Global Climate Change Impacts in the U.S.

ARS Water Availability and Watershed Management
Customer Workshop
Chicago, IL

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globalchange.gov/usimpacts

This report summarizes the science and impacts of climate change in the U.S.

Plain language, authoritative

US Global Change Research Program report, led by NOAA

Extensive review: public reviews (2), blue ribbon expert review, federal agency (GCRP) review

Draws from all previous assessments, global and national (IPCC, CCSP etc)

Author team was 31-members and included federal, academic and private sector experts

Key Findings from the Entire Report

1. **Global warming is unequivocal and primarily human-induced.**

2. **Climate changes are underway in the United States and are projected to grow.**

3. Widespread climate-related impacts are occurring now and are expected to increase.

4. **Climate change will stress water resources.**

5. **Crop and livestock production will be increasingly challenged.**

6. Coastal areas are at increasing risk from sea-level rise and storm surge.

7. Risks to human health will increase.

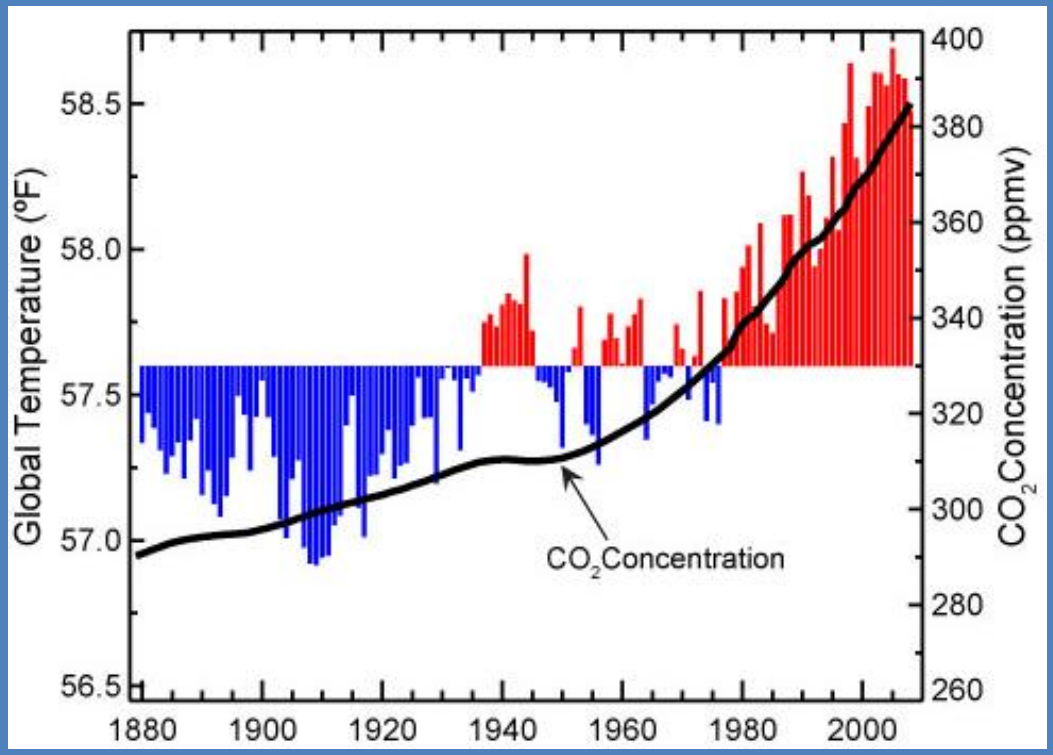
8. **Climate change will interact with many social and environmental stresses.**

9. Thresholds will be crossed, leading to large changes in climate and ecosystems.

10. Future climate change and its impacts depend on choices made today.

1. Global warming is unequivocal and primarily human induced

Global Temperature and CO_2

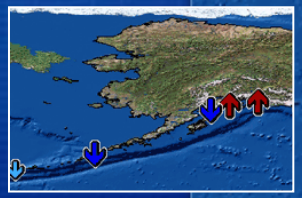


Human fingerprints have been identified in many aspects of climate change

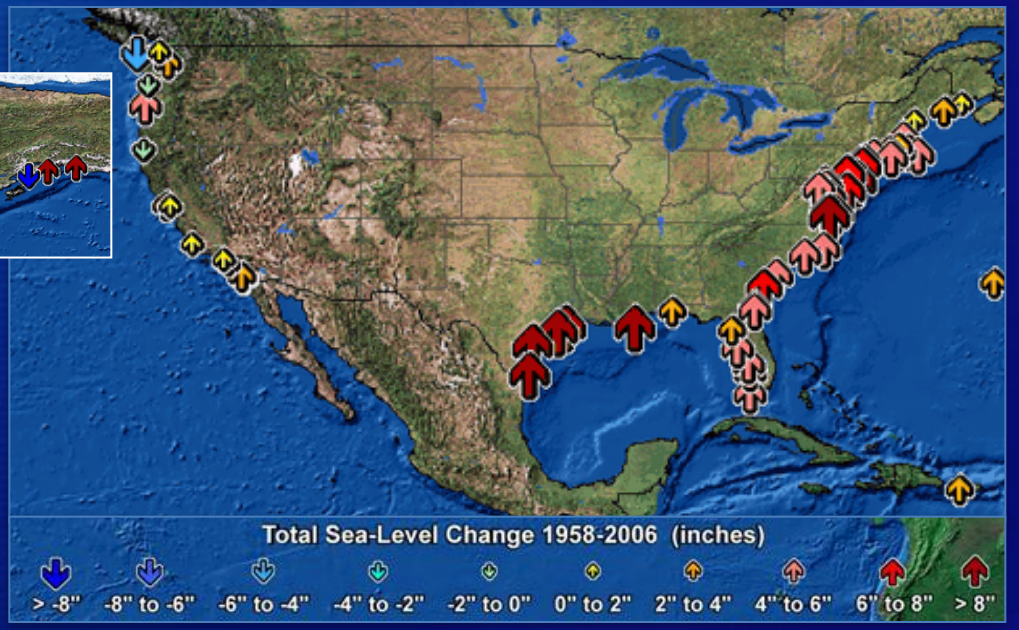
- Temperature
- Precipitation
- Ocean heat content
- Atmospheric moisture
- Arctic sea ice

2. Climate changes are underway in the U.S. and are projected to grow

- Temperature rise
- Sea-level rise
- Increase in heavy downpours
- Rapidly retreating glaciers
- Thawing permafrost
- Longer growing season
- Longer ice-free season in the ocean and on lakes and rivers
- Earlier snowmelt
- Changes in river flows

