Tropical Cyclones and Hurricanes

Lecture – ENV 407

Hurricane Isabel, 2003 (from ISS)

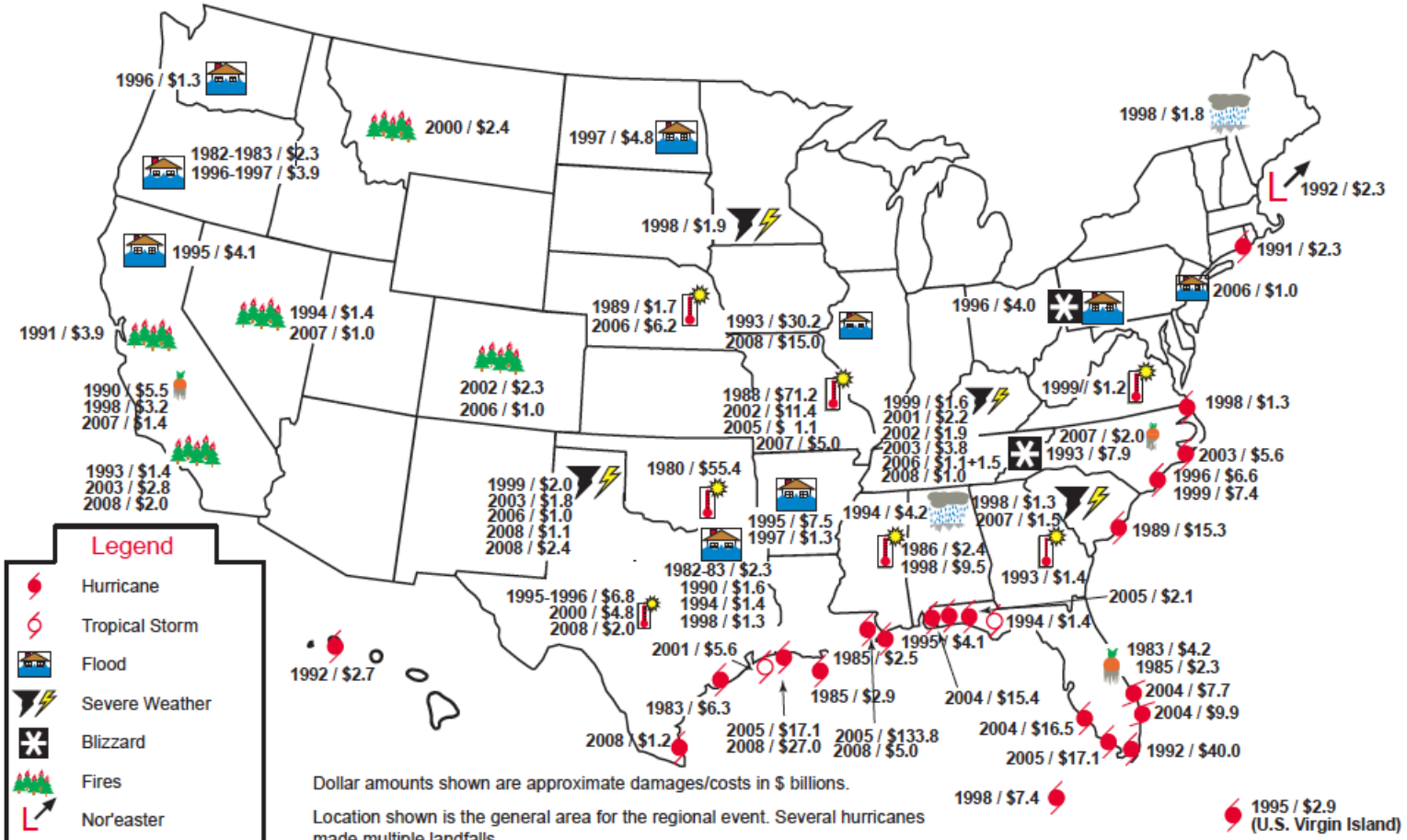
What are Hurricanes?

- 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



Dollar amounts shown are approximate damages/costs in $ billions.

Location shown is the general area for the regional event. Several hurricanes made multiple landfalls.

Additional information for these events is available at NCDC WWW site www.ncdc.noaa.gov/ol/reports/billionz.html

The U.S. has sustained 90 weather related disasters over the last 29 years with overall damages/costs exceeding $1.0 billion for each event. Total costs for the 90 events exceed $700 billion using a GNP inflation index.

NOAA's
National Climatic Data Center

Katrina (2005)

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

Fig. 11-24, p. 320

Galveston, TX (1900)

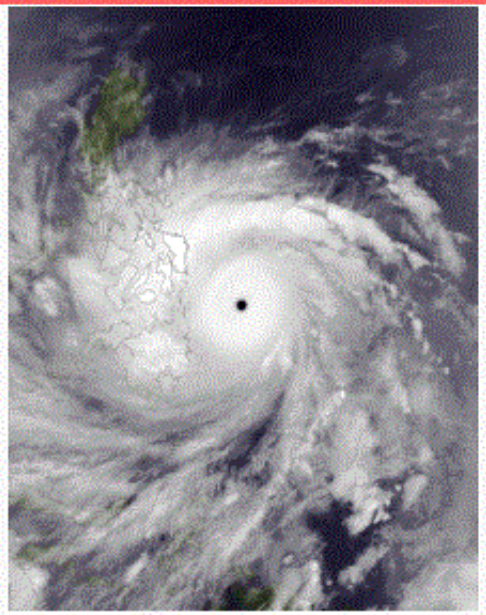
The Greatest Loss of Life of any U.S. Meteorological Event (8000 died)

Typhoon Haiyan

Typhoon Haiyan (Yolanda)

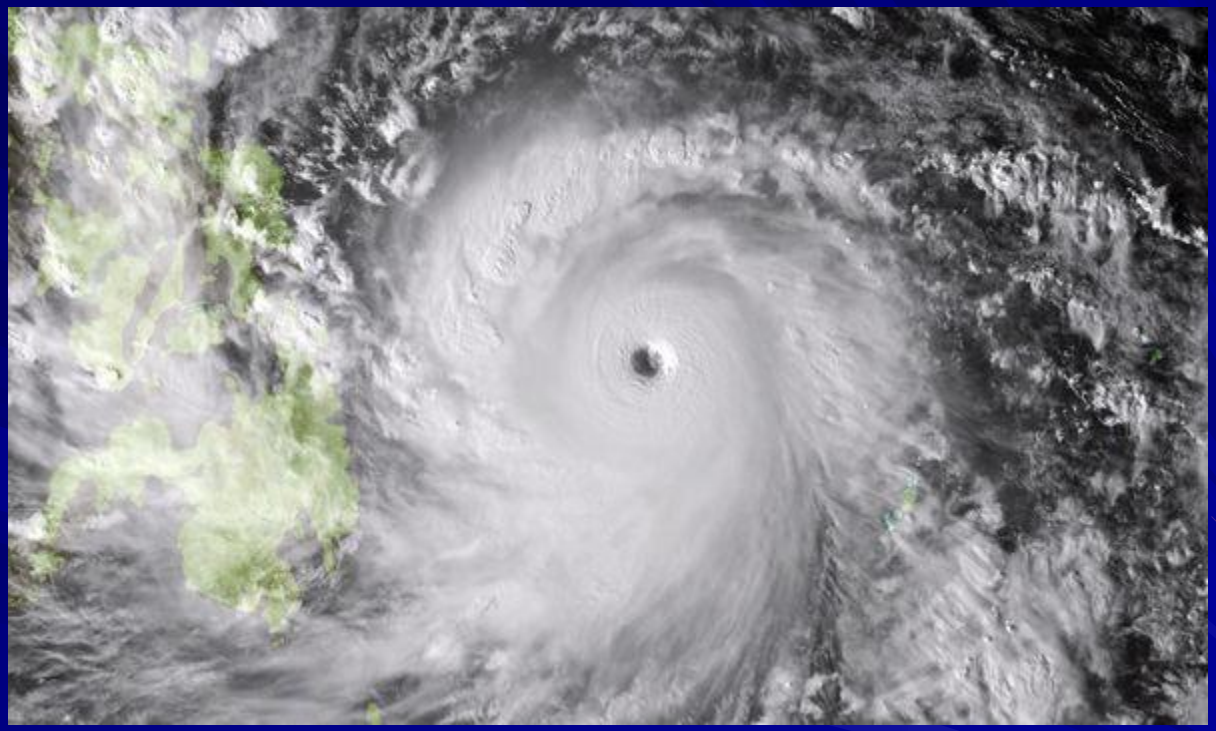
Typhoon (JMA)

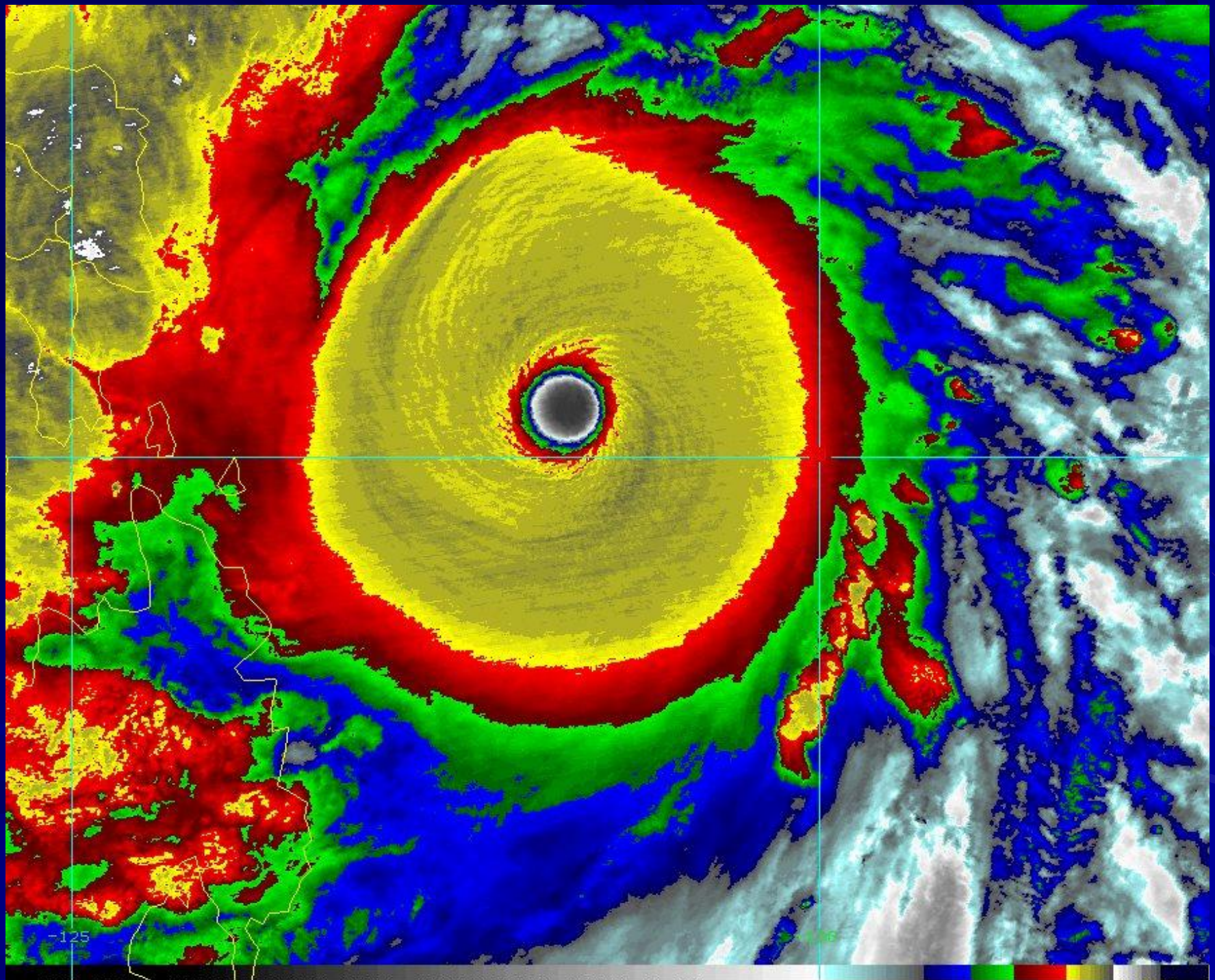
Category 5 super typhoon (SSHS)

