

Tropical Cyclones and Hurricanes

Lecture 14 - ENV 407

Hurricane Isabel, 2003 (from ISS)

What are Hurricanes?

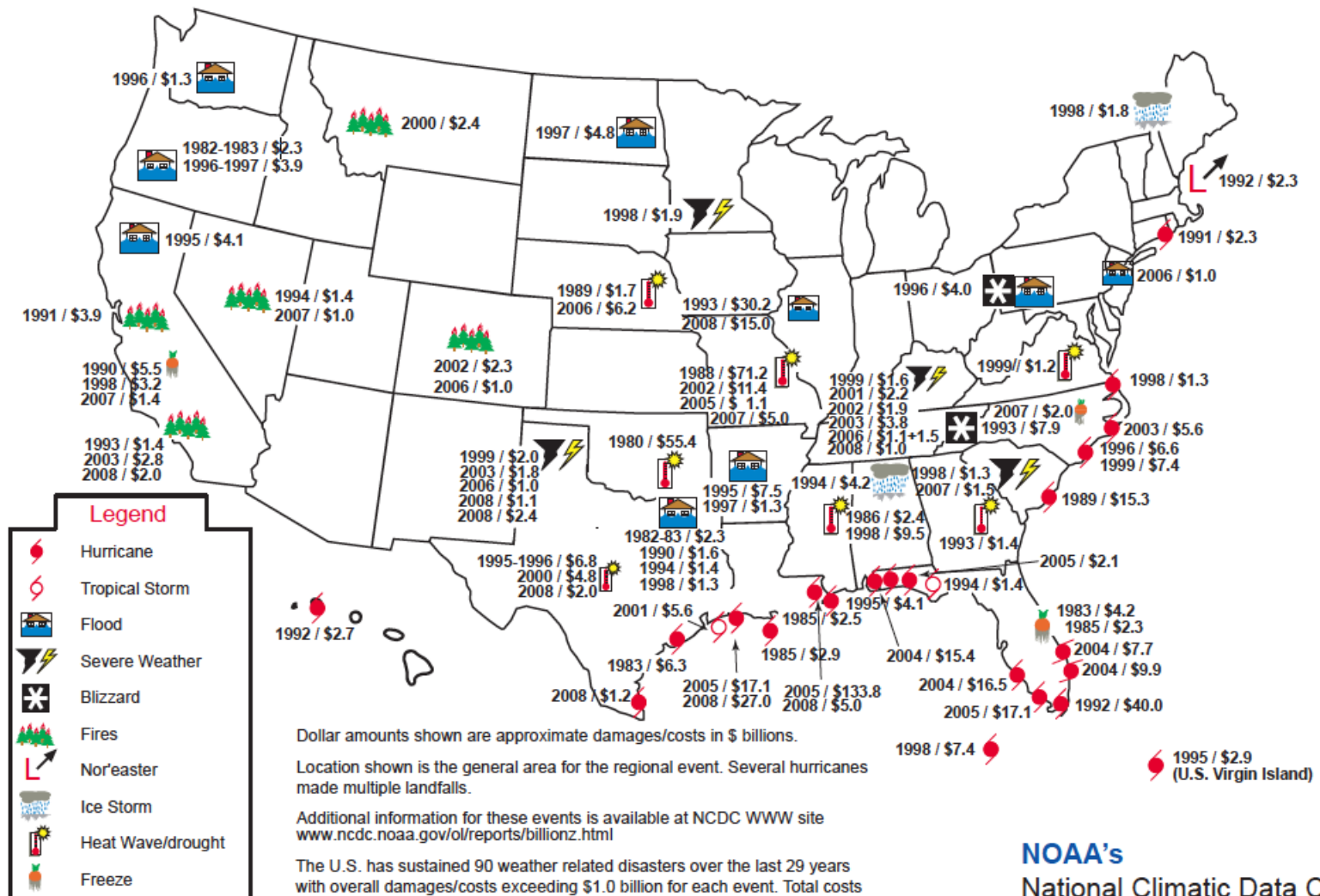
- A tropical cyclone with sustained one-minute winds of at least 74 mph (64 knots), at an elevation of 10 meters.
- Derived from the Spanish word "huracan" , which was most likely inspired by Hunraken, the name for the ancient Mayan storm god or Hurakan, the Quiche god of thunder



What are Hurricanes?

- They are tropical cyclones (low pressure areas) with sustained winds at least 64 knots (74 mph). Strongest hurricane on record (Camille) had winds exceeding 200 mph.
- Typically 500-1000 km in diameter (smaller than midlatitude cyclones).
- Can be associated with heavy rains (10-20 inches!), tornadoes, and storm surges on the coast.
- Also called typhoons and tropical cyclones
- Mediterranean "versions" called "Medicanes"

Billion Dollar Weather Disasters 1980 - 2008



Katrina (2005)

- 1833 deaths
- 125 billion in damage
- Most destructive hurricane in U.S. history







Galveston, TX (1900)



The Greatest Loss of Life of
any U.S. Meteorological
Event (8000 died)

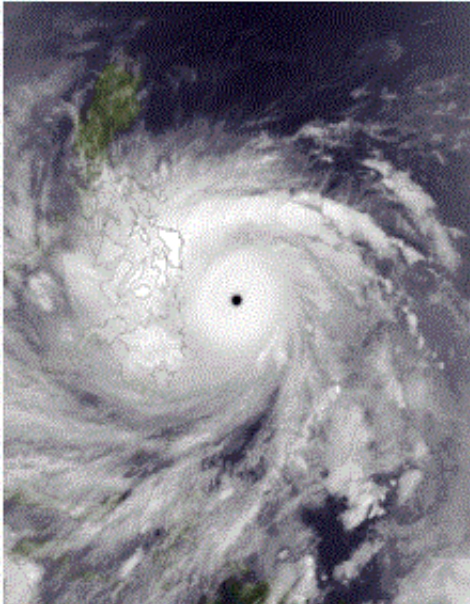




Typhoon Haiyan (Yolanda)

Typhoon (JMA)

Category 5 super typhoon (SSHs)



Typhoon Haiyan at peak intensity, on November 7

Formed November 3, 2013

Dissipated November 11, 2013

Highest winds 10-minute sustained:
230 km/h (145 mph)

1-minute sustained:
315 km/h (195 mph)

Lowest pressure 895 mbar (hPa); 26.43 inHg
(Estimated)

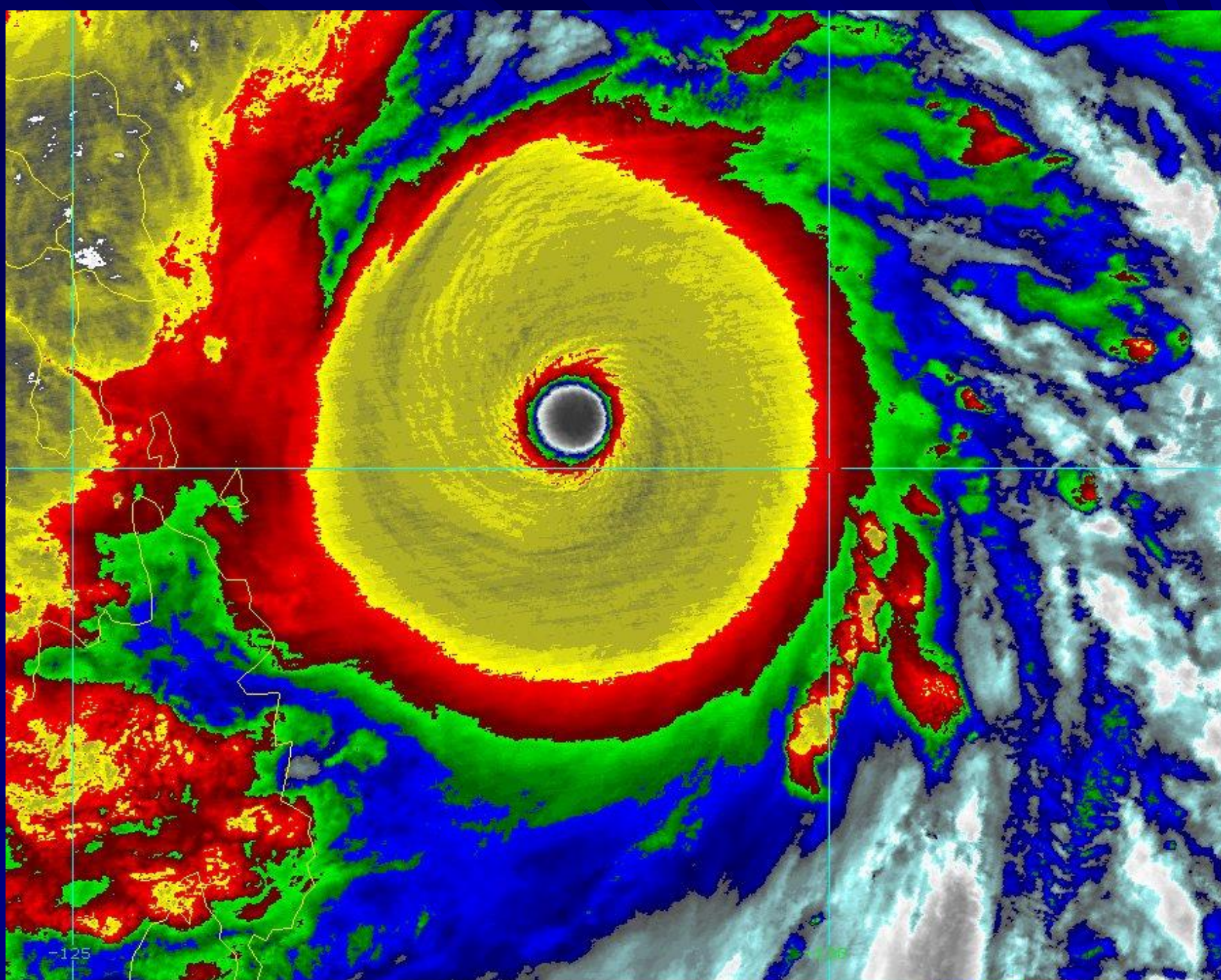
Fatalities 5,716 confirmed

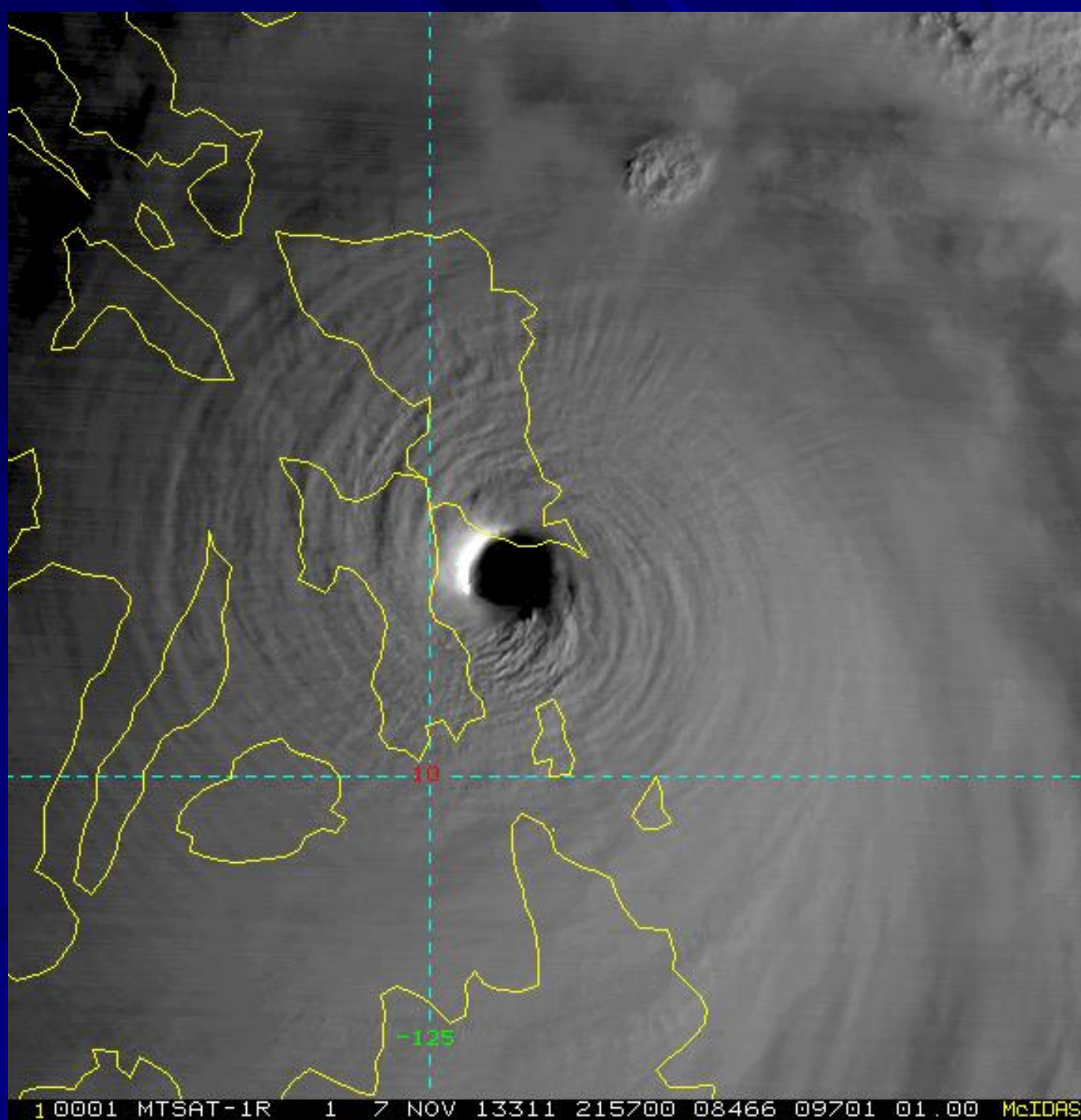
Damage \$2.38 billion (2013 USD)
(Preliminary total)

Areas affected Micronesia • Philippines •
Southern China • Vietnam

Typhoon Haiyan







Experience a hurricane

<http://www.youtube.com/watch?v=H9VpwmtnOZc>

<http://www.youtube.com/watch?v=6LPM-0xiVvM>

<http://www.youtube.com/watch?v=UeM-cjTEEA8&feature=related>

Classification of Tropical Storms

- **Disturbance:** Group of thunderstorms in the tropics present for at least 24 hours
- **Wave:** No circulation, winds <25 mph, all directions
- **Tropical Cyclone:** Non-frontal synoptic scale low-pressure system over tropical or sub-tropical waters with organized convection (i.e. thunderstorm activity) and definite cyclonic surface wind circulation.
- **Tropical Depression:** TC, surface winds < 39 mph.
- **Tropical Storm:** TC with winds 39 to 74 mph.
- **Hurricane:** TC with winds $\geq$ 74 mph; visible eye
- **Major Hurricane:** TC with winds $\geq$ 114 mph

