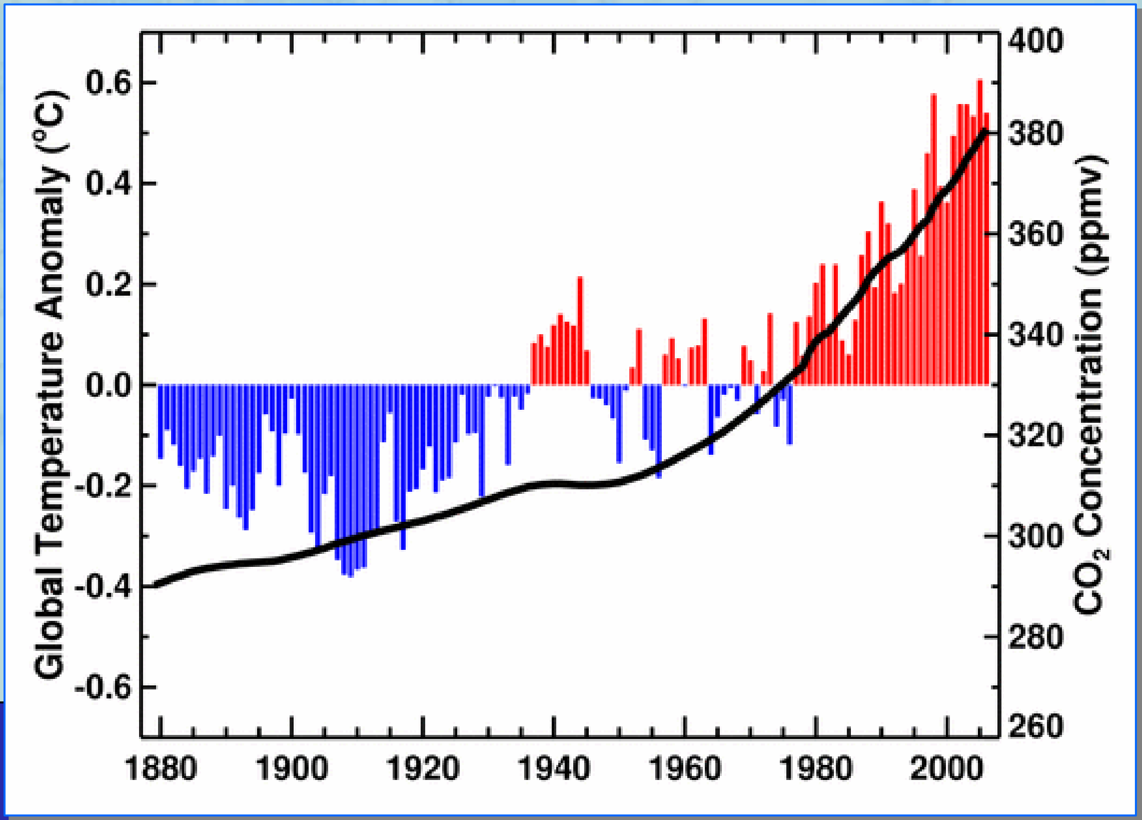
# Weather & Climate Extremes in a Changing Climate:

# New Disaster Reduction Imperatives

**Presented to the Subcommittee on Natural Disaster Reduction**





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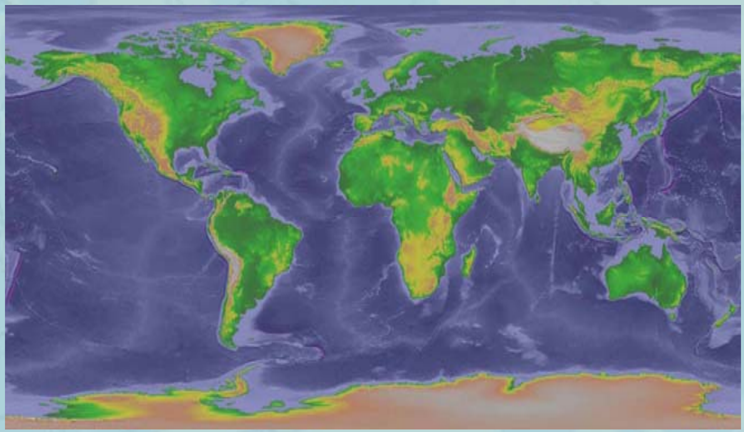
# 1) Background

A) Forcings
B) Temperature
C) Precipitation
D) Sea level rise
E) Sea Ice
F) Greenland
G) Snow cover Extent

