

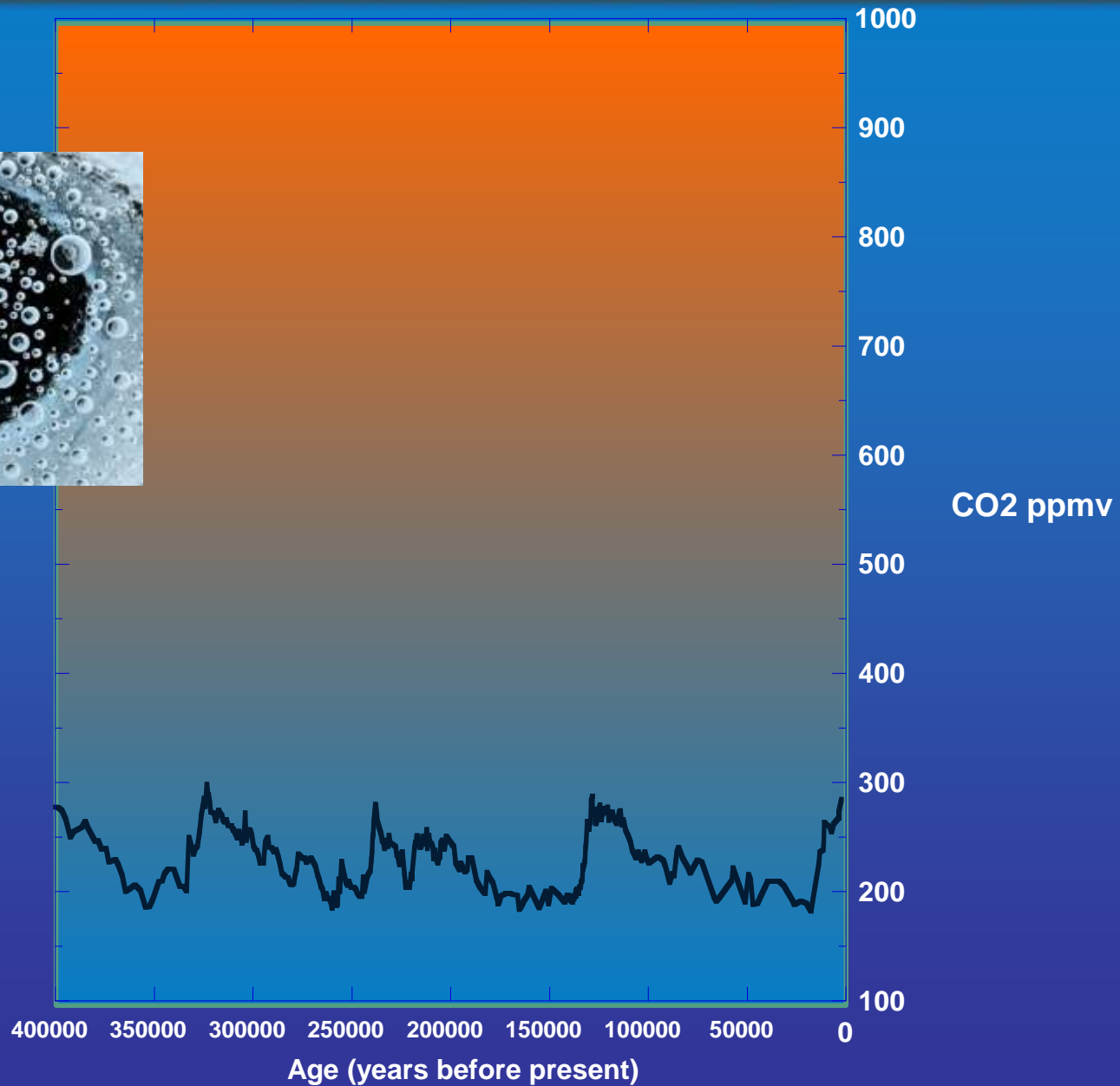


A Perfect Storm: The Collision of Hurricanes, Climate Change and Coastal Population Growth

