Climate Change and Water Resources, What We Know, and Why We Should Care

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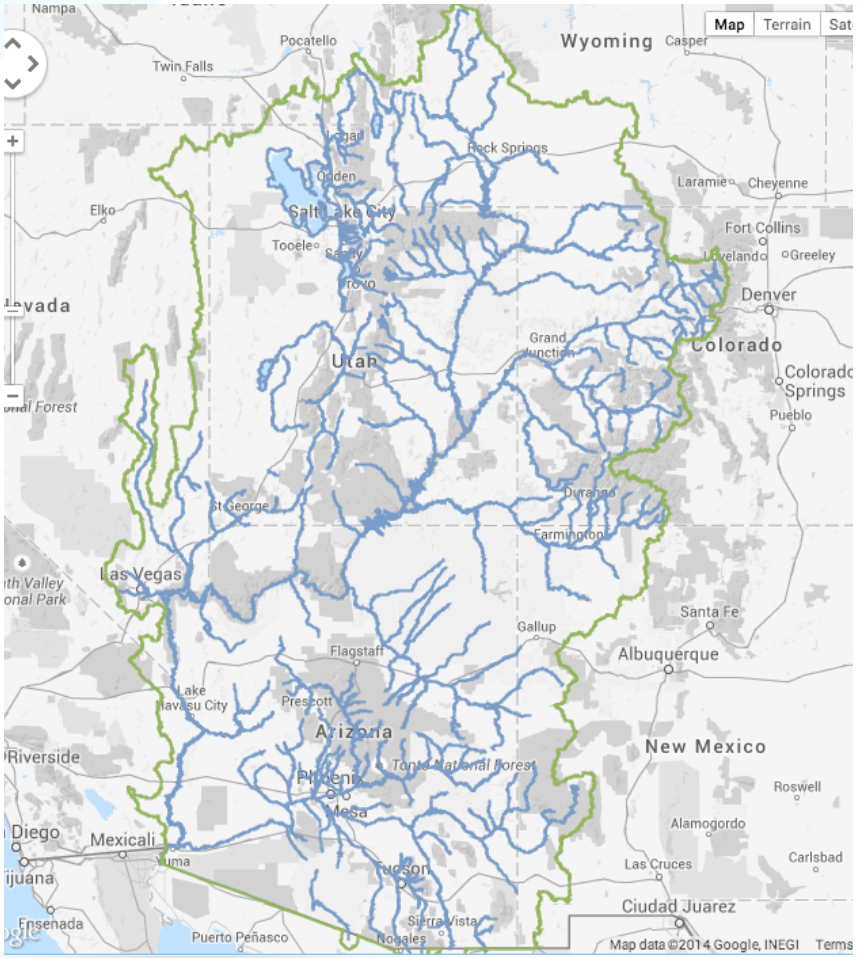
COLORADO BASIN RIVER FORECAST CENTER CBRFC

What is the Western Water Assessment?

Climate information and research

Resource management & decision-making

What is the CBRFC ?



- An office in NOAA
  - National Weather Service
  - One of 13 RFCs in the nation
  - Co-located with Salt Lake City Weather Forecast Office
- Colorado River Basin and Eastern Great Basin Regions

Outline

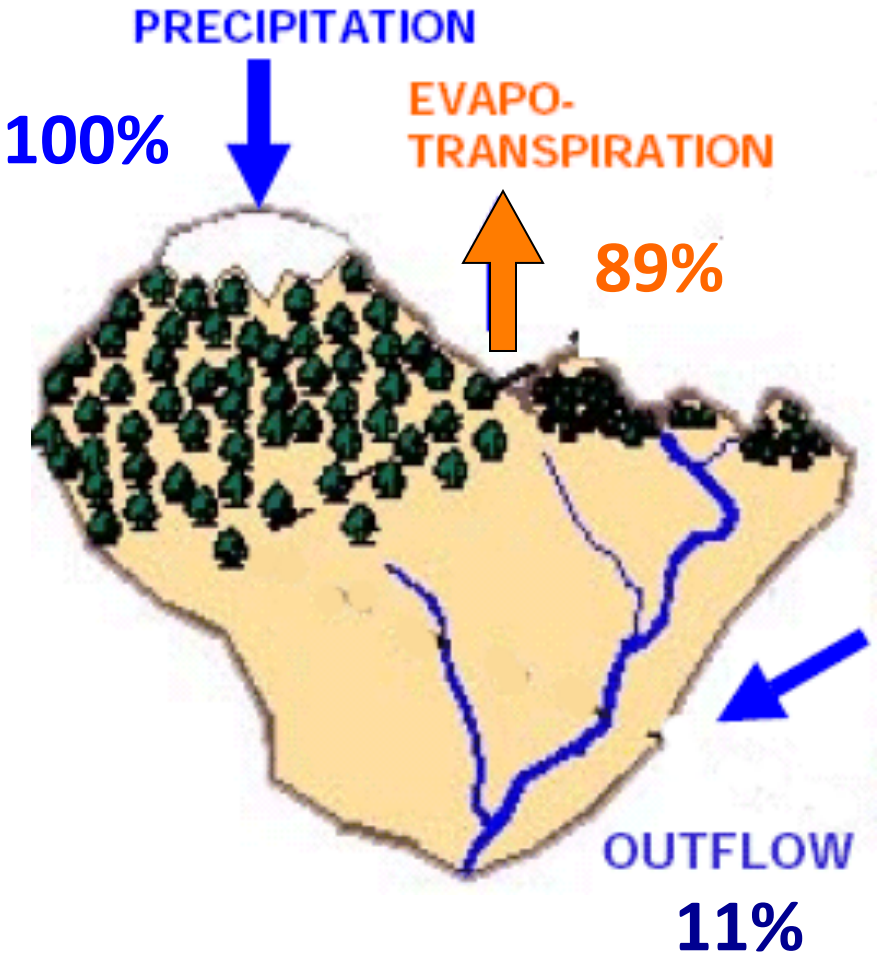
- Intro to water cycle, drought, observed and paleo climate variability and trends in Utah
- Projections of climate change for Utah and the West
- Implications for water supply and beyond
- Example water management and planning assessments
- Example potential adaptive strategies

Weather vs. Climate:

- *Climate is the statistics of weather*
- *"Weather tells you what to wear on any given day; climate tells you what wardrobe to have"*
- *"If you don't like the weather: Wait 5 minutes!, if you don't like the climate, Move!' (Denning)*

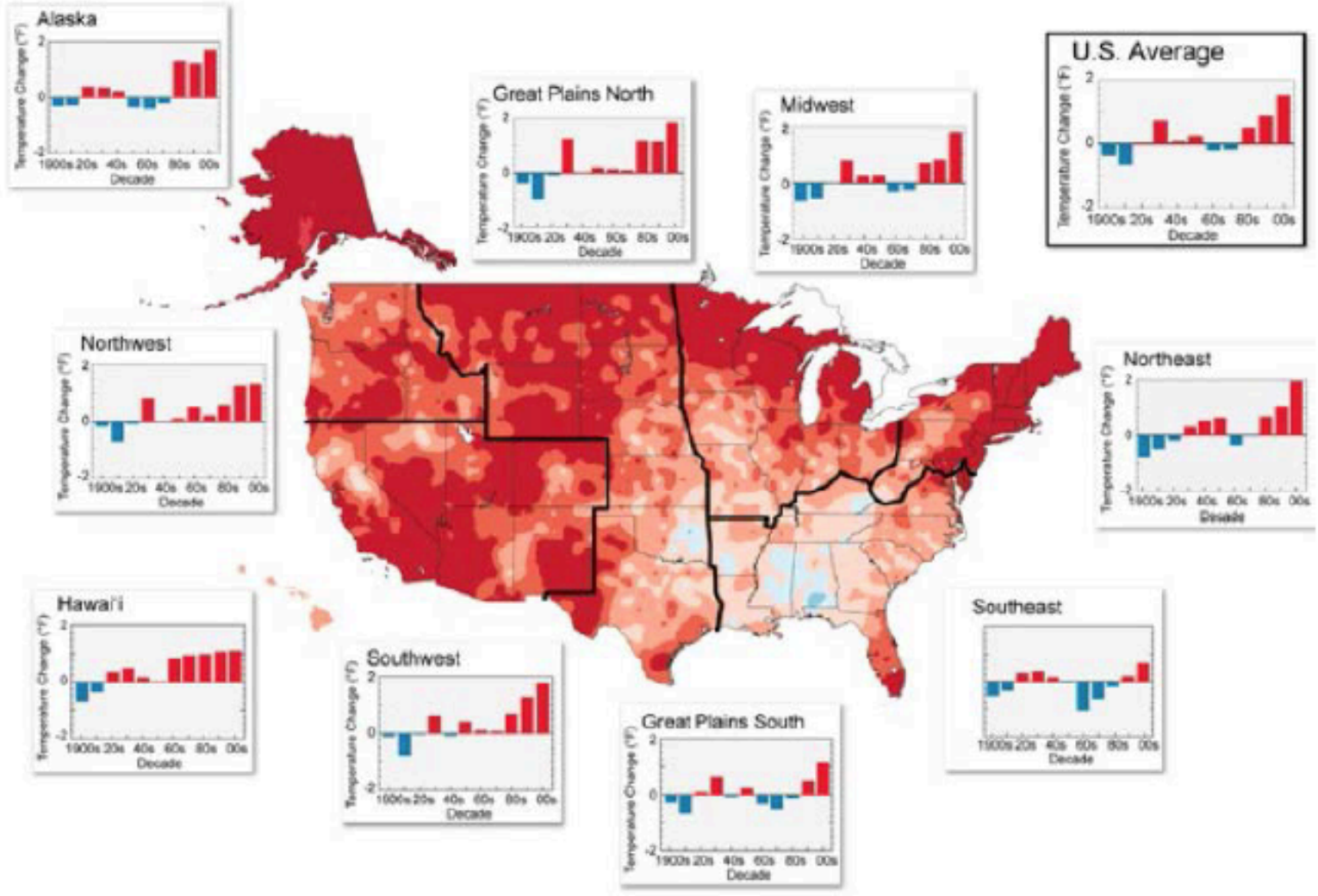
Streamflow reflects precipitation and evapotranspiration

Utah statewide



- Variation in streamflow is driven mainly by variability in annual **precipitation**
- **Temperature**, humidity, and winds affect **evapo-transpiration** (loss of water from the surface and vegetation)

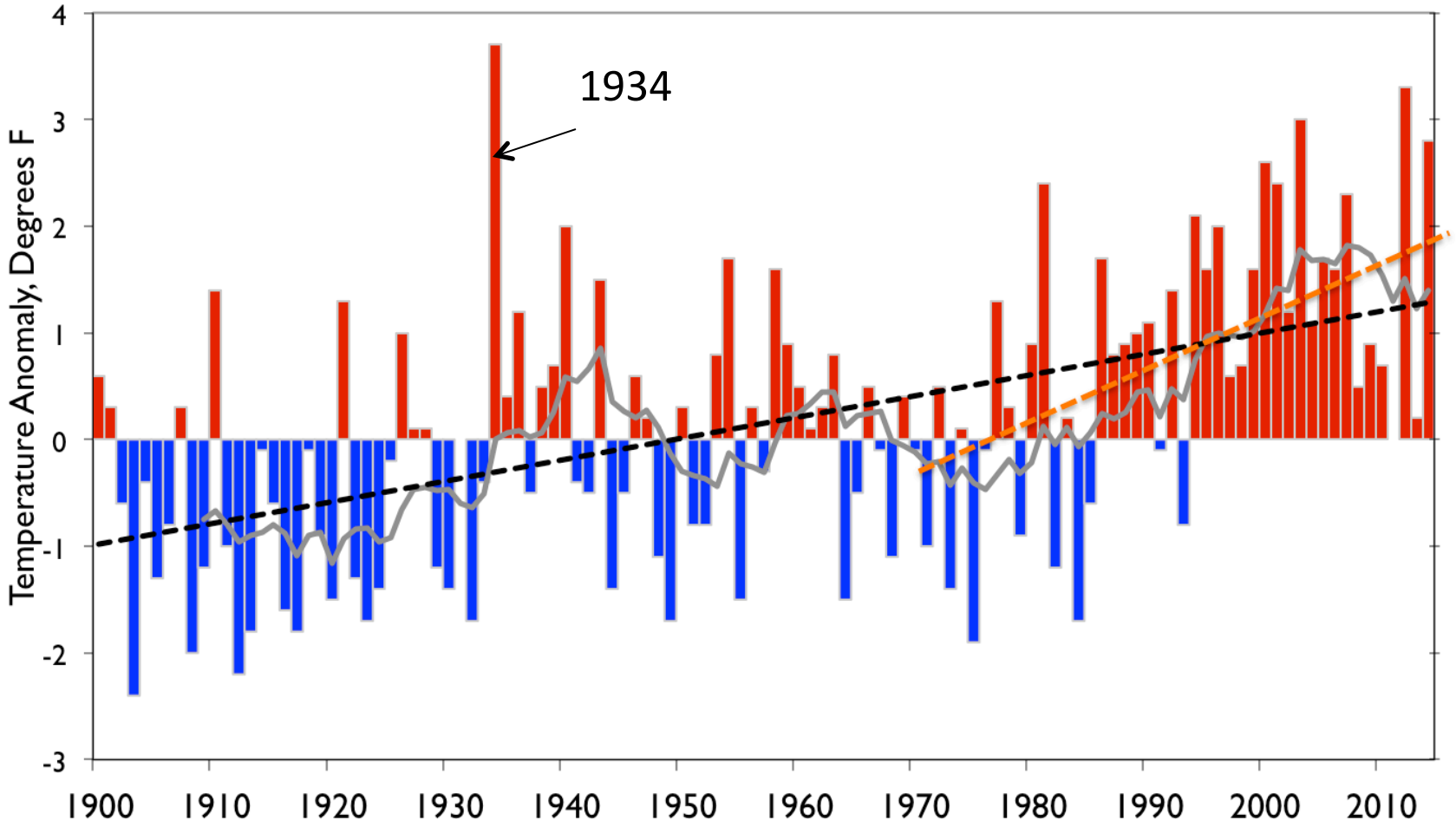
Since 1990, West has been 1° F to 2° F warmer than before 1960



