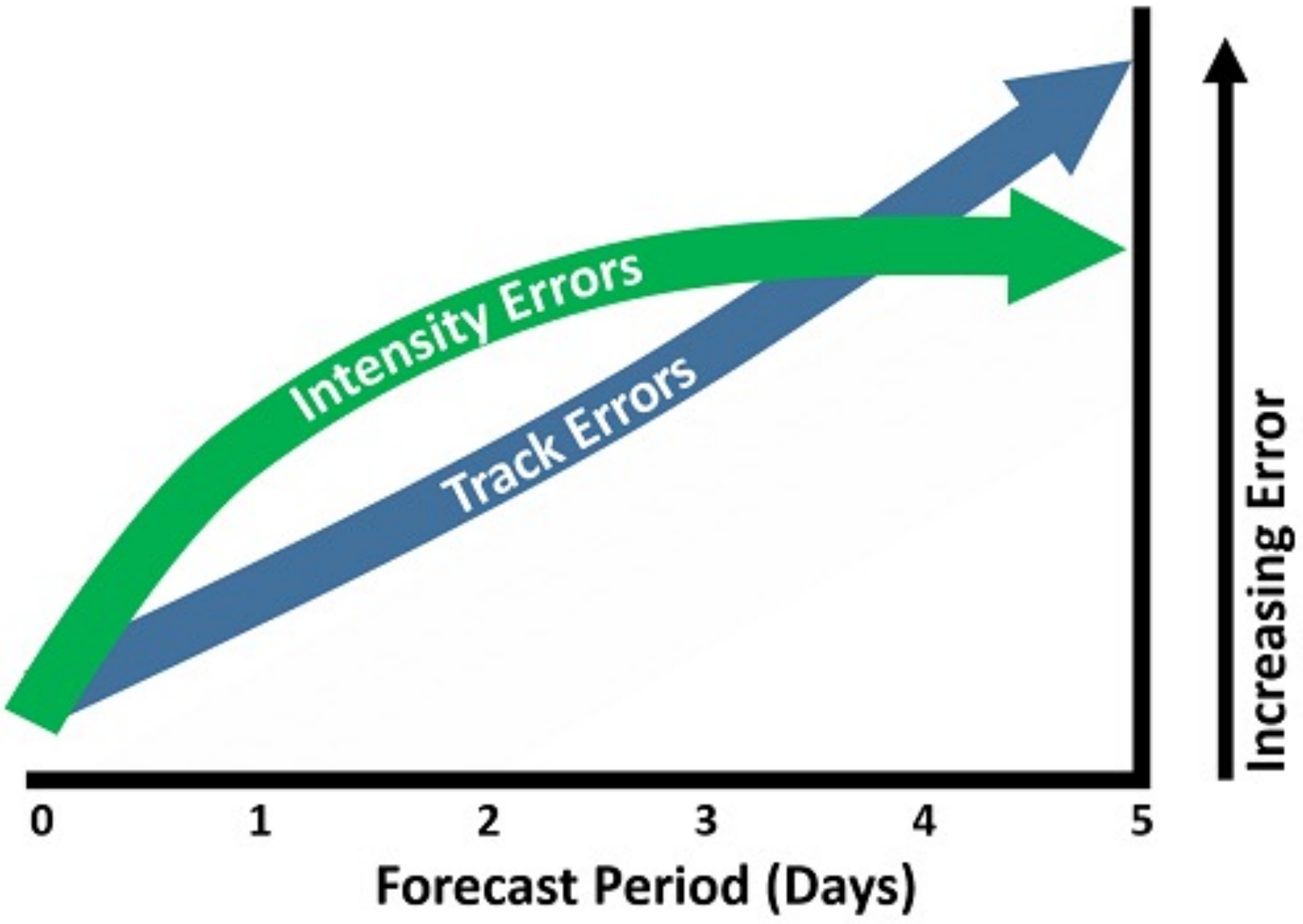
Unit 3:
Understanding Forecast Uncertainty

Unit 3 Objectives

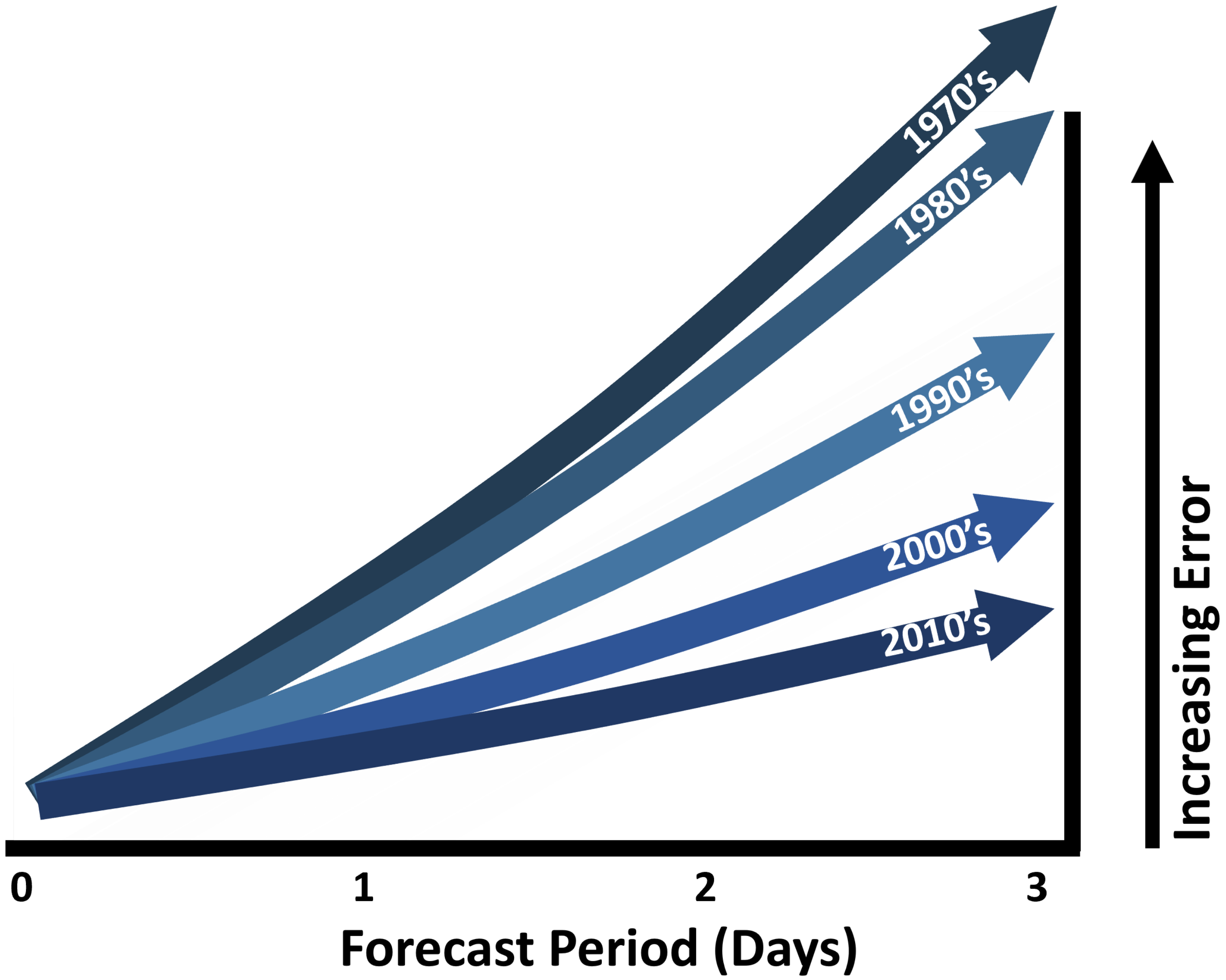
At the end of this unit, you should be able to:

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



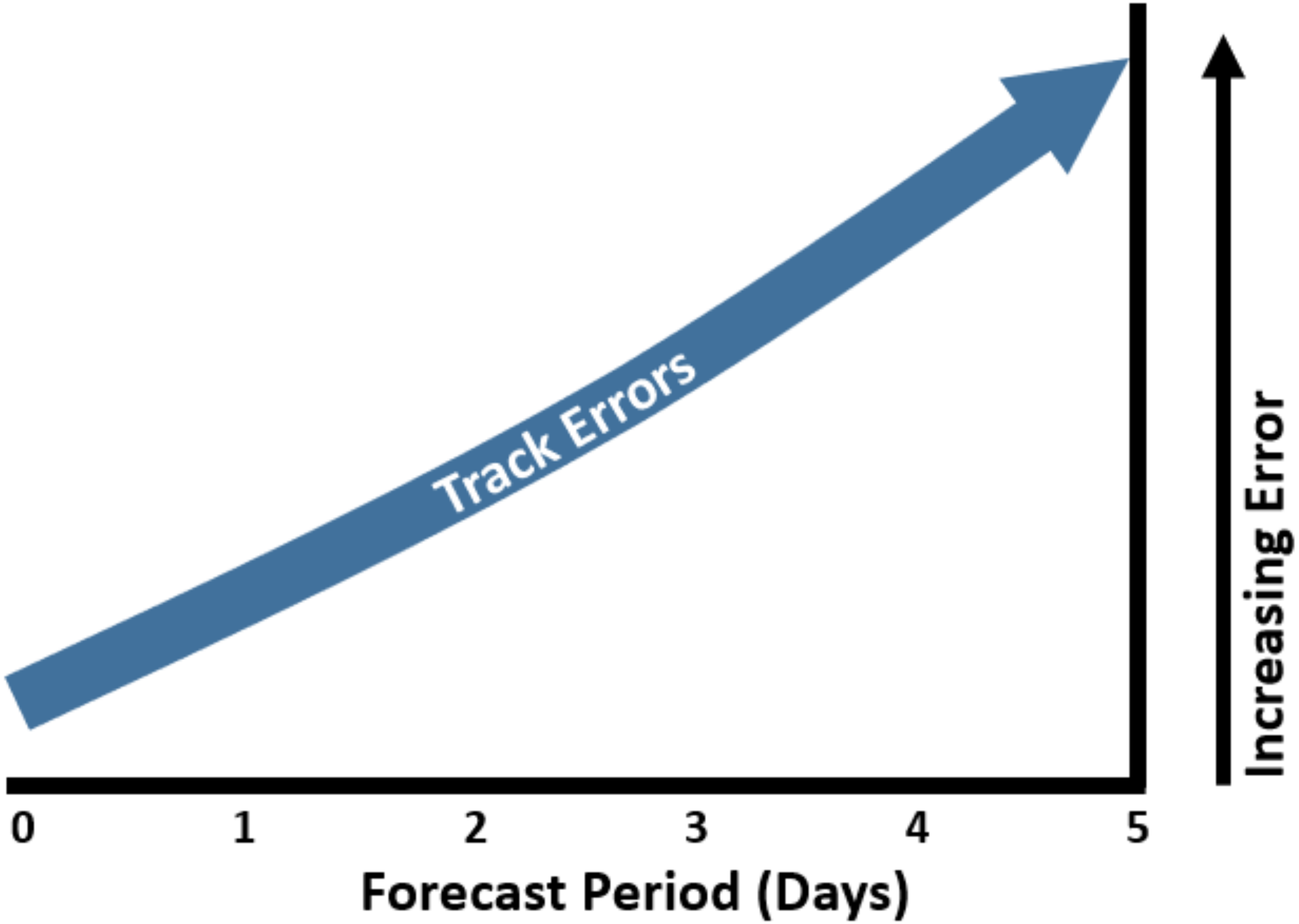
Forecasts are Improving, But Not Perfect



NHC 5-Year Averages: Track Errors

Track Errors

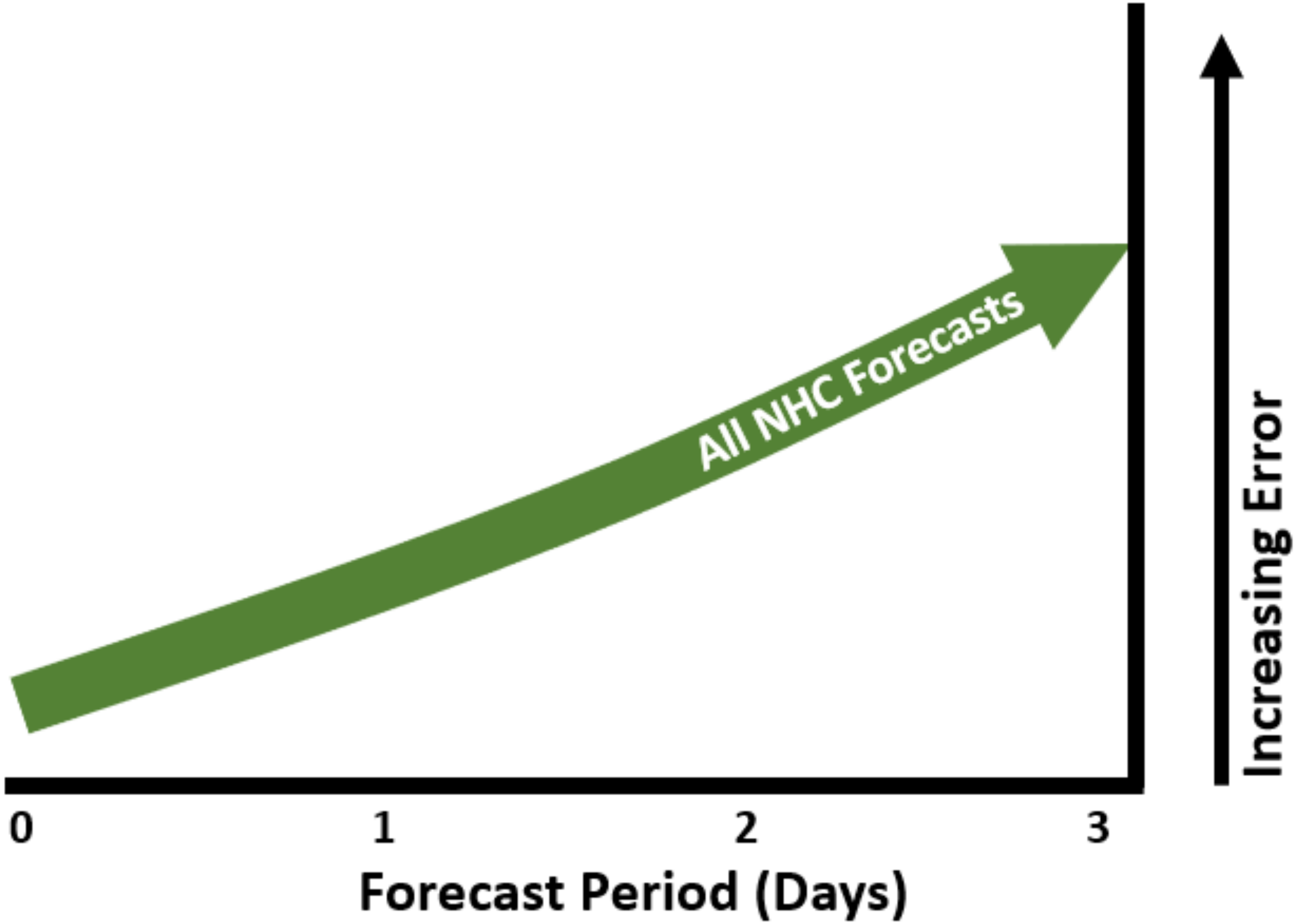
- Increase 40 miles (35 nautical miles (nm)) per day



