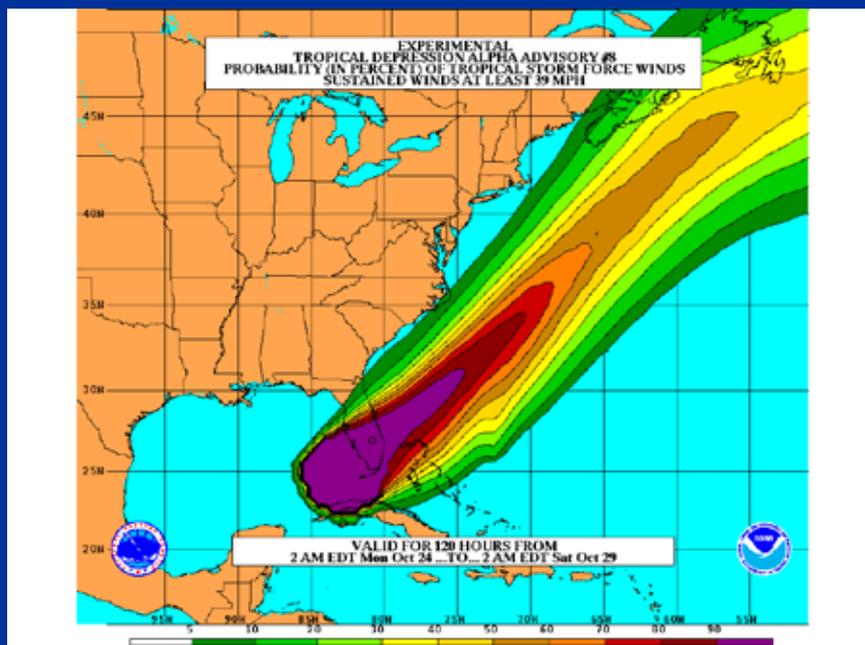


Progress Toward Operational Implementation of Tropical Cyclone Wind Speed Probability Products

IHC



22 March 2006

Richard Knabb, Edward Rappaport, Michelle Mainelli, James Franklin,
Chris Lauer, and Alison Krautkramer - **National Hurricane Center**

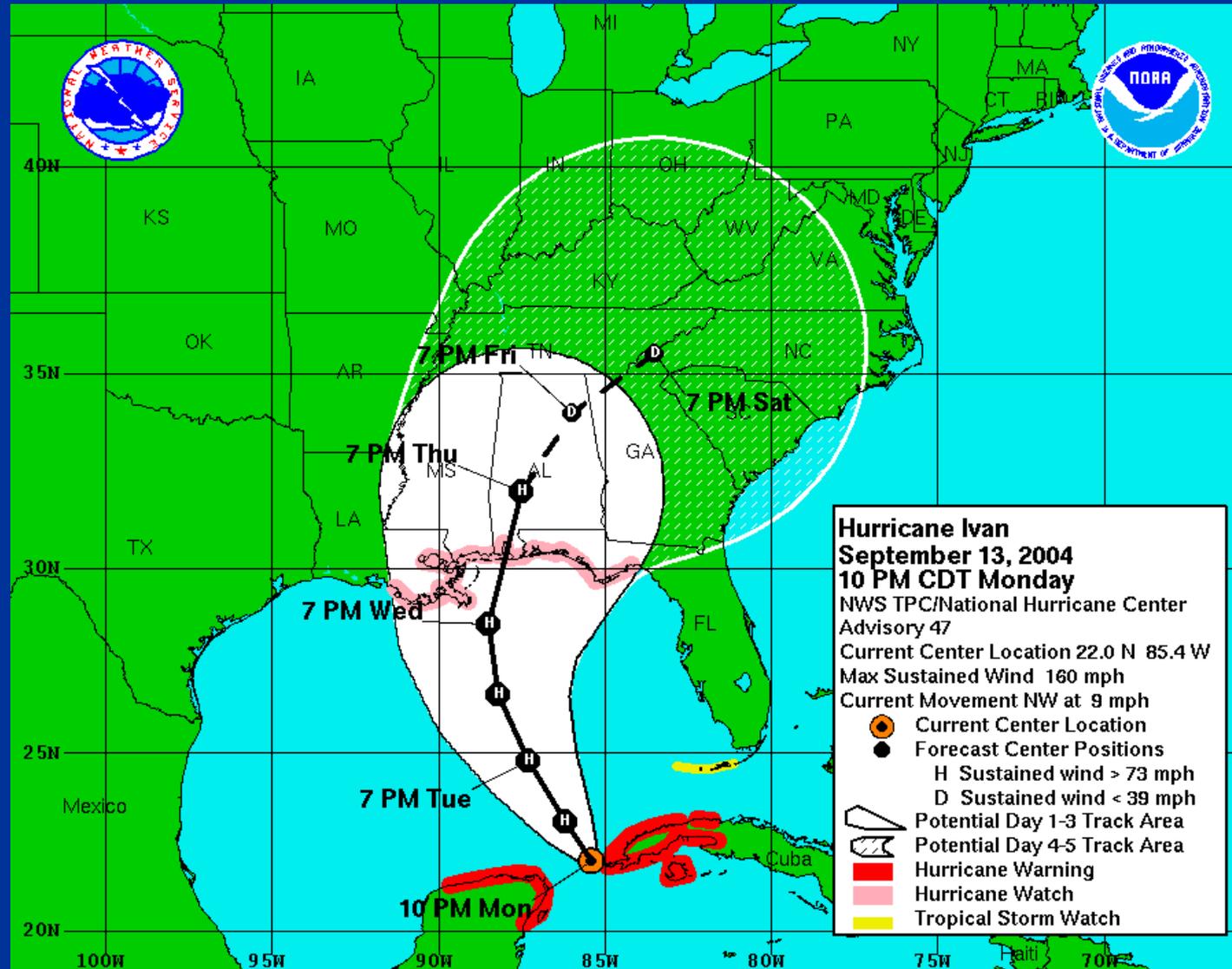
Scott Kiser and Tim Schott - **NWS Headquarters**

Mark DeMaria – **NESDIS** and John Knaff - **CIRA**

Existing TPC/NHC Products Used to Convey Uncertainty

Watch/
Warning
Graphic

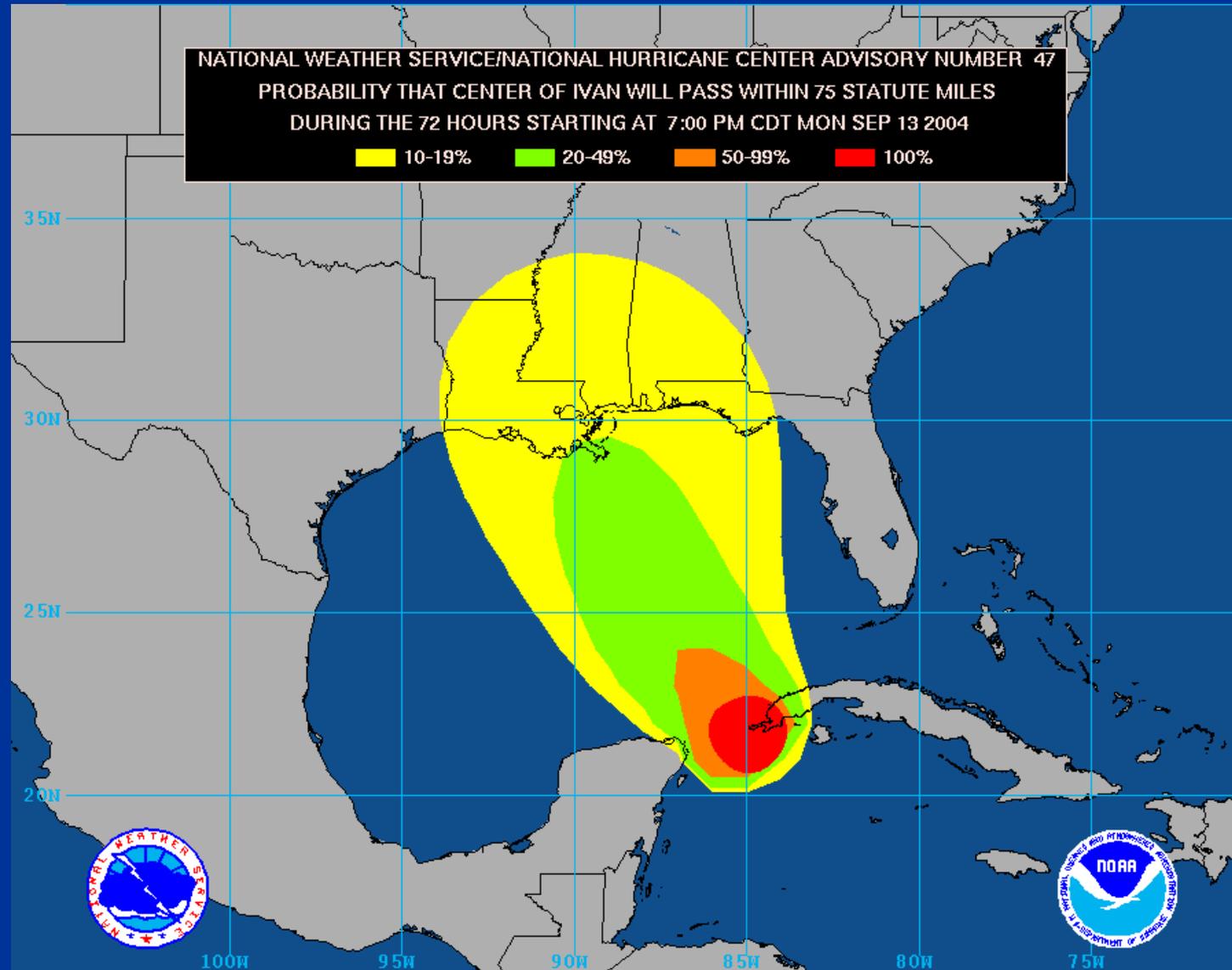
Indicates
forecast
track and
long-term
mean error



