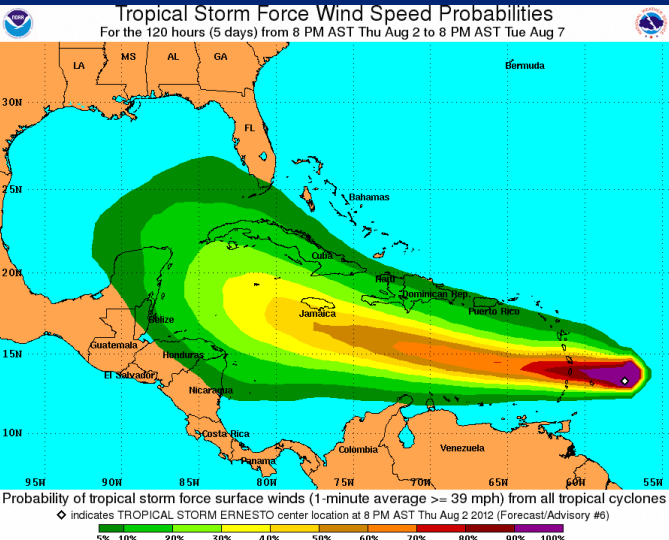


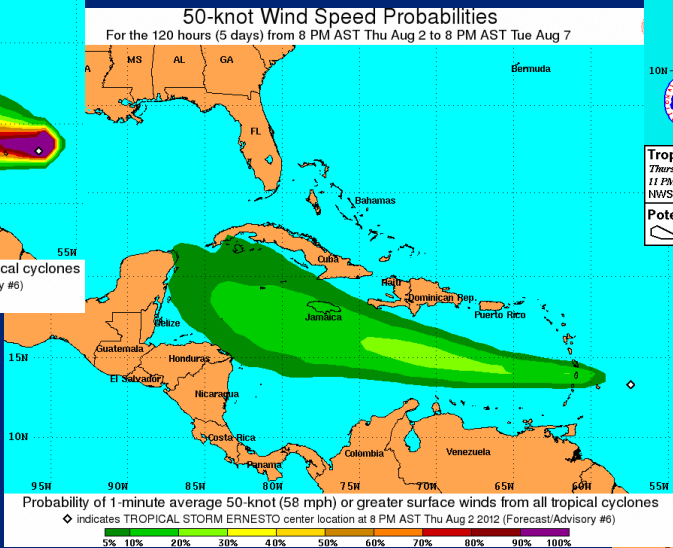


# Wind Speed and Intensity Probability Products

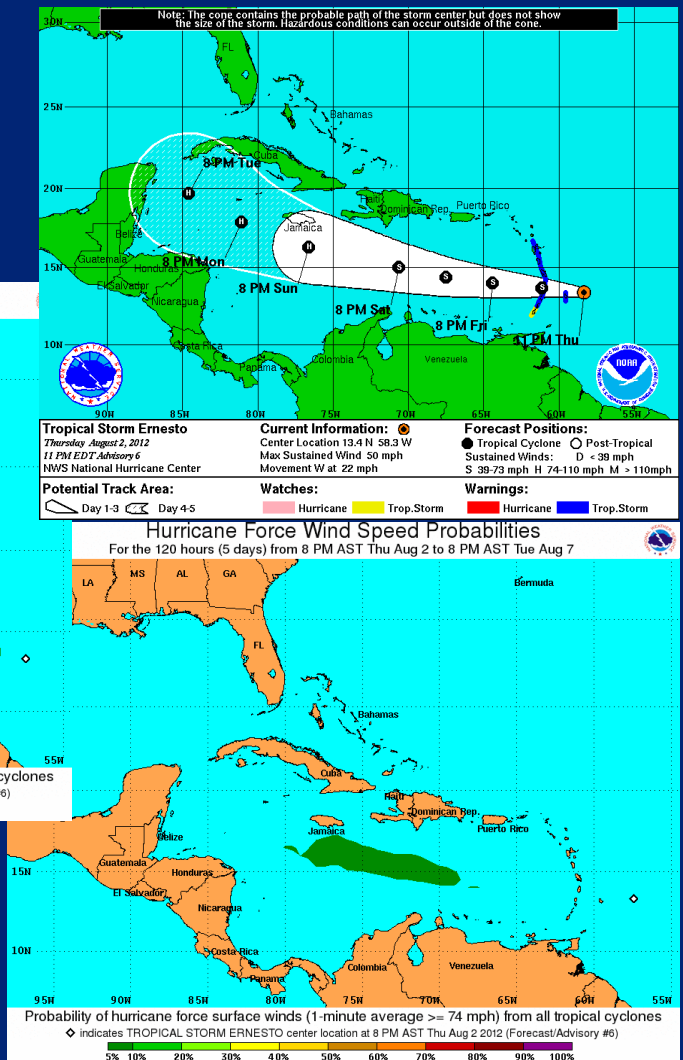




Tropical Storm Force



50-kt



Hurricane Force

Daniel Brown  
National Hurricane Center  
2016 WMO Course  
8 March 2016

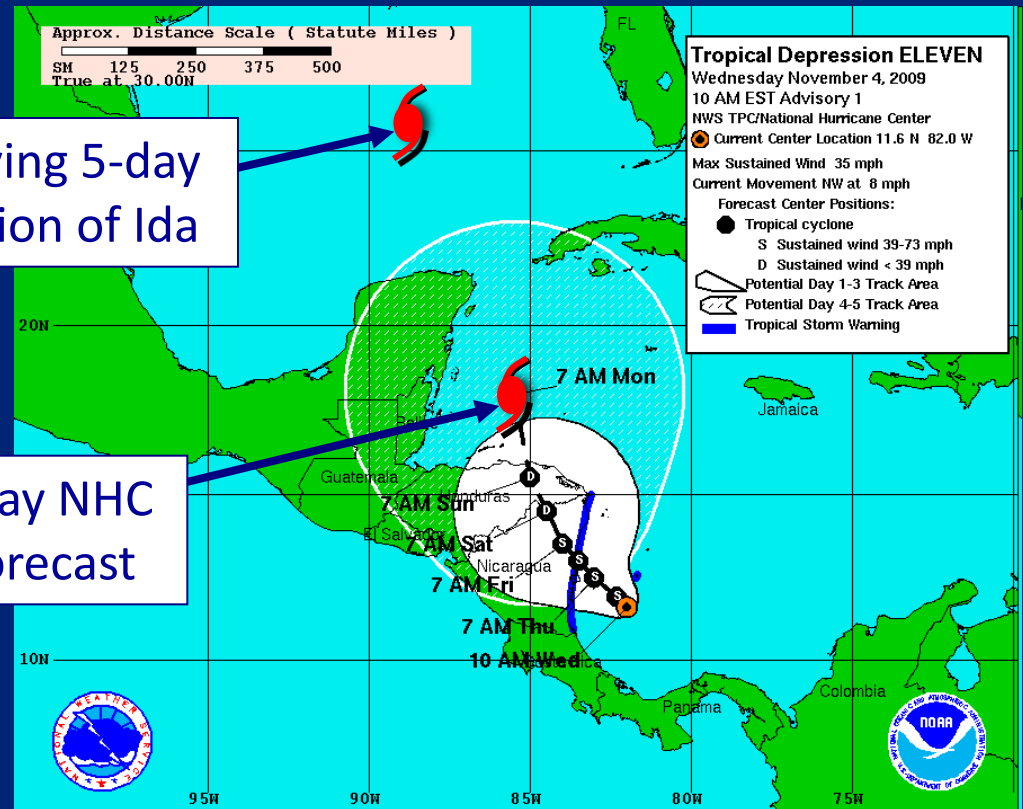
# How Can You, as Decision Makers, Deal with Forecast Uncertainty?

TD 11 (later  
Hurricane Ida)  
Advisory Number 1  
Issued 10:00 AM EST  
4 November 2009