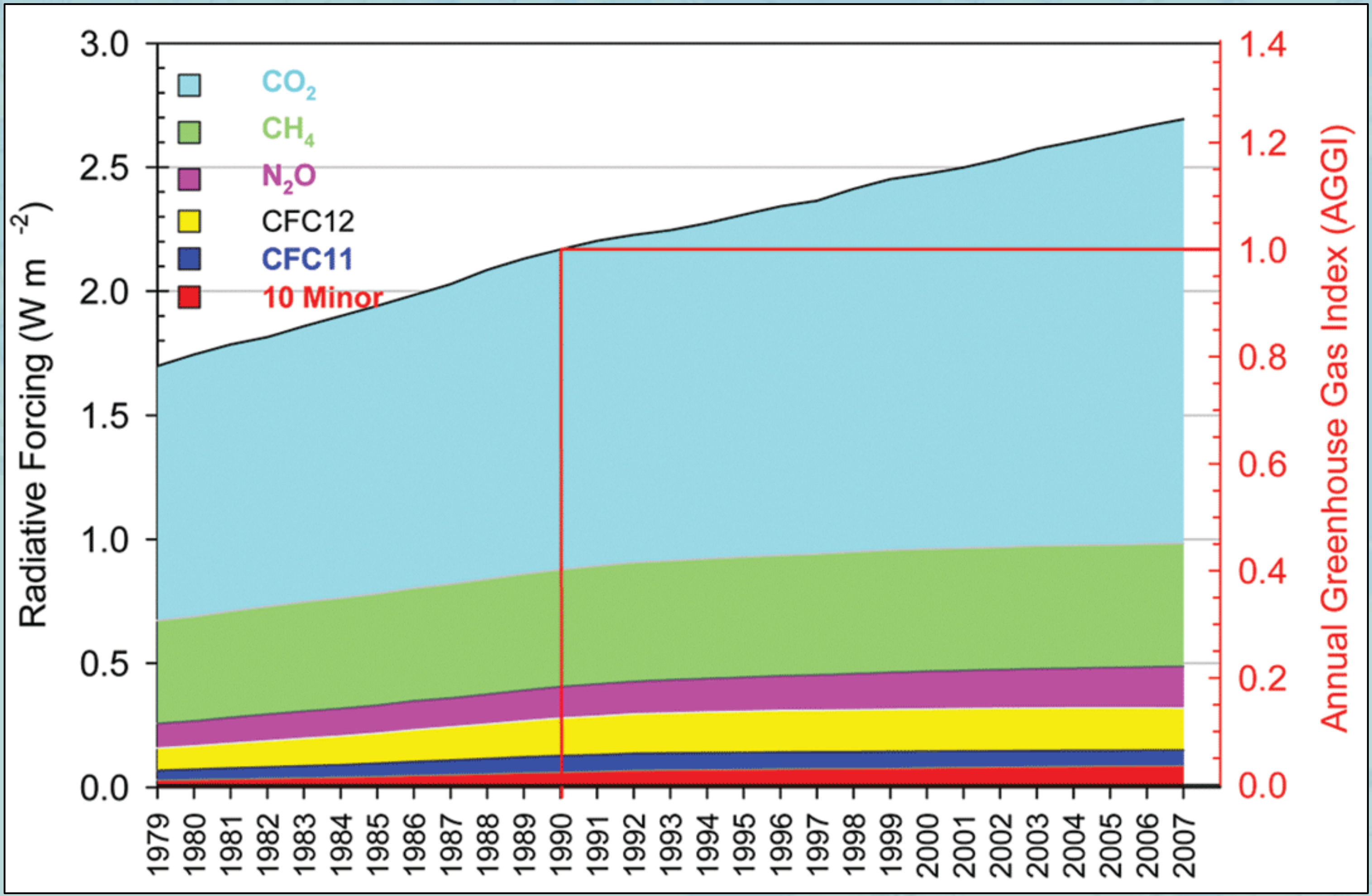


# 2) North America Extremes (CCSP 3.3)

A) Temperature
B) Precipitation
C) Drought
D) Hurricanes
E) Other Storms

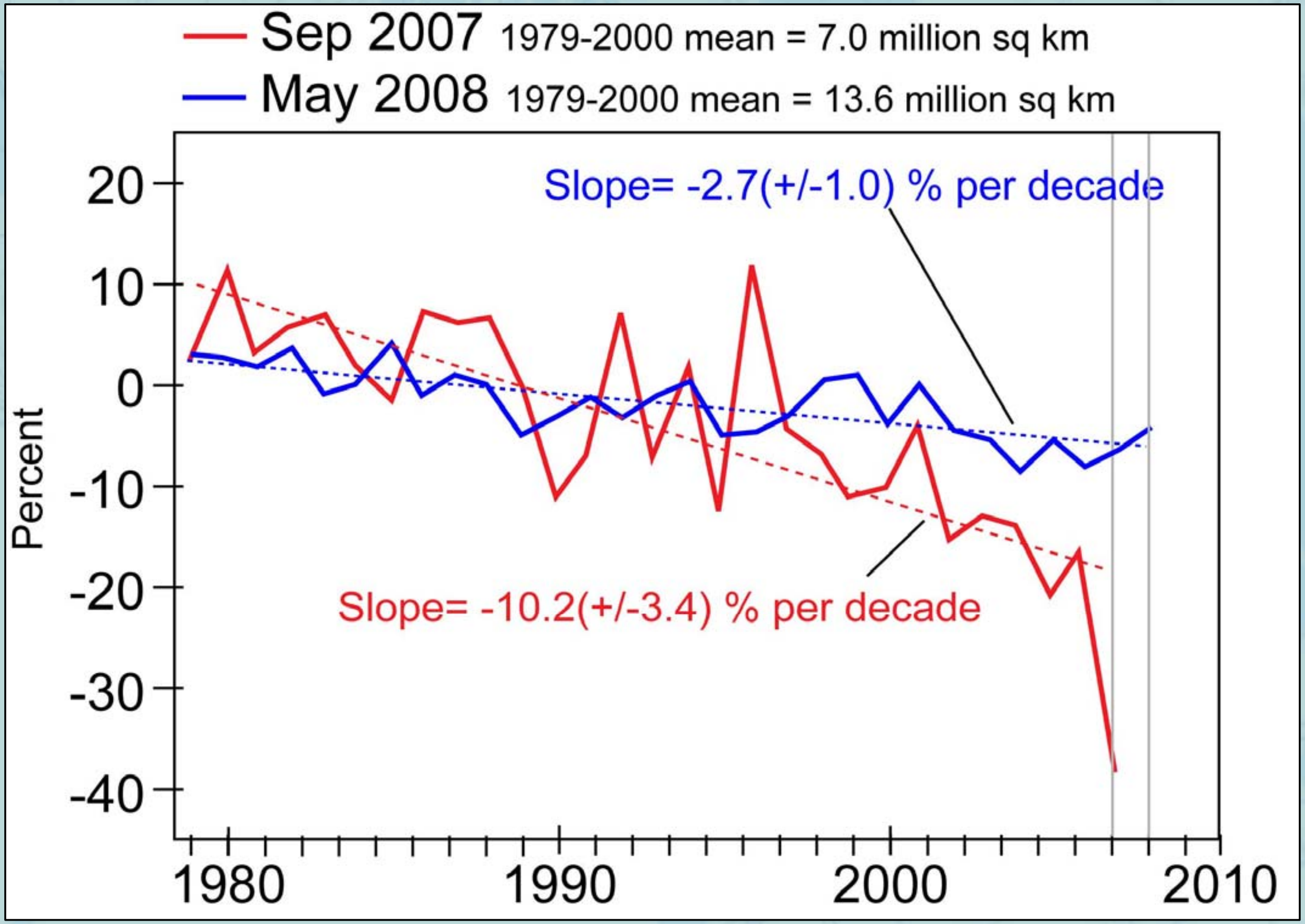
# 3) Reducing Uncertainty

# The NOAA Annual Greenhouse Gas Index (AGGI)

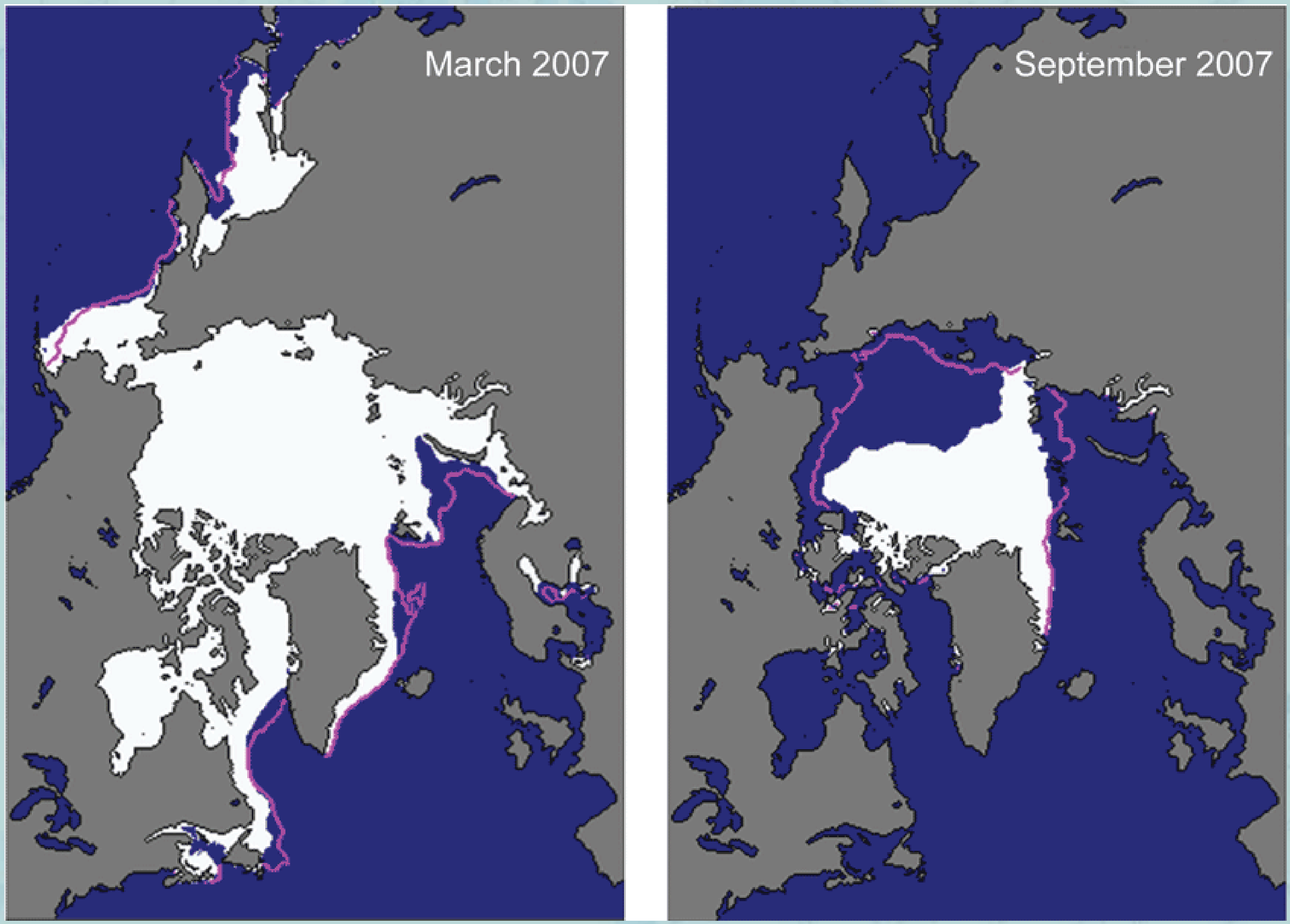



Calculated from the total direct radiative forcing normalized to 1990, the baseline year of the Kyoto Protocol *(Source: D. Hoffman, NOAA/ESRL)*

# Arctic Sea Ice Extent

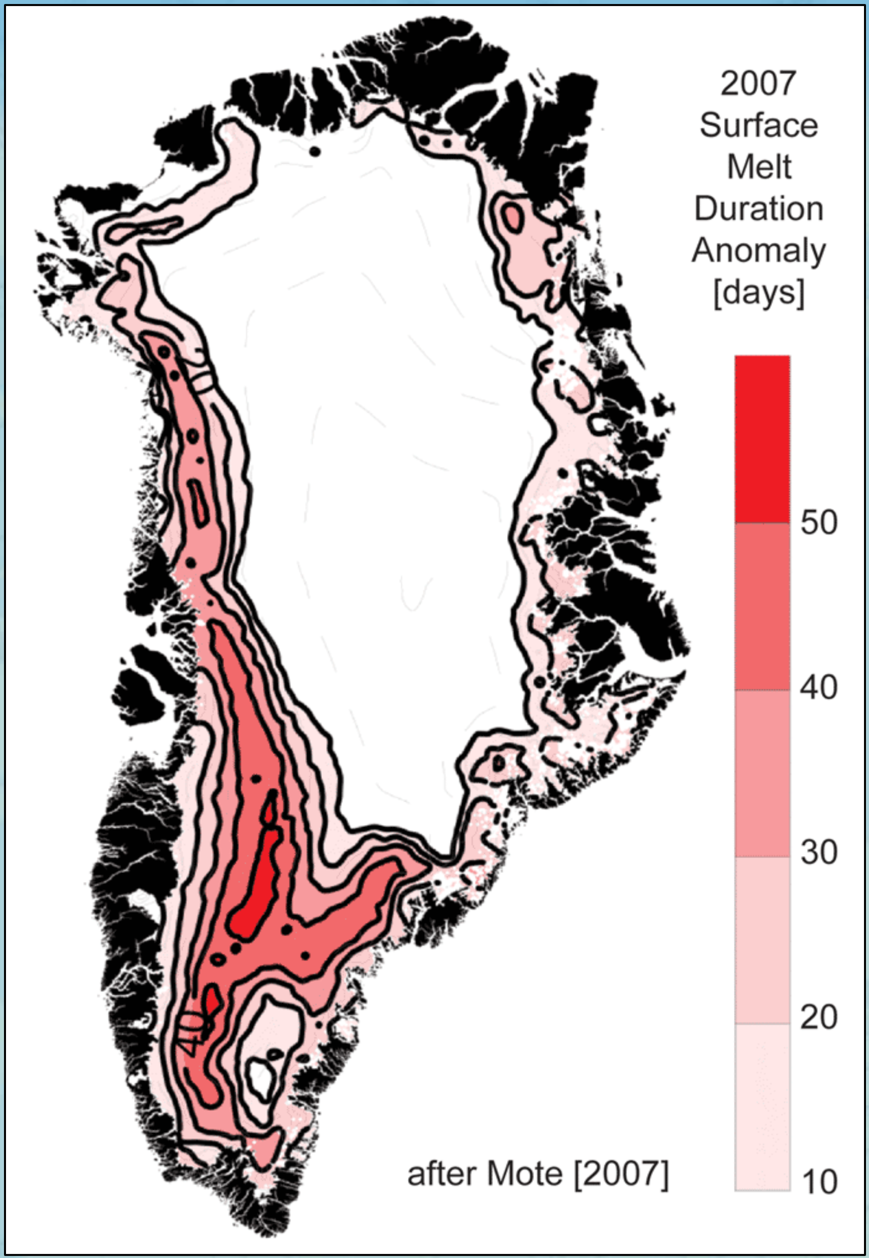


# Sea ice extent in March 2007 and September 2007



Surface melt duration departure from average for summer (Jun-Aug) 2007 from SSM/I; units are days.

