Third National Climate Assessment

Overview of the Process and Findings of the Water Resources Chapter

June 12, 2014

Aris Georgakakos
Georgia Institute of Technology
Convening Lead Author,
Water Resources Chapter

Paul Fleming
Seattle Public Utilities
Convening Lead Author
Water Resources Chapter

Outline

- Primary messages
- NCA structure and process
- Water Resources chapter key messages and findings
- Discussion

NCA Topline Messages

- Human-induced climate change has moved into the present
- Americans are already feeling the effect of increases in some types of extreme weather and sea level rise
- Impacts are evident in every region and important sectors
- There are many actions we can take to reduce future climate change and its impacts and to prepare for impacts we can't avoid

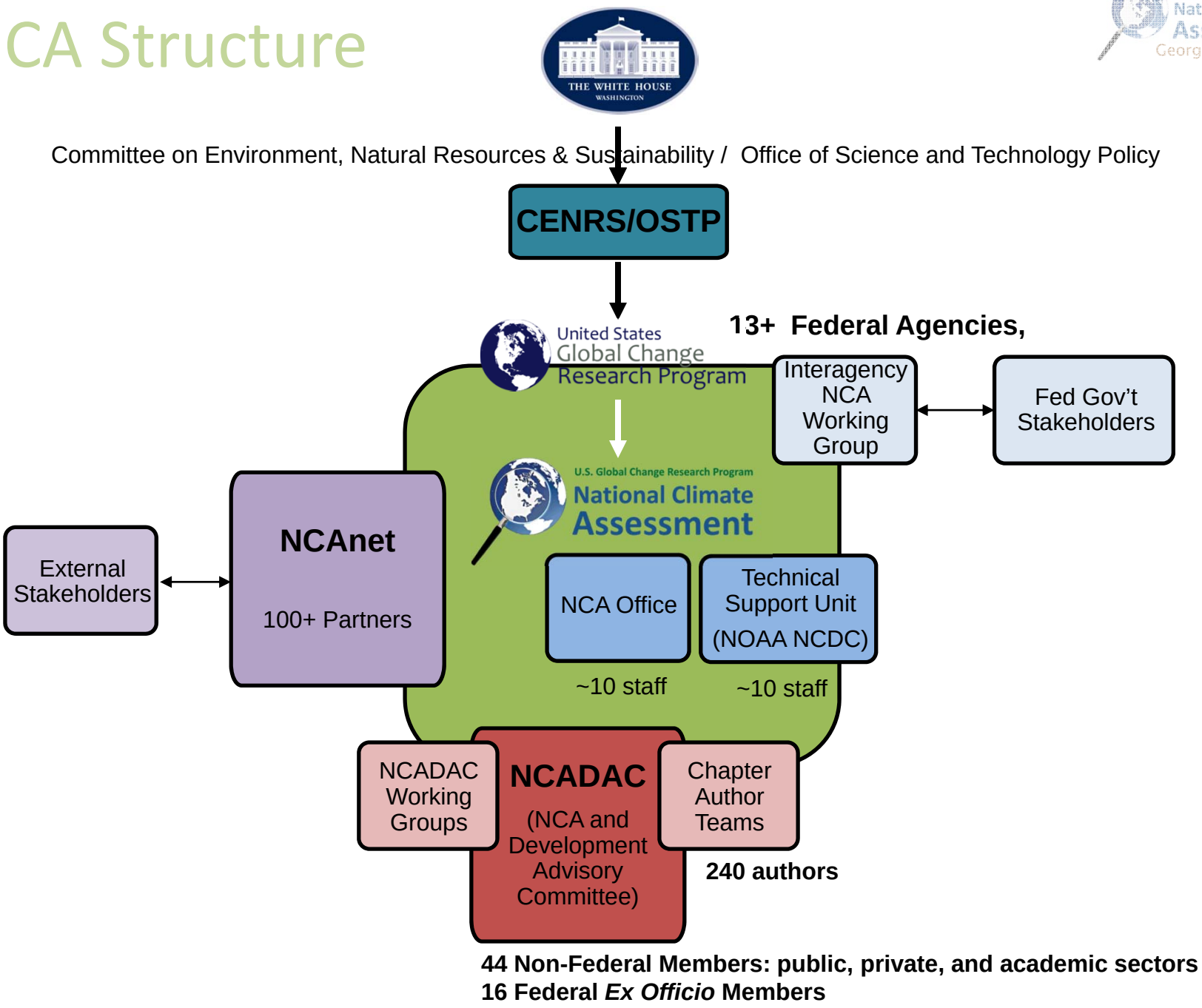
Vision of the NCA

Advance an **inclusive, broad-based, and sustained process** for assessing and communicating scientific knowledge of the impacts, risks, and vulnerabilities associated with a changing global climate **in support of decision-making** across the United States.

Goal 3 from the US Global Change Research Program (USGCRP) Strategic Plan: **Conduct Sustained Assessments**

Build sustained assessment capacity that improves the Nation's ability to understand, anticipate, and respond to global change impacts and vulnerabilities

NCA Structure



Sectors

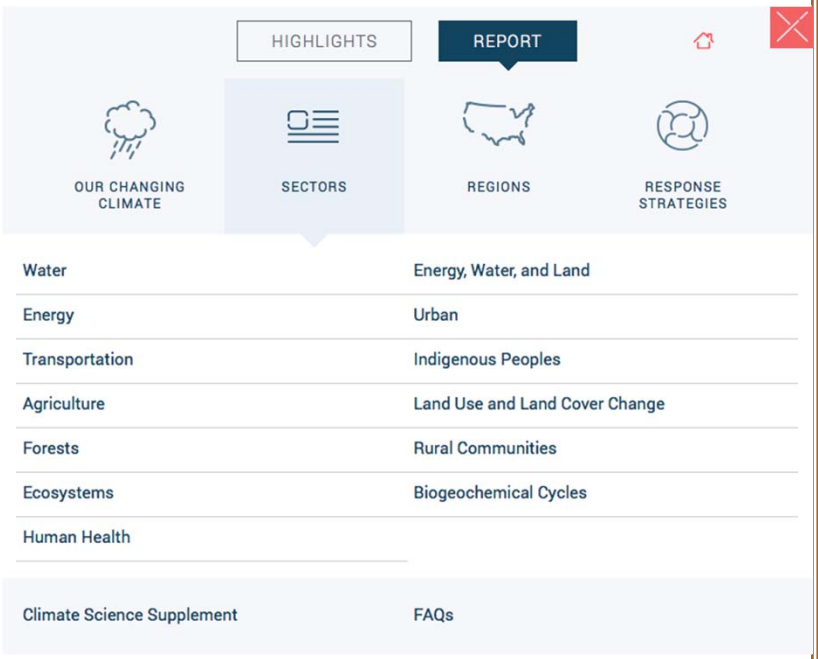
- Water Resources
- Energy Supply and Use
- Transportation
- Agriculture
- Forests
- Ecosystems and Biodiversity
- Human Health

Cross-Cuts

- Energy, Water and Land
- Urban Systems, Infrastructure, & Vulnerability
- Indigenous Peoples
- Land Use & Land Cover Change
- Rural Communities
- Biogeochemical Cycles
- Oceans
- Coasts

NCA Products

- Full synthesis document
- Stand alone chapters
- Highlights document
- Dynamic website



What is new about the Third NCA

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

- Update of impacts assessment
- Confidence levels and traceable accounts – “line of sight” between data and conclusions
- Decision-making support in a “risk-based” framework
- Assesses progress in response activities
  - adaptation (preparedness)
  - mitigation (managing emissions of heat-trapping gases)
- Fosters sustained scientific process
- Web-based and transparent



Sustained Assessment

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

- Special report of the NCADAC
- Goal: Enhance the ability of *decision-makers at multiple scales throughout* the United States to anticipate, mitigate and adapt to changes in the global environment
- Four elements:
  - Establish mechanisms to support enduring collaborative partnerships
  - Enhance scientific foundations for managing risks and opportunities of climate change
  - Provide infrastructure to support a sustained process
  - Diversify resource base and set priorities



Climate Change Impacts in the United States

CHAPTER 3
WATER RESOURCES

Convening Lead Authors
Aris Georgakakos, Georgia Institute of Technology
Paul Fleming, Seattle Public Utilities

Lead Authors
Michael Dettinger, U.S. Geological Survey
Christa Peters-Lidard, National Aeronautics and Space Administration
Terese (T.C.) Richmond, Van Ness Feldman, LLP
Ken Reckhow, Duke University
Kathleen White, U.S. Army Corps of Engineers
David Yates, University Corporation for Atmospheric Research

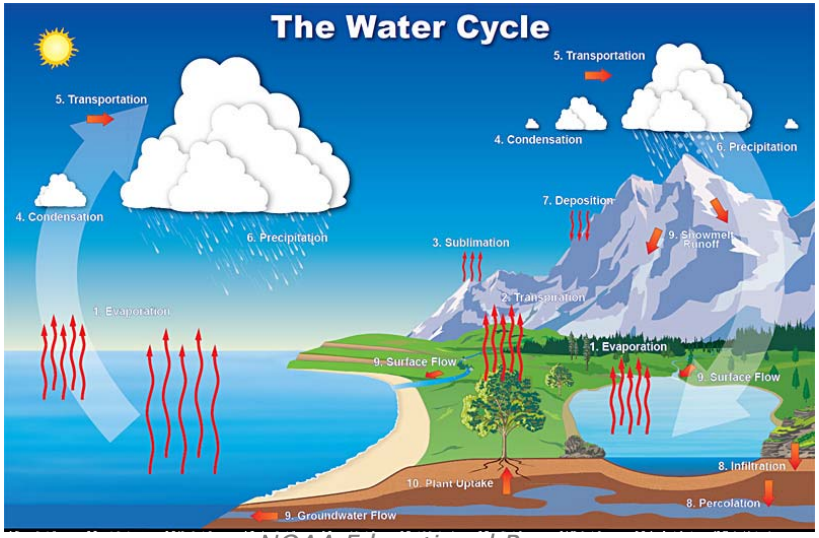
Water Resources Chapter Themes

- **Water Cycle Changes:** **Observed, projected.**

Fluxes: Precipitation (Averages, Extremes)
Evapotranspiration
Runoff, Streamflow,
GW Recharge