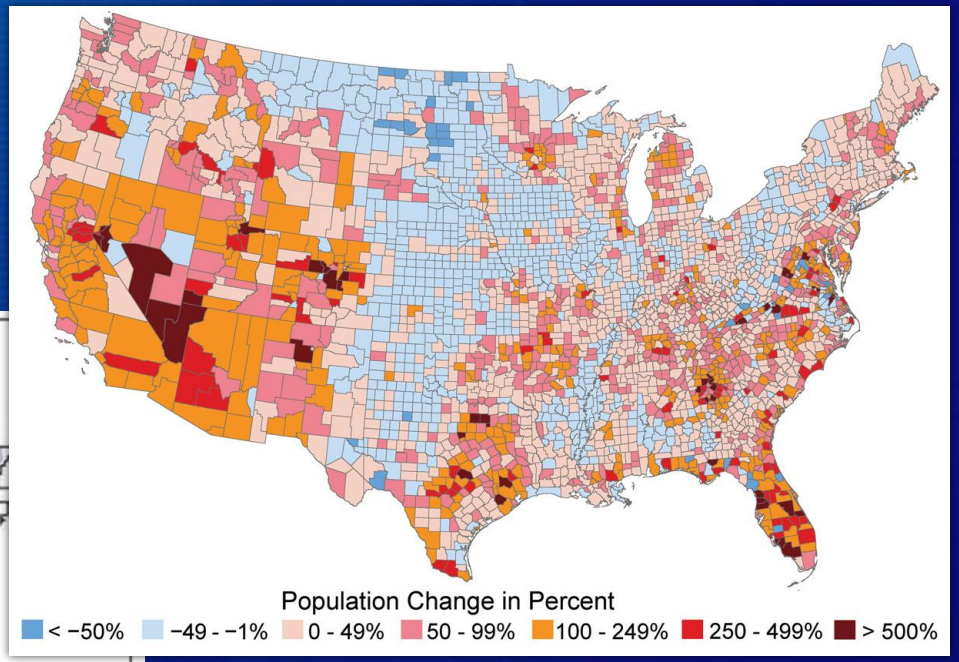


Observed U.S. Sea-Level Changes

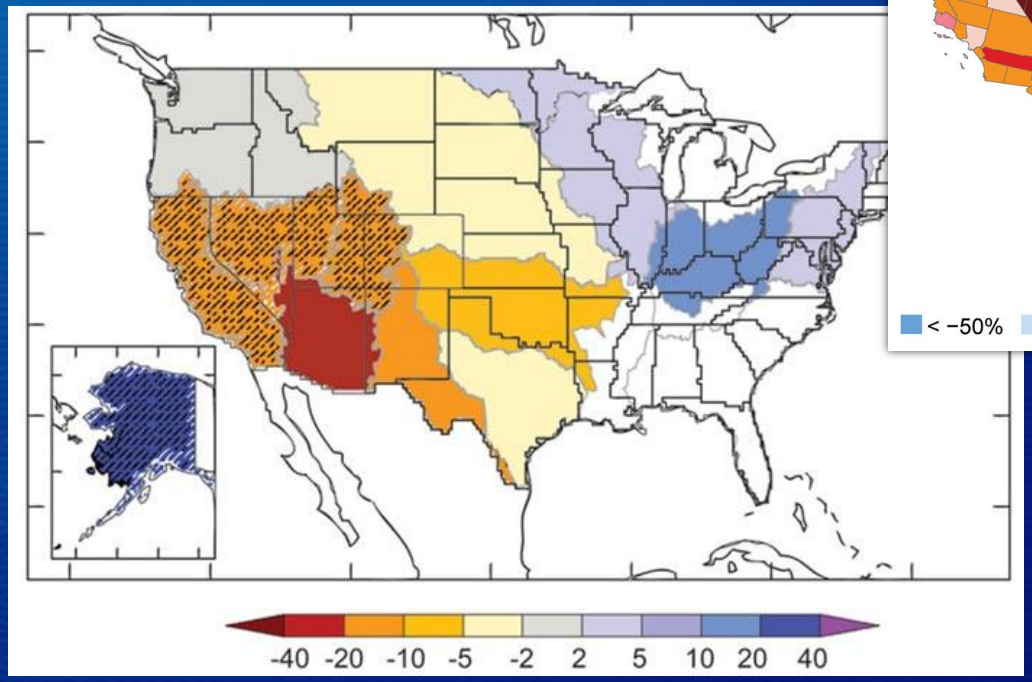


4. Climate change will stress water resources

Change in Population from 1970 to 2008



Projected Changes in Annual Runoff



The water cycle will change in fundamental ways

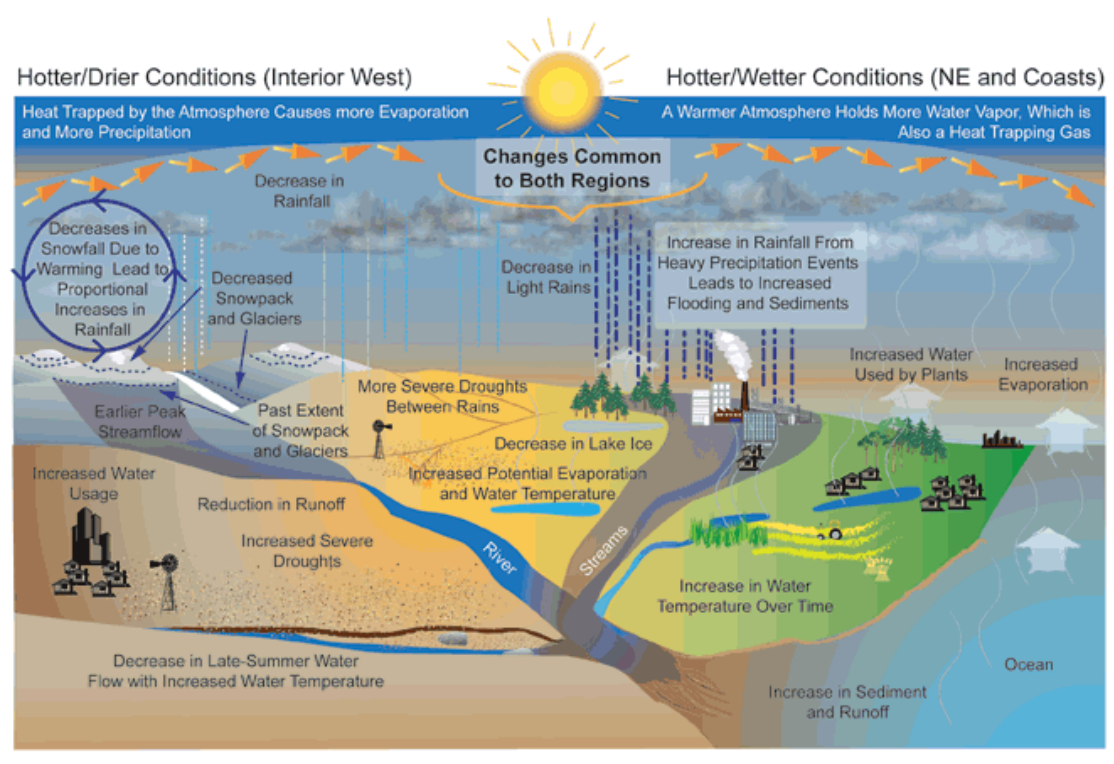
- The water cycle is a primary mechanism by which the Earth moves heat from areas with too much to areas with too little.

- A warmer climate means more water vapor in the atmosphere - every 1F increase means 4% increase in moisture holding.