Pictures of Tropical Storms

Hurricane Edward

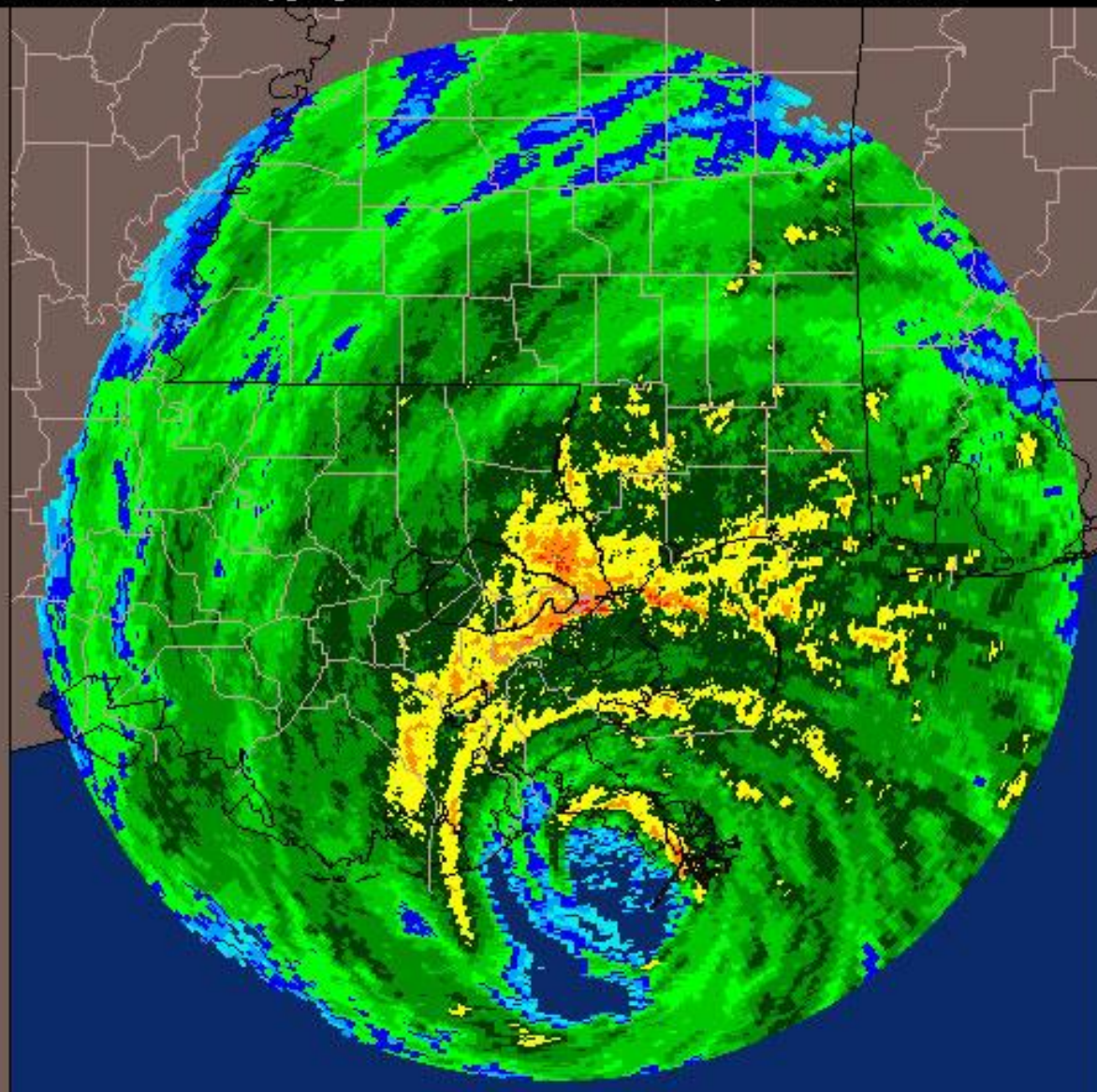
Tropical Storm Fran

Tropical Depression #7

Hurricane Features:

Eye (nearly clear)
Eye Wall Rainband
Spiral Rainbands



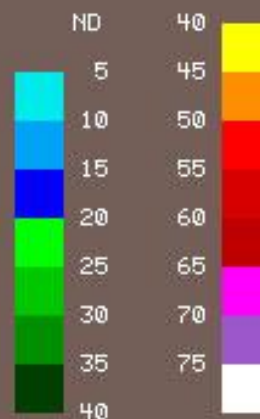


BASE
REFLECTIVITY

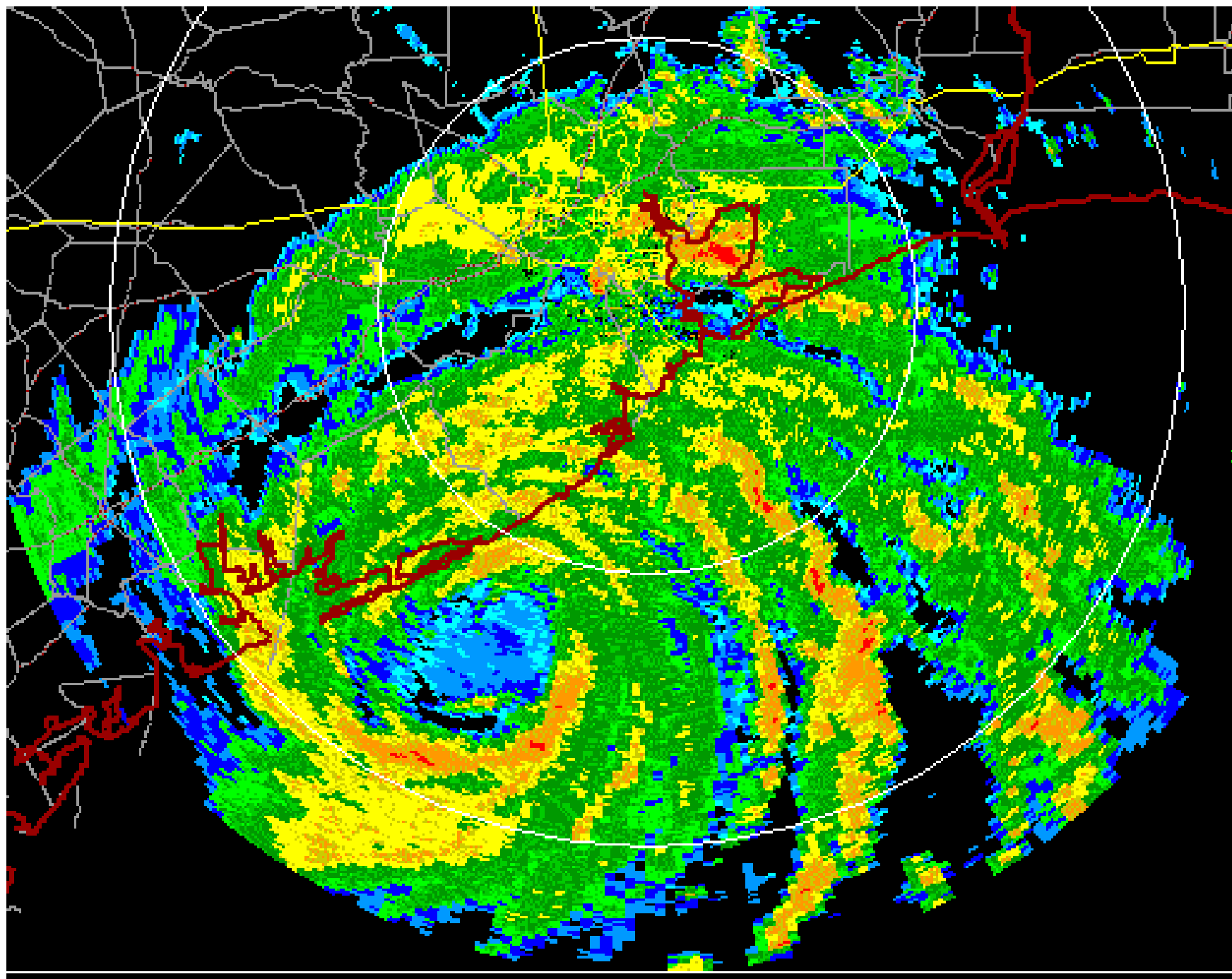
LIX

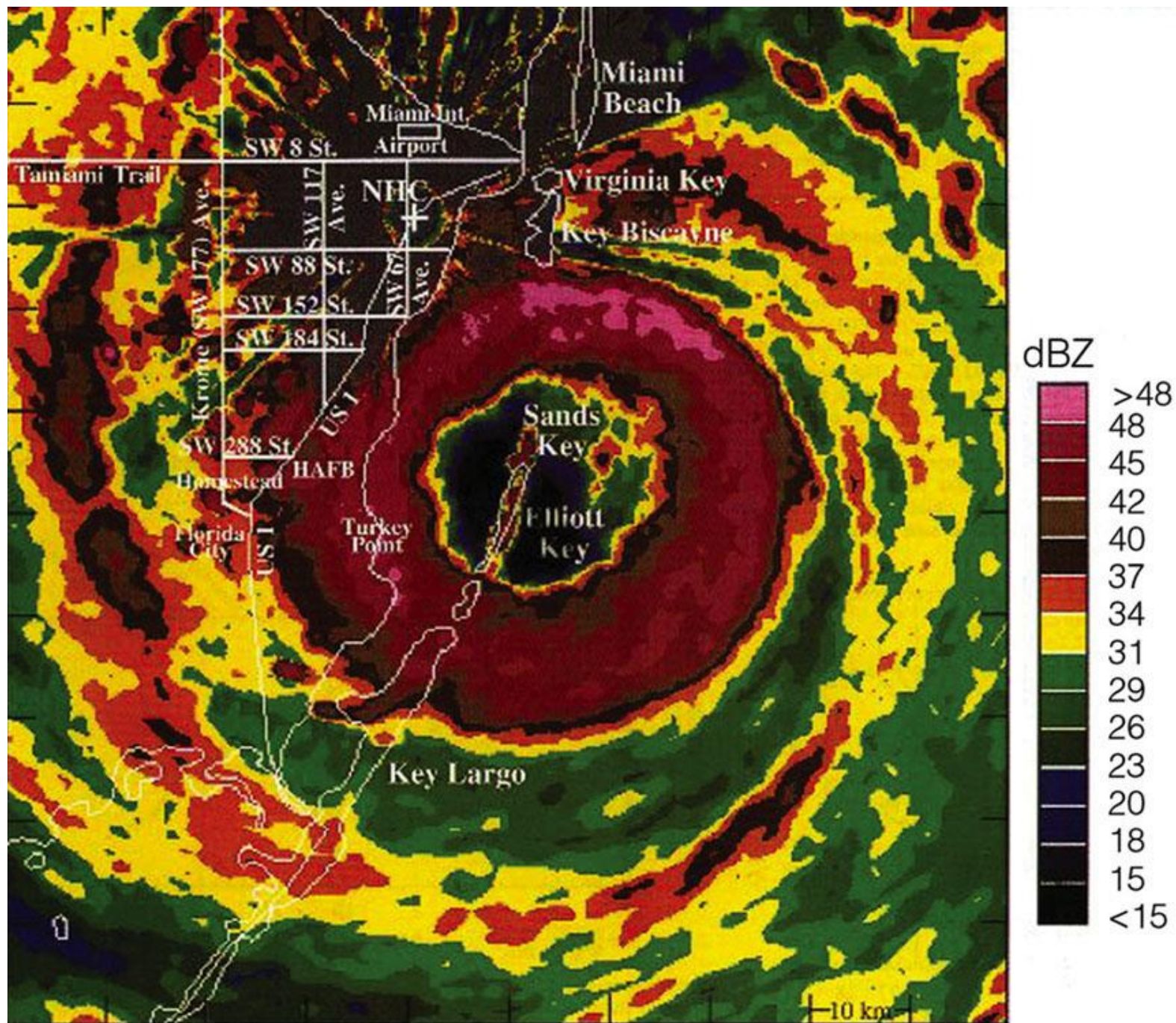
08/29/05 1022Z
RANGE: 230 KM
RES: 1 KM X 1 DEGREE
MODE: PRECIPITATION
ELEV: 0.5 DEGREES

