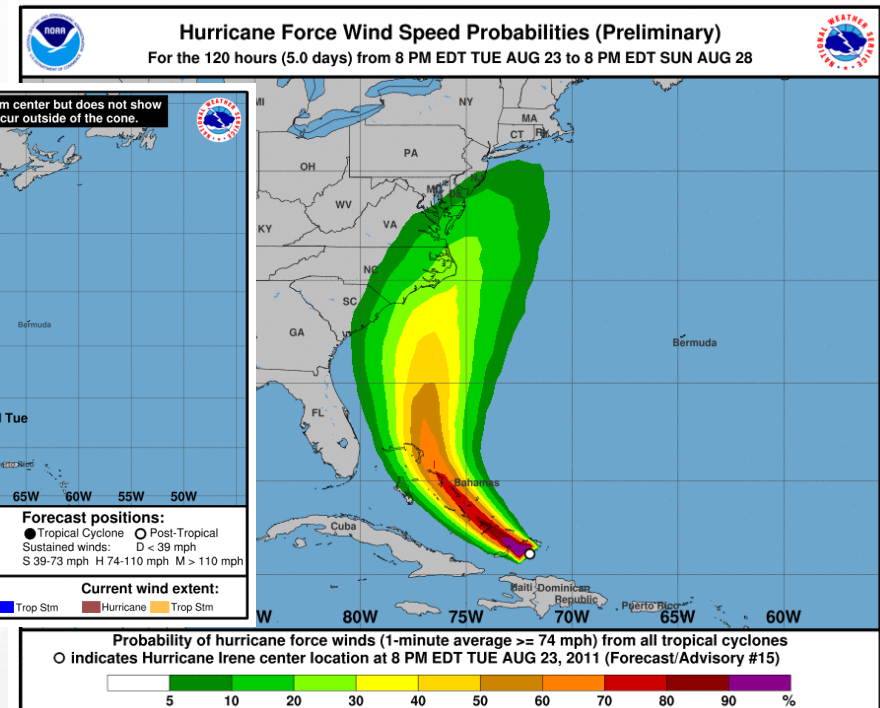
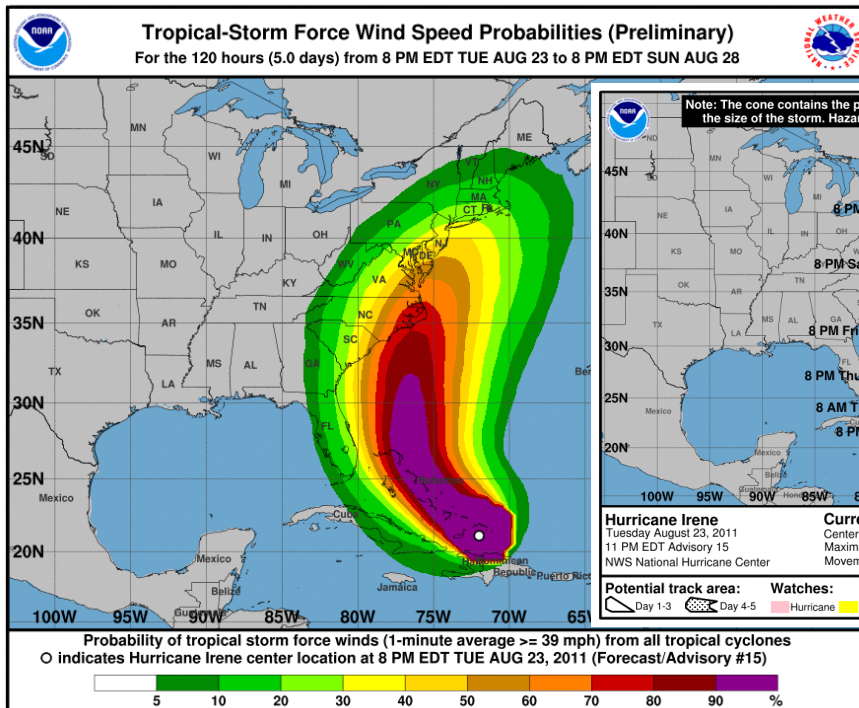




Wind Speed Probability Products



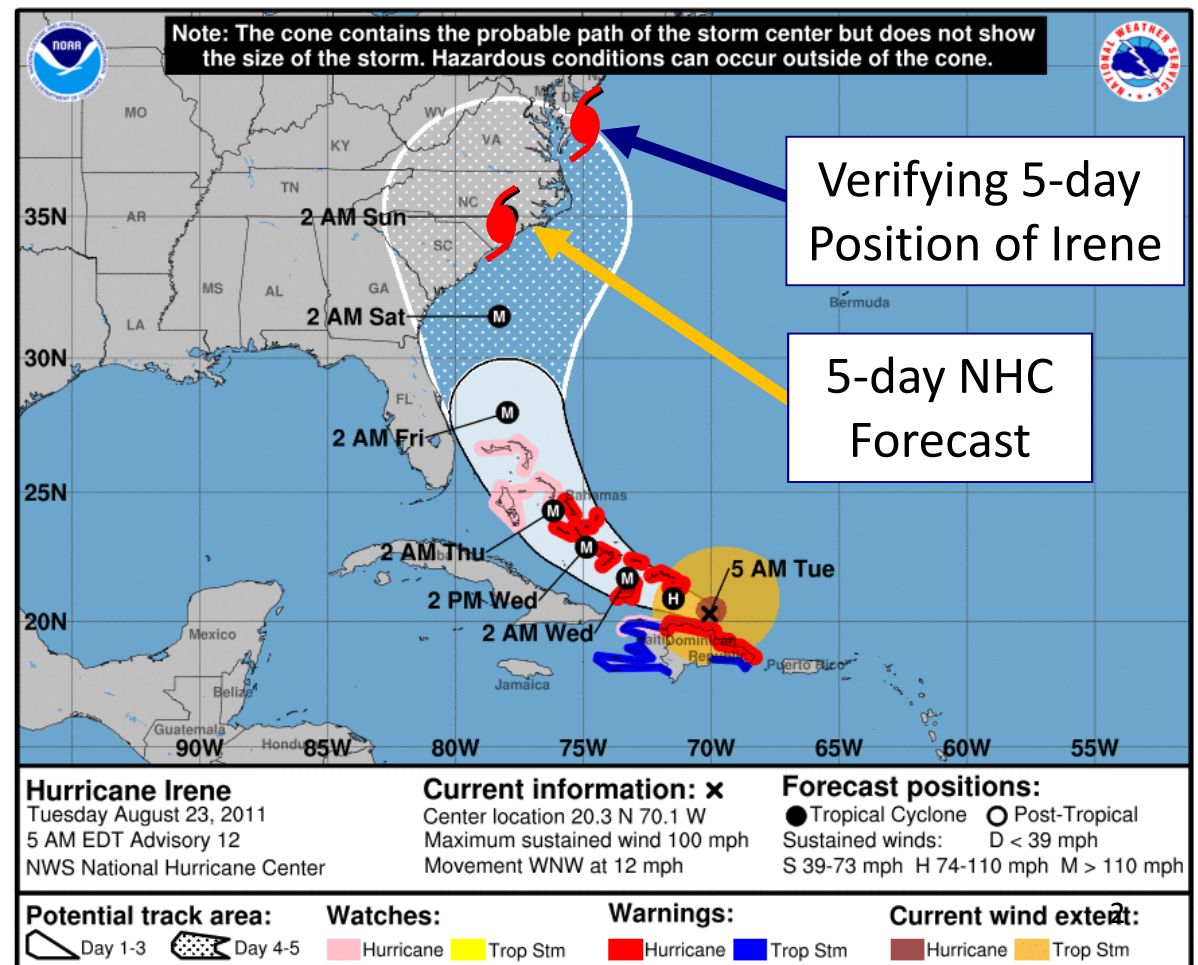
Daniel Brown
National Hurricane Center
2018 WMO Course
6 March 2018

Wind Speed Probabilities

A Tool to Deal with Uncertainty

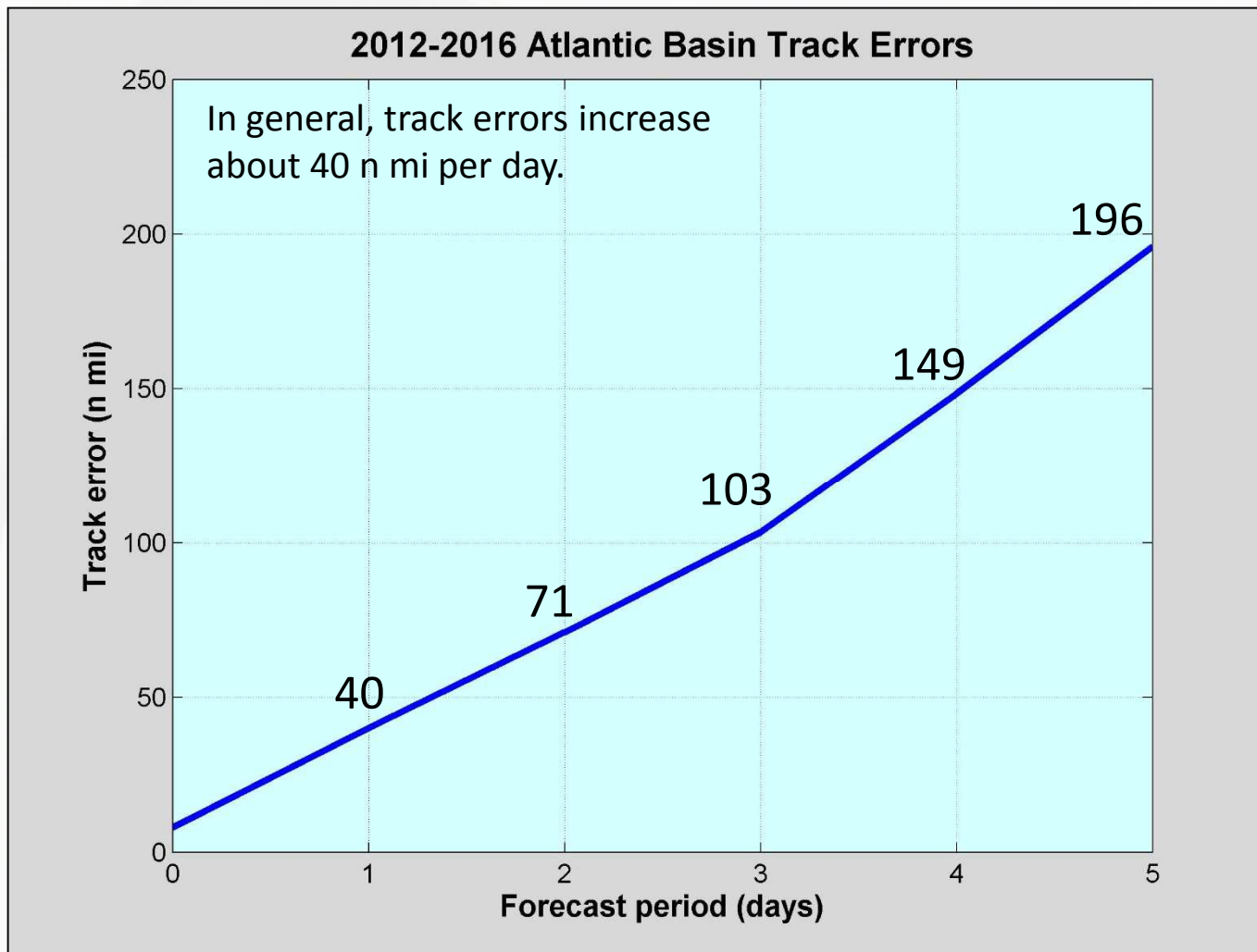
Hurricane Irene
Advisory Number 12
Issued 5:00 AM EDT
23 August 2011