- A warmer climate also means more evaporation, more precipitation GLOBALLY but regional losers.

- Storm tracks expected to move northward.

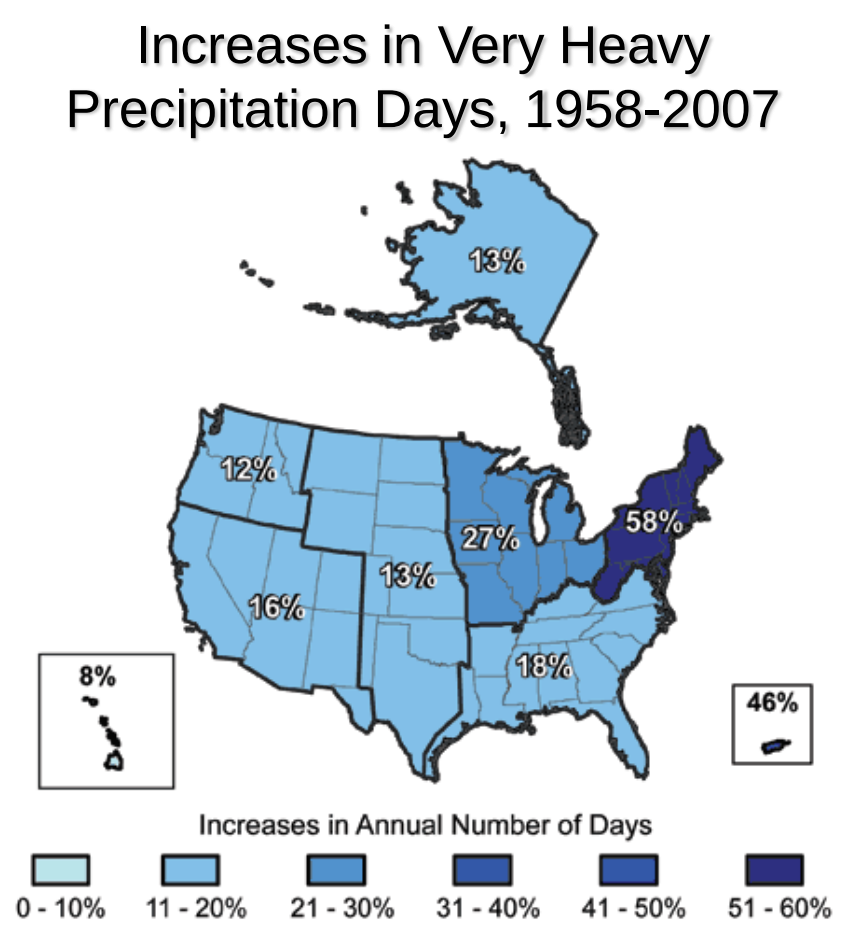
- Wet gets Wetter, Dry gets Drier.

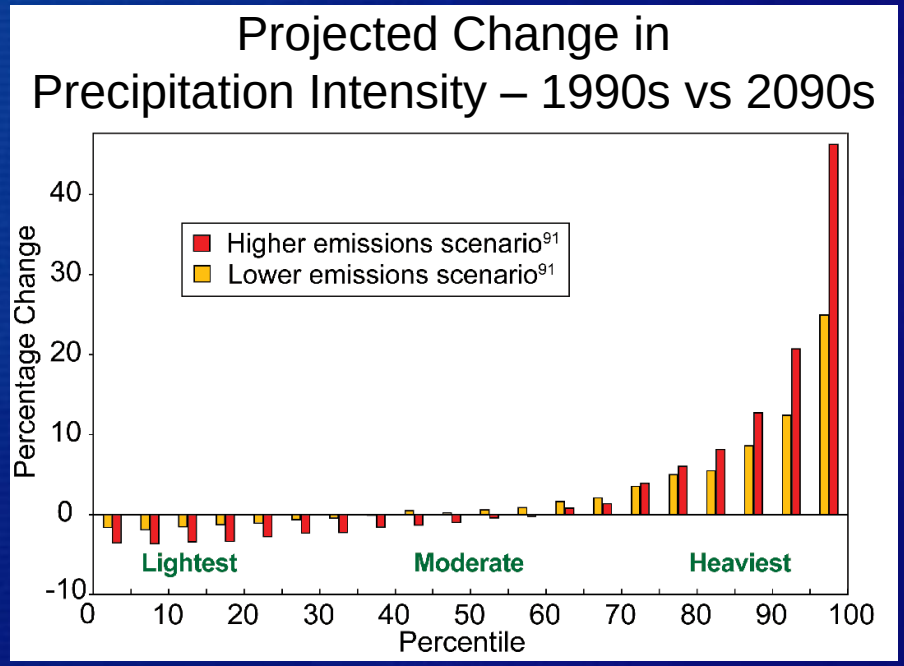


The Water Cycle is already changing

Observed Water-Related Changes During the Last Century[142]		
Observed Change	**Direction of Change**	**Region Affected**
One to four week earlier peak streamflow due to earlier warming-driven snowmelt	Earlier	West and Northeast
Proportion of precipitation falling as snow	Decreasing	West and Northeast
Duration and extent of snow cover	Decreasing	Most of the United States
Mountain snow water equivalent	Decreasing	West
Annual precipitation	Increasing	Most of the United States
Annual precipitation	Decreasing	Southwest
Frequency of heavy precipitation events	Increasing	Most of the United States
Runoff and streamflow	Decreasing	Colorado and Columbia River Basins
Streamflow	Increasing	Most of East
Amount of ice in mountain glaciers	Decreasing	U.S. western mountains, Alaska
Water temperature of lakes and streams	Increasing	Most of the United States
Ice cover on lakes and rivers	Decreasing	Great Lakes and Northeast
Periods of drought	Increasing	Parts of West and East
Salinization of surface waters	Increasing	Florida, Louisiana
Widespread thawing of permafrost	Increasing	Alaska

