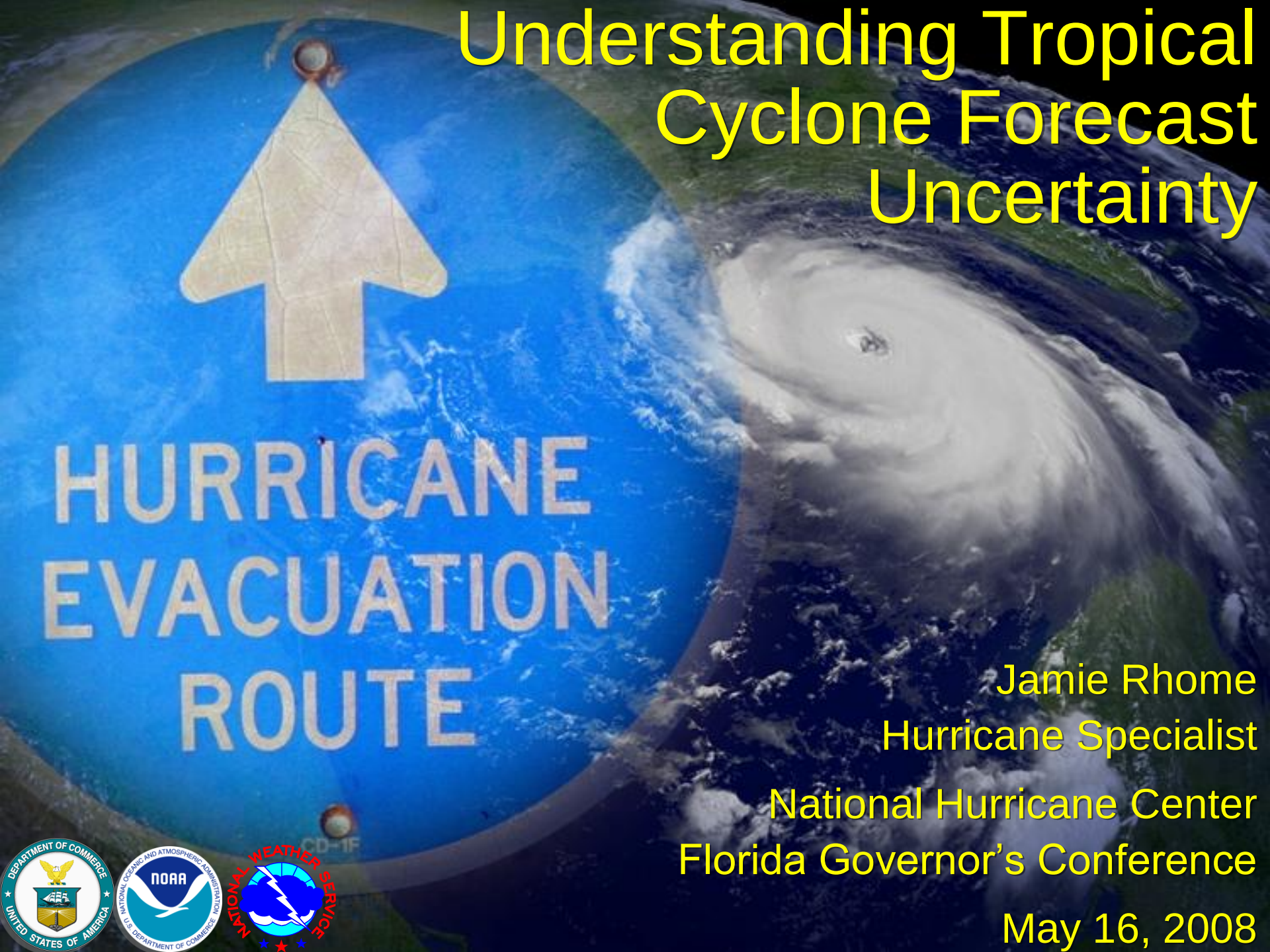
Understanding Tropical Cyclone Forecast Uncertainty



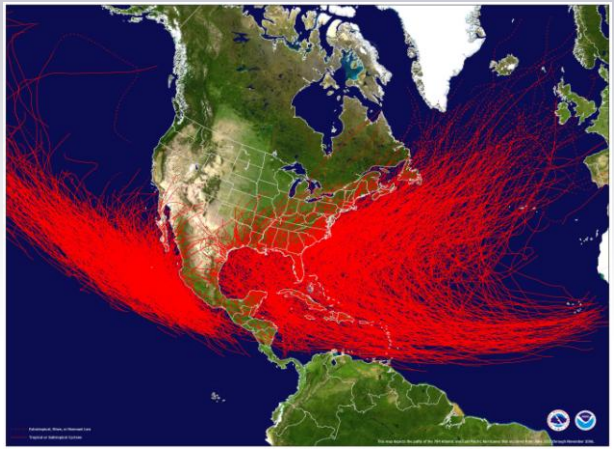
Jamie Rhome
Hurricane Specialist
National Hurricane Center

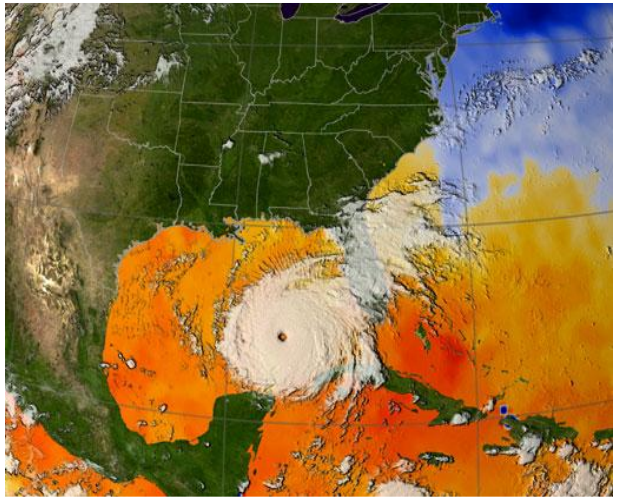
Florida Governor's Conference

May 16, 2008

Outline

- "Houston, We Have a Problem"
  - Trends in Coastal Population
  - Trends in Hurricane Predictability
- The Forecast
  - Dealing with Uncertainty
  - Public Understanding/Perception
  - Forecast Challenges
  - New Genesis Forecast Product
- Where the Rubber Meets the Road
  - Communicating Uncertainty





