

# Forecasting at the National Hurricane Center

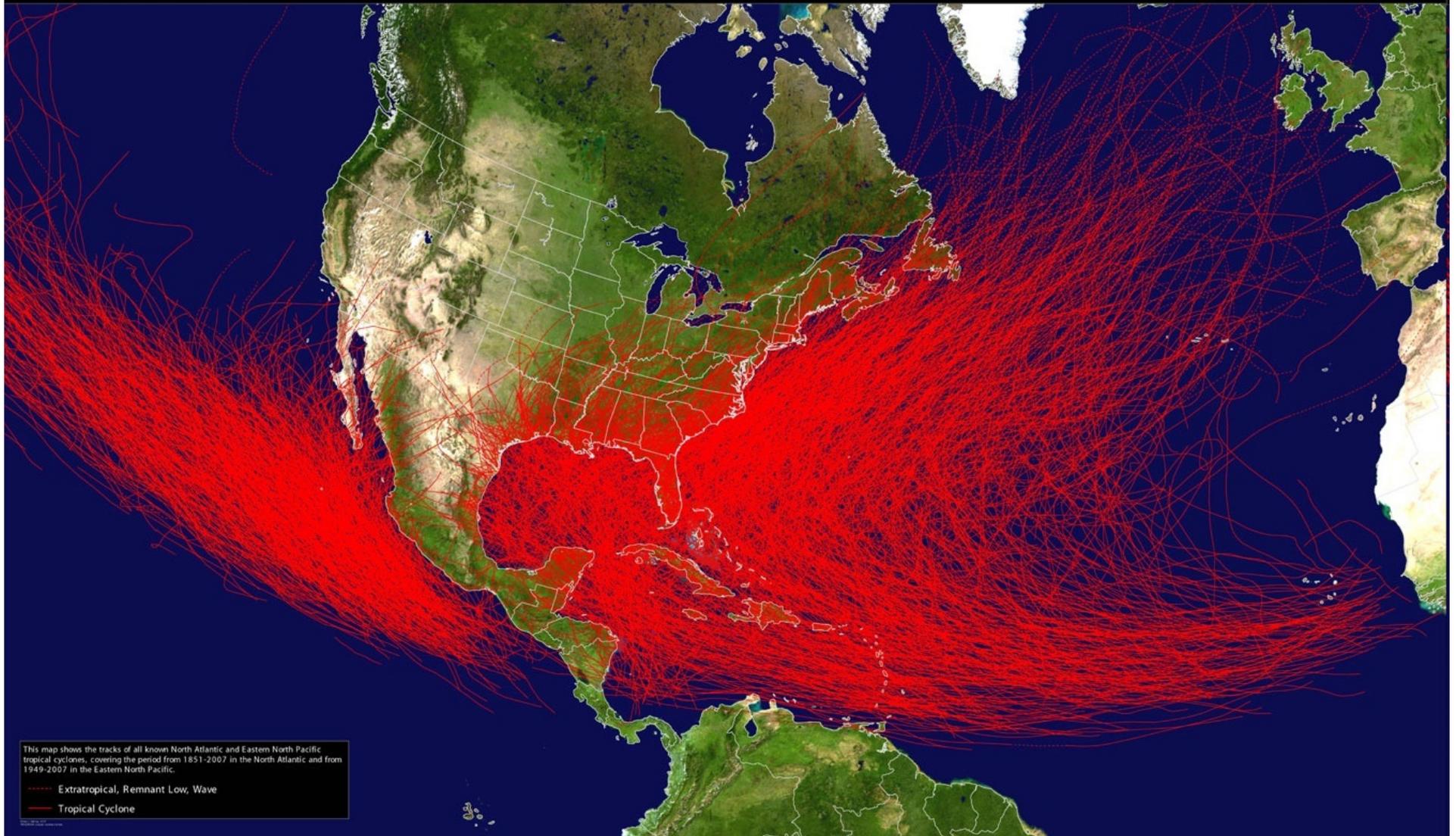
Chris Landsea  
Science and Operations Officer  
National Hurricane Center

CMMAP Workshop  
10 January, 2012



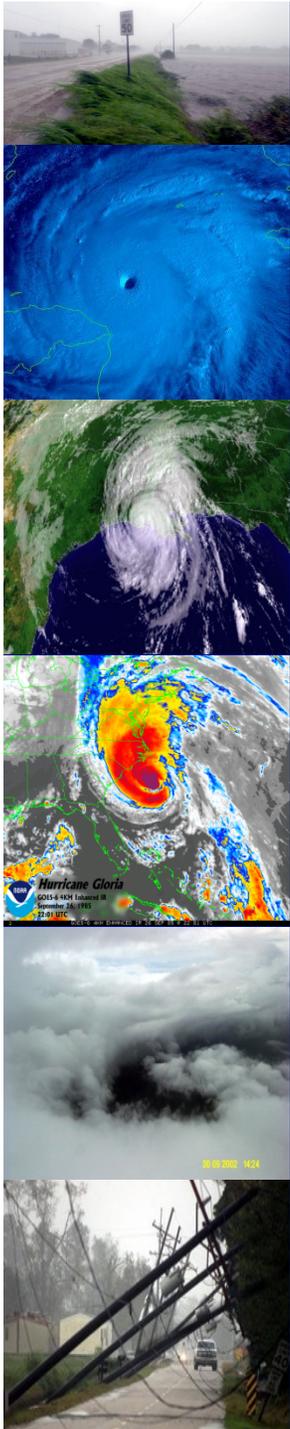
# Tropical Cyclone History

Data from 1949 in the Pacific, from 1851 in the Atlantic



This map shows the tracks of all known North Atlantic and Eastern North Pacific tropical cyclones, covering the period from 1851-2007 in the North Atlantic and from 1949-2007 in the Eastern North Pacific.

- Extratropical, Remnant Low, Wave
- Tropical Cyclone



# NHC MISSION

To save lives, mitigate property loss,  
and improve economic efficiency  
by issuing the best  
watches, warnings, forecasts and analyses of  
hazardous tropical weather, and by  
increasing understanding of these hazards

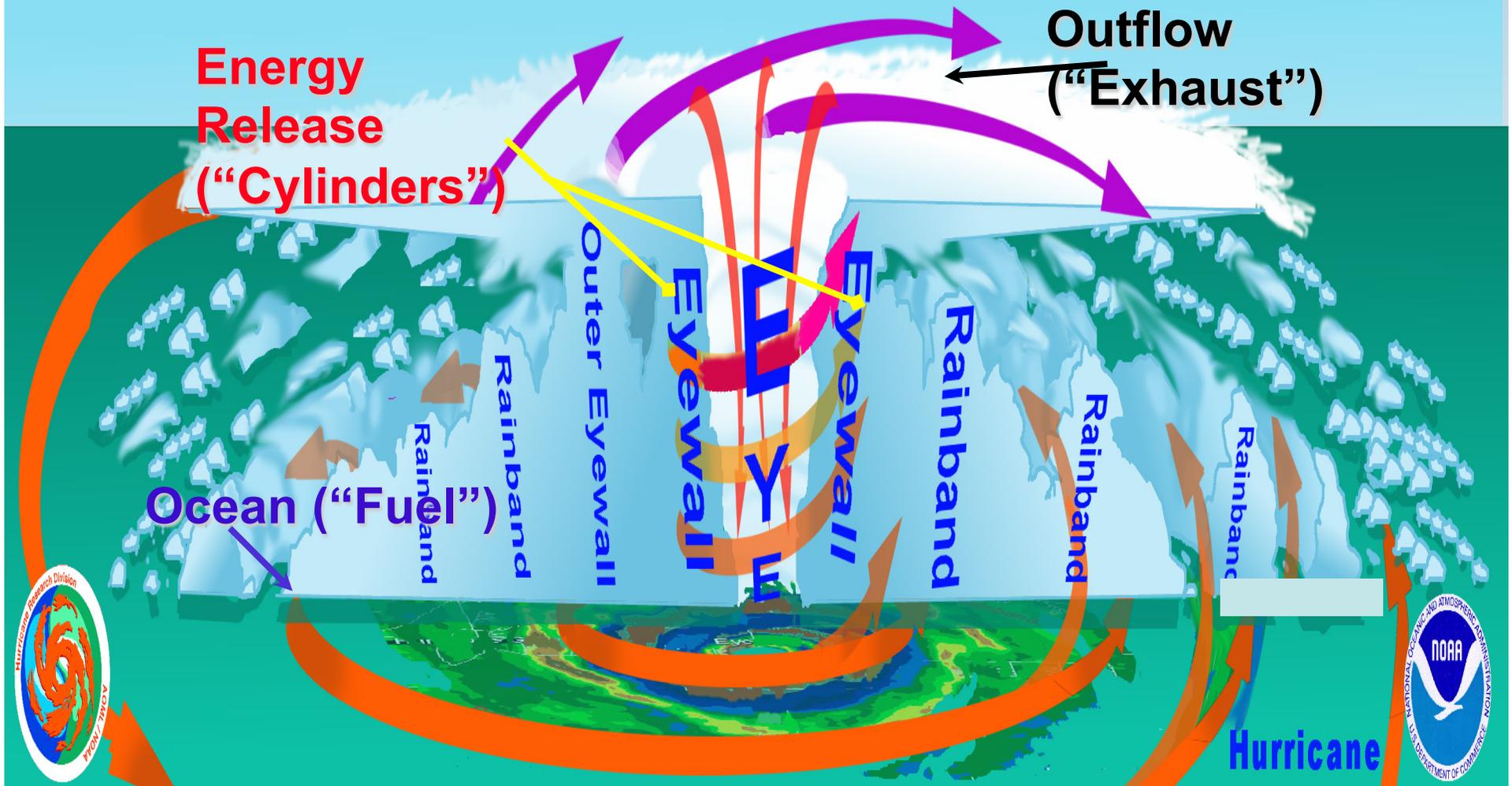
# NHC VISION

To be America's calm, clear and trusted  
voice in the eye of the storm,  
and, with our partners,  
enable communities to be safe  
from tropical weather threats



# Nature's great heat engine...

# The Hurricane

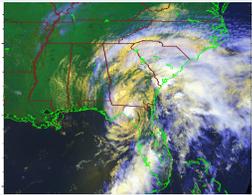
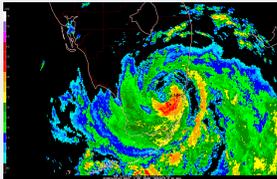
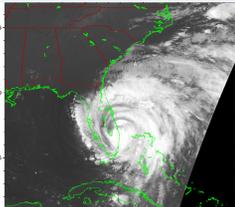
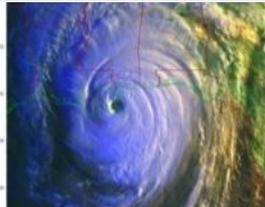
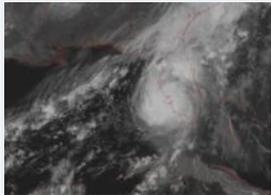
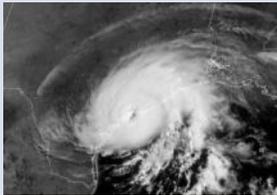
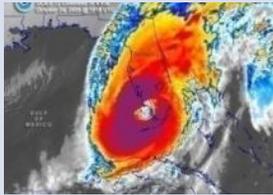
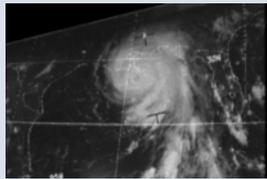


# What is a Hurricane?

- *A type of Tropical Cyclone*
  - *Closed surface circulation*
  - *Winds rotate counter-clockwise*
  - *Produces organized thunderstorm activity*
- 
- ***Tropical Depression***  
*Sustained winds are less than 39 mph*
  - ***Tropical Storm***  
*Sustained winds are between 39-73 mph*
  - ***Hurricane***  
*Sustained winds are 74 mph or greater*

# Saffir-Simpson Hurricane Scale

- *Categorizes hurricanes by wind speed*

			MAJOR HURRICANES		
Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
39-73 mph (34-63 kt)	74-95mph (64-82 kt)	96-110 mph (83-95 kt)	111-130 mph (96-113 kt)	131-155 mph (114-135 kt)	> 155 mph (> 136 kt)
					
<b>Alberto</b> (2006)	<b>Katrina</b> (FL - 2005)	<b>Frances</b> (2004)	<b>Katrina</b> (LA - 2005)	<b>Charley</b> (2004)	<b>Andrew</b> (1992)
					
<b>Allison</b> (2001)	<b>Claudette</b> (2003)	<b>Isabel</b> (2003)	<b>Wilma</b> (FL- 2005)	<b>Hugo</b> (1989)	<b>Camille</b> (1969)



# Saffir-Simpson Hurricane Wind Scale

Surge, rainfall, and pressure fit the scale like a square peg in a round hole



<http://www.nhc.noaa.gov/aboutsshs.shtml>

Category	Central Pressure		Winds (mph)	Surge	Damage
	Millibars	Inches			
5	< 920	< 27.17	>155	>18'	Catastrophic
4	944-920	27.88-27.17	131-155	13'-18'	Extreme
3	964-945	28.47-27.91	111-130	9'-12'	Extensive
2	979-965	27.91-28.50	96-110	6'-8'	Moderate
1	≤ 980	≤ 28.94	74-95	4'-5'	Minimal



**KATRINA (3)**



**IKE (2)**



**CHARLEY (4)**

# Wind-caused Damage



# Storm Surge



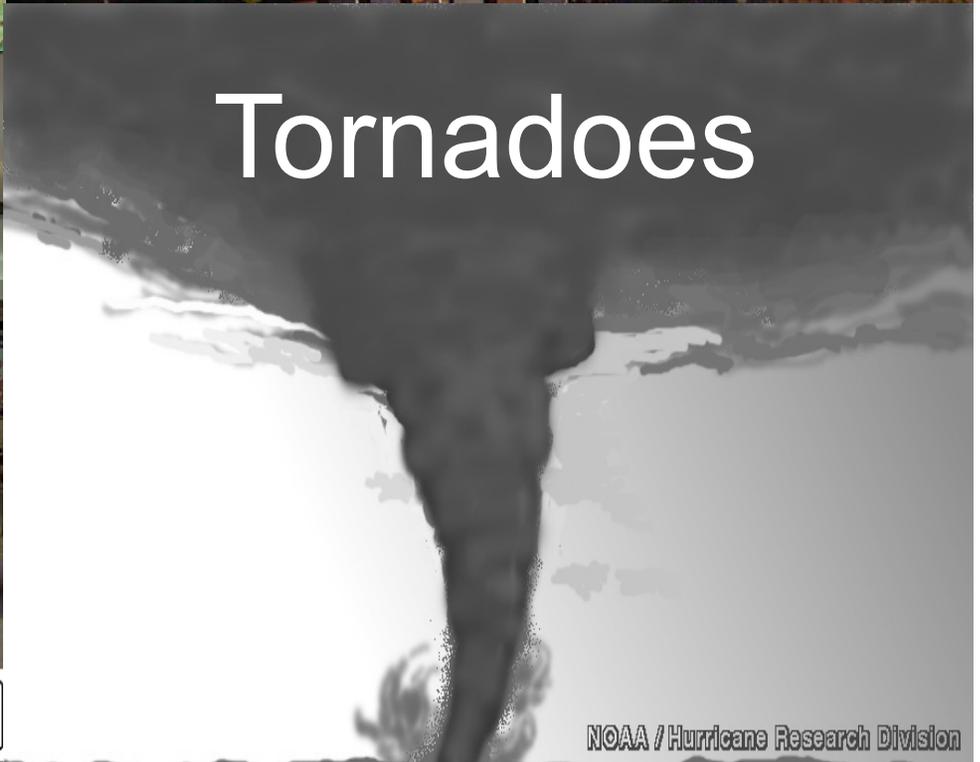
# Inland Flooding



Buffalo Bayou, Downtown Tunnel Flooded, 6/9/01



# Tornadoes





Before Katrina...

