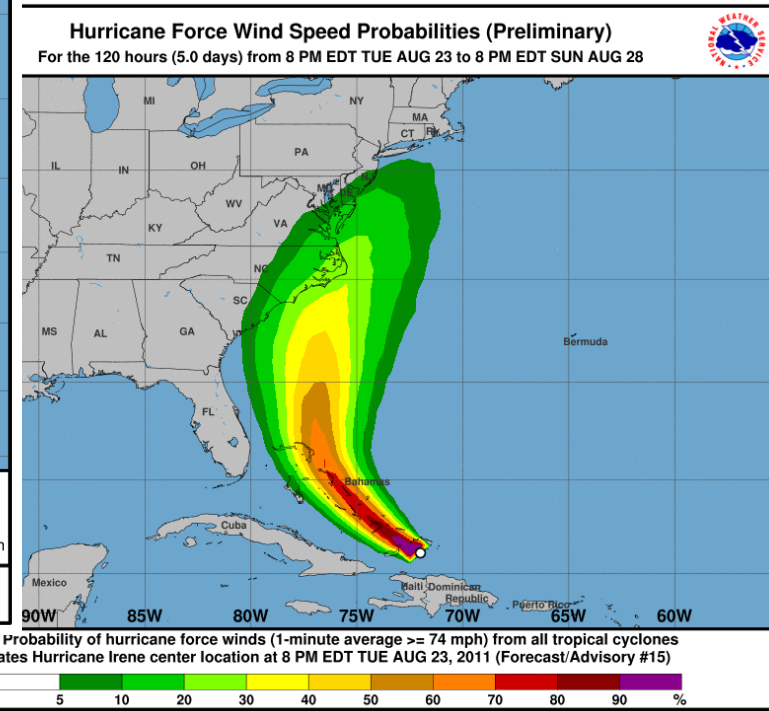
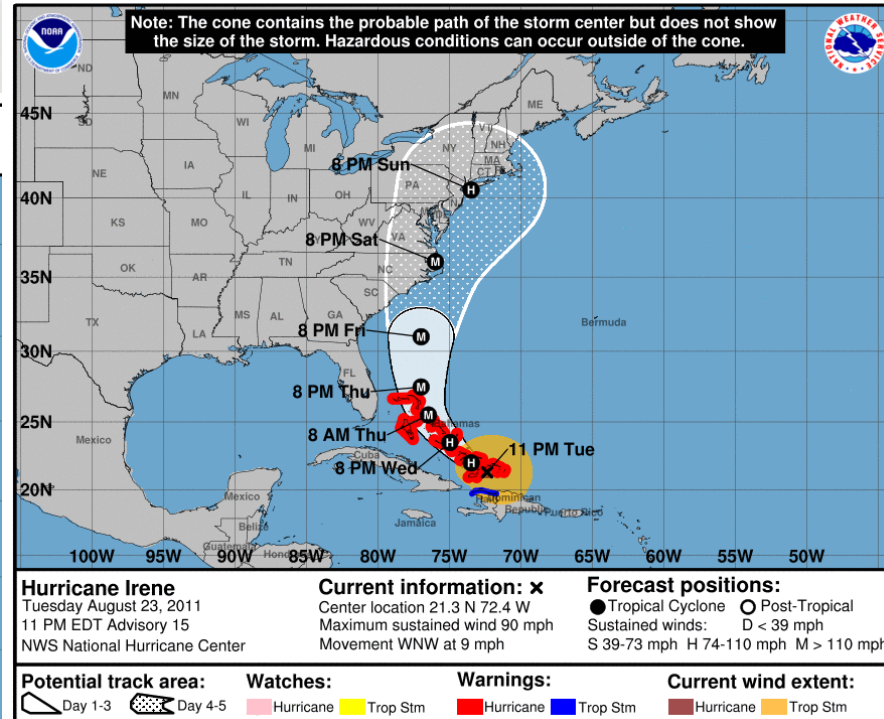
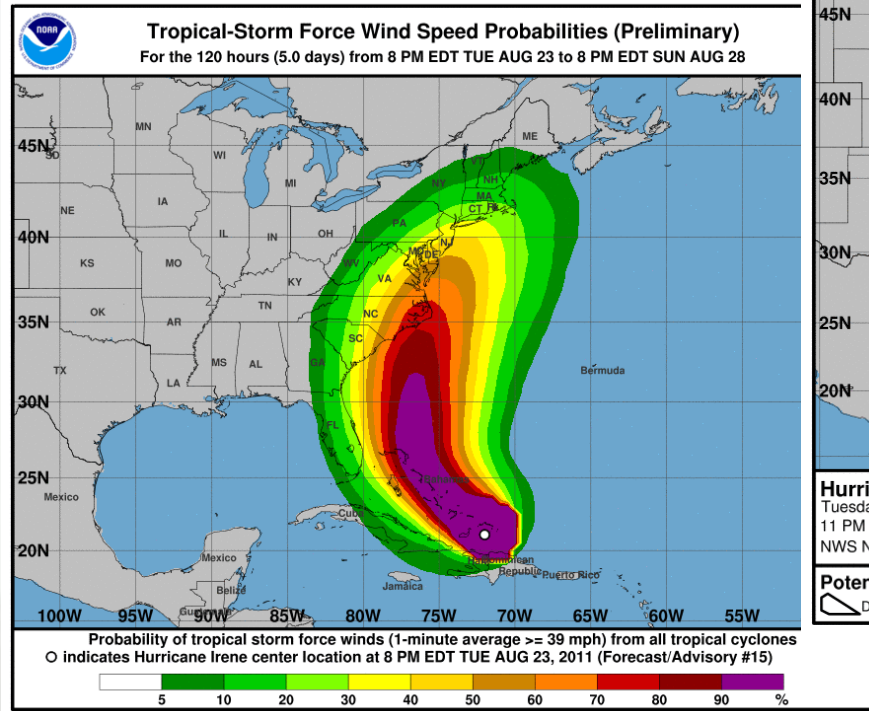