Coastal County Population, Texas to Maine 1900 - 2000

53% of the U.S. population now live within 50 miles of the coast

Population

50,000,000
45,000,000
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0

1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000

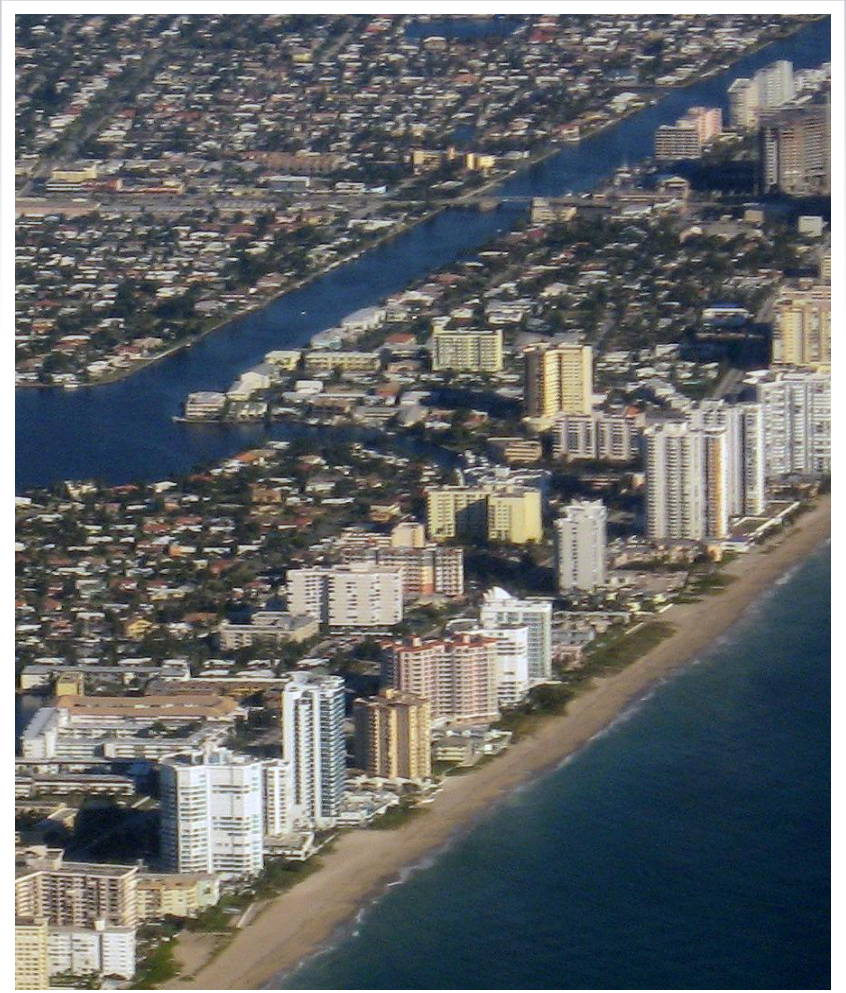
Year

Miami: Then and Now

Great Miami Hurricane:$140-157 Billion Today

Miami Beach 1926

Miami Beach 2006

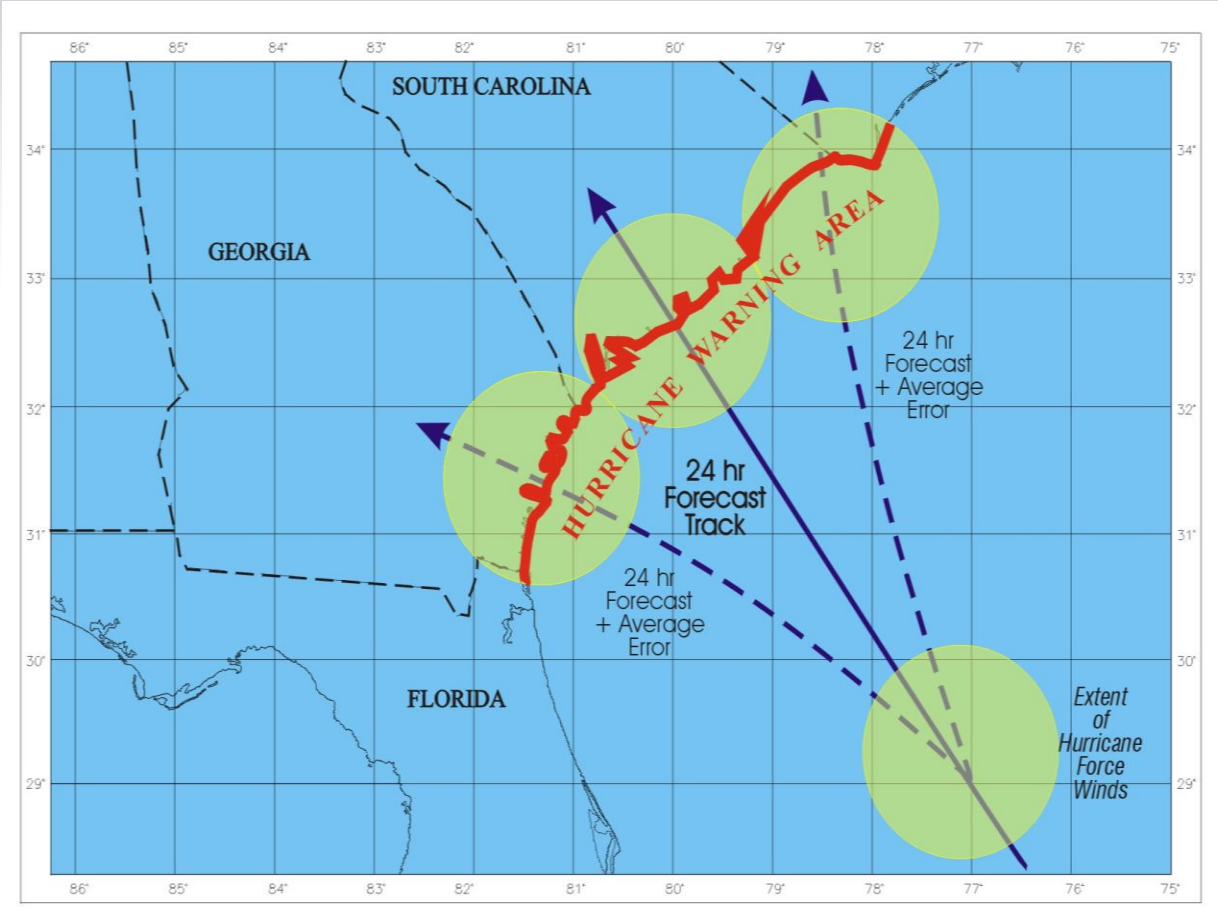


Wendler Collection

Joel Gratz © 2006


DODGE RAM
NISSAN

Dealing with Uncertainty: Watch/Warning Philosophy

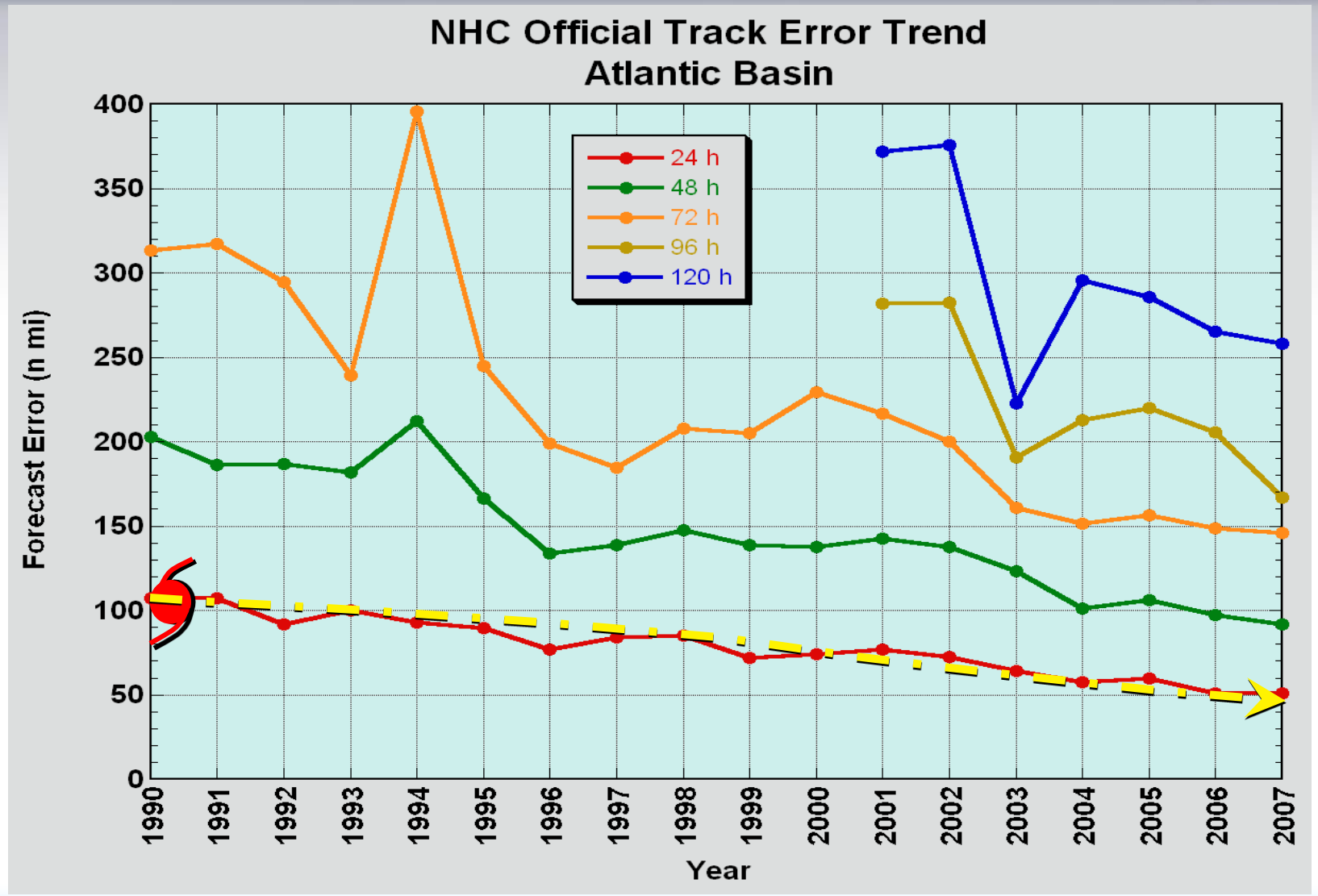


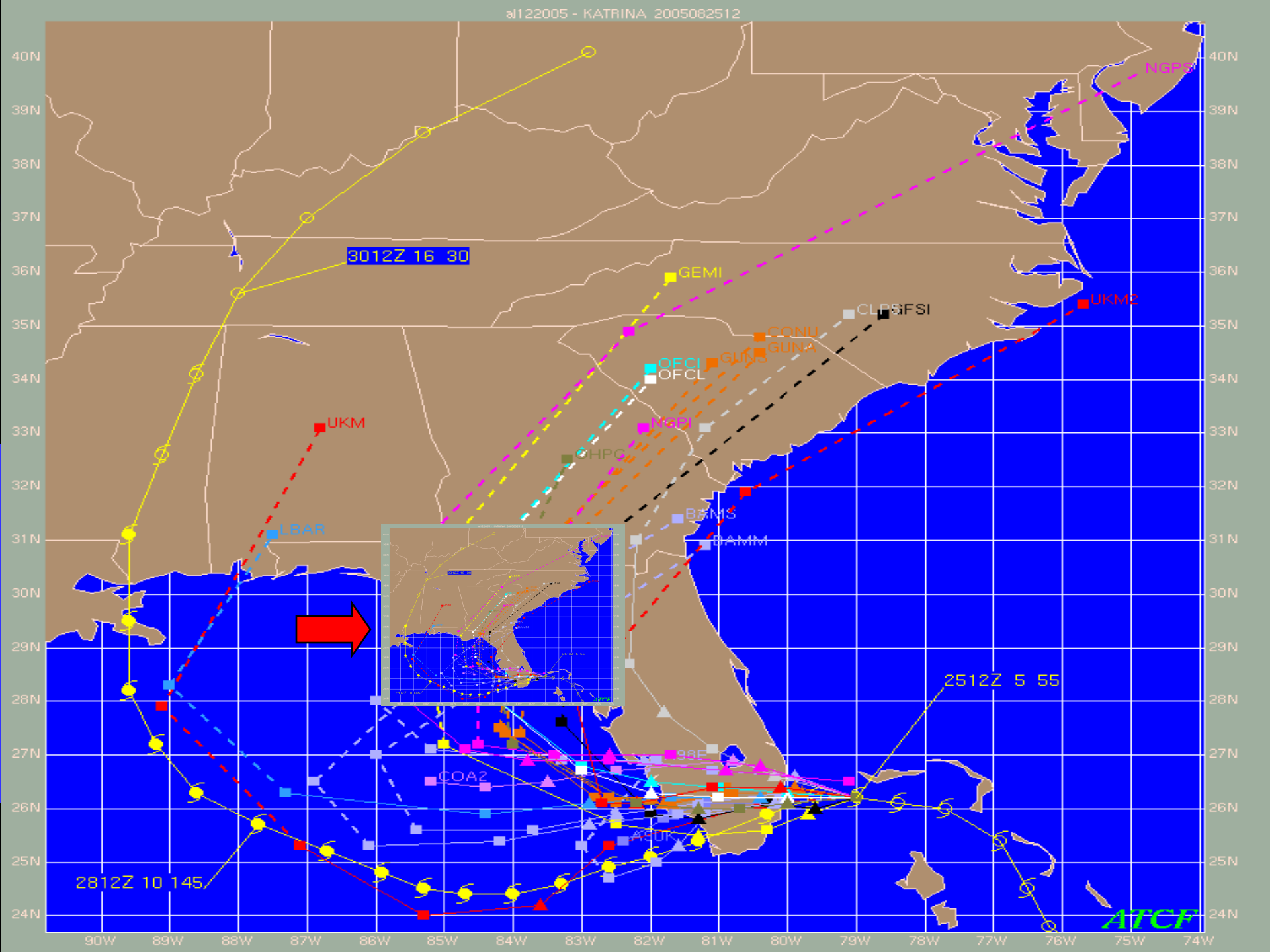
Average storm-total watch and warning length: 300-400 miles

Average size of area w/ hurricane winds: 100 miles

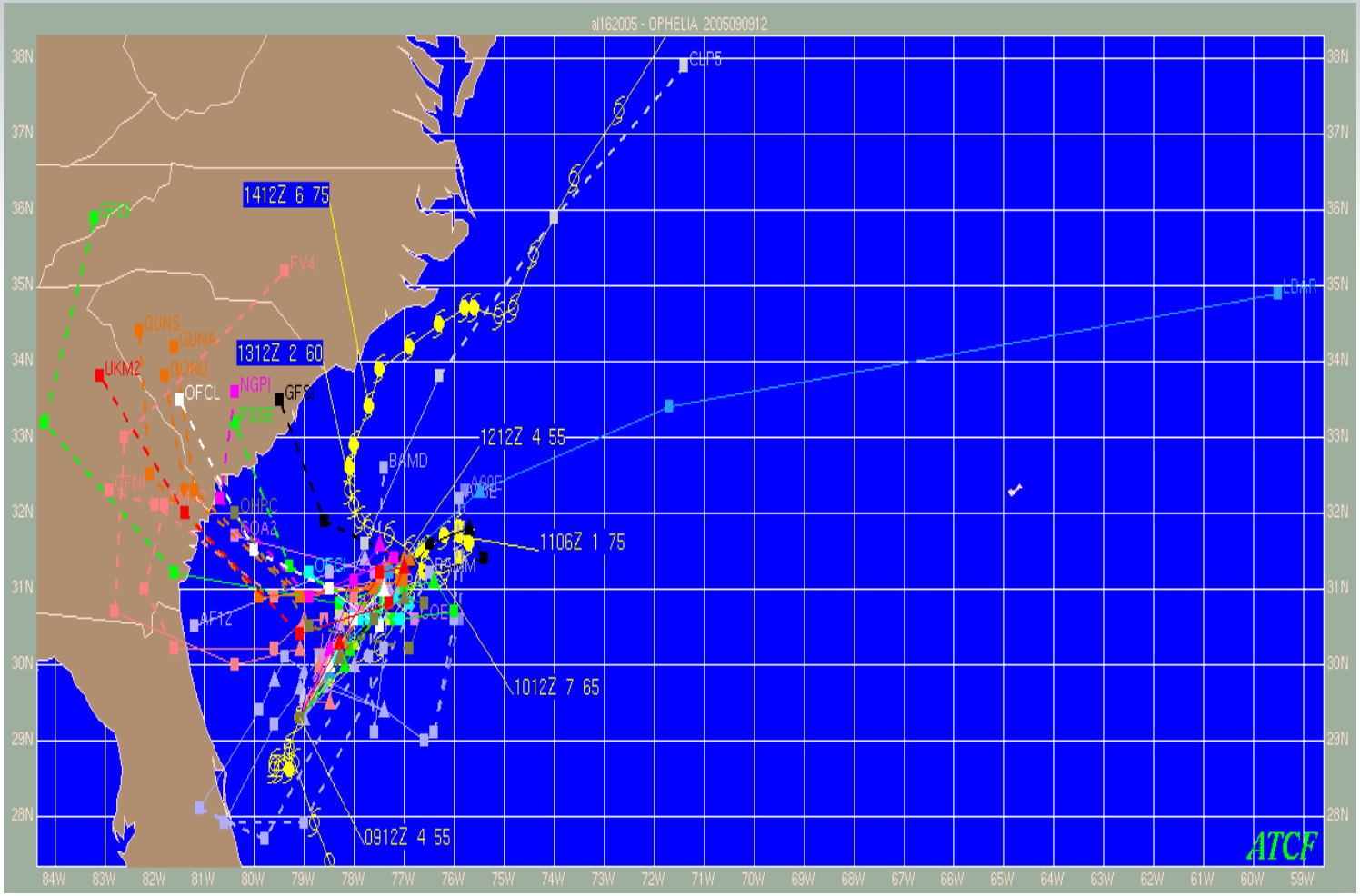
Probability of hurricane winds at any point under watch or warning: ~**20-33%**

