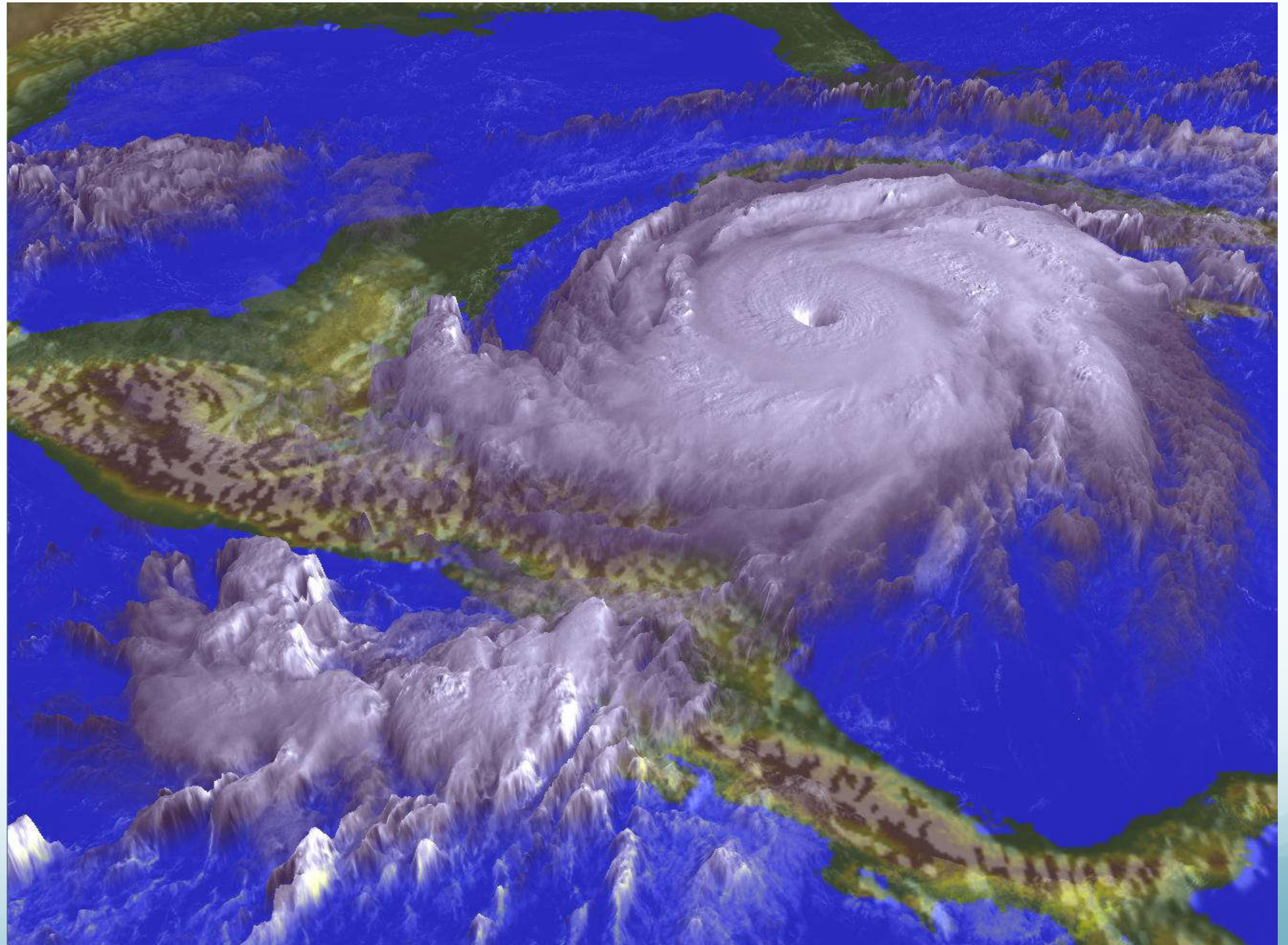


ATM S 103

Hurricanes and Thunderstorms

Their Science and Impacts



Hurricane Mitch

The Final

- 8:30-10:20 AM Thursday June 13th
- **Bring a scantron form**
- Material covered:
 - 50% Homework 7-9; Readings weeks 7-10; associated lecture slides (May 17 to end of class).
 - 50% earlier material
- 45 questions
- Closed book, notes, electronics.
- CLUE session: tomorrow (June 6), 6:30-8:00pm (MGH 231)

W Which is NOT true about Hurricane Sandy?

