NATS 101
Section 13: Lecture 29

Hurricanes

Why are the tropics different from the mid-latitudes?

Virgin Islands

There are no big temperature gradients, gentle trade winds.

Weather is usually pretty quiescent on a Caribbean island, for example.

- **In the mid 80s pretty much all year**
- **Garden variety thunderstorms due to sea breeze.**
- **Some stronger thunderstorms in summer when ITCZ is around**

Recall that mid-latitude cyclones derive their energy from the

_____

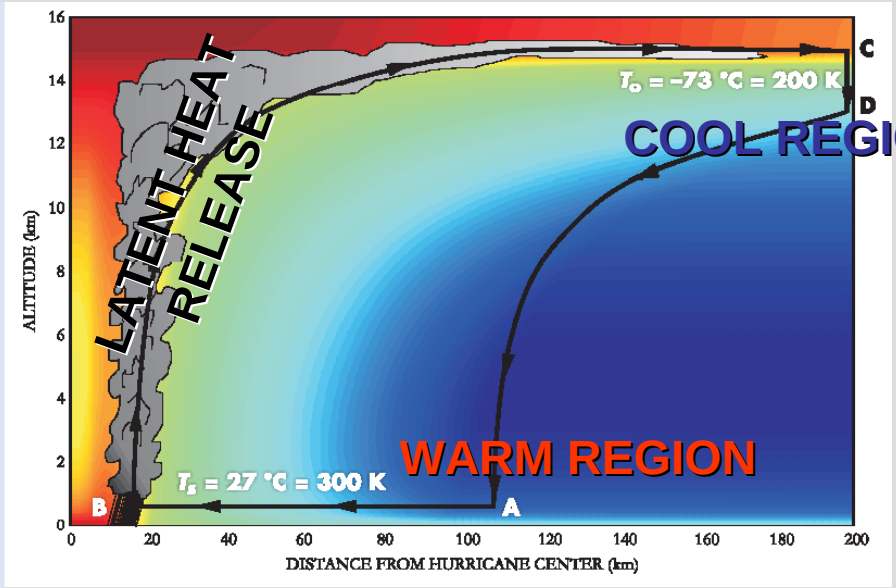
Because there are virtually no _____ differences in the tropics, a storm in the tropics has to get it's energy from a different source.

WARM MOIST AIR WHICH RELEASES ITS ENERGY BY CONDENSATION IN CLOUDS.

The Atmosphere's Heat Engine

Energy is transferred from a warm region to a cool region, converting some of that energy to do mechanical work—or kinetic energy.

Tropopause



Surface

(Emmanuel)

<u>In the hurricane</u>:

Warm region = warm and moist air above ocean's surface
Cool region = cold cloud top (the exhaust)
Energy conversion takes place by latent heat release in the cloud.

So what do we need to get the atmospheric engine going?

Take the analogy of moving a piston in a car engine, which requires:

Fuel = Favorable environmental conditions

Spark = A triggering disturbance

Ingredients for a Hurricane

Favorable environmental conditions

Warm water (>82 °F) through a deep layer

Conditionally unstable atmosphere

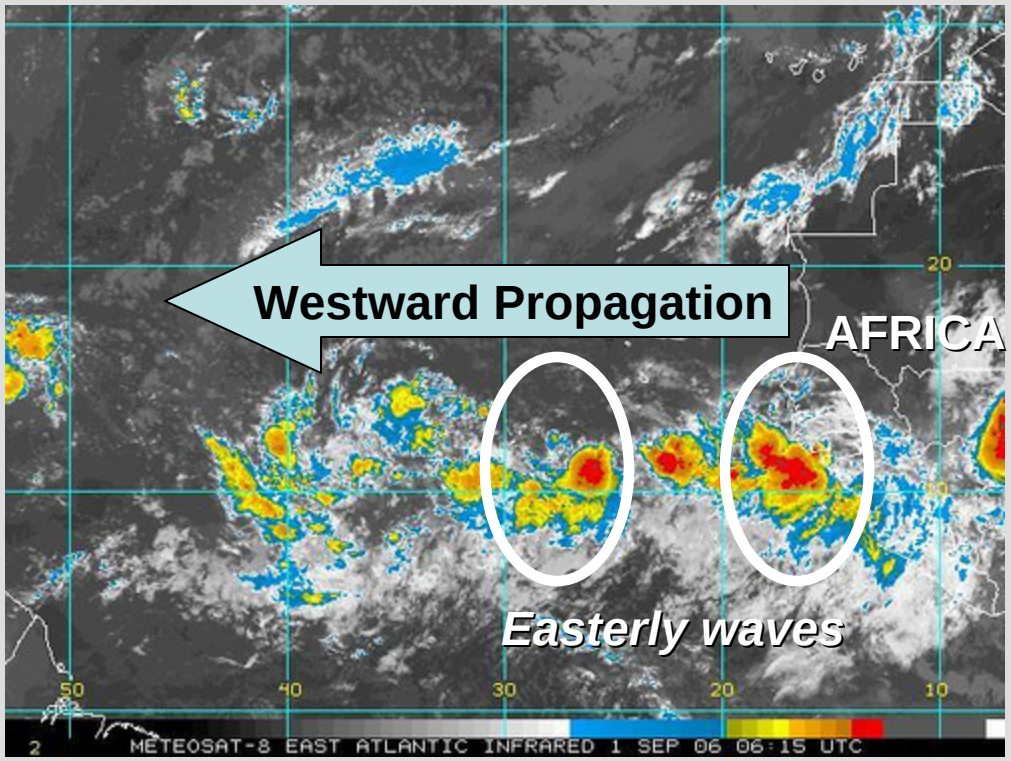
Very moist air through a deep layer

Weak vertical wind shear

Triggering disturbance

Typically a tropical easterly wave, or enhanced area of thunderstorms which propagates westward within the ITCZ.