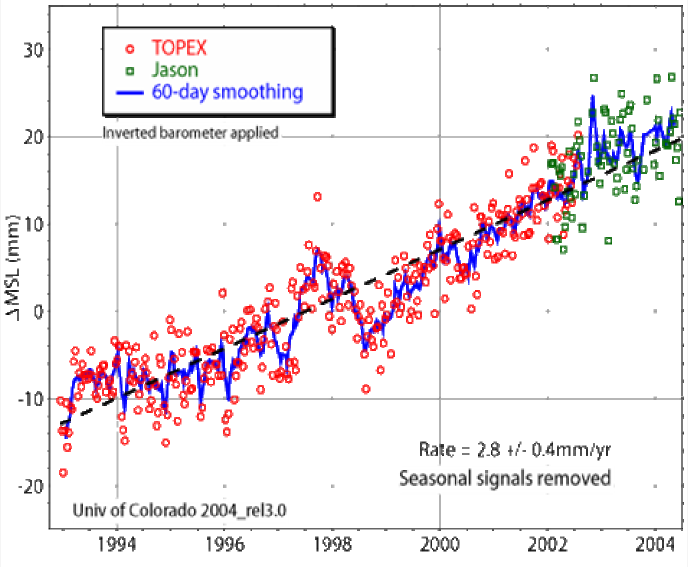
The average is based on the summers from 1973-2000 (excluding 1975, 1977 and 1978).



# Sea Level Rise

- Geographical patterns similar to upper ocean heat content change
  - Suggests that regional sea level changes are largely controlled by thermal processes
  - Additional trend is likely due to melting of grounded ice on Greenland and/or Antarctica
- Trend is significantly higher than 20th century rate of 1.8 ±0.3 mm from tide gauge measurements over past 50-100 yrs
  - Is this part of a longer-term trend or just decadal variability?

Global Sea Level Changes from Satellite Altimeter Observations



# North America

**Observed changes in North American extreme events, assessment of human influence for the observed changes, and likelihood that the changes will continue through the 21st century[1].**

| Phenomenon and direction of change | Where and when these changes occurred in past 50 years | Linkage of human activity to observed changes | Likelihood of continued future changes in this century |
|---|---|---|---|
| Warmer and fewer cold days and nights | Over most land areas, the last 10 years had lower numbers of severe cold snaps than any other 10-year period | Likely warmer extreme cold days and nights, and fewer frosts[2] | Very likely[4] |
| Hotter and more frequent hot days and nights | Over most of North America | Likely for warmer nights[2] | Very likely[4] |
| More frequent heat waves and warm spells | Over most land areas, most pronounced over northwestern two thirds of North America | Likely for certain aspects, e.g., night-time temperatures; & linkage to record high annual temperature[2] | Very likely[4] |
| More frequent and intense heavy downpours and higher proportion of total rainfall in heavy precipitation events | Over many areas | Linked indirectly through increased water vapor, a critical factor for heavy precipitation events[3] | Very likely[4] |
| Increases in area affected by drought | No overall average change for North America, but regional changes are evident | Likely, Southwest USA.[3] Evidence that 1930's & 1950's droughts were linked to natural patterns of sea surface temperature variability | Likely in Southwest U.S.A., parts of Mexico and Carribean[4] |
| More intense hurricanes | Substantial increase in Atlantic since 1970; Likely increase in Atlantic since 1950s; increasing tendency in W. Pacific and decreasing tendency in E. Pacific (Mexico West Coast) since 1980[5] | Linked indirectly through increasing sea surface temperature, a critical factor for intense hurricanes[5]; a confident assessment requires further study[3] | Likely[4] |

[1]Based on frequently used family of IPCC emission scenarios
[2]Based on formal attribution studies and expert judgment
[3]Based on expert judgment
[4]Based on model projections and expert judgment
[5]As measured by the Power Dissipation Index (which combines storm intensity, duration and frequency)

# TEMPERATURE EXTREMES

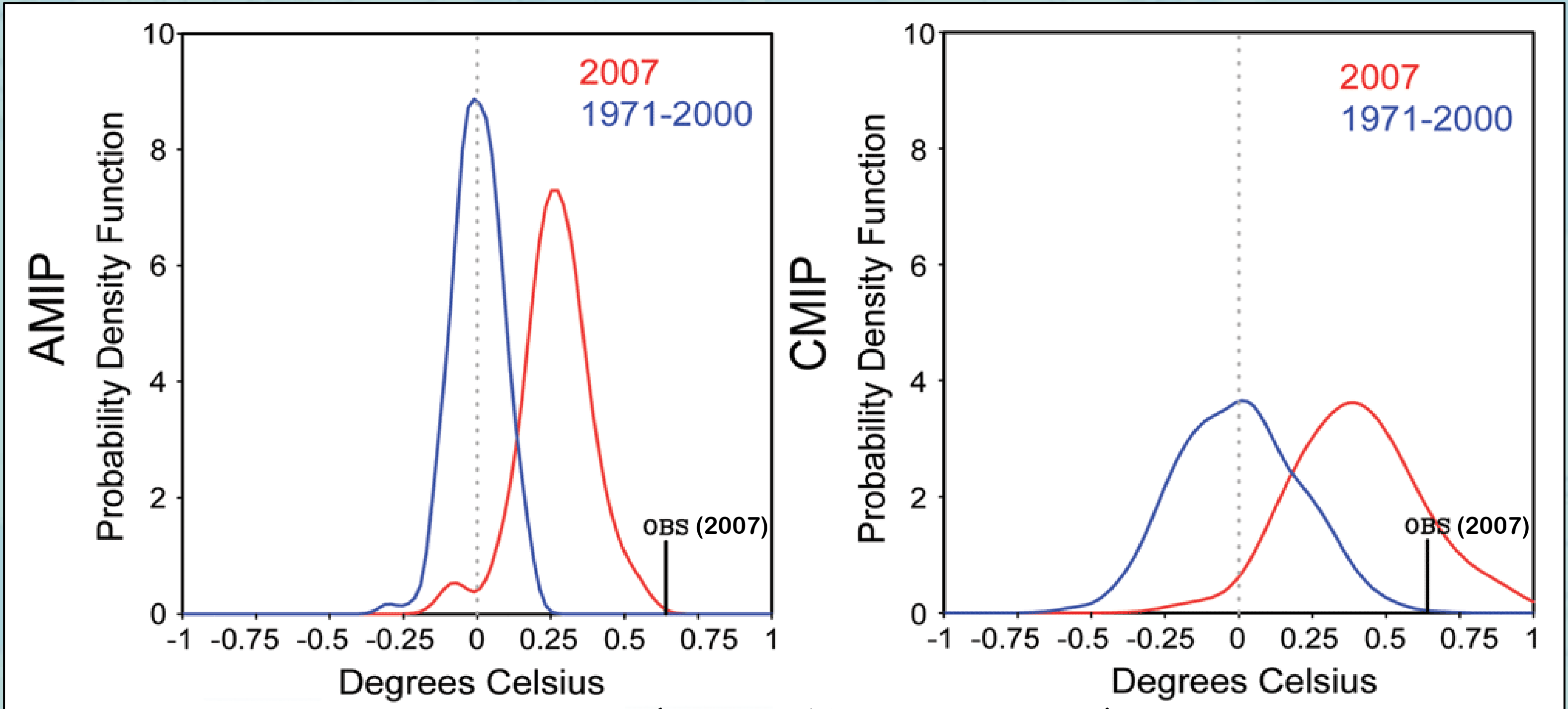
## Observed Changes

- Since the record hot year of 1998, six of the last ten years (1998-2007) have had annual average temperatures that fall in the hottest 10% of all years on record for the U.S.
- Over recent decades ----
  - Most of North America is experiencing more unusually hot days and nights (since 1950 – best coverage).
- The number of heat waves (extended periods of extremely hot weather) has been increasing…but,
  - Heat waves of the 1930s (*e.g.*, daytime temperatures) remain the most severe in the U.S. historical record.
- There have been fewer unusually cold days during the last few decades.
  - The last 10 years have seen fewer severe cold waves than for any other 10-year period in the historical record, which dates back to 1895.
  - There has been a decrease in frost days and a lengthening of the frost-free season.

