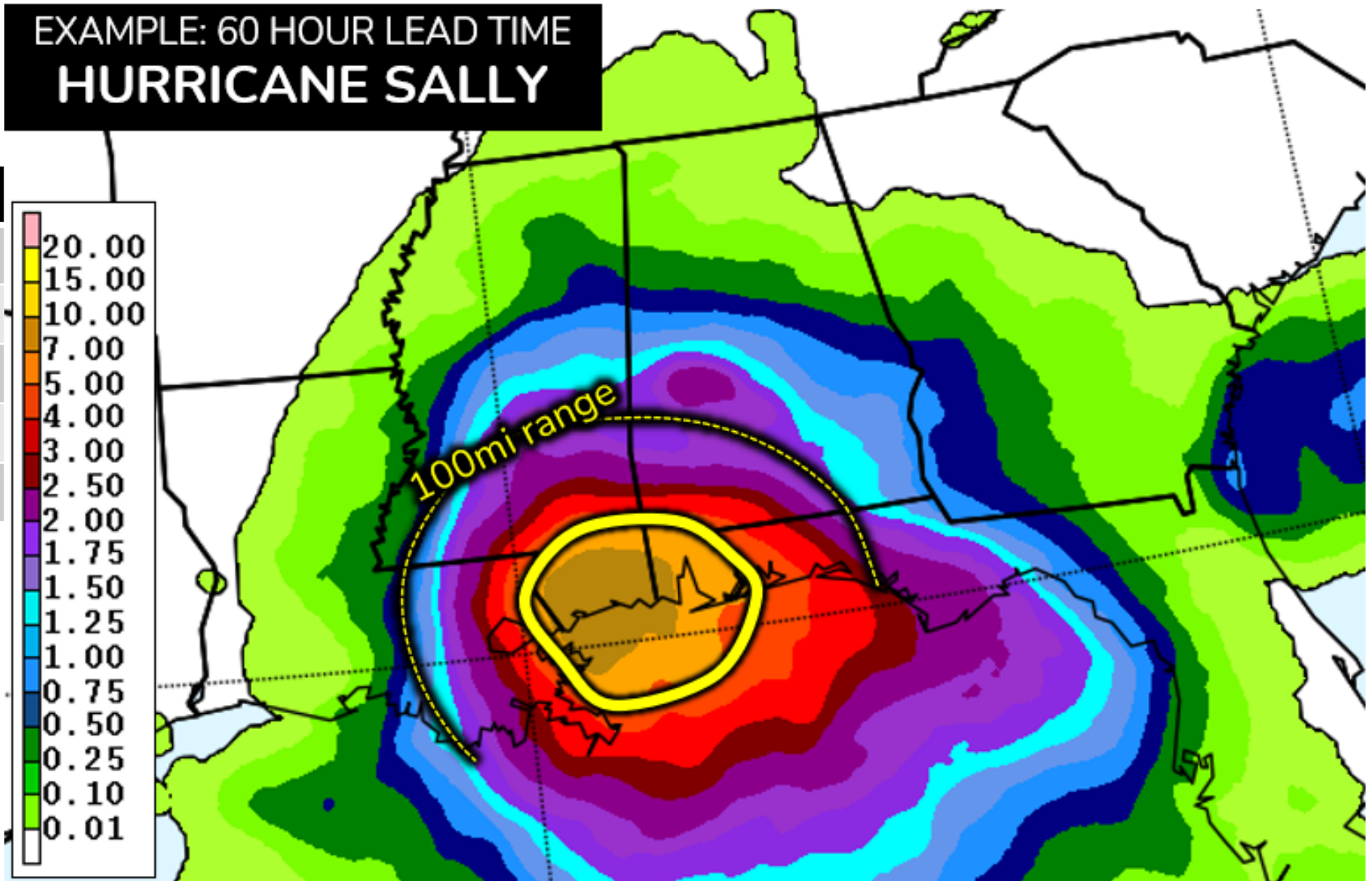
**5-Day Rainfall Totals**  
June 5 - 9



# Rainfall Forecast Error

EXAMPLE: 60 HOUR LEAD TIME  
HURRICANE SALLY

Lead Time	Avg. Error
12 hours	55 miles
36 hours	71 miles
60 hours	98 miles
84 hours	137 miles
108 hours	170 miles

