ATM S 111: Global Warming Hurricanes

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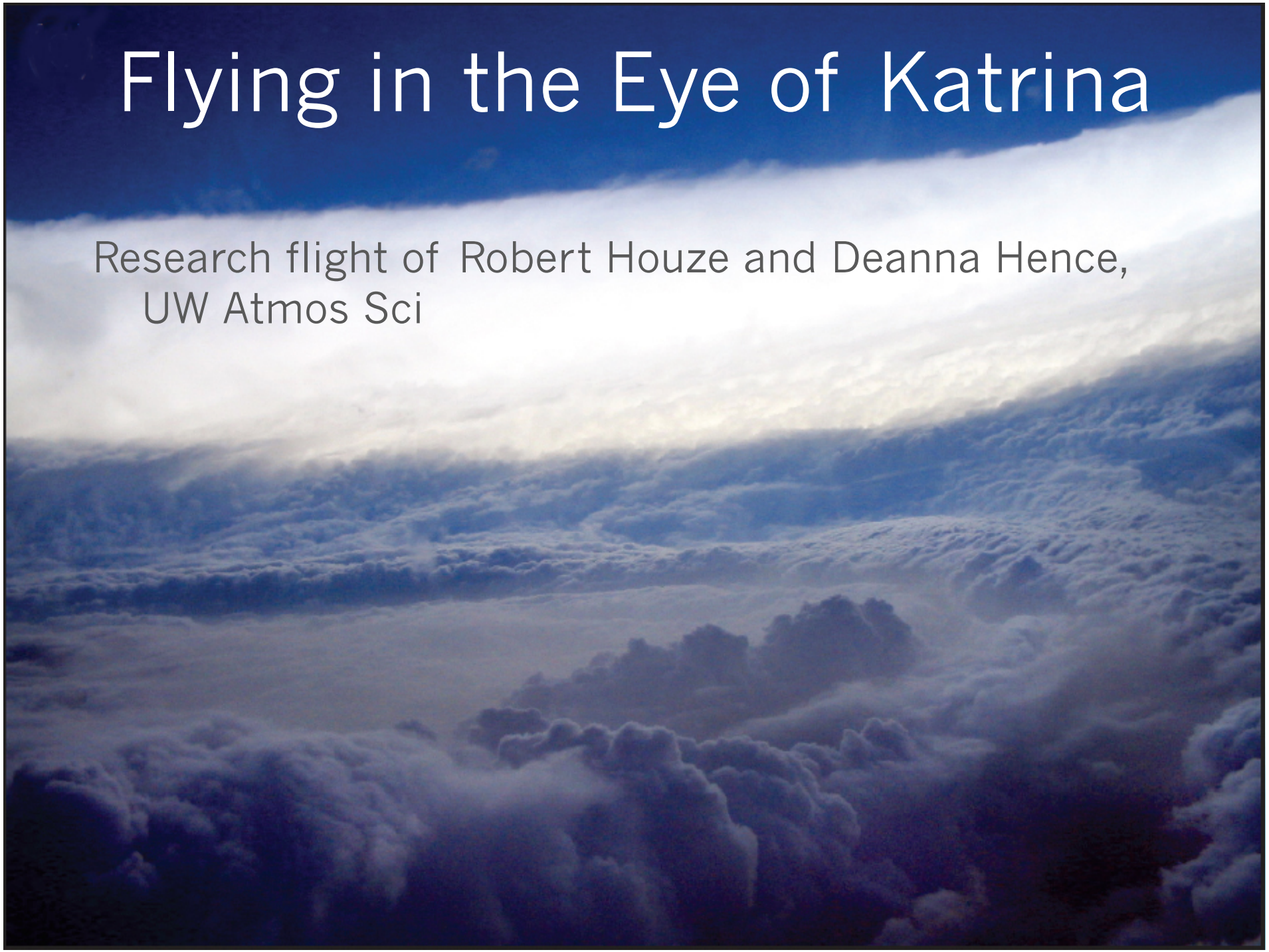
Day 19: July 19 2010


Hurricane Katrina
August 28, 2005

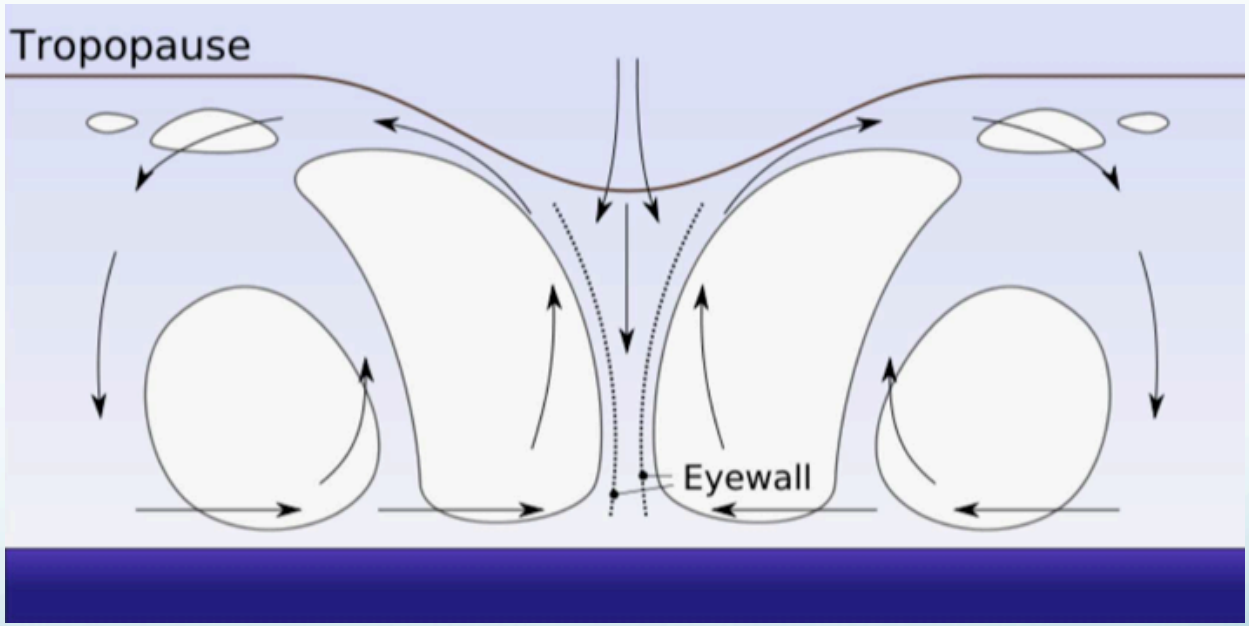
Flying in the Eye of Katrina



Research flight of Robert Houze and Deanna Hence,
UW Atmos Sci

Profile of a Tropical Cyclone

- Hurricane = typhoon = cyclone – all different words for the same thing
- Tropical cyclone is the generic term used by atmospheric scientists.

