



# Hurricanes in the Earth System: NASA Perspectives on the 2005 and 2004 Hurricane Seasons

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# Key Contributions from NASA on Characterizing and Understanding

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- Hurricane/Cyclone Genesis
- Intensification
- Landfall Processes and Flooding
- Evidence of Applications Usage



# NASA Earth Observatories





## Big Picture Generally Governs Hurricane Evolution

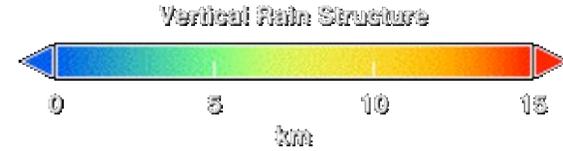
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- Upper Level Shear, Jet Stream Location, El Nino- La Nina, W. African Rainfall all contribute to a conducive hurricane environment, but they still are rare over a given season

*If Characterizing and Understanding Anything on Earth is “As Only NASA Can”--its hurricanes (lots of “earth ingredients” + over water)*



# Terrible Twins: Rita and Katrina

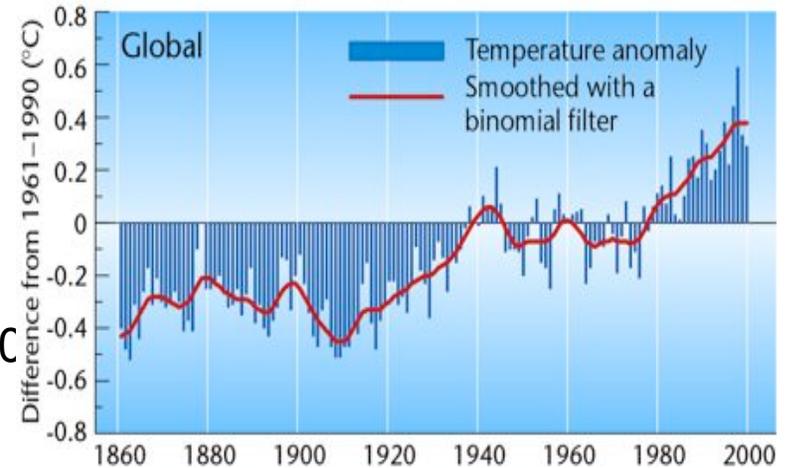




# Is it Global Warming or Climate Change?

## Probably Too Early To Say this

However, a few respected experts Webster et al. (2000) (NCAR) and Kerry Emanuel (MIT) may think so.



Trenberth says that:

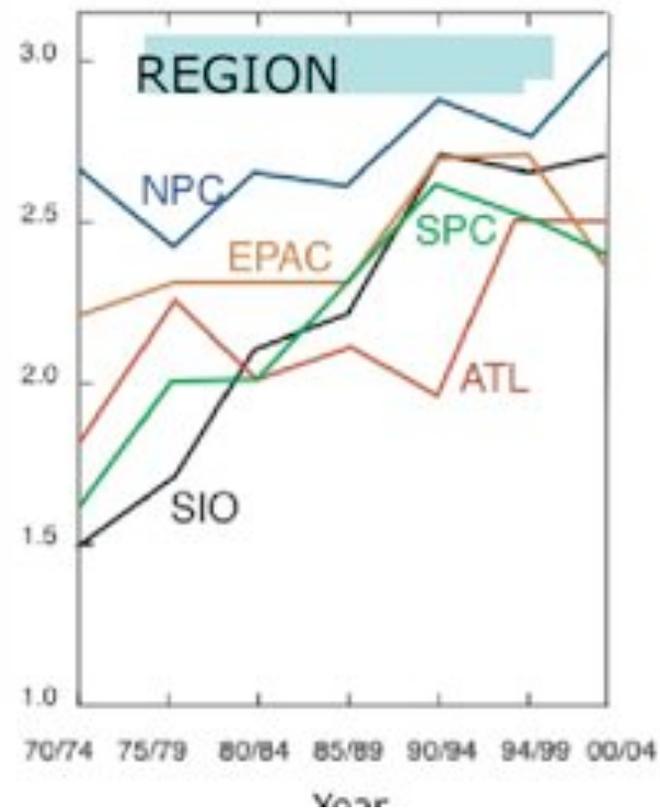
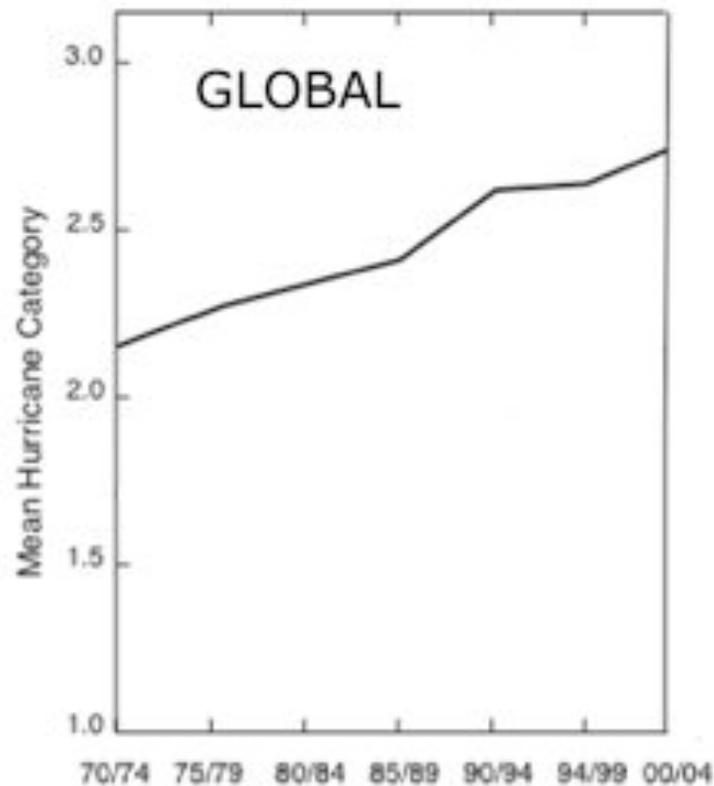
- **Sea temperatures have risen nearly 1 degree in the tropics over the last century. Most of the rise coming since 1970, and most of that increase can be attributed to the release of carbon dioxide into the atmosphere through the burning of coal and gasoline, he said.**
- **Global warming has raised the heat available to a major storm by about 7 percent.**

Emanuel links global warming to increased storm intensity



# Hurricanes and Global Warming

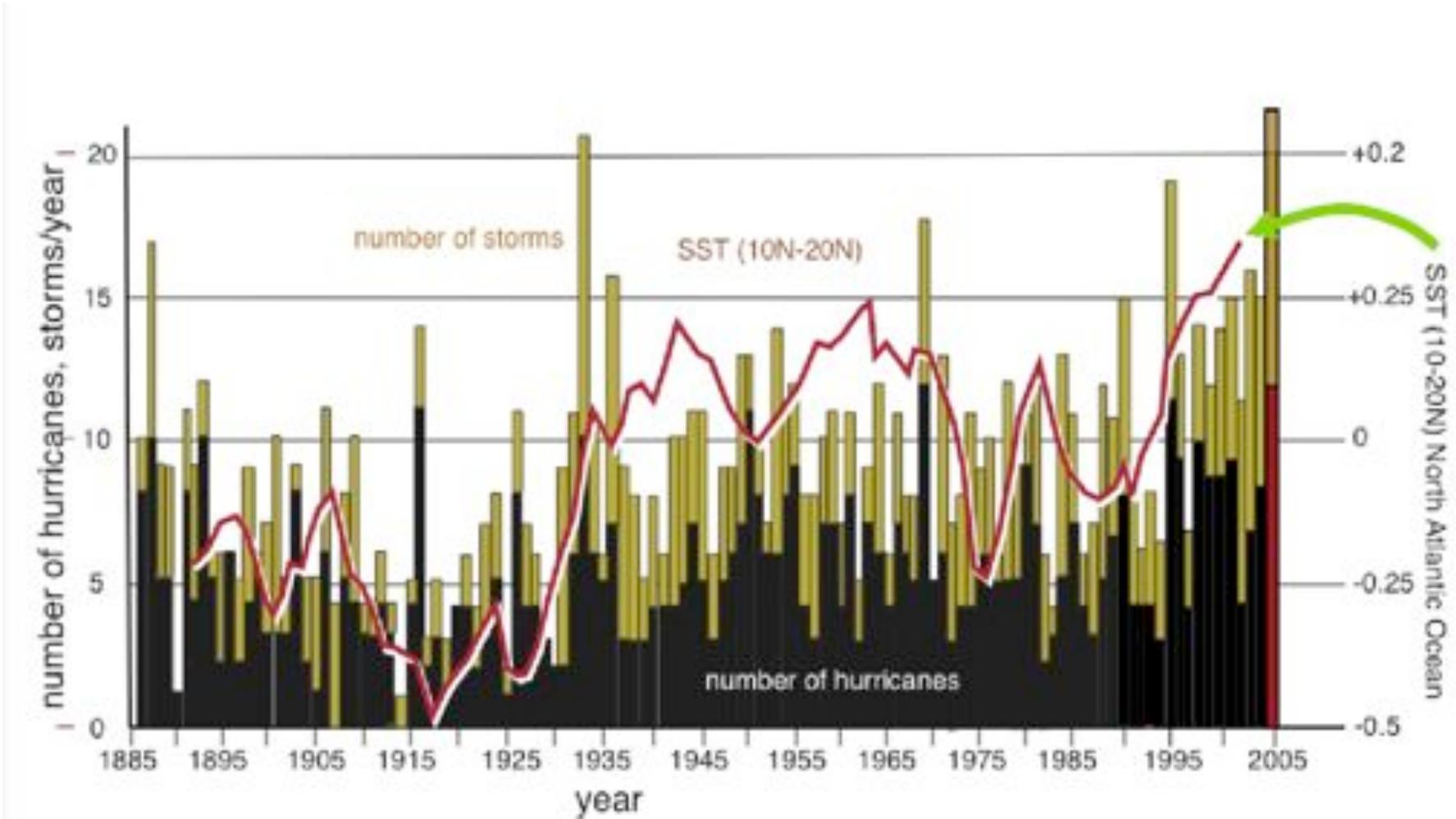
## Increase in average hurricane intensity