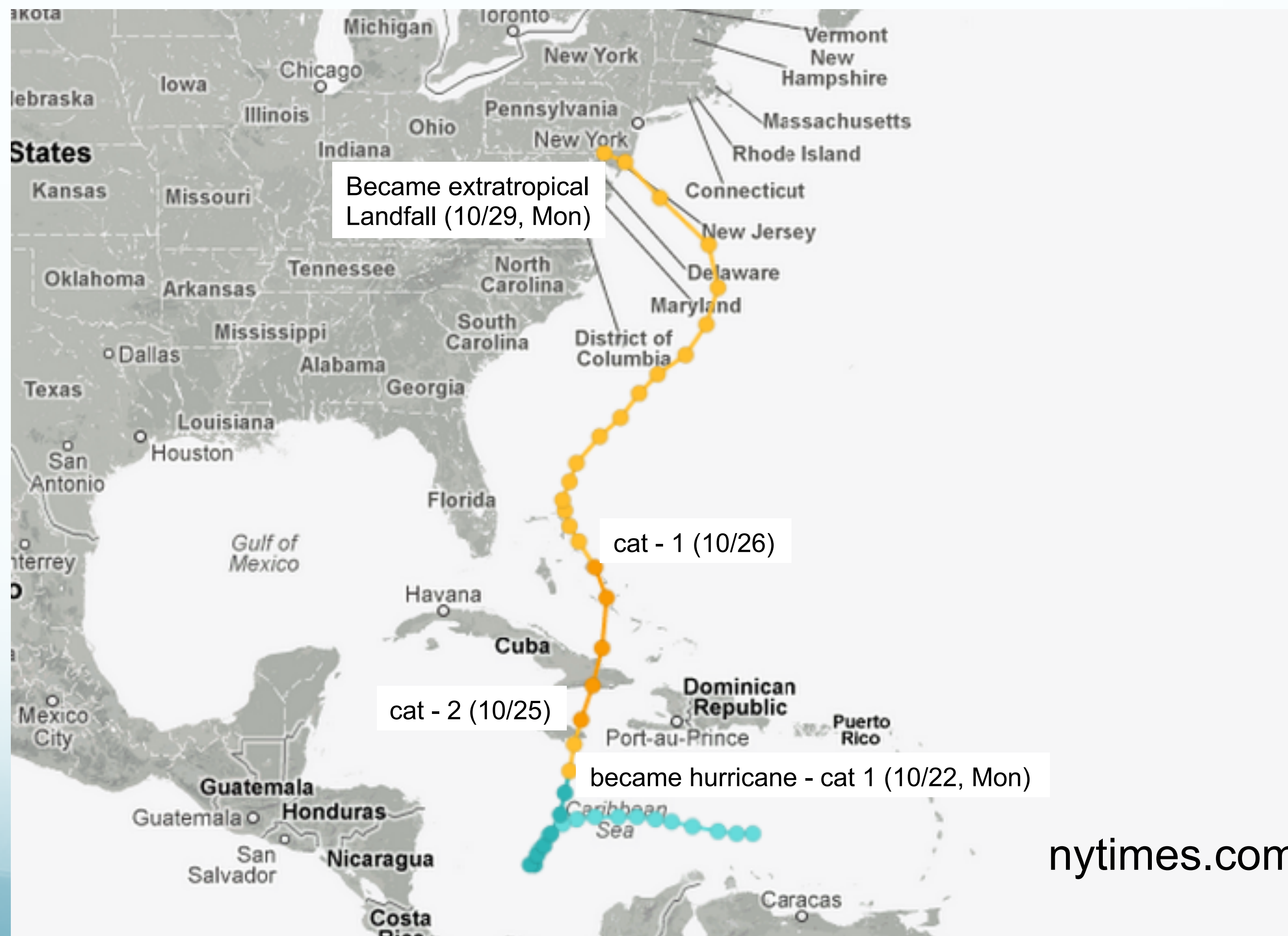
Hit as high tide

Was Cat 5 hurricane at some point in its lifetime

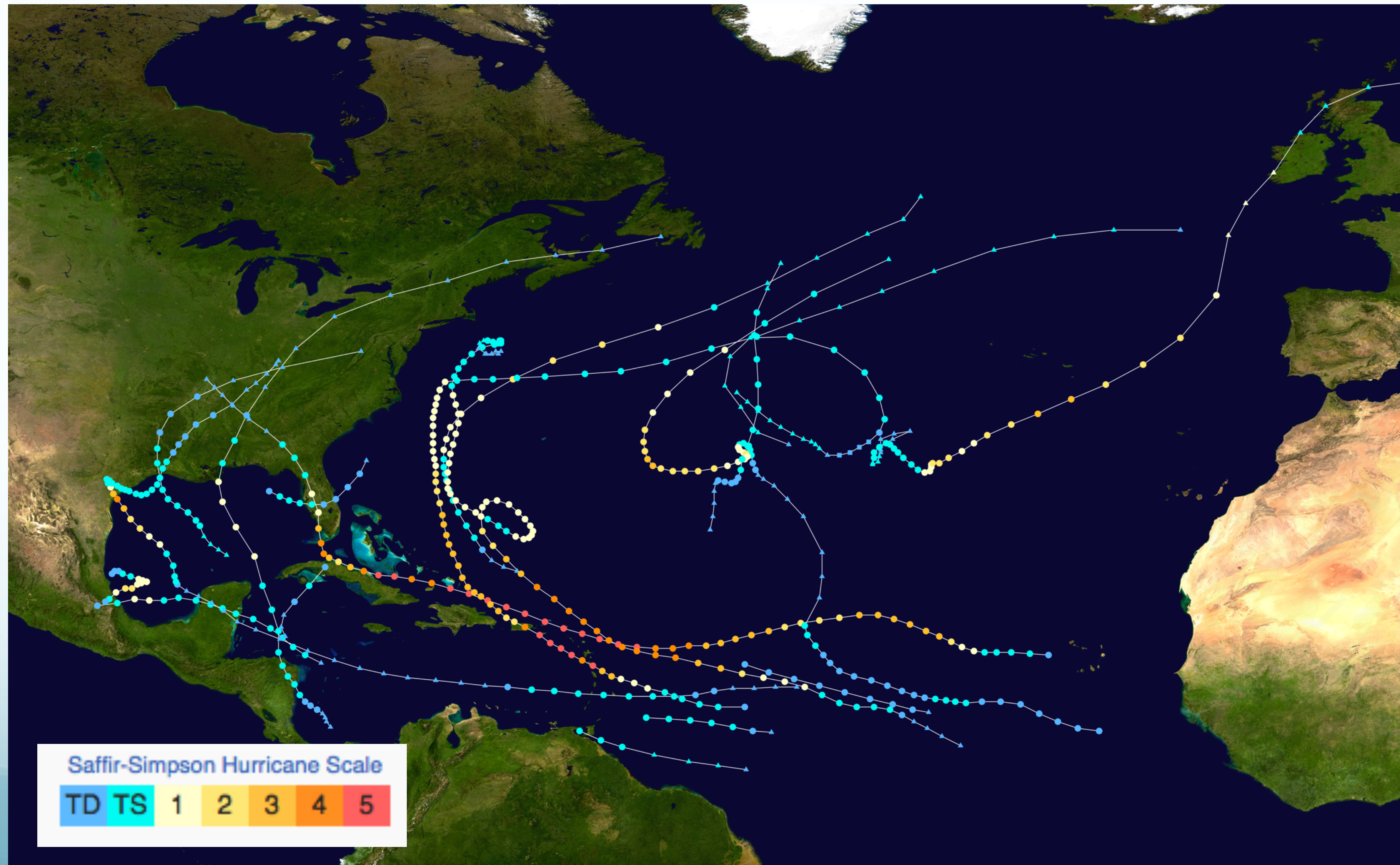
Did significant damage to New York City

Hit as an extratropical storm

Answer: B



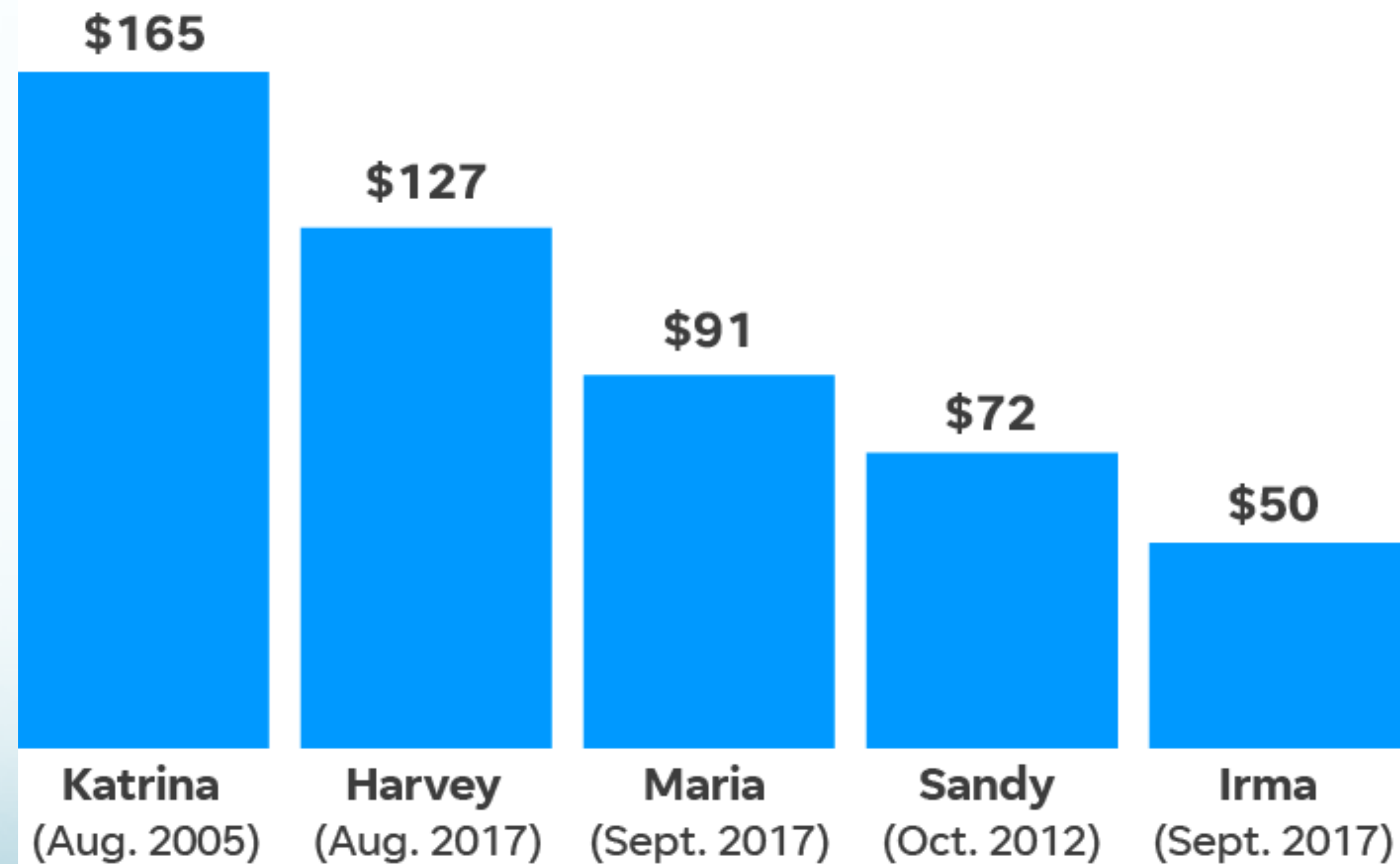
Atlantic Storms of 2017



Atlantic Storms of 2017

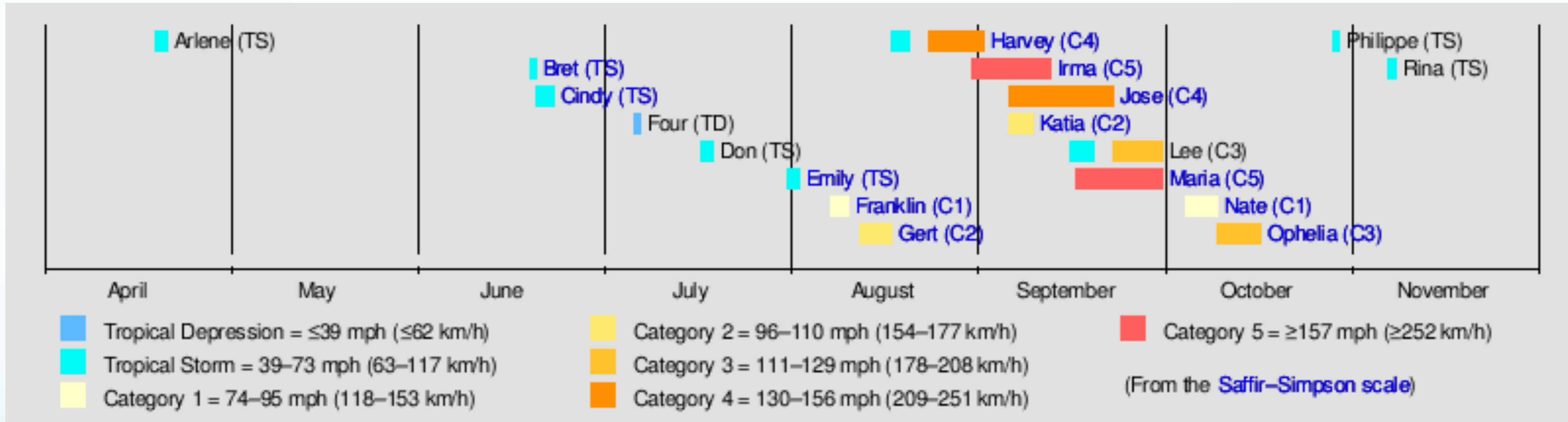
Five costliest hurricanes to strike the U.S.

(2018 dollars, in billions)

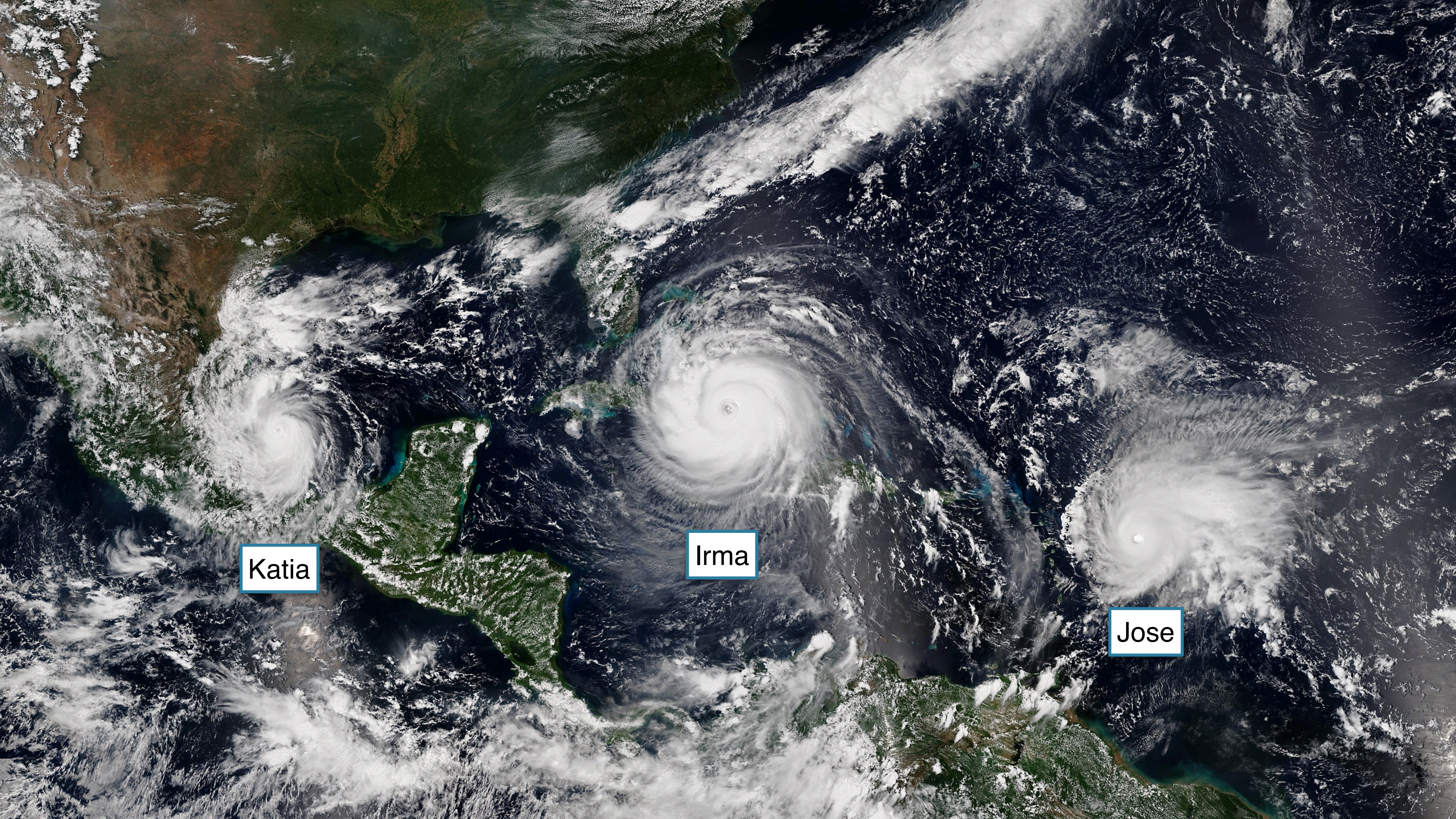


SOURCE NOAA
Frank Pompa/USA TODAY

Atlantic Storms of 2017



https://upload.wikimedia.org/wikipedia/commons/transcoded/3/3e/Hurricane_Tracks_from_2017_with_Precipitation_and_Cloud_Data.webm/Hurricane_Tracks_from_2017_with_Precipitation_and_Cloud_Data.webm.360p.vp9.webm

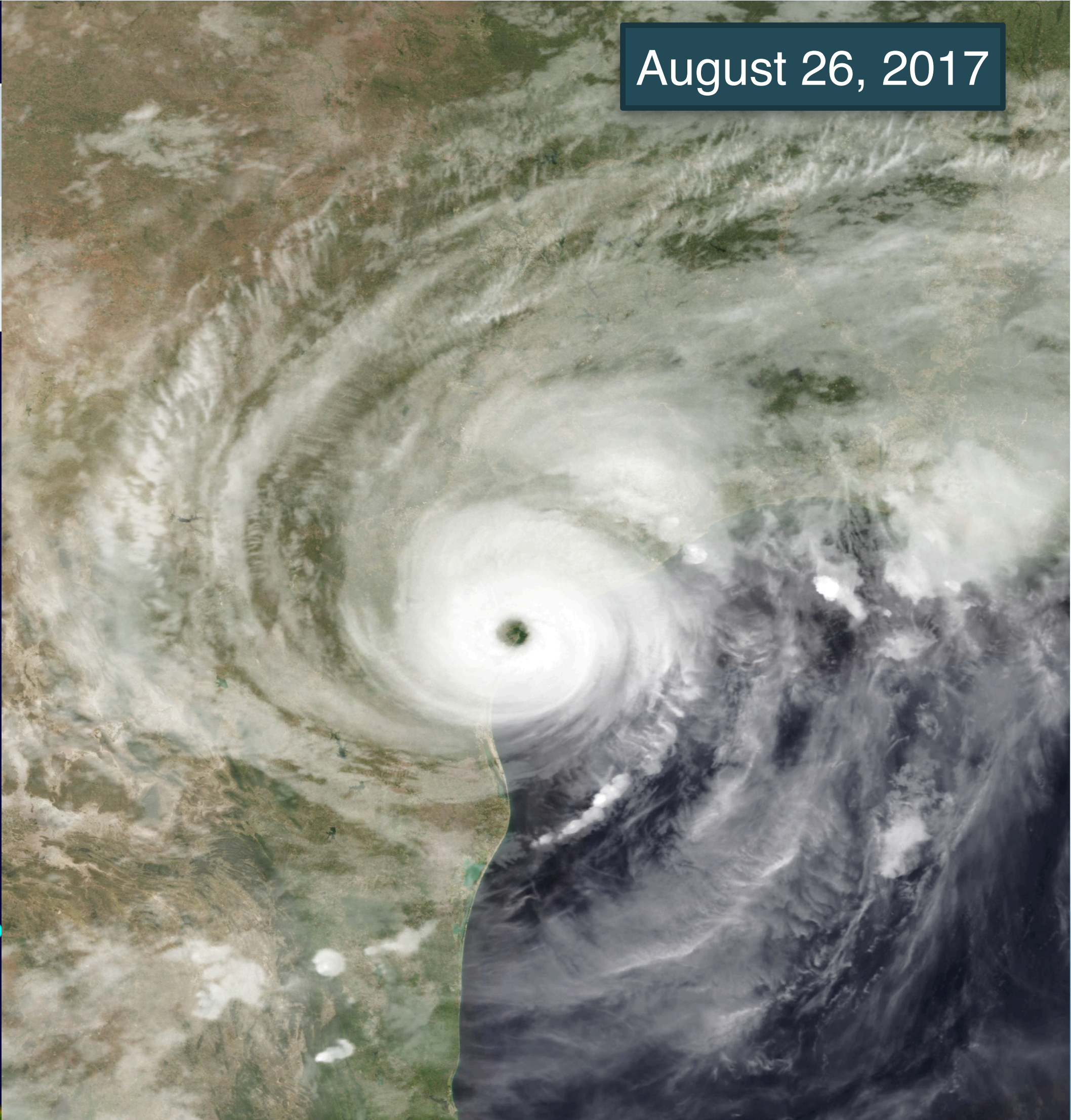
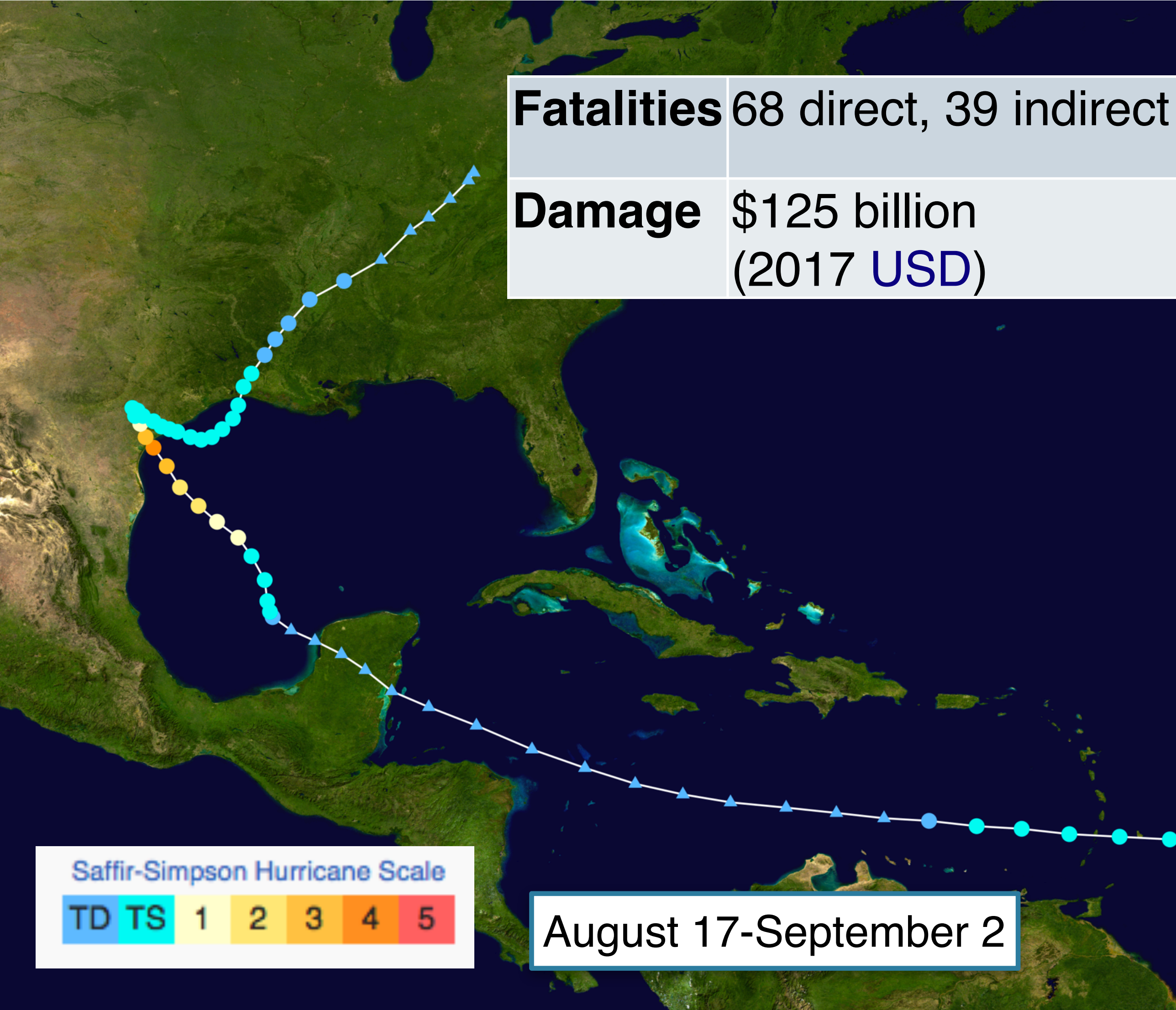


