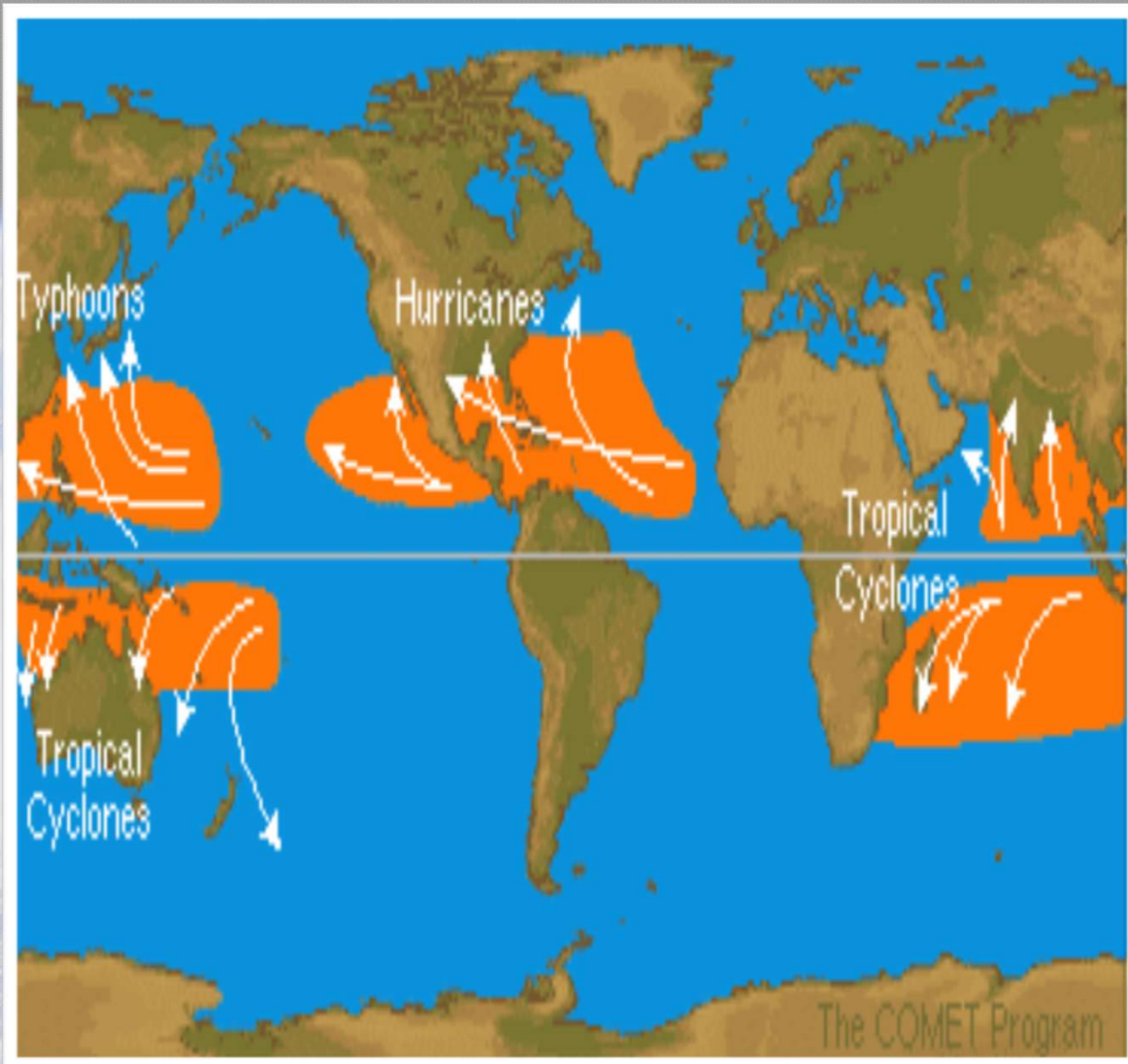


A satellite image of a large hurricane system over the Pacific Ocean, showing a distinct eye and spiral cloud bands. The text is overlaid on the top half of the image.