5-day position error  
about 600 miles

Verifying 5-day  
Position of Ida

5-day NHC  
Forecast

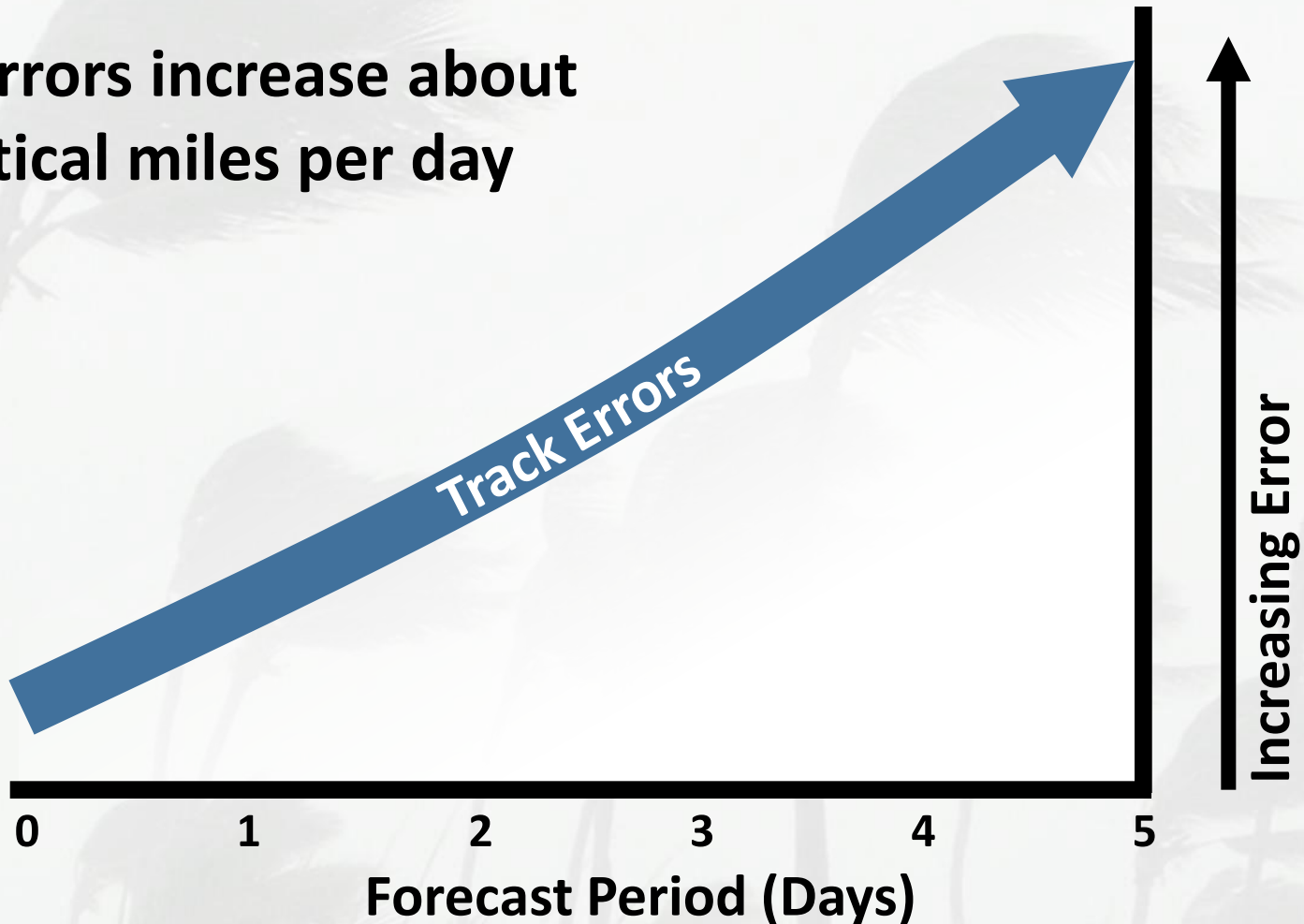


NHC probability products can help

# Forecast Track Errors

*NHC 5-Year Averages*

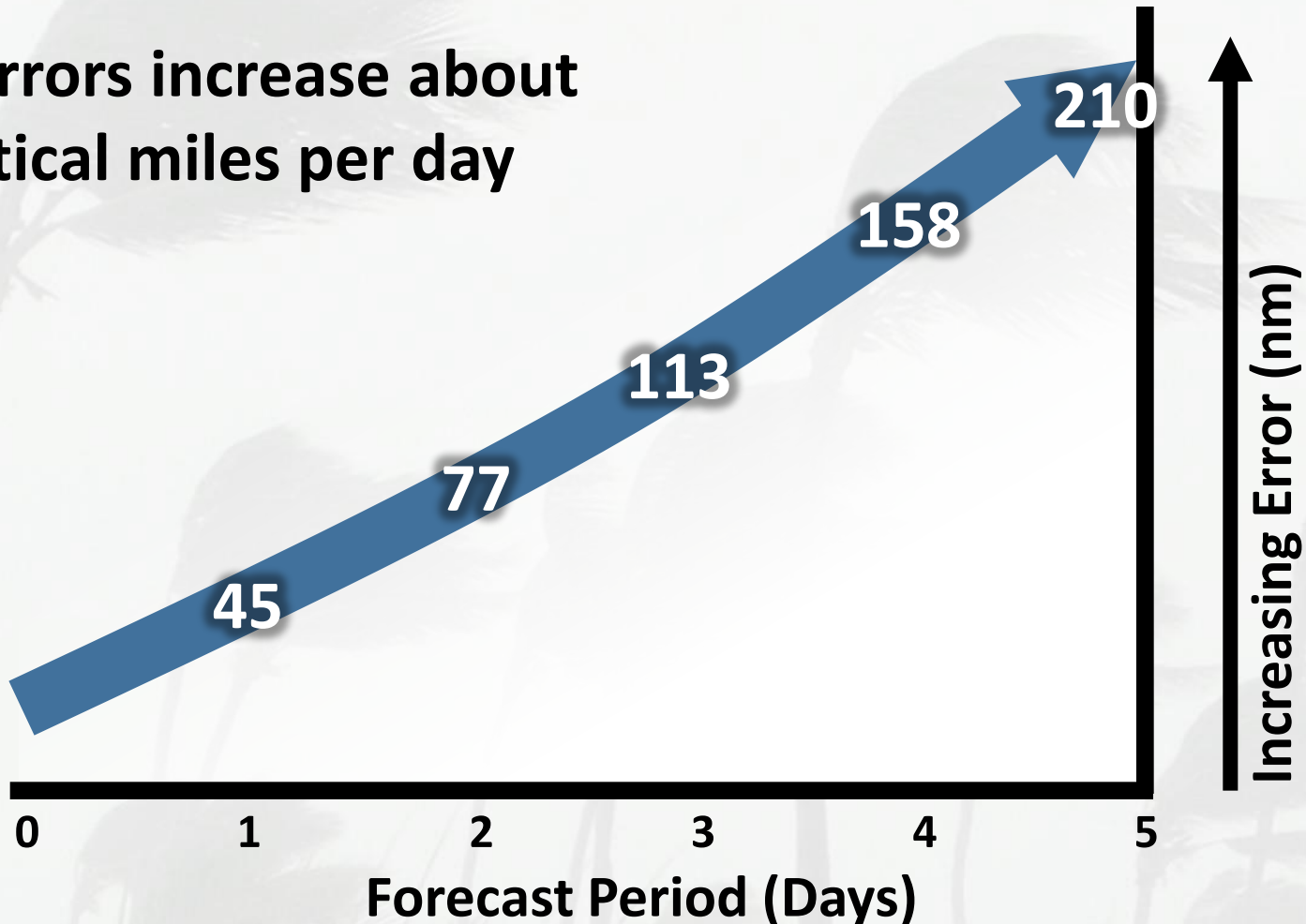
Track errors increase about  
40 nautical miles per day



# Forecast Track Errors

*NHC 5-Year Averages*

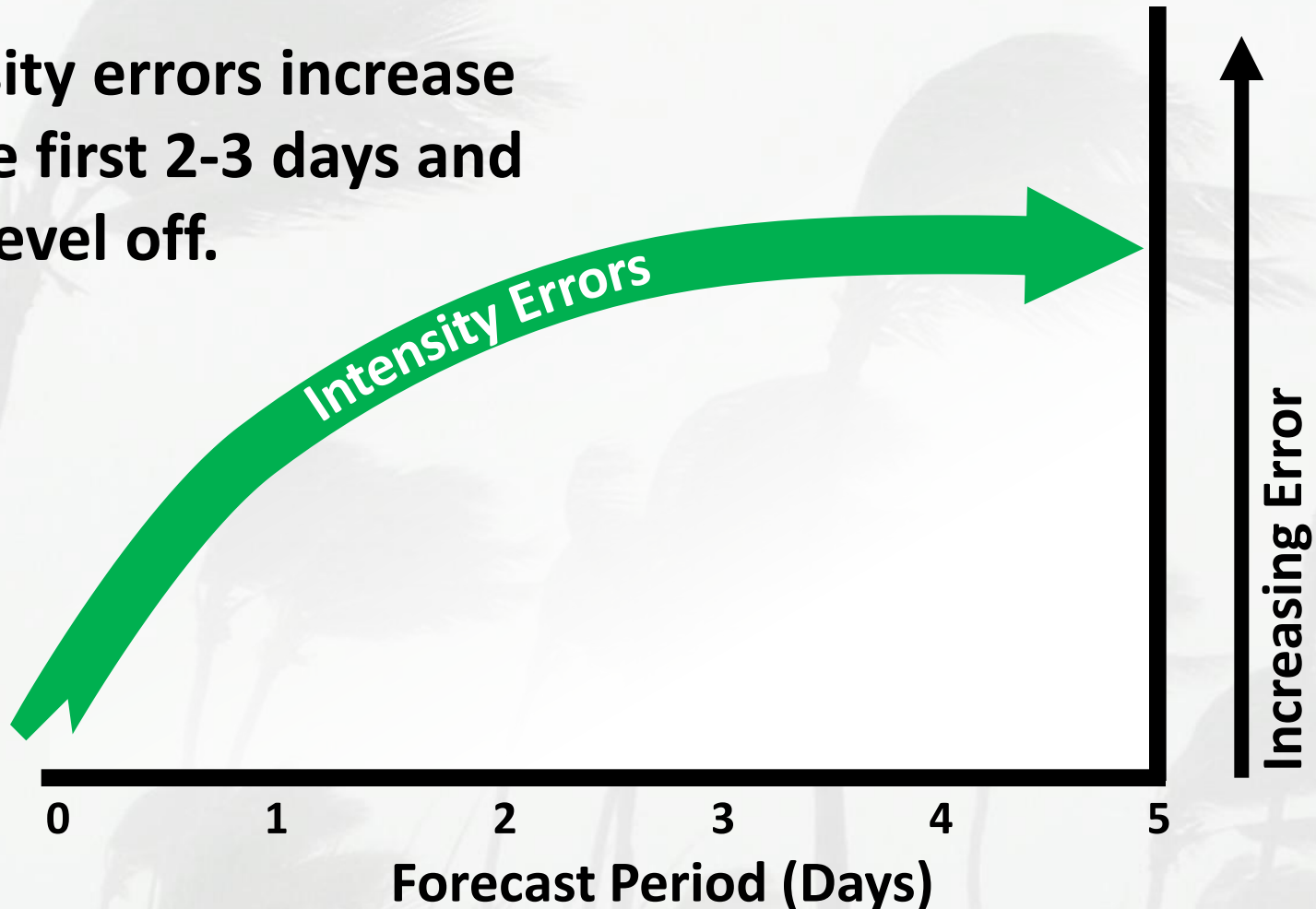
Track errors increase about  
40 nautical miles per day



# Forecast Intensity Errors

*NHC 5-Year Averages*

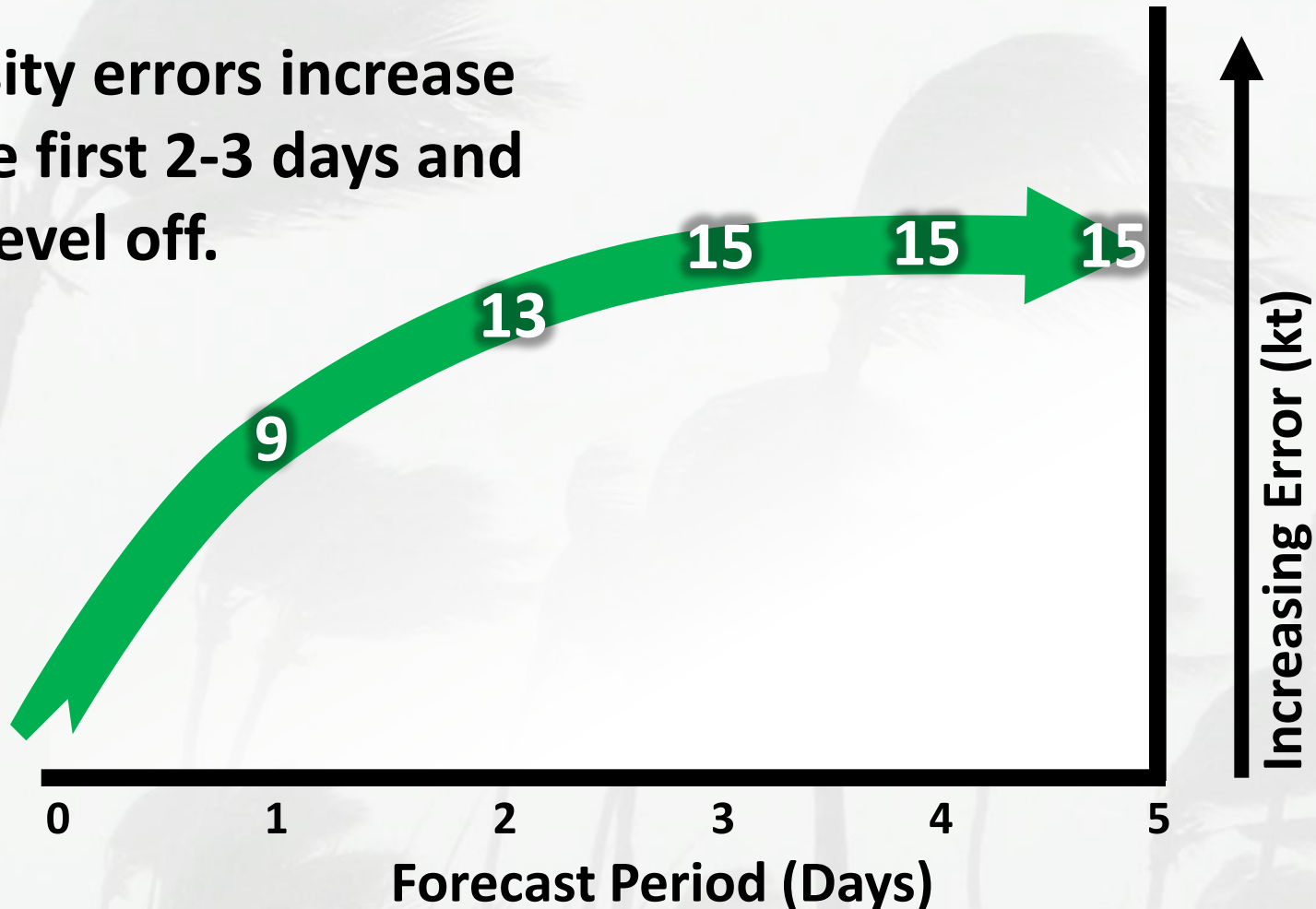
Intensity errors increase for the first 2-3 days and then level off.



# Forecast Intensity Errors

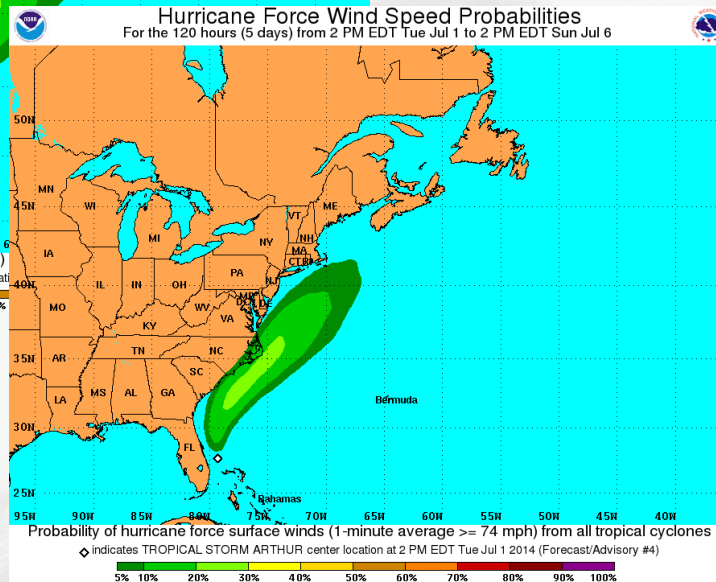
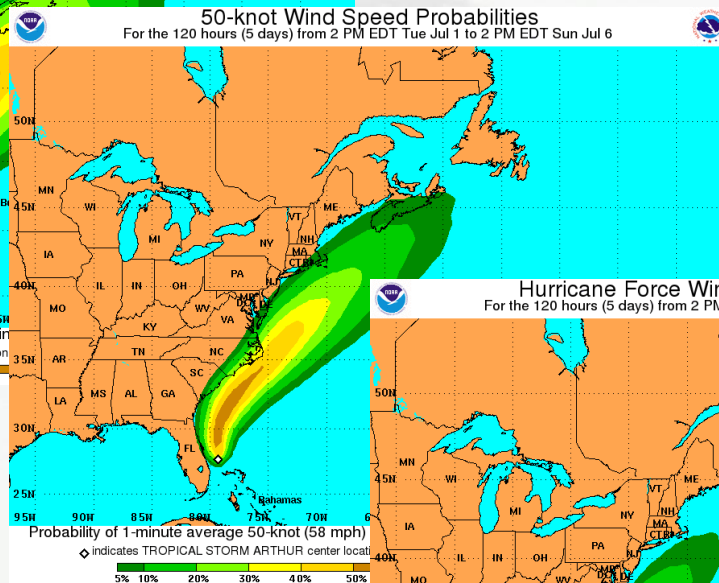
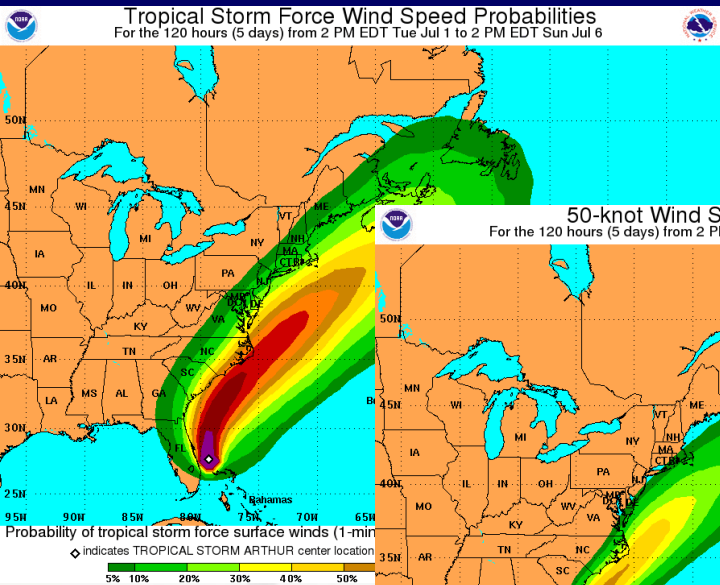
*NHC 5-Year Averages*

