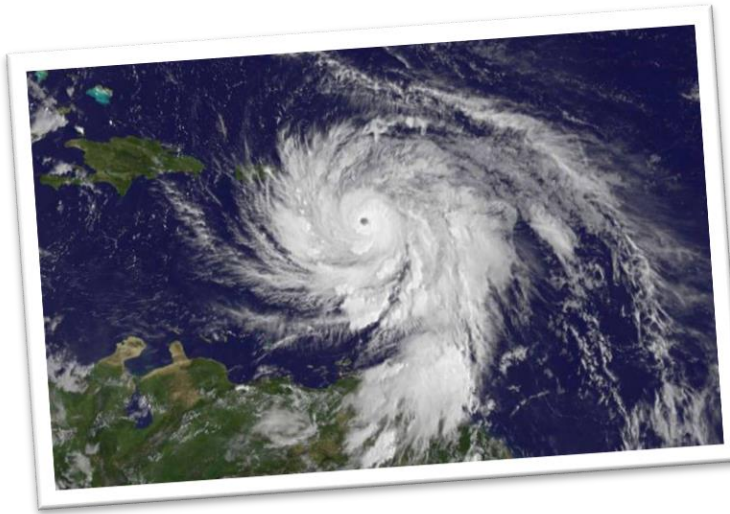


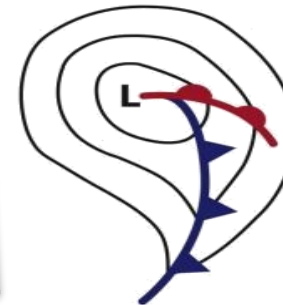
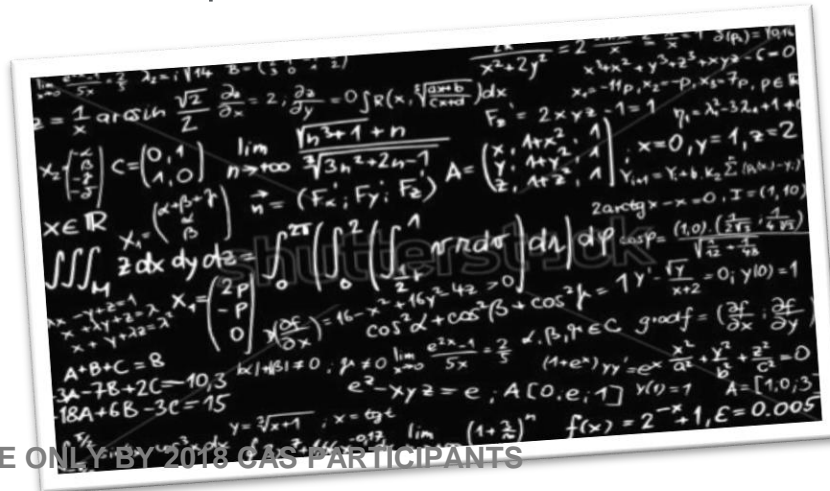
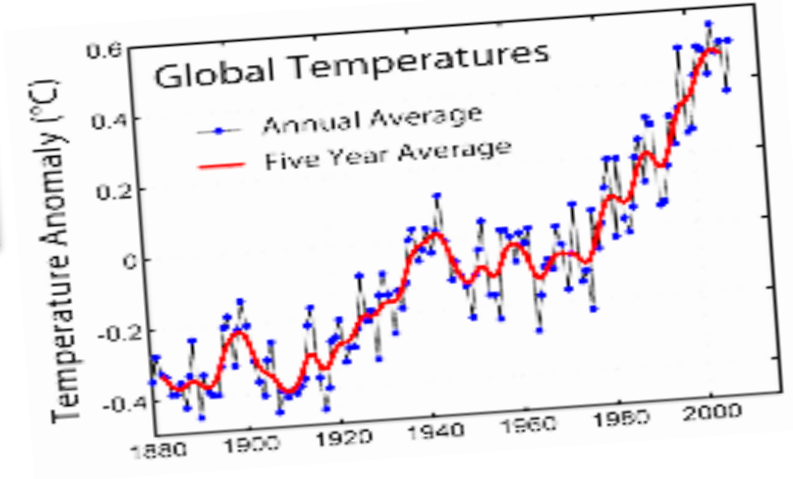
Recent Weather Extremes: Outliers or the New Norm?

Peter Sousounis, Ph.D.
AIR Worldwide
Boston, MA

Presentation Outline

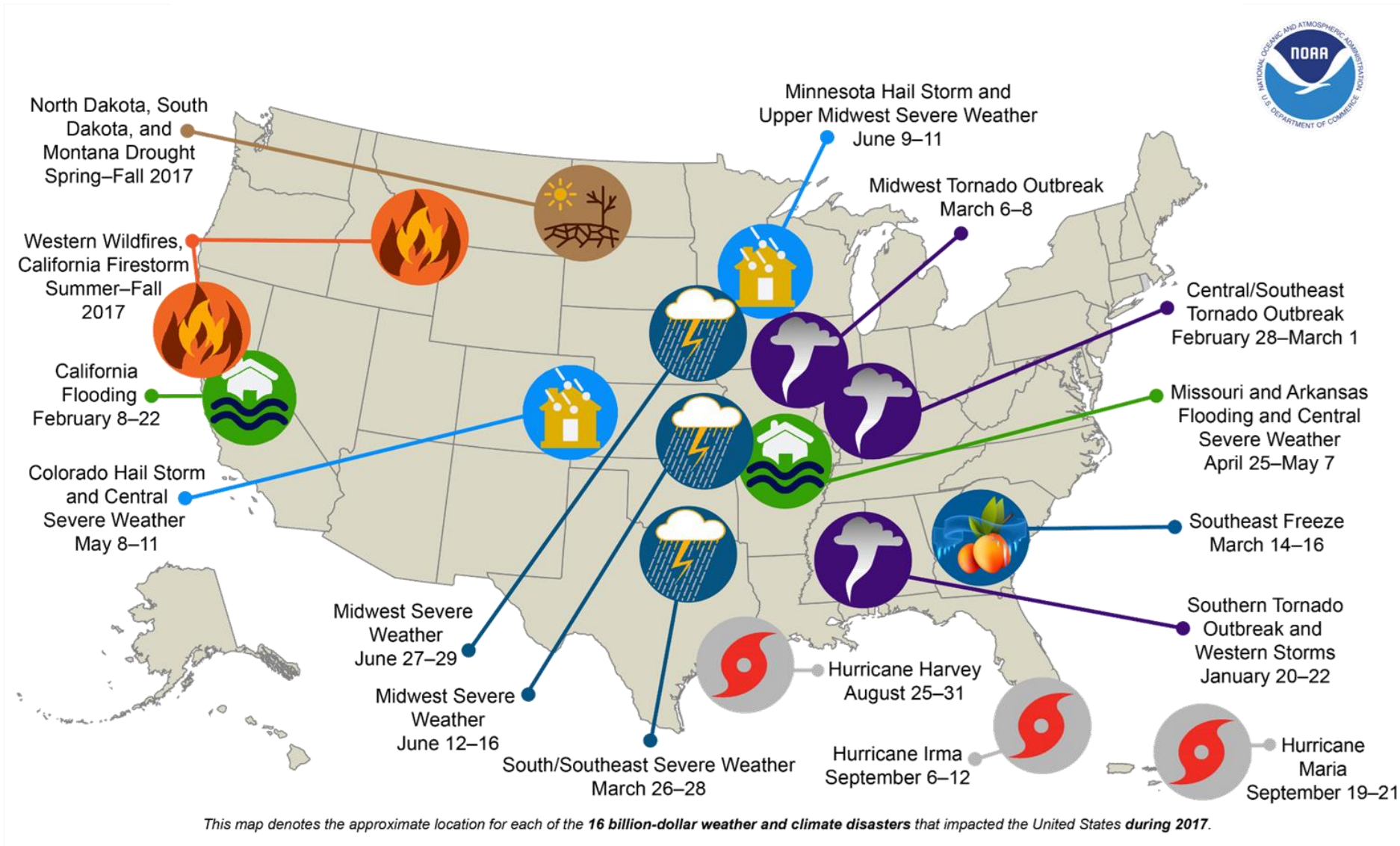


- Some Recent Extremes
- Extreme Event Attribution
- Expected Impacts of Climate Change
- Putting Recent Extremes into Perspective