African Easterly Waves
A Trigger for Atlantic Hurricanes



Meteosat
Enhanced IR Imagery

Areas of enhanced thunderstorms propagating westward

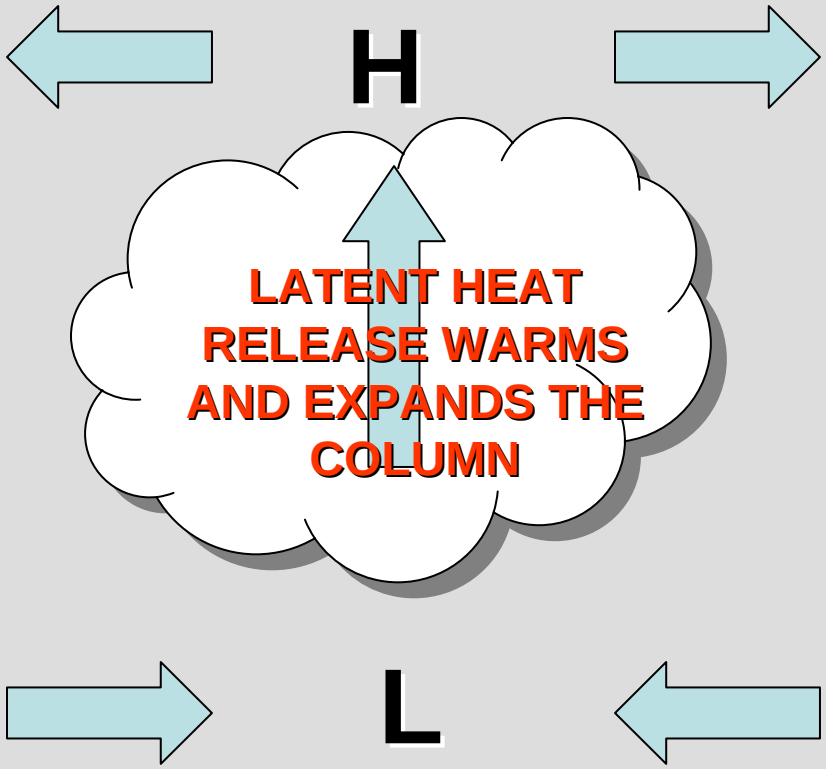
Thunderstorms originate in west Africa .

If the cluster of thunderstorms within the easterly wave grow to be large enough, they may start to feel the effects of the Earth's rotation.

Then they start to spin about an deepening area of low pressure.

Why does the surface pressure drop?

ALOFT
High pressure and
_____



SURFACE
Low pressure and
_____

Once this process gets going, the surface low can continue to deepen and the storm can grow so long as the environmental conditions are right!

Tropical Depression

Tropical depression which later became Hurricane Rita (2005)

Low pressure system becomes “closed off” and starts to spin about an axis of rotation.

<u>Winds</u>: About 20- 40 miles per hour.

Tropical Storm

Tropical Storm Katrina

<u>Winds</u>: 35 – 75 mph

Storm gets a name assigned.

The names in the Atlantic alternate between male and female names of English, French, or Spanish origin.

ONCE THE WINDS EXCEED 75 MPH, THE STORM IS A HURRICANE.

Hurricanes are called various other names throughout the world, but it is basically the same type of storm.

Tropical Cyclone Nomenclature

NORTHERN HEMISPHERE: Counterclockwise rotation

Hurricane: Atlantic and East Pacific

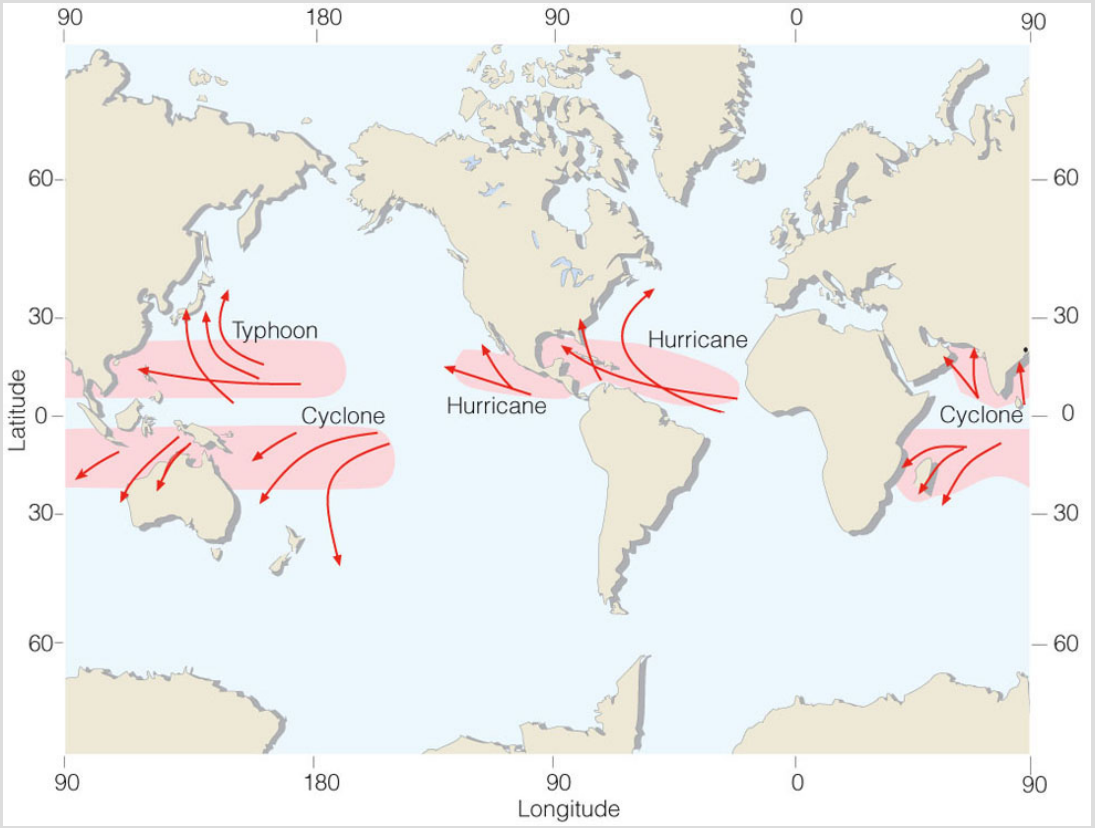
Typhoon: North Pacific

Cyclone: Northern Indian Ocean (including Bay of Bengal and Arabian Sea)

SOUTHERN HEMISPHERE: Clockwise rotation

Cyclone: South Pacific and Southern Indian Ocean

Tropical cyclone genesis regions (red) and tracks



Observations:

Tropical cyclones form in warm tropical waters, starting about 5° latitude AWAY from the equator.

Initially move west and curve around subtropical ridges.

Why don't hurricanes form off the west coast of continents, like North and South America?