# TEMPERATURE EXTREMES

## Attribution of Changes

Probability distribution functions (PDFs) of the globally averaged 2007 annual land surface temperature

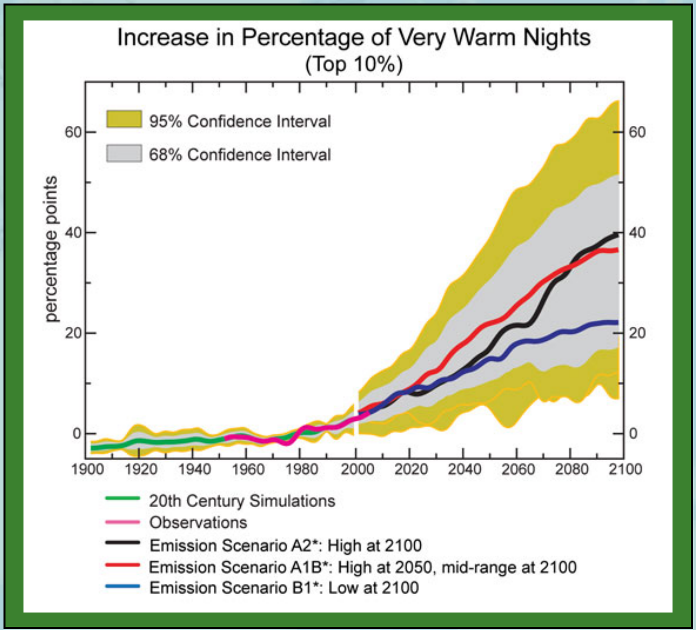



*(Source: NOAA CSI Team)*

# TEMPERATURE EXTREMES

## Projected Changes

- Abnormally hot days and nights and heat waves are very likely to become more frequent.
- Cold days and cold nights are very likely to become much less frequent.
- The number of days with frost is very likely to decrease.
- Increase in the percent of days in a year over North America in which the daily low temperature is unusually warm (falling in the top 10% of annual daily lows).
- Sea ice extent is expected to continue to decrease increasing extreme episodes of coastal erosion in Arctic Alaska and Canada.




# PRECIPITATION EXTREMES

## Observed Changes

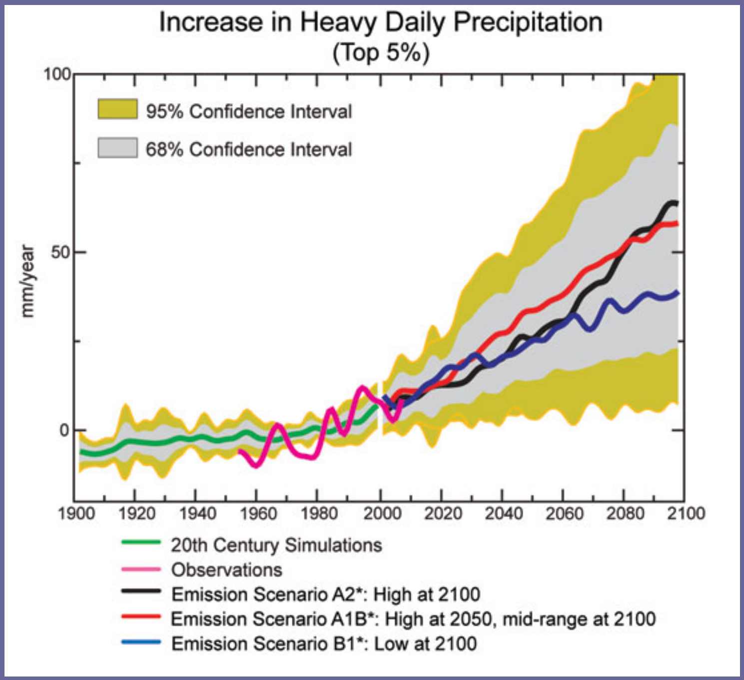
- Heavy downpours have become more frequent and more intense in recent decades over most of North America and now account for a larger percentage of total precipitation.
  - Intense precipitation events (the heaviest 1%) in the continental U.S. increased by 20% over the past century while total precipitation increased by 7%.

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

# PRECIPITATION EXTREMES

## Attribution of Changes

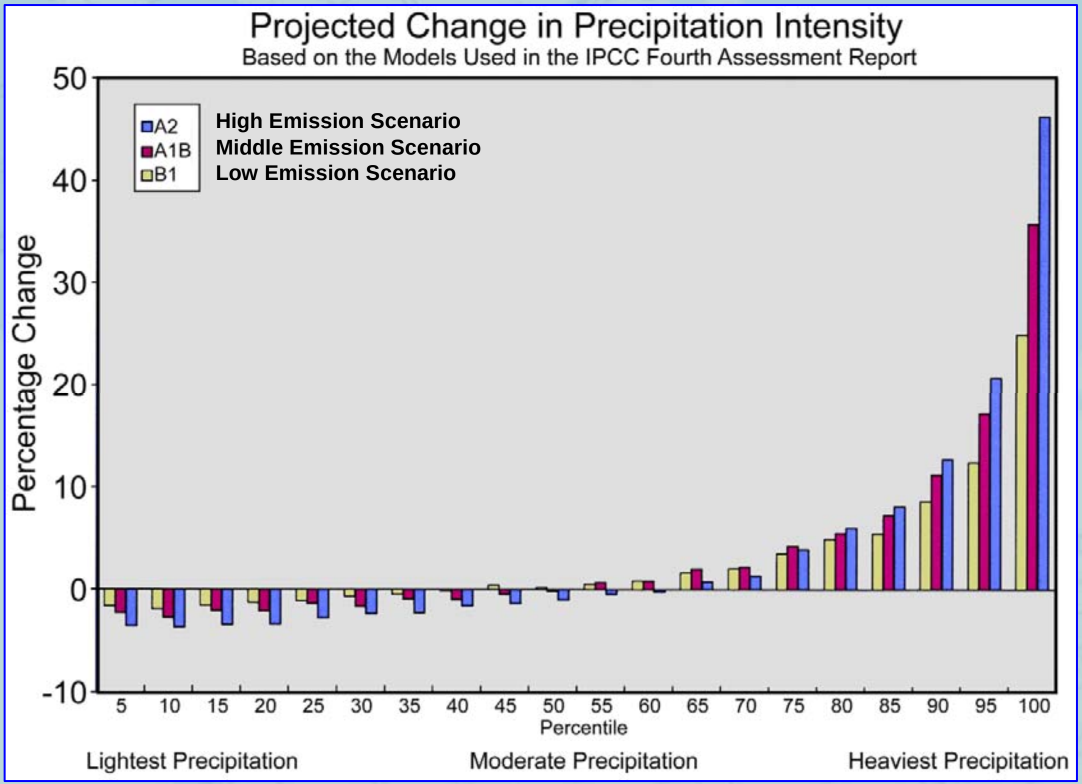
The increase in precipitation intensity is consistent with the observed increases in atmospheric water vapor (linked to human-induced increases in greenhouse gases).




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

# PRECIPITATION EXTREMES
# Projected Changes

- The lightest precipitation is projected to decrease.
- The heaviest precipitation is projected to increase strongly.
- Higher greenhouse gas emission scenarios produce larger changes in extreme precipitation.