ATMO 102 Pacific Climates and Cultures

Lecture: Introduction to Hurricanes

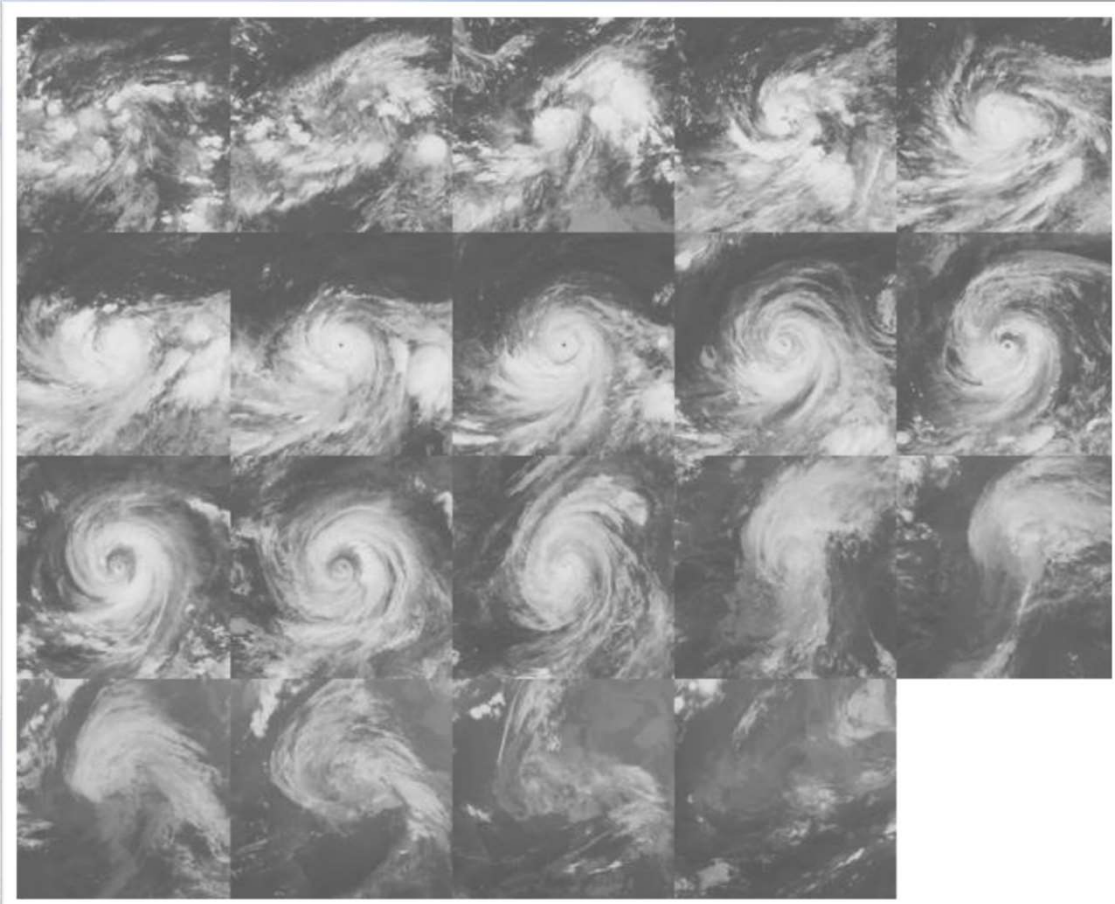


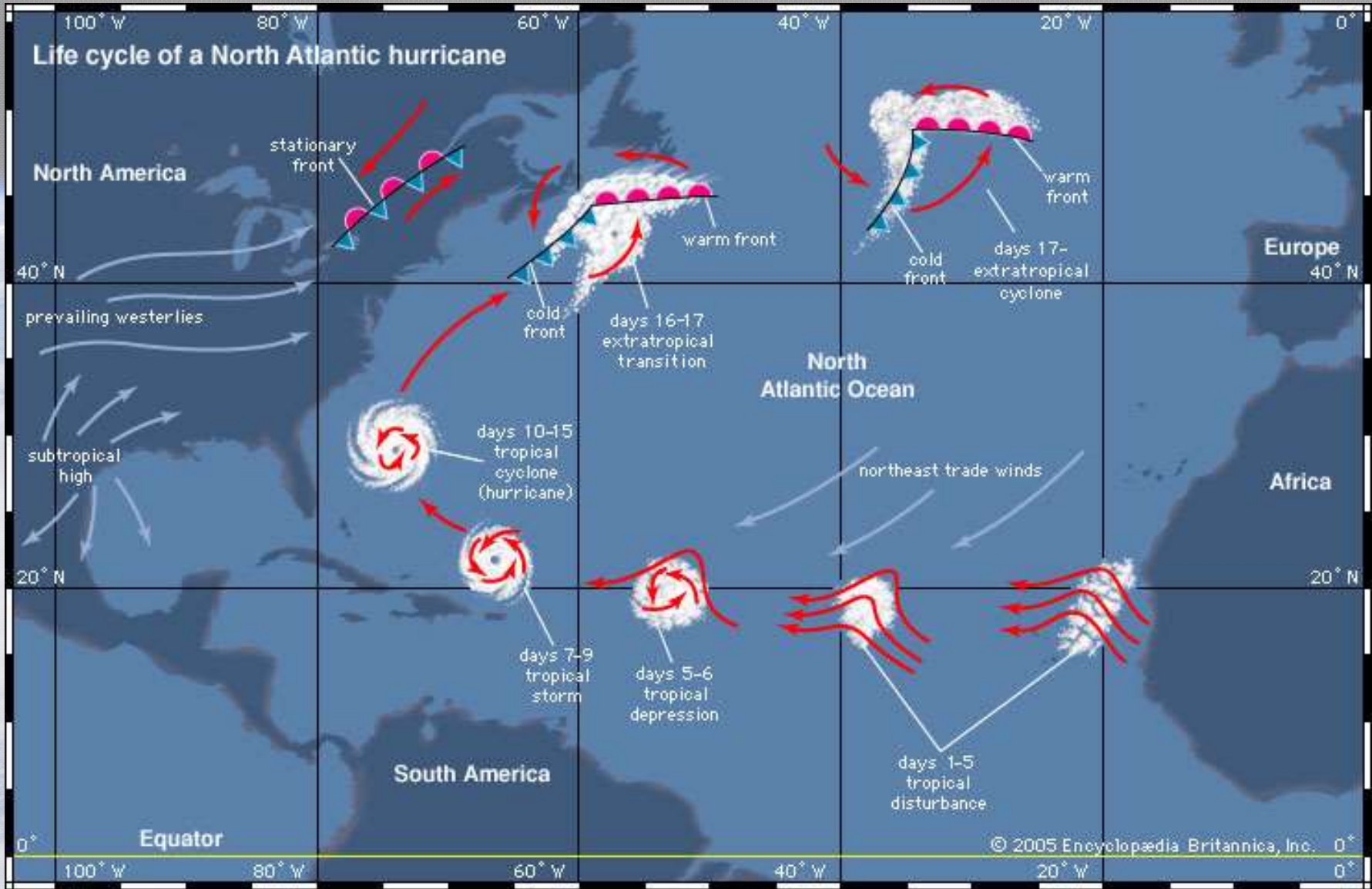
Formation Regions

- Form in the Tropics
- Hurricanes are called by other names (depends on where they occur)
 - **Hurricanes** in the Atlantic and East Pacific
 - **Cyclones** in the Indian Ocean near Australia
 - **Typhoons** off the coast of China and Indonesia

