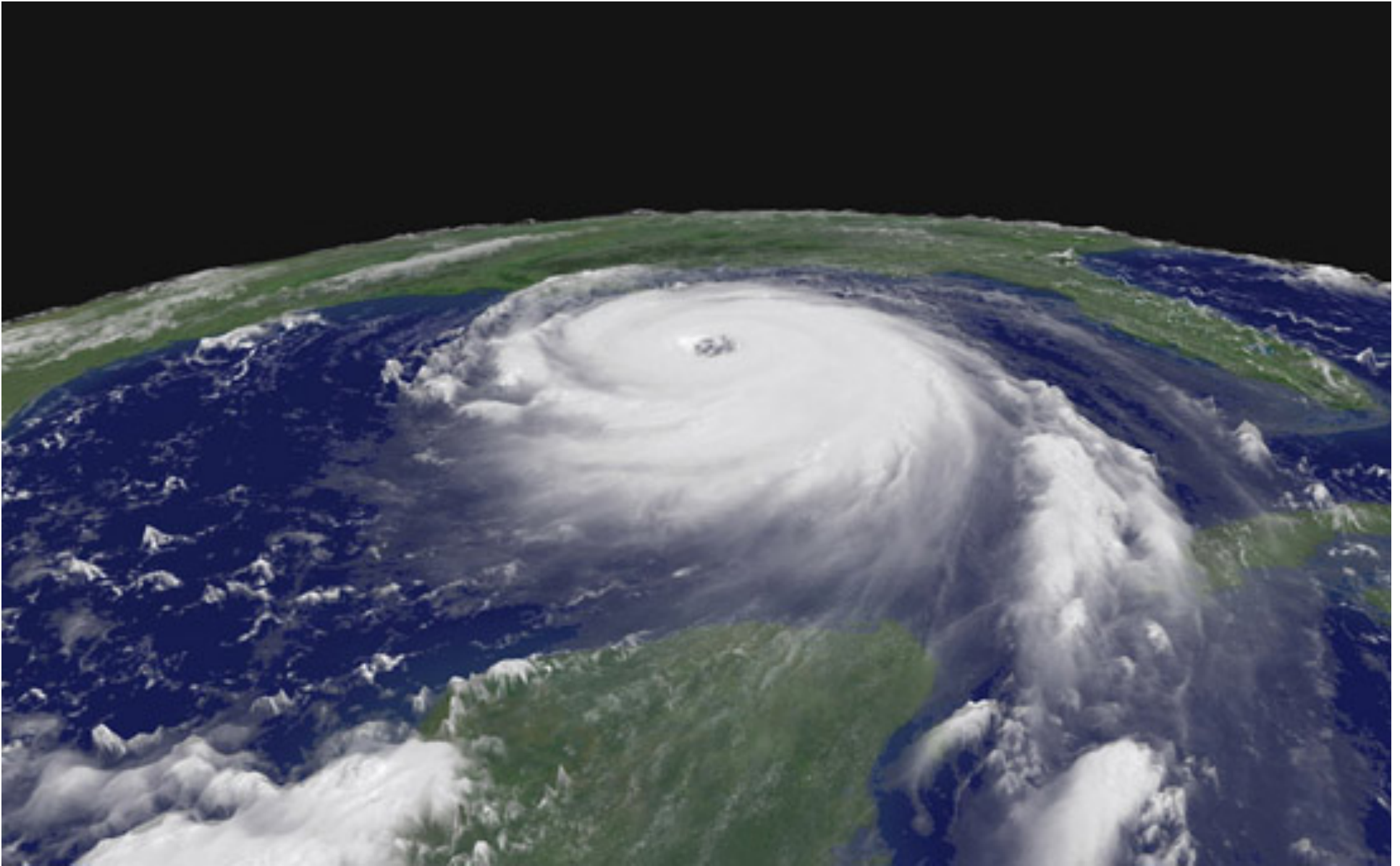


PCC 587, Fundamentals of Climate Change



DARGAN M. W. FRIERSON
DEPARTMENT OF ATMOSPHERIC SCIENCES

11/13/2013

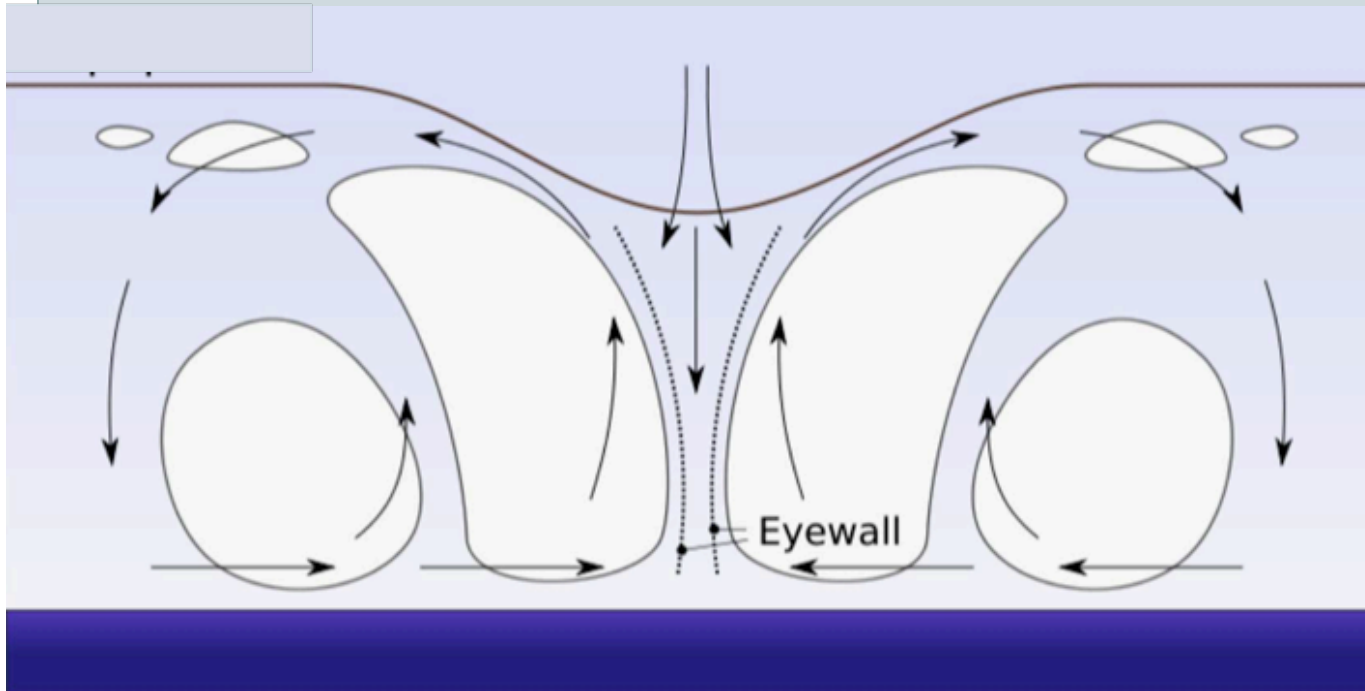


Huracan: evil Taino & Mayan god of winds & destruction

Profile of a Tropical Cyclone



- Hurricane = typhoon = cyclone
 - All different words for the same thing



Eye: clear area in the center

Eyewall: clouds immediately surrounding eye (highest winds & rain)