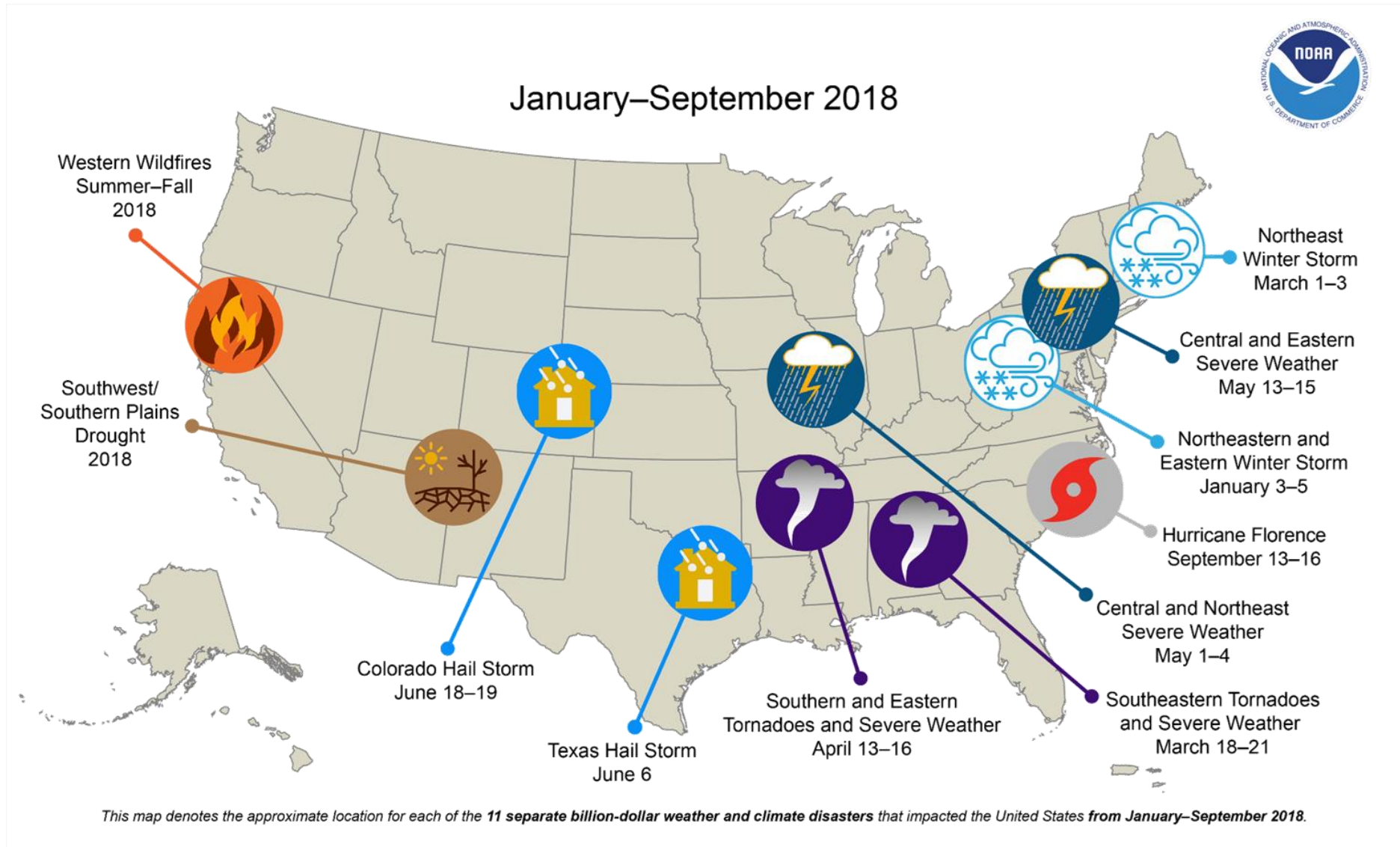


Some Recent Extremes

US 2017 Billion Dollar Weather and Climate Disasters



US 2018 Billion Dollar Weather and Climate Disasters



Extreme Event Attribution

What is Extreme Event Attribution?

Maria was the third Cat 5 hurr in 2017 to strike US Territory



Several Nor'easters in March 2018 Battered New England

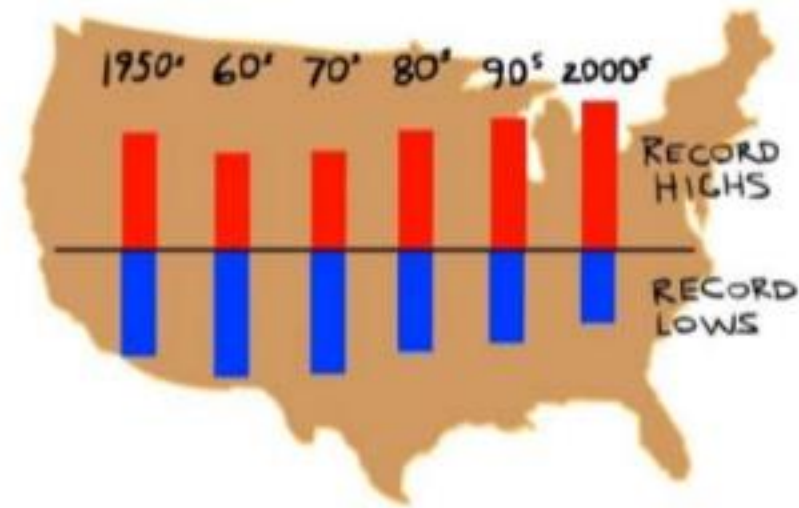
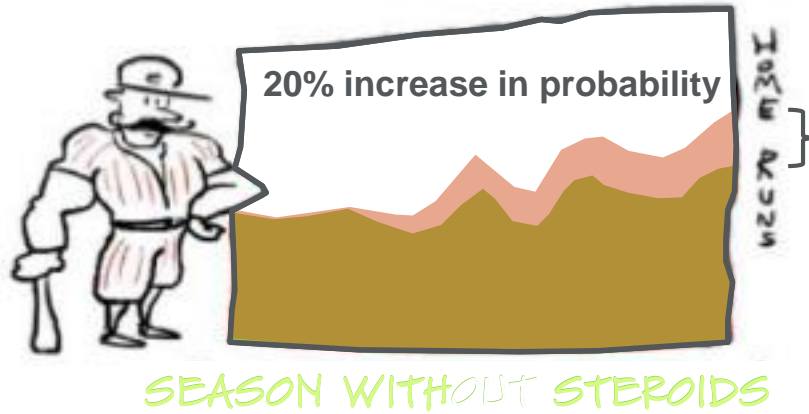


Florence 2018 turned Wilmington, NC into an island for days

Extreme event attribution is a new branch of climate change science tasked with evaluating the degree to which anthropogenic global warming was responsible for a particular extreme event

The Analogy with Baseball and Steroids

The weather on steroids



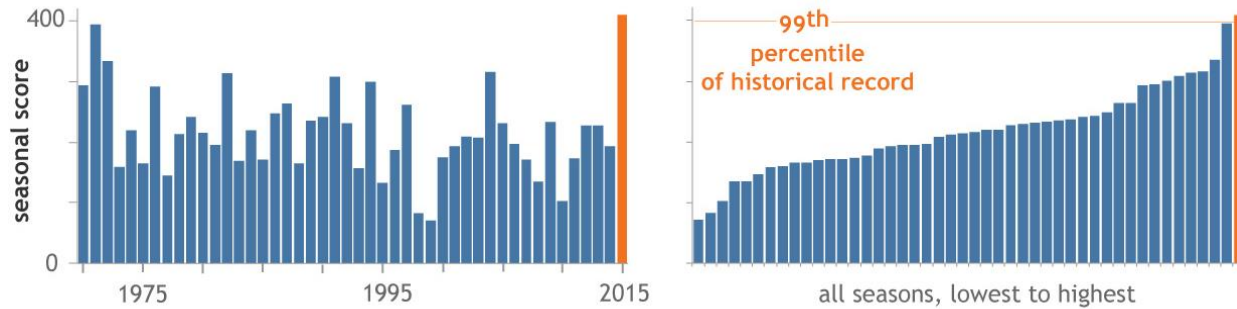
An analogy...
Climate warming is changing
the weather like steroids
change a baseball player.