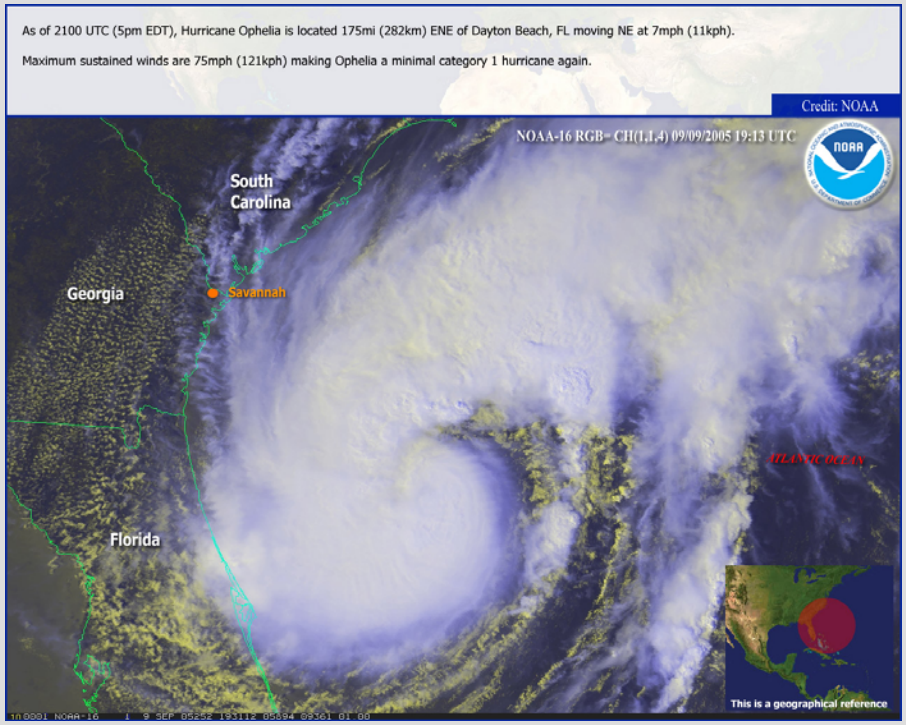
Hurricane Intensity given by the Saffir-Simpson Scale

Categories range from 1 to 5.

MAJOR HURRICANE IS CATEGORY 3 OR ABOVE

(We'll look at some from the 2005 season)

Category 1 Hurricane



Hurricane Ophelia

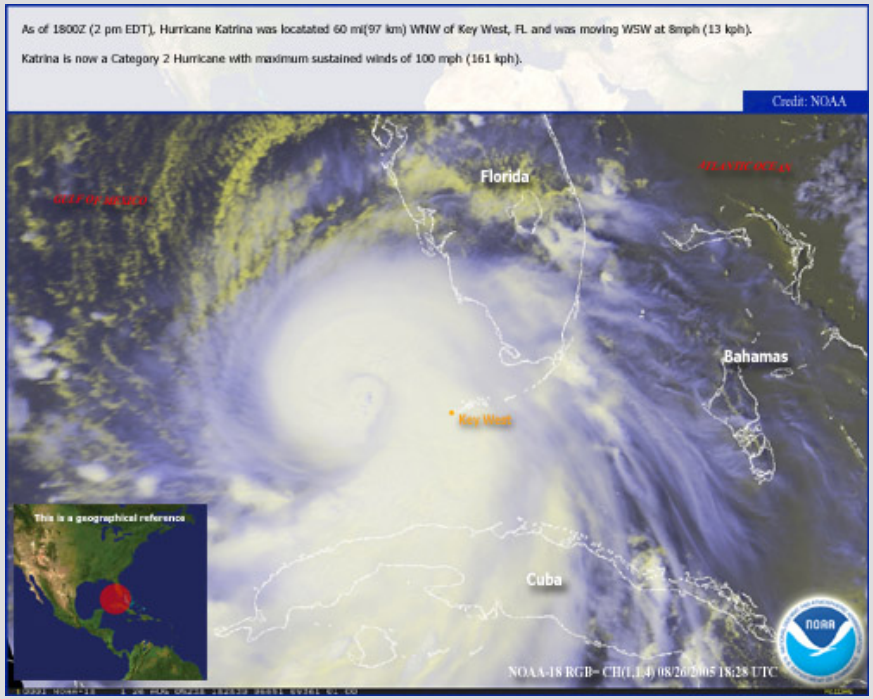
<u>Winds</u>: 74-95 mph

<u>Pressure</u>: A little more than 980 mb

<u>DAMAGE</u>

Tree branches, shrubs, and unanchored objects.

Category 2 Hurricane



Hurricane Katrina

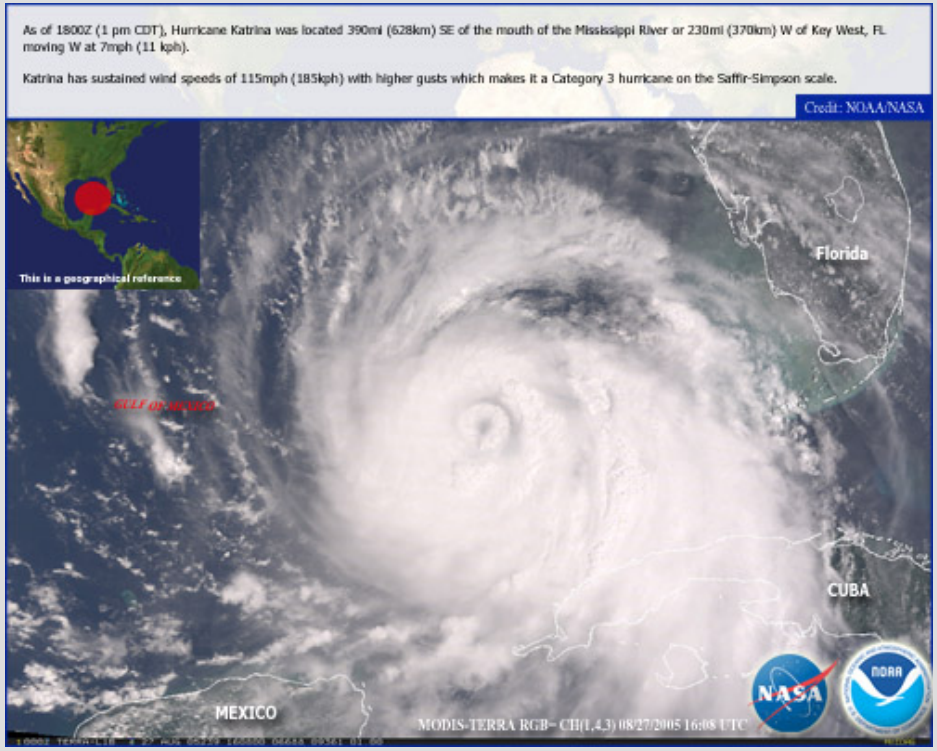
<u>Winds</u>: 96-110 mph

<u>Pressure</u>: 965 – 979 mb

<u>DAMAGE</u>

Trees blown down, damage to mobile homes and roofs of buildings.