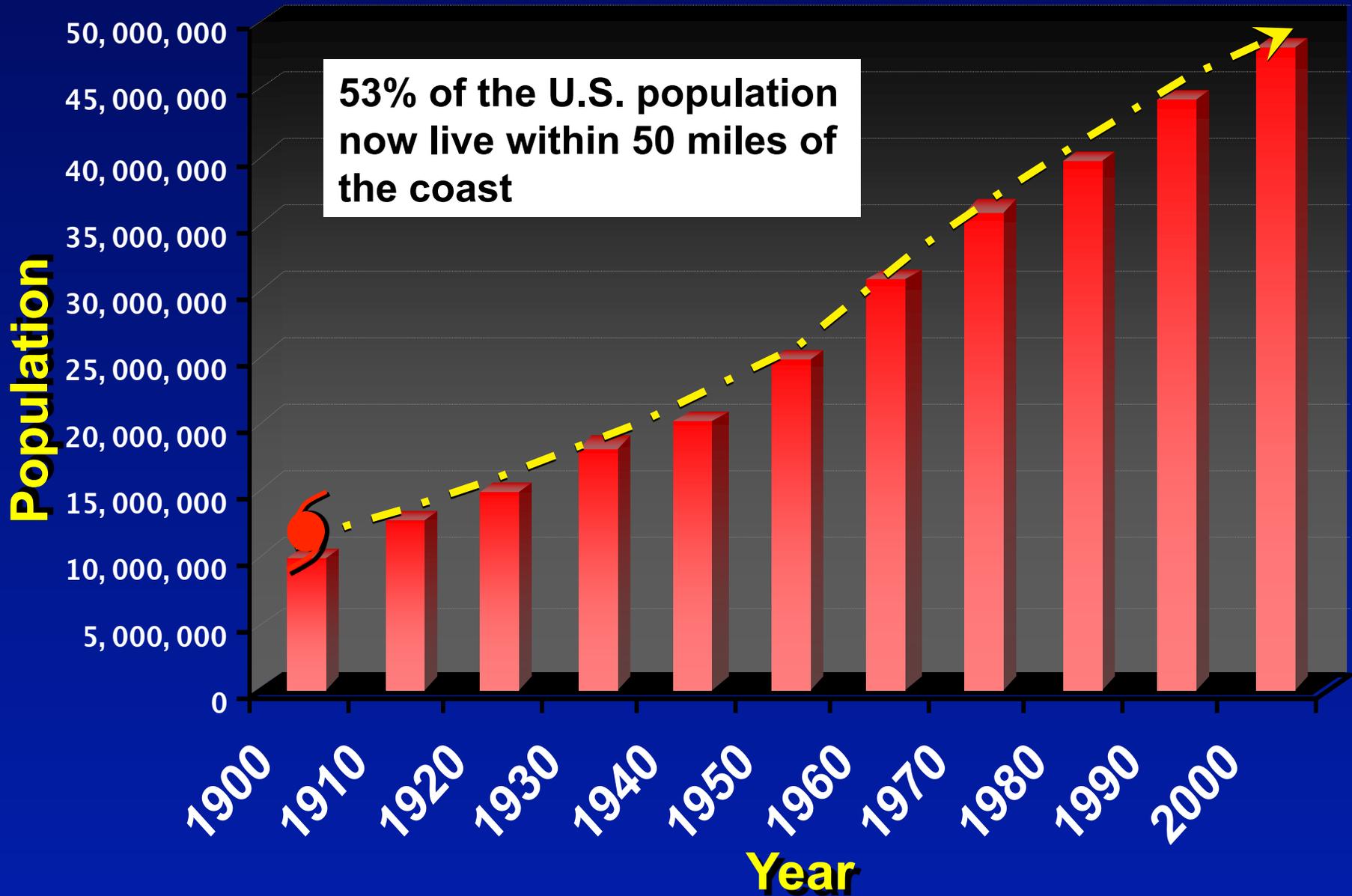
David & Kimberly King  
Waveland, MS



...After Katrina

David & Kimberly King  
Waveland, MS

# Coastal County Population, Texas to Maine 1900 - 2000



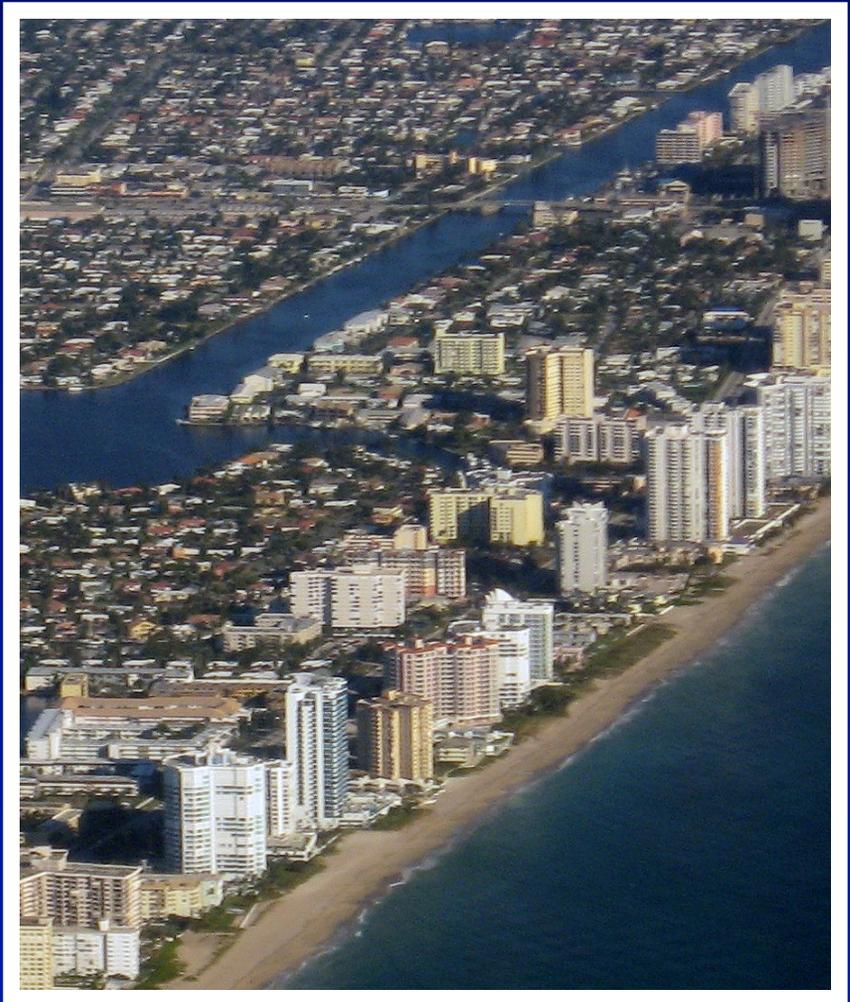
# U.S. Coastlines: Then and Now

1926 Great Miami Hurricane: \$140-157 Billion Today

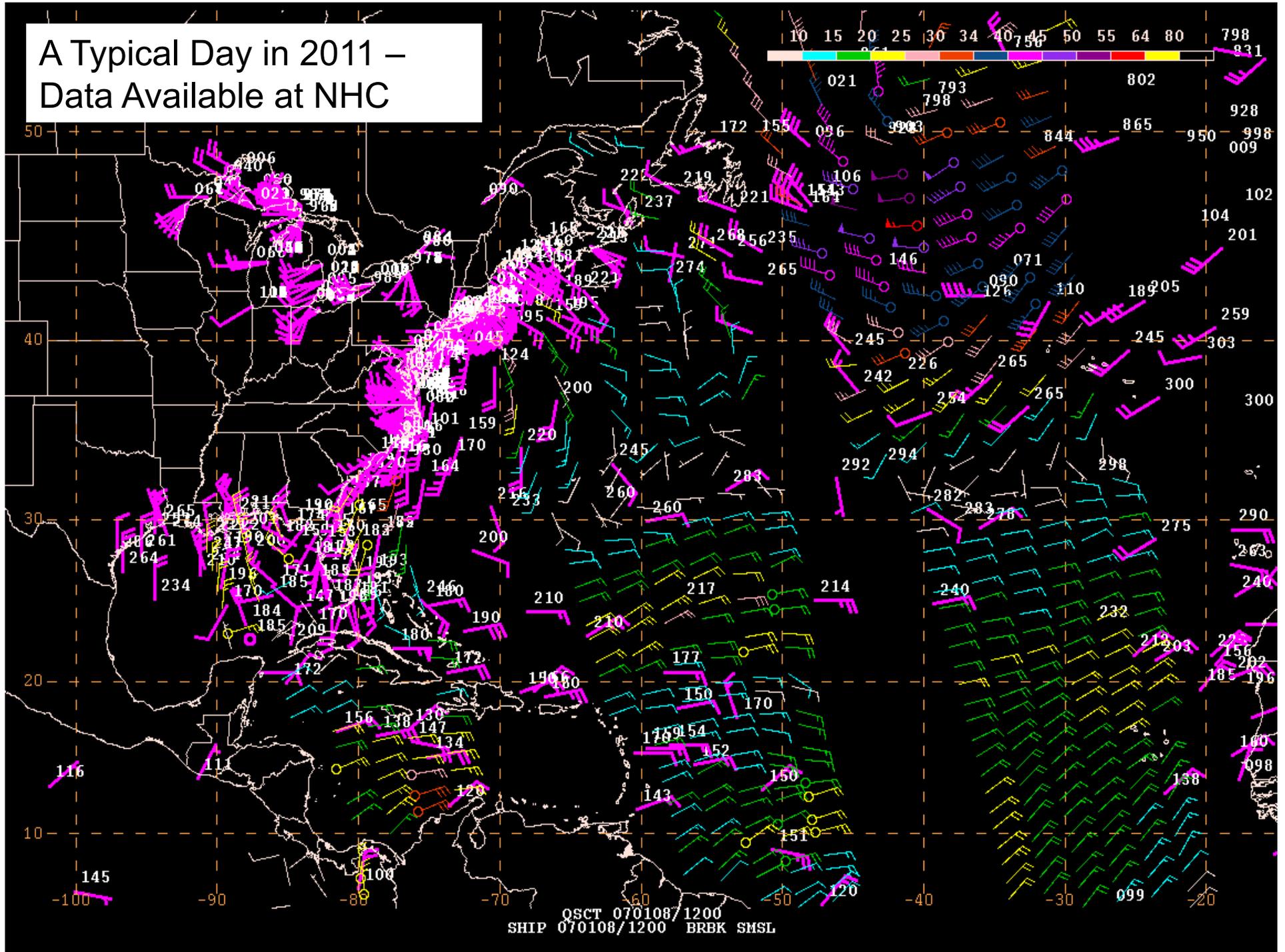
Miami Beach 1926



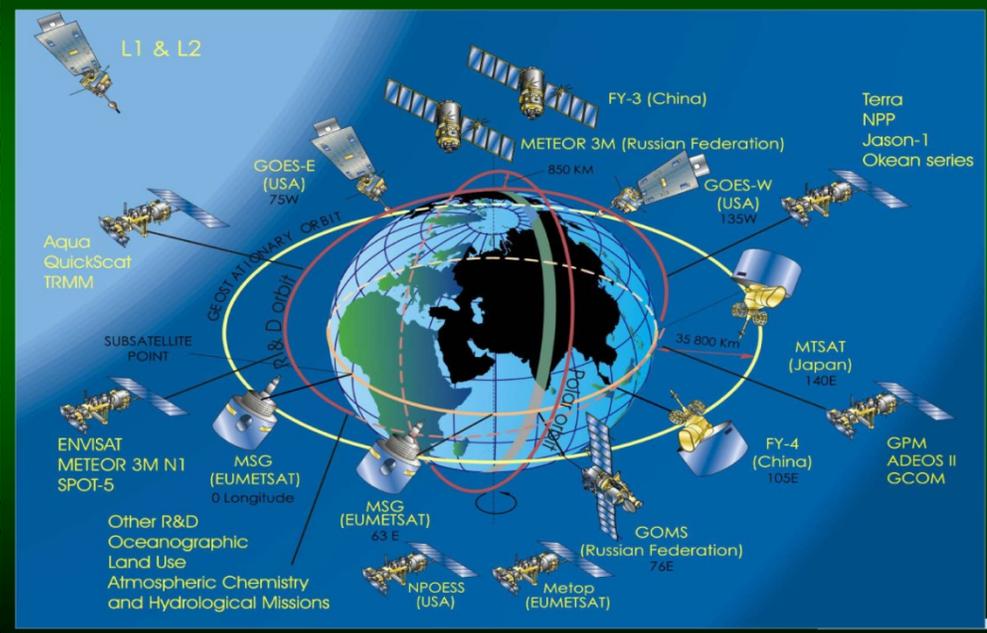
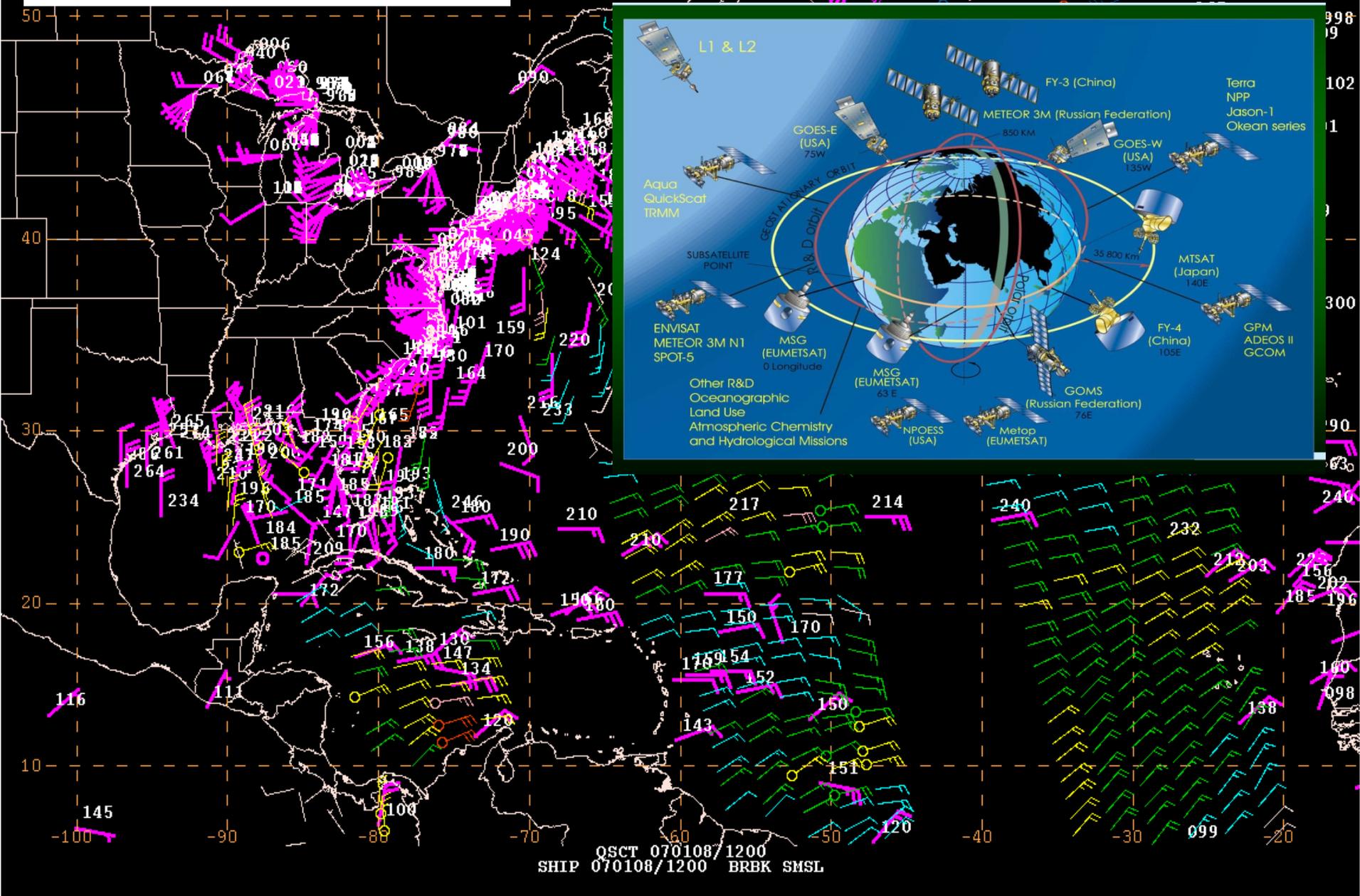
Miami Beach 2006



# A Typical Day in 2011 – Data Available at NHC



# A Typical Day in 2011 – Data Available at NHC

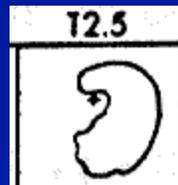
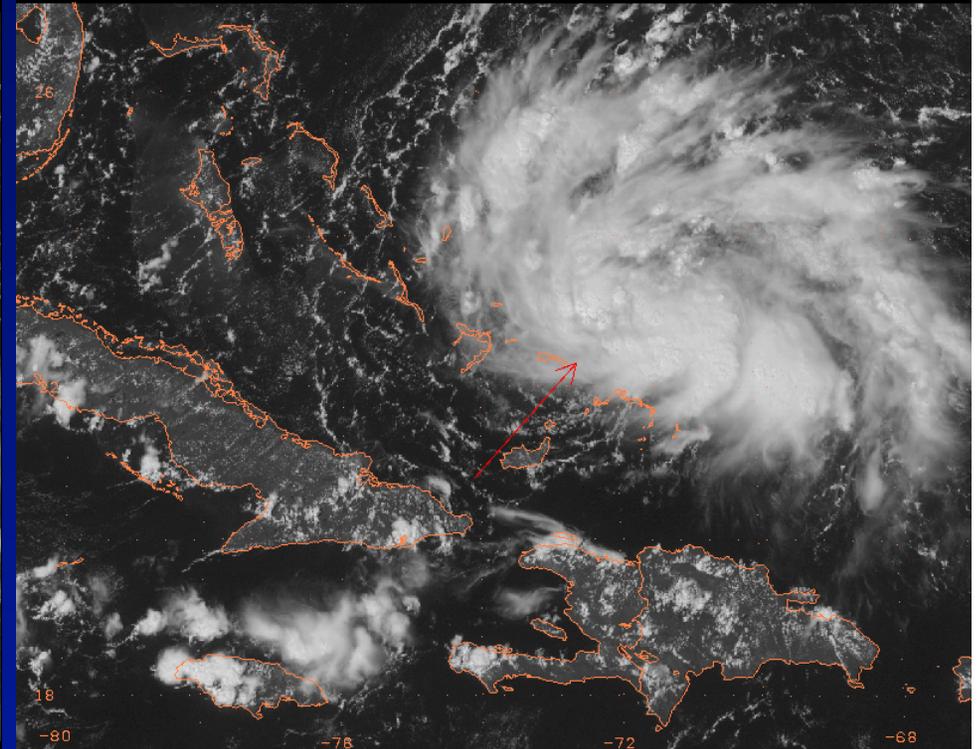
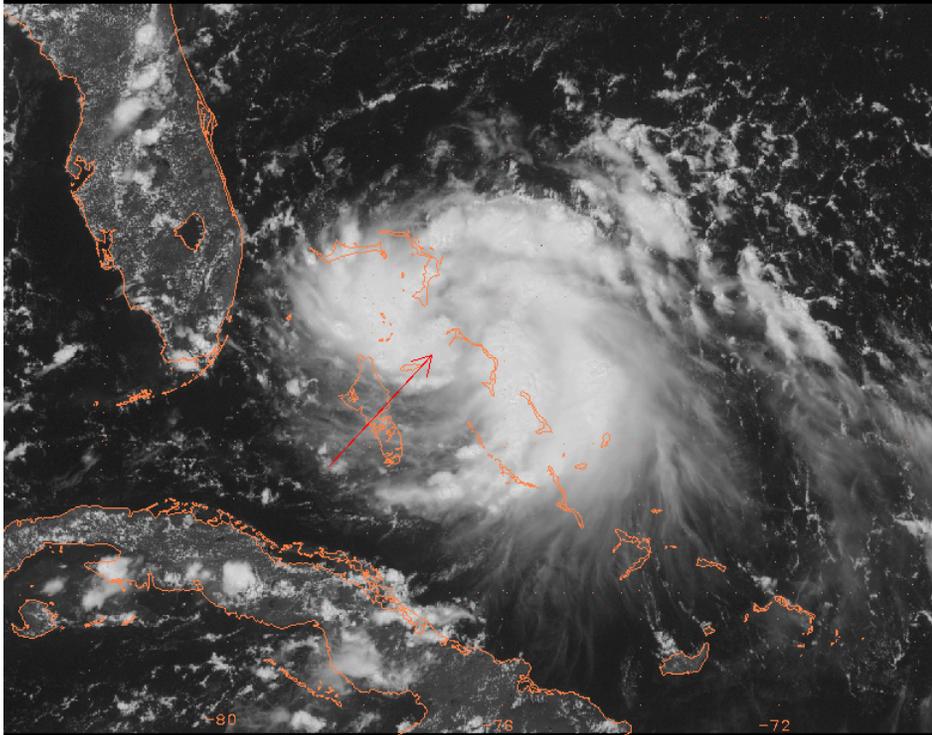


QSCY 070108/1200  
SHIP 070108/1200 BRBK SMSL

# Dvorak Classifications

Katrina August 24

Rita September 18



# 0430 UTC 27 August GOES-10 IR

08/27/04 0000Z 10E GEORGETTE  
08/27/04 0411Z SSMI F-15 COMPOSITE  
08/27/04 0245Z GOES-10 IR

**0600 UTC Classification**  
**“Really an embedded center but**  
**constrained to not use it”**  
 **$3.5/3.5 = 55$  kt**

acts.html



“Miss Piggy” Built in 1976 at Lockheed-Martin, Marietta, Georgia



“Kermit” Built in 1975 at Lockheed-Martin, Marietta, Georgia

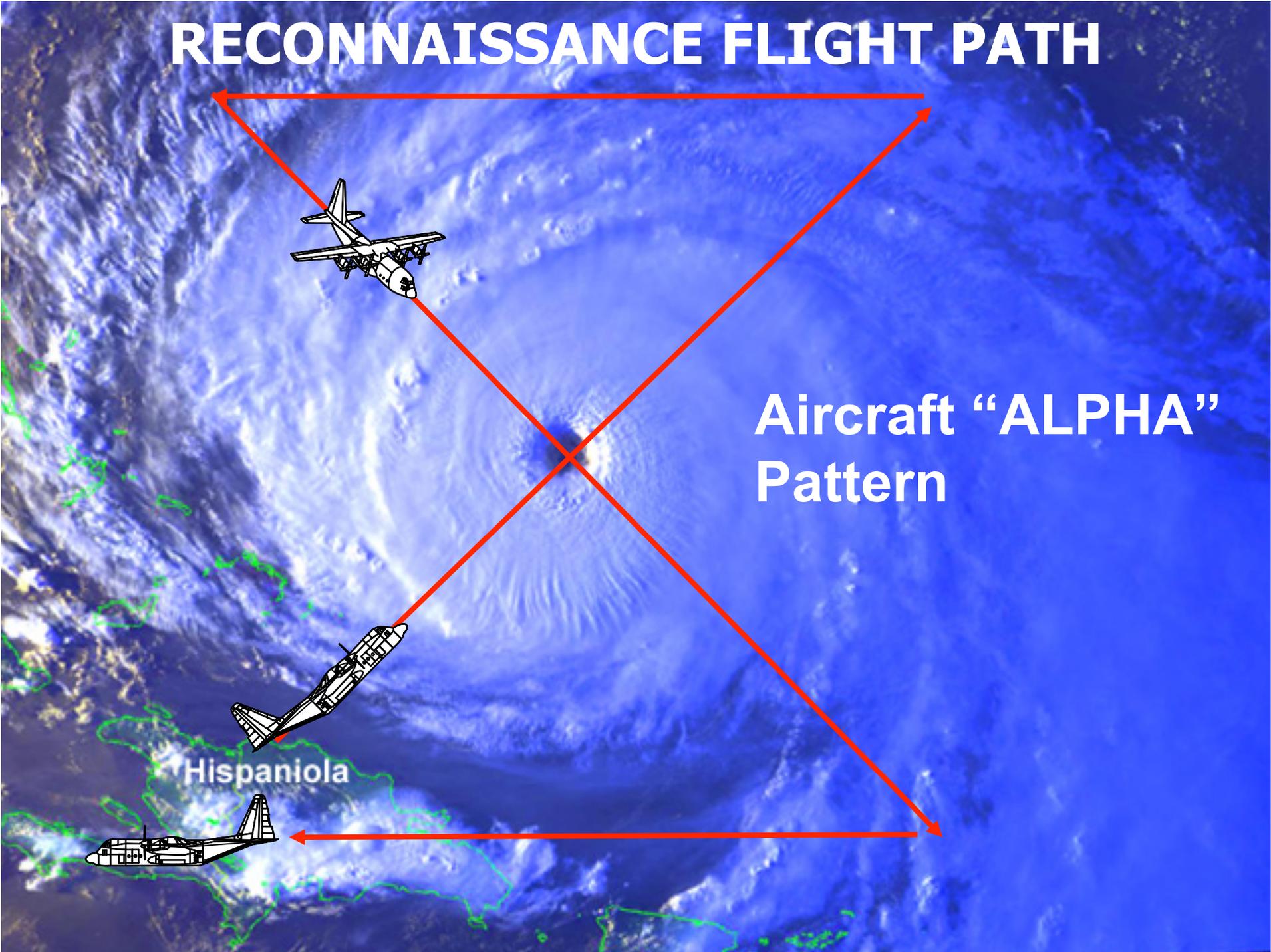


“Gonzo” Built in 1994 at Gulfstream Aerospace Corporation in Savannah Georgia

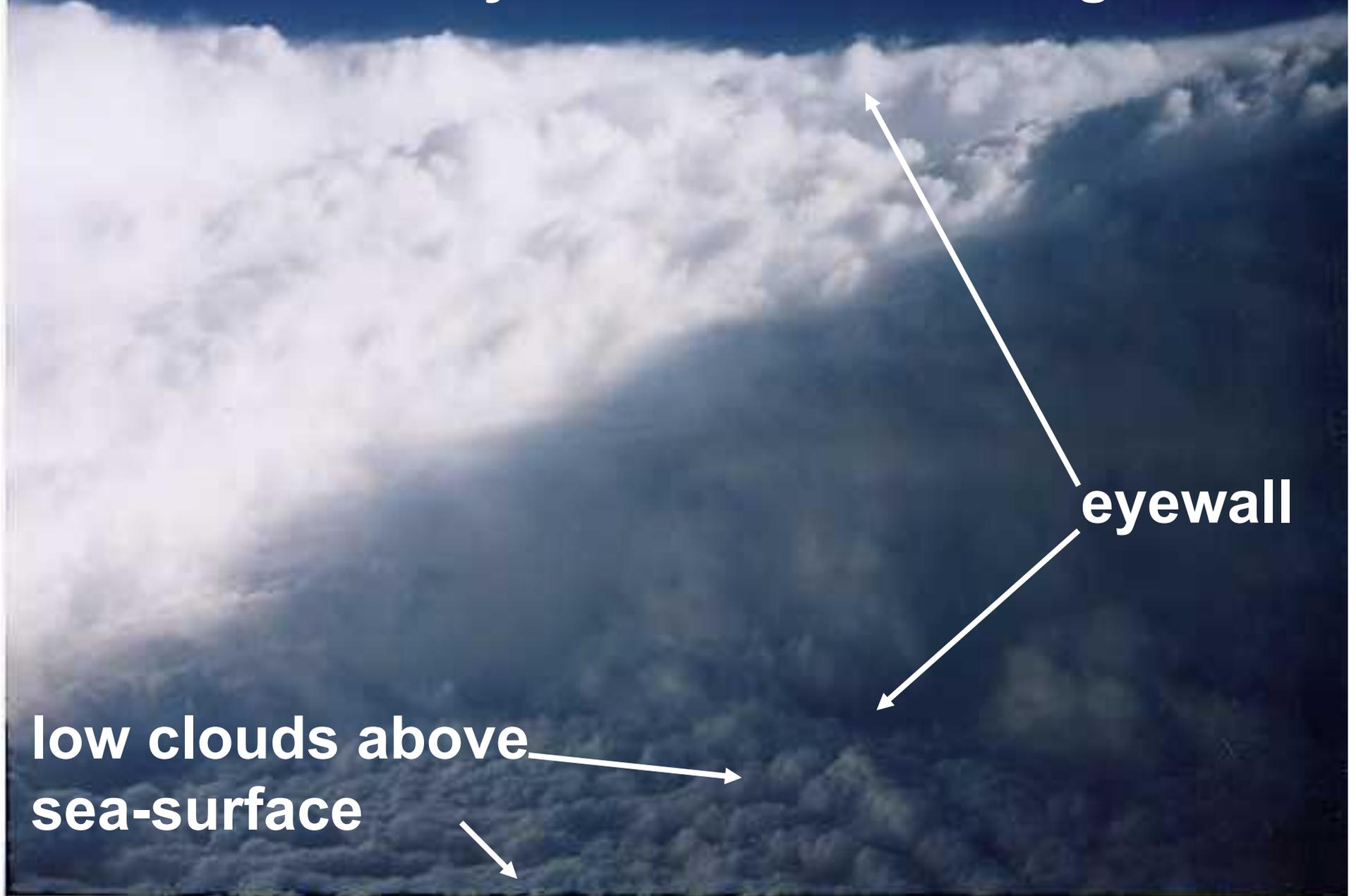
# RECONNAISSANCE FLIGHT PATH

Aircraft "ALPHA"  
Pattern

Hispaniola

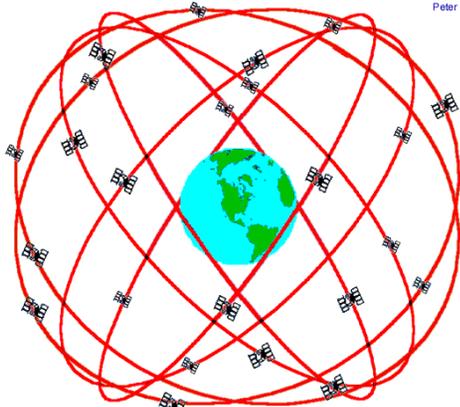


# Within the Eye of Hurricane Georges



**eyewall**

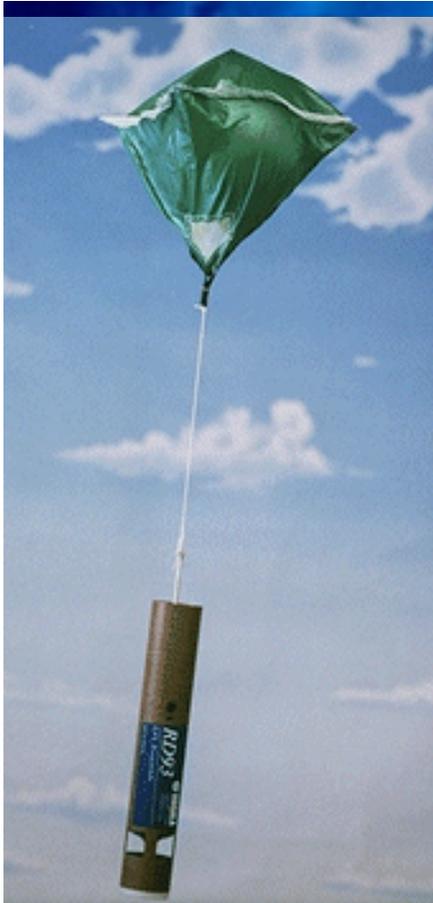
**low clouds above  
sea-surface**



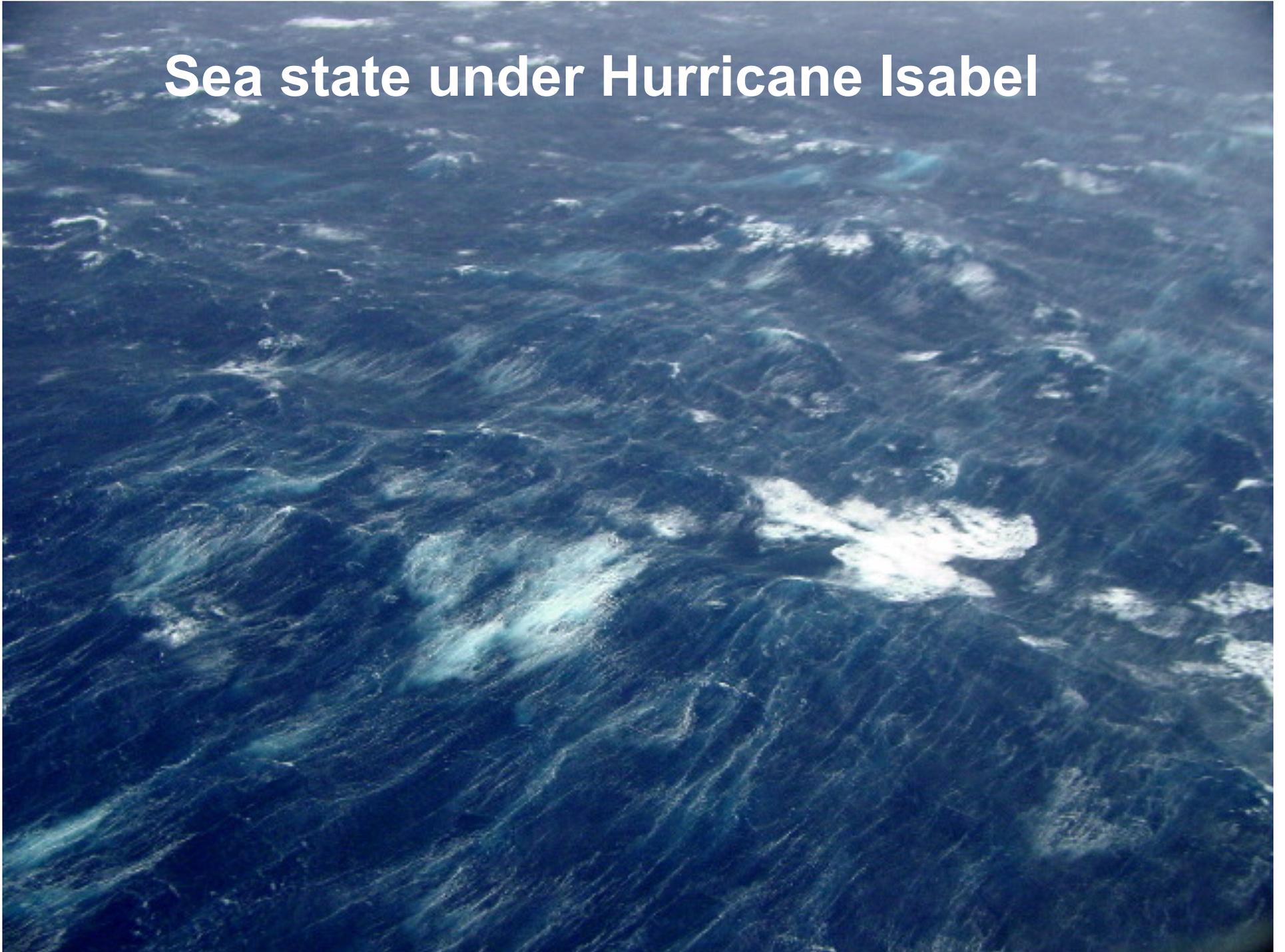
GPS Nominal Constellation  
24 Satellites in 6 Orbital Planes  
4 Satellites in each Plane  
20,200 km Altitudes, 55 Degree Inclination

# GPS DROPWINDSONDE

- Developed in conjunction with the NOAA Gulfstream-IV jet aircraft. First use for hurricane was late in 1996 season.
- GPS dropsondes provide, for the first time, direct measurements of the winds at low levels in the hurricane eyewall.
- Dropsonde data reveal that the structure of the eyewall is very complex, and can vary tremendously from storm to storm.

