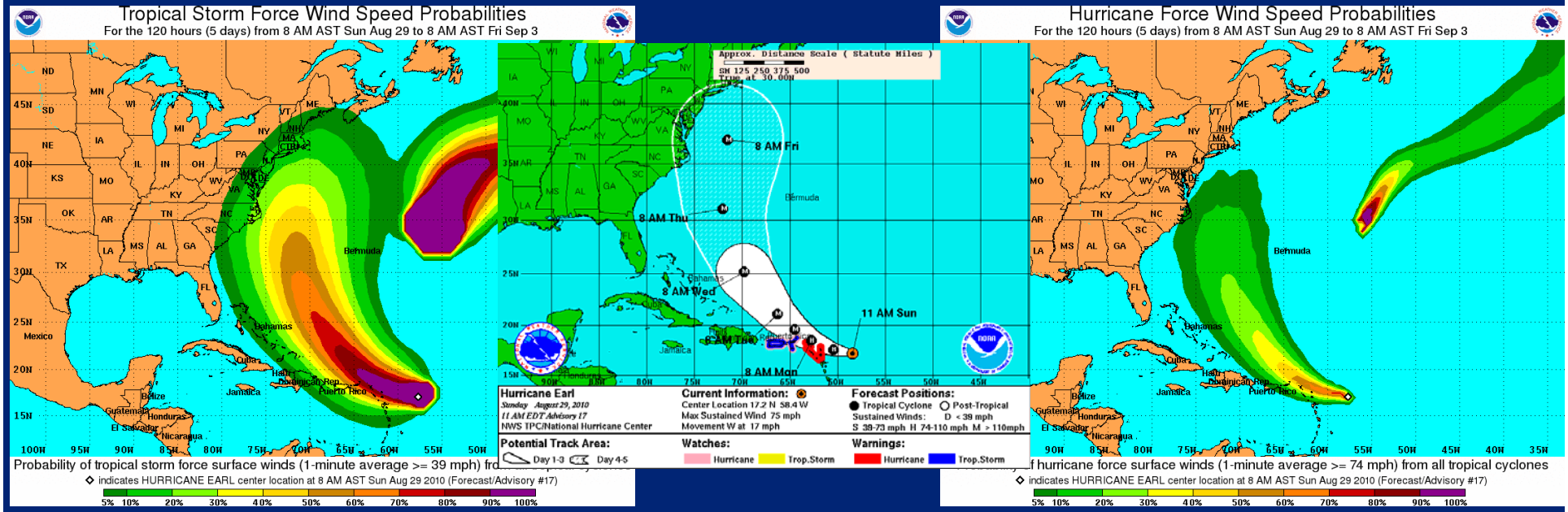
Wind Speed and Intensity Probabilities



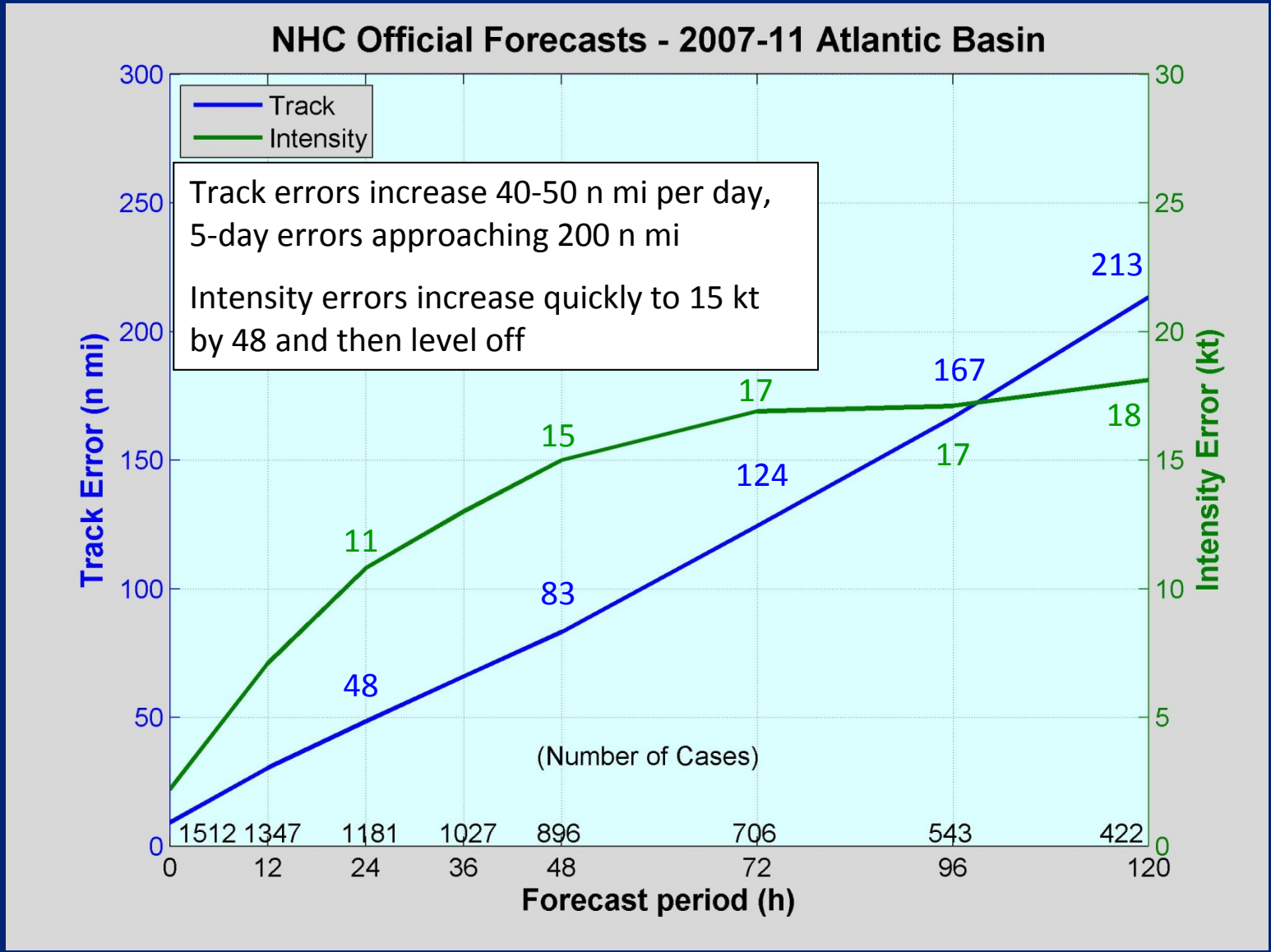
Daniel P. Brown

National Hurricane Center

L311 Course for Coastal Communities

25 March 2013

Atlantic 5-Year Mean NHC Forecast Errors

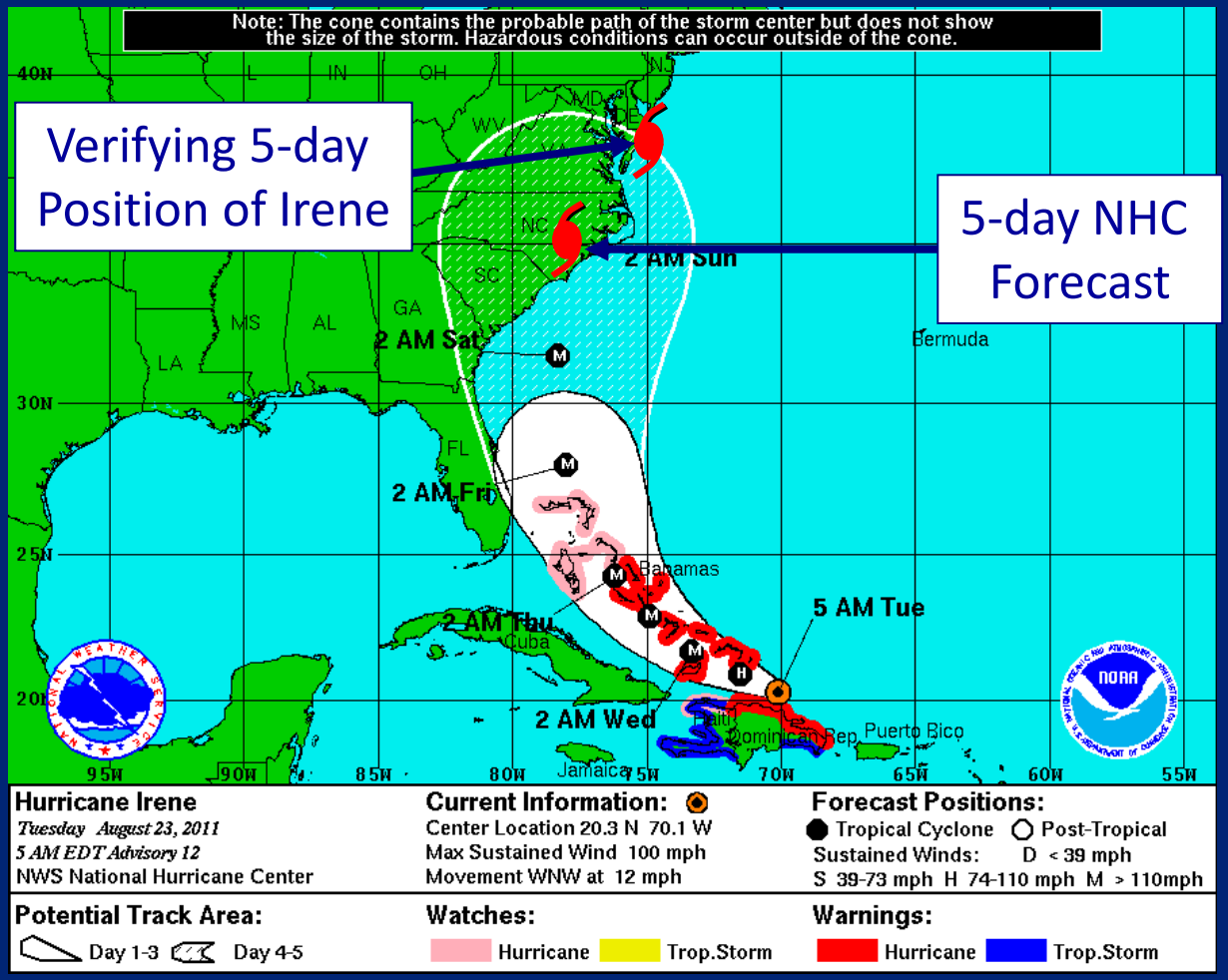


How Can You, as Decision Makers, Deal with Forecast Uncertainty?