Existing TPC/NHC Products Used to Convey Uncertainty

Strike Probability Graphic

Indicates chances of a “close approach” of the center



Existing TPC/NHC Products Used to Convey Uncertainty

```

ZCZC MIASPPAT4 ALL
TTAA00 KNHC DDHMM
HURRICANE IVAN PROBABILITIES NUMBER 47
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL
11 PM EDT MON SEP 13 2004

PROBABILITIES FOR GUIDANCE IN HURRICANE PROTECTION
PLANNING BY GOVERNMENT AND DISASTER OFFICIALS

AT 11 PM EDT...0300Z...THE CENTER OF IVAN WAS LOCATED NEAR
LATITUDE 22.0 NORTH...LONGITUDE 85.4 WEST

CHANCES OF CENTER OF THE HURRICANE PASSING WITHIN 65 NAUTICAL MILES
OF LISTED LOCATIONS THROUGH 8PM EDT THU SEP 16 2004

LOCATION          A  B  C  D  E  LOCATION          A  B  C  D  E
24.8N 87.3W     40 X X X 40  PENSACOLA FL     X X 9 7 16
26.6N 88.2W     10 18 X 1 29  MOBILE AL        X 1 10 6 17
28.5N 88.5W     X 15 6 1 22  GULFPORT MS     X 1 12 5 18
MUAN 219N 850W  99 X X X 99  BURAS LA        X 7 11 2 20
FT PIERCE FL   X X X 2 2   NEW ORLEANS LA  X 3 12 3 18
COCOA BEACH FL X X X 3 3   NEW IBERIA LA   X 1 10 5 16
DAYTONA BEACH FL X X X 4 4   PORT ARTHUR TX  X X 4 6 10
JACKSONVILLE FL X X X 5 5   GALVESTON TX   X X 2 5 7
SAVANNAH GA   X X X 4 4   FREEPORT TX    X X 1 4 5
CHARLESTON SC X X X 2 2   PORT O CONNOR TX X X X 2 2
MARCO ISLAND FL X X 1 2 3   GULF 29N 85W   X 1 7 5 13
FT MYERS FL   X X 1 2 3   GULF 29N 87W   X 6 9 3 18
VENICE FL     X X 2 3 5   GULF 28N 89W   X 19 4 1 24
TAMPA FL     X X 1 5 6   GULF 28N 91W   X 11 6 2 19
CEDAR KEY FL  X X 1 6 7   GULF 28N 93W   X 2 5 4 11
ST MARKS FL   X X 2 8 10  GULF 28N 95W   X X 1 3 4
APALACHICOLA FL X X 5 7 12  GULF 27N 96W   X X X 2 2
PANAMA CITY FL X X 6 8 14

COLUMN DEFINITION  PROBABILITIES IN PERCENT
A IS PROBABILITY FROM NOW TO 8PM TUE
FOLLOWING ARE ADDITIONAL PROBABILITIES
B FROM 8PM TUE TO 8AM WED
C FROM 8AM WED TO 8PM WED
D FROM 8PM WED TO 8PM THU
E IS TOTAL PROBABILITY FROM NOW TO 8PM THU
X MEANS LESS THAN ONE PERCENT
    
```

Strike
Probability
Text
Product

Why a new probability product?

Need for improved means of conveying tropical cyclone forecast uncertainty to various types of users

- New product is about a *weather event* at any specific location
- Conveys chances of wind speeds of at least particular thresholds
 - 34 kt (tropical storm force)
 - 50 kt
 - 64 kt (hurricane force)
- Accounts for combined uncertainty in track, intensity, and size
- Extends to 5 days
- Includes inland locations
- Will replace strike probabilities in 2006

What are the new wind speed probability products?

- Text product (one per storm)
 - Atlantic (NHC)
 - Eastern Pacific (NHC)
 - Central Pacific (CPHC)
- Website graphics (basin-wide and storm-centered)
 - Atlantic (NHC)
 - Eastern Pacific (NHC)
 - Central Pacific (CPHC)
 - Western Pacific (CPHC)

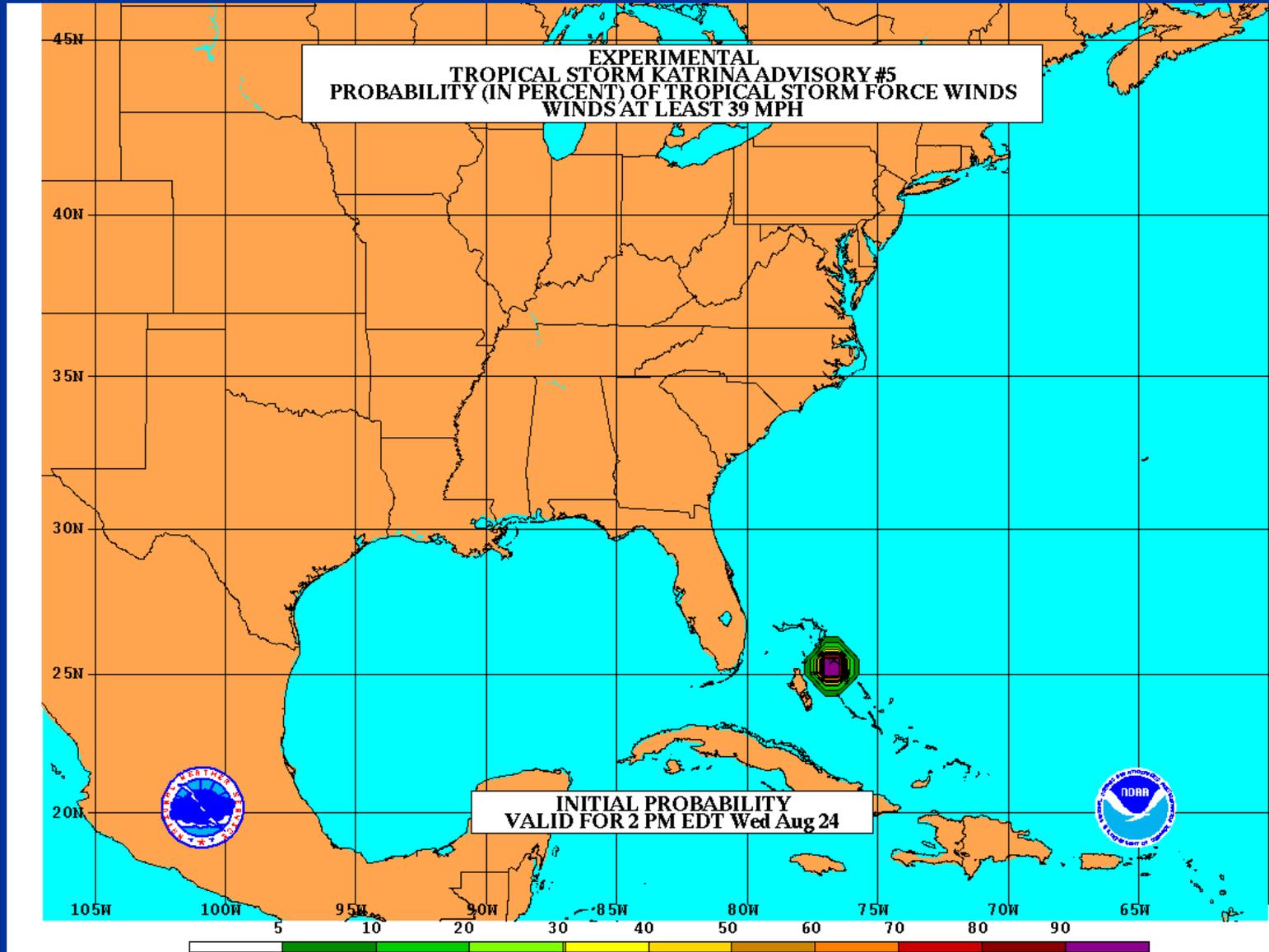
What do the new probability products tell you?

