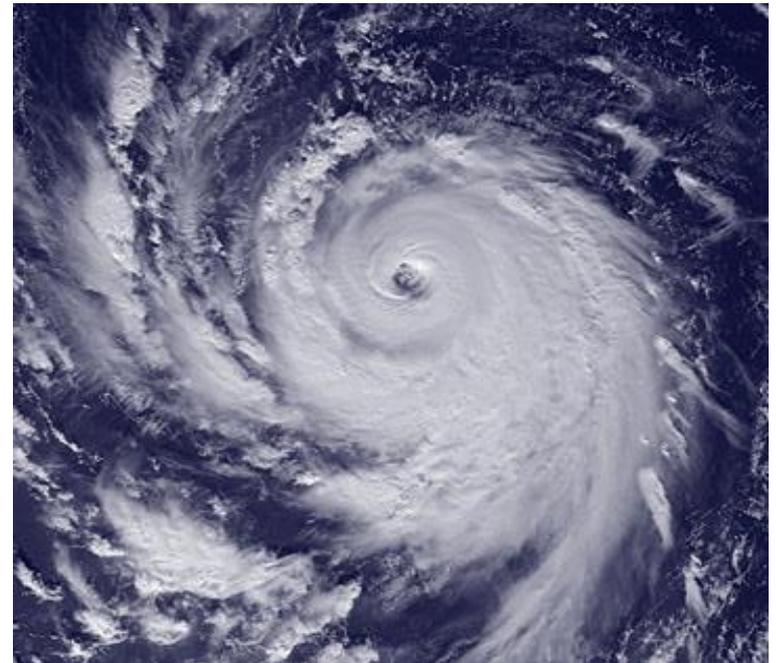


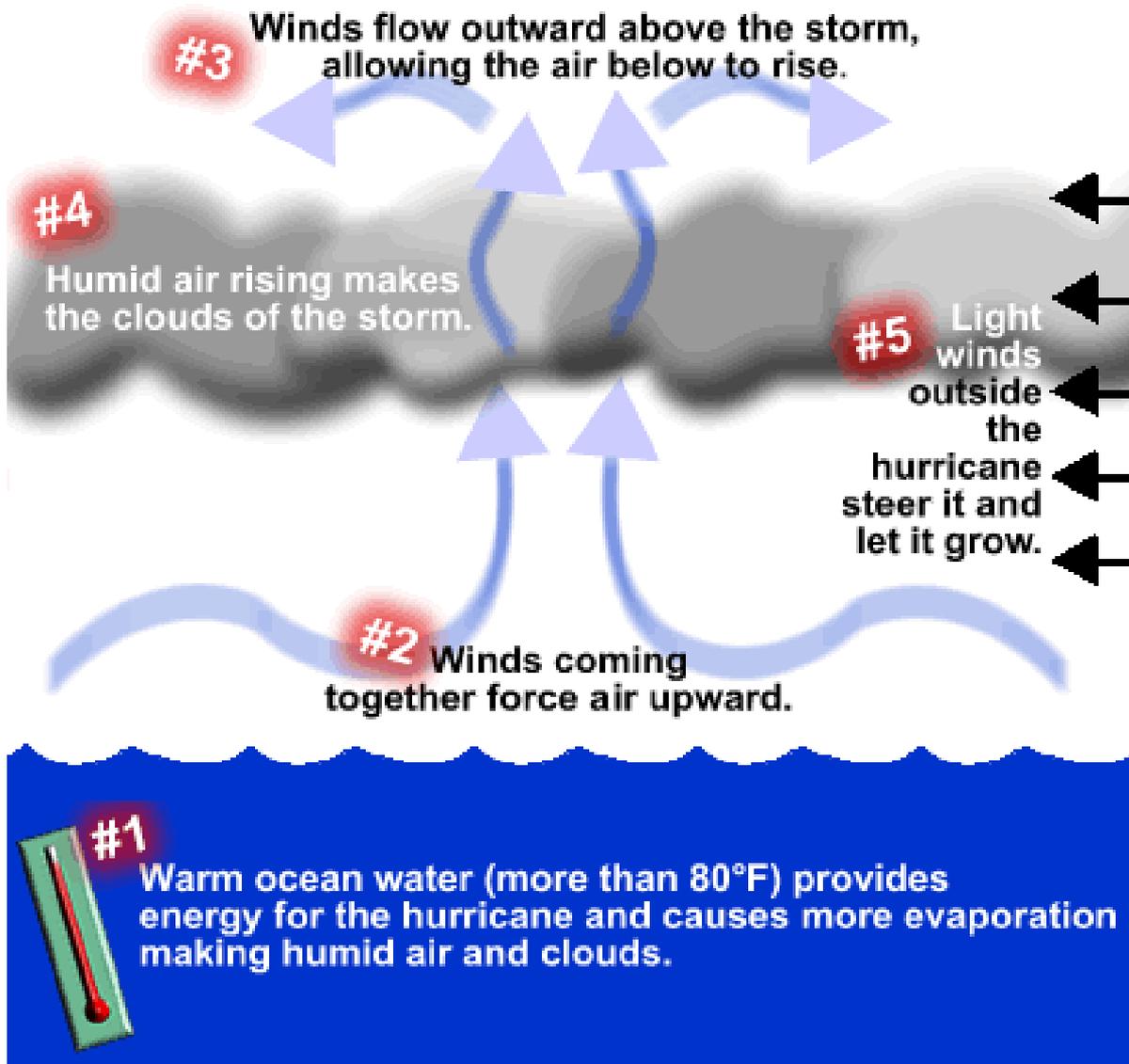
# Cyclonic Storm

A cyclonic storm is a large-scale **rapidly rotating storm system** characterized by a **low-pressure center, strong winds**, and a spiral arrangement of thunderstorms that produce **heavy rain**.

- Formed from *organized groups of thunderstorms*.
- Classified depending on its strength and location:
  - Tropical Depression
  - Tropical Storm
  - Tropical cyclone (Southern Hemisphere and Indian Ocean)
  - Typhoon (Northwestern Pacific)
  - Hurricane (Northeast Pacific or North Atlantic)



# Ingredients of a Cyclonic Storm



- **Warm water**  
(at least 26.5°C/  
79.7°F are needed  
down to a depth of  
at least 50 m/ 160 ft)
- **Time to grow**
- **Conditions  
to develop  
circulation**  
(location off equator)
- **Light upper  
level winds**  
(wind shear destroys  
thunderstorm  
organization)

# Winds, Pressure, Rotation

- “Hurricane strength” wind speeds **> 74 mph**.
- Barometric pressure inside a cyclonic storm is **LOW**.
- In which direction does a cyclonic storm rotate?