Tropical Cyclone Life Cycle

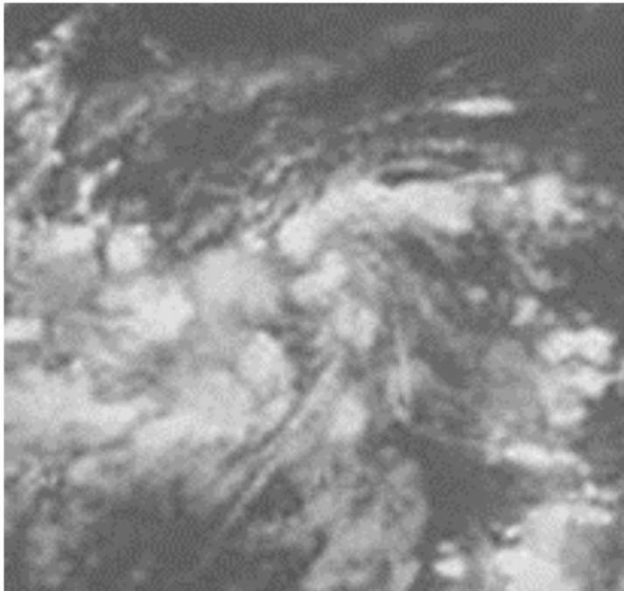
- 1. Tropical Depression:** surface wind < 39 mph (33 kt)
- 2. Tropical Storm:** $39 \leq$ surface wind ≤ 74 mph (64 kt)
- 3. Hurricane:** surface winds > 74 mph (65 kt)





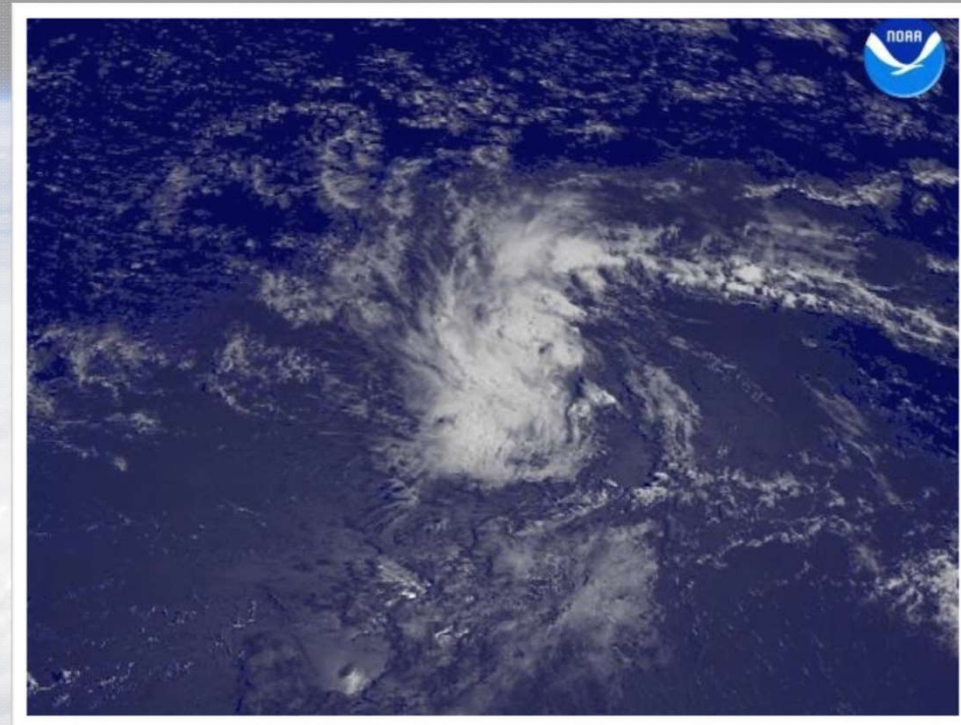
Tropical Disturbance

- The majority of tropical storms and hurricanes start out as **tropical disturbances**.
- These weather systems are **unorganized masses of thunderstorms** with very little, if any, organized wind circulation.
- During the hurricane season in the Atlantic Ocean and Gulf of Mexico, tropical disturbances often grow from a pattern of stormy weather, called an **African easterly wave**.
- These waves typically emerge every three or four days off the west coast of Africa and then drift west within the trade winds into the Atlantic Ocean.
- If weather and ocean conditions continue to be favorable, the system may then strengthen.



Tropical Depression

- As a system continues to become organized and winds begin to circulate, it may become a tropical depression, the **weakest form of tropical cyclone**.
- It is called a “**depression**” because it has low, or depressed, air pressure at its center.
- As the system develops, **winds converge towards the center and the pressure near the center drops**.
- During this transition, the **disturbance begins to obtain its energy from the ocean** instead of from horizontal temperature gradients in the atmosphere and the environmental wind.



Tropical Depression 6 from the 2004 Atlantic hurricane season. Instead of a round appearance similar to hurricanes, these weather systems look like individual thunderstorms that are grouped together.