DBZ

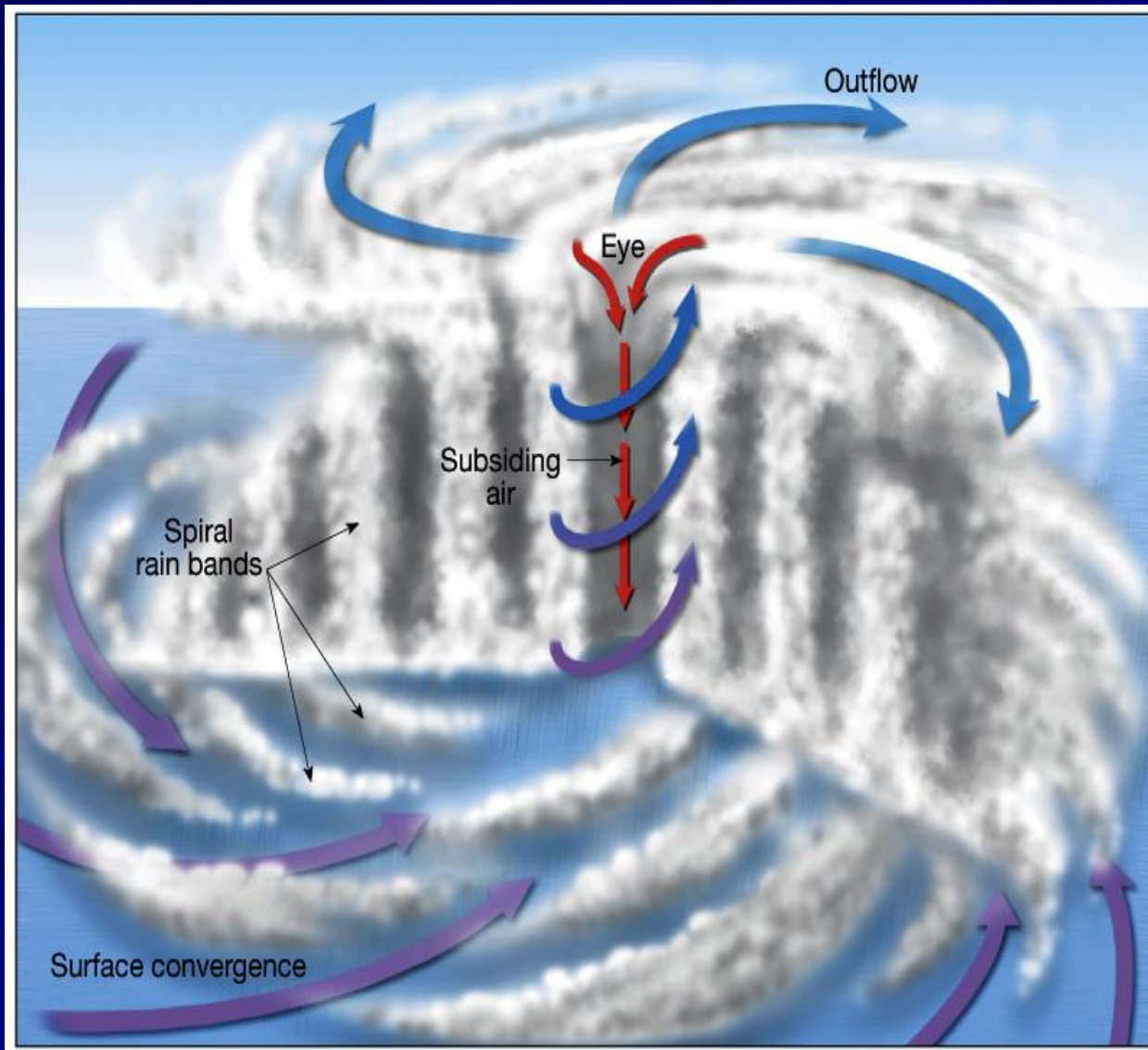


MAX DBZ: 55





Anatomy of a hurricane



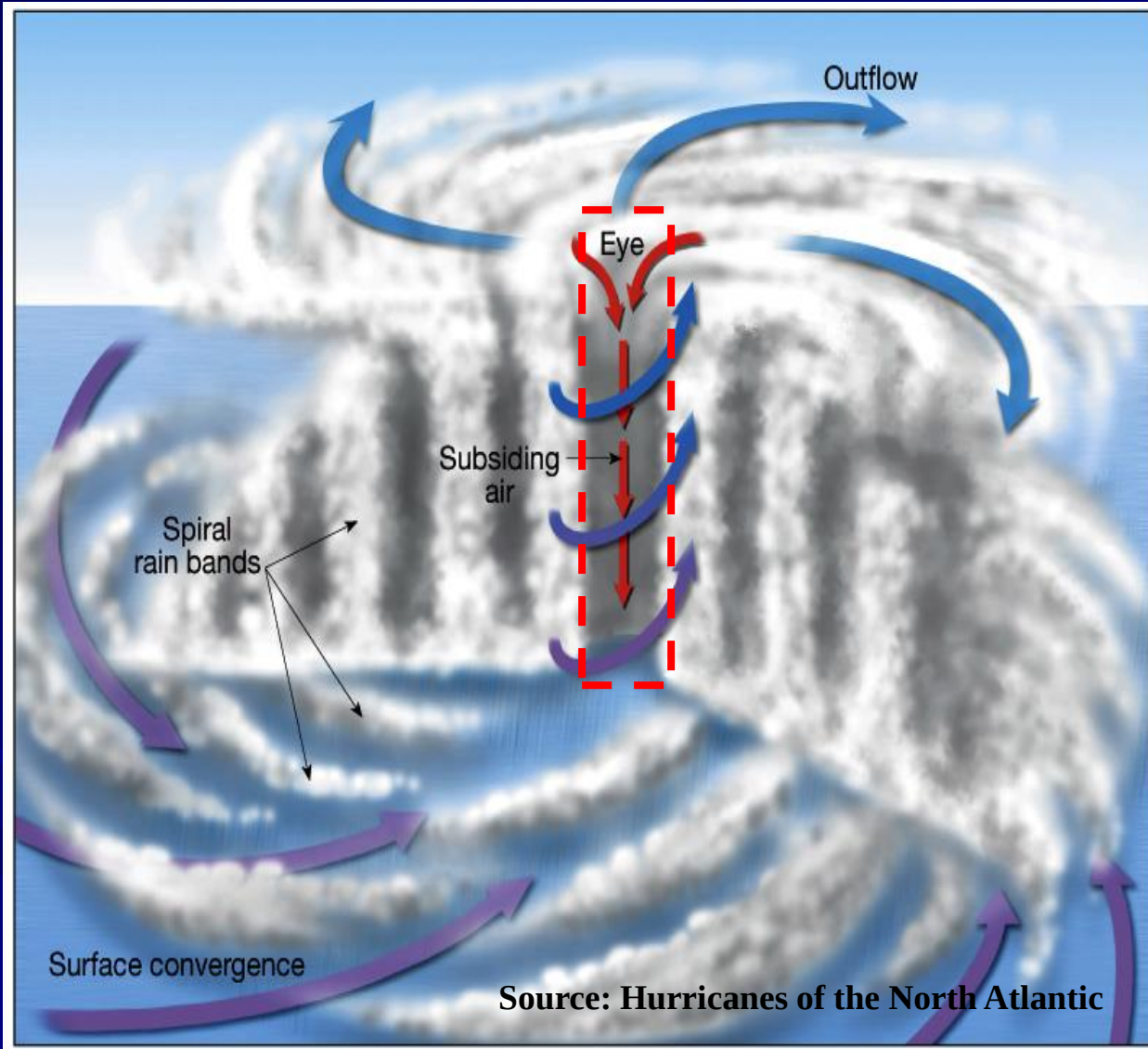
Cyclonic in the lower levels and anticyclonic in the upper levels.

Air in the "eye" region is subsiding (cloud free).

Clouds near the eye is called the eye "wall".

Outside you have "rain" bands.

Anatomy of a hurricane



Eye region:
Generally free of tall clouds.

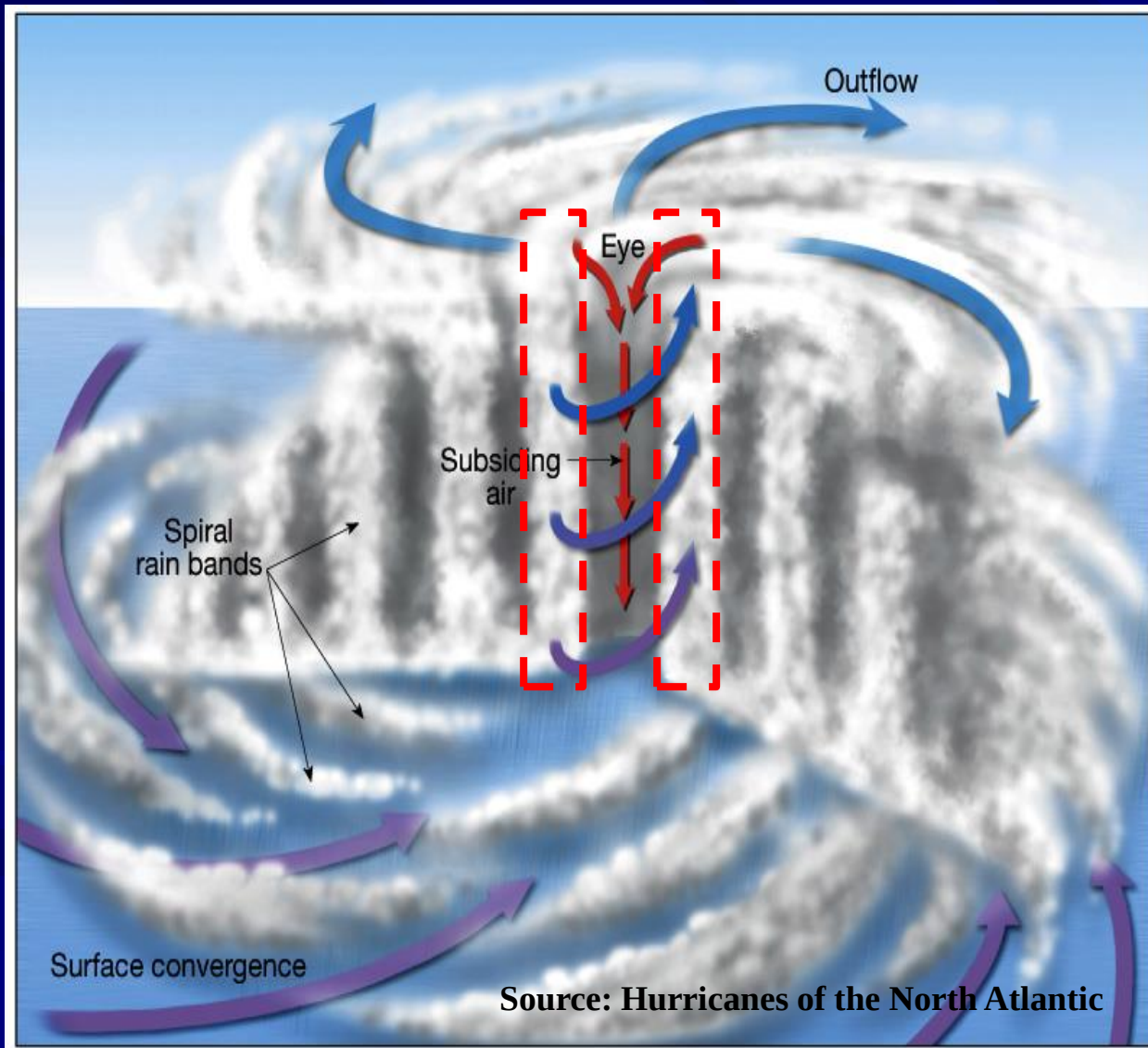
Winds are light.

Air aloft is warm and dry.

Surface air pressures are lowest.

Diameter: 16 to 70km

Anatomy of a hurricane



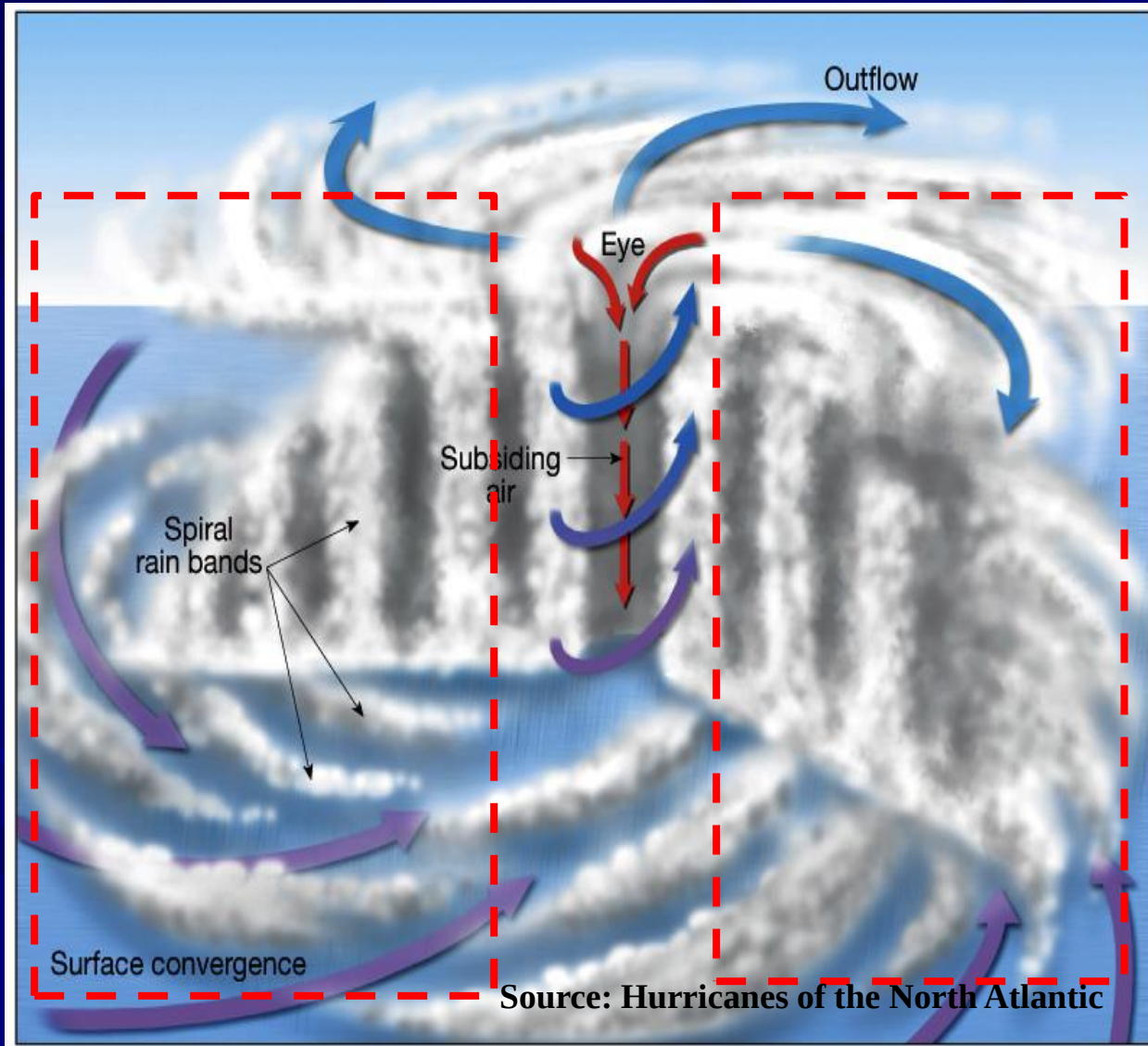
Eye wall:

Ring of cumulonimbus clouds around the eye.

Location of the strongest winds, heaviest rain and intense rising motion.