**COUNTERCLOCKWISE**  
in **Northern** Hemisphere



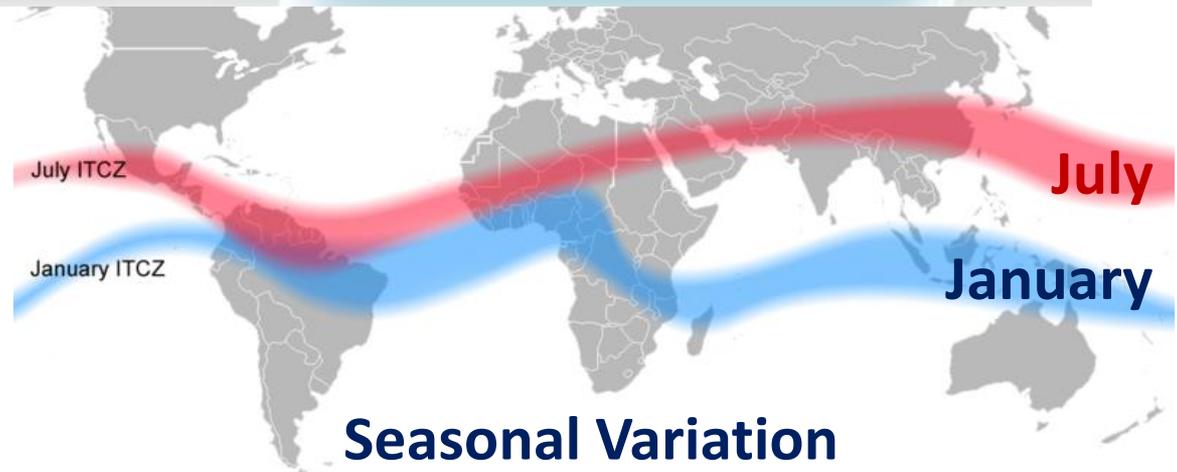
**CLOCKWISE**  
in **Southern** Hemisphere

# Where are Hurricanes Forming?

## InterTropical Convergence Zone (ITCZ)



Area of low pressure near the Equator, a worldwide band of thunderstorm activity.



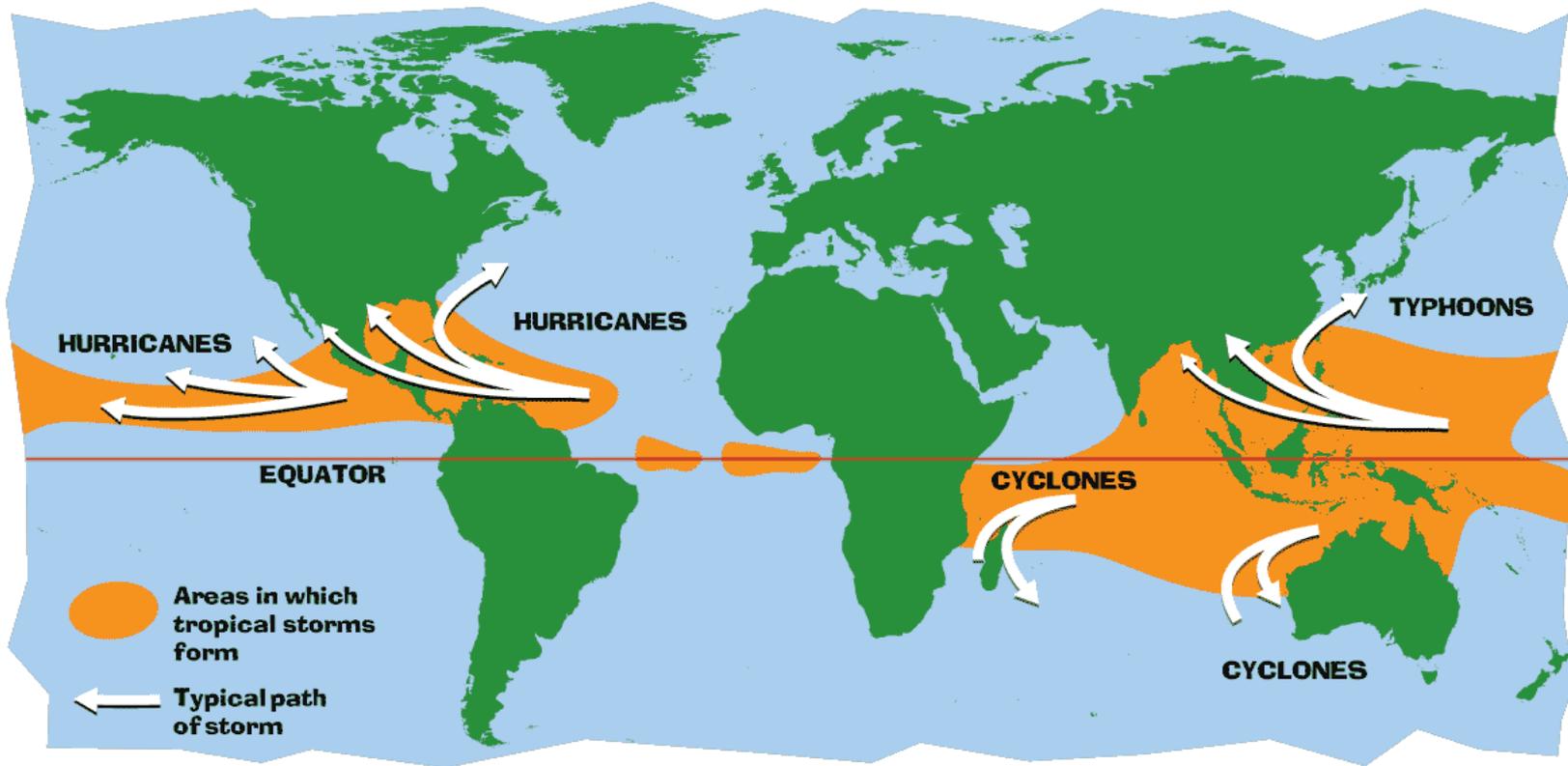
# When is Hurricane Season?

- Northern Atlantic Ocean: a **distinct cyclone season** occurs from **June 1 to November 30** (peaking from late August through September).



- Northeast Pacific Ocean: May 15 to November 30.
- Northwest Pacific: **year-round** (a minimum in February and March and a peak in early September).
- North Indian basin: April to December (has two peaks - May and November).
- Southern Hemisphere: **year-round** (peaking mid-February to early March).

