Please note that this presentation was given during the United Nations Climate Change Conference (COP-15) in Copenhagen, December 7-18, 2009 for more information please visit http://www.cop15.state.gov/ .

Extreme Weather and Climate Events in a Changing Climate

Presented by Thomas R. Karl
Lead, United States National Oceanic and Atmospheric Administration (NOAA) Climate Services
Director, U.S.A. NOAA National Climatic Data Center

With contributions from Thomas R. Armstrong
Senior Advisor for Global Change Programs
U.S. Geological Survey U.S.A. Department of Interior

United States Global Change Research Program

December 8, 2009

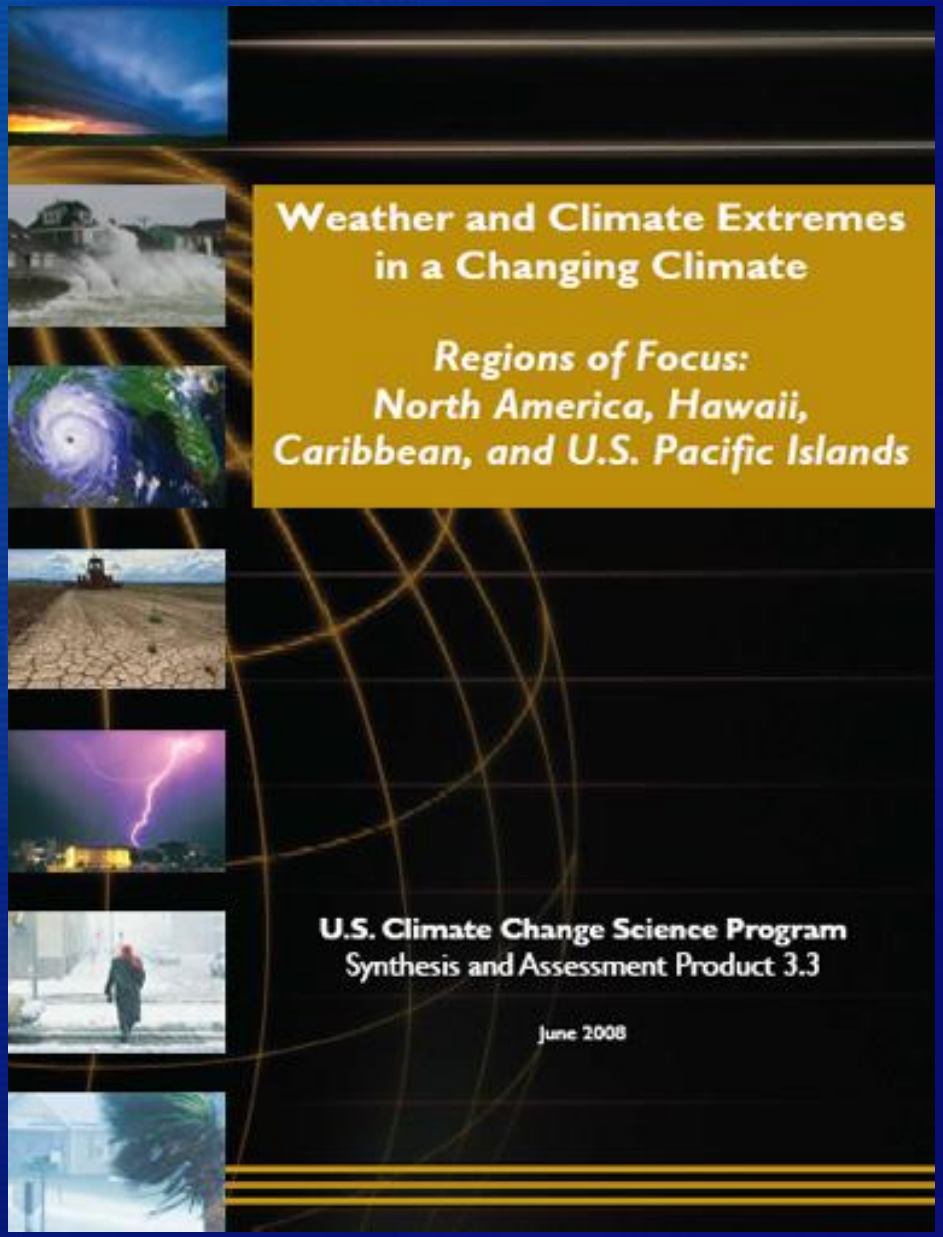
The report summarizes the science and impacts of weather and climate extremes on North America within the context of global climate change

US Global Change Research Program report, led by NOAA

Extensive review (pubic and peer review)

Draws from all previous assessments, global and national (IPCC, U.S. National Academy of Sciences, etc.)

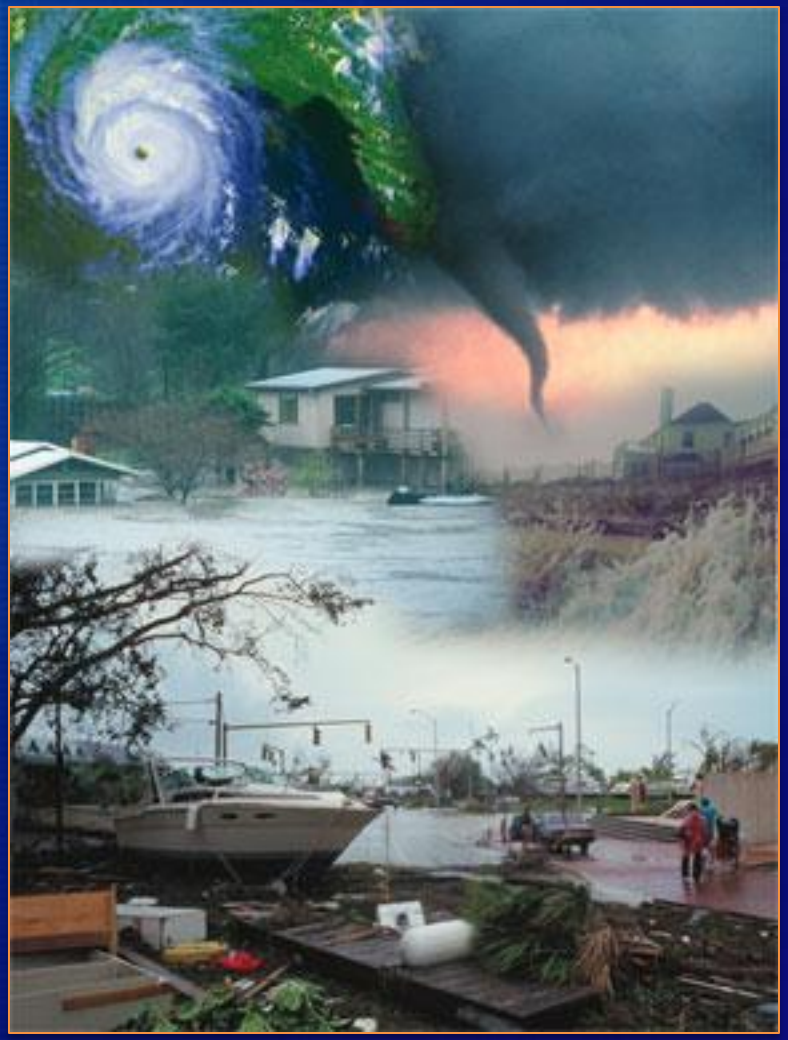
Author team was a Federal Advisory Committee body and included federal, academic and private sector experts



Weather and Climate Extremes in a Changing Climate

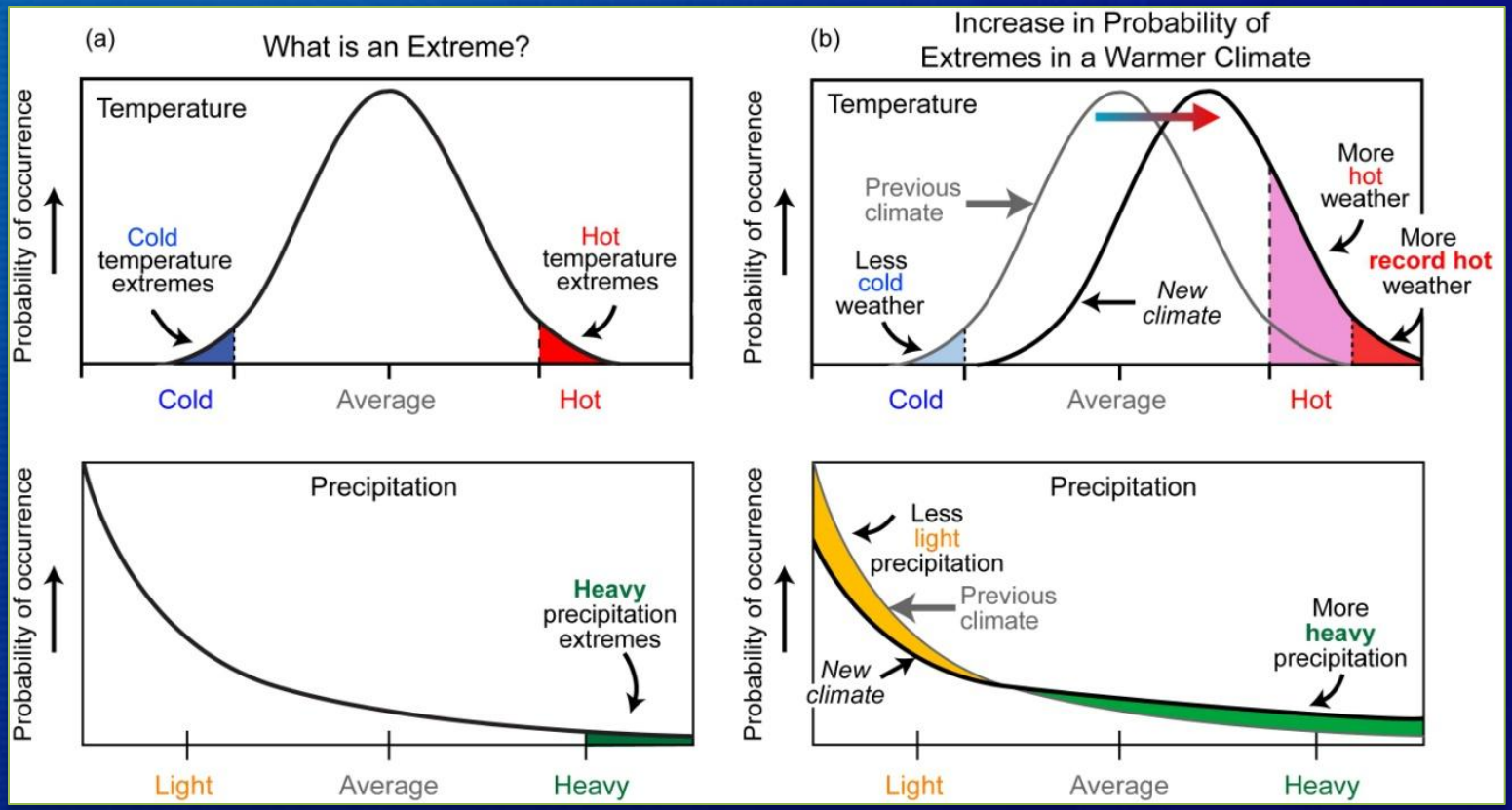
Motivation

"Changes in extreme weather and climate events have significant human impacts and are among the most serious challenges to society in coping with a changing climate."