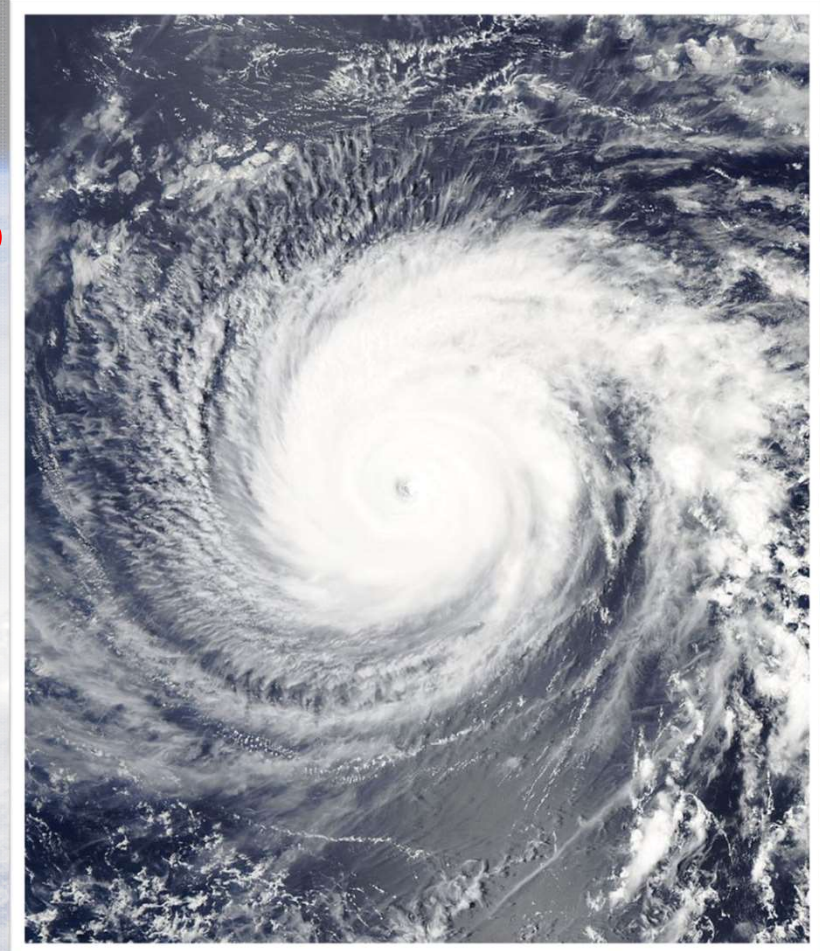


Tropical Storm

- As bands of thunderstorms continue to develop, the depression may intensify into a **tropical storm with maximum sustained wind speeds of 63-117.5 km/hr (39-73mph)**.
- A tropical storm usually forms in this manner (i.e. from an **intensifying tropical depression**).
- Once a system is classified as a **tropical storm, it is given a name**.
- Approximately 100 tropical cyclones form globally each calendar year. Many of them die out before they can grow stronger, with only approximately half of them (50) eventually strengthening into a mature hurricane (or typhoon).

Hurricanes

- If a tropical cyclone obtains a maximum **sustained wind speed greater than or equal to 119 km/hr (74 mph)**, it is reclassified as a hurricane (Typhoon or Cyclone).
- At this point, the recognizable, **cloud-free eye** of a hurricane typically forms.
- In the Atlantic, Central Pacific, or Eastern Pacific regions, hurricane intensity is often classified based on maximum surface wind speed using the **five categories of the Saffir-Simpson Hurricane Wind Scale**.



Hurricane Jimena – Category 4

Quick Hurricane Facts



- Strong Center of **Low Pressure**
- Sustained winds **> 74 mph** (64 kts)
 - To be considered a Category 1 Hurricane
- On average there are 45 hurricanes world wide every year
- Size ranges from 60 miles – 900 miles in diameter with a **typical size of about 400 miles**
- Can last from **days to weeks**

Ingredients for Hurricane Formation

1. Warm ocean Temp ($>80^{\circ}\text{F}$, 27°C) that is deep (~ 200 m in depth)

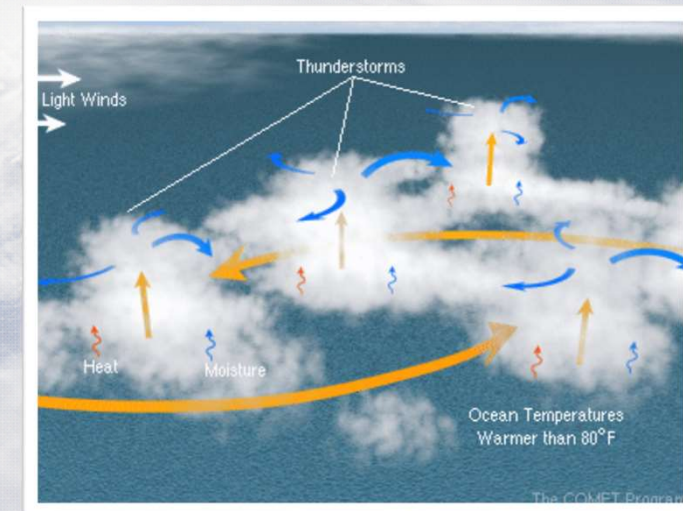
- Because you need lots of evaporation
- So when winds churn up the water, you still have WARM water.
- Both only happen equator-ward of 20°N , S