# Formation and Typical Paths

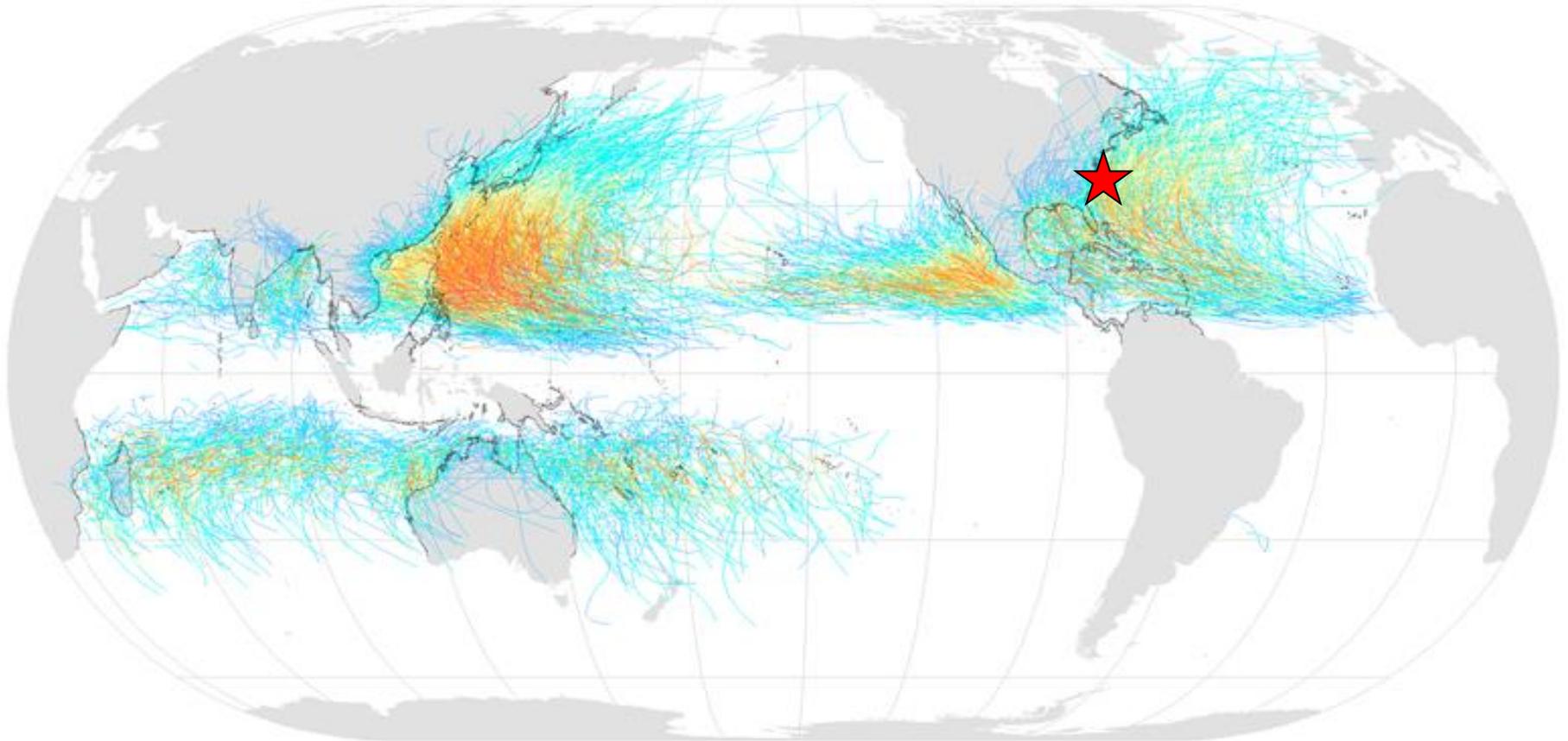


The majority of cyclonic storms **form between 10 and 30 degrees** of latitude away of the equator:

- **87%** between **10-20 degrees north or south**,
- **rarely** form or move **within 5 degrees** of the equator where Coriolis effect (responsible for storm rotation) is low.

# Historical Data

## Tropical Cyclones, 1945–2006



Saffir-Simpson Hurricane Scale:

tropical  
depression

tropical  
storm

hurricane  
category 1

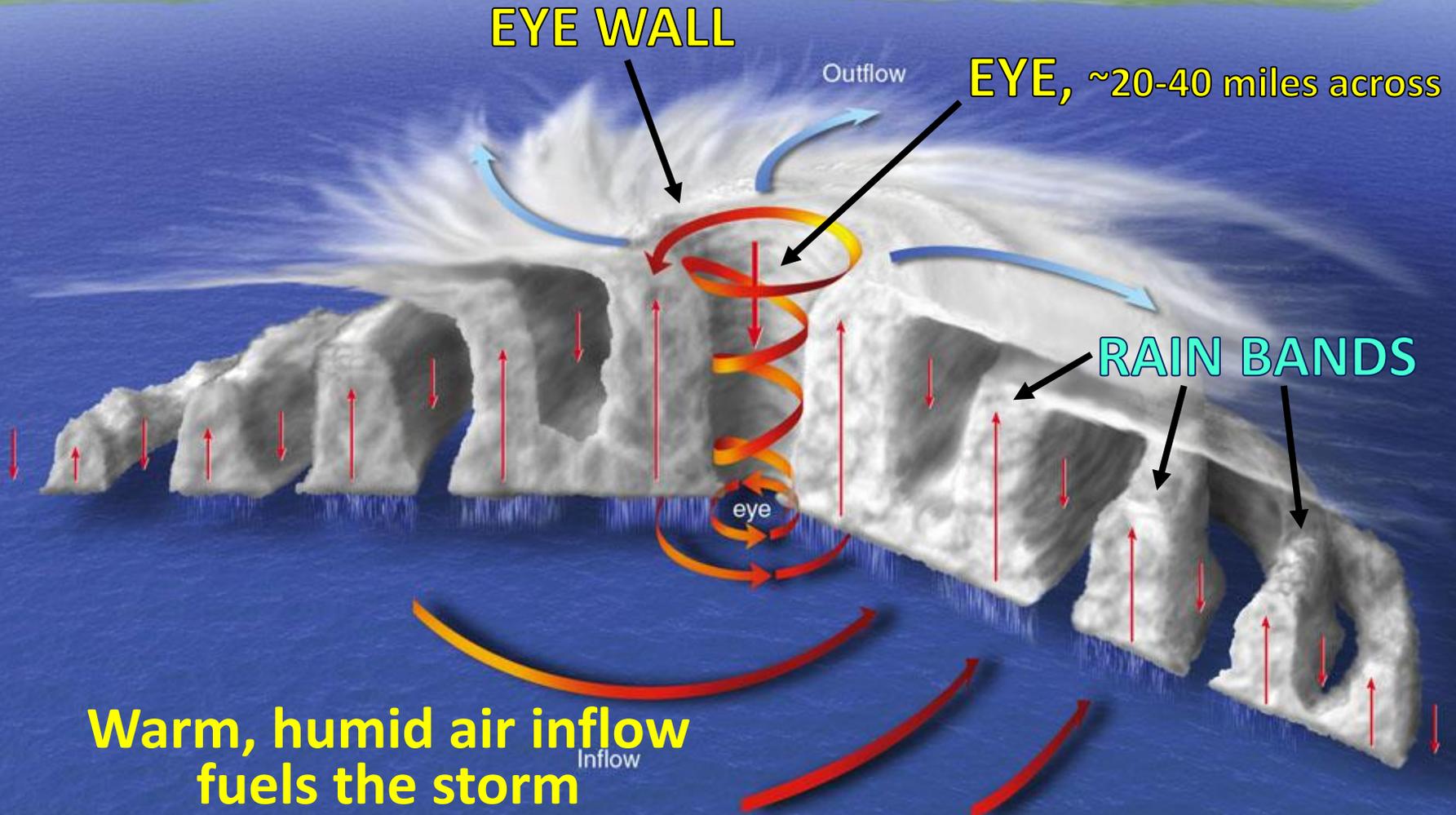
hurricane  
category 2

hurricane  
category 3

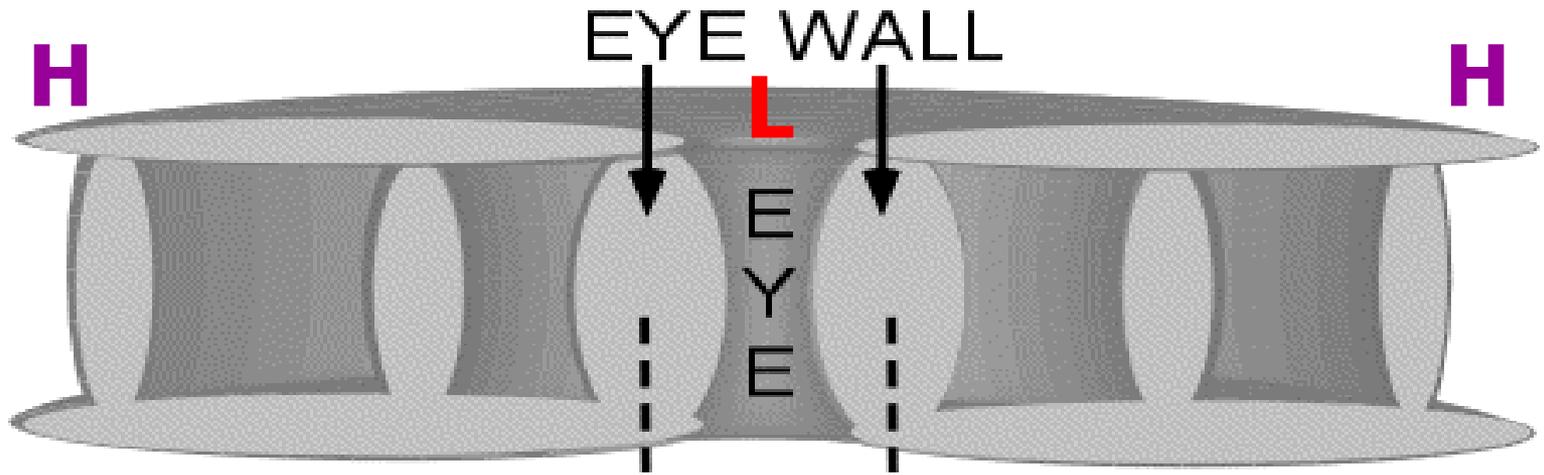
hurricane  
category 4

hurricane  
category 5

# Hurricane Structure

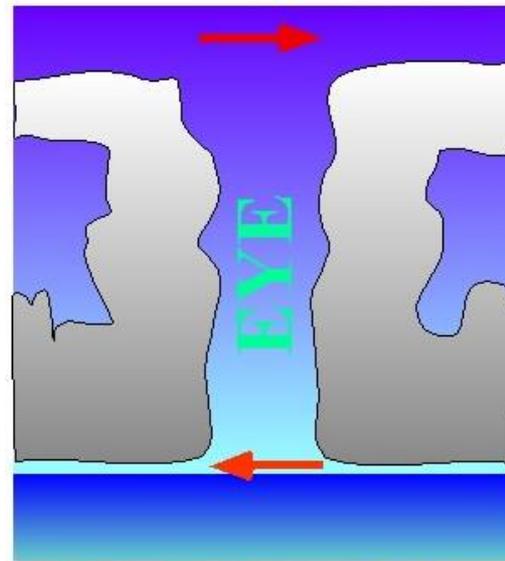


# Pressure and Wind Speed Profile

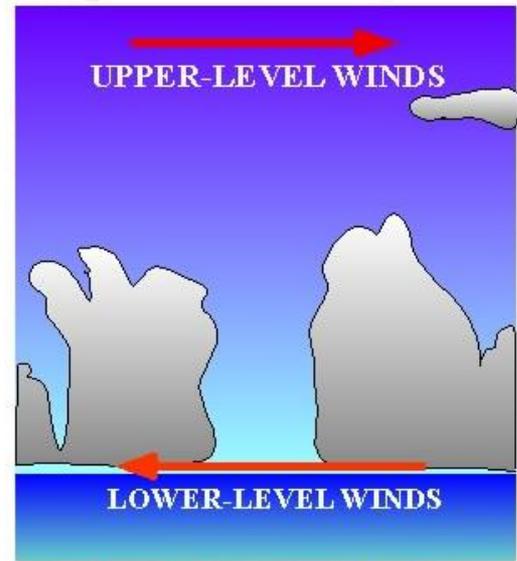


# What destroys a hurricane?

- Strong vertical wind shear causes convection and loss of vertical storm organization.
- Cold water (moving over waters significantly below 26.5 °C/79.7 °F).



*WEAK SHEAR = FAVORABLE*



*STRONG SHEAR = UNFAVORABLE*



- Movement over land - most strong storms lose their strength very rapidly after **landfall** and become disorganized areas of low pressure within a day or two as a result of **friction** and **lack of moisture**.

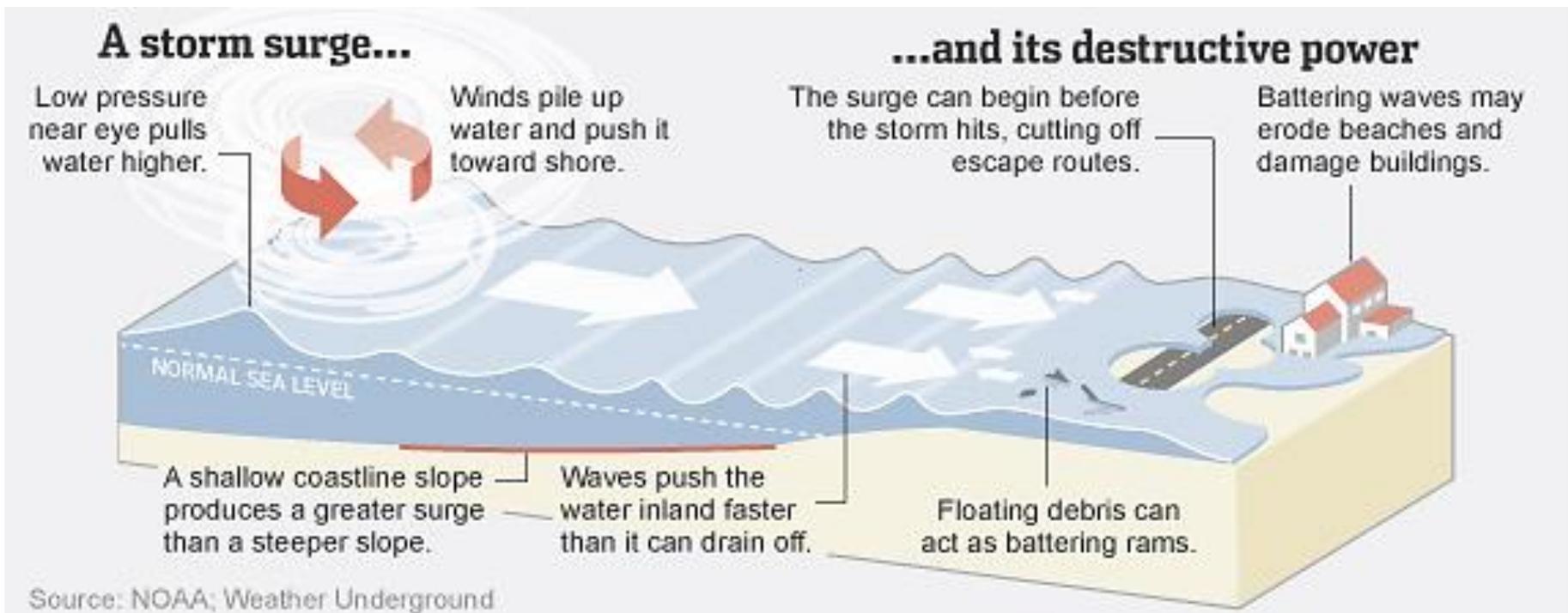
# Measuring Hurricane Strength

## Saffir-Simpson Hurricane Scale

Category	Wind speed (mph)	Storm surge (feet)
<b>5</b>	<b>156+</b>	<b>More than 18</b>
<b>4</b>	<b>131–155</b>	<b>13–18</b>
<b>3</b>	<b>111–130</b>	<b>9–12</b>
<b>2</b>	<b>96–110</b>	<b>6–8</b>
<b>1</b>	<b>74–95</b>	<b>4–5</b>
<b>Additional classifications</b>		
<b>Tropical storm</b>	<b>39–73</b>	<b>0–3</b>
<b>Tropical depression</b>	<b>0–38</b>	<b>0</b>