Storages: Snow Cover, SWE
Lakes/Reservoirs/Wetlands
Soil Moisture
Groundwater

Water Quality:
Water Temp, Sediment,
Nutrient Loads, DO, Pollutants



NOAA Educational Resources

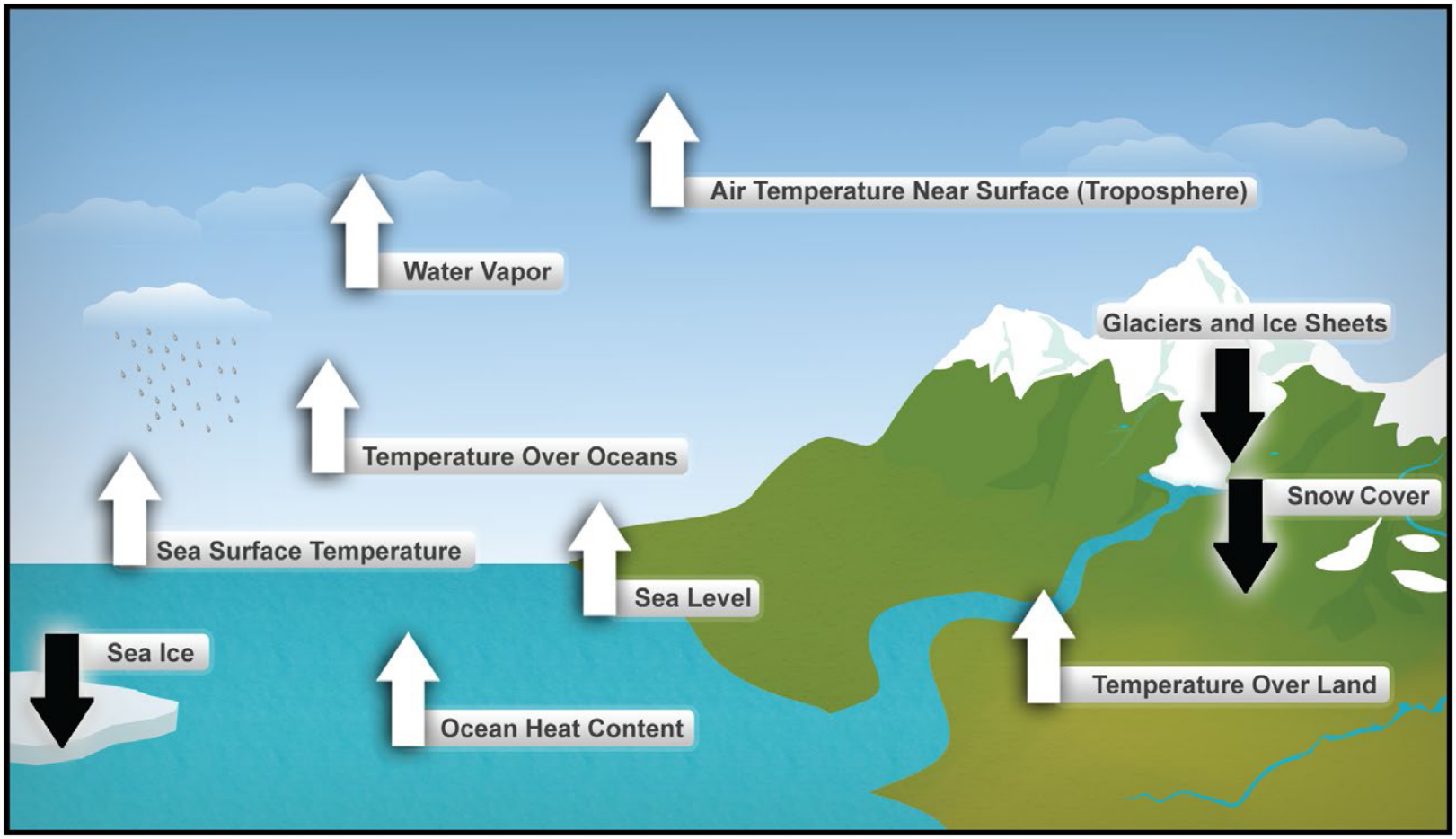
- **Water Demand/Use Changes:** **Observed, projected.**
  - **Freshwater withdrawals from streams, rivers, lakes, and aquifers (off-stream water uses):** Municipal, industrial, and agricultural water supply; Cooling of re-circulating power plants
  - **In-stream, lake, and wetland water flows, levels, and quality:** Hydropower production; Cooling of once-through power plants, Navigation, Recreation, Waste assimilation, Ecosystem services.

- **Key Water Resources Vulnerabilities.**

- **Management, Adaptation, and Institutional Responses.**

Indicators of a Warming World

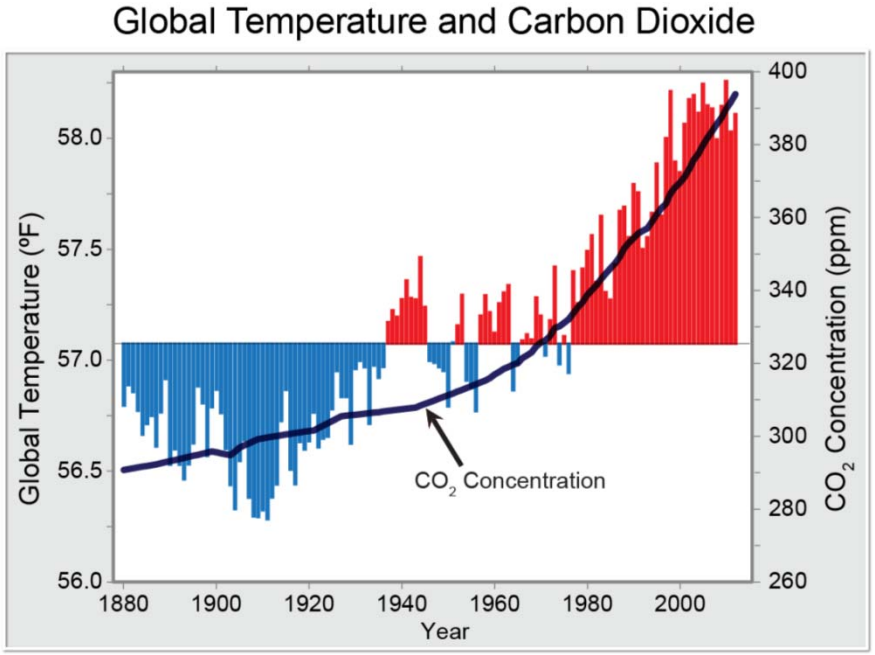
3rd NCA, Climate Chapter

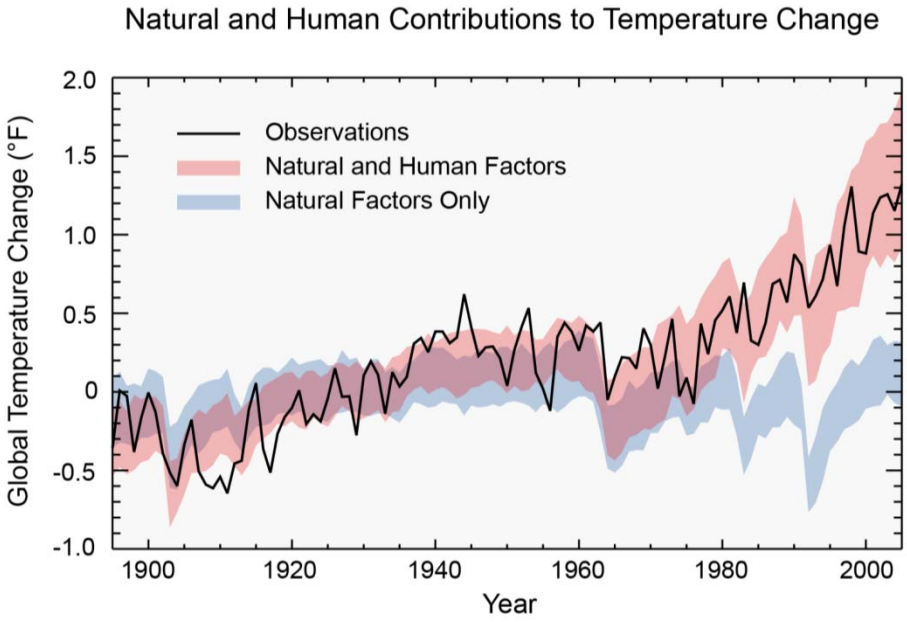


- **Key indicators measured globally over many decades consistently show that the Earth's climate is warming.**

Global Temperature Change and Attribution

3rd NCA, Climate Chapter





- **Global temperature increases are highly unusual in recent decades.**
- **2000-2009 was the warmest decade in at least 1300 years.**