Slide from Webster, Curry, et al.  
(2005) AMS Environmental Seminar Series



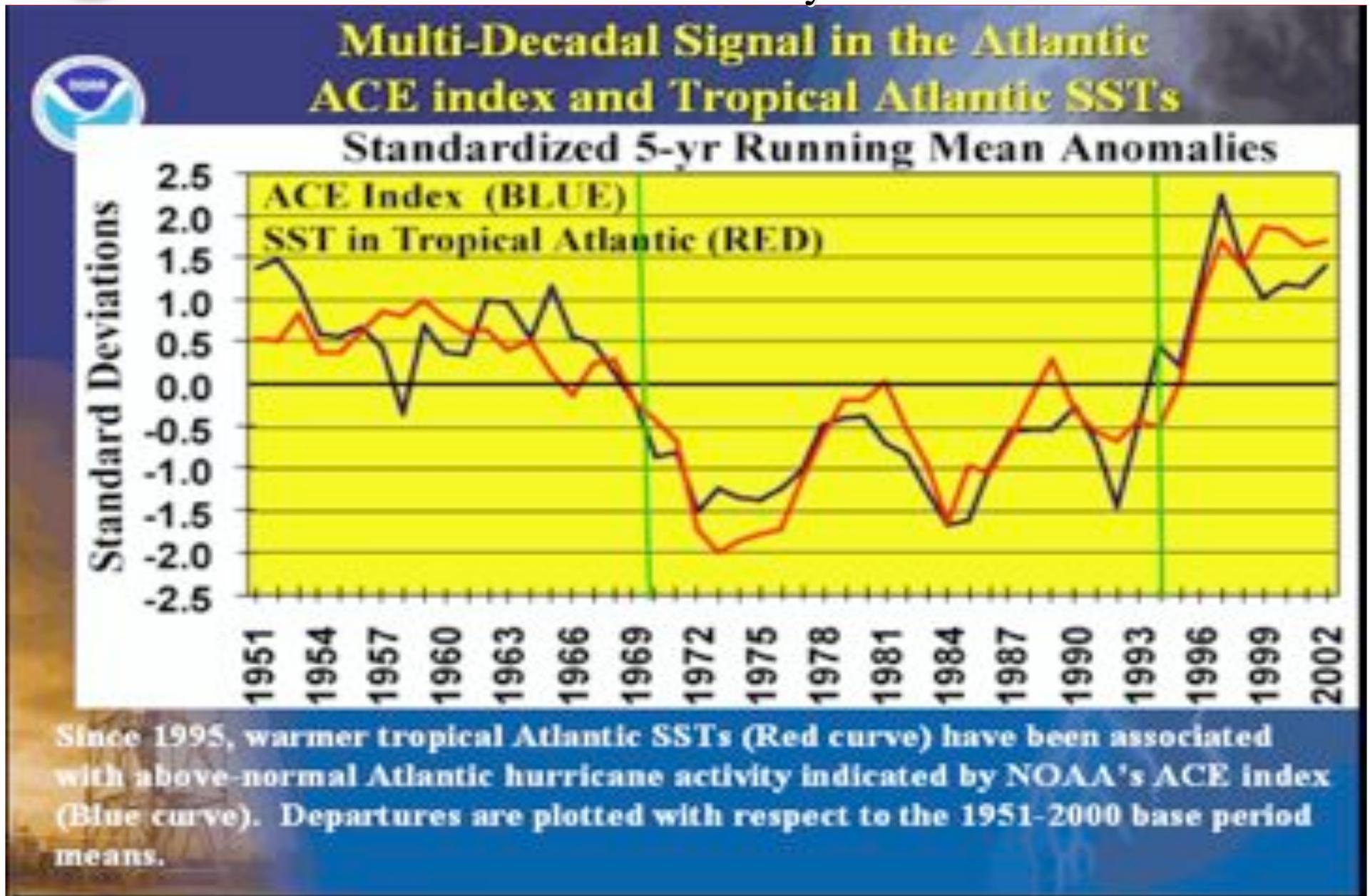
# Hurricanes and Global Warming



Slide from Webster, Curry, et al.  
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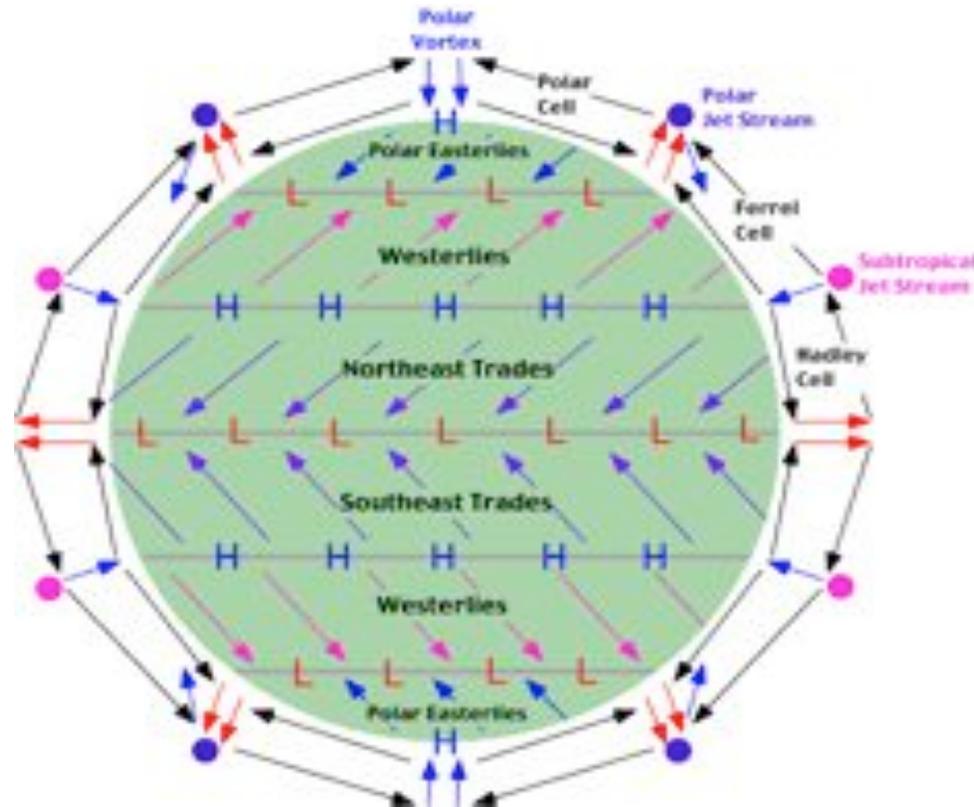


## Or Can Recent Hurricane Seasons Be Explained by Natural Variability?





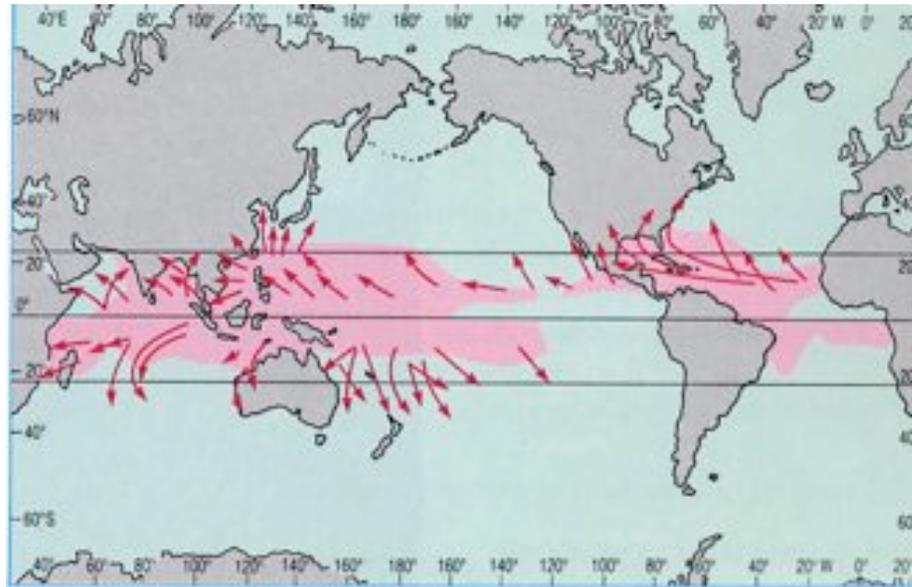
# Hurricanes Are One Way Earth Puts Itself on a Heat, Moisture, and Momentum “Diet”