5-day position error
about 270 miles



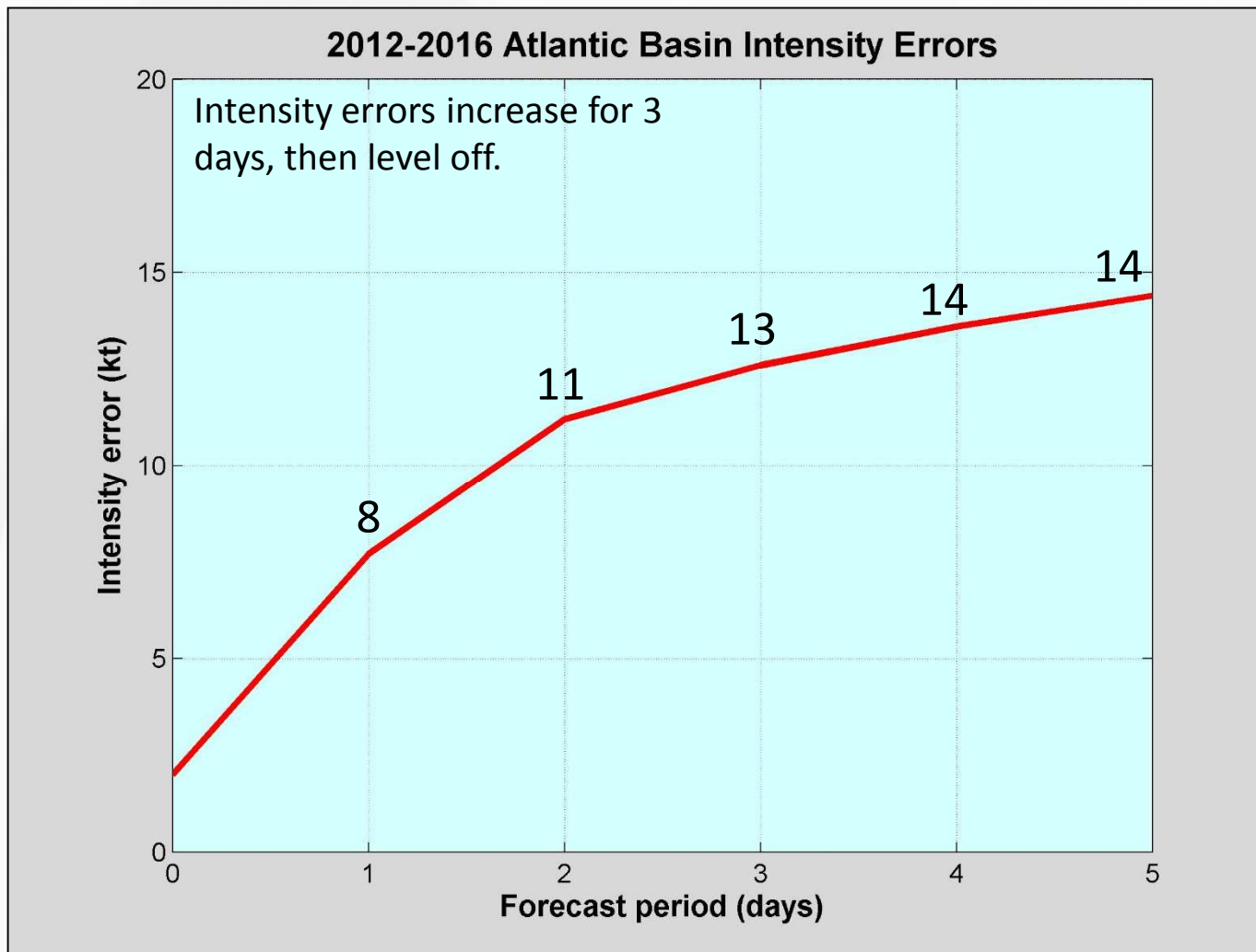
Forecast Track Errors

NHC 5-Year Averages



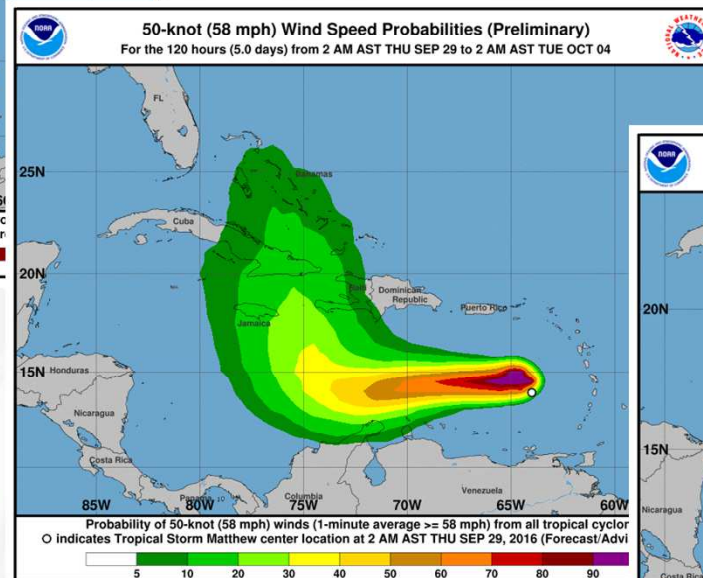
Forecast Intensity Errors

NHC 5-Year Averages



Wind Speed Probabilities

How Likely. Arrival Times. Inland Threat

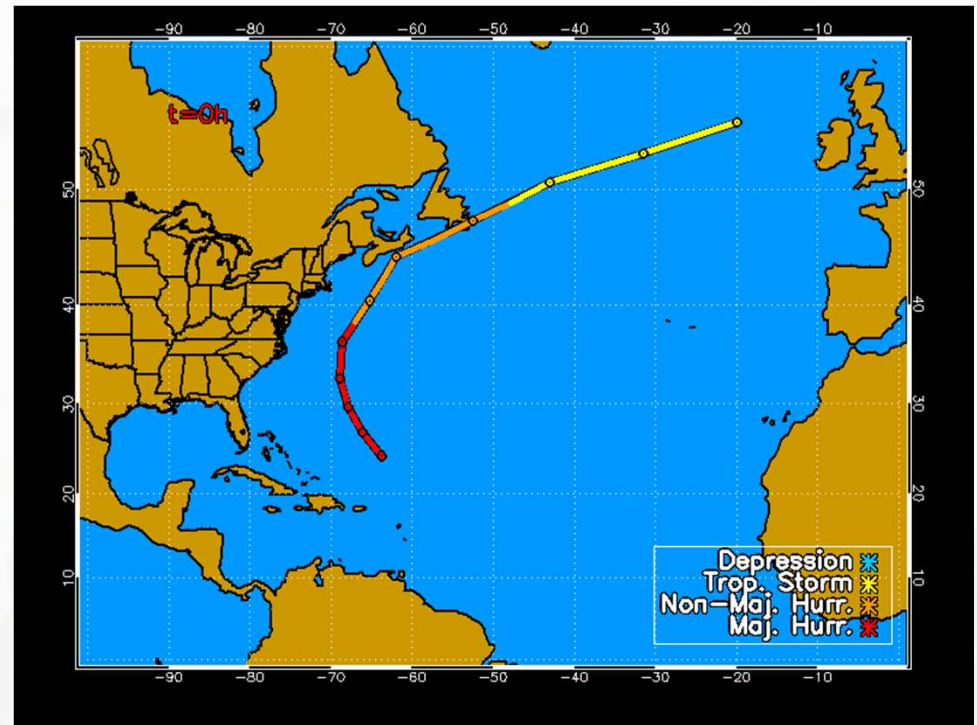


Graphics depicts location-specific cumulative probabilities of tropical-storm-force, 50-kt, and hurricane-force winds.

Wind Speed Probabilities

How They are Created

- 1,000 **realistic alternative scenarios** (realizations) are created using
 - Official NHC track and intensity forecasts
 - Historical NHC track and intensity forecast errors
 - Climatology and persistence wind radii model
- Accounts for weakening of storms over land
- Uses model spread to account for track forecast uncertainty
- Probability of exceeding 34, 50, and 64 kt wind thresholds are computed