Spiral rain bands: outer raining areas

- **Rising** areas have **rain & clouds**, **sinking** areas are **dry**

Hurricane Katrina

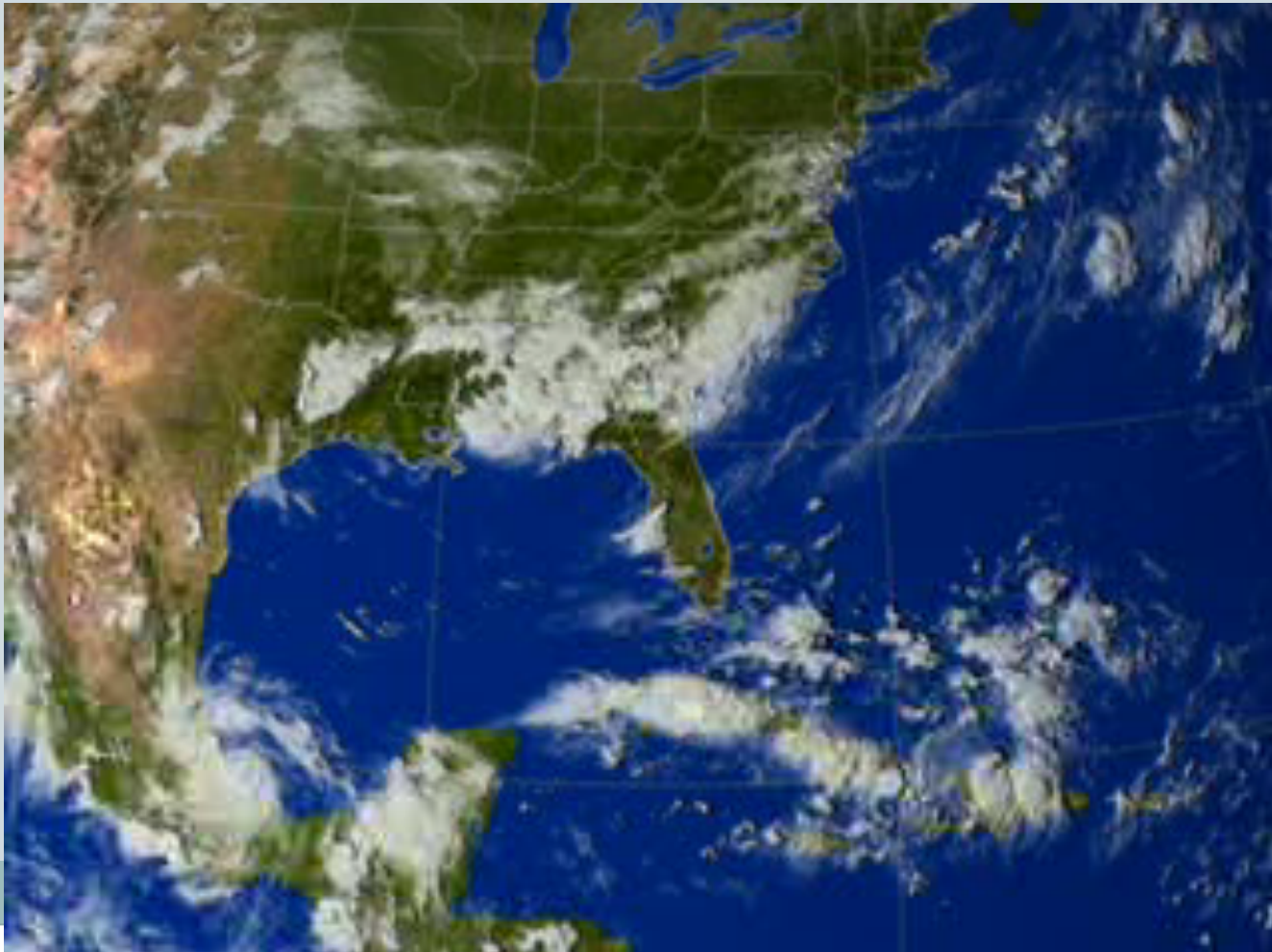
August 28, 2005



Hurricane Katrina



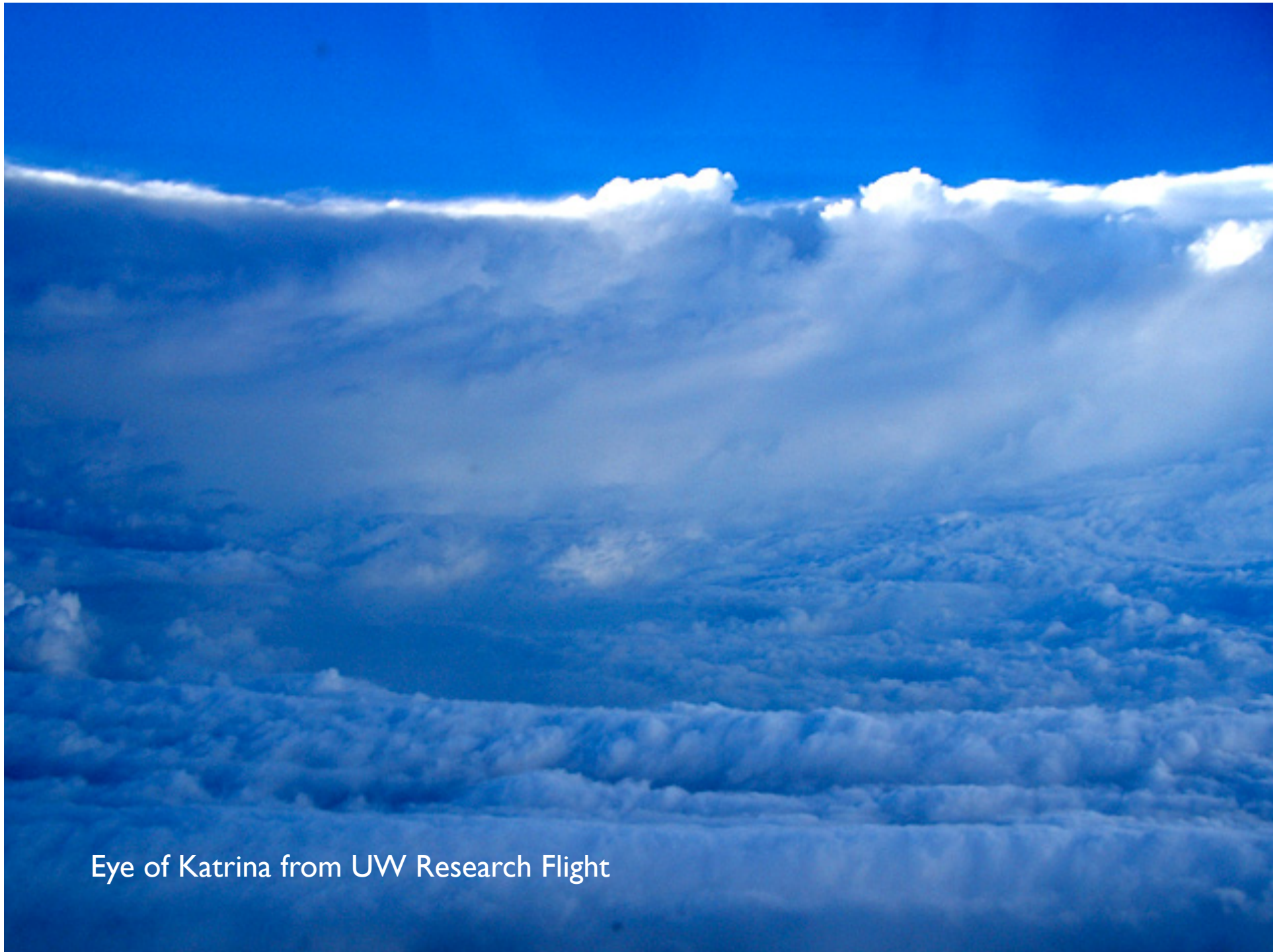
- Clouds and rain accumulation



Flying in the Eye of Katrina

Research flight of Professor Houze, UW Atmos Sci





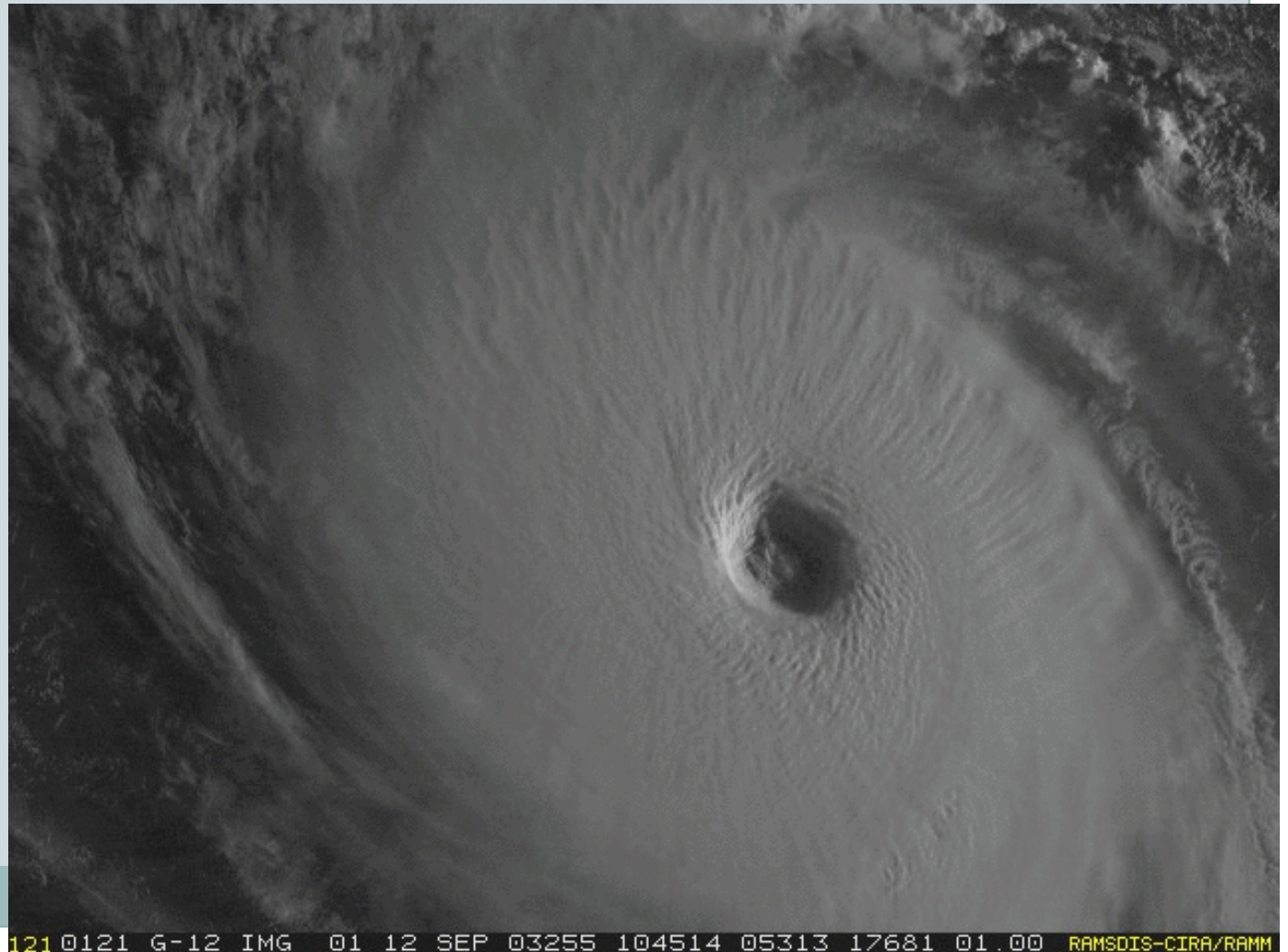
Eye of Katrina from UW Research Flight