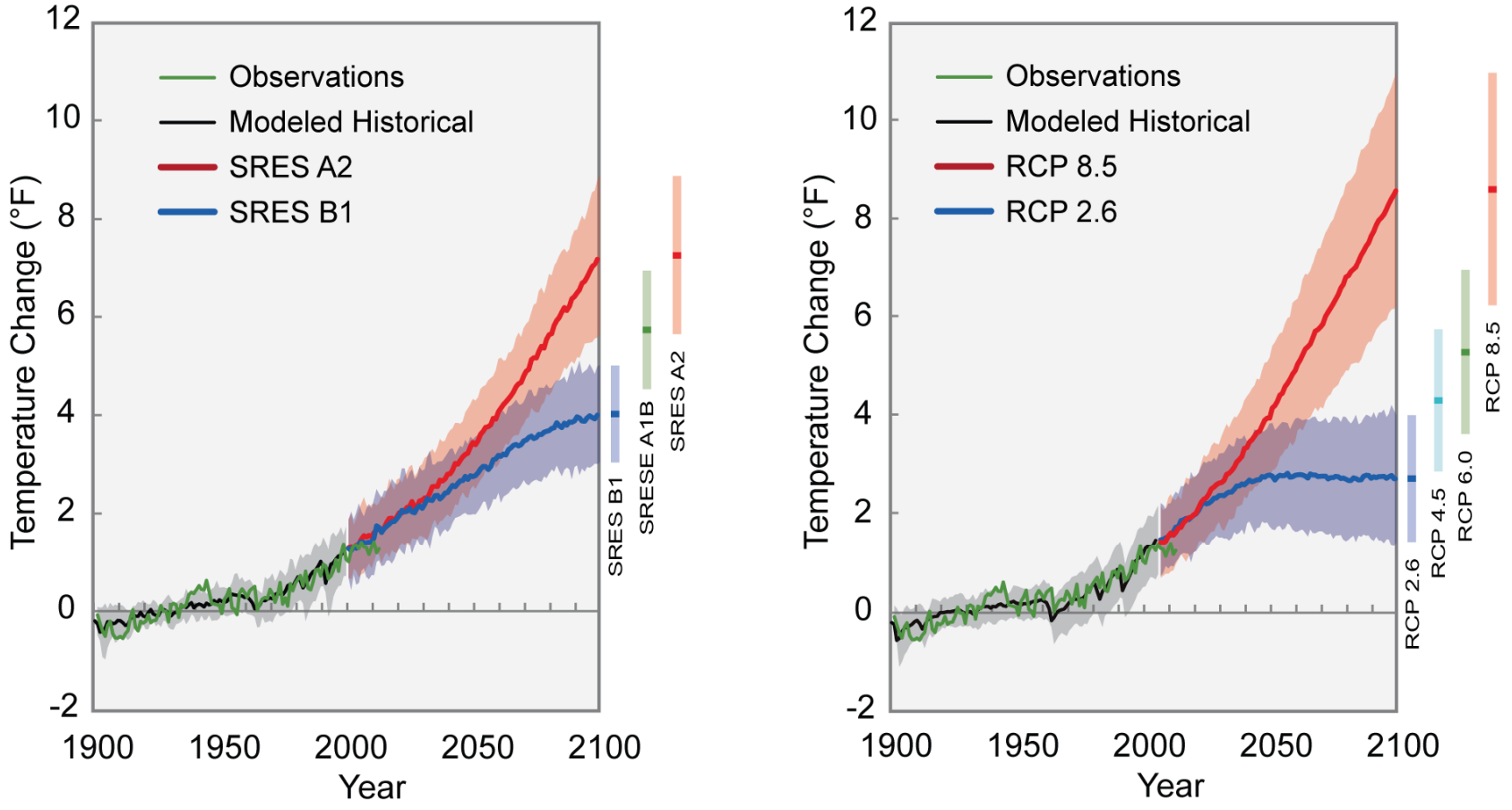
- **Natural factors (solar forcing, volcanoes) cannot explain warming.**
- **Changes are consistent with human-caused emissions.**
- **Models reproduce warming only when emissions are included.**

Global Temperature

3rd NCA, Climate Chapter

Observed and Projected Global Temperature Change

[Relative to 1901-1960 Avg.]



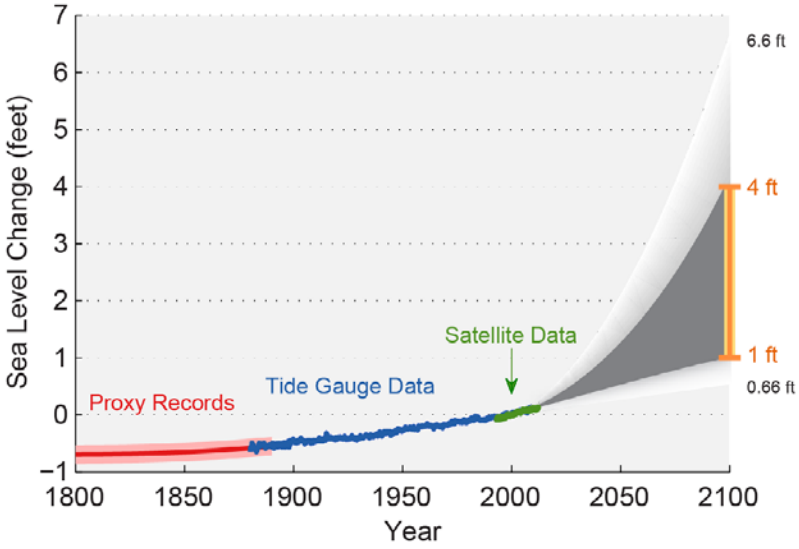
- **Global temperatures are projected to increase by 2.5 ºF (RCP 2.6) to 8 ºF (RCP 8.5) by the end of the century.**

Global Sea Level Rise

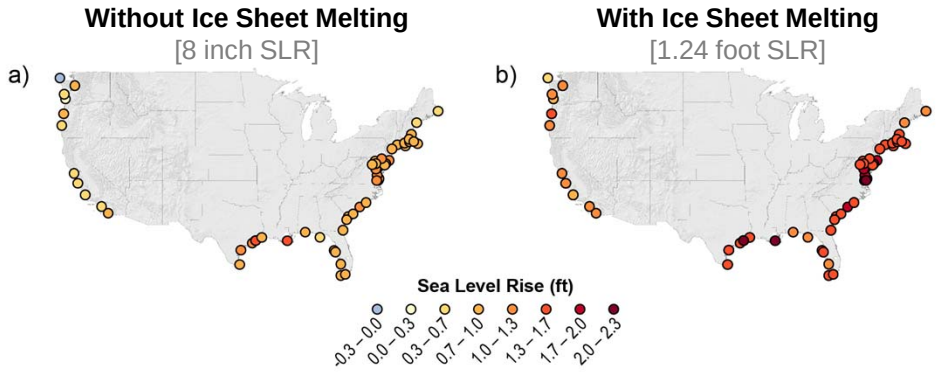
3rd NCA, Climate and Coastal Chapters

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

Estimated, Observed, Projected Sea Level Rise



Projected SLR and US Flooding by 2050

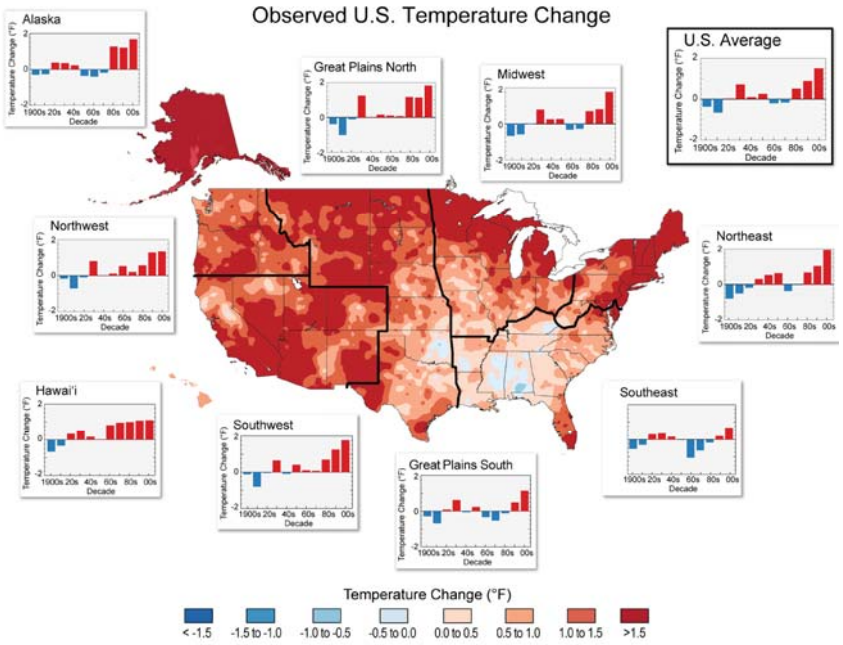


- **Sea level has risen by 8 inches since 1880, and it is projected to increase by 1 to 4 feet by 2100.**
- **SLR has critical flooding implications for many US coastal regions with up to 2 feet SLR by 2050.**

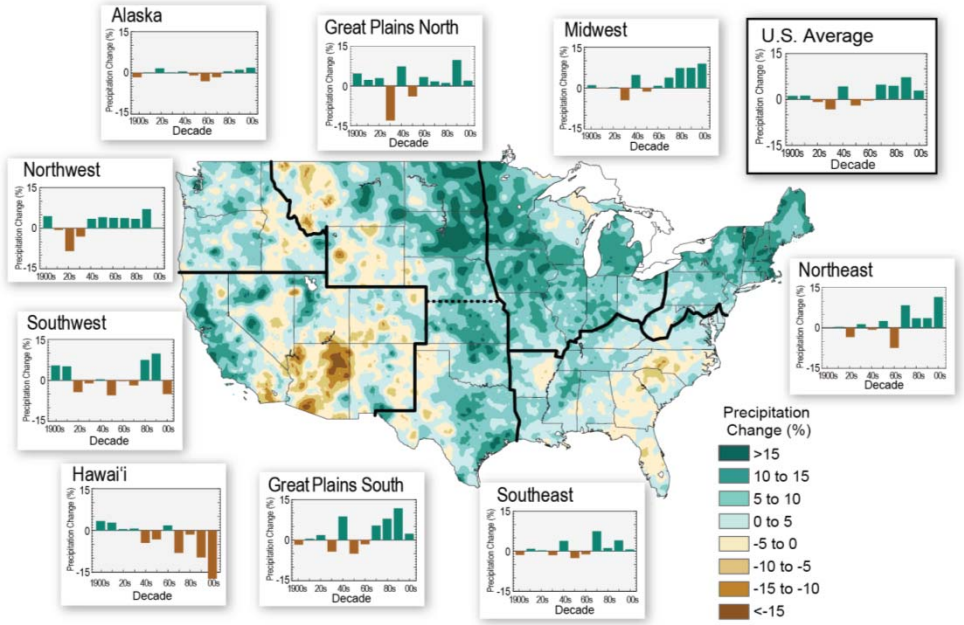
Observed U.S. Temperature and Precipitation Change

