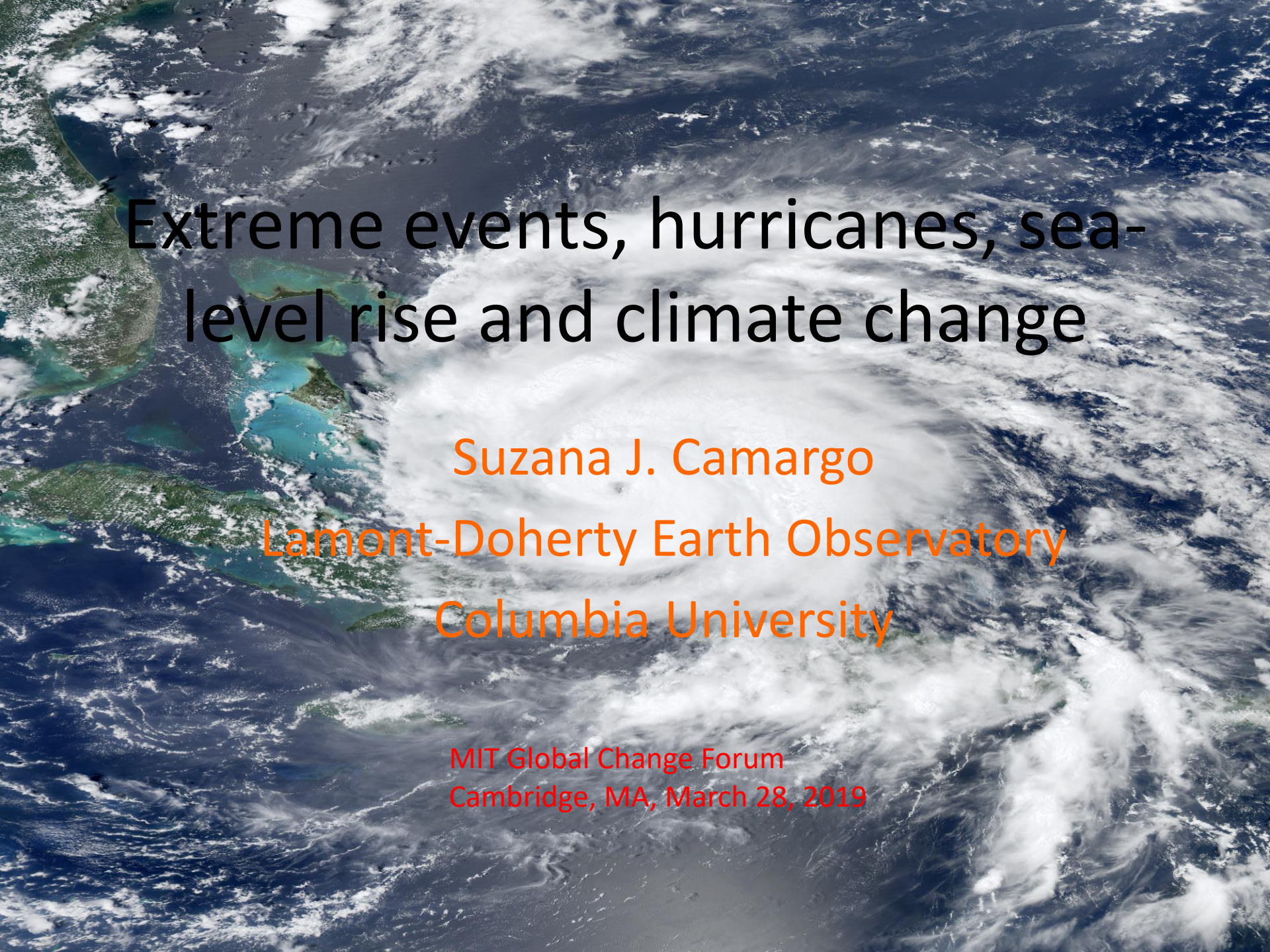


Extreme events, hurricanes, sea-level rise and climate change

Suzana J. Camargo
Lamont-Doherty Earth Observatory
Columbia University

MIT Global Change Forum
Cambridge, MA, March 28, 2019

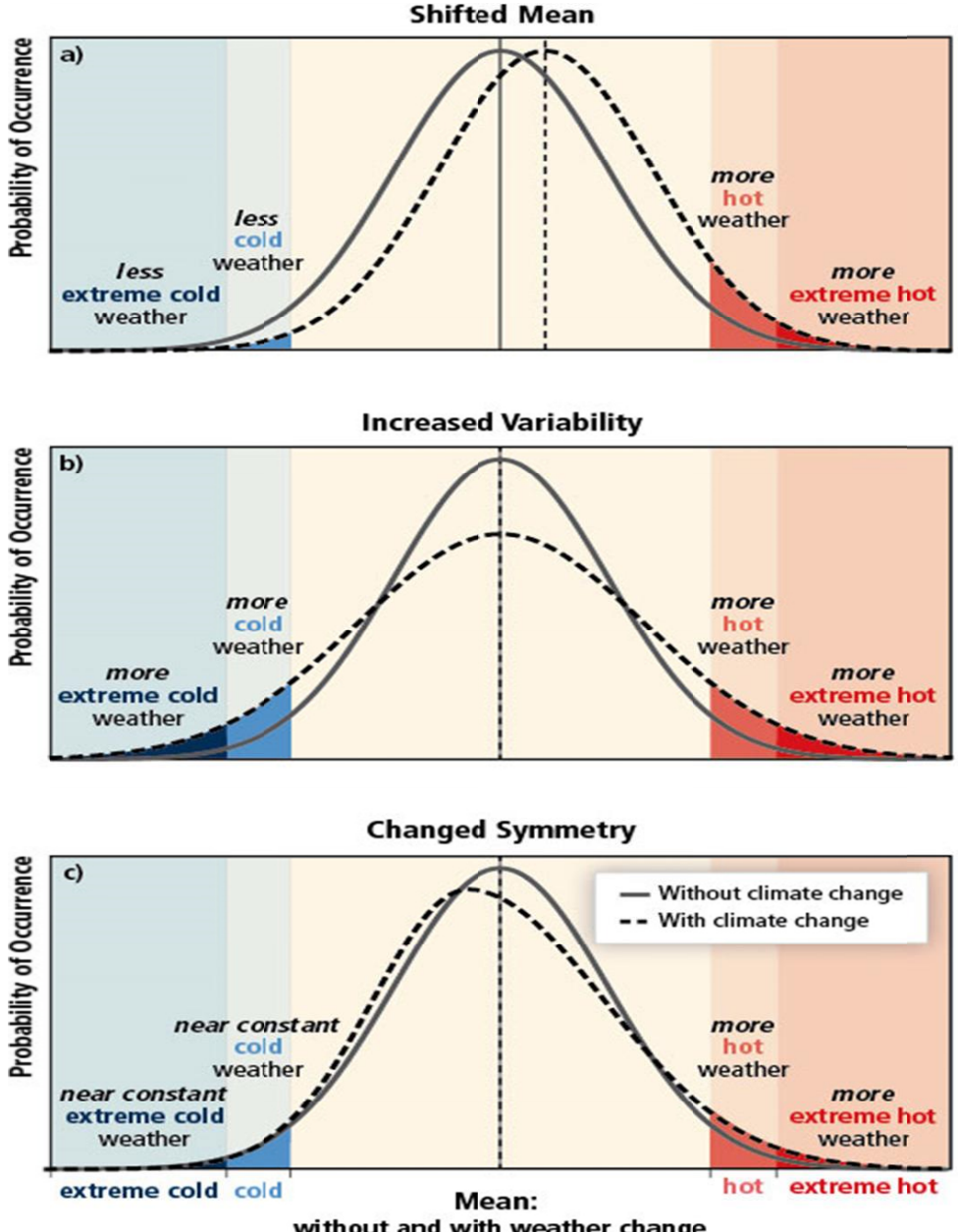
Extreme Events Issues

- Society has become more vulnerable to extreme events. Population and infrastructure increases, pollution event associated with storm run off, more coastal development, etc…
- Lack of long-term climate data suitable for analysis of extremes. Few countries (United States, Australia, South Africa, Norway) have reliable precipitation data prior to World War II.
- How will climate change modify extreme events?
- Did climate change contribute to a specific extreme event?