Tropical Storm Irene
Advisory Number 12

Issued 5:00 AM EDT
23 August 2011

5-day position error about 270 miles

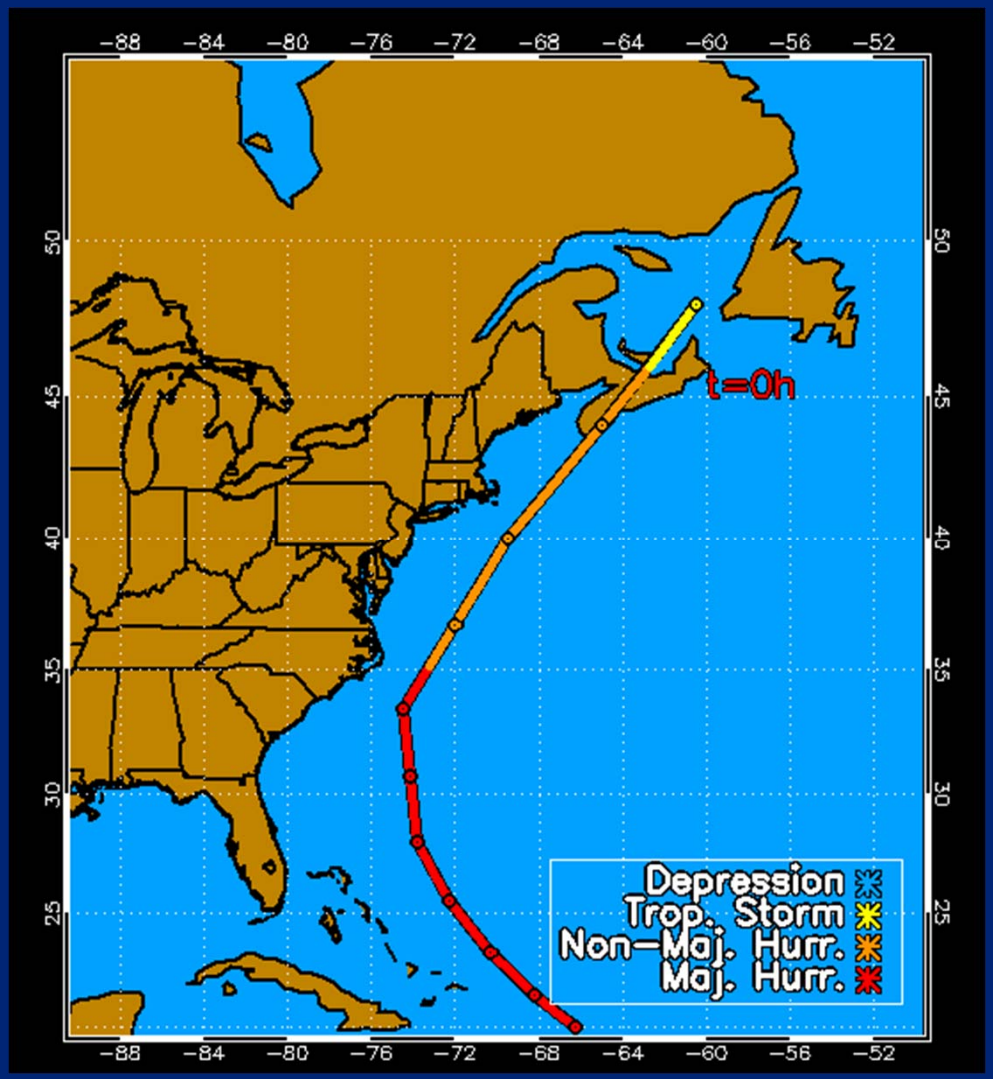


NHC probability products can help

Overview of Wind Speed Probability Products

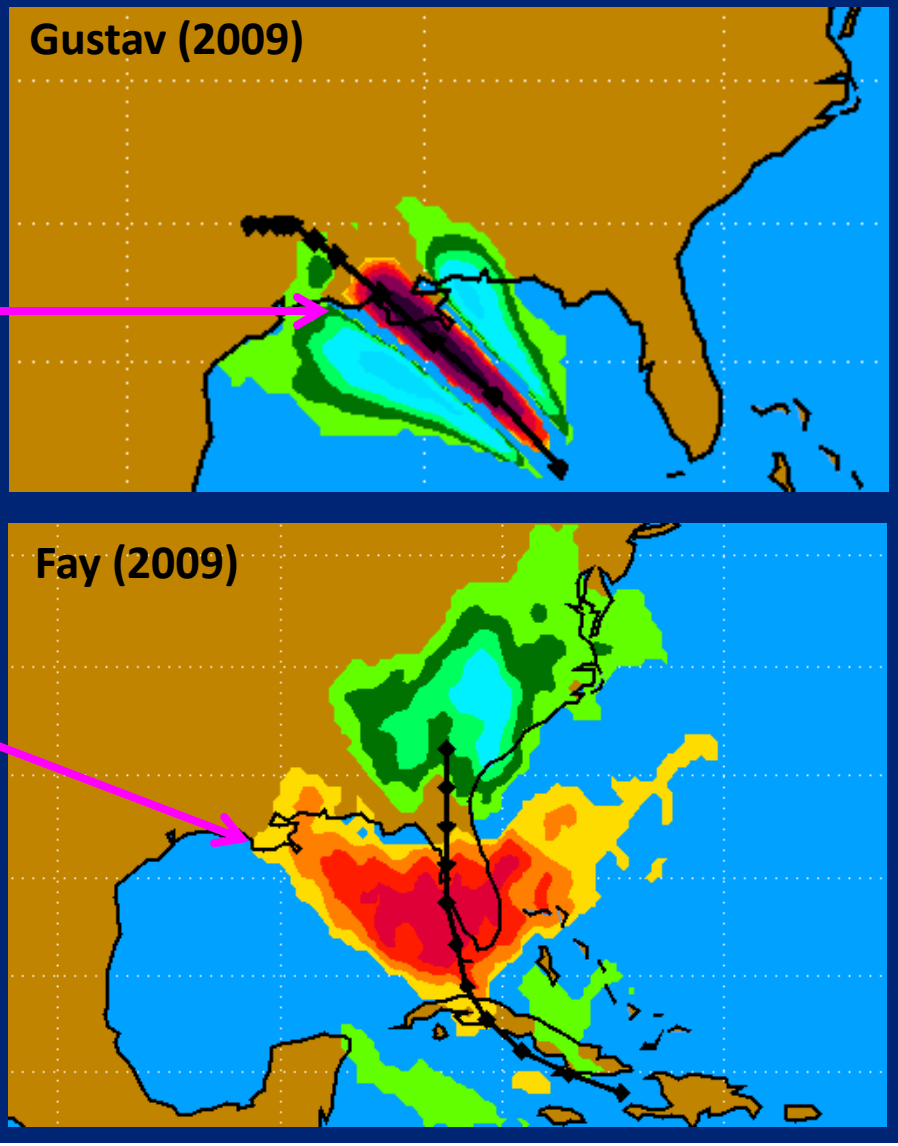
How the Wind Speed/Intensity Probabilities are Created

- 1,000 realistic alternative scenarios created using
  - Official NHC track, intensity and wind radii forecasts
  - Historical NHC track and intensity forecast errors
  - Climatology and persistence wind radii model
- Probability of exceeding 34, 50, and 64 kt wind thresholds computed
- Accounts for inland wind decay



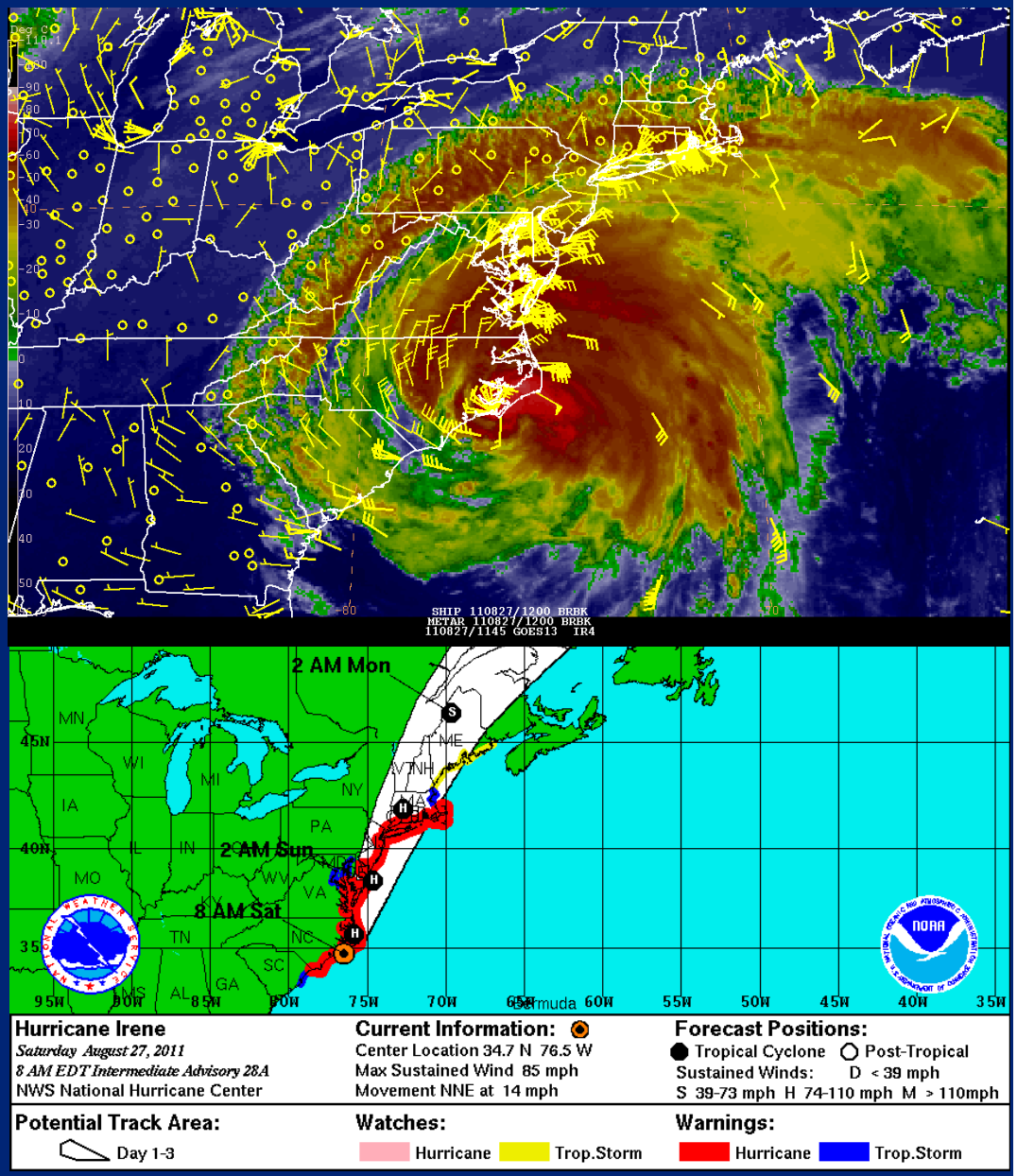
Influence of Track Forecast Uncertainty on Probability Products

- Different historical NHC track forecast errors are sampled depending on how much spread (disagreement) there is in the track model guidance
- If track model spread is small (good model agreement)
  - Probability swath will be narrower with higher probabilities along the official NHC forecast track and lower values along the edges
- If track model spread is large (poor model agreement)
  - Probability swath will be wider, with lower values along the NHC official forecast track and a wider area of low probabilities along the edges



Impacts Can be Felt Well Outside the Cone

- The cone only displays information about track uncertainty
- It contains no information about impacts!
- Impacts can occur well outside the area enclosed by the cone
  - Storm center is expected to move outside the cone about 1/3 of the time
  - Cone narrows near the time of greatest impact due to decreasing official track forecast errors

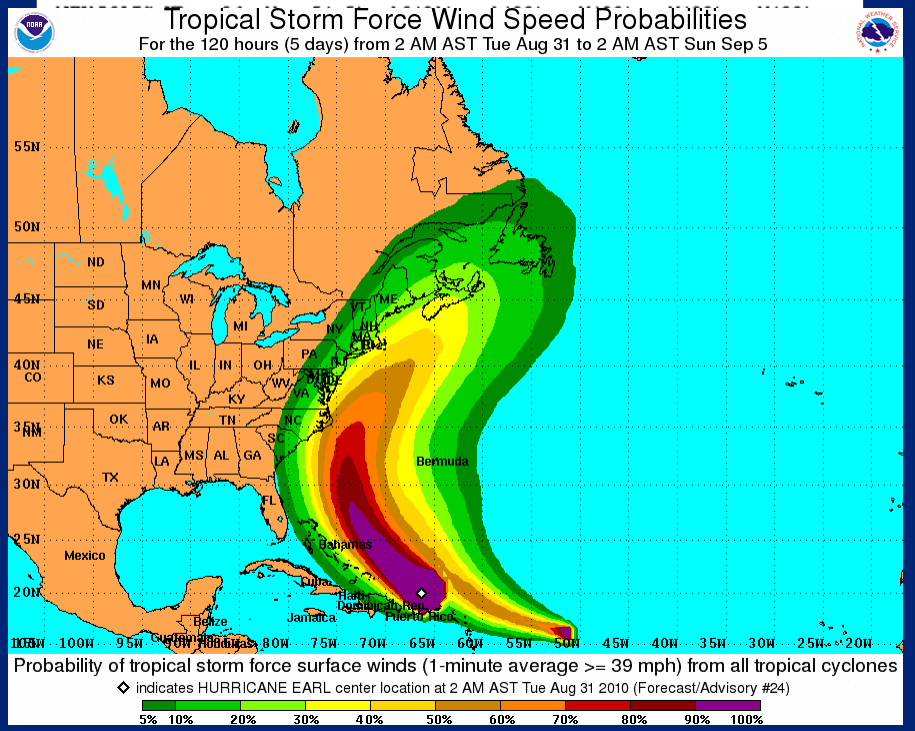


Available Probability Products

1. Wind Speed Probability Product

- Depicts location-specific probabilities for 34-kt (TS-force), 50-kt (58-mph), and 64-kt (hurricane-force) winds
- Text product contains cumulative and individual time period onset probabilities for a fixed set of locations
- Graphic depicts cumulative probabilities for points over a large domain

NEW YORK CITY	34	X	1(1)	32(33)	11(44)	X(44)	X(44)	X(44)
NEW YORK CITY	50	X	X(X)	3(3)	6(9)	X(9)	X(9)	X(9)
NEW YORK CITY	64	X	X(X)	1(1)	1(2)	X(2)	X(2)	X(2)
NEWARK NJ	34	X	X(X)	26(26)	9(35)	X(35)	X(35)	X(35)
NEWARK NJ	50	X	X(X)	2(2)	3(5)	X(5)	X(5)	X(5)
TRENTON NJ	34	X	1(1)	25(26)	6(32)	X(32)	X(32)	X(32)
TRENTON NJ	50	X	X(X)	3(3)	1(4)	X(4)	X(4)	X(4)
ATLANTIC CITY	34	X	4(4)	44(48)	3(51)	X(51)	X(51)	X(51)
ATLANTIC CITY	50	X	X(X)	9(9)	2(11)	X(11)	X(11)	X(11)
ATLANTIC CITY	64	X	X(X)	3(3)	1(4)	X(4)	X(4)	X(4)
BALTIMORE MD	34	X	3(3)	14(17)	1(18)	X(18)	X(18)	X(18)
DOVER DE	34	X	7(7)	29(36)	2(38)	X(38)	X(38)	X(38)
DOVER DE	50	X	X(X)	6(6)	1(7)	X(7)	X(7)	X(7)
DOVER DE	64	X	X(X)	1(1)	X(1)	X(1)	X(1)	X(1)



Available Probability Products

2. Intensity Probability Table

- Shows probability of tropical cyclone intensity (maximum wind) falling in various categories
- Tropical depression, tropical storm, hurricane, and Saffir-Simpson Hurricane Wind Scale categories 1-5
- Available at the top of the wind speed probability text product and as a stand-alone graphic

```
I.  MAXIMUM WIND SPEED (INTENSITY) PROBABILITY TABLE

CHANCES THAT THE MAXIMUM SUSTAINED (1-MINUTE AVERAGE) WIND SPEED OF
THE TROPICAL CYCLONE WILL BE WITHIN ANY OF THE FOLLOWING CATEGORIES
AT EACH OFFICIAL FORECAST TIME DURING THE NEXT 5 DAYS.
PROBABILITIES ARE GIVEN IN PERCENT.  X INDICATES PROBABILITIES LESS
THAN 1 PERCENT.


      - - - MAXIMUM WIND SPEED (INTENSITY) PROBABILITIES - - -

VALID TIME   06Z THU 18Z THU 06Z FRI 18Z FRI 18Z SAT 18Z SUN 18Z MON
FORECAST HOUR   12      24      36      48      72      96     120
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
DISSIPATED       X       X       X       X       9      26      NA
TROP DEPRESSION  X       X       X       1      17      33      NA
TROPICAL STORM   X       X       3      17      53      36      NA
HURRICANE       99      99      97      81      20       4      NA
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
HUR CAT 1        X       5      23      42      16       4      NA
HUR CAT 2        2      21      37      23       3       1      NA
HUR CAT 3       63      56      30      12       1       X      NA
HUR CAT 4       34      17       7       3       X       X      NA
HUR CAT 5        1       1       1       X       X       X      NA
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
FCST MAX WIND  115KT   110KT   100KT    90KT    60KT    40KT    NA
```

