Hurricanes: Formation Mechanisms, Forecasting, and Impacts in North Carolina

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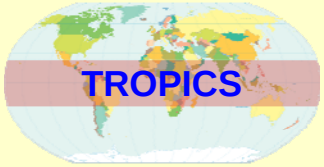
The Tropics

- Located 23½° N to 23½° S



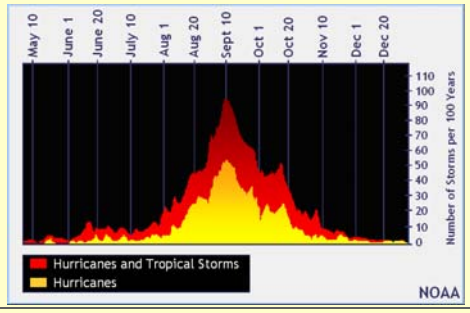
- Large amount of solar radiation
- Little seasonal variation
- Warm water → tremendous latent heat source
- High relative humidity promotes cumulus cloud development
- Surface winds from the east

What are Tropical Cyclones?

- A cyclone that originates over warm, tropical oceans
- Includes tropical depressions, tropical storms, hurricanes, and typhoons
- Different structure than midlatitude frontal cyclones → no fronts!

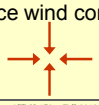
Atlantic Hurricane Season

The official Atlantic hurricane season is from June 1 to November 30



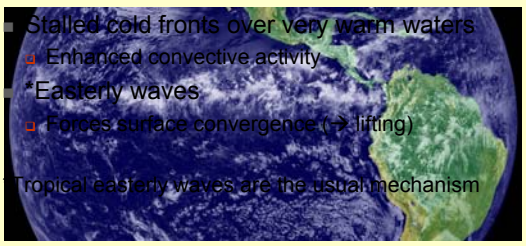
Optimal Conditions for Tropical Cyclone Development

- Sea surface temperatures > 80°F (> 26.5°C)
  - Deep layer of warm water
- No significant land mass interaction
  - Avoids dry air entrainment (mixing with dry air)
  - Retains source of energy: evaporation
- Favorable wind profiles
  - Vertical: little to no vertical shear
  - Horizontal: surface wind convergence



Formation Mechanisms

- Inter-Tropical Convergence Zone (ITCZ)
  - Persistent thunderstorm formation
- Stalled cold fronts over very warm waters
  - Enhanced convective activity
- *Easterly waves
  - Forces surface convergence (→ lifting)



*Tropical easterly waves are the usual mechanism

Stages of Development

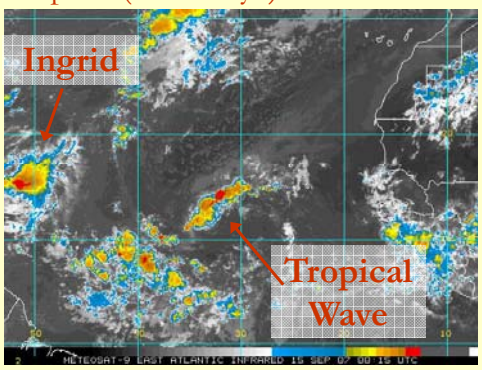
- Tropical ("Easterly") Wave
- Tropical Disturbance
- Tropical Depression (given a number)
- Tropical Storm (given a name)
- Hurricane (categories 1 thru 5)

Increasing Organization

Tropical ("Easterly") Waves

- Troughs of low pressure
  - Found in the easterly trade winds
- Migrate westward at low latitudes
  - i.e., they move from east to west
- Surface wind convergence
  - On the east side of the trough axis

Tropical ("Easterly") Wave



Tropical Disturbance

- Broad area of disorganized clusters of thunderstorms
- Commonly exist only 24 to 48 hours

Key question: Can thunderstorm convection maintain itself?