Katia

Irma

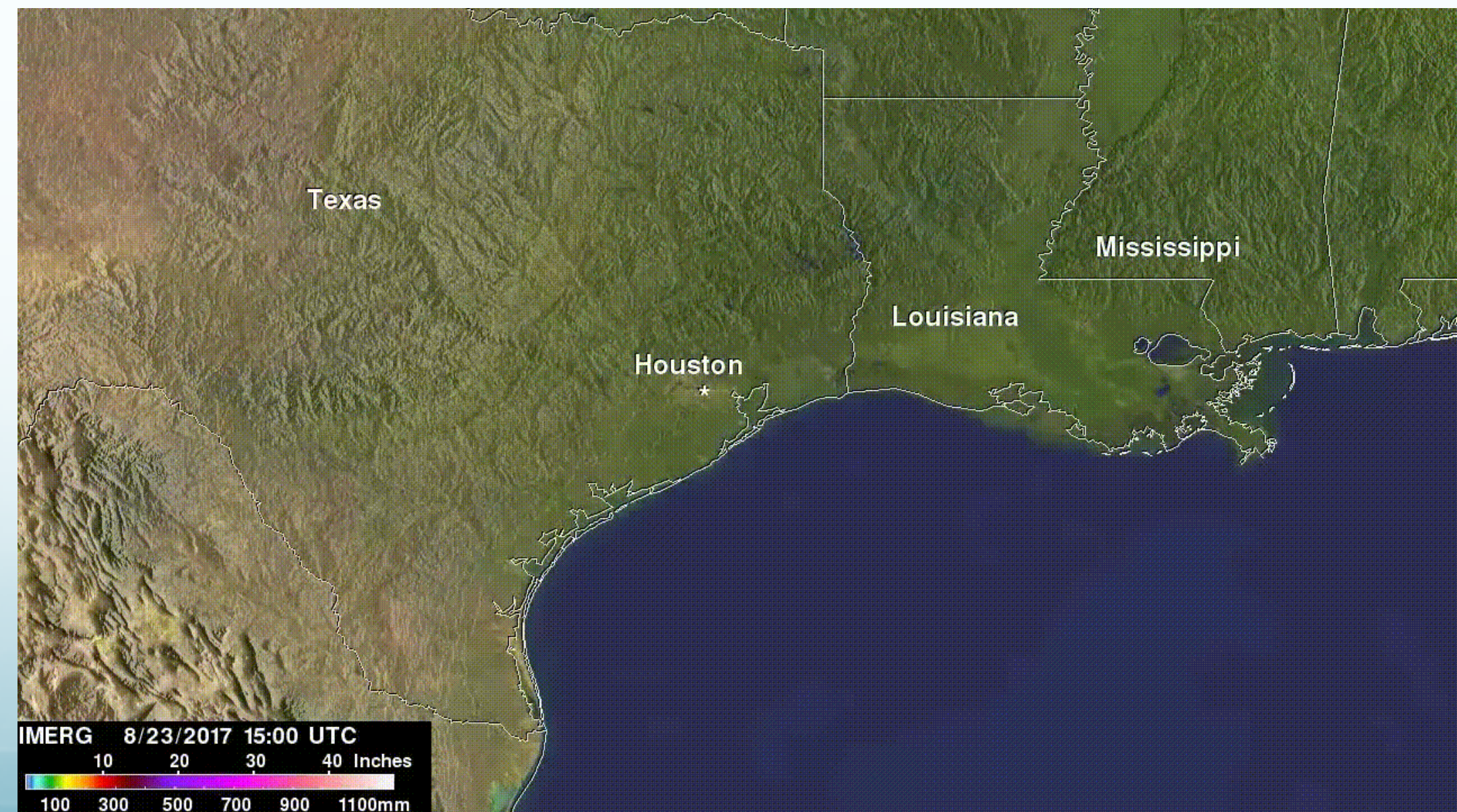
Jose

Hurricane Harvey



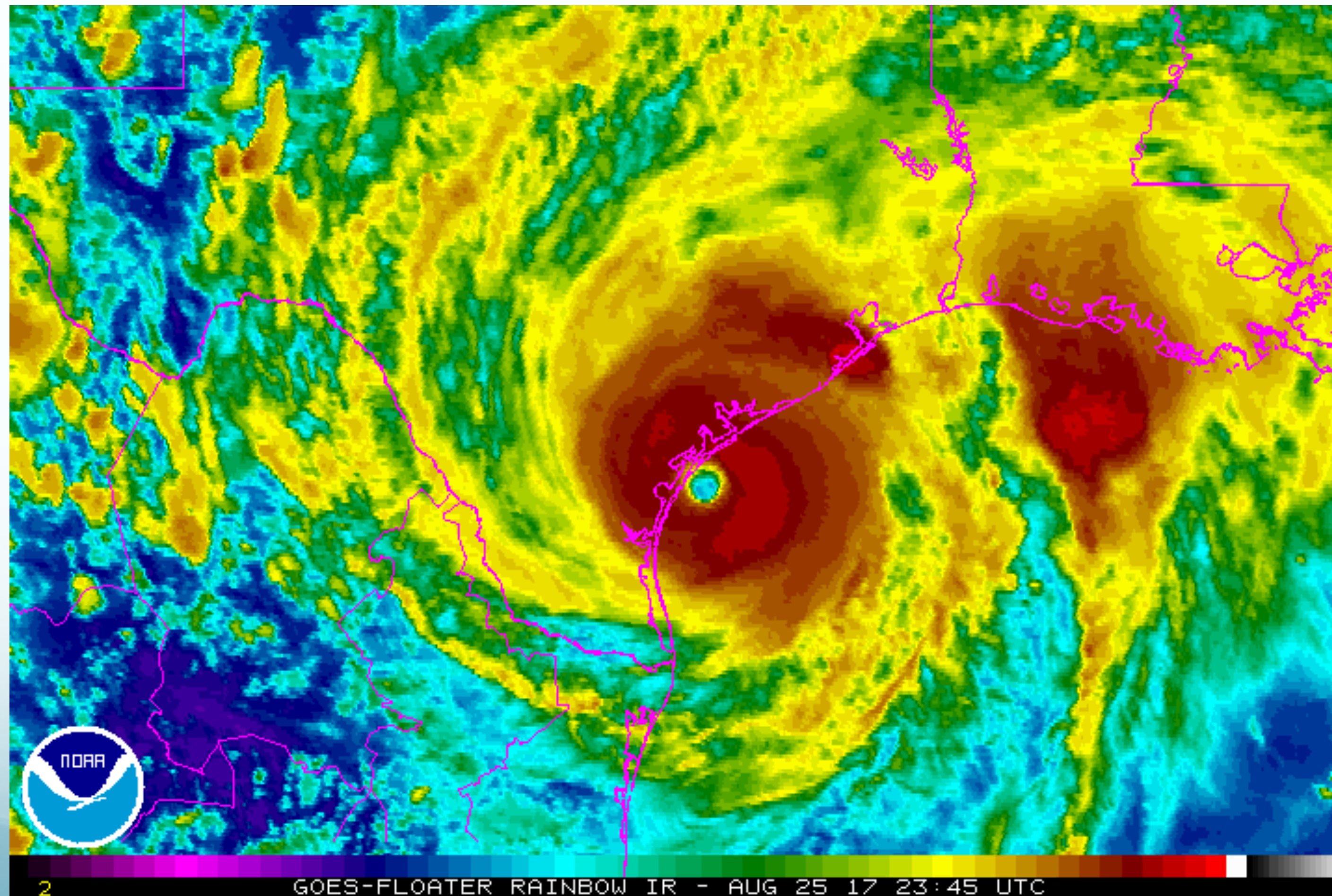
Hurricane Harvey

- Hurricane Harvey: ties Katrina for costliest hurricane ever (before adjusting for inflation)
 - Many areas received over 40 inches of rain
 - Stalled out, giving huge precipitation totals near Houston



Hurricane Harvey

- Infrared satellite map



Harvey Impacts

- Wettest hurricane to hit US
 - 60" of rainfall in Nederland, TX
 - Many Houston suburbs over 2 feet of rain
- Over 100 deaths
- Similar economic losses to Katrina (before adjusting for inflation)