2. Coriolis is needed to initiate the spinning

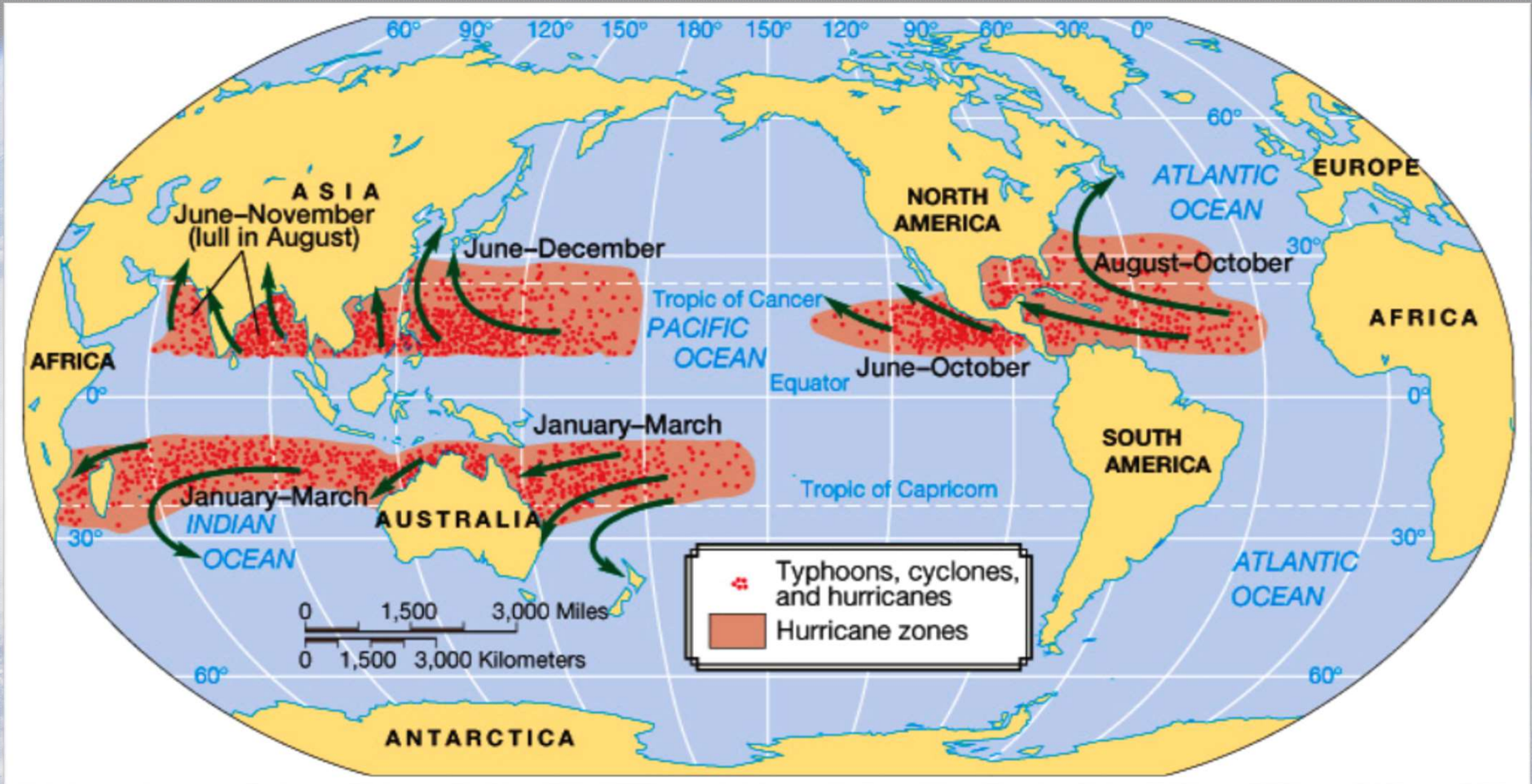
- Need to be between $> 5^{\circ}\text{N}$, S