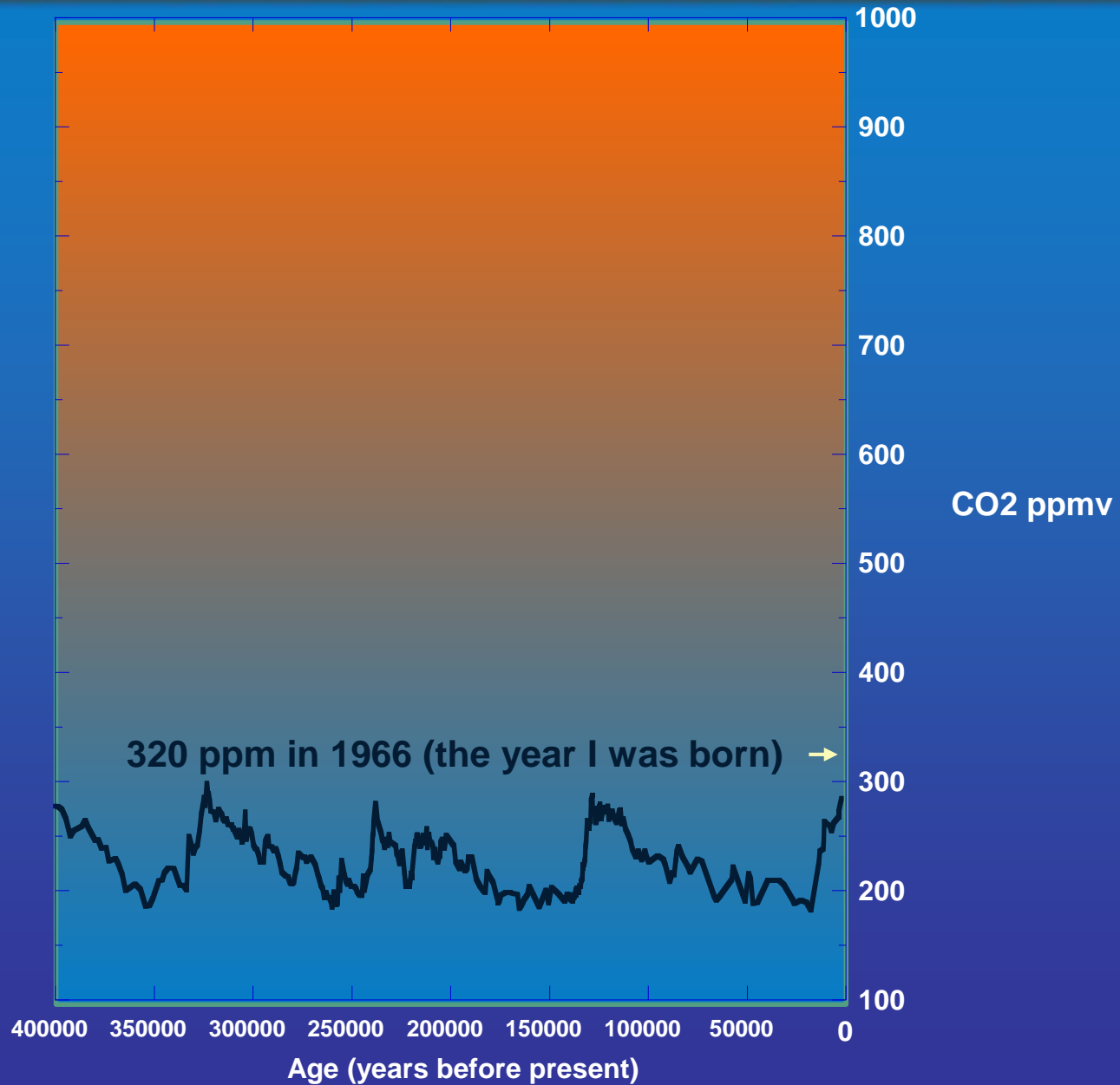


Jeff Donnelly
Woods Hole Oceanographic Institution

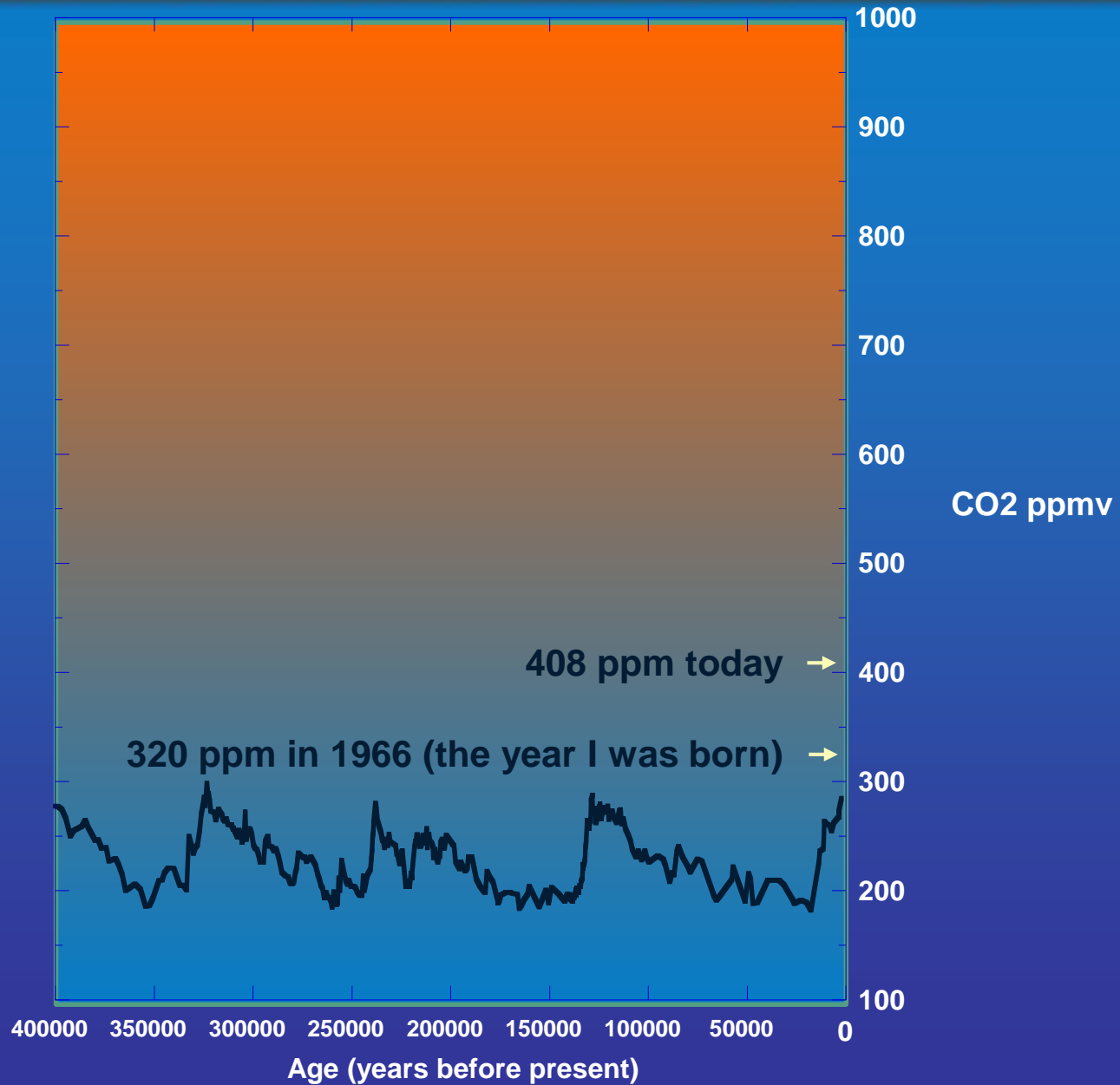
Human caused climate change



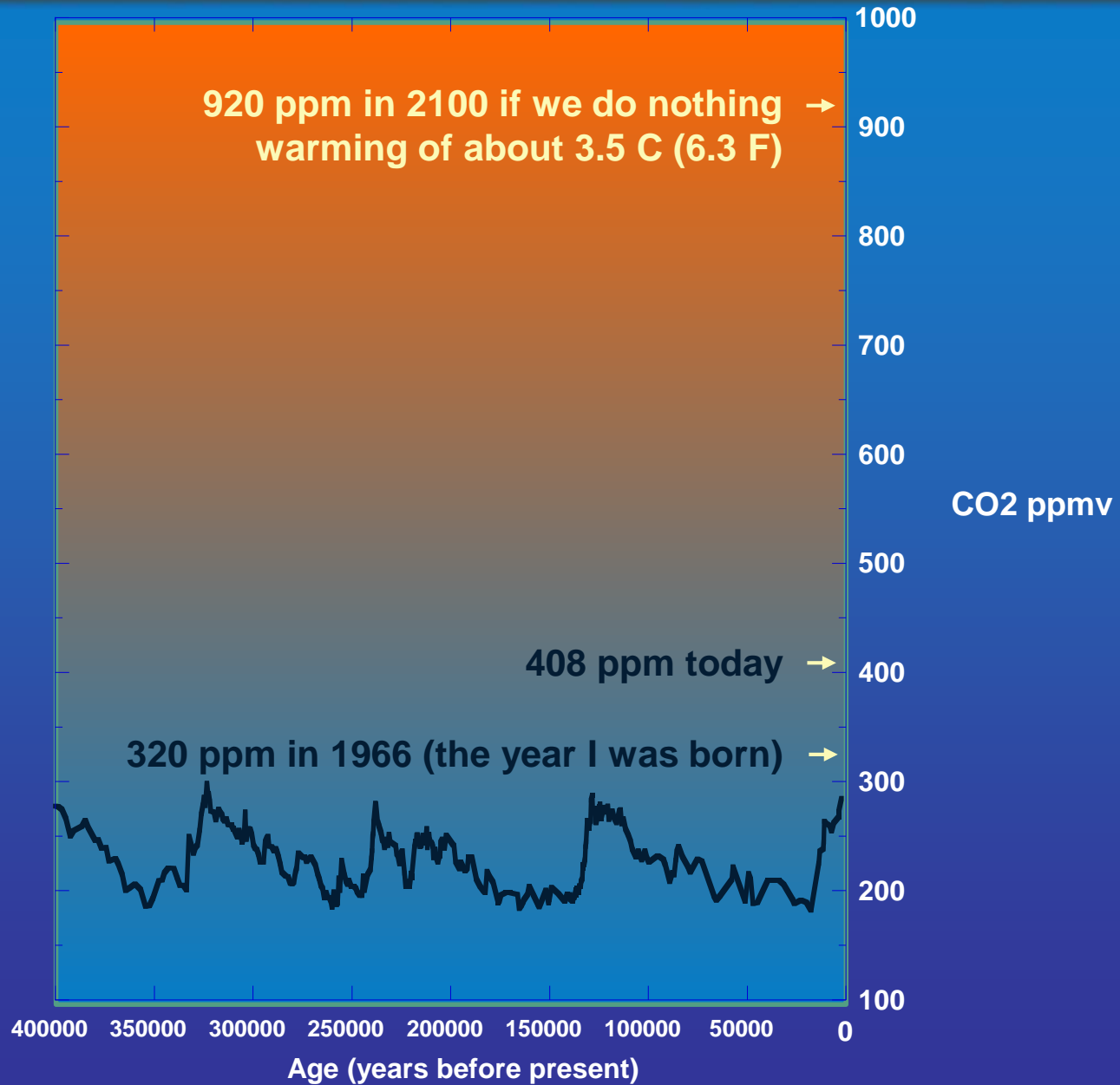
Human caused climate change



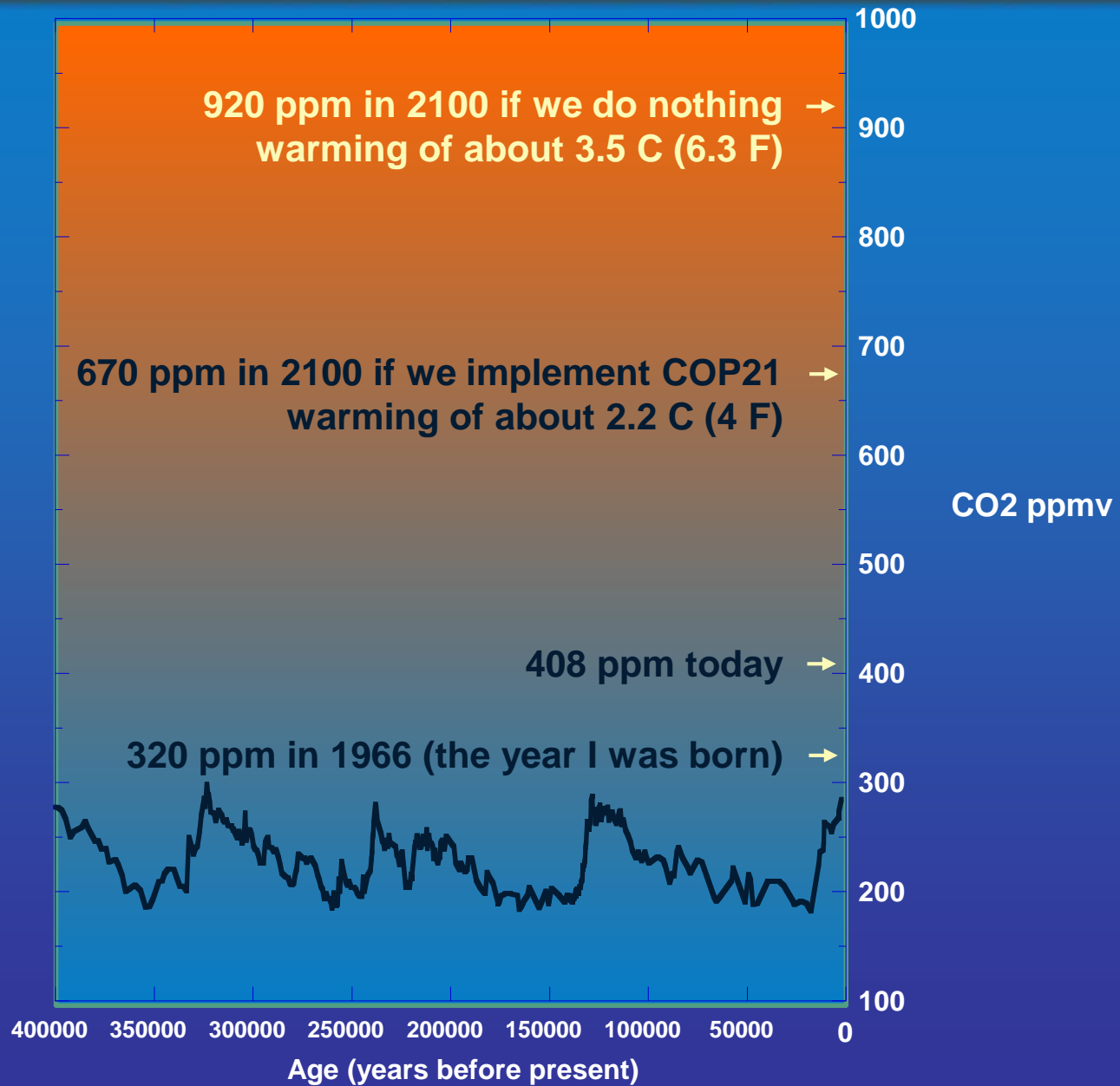
Human caused climate change



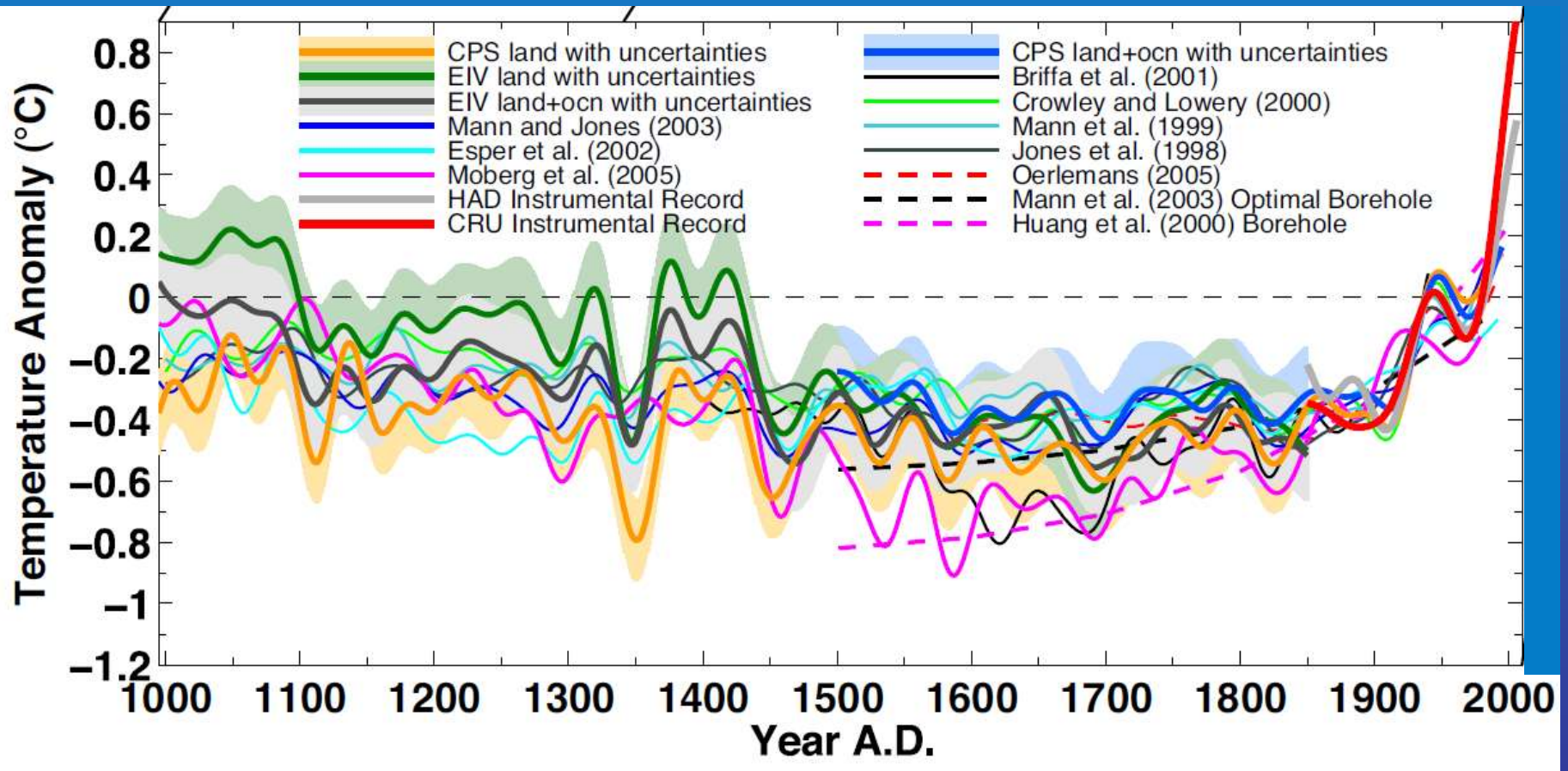
Human caused climate change



Human caused climate change



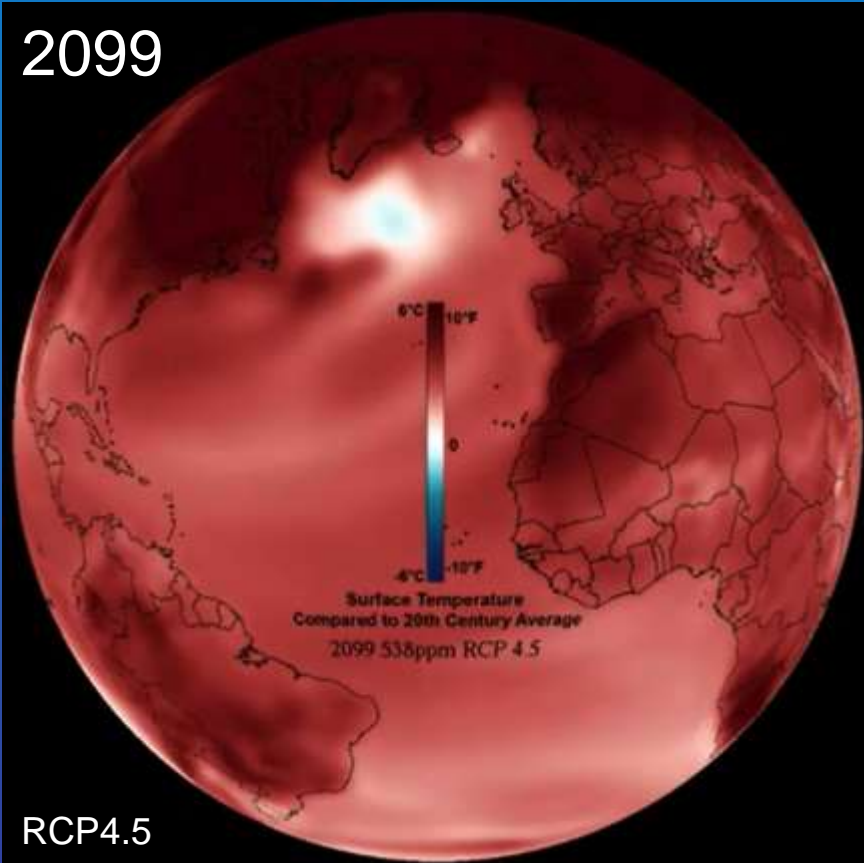
Our World is Warming



Temperatures Will Continue to Warm



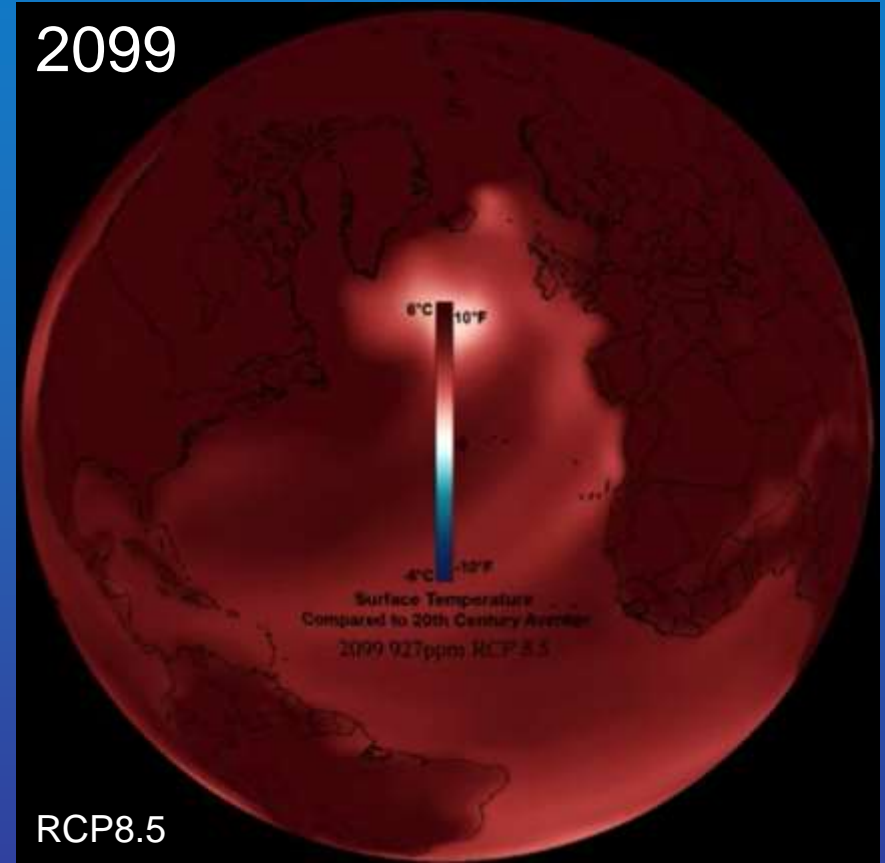
2099



RCP4.5

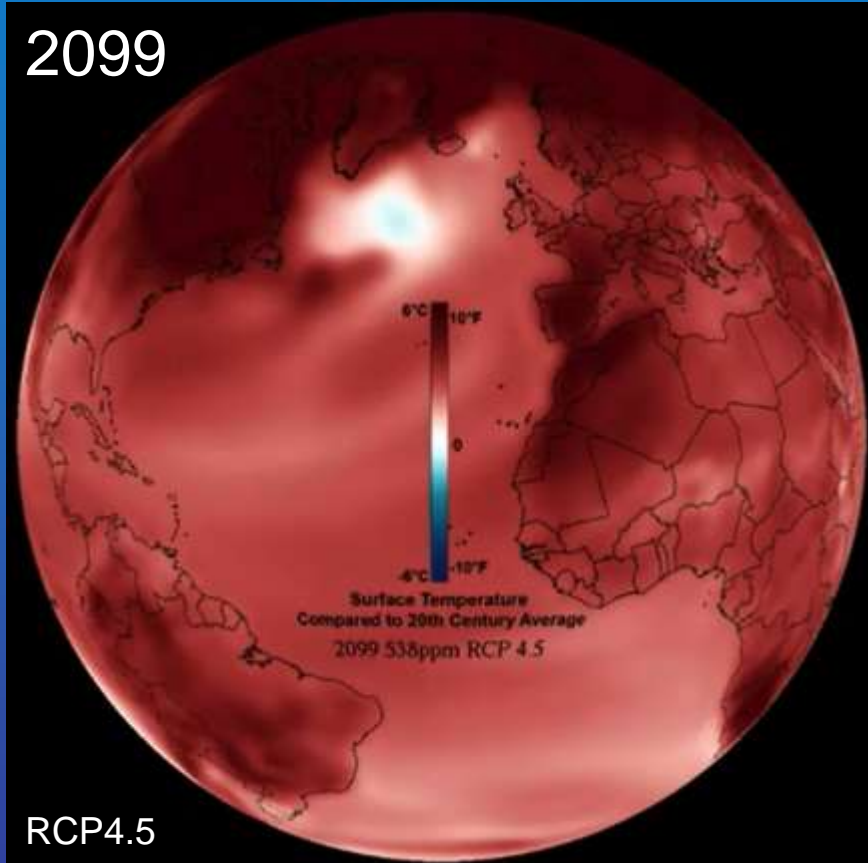
Similar to COP 21

2099

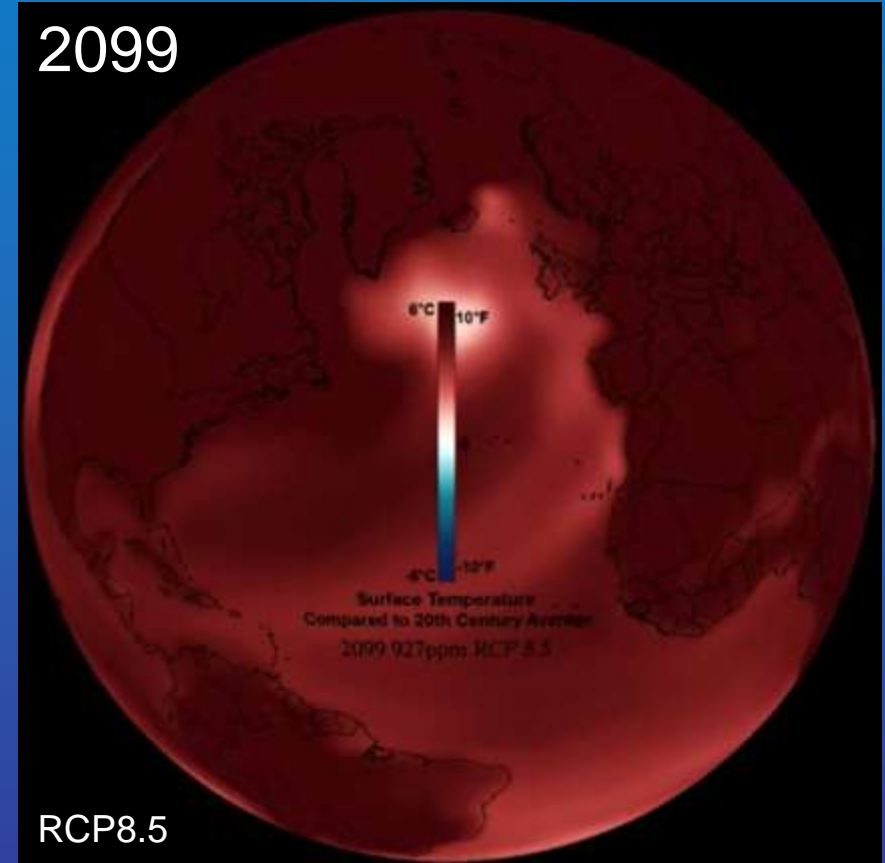


RCP8.5

Temperatures Will Continue to Warm

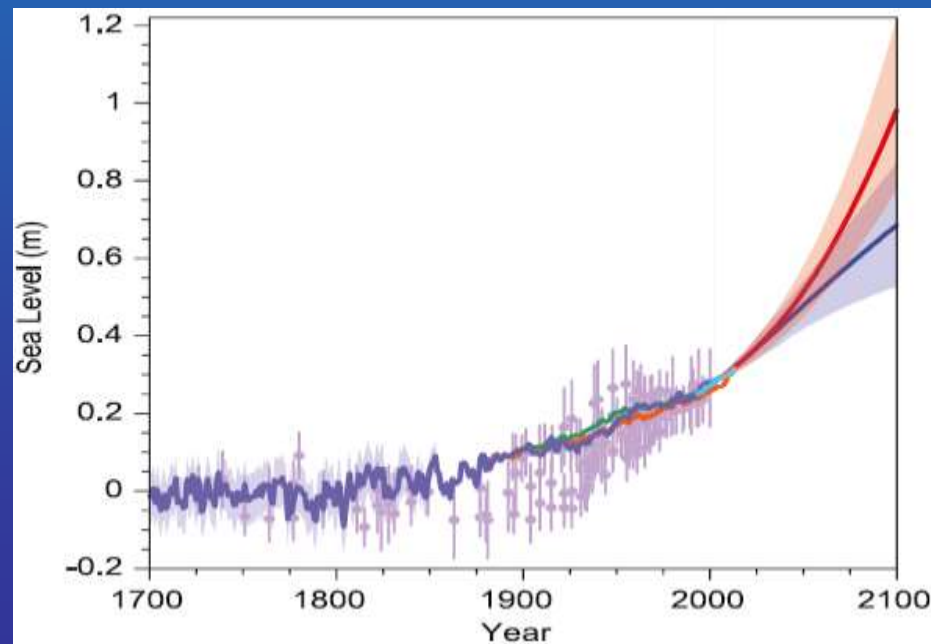


Similar to COP 21



How will warming impact sea level
and hurricane activity?