Intensity errors increase for the first 2-3 days and then level off.



# Wind Speed Probabilities

## *How Likely. Arrival Times. Inland Threat*



Graphics depicts location-specific cumulative probabilities of tropical-storm-force, 58 mph, and hurricane-force winds.

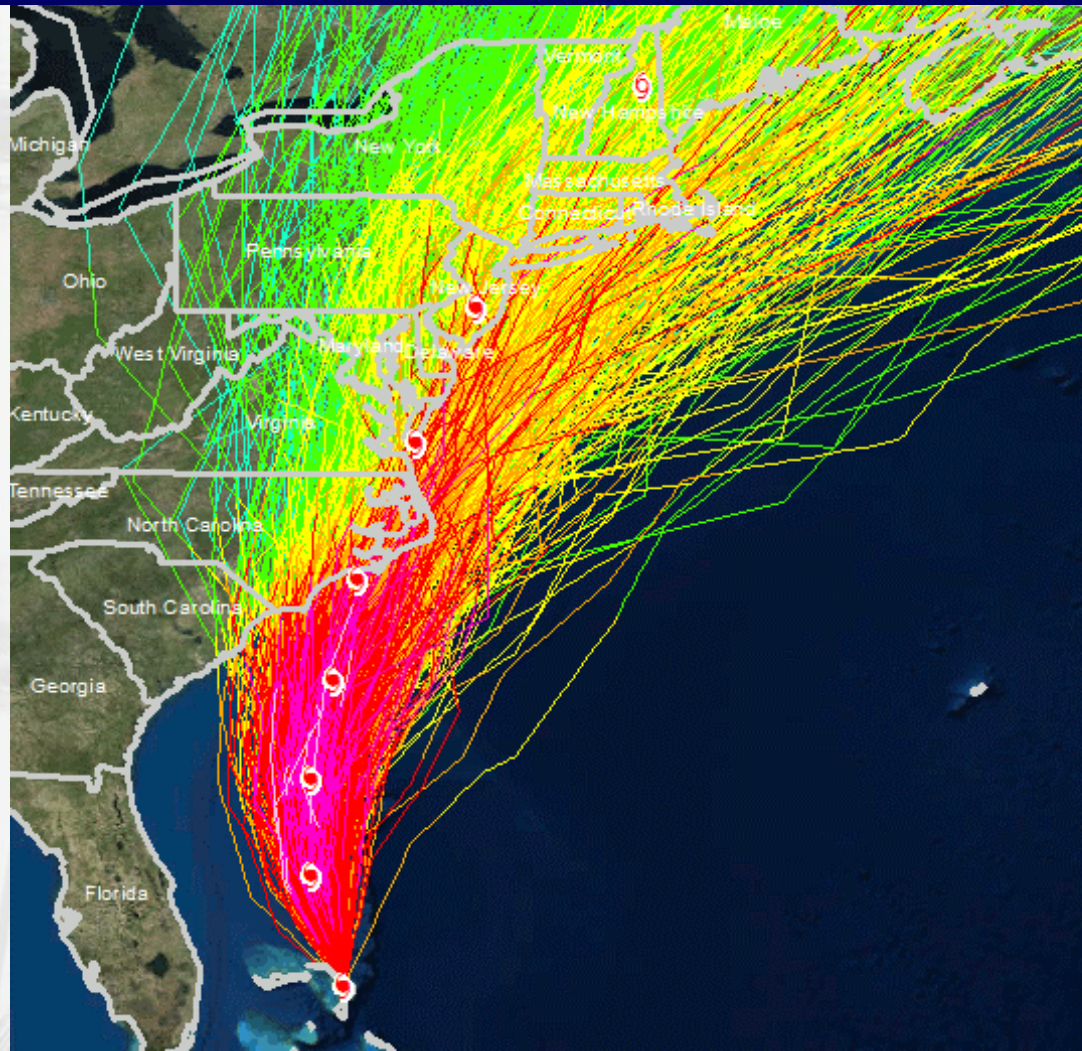


# Wind Speed Probabilities

*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***

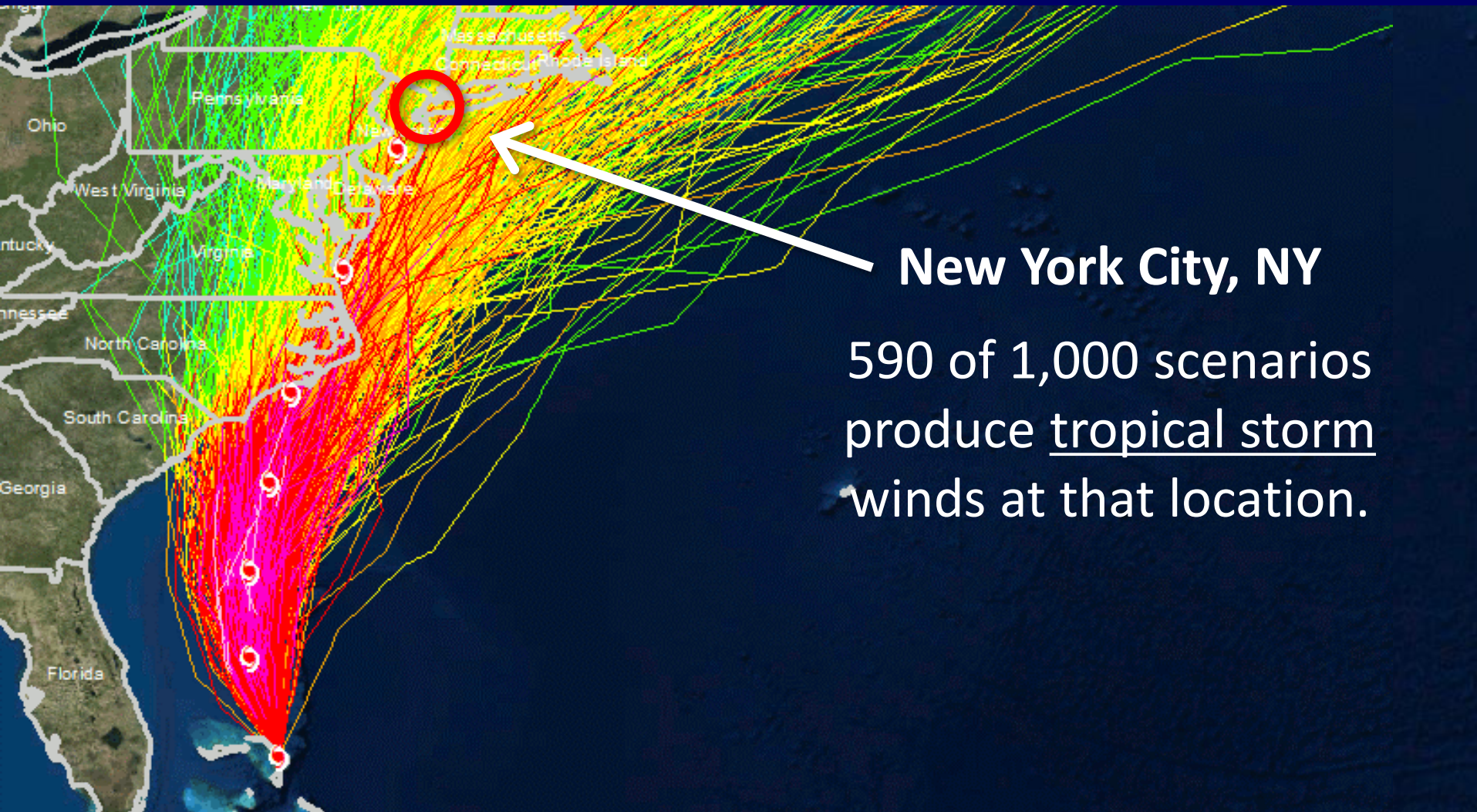
Past NHC track forecast errors are correlated to the spread of track model guidance