Wind Speed Probabilities



Daniel Brown
National Hurricane Center
2022 WMO Course
3 March 2022

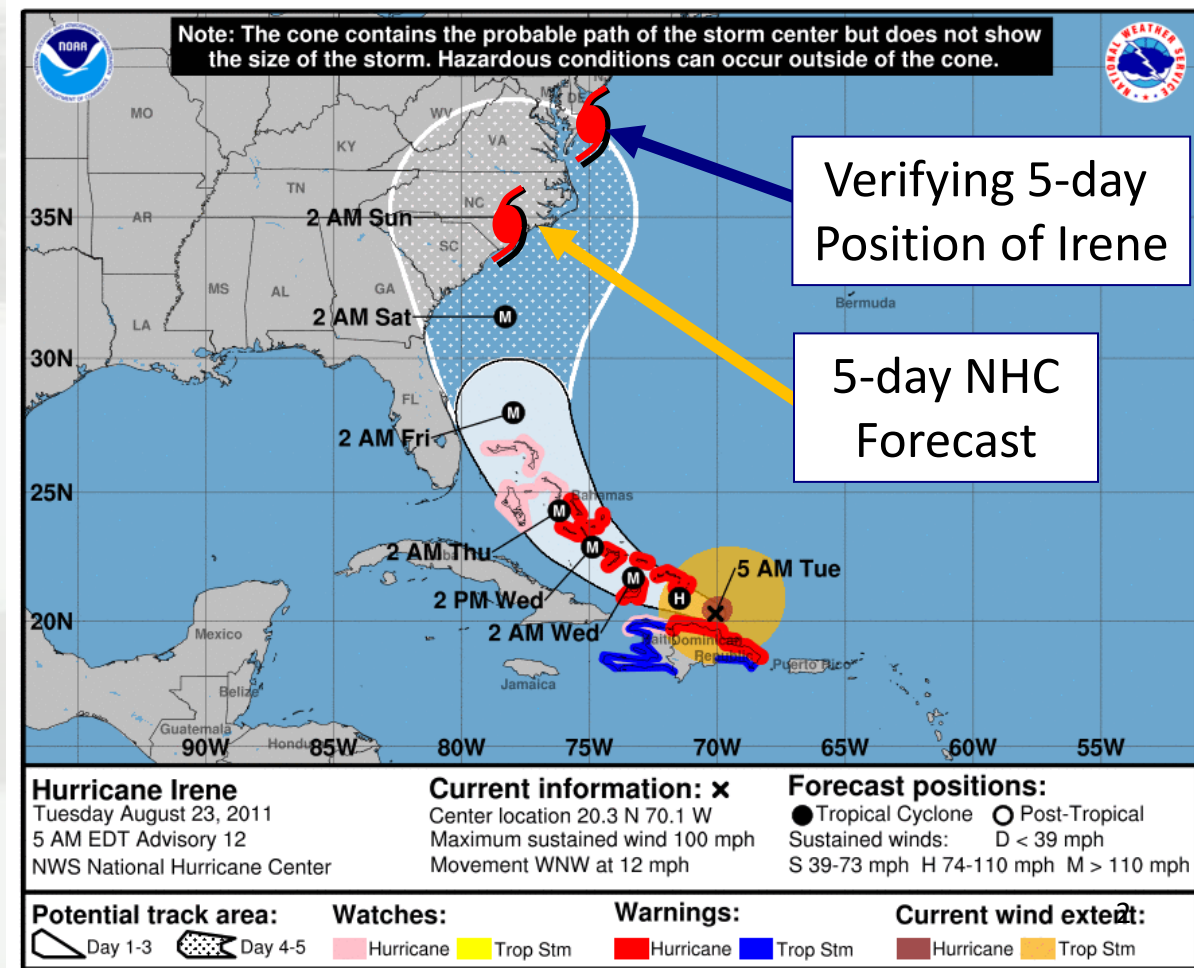
Wind Speed Probabilities

A Tool to Deal with Uncertainty

Hurricane Irene
Advisory Number 12

Issued 5:00 AM EDT
23 August 2011

5-day position error
about 270 miles

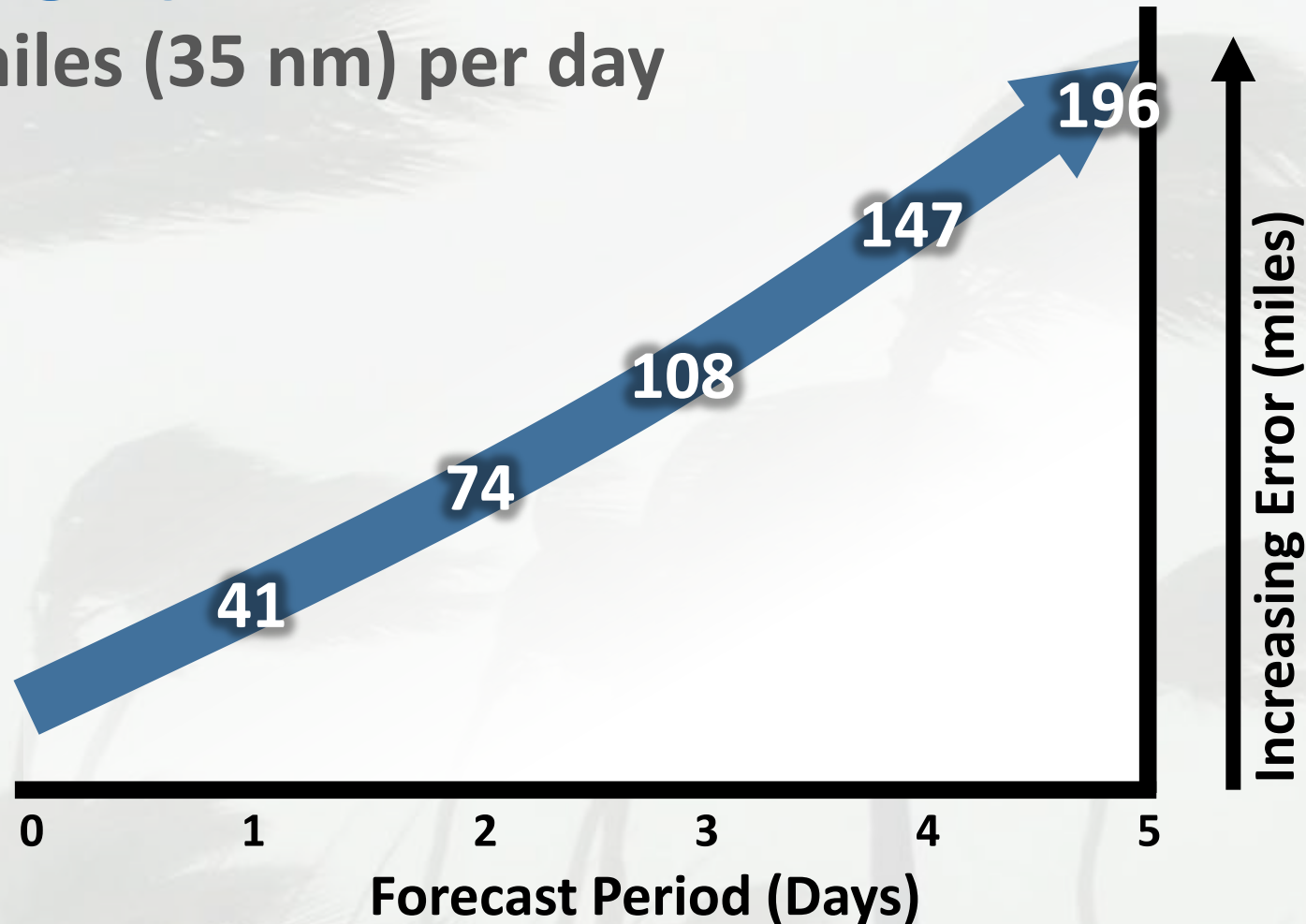


FORECAST TRACK ERRORS

NHC 5-year Averages

TRACK ERRORS

Increase 40 miles (35 nm) per day

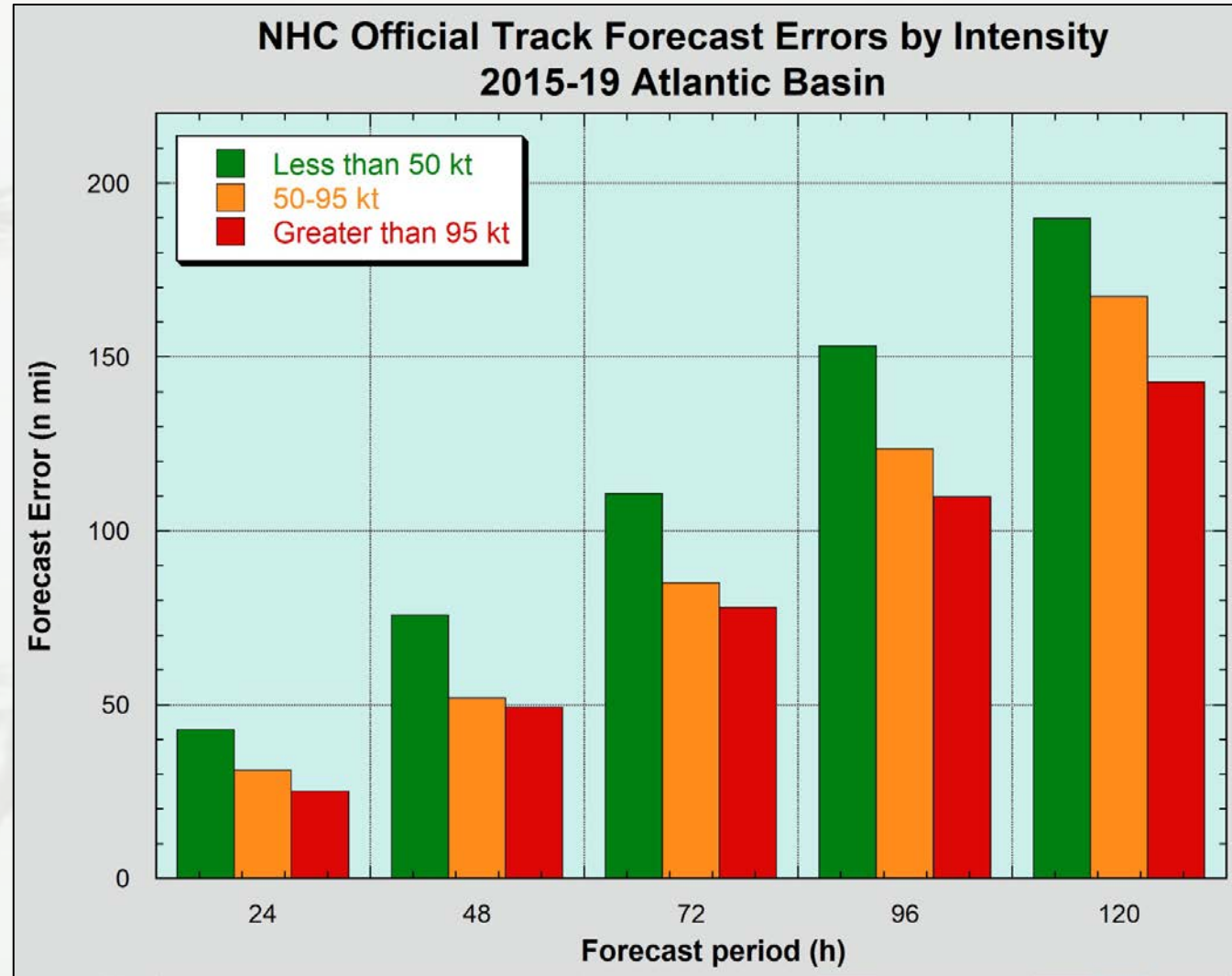


FORECAST TRACK ERRORS

Based on Initial Intensity

More Uncertainty for Tropical Depressions and low-end Tropical Storms

Track errors for TDs and low-end TSs increase by 40 to 45 miles (35-40 nm) per day vs. about 40 miles per day overall.

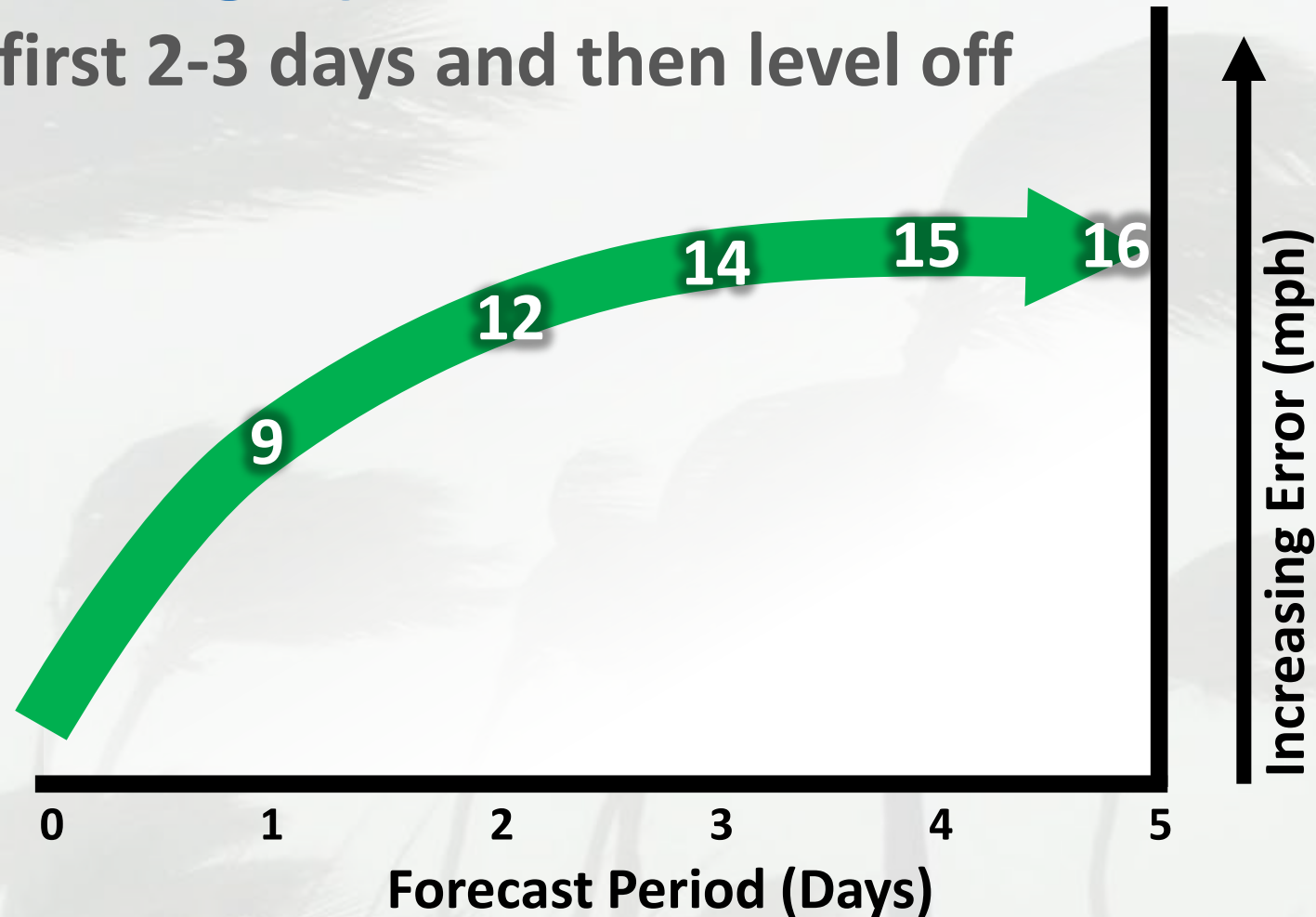


FORECAST INTENSITY ERRORS

NHC 5-year Averages

INTENSITY ERRORS

Increase the first 2-3 days and then level off

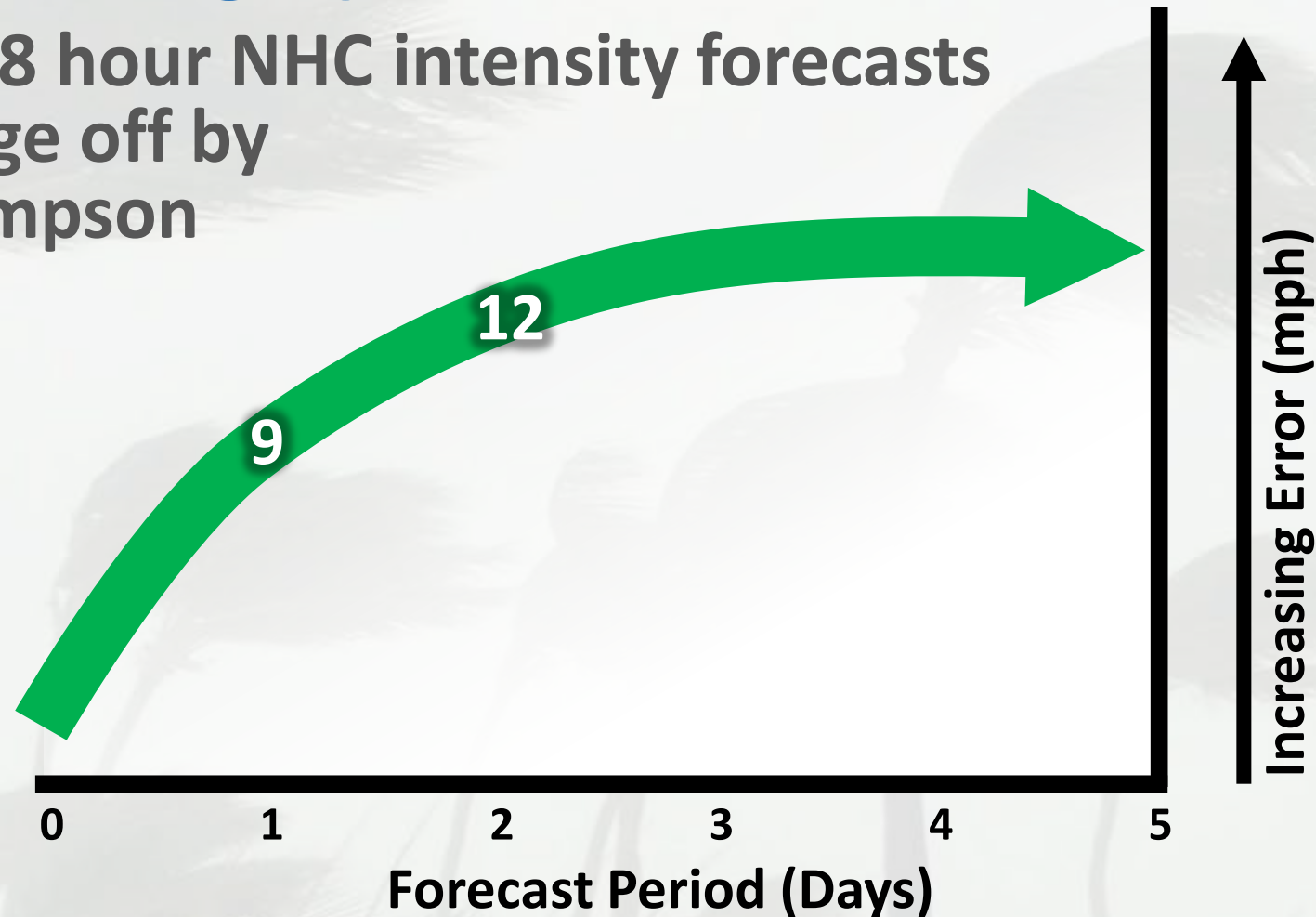


FORECAST INTENSITY ERRORS

NHC 5-year Averages

INTENSITY ERRORS

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



FORECAST INTENSITY ERRORS

Rapid Strengthening

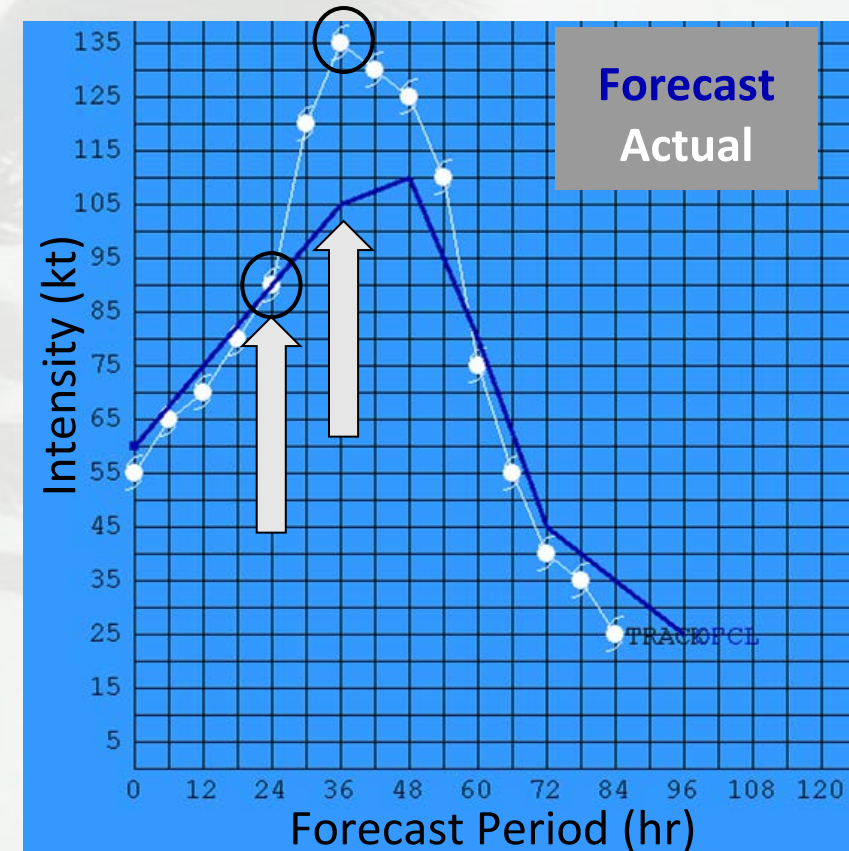
RAPID INTENSIFICATION

Rapid intensification remains a forecast challenge and often results in very large errors

- Our ability to recognize conditions that favor rapid intensification has improved, however forecasting the extent and timing of that intensification remains difficult.