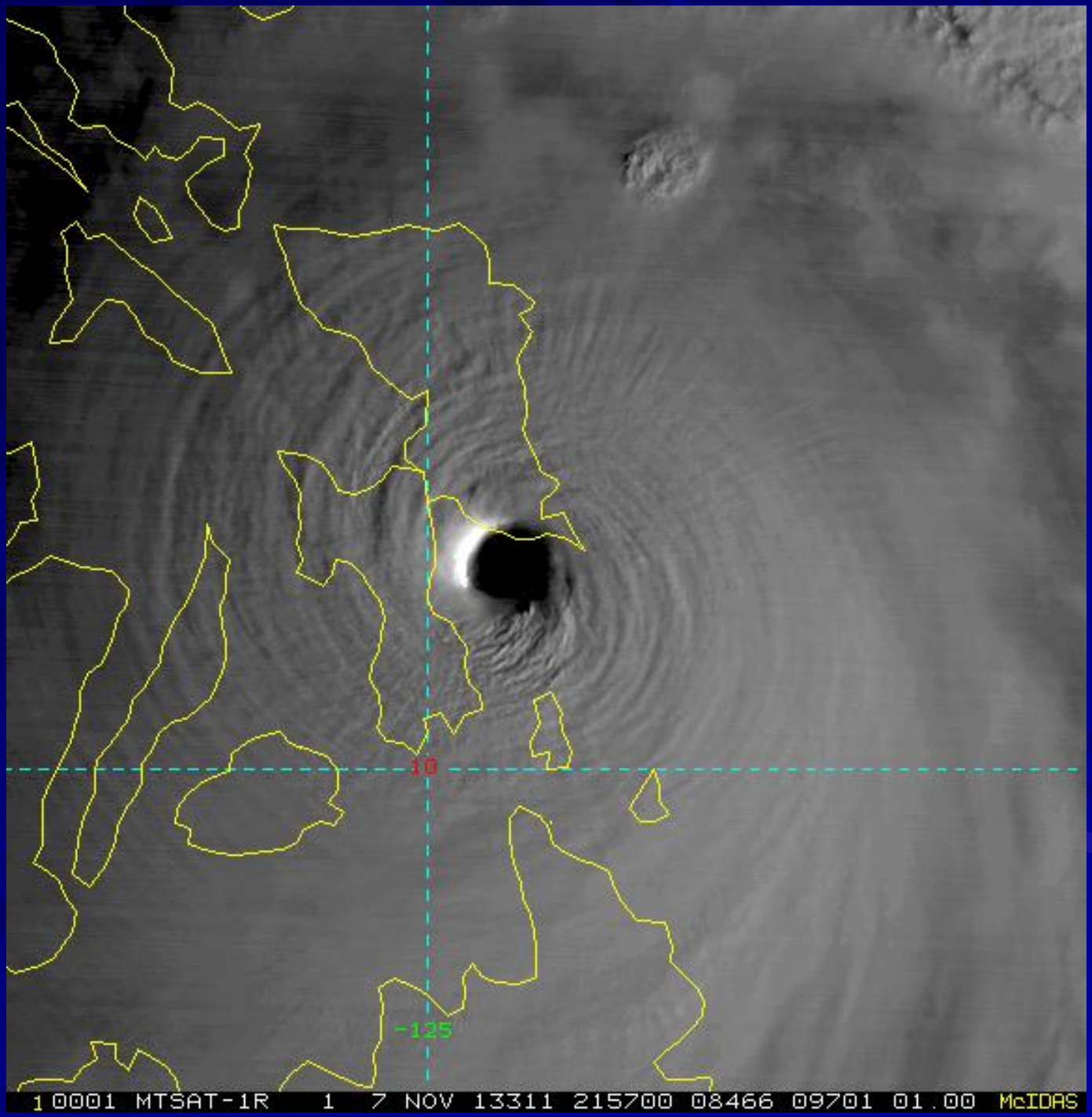


Typhoon Haiyan at peak intensity, on November 7

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




-125


10
-125
1 0001 MTSAT-1R 1 7 NOV 13311 215700 08466 09701 01.00 McIDAS

Experience a hurricane

https://www.youtube.com/watch?v=F0DnuW5IbUg

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

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

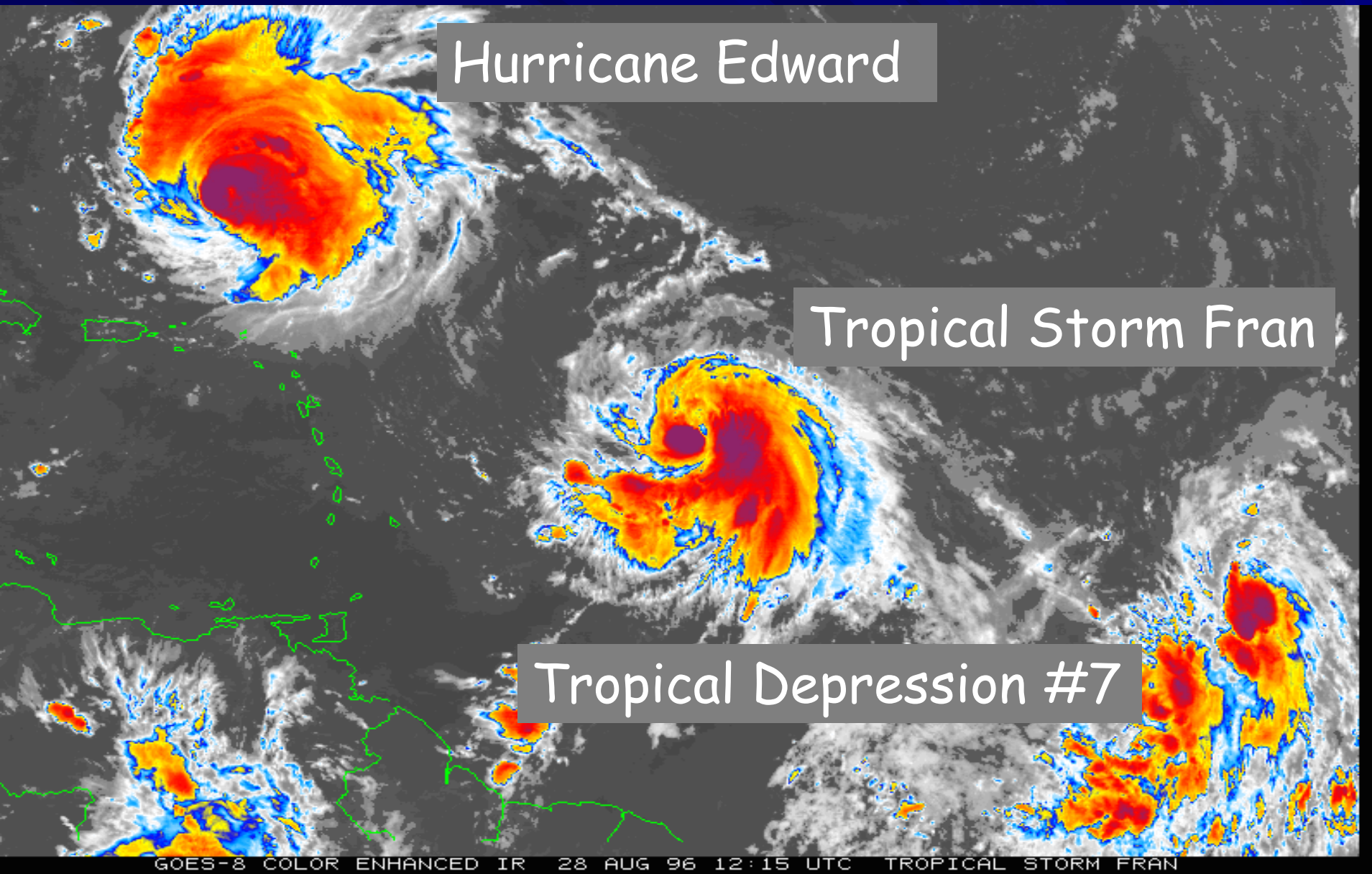
http://www.youtube.com/watch?v=UeM-cjTEEA8&feature=related

https://www.youtube.com/watch?v=AMV6758nosU

Classification of Tropical Storms

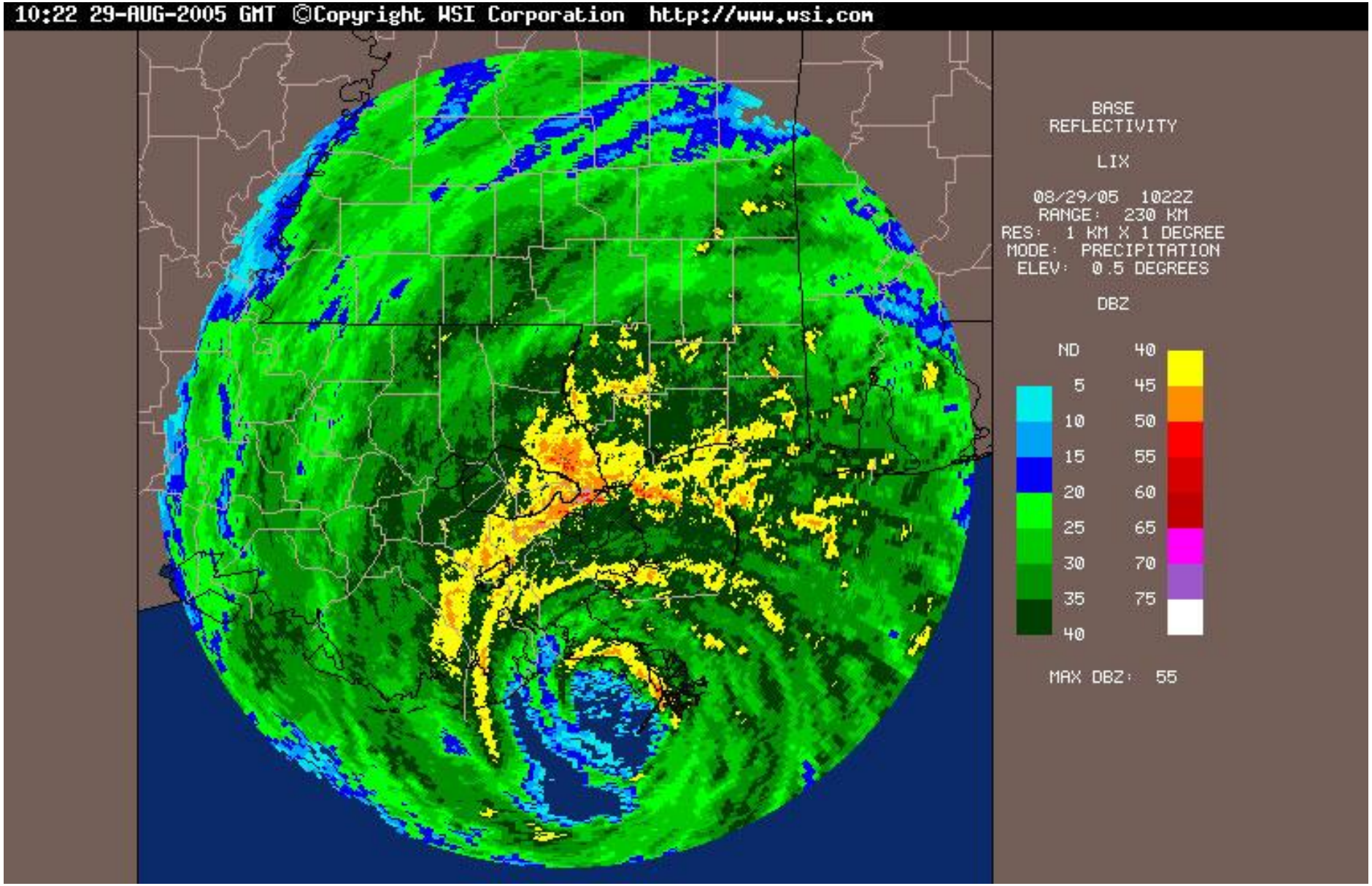
- Disturbance: Group of thunderstorms in the tropics present for at least 24 hours
- Wave: No circulation, winds <25 mph, all directions
- Tropical Cyclone: Non-frontal synoptic scale low-pressure system over tropical or sub-tropical waters with organized convection (i.e. thunderstorm activity) and definite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

Pictures of Tropical Storms



Hurricane Features:

