

ATM S 103

# Hurricanes and Thunderstorms

Their Science and Impacts

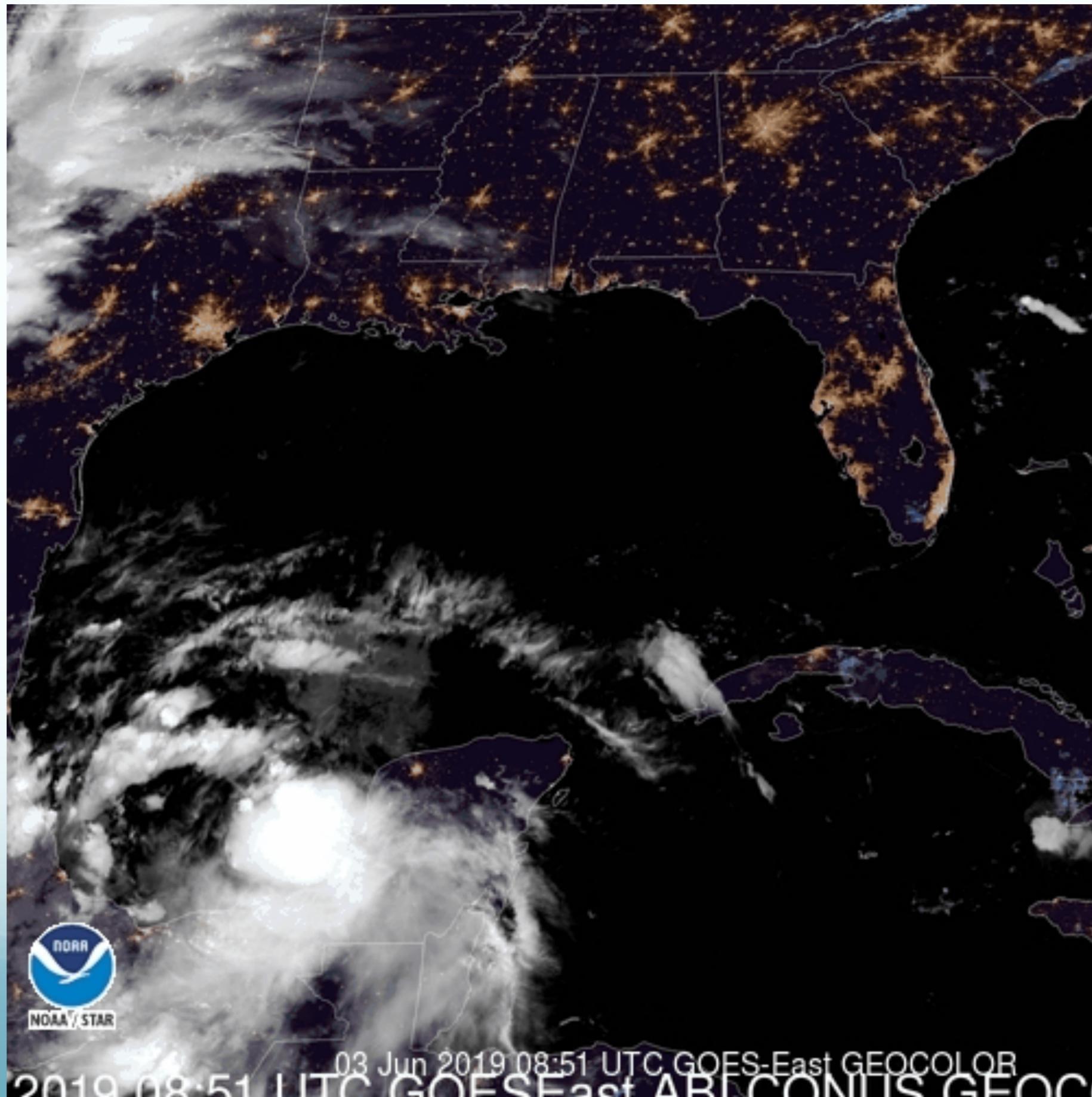


# Atmospheric Sciences Major

- Three tracks
  - Meteorology
  - Climate
  - Atmospheric Chemistry and Air Quality
- Undergraduate Major
  - <https://atmos.uw.edu/students/undergraduate-program/>
- Careers in Atmospheric Science
  - <https://atmos.uw.edu/students/careers-in-atmospheric-science/>

# The Final

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



<https://www.star.nesdis.noaa.gov/GOES/index.php>



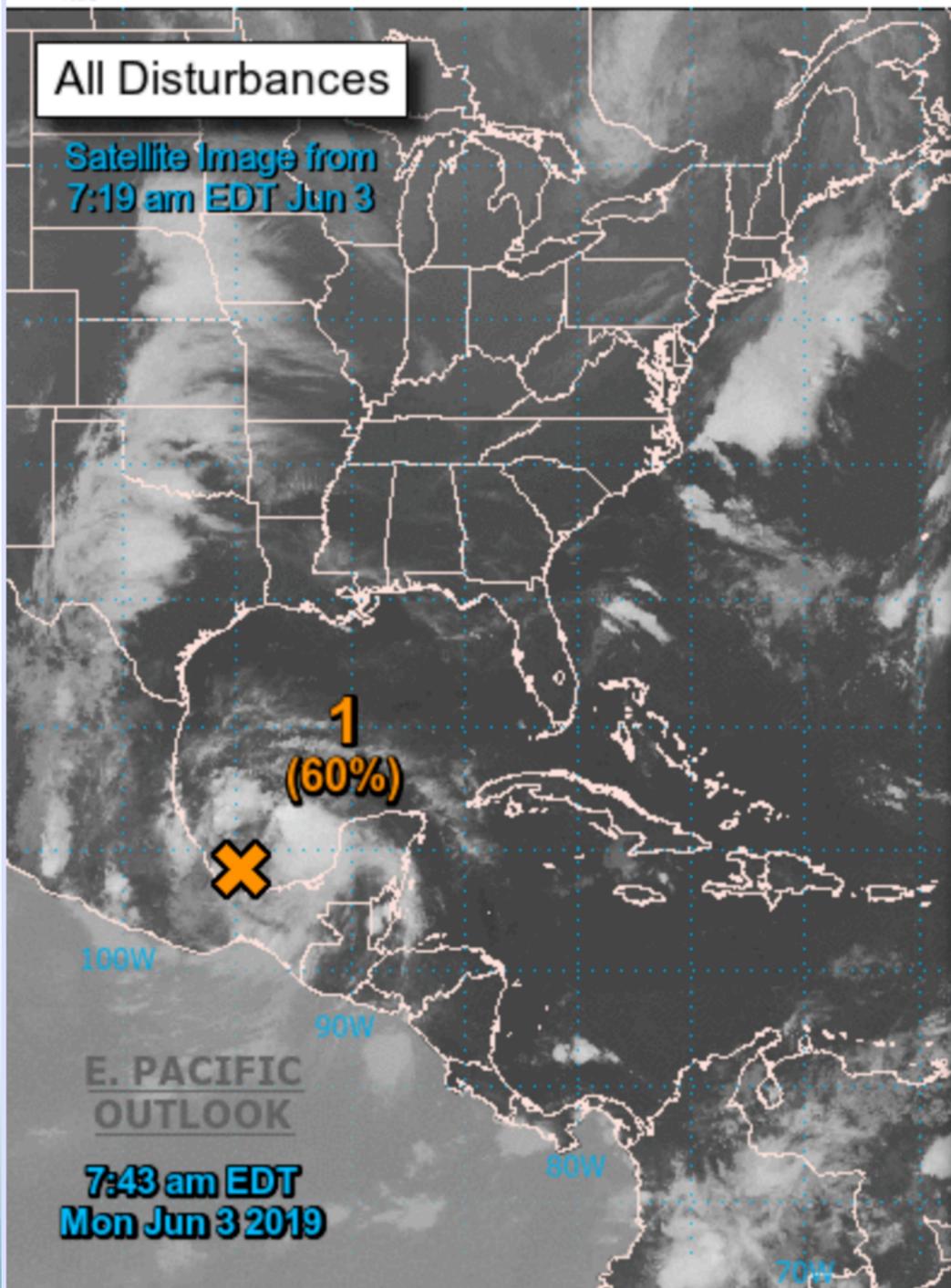
# Two-Day Graphical Tropical Weather Outlook

National Hurricane Center Miami, Florida



All Disturbances

Satellite Image from  
7:19 am EDT Jun 3



Tropical Weather Outlook  
 NWS National Hurricane Center Miami FL  
 800 AM EDT Mon Jun 3 2019

For the North Atlantic...Caribbean Sea and the Gulf of Mexico:

1. A broad area of low pressure is producing disorganized shower and thunderstorm activity over the Bay of Campeche. This system is expected to move slowly northwestward toward the northeastern coast of Mexico, and could become a tropical cyclone before it moves inland in a day or two. Regardless of development, the disturbance will likely produce heavy rainfall over portions of southern and eastern Mexico during the next few days. An Air Force Reserve reconnaissance aircraft will investigate the disturbance this afternoon, if necessary. Interests along the Gulf coast of Mexico should monitor the progress of this system.

\* Formation chance through 48 hours...medium...60 percent.

\* Formation chance through 5 days...medium...60 percent.

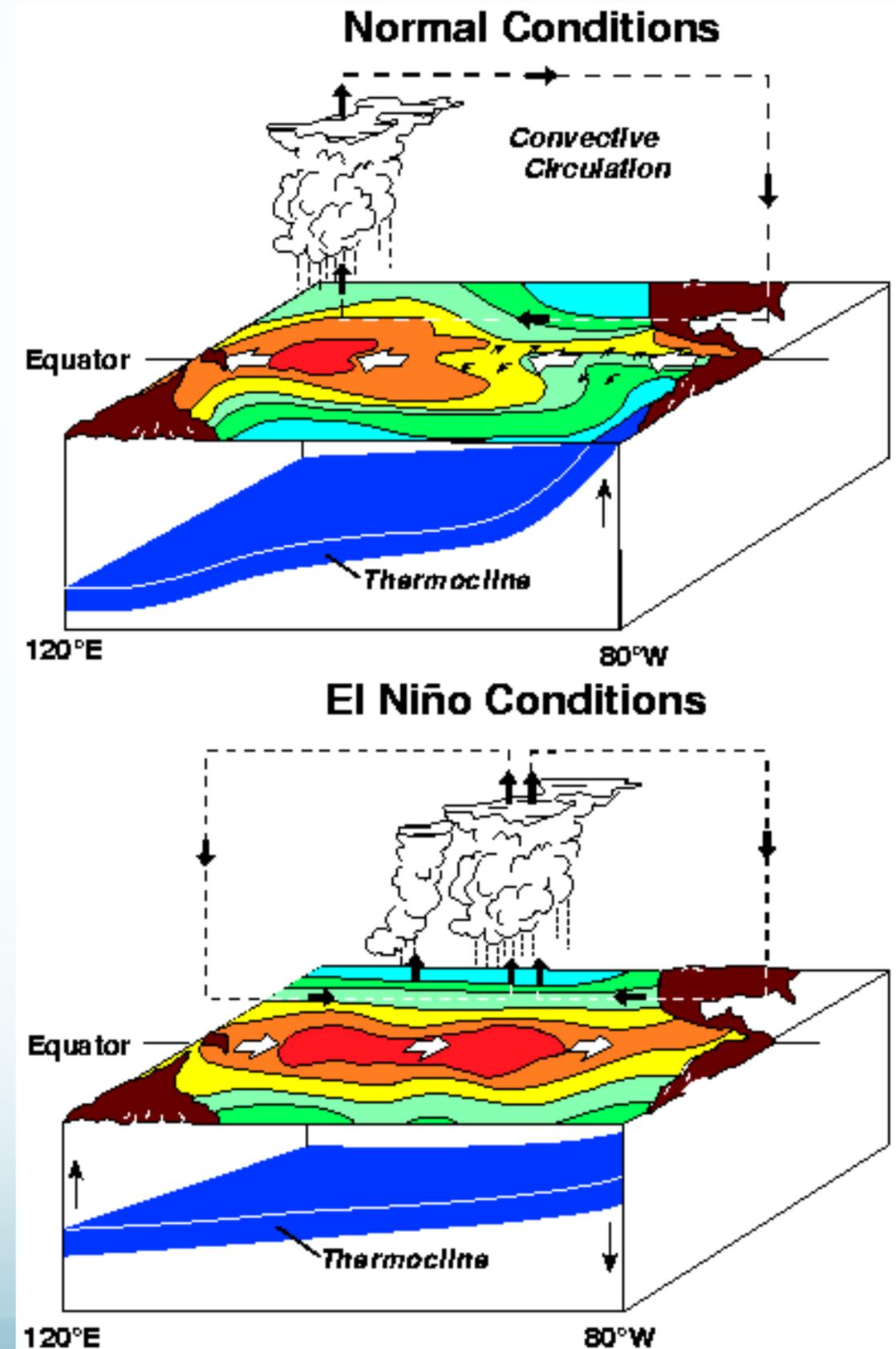
Current Disturbances and Two-Day Cyclone Formation Chance: < 40% 40-60% > 60%  
 Tropical or Sub-Tropical Cyclone: Depression Storm Hurricane  
 Post-Tropical Cyclone or Remnants

# Topics for today

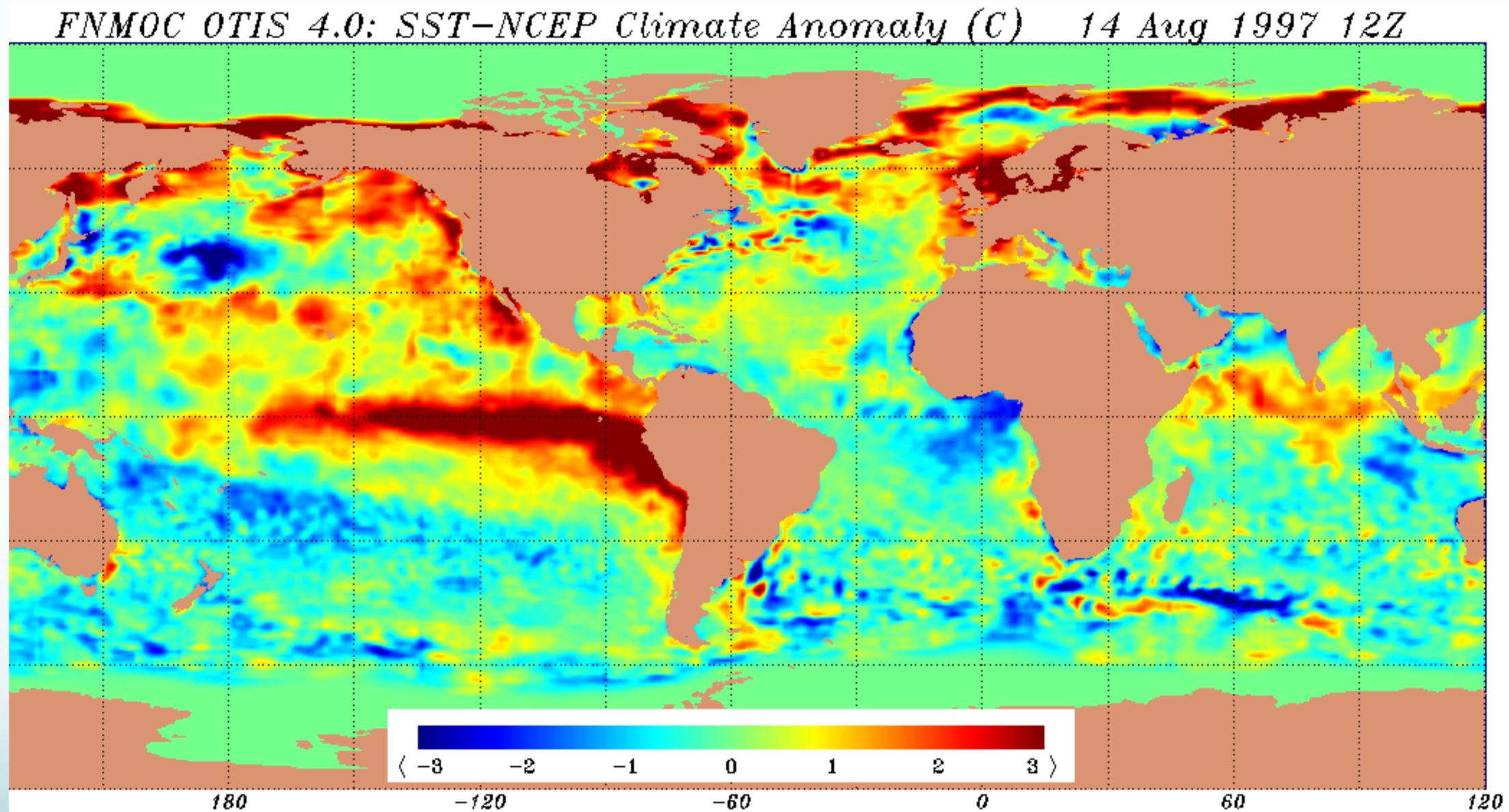
- El Niño and hurricanes
- Forecasting hurricanes