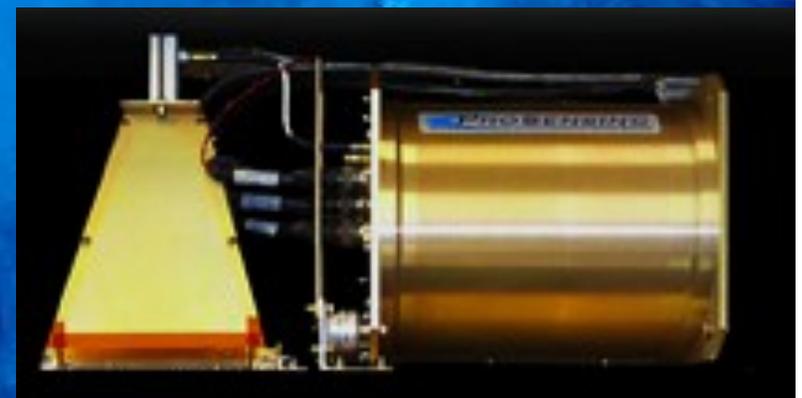
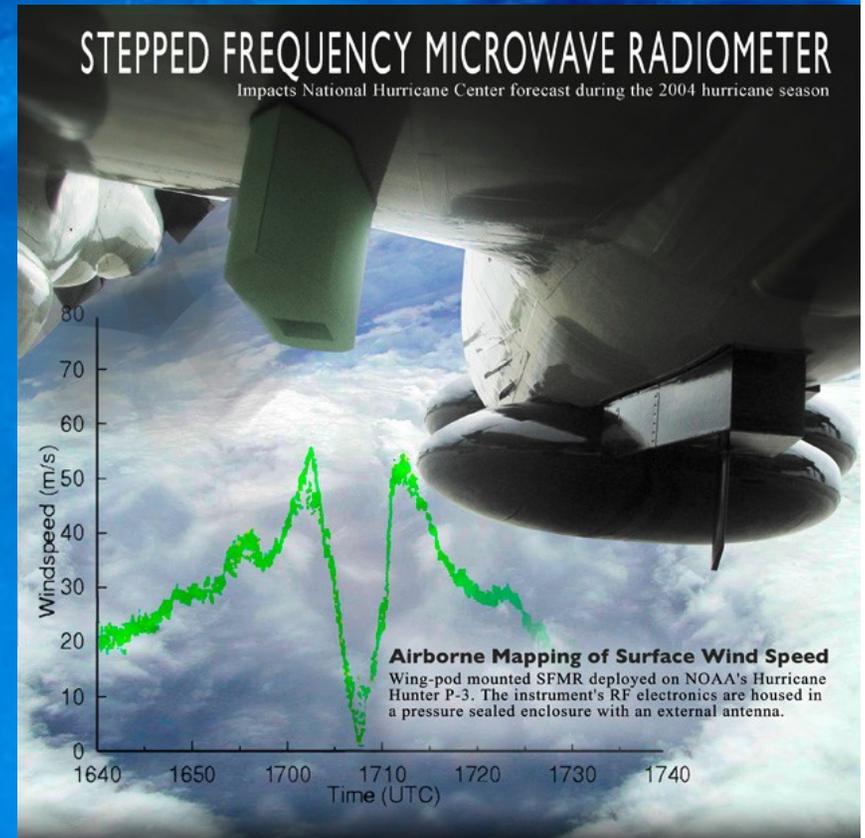


# Sea state under Hurricane Isabel

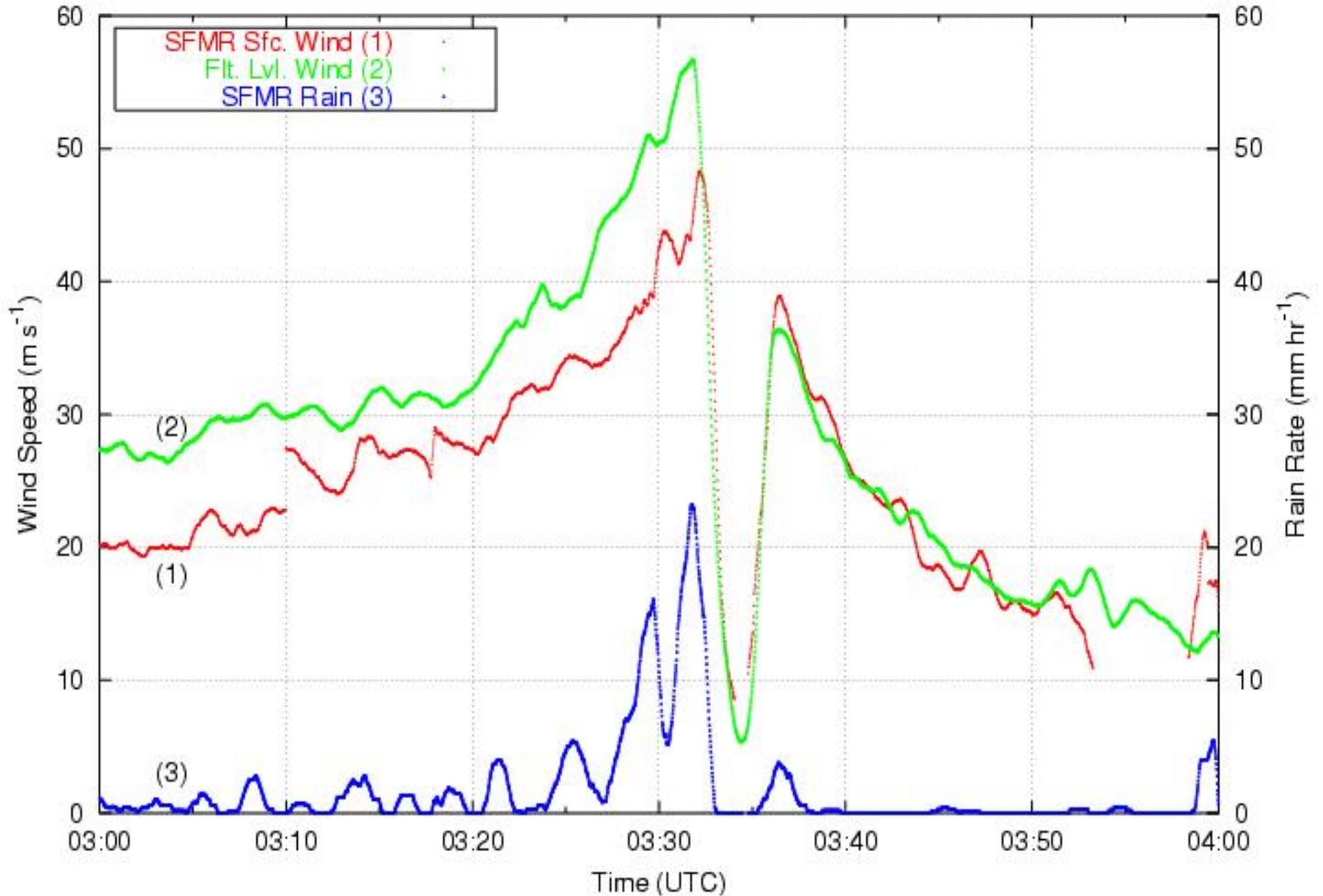


# Stepped-Frequency Microwave Radiometer

- Measures nadir brightness temperature at 6 C-band frequencies.
- Geophysical model function relates emissivity to wind speed. Emissivity depends on surface foam coverage and rain rate.
- Calibrated with GPS dropsonde data.
- First data from C-130s in 2007.



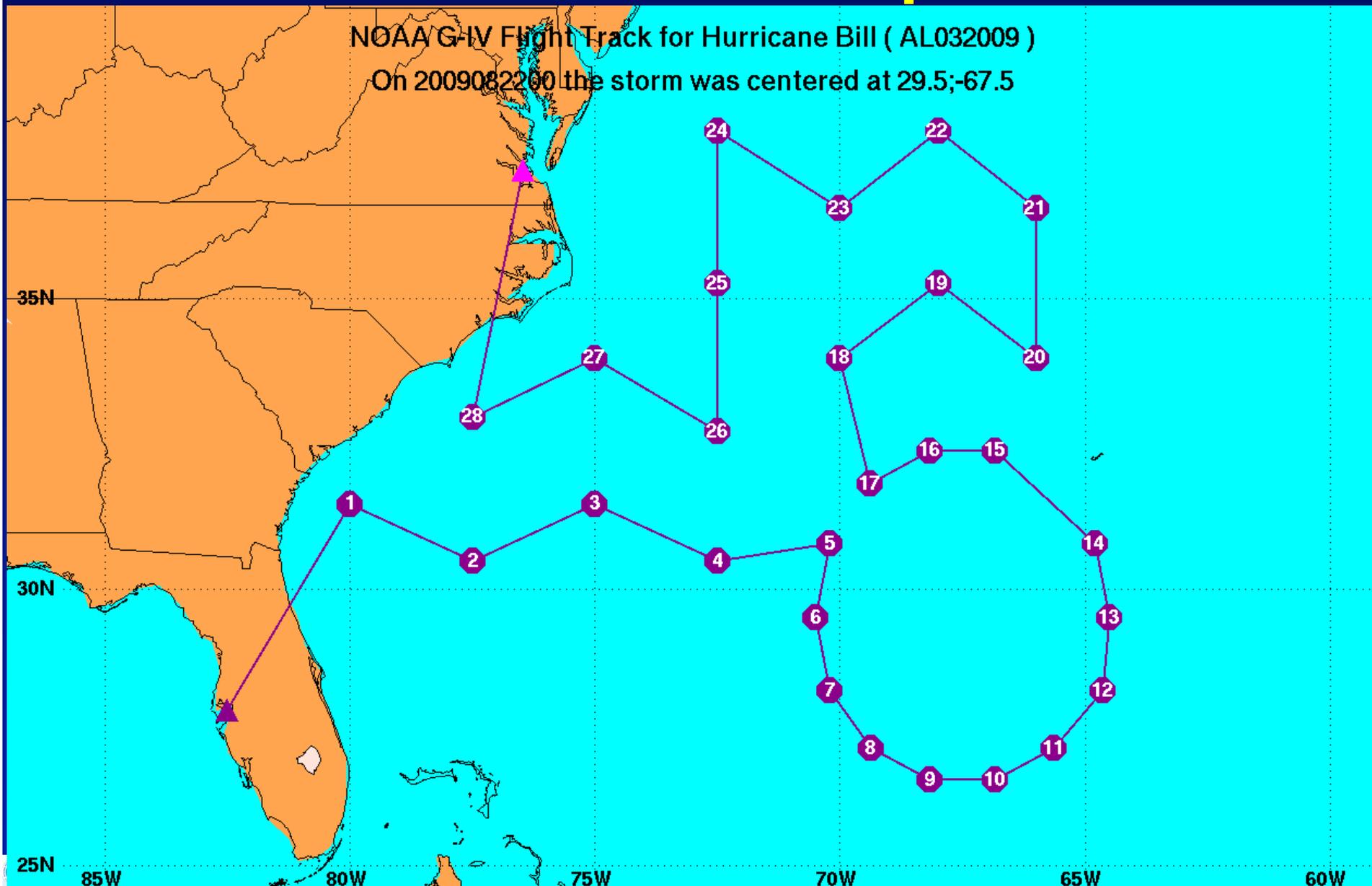
Hurricane Lili (2002/10/02)  
Cross-Track Winds and Rain



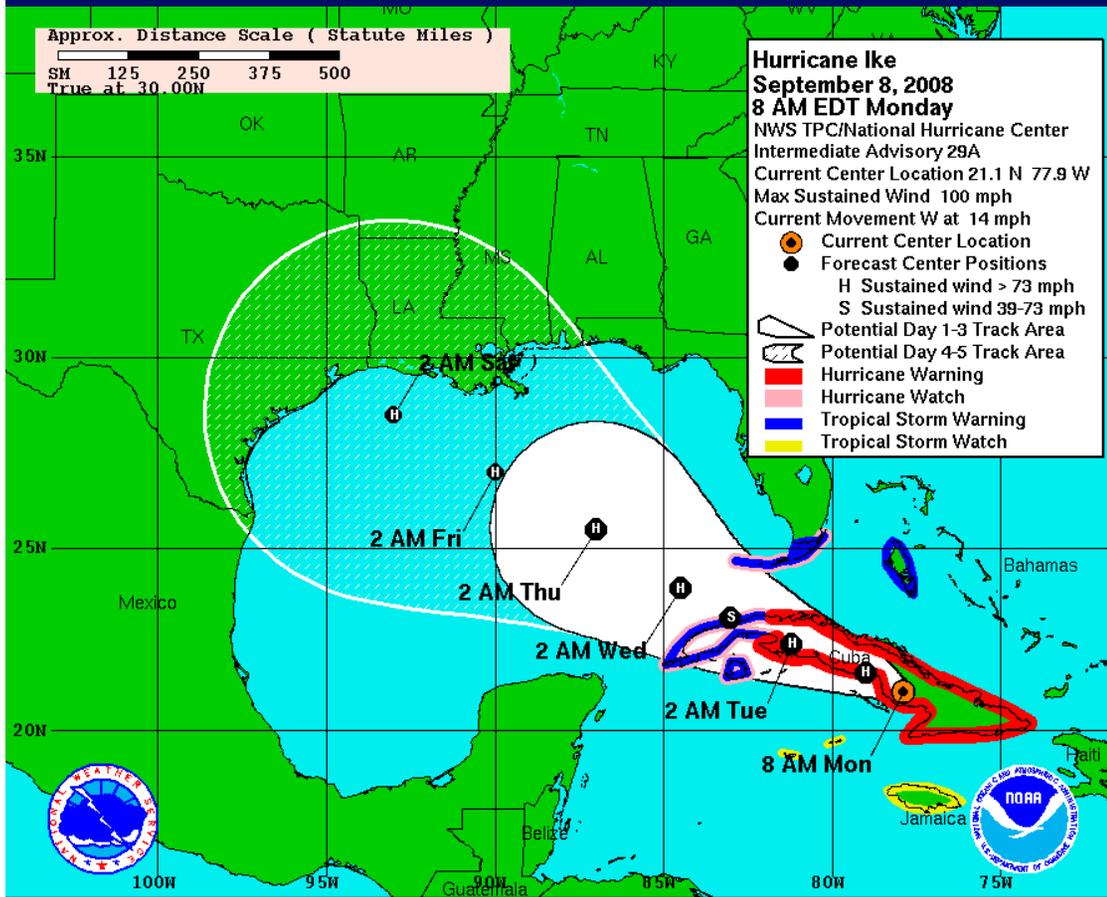
# G-IV Aircraft Synoptic Surveillance Mission and GPS Dropsondes

NOAA G-IV Flight Track for Hurricane Bill ( AL032009 )

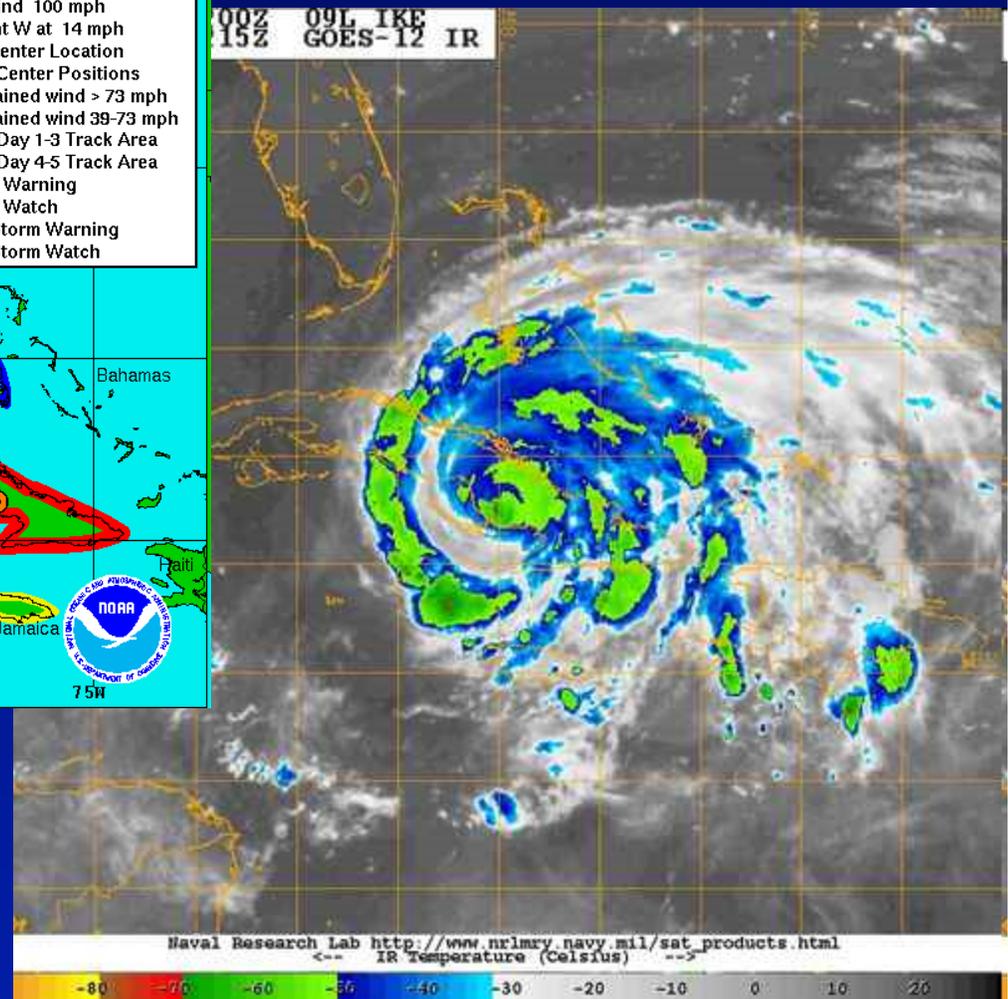
On 2009082200 the storm was centered at 29.5;-67.5