Track Forecast Errors Cut in Half in 15 Years

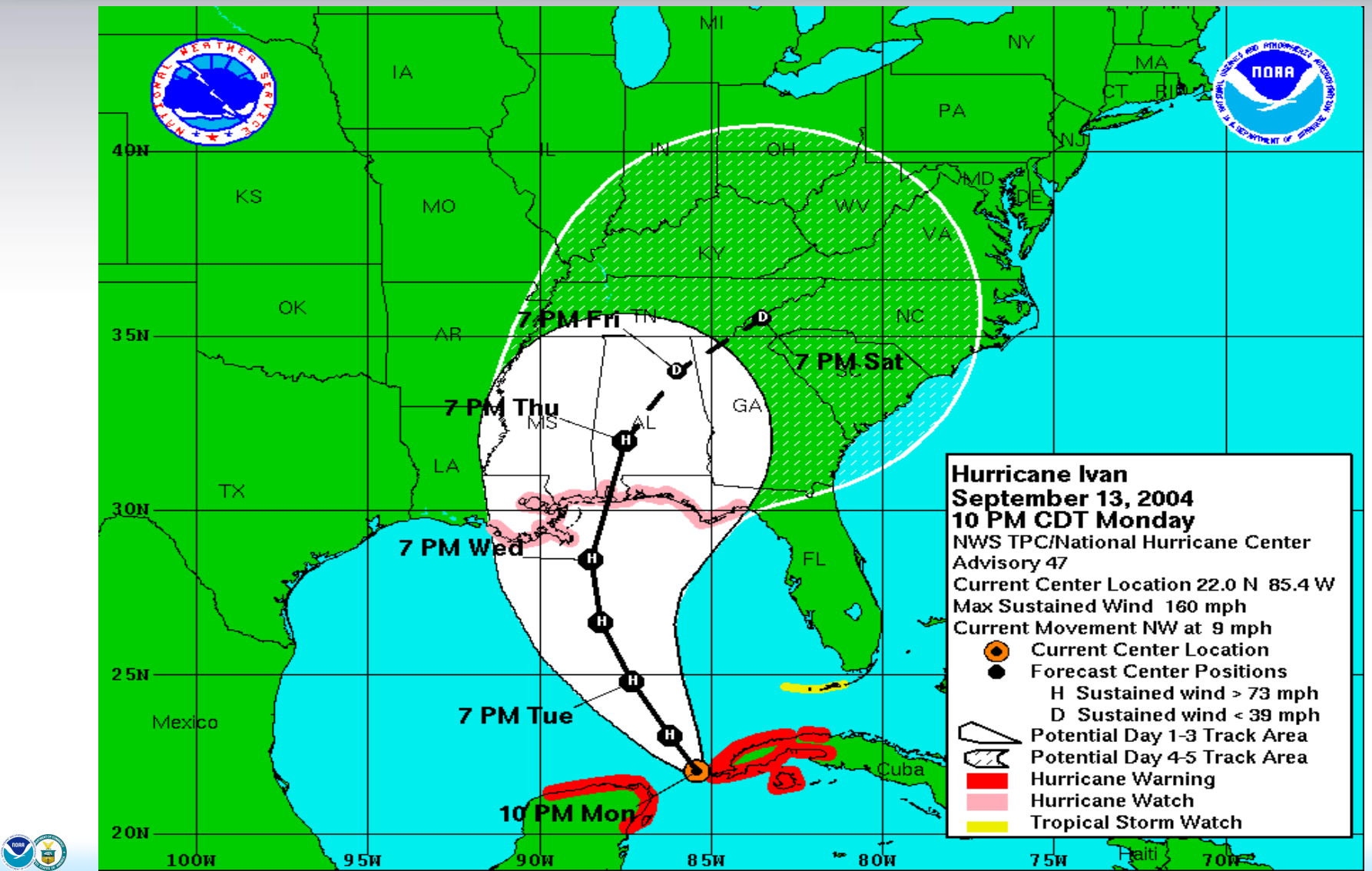


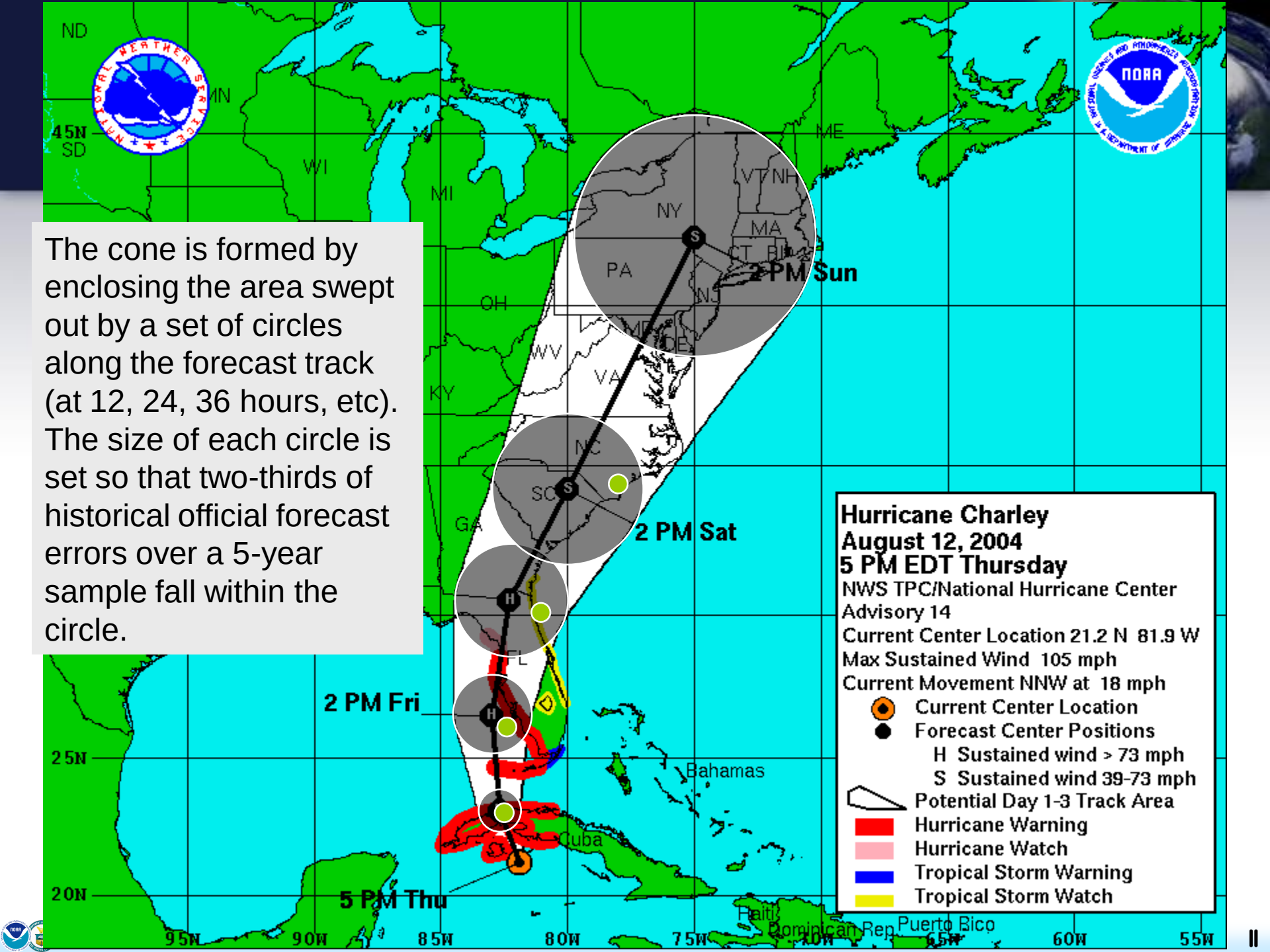

al122005 - KATRINA 2005082512
3012Z 16 30
2812Z 10 145
2512Z 5 55
NGPS
GEMI
UKM2
CLPSGFSI
CONU
GUNA
GUNS
OFCI
OFCL
UKM
NGPI
OHPC
BAMS
BAMM
LBAR
SSE
COA2
AGUK
ATCF
90W
89W
88W
87W
86W
85W
84W
83W
82W
81W
80W
79W
78W
77W
76W
75W
74W
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
27N
26N
25N
24N

Track Guidance
(the squashed spider pattern)
Ophelia 1200 UTC 9 September

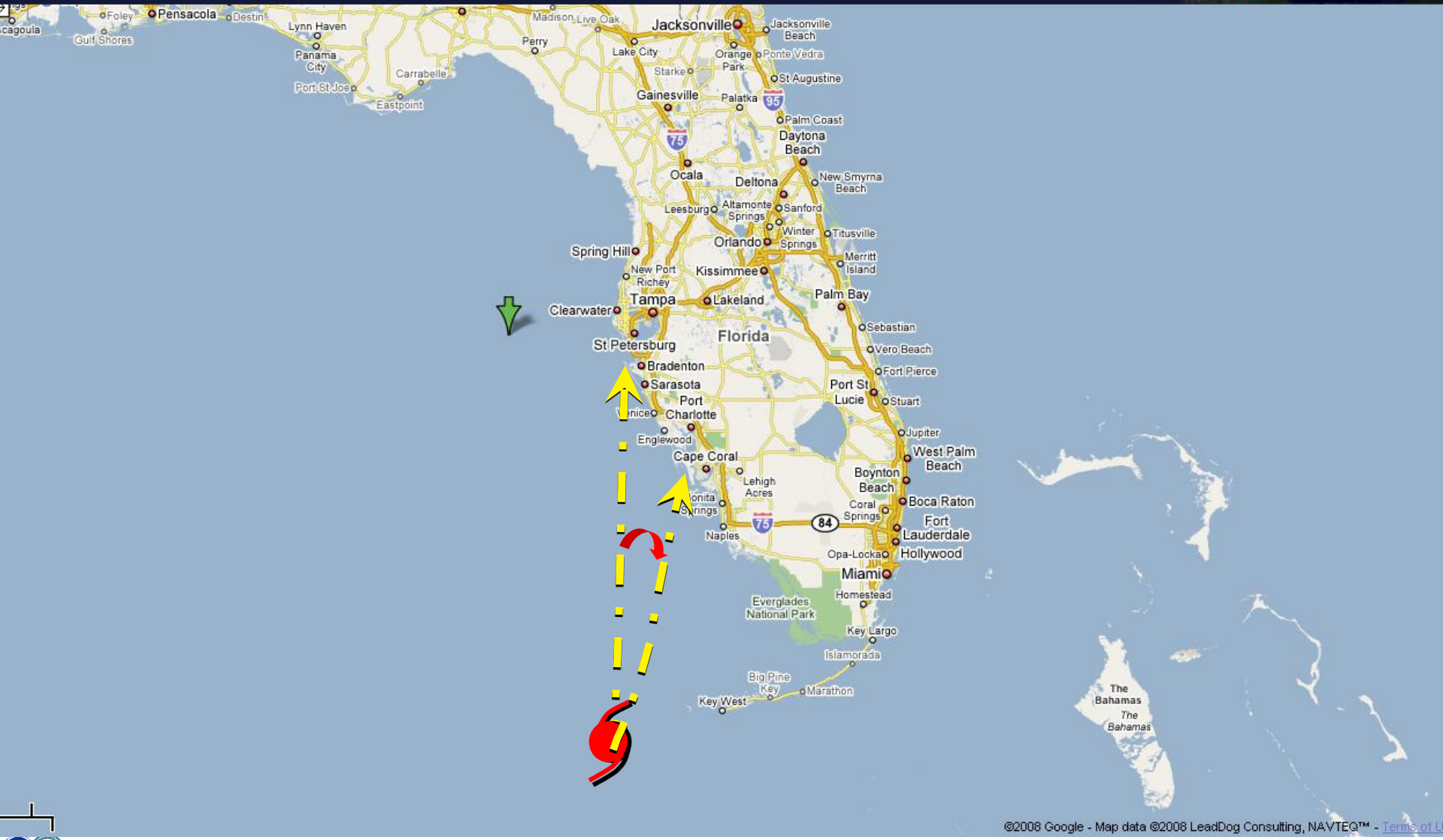


The "Cone of Uncertainty" and the "Skinny Black Line"