- Critical to future intensification

The tropical disturbance that would become Hurricane Humberto

Tropical Depression

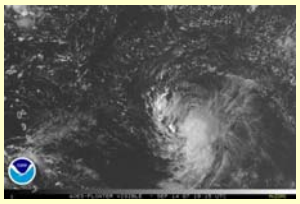
- A tropical system that has a closed wind circulation
- Winds typically range from 20–38 m.p.h.
- Given a "number" by National Hurricane Center
  - Subsequently tracked

Tropical Depression

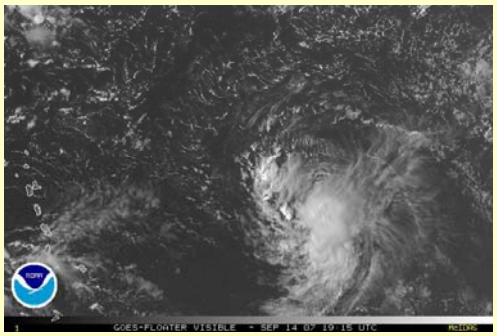
18 September 2005: The tropical depression that would become Hurricane Rita

Tropical Storm

- Definition: a cyclonic circulation originating over tropical oceans with sustained surface winds of at least 39 m.p.h.
- Tropical storm gets a name



Tropical Storm



14 September 2007: Tropical Storm Ingrid at 3:15 p.m. EDT

Atlantic Storm Names

2008	2009	2010	2011	2012	2013
Arthur	Ana	Alex	Arlene	Alberto	Andrea
Bertha	Bill	Bonnie	Bret	Beryl	Barry
Cristobal	Claudette	Colin	Cindy	Chris	Chantal
Dolly	Danny	Danielle	Don	Debby	Dorian
Edouard	Erika	Earl	Emily	Ernesto	Erin
Fay	Fred	Fiona	Franklin	Florence	Fernand
Gustav	Grace	Gaston	Gert	Gordon	Gabrielle
Hanna	Henri	Hermine	Harvey	Helene	Humberto
Ike	Ida	Igor	Irene	Isaac	Ingrid
Josephine	Joaquin	Julia	Jose	Joyce	Jerry
Kyle	Kate	Karl	Katia	Kirk	Karen
Laura	Larry	Lisa	Lee	Leslie	Lorenzo
Marco	Mindy	Matthew	Maria	Michael	Melissa
Nana	Nicholas	Nicole	Nate	Nadine	Nestor
Omar	Odette	Otto	Ophelia	Oscar	Olga
Paloma	Peter	Paula	Philippe	Patty	Pablo
Rene	Rose	Richard	Rina	Rafael	Rebekah
Sally	Sam	Shary	Sean	Sandy	Sebastien
Teddy	Teresa	Tomas	Tammy	Tony	Tanya
Vicky	Victor	Virginie	Vince	Valerie	Van
Wilfred	Wanda	Walter	Whitney	William	Wendy

Hurricane

- Maximum sustained winds of at least 74 m.p.h.
- Most organized stage of a tropical cyclone
  - Well-defined structure with distinct parts
- Positive feedback mechanism at its finest
  - Can last more than 20 days in some cases
  - Can travel over 1000 km
- Categorized further based on intensity

Hurricane Classification

Saffir-Simpson Scale

5 categories based on intensity

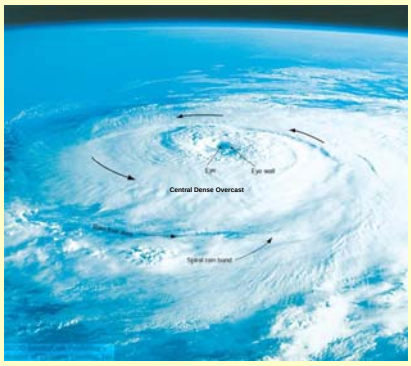
Table 12–2 The Saffir-Simpson Scale

Category	Pressure mb	Wind Speed km/hr	Wind Speed mph	Storm Surge m	Storm Surge ft	Damage
1	≥ 980	119–154	74–95	1–2	4–5	Minimal
2	965–979	155–178	96–110	2–3	6–8	Moderate
3	945–964	179–210	111–130	3–4	9–12	Extensive
4	920–944	211–250	131–155	4–6	13–18	Extreme
5	< 920	> 250	> 155	> 6	> 18	Catastrophic