Track Errors – All NHC Forecasts

All NHC Forecasts

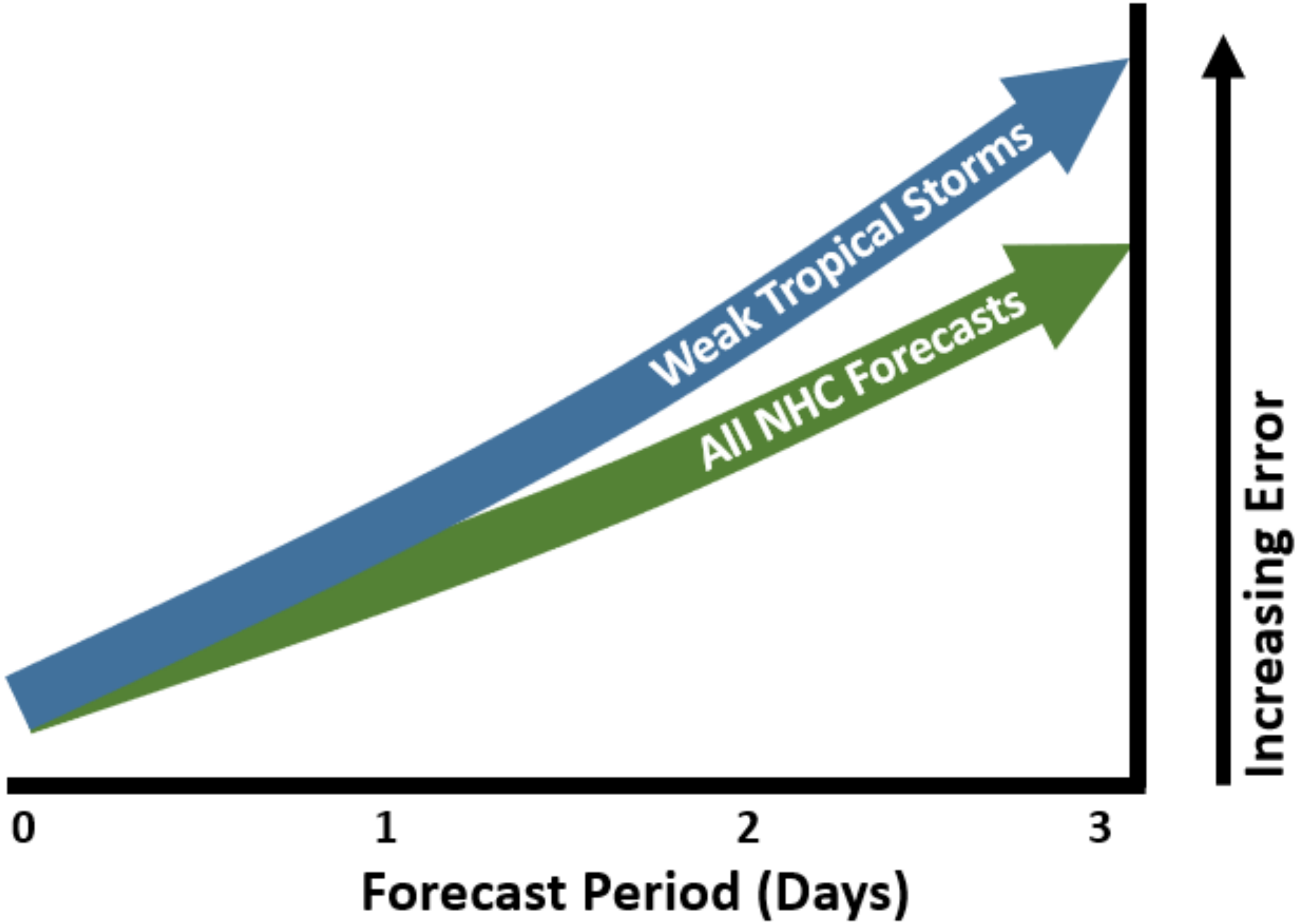
- Track errors increase about 35-40 miles per day



Track Errors – Weak TS

Weak Tropical Storms

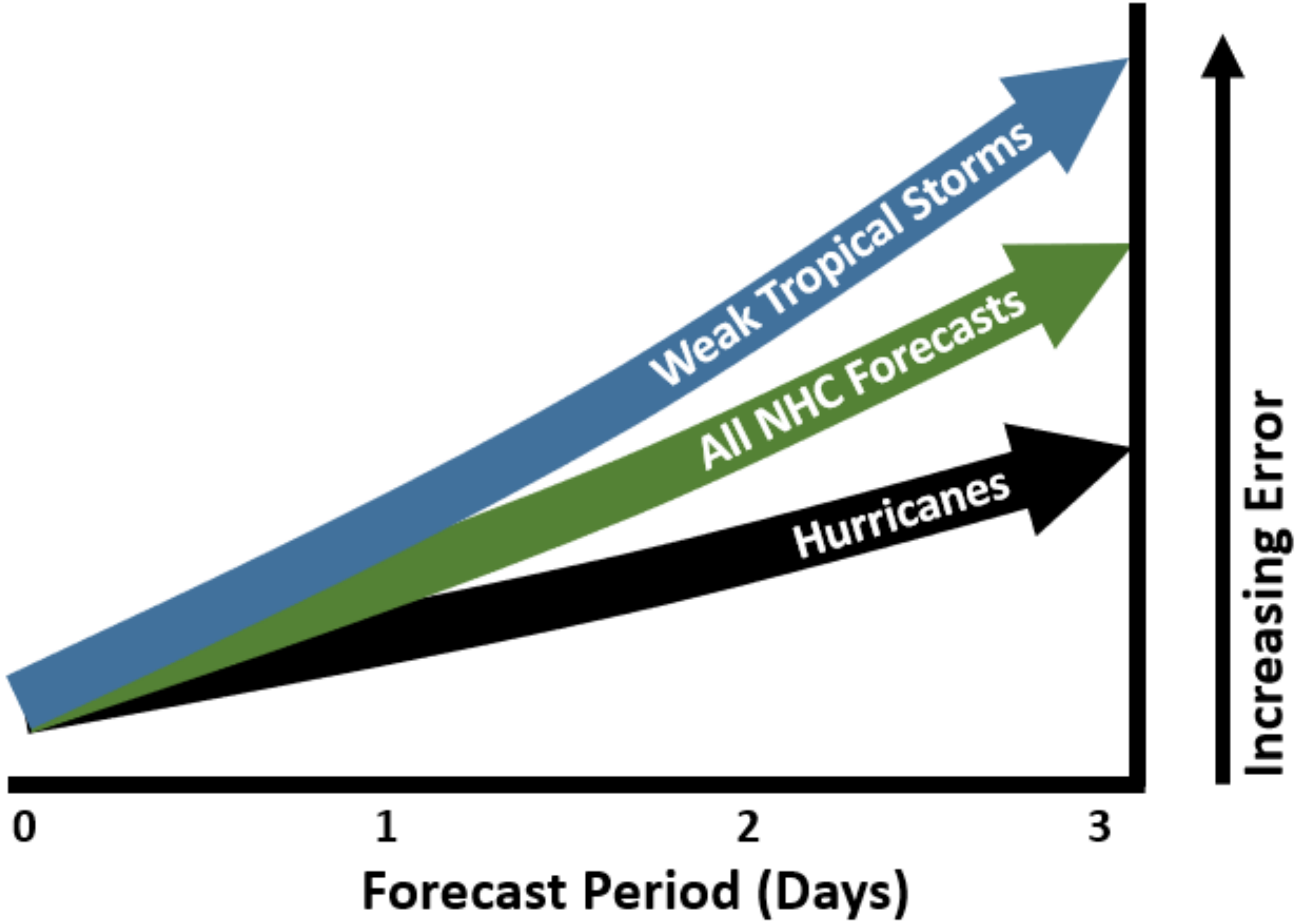
- Track errors increase about 40-45 miles per day



Track Errors – Hurricane

Hurricanes

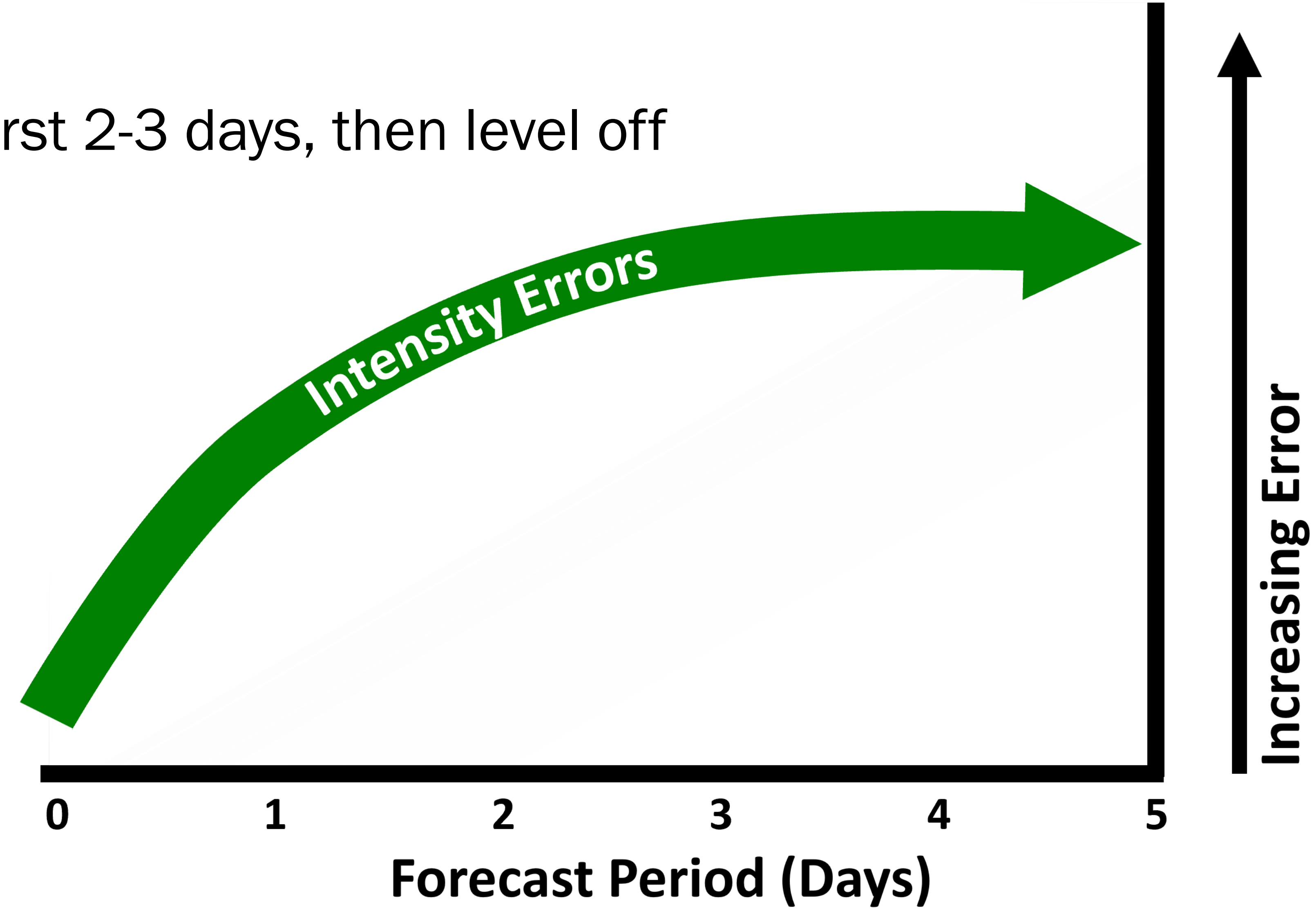
- Track errors increase about 25-30 miles per day



NHC 5-Year Averages: Intensity Errors

Intensity Errors

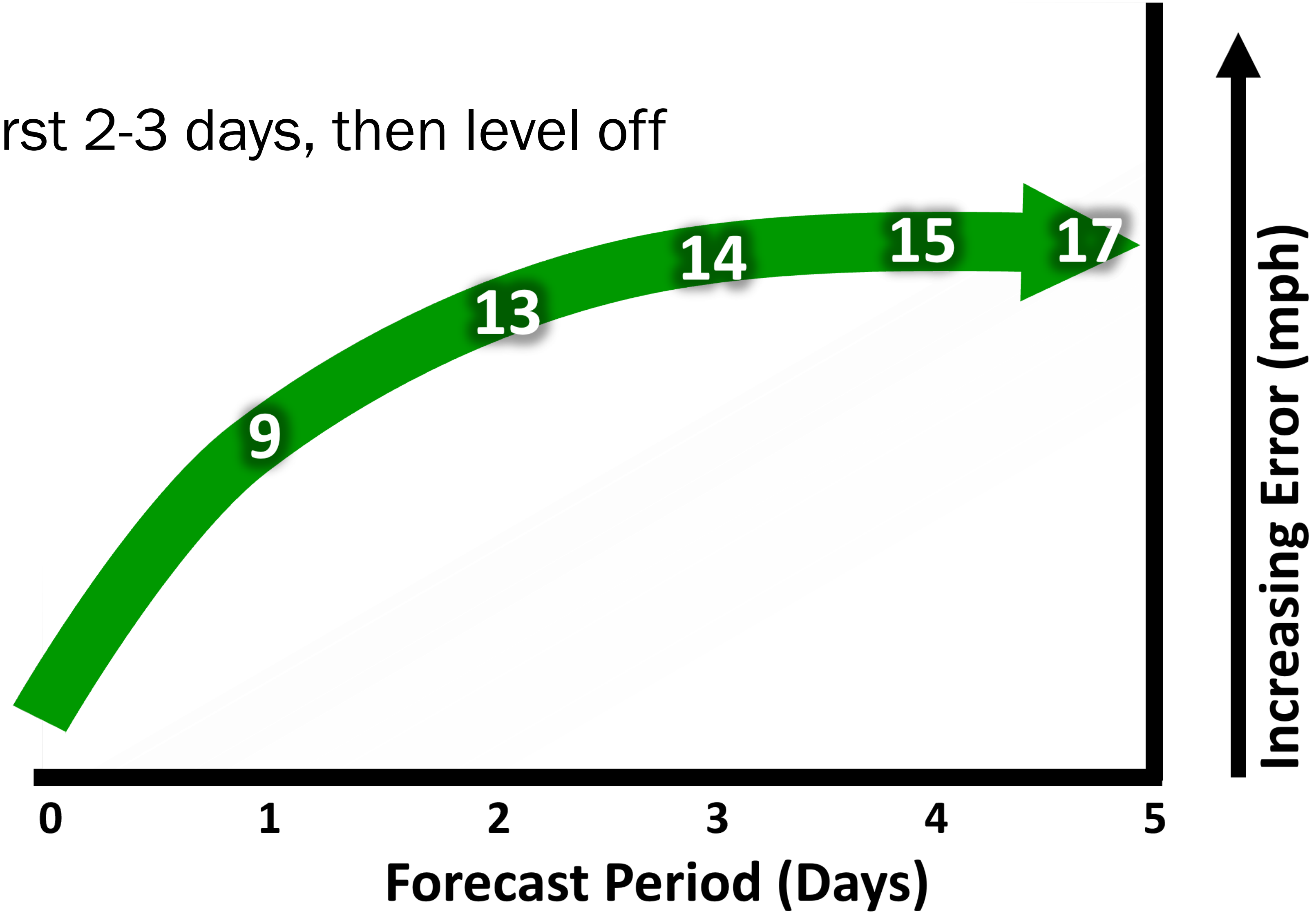
- Increase the first 2-3 days, then level off



Intensity Errors Over 5 Days

Intensity Errors

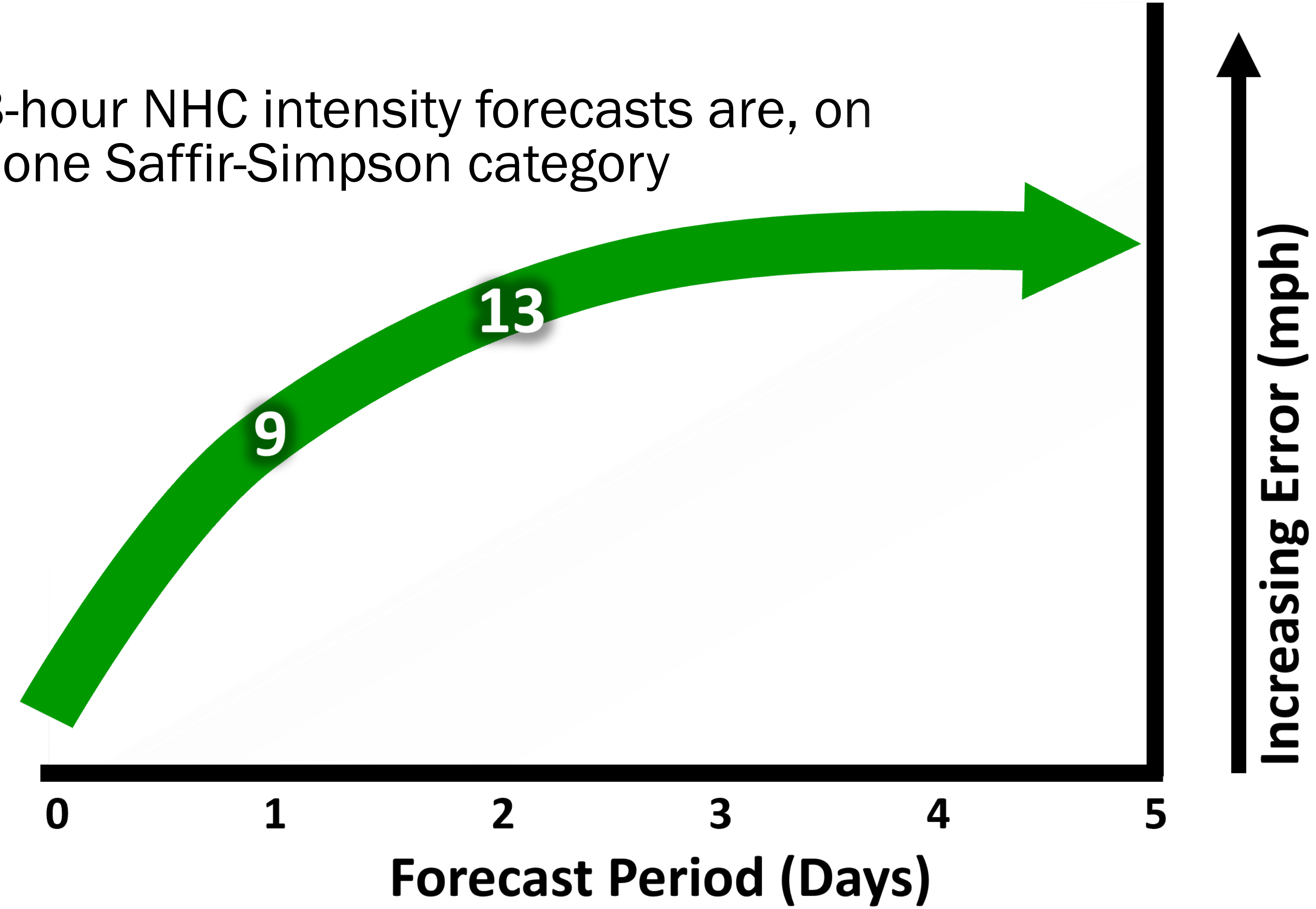
- Increase the first 2-3 days, then level off