370 of 1,000 realizations bring 34-kt winds to Nantucket, Massachusetts

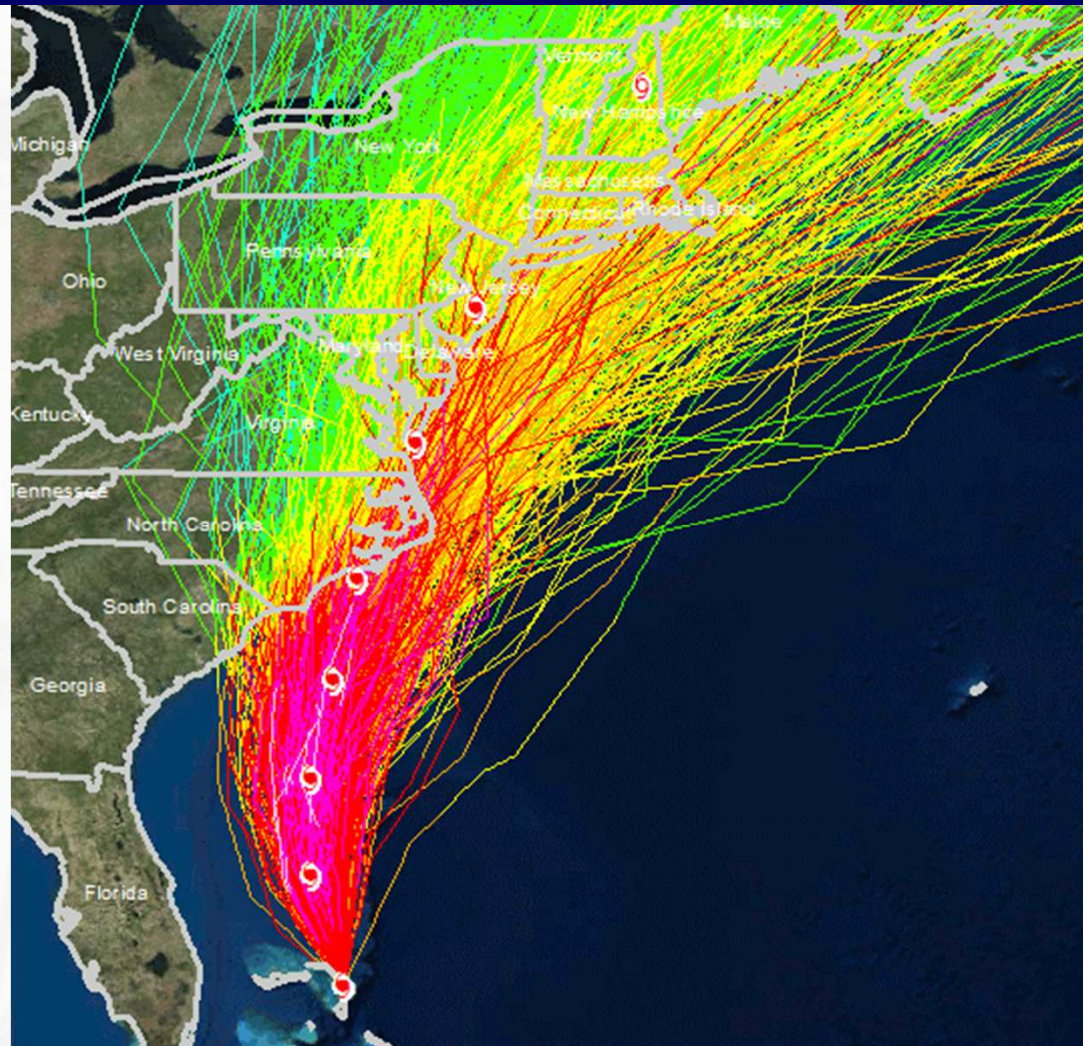
$370/1,000 = 0.37 = 37\%$ chance of tropical storm force winds at Nantucket

Wind Speed Probabilities

How are they generated?

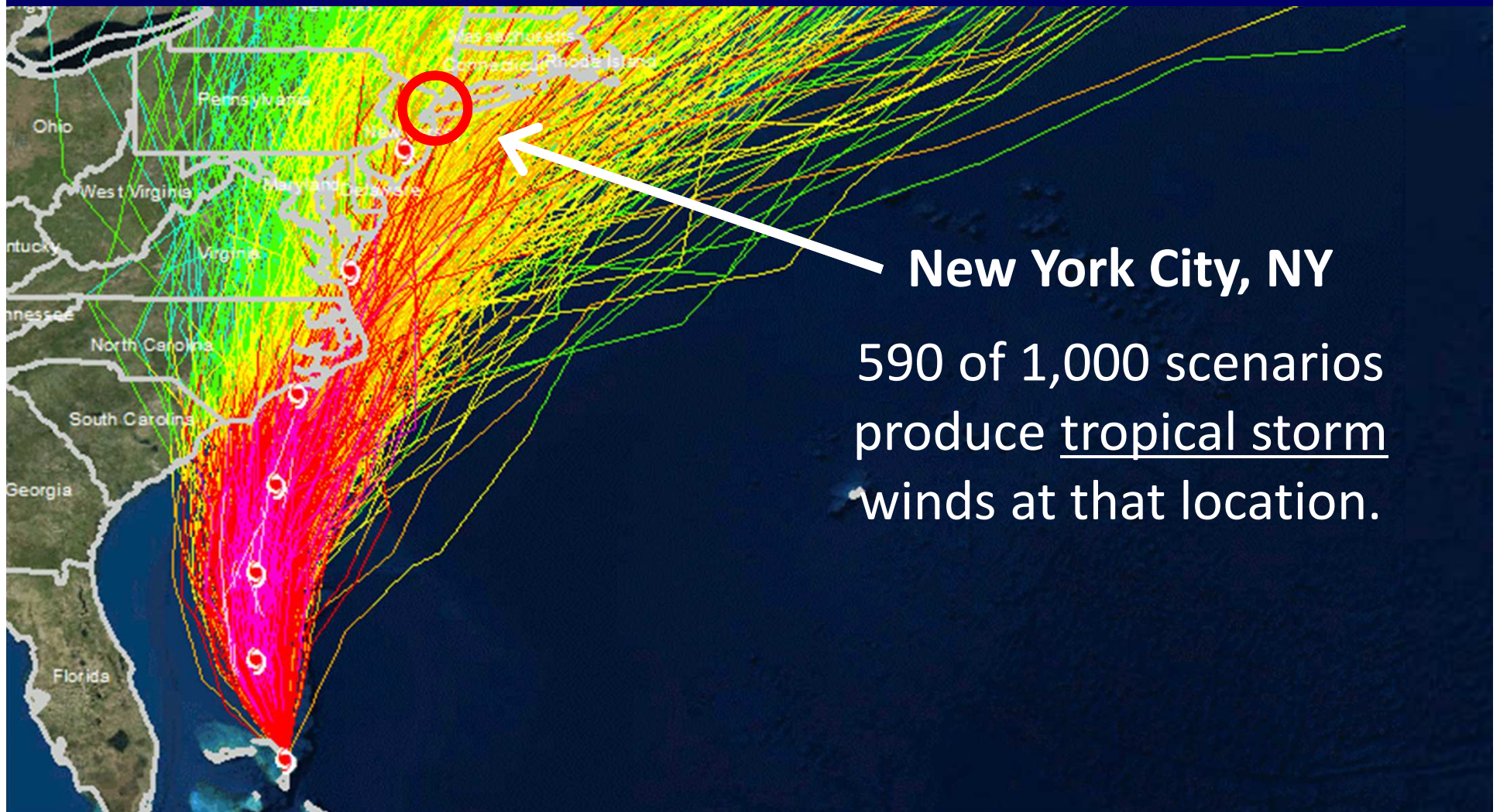
- **1,000 realistic alternative scenarios are created**
 - Official NHC forecast
 - Historical NHC track and intensity forecast errors
 - Climatology and persistence wind radii model
- **Weakening over land**
- ***Track model spread***

Past NHC track forecast errors are correlated to the spread of track model guidance



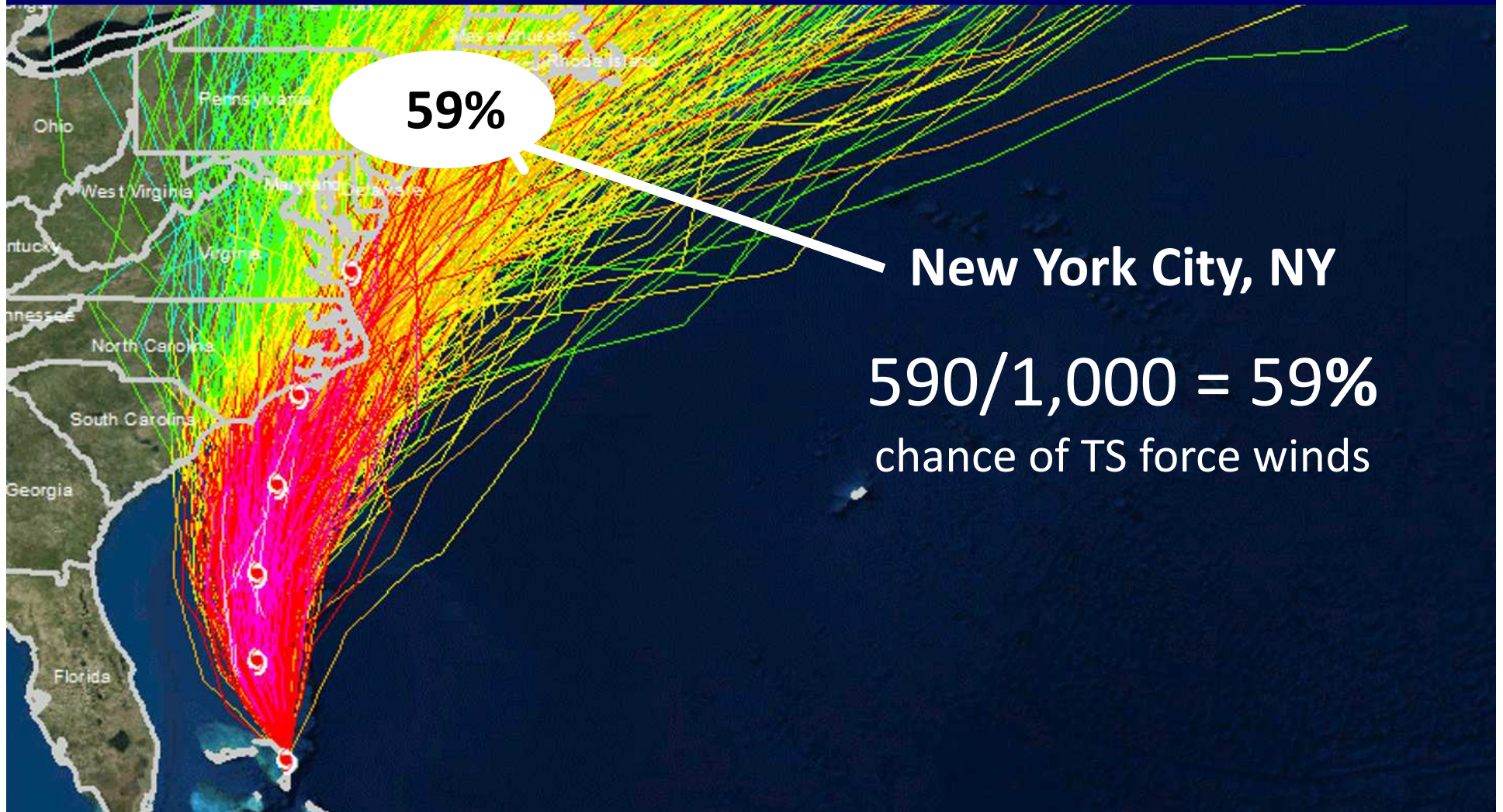
Wind Speed Probabilities

How are they generated?