Satellite Images of Hurricane Isabel

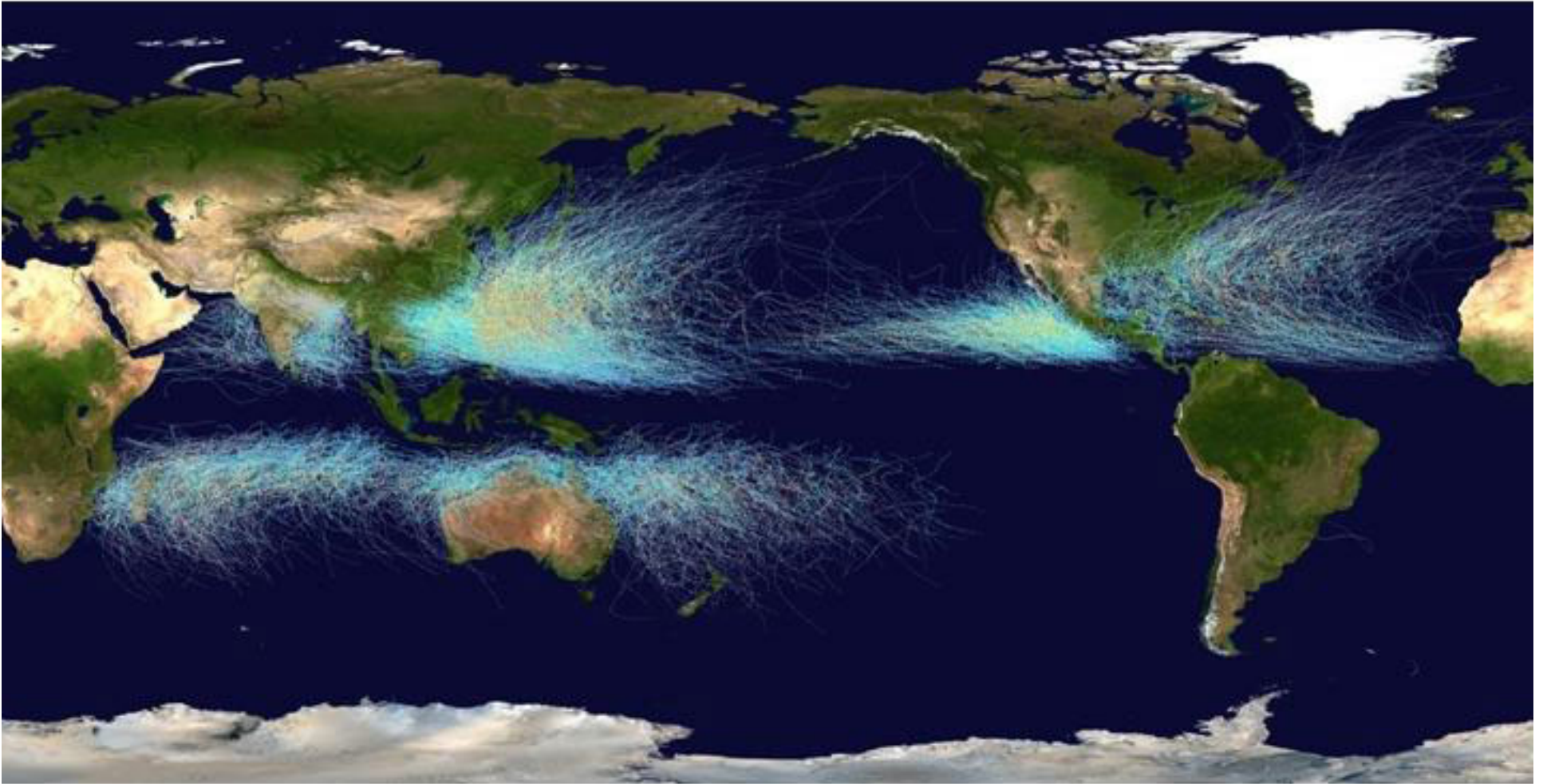


Some images here
(during the slow
parts) are shown
1 minute between
frames

Note eyewall
rotates very fast!
High winds there



121 0121 G-12 IMG 01 12 SEP 03255 104514 05313 17681 01.00 RAMSDIS-CIRA/RAH1

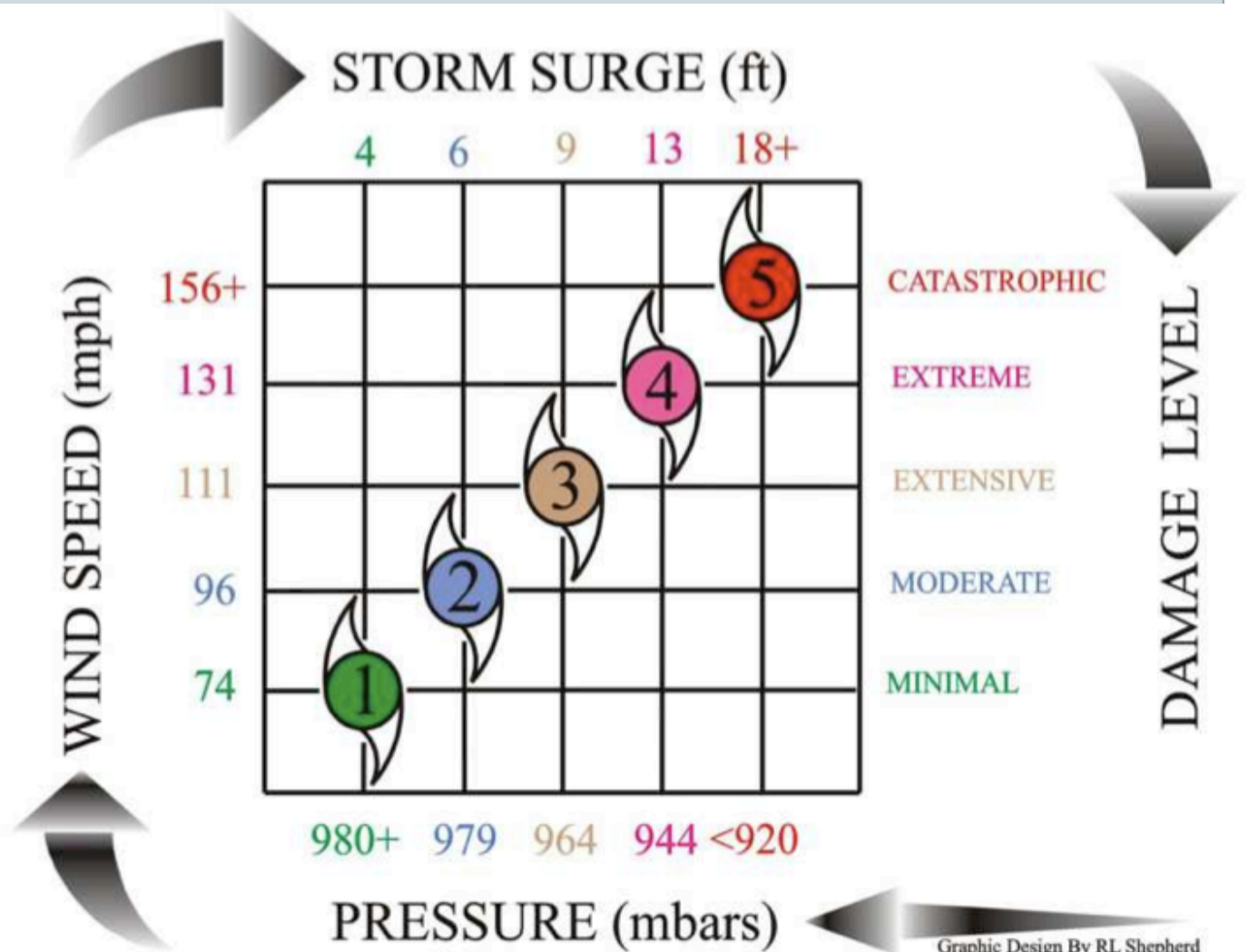


Worldwide hurricane tracks

Hurricanes occur over the **warmest** waters...
But not right at the equator! (Coriolis force is required)