Credit Gerald Meehl, 2012)

Extreme Event Attribution Typically Involves Analyzing Data and Running Climate Models

OBSERVATIONS

Seasonal cyclone energy in the western North Pacific (1970-2015)

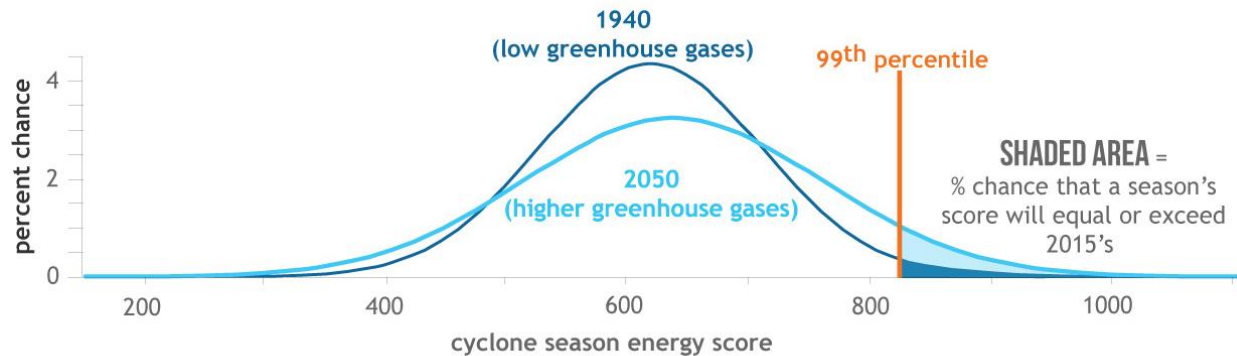


Attribution analyses generally involve splitting historical record into two time periods and testing for statistically significant differences in extreme events

Models allow scientists to test whether there is a plausible physical link between global warming and behavior of a particular kind of extreme event

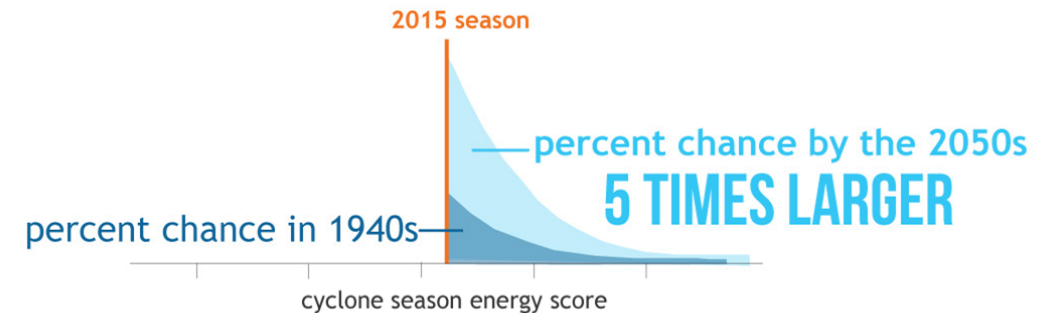
MODELS

Odds of a North Pacific cyclone season in the 99th percentile



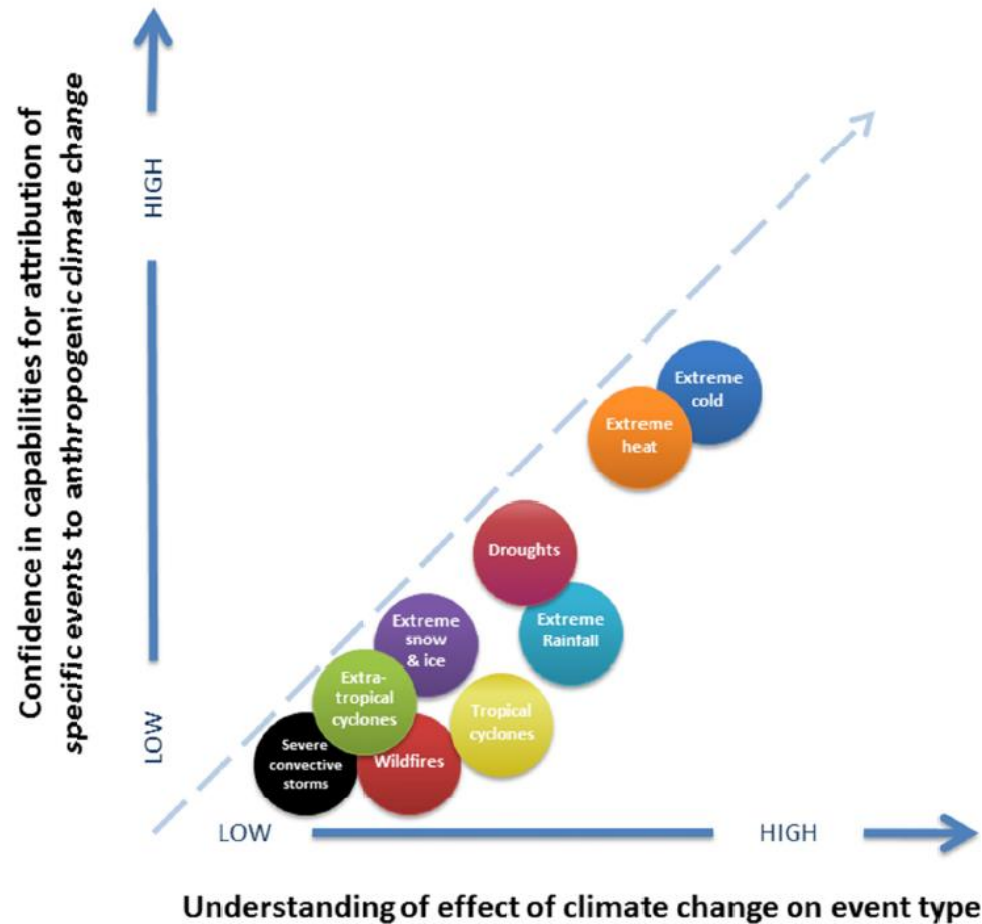
CHANGING RISK

of a western North Pacific cyclone season like 2015's



from climate.gov

Which Types of Events Have Been Most Likely Influenced by Climate Change?



from [climate.gov](https://www.climate.gov)