Wind Speed Probabilities

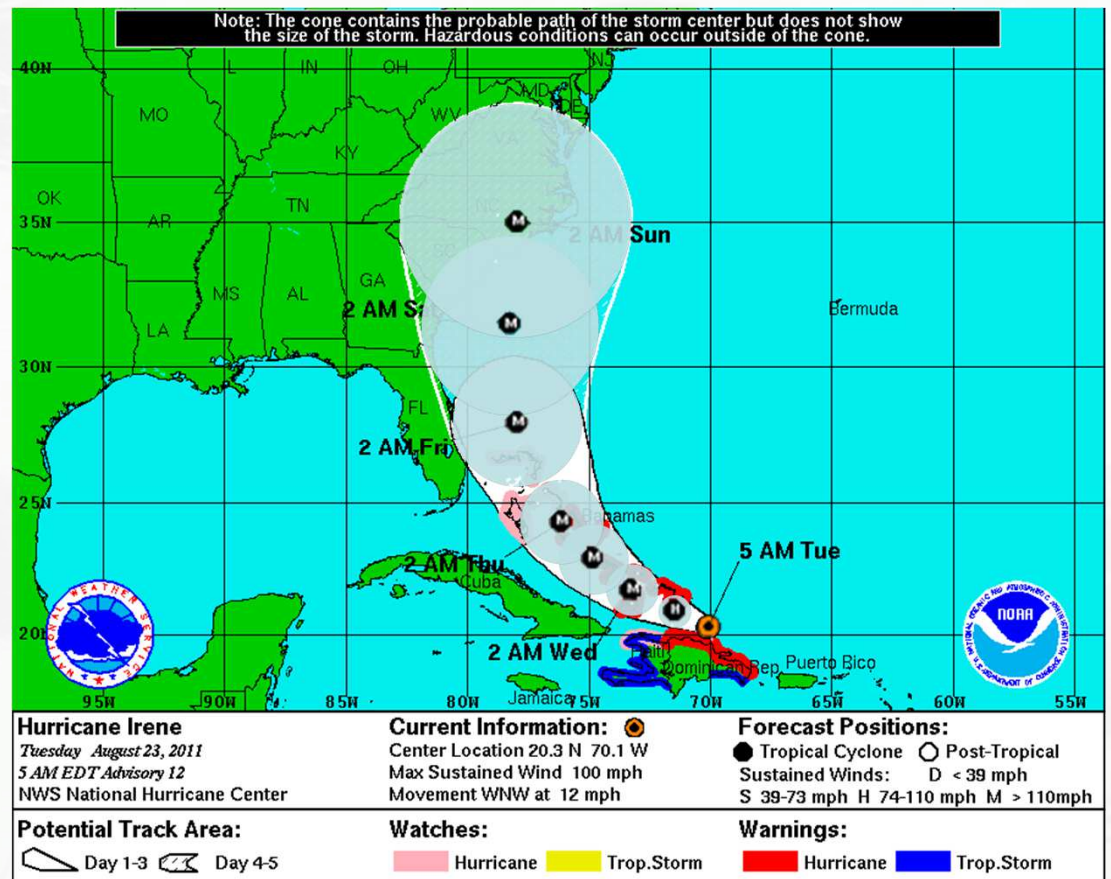
How are they generated?



NHC Forecast Cone

The cure for the skinny black line?

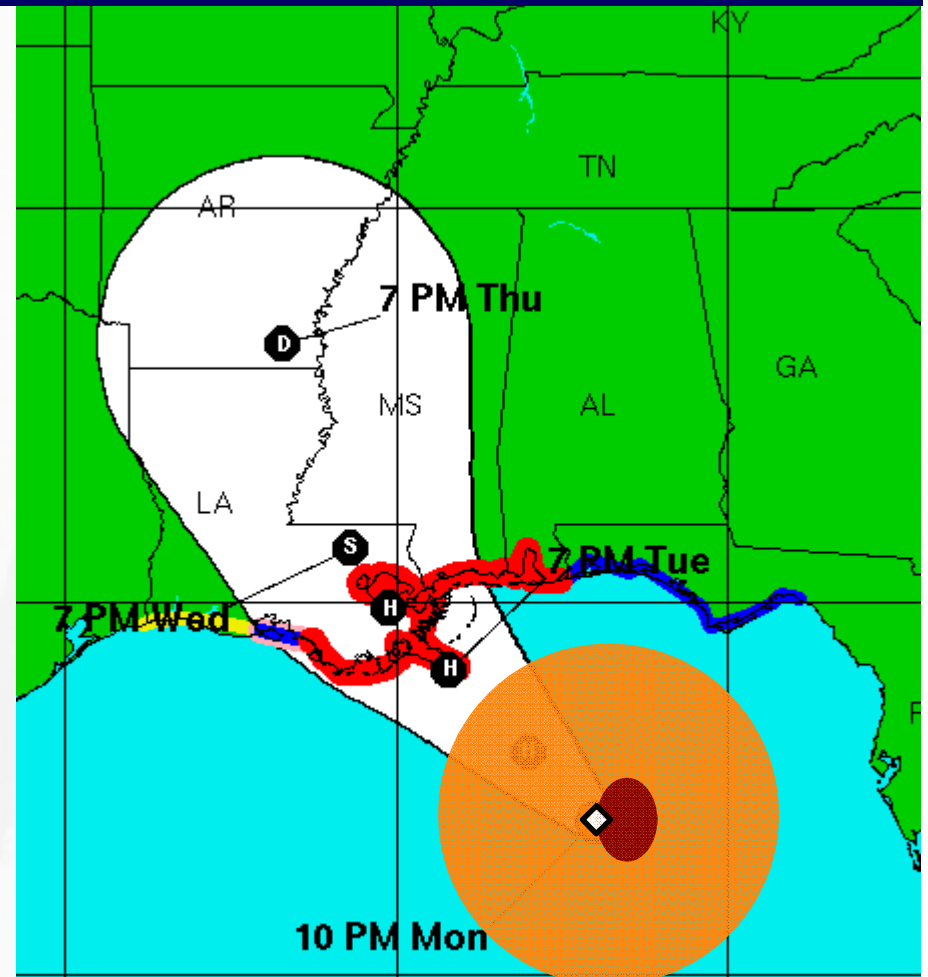
- Represents probable track of tropical cyclone center
- Formed by connecting circles centered on each forecast point
- The size of each circle is created using NHC track errors, so that the actual storm position will be within the circle 67% of the time.



NHC Forecast Cone

No worries, not in the cone?

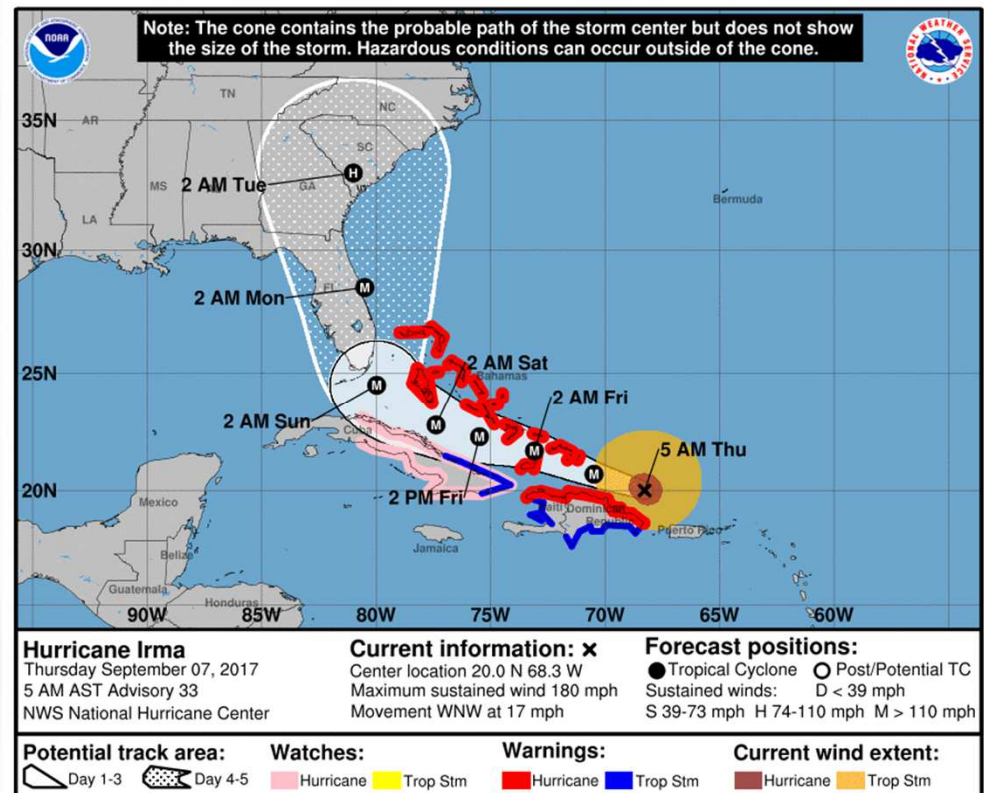
- The cone only displays information about track uncertainty
- It contains no information about specific impacts
- **Tropical Cyclone impacts can occur well outside the area enclosed by the cone**
 - TC center is expected to move outside the cone about 1/3 of the time