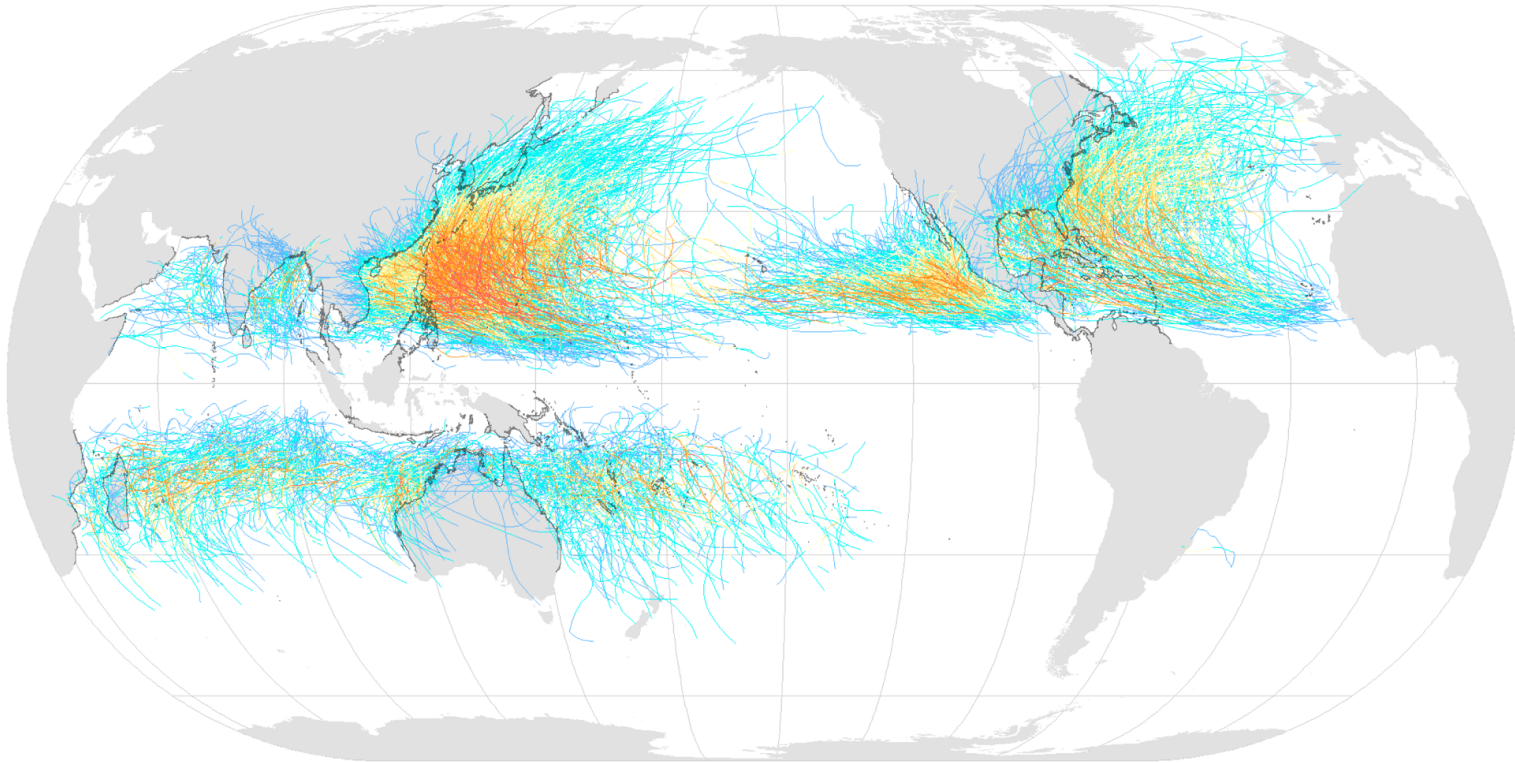
Saffir-Simpson Hurricane Scale

Higher category
= higher winds
= more storm
surge
= lower pressure
in the eye



Tracks Colored by Category

Tropical Cyclones, 1945–2006



Saffir-Simpson Hurricane Scale:

tropical
depression

tropical
storm

hurricane
category 1

hurricane
category 2

hurricane
category 3

hurricane
category 4

hurricane
category 5

- Many strongest storms are around Taiwan, Philippines

Evaporation and Condensation in Hurricanes



- **Condensation** is the energy source & **evaporation** provides the fuel
 - The **strong winds** in hurricanes causes **more evaporation** from the ocean surface
- **Warm ocean temperatures: first requirement** for hurricanes
 - Hurricanes weaken when they pass over land due to lack of evaporation

Requirements for Hurricanes

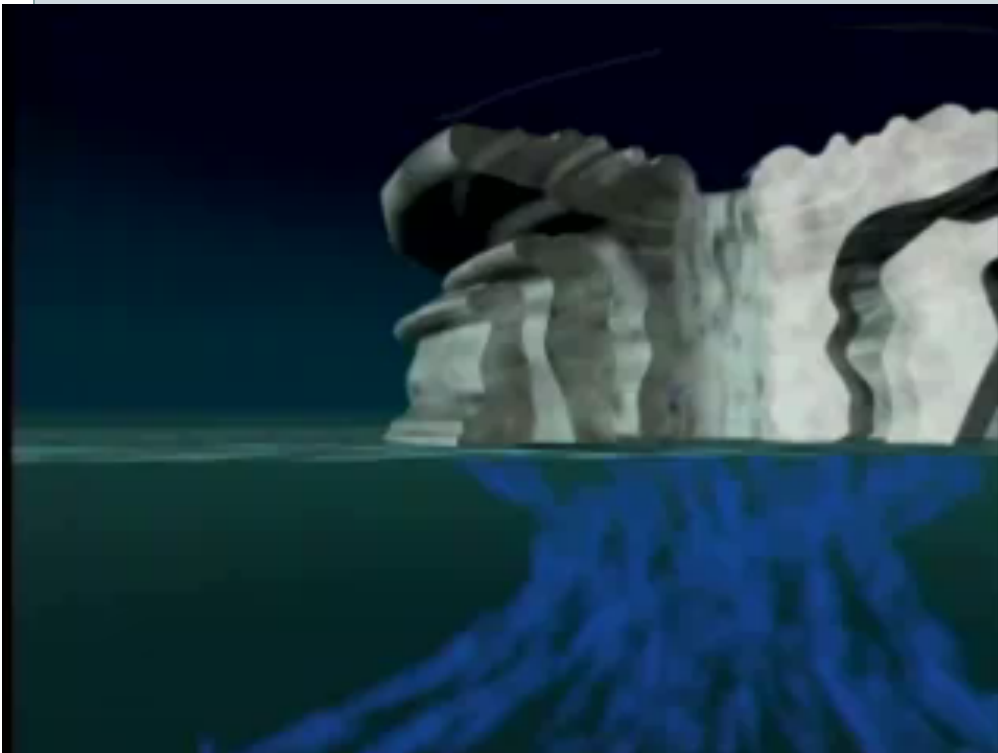


- Sea surface temperatures must be above 26° C (79° F)
 - This should shift to a warmer temperature threshold in a warmer climate though
- Must be at least 5 degrees off the equator
 - Coriolis force is required (Coriolis force is why storms rotate opposite in Northern and Southern Hemispheres)
- Not much wind shear
 - Wind shear: when the winds change with height
 - ✦ This rips hurricanes apart
- Can't be too cold below the surface either