# Wind Speed Probabilities

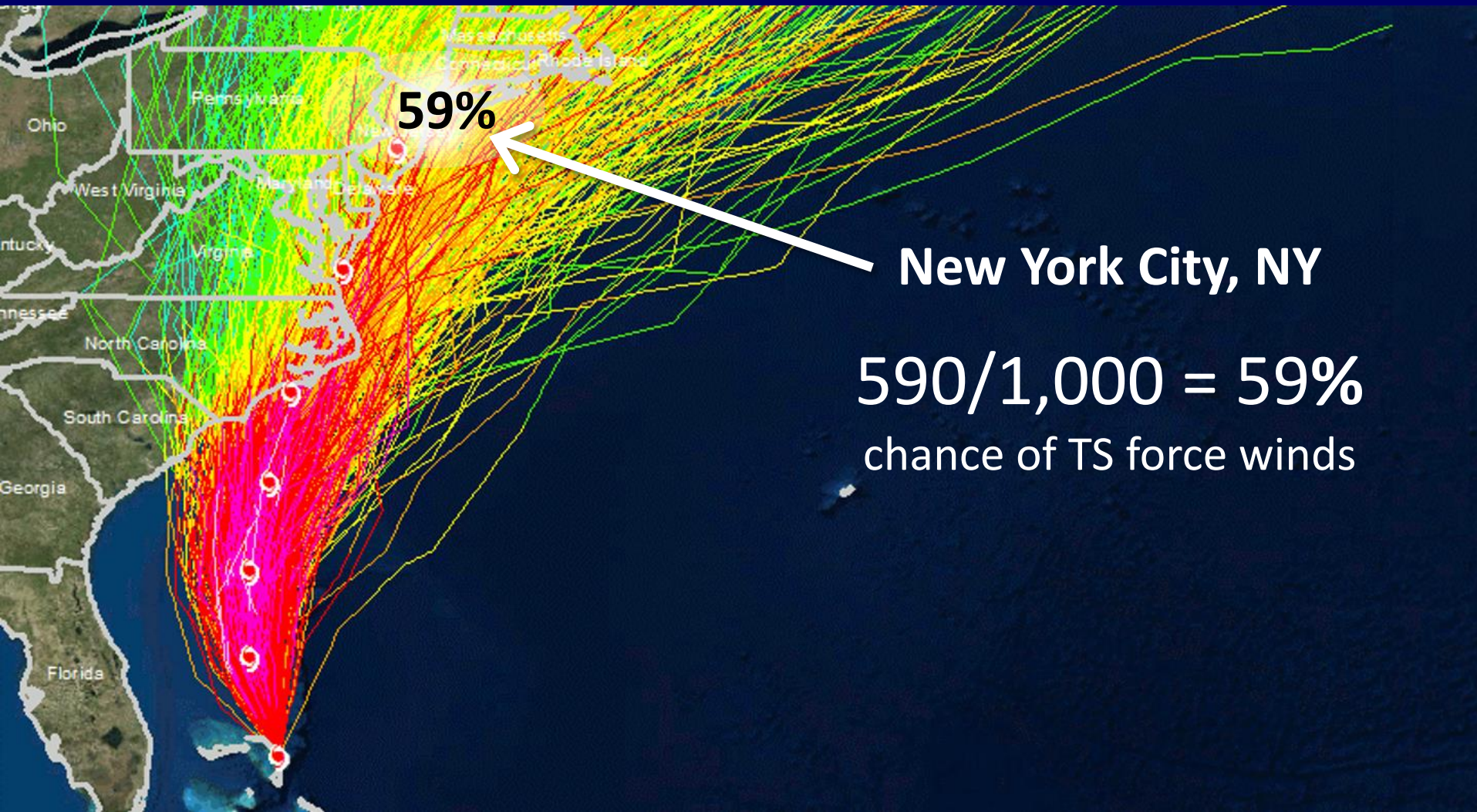
*How are they generated?*





# Wind Speed Probabilities

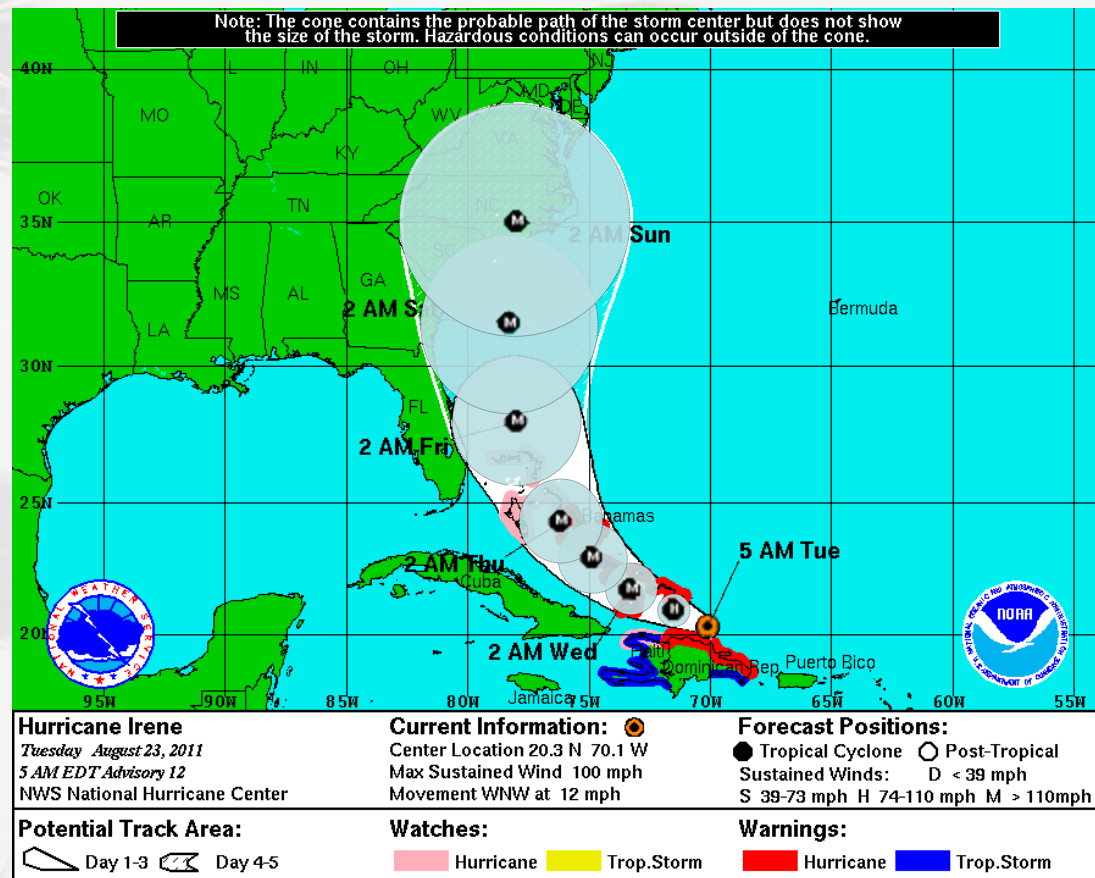
*How are they generated?*



# NHC Forecast Cone

*The cure for the skinny black line?*

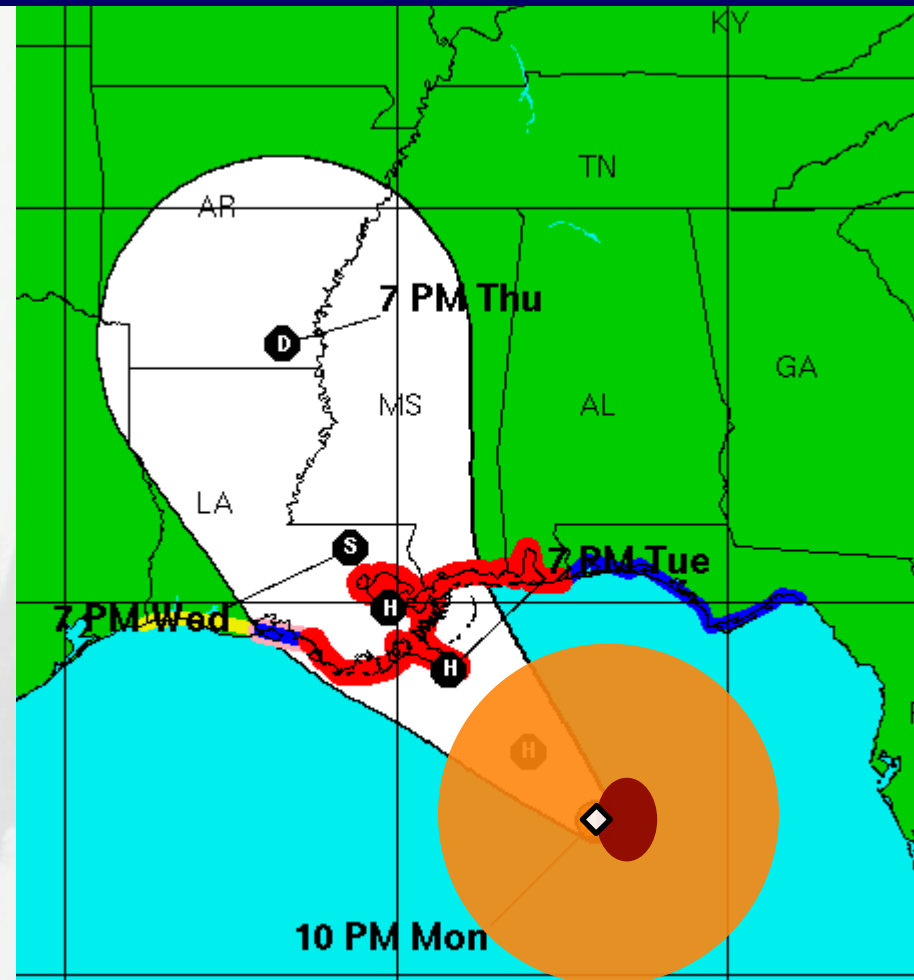
- Represents probable track of tropical cyclone center
- Formed by connecting circles centered on each forecast point
- The size of each circle is created using NHC track errors, so that the actual storm position will be within the circle 67% of the time.



