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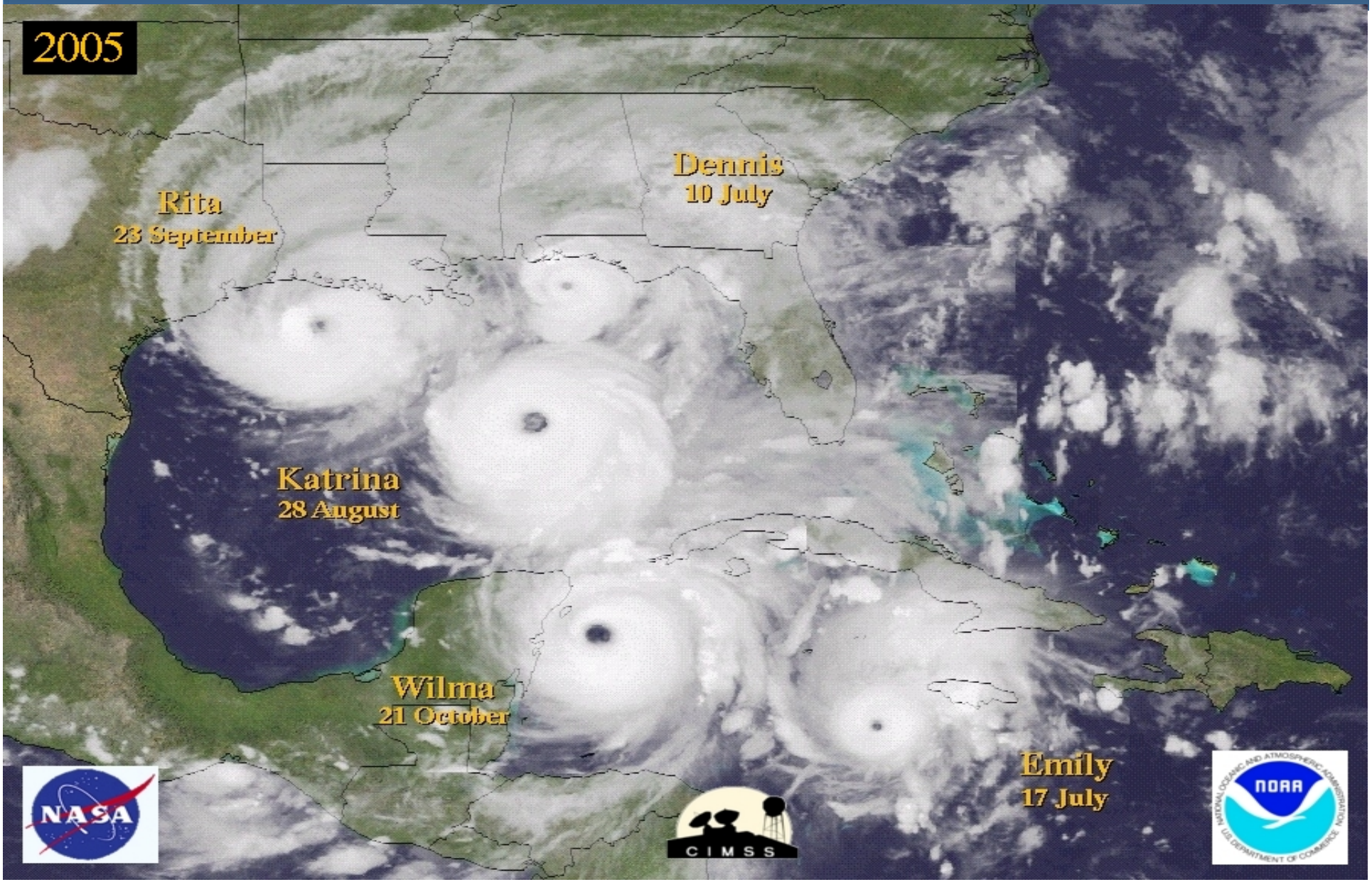
Ivan, Katrina, Rita: A New Era of Hurricane Activity?



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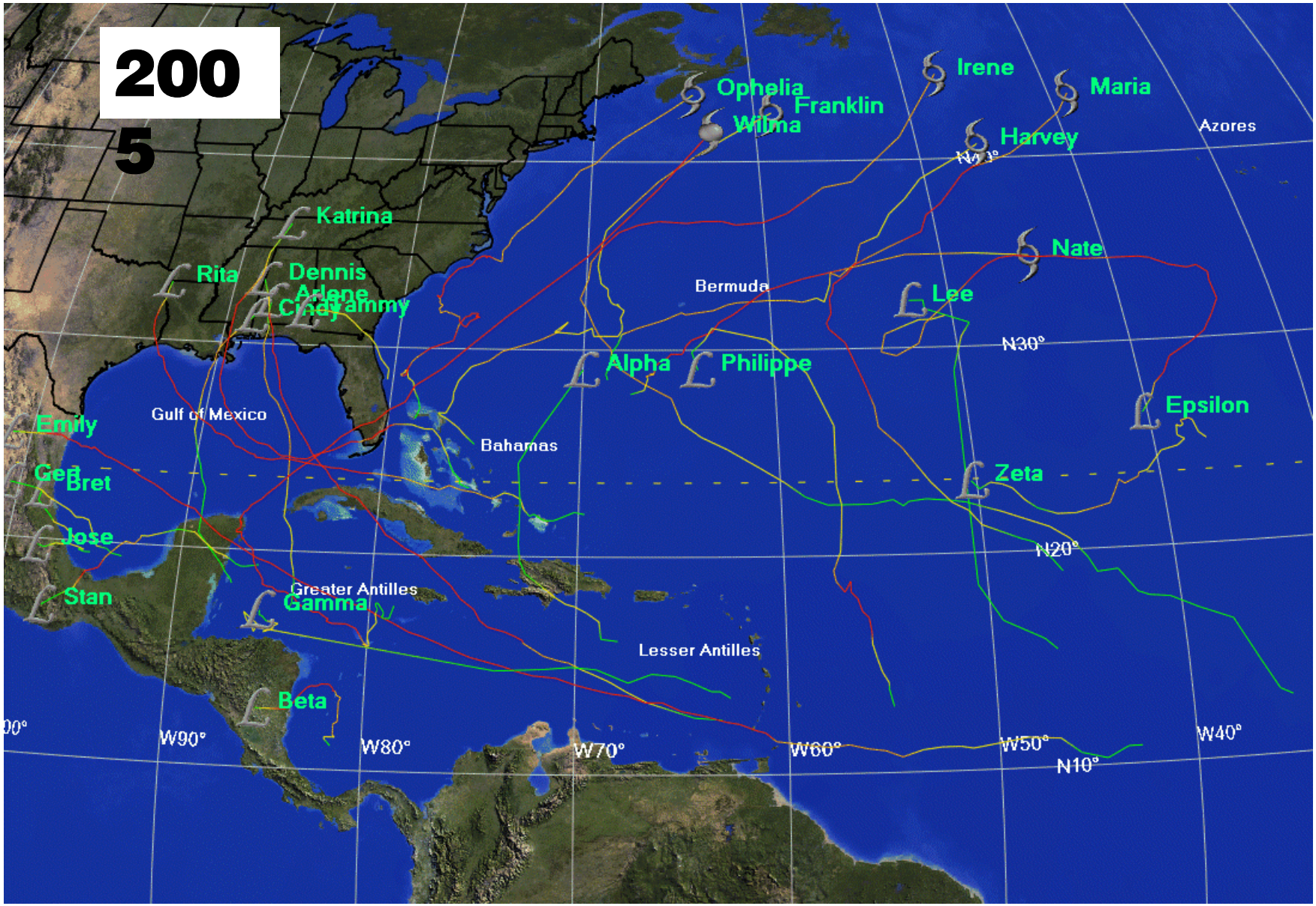

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2005 – A Record-Breaking Season

- **Most Named Storms (27)**
- **Most Hurricanes (15)**
- **Costliest Natural Disaster in U.S. History (Katrina)**
- **Deadliest Hurricane Since 1928 (Katrina)**
- **Most Intense Hurricane (Wilma – 882mb)**
- **Largest Pressure Fall in 24 hrs (Wilma 980mb–882mb)**

And there were many more….

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2005 – A Record-Breaking Season

- **Most Named Storms in July (5)**
- **Most Major Hurricanes in July (2)**
- **Strongest July Gulf Hurricane (Dennis)**
- **Most Named Storms in October (6)**
- **Most Category 5s (4) – Emily, Katrina, Rita, Wilma**
- **Costliest Season in U.S. History ($150+ billion)**

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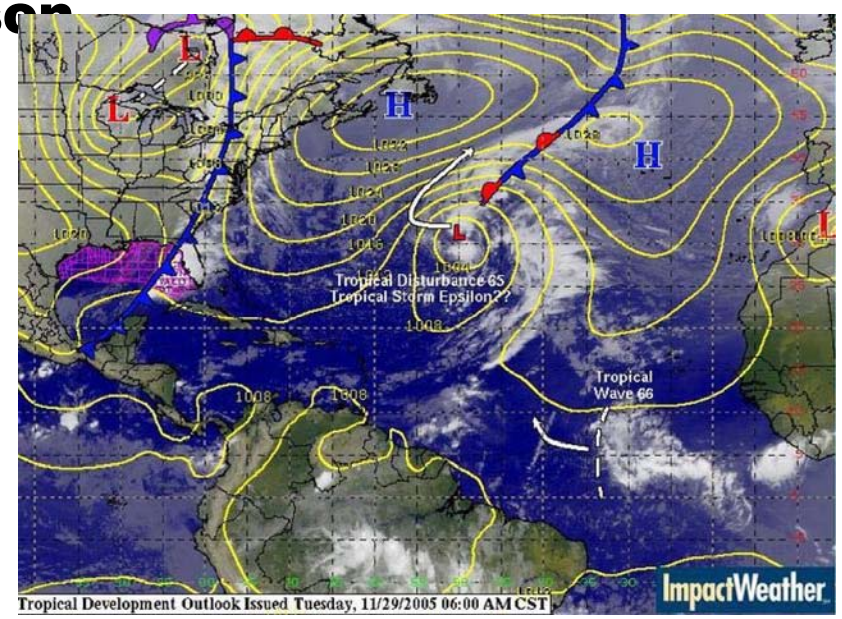
Tropical Cyclone Climatology Says:

- 60-80 Tropical waves per season
- About 10-15% develop into named storms
- 60% of named storms originate as tropical waves
- About 10 named storms per season

2005 Waves / Disturbances

- 66 Waves/Disturbances identified
- 30 Reached tropical depression strength or greater
- **Development ratio of over 45%**



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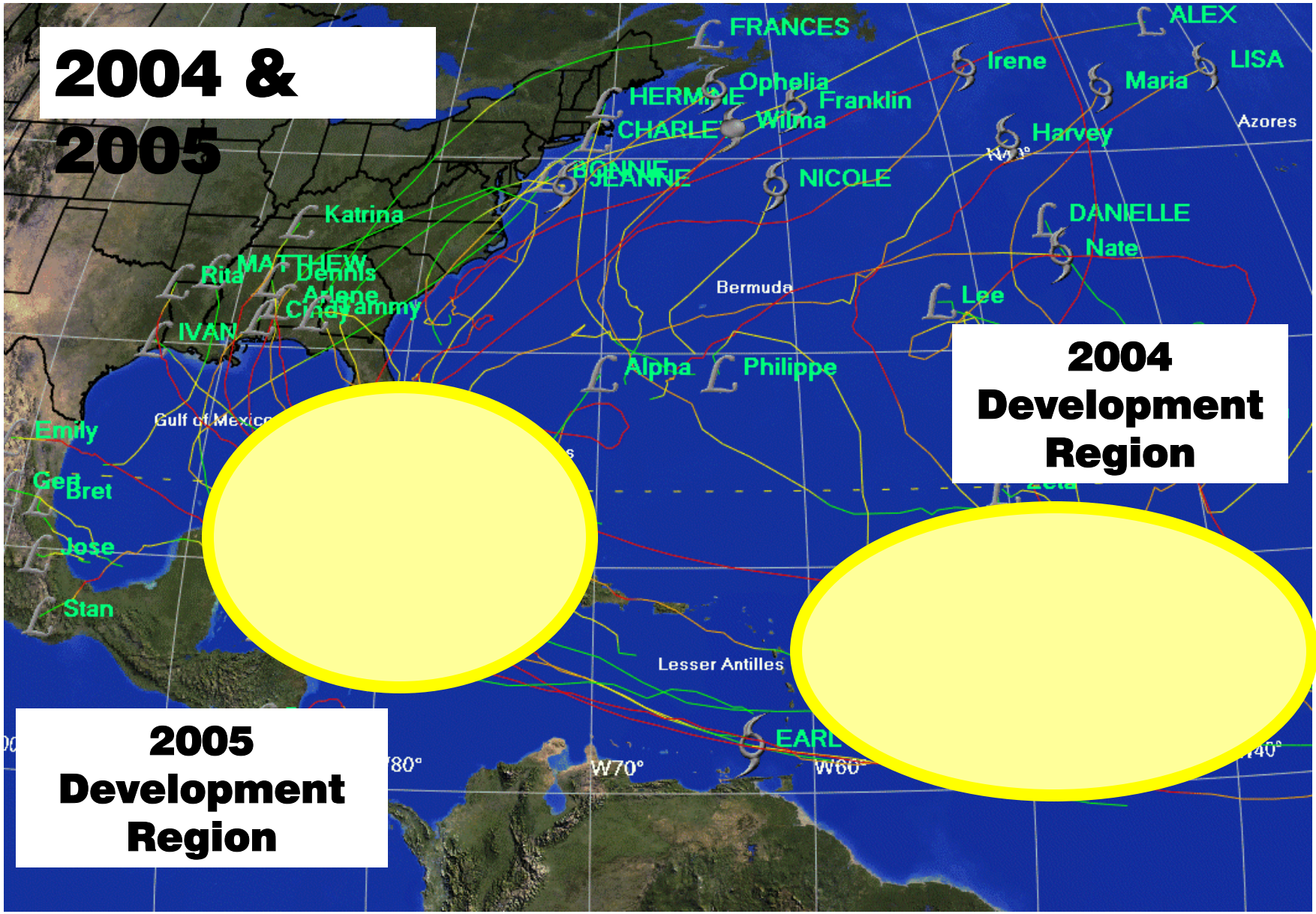

The 2005 Atlantic Hurricane Season . . .

NAME	DATES	Pressure (MB)	WIND (MPH)	Direct Deaths	U.S. Damage
1. TS Arlene	June 8-13	989	70	0	Minimal
2. TS Bret	June 28-30	1002	40	2	0
3. H Cindy	July 3-7	992	75	1	$320 million
4. IH Dennis	July 5-11	930	145	41	$2.23 billion
5. IH Emily	July 11-21	929	160	6	Minimal
6. TS Franklin	July 21-27	1000	70	0	0
7. TS Gert	July 23-25	1005	45	0	0
8. TS Harvey	Aug. 2-8	994	55	0	0
9. H Irene	Aug. 4-18	975	95	0	0
10. TS Jose	Aug. 22-23	1002	50	6	0
11. IH Katrina	Aug 23-31	902	175	1400+?	$150+ Billion
12. TS Lee	Aug. 22-Sept. 2	1007	40	0	0
13. IH Maria	Sept. 1-10	960	115	0	0
14. H Nate	Sept. 5-11	979	90	0	0
15. H Ophelia	Sept. 6-18	976	90	0	$70 million
16. H Philippe	Sept. 17-24	985	80	0	0

. . . The 2005 Atlantic Hurricane Season

NAME	DATES	Pressure (MB)	Wind (MPH)	Direct Deaths	U.S. Damage
17. IH Rita	Sept. 18-26	895	180	6 (113 indirect)	$9-15 billion
18. H Stan	Oct. 1-5	979	80	2000+	0
19. TS Tammy	Oct. 5-6	1001	50	2	0
20. H Vince	Oct. 9-11	987	75	0	0
21. IH Wilma	Oct. 15-25	882	185	22	$12.2 billion
22. TS Alpha	Oct. 22-24	998	50	26	0
23. IH Beta	Oct. 27-31	960	115	?	0
24. TS Gamma	Nov. 18-21	1004	45	20	0
25. TS Delta	Nov. 23-28	980	70	0	0
26. H Epsilon	Nov. 29-Dec. 8	979	85	0	0
27. TS Zeta	Dec. 30-Jan 6	994	60	0	0

The 2004 Atlantic Hurricane Season

NAME	DATES	Pressure (MB)	Max. Wind (MPH)	Direct Deaths	U.S. Damage
1. H. Alex	Jul. 31-Aug. 6	957	120	1	$5 Million
2. T.S. Bonnie	Aug. 9-12	1000	65	0	Minimal
3. IH. Charley	Aug. 9-15	941	145	15	$14 Billion
4. H. Danielle	Aug. 13-21	970	100	0	0
5. T.S. Earl	Aug 13-16	1004	45	0	0
6. IH. Frances	Aug. 25-Sep. 9	935	145	7	$9 Billion
7. H. Gaston	Aug. 27-Sep. 1	991	75	0	$130 Million
8. T.S. Hermine	Aug. 29-31	1000	50	0	Minimal
9. IH. Ivan	Sep. 2-24	910	165	94	$15 Billion
10. IH. Jeanne	Sep. 13-28	950	125	3100+	$7 Billion
11. IH. Karl	Sep. 16-24	952	145	4	0
12. H. Lisa	Sep. 19-Oct. 3	987	75	0	0
13. T.S. Matthew	Oct. 8-10	997	45	0	Minimal
14. S.T.S. Nicole	Oct. 10-11	988	50	0	0
15. T.S. Otto	Nov. 30-Dec. 2	997	50	0	0

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The “Big Three” Hurricanes of 2004-2005

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Damage From Ivan, Katrina, and Rita

Hurricane	Platforms Destroyed	Platforms Damaged	Rigs Destroyed	Rigs Damaged	Pipelines Damaged
Ivan	7	31	1	10	100
Katrina	46	20	4	9	100
Rita	69	32	1	10	83

Source: MMS, Jan. 19, 2006

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November 14, 1947?

The first oil well out of sight of land was brought in by Kerr-McGee in the Gulf of Mexico about 45 miles south of Morgan City in the Ship Shoal Block 32 Field, marking the birth of the offshore oil and gas industry.

Source:
Louisiana Mid-Continent Oil and Gas Association

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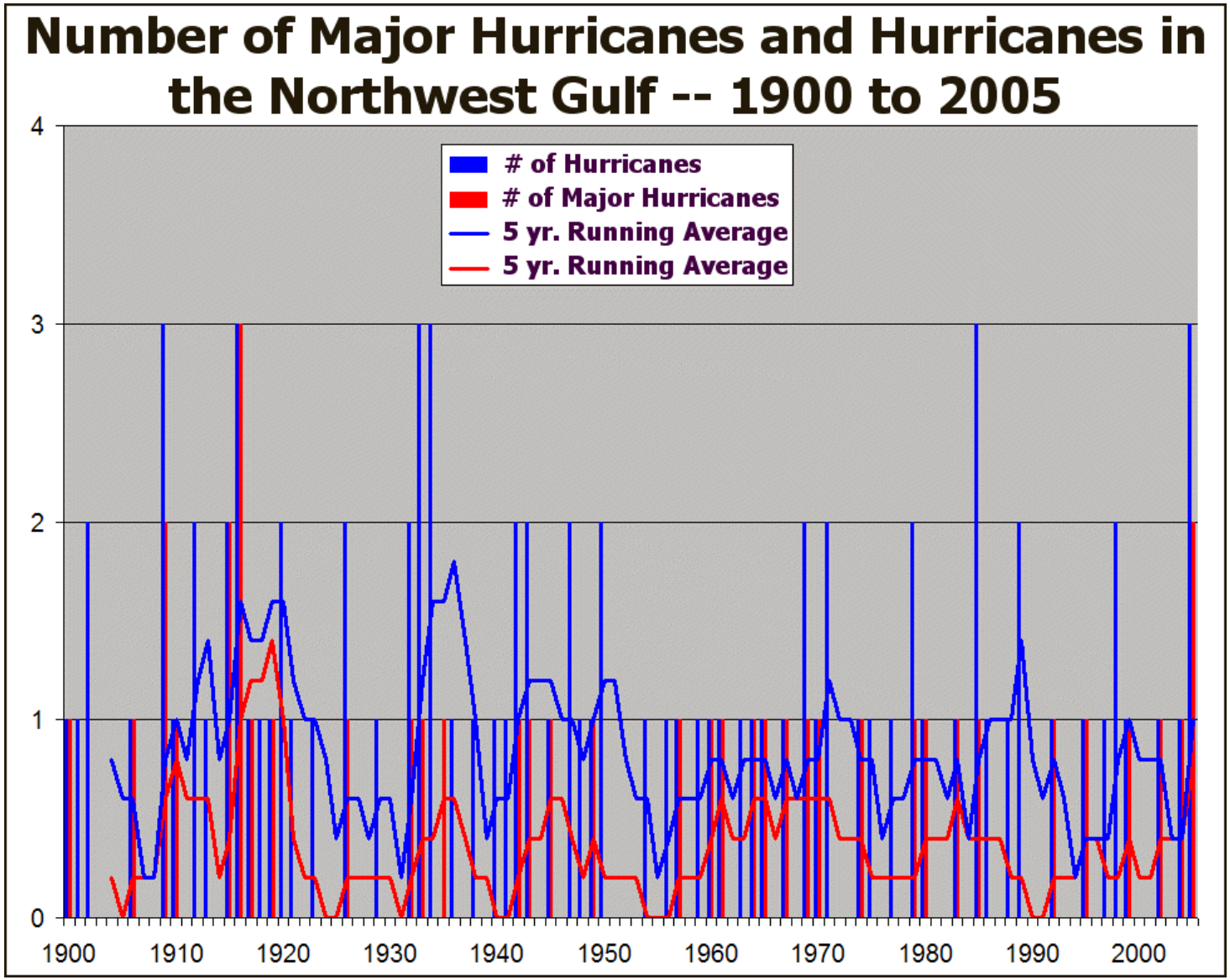

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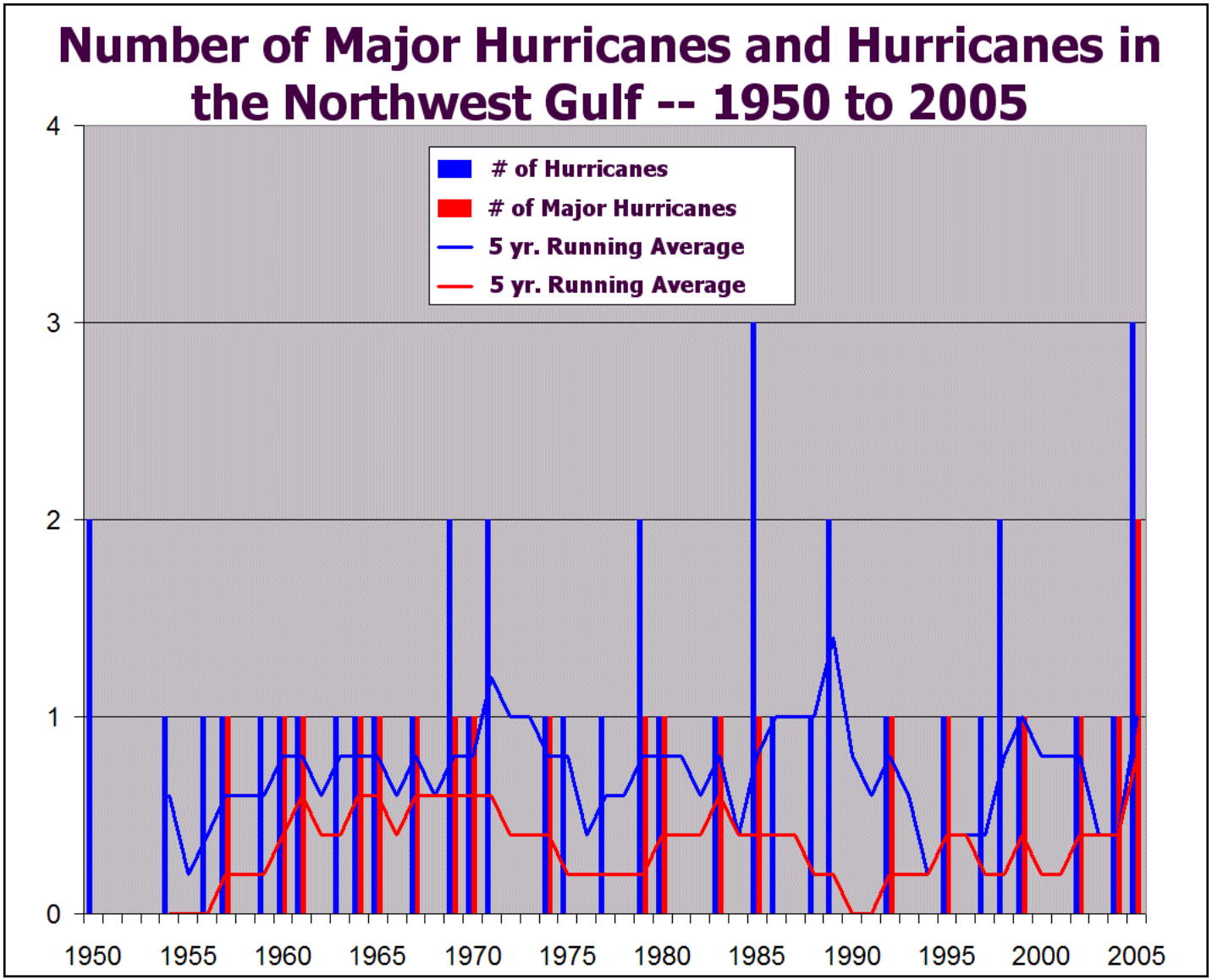

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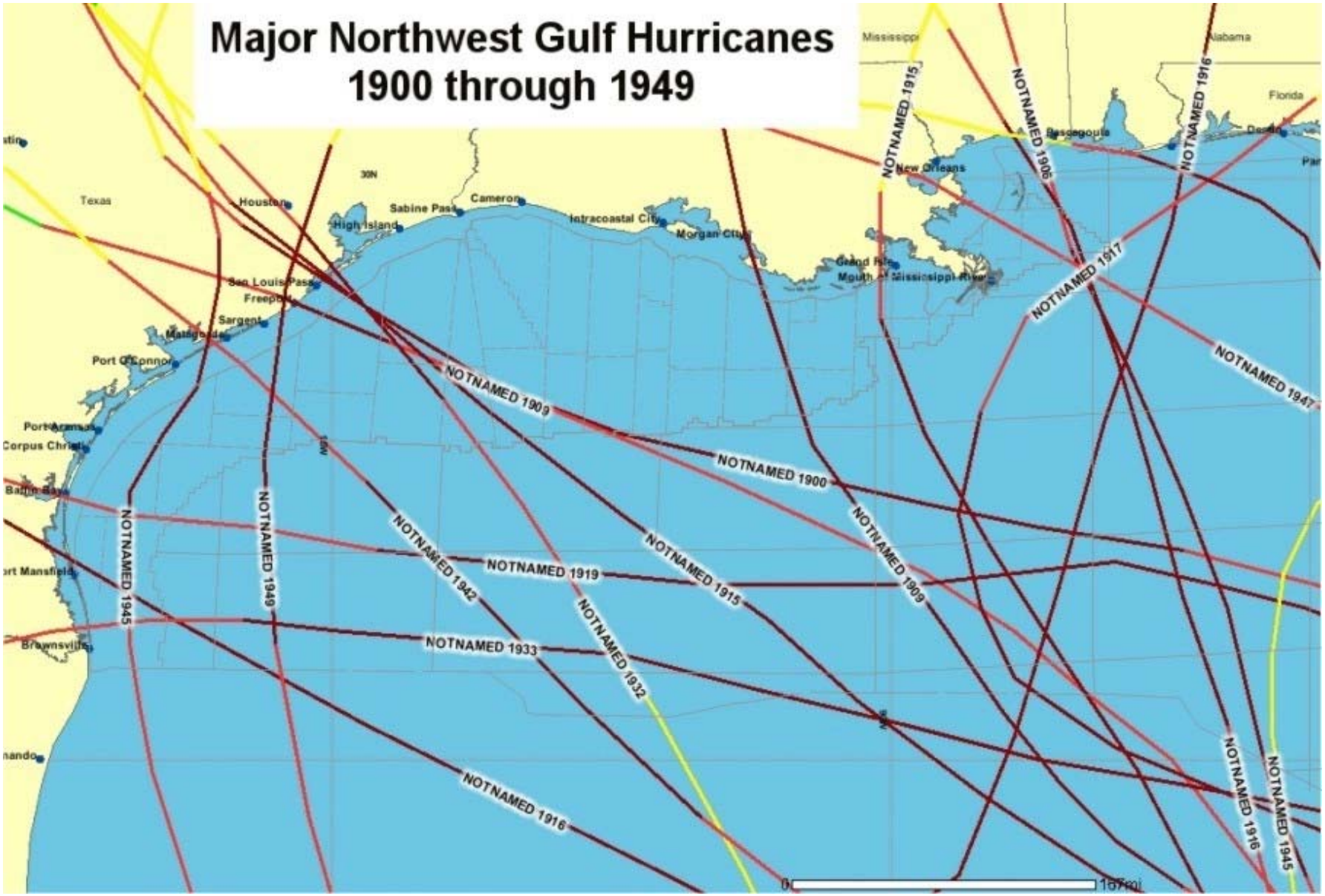