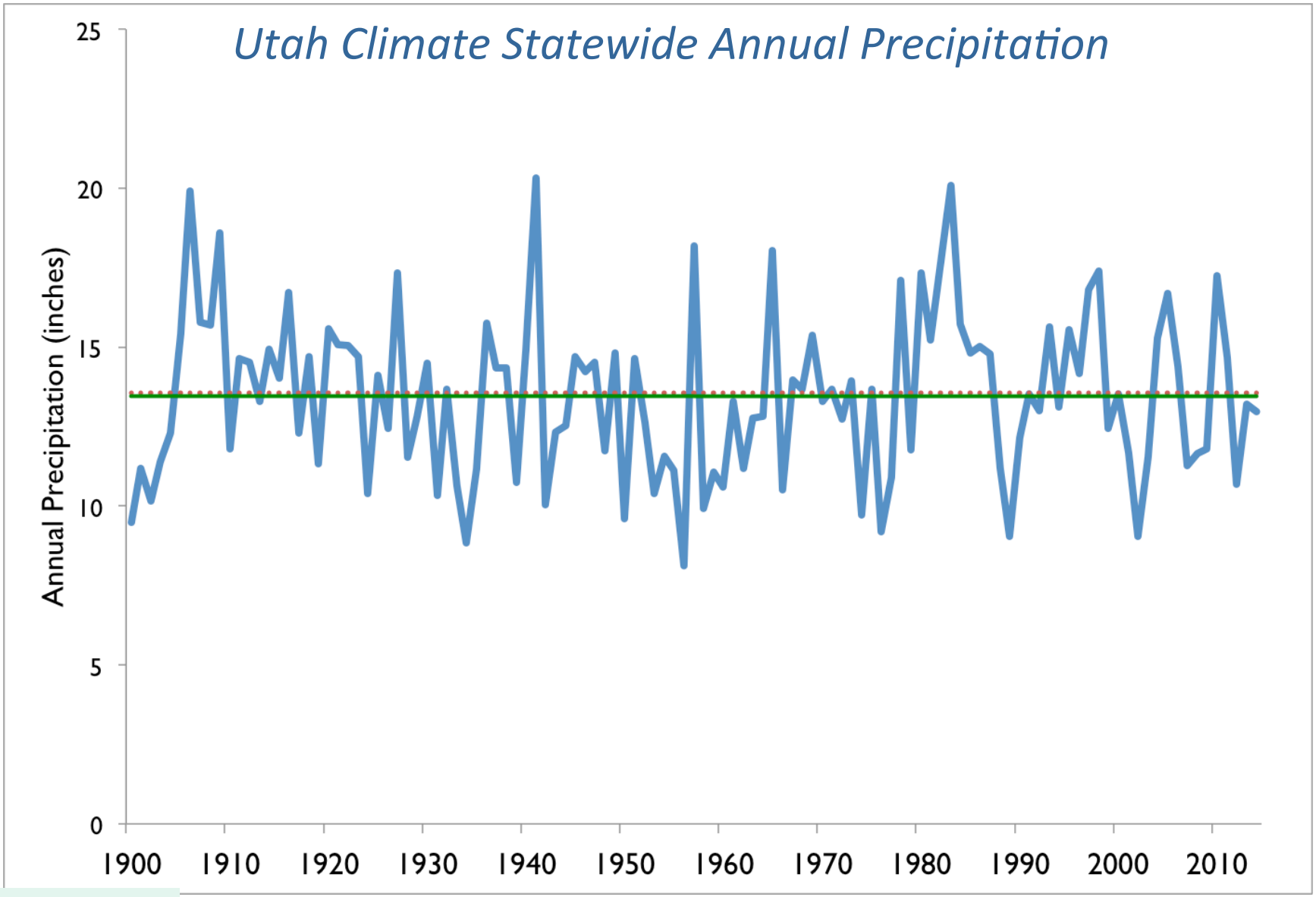
Observed

3rd NCA, Figure 2.7

Utah Statewide Annual Average Temperature



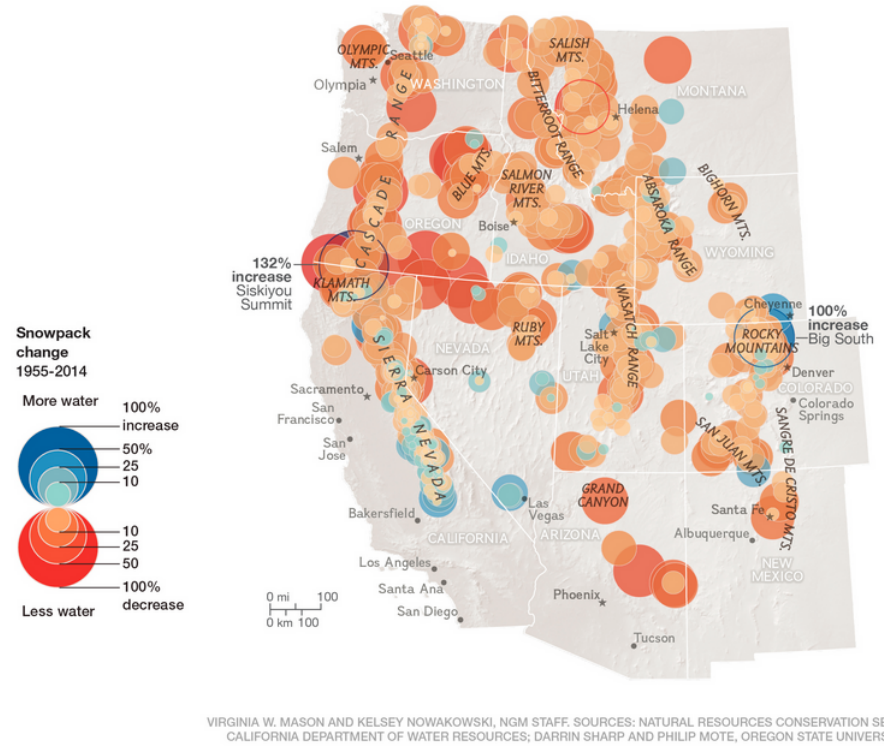
Observed


Utah Climate Statewide Annual Precipitation
Annual Precipitation (inches)
25
20
15
10
5
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Observed

Less Spring Snowpack

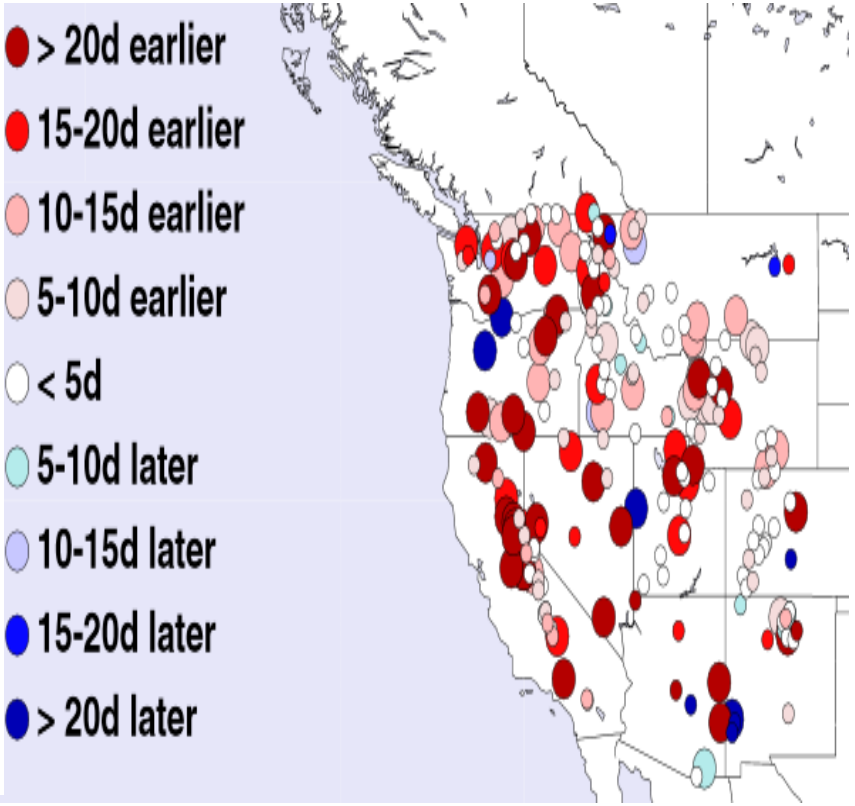
Sharp and Mote National Geographic 2014



VIRGINIA W. MASON AND KELSEY NOWAKOWSKI, NGM STAFF. SOURCES: NATURAL RESOURCES CONSERVATION SERVICE; CALIFORNIA DEPARTMENT OF WATER RESOURCES; DARRIN SHARP AND PHILIP MOTE, OREGON STATE UNIVERSITY