# Tropical Cyclone Forecasting



00Z 09L IKE  
 15Z GOES-12 IR

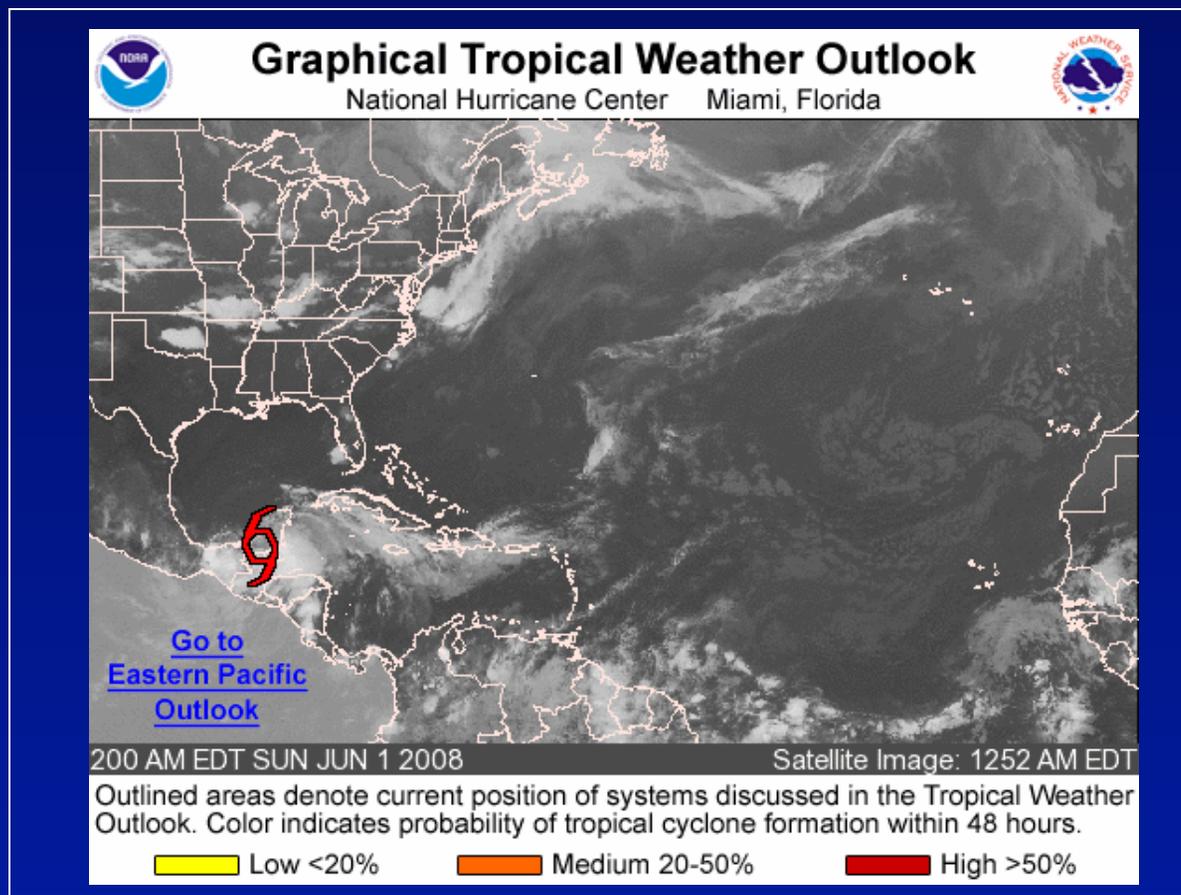




# Graphical Tropical Weather Outlook



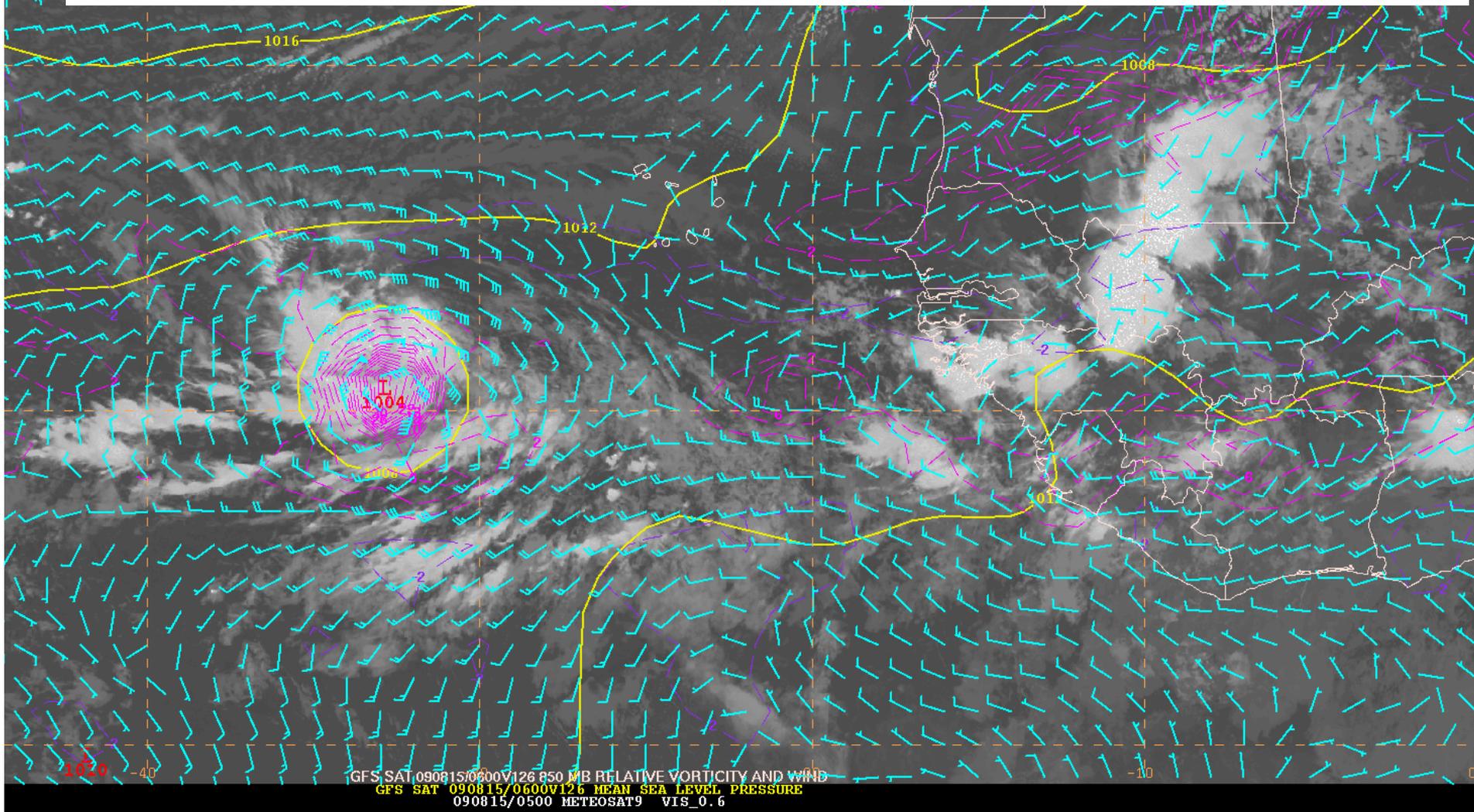
- *became operational in 2009*
- *will provide exact chance for formation*



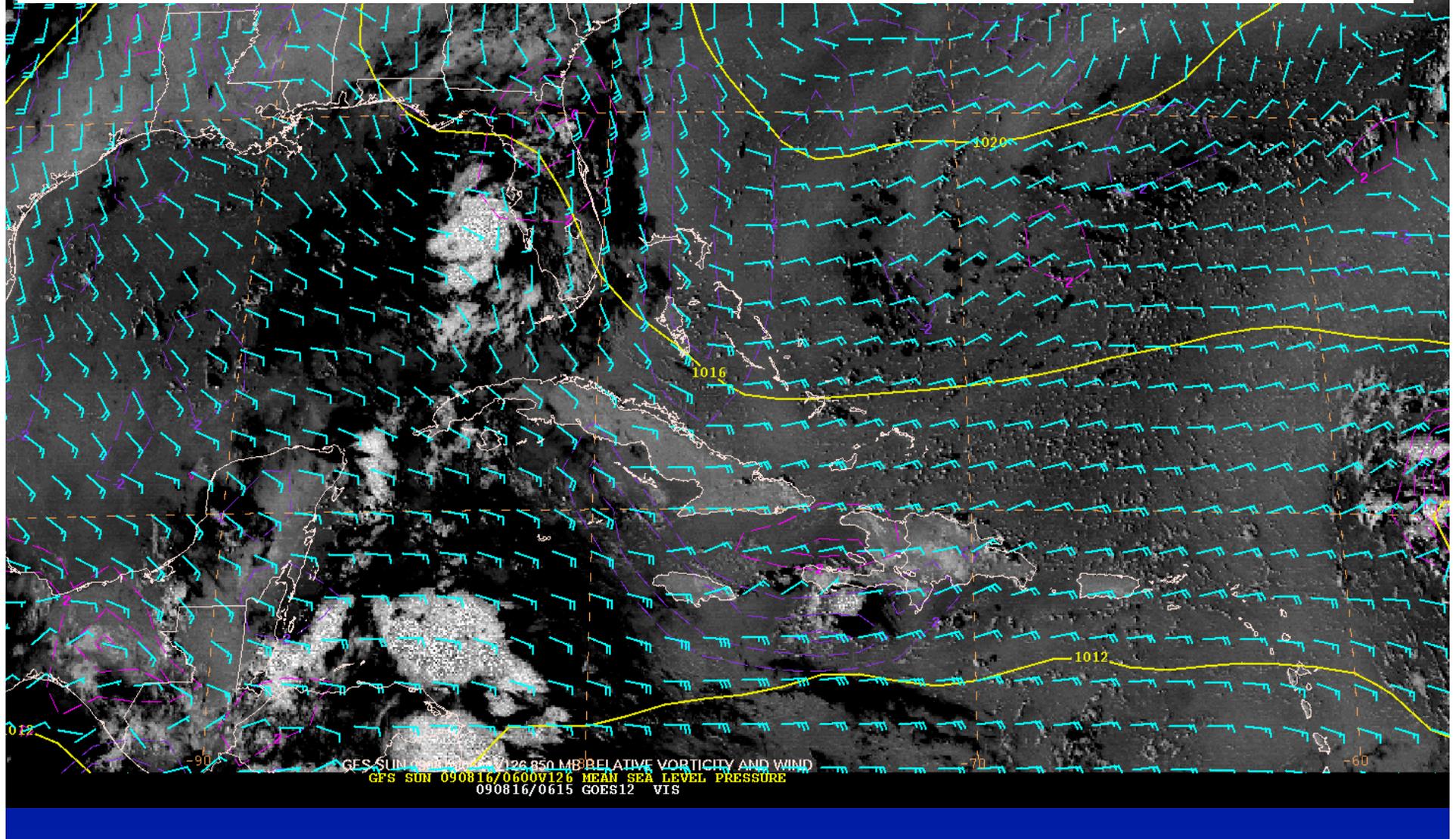
Shows on satellite pictures the current locations of areas of disturbed weather and provides categorical estimates of development potential over the next 48 hours.



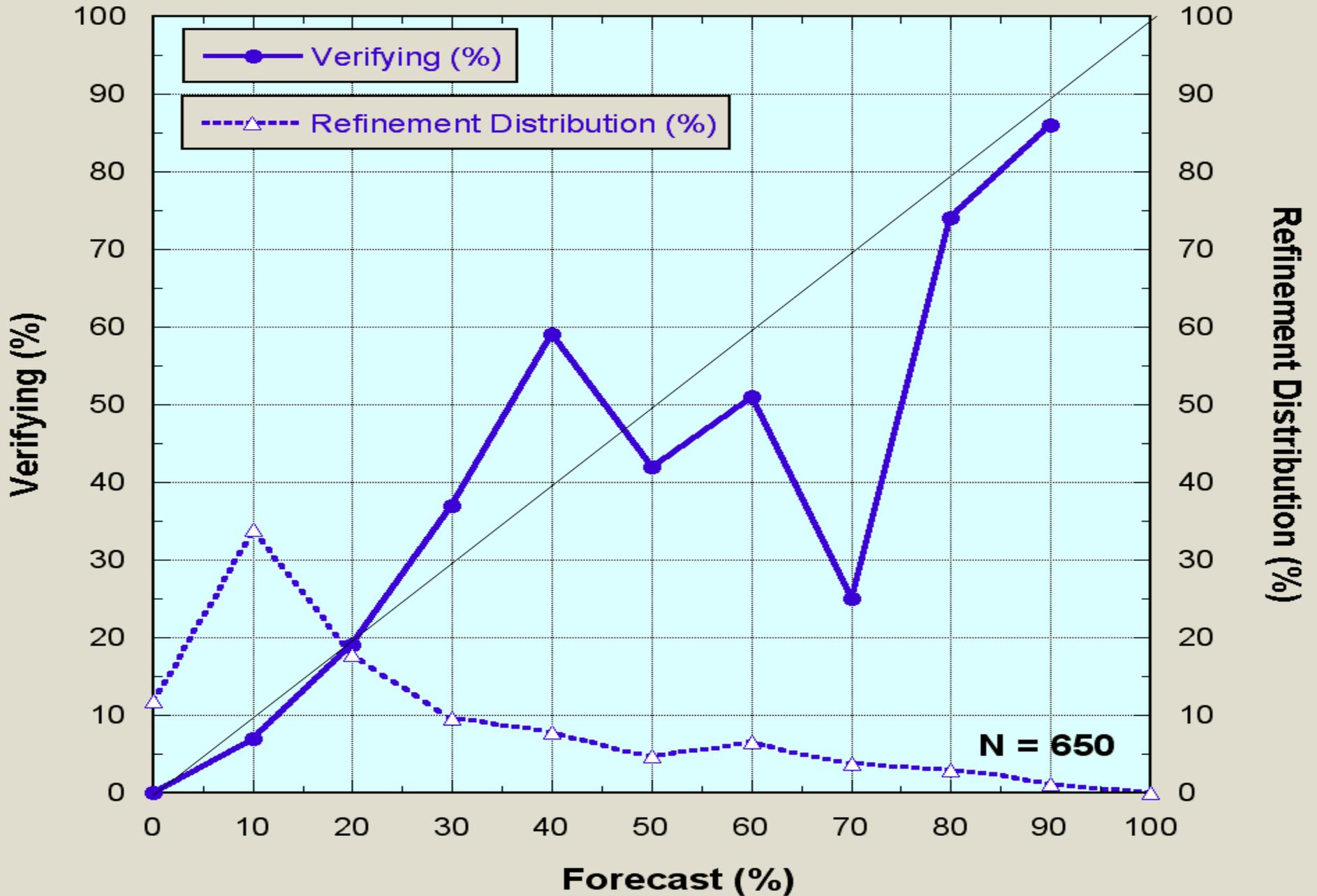
1020 Genesis of Bill was well predicted by the GFS (another case of good GFS forecasts of eastern tropical Atlantic genesis). This is a series of model forecasts of sea level pressure and 850 mb winds/vorticity, starting from 126 hours out, all verifying at the time of genesis (0600 UTC 8/15/09).



Claudette's formation was not well anticipated by the GFS or by the NHC forecasters (another case of models underforecasting Gulf genesis). This is a series of model forecasts of sea level pressure and 850 mb winds/vorticity, starting from 126 hours out, all verifying at the time of genesis (0600 UTC 8/16/09).



# 2010 OFCL 48-h Genesis Forecasts Atlantic Basin

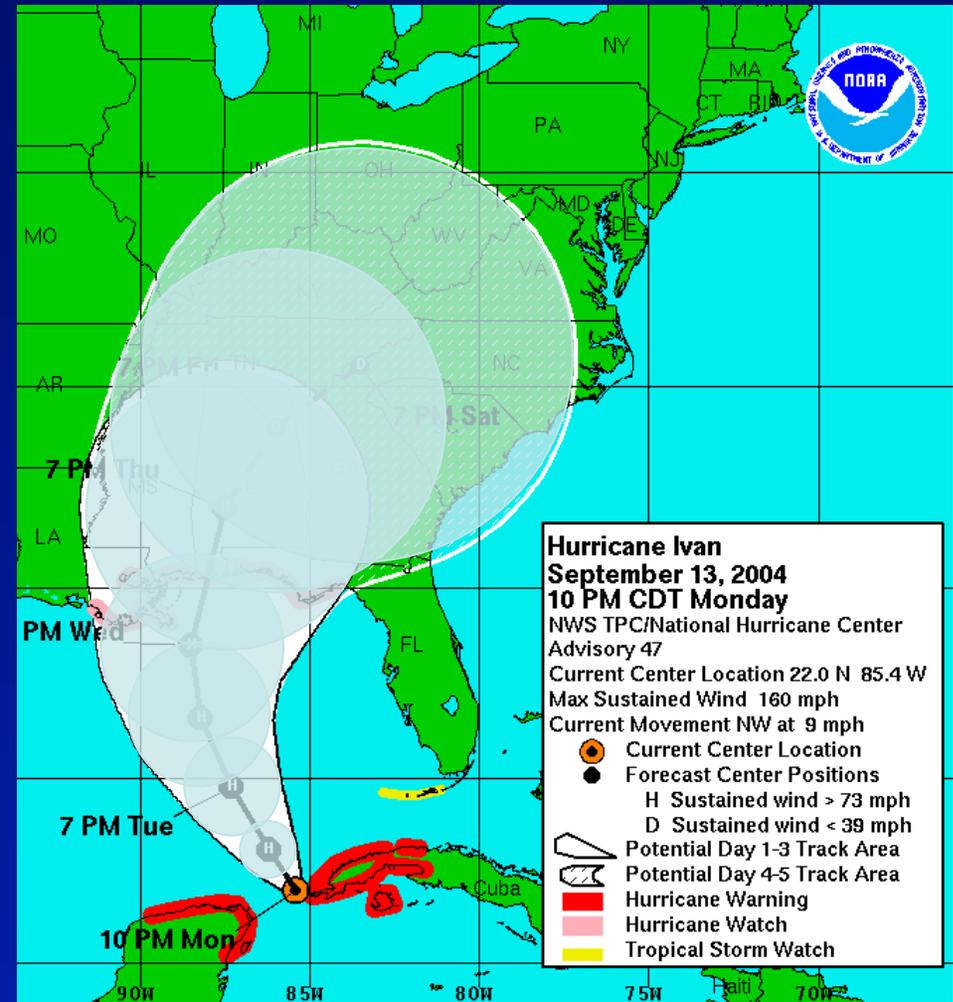


# NHC Forecast Cone

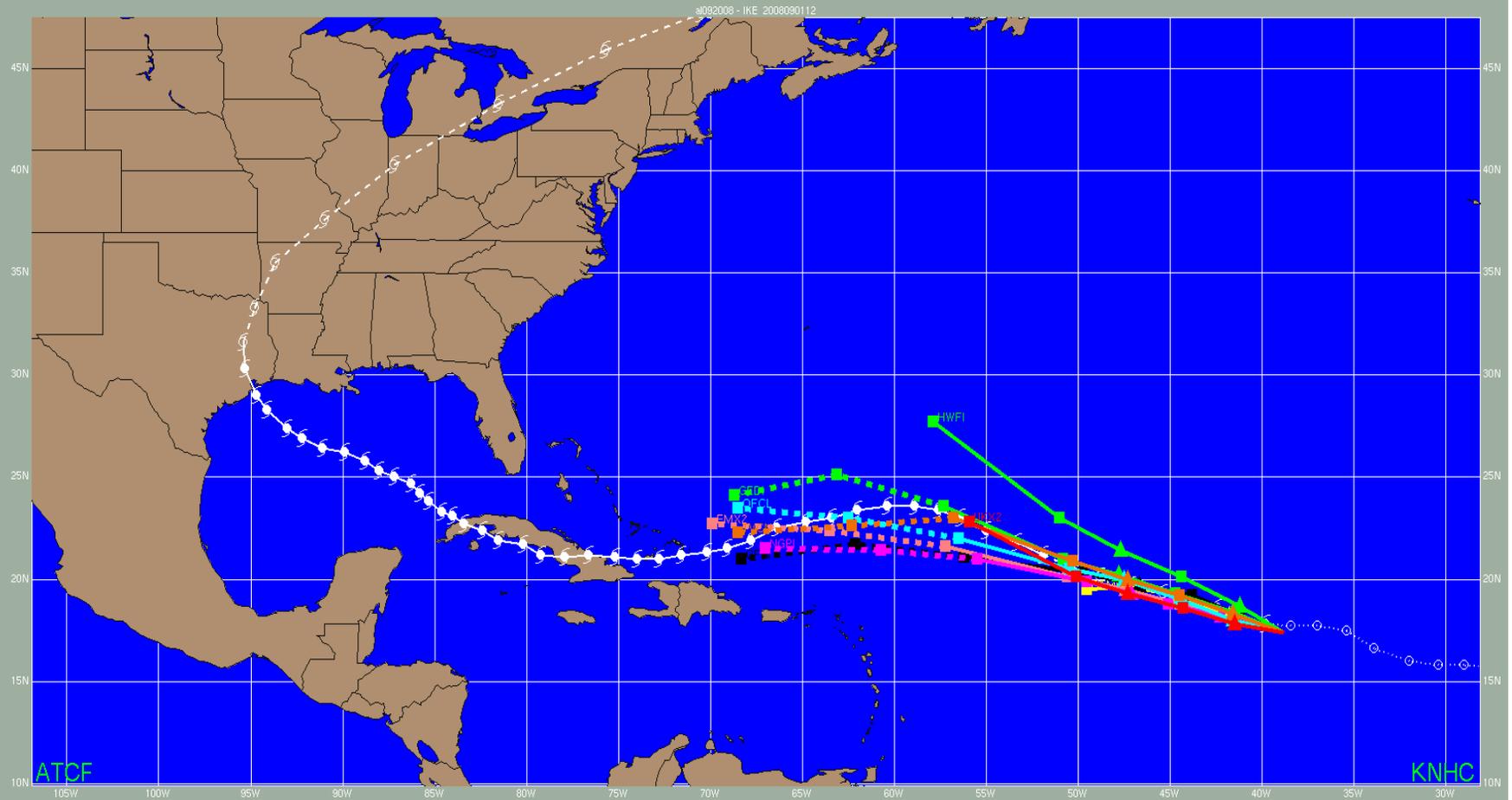
Represents the probable track of the center of the tropical cyclone.

Formed by connecting circles centered on each forecast point (at 12, 24, 36 h, etc.)

Size of the circles determined so that, say, the actual storm position at 48 h will be within the 48-h circle 67% of the time.