# El Niño

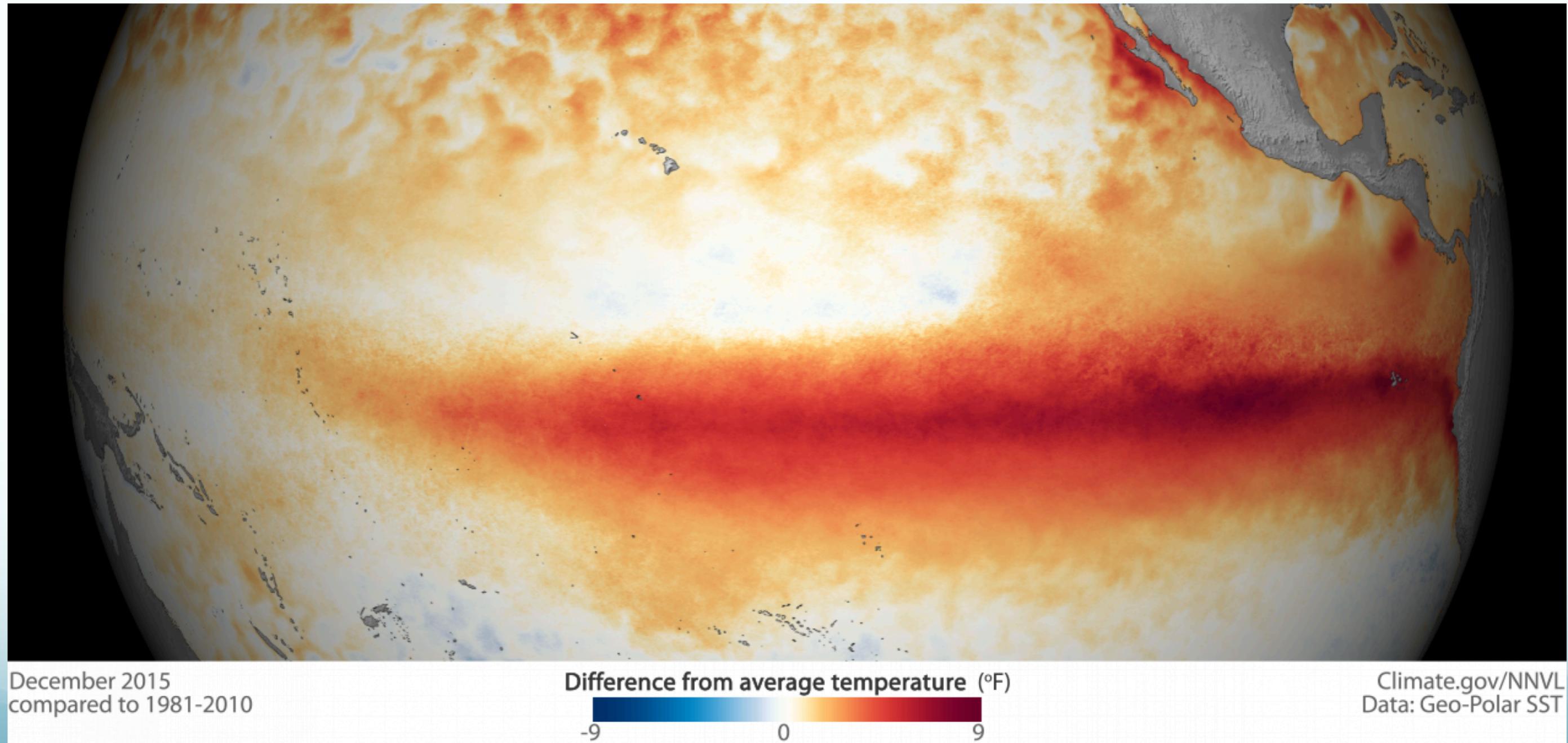
- Is the absence of typical cold conditions in the eastern equatorial Pacific
- Warm **anomaly** (difference from average conditions)
- Influences the atmosphere by shifting thunderstorm activity eastward along the equator



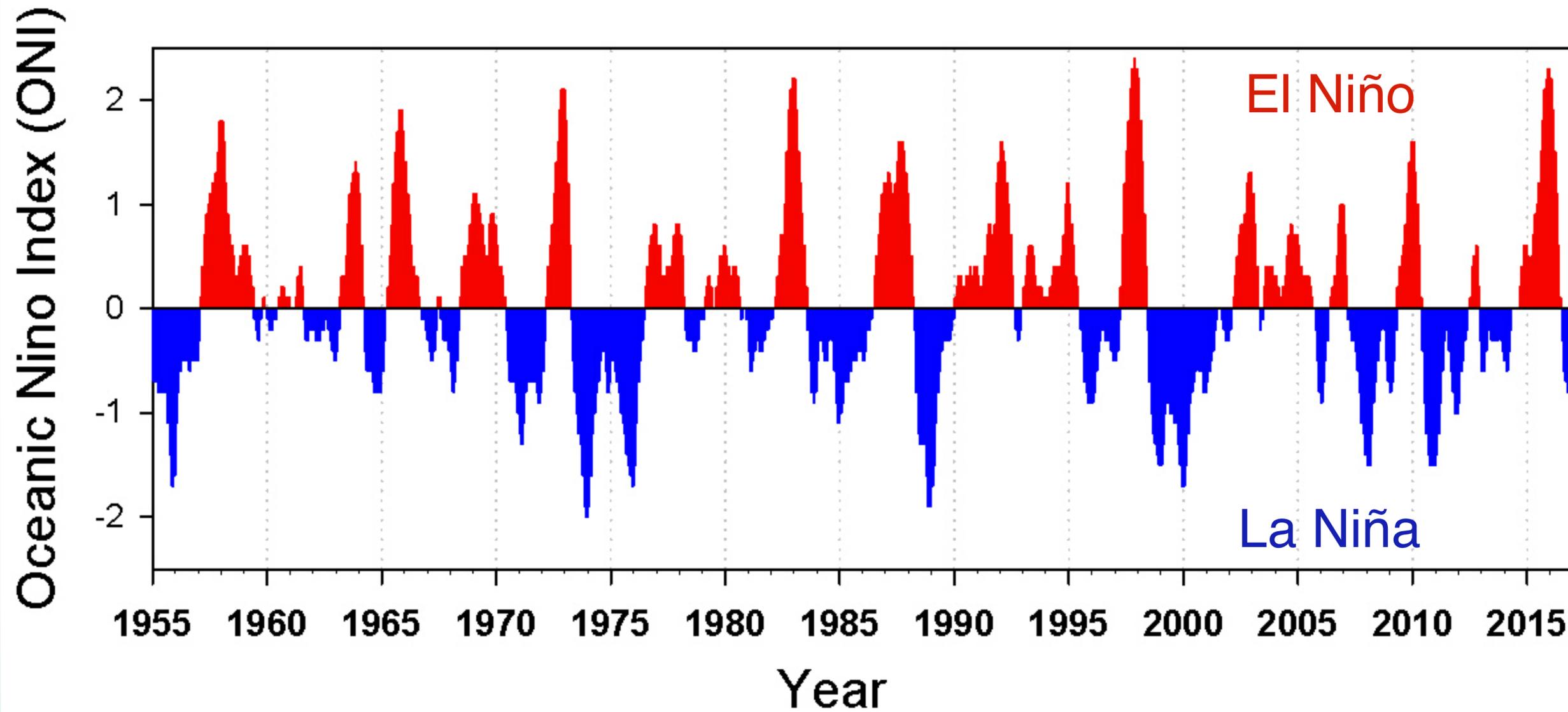
# 1997-1998 El Niño SST Anomaly



# 2015-2016 El Niño Sea-Surface-Temperature Anomaly



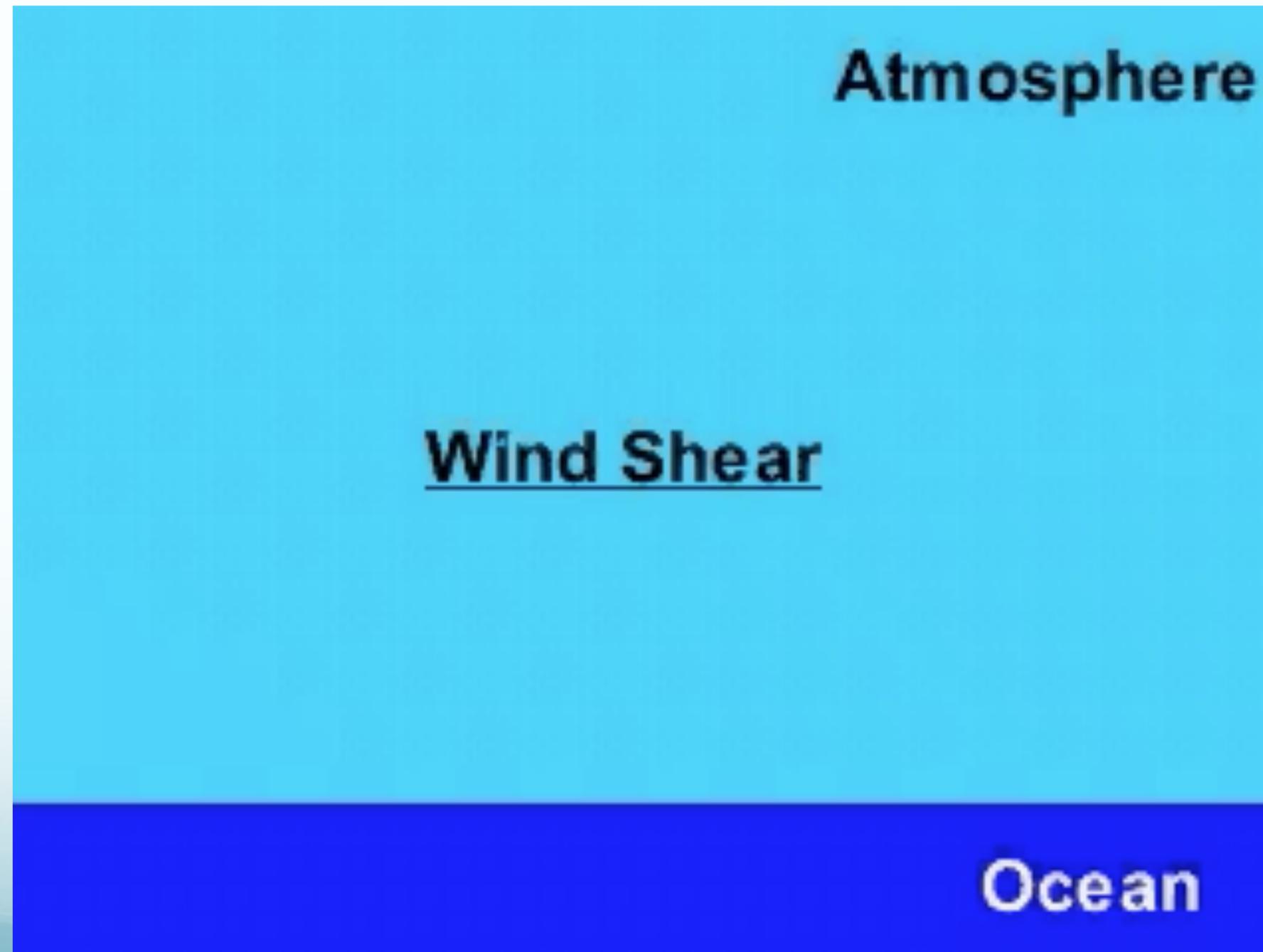
# East Pacific Sea-Surface Temperature Anomaly by Year



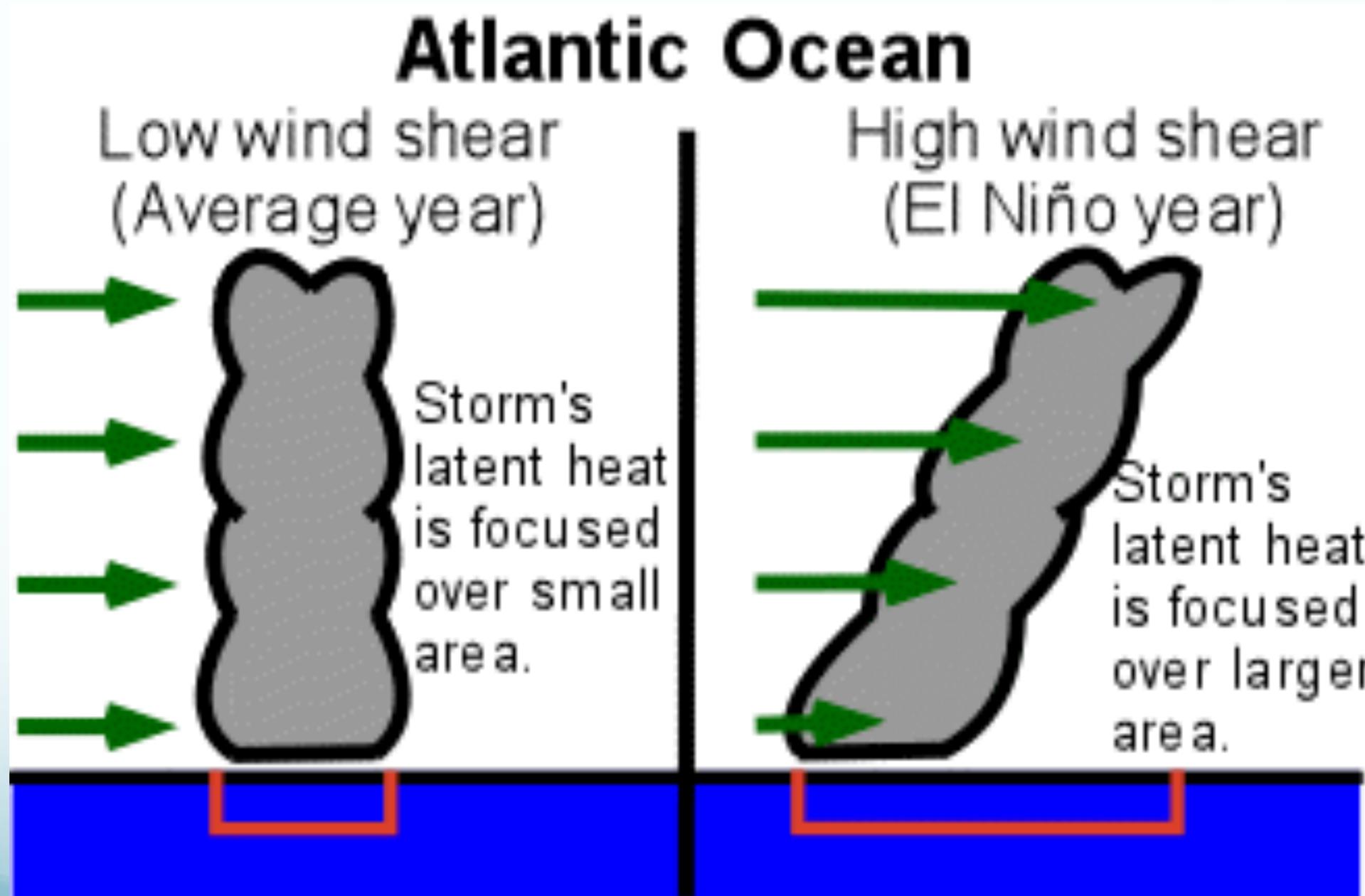
# Some El Niño Impacts

- **Increases** the environmental vertical wind shear in the Tropical Atlantic
- **Decreases** the environmental vertical wind shear in the Eastern Pacific
- Tends to make the winters warmer and drier in the Pacific Northwest

