Sea Level Rise

Past, Present, Future

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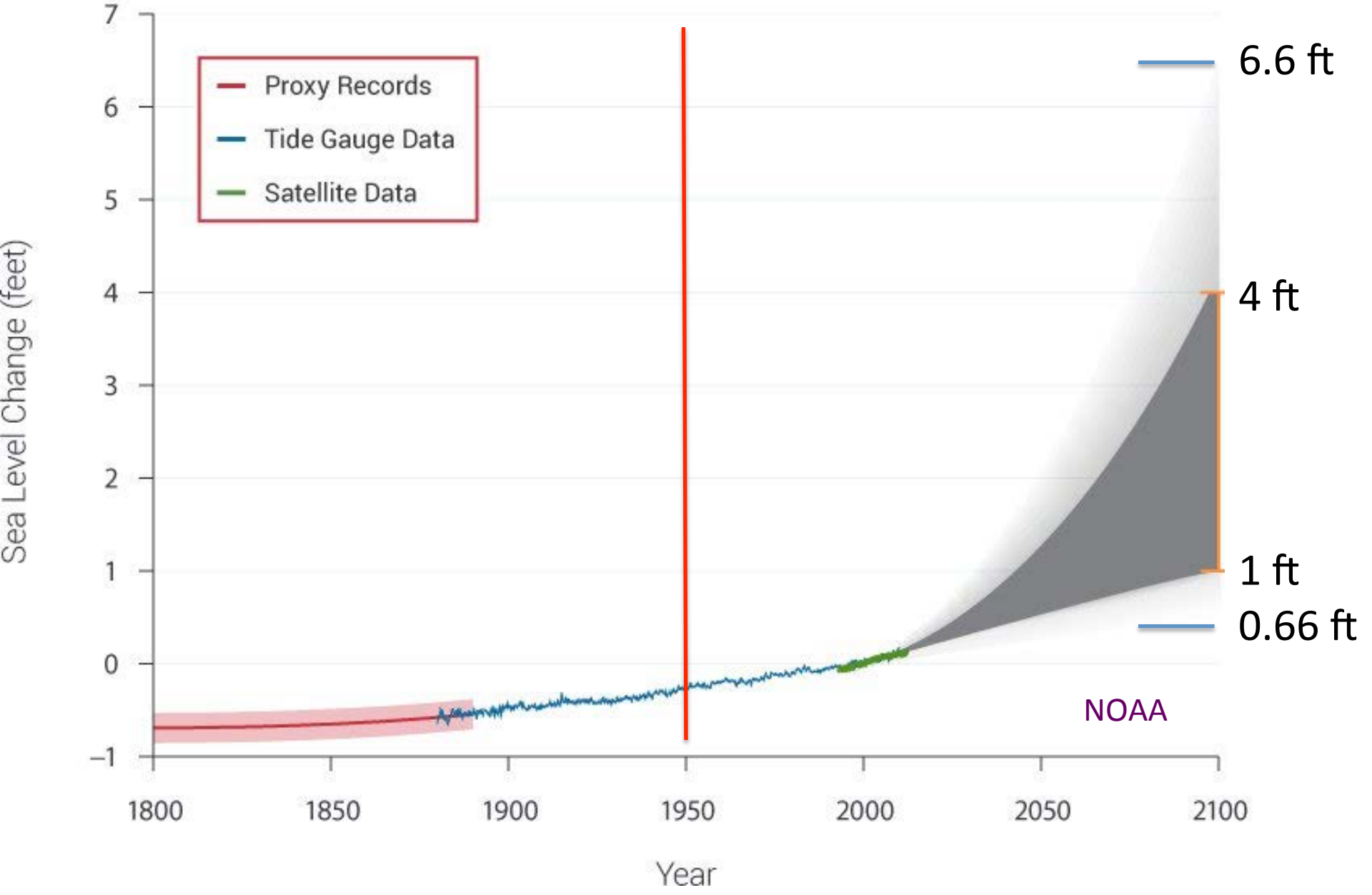
“That’s the big thing – sea-level rise – the planet could become ungovernable.” – Dr. James Hansen, former Director, NASA GISS

“We’re talking about literally giving up on our coastal cities of the world and moving inland.” – Dr. Michael Mann, Penn State

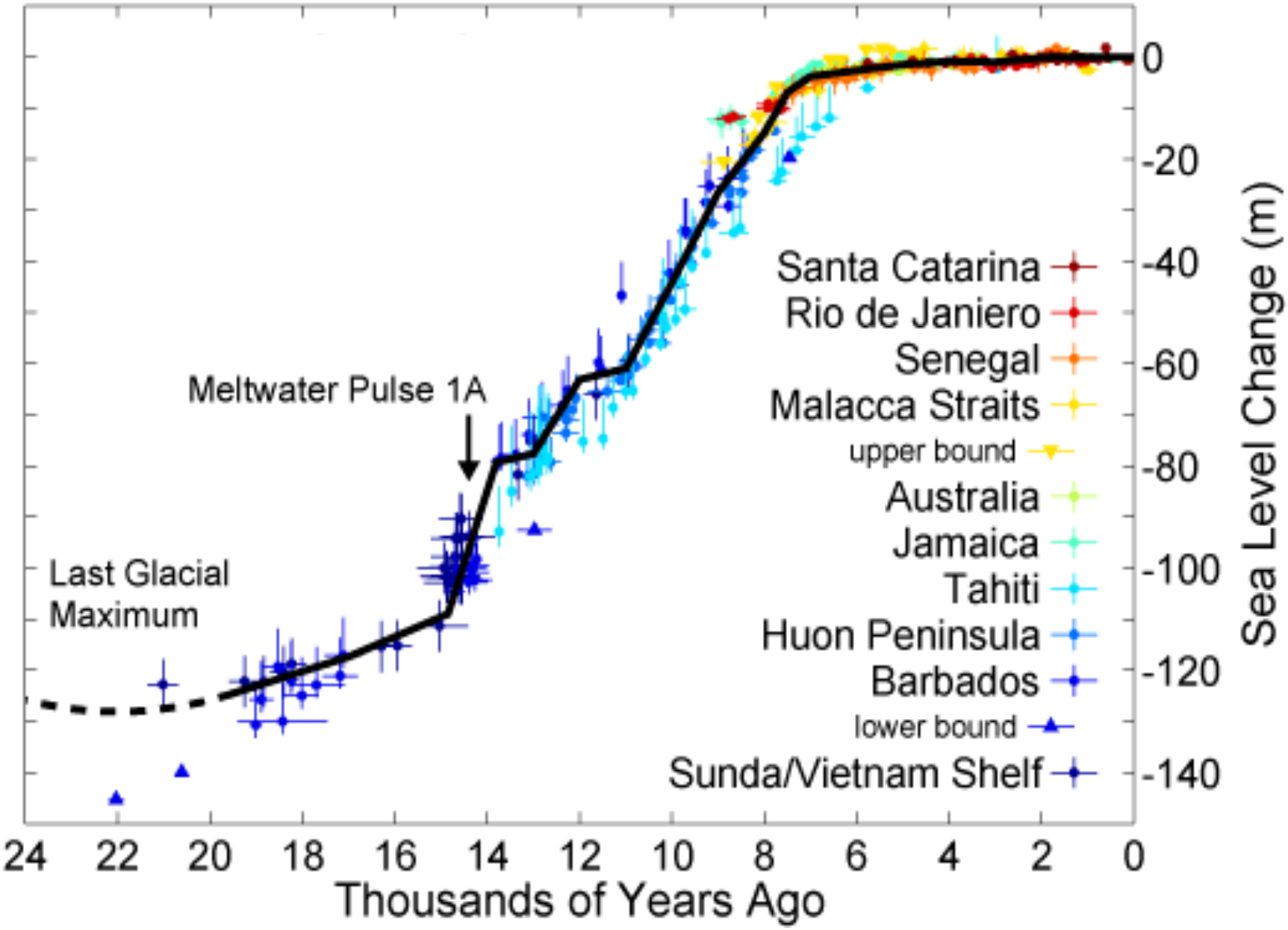
Past and Projected Changes in Global Sea Level



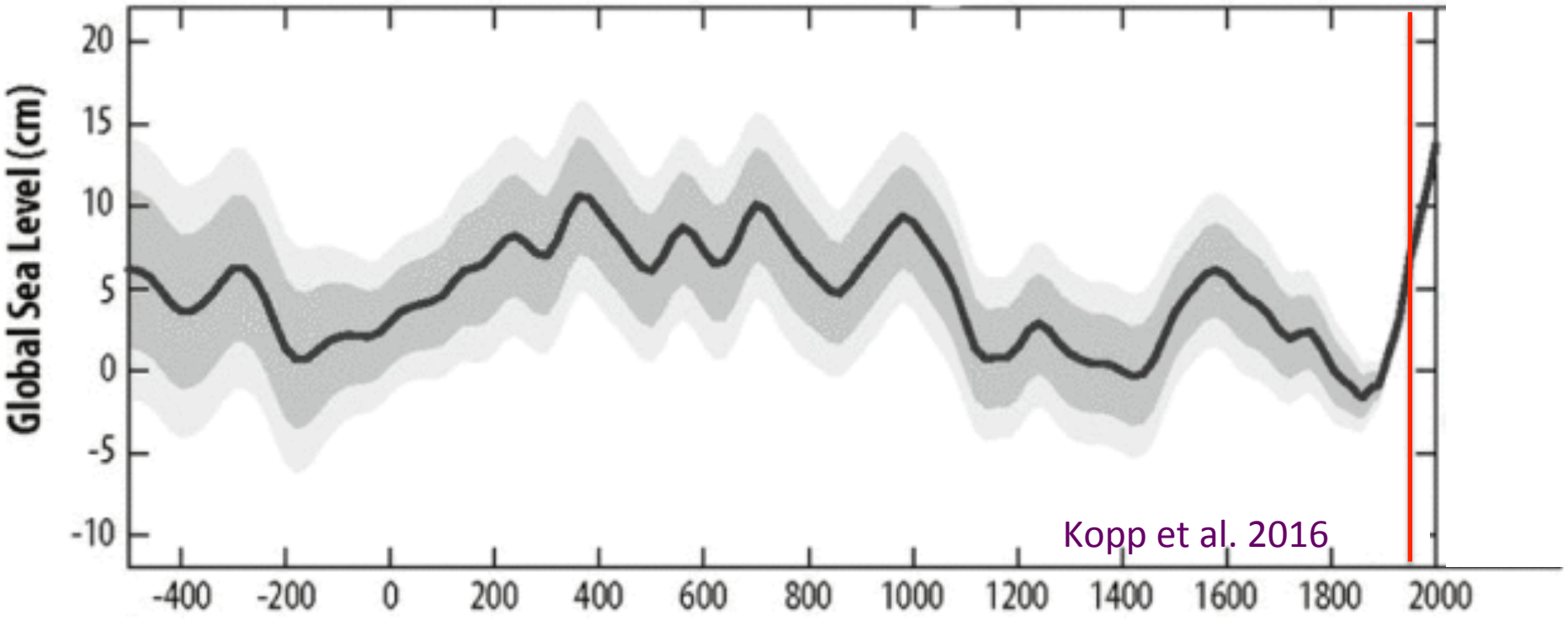
Sea Level Rise Questions

- Is the recent sea level rise unusual?
- What are the causes of sea level rise?
- How much sea level rise can we expect by 2050?
- What are the specific concerns regarding sea level rise in SE US?
- How will hurricanes and storm surges impact coastal cities?