Sub-surface temperatures



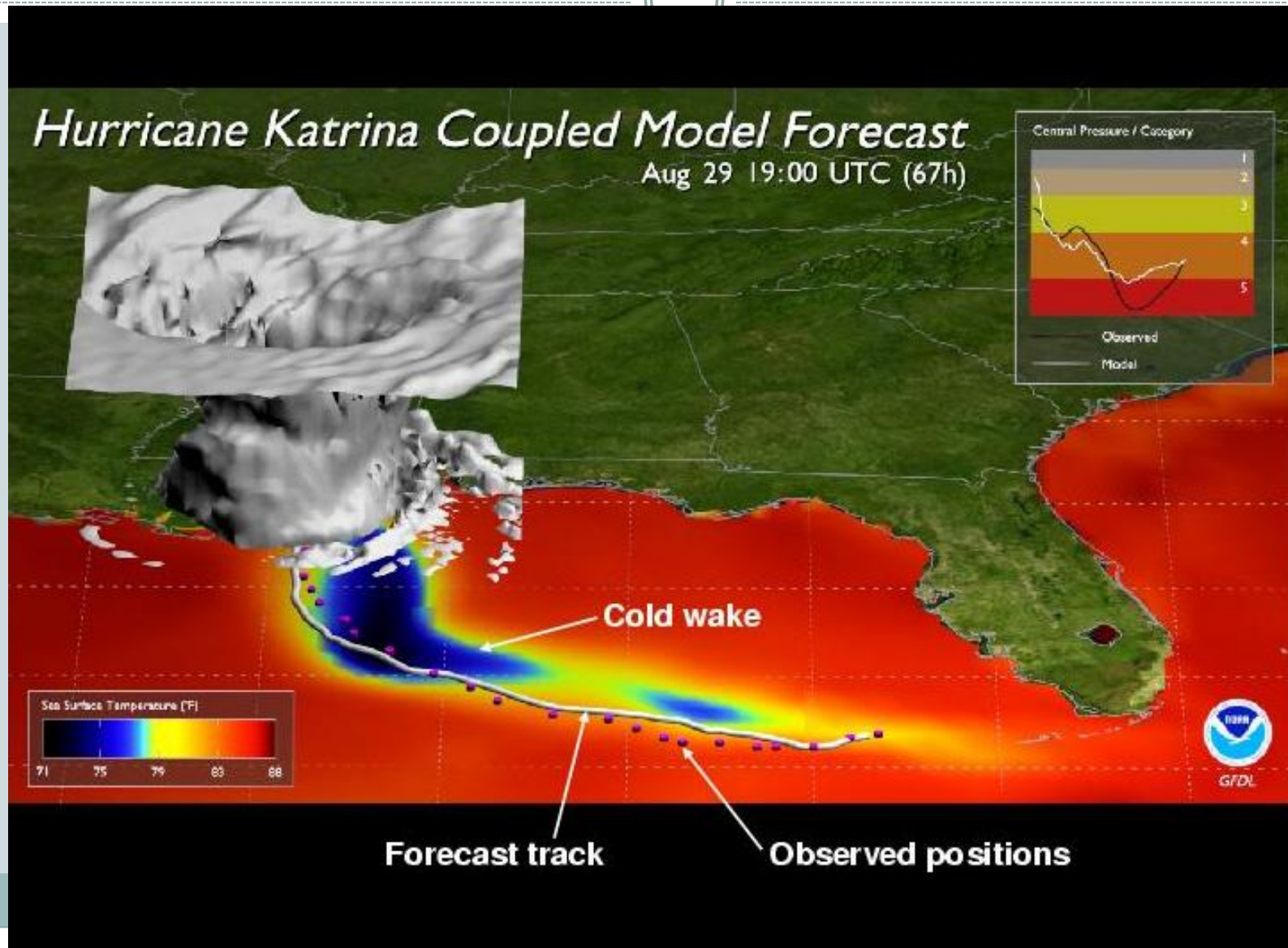
- When hurricanes pass by, they churn up colder water from below
 - You can see a cold wake in the surface temperature behind hurricanes



Here, the first storm churns up cold waters and leaves a cold wake.

The second storm loses strength when it intersects the cold water trail.

Cold Ocean Temperatures in Katrina's Wake



Hurricane Damages

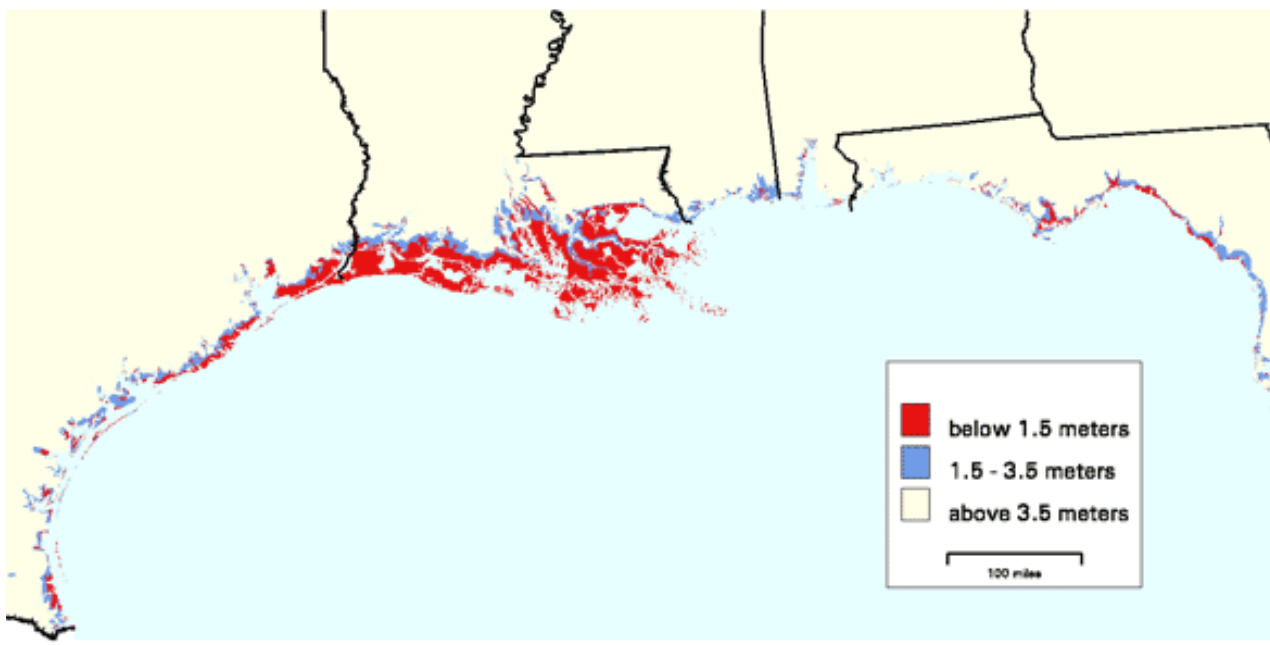
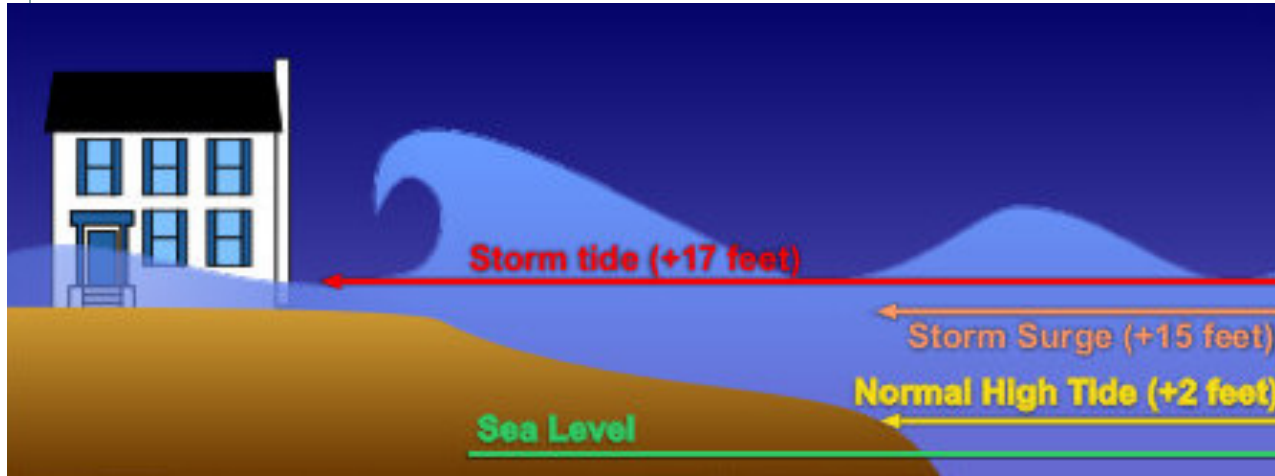


- Damages in hurricanes are caused by:
 - Winds
 - Storm surge
 - ✦ High winds pushing water towards the land
 - Flooding
- Financial damages from hurricanes is increasing, but this is primarily due to more people living on the coast