Floods and Droughts will become more common



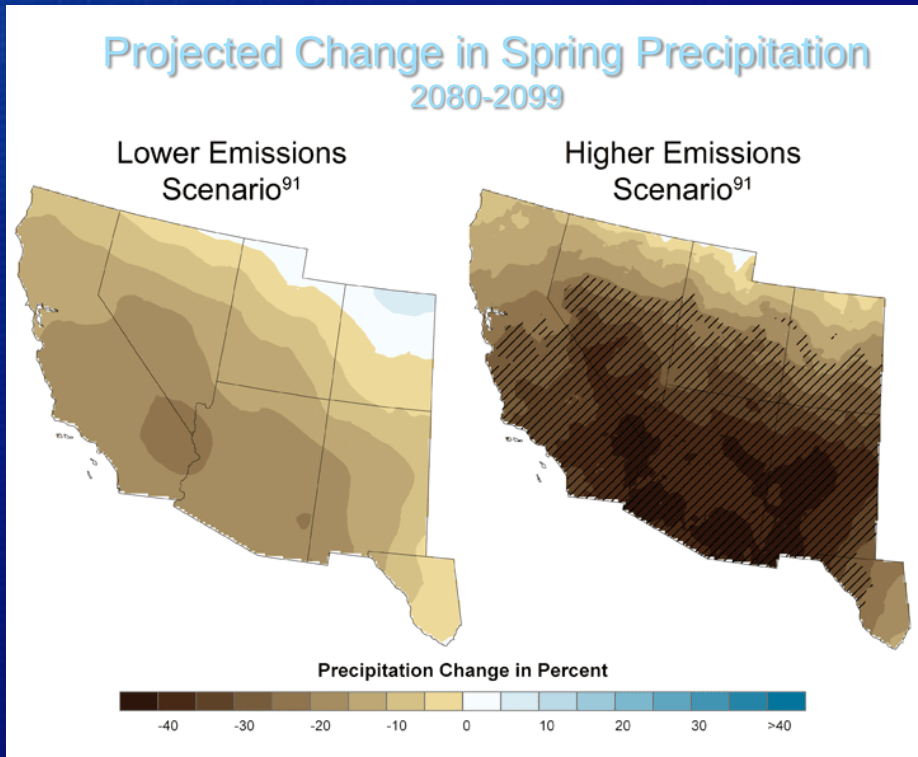


Floods and Droughts will become more common

- No clear national drought trend, but increasing temperatures have made droughts more severe.

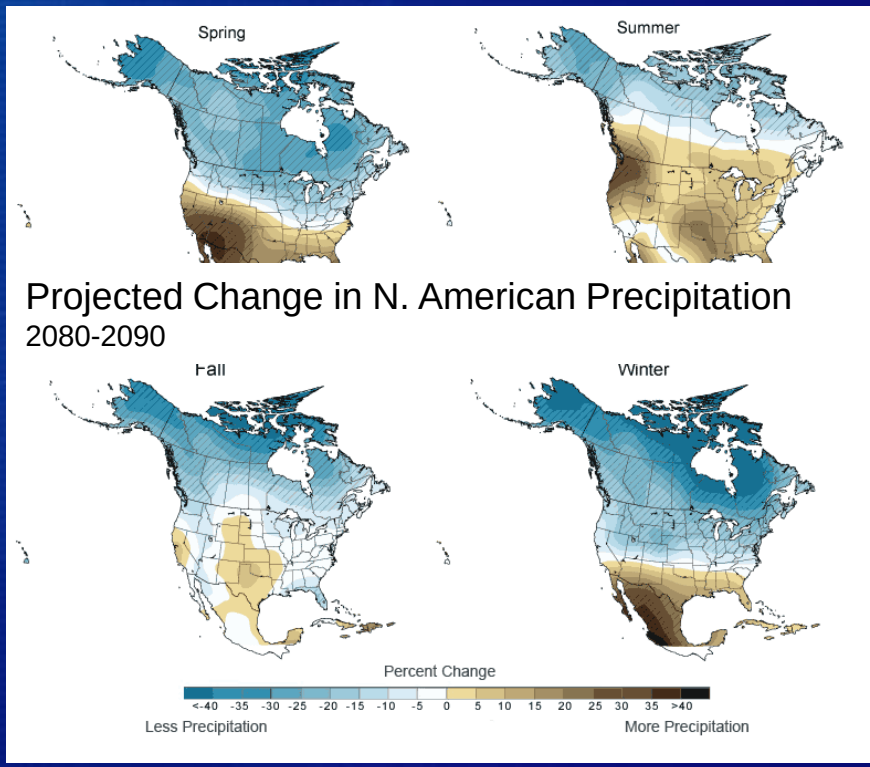
- Projections show longer dry periods between precipitation, especially in arid areas, mid continent and Southwest.

- Northward shift in winter and spring storm tracks will reduce precipitation in some regions.



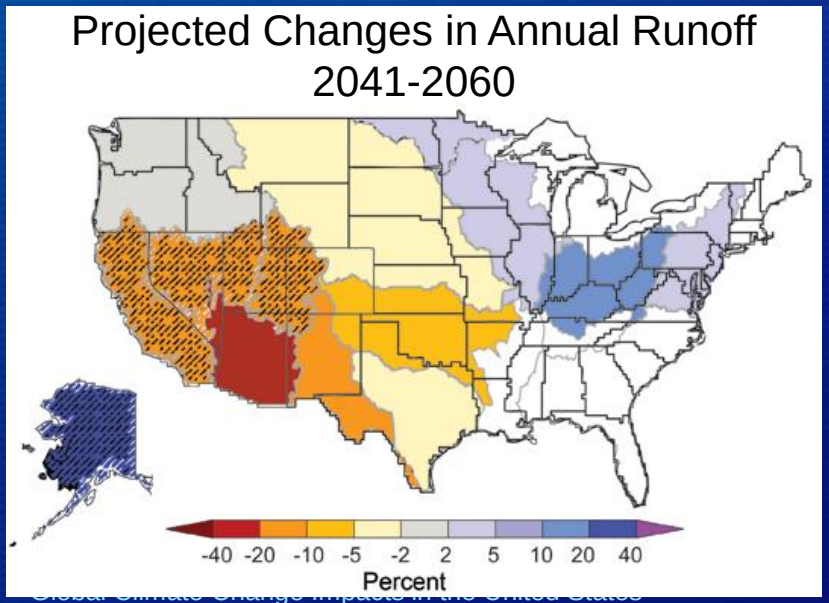
Precipitation and Runoff are projected to change regionally

- Precipitation and Runoff likely to
  - increase in Northeast and Midwest in winter and Spring
  - decrease in West, especially Southwest in spring and summer
- Wet Wetter, Dry Drier
- Summer soil-moisture reductions consistent finding