Earlier Snowmelt Runoff

Stewart, 2009

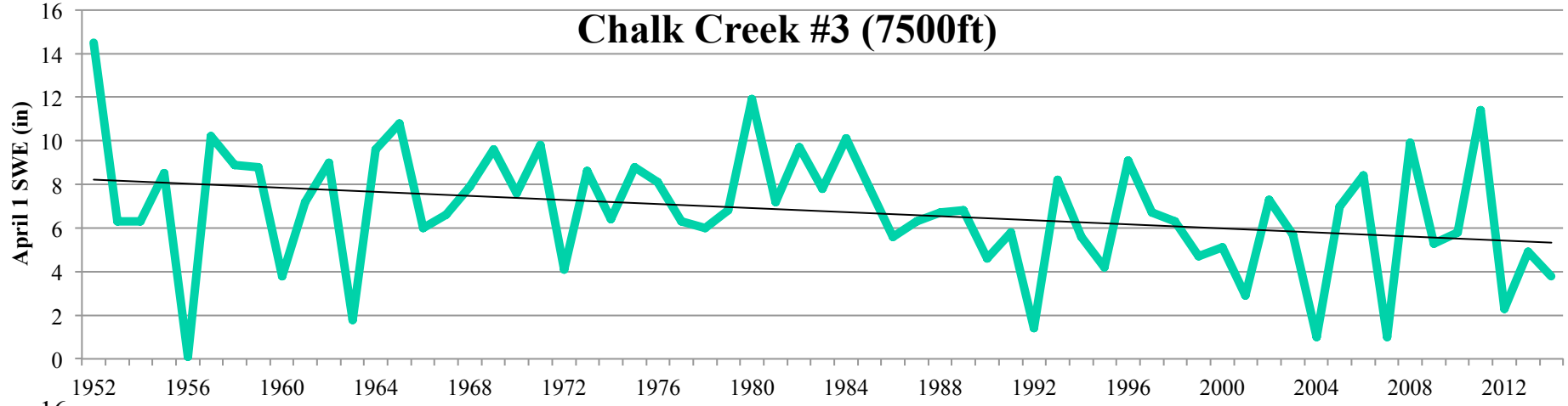


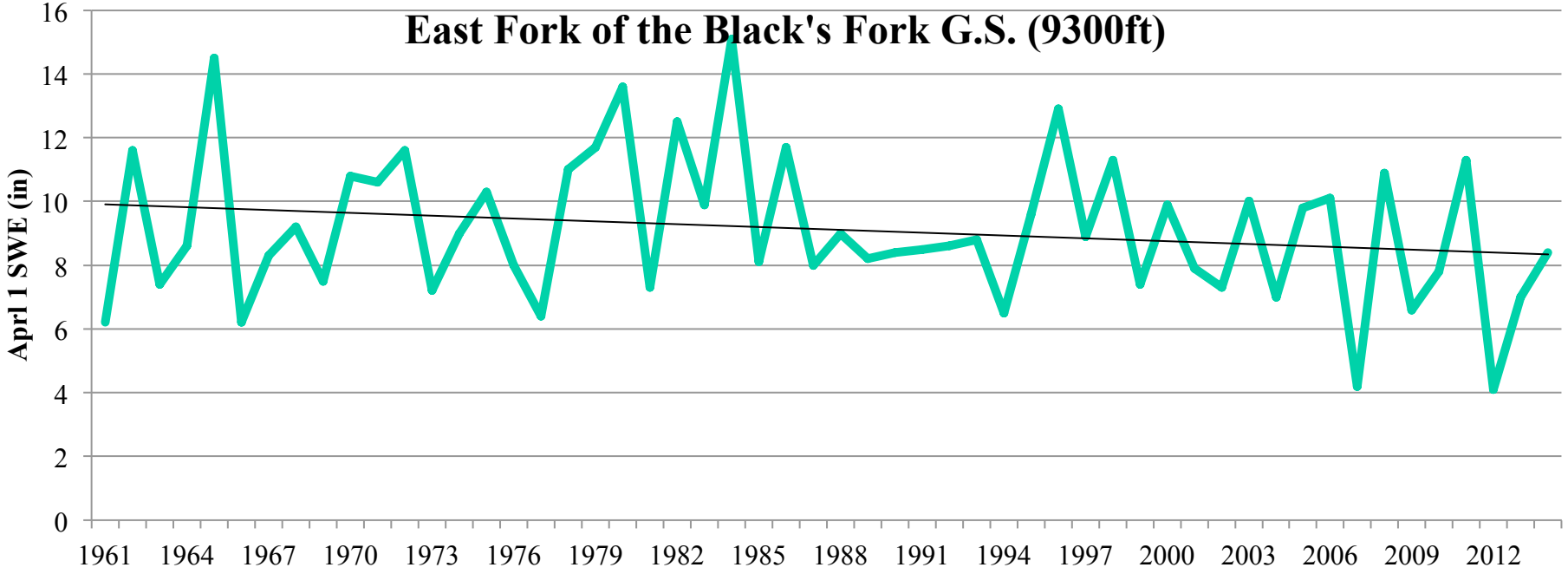
Observed

CBRFC Colorado Basin River Forecast Center

A few Long-Term Utah Snow Courses (14 of 21 look like these)

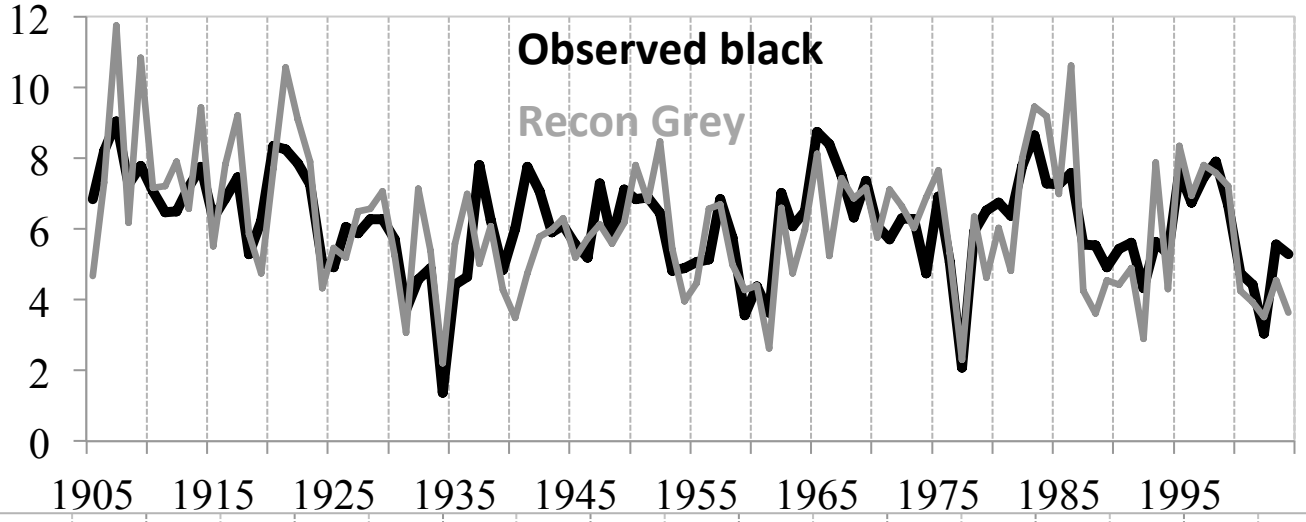
(Only 3 statistically significant decreases, no significant increases)

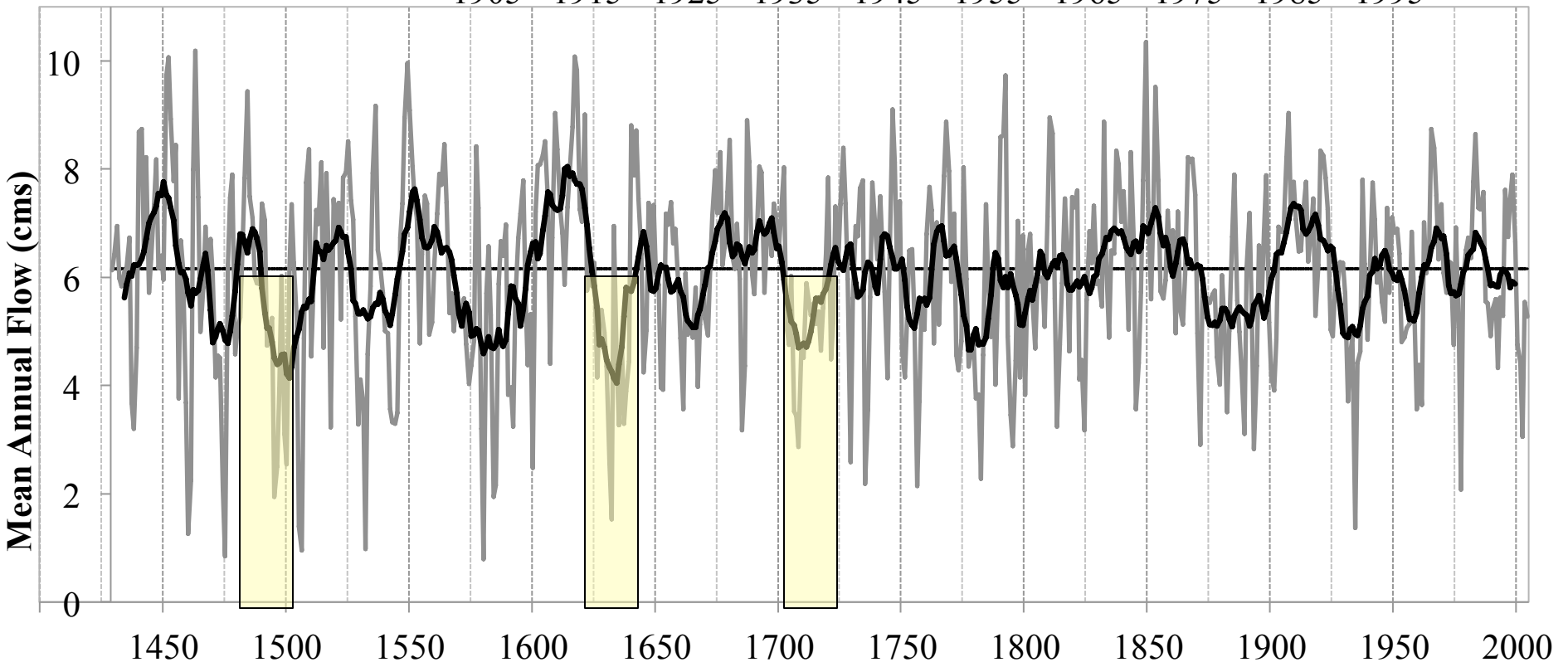




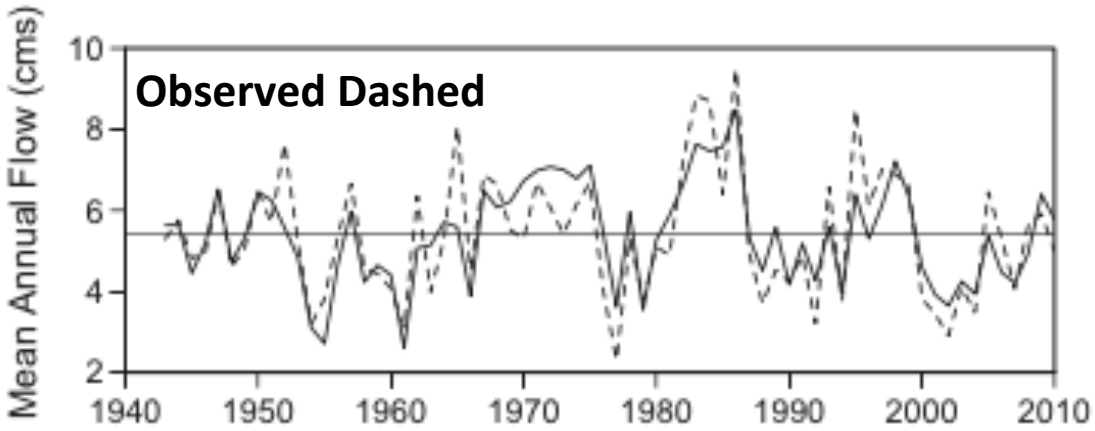
Weber nr Oakley 576 year reconstruction

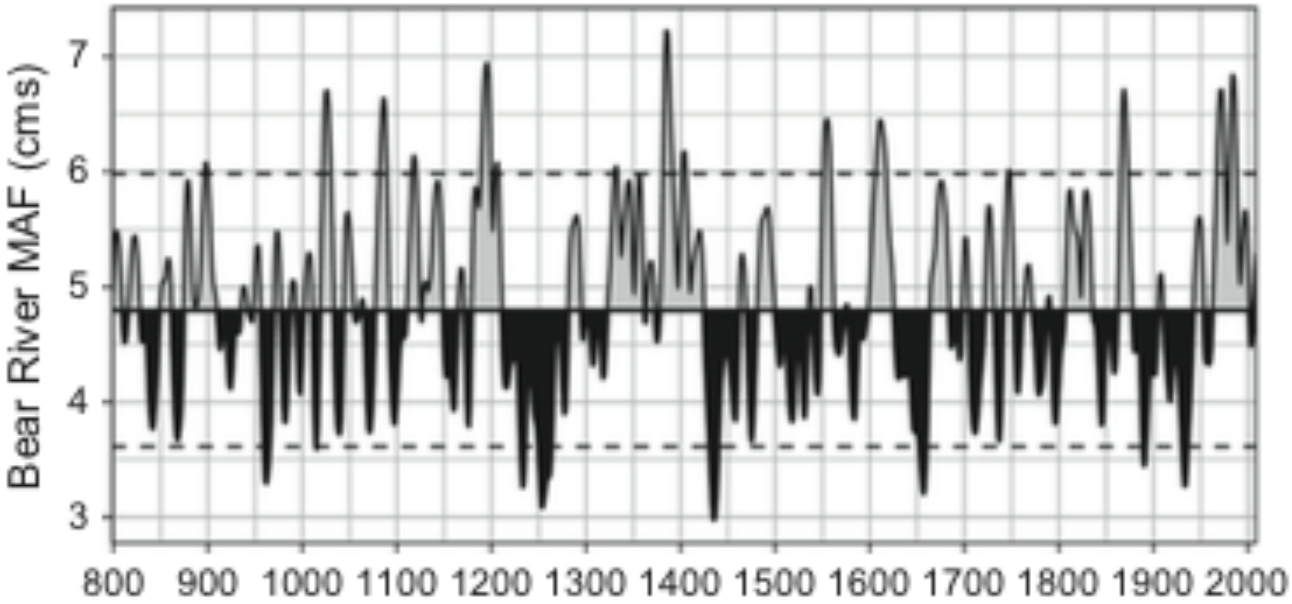
Bekker et al. 2014





Bear nr UT/WY stateline 1200 year reconstruction





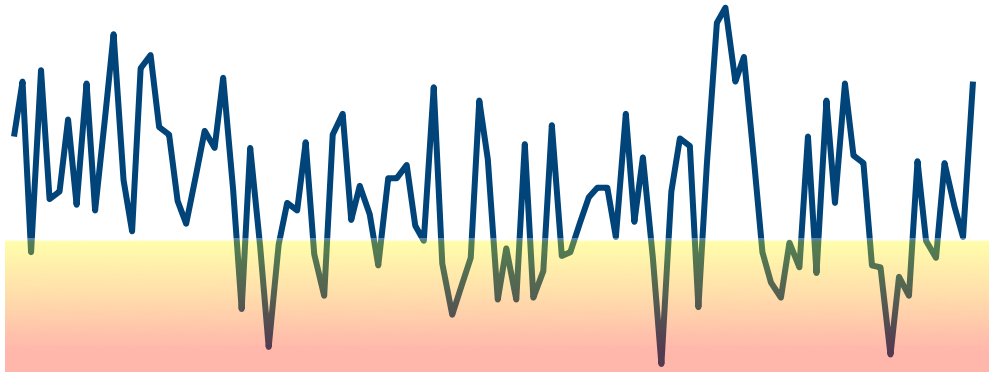
DeRose et al. 2015

Utah's climate has always been changing…

- *But temperatures in the past decade were the highest in 100 years, possibly for much longer*
- *More winter rain vs. snow*
- *These observations alone may not cause concern*
- *But we might want to take into account the additional paleo-variability seen in precipitation and drought in our planning*