Winds



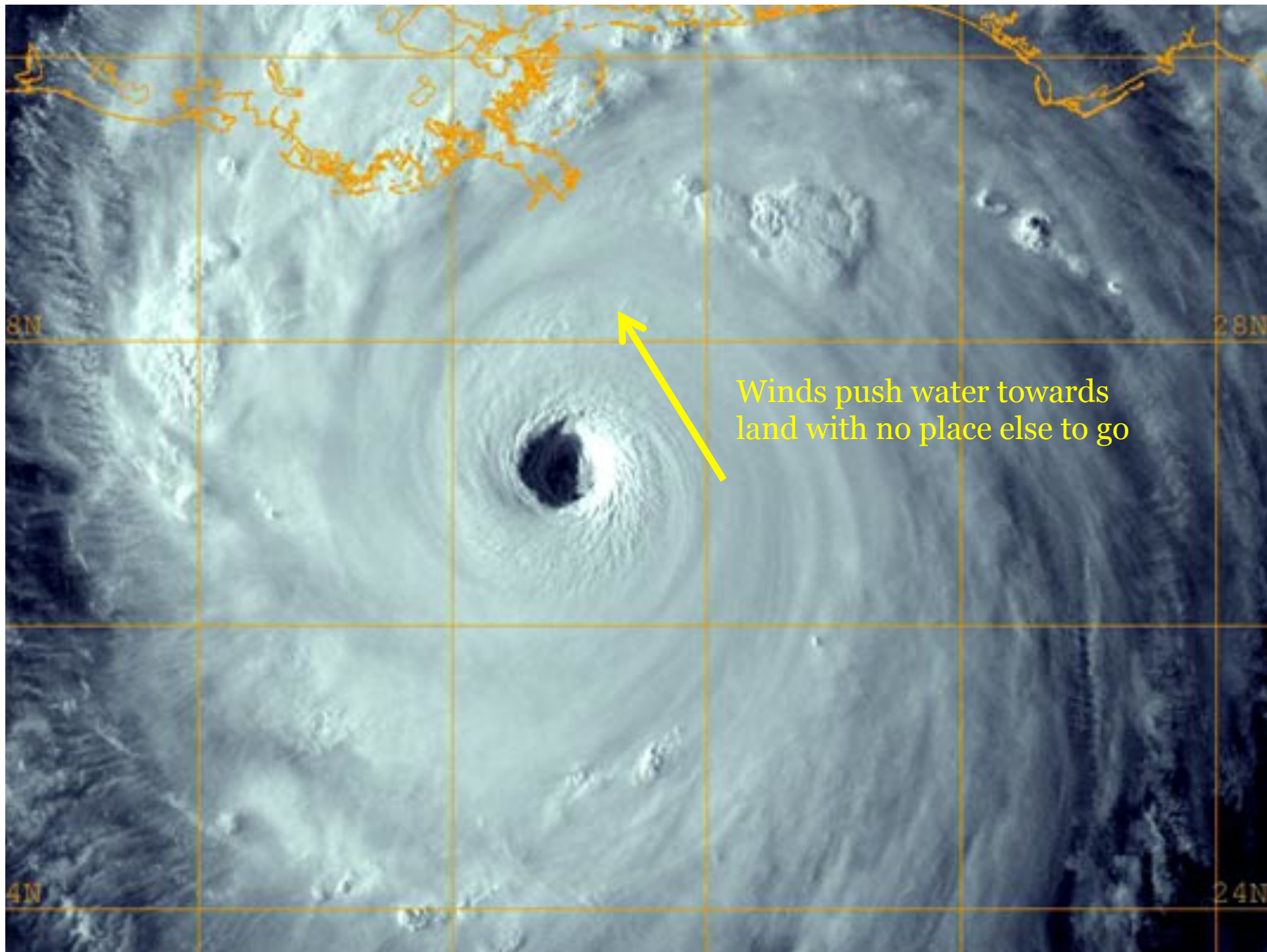
Storm surge



Storm Surge Before and After

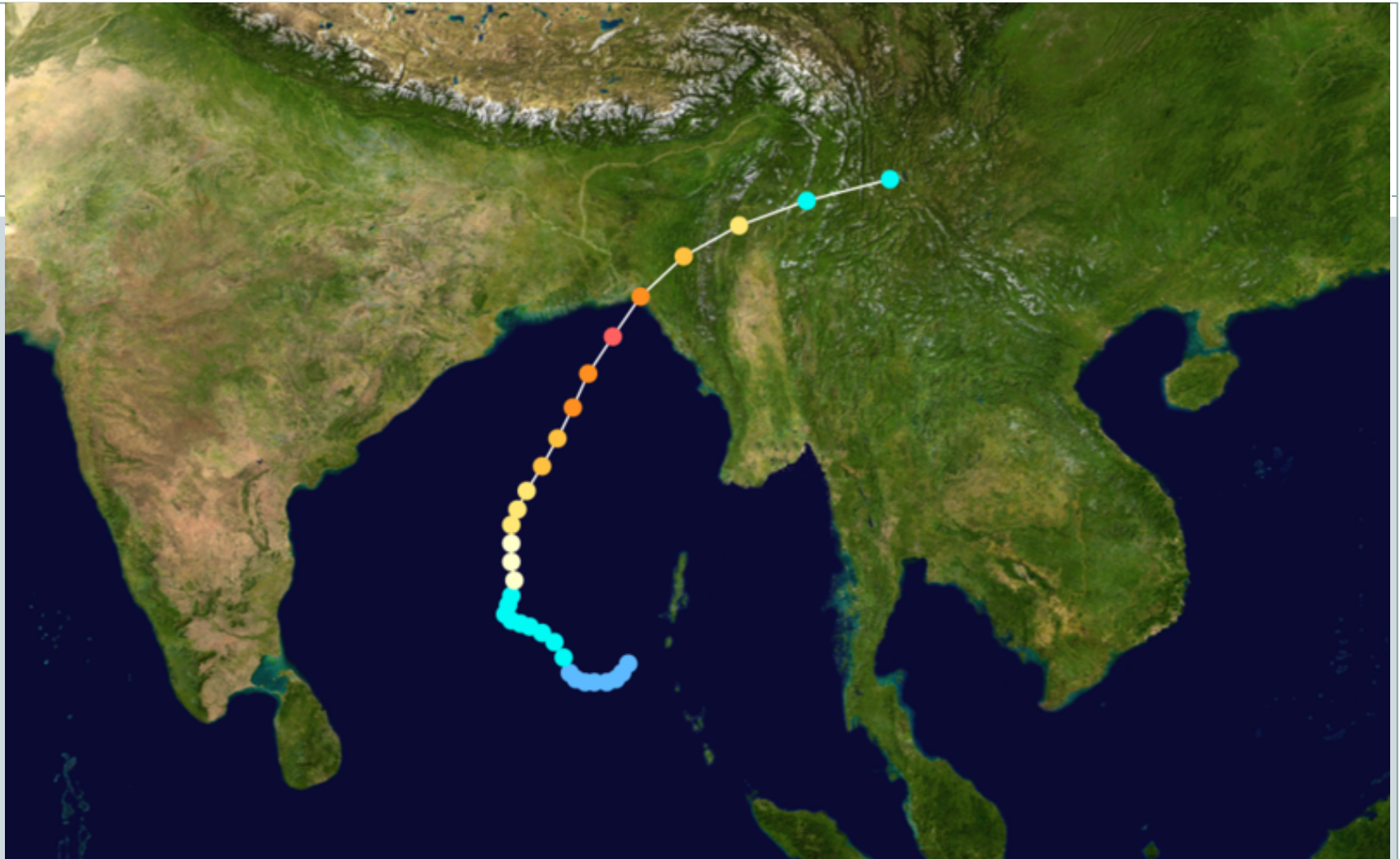


High winds pushing water towards the land



Flooding





1991 Bangladesh cyclone: 144,000 fatalities, left 10 million homeless

Hurricanes and Global Warming

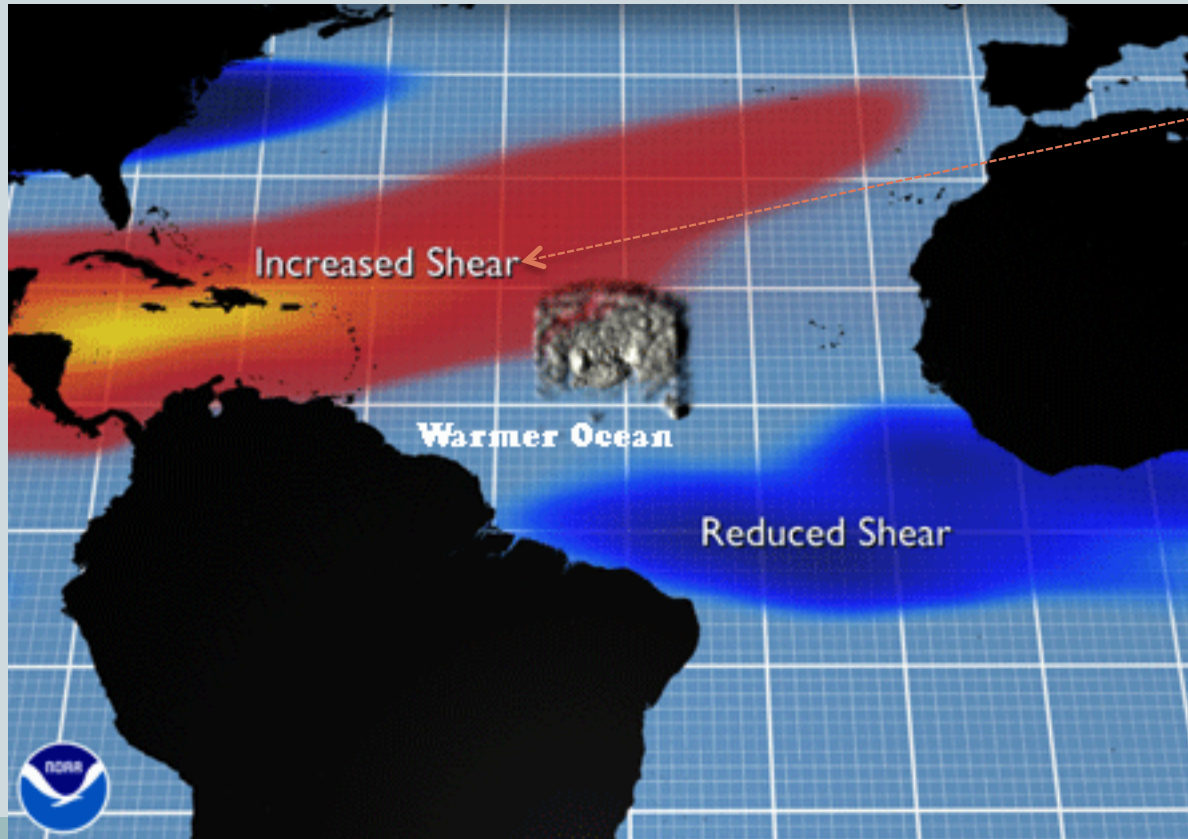


- Warmer temperatures means:
 - Warmer ocean
 - More water vapor in the air
 - ✦ Water vapor is like gasoline for hurricanes
- Shouldn't these mean stronger storms?
- Yes, but it's not so simple...

Shears Can Change...



- A prediction from a computer model of global warming



Increased shear over the Gulf of Mexico would act to *weaken* hurricanes

Would offset some of the increase in strength due to increased temperatures...

Also the **atmosphere tends to stabilize** when there's more moisture