Global sea level rise – past 24,000 years



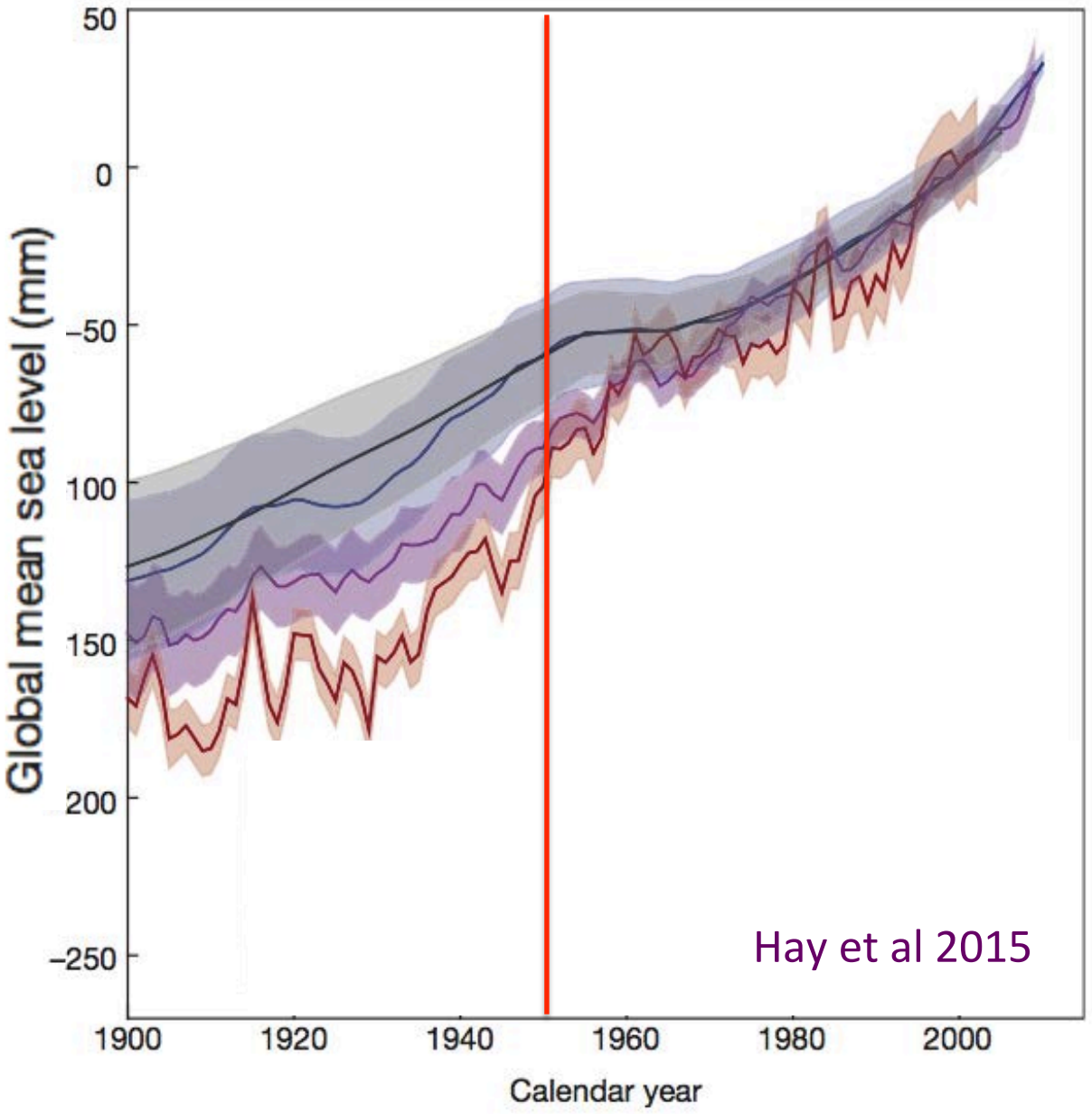
Paleo-reconstruction of global sea levels past 2500 years



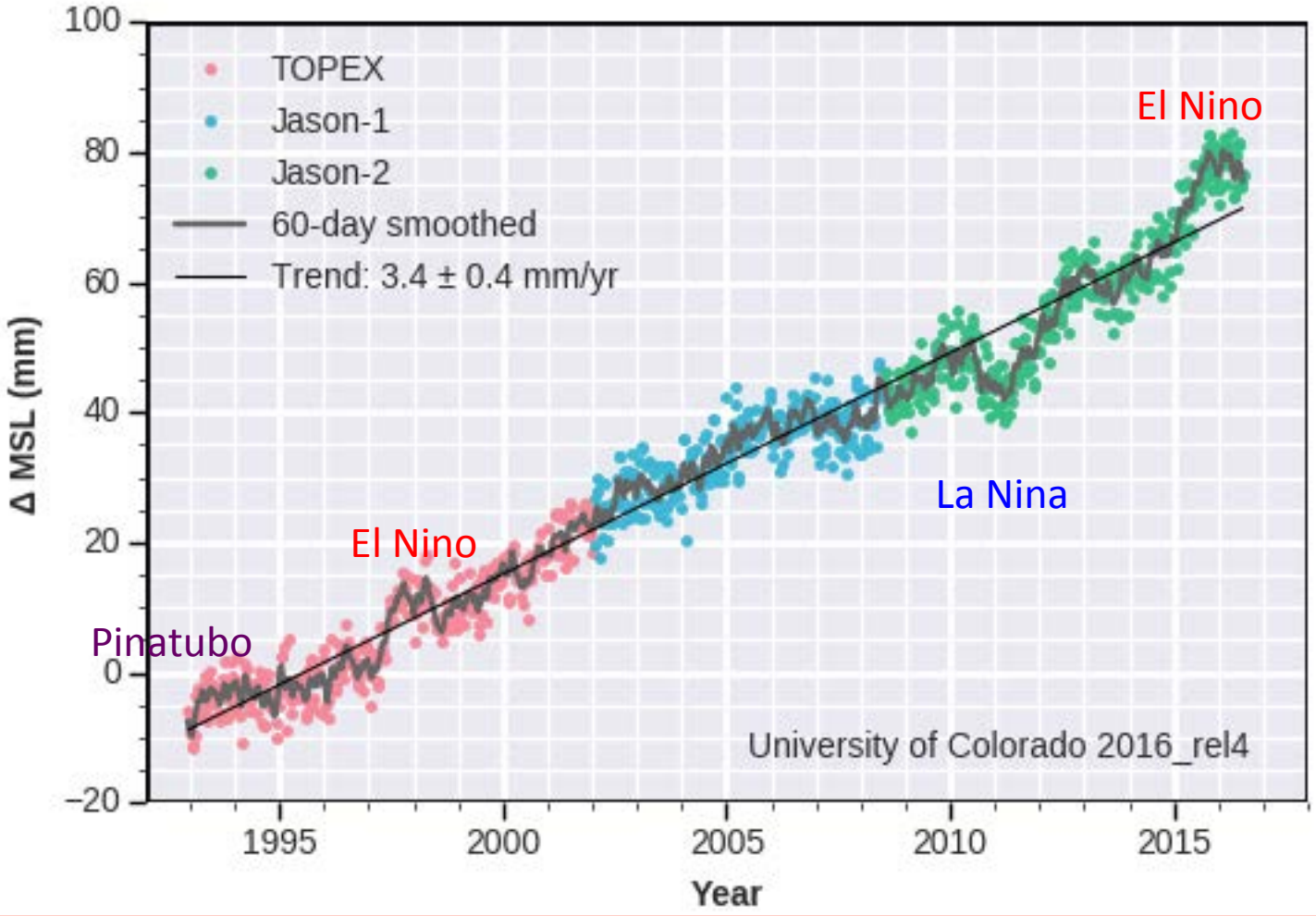
- Global sea level has varied ~ 10 inches over past 2500 years: sun, volcanoes, ocean oscillations
- We can't tell whether current peak is greater than peaks 400-1000 AD

Global sea level rise since 1900

- Sea level rise since 1900: ~ 8 inches
- Increasing uncertainty prior to 1960
- Substantial sea level rise prior to 1950
- No evidence of SLR acceleration in recent decades

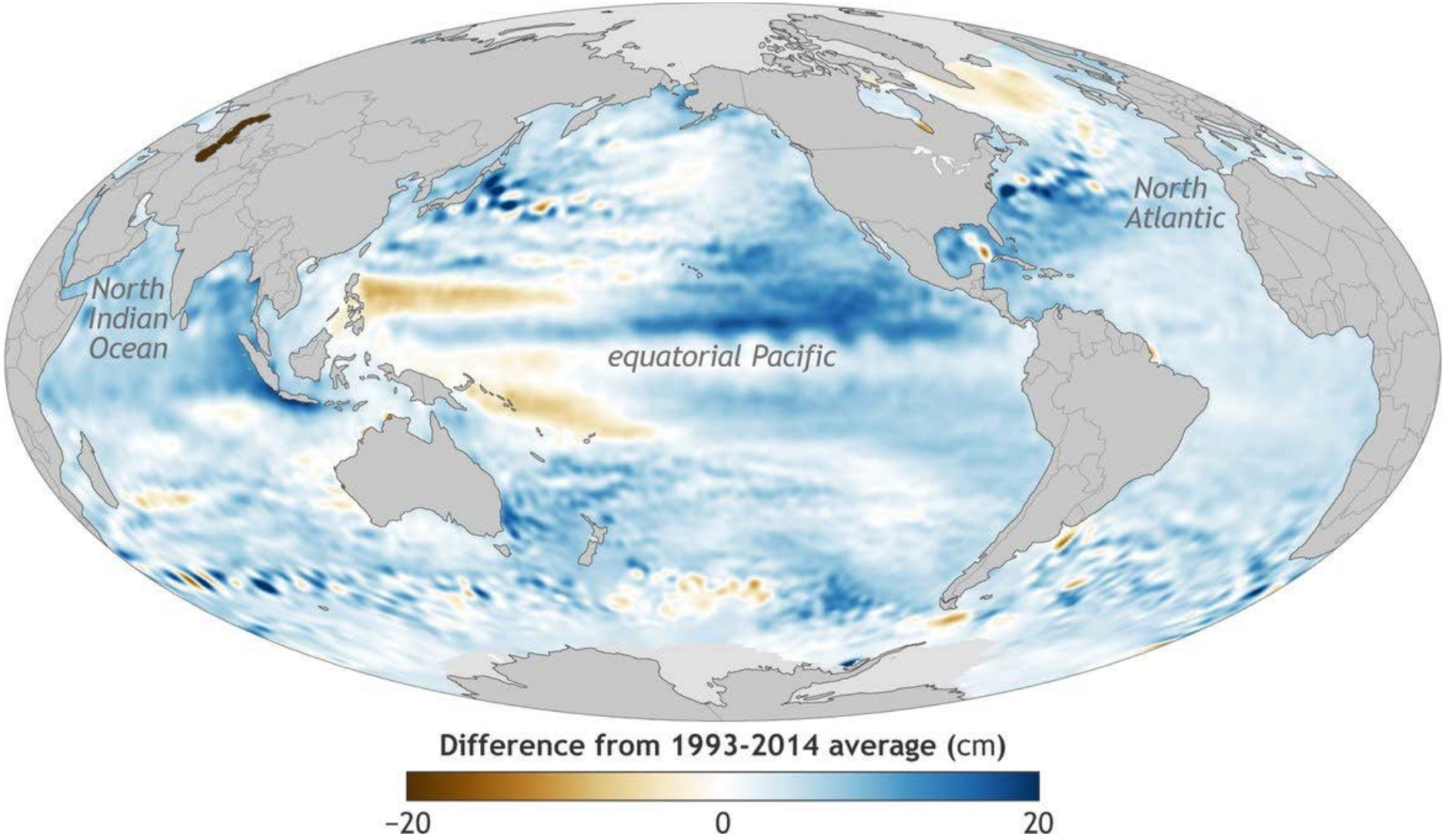


Global mean sea level rise (mm)



