Balancing on a Rollercoaster:
Water Policy and Planning in a Changing Climate

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Water UCI

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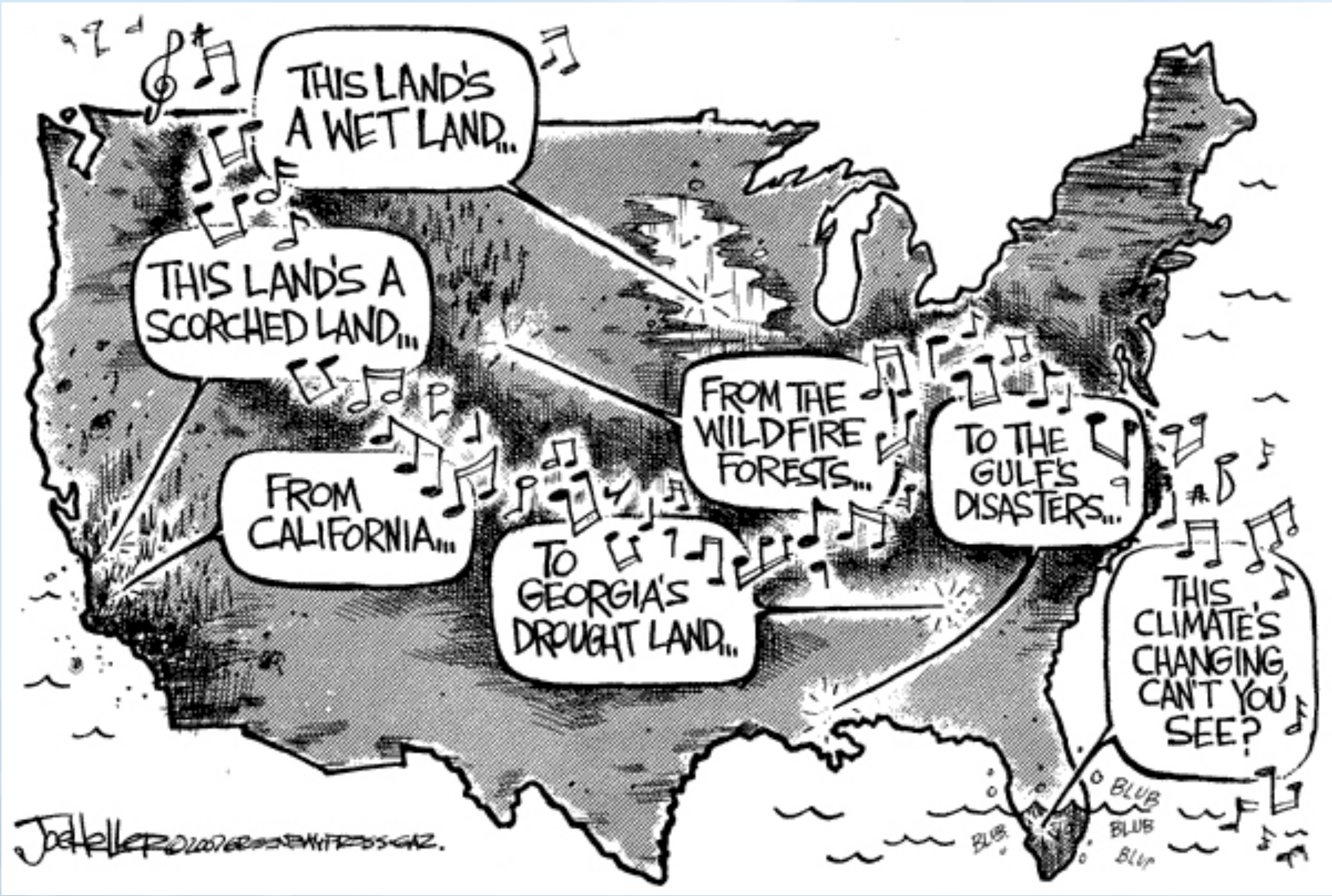
NCAR

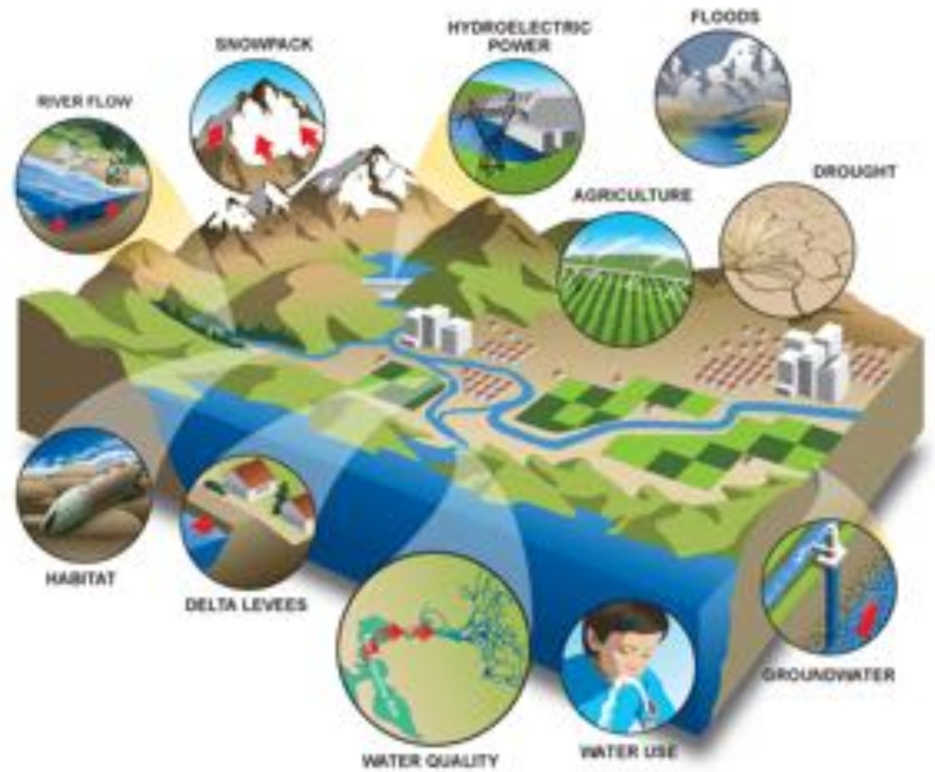
Both Globally and Close to Home …

Changes in the water cycle will play a central role in determining how climate change will affect human well-being and sustainability of natural systems



The Balancing Problem

- Water is characterized by a web of interconnected uses and values
- Governance arrangements: rights, responsibilities, process
- Resilience depends on decisions made by:
  - individuals
  - private organizations
  - governmental units from local to international scales

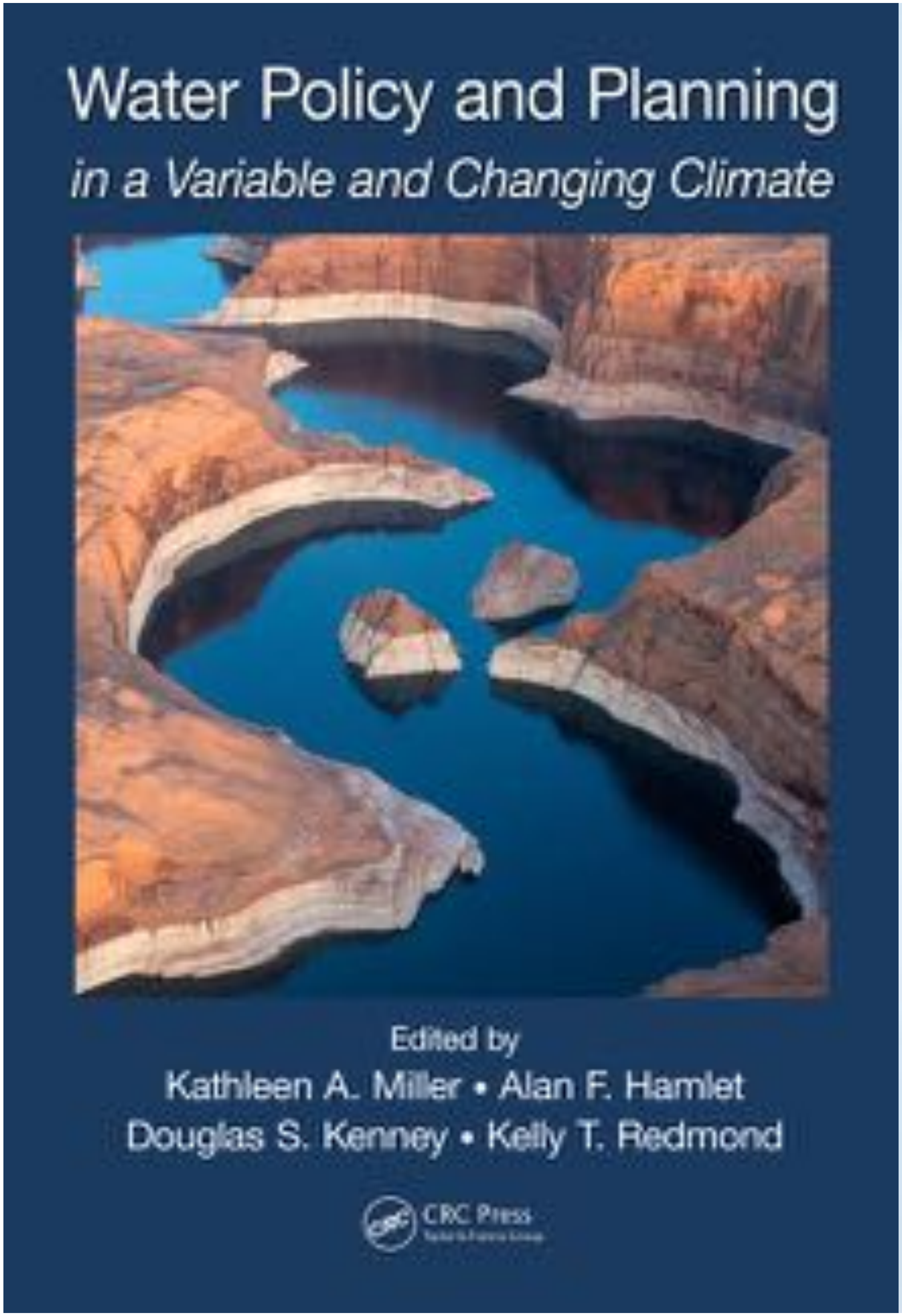


Source: California DWR

Some pressing policy issues

- How can we preserve viable populations of threatened or endangered water-dependent species as summer flows decline & water temperatures rise?
- What is the best way to ensure reliable urban and agricultural water supplies as seasonal flow regimes change & drought risks change?
- How can communities improve their flood resilience in response to projected increases in heavy runoff events?
- Who should bear the costs / enjoy benefits of policy changes?

Addressing water challenges – requires mutual understanding and collaboration between the science and policy communities



A Bridging Resource

Goal: promote collaboration & effective use of science information to address water resource challenges

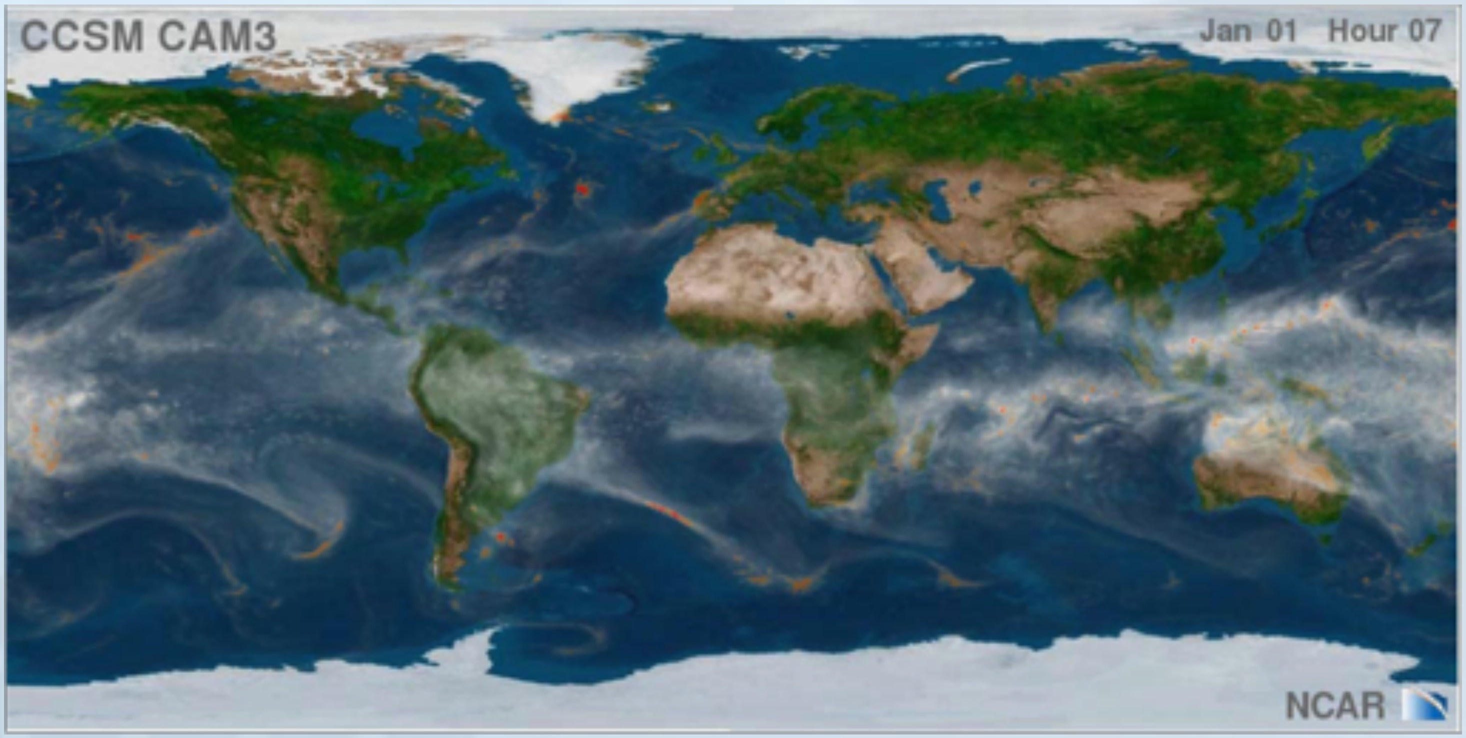
What do participants in water policy processes need to understand about climate science?

Science is a process of discovery, not a repository of unchanging “truth”——

Uncertainty does not mean that climate change risks are not real

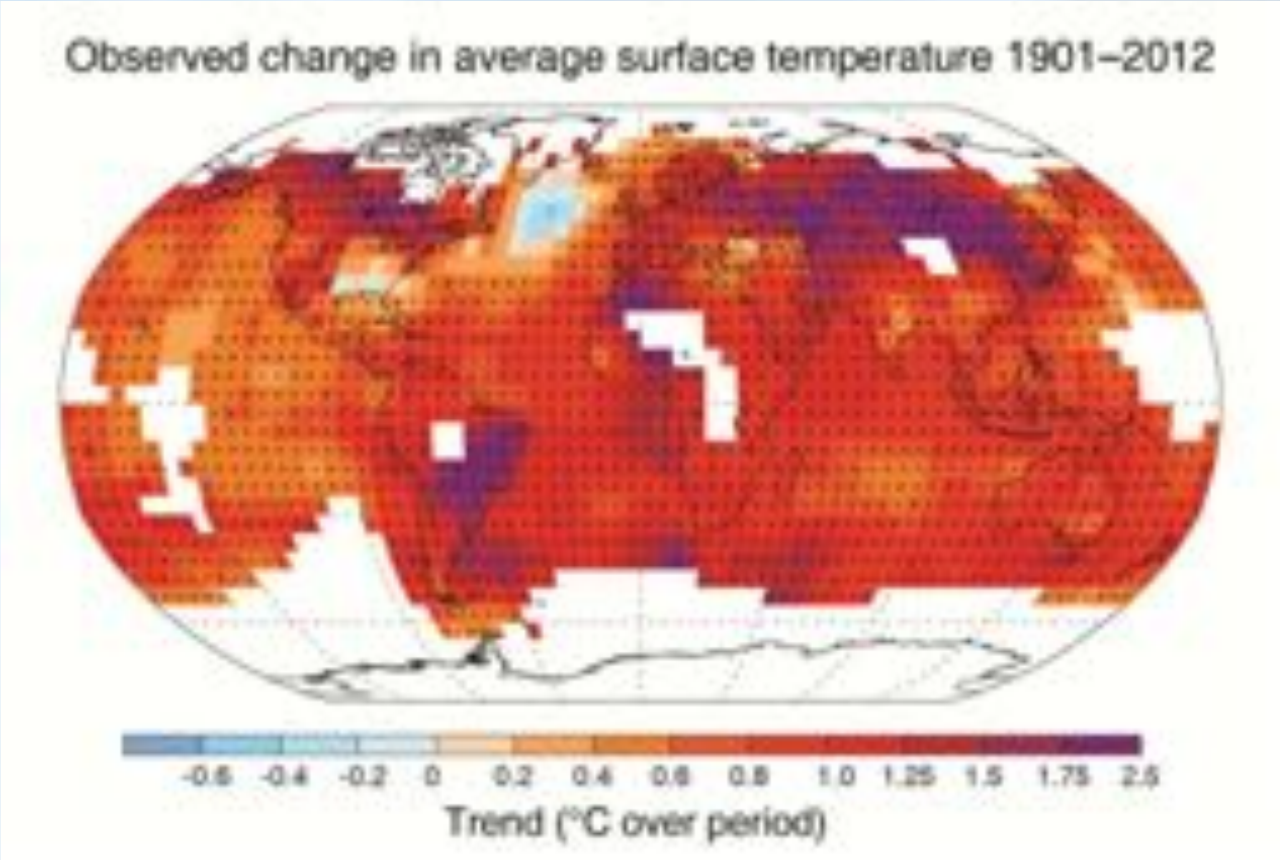
Cutting through the confusion

- Focus on the long term
- Recognize the complexity of the climate system
- Understand the science behind the projections
- Rely on systematic analysis of multiple lines of evidence



What do we know?