Eye (nearly clear)
Eye Wall Rainband
Spiral Rainbands


10:22 29-AUG-2005 GMT ©Copyright WSI Corporation http://www.wsi.com
BASE
REFLECTIVITY
LIX
08/29/05 1022Z
RANGE: 230 KM
RES: 1 KM X 1 DEGREE
MODE: PRECIPITATION
ELEV: 0.5 DEGREES
DBZ
ND
5
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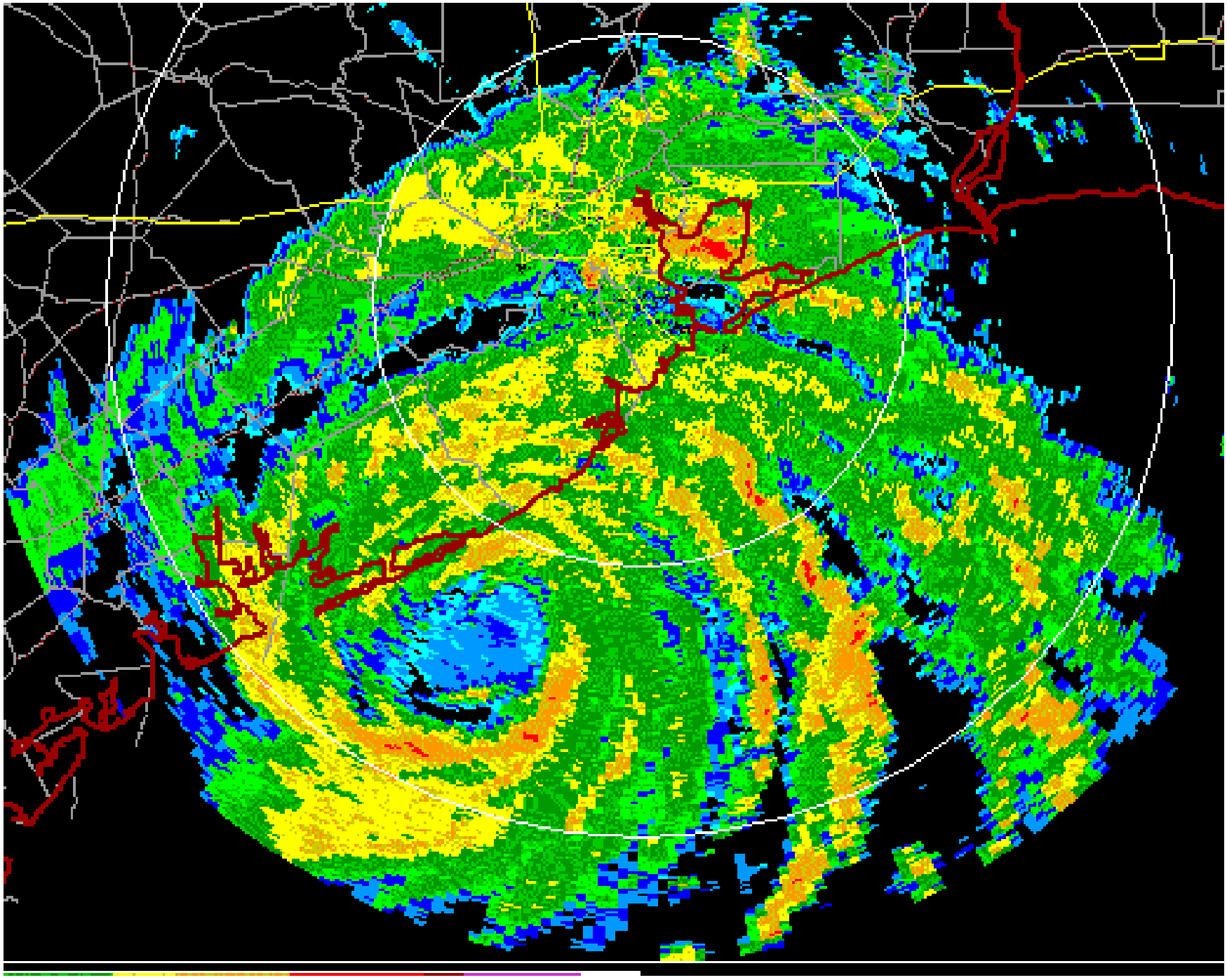
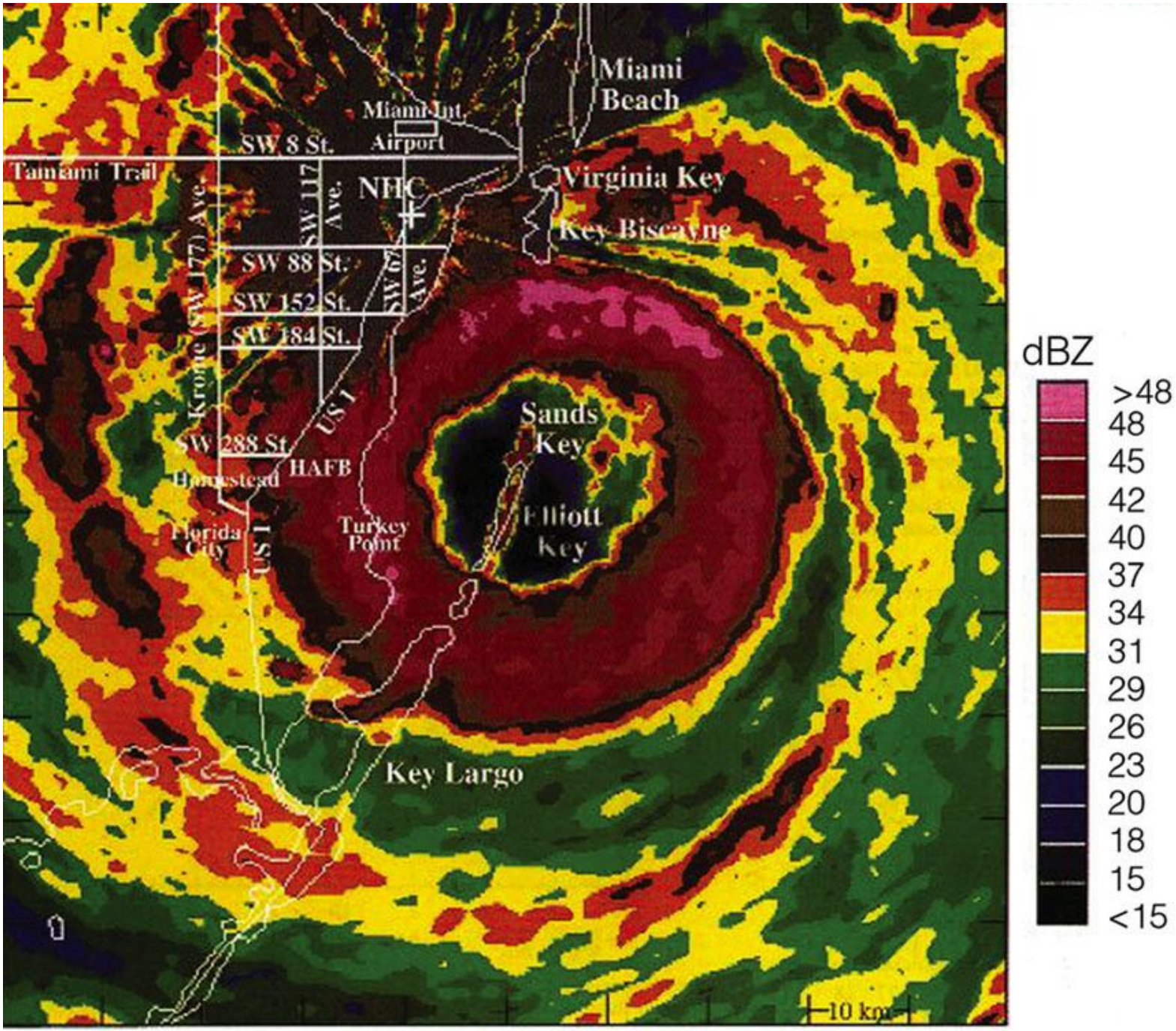
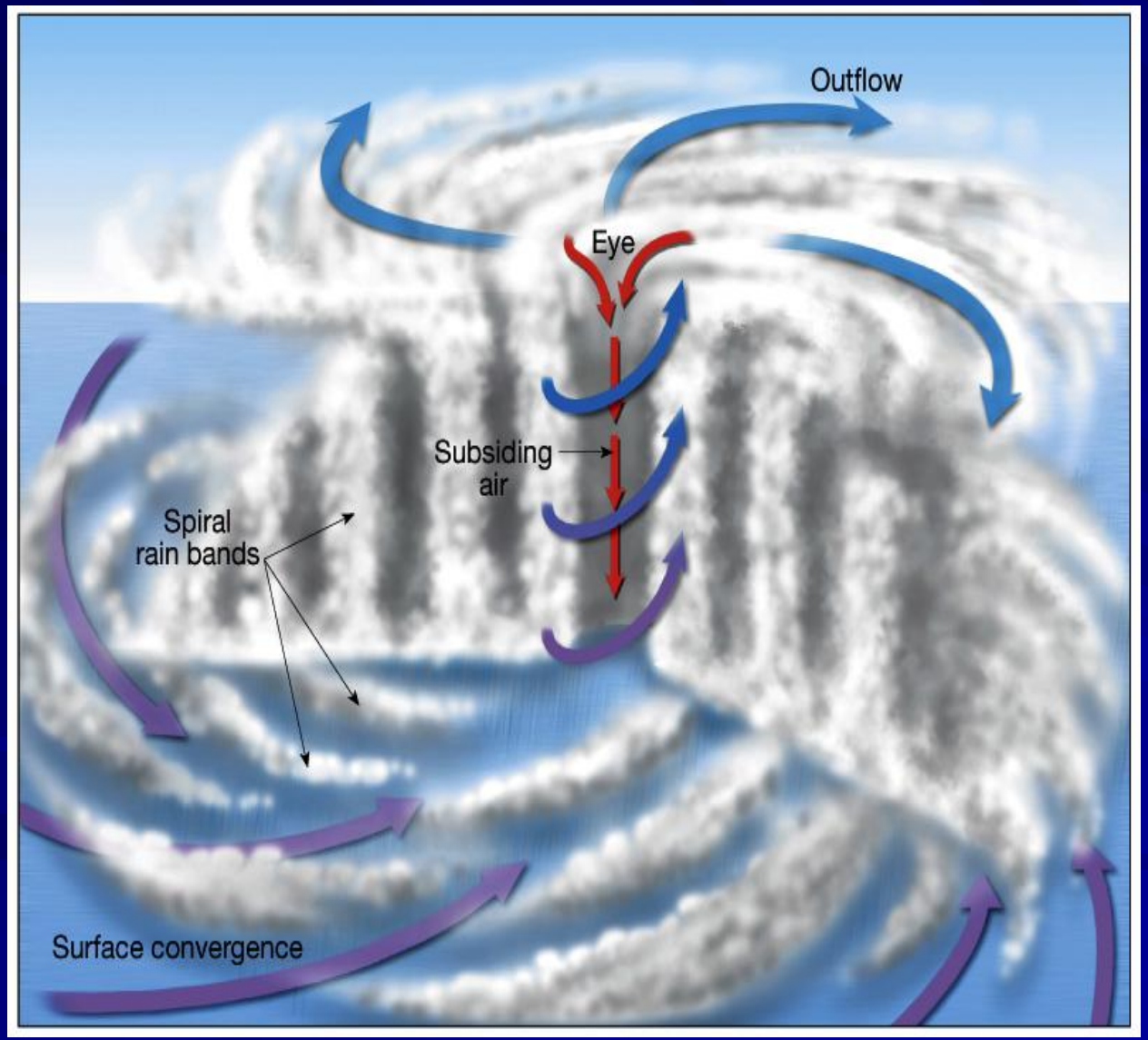
70
75
MAX DBZ: 55





Anatomy of a hurricane



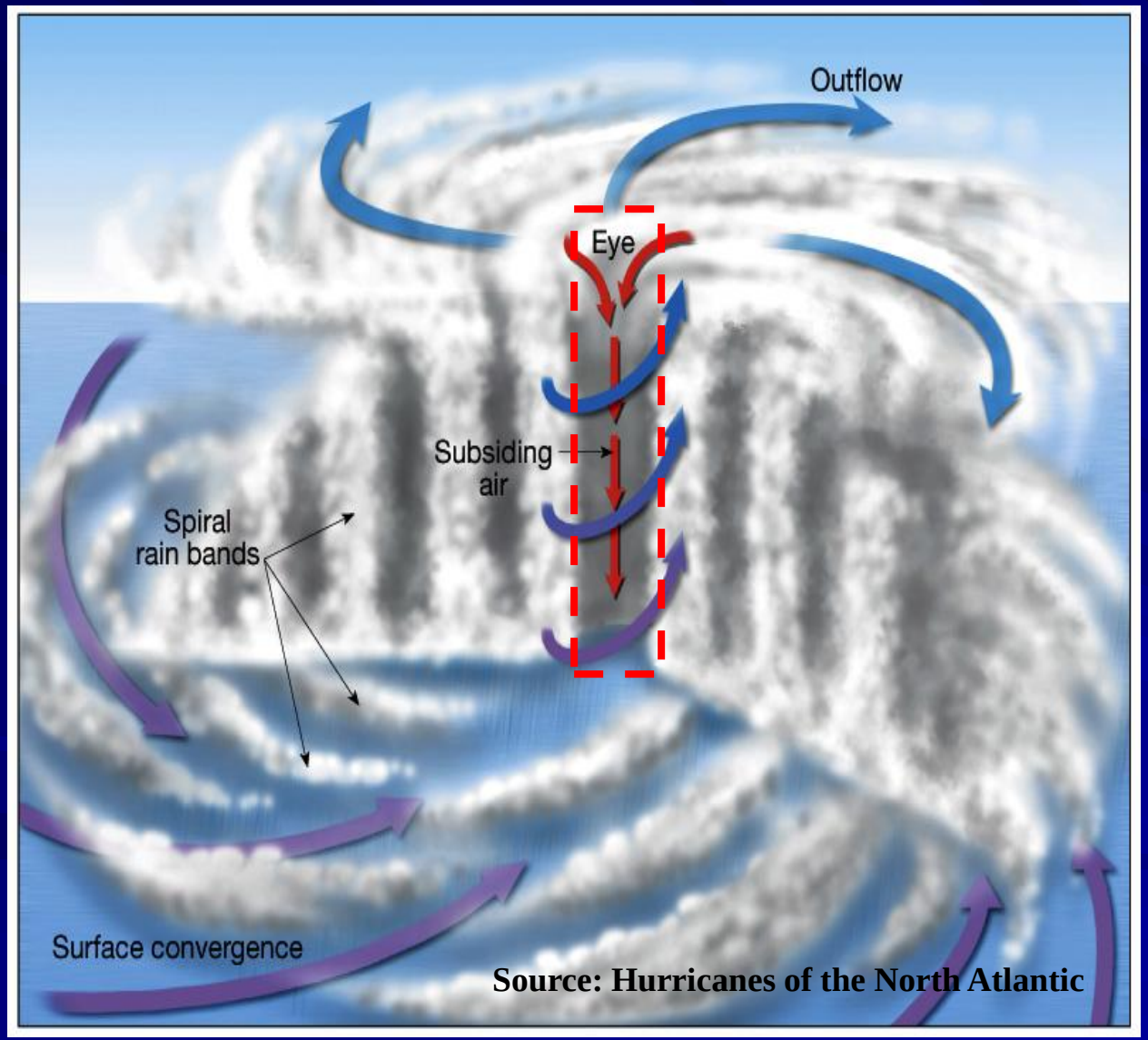
Cyclonic in the lower levels and anticyclonic in the upper levels.

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.

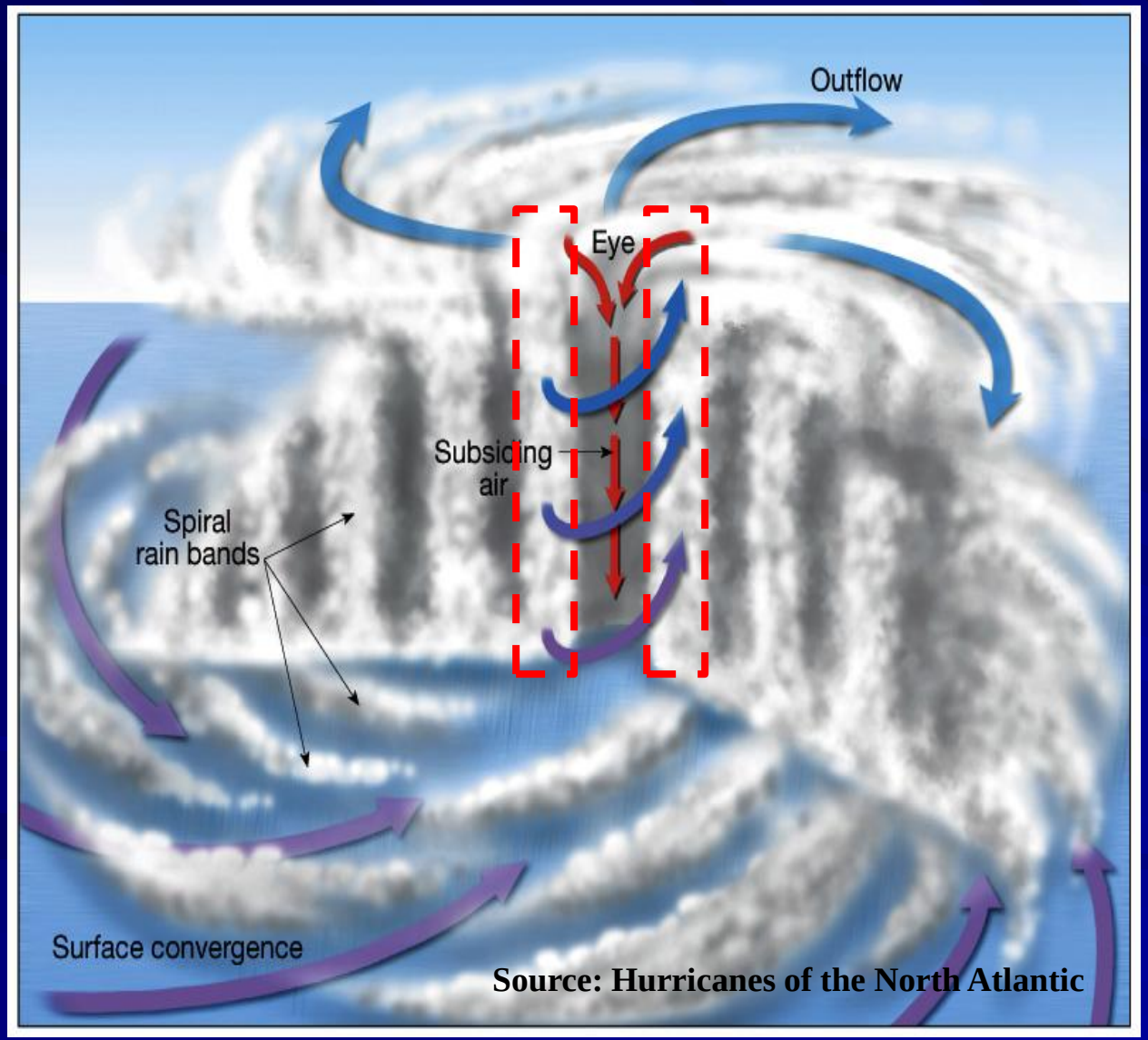
Winds are light.

Air aloft is warm and dry.

Surface air pressures are lowest.

