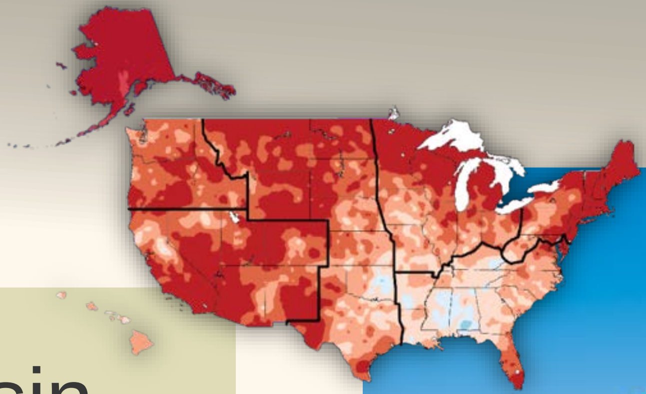
November 30, 2016

Lower Santa Cruz River Basin Study: Climate Change, Water and the Environment: Managing Risk in the Tucson Basin



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Arizona | Institute of the Environment

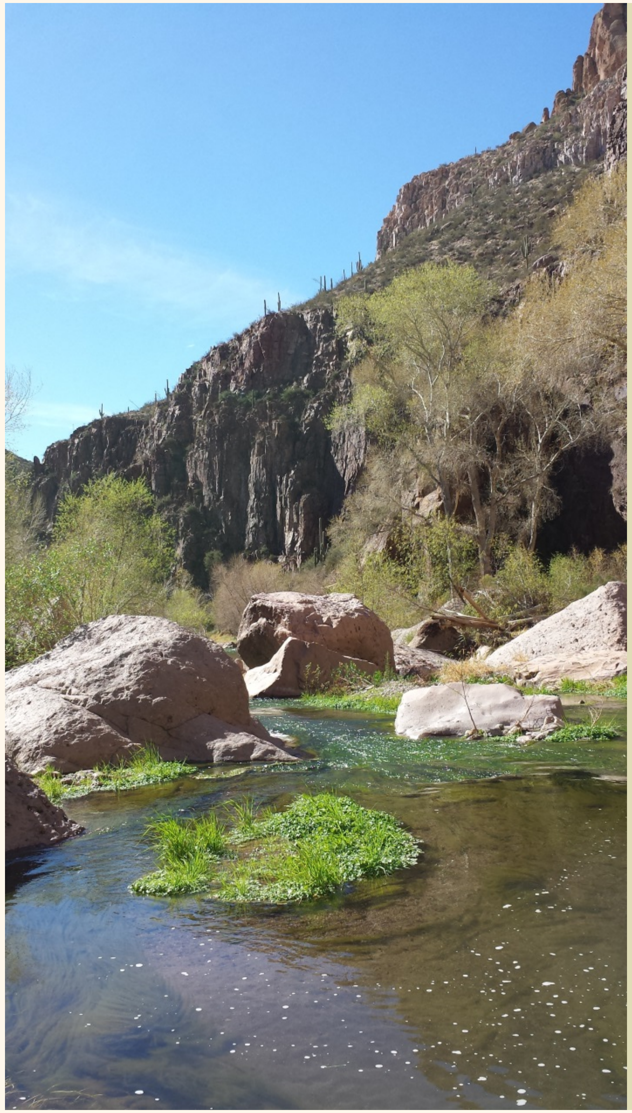
College of Agriculture and Life Sciences

Center for Climate Adaptation Science and Solutions

The Third National Climate Assessment (NCA3)

GCRA (1990), Section 106

…not less frequently than every 4 years, the Council shall prepare… an assessment



Goal

- Enhance the ability of the United States to **anticipate, mitigate, and adapt** to changes in the global environment.