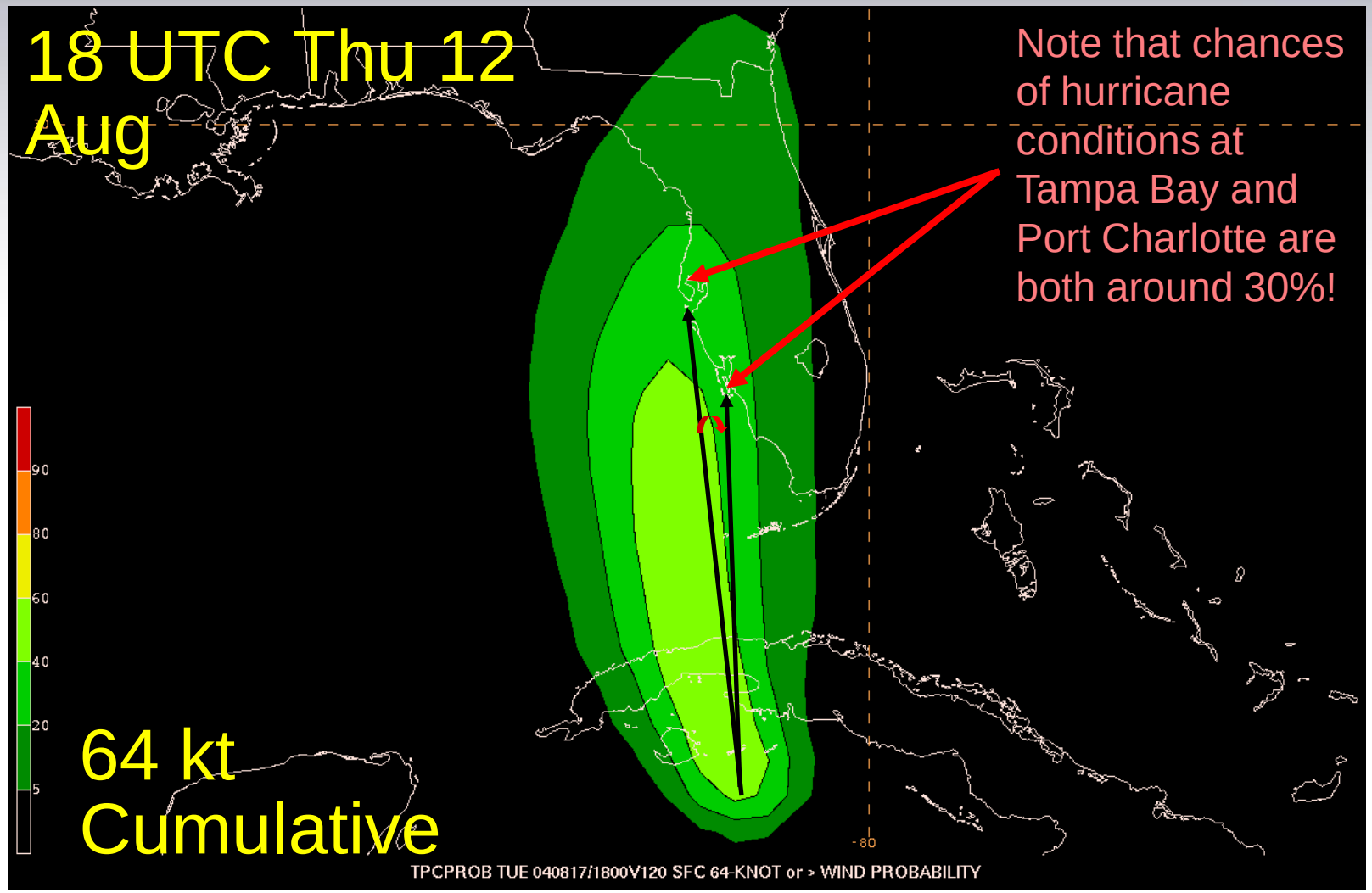



The cone is formed by enclosing the area swept out by a set of circles along the forecast track (at 12, 24, 36 hours, etc). The size of each circle is set so that two-thirds of historical official forecast errors over a 5-year sample fall within the circle.
2 PM Sun
2 PM Sat
2 PM Fri
5 PM Thu
Hurricane 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
ND
MN
SD
WI
MI
ME
VT
NH
NY
MA
CT
RI
PA
NJ
OH
WV
VA
KY
NC
SC
GA
FL
Bahamas
Cuba
Haiti
Dominican Rep.
Puerto Rico
45N
25N
20N
95W
90W
85W
80W
75W
70W
65W
60W
55W

Public Perception of Forecast

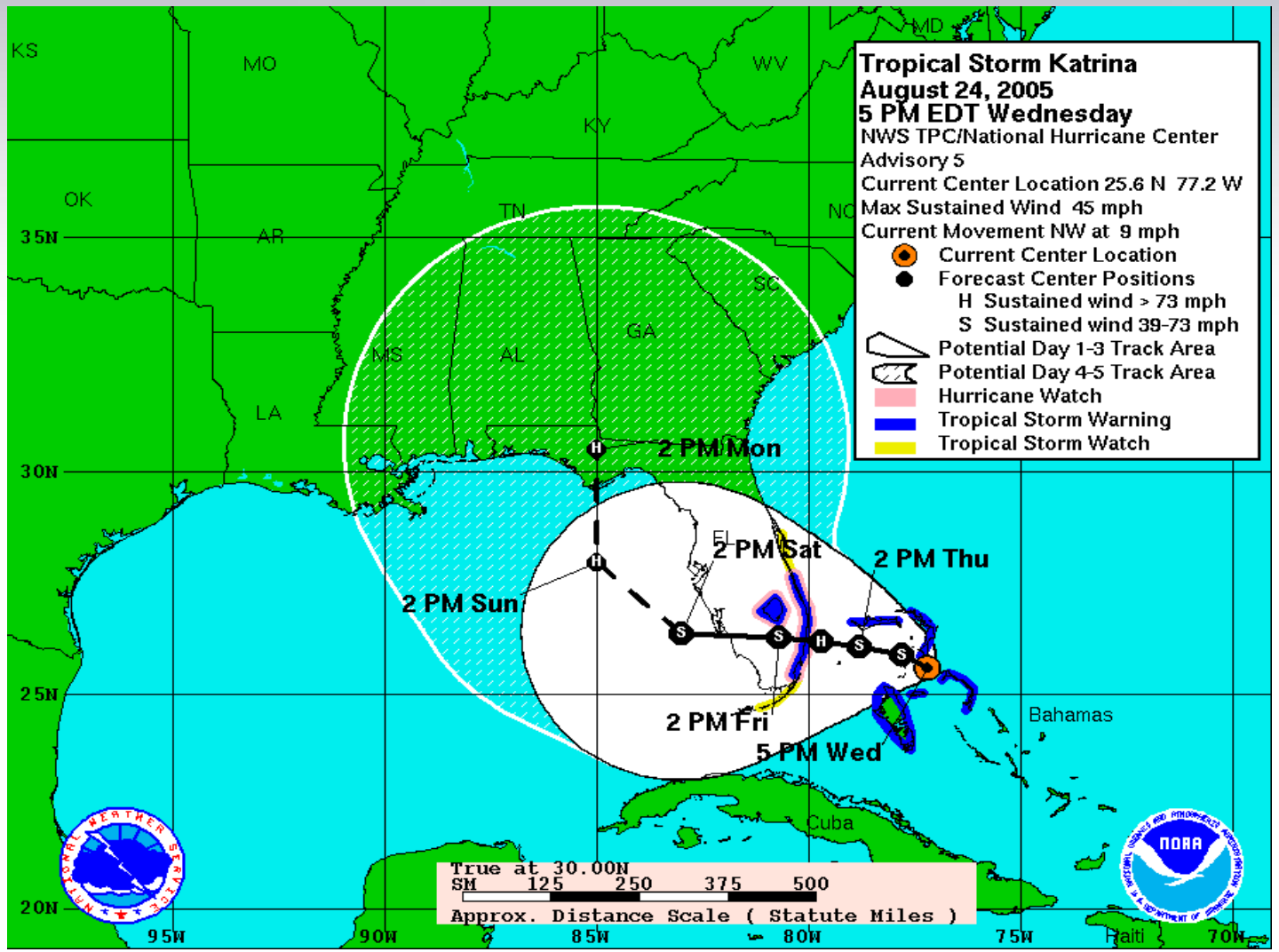


Articulating Track Uncertainty



Hurricane Charley (2004)

Example: Katrina's Landfall in South Florida

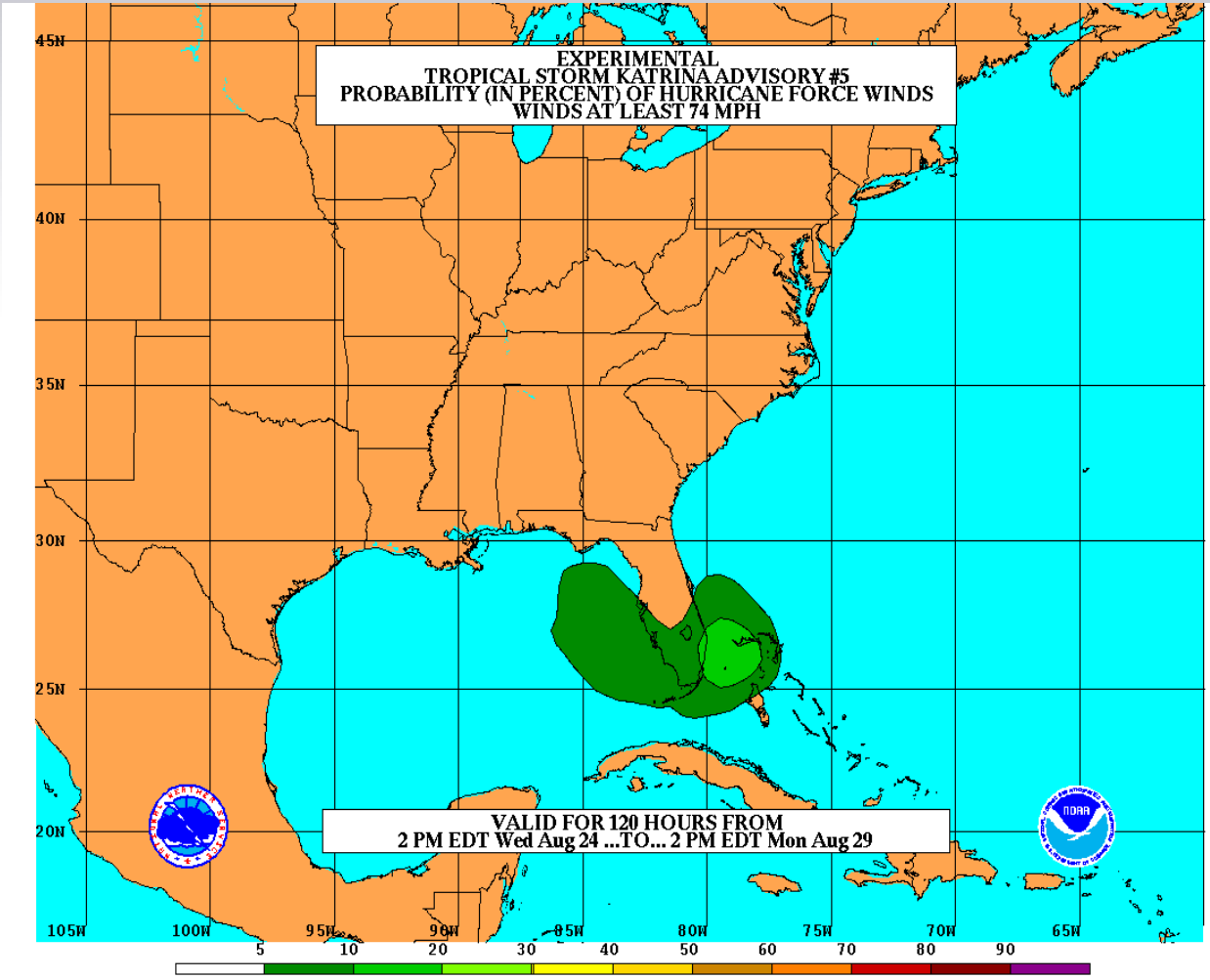


Understanding Probability

- The probability of experiencing hurricane force conditions in South Florida 10-20% yet people were caught off guard. Why?

- The odds of winning the Mega Million dollar lottery are1 in 135,145,920 yet ~50% of Americans play the lottery (AP).

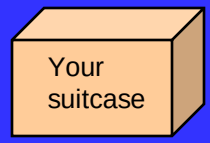
- What percentage of South Florida residents prepared for hurricane conditions? Likely far less than 50%



If you say “No Deal”, there is only a 20% chance of knocking the $1 million case out of play in the next round.

Deal or No Deal?