Harvey flooding

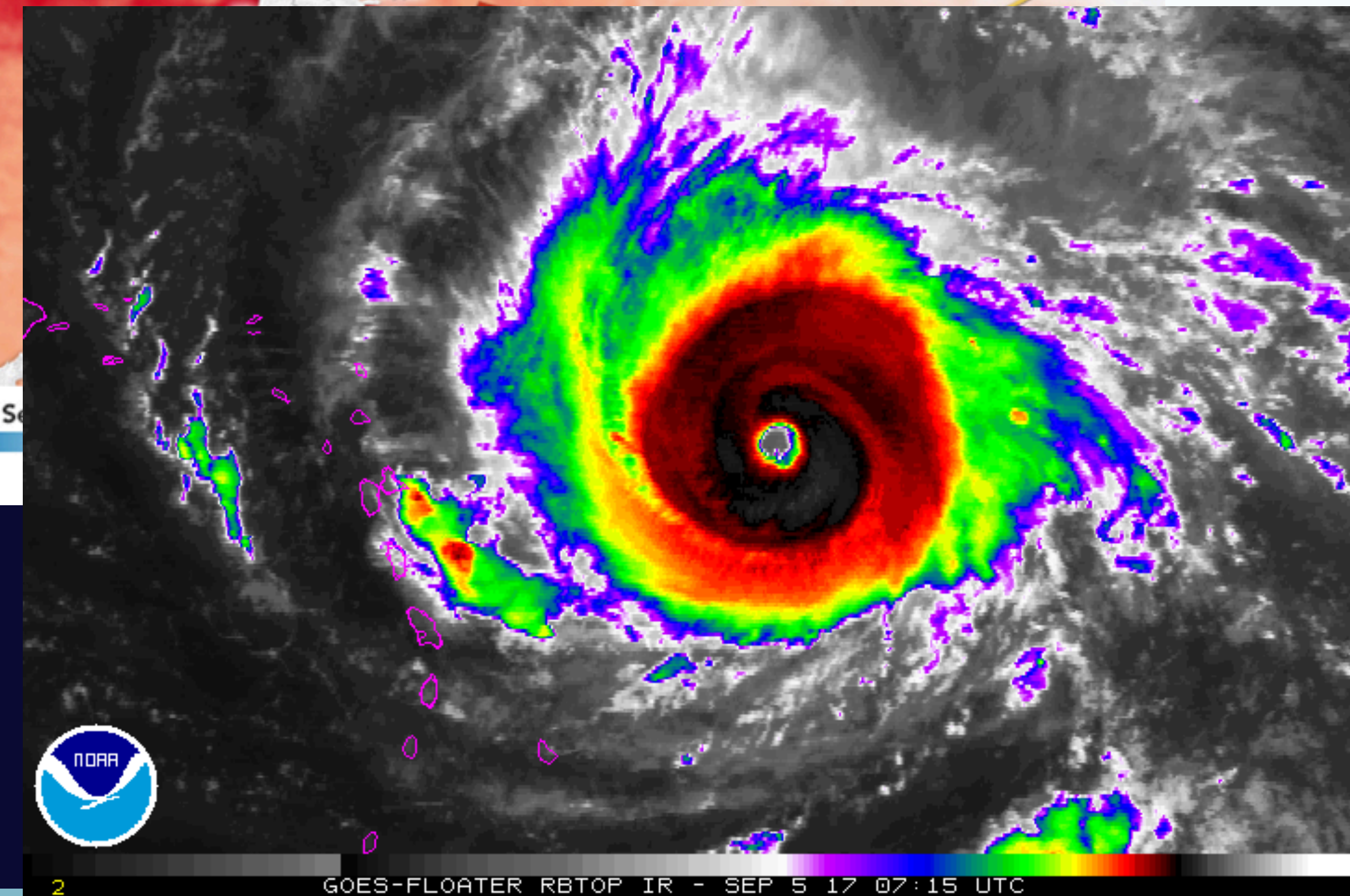
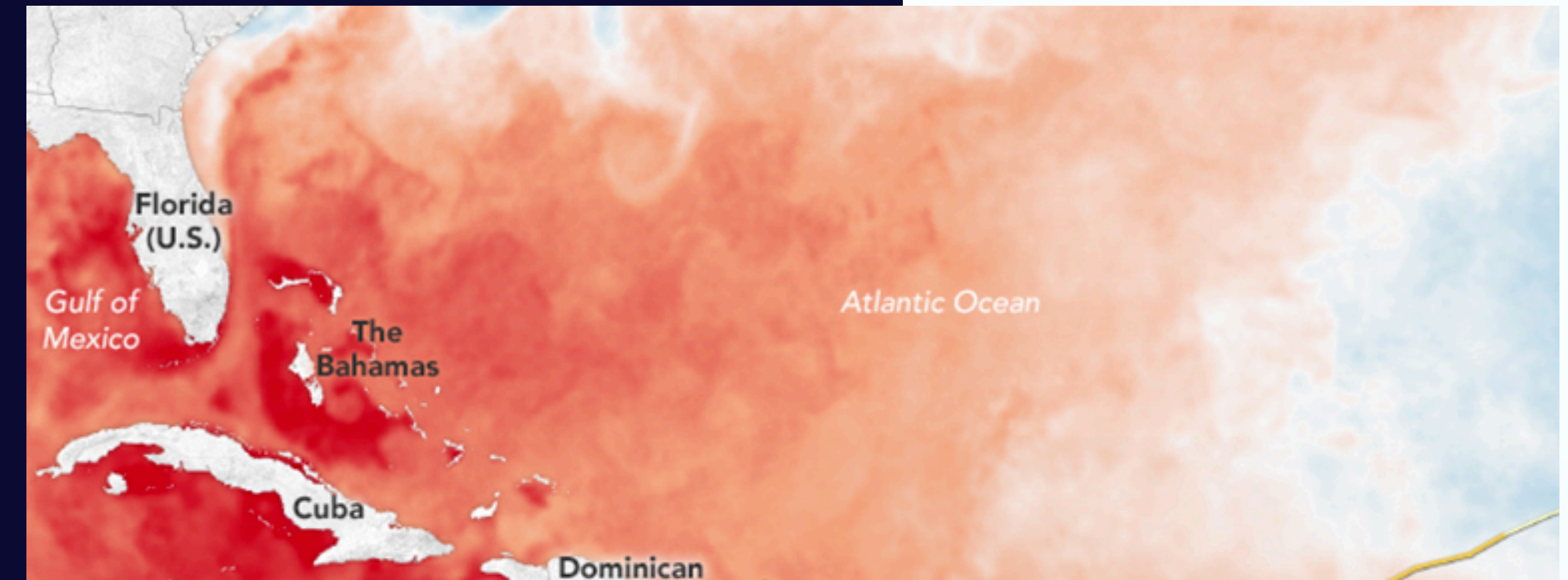


Harvey flooding



Hurricane Irma

Fatalities	52 direct, 82 indirect
Damage	\$77.16 billion (2017 USD)



Saffir-Simpson Hurricane Scale

TD	TS	1	2	3	4	5
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August 30-September 13

Hurricane Irma

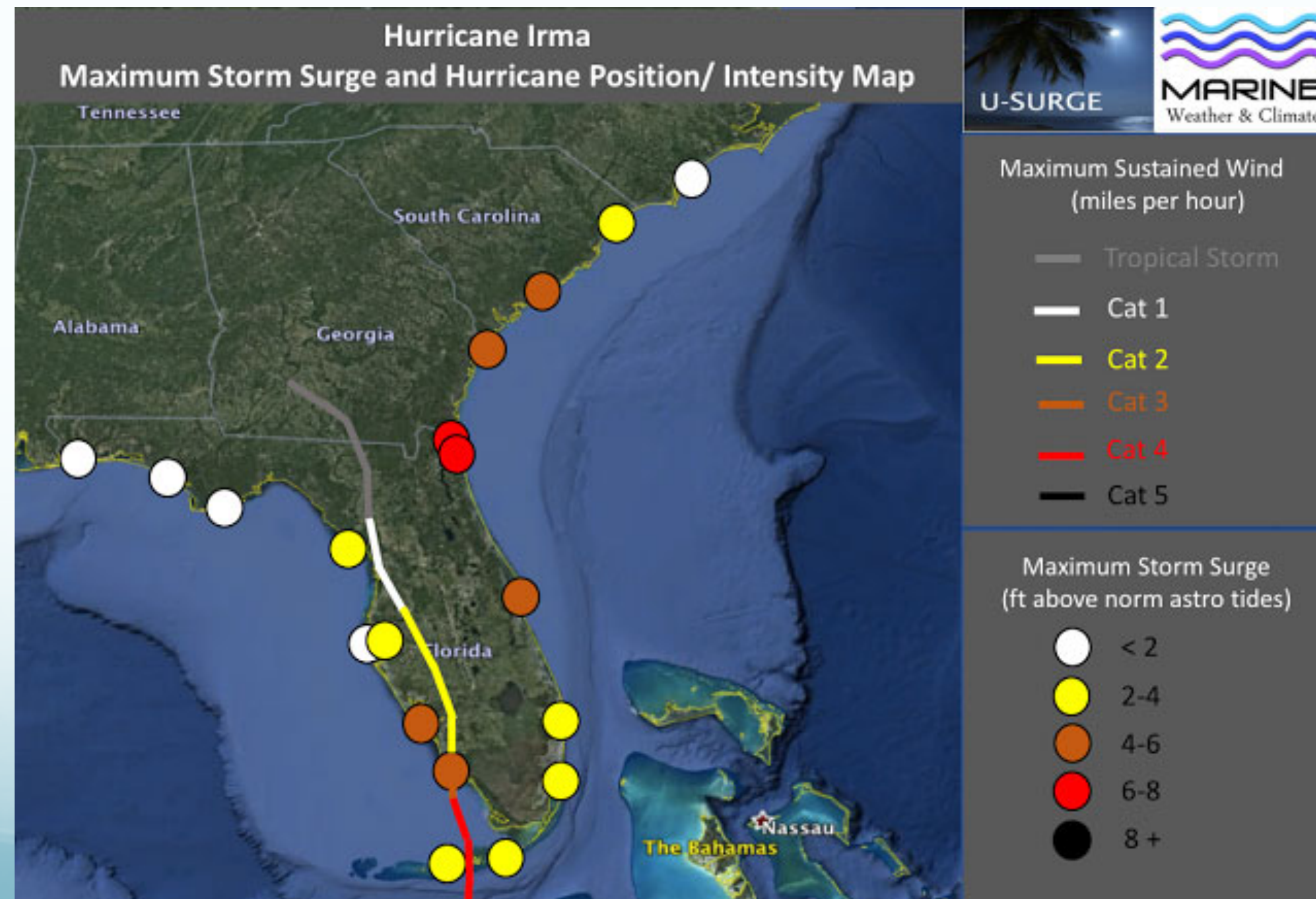
- Strongest storm ever in the open Atlantic Ocean
 - 180 mph winds
- 134 deaths
- Massive damage to Florida Keys in US, Caribbean islands such as Barbuda, Virgin Islands

Irma effect on vegetation



Irma storm surge

- Not bad on Gulf coast!
- Negative (?) storm surge in some places



W What causes negative storm surge?

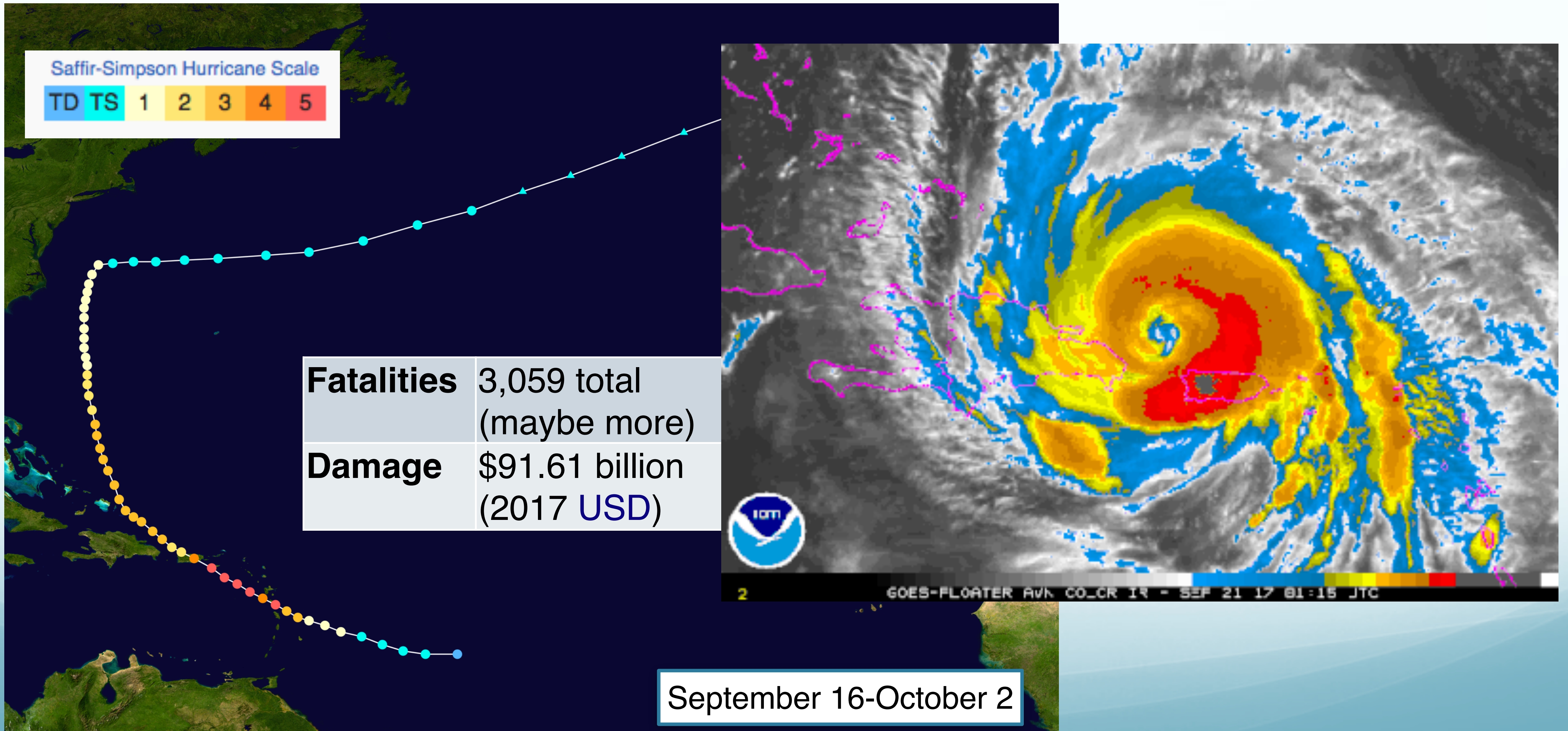
When winds push water away from the coast