3. Low values of vertical wind sheer

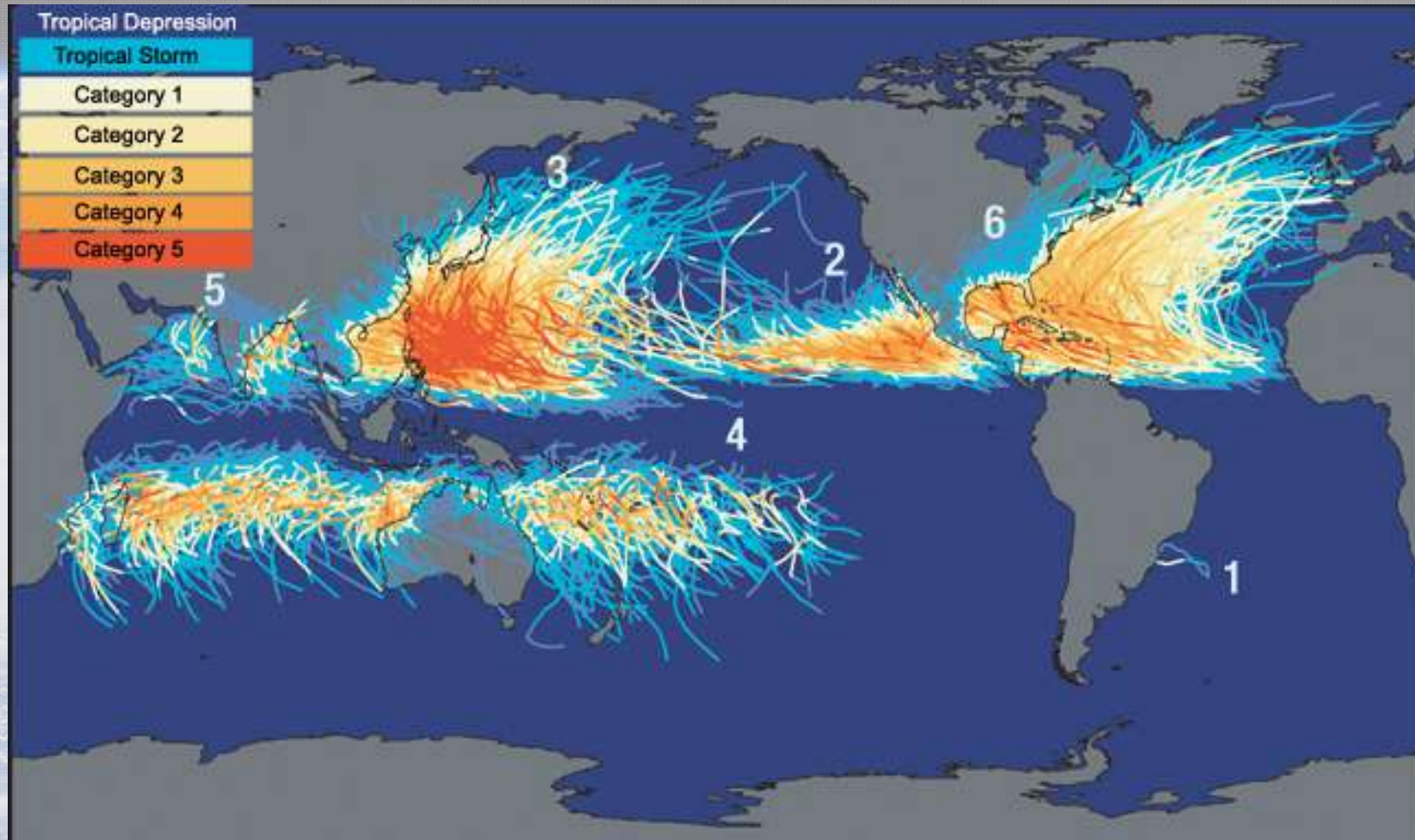
- Necessary for the storm to organize



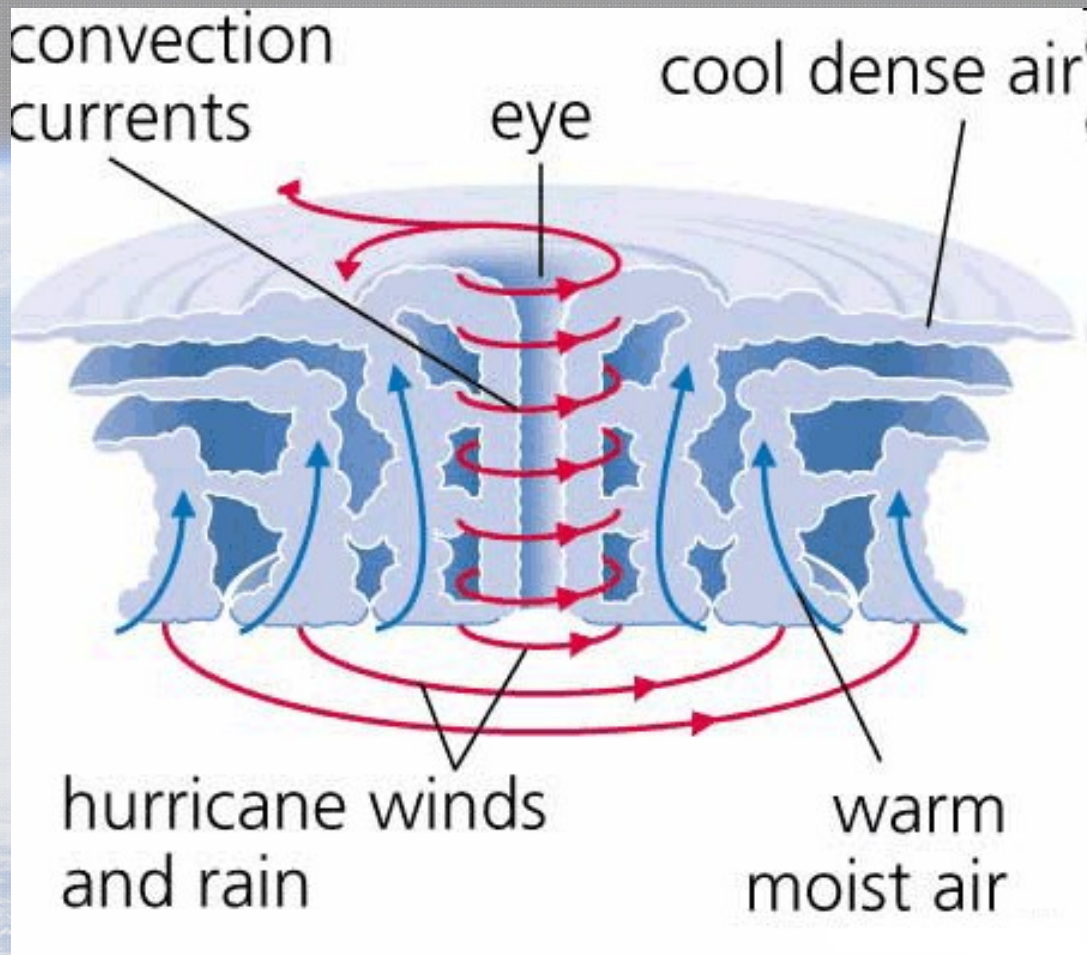
Where do these ingredients Occur?