Intensity Error Over 48 Hours

Intensity Errors

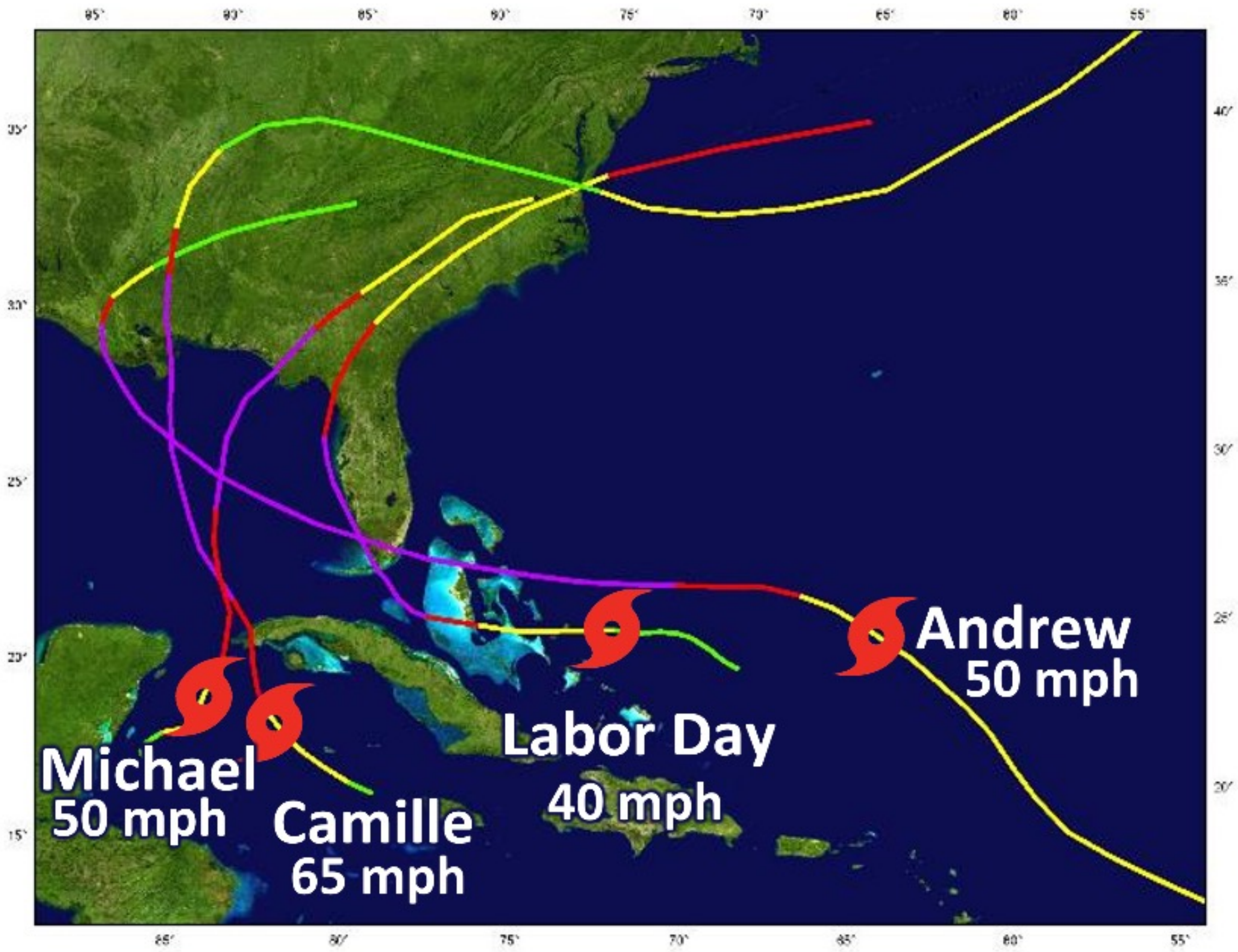
- The 24- and 48-hour NHC intensity forecasts are, on average, off by one Saffir-Simpson category



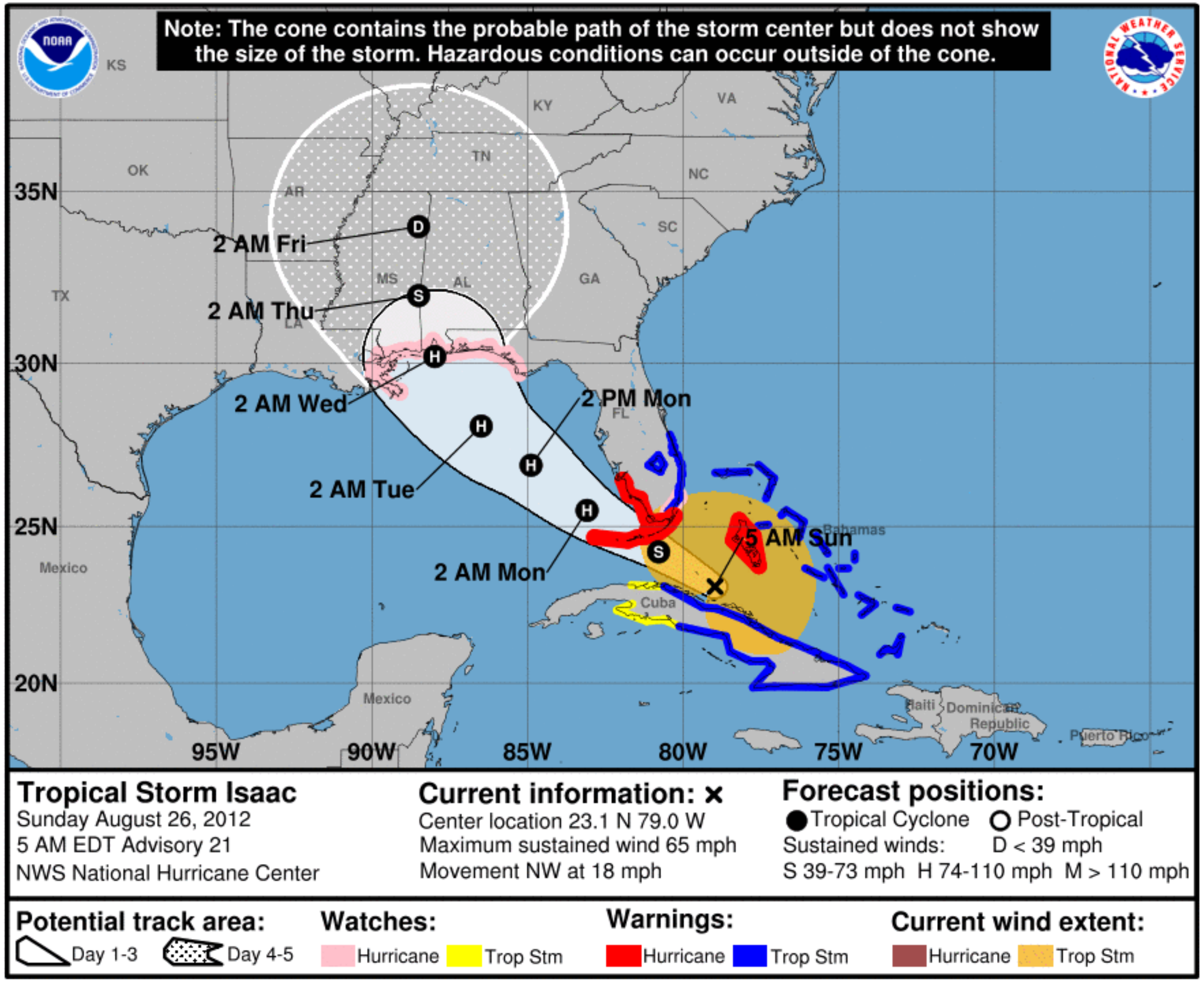
Rapid Intensification

Where were these Category 5 Hurricanes three days before landfall?

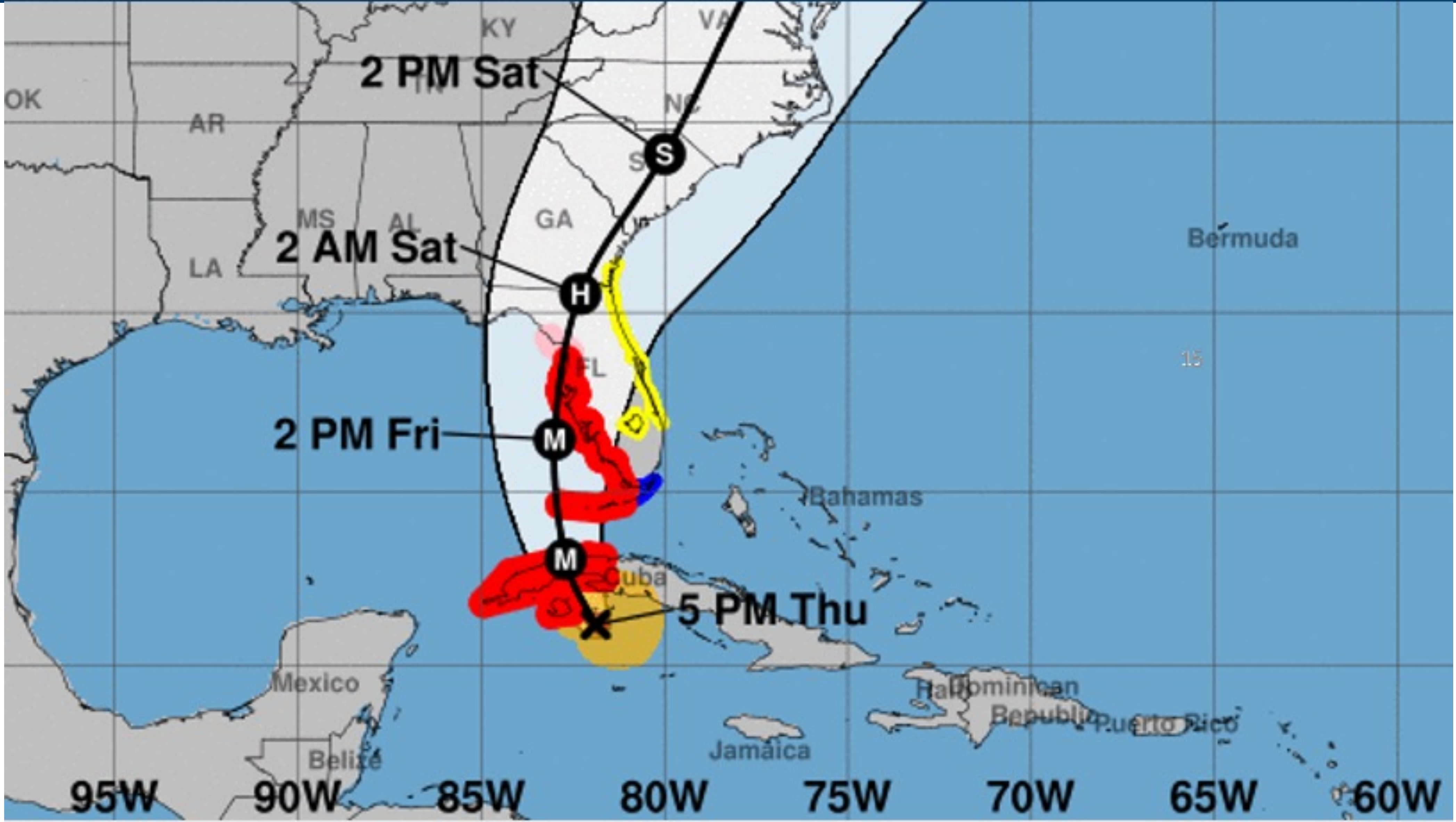
- Labor Day (1935)
- Camille (1969)
- Andrew (1992)
- Michael (2018)



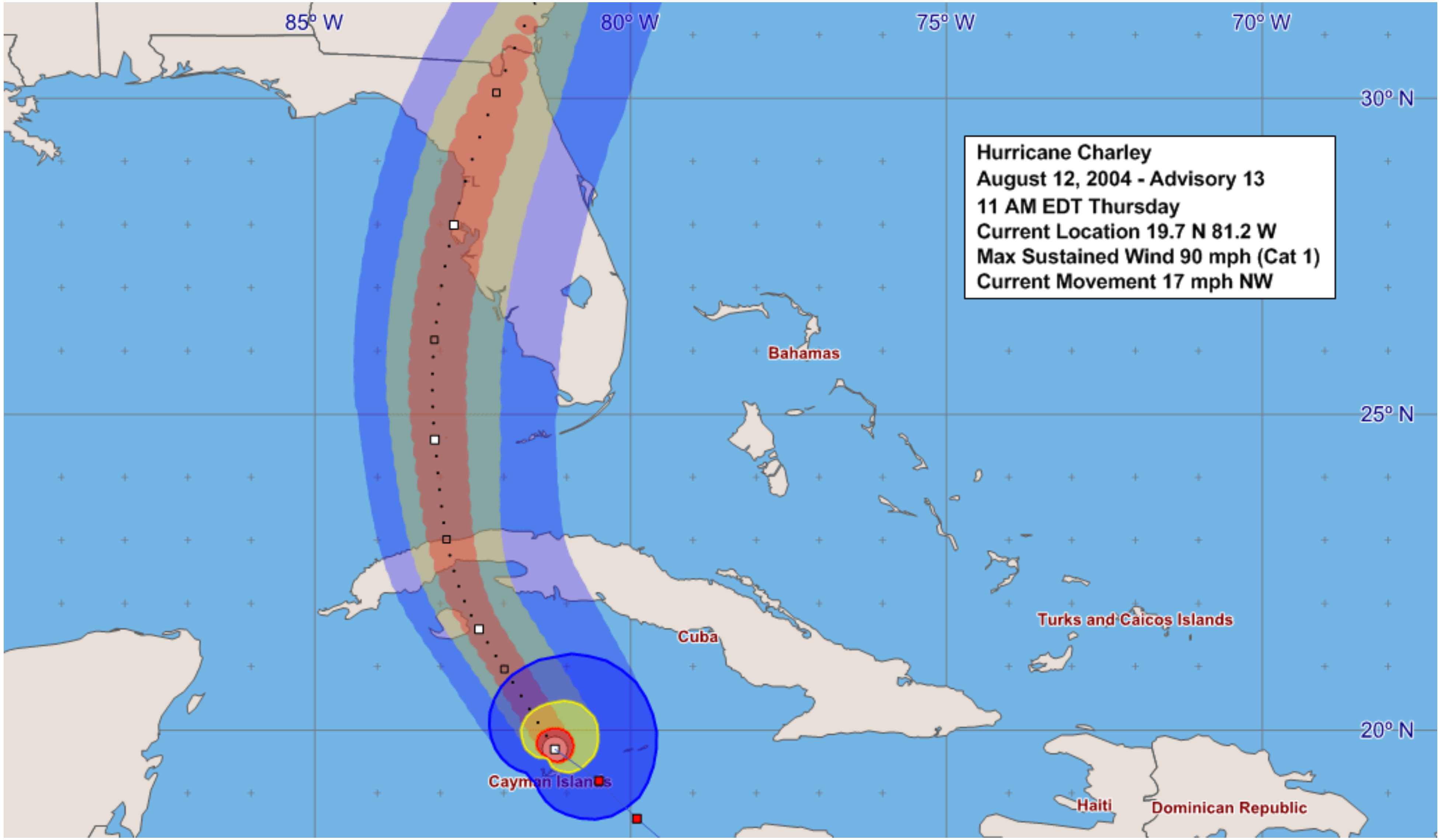
Forecast Error Cone – Probable Track, Watches, Warnings