"Hot towers" linked to rapid intensification

Anatomy of a hurricane

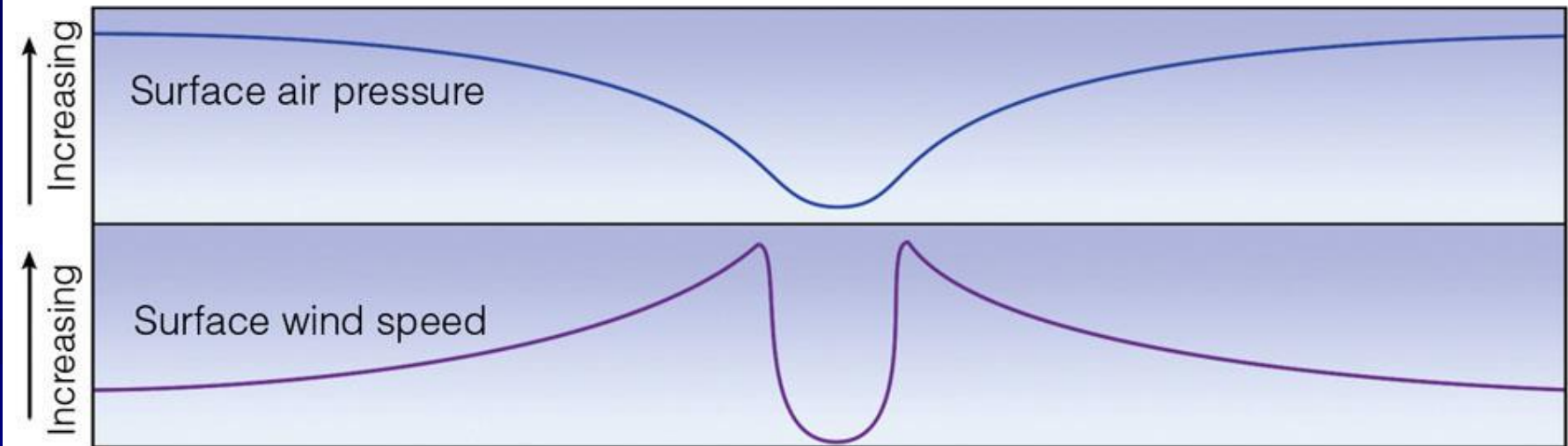
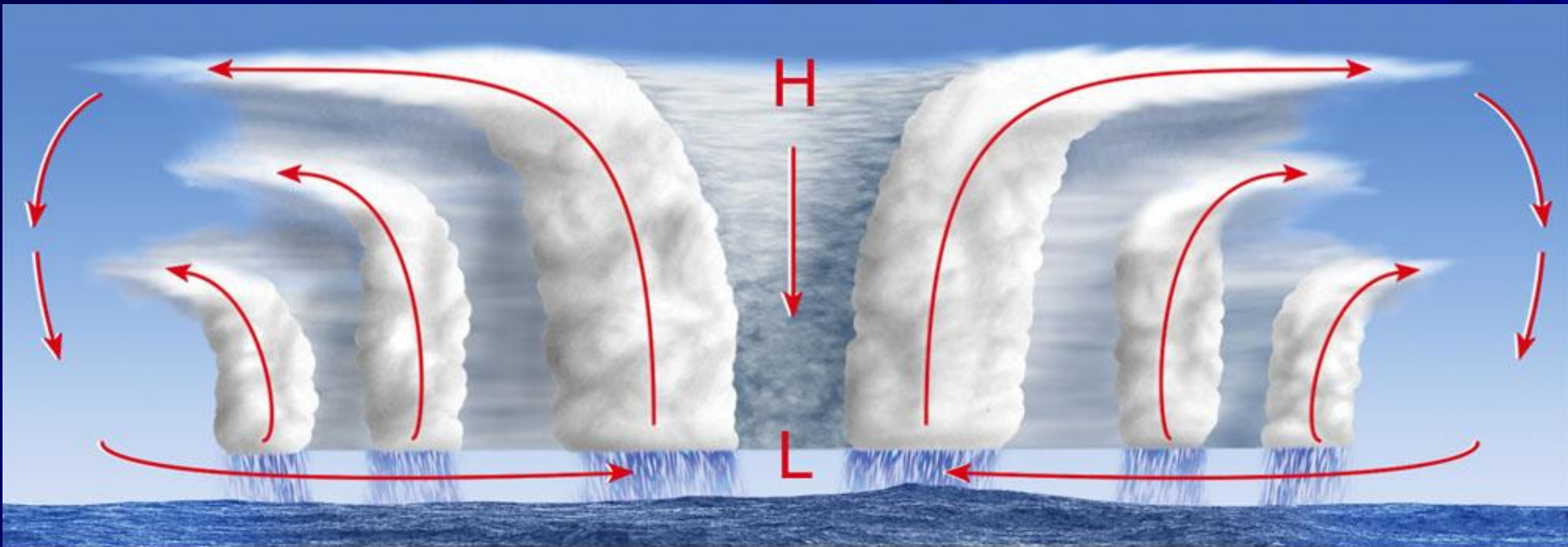


Spiral bands:

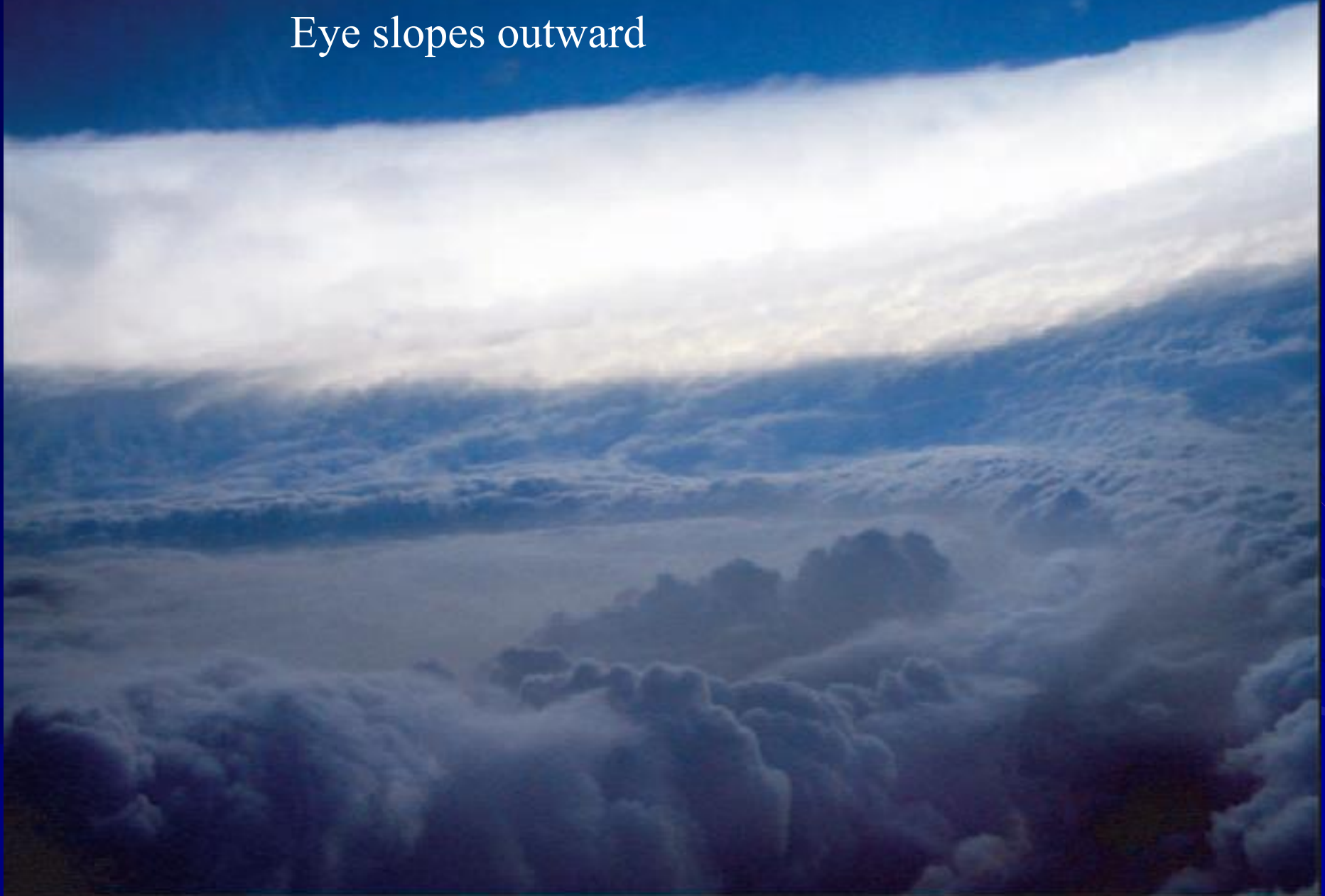
Heavy rains and squalls (strong winds of short duration)

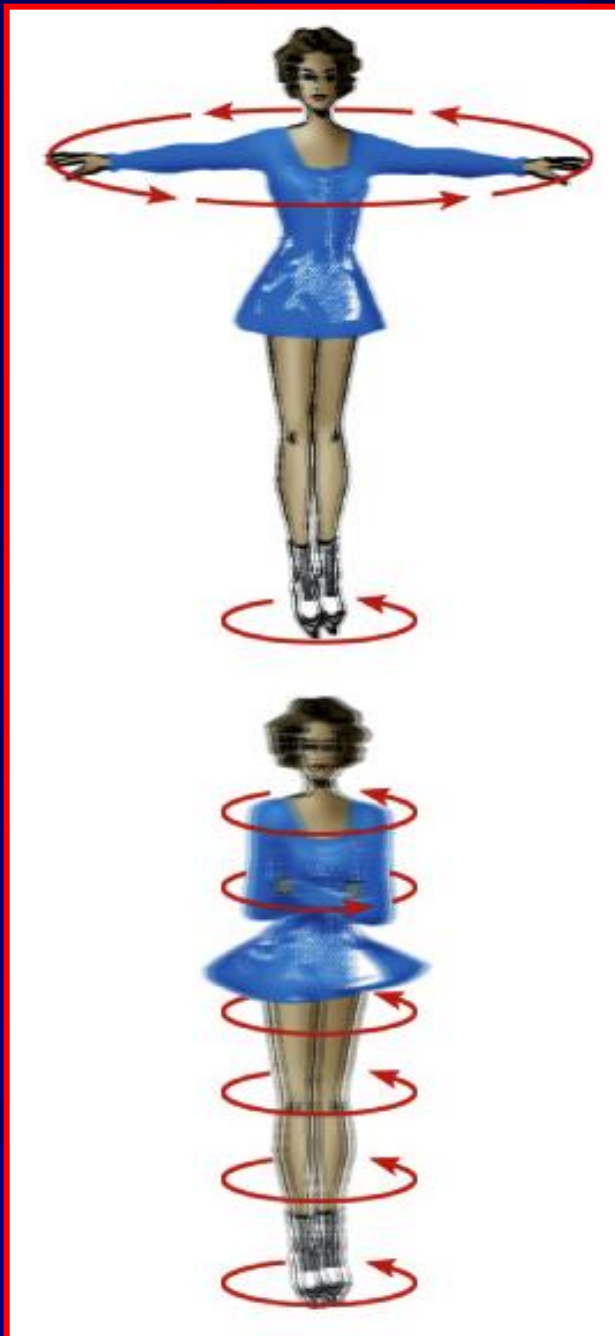
Outermost bands can be 1000 km from hurricane center.

Convergence supplies water vapor needed to sustain storm.



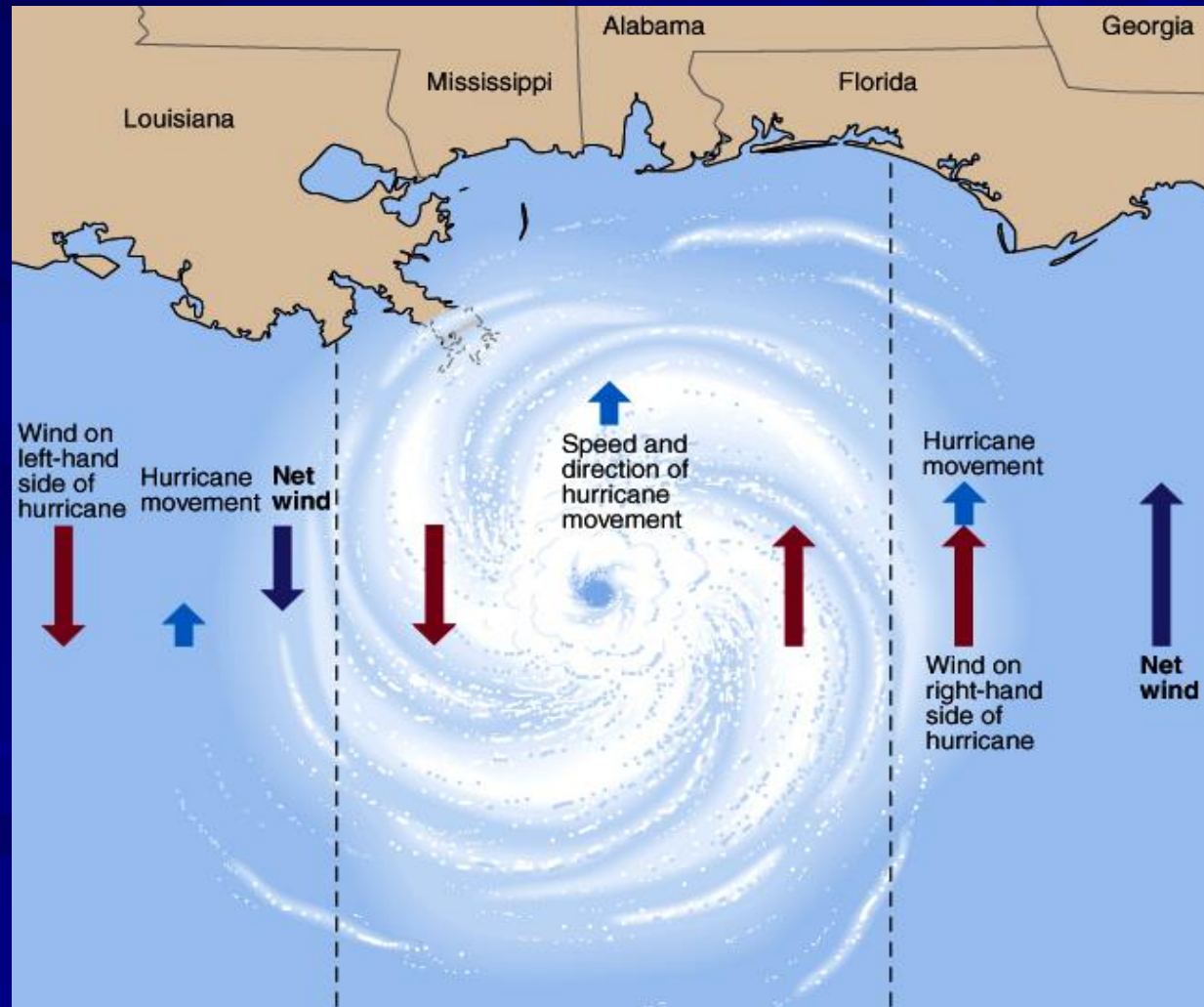
Eye slopes outward





In much the same way an ice skater spins more quickly as her arms are tucked close into her body, a hurricane also spins at a faster pace near the center than near the outer edge.