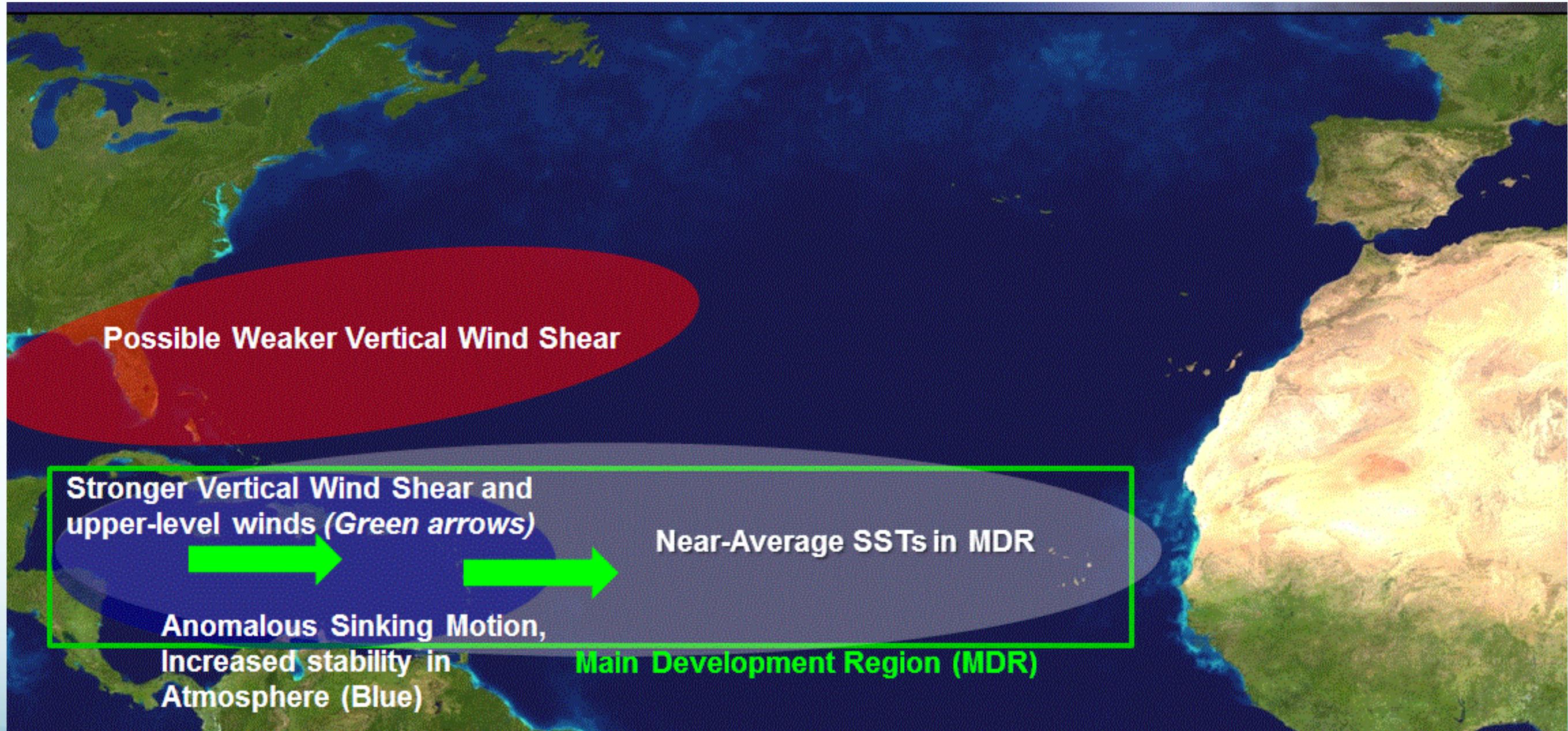
# Vertical wind shear and hurricane development



# El Niño and Atlantic Hurricanes



# El Niño Impacts in Atlantic



W

Vertical wind shear \_\_\_ the formation of strong tornadoes and \_\_\_  
the formation of hurricanes

inhibits, helps

helps, inhibits

inhibits,  
inhibits

helps, helps

# Answer

- Vertical wind shear helps make strong tornadoes by:
  - Making an environment favorable for supercell thunderstorms
  - Providing a source of initial rotation around a horizontal axis that gets tilted into the vertical in the thunderstorm updraft
- As just discussed, vertical wind shear tends to tear hurricanes apart by shifting the top of the storm relative to the bottom.

# “Superstorm” Sandy



About \$65 billion in  
damages in the US

Seaside Heights, NJ





## Most Atlantic hurricanes initially travel westward because

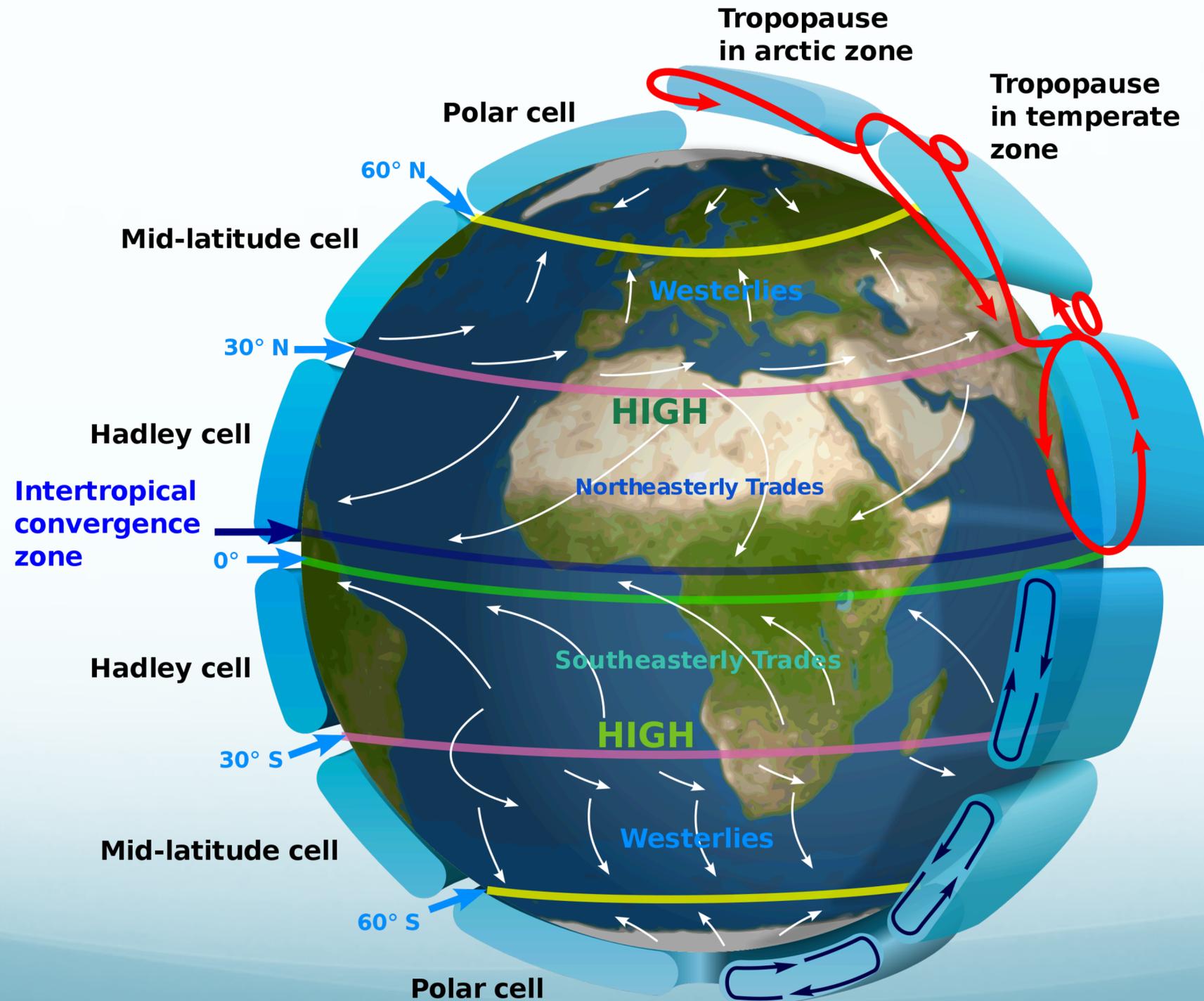
the winds near the equator  
blow westward.

the Coriolis force makes  
them travel westward.

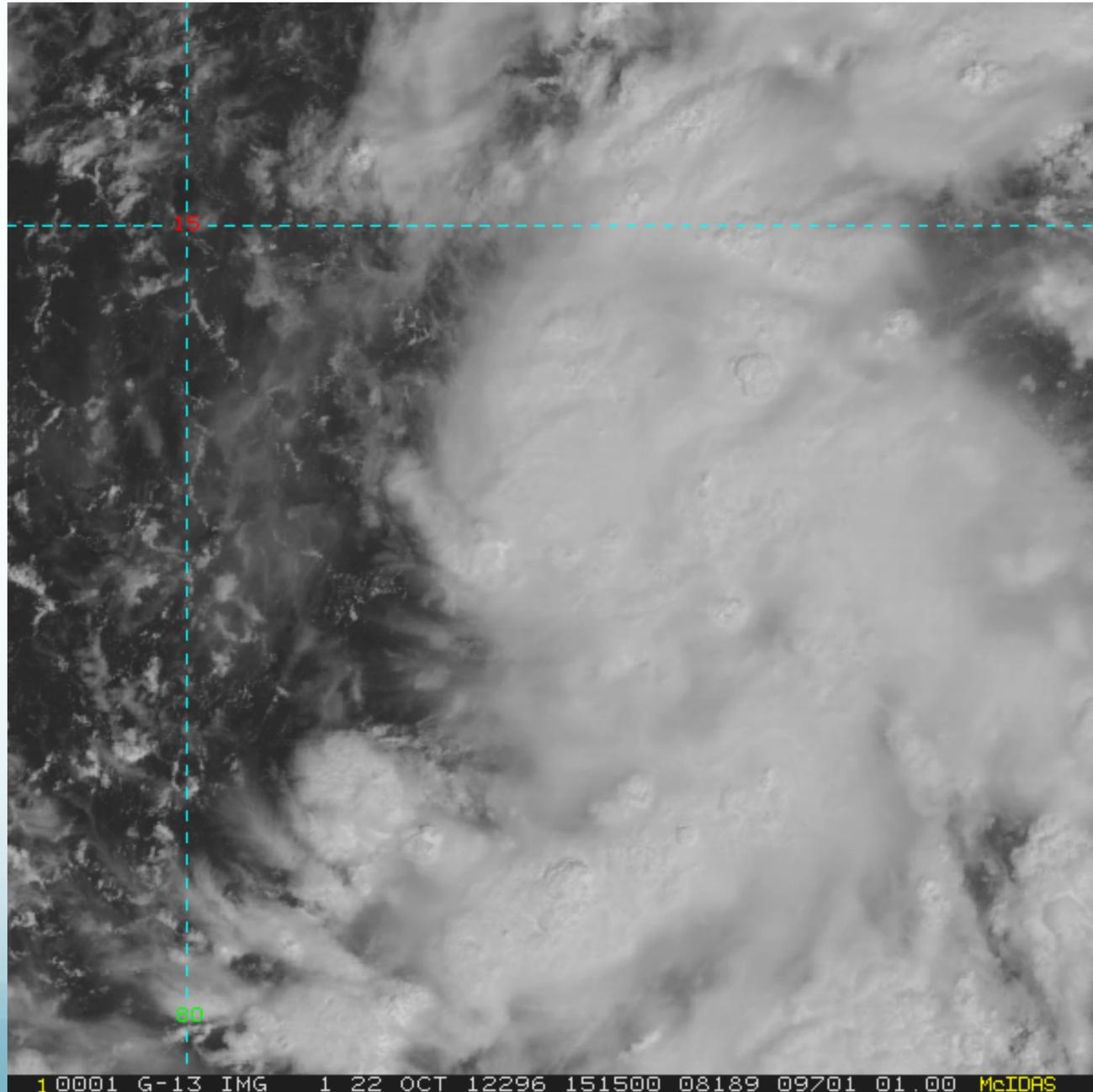
vertical wind shear favors  
storms that travel westward.

all of these answers are  
correct.

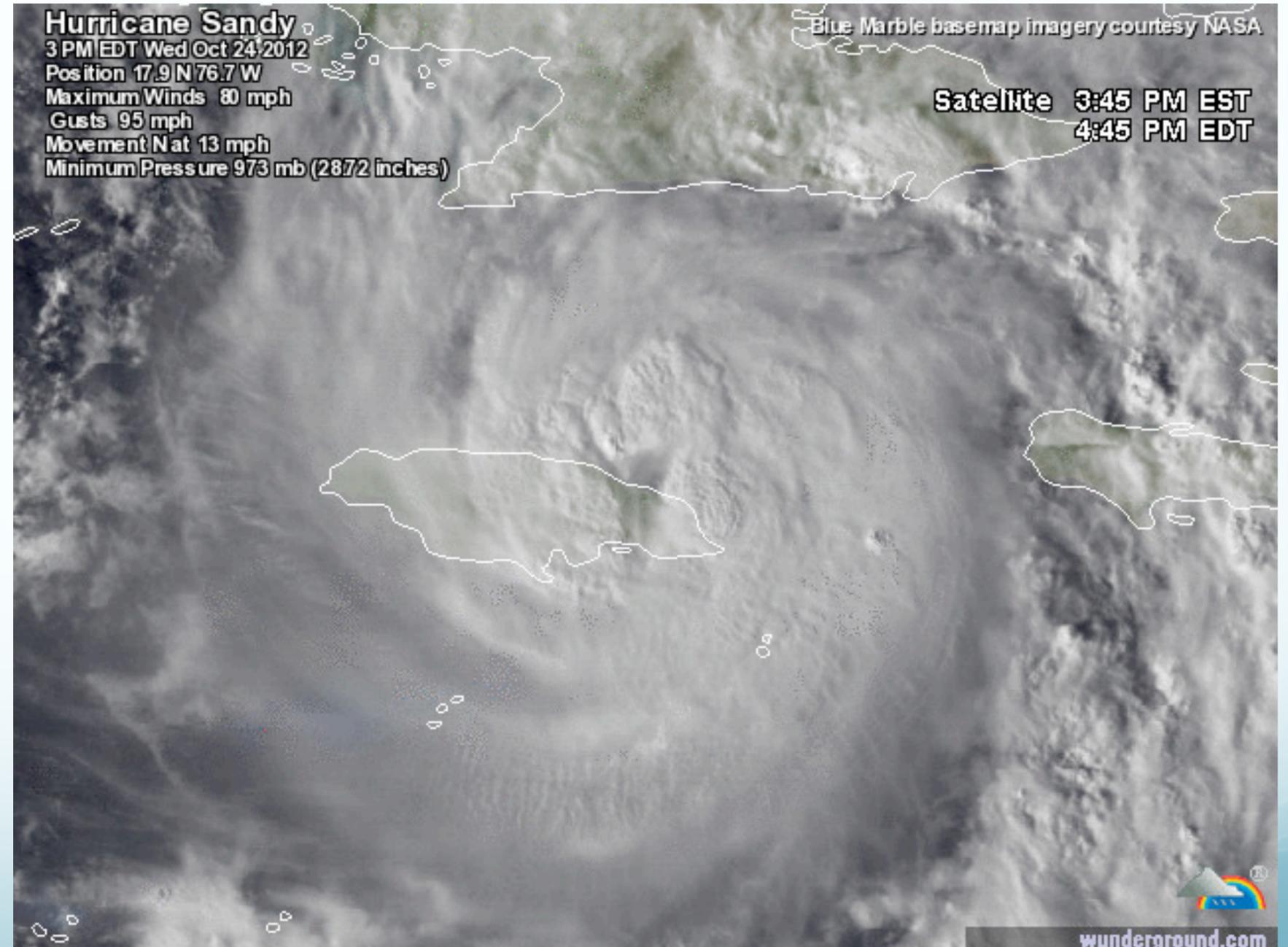
# Answer: Trade Wind



# Sandy



Oct. 22, 2012, NHC names Tropical Depression 18, then a few hours later upgrades to Tropical Storm Sandy