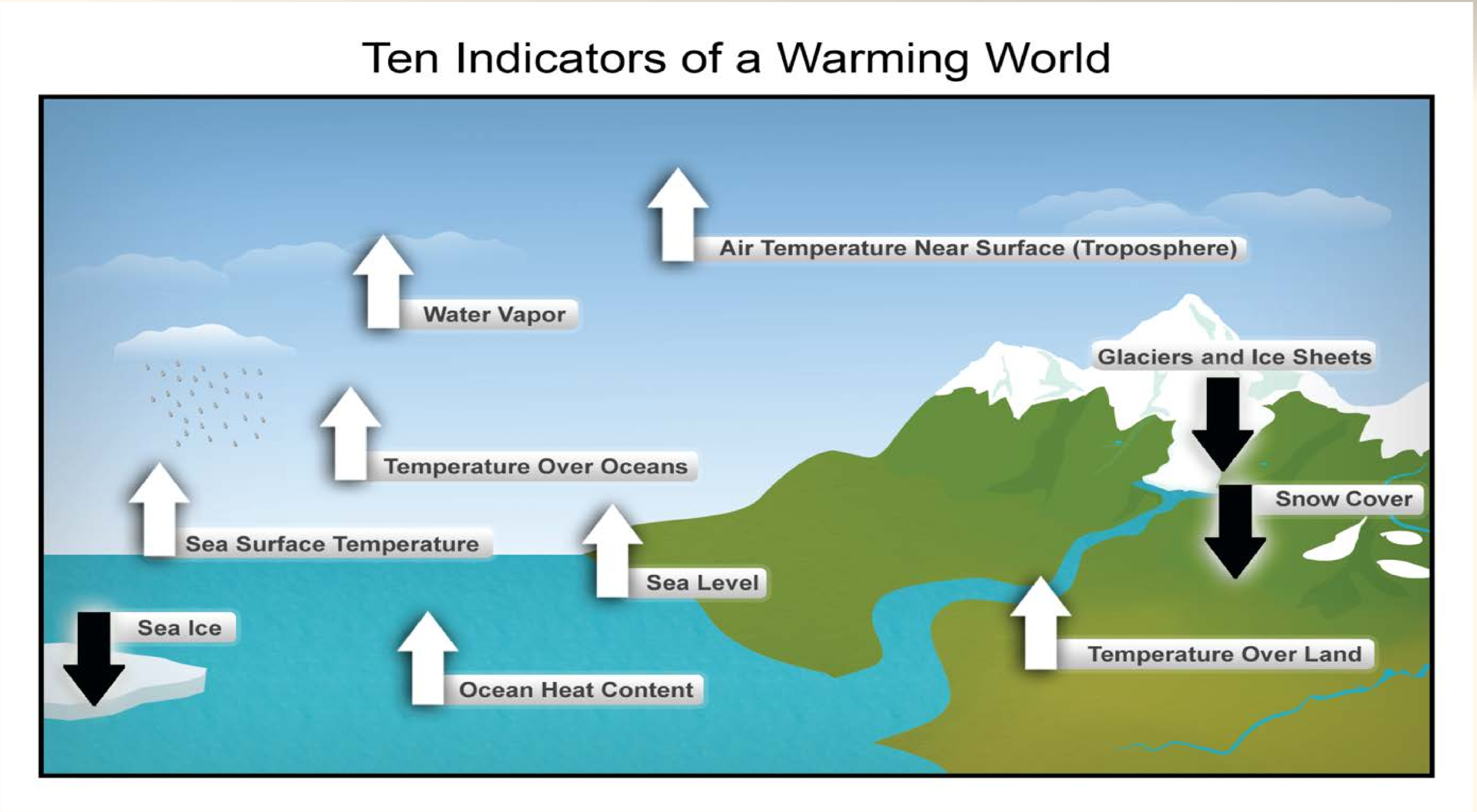
Vision

- 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 US.