## Big Picture Generally Governs Hurricane Evolution

- Characteristic tracks followed by tropical cyclones. The red shaded regions are those areas where the SST exceeds  $27^{\circ}\text{C}$  in summer





# What Was Going in the 2005 Hurricane Season?



## NOAA's Updated 2005 Atlantic Hurricane Outlook

**95% to 100% Chance of an Above-Normal Season**  
(Measured by forecasted numbers, strength, and duration of named storms)

### Forecasted Seasonal Totals

18-21 Tropical Storms

9-11 Hurricanes

5-7 Major Hurricanes

180%-270% of median ACE value

### Forecasted for August-November 2005

11-14 Tropical Storms

7-9 Hurricanes

3-5 Major Hurricanes

110%-200% of median ACE value

### Already during 2005:

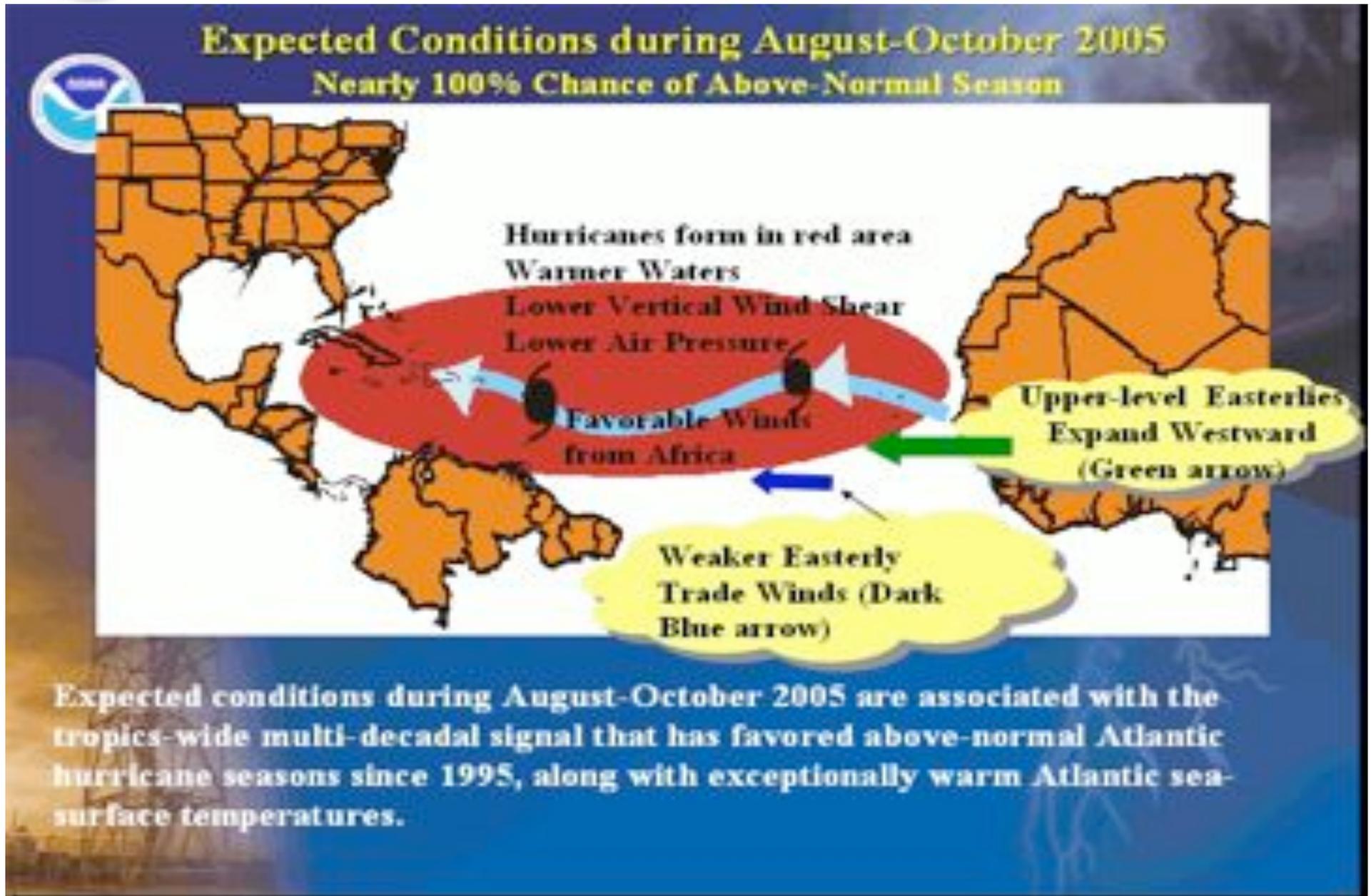
7 Tropical Storms,

2 Major Hurricanes (Dennis and Emily)

ACE index = 70% of median



## What Was Going in the 2005 Hurricane Season?





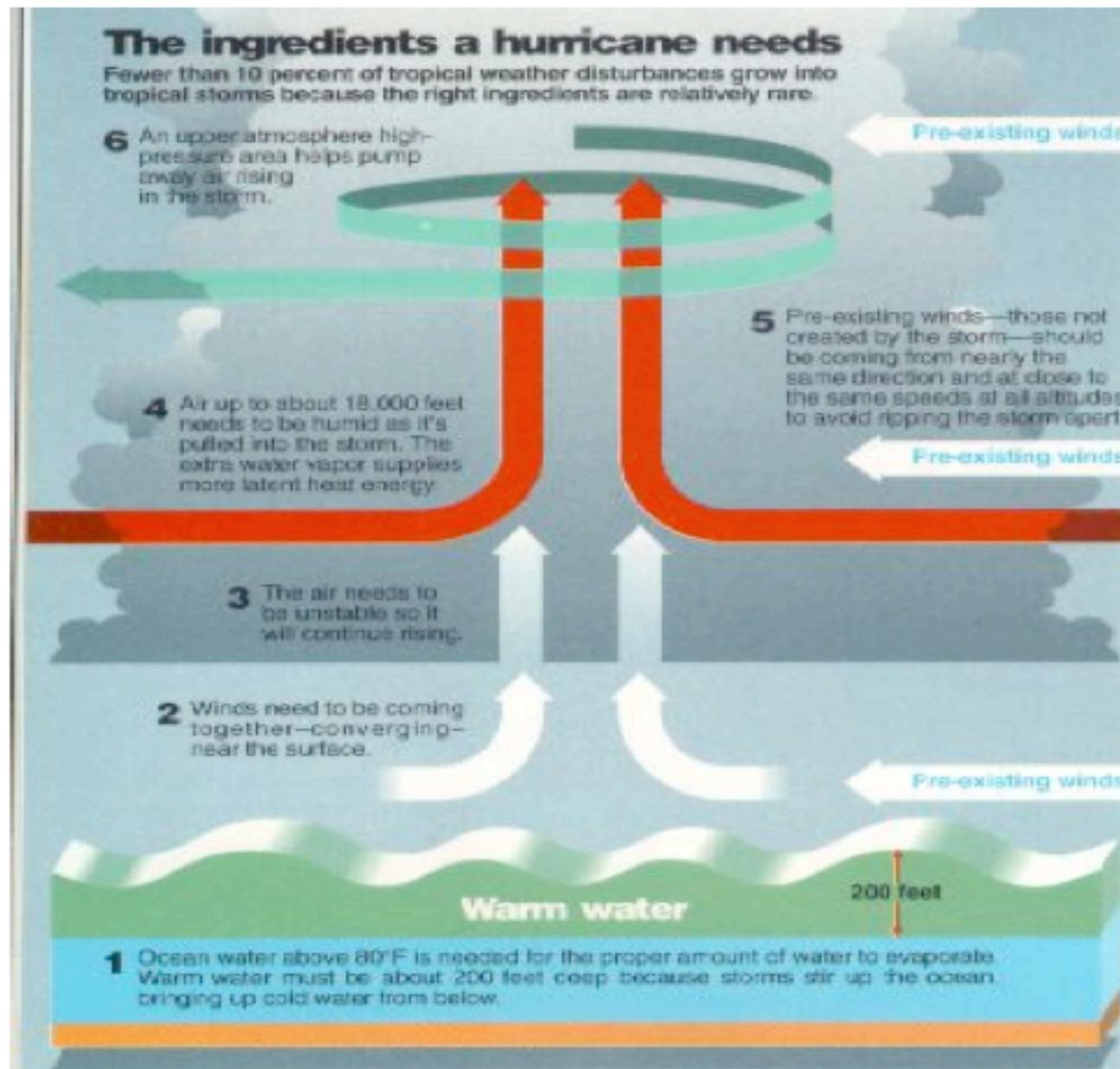
# Katrina Started As A Modest Storm

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# The Hurricane Genesis Problem Is Perplexing!