Intensity (Maximum Wind Speed) Probability Table
Hurricane Earl Advisory Number 25
11:00 AM AST Aug 31 2010

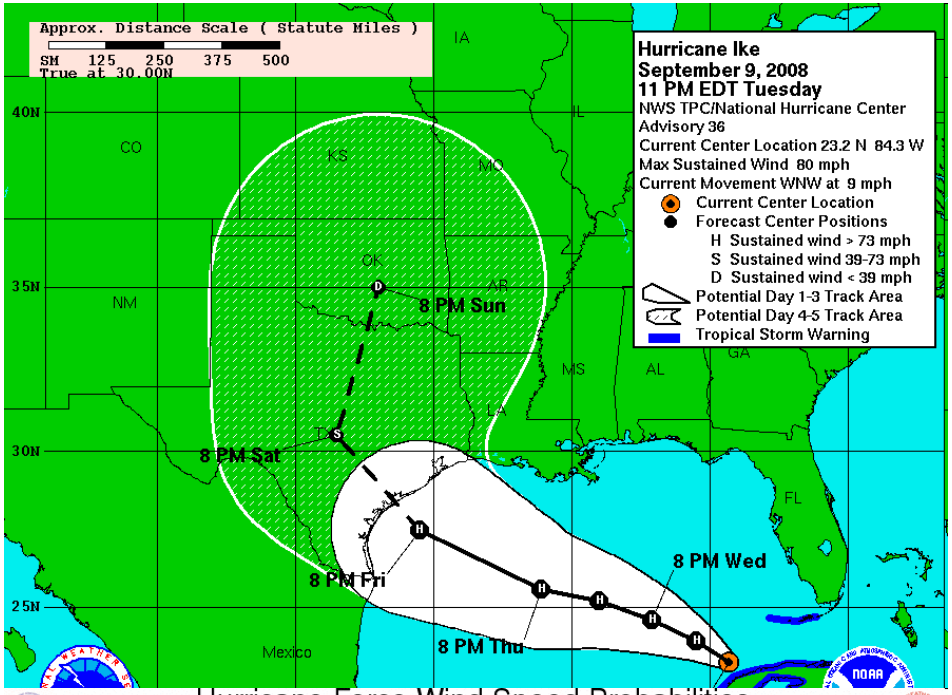
	Forecast Time						
Wind Range (mph)	12 hour for 8 PM Tue	24 hour for 8 AM Wed	36 hour for 8 PM Wed	48 hour for 8 AM Thu	72 hour for 8 AM Fri	96 hour for 8 AM Sat	120 hour for 8 AM Sun
Dissipated	<1%	<1%	<1%	<1%	1%	6%	15%
Tropical Depression (<39)	<1%	<1%	<1%	<1%	2%	11%	13%
Tropical Storm (39-73)	<1%	<1%	1%	2%	19%	44%	43%
Hurricane (all categories)	99%	99%	99%	98%	78%	39%	30%
-- Category 1 (74-95)	<1%	2%	6%	12%	33%	27%	20%
-- Category 2 (96-110)	3%	7%	17%	24%	24%	8%	7%
-- Category 3 (111-130)	60%	47%	48%	39%	16%	3%	2%
-- Category 4 (131-155)	35%	40%	24%	20%	5%	1%	1%
-- Category 5 (>155)	2%	5%	4%	4%	1%	<1%	<1%
Forecast Maximum Wind	135 mph	140 mph	135 mph	135 mph	115 mph	90 mph	65 mph

Why do Small Probabilities of Extreme Events Matter?

U.S. Hurricane Watch and Warning Statistics (2000-2008)

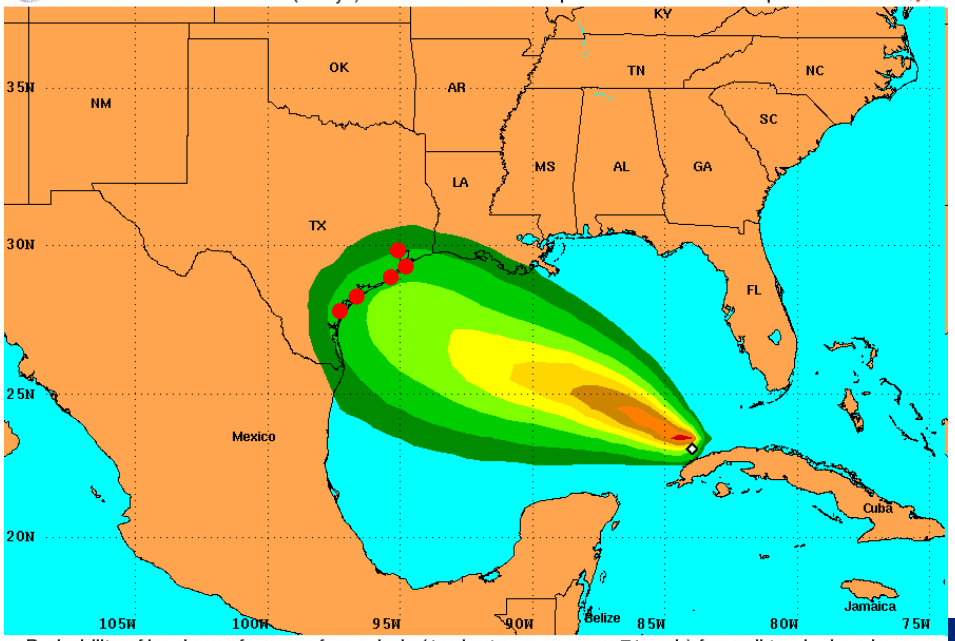
- Average storm-total watch length — 477 miles
- Average storm-total length w/ hurricane winds for cases when watch issued — 89 miles
- Probability of hurricane winds at point under watch — **19%**

- Average storm-total warning length — 403 miles
- Average storm-total length w/ hurricane winds for cases when warning issued — 99 miles
- Probability of hurricane winds at warned point — **25%**



Hurricane Force Wind Speed Probabilities

For the 120 hours (5 days) from 8 PM EDT Tue Sep 9 to 8 PM EDT Sun Sep 14

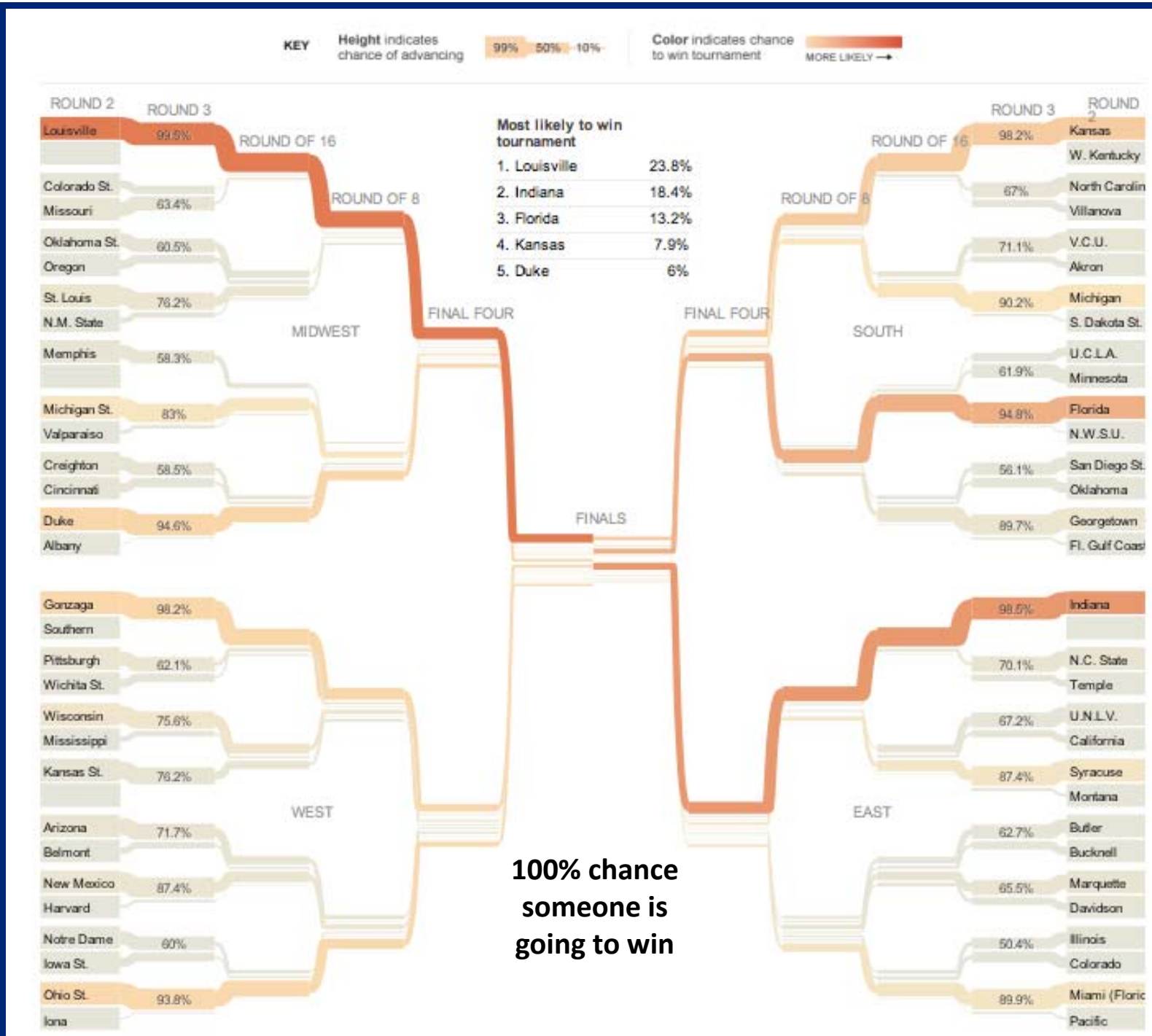


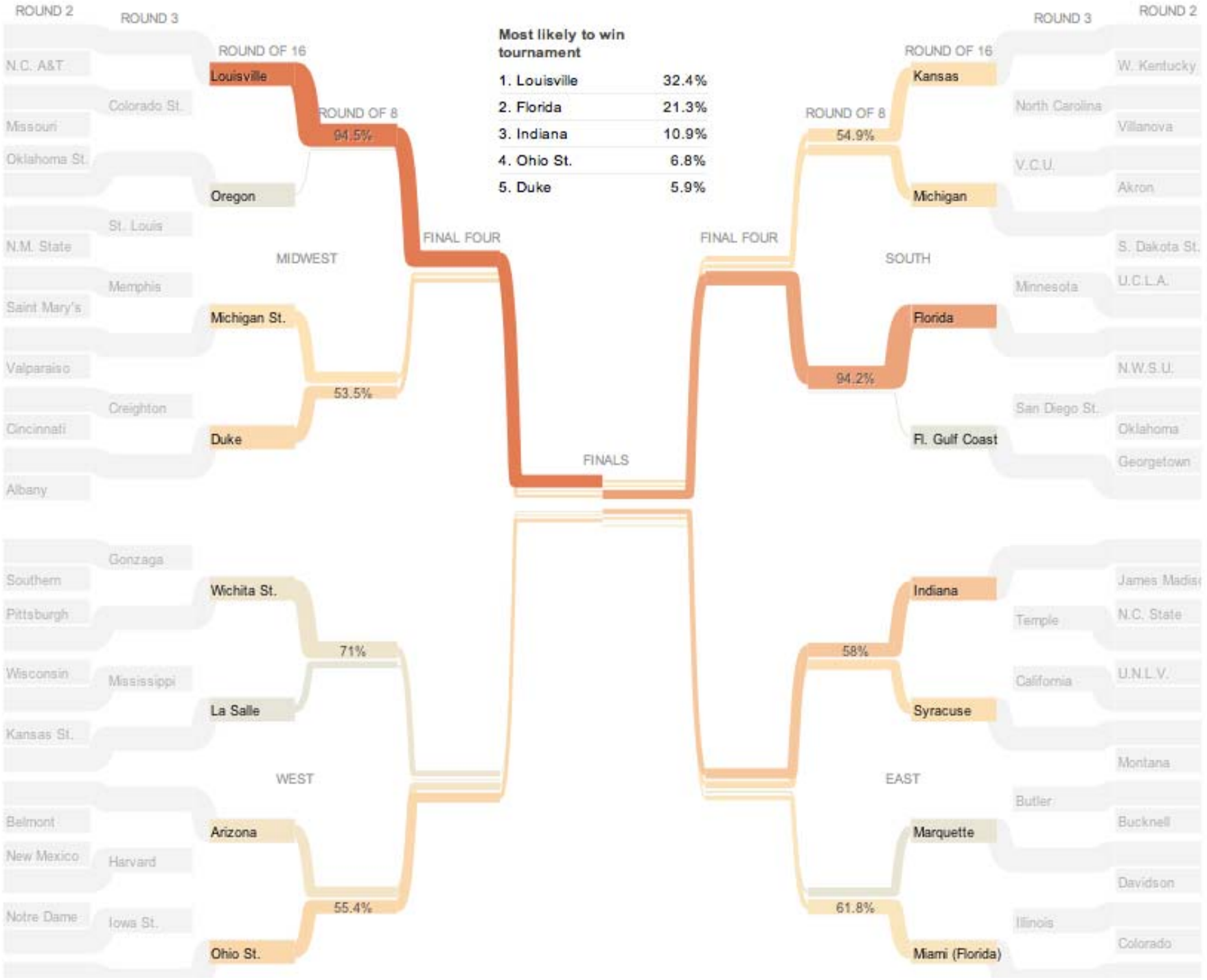
Probability of hurricane force surface winds (1-minute average >= 74 mph) from all tropical cyclones

