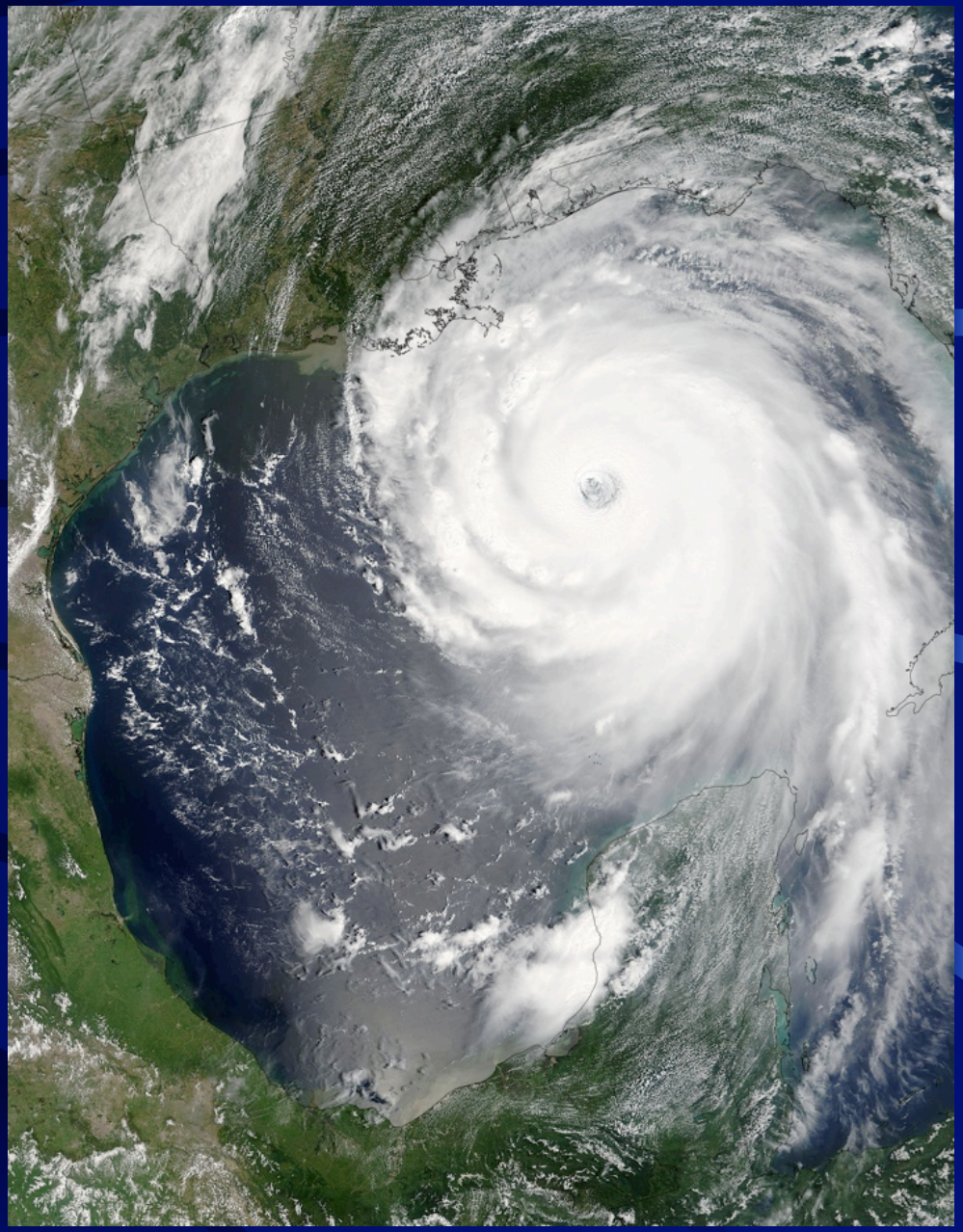
Hurricanes

Part I Structure and Climatology

by Professor Steven Businger



Hurricane Katrina

Hurricanes

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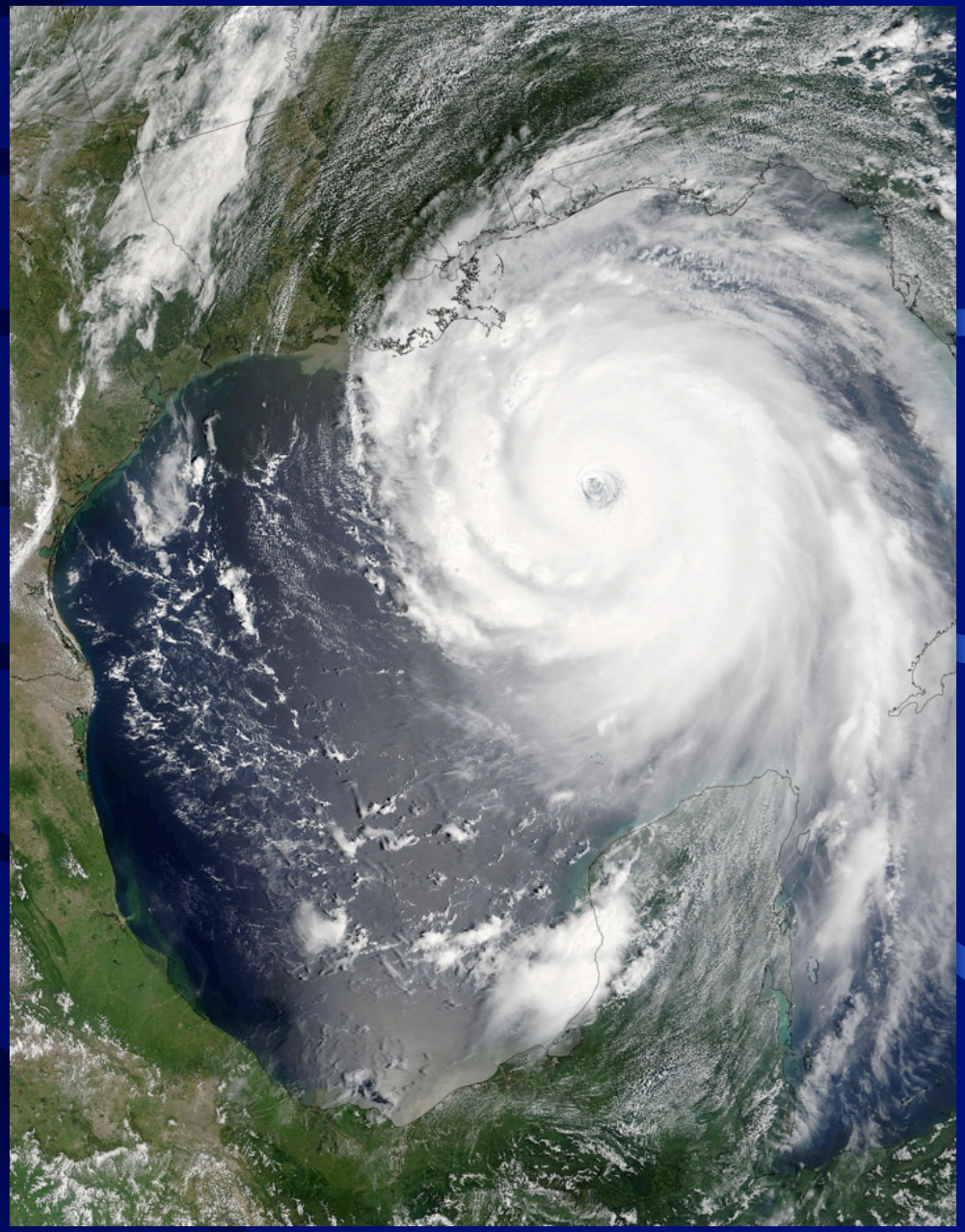
- What is a hurricane?
- What is the structure or anatomy of a hurricane?
- How to build a hurricane - hurricane energy
- Hurricane climatology - when and where



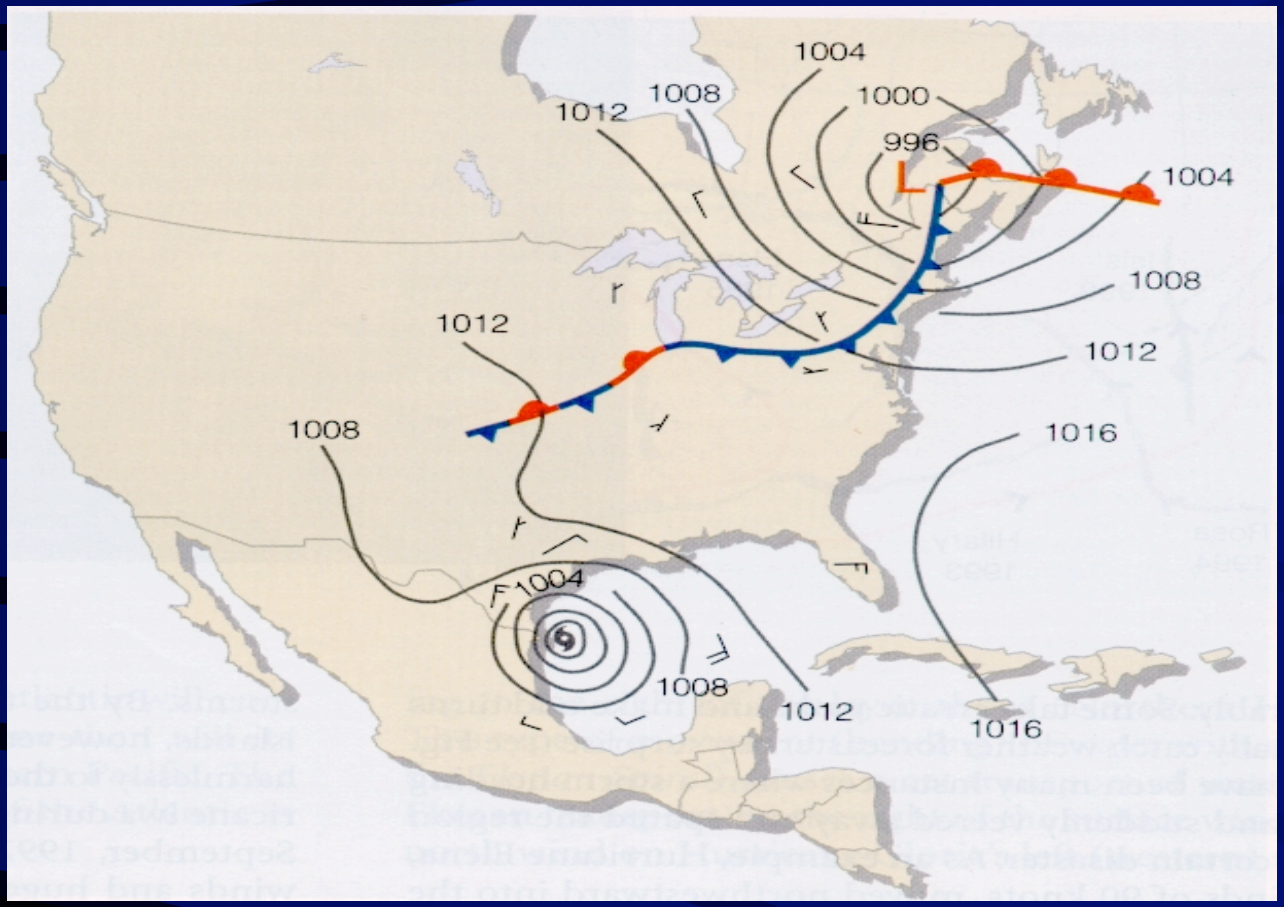
Hurricane Katrina

Hurricane are Tropical Cyclones

Hurricanes are a member of a family of cyclones called Tropical Cyclones. West of the dateline these storms are called Typhoons. In India and Australia they are called simply Cyclones.