NHC Forecast Cone

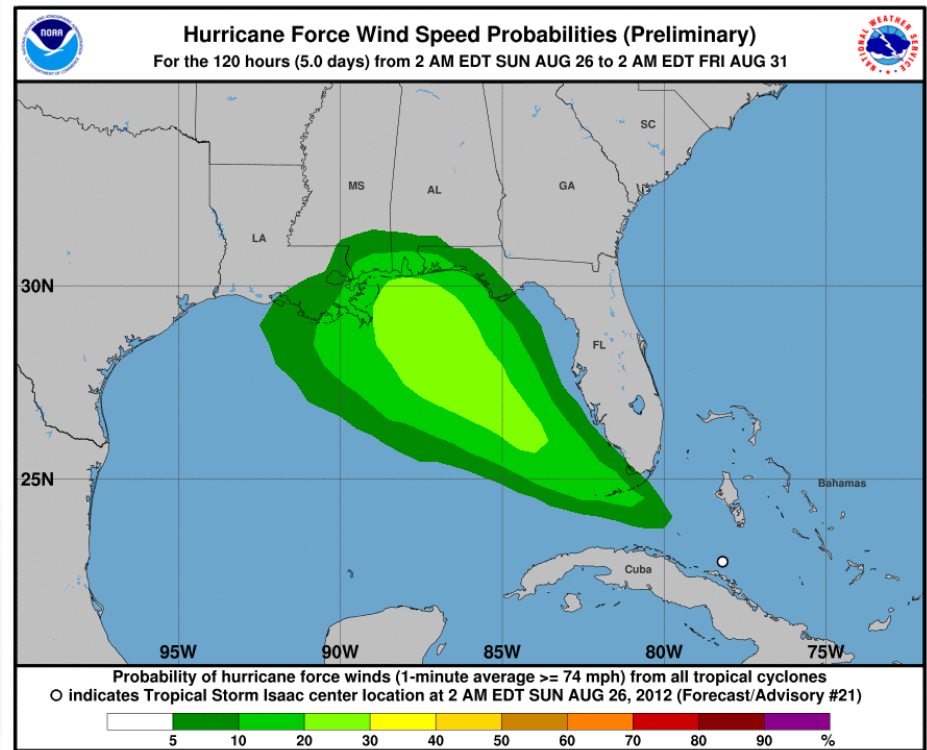
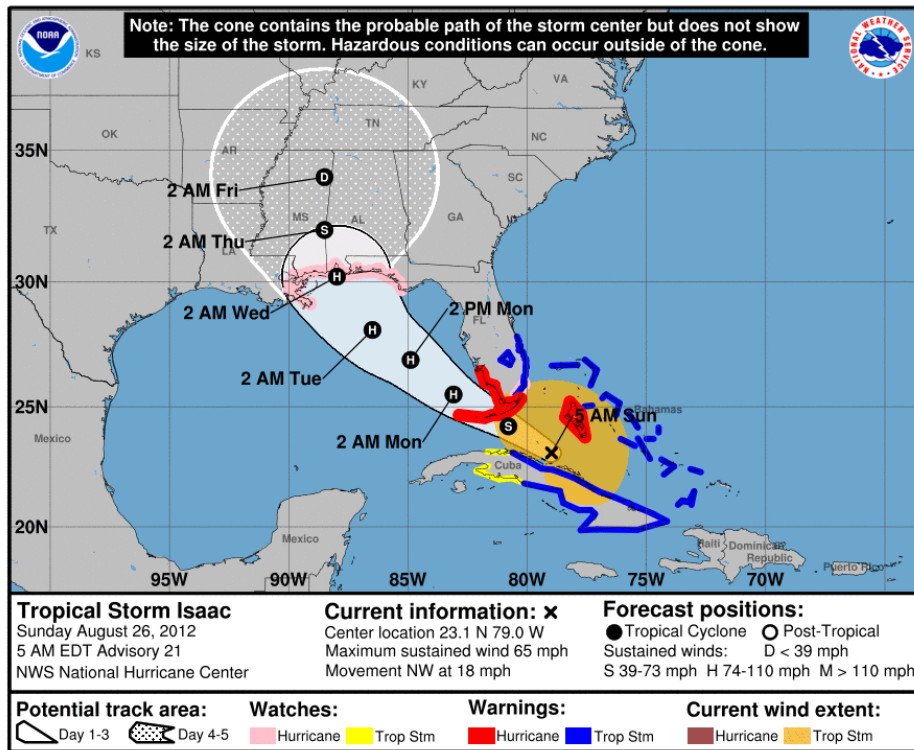
No worries, not in the cone?

- New NHC cone graphics allow users to toggle on/off the initial wind field.
- Provides information on storm size.
- Helps illustrate that the wind hazard occurs outside the cone.



Wind Speed Probabilities

Probabilities vs. The Cone



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

Wind Speed Probabilities

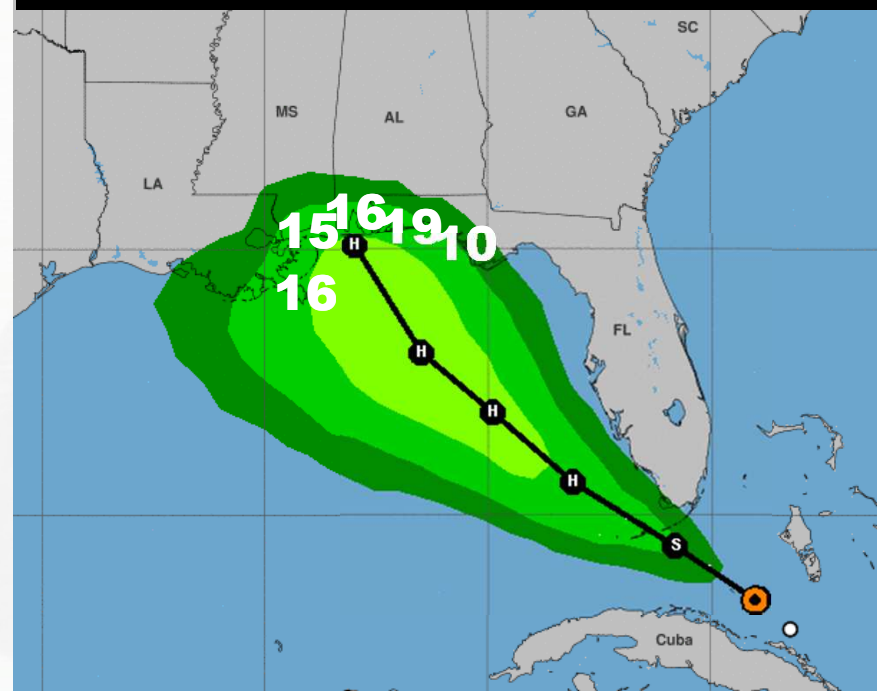
Tropical Storm Isaac (2012)

TROPICAL STORM ISAAC WIND SPEED PROBABILITIES NUMBER 21
 NWS NATIONAL HURRICANE CENTER MIAMI FL AL092012
 0900 UTC SUN AUG 26 2012

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 06Z MON	FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
PANAMA CITY FL 34	X	2(2)	22(24)	30(54)	16(70)	3(73)	X(73)
PANAMA CITY FL 50	X	X(X)	1(1)	10(11)	13(24)	2(26)	1(27)
PANAMA CITY FL 64	X	X(X)	X(X)	2(2)	6(8)	1(9)	1(10)
PENSACOLA FL 34	X	X(X)	10(10)	32(42)	30(72)	6(78)	2(80)
PENSACOLA FL 50	X	X(X)	X(X)	6(6)	27(33)	5(38)	2(40)
PENSACOLA FL 64	X	X(X)	X(X)	2(2)	13(15)	3(18)	1(19)
MOBILE AL 34	X	X(X)	5(5)	24(29)	36(65)	8(73)	2(75)
MOBILE AL 50	X	X(X)	X(X)	3(3)	23(26)	8(34)	2(36)
MOBILE AL 64	X	X(X)	X(X)	1(1)	10(11)	4(15)	1(16)
GULFPORT MS 34	X	X(X)	3(3)	22(25)	35(60)	9(69)	3(72)
GULFPORT MS 50	X	X(X)	X(X)	3(3)	21(24)	8(32)	2(34)
GULFPORT MS 64	X	X(X)	X(X)	X(X)	9(9)	5(14)	1(15)
BURAS LA 34	X	X(X)	4(4)	22(26)	30(56)	8(64)	2(66)
BURAS LA 50	X	X(X)	X(X)	3(3)	21(24)	6(30)	3(33)
BURAS LA 64	X	X(X)	X(X)	X(X)	11(11)	4(15)	1(16)

Chance of Hurricane Force Winds over the 5-day forecast (cumulative)

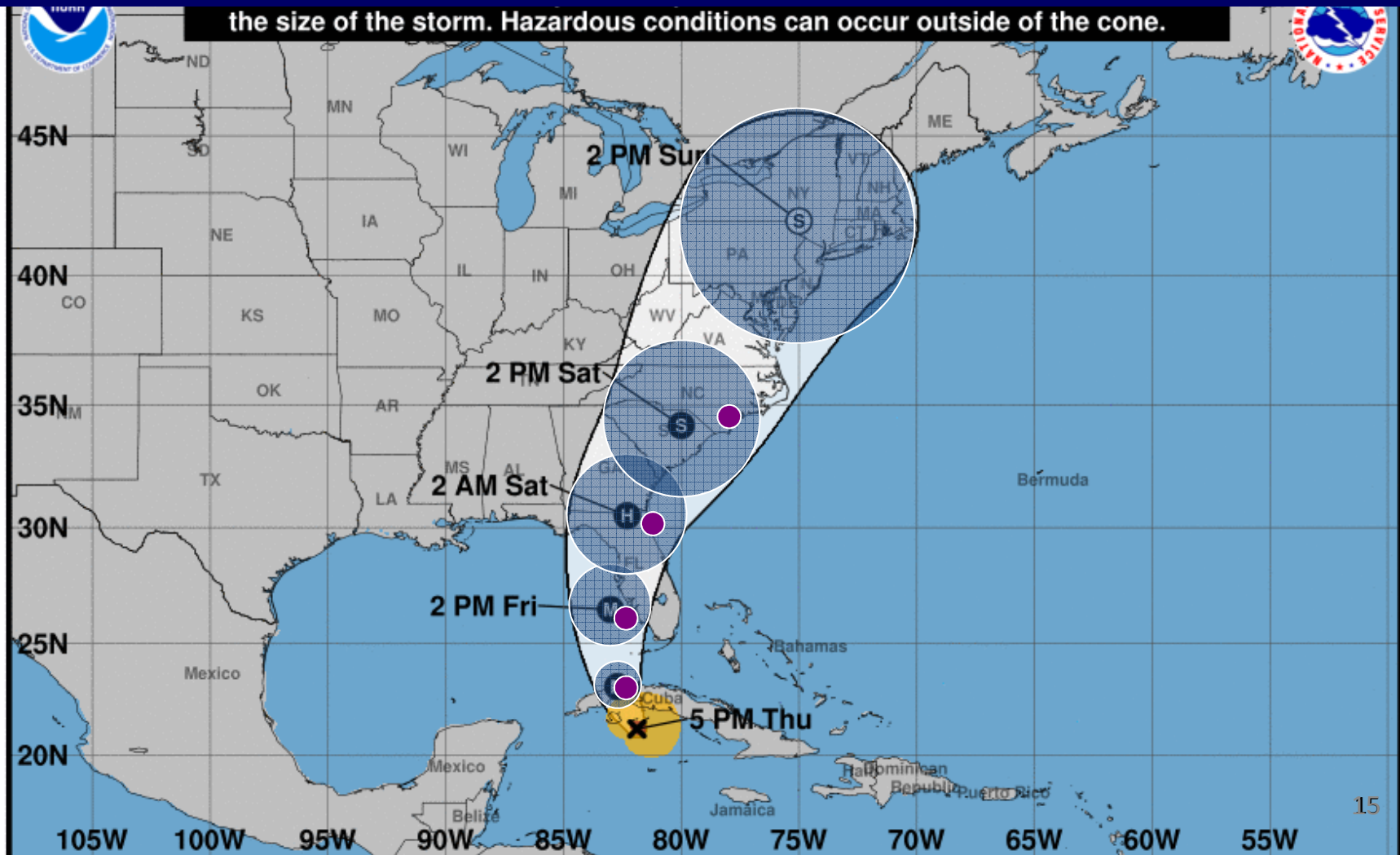


Probability of hurricane force winds (1-minute average ≥ 74 mph) from all tropical cyclones
 O indicates Tropical Storm Isaac center location at 2 AM EDT SUN AUG 26, 2012 (Forecast/Advisory #21)