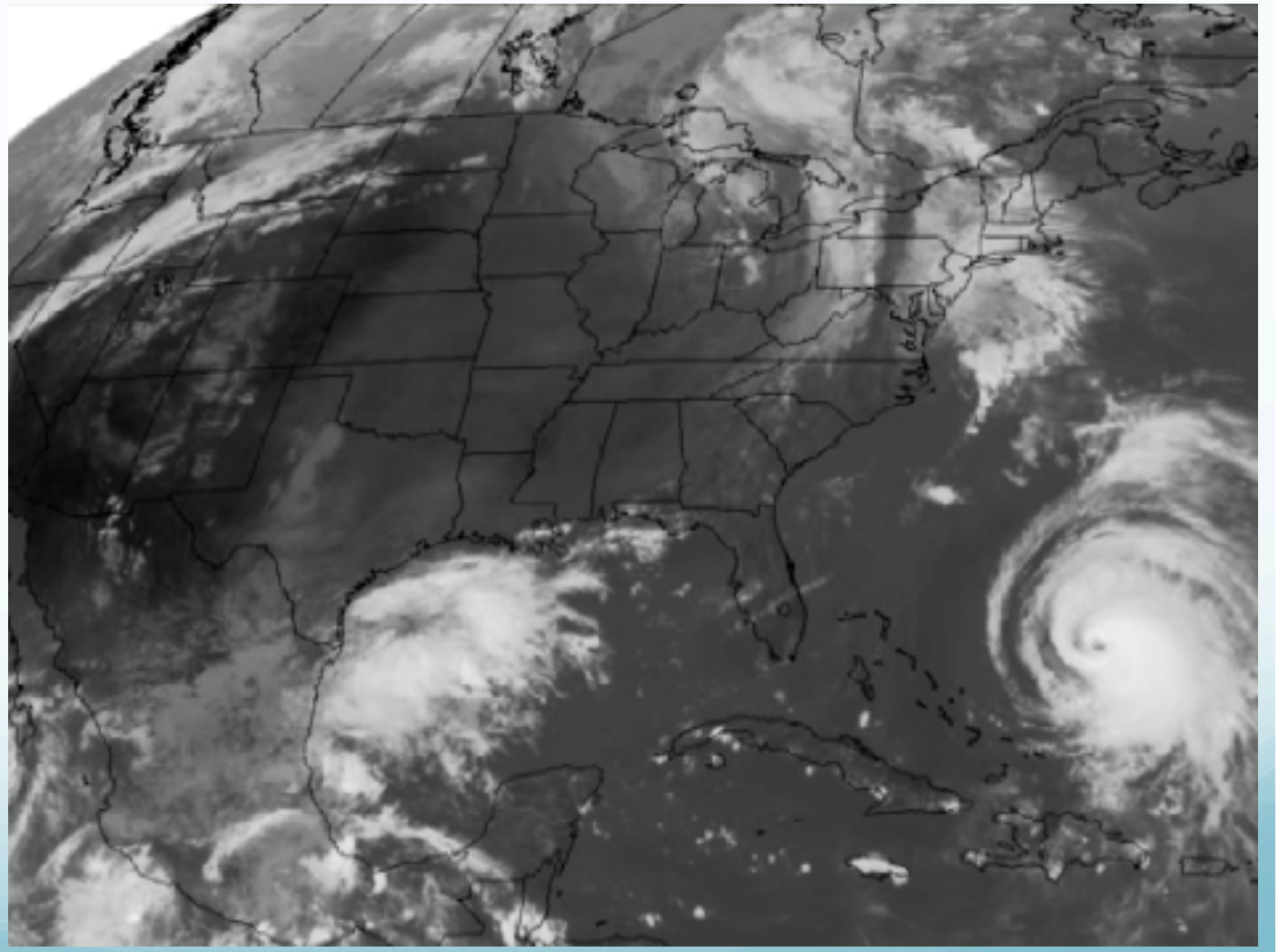


- **Rising** motion has **rain** & **clouds**, **sinking** motion is **dry**

Satellite Images of Hurricane Isabel

Hurricane dissipates shortly after landfall

Eyewall rotates very fast!
High winds there



What drives a hurricane?

- Turns out **water vapor** is the fuel
- Remember we said **evaporation** of water causes **cooling**?
  - This is how sweat cools you off
- The opposite happens when **water vapor condenses** (turns back into liquid)
  - **Heat is released** when **condensation** occurs
  - Condensation is like gasoline for hurricanes!

Condensational Heating

- Heat release from a hurricane:
  - 1.5 cm/day of average rainfall in a circle of radius 660 km
  - The heat released from this condensation is 52 quintillion Joules per day of energy
  - 200 times the world electricity generating capacity!

Evaporation and Condensation in Hurricanes

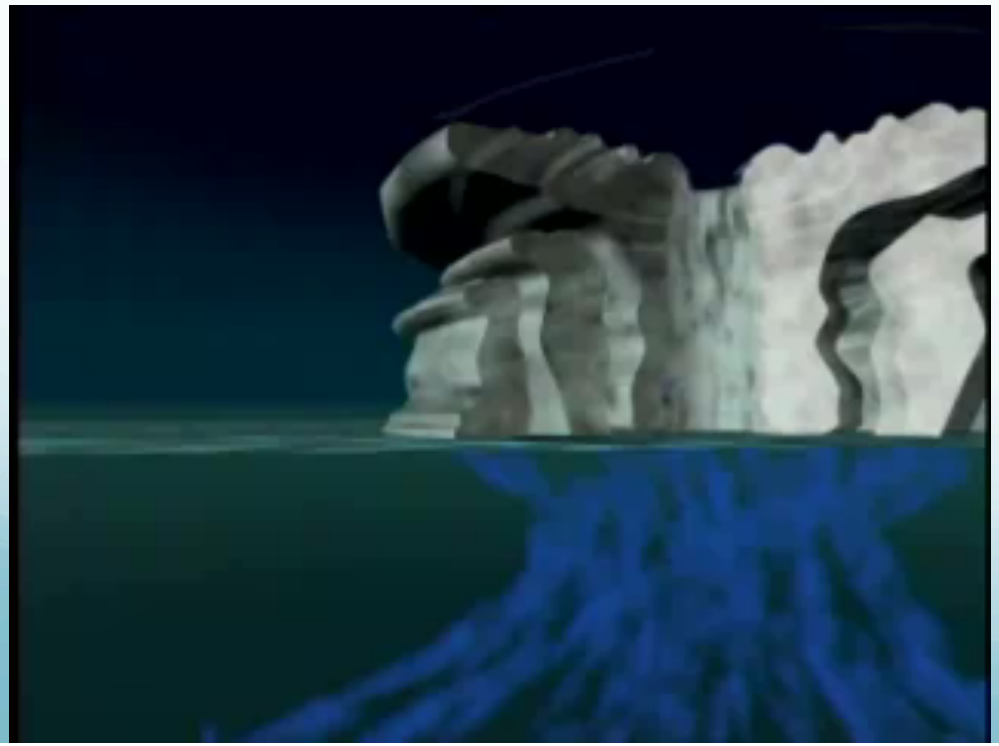
- **Condensation** is the energy source & **evaporation** provides the fuel
  - The **strong winds** in hurricanes causes **more evaporation** from the ocean surface
- Remember **warmer air** can hold more moisture
  - Also evaporation can occur more easily from a **warmer ocean**
- **Warm ocean temperatures**: first **requirement** for hurricanes

Requirements for Hurricanes

- Sea surface temperatures must be above 26° C (79° F)
  - This may shift to a warmer temperature threshold in a warmer climate though
- Must be at least 5 degrees off the equator
  - Fun fact: The Coriolis effect is required for hurricanes (and this is zero at the equator)
- Not much wind shear
  - Wind shear: when the winds change with height
    - This rips hurricanes apart
- Ocean temperatures must be warm a bit below the surface (~100 m)