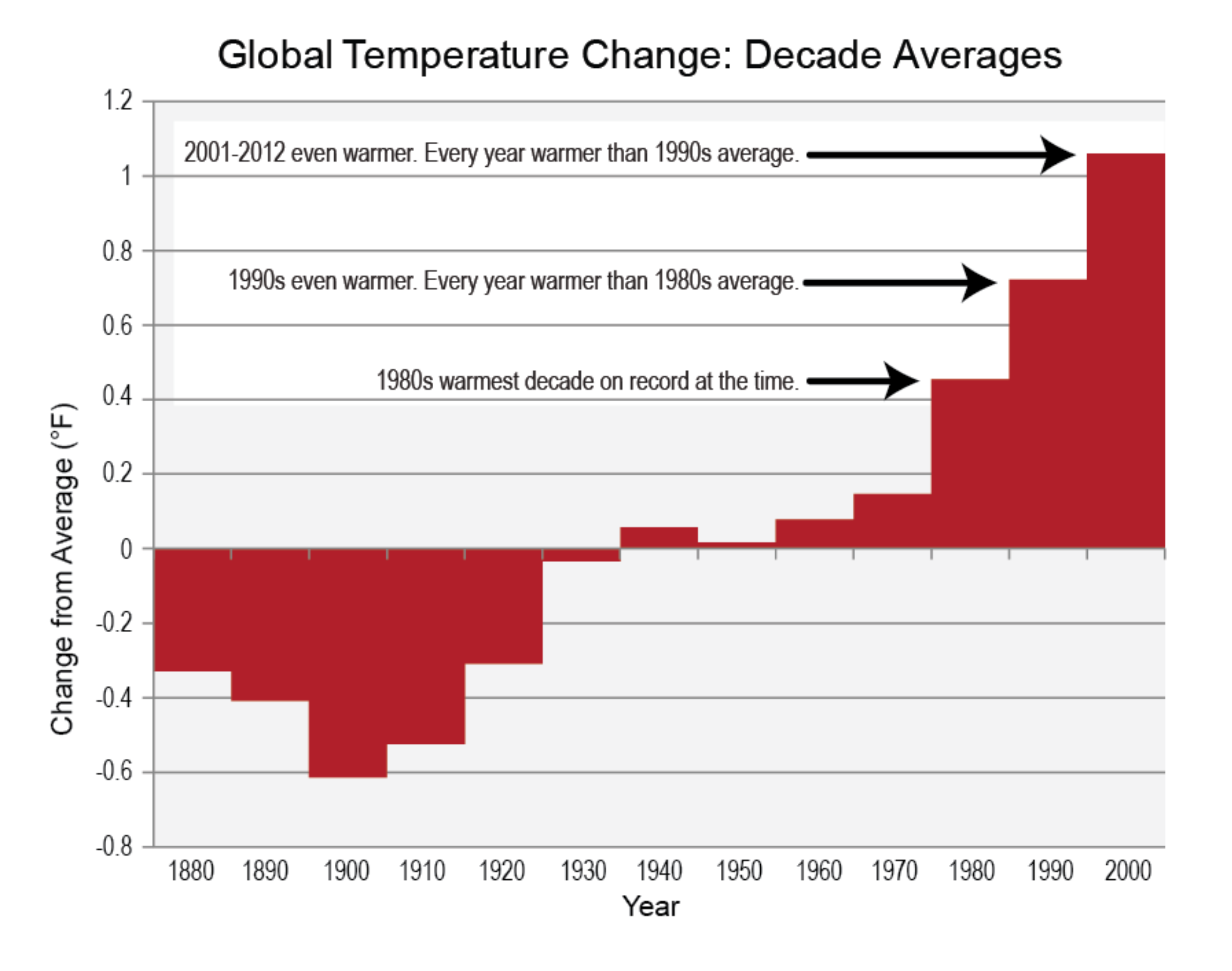
NCA3 Approach

- Large number of authors (300) and advisory committee members (60);
- National Academies, public, 13 agencies, White House review
- Wide diversity of perspectives and the potential for reaching into multiple existing ‘knowledge networks’
- Building the concept of a sustained assessment
- Fully transparent access to data; electronic delivery; traceable accounts