- Greenhouse gas concentrations are increasing
- Earth's climate has warmed & warming will continue
- Impacts on natural systems and human activities are inevitable



Warming accelerates the hydrologic cycle

Surface temperature

Evaporation

Water holding capacity

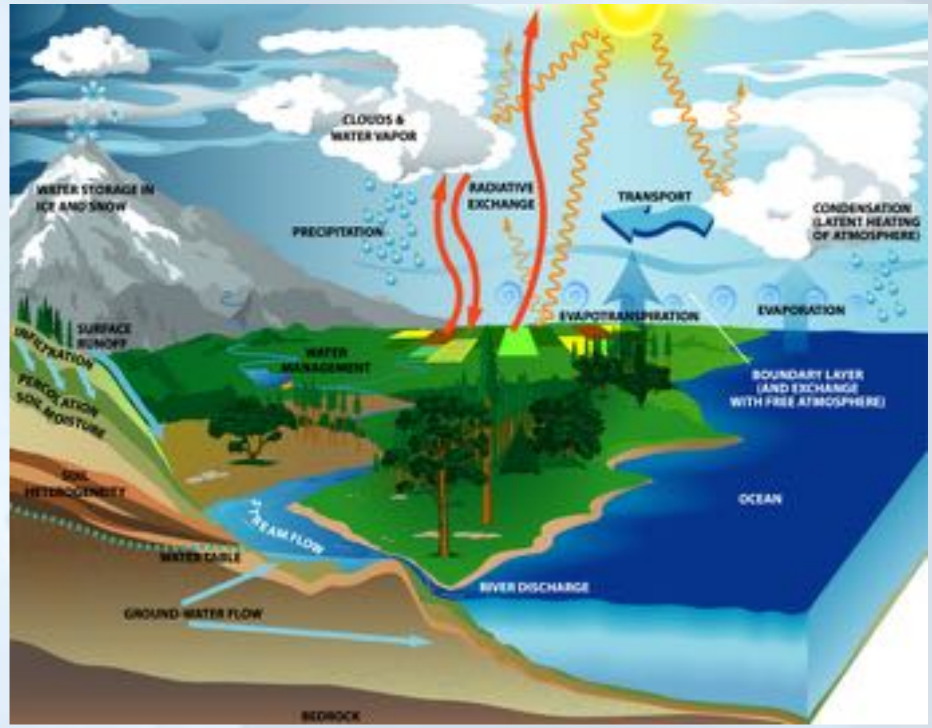
Atmospheric moisture

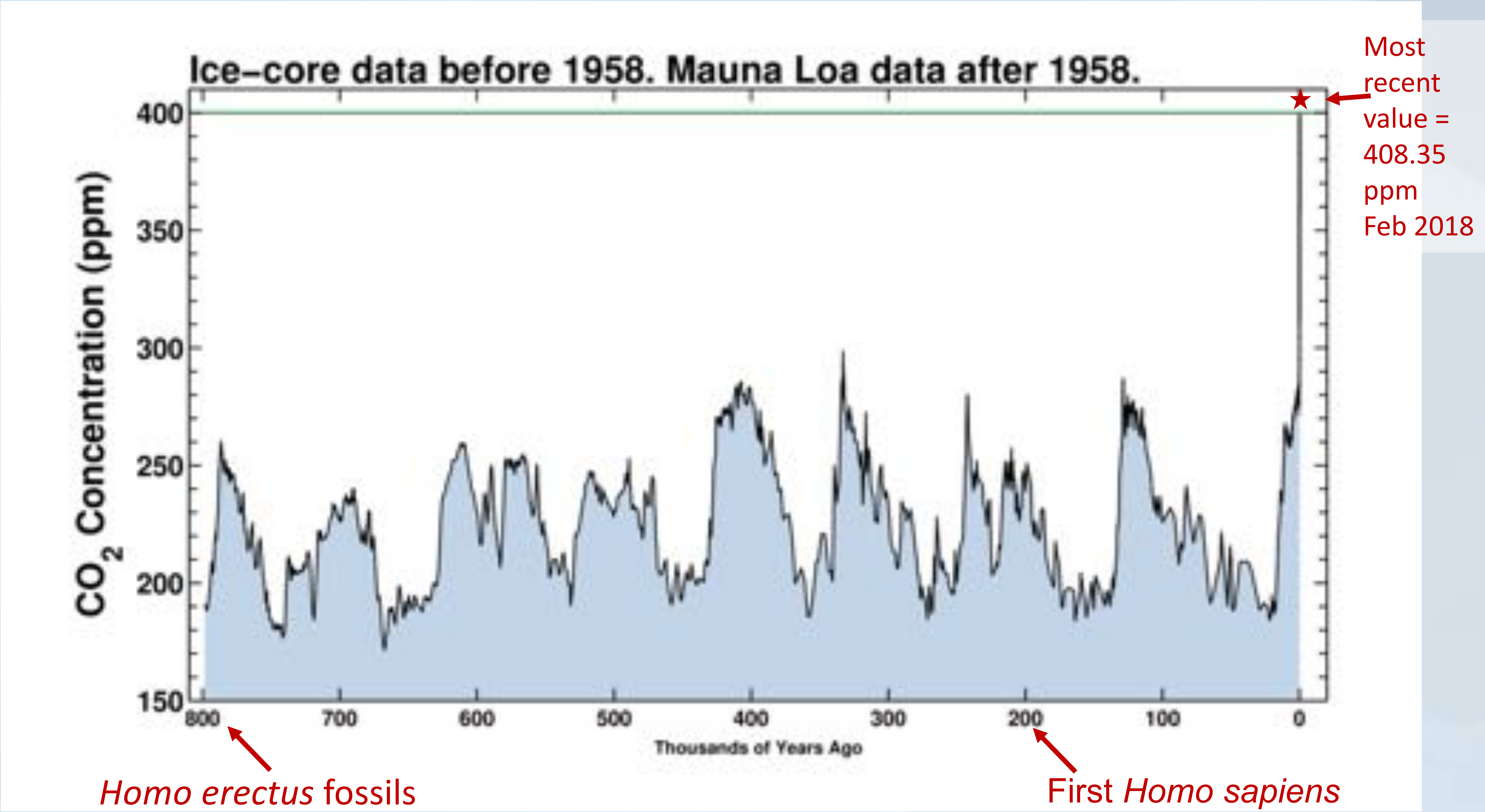
Enhanced Greenhouse

Rain intensity

Rain frequency ?

Floods & Droughts

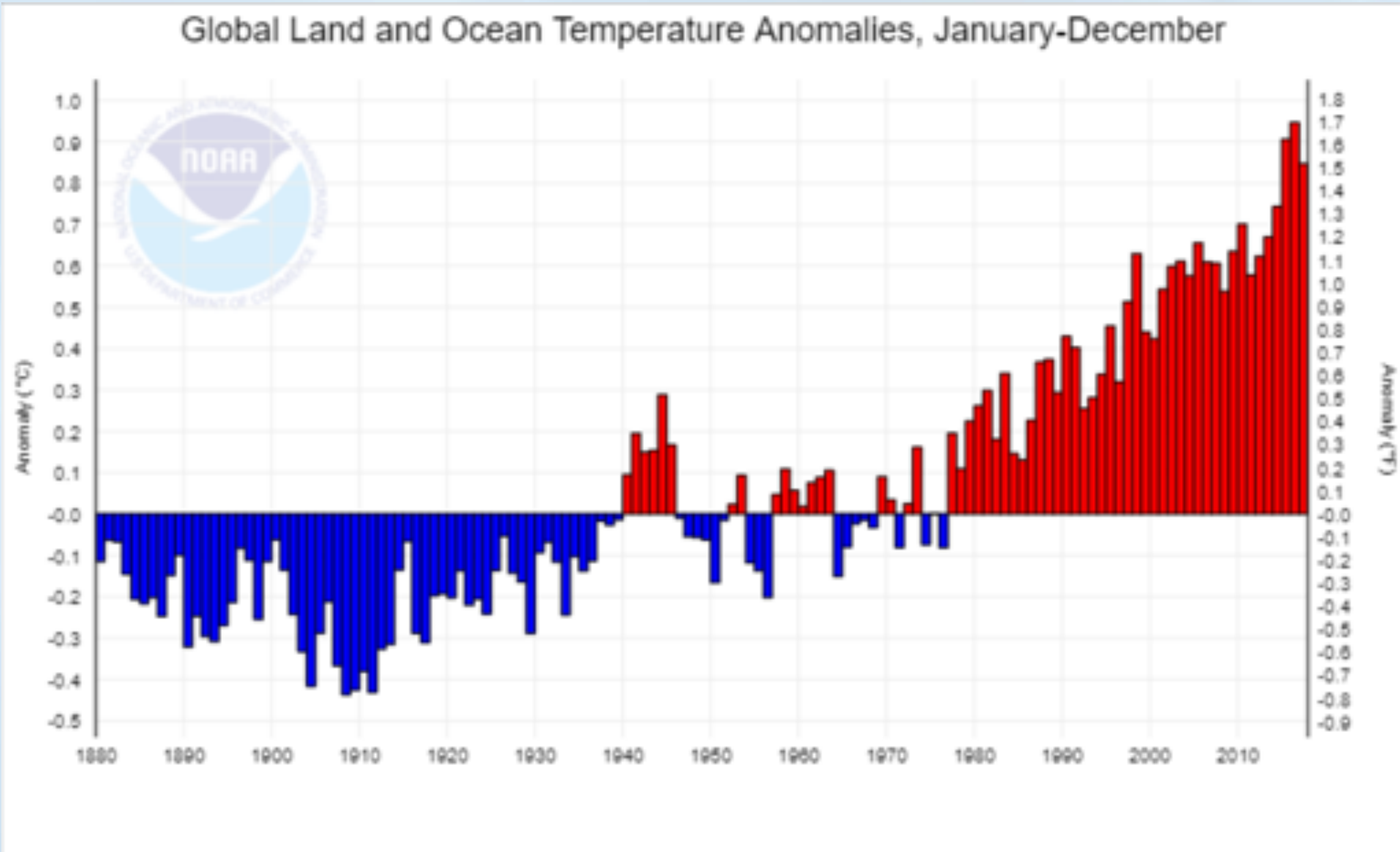




Atmospheric CO_2 concentrations over the past 800,000 years

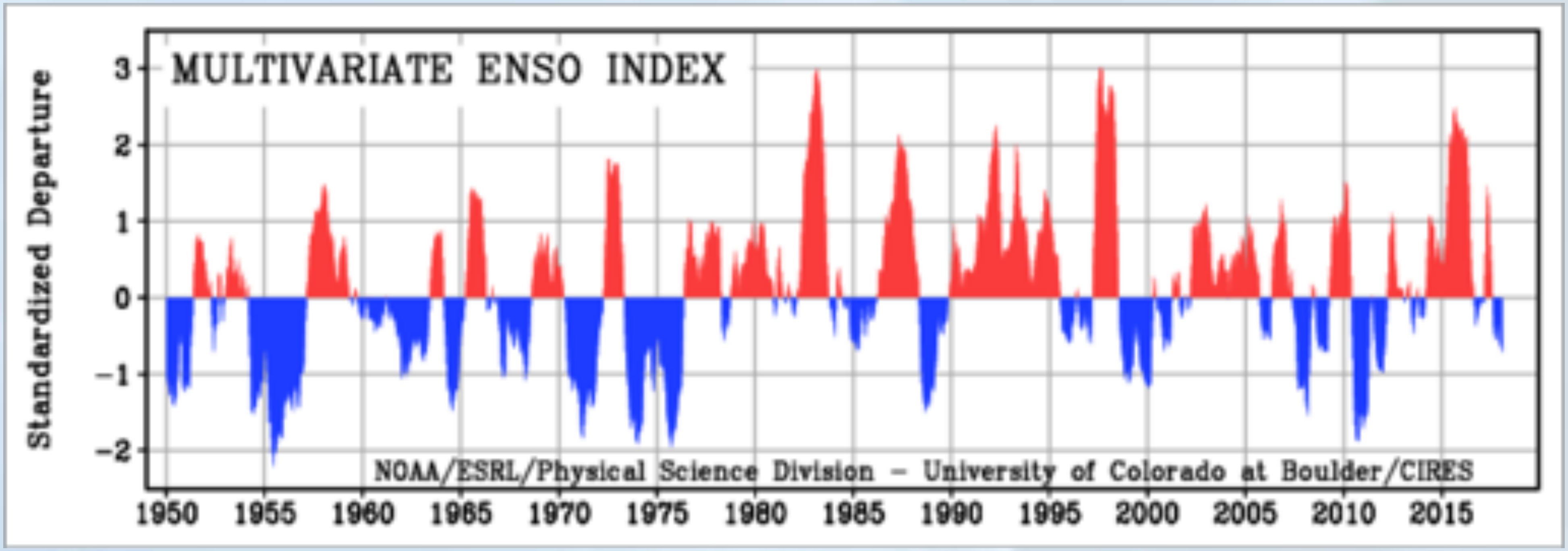
Source: Adapted from Scripps Institution of Oceanography & Smithsonian Institution

Difference relative to 20th Century average.



In 2017, the average temperature across global land and ocean surfaces was 0.85°C (1.53°F) above the 20th century average. The 22 warmest years on record have all occurred in the last 23 years – The past 4 years have been the warmest on record.

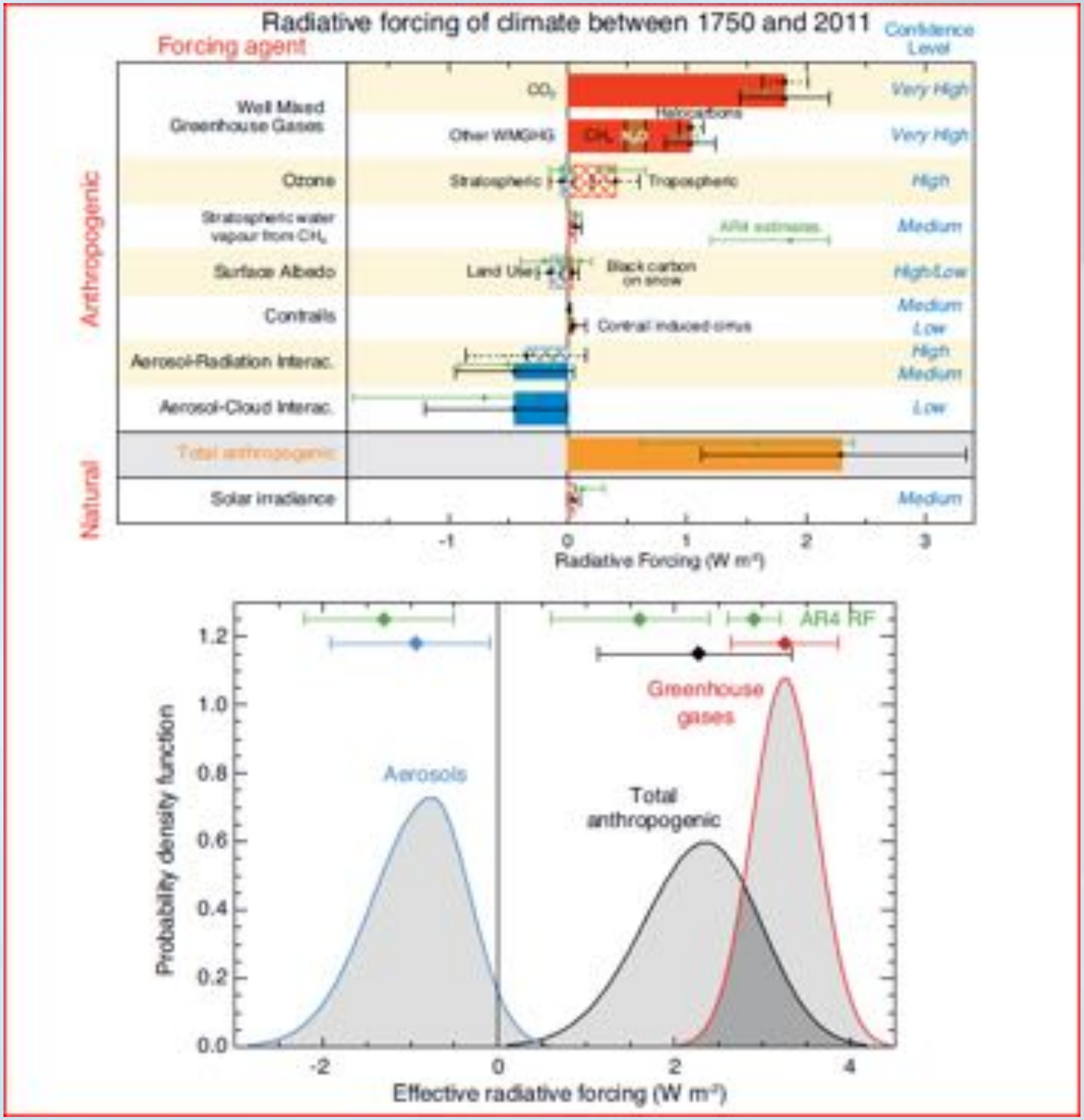
El Niño affects, but does not explain the observed warming



Updated March 7, 2018

Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.