Bank’s offer $200,000

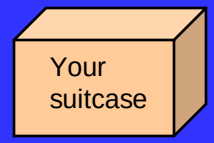


.01	
.10	
1.00	
5.00	
	1,000,000

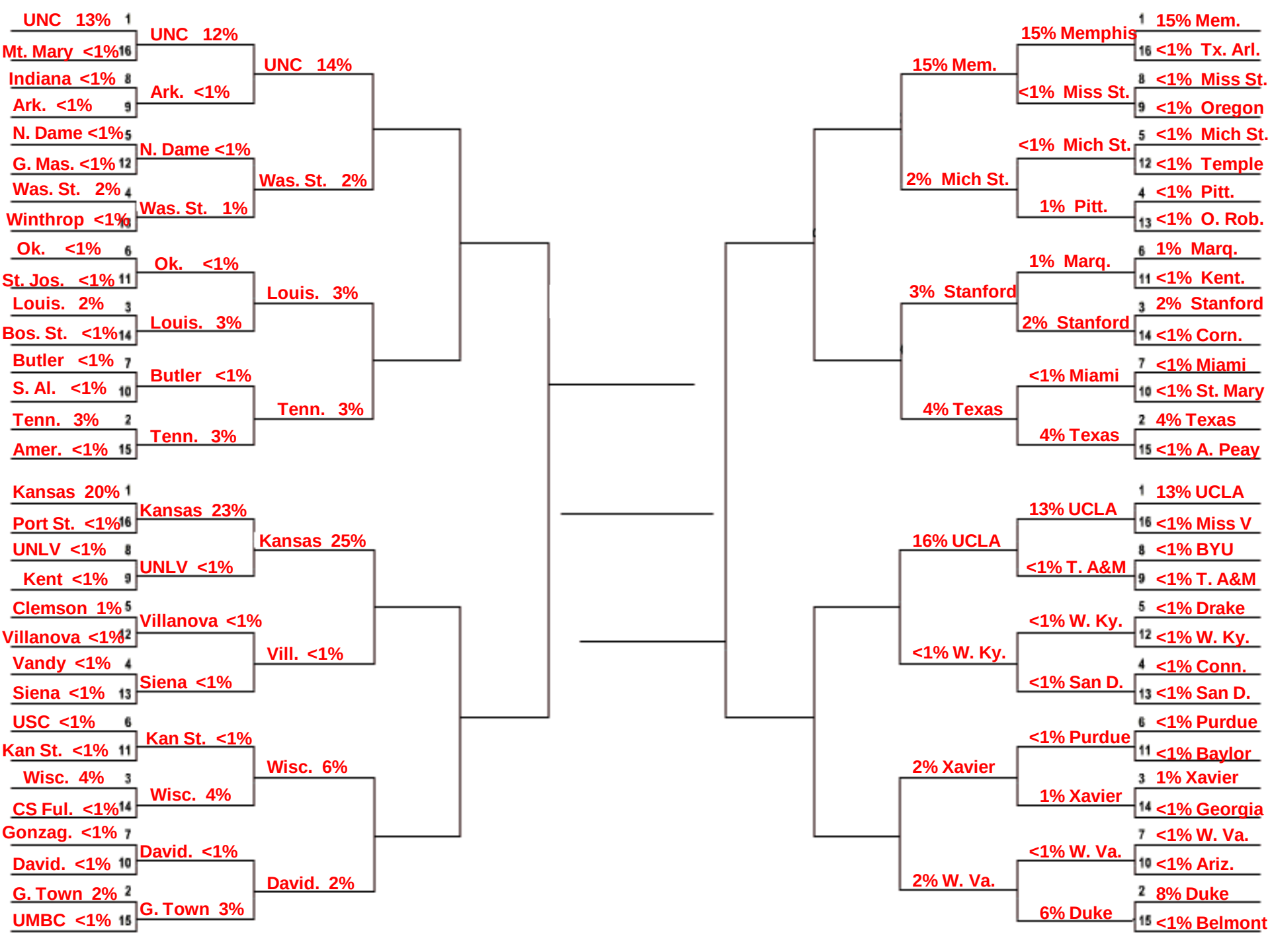
Extreme event!

Deal or No Deal?

Bank's offer $2.50



.01	
.10	
1.00	
5.00	


UNC 13% 1
Mt. Mary <1% 16
Indiana <1% 8
Ark. <1% 9
N. Dame <1% 5
G. Mas. <1% 12
Was. St. 2% 4
Winthrop <1% 13
Ok. <1% 6
St. Jos. <1% 11
Louis. 2% 3
Bos. St. <1% 14
Butler <1% 7
S. Al. <1% 10
Tenn. 3% 2
Amer. <1% 15
Kansas 20% 1
Port St. <1% 16
UNLV <1% 8
Kent <1% 9
Clemson 1% 5
Villanova <1% 12
Vandy <1% 4
Siena <1% 13
USC <1% 6
Kan St. <1% 11
Wisc. 4% 3
CS Ful. <1% 14
Gonzag. <1% 7
David. <1% 10
G. Town 2% 2
UMBC <1% 15
UNC 12%
Ark. <1%
N. Dame <1%
Was. St. 1%
Ok. <1%
Louis. 3%
Butler <1%
Tenn. 3%
Kansas 23%
UNLV <1%
Villanova <1%
Siena <1%
Kan St. <1%
Wisc. 4%
David. <1%
G. Town 3%
UNC 14%
Was. St. 2%
Louis. 3%
Tenn. 3%
Kansas 25%
Vill. <1%
Wisc. 6%
David. 2%
15% Mem.
<1% Miss St.
2% Mich St.
1% Pitt.
1% Marq.
3% Stanford
2% Stanford
<1% Miami
4% Texas
4% Texas
16% UCLA
<1% T. A&M
<1% W. Ky.
<1% San D.
<1% Purdue
2% Xavier
1% Xavier
<1% W. Va.
2% W. Va.
6% Duke
15% Memphis
<1% Mich St.
1% Pitt.
3% Stanford
2% Stanford
<1% Miami
4% Texas
4% Texas
13% UCLA
<1% T. A&M
<1% W. Ky.
<1% San D.
<1% Purdue
2% Xavier
1% Xavier
<1% W. Va.
2% W. Va.
6% Duke
1 15% Mem.
16 <1% Tx. Arl.
8 <1% Miss St.
9 <1% Oregon
5 <1% Mich St.
12 <1% Temple
4 <1% Pitt.
13 <1% O. Rob.
6 1% Marq.
11 <1% Kent.
3 2% Stanford
14 <1% Corn.
7 <1% Miami
10 <1% St. Mary
2 4% Texas
15 <1% A. Peay
1 13% UCLA
16 <1% Miss V
8 <1% BYU
9 <1% T. A&M
5 <1% Drake
12 <1% W. Ky.
4 <1% Conn.
13 <1% San D.
6 <1% Purdue
11 <1% Baylor
3 1% Xavier
14 <1% Georgia
7 <1% W. Va.
10 <1% Ariz.
2 8% Duke
15 <1% Belmont

What Does the Wind Speed Probability Product Tell You?

What are the chances this event is going to happen to me?

- *Do I need to prepare?*
- Cumulative period probabilities
- Graphics and text products

When is the event most likely to start at my location?

- *How much time do I have left to prepare?*
- Individual period probabilities
- Text product

Bottom line: these are *preparedness* products

Interpretation of Text Output

Individual period probabilities (chance that winds of indicated speed will *start* during each period) are *outside* the parentheses

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)

Interpretation of Text Output

Values in last column are same as shown on graphical products

Cumulative probabilities (chances that winds of indicated speed will *occur* between start of forecast and end of each period) are *inside* the parentheses

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)
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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)

Interpretation of Text 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?

34 kt probabilities at Charlotte NC

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)

Interpretation of Text Output

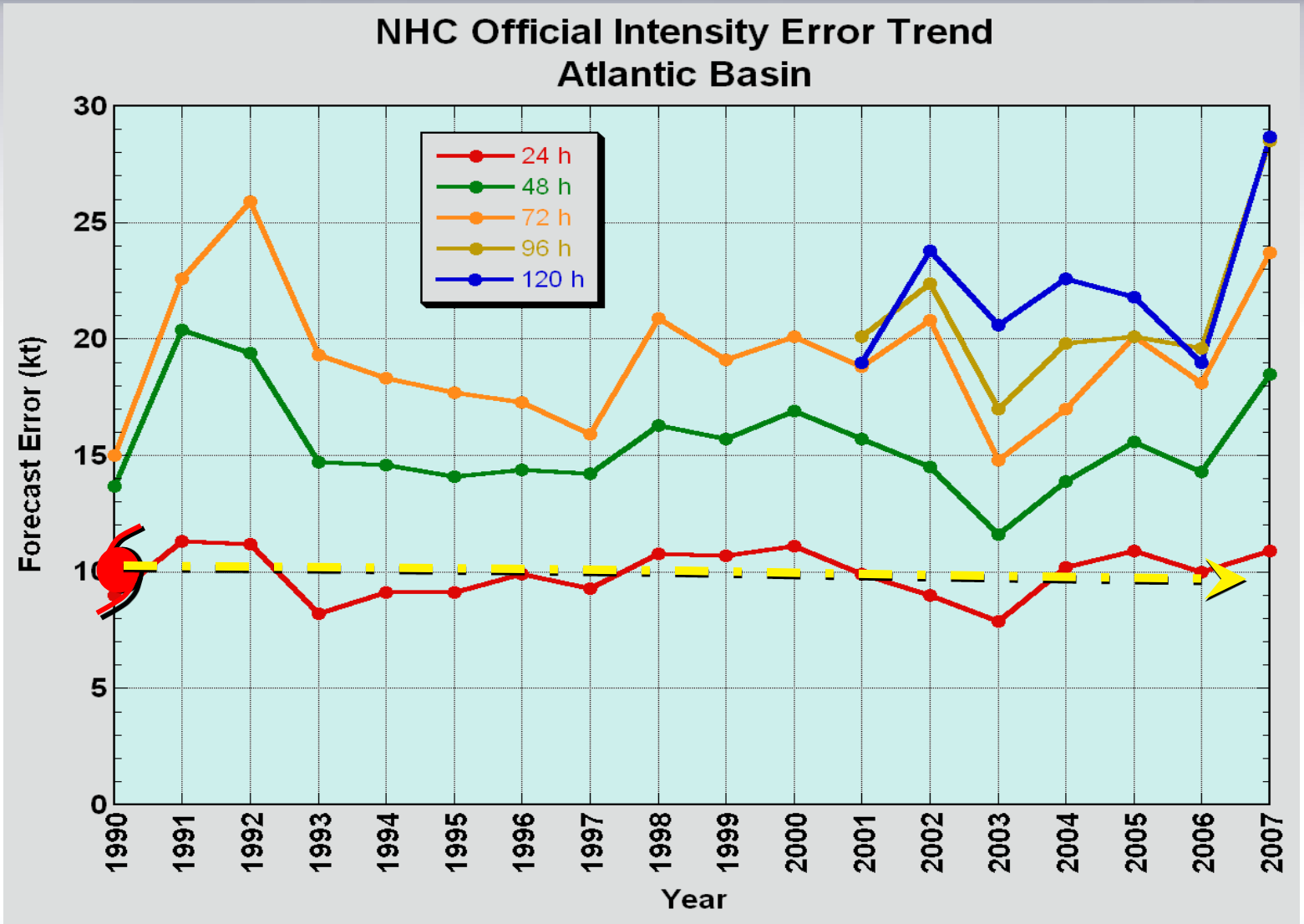
What is the chance that winds of tropical storm force (34 kt or greater) will occur at Charlotte NC during the next five days?