Observed

Drought: driven by *precipitation* deficit, exacerbated by above-normal temperatures

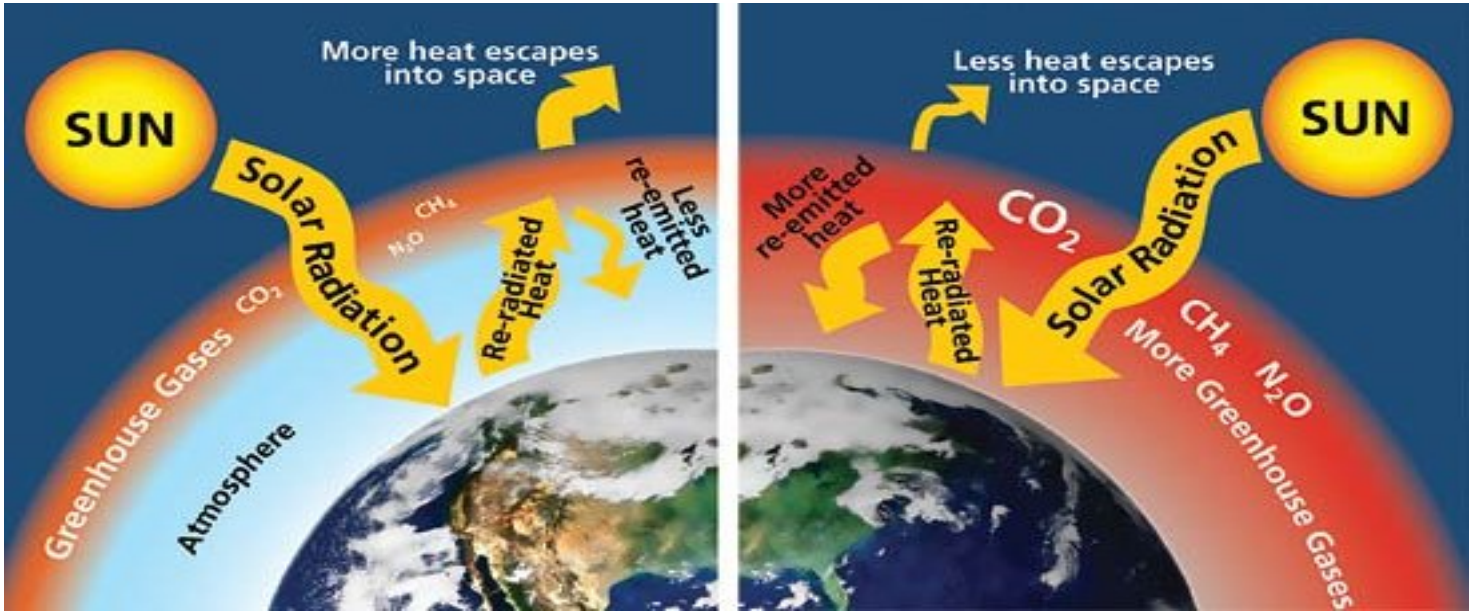


Middle photo: Jane Stulp

So what's different now?

Increasing greenhouse gases (GHGs) are causing more heat to be retained at the surface and lower atmosphere

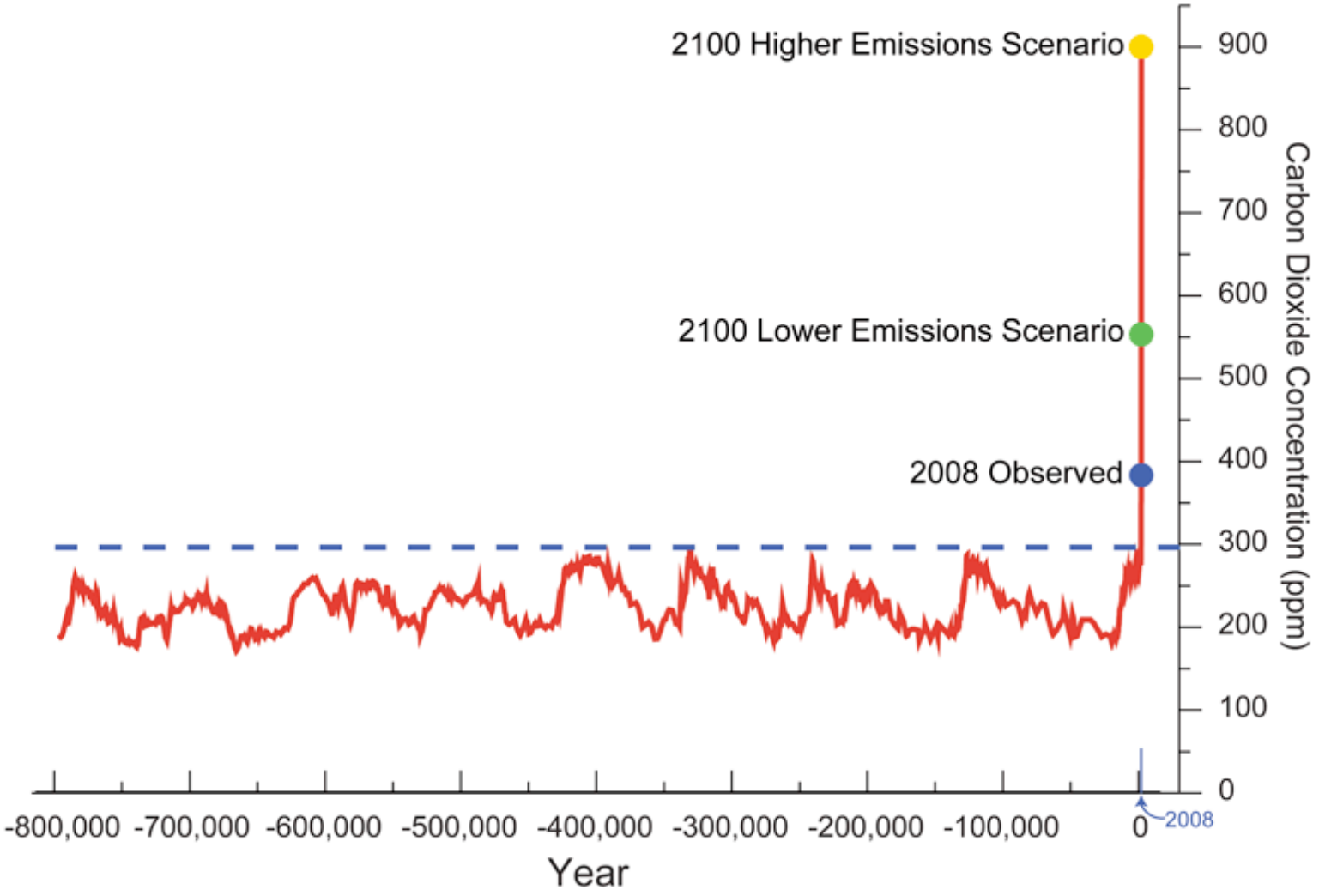
Past - Natural greenhouse effect *Today into the future*



- CO_2 in atmosphere now 40% higher than in 1750 and highest in at least 800,000 years
- Doubling of CO_2 causes 2°F warming globally; cloud and water vapor *feedbacks* will add to that warming

Image source: National Park Service

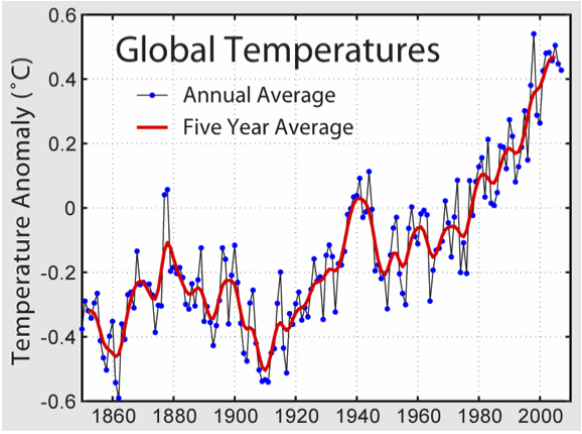
CO_2 : 800,000 Years Record

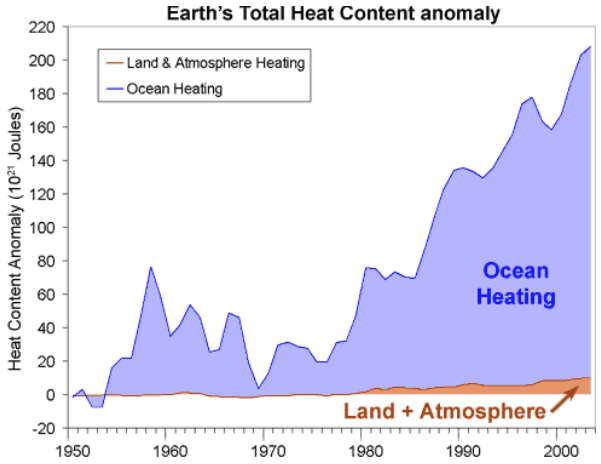


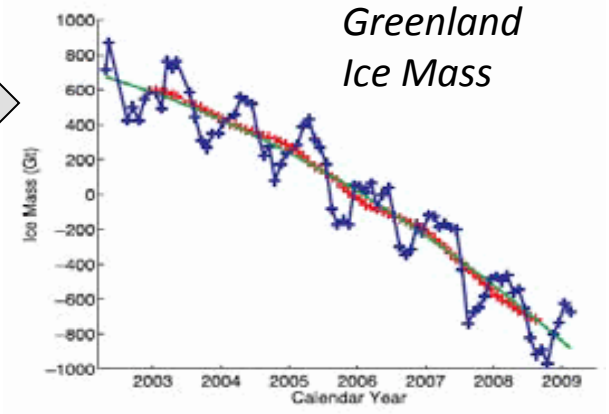
www.ncdc.noaa.gov/indicators/

Globally, multiple lines of evidence of unusual climate change

- **Increasing global land surface and sea surface temperatures**
- Increasing lower atmosphere temperatures (satellites)
- **Increasing total ocean heat content**
- Increasing sea level
- Increasing atmospheric water vapor
- Increasing global drought
- Decrease in alpine glacier mass
- **Decrease in Arctic sea ice area, polar ice mass**
- Northward and upward movements in animal and plant species