# Hurricane Ike Track models

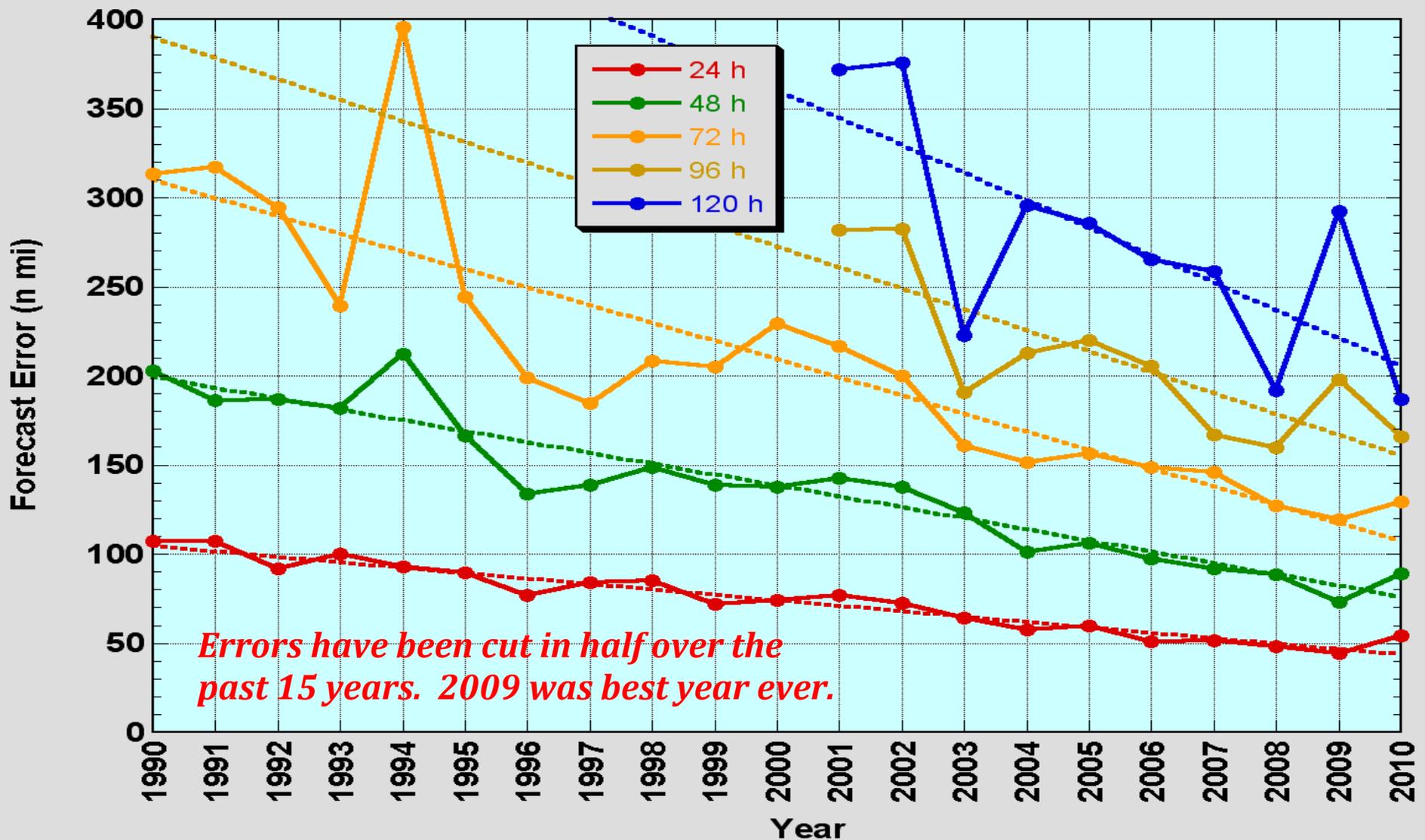




# Improvements in Forecast Models and Increased Satellite Data has Led to a Large Reduction in NHC Track Errors

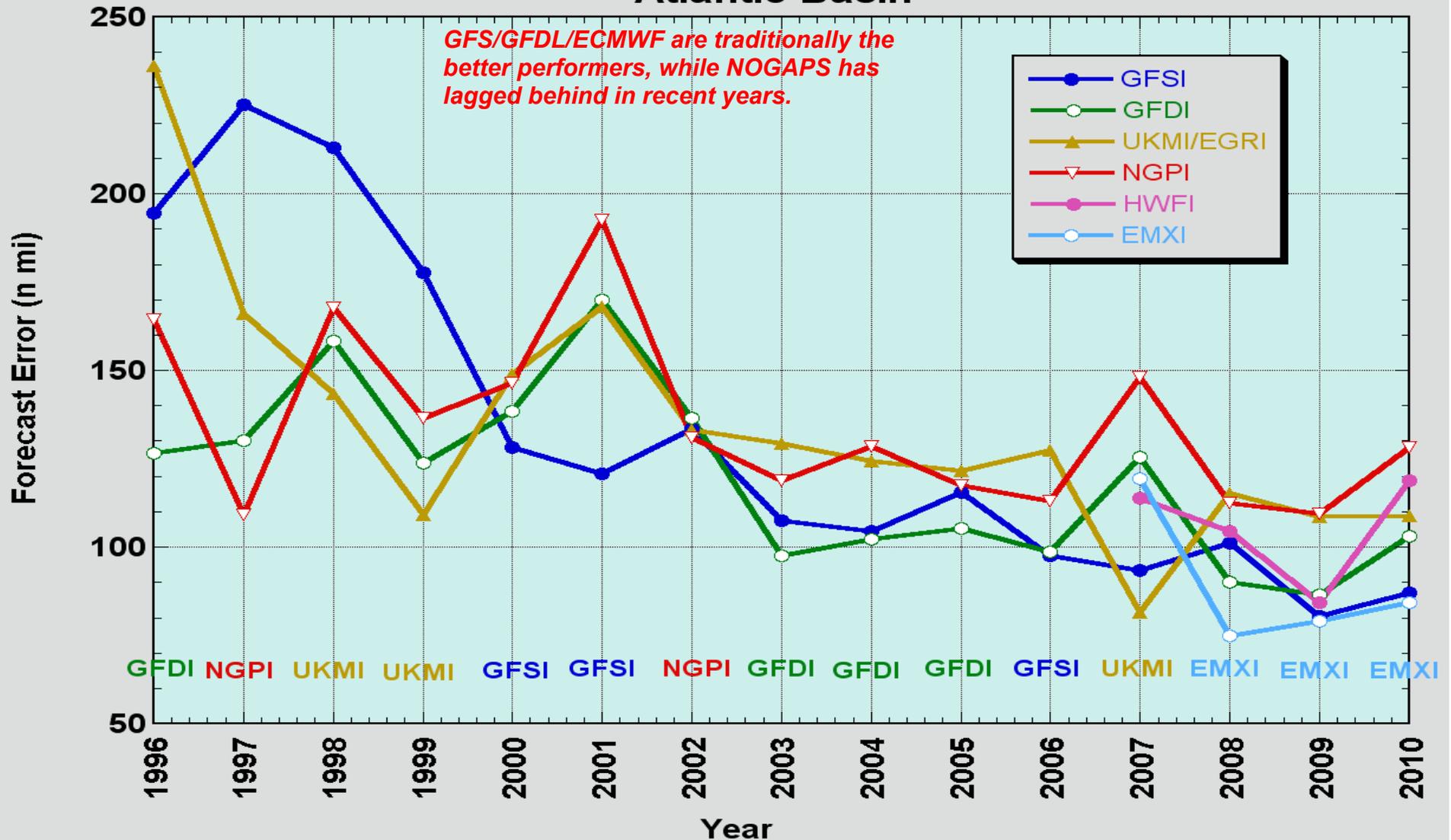


## NHC Official Track Error Trend Atlantic Basin

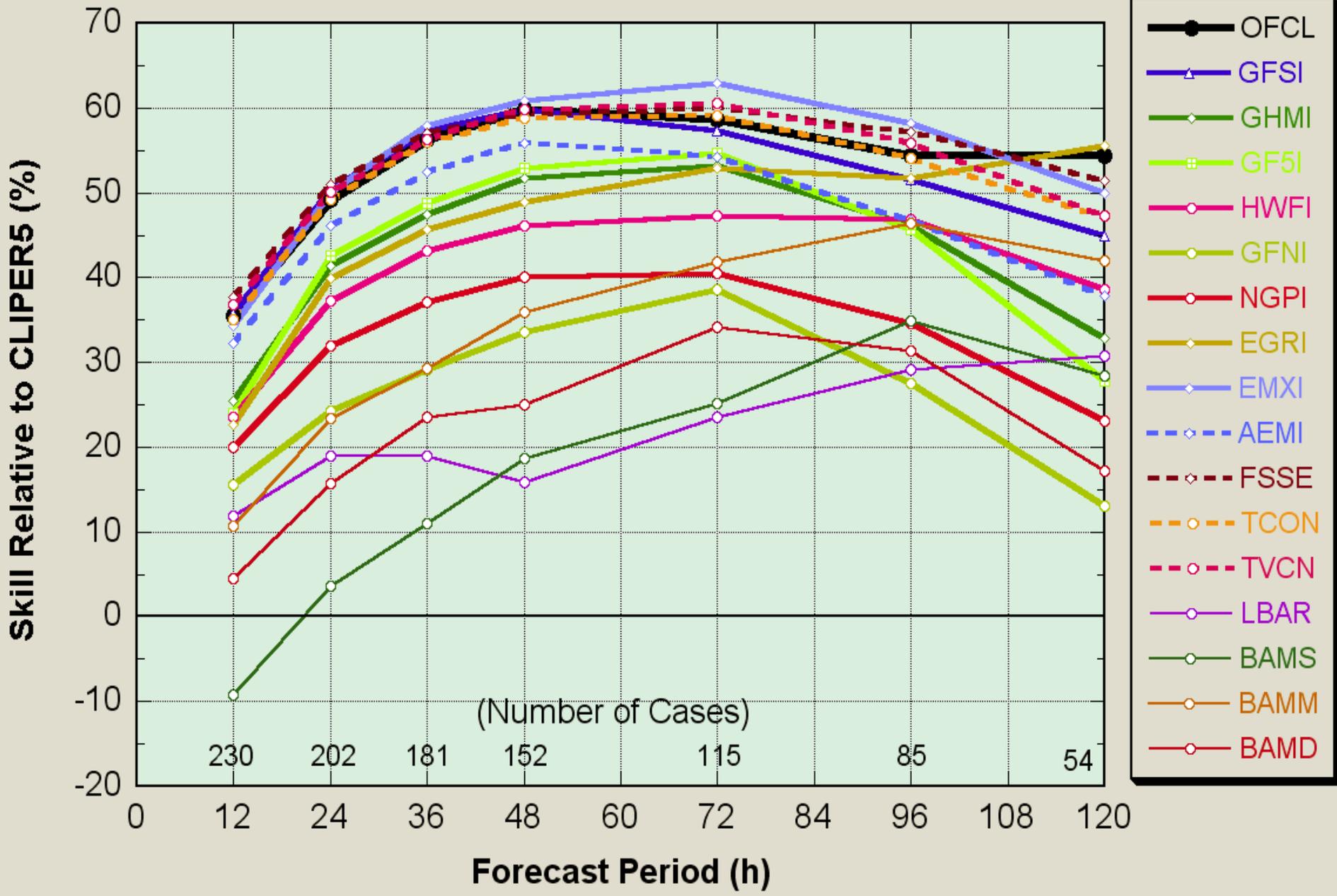


# Guidance Trends – 2 Days

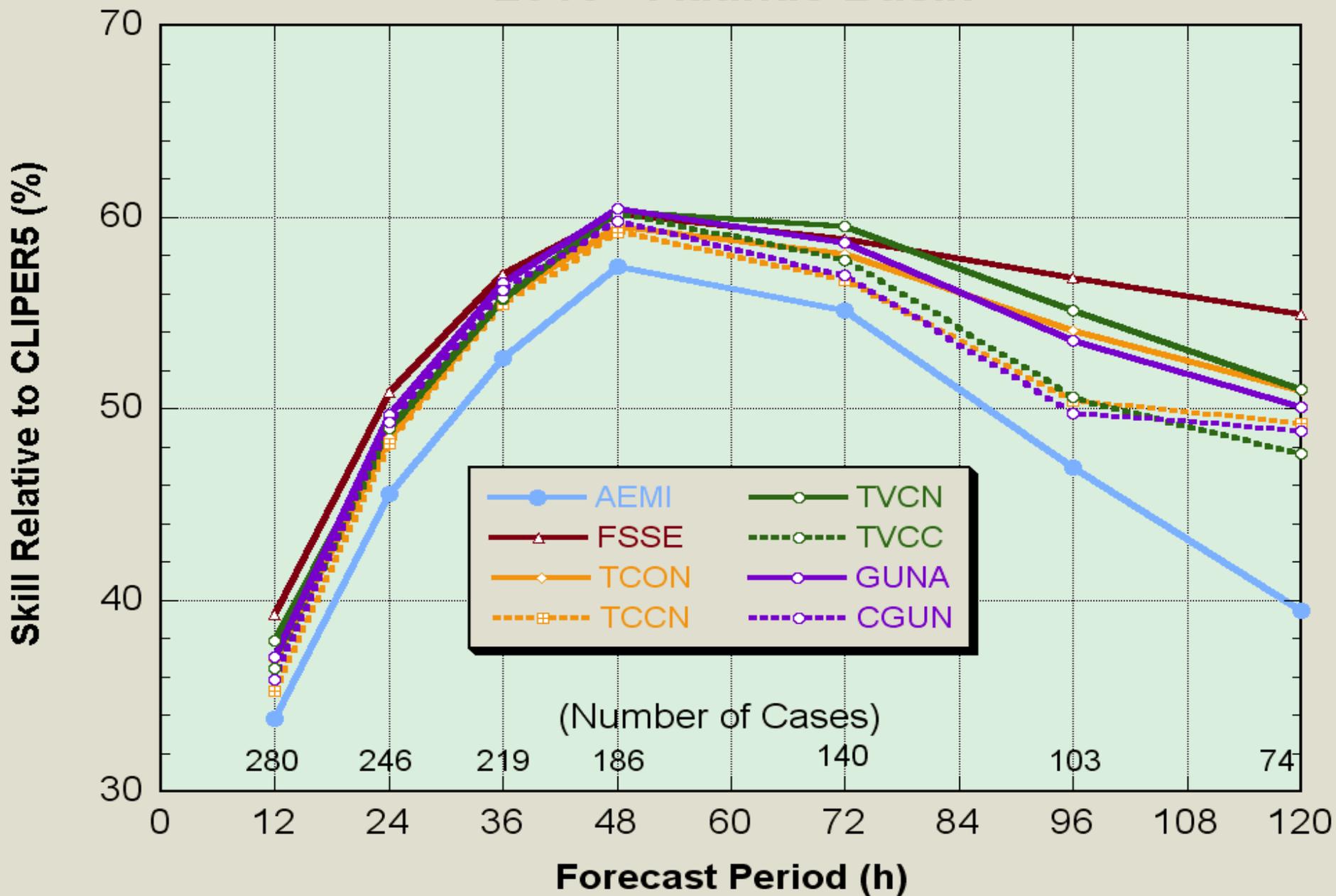
## 48-h Track Forecast Guidance Trends Atlantic Basin



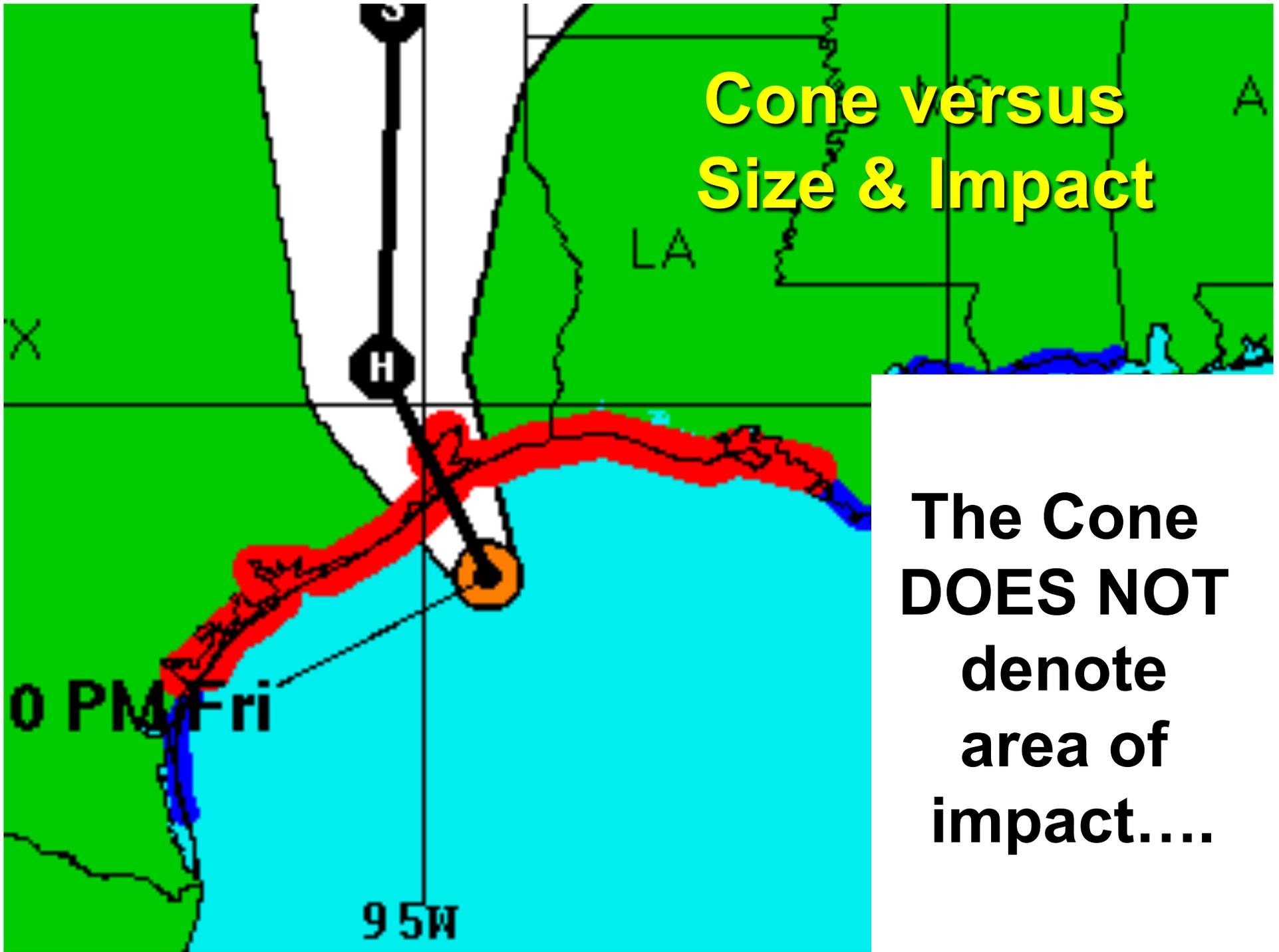
# Track Forecast Skill (Early Models) 2010 - Atlantic Basin



# Track Forecast Skill (Consensus Models) 2010 - Atlantic Basin

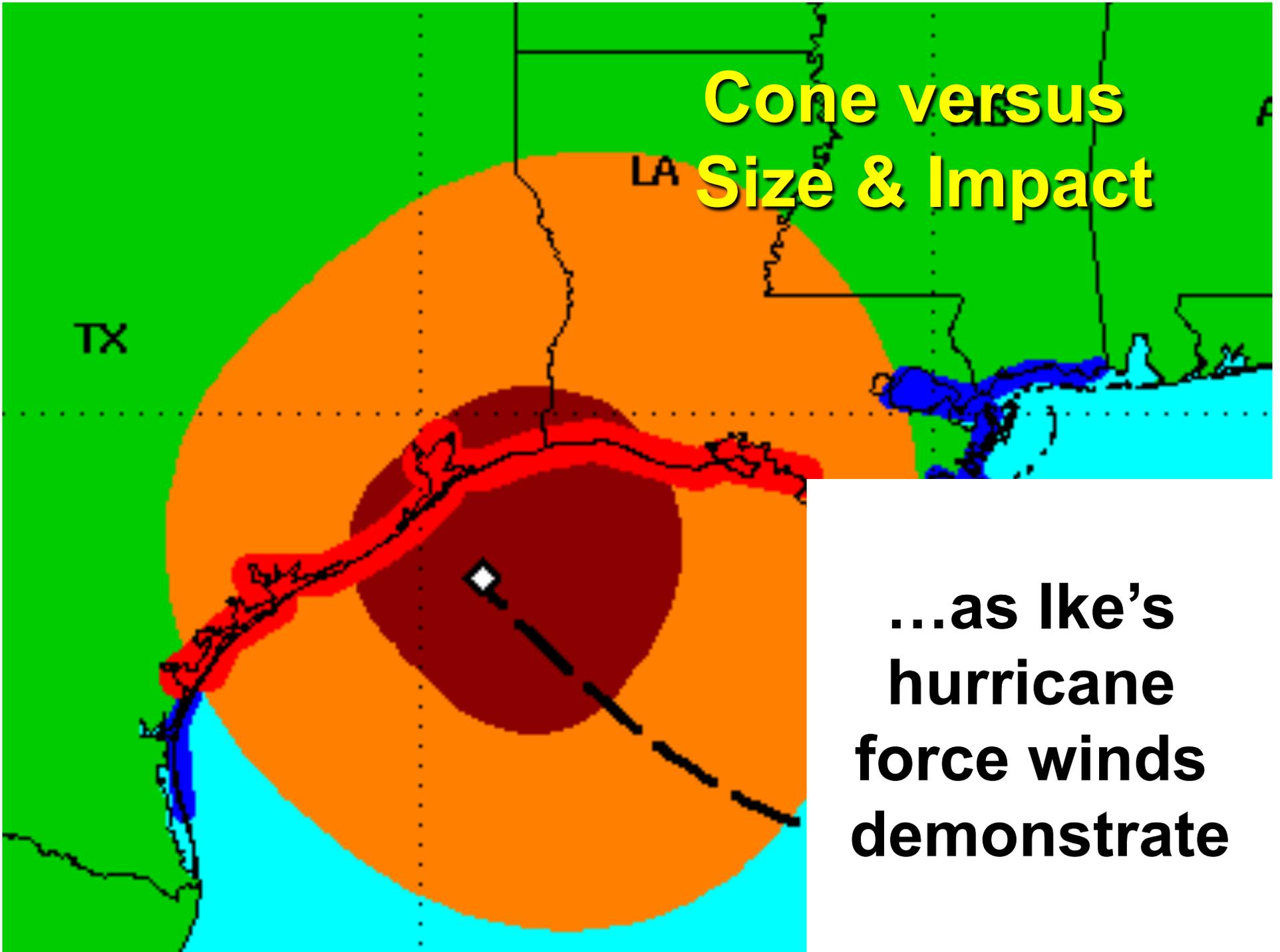


# Cone versus Size & Impact



**The Cone  
DOES NOT  
denote  
area of  
impact....**

# Cone versus Size & Impact



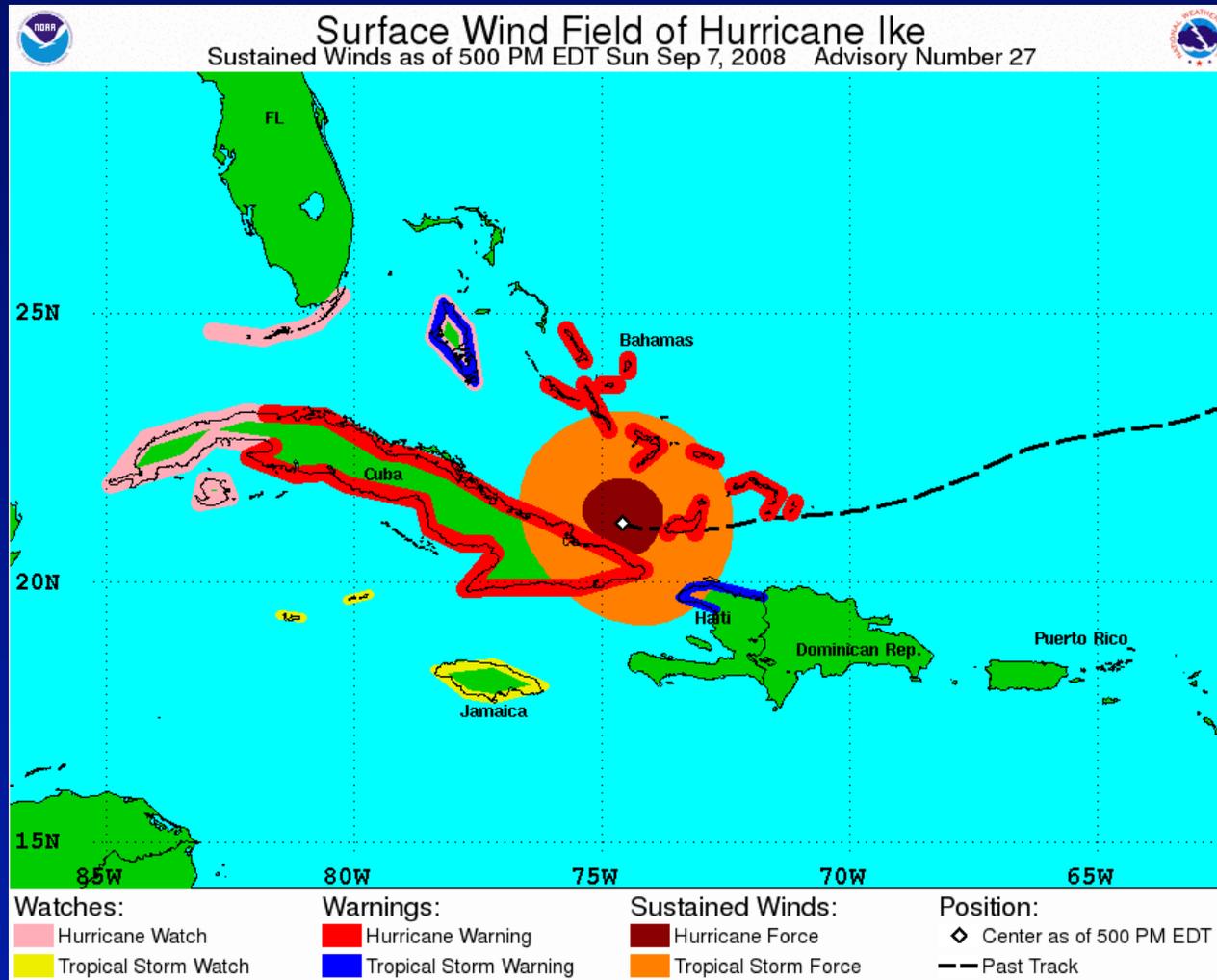
**...as Ike's  
hurricane  
force winds  
demonstrate**



# Tropical Cyclone Wind Field



- *became operational in 2009*



Shows:

Wind field

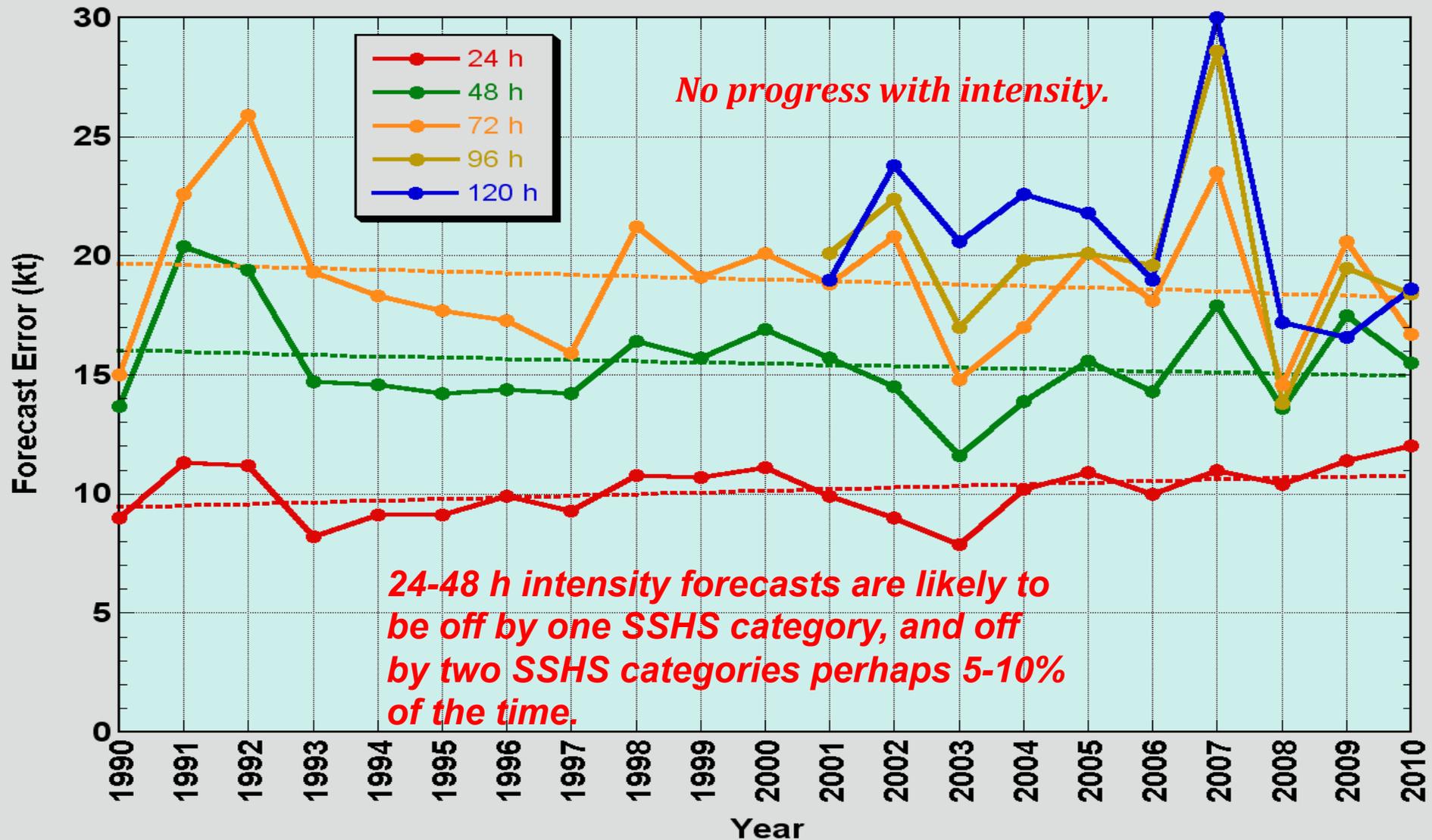
Past track

Current watches/warnings



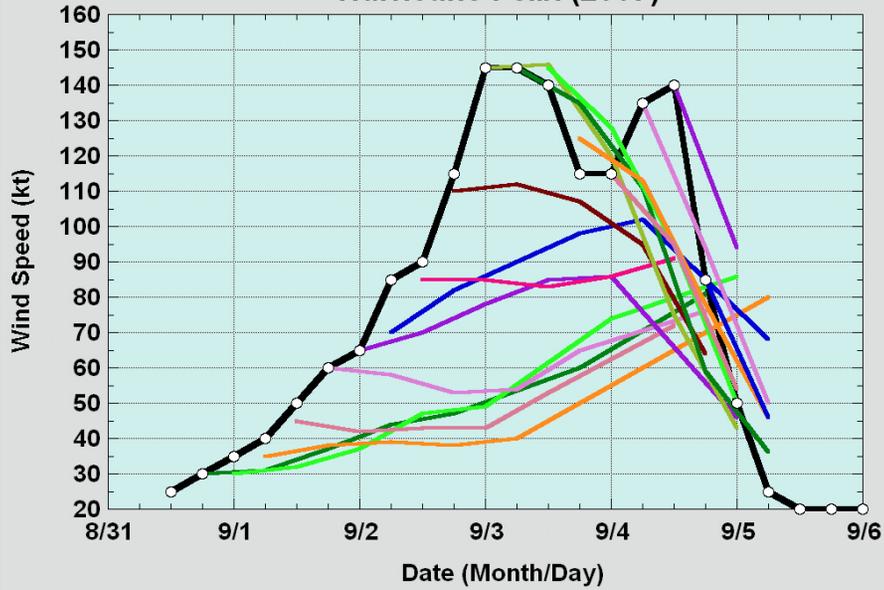
# Atlantic Intensity (Wind) Error Trends

## NHC Official Intensity Error Trend Atlantic Basin

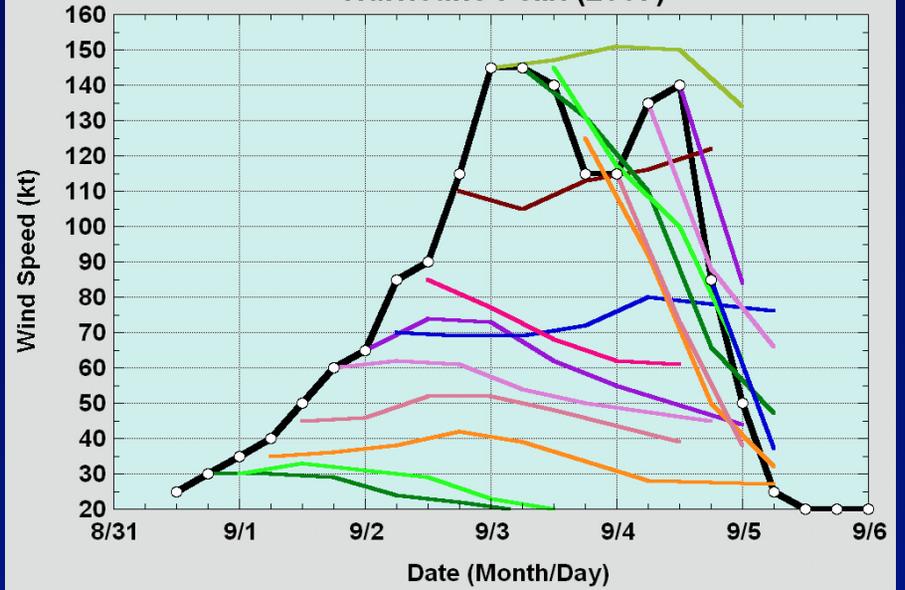


# Lots of problems with dynamical guidance for predicting intensity change

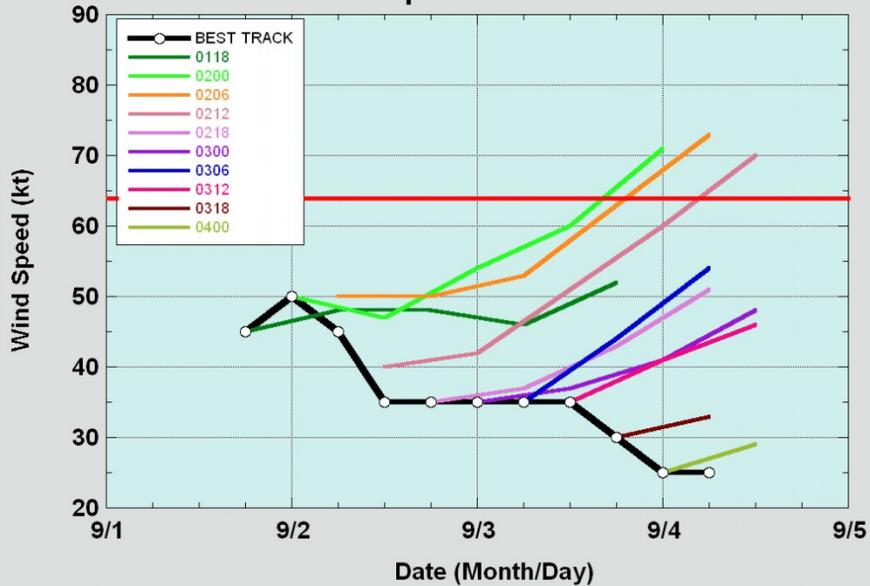
### GHMI Forecasts Hurricane Felix (2007)



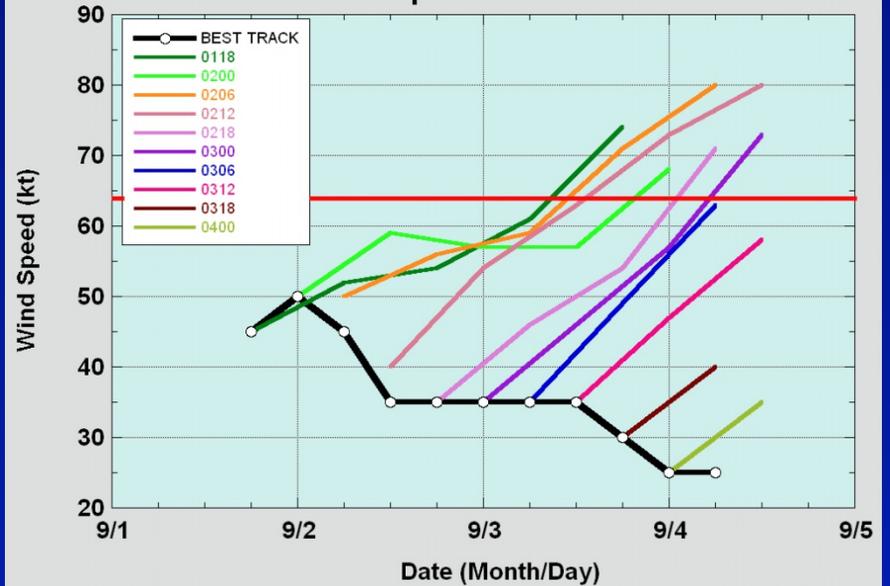
### HWFI Forecasts Hurricane Felix (2007)



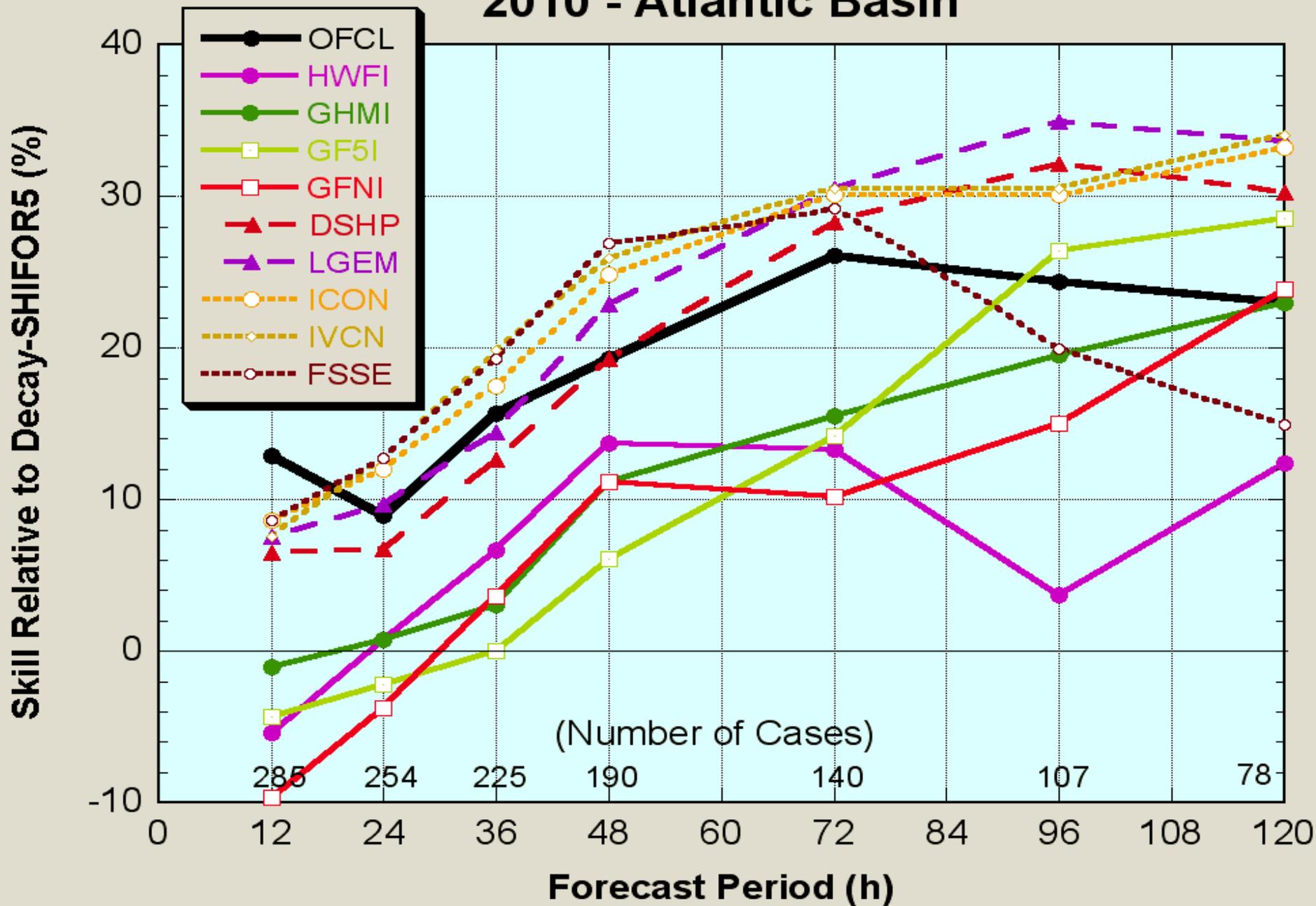
### GHMI Forecasts Tropical Storm Erika



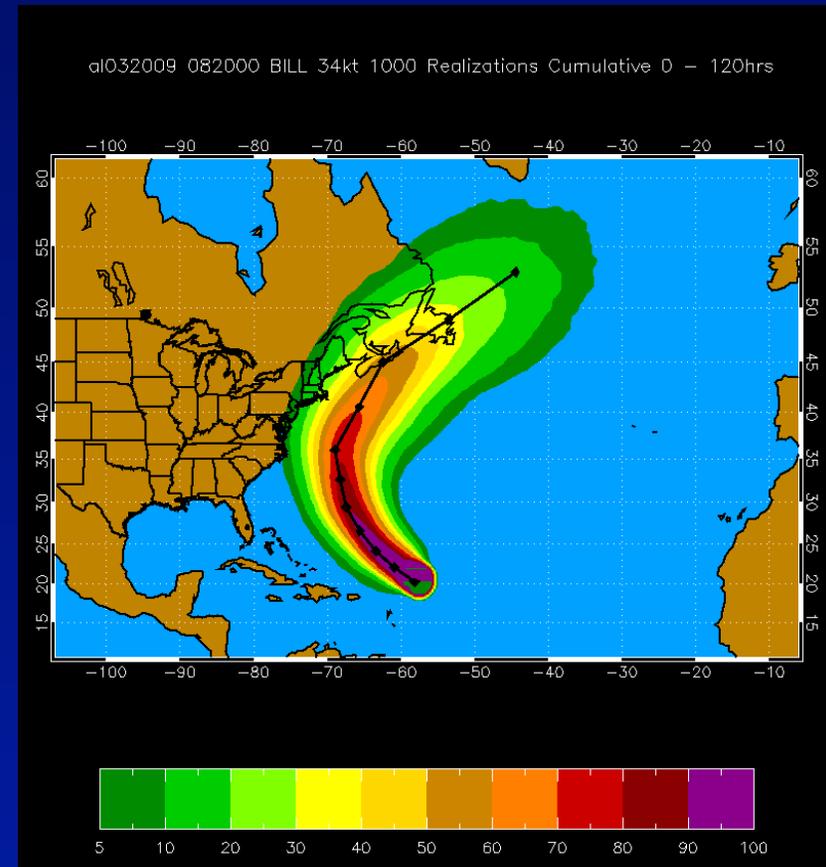
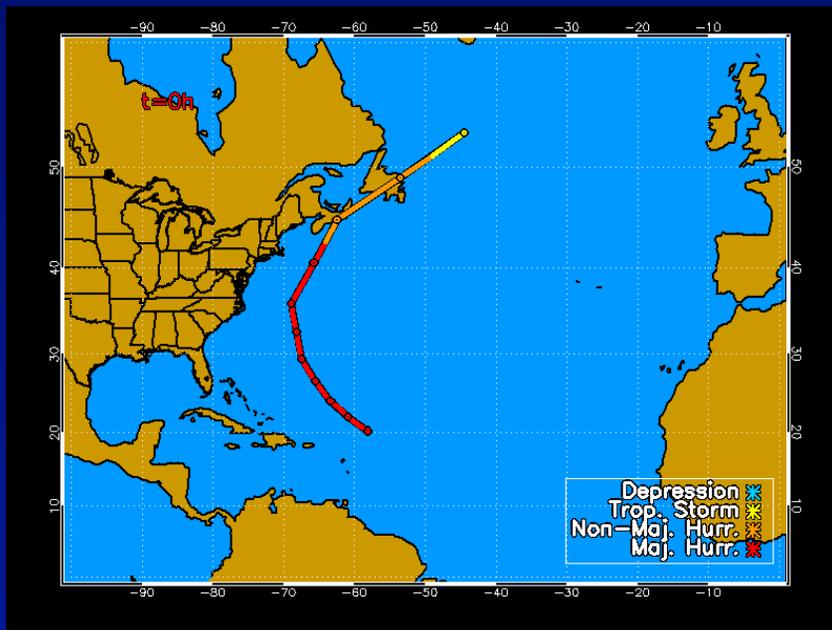
### HWFI Forecasts Tropical Storm Erika



# Intensity Forecast Skill (Early Models) 2010 - Atlantic Basin



# Wind Speed Probabilities Hurricane Bill 20 Aug 2009 00 UTC



## 1000 Track Realizations



# Wind Speed Probabilities



ZCZC MIAPWSAT4 ALL  
 TTA000 KNHC DDHMM  
 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)

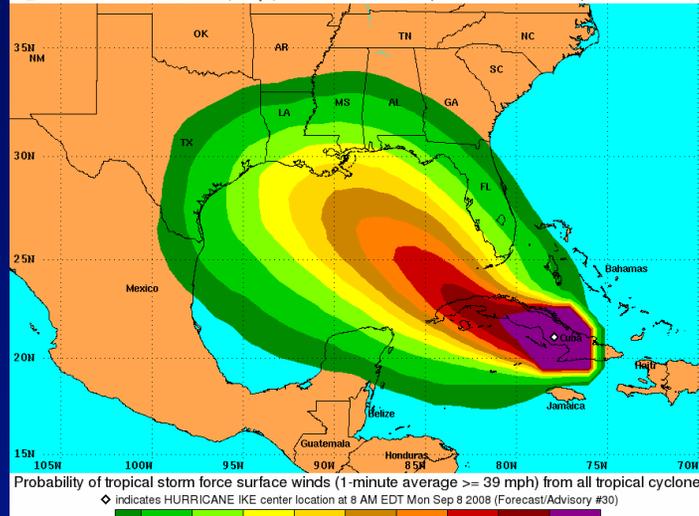
PROBABILITIES ARE GIVEN IN PERCENT X INDICATES PROBABILITIES LESS THAN 10% LOCATIONS SHOWN WHEN THEIR TOTAL PROBABILITY IS AT LEAST 2.5 PERCENT Z INDICATES UNIVERSAL COORDINATED

**Shows the chance of a particular event occurring at a specific location**

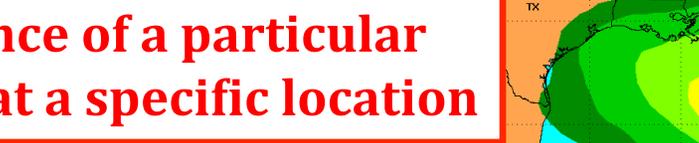
--- WIND SPEED PROBABILITIES FOR SELECTED LOCATIONS ---

TIME PERIODS	FROM	FROM		FROM		FROM		FROM		
		TO	TO	TO	TO	TO	TO	TO	TO	
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)			

Tropical Storm Force Wind Speed Probabilities  
 For the 120 hours (5 days) from 8 AM EDT Mon Sep 8 to 8 AM EDT Sat Sep 13



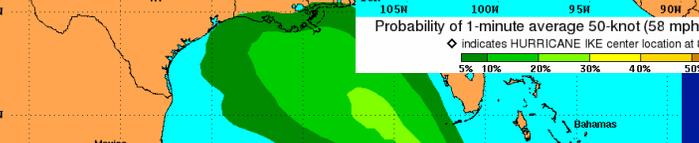
Probability of tropical storm force surface winds (1-minute average  $\geq$  39 mph) from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)



Probability of hurricane force surface winds (1-minute average  $\geq$  74 mph) from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)



Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)



Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)



Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)

Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)

Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)

Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)

Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)

Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)

Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)

Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)

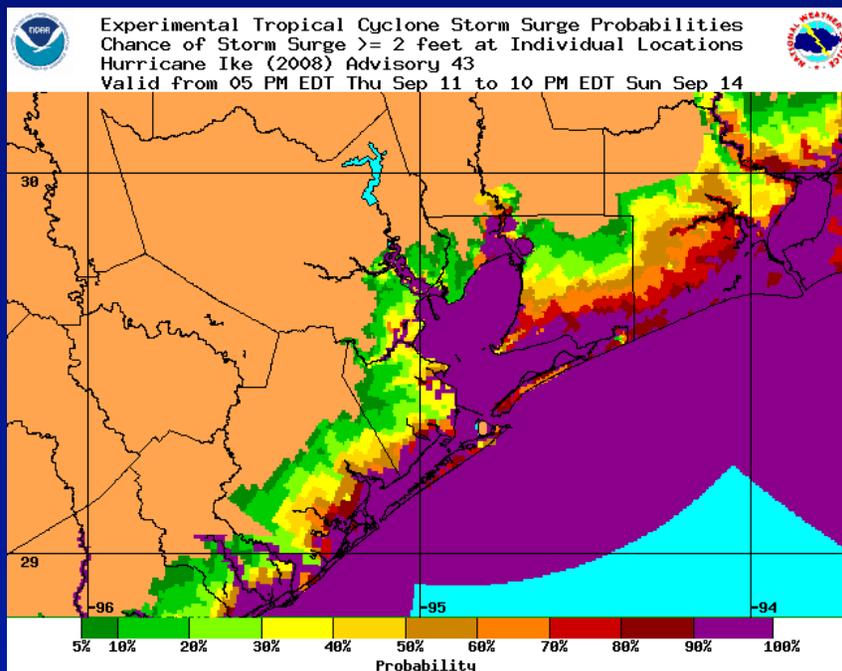
Probability of 1-minute average 50-knot (58 mph) or greater surface winds from all tropical cyclones  
 ◊ indicates HURRICANE IKE center location at 8 AM EDT Mon Sep 8 2008 (Forecast/Advisory #30)



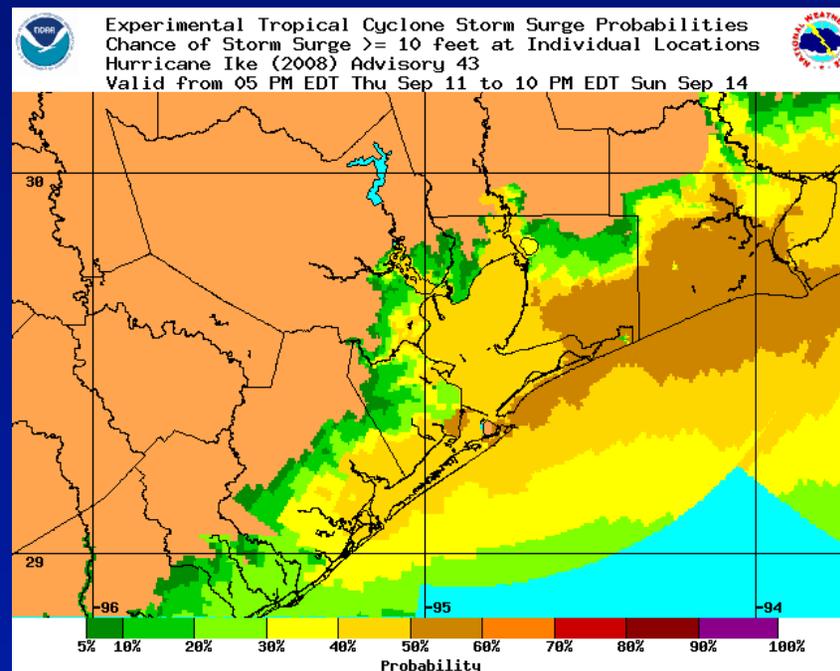
# Storm Surge Probability

- *became operational in 2009*
- *available in 1-ft increments from 2 to 25 ft*
- *run when a Hurricane Watch or Warning is in effect*

## Chance of surge > 2 ft



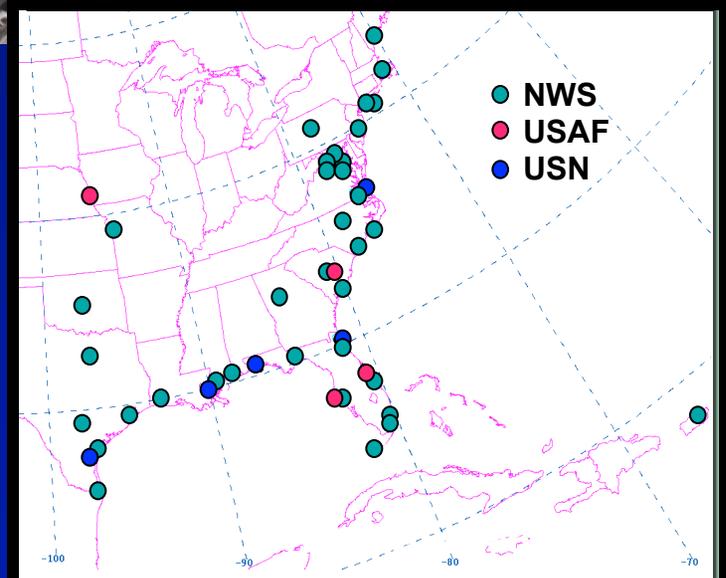
## Chance of surge > 10 ft



# Forecast Coordination

## Hurricane Hotline

- ✓ Other NWS/NCEP National Centers (HPC, OPC, SPC)
- ✓ Local NWS Offices
- ✓ DOD
- ✓ Other federal agencies