[IPCC AR5 WG1 Summary for Policy Makers: September 2013]

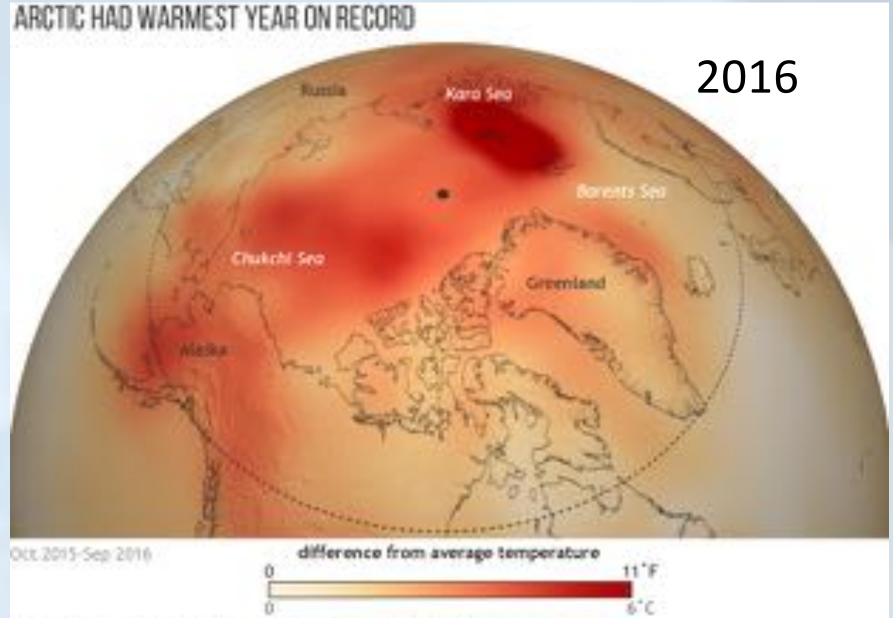


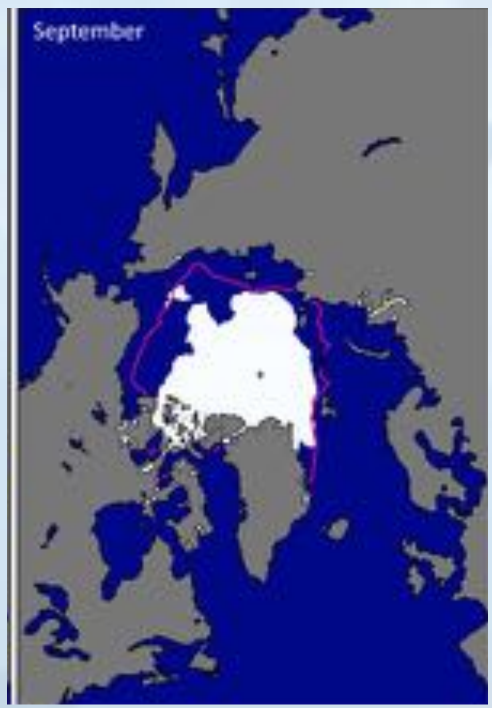
Arctic Warming is accelerating

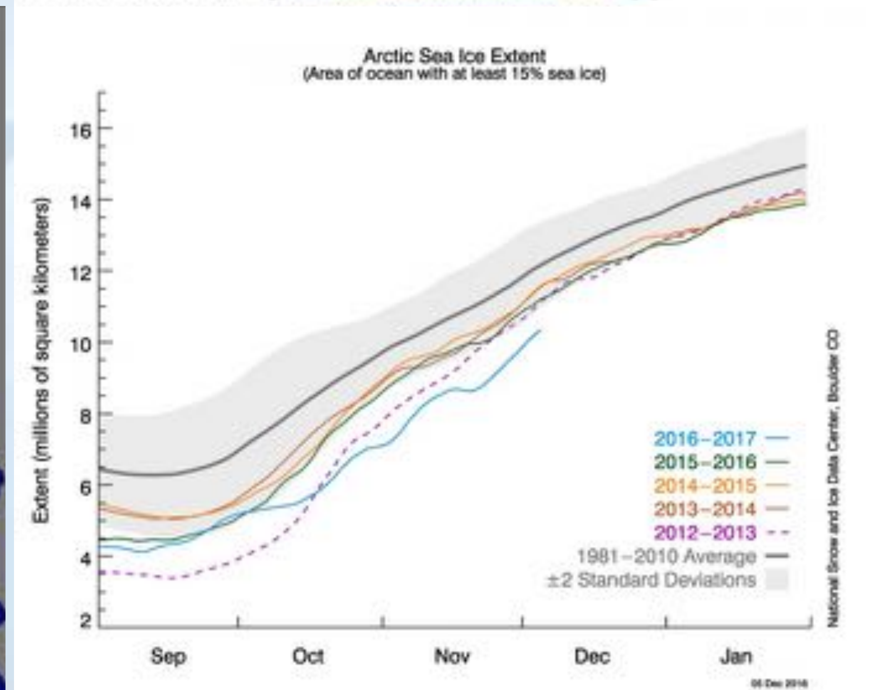
Darker surface reflects less energy back to space ⟶ positive feedback

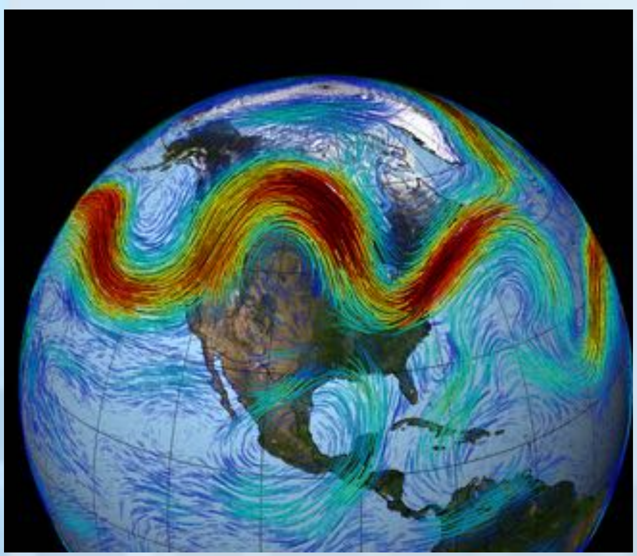
Warming affects circulation patterns – deep loops in jetstream

Loss of land-based ice is contributing to sea-level rise

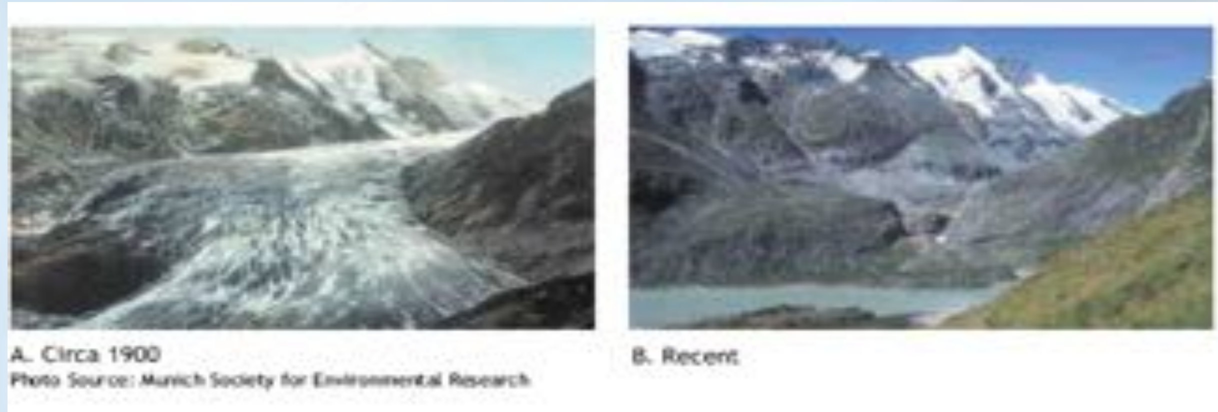




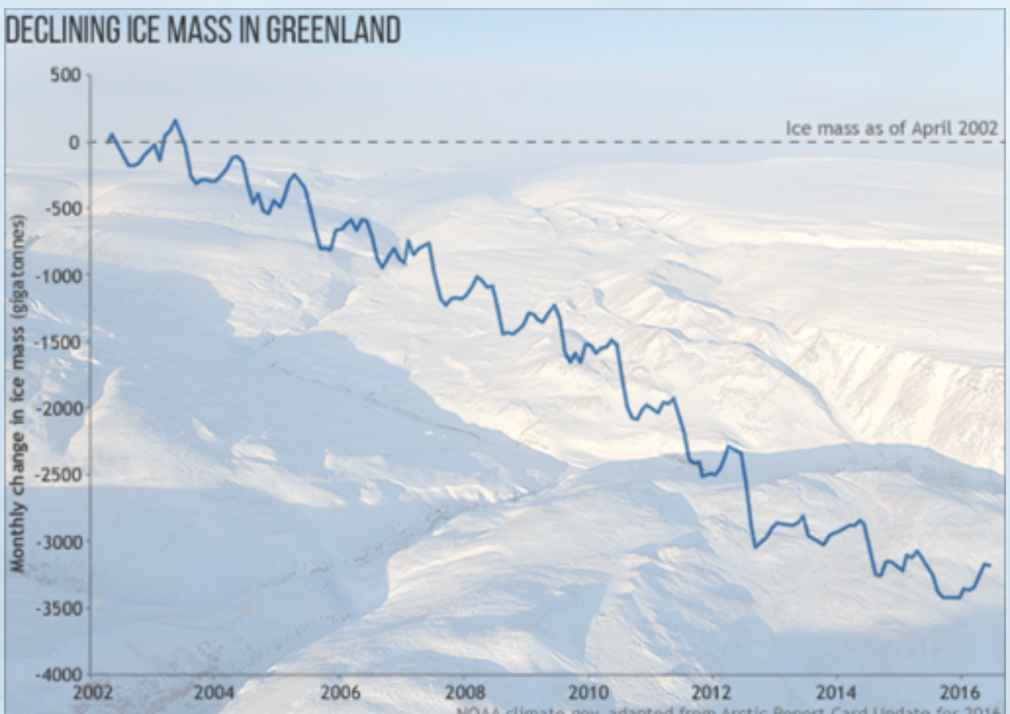




Declining Snow & Ice



1900 Alpine glacier, Austria 2003

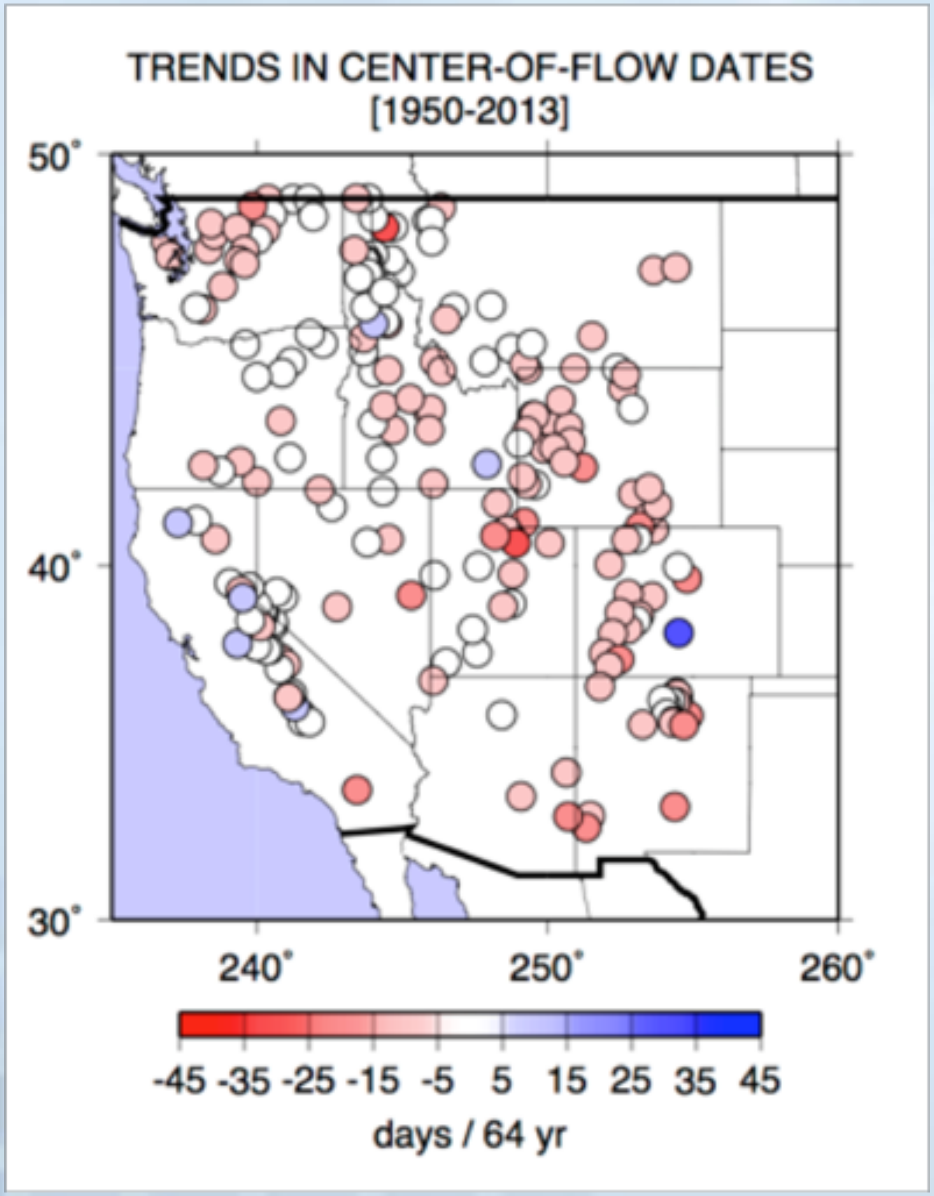


1909

Toboggan Glacier Alaska

2000

Snowmelt is occurring earlier in many mountain areas

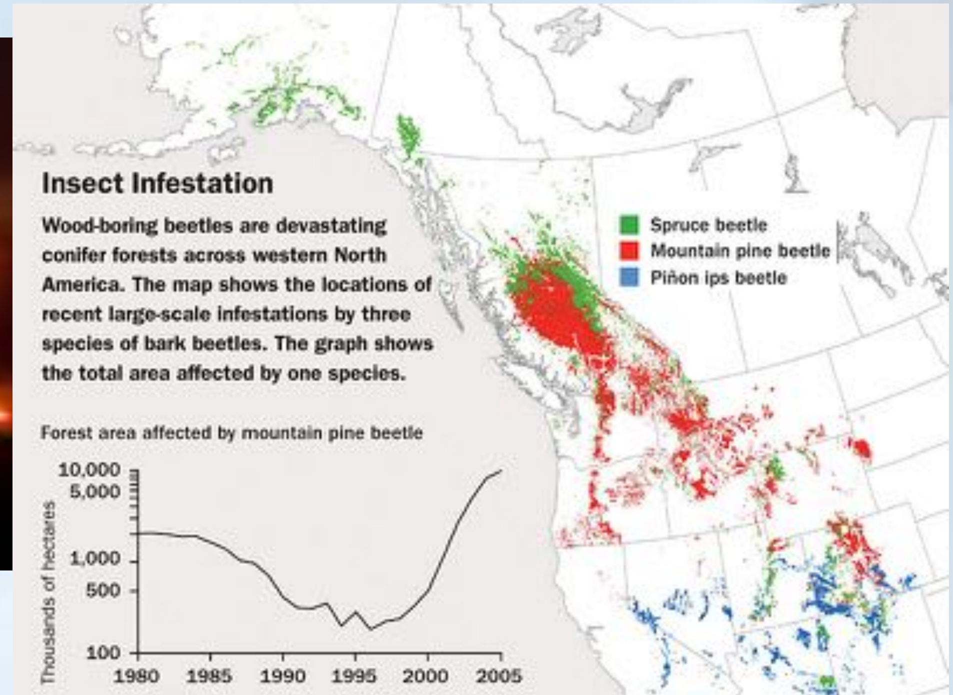


Change in streamflow timing as measured by linear trend over 1950–2013 of center of mass (date when half of the annual streamflow has been discharged) for snowmelt-dominated streams in the West.