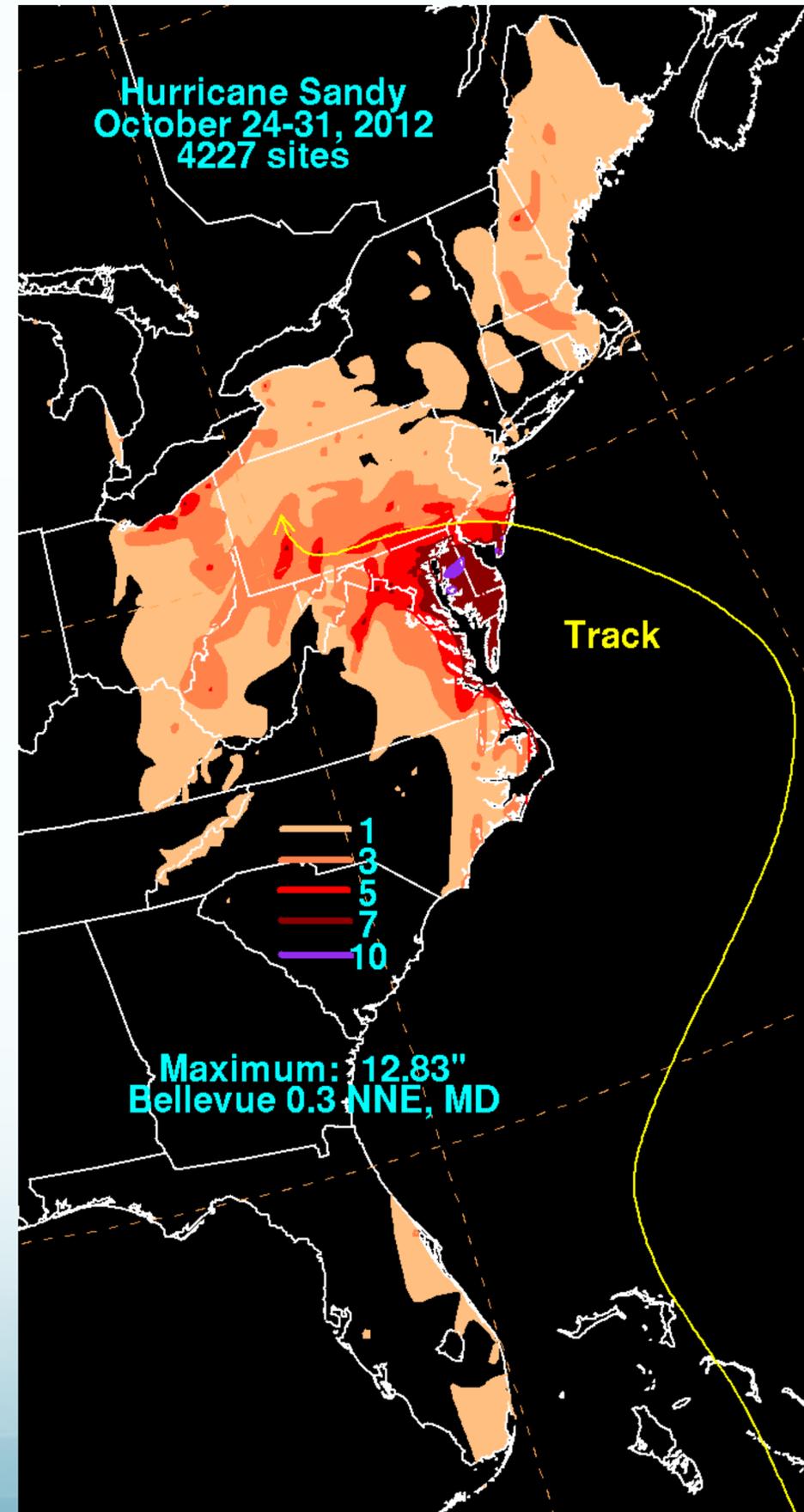
Wed. 10/24 – landfall in Jamaica (cat 1)  
Cuba next day 10/25 (cat 2)

# Satellite Loop: Oct 21 – 31, 2012

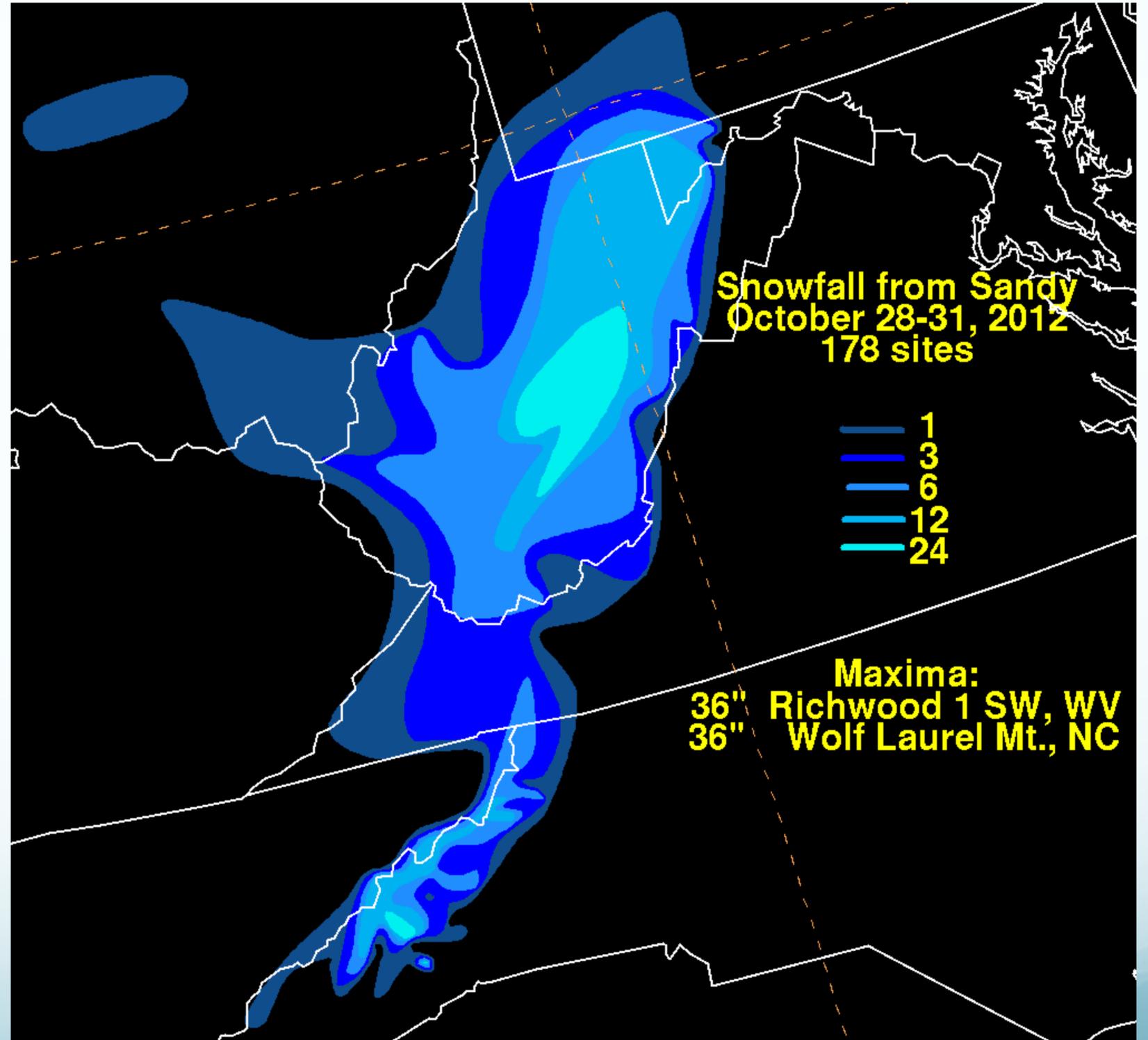
Landfall 23:30 UTC October 29<sup>th</sup> (7:30 PM EDT)