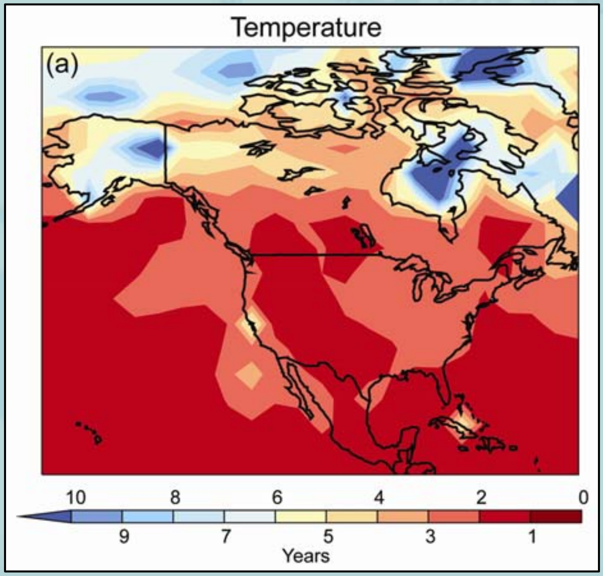


# TEMPERATURE & PRECIPITATION

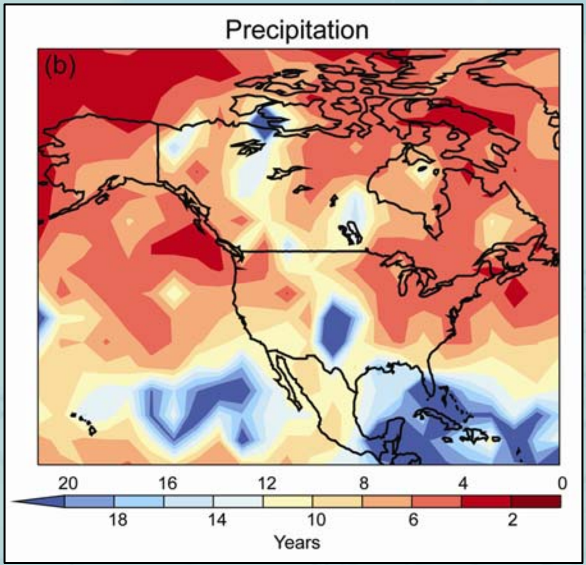
## Projected Changes

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

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

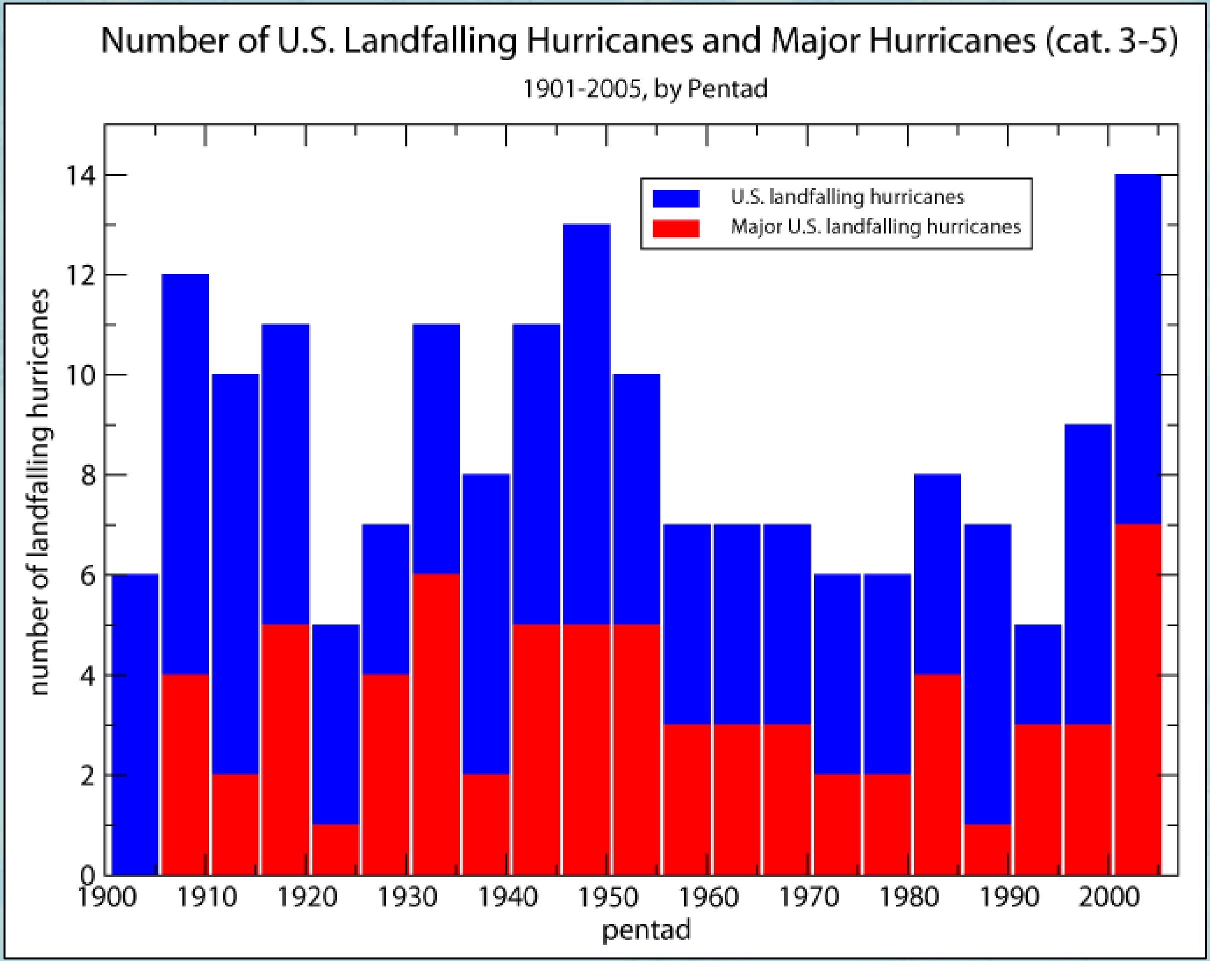



Simulations for 2090-2099 indicating how currently rare extremes (1 in 20 year event) are projected to become more commonplace



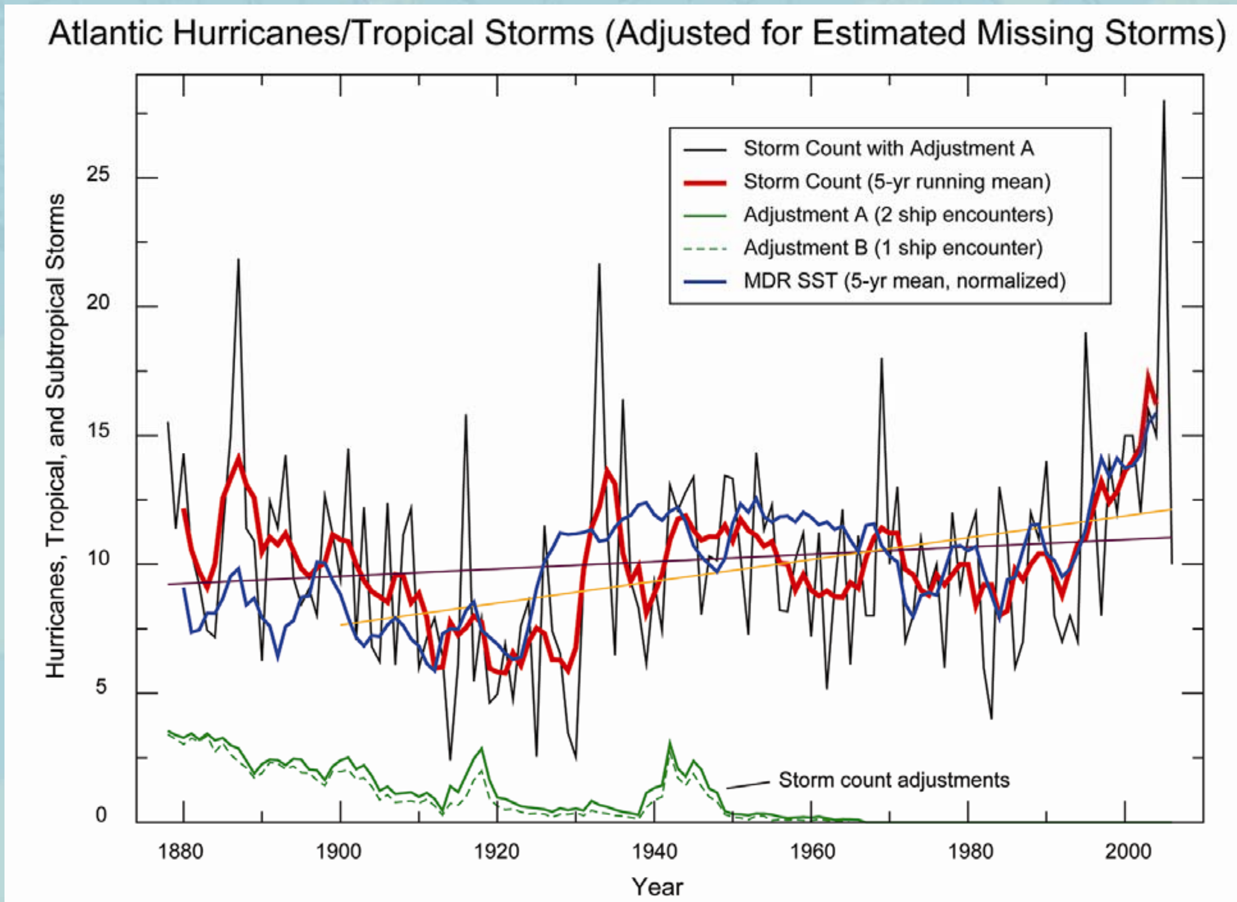
# STORMS & HURRICANES

## Observed Changes



# STORMS & HURRICANES

## Observed Changes




Atlantic hurricanes and tropical storms for 1878-2006, adjusted for missing storms.

**Black curve** is adjusted annual storm count,

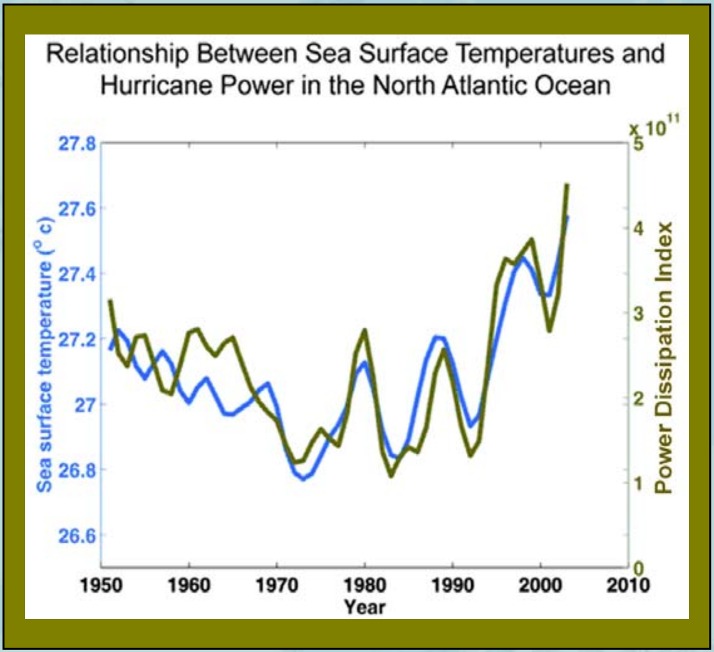
Red curve is 5-year running mean, and

Blue curve is a normalized 5-year running mean SST index for Main Development Region