3rd NCA, Climate Chapter

Temperature Change
[1991-2012 Relative to 1901-1960]



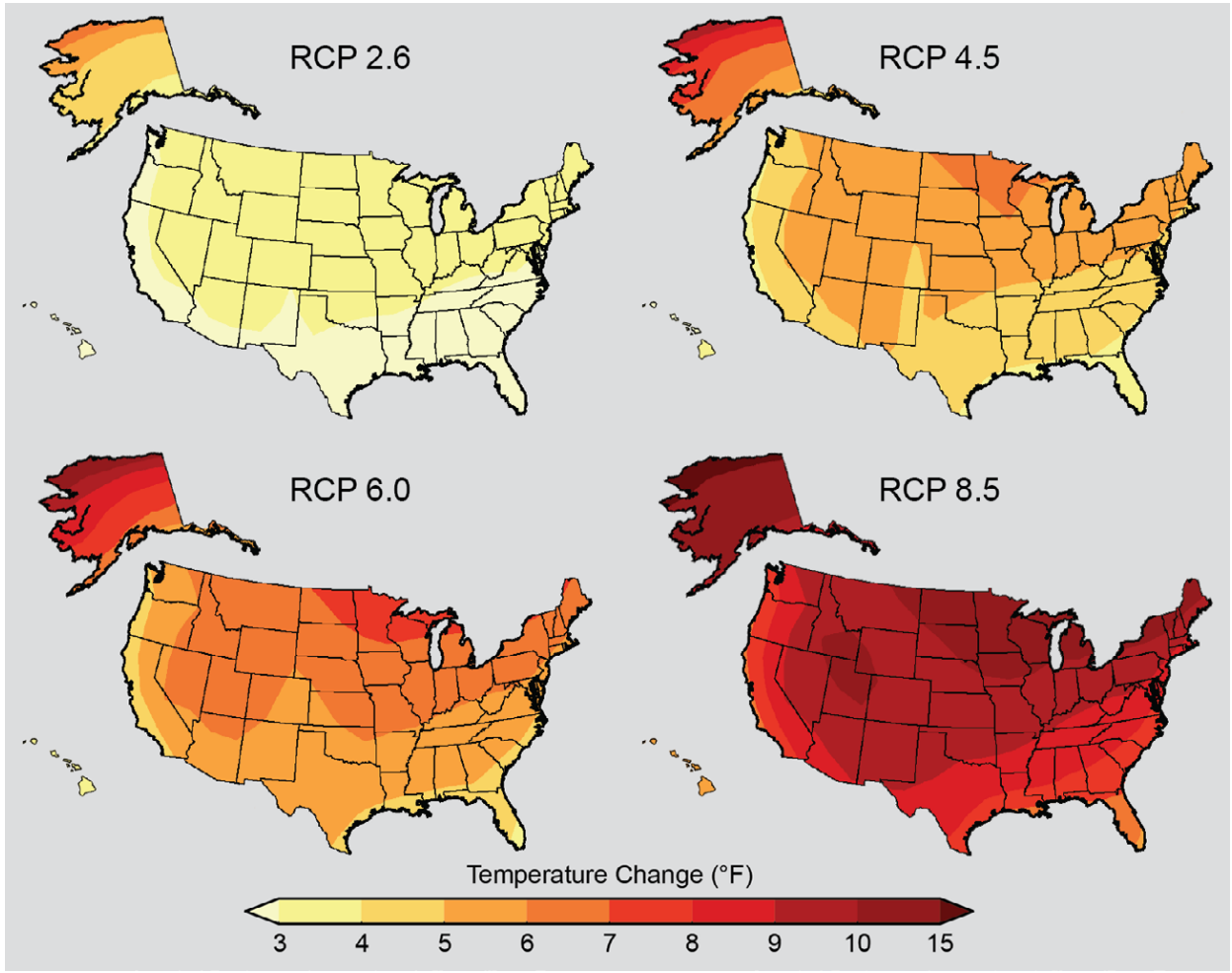
Precipitation Change
[1991-2012 Relative to 1901-1960]



- **Recent decades are warmer in every US region.**
- **2001 to 2012 was warmer than any previous decade in every region.**
- **Most US regions experience wetter conditions (0.16 inches / decade).**

U.S. Temperature Projections

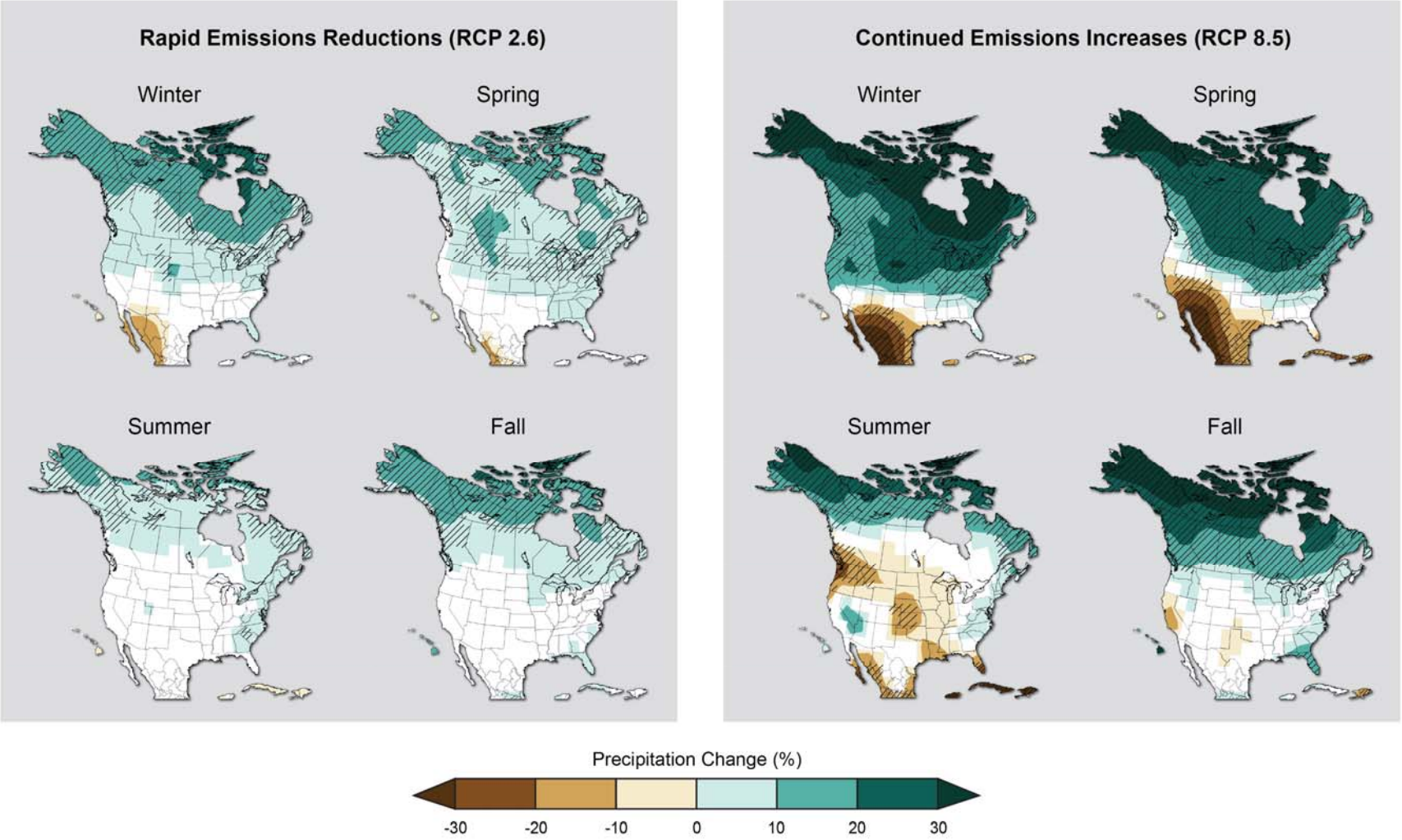
3rd NCA, Climate Chapter



- **US temperature projections indicate consistent warming in the coming decades across all models in the range 3 to 10 °F.**
- **Projected temperature increase is higher than model-to-model range.**