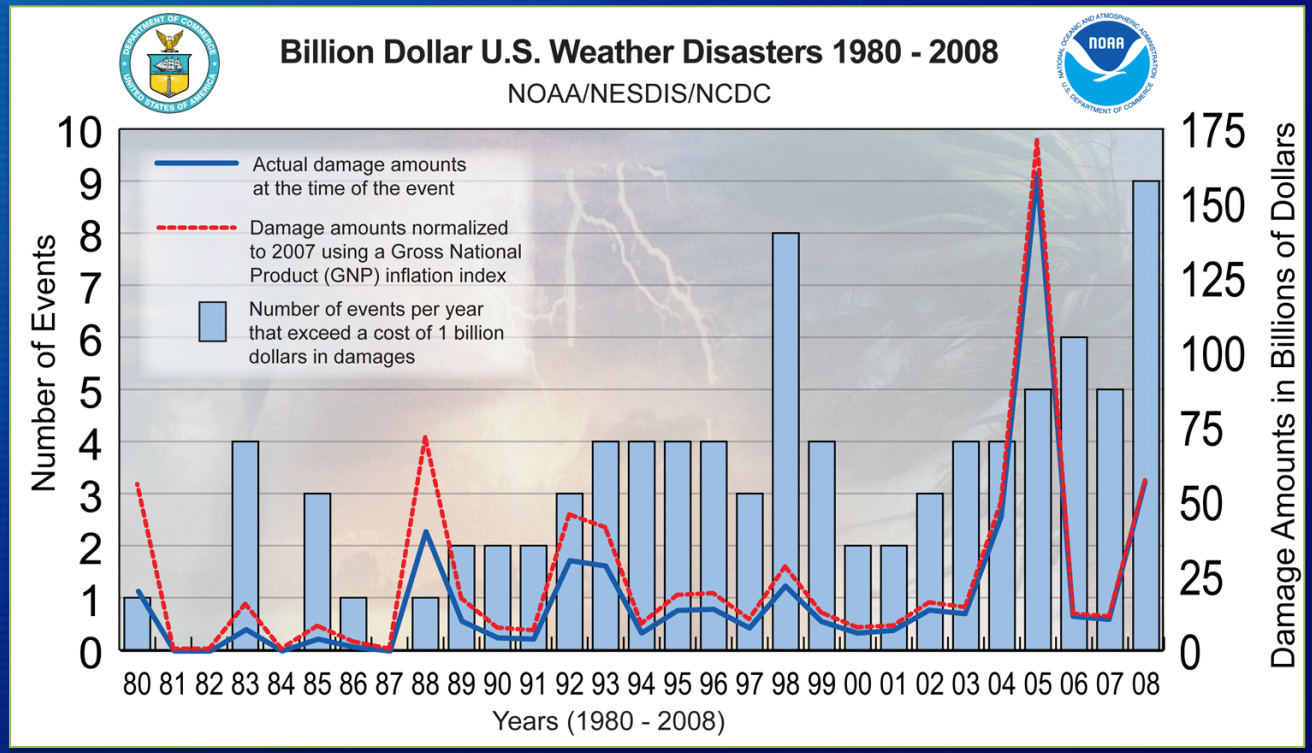
What are Extremes and why do they Matter?

Small changes in averages for many variables result in larger changes in extremes.



What are Extremes and Why do they Matter?

On balance, the majority of events outside the historical range have primarily negative impacts.



** This graphic does not include losses that are non-monetary, e.g., loss of life, biodiversity etc.*

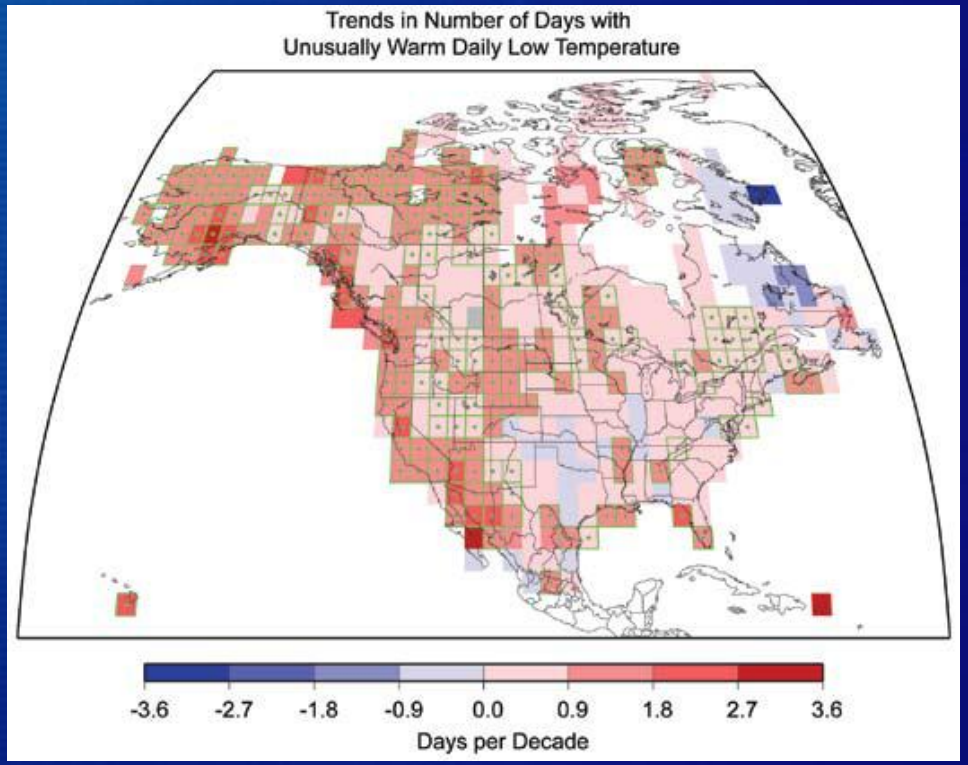
Temperature Extremes

Over recent decades ----

More unusually hot days and nights.

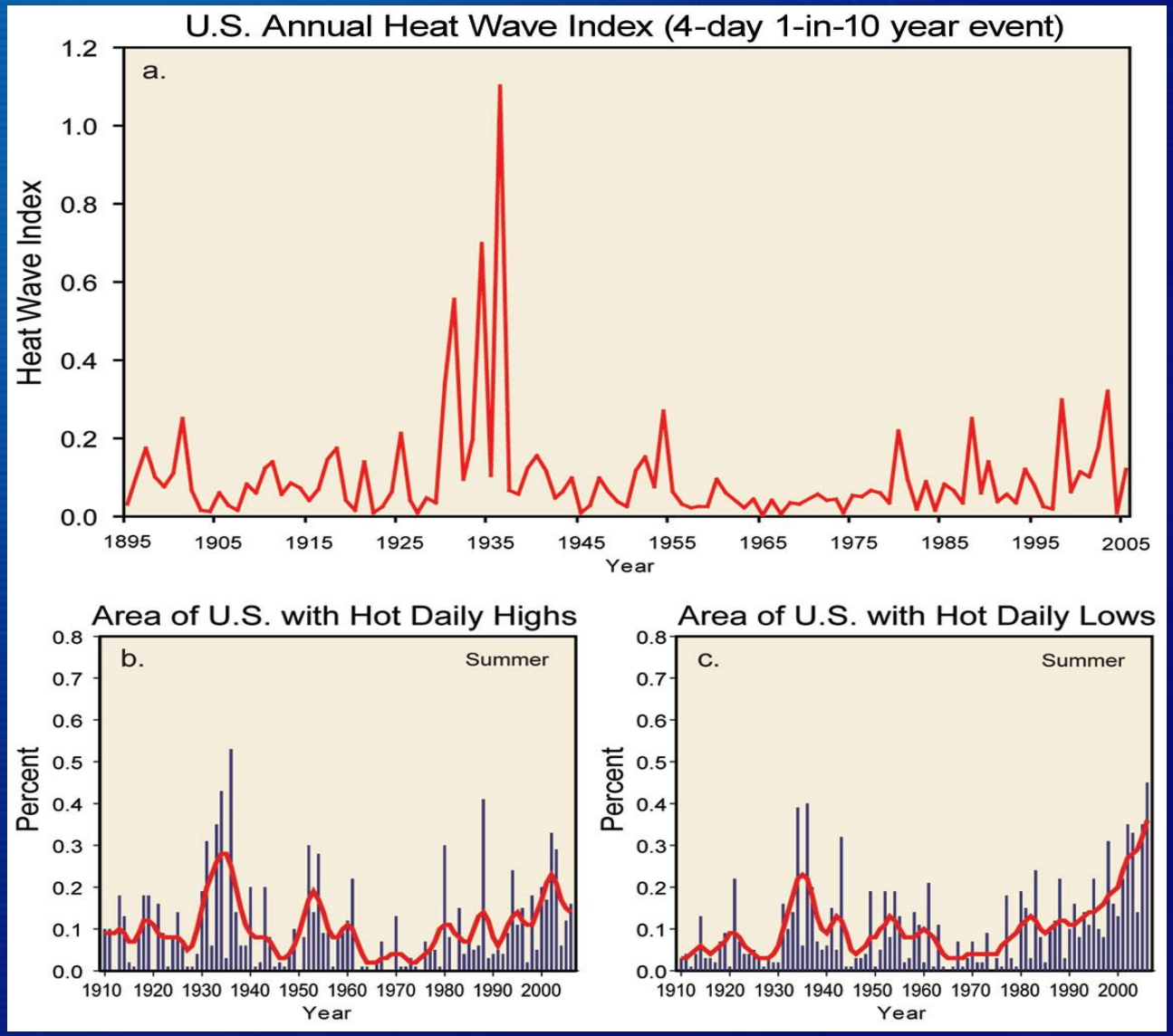
Fewer unusually cold days during the last few decades.