5 10 20 30 40 50 60 70 80 90 %

Wind Speed Probabilities

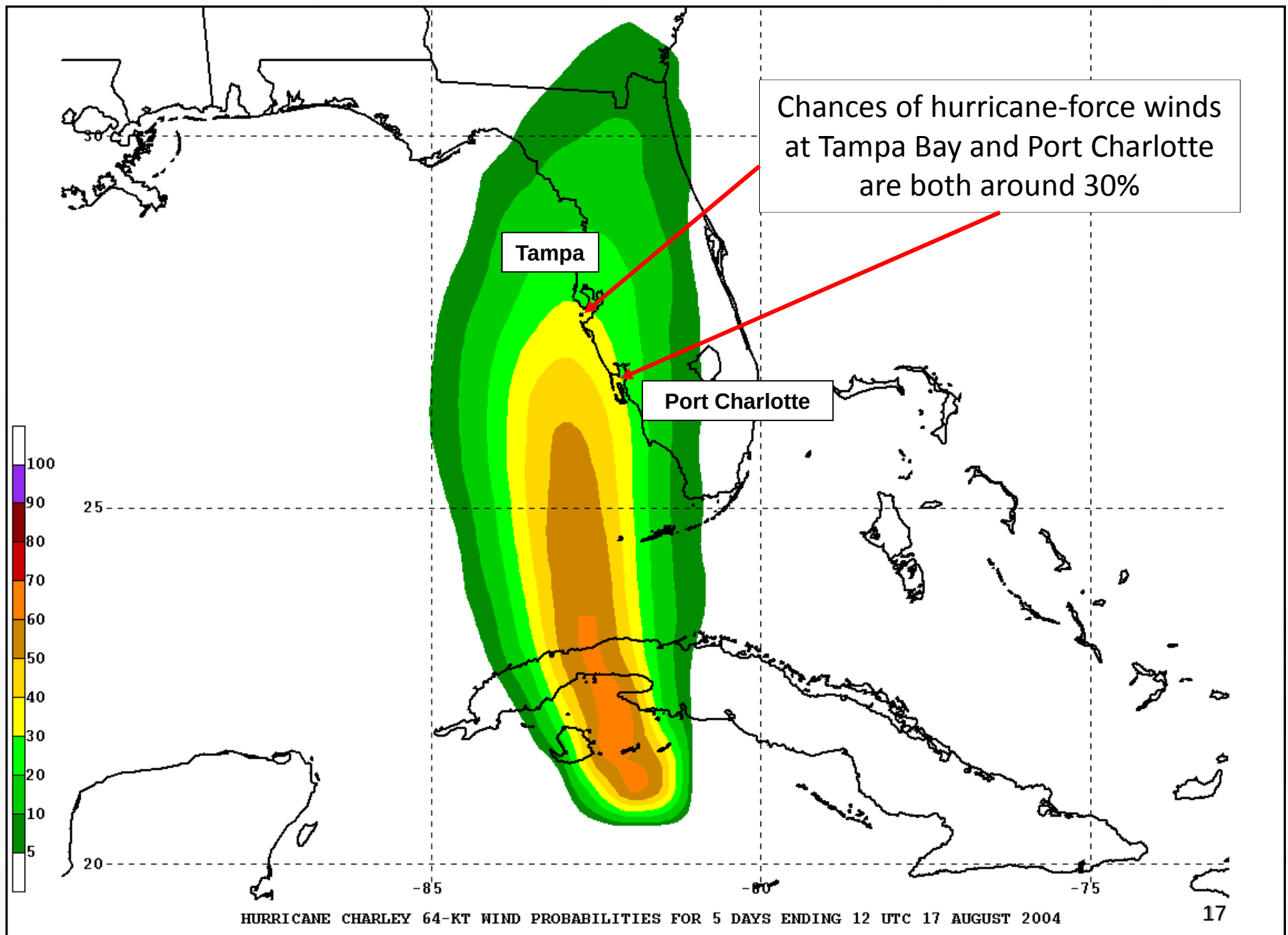
Hurricane Charley (2004)



Hurricane Charley

Would alternate scenarios help?





Wind Speed Probabilities

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TROPICAL DEPRESSION ONE WIND SPEED PROBABILITIES NUMBER 1
NWS NATIONAL HURRICANE CENTER MIAMI FL AL012014
0300 UTC TUE JUL 01 2014

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS	FROM 12Z WED TO 00Z THU	FROM 00Z THU TO 12Z THU	FROM 12Z THU TO 00Z FRI	FROM 00Z FRI TO 12Z FRI	FROM 12Z FRI TO 12Z SAT	FROM 12Z SAT TO 12Z SUN	FROM 12Z SUN TO 12Z MON
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
OCEAN CITY MD	34 X	X(X)	X(X)	X(X)	1(1)	20(21)	1(22)
OCEAN CITY MD	50 X	X(X)	X(X)	X(X)	X(X)	5(5)	1(6)
OCEAN CITY MD	64 X	X(X)	X(X)	X(X)	X(X)	1(1)	X(1)
RICHMOND VA	34 X	X(X)	X(X)	X(X)	2(2)	10(12)	X(12)
NORFOLK NAS	34 X	X(X)	X(X)	X(X)	5(5)	19(24)	X(24)
NORFOLK NAS	50 X	X(X)	X(X)	X(X)	X(X)	4(4)	X(4)
NORFOLK VA	34 X	X(X)	X(X)	X(X)	5(5)	21(26)	X(26)
NORFOLK VA	50 X	X(X)	X(X)	X(X)	X(X)	5(5)	X(5)
WALLOPS CDA	34 X	X(X)	X(X)	X(X)	1(1)	20(21)	1(22)

Depicts location-specific probabilities

- Tropical-storm-force

Wind Speed Probabilities

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TROPICAL DEPRESSION ONE WIND SPEED PROBABILITIES NUMBER 1
NWS NATIONAL HURRICANE CENTER MIAMI FL AL012014
0300 UTC TUE JUL 01 2014

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS	FROM 12Z WED 00Z THU	FROM 12Z THU 00Z FRI	FROM 12Z FRI 12Z SAT	FROM 12Z SAT 12Z SUN	FROM 12Z SUN 12Z MON		
	TO 00Z THU	TO 12Z THU	TO 12Z FRI	TO 12Z SAT	TO 12Z MON		
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
OCEAN CITY MD	34 X	X(X)	X(X)	X(X)	1(1)	20(21)	1(22)
OCEAN CITY MD	50 X	X(X)	X(X)	X(X)	X(X)	5(5)	1(6)
OCEAN CITY MD	64 X	X(X)	X(X)	X(X)	X(X)	1(1)	X(1)
RICHMOND VA	34 X	X(X)	X(X)	X(X)	2(2)	10(12)	X(12)
NORFOLK NAS	34 X	X(X)	X(X)	X(X)	5(5)	19(24)	X(24)
NORFOLK NAS	50 X	X(X)	X(X)	X(X)	X(X)	4(4)	X(4)
NORFOLK VA	34 X	X(X)	X(X)	X(X)	5(5)	21(26)	X(26)
NORFOLK VA	50 X	X(X)	X(X)	X(X)	X(X)	5(5)	X(5)
WALLOPS CDA	34 X	X(X)	X(X)	X(X)	1(1)	20(21)	1(22)

Depicts location-specific probabilities

- Tropical-storm-force
- 58 mph

Wind Speed Probabilities

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0300 UTC TUE JUL 01 2014

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TIME PERIODS	FROM 12Z WED TO 00Z THU	FROM 00Z THU TO 12Z THU	FROM 12Z THU TO 00Z FRI	FROM 00Z FRI TO 12Z FRI	FROM 12Z FRI TO 12Z SAT	FROM 12Z SAT TO 12Z SUN	FROM 12Z SUN TO 12Z MON
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
OCEAN CITY MD	34 X	X(X)	X(X)	X(X)	1(1)	20(21)	1(22)
OCEAN CITY MD	50 X	X(X)	X(X)	X(X)	X(X)	5(5)	1(6)
OCEAN CITY MD	64 X	X(X)	X(X)	X(X)	X(X)	1(1)	X(1)
RICHMOND VA	34 X	X(X)	X(X)	X(X)	2(2)	10(12)	X(12)
NORFOLK NAS	34 X	X(X)	X(X)	X(X)	5(5)	19(24)	X(24)
NORFOLK NAS	50 X	X(X)	X(X)	X(X)	X(X)	4(4)	X(4)
NORFOLK VA	34 X	X(X)	X(X)	X(X)	5(5)	21(26)	X(26)
NORFOLK VA	50 X	X(X)	X(X)	X(X)	X(X)	5(5)	X(5)
WALLOPS CDA	34 X	X(X)	X(X)	X(X)	1(1)	20(21)	1(22)

Depicts location-specific probabilities

- Tropical-storm-force
- 58 mph
- Hurricane-force

Wind Speed Probabilities

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TIME PERIODS	FROM 12Z WED TO 00Z THU	FROM 00Z THU TO 12Z THU	FROM 12Z THU TO 00Z FRI	FROM 00Z FRI TO 12Z FRI	FROM 12Z FRI TO 12Z SAT	FROM 12Z SAT TO 12Z SUN	FROM 12Z SUN TO 12Z MON
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
OCEAN CITY MD	34	X	X(X)	X(X)	X(X)	1(1)	20(21)
OCEAN CITY MD	50	X	X(X)	X(X)	X(X)	5(5)	1(6)
OCEAN CITY MD	64	X	X(X)	X(X)	X(X)	1(1)	X(1)
RICHMOND VA	34	X	X(X)	X(X)	X(X)	2(2)	10(12)
NORFOLK NAS	34	X	X(X)	X(X)	X(X)	5(5)	19(24)
NORFOLK NAS	50	X	X(X)	X(X)	X(X)	4(4)	X(4)
NORFOLK VA	34	X	X(X)	X(X)	X(X)	5(5)	21(26)
NORFOLK VA	50	X	X(X)	X(X)	X(X)	5(5)	X(5)
WALLOPS CDA	34	X	X(X)	X(X)	X(X)	1(1)	20(21)