Answers to three main questions:

- **What are the chances this event is going to happen to me?**
 - *Do I need to prepare?*
 - **Cumulative** period probabilities
 - New graphics and text products from NHC and CPHC
- **When is the event most likely to start at my location?**
 - *How much time do I have left to prepare?*
 - **Individual** period probabilities
 - New text products from NHC and CPHC
- **What are the chances this event will be happening to me on a particular day (or part of a day)?**
 - *How long will the storm last? Will the weather be bad on Saturday?*
 - **Incremental** probabilities
 - Potential **future** products from local NWS Forecast Offices

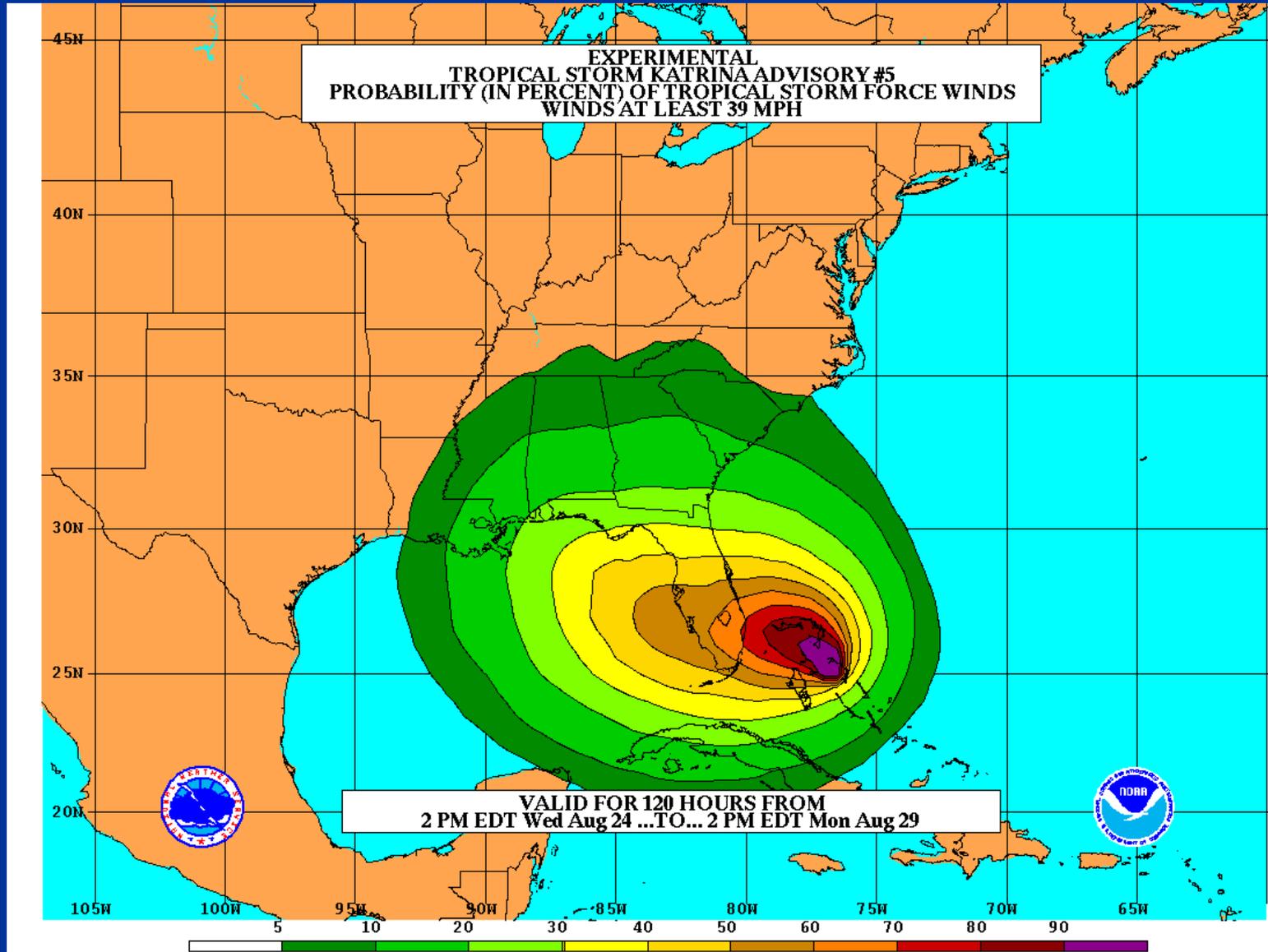