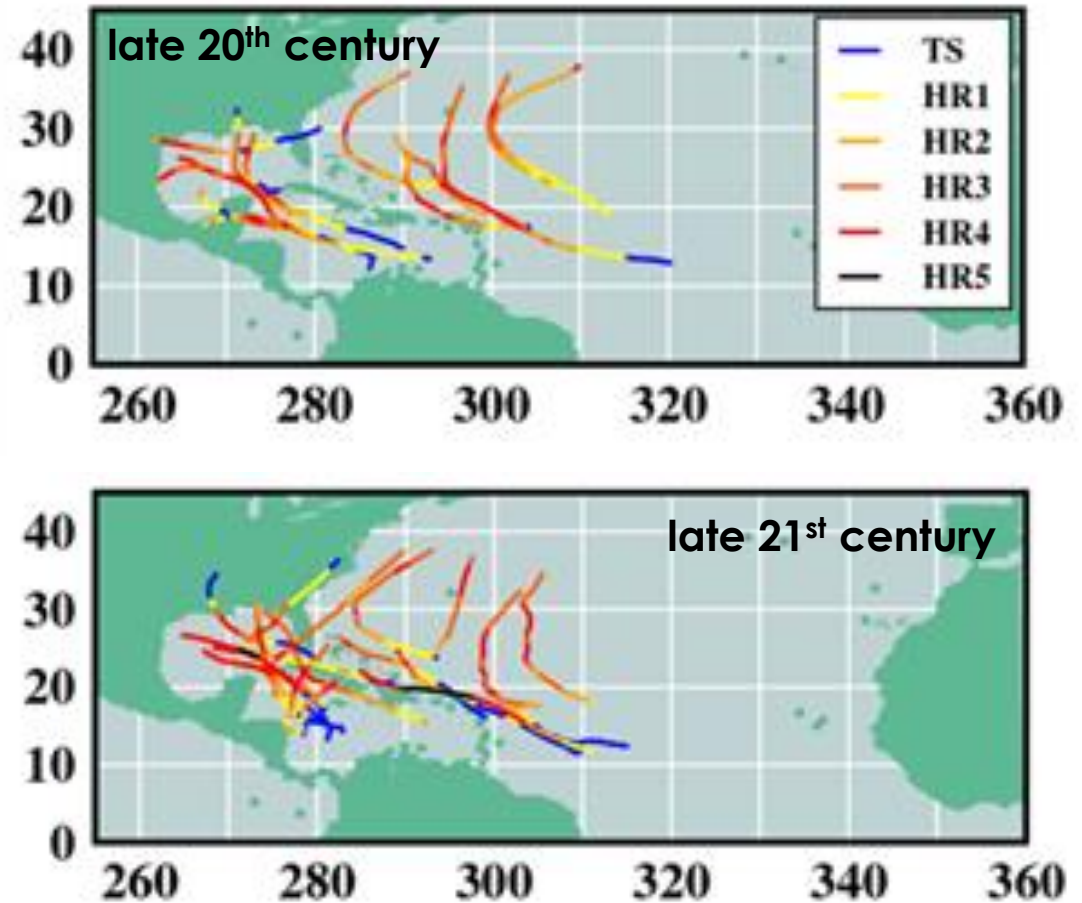
overall confidence in event attribution is strongest for extreme event types that are:

- adequately simulated in climate models
- have a long-term historical record of observations
- are linked to human-caused climate change through an understood and robustly simulated physical mechanism

Expected Impacts of Climate Change on Tropical Cyclones

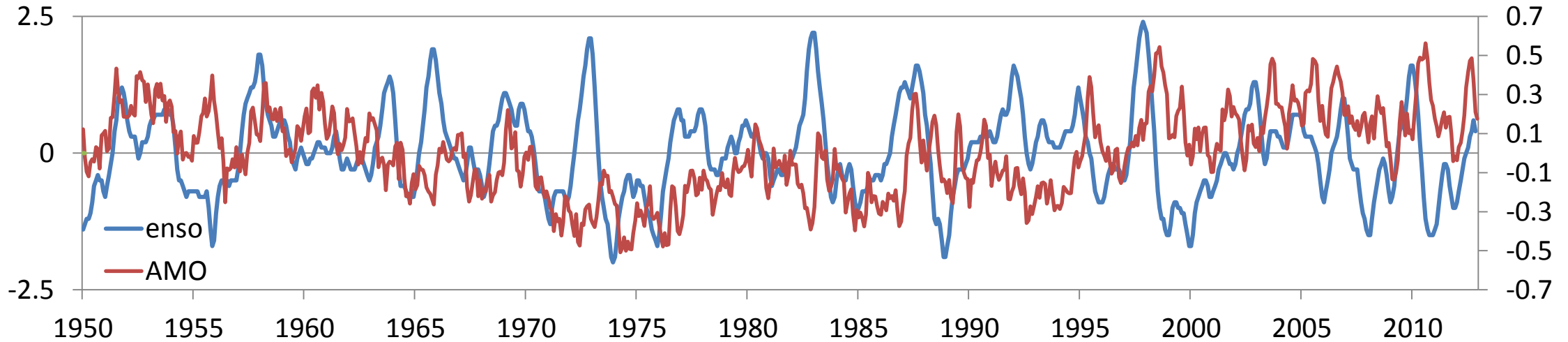
TC Frequency Will Likely Decrease

- General Circulation Models do show increase in Cat 4s and 5s by later this century
- Overall decrease in Tropical Cyclone numbers - mainly from fewer weak ones
- Precipitation will increase for several reasons
- Storm surge threat will increase because of sea level rise and because of stronger storms



Several Factors are Clouding Our View

Historical Climate Indices



Data quality

Length of record

Climate change happening slowly

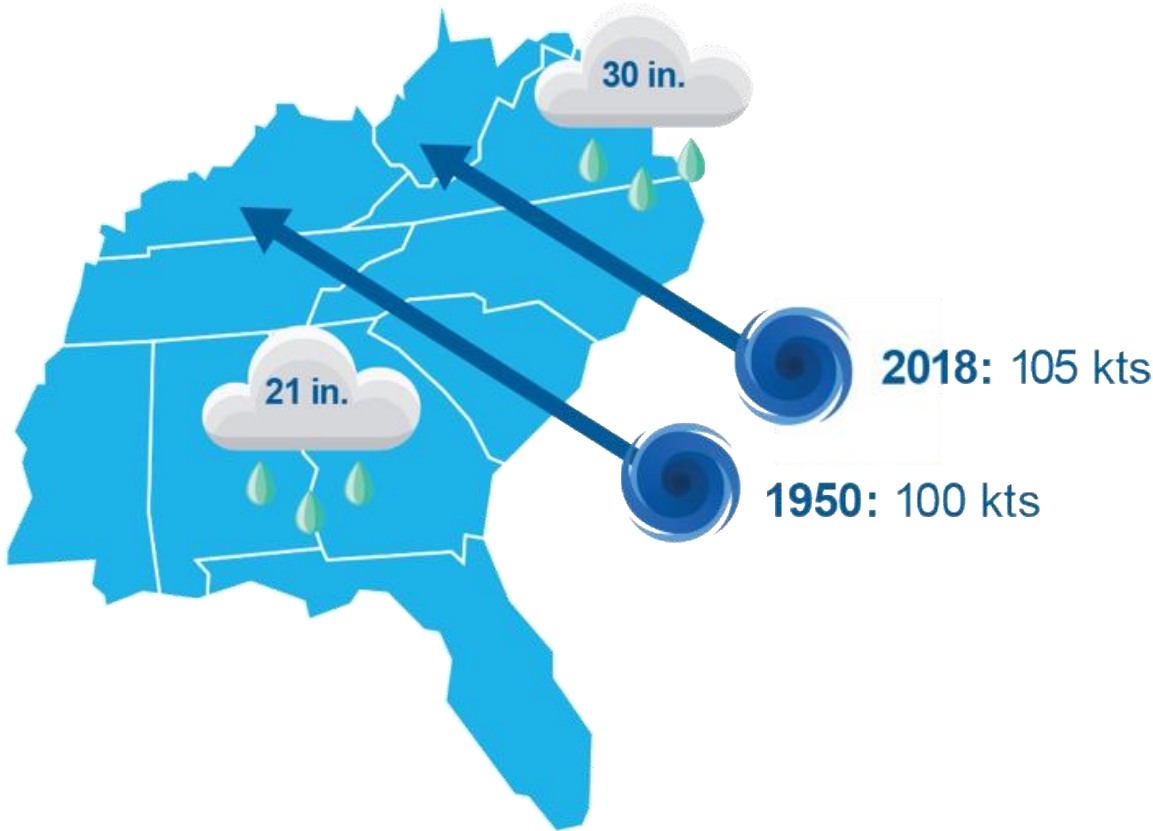
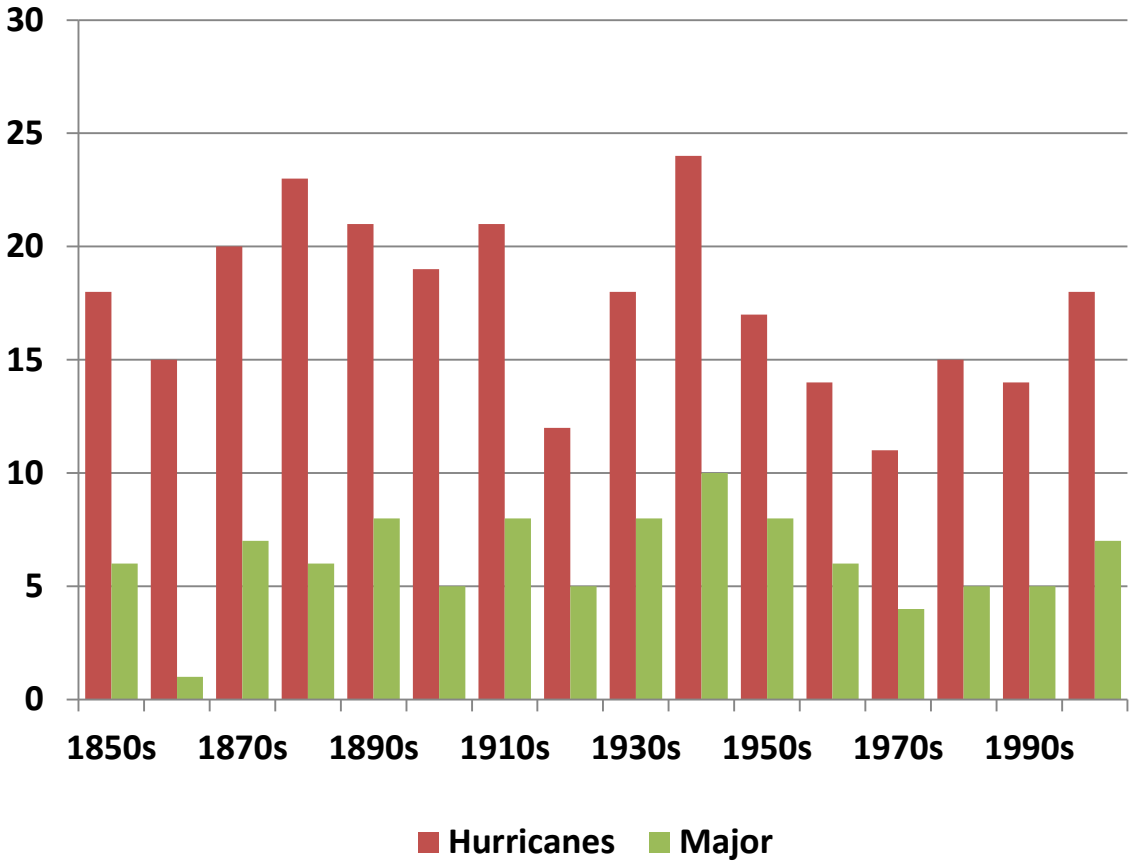
Climate change signal is small compared to the noise of climate variability