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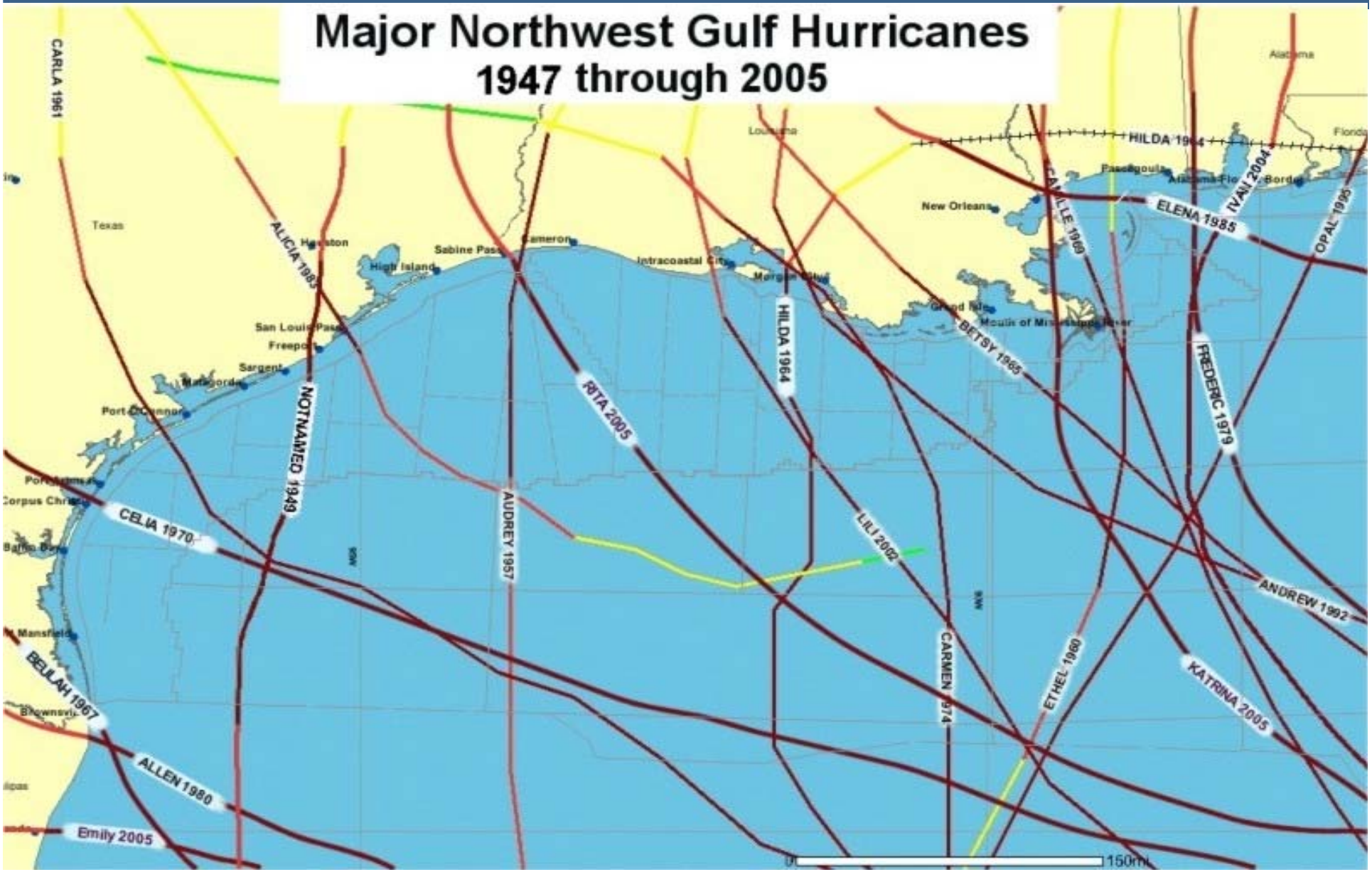
Major Northwest Gulf Hurricanes
1947 through 2005



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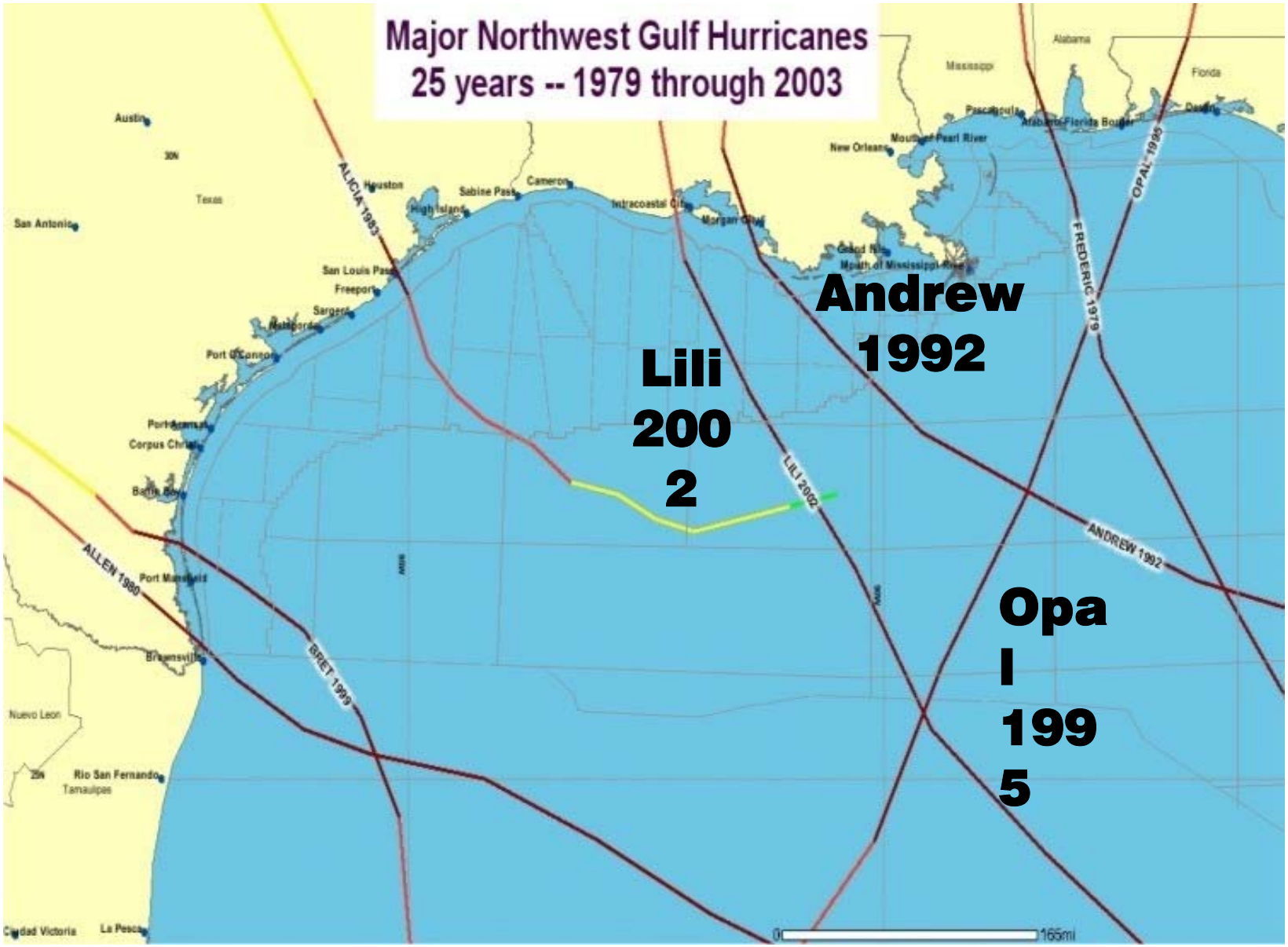

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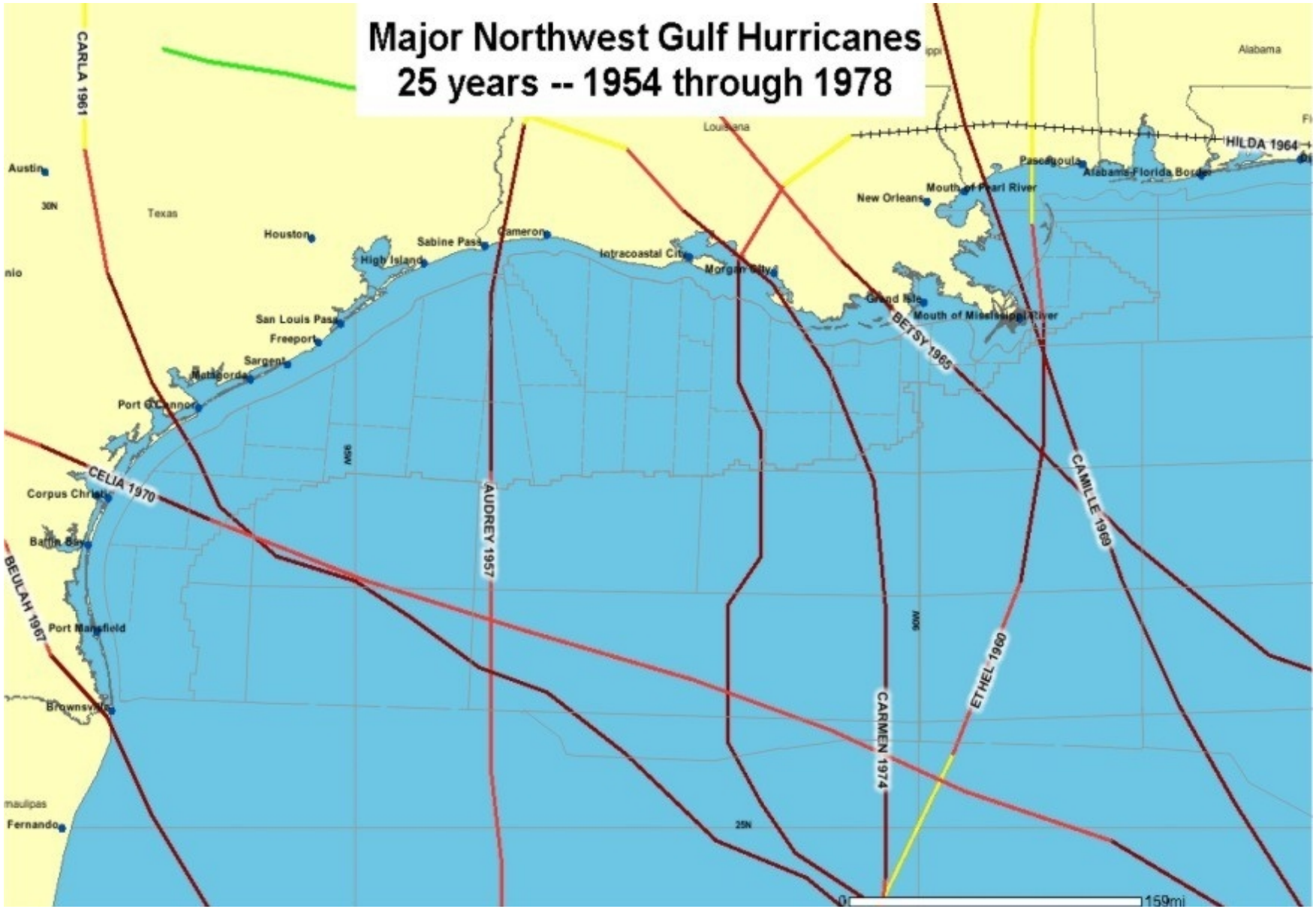

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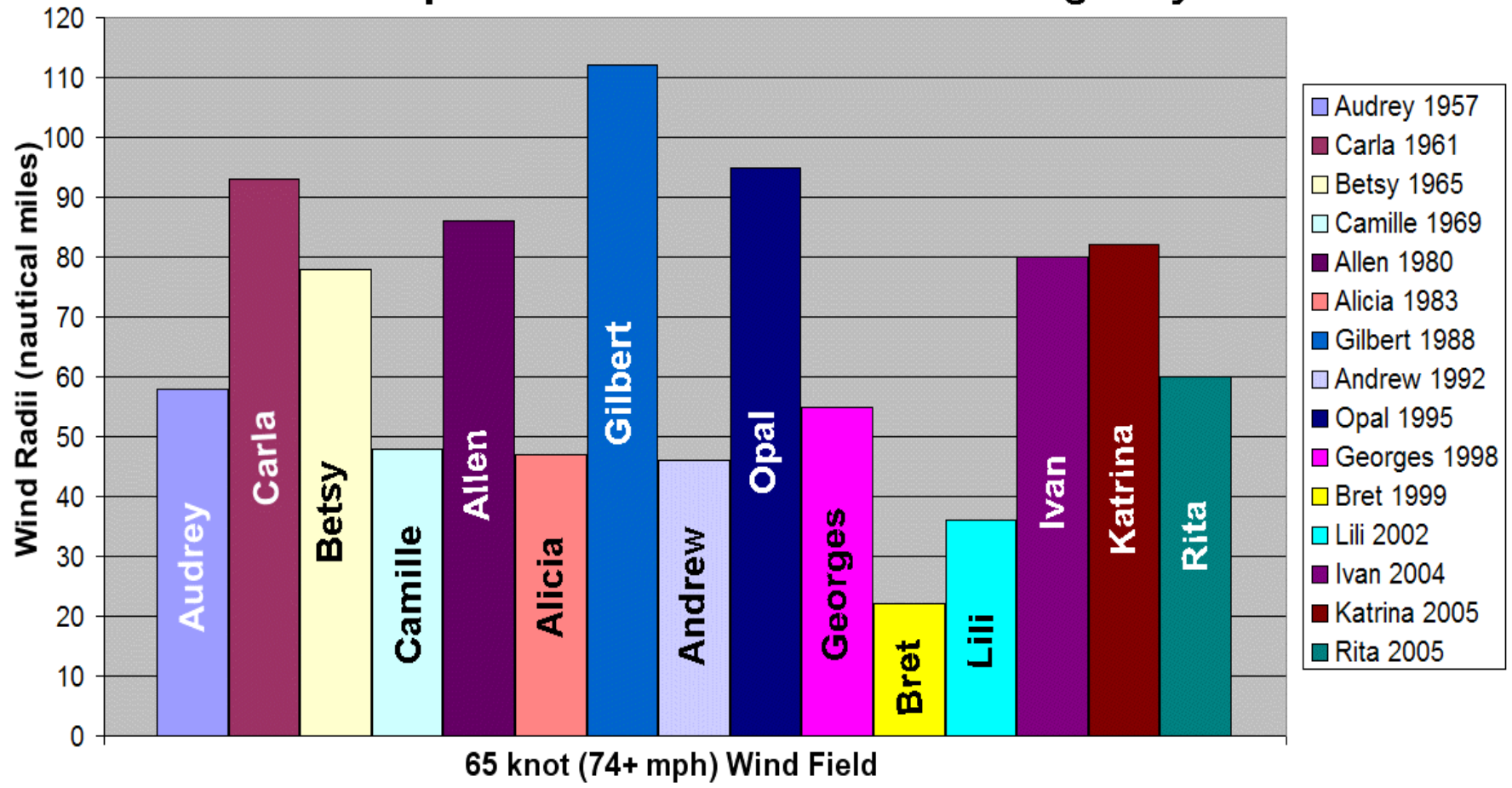
Northwest Gulf Major Hurricanes 1957 - 2005

65 kt. / 74+ mph Wind Radii / Listed Chronologically



Not Shown: Hilda '64, Beulah '67, Celia '70, Carmen '74, Frederic '79, Elena '85

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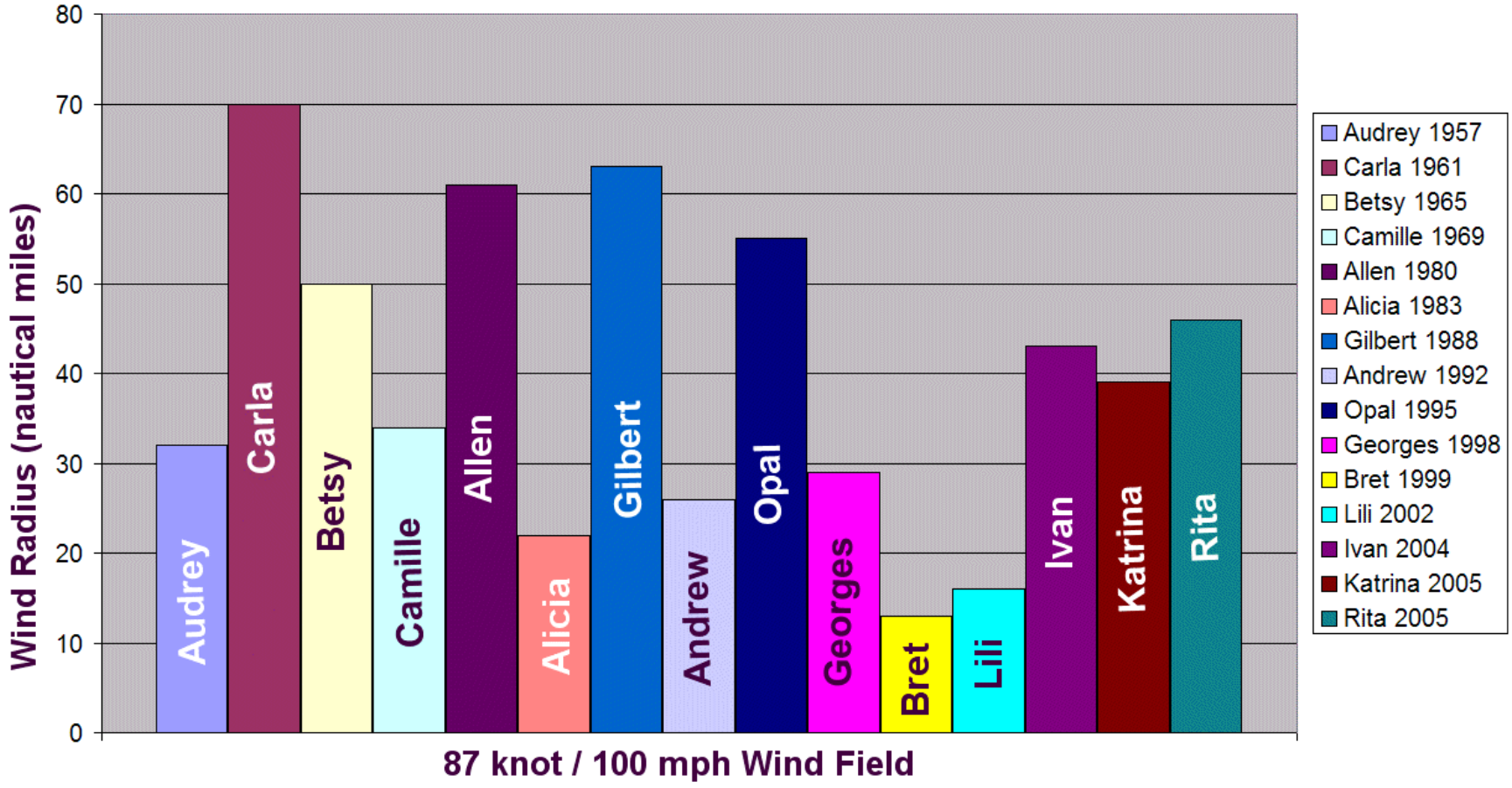
Northwest Gulf Major Hurricanes 1957 - 2005

87 kt. / 100 mph Wind Radii / Listed Chronologically



Not Shown: Hilda '64, Beulah '67, Celia '70, Carmen '74, Frederic '79, Elena '85

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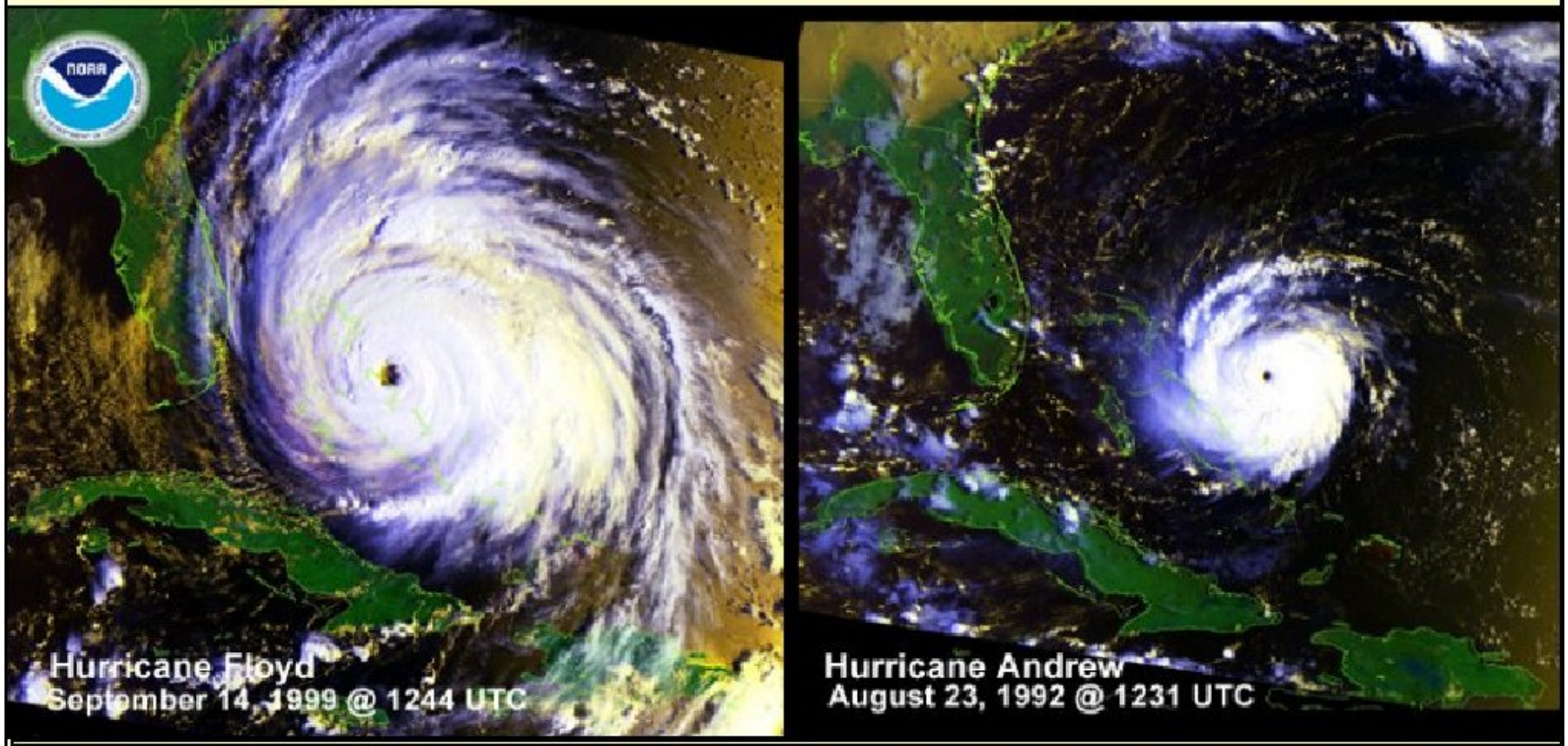
All Hurricanes are NOT Alike



Variability in Size - Floyd vs. Andrew

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The Problems With Saffir-Simpson

Saffir-Simpson Scale

Category	Wind (mph)	Pressure (inches)	Surge (feet)
1	74-95	> 28.94	4 - 5
2	96-110	28.50-28.93	6 - 8
3	111-130	27.91-28.49	9 - 12
4	131-155	27.17-27.90	13 - 18
5	> 155	< 27.16	> 18

- Based only on max winds
- Max winds may be isolated
- Storm surge is more related to a hurricane's size
- Does not consider size and scope of a hurricane's wind field
- Not a good estimate of potential damage
- Doesn't consider tropical storms

Assumes that all hurricanes are alike

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Our Solution

Devise a new scale for classifying hurricanes that takes into consideration more than just maximum surface winds:

Size (1-25 points)

- Examines the total coverage of the 35+, 50+, 65+, and 87+ knot wind fields

Intensity (1-25 points)

- Points assigned using the exponential relationship between wind speed and the force exerted on an object

The Result: A 50-point scale that better represents a tropical cyclone's true destructive potential – the

Hurricane Severity Index (HSI)

Developed by: Chris Hebert and Bob Weinzapfel

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Determining Size Points

- Tropical Storm (39-57 mph) – gets from 1-3 points
- Tropical Storm (58-73 mph) – gets from 1-4 points
- Hurricane (74-99 mph) – gets from 1-8 points
- Hurricane (100+ mph) – gets from 1-10 points

A total of 25 size points is possible.

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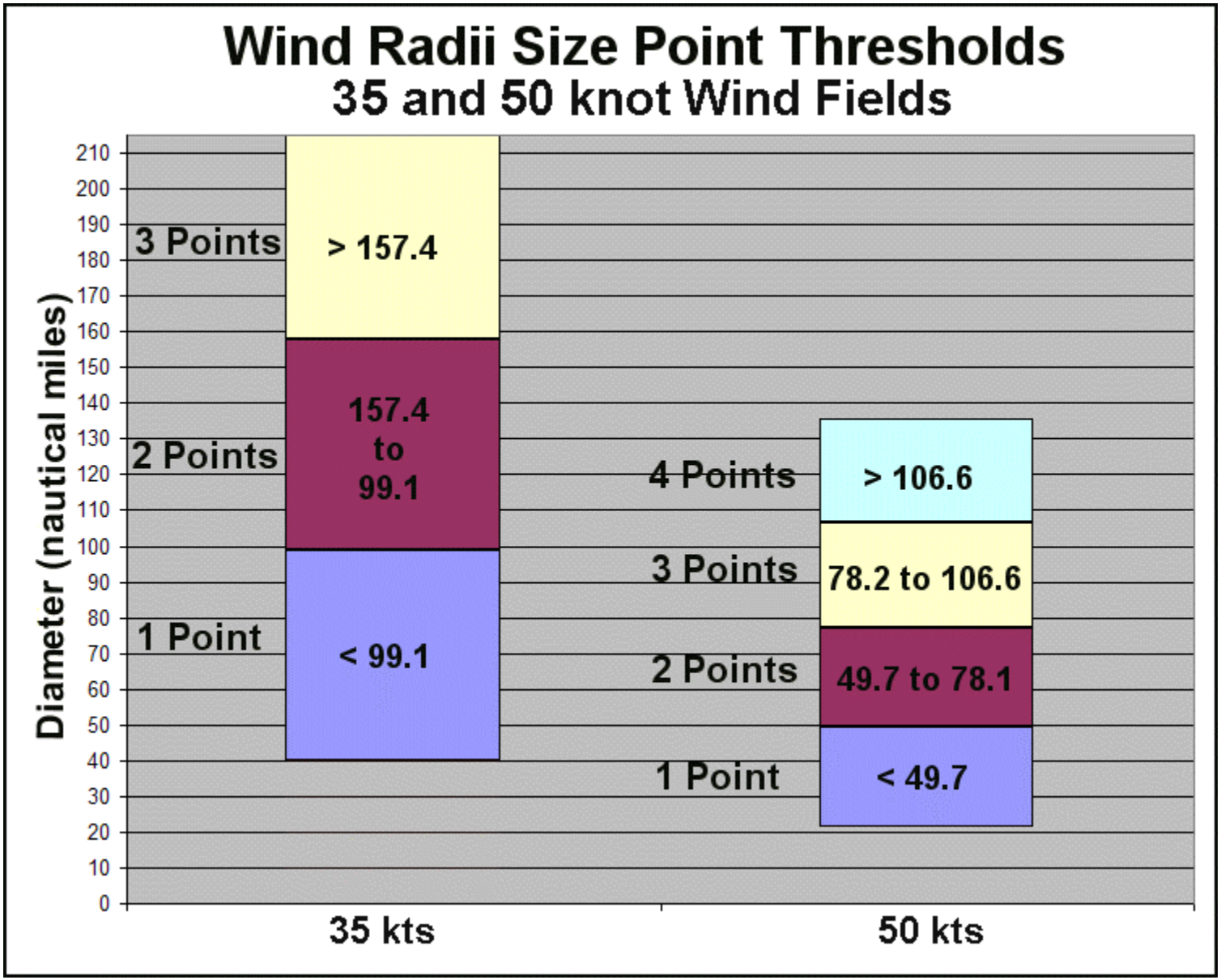

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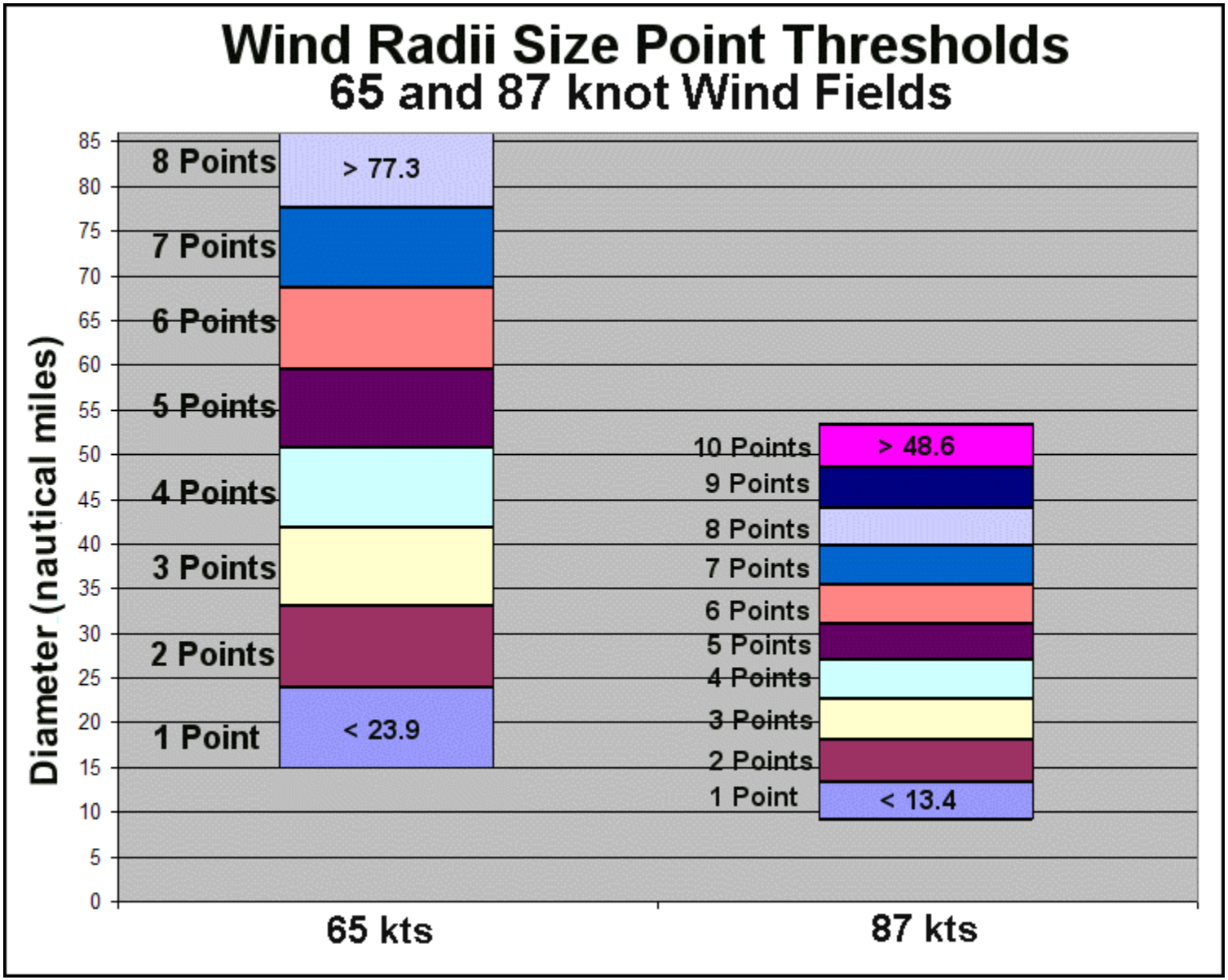

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Determining Intensity Points

- Wind force on an object is an exponential function (twice the wind speed equals four times the wind force)
- Developed an exponential 25-point intensity scale that assigns 1 point for a 30 kt (35 mph) tropical depression and up to 25 points for a hurricane with winds above 150 kts (175 mph)

A total of 25 size points is possible.