Projected Change in N. American Precipitation
2080-2090

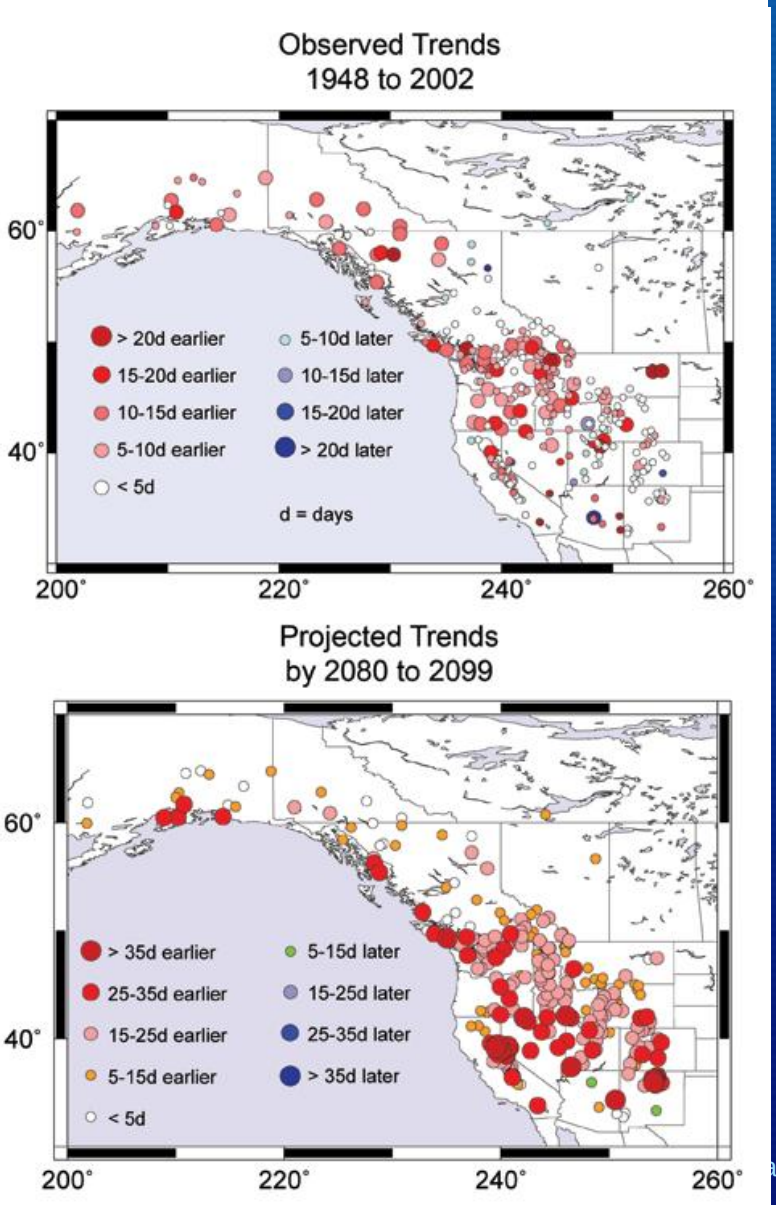
Projected Changes in Annual Runoff
2041-2060



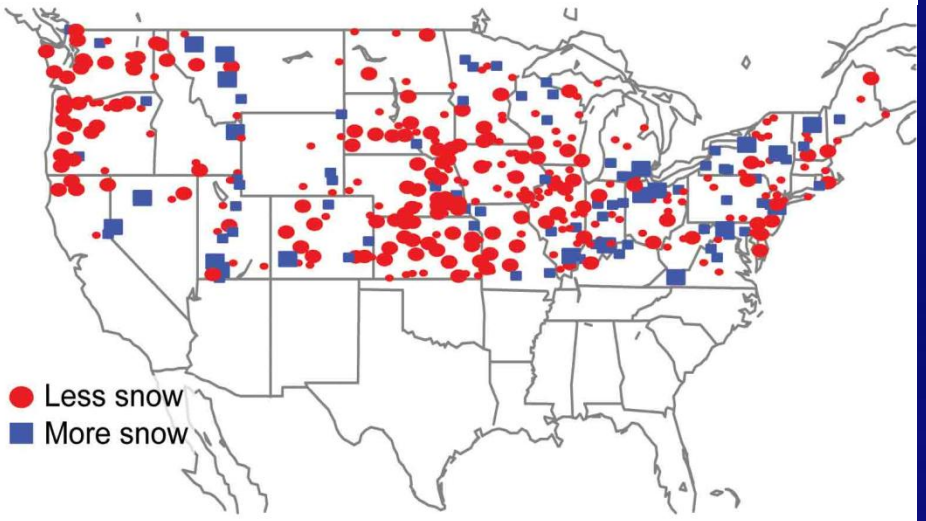
Snow-dominated areas will experience changes

- Snow is a natural reservoir
- Snowpack reductions in West and Northeast already occurring at low elevations
- More rain and less snow in winter
- Advances in Runoff Timing in West (20 days) and NE (14 days) already
- Runoff timing projections are for up to 60-day advance in West, 14-day in East

Observed and Projected Trends in Peak Streamflow Timing



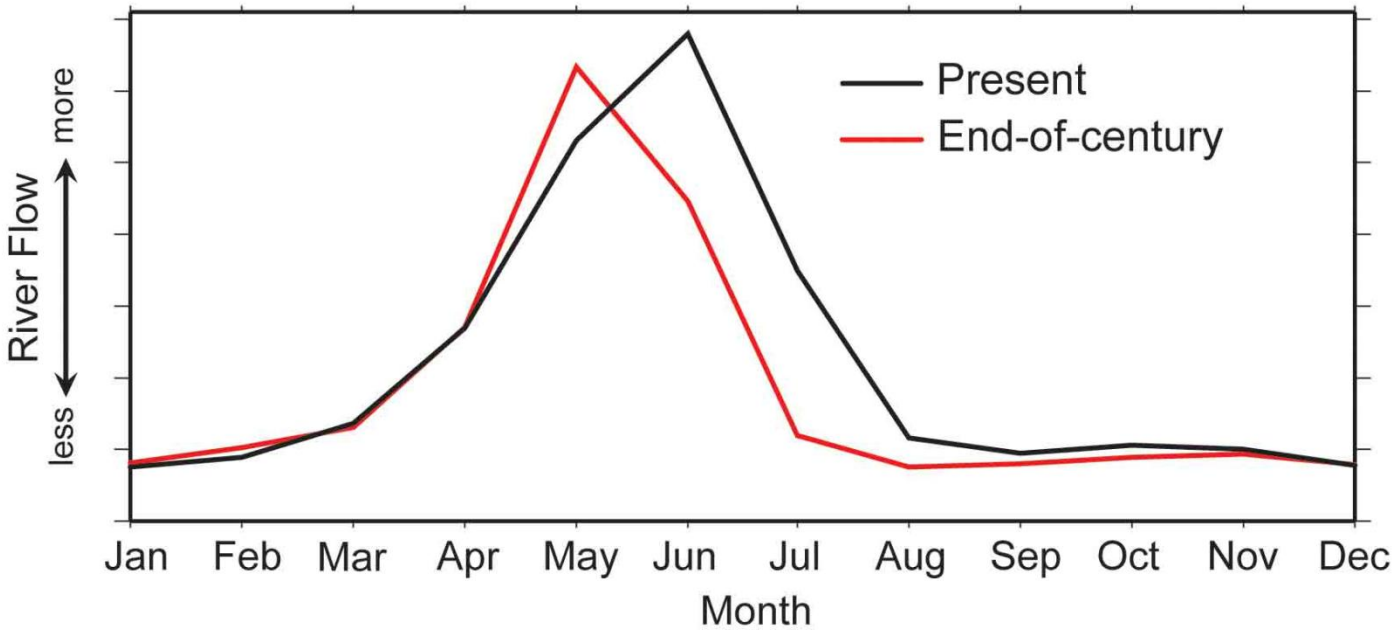
Changes in Snowfall Contributions to Wintertime Precipitation
1949-2005



Snow-dominated areas will experience changes

- Annual Runoff Pattern will change
  - Runoff will occur earlier (previous slide)
  - Lower and Warmer Flows in late summer
  - Some regions will see annual declines in flow (previous slide)