NHC Website Probability Graphics

34 kt
example



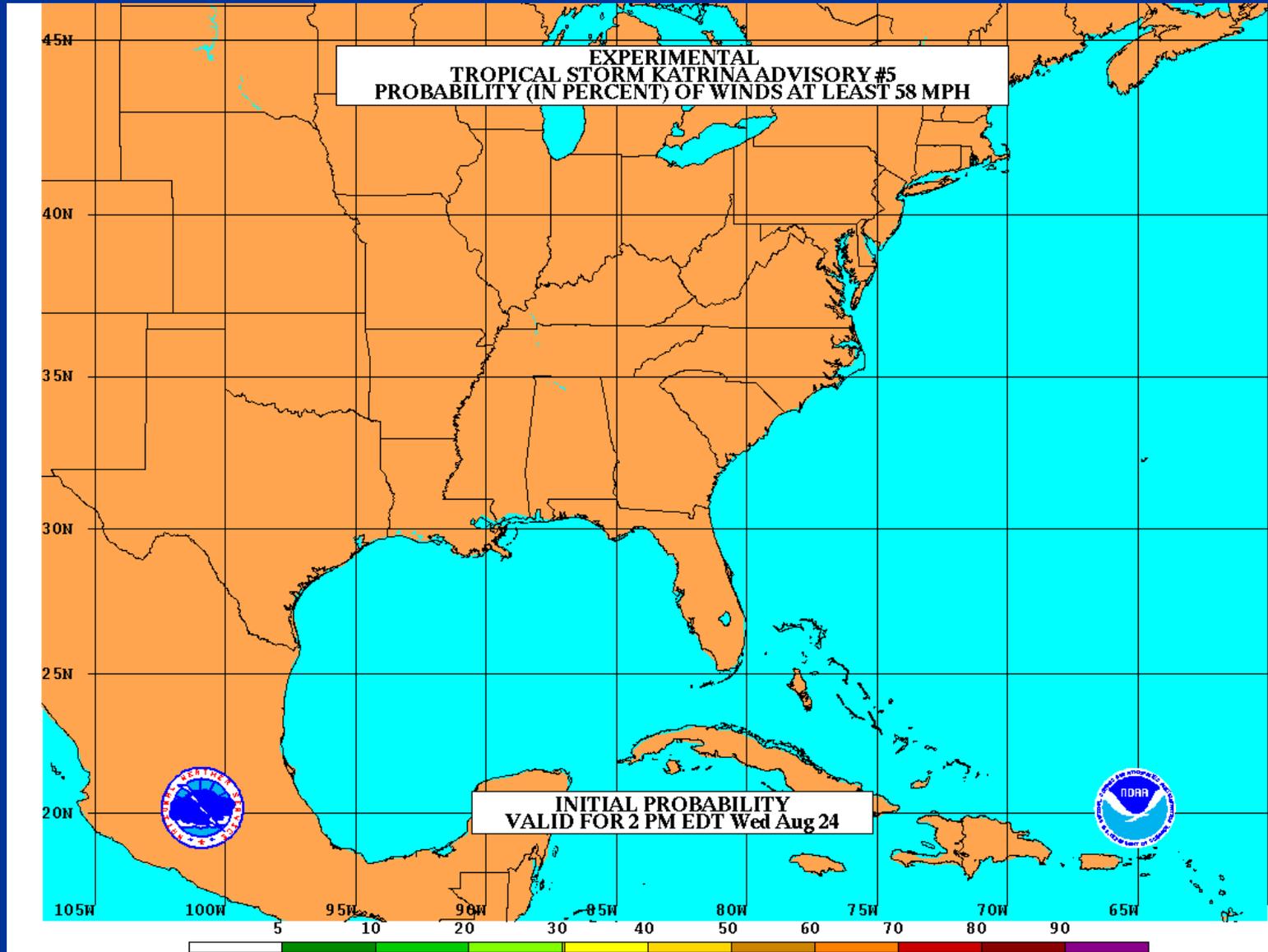
NHC Website Probability Graphics

34 kt
example



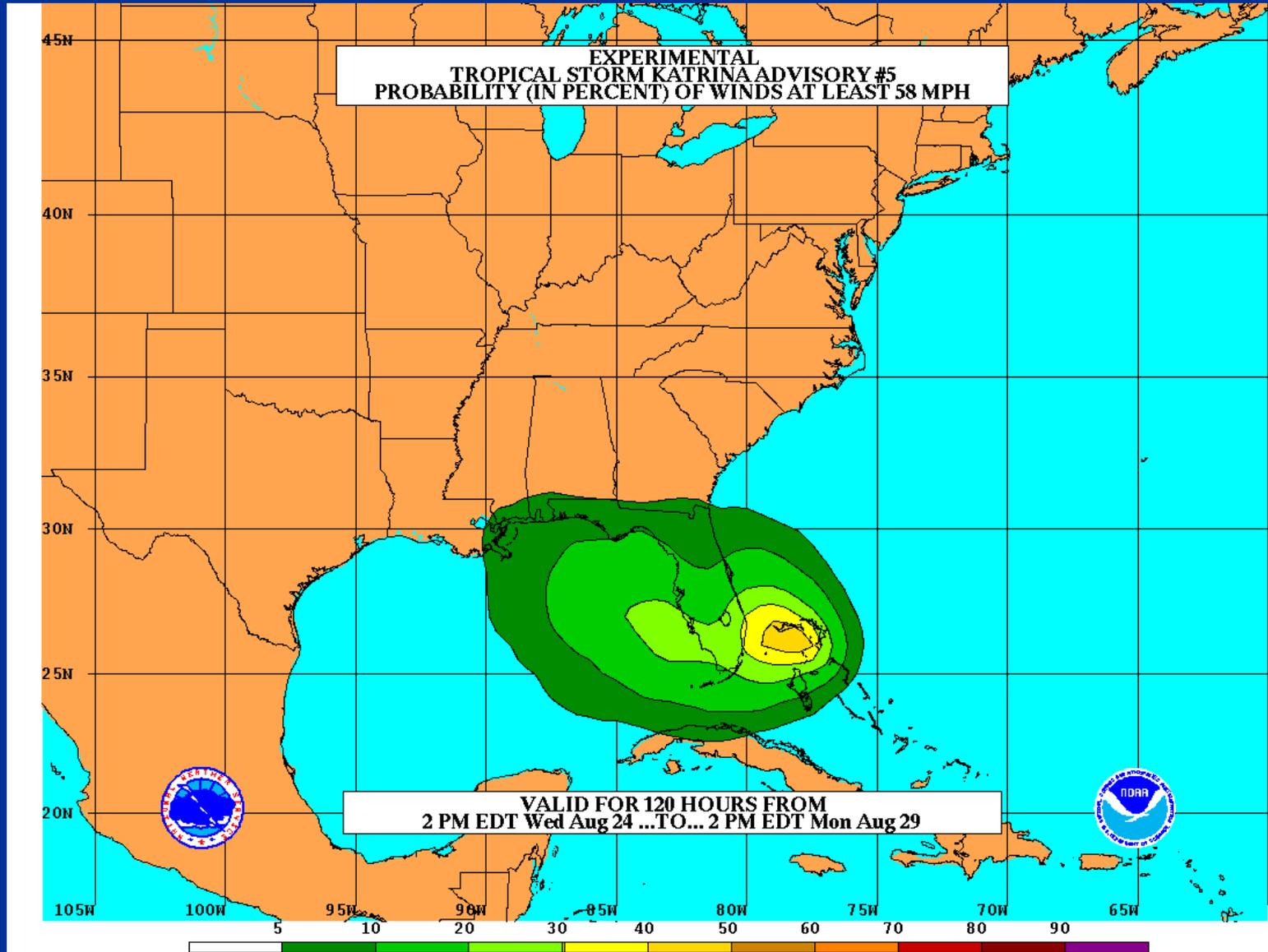
NHC Website Probability Graphics

50 kt
example



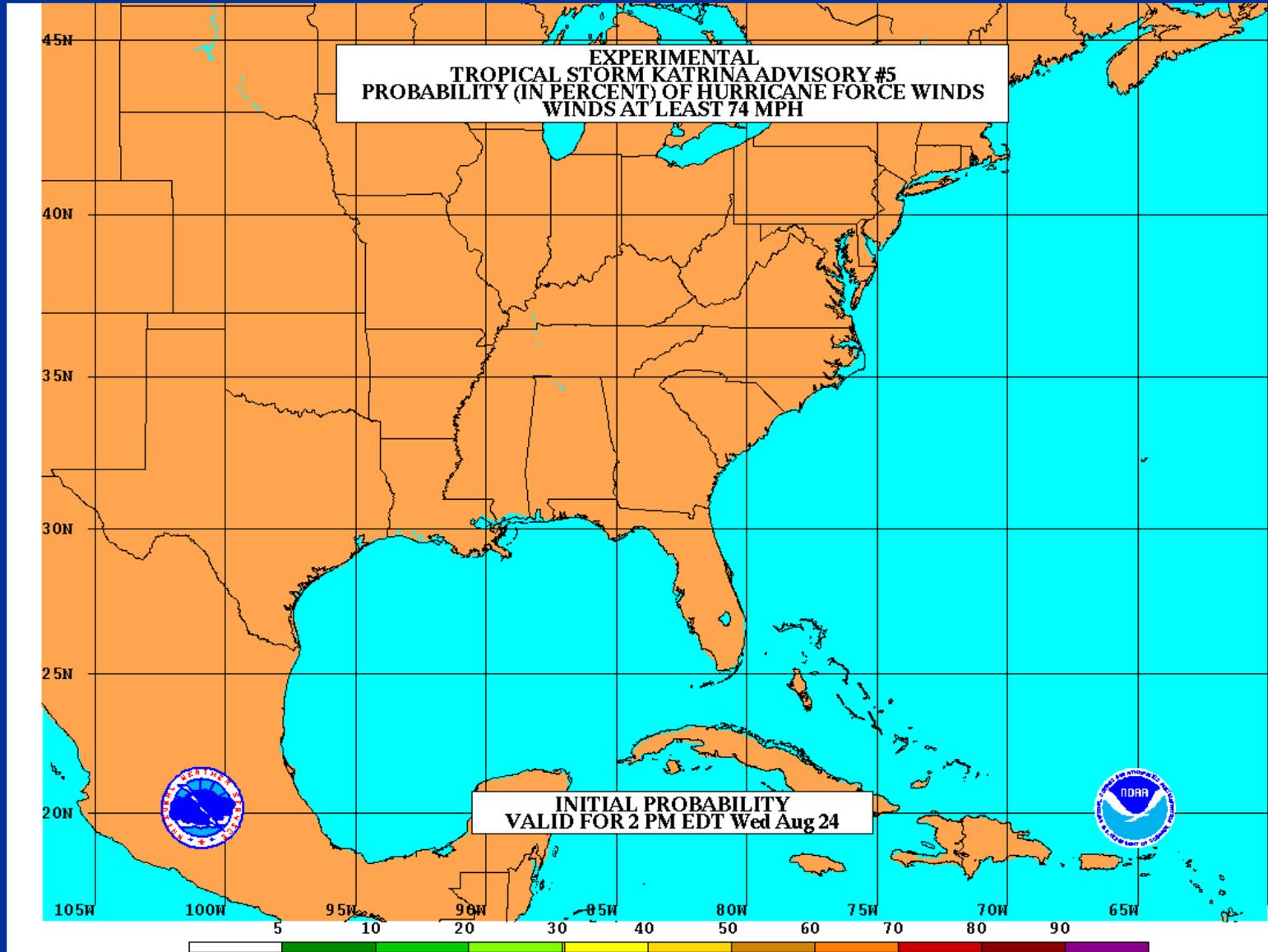
NHC Website Probability Graphics

50 kt
example



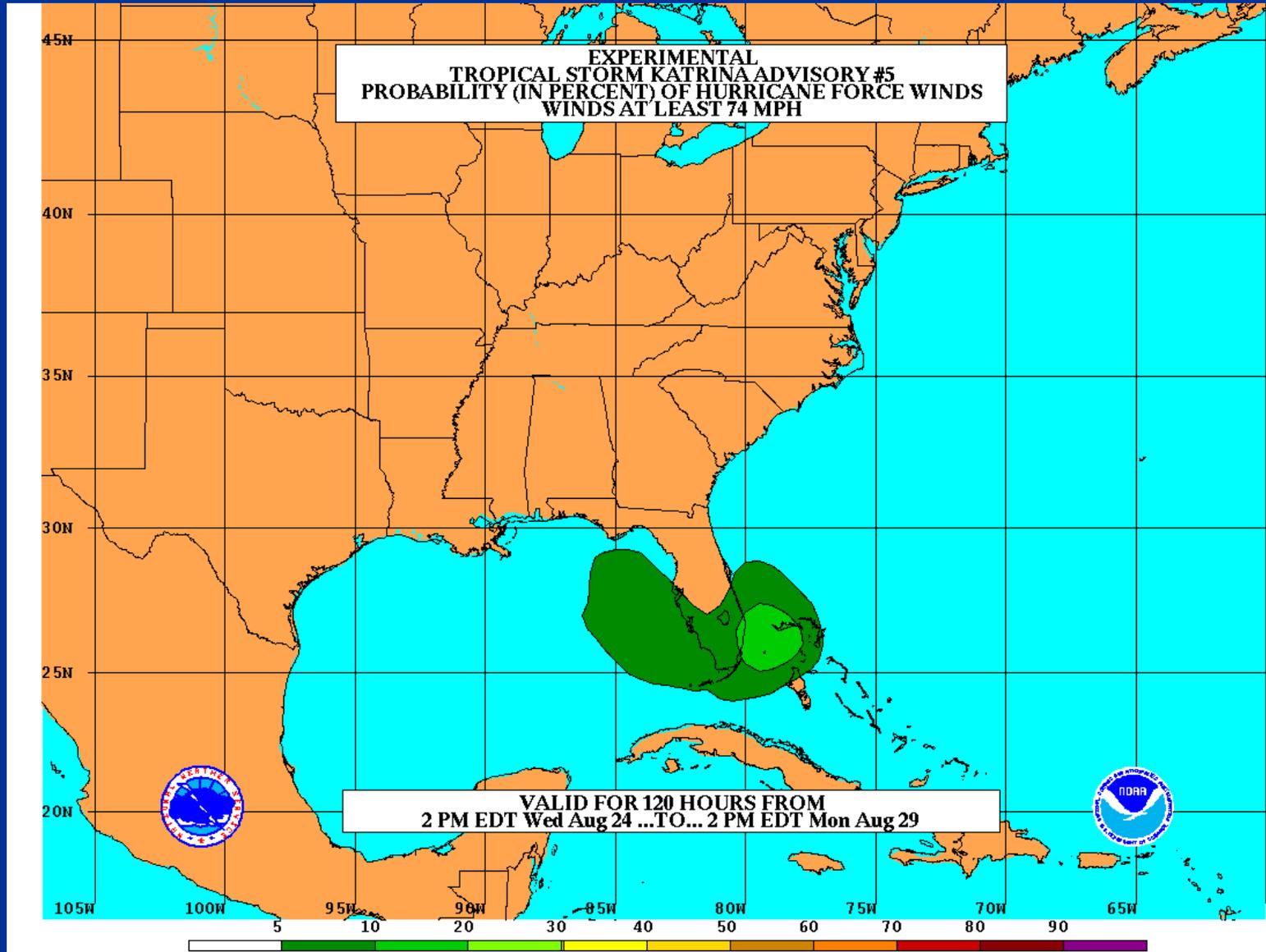
NHC Website Probability Graphics

64 kt
example



NHC Website Probability Graphics

64 kt
example



Wind Speed Probability Text Product (abbreviated)

ZCZC MIAPWSAT4 ALL
TTAA00 KNHC DDHHMM
HURRICANE WILMA PROBABILITIES NUMBER 20
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL
0900Z THU OCT 20 2005

...THIS IS AN EXPERIMENTAL PRODUCT FOR 2005...