Shorter loop

# Sandy Rainfall



# Sandy Snowfall

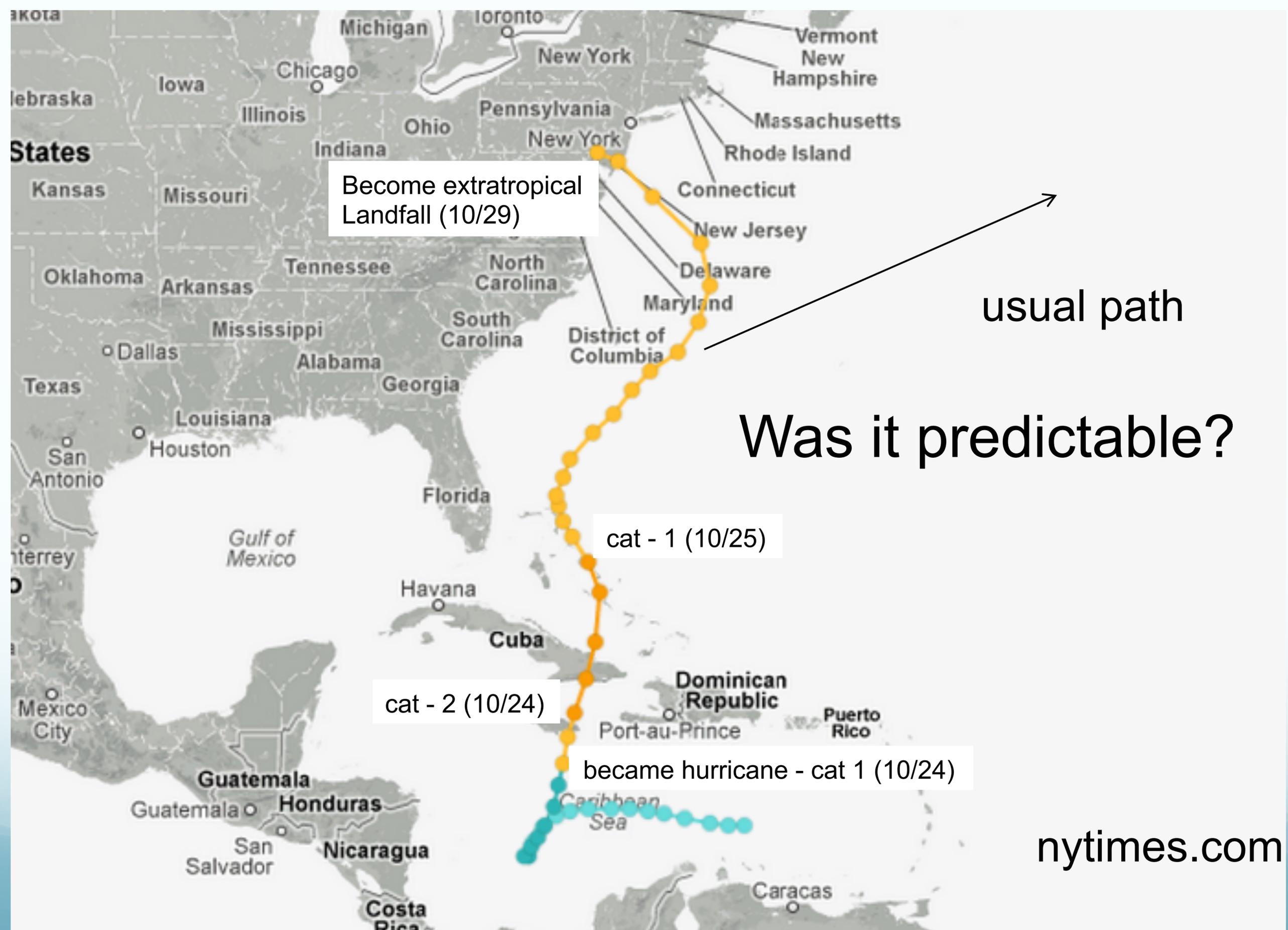


# Striking NYC

- Power outages in Manhattan, destruction in Rockaway, Queens

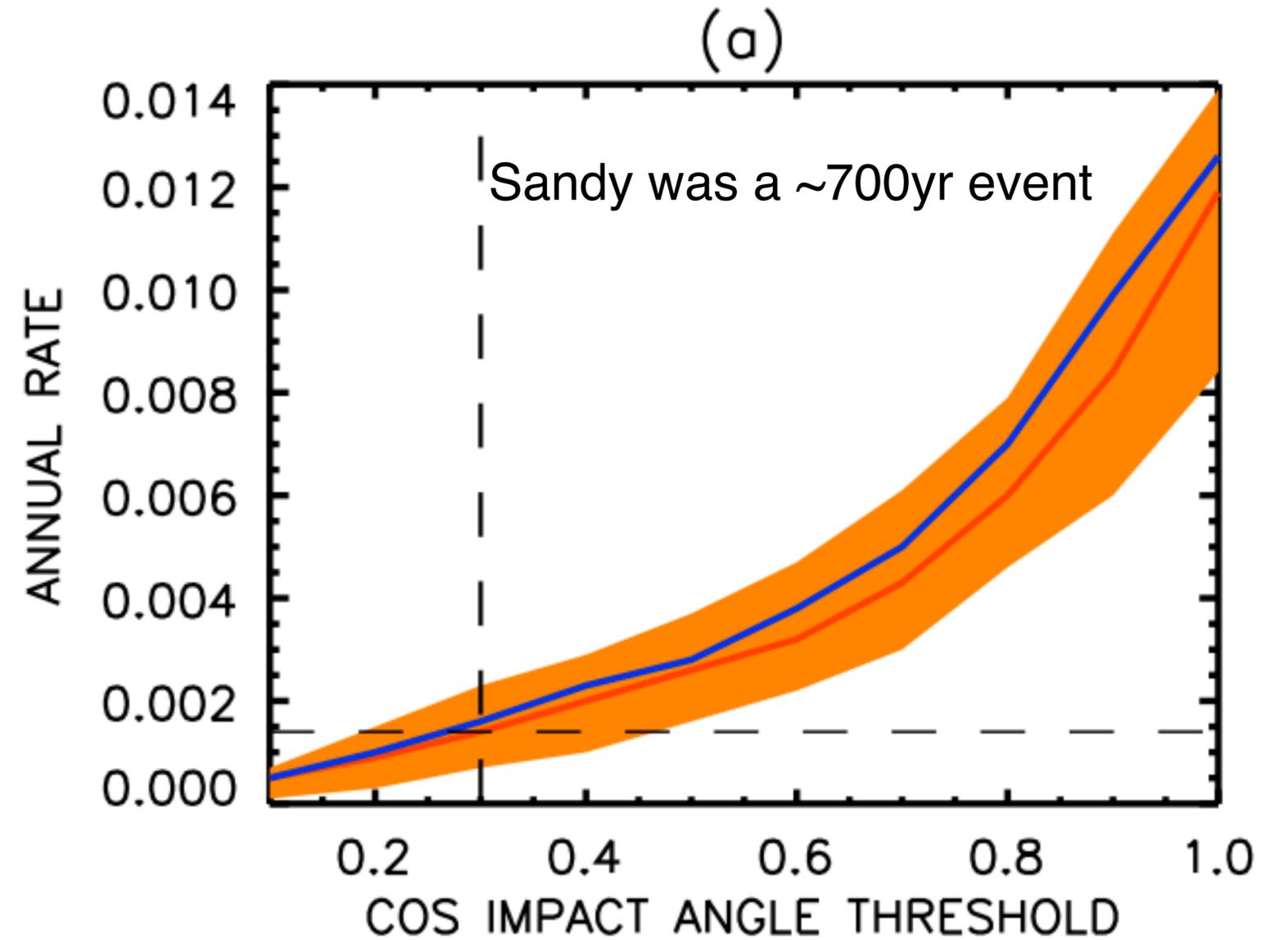
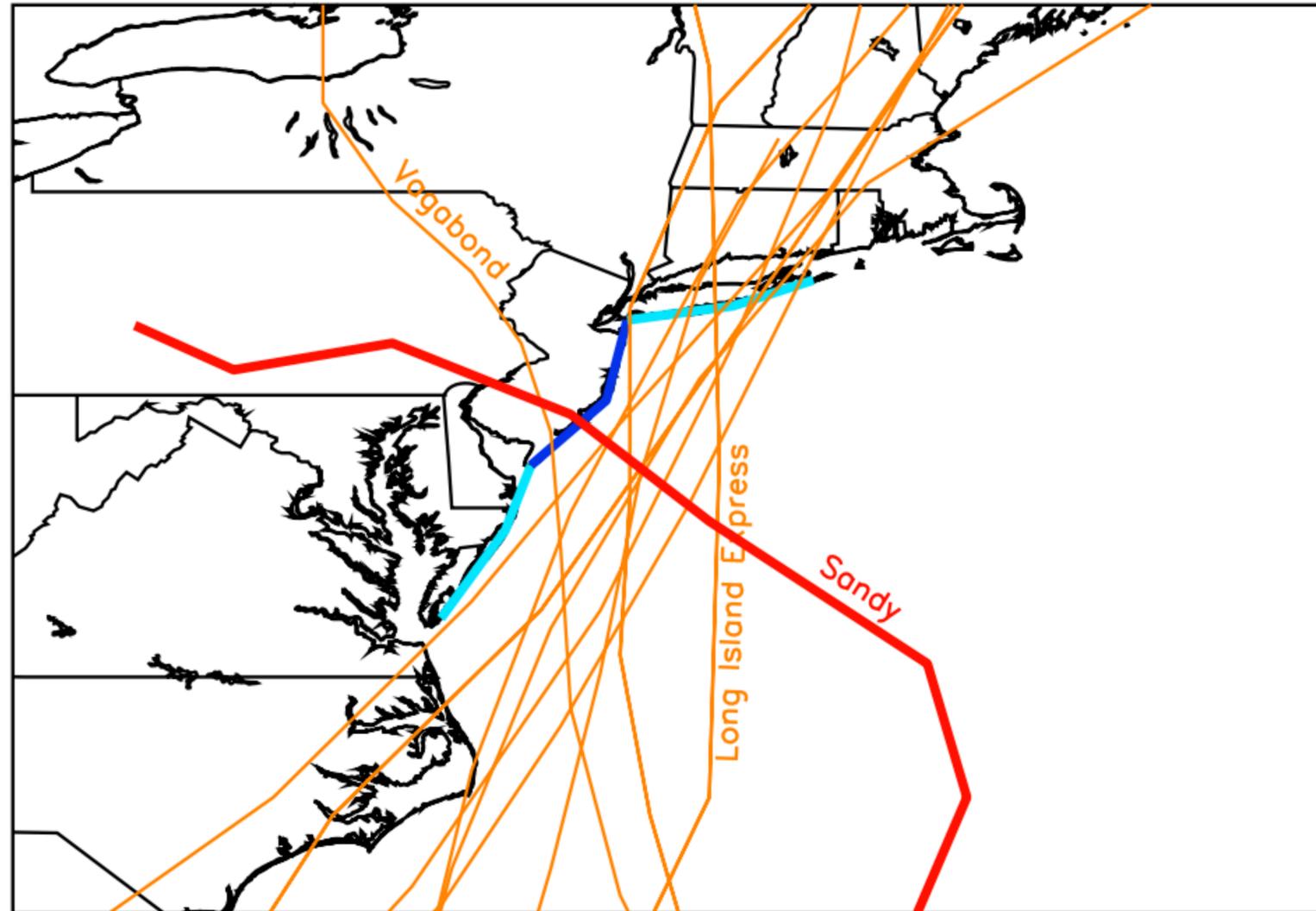
[BBC - Anatomy of a Superstorm Sandy](#)





nytimes.com

# How rare an event was this?



# Was it predictable?

Valid 2012 10 25 0000 UTC



Valid 2012 10 25 0000 UTC



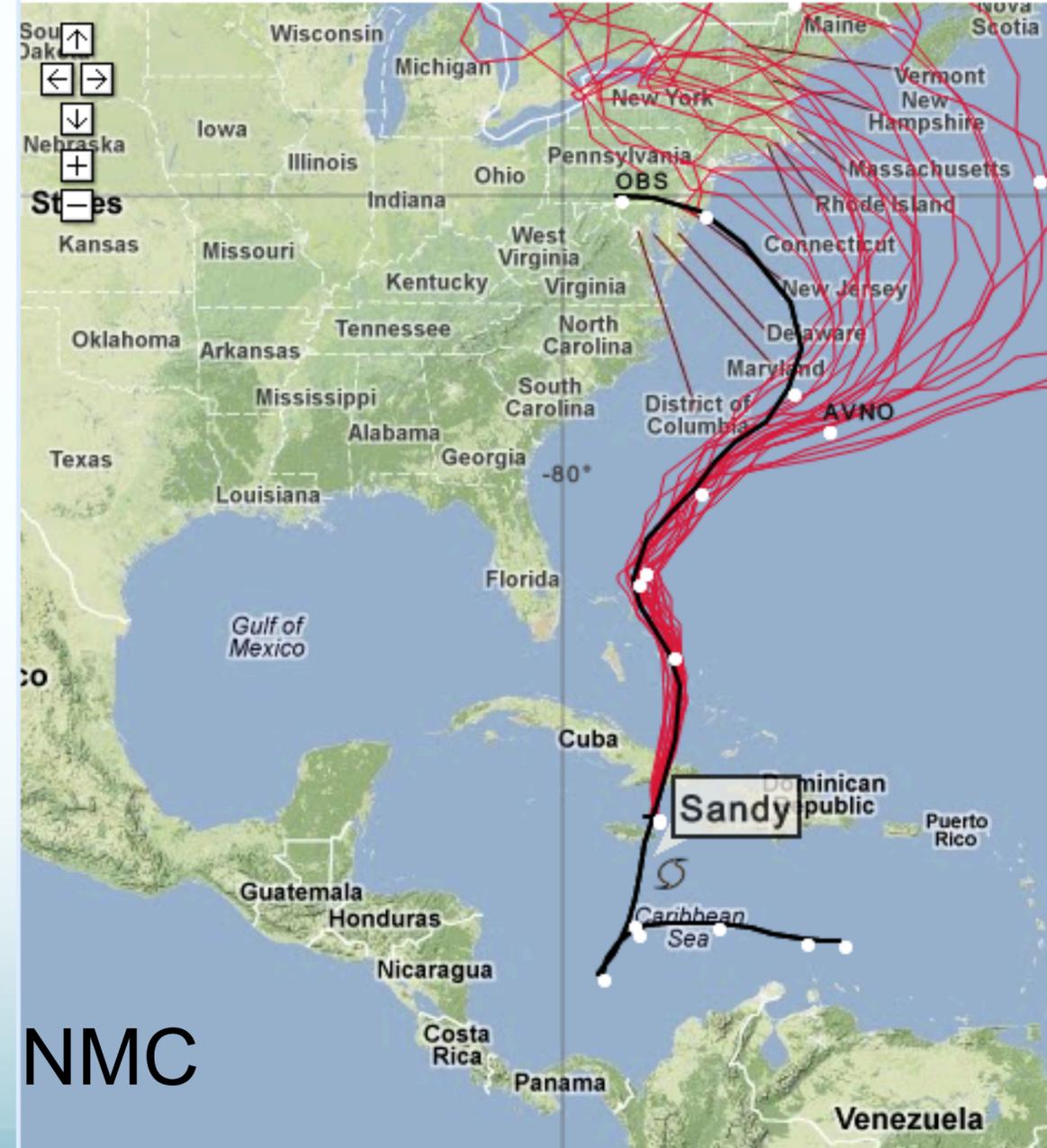
# Was it predictable?