Not looking at the right features

Numerical climate models are not correctly guiding us

Some Climate Change Impacts on TCs are Evident Now

Historical record does not show any trend in US hurricane landfall frequency



Historical record does show trend in forward speed, latitude of maximum intensity, and intensity

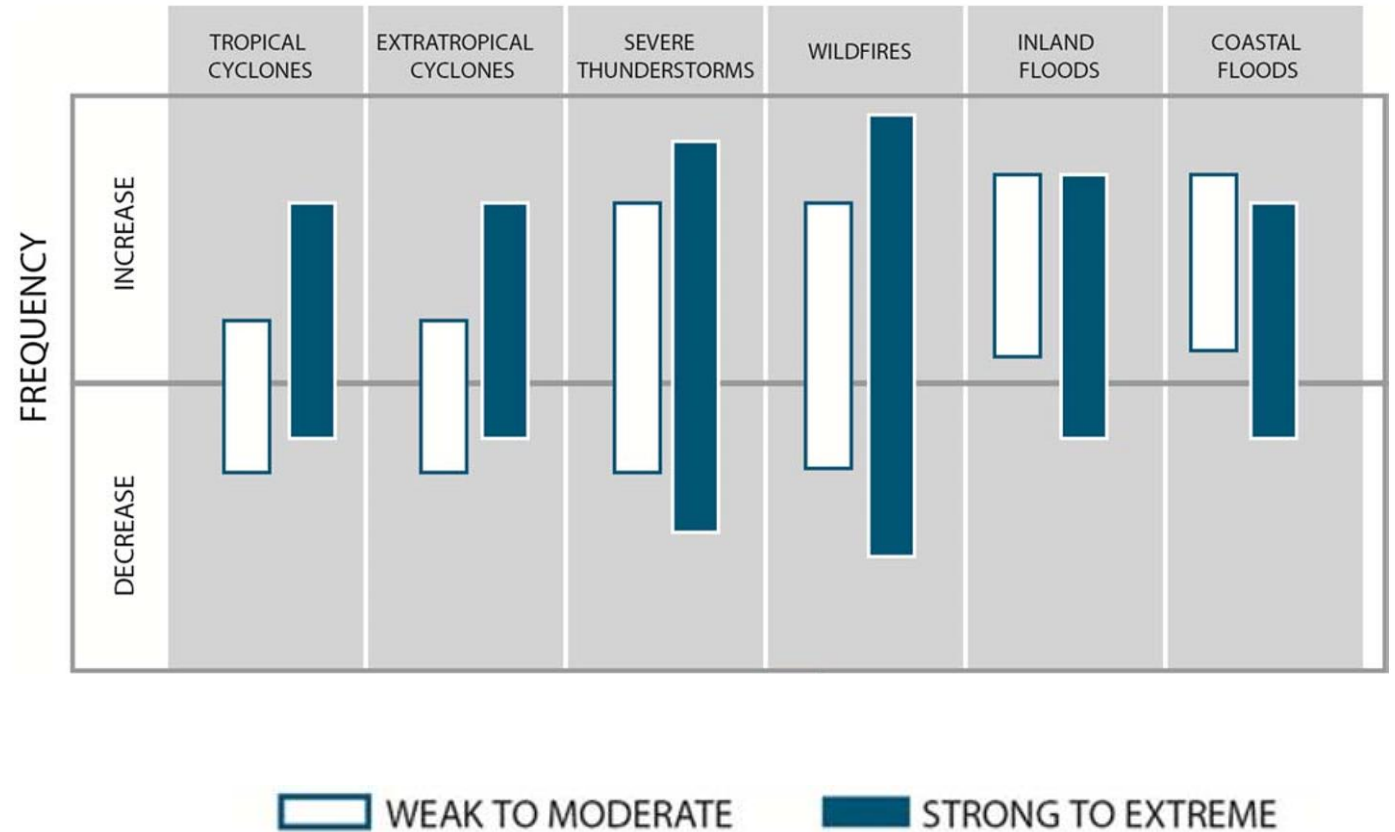
Most Weather Systems Will Become More Extreme

Climate Change Impacts on Extreme Weather

June 2017

Peter J. Sousounis, Ph.D.
AIR-Worldwide
Boston, MA

Christopher M. Little, Ph.D.
Atmospheric and Environmental Research
Lexington, MA