(Cayan et al. 2016)

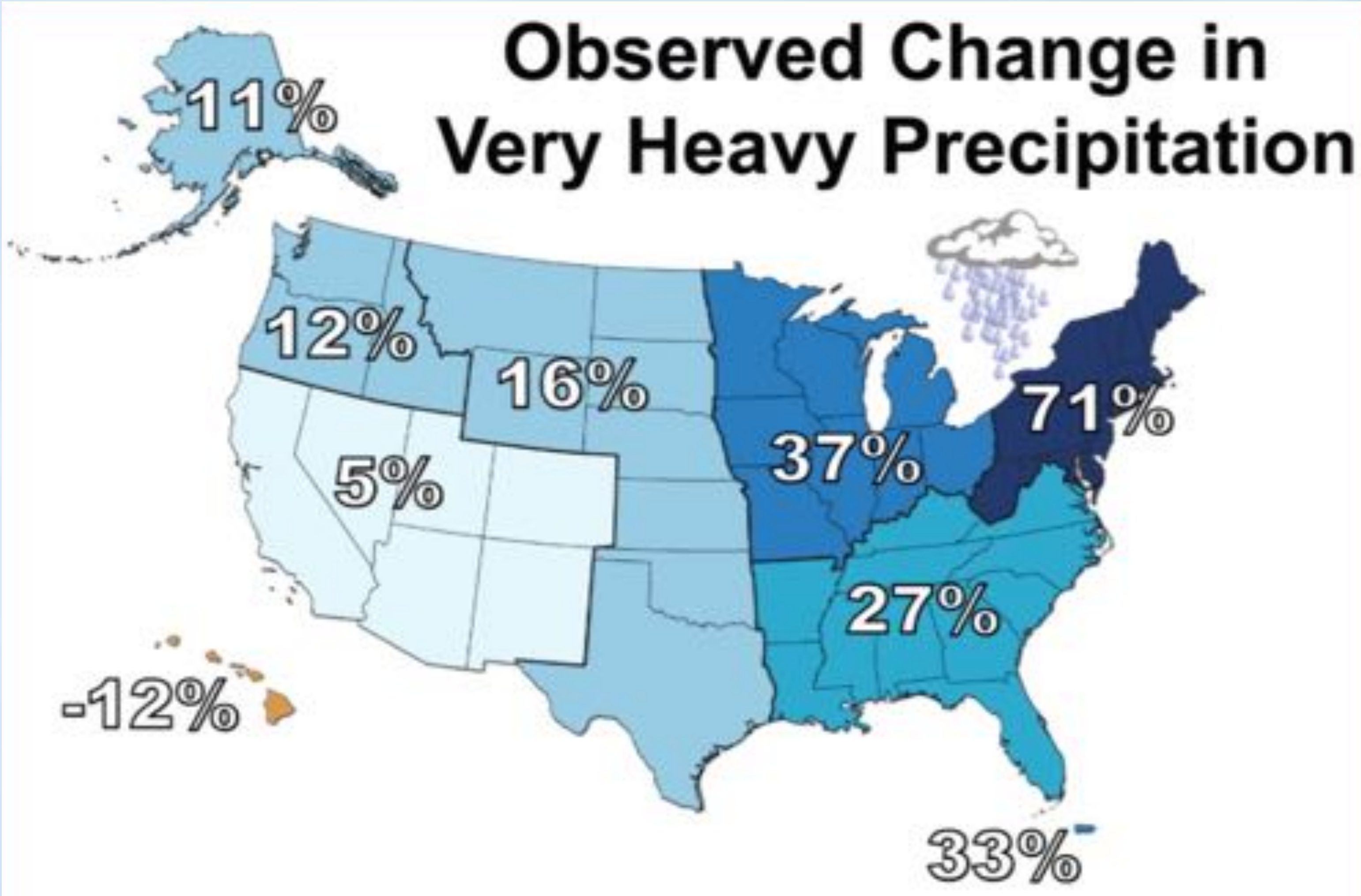
Climate-driven ecological changes:

Likely to affect water resources



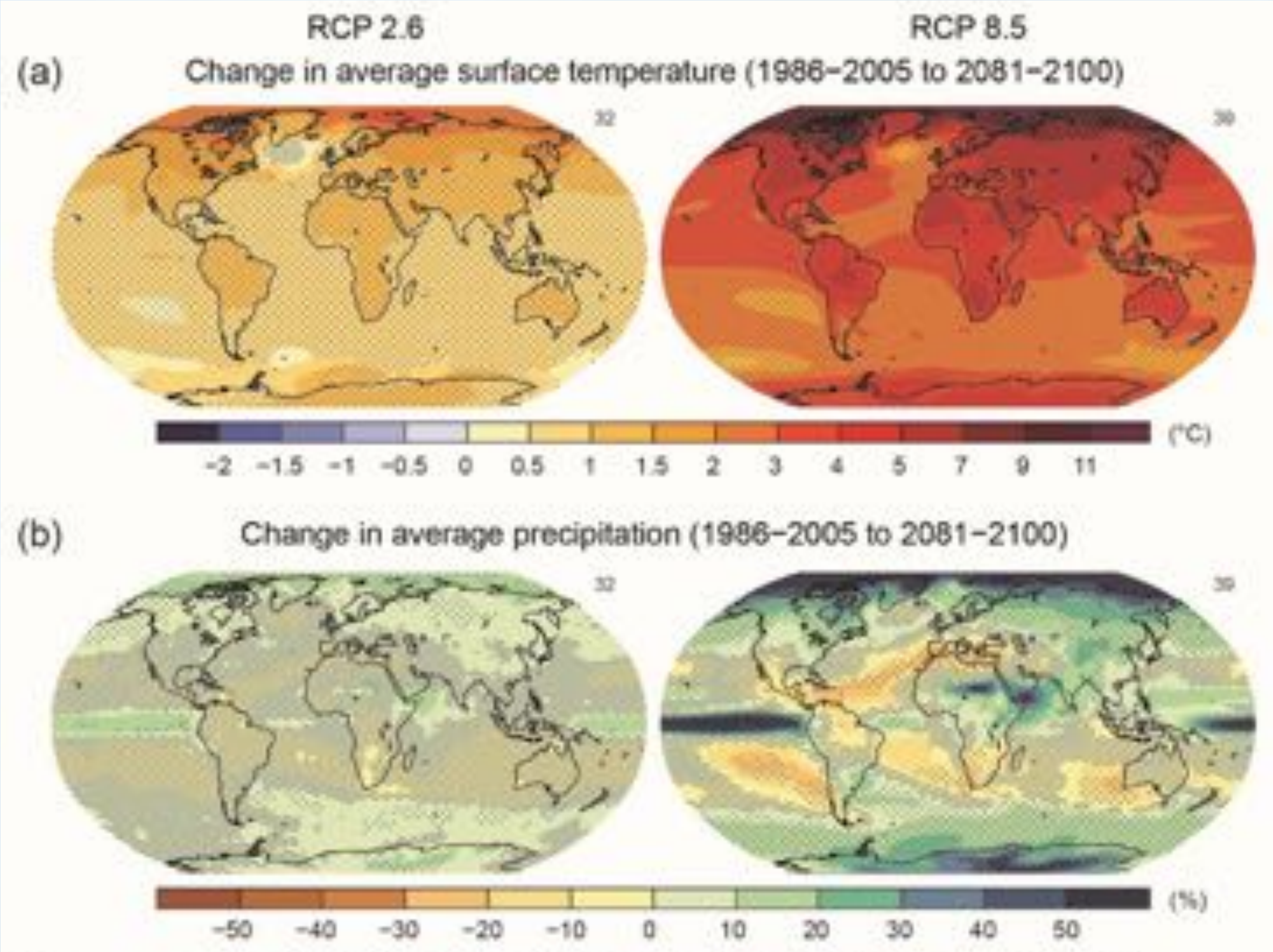
Raffa et al (2008)

Hayman Fire burn area – 2002 & Denver's Cheesman Reservoir



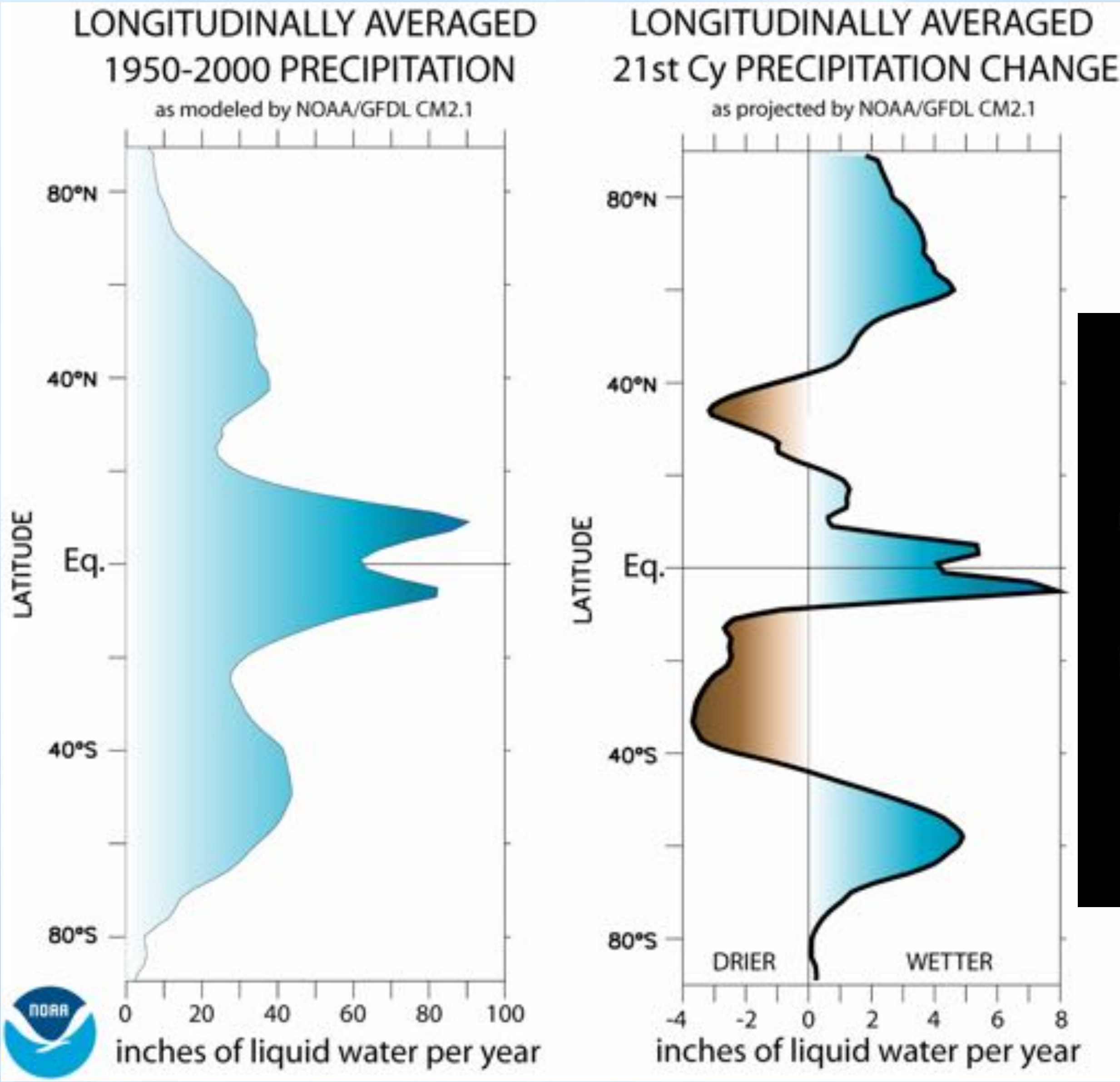
Percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012

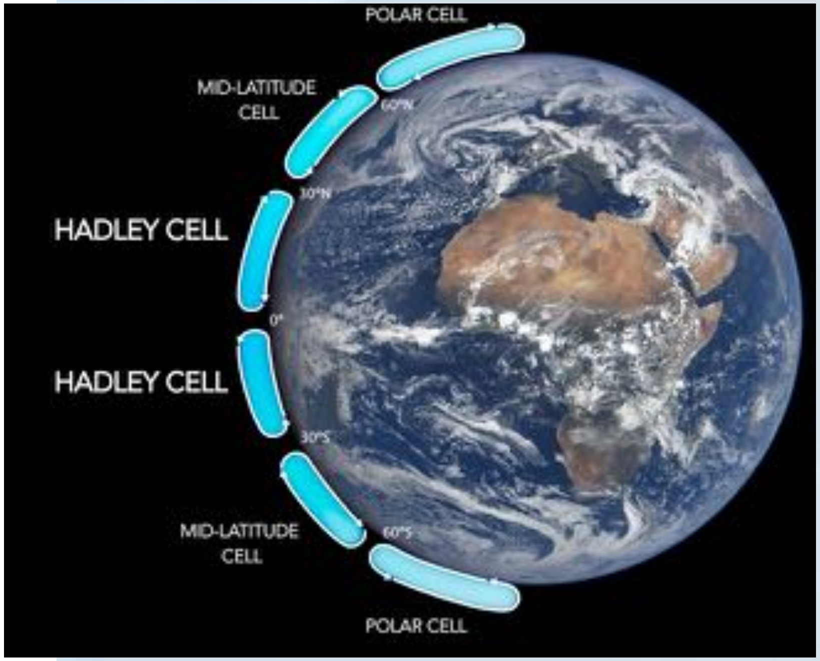
Projected Climate Changes



Multi-model mean results for low and high emissions scenarios: (a) annual mean surface temperature change, (b) average percent change in annual mean precipitation Stippling =multi-model mean change is large compared to natural internal variability > 2 standard deviations of natural internal variability & at least 90% of models agree on the sign of change. Hatching = change < 1 standard deviation of natural internal variability. (Source IPCC 2013)

Uneven hydrologic impacts: wet regions likely to be wetter and dry regions drier

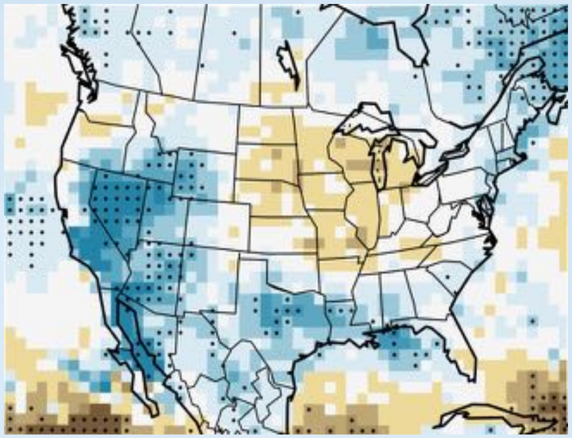




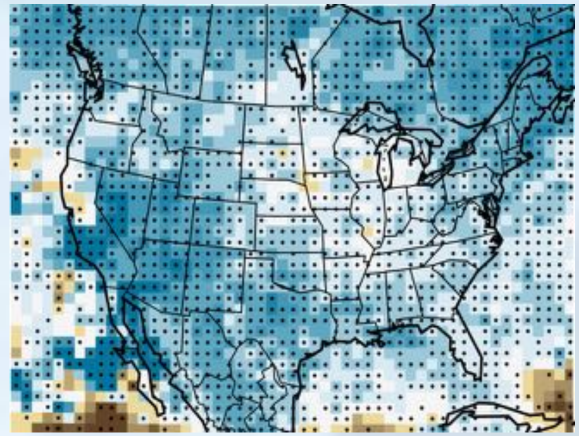
Changes in Precipitation & Hourly Extremes