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



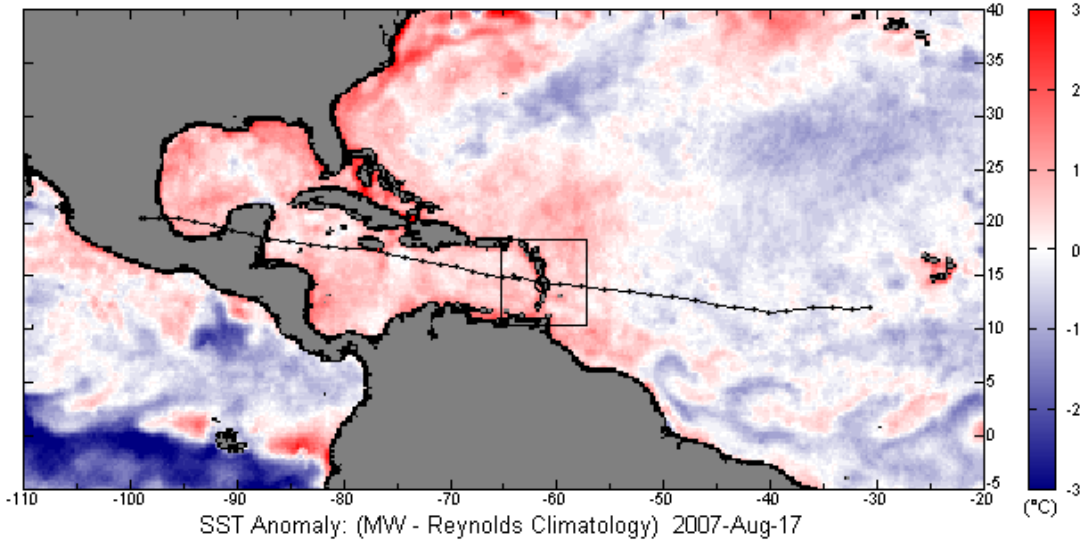
Here, the first storm churns up cold waters and leaves a cold wake.

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

Hurricane Dean's Cold Wake

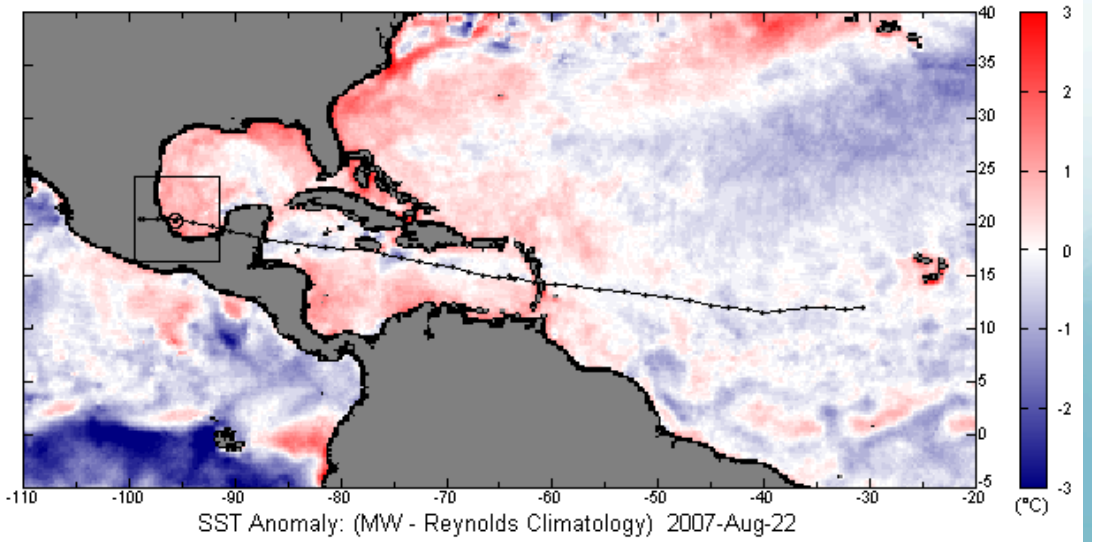
- Dean, 2007

Before:

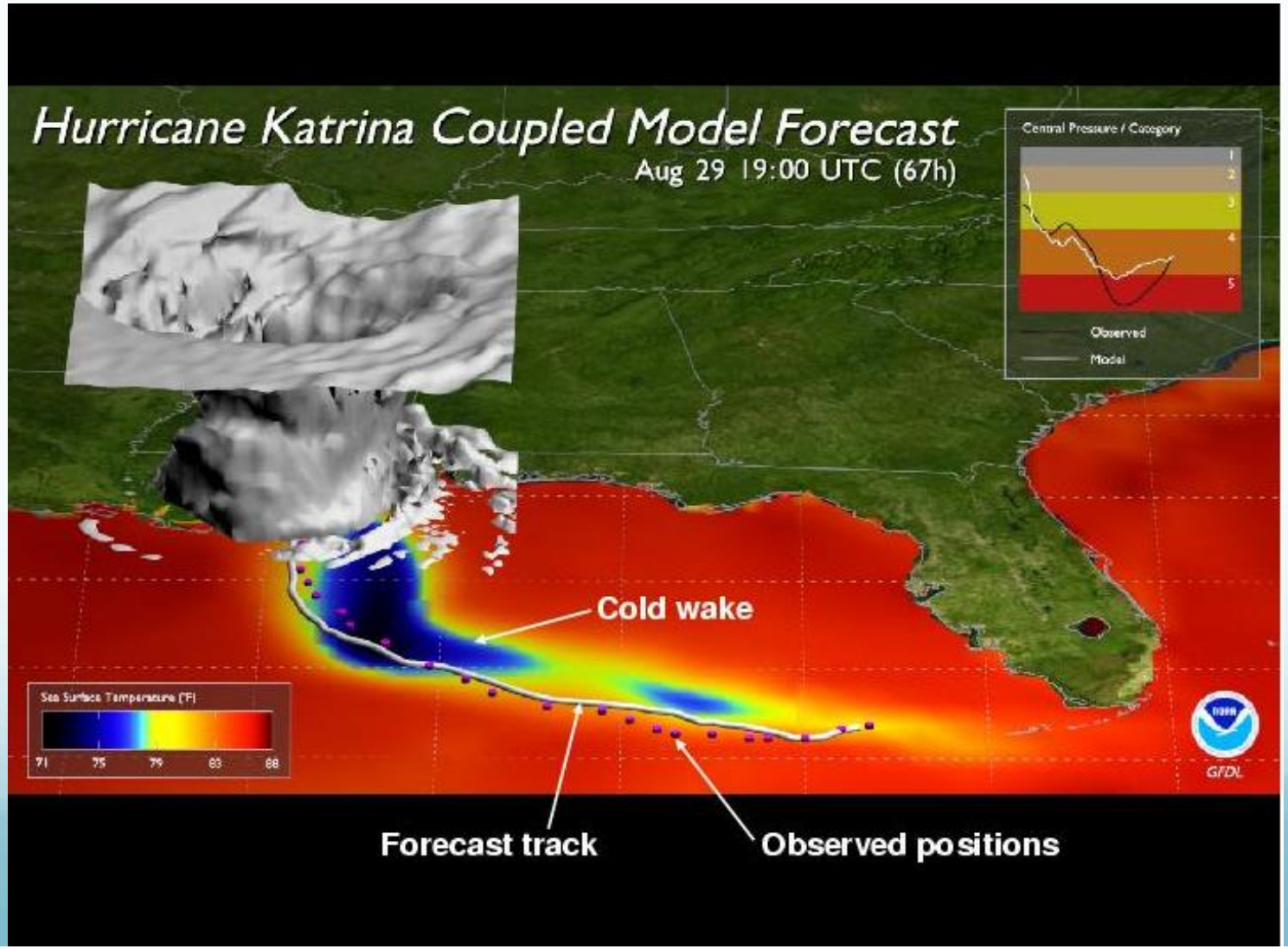


This process can keep a single hurricane from getting too strong

After:



Cold Ocean Temperatures in Katrina's Wake

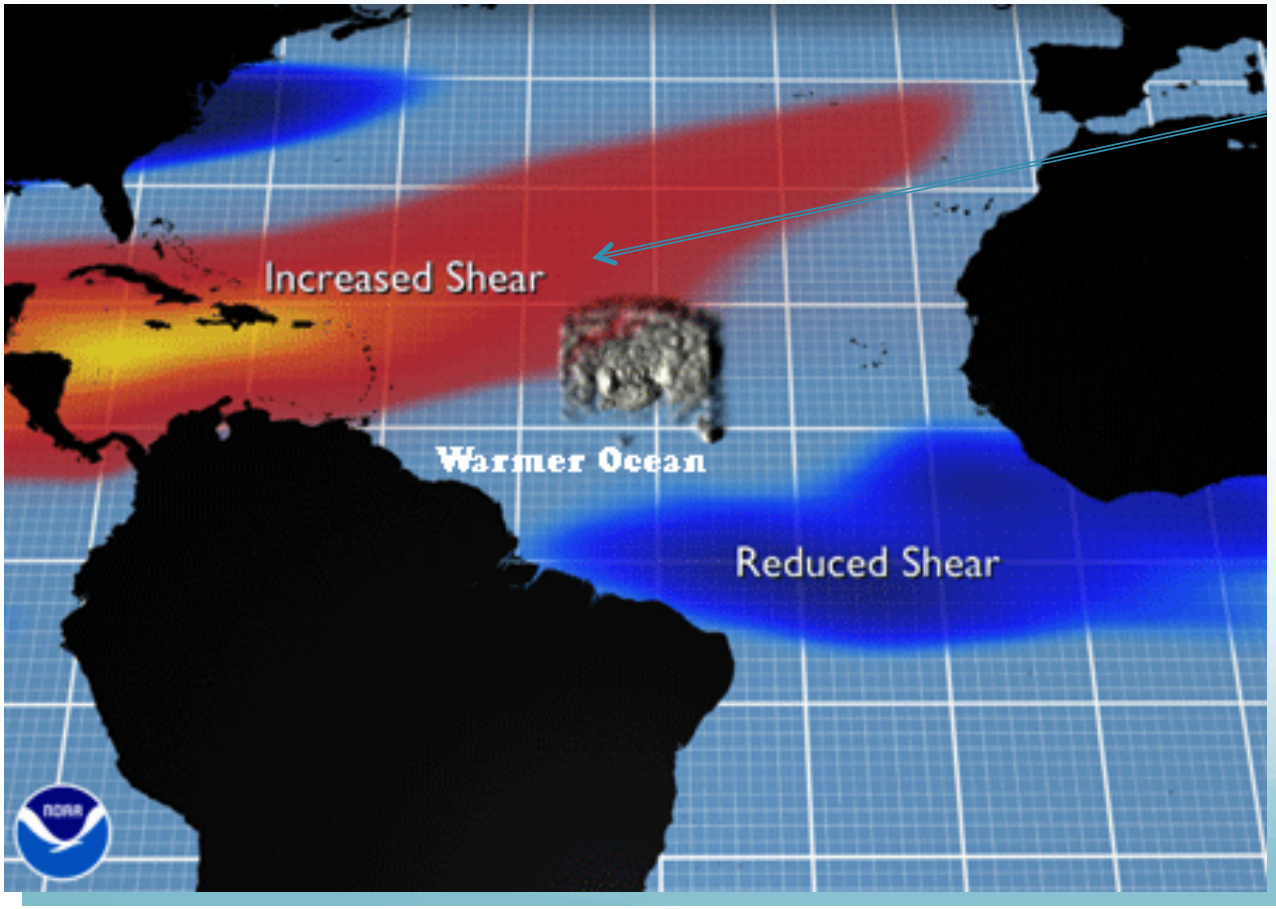


Hurricanes and Global Warming

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

Shear Can Change...

- Wind shear is how much the wind speed/direction changes as you go up in altitude.
- Lots of shear tends to tear tropical cyclones apart.



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

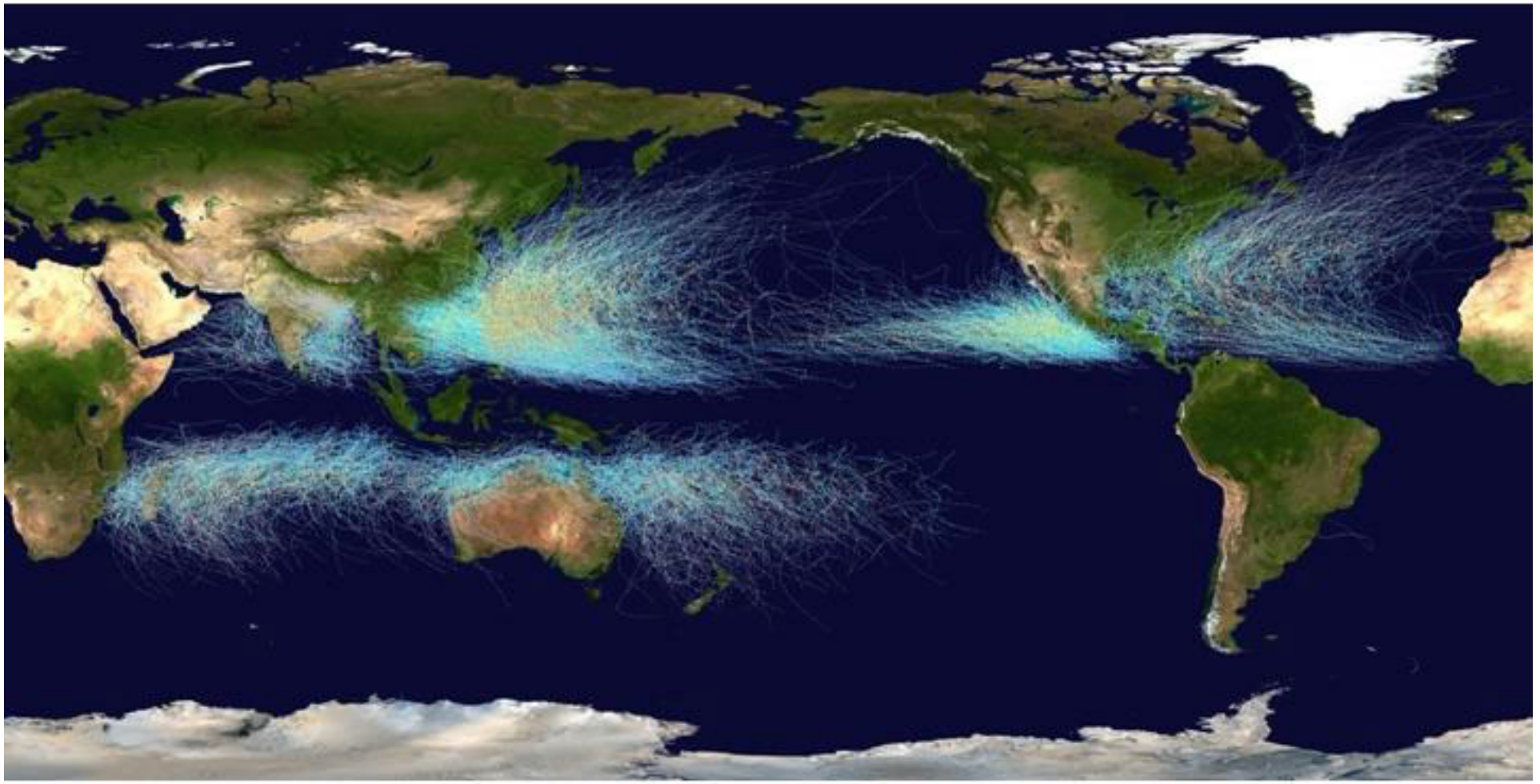
Such a change would offset some of the increase in strength due to increased temperatures in this part of the world...