Sea Level Change

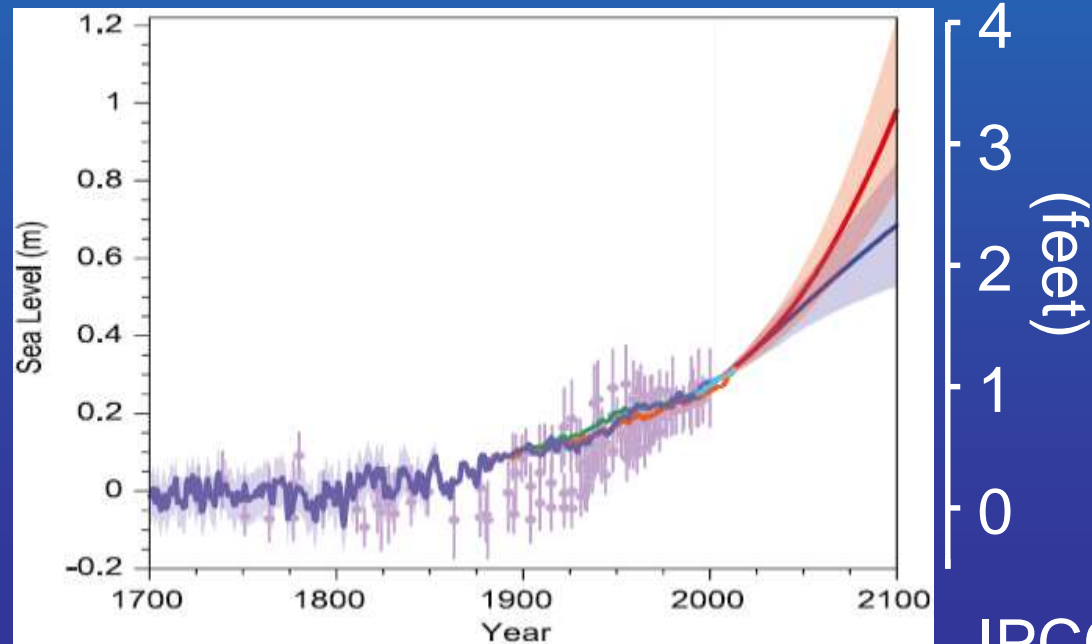


IPCC AR5

Sea Level Change

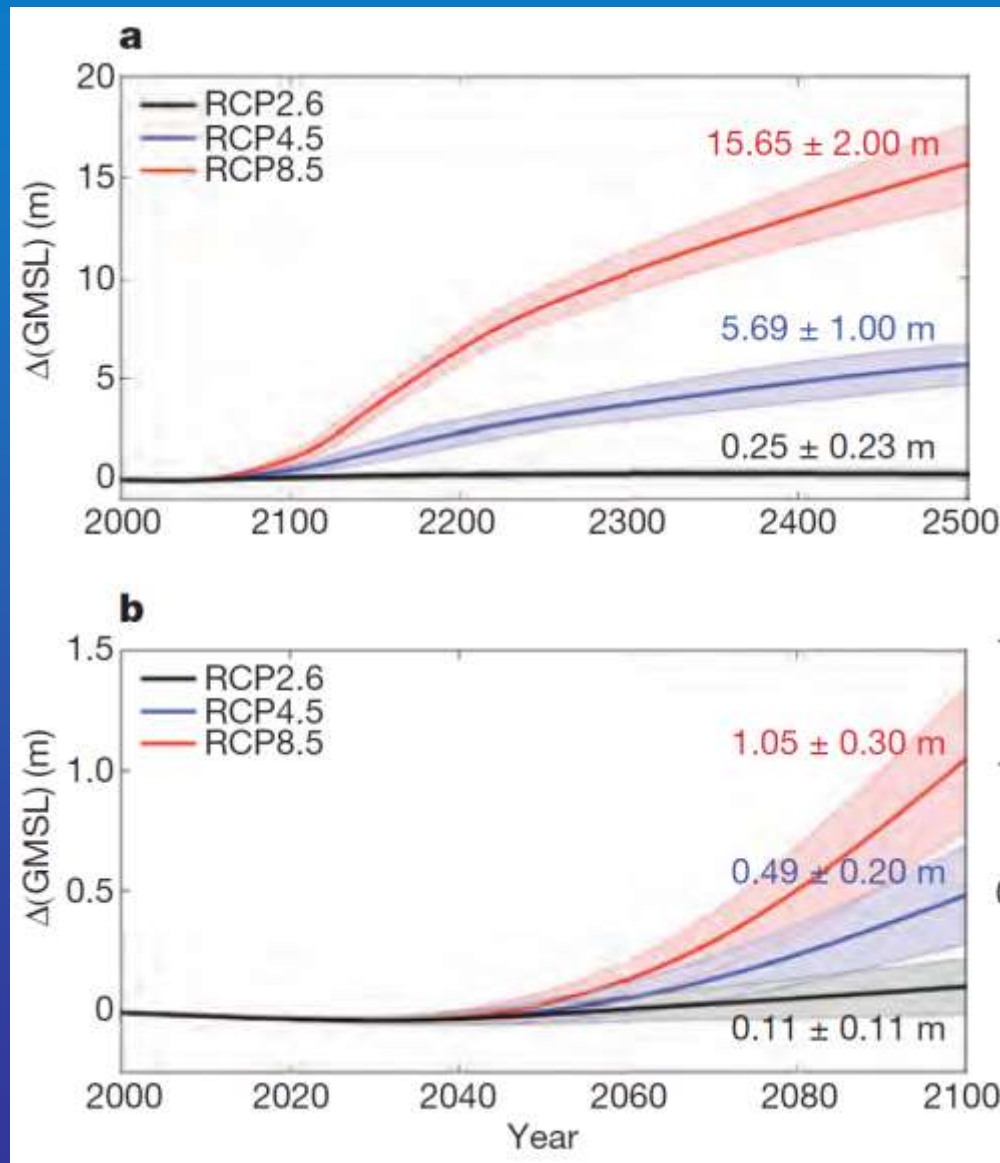


Does not include potential contributions from ice sheets



IPCC AR5

Potential Antarctic Ice Contribution



51 feet

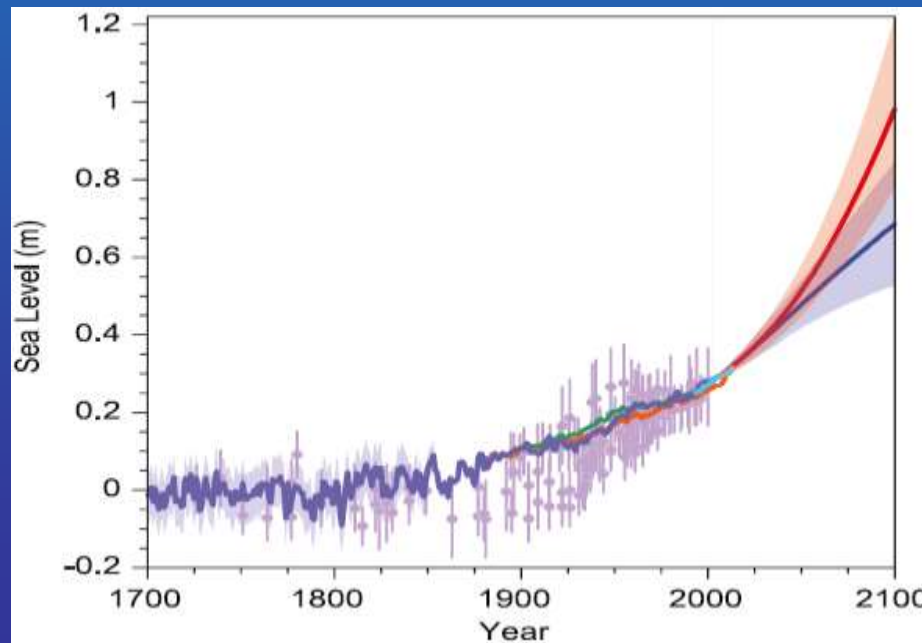
19 feet

3 feet

Sea Level Change

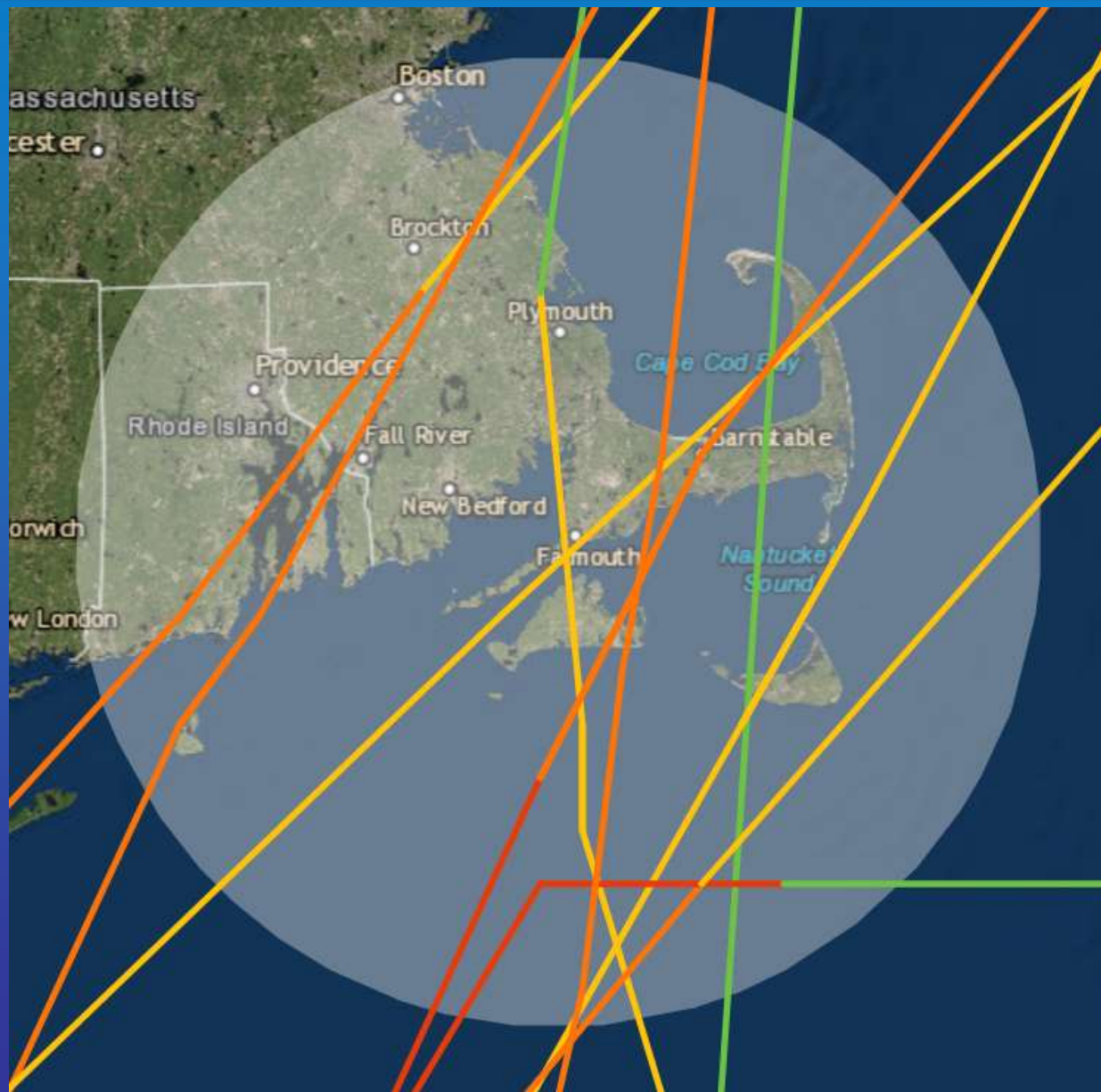


On our current emissions trajectory we should expect global sea level to rise between 5 and 8 feet by 2100 if we include contributions from Antarctica

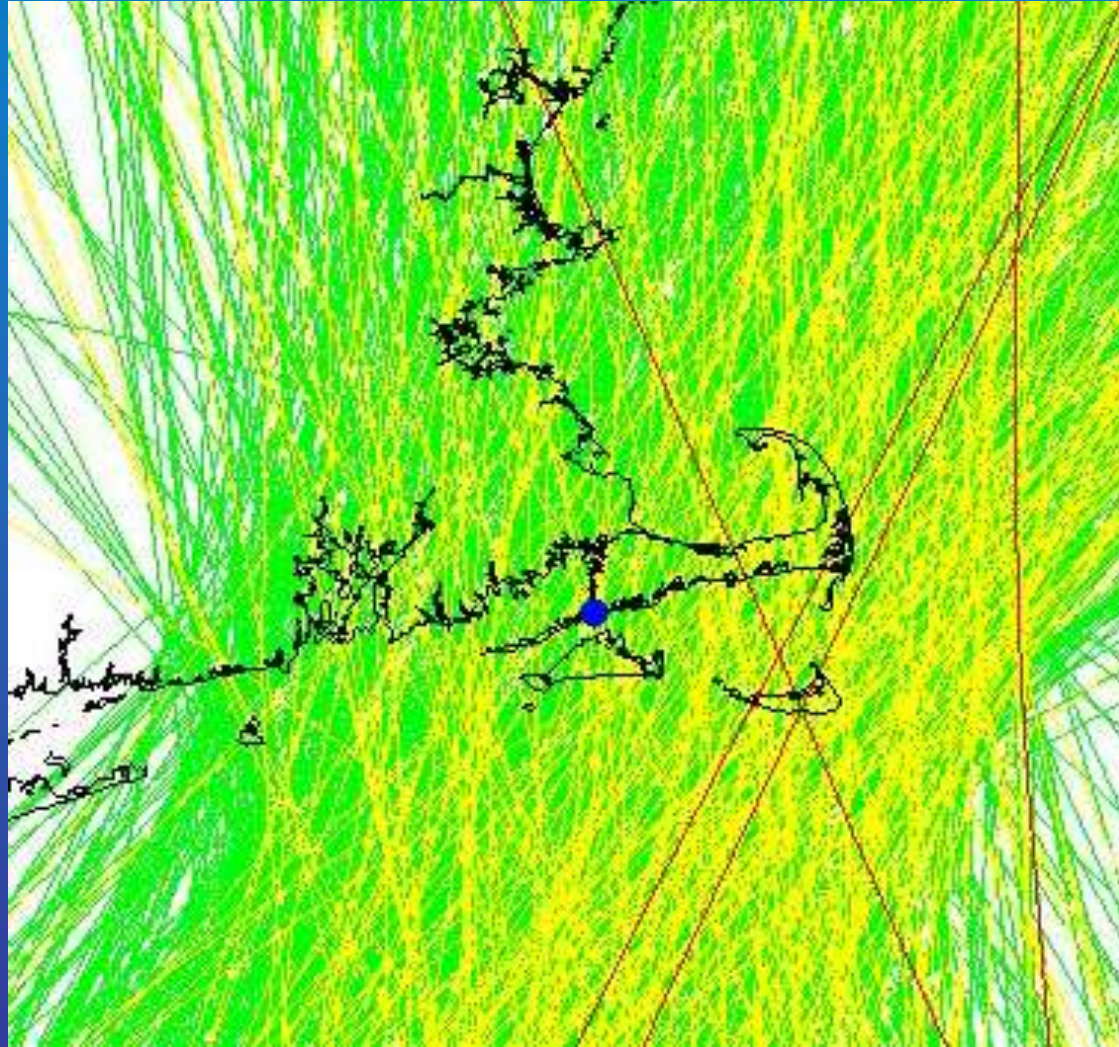


IPCC AR5

Historical hurricanes since 1851



Simulated hurricanes under modern climate



Return Period
Cat 2 – 7 years
Cat 3 – 33 years
Cat 4 – 2000 years

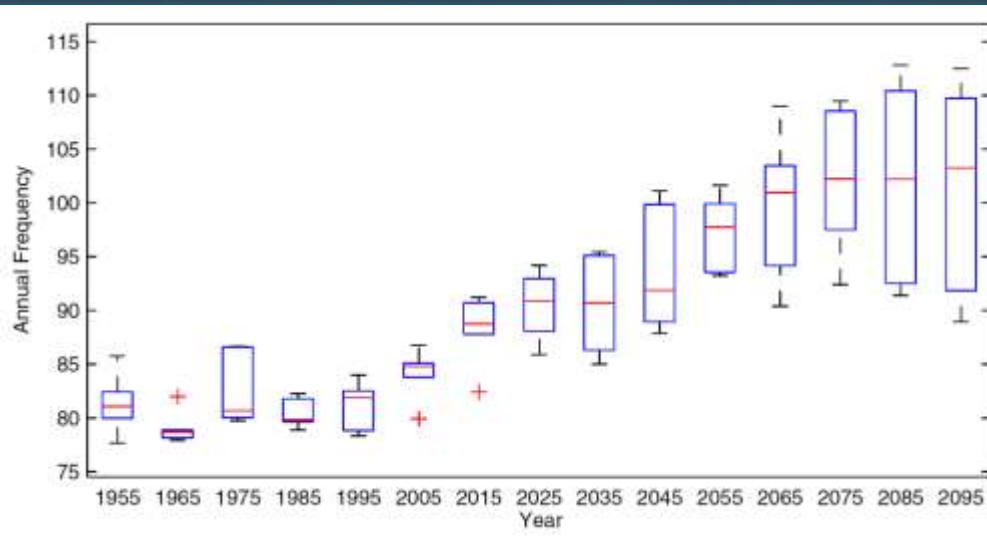
8000 years

17,354 total storms passing within 100 km of Woods Hole.