Depicts location-specific probabilities

- Tropical-storm-force
- 58 mph
- Hurricane-force

Onset probabilities

- Individual time period

Wind Speed Probabilities

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- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS	FROM 12Z WED TO 00Z THU	FROM 00Z THU TO 12Z THU	FROM 12Z THU TO 00Z FRI	FROM 00Z FRI TO 12Z FRI	FROM 12Z FRI TO 12Z SAT	FROM 12Z SAT TO 12Z SUN	FROM 12Z SUN TO 12Z MON
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
OCEAN CITY MD 34	X	X (X)	X (X)	X (X)	1 (1)	20 (21)	1 (22)
OCEAN CITY MD 50	X	X (X)	X (X)	X (X)	X (X)	5 (5)	1 (6)
OCEAN CITY MD 64	X	X (X)	X (X)	X (X)	X (X)	1 (1)	X (1)
RICHMOND VA 34	X	X (X)	X (X)	X (X)	2 (2)	10 (12)	X (12)
NORFOLK NAS 34	X	X (X)	X (X)	X (X)	5 (5)	19 (24)	X (24)
NORFOLK NAS 50	X	X (X)	X (X)	X (X)	X (X)	4 (4)	X (4)
NORFOLK VA 34	X	X (X)	X (X)	X (X)	5 (5)	21 (26)	X (26)
NORFOLK VA 50	X	X (X)	X (X)	X (X)	X (X)	5 (5)	X (5)
WALLOPS CDA 34	X	X (X)	X (X)	X (X)	1 (1)	20 (21)	1 (22)

Depicts location-specific probabilities

- Tropical-storm-force
- 58 mph
- Hurricane-force

Onset probabilities

- Individual time period

Cumulative probabilities

Wind Speed Probabilities

Tropical Storm Isaac

TROPICAL STORM ISAAC WIND SPEED PROBABILITIES NUMBER 21
 NWS NATIONAL HURRICANE CENTER MIAMI FL AL092012
 0900 UTC SUN AUG 26 2012

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 06Z MON	FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
PANAMA CITY FL 34	X	3(3)	22(25)	30(55)	16(71)	2(73)	1(74)
PANAMA CITY FL 50	X	X(X)	1(1)	13(14)	15(29)	2(31)	1(32)
PANAMA CITY FL 64	X	X(X)	X(X)	3(3)	6(9)	2(11)	1(12)
PENSACOLA FL 34	X	X(X)	10(10)	32(42)	31(73)	5(78)	X(78)
PENSACOLA FL 50	X	X(X)	X(X)	6(6)	28(34)	5(39)	1(40)
PENSACOLA FL 64	X	X(X)	X(X)	1(1)	14(15)	3(18)	X(18)
MOBILE AL 34	X	X(X)	5(5)	24(29)	35(64)	8(72)	1(73)
MOBILE AL 50	X	X(X)	X(X)	3(3)	22(25)	8(33)	1(34)
MOBILE AL 64	X	X(X)	X(X)	1(1)	8(9)	4(13)	1(14)
GULFPORT MS 34	X	X(X)	3(3)	21(24)	34(58)	10(68)	1(69)
GULFPORT MS 50	X	X(X)	X(X)	2(2)	19(21)	7(28)	2(30)

How likely are
 Tropical Storm
 (34kt) winds at
 Pensacola, FL over
 the next 5 days?

← Pensacola, FL

Wind Speed Probabilities

Tropical Storm Isaac

TROPICAL STORM ISAAC WIND SPEED PROBABILITIES NUMBER 21
 NWS NATIONAL HURRICANE CENTER MIAMI FL AL092012
 0900 UTC SUN AUG 26 2012

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 06Z MON	FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
PANAMA CITY FL 34	X	3(3)	22(25)	30(55)	16(71)	2(73)	1(74)
PANAMA CITY FL 50	X	X(X)	1(1)	13(14)	15(29)	2(31)	1(32)
PANAMA CITY FL 64	X	X(X)	X(X)	3(3)	6(9)	2(11)	1(12)
PENSACOLA FL 34	X	X(X)	10(10)	32(42)	31(73)	5(78)	X(78)
PENSACOLA FL 50	X	X(X)	X(X)	6(6)	28(34)	5(39)	1(40)
PENSACOLA FL 64	X	X(X)	X(X)	1(1)	14(15)	3(18)	X(18)
MOBILE AL 34	X	X(X)	5(5)	24(29)	35(64)	8(72)	1(73)
MOBILE AL 50	X	X(X)	X(X)	3(3)	22(25)	8(33)	1(34)
MOBILE AL 64	X	X(X)	X(X)	1(1)	8(9)	4(13)	1(14)
GULFPORT MS 34	X	X(X)	3(3)	21(24)	34(58)	10(68)	1(69)
GULFPORT MS 50	X	X(X)	X(X)	2(2)	19(21)	7(28)	2(30)

How likely are
 Tropical Storm
 (34kt) winds at
 Pensacola, FL over
 the next 5 days?

← Tropical Storm
 (34kt)

Wind Speed Probabilities

Tropical Storm Isaac

TROPICAL STORM ISAAC WIND SPEED PROBABILITIES NUMBER 21
 NWS NATIONAL HURRICANE CENTER MIAMI FL AL092012
 0900 UTC SUN AUG 26 2012

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

TIME PERIODS	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 06Z MON	FROM 06Z MON TO 18Z MON	FROM 18Z MON TO 06Z TUE	FROM 06Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU	FROM 06Z THU TO 06Z FRI
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
PANAMA CITY FL 34	X	3(3)	22(25)	30(55)	16(71)	2(73)	1(74)
PANAMA CITY FL 50	X	X(X)	1(1)	13(14)	15(29)	2(31)	1(32)
PANAMA CITY FL 64	X	X(X)	X(X)	3(3)	6(9)	2(11)	1(12)
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MOBILE AL 64	X	X(X)	X(X)	1(1)	8(9)	4(13)	1(14)
GULFPORT MS 34	X	X(X)	3(3)	21(24)	34(58)	10(68)	1(69)
GULFPORT MS 50	X	X(X)	X(X)	2(2)	19(21)	7(28)	2(30)

How likely are
 Tropical Storm
 (34kt) winds at
 Pensacola, FL over
 the next 5 days?

5 days (120 h)

Tropical Storm
 (34kt)

Wind Speed Probabilities

Tropical Storm Isaac

TROPICAL STORM ISAAC WIND SPEED PROBABILITIES NUMBER 21
 NWS NATIONAL HURRICANE CENTER MIAMI FL AL092012
 0900 UTC SUN AUG 26 2012

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

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GULFPORT MS 50	X	X(X)	X(X)	2(2)	19(21)	7(28)	2(30)

How likely are
 Tropical Storm
 (34kt) winds at
 Pensacola, FL over
 the next 5 days?

← 78% chance of
 TS winds at
 Pensacola, FL
 over 5 days

Wind Speed Probabilities

Tropical Storm Isaac

TROPICAL STORM ISAAC WIND SPEED PROBABILITIES NUMBER 21
 NWS NATIONAL HURRICANE CENTER MIAMI FL AL092012
 0900 UTC SUN AUG 26 2012

- - - - WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS - - - -

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FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
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When are Tropical Storm (34kt) winds most likely to start at Pensacola, FL?

← Pensacola, FL

Wind Speed Probabilities

Tropical Storm Isaac

TROPICAL STORM ISAAC WIND SPEED PROBABILITIES NUMBER 21
 NWS NATIONAL HURRICANE CENTER MIAMI FL AL092012
 0900 UTC SUN AUG 26 2012

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When are Tropical Storm (34kt) winds most likely to start at Pensacola, FL?

← Tropical Storm (34kt)

Wind Speed Probabilities

Tropical Storm Isaac

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When are Tropical Storm (34kt) winds most likely to start at Pensacola, FL?

Wind Speed Probabilities

Tropical Storm Isaac

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When are Tropical Storm (34kt) winds most likely to start at Pensacola, FL?

32% chance

Tropical Storm winds begin during the period between **2pm Mon to 2am Tue (12 hr)**

31% chance

Tropical Storm winds begin during the period between **2am Tue to 2am Wed (24 hr)**