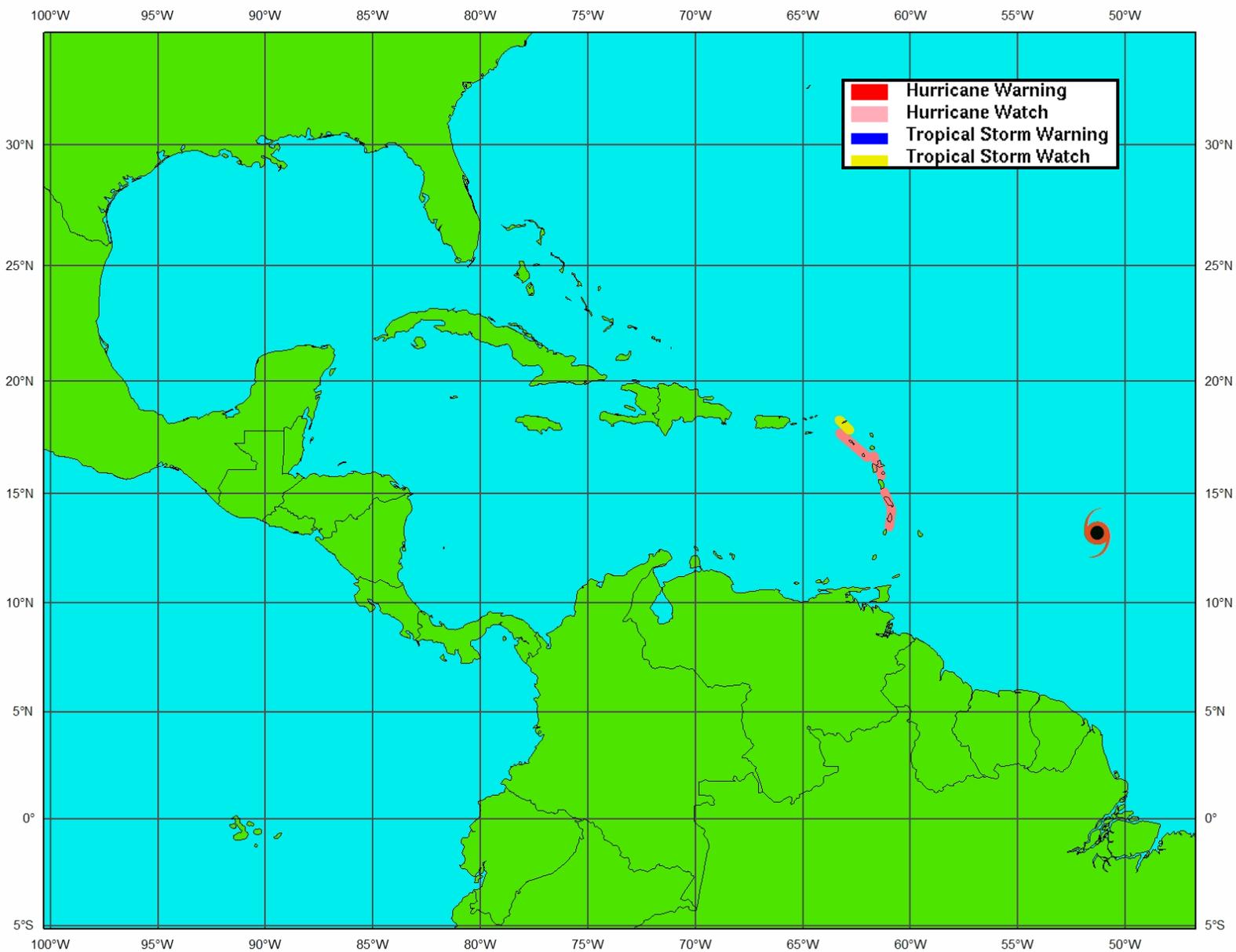


# WORLD METEOROLOGICAL ORGANIZATION Regional Association IV (RA-IV) Coordination



**RSMC=**  
**Regional Specialized Meteorological Center;**  
**RA-IV countries include Caribbean area,**  
**Central America, Mexico, Canada, and Bermuda.**

# Hurricane Dean watches and warnings



# OPERATIONAL COMMUNICATIONS

## WITH KEY DECISION-MAKERS



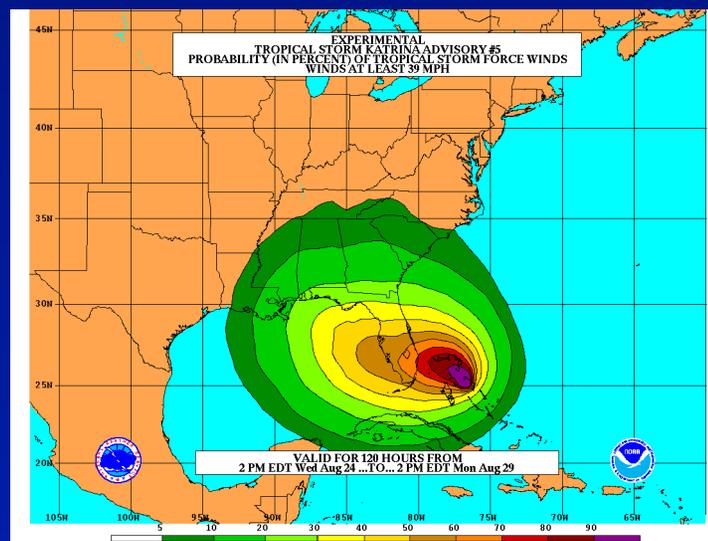
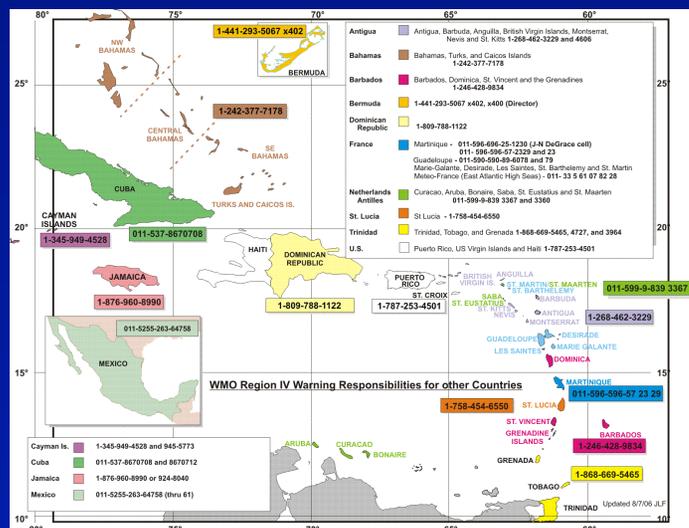
President George W. Bush and Deputy Chief of Staff Joe Hagin, center, during a video teleconference with NHC and emergency managers

## WITH THE MEDIA



## WITH THE PUBLIC

## WITH INTERNATIONAL PARTNERS



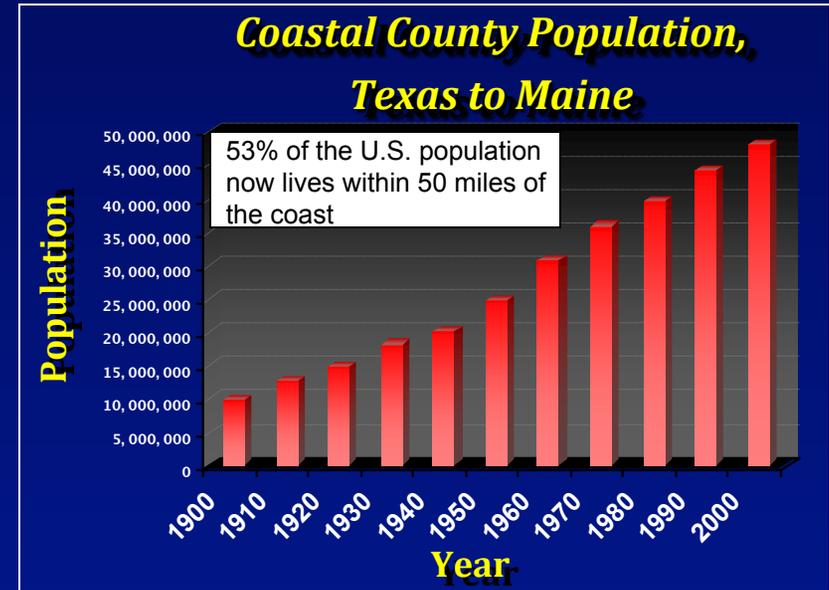
# OUTREACH AND EDUCATION



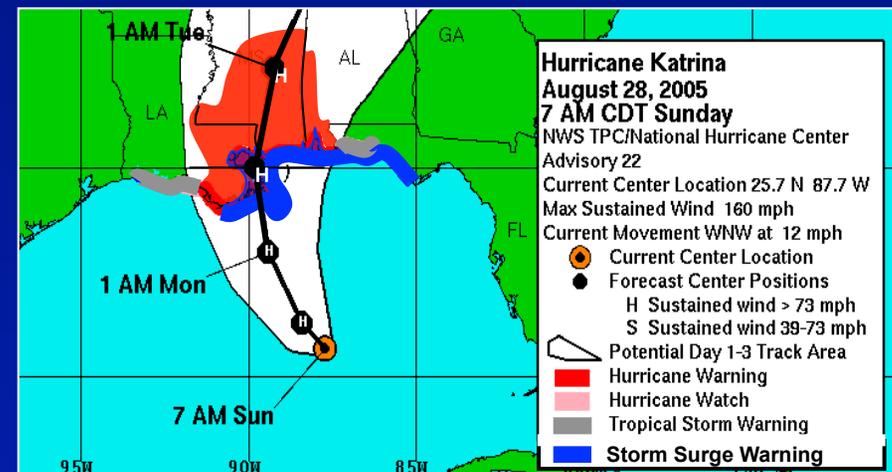
- ❖ National Hurricane Preparedness Week
- ❖ FEMA workshop for emergency managers
- ❖ Hurricane Awareness Tours
- ❖ National Hurricane Conference (& others)
- ❖ WMO workshop for international meteorologists
- ❖ U.S. Interdepartmental Hurricane Conference

# Possible Changes for 2012 and Beyond

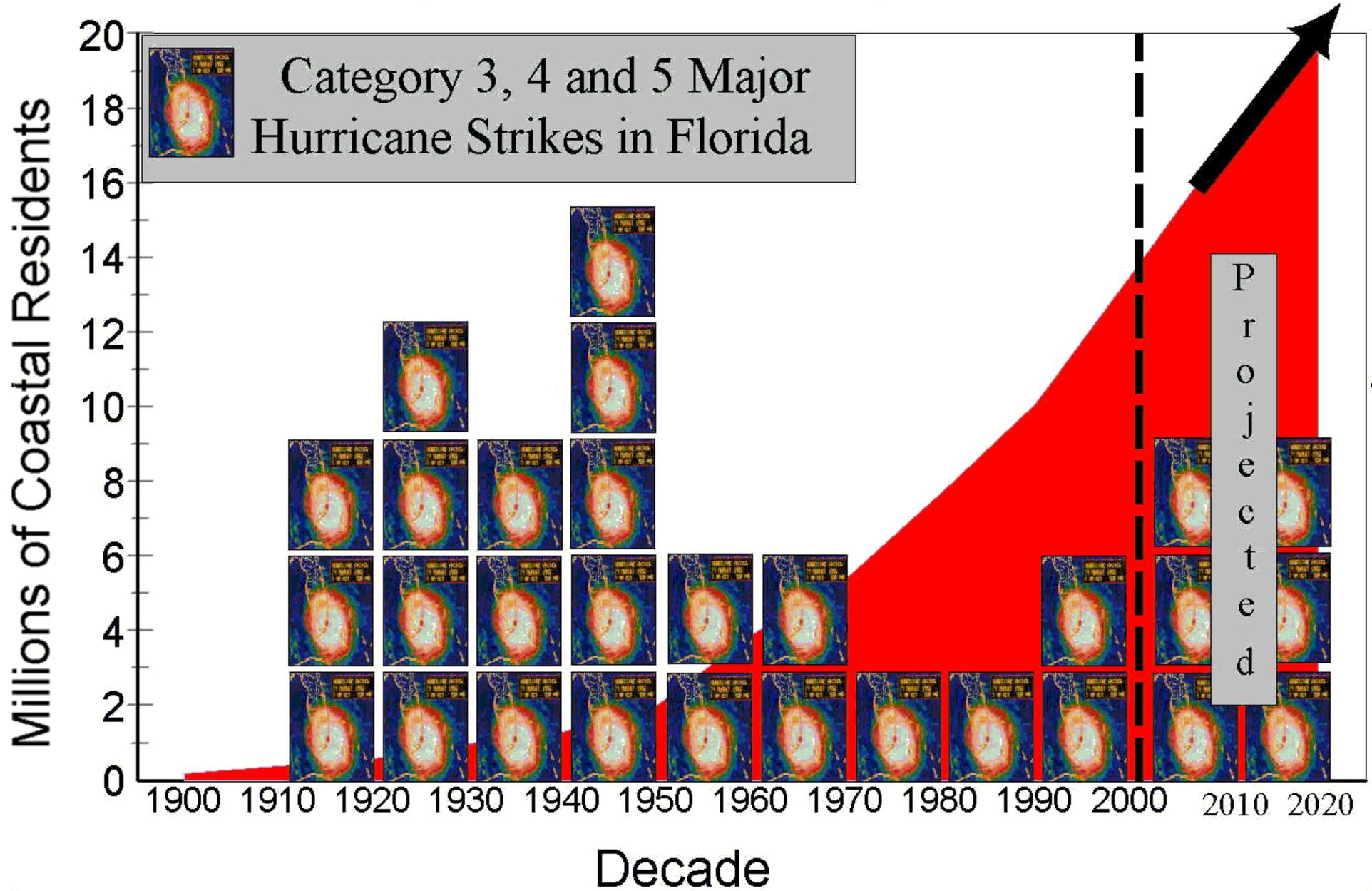
- 7 Day Track and Intensity Forecasts
  - Testing in 2012
- Track, Intensity and Size Forecasts BEFORE Genesis
  - Testing in 2011
- Five Day Genesis Forecasts
  - Testing in 2009-2011
- Storm Surge Warnings
  - Testing in 2012



Evacuation decisions in many cases must be made more than 24 h before landfall

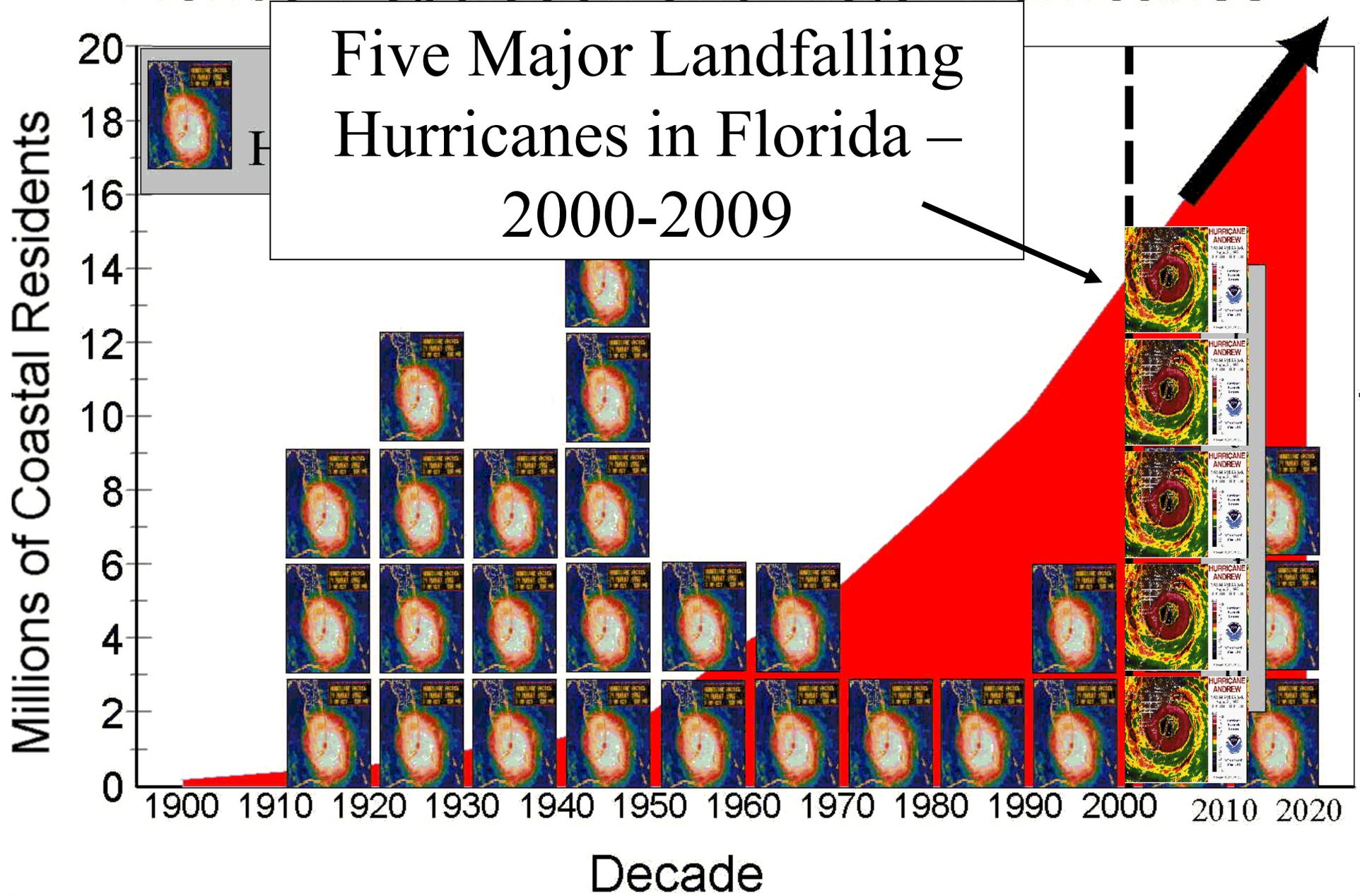


# Florida Population and Major Hurricanes



# Florida Population and Major Hurricanes

Five Major Landfalling Hurricanes in Florida – 2000-2009





# Forecasting at the National Hurricane Center

Chris Landsea  
Science and Operations Officer  
National Hurricane Center

CMMAP Workshop  
10 January, 2012

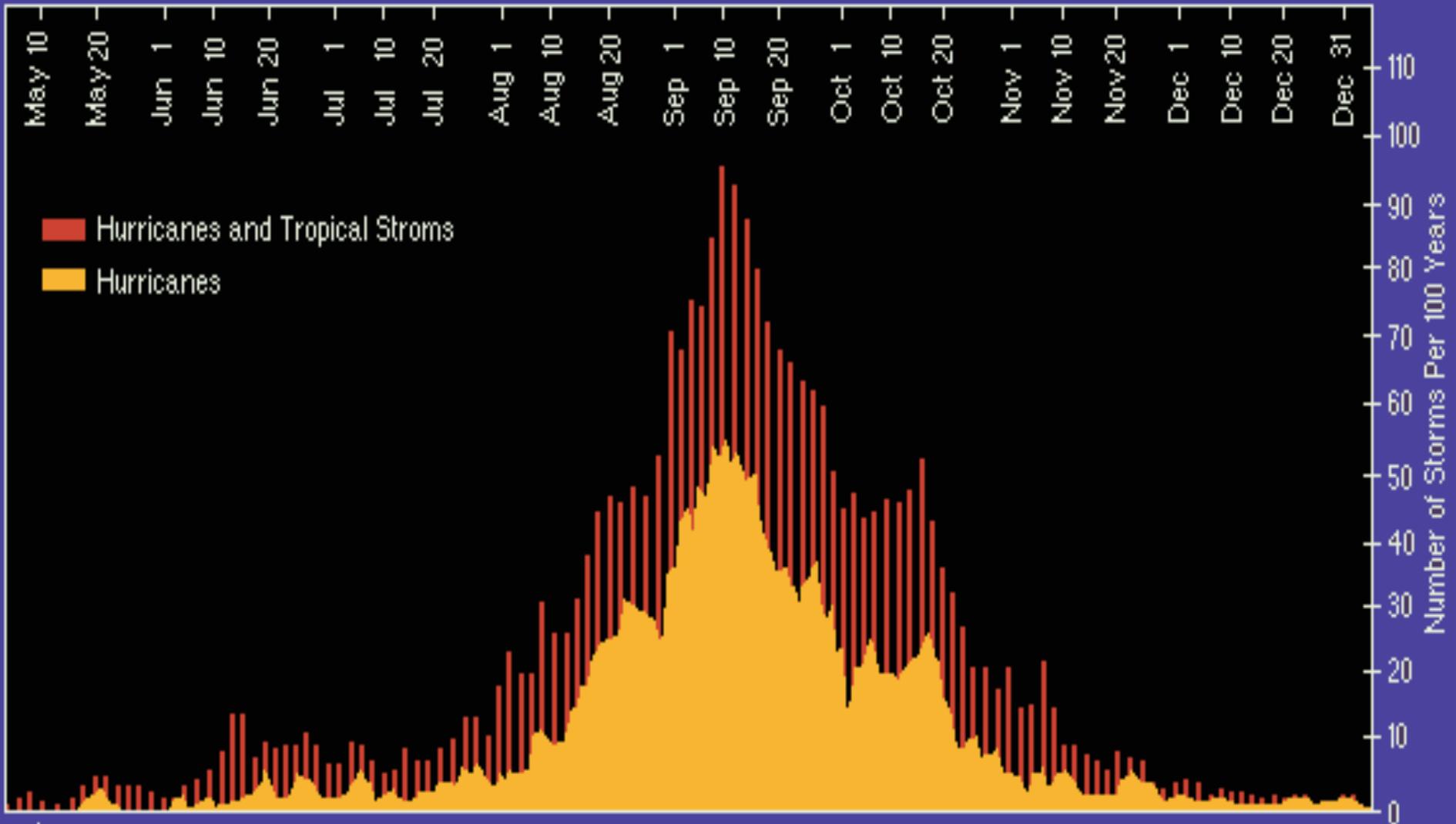


# Global Tropical Cyclones



Average: **85** Per Year World Wide

# Atlantic Hurricane Basin Climatology

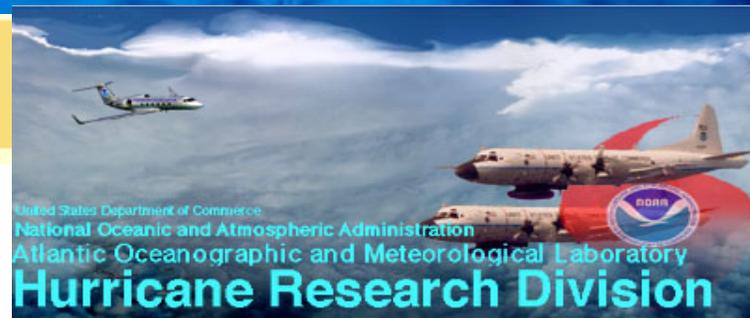


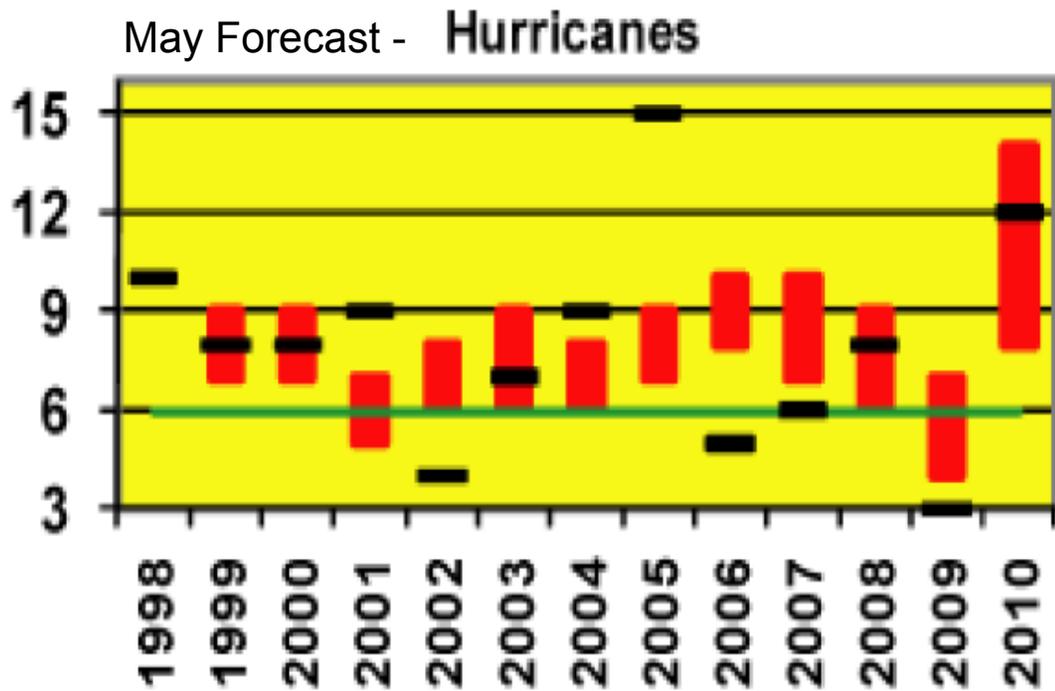
# NOAA's 2010 Atlantic Hurricane Outlook