1049 Cat 2 storms (green), 242 Cat 3 storms (yellow) and four Cat 4 storms (red).

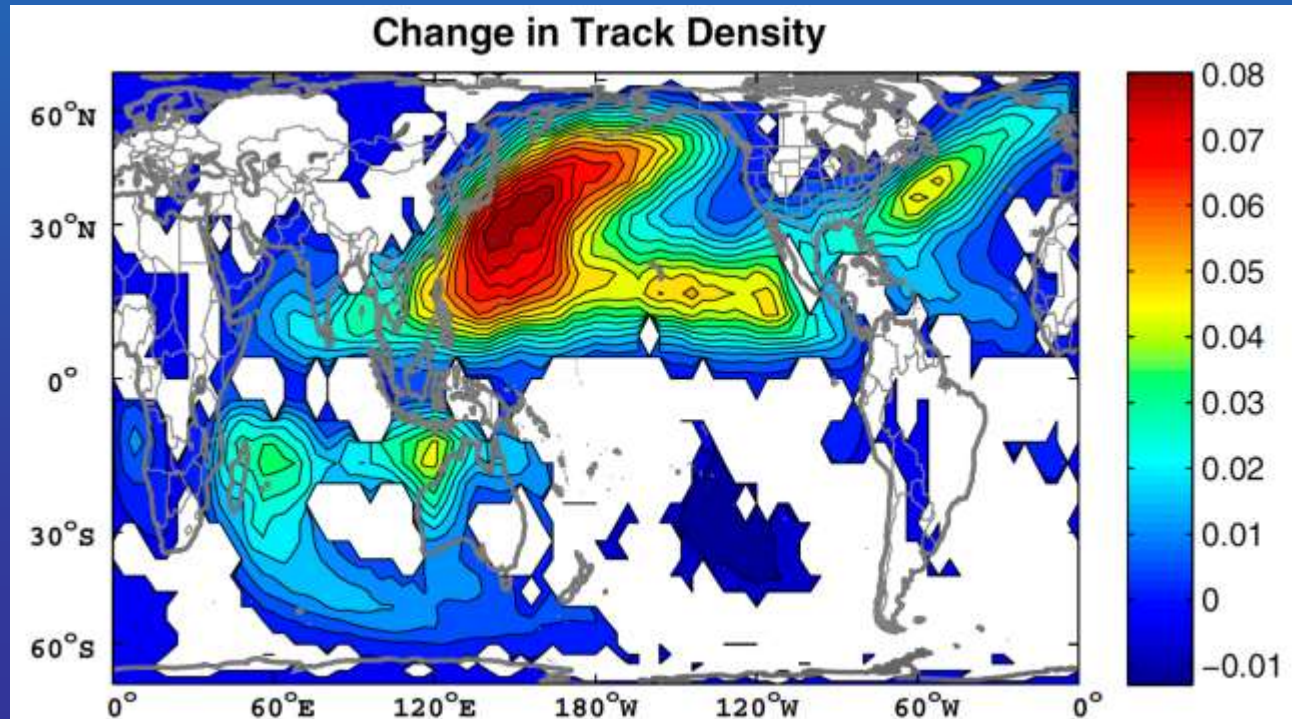
No Cat 5 storms were simulated.

What Might the Future Hold?



Frequency of hurricanes may increase (particularly intense storms)

From Emanuel, 2013 PNAS
Using IPCC AR5 models



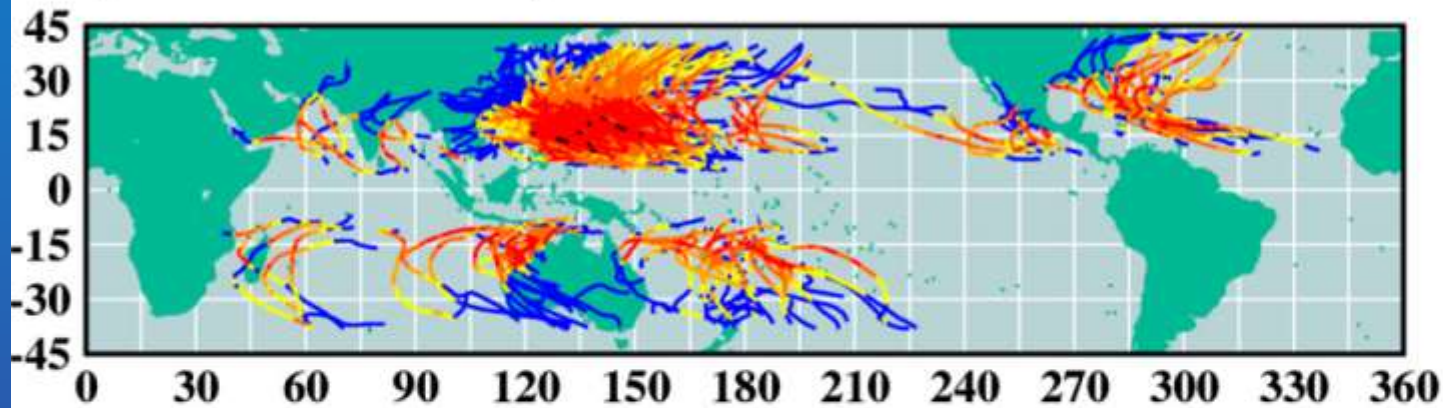
What Might the Future Hold?



KNUTSON ET AL.

28% increase globally
42% increase in Atlantic

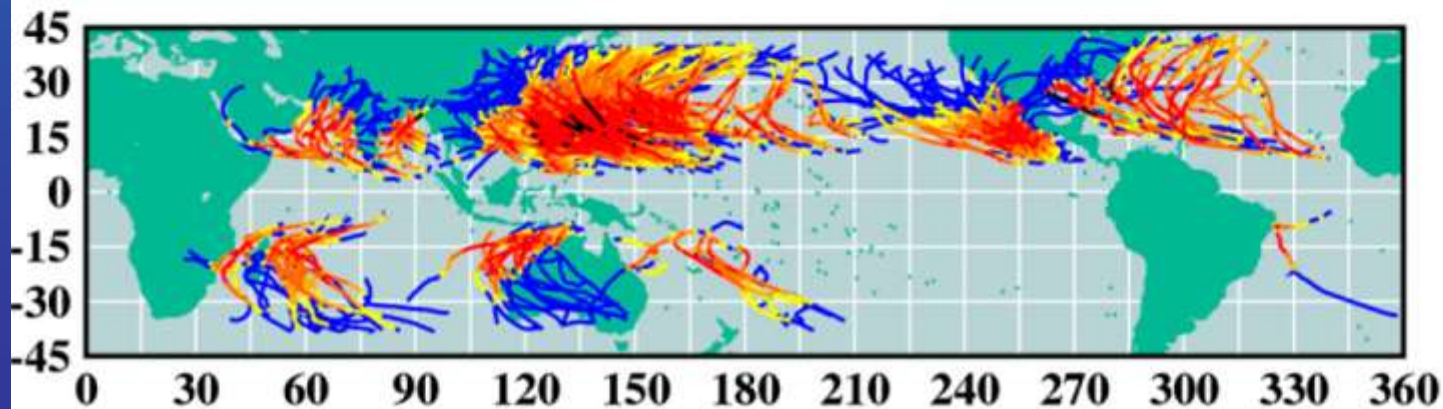
a) Present Day Simulation: 244 Cat 4-5 storms



Storm
Category



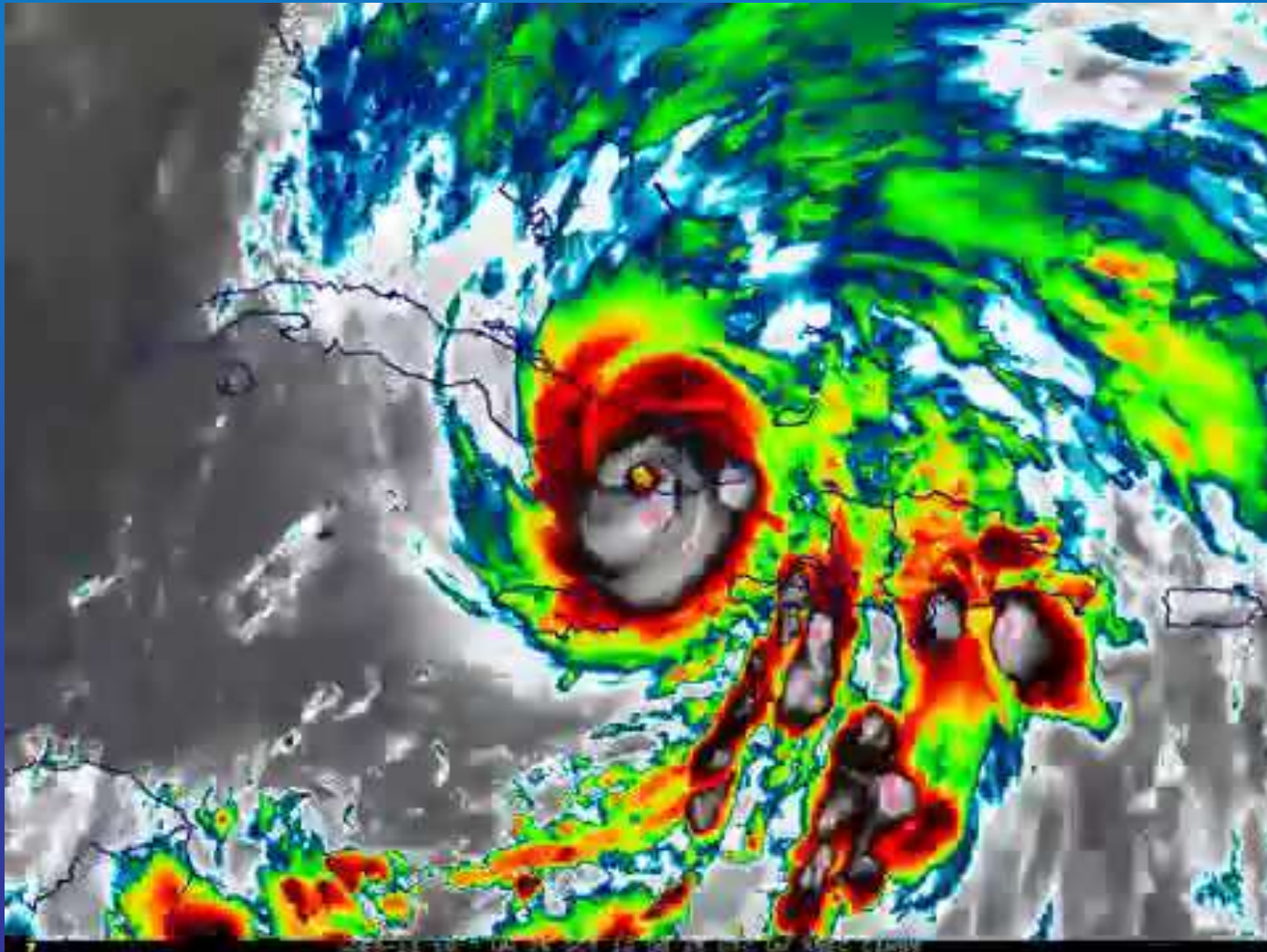
b) RCP4.5 Late 21st Century: 313 Cat 4-5 storms



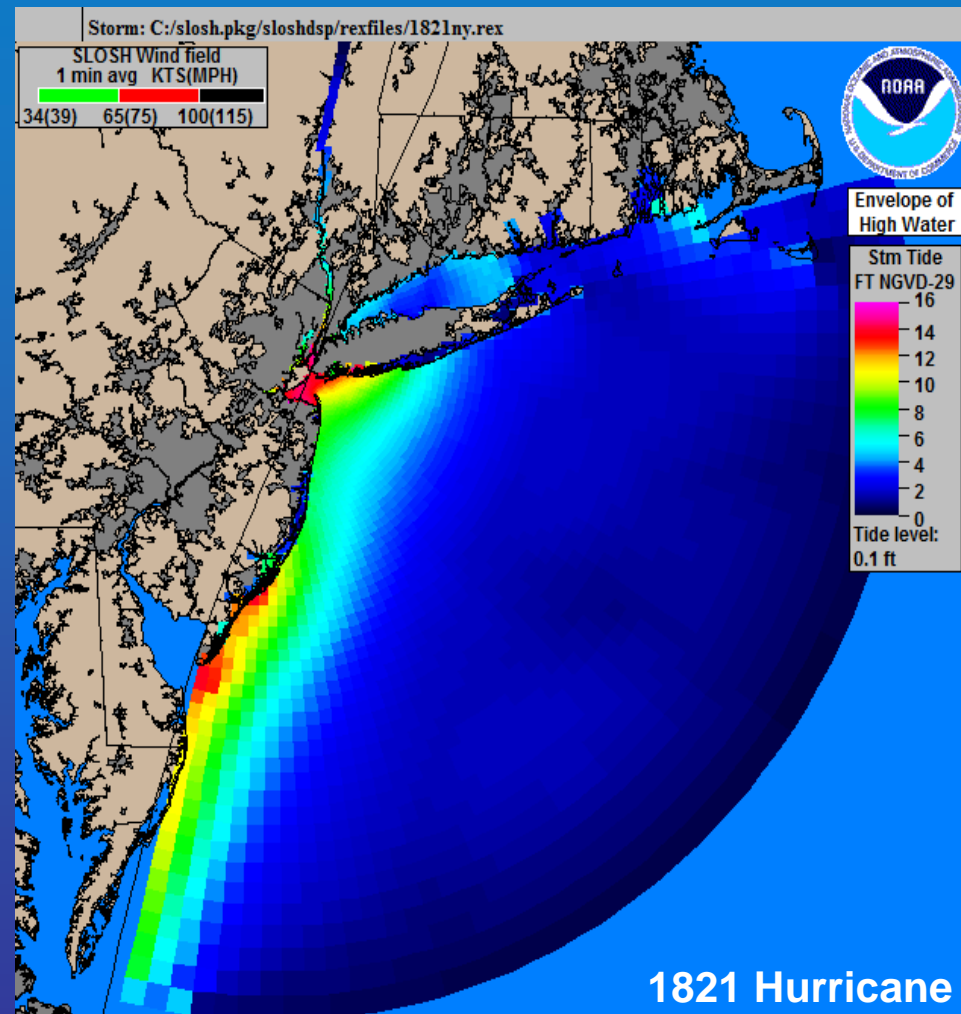
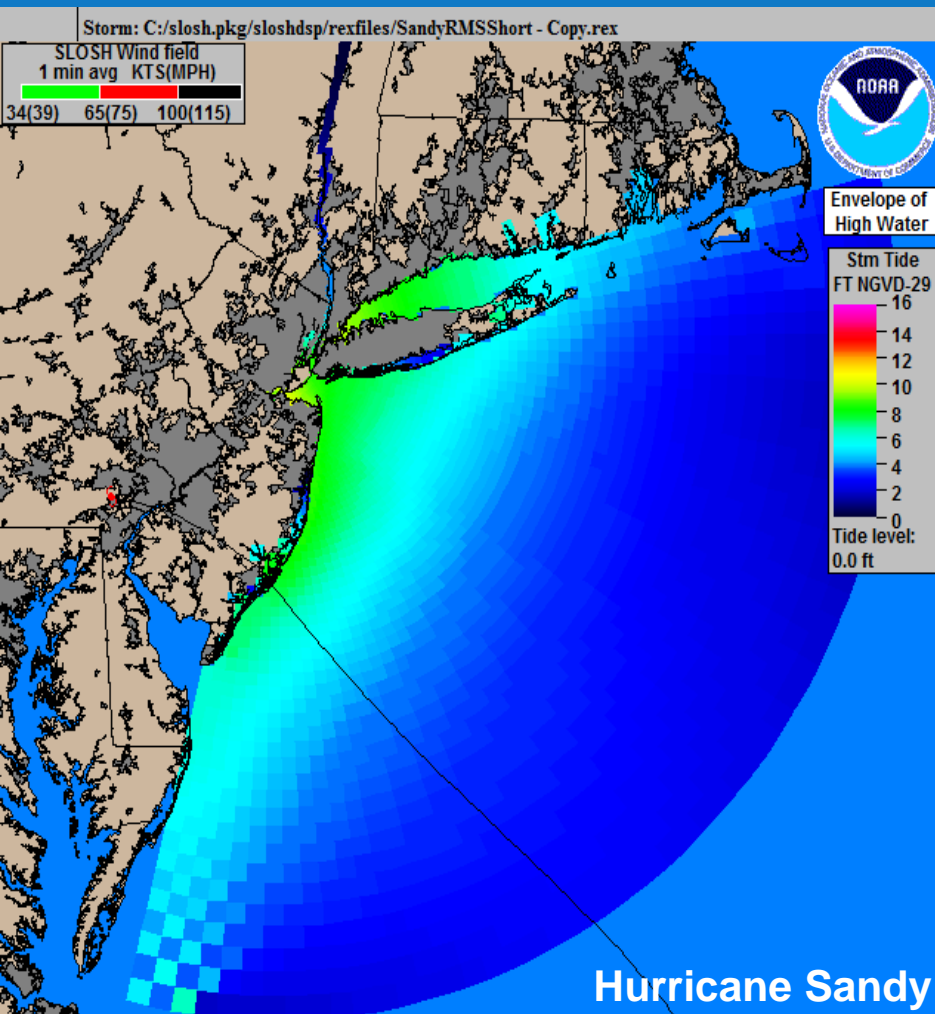
Hurricane Sandy 2012