U.S. Precipitation Projections

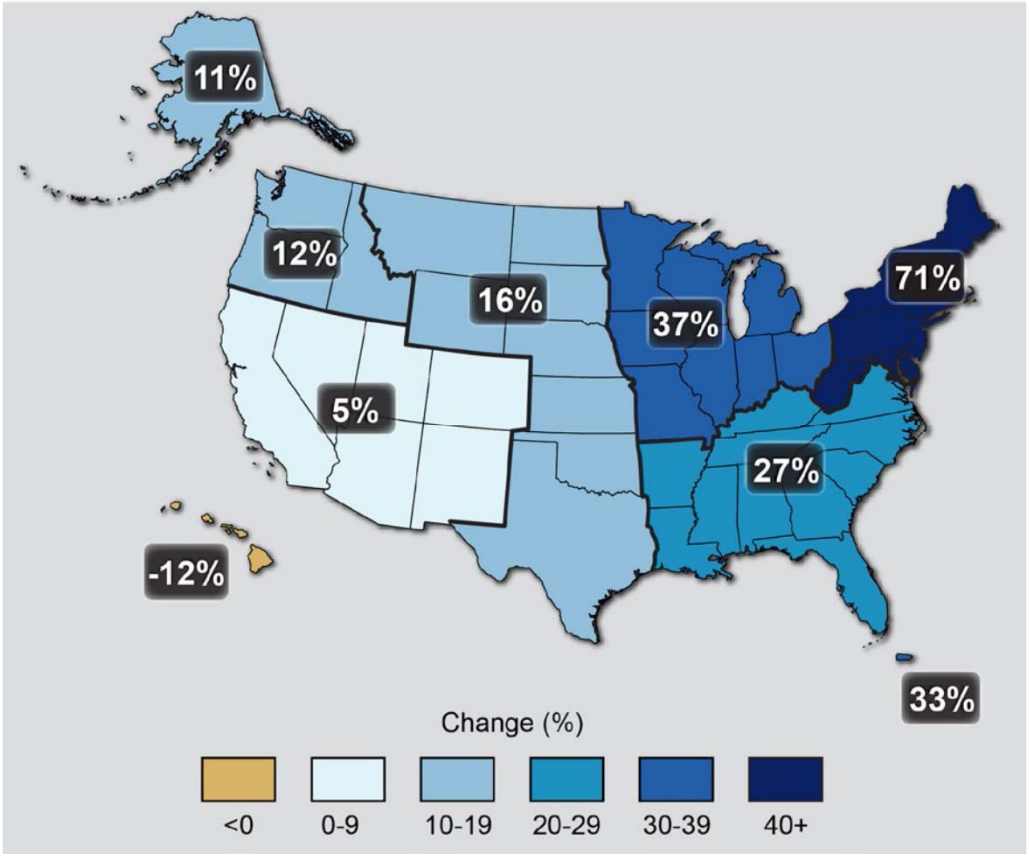
3rd NCA, Climate Chapter



- Con. US in the transition zone between drier subtropics and wetter north.
- Precipitation projections show consistent spring **reductions** in the Southwest and **increases** in the Northeast, Midwest, and Alaska.
- **Dry spells** are expected to increase in most regions.

Very Heavy Precipitation Change [1958-2012]

3rd NCA, Climate Chapter



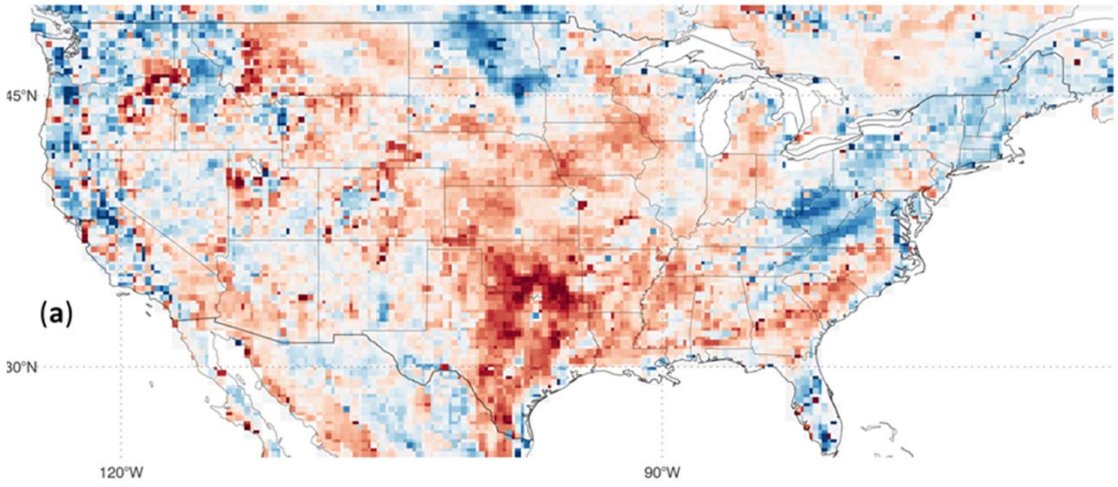
- **Very heavy precipitation** [1% of all daily events] **has increased** and is **expected to increase further** in all US regions.
- Events with 1:20 year frequencies are expected to occur 1:15 to 1:5 by 2100.
- Trends are larger than natural variations for Northeast, Midwest, Southeast, Great Plains, Alaska, and Puerto Rico.

Soil Moisture Trends [1988-2012]

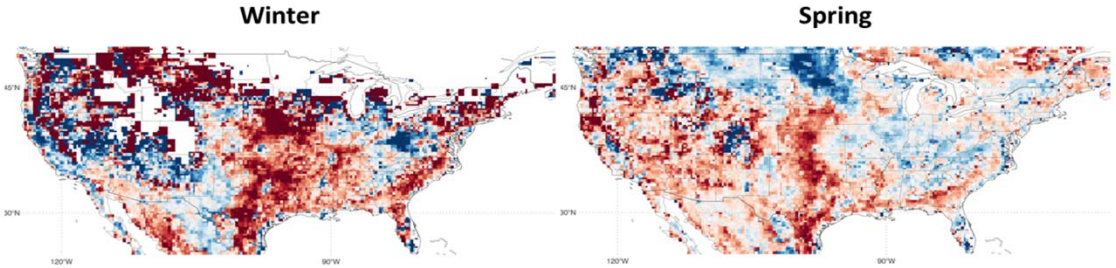
3rd NCA Water Chapter

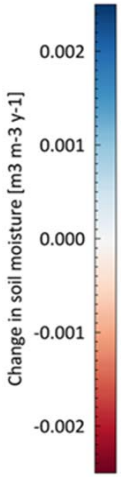
U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

Annual

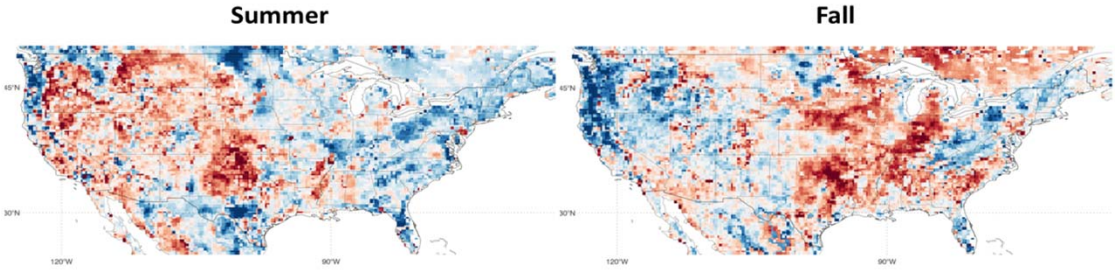


[Dorigo et al., 2012]





Seasonal



- **Annual surface soil moisture changes: Drying trends in many US regions.**
- **Seasonal changes: Potential impacts on streamflow, flooding, GW recharge, and agriculture.**

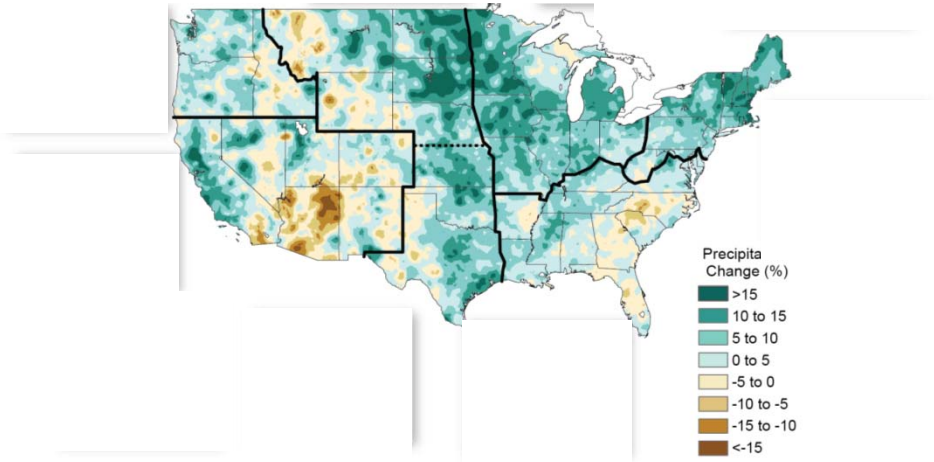
Evapotranspiration
3rd NCA Water Chapter

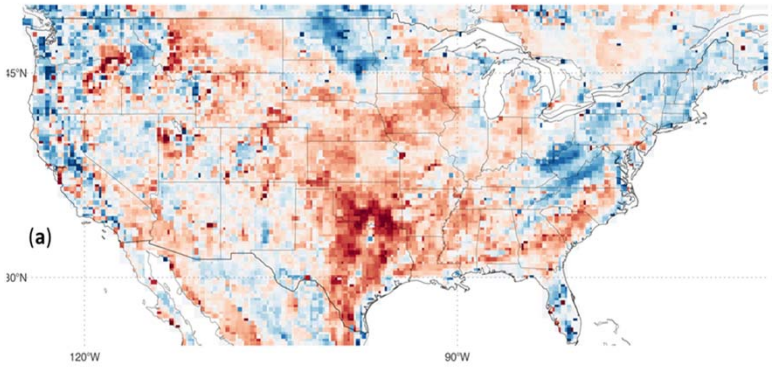
U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

- Second largest component of the water cycle, after precipitation.
- Regulates soil moisture, groundwater recharge, and runoff.
- Transpiration ~ 80-90% of total ET on land.
- Depends on temperature, solar energy, winds, humidity, and moisture availability.

- Regional ET estimation and projections are uncertain.

- Potential ET is expected to increase with temperature.
- Actual ET will depend on regional soil moisture changes.