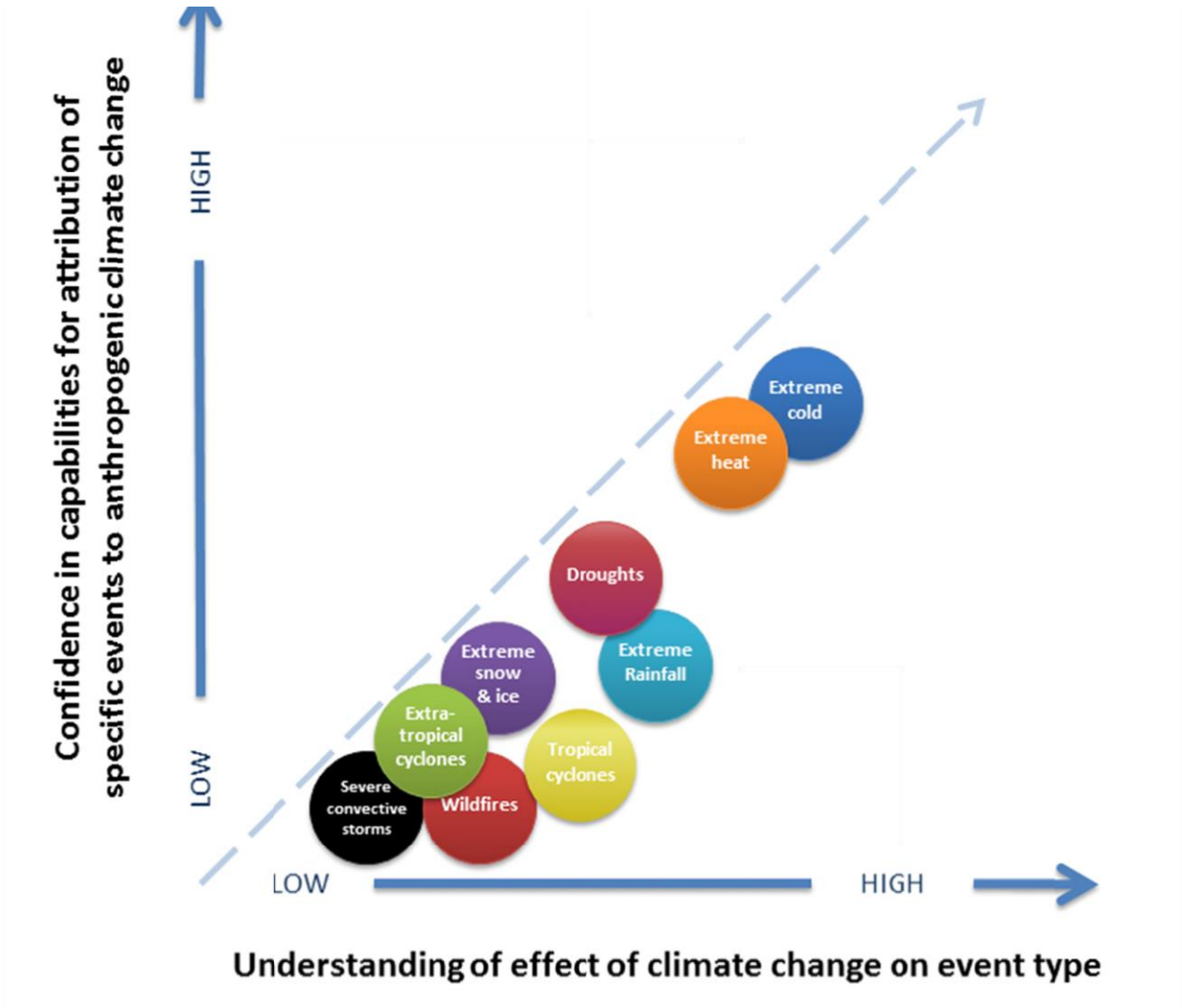
Societal Impacts

- Frequency and/or intensity of extremes can cause major problems.
- Impact of climate change on society and ecosystems could be due to changes in the physical system or to changes in the vulnerability of society.
- Is the frequency of extreme events currently changing and/or is only the perception of an increase exacerbated by enhanced media coverage?
- Alternative definition of extreme event: impact that an event has on society: loss of life, economic losses, infrastructure destruction, pollution.

Why are these changes important?



Extreme events and climate change



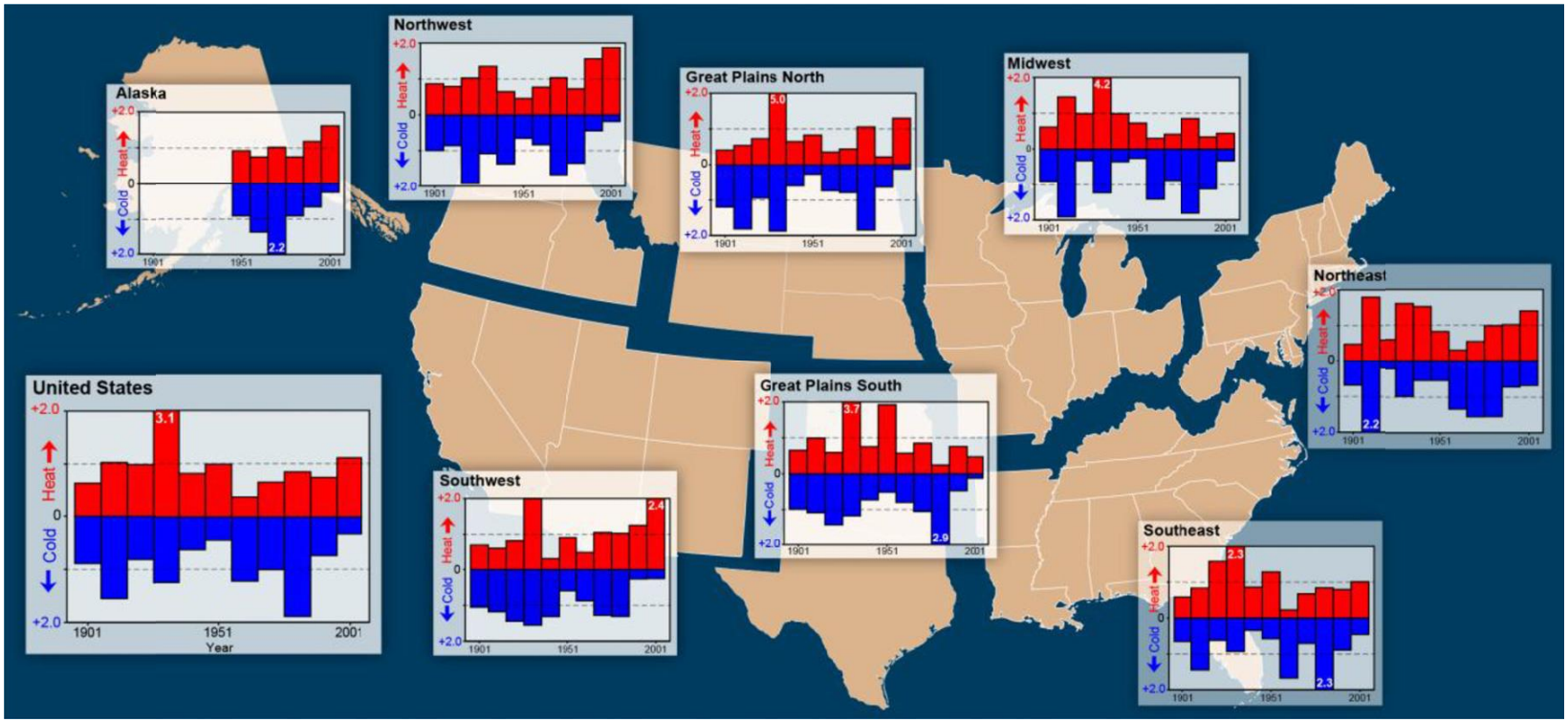
PNAS, 2015

Extremes and climate climate change II

● = high ⊙ = medium ○ = low	Capabilities of Climate Models to Simulate Event Class	Quality/Length of the Observational Record	Understanding of Physical Mechanisms that Lead to Changes in Extremes as a Result of Climate Change
Extreme cold events	●	●	●
Extreme heat events	●	●	●
Droughts	⊙	⊙	⊙
Extreme rainfall	⊙	⊙	⊙
Extreme snow and ice storms	⊙	○	⊙
Tropical cyclones	○	○	⊙
Extratropical cyclones	⊙	○	○
Wildfires	○	⊙	○
Severe convective storms	○	○	○