Putting the 2017 Hurricane Records into Perspective

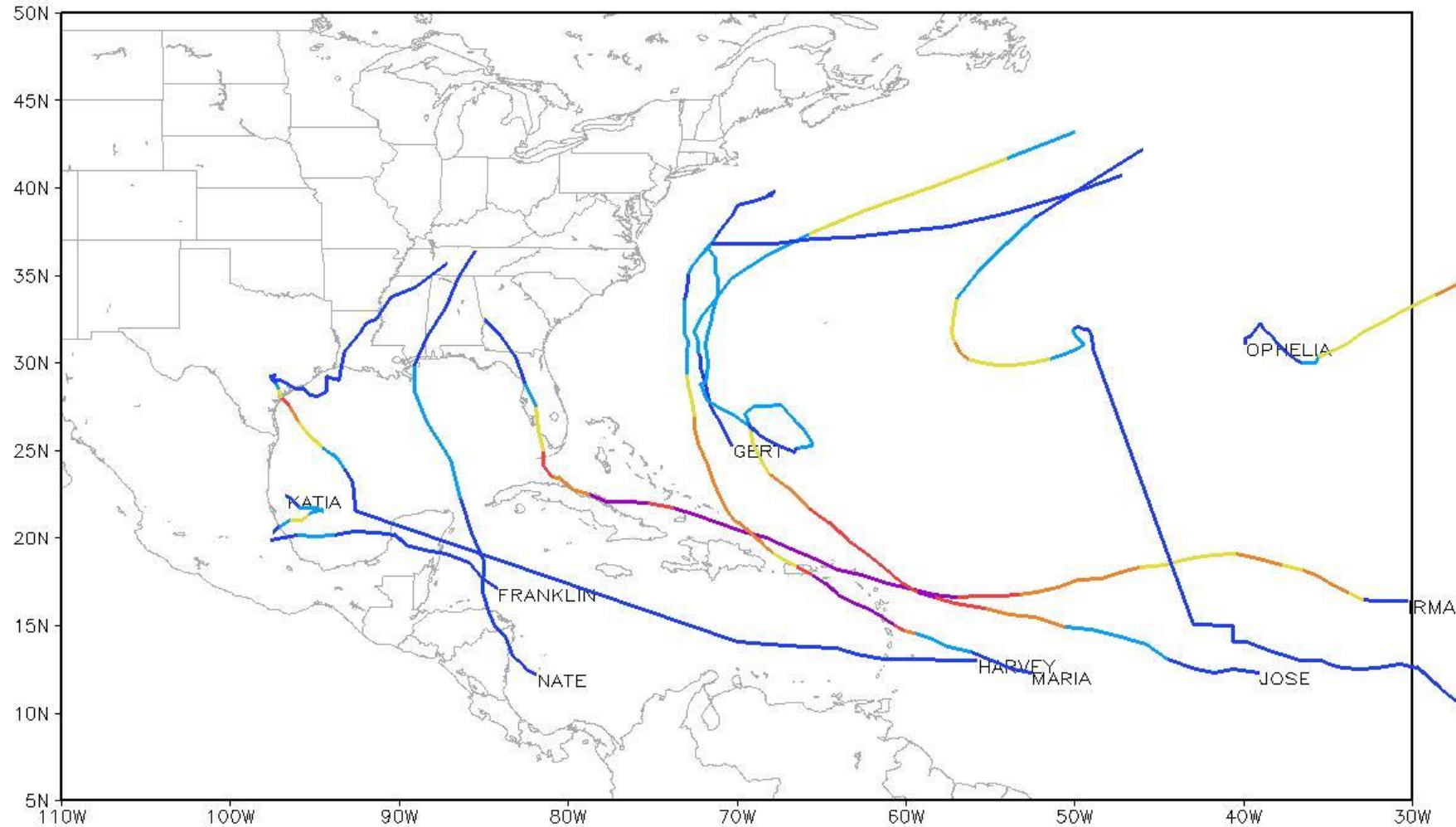
Climate Change and Weather

What About Those Hurricane Records in 2017?

2017 Hurricane Season

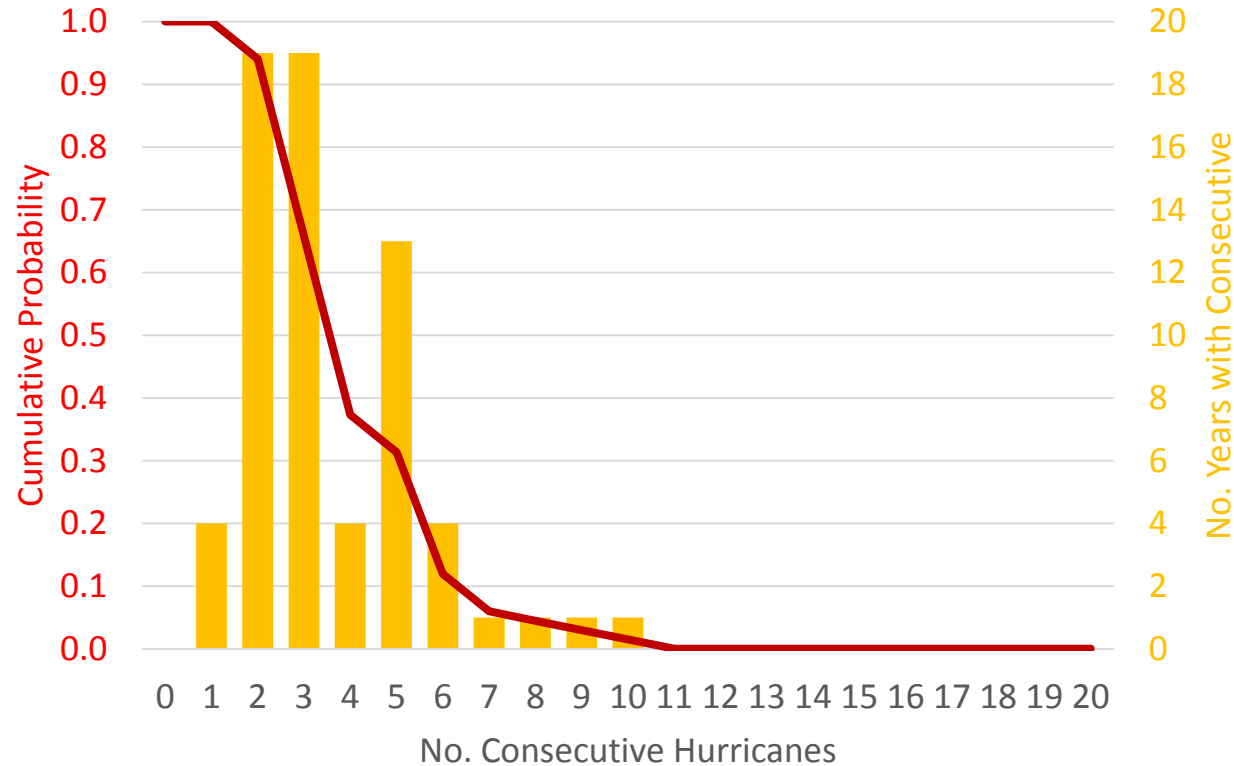
Atlantic Basin

- 2 Cat 4 landfalls in 15 days
- 2 Cat 4s at the same time
- 3 hurricanes at same time
- 3 Cat 4 landfalls in US/Territories
- 4 hurricanes in August
- 10 hurricanes in a row



How Unique was 10 Hurricanes in a Row?

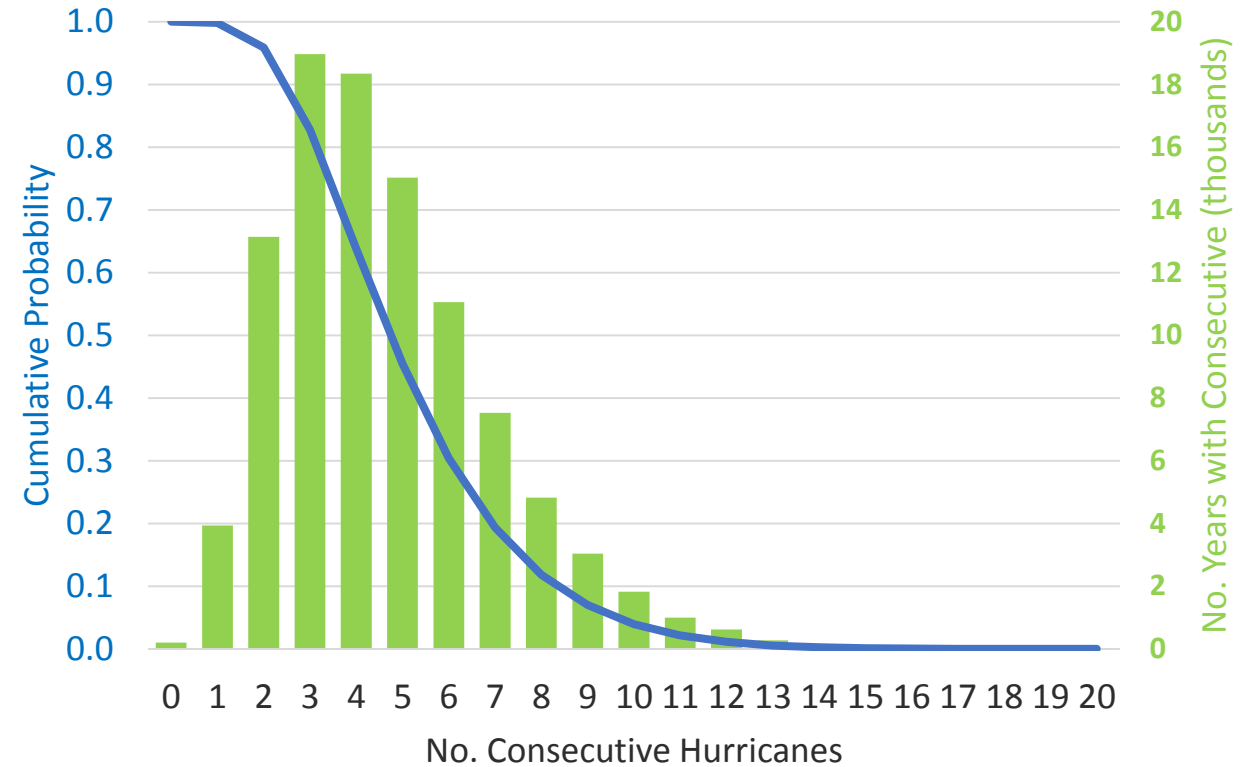
Probability of Consecutive Cat 1s or Higher