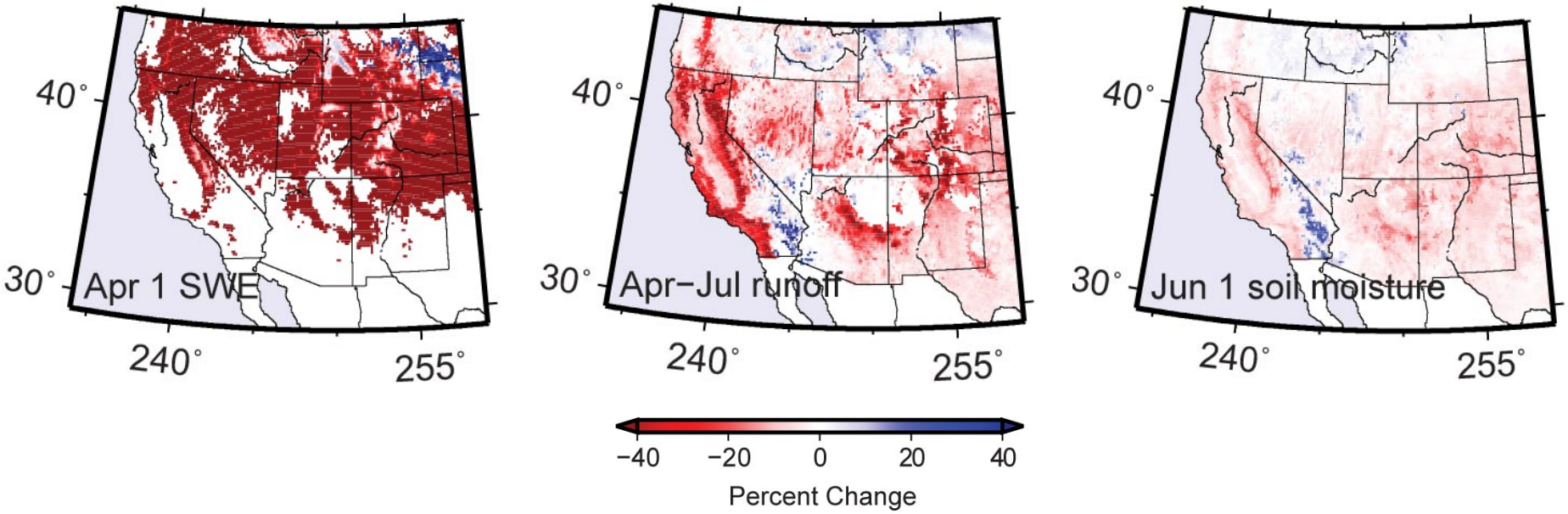


Projected Changes in SWE, Runoff, & Soil Moisture

3rd NCA Water Chapter

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

SWE | **Runoff** | **Soil Moisture**

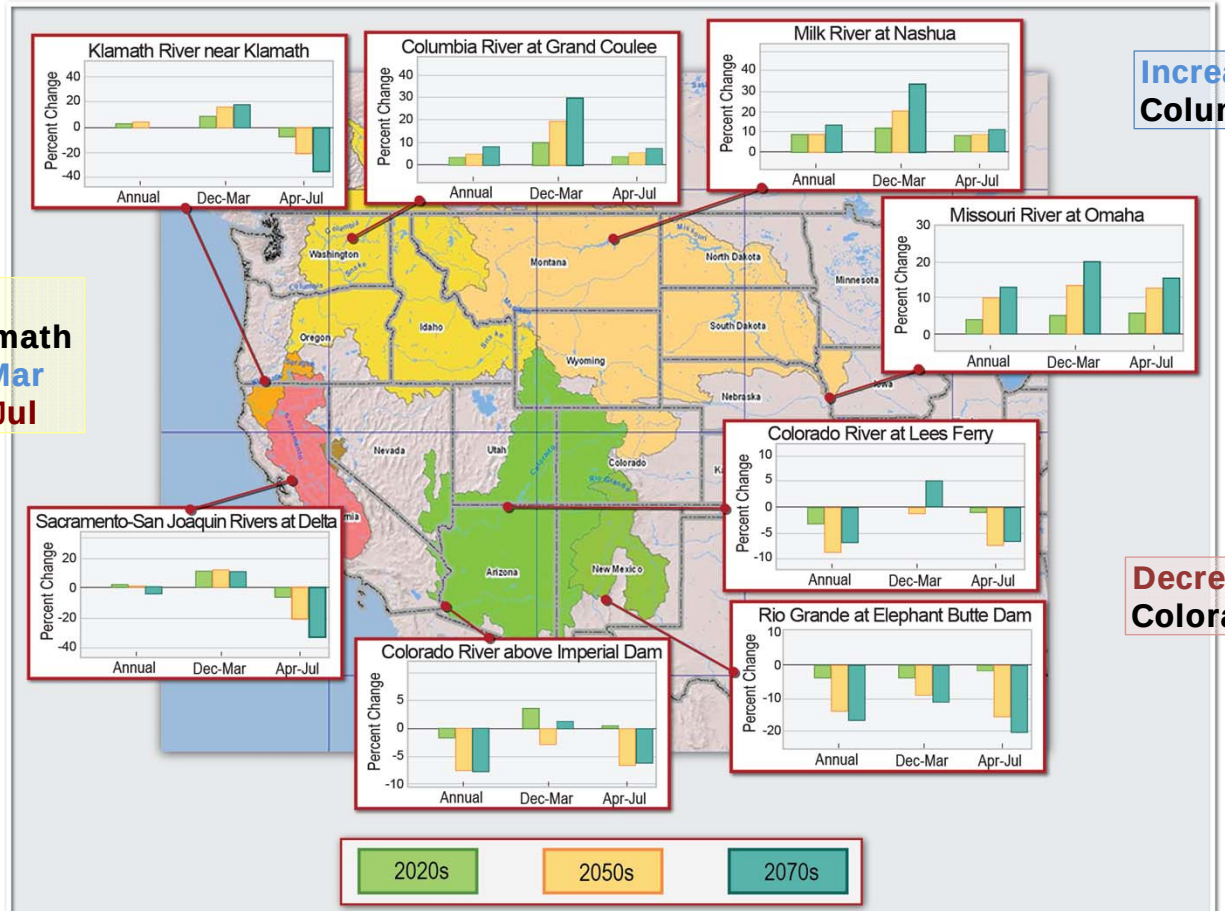


Projected [A2] Changes for 2041-2070 as Percent from 1971-2000 [Cayan et al., 2013]

- Projections indicate
  - **major losses in snowpack** water content (SWE);
  - **significant reductions in runoff** in California, Arizona, central Rockies;
  - **reductions in soil moisture** across the Southwest.

Projected Streamflow Changes [Western US]
3rd NCA Water Chapter

Mixed Response:
Sacramento, Klamath
Increases: Dec - Mar
Decreases: Apr - Jul



Increases:
Columbia, Missouri

Decreases:
Colorado, Rio Grande

Changes Relative to 1990s; Ensemble of emission scenarios and GCMs

US Bureau of Reclamation, 2011

- **Streamflow increases are observed and projected in northern states.**
- **Streamflow decreases are observed and projected in southern states.**
- **Flow peaks occur earlier due to earlier snowmelt, declines of spring snowpack, and more rain than snow. Increases in cold season, decreases in warm season.**
- **By 2070, projected changes exceed historical variability.**

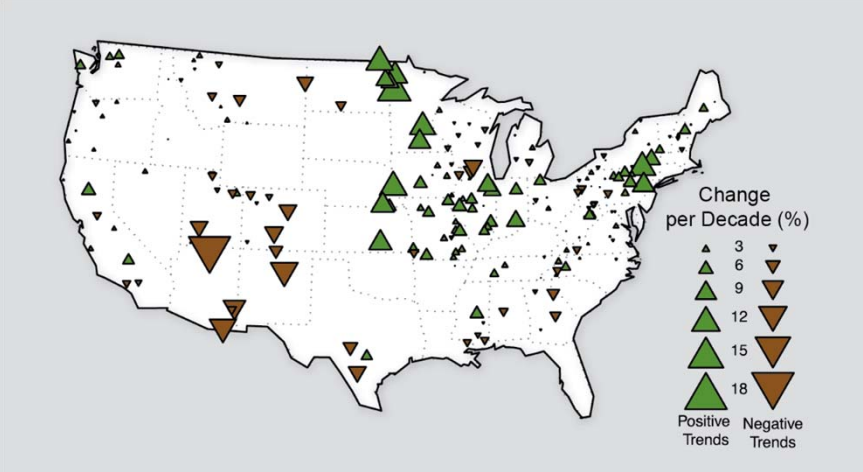
Flood Types and Expected Trends
3rd NCA Water Chapter