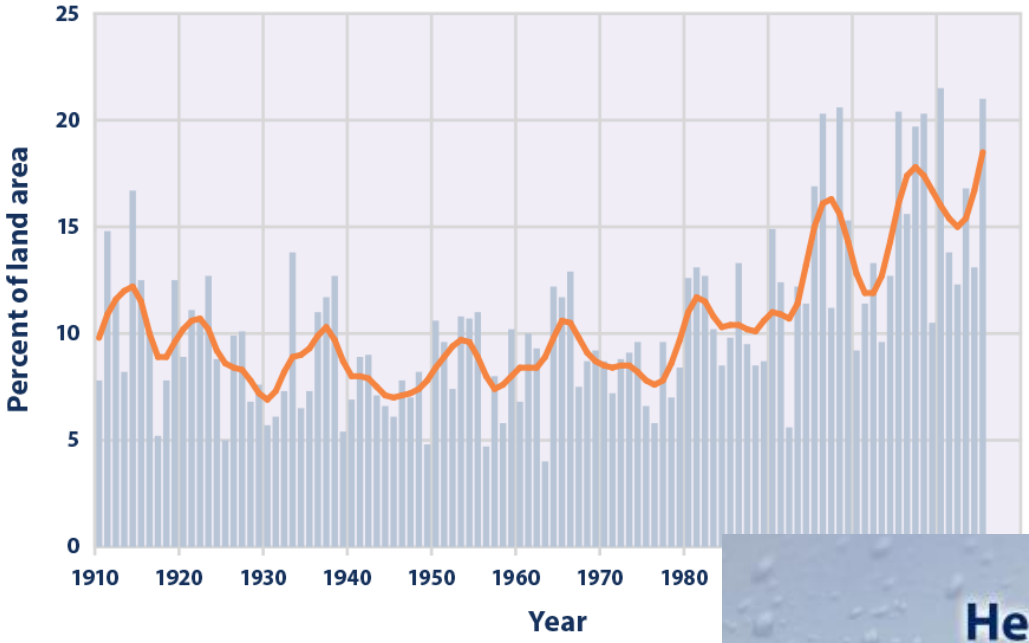
PNAS, 2015

Hot and Cold waves trends

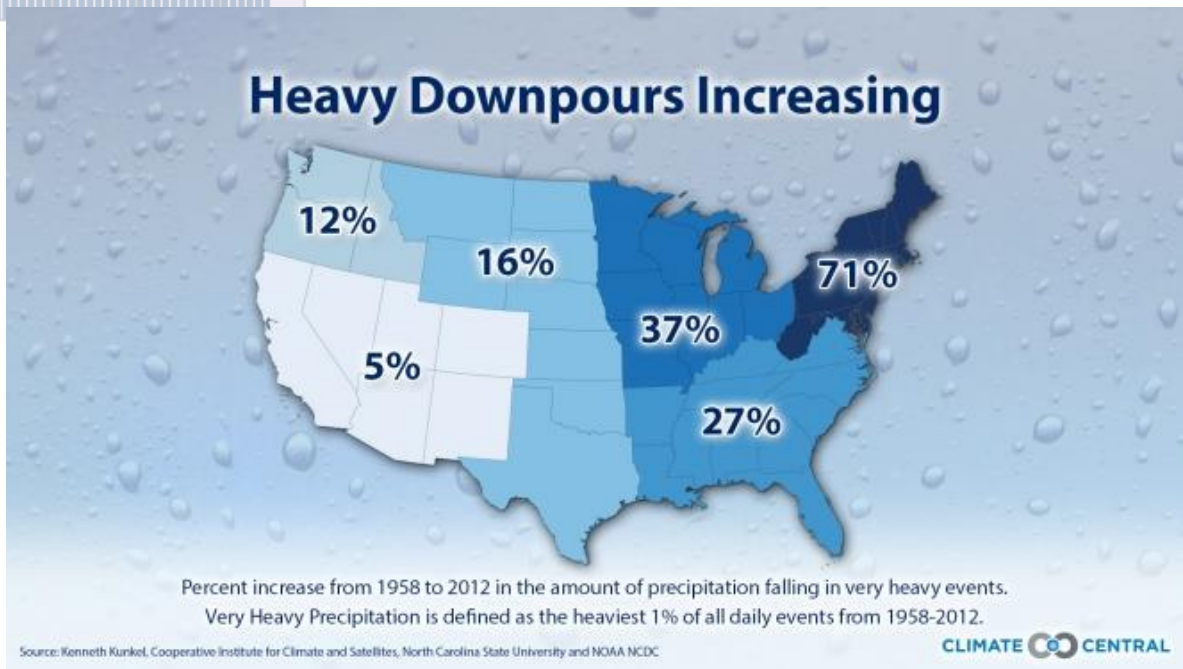


- Last decades:
- Increase in number of heat waves
- Decrease in number of cold waves
- Peterson et al. 2013

Extreme precipitation trends



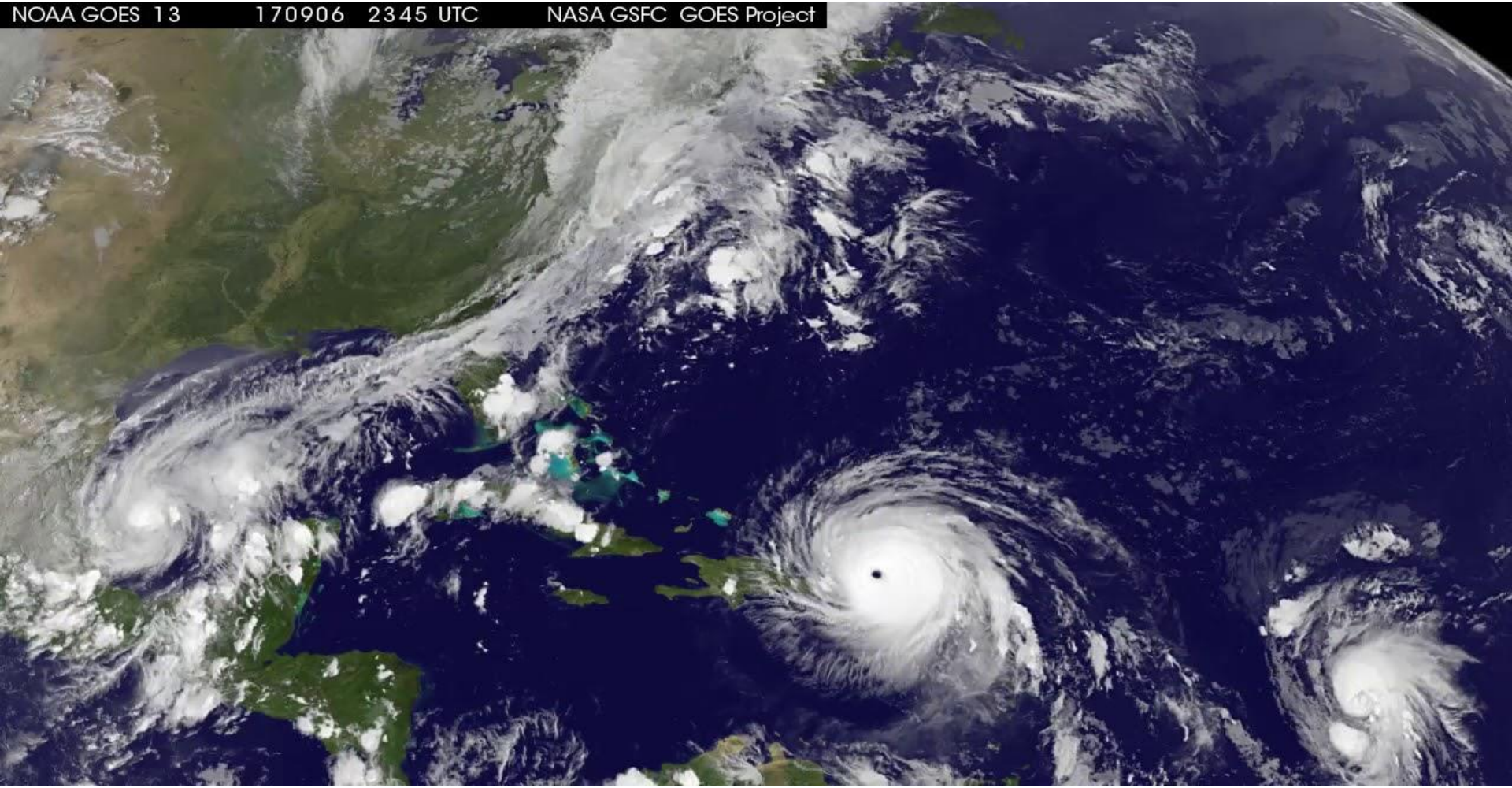
Extreme one-day precipitation events over US 48 contiguous states
NOAA



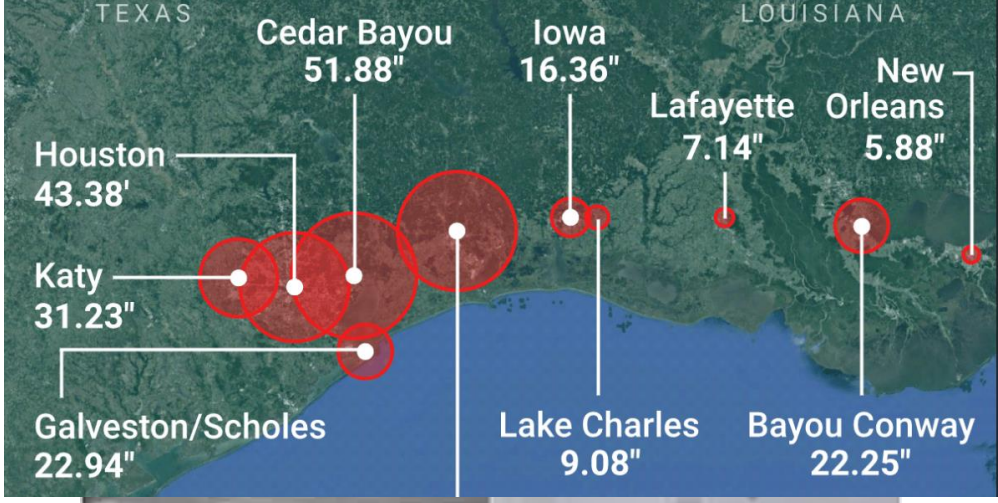
Attribution of Extreme Events

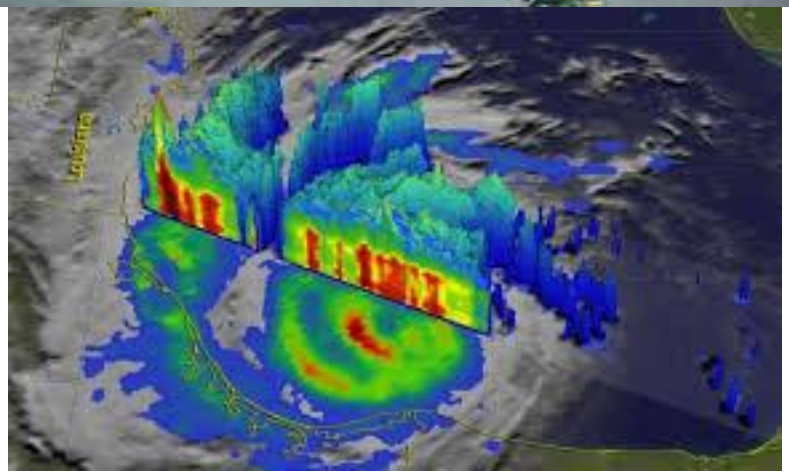
- Did anthropogenic climate change increase the probability of occurrence of a specific extreme event?