Increasing number of heat waves, but 1930s still most severe



The last 10 years - fewer severe cold waves than for any other 10-year period in the historical record, back to 1895.

Temperature Extremes



United States Global Change Research Program

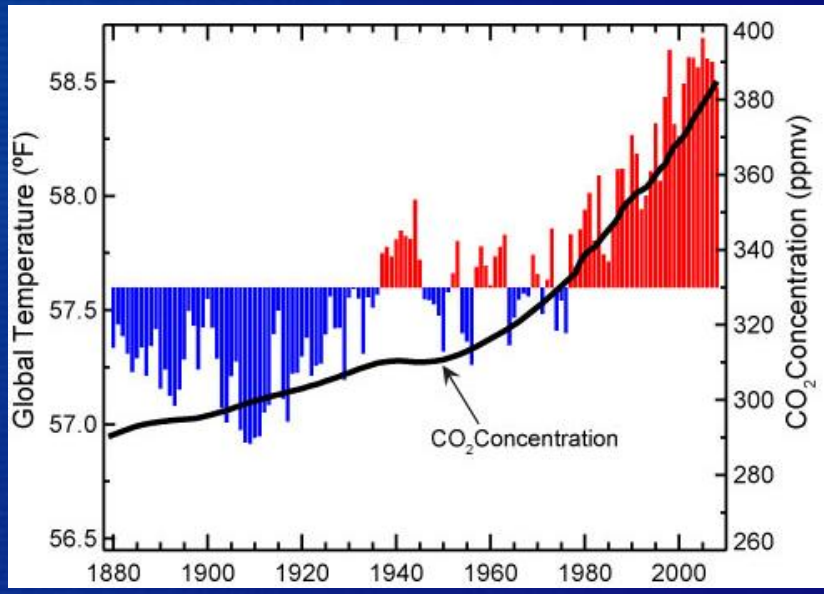
Temperature Extremes

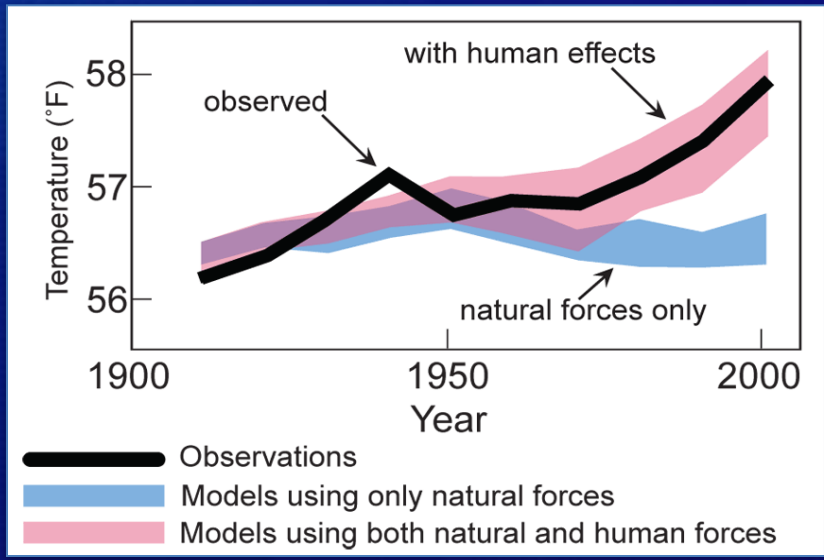
Attribution of Changes --

- Human-induced warming has likely caused much of the average temperature increase in North America over the past 50 years and, consequently, changes in temperature extremes.

For example…

- The effect of human-induced emissions of greenhouse gases has been associated with the very hot year of 2006 in the U.S.





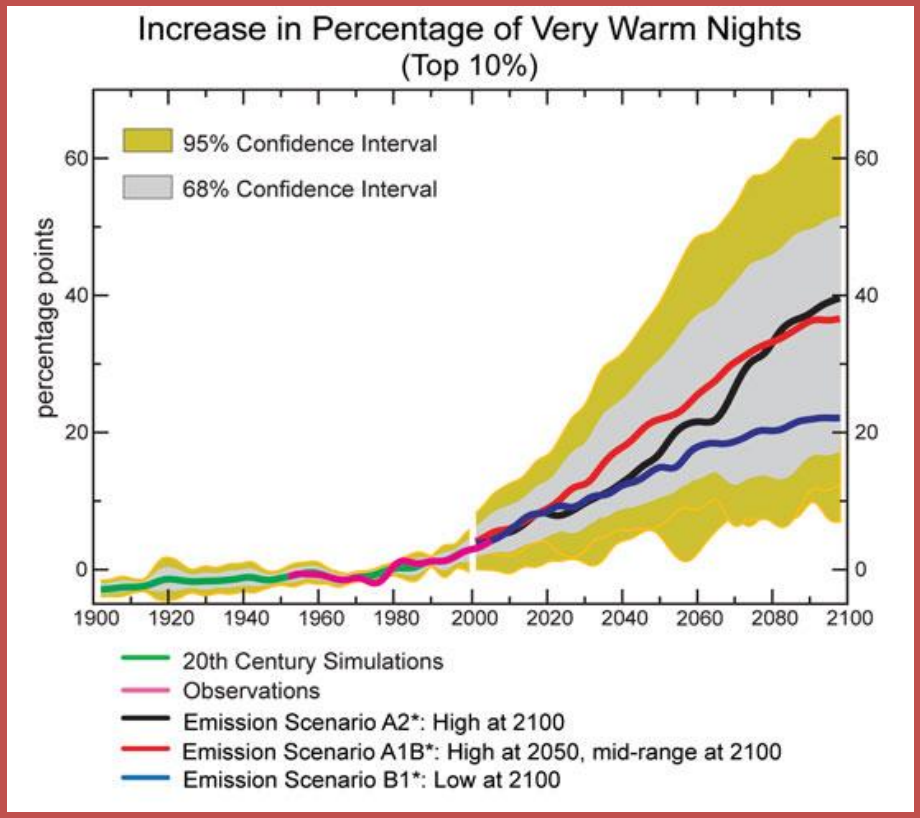
Temperature Extremes

Projected Changes --

Hot days and nights, and heat waves - very likely more frequent.

Cold days and cold nights - very likely much less frequent.

Days with frost – very likely to decrease.

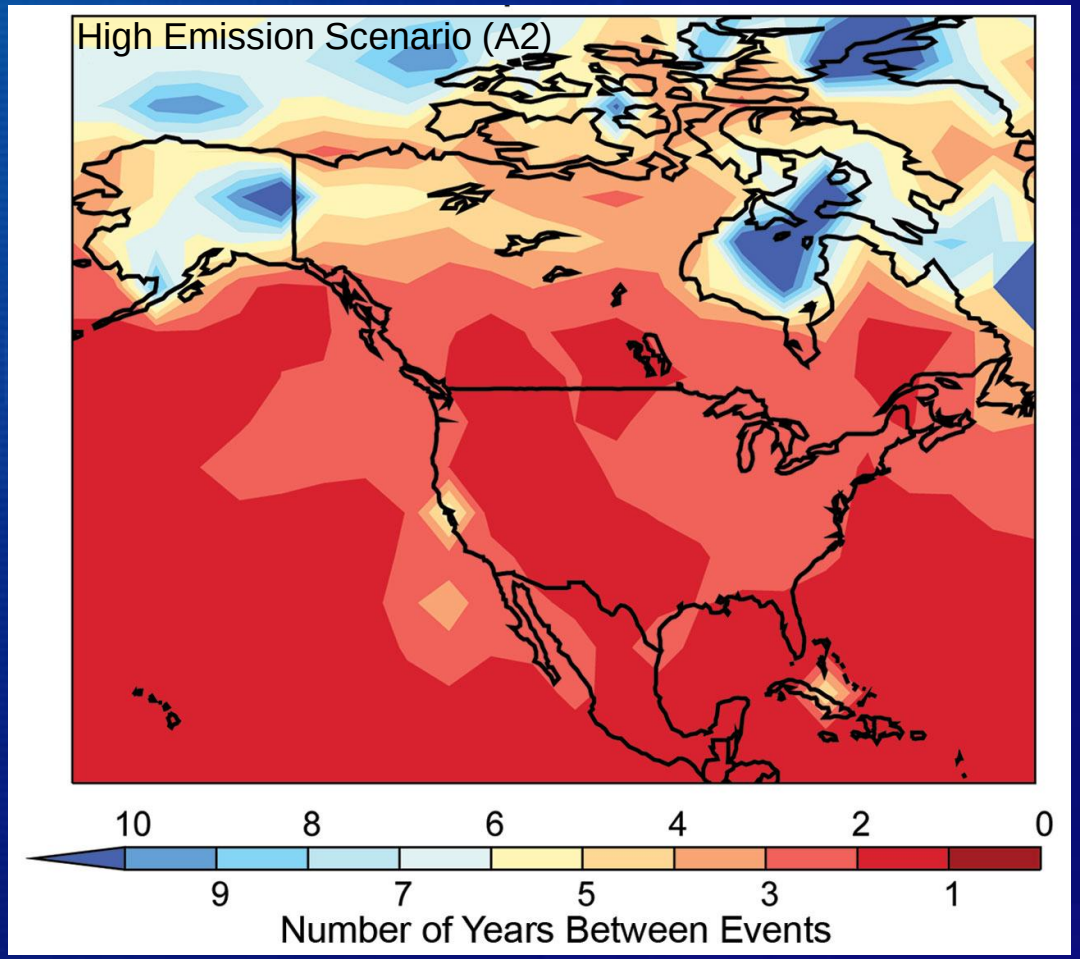


Temperature Extremes

Projected Changes --

Hot days currently experienced once every 20 years would occur every other year or more by the end of the century