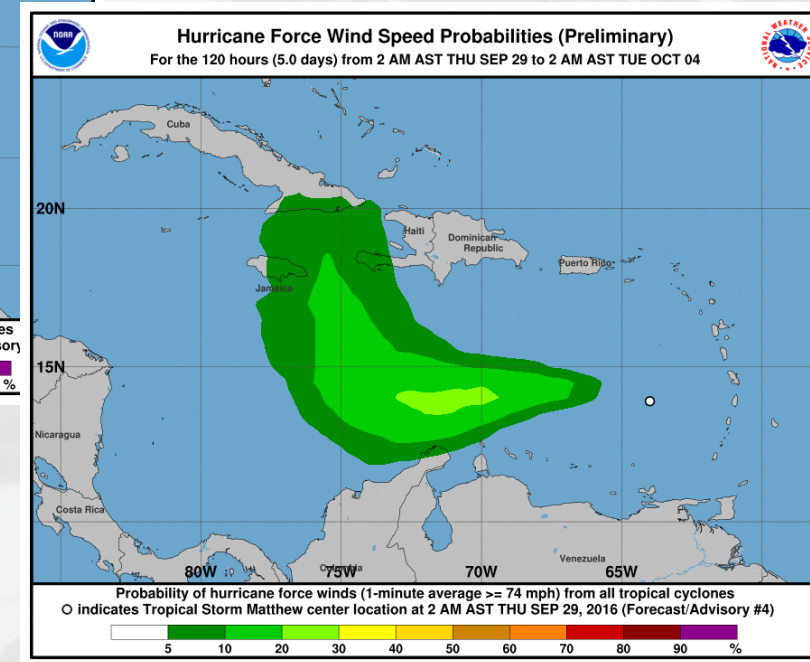
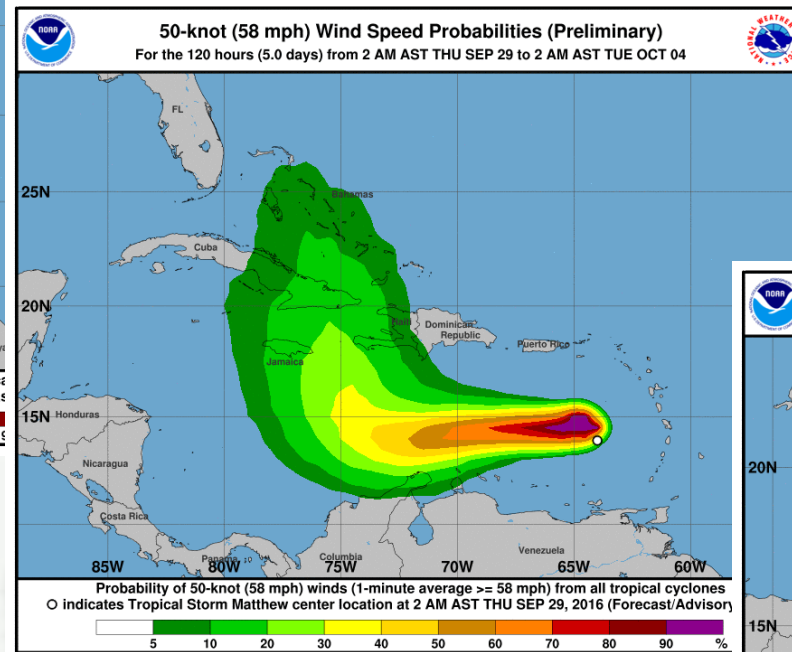
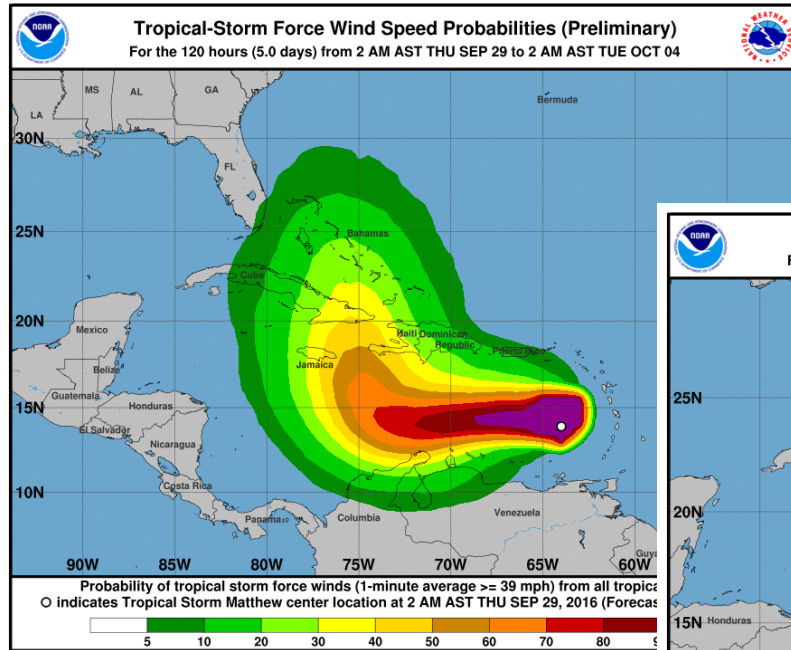
Example: Iota Advisory 7 (2020)

Initial Intensity:	55 kt	Initial Intensity:	55 kt
24h Forecast:	90 kt	36h Forecast:	105 kt
Actual Intensity:	90 kt	Actual Intensity:	135 kt
24 h Error:	0 kt	36 h Error:	30 kt



Wind Speed Probabilities

How Likely. Arrival Times. Inland Threat



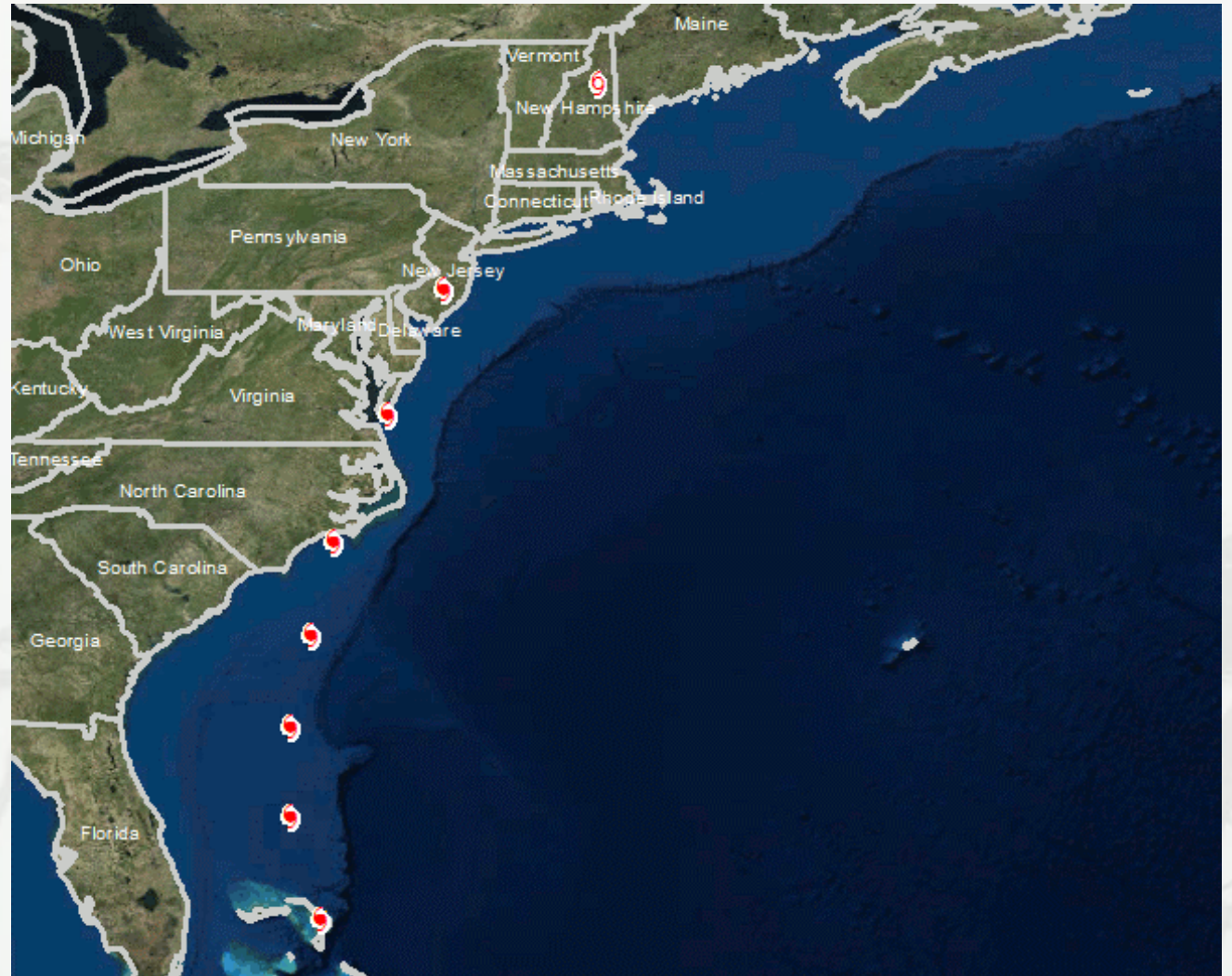
Graphics depicts location-specific cumulative probabilities of tropical-storm-force, 50-kt, and hurricane-force winds.

WIND SPEED PROBABILITIES

How are they generated?