Hurricanes



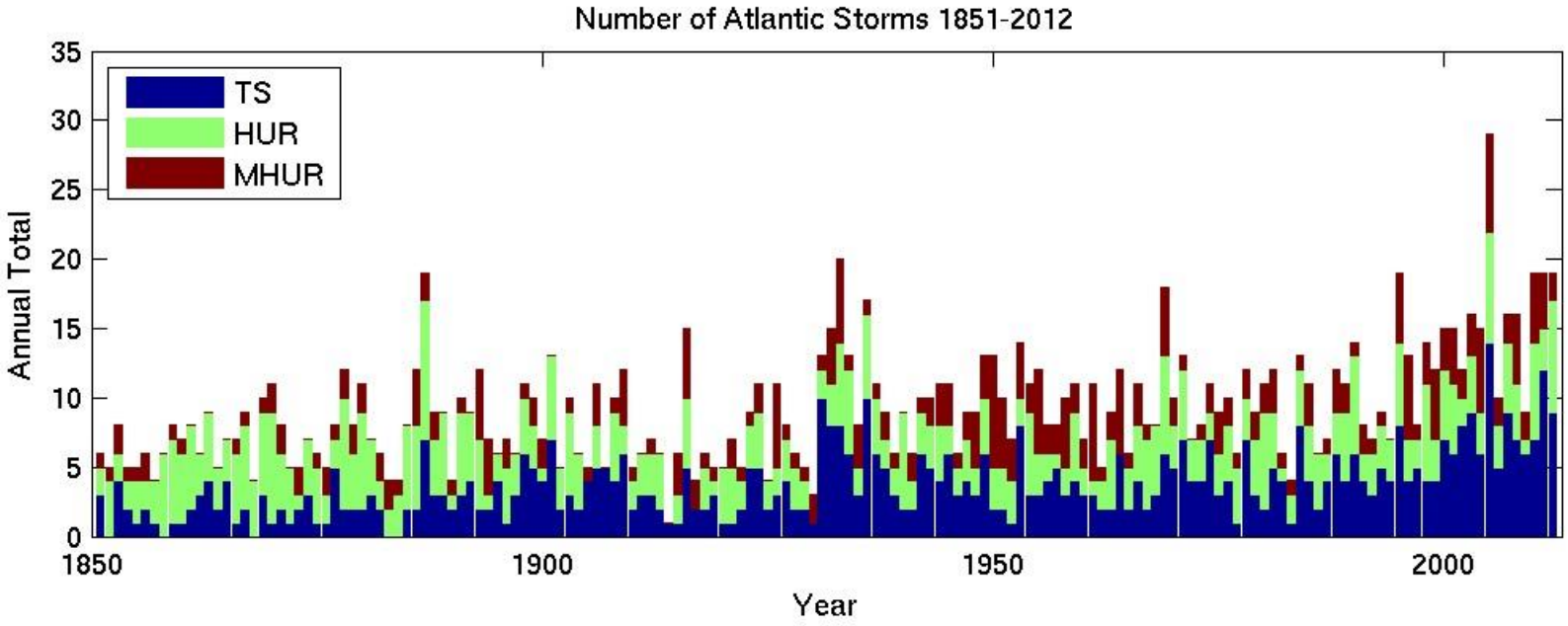
Katia Irma Jose

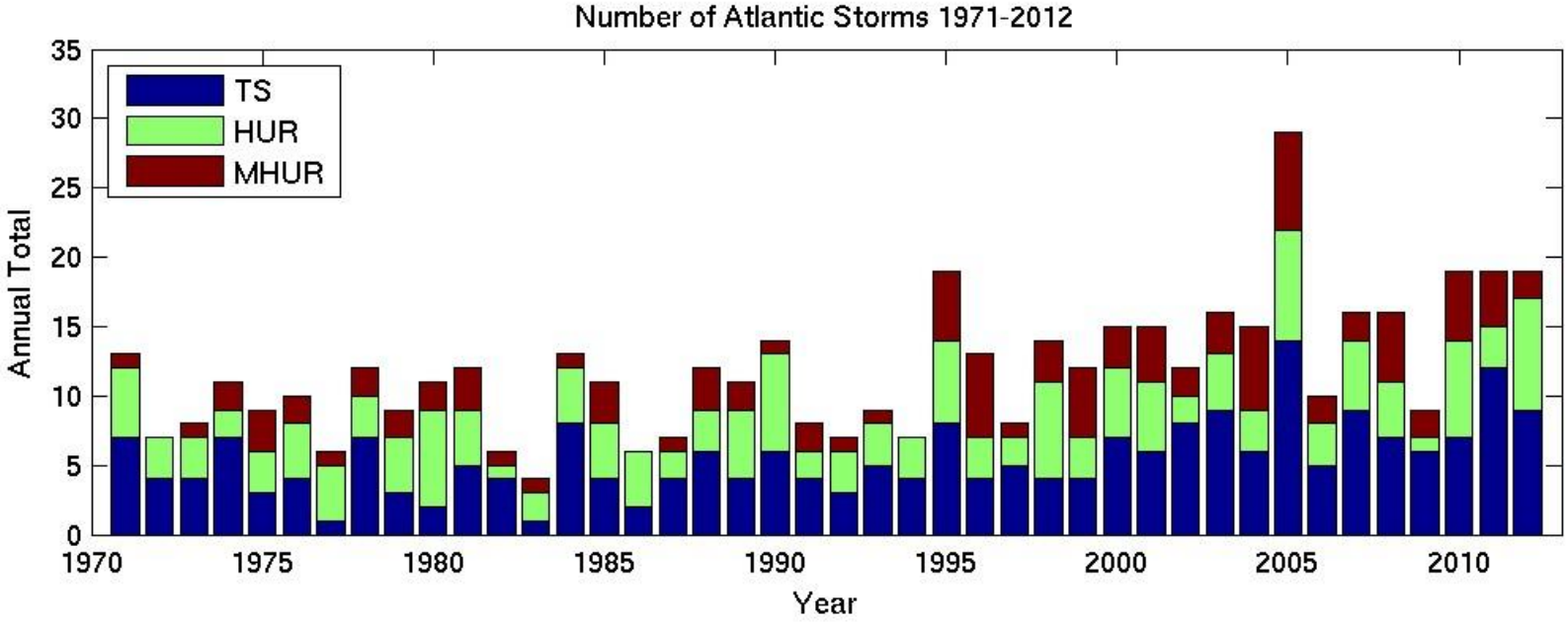

TEXAS
LOUISIANA
Cedar Bayou
51.88"
Iowa
16.36"
Lafayette
7.14"
New
Orleans
5.88"
Houston
43.38'
Katy
31.23"
Galveston/Scholes
22.94"
Lake Charles
9.08"
Bayou Conway
22.25"