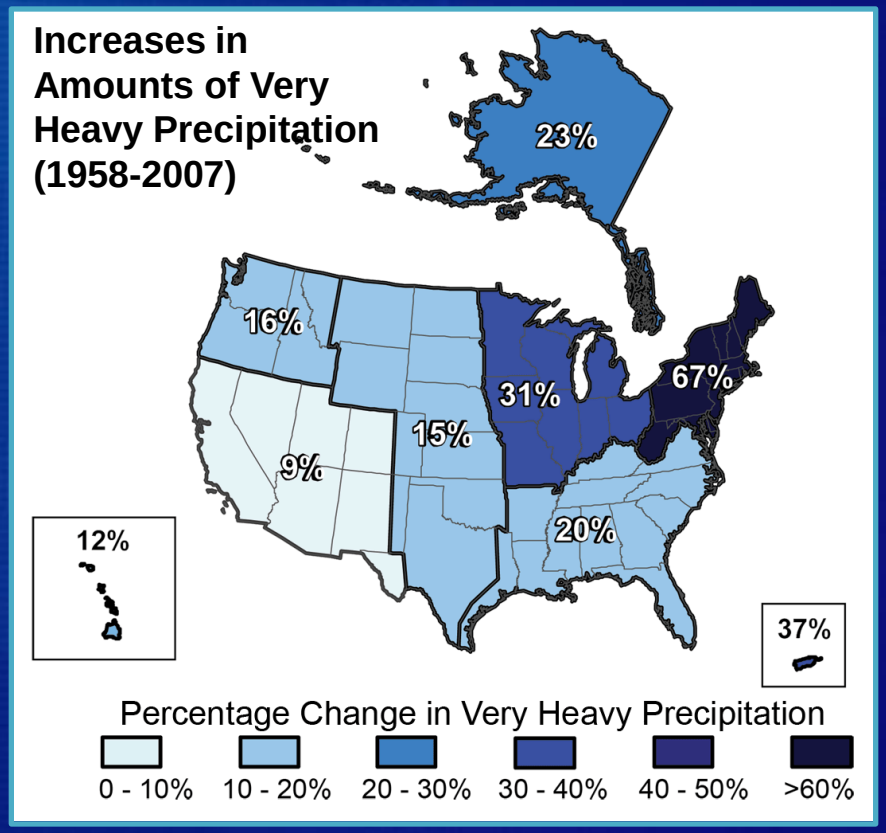
Temperature



Precipitation Extremes

Observed Changes --

Intense precipitation events (the heaviest 1%) in the continental U.S. increased by 20% over the past century while total precipitation increased by 7%.



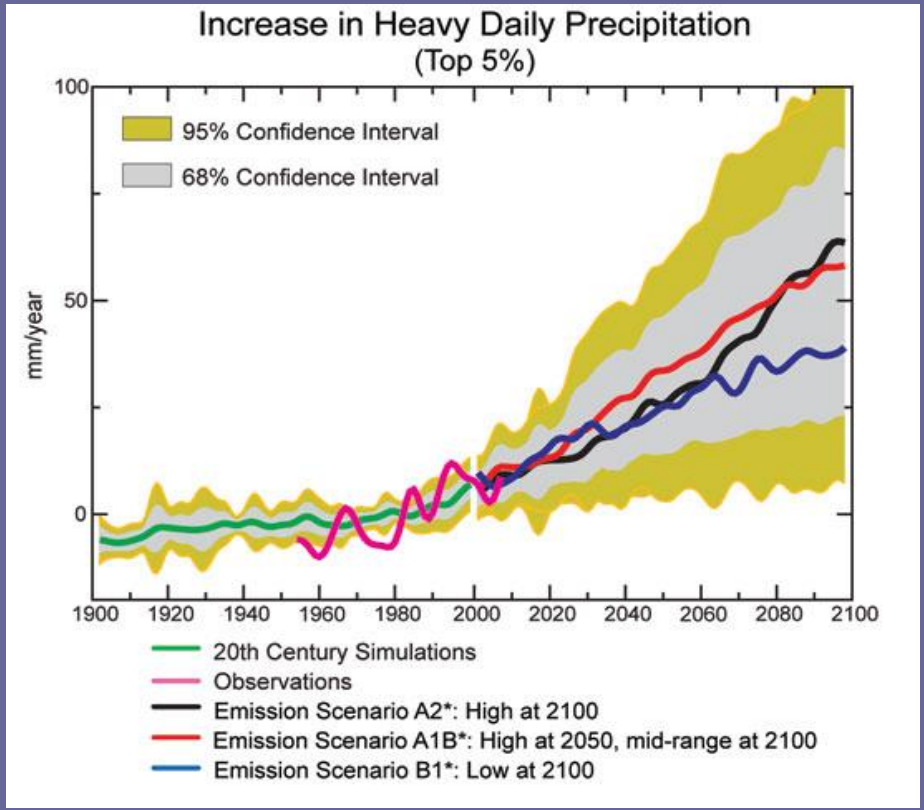
North American Monsoon

- The season is beginning about 10 days later than usual in Mexico.
- In the SW, - fewer rain events, but events are more intense.

Precipitation Extremes

Attribution of Changes --

The increase in precipitation intensity is consistent with the observed increases in atmospheric water vapor (linked to human-induced increases in greenhouse gases).

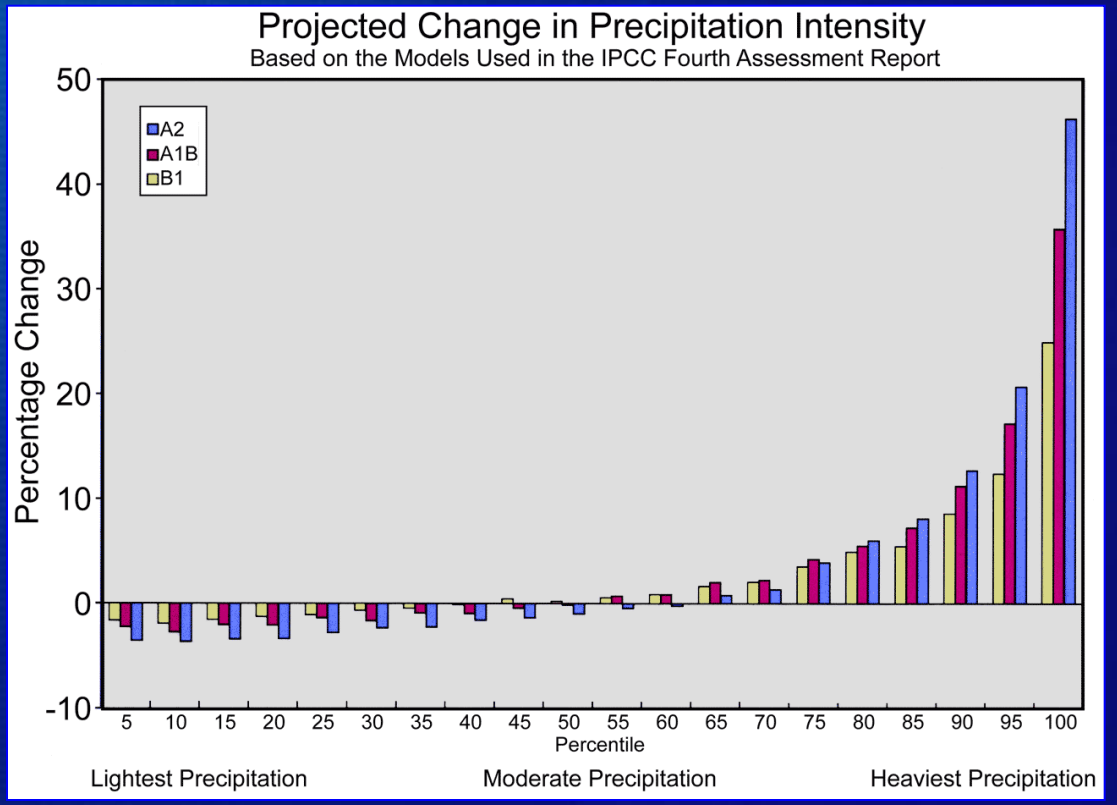


Increase in the amount of daily precipitation over North America that falls in heavy events

Precipitation Extremes

Projected Changes --

- Lightest precipitation is projected to decrease.
- Heaviest precipitation is projected to increase strongly.
- Higher greenhouse gas emission scenarios produce larger changes in extreme precipitation.