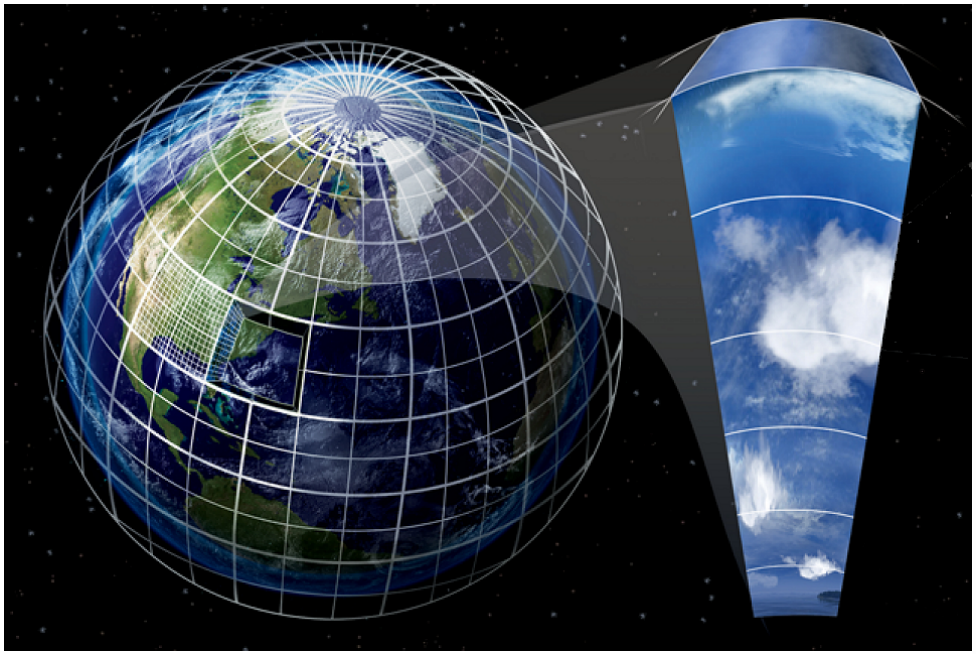


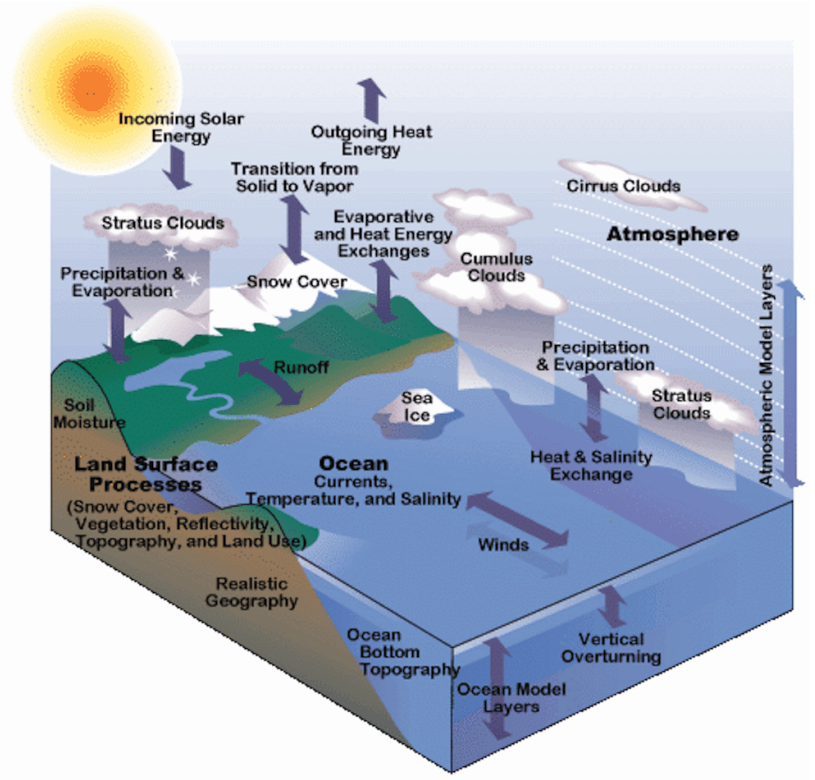




Observed

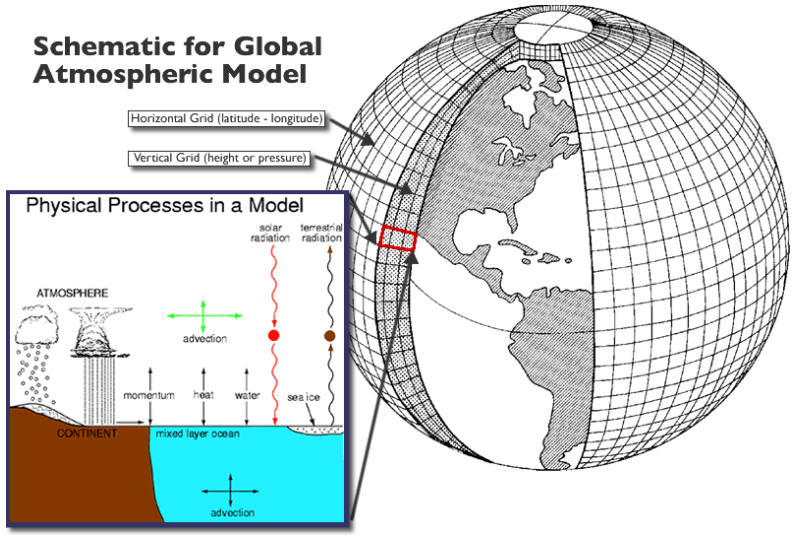
Global climate models (GCMs): tools to quantitatively explore potential future climates, based on our physical understanding of the system





Figures 3-1 & 3-2

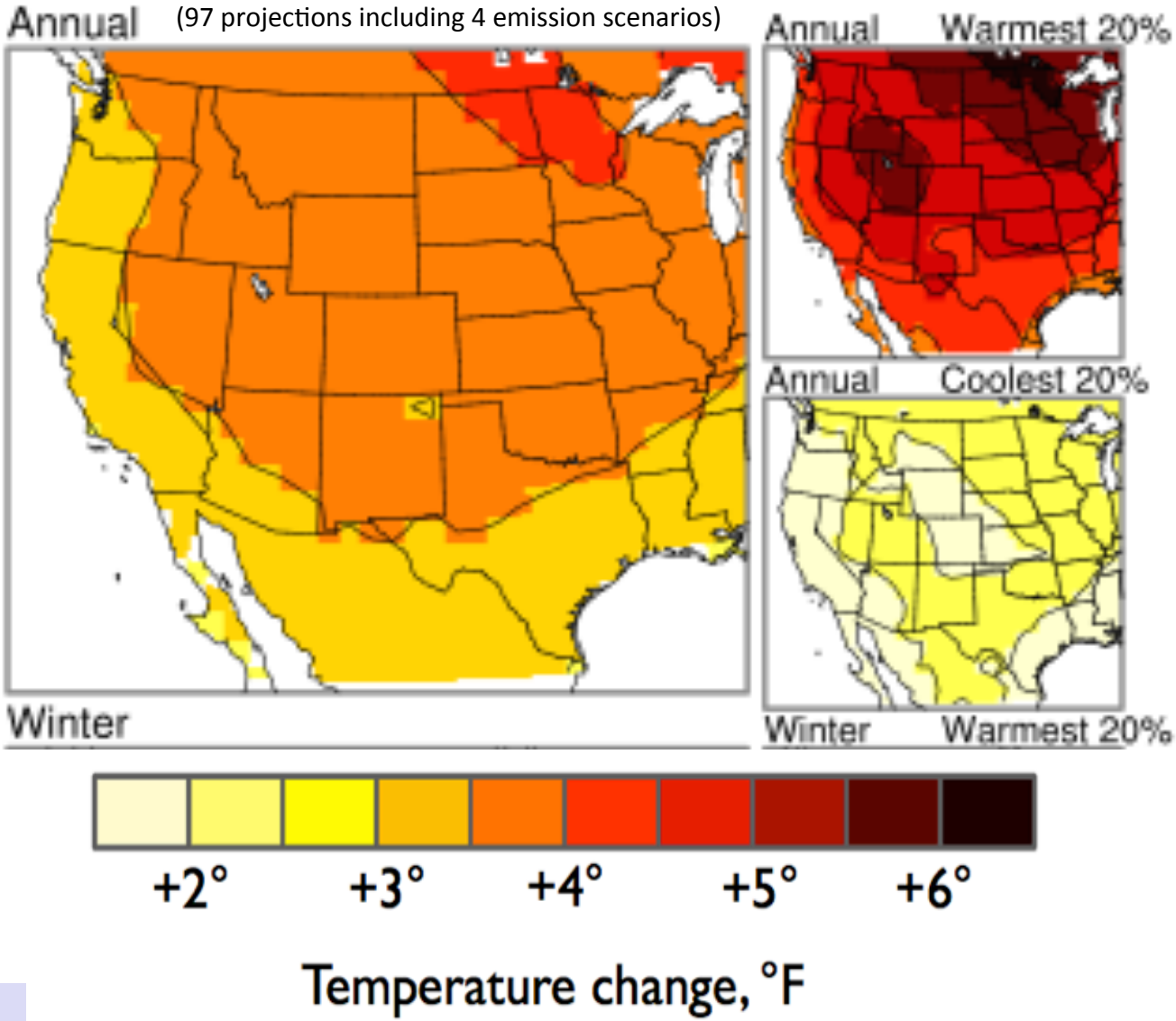
Global climate models (GCMs)



GCMs simulate the complex interactions among the land, oceans, atmosphere

- *More than 30 different GCMs have been developed*
- *It is very important to compare results from different GCMs, and to use multi-model averages*
- *GCM output is coarse-resolution and generally needs to be downscaled to be used in planning*
- *GCMs are not crystal balls—they're a tool to help us understand the potential envelope of future climate*

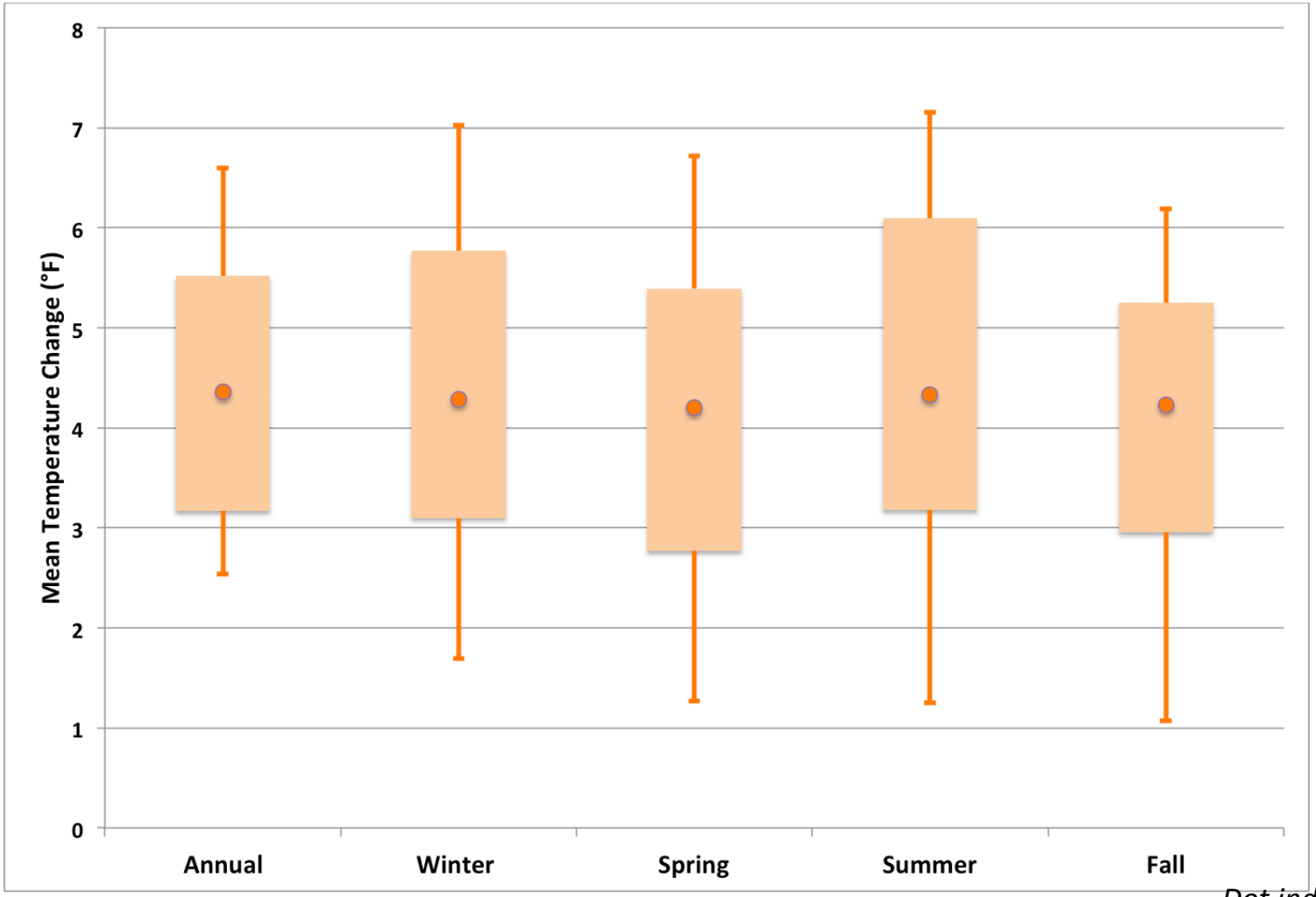
Utah continues to warm in all projections, by 2.5°F to 5.5°F by 2060