AT 0900Z THE CENTER OF HURRICANE
WILMA WAS LOCATED NEAR LATITUDE 18.3 NORTH...
LONGITUDE 85.0 WEST WITH
MAXIMUM SUSTAINED WINDS NEAR 130 KTS...150 MPH...240 KM/HR.

CHANCES OF EXPERIENCING WIND SPEEDS OF AT LEAST

...34 KT (39 MPH... 63 KPH)...

...50 KT (58 MPH... 93 KPH)...

...64 KT (74 MPH...119 KPH)...

FOR LOCATIONS AND TIME PERIODS DURING THE NEXT 5 DAYS

PROBABILITIES FOR LOCATIONS ARE GIVEN AS IP(CP) WHERE

IP IS THE PROBABILITY OF THE EVENT BEGINNING DURING
AN INDIVIDUAL TIME PERIOD (INDIVIDUAL PROBABILITY)

(CP) IS THE PROBABILITY OF THE EVENT OCCURRING BETWEEN
06Z THU AND THE FORECAST HOUR (CUMULATIVE PROBABILITY)

PROBABILITIES ARE GIVEN IN PERCENT

X INDICATES PROBABILITIES LESS THAN 0.5 PERCENT

LOCATIONS SHOWN WHEN THEIR TOTAL CUMULATED 5-DAY

PROBABILITY IS AT LEAST 2.5 PERCENT

Z INDICATES UNIVERSAL COORDINATED TIME (GREENWICH)

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

TIME PERIODS	FROM 06Z THU		FROM 18Z THU		FROM 06Z FRI		FROM 18Z FRI		FROM 06Z SAT		FROM 06Z SUN		FROM 06Z MON	
	TO 18Z THU	TO 06Z FRI	TO 18Z FRI	TO 06Z SAT	TO 18Z SAT	TO 06Z SUN	TO 18Z SUN	TO 06Z MON	TO 18Z MON	TO 06Z TUE	TO 18Z TUE	TO 06Z WED	TO 18Z WED	
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)							
LOCATION	KT													
MIAMI FL	34 X	X(X)	X(X)	2(2)	16(18)	23(41)	5(46)							
MIAMI FL	50 X	X(X)	X(X)	X(X)	6(6)	11(17)	3(20)							
MIAMI FL	64 X	X(X)	X(X)	X(X)	2(2)	5(7)	1(8)							
KEY WEST FL	34 X	X(X)	2(2)	7(9)	26(35)	18(53)	3(56)							
KEY WEST FL	50 X	X(X)	X(X)	1(1)	14(15)	11(26)	1(27)							
KEY WEST FL	64 X	X(X)	X(X)	X(X)	8(8)	5(13)	1(14)							
MARCO ISLAND	34 X	X(X)	X(X)	5(5)	20(25)	23(48)	4(52)							
MARCO ISLAND	50 X	X(X)	X(X)	1(1)	10(11)	12(23)	2(25)							
MARCO ISLAND	64 X	X(X)	X(X)	X(X)	5(5)	6(11)	X(11)							

Example Interpretation of Output

What is the chance that winds of tropical storm force (34 kt or greater) will occur at Charlotte NC during the next five days?

TIME PERIODS	FROM 18Z FRI TO 06Z SAT	FROM 06Z SAT TO 18Z SAT	FROM 18Z SAT TO 06Z SUN	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 18Z MON	FROM 18Z MON TO 18Z TUE	FROM 18Z TUE TO 18Z WED
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
RALEIGH NC	34 X	X(X)	X(X)	2(2)	10(12)	8(20)	10(30)
RALEIGH NC	50 X	X(X)	X(X)	X(X)	2(2)	3(5)	5(10)
RALEIGH NC	64 X	X(X)	X(X)	X(X)	X(X)	2(2)	2(4)
CAPE HATTERAS	34 X	X(X)	X(X)	1(1)	4(5)	3(8)	7(15)
CAPE HATTERAS	50 X	X(X)	X(X)	X(X)	X(X)	1(1)	2(3)
CHARLOTTE NC	34 X	X(X)	X(X)	3(3)	18(21)	12(33)	9(42)
CHARLOTTE NC	50 X	X(X)	X(X)	X(X)	4(4)	6(10)	4(14)
CHARLOTTE NC	64 X	X(X)	X(X)	X(X)	2(2)	2(4)	2(6)

34 kt
probabilities
at Charlotte
NC



Example Interpretation of Output

What is the chance that winds of tropical storm force (34 kt or greater) will occur at Charlotte NC during the next five days?

42%

TIME PERIODS	FROM 18Z FRI TO 06Z SAT	FROM 06Z SAT TO 18Z SAT	FROM 18Z SAT TO 06Z SUN	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 18Z MON	FROM 18Z MON TO 18Z TUE	FROM 18Z TUE TO 18Z WED
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
RALEIGH NC	34 X	X(X)	X(X)	2(2)	10(12)	8(20)	10(30)
RALEIGH NC	50 X	X(X)	X(X)	X(X)	2(2)	3(5)	5(10)
RALEIGH NC	64 X	X(X)	X(X)	X(X)	X(X)	2(2)	2(4)
CAPE HATTERAS	34 X	X(X)	X(X)	1(1)	4(5)	3(8)	7(15)
CAPE HATTERAS	50 X	X(X)	X(X)	X(X)	X(X)	1(1)	2(3)
CHARLOTTE NC	34 X	X(X)	X(X)	3(3)	18(21)	12(33)	9(42)
CHARLOTTE NC	50 X	X(X)	X(X)	X(X)	4(4)	6(10)	4(14)
CHARLOTTE NC	64 X	X(X)	X(X)	X(X)	2(2)	2(4)	2(6)

34 kt probabilities at Charlotte NC

Example Interpretation of Output

What is the chance that winds of tropical storm force (34 kt or greater) will occur at Charlotte NC during the next five days?

42%

When are these winds most likely to start?

TIME PERIODS	FROM 18Z FRI TO 06Z SAT	FROM 06Z SAT TO 18Z SAT	FROM 18Z SAT TO 06Z SUN	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 18Z MON	FROM 18Z MON TO 18Z TUE	FROM 18Z TUE TO 18Z WED
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
RALEIGH NC	34 X	X(X)	X(X)	2(2)	10(12)	8(20)	10(30)
RALEIGH NC	50 X	X(X)	X(X)	X(X)	2(2)	3(5)	5(10)
RALEIGH NC	64 X	X(X)	X(X)	X(X)	X(X)	2(2)	2(4)
CAPE HATTERAS	34 X	X(X)	X(X)	1(1)	4(5)	3(8)	7(15)
CAPE HATTERAS	50 X	X(X)	X(X)	X(X)	X(X)	1(1)	2(3)
CHARLOTTE NC	34 X	X(X)	X(X)	3(3)	18(21)	12(33)	9(42)
CHARLOTTE NC	50 X	X(X)	X(X)	X(X)	4(4)	6(10)	4(14)
CHARLOTTE NC	64 X	X(X)	X(X)	X(X)	2(2)	2(4)	2(6)

34 kt
probabilities
at Charlotte
NC



Example Interpretation of Output

What is the chance that winds of tropical storm force (34 kt or greater) will occur at Charlotte NC during the next five days?

42%

When are these winds most likely to start?

From 18Z Sun to 18Z Mon (18% chance)

TIME PERIODS	FROM 18Z FRI TO 06Z SAT	FROM 06Z SAT TO 18Z SAT	FROM 18Z SAT TO 06Z SUN	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 18Z MON	FROM 18Z MON TO 18Z TUE	FROM 18Z TUE TO 18Z WED
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
LOCATION	KT						
RALEIGH NC	34 X	X(X)	X(X)	2(2)	10(12)	8(20)	10(30)
RALEIGH NC	50 X	X(X)	X(X)	X(X)	2(2)	3(5)	5(10)
RALEIGH NC	64 X	X(X)	X(X)	X(X)	X(X)	2(2)	2(4)
CAPE HATTERAS	34 X	X(X)	X(X)	1(1)	4(5)	3(8)	7(15)
CAPE HATTERAS	50 X	X(X)	X(X)	X(X)	X(X)	1(1)	2(3)
CHARLOTTE NC	34 X	X(X)	X(X)	3(3)	18(21)	12(33)	9(42)
CHARLOTTE NC	50 X	X(X)	X(X)	X(X)	4(4)	6(10)	4(14)
CHARLOTTE NC	64 X	X(X)	X(X)	X(X)	2(2)	2(4)	2(6)