Historical – 996 hPa

Note: for other analyses hurricane defined when central pressure is at or below 996 mb

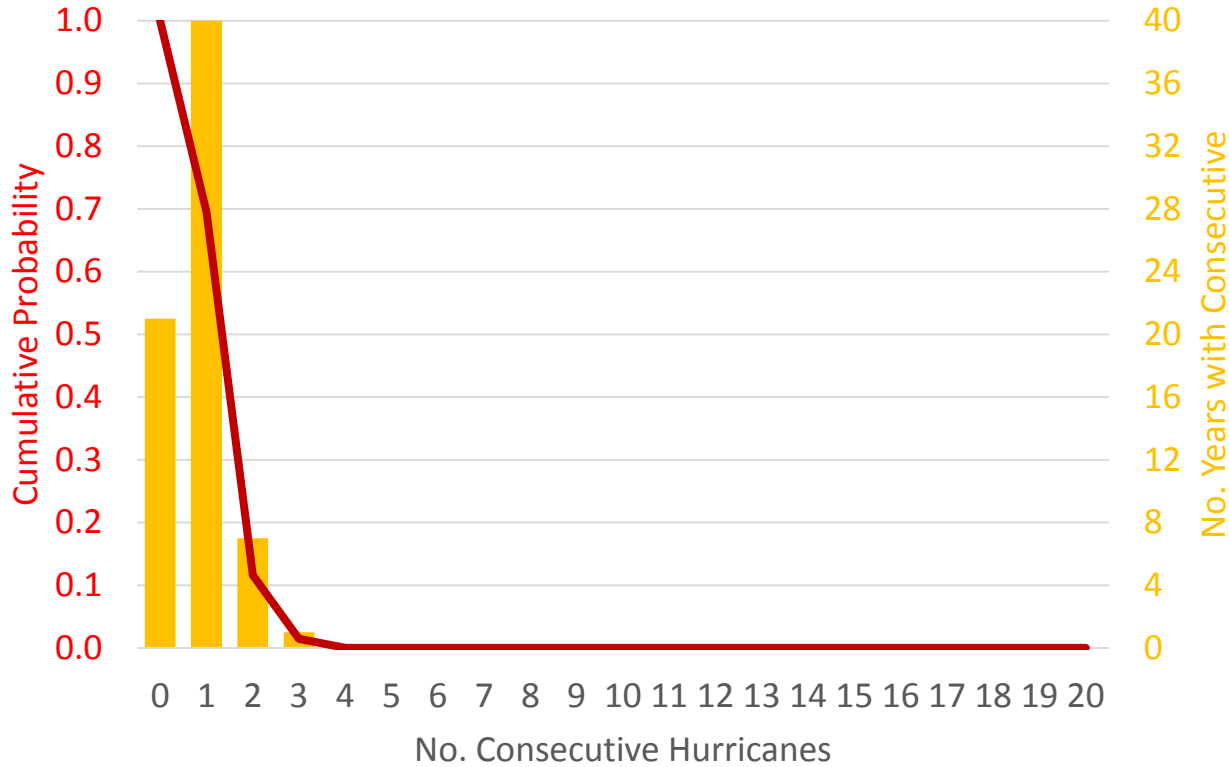
Probability of Consecutive Cat 1s or Higher



Stochastic – 996 hPa

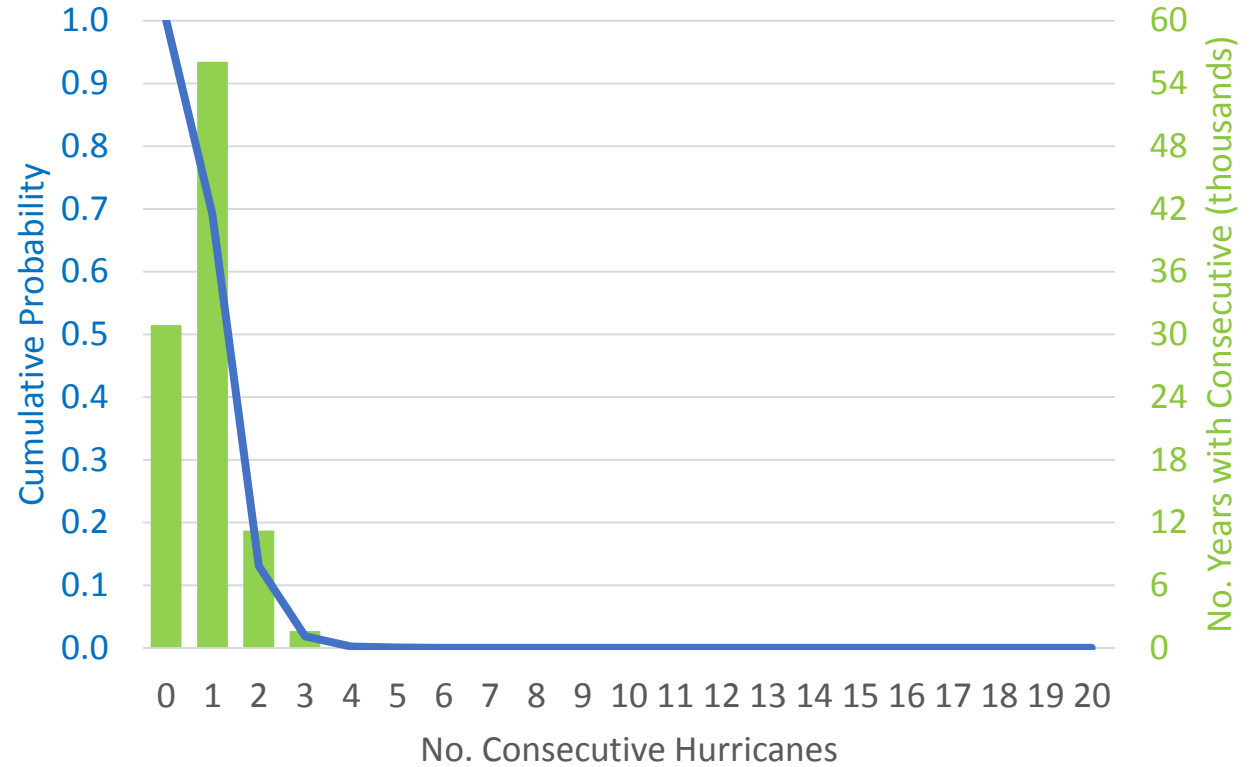
How about Three Cat 4s in a Row?