A prediction from a computer model of global warming

Have Tropical Cyclones 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, it turns out that only 10% of all tropical cyclones occur in the Atlantic

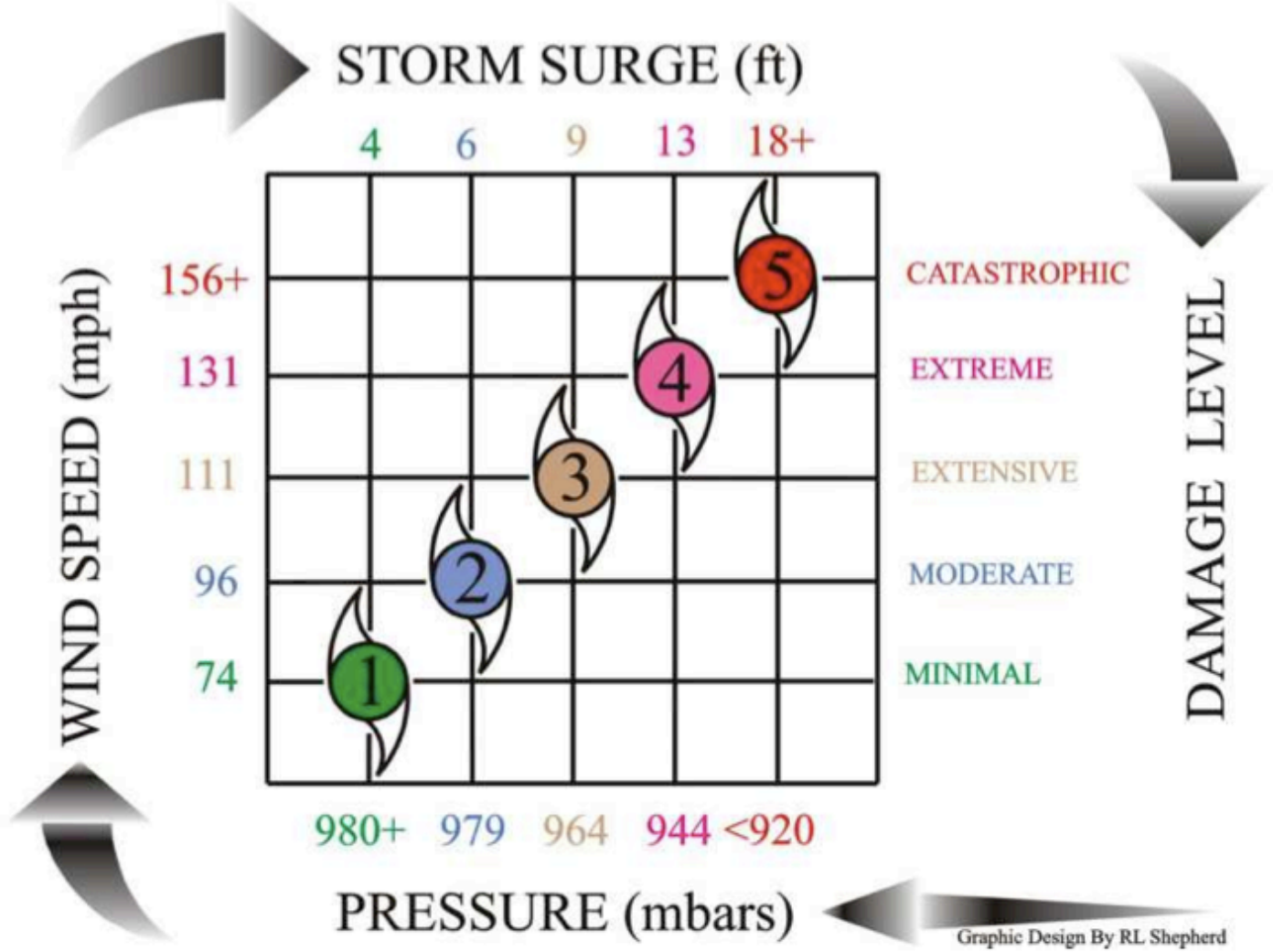
Background Image courtesy of NASA



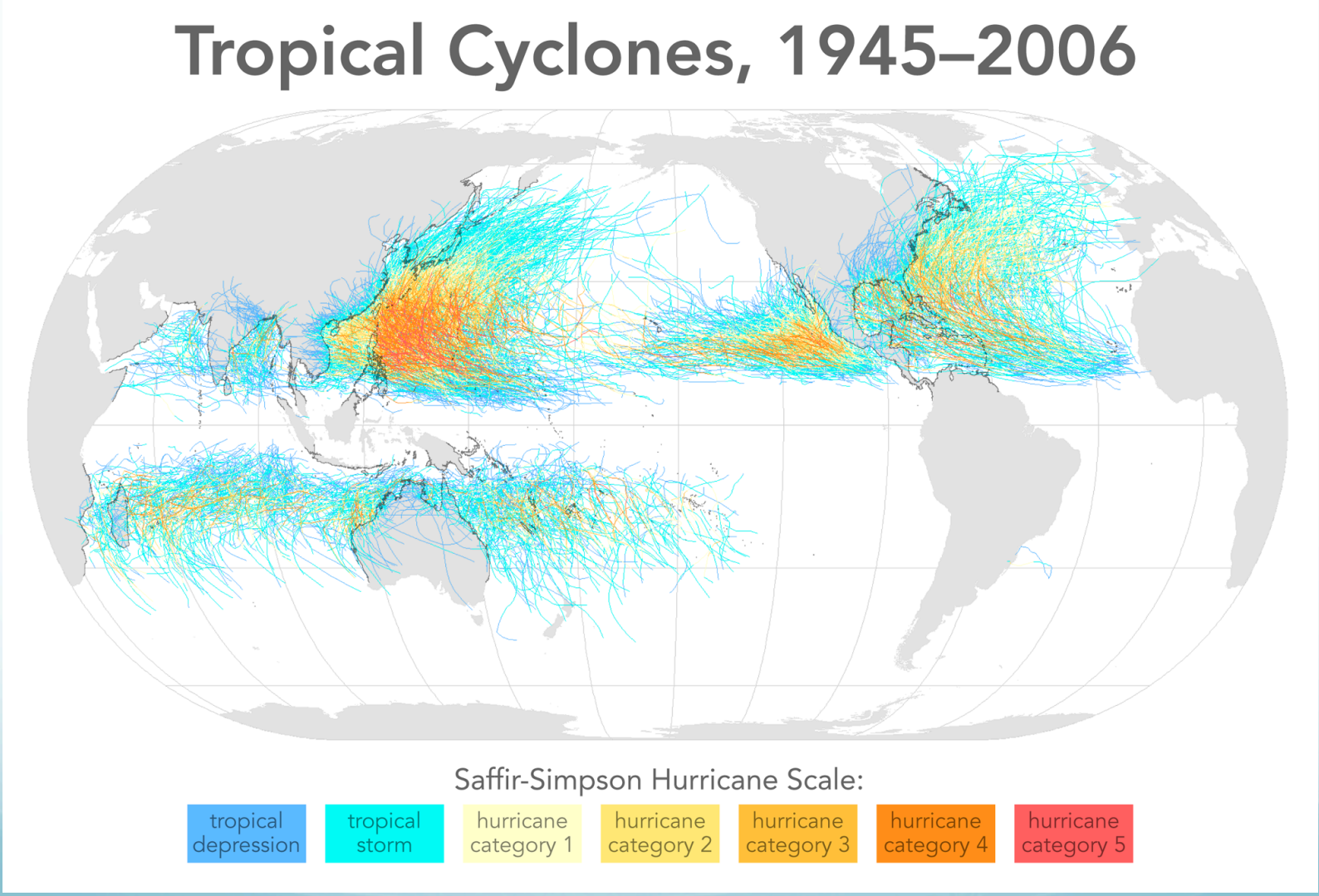
Worldwide Tropical Cyclone Tracks

Saffir-Simpson Hurricane Scale

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



Tracks Colored by Category



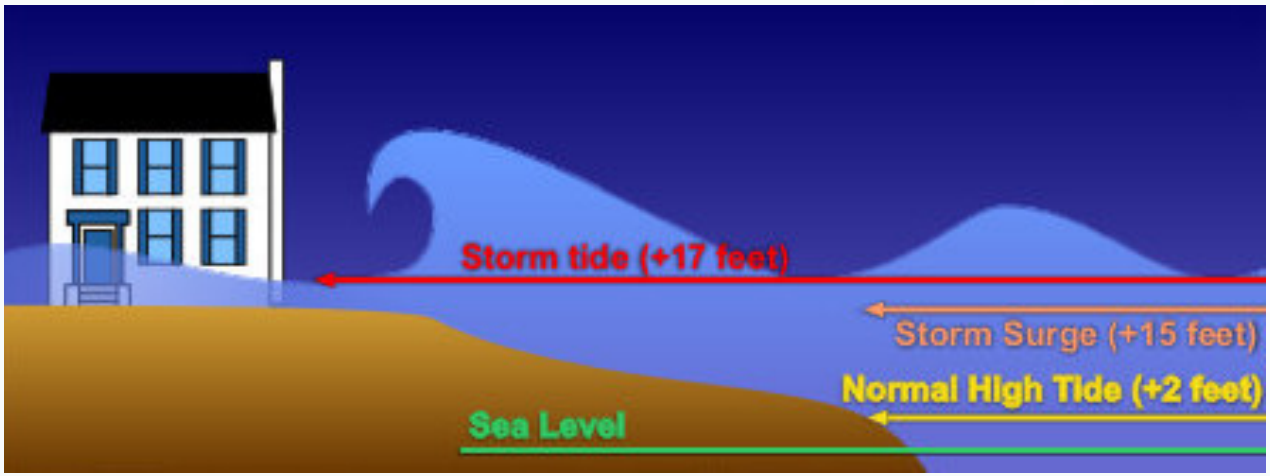