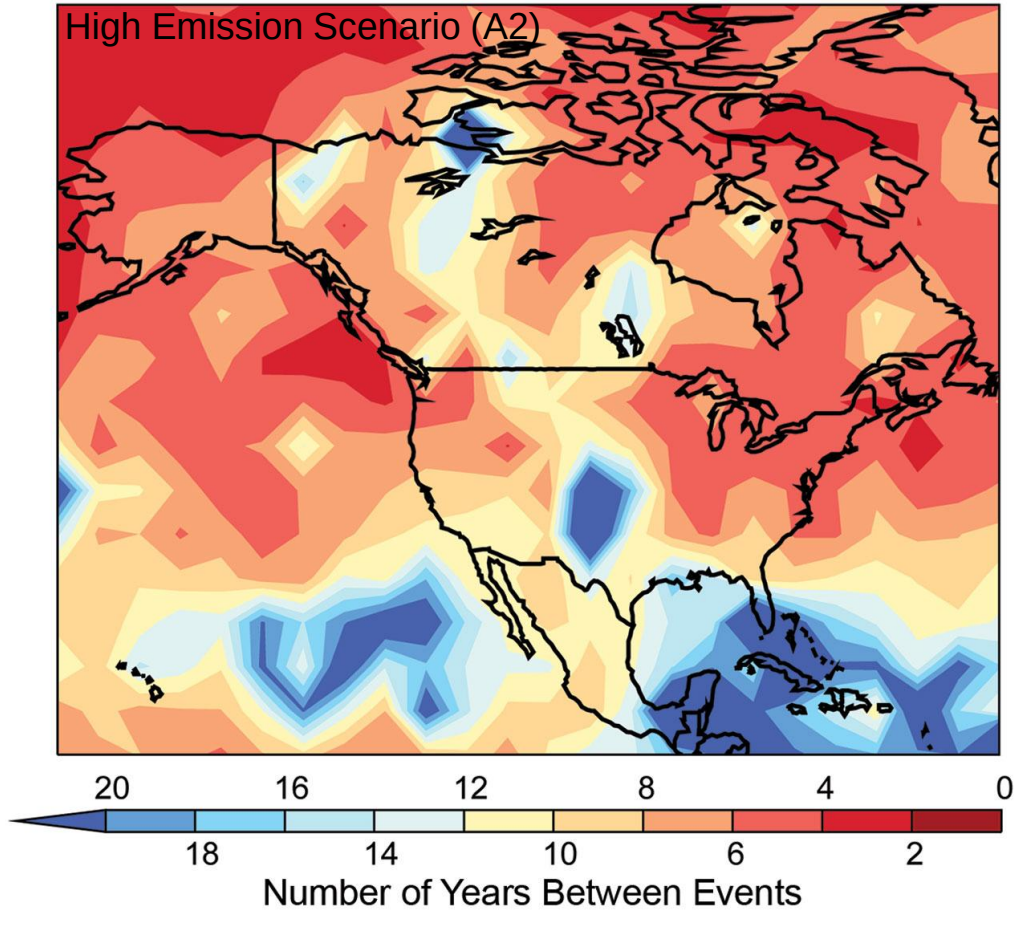


Precipitation Extremes

Projected Changes --

Daily total precipitation events that occur on average every 20 years would occur once every 4-6 years for NE North America

Precipitation

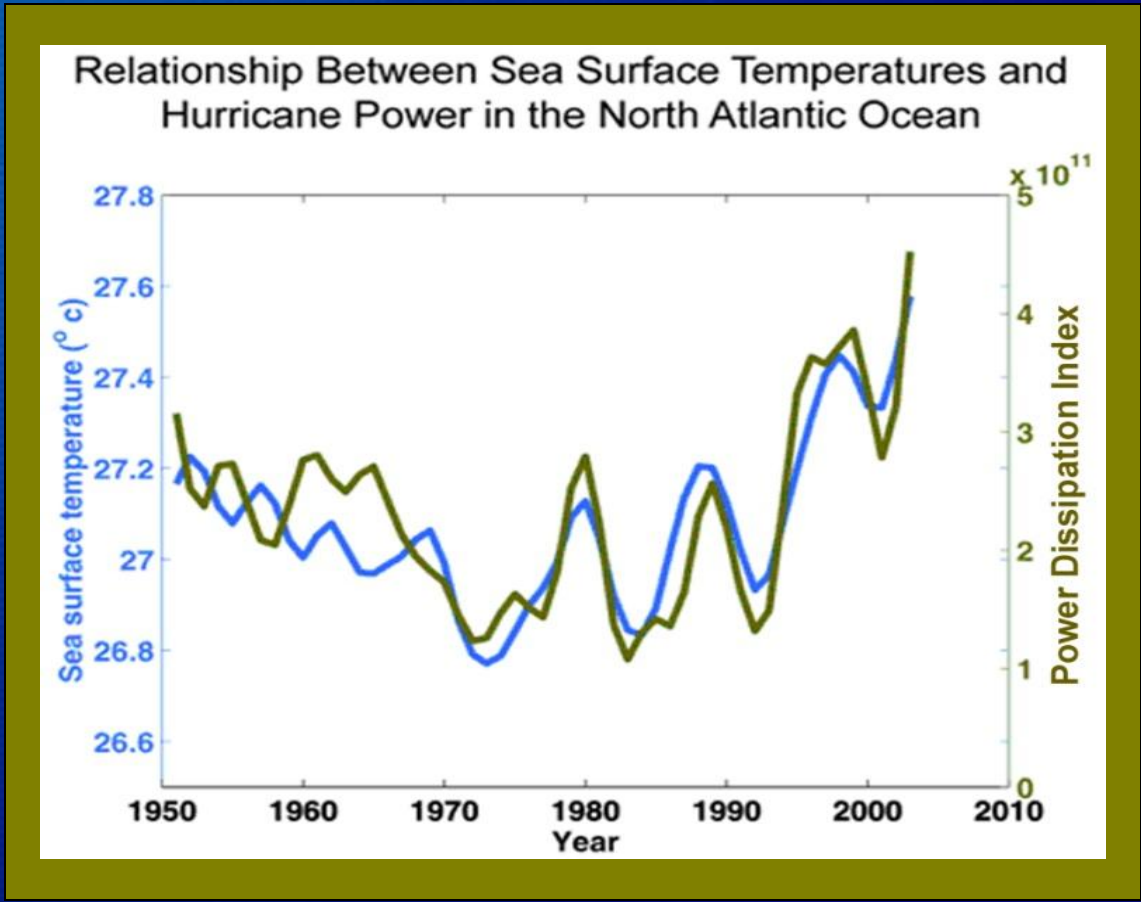


Storms and Hurricanes

Attribution of Changes --

Evidence suggests a Substantial human contribution to recent hurricane activity.

However, a confident assessment of human influence on hurricanes will require further studies with models and observations.

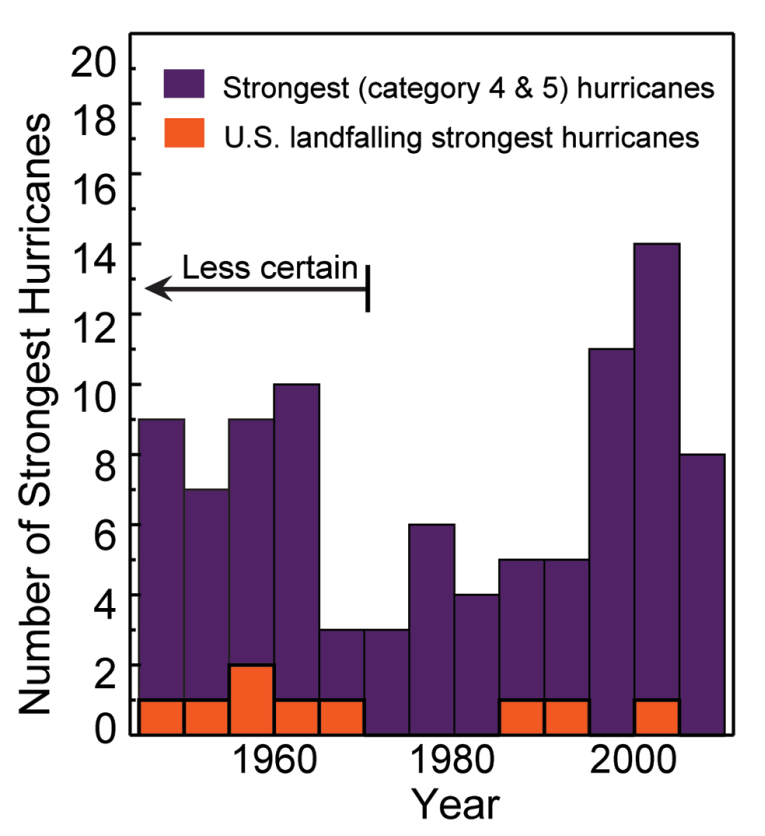


Sea surface temperatures (blue) and the Power Dissipation Index (green) for North Atlantic hurricanes