Characteristics of Tropical Cyclones

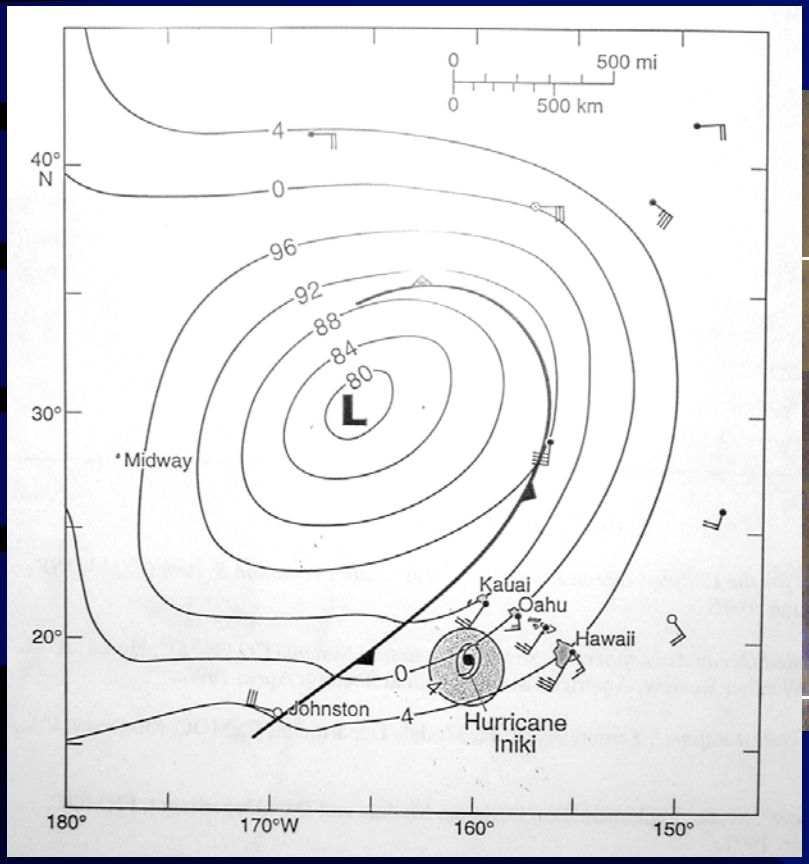
Low pressure systems that don’t have fronts
Cyclonic winds (counter clockwise in Northern Hemisphere)
Anticyclonic outflow (clockwise) at upper levels
Warm at their center or core
Wind speeds decrease with height
Symmetric structure about clear "eye"
Condensation of water vapor primary energy (heat) source
Form over warm tropical and subtropical oceans

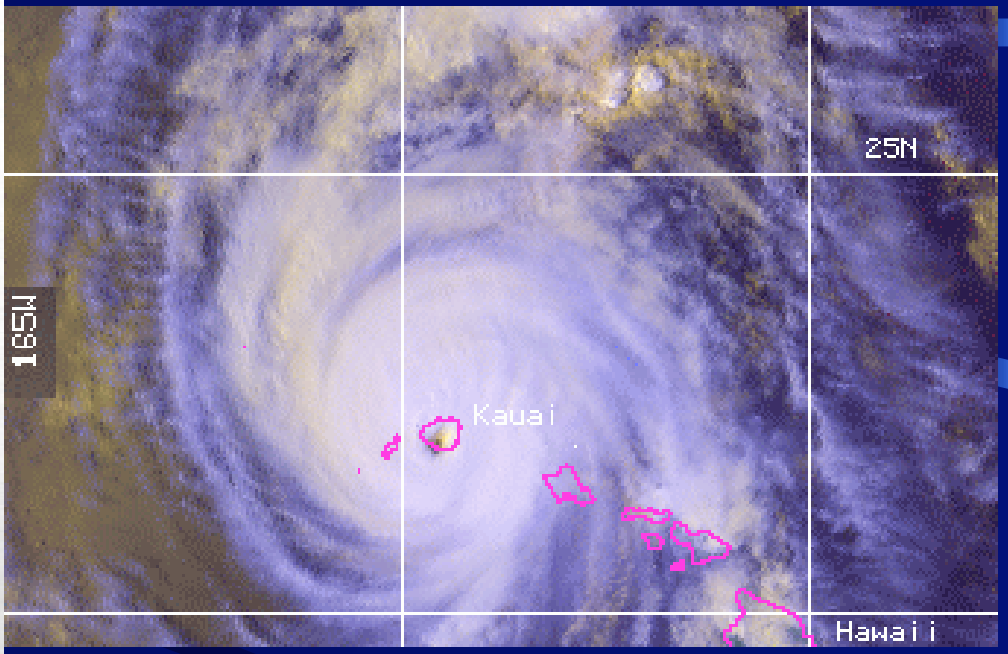


Differences between hurricanes and midlatitude storms:

- energy source (latent heat vs temperature gradients)
- vertical structure (warm vs. cold core lows; hurricanes decay with height: no jet stream aloft over hurricanes).
- horizontal structure (fronts vs. no fronts; horizontal scale)

A Question of Scale





1980 Winter Storm vs. Hurricane Iniki,
2 PM HST on September 12, 1992

Tropical Cyclone Life Cycle

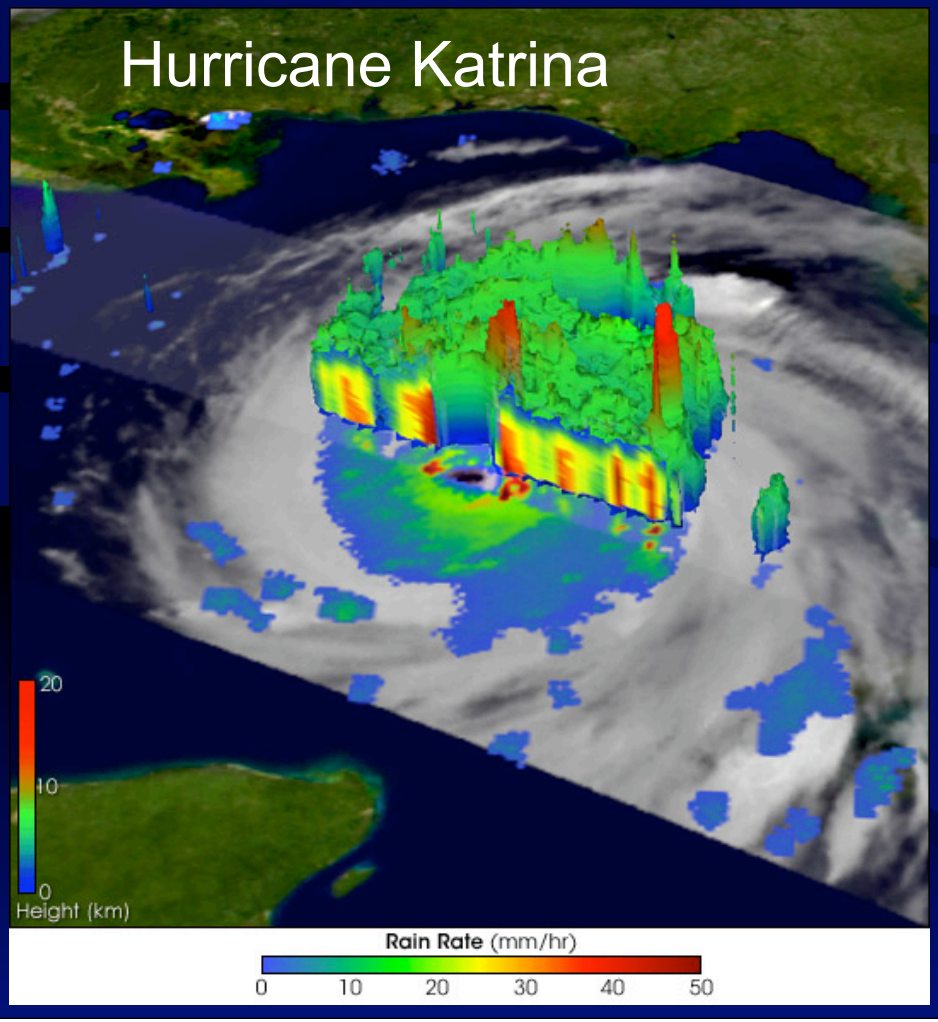
Stages of storm development

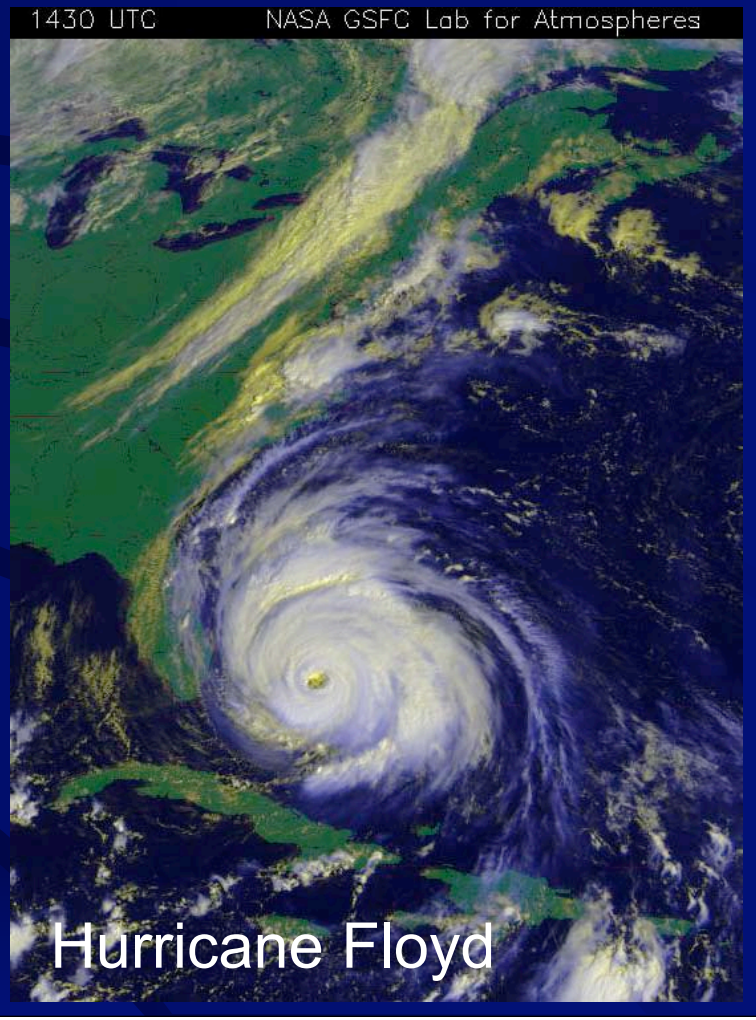
2. Tropical Depression: surface wind < 39 mph (33 kt)
3. Tropical Storm: 39 ≤ surface wind ≤ 74 mph (64 kt)
4. Hurricane: surface winds > 74 mph (65 kt)

Tropical storms and hurricanes are named.

Anatomy or Structure

Basic structure includes spiral rainbands and a concentric eye wall that surrounds a clear eye.