◇ indicates HURRICANE IKE center location at 8 PM EDT Tue Sep 9 2008 (Forecast/Advisory #36)

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

```
ZCZC MIAPWSAT4 ALL
TTAA00 KNHC DDHHMM
HURRICANE IKE WIND SPEED PROBABILITIES NUMBER  36
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL   AL092008
0300 UTC WED SEP 10 2008

AT 0300Z THE CENTER OF HURRICANE IKE WAS LOCATED NEAR LATITUDE 23.2
NORTH...LONGITUDE 84.3 WEST WITH MAXIMUM SUSTAINED WINDS NEAR 70 KTS
...80 MPH...130 KM/HR.

PORT ARTHUR TX 34  X   X( X)   X( X)   6( 6)  32(38)   8(46)   1(47)
PORT ARTHUR TX 50  X   X( X)   X( X)   1( 1)  12(13)   5(18)   1(19)
PORT ARTHUR TX 64  X   X( X)   X( X)   X( X)   5( 5)   3( 8)   X( 8)

GALVESTON TX   34  X   X( X)   1( 1)   6( 7)  38(45)  11(56)   2(58)
GALVESTON TX   50  X   X( X)   X( X)   1( 1)  20(21)   7(28)   2(30)
GALVESTON TX   64  X   X( X)   X( X)   X( X)   9( 9)   5(14)   X(14)

HOUSTON TX     34  X   X( X)   X( X)   4( 4)  33(37)  13(50)   2(52)
HOUSTON TX     50  X   X( X)   X( X)   X( X)  14(14)   8(22)   1(23)
HOUSTON TX     64  X   X( X)   X( X)   X( X)   5( 5)   4( 9)   1(10)

AUSTIN TX      34  X   X( X)   X( X)   X( X)  17(17)  17(34)   2(36)
AUSTIN TX      50  X   X( X)   X( X)   X( X)   2( 2)   6( 8)   1( 9)
AUSTIN TX      64  X   X( X)   X( X)   X( X)   1( 1)   1( 2)   X( 2)

SAN ANTONIO TX 34  X   X( X)   X( X)   X( X)  16(16)  18(34)   3(37)
SAN ANTONIO TX 50  X   X( X)   X( X)   X( X)   4( 4)   7(11)   X(11)
SAN ANTONIO TX 64  X   X( X)   X( X)   X( X)   X( X)   2( 2)   X( 2)

FREEPORT TX    34  X   X( X)   X( X)   7( 7)  40(47)  12(59)   2(61)
FREEPORT TX    50  X   X( X)   X( X)   1( 1)  22(23)  10(33)   2(35)
FREEPORT TX    64  X   X( X)   X( X)   X( X)  10(10)   5(15)   1(16)

GFMX 28ON 95OW 34  X   X( X)   1( 1)  13(14)  44(58)  10(68)   2(70)
GFMX 28ON 95OW 50  X   X( X)   X( X)   3( 3)  29(32)   8(40)   3(43)
GFMX 28ON 95OW 64  X   X( X)   X( X)   1( 1)  16(17)   6(23)   2(25)

PORT O CONNOR  34  X   X( X)   X( X)   5( 5)  38(43)  16(59)   4(63)
PORT O CONNOR  50  X   X( X)   X( X)   1( 1)  19(20)  10(30)   4(34)
PORT O CONNOR  64  X   X( X)   X( X)   X( X)   9( 9)   8(17)   1(18)

CORPUS CHRISTI 34  X   X( X)   X( X)   3( 3)  29(32)  16(48)   3(51)
CORPUS CHRISTI 50  X   X( X)   X( X)   X( X)  12(12)  10(22)   3(25)
CORPUS CHRISTI 64  X   X( X)   X( X)   X( X)   5( 5)   5(10)   1(11)
```


KEY
Height indicates chance of advancing
99% 50% 10%
Color indicates chance to win tournament
MORE LIKELY
ROUND 2
ROUND 3
ROUND OF 16
ROUND OF 8
FINAL FOUR
FINALS
MIDWEST
WEST
SOUTH
EAST
Most likely to win tournament
1. Louisville 23.8%
2. Indiana 18.4%
3. Florida 13.2%
4. Kansas 7.9%
5. Duke 6%
Louisville
99.5%
Colorado St.
Missouri
63.4%
Oklahoma St.
Oregon
60.5%
St. Louis
N.M. State
76.2%
Memphis
58.3%
Michigan St.
Valparaiso
83%
Creighton
Cincinnati
58.5%
Duke
Albany
94.6%
Gonzaga
Southern
98.2%
Pittsburgh
Wichita St.
62.1%
Wisconsin
Mississippi
75.6%
Kansas St.
76.2%
Arizona
Belmont
71.7%
New Mexico
Harvard
87.4%
Notre Dame
Iowa St.
60%
Ohio St.
Iona
93.8%
Kansas
W. Kentucky
98.2%
North Carolin
Villanova
67%
V.C.U.
Akron
71.1%
Michigan
S. Dakota St.
90.2%
U.C.L.A.
Minnesota
61.9%
Florida
N.W.S.U.
94.8%
San Diego St.
Oklahoma
56.1%
Georgetown
Fl. Gulf Coas
89.7%
Indiana
98.5%
N.C. State
Temple
70.1%
U.N.L.V.
California
67.2%
Syracuse
Montana
87.4%
Butler
Bucknell
62.7%
Marquette
Davidson
65.5%
Illinois
Colorado
50.4%
Miami (Floric
Pacific
89.9%
100% chance someone is going to win


ROUND 2
ROUND 3
ROUND OF 16
ROUND OF 8
FINAL FOUR
FINALS
MIDWEST
WEST
SOUTH
EAST
N.C. A&T
Colorado St.
Missouri
Oklahoma St.
St. Louis
N.M. State
Memphis
Saint Mary's
Valparaiso
Creighton
Cincinnati
Albany
Gonzaga
Southern
Pittsburgh
Wisconsin
Mississippi
Kansas St.
Belmont
New Mexico
Harvard
Notre Dame
Iowa St.
Louisville
Oregon
Michigan St.
Duke
Wichita St.
La Salle
Arizona
Ohio St.
94.5%
53.5%
71%
55.4%
Most likely to win tournament
1. Louisville 32.4%
2. Florida 21.3%
3. Indiana 10.9%
4. Ohio St. 6.8%
5. Duke 5.9%
Kansas
Michigan
Florida
Fl. Gulf Coast
Indiana
Syracuse
Marquette
Miami (Florida)
54.9%
94.2%
58%
61.8%
North Carolina
Villanova
V.C.U.
Akron
Minnesota
S. Dakota St.
U.C.L.A.
N.W.S.U.
San Diego St.
Oklahoma
Georgetown
Temple
N.C. State
California
U.N.L.V.
Montana
Butler
Bucknell
Davidson
Illinois
Colorado
W. Kentucky

Who is going to get hurricane force winds?

5 day forecast

Who is going to get hurricane force winds?

4 day forecast

Who is going to get hurricane force winds?

3 day forecast

Who is going to get hurricane force winds?

2 day forecast

Who is going to get hurricane force winds?

1 day forecast

Interpreting the Wind Speed Probability Text Product

Wind Speed Probability Text Product

```
ZCZC MIAPWSAT2 ALL
TTAA00 KNHC DDHHMM
HURRICANE EARL WIND SPEED PROBABILITIES NUMBER  24
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL   AL072010
0900 UTC TUE AUG 31 2010

AT 0900Z THE CENTER OF HURRICANE EARL WAS LOCATED NEAR LATITUDE 20.5
NORTH...LONGITUDE 66.7 WEST WITH MAXIMUM SUSTAINED WINDS NEAR 115
KTS...135 MPH...215 KM/HR.

Z INDICATES COORDINATED UNIVERSAL TIME (GREENWICH)
   ATLANTIC STANDARD TIME (AST)...SUBTRACT 4 HOURS FROM Z TIME
   EASTERN  DAYLIGHT TIME (EDT)...SUBTRACT 4 HOURS FROM Z TIME
   CENTRAL  DAYLIGHT TIME (CDT)...SUBTRACT 5 HOURS FROM Z TIME


I.  MAXIMUM WIND SPEED (INTENSITY) PROBABILITY TABLE

CHANCES THAT THE MAXIMUM SUSTAINED (1-MINUTE AVERAGE) WIND SPEED OF
THE TROPICAL CYCLONE WILL BE WITHIN ANY OF THE FOLLOWING CATEGORIES
AT EACH OFFICIAL FORECAST TIME DURING THE NEXT 5 DAYS.
PROBABILITIES ARE GIVEN IN PERCENT.  X INDICATES PROBABILITIES LESS
THAN 1 PERCENT.

      - - - MAXIMUM WIND SPEED (INTENSITY) PROBABILITIES - - -

VALID TIME   18Z TUE 06Z WED 18Z WED 06Z THU 06Z FRI 06Z SAT 06Z SUN
FORECAST HOUR   12      24      36      48      72      96     120
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
DISSIPATED       X       X       X       X       X       3      21
TROP DEPRESSION  X       X       X       X       1       8      29
TROPICAL STORM   X       X       1       2      13      39      40
HURRICANE       99      99      99      98      86      50      10
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
HUR CAT 1        X       2       4      12      30      33       9
HUR CAT 2        2       7      12      25      25      11       1
HUR CAT 3       38      48      45      38      22       5       1
HUR CAT 4       57      38      33      19       8       1       X
HUR CAT 5        3       5       5       4       1       X       X
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
FCST MAX WIND  120KT   120KT   120KT   115KT   105KT    85KT    60KT

II. WIND SPEED PROBABILITY TABLE FOR SPECIFIC LOCATIONS

CHANCES OF SUSTAINED (1-MINUTE AVERAGE) 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

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

            FROM    FROM    FROM    FROM    FROM    FROM    FROM
  TIME    06Z TUE 18Z TUE 06Z WED 18Z WED 06Z THU 06Z FRI 06Z SAT
PERIODS     TO      TO      TO      TO      TO      TO      TO
          18Z TUE 06Z WED 18Z WED 06Z THU 06Z FRI 06Z SAT 06Z SUN

FORECAST HOUR    (12)    (24)    (36)    (48)    (72)    (96)   (120)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
LOCATION       KT

EASTPORT ME    34  X   X( X)   X( X)   X( X)   X( X)   5( 5)  27(32)
EASTPORT ME    50  X   X( X)   X( X)   X( X)   X( X)   1( 1)  13(14)
EASTPORT ME    64  X   X( X)   X( X)   X( X)   X( X)   X( X)   5( 5)

BAR HARBOR ME  34  X   X( X)   X( X)   X( X)   X( X)   7( 7)  22(29)
BAR HARBOR ME  50  X   X( X)   X( X)   X( X)   X( X)   1( 1)  10(11)
BAR HARBOR ME  64  X   X( X)   X( X)   X( X)   X( X)   X( X)   5( 5)

AUGUSTA ME     34  X   X( X)   X( X)   X( X)   X( X)   7( 7)  15(22)
AUGUSTA ME     50  X   X( X)   X( X)   X( X)   X( X)   X( X)   8( 8)
AUGUSTA ME     64  X   X( X)   X( X)   X( X)   X( X)   X( X)   2( 2)

PORTLAND ME    34  X   X( X)   X( X)   X( X)   X( X)  10(10)  11(21)
PORTLAND ME    50  X   X( X)   X( X)   X( X)   X( X)   2( 2)   5( 7)
PORTLAND ME    64  X   X( X)   X( X)   X( X)   X( X)   X( X)   3( 3)

CONCORD NH     34  X   X( X)   X( X)   X( X)   X( X)  11(11)   7(18)
CONCORD NH     50  X   X( X)   X( X)   X( X)   X( X)   2( 2)   3( 5)
CONCORD NH     64  X   X( X)   X( X)   X( X)   X( X)   X( X)   1( 1)

BOSTON MA      34  X   X( X)   X( X)   X( X)   X( X)  18(18)   9(27)
BOSTON MA      50  X   X( X)   X( X)   X( X)   X( X)   5( 5)   6(11)
BOSTON MA      64  X   X( X)   X( X)   X( X)   X( X)   2( 2)   2( 4)

HYANNIS MA     34  X   X( X)   X( X)   X( X)   X( X)  29(29)   9(38)
HYANNIS MA     50  X   X( X)   X( X)   X( X)   X( X)  10(10)   7(17)
HYANNIS MA     64  X   X( X)   X( X)   X( X)   X( X)   4( 4)   4( 8)

NANTUCKET MA   34  X   X( X)   X( X)   X( X)   X( X)  33(33)  10(43)
NANTUCKET MA   50  X   X( X)   X( X)   X( X)   X( X)  13(13)   8(21)
NANTUCKET MA   64  X   X( X)   X( X)   X( X)   X( X)   5( 5)   5(10)
```

Example Interpretation of Output

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)

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

Example Interpretation of Output

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)

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%

Example Interpretation of Output

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)

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?

Example Interpretation of Output

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)	[illegible]	[illegible]
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)

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?