# What is Storm Surge?

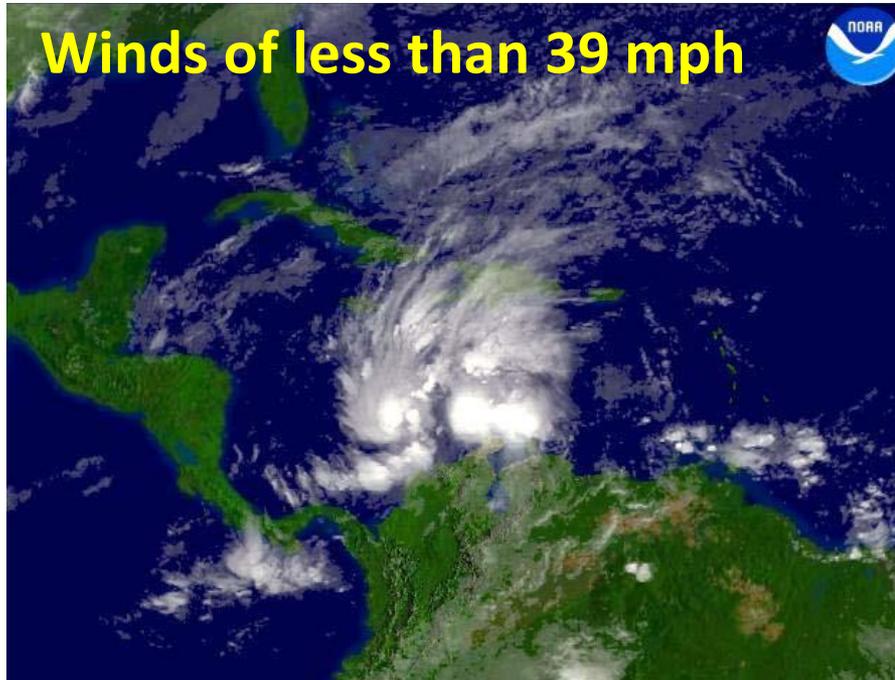
Storm surge is an abnormal rise of water generated by a storm, **over and above** the predicted **astronomical tides**.



Important factors: storm **intensity** (wind speed) and size, **forward speed**, **angle of approach** to the coast, central pressure (minimal contribution in comparison to the wind), the **coastline shape and bathymetry**.

# Stages of Hurricane Development

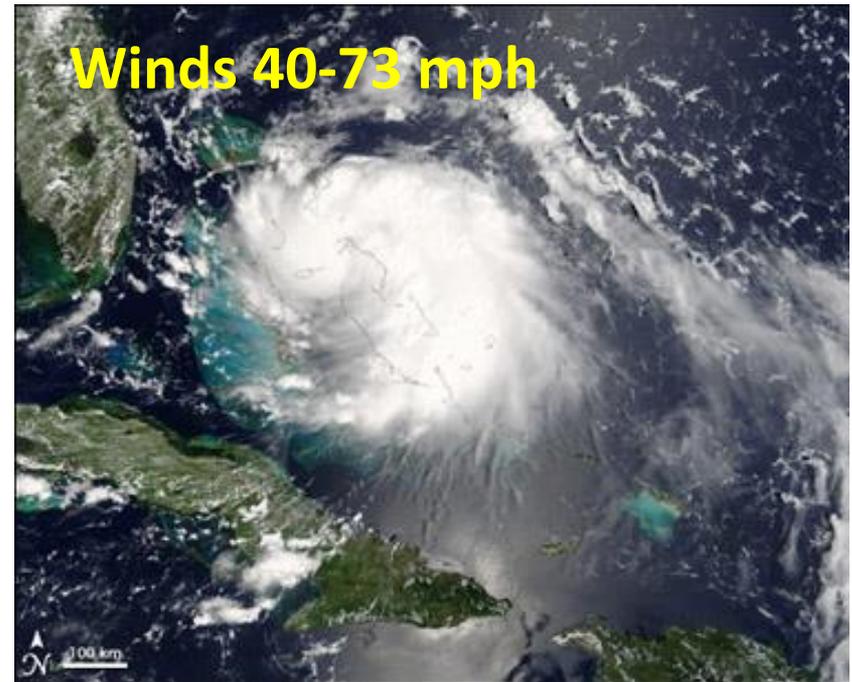
## 1. Tropical Depression (Wave)



**Lacks structure** – no well developed feeder bands or eye.

**Not given a name yet.**

## 2. Tropical Storm



**Feeder bands** are beginning to develop. Eye and eye wall still not well formed.

In the Atlantic, storms are **given a name** at that stage.

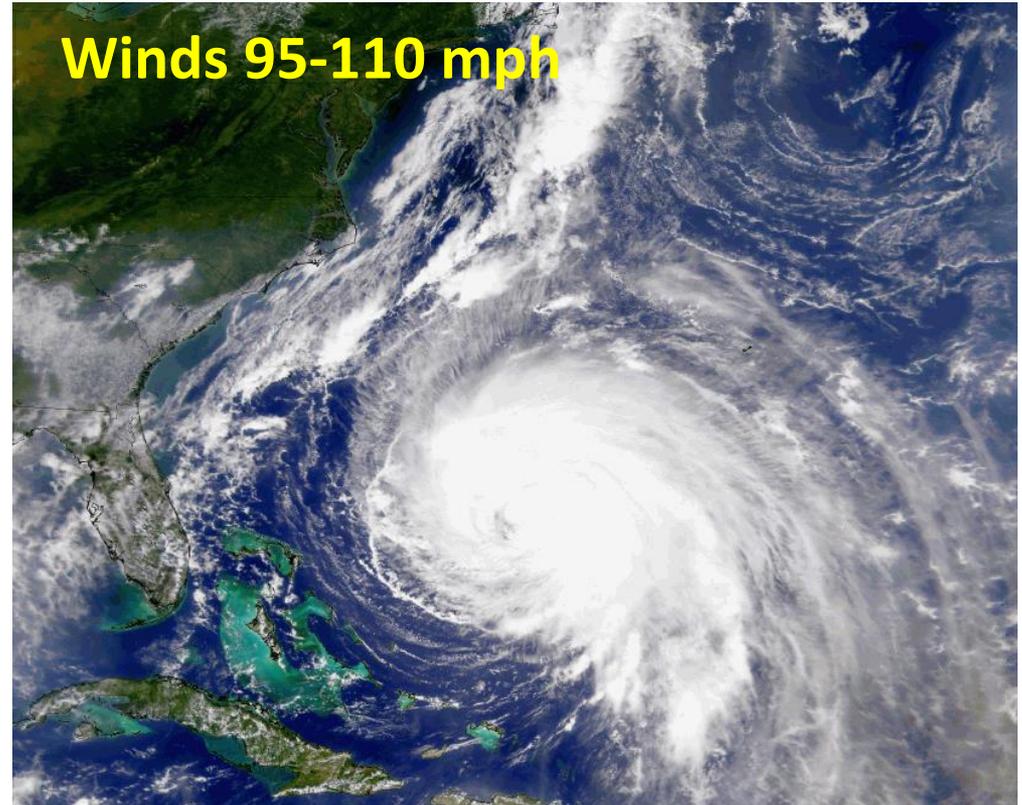
# Stages of Hurricane Development

## 3. Category 1 Hurricane



Well developed feeder bands. An **eye** begins to form.