# STORMS & HURRICANES

## Attribution of Changes

- It is very likely that the human induced increase in greenhouse gases has contributed to the increase in SSTs in the hurricane formation regions.
- There is a strong statistical connection between tropical Atlantic SSTs and Atlantic hurricane activity.
- This 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 & HURRICANES

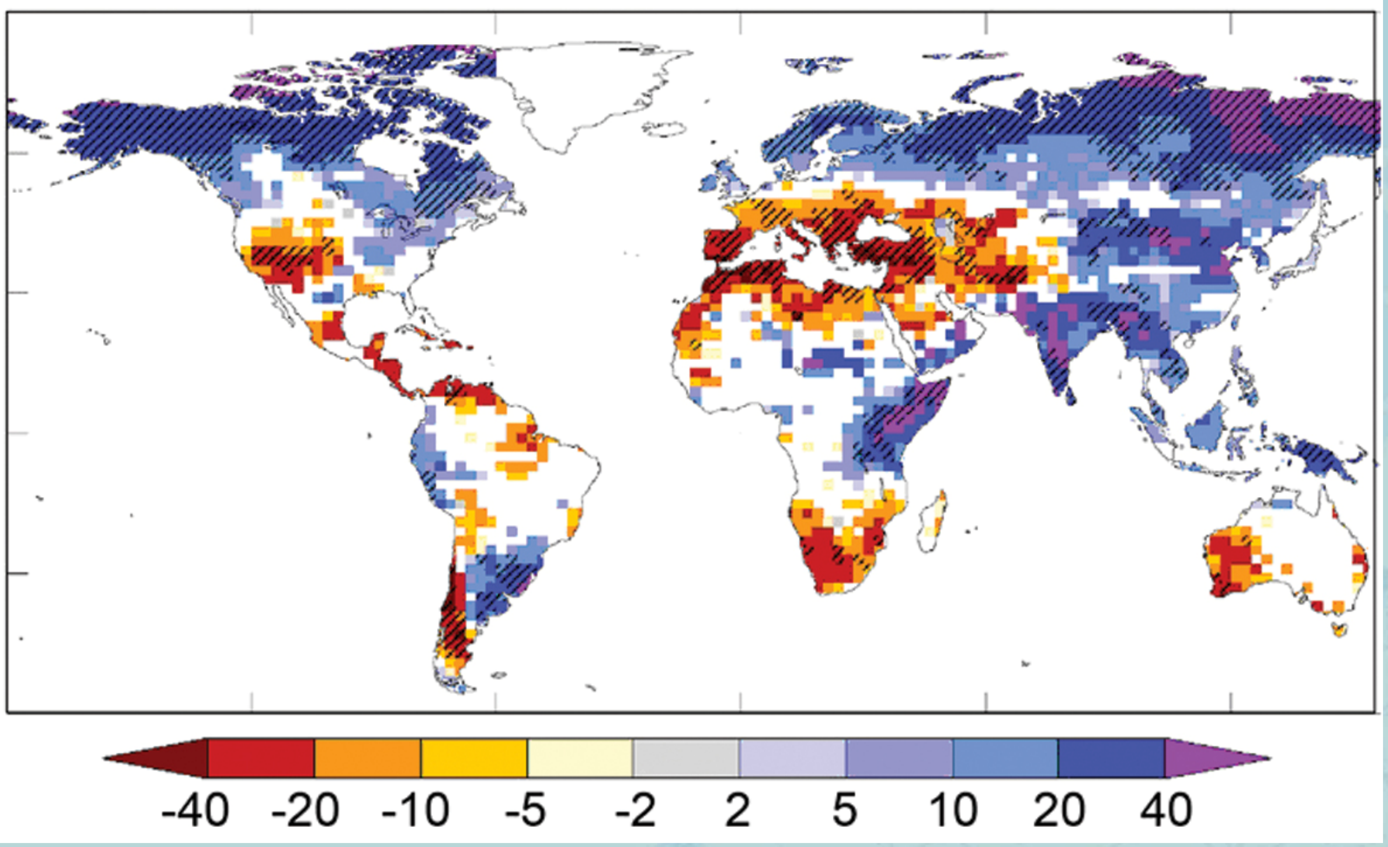
## Projected Changes

- It is 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

## Projected Changes

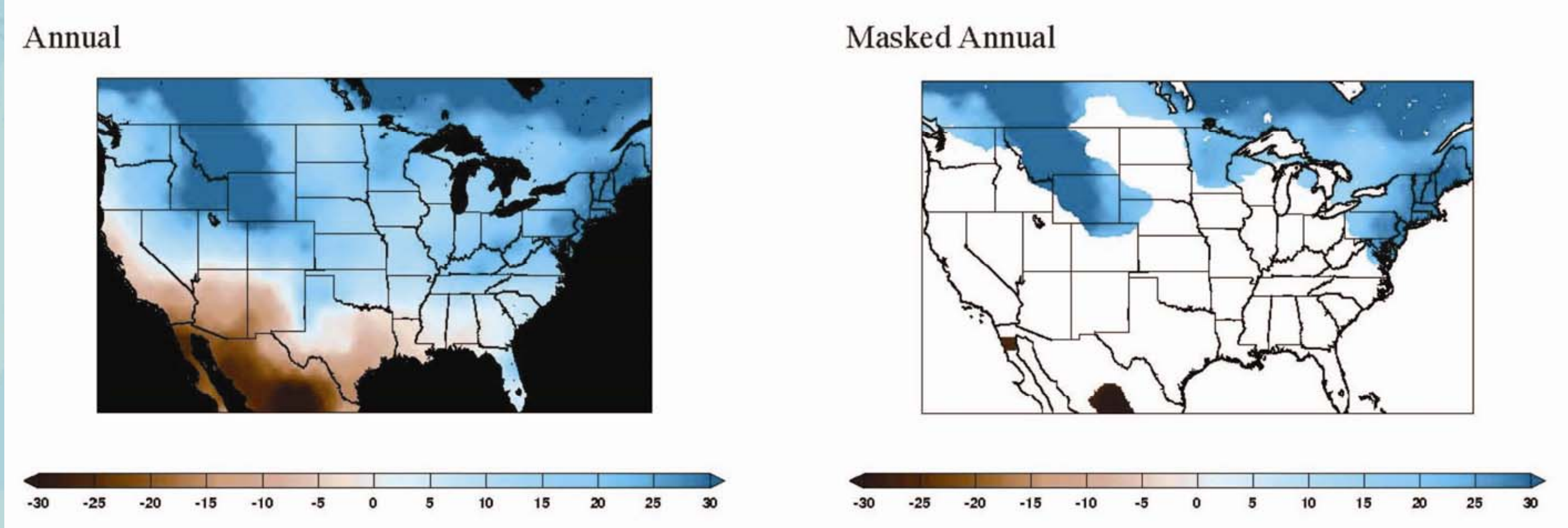
Percent change in Annual Runoff (2090-2099)



# DROUGHT

## Projected Changes

Model Projected Changes (2080-2099) in Precipitation
(Average and regions of model agreement A2 scenario)



# DROUGHT

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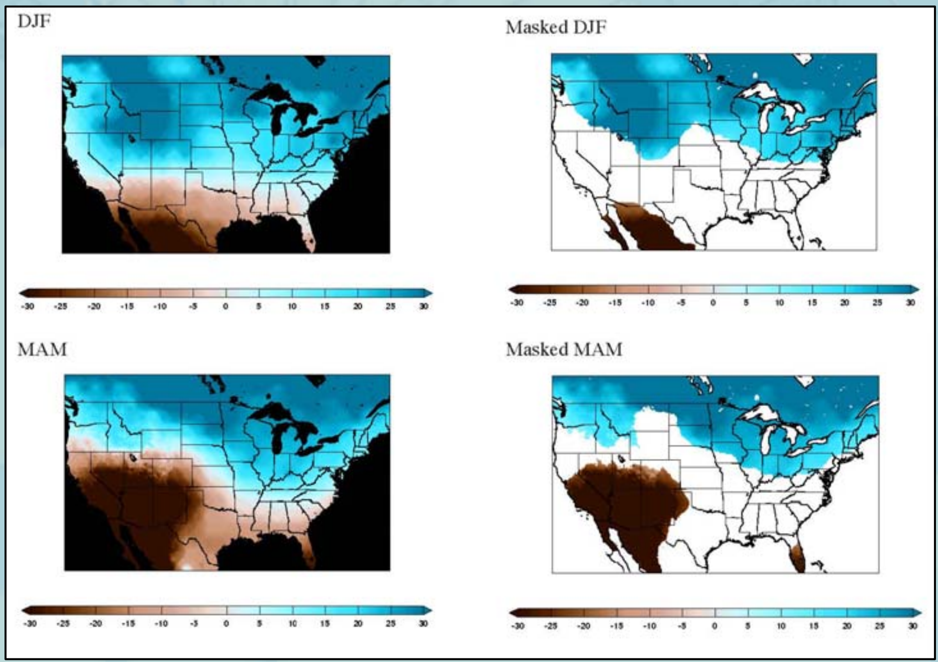
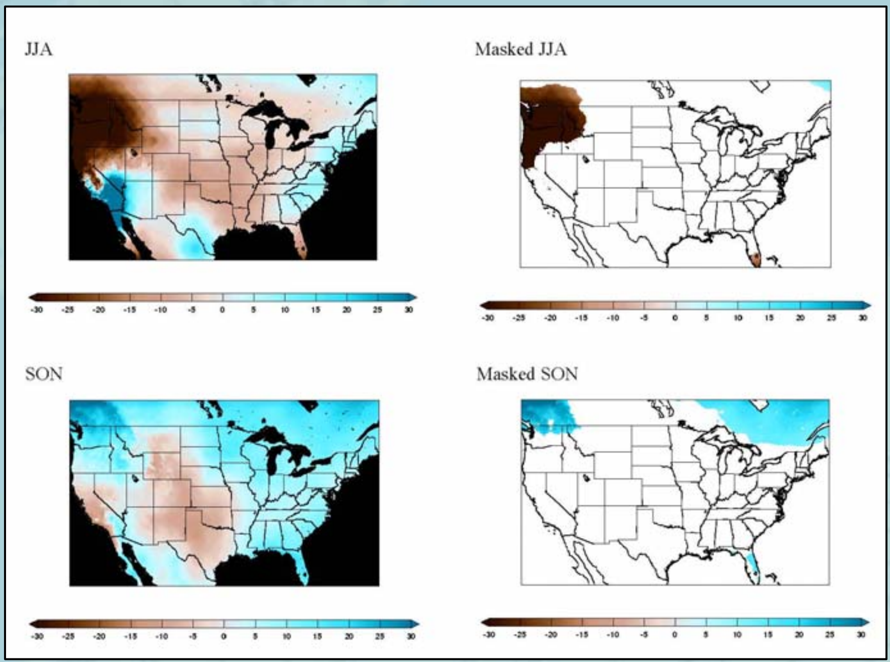