When pressure in the hurricane is very high

When more dense cold water comes to the surface

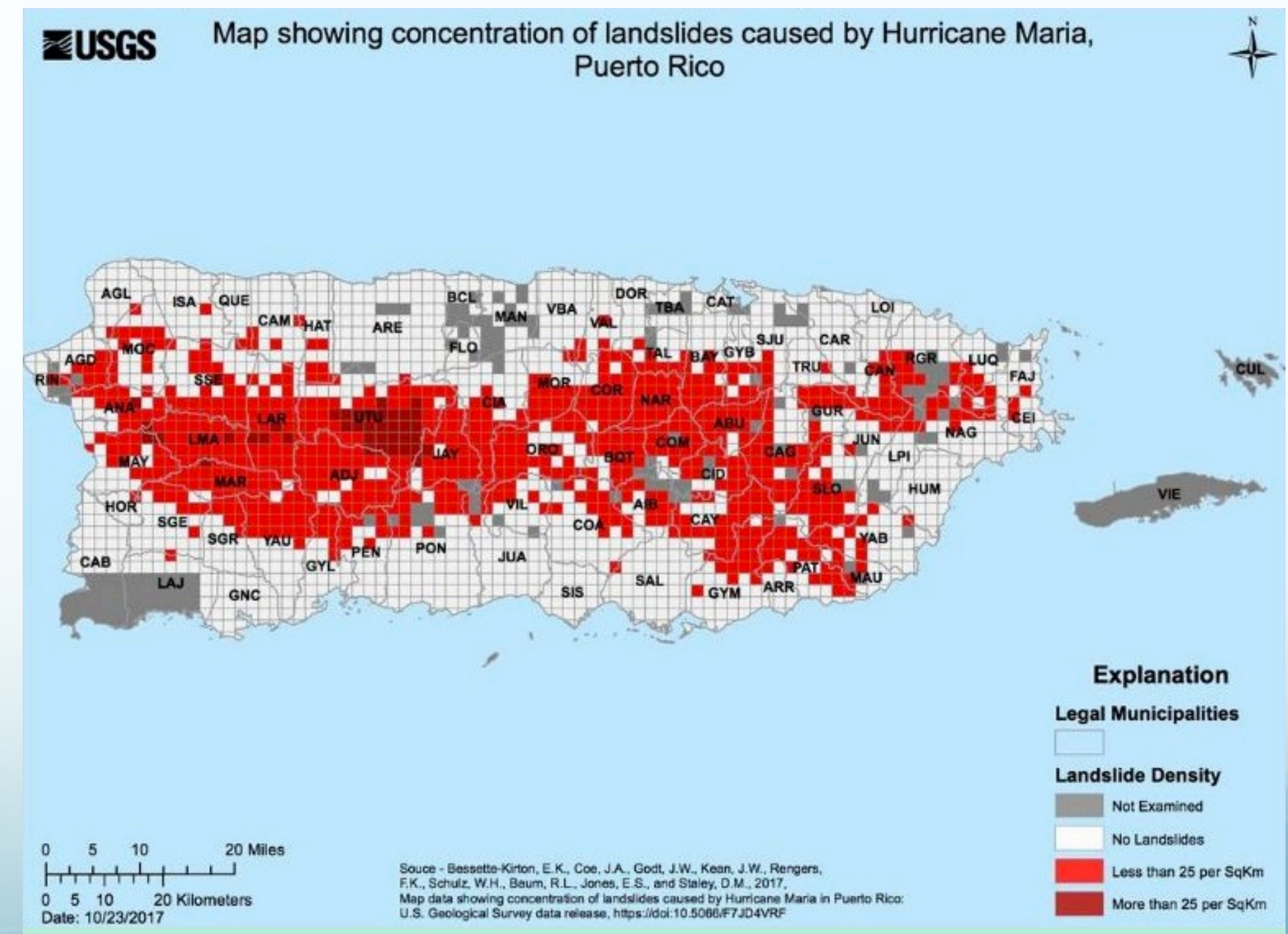
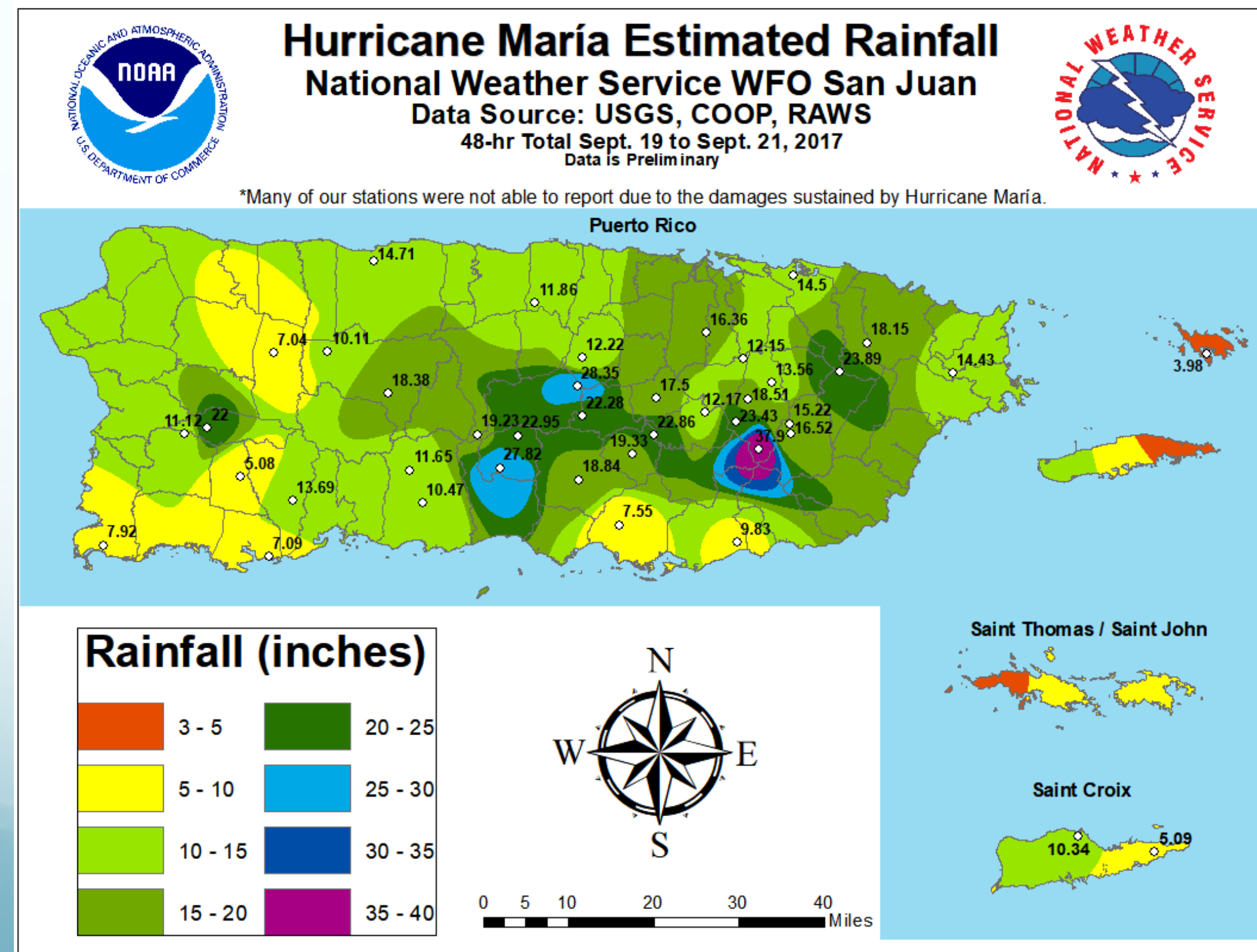
Answer: winds push water away from shore

Hurricane Maria



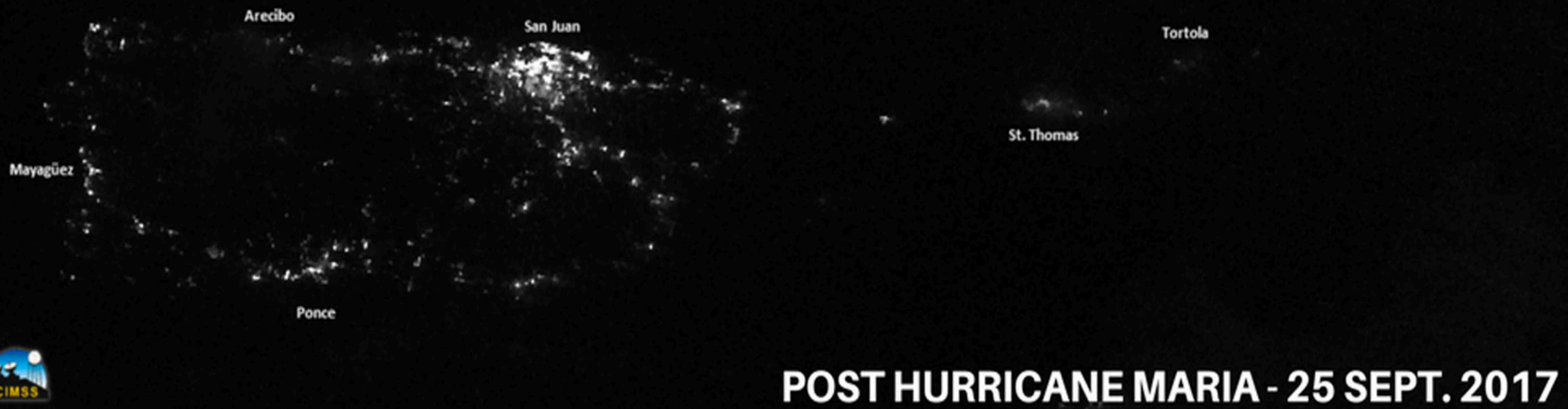
Hurricane Maria

- Rapidly intensified from tropical storm to Cat 5
- Direct hit on Puerto Rico as Cat 4



New study says Maria killed over 4600

- Independent analysis released from Harvard School of Public Health: 4645 additional deaths between Sept 30 and Dec 31
- Best total estimate: 5700 in total
- How??
 - Most died from lack of medical care long after the storm
 - Biggest blackout in US history



Puerto Rico Electrical Grid

- How did such a massive blackout happen?
 - 60,000 power poles toppled by storm
 - Decaying grid
 - Extremely slow reconstruction efforts
- Puerto Rico had been in deep financial distress due to debt crisis
 - No funding for modernization to power plant/electrical grid for years
 - Not even routine maintenance

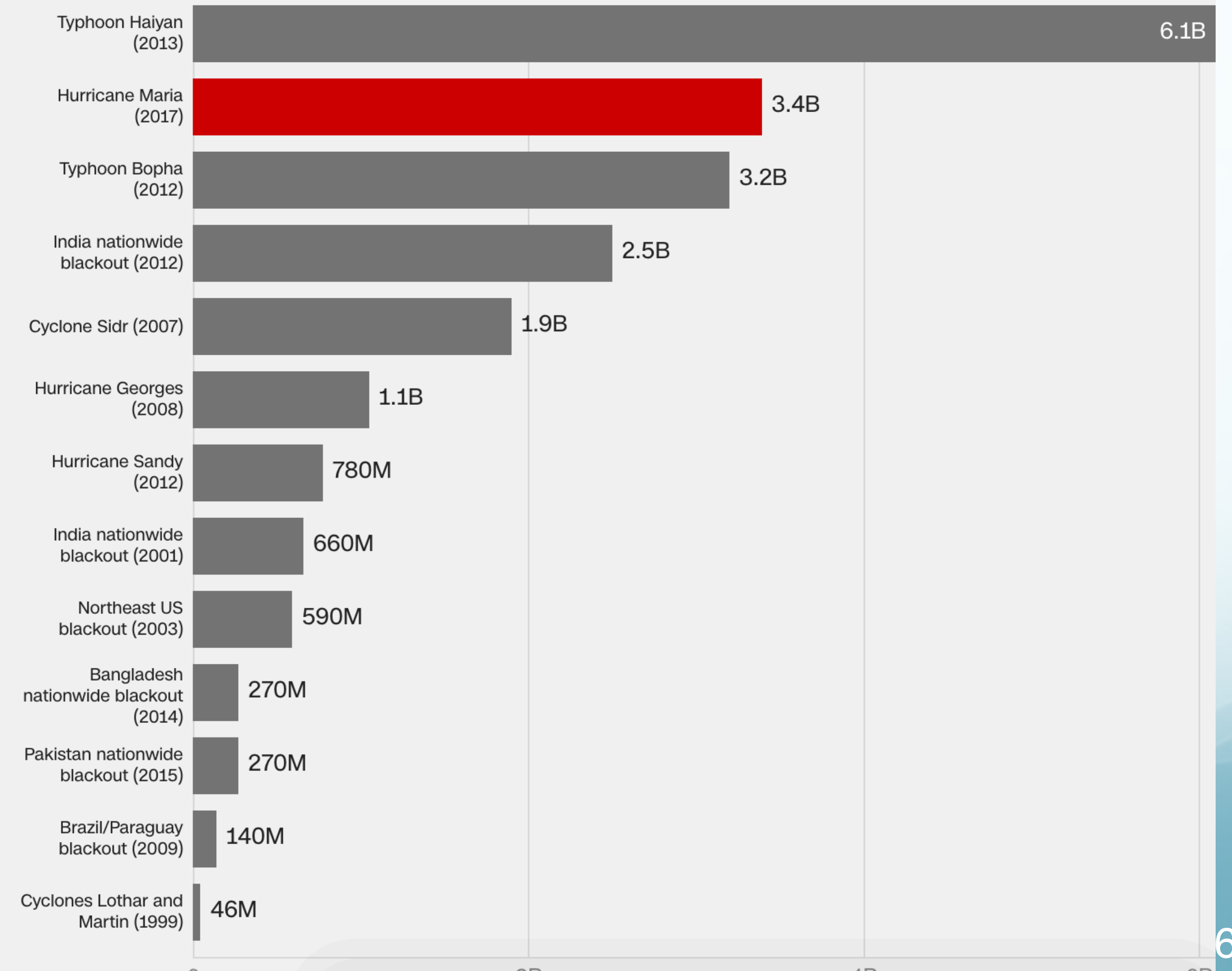
[Vox video](#)

Blackout in Puerto Rico

- Biggest blackout in US history
 - Took over this title in last October
- Now 2nd biggest ever in world history
 - First: Typhoon Haiyan (2013)
- On April 18, 2018, all of PR lost power
 - A bulldozer ran over a cable
 - 840k lost power the previous week when a tree fell on a power line

Major global blackouts

Customer-hours of lost electricity service, with estimates based on available data. This is not a definitive ranking but rather a selection of some of the largest and most well-known blackouts.