Valid 2012 10 25 0000 UTC



ECMWF

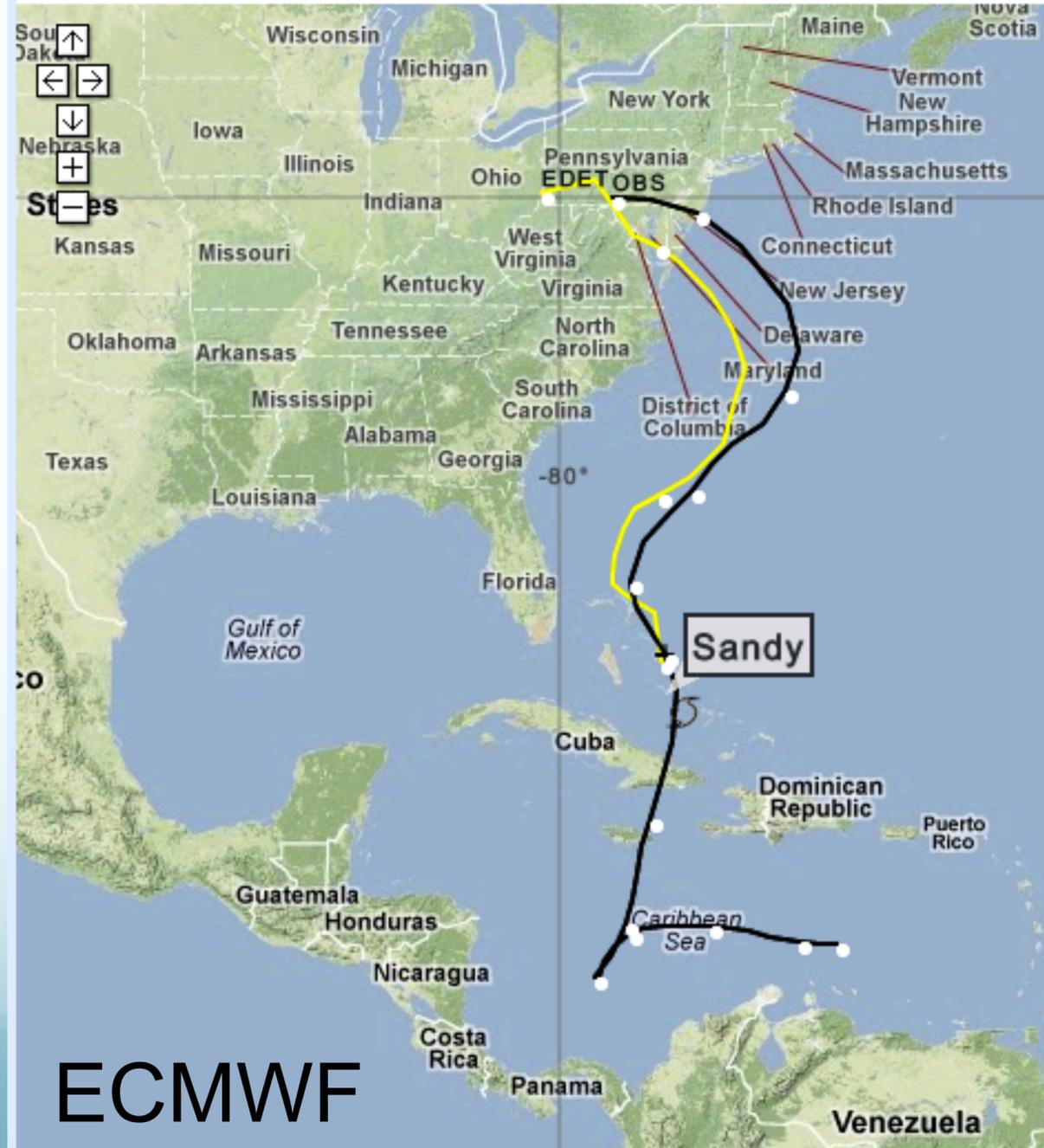
Valid 2012 10 25 0000 UTC



NMC

# Was it predictable?

Valid 2012 10 26 0000 UTC

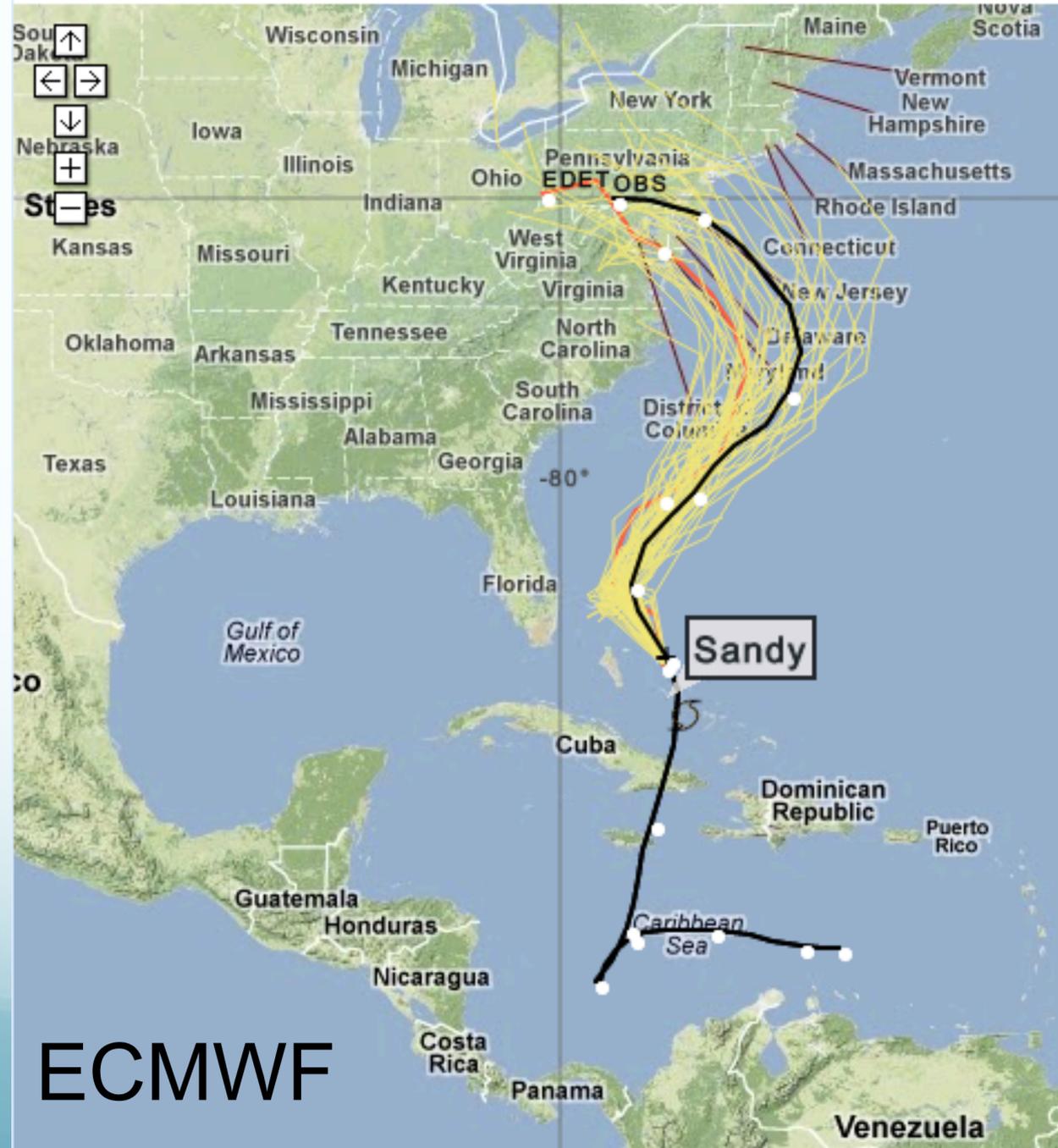


Valid 2012 10 26 0000 UTC

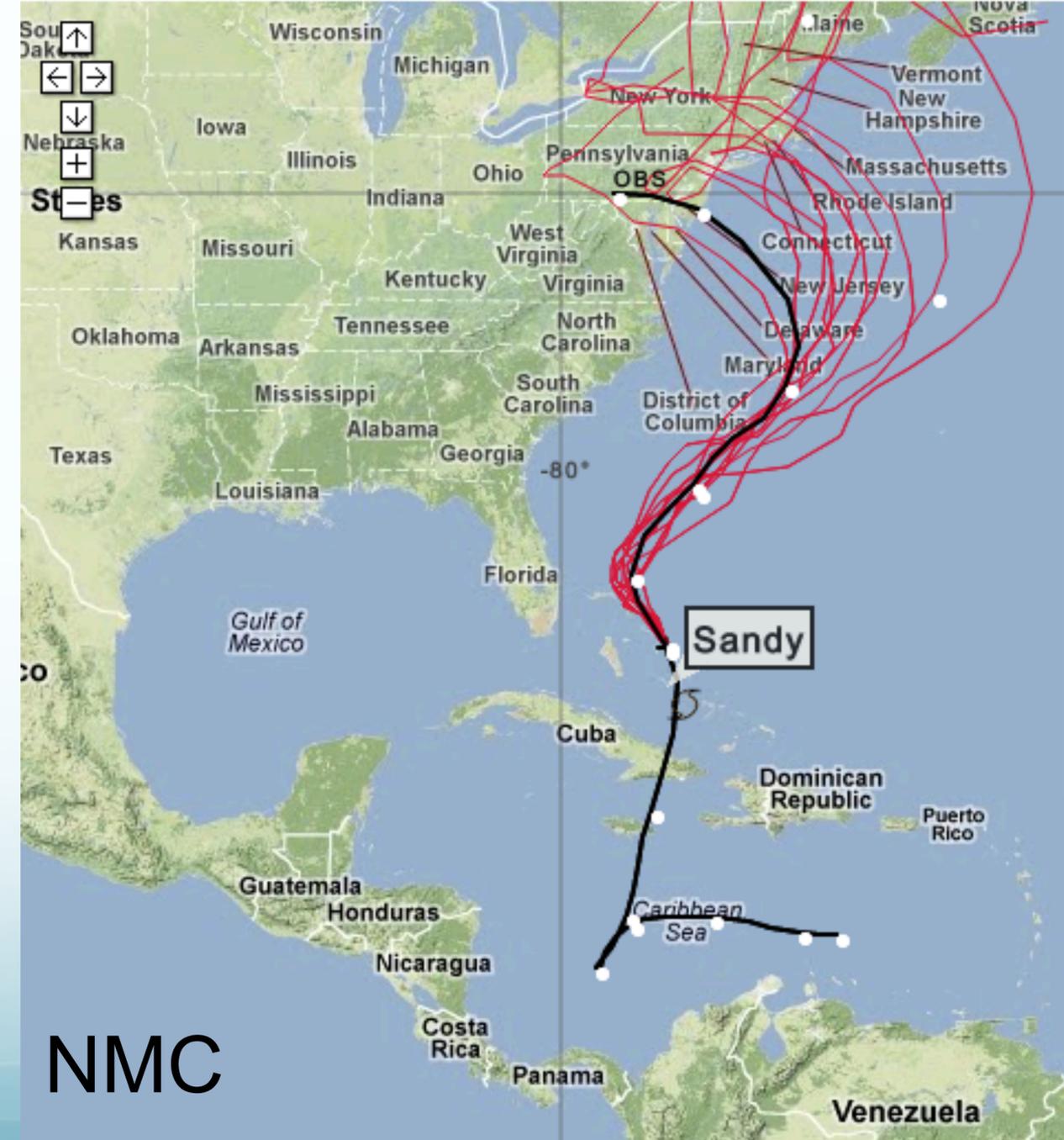


# Was it predictable?

Valid 2012 10 26 0000 UTC



Valid 2012 10 26 0000 UTC



# Was it predictable?

Valid 2012 10 27 0000 UTC

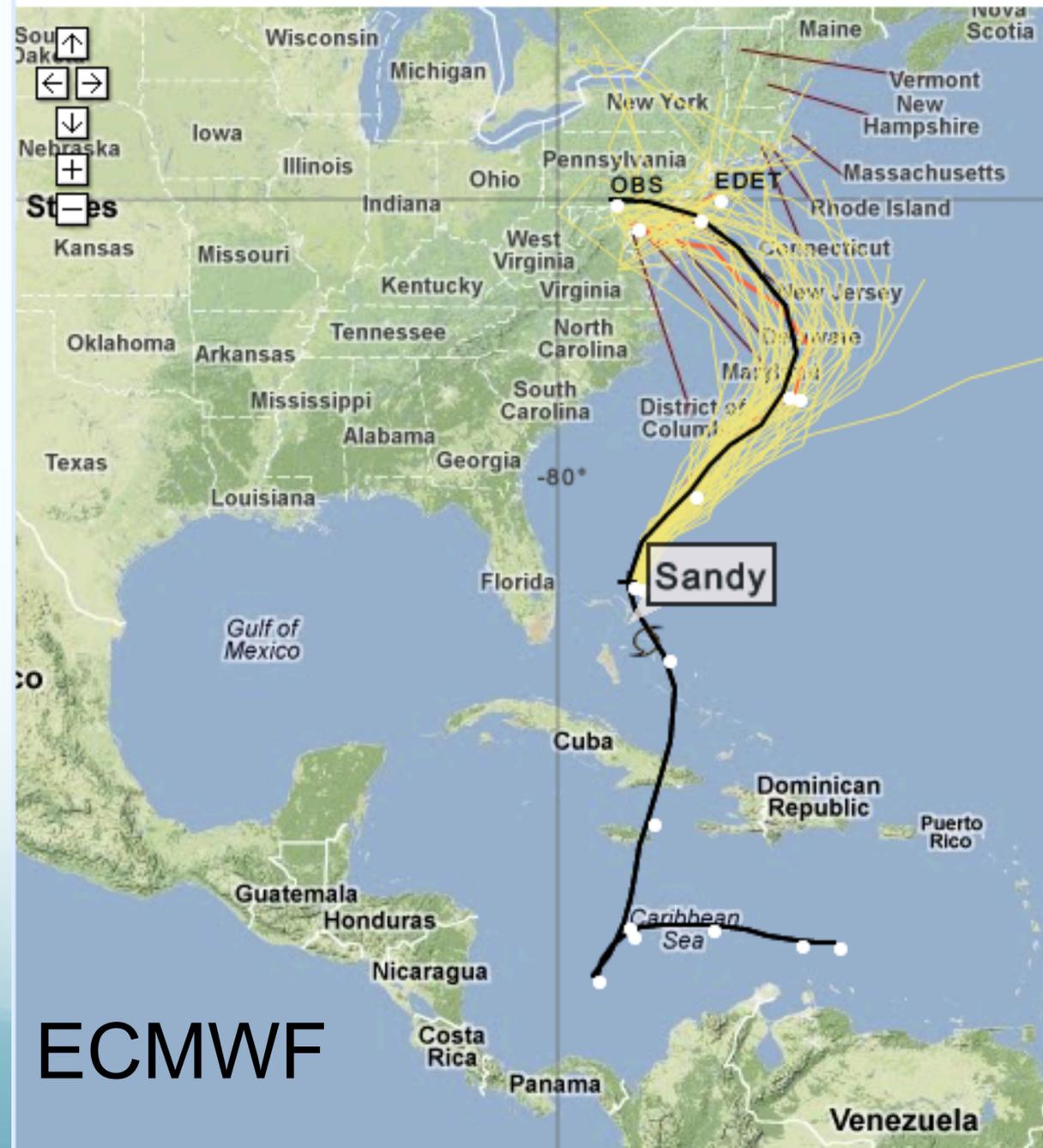


Valid 2012 10 27 0000 UTC

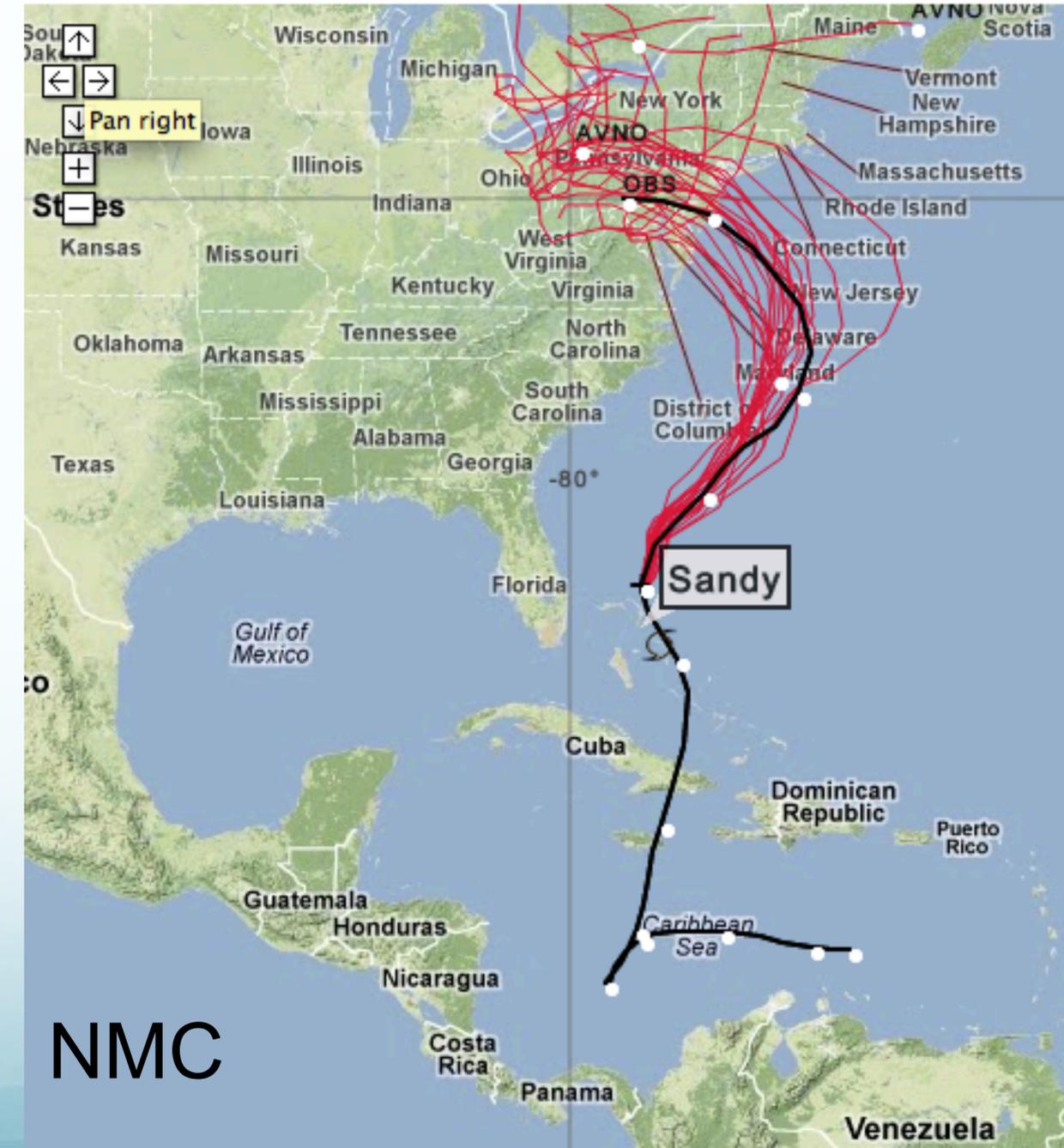


# Was it predictable?

Valid 2012 10 27 0000 UTC



Valid 2012 10 27 0000 UTC



# Forecasting Hurricanes

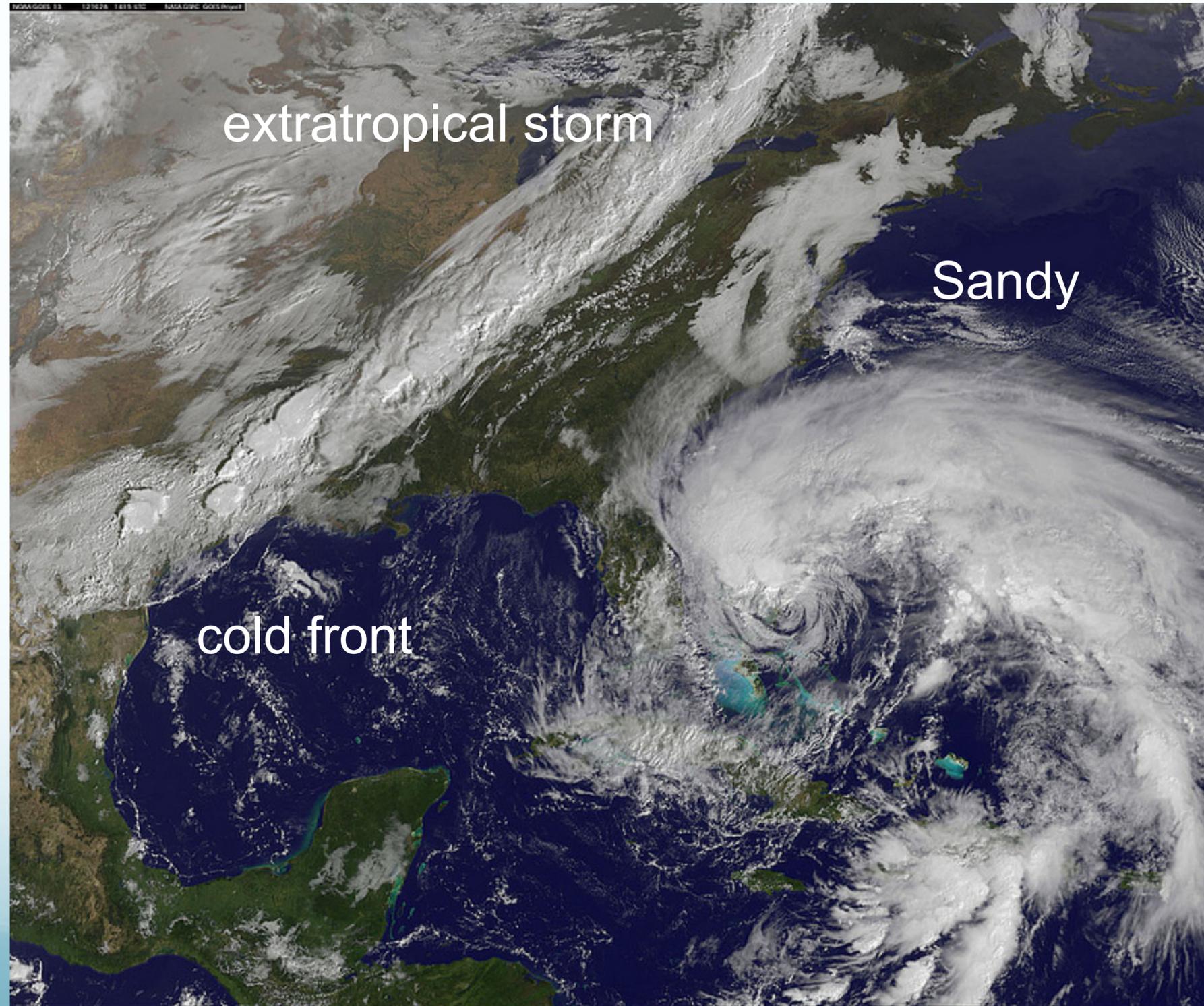
- Sandy forecast was good — by the European Center!
  - Led to improvements in NWS computing resources
- Key issue is forecast lead time