- ~3 inches since 1993. Recent research: trend ~ 2.7 mm/yr
- Satellite data set is too short and too uncertain to discern a significant acceleration

Global variations in sea level rise (1993-2014)



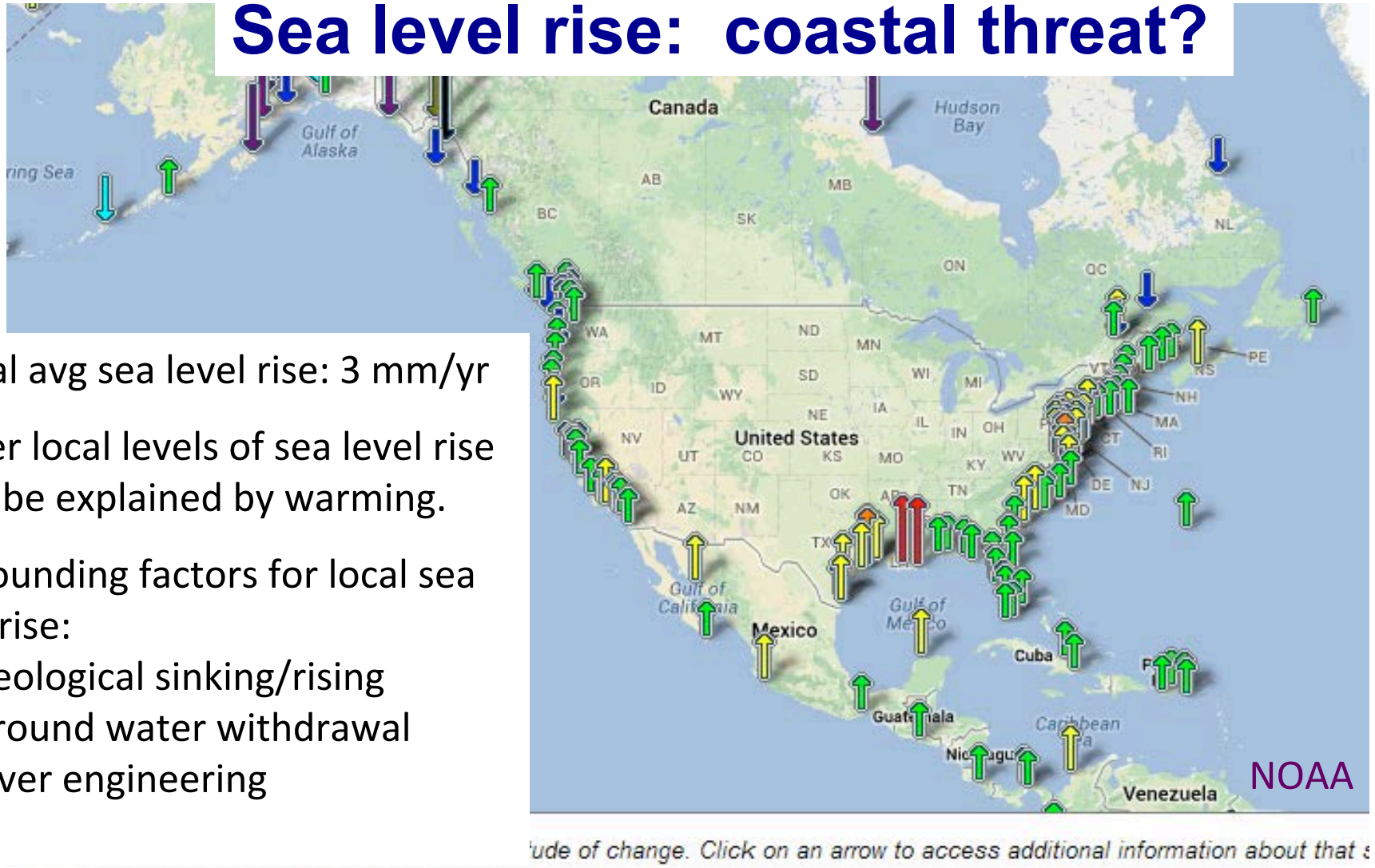
Sea level rise: coastal threat?

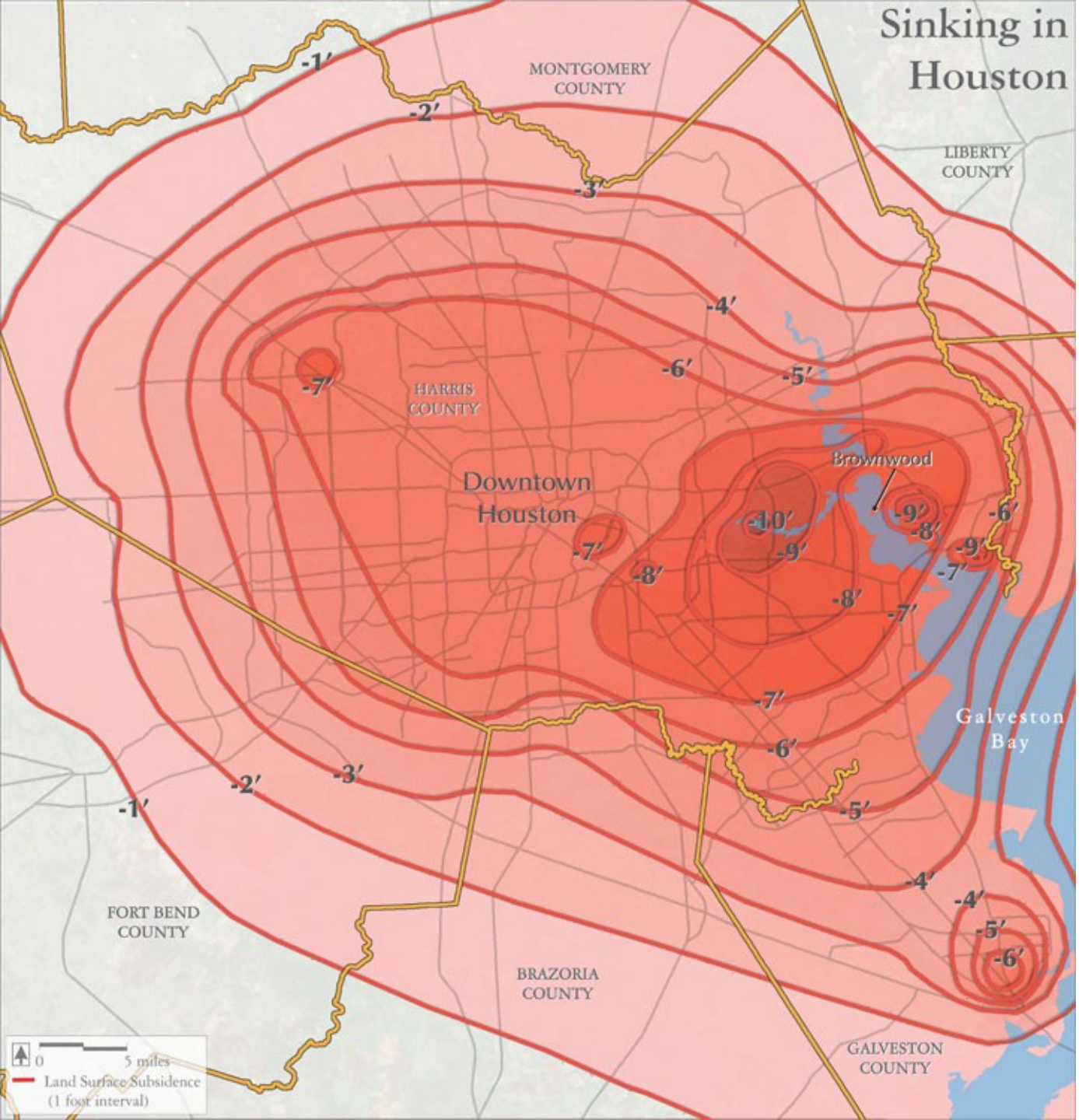
Global avg sea level rise: 3 mm/yr

Higher local levels of sea level rise can't be explained by warming.

Confounding factors for local sea level rise:

- Geological sinking/rising
- Ground water withdrawal
- River engineering





Sinking in Houston

Up to 10 ft sinking since 1920

Groundwater withdrawal causes massive subsidence

Increases flood risk

Ruins the efficiency of city drainage systems

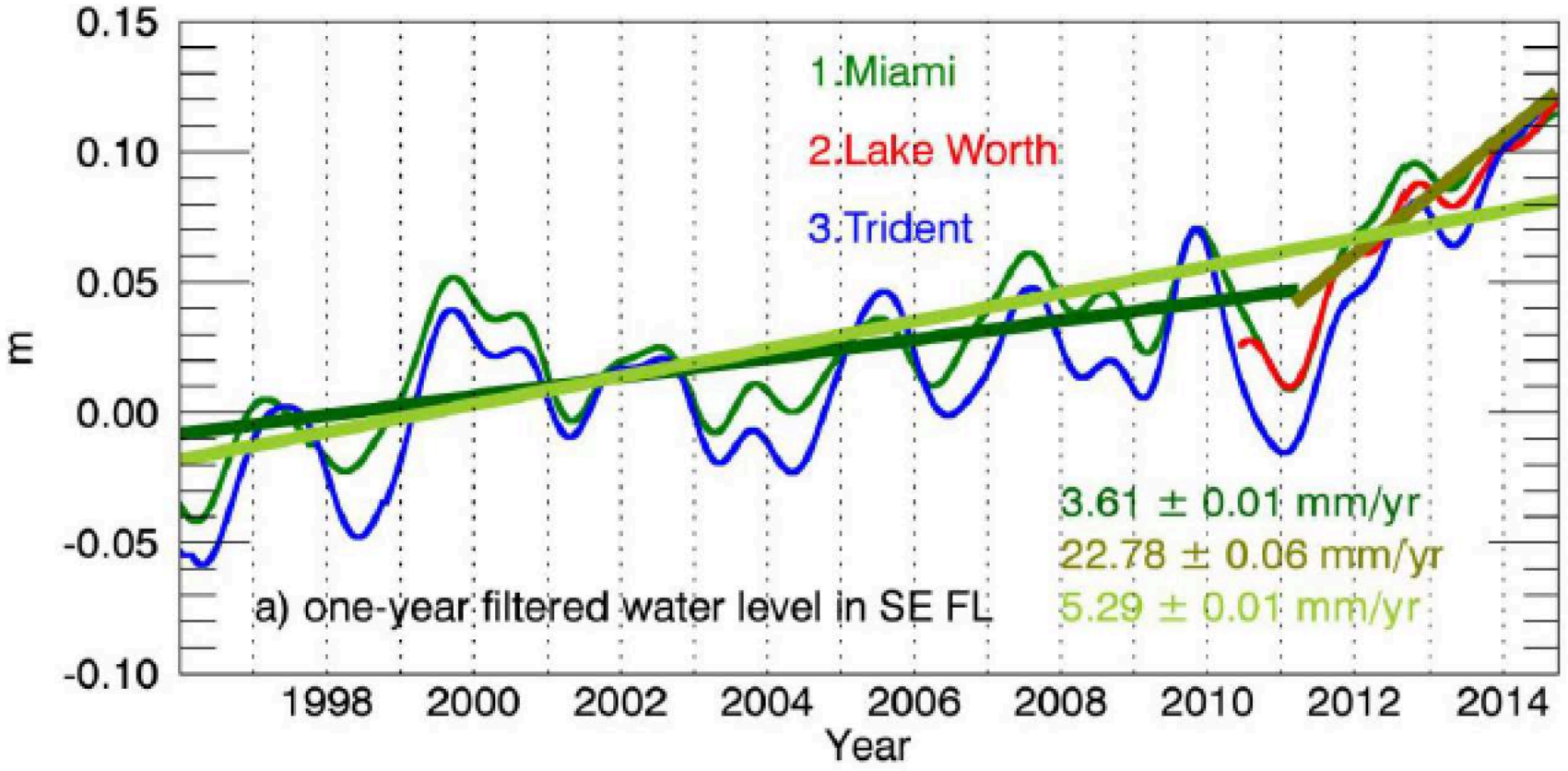
New Orleans

Following Katrina, federal government build levees, flood walls and pumps to protect against hurricanes