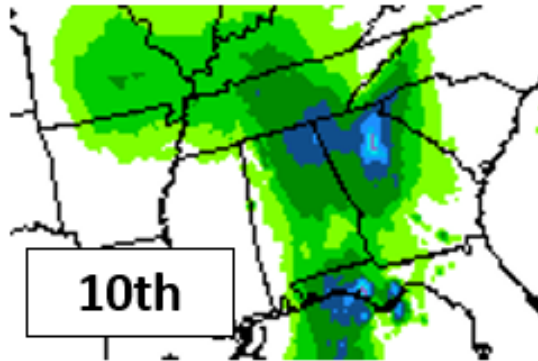
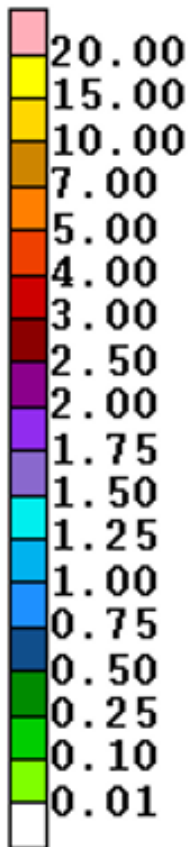


2016-2021 Displacement Error  
of 2" Rainfall Forecast Contour

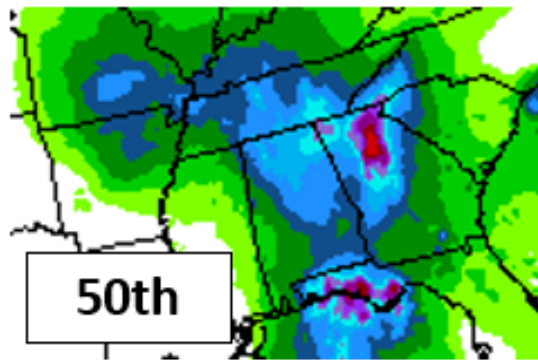