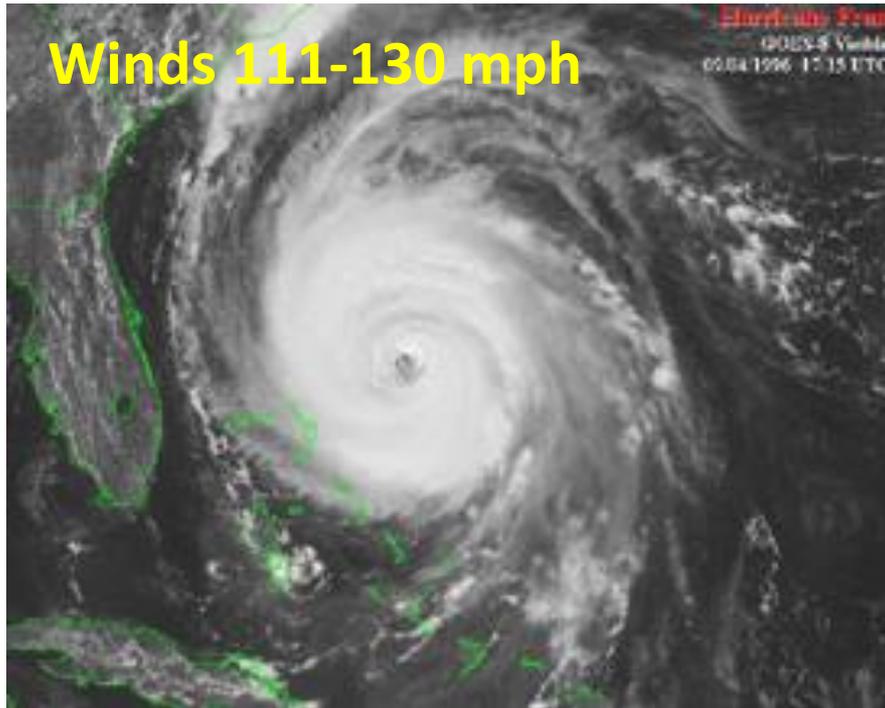
## 4. Category 2 Hurricane



An **eye and eye wall** are usually very well formed.  
Storm is tightening around center.

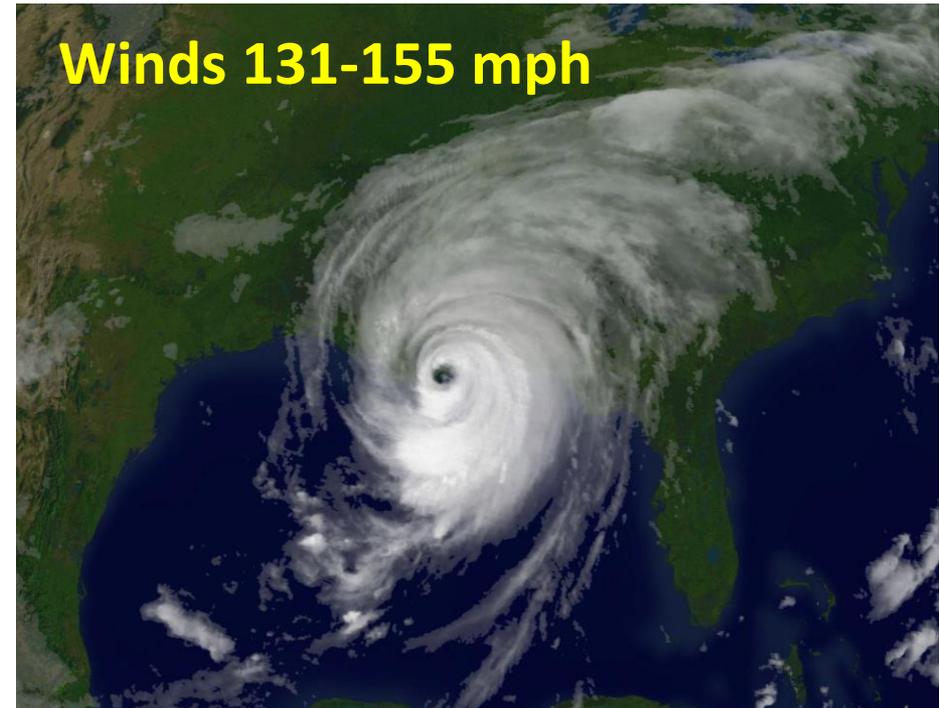
# Stages of Hurricane Development

## 5. Category 3 Hurricane



Now a **“Major Storm”**.  
**Intense flooding and building damage** will occur to most areas on the coast. Further inland, the damage will still be substantial.

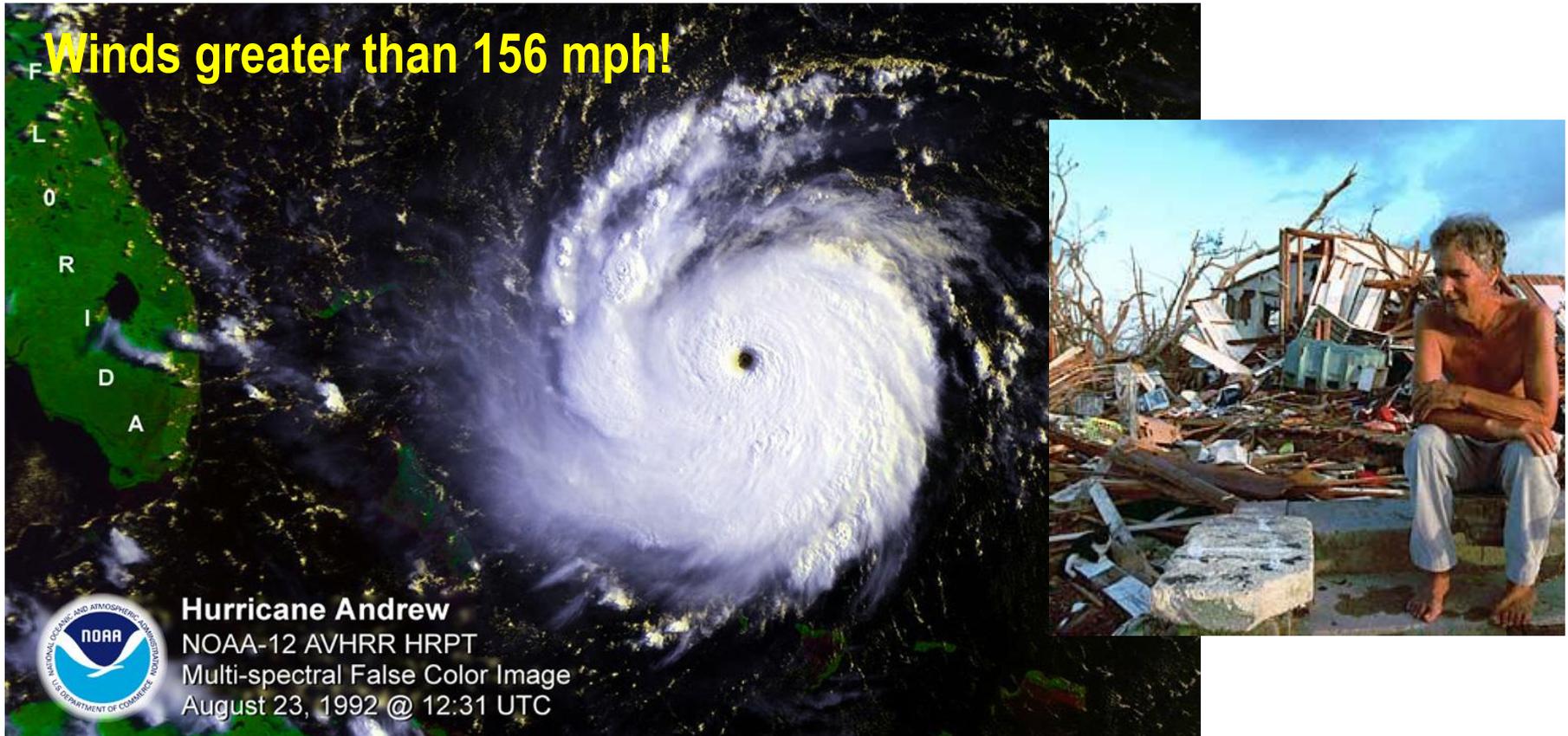
## 6. Category 4 Hurricane



All shrubs, signs and trees blown down. **Extensive damage** to doors and windows.  
**Major damage** to lower floors of structures near the coast **due to storm surge**.