Projected

Projected 2060 Temperature change in Utah

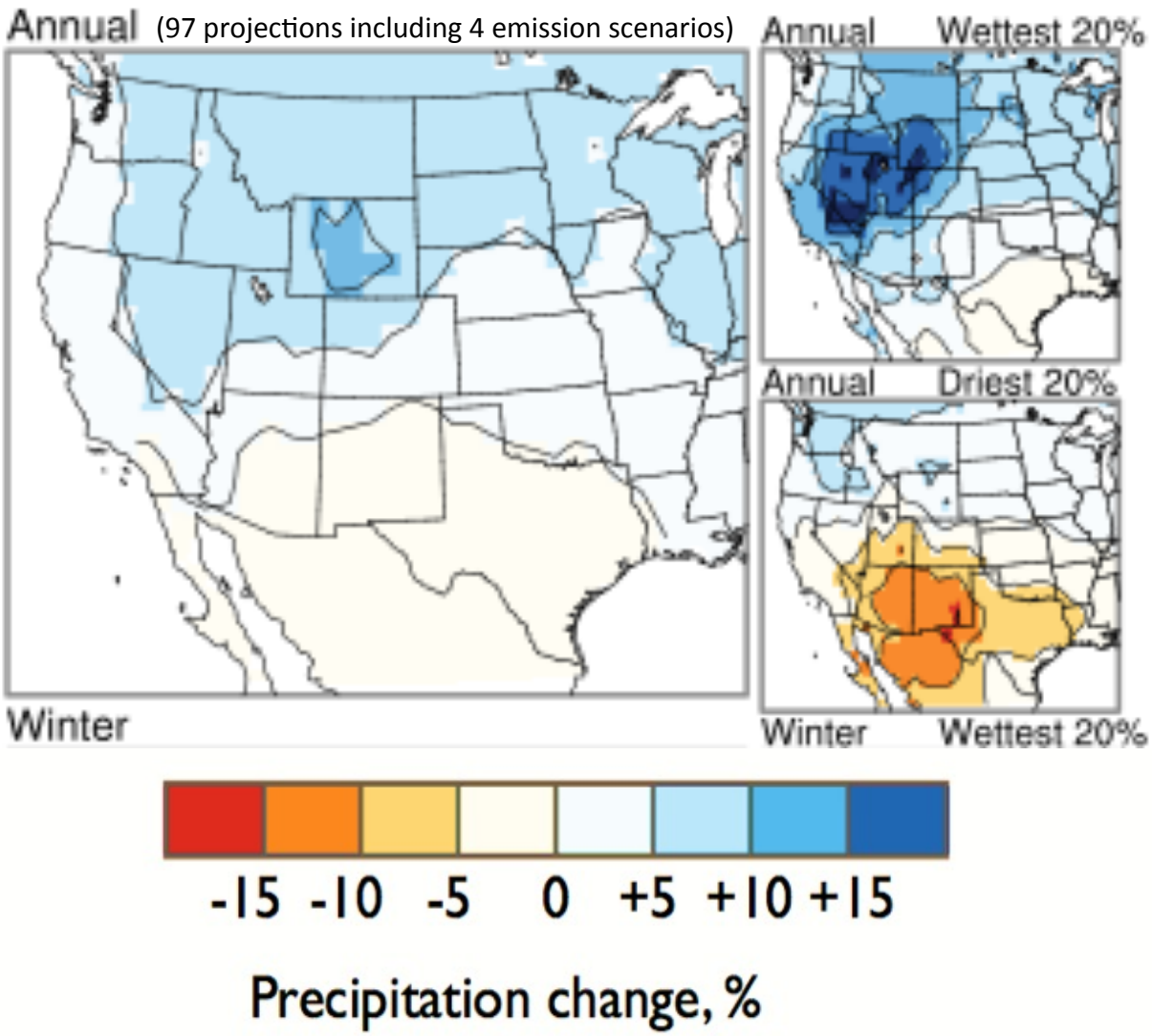
(Change from 1981-2010 to 2045-2064) (97 projections including 4 emission scenarios)



Dot indicates median, box center 50%, whiskers 10 and 90%

Projected

Utah statewide precipitation change by 2060 uncertain; we're between regions expected to get drier and wetter



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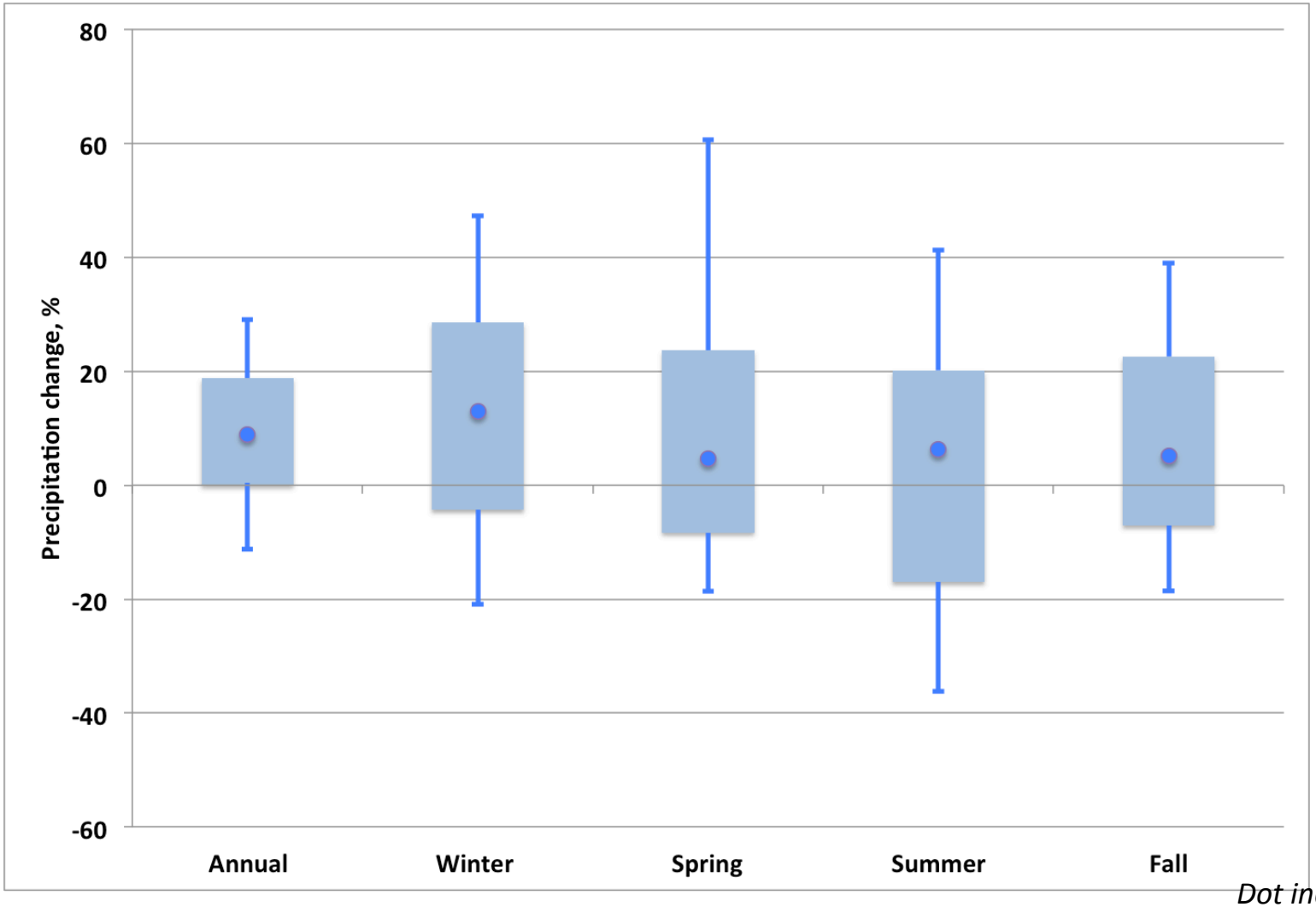
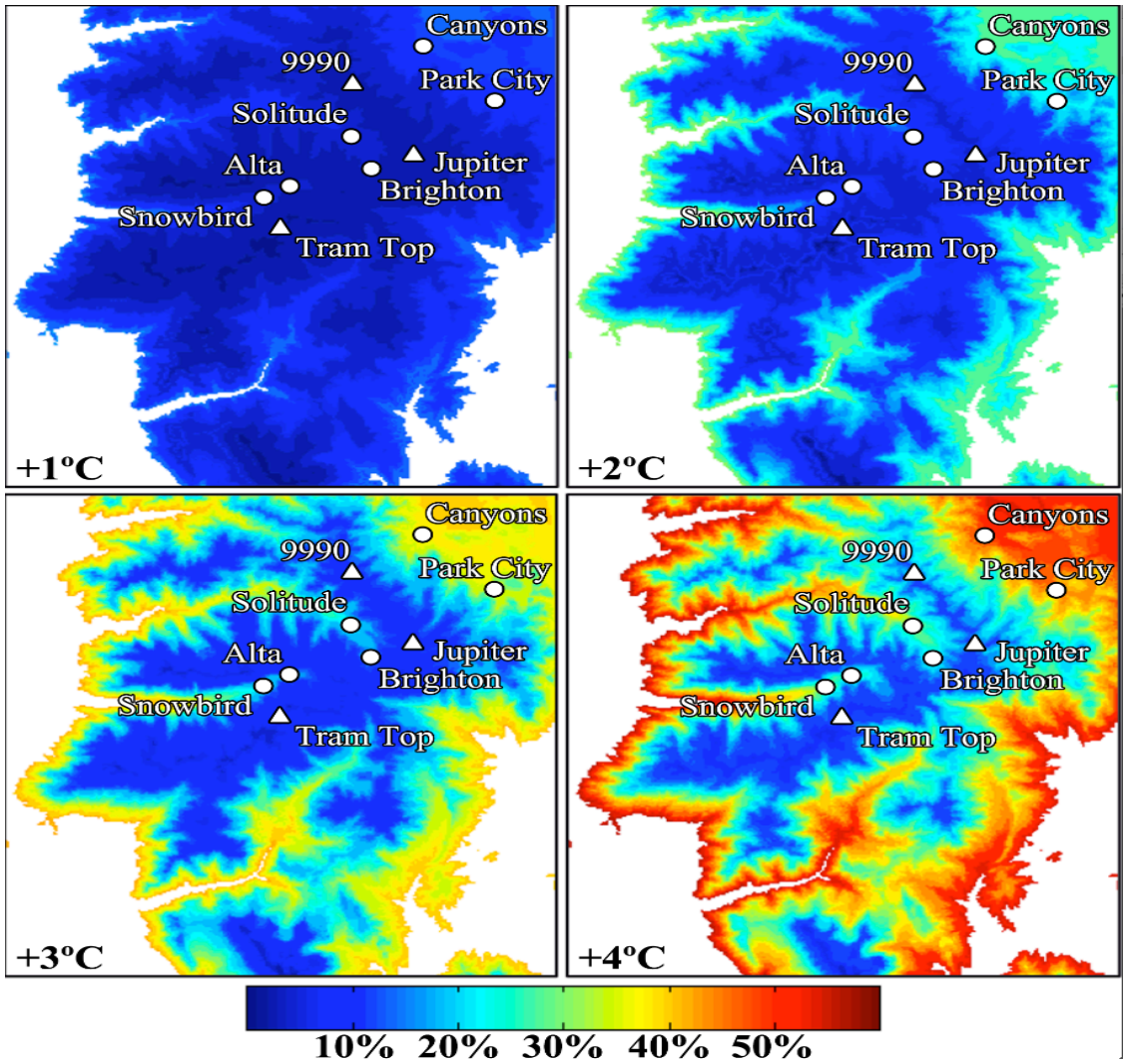


Dot indicates median, box center 50%, whiskers 10 and 90%

Projected

Modeled Change in Snow to Rain Percentage per °C of warming



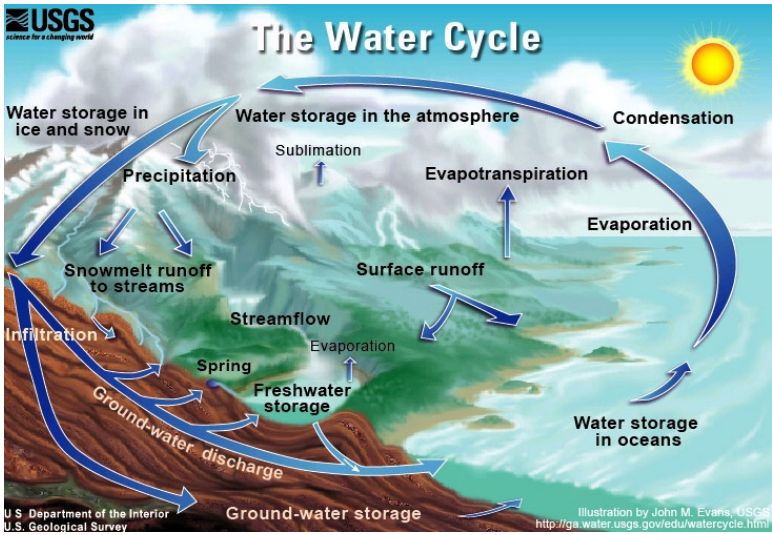
Projected

Jones 2010, Steenburgh 2014

Multiple projected impacts of warming on the water cycle

With higher temperatures, assuming no precipitation change:

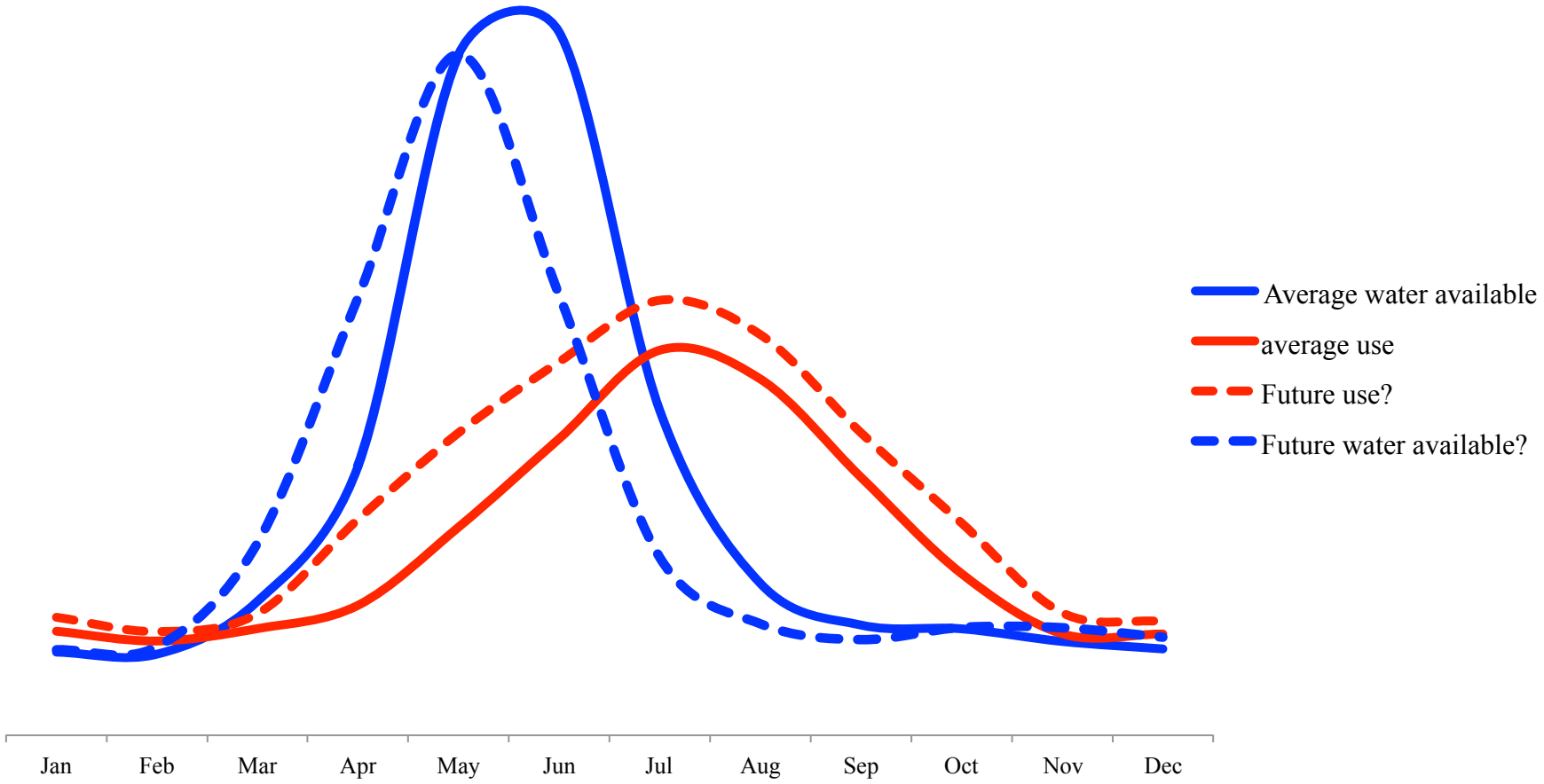
- Increased evaporation and transpiration
- More rain, less snow
- Reduced snowpacks
- Earlier peak runoff
- Reduced annual flows
- Reduced groundwater recharge
- Reduced soil moisture
- Greater plant moisture stress
- Increased water demand
- Warmer water temperatures and related water quality issues



➢ *These are all impacts currently associated with drought…they will tend to occur more often in a warming climate*

Projected

Potential Water Supply and Demand Shifts



Projected

General approach for projecting basin-scale changes to hydrology used in WWCRA & Basin Study and new CMIP5-based hydrology projections (USACE, NCAR, Reclamation, et al.)

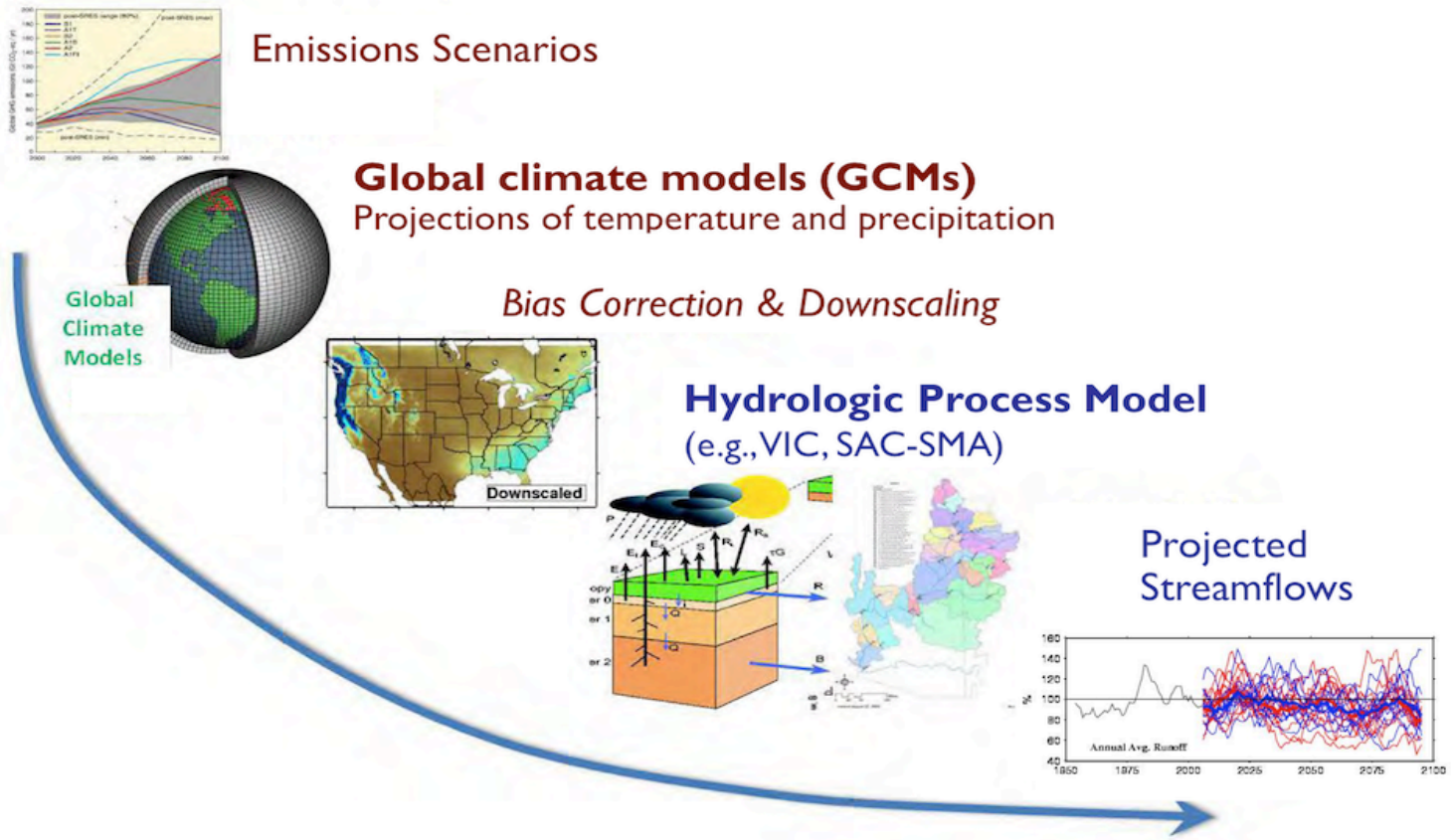


Figure 5-19

Planning and Management Studies

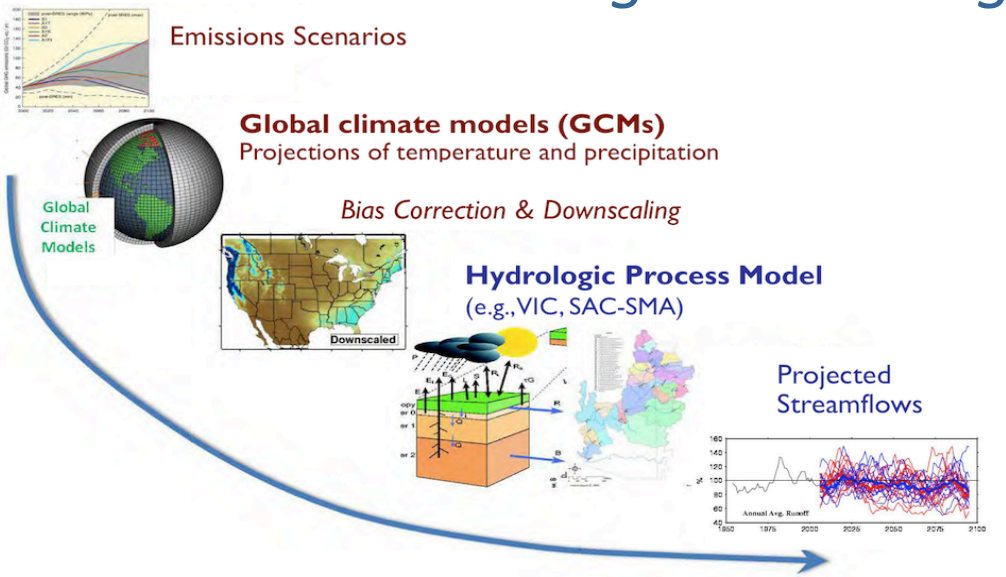
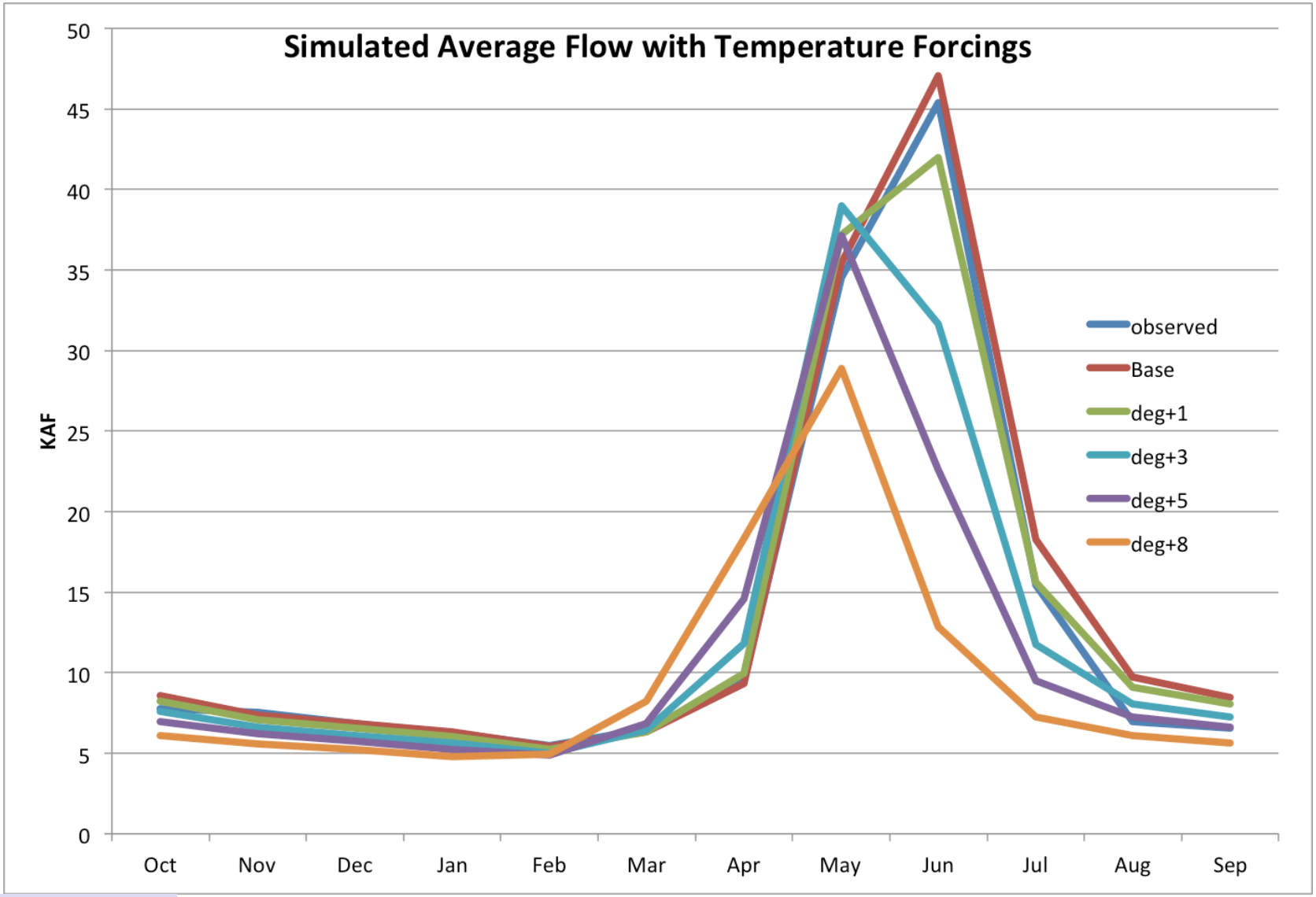