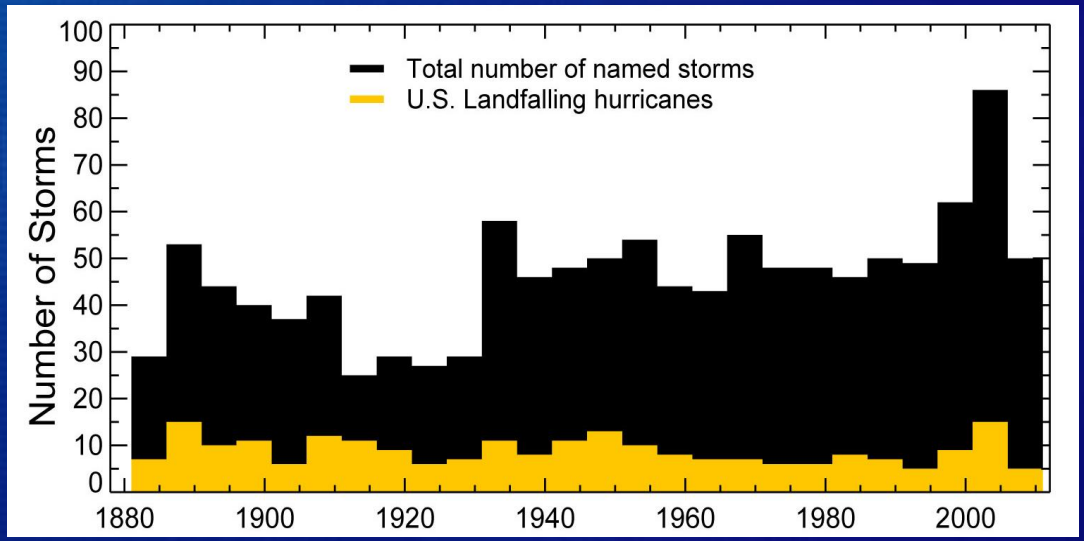
Storms and Hurricanes

Observed Changes --

Atlantic Basin Strongest Hurricanes



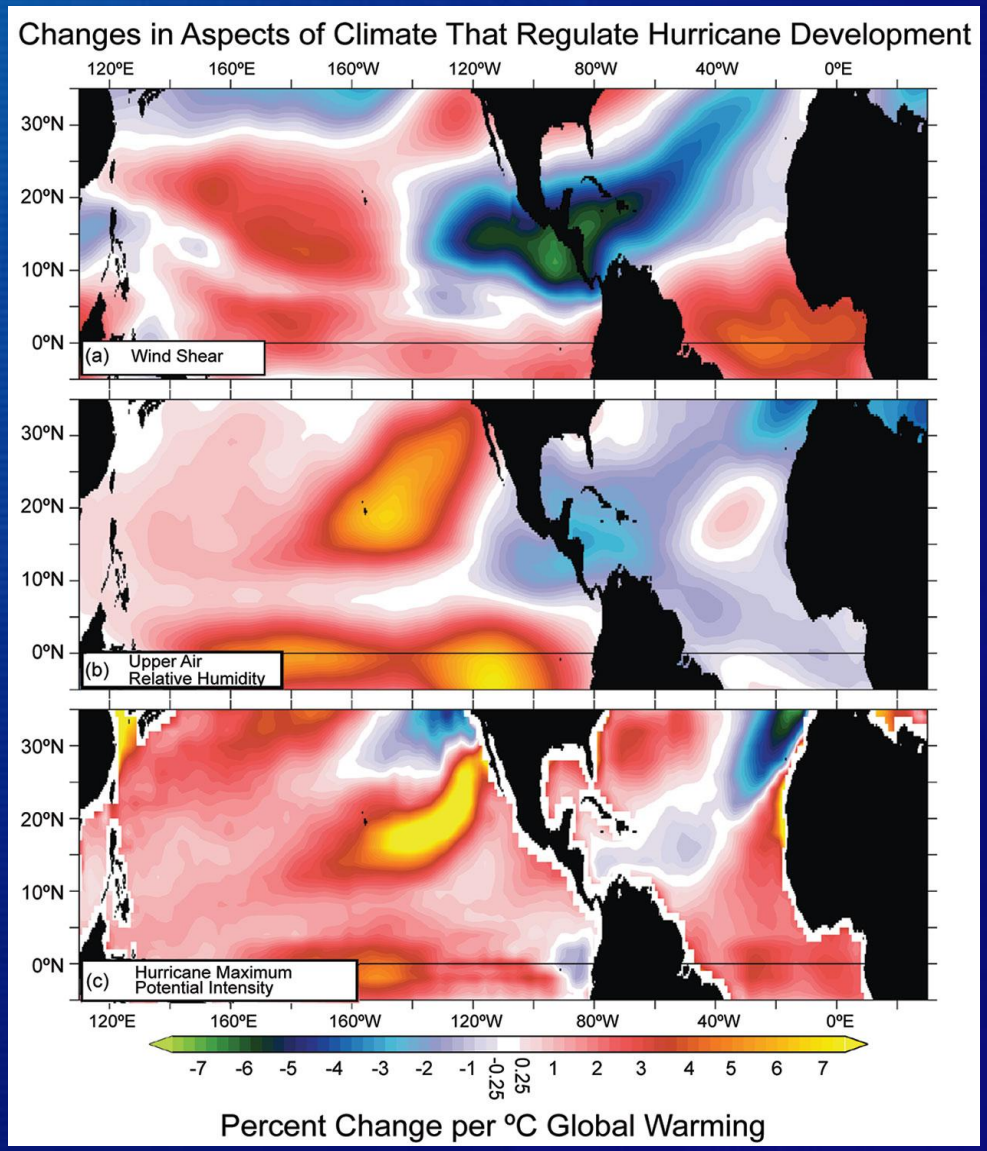
Atlantic Tropical Storms and Hurricanes



Storms and Hurricanes

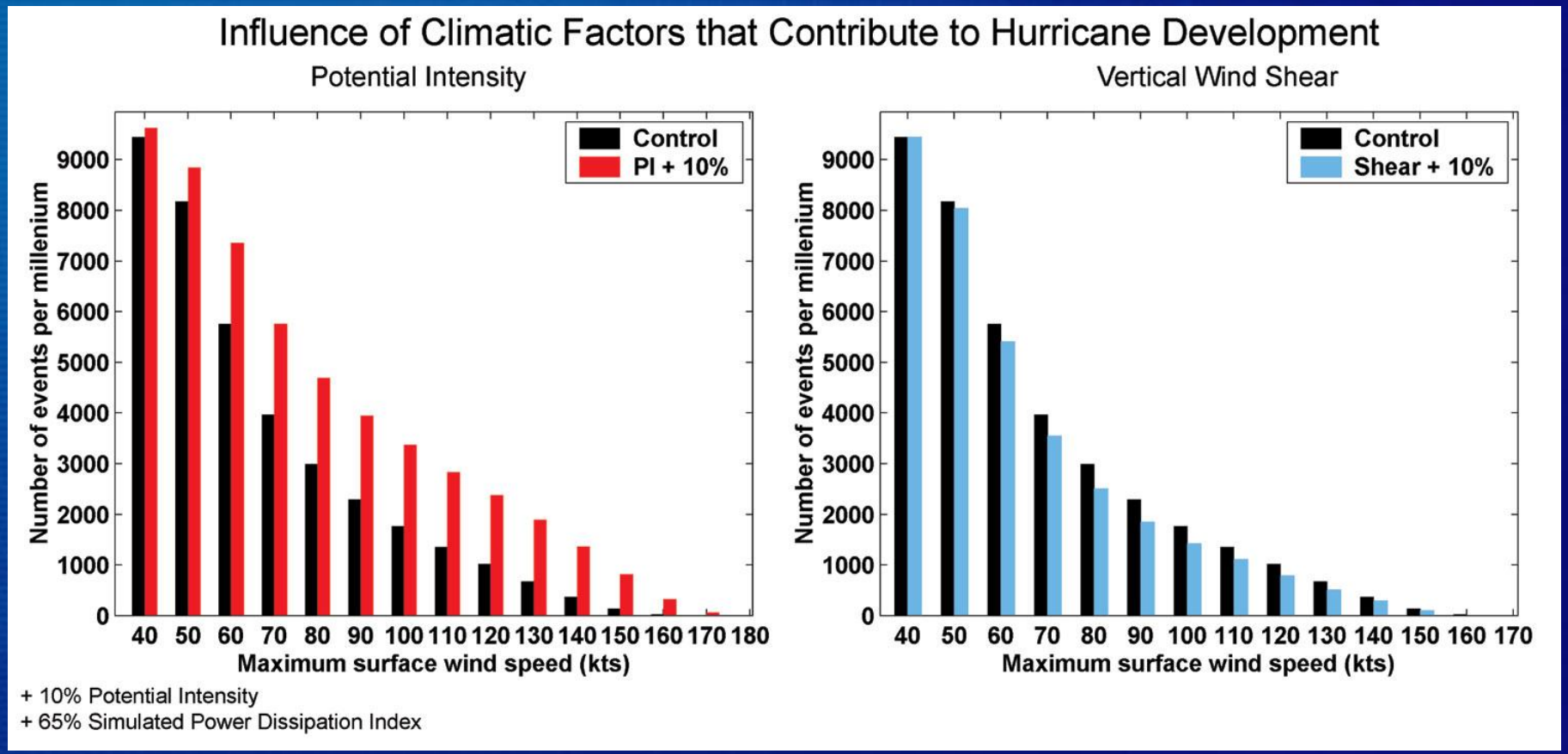
Model Simulations based on ensembles using middle emission scenario (A1B) –
Vecchi and Soden (2007)

Blue areas represent regions that are detrimental for hurricane development



Storms and Hurricanes

Model Simulations results based on a simplified ocean atmosphere coupled hurricane intensity prediction model (3000 synthetic storm tracks for the North Atlantic) Emanuel (2006)



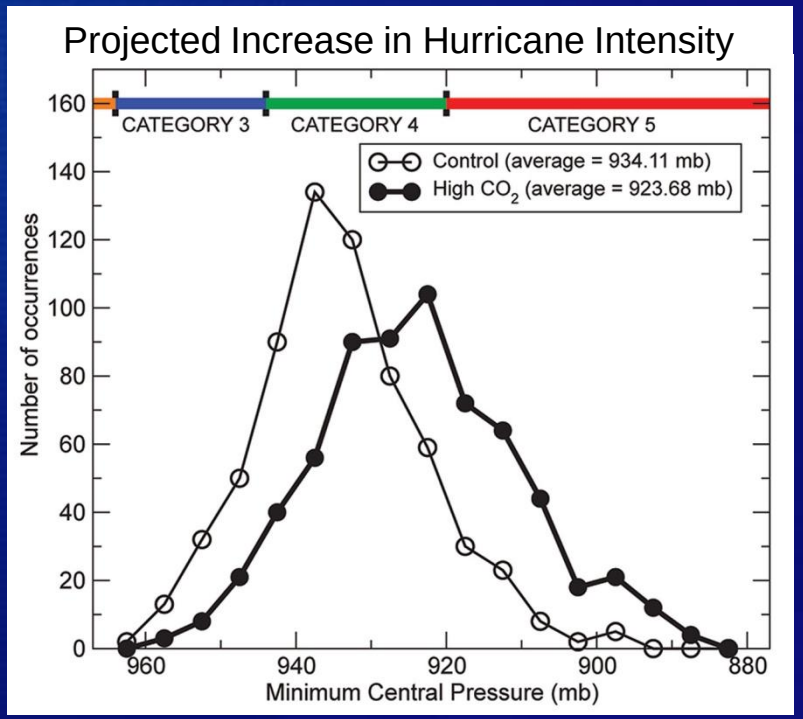
Storms and Hurricanes

Projected Changes --

Likely that hurricane rainfall and wind speeds will increase in response to human-caused warming.

For each 1°C increase in tropical sea surface temperatures, core rainfall rates will increase by 6-18%.

Surface wind speeds of the strongest hurricanes will increase by about 1-8%.