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

No Progress with Intensity



VERIFYING:
160 KNOTS

* ATLANTIC SHIPS INTENSITY FORECAST *
* GOES/OHC INPUT INCLUDED *

WILMA 10/18/05 18 UTC

TIME (HR)	0	6	12	18	24	36	48	60	72	84	96	108	120
V (KT) NO LAND	70	75	81	86	92	100	105	108	109	106	101	92	80
V (KT) LAND	70	75	81	86	92	100	105	108	109	106	101	67	61

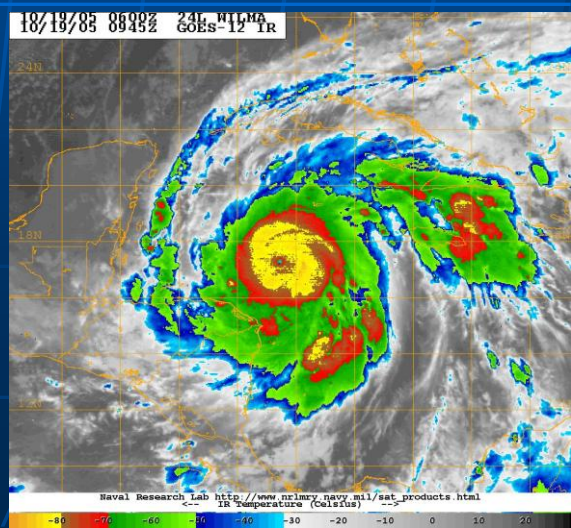
** 2005 ATLANTIC RAPID INTENSITY INDEX **
(25 KT OR MORE MAX WIND INCREASE IN NEXT 24 HR)

WILMA 10/18/05 18 UTC

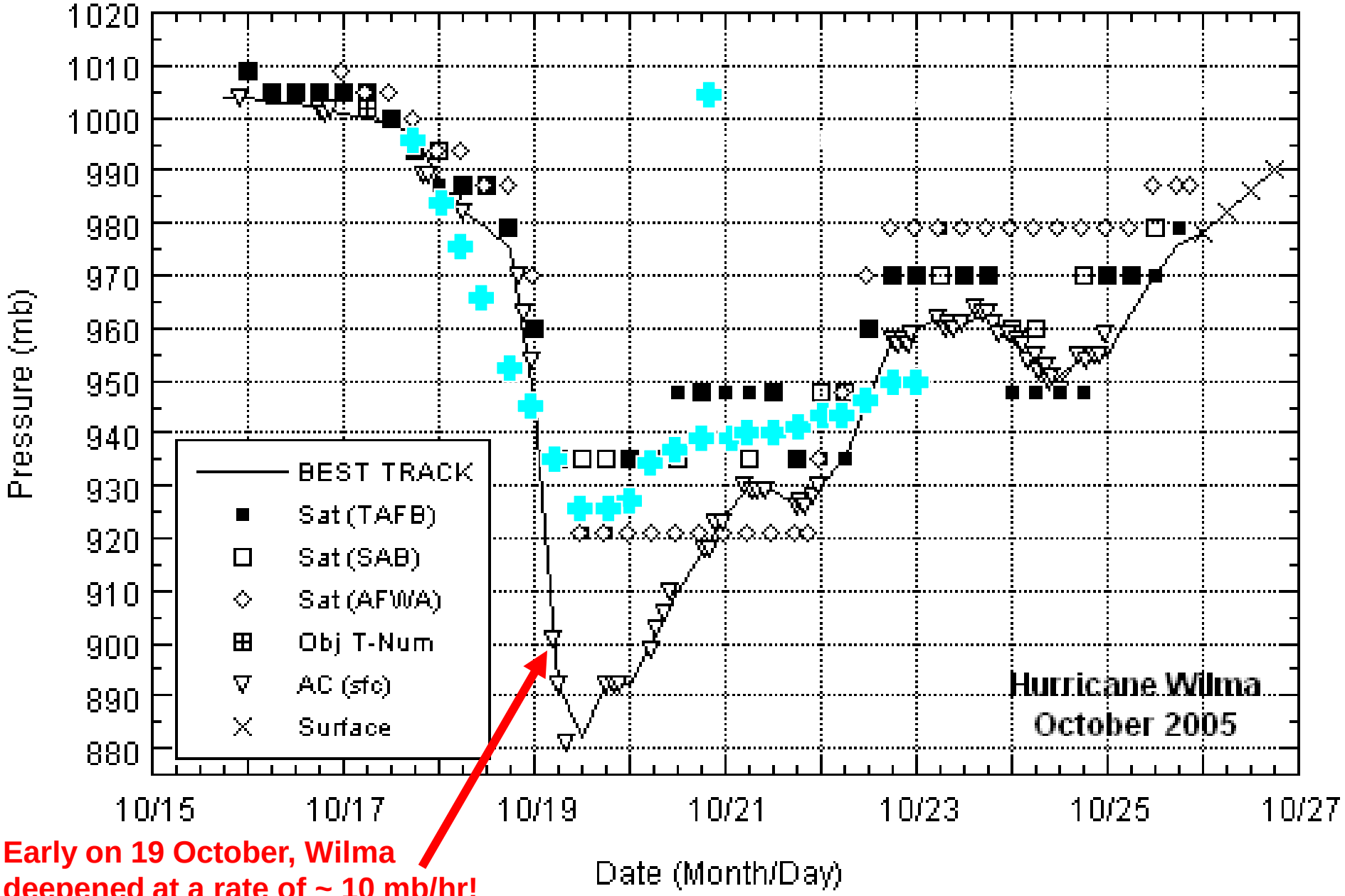
12 HR PERSISTENCE (KT)	Value: 10.0	Range: -20.0 to 25.0	Scaled value:	0.90
850-200 MB SHEAR (KT)	Value: 8.1	Range: 42.5 to 2.5	Scaled value:	0.86
SST (C)	Value: 29.3	Range: 24.3 to 30.4	Scaled value:	0.82
POT = MPI-VMAX (KT)	Value: 92.0	Range: 27.1 to 136.4	Scaled value:	0.59
850-700 MB REL HUM (%)	Value: 81.6	Range: 57.0 to 88.0	Scaled value:	0.79
% area w/pixels <-30 C	Value: 98.0	Range: 17.0 to 100.0	Scaled value:	0.98
STD DEV OF IR BR TEMP	Value: 15.8	Range: 37.5 to 8.0	Scaled value:	0.74

Scaled RI index= 5.68 Prob of RI= 59.4% is 4.9 times the sample mean(12.1%)

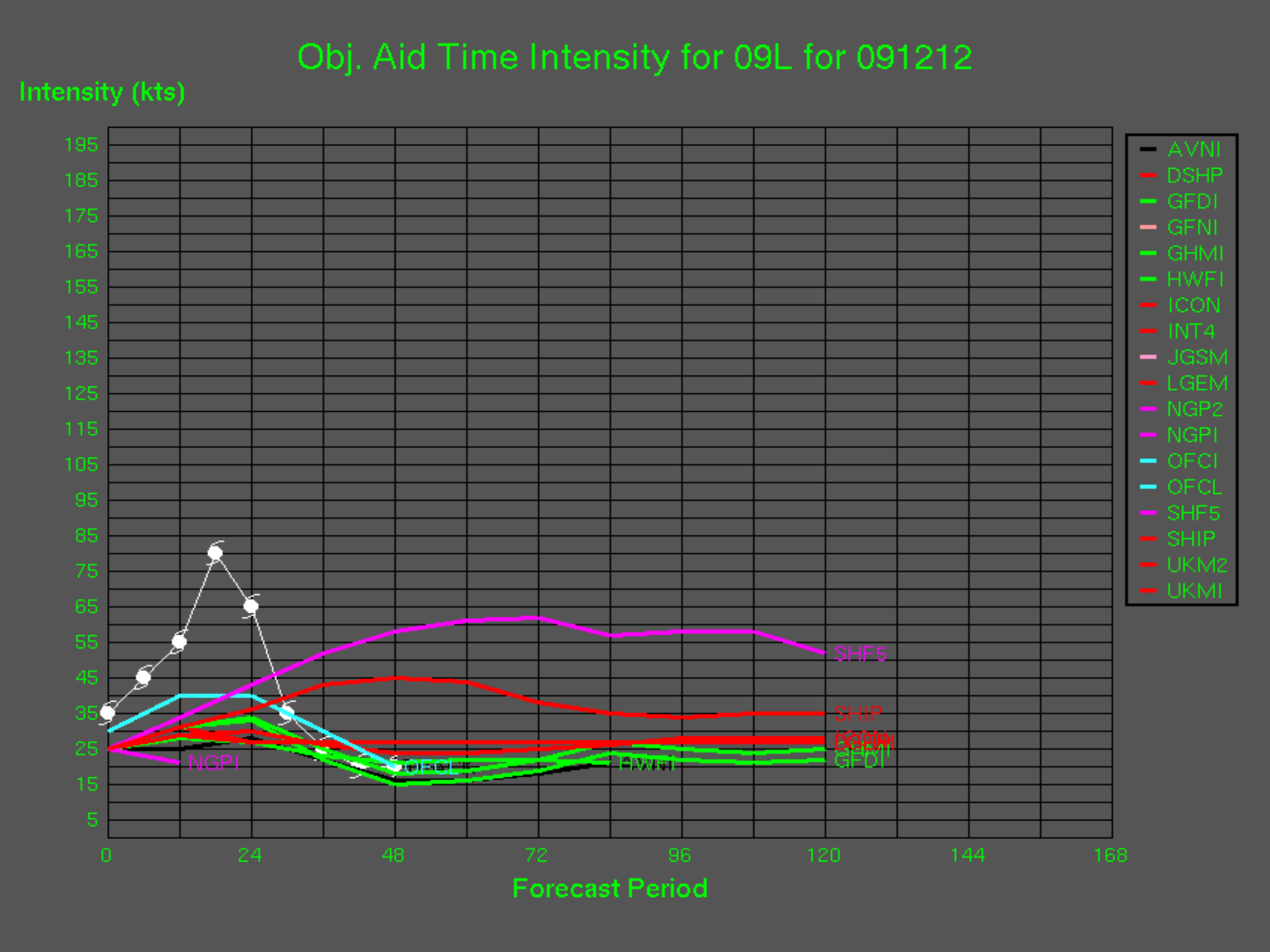
WILMA INTENSIFIED FROM A TROPICAL STORM TO A CAT. 5 HURRICANE IN 24 HOURS!