# OTHER STORMS

## Observed Changes

### Snowstorms

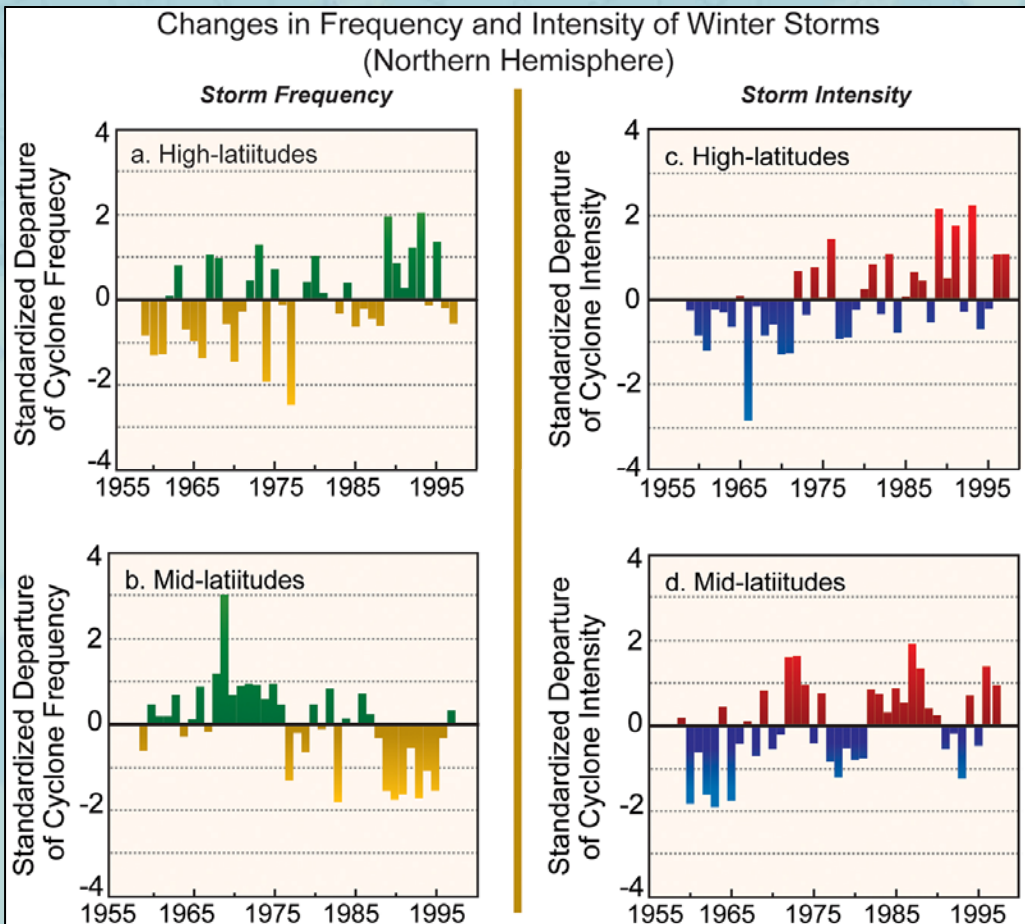
- Over the 20th century, there has been considerable decade-to-decade variability in the frequency of snow storms (6 inches or more) and ice storms.
- There has been a northward shift in snow storm occurrence, and this shift, combined with higher temperature, is consistent with a decrease in snow cover extent over the U.S.
- In northern Canada, there has also been an observed increase in heavy snow over the same time period.
- Changes in heavy snow events in southern Canada are dominated by decade to decade variability.

### 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

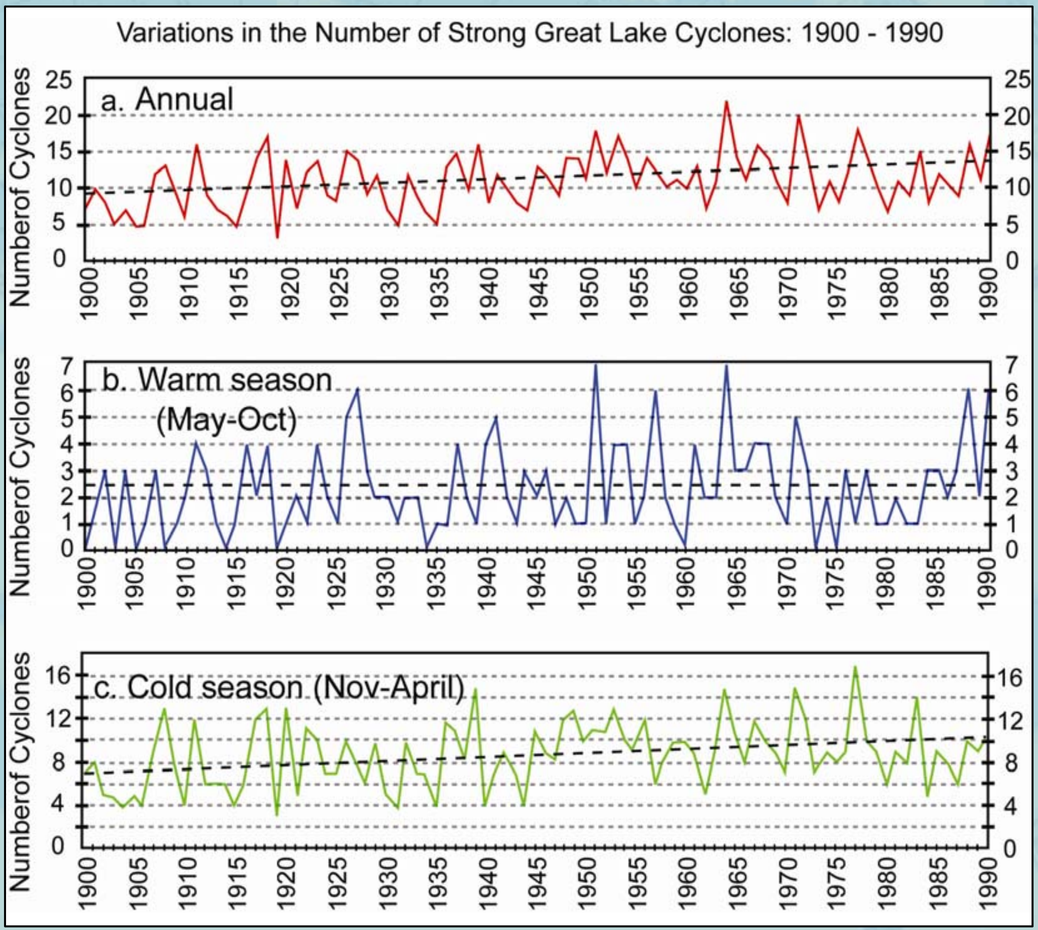
## Observed Changes




Changes from average (1959-1997) in the number of winter storms each year in the Northern Hemisphere for high and mid-latitudes, and the change from average of winter storm intensity in the Northern Hemisphere each year for high and mid-latitudes.