68 billion in damage
148 fatalities



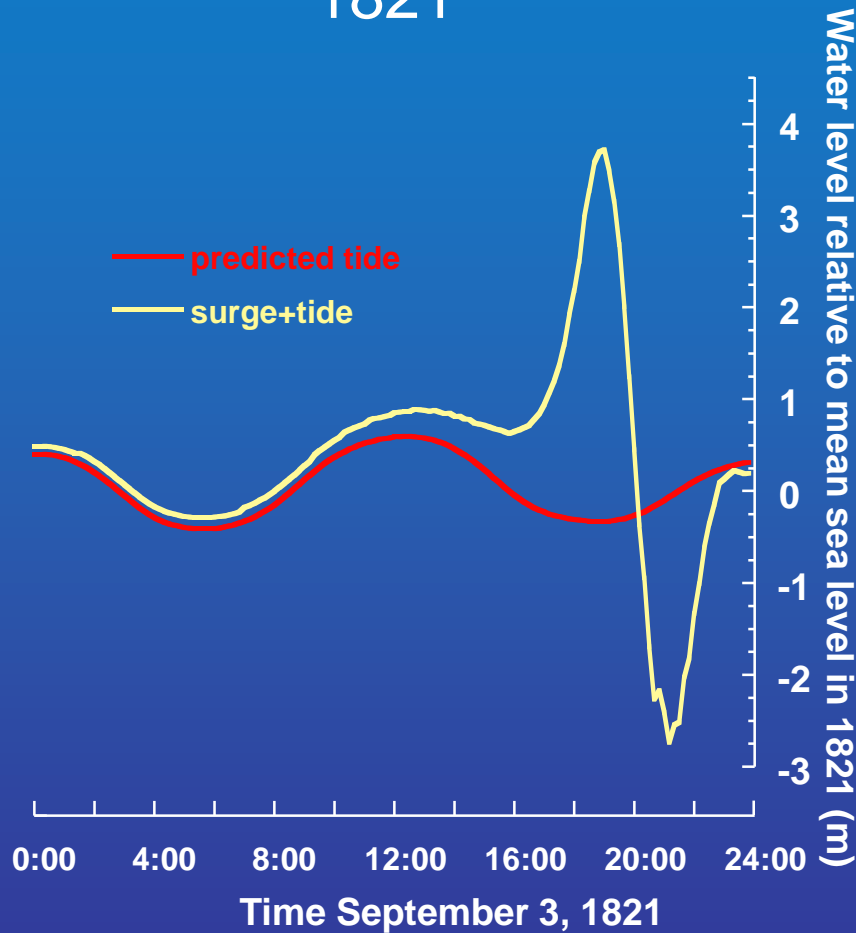
1821 Hurricane vs. Sandy



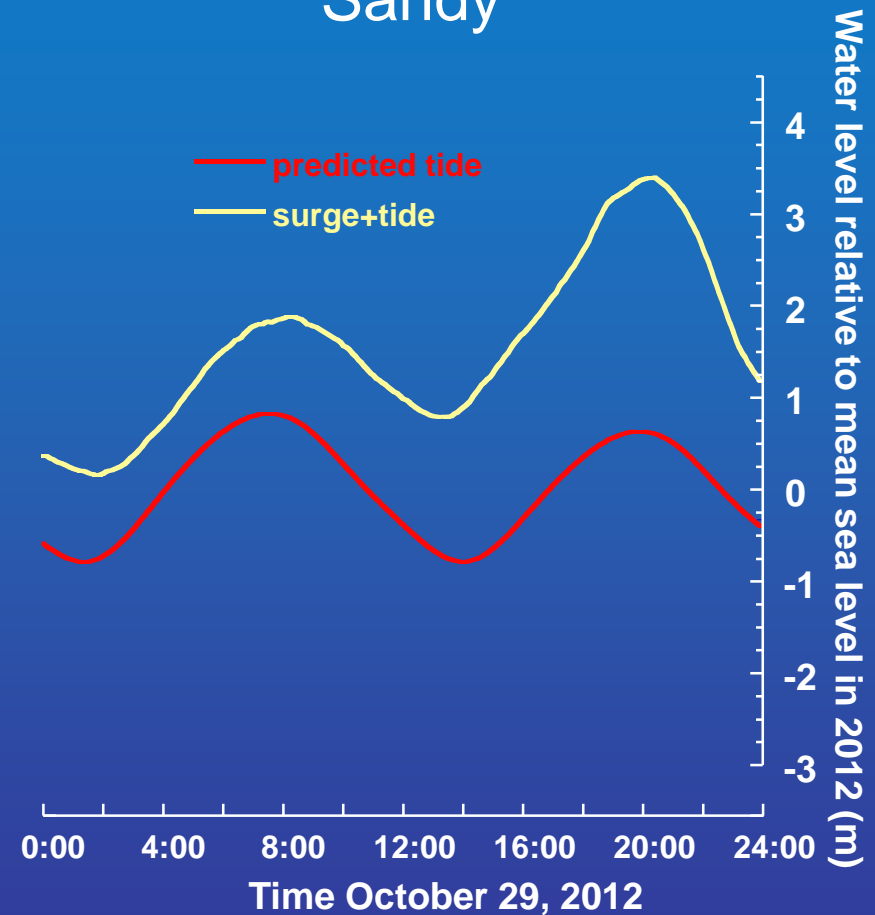
1821 Hurricane vs. Sandy in NYC



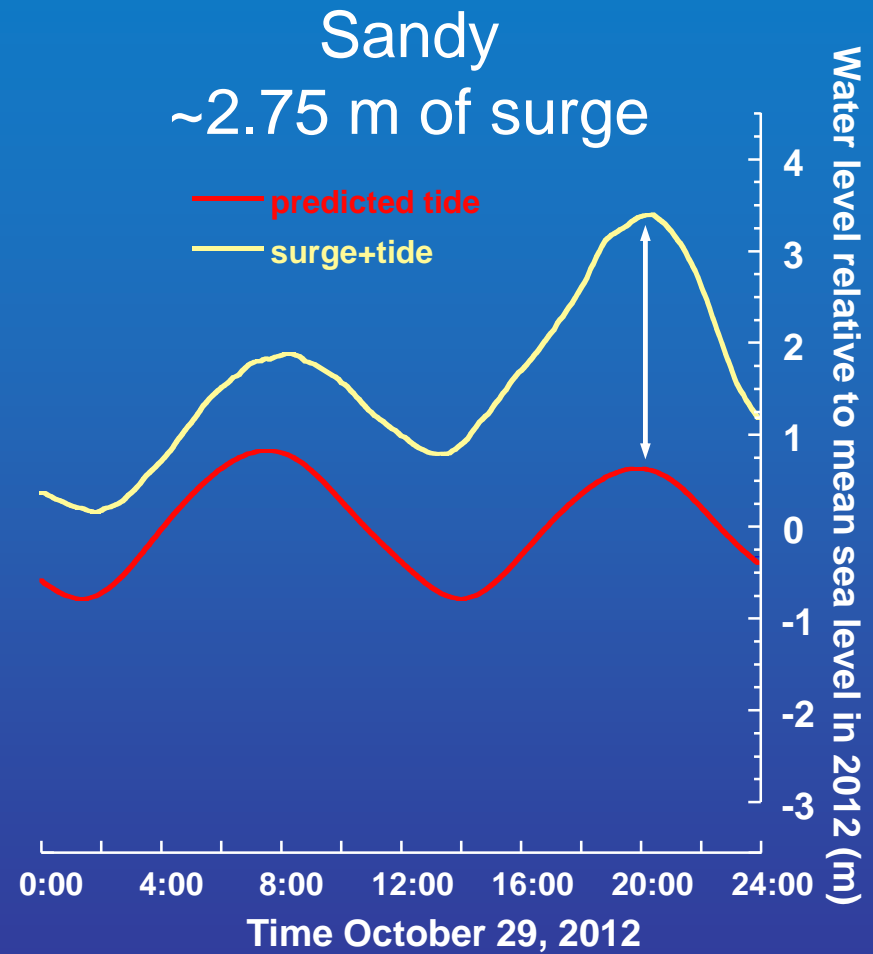
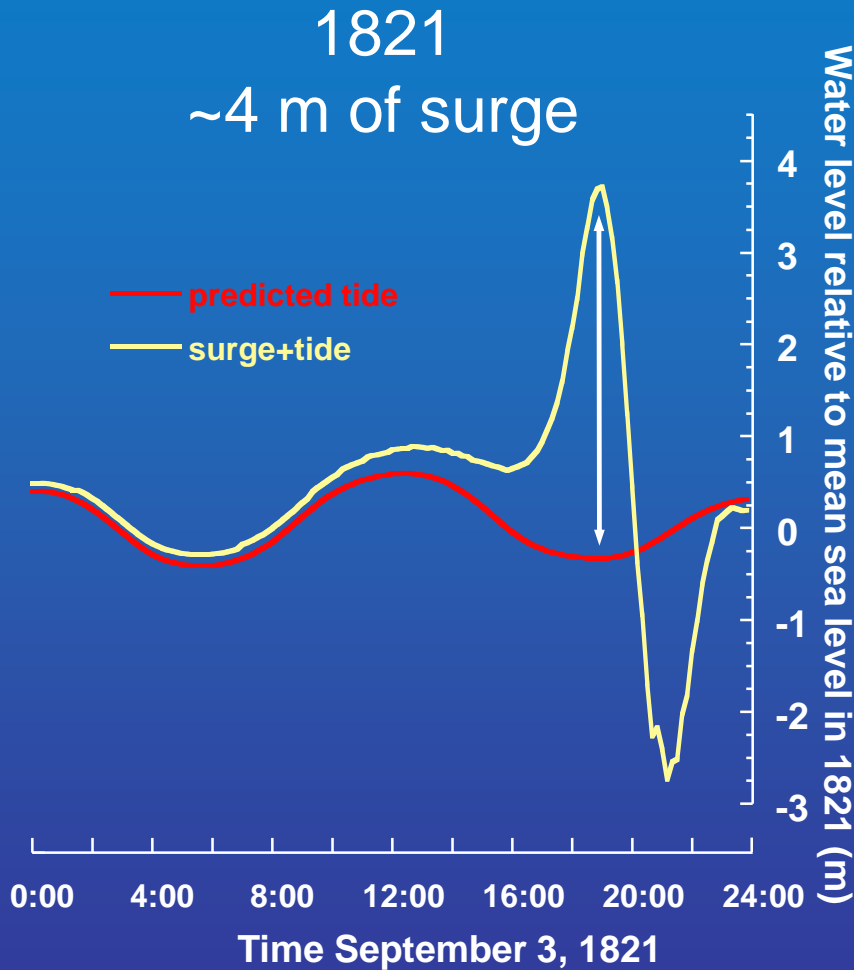
1821



Sandy



1821 Hurricane vs. Sandy in NYC



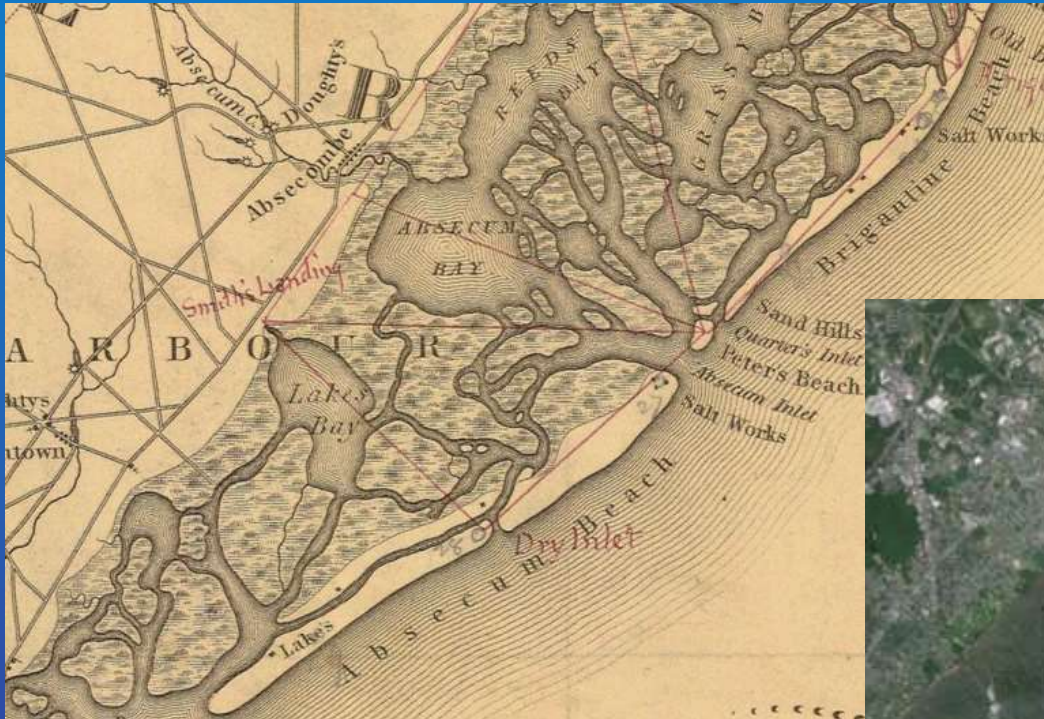
Why so much damage from Sandy?



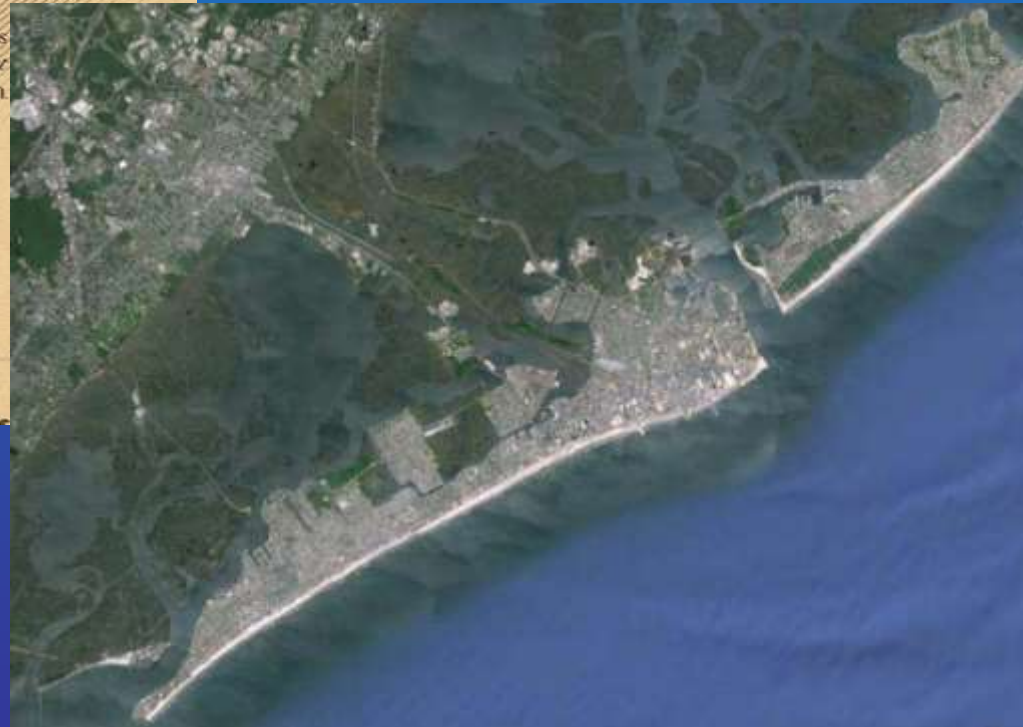
Why so much damage from Sandy?