# Direct Fatalities

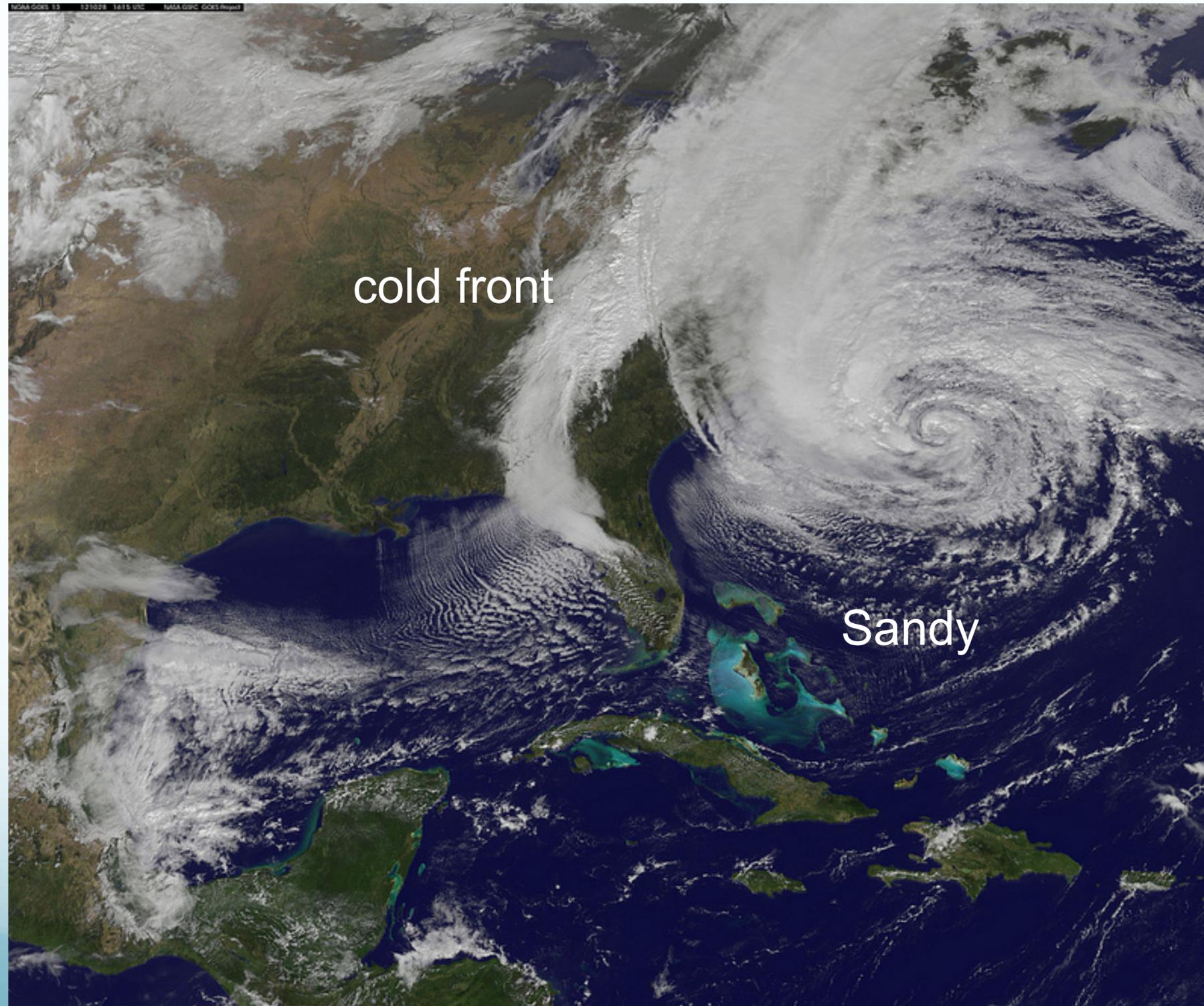
- US 73
- Haiti 54
- Cuba 11



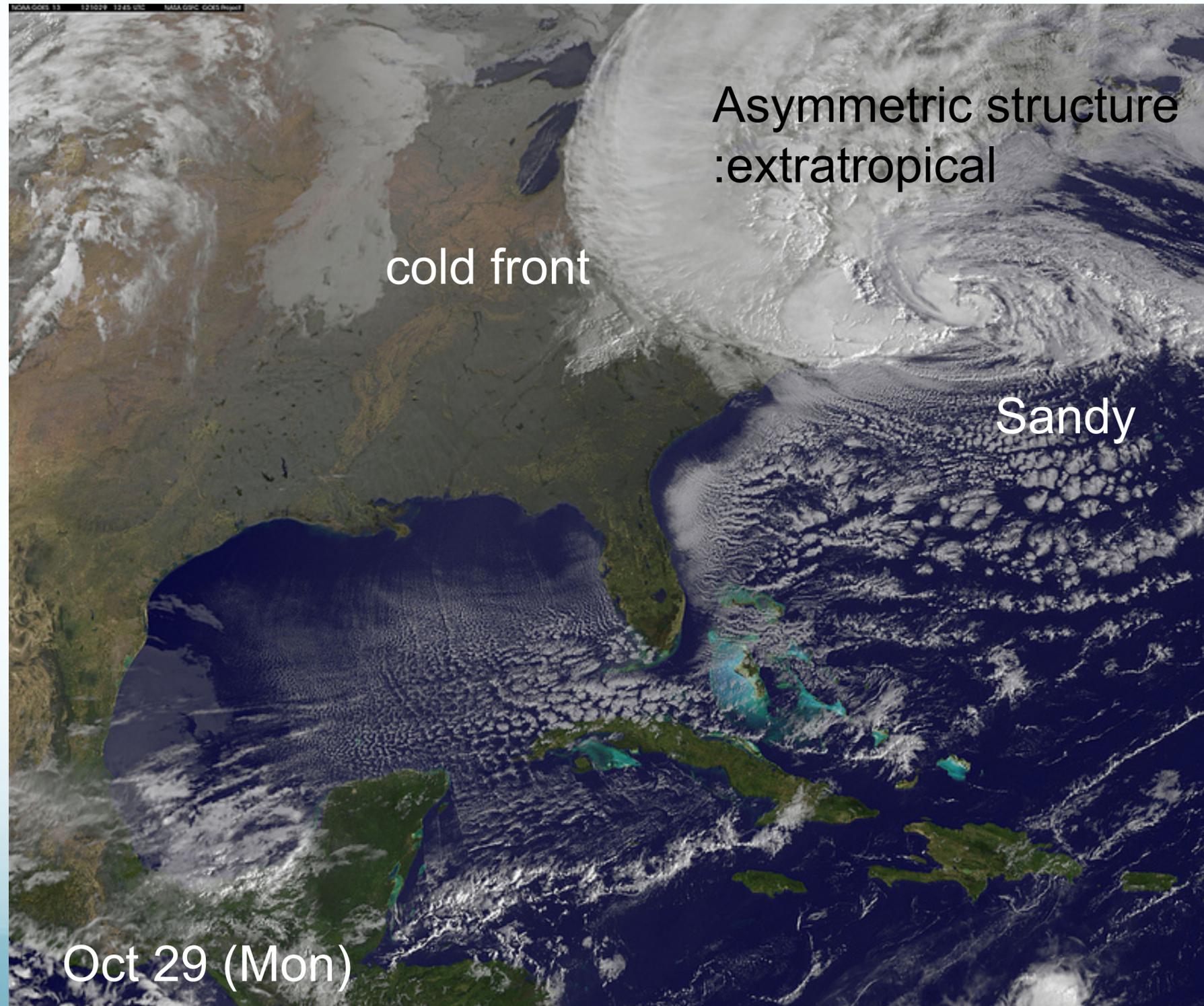
# Sandy's Transition to Extratropical Cyclone



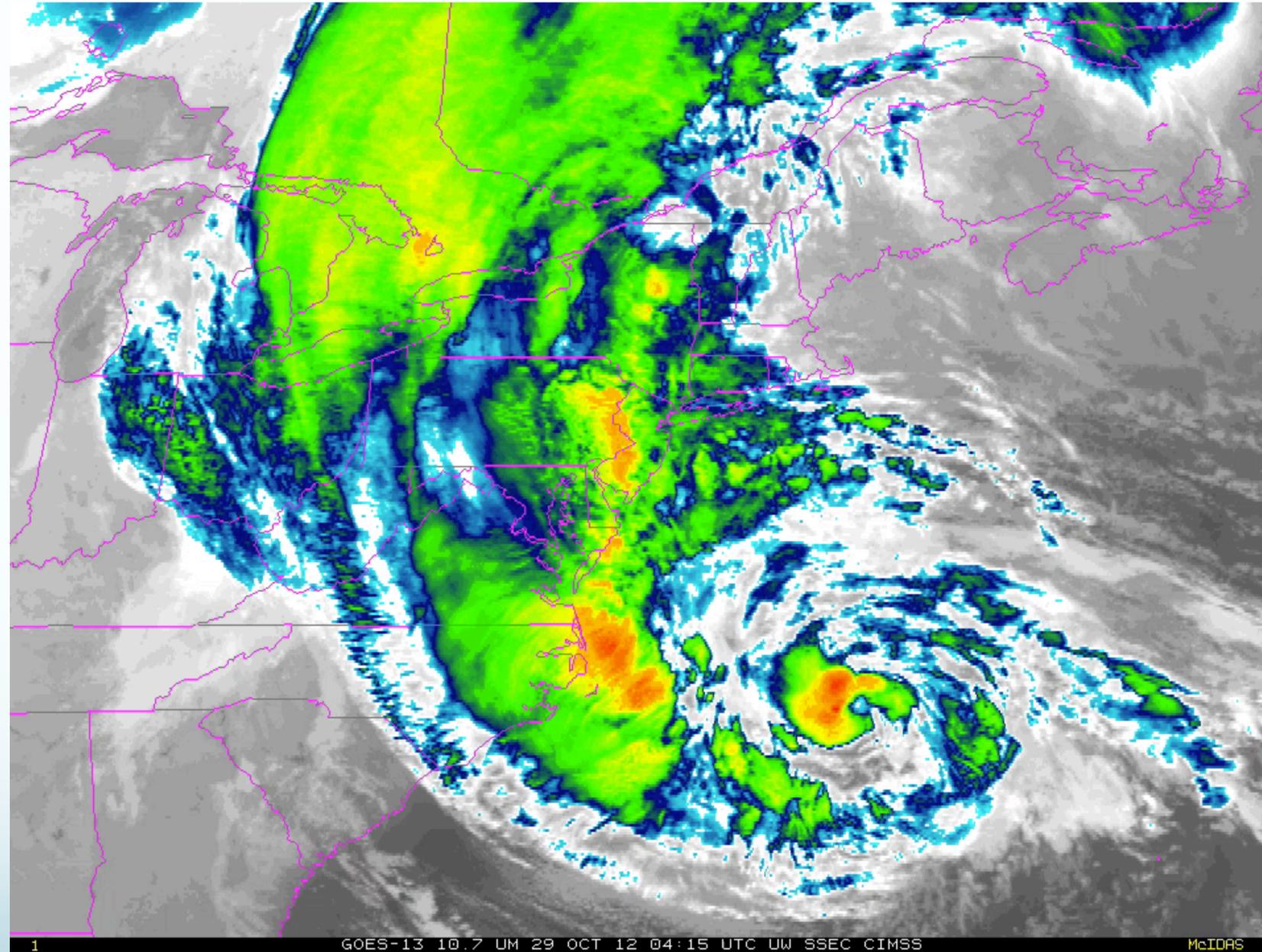
# Sandy's Transition to Extratropical Cyclone



# Sandy's Transition to Extratropical Cyclone



# Enhanced IR Satellite Loop Shows Transition to Extratropical Cyclone



# The Transition to Extratropical Caused

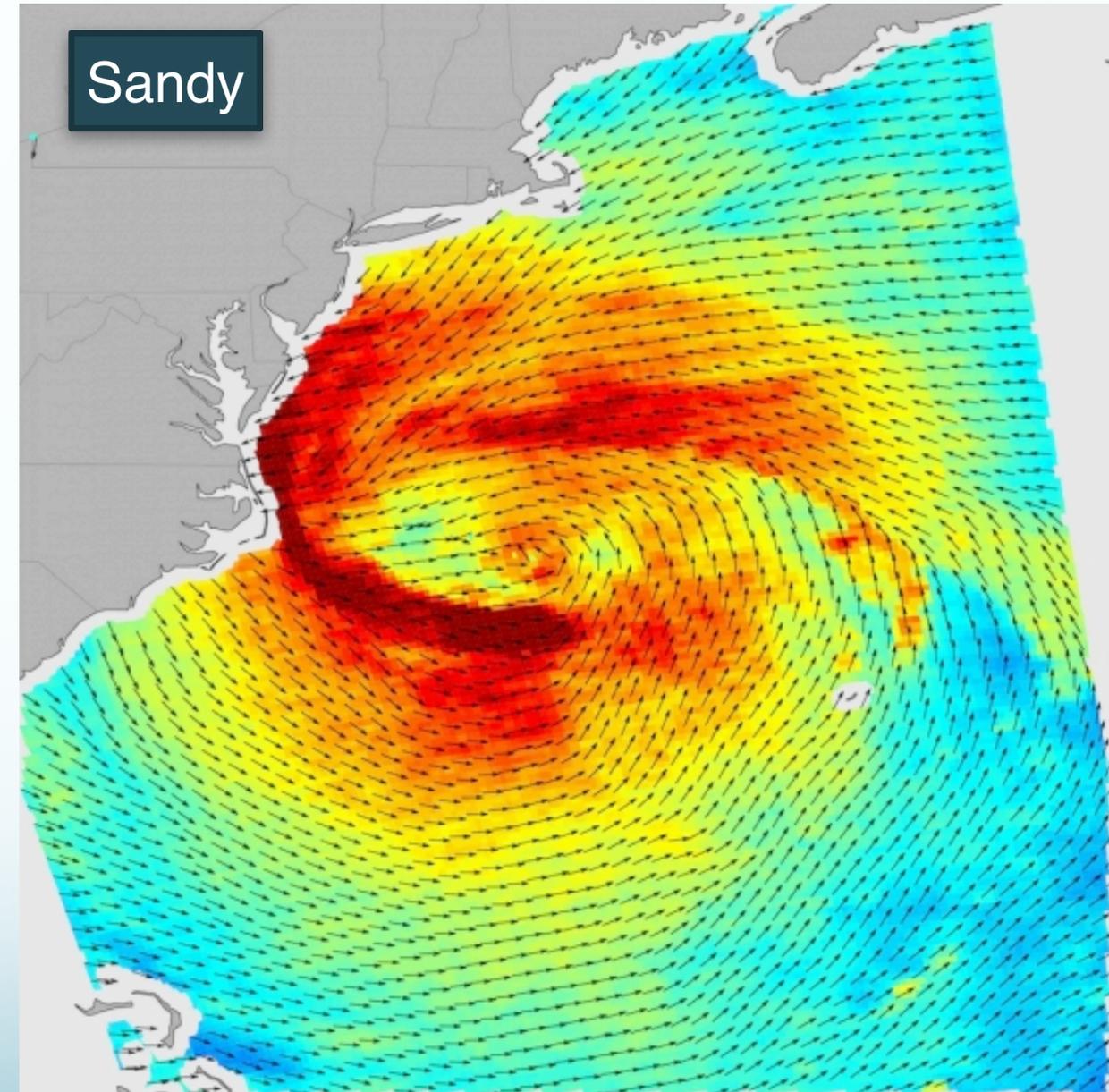
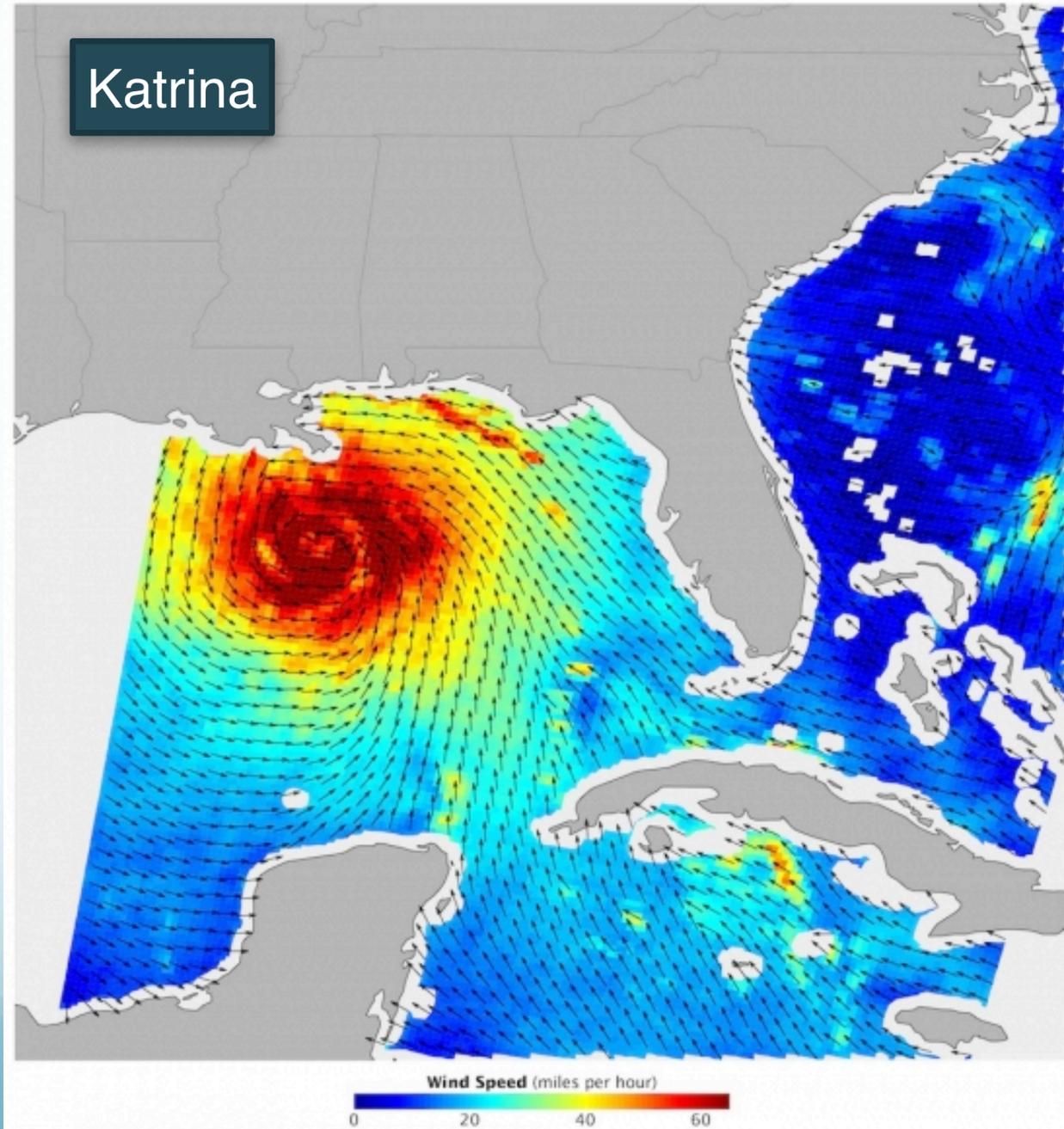
- Confusion about NOAA forecasts
  - NHC or local offices to issue the warnings?
  - June 1, 2013: hurricane and tropical storm watches and warnings broadened to allow them to be issued or remain in effect after a tropical cyclone becomes post-tropical.
- Confusion about insurance
  - Large deductibles for hurricane insurance (1-5%)
  - Not necessary to pay deductible since it wasn't a hurricane!