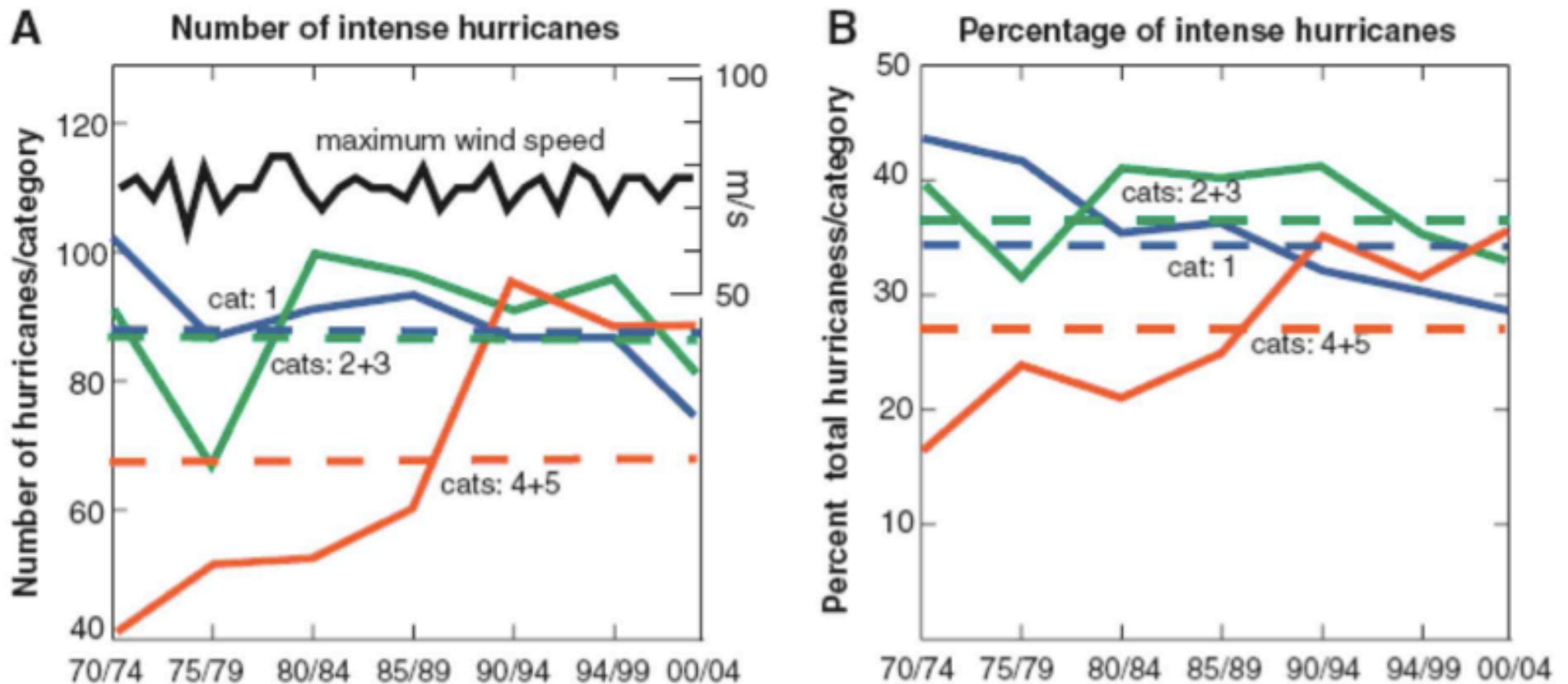
Have Hurricanes Been Changing?



- In 2005 in the Atlantic, there were:
 - 3 of 6 strongest storms ever (Wilma, Rita, and Katrina)
 - 27 named storms (smashing the previous record of 21)
 - ✦ Ran out of letters in the alphabet
 - Q, U, X, Y and Z are not used...
 - ✦ Had to use Alpha, Beta, Gamma, Delta, Epsilon, and Zeta
- But we know better to say that ***one season*** is due to global warming...
 - Plus, only **10%** of the world's hurricanes occur in the Atlantic

Recent Changes in Hurricanes Worldwide

- Recent study claims the strongest have increased



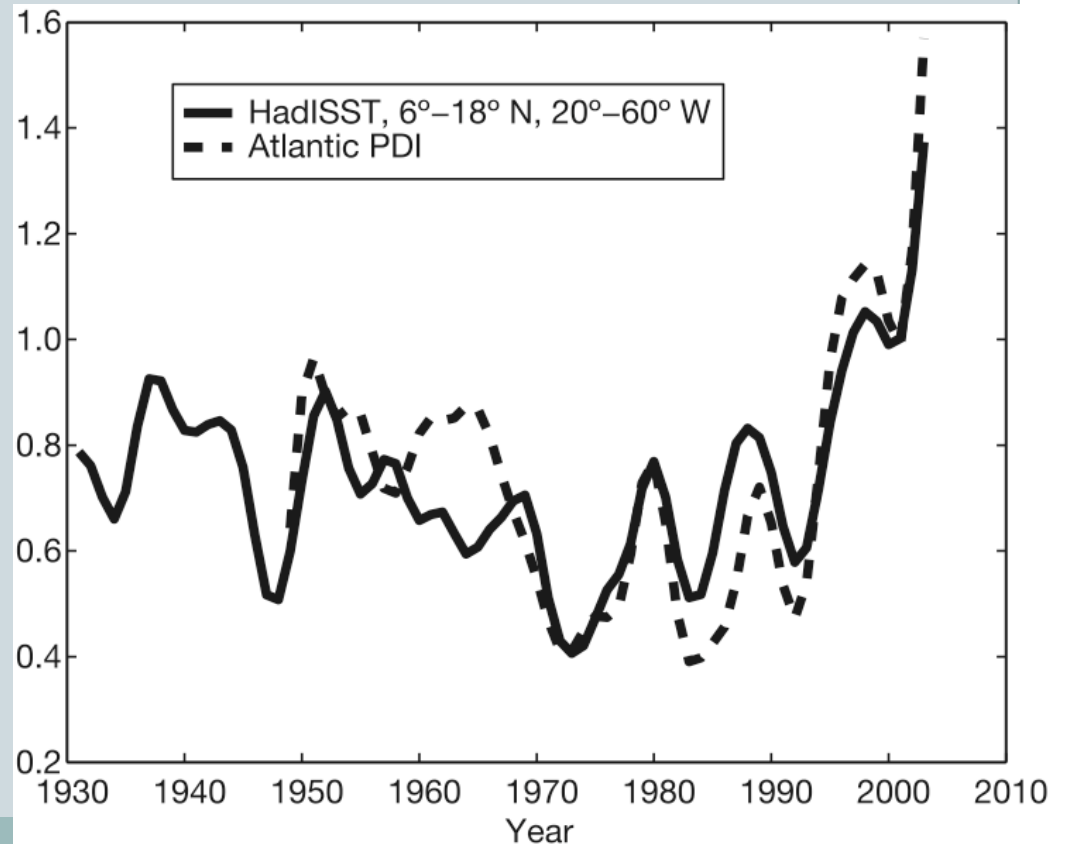
Claims Cat. 4 & 5 have increased 50%

Recent Changes in Hurricanes

- “Power dissipation index”: better measure of strength that combines **frequency**, **intensity** and **duration**