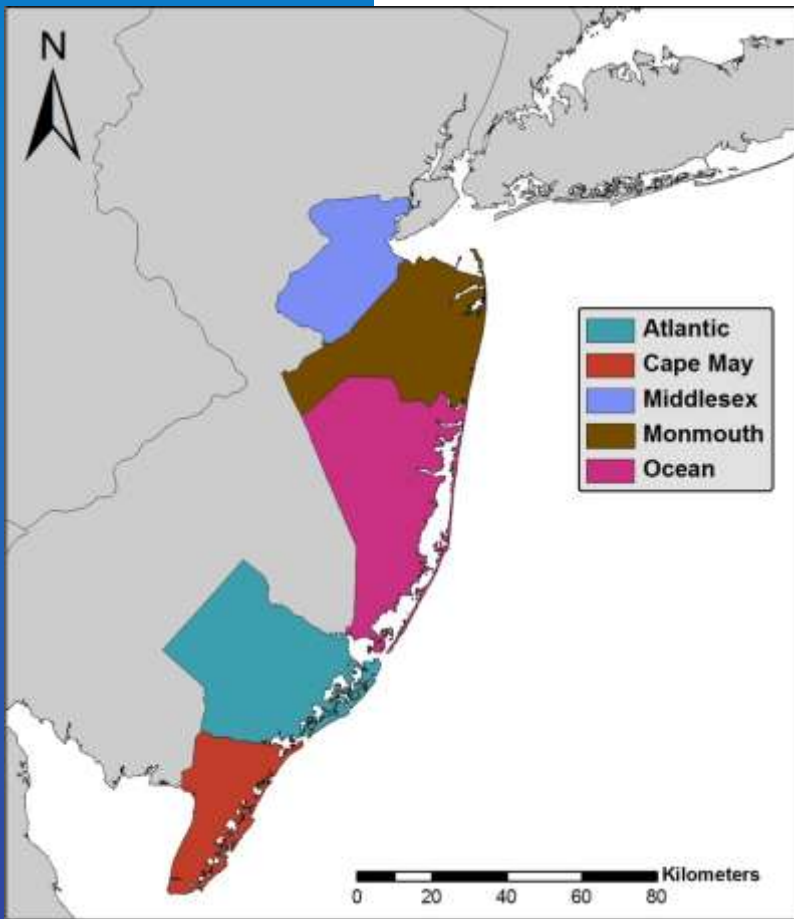
Future home of
Atlantic City (ca. 1833)



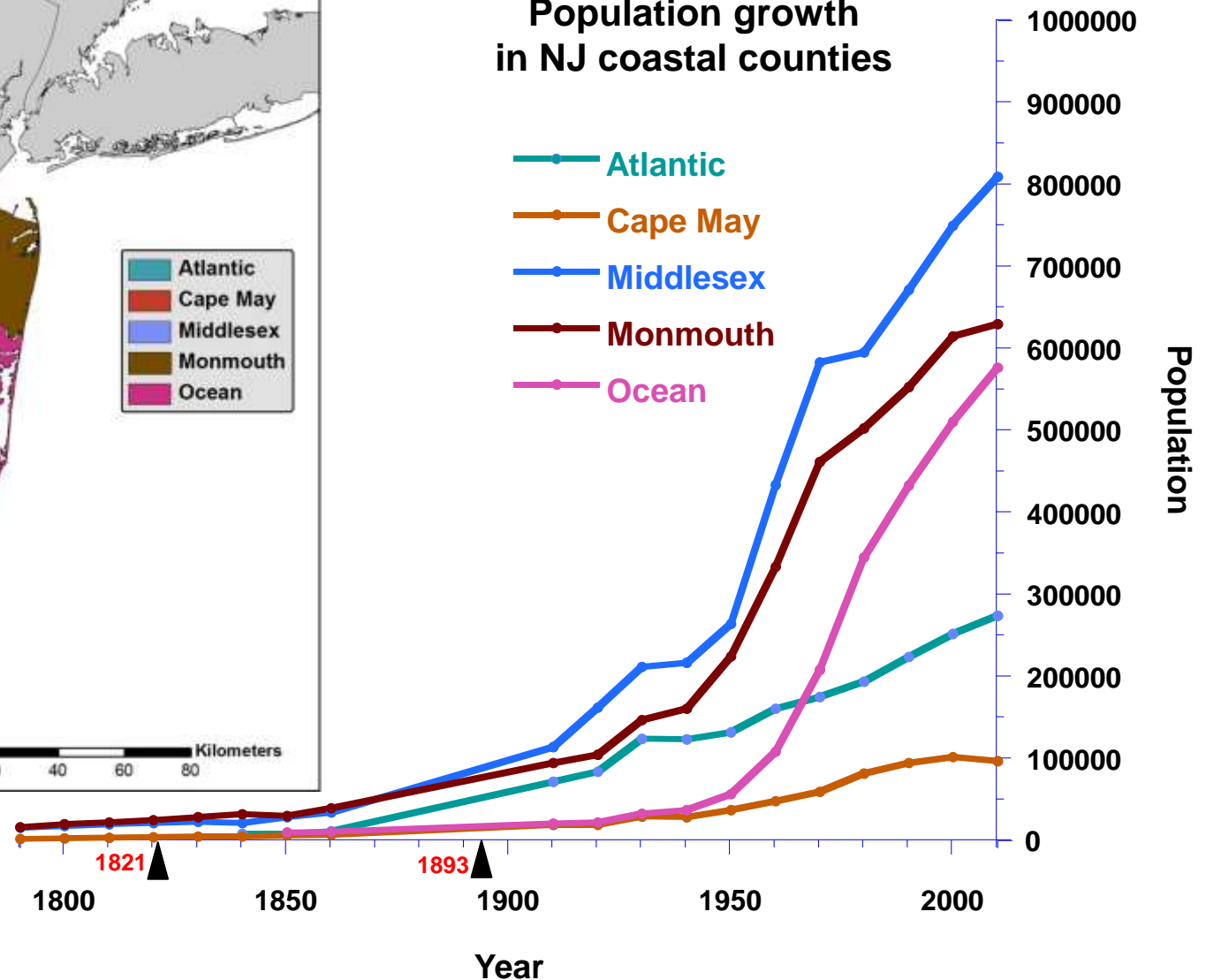
today



Why so much damage from Sandy?