2017 flooding:

A large number of drainage pumps were out of service.

Pumps must suck rainwater out of storm drains and canals and push into a nearby lake or other water body.

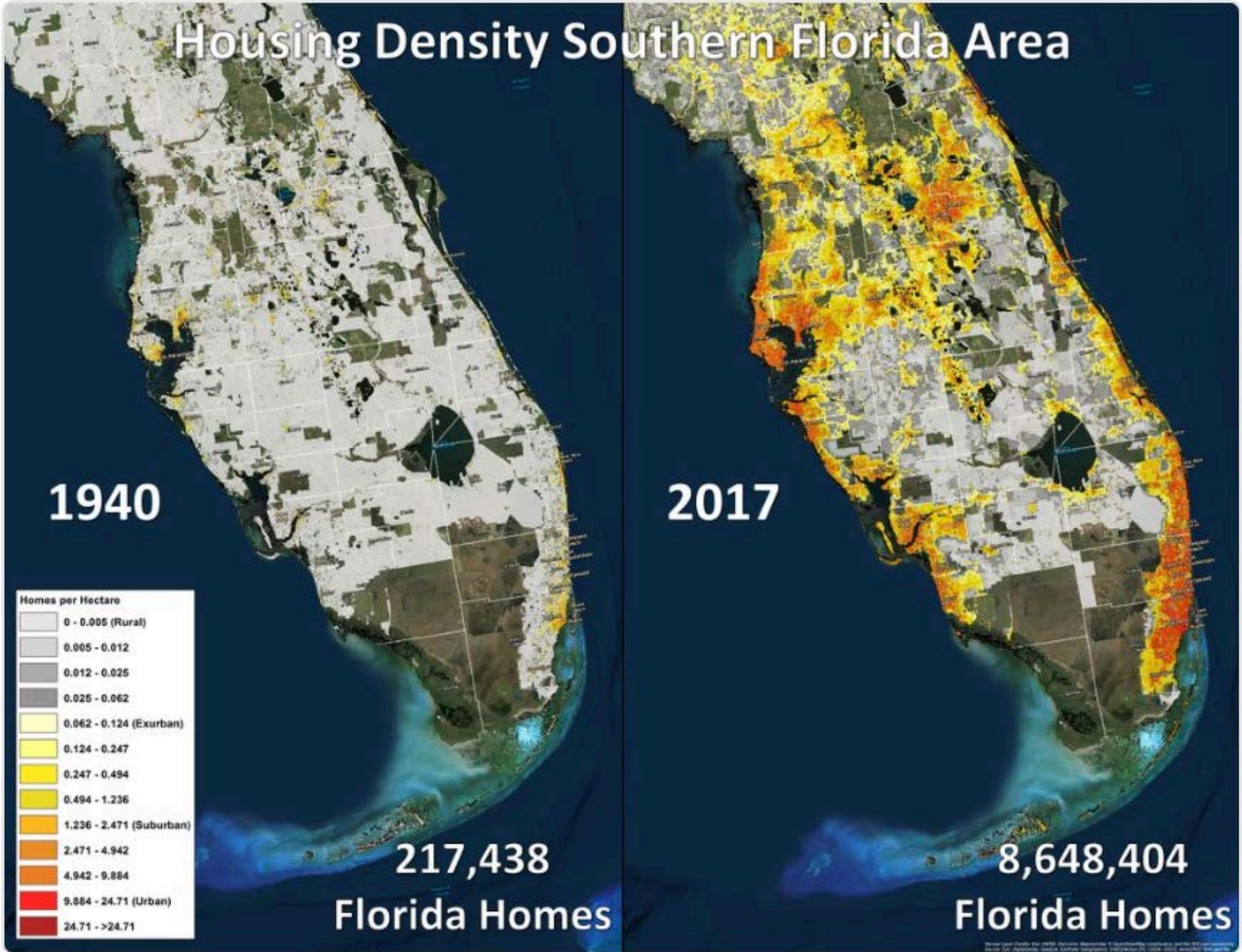


Recent accelerating sea level rise on the south U.S. Atlantic coast has been caused by El Nino and the North Atlantic Oscillation pattern

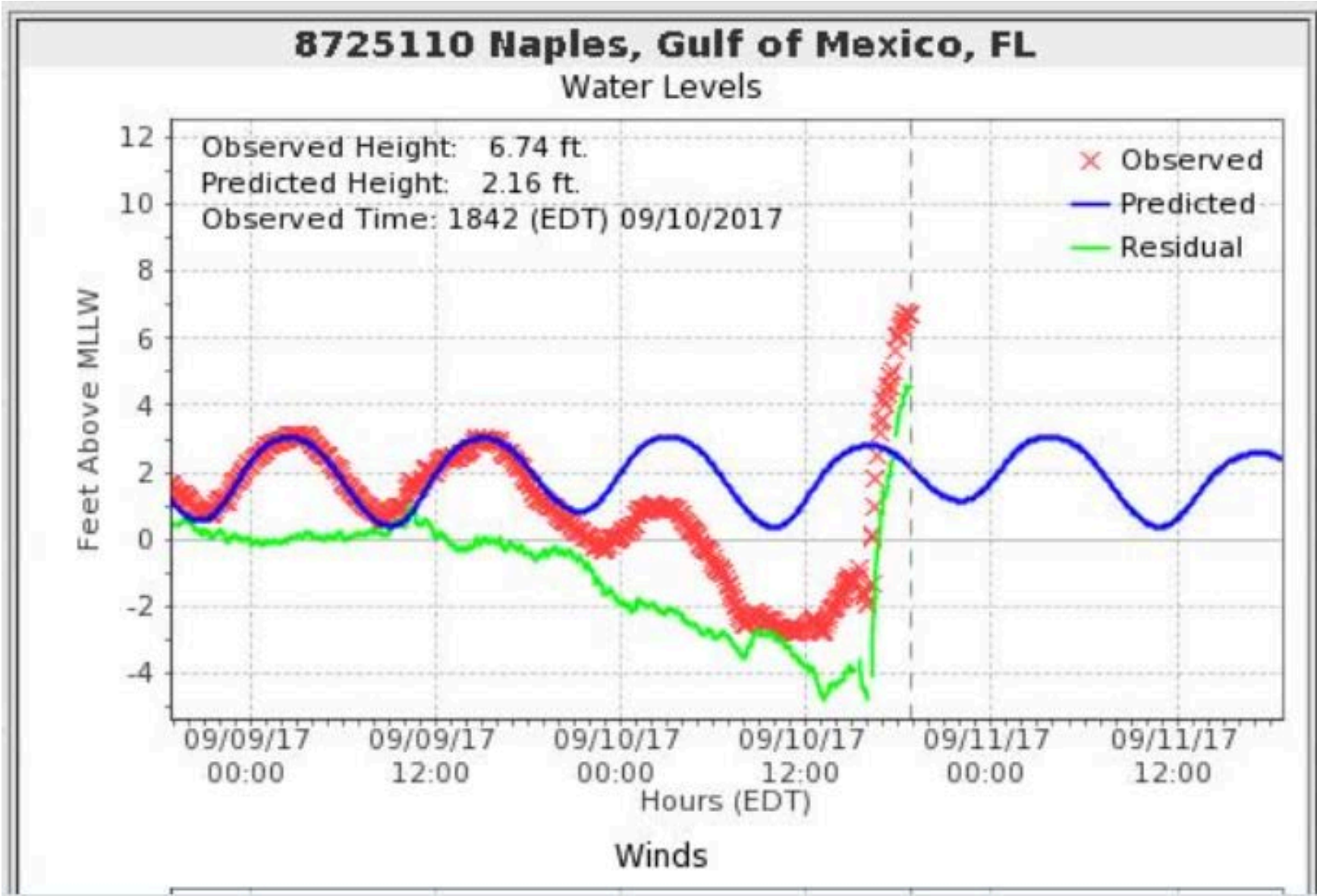
Valle-Levenson et al.(2017)

Miami: High Tide Event

Credit: Dr. Jennifer Jurado


Housing Density Southern Florida Area
1940
2017
Homes per Hectare
0 - 0.005 (Rural)
0.005 - 0.012
0.012 - 0.025
0.025 - 0.062
0.062 - 0.124 (Exurban)
0.124 - 0.247
0.247 - 0.494
0.494 - 1.236
1.236 - 2.471 (Suburban)
2.471 - 4.942
4.942 - 9.884
9.884 - 24.71 (Urban)
24.71 - >24.71
217,438
Florida Homes
8,648,404
Florida Homes

Hurricane Irma's Storm Surge



Coastal urban flooding issues

Population growth and urban development in coastal regions, flood plains and marsh/swamps are a ticking time bomb

Concrete jungles leave no place for the water to go

Inadequate municipal wastewater infrastructure is causing floodwaters to be filled with sewage waste

Safe Drinking Water Act violations are exacerbated during floods

Drainage infrastructure that requires pumps will be inoperative with loss of electric power