# Probabilistic Rainfall Forecasts

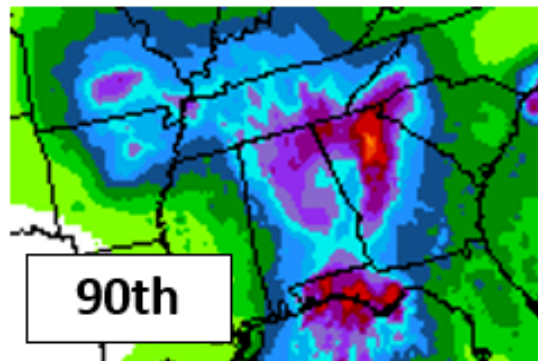
## In Percentiles



10<sup>th</sup> Percentile  
Expect at least this  
much rainfall

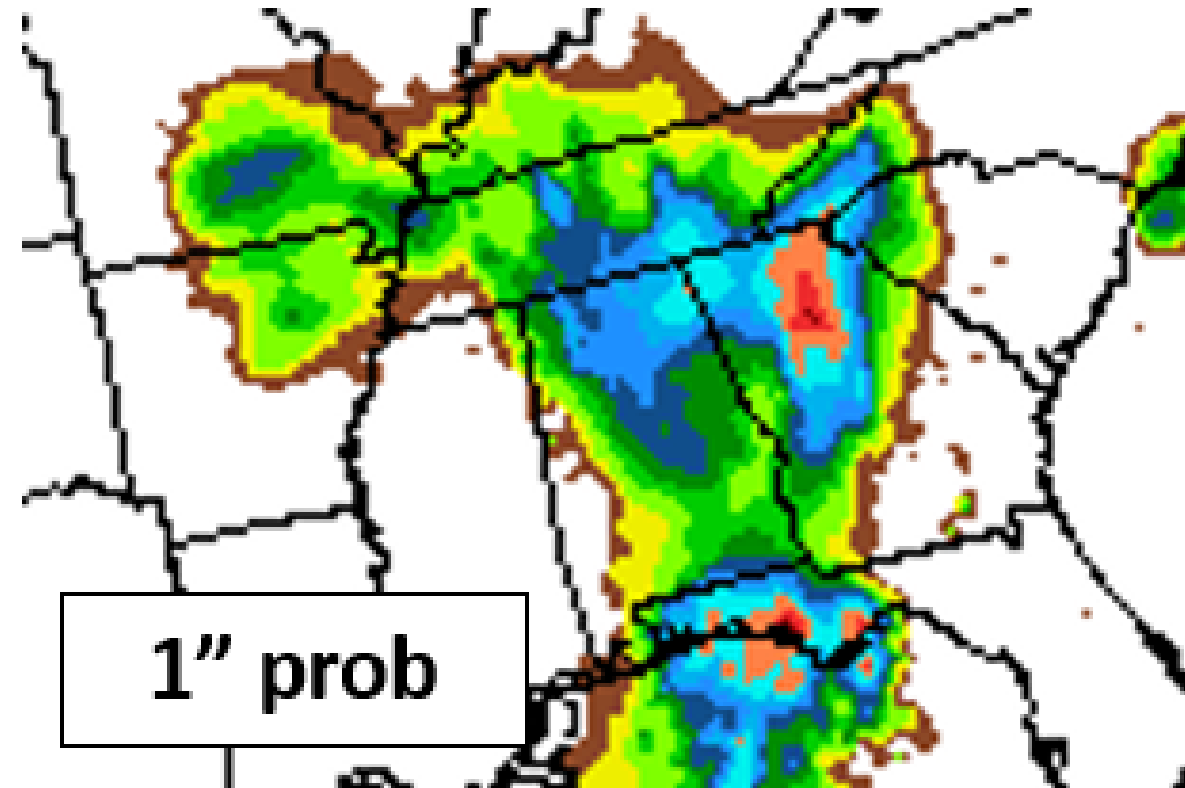
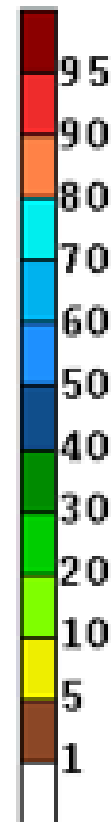