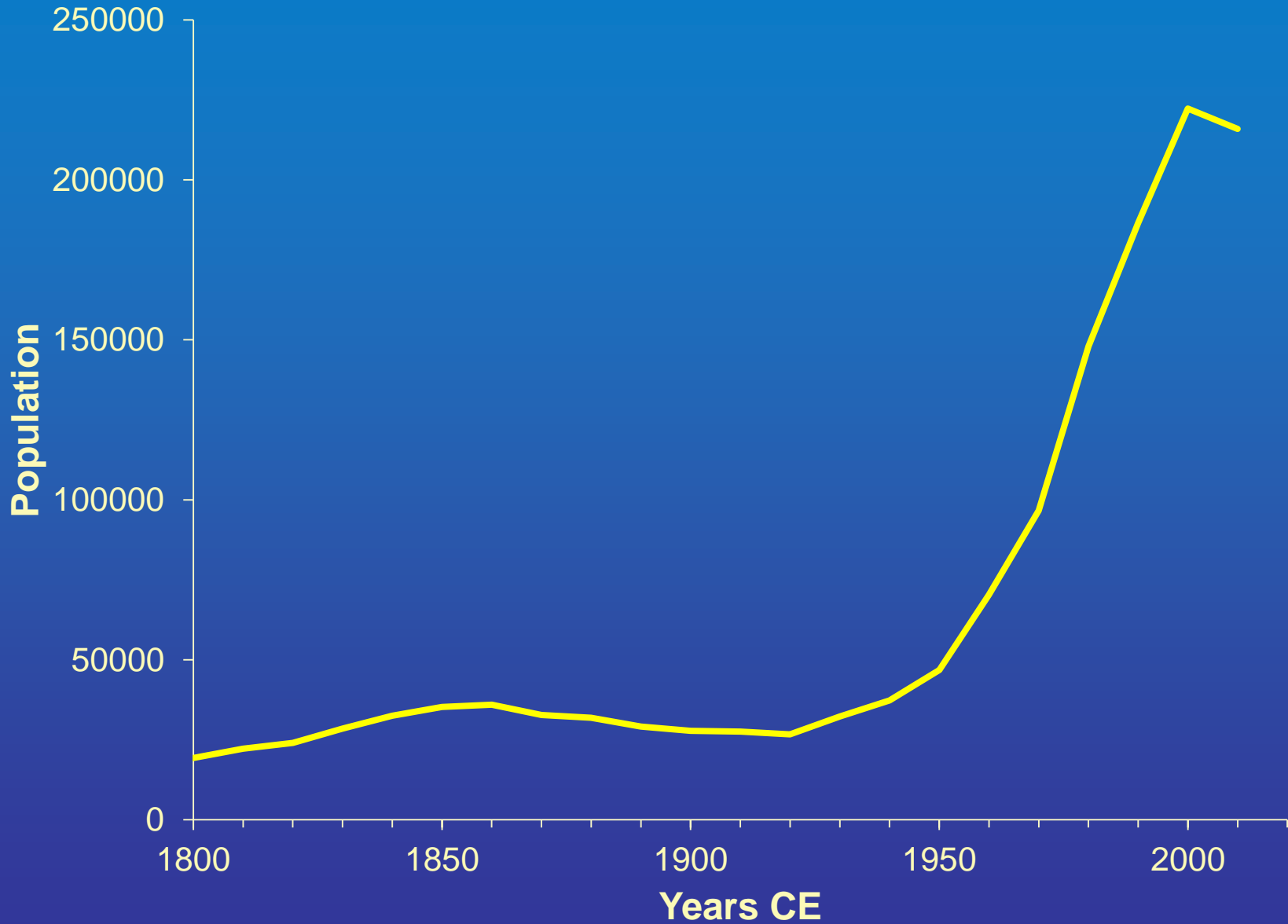


Population growth in NJ coastal counties

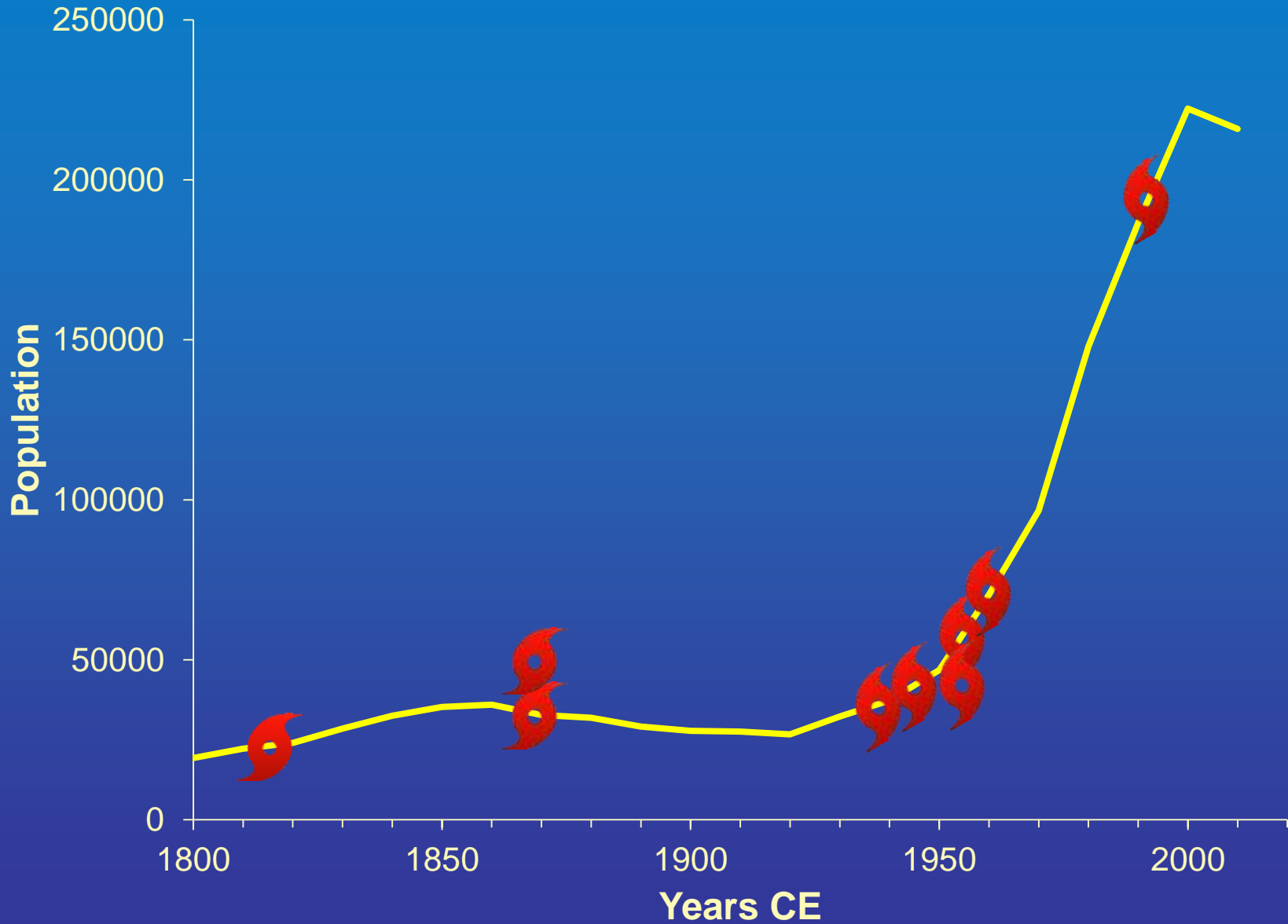


Source: New Jersey Department of Labor and Workforce Development

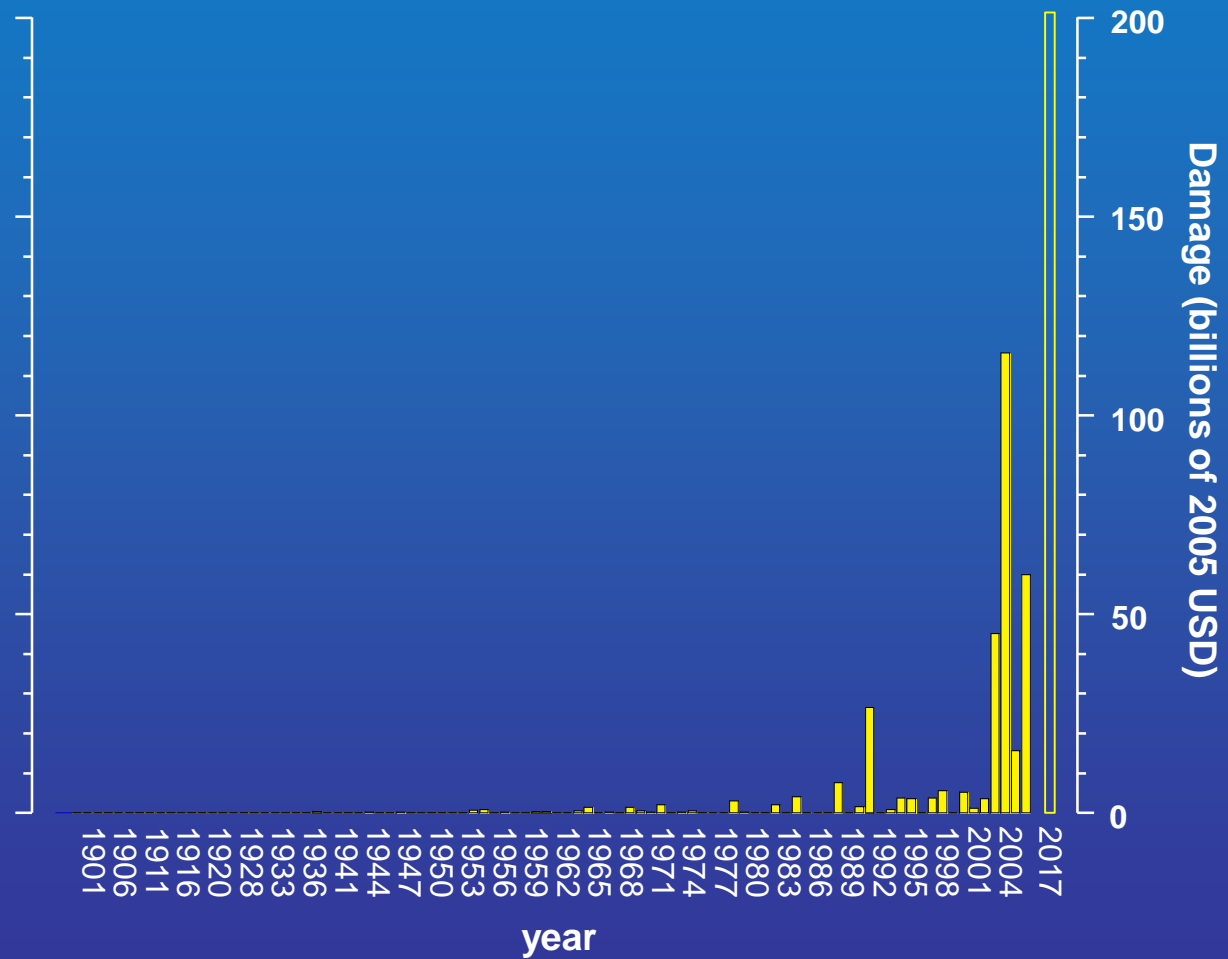
Barnstable County Population



Barnstable County Population



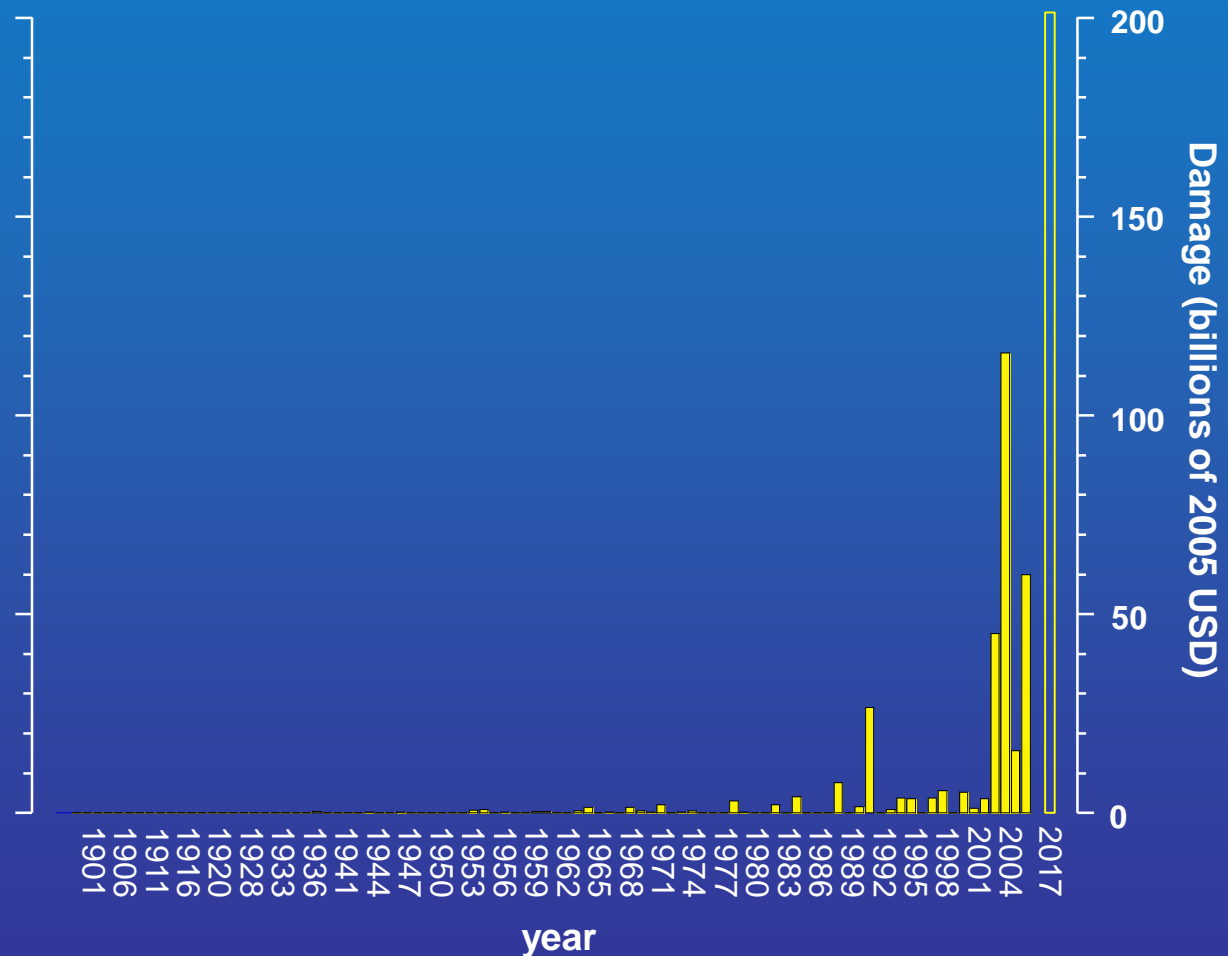
US Hurricane Damage



US Hurricane Damage



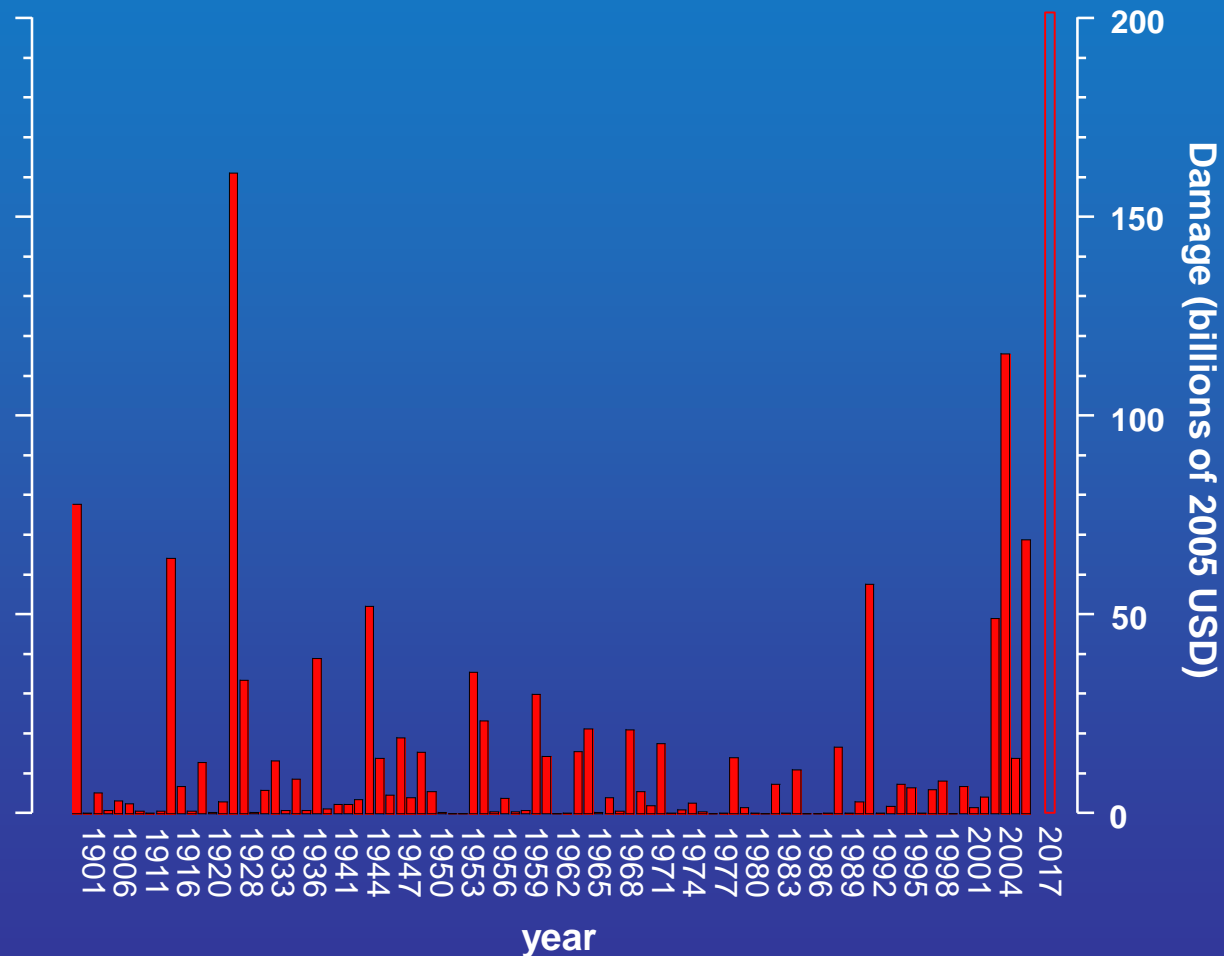
But what if these storms were to strike today?



US Hurricane Damage



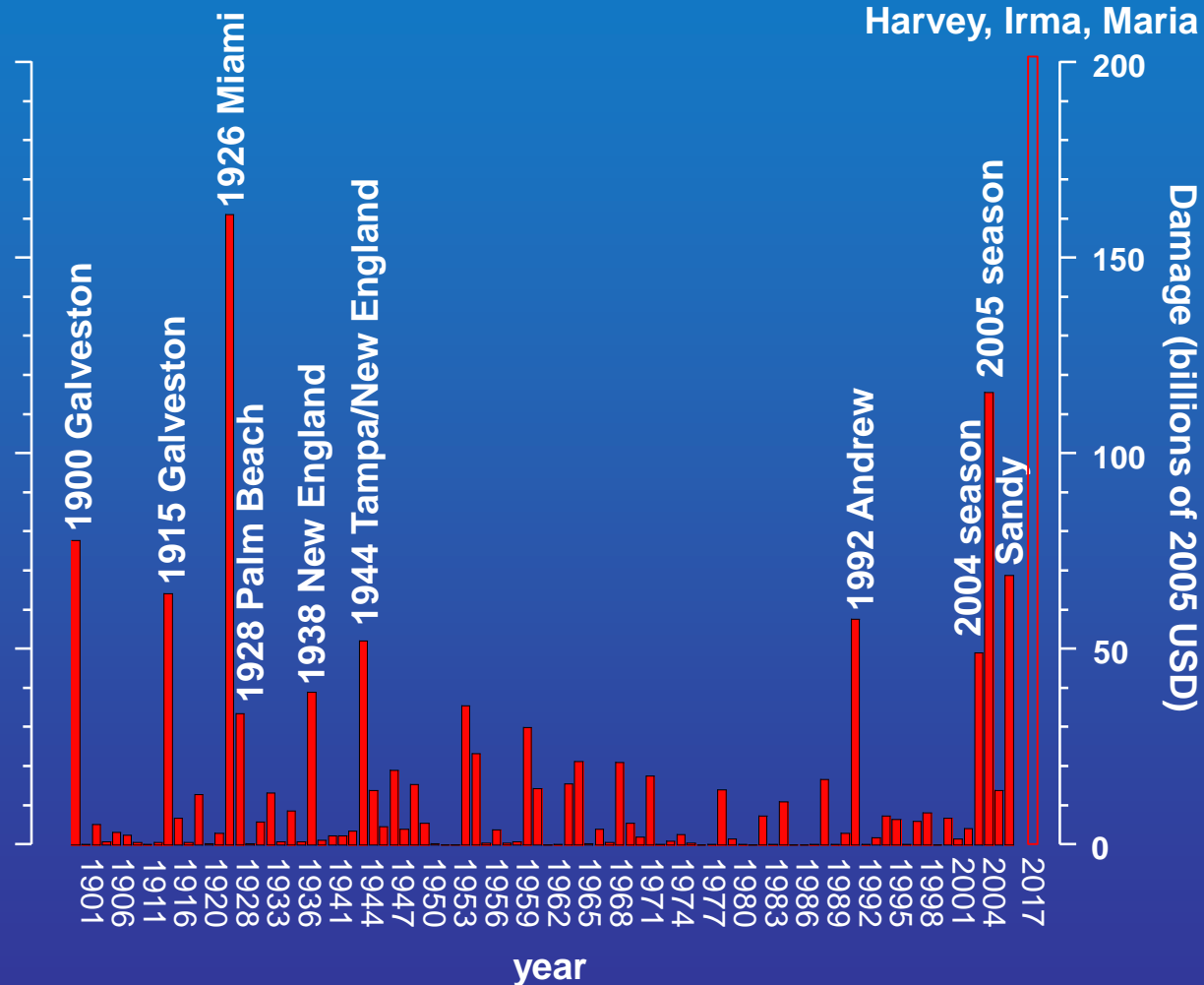
Damage accounting for increased wealth and population