- Many strongest storms are around Taiwan, Philippines

Hurricane Damages

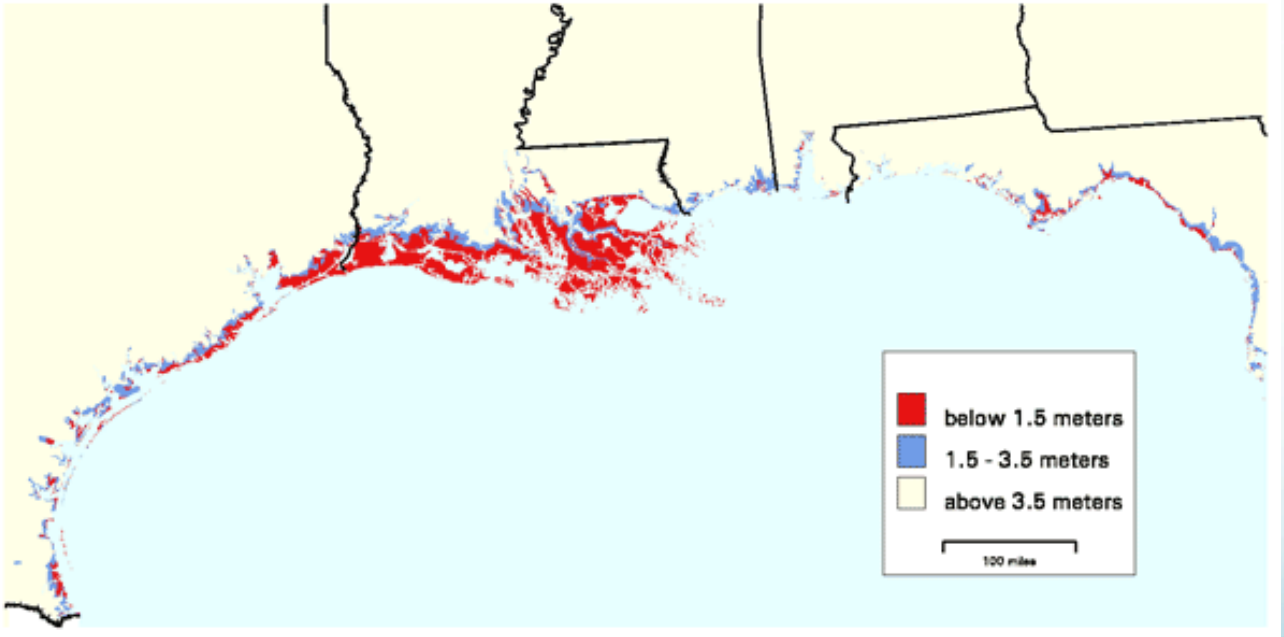
- Damages in hurricanes are caused by:
  - Winds
  - Storm surge – high winds pushing water towards the land
  - Flooding

- Financial damages from hurricanes is increasing, but this is primarily due to more people living on the coast

Storm surge

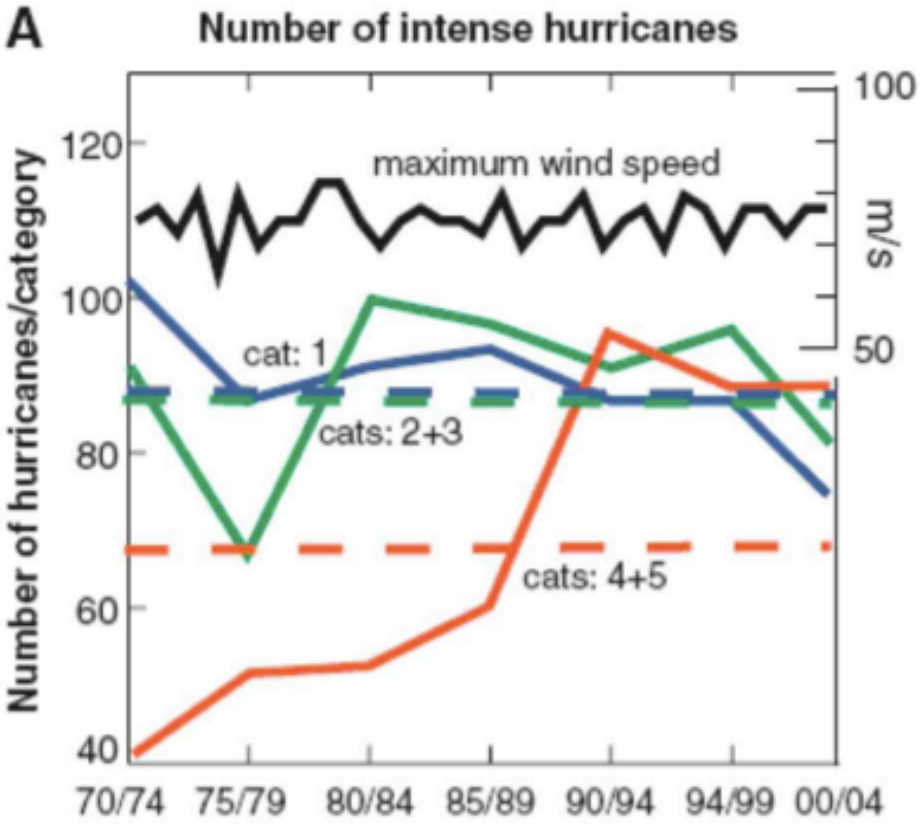

Storm tide (+17 feet)
Storm Surge (+15 feet)
Normal High Tide (+2 feet)
Sea Level