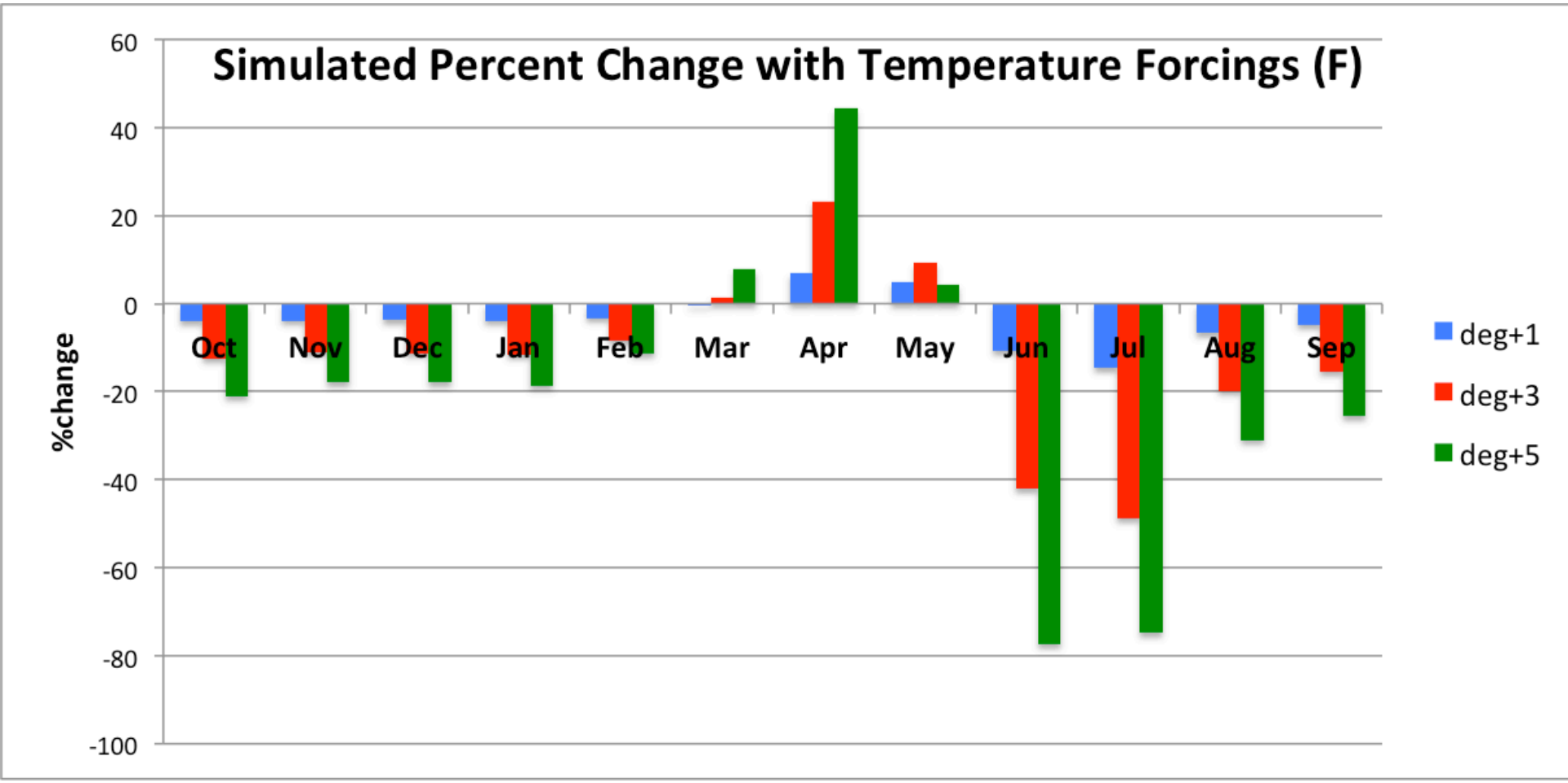
Figure 11.2. Basic elements of a climate adaptation process. Reproduced with permission from Bierbaum et al. (20

Duchesne nr Tabiona average Temperature Sensitivities



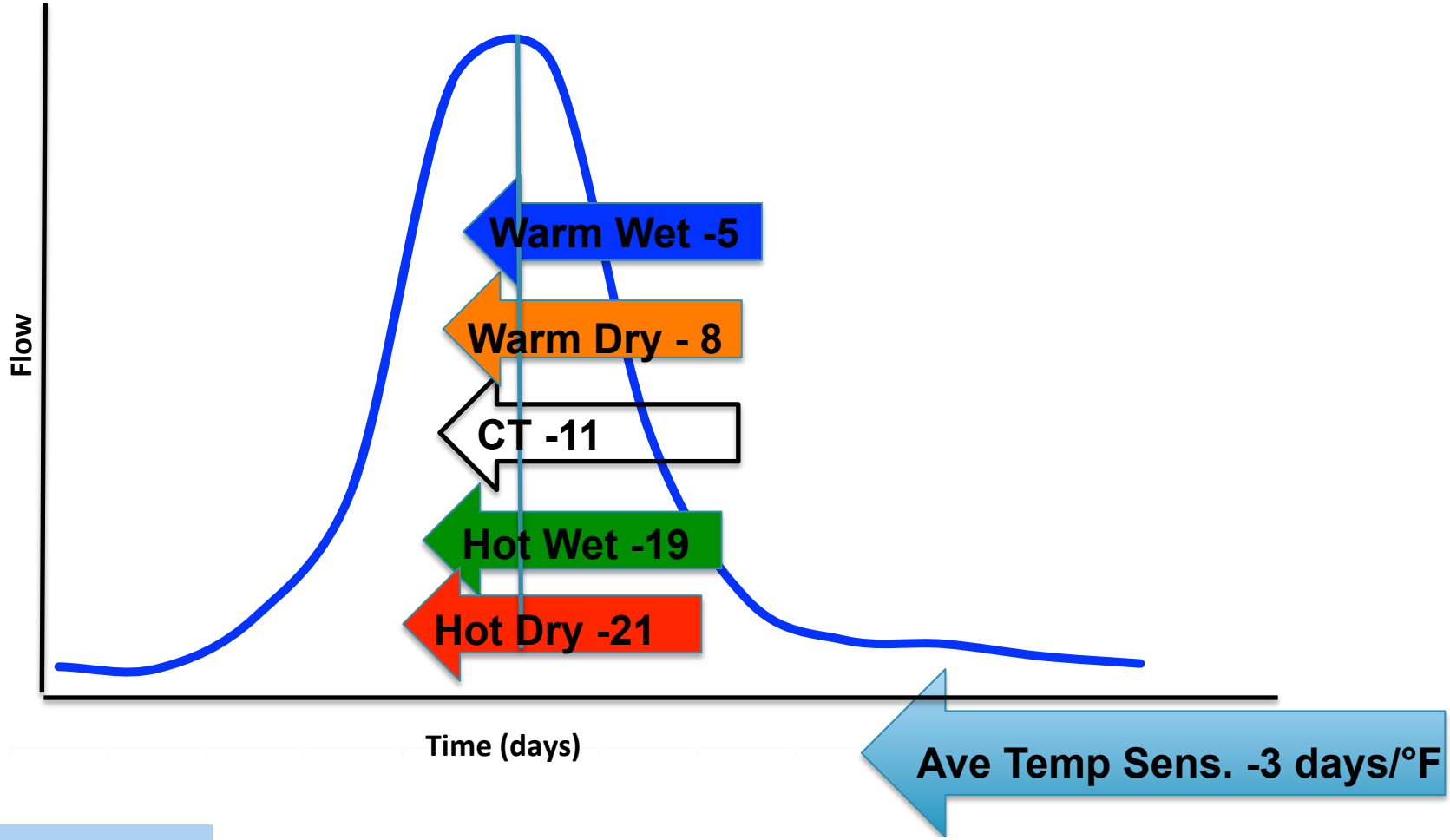
Projected

Duchesene nr Tabiona Monthly Sensitivities



Projected

Average change in the centroid of runoff Duchesene at Tabiona (Mid Century)



Projected

Planning and Management Assessment Examples

- *The Colorado River Basin Study: http://www.usbr.gov/lc/region/programs/crbstudy.html*
- *Joint Front Range Climate Vulnerability Study: http://cwcb.state.co.us/environment/climate-change/Pages/JointFrontRangeClimateChangeVulnerabilityStudy.aspx*
- *Weber Basin Water Conservancy District (in progress)*
- *Salt Lake City Study: http://journals.ametsoc.org/doi/abs/10.1175/2012EI000501.1*
- *Boulder Colorado Study: http://treeflow.info/docs/boulder_climatechange_report_2009.pdf*
- *Tree ring planning examples: http://treeflow.info/applications.html*

Examples of potential Adaptive Strategies

- *Watershed planning and source protection*
- *Infrastructure (storage reservoirs and ASR)*
- *Water Markets*
- *Conservation incentives*
- *Municipal Conservation*
- *Agricultural Efficiency (conveyance and on farm)*
- *Water Reuse*
- *Policy/Management Changes*
- *Cooperation vs. conflict/litigation – Watershed partnerships*

The take-home messages

- Utah's climate has always been highly variable, but—
- Increasing greenhouse gases--by trapping more heat in the climate system--are becoming a major driver of climate change
- Changes are already occurring locally, regionally, and globally and are expected to become much larger
- In UT, temperature is projected to increase by ~4°F (range 2-7) by mid- century and ~6°F (range 3-10) by late century —outside of past bounds
- The trajectory of future precipitation in UT is less clear
- The expected warming presents major challenges for managing water resources.

The take-home messages – Water Resources

- Change of runoff timing
- Loss of snowpack storage
- Water temperature- water quality concerns
- Increasing landscape and agricultural water demand
- Significant uncertainty on annual runoff volumes due to precipitation uncertainties, future emissions and modeling uncertainties
- Specific local impacts are challenging, science is advancing, but many uncertainties will persist. (Can't delay planning till local uncertainties are minimized)
- Flooding and extreme events

Webtools and Resources

- *U.S. Climate Resilience Toolkit: https://toolkit.climate.gov/taking-action?page=1*
- *EPA Climate Ready Water Utilities Toolbox: http://www.epa.gov/safewater/watersecurity/climate/toolbox.html*
- *The Water Utility Climate Alliance: http://www.wucaonline.org/html/*
- *Western Water Assessment: http://wwa.colorado.edu/*
- *Reclamation West-Wide Climate Risk Assessment: http://www.usbr.gov/WaterSMART/docs/west-wide-climate-risk-assessments.pdf*
- *Colorado Basin River Forecast Center: www.cbrfc.noaa.gov*
- *NOAA's Climate Change Web Portal: http://www.esrl.noaa.gov/psd/ipcc/cmip5/ccwp.html*

WWA Snow Monitoring Workshops - late summer 2015

- One-day workshops in Wyoming, Colorado, and Utah for water managers and others who track SWE/runoff
- Date/location of UT workshop TBD; mid-July to end -Aug

Objectives

- Describe existing snow monitoring networks and products, and their use
- Introduce new spatially-explicit snow products, and gauge interest and capacity to use them
  - MODIS-based SWE estimates (Molotch)
  - LIDAR-based SWE estimates (NASA JPL)
- Produce recommendations to improve snowpack monitoring network

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