# NHC Forecast Cone

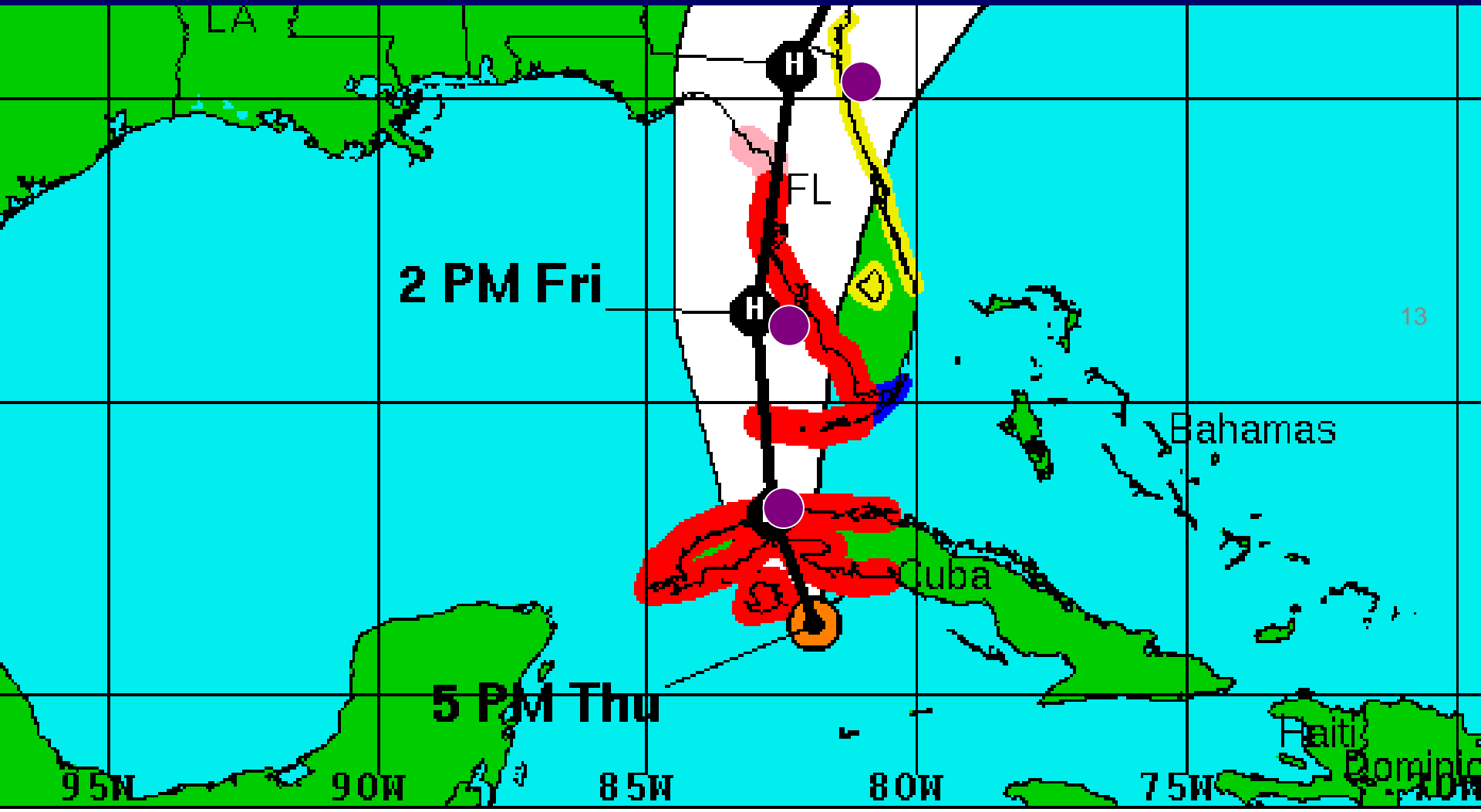
*No worries, not in the cone?*

- 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



# Hurricane Charley

*Don't focus on the skinny black line.*

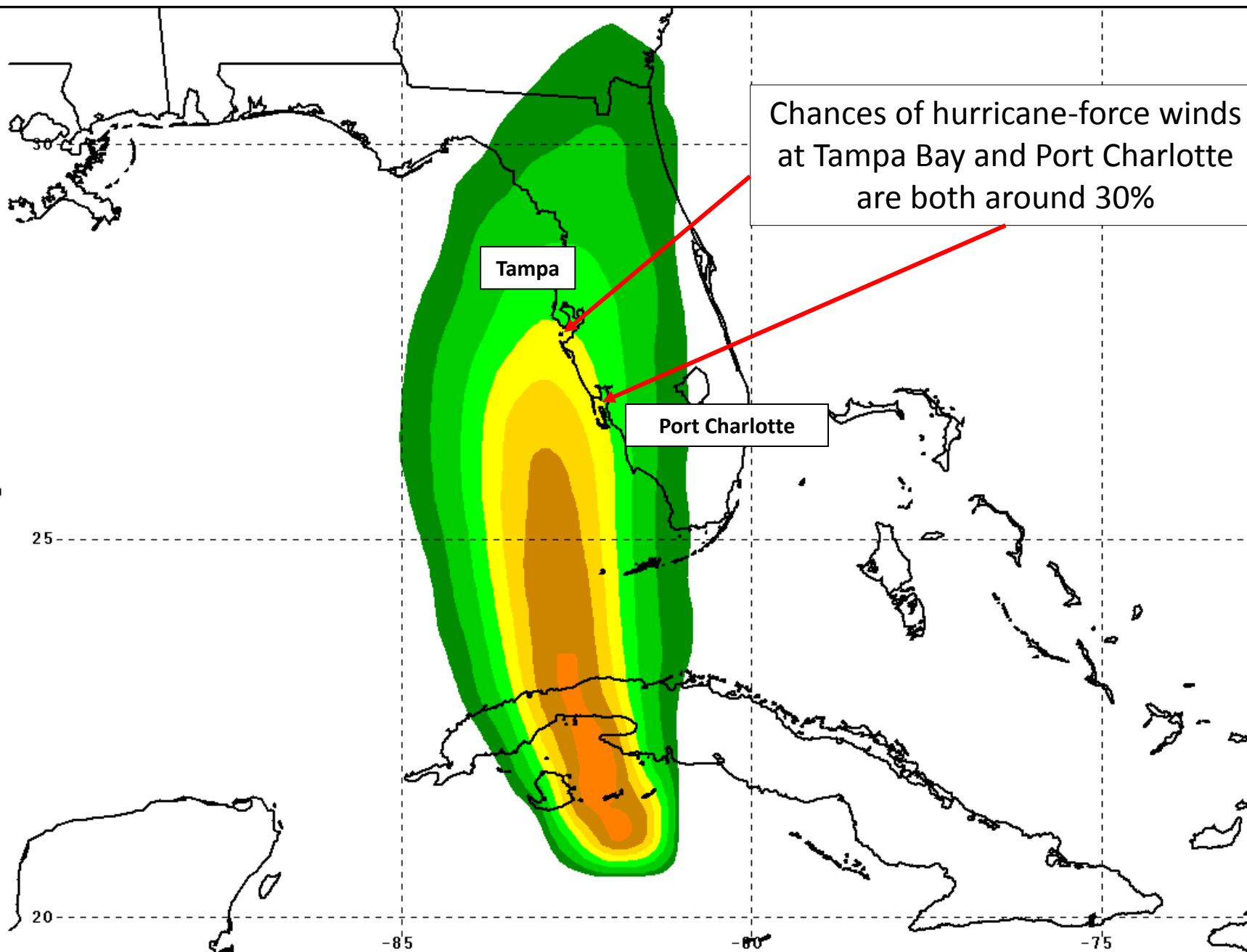




# Hurricane Charley

*Would alternate scenarios help?*





HURRICANE CHARLEY 64-KT WIND PROBABILITIES FOR 5 DAYS ENDING 12 UTC 17 AUGUST 2004

# Wind Speed Probabilities

*How Likely. Arrival Times. Inland Threat*

- **Location-specific probabilities**

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

- **Text product**  
(fixed set of locations)

- Cumulative probabilities
- Onset probabilities

PANAMA CITY FL	34	1	11(12)	20(32)	13(45)	7(52)	1(53)	1(54)
PANAMA CITY FL	50	X	X( X)	3( 3)	4( 7)	3(10)	1(11)	X(11)
PANAMA CITY FL	64	X	X( X)	X( X)	1( 1)	1( 2)	X( 2)	X( 2)

COLUMBUS GA	34	X	X( X)	3( 3)	6( 9)	11(20)	2(22)	1(23)
-------------	----	---	-------	-------	-------	--------	-------	-------

MONTGOMERY AL	34	X	X( X)	7( 7)	10(17)	18(35)	3(38)	1(39)
MONTGOMERY AL	50	X	X( X)	X( X)	X( X)	5( 5)	2( 7)	X( 7)
MONTGOMERY AL	64	X	X( X)	X( X)	X( X)	1( 1)	1( 2)	X( 2)

PENSACOLA FL	34	X	6( 6)	24(30)	25(55)	14(69)	2(71)	X(71)
PENSACOLA FL	50	X	X( X)	2( 2)	14(16)	12(28)	1(29)	1(30)
PENSACOLA FL	64	X	X( X)	X( X)	4( 4)	5( 9)	2(11)	X(11)

GFMX 290N 870W	34	2	19(21)	45(66)	14(80)	3(83)	1(84)	X(84)
GFMX 290N 870W	50	X	1( 1)	24(25)	18(43)	3(46)	1(47)	X(47)
GFMX 290N 870W	64	X	X( X)	5( 5)	10(15)	3(18)	1(19)	X(19)

MOBILE AL	34	X	3( 3)	22(25)	31(56)	20(76)	2(78)	X(78)
MOBILE AL	50	X	X( X)	2( 2)	15(17)	21(38)	2(40)	X(40)
MOBILE AL	64	X	X( X)	X( X)	3( 3)	12(15)	1(16)	X(16)

GULFPORT MS	34	X	3( 3)	22(25)	33(58)	21(79)	2(81)	X(81)
GULFPORT MS	50	X	X( X)	2( 2)	19(21)	22(43)	2(45)	X(45)
GULFPORT MS	64	X	X( X)	X( X)	5( 5)	13(18)	2(20)	X(20)

STENNIS SC	34	X	2( 2)	19(21)	32(53)	23(76)	3(79)	1(80)
STENNIS SC	50	X	X( X)	1( 1)	15(16)	22(38)	2(40)	X(40)
STENNIS SC	64	X	X( X)	X( X)	4( 4)	12(16)	1(17)	X(17)

BURAS LA	34	X	5( 5)	29(34)	33(67)	14(81)	2(83)	1(84)
BURAS LA	50	X	X( X)	5( 5)	25(30)	15(45)	2(47)	X(47)
BURAS LA	64	X	X( X)	1( 1)	8( 9)	11(20)	1(21)	X(21)

GFMX 280N 890W	34	X	13(13)	47(60)	18(78)	5(83)	1(84)	X(84)
GFMX 280N 890W	50	X	X( X)	23(23)	19(42)	5(47)	1(48)	X(48)
GFMX 280N 890W	64	X	X( X)	5( 5)	12(17)	4(21)	X(21)	1(22)

JACKSON MS	34	X	X( X)	3( 3)	11(14)	33(47)	6(53)	1(54)
JACKSON MS	50	X	X( X)	X( X)	X( X)	12(12)	4(16)	X(16)

# Wind Speed Probabilities

*How Likely. Arrival Times. Inland Threat*

- **Location-specific probabilities**

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

- **Text product**  
(fixed set of locations)

- Cumulative probabilities
- Onset probabilities

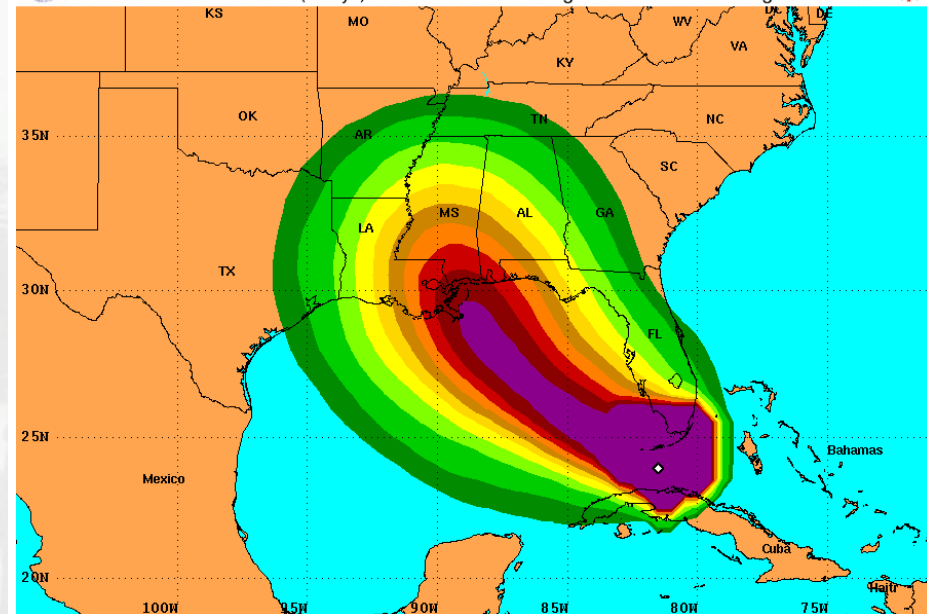
- **Graphical product**

- Cumulative probabilities for points over a large domain

PANAMA CITY FL	34	1	11(12)	20(32)	13(45)	7(52)	1(53)	1(54)
PANAMA CITY FL	50	X	X( X)	3( 3)	4( 7)	3(10)	1(11)	X(11)
PANAMA CITY FL	64	X	X( X)	X( X)	1( 1)	1( 2)	X( 2)	X( 2)
COLUMBUS GA	34	X	X( X)	3( 3)	6( 9)	11(20)	2(22)	1(23)
MONTGOMERY AL	34	X	X( X)	7( 7)	10(17)	18(35)	3(38)	1(39)
MONTGOMERY AL	50	X	X( X)	X( X)	X( X)	5( 5)	2( 7)	X( 7)
MONTGOMERY AL	64	X	X( X)	X( X)	X( X)	1( 1)	1( 2)	X( 2)
PENSACOLA FL	34	X	6( 6)	24(30)	25(55)	14(69)	2(71)	X(71)



**Tropical Storm Force Wind Speed Probabilities**  
For the 120 hours (5 days) from 2 PM EDT Sun Aug 26 to 2 PM EDT Fri Aug 31





Probability of tropical storm force surface winds (1-minute average  $\geq 39$  mph) from all tropical cyclones

◇ indicates TROPICAL STORM ISAAC center location at 2 PM EDT Sun Aug 26 2012 (Forecast/Advisory #23)

5% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%


# Wind Speed Probabilities

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Most Extreme

**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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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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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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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 periods


# Wind Speed Probabilities

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

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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