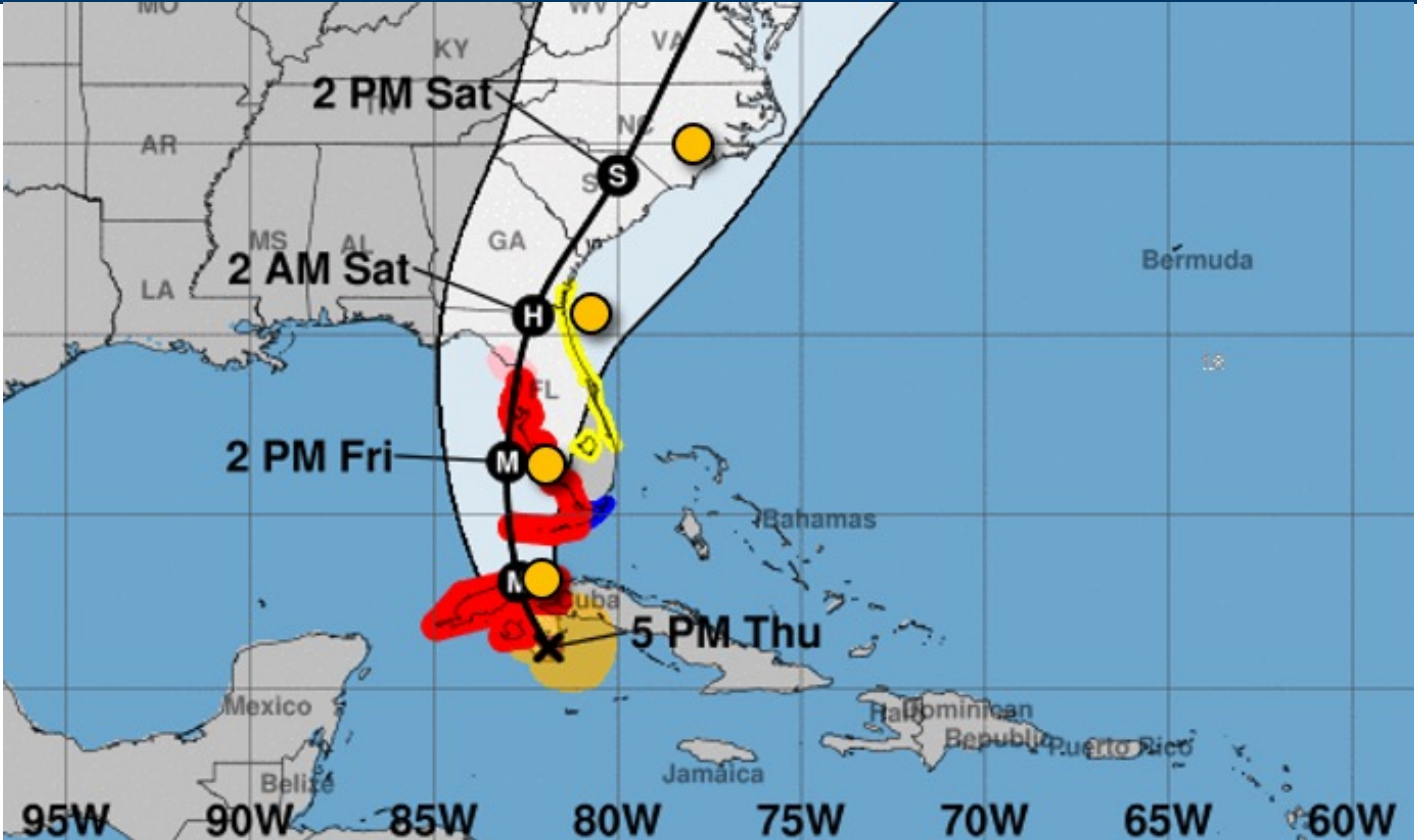
Don’t Focus on the Skinny Black Line



Hurricane Charley



Forecast vs. Observed



Would Alternate Scenarios Help?

How Are WSP Generated?

More scenarios

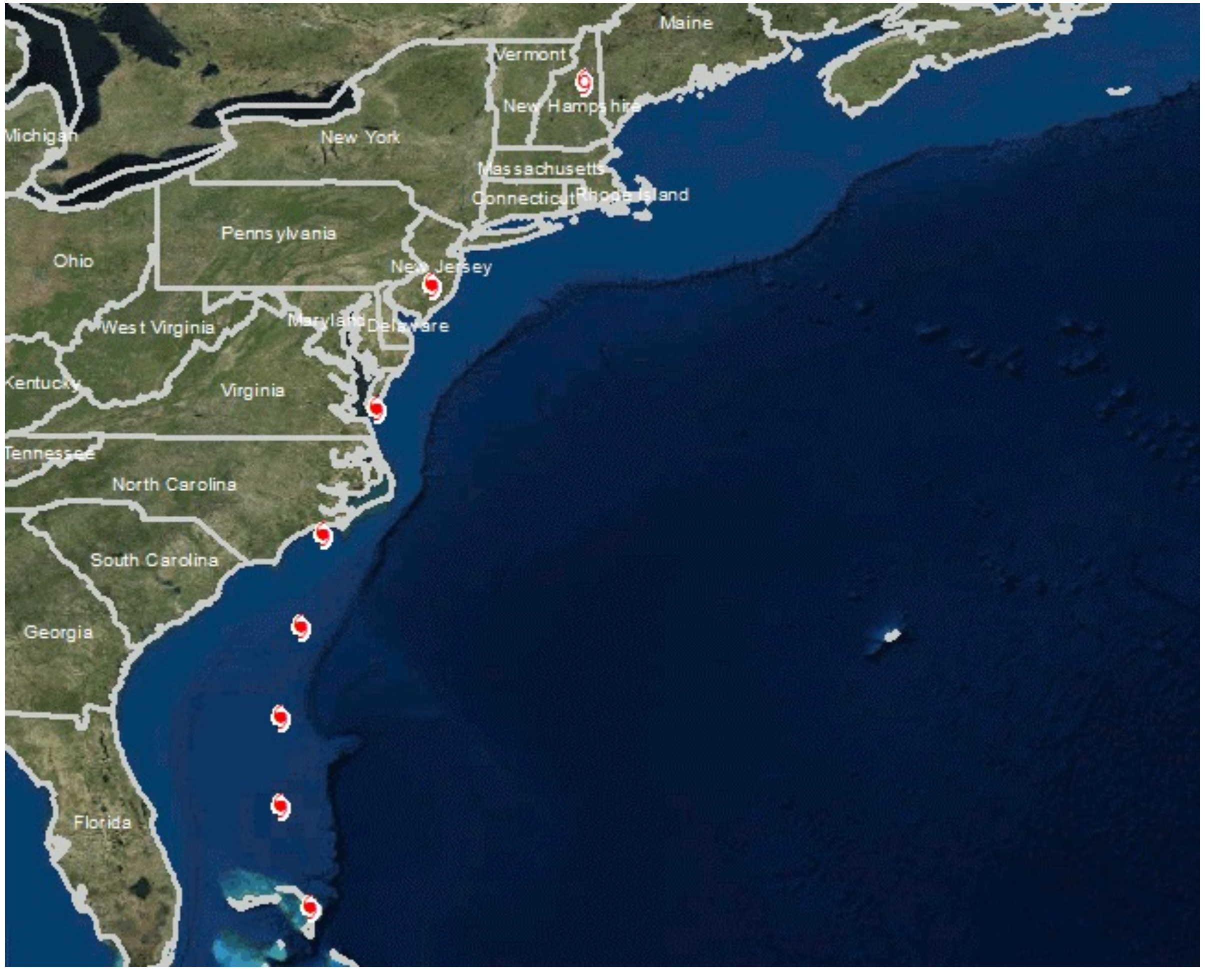
1,000 realistic alternative scenarios are generated

- Official NHC forecast
- Historical track and intensity forecast errors

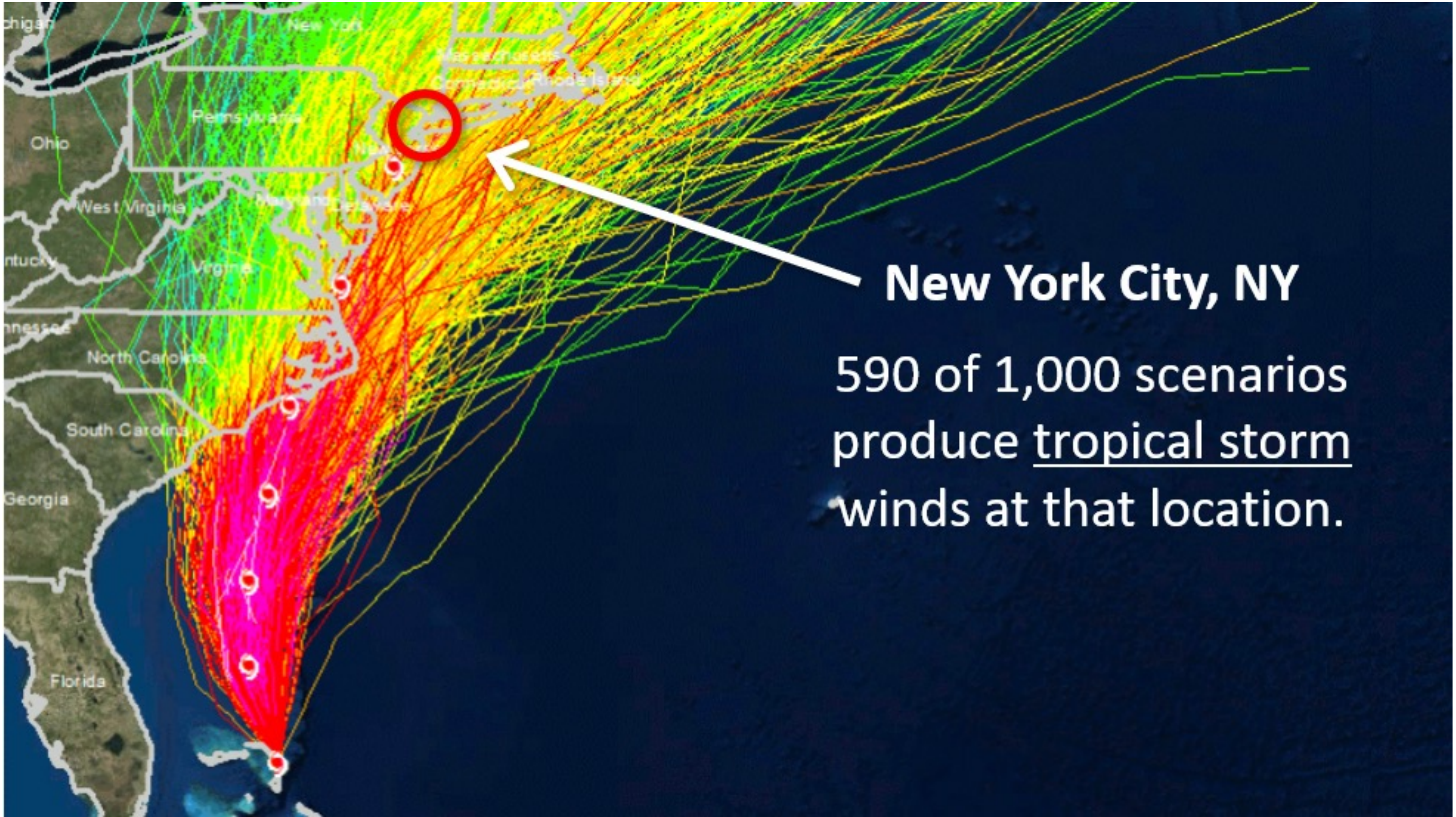
Weakening over land

Track model spread

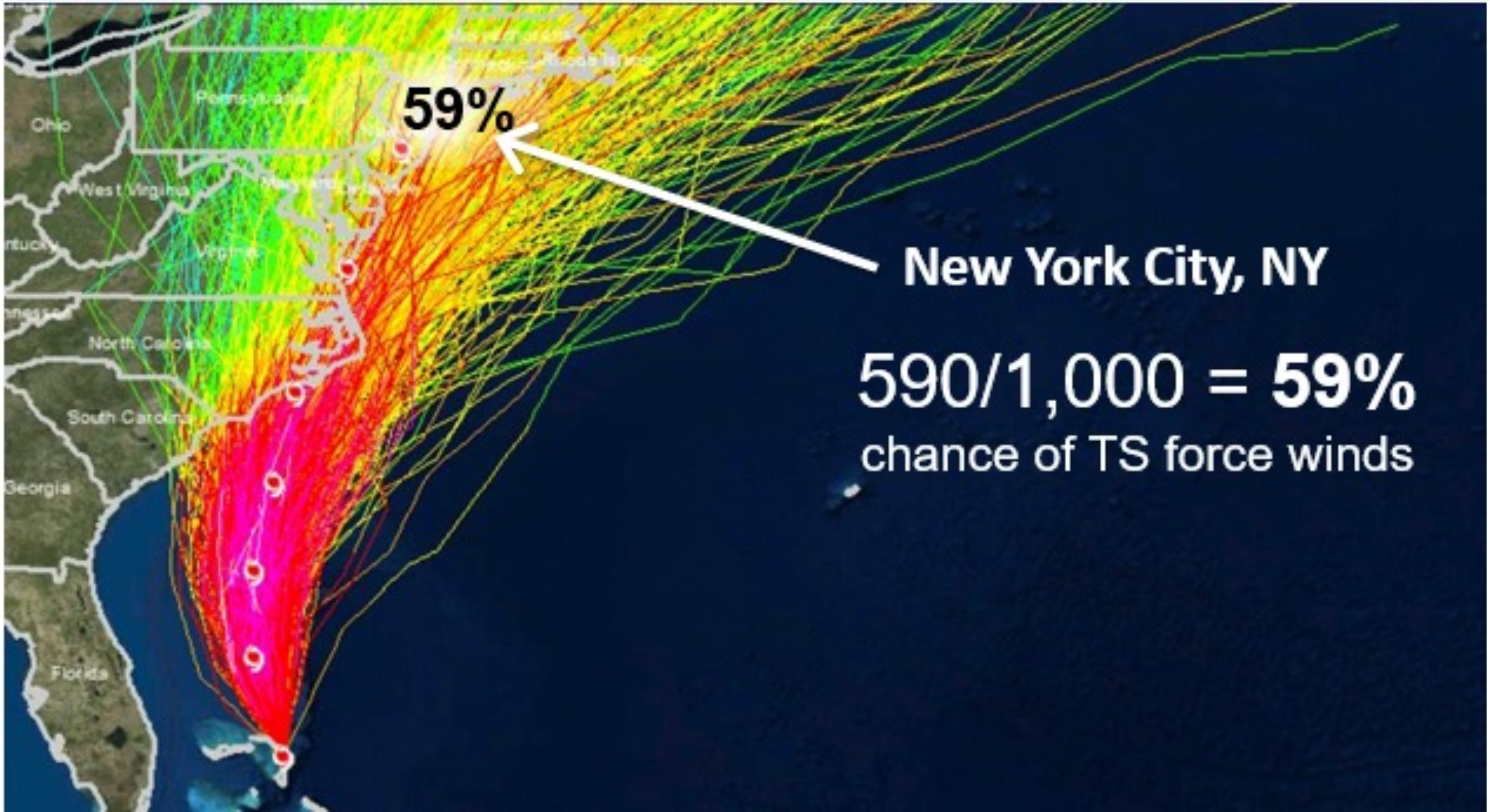
- Forecast track errors are correlated to the spread of model guidance



How Are WSP Generated? 2

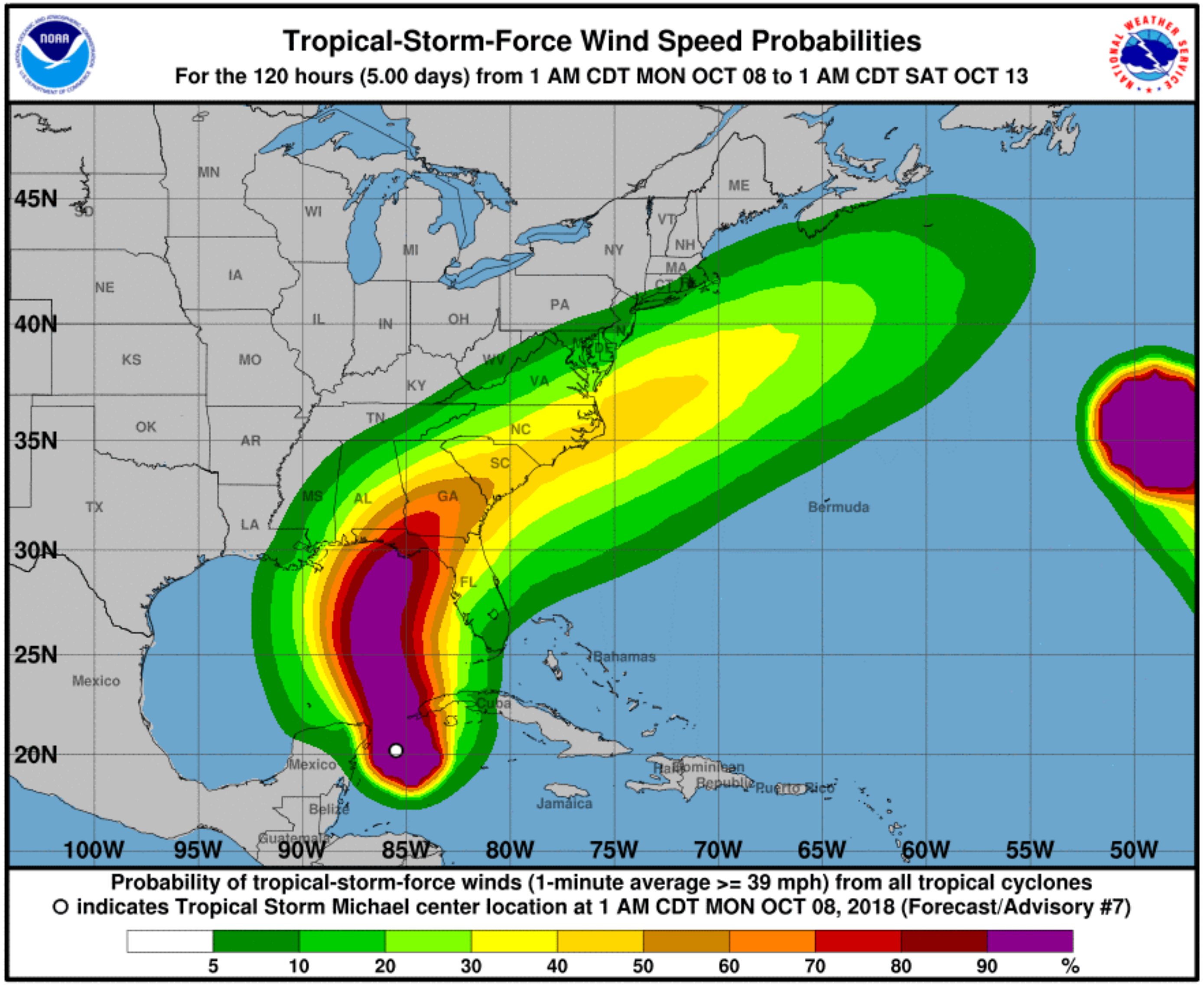


How Are WSP Generated? 3



What Does 59% Chance Mean?