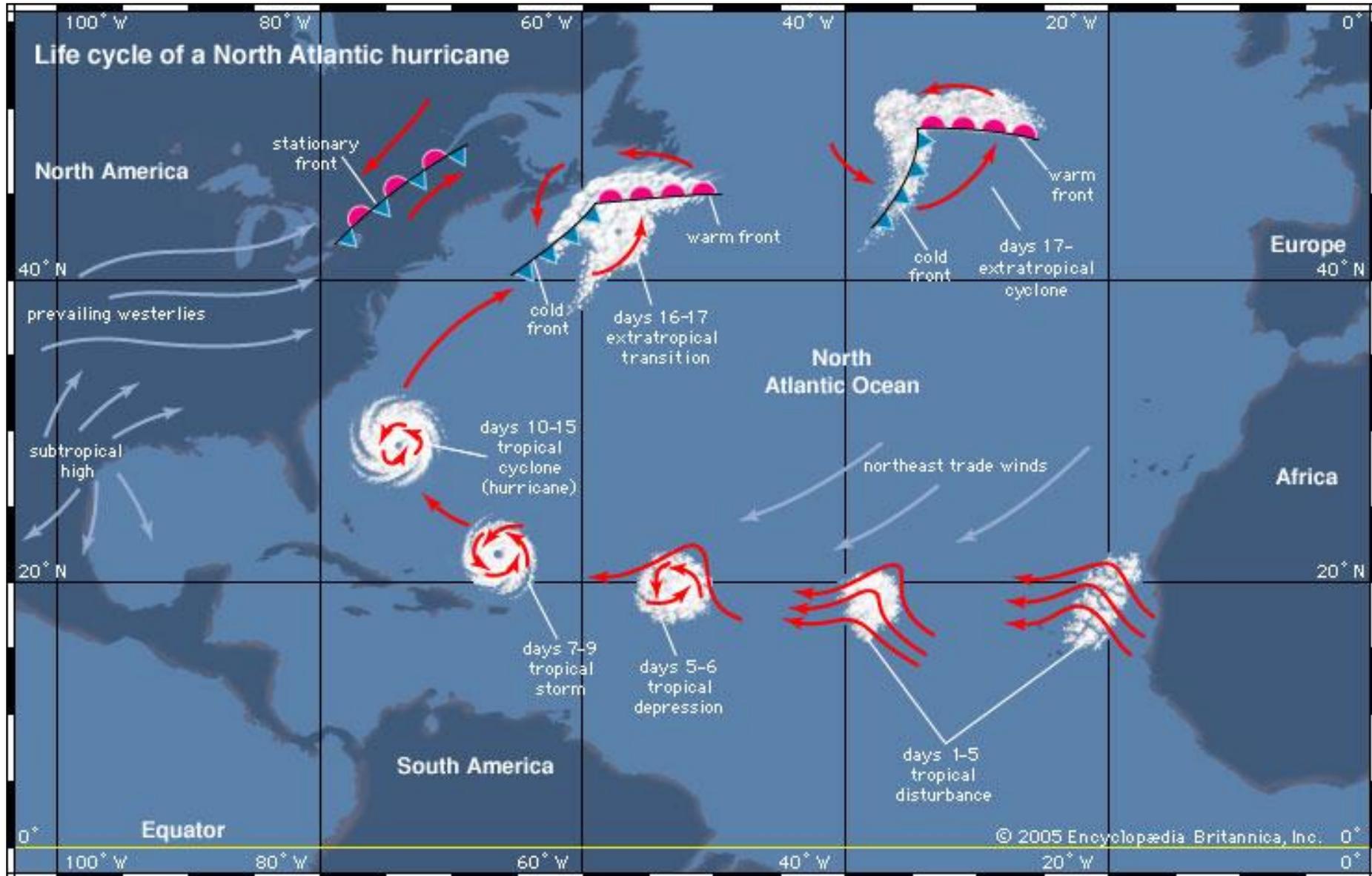
# Stages of Hurricane Development

## Stage 7 – Category 5 Hurricane



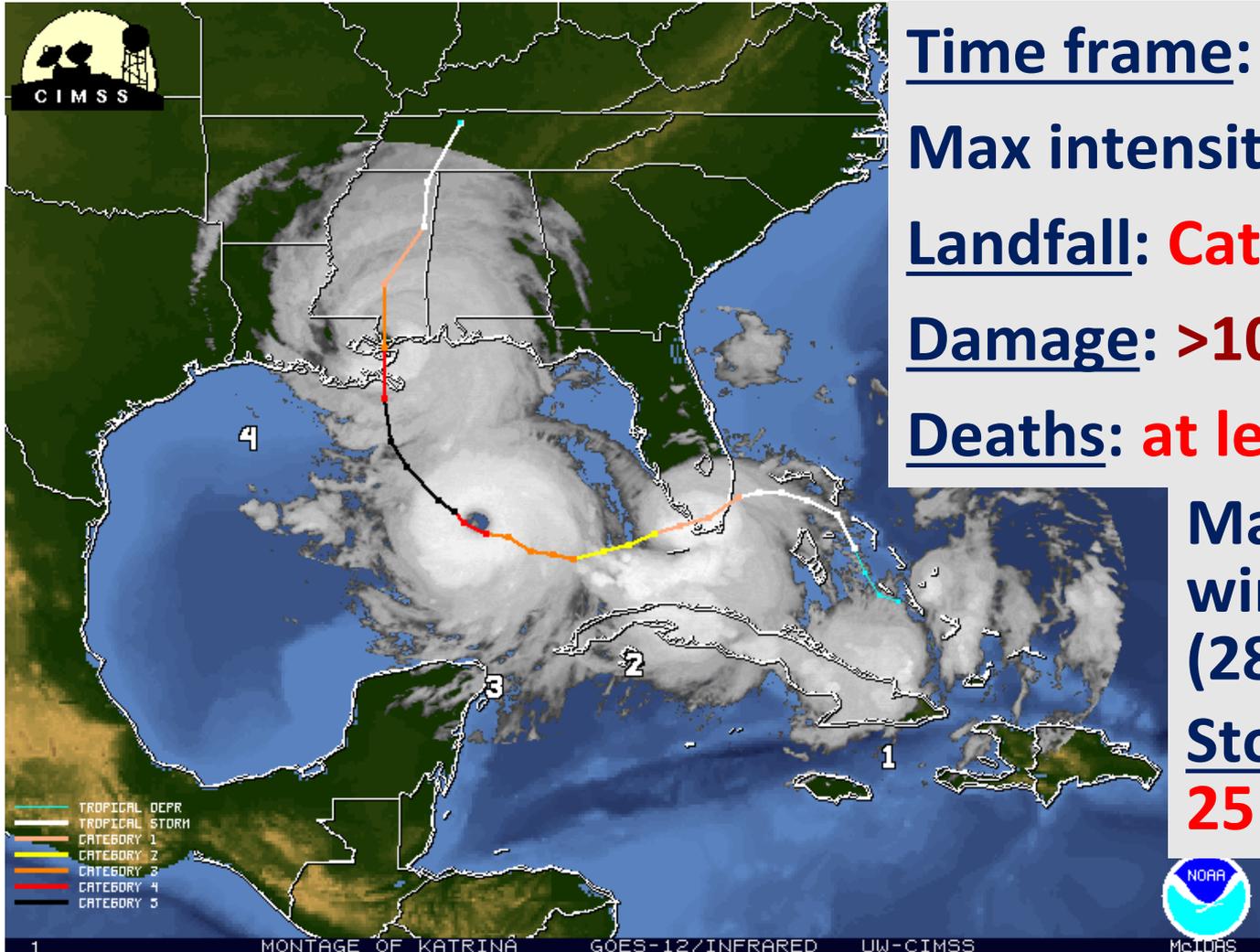
**Complete roof failure** on many residential and industrial buildings. Some **complete building failures**. **Massive evacuation** of residential areas on low ground (5-10 miles).