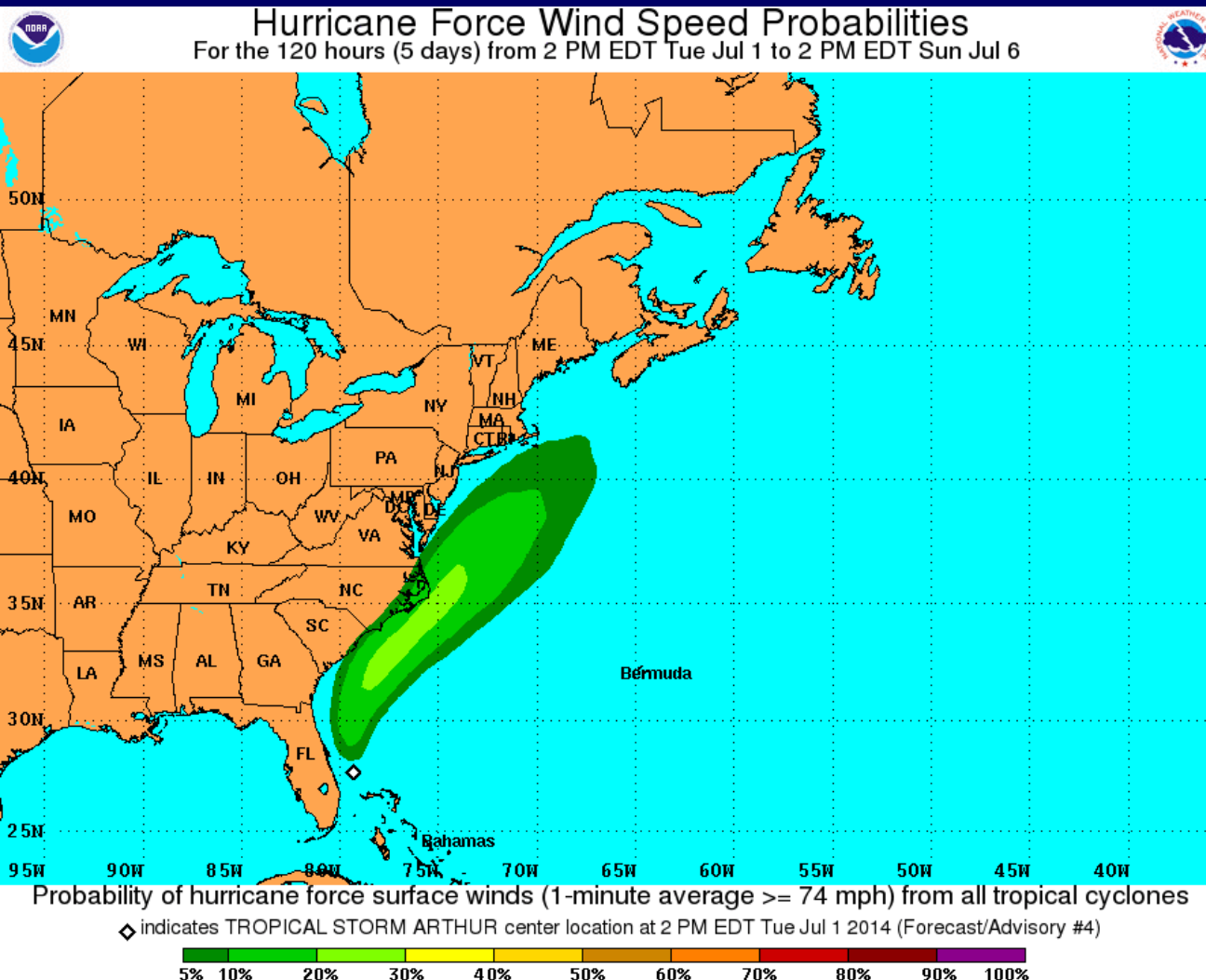
Onset probabilities

- Individual time period

Cumulative probabilities

# Wind Speed Probabilities

## *Graphical Product*



**Depicts location-specific probabilities**

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



# Wind Speed Probabilities

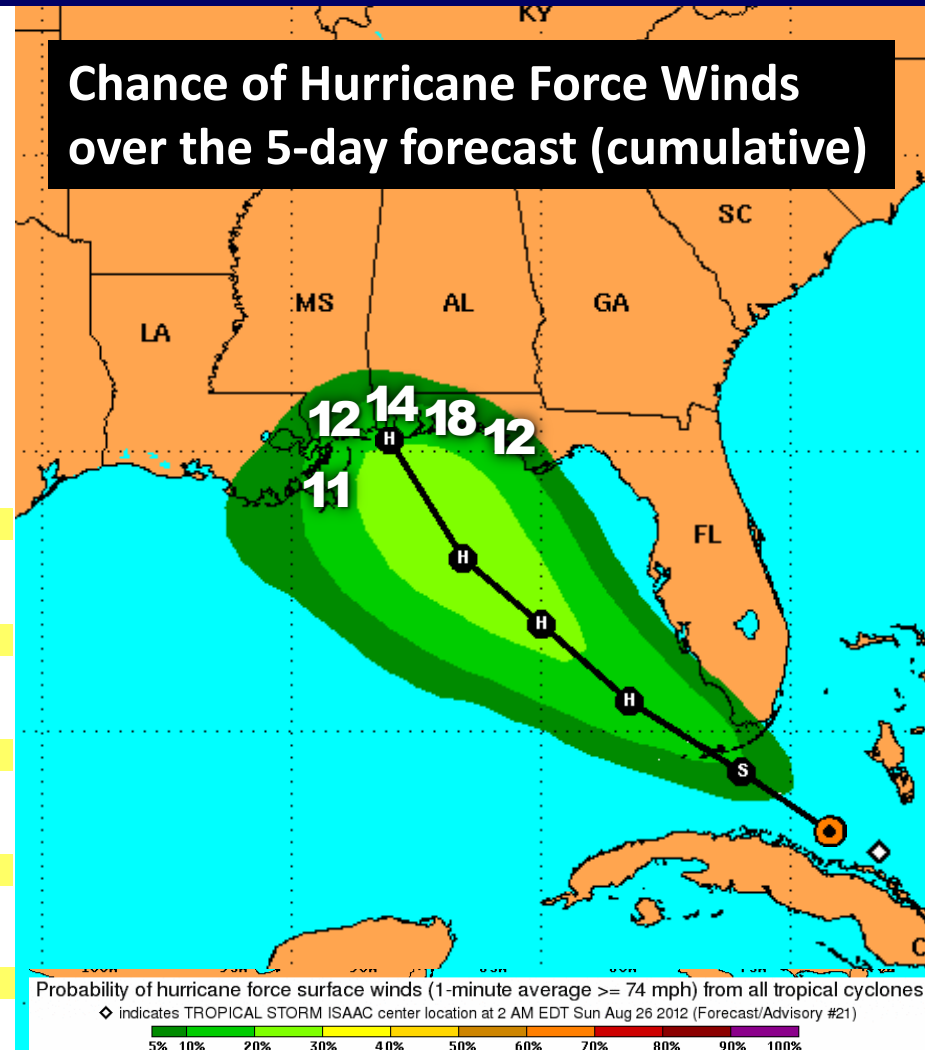
## Tropical Storm Isaac

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)
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)
GULFPORT MS 64	X	X ( X)	X ( X)	X ( X)	8 ( 8)	3 (11)	1 (12)
BURAS LA 34	X	X ( X)	4 ( 4)	19 (23)	31 (54)	7 (61)	1 (62)
BURAS LA 50	X	X ( X)	X ( X)	2 ( 2)	18 (20)	6 (26)	1 (27)
BURAS LA 64	X	X ( X)	X ( X)	X ( X)	7 ( 7)	4 (11)	X (11)

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



# Wind Speed Probabilities

## *Tropical Storm Isaac*

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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)
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GULFPORT MS 64	X	X ( X)	X ( X)	X ( X)	2 ( 2)	2 (11)	1 (12)

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

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

← Tropical Storm  
(34kt)

# Wind Speed Probabilities

## Tropical Storm Isaac

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--------------	-------------------------	-------------------------	-------------------------	-------------------------	-------------------------	-------------------------	-------------------------

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)
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GULFPORT MS 64	X	X ( X)	X ( X)	X ( X)	2 ( 2)	2 (11)	1 (12)

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  
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LOCATION	KT							
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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*

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FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
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LOCATION	KT
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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  
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LOCATION	KT
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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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LOCATION	KT						
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GULFPORT MS 64	X	X ( X)	X ( X)	X ( X)	2 ( 2)	2 (11)	1 (12)

**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**

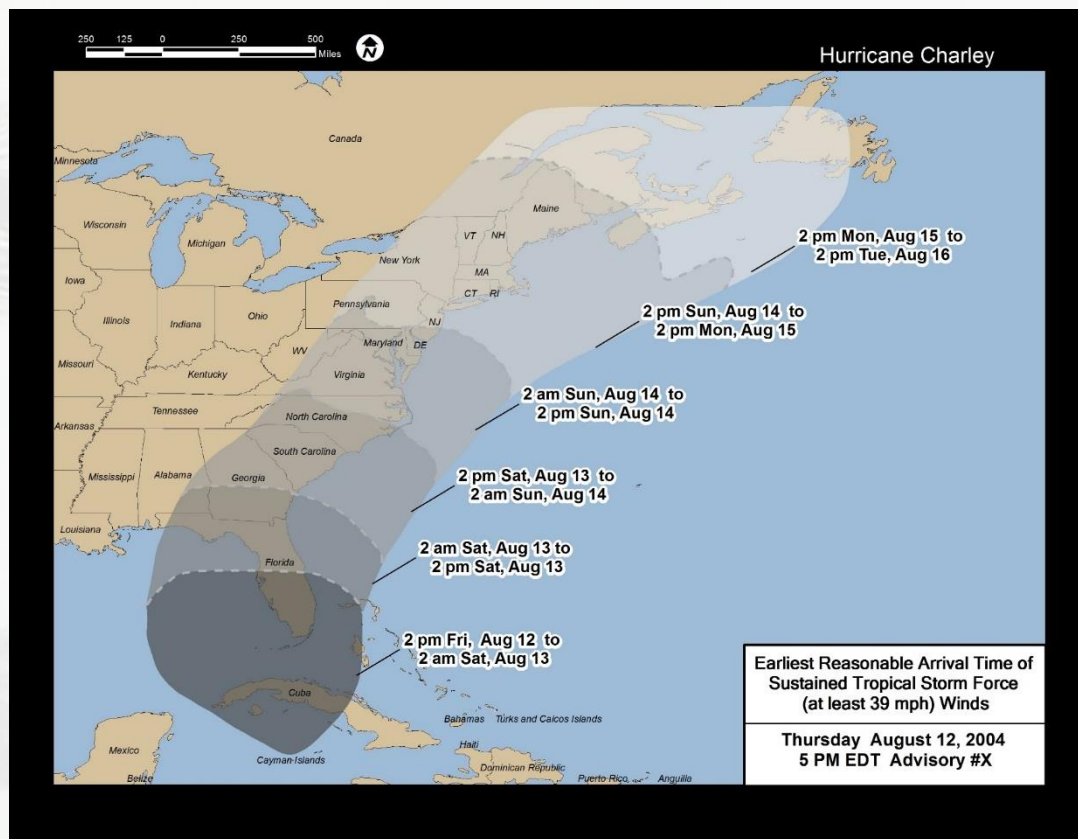
Tropical Storm winds begin during the period between **2am Tue to 2am Wed (24 hr)**

# Summary

- Wind speed probability products can 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
  - Likelihood of tropical cyclone intensity
- “Low” probabilities of extreme events often warrant action!

# Prototype Time of Arrival Graphic

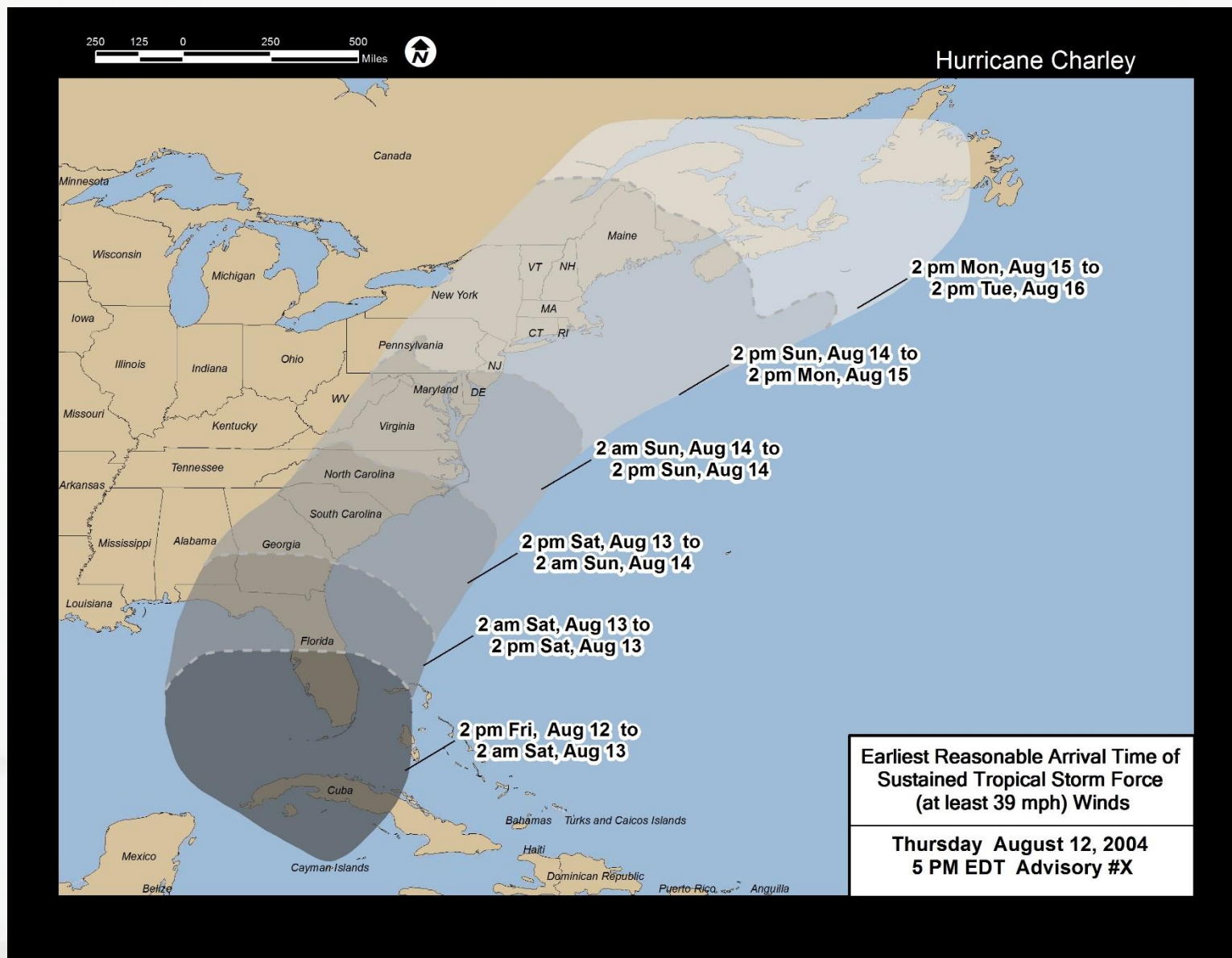
- Uses timing information from the same realizations used to create the NHC wind speed probability products
- Accounts for forecast uncertainty
- Provides graphical depiction of potential arrival times of tropical-storm-force winds