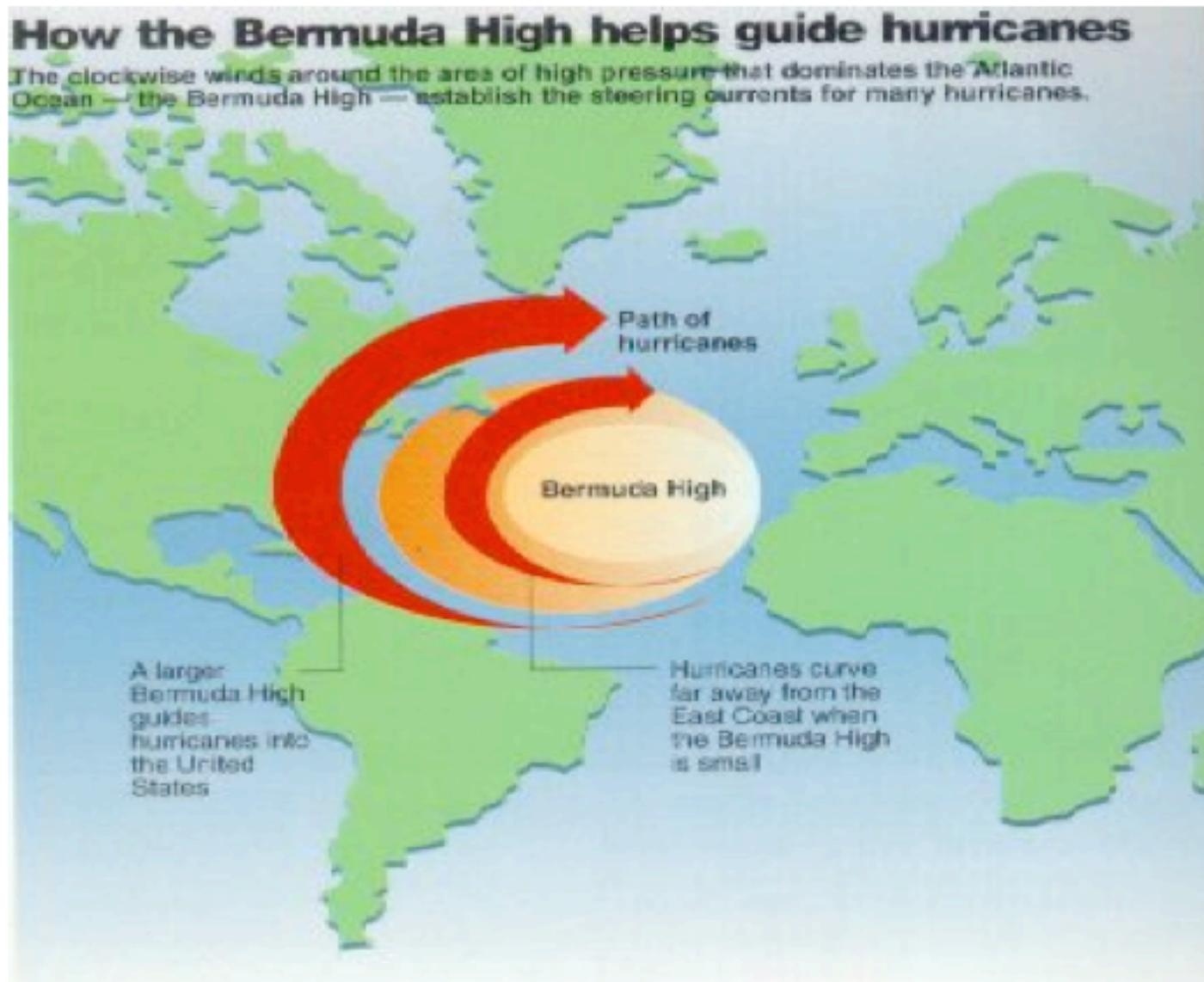
## **Katrina-Historic Storm, 4th Lowest Pressure (902 mb) in Atlantic Basin**

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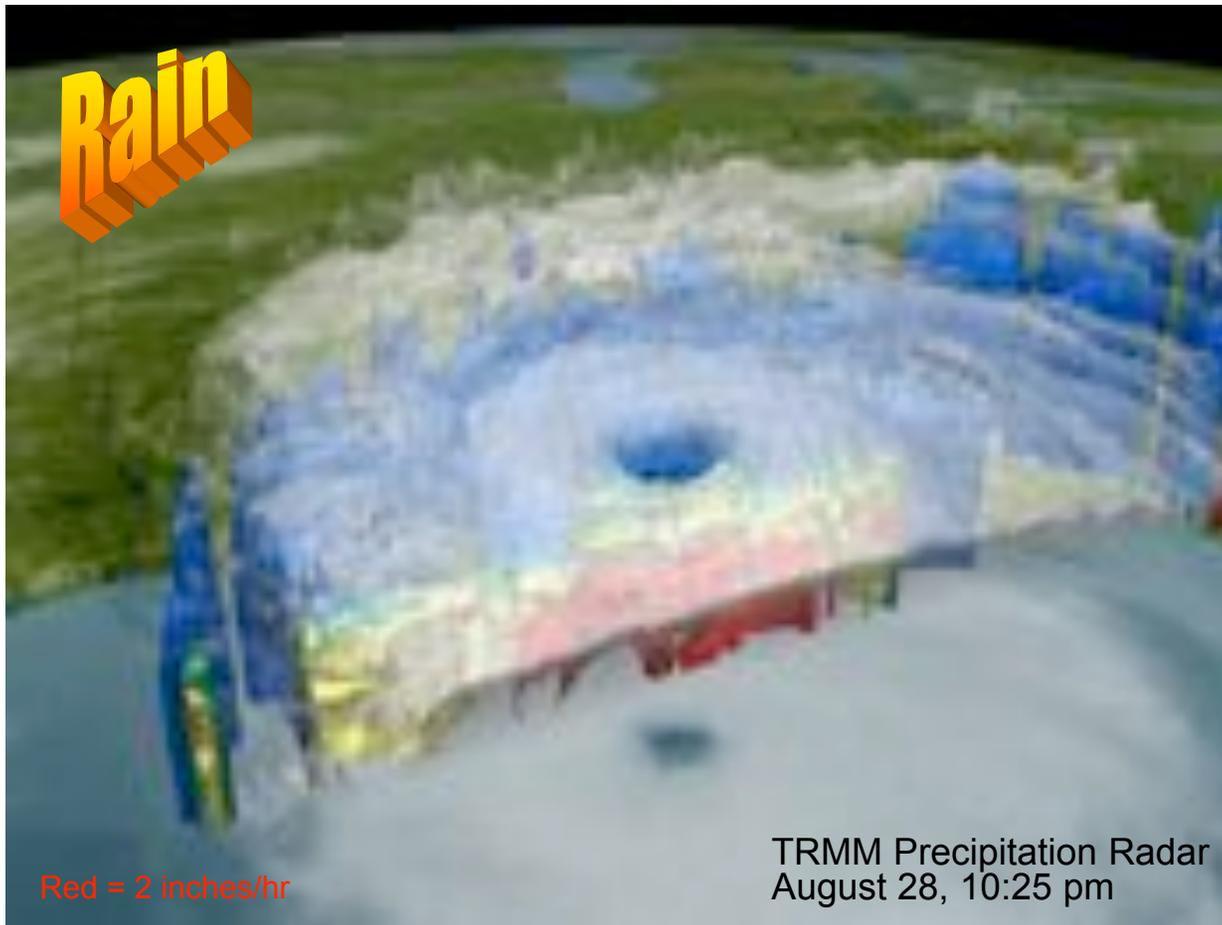


## SSTs and the Bermuda High Pressure???





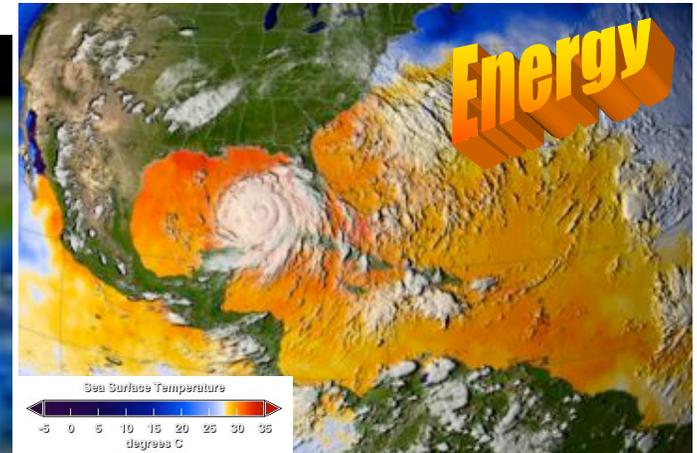
# NASA Earth Science Spacecraft Observe the Birth and Intensification of Deadly Category 5 Hurricane Katrina