# OTHER STORMS

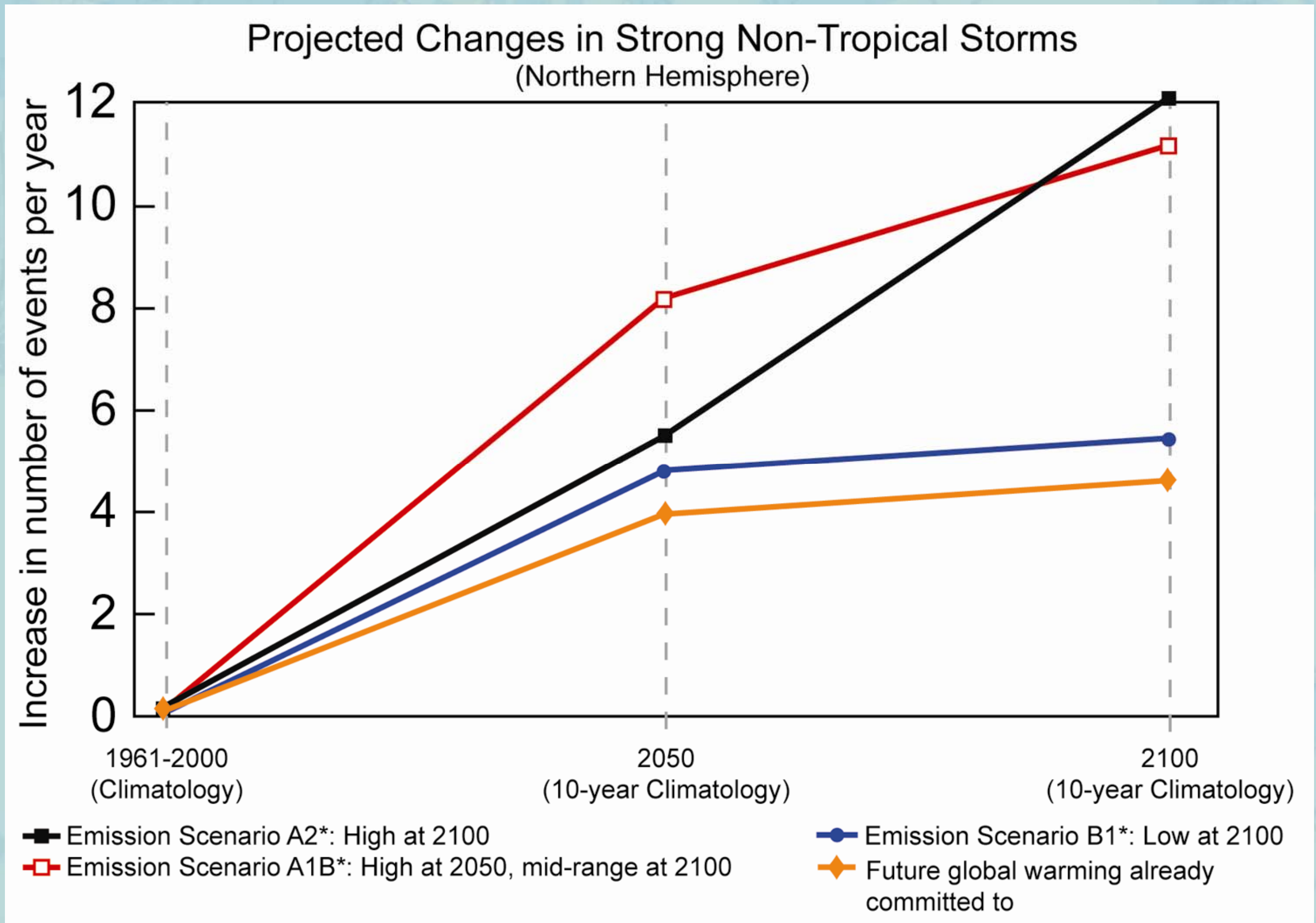
## Observed Changes



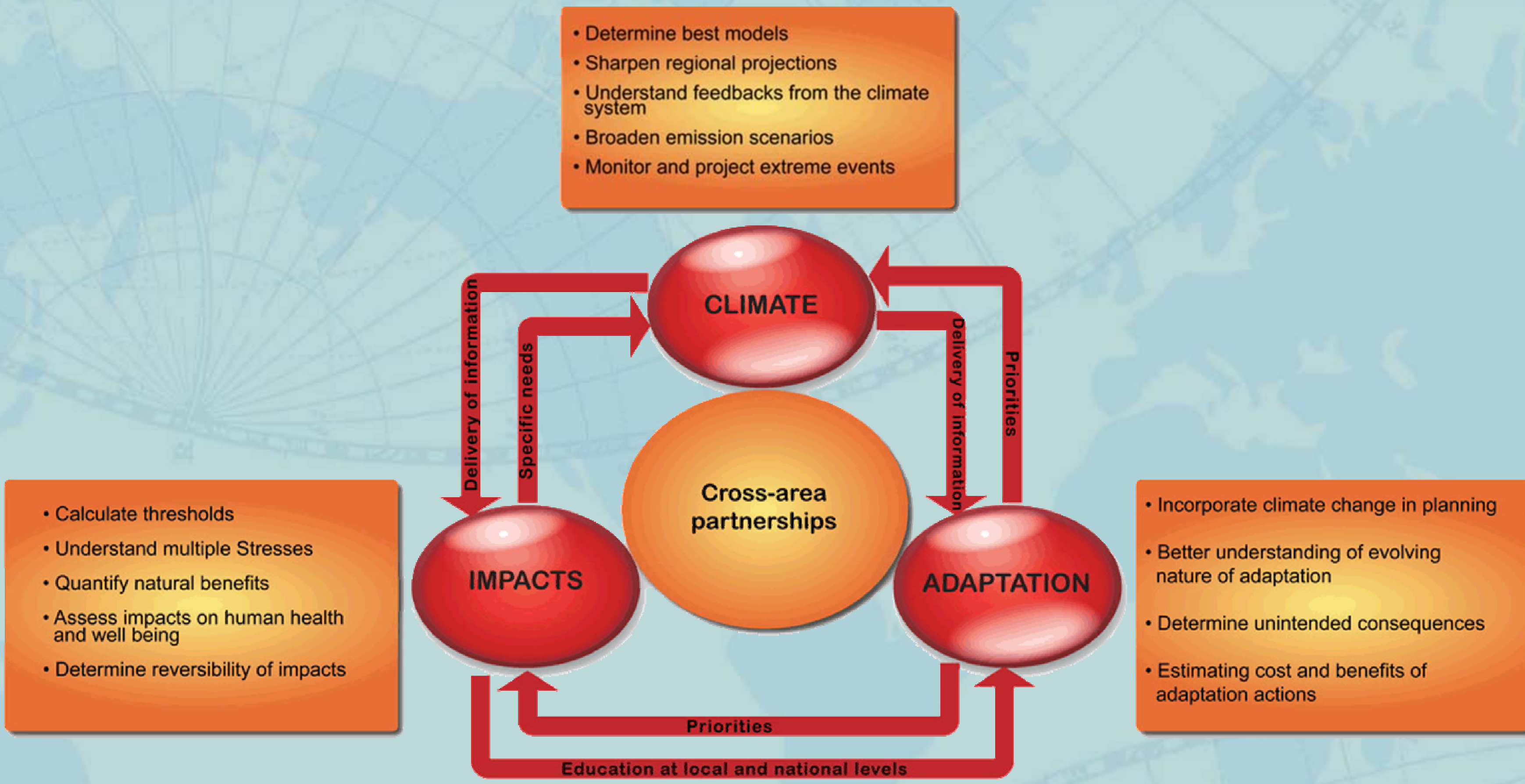

Time series of the number of strong cyclones (< 992mb) across the Great Lakes region over the period 1900-1990.

# OTHER STORMS

## Projected Changes



# PATHWAYS FORWARD




*Source: Unified Synthesis Product (First Draft, July '08)*

# PHYSICAL CLIMATE

***Assuring continued capability for documenting climate system evolution***

Essential climate variables are not being adequately monitored. How can we do a better job of detecting changes in essential climate variables?

***Determine best models***

There are now well over a dozen climate models. What models are best for what purpose? Can more reliance be placed on some models?

***Improve regional projections***

Climate change information particularly important for local and regional decision making. How can we provide local-scale climate change information to decision makers?

***Understand how the climate system responds to change***

Earth system feedbacks to global climate change are not generally modeled. What potentially important effects are they ignoring?

***Expand emission scenarios***

Global carbon emissions now exceed the highest IPCC emission scenarios of future change. What can be done to better inform policy?

***Monitor and project extreme events***

Extreme events have tremendous impacts, yet many kinds of events are not being accurately observed and adequately projected. How can this be addressed?

# IMPACTS

***Calculate thresholds***

Crossing certain thresholds can lead to dramatic effects. Are there other thresholds we should be watching for?

***Understand multiple stresses***

Multiple stresses are common in society and the environment. And so we need to be prepared to deal with multiple stresses. Is climate change likely to produce other complex stresses that we should know about? Community Resilience Indicators?

***Quantify natural benefits***

Nature provides us with many benefits such as food, fuel and fiber as well as many services we take for granted such as the cleansing of air and water. Are there benefits that we depend upon that are in jeopardy?

***Assess impacts on human health and well being***

Climate change is going to impact many aspects of human health and well being. Are these impacts being adequately measured and projected so we can take action before a problem gets too serious?

***Determine reversibility of impacts***

Some aspects of climate change appear to be irreversible. Are the irreversible impacts being monitored adequately so that we can take precautions?

# ADAPTATION

***Incorporate climate change in planning***

We didn't pay much attention to climate change in the past and our country developed just fine. Why do we need to pay so much attention to it now?

***Better understanding of evolving nature of adaptation***

Climate is no longer constant. It will now continuously evolve so adaptation must also be dynamic. How can this adaptation be most effective?

Community Resilience Indicators?

***Determine unintended consequences***

We've seen food prices sky rocket around the world while more corn is being turned into fuel forcing corn growth for food onto more marginal land. This consequence was not widely discussed when ethanol policy was being debated. Are there other unintended consequences awaiting us?

***Estimating costs and benefits of adaptation actions***

The Unified Synthesis Product outlines a number of adaptation strategies to help society cope with climate change in the context of other stresses. Do we have adequate methods to carry out cost-benefit analyses for such adaptation strategies?

# Questions?