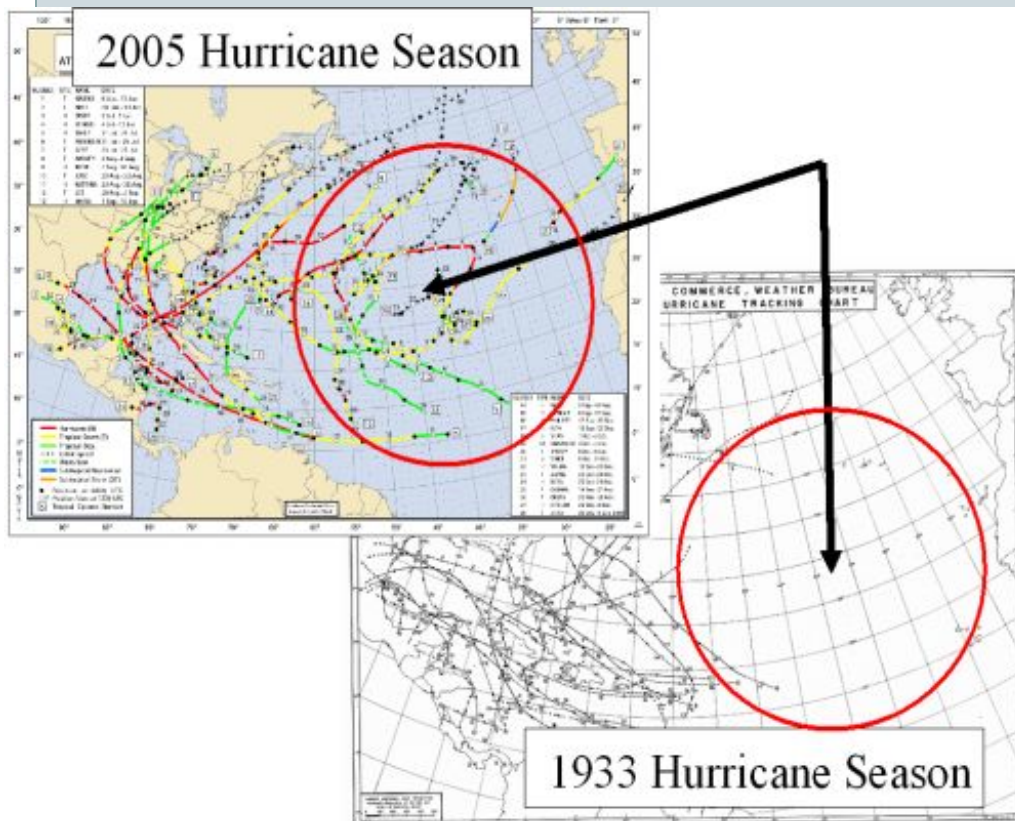
PDI in the Atlantic is highly correlated with Atlantic Ocean temperatures

This study suggests that hurricanes will continue to strengthen with global warming



Recent Changes in Hurricanes Worldwide

- Observational record with full coverage is relatively short though
 - Before the 1970s we didn't have satellite data



Paper by Chris Landsea argues that over the long term, recording instruments changed, not hurricanes

Observed Hurricane Changes



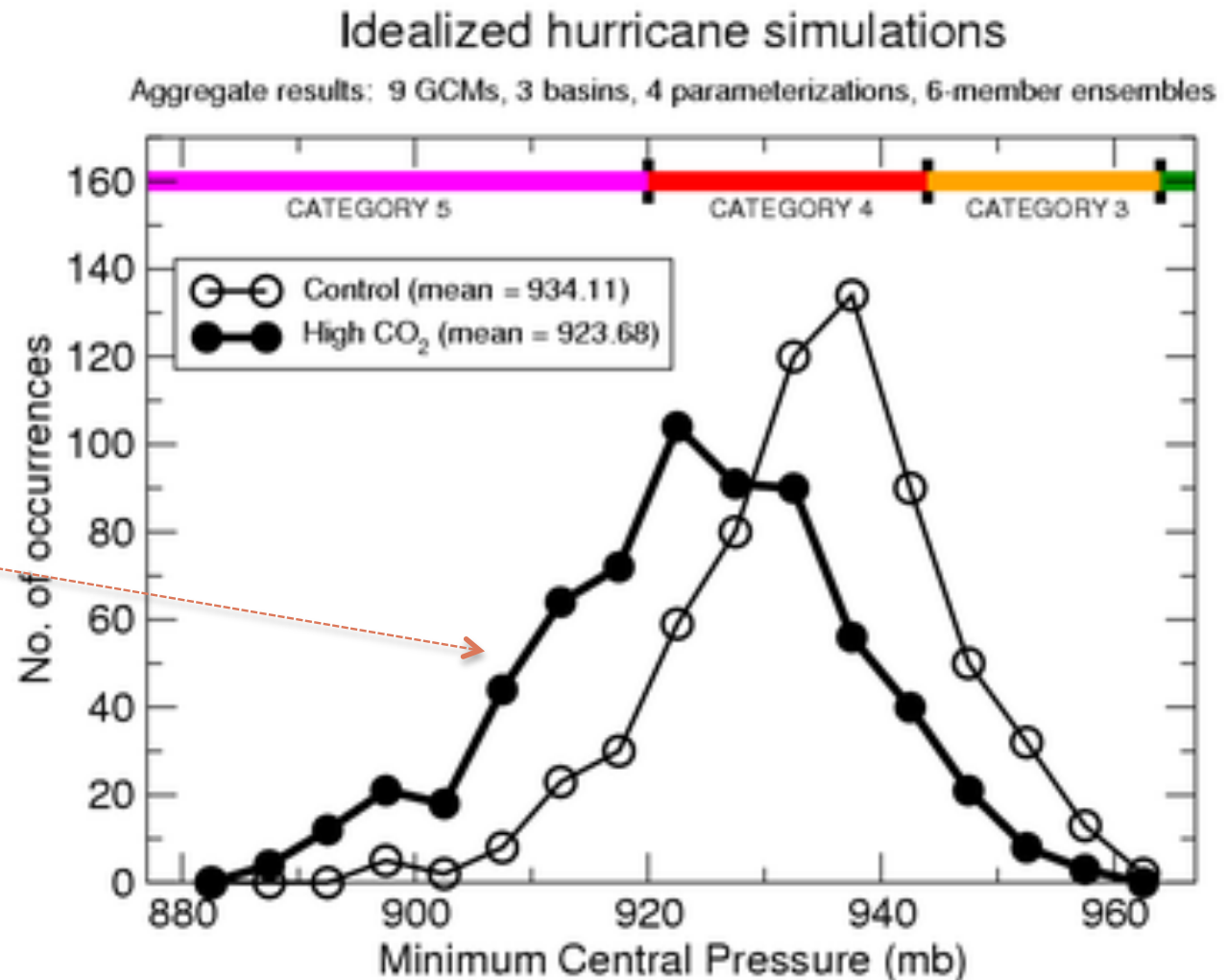
- Debate was rather heated for a while
- Results are still somewhat contentious
- Fundamental problem is that the observed record is short, and hurricanes are relatively rare events
- How about computer modeling results?
 - These are difficult too: global climate models aren't high enough resolution to capture hurricanes well

Recent model results are suggesting **fewer** but **more intense** storms



More really strong storms in warmer climate (darker line is high CO₂ climate)

Fewer storms overall though



← Stronger

Weaker →

Can individual hurricanes like Hurricane Katrina be attributed to global warming?

No

Can it be said that global warming made an individual hurricane like Hurricane Katrina stronger than it would have otherwise been?

Not a good way to frame the question. Confuses climate and weather.

Are hurricanes becoming more intense?

The evidence is suggestive, but not conclusive at this point.

Should we expect that hurricanes will become more intense?

Yes. Heavier rains, stronger winds, stronger storm surges.

Summary of Future of Hurricanes



- Data seems to show an increase in strength globally
 - Some argue that data quality is not good enough to make the case though
- Models suggest the **strongest** storms will become more frequent and stronger
 - But also a **reduction in the total number** of storms
- Should be much scientific progress in this field over the next decade!
 - As model resolution increases and we get more data