CATEGORY 3 HURRICANE



Hurricane Katrina

<u>Winds</u>: 111-130 mph

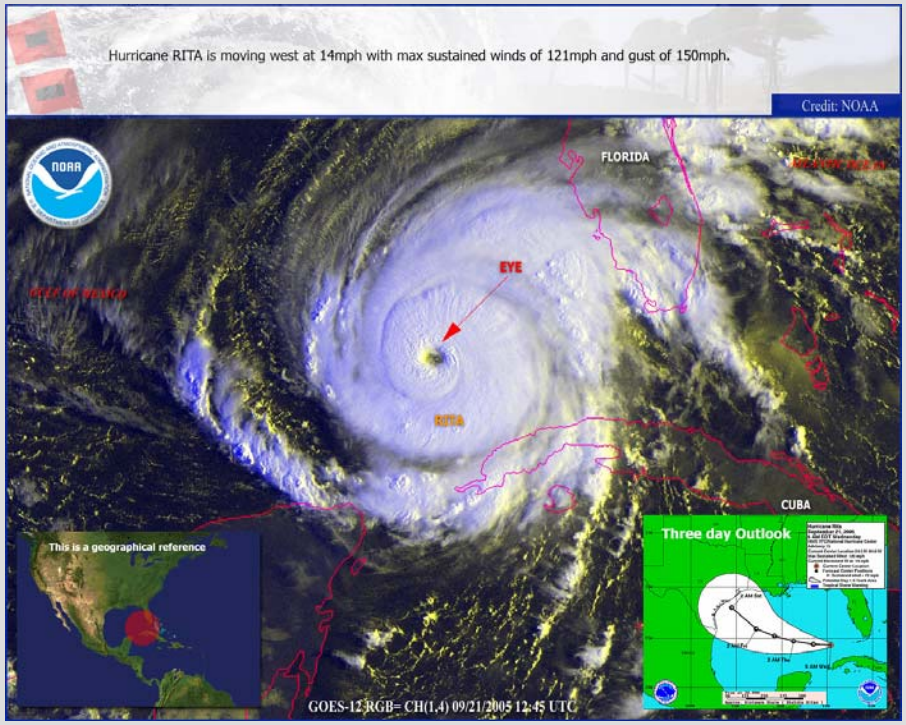
<u>Pressure</u>: 945 – 964 mb

By this point, storm typically has a defined eye in the center.

<u>DAMAGE</u>

Large trees blown down, mobile homes destroyed, structural damage to buildings.

CATEGORY 4 HURRICANE



Hurricane Rita

<u>Winds</u>: 131-155 mph

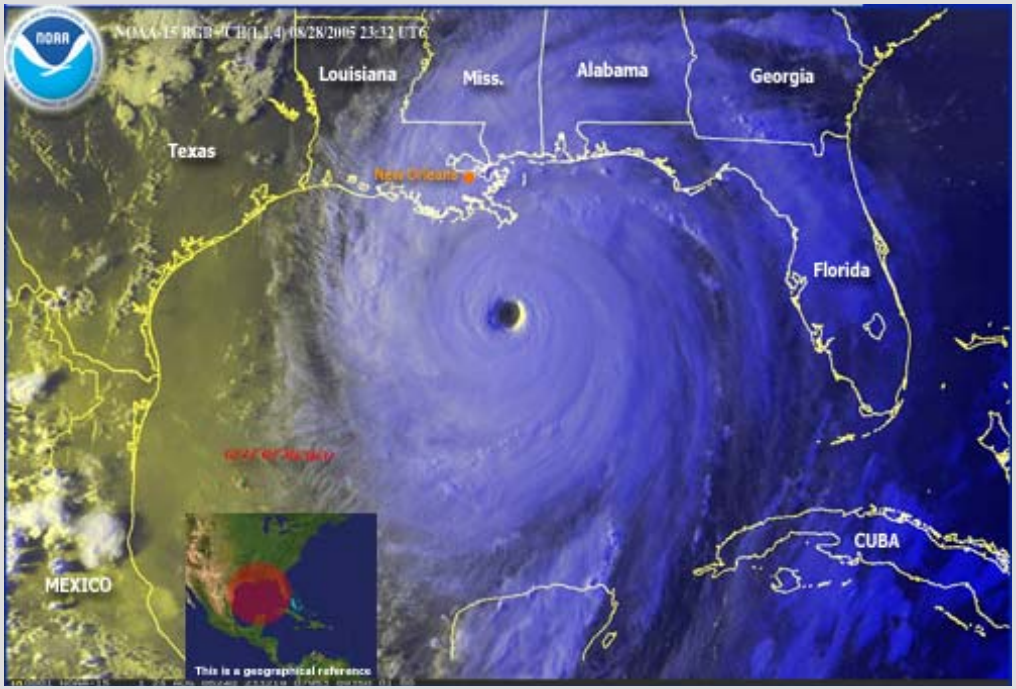
<u>Pressure</u>: 920 – 944 mb

Storm has very well defined eye and a symmetrical shape.

<u>DAMAGE</u>

Extensive damage to infrastructure, severe structural damage to homes and buildings, inland flooding as far as about 5 miles.

CATEGORY 5 HURRICANE



Hurricane Katrina
August 29, 2005
(Figure from Lecture 1)

<u>Winds</u>: 156 mph and greater

<u>Pressure</u>: Below 920 mb

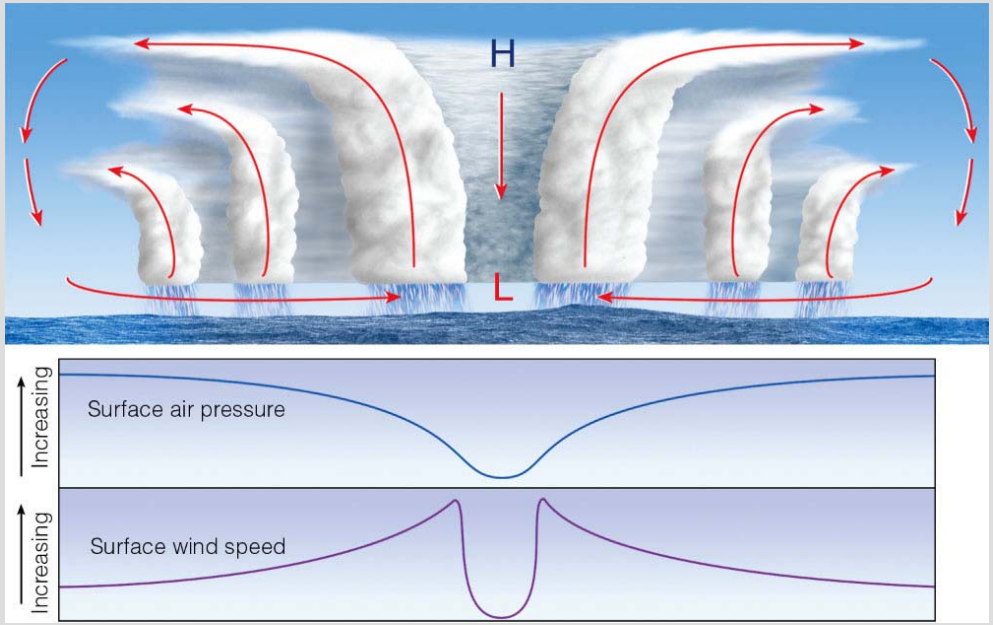
As in Category 4, a very symmetrical structure and well defined eye—that is even smaller!