“Blue Roof” Program

- Temporary plastic roofs installed on damaged houses
- Key to get these installed immediately to avoid mold damage
- Only 439 installed within first 30 days after Maria



Compared with 4500 installed within 30 days after Irma
2 weeks before any were installed in PR

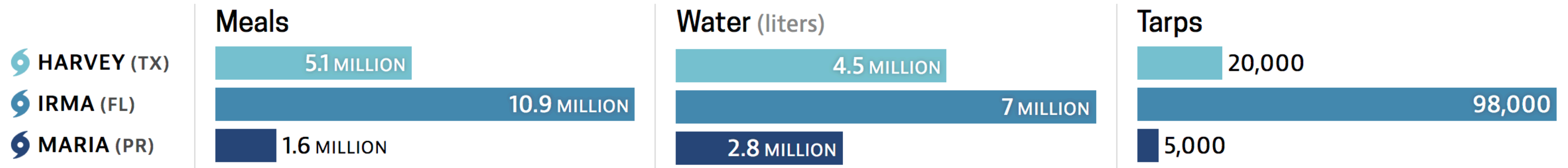
[Link to buy](#)

Why so slow?

- When Maria hit, there was no blue roof material on the island
 - Had been moved to US Virgin Islands who needed it after Hurricane Irma
- Hard to transport materials from mainland to the island

Immediate Response

Supplies delivered nine days after each storm



Blue roof delays

- First contract (\$9.2 million) for blue roof delivery awarded to Florida-based Bronze Star on Oct 10
 - No prior disaster contracts (company had formed the month before)
 - Contract cancelled in November after no roofs were delivered
- Ceres Environmental Services is an experienced disaster contractor that installs the roofs
 - Also didn't meet their contract requirements
 - Local subcontractors blamed Ceres for limited training and inadequate pay
 - Later contract for local business given to Ceres Caribe — not actually local

Last Blue Roof

- 30,000 blue roofs installed by Dec 30
- Blue roof number 59,469 installed by March, 6 months after Maria hit
- Final government report said slow pace was due to “bureaucratic delays associated with mobilizing personnel, a lack of pre-planning for this type of mission in Puerto Rico and the intricacies and unacceptable timelines associated with federal procurement actions.”

Storm of the Century

W

In which country were the most lives lost to a single tropical cyclone AFTER 2000?

Bagladesh

Myanmar

Philippines

United
States

Start the presentation to see live content. Still no live content? Install the app or get help at Pollev.com/app

Total Results

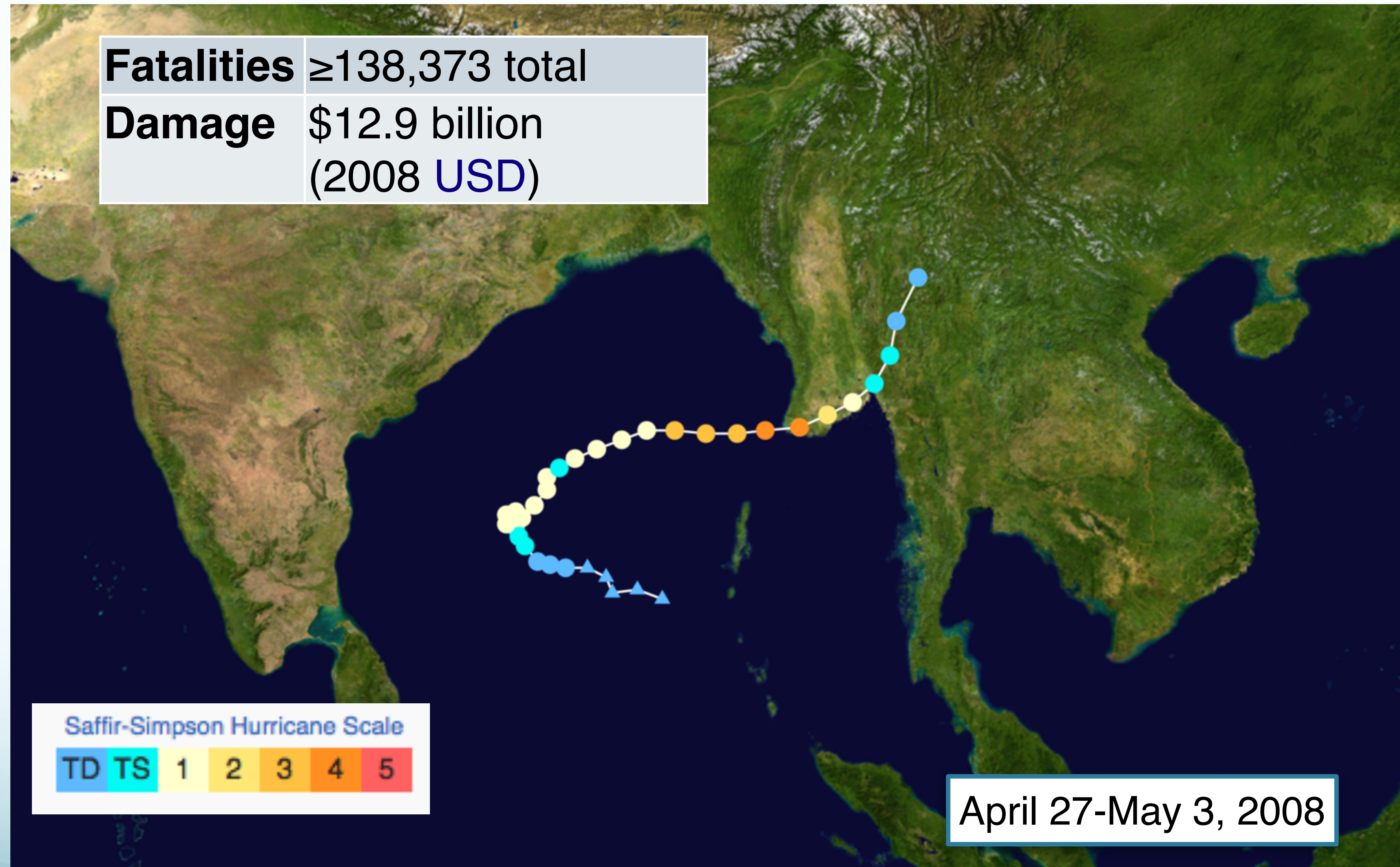
Answer

- After 2000, the most lives were lost to a tropical cyclone in Myanmar.

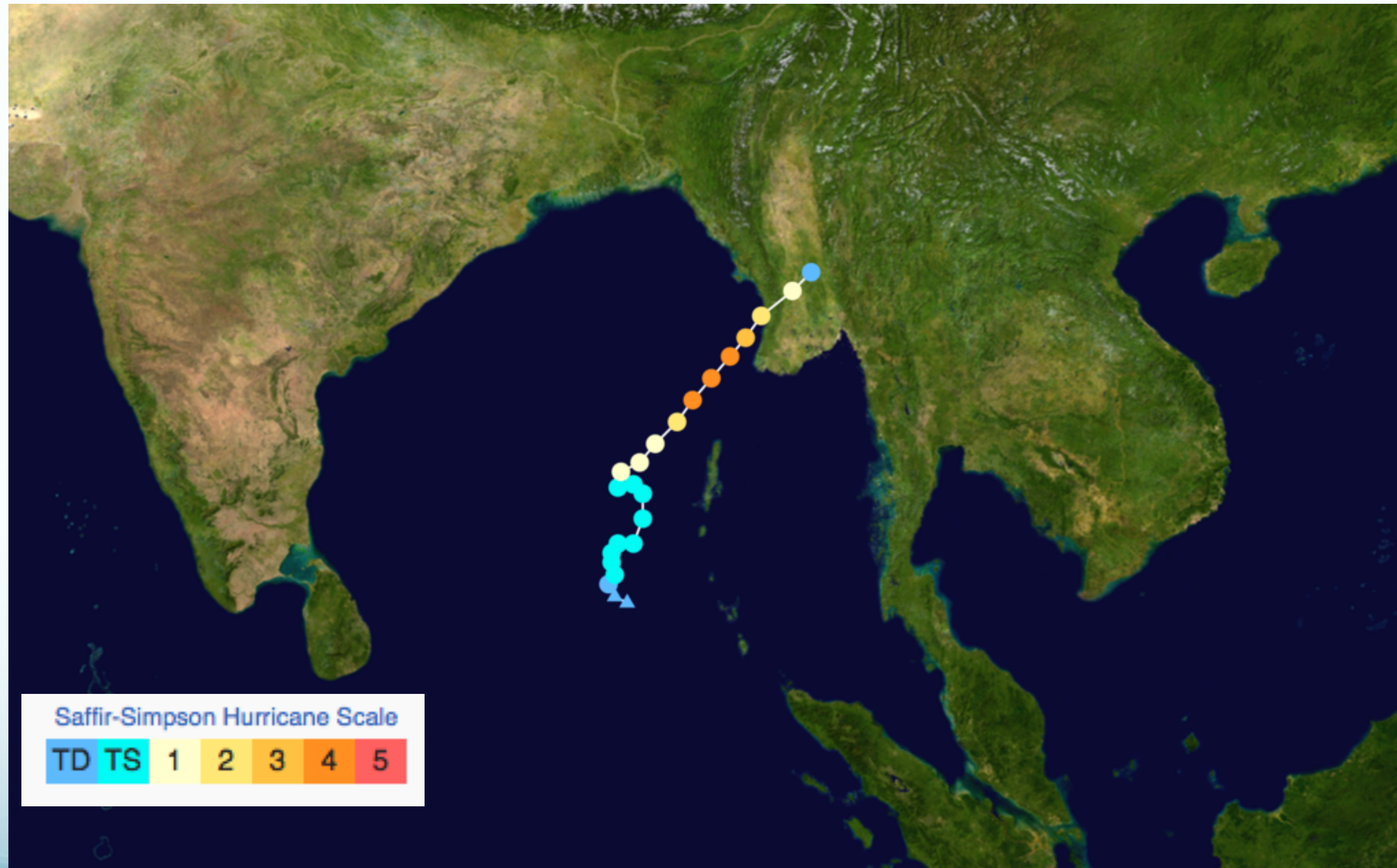
Ten Deadliest Tropical Cyclones

Rank	Name / Areas of Largest Loss	Year	Ocean Area	Deaths
1.	Great Bhola Cyclone, Bangladesh	1970 [Nov 12]	Bay of Bengal	300,000 - 500,000
2.	Hooghly River Cyclone, India and Bangladesh	1737	Bay of Bengal	300,000
3.	Haiphong Typhoon, Vietnam	1881	West Pacific	300,000
4.	Coringa, India	1839	Bay of Bengal	300,000
5.	Backerganj Cyclone, Bangladesh	1584	Bay of Bengal	200,000
6.	Great Backerganj Cyclone, Bangladesh	1876	Bay of Bengal	200,000
7.	Chittagong, Bangladesh	1897	Bay of Bengal	175,000
8.	Super Typhoon Nina, China	1975 [Aug 5]	West Pacific	171,000
9.	Cyclone 02B, Bangladesh	1991 [May 5]	Bay of Bengal	138,866
10.	Cyclone Nargis, Myanmar	2008 [May 3]	Bay of Bengal	138,366

Nargis



Cyclone Mala, 2006 (37 killed)