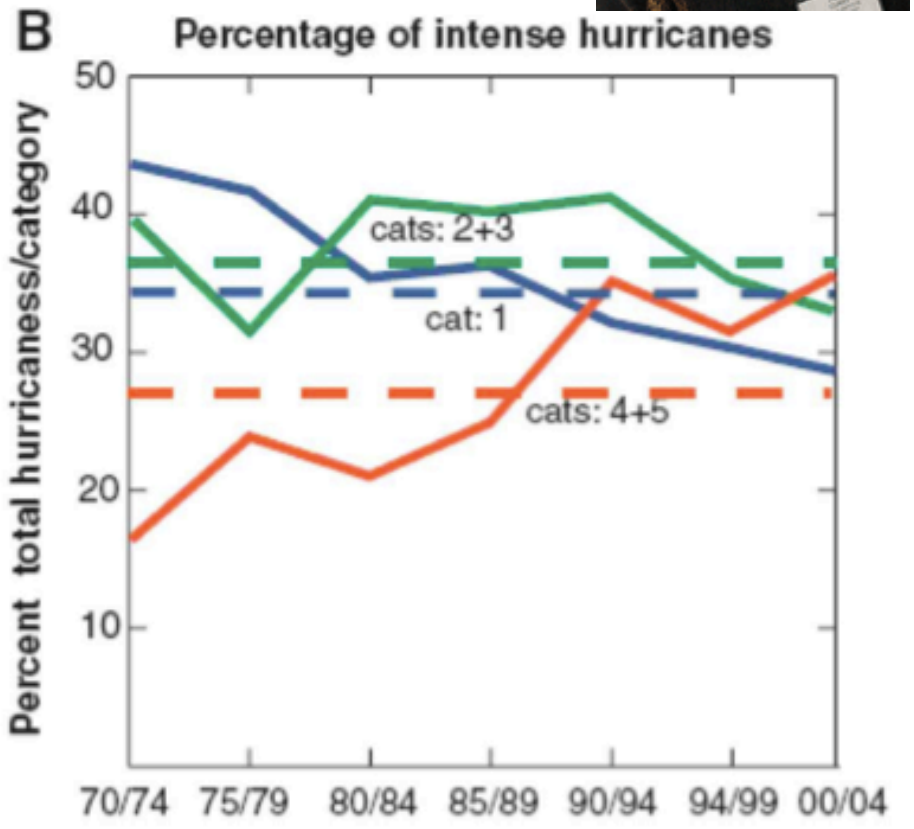

Storm Surge Before and After


below 1.5 meters
1.5 - 3.5 meters
above 3.5 meters
100 miles

Worldwide Hurricane Damage

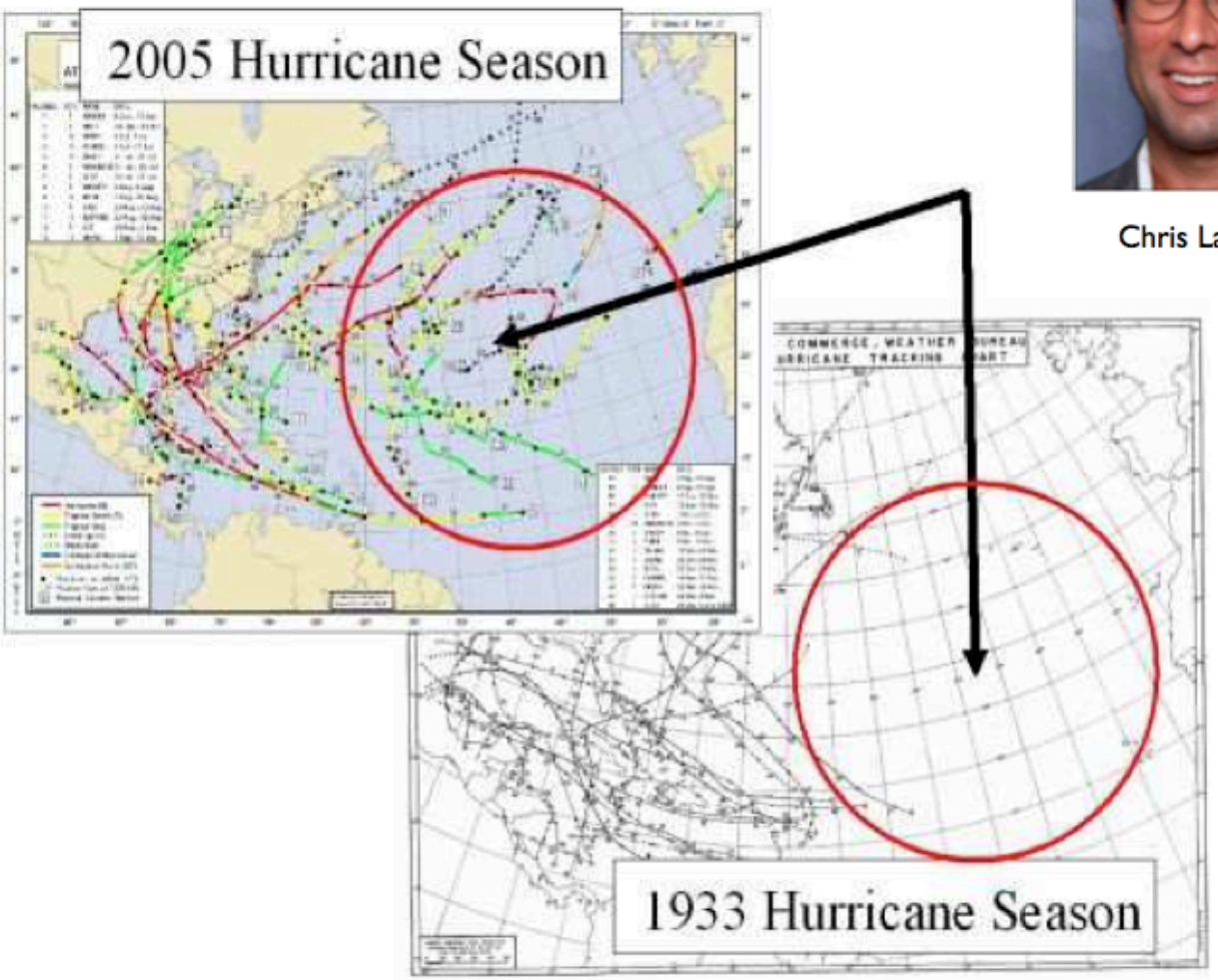
- Study by Webster, Holland, Curry & Chang