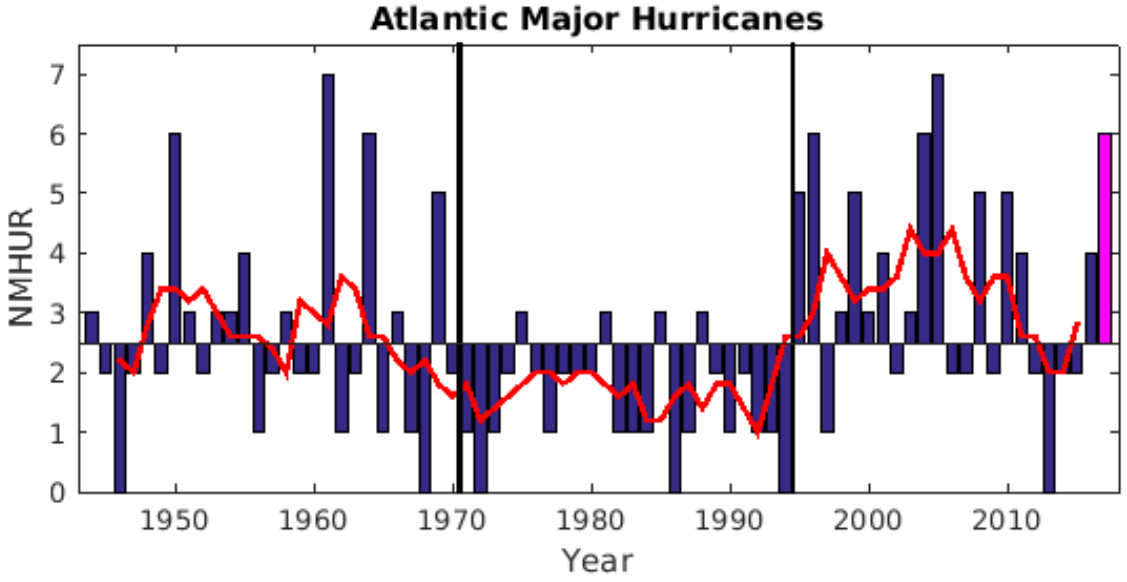

Observed Precipitation
Houston

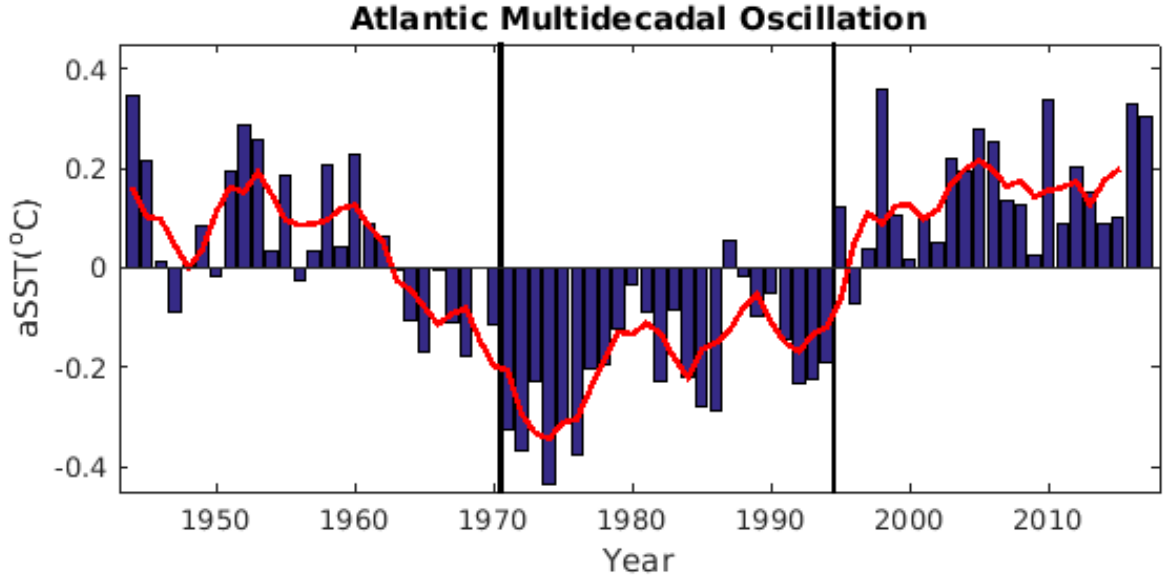

Expected Storm Total Rainfall
Hurricane Harvey
Austin / San Antonio
Note: There will likely be locally higher amounts
10-20 inches along and east of I-35 Friday through Tuesday.
Local amounts in excess of 25 inches possible near and south of I-10
Rainfall forecast amounts still subject to large changes depending on path of Harvey after landfall.
Expecting steep drop off in rainfall values on western extent of rain area.


Number of Atlantic Storms 1851-2012
TS
HUR
MHUR
Annual Total
Year
0
5
10
15
20
25
30
35
1850
1900
1950
2000


Number of Atlantic Storms 1971-2012
TS
HUR
MHUR
Annual Total
Year
0
5
10
15
20
25
30
35
1970
1975
1980
1985
1990
1995
2000
2005
2010