Hard to maintain this strength for very long because of the hurricane's internal dynamics.

<u>DAMAGE</u>

INFRASTRUCTURE SEVERELY DAMAGED. NEARLY TOTAL DEVASATION OF ALL STANDING STRUCTURES. COASTAL ZONES WIPED CLEAN BY HIGH STORM SURGE.

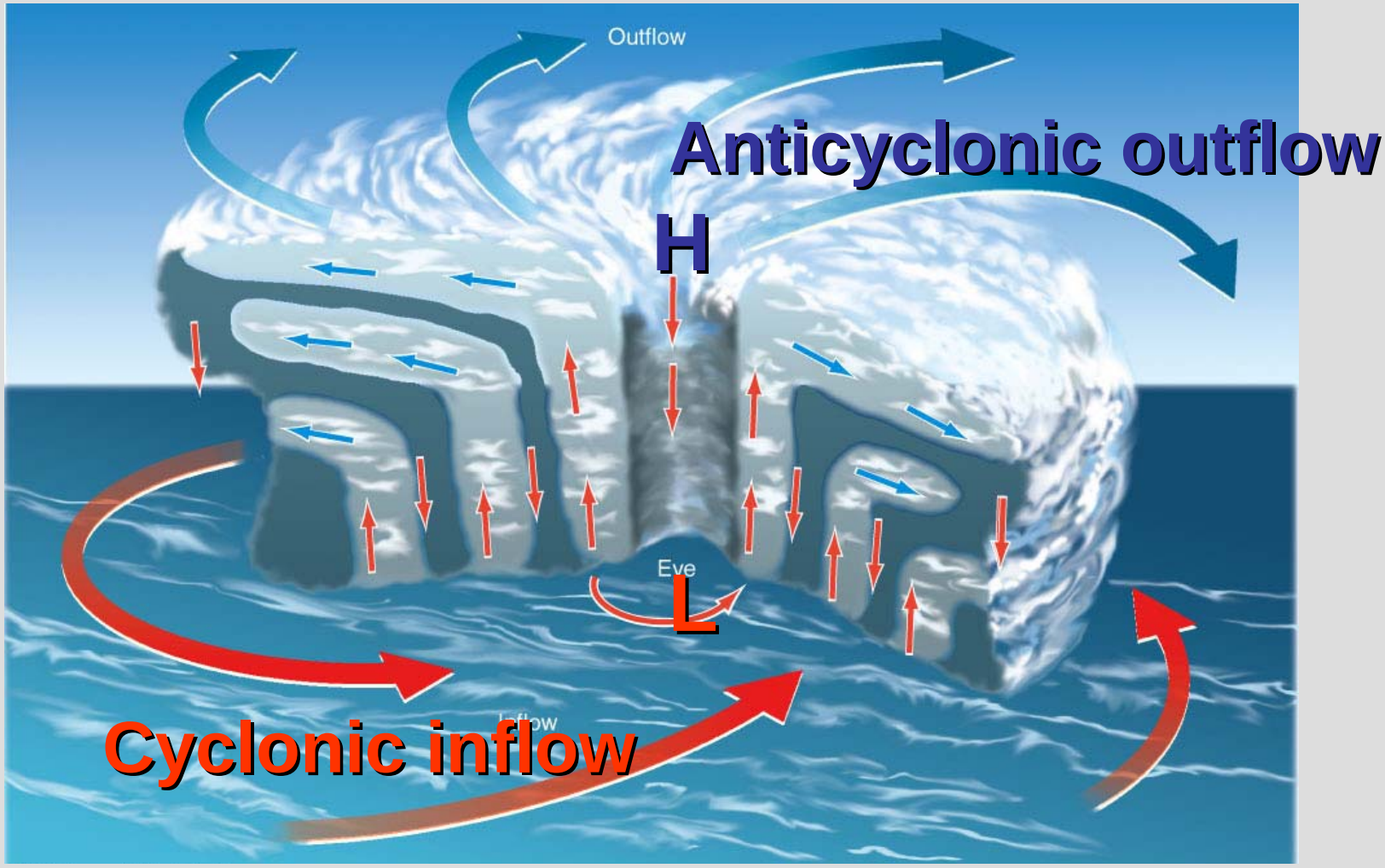
Structure of a Mature Hurricane



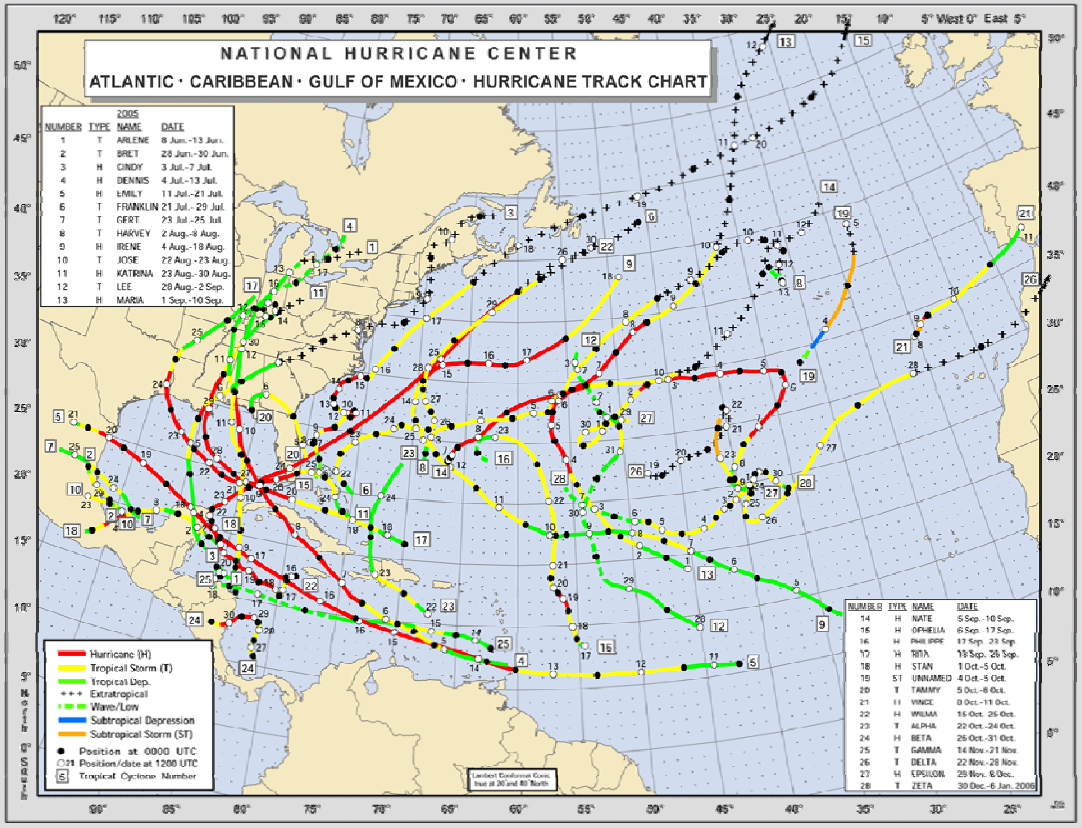
Well organized rain bands, of increasing severity the closer to the center