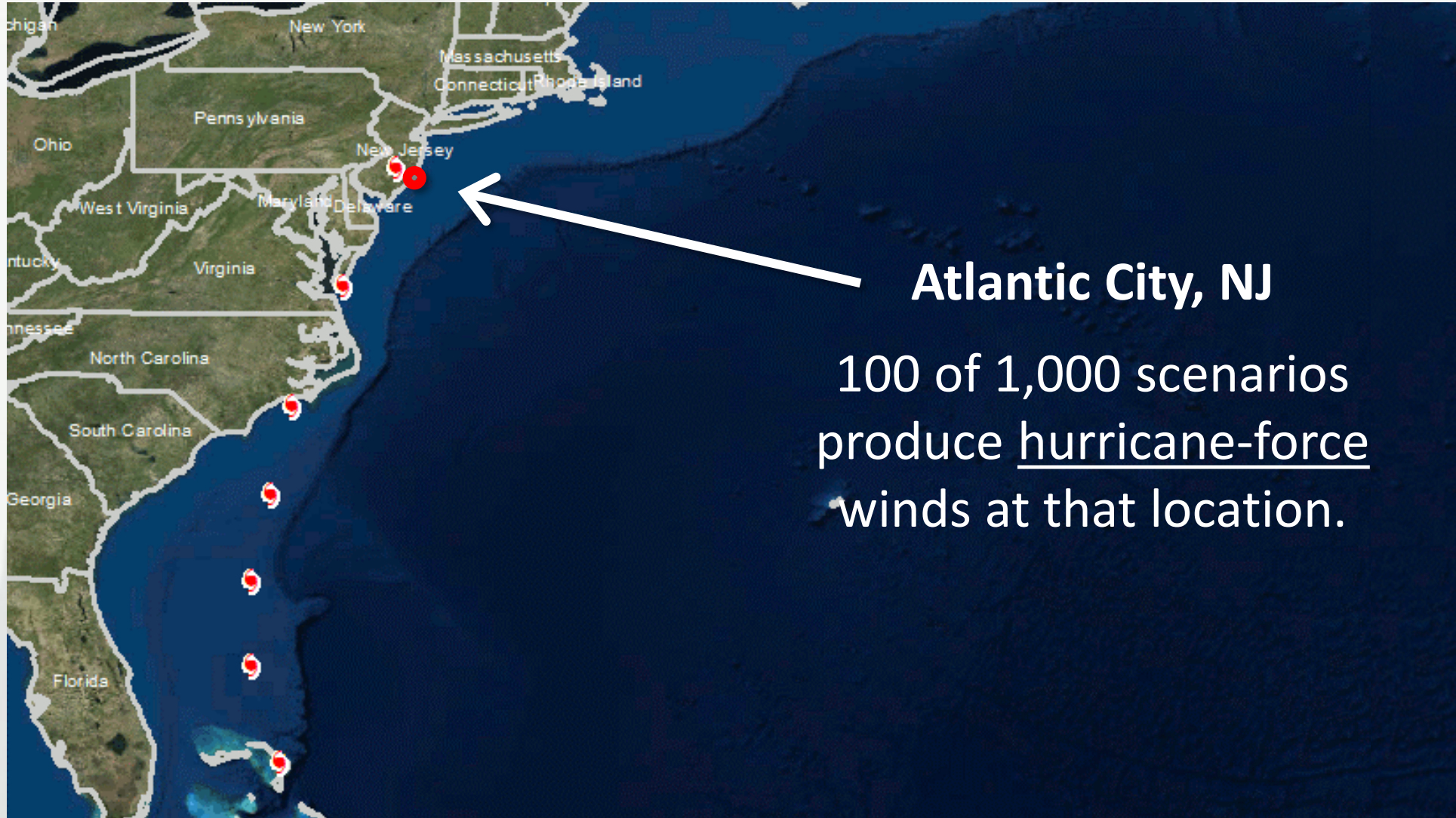
MORE SCENARIOS

- **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



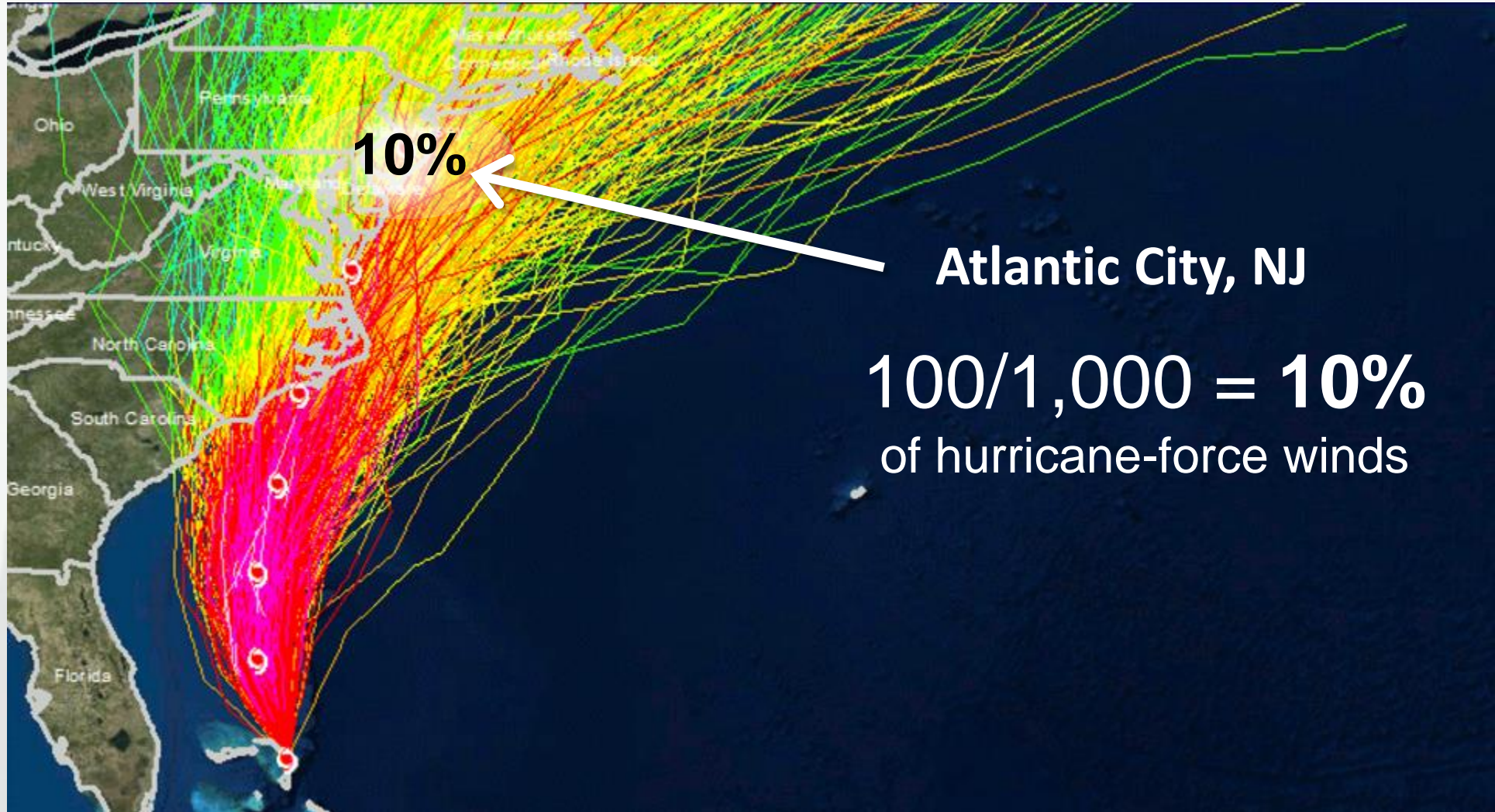
WIND SPEED PROBABILITIES

How are they generated?



WIND SPEED PROBABILITIES

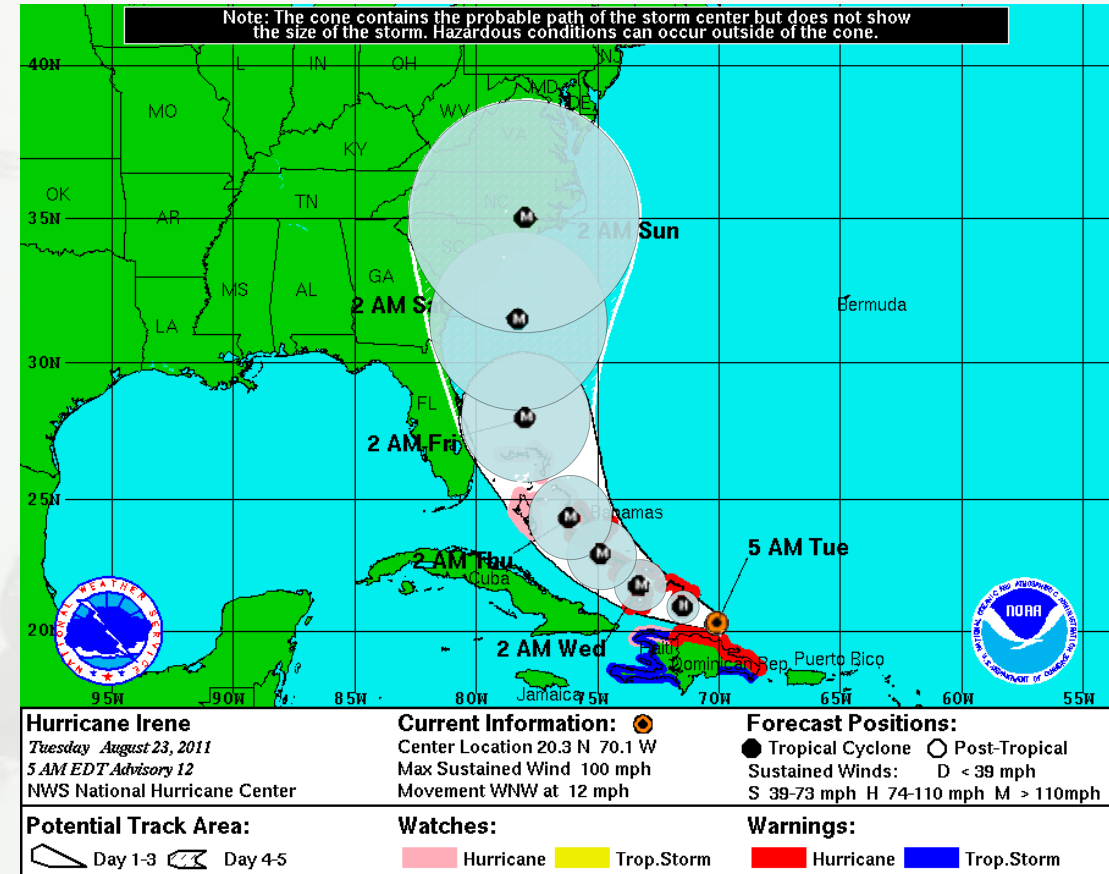
How are they generated?



NHC FORECAST CONE

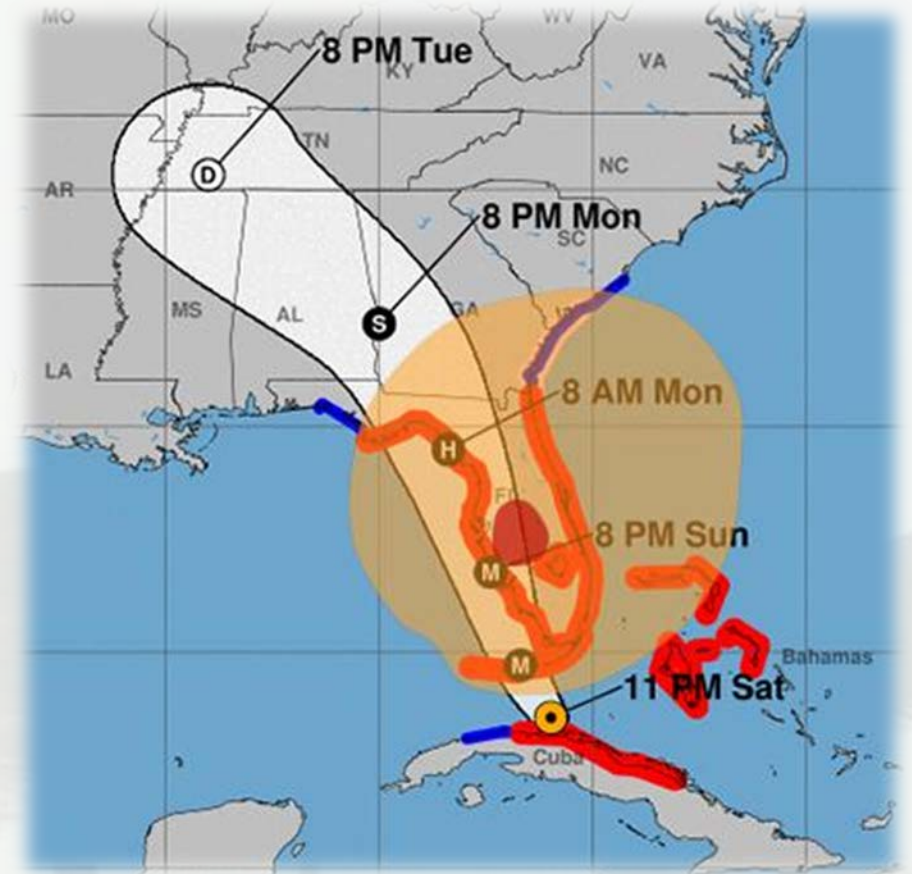
The cure for the skinny black line?

- Represents probable track of tropical cyclone center
- Formed by connecting circles centered on each forecast point
- The size of each circle is created using NHC track errors, so that the actual storm position will be within the circle 67% of the time.



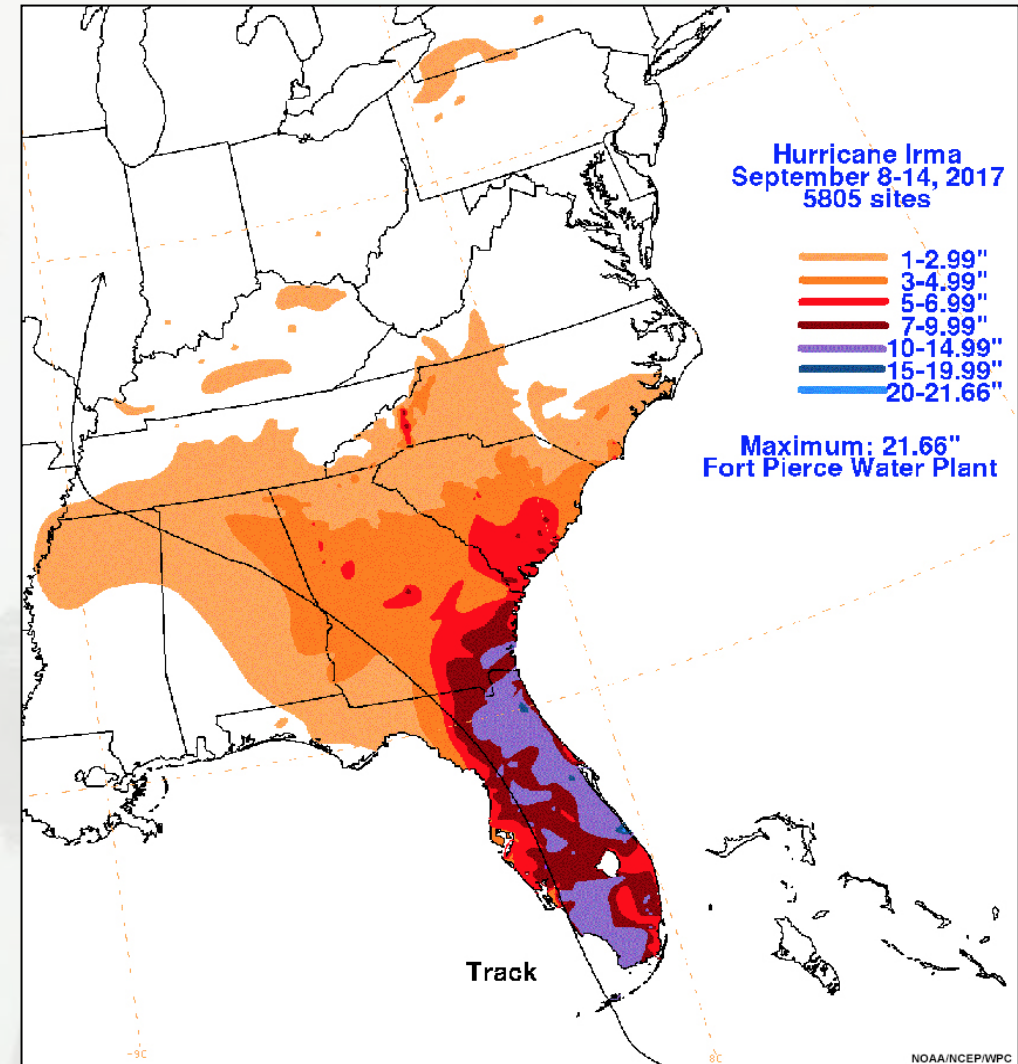
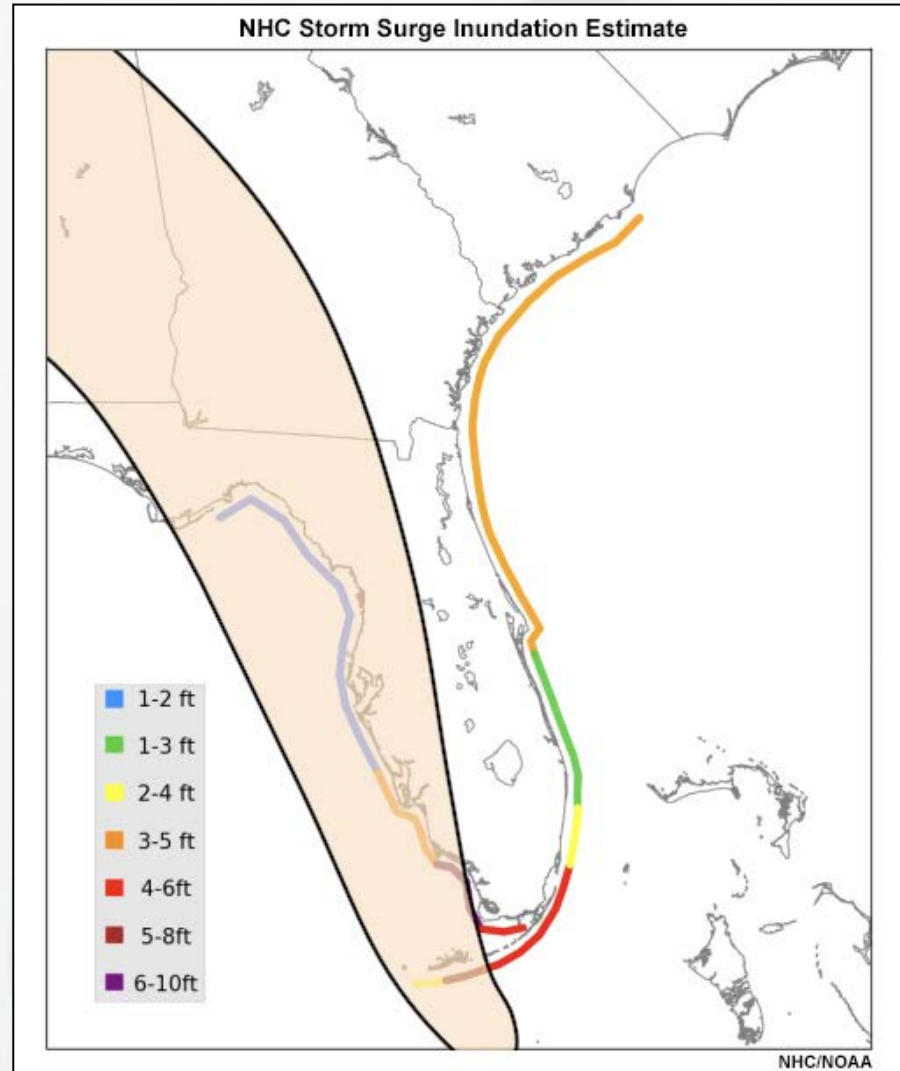
No worries, not in the cone?