Diameter: 16 to 70km

Anatomy of a hurricane



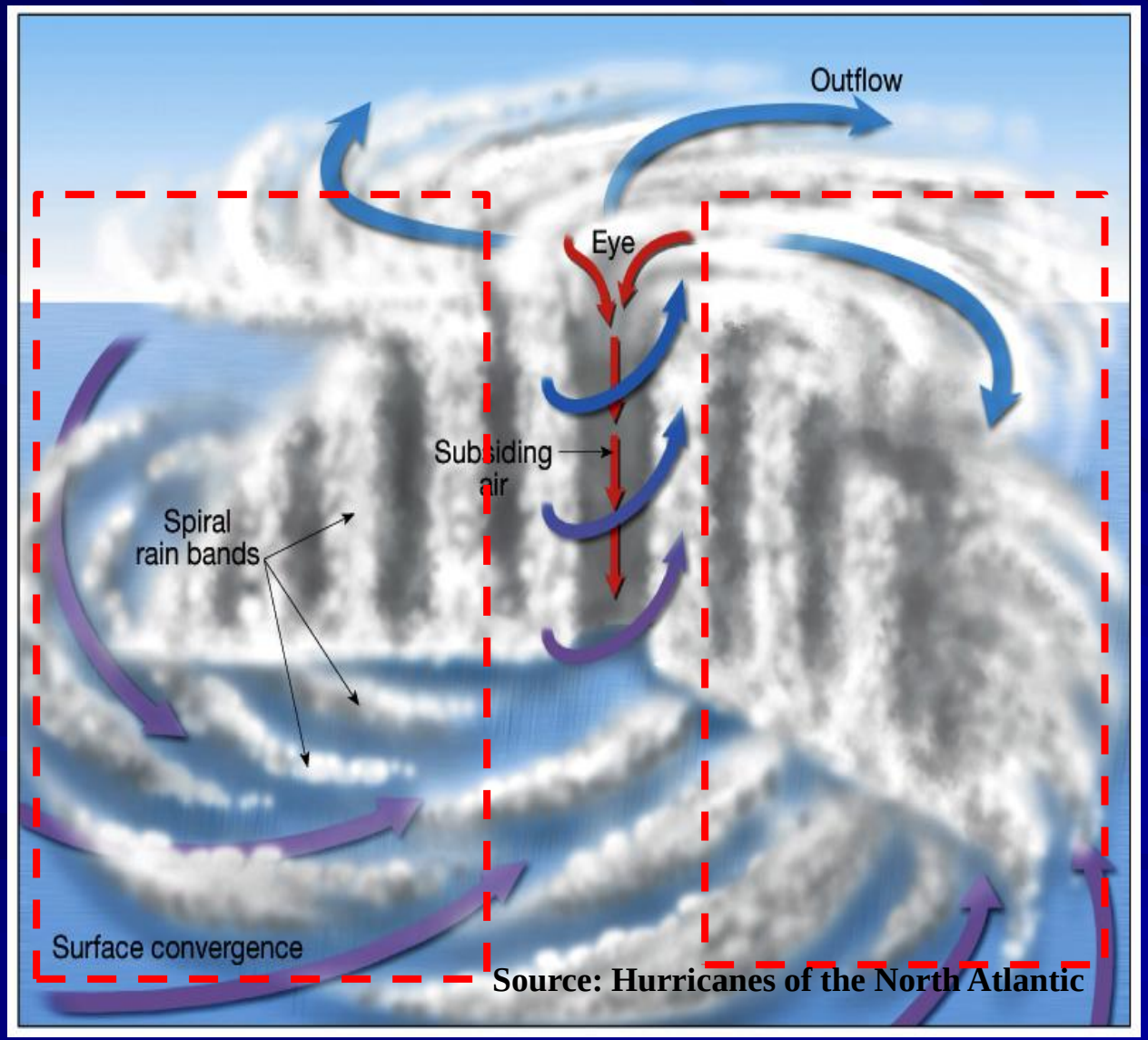
Eye wall:

Ring of cumulonimbus clouds around the eye.

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

"Hot towers" linked to rapid intensification

Anatomy of a hurricane



Source: Hurricanes of the North Atlantic

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.

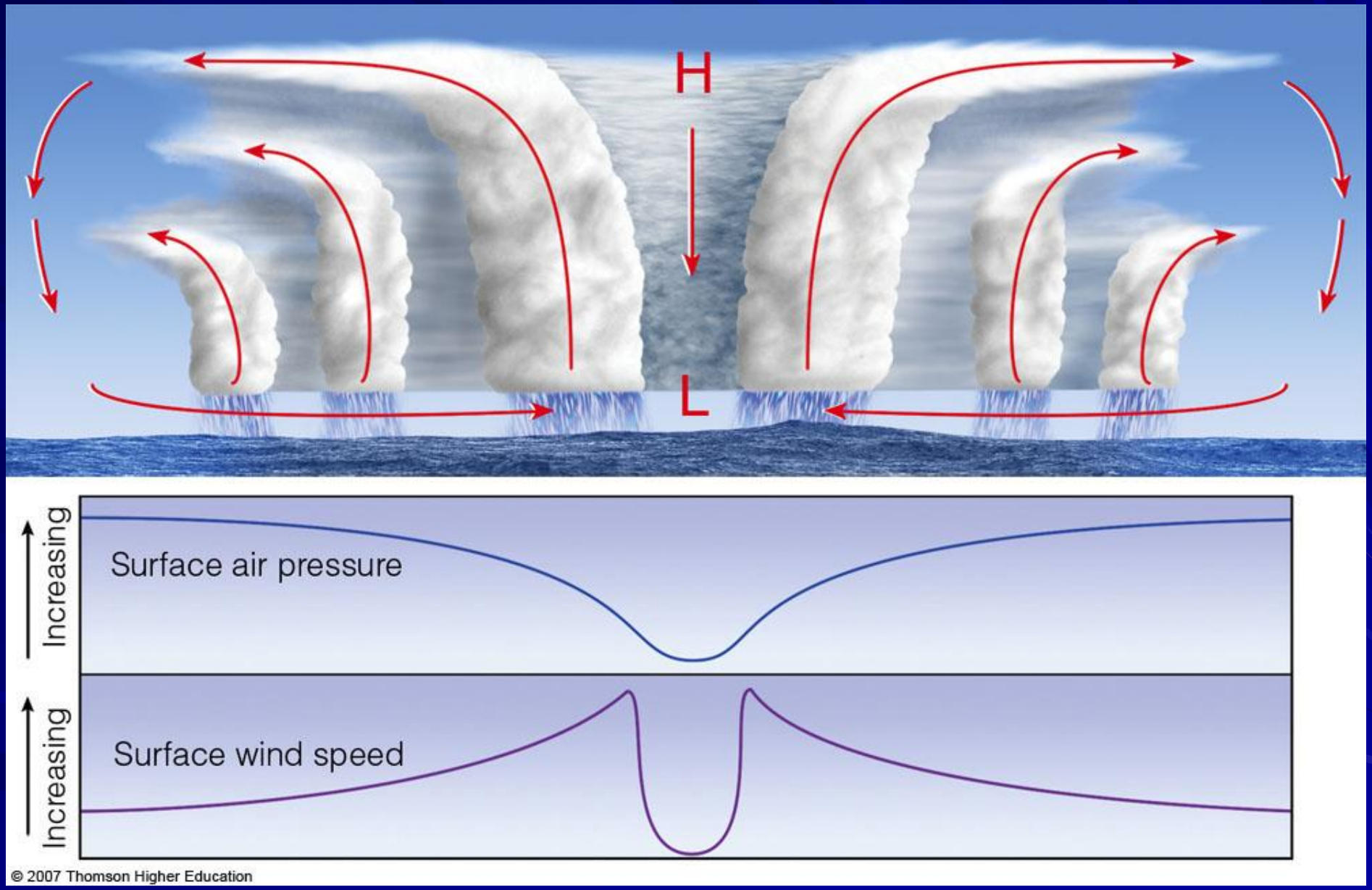
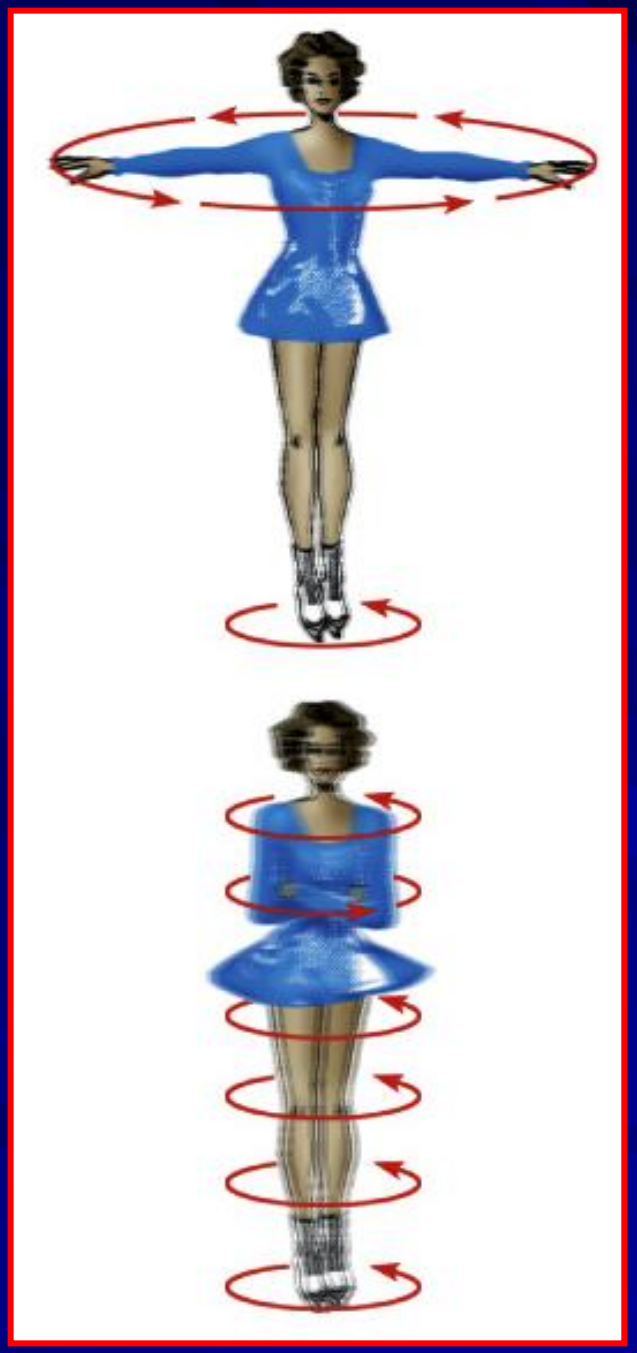

H
L
Increasing
Surface air pressure
Increasing
Surface wind speed
© 2007 Thomson Higher Education

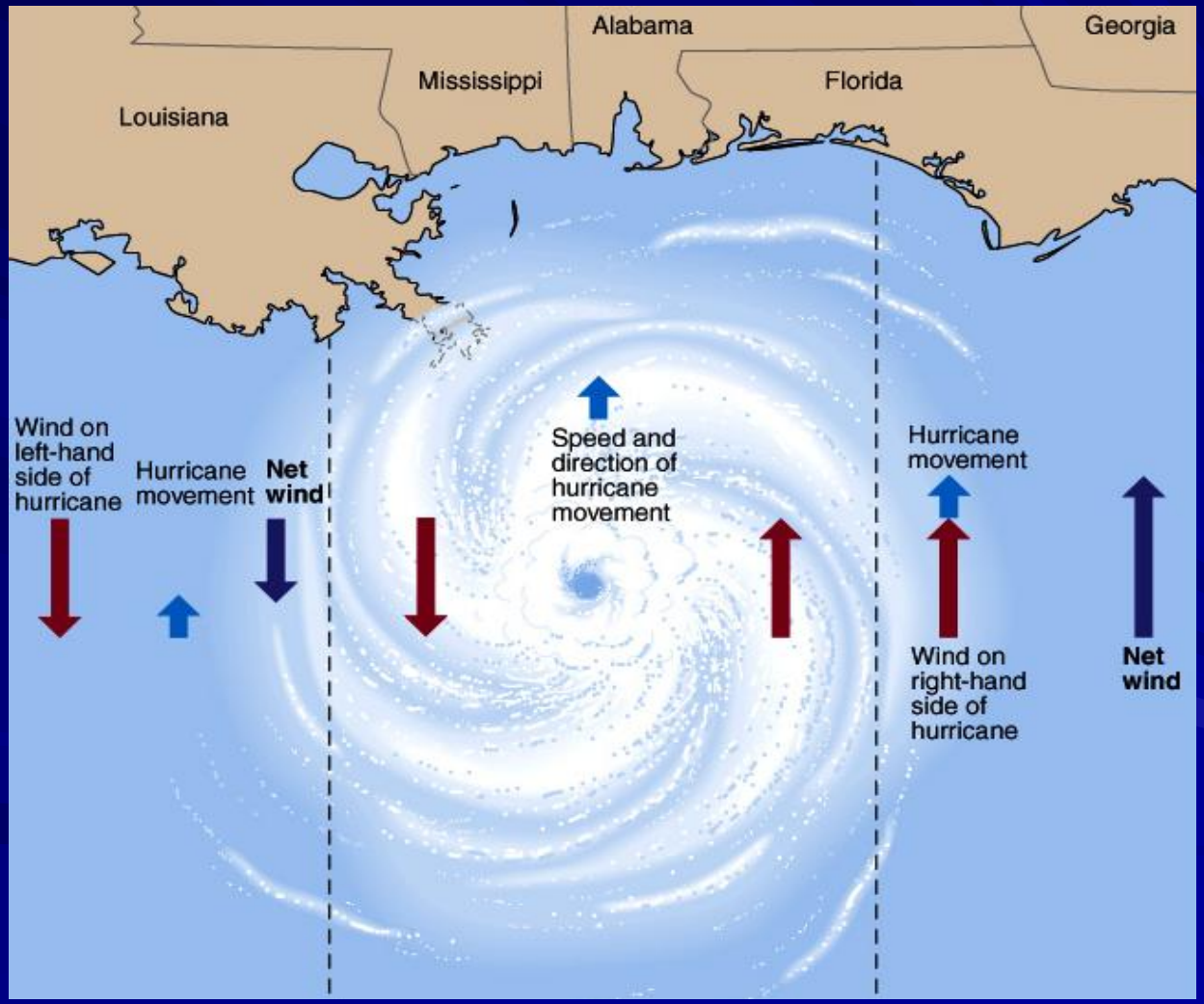
Fig. 11-8, p. 305


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."