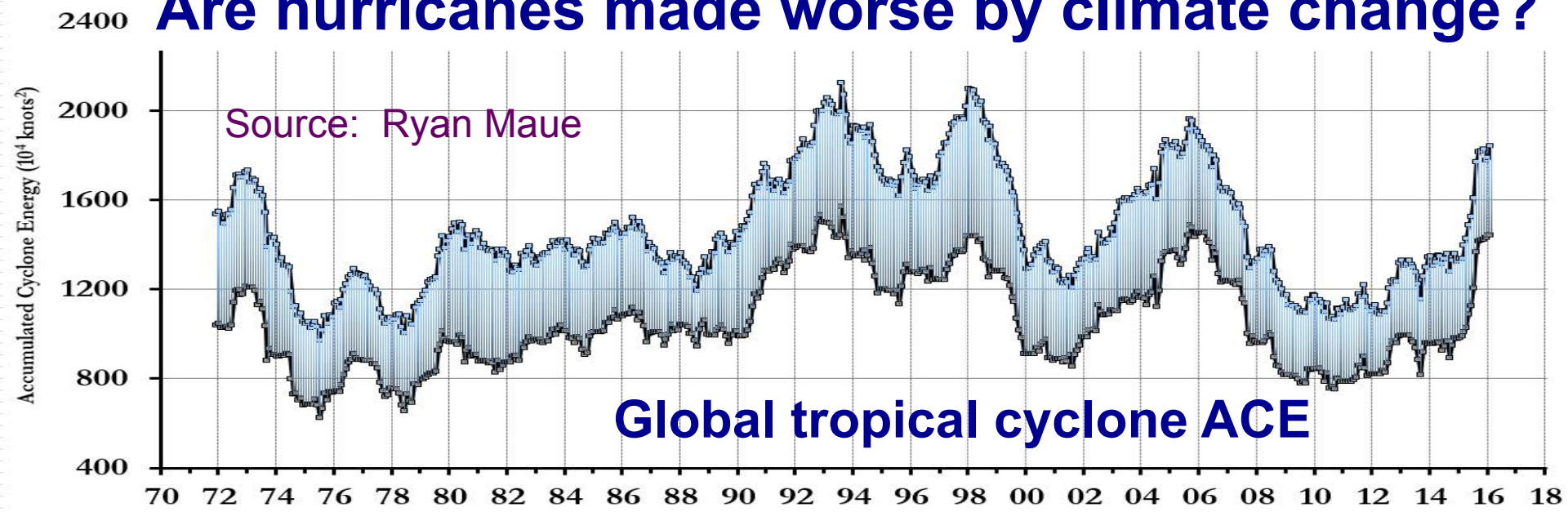
Solutions:

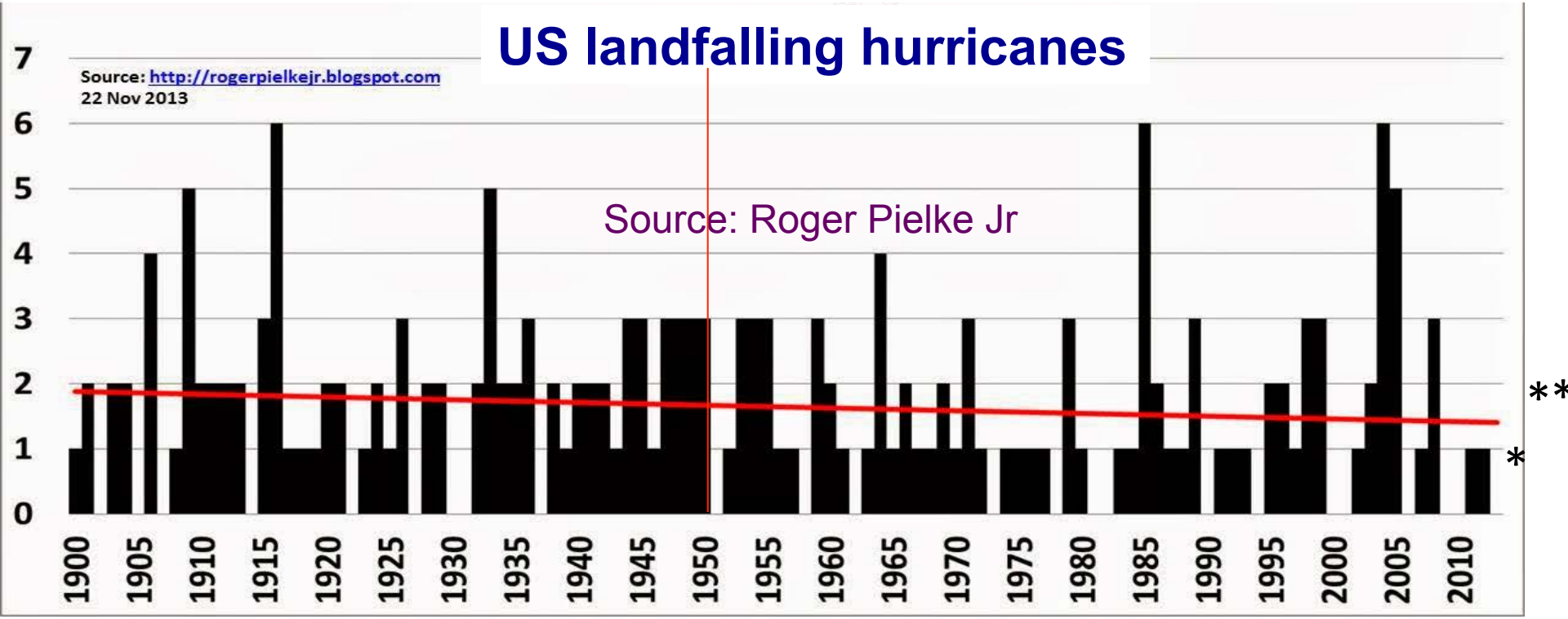
- Land use policy
- Better infrastructure and engineering

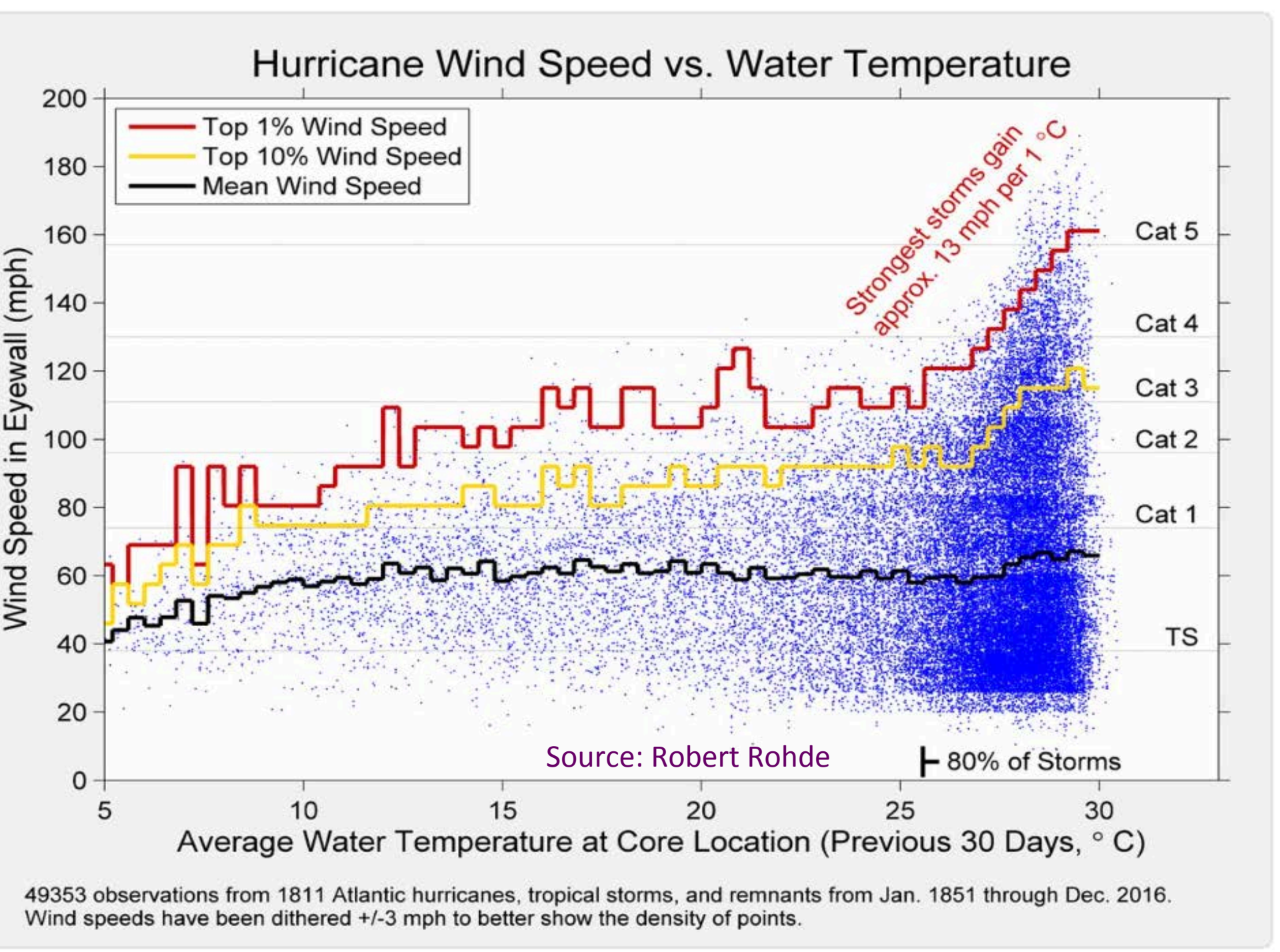
Is global warming making hurricanes more dangerous?

Rank	Hurricane	Year	Category (at landfall)	Minimum pressure, in millibars
1	Florida Keys	1935	5	892
2	Hurricane Camille	1969	5	900
3	Hurricane Katrina	2005	3	920
4	Hurricane Andrew	1992	5	922
5	Indianola, Texas	1886	4	925
6	Florida Keys & South Texas	1919	4	927
7	Hurricane Irma	2017	3	929
7	Lake Okeechobee, Florida	1928	4	929
8	Hurricane Donna	1960	4	930
9	New Orleans, Louisiana	1915	4	931
9	Hurricane Carla	1961	4	931
11	Last Island, Louisiana	1856	4	934
12	Hurricane Hugo	1989	4	934
13	Miami, Florida	1926	4	935
14	Galveston, Texas	1900	4	936
15	Hurricane Rita	2005	3	937
16	Hurricane Harvey	2017	4	938
16	Brunswick, Georgia	1898	4	938
16	Hurricane Hazel	1954	4	938
17	SE Florida, SE Louisiana, Mississippi	1947	4	940
18	Northern Texas	1932	4	941
19	Hurricane Charley	2004	4	941
20	Hurricane Gloria	1989	3	942