-



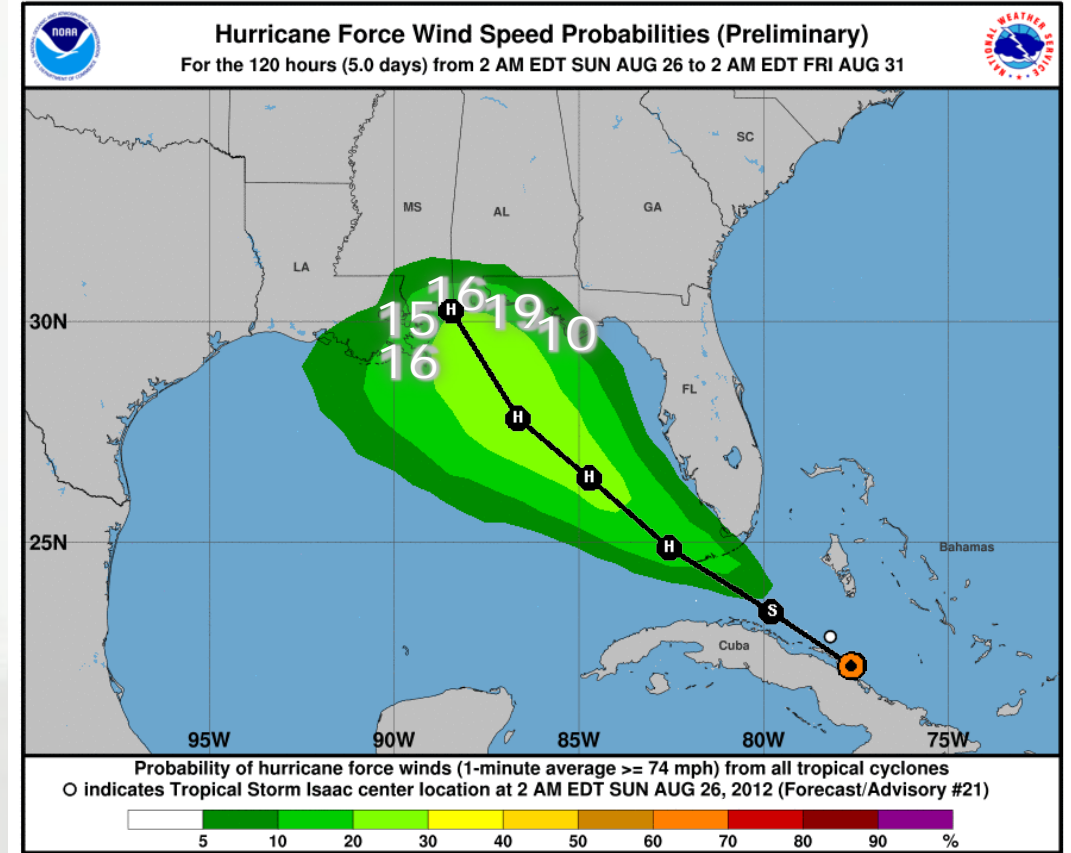
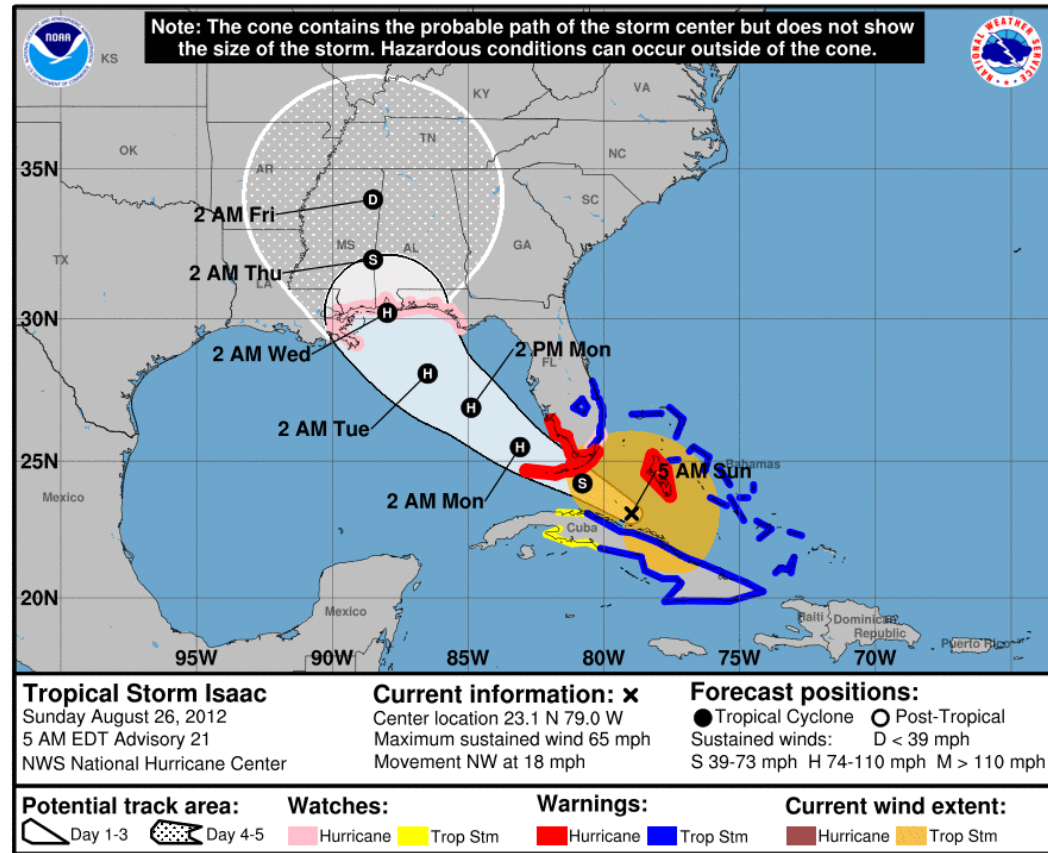
NHC FORECAST CONE

No worries, not in the cone?



WIND SPEED PROBABILITIES

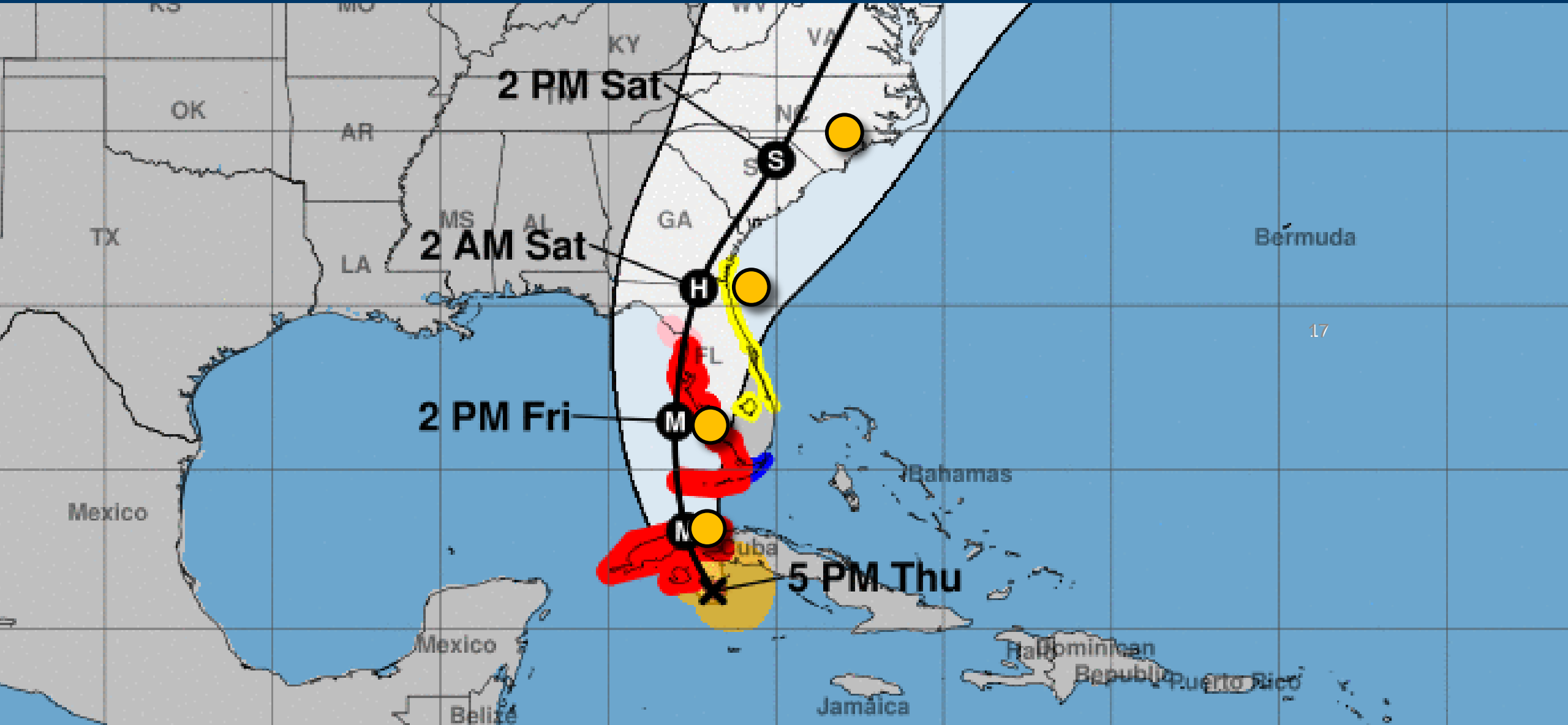
Probabilities vs. The Cone?



Tropical Storm Isaac Advisory 21
5:00 AM EDT 26 Aug 2012

HURRICANE CHARLEY

Don't focus on the skinny black line.



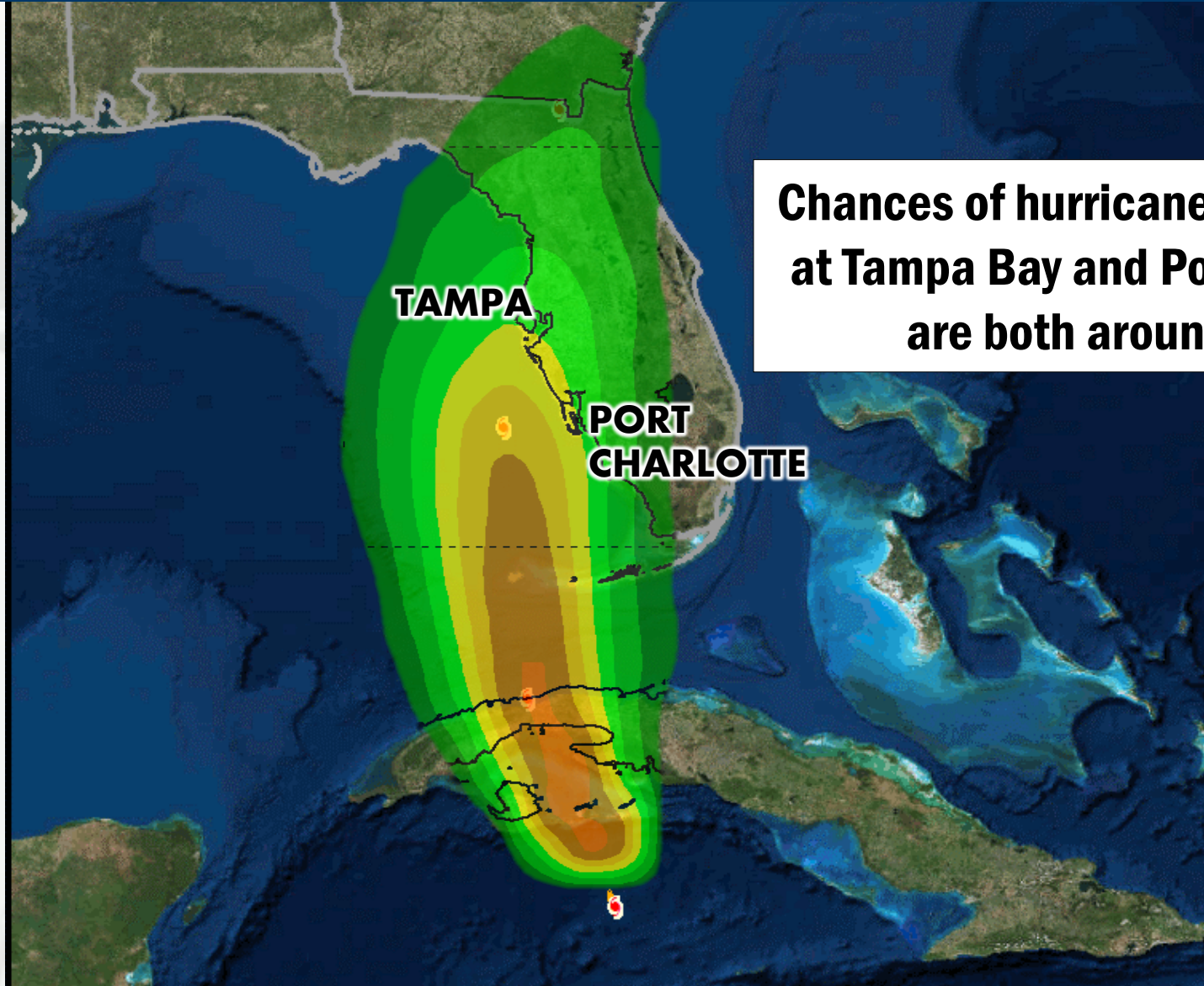
HURRICANE CHARLEY

Would alternate scenarios help?