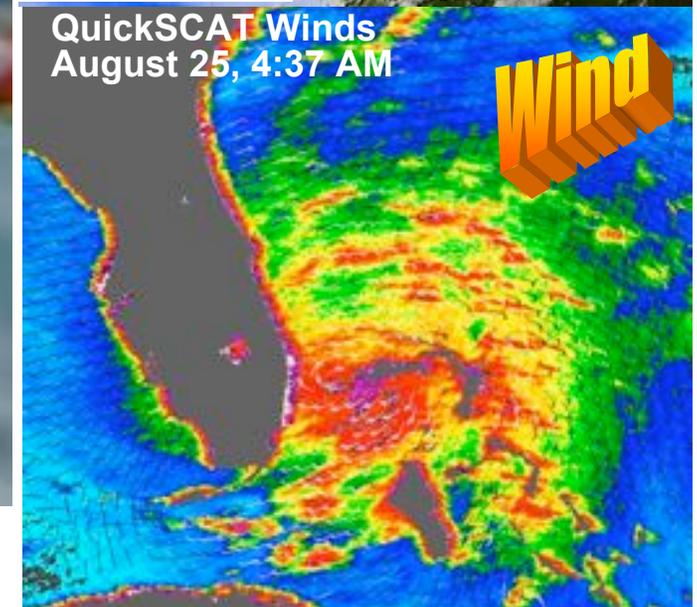
Lori Perkins, NASA GSFC

Jeff Halverson  
TRMM Education and Outreach Scientist

AMSR-E (Aqua) SSTs August 15-27



QuickSCAT Winds  
August 25, 4:37 AM



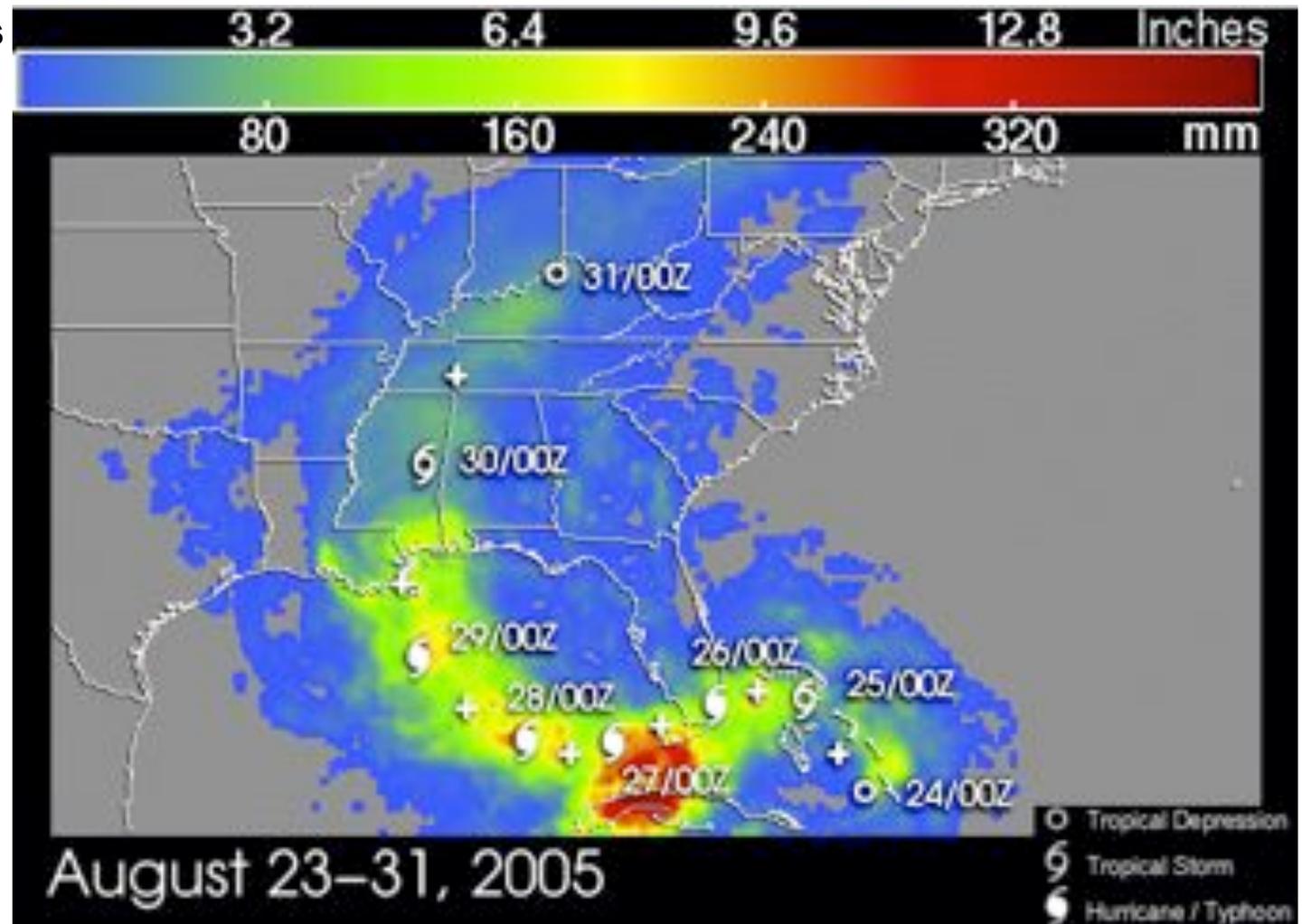
QuickSCAT Science Team, JPL

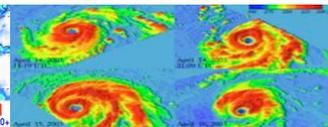
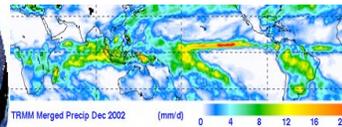
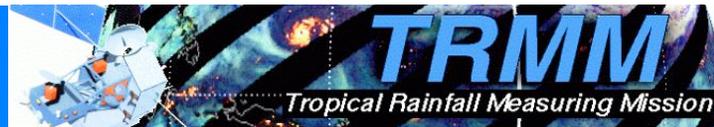


# NASA Multi-Satellite Precipitation Analysis (MPA) of Hurricane Katrina's Rain Accumulation

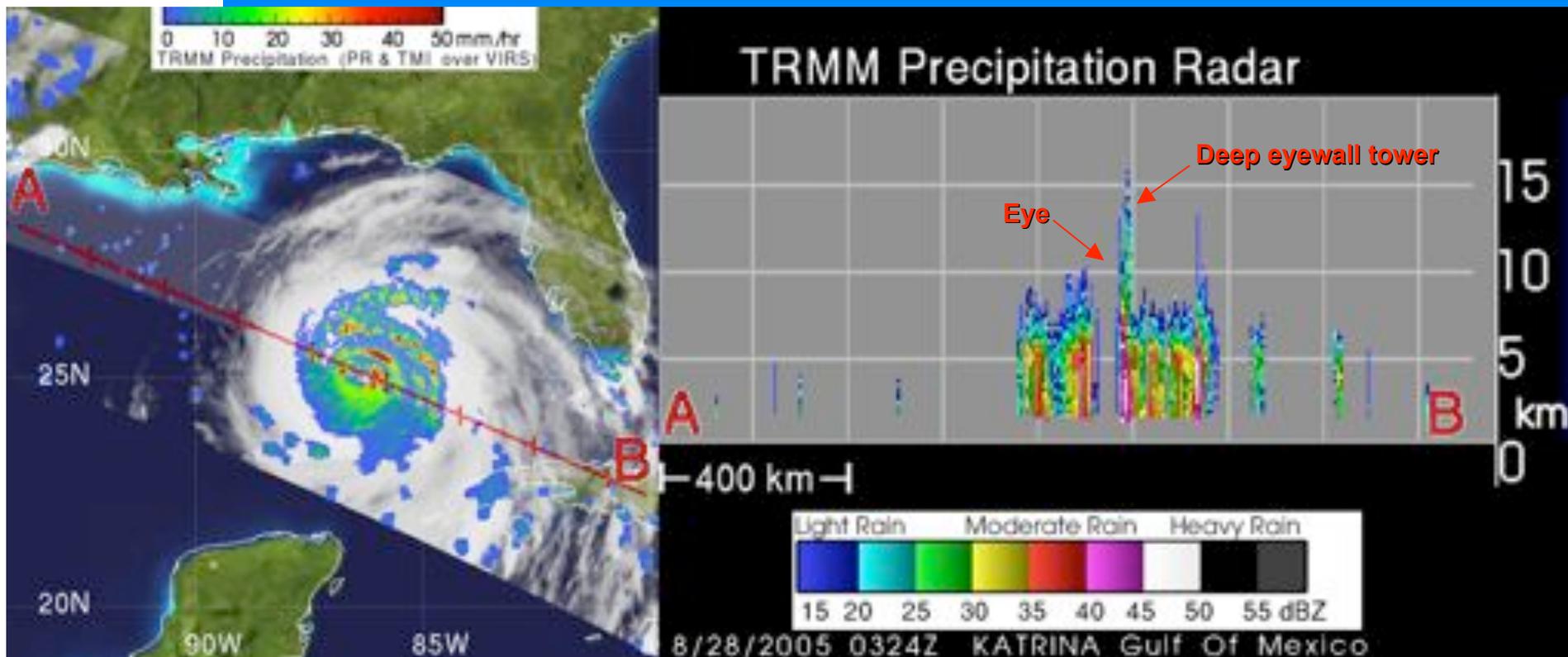
<http://trmm.gsfc.nasa.gov>

- ◆ Rain history of Katrina from genesis over Bahamas to her extratropical transition over the Ohio Valley
- ◆ Heaviest rains fell as the storm was Cat 1 during and after landfall over south Florida
- ◆ Rain swath widened dramatically as the storm intensified to Cat 5
- ◆ Rapid forward speed limited inland rain accumulations
- ◆ Rain swath traces a broad arc around the western flank of the Atlantic subtropical ridge