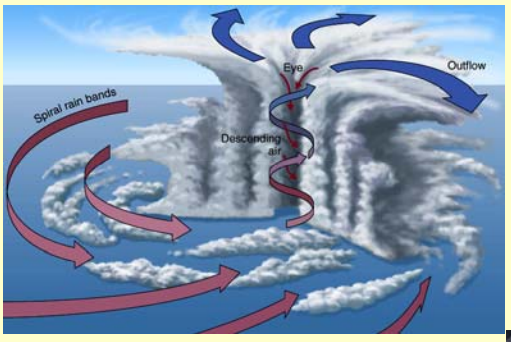
Hurricane Structure

- Eye
- Eye wall
- Central dense overcast
- Spiral rain bands
- Rain-free area

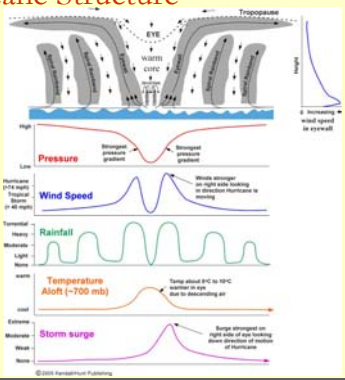
Hurricane Structure



Vertical Slice of a Hurricane

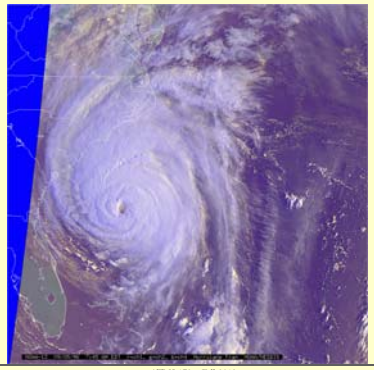


Hurricane Structure



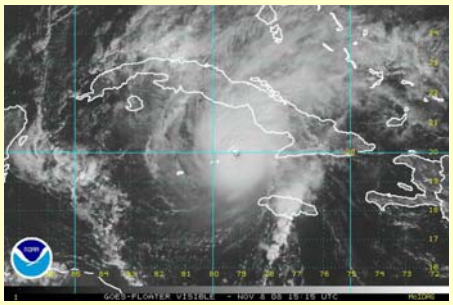
Hurricane Ophelia – Category 1 (2005)

Hurricane Fran – Category 3 (1996)



Hurricane Gert – Category 4 (1999)

Hurricane Paloma – Category 4 (2008)

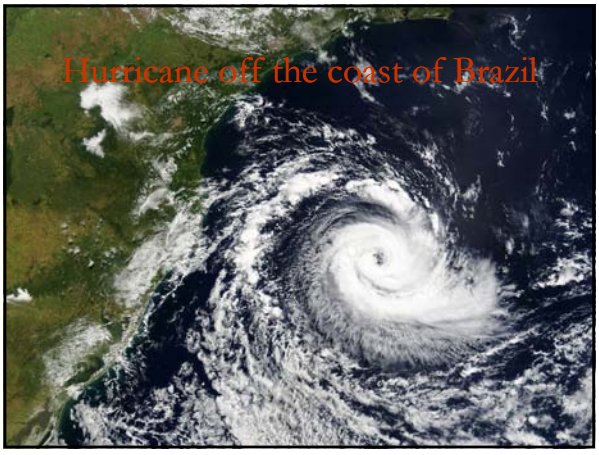


Hurricane Katrina – Category 5 (2005)

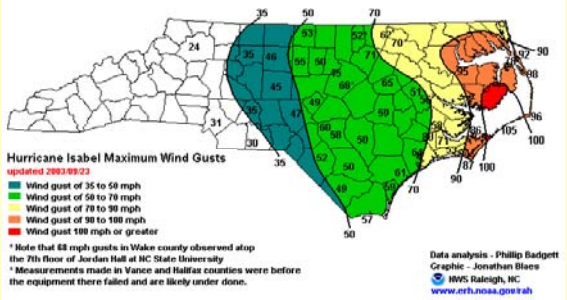
Hurricane Isabel – Category 5 (2003)

Hurricanes Around the World

- Atlantic and Central/East Pacific: Hurricanes
- Western Pacific: Typhoons
  - Formerly "willy-willy" in Australia, but that's also the name for an Australian dust devil
- South Pacific/Indian Oceans: Cyclones
- Most common in West Pacific
  - Can occur year-round
- Rare in South Atlantic