Most severe band is the EYE WALL, right before the EYE. This is where the strongest winds occur.

***THE EYE*: An area of relative clear, calm winds and sinking air. Sinking air warms due to compression. Where the lowest pressure occurs.**


Outflow
Anticyclonic outflow
H
Eye
L
Cyclonic inflow

Hurricane Tracks: 2005



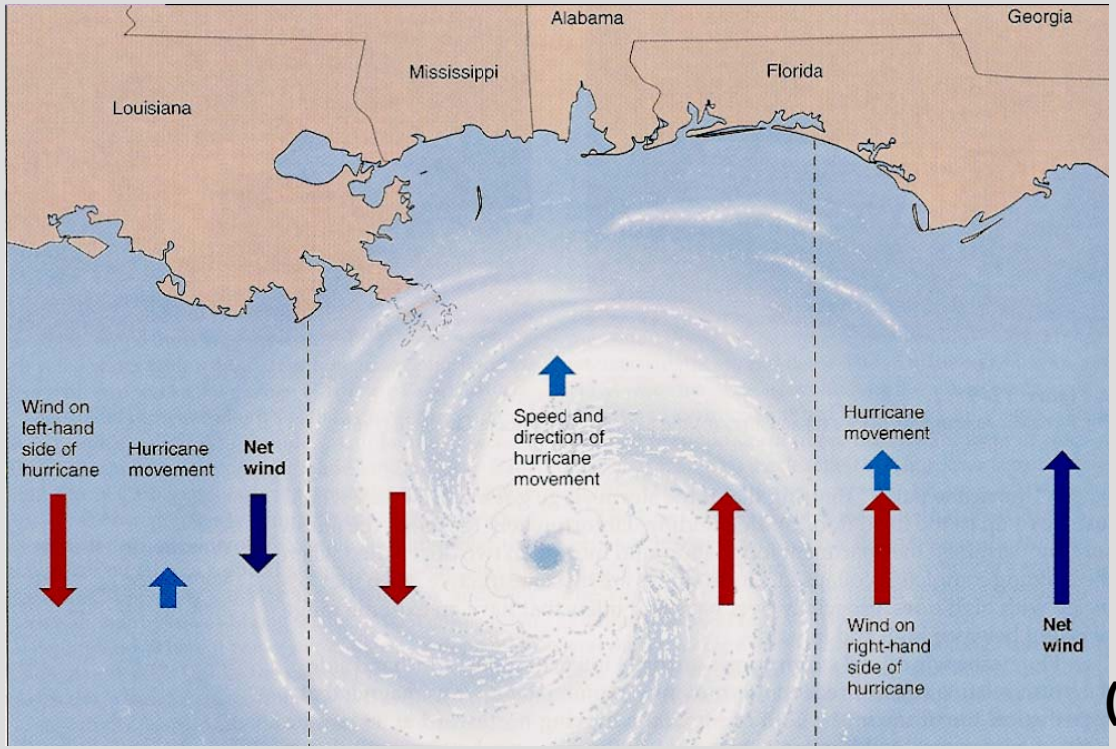
Each storm has a UNIQUE track that is dependent on the specific weather situation at the time.

Track forecasting is actually pretty good up to a few days, but forecasting intensity is still very hard!

So once a hurricane reaches land, what happens?

Depends on how strong the storm is and which side of it you're on.

Asymmetry of hurricane winds: Gulf coast example



(Agudo and Burt)

West side of storm = WEAK SIDE

Wind speed is lower because direction is opposite to hurricane movement

East side of storm = STRONG SIDE

Wind speed is higher because direction is with hurricane movement.