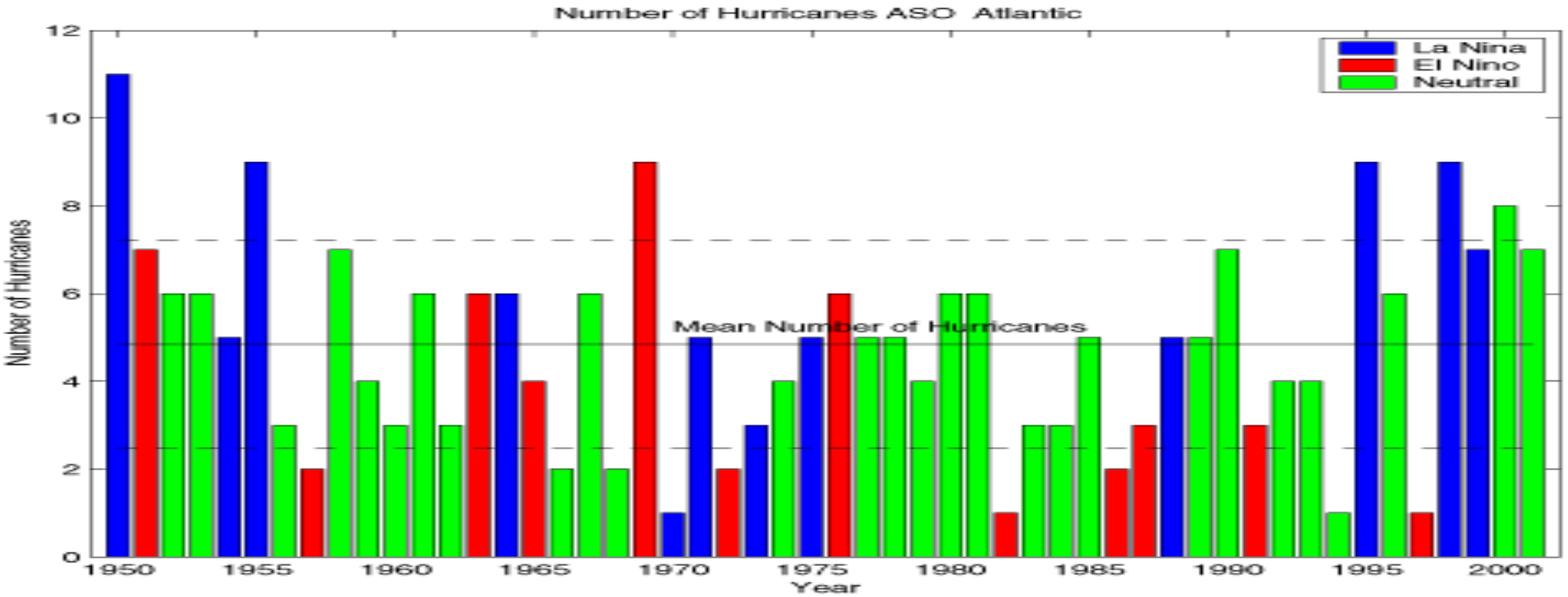
Atlantic Multi-Decadal Signal



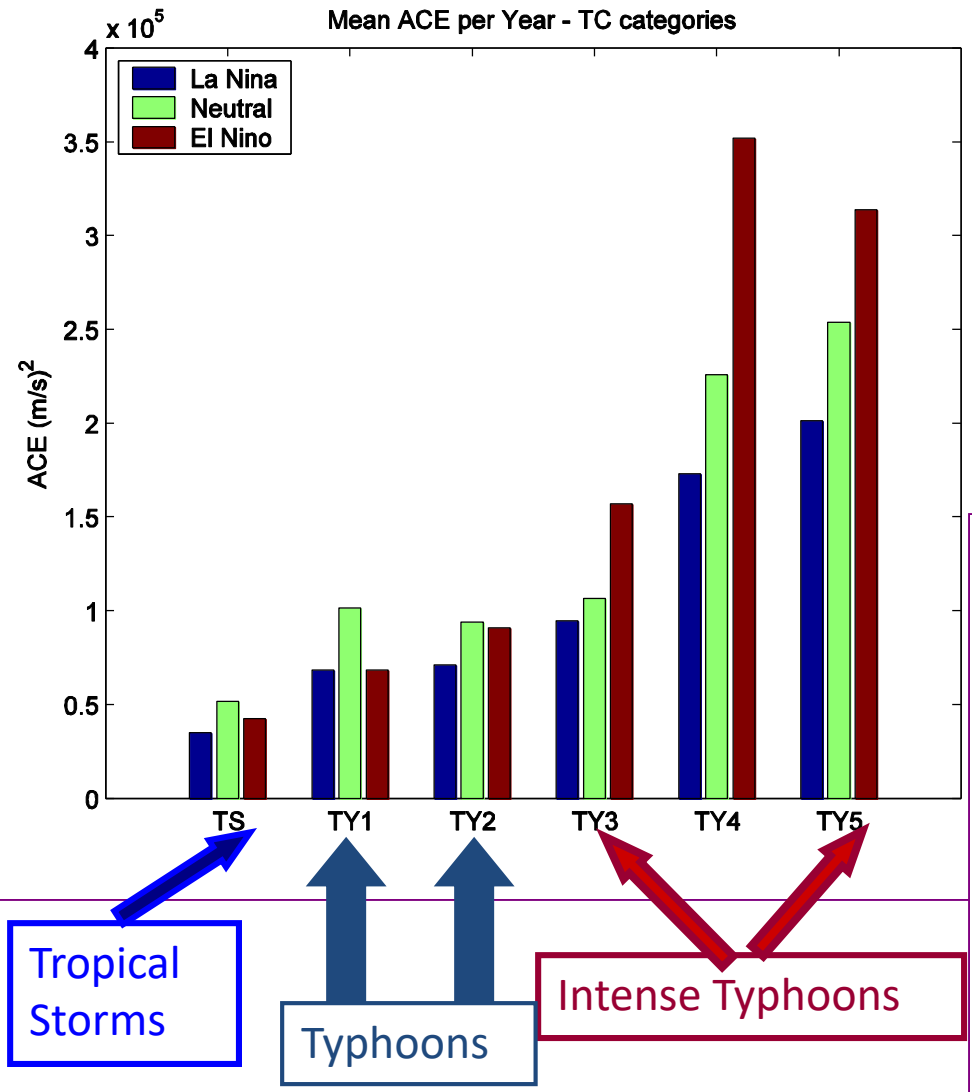


Atlantic Hurricanes and ENSO (2)

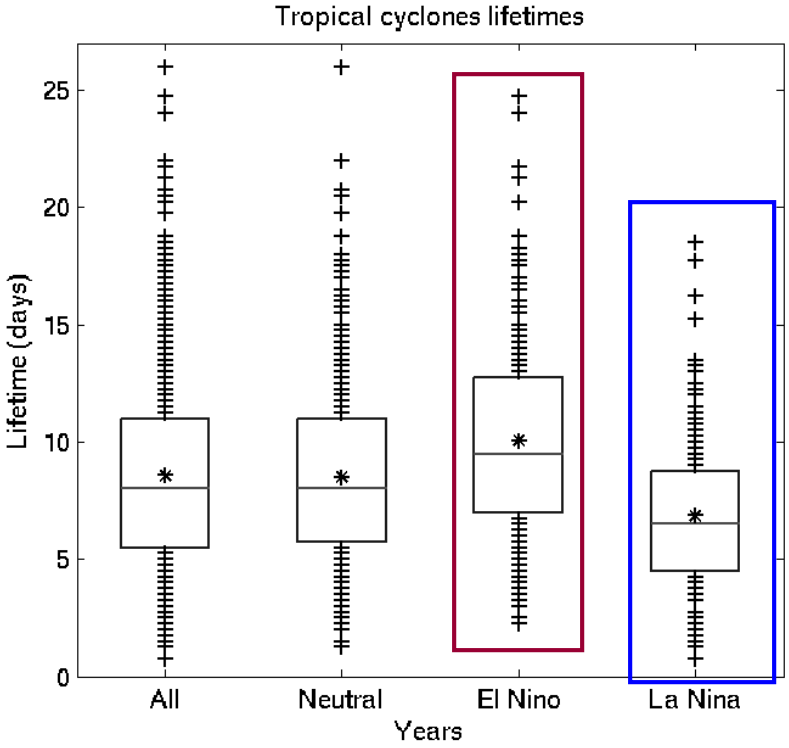
- In El Niño (La Niña) years there are fewer (more) hurricanes in the Atlantic (Gray, 1984).
- Factors:
  - Larger vertical wind shear (Shapiro, 1987).
  - Changes in atmospheric temperature and stability (Tang and Neelin, 2004).



Typhoons and ENSO



More intense and typhoons with long lifetimes in El Niño years



Tropical Cyclones Lifetimes

Source: Camargo & Sobel, J. Climate (2005)

Climate change – possible influences on hurricanes:

- Increase in sea surface temperature.
- Increase in the atmospheric temperature.
- Increase in the evaporation in the atmosphere (more humidity in the atmosphere)

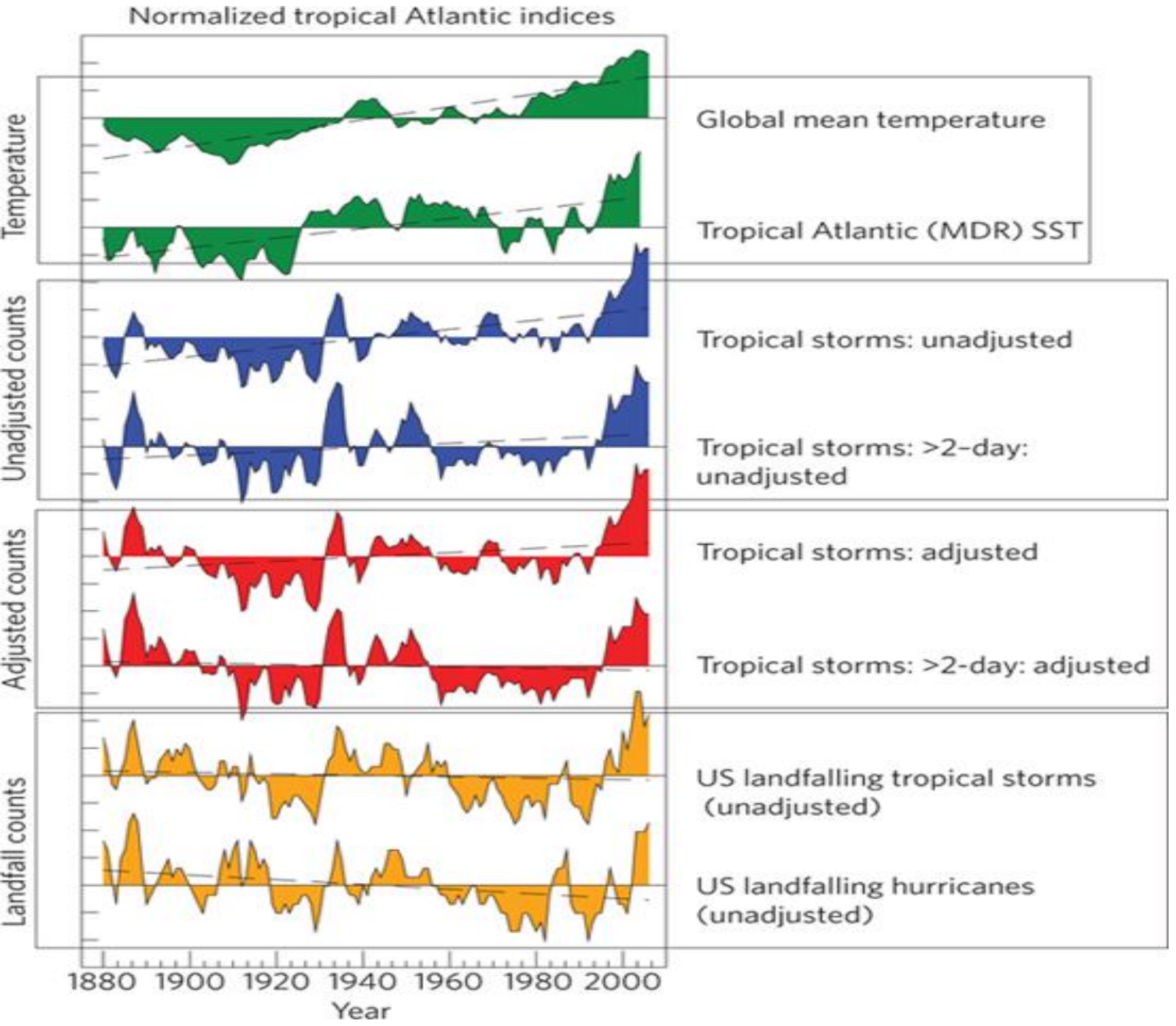
Hurricanes and Climate Change

- How could hurricanes change with global warming?
  - Frequency
  - Intensity
  - Duration
  - Precipitation
  - Areas affected