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

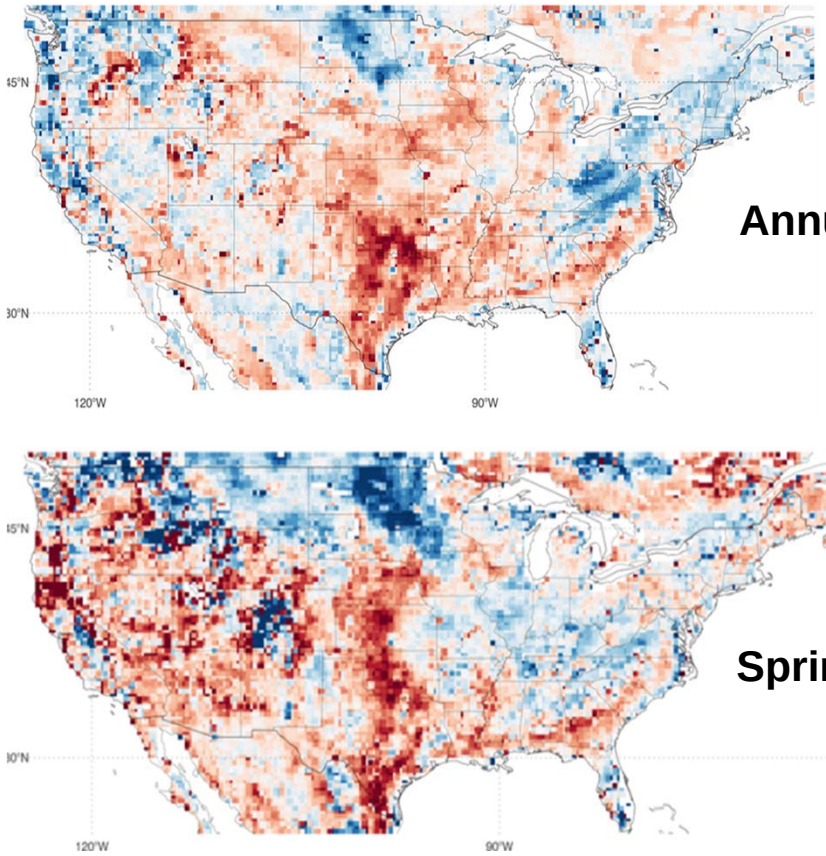
- **Flash and Urban Flooding: Expected to Increase.**
- **Riverine Flooding: Uncertain, as it depends on several factors [**basin size, spatial precipitation structure, soil moisture, time of year, snow cover, land use, terrain, etc.**]**
- **Coastal Flooding: Expected to increase in many coastal areas.**

- **Floods threaten lives and disrupt critical infrastructure.**
- **In the US, from 1959 to 2005, floods caused 4,585 deaths and property and crop damage averaging 8.22 billion dollars per year [Ashley and Ashley, 2008 , NOAA 2013].**

Flood Magnitude Trends [1920 – 2008]
3rd NCA Water Chapter



Peterson et al., 2013



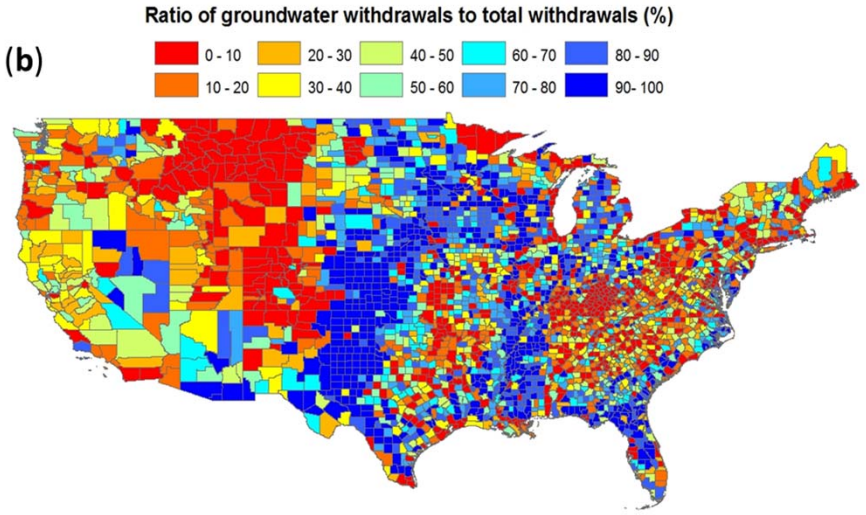
Dorigo et al., 2012

- Significant increasing trends in Midwest and Northeast.
- Significant decreasing trends in Southwest.
- Local flooding trends and projections depend on many factors.

Groundwater Availability
3rd NCA Water Chapter

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

Principal U.S. Groundwater Aquifers

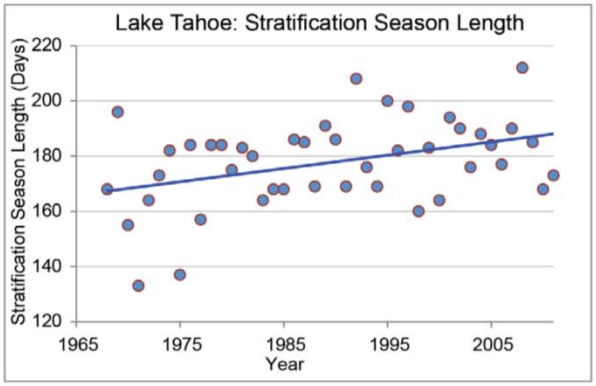


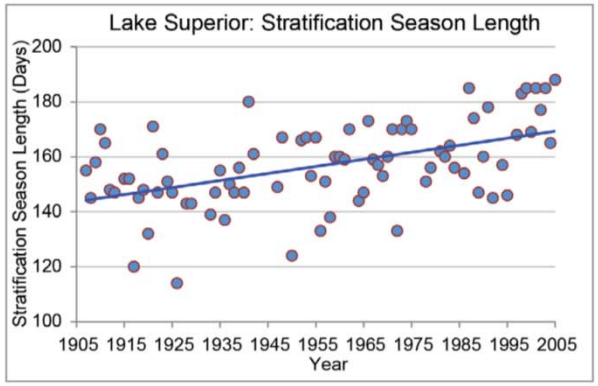
- **Groundwater is the main water supply source for many US regions. [Great Plains, Mississippi Valley, east central US, Great Lakes region, Florida, etc.]**
- **GW provides buffer against droughts.**
- **GW is susceptible to the combined stresses of climate change (slow to manifest) and water use changes (more immediate impacts).**
- **Climate change impacts depend on several factors [geology, frequency and intensity of rainfall, seasonal timing of recharge events, GW-SW interactions, etc.]**
- **Coastal aquifers are vulnerable to inland droughts/floods, increased withdrawals, and SLR.**
- **GW is poorly monitored; Need for national groundwater monitoring framework.**

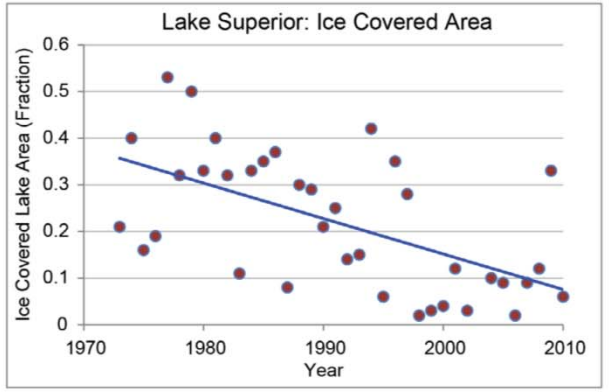
Impacts on Water Quality
3rd NCA Water Chapter

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

- **Increasing air and water temperatures, more intense precipitation and runoff, and intensifying droughts can decrease water quality.**







Climate change is expected to impact several water quality factors:

- Water temperature
- Sediment generation and transport
- Nutrient concentrations and residence times
- Algal blooms and oxygen conditions
- Contaminant loads

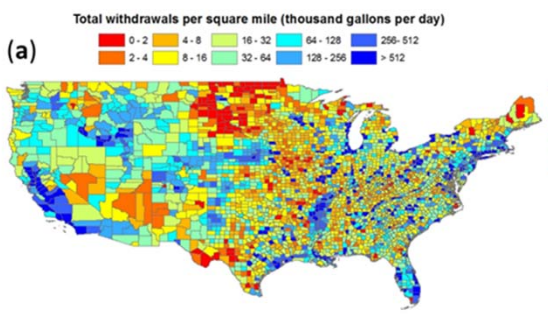
Strategies aiming to reduce sediment, nutrient, and contaminant loads at the source remain the most effective management responses.

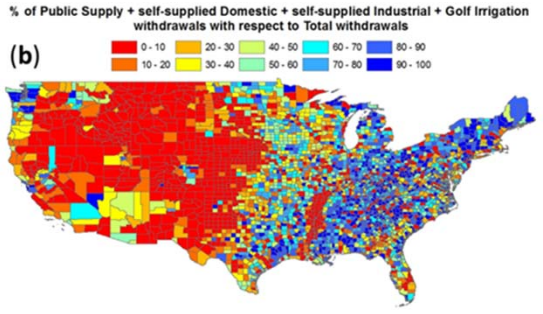
Current Water Use [Withdrawals]
3rd NCA Water Chapter