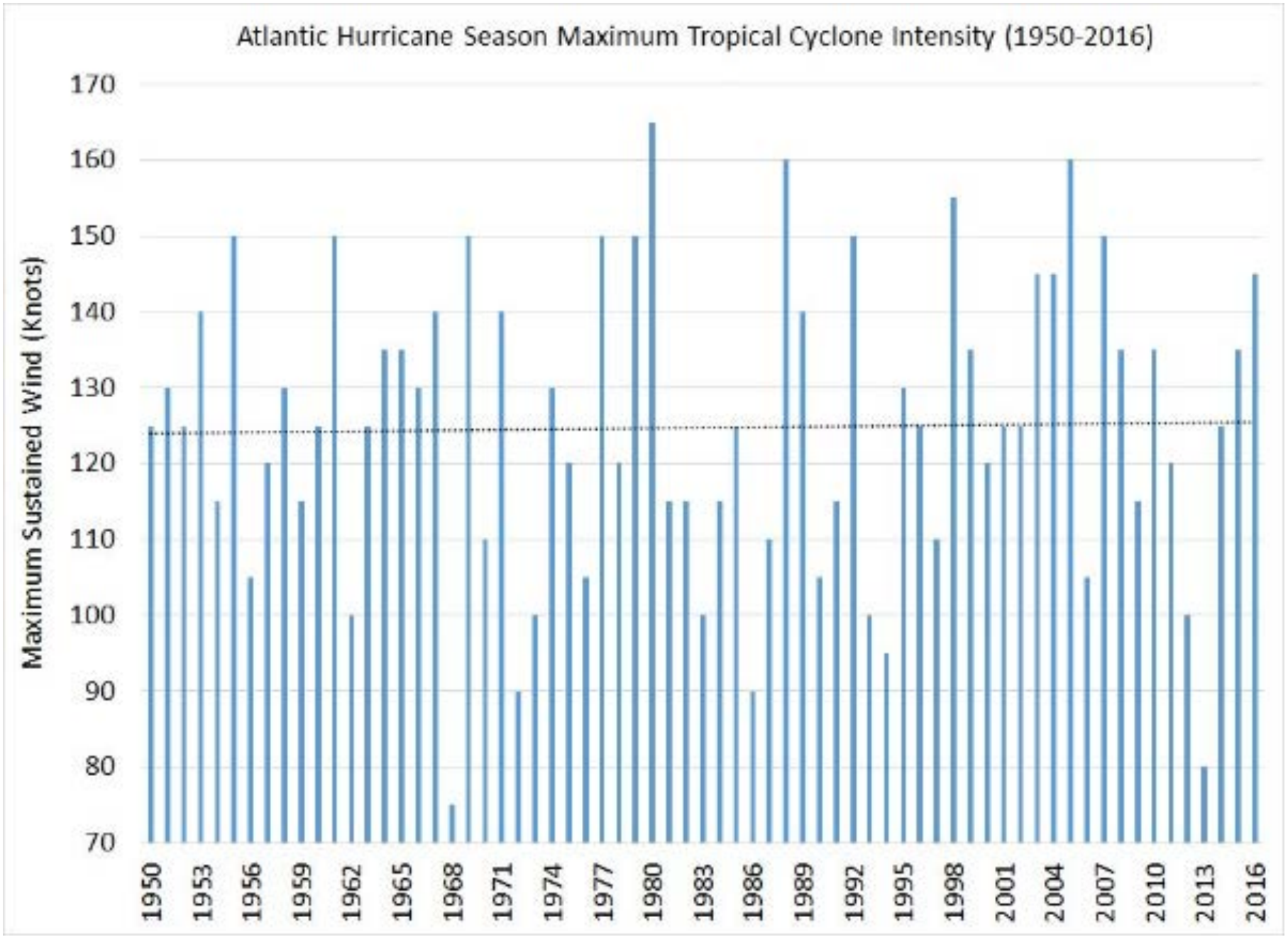
Are hurricanes made worse by climate change?



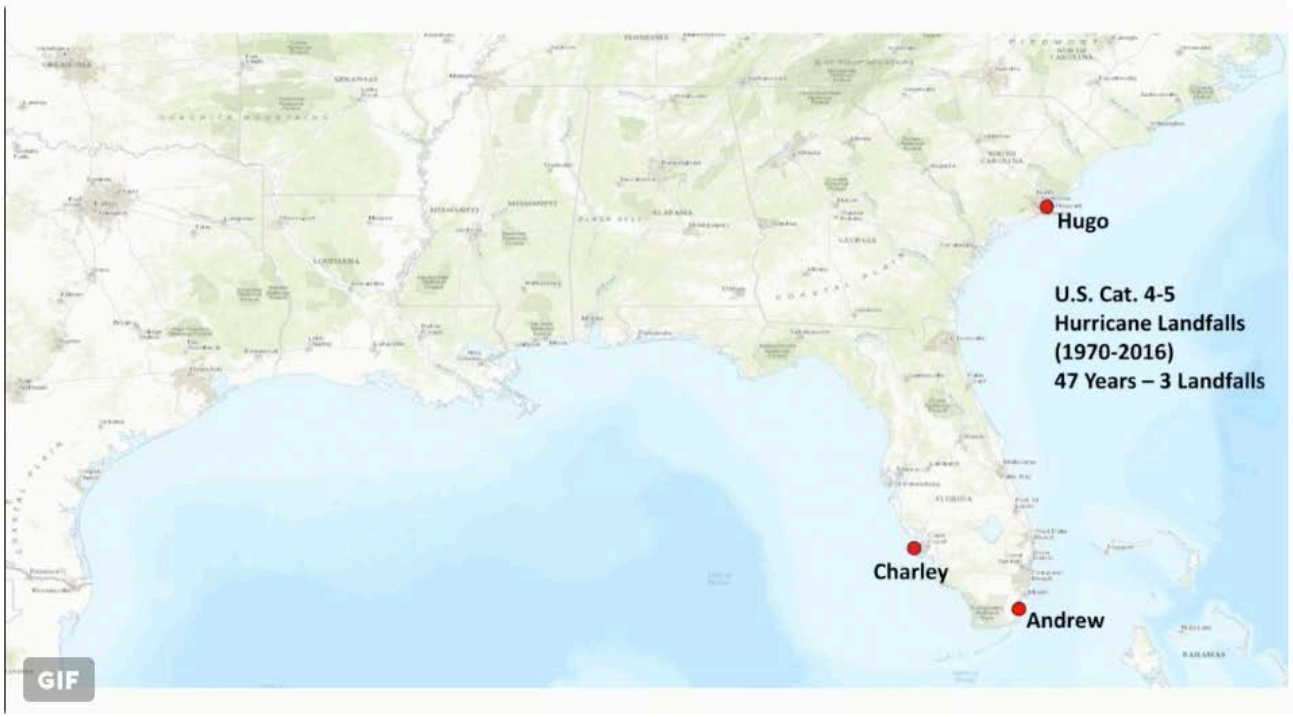




49353 observations from 1811 Atlantic hurricanes, tropical storms, and remnants from Jan. 1851 through Dec. 2016.
Wind speeds have been dithered +/-3 mph to better show the density of points.



Source: Phil Klotzbach

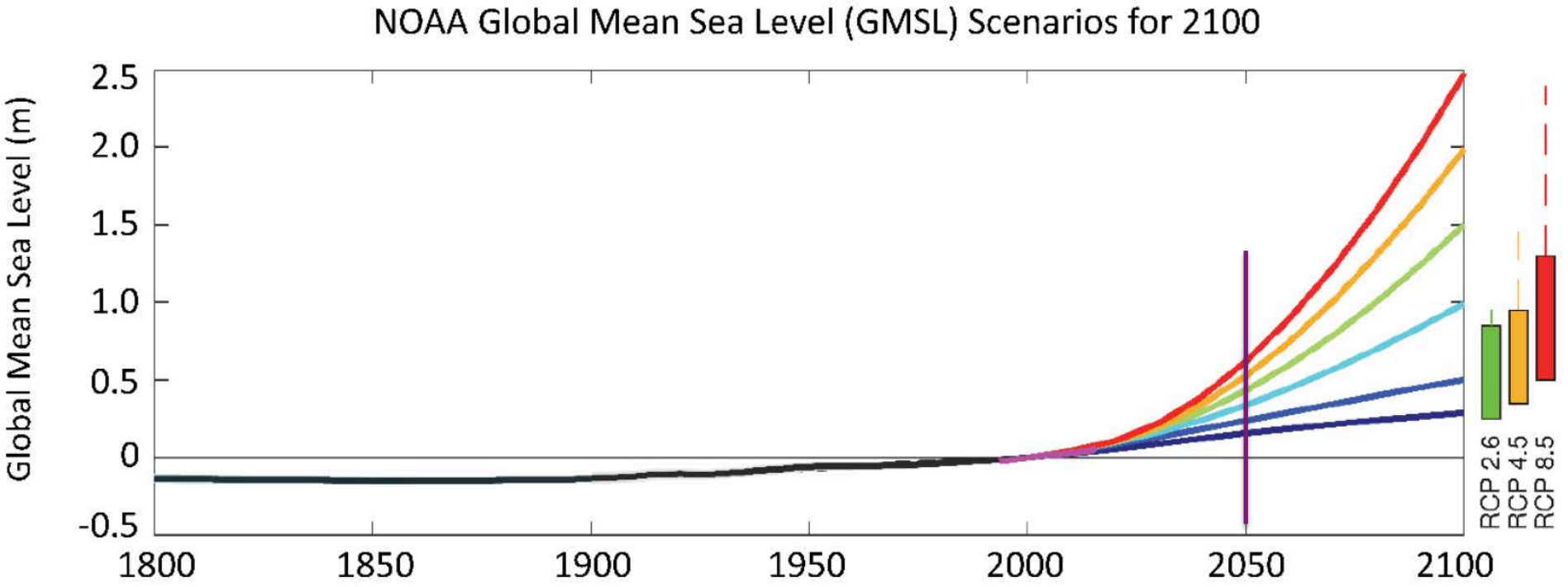


1970-2016:
3 landfalls Cat 4/5

1926-1969:
14 landfalls Cat 4/5

Whither Sea Level Rise in the 21st Century?

21st century projections of sea level rise



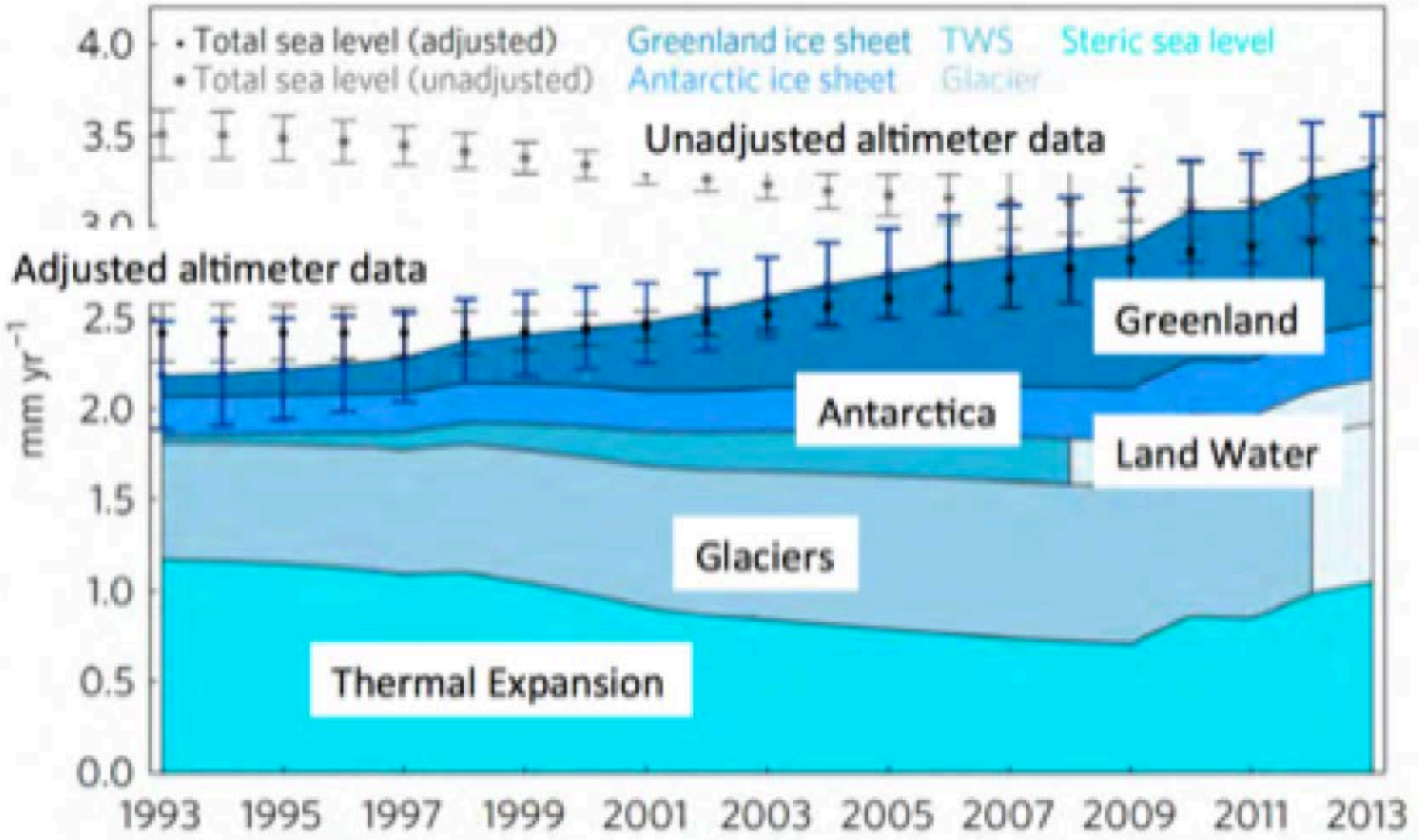
JC concerns that these projections are **too high**:

- Evidence that climate models are running too 'hot'
- Neglect of multi-decadal and longer ocean oscillations
- Neglect of volcanic eruptions and solar variations

Probability of sea level rise scenarios for 2100

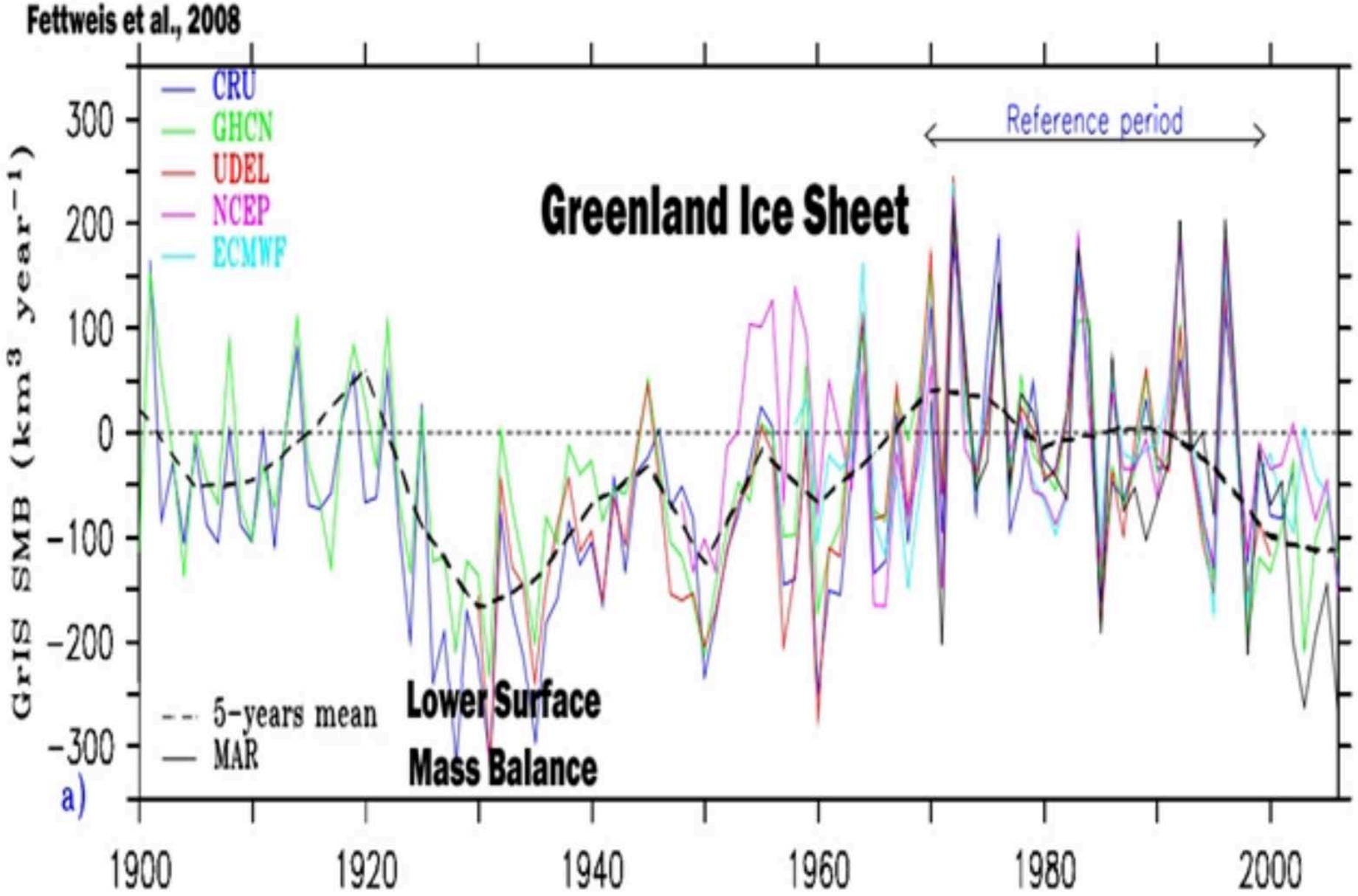
	EMISSIONS		
Scenarios	RCP2.6 Peak ~2020	RCP4.5 Peak ~2040	RCP8.5 Extreme
SLR			
1 ft	94%	**98%**	100%
1.6 ft	49%	**73%**	96%
3.3 ft	2%	**3%**	17%
4.9 ft	0.4%	0.5%	1.3%
6.6 ft	0.1%	0.1%	0.3%
8.2 ft	0.05%	0.05%	0.1%

What is causing recent sea level rise?

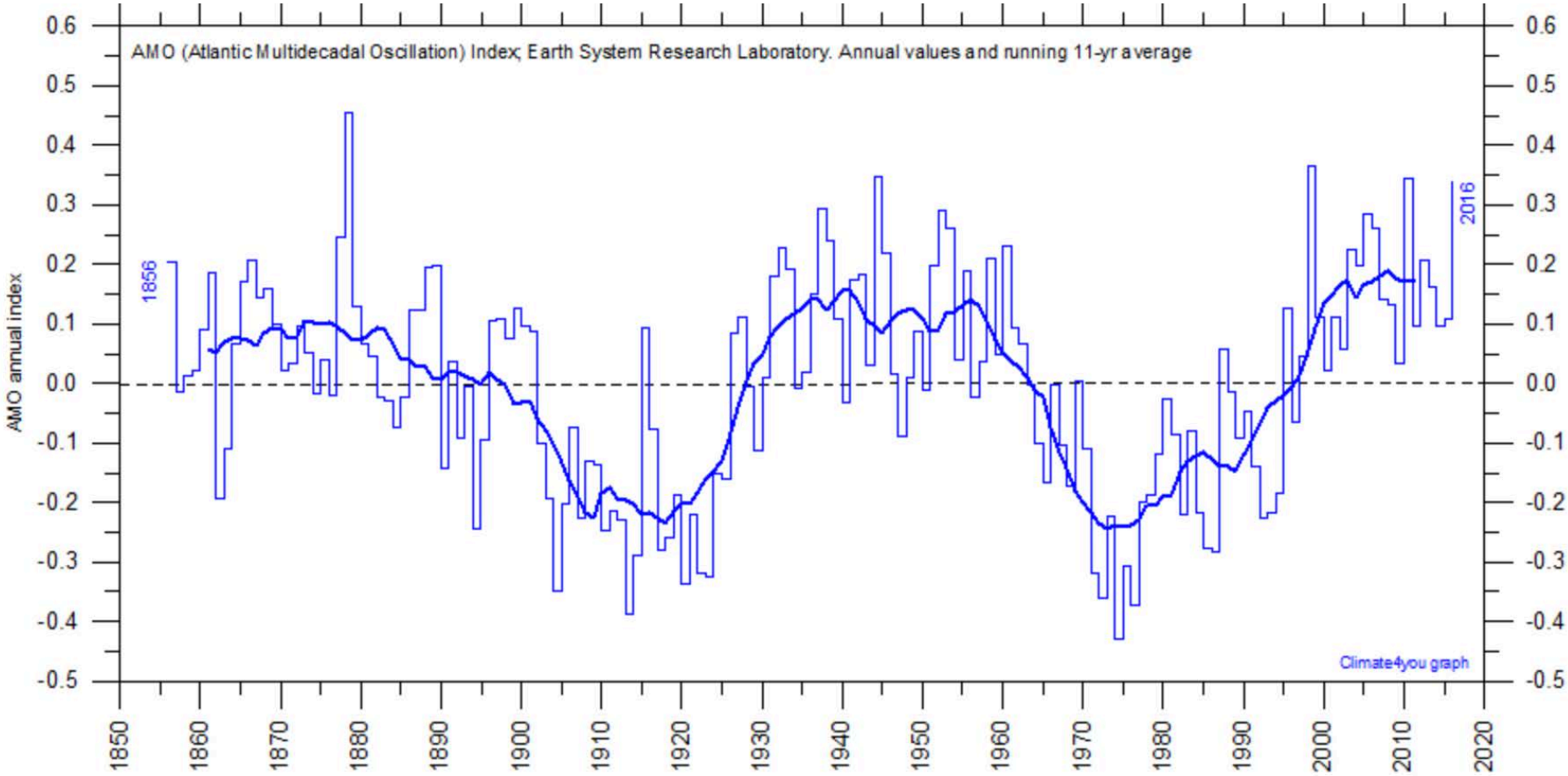


From Cheng et al. 2017

Variations in Greenland glacier mass balance



Atlantic Multidecadal Oscillation (AMO)