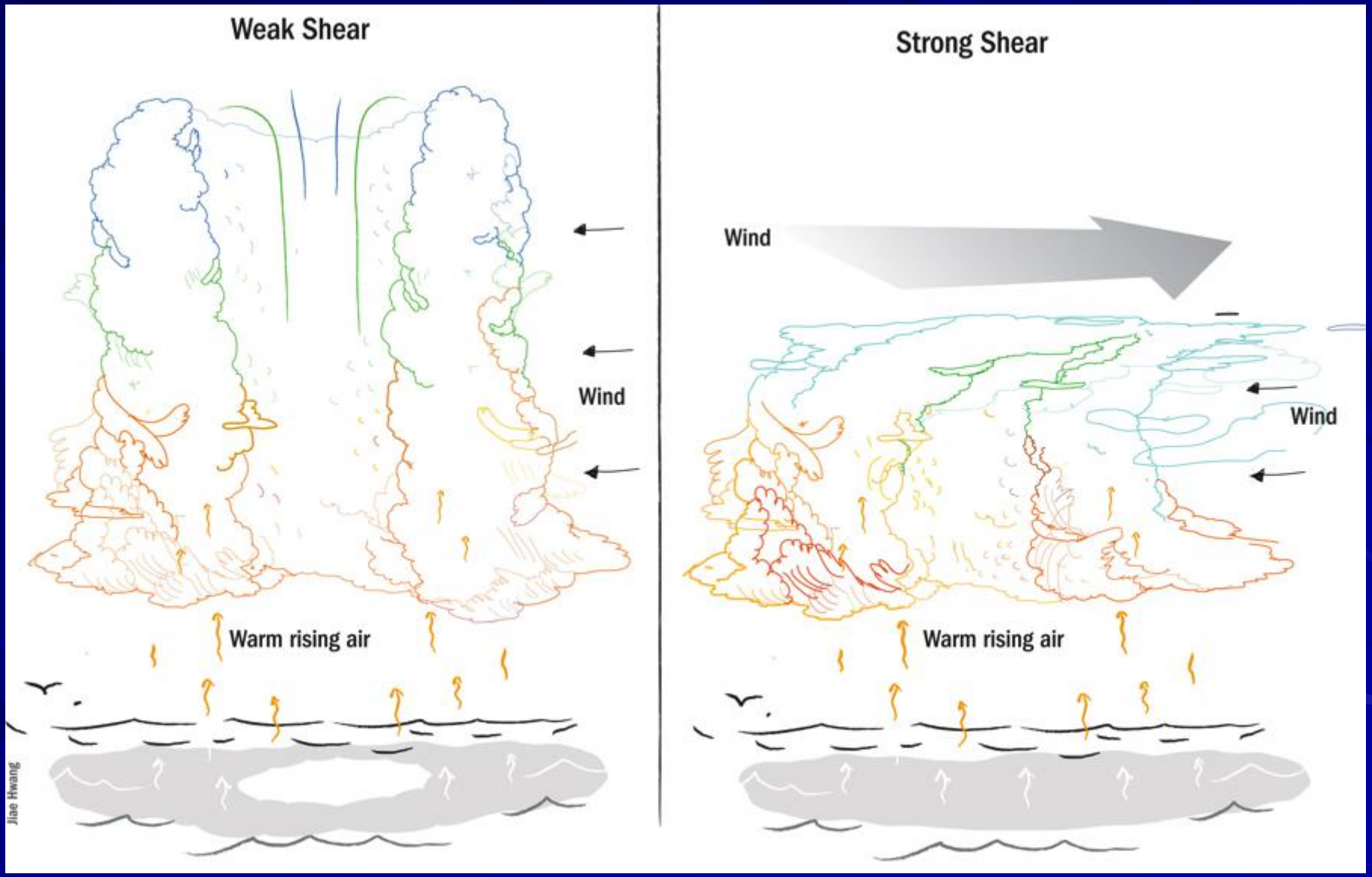
Table 11.2, p. 313

Genesis of a hurricane

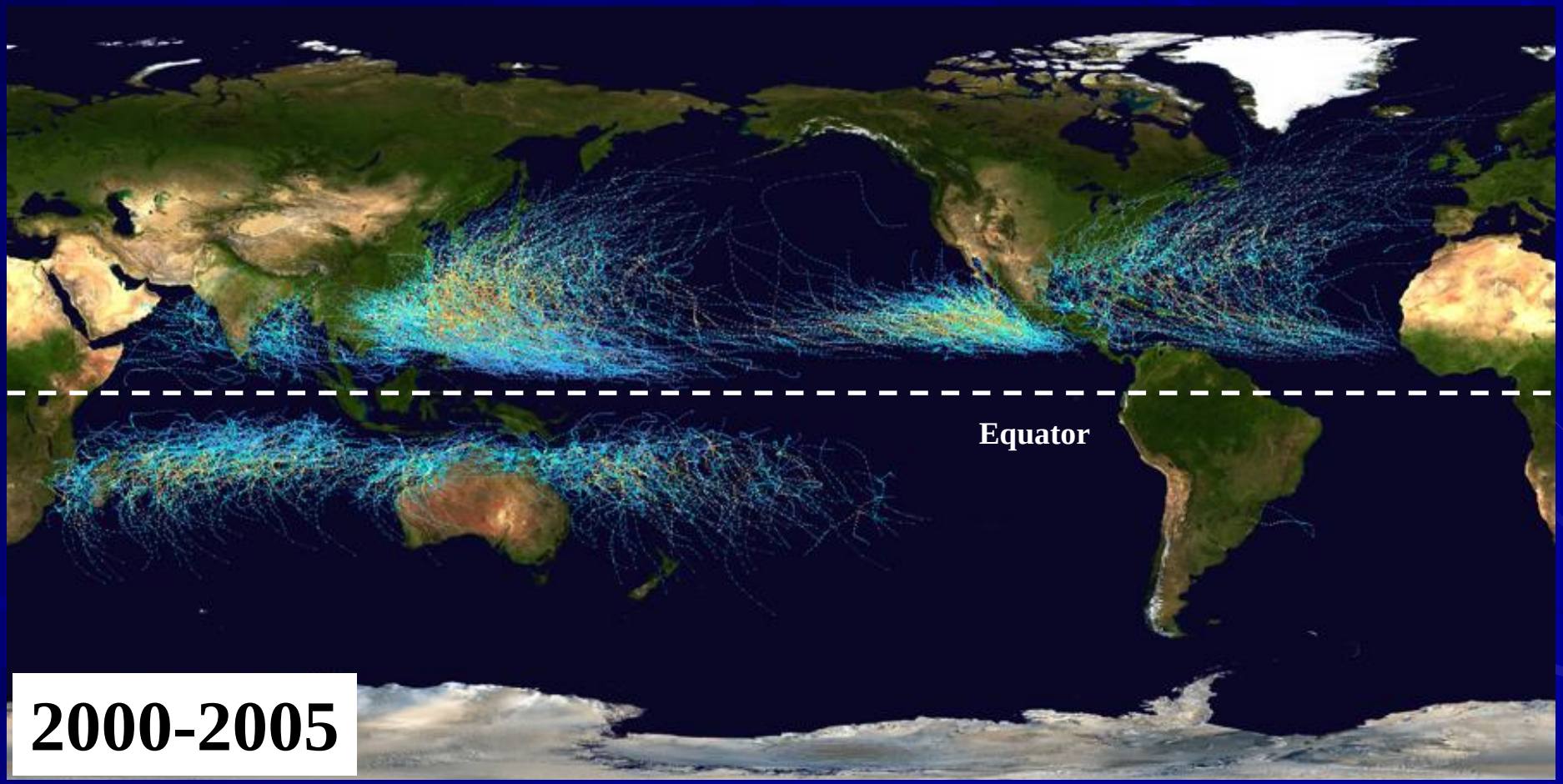
TC genesis typically requires the following:

- 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

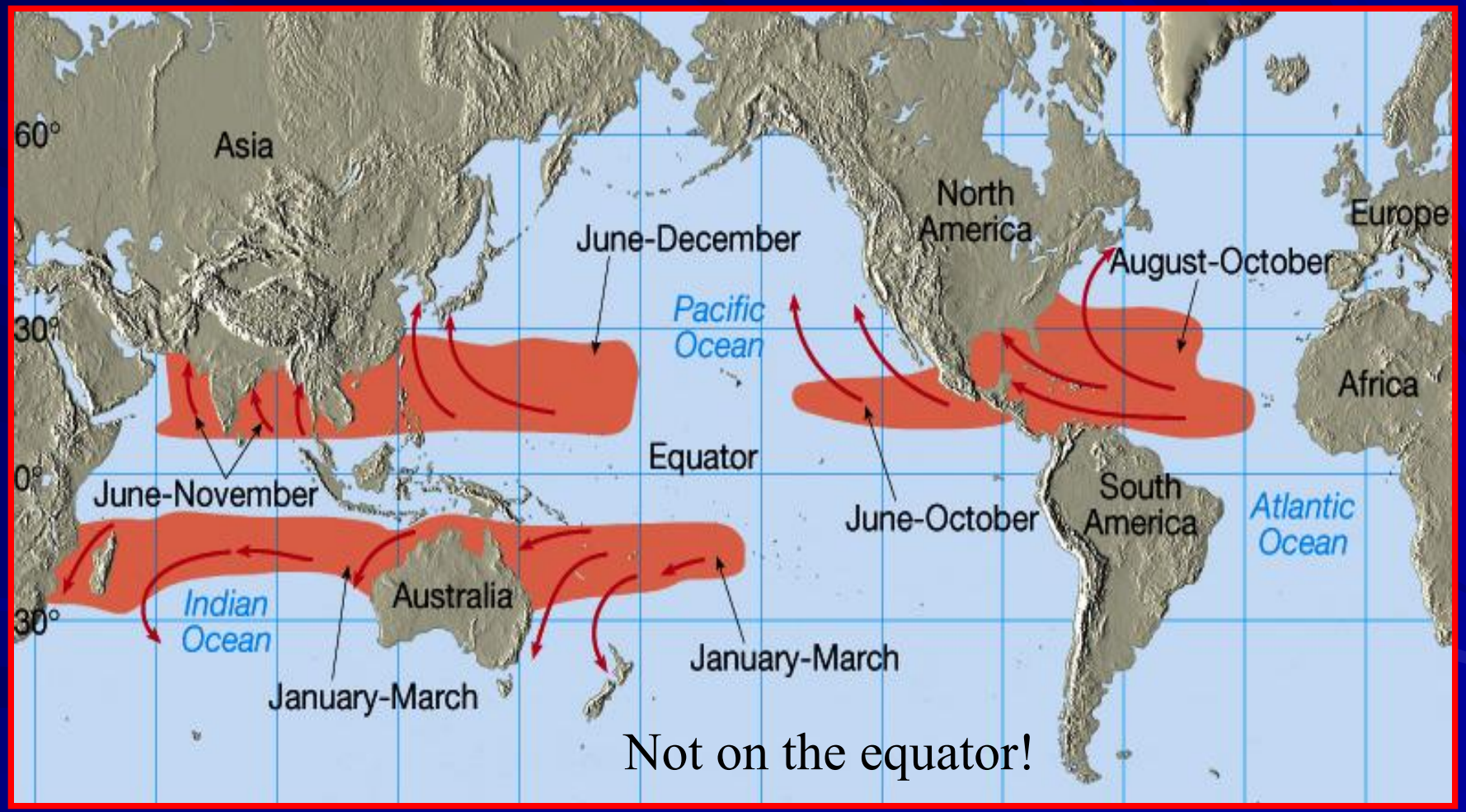


Tropical Cyclone Occurrences and Geographic Distribution

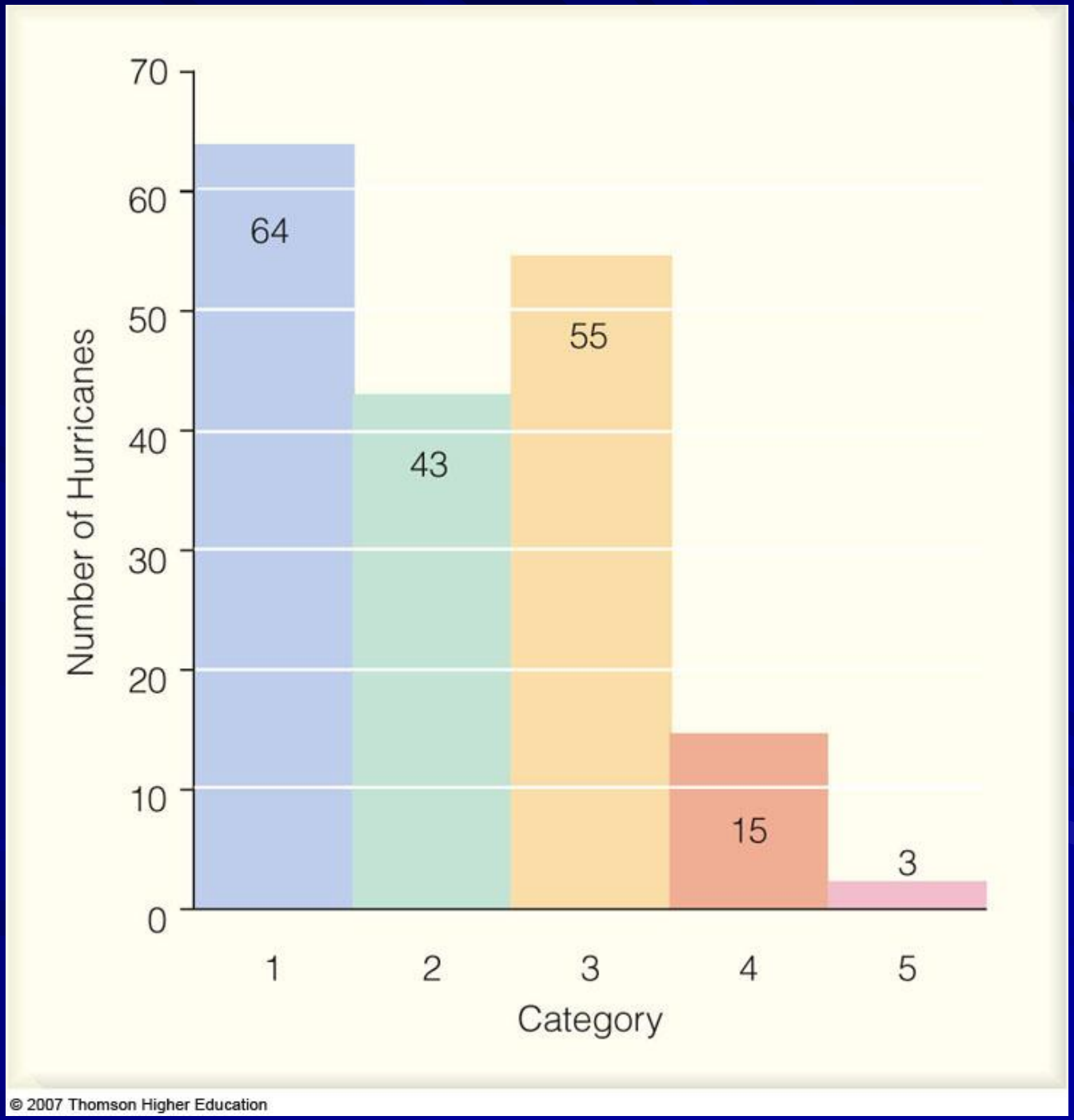


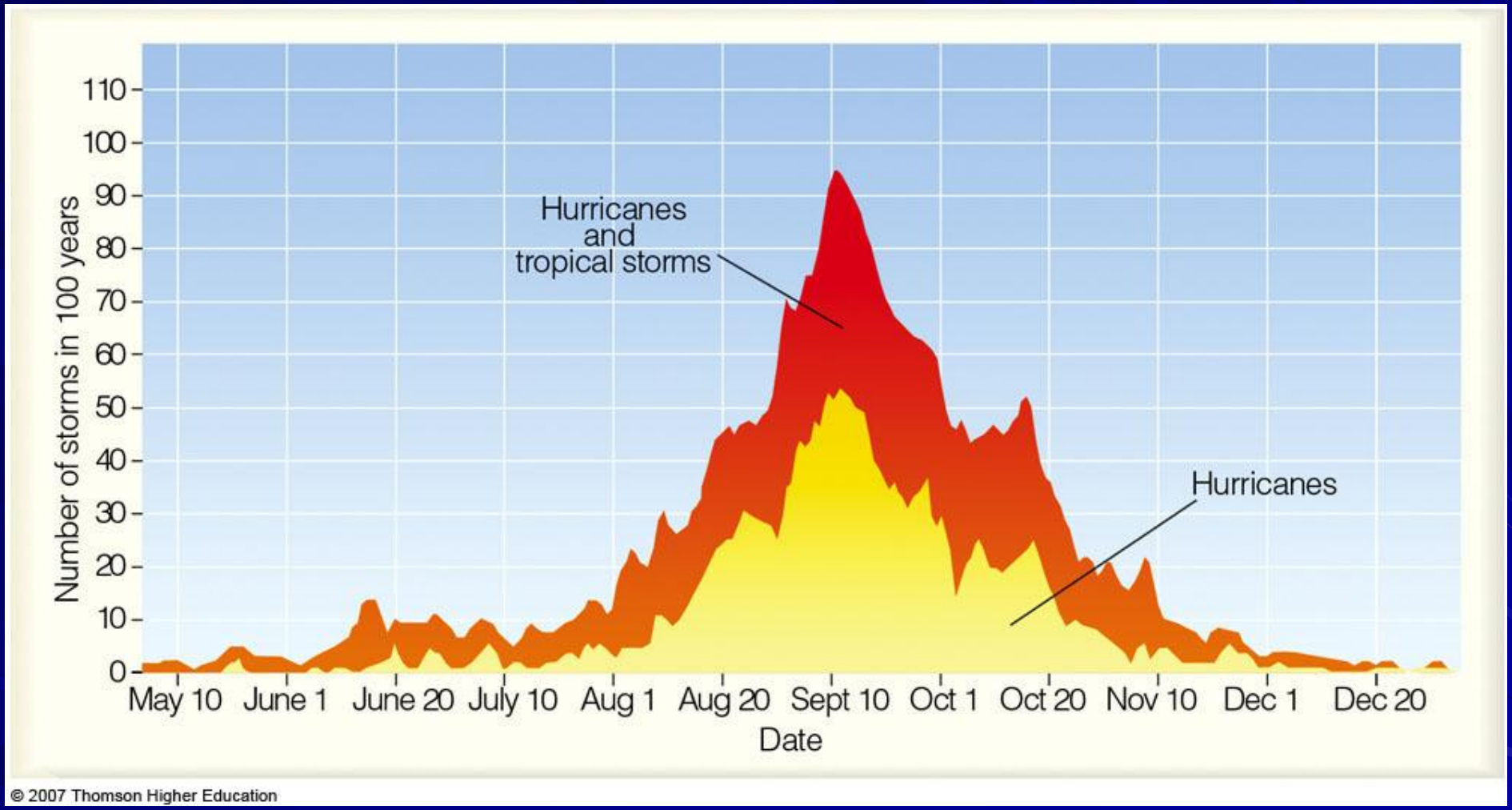
TC generated a few degrees off the Equator

Tropical Cyclone Occurrences and Geographic Distribution



TC generated when the surface water is warm



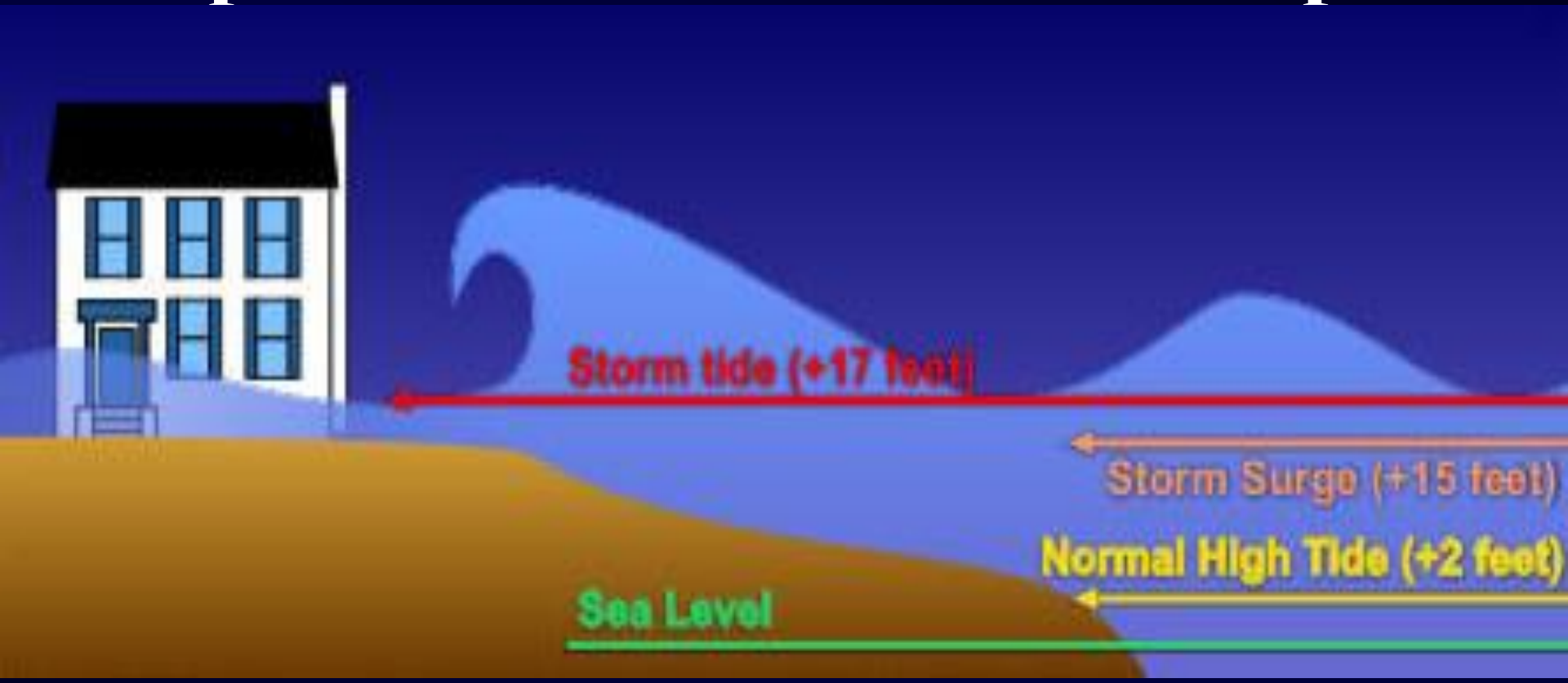


Atlantic Basin Hurricanes and Tropical Storms

Tropical Cyclone Hazards

- Storm Surge
- High Winds
- Inland Flooding
- Tornados

Tropical Storm/ Hurricane Impacts

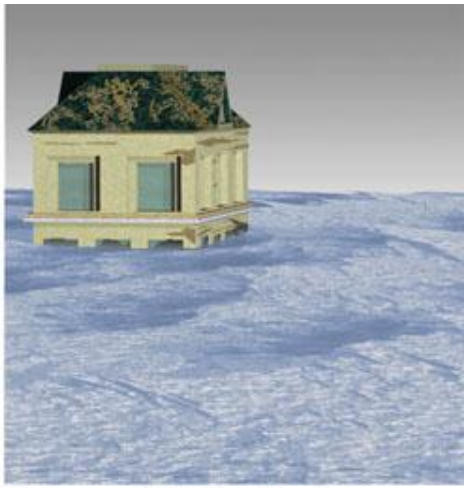


- Storm Surge - simply water that is pushed toward the shore by the force of the winds swirling around the storm.
- Advancing surge combines with normal tides to create the hurricane storm tide - can increase the average water level 15 feet or more.

Normal high tide

Category 1 [4-foot rise]

Category 3 [12-foot rise]



Category 5 [20-foot rise]

(a) (b)

Before and after Hurricane Iva, Sept 2004, coastal Alabama

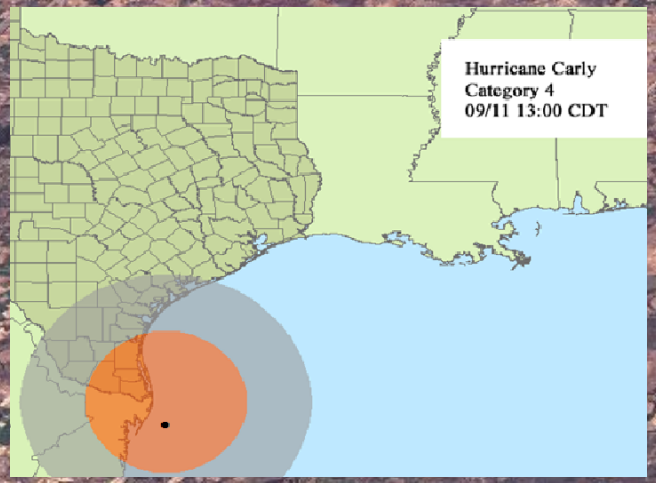
Before a hurricane …

After a hurricane.

Storm Surge Video

http://www.youtube.com/watch?v=nV6Qtrt2CNQ&feature=fvsr

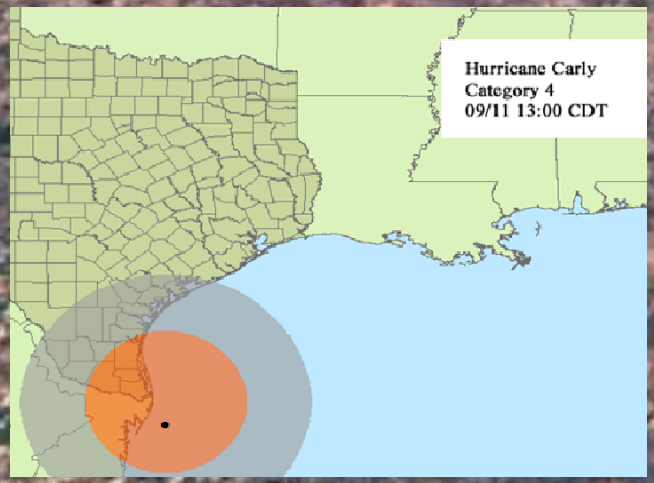
http://www.youtube.com/watch?v=l9vDSWugz08