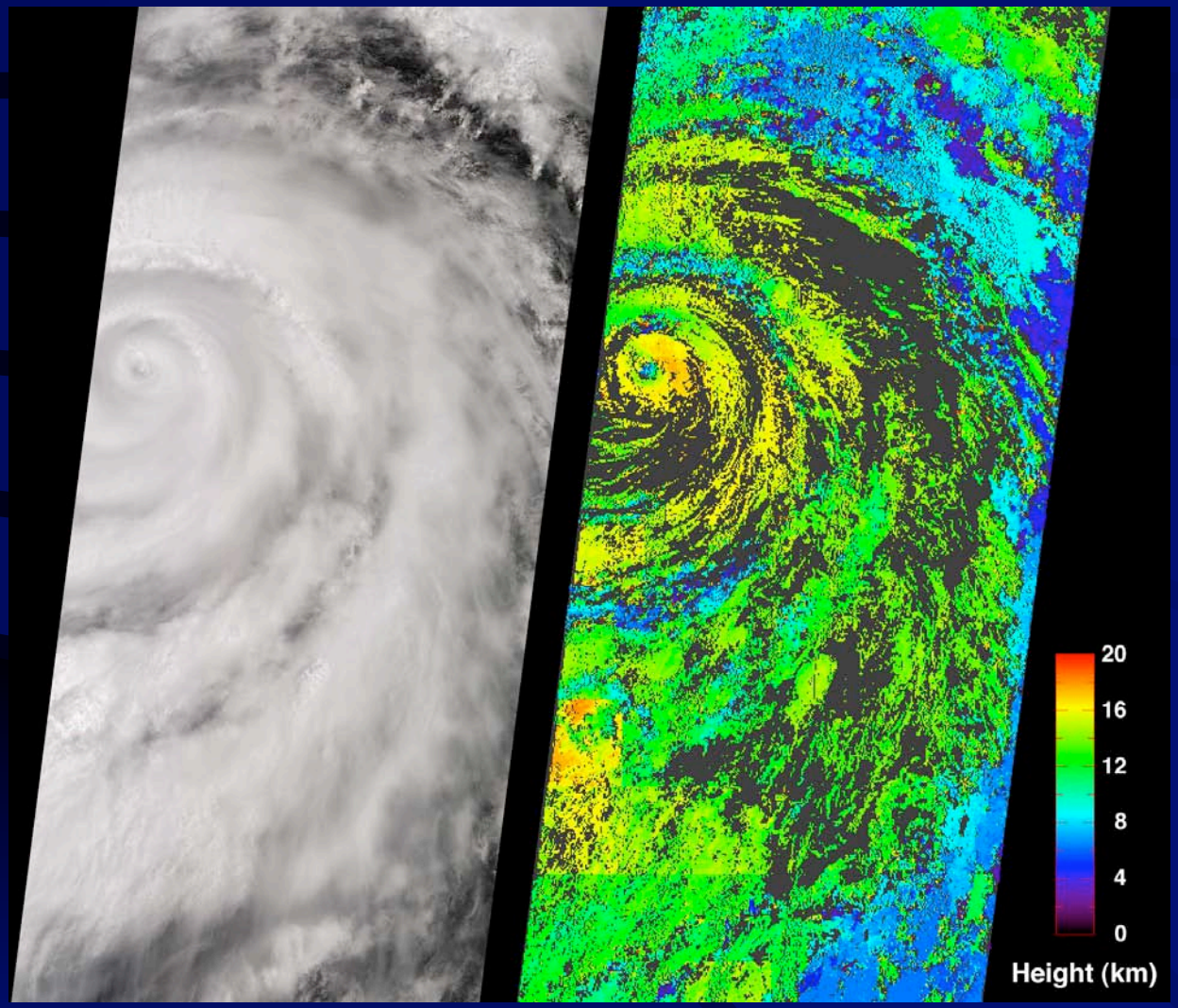




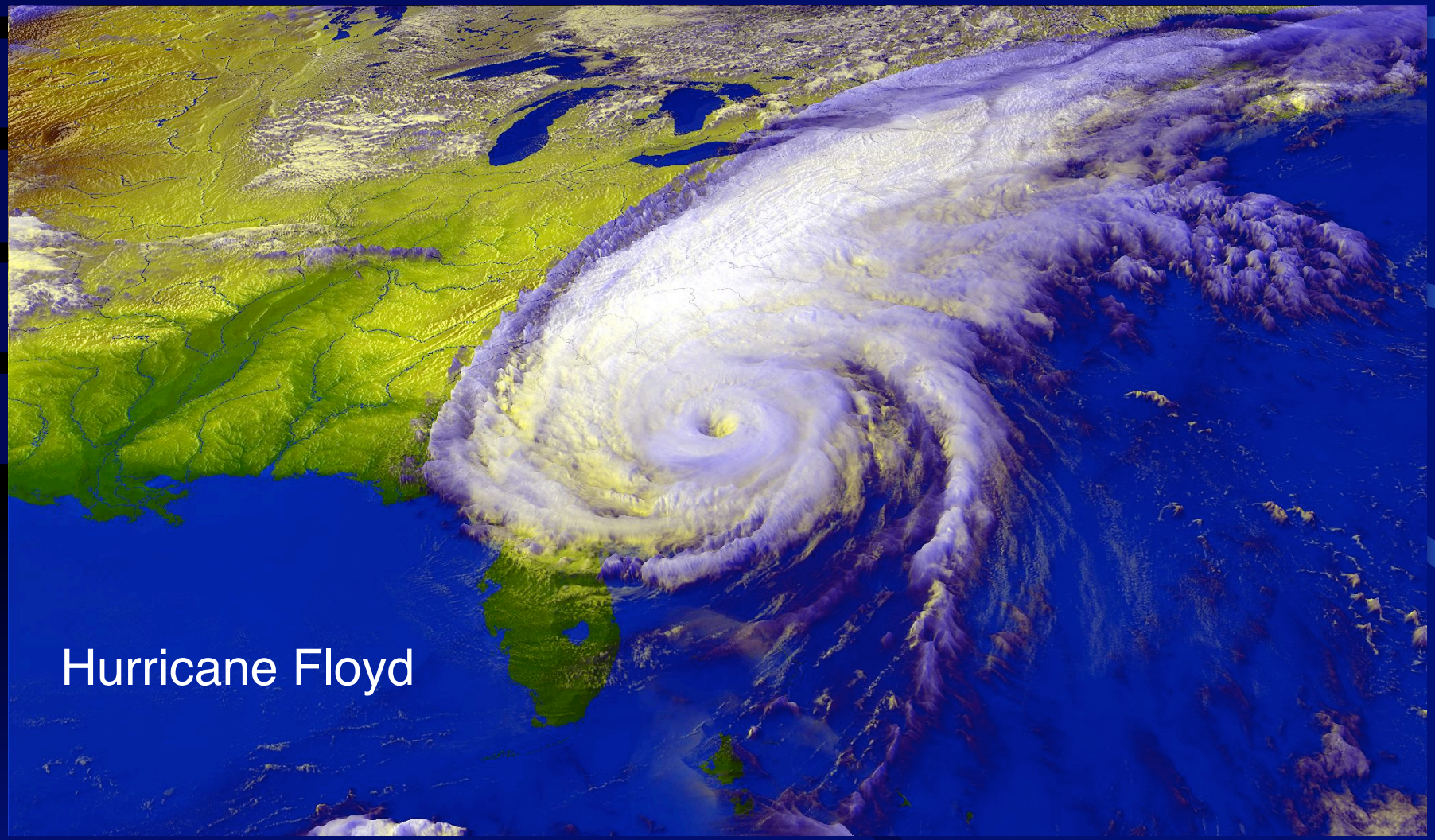
Hurricane Structure

Hurricane Alberto
Hurricanes are much broader than they are tall.