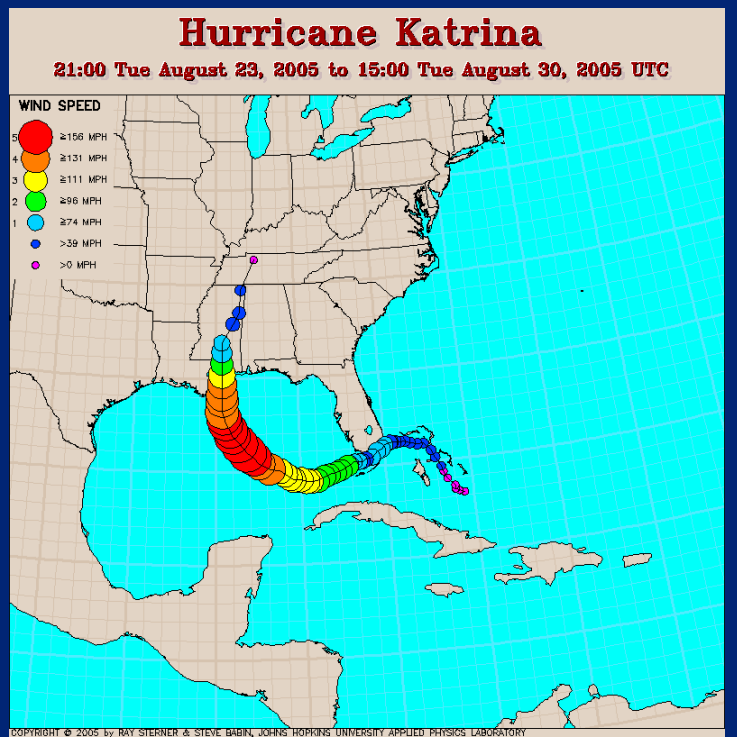
From 18Z Sun to 18Z Mon (18% chance)

Case Example
Hurricane Katrina (2005)

Hurricane Katrina (2005)

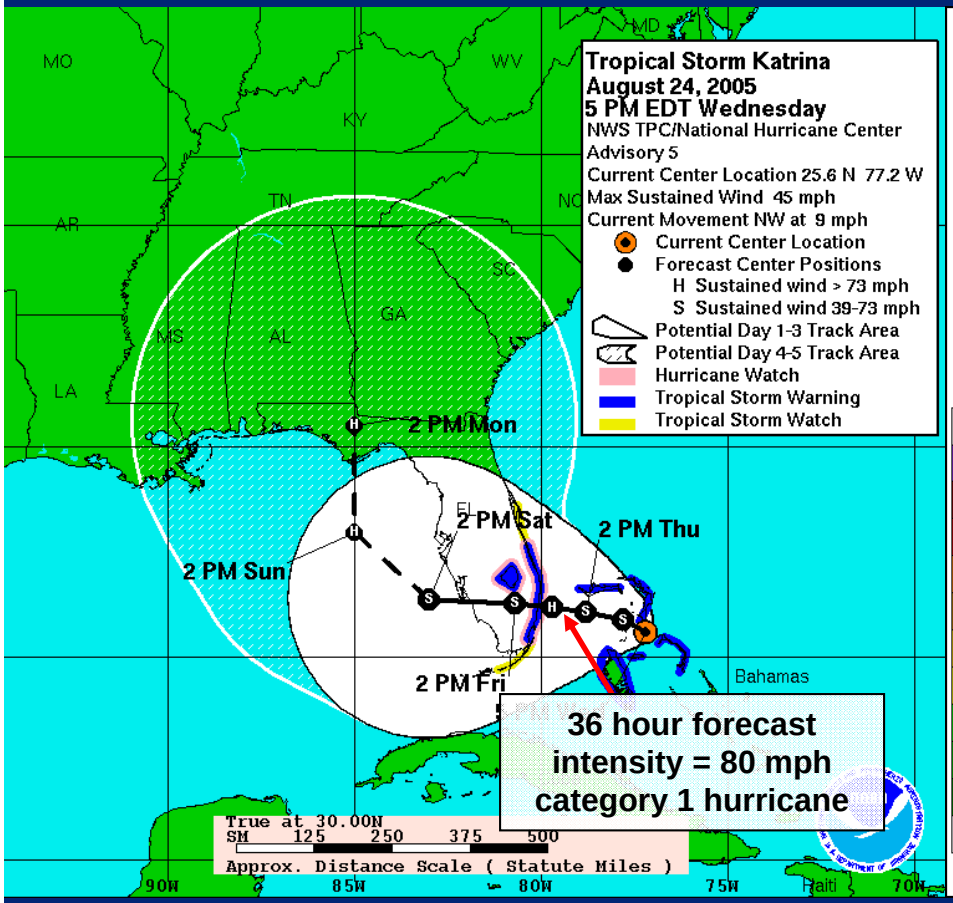
- Two examples of how probabilities evolve

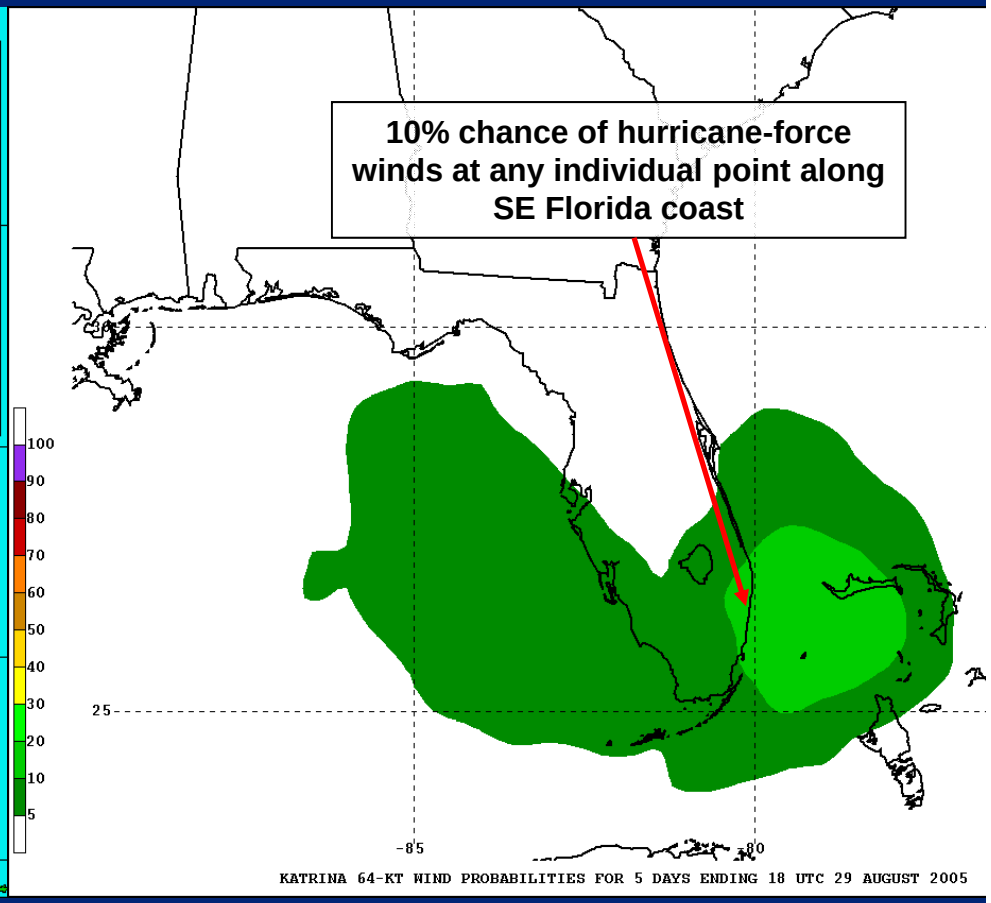
1. Landfall of a marginal hurricane in South Florida
   - Small probabilities of hurricane force winds over much of south FL due to uncertainty in track and intensity
2. Landfall of a major hurricane along the Gulf Coast
   - Initially small probabilities at locations along the Gulf Coast increase markedly along the track of Katrina as landfall approaches
   - Hurricane conditions are almost a certainty *somewhere*



Magnitudes of Cumulative Probabilities Vary Greatly But Realistically

Katrina Advisory #5

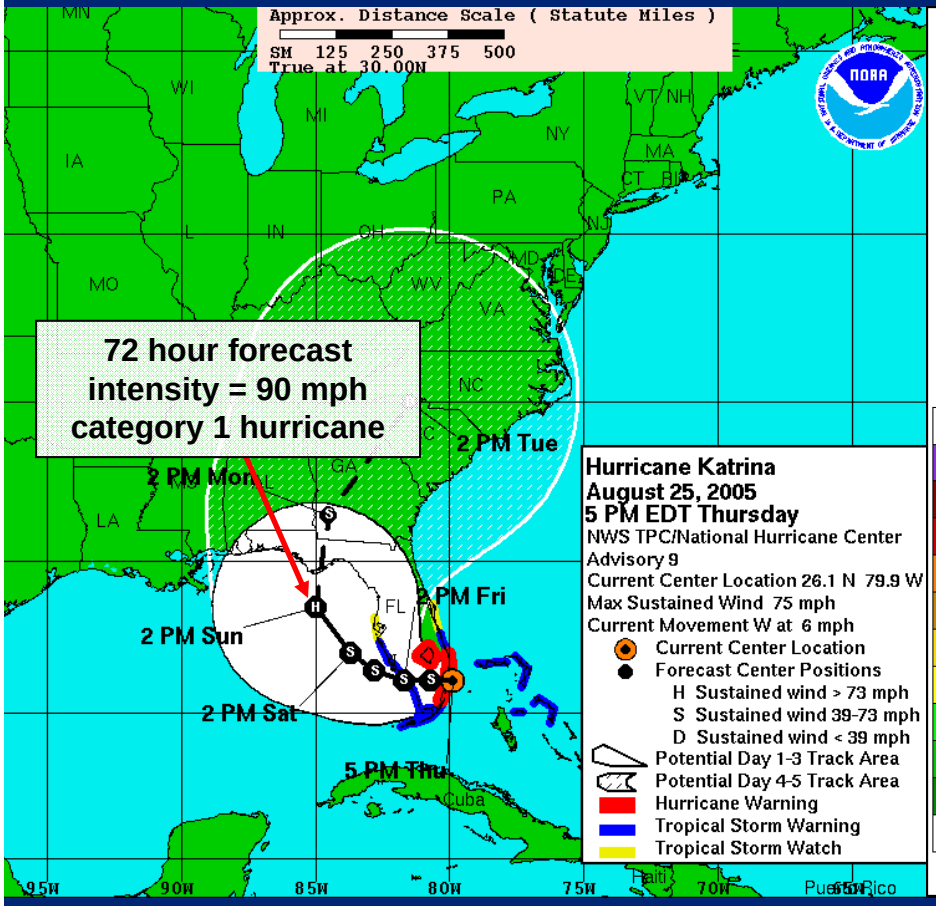


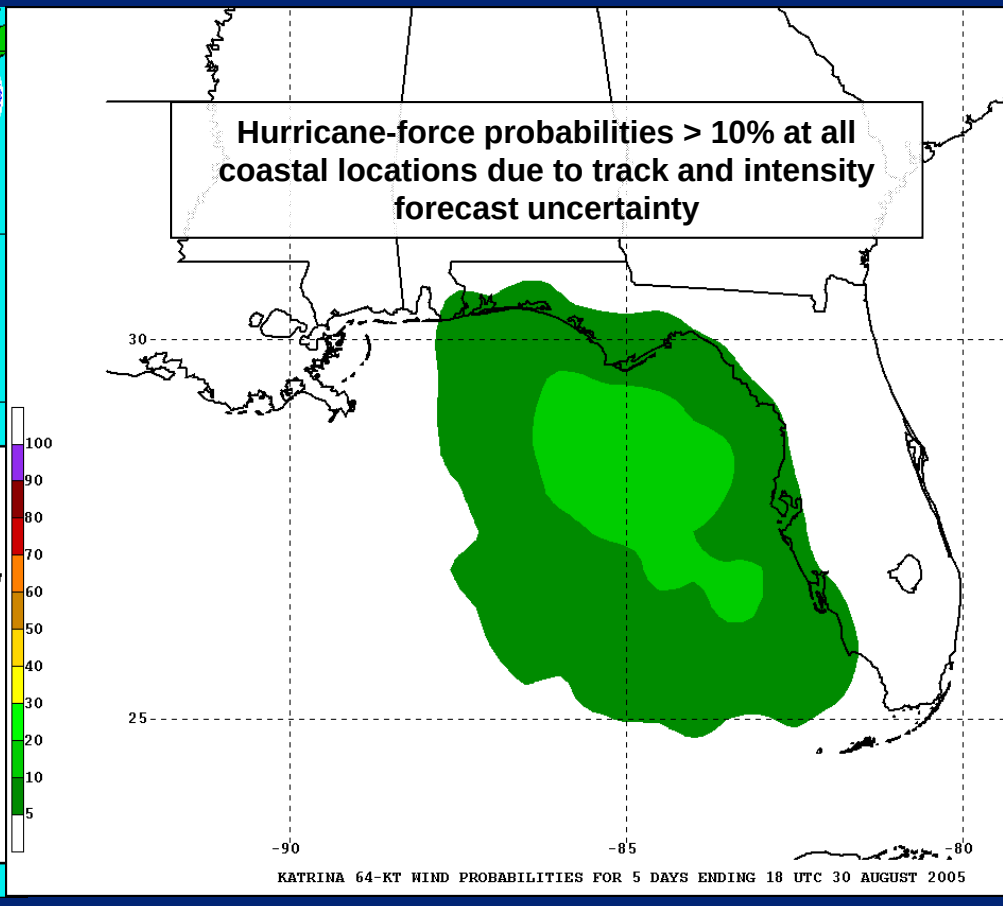


Low probability of hurricane-force winds due to small size of hurricane force wind field and uncertainty as to whether Katrina will even be a hurricane at landfall