Issues – TC trends

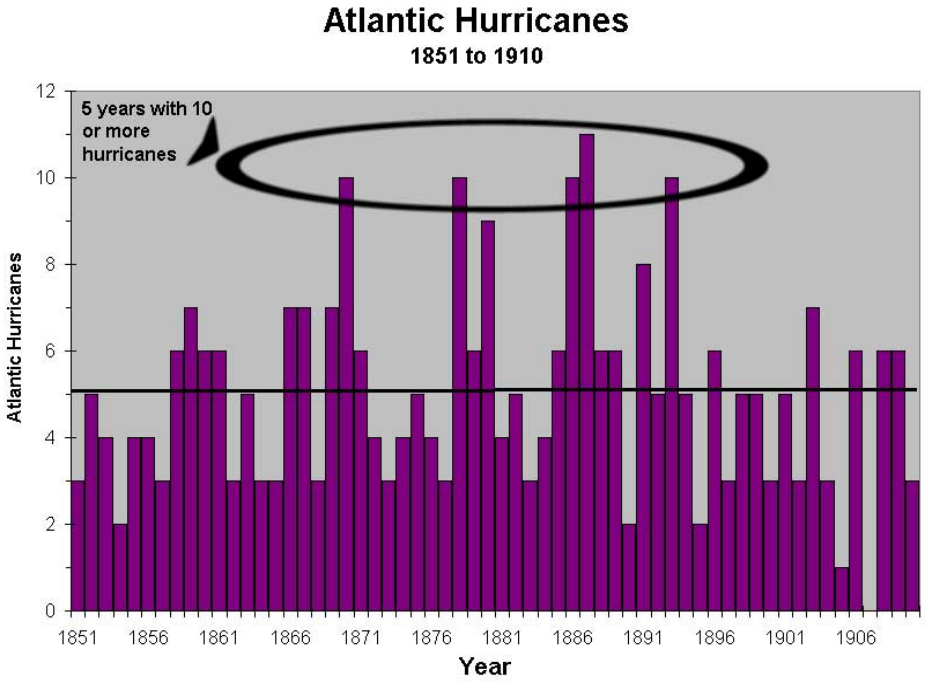
- Large amplitude fluctuations of climate variability for TCs (frequency and intensity) – trend attribution is difficult.
- Global historical records of TCs – availability and quality limited – large error bars
- Uncertainty: past changes in TC variability have exceeded what is expected from nature climate variability.

Knutson et al. 2010

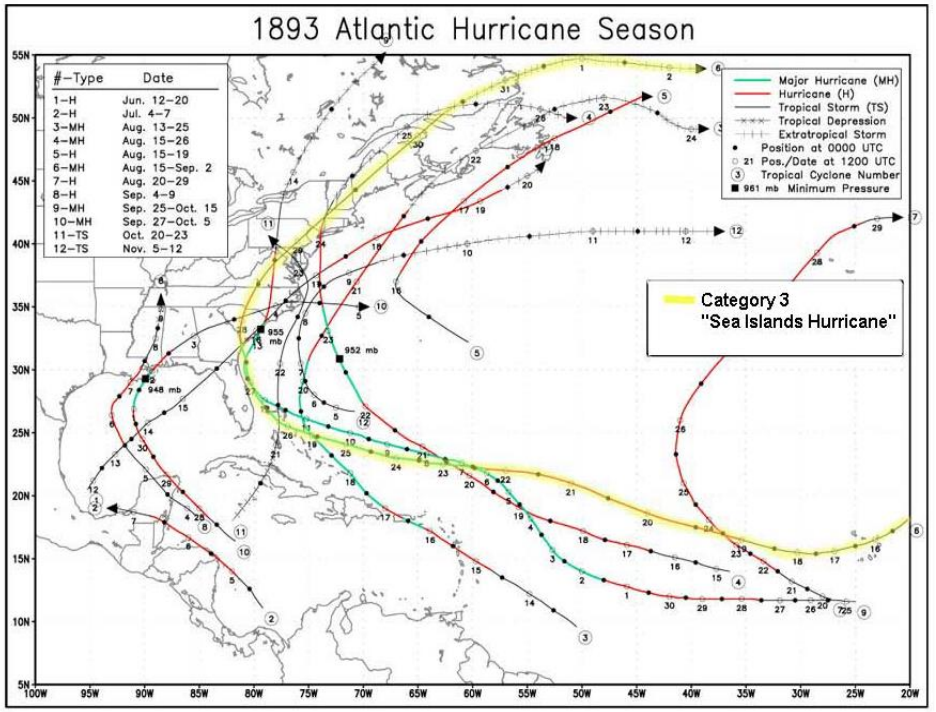


Vecchi and Knutson, 2008

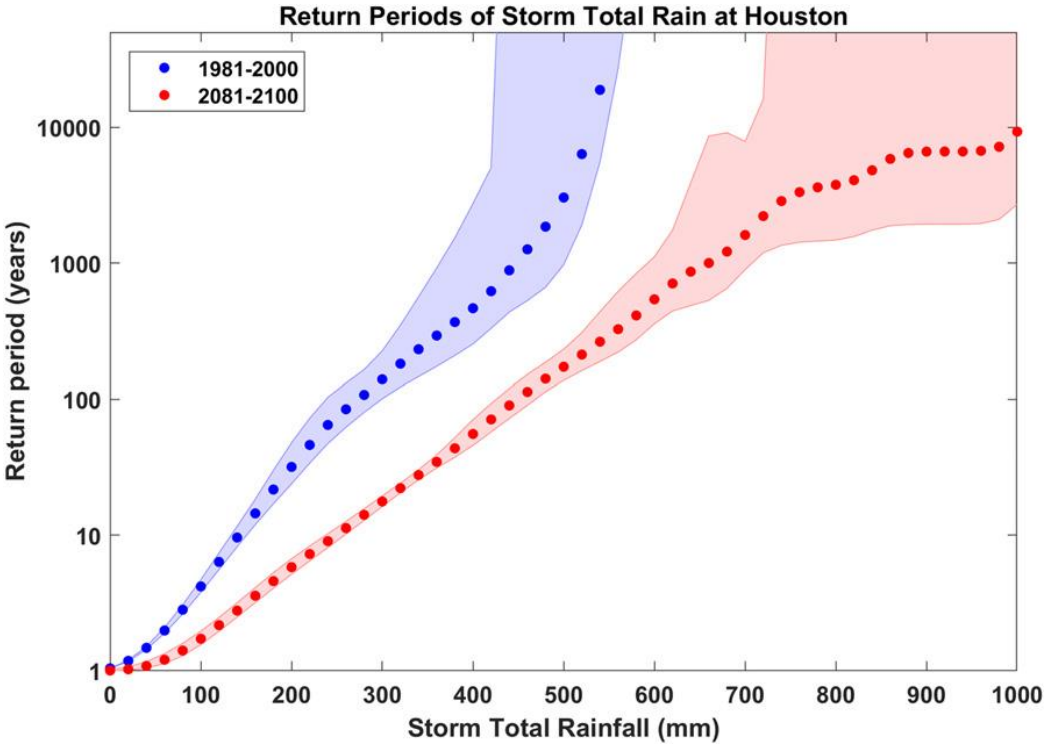
HURDAT Reanalysis project



The average annual count for Atlantic hurricanes is 5.1.



Hurricane Harvey attribution studies



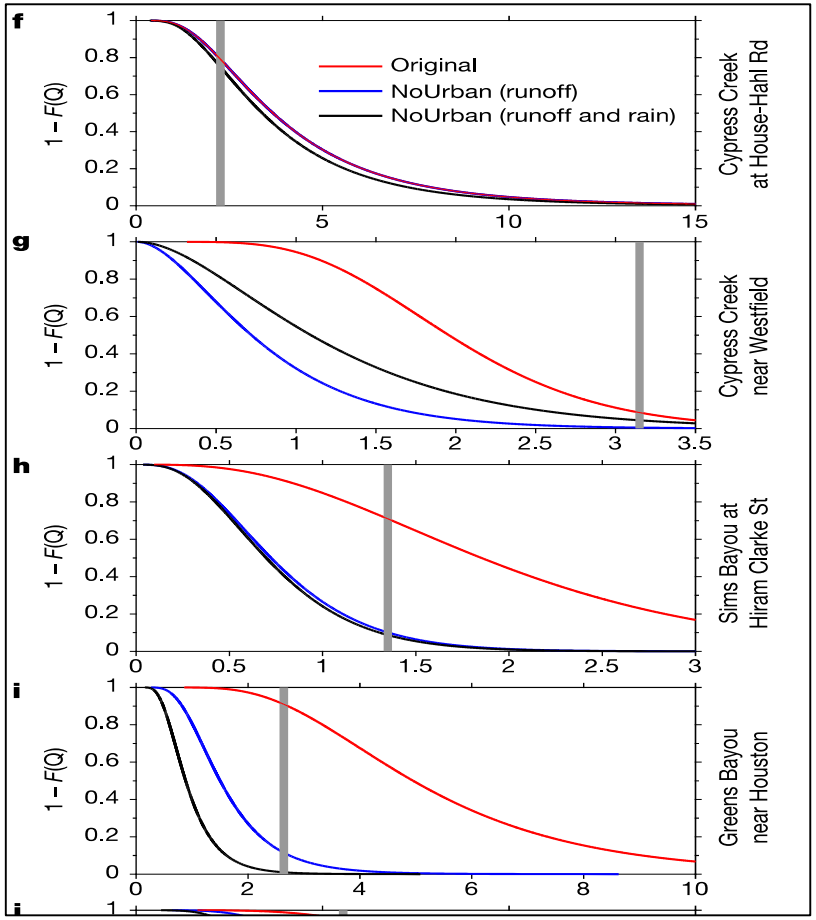
Emanuel PNAS 2017

Likely increase of 6% in 2017

Urbanization exacerbated the rainfall and flooding caused by hurricane Harvey in Houston

Wei Zhang[1], Gabriele Villarini[1]*, Gabriel A. Vecchi[2,3] & James A. Smith[4]

Nature, 563, 384-388, 2019, doi: 10.1038/s41586-018-0676-z.