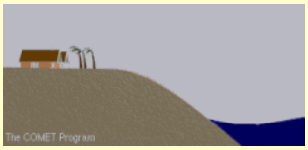
Hurricane Dangers: Straight-line winds



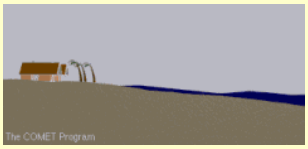
Hurricane Dangers: Storm Surge

Sea Water Pushed Onshore by Wind

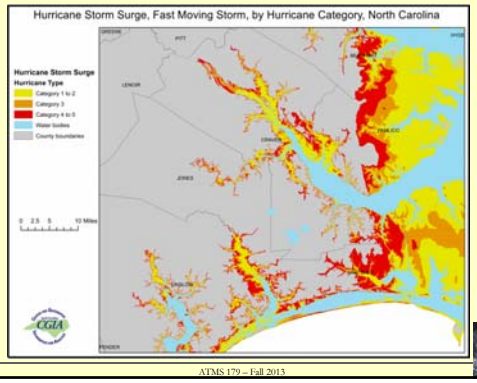
- High terrain
- Steep slope
- Less surge danger



- Low terrain
- Gentle slope
- More surge danger

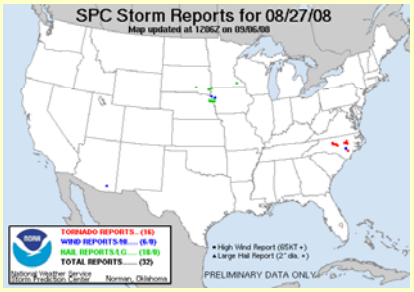


Hurricane Dangers: Storm Surge



Hurricane Dangers: Tornadoes

- Frictional drag enhances vertical shear
- Generally weak (EF0 to maybe EF2)



Sixteen tornado reports in NC during passage of remnants of Fay

Hurricane Dangers: Inland Rain

Do you recognize this place?

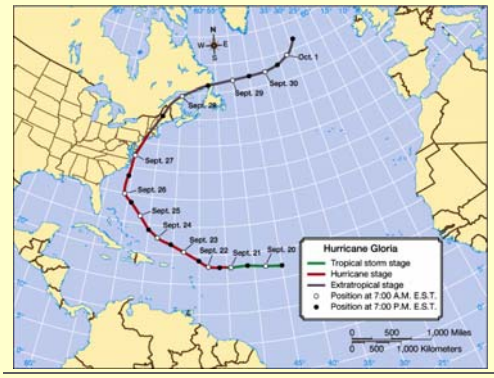
Hurricane Dangers: Inland Rain

Inland flooding is the *deadliest* hurricane killer

Storm Motion

- Tropical storms are guided by upper-level flow
  - Initially guided westward by surface trade winds
  - Tend to "recurve" to northeast as these storms approach the middle latitudes
- Flow can steer storms out to sea or toward land

Storm Motion



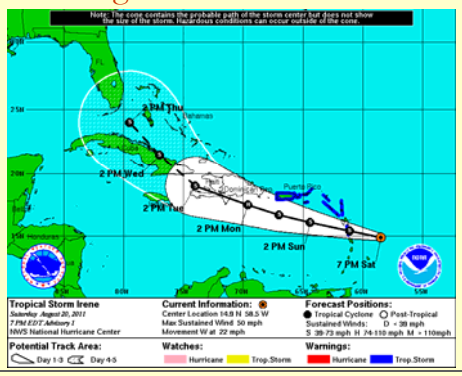
Forecasting

- Computer models simulate storm's environment and predict its motion
- Approach to land triggers watches and warnings

Forecasting

- Hurricane **Watch**:
  - Hurricane conditions (winds ≥74 m.p.h.) *possible* in 36 hrs
- Hurricane **Warning**:
  - Hurricane conditions *expected* within 24 hrs
- Same procedure for tropical storm watches/warnings

Forecasting



Visit the National Hurricane Center for more information (www.nhc.noaa.gov)