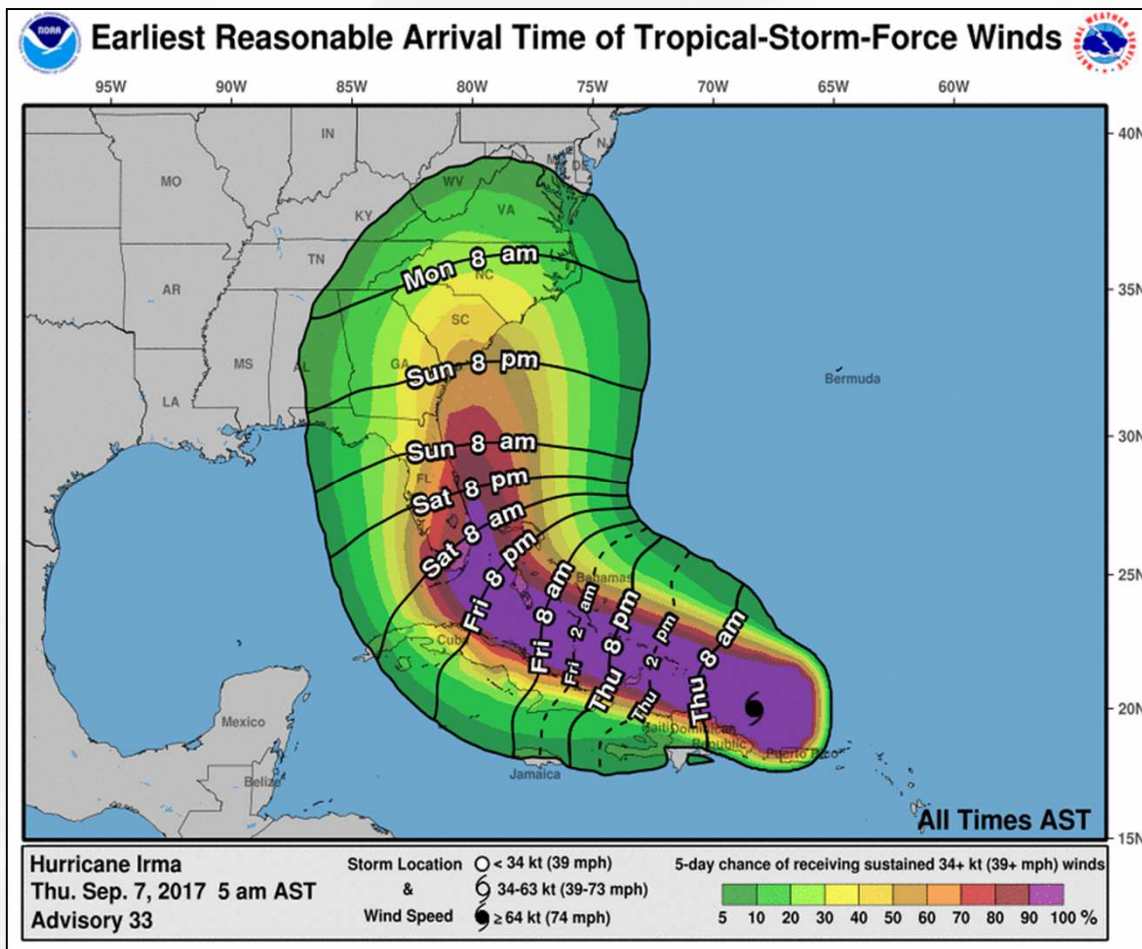
Wind Speed Probabilities

Onset Timing

- Important information about the onset of wind conditions is contained in the probabilities
- Text product allows you to compare onset probabilities for different time periods
- New graphics show earliest reasonable and most likely times of arrival of TS winds for planning

Wind Speed Probabilities

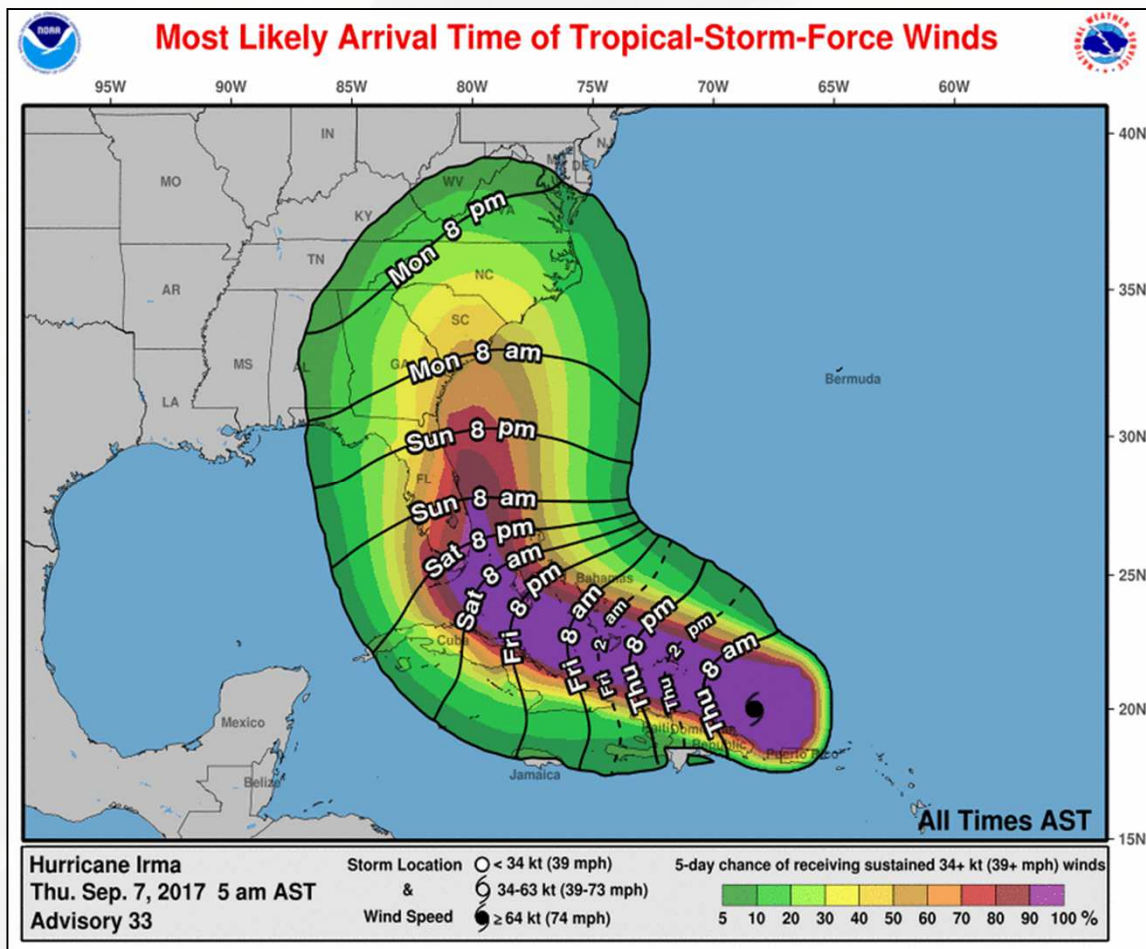
Experimental Graphic – Earliest Reasonable Arrival Time of Sustained TS Winds



- Shows earliest reasonable arrival time of TS winds (black contours) and cumulative TS wind speed probabilities (colors)
- Identifies the time window that users at individual locations can safely assume will be free from TS winds
 - Based on the time that has ≤ 10% chance of seeing sustained TS winds before the indicated time
- Best for users with low tolerance for risk

Wind Speed Probabilities

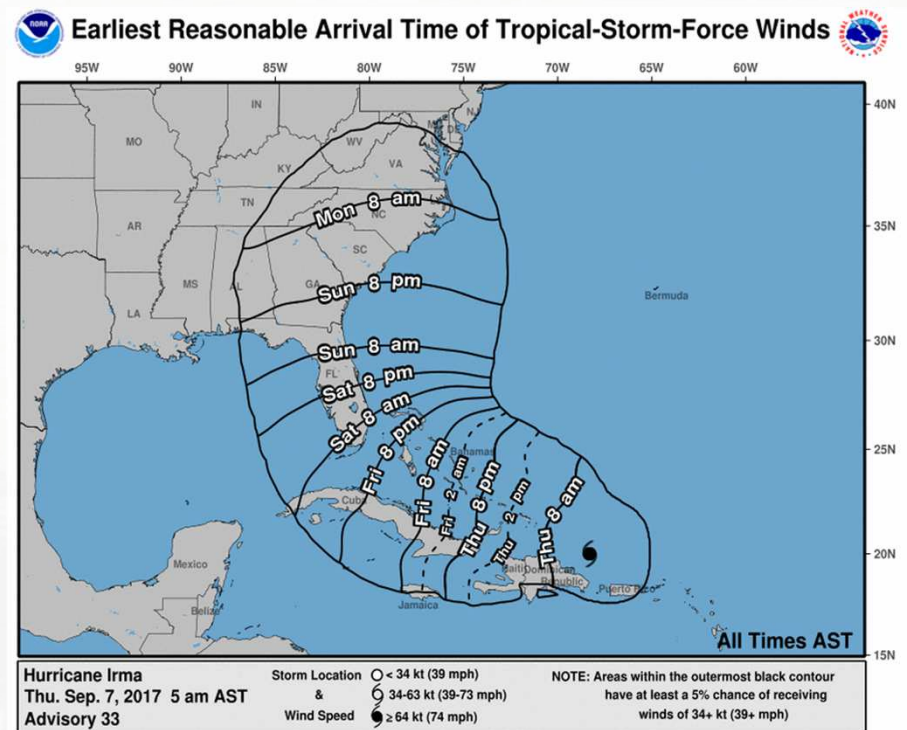
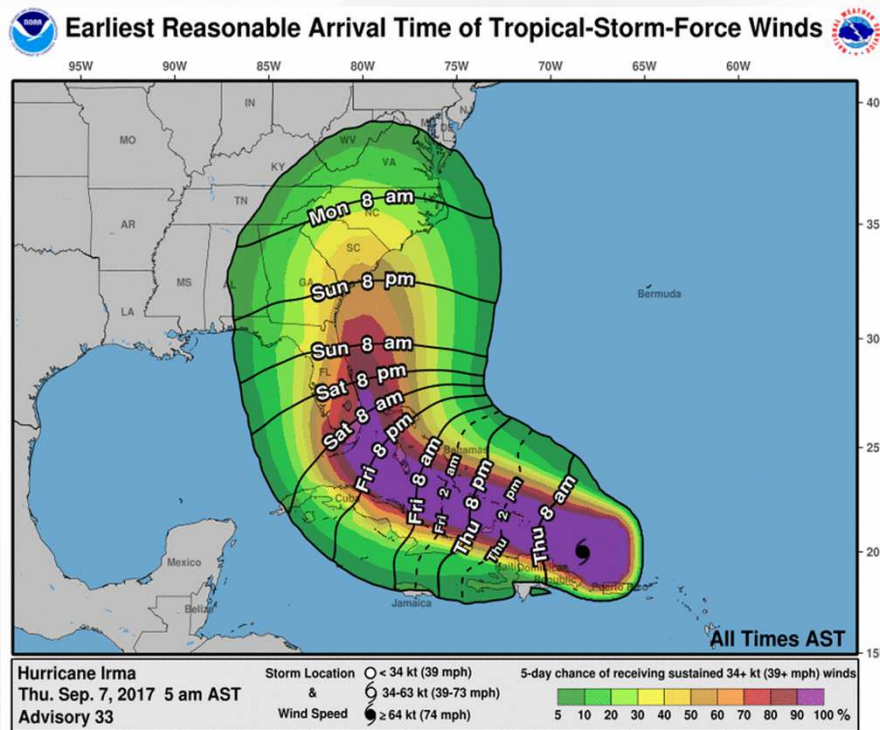
Experimental Graphic – Most Likely Arrival Time of Sustained TS Winds



- Shows most likely arrival time of TS winds (black contours) and cumulative TS wind speed probabilities (colors)
- Shows the time before or after which the onset of sustained TS winds is equally likely
- Best for users that are willing to risk not having completed preparations before TS winds arrive
- Prototype graphic for 2017

Wind Speed Probabilities

Versions of the graphics with and without the Wind Speed Probabilities



Wind Speed Probabilities

Summary

- Wind speed probability products help you deal with the uncertainty inherent in forecasting tropical cyclones
- Provide additional information beyond what is available in deterministic forecasts for:
 - Timing of event onset
 - Likelihood of various wind speeds occurring at your location
- “Low” probabilities of extreme events often warrant action!