WRF 4 km – RCP8.5, 100 year climate change signal

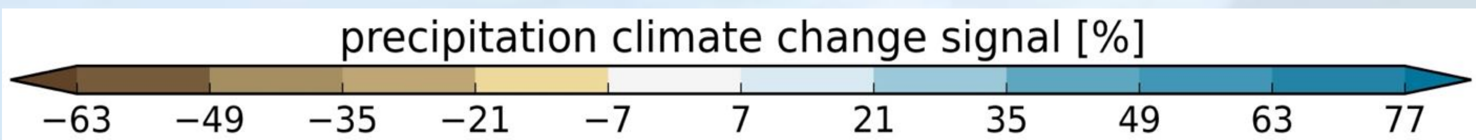
Summer



Changes in mean precipitation

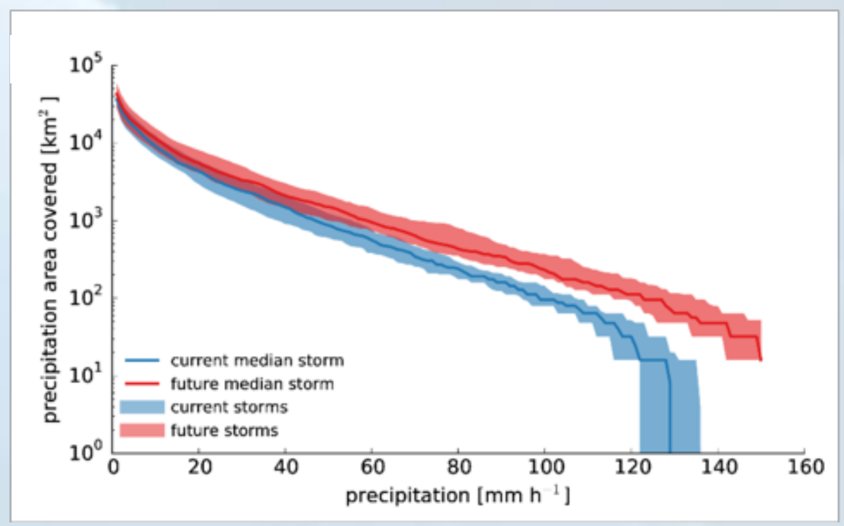


Changes in Hourly Extreme precipitation



Southeast: larger storm area + heavier rain rate = total median storm runoff up by 55%

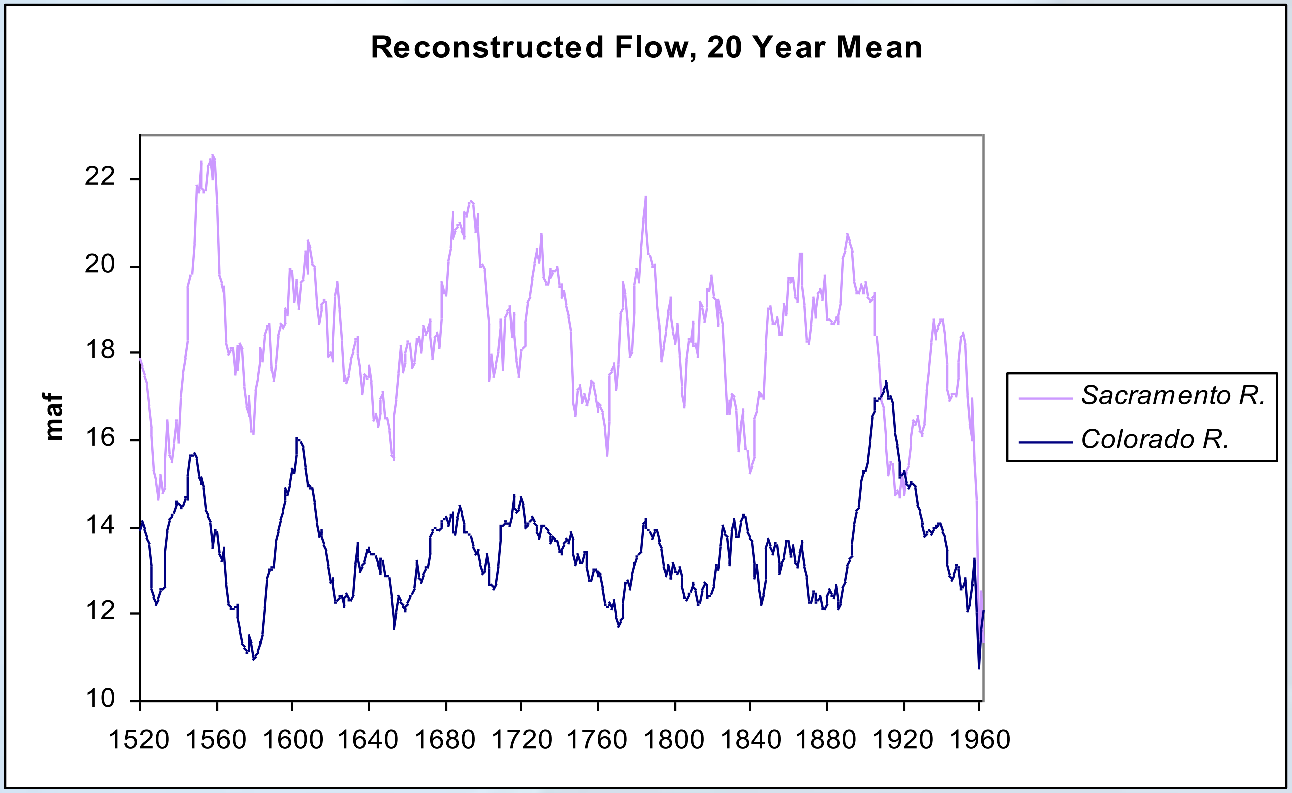
Prein et al. 2016. Nature Climate Change.



Natural Variability will continue

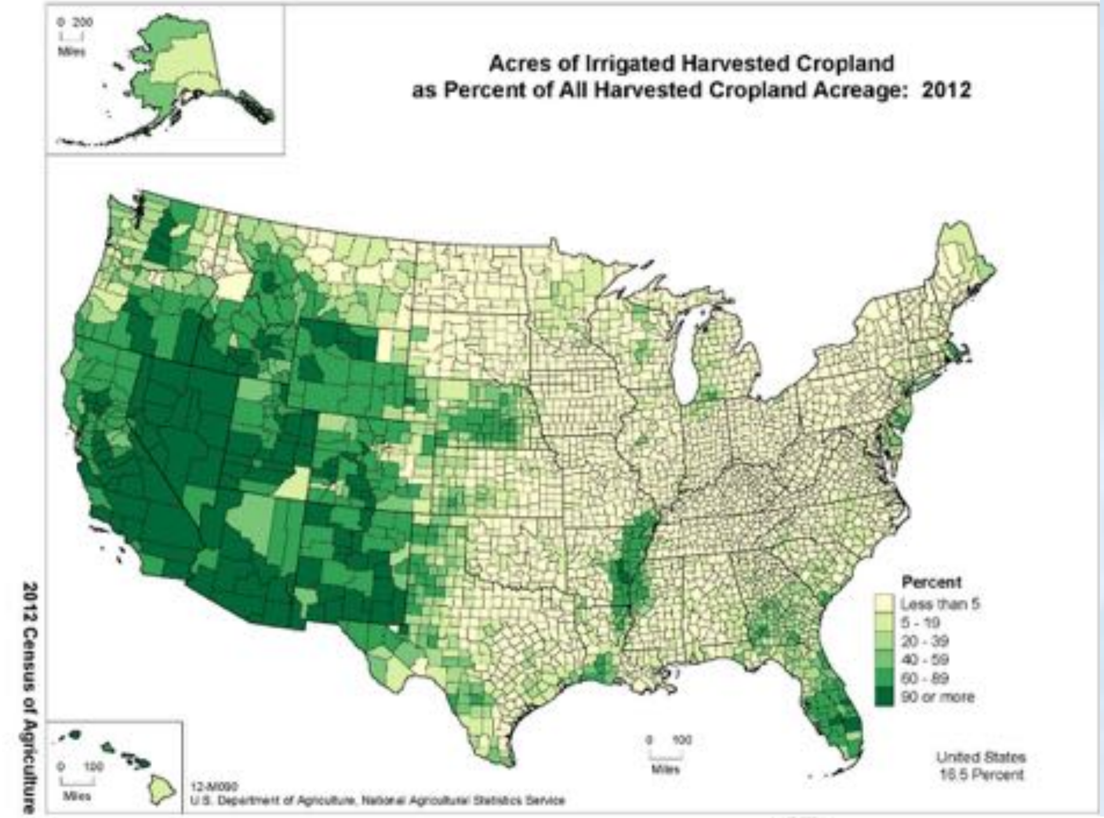
- Water supplies can change dramatically, and for extended periods, as a result of natural variability

- Global climate change adds further uncertainty

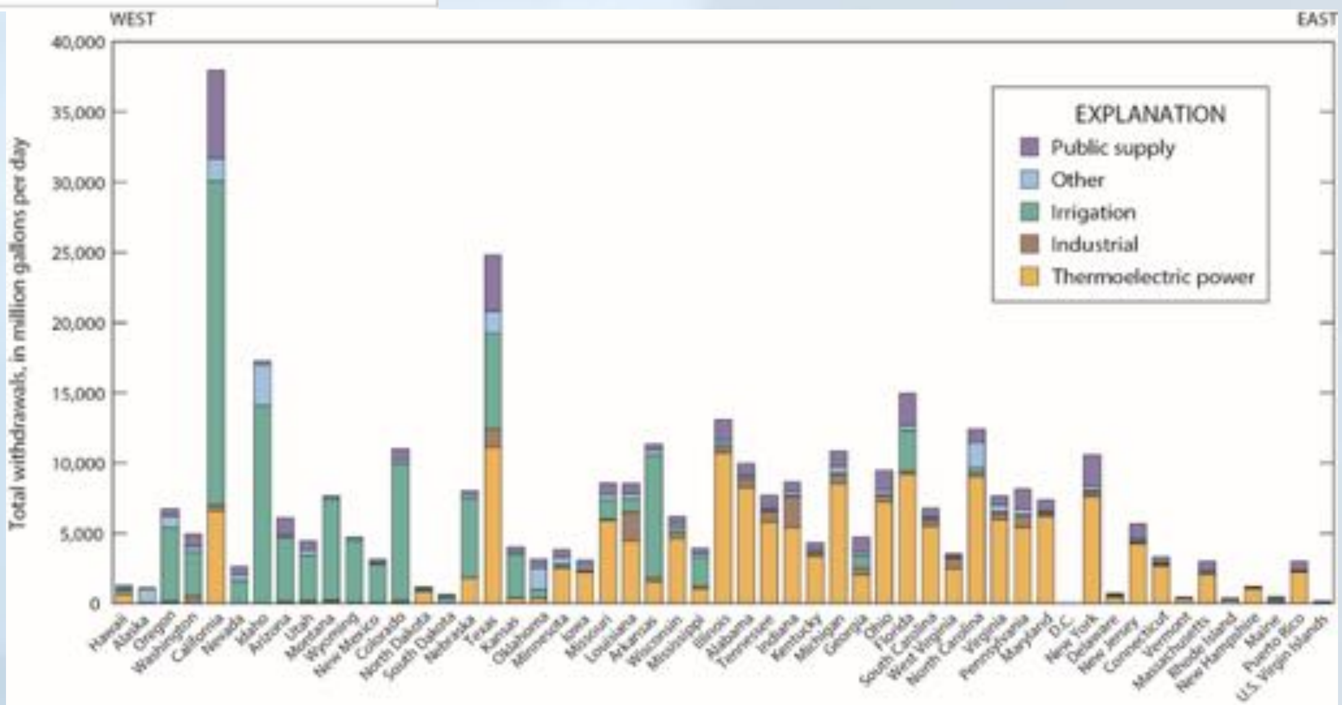


What do scientists need to understand about water policy?

- Water resources best understood as human-dominated systems
- There are many actors – not one voice
- Governance arrangements define:
  - Rights & responsibilities
  - Boundaries of authority
  - Mechanisms for conflict resolution
  - Process for defining & promoting social objectives

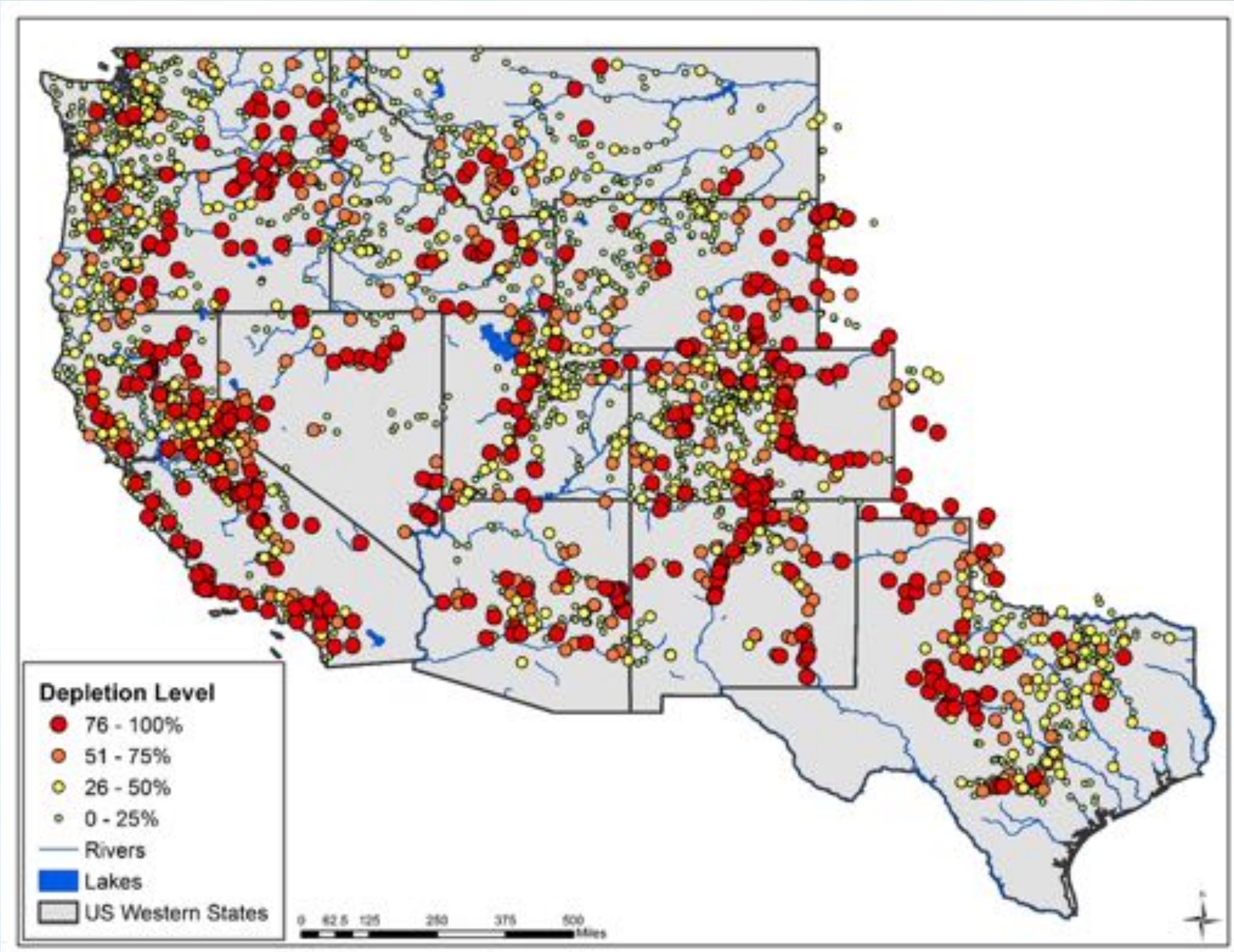


Irrigated agriculture accounts for the lion's share of water use in the US West

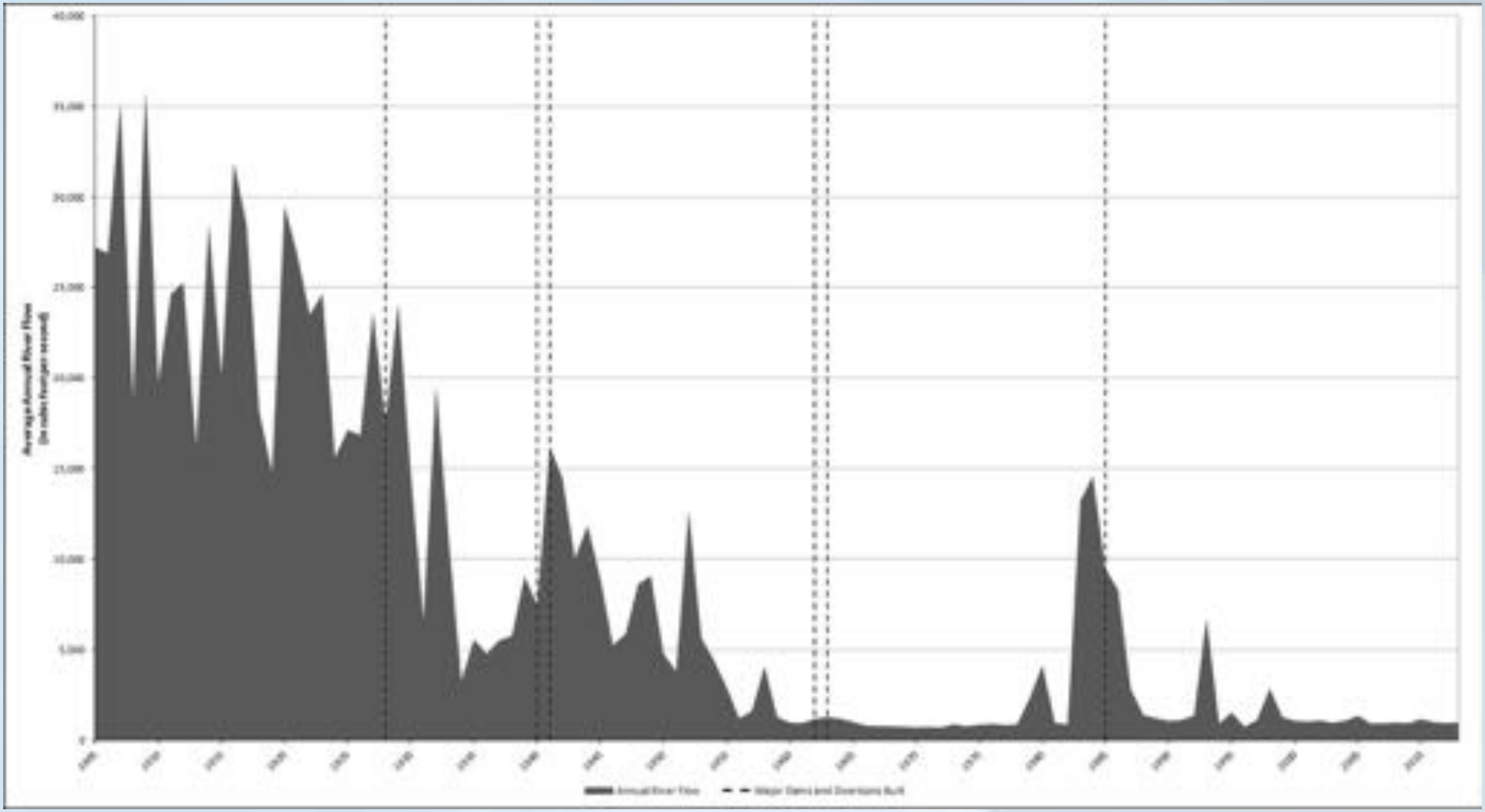


Total water withdrawals showing category of use by state from west to east, 2010

Source: Maupin, et al., 2014. *Estimated Use of Water in the United States in 2010:* U.S. Geological Survey Circular 1405



River flow depletion (>3400 USGS gauging Stations) for the month of September. Estimated using ratio of measured September flow averages to modeled estimates of natural September flows since 1950.
(Data provided by Daren Carlisle, US Geological Survey.)