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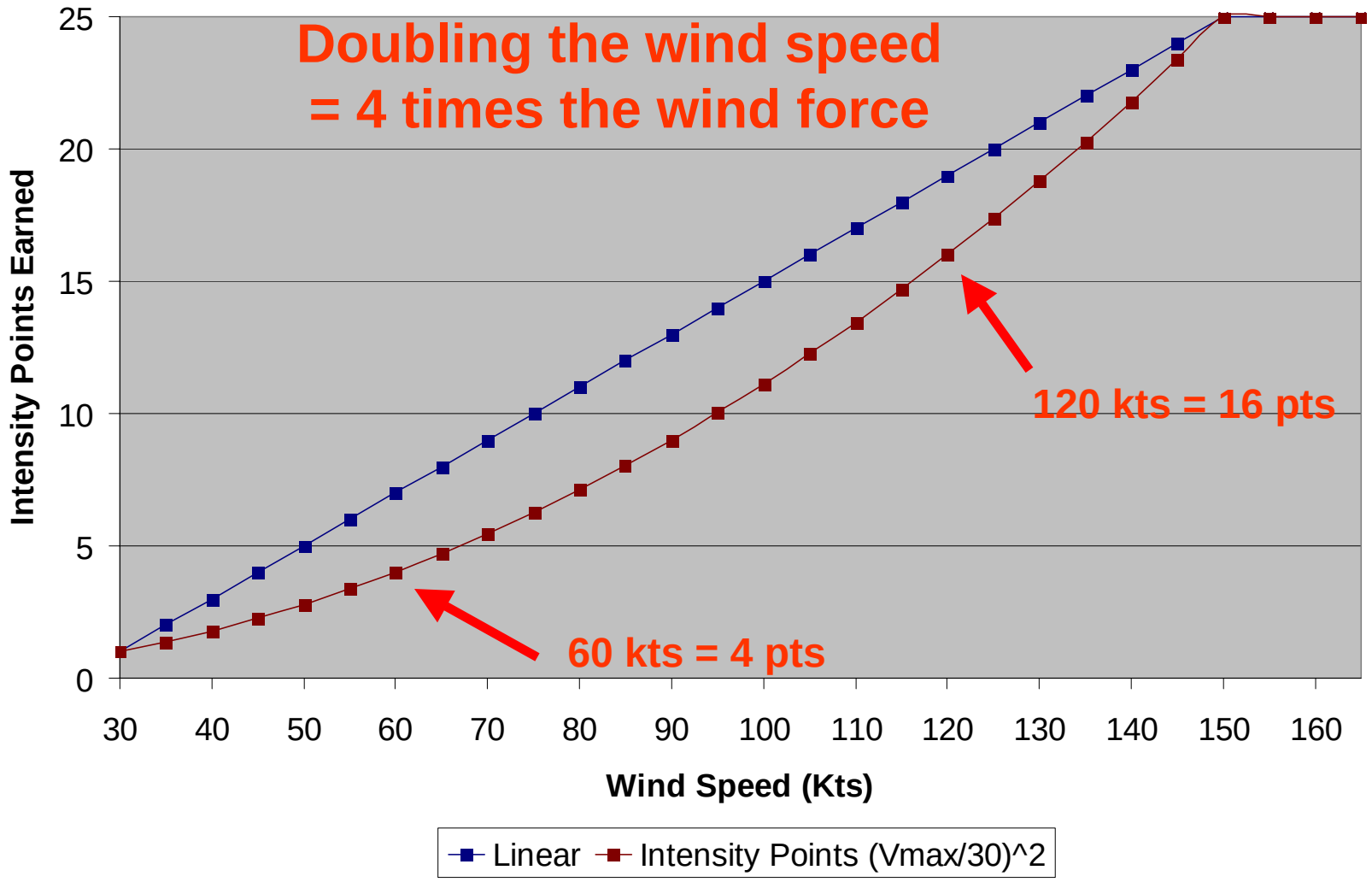
Assignment of Intensity Points Based on Max Sustained Winds



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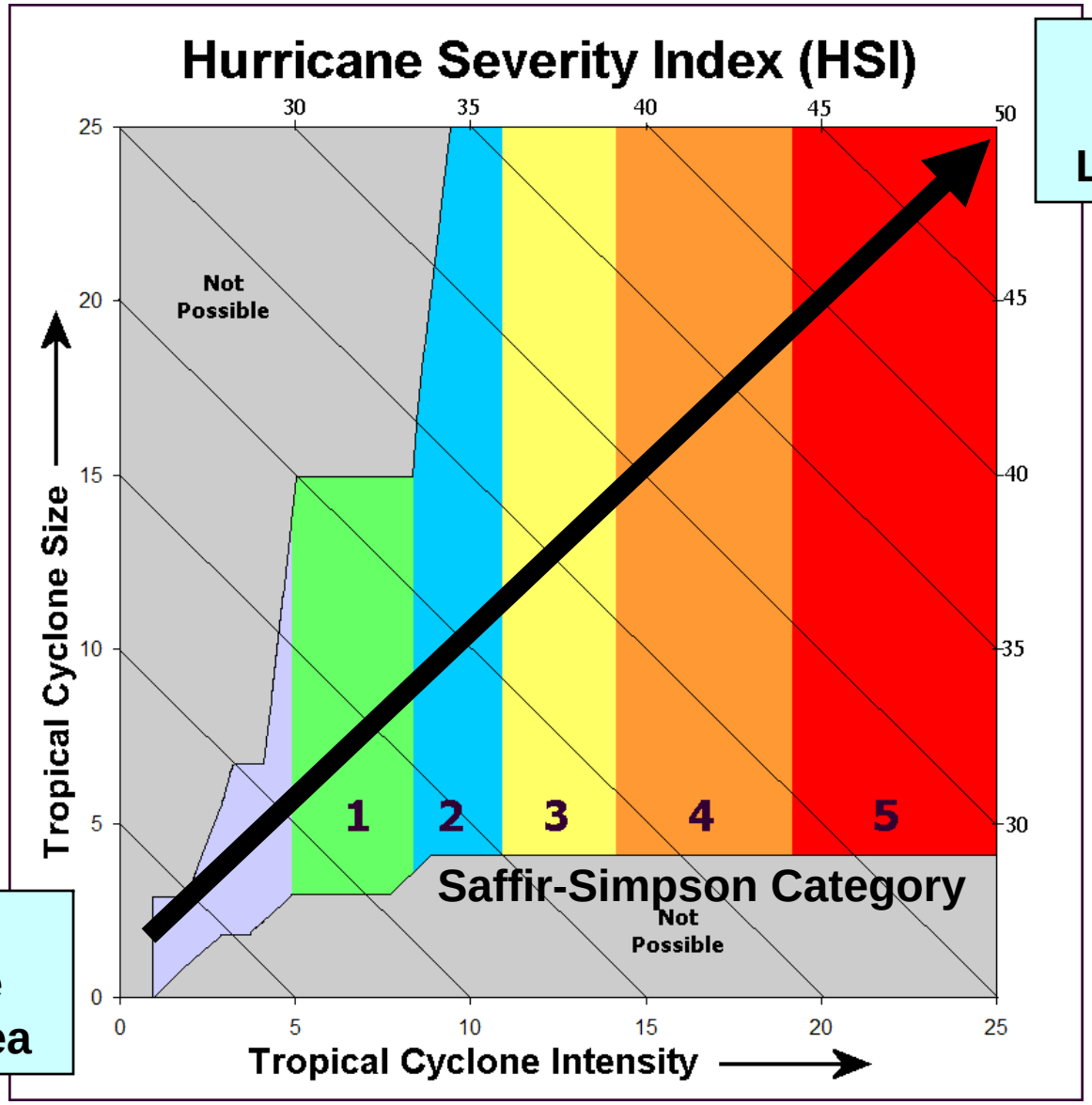

Severe Damage Large Area

Minimal Damage Small Area

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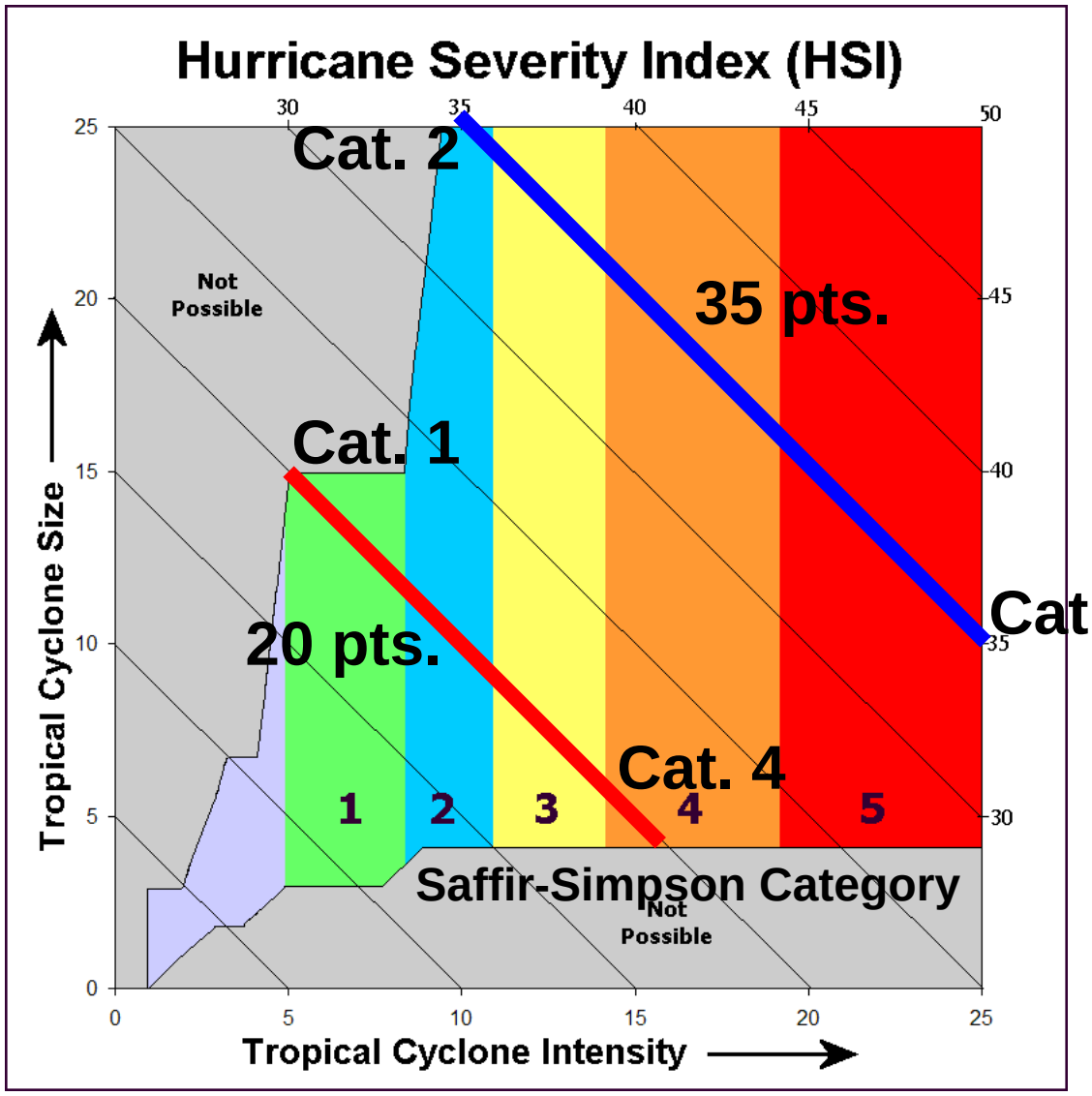

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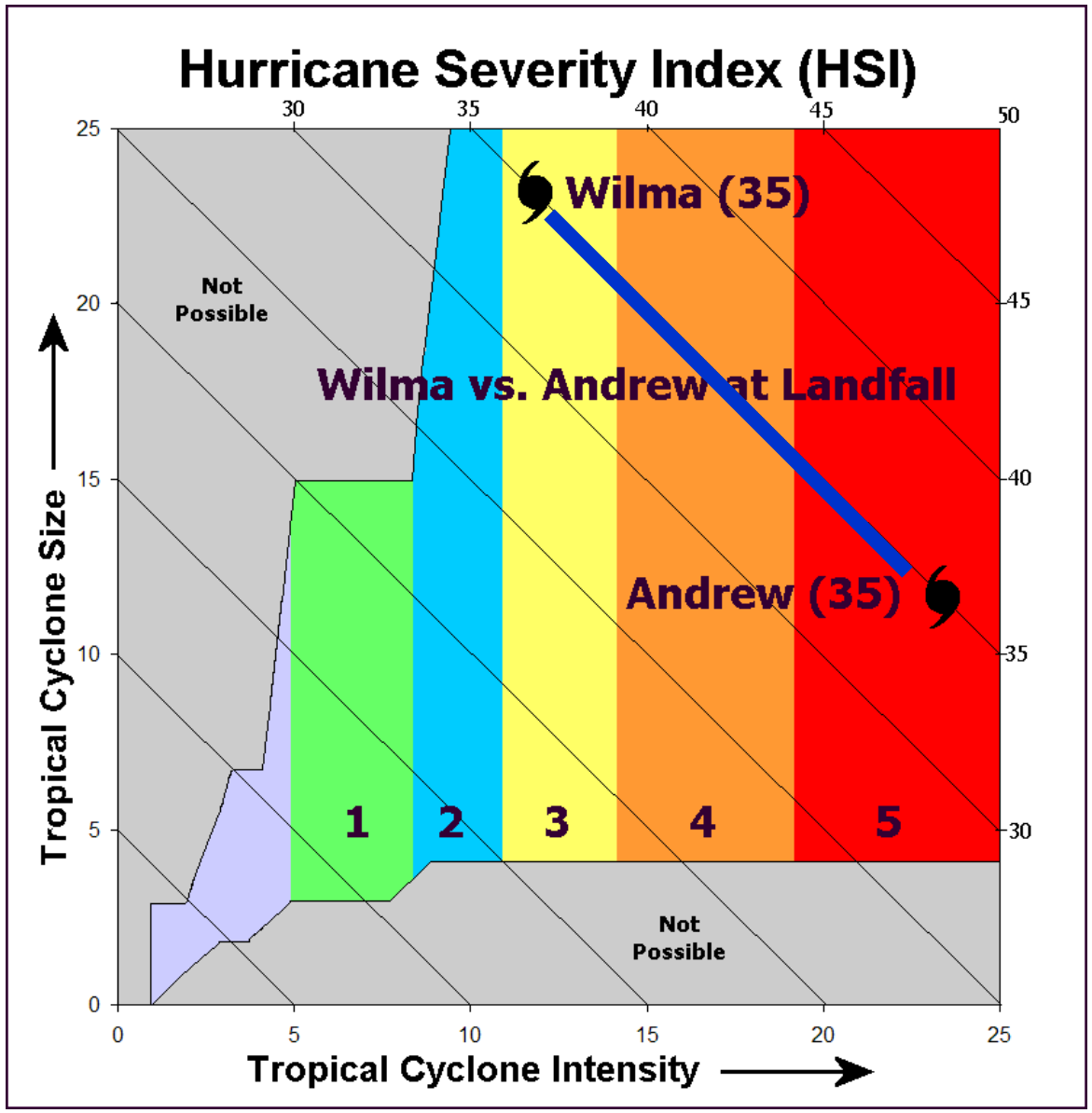

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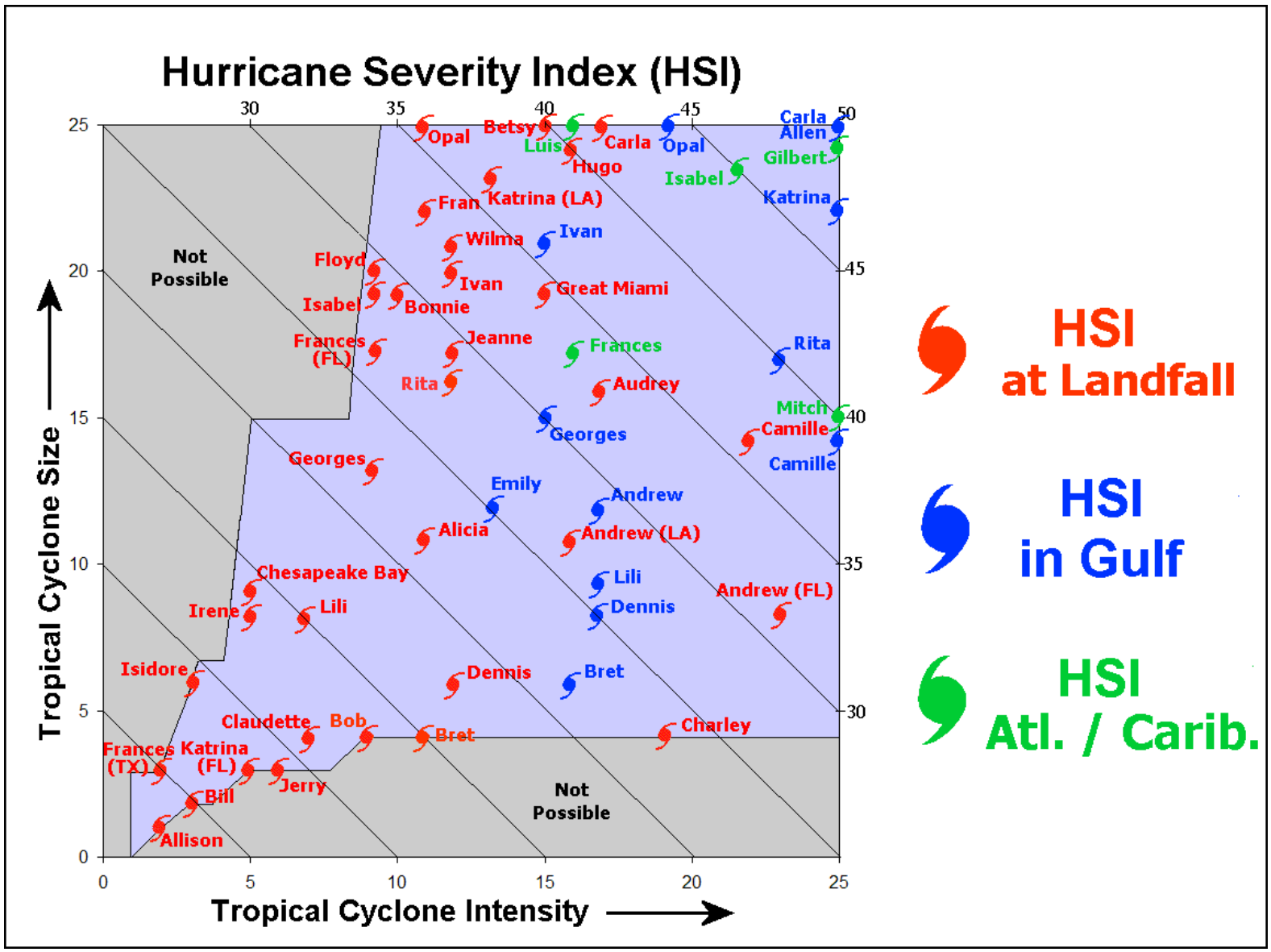


H. Ivan – 145 kts/165 mph
(Sep. 2-24, 2004)
Image Index
1: 2004SEP02/21:00:00UTC
2: 2004SEP04/01:30:00UTC
3: 2004SEP05/01:45:00UTC
4: 2004SEP06/01:45:00UTC
5: 2004SEP06/21:15:00UTC
6: 2004SEP07/21:15:00UTC
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9/4
01Z
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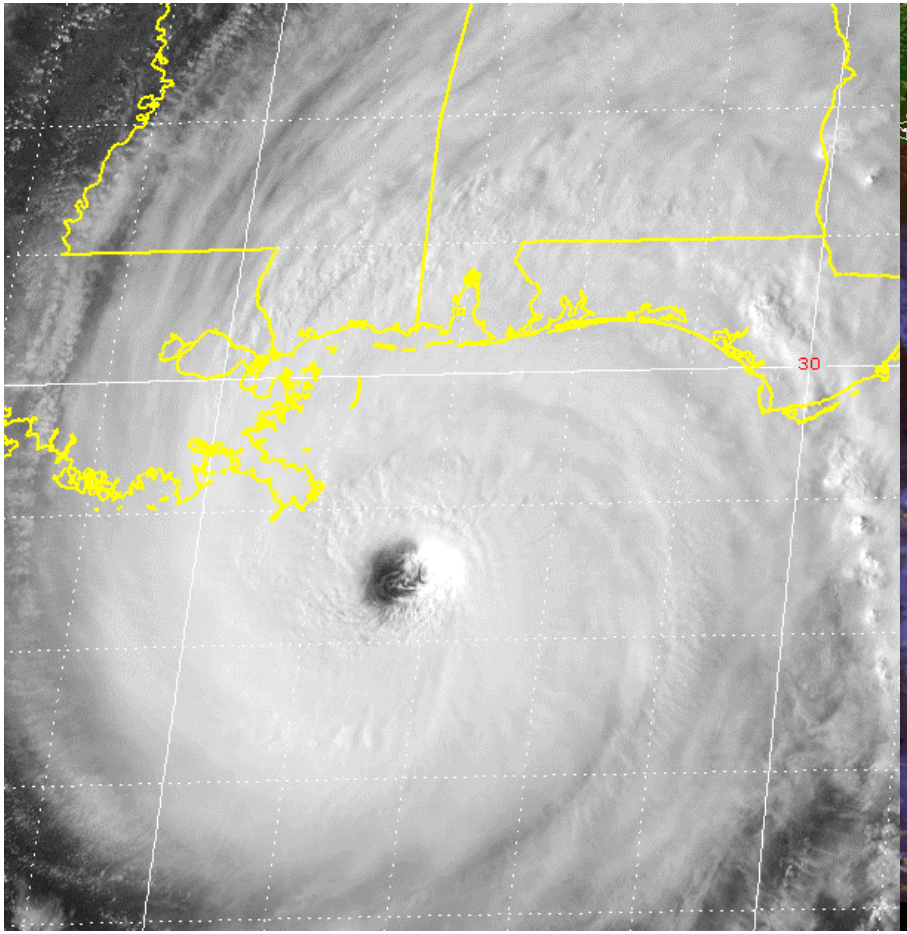
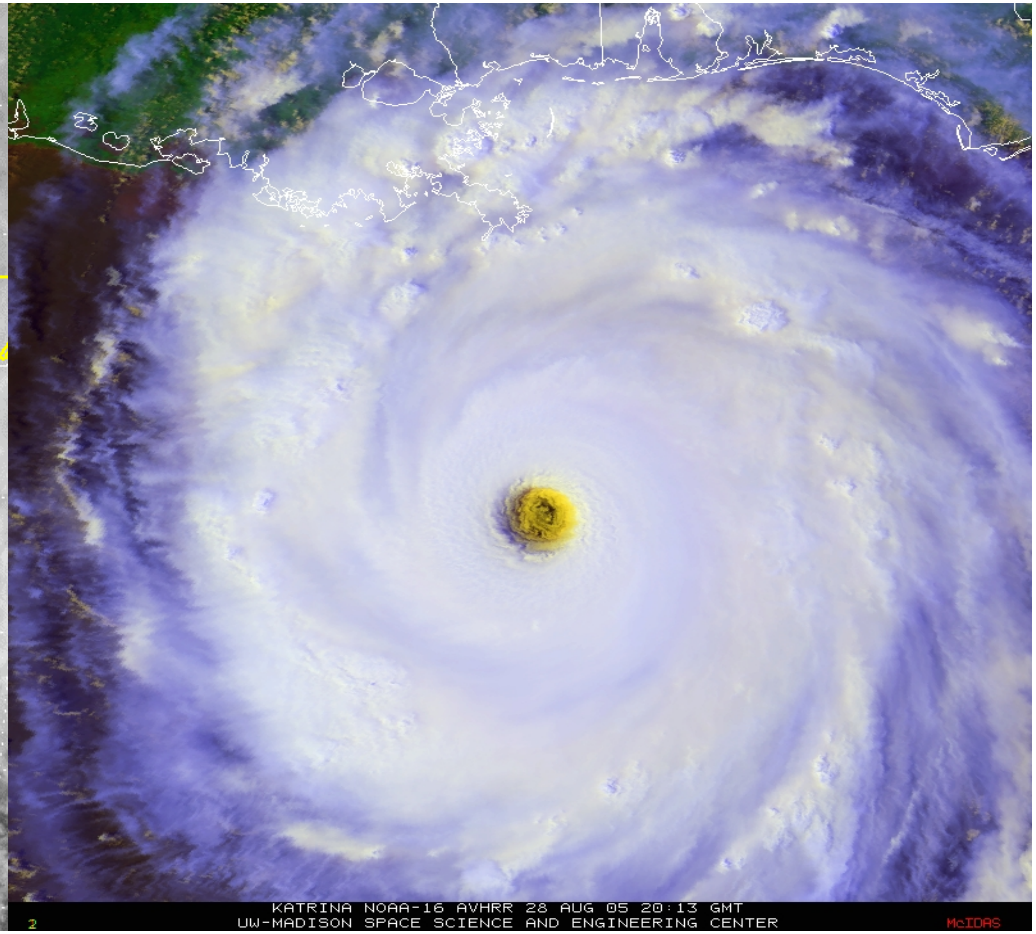
9/2
21
TROPICAL DEPR
TROPICAL STORM
CATEGORY 1
CATEGORY 2
CATEGORY 3
CATEGORY 4
CATEGORY 5
NOAA
1
MONTAGE OF IVAN
GOES-12/INFRARED
UW-CIMSS
McIDAS

Hurricanes Ivan and Katrina Prior to Landfall – Very Similar

Hurricane Ivan – 115 kts / 135 mph
Storm Surge – 10-15 ft
Size Points – 21
Intensity Points – 15
HSI at Landfall = 36

Hurricane Katrina – 125 kts / 150 mph
Storm Surge – 28-32 ft
Size Points – 21
Intensity Points – 17
HSI at Landfall = 38

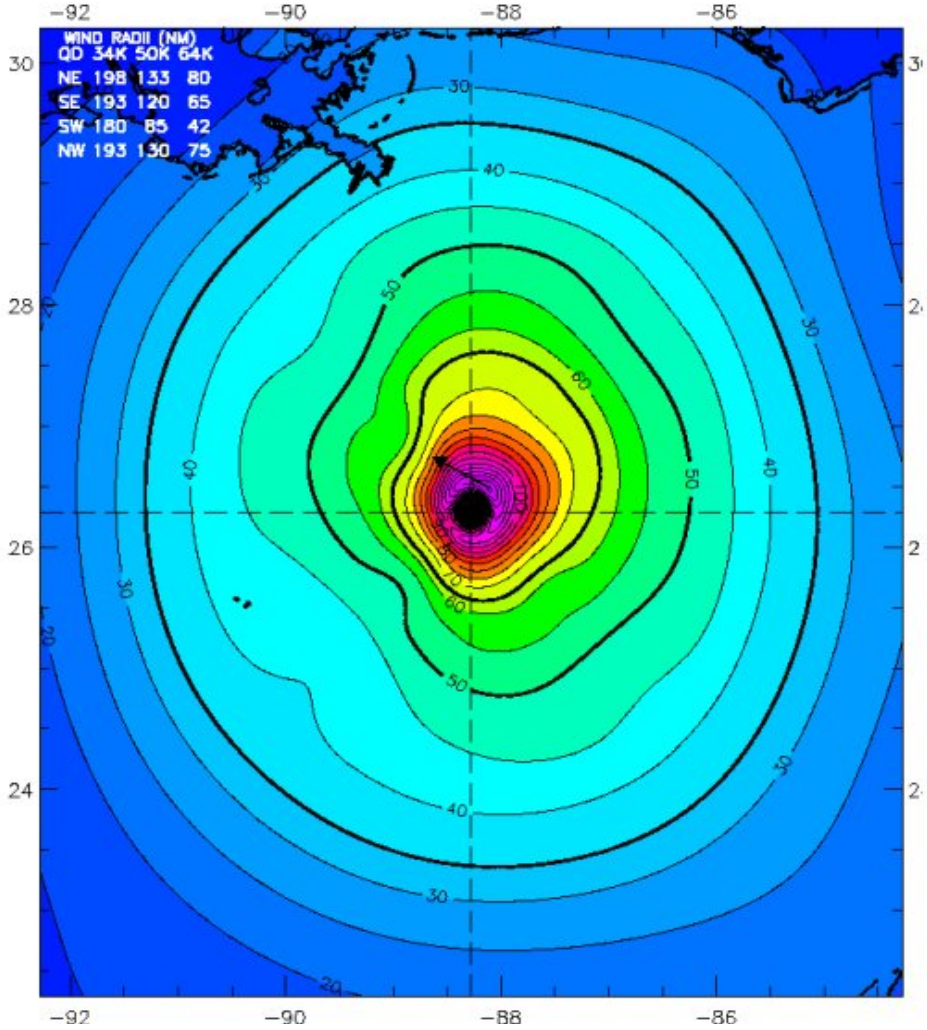




Hurricane Al12.2005 1630 UTC 28 AUG 2005

Max 1–min sustained surface winds (kt) for marine exposure

Analysis based on GPSSONDE_MBL from 1107 – 1503 z; GPSSONDE_WL150 from 1107 – 15
CMAN from 1105 – 1600 z; SHIP from 1150 – 1514 z; MOORED_BUOY from 1109 – 1550 z;
AFRES adj. to surface from mean height 2898 m from 1105 – 1555 z;
GPSSONDE_SFC from 1107 – 1503 z; GOES from 1302 – 1302 z;
1630 z position extrapolated from 1500 z Vortex wind center using 320 deg @ 10 kts; mslp = 90