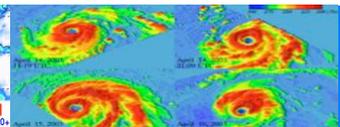
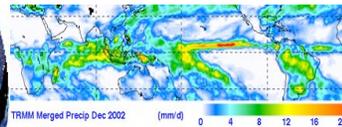
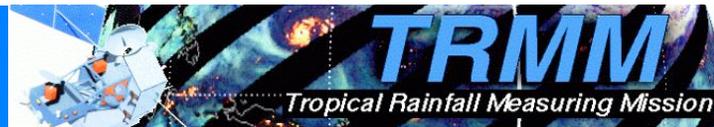


# TRMM 3D Precipitation Radar View of Hurricane Katrina

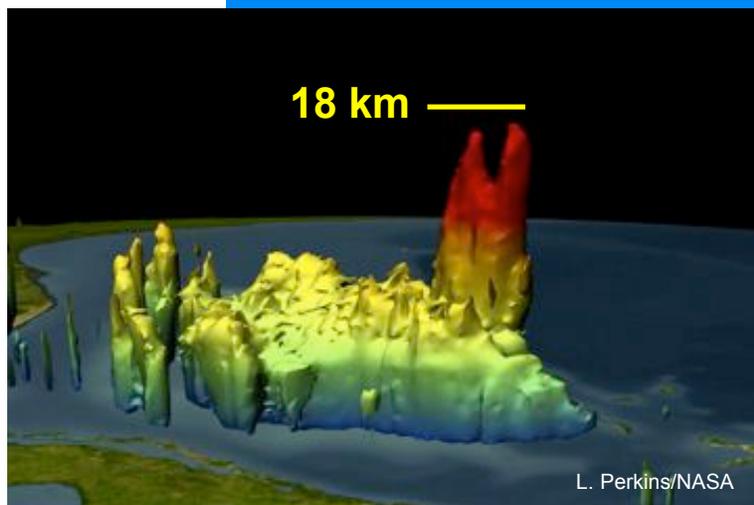


- ◆ Vertical rain structure as revealed by the TRMM Precipitation Radar in near-real time
- ◆ TRMM is the only satellite that can provide rain structure information over open oceans, the breeding and intensification grounds of most tropical cyclones
- ◆ Energy-releasing deep convective clouds (to 16 km) in the eyewall of Katrina on August 28 occurred while the storm was intensifying to Cat 5; TRMM data have established this association in many storms

TRMM E/PO Team  
Halverson, Pierce, Lang



# TRMM Images Impressive Rain Structures in Hurricane Rita

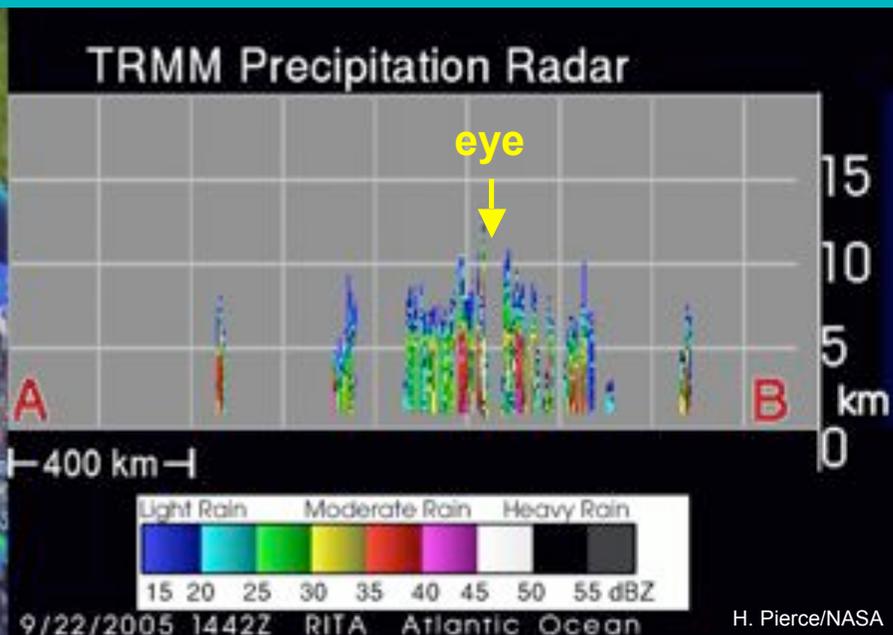
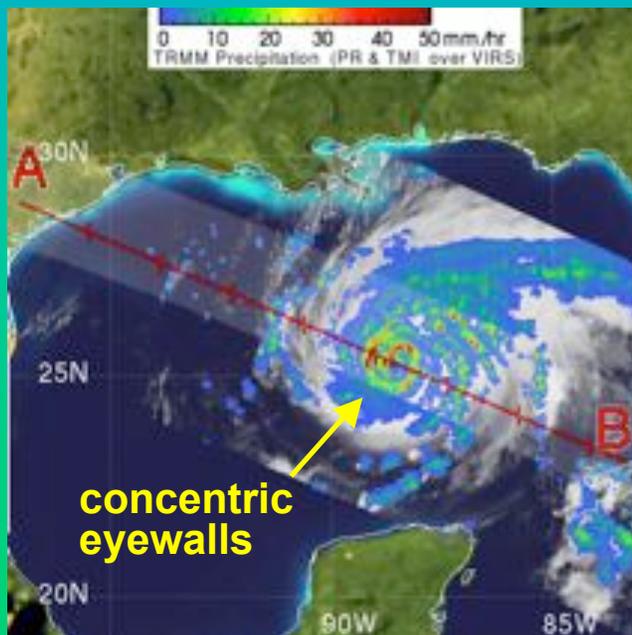


Sept 19, 2005 - 3D rain isosurface of TS Rita  
Colors emphasize vertical height structure  
Twin 18 km deep hot towers fired off in first of two convective bursts in Rita's core presaging her rapid intensification  
This first burst occurred when Rita was positioned over 33° C SSTs in the Bahama Banks

Rita as Cat 5  
Sept 22, 2005

Eyewall  
Replacement  
Cycle (ERC)  
commencing

erson  
E/PO  
st



H. Pierce/NASA



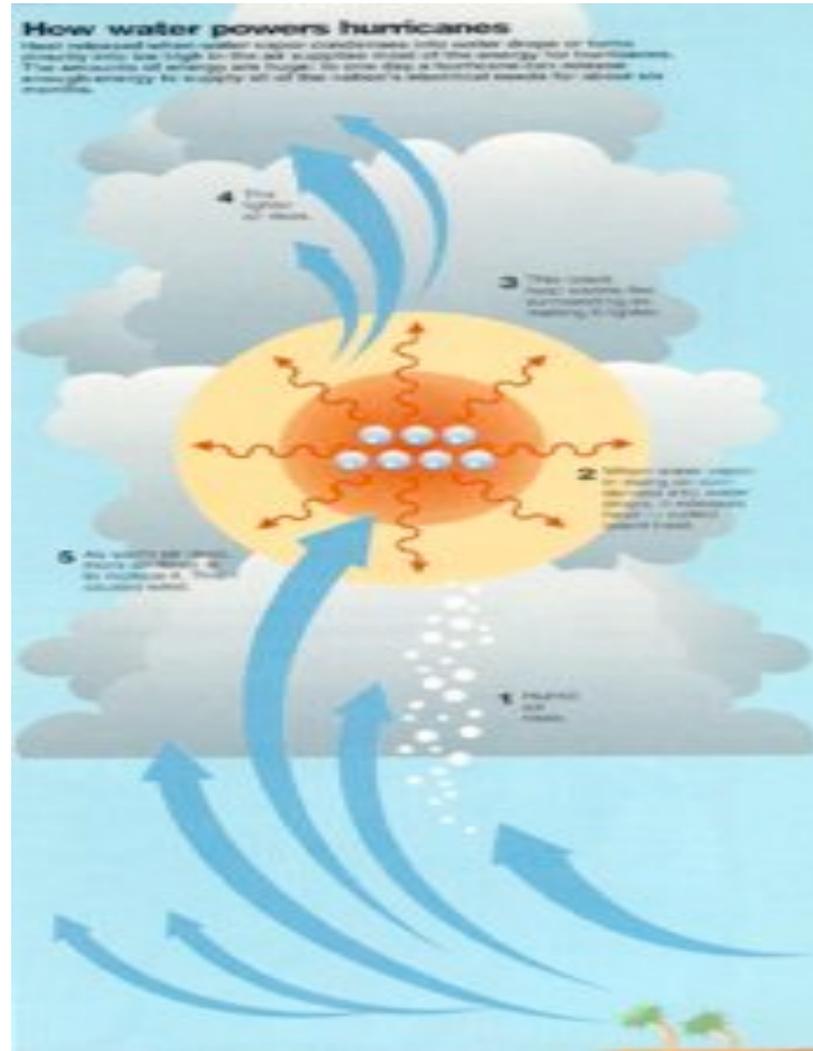
## NASA Data Helps Monitor Rita's Fuel Supply

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- Tropical Cyclone Heat Potential (TCHP) field in the Gulf of Mexico during September 22, 2005. The path of Hurricane Rita is indicated with circles spaced every 3 hours with their size and color representing intensity (see legend). This hurricane intensified to category 5 as it traveled over the Loop Current and a warm core ring (the finger of red and yellow). Rita diminished to category 3 as its path went over a region of lower TCHP (and cooler waters) outside the Loop Current and ring. The diamonds indicate the National Hurricane Center predicted track and intensity as it makes landfall, and are spaced by 24 hours. Altimeter data on NASA's Jason-1, the US Navy's GFO, and the European Envisat satellites provide sea surface height data used in generating the TCHP fields.