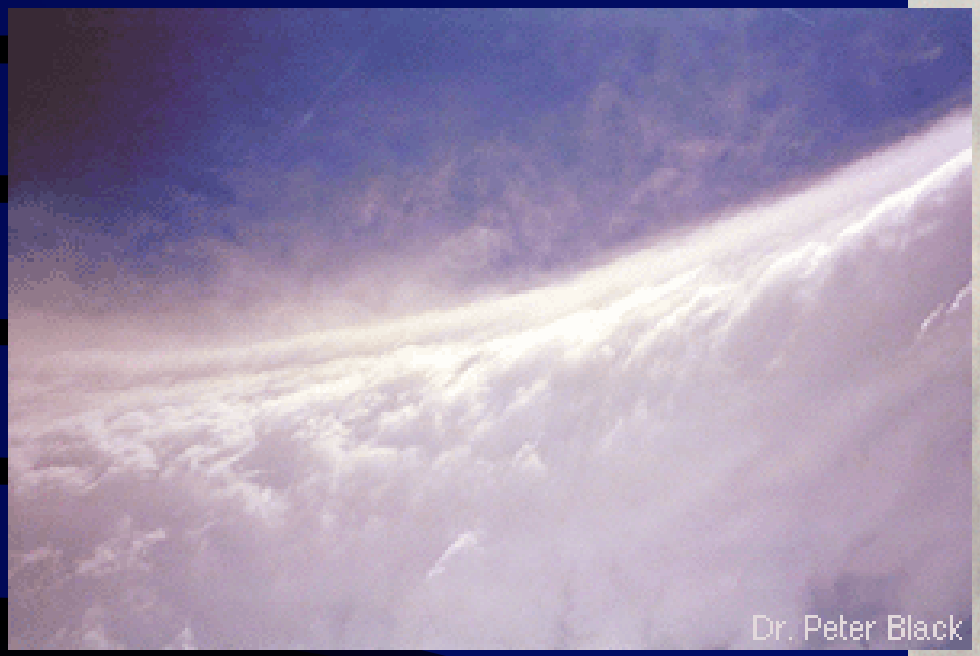
Satellite Derived Cloud Height



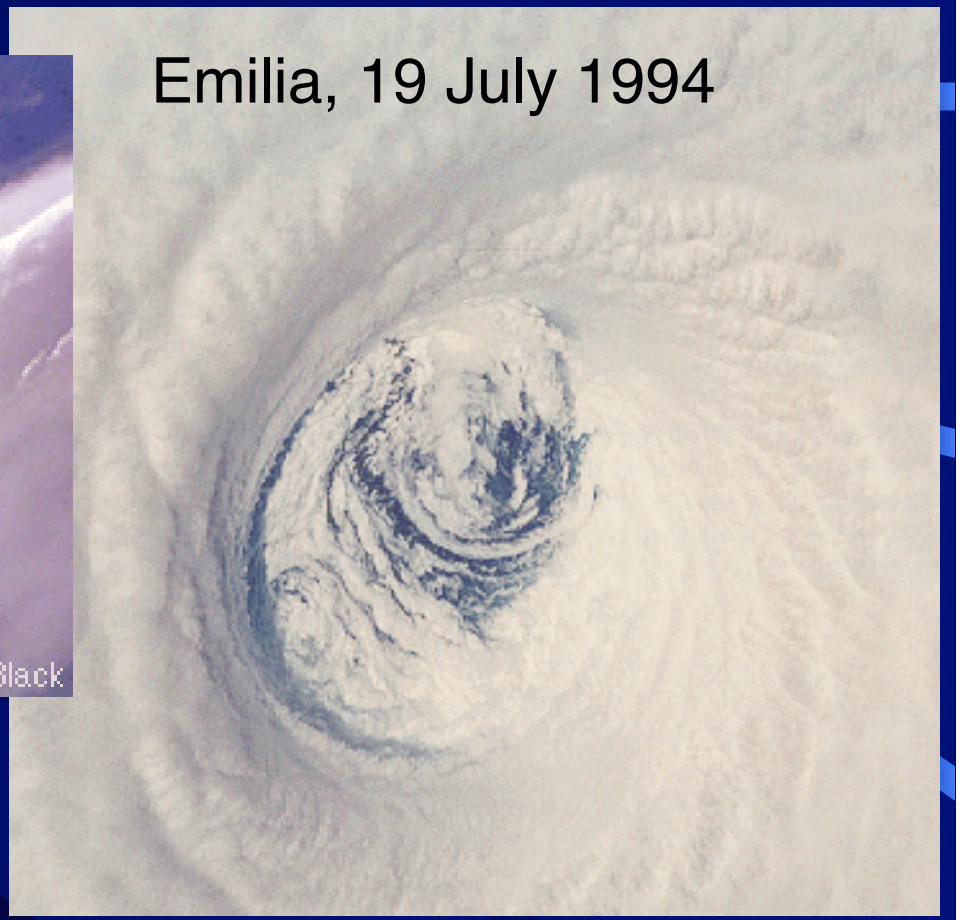
Hurricane Structure



Hurricane Structure



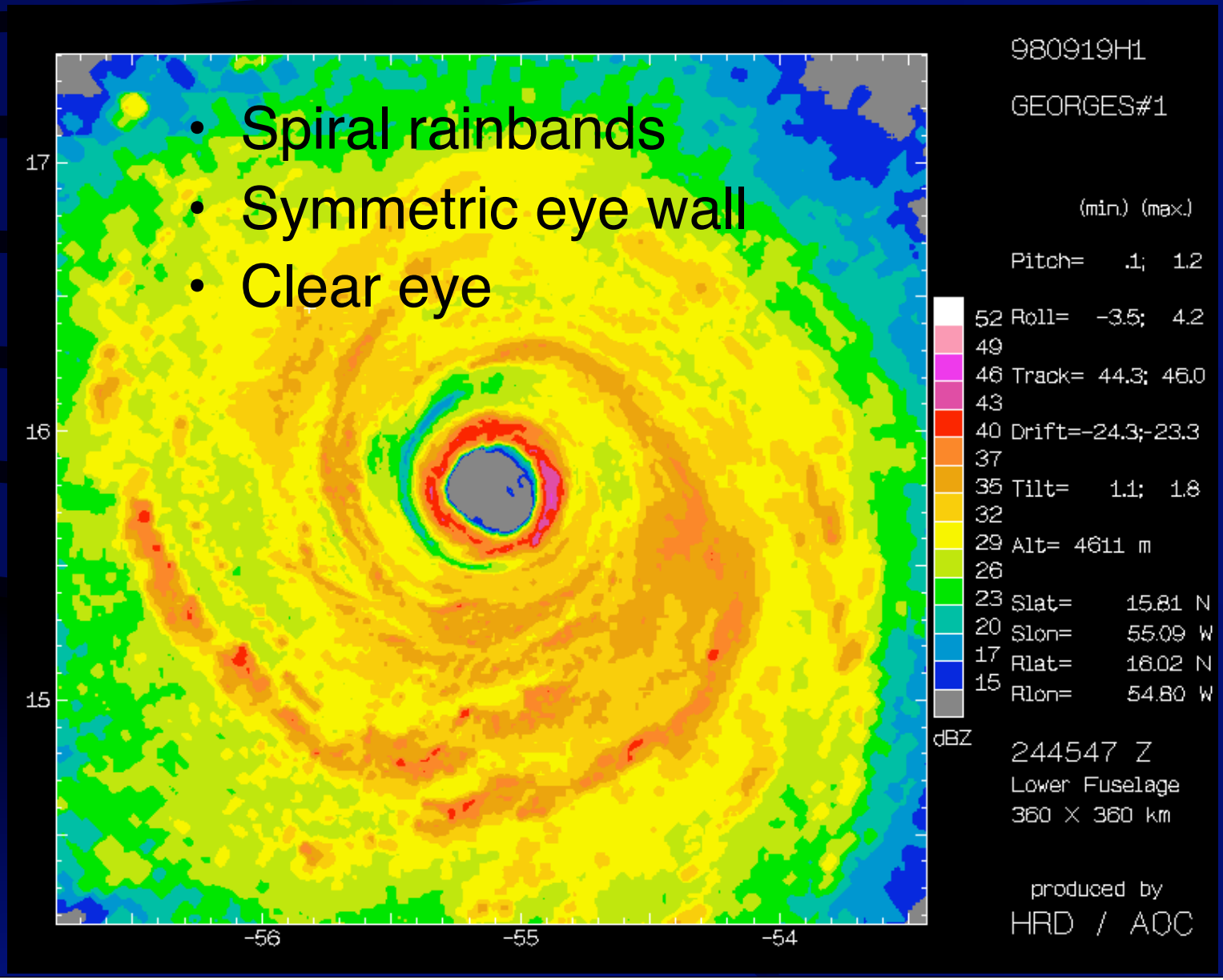
Hurricane Inez



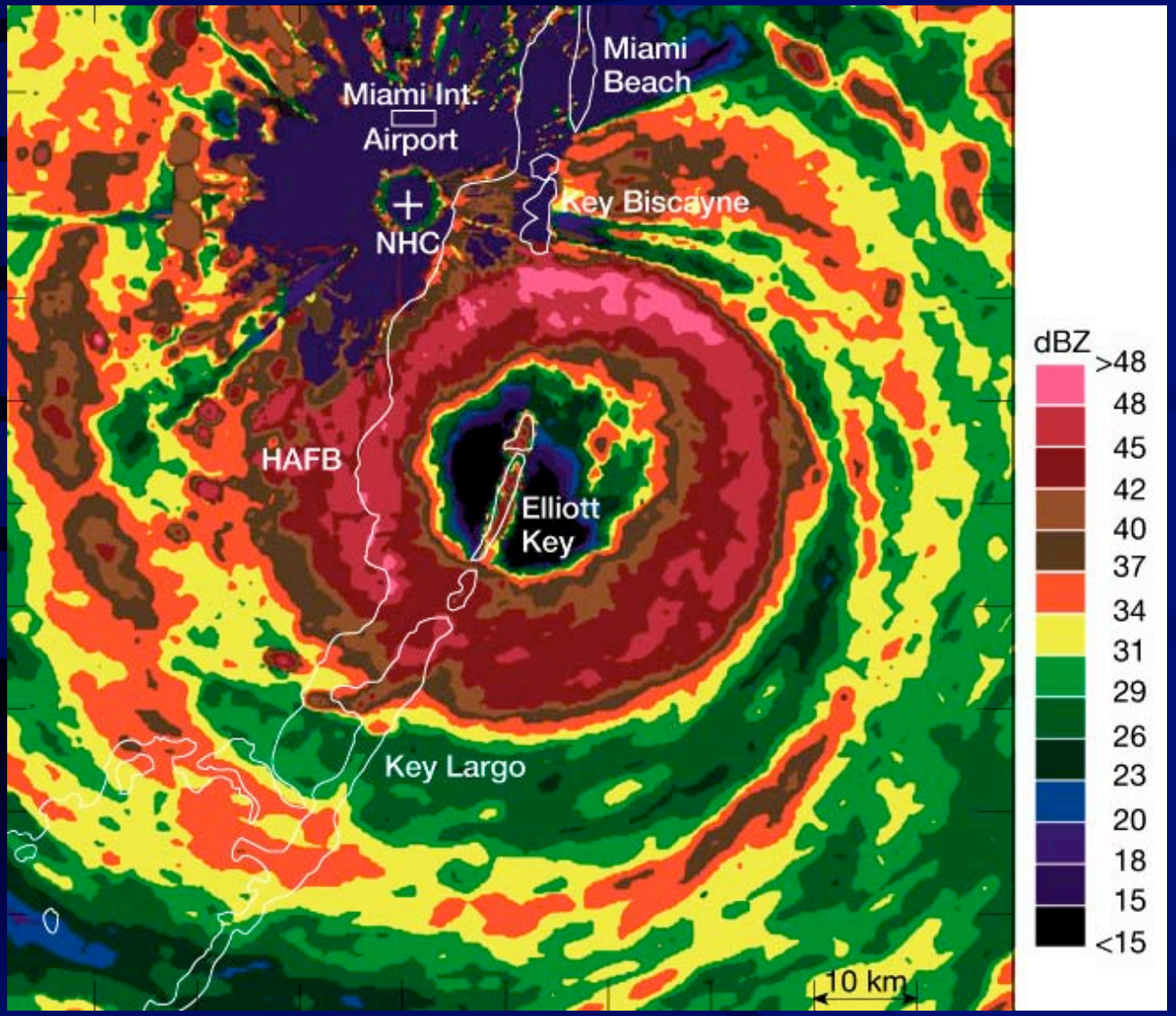
Emilia, 19 July 1994

Note the stadium structure of the eye.

Radar Observations

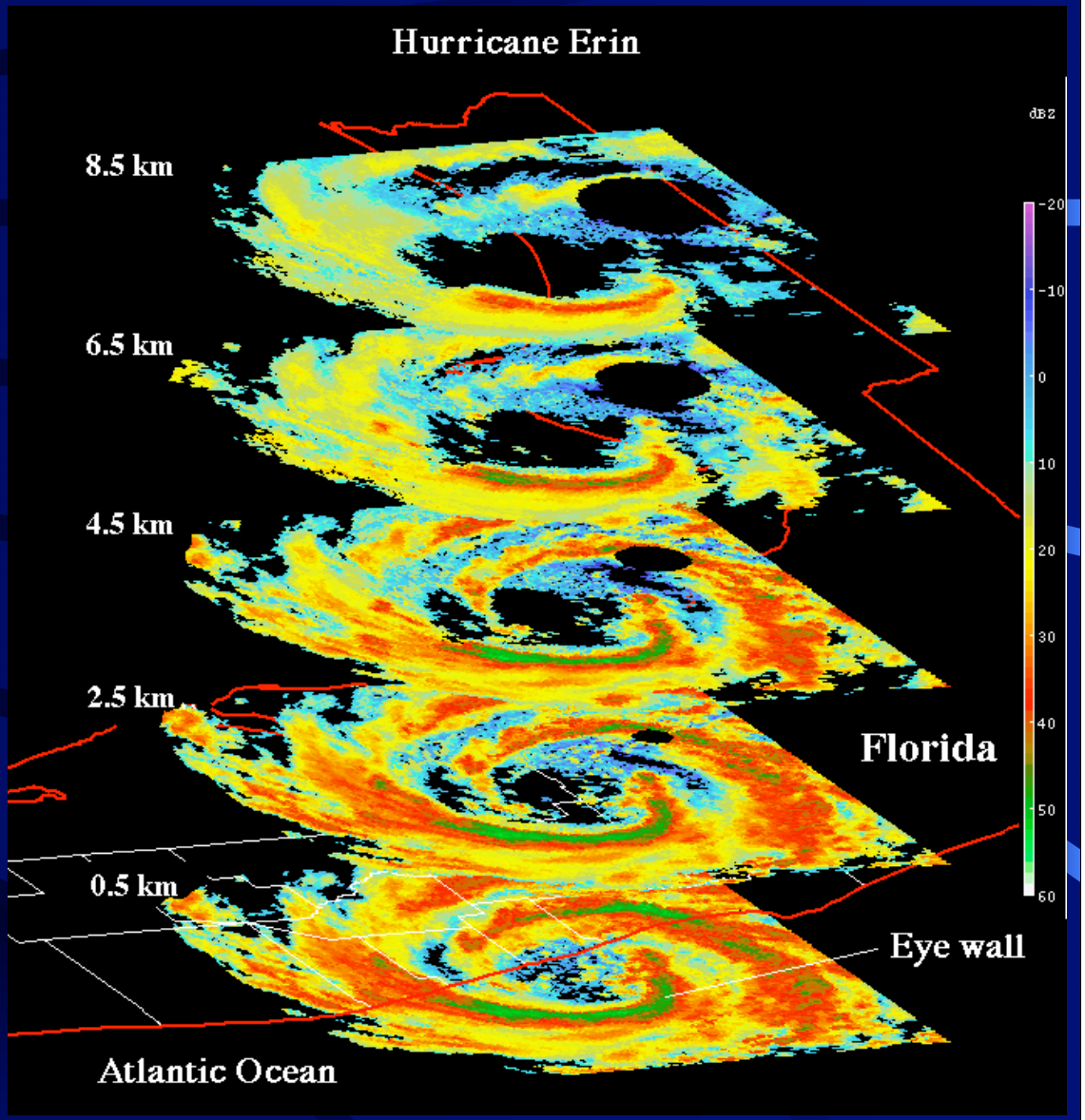


Radar Observations of Andrew

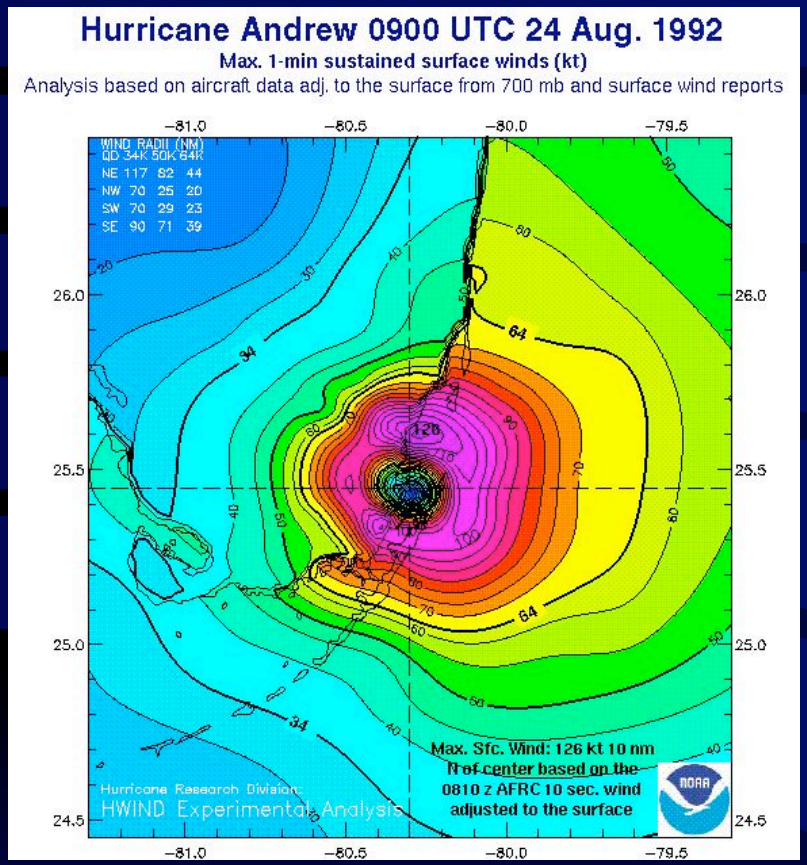


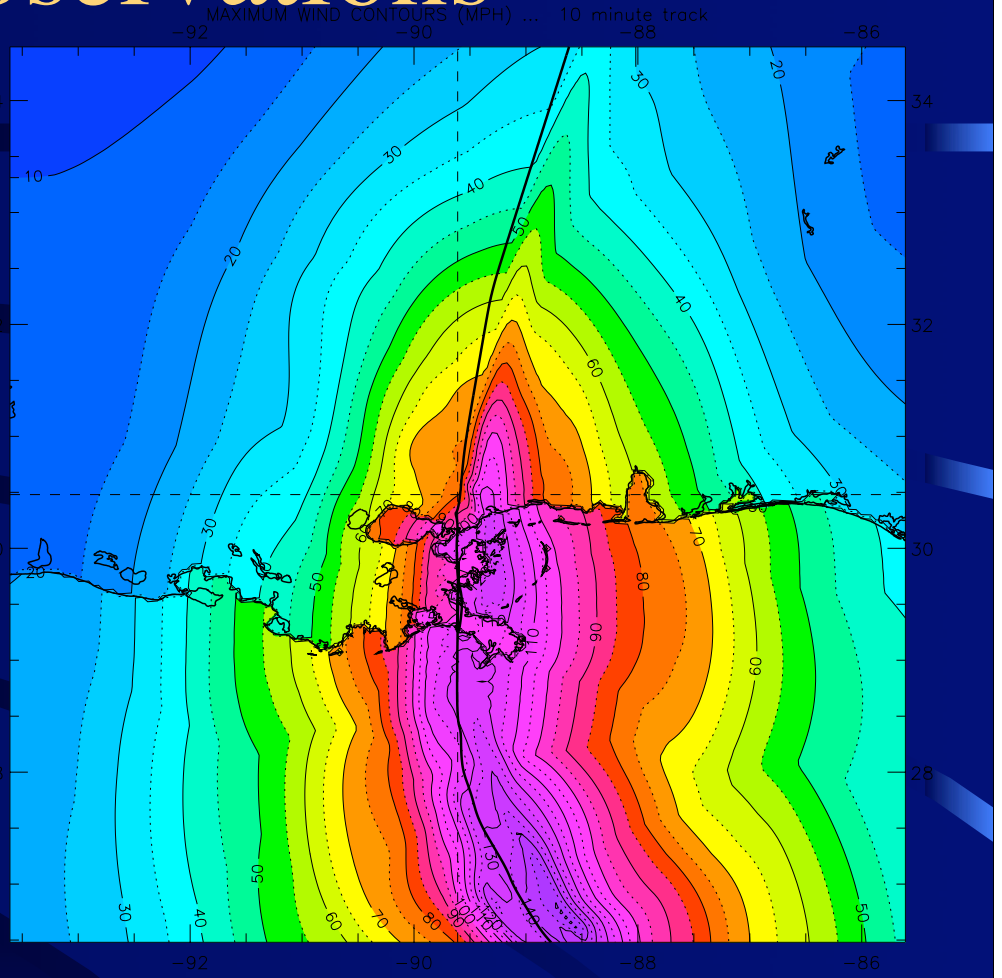
Hurricanes weaken with height

Structure seen in radar data.