<u>Season and Activity Type</u>	<u>May 2010 Outlook</u>	<u>Aug 2010 Outlook</u>	<u>Observed Activity</u>	<u>Climatology</u>
<b>Chance Above Normal</b>	<b>85%</b>	<b>90%</b>	<b>Very Busy!</b>	<b>33%</b>
<b>Chance Near Normal</b>	<b>10%</b>	<b>10%</b>		<b>33%</b>
<b>Chance Below Normal</b>	<b>5%</b>	<b>0%</b>		<b>33%</b>
<b>Named Storms</b>	<b>14-23</b>	<b>14-20</b>	<b>19</b>	<b>11</b>
<b>Hurricanes</b>	<b>8-14</b>	<b>8-12</b>	<b>12</b>	<b>6</b>
<b>Major Hurricanes</b>	<b>3-7</b>	<b>4-6</b>	<b>5</b>	<b>2</b>
<b>ACE % of Median</b>	<b>155-270%</b>	<b>170-260%</b>	<b>190%</b>	<b>100%</b>

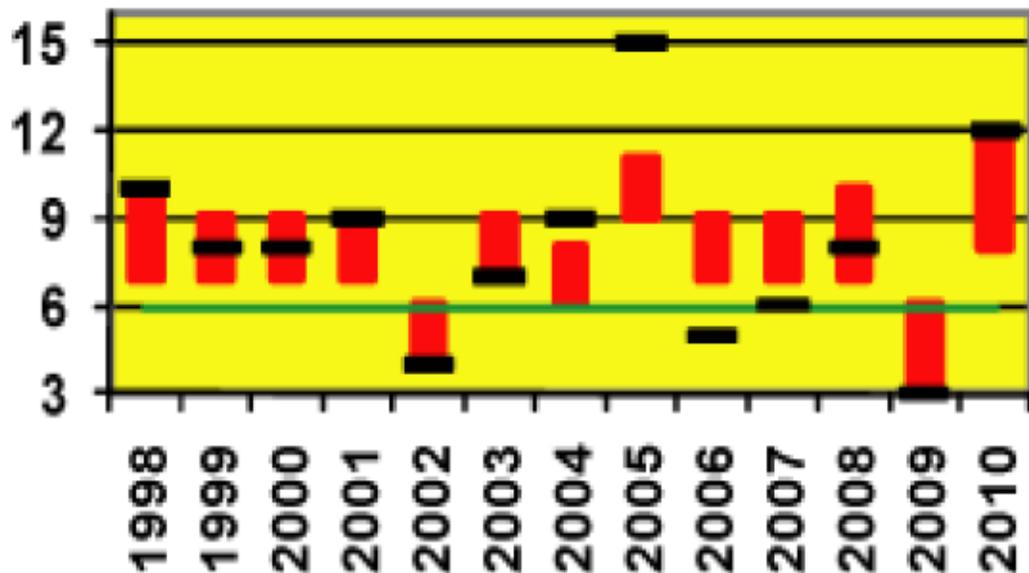
**Climate Prediction Center**

National Hurricane Center





August Forecast - Hurricanes



# NOAA Seasonal Outlook

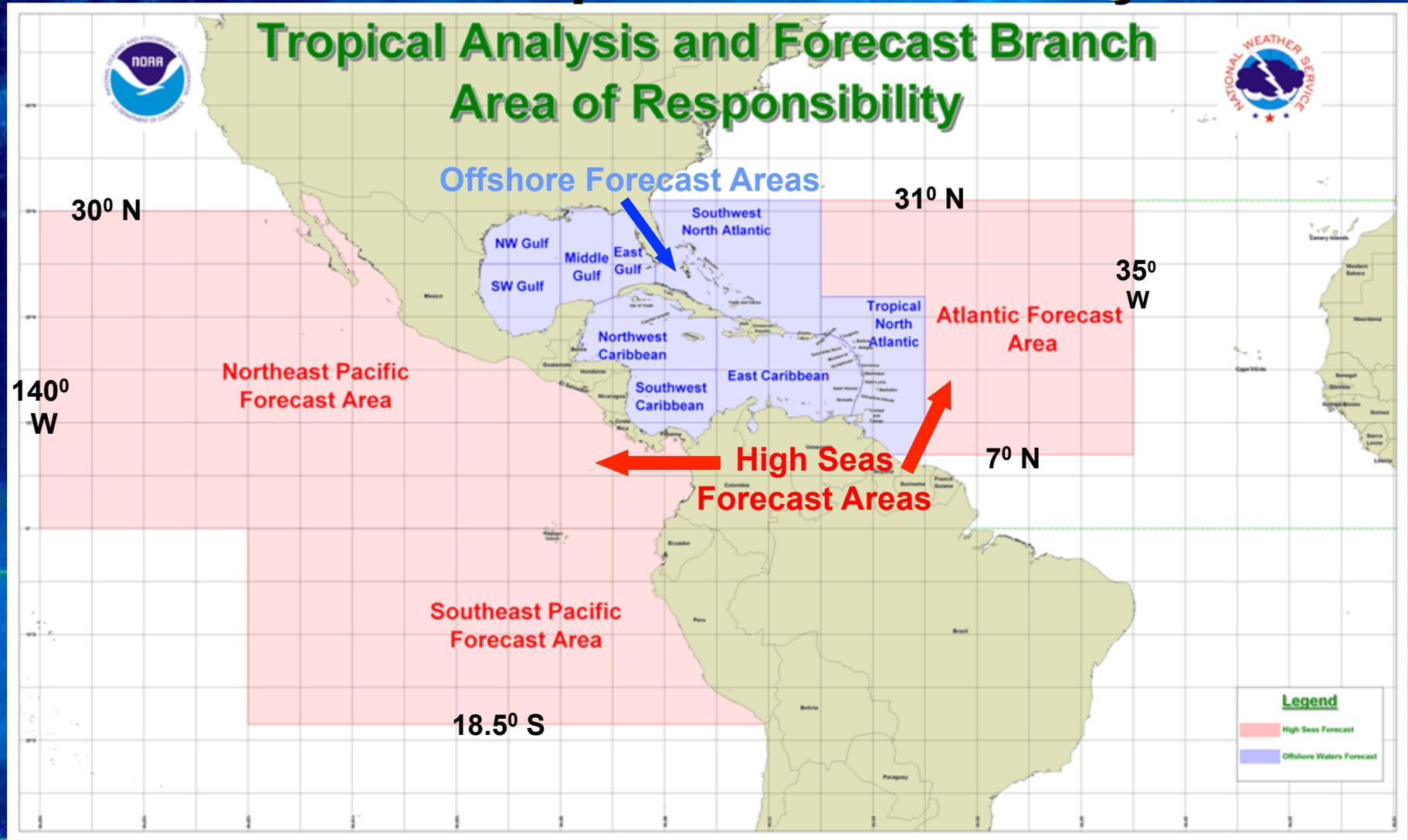
## Caveats:

- 1) Forecasts only modestly skillful;
- 2) Says nothing about US landfalls

# Tropical Analysis Forecast Branch Marine Forecasts



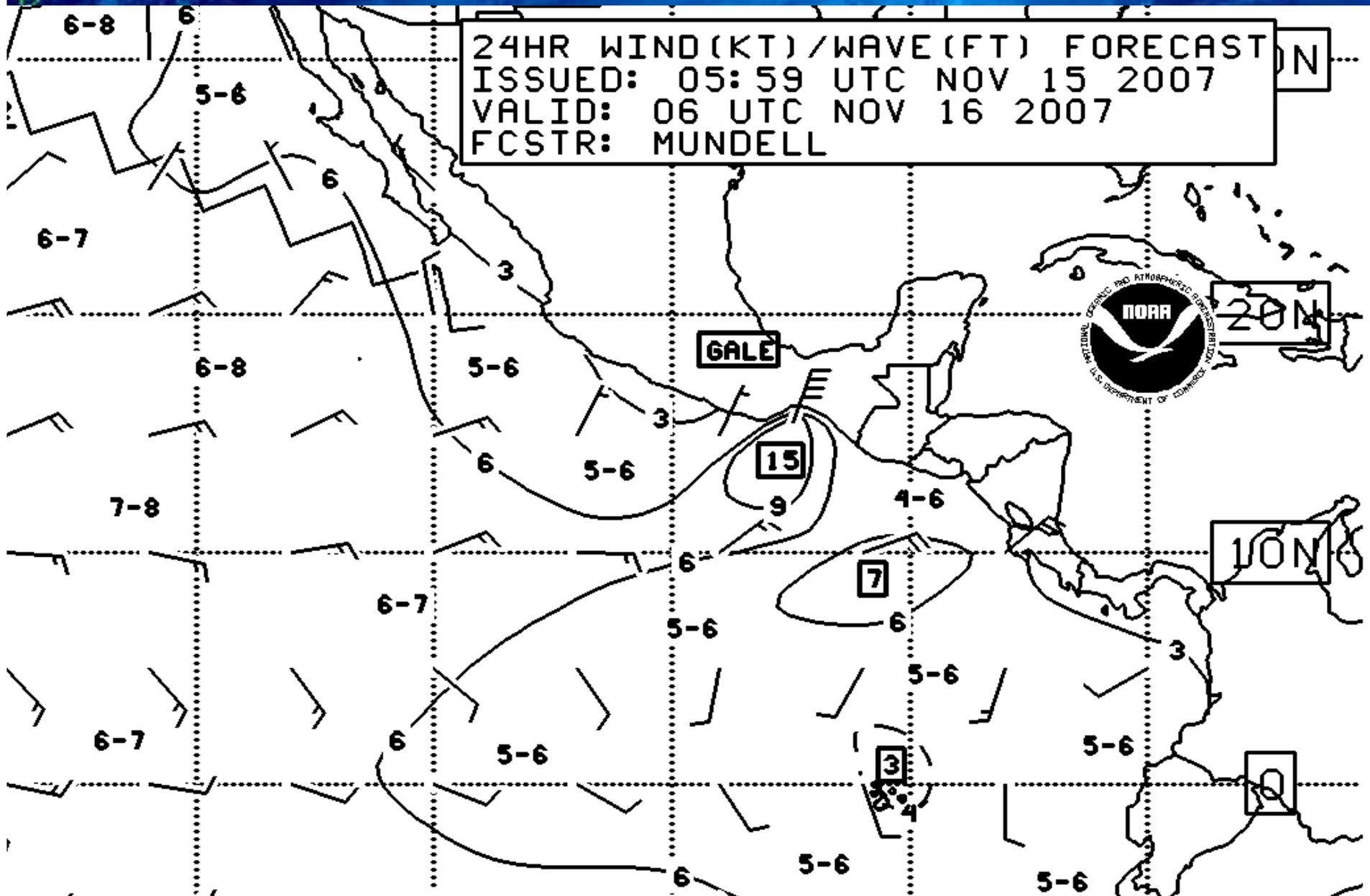
# TAFB produces 57 graphic products & 48 text products each day.



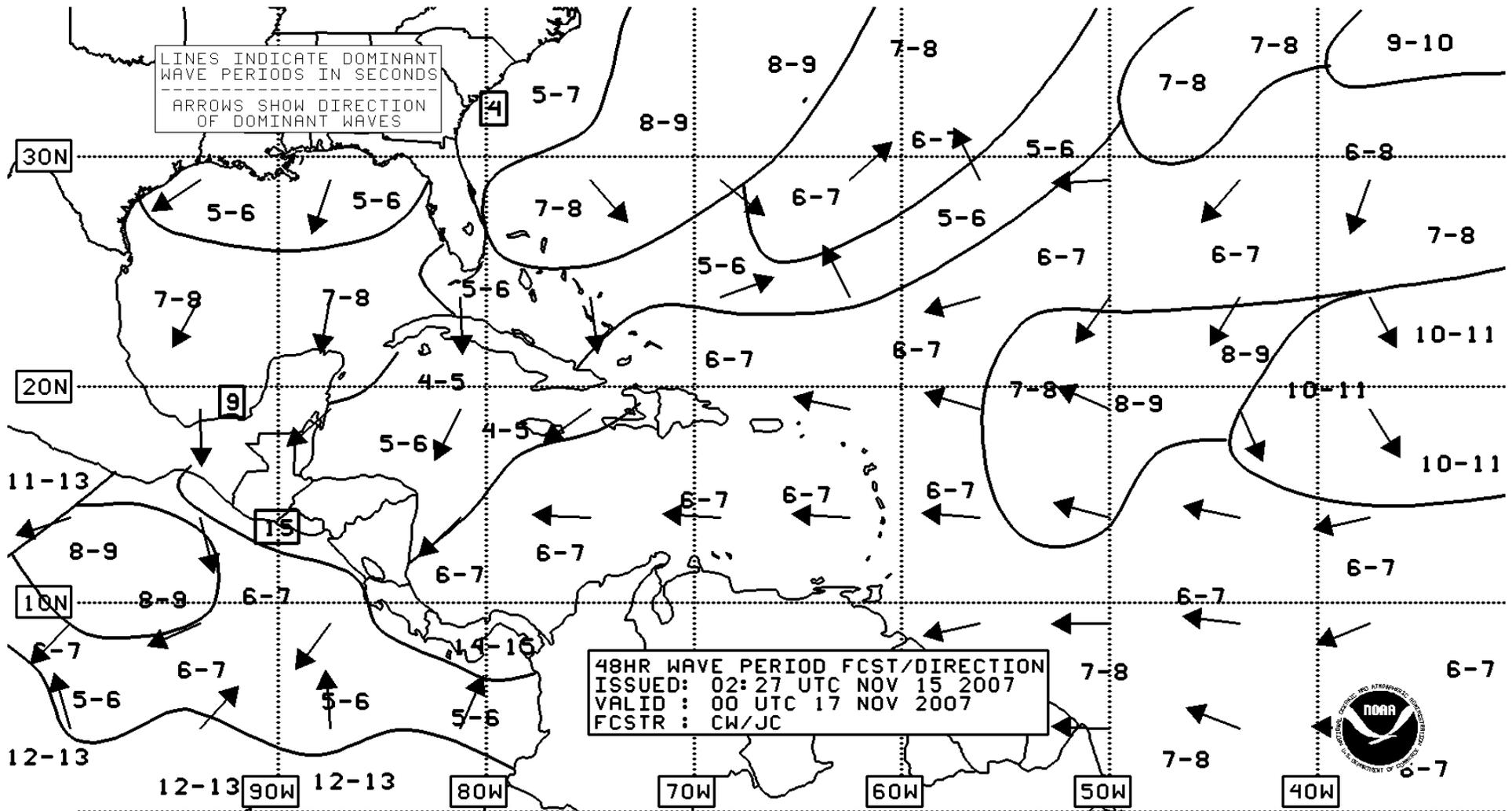
~ 14 million sq. nautical miles

# Wave Height & Surface Wind Forecasts

24HR WIND(KT)/WAVE(FT) FORECAST  
ISSUED: 05:59 UTC NOV 15 2007  
VALID: 06 UTC NOV 16 2007  
FCSTR: MUNDELL



# Wave Period & Direction Forecast



NWS/NCEP - TROPICAL PREDICTION CENTER/TAFB

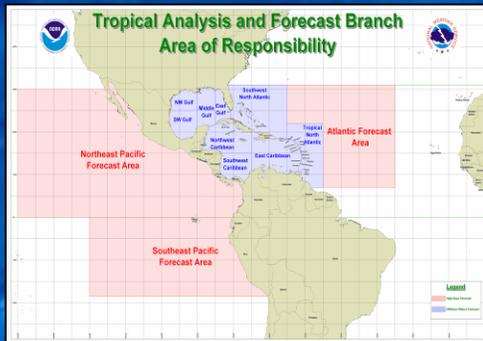
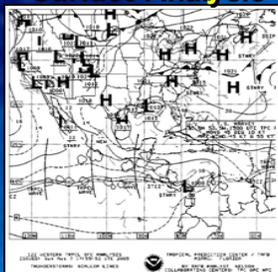
# Suite of Marine Radiofax Charts Produced by TAFB



## Pt. Reyes and Honolulu Radiofax Surface Analysis

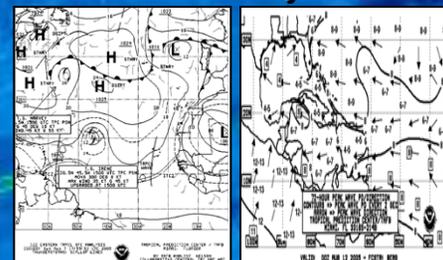
**Pt. Reyes Broadcast Frequencies**  
 4346 kHz  
 8682 kHz  
 12786 kHz  
 17151.2 kHz  
 22527 kHz

**Honolulu Broadcast Frequencies**  
 9982.5 kHz  
 11090 kHz  
 16135 kHz  
 23331.5 kHz

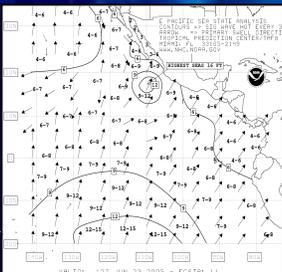


## New Orleans Radiofax Surface Analysis

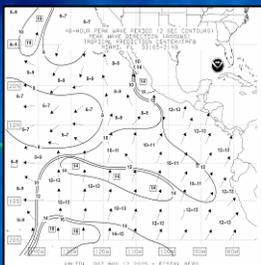
**New Orleans Broadcast Frequencies**  
 4317.9 kHz  
 8503.9 kHz  
 12789.9 kHz  
 17146.9 kHz



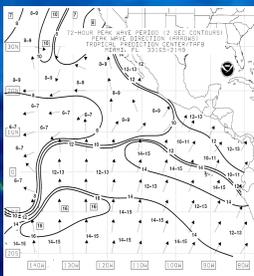
## Sea State Analysis



## Peak Wave Period & Swell Direction

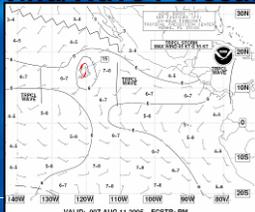


48 hr.

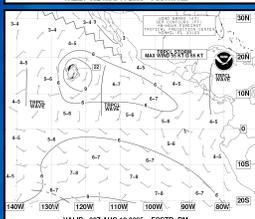


72 hr.

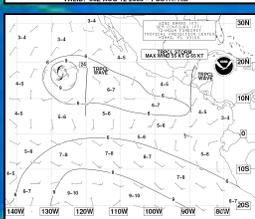
## Wind/Wave Forecasts



24 hr.

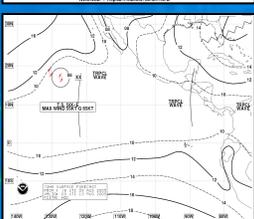
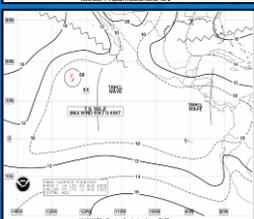
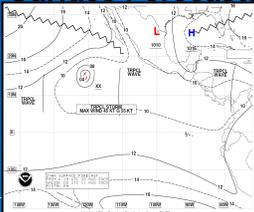


48 hr.

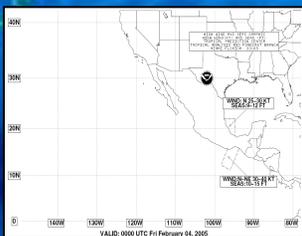


72 hr.

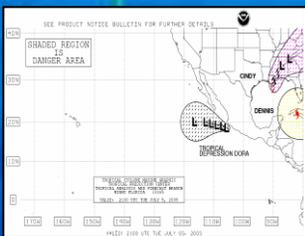
## Surface Forecasts



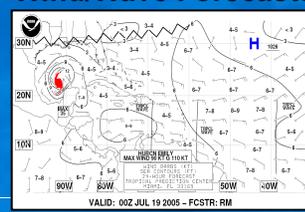
## High Wind Graphic



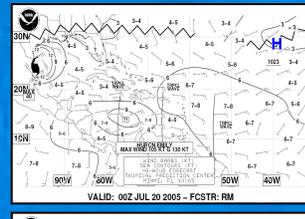
## TC Danger Graphic



## Wind/Wave Forecasts



24 hr.

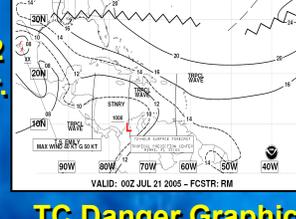
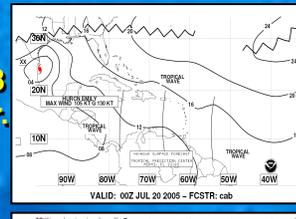
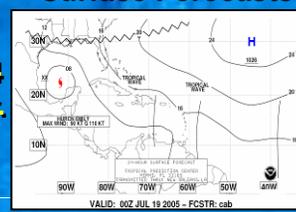


48 hr.

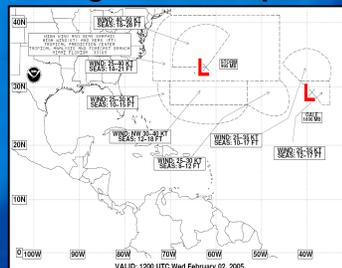


72 hr.

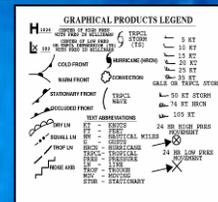
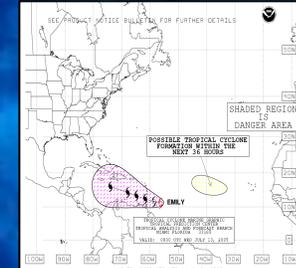
## Surface Forecasts



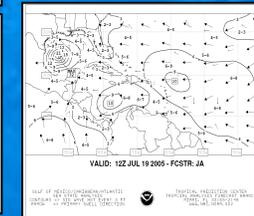
## High Wind Graphic



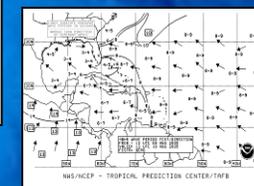
## TC Danger Graphic



## Sea State Analysis



## Peak Wave Period & Swell Direction



48 hr.



72 hr.

# THE NATIONAL HURRICANE CENTER:

- Is the Regional Specialized Meteorological Center (RSMC) for the World Meteorological Organization (WMO) Region-IV Hurricane Committee
- Has overall U.S. National Weather Service responsibility for tropical cyclone forecasts and warnings for the Atlantic and Eastern Pacific Oceans east of 140° West longitude (**Hurricane Specialist Unit**)
- Issues marine forecasts and graphical products for portions of the Atlantic and Eastern Pacific (**Tropical Analysis and Forecast Branch**)

# Experimental Gridded Marine Forecasts

- Winds and waves - [http://www.nhc.noaa.gov/tafb/gridded\\_marine/](http://www.nhc.noaa.gov/tafb/gridded_marine/)