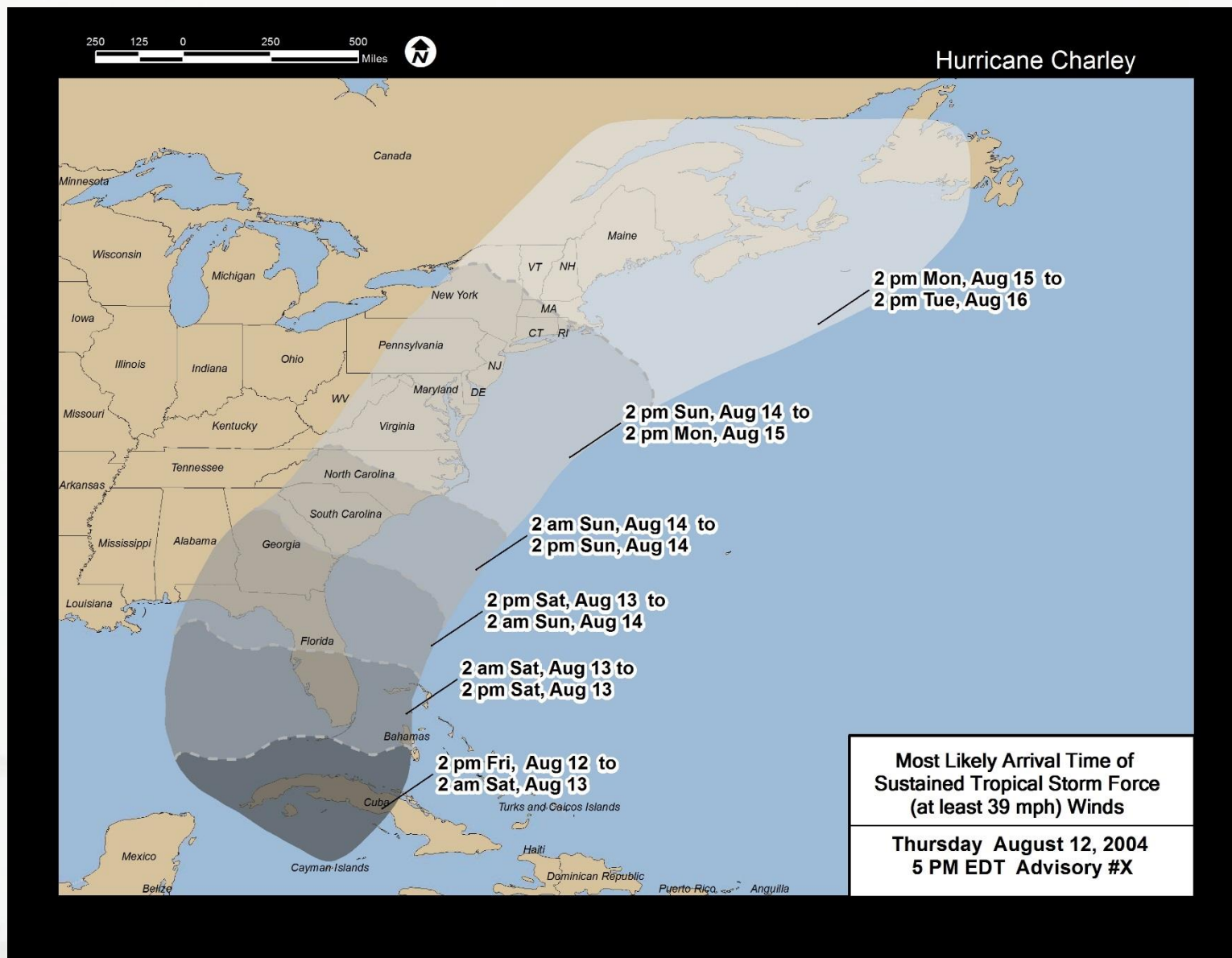


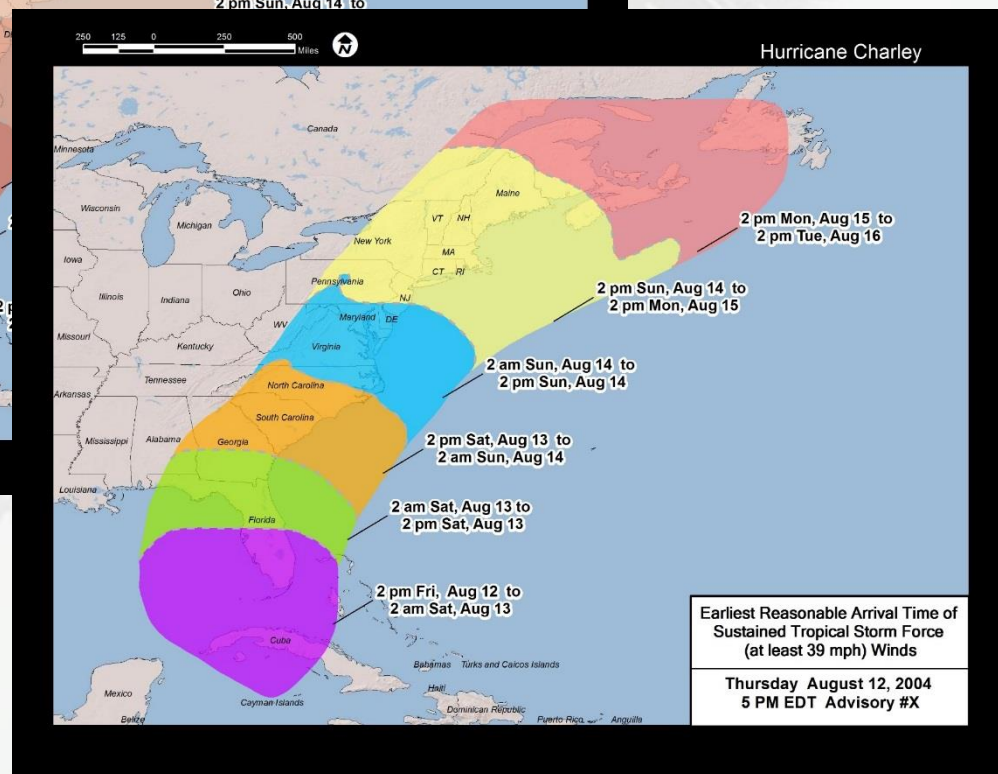
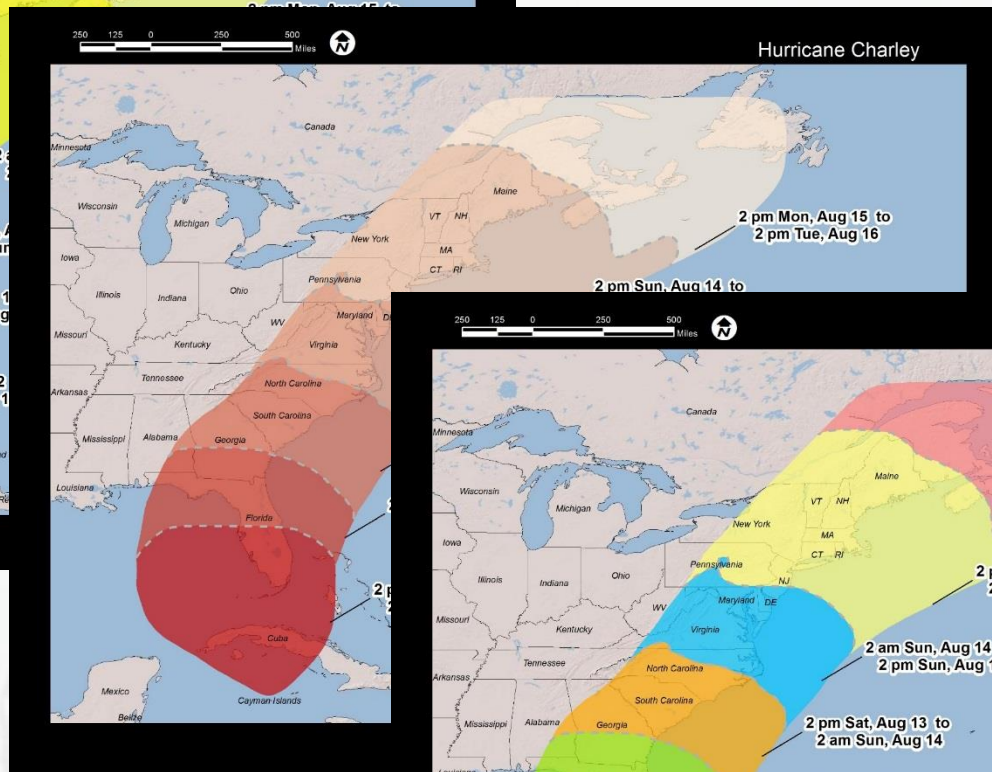
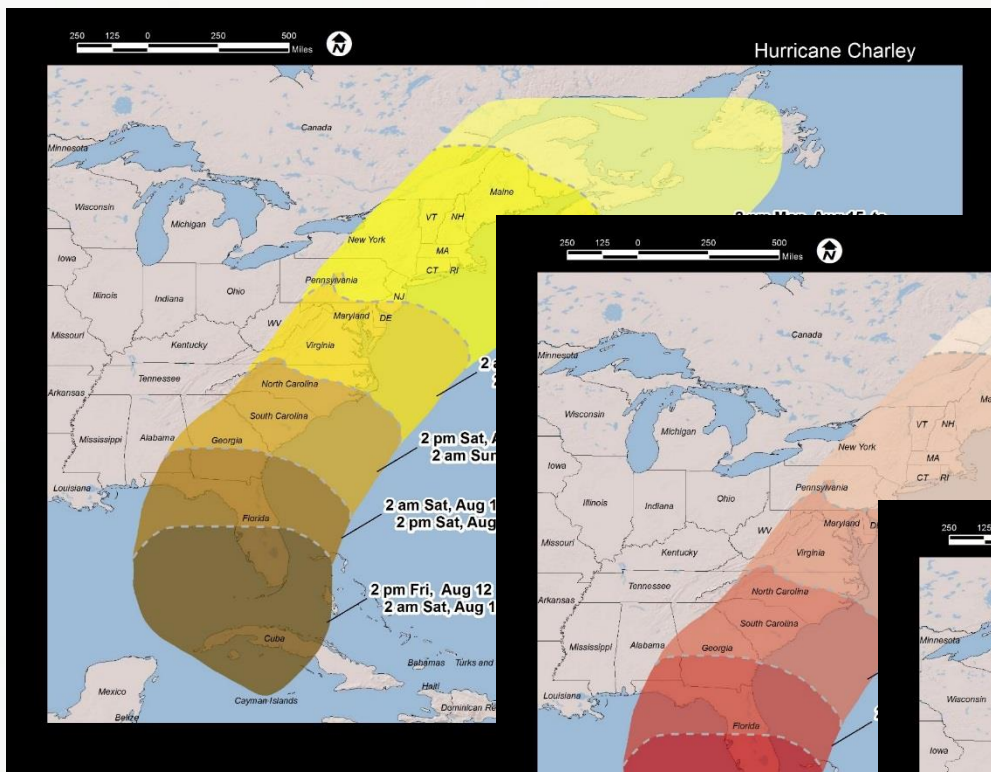


# Earliest Reasonable Arrival Time (10%)



# Most Likely Arrival Time (50%)





**Thanks!!!**

**Questions/Comments**



# Wind Speed Probabilities

## *Hurricane Katrina*

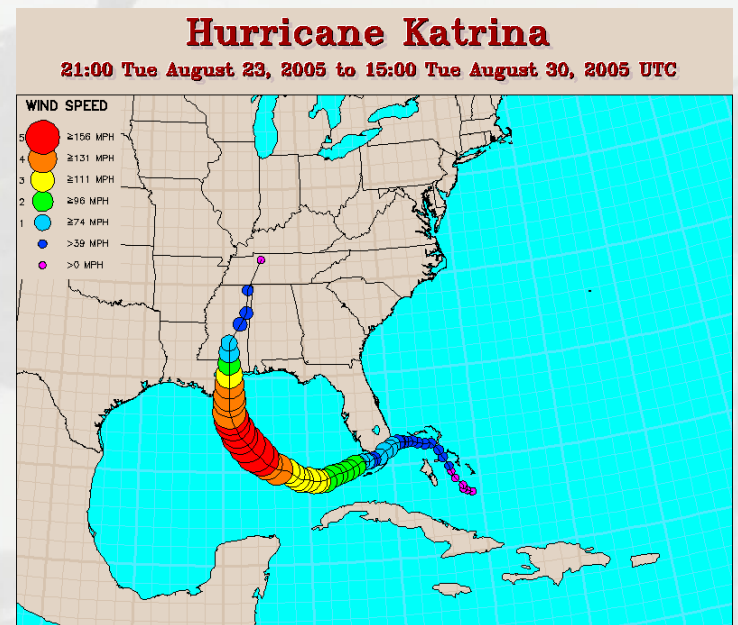
### Landfall of a marginal hurricane in South Florida