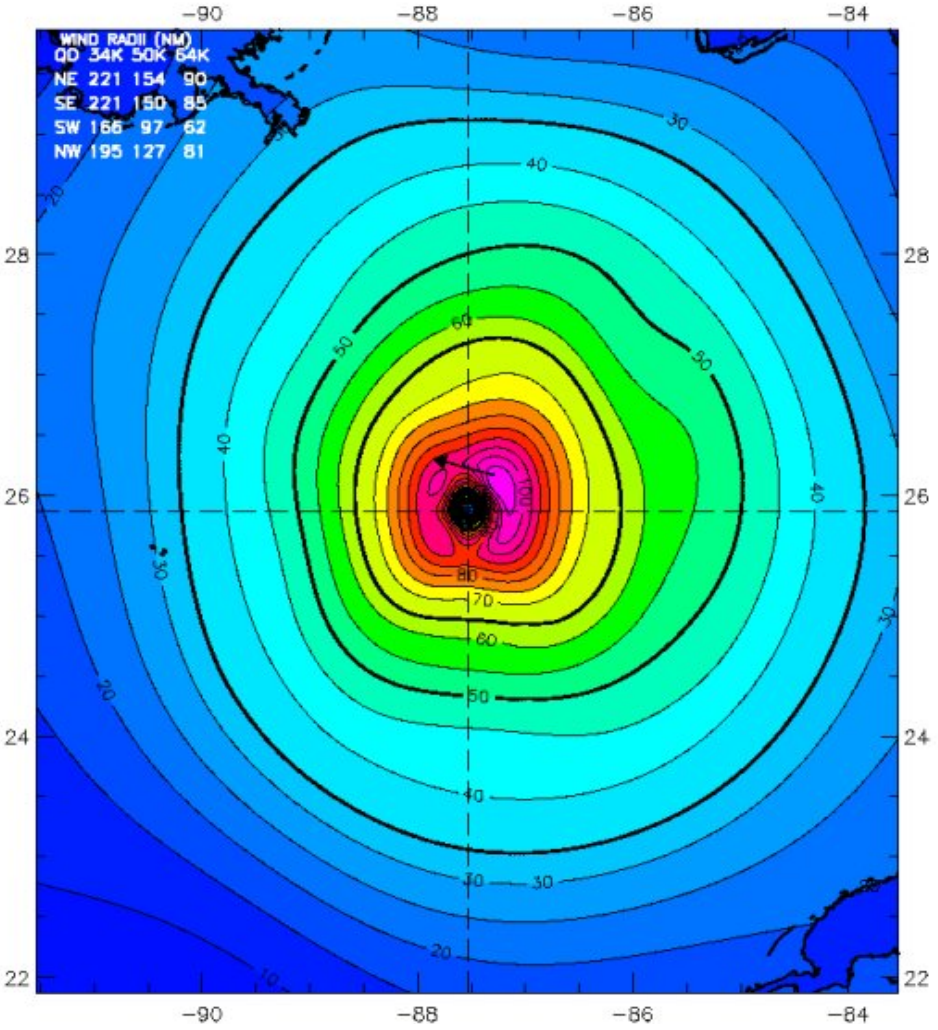
Katrina (150mph)

NOAA / AOML / Hurricane Research Division

Hurricane Ivan 0730 UTC 15 Sep 2004

Max 1–min sustained surface winds (kt) for marine exposure

Analysis based on SHIP from 0550 – 0550 z; GOES from 0702 – 0702 z;
CMAN_LD_TO from 0209 – 0209 z; SFMR43 from 0204 – 0204 z;
TOWER_LD_TO from 0204 – 0204 z; MOORED_BUOY from 0209 – 1059 z;
GPSSONDE_SFC from 0206 – 0206 z; CMAN from 0205 – 0205 z;
GPSSONDE_WL150 from 0206 – 0206 z;
0730 z position interpolated from 0600 ATCF; mslp = 935.0 mb



Ivan (135 mph)

sureme

NOAA / AOML / Hurricane Research Division

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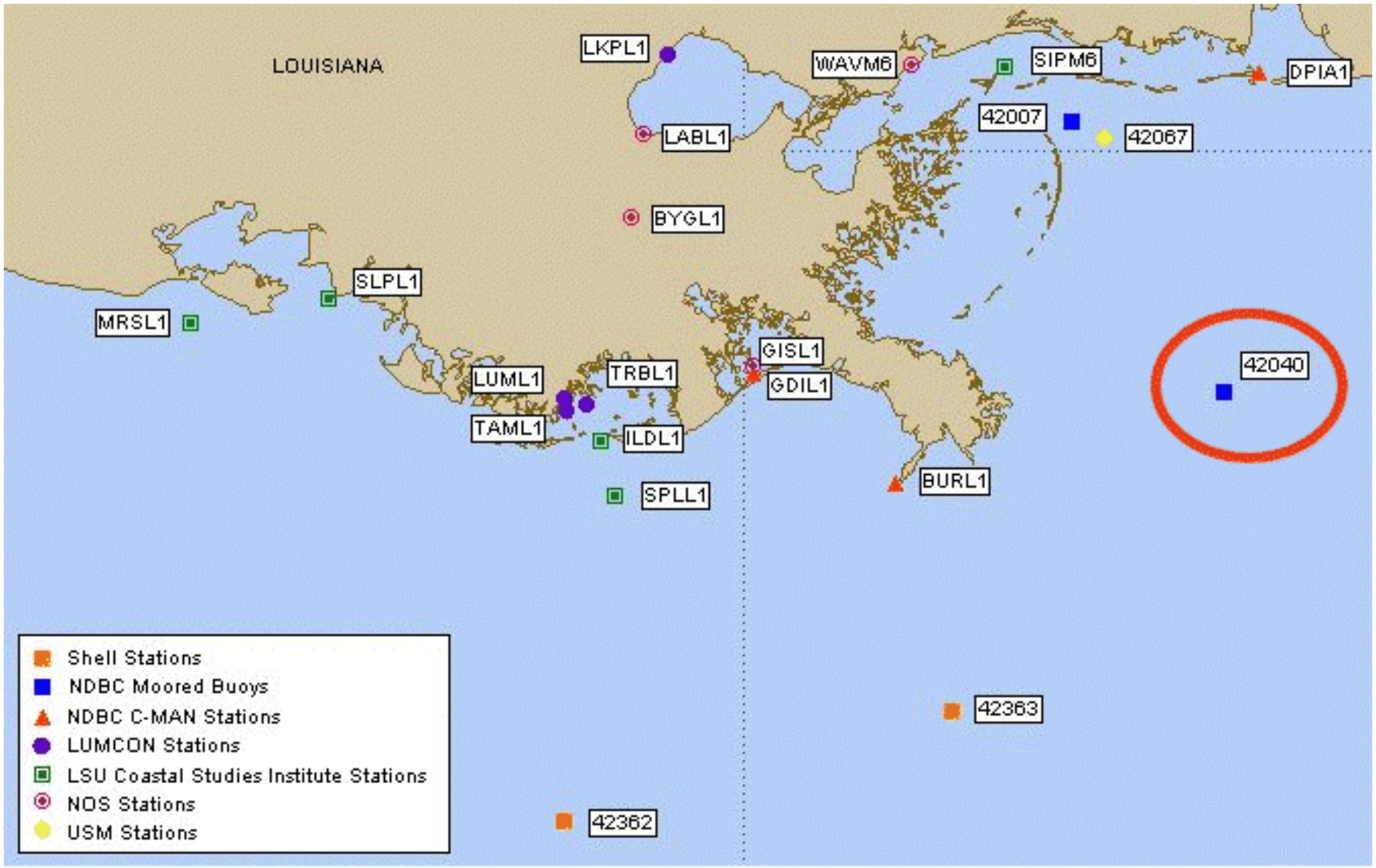

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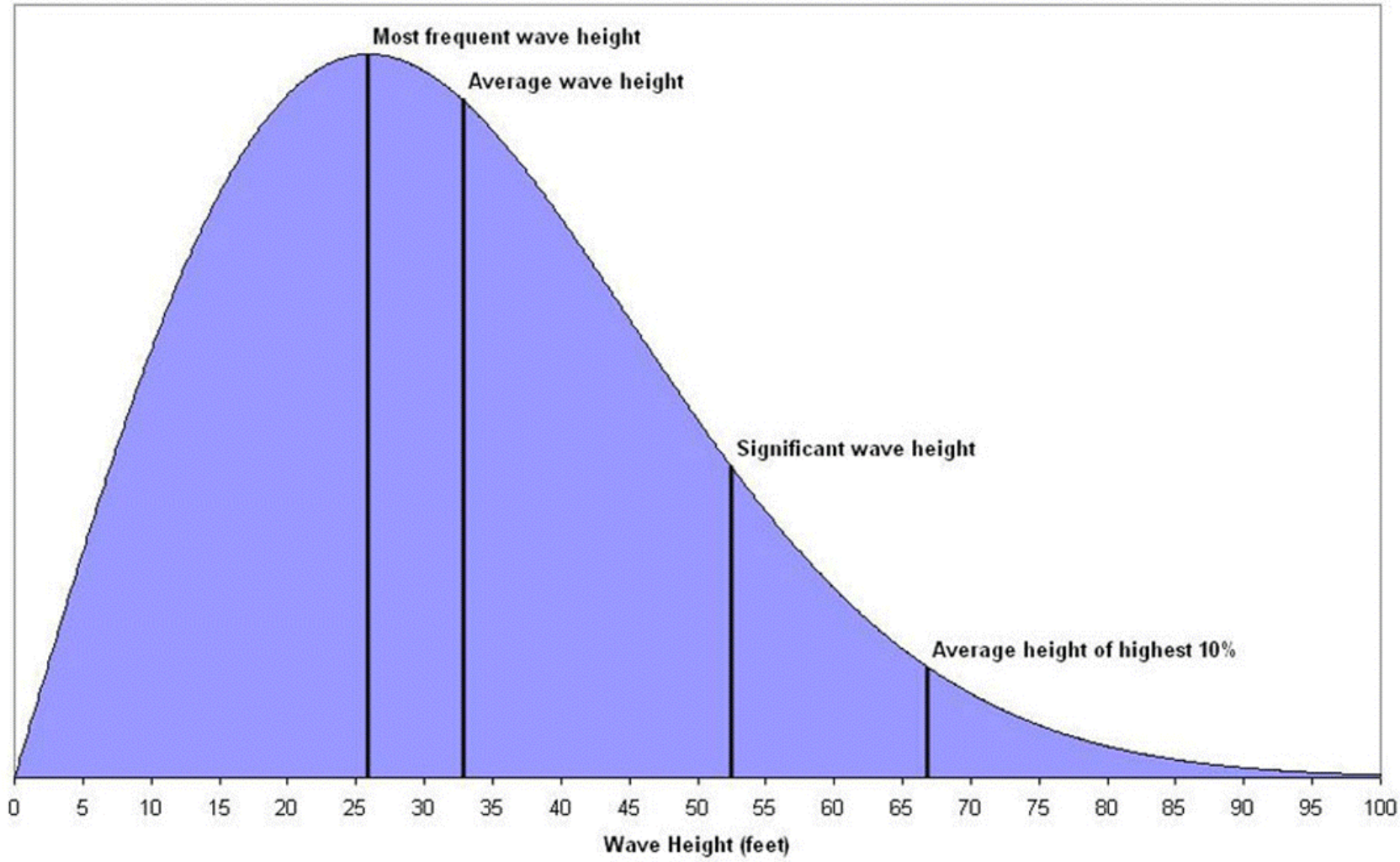
Rayleigh Wave Distribution for Buoy 42040 During Hurricane Ivan



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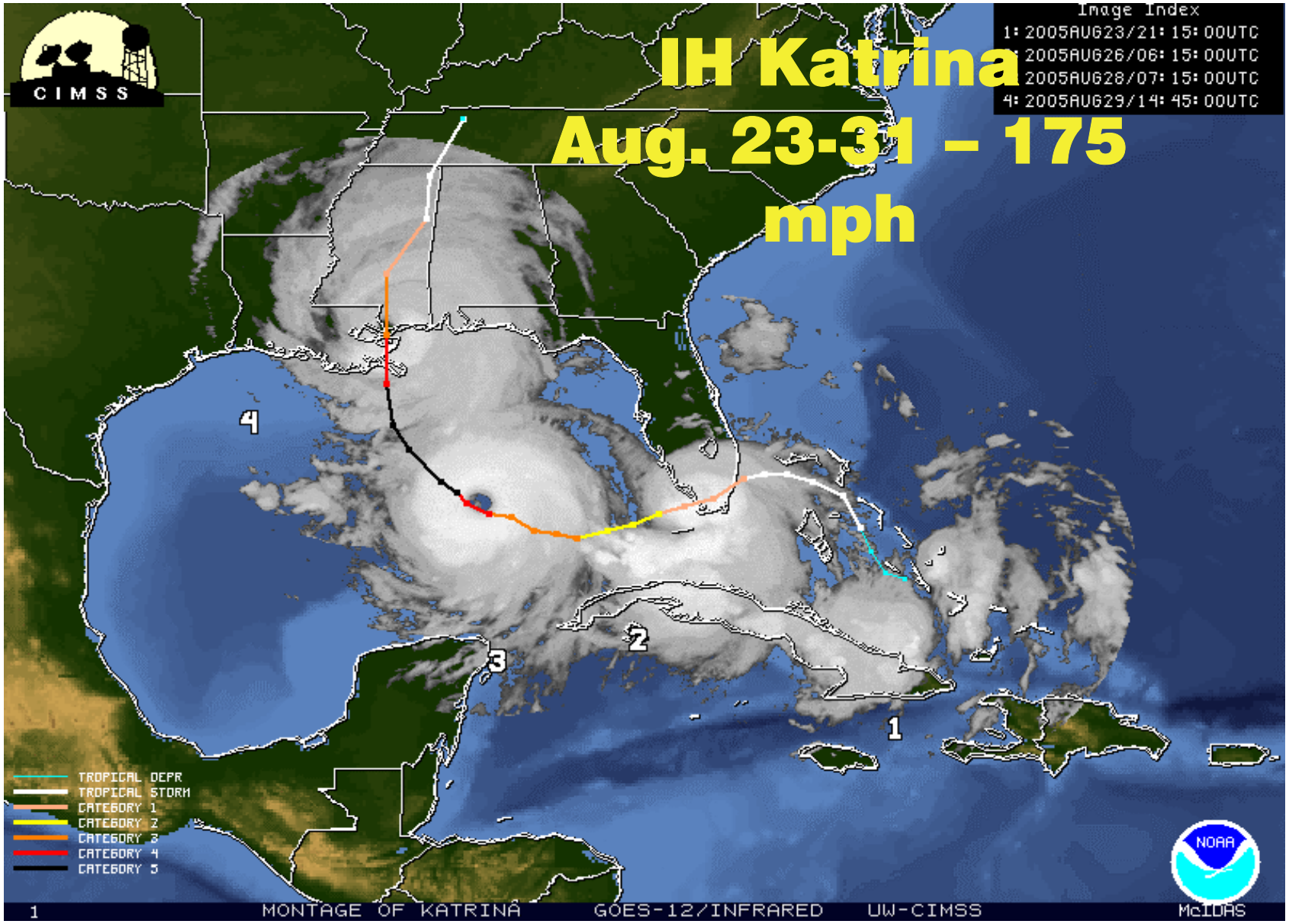

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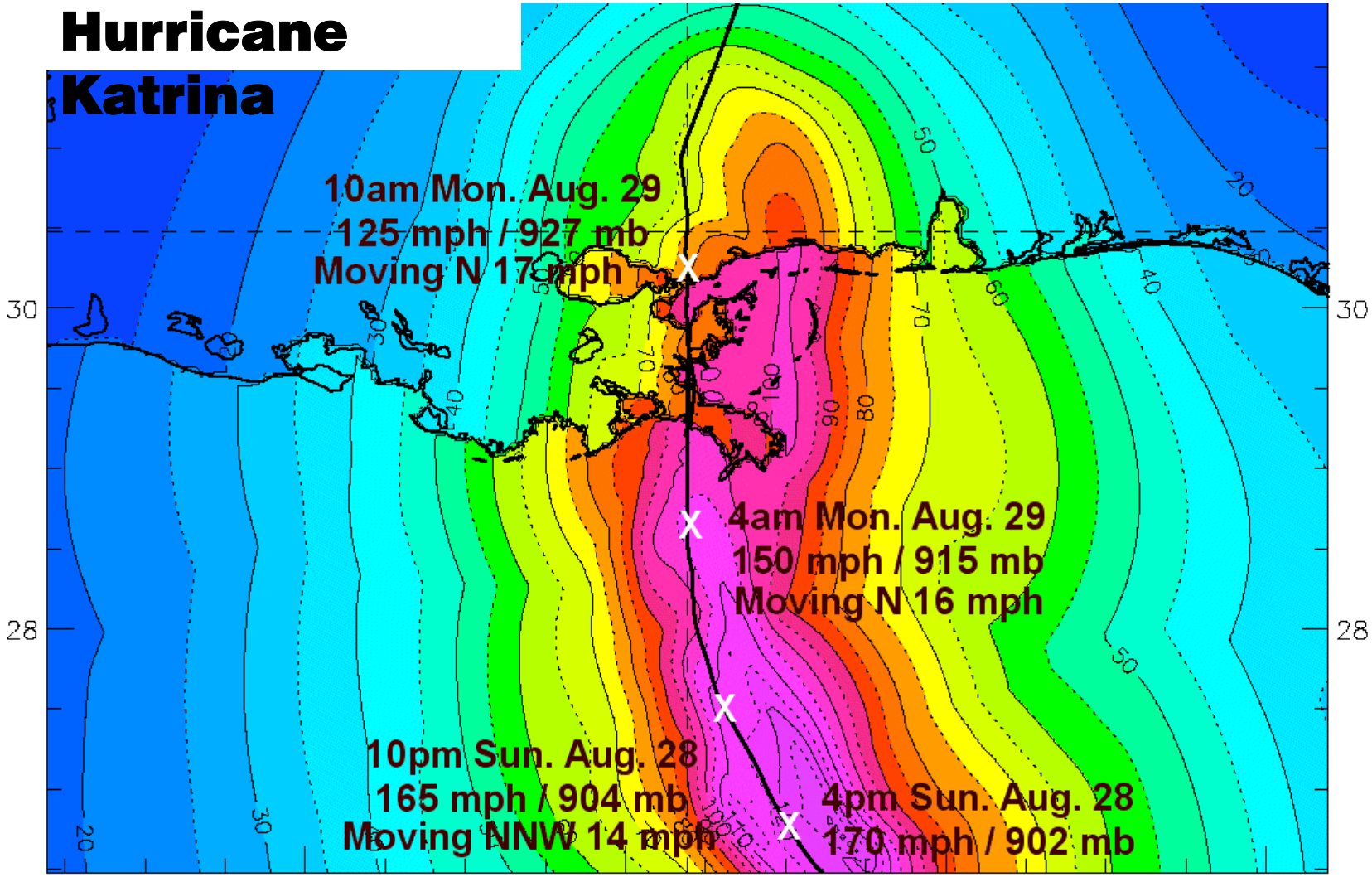
Hurricane Katrina



Maximum Wind Contours (knots)

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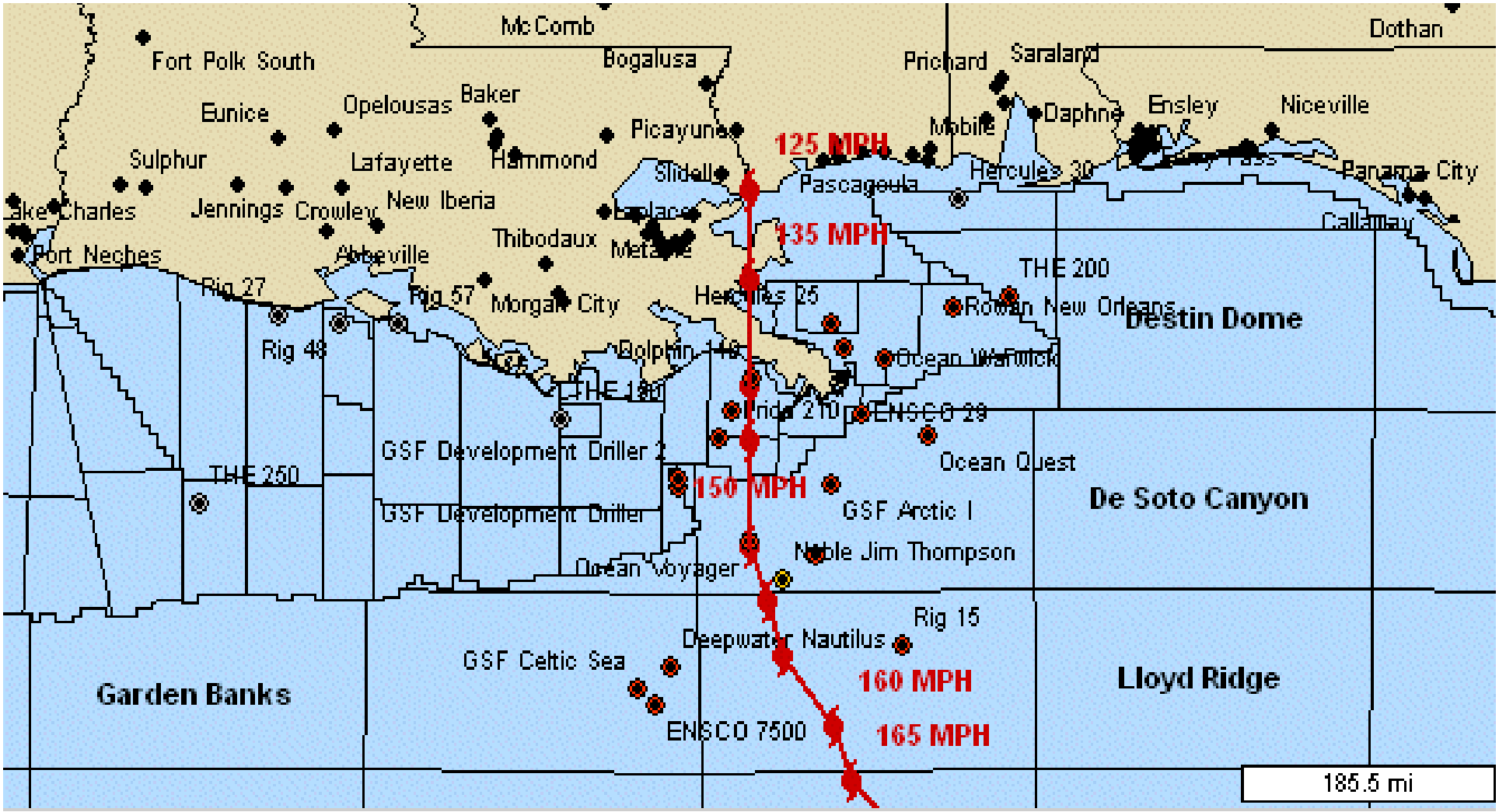
Hurricane Katrina's Track Across Northwest Gulf



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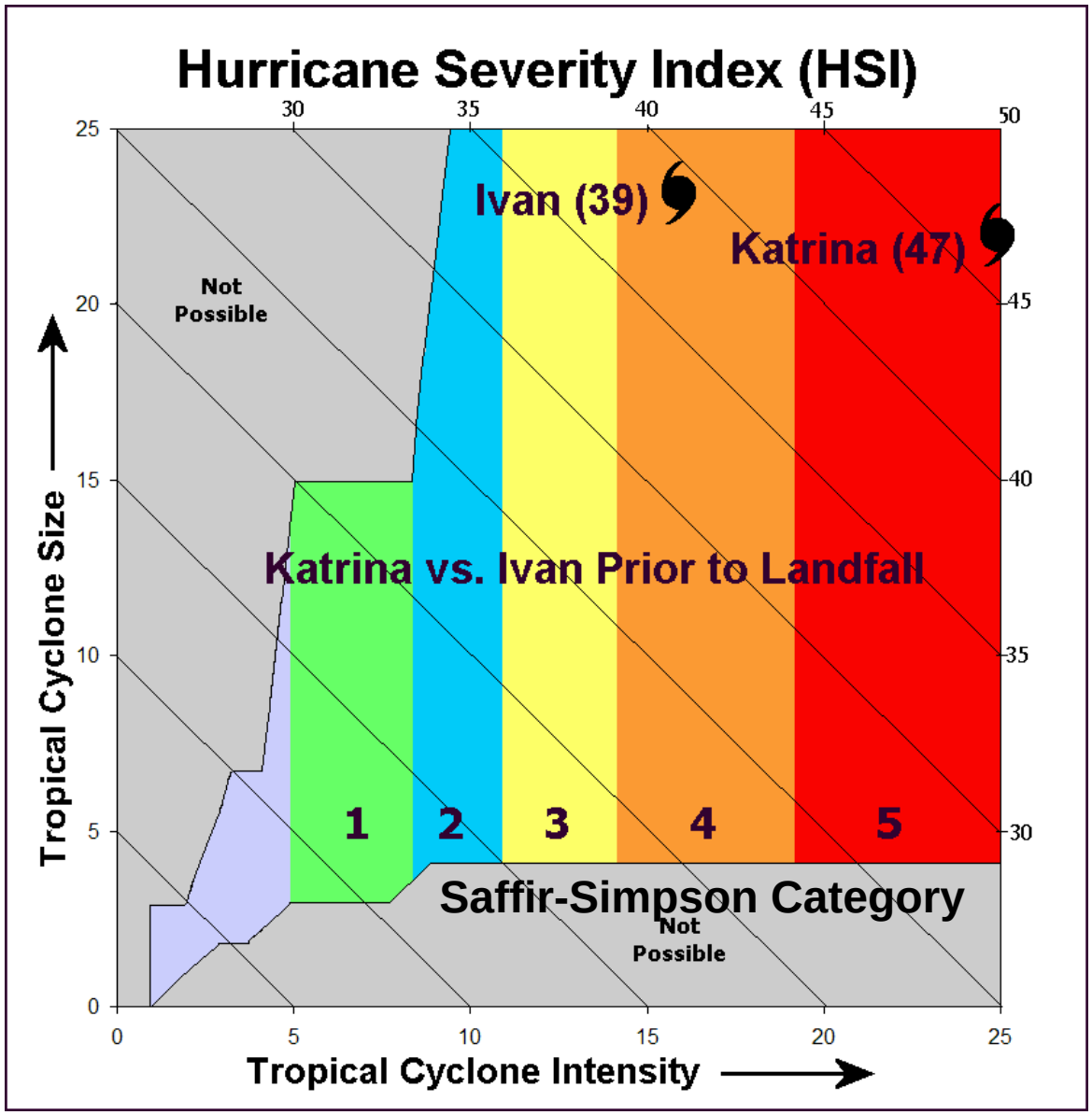