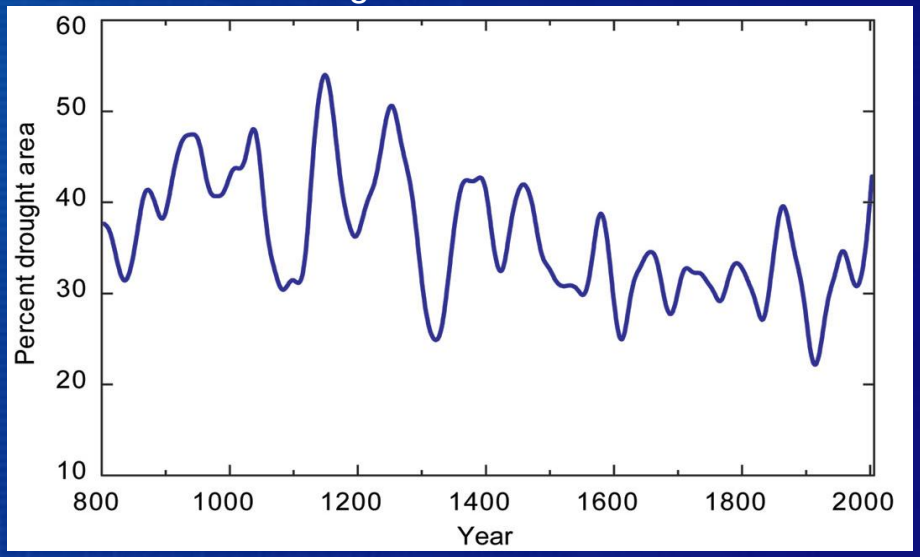
Drought

Observed Changes --

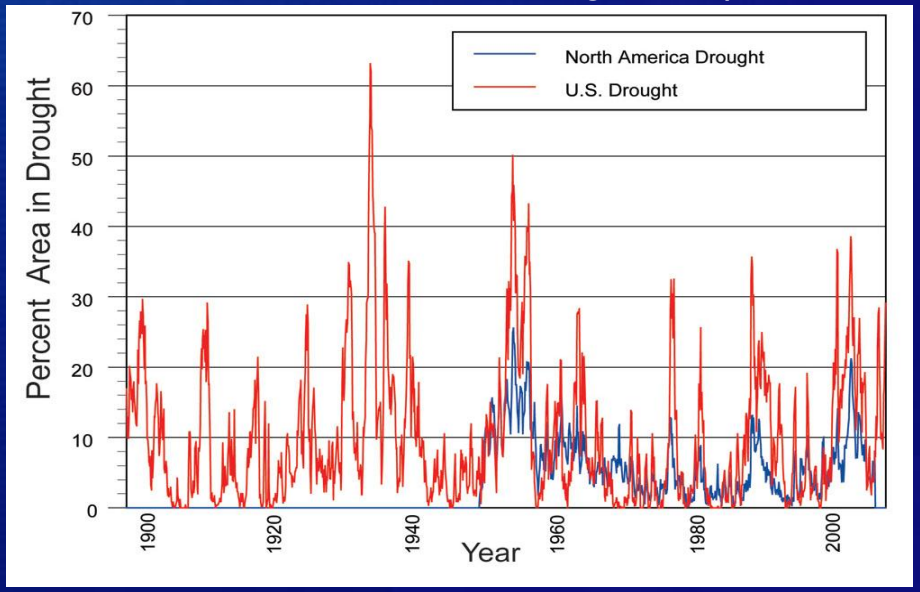
No overall trend for North America

Recent regional tendencies toward more severe droughts in the Southwestern U.S. parts of Canada and Alaska and Mexico.

Western U.S. Drought Area for the Last 1200 Years



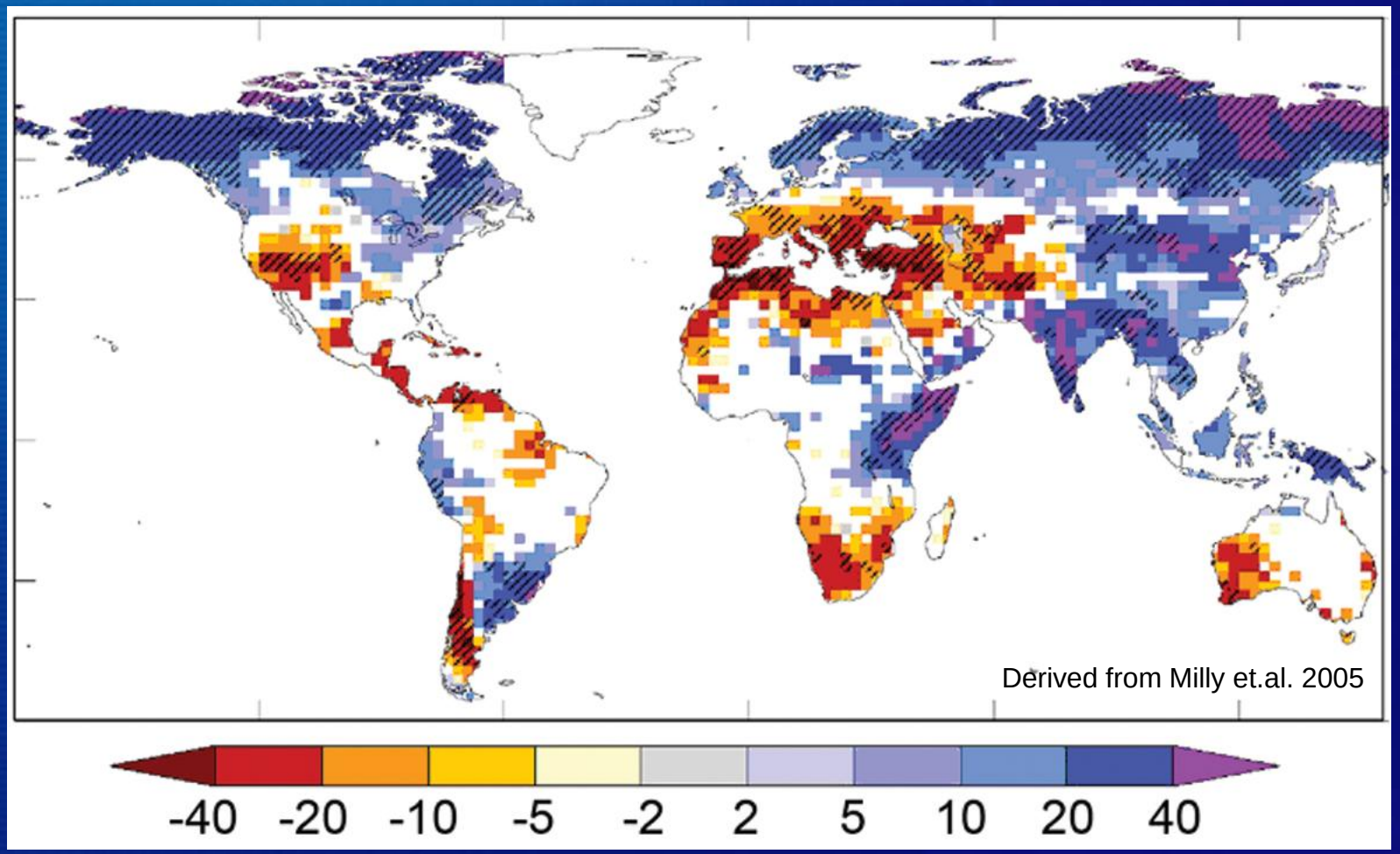
U.S. and North American Drought Comparison



Drought

Projected Changes --

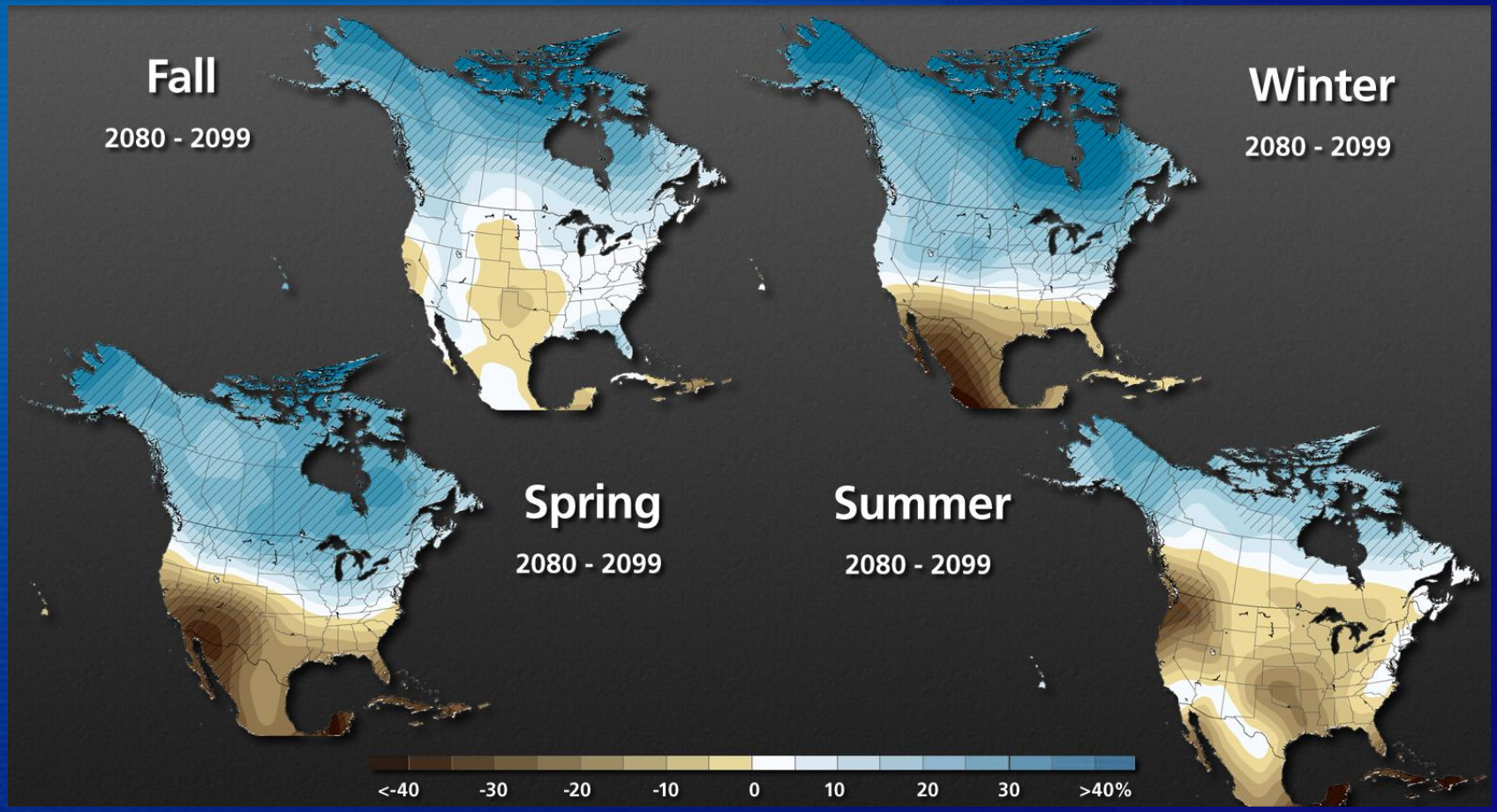
Percent change in Annual Runoff (2090-2099)