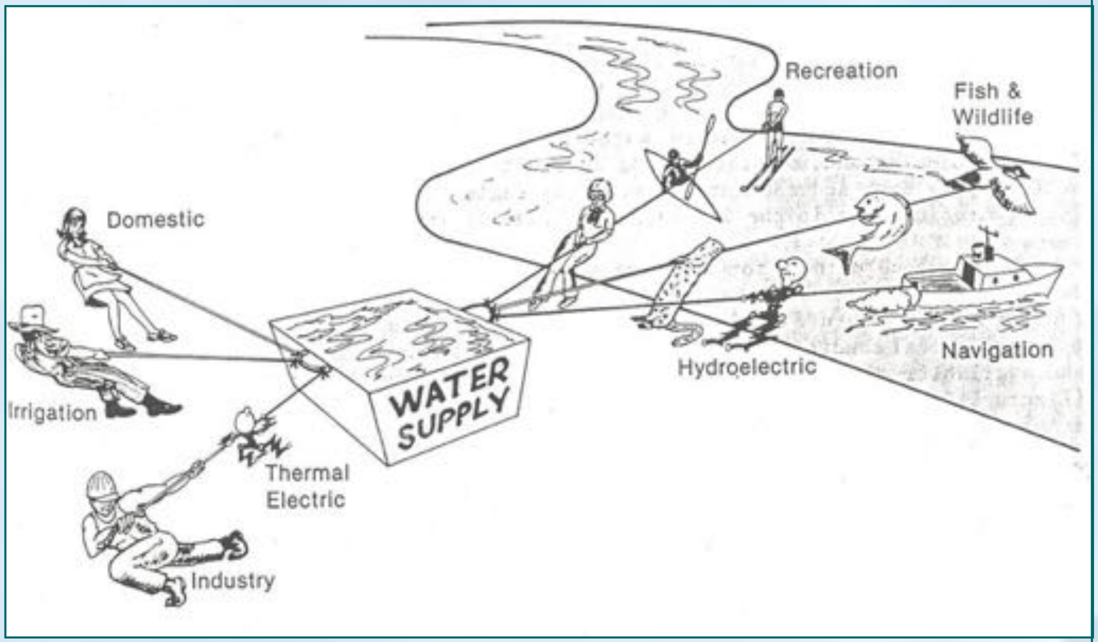
Average annual river flow (cfs), lower Colorado River @ Yuma AZ

The River now dries completely before reaching its delta in Mexico.

Large Reservoirs: Lake Mead (1928); Flaming Gorge (1962); Lake Powell (1963)

Large diversion canals: All-American Canal (1940); Colorado River Aqueduct (1941); Central Arizona Project (1985)

Water Policy Process – Some Realities



"We are not all in this together" (Doug Kenney, CU Natural Resources Law Center)

- Any change can affect multiple users/values
- Policy discussions – often contentious
- Numerous uncertainties

→ Transparency & high quality transdisciplinary information needed: e.g. biophysical, socioeconomic, psychological

Hopeless tug of war? Or effective multi-layered governance system ?

→ Depends on the rules governing the policy process

Social science & climate resilience

- Uncertainty can fuel conflicts
- Diverse stakeholders with contrasting beliefs about how a system functions and how it will respond to proposed changes
- Better approaches needed for equitable and effective conflict resolution → continuing need for fundamental social science research

e.g. information processing, risk perception, strategic behavior, preference formation and the dynamics of multi-stakeholder decision processes.

Drought & Interstate Water War

Apalachicola-Chattahoochee-Flint River Basin FL v GA

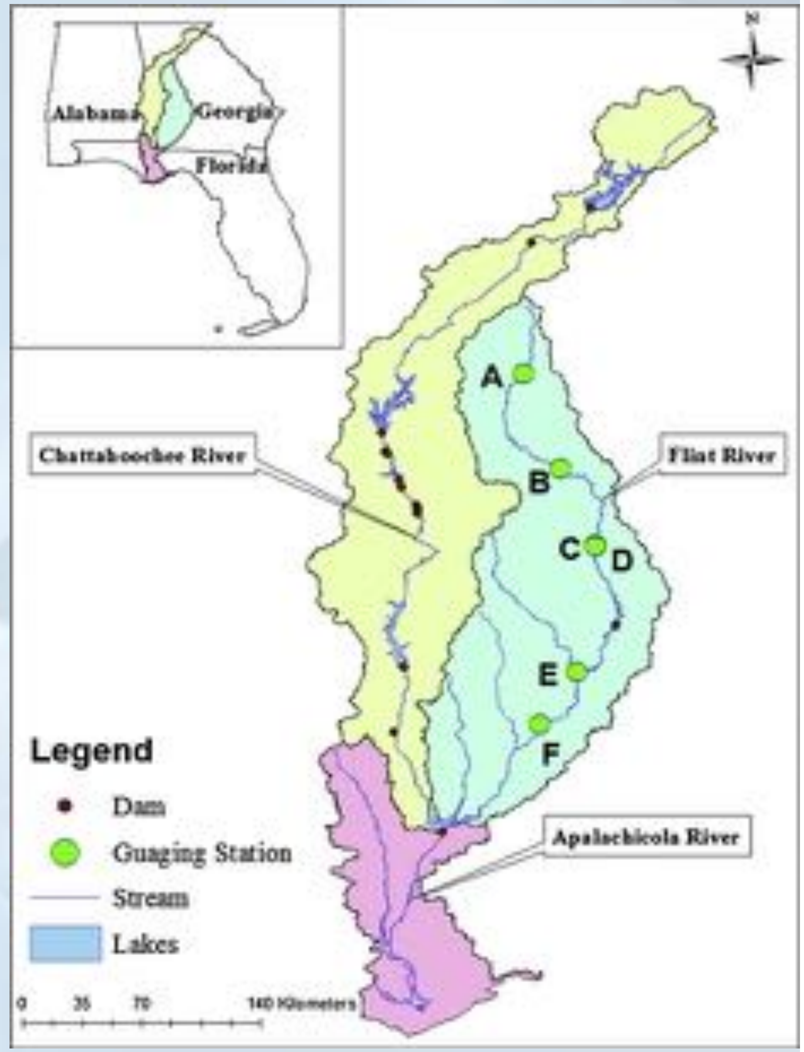
NOAA SARP Award NA13OAR4310118

Atlanta area population growth → increased dependence on water from Lake Lanier

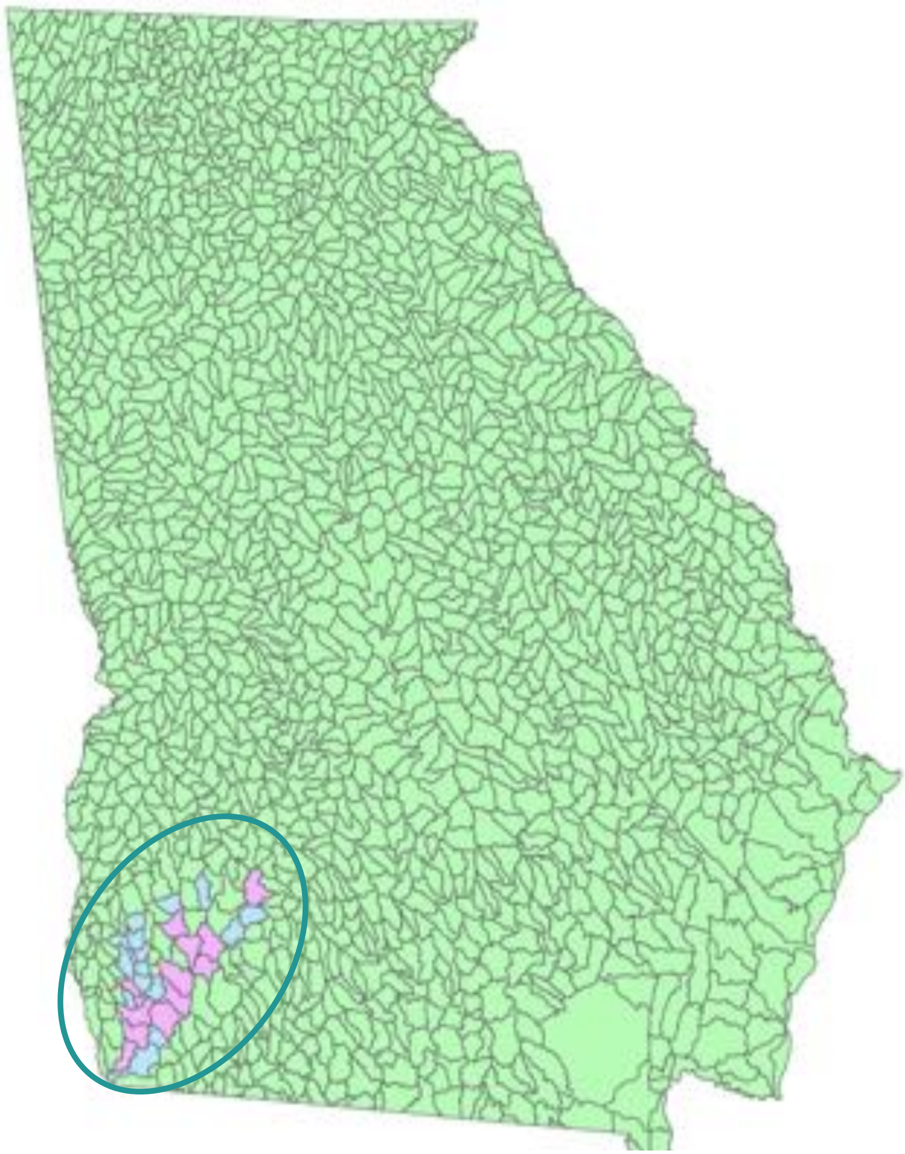
Georgia riparian water law → poorly controlled irrigation expansion

Interstate conflict/litigation over flows to Florida

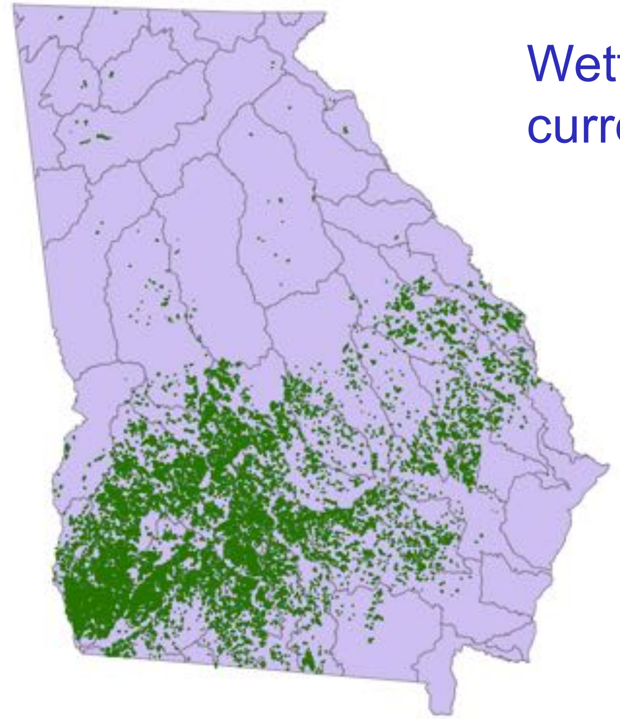
- Oct. 1, 2013: Florida initiated Supreme Court equitable apportionment suit – requesting caps on Georgia's water consumption
- 2014: Court appoints Special Master
- Oct 2016 – Feb 2017: Hearing & rejection recommendation
- Jan 2018: Full Supreme Court hears case (ruling expected in June)



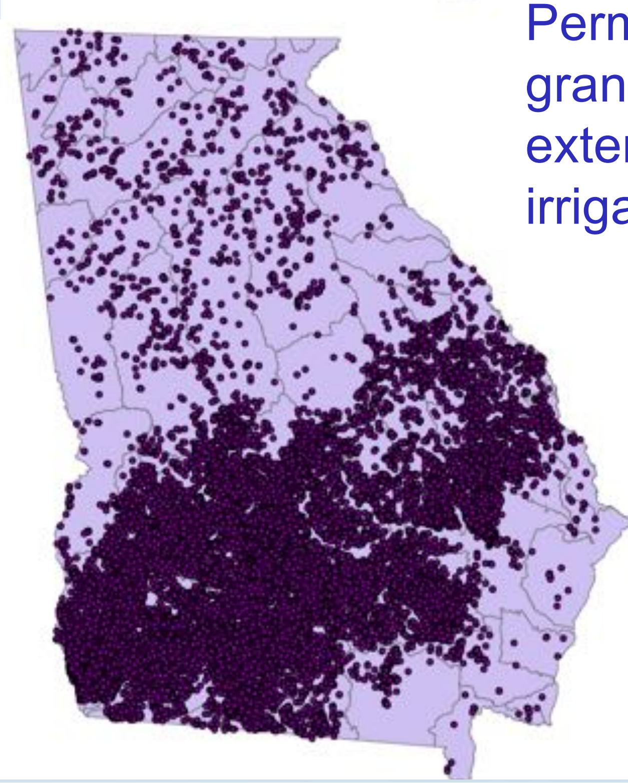
Source: Singh et al. J.Hydrology, 2015



Lower Flint Basin: HUC 12 sub-basins Capacity (Pink) & Restricted (Blue) – Moratorium on new permits; No restrictions on water use by existing permits



Wetted acres = currently irrigated



Permitted acres = grandfathered – extension of irrigation allowed

Drought Impacts on streamflows

Combined effects of reduced recharge and increased irrigation

Complex aquifer/stream interconnections

Impacts of irrigation on streamflow highly variable over time & space

Environmental impacts of irrigation & its economic value increase during drought periods