Wind Observations



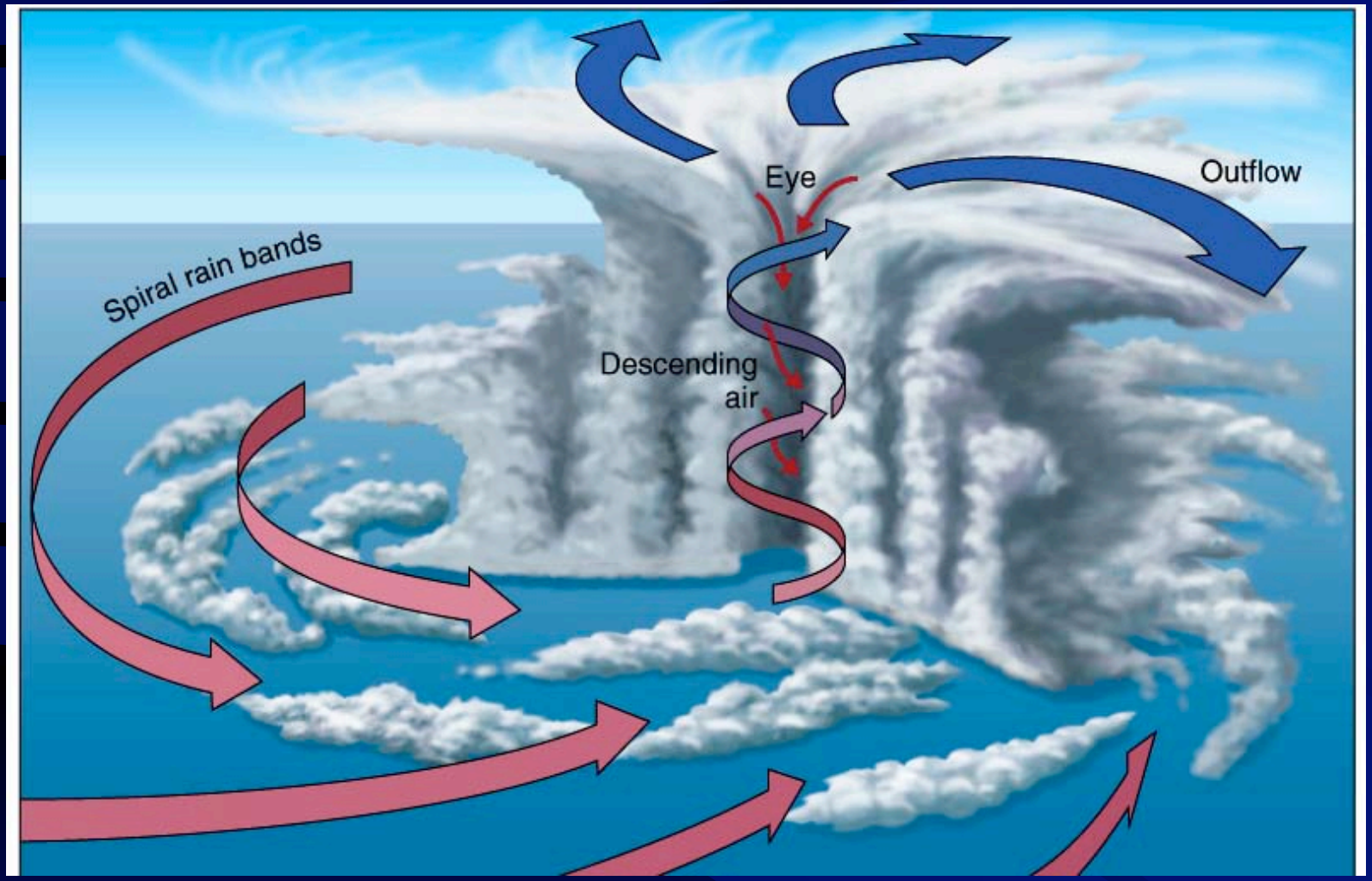


Wind distributions in Andrew and Katrina

Hurricane Anatomy/Structure

Hurricanes are “Warm-Core Lows”
Note where rising and sinking motion occurs.

Hurricane Anatomy/Structure



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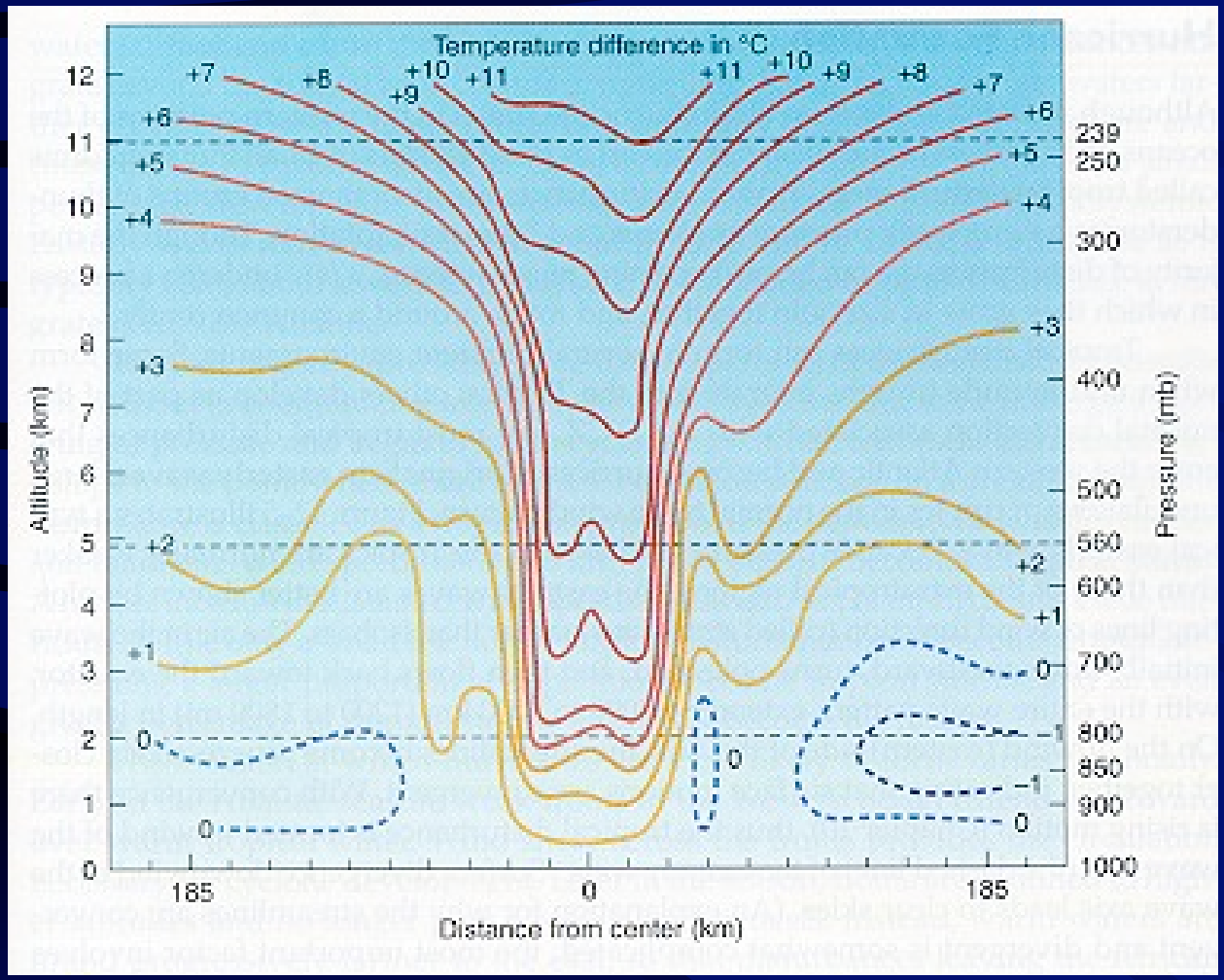
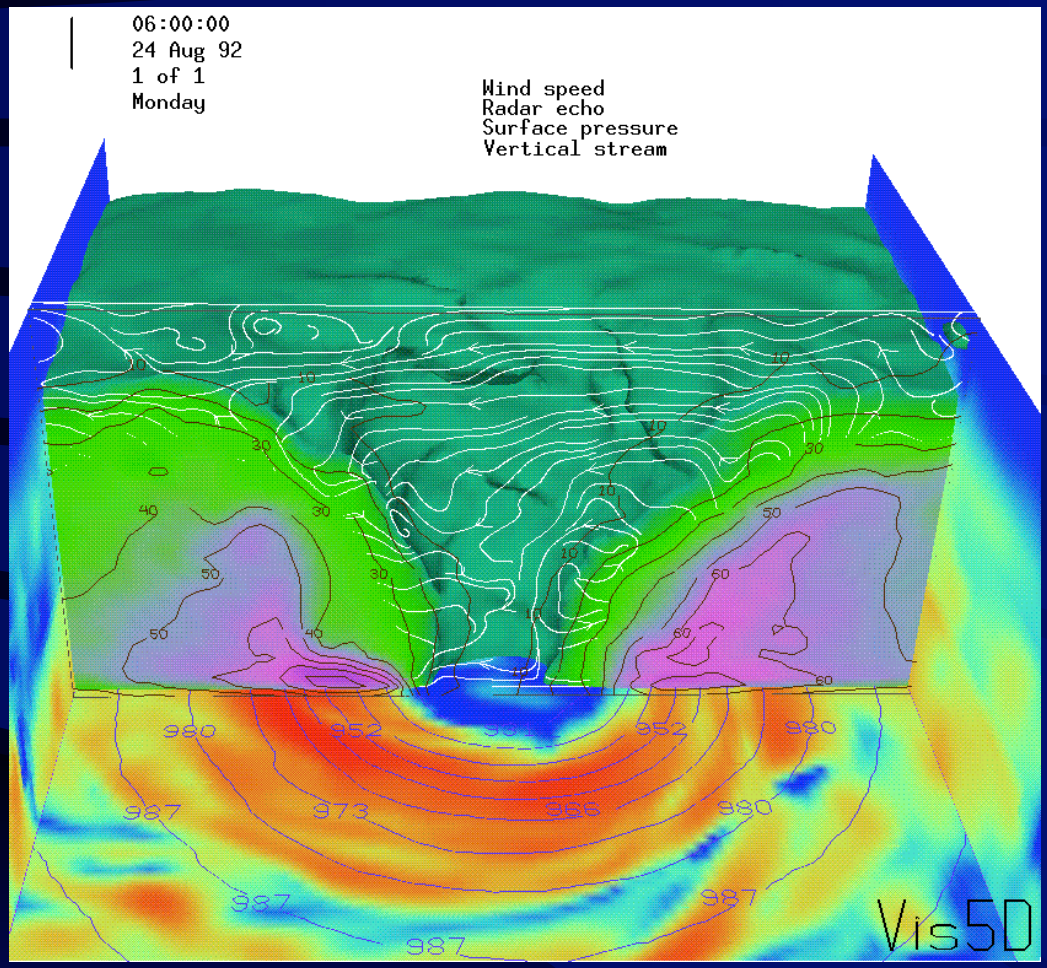


Hurricanes are “Warm-Core Lows”

Model of Hurricane



Purple = heavy rains

Red = high winds

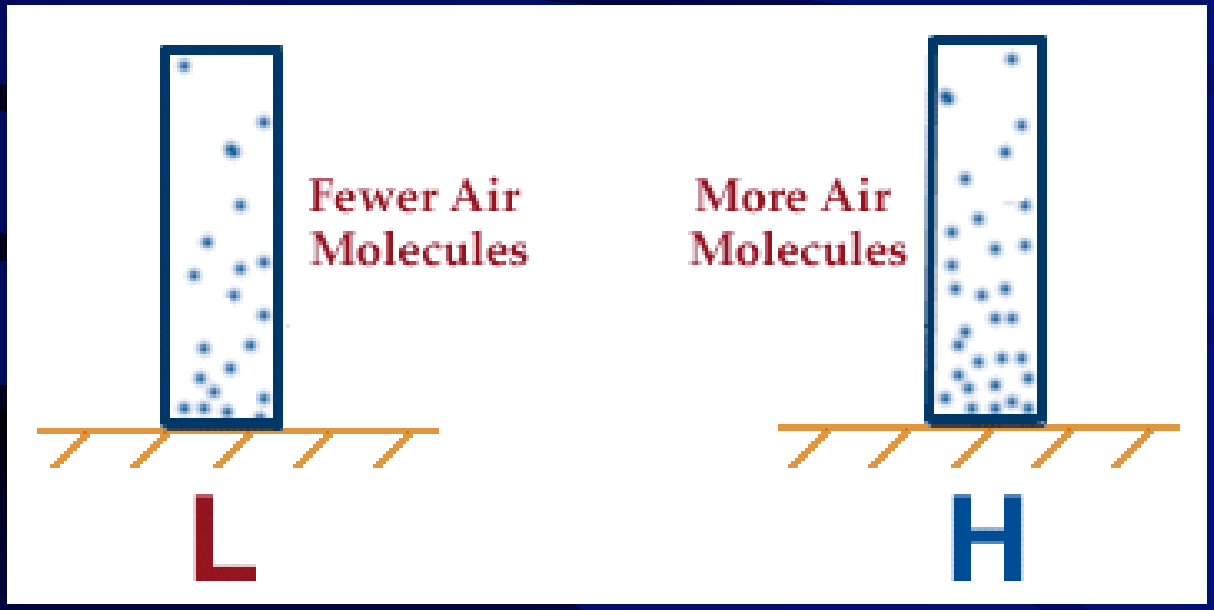
Hurricane Energy Source

Condensation of Water Vapor is the Key

- Hurricanes (a.k.a. Typhoons, Tropical cyclones) are giant engines that convert heat into wind energy.
- Consider a rain rate of 2 inches per day over an area of 300 mi radius (typical for tropical depression, tropical storm, and hurricane)
- Over a 7 day lifecycle, the energy released is equal to 50,000 1 MT nuclear explosions!
- This is equivalent to the total explosive yield of the nuclear arsenals of the US and USSR at the height of the Cold War!

To Build a Hurricane

Since pressure is the weight of the air, the atmosphere must concentrate warm, moist air over one place to create very low pressure at sea level.



Warm air molecules move faster and take up more space resulting in lower sea-level pressure.