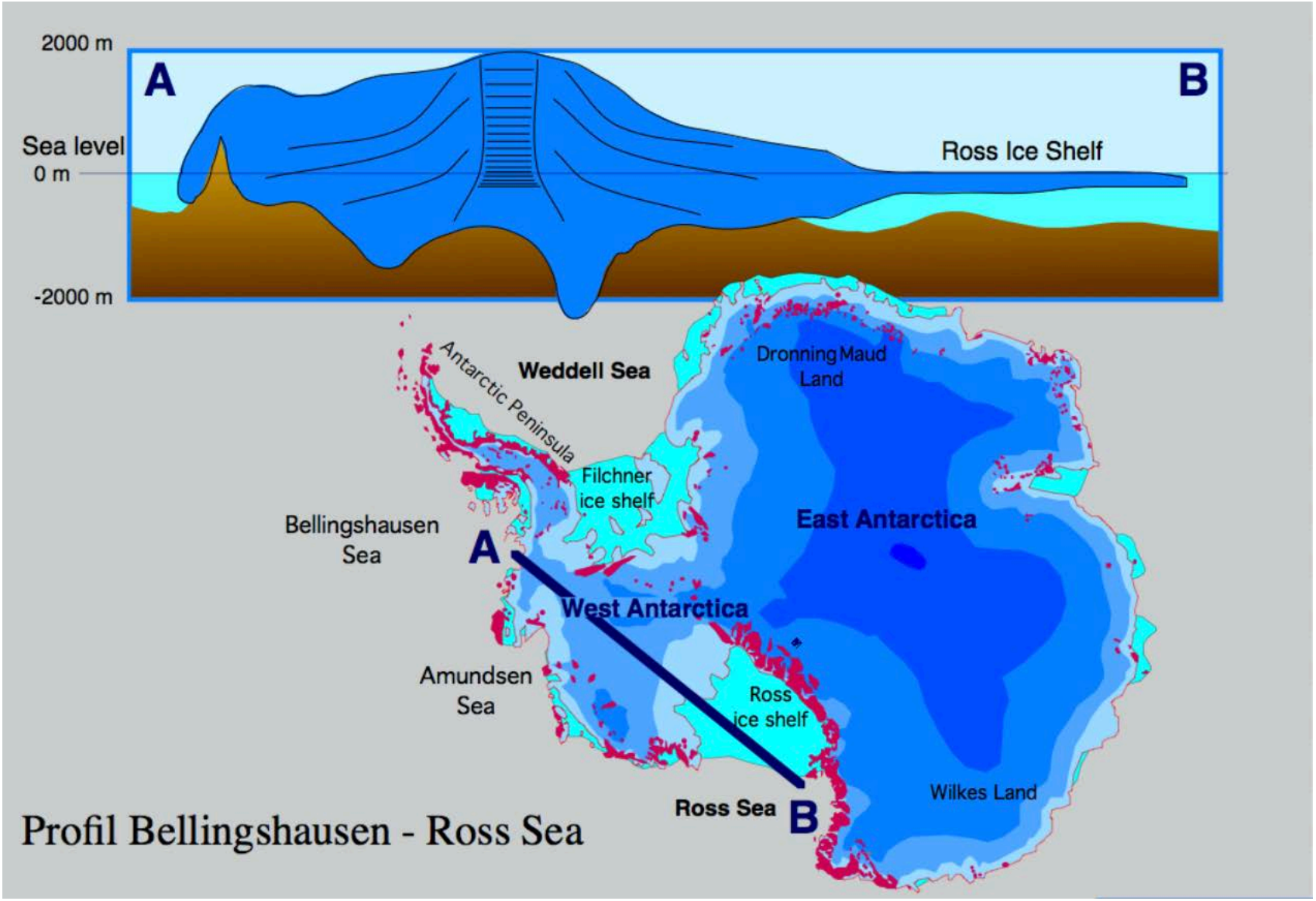
Warm AMO:

- Net melting of Greenland
- Active Atlantic hurricanes
- Greater SLR

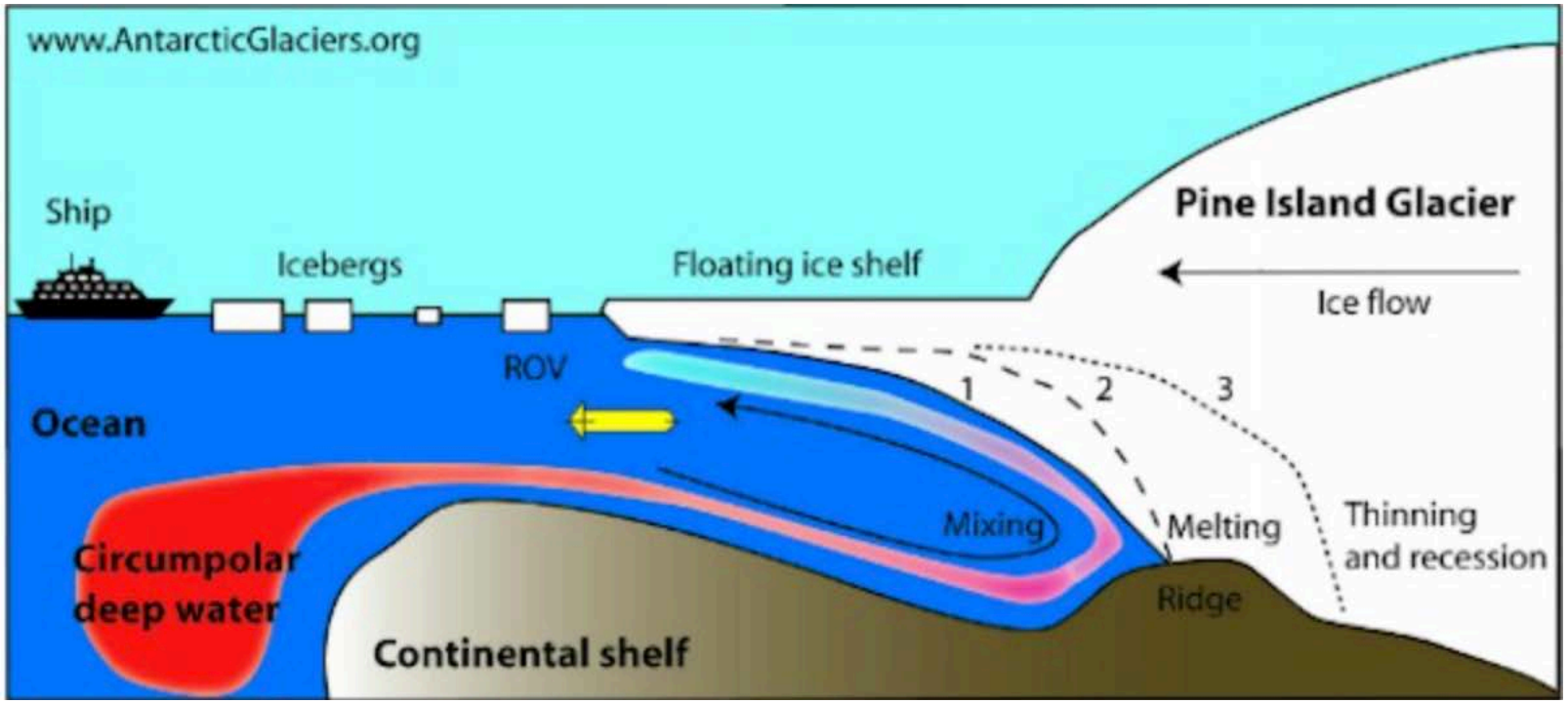
Next shift to cool phase?

- ~ 2025 – 2040?

West Antarctic Ice Sheet (WAIS)

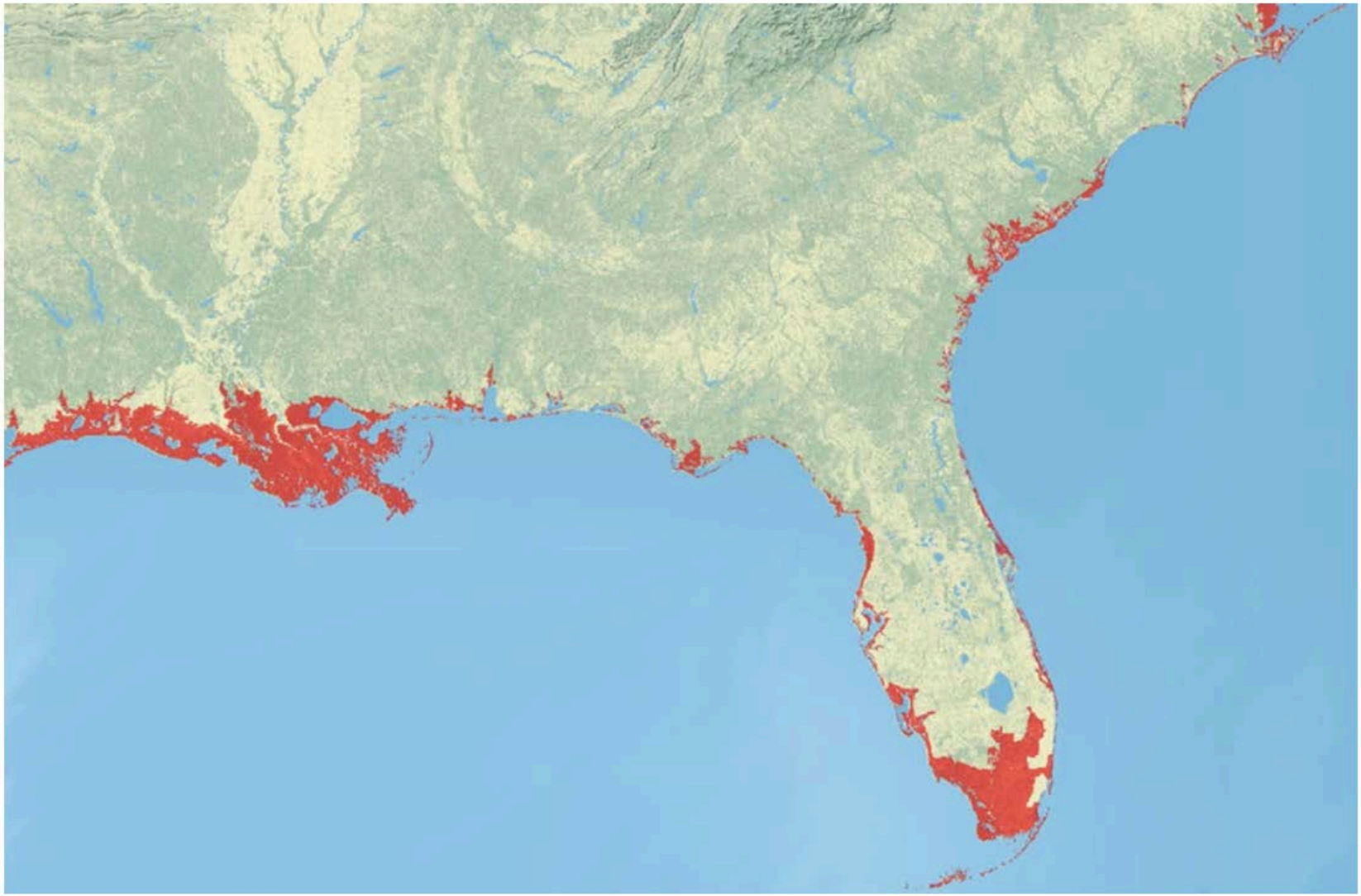


WAIS collapse?



- WAIS collapsed during previous interglacial ~125,000 years ago
- WAIS could collapse rapidly (1-2 centuries) via dynamic instability
- Complete collapse would raise sea level by **10 feet**
- Collapse is possible, but too uncertain to assign probability

10 ft of sea level rise . . .



If the West Antarctic Ice Sheet collapsed, it would cause some 10 feet of sea level rise, and nearly every mile of the southeast U.S. coastline would be inundated. Large regions of Florida and Louisiana would flood.

JC's Sea Level Rise Prediction: 2050

Global sea level rise:

3 to 8 inches

Regional predictions (AMO cool phase):

- SLR acceleration north of Cape Hatteras
- SLR in SE US no longer accelerating

Atlantic hurricanes (AMO cool phase):

- Lower overall hurricane activity
- Fewer major hurricanes

Conclusions

- Local sea level rise is driven by many factors
- Assumptions about sea level rise from future global warming may be of minor relevance to local sea level rise
- Financial and local mitigation decisions about the future need to consider the entire local context of level rise

"If we only look at the problem starting with just the climate signal, then it leads down a different path than if we look at components of sea level rise that are important to decision-makers." - Kathleen White, US Army Corps of Engineers

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