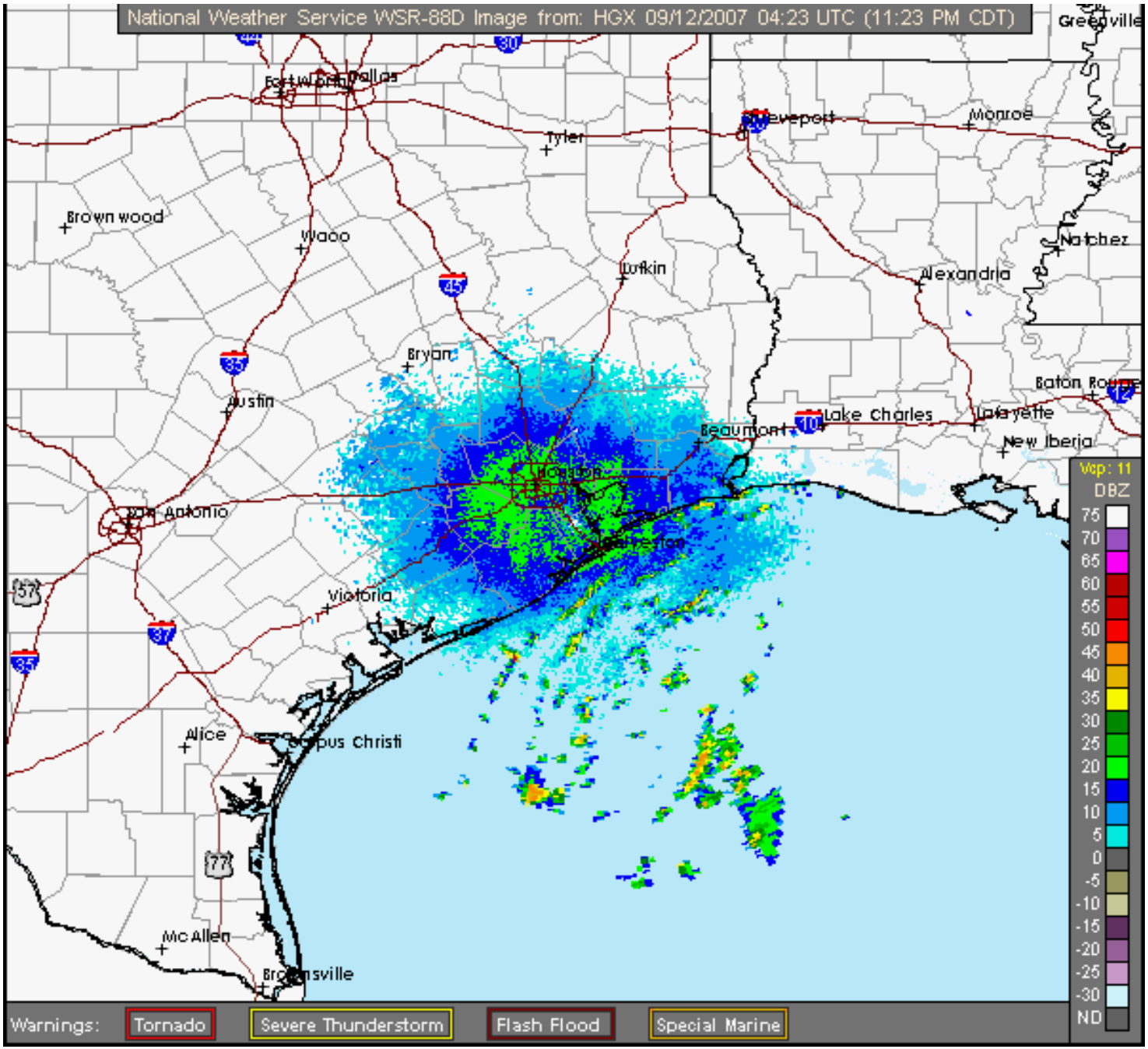


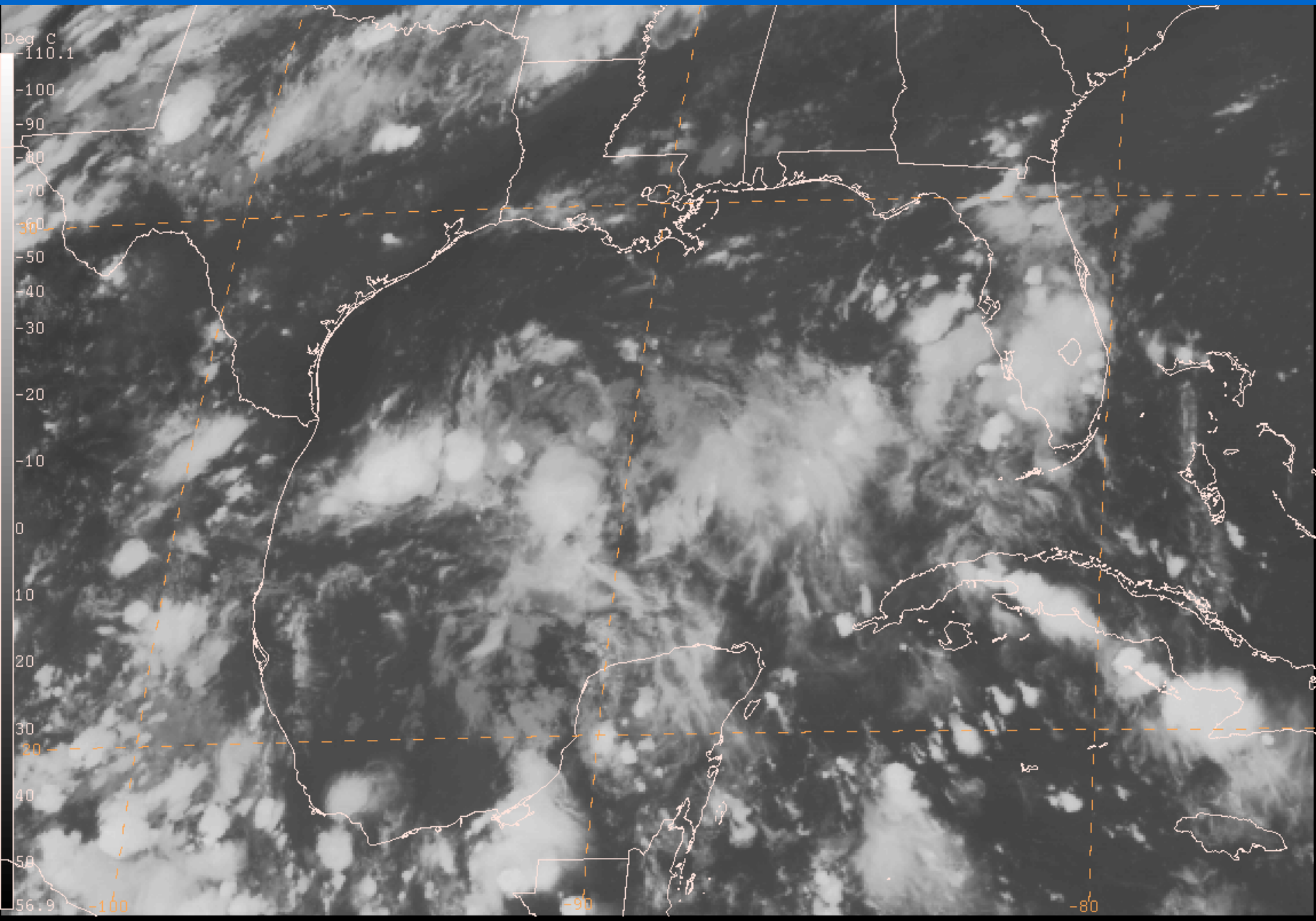
GFDL model did capture some, but hardly all, of Wilma's rapid deepening.



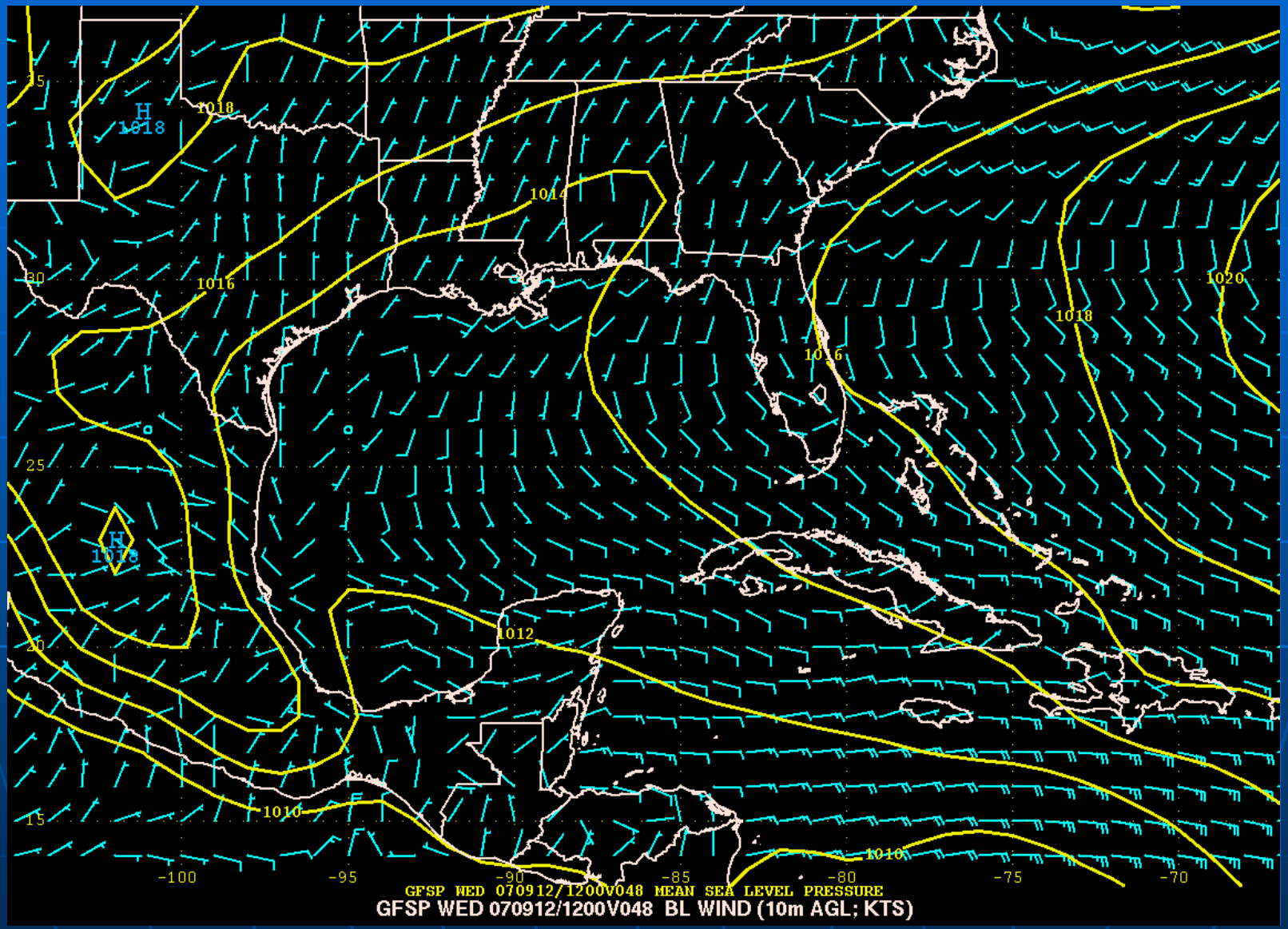
Early on 19 October, Wilma deepened at a rate of ~ 10 mb/hr!


Obj. Aid Time Intensity for 09L for 091212
Intensity (kts)
195
185
175
165
155
145
135
125
115
105
95
85
75
65
55
45
35
25
15
5
0
24
48
72
96
120
144
168
Forecast Period
AVNI
DSHP
GFDI
GFNI
GHMI
HWFI
ICON
INT4
JGSM
LGEM
NGP2
NGPI
OFCI
OFCL
SHF5
SHIP
UKM2
UKMI
SHF5
SHIP
NGPI
OFCL
AVNI
GFDI


National Weather Service WSR-88D Image from: HGX 09/12/2007 04:23 UTC (11:23 PM CDT)
Greenville
Shreveport
Monroe
Tyler
Brownwood
Waco
Natchez
Lufkin
Alexandria
Bryan
Austin
Baton Rouge
Lake Charles
Lafayette
Beaumont
New Iberia
San Antonio
Houston
Victoria
Alice
Corpus Christi
McAllen
Brownsville
Vcp: 11
DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
ND
Warnings:
Tornado
Severe Thunderstorm
Flash Flood
Special Marine

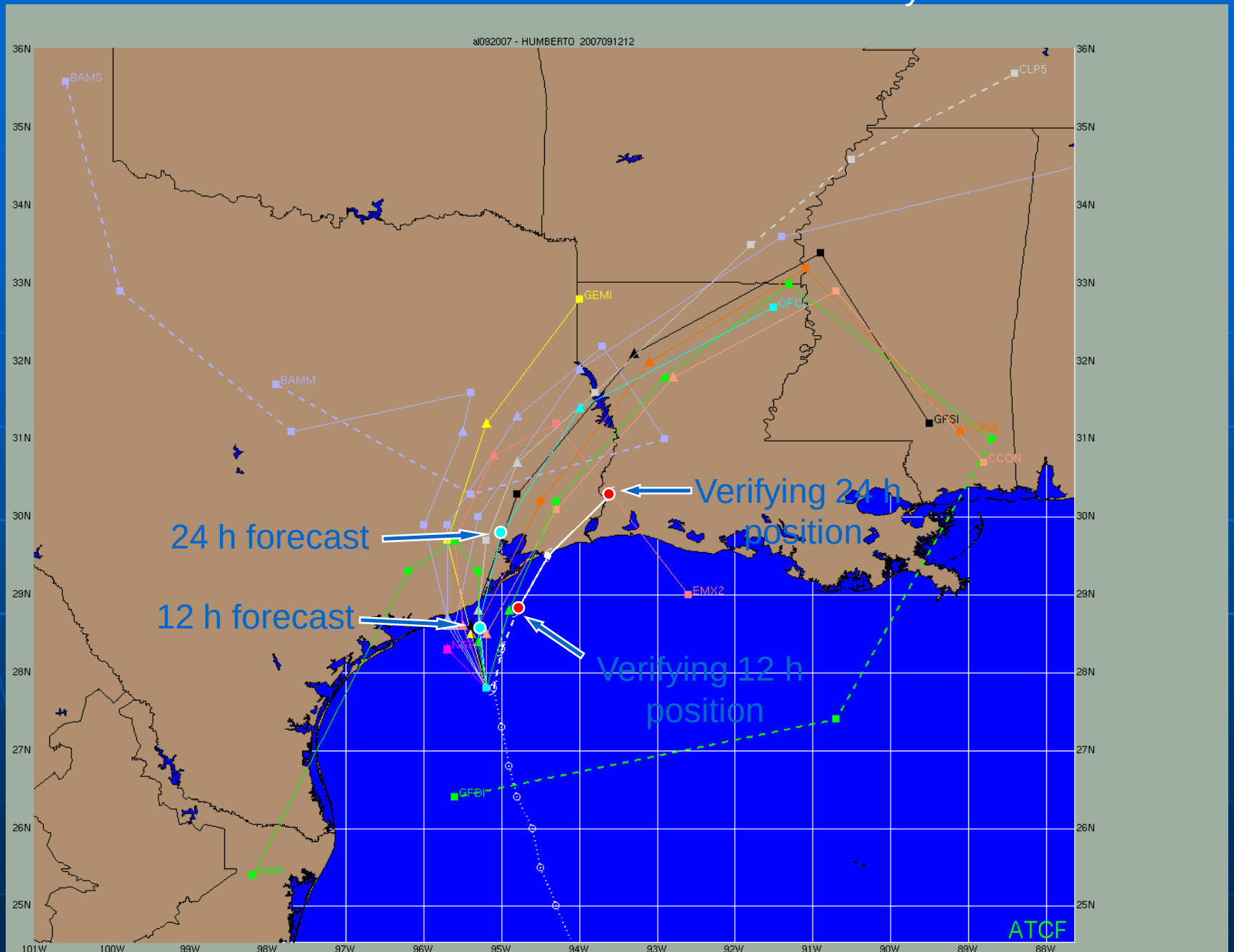

Deg C
-110.1
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
56.9
-100
-90
-80
070910/2345 GOES12 IR4