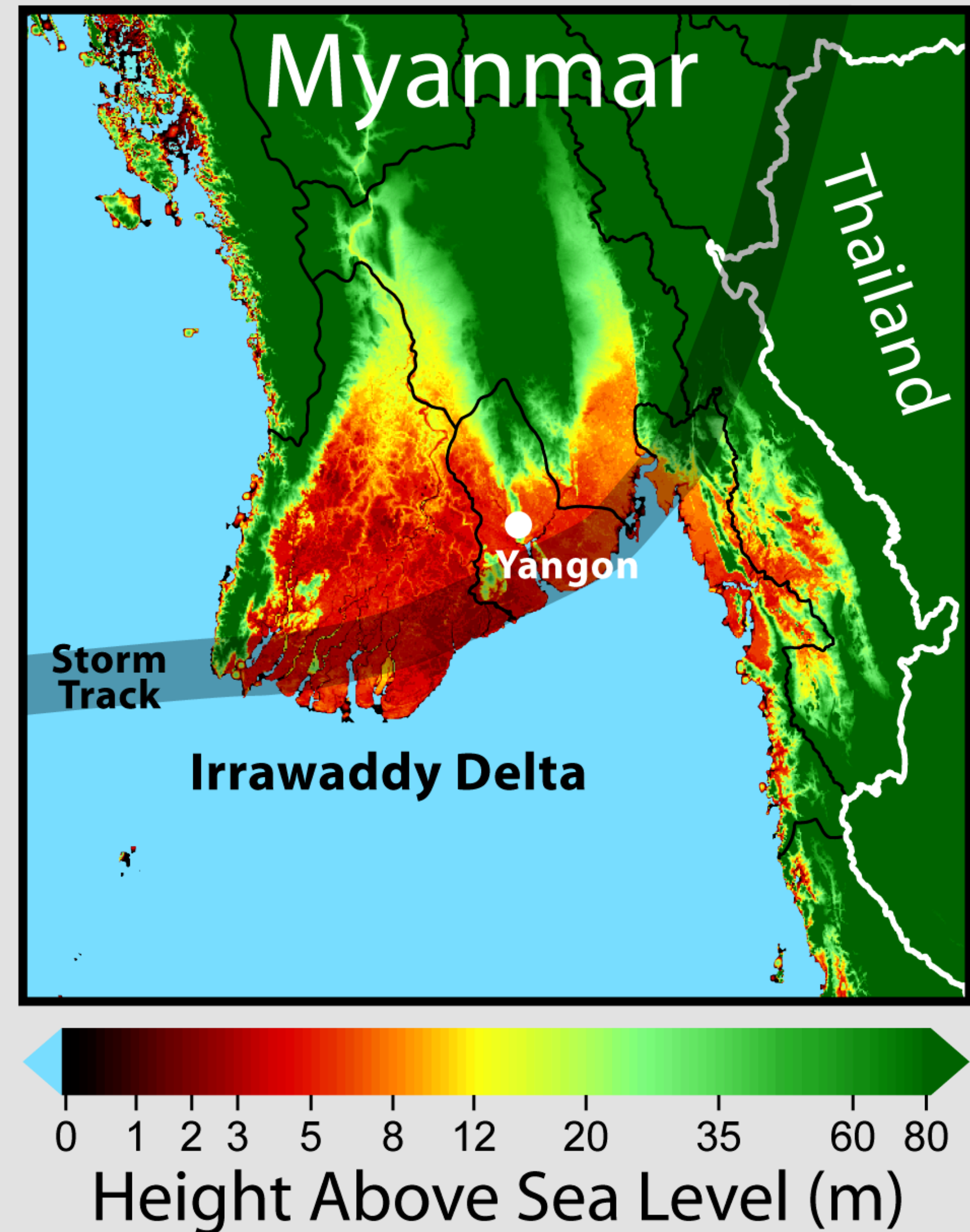


Deadly Track

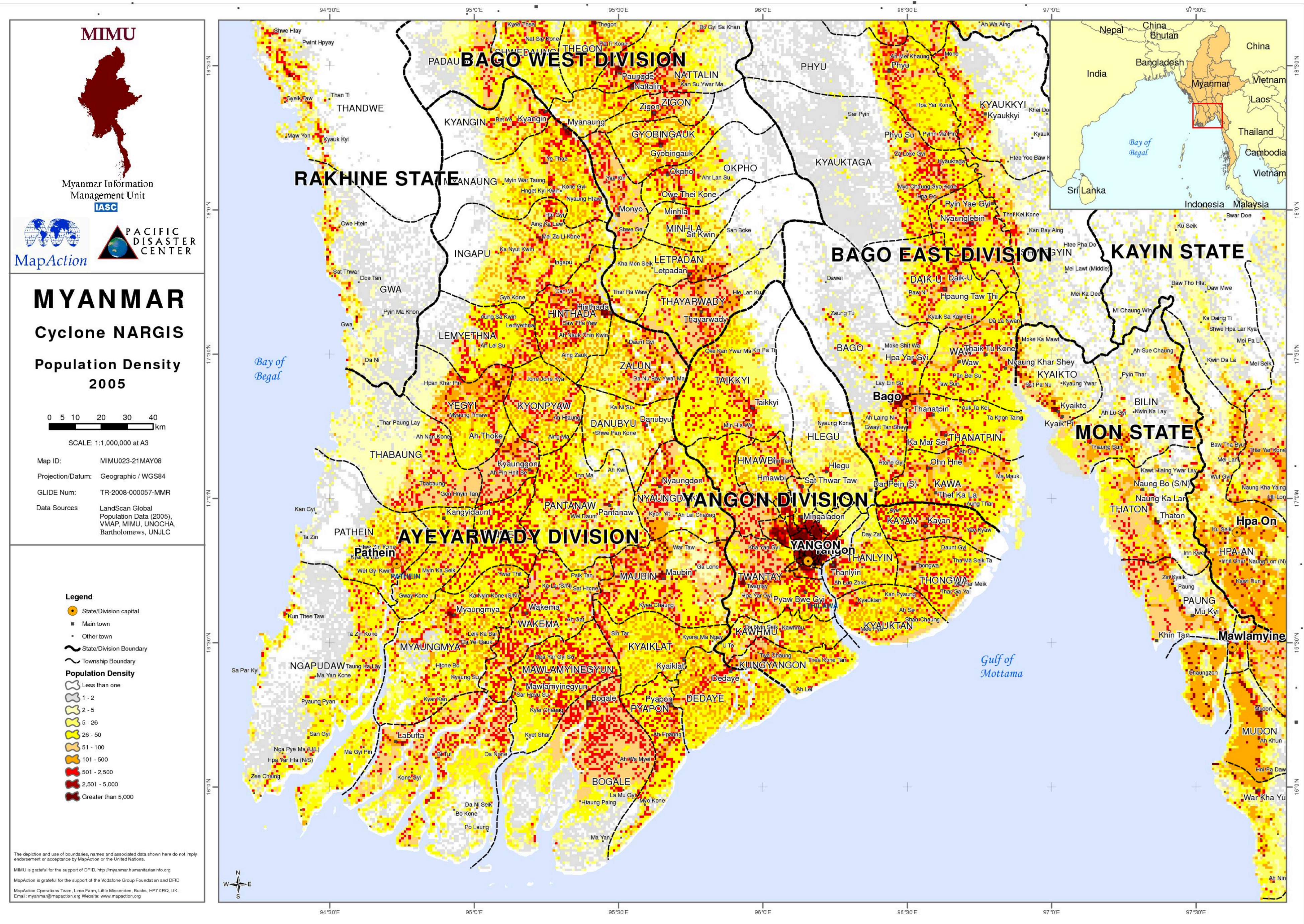
Retained intensity because it stayed close to the sea.

Storm surge penetrated 25 miles inland

Disaster Area Topography

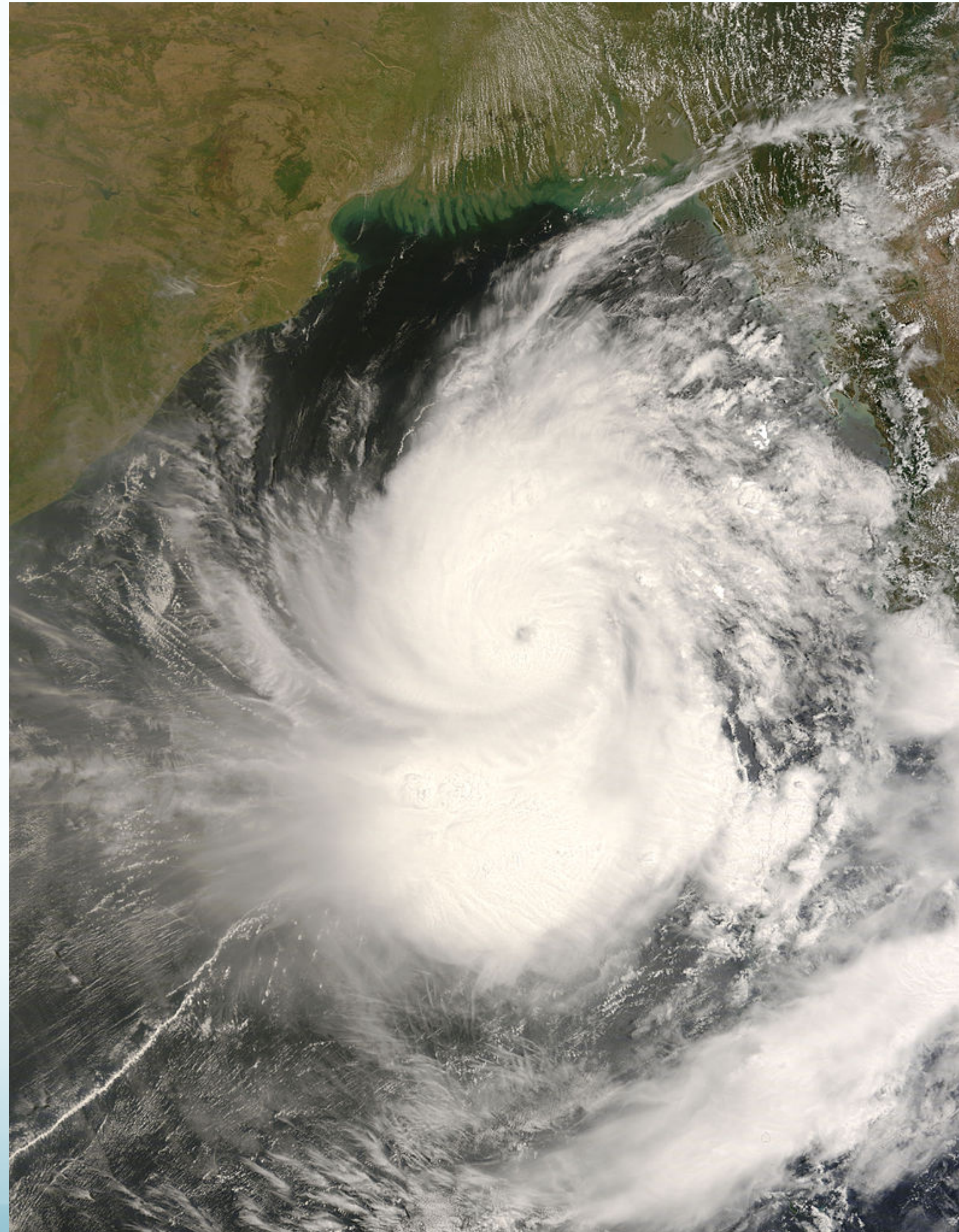


Population density



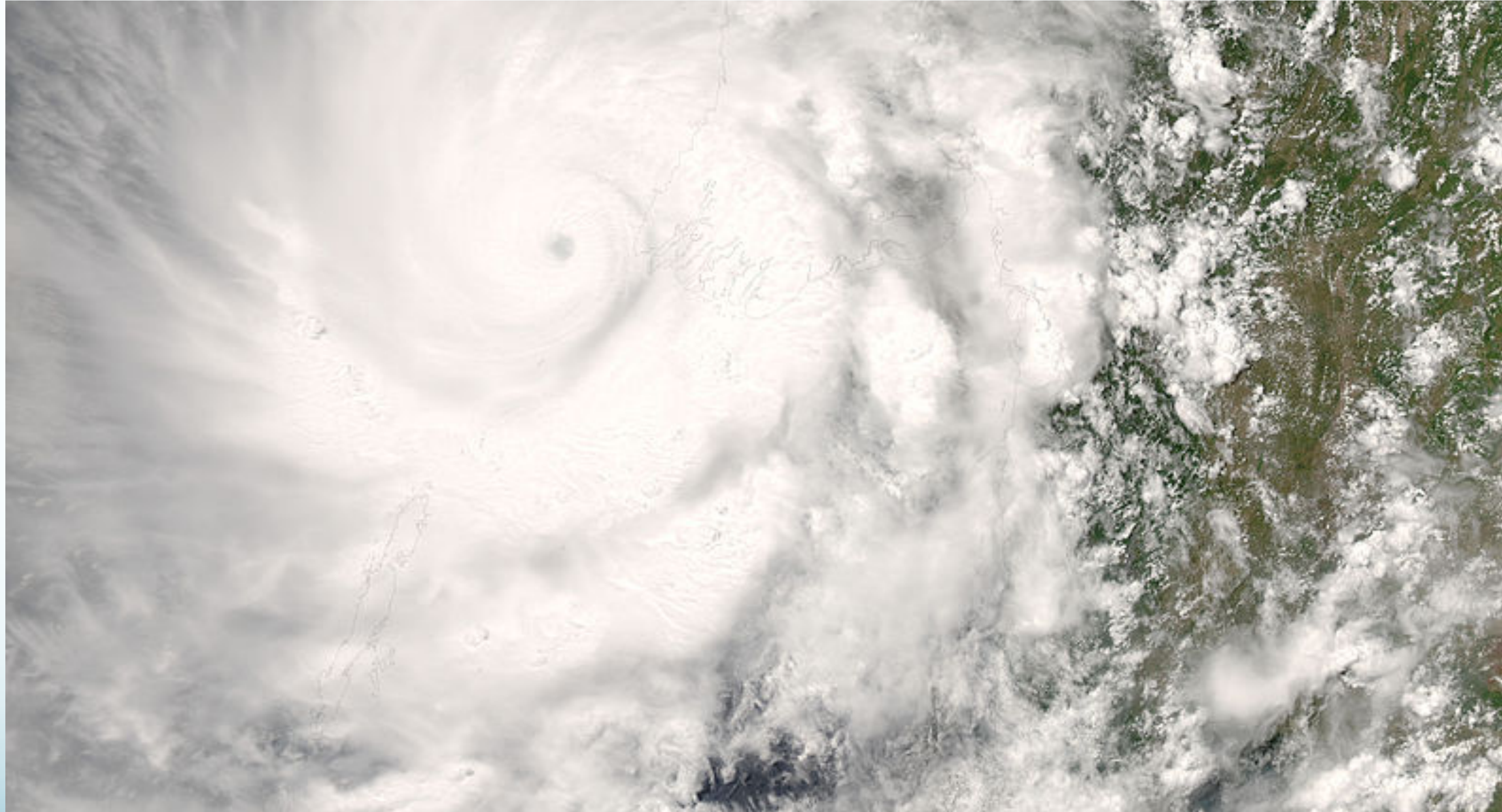
Tropical Cyclone Nargis

May 1, 2008



Nargis Near Landfall

May 2, 2008; JTWC wind estimate 135 mph (Cat 4)