Tropical Cyclone and Storm Tracks



The strength of the storms is color coded along the tracks, with light blue for weak tropical storms and orange and red for strong hurricanes (cat 3-5)

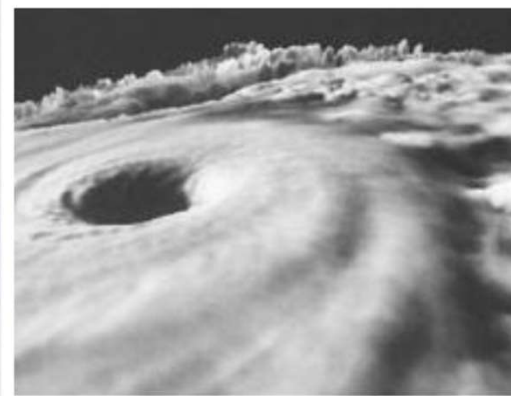


Hurricane Structure

- As air rushes inward in a spiral pattern “bands” of clouds and thunderstorms are formed.
- **Closest to the “eye” you get**
 - The most severe thunderstorms
 - The most intense rain and wind
 - The eye wall has the highest wind and rain, encircles the eye
- **There can be more than three sets of bands**

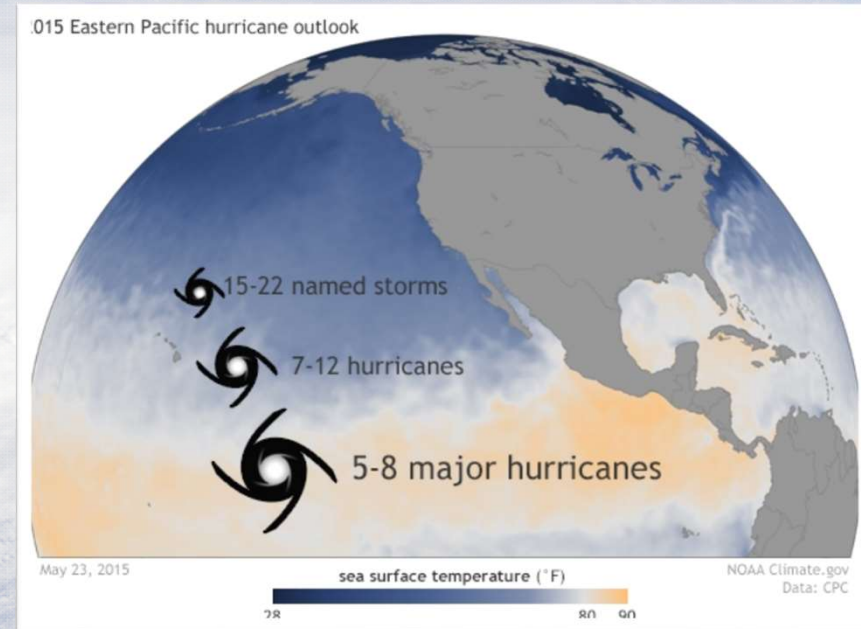
Hurricane Eye

- Surrounded by the **Eye Wall** with severe thunderstorms
- In the Eye air is converging toward the center
- **Spiraling DOWNWARD** and **INWARD**
- Has a very intense High pressure located above it
- Subsiding air = **CLEAR SKIES**
- Usually **30-60 miles in diameter**



Hurricane Intensification

- The storm can intensify if there is:
 - **Weak vertical shear** which allows the energy from condensation to be concentrated over a small area
 - **Relatively moist humid air in the upper troposphere**
 - So you can get lots of condensation
 - **Cold upper atmospheric conditions**
 - Which leads to a large PGF



• Atlantic Names

2019	2020	2021	2022	2023	2024
Andrea	Arthur	Ana	Alex	Arlene	Alberto
Barry	Bertha	Bill	Bonnie	Bret	Beryl
Chantal	Cristobal	Claudette	Colin	Cindy	Chris
Dorian	Dolly	Danny	Danielle	Don	Debby
Erin	Edouard	Elsa	Earl	Emily	Ernesto
Fernand	Fay	Fred	Fiona	Franklin	Francine
Gabrielle	Gonzalo	Grace	Gaston	Gert	Gordon
Humberto	Hanna	Henri	Hermine	Harold	Helene
Imelda	Isaias	Ida	Ian	Idalia	Isaac
Jerry	Josephine	Julian	Julia	Jose	Joyce
Karen	Kyle	Kate	Karl	Katia	Kirk
Lorenzo	Laura	Larry	Lisa	Lee	Leslie
Melissa	Marco	Mindy	Martin	Margot	Milton
Nestor	Nana	Nicholas	Nicole	Nigel	Nadine
Olga	Omar	Odette	Owen	Ophelia	Oscar
Pablo	Paulette	Peter	Paula	Philippe	Patty
Rebekah	Rene	Rose	Richard	Rina	Rafael
Sebastien	Sally	Sam	Shary	Sean	Sara
Tanya	Teddy	Teresa	Tobias	Tammy	Tony
Van	Vicky	Victor	Virginie	Vince	Valerie
Wendy	Wilfred	Wanda	Walter	Whitney	William

• Hawaii gets their own Names!

List 1	List 2	List 3	List 4
Akoni	Aka	Alika	Ana
Ema	Ekeka	Ele	Ela
Hone	Hene	Huko	Halola
Iona	Iolana	Iopa	Iune
Keli	Keoni	Kika	Kilo
Lala	Lino	Lana	Loke
Moke	Mele	Maka	Malia
Nolo	Nona	Neki	Niala
Olana	Oliwa	Omeka	Oho
Pena	Pama	Pewa	Pali
Ulana	Upana	Unala	Uluka
Wale	Wene	Wali	Walaka

Naming Hurricanes

- When they reach tropical storm strength (**40-74 mph**)
- Used to be all **women's names (1953-1977)**
- Now they **alternate** male-female
- Names are "**Retired**" if they cause enough damage.