Magnitudes of Cumulative Probabilities Vary Greatly But Realistically

Katrina Advisory #9

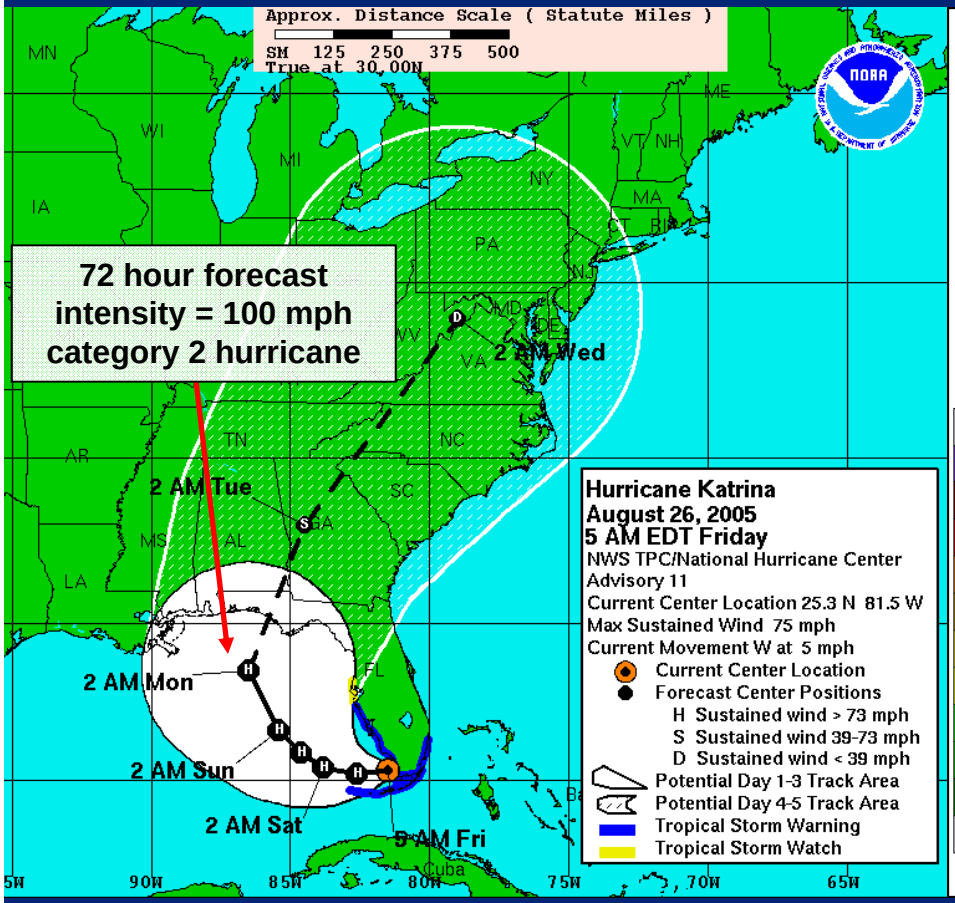


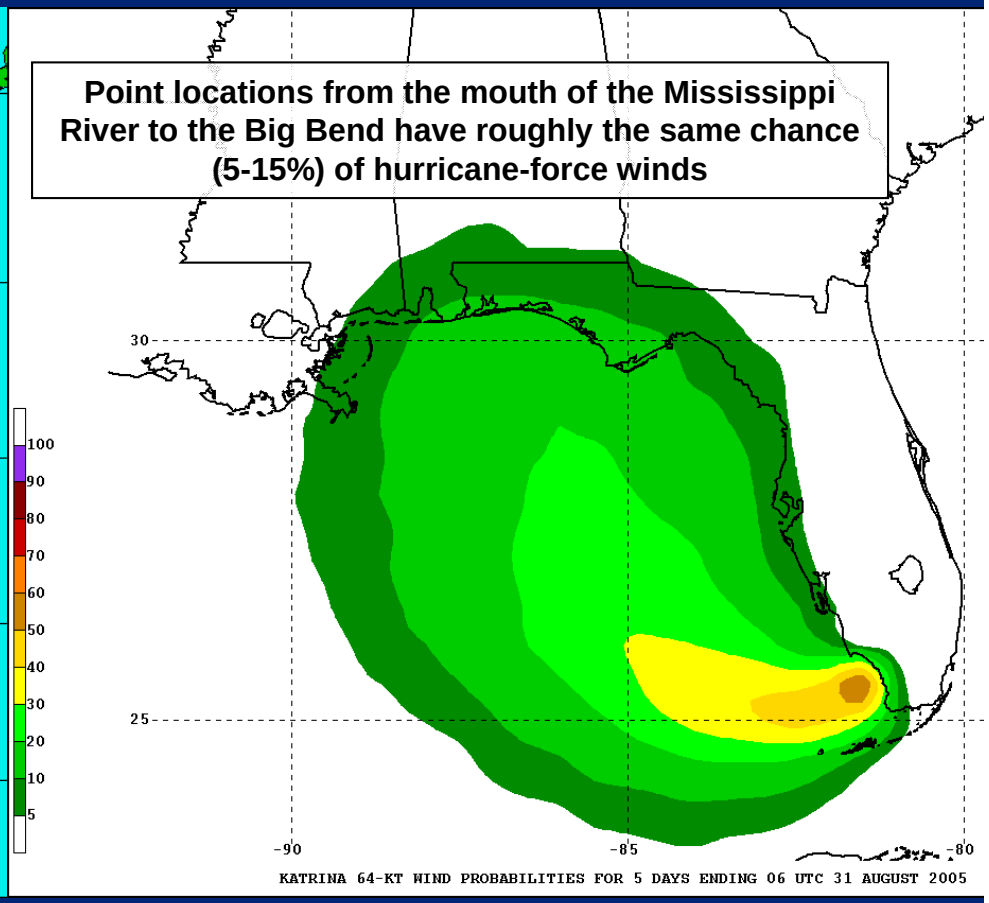


Low probability of hurricane-force winds due to uncertainty in track and whether Katrina will be a hurricane at landfall

Magnitudes of Cumulative Probabilities Vary Greatly But Realistically

Katrina Advisory #11

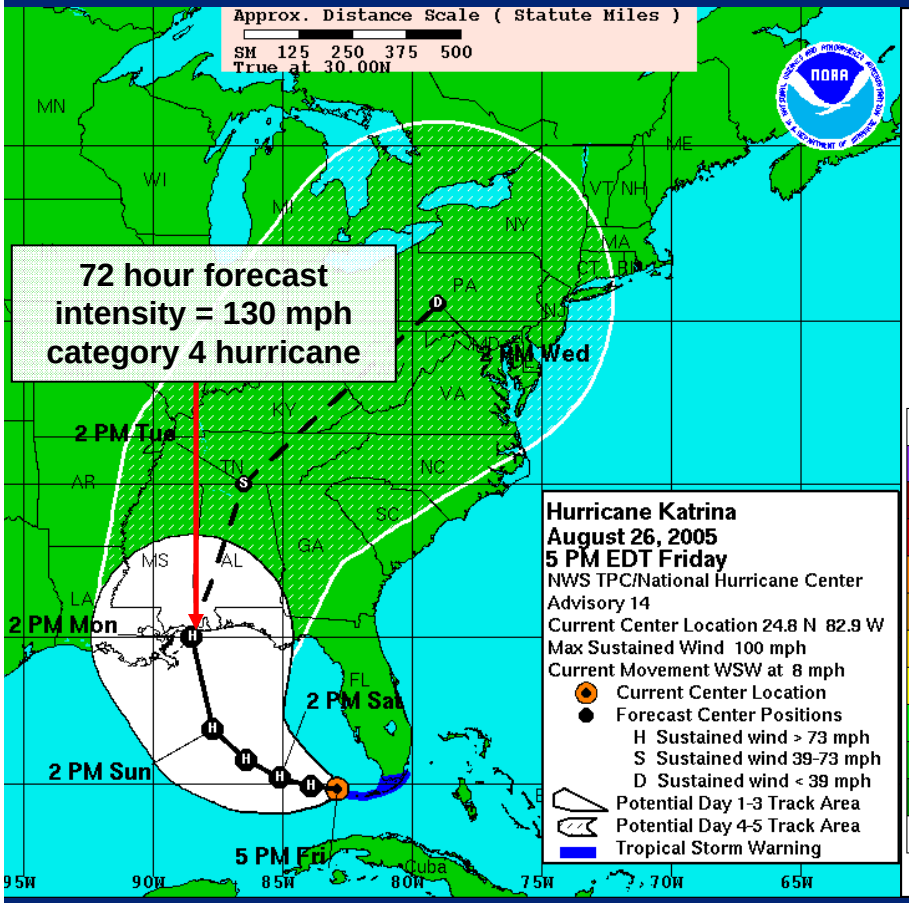


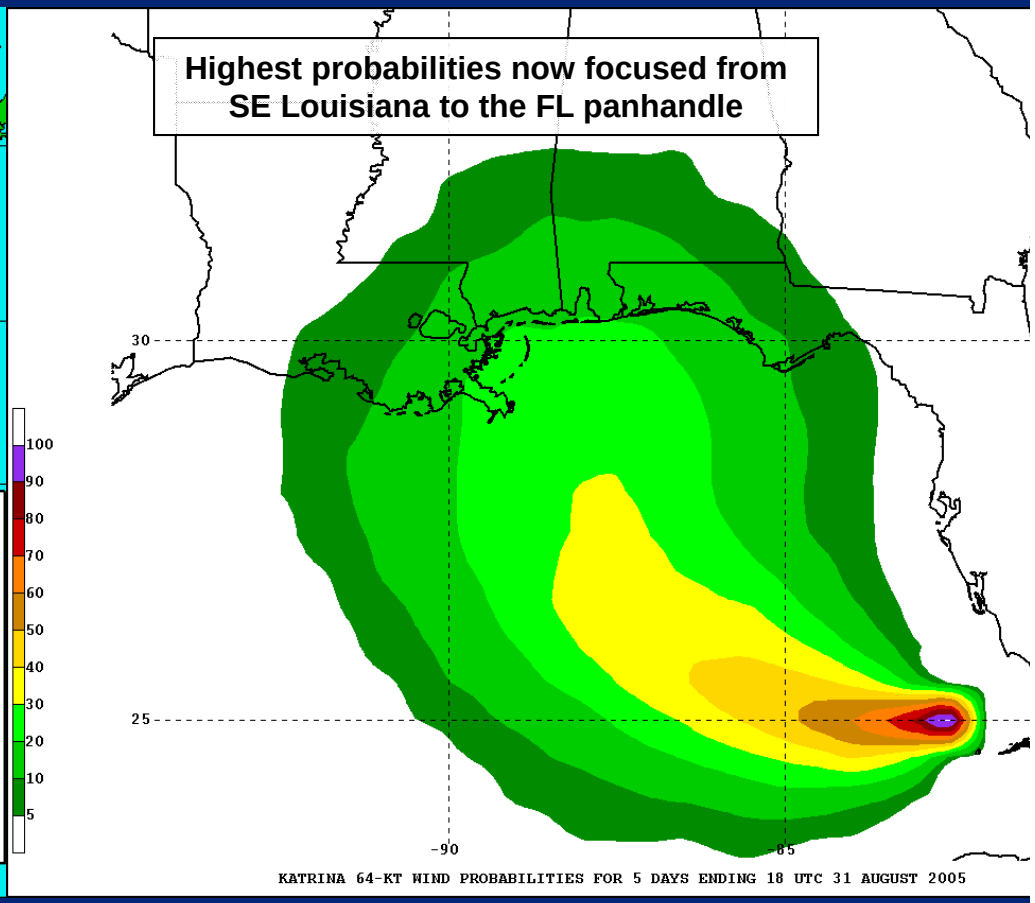


Probabilities begin to increase due to increase in intensity forecast even though track uncertainty remains similar – becoming more likely that hurricane-force winds will occur *somewhere*