Causes of hurricane damage at landfall

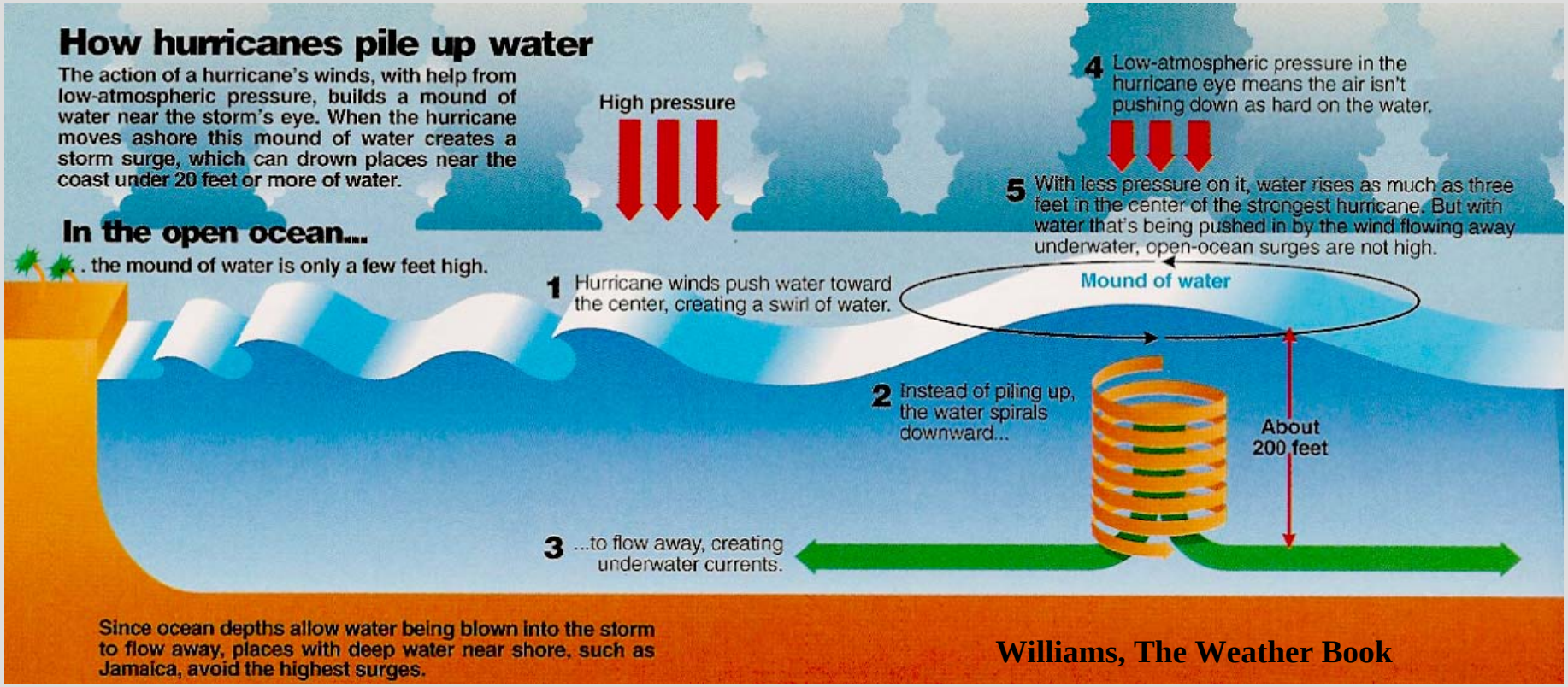
WIND and weak tornadoes (F1 – F2)

RAIN: Typically 10 inches and higher

STORM SURGE: Abnormal rise of sea water at the coastline

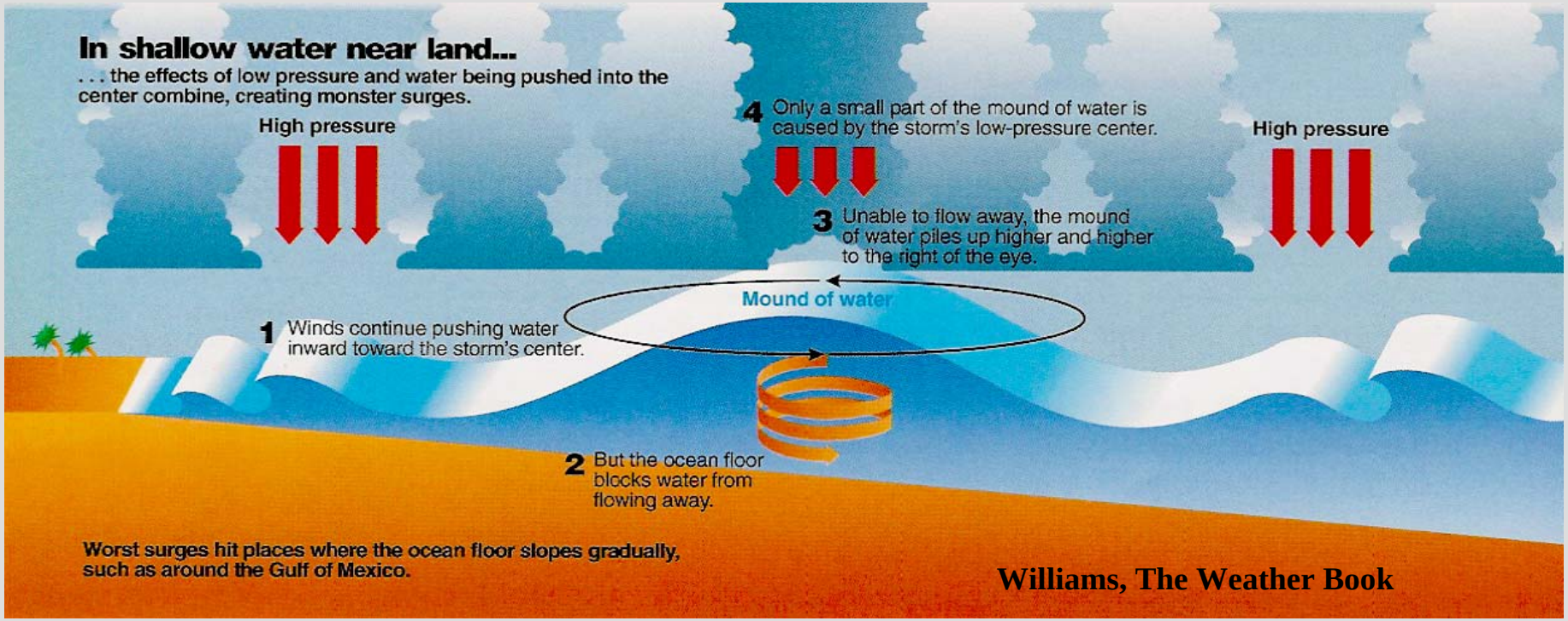
Which of these is the most dangerous? Why?