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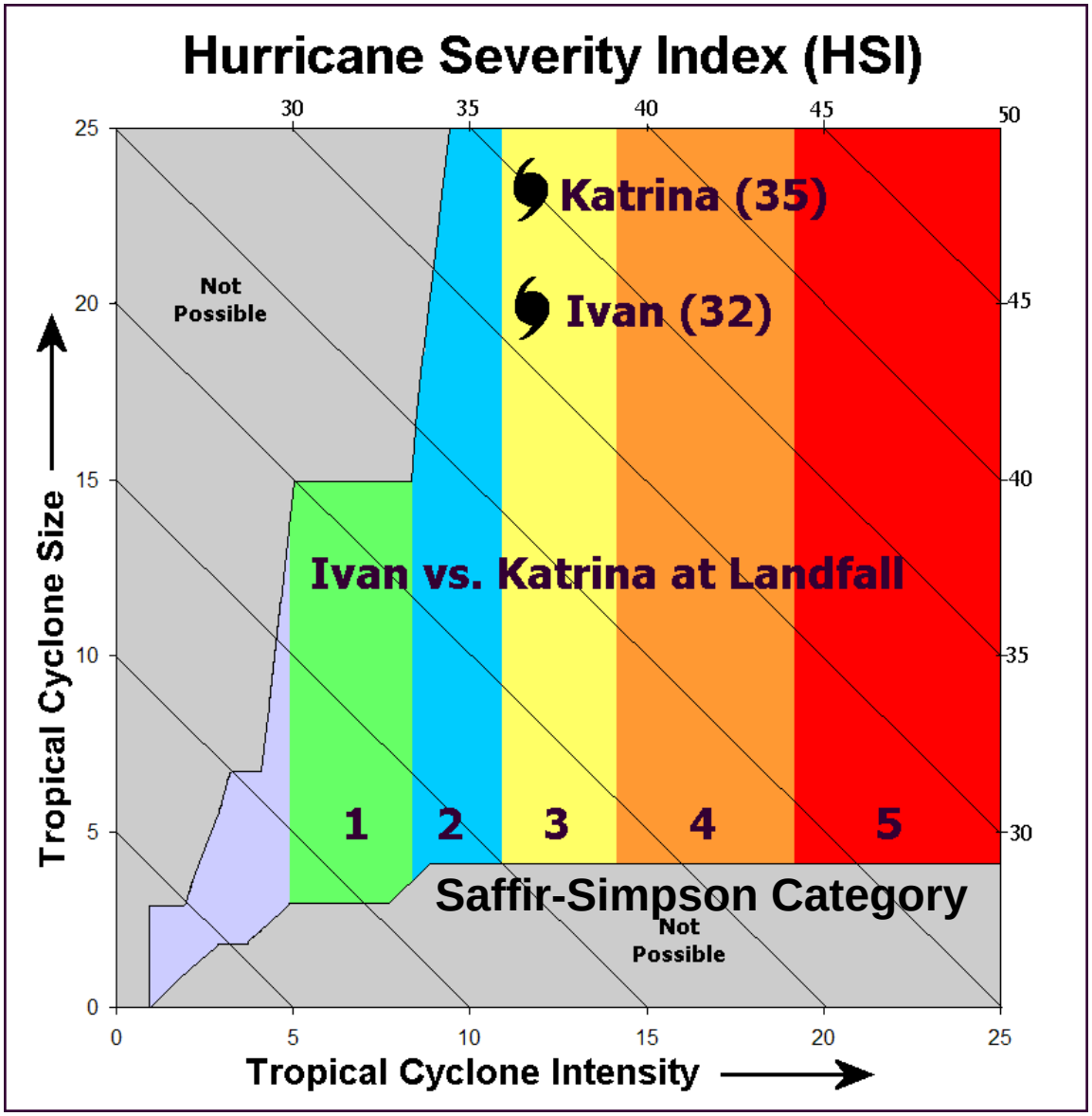

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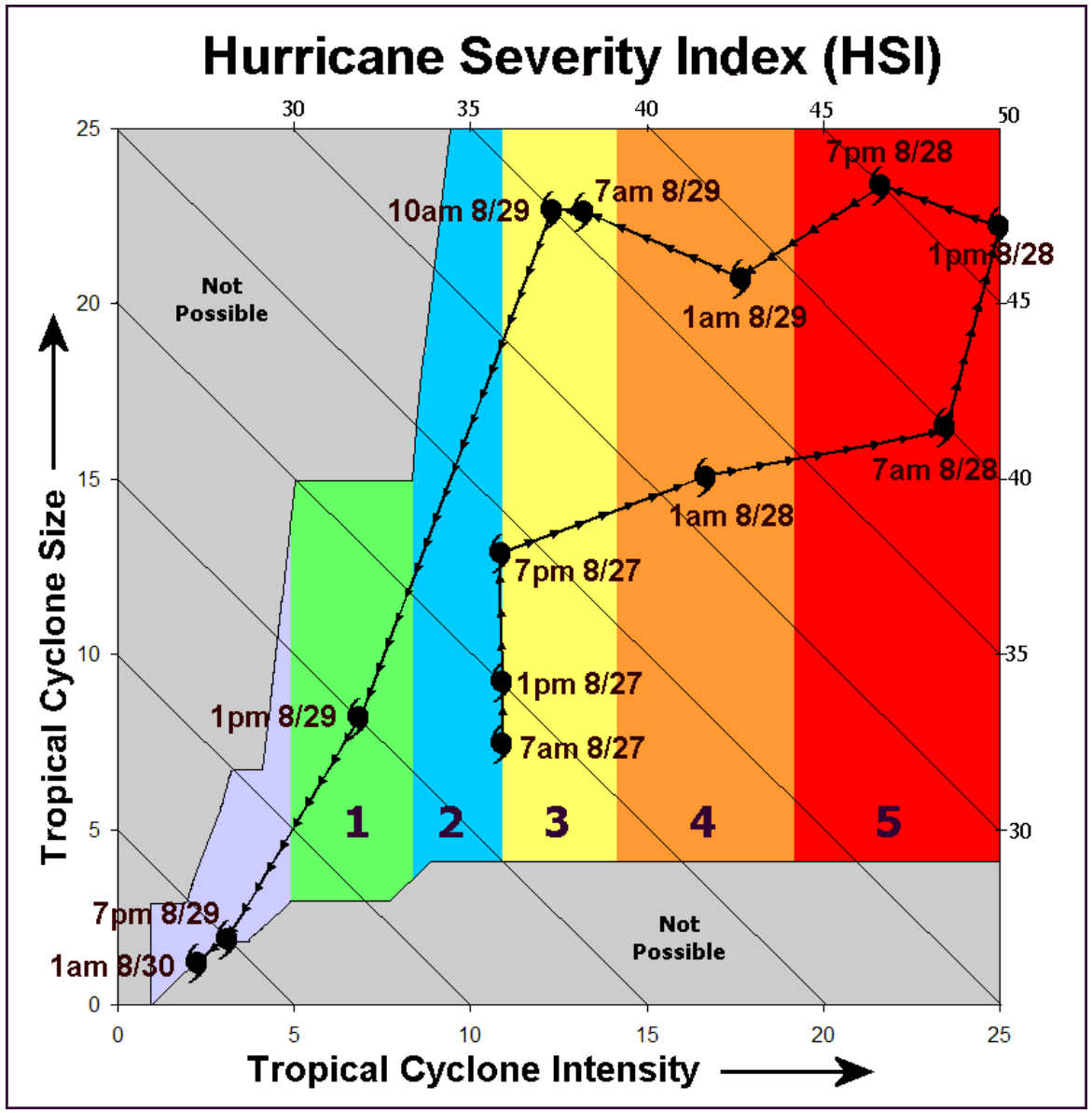

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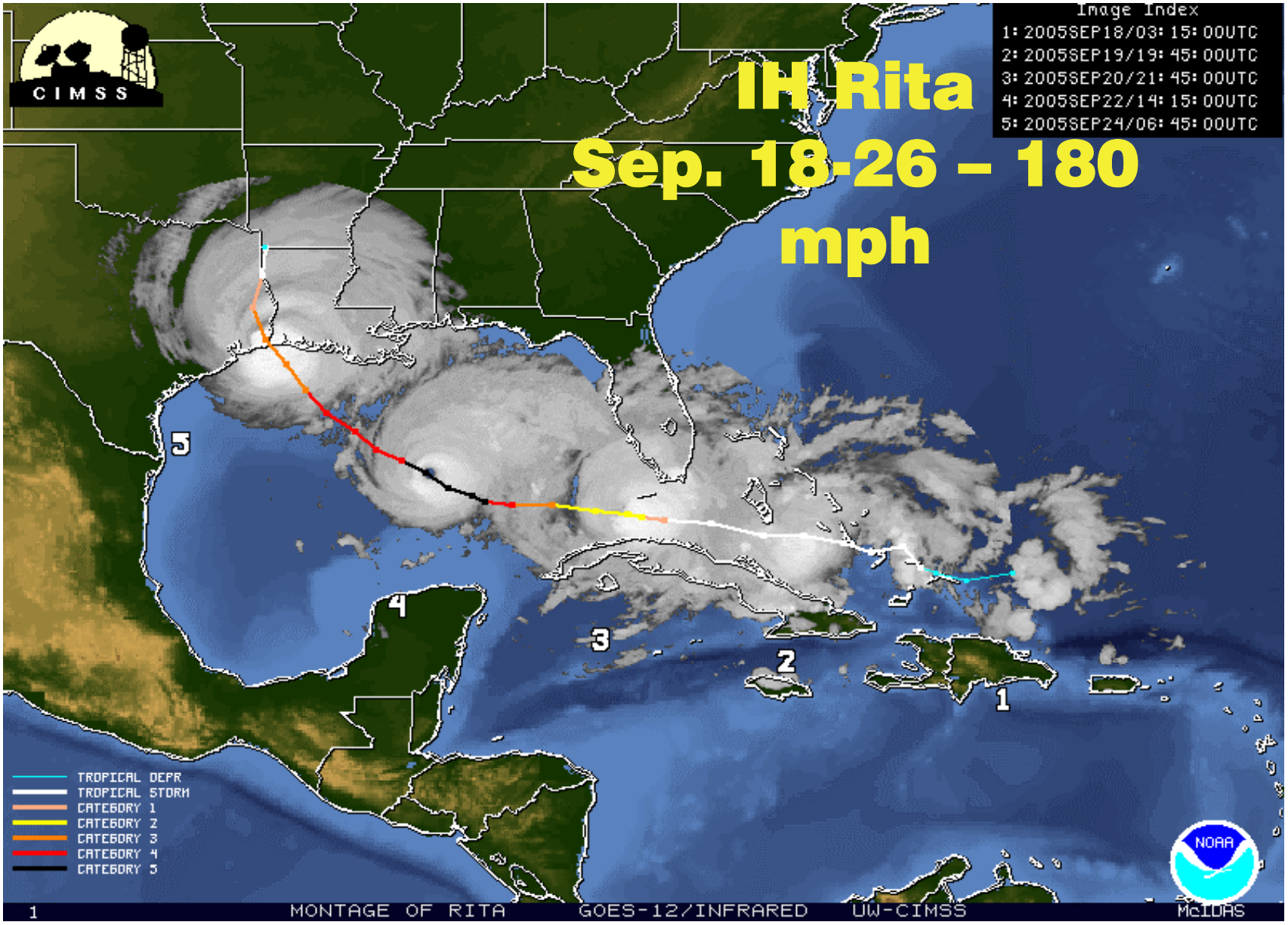
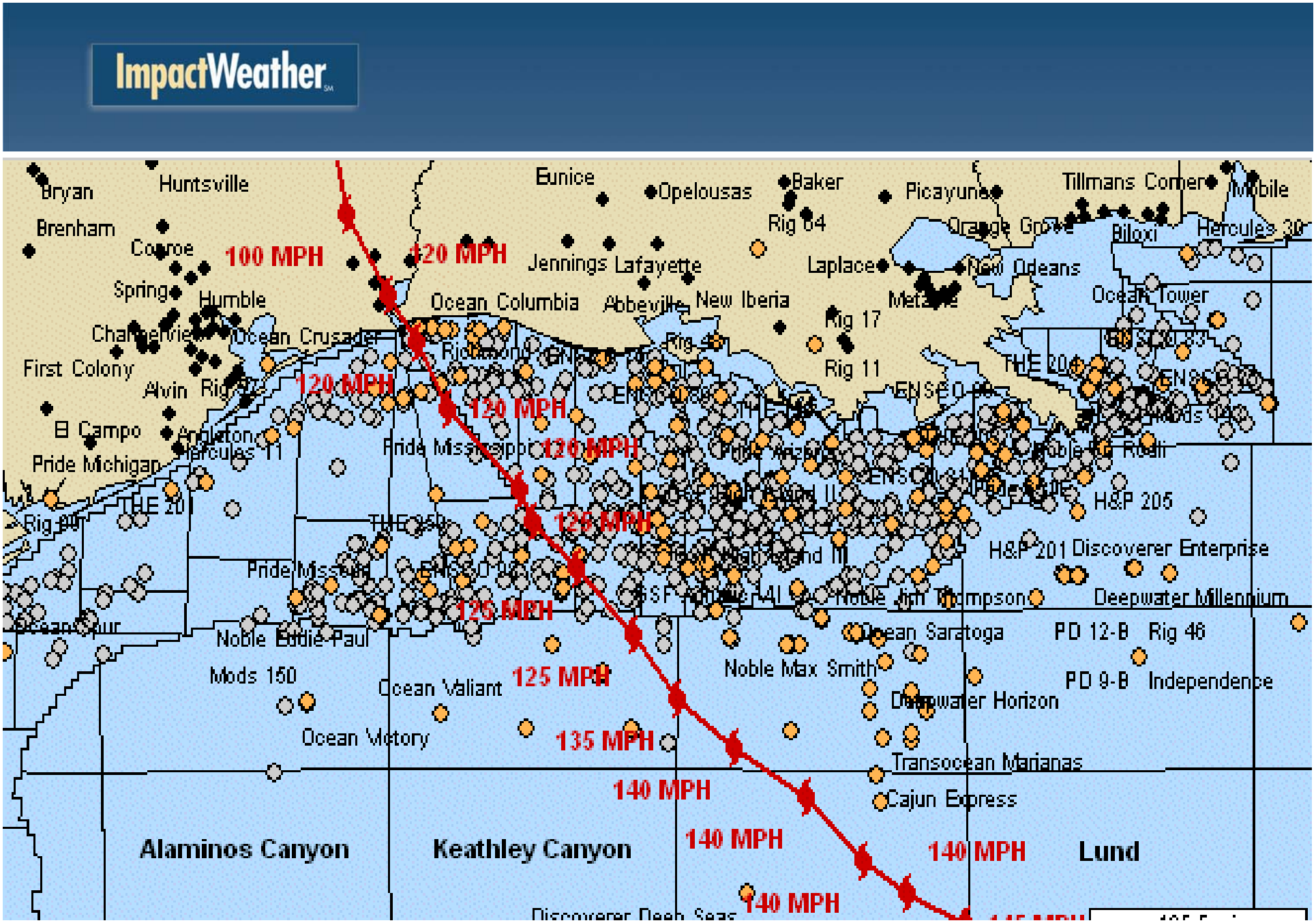
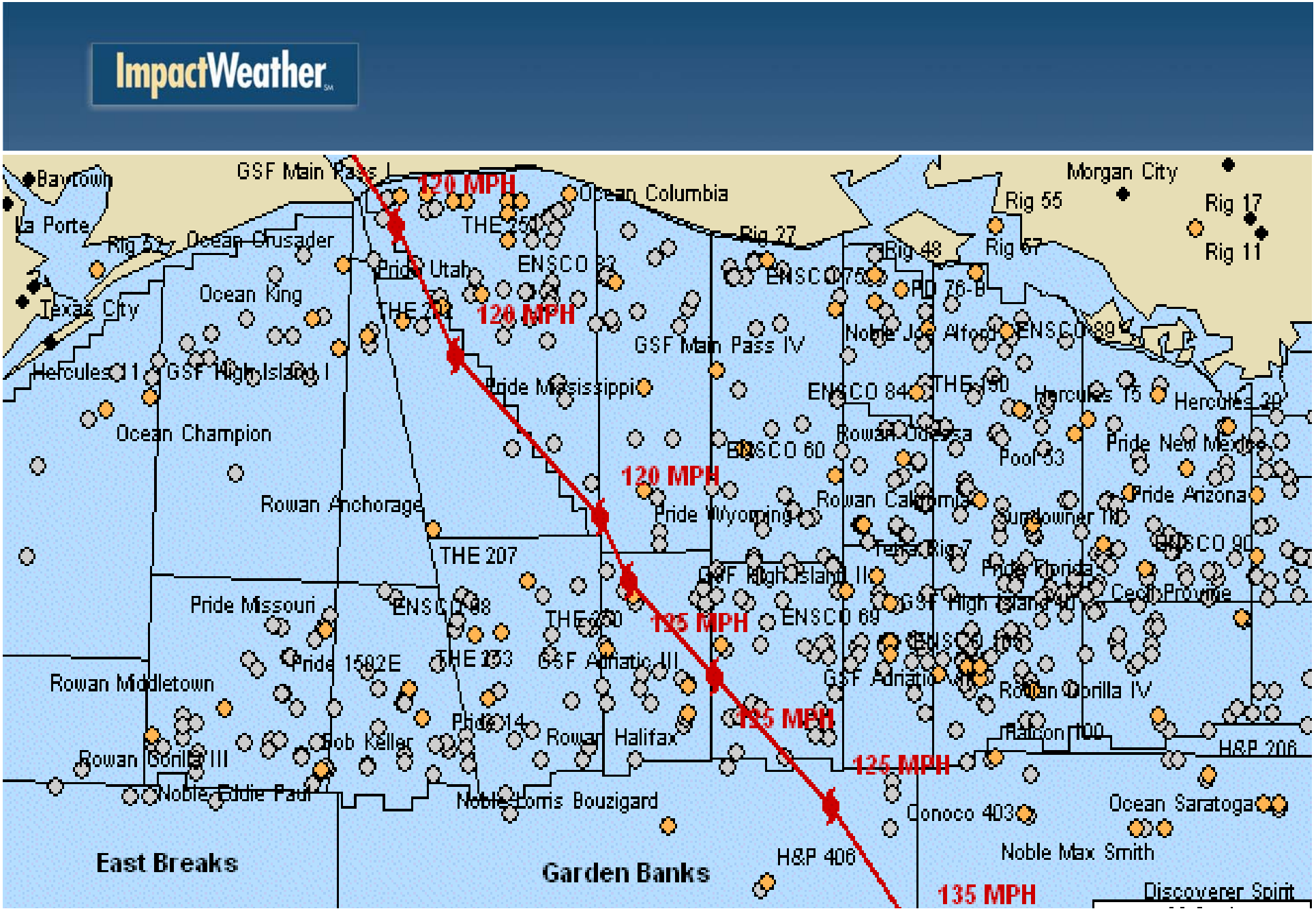




Hurricane Rita's Track Across Northwest Gulf

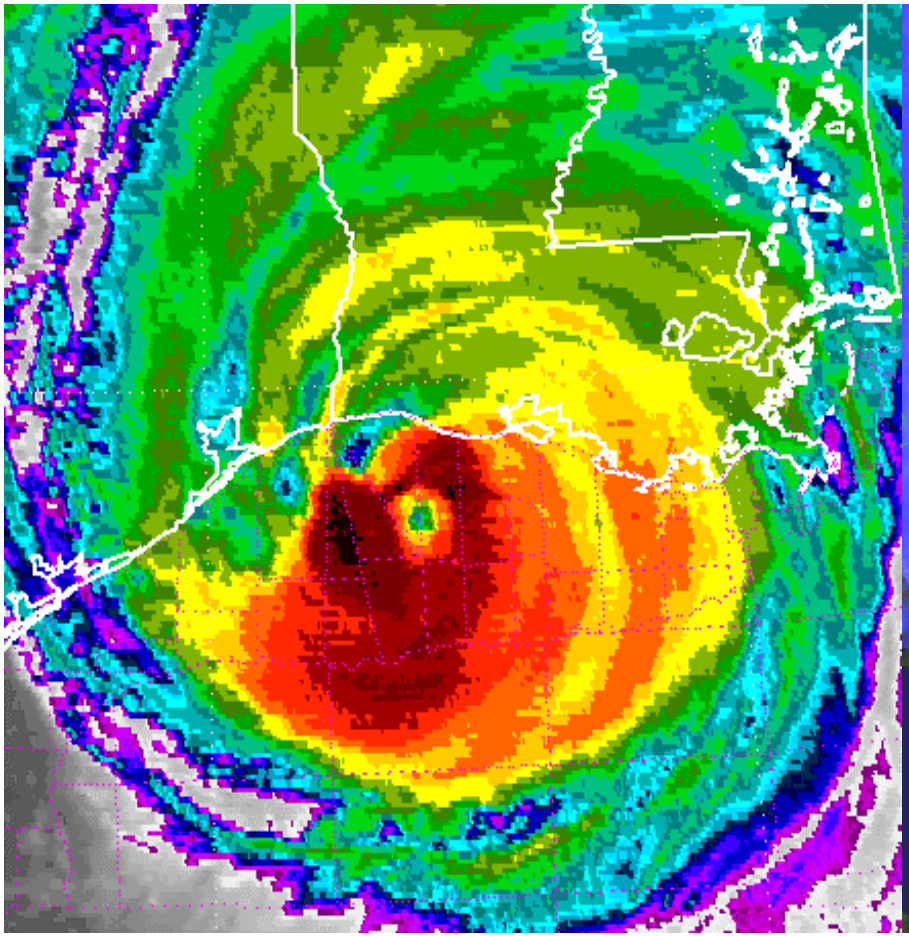


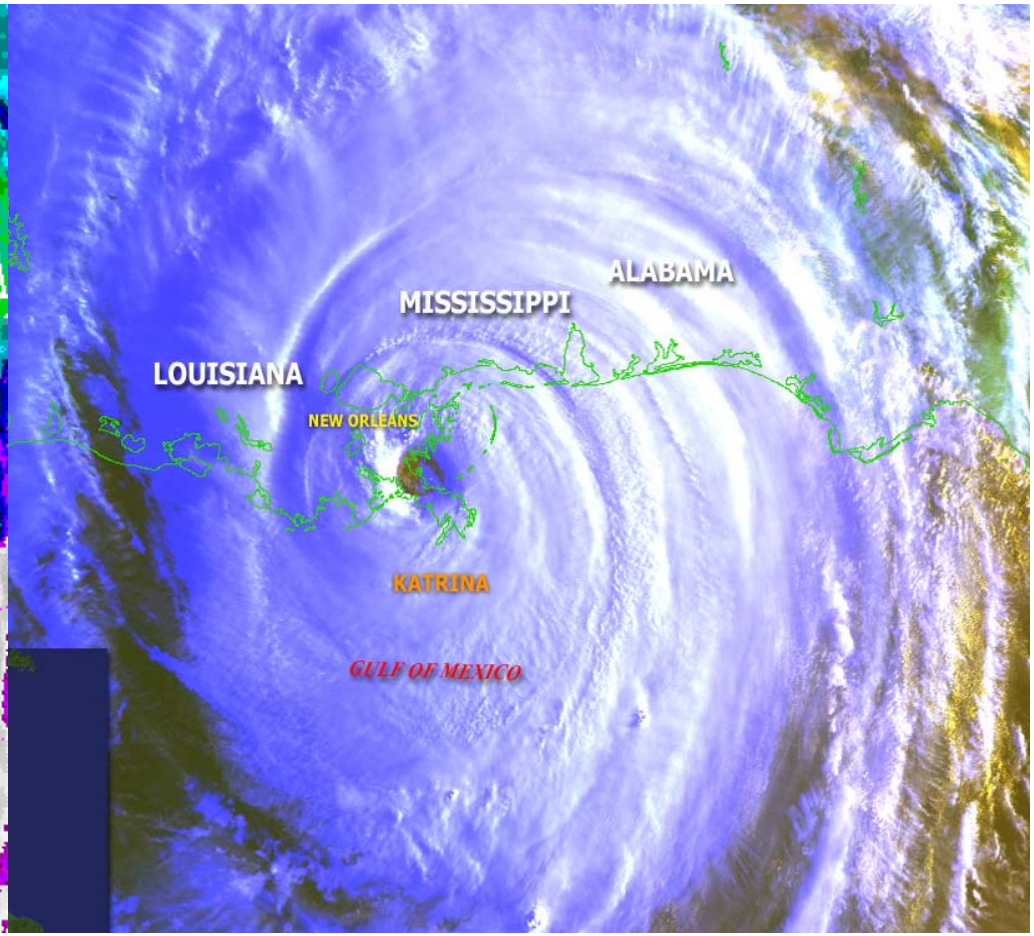
Hurricane Rita's Track Across Northwest Gulf

Hurricanes Rita and Katrina at Landfall

Hurricane Rita – 100 kts / 115 mph
Storm Surge – 15-20 ft
Size Points – 16
Intensity Points – 11
HSI at Landfall = 27

Hurricane Katrina – 110 kts / 125 mph
Storm Surge – 28-32 ft
Size Points – 23
Intensity Points – 13
HSI at Landfall = 36





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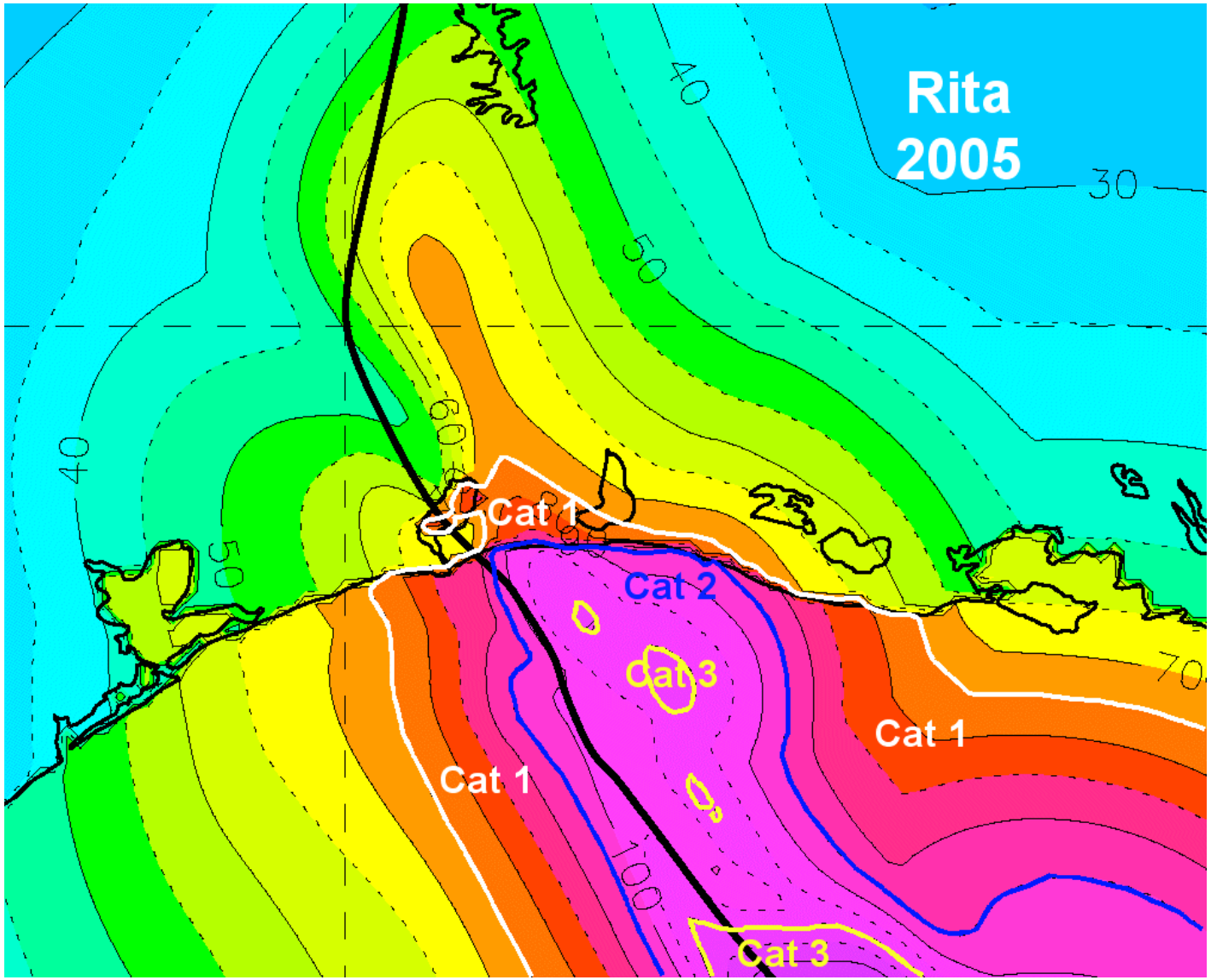

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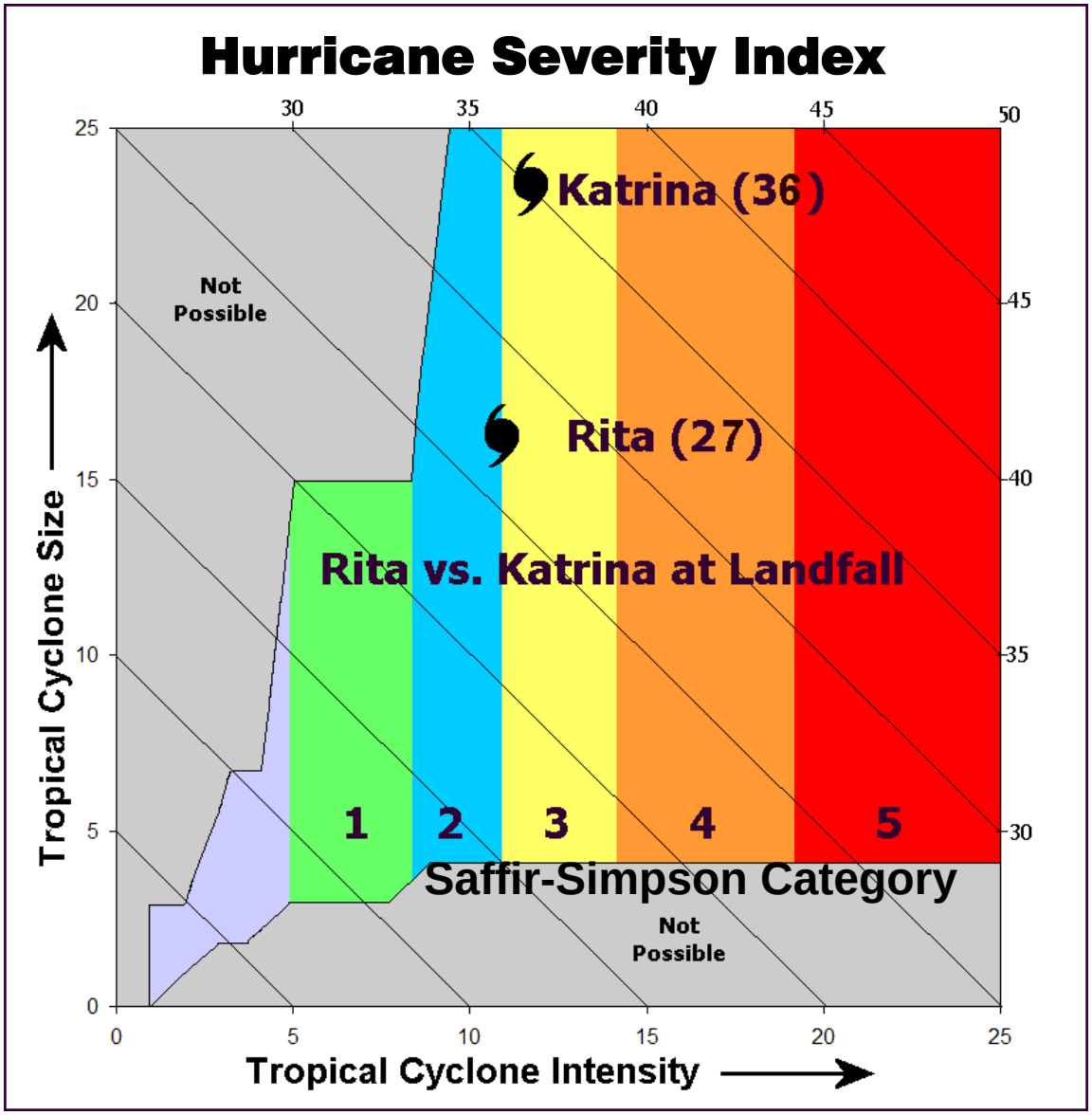