Hurricane Energetics

- Tropical cyclones are rare
- Roughly 80 per year worldwide
- Assume a one week life span
- Result – 1-2 storms any day in an area half the surface area of the planet
- Reason – you need to bring 5 prerequisites together to produce a storm

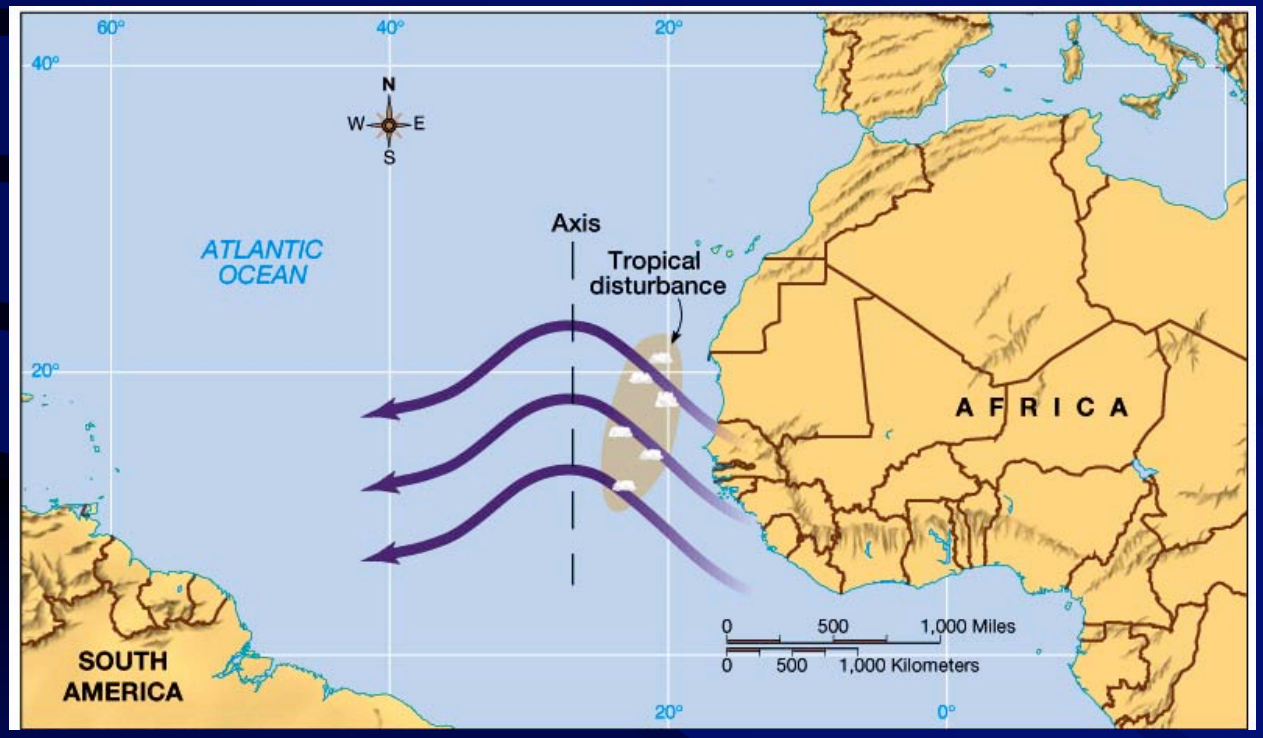
How to Build a Hurricane: Five Prerequisites

To build a hurricane the atmosphere must concentrate warm, moist air over one place.

1. Warm ocean water with a temperature > 80˚ F
2. An area of low pressure. Converging winds enhance spin.
3. Thunderstorms – deep unstable air. (Moist air weighs less than dry air, contributing to lower surface pressure.)
4. Little change in the wind speed or direction with height over the developing storm (to keep the warm air together).
5. Genesis must occur ≥3˚ from Equator to allow for sufficient spin (Coriolis force).

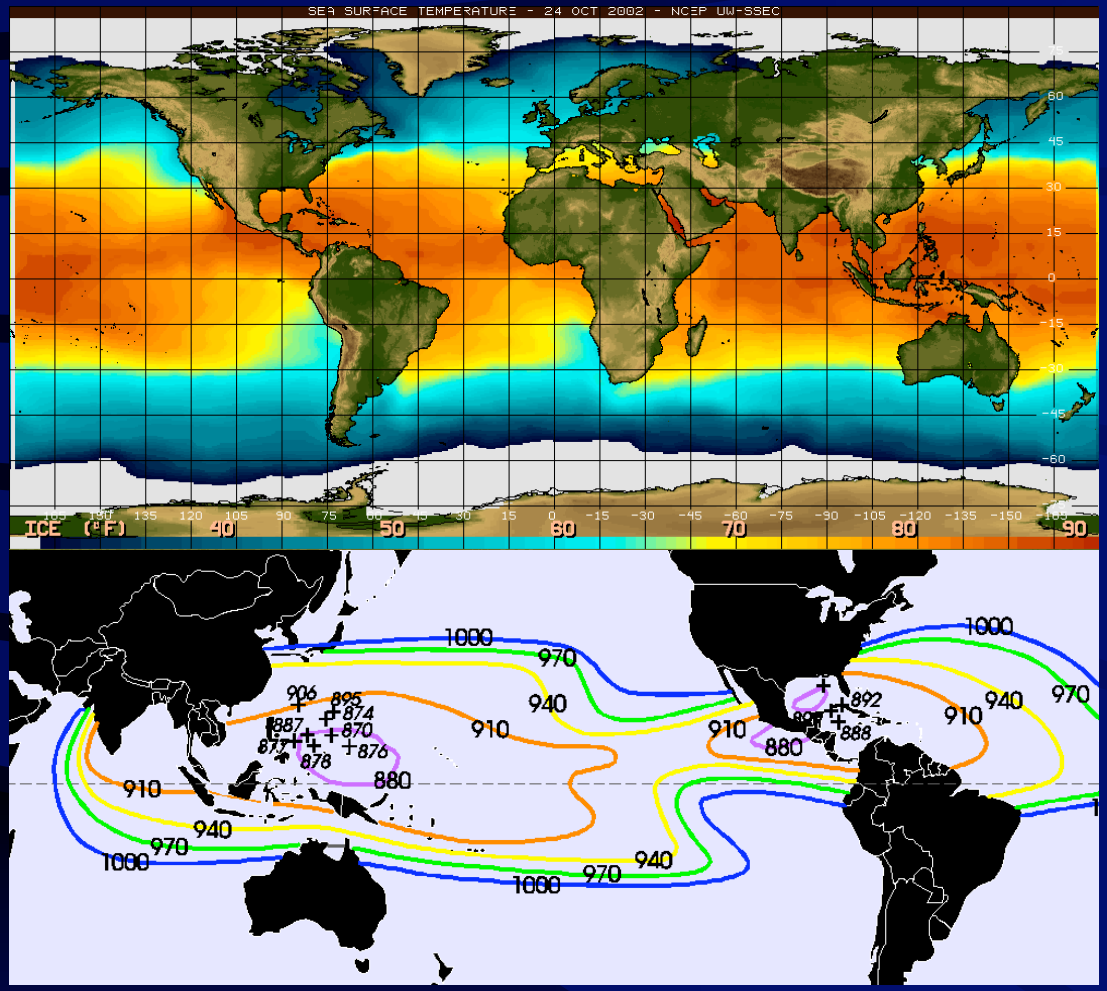
Prerequisite for Hurricane Formation

We need a surface low to form in the tropics that has deep moisture and thunderstorms



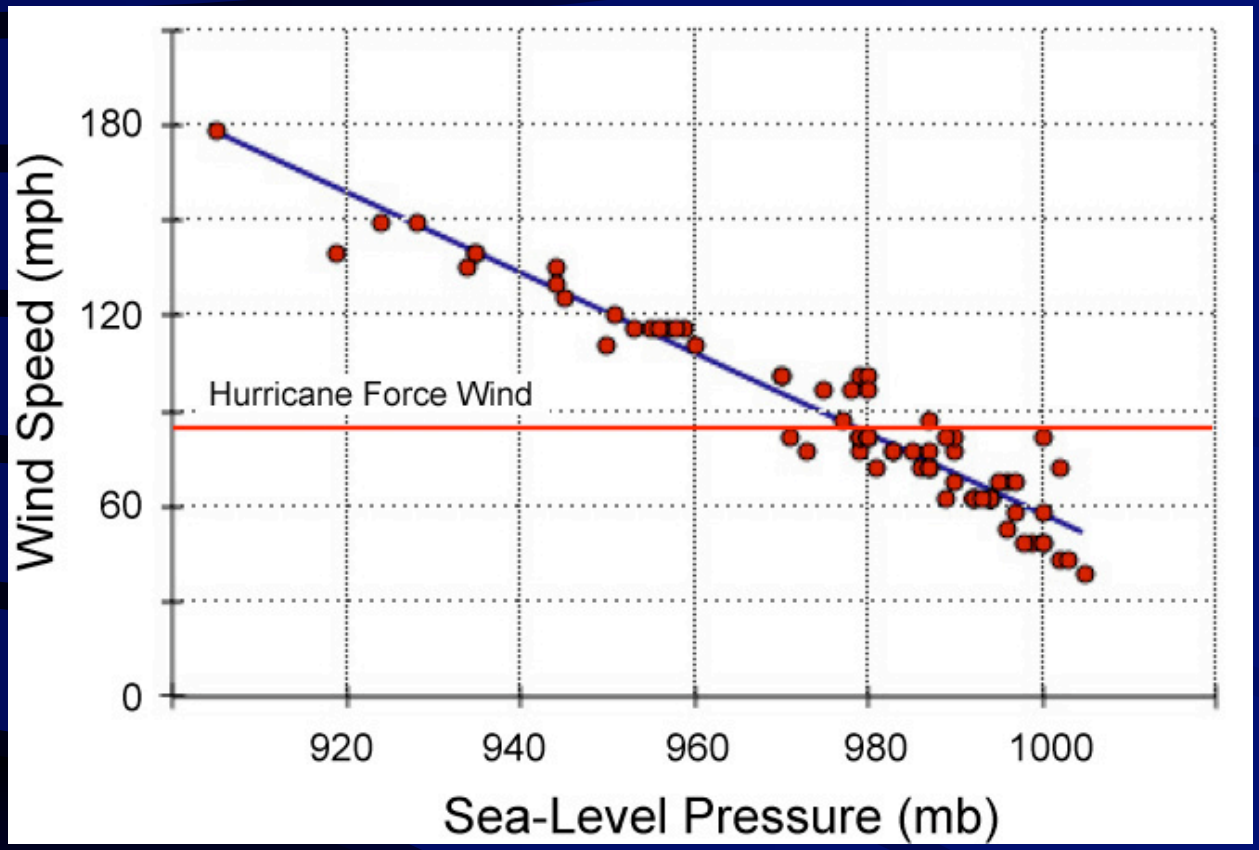
Easterly Waves form over Africa and track westward.

Hurricane Energy Source



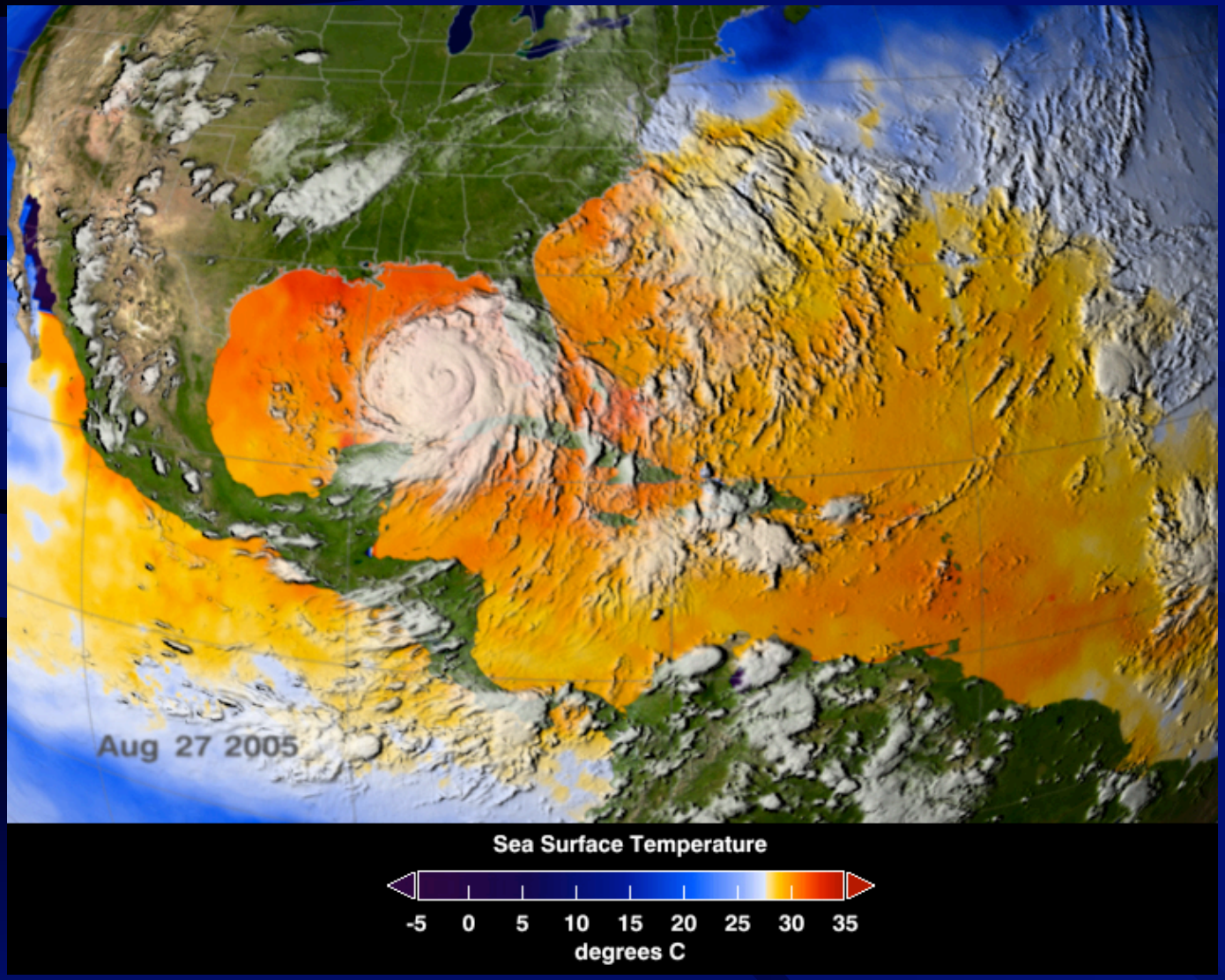
Observed sea surface temperature and predicted minimum central pressure at sea level in tropical cyclones.