50<sup>th</sup> Percentile  
Best guess, or most  
likely, rainfall

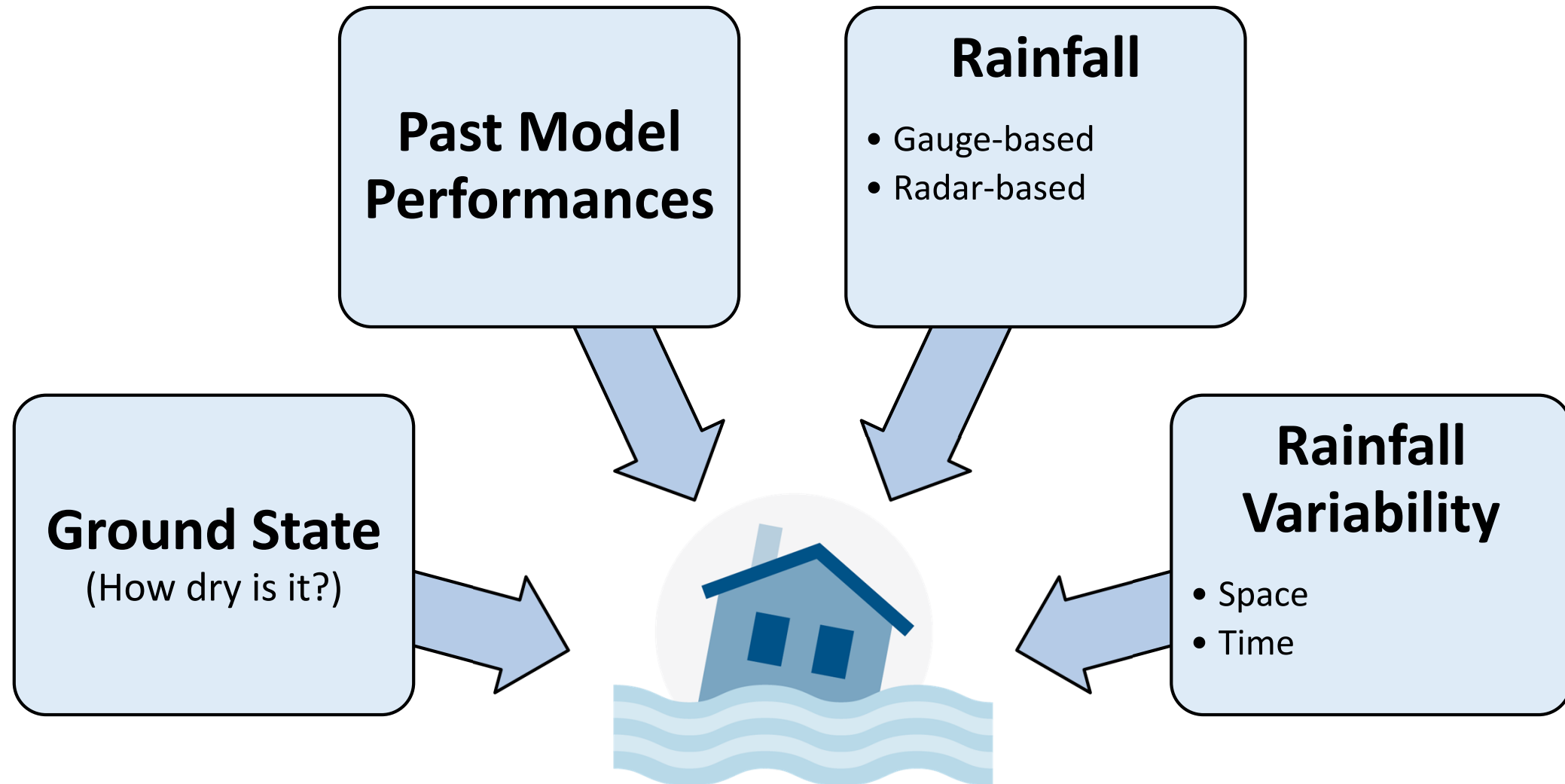


90<sup>th</sup> Percentile  
Reasonable high-end  
scenario

## Rainfall Probability



# Flooding Forecast Considerations



# Ensemble Forecasting

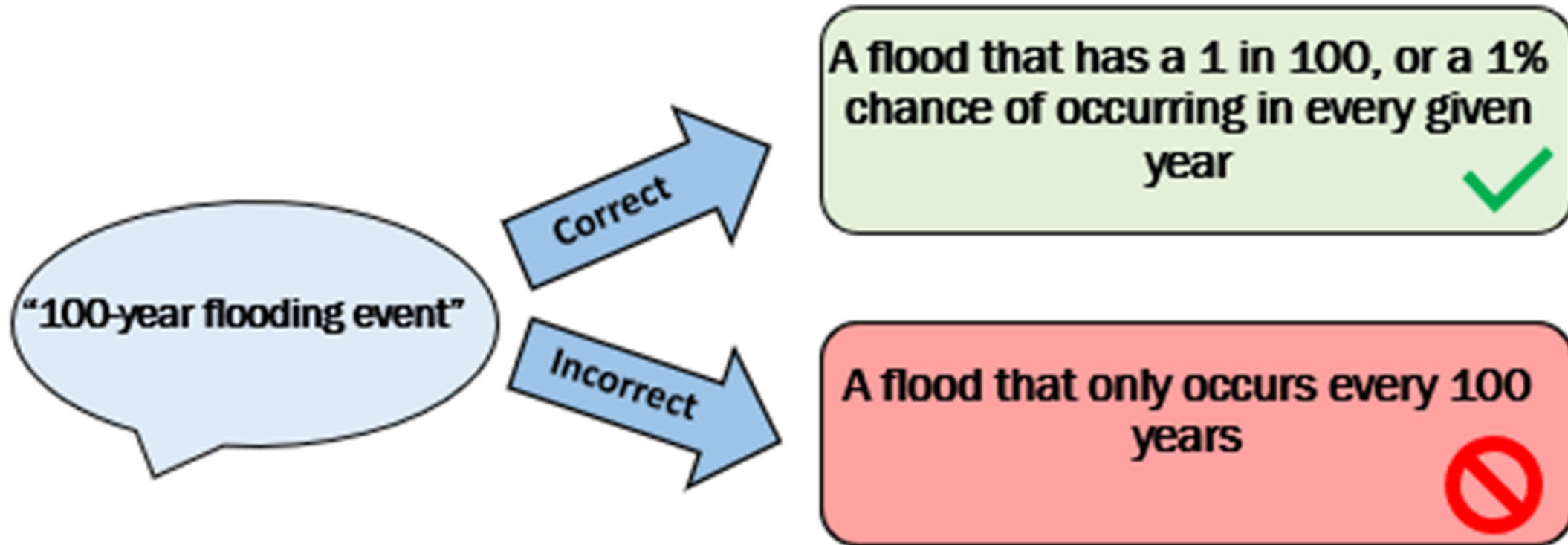


## NAEFS River Ensemble Forecast on Sat. Aug 28, 2021; 4-5 days before Hurricane Ida's remnants arrived

(Recreated from the official product)

River	City, ST	10%	30%	50%	70%	90%
Lehigh River	Lehighton, PA	12.2	8.7	6.6	5.2	5.1
Delaware River	Tocks Island, NJ	25.2	15.1	11.3	7.8	7.7
Delaware River	Riegelsville, PA	28.1	21.4	13.6	8.4	8.2
Delaware River	Washington Xing, NJ	19.1	13.8	8.7	3.6	3.1
Schuylkill River	Pottstown, PA	18.1	11.7	7.7	4.3	3.8
Schuylkill River	Philadelphia, PA	13.1	10.3	8.7	7.3	6.6
Brandywine Creek	Chadds Ford, PA	13.0	7.6	5.2	3.9	2.7
Neshaminy Creek	Langhorne, PA	16.2	8.3	5.6	3.7	2.6
Conococheauge Creek	Fairview, MD	15.3	10.0	6.2	3.6	2.5
Potomac River	Shepherdstown, WV	24.1	14.7	9.6	5.7	3.9
Monocacy River	Frederick, MD	21.1	9.3	6.9	4.8	2.7

# Recurrence Intervals



Technical term: Annual Exceedance Probability (AEP)  
A 100-year rainfall event  $\neq$  100-year flood

Note:  
500-year flooding event = 2% chance every year  
1000-year flooding event = .1% chance every year

# Questions/Comments?



FEMA

A composite image featuring a screenshot of the National Hurricane Center (NHC) website on the left and a blue "EVACUATION ROUTE" sign with a right-pointing arrow on the right. The website screenshot shows the NHC logo, navigation tabs (Home, News, Organization, Search), and a "Top News of the Day" section with several bullet points. Below the news is a map titled "Atlantic Tropical Cyclone Activity" showing the Atlantic Ocean and the Eastern United States, with a red dot labeled "ARTHUR" off the coast. The sign is circular with a hurricane icon and the text "EVACUATION ROUTE" in white on a blue background, with a rectangular sign below it containing a white arrow pointing right. The background of the entire image is a blurred photograph of palm trees.