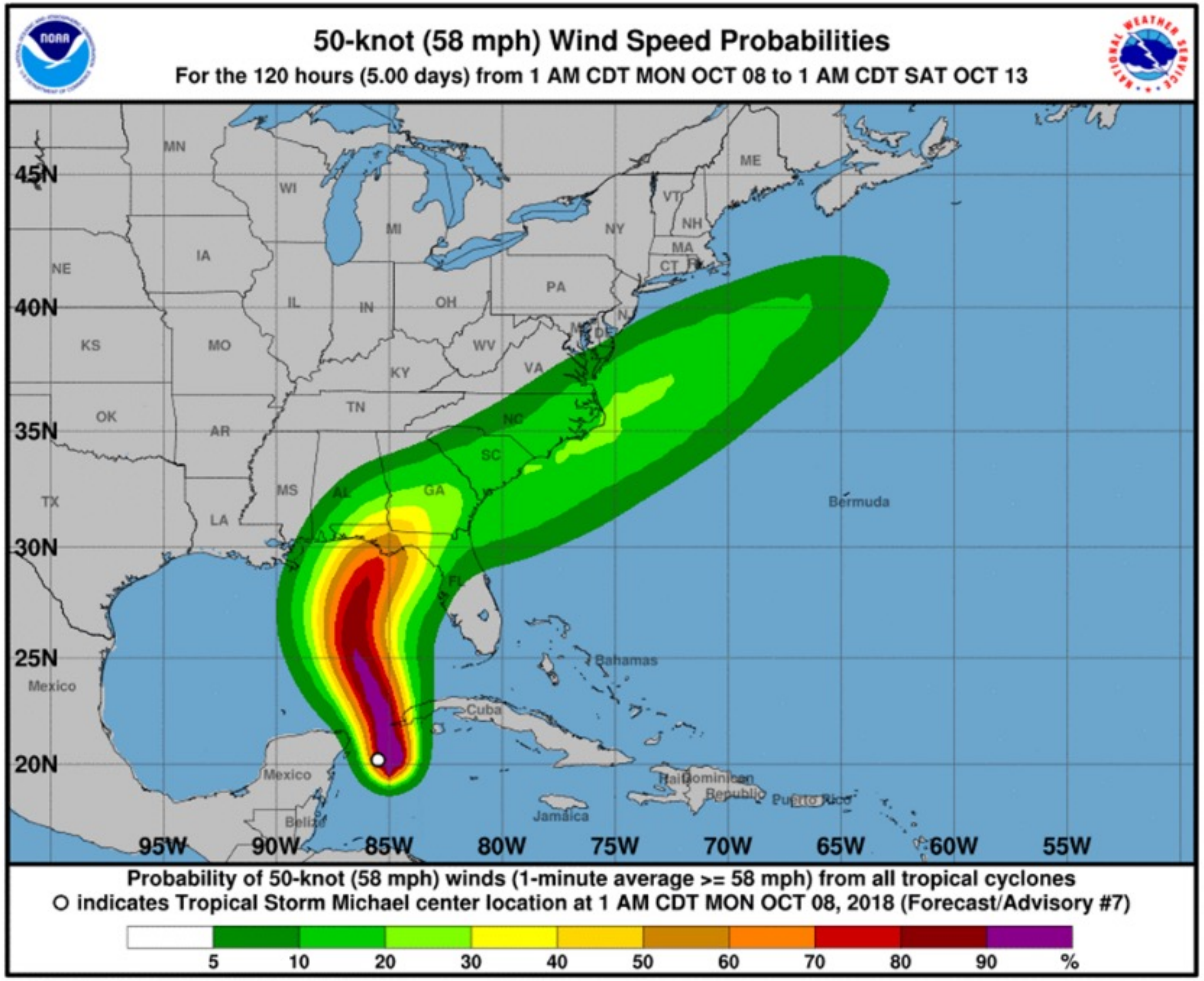
5-Day Cumulative Graphic: TS-Force



Location-specific Probabilities

- **Tropical Storm-Force**
- 58 mph ("Strong" Tropical Storm)
- Hurricane-Force

5-Day Cumulative Graphic: 58 mph



Location-specific Probabilities

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5-Day Cumulative Graphic: Hurricane-Force

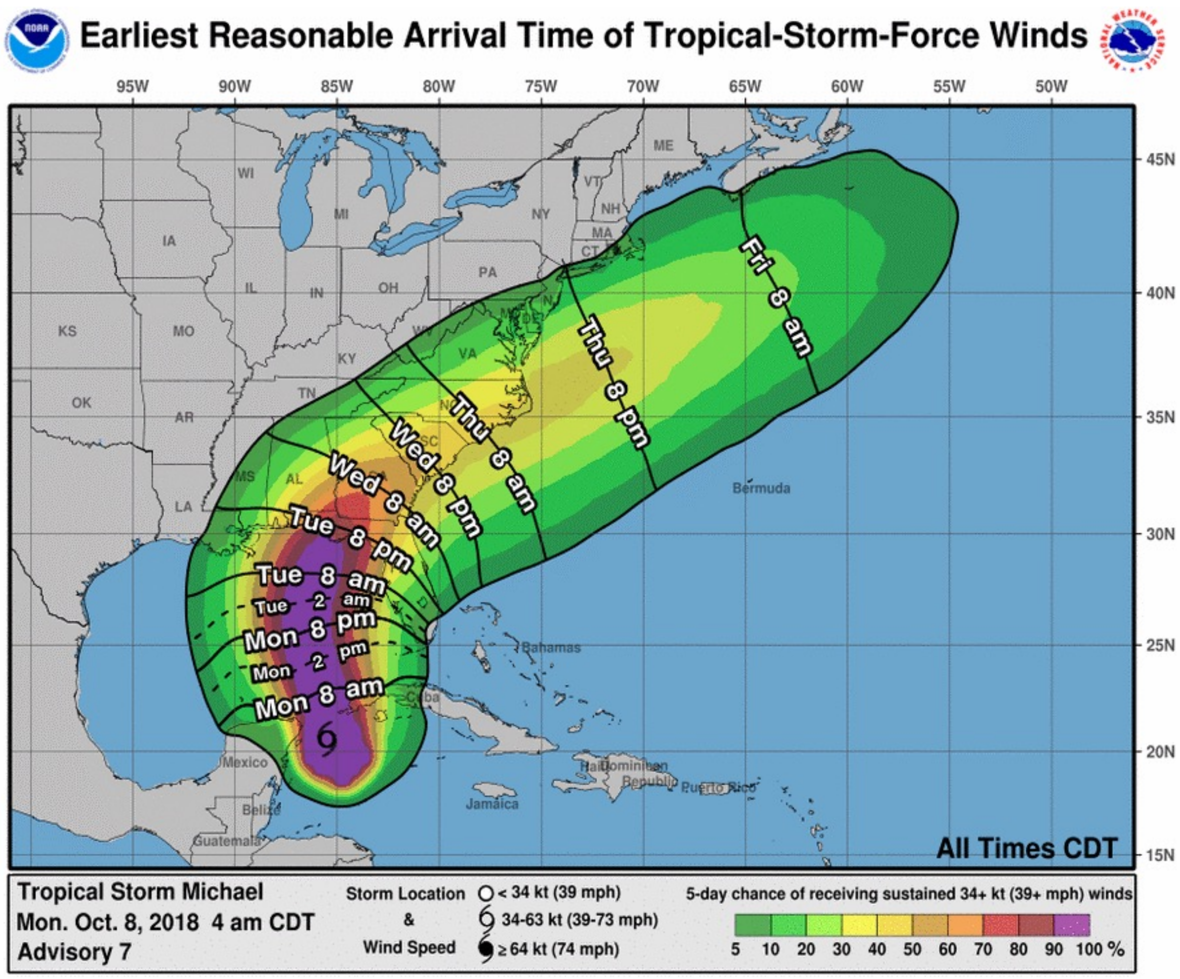
Location-specific Probabilities

- **Tropical Storm-Force**
- 58 mph ("Strong" Tropical Storm)
- Hurricane-Force

Earliest Reasonable Onset of TS Winds

Earliest Reasonable

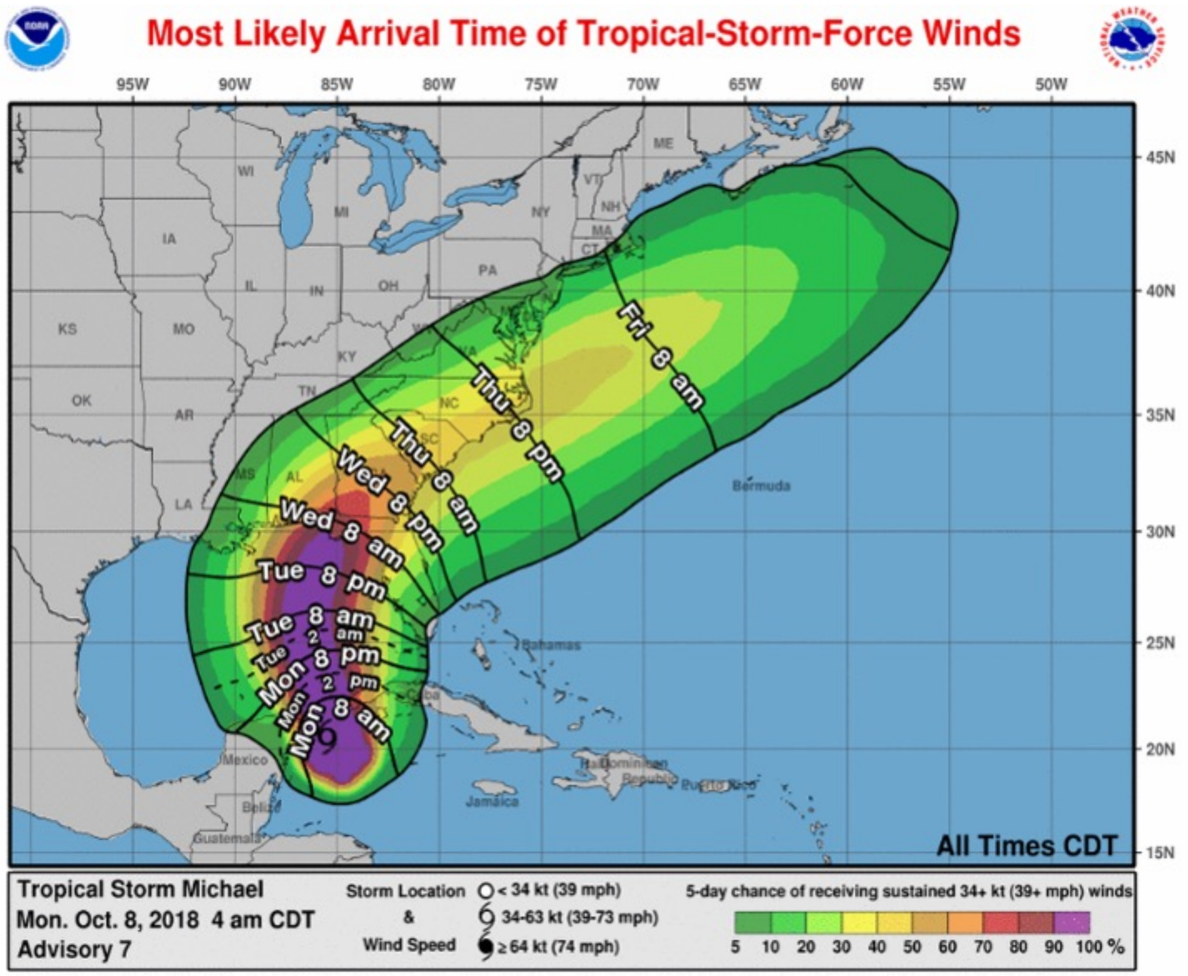
- 10% chance of onset
  (Most conservative timing)
- Black Contours: Arrival time of TS winds
- Color fill: 5-day cumulative TS probabilities