HURRICANE CHARLEY


Would alternate scenarios help?



**Chances of hurricane-force winds
at Tampa Bay and Port Charlotte
are both around 30%**

WIND SPEED PROBABILITIES

Text Product


<div><div></div><div>NATIONAL HURRICANE CENTER</div><div>NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION</div></div>									
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER 7									
NWS NATIONAL HURRICANE CENTER MIAMI FL AL142018									
0900 UTC MON OCT 08 2018									
- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -									
TIME	FROM	FROM	FROM	FROM	FROM	FROM	FROM	FROM	
PERIODS	06Z MON	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI		
	TO	TO	TO	TO	TO	TO	TO		
	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	06Z SAT		
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)		
- - - - -									
LOCATION	KT								
TALLAHASSEE FL	34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)	
TALLAHASSEE FL	50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)	
TALLAHASSEE FL	64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)	
APALACHICOLA	34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)	
APALACHICOLA	50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)	
APALACHICOLA	64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)	
PANAMA CITY FL	34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)	
PANAMA CITY FL	50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)	
PANAMA CITY FL	64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)	

Location-Specific Probabilities

- Tropical-Storm-Force
- 58 mph
- Hurricane-Force

WIND SPEED PROBABILITIES

Text Product


<div><div></div><div>NATIONAL HURRICANE CENTER</div><div><small>NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION</small></div></div>								
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER 7								
NWS NATIONAL HURRICANE CENTER MIAMI FL AL142018								
0900 UTC MON OCT 08 2018								
- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -								
TIME	FROM	FROM	FROM	FROM	FROM	FROM	FROM	
PERIODS	06Z MON	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	
	TO	TO	TO	TO	TO	TO	TO	
	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	06Z SAT	
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)	
- - - - -								
LOCATION	KT							
TALLAHASSEE FL 34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)	
TALLAHASSEE FL 50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)	
TALLAHASSEE FL 64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)	
APALACHICOLA 34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)	
APALACHICOLA 50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)	
APALACHICOLA 64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)	
PANAMA CITY FL 34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)	
PANAMA CITY FL 50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)	
PANAMA CITY FL 64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)	

Location-Specific Probabilities

- Tropical-Storm-Force
- 58 mph
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WIND SPEED PROBABILITIES

Text Product



<div><div></div><div>NATIONAL HURRICANE CENTER</div><div><small>NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION</small></div></div>								
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER 7								
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TIME	FROM	FROM	FROM	FROM	FROM	FROM	FROM	
PERIODS	06Z MON	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	
	TO	TO	TO	TO	TO	TO	TO	
	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	06Z SAT	
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)	
- - - - -								
LOCATION	KT							
TALLAHASSEE FL 34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)	
TALLAHASSEE FL 50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)	
TALLAHASSEE FL 64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)	
APALACHICOLA 34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)	
APALACHICOLA 50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)	
APALACHICOLA 64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)	
PANAMA CITY FL 34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)	
PANAMA CITY FL 50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)	
PANAMA CITY FL 64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)	

Location-Specific Probabilities

- Tropical-Storm-Force
- 58 mph
- Hurricane-Force

WIND SPEED PROBABILITIES

Text Product


<div><div><div></div><div><div>NATIONAL HURRICANE CENTER</div><div>NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION</div></div></div></div>								
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER 7								
NWS NATIONAL HURRICANE CENTER MIAMI FL AL142018								
0900 UTC MON OCT 08 2018								
- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -								
TIME PERIODS	FROM	FROM	FROM	FROM	FROM	FROM	FROM	
	06Z MON	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	
	TO	TO	TO	TO	TO	TO	TO	
	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	06Z SAT	
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)	
- - - - -								
LOCATION	KT							
TALLAHASSEE FL 34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)	
TALLAHASSEE FL 50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)	
TALLAHASSEE FL 64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)	
APALACHICOLA 34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)	
APALACHICOLA 50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)	
APALACHICOLA 64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)	
PANAMA CITY FL 34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)	
PANAMA CITY FL 50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)	
PANAMA CITY FL 64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)	

Onset Probabilities

- Timing information

WIND SPEED PROBABILITIES

Text Product



<div><div><div><div>NATIONAL HURRICANE CENTER</div><div>NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION</div></div></div></div>								
TROPICAL STORM MICHAEL WIND SPEED PROBABILITIES NUMBER 7								
NWS NATIONAL HURRICANE CENTER MIAMI FL AL142018								
0900 UTC MON OCT 08 2018								
- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -								
TIME PERIODS	FROM	FROM	FROM	FROM	FROM	FROM	FROM	
	06Z MON	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	
	TO	TO	TO	TO	TO	TO	TO	
	18Z MON	06Z TUE	18Z TUE	06Z WED	06Z THU	06Z FRI	06Z SAT	
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)	
- - - - -								
LOCATION	KT							
TALLAHASSEE FL 34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)	
TALLAHASSEE FL 50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)	
TALLAHASSEE FL 64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)	
APALACHICOLA 34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)	
APALACHICOLA 50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)	
APALACHICOLA 64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)	
PANAMA CITY FL 34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)	
PANAMA CITY FL 50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)	
PANAMA CITY FL 64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)	

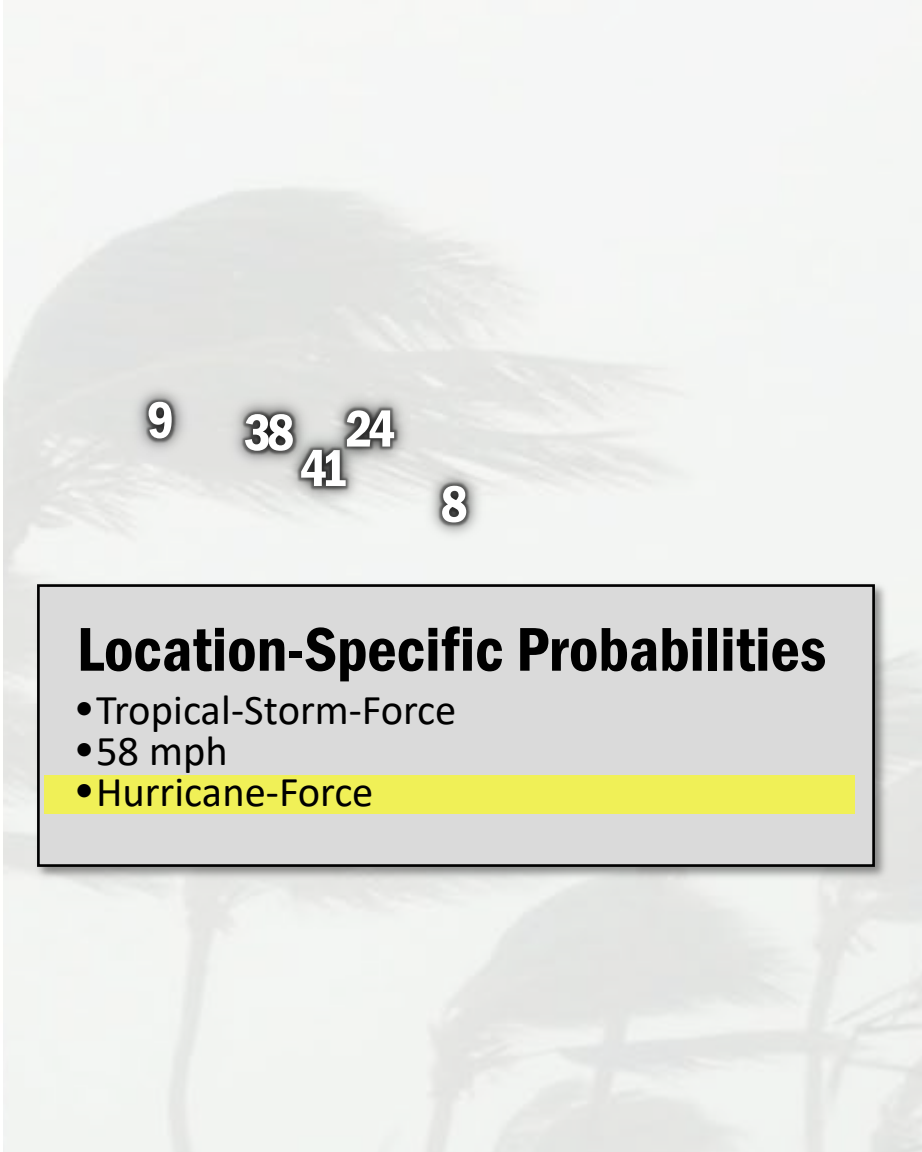
Cumulative Probabilities

- Total chance through the time period

WIND SPEED PROBABILITIES

5-Day Cumulative Graphic

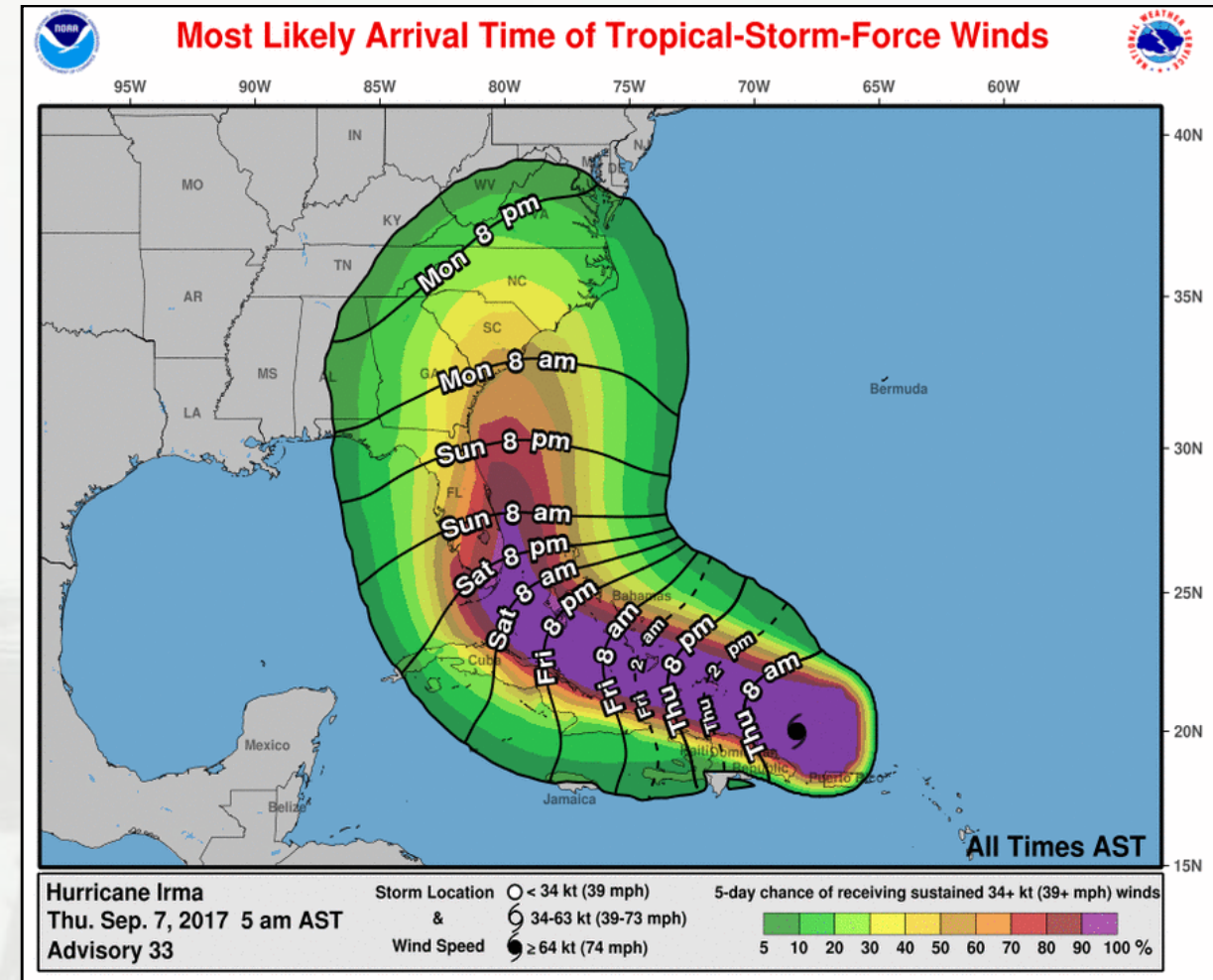
<div><div></div><div>NATIONAL HURRICANE CENTER</div><div>NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION</div></div>								
TIME PERIODS	FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 18Z TUE	FROM 18Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI	FROM 06Z FRI TO 06Z SAT	
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)	
LOCATION	KT							
CEDAR KEY FL	34	X	X(X)	3(3)	15(18)	43(61)	2(63)	X(63)
CEDAR KEY FL	50	X	X(X)	X(X)	1(1)	20(21)	1(22)	X(22)
CEDAR KEY FL	64	X	X(X)	X(X)	X(X)	7(7)	1(8)	X(8)
TALLAHASSEE FL	34	X	X(X)	1(1)	6(7)	68(75)	6(81)	X(81)
TALLAHASSEE FL	50	X	X(X)	X(X)	1(1)	41(42)	6(48)	X(48)
TALLAHASSEE FL	64	X	X(X)	X(X)	X(X)	20(20)	4(24)	X(24)
APALACHICOLA	34	X	X(X)	5(5)	29(34)	57(91)	1(92)	X(92)
APALACHICOLA	50	X	X(X)	X(X)	6(6)	59(65)	2(67)	X(67)
APALACHICOLA	64	X	X(X)	X(X)	1(1)	39(40)	1(41)	X(41)
PANAMA CITY FL	34	X	X(X)	4(4)	26(30)	60(90)	1(91)	X(91)
PANAMA CITY FL	50	X	X(X)	X(X)	6(6)	57(63)	1(64)	X(64)
PANAMA CITY FL	64	X	X(X)	X(X)	1(1)	37(38)	X(38)	X(38)
PENSACOLA FL	34	X	X(X)	1(1)	8(9)	43(52)	2(54)	X(54)
PENSACOLA FL	50	X	X(X)	X(X)	1(1)	20(21)	1(22)	X(22)
PENSACOLA FL	64	X	X(X)	X(X)	X(X)	9(9)	X(9)	X(9)