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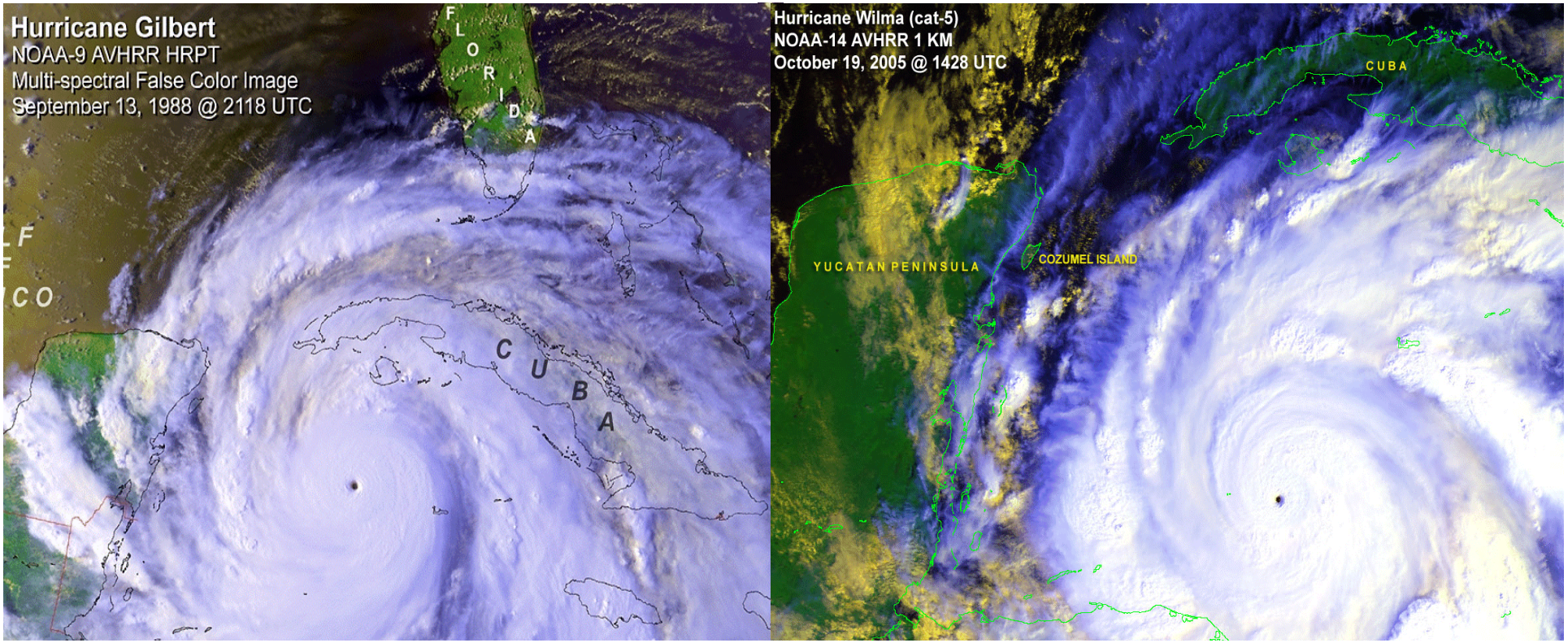
Hurricane Gilbert – 160 kts / 185 mph
Saffir-Simpson Category – 5
Size Points – 24
Intensity Points – 25
HSI at Landfall = 49

Hurricane Wilma – 160 kts / 185 mph
Saffir-Simpson Category – 5
Size Points – 5
Intensity Points – 25
HSI at Landfall = 30



Hurricanes Gilbert and Wilma at Peak Intensity

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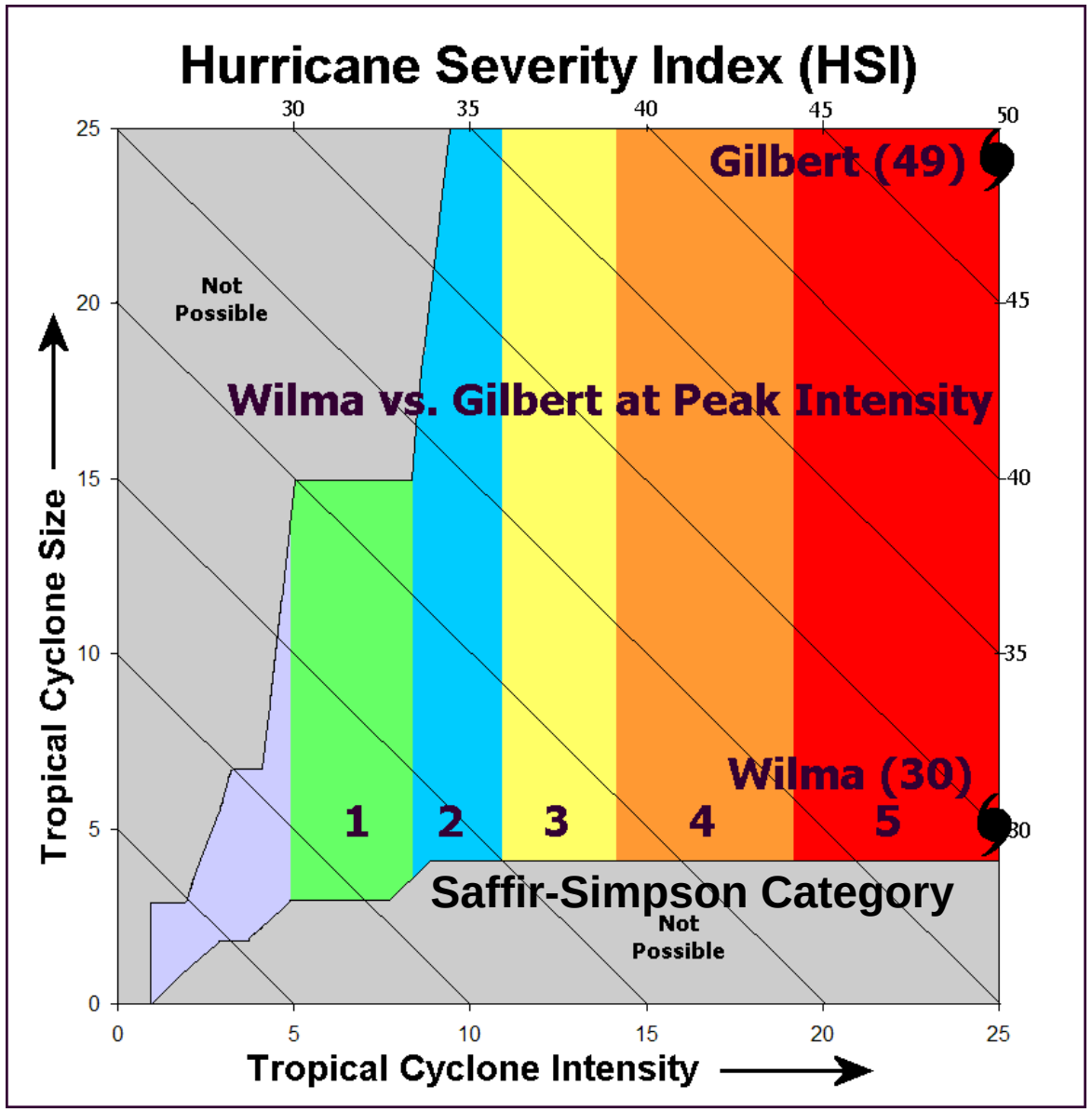

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Conclusions

- Hurricane size is very important in predicting potential damage
- Larger wind field means greater chance of experiencing hurricane-force winds or greater
- Greater risk of prolonged hurricane-force wind
- Greater expanse of 65+ knot wind leads to much larger wave generation
- Saffir-Simpson scale is inadequate

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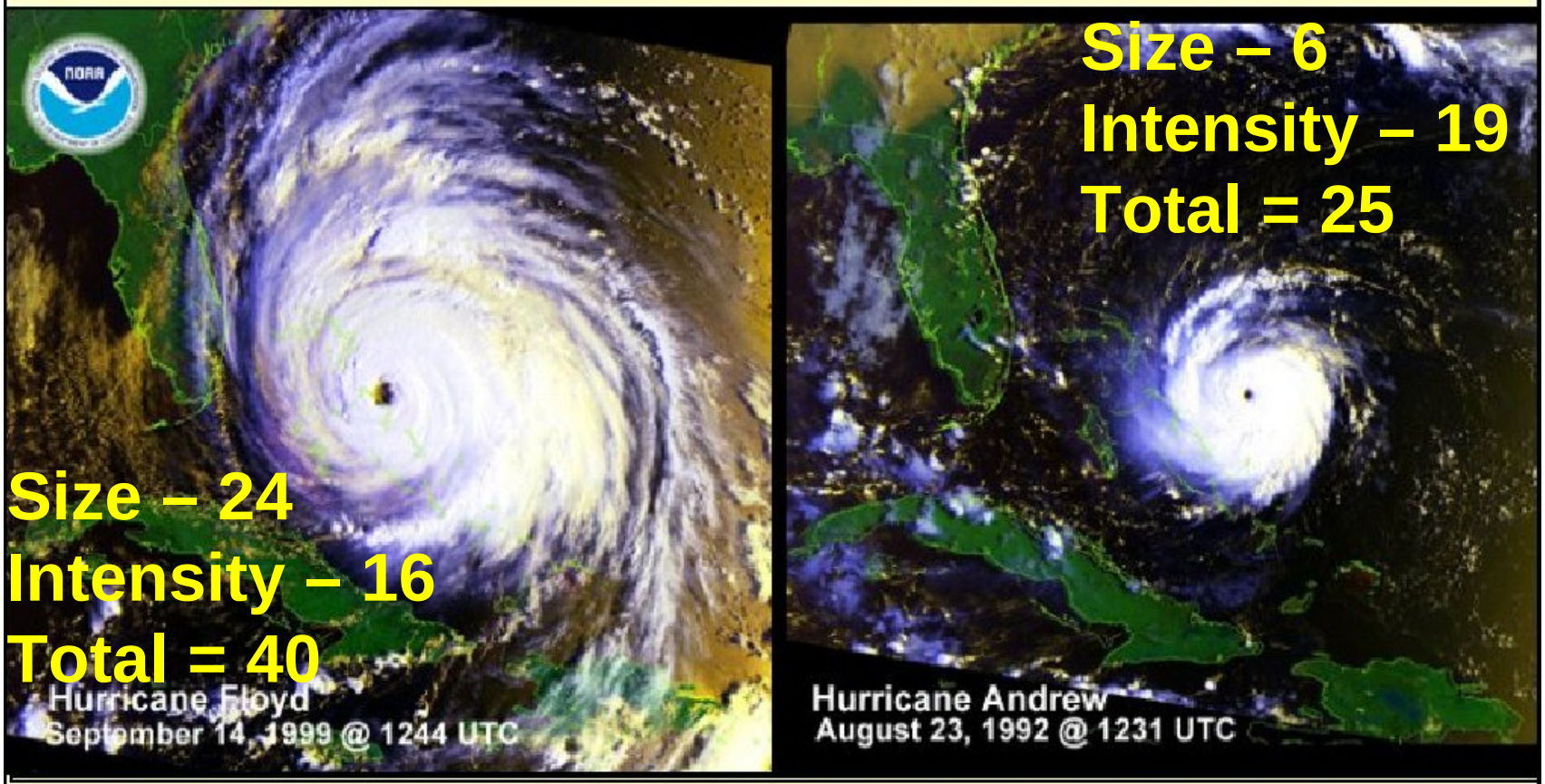
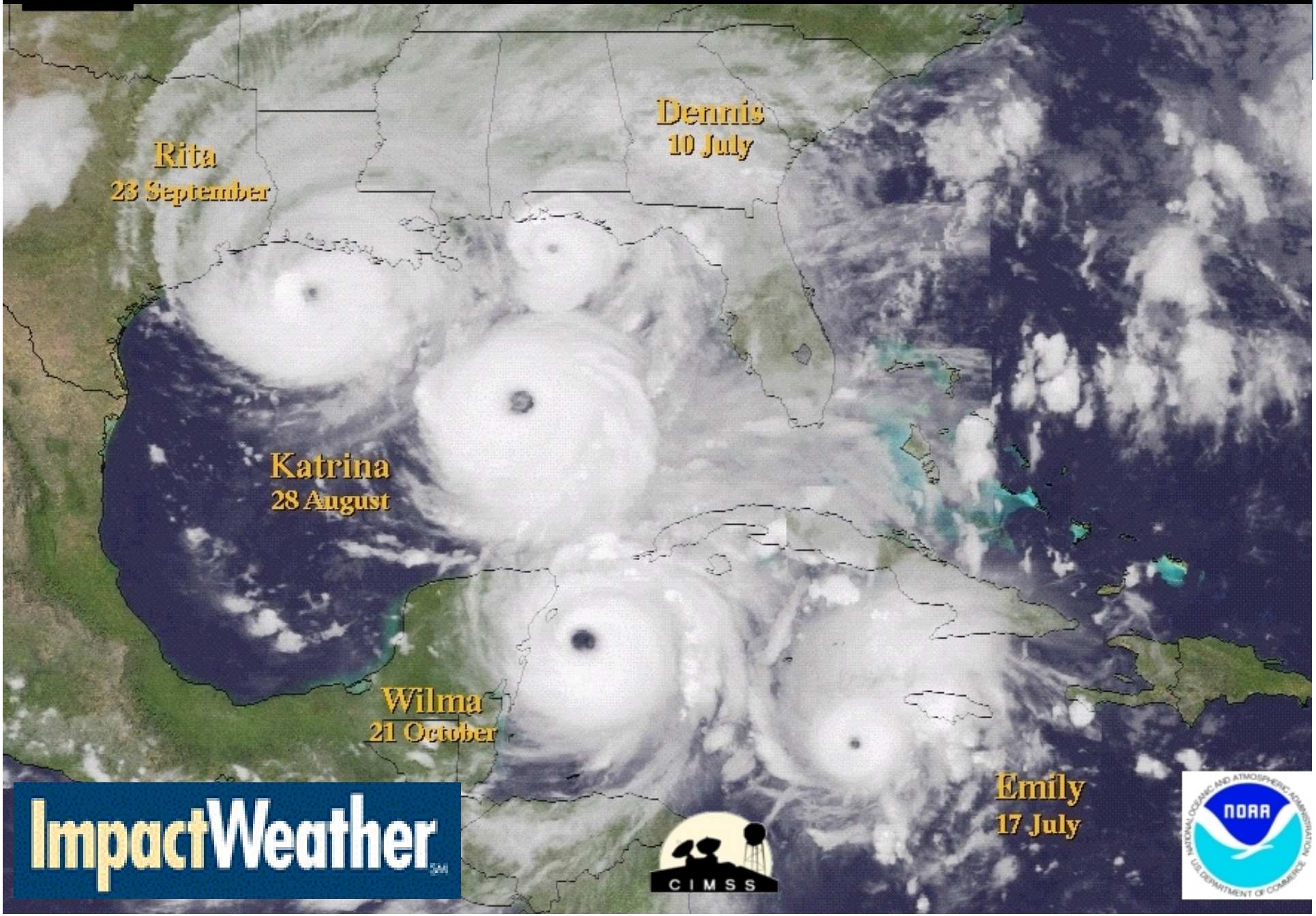
All Hurricanes are NOT Alike



Variability in Size - Floyd vs. Andrew

Outlook for the 2006 Hurricane Season



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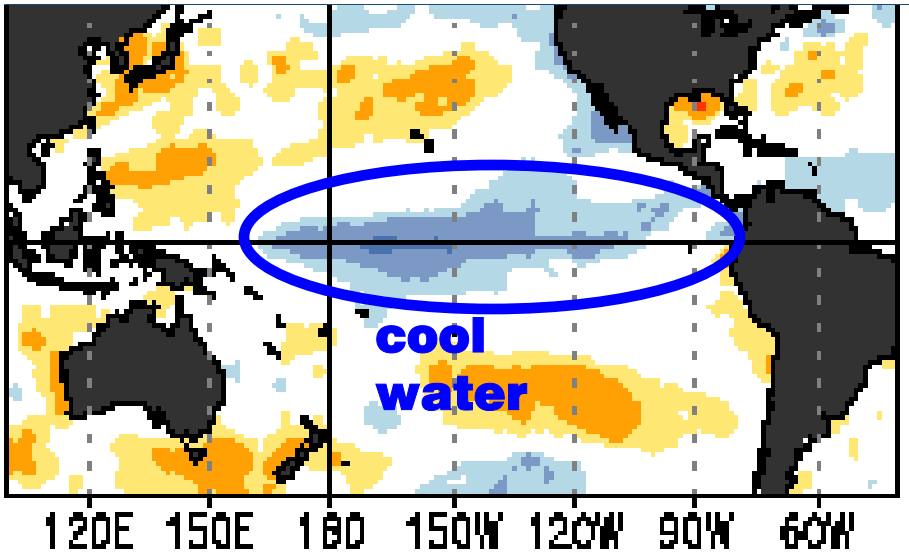
Major Seasonal Predictors

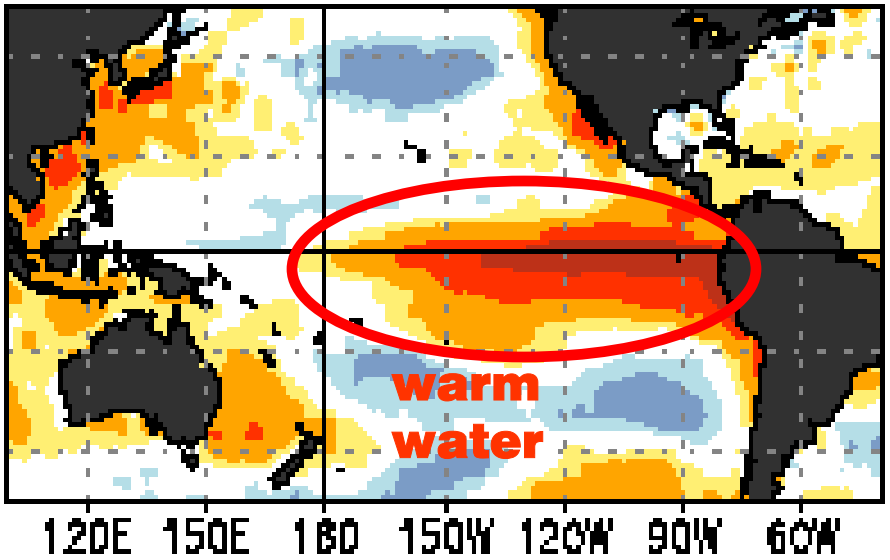
- Strength of El Niño / La Niña
- Strength of Azores-Bermuda High
- Atlantic Sea Surface Temperature Regime
  (warm vs. cold)
- Subtropical Eastern Pacific Sea Surface
  Temperatures



La Niña

Upper-Level winds tend to be more favorable for hurricane development.

La Niña years have more named storms in the Atlantic Basin.



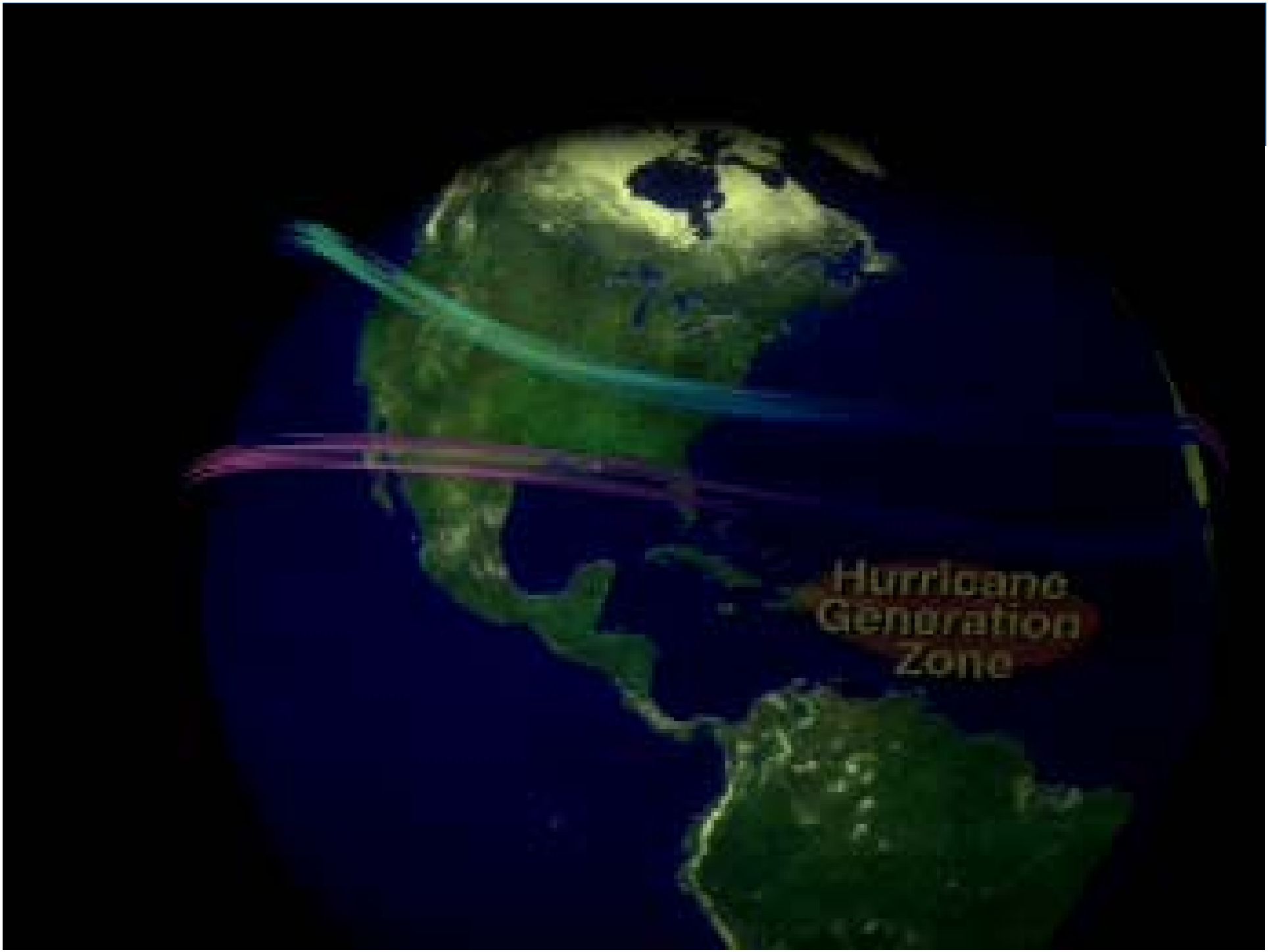
El Niño

Upper-Level winds tend to be unfavorable for development.

El Niño years have fewer named storms in the Atlantic Basin.

1983 - Alicia hit Houston/Galveston as a Cat 3 (4 named storms)
1992 - Cat 5 Hurricane Andrew hit south Florida (7 named storms)

Another reason to NOT just focus on predicted storm numbers


Hurricane
Generation
Zone

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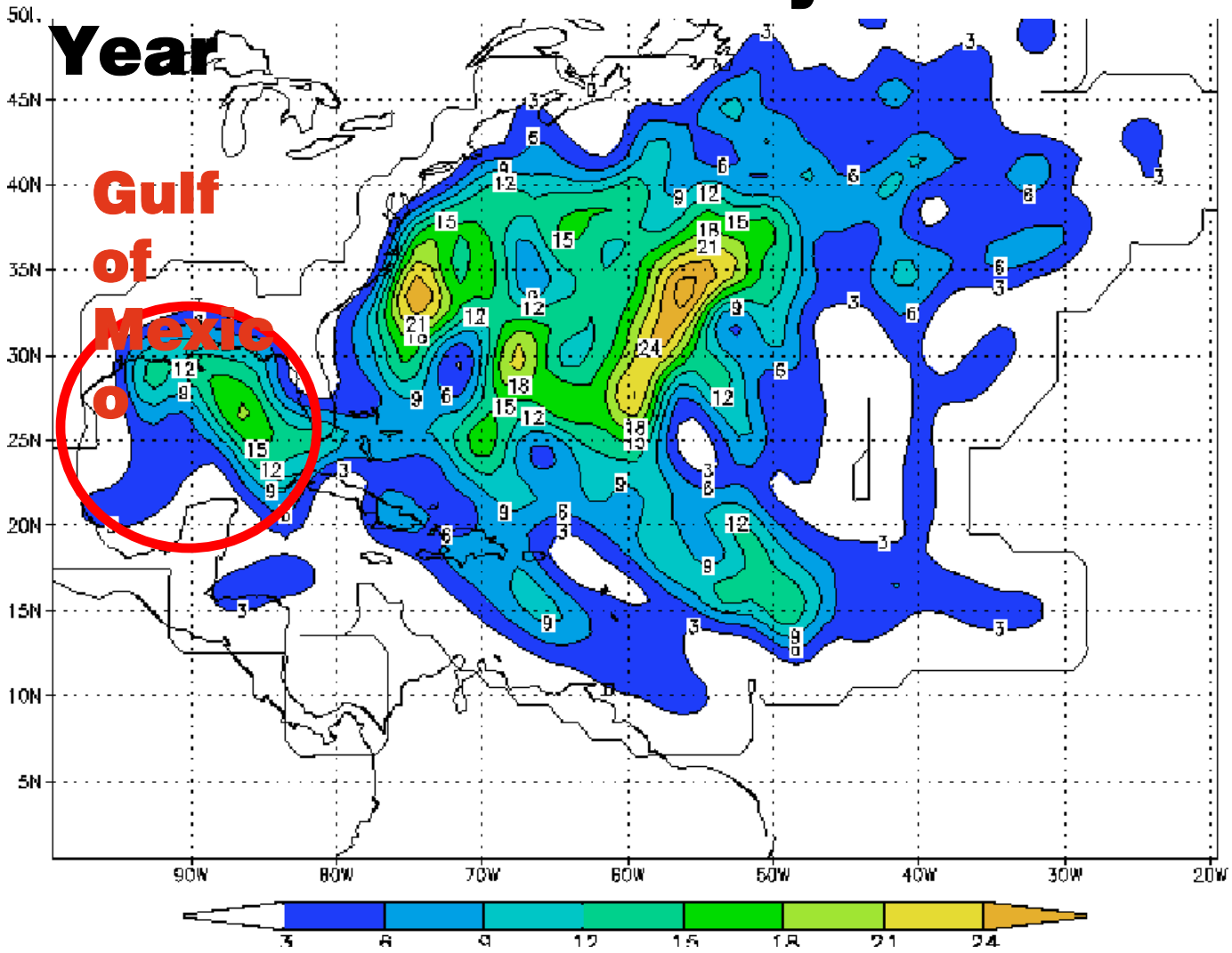
Hurricane Probability – El Niño Year