Most Likely Onset of TS Winds

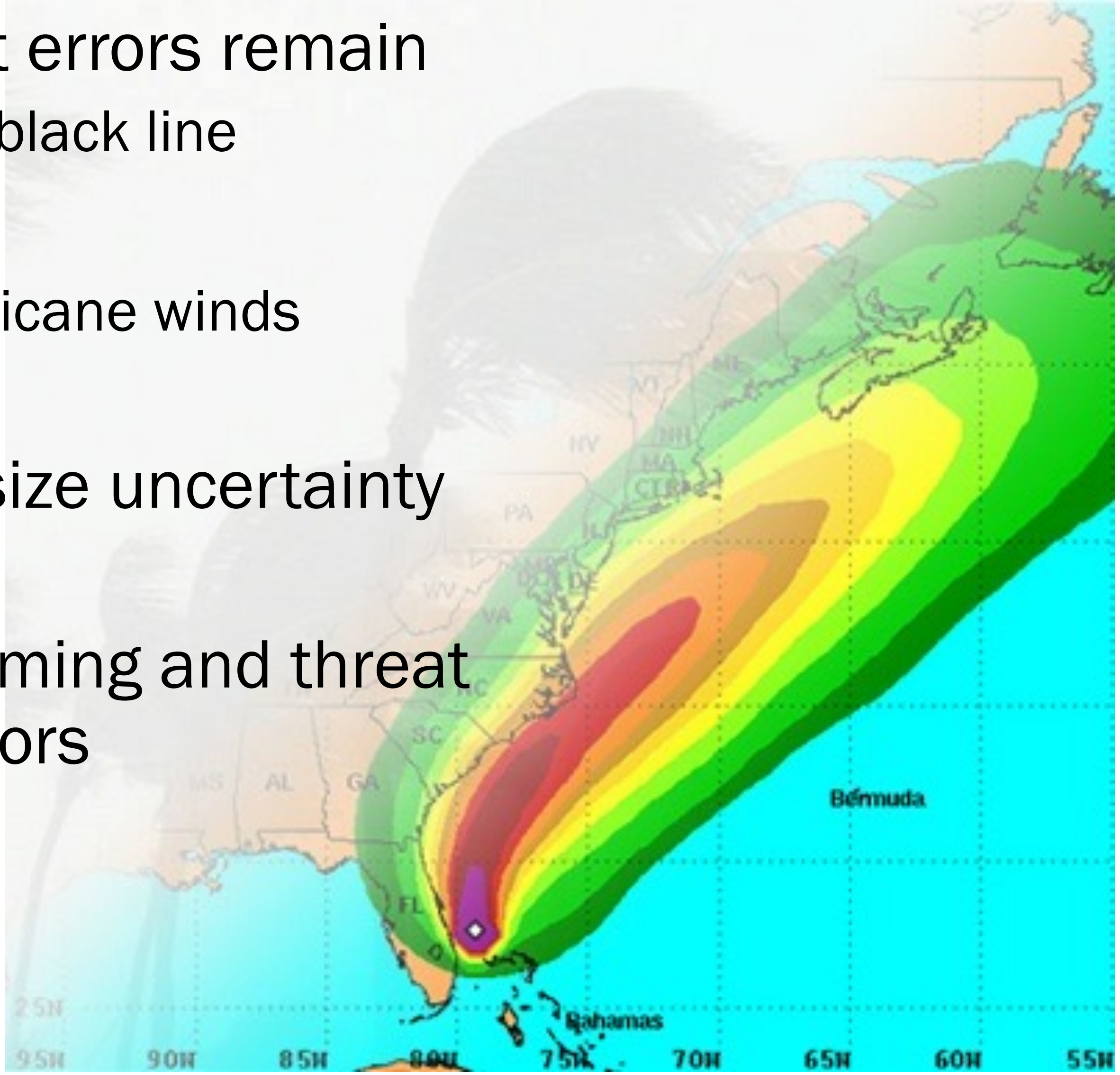
Most Likely

- 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

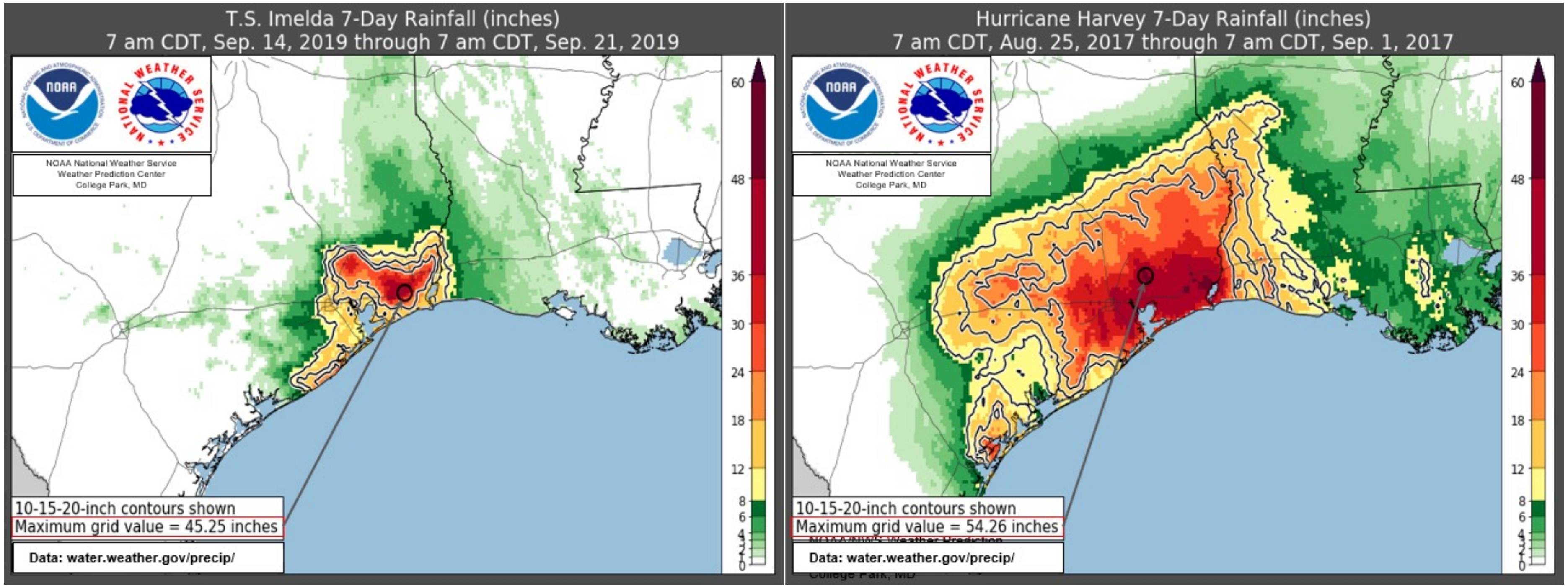


Wind Speed Probabilities – Summary

- 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

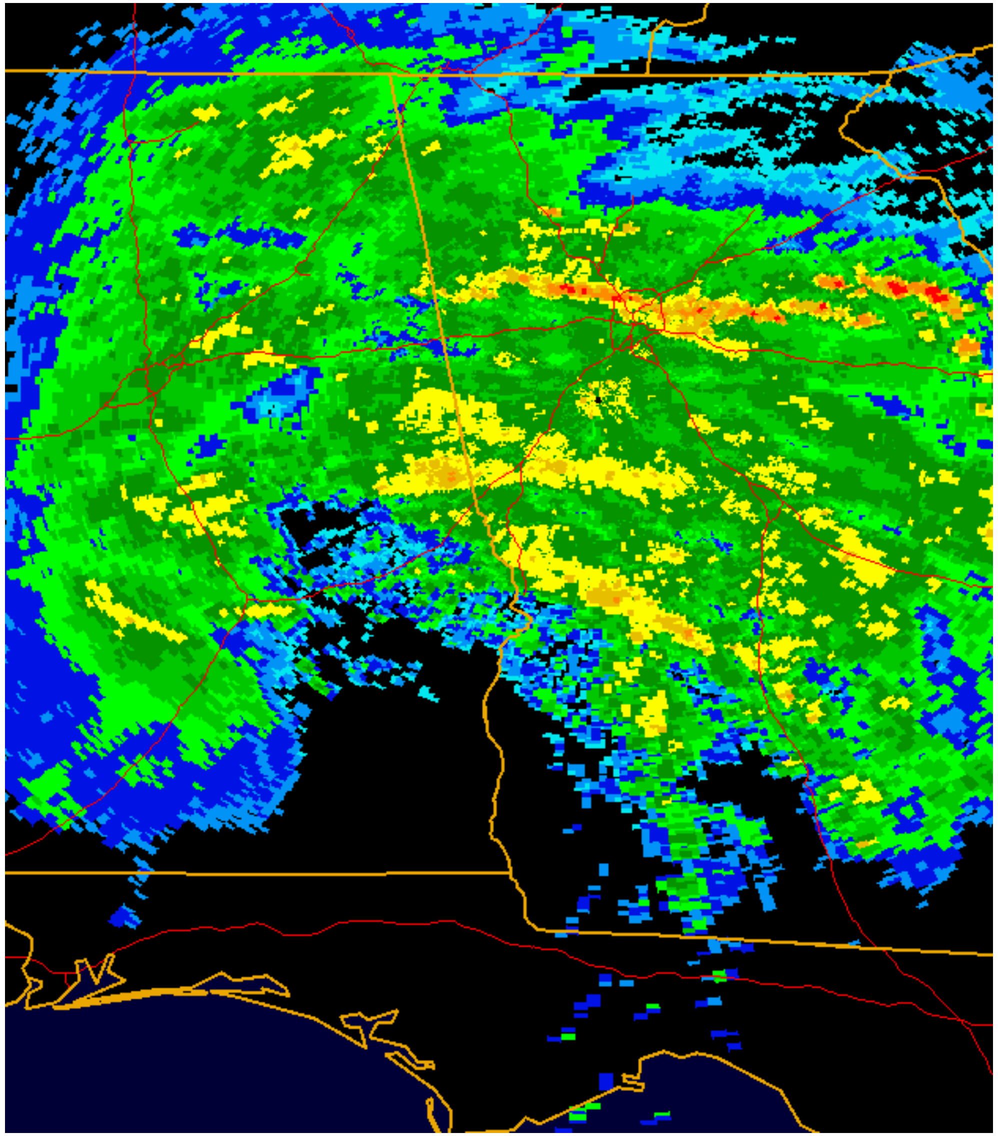


Rainfall Predictability Challenges

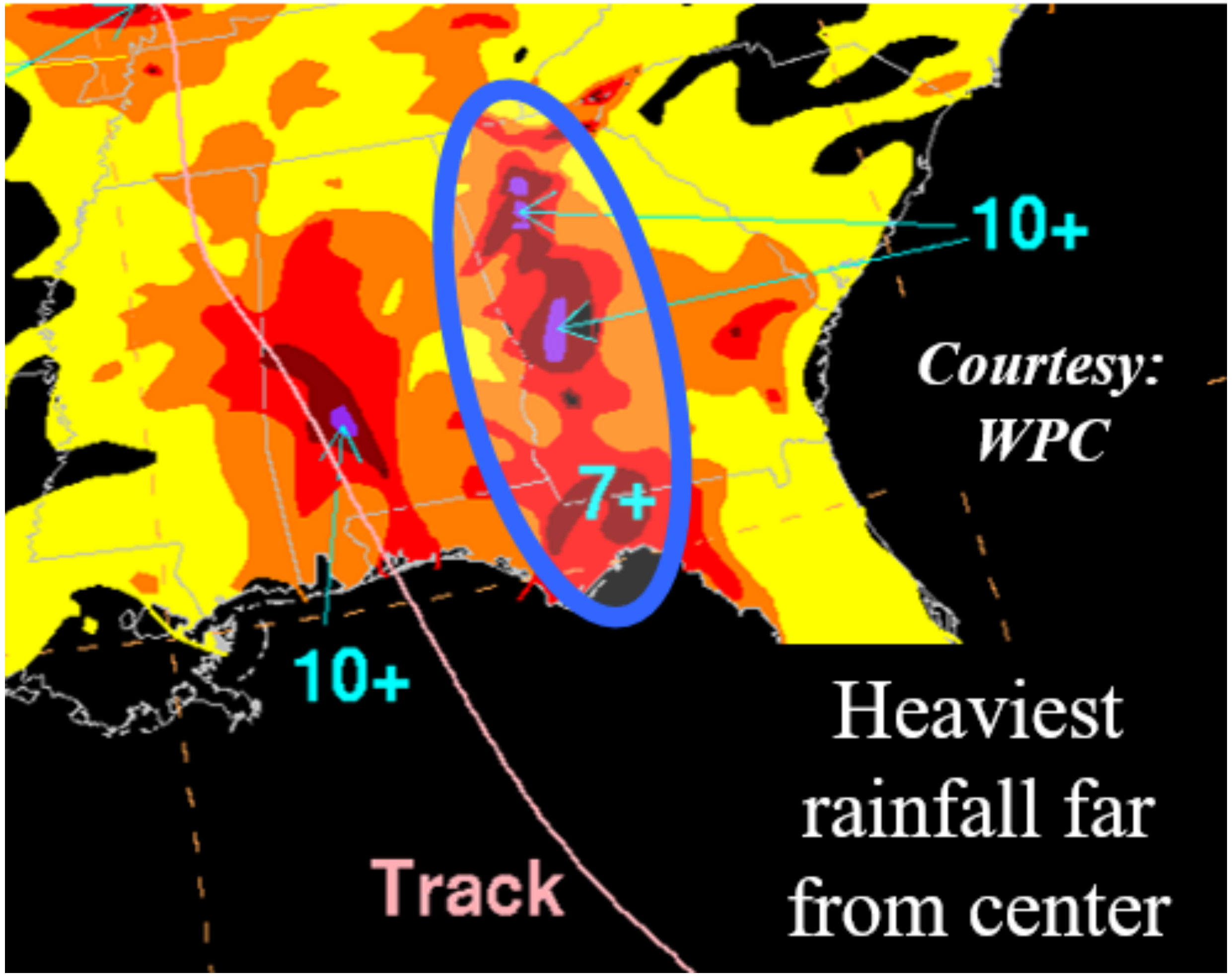


- Small, less organized storms can produce localized extreme rainfall maxima
- Slow storm motion remains a factor
- Less lead time and placement can make a big difference in impacts
- Extreme events at this scale can be more obvious at longer lead times, but remember placement error

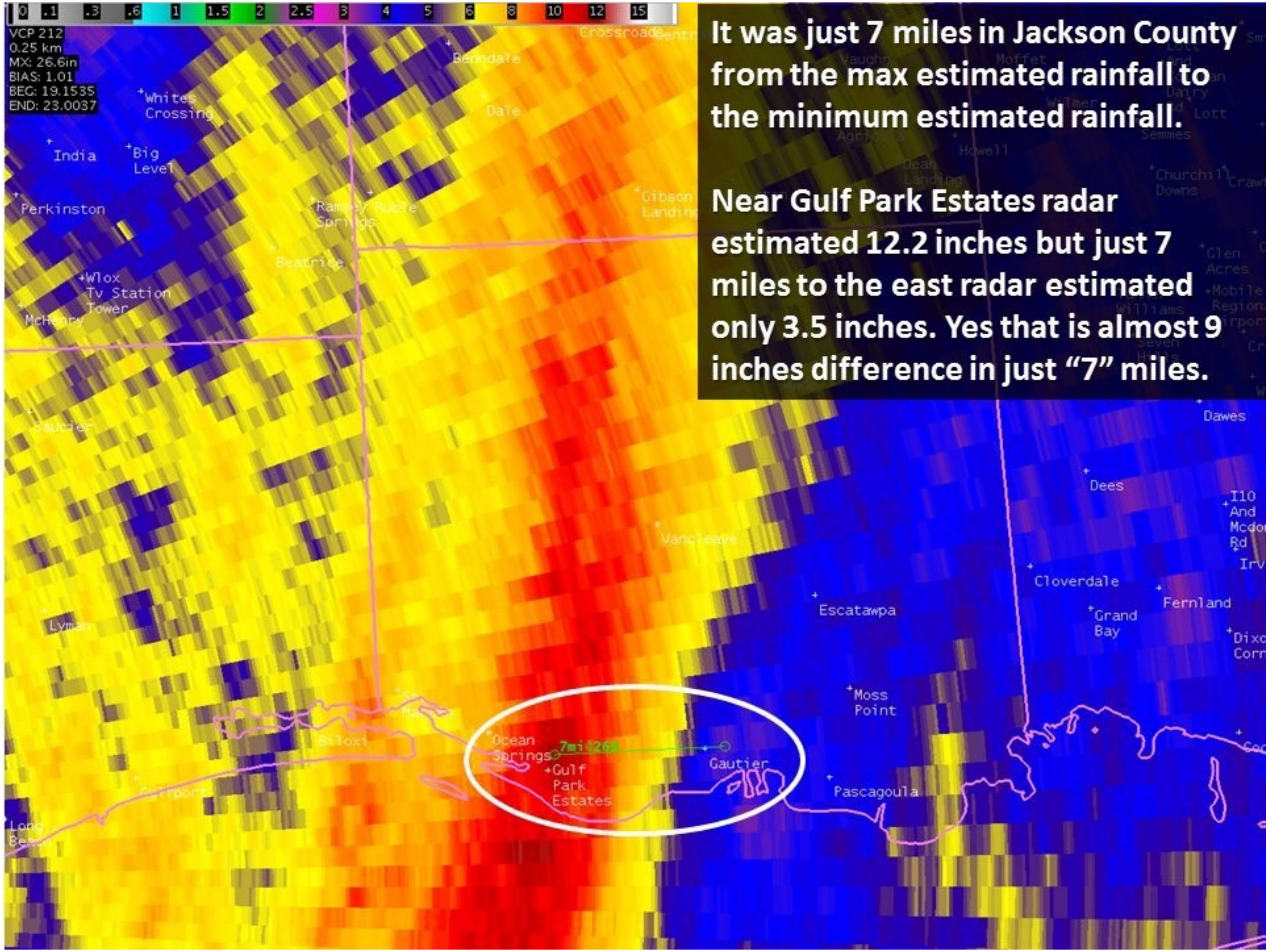
Placement of Persistent Rain Bands?