Claims the strongest storms (Cat. 4 & 5) have increased 50%

Chris Landsea

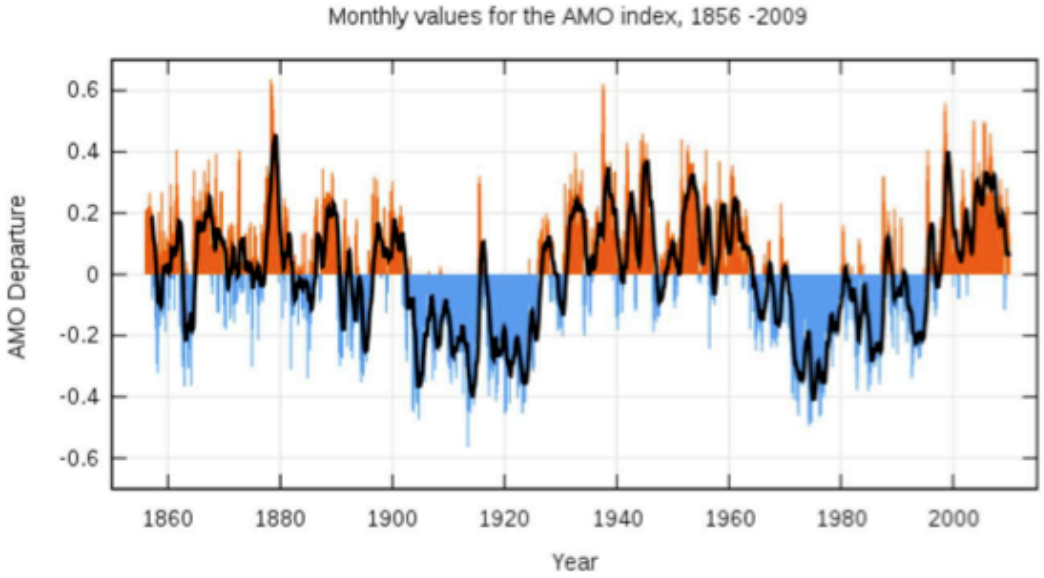


Argues that recording instruments changed not the hurricanes

William Gray

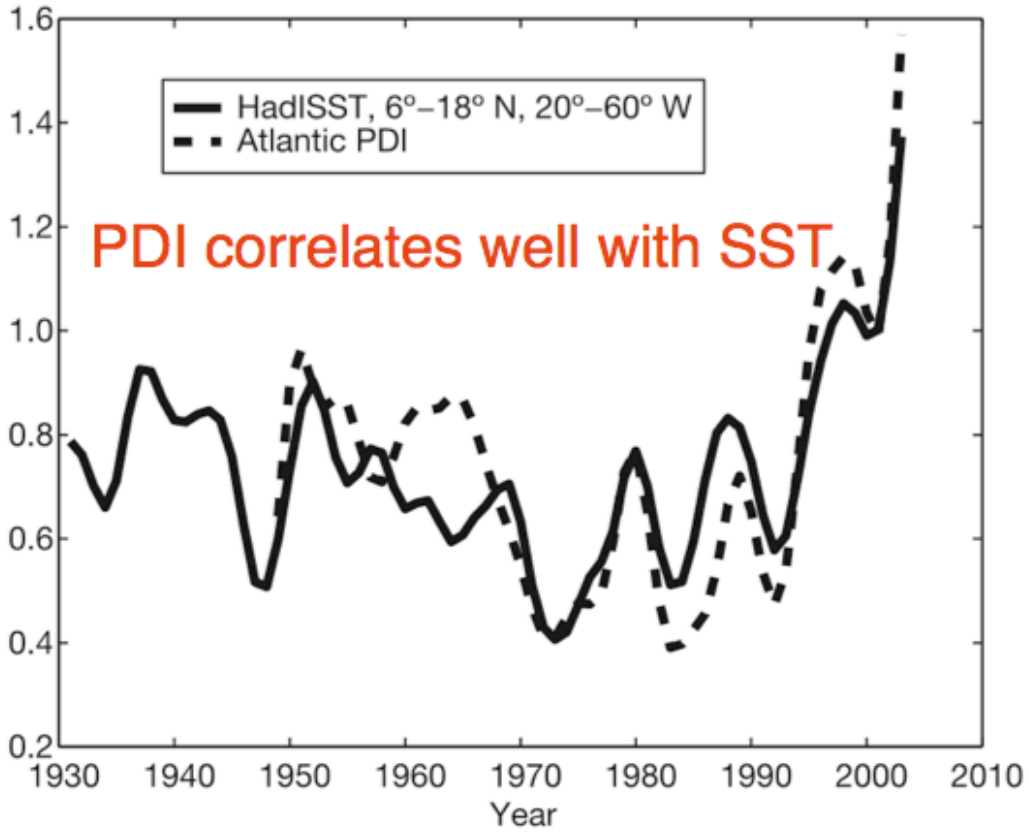
Made a career predicting hurricanes each season, mainly from ocean temperature and El Nino index

Claims hurricanes are tied to Atlantic Multidecadal Oscillation (probably varies with Atlantic deep water formation)



Correlation with hurricanes is weak and only applicable to Atlantic

Are hurricanes becoming more intense?



Kerry Emanuel

PDI stands for "power dissipation index" a measure of the cube of the maximum wind speed

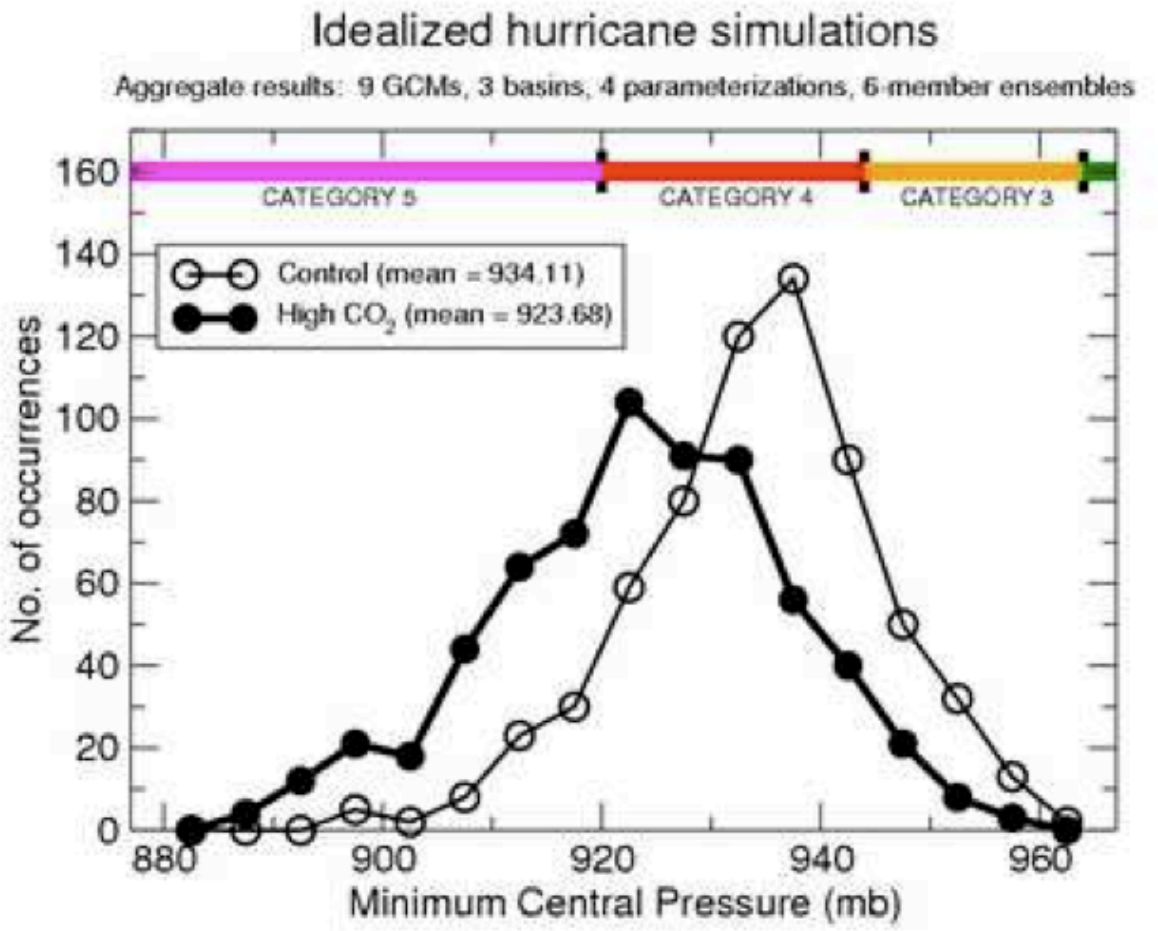
SST = sea surface temperature

Hurricane Changes with Global Warming

- Have tropical cyclones gotten more common or more severe in the 20th Century?
  - 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 don't resolve hurricanes.
  - Like clouds, hurricanes must be simulated indirectly in GCMs.
  - GCMs aren't programmed do this automatically (like with clouds), but some have done this in studies.

Knutson and Tuleya (2004) said fewer total but more frequent intense storms

Tom Knutson



← 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 Hurricanes

- Data seems to show an increase in strength globally
  - However, some argue that data quality is not good enough to make the case
  - Rare events need long data records; until 1970s the only hurricane observations were from land.
- 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