Brownsville

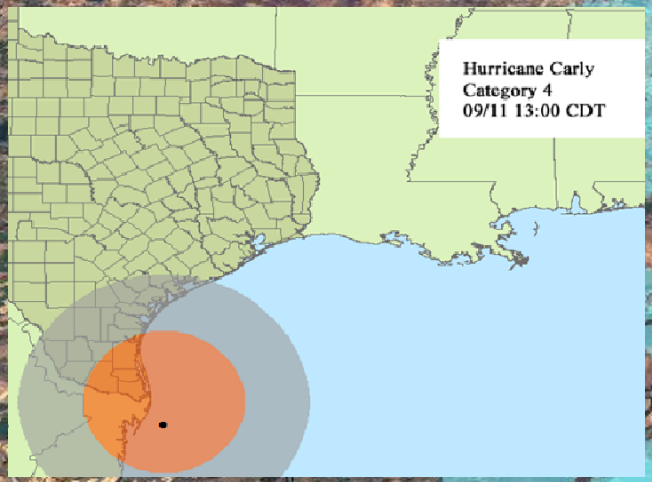
Source: UT Space Science Center

Brownsville / South Padre I.
Mean Sea Level



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

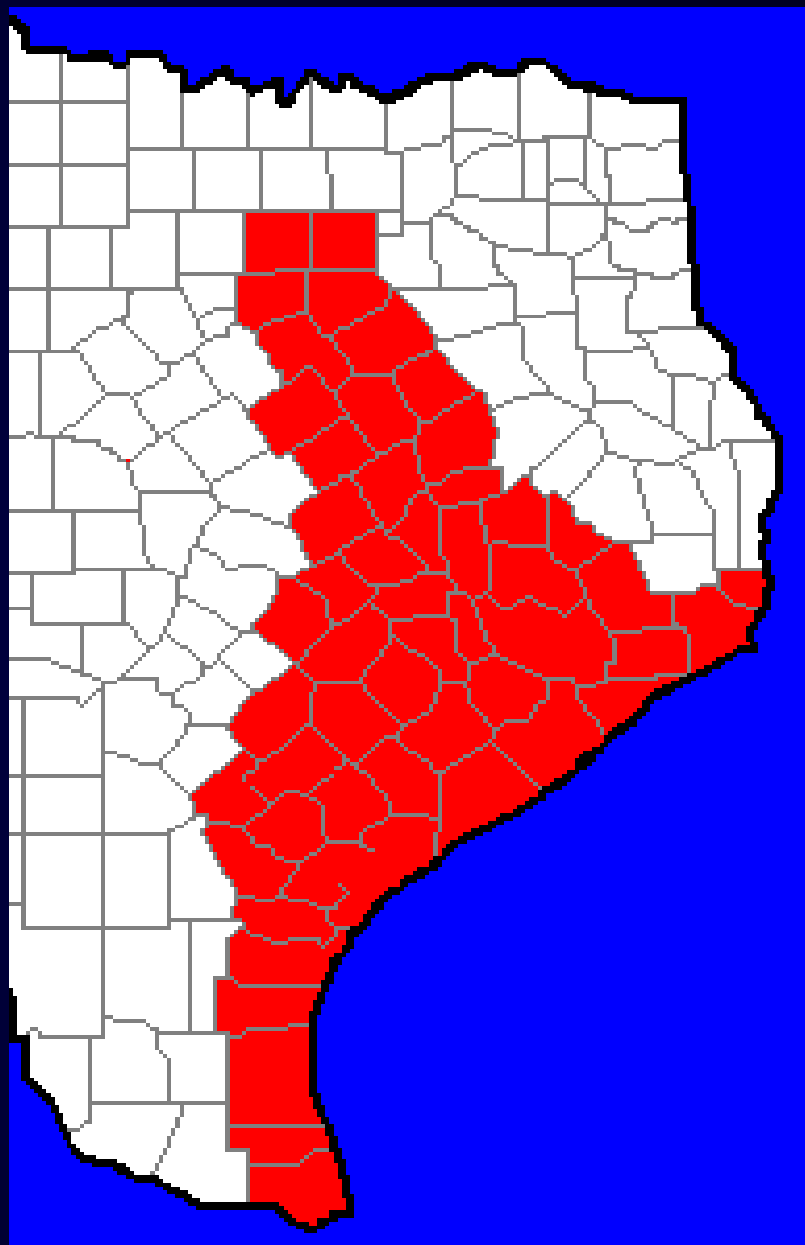
Source: UT Space Science Center

Tropical Storm/ Hurricane Impacts

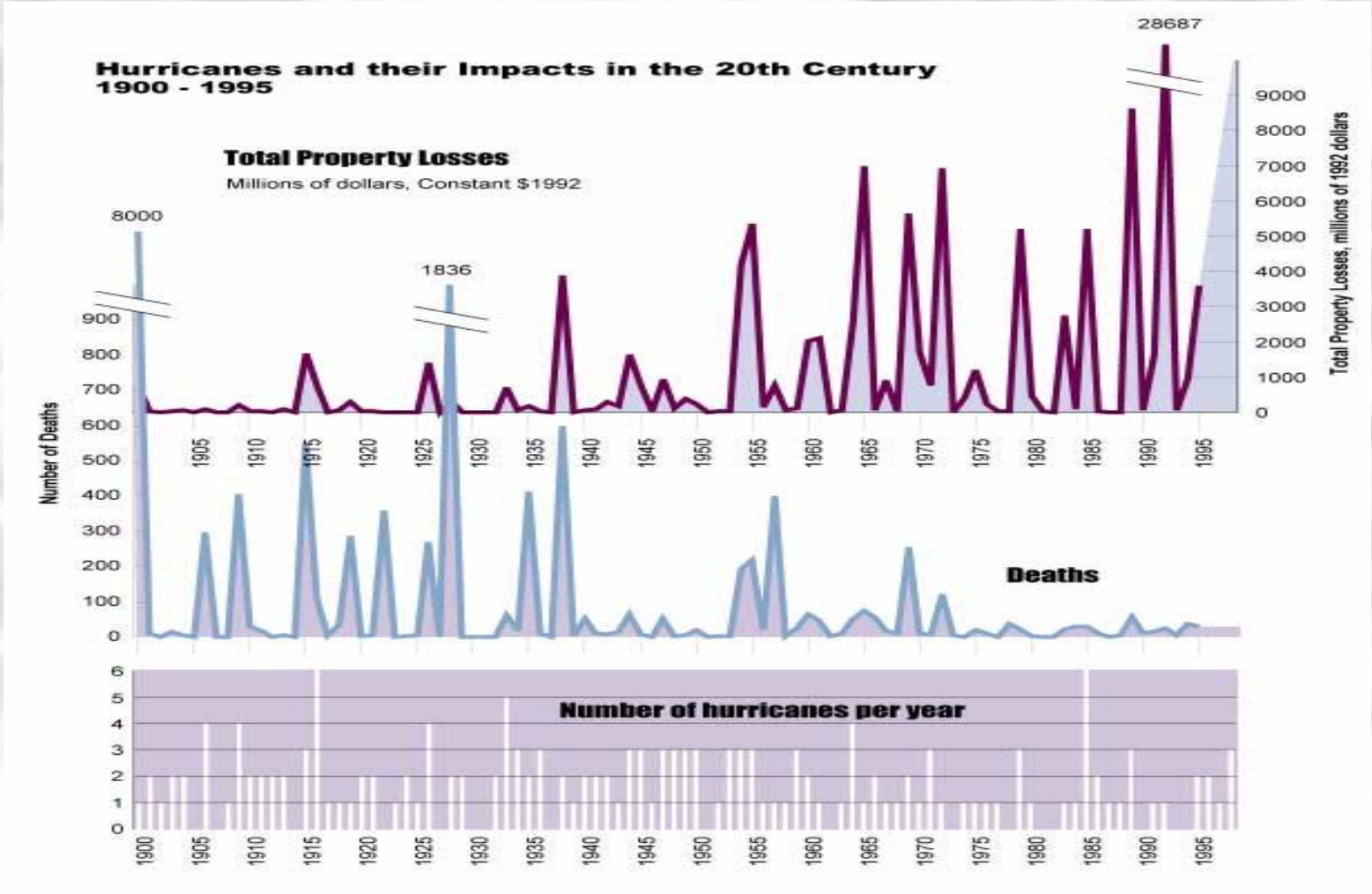
Heavy rains create **inland flooding** that results in fatalities and/or loss of property. An example is Hurricane Carla **where i**n Jefferson County, 180 miles from the land falling storm, $17.5 million in damage occurred, with $14 million of it water damage. Rain totaled up to 19". Three to four feet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



www.usgcrp.gov/.../
overviewChangingNation.htm

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

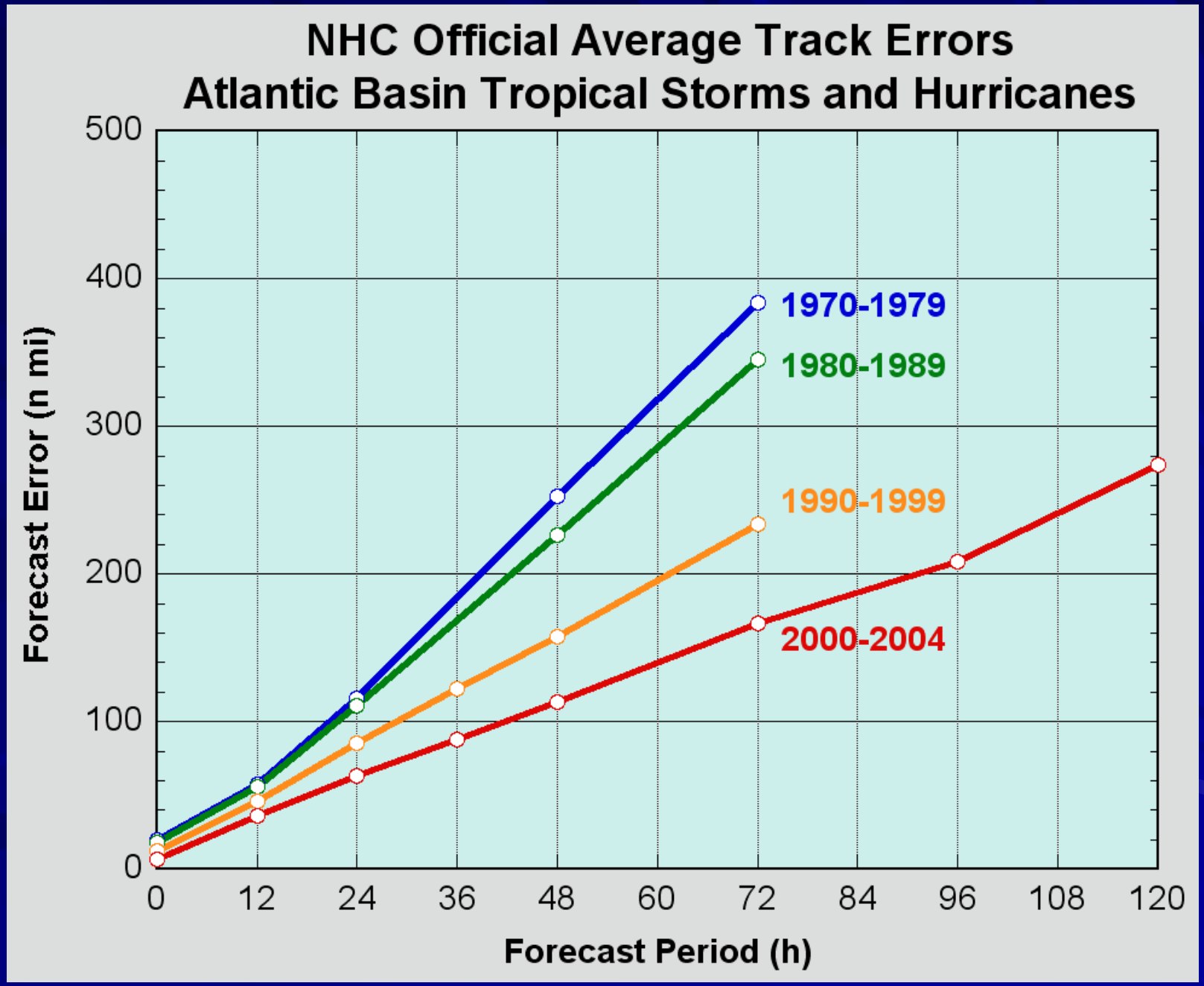
Observations are often inadequate for forecast needs

- 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

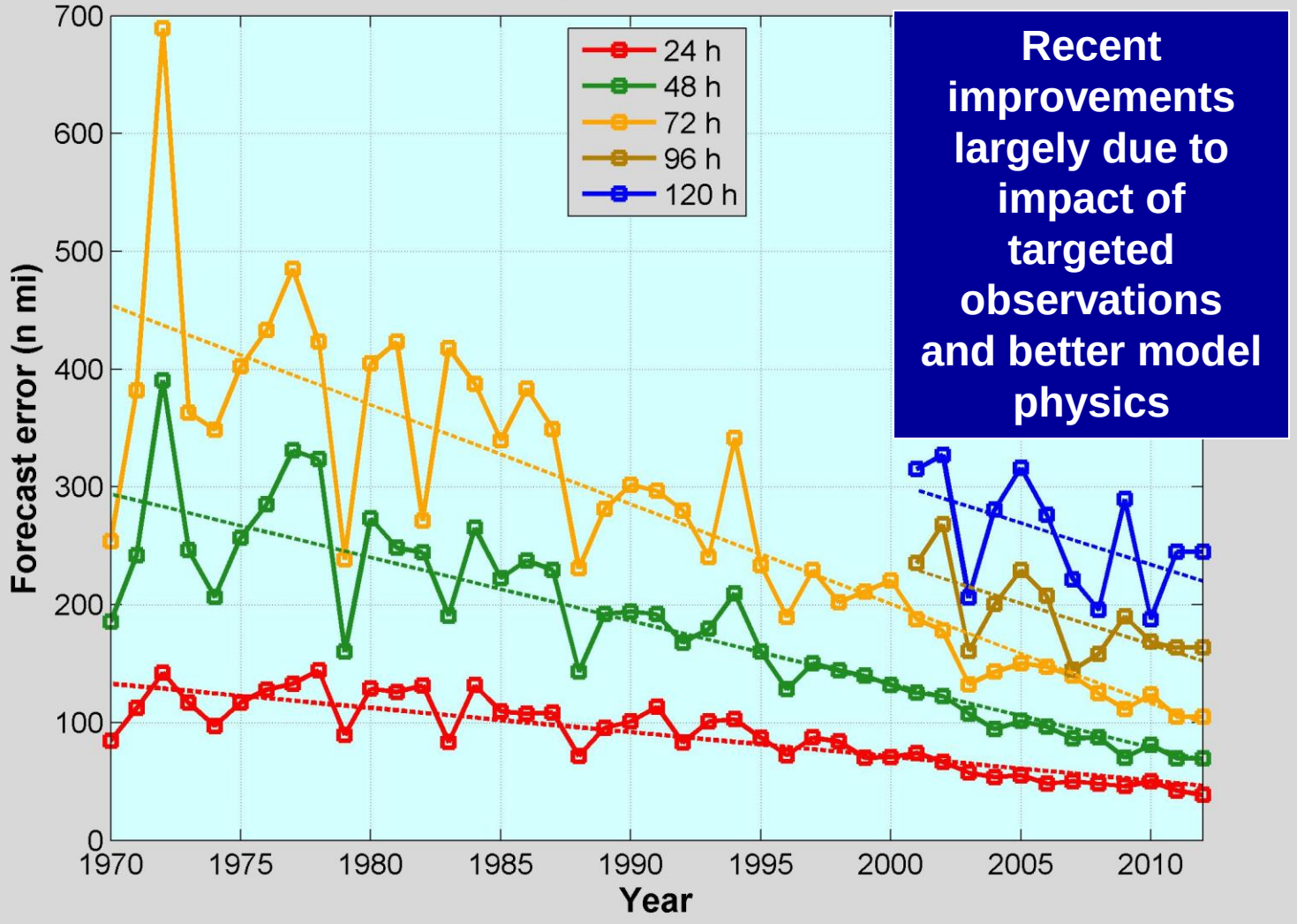
Models limited by resolution & processing speed