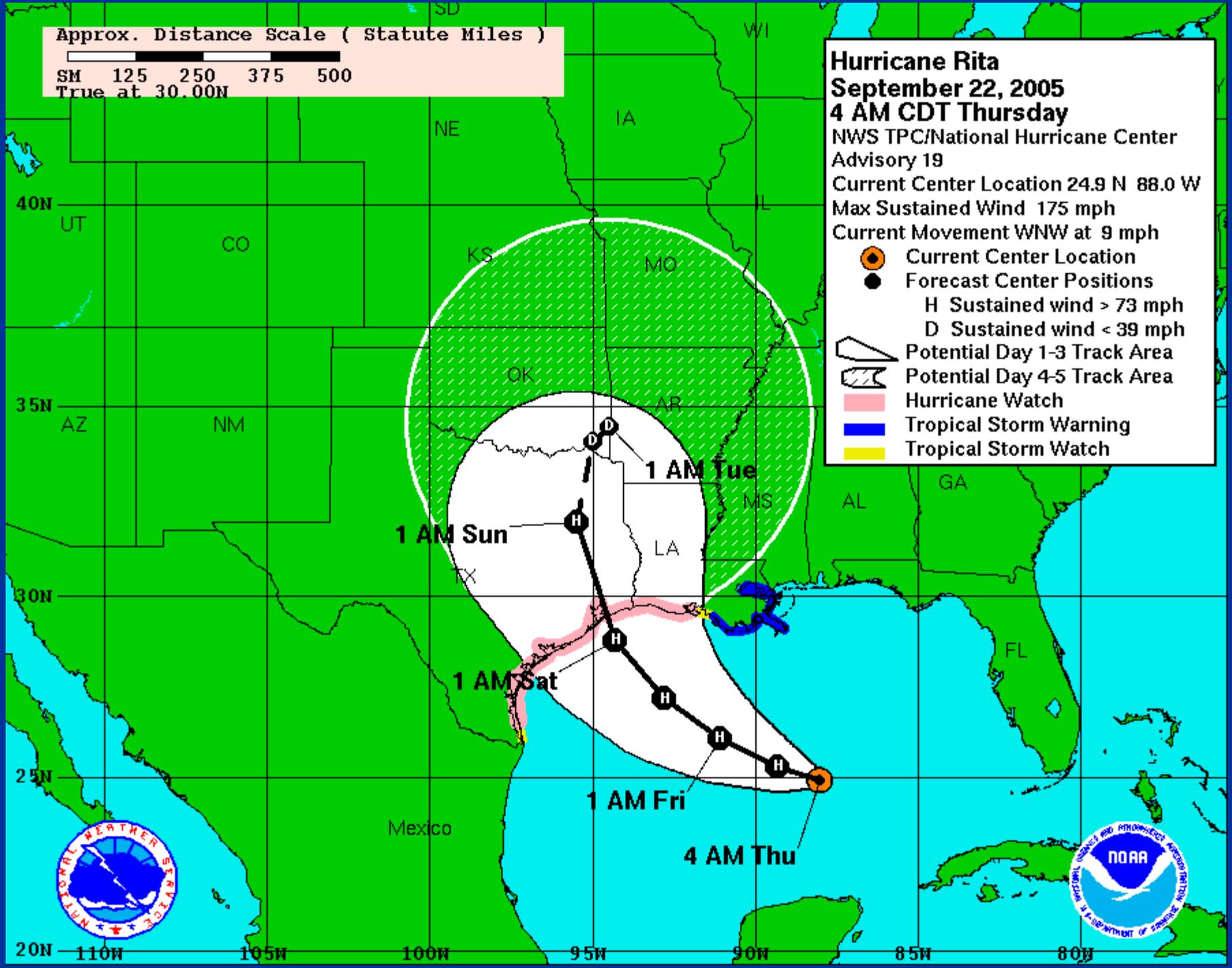
34 kt probabilities at Charlotte NC

Approx. Distance Scale (Statute Miles)



Hurricane Rita
September 22, 2005
4 AM CDT Thursday
NWS TPC/National Hurricane Center
Advisory 19
Current Center Location 24.9 N 88.0 W
Max Sustained Wind 175 mph
Current Movement WNW at 9 mph

- Current Center Location
- Forecast Center Positions
 - H Sustained wind > 73 mph
 - D Sustained wind < 39 mph
- ▨ Potential Day 1-3 Track Area
- ▨ Potential Day 4-5 Track Area
- ▨ Hurricane Watch
- ▨ Tropical Storm Warning
- ▨ Tropical Storm Watch

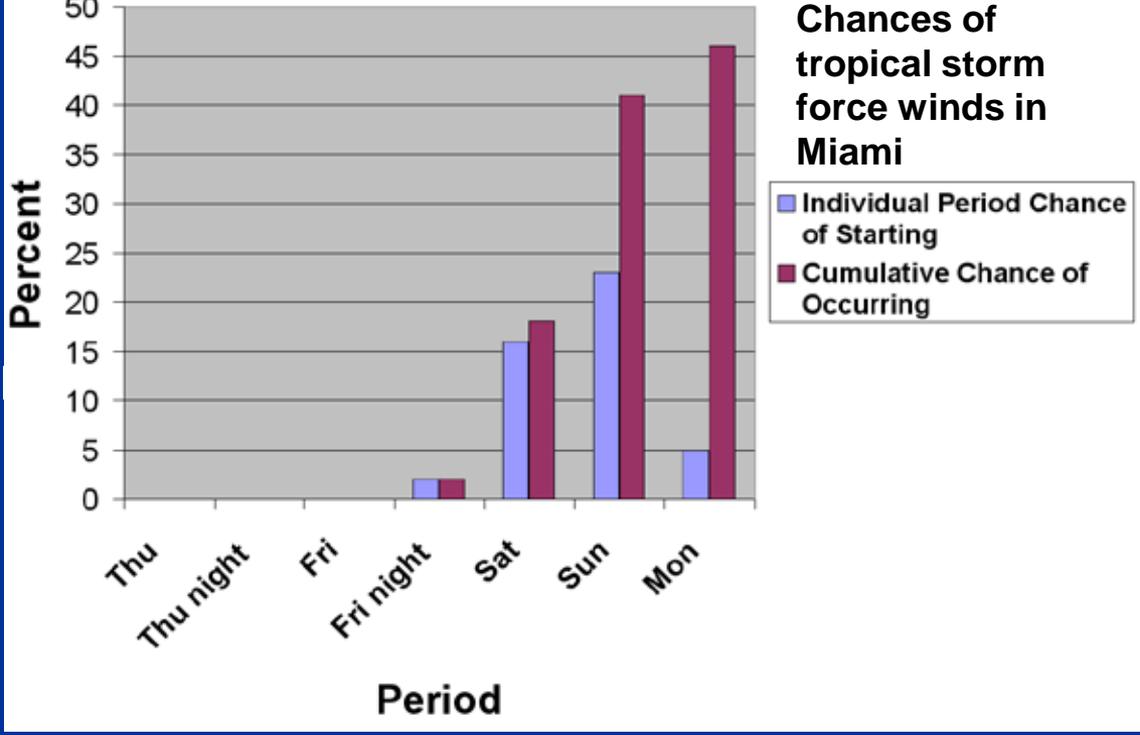


Exact track forecast goes over Galveston, but there is also a significant chance of hurricane force winds farther east where actual landfall occurred.

TIME PERIODS	FROM 06Z THU		FROM 18Z THU		FROM 06Z FRI		FROM 18Z FRI		FROM 06Z SAT		FROM 06Z SUN		FROM 06Z MON		FROM 06Z TUE	
	TO 18Z THU	TO 06Z FRI	TO 06Z FRI	TO 18Z FRI	TO 06Z SAT	TO 18Z SAT	TO 06Z SUN	TO 18Z SUN	TO 06Z MON	TO 18Z MON	TO 06Z TUE	TO 18Z TUE	TO 06Z WED	TO 18Z WED	TO 06Z THU	TO 18Z THU
FORECAST HOUR	(12)		(24)		(36)		(48)		(72)		(96)		(120)			
LOCATION	KT															
NEW IBERIA LA	34	1	8	(9)	28	(37)	19	(56)	8	(64)	X	(64)	X	(64)		
NEW IBERIA LA	50	X	X	(X)	9	(9)	12	(21)	6	(27)	1	(28)	1	(29)		
NEW IBERIA LA	64	X	X	(X)	3	(3)	7	(10)	4	(14)	1	(15)	X	(15)		
PORT ARTHUR TX	34	X	4	(4)	27	(31)	31	(62)	16	(78)	2	(80)	1	(81)		
PORT ARTHUR TX	50	X	X	(X)	8	(8)	26	(34)	14	(48)	2	(50)	1	(51)		
PORT ARTHUR TX	64	X	X	(X)	2	(2)	15	(17)	12	(29)	2	(31)	X	(31)		
GALVESTON TX	34	X	5	(5)	29	(34)	31	(65)	15	(80)	3	(83)	1	(84)		
GALVESTON TX	50	X	X	(X)	12	(12)	27	(39)	15	(54)	2	(56)	2	(58)		
GALVESTON TX	64	X	X	(X)	4	(4)	19	(23)	12	(35)	1	(36)	1	(37)		
HOUSTON TX	34	X	1	(1)	22	(23)	32	(55)	19	(74)	3	(77)	2	(79)		
HOUSTON TX	50	X	X	(X)	4	(4)	23	(27)	17	(44)	2	(46)	1	(47)		
HOUSTON TX	64	X	X	(X)	1	(1)	12	(13)	13	(26)	1	(27)	X	(27)		
FREEPORT TX	34	X	3	(3)	28	(31)	29	(60)	16	(76)	3	(79)	1	(80)		
FREEPORT TX	50	X	X	(X)	9	(9)	24	(33)	14	(47)	2	(49)	2	(51)		
FREEPORT TX	64	X	X	(X)	4	(4)	15	(19)	11	(30)	2	(32)	X	(32)		
PORT O CONNOR	34	X	2	(2)	18	(20)	23	(43)	16	(59)	4	(63)	2	(65)		
PORT O CONNOR	50	X	X	(X)	5	(5)	13	(18)	11	(29)	3	(32)	2	(34)		
PORT O CONNOR	64	X	X	(X)	2	(2)	7	(9)	8	(17)	2	(19)	1	(20)		
CORPUS CHRISTI	34	X	X	(X)	8	(8)	14	(22)	11	(33)	5	(38)	2	(40)		
CORPUS CHRISTI	50	X	X	(X)	1	(1)	4	(5)	7	(12)	2	(14)	1	(15)		
CORPUS CHRISTI	64	X	X	(X)	1	(1)	1	(2)	5	(7)	1	(8)	1	(9)		
BROWNSVILLE TX	34	X	X	(X)	4	(4)	6	(10)	6	(16)	4	(20)	1	(21)		
BROWNSVILLE TX	50	X	X	(X)	1	(1)	1	(2)	2	(4)	2	(6)	1	(7)		
BROWNSVILLE TX	64	X	X	(X)	X	(X)	1	(1)	1	(2)	X	(2)	1	(3)		