Before and After Nargis



April 15, 2008

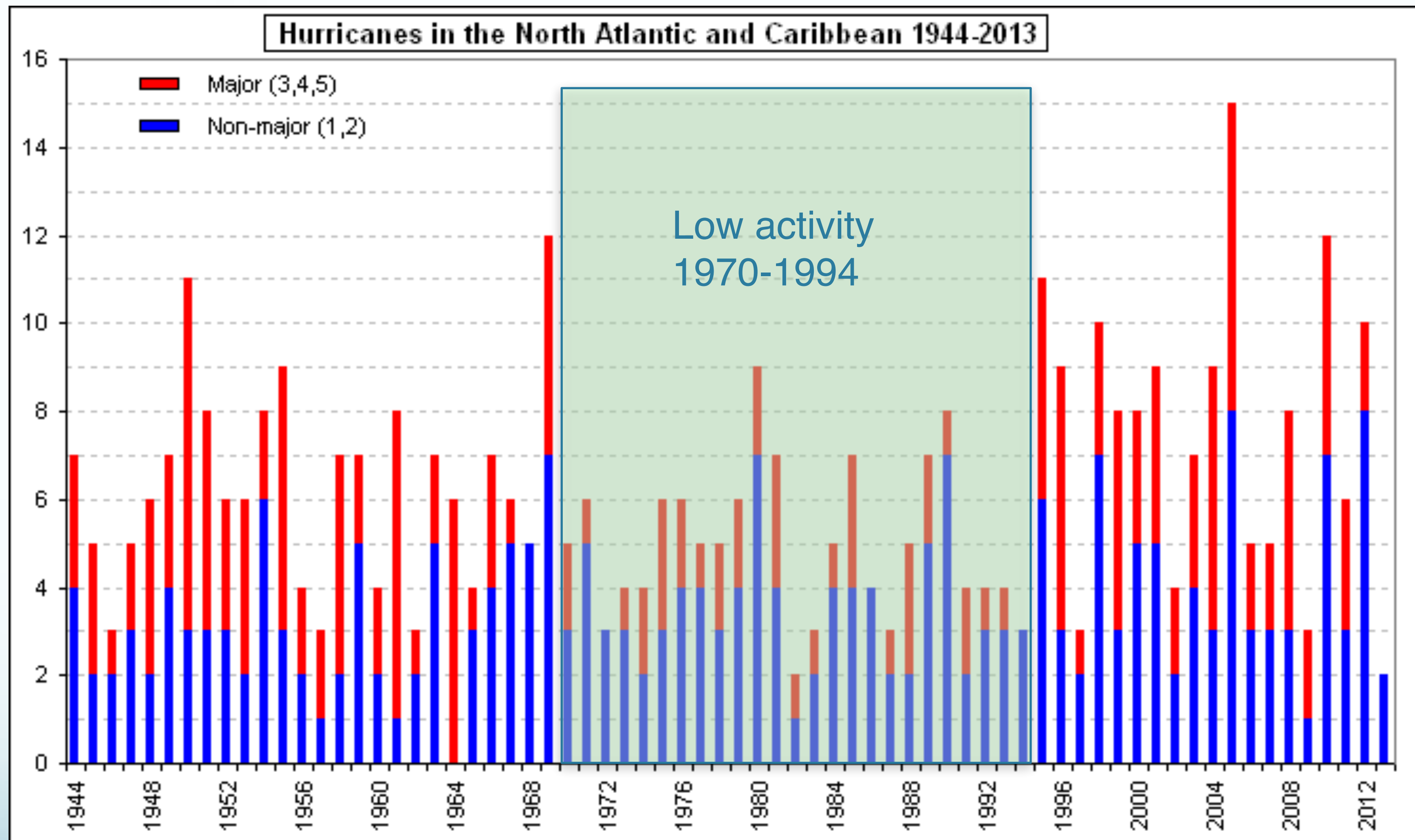
Extensive flooding 3 days after landfall



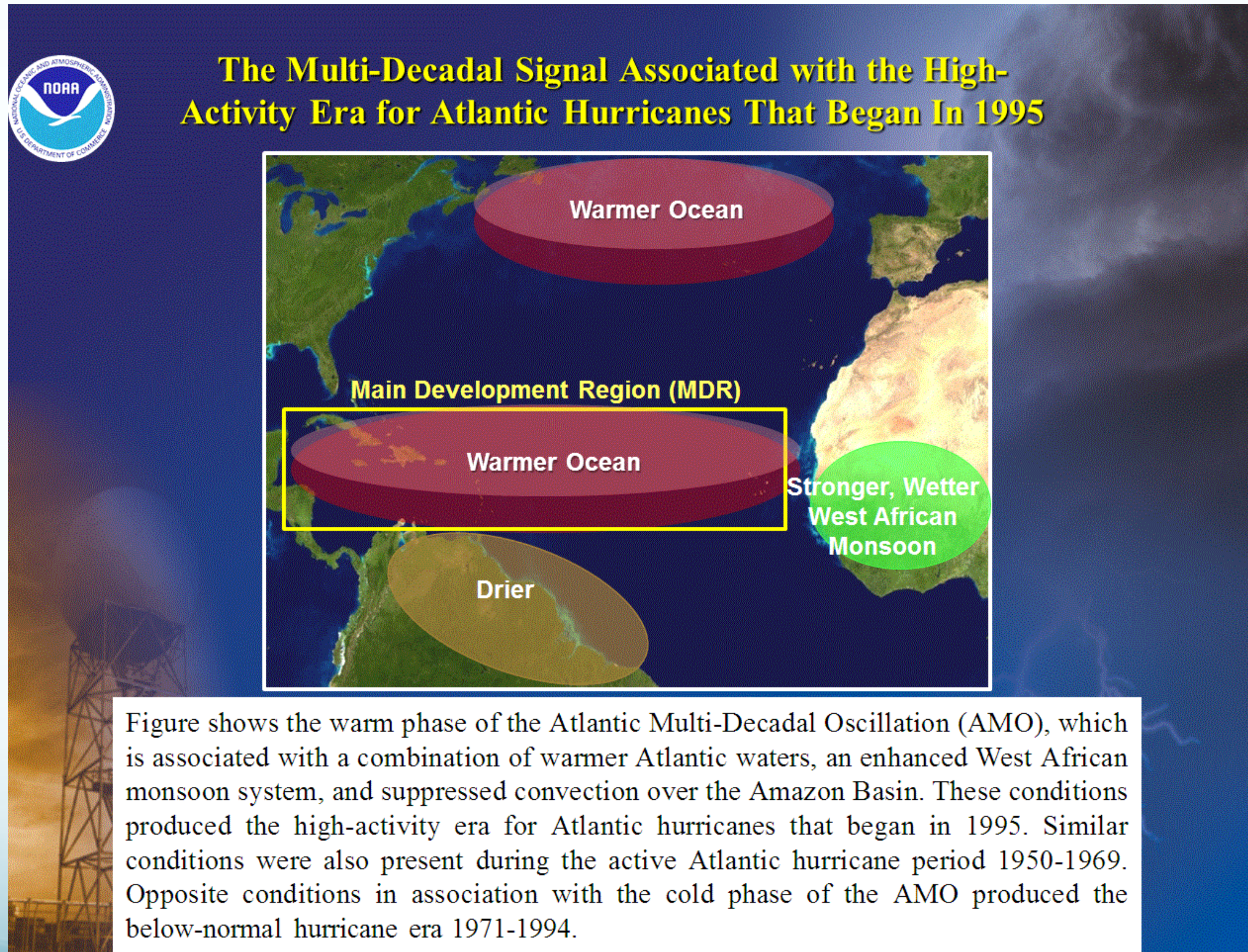
May 5, 2008

[New York Times report](#)

Decadal Variations in Atlantic Hurricane Activity



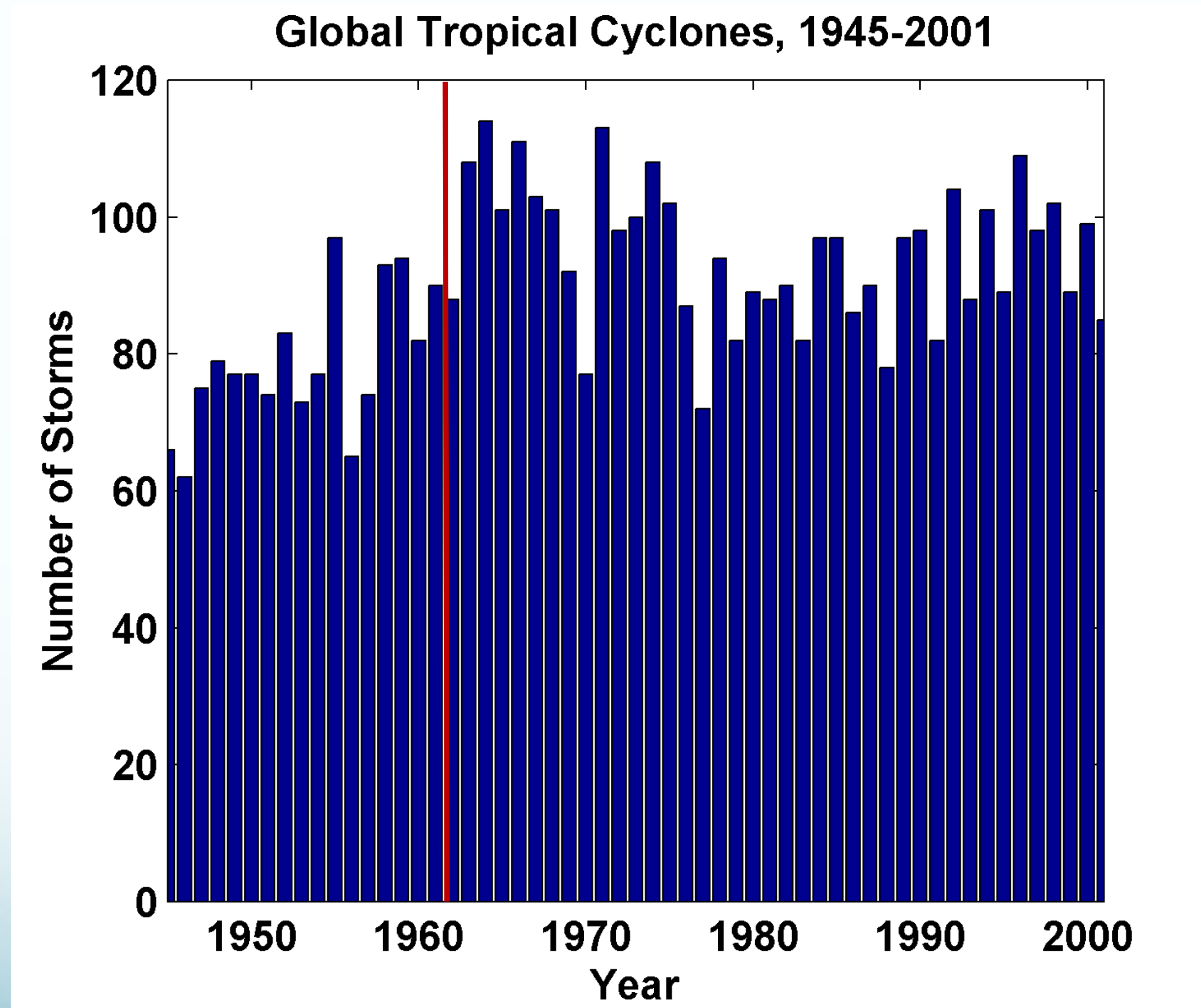
What changes over the decades?



Decadal Variations

- More **Atlantic** tropical storms and major hurricanes in 1995 – 2013 than 1970 – 1994.
 - But 1950-1970 was another active period.
- Natural variability?
 - Sea surface temperatures: Atlantic Multi-Decadal Oscillation
 - Vertical shear: El Niño
- Try looking worldwide because
 - Increases in activity in one region often accompany decreases in another.

Annual Number of Tropical Cyclones Worldwide



W

The record likely shows fewer tropical cyclones prior to the early 1960's because

There simply were fewer then.

After the early 1960s, more ships started encountering tropical cyclones and reporting them.

After the early 1960s, satellites were monitoring all the world's oceans, recording images of almost all tropical cyclones.

Answer

We became better able to detect more tropical cyclones when satellites became operational.

(Ships are now better at avoiding tropical cyclones.)