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

USGS, 2005

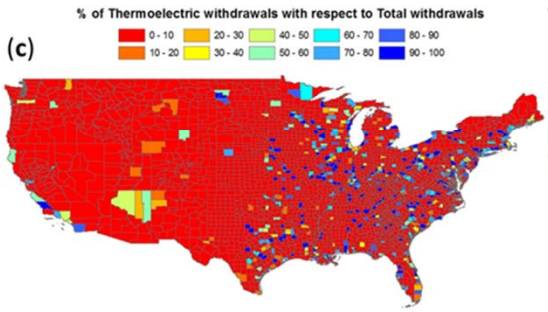
Total/sqmi
1000 g/d

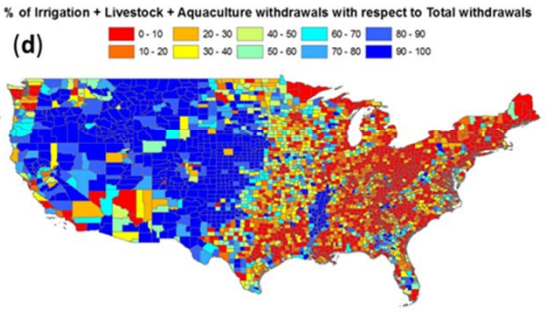




M&I/Total %

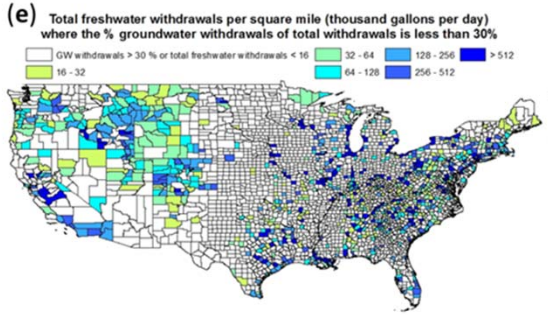
Thermo/Total %

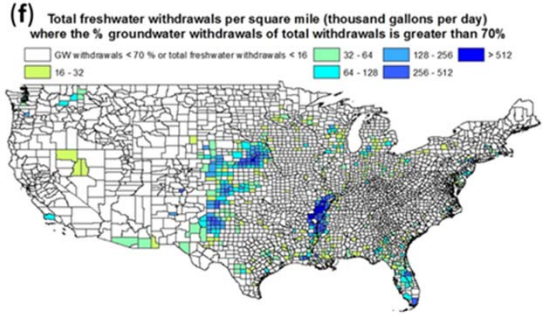




Irr-Liv-Aqu/Total %

Primarily SW

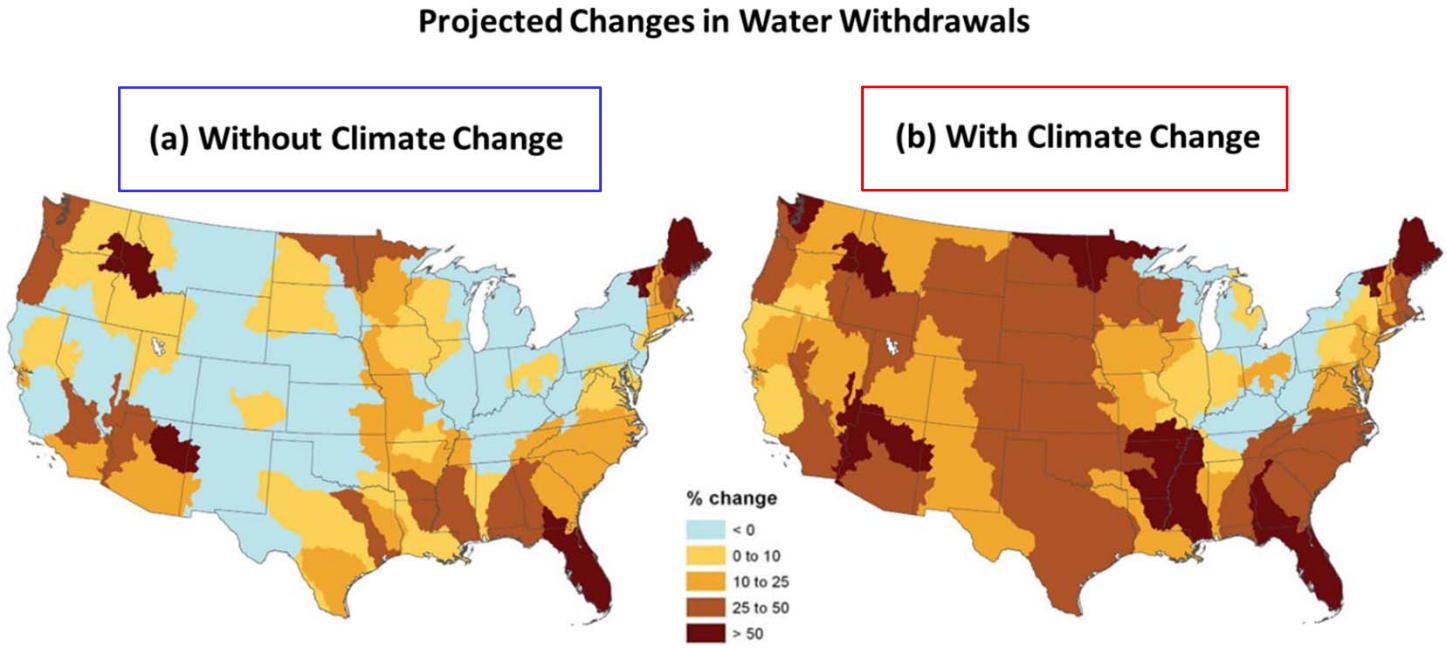




Primarily GW

- Largest withdrawals occur in the drier western states for crop irrigation.
- In the east, water withdrawals mainly serve municipal, industrial, and thermoelectric uses.
- Groundwater withdrawals are intense in parts of the SE, SW, NW, GPs, Miss. Valley, FL, GA.

Projected Water Use Withdrawals
3rd NCA Water Chapter



Brown et al. 2013

- **Water demand is projected to increase substantially across the US.**

(a) Projected water demand change (%) from 2005 to 2060 assuming change in population and socioeconomic conditions consistent with the A1B emissions scenario, but with *no change in climate*.

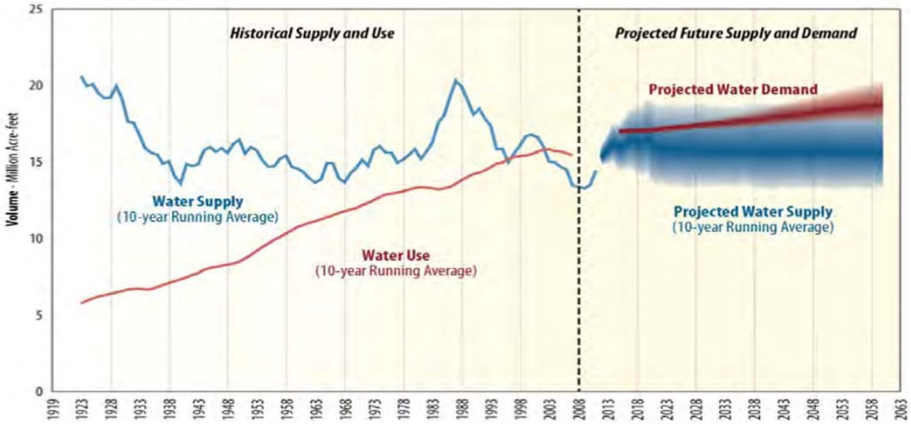
(b) Projected water demand change (%) due to combined changes in population, socioeconomic conditions, *and* climate change consistent with the A1B emissions scenario.

Climate Change Impacts on Water Management
3rd NCA Water Chapter

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

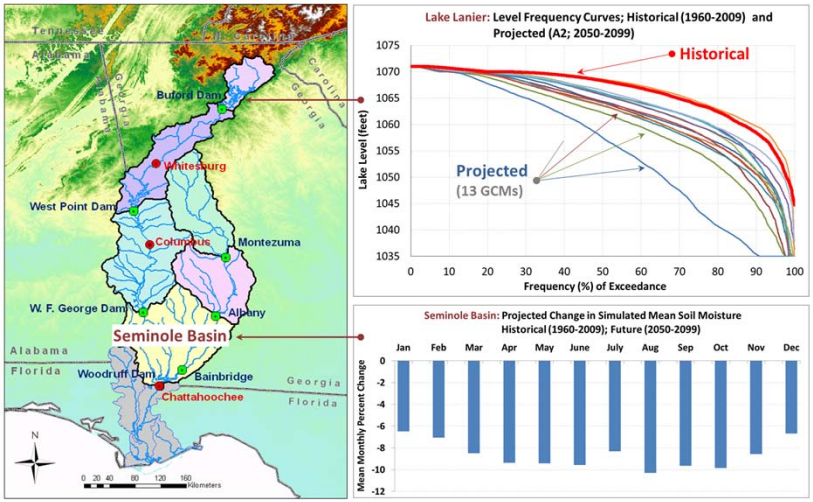
- **Water resources managers will encounter new risks that may not be managed with existing practices** [California, Southwest, Southeast, Northwest, Great Plains, Great Lakes, etc.].

Historical and Projected Water Supply and Demand for the Colorado River Basin



- **Median water demand exceeds supply by 3.2 MAF by 2060.**
  [Colorado River Basin WS&D Study, USBR 2012]

Projected Hydrologic and Water Resources Impacts for the ACF River Basin



- **Runoff has been and is projected to decrease** [Reservoir Mgt/WS/Env Impacts].
- **Soil moisture has been and is projected to decrease, esp. in summer** [Impacts for Ag.]
- **Droughts and floods projected to intensify.**
  [Georgakakos and Zhang, 2011]

- **Increasing resilience and enhancing adaptive capacity provide opportunities to strengthen water resource management and planning for climate impacts.**
- **Effective climate adaptation strategies may include: Conservation programs; more flexible, risk-based, and adaptive operating rules for reservoirs; integrated SW-GW mgt; better monitoring and assessment of statewide water use; more effective engagement of all relevant stakeholders.**

Water Resources: Priority Research Areas

U.S. Global Change Research Program
National Climate Assessment
Georgakakos-Fleming

- Develop more specific ***regional*** information about soil moisture, groundwater recharge and storage, and evapotranspiration, and their role in the hydrologic cycle and water supply availability.

- Understand how hydrological drivers of water supply interact with changing patterns of water demand and evolving water management practices to increase risks of drought, or influence the effectiveness of adaptation options.

- Support risk-based decision approaches, including more effective means to communicate interactions of multiple stresses and levels of scientific confidence and uncertainty.

- Research alternative institutional strategies to support integrated management, including possible revisions to legal codes and policy practices.

- Provide scenario-based guidance to stakeholders to understand climate variability and change in the near- and longer-term in order to support them in their decisions and policies.

- Develop indicators that allow for timely reporting and enhanced public understanding of climate change impacts, including abrupt changes and extreme events.

Questions

Thank you

Aris Georgakakos, Georgia Institute of Technology
Aris.Georgakakos@ce.gatech.edu

Paul Fleming, Seattle Public Utilities Paul.Fleming@seattle.gov

NCA: http://nca2014.globalchange.gov/
NCAnet: http://ncanet.usgcrp.gov/home
Indicators: http://www.globalchange.gov/what-we-do/assessment/indicators