Hurricane Damage

1. Wind Damages

- Hurricanes move at ~45 miles an hour
- Spirally converging air moves at a much faster velocity
- The velocity of the winds you experience depends on your location within the hurricane:
- You add the wind speed of motion to the wind speed of rotation ($100 \text{ mph} + 45 \text{ mph} = 145 \text{ mph}$) when it's coming towards you
- You subtract the wind speed of motion from the that of rotation ($100 - 45 = 65 \text{ mph}$) when it's going away.





Hurricane Damage

2. Storm Surges

- The abnormal rise of the sea along the shore as the result of strong winds.
- Can be as high as 7 m (21 ft) but are typically 1-2 m
- On top of this, waves around 6-15 m can occur!!!

Hurricane Damage

A storm surge...

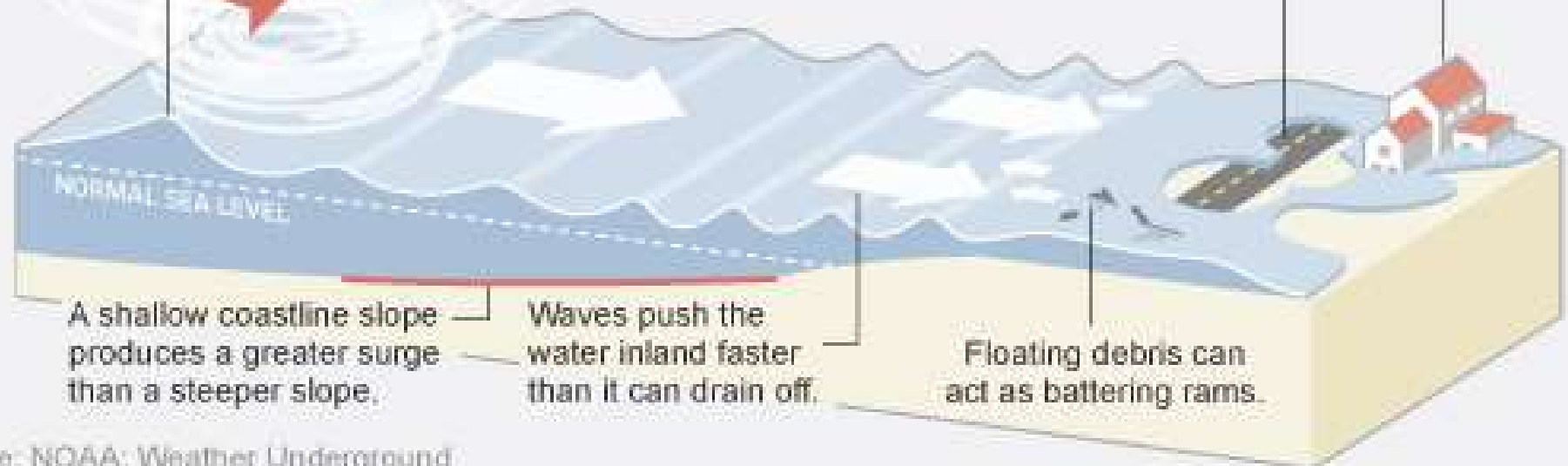
Low pressure near eye pulls water higher.

Winds pile up water and push it toward shore.

...and its destructive power

The surge can begin before the storm hits, cutting off escape routes.

Battering waves may erode beaches and damage buildings.



Source: NOAA; Weather Underground

Hurricane Damage

3. Flooding

- Caused by intense rains that accumulate
- Rain accumulation can be up to 10 ft/day
- Typical numbers are 1-3 ft/day



Hurricane Classification Saffir-Simpson Scale

Saffir-Simpson Scale for Hurricane Classification				
Strength	Wind Speed (Kts)	Wind Speed (MPH)	Pressure (Millibars)	Pressure
Category 1	64- 82 kts	74- 95 mph	>980 mb	28.94 "Hg
Category 2	83- 95 kts	96-110 mph	965-979 mb	28.50-28.91 "Hg
Category 3	96-113 kts	111-130 mph	945-964 mb	27.91-28.47 "Hg
Category 4	114-135 kts	131-155 mph	920-944 mb	27.17-27.88 "Hg
Category 5	>135 kts	>155 mph	919 mb	27.16 "Hg
Tropical Cyclone Classification				
Tropical Depression		20-34kts		
Tropical Storm		35-63kts		
Hurricane		64+kts or 74+mph		

Hurricane Decay

- When conditions become **unfavorable** the hurricane starts to **decay**
 1. **Colder sea surface temperatures**
 - <80F will cause the storm to weaken or even dissipate.
 2. **Land, of course**
 - friction caused by a large land mass, and their terrain cuts off the hurricane's circulation, and squeezes out the storm's moisture
 3. **Shearing winds aloft**
 - Hostile upper level wind conditions produce shearing, which blow off the high cloud tops of these storms, and causes them to become disorganized.
 4. **Sinking air**
 - Sinking air from high pressure hinders thunderstorm development.

Hurricane Tracks 12 El Nino Events ASO



Trajectory is “C” shaped and ultimately brings them over cold waters

Horizontal View of Hurricane Isabel in September, 2003
[TRMM Precipitation Radar]