Probability of Consecutive Cat 4s or Higher



Historical – 945 hPa

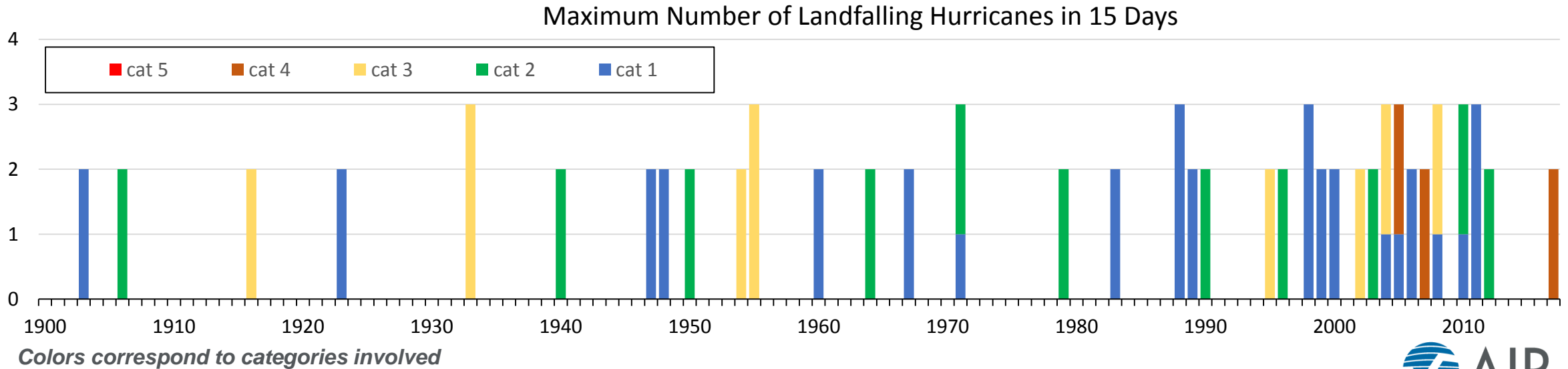
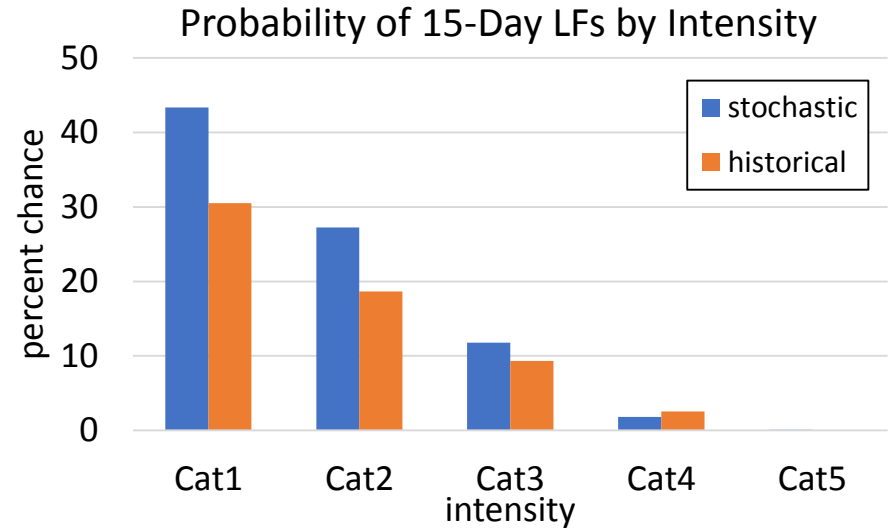
Probability of Consecutive Cat 4s or Higher



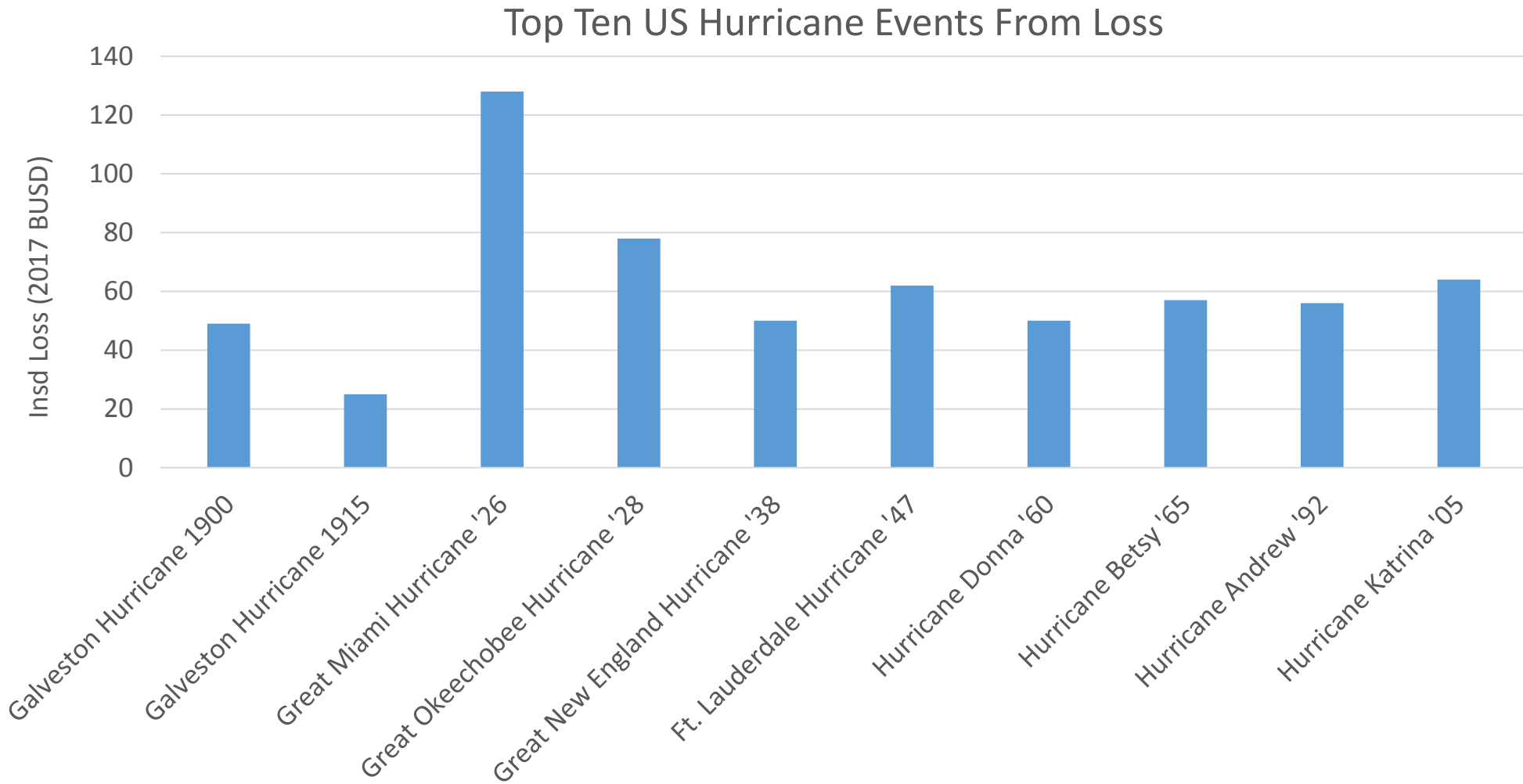
Stochastic – 945 hPa

How Likely are 2 Cat 4 LFs in 15 Days?

- Multiple ATL Basin LFs in 2 weeks is quite common historically
- More 2 week LFs since 1951
- More 2 week LFs during 1983-2017 than 1951-82
- Stochastic probabilities similar to historical ones
- For two Cat 4s in 2 weeks historical probability is 2.54% vs 1.82% for stochastic



Recent Hurricane Loss Activity Still within Historical Norm



Summary

- Weather extremes *seem* to be happening more frequently
- Extreme event attribution shows promise to understand impact of global warming
- Extremes expected to increase in intensity and frequency by 2100
- Some climate change impacts are detectable now
- Most 2017 hurricane extremes are within current model expected probabilities