# NWS Definition of Hurricane

- Sandy definitely had hurricane force winds! But not a hurricane at landfall??
- Must have
  - Warm core
  - No cold or warm fronts
  - Organized deep thunderstorms
- Sandy was extratropical because latter 2 not satisfied

# Katrina vs. Sandy - Wind Speed

Hurricane Katrina August 28, 2005



Very large wind field

# W When is the worst time for storm surge to arrive at the coast?

Low tide because changes are more abrupt

High tide because there's more flooding

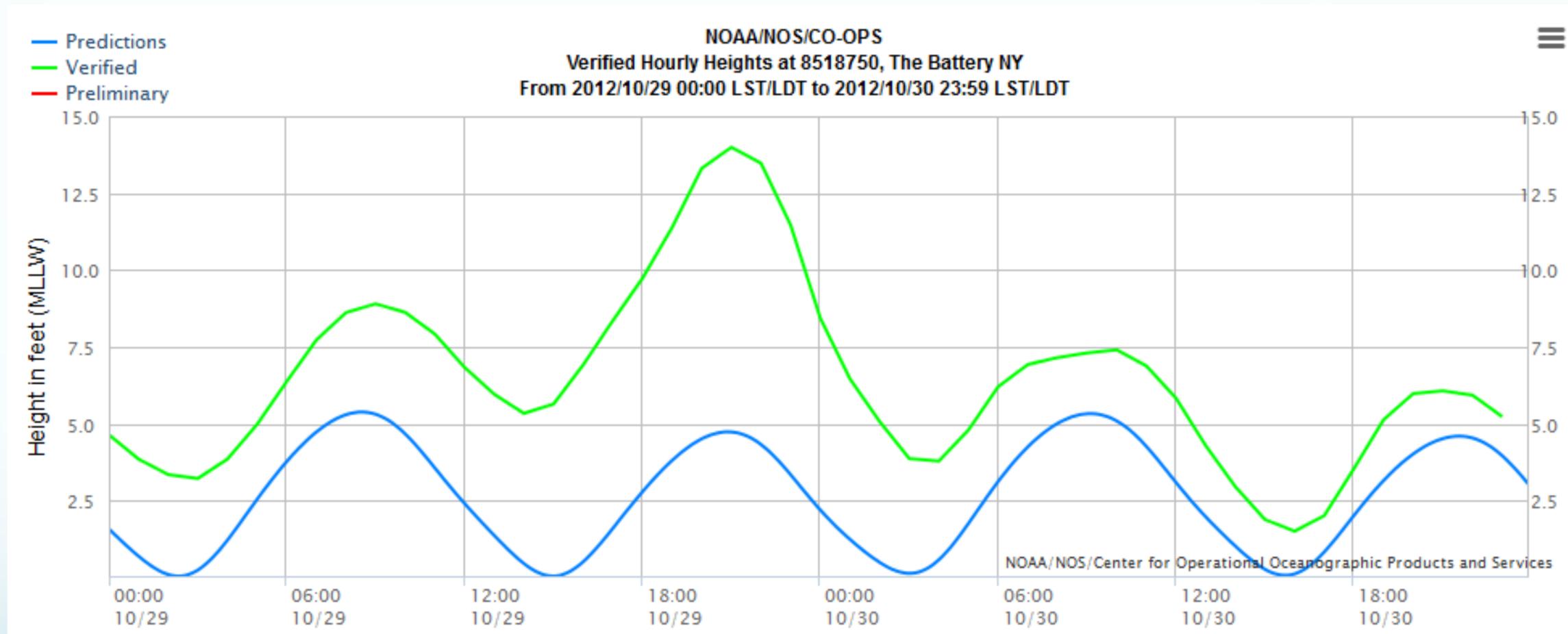
When the tide generates the biggest waves

# Answer

- The worst time for a storm surge is that coinciding with astronomical high tide because the storm surge rides on top of the tides.
- How did this play out with Sandy?

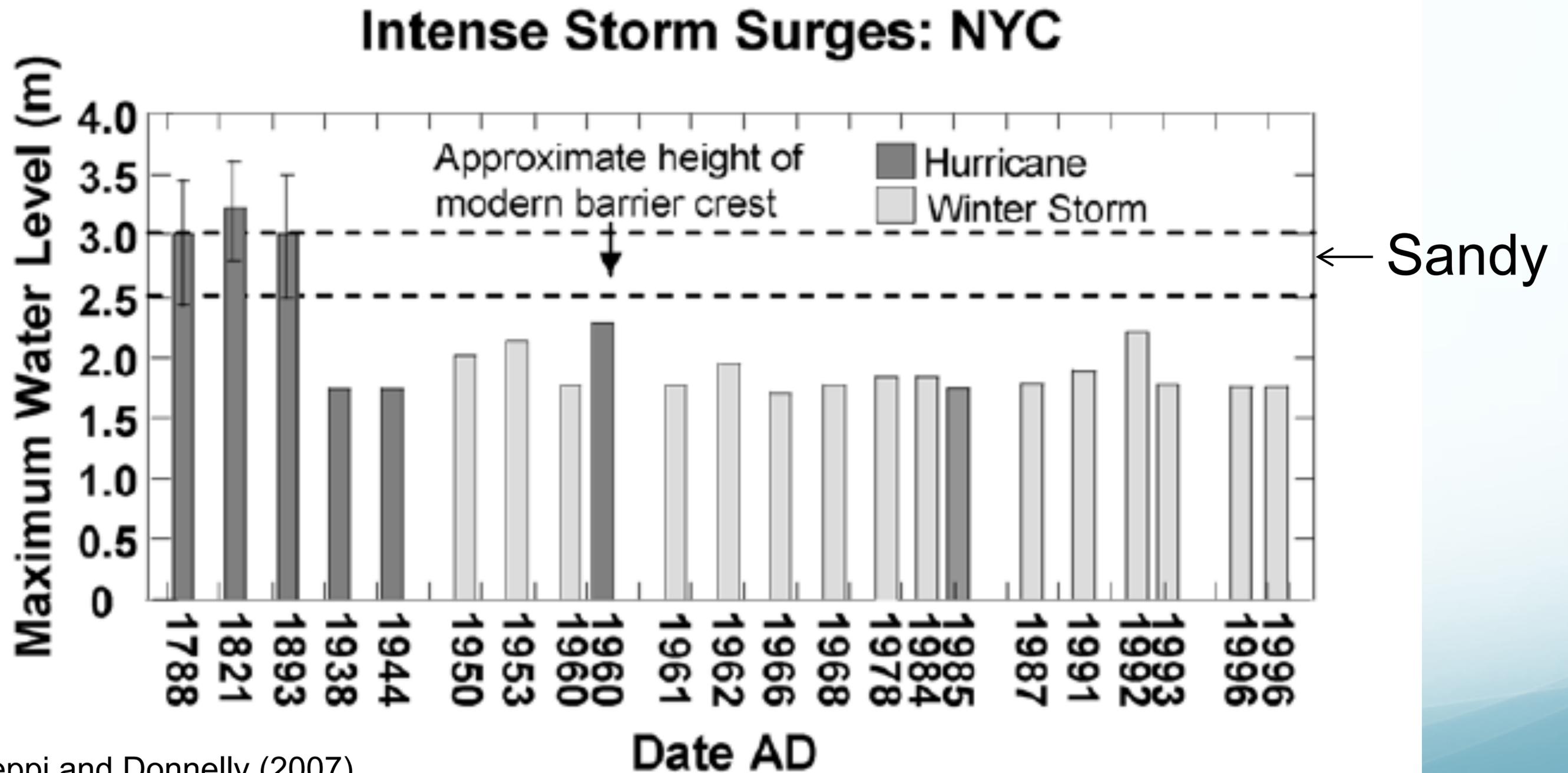
# Tide Gauge at Southern Tip of Manhattan

Maximum storm surge about high tide.



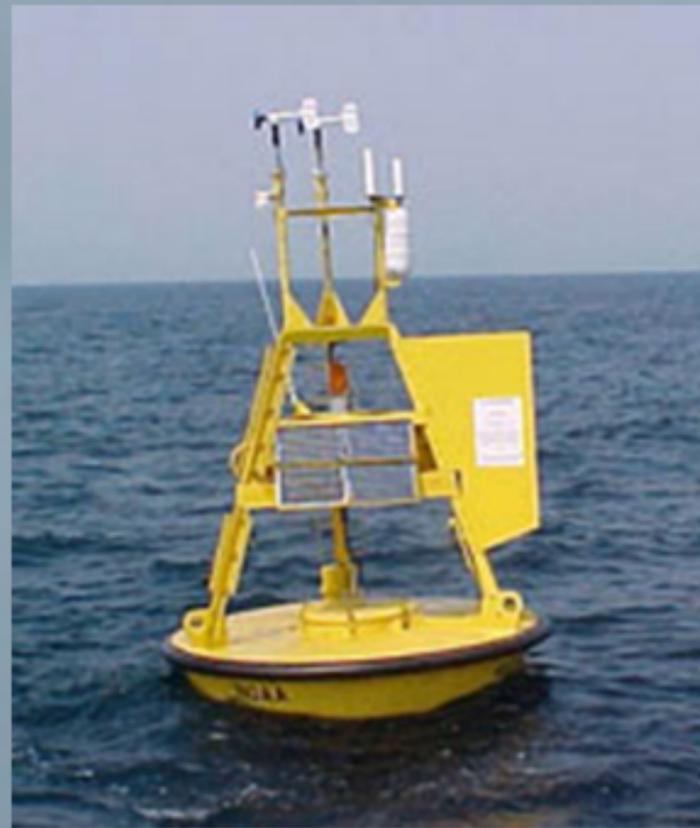
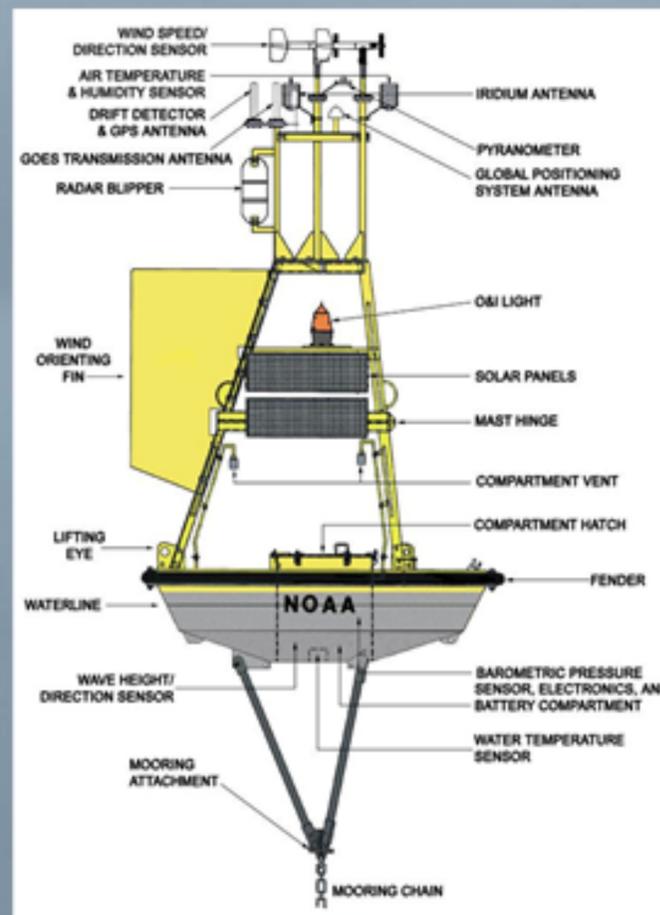
Predictions are only for the astronomical tides.

# Storm surge at Battery highest ever recorded by tide gauge (since 1920)



Scilleppi and Donnelly (2007)

## RECORD SETTING WAVE HEIGHTS AT OFFSHORE BUOYS DURING COASTAL STORM SANDY



Images Courtesy National Data Buoy Center (NDBC)



1. **BUOY 44065**; 15 NAUTICAL MILES SE OF BREEZY POINT, NY; RECORDS ONLY DATE BACK TO 2008.
2. **BUOY 44025**; 30 NAUTICAL MILES SOUTH OF ISLIP, NY; RECORDS DATE BACK TO 1975.

- **AT BUOY 44065, A WAVE HEIGHT OF 32.5 FEET REPORTED AT 8:50 PM EDT OCTOBER 29, 2012 EXCEEDED THE PREVIOUS RECORD OF 26 FEET SET AROUND 9 AM EDT AUGUST 28, 2011, ASSOCIATED WITH IRENE.**
- **AT BUOY 44025, A 31 FOOT WAVE HEIGHT WAS RECORDED AT ABOUT 8PM EDT OCTOBER 29, 2012, EXCEEDED THE PREVIOUS RECORD OF 30 FEET SET ON DECEMBER 11, 1992.**
- **ONE CAN INFER FROM THE DATA THAT THESE WAVE HEIGHTS WERE THE LARGEST SINCE RECORD KEEPING BEGAN IN THIS PORTION OF THE WESTERN ATLANTIC IN 1975.**

\*\* RECORD INFORMATION COURTESY OF US NATIONAL WEATHER SERVICE MOUNT HOLLY NJ



# New Jersey

Waves in Long Branch



# After and Before



# Before and After

Bridgehampton, NY

Some areas are built up  
as the sand is moved.



# Flooding of subways/trains

- Hoboken PATH train station

The newly remodeled South Ferry station was destroyed, not reopened until 2017