Low Sea-level Pressure – Strong Winds



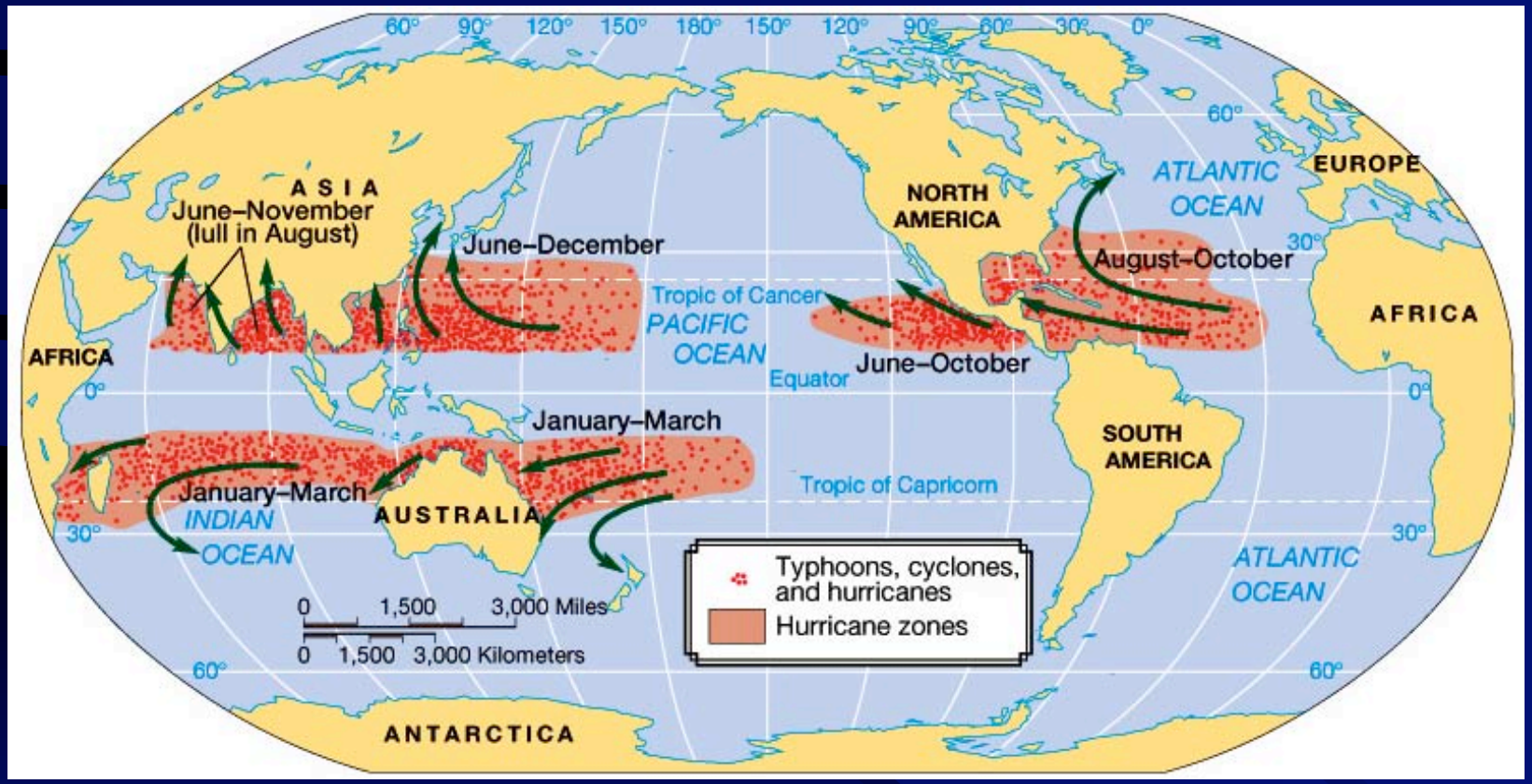
Relationship between surface pressure and wind speed for a number of tropical cyclones. Tropical cyclones are classified as hurricanes when their pressure is 980 millibars or lower, and sustained wind speeds are greater than 74 mph.

Hurricane Katrina and SST



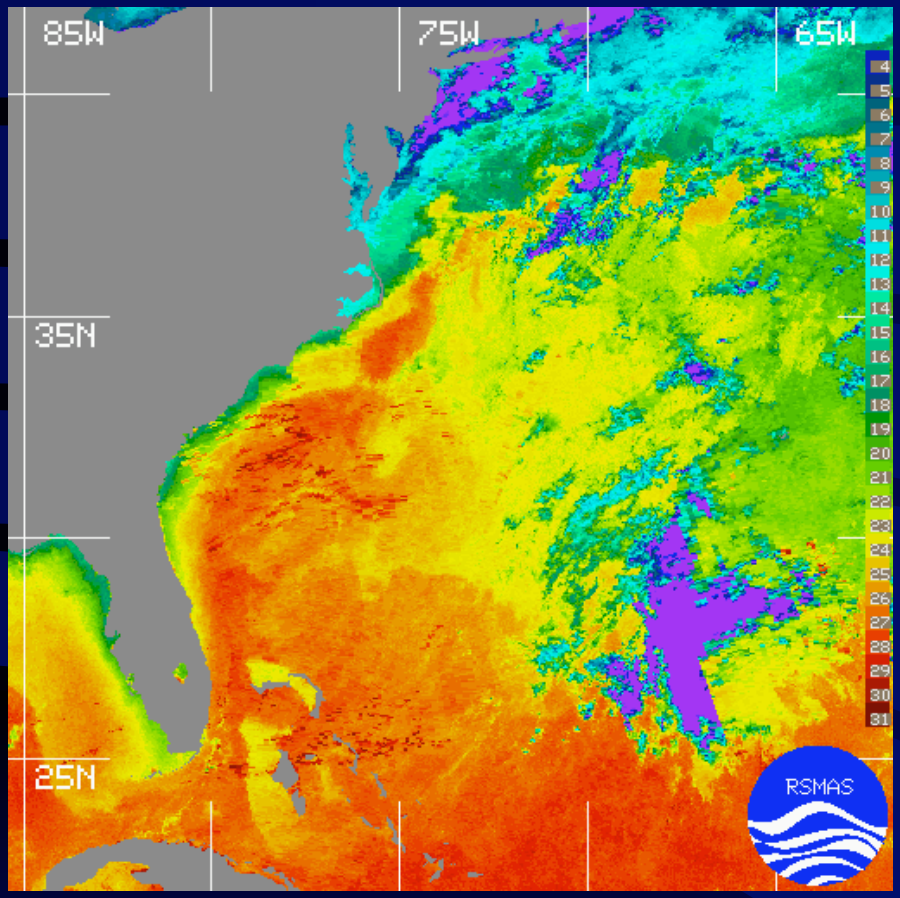
Hurricane Climatology

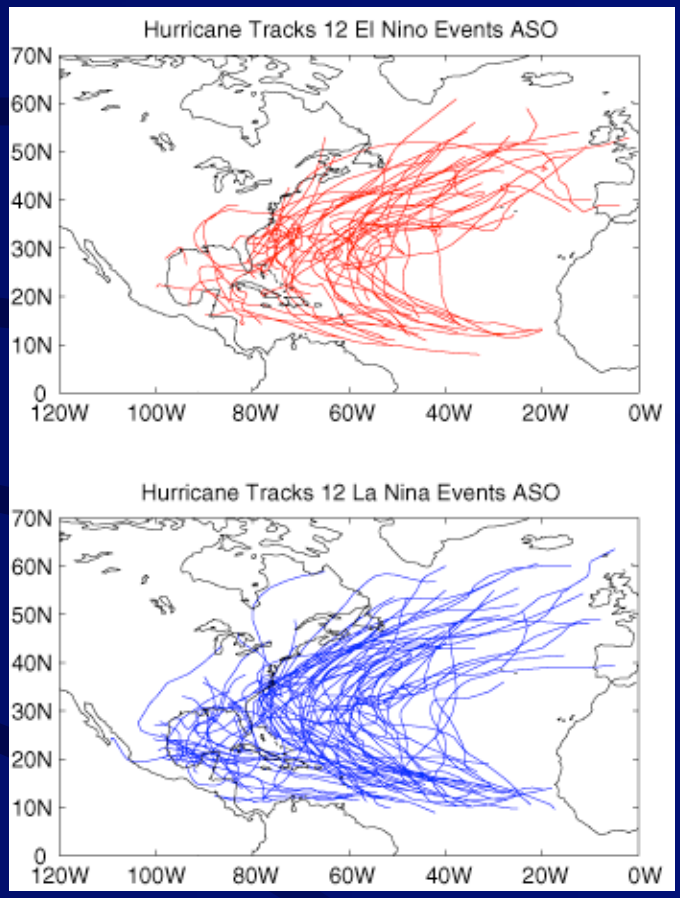
1. Warm Water SST > 26 C (80˚F)
2. A surface low with unstable air and deep moisture.
3. Low wind shear



Where and when do these conditions exist in the world?