- Low probabilities of hurricane force winds



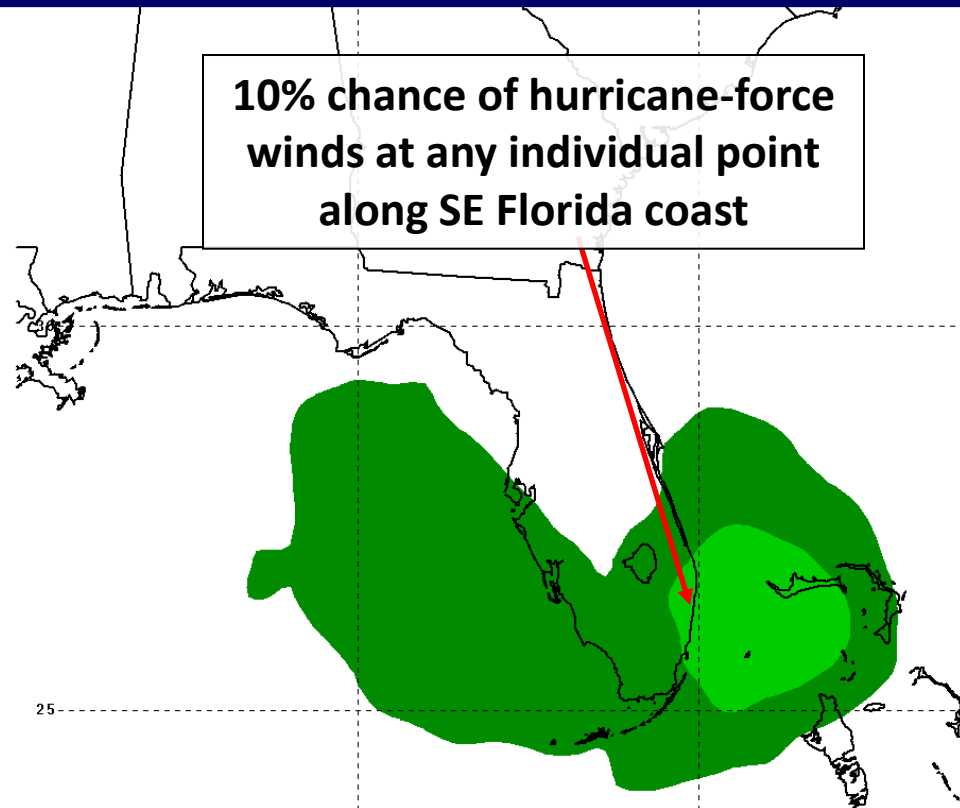
### Landfall of a major hurricane along the Gulf Coast

- Increasing probabilities along the forecast as landfall approaches



# Wind Speed Probabilities

## *Hurricane Katrina – Adv #5*



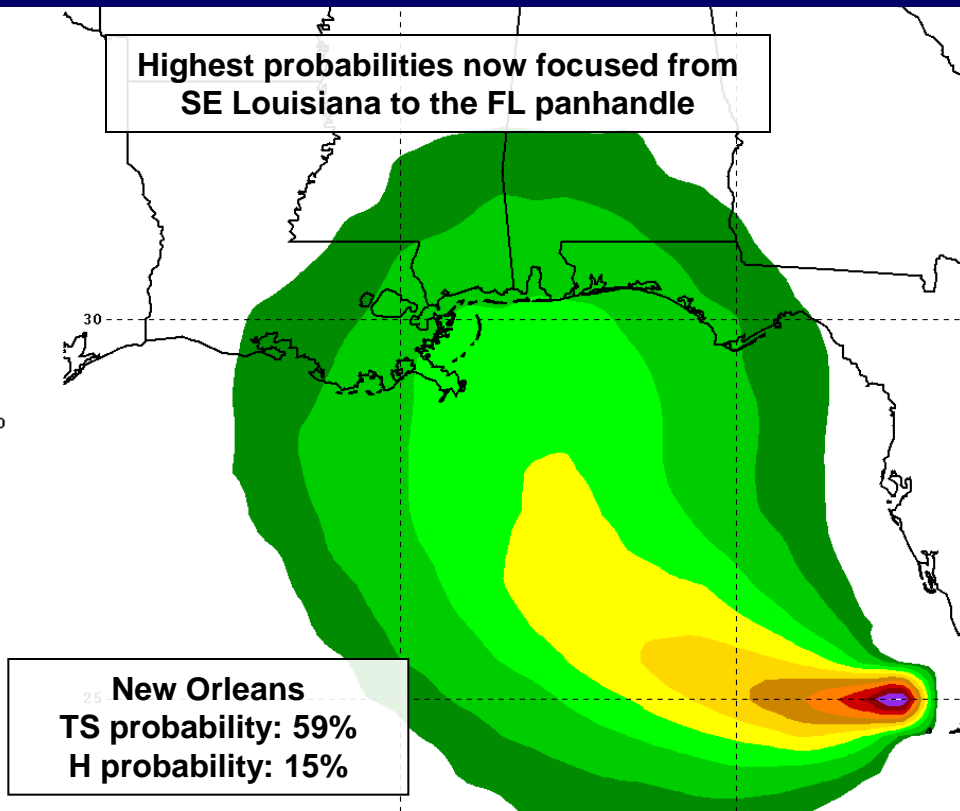
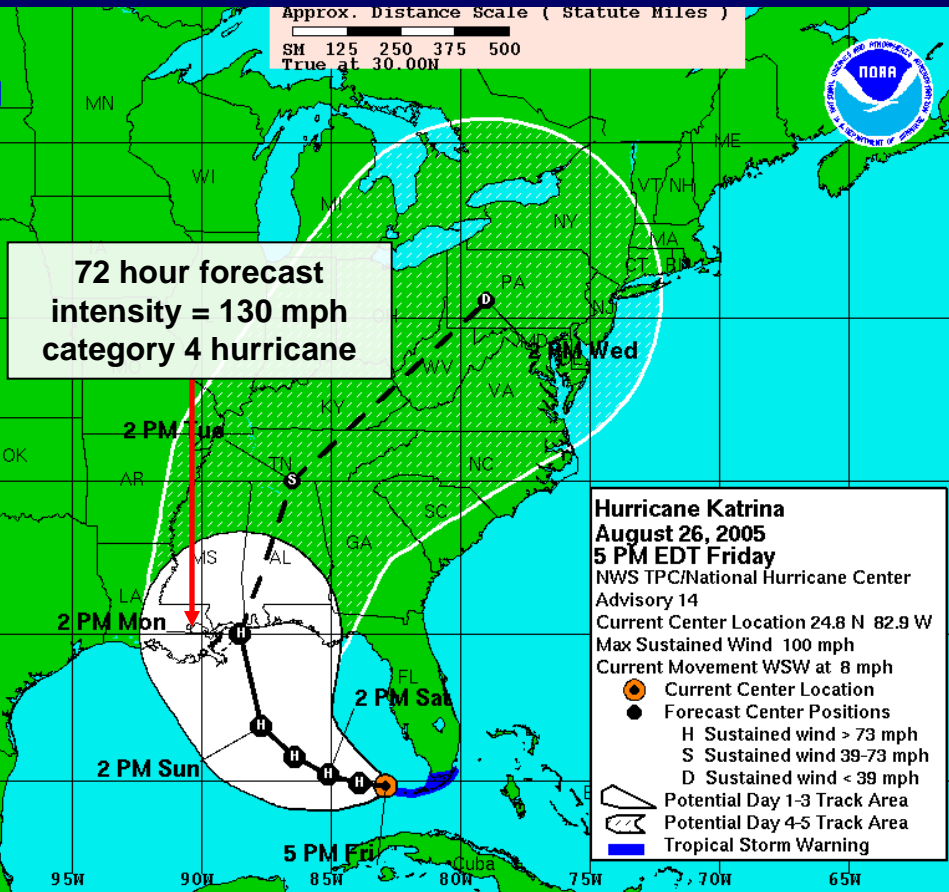
### Low Probability

Uncertainty if Katrina will be a hurricane and the small size of hurricane wind field



# Wind Speed Probabilities

## Hurricane Katrina – Adv #14

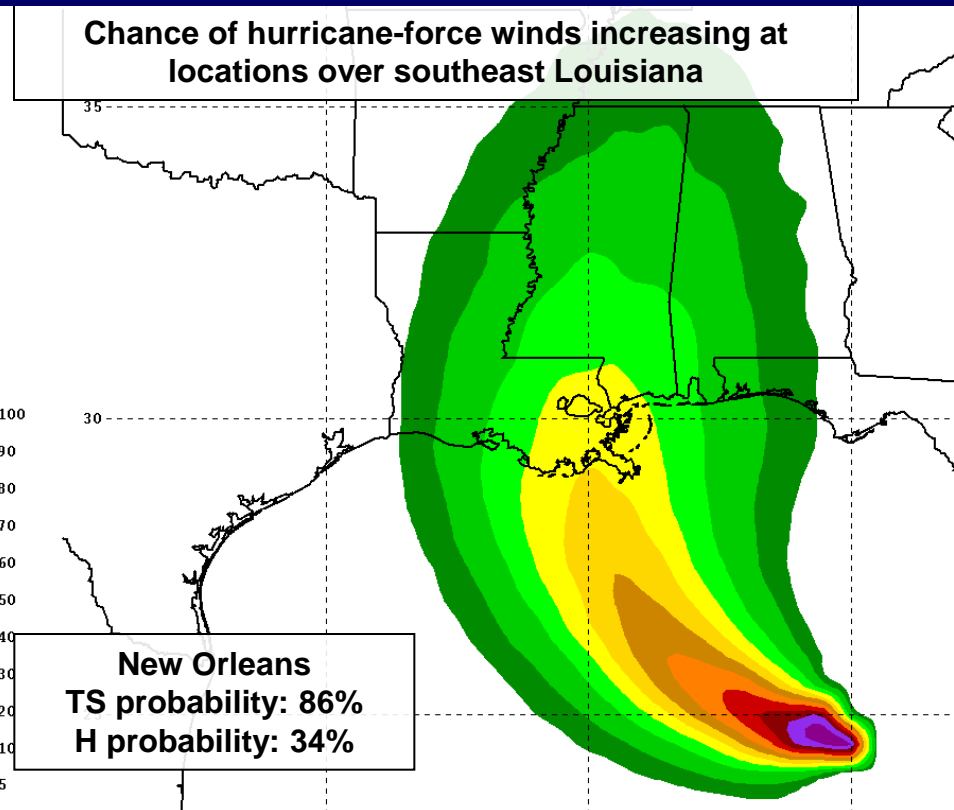
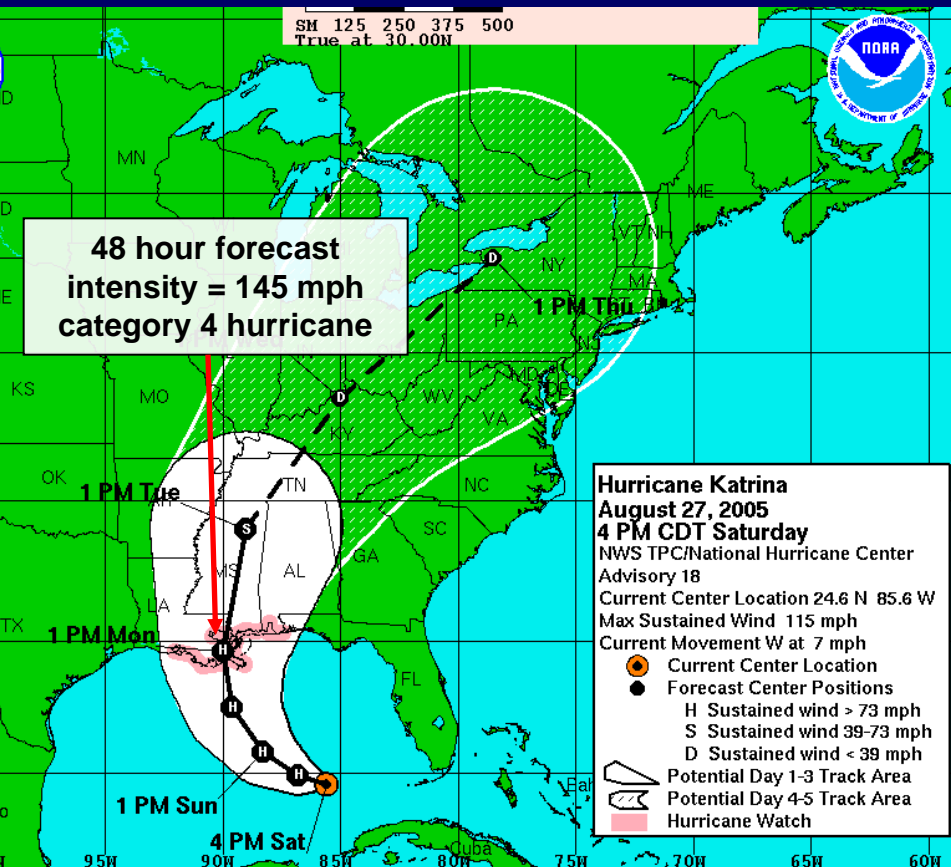


### Increasing Probabilities

Increasing intensity forecast and decrease in track forecast uncertainty

# Wind Speed Probabilities

## *Hurricane Katrina – Adv #18*



### High Probability

Increasing intensity forecast and greater track certainty – 48hr until landfall