TIME OF ARRIVAL OF TS-FORCE WINDS

Information on Arrival of Wind Hazzard

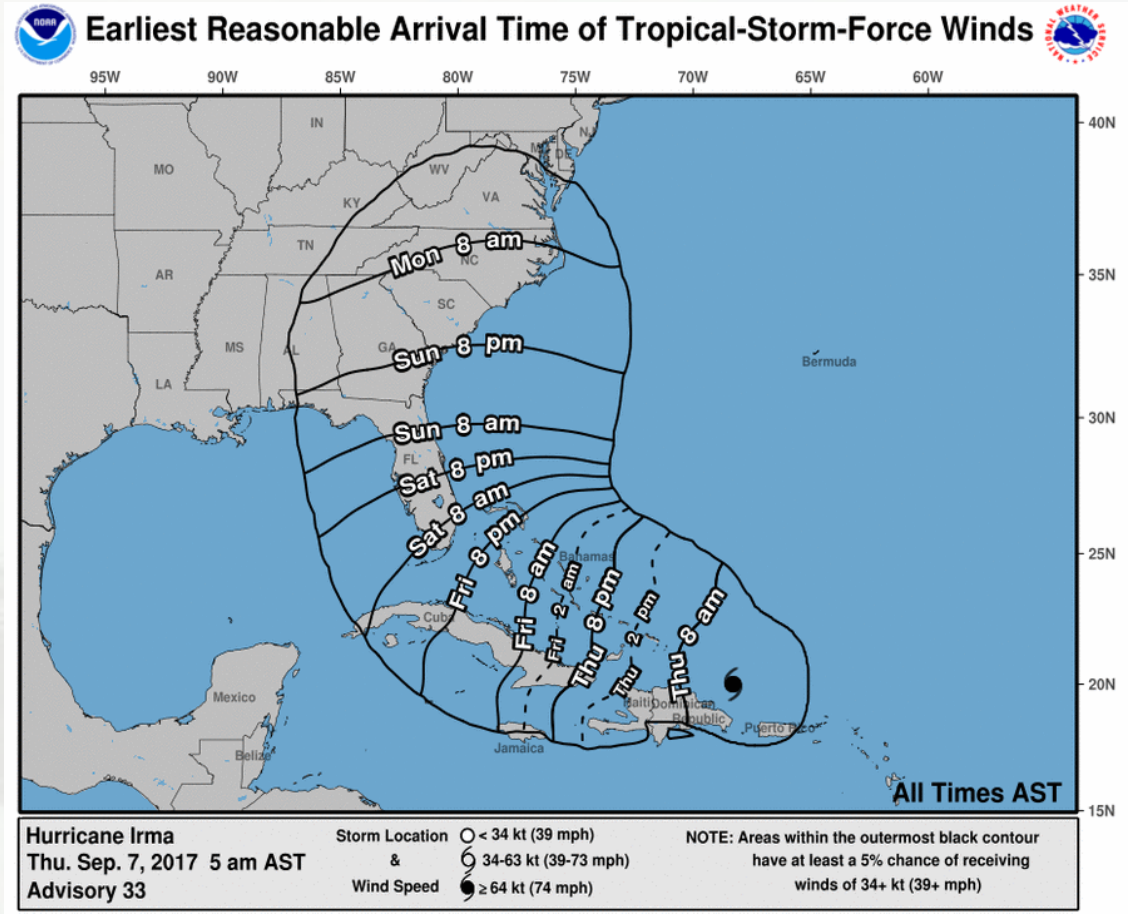
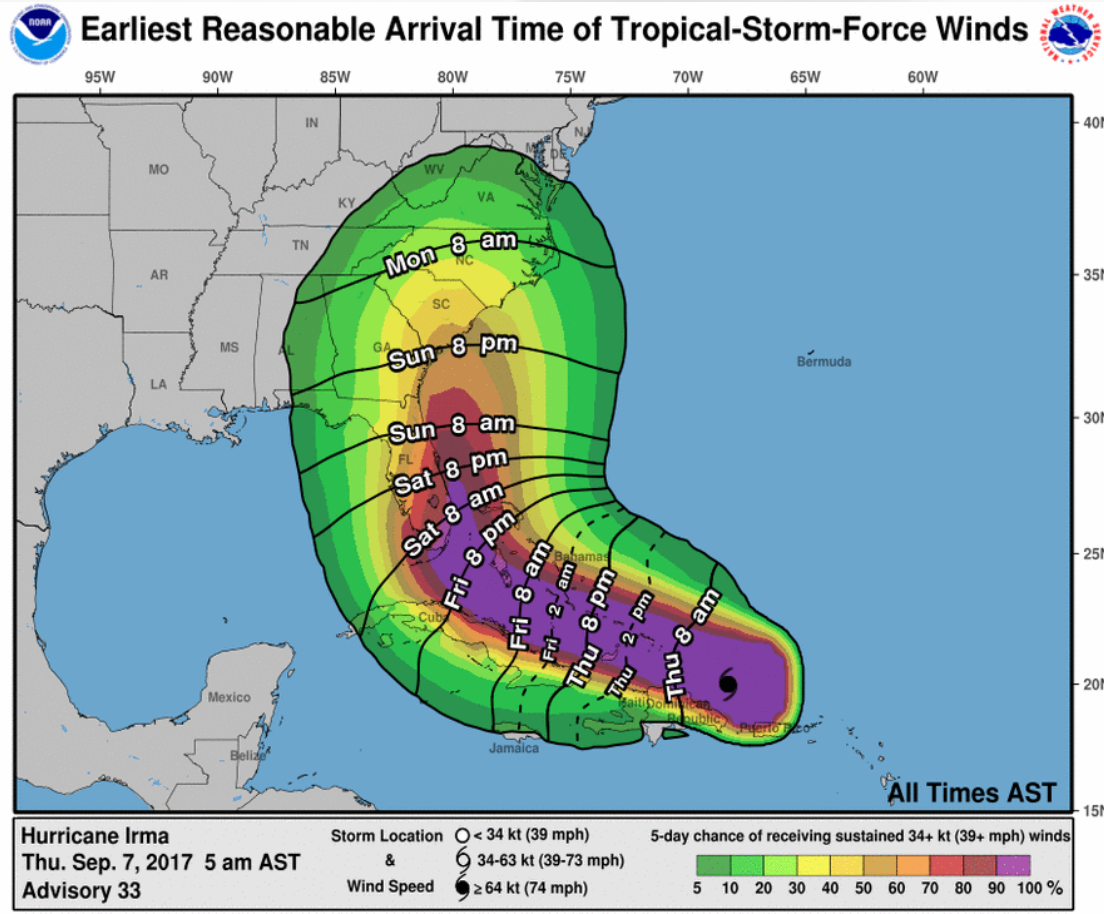
- Separate graphics provide most likely and earliest reasonable arrival times of TS-force winds
- Accounts for typical track, intensity, and size uncertainty
- **Provides time when preparations should be complete**
- **Earliest Reasonable** - best for users with low tolerance for risk



Earliest Reasonable Time of Arrival

TIME OF ARRIVAL OF TS-FORCE WINDS

Versions of the graphics with and without the location specific wind speed probabilities



WIND TIMING UNCERTAINTY

Importance and Causes

WIND TIMING

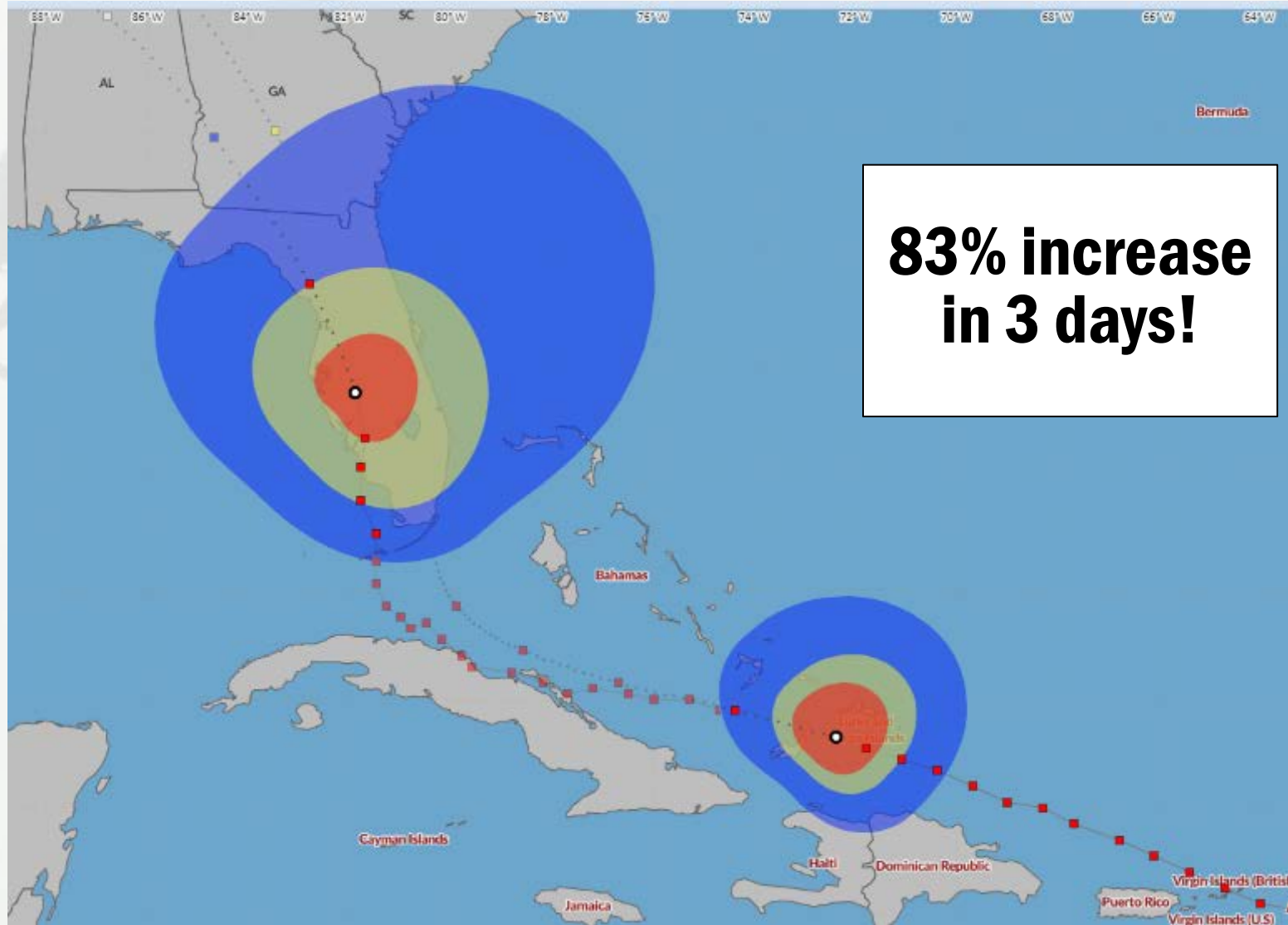
Critical for preparedness and evacuation decision making

- **Major sources of uncertainty in wind timing:**
 - **Track** – Forward speed, direction of motion, and location of center relative to given location
 - **Storm Size** – How far will TS winds extend from the center? Difficult to forecast and highly variable
- **Time of Arrival graphics designed to account for uncertainty in arrival of TS-force winds and provide timing information**