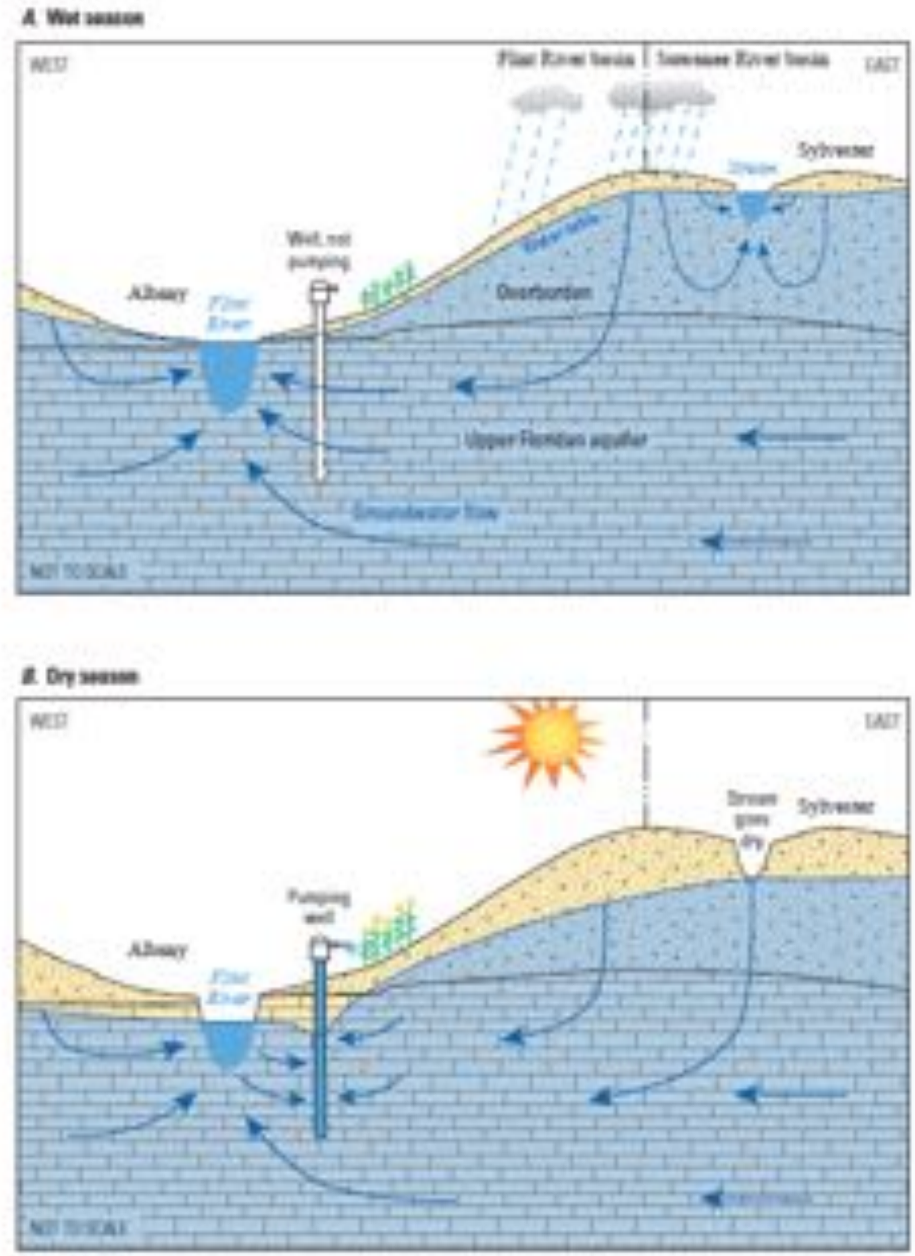
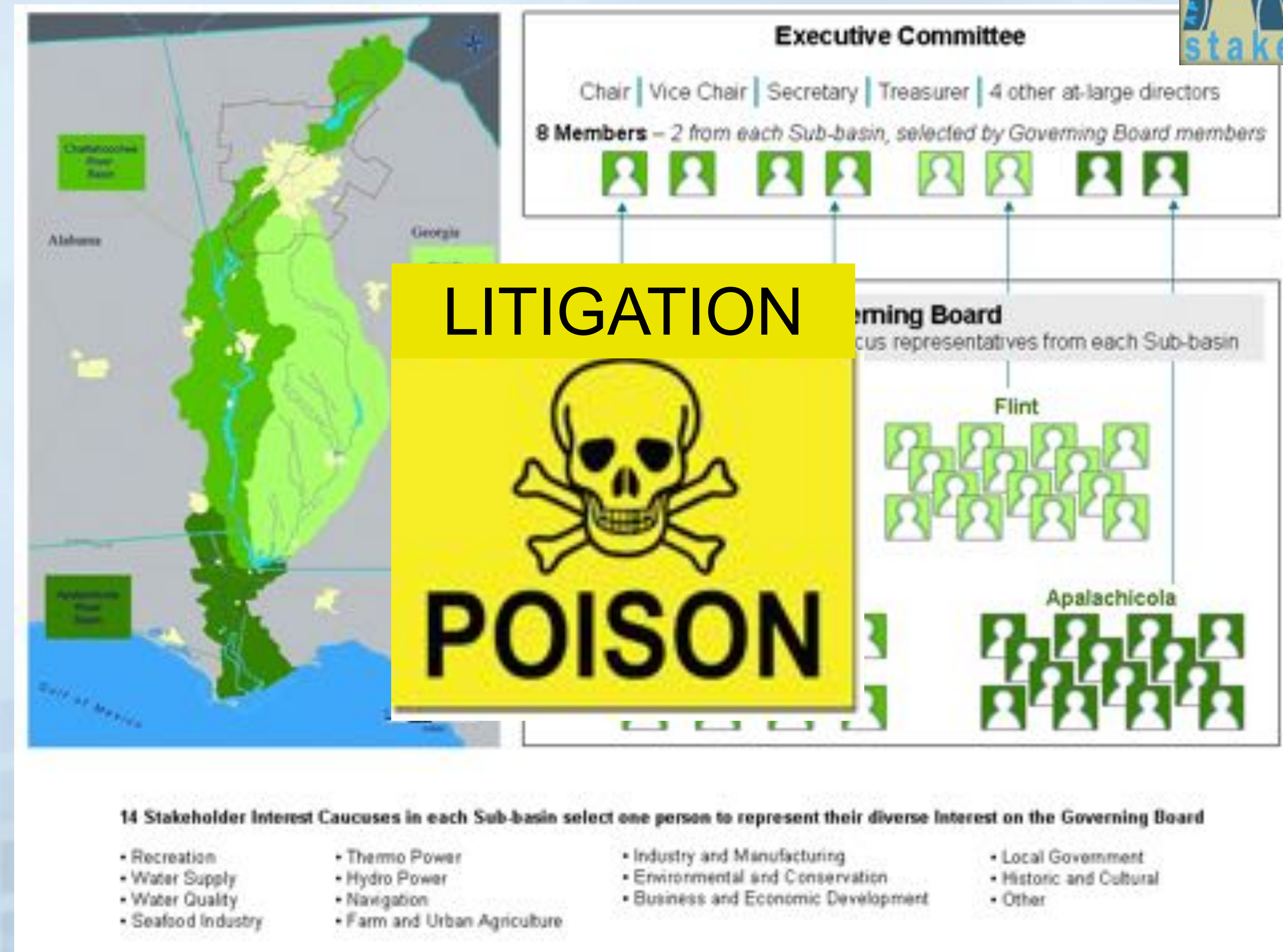


Figure 3. Schematic cross sections showing the hydrologic connection between the Flint River, the overburden sediments of the upper semiconfining unit, and the Upper Floridan aquifer in Georgia during (A) the wet season and (B) the dry, summer growing season.

Ongoing Stakeholder Process



Ugly & expensive fight

States' legal teams in control of evidence gathering & argumentation (goal = WIN):

- Deeply entrenched positions
- Big guns
- Relentless bombardment of the opposing team
- Costly, but little progress

Strategies:

- Exploit uncertainties – paint opposing experts as dishonest or incompetent
- Select data, models & assumptions to support own case
- Frame questions narrowly

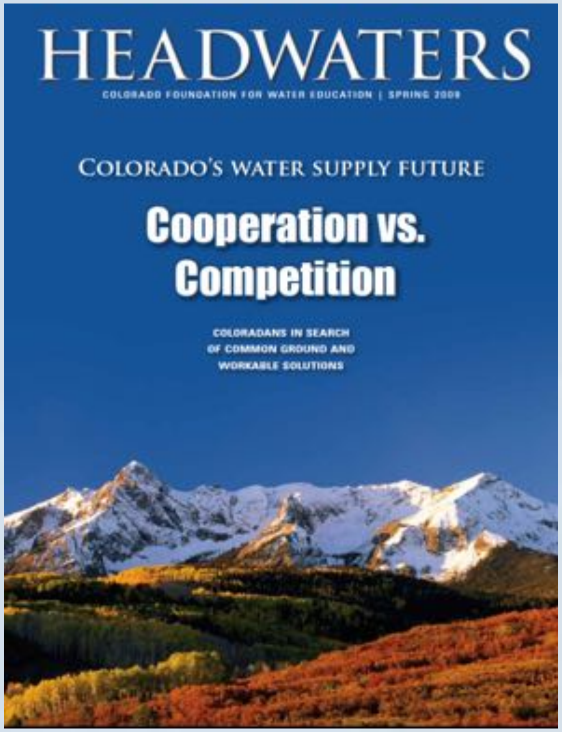
Colorado's water planning process

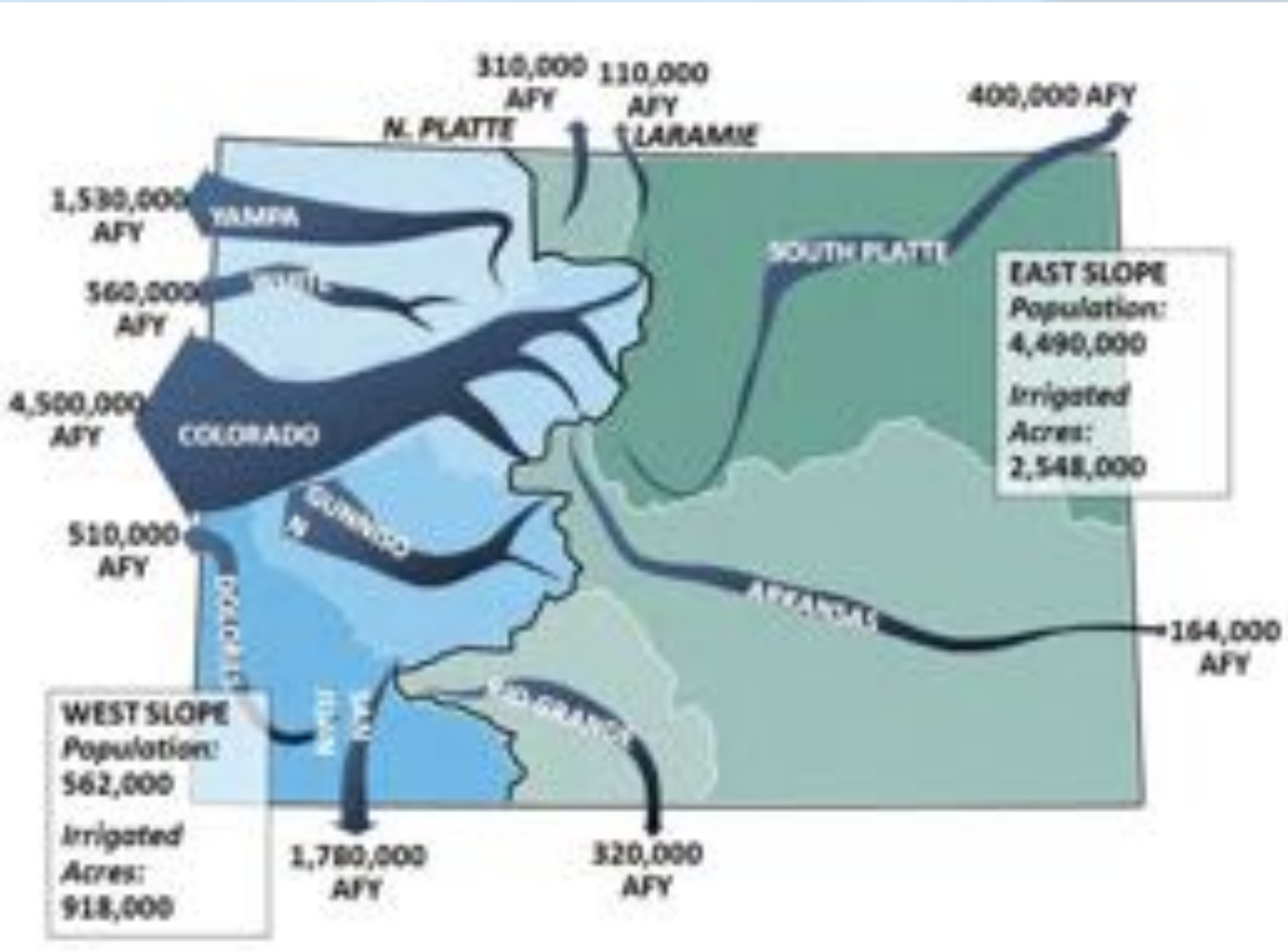
Triggered by 2002 Severe statewide drought

- 9 Basin Roundtables – tasked with assessing water supplies; consumptive & non-consumptive water needs & participating in:
- Interbasin Compact Committee

Principles:

- Encourage urban conservation / smart growth
- Affirm prior appropriation & existing rights
- Improve management capacity & information base for effective local control
- Maintain healthy watersheds, rivers & wildlife
- Promote vibrant agricultural economy
- Create new flexibility for water sharing
- Avoid large new transbasin diversions




310,000 AFY
110,000 AFY
N. PLATTE
LARAMIE
400,000 AFY
1,530,000 AFY
YAMPA
560,000 AFY
SOUTH PLATTE
EAST SLOPE
Population: 4,490,000
Irrigated Acres: 2,548,000
4,500,000 AFY
COLORADO
510,000 AFY
164,000 AFY
WEST SLOPE
Population: 562,000
Irrigated Acres: 918,000
1,780,000 AFY
320,000 AFY

Colorado's Interstate Compacts

Define water delivery obligations to downstream states

North Platte Decrees (US Supreme Court)

South Platte River Compact - 1923

Colorado River Compact – 1922

Upper Colorado River Compact – 1948

Republican River Compact - 1942

La Plata River Compact – 1922

Animas-La Plata Project Compact - 1969

Rio Grande River Compact – 1938

Costilla Creek Compact - 1944 (Rev. 1963)