Destruction most intense on right side of cyclone (wind + storm speed)



Classification of Hurricanes

■ TABLE 11.2 Saffir-Simpson Hurricane Damage-Potential Scale

SCALE NUMBER (CATEGORY)	CENTRAL PRESSURE		WINDS		STORM SURGE		DAMAGE
	mb	in.	mi/hr	knots	ft	m	
1	≥980*	≥28.94	74–95	64–82	4–5	~1.5	Damage mainly to trees, shrubbery, and unanchored mobile homes
2	965–979	28.50–28.91	96–110	83–95	6–8	~2.0–2.5	Some trees blown down; major damage to exposed mobile homes; some damage to roofs of buildings
3	945–964	27.91–28.47	111–130	96–113	9–12	~2.5–4.0	Foliage removed from trees; large trees blown down; mobile homes destroyed; some structural damage to small buildings
4	920–944	27.17–27.88	131–155	114–135	13–18	~4.0–5.5	All signs blown down; extensive damage to roofs, windows, and doors; complete destruction of mobile homes; flooding inland as far as 10 km (6 mi); major damage to lower floors of structures near shore
5	<920	<27.17	>155	>135	>18	>5.5	Severe damage to windows and doors; extensive damage to roofs of homes and industrial buildings; small buildings overturned and blown away; major damage to lower floors of all structures less than 4.5 m (15 ft) above sea level within 500 m of shore

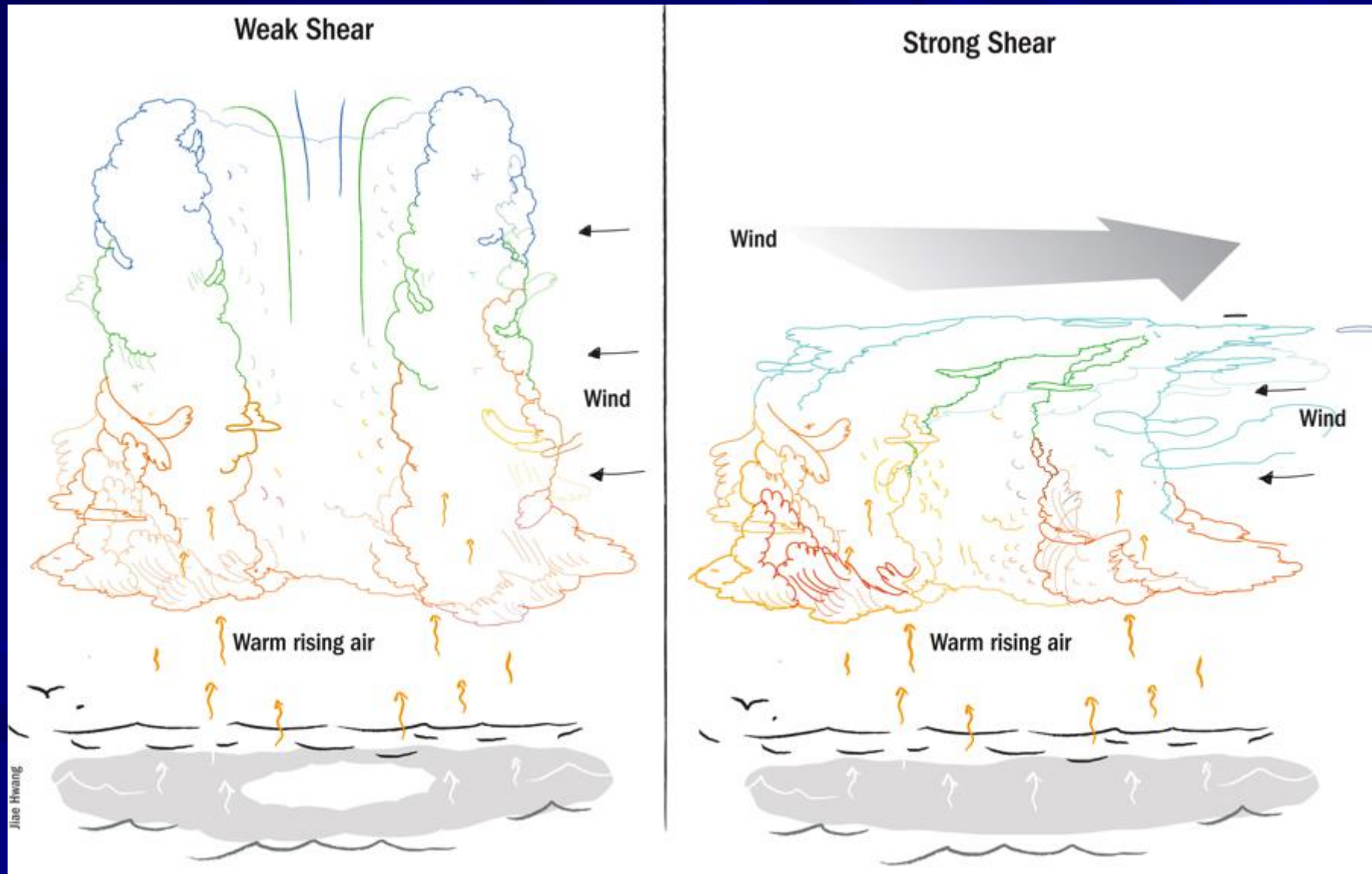
*Symbol > means “greater than”; < means “less than”; ≥ means “equal to or greater than”; ~ means “approximately equal to.”

Genesis of a hurricane

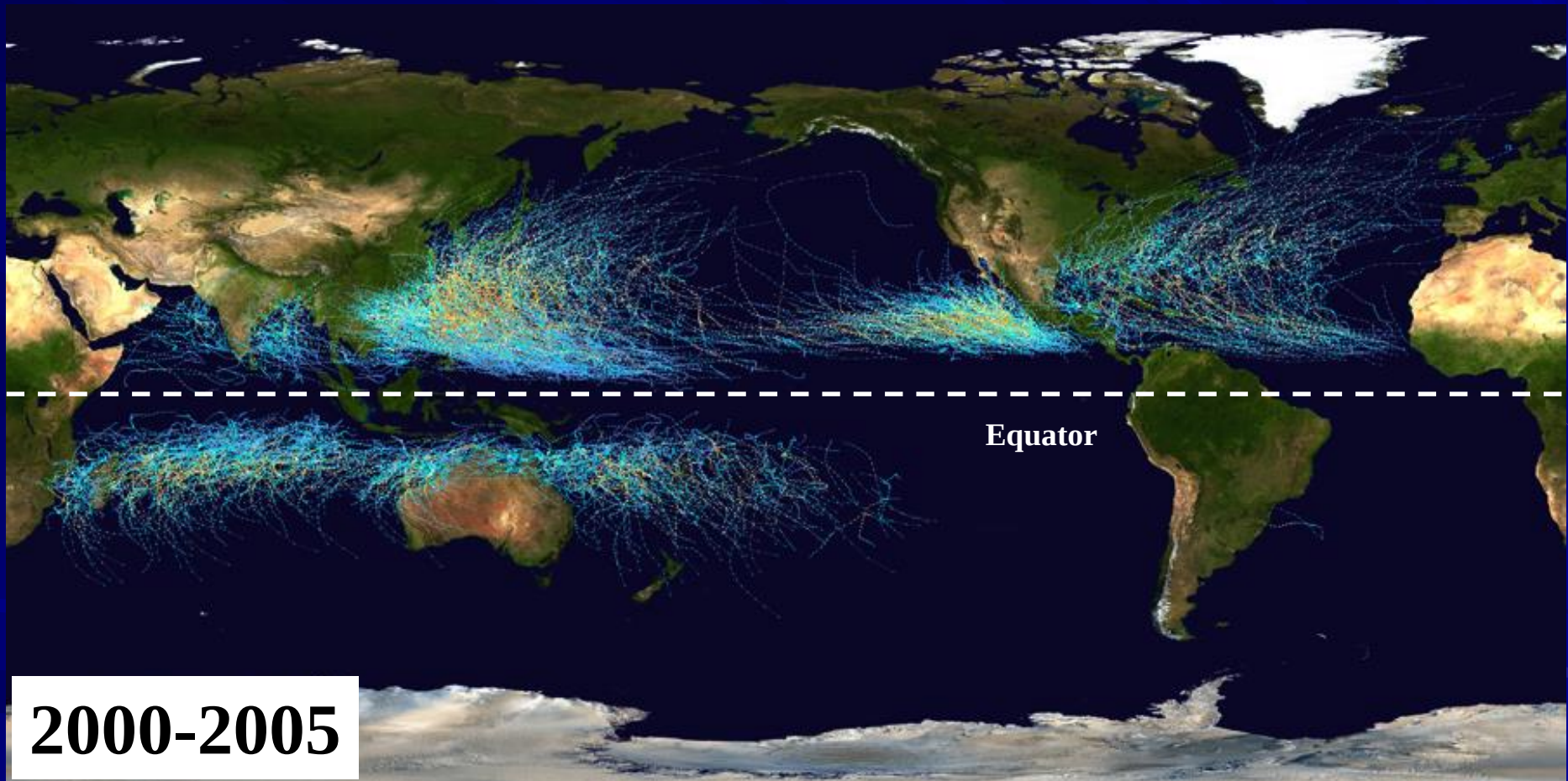
TC genesis typically requires the following:

- Tropical Disturbance with thunderstorms (to establish vertical motion)
- Distance of 200-300 km from the equator (for Coriolis to allow rotation to develop)
- Ocean temperatures at 27°C or warmer (to establish enough water vapor to "fuel" hurricane)
- Abundant moisture - low and middle part of atmosphere (to assist storm development)
- Weak vertical wind shear (to help organization)
- If upper level outflow > lower level inflow the pressure will drop and the storm will intensify.