Magnitudes of Cumulative Probabilities Vary Greatly But Realistically

Katrina Advisory #14

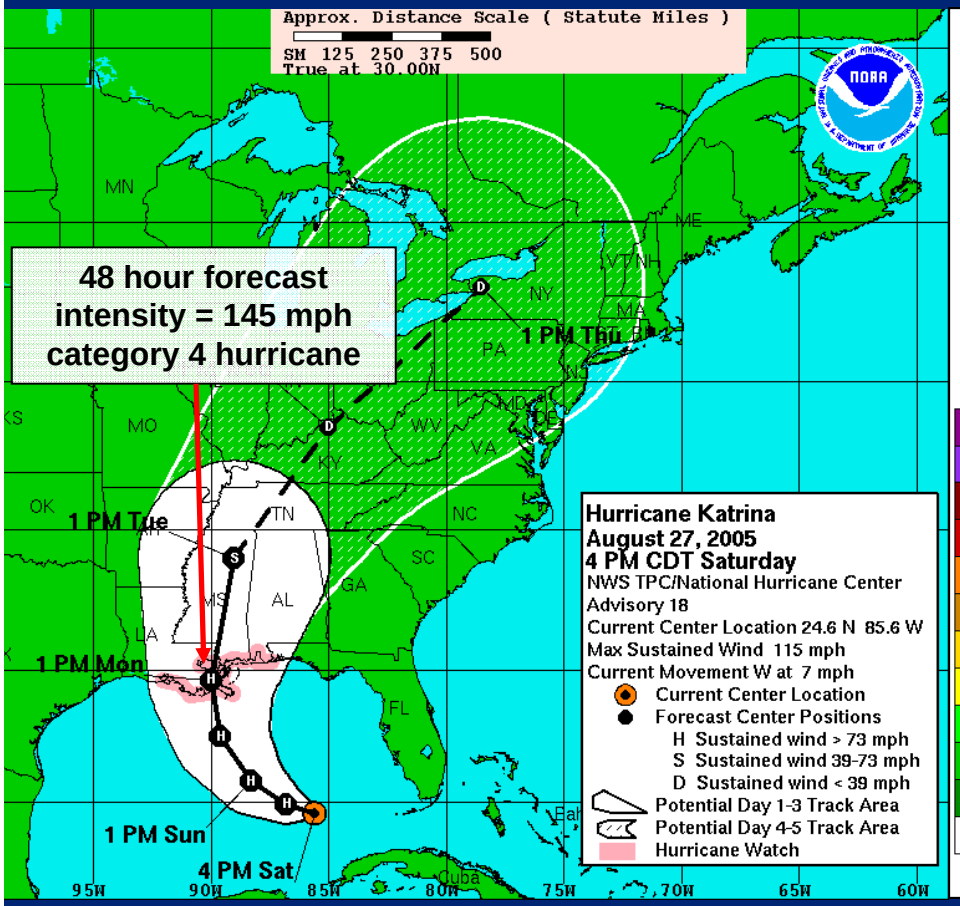


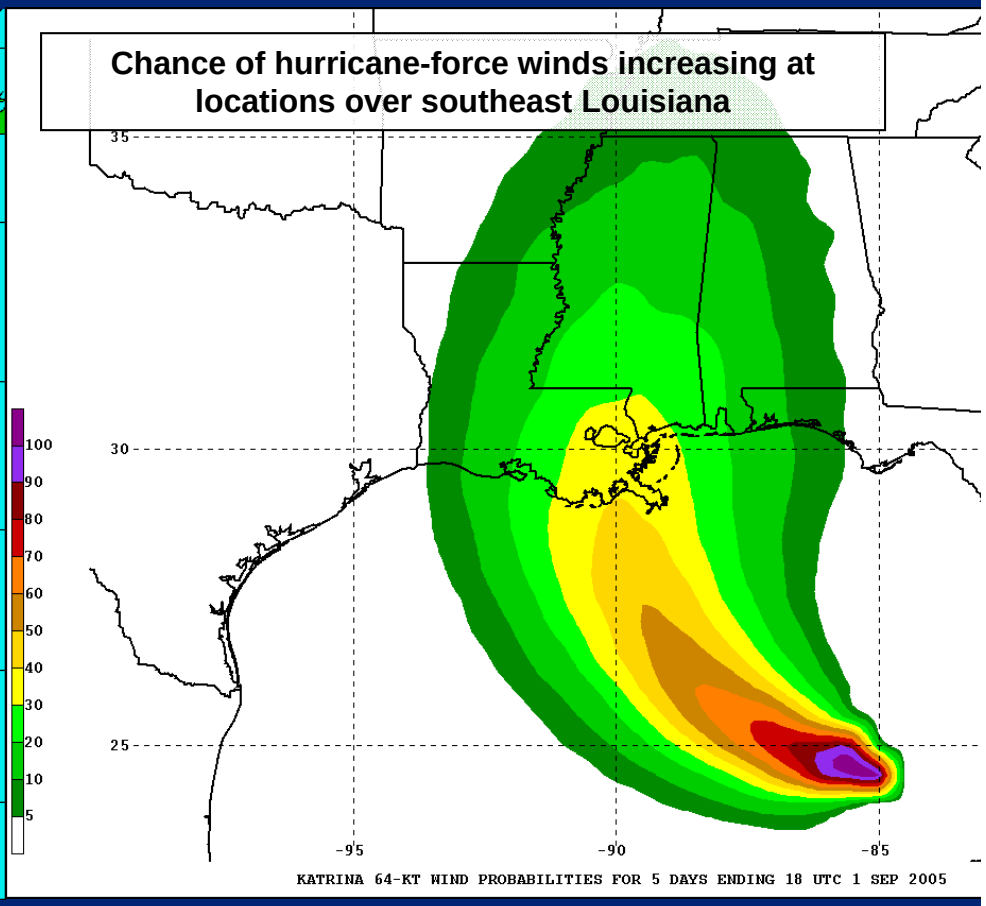


Probabilities increase further due to continued increase in intensity forecast and slight decrease in track forecast uncertainty with landfall forecast in about 72 h

Magnitudes of Cumulative Probabilities Vary Greatly But Realistically

Katrina Advisory #18

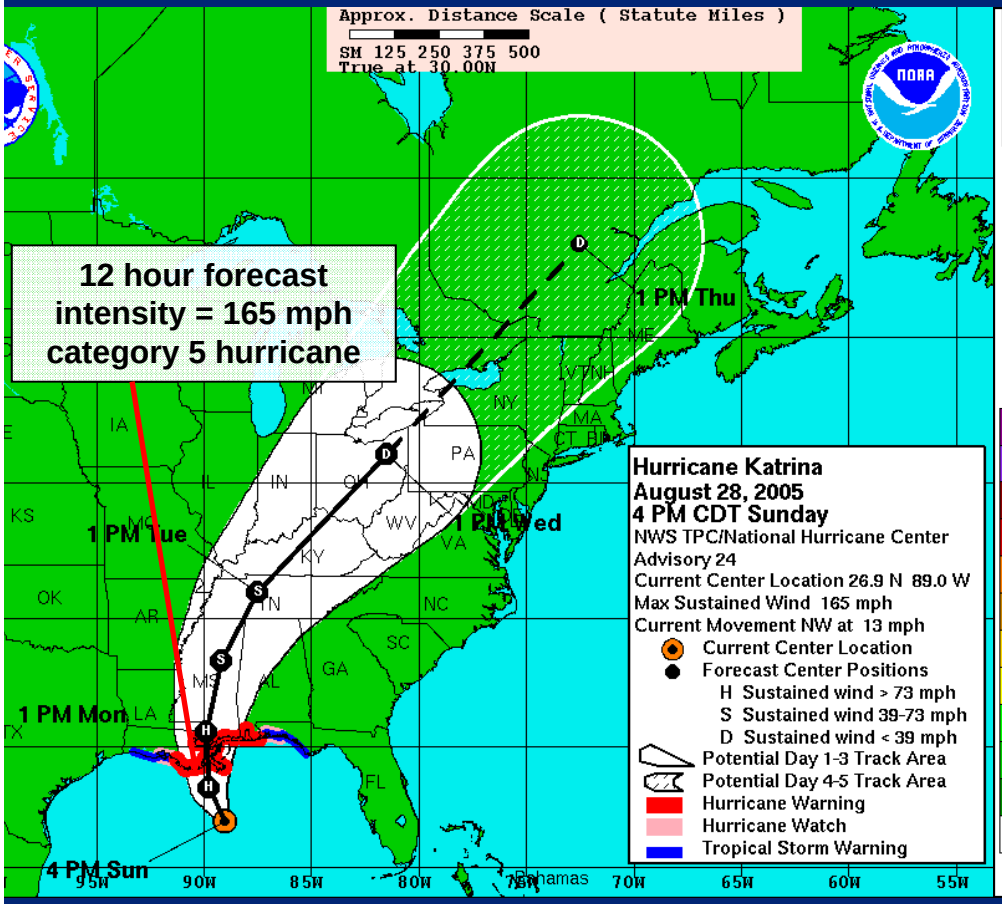


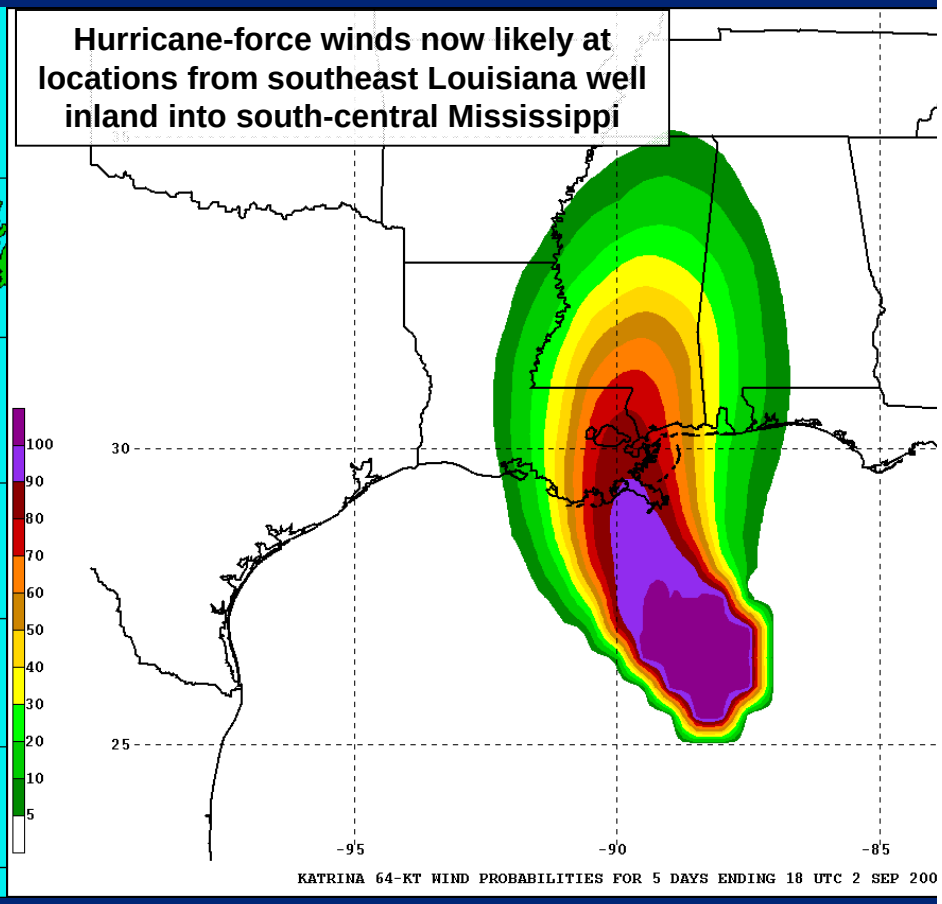


Probabilities along central Gulf coast increase dramatically due to increase in intensity forecast and decrease in track forecast uncertainty with landfall forecast in about 48 h

Magnitudes of Cumulative Probabilities Vary Greatly But Realistically

Katrina Advisory #24



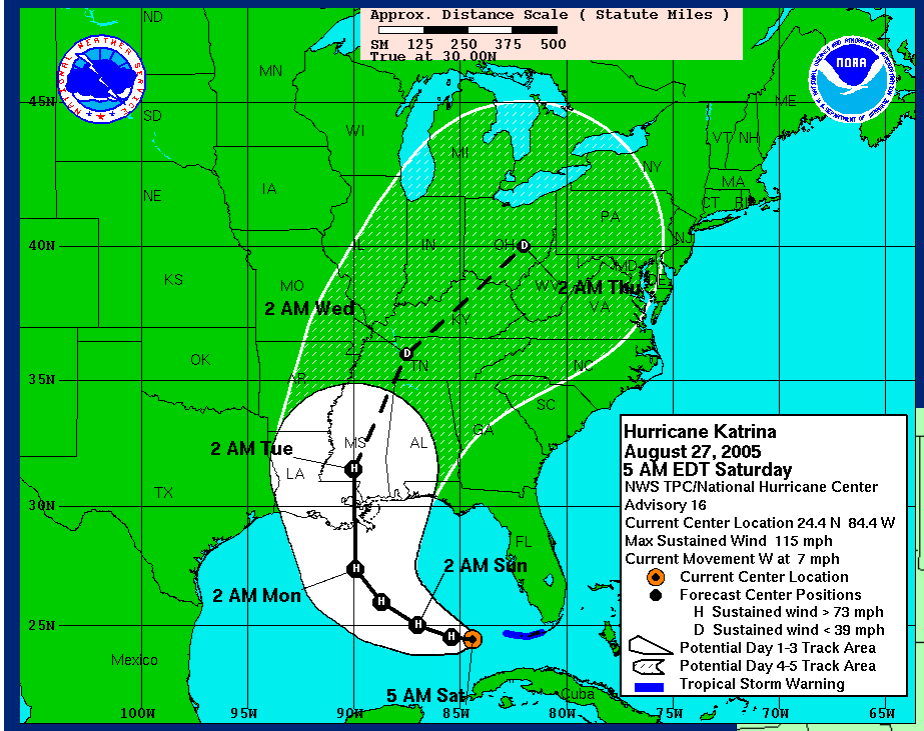


Landfall now within 12 to 24 h, hurricane force winds almost a certainty along forecast track given large size and strength of Katrina along with small short-range track uncertainty

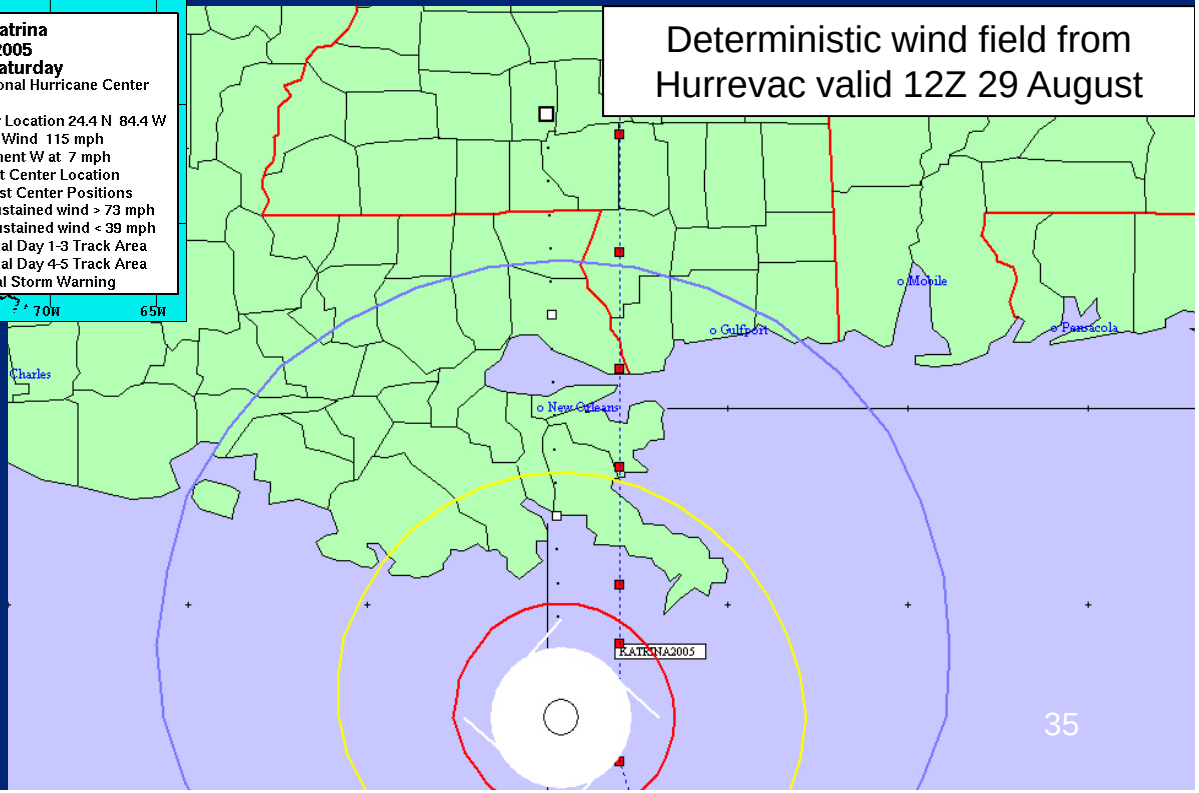
Timing Information About Wind Onset

Onset of 34-kt Winds

Katrina (2005)