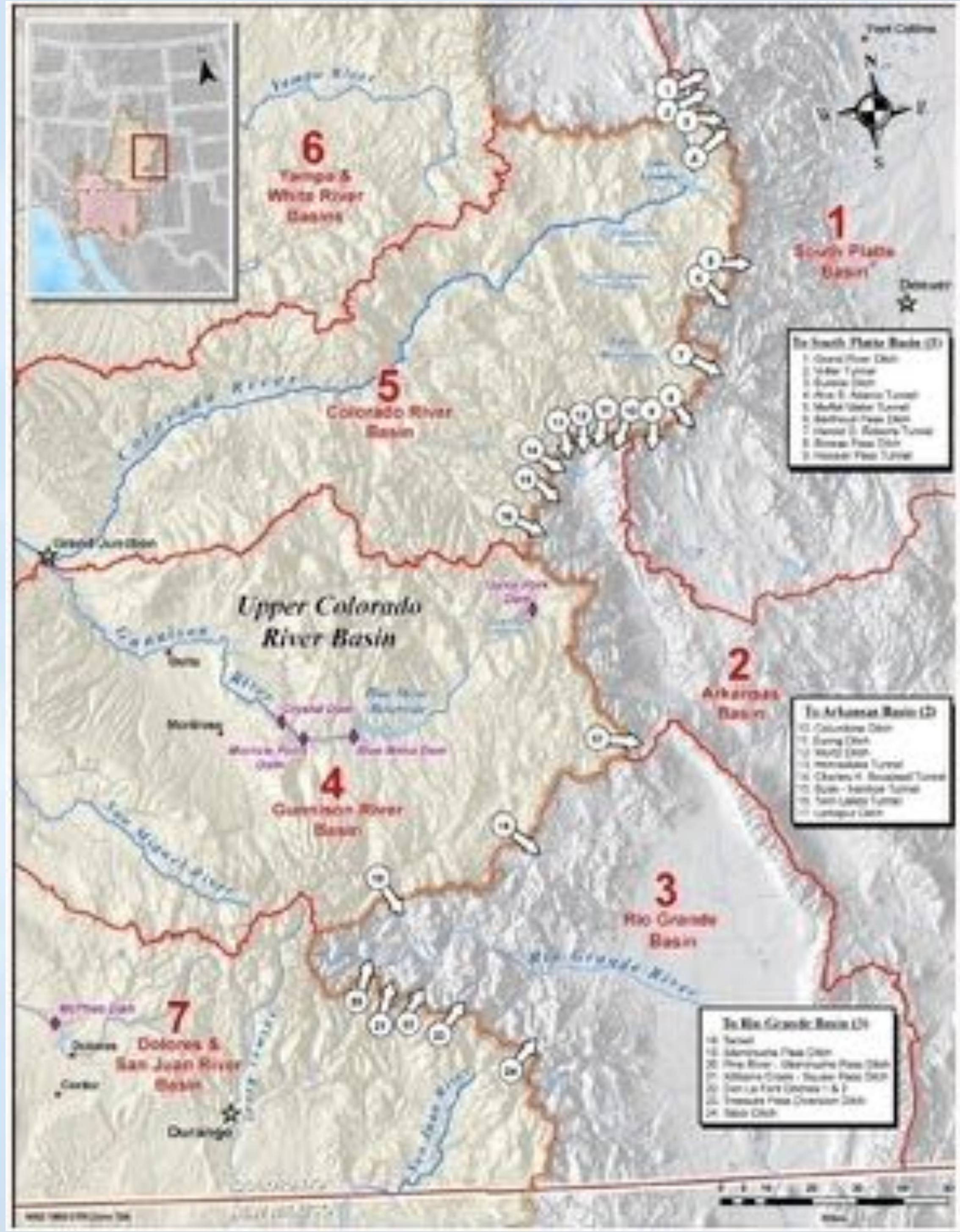
Arkansas River Compact - 1948

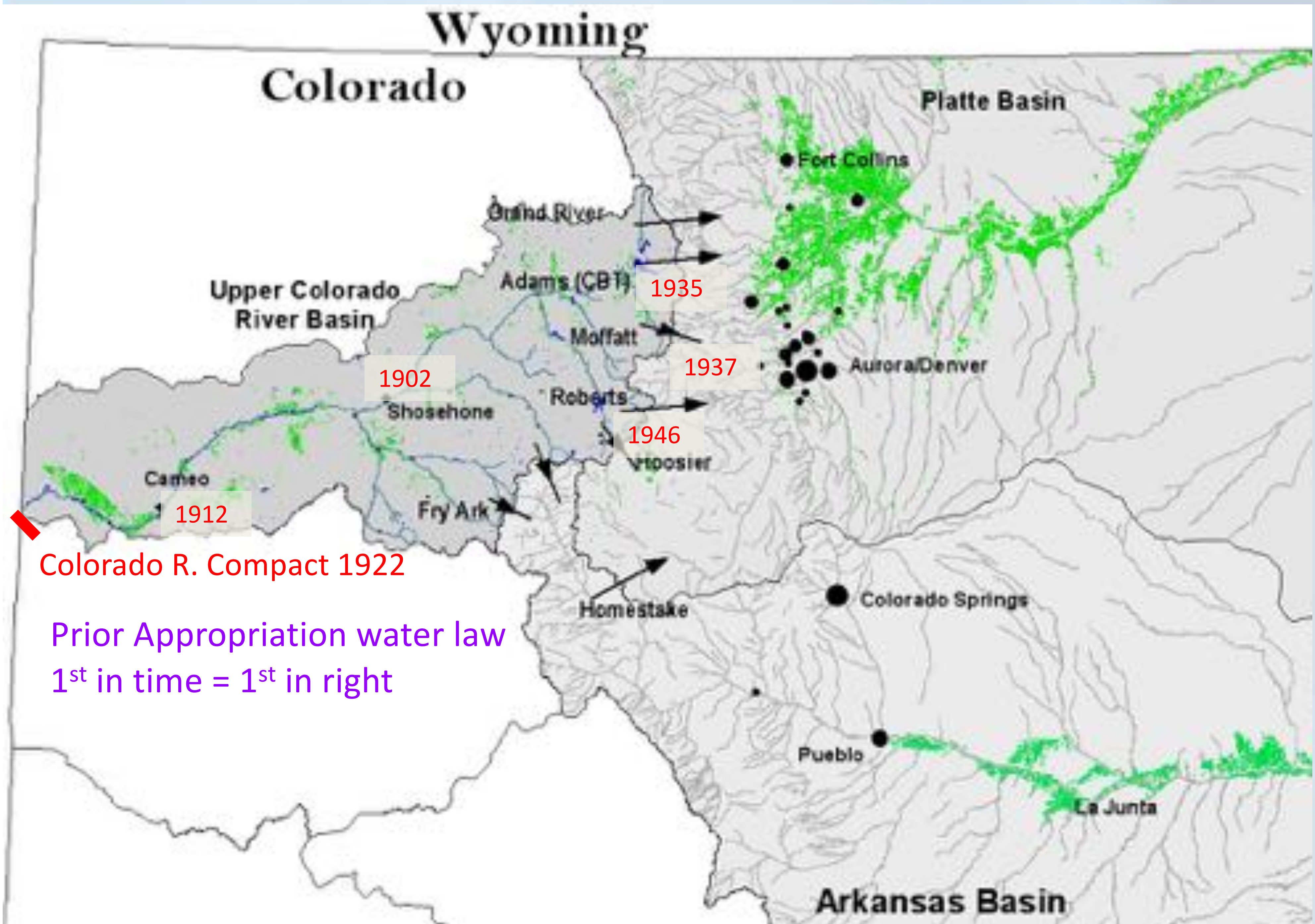
Colorado Transbasin Diversions:

24 major transbasin diversions

Roughly 25% of in-state consumptive use of Colorado River

≈ 72% of surface water deliveries by major Front Range (East slope) cities & irrigation water providers




Wyoming
Colorado
Platte Basin
Fort Collins
Grand River
Adams (CBT)
1935
Upper Colorado
River Basin
Moffatt
1937
Aurora/Denver
1902
Shoshone
Roberts
1946
Cameo
1912
Fry Ark
Colorado R. Compact 1922
Homestake
Colorado Springs
Prior Appropriation water law
1st in time = 1st in right
Pueblo
La Junta
Arkansas Basin

Shoshone Hydroelectric Plant – Senior Water Rights:

1250 CFS (1902);
158 CFS (1929)
Shoshone Call

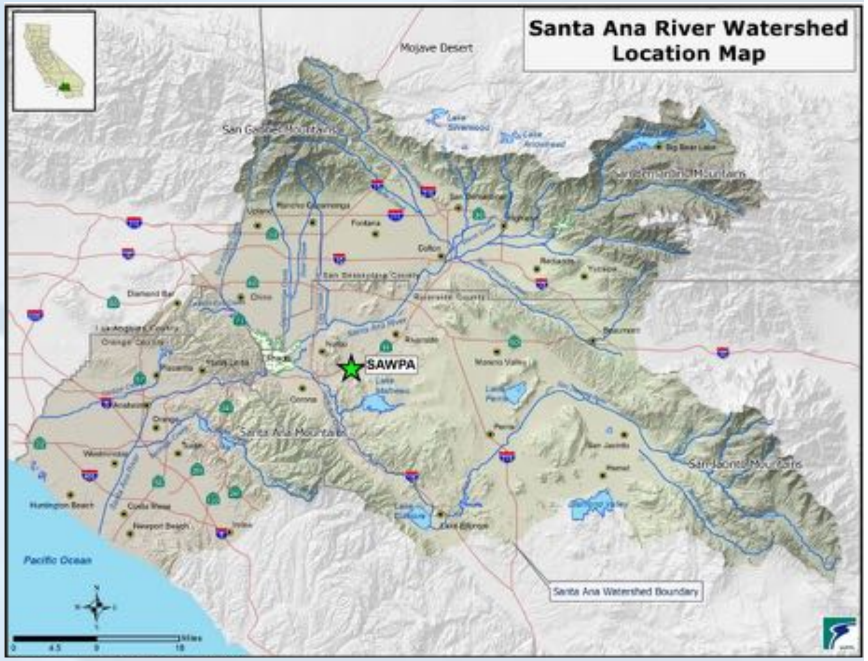
(Xcel Energy)

- Commands the entire flow of the Colorado River at that point for much of the year
- Drought-year agreement for upstream reservoir storage

Santa Ana River Watershed Project Authority (SAWPA)

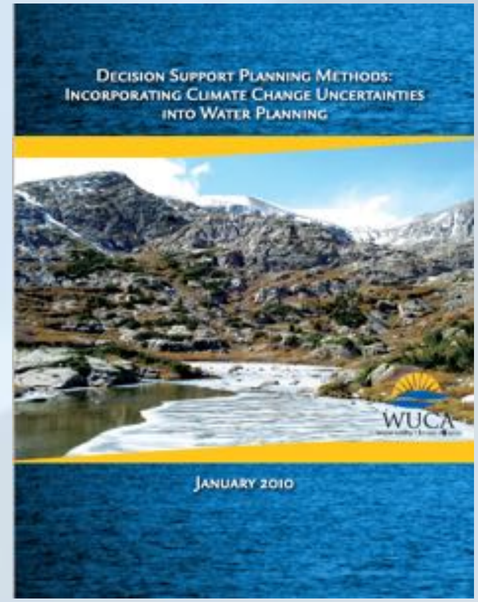
Follows an innovative policy process:

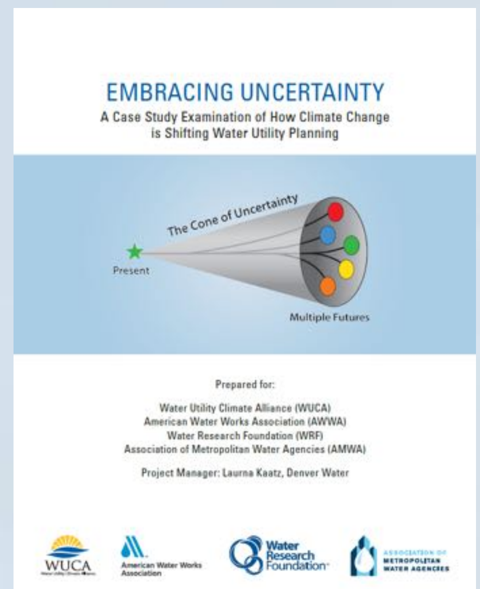
- Created in 1969 to settle bitter litigation
- Adopted "One Water One Watershed" approach to integrated resource planning
- Ten "pillar" working groups– moving away from a focus on old problems to options for creating a desirable future
- Inclusive and diverse membership brings fresh perspectives & limited "baggage"
- Success in addressing tough problems: limited local water supplies, rapid development, high salinity, wildfire impacts



Water Utility Climate Alliance

Providing leadership on municipal water industry planning for climate change adaptation




EMBRACING UNCERTAINTY

A Case Study Examination of How Climate Change is Shifting Water Utility Planning

The Cone of Uncertainty

Present

Multiple Futures

Prepared for:

Water Utility Climate Alliance (WUCA)
American Water Works Association (AWWA)
Water Research Foundation (WRF)
Association of Metropolitan Water Agencies (AMWA)

Project Manager: Laurna Kaatz, Denver Water

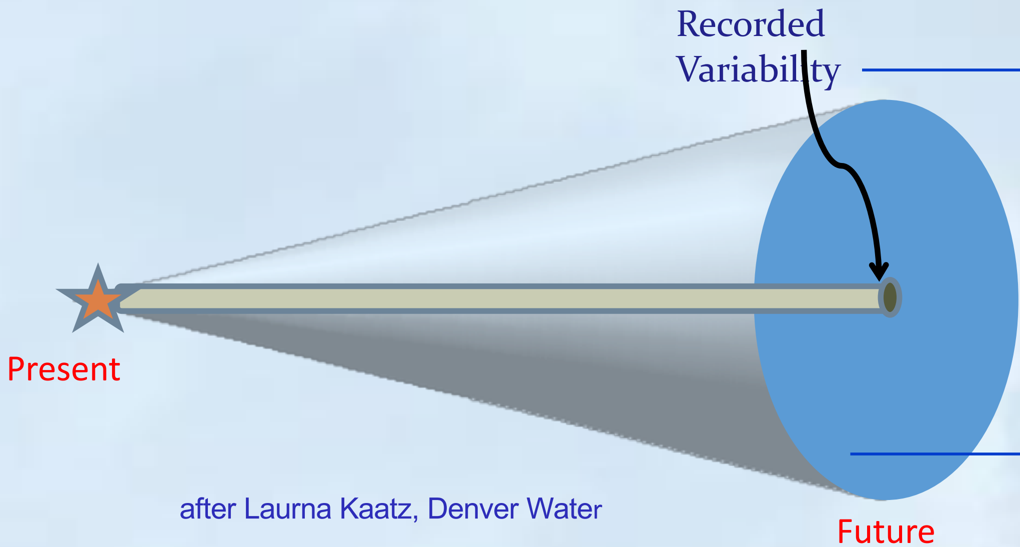
WUCA

American Water Works Association

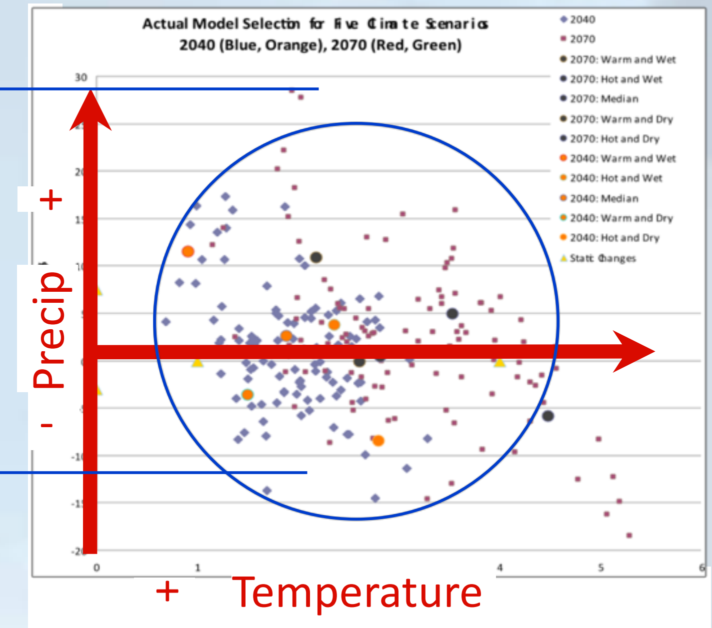
Water Research Foundation

Association of Metropolitan Water Agencies

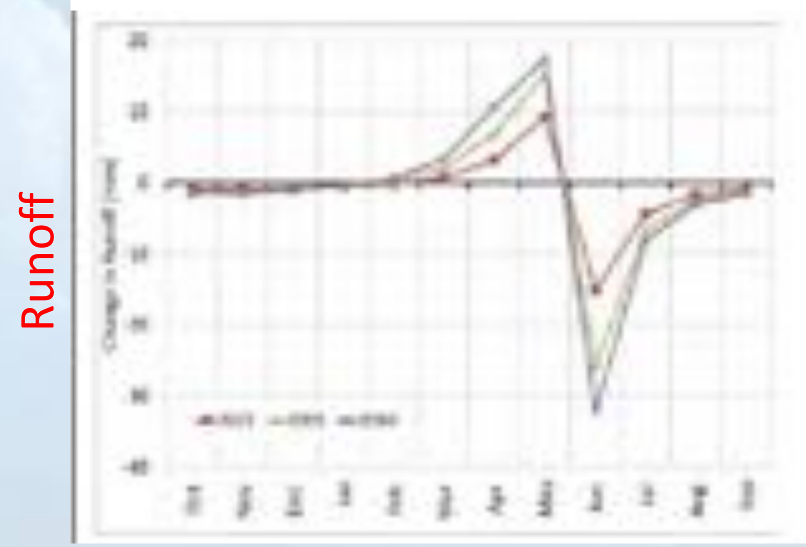
The "Practitioner's Dilemma"



after Laurna Kaatz, Denver Water



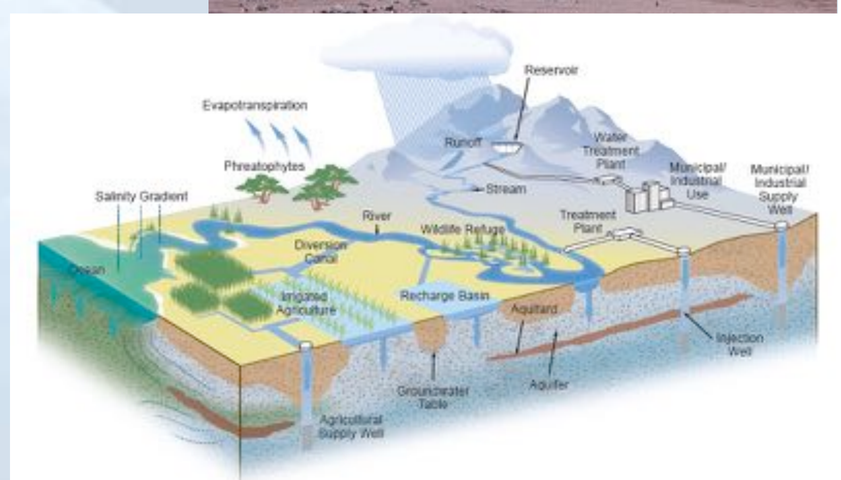
Mean Monthly Projected Change
Colorado River at Glenwood Springs



- ❖ "Cone of Uncertainty" – A challenge for water managers
- ❖ But planning isn't stymied – Need to take it into account
- ❖ Warmer temperatures, alone, affect usable water supplies

Uncertainty is unavoidable

- Decisions need to be made despite future climate uncertainty
  – Risk management is the central task
- Some plausible scenarios are more troubling than others
  – How well will the decision work if those occur? Seek robust options
- Need to understand and address physical, social and legal complexities
  – Integrated water resource assessment
  – Transparent and inclusive decision process



Thanks

Colorado River – Credit: Ted Melis