Chances of tropical storm force winds in Miami



Hurricane Wilma
October 20, 2005
4 AM CDT Thursday
 NWS TPC/National Hurricane Center
 Advisory 20
 Current Center Location 18.3 N 85.0 W
 Max Sustained Wind 150 mph
 Current Movement WNW at 8 mph

- Current Center Location
- Forecast Center Positions
- Sustained wind > 73 mph
- Potential Day 1-3 Track Area
- Potential Day 4-5 Track Area
- Hurricane Warning
- Hurricane Watch
- Tropical Storm Warning

Challenges and Ongoing Work

- Significant training and outreach needed
 - Lessen the focus on exact track forecast
 - Do users understand probabilities?
 - “Small” probabilities
- Enhancements to graphical products
 - Faster creation of grids and graphics created from them
- Potential use by NWS forecast offices in their products
- Verification
- Objective guidance for watch/warning breakpoints
- Gridded products for NDFD

Supplemental Slides

Who Would Use Wind Speed Probabilities?

Primary Users	Application
Emergency managers, professional decision makers	Risk assessment; decision making
Department of Defense	Risk assessment; decision making
TPC/NHC, CPHC, JTWC, and int'l offices with TC warning responsibility	Watch/warning calibration; supplement to deterministic data; communication of risk
NWS Forecast Offices	Enhanced text or graphical products

Desired Users	Application
Media	Communication of risk
Public	Risk assessment and/or decision making by knowledgeable users

Wind Speed Probability Methodology

- Create large set of plausible tracks and intensities (ensemble members) roughly centered around the current official forecast
 - Determined by random sampling of historical track and intensity errors in official forecasts (since 2001)
 - Intensities consider whether a particular ensemble member is over land or water

Wind Speed Probability Methodology

- The size of the tropical cyclone (set of wind radii) for each ensemble member is determined by a climatology and persistence (CLIPER) model and its error components
 - CLIPER models provide:
 - A baseline forecast for evaluating the skill of other models and forecasts
 - Basic guidance to use in making forecast for current storm
 - A general idea of how difficult a forecast was (based on CLIPER errors)
 - Wind radii CLIPER combines:
 - Recent trends and persistence in initial wind radii of the current storm
 - Climatological radii (based on operational estimates in several past storms) that vary with the storm's initial and forecast location, forward speed, and intensity. In general:
 - **Storms get larger in middle latitudes**
 - **Stronger storms have larger wind radii**
 - **Faster storms have larger wind radii to the right of direction of motion**
 - For wind radii CLIPER, persistence dominates through about 36 h of the forecast, then climatology dominates

Wind Speed Probability Methodology

- Operational wind radii definition:
 - *Maximum* extent of a particular wind speed somewhere in a quadrant of the storm
 - Creating wind swaths from these radii can overestimate area affected by that wind speed
- For wind speed probabilities, adjustment is made so that the wind radii represent the *average* (not maximum) extent of winds in each quadrant
- This adjustment makes wind speed probabilities more realistic for describing what might actually happen at any location

Wind Speed Probability Methodology

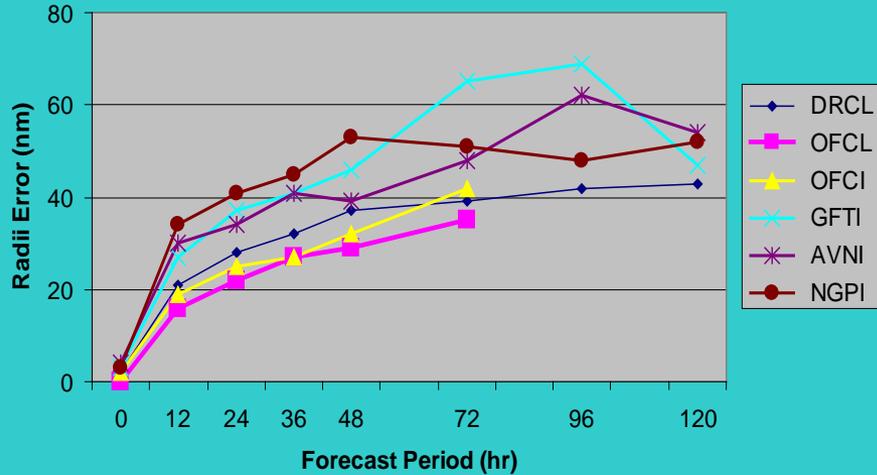
- Swaths of particular wind speeds are then computed for each ensemble member.
- Probabilities are computed on a lat-lon grid (0.5 degree) by counting the fraction of ensemble members in which each grid point falls within a swath of each wind speed.

Wind Speed Probability Methodology

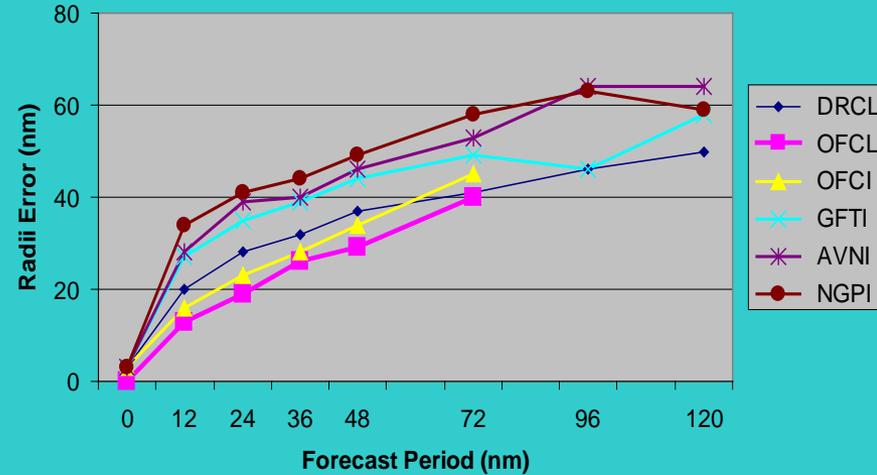
- Computed and output on a single Northern Hemispheric grid
- Done after each forecast cycle for all active tropical cyclones in the following basins:
 - Atlantic (includes Caribbean and Gulf of Mexico)
 - Eastern Pacific
 - Central Pacific
 - Western Pacific
- Can be converted to graphics and text