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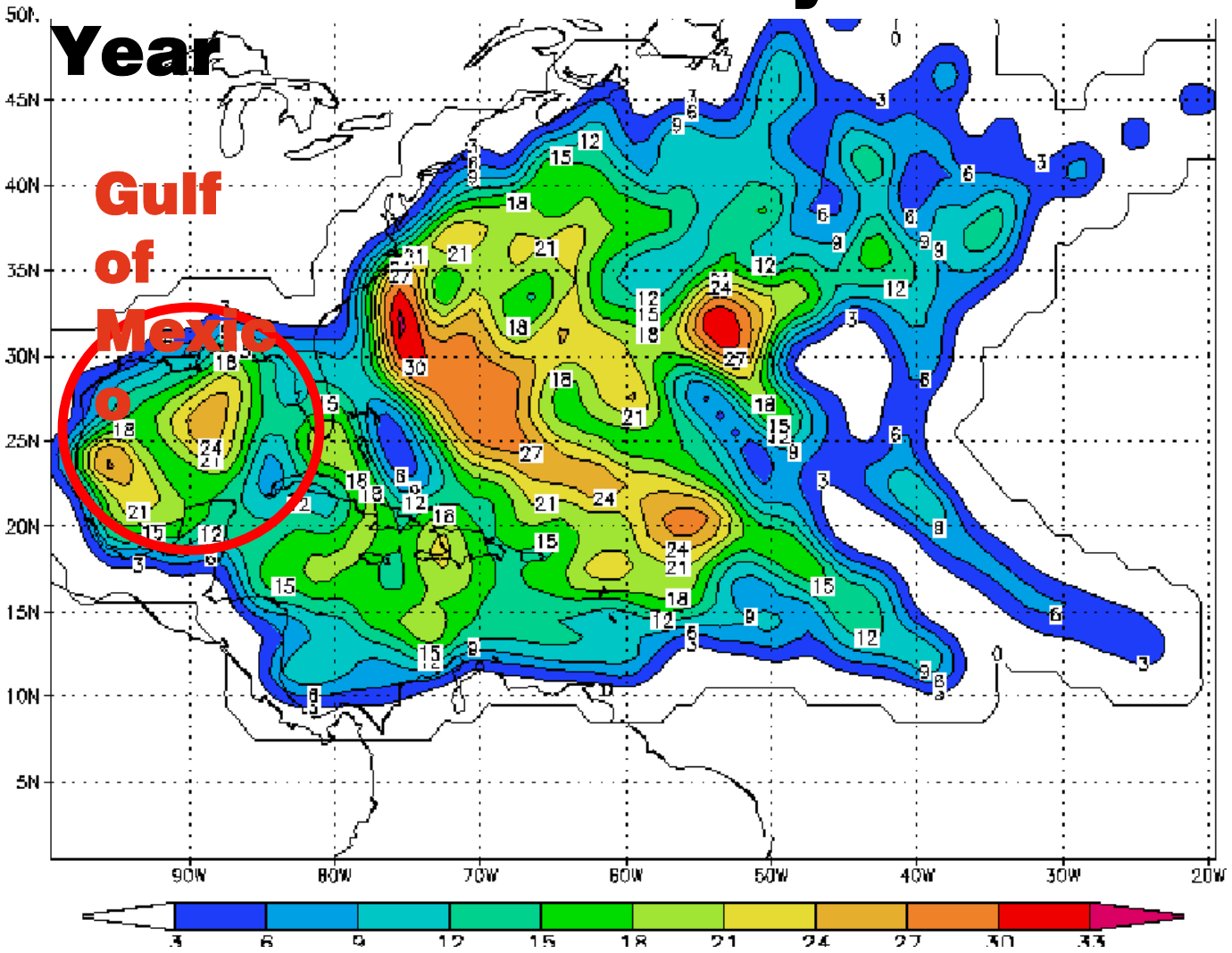
Hurricane Probability – La Niña Year



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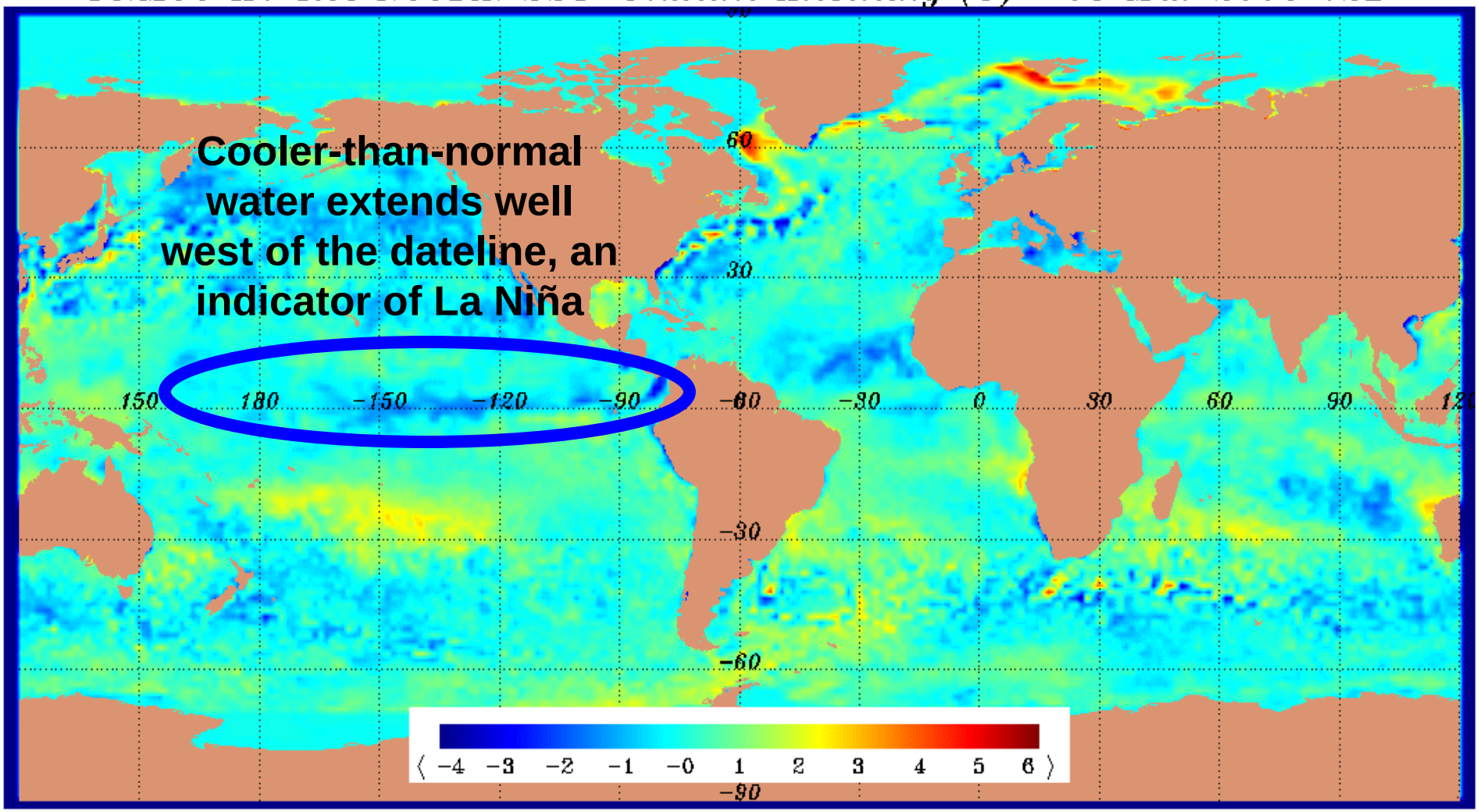
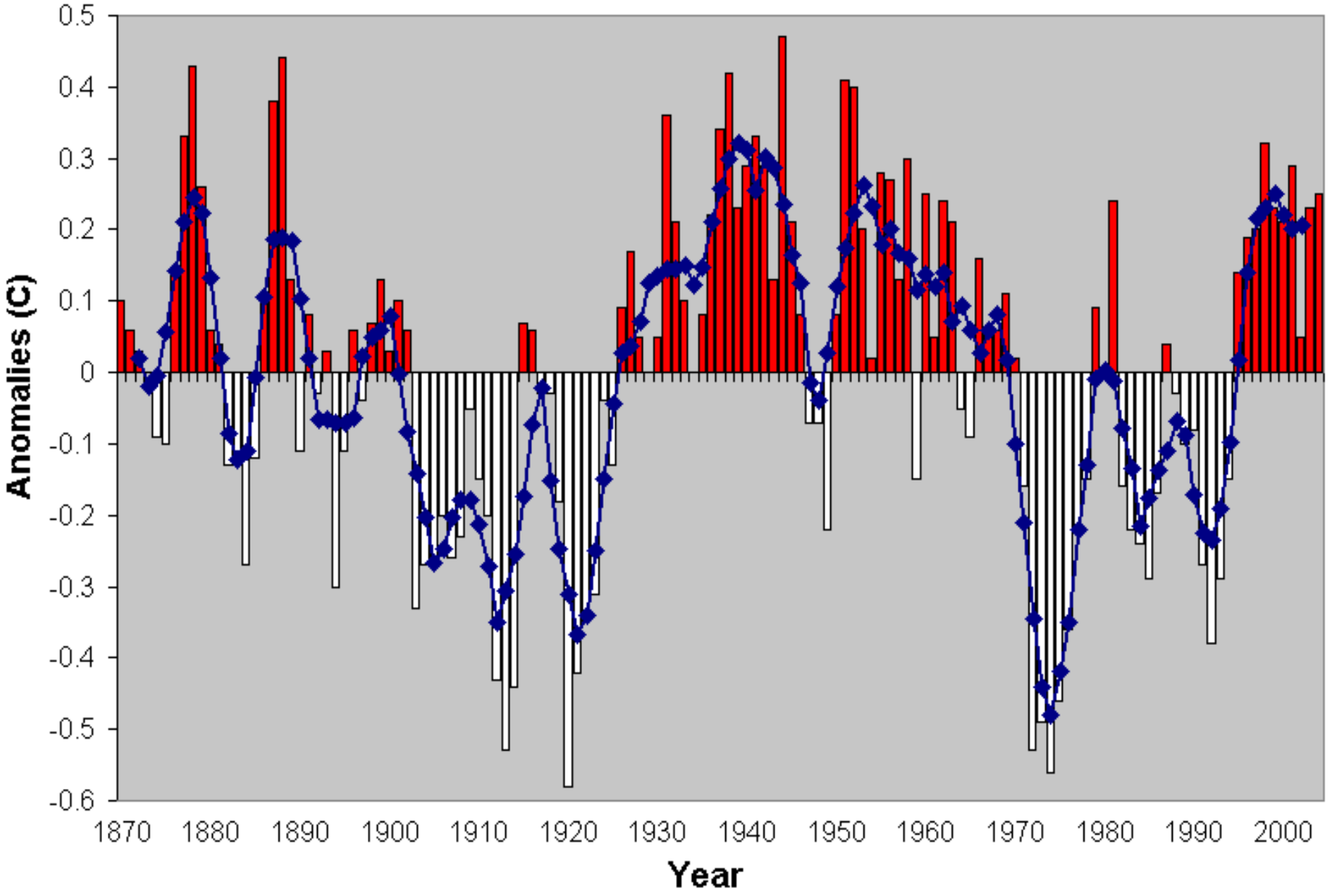
Weak La Niña in Progress for 2006



Atlantic SST Multidecadal Mode

1870-2004



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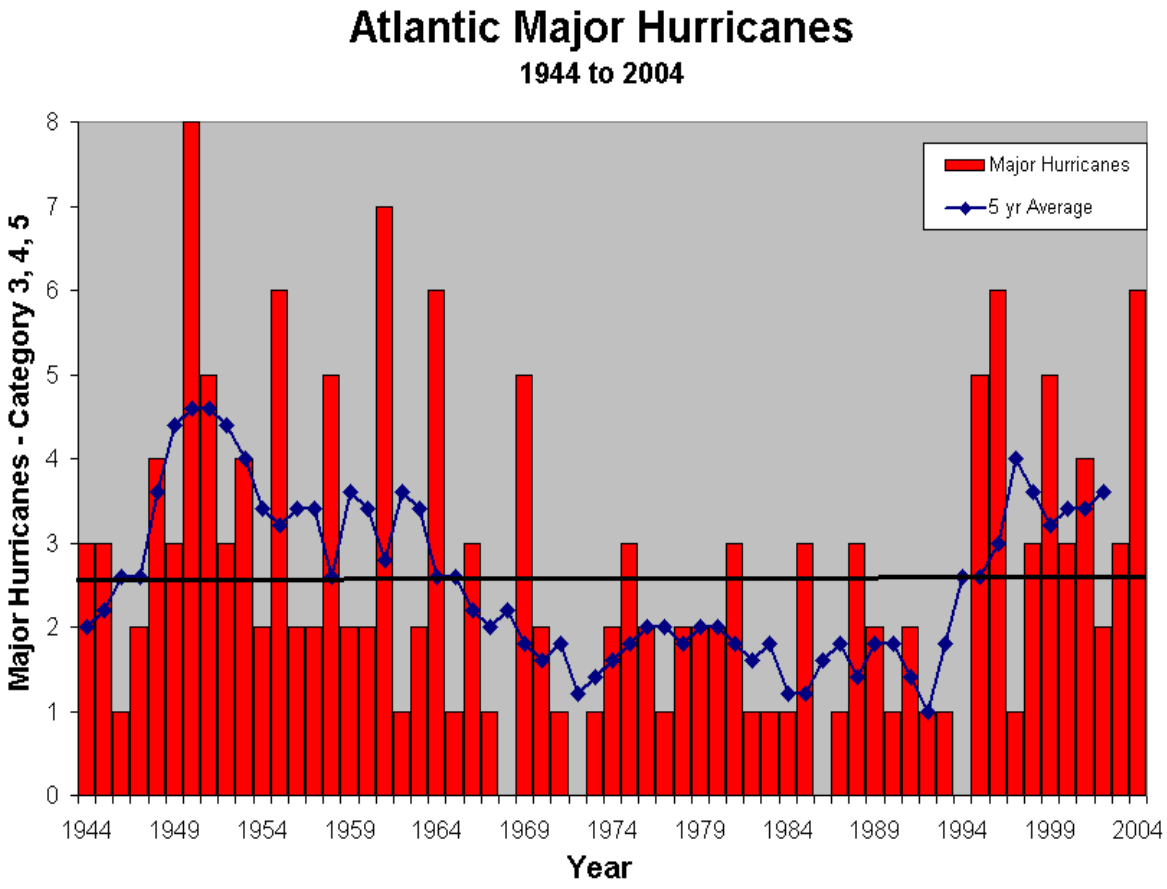

Major hurricanes (Saffir-Simpson Category 3-4-5) are much more likely during warm Atlantic regimes, as we're in now. Cool regimes yield about 2 major hurricanes per season, warm regimes closer to 4.

“Cold Atlantic”
Sea Surface Temperature
Regime Statistics

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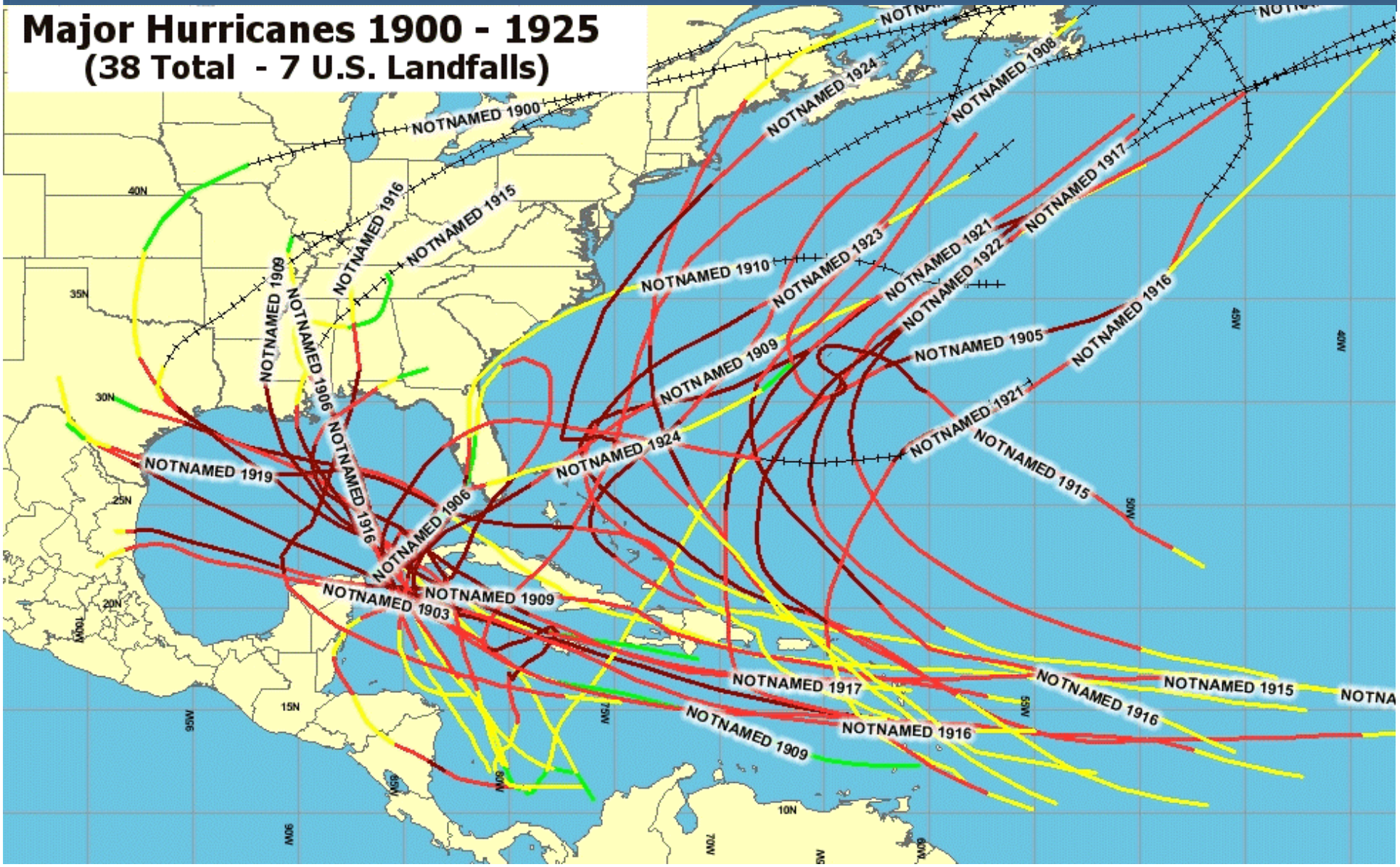
Major Hurricanes 1900 - 1925
(38 Total - 7 U.S. Landfalls)



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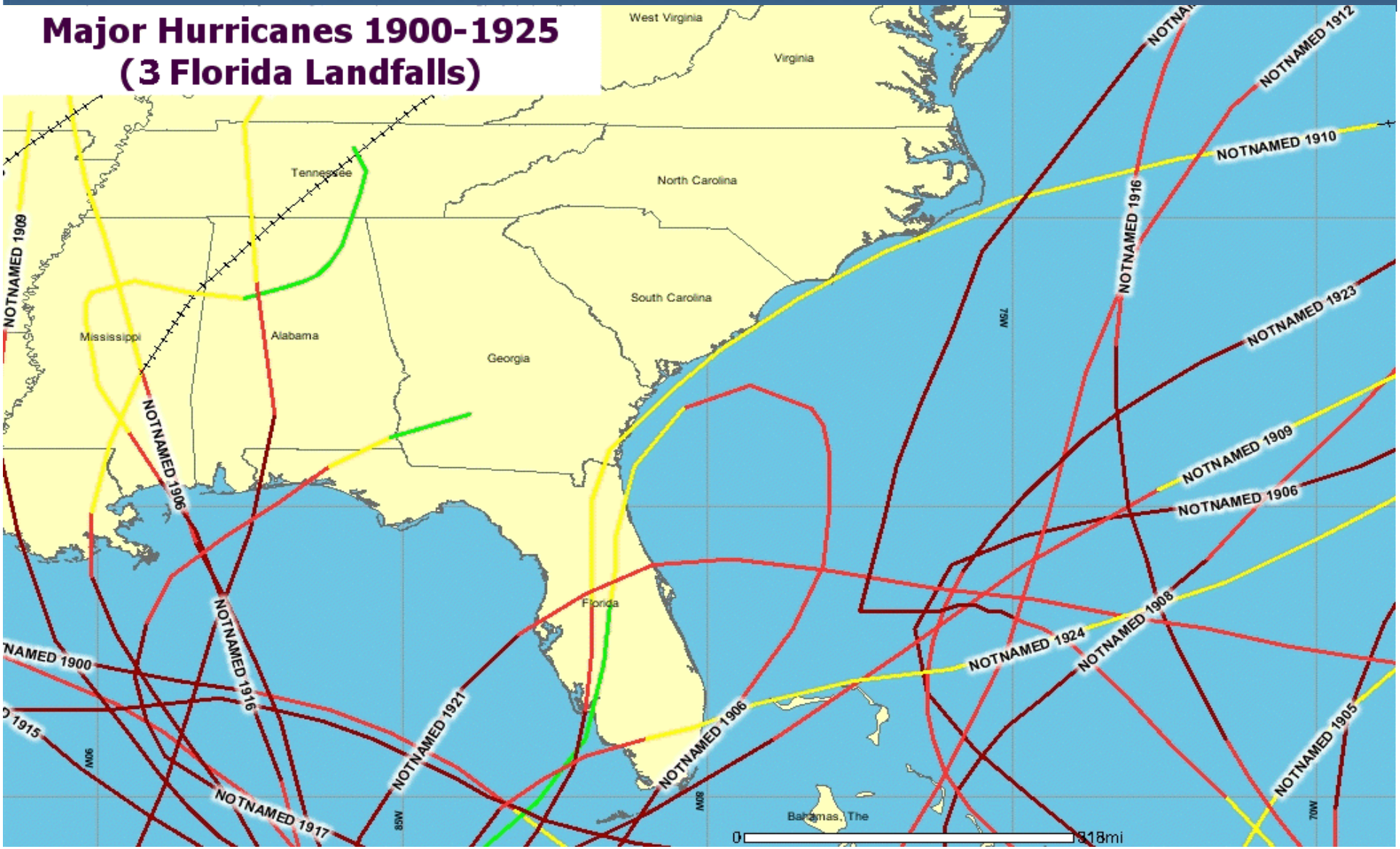
Major Hurricanes 1900-1925
(3 Florida Landfalls)



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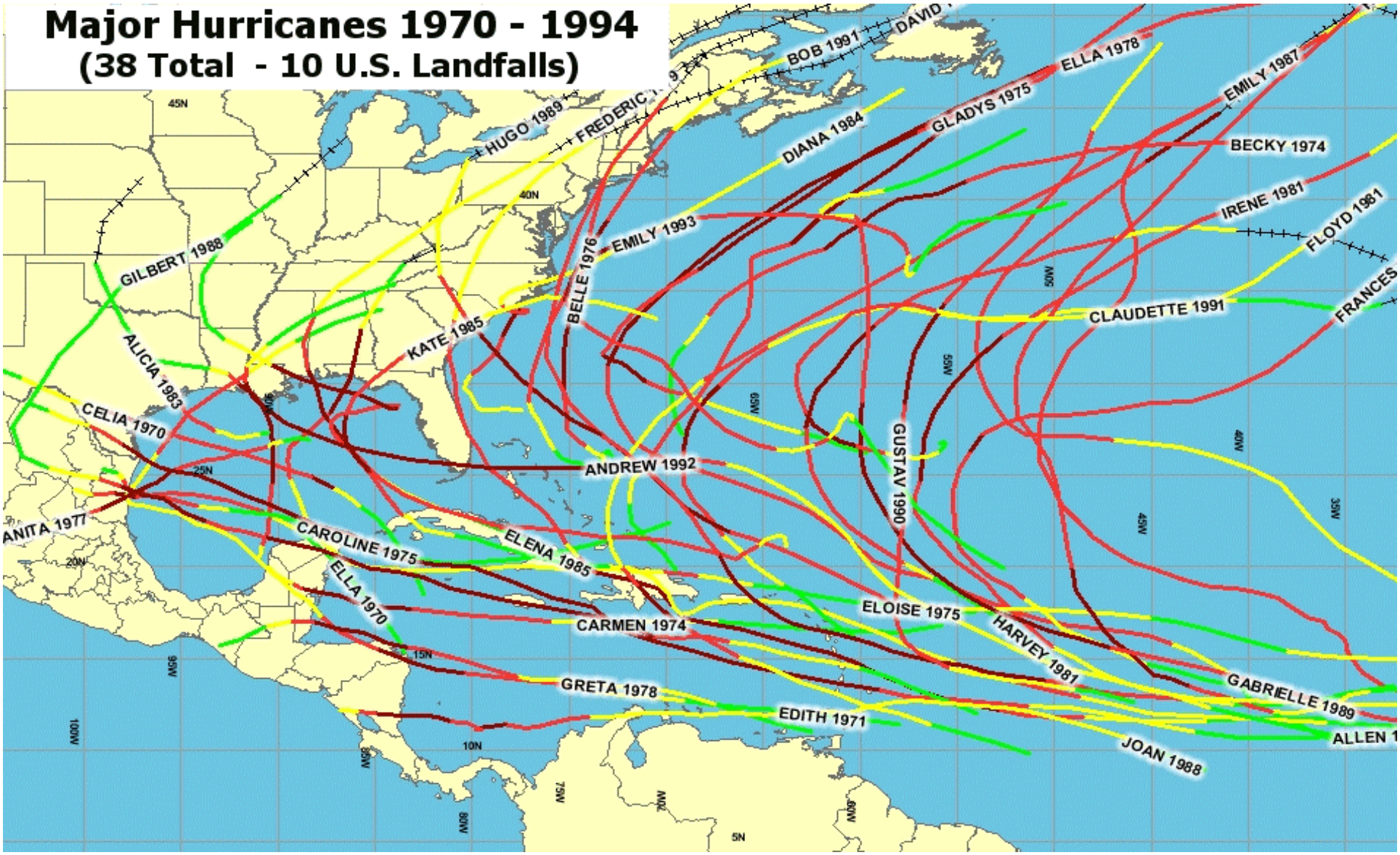
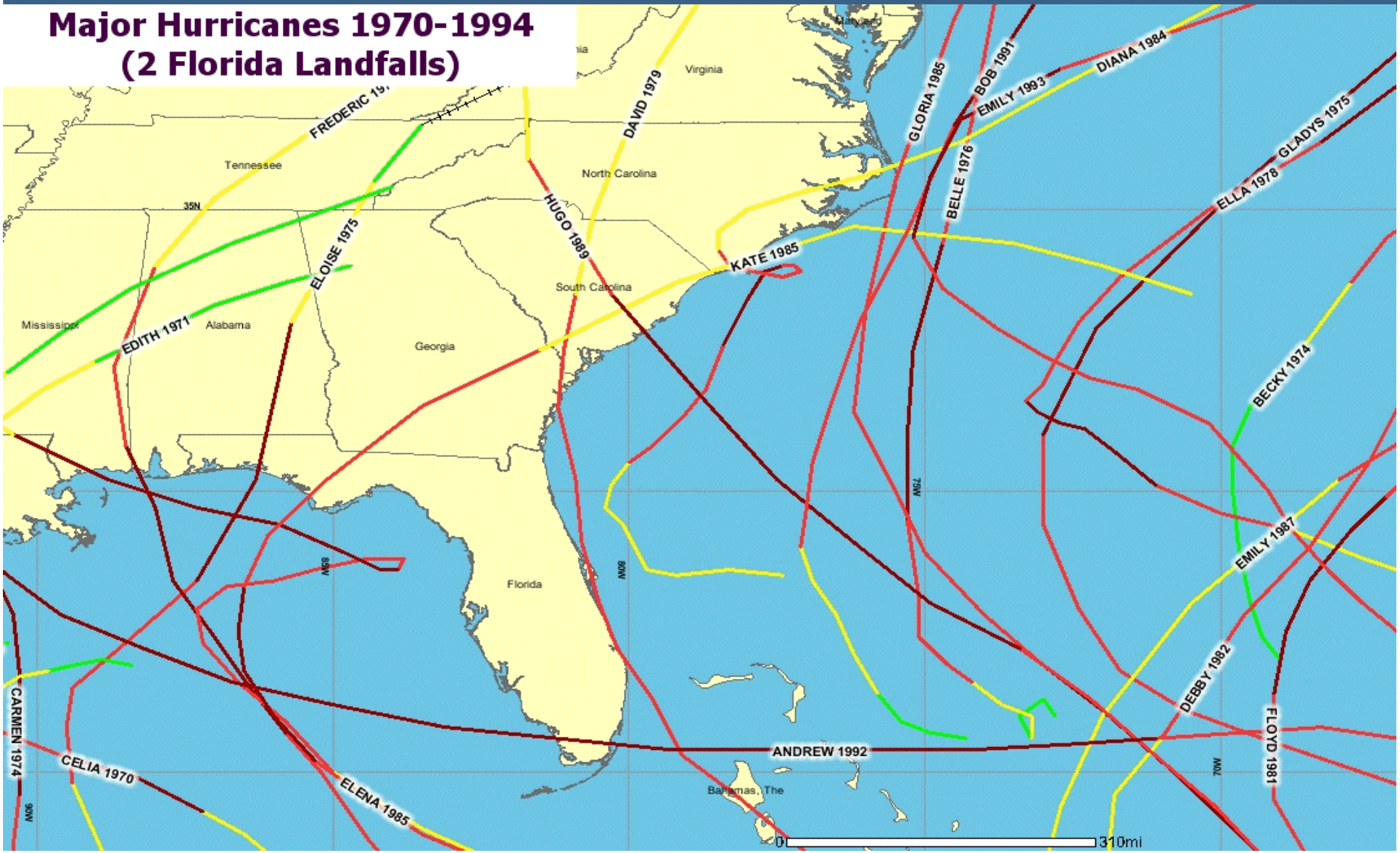
Major Hurricanes 1970 - 1994
(38 Total - 10 U.S. Landfalls)



ImpactWeather SM

Major Hurricanes 1970-1994
(2 Florida Landfalls)