GFS 48-H SEA-LEVEL PRES. FCST FROM 9/10/07 1200 UTC



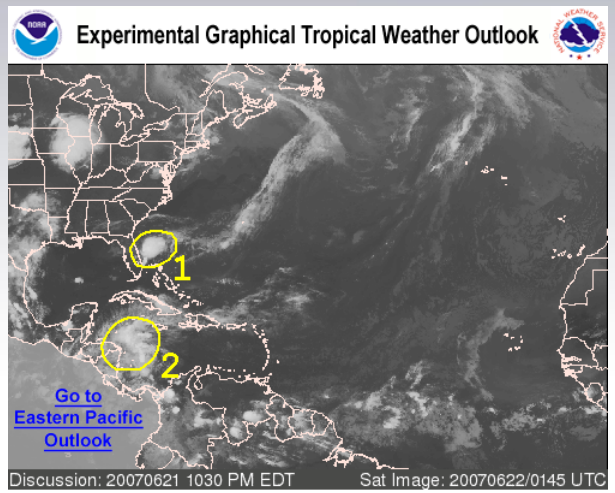
THE GFS FAILED TO DEPICT THE GENESIS OF HURRICANE HUMBERTO

Humberto Track Guidance For First Advisory

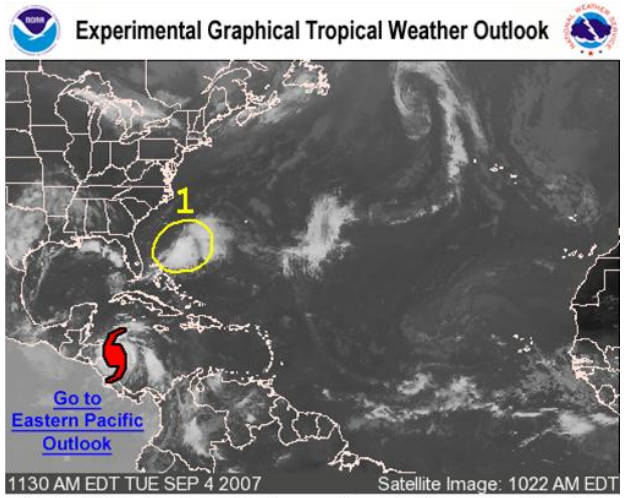


The Graphical Tropical Weather Outlook

- A visual companion product to the text Tropical Weather Outlook
- A web-based graphic superimposed on the most recently available geostationary satellite mosaic of the GOES-East, GOES-West, and Meteosat 9 satellites
- Indicates the ***current*** locations of areas of disturbed weather discussed in the TWO by encircling them. No indication of motion or forecast
- Active tropical cyclones are also shown on the Graphical TWO in the form of a cyclone symbol



The highlighted and numbered areas, if any, indicate current locations of weather systems discussed in the Tropical Weather Outlook below.



The highlighted and numbered areas, if any, indicate current locations of weather systems discussed in the Tropical Weather Outlook below.

GTWO Changes for 2008

1. Move the issuance times of the operational text Tropical Weather Outlook (TWO) and the experimental graphical TWO for both the Atlantic and East Pacific basins to synoptic time.

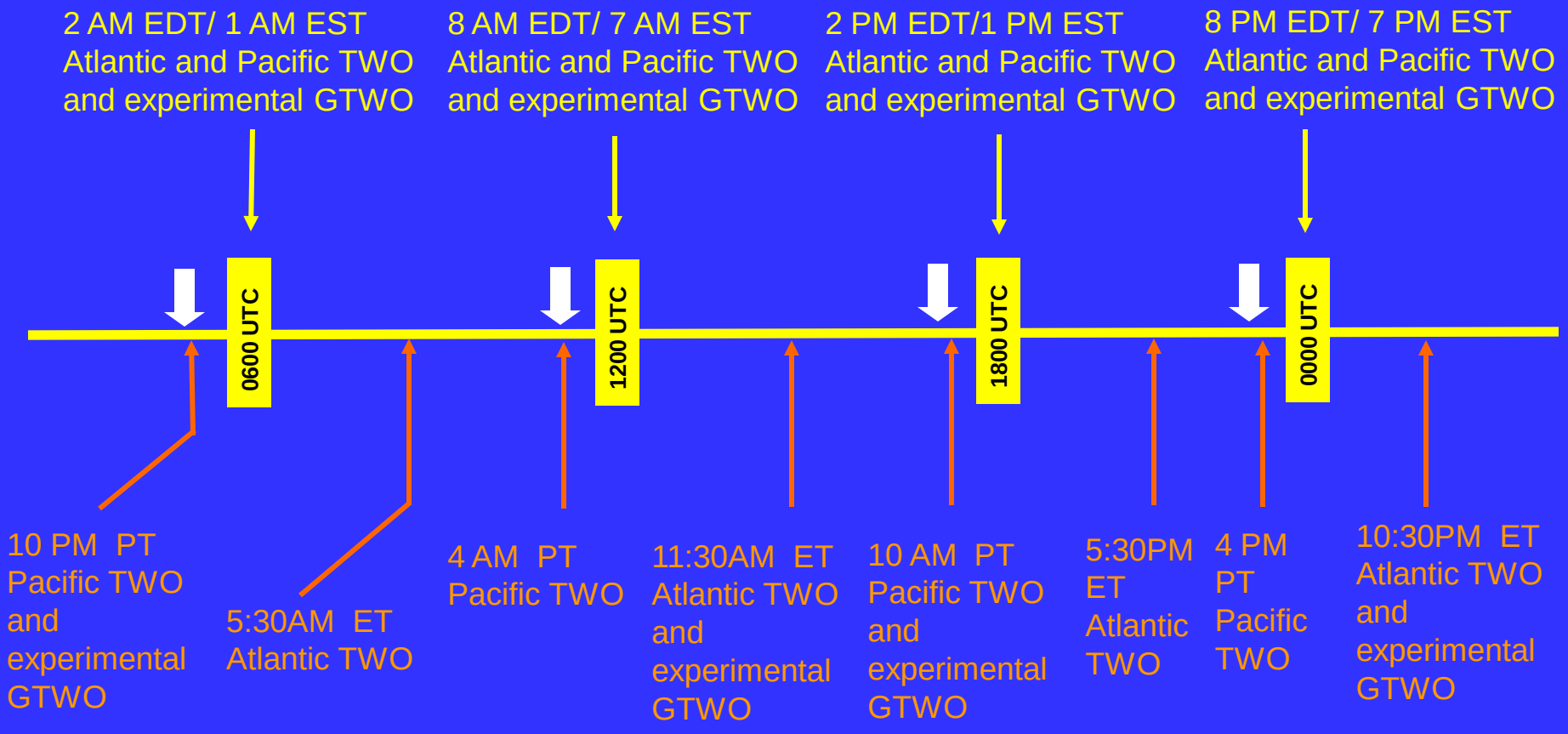
2. Increase the availability of the graphical TWO from two times daily to four times daily.

3. Include 3-tiered categorical genesis forecasts (color-coding) in the experimental graphical TWO.

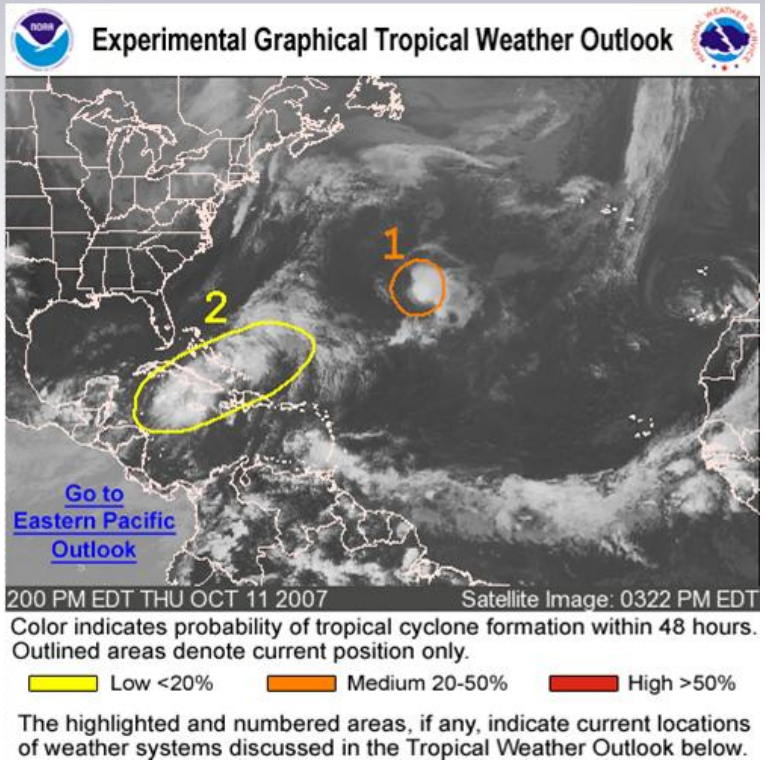
-Low-probability of genesis less than 20%
-Medium-probability of genesis between 20-50%
-High-probability of genesis greater than 50%

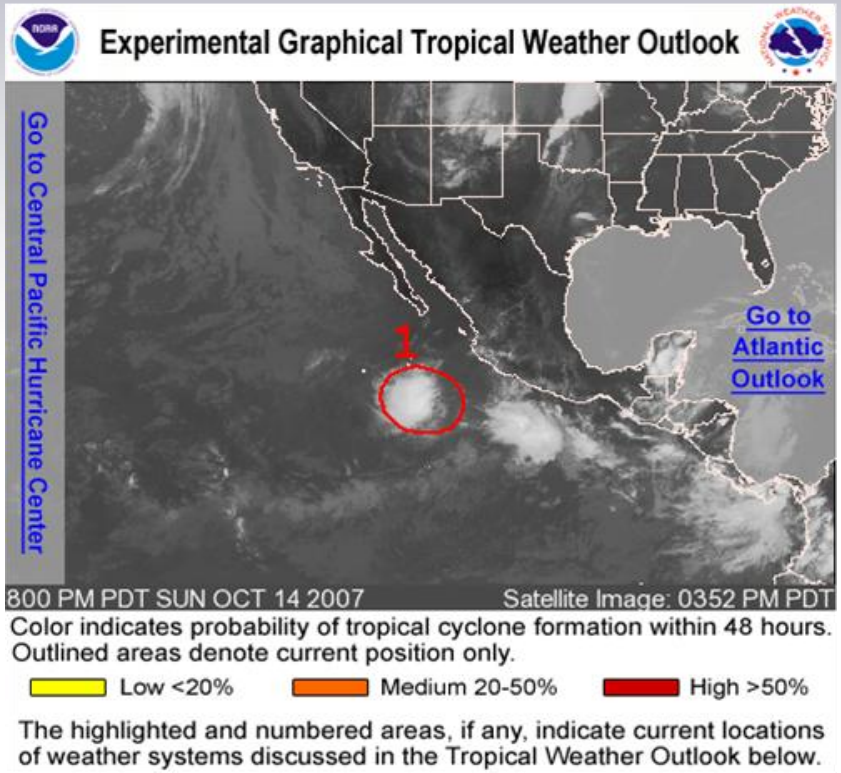
New 2008 TWO and GTWO Issuance Times Shown in Yellow with Old 2007 Issuance Times Shown in Orange

indicates approximate arrival time of numerical model guidance



2008 GTWO





[Example 1 Graphical Tropical Weather Outlook.htm]

[Example 2 Graphical Tropical Weather Outlook.htm]

The (THEY) Effect

Those Hurricane Expert Yahoos

They say its coming here

They say its going to miss us

They say its going to be bad

They say its not going to be bad

They say it could be windy

They say it will rain a lot