- Onset of 34-kt winds based on deterministic forecast issued with Advisory 16
  - New Orleans, LA – 8/29 (Mon.) 08Z
  - Gulfport, MS – 8/29 (Mon.) 11Z



Wind Speed Probabilities

Katrina (2005) Advisory 16

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

	FROM	FROM	FROM	FROM	FROM	FROM	FROM
TIME	06Z SAT	18Z SAT	06Z SUN	18Z SUN	06Z MON	06Z TUE	06Z WED
PERIODS	TO	TO	TO	TO	TO	TO	TO
	18Z SAT	06Z SUN	18Z SUN	06Z MON	06Z TUE	06Z WED	06Z THU
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
NEW ORLEANS LA 34	X	1(1)	9(10)	28(38)	34(72)	5(77)	X(77)
GULFPORT MS 34	X	1(1)	8(9)	23(32)	35(67)	5(72)	1(73)

Wind Speed Probabilities
Katrina (2005) Advisory 16

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

TIME PERIODS	FROM 06Z SAT TO 18Z SAT	FROM 18Z SAT TO 06Z SUN	FROM 06Z SUN TO 18Z SUN	FROM 18Z SUN TO 06Z MON	FROM 06Z MON TO 06Z TUE	FROM 06Z TUE TO 06Z WED	FROM 06Z WED TO 06Z THU
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
NEW ORLEANS LA 34	X	1(1)	9(10)	28(38)	34(72)	5(77)	X(77)
GULFPORT MS 34	X	1(1)	8(9)	23(32)	35(67)	5(72)	1(73)

Most likely period of onset of 34-kt winds at New Orleans and Gulfport is between 06Z Monday 8/29 and 06Z Tuesday 8/30

Wind Speed Probabilities
Katrina (2005) Advisory 16

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

TIME	FROM 06Z SAT	FROM 18Z SAT	FROM 06Z SUN	FROM 18Z SUN	FROM 06Z MON	FROM 06Z TUE	FROM 06Z WED
PERIODS	TO 18Z SAT	TO 06Z SUN	TO 18Z SUN	TO 06Z MON	TO 06Z TUE	TO 06Z WED	TO 06Z THU
FORECAST HOUR	(12)	(24)	(36)	(48)	(72)	(96)	(120)
NEW ORLEANS LA	34 X	1(1)	9(10)	28(38)	34(72)	5(77)	X(77)
GULFPORT MS	34 X	1(1)	8(9)	23(32)	35(67)	5(72)	1(73)

However, the probability that 34-kt winds will start **prior to** 06Z Monday 8/29 at both New Orleans and Gulfport is nearly as large!

What Actually Happened?

- Onset of 34-kt winds occurred between 00Z and 06Z Monday 8/29 at New Orleans and Gulfport
  - At least **3 hours** earlier than shown by the official forecast at New Orleans
  - At least **5 hours** earlier than shown by the official forecast at Gulfport

Lesson

- Important information about the onset of wind conditions is contained in the probabilities
- Examine trends from advisory to advisory
  - How are probabilities of onset changing?
  - Are chances of onset nearly equal between two consecutive time periods?

Intensity Probability Table Examples

Hurricane Danielle Intensity Probability Table

Advisory 16 – 11 AM EDT 25 Aug. 2010

Intensity (Maximum Wind Speed) Probability Table
Hurricane Danielle Advisory Number 16
11:00 AM AST Aug 25 2010

Wind Range (mph)	Forecast Time						
	12 hour for 8 PM Wed	24 hour for 8 AM Thu	36 hour for 8 PM Thu	48 hour for 8 AM Fri	72 hour for 8 AM Sat	96 hour for 8 AM Sun	120 hour for 8 AM Mon
Dissipated	<1%	<1%	<1%	<1%	<1%	1%	1%
Tropical Depression (<39)	<1%	<1%	1%	1%	1%	2%	6%
Tropical Storm (39-73)	8%	12%	19%	17%	14%	17%	38%
Hurricane (all categories)	92%	88%	81%	82%	85%	81%	55%
-- Category 1 (74-95)	76%	57%	49%	41%	31%	32%	32%
-- Category 2 (96-110)	13%	22%	21%	23%	24%	24%	14%
-- Category 3 (111-130)	2%	7%	8%	14%	21%	19%	7%
-- Category 4 (131-155)	<1%	1%	2%	3%	7%	5%	2%
-- Category 5 (>155)	<1%	<1%	<1%	1%	1%	1%	<1%
Forecast Maximum Wind	85 mph	90 mph	90 mph	100 mph	110 mph	110 mph	100 mph

- Official NHC 48-h intensity forecast: 100 MPH (Category 2)
- Verifying intensity: 135 MPH (Category 4)

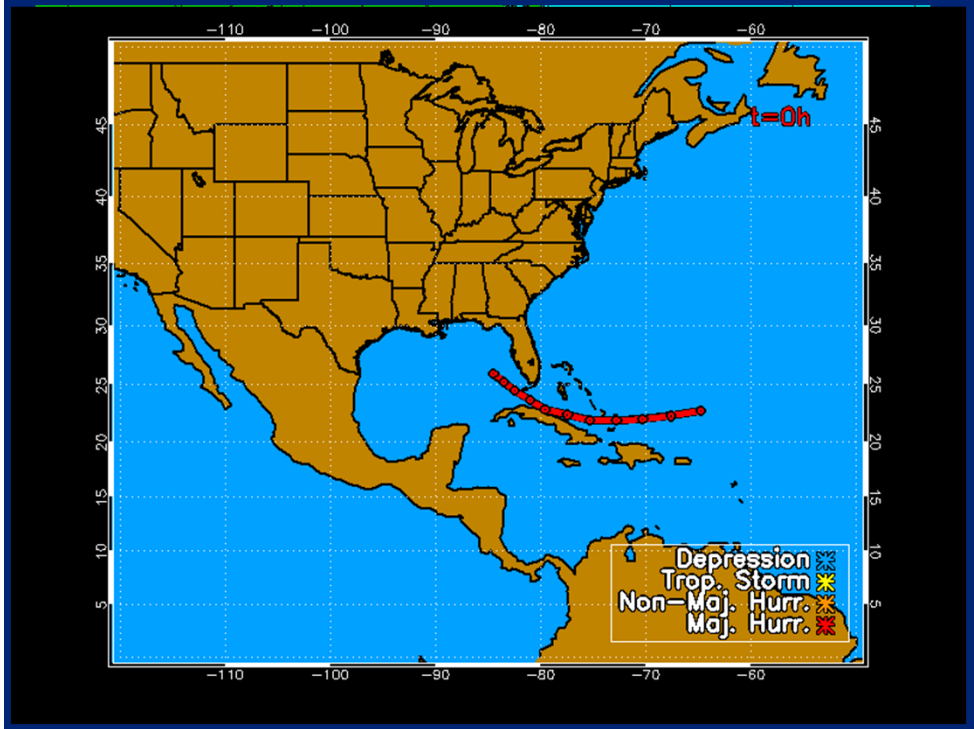
3% chance of category 4 hurricane in 48 h verifies

Impact of Land Interaction on Intensity Probabilities

- Even if the official track forecast does take the TC over land, many of the 1,000 track realizations can move over land to track uncertainty
- This often occurs in the western part of the Atlantic basin due to numerous islands and large landmasses
- When this occurs, the intensity probabilities will often spread out over a large range of possible intensities, particularly late in the forecast period

Impact of Land Interaction on Intensity Probabilities

Hurricane Ike – 11 PM EDT 5 Sep 2008



Intensity (Maximum Wind Speed) Probability Table
Hurricane Ike Advisory Number 20
11:00 PM AST Sep 5 2008

Wind Range (mph)	Forecast Time: 12 hour for 8 AM Sat	24 hour for 8 PM Sat	36 hour for 8 AM Sun	48 hour for 8 PM Sun	72 hour for 8 PM Mon	96 hour for 8 PM Tue	120 hour for 8 PM Wed
Dissipated	<1%	<1%	<1%	<1%	3%	6%	16%
Tropical Depression (<39)	<1%	<1%	<1%	<1%	3%	5%	8%
Tropical Storm (39-73)	<1%	1%	3%	4%	9%	11%	12%
Hurricane (all categories)	99%	99%	97%	95%	85%	79%	65%
-- Category 1 (74-95)	3%	11%	11%	11%	17%	18%	13%
-- Category 2 (96-110)	32%	35%	25%	14%	19%	18%	14%
-- Category 3 (111-130)	59%	44%	44%	39%	30%	24%	18%
-- Category 4 (131-155)	5%	8%	15%	26%	16%	16%	16%
-- Category 5 (>155)	1%	1%	2%	6%	3%	3%	4%
Forecast Maximum Wind	115 mph	115 mph	120 mph	135 mph	125 mph	125 mph	135 mph

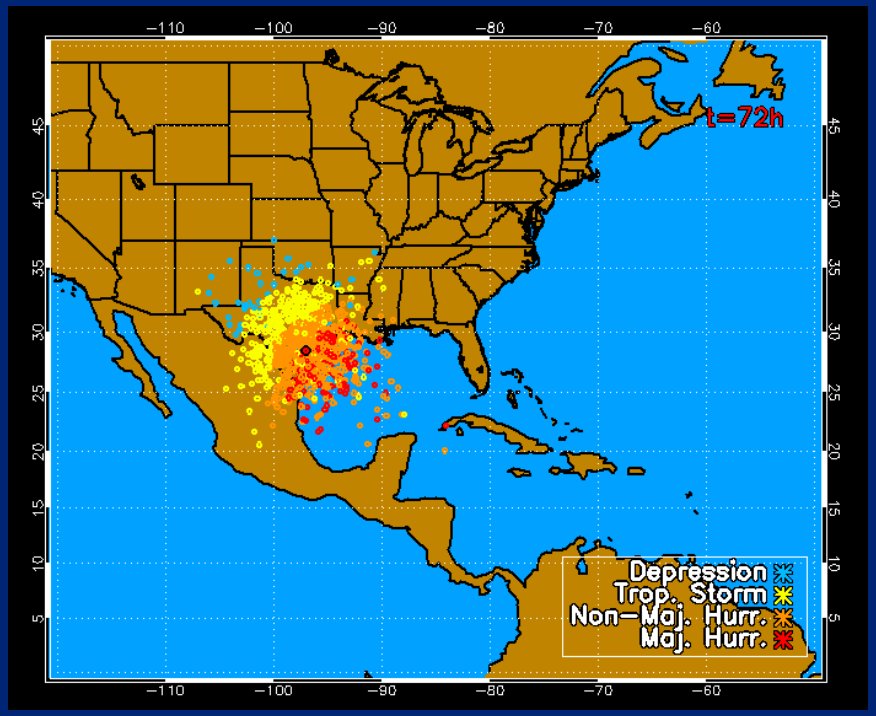
- Official forecast shows Ike avoiding significant land interaction and remaining a major hurricane through 5 days
- Probabilities show the potential for land interaction as intensity probabilities spread out across categories 1-4 by days 4 and 5

Impact of Land Interaction on Intensity Probabilities

- The intensity probability table CANNOT be used to estimate the intensity at landfall
- Probabilities are valid at a specific TIME – not location
  - Some realizations will move faster than the official forecast and already be inland at the time of landfall in the official forecast
  - These inland realizations will be weaker and contribute to lower intensity probabilities at the forecast time period closest to landfall
- We are working with a new tool that computes the probability of landfall occurring in specific categories

Hurricane Ike

Advisory 38 – 10 AM CDT 10 Sep 2008



Intensity (Maximum Wind Speed) Probability Table
Hurricane Ike Advisory Number 38
10:00 AM CDT Sep 10 2008

	Forecast Time						
Wind Range (mph)	12 hour for 7 PM Wed	24 hour for 7 AM Thu	36 hour for 7 PM Thu	48 hour for 7 AM Fri	72 hour for 7 AM Sat	96 hour for 7 AM Sun	120 hour for 7 AM Mon
Dissipated	<1%	<1%	<1%	<1%	1%	55%	73%
Tropical Depression (<39)	<1%	<1%	<1%	<1%	4%	20%	16%
Tropical Storm (39-73)	1%	2%	2%	3%	26%	12%	6%
Hurricane (all categories)	99%	98%	98%	97%	69%	13%	6%
-- Category 1 (74-95)	23%	19%	11%	12%	25%	2%	<1%
-- Category 2 (96-110)	59%	43%	24%	20%	16%	2%	1%
-- Category 3 (111-130)	16%	32%	46%	38%	18%	5%	3%
-- Category 4 (131-155)	1%	4%	15%	23%	8%	3%	2%
-- Category 5 (>155)	1%	1%	2%	4%	2%	1%	<1%
Forecast Maximum Wind	105 mph	110 mph	120 mph	125 mph	120 mph	40 mph	30 mph

- Official Forecast shows landfall around 72 h with forecast intensity of 120 mph (Category 3)
- Many realizations are already well inland by 72 h, and intensity probabilities shows nearly equal or higher probability of category 1 or 2 at 72 h
- Actual landfall intensity: 110 MPH (Category 2)
- Intensity at 72 h (12Z 13 September): 100 MPH (Category 2)

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
  - Likelihood of tropical cyclone intensity
- “Low” probabilities of extreme events often warrant action!

- https://cdp.dhs.gov/femasid