WIND TIMING UNCERTAINTY

Importance and Causes



WIND TIMING UNCERTAINTY

Current product limitations

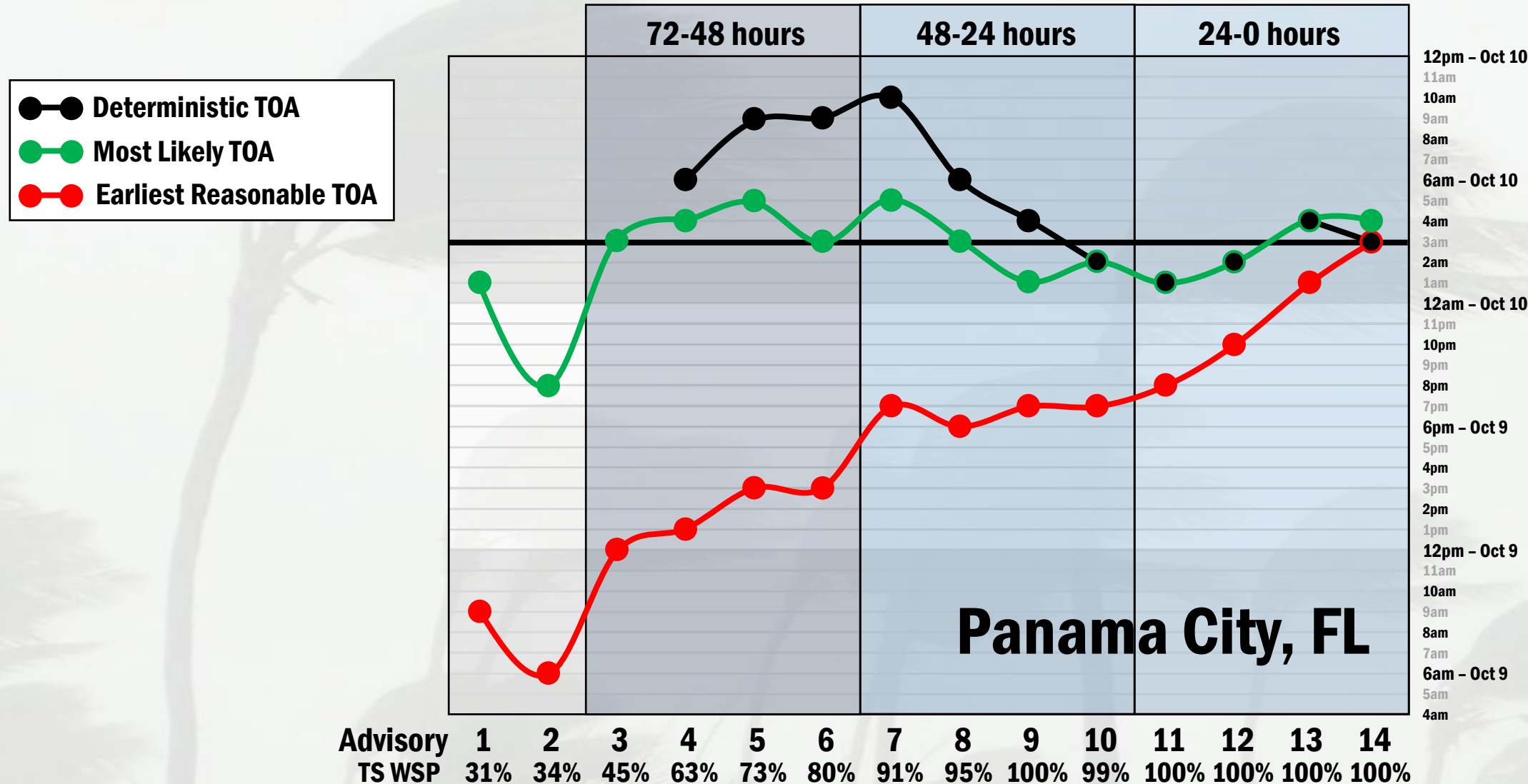
TIME OF ARRIVAL

Current Time of Arrival (TOA) products have some limitations:

- **Storms that stall or move very slowly (<5 mph)**
 - TOA products can show much earlier onset times than what is conveyed in the official forecast (e.g., Dorian)
- **Storms with much larger/smaller than typical wind fields**
 - TOA products will not handle the timing of these storms well, especially beyond the first 24-36 hours.

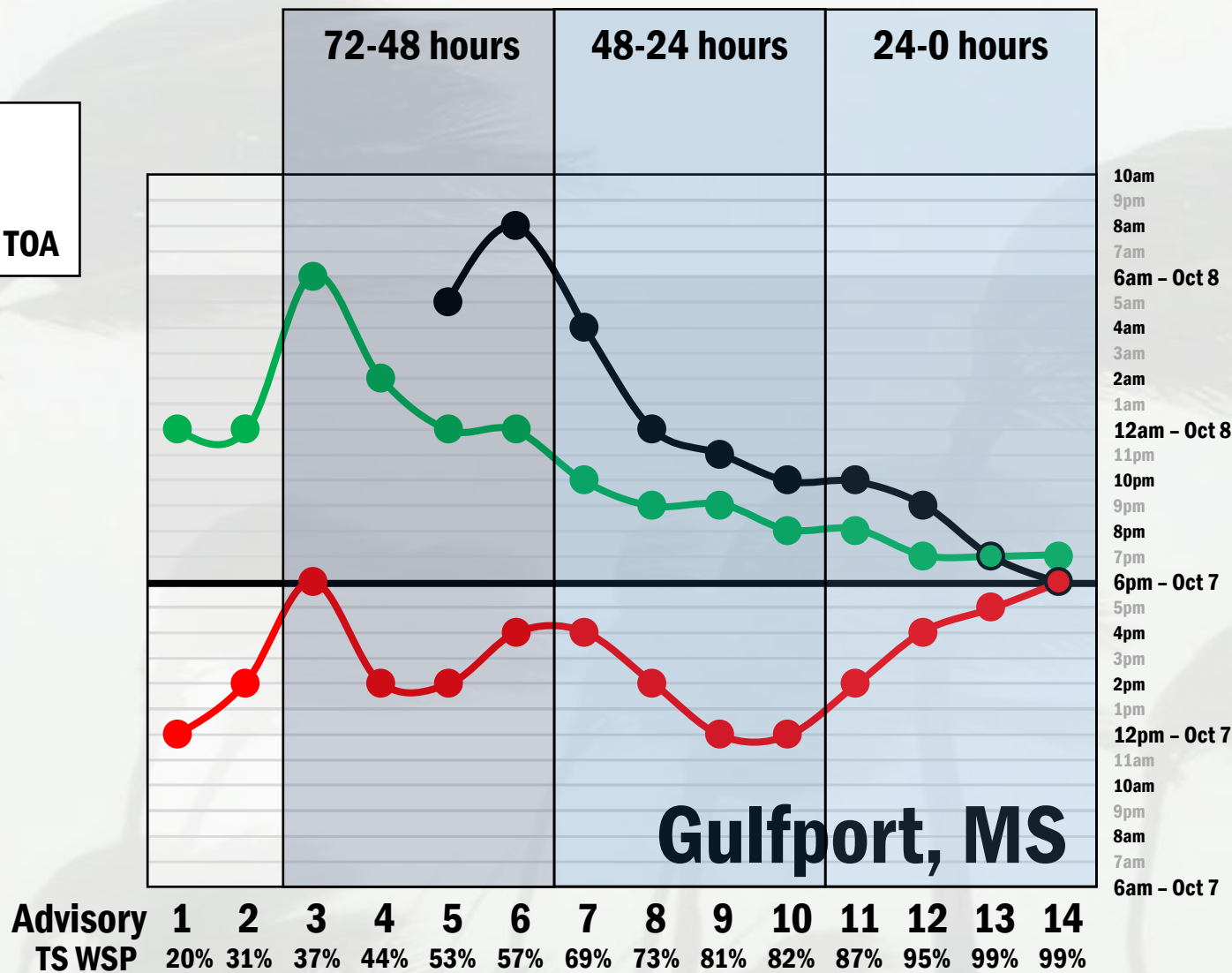
TIME OF ARRIVAL OF TS WINDS

Hurricane Michael (2018)



TIME OF ARRIVAL OF TS WINDS

Hurricane Nate (2017)



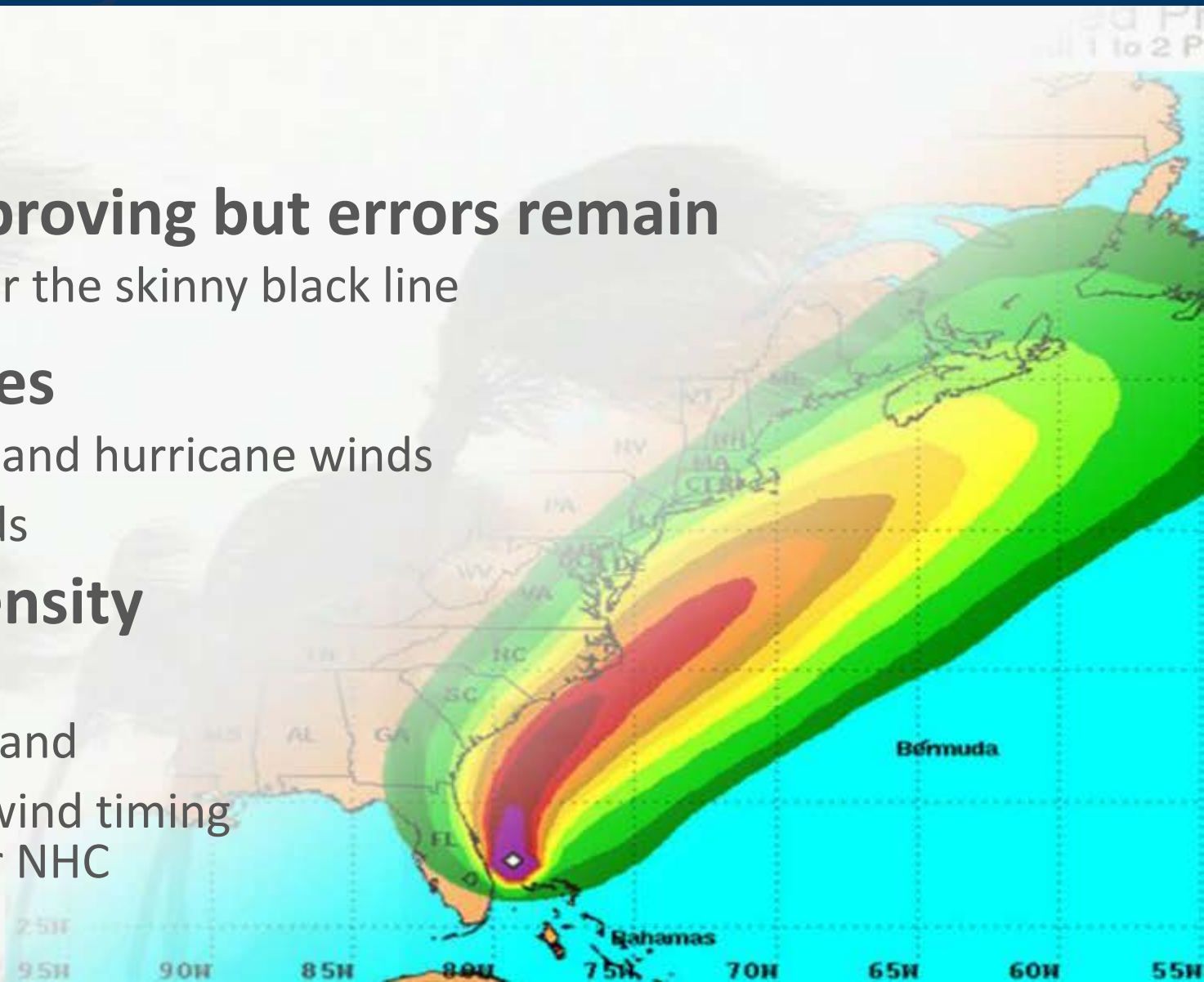
WIND SPEED PROBABILITIES

Summary



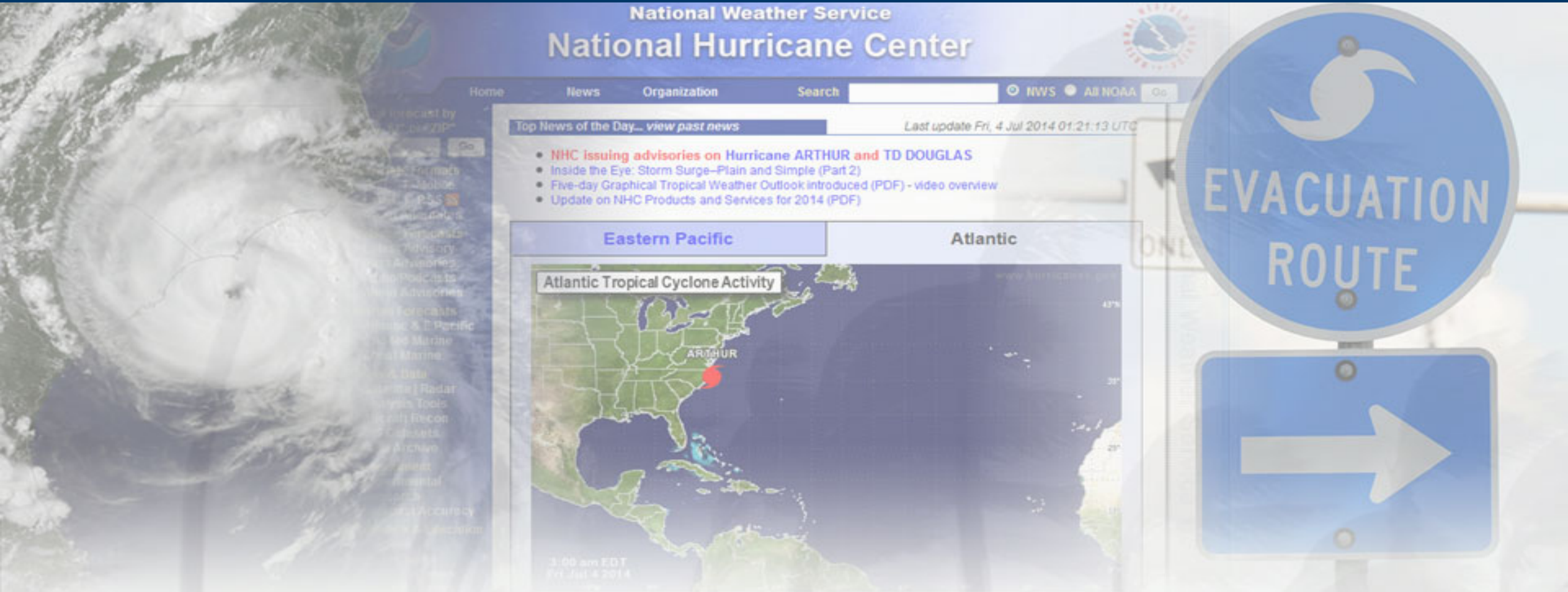
SUMMARY

- **NHC's forecasts are improving but errors remain**
 - Error cone is not the cure for the 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



HURRICANE READINESS

A Short Course



Questions/Comments?