Wind shear and TC genesis

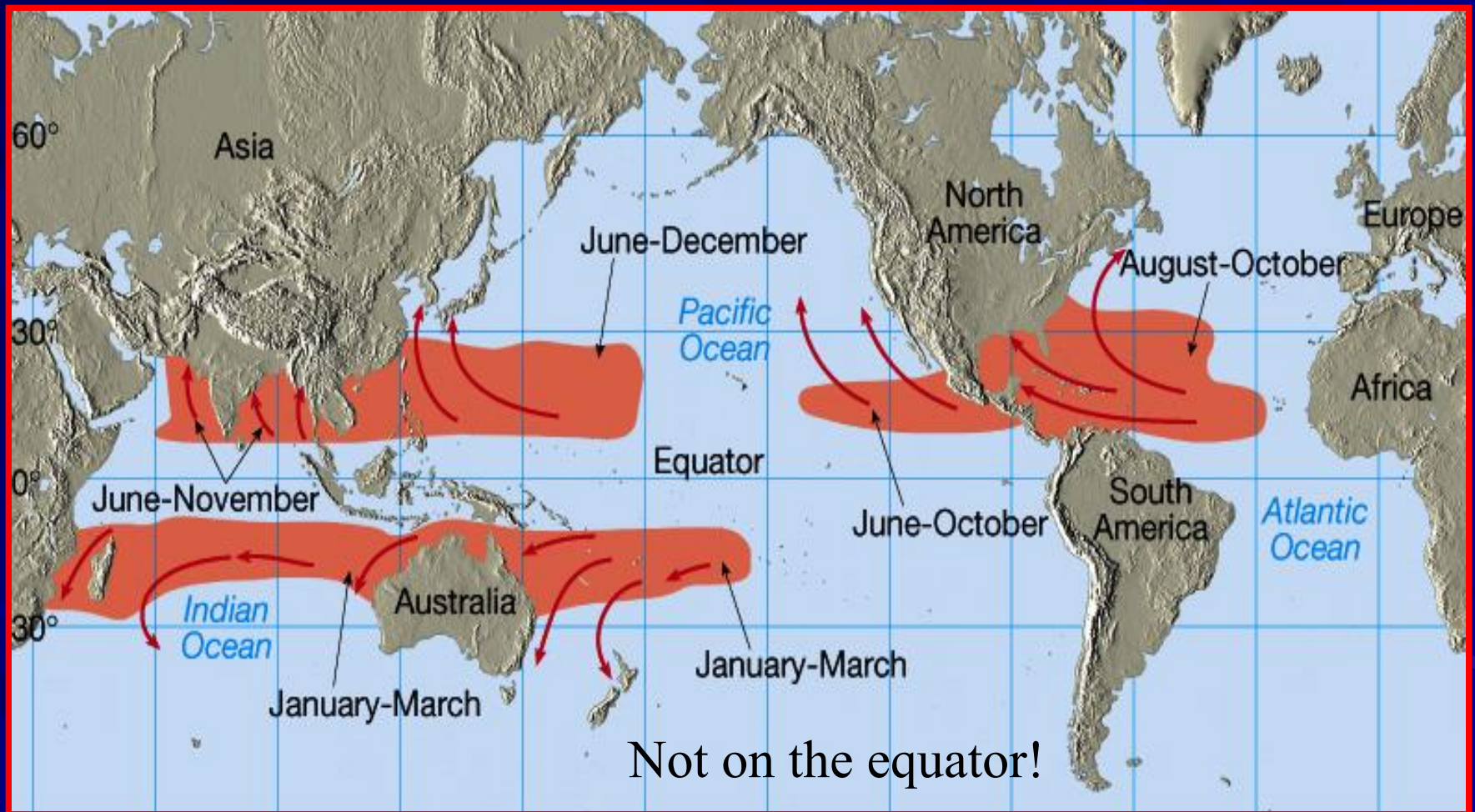


Tropical Cyclone Occurrences and Geographic Distribution

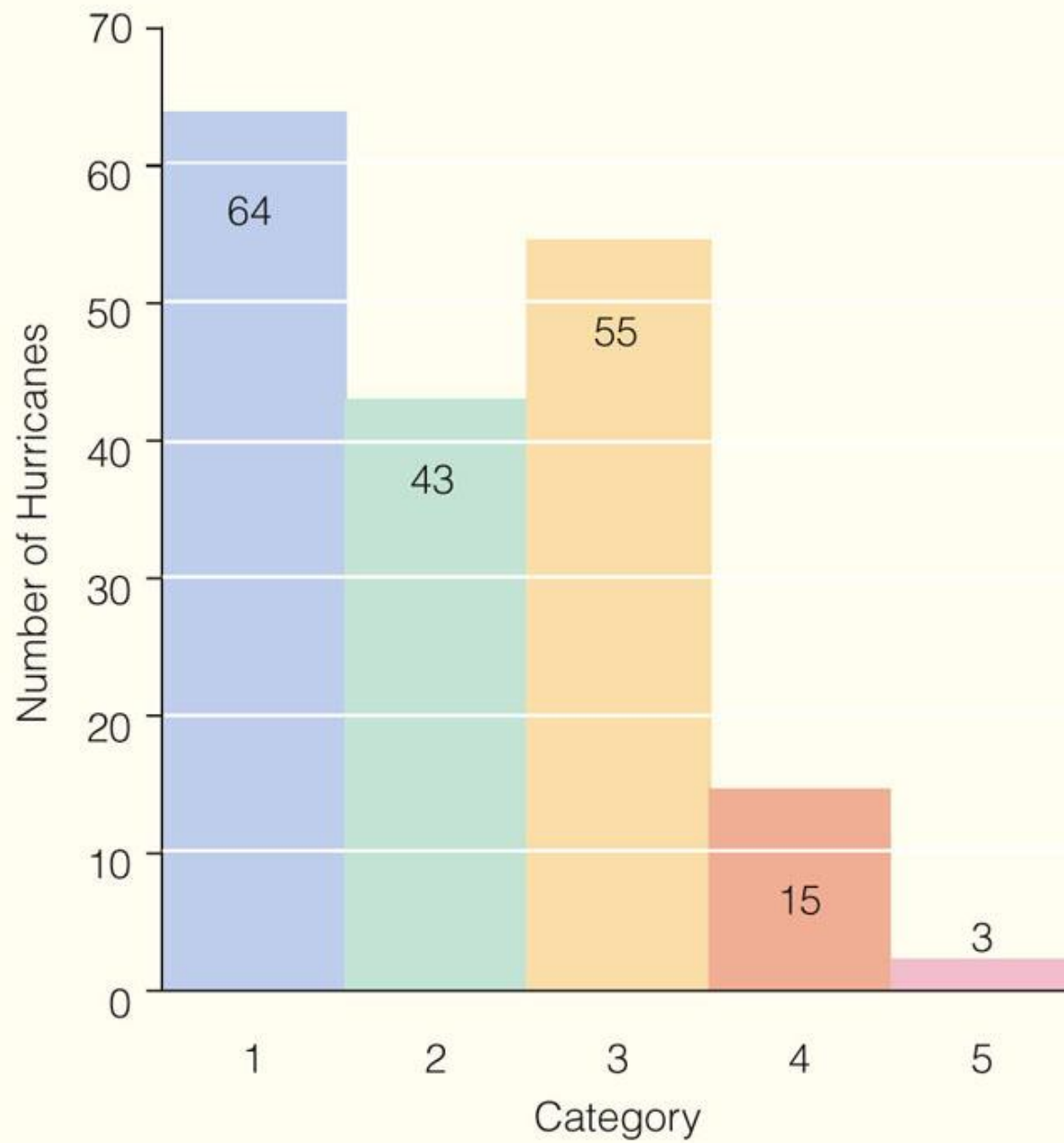


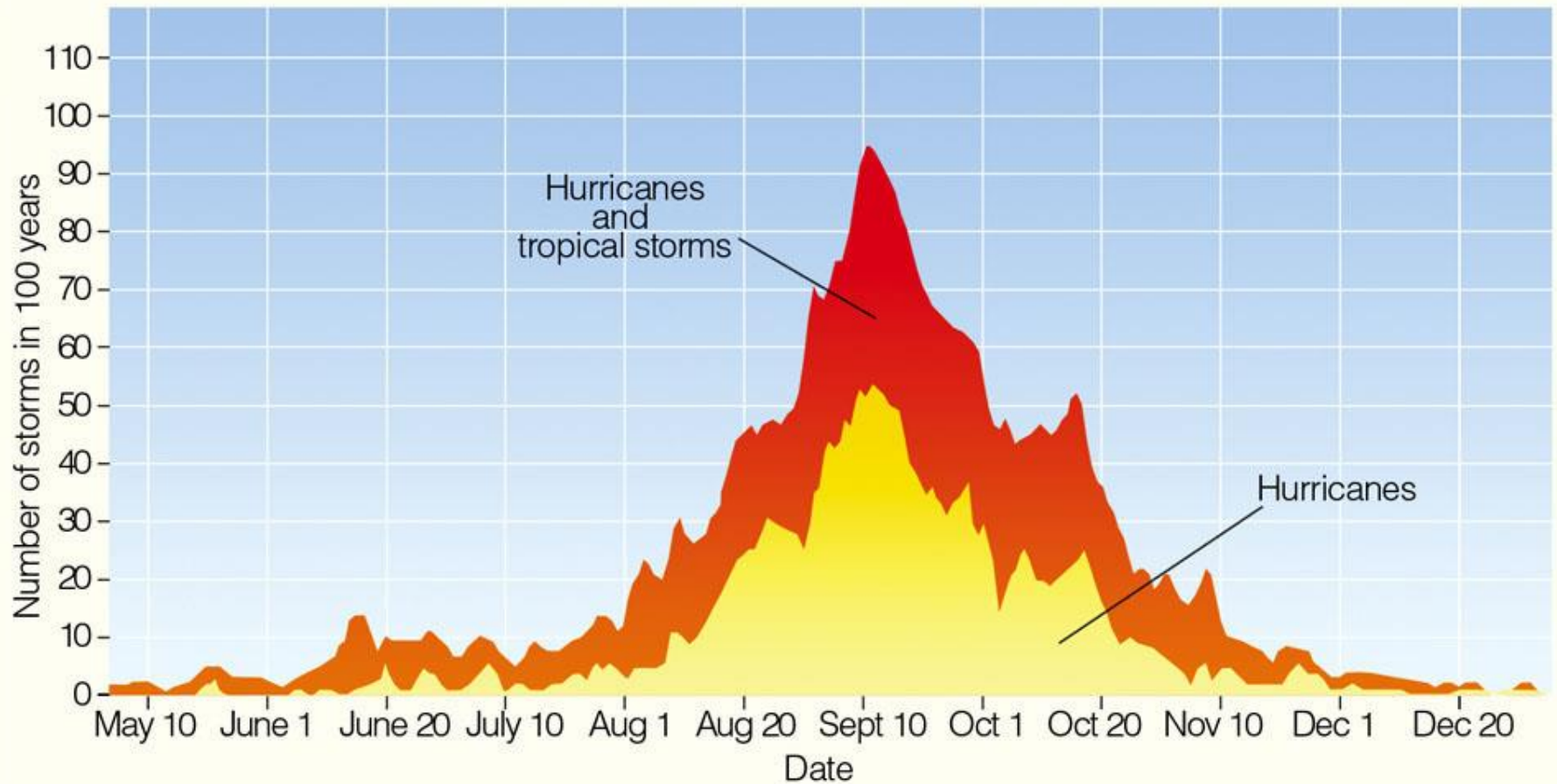
TC generated a few degrees off the Equator

Tropical Cyclone Occurrences and Geographic Distribution



TC generated when the surface water is warm





© 2007 Thomson Higher Education

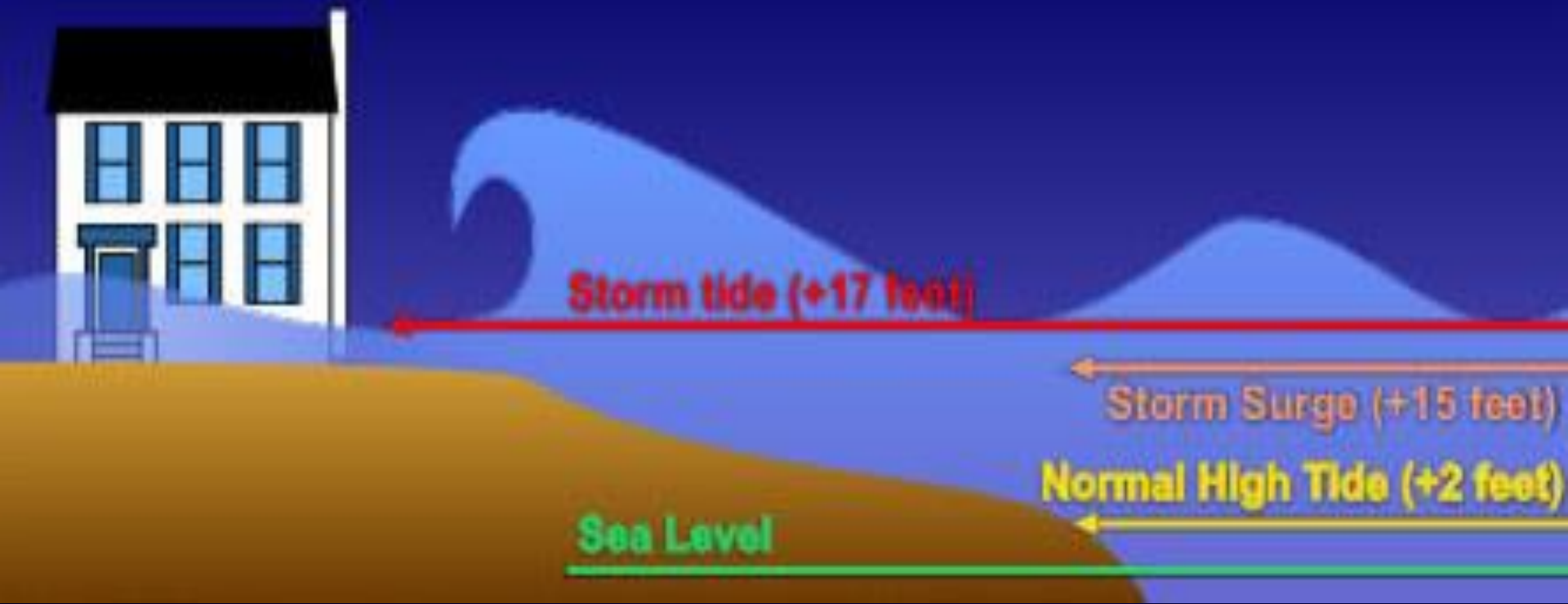
Atlantic Basin Hurricanes and Tropical Storms

Tropical Cyclone Hazards

- Storm Surge
- High Winds
- Inland Flooding
- Tornadoes



Tropical Storm/ Hurricane Impacts



- Storm Surge - simply water that is pushed toward the shore by the force of the winds swirling around the storm.
- Advancing surge combines with normal tides to create the hurricane storm tide - can increase the average water level 15 feet or more.



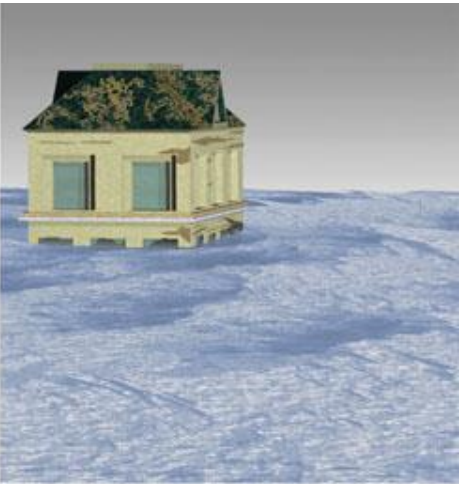
Normal high tide



Category 1 [4-foot rise]



Category 3 [12-foot rise]



Category 5 [20-foot rise]



(a)



(b)

© 2007 Thomson Higher Education

Before and after Hurricane Iva, Sept 2004, coastal Alabama



Before a
hurricane
...

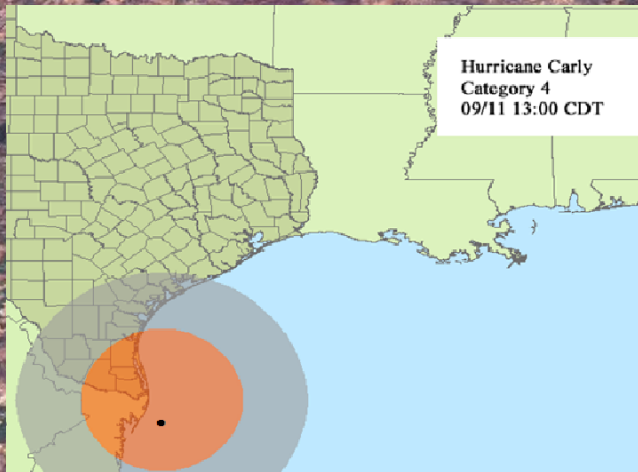


After a
hurricane.

Storm Surge Video

<http://www.youtube.com/watch?v=nV6Qtrt2CNQ&feature=fvsrc>

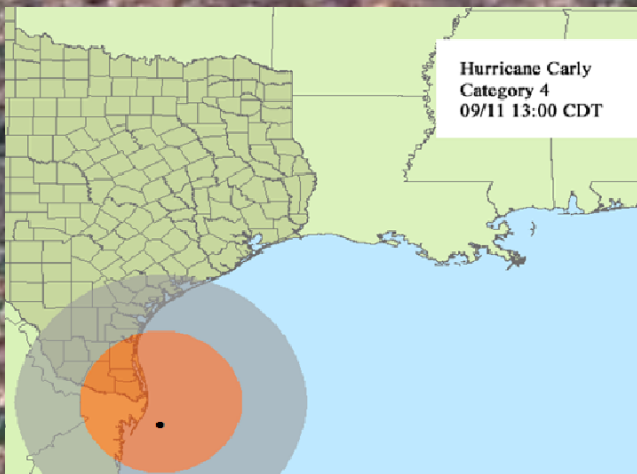
<http://www.youtube.com/watch?v=l9vDSWugz08>



Brownsville

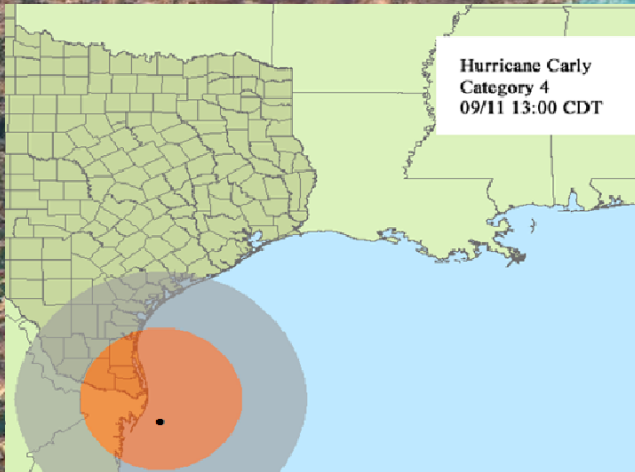
**Brownsville / South Padre I.
Mean Sea Level**