US Hurricane Damage



Damage accounting for increased wealth and population

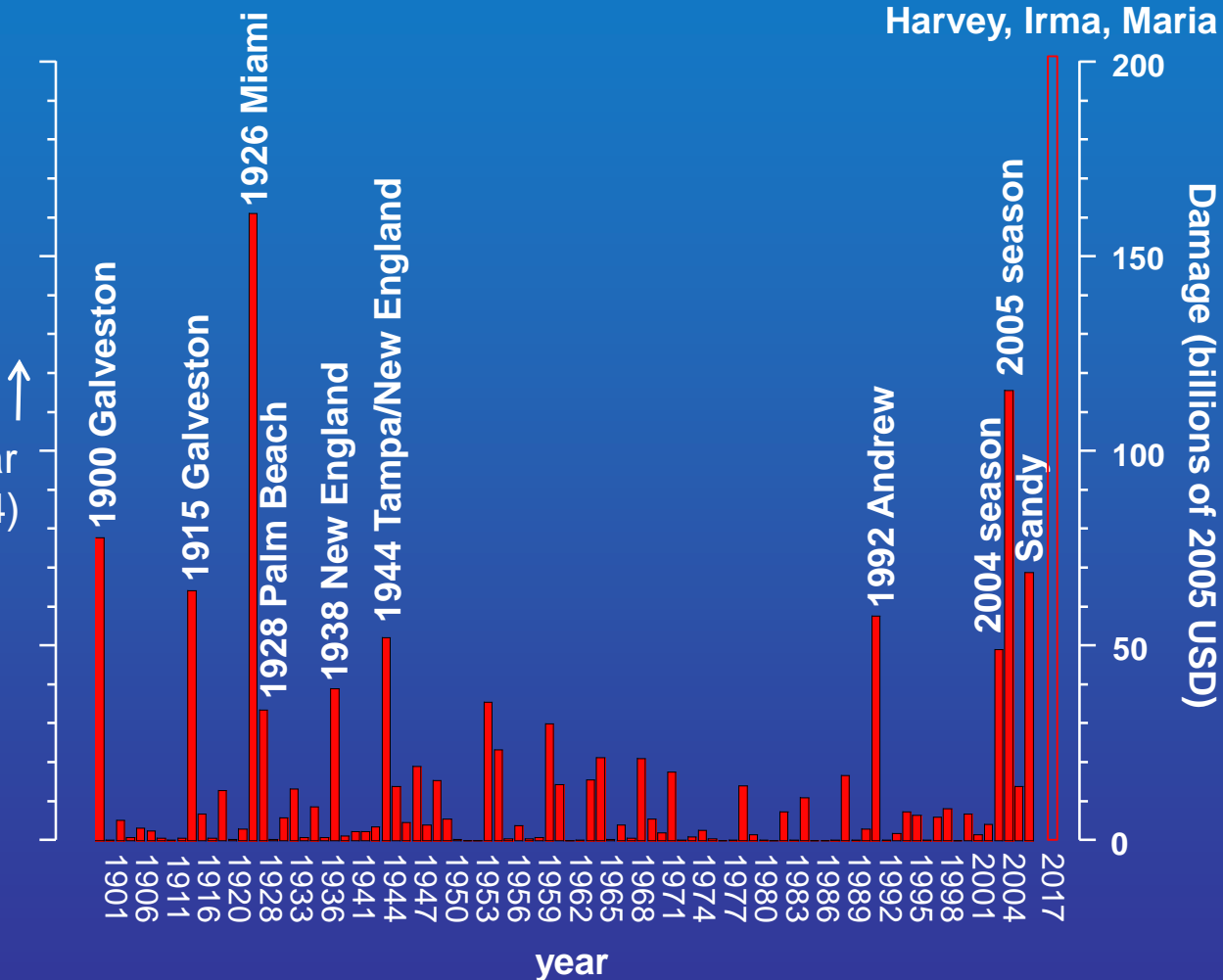


US Hurricane Damage

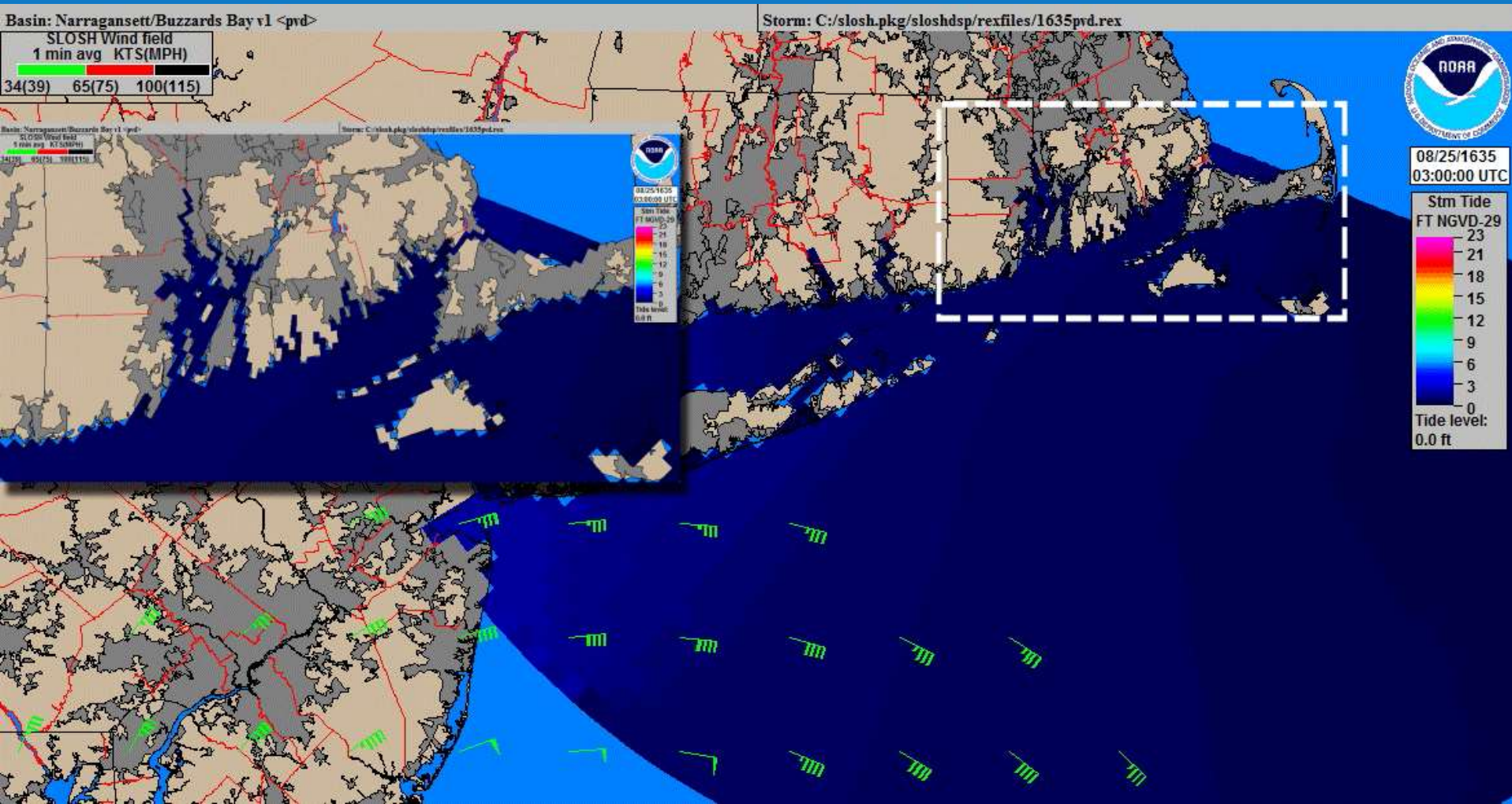


Damage accounting for increased wealth and population

A Hurricane like 1821 would likely be more than a 107 billion dollar event (Swiss Re, 2014)



Storm surge from the Great Colonial Hurricane of 1635



Great Colonial Hurricane of 1635



John Winthrop
(Governor of Massachusetts Bay Colony)

“The tide rose at Narragansett fourteen feet higher than ordinary, and drowned eight Indians flying from their wigwams”

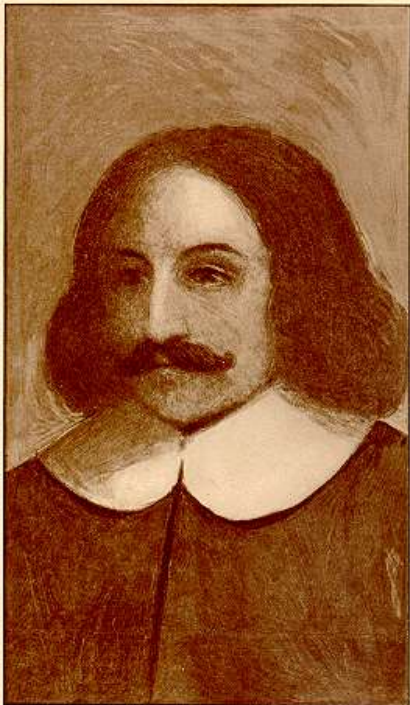


William Bradford (Governor of Plymouth Colony)

“...a mighty storm of wind and rain as none living in these parts, either English or Indians ever saw”

“It caused the sea to swell to the south wind of this place above 20 foot right up and down, and made many of the Indians to climb into trees for their safety”

“It blew down many hundred thousands of trees, turning up the stronger by the roots and breaking the higher pine trees off in the middle”



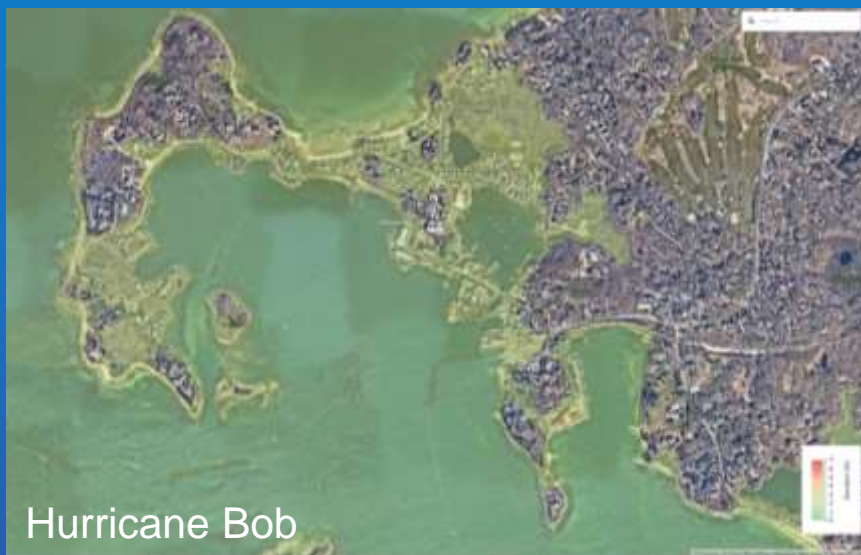
Copyright, 1994, by A. S. Foxhall, Plymouth
GOVERNOR WILLIAM BRADFORD

Hurricane Surge in Woods Hole



What if they were to hit this season?

Or in the future with 5 feet of SLR?



1635

1635 +5 feet

Long-term Hurricane Records

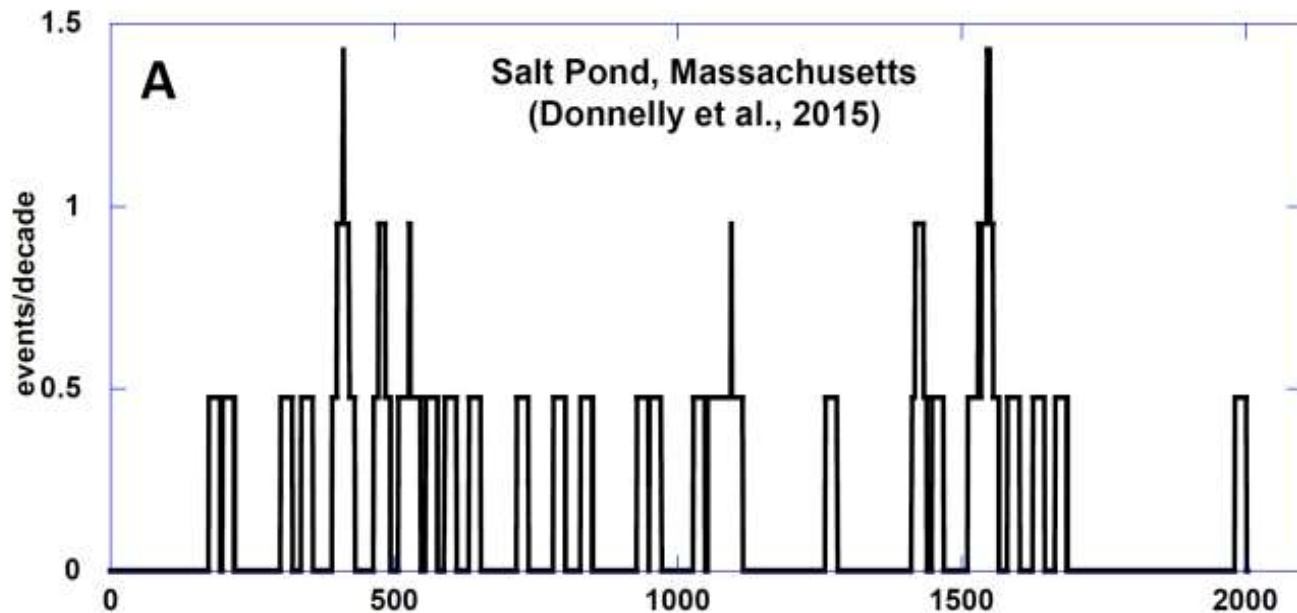


Overwash sand layer

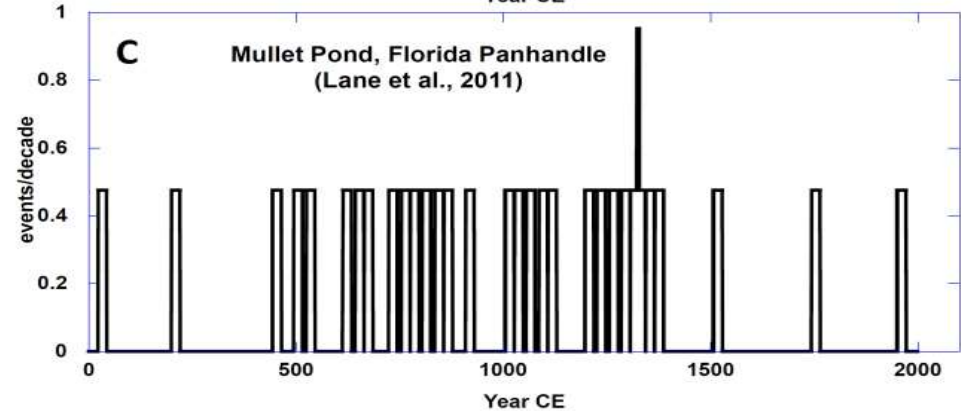
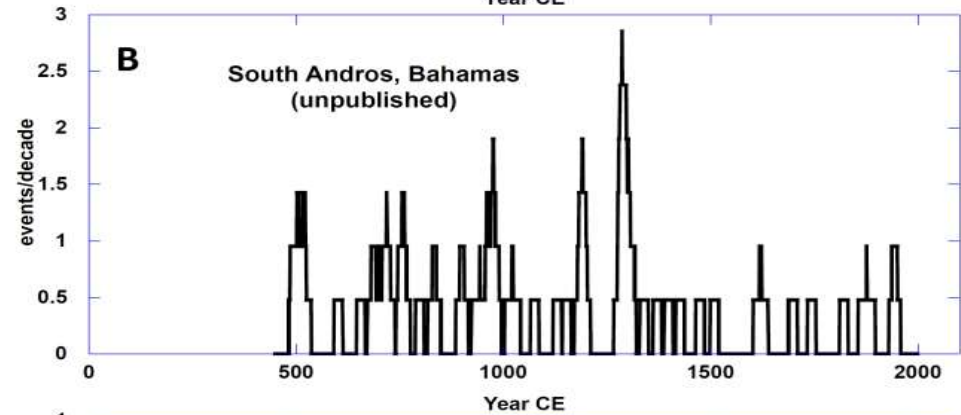
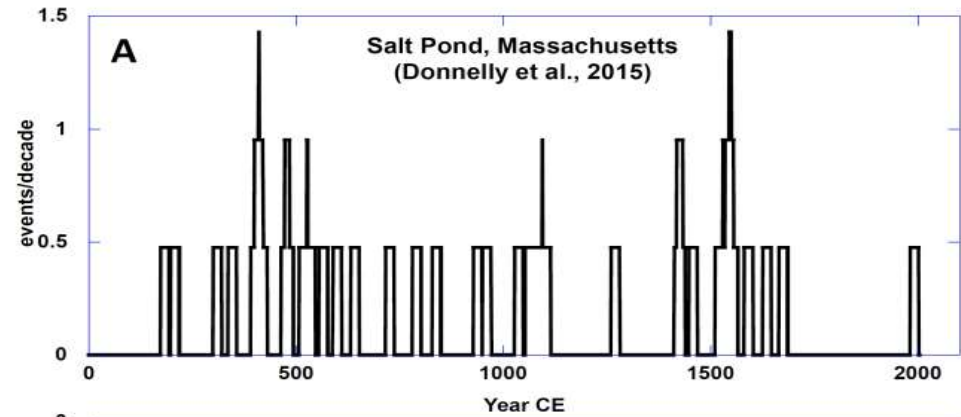
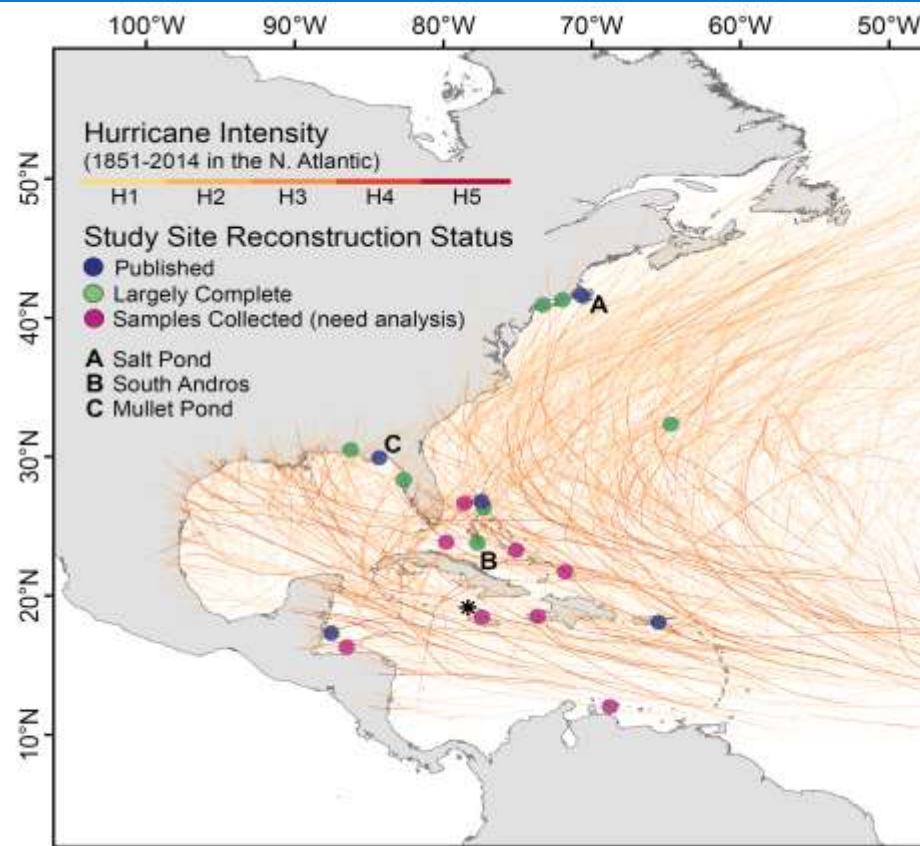
Overwash sand layer

1 foot

Overwash sand layer
Overwash sand layer



Regional Patterns



Summary



Summary



- Sea level is currently rising at a rate not seen in at least 6,000 years. And we should expect that it will rise several more feet by 2100 CE (and perhaps tens of feet by 2500 CE).

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- Most modeling studies indicate we should expect more frequent intense hurricanes. But significant geographic variability is likely and uncertainty is high.

Summary



- Sea level is currently rising at a rate not seen in at least 6,000 years. And we should expect that it will rise several more feet by 2100 CE (and perhaps tens of feet by 2500 CE).
- Most modeling studies indicate we should expect more frequent intense hurricanes. But significant geographic variability is likely and uncertainty is high.
- Paleo-records suggest the climate system before human interference was capable of producing intervals of heightened hurricane activity. In many cases the activity in these intervals exceeded those experienced historically.

Summary



- The negative impacts of future hurricane activity will be greatly exacerbated by continuing sea-level rise and coastal population growth, regardless of whether or not we experience significant increases in hurricane landfalls.

Summary



- The negative impacts of future hurricane activity will be greatly exacerbated by continuing sea-level rise and coastal population growth, regardless of whether or not we experience significant increases in hurricane landfalls.
- The good news is we have many tools to mitigate the impacts of hurricanes. And they no longer take us by surprise because of our excellent forecasting and monitoring abilities, and capacity for communication.

Thank you!



Further Reading:

Early American Hurricanes, D.M. Ludlum

A Wind to Shake the World, E.S. Allen

Sudden Sea: The Great Hurricane of 1938, R.A. Scotti

Issac's Storm, Erik Larson