Storm-Total Rainfall

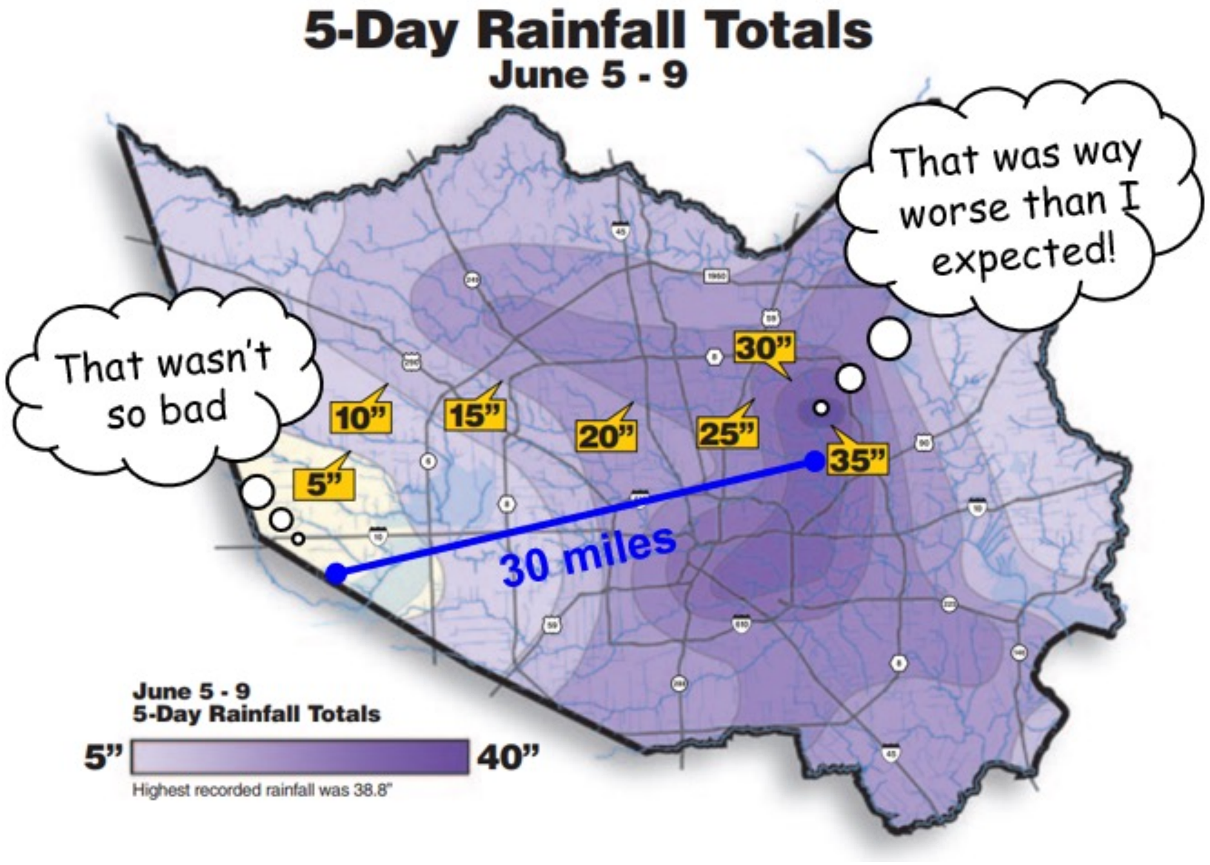


TS Cindy (2017) Forecast Challenge



Messaging Issues

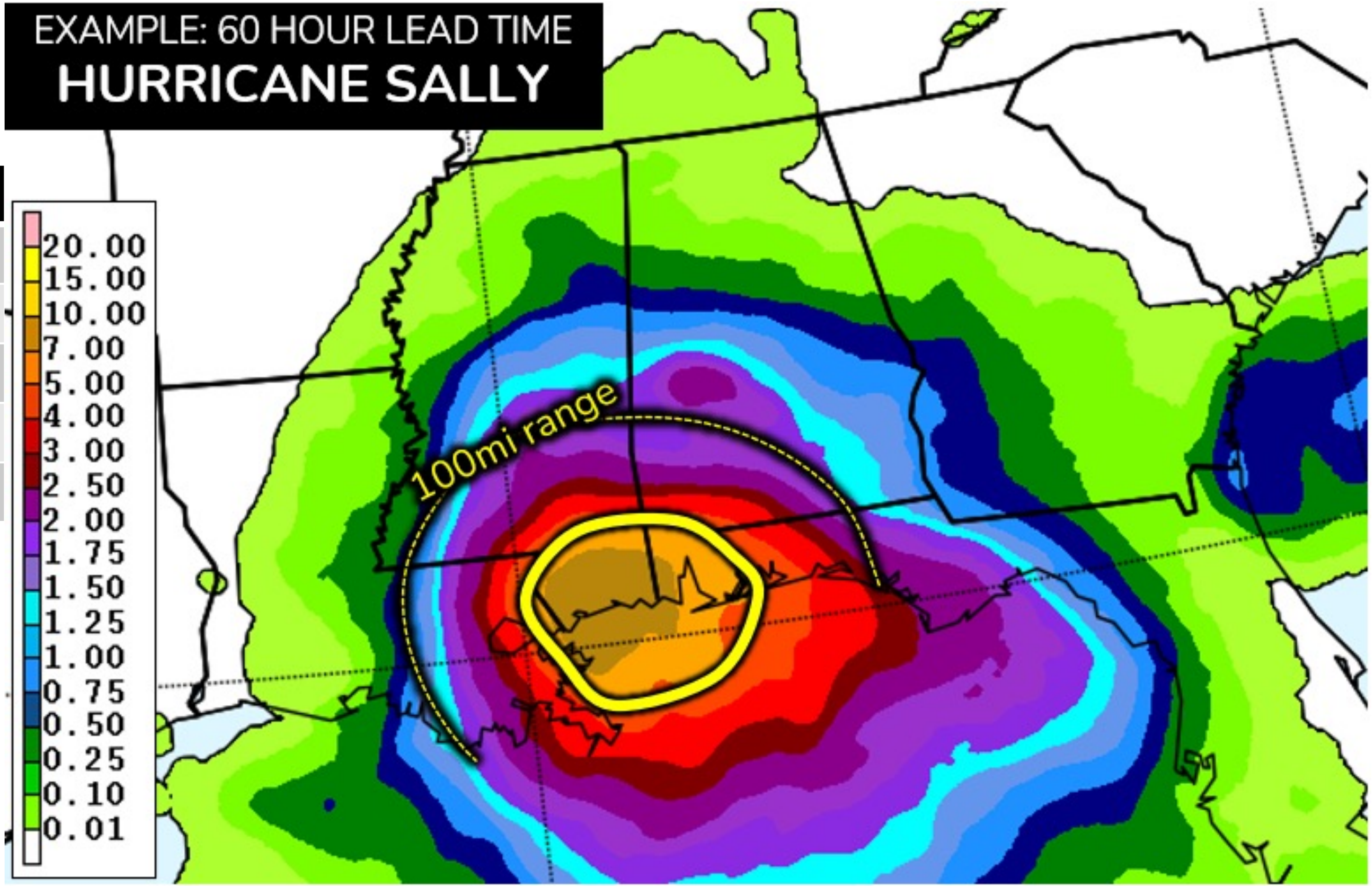
Extreme rain gradients in banding in slow-moving, disorganized storms present messaging issues.



Rainfall Forecast Interpretation

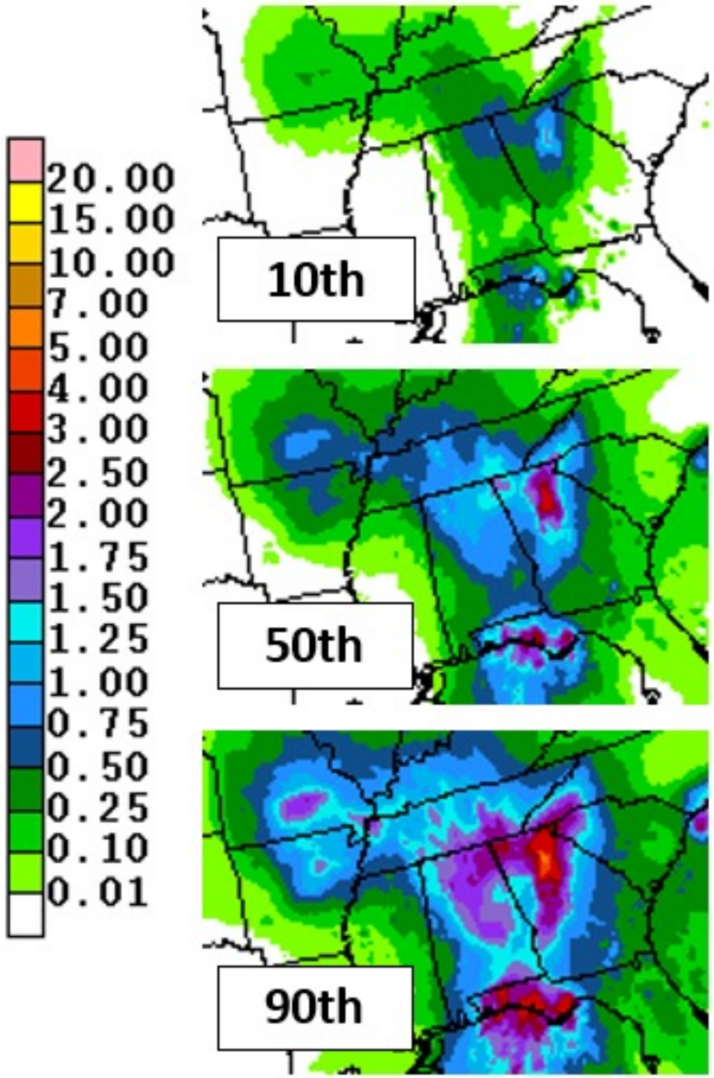
Lead Time	Avg. Error
12 hours	55 miles
36 hours	71 miles
60 hours	98 miles
84 hours	137 miles
108 hours	170 miles

2016-2021 Displacement Error of 2” Rainfall Forecast Contour



Probabilistic Rainfall Forecasts

In Percentiles

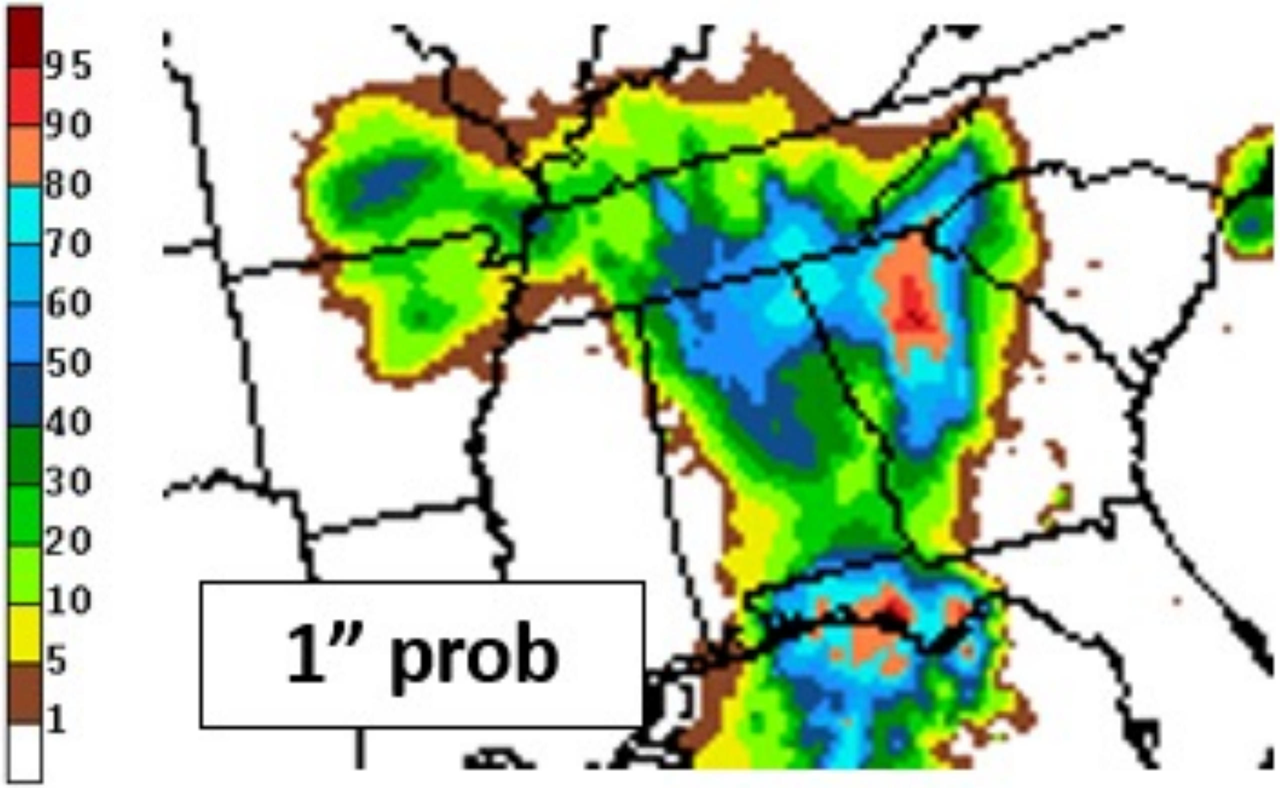


__10th Percentile__
Expect at least this much rainfall

__50th Percentile__
Best guess, or most likely, rainfall

__90th Percentile__
Reasonable high-end scenario

Rainfall Probability



Flooding Forecast Considerations

Ground State (How dry is it?)

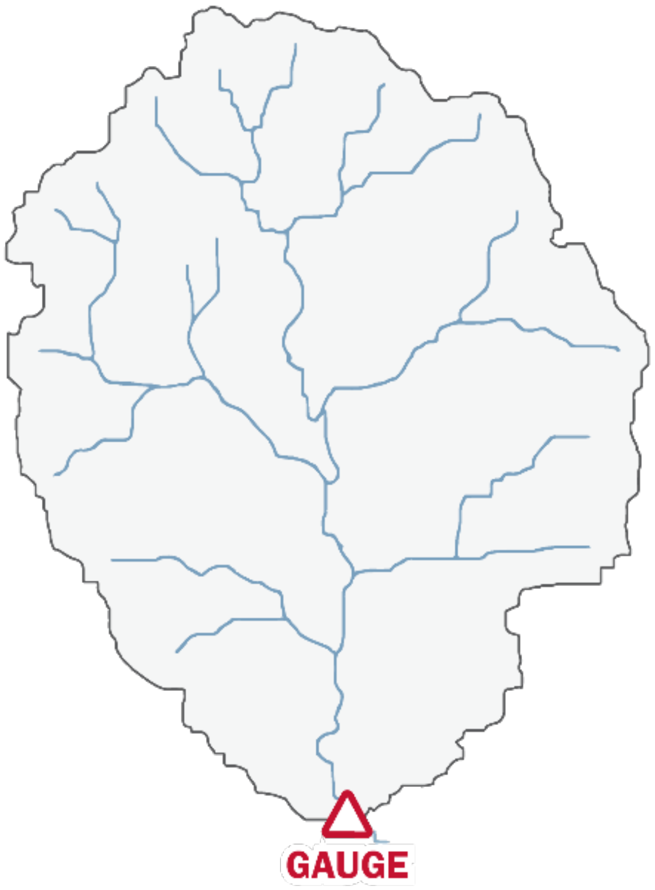
Past Model Performances

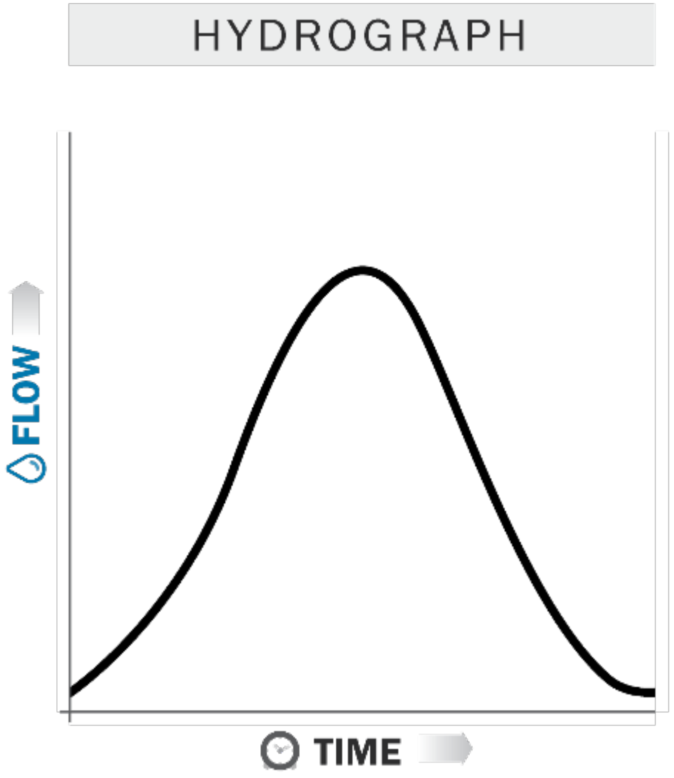
Rainfall (Gauge-based or Radar-based?)