Source: UT Space Science
Center



Brownsville

Hurricane Carly
9/11 at 0100 CDT
MEOW NW at 8 MPH
Surge: 4.3 Feet



Brownsville

**Hurricane Carly
9/11 at 1500 CDT
MEOW NW at 8 MPH
Surge: 17.3 Feet**

**Source: UT Space Science
Center**

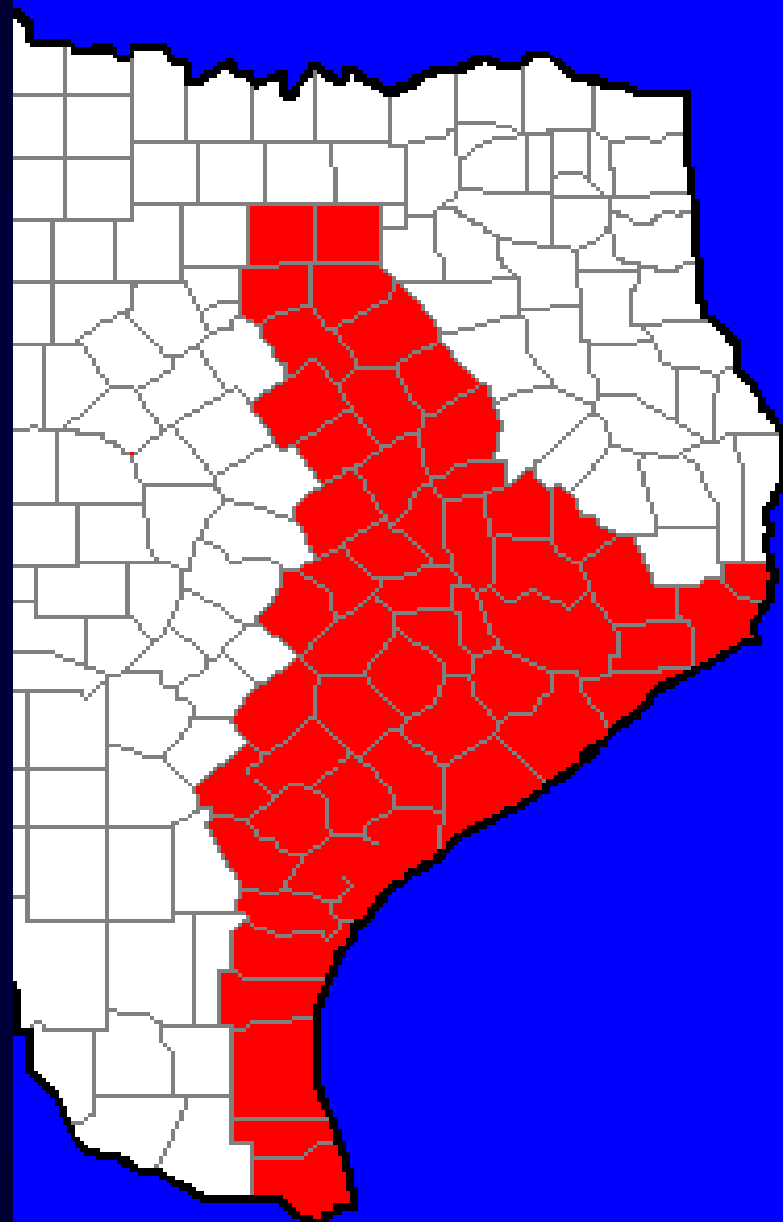
Tropical Storm/ Hurricane Impacts



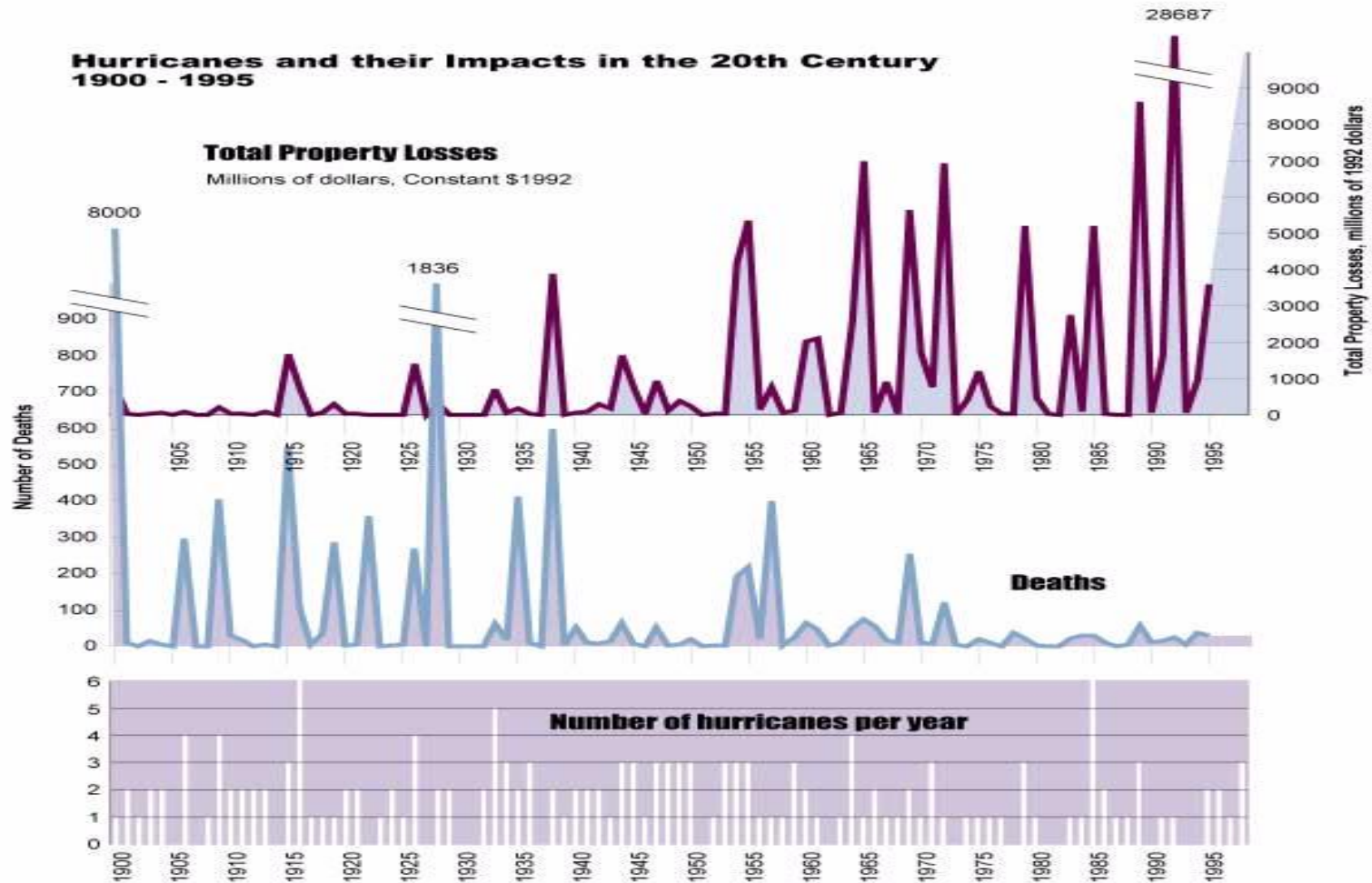
Heavy rains create inland flooding that results in fatalities and/or loss of property. An example is Hurricane Carla **where** in Jefferson County, 180 miles from the land falling storm, \$17.5 million in damage occurred, with \$14 million of it water damage. Rain totaled up to 19". Three to four feet of water flooded Port Arthur. Total damages from Carla estimated near \$400 million.

Tropical Storm/ Hurricane Impacts

- Tornadoes
 - Hurricane Carla had its greatest impact in Texas.
 - Twenty-six tornadoes were spawned
 - one tore apart 120 buildings and killed 6 in Galveston
 - Hurricane Beulah spawned over 100 tornadoes



Hurricane Deaths Have Decreased— Property Losses Have Increased



TC Forecasting



National Hurricane Center (NHC), Miami, FL

TC Forecasting: Accomplishments and failures

- During the past thirty years there has been a substantial improvement in hurricane track forecasts as computer models improved and more data became available to describe their environment.
- Over the same period only minimal improvement is hurricane intensity forecasts.

TC Forecasting: The Challenge

Lack of observations (TCs are often far from land)

- Only the Atlantic Basin has routine aircraft penetration
- Rest of world relies on satellites and occasional ships and buoys

Observations are often inadequate for forecast needs

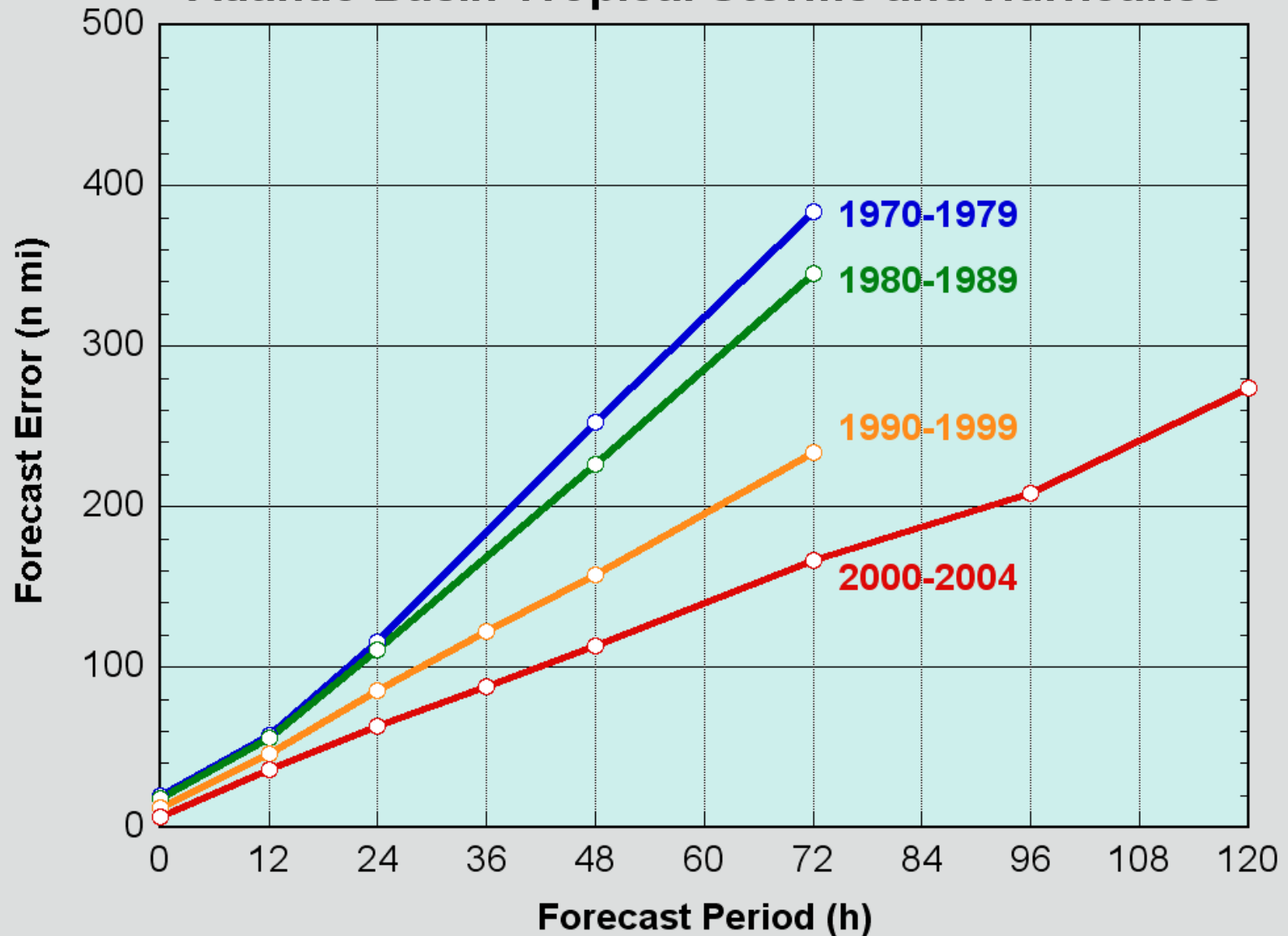
- At times, discerning current intensity and location can be difficult
- Some numerical models don't even "know the TC exists" and a vortex must be inserted
- Most models struggle forecasting evolution of the environment

Models limited by resolution & processing speed

- Most forecast models don't resolve the eye or eyewall
- 3-6 day forecasts of the region must be complete in a few hours

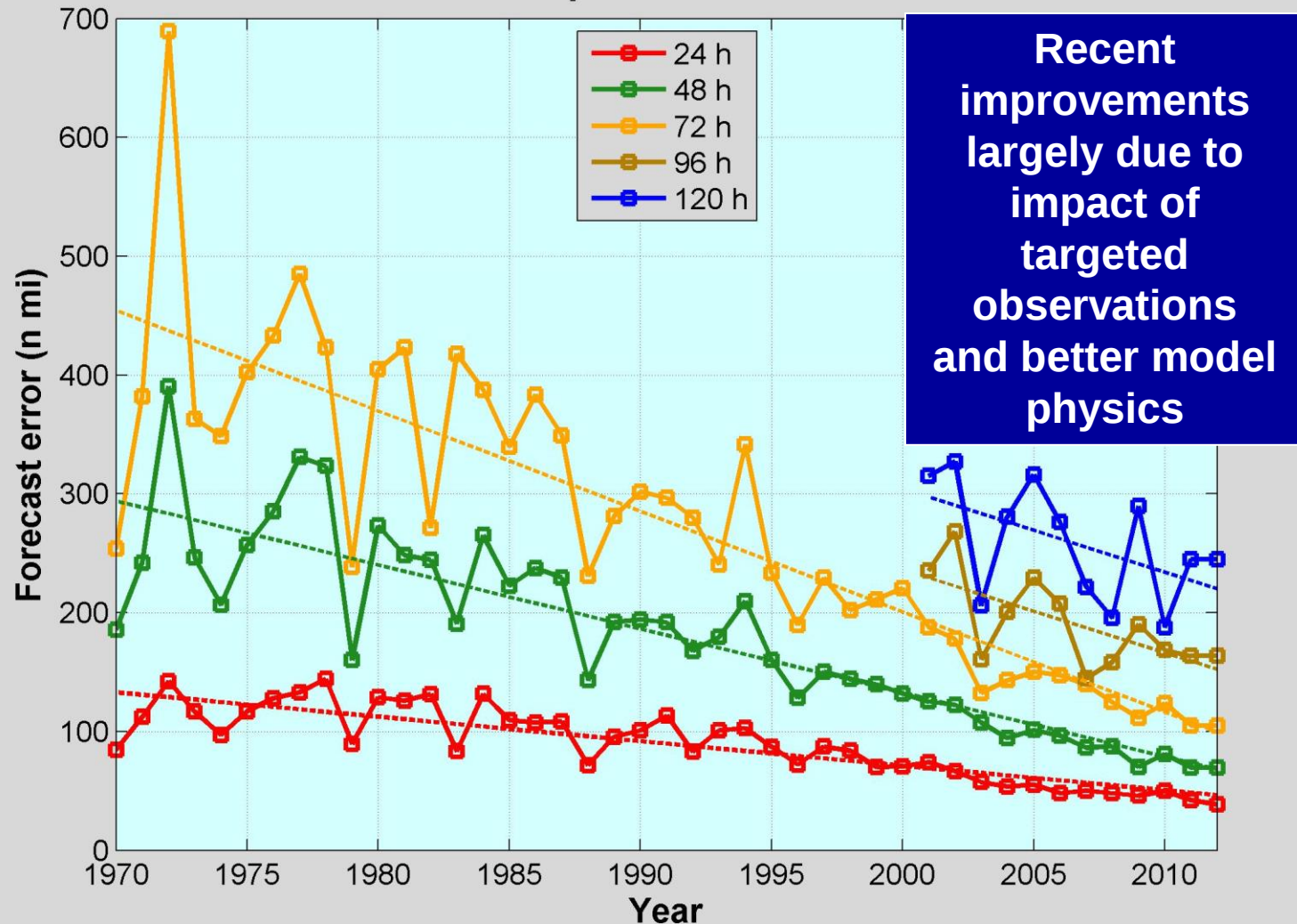
Incomplete understanding of meso- and convective-scale dynamics - and microphysics