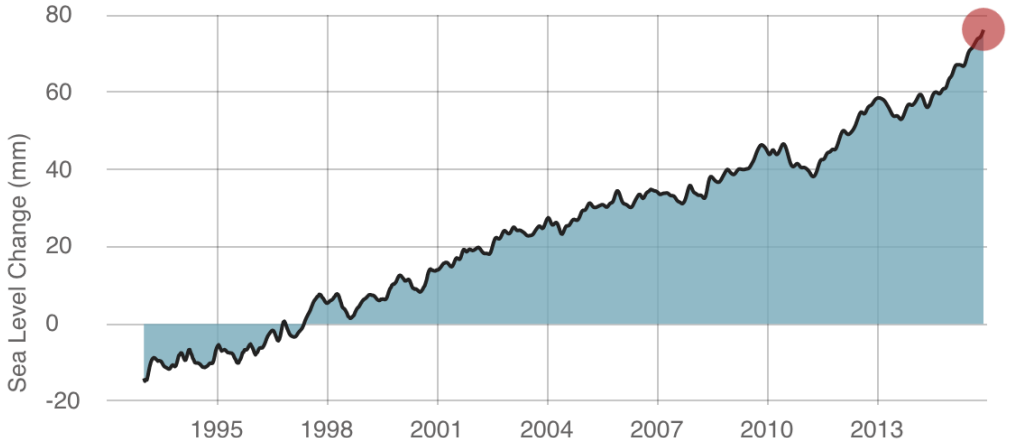
Sea level rise

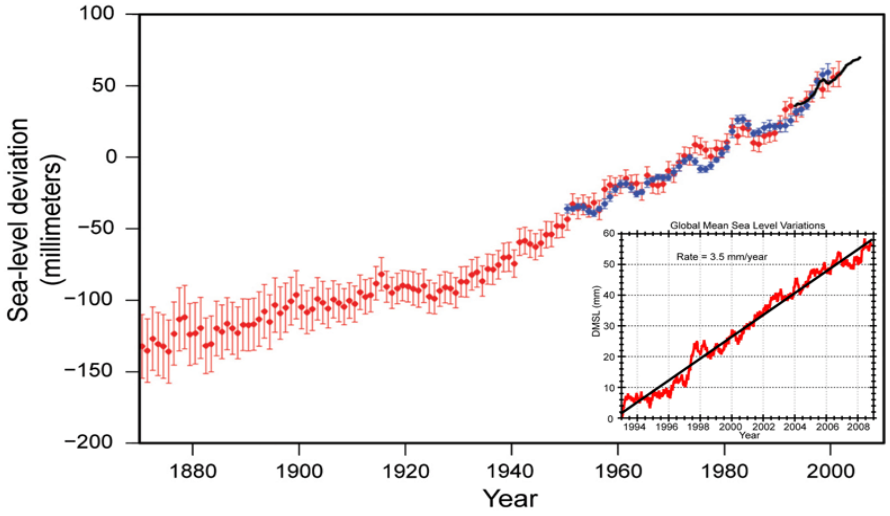
SATELLITE DATA: 1993-PRESENT

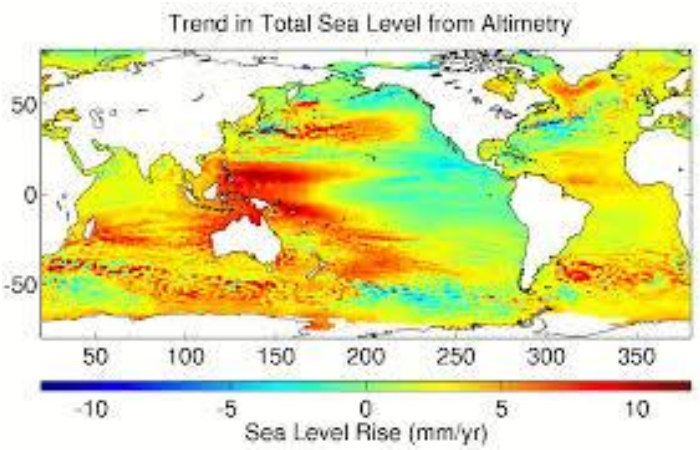
Data source: Satellite sea level observations.
Credit: NASA Goddard Space Flight Center

RATE OF CHANGE

↑ 3.41
mm per year

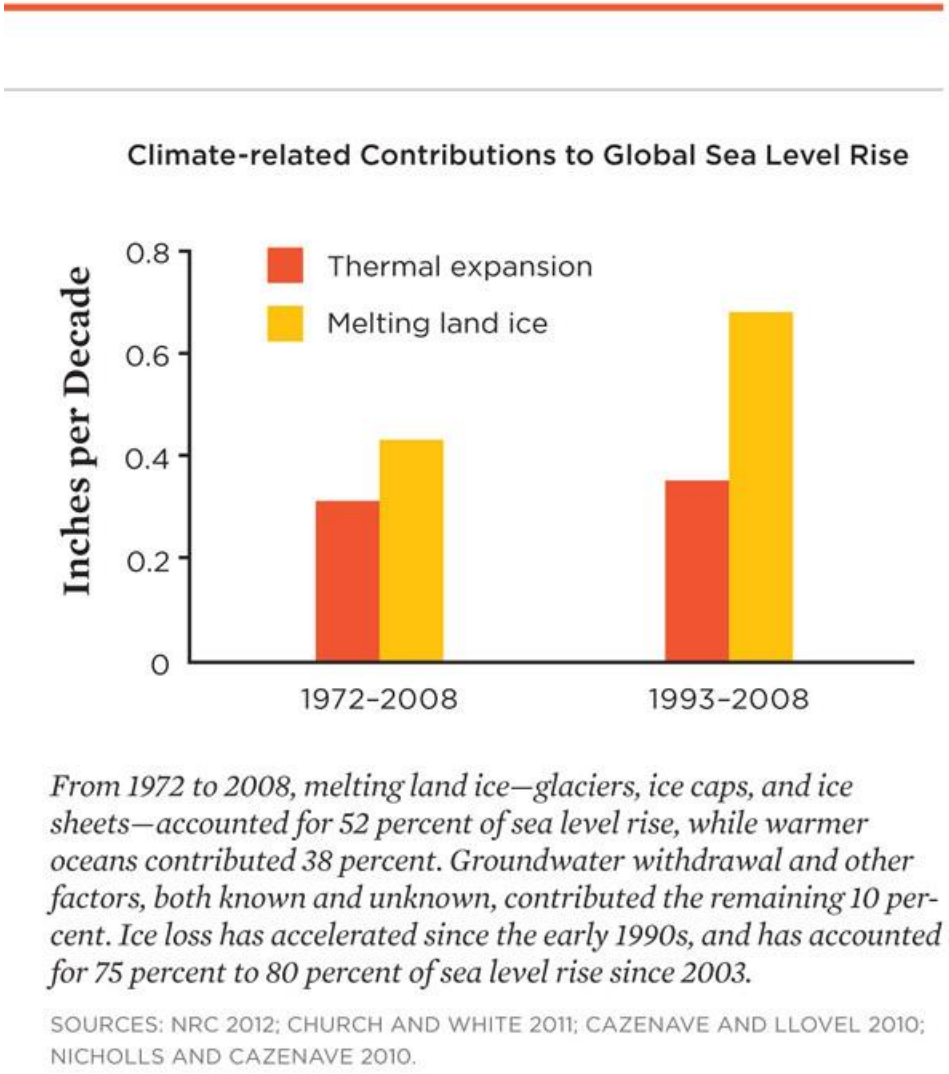






Reasons for sea-level rise

- Warmer ocean: thermal expansion of the ocean – waters expand with temperature
- Melting land ice (glaciers, ice caps, ice sheets) – additional water in the oceans.



From 1972 to 2008, melting land ice—glaciers, ice caps, and ice sheets—accounted for 52 percent of sea level rise, while warmer oceans contributed 38 percent. Groundwater withdrawal and other factors, both known and unknown, contributed the remaining 10 percent. Ice loss has accelerated since the early 1990s, and has accounted for 75 percent to 80 percent of sea level rise since 2003.

SOURCES: NRC 2012; CHURCH AND WHITE 2011; CAZENAVE AND LLOVEL 2010; NICHOLLS AND CAZENAVE 2010.

Climate Change Projections

- Increase in storm surge due to sea level rise
- Increase in tropical cyclone precipitation (mean and peak) – likely in some areas.
- Changes in hurricane intensity – intense hurricanes happening more frequently.
- Changes in hurricane frequency – fewer tropical cyclones (most studies)
- Regions with hurricane occurrence is NOT expected to change.

Future Projections – TCs and Climate Change

- Based on theory and models
- Globally averaged intensity of TCs shift towards stronger storms – 2-11% by 2100
- Globally averaged frequency of TCs decreases on the order of 6-34%
- Increases of ~ 20% of the precipitation rate within 100km of the storm center.
- Projected changes for individual basins – uncertain.

Knutson et al. 2010