**2005 ATLANTIC 34-KT RADII ERROR
NORTHWEST QUADRANT**

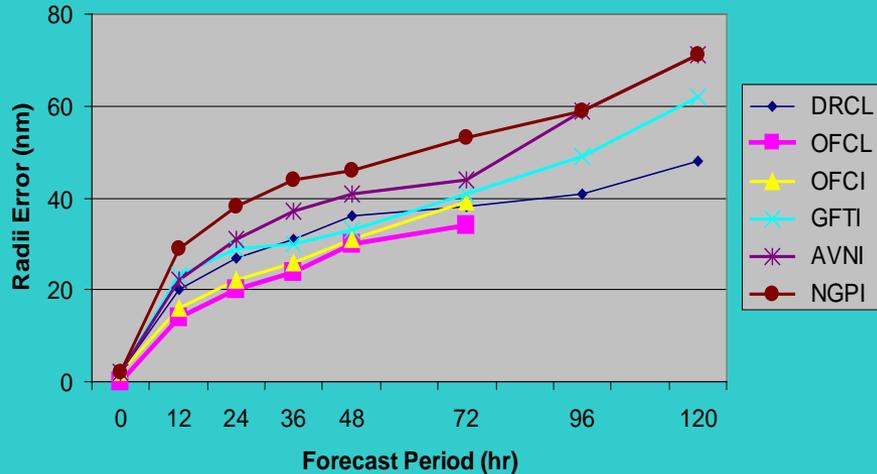


**2005 ATLANTIC 34-KT RADII ERROR
NORTHEAST QUADRANT**

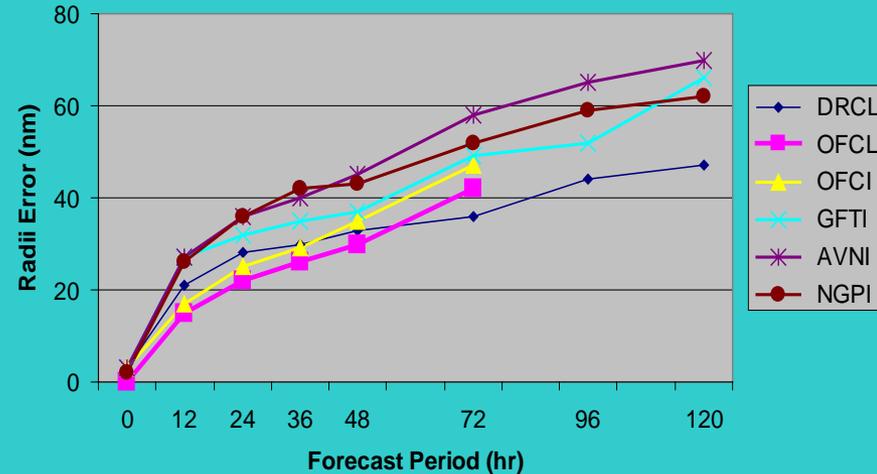


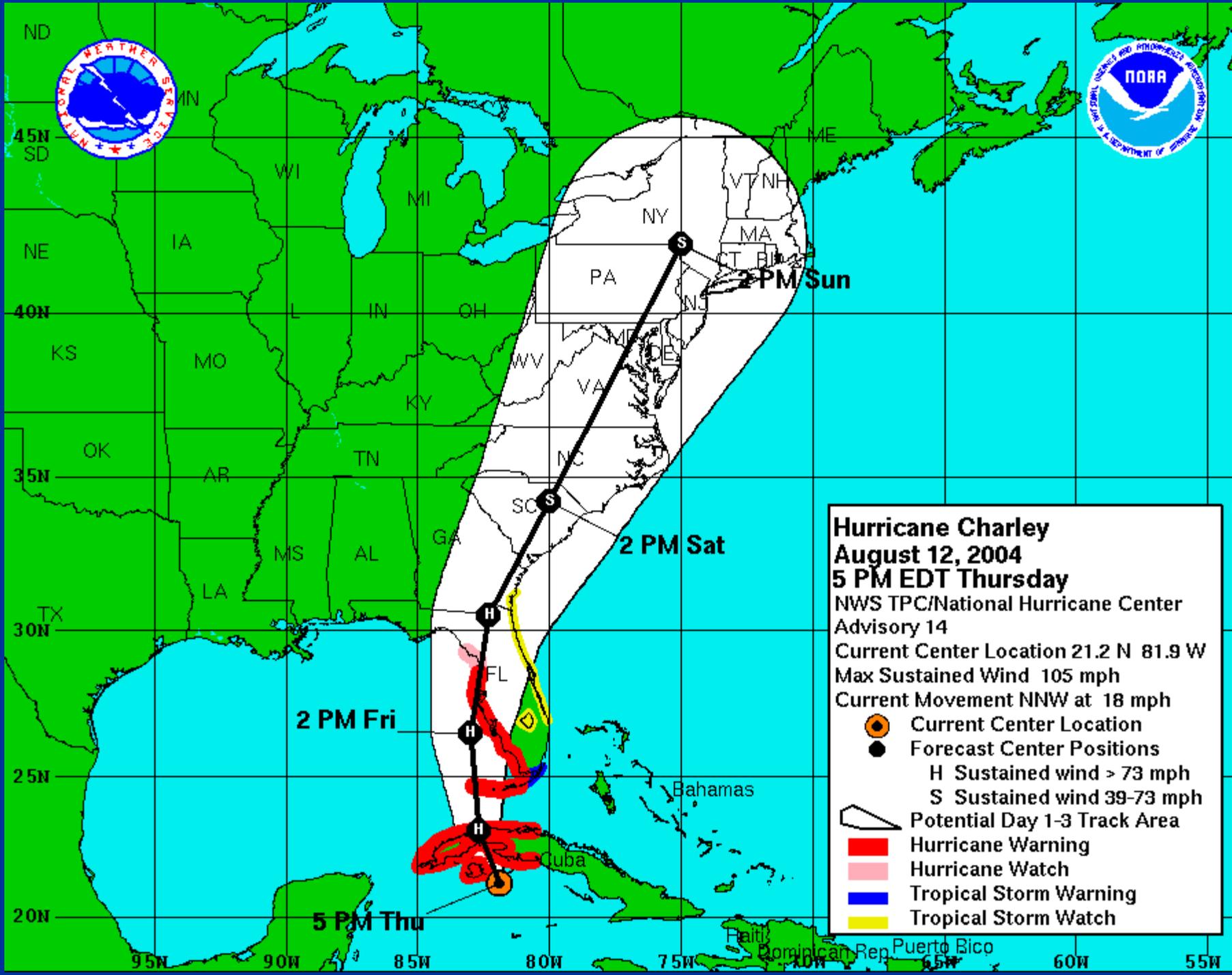
**34-KT WIND RADII FORECAST VERIFICATION:
“DRCL” IS A CLIPER MODEL**

**2005 ATLANTIC 34-KT RADII ERROR
SOUTHWEST QUADRANT**



**2005 ATLANTIC 34-KT RADII ERROR
SOUTHEAST QUADRANT**





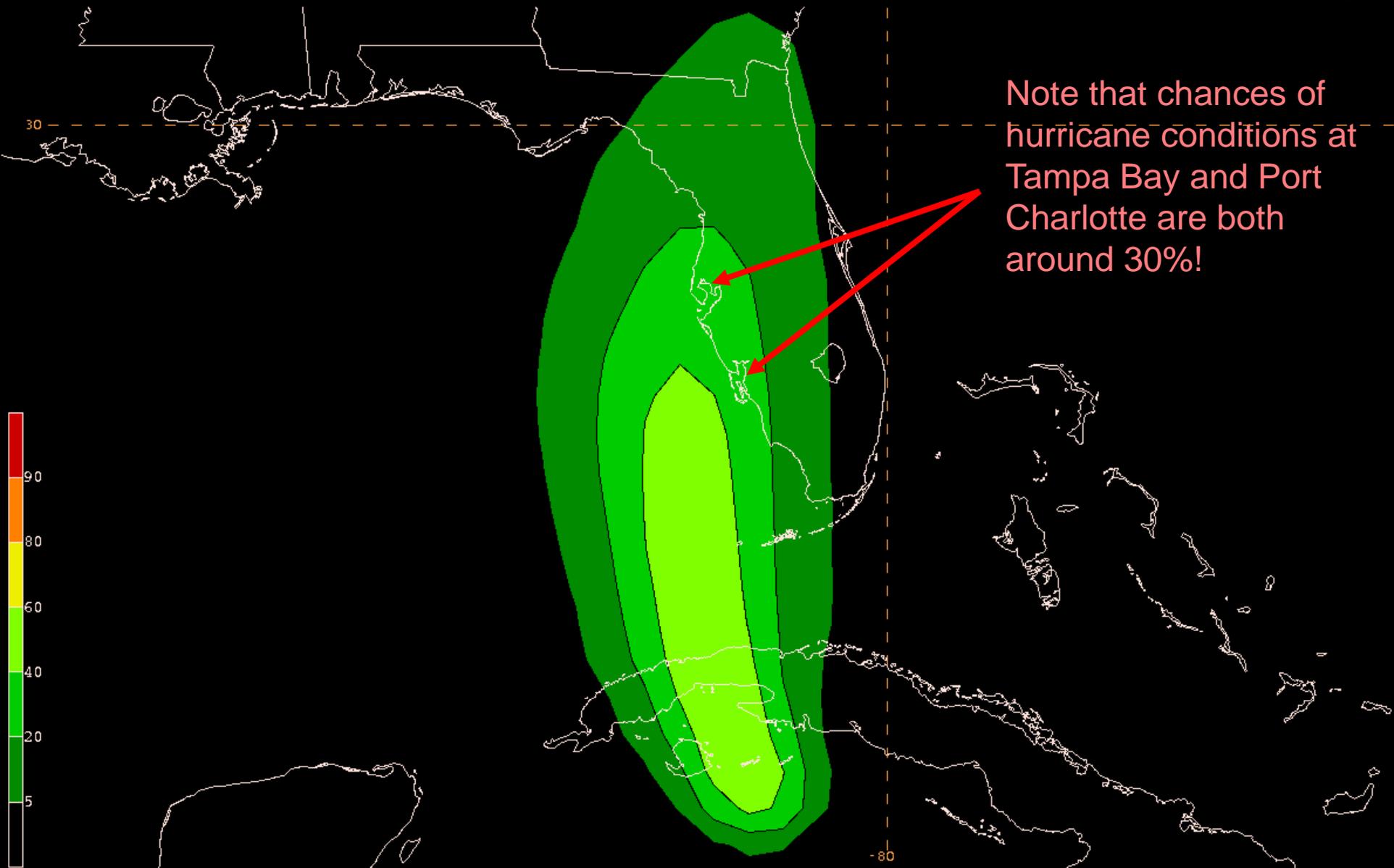
Hurricane Charley
August 12, 2004
5 PM EDT Thursday
NWS TPC/National Hurricane Center
Advisory 14
Current Center Location 21.2 N 81.9 W
Max Sustained Wind 105 mph
Current Movement NNW at 18 mph

- Current Center Location
- Forecast Center Positions
 - H Sustained wind > 73 mph
 - S Sustained wind 39-73 mph
- ▭ Potential Day 1-3 Track Area
- Hurricane Warning
- Hurricane Watch
- Tropical Storm Warning
- Tropical Storm Watch

64 kt Cumulative

0-120 h

18 UTC Thu 12 Aug



TPCPROB TUE 040817/1800V120 SFC 64-KNOT or > WIND PROBABILITY

Hurricane Charley (2004)