NHC Official Average Track Errors Atlantic Basin Tropical Storms and Hurricanes



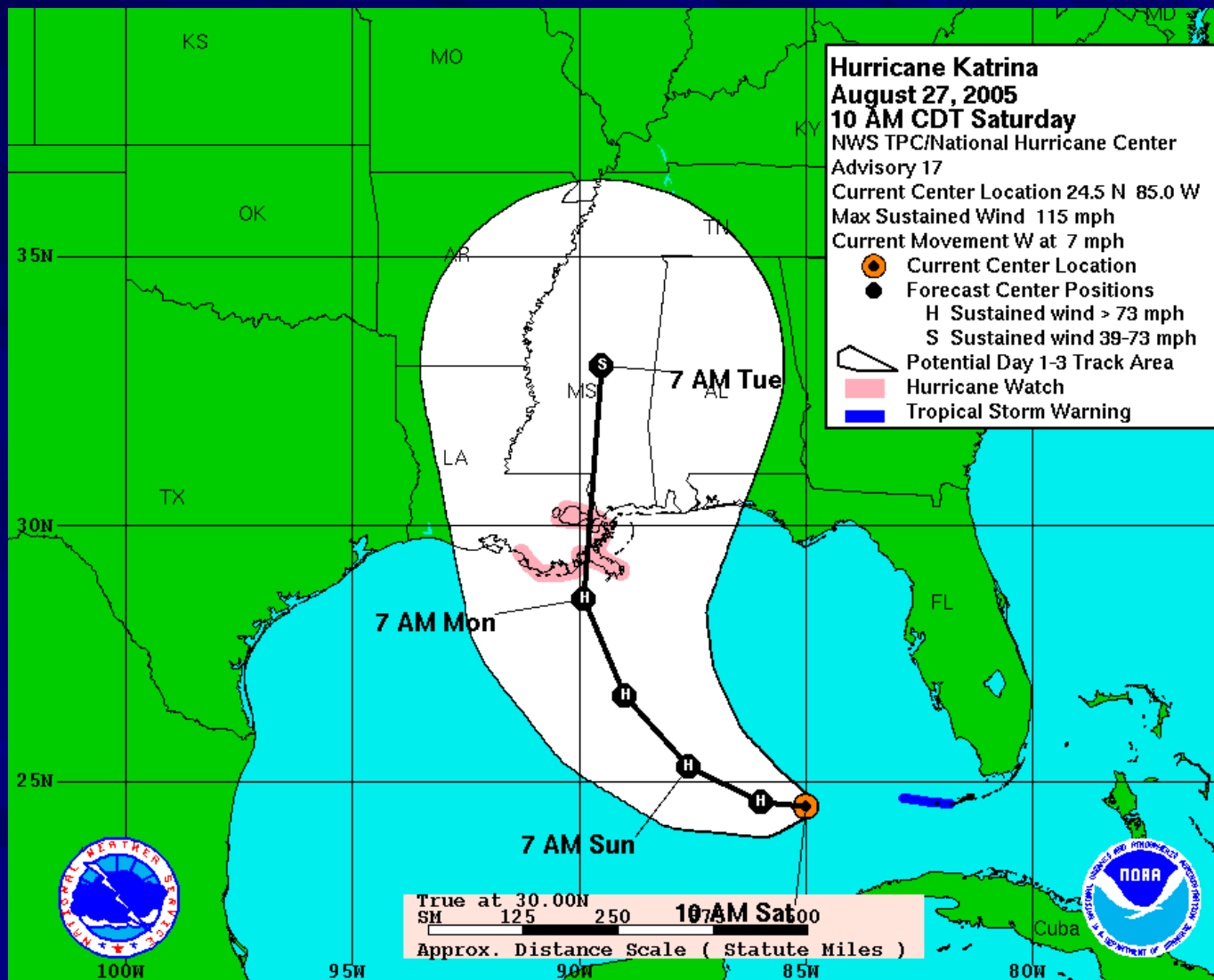
TC Forecasting: Track

NHC Official Annual Average Track Errors
Atlantic Basin Tropical Storms and Hurricanes

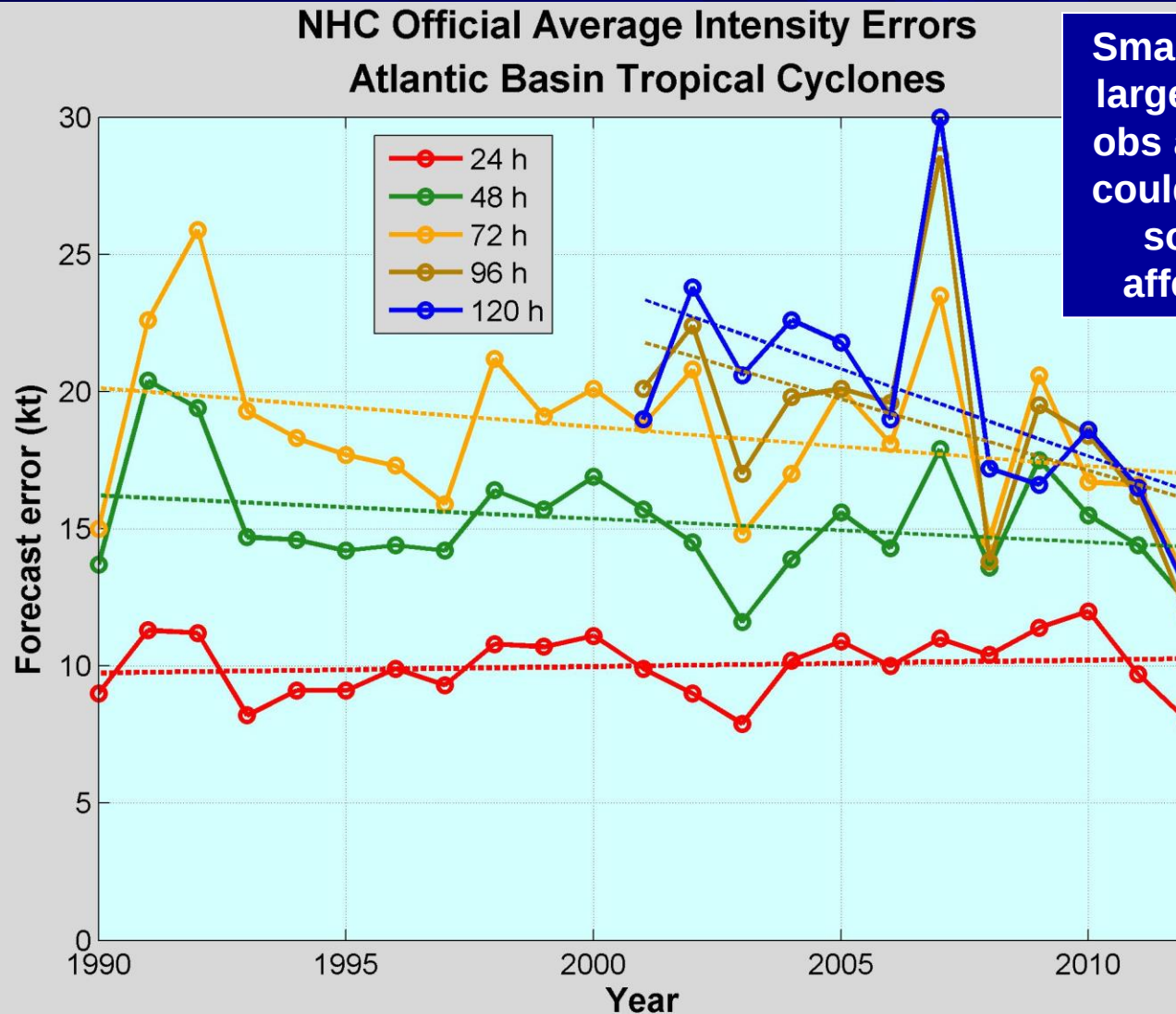


Katrina

48-h Before: Virtually a Perfect Forecast of Track



TC Forecasting: Intensity



Small improvements
largely due to better
obs and models, but
could we be missing
something that
affects intensity?

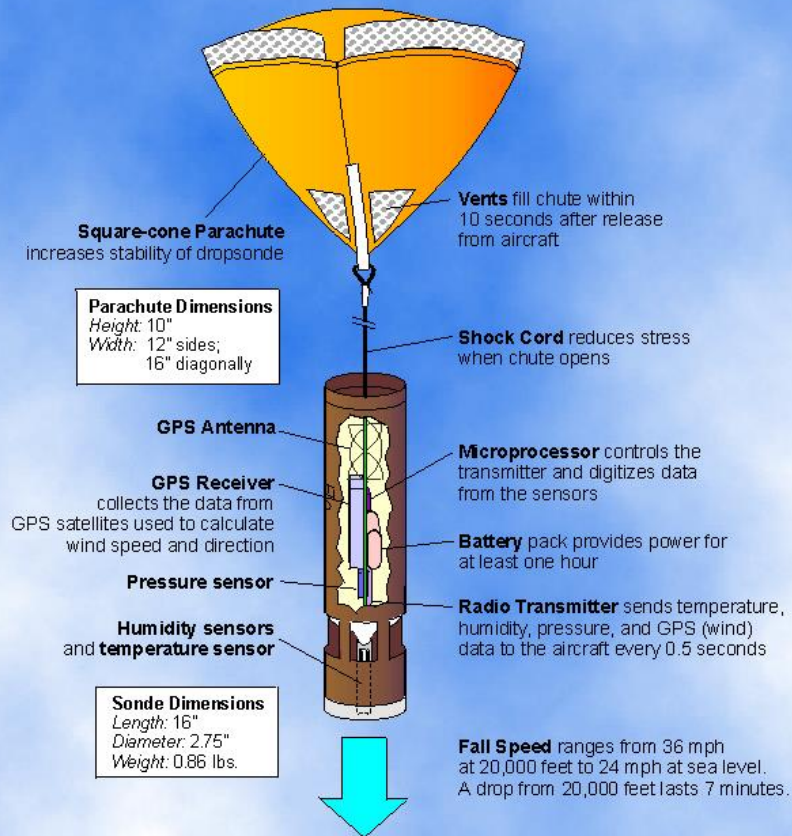


NOAA P3
"Hurricane Hunter"
Aircraft



NCAR GPS Dropsonde

the definitive atmospheric profiling tool



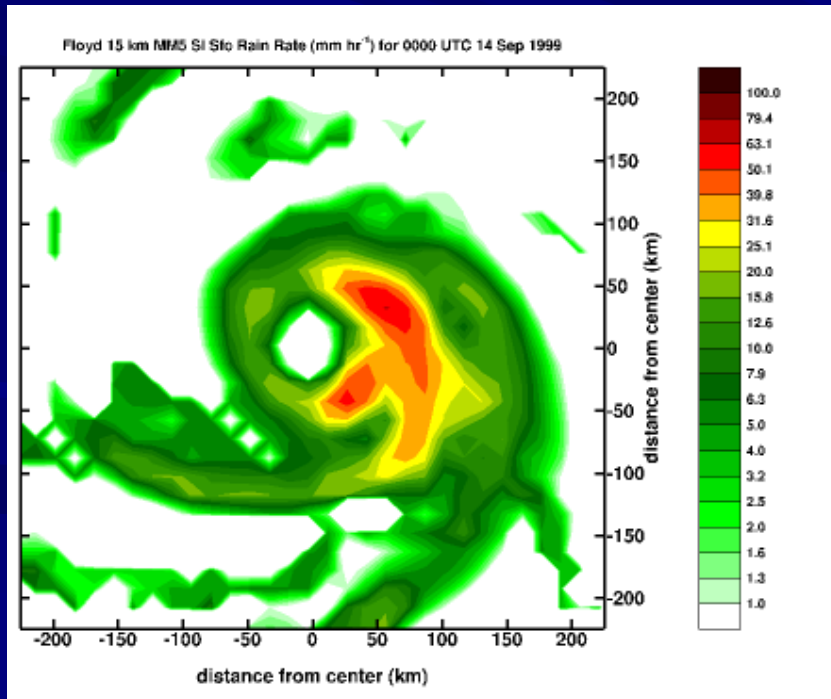


Gulfstream IV-SP (G-IV) is a high altitude, high speed, twin turboprop jet aircraft

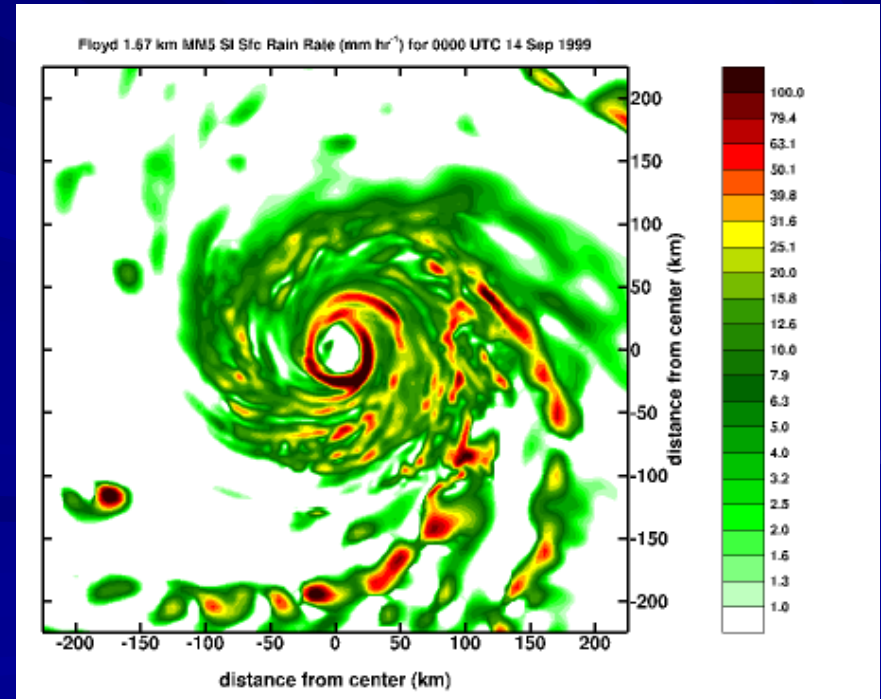
Substantial Promise

- Use of higher resolution prediction, aerosol-cloud interactions and better data around and in hurricanes should improve intensity predictions.

15-km grid spacing



1.67 km grid spacing



U.S Hurricane Headquarters

www.nhc.noaa.gov

Most Visited | Blog | Extreme | W Langley | WXUnder | Google | BlogSum | MODIS | Langley | ST | SnowWatch | Camano

National Weather Service
National Hurricane Center

Home News Organization

Local forecast by "City, St" or "ZIP"
 Go

Alternate Formats
Text | Mobile
Email | RSS
About Alternates

Cyclone Forecasts
Latest Advisory
Past Advisories
Audio/Podcasts
About Advisories

Marine Forecasts
Atlantic & E Pacific
Gridded Marine
About Marine

Tools & Data
Satellite | Radar
Analysis Tools
Aircraft Recon
GIS Datasets
Data Archive

Development
Experimental
Research
Forecast Accuracy

Outreach & Education
Prepare
Storm Surge
About Cyclones
Cyclone Names
Wind Scale
Most Extreme
Forecast Models
Breakpoints
Resources

Top News of the Day... [view past news](#) Last update Tue, 3 Dec 2013 04:31:14 UTC

- NOAA: Slow Atlantic hurricane season comes to a close
- December issue of the Q&A with NHC series available
- Minor Changes to High Seas Forecast Areas Effective December 3 (PDF)

Eastern Pacific **Atlantic**

Atlantic Marine Forecasts



Click Region for Current Marine Forecast

[Graphical Tropical Weather Outlook](#) | [Active Storms](#) | [Marine Forecasts](#)

Atlantic - Caribbean Sea - Gulf of Mexico

[Tropical Weather Outlook](#) [Tropical Weather Discussion](#)