Surge: Hurricane in open ocean



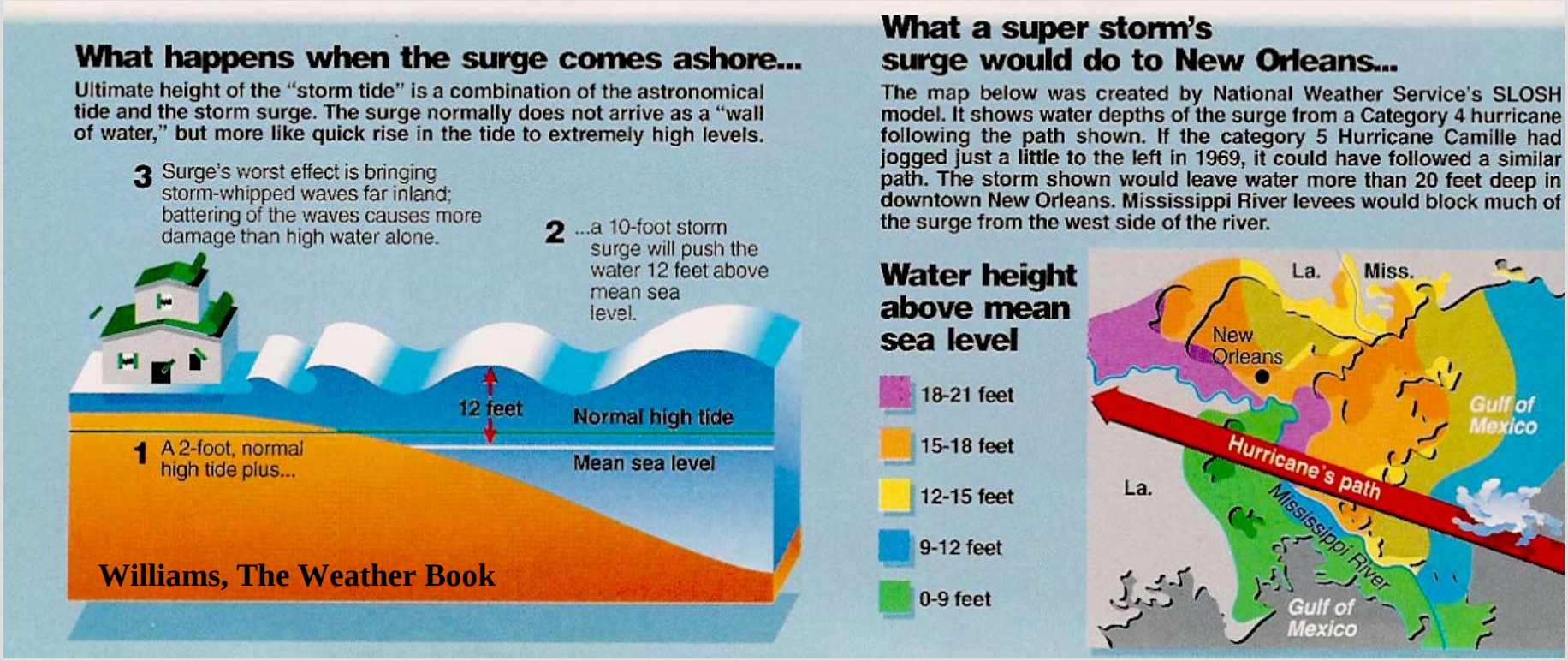
Williams, The Weather Book

Surge: Hurricane nearing coastline



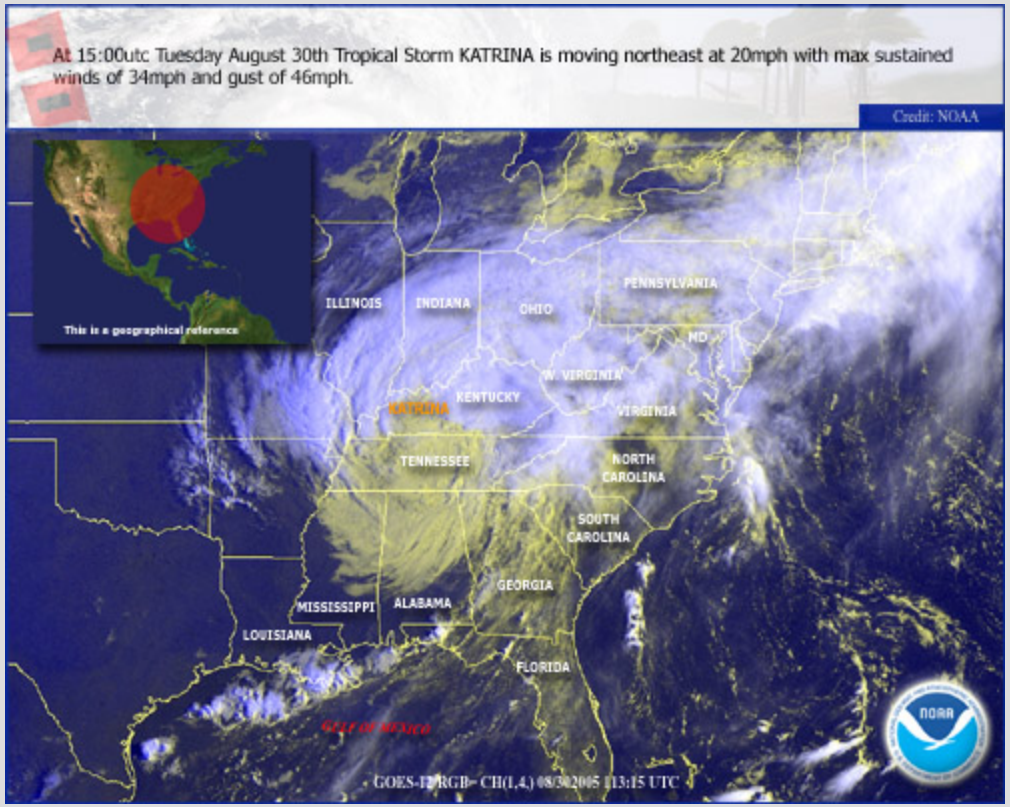
Williams, The Weather Book

Surge: Hitting coastline



IT WAS <u>WELL KNOWN</u> IN THE METEOROLOGICAL COMMUNITY <u>PRIOR</u> TO KATRINA THAT NEW ORLEANS WAS A MAJOR DISASTER WAITING TO HAPPEN!

Hurricane Demise



Tropical Storm Katrina

Once a hurricane makes landfall, it rapidly weakens because:

It is cut off from it's fuel source of warm water.

Frictional effects of the land cause the eye to fill in.

If it goes over colder open water (like the North Atlantic), only the first one of these effects happens...

Summary of Lecture 29

The tropics are different from the mid-latitudes because there are no large temperature gradients.

A hurricane is essentially a heat engine. To get going need:

Favorable environment: SST, instability, low shear

Triggering disturbance

The triggering disturbance is typically a tropical wave (which originates off west Africa for Atlantic hurricanes).

The order of intensity in hurricane development: tropical wave, tropical depression, tropical storm, and hurricane (with categories 1-5).

Hurricanes form in warm tropical water away from the equator and move around subtropical highs. They rapidly weaken once they make landfall.

Mature hurricanes have: 1) rain bands, increasing in severity to center; 2) clear and calm eye in the center; 3) cyclonic inflow at surface and anti-cyclonic outflow aloft.

The causes of damage at hurricane landfall are wind, rain, and storm surge. The storm surge is the most dangerous.

Review Questions

Reading: Chapter 18

Chapter 15

Questions for Review: 1,3,4,5,6,7,8,9,10,11,13,14,15,16,18,21 (8th ed.)
1,3,4,5,6,7,8,10,11,12,15,15,17,18,24 (9th ed.)

Questions for Thought: 1,2,4,7,8,9

Problems and Exercises: 1