Drought

Projected Change in North American Precipitation

Percent Change



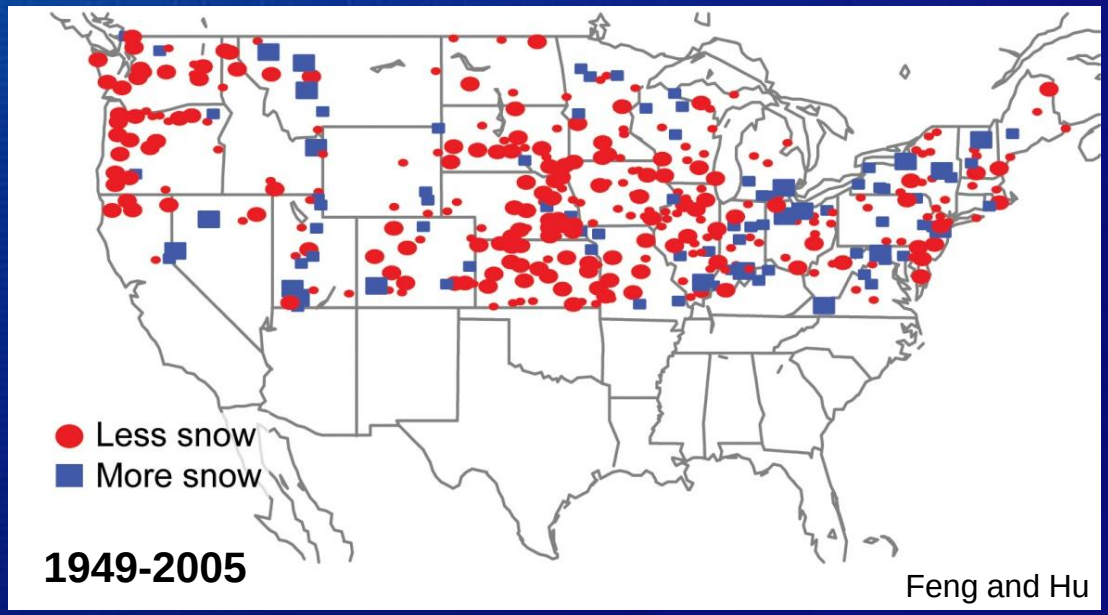
Higher Emissions Scenario (A2)

Other Storms

Observed Changes --

Snowstorms

There has been a northward shift in snow storm occurrence, and this shift, combined with higher temperature, is consistent with a decrease in snow cover extent over North America.



Other Storms

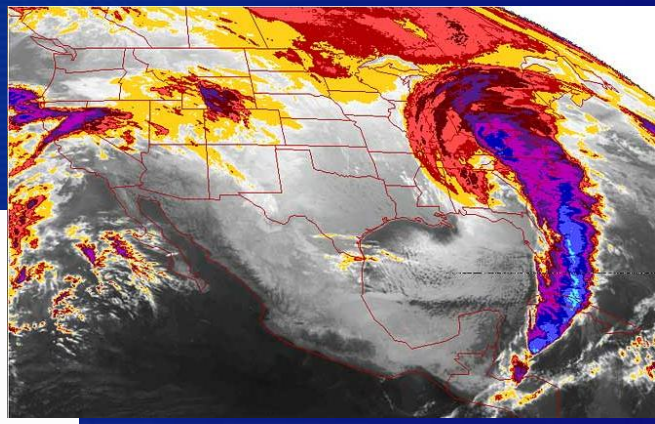
Observed Changes --

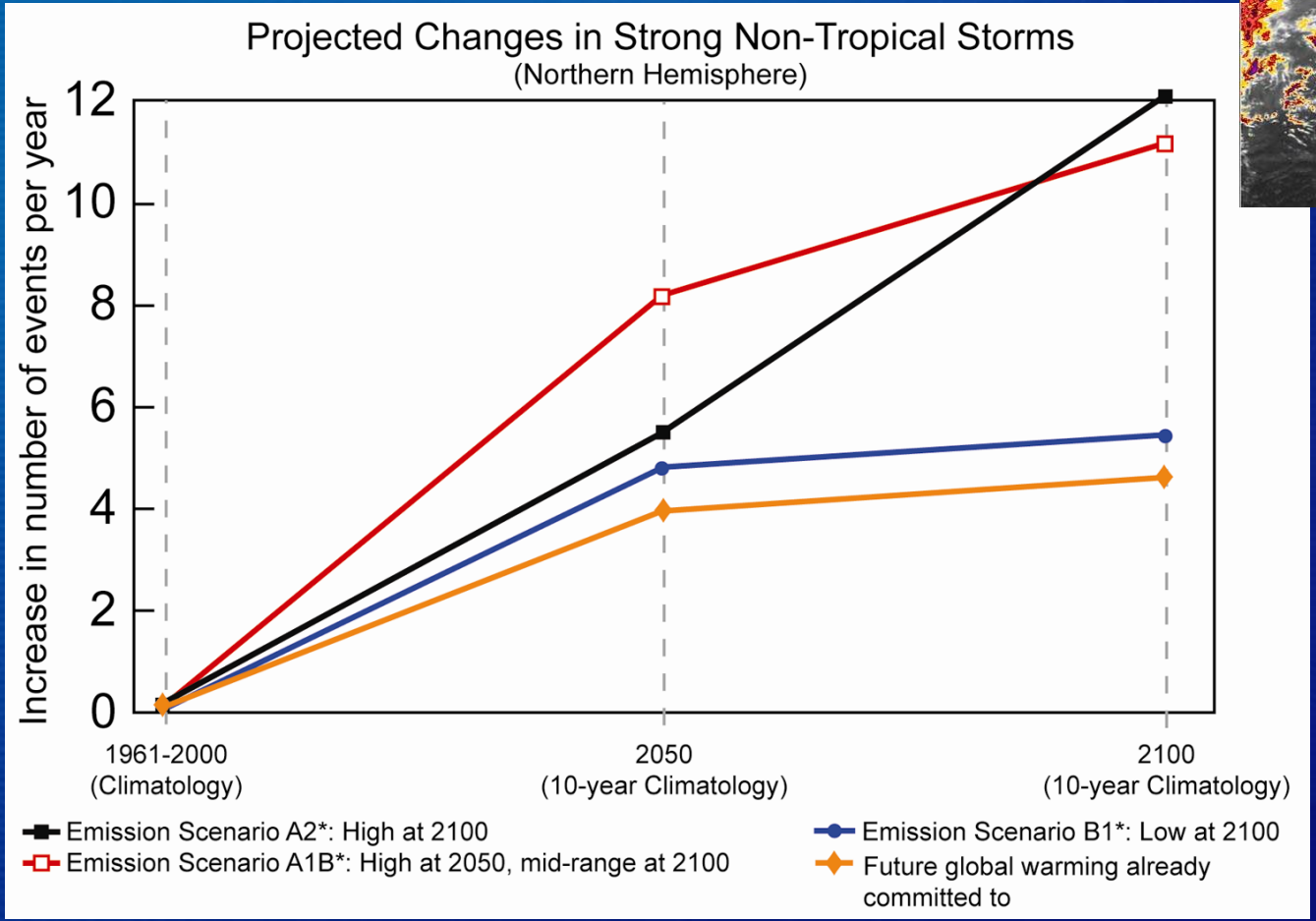
Local Severe Weather

The data used to examine changes in the frequency and severity of tornadoes and severe thunderstorms are inadequate to make definitive statements about actual changes.

Other Storms

Projected Changes --





Red text: CCSP SAP 3.3

Comparison of IPCC AR4 & CCSP 3.3 Extremes

Black text: IPCC

Phenomenon and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960) and global	Likelihood of a human contribution to observed trend	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	Very likely	Likely	Virtually certain
	Last 10 years lower numbers of severe cold waves than any other 10-year period	Fewer frosts, lengthening freeze-free period	Very likely
Warmer days and more frequent hot days and nights over most land areas	Very likely	Likely (nights)	Virtually certain
	Most of N. America since 1950 Warm nights, days comparable to 1930s in some states	Likely Some aspects	Very Likely
Warm spells/heat waves. Frequency increases over most land areas	Likely	More likely than not	Very likely
	Primarily NW two thirds of North America	Likely certain aspects, e.g., night-time temperatures & record high annual temps	Very Likely
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	Likely	More likely than not	Very likely
	Virtually Certain	Triple attribution: Linked via water vapor increases Linked to global warming Linked to greenhouse effects	Very likely
Area affected by droughts increases	Likely in many regions since 1970	No formal attribution - evidence for linkage between SST patterns and 1930's & 1950's drought	Likely
	No overall trend for U.S., but regional trends evident (more precip offsets temp increase in most areas)	No formal attribution studies. Evidence that 1930's &1950's drought linked to SST patterns	Likely in SW North America
Intense tropical cyclone activity increases	Likely in many regions since 1970	More likely than not	Likely
	North Atlantic since 1970 Likely N. Atlantic since 1950 Likely Decrease in Eastern Pacific (Mexico West Coast) since 1980	Double attribution issue. Evidence for substantial human influence on SST. Confident linkage to hurricanes not possible. Requires more study.	Likely

Conclusions

- Many climate extremes are already increasing as well as their associated impacts
- Scientific methods have only recently been able to attribute human causes to some changes in extremes at the scale of a continent.
- In the future,
  - heat waves and heavy downpours are very likely to further increase in frequency and intensity.
  - Substantial areas of North America are likely to have more frequent droughts of greater severity.
  - Hurricane wind speeds, rainfall intensity, and storm surge levels are likely to increase.
  - The strongest cold season storms are likely to become more frequent, with stronger winds and more extreme wave heights.
- Current and future impacts depend not only on the changes in extremes, but also on responses by human and natural systems.

Thank you.

Questions?

www.commerce.gov/cop15