# Hurricanes Really Are Heat Engines-Intensity Change Still A Big Mystery!



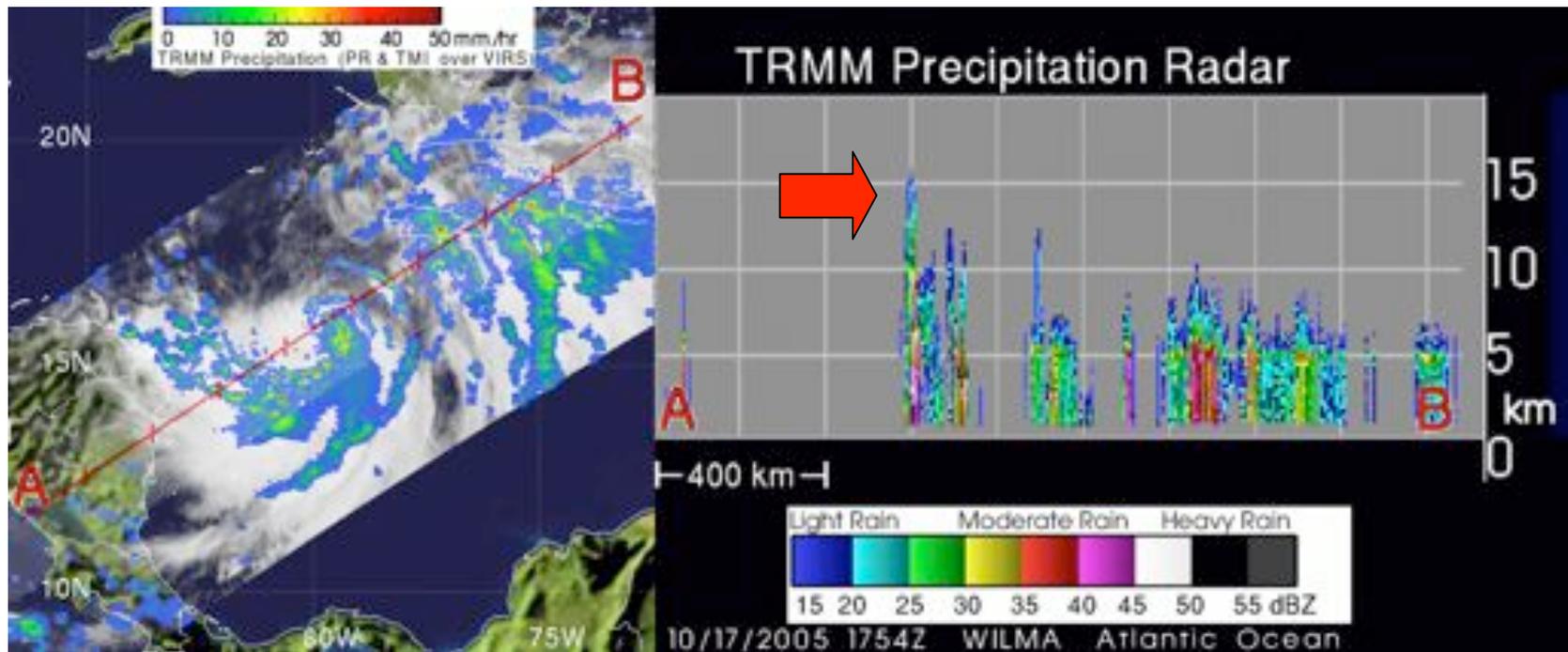


# TRMM Captures “Hot Towers” Igniting Hurricane Wilma’s Heat Engine

Hurricane Wilma is the 21st named storm of the 2005 Atlantic hurricane season, and the 3rd Category 5 to develop in the western Caribbean.

Wilma underwent extremely rapid intensification commencing late on October 18th, deepening 95 mb in 24 hours (at a rate of 8 mb/hr for several hours).

TRMM captured very deep (15-16 km) “hot towers” in the eyewall during the genesis/early deepening phase, within convective bursts that likely “primed the engine.”

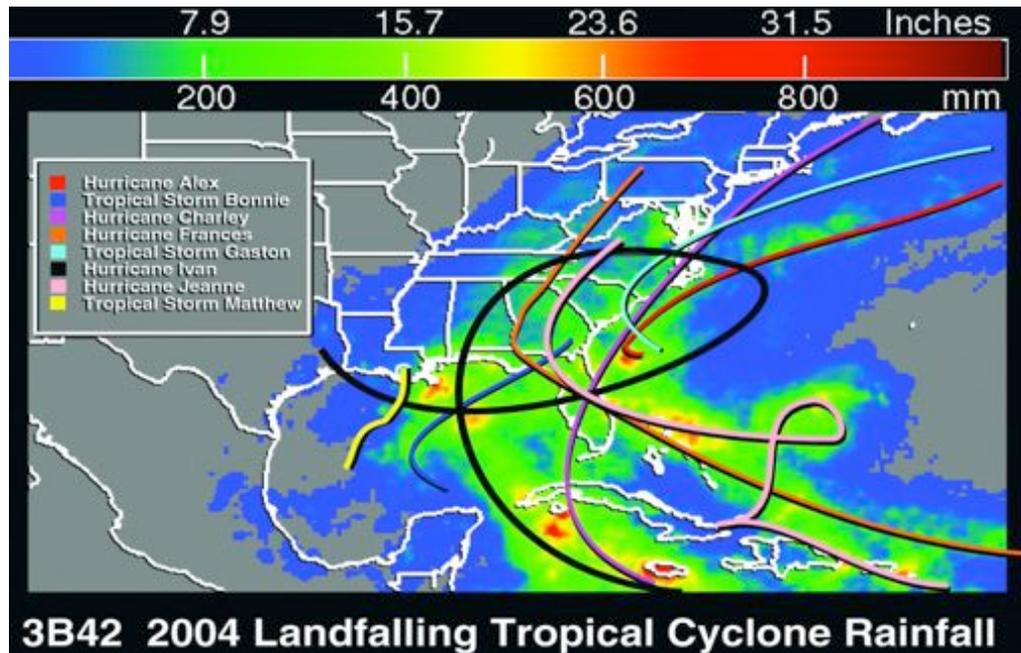


[trmm.gsfc.nasa.gov](http://trmm.gsfc.nasa.gov)