Green River, A Tributary of the Colorado River

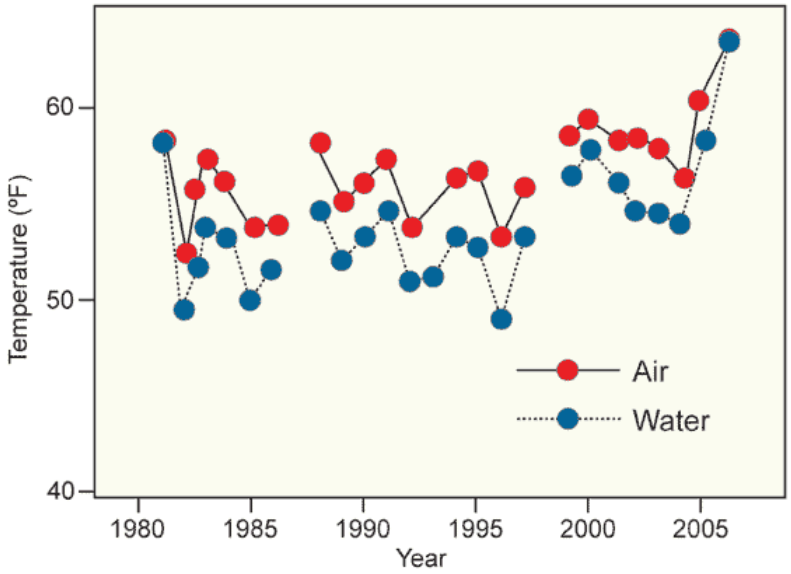


Water quality and groundwater will change

Water Quality Changes

- Higher air temps = higher water temps
- Higher water temps = less dissolved oxygen
  = higher metabolic rates
- Longer periods of summer lake stratification with no mixing of top and bottom waters
- Pollution generally made worse by higher temps and lower flows
- Heavy Downpours = sediments and pathogens

Lake Superior Air and Water Temperatures, 1979-2006



Water quality and groundwater will change

Groundwater Changes

- **Large Percentages of Americans Use GW**
- **Changes not well understood but increased water demands will stress resource**
- **Changes in recharge due to storm intensity changes in some regions**
- **Small changes in shallow aquifers can affect river "baseflow"**
- **Salt water intrusion into coastal aquifers expected as sea level rises**

Water Systems are already stressed

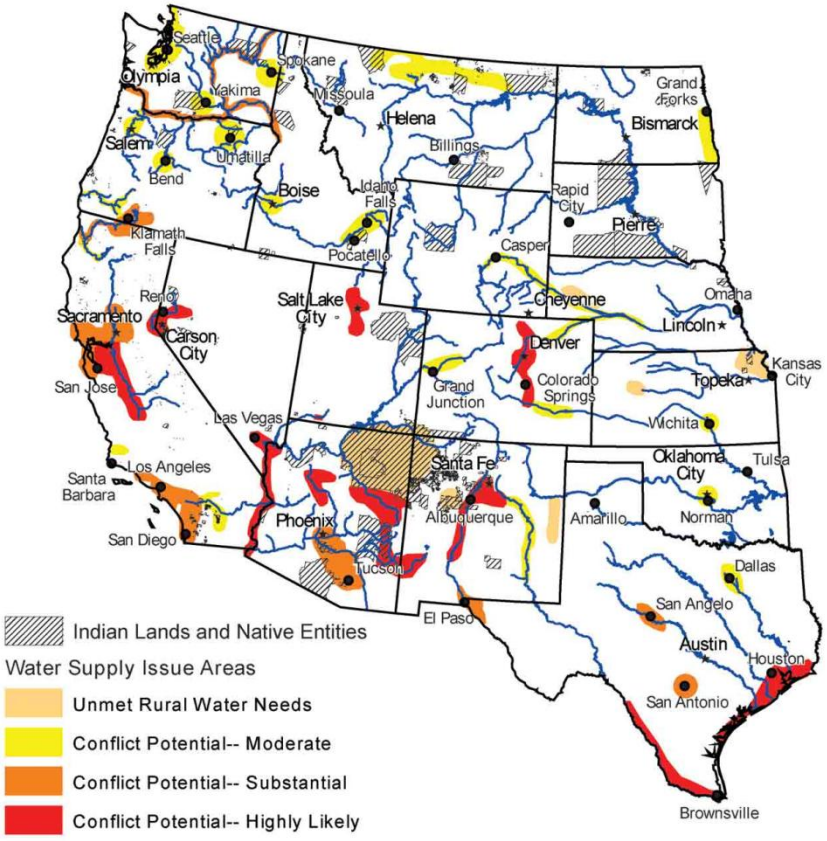
- Climate Change will place another burden on already stressed water systems

- Rapid National and Regional Population Growth
  - Over 300m now, 420m by 2050
  - West
  - Southeast

- Aging Water Infrastructure
  - Enormous Backlog of needs
  - Sewer Overflows Common
  - Very expensive to fix

- Many Existing Water Disputes
  - Bay Delta CA
  - Southeast
  - Colorado River
  - Klamath
  - Great Lakes
  - Rio Grande

Potential Water Supply Conflicts by 2025 without climate change



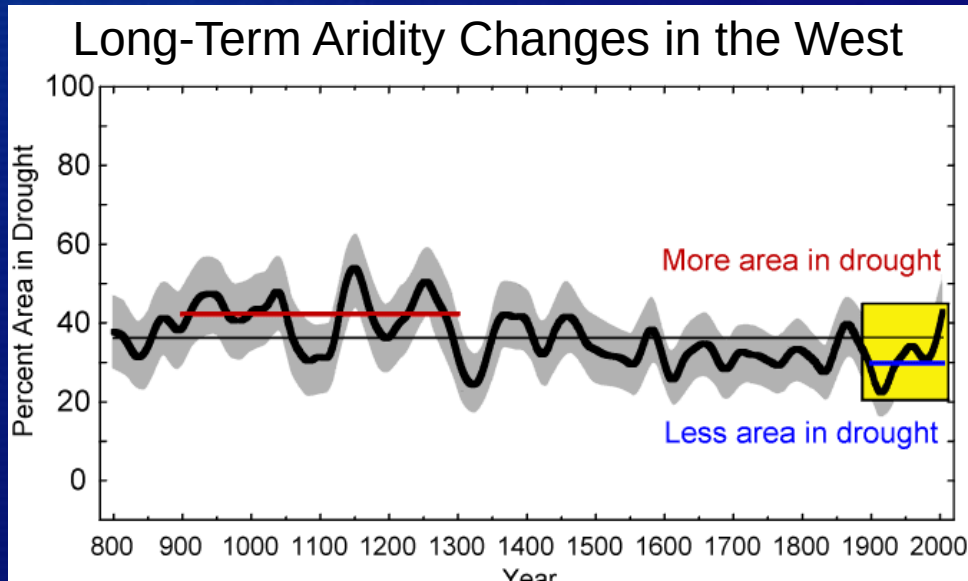
The past century is no longer a guide to water management

- Historical Data Used to Manage Water Resources in 20th Century
- However…
  - Climate Change is already altering water cycle
  - More changes are expected
  - Paleoclimate studies tell us the past has been very different