“Warm Atlantic”
Sea Surface Temperature
Regime Statistics

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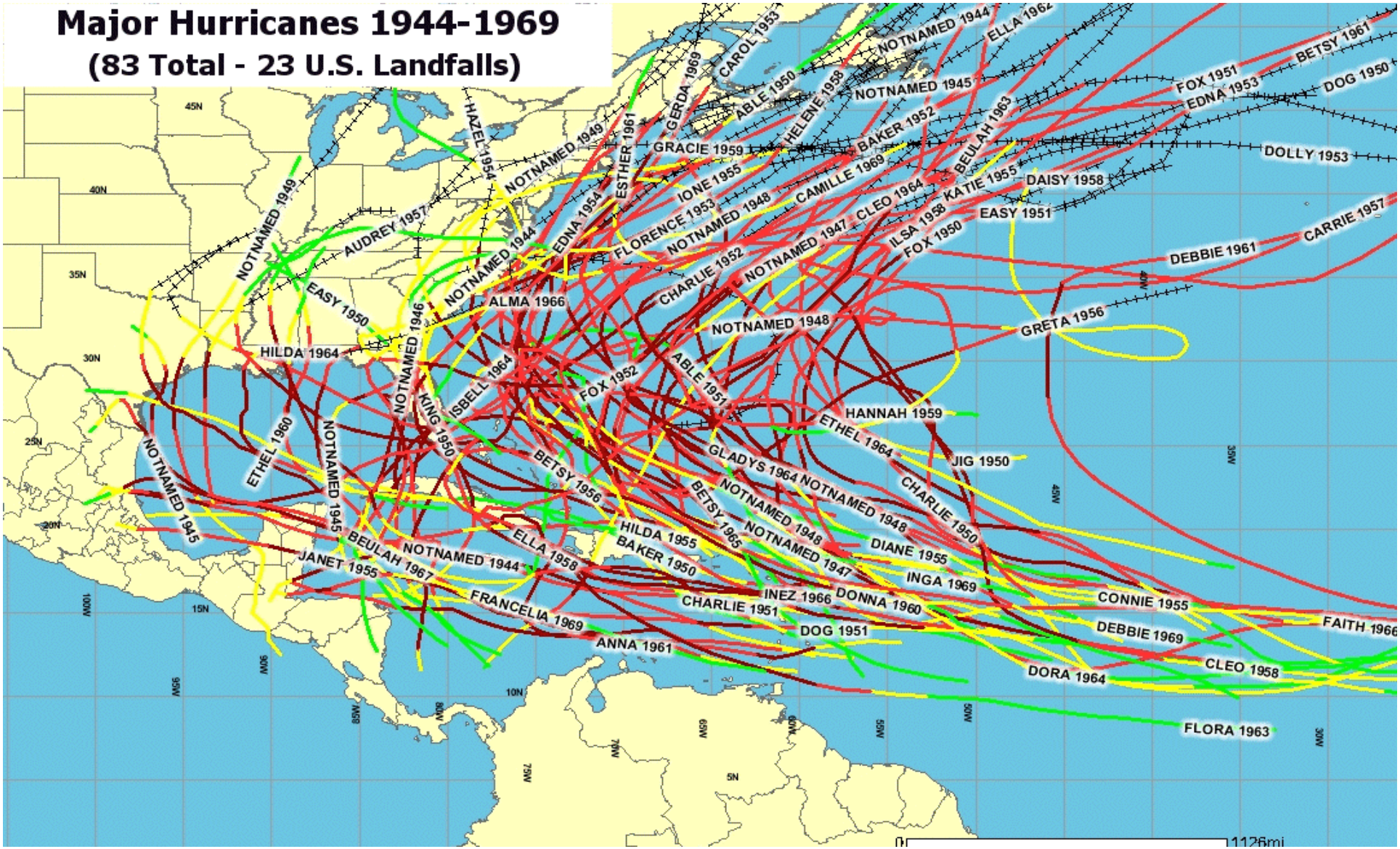
Major Hurricanes 1944-1969

(83 Total - 23 U.S. Landfalls)



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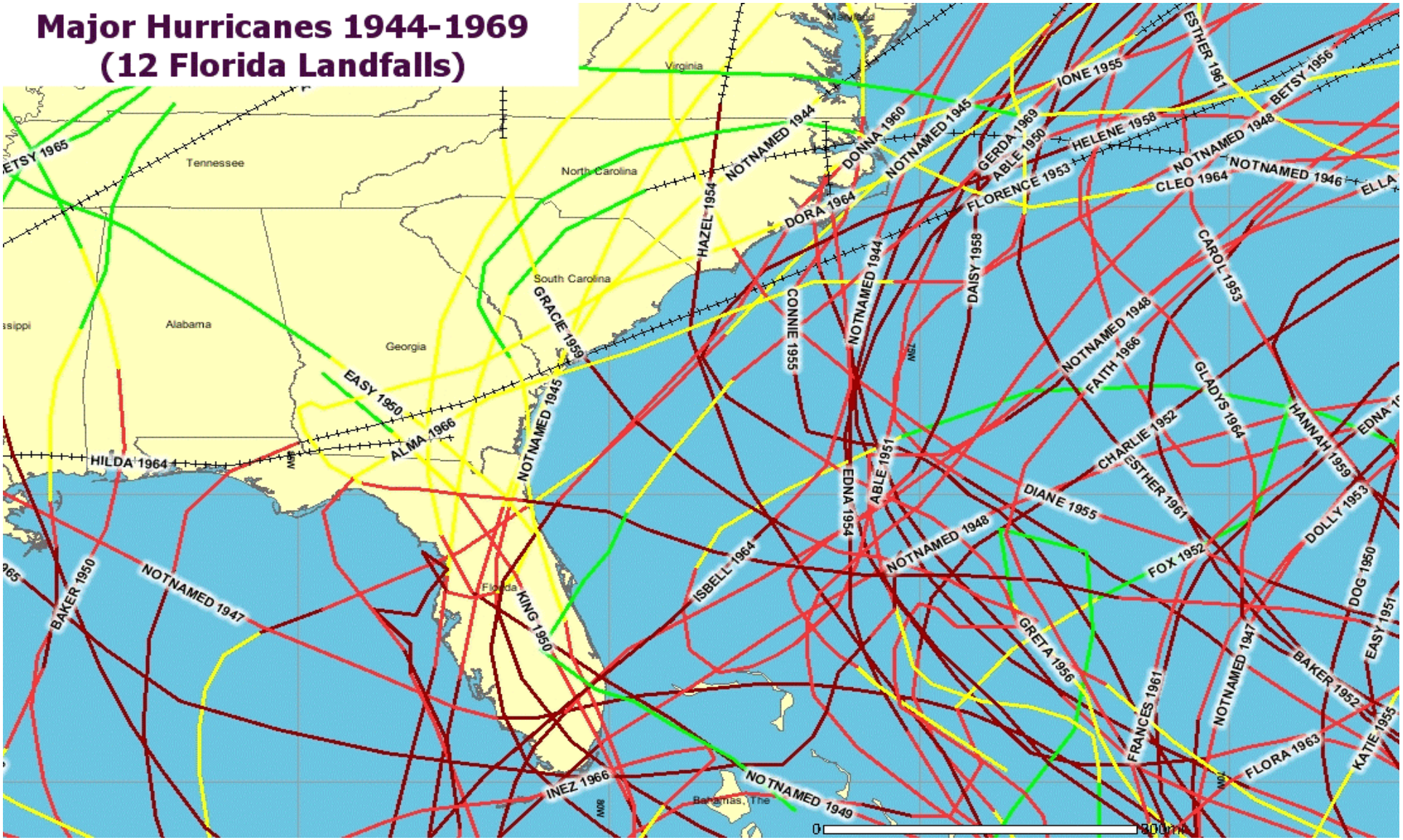
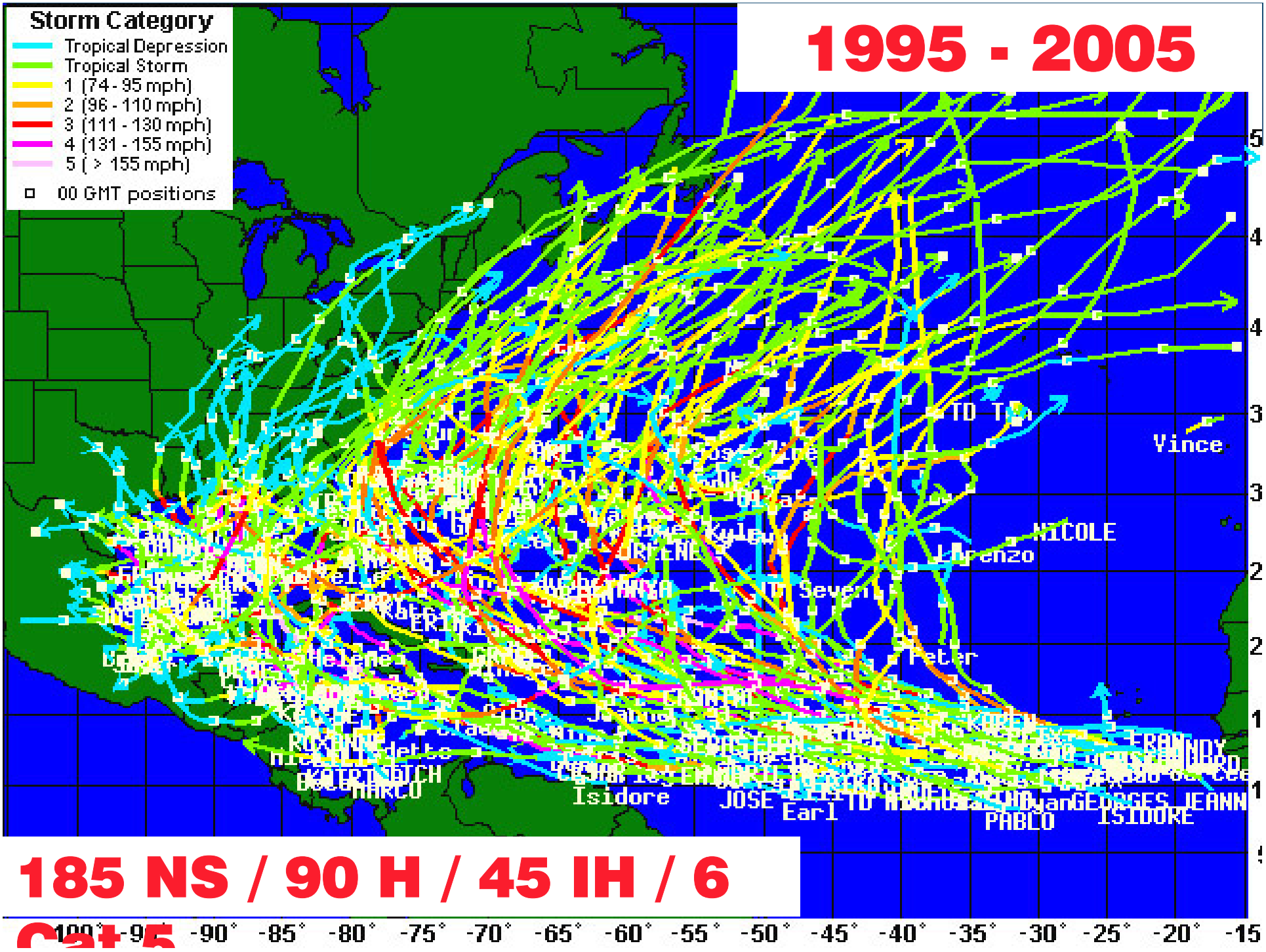
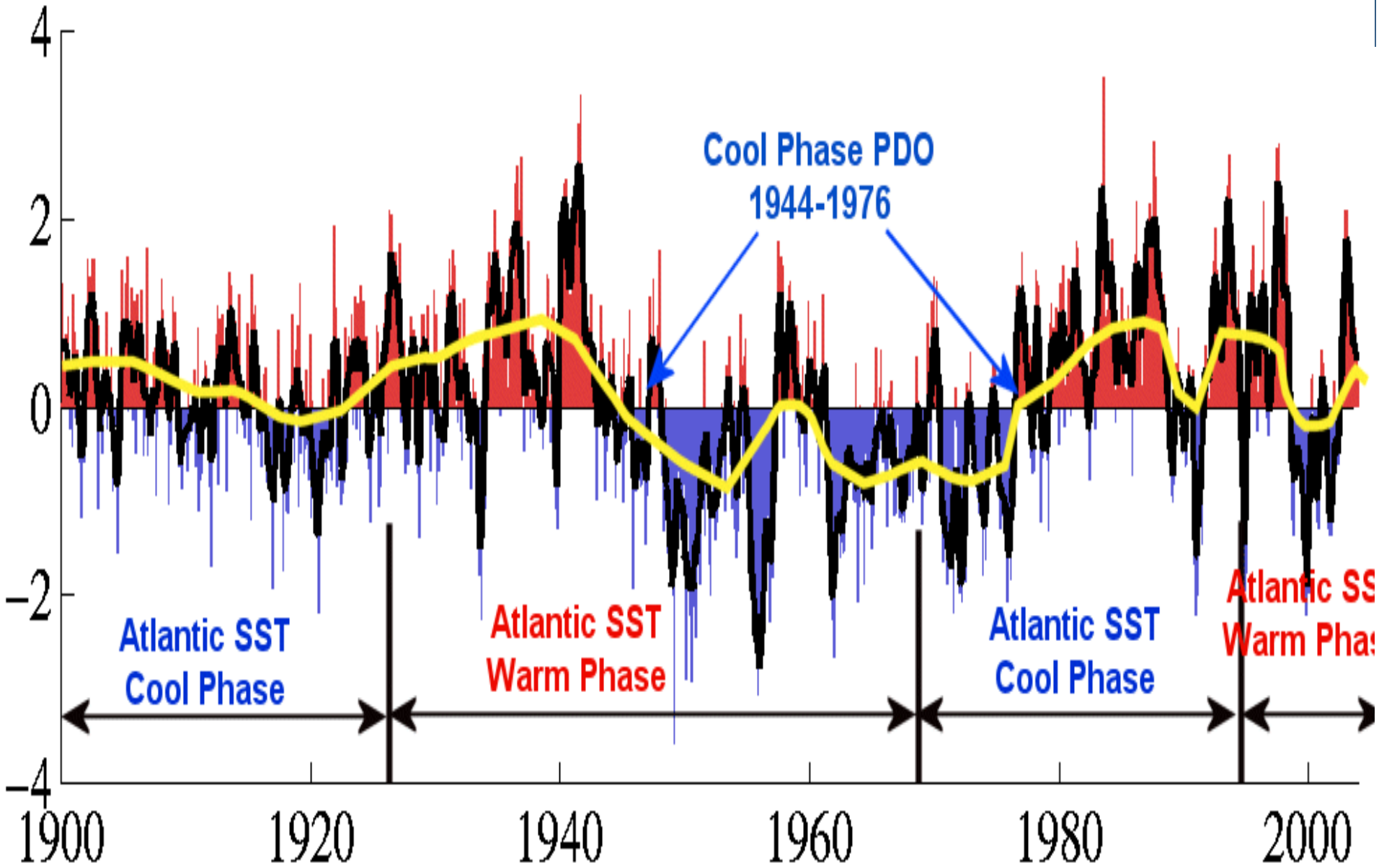
Major Hurricanes 1944-1969
(12 Florida Landfalls)




Storm Category
Tropical Depression
Tropical Storm
1 (74 - 95 mph)
2 (96 - 110 mph)
3 (111 - 130 mph)
4 (131 - 155 mph)
5 (> 155 mph)
00 GMT positions
1995 - 2005
Vince
NICOLE
Lorenzo
Peter
Isidore
JOSE
Earl
PABLO
ISIDORE
185 NS / 90 H / 45 IH / 6
Cat 5
-90° -85° -80° -75° -70° -65° -60° -55° -50° -45° -40° -35° -30° -25° -20° -15


monthly values for the PDO index: January 1900–December 2003
4
2
0
−2
−4
1900
1920
1940
1960
1980
2000
Cool Phase PDO
1944-1976
Atlantic SST
Cool Phase
Atlantic SST
Warm Phase
Atlantic SST
Cool Phase
Atlantic SS
Warm Phas

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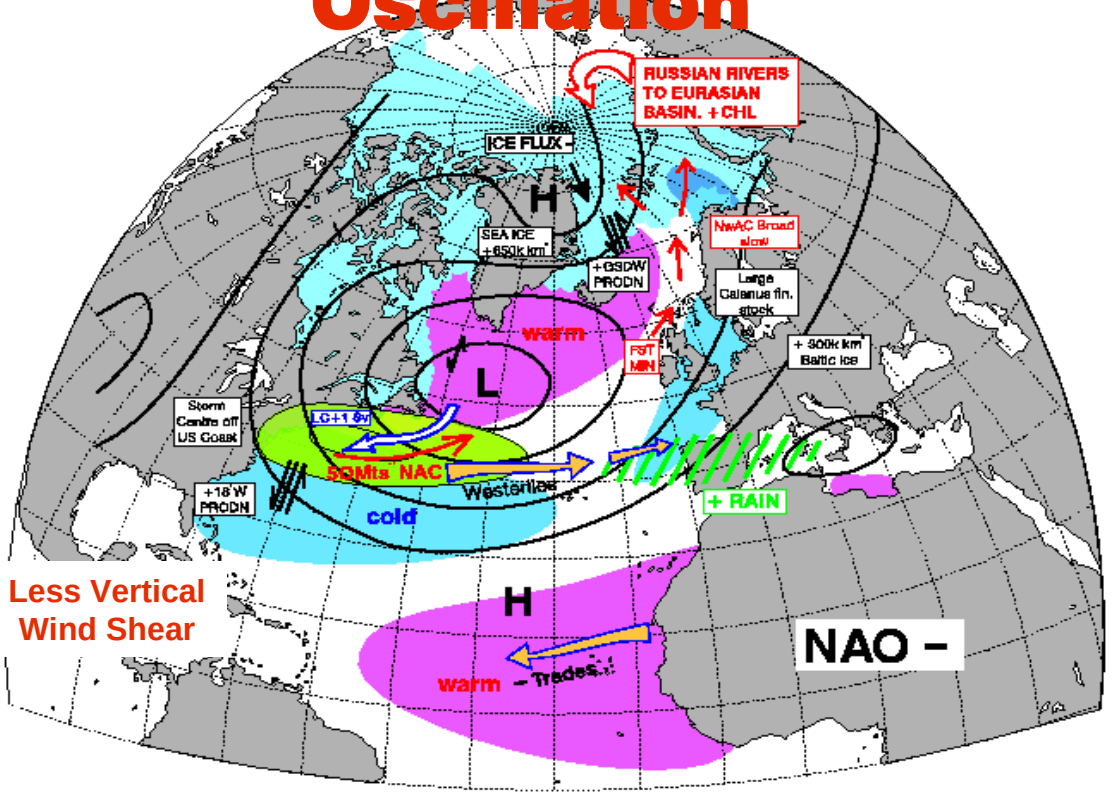
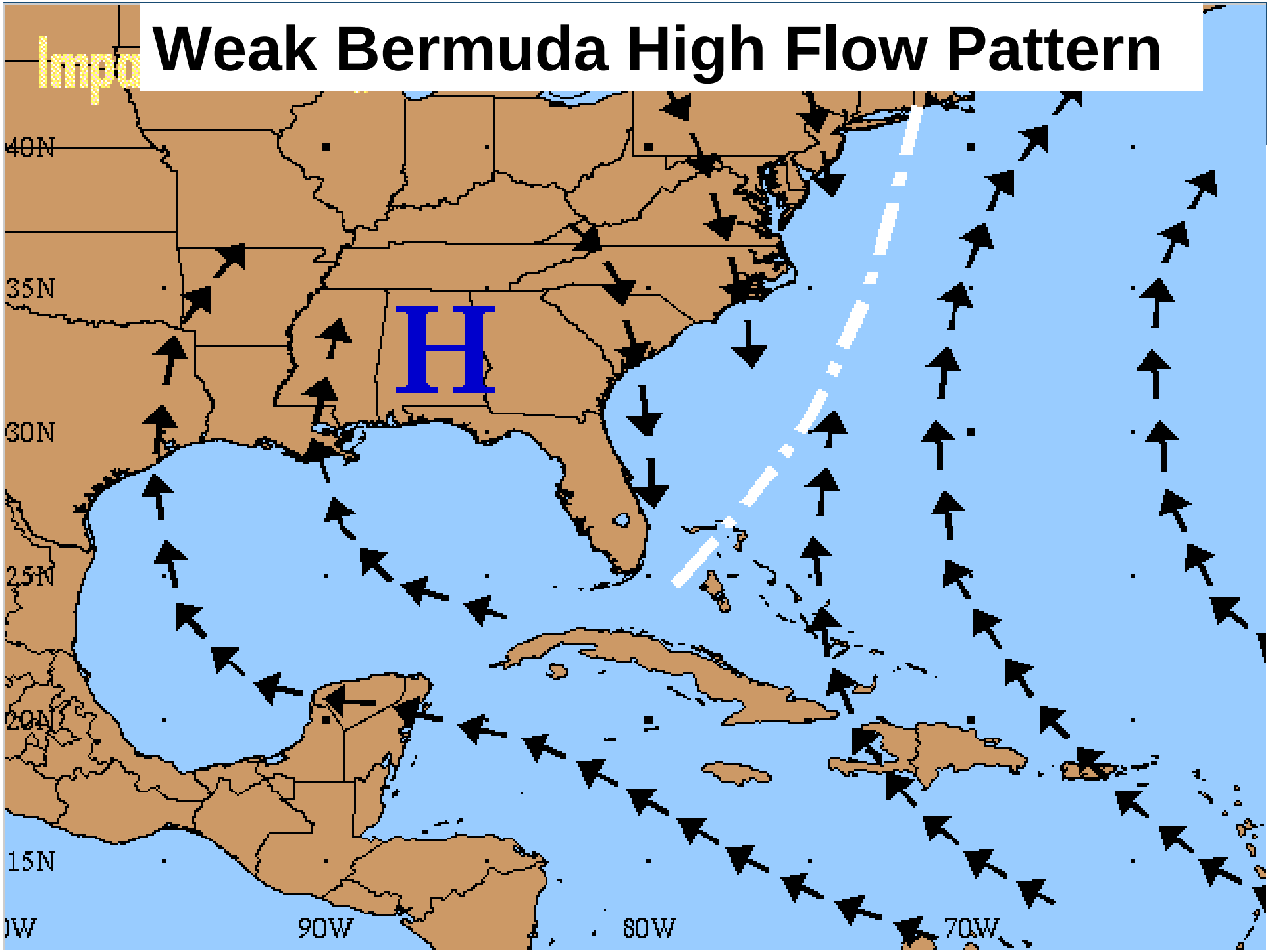
Effects of a Negative North Atlantic Oscillation



The pattern above represents a likely pattern for the upcoming hurricane season. A slightly weaker than normal Bermuda High would reduce wind shear in the Caribbean Sea, allowing for increased development there over a normal season.

Weak Bermuda High Flow Pattern



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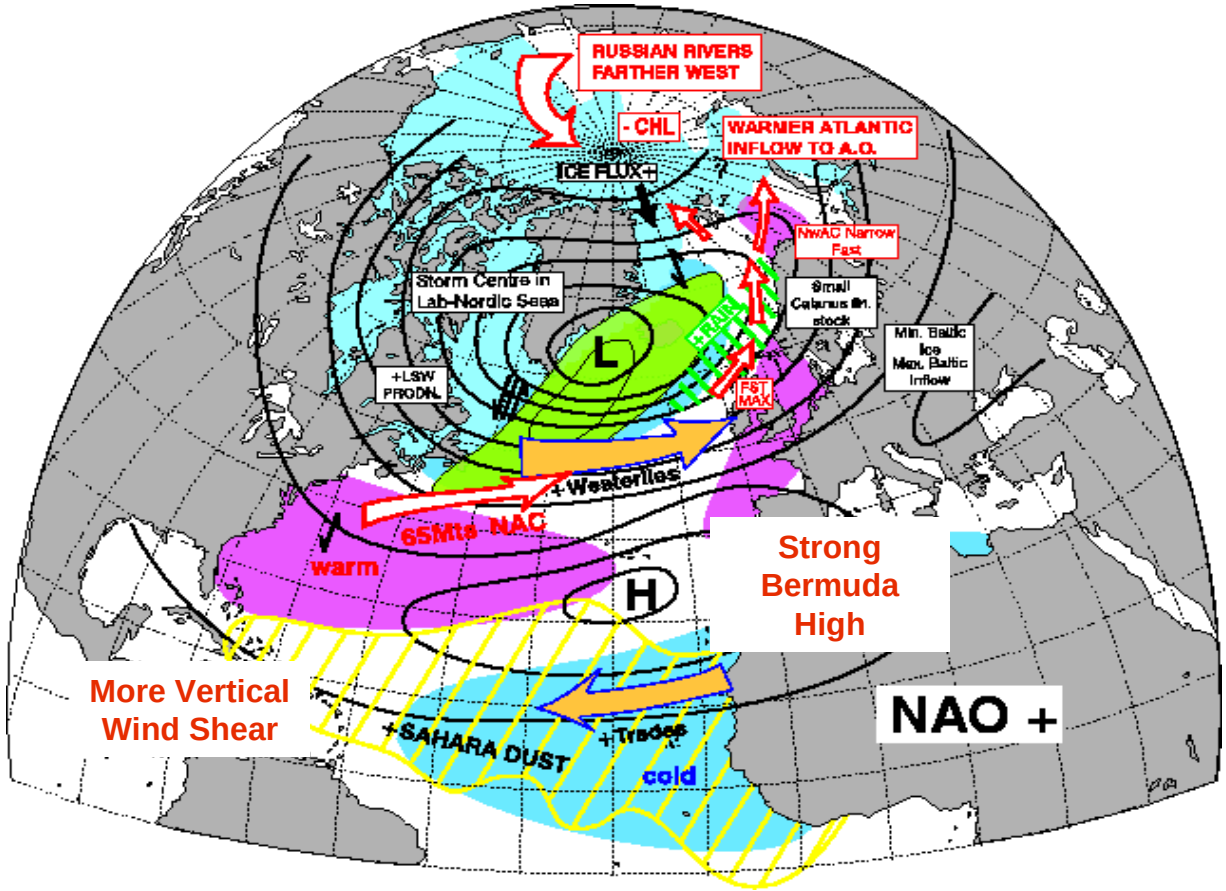
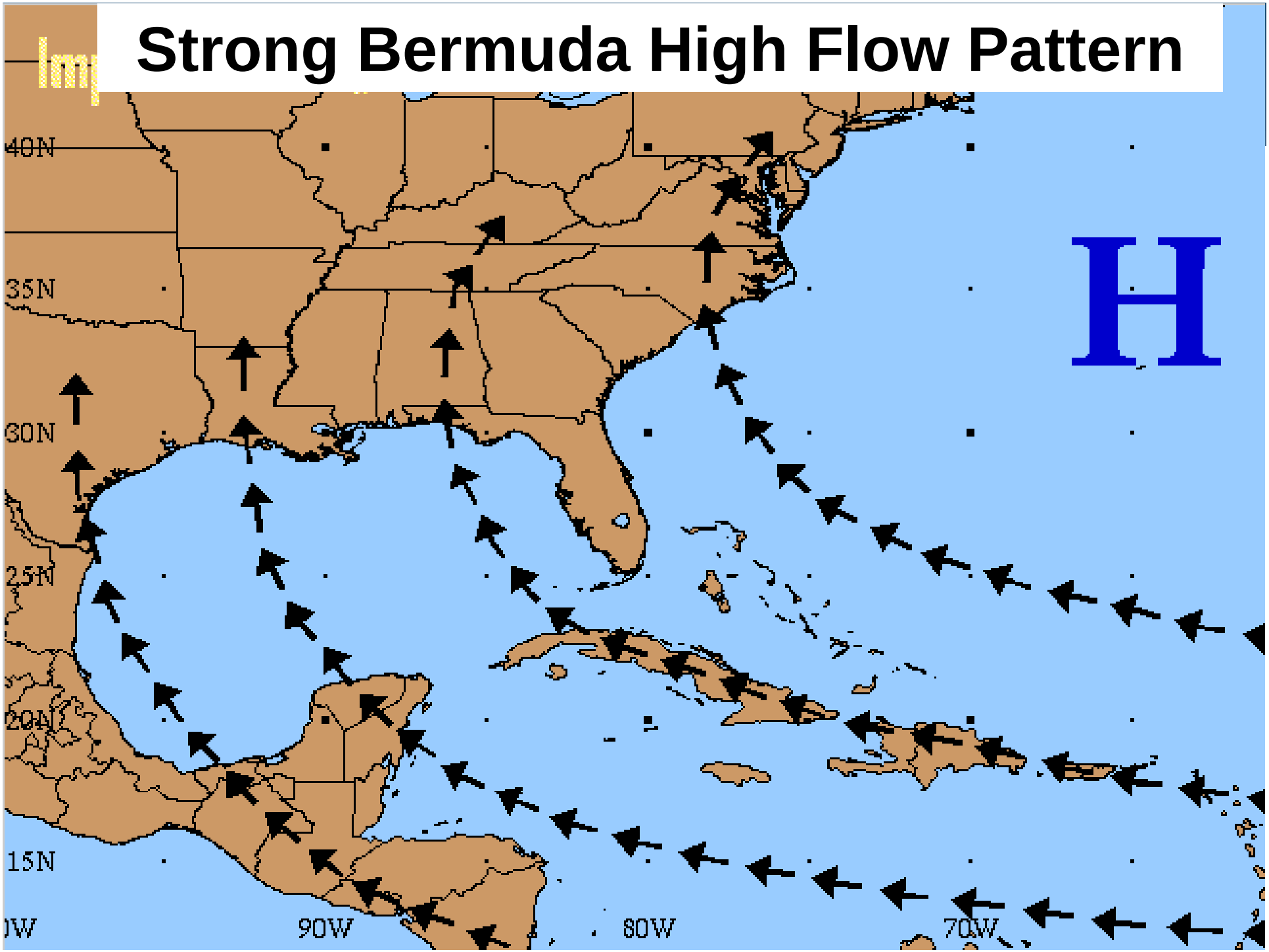
Effects of a Positive North Atlantic Oscillation



This graphic represents the opposite of what we expect in 2006. Such a pattern was dominant from 1979-1994, prior to the recent upsurge in tropical cyclone development.

Strong Bermuda High Flow Pattern



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What's in Store for 2006?

- 16 Named Storms (normal = 10)
- 9 Hurricanes (normal = 6)
- 4 Major Hurricanes (normal = 2)
- Major Hurricane Landfall Increasingly Likely in the southeast U.S. (Florida through Virginia)
- Northwest Gulf of Mexico at an elevated risk of a major hurricane

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Summary With Respect to Gulf of Mexico Threats

- 1-2 named storms likely prior to August 1st. At least one of those named storms will likely affect the northwest or north-central Gulf of Mexico, probably as a tropical storm or Category 1-2 hurricane.
- 5-6 named storms likely in both August and September. There is a good chance that at least 2 storms per month will affect the Gulf of Mexico. One or two of these could be major hurricanes.
- Late season (Oct-Nov) activity is once-again likely. Perhaps 2-4 named storms will form after September. One of those could affect the Gulf of Mexico, but typically these late season storms tend to track northeastward toward Florida (like Wilma last year).

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Questions?

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