- 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

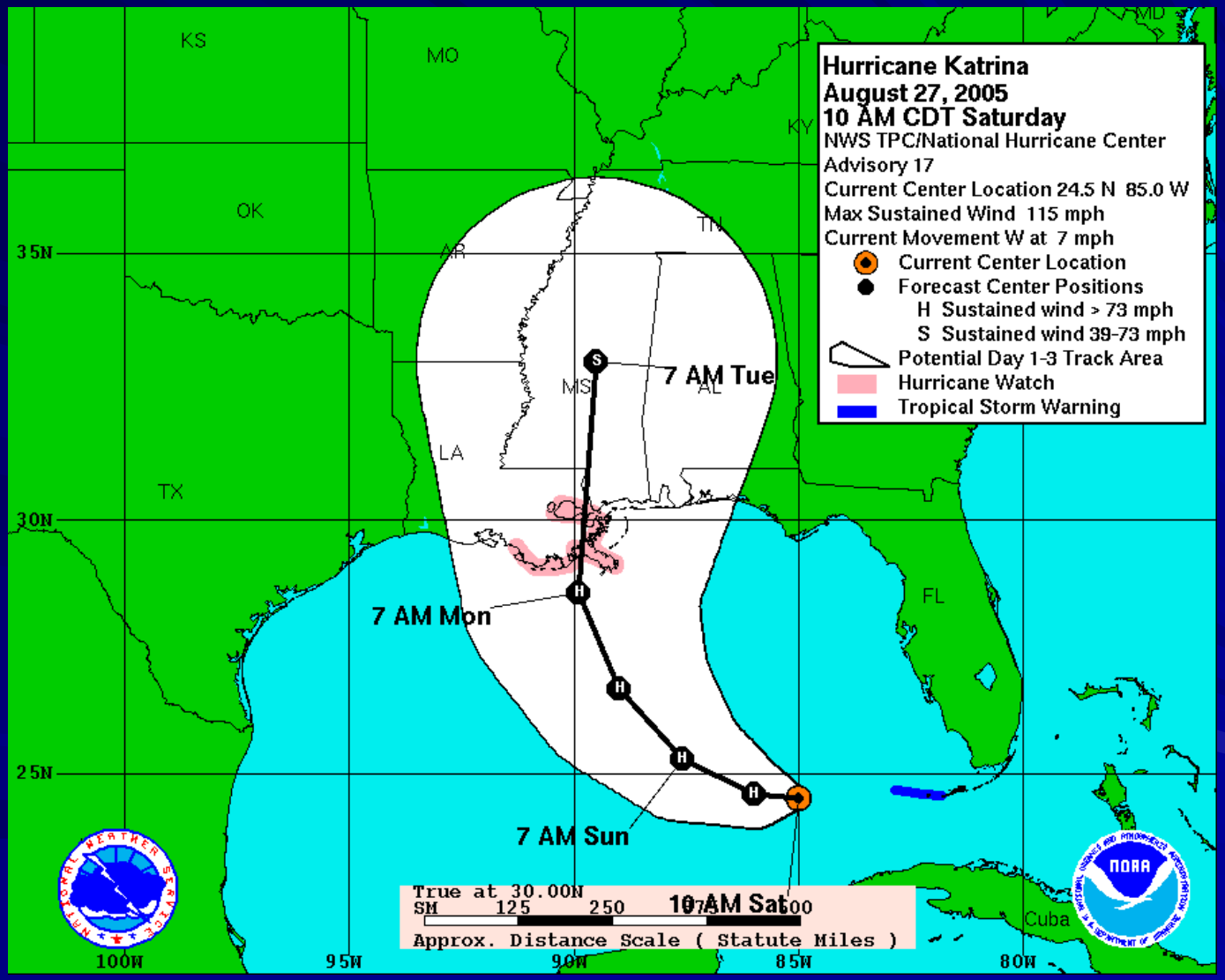

NHC Official Average Track Errors
Atlantic Basin Tropical Storms and Hurricanes
Forecast Error (n mi)
500
400
300
200
100
0
0
12
24
36
48
60
72
84
96
108
120
Forecast Period (h)
1970-1979
1980-1989
1990-1999
2000-2004

TC Forecasting: Track

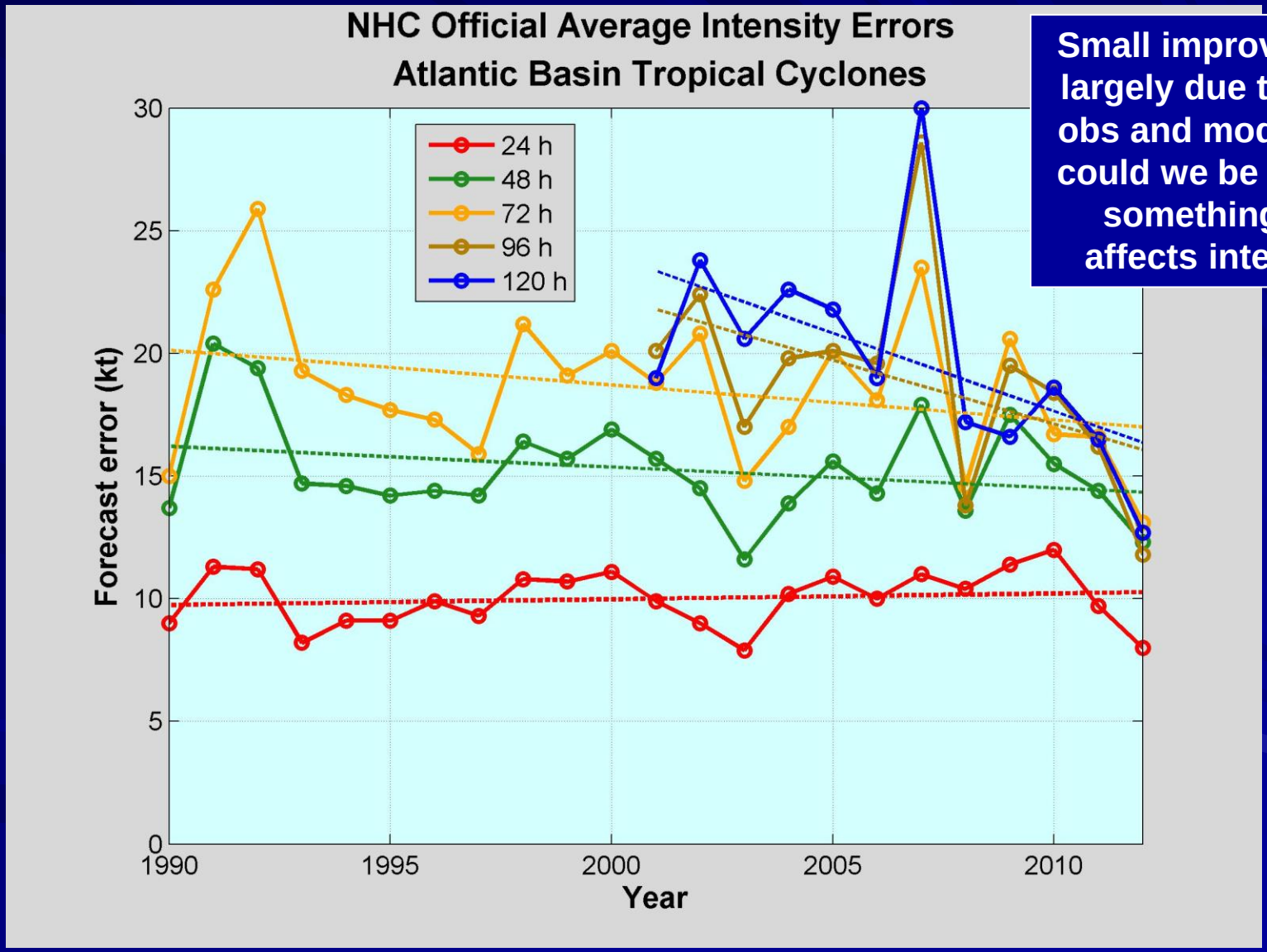


Recent improvements largely due to impact of targeted observations and better model physics

Katrina
48-h Before: Virtually a Perfect Forecast of Track



TC Forecasting: Intensity

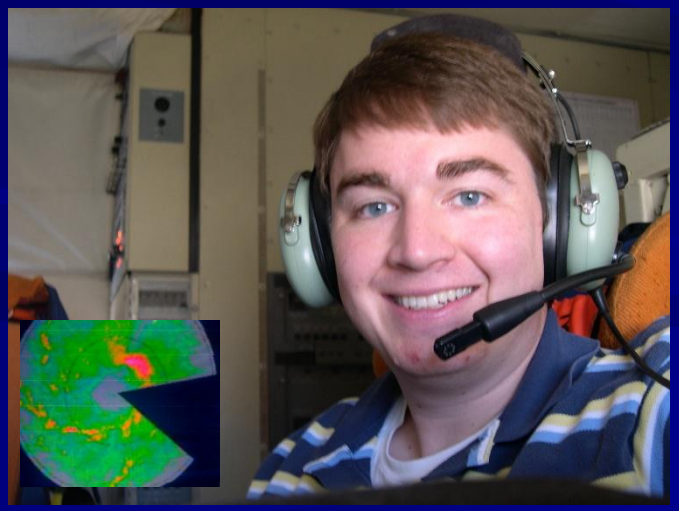


Small improvements largely due to better obs and models, but could we be missing something that affects intensity?

NOAA P3 "Hurricane Hunter" Aircraft

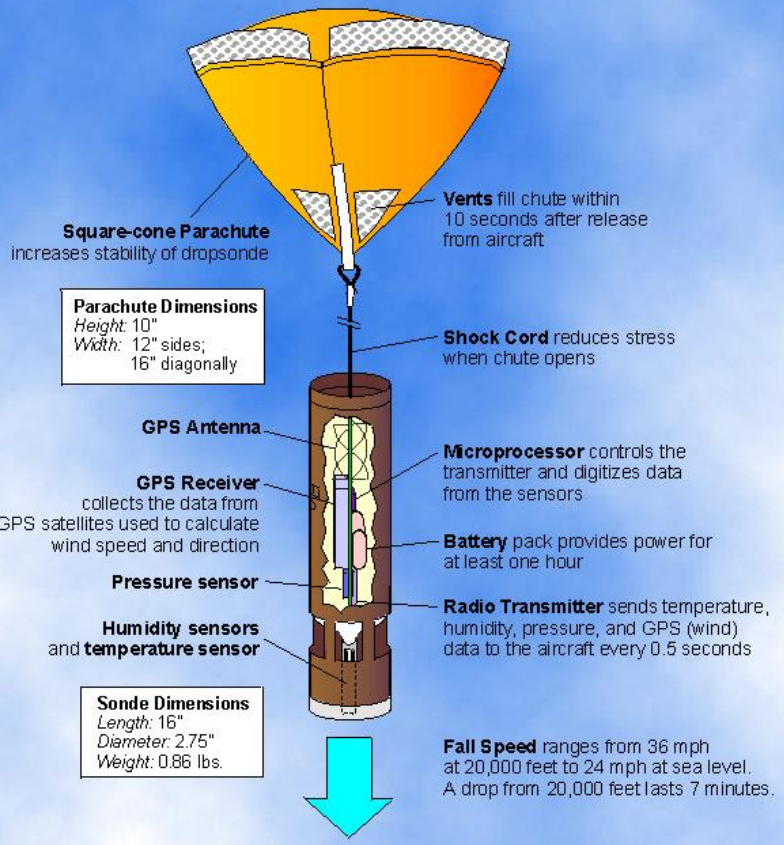
https://www.youtube.com/watch?v=AMV6758nosU

LAPI members chasing hurricanes (~ 2010-2012)…



NCAR GPS Dropsonde

the definitive atmospheric profiling tool



Square-cone Parachute increases stability of dropsonde

Parachute Dimensions
Height: 10"
Width: 12" sides;
16" diagonally

Vents fill chute within 10 seconds after release from aircraft

Shock Cord reduces stress when chute opens

GPS Antenna

GPS Receiver collects the data from GPS satellites used to calculate wind speed and direction

Pressure sensor

Humidity sensors and **temperature sensor**

Microprocessor controls the transmitter and digitizes data from the sensors

Battery pack provides power for at least one hour

Radio Transmitter sends temperature, humidity, pressure, and GPS (wind) data to the aircraft every 0.5 seconds

Sonde Dimensions
Length: 16"
Diameter: 2.75"
Weight: 0.86 lbs.

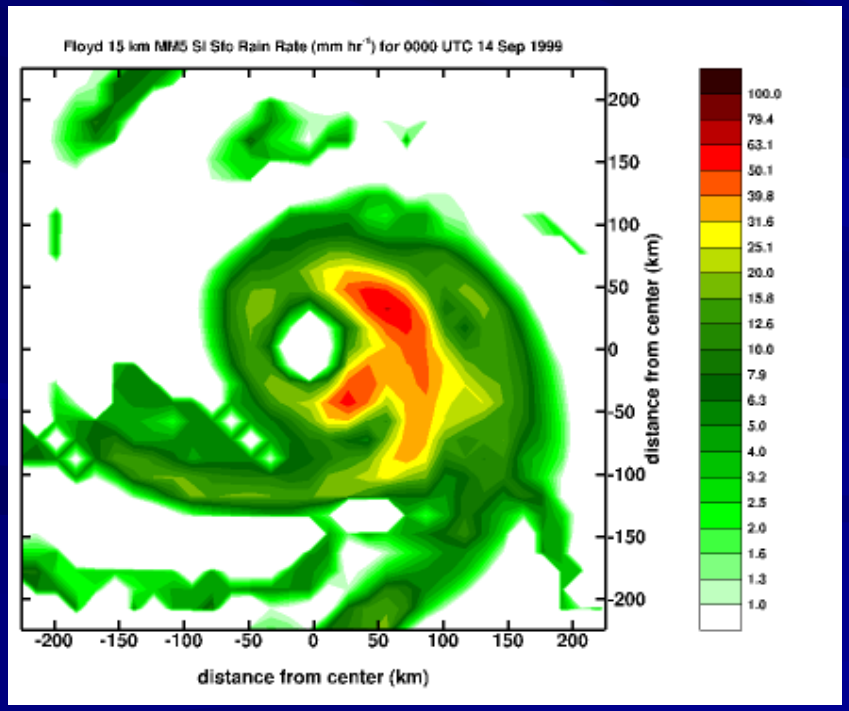
Fall Speed ranges from 36 mph at 20,000 feet to 24 mph at sea level. A drop from 20,000 feet lasts 7 minutes.

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

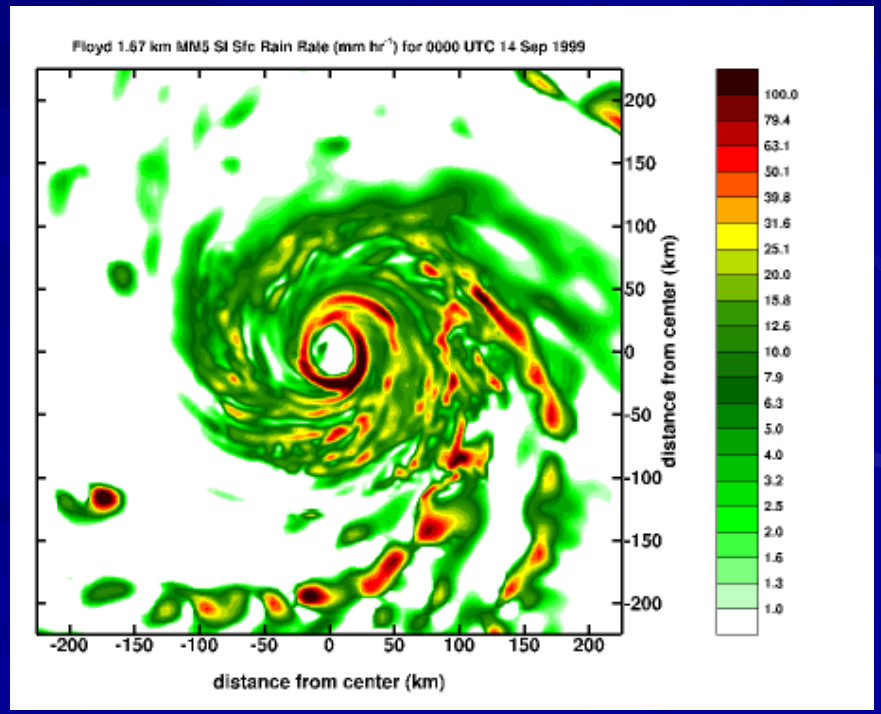
Substantial Promise

- 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