- Many Institutional Barriers to Change
  - Laws, Decrees, Compacts difficult to modify
  - Flood Control rule curves might require EIS to modify
  - Transferring ag water can be difficult

- Changing Water Demands
  - More Research Needed

- All these stresses mean water management will be doubling challenging



Water is connected to many other sectors

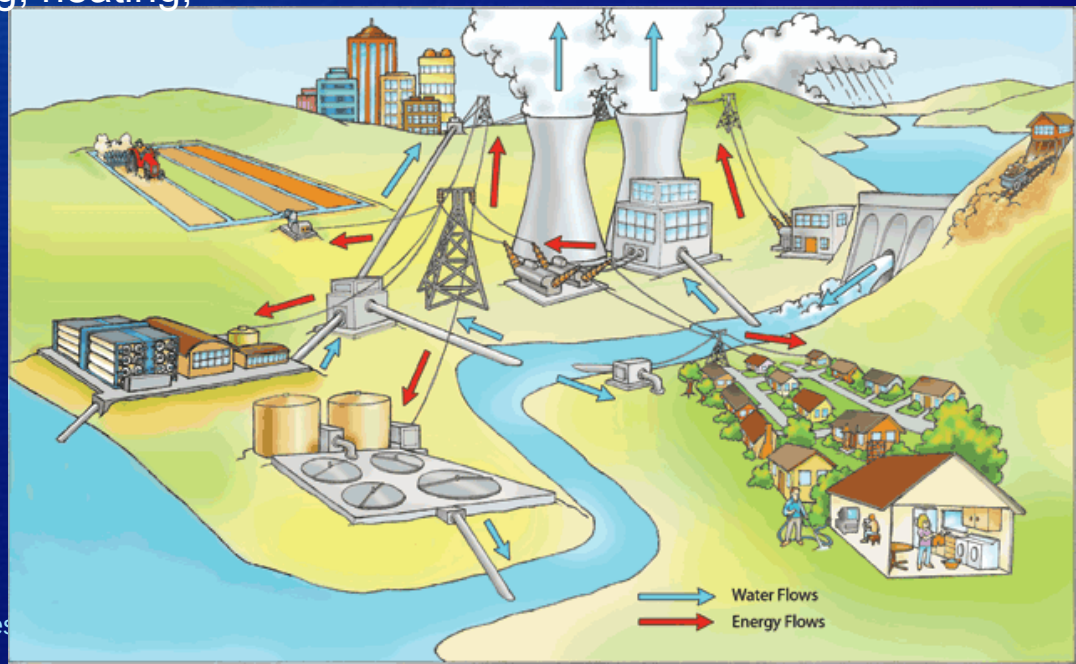
Highlights of Water-Related Impacts by Sector	
Sector	**Examples of Impacts**
Human Health	Heavy downpours increase incidence of waterborne disease and floods, resulting in potential hazards to human life and health.[163]
Energy Supply and Use	Hydropower production is reduced due to low flows in some regions. Power generation is reduced in fossil fuel and nuclear plants due to increased water temperatures and reduced cooling water availability.[191]
Transportation	Floods and droughts disrupt transportation. Heavy downpours affect harbor infrastructure and inland waterways. Declining Great Lakes levels reduce freight capacity.[192]
Agriculture and Forests	Intense precipitation can delay spring planting and damage crops. Earlier spring snowmelt leads to increased number of forest fires.[193]
Ecosystems	Coldwater fish threatened by rising water temperatures. Some warmwater fish will expand ranges.[70]

Water and energy are linked

- Energy systems use large amounts of water
- Water systems use large amounts of energy

- **Energy Sector Use of Water…**
- Energy generation uses water for hydropower and for cooling water
- Withdrawals of cooling water are very large, almost equal to agriculture
- Water consumption by power plants is half that of all domestic use

- **Water Sector Use of Energy…**
- Water is heavy and takes lots of energy to heat
- 4% of nation's electricity goes to pumping, heating, treating water and wastewater
- Different water sources require vastly different amounts of energy
  - Desalination requires large amounts of energy
  - Conserving water has the dual benefit of conserving energy and may reduce greenhouse gases



Key Findings from the Water Resources Chapter of the Report

- Climate Change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses
- Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between)
- Precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West, especially in the Southwest, in spring and summer
- In areas where snowpack dominates, the timing of runoff will continue to shift to earlier in the spring and flows will be lower in late summer
- Surface water quality and groundwater quantity will be affected by a changing climate
- Climate change will place additional burdens on already stressed water systems
- **The past century is no longer a reasonable guide to the future for water management**

Key Findings from the Agriculture Chapter of the Report

- Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields.

- Extreme events such as heavy downpours and droughts are likely to reduce crop yields because excesses or deficits of water have negative impacts on plant growth.

- Weeds, diseases, and insect pests benefit from warming, and weeds also benefit from a higher carbon dioxide concentration, increasing stress on crop plants and requiring more attention to pest and weed control.

- Forage quality in pastures and rangelands generally declines with increasing carbon dioxide concentration because of the effects on plant nitrogen and protein content, reducing the land's ability to supply adequate livestock feed.

- Increased heat, disease, and weather extremes are likely to reduce livestock productivity.

Key Findings from the Entire Report

1. Global warming is unequivocal and primarily human-induced.

2. Climate changes are underway in the United States and are projected to grow.

3. Widespread climate-related impacts are occurring now and are expected to increase.

4. **Climate change will stress water resources.**

5. **Crop and livestock production will be increasingly challenged.**

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7. Risks to human health will increase.

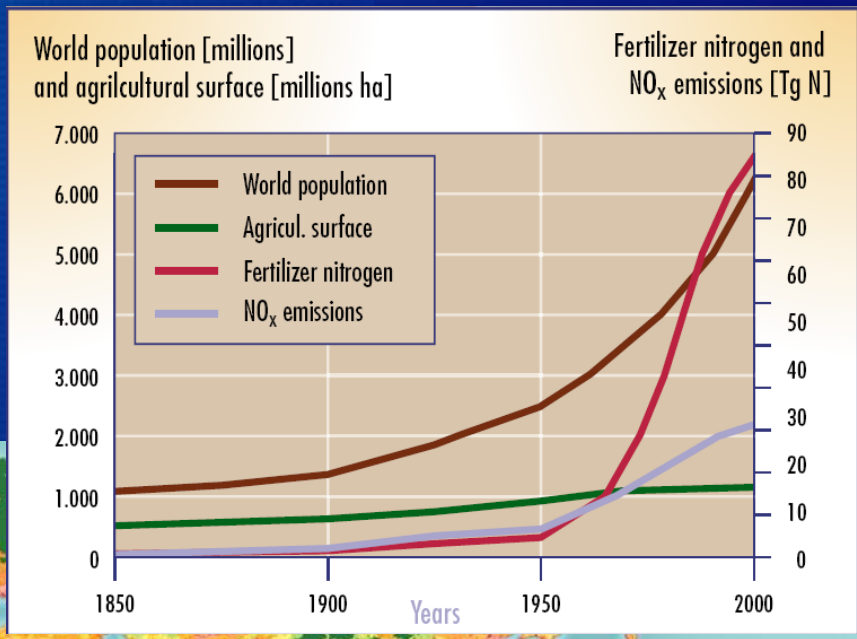
8. **Climate change will interact with many social and environmental stresses.**