Jeff Halverson, TRMM Outreach Scientist



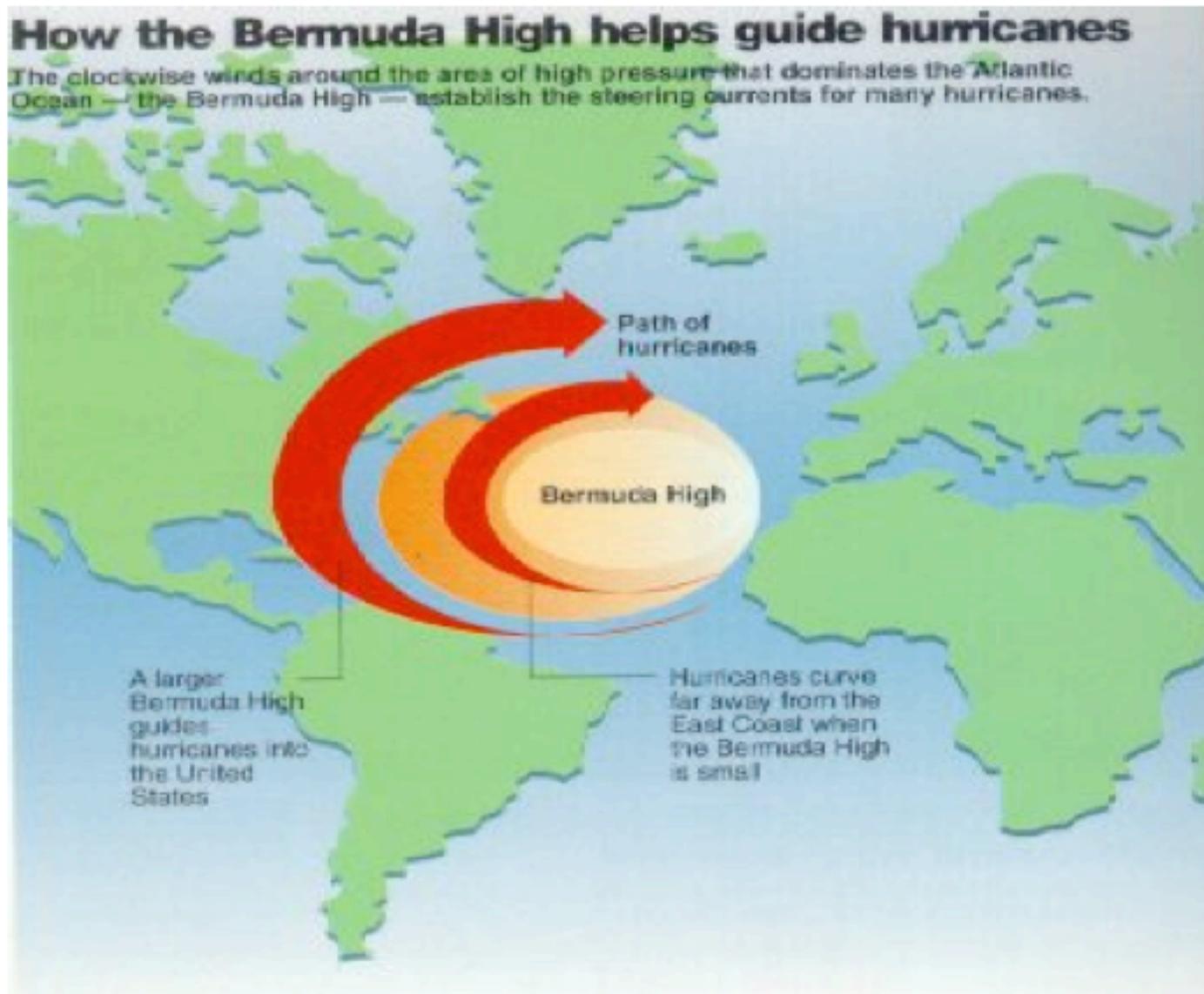
## What Was Going in the 2004 Hurricane Season?



- Did we re-enter a multi-decadal active phase of higher SST, Reduced Shear (possibly started 1995)???
- No El Nino
- SSTs were running ~1 deg warmer than average
- The Meteorology of Atlantic High Pressure
- Other Factors



# Florida Really Didn't Have A Bulleye's Eye, Blame High Pressure



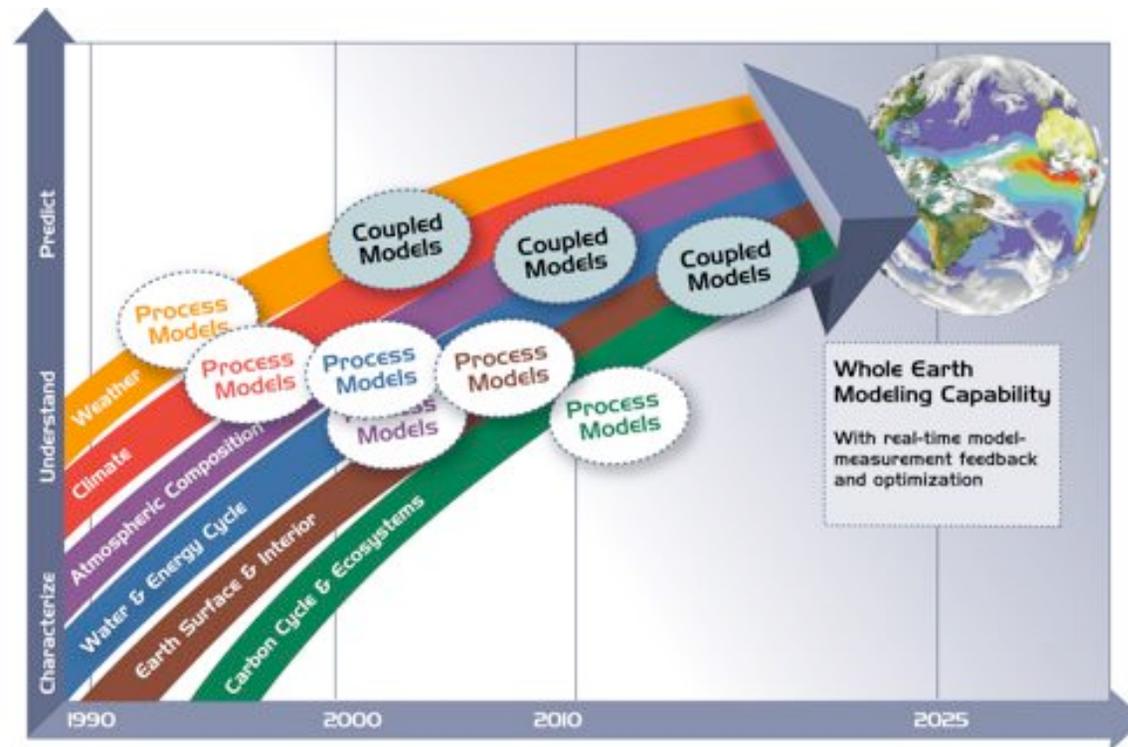


# 2004's Famous Florida Four





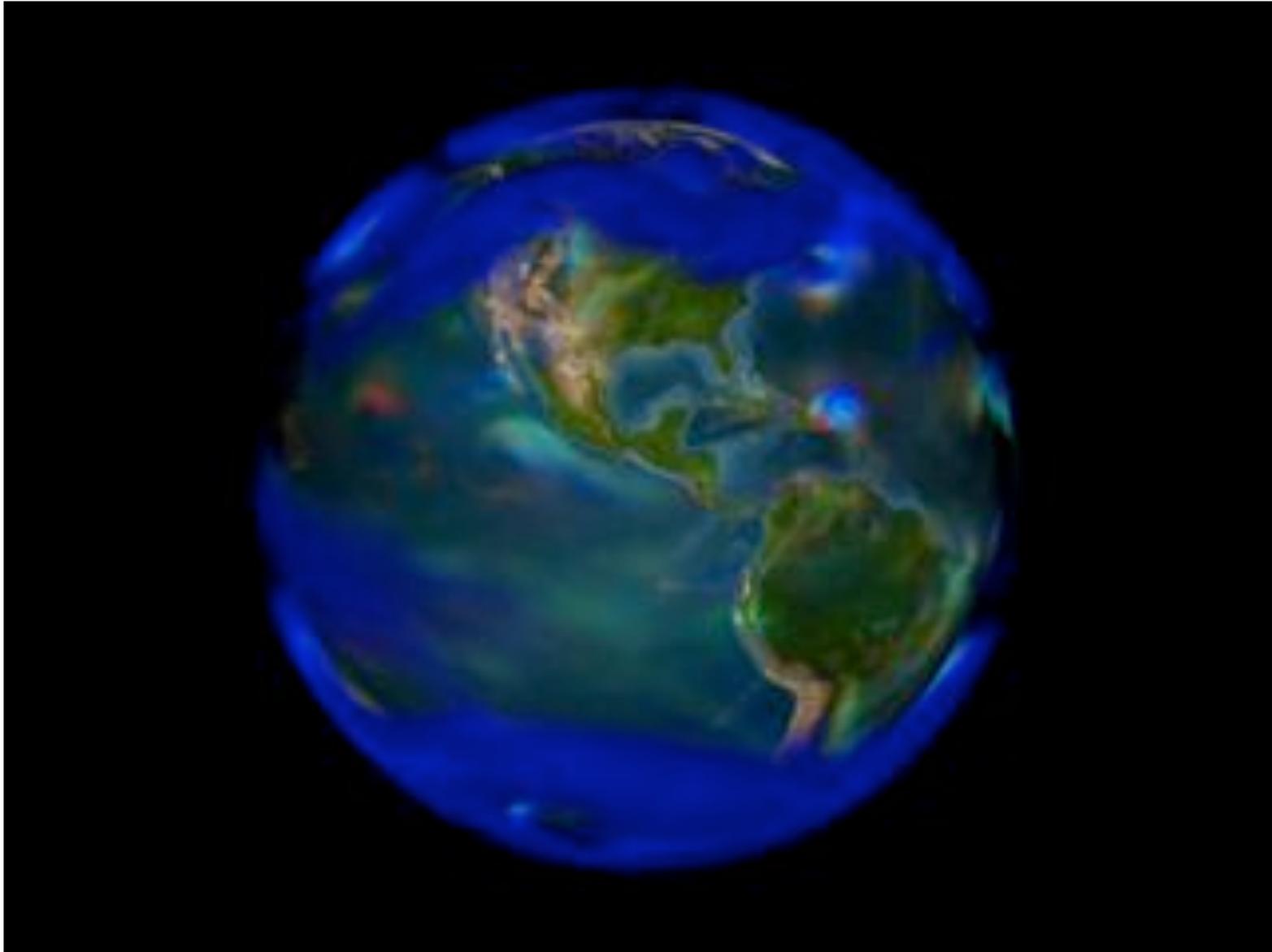
# Dr. Robert Atlas will discuss recent advances in global Modeling of Hurricanes and NASA's Role





# Global Model of Hurricanes in 2004

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# Flood Assessment



August 30, 2005



August 27, 2005

- Flood Extent of Katrina-Using NASA Satellite Data