Rainfall Variability

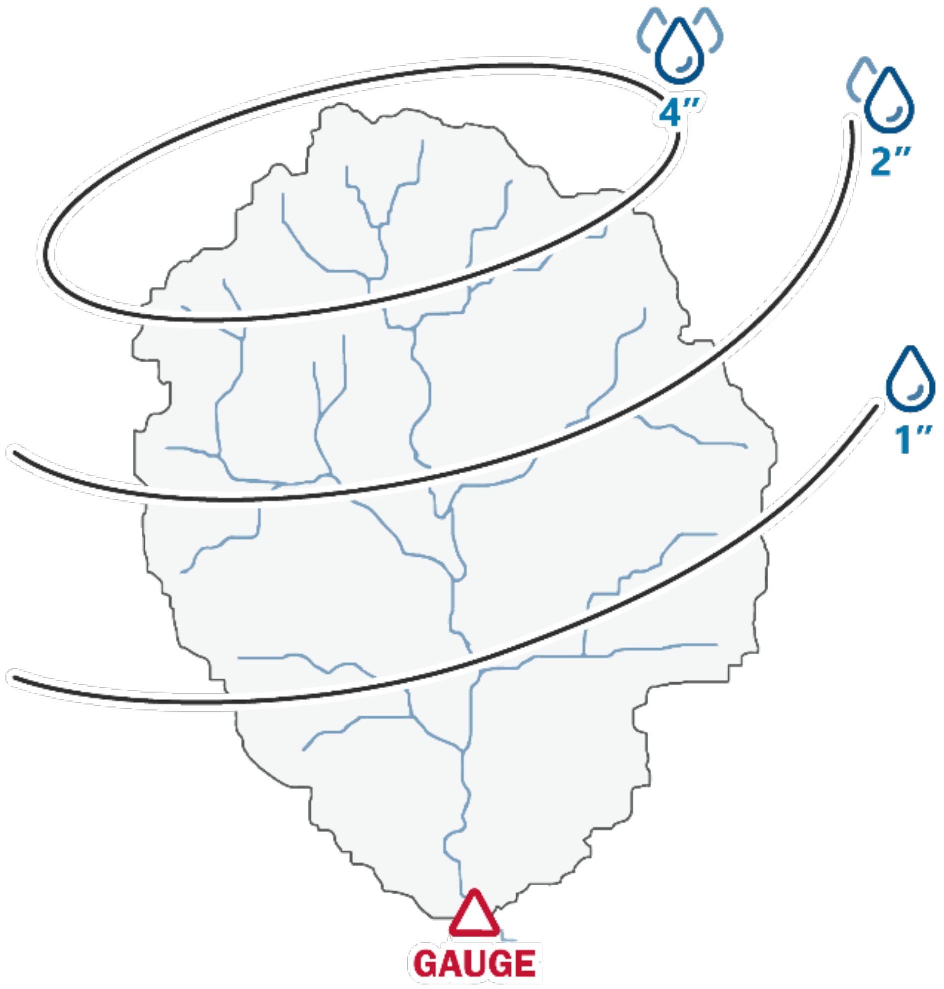
- Space
- Time

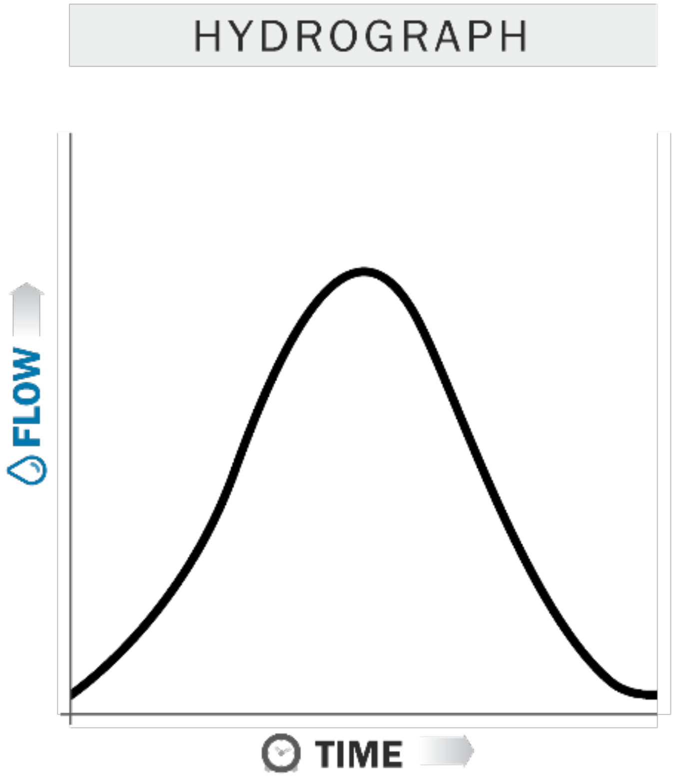
Rainfall Variability – Baseline



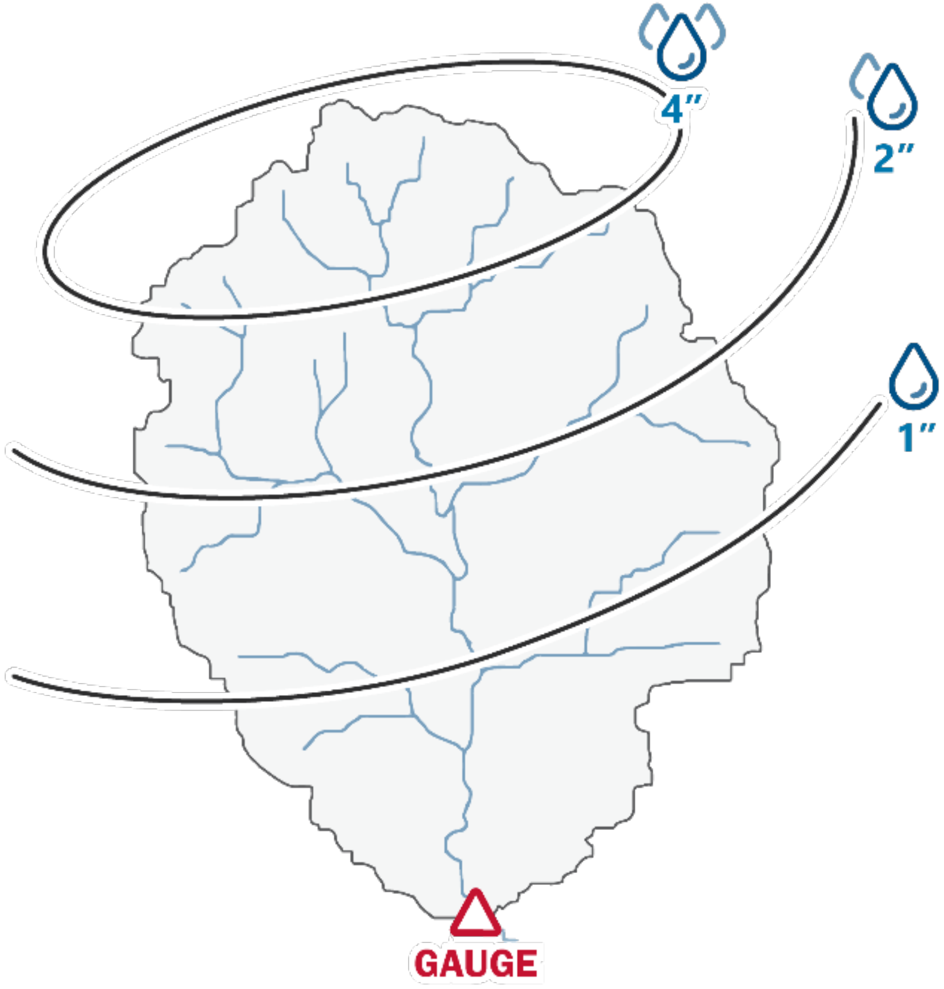


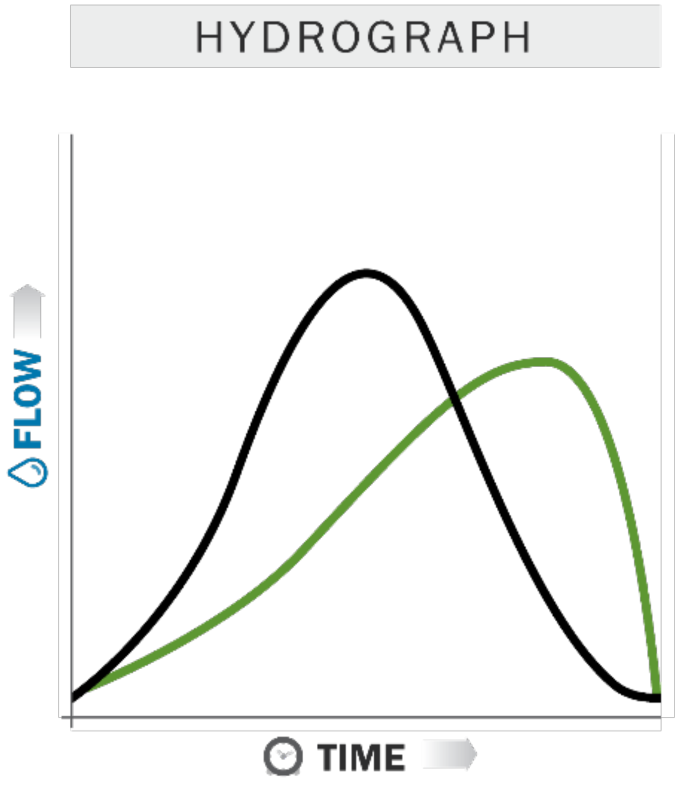
Rainfall Variability – Heavy Upstream



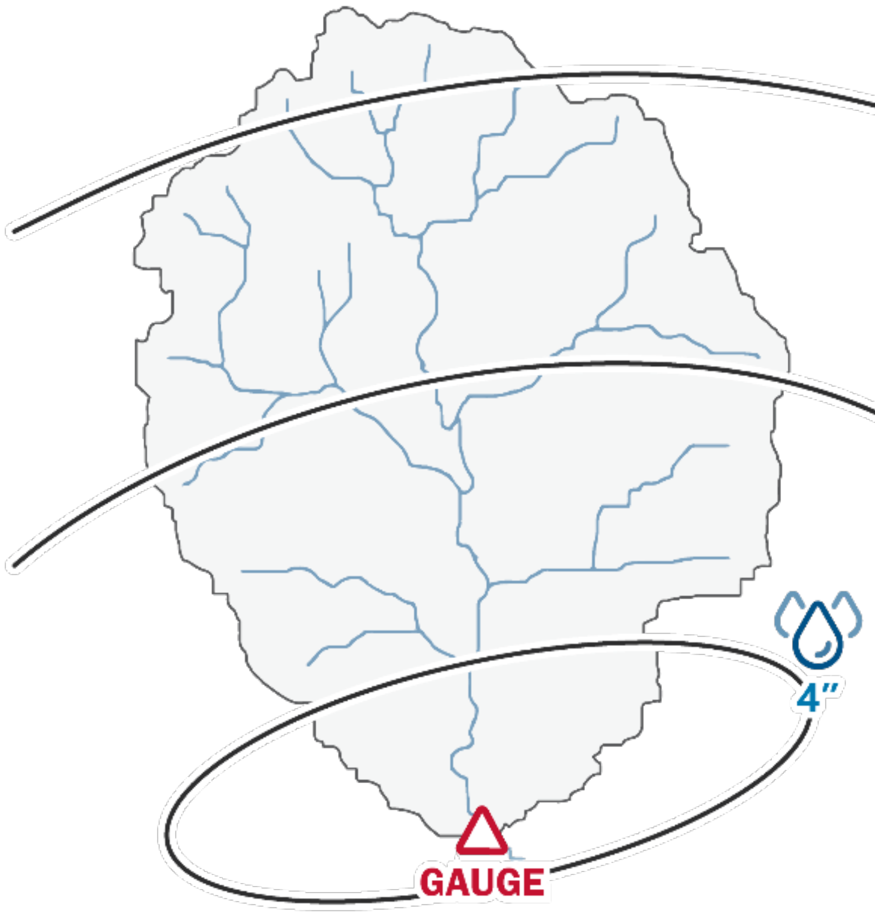


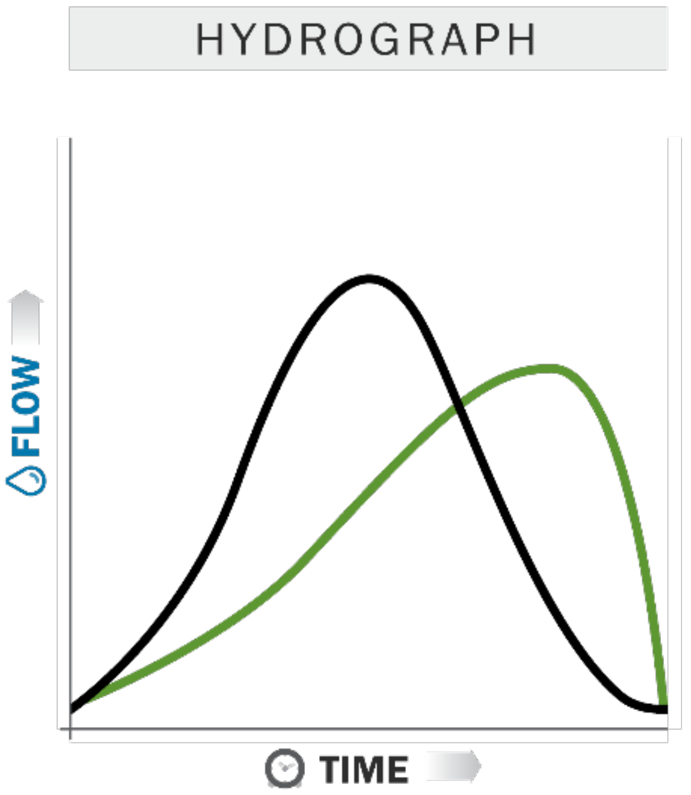
Rainfall Variability – Left Shift Hydrograph



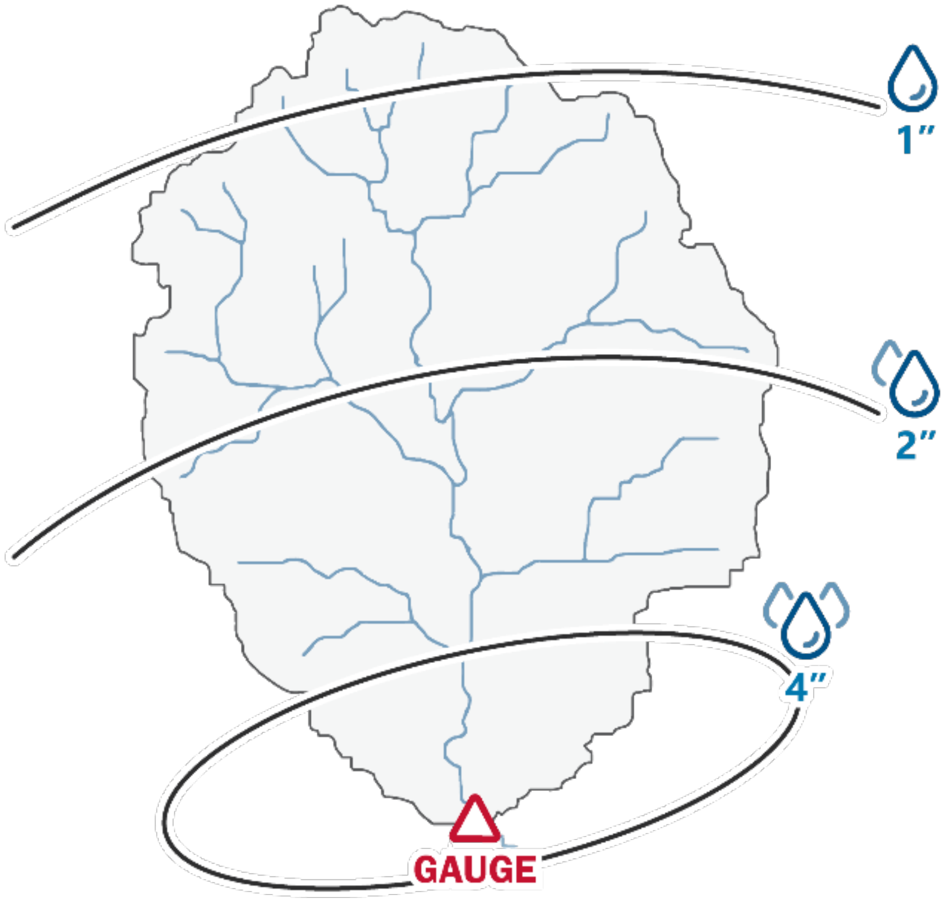


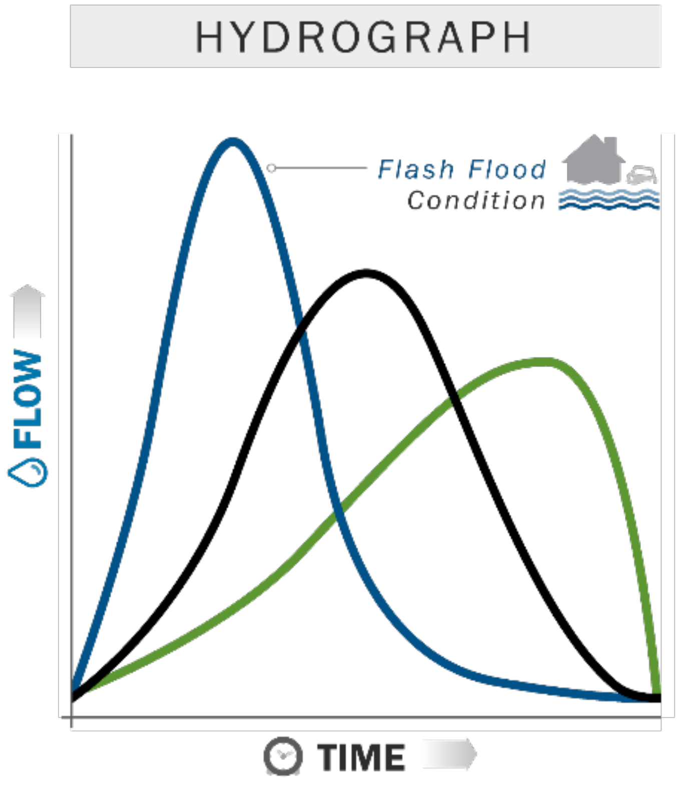
Rainfall Variability – Heavy At Gauge





Rainfall Variability – Right Shift Hydrograph





Ensemble Forecasting

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

(Recreated from the official product)

River	City, ST	10%	20%	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

"100-Year ~~Flood~~ Recurrence Interval"

A flood that has a 1 in 100, or a 1% chance of occurring in any given year

"500-Year ~~Flood~~ Recurrence Interval"

Flood that has 1 in 500, or a 0.2% chance of occurring in any given year

- Does NOT mean a 100- or 500-year flood occurs once every 100 or 500 years
- Technical term: Annual Exceedance Probability (AEP)
- Also, a 100-year rainfall event ≠ 100-year flood

Questions/Comments?