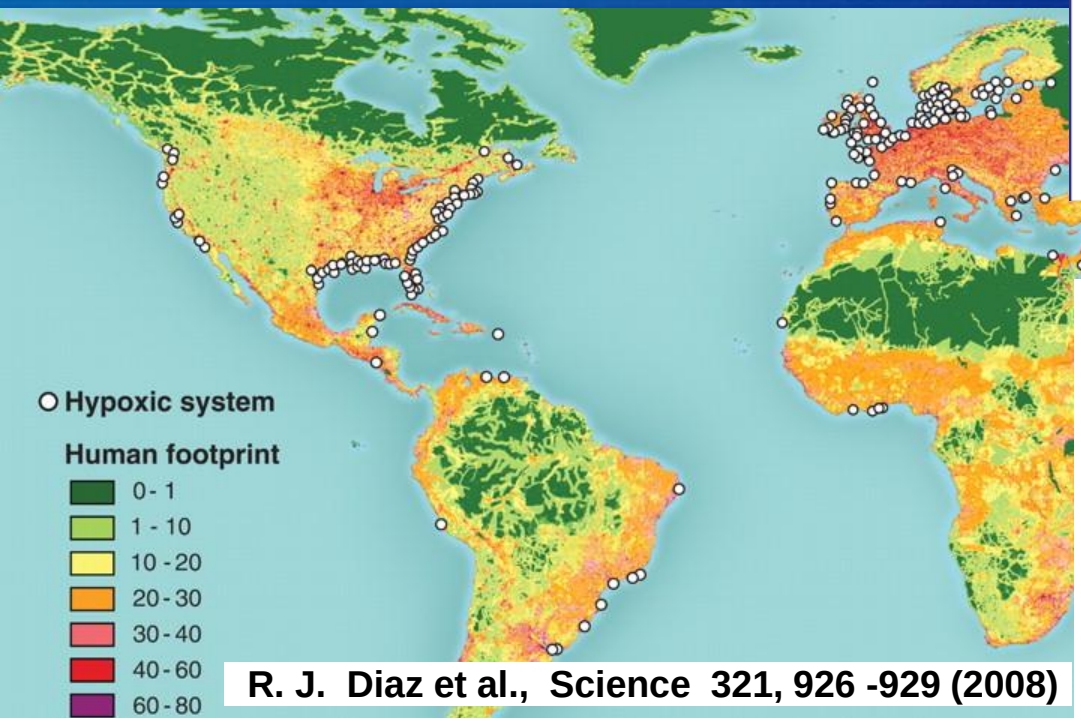
9. Thresholds will be crossed, leading to large changes in climate and ecosystems.

10. Future climate change and its impacts depend on choices made today.

Climate change will interact with many social and environmental stresses.

Nitrogen as an example...





R. J. Diaz et al., Science 321, 926 -929 (2008)

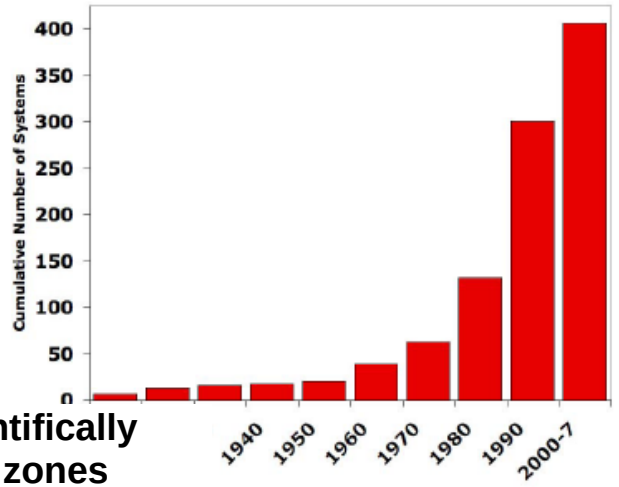


Fig. 1. Global distribution of 400-plus systems that have scientifically reported accounts of being eutrophication-associated dead zones

Closing Thoughts

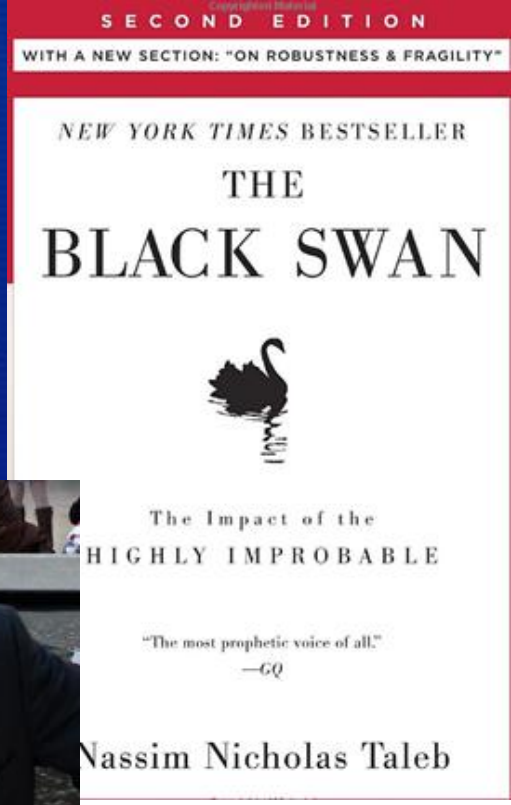
1. Climate Change is _really_ important

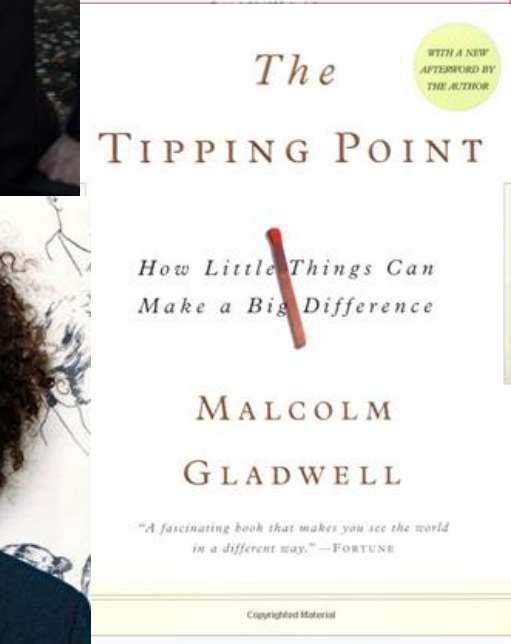
2. Changes in water availability will be the delivery mechanism for many of the most important impacts of climate change

3. But climate is not the only stress... Population, Water, Environmental, and Energy all in play

4. These are anything but normal times...Black Swan era

4. It is tempting to think that this century is a mystery, but maybe it is more of a puzzle...





Thank you!

Questions.

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