# North Atlantic Hurricane Lifecycle



# Hurricane Katrina, 2005

the **costliest** hurricane ever recorded in the Atlantic



Time frame: **August 23-31**

Max intensity: **Category 5**

Landfall: **Category 3**

Damage: **>100 billion USD**

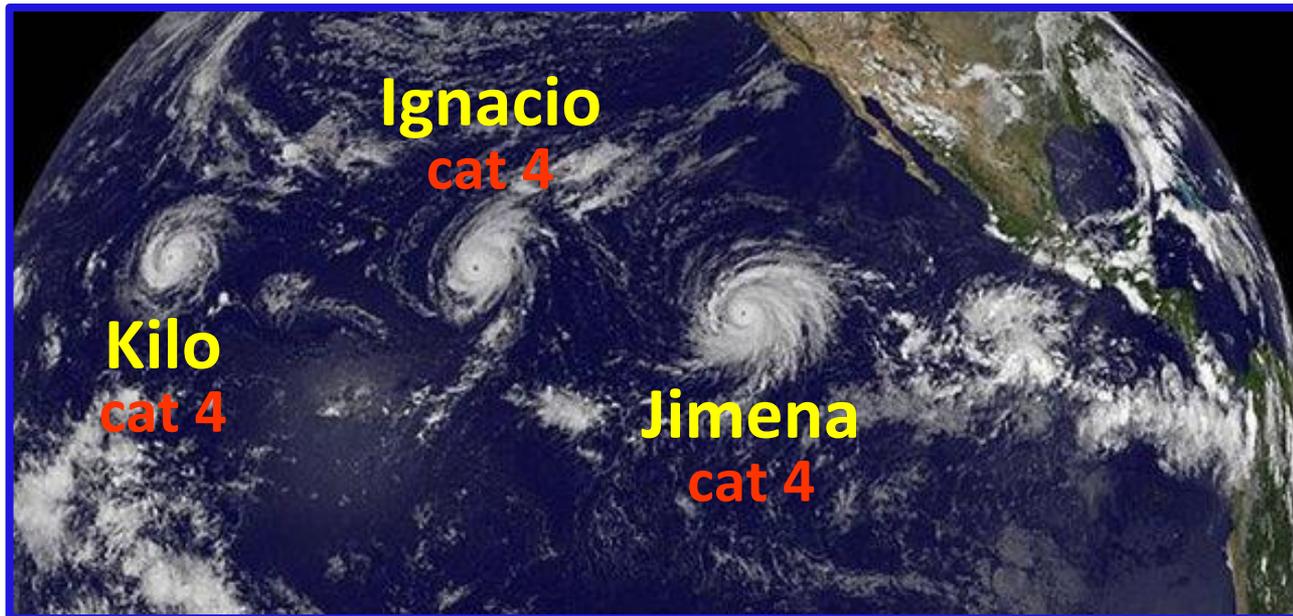
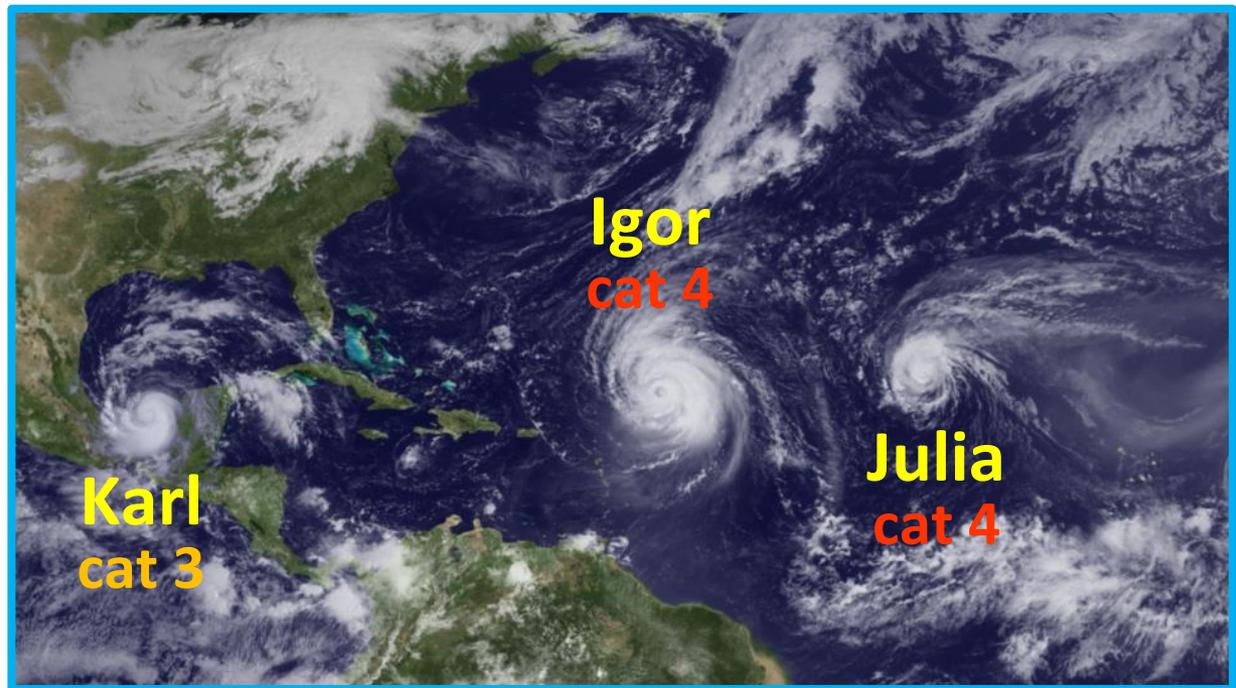
Deaths: **at least 1,833**

Max sustained winds: **175 mph (280 km/h)**

Storm surge: **25 to 28 feet**

# At Once...

North  
Atlantic  
Basin,  
09/19/10



Pacific  
Basin,  
08/31/15