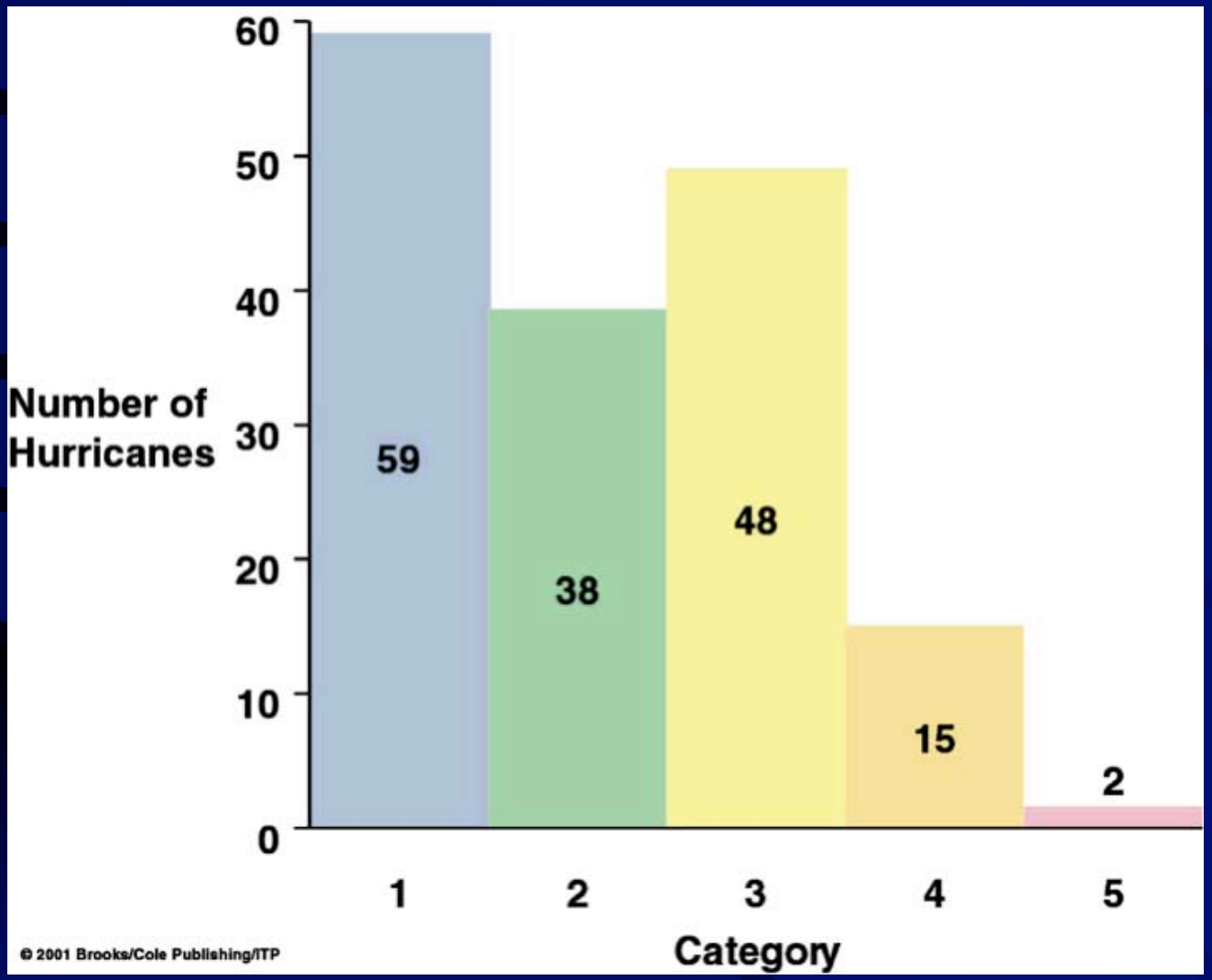
Hurricane Climatology



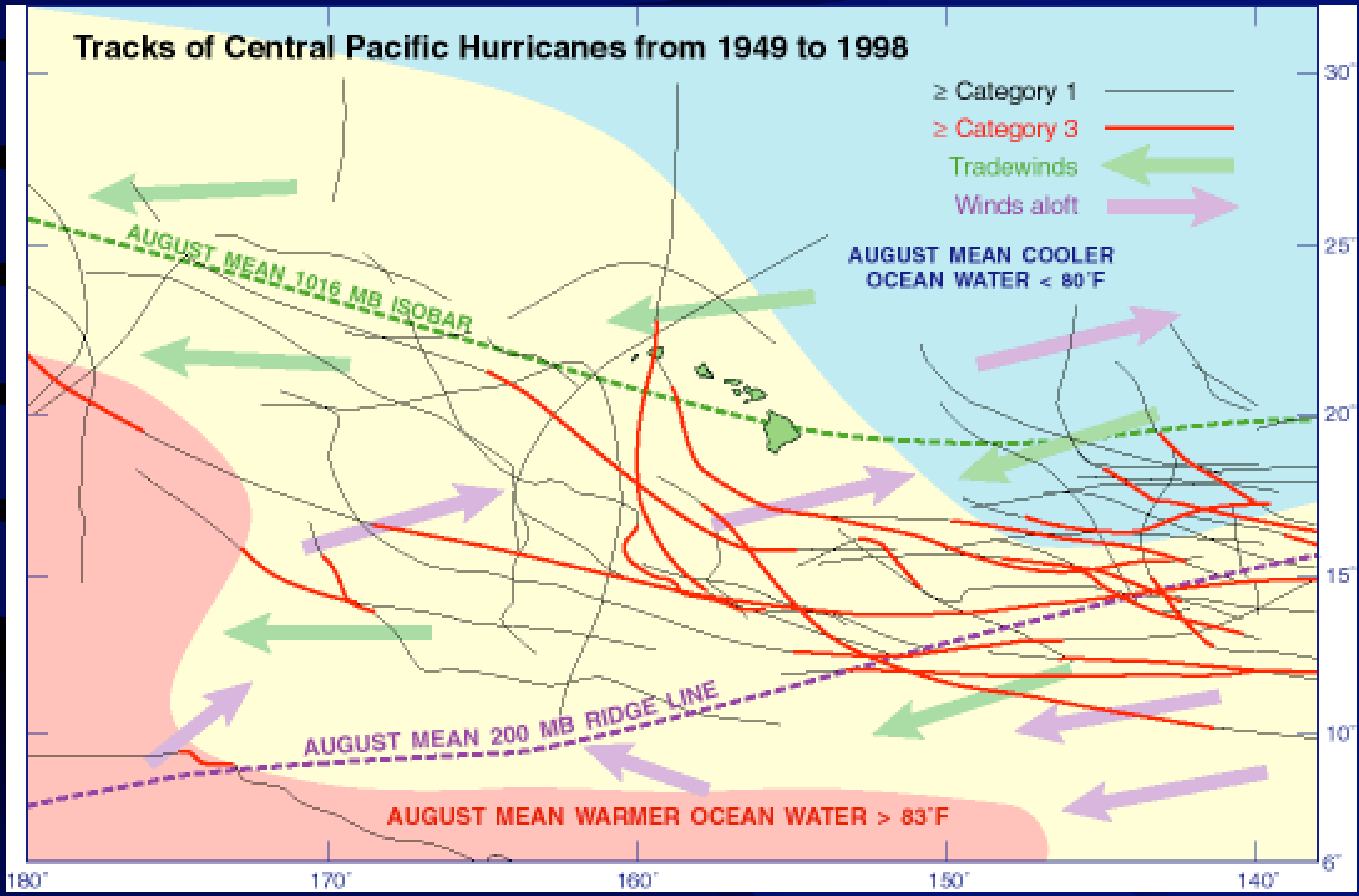


Hurricanes travel the warm Gulf Stream

Hurricane Climatology



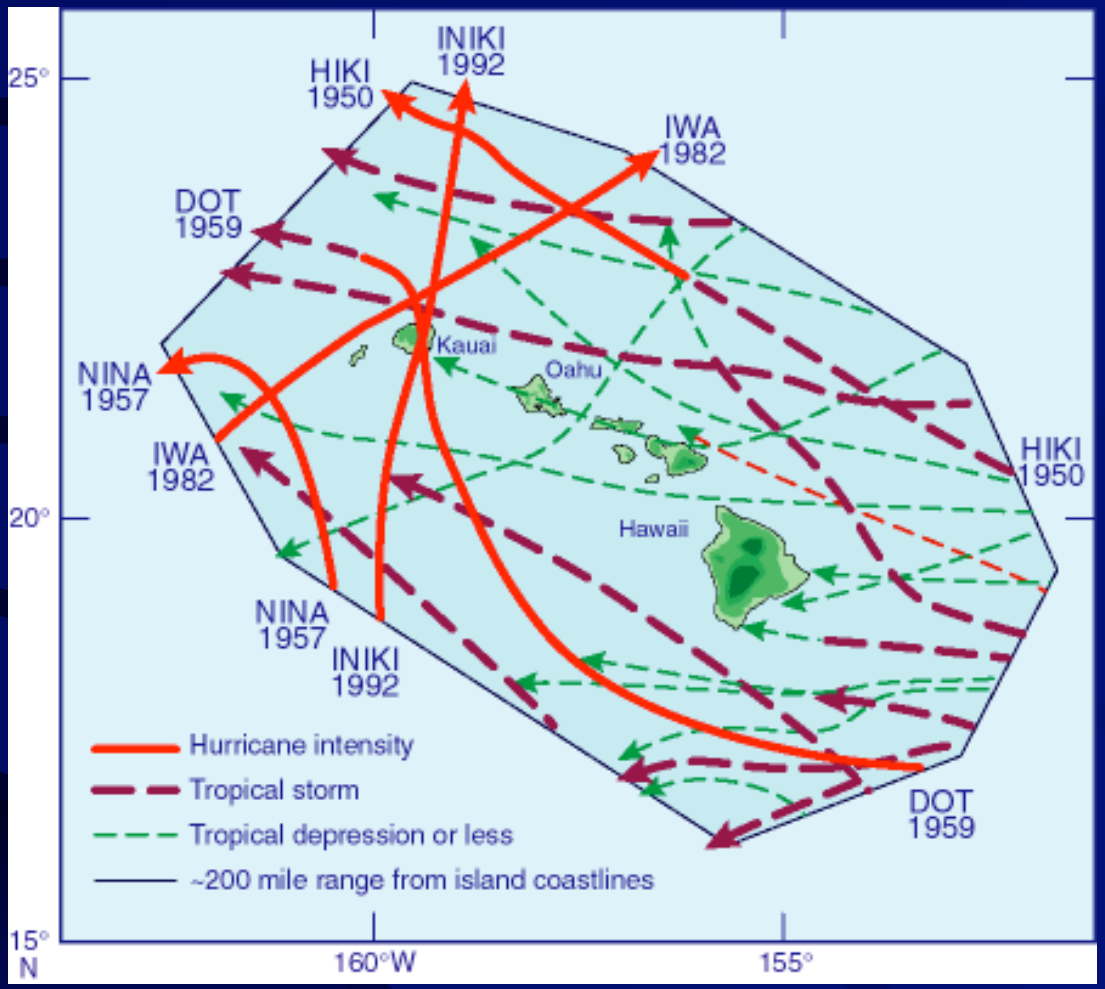
Hawaii Hurricane Climatology



Hurricane tracks in the central Pacific from 1949-1998

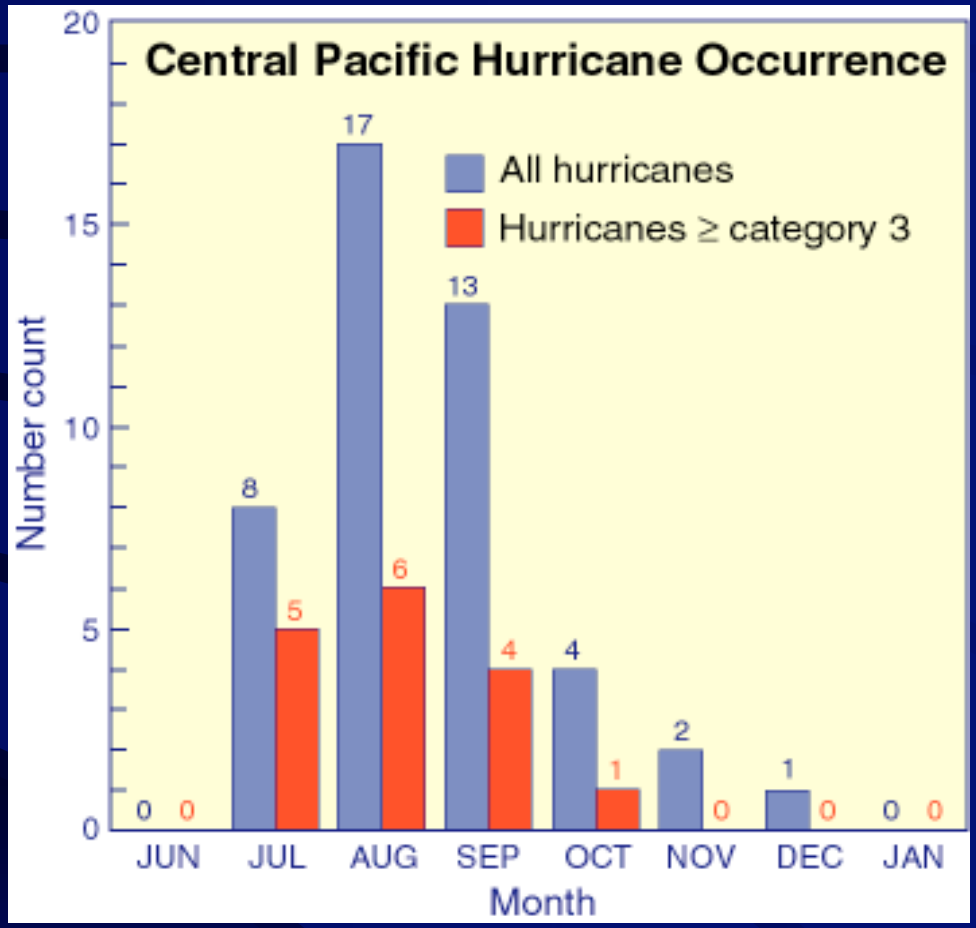
Hawaii Hurricane Impacts

Tropical Cyclone tracks within 200 miles of the Hawaiian Islands since 1949.

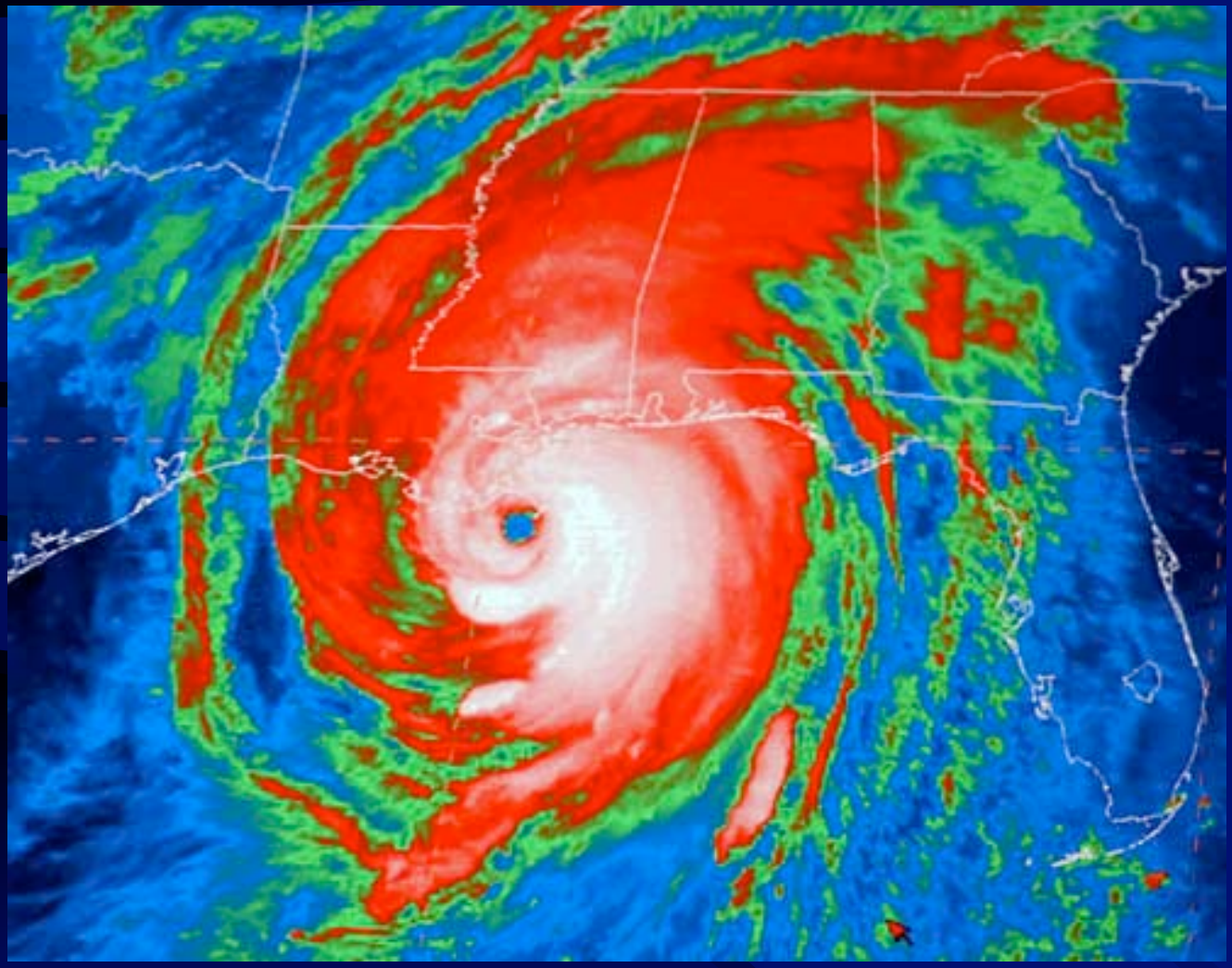


Central Pacific Hurricane Climatology

Number of hurricanes per month in the central Pacific.



Questions?



Hurricane Katrina