NCA 2014: Climate Change Indicators



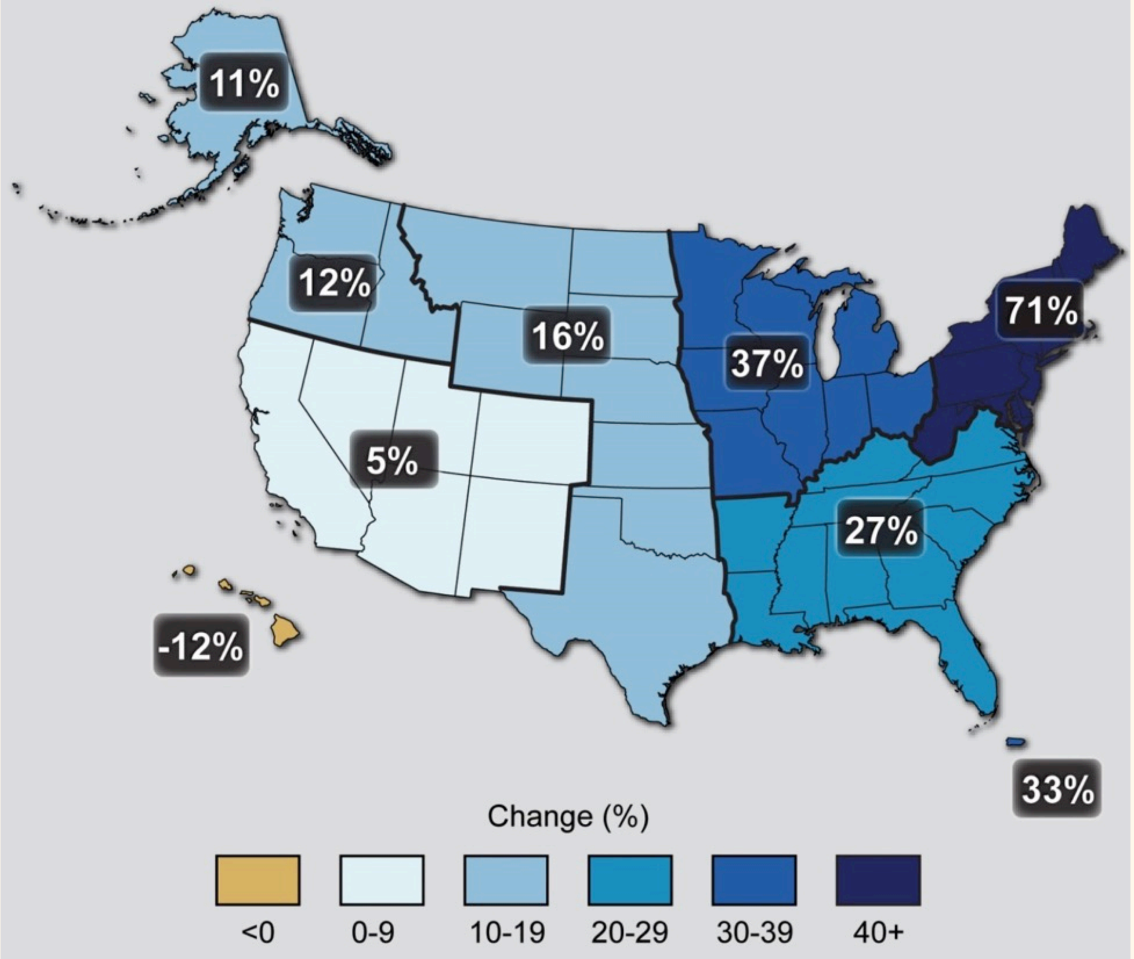
NCA 2014: Global Temperature Increases



Average temperature by decade and the overall average for 1901 to 2000. The far right bar includes data for 2001-2012. (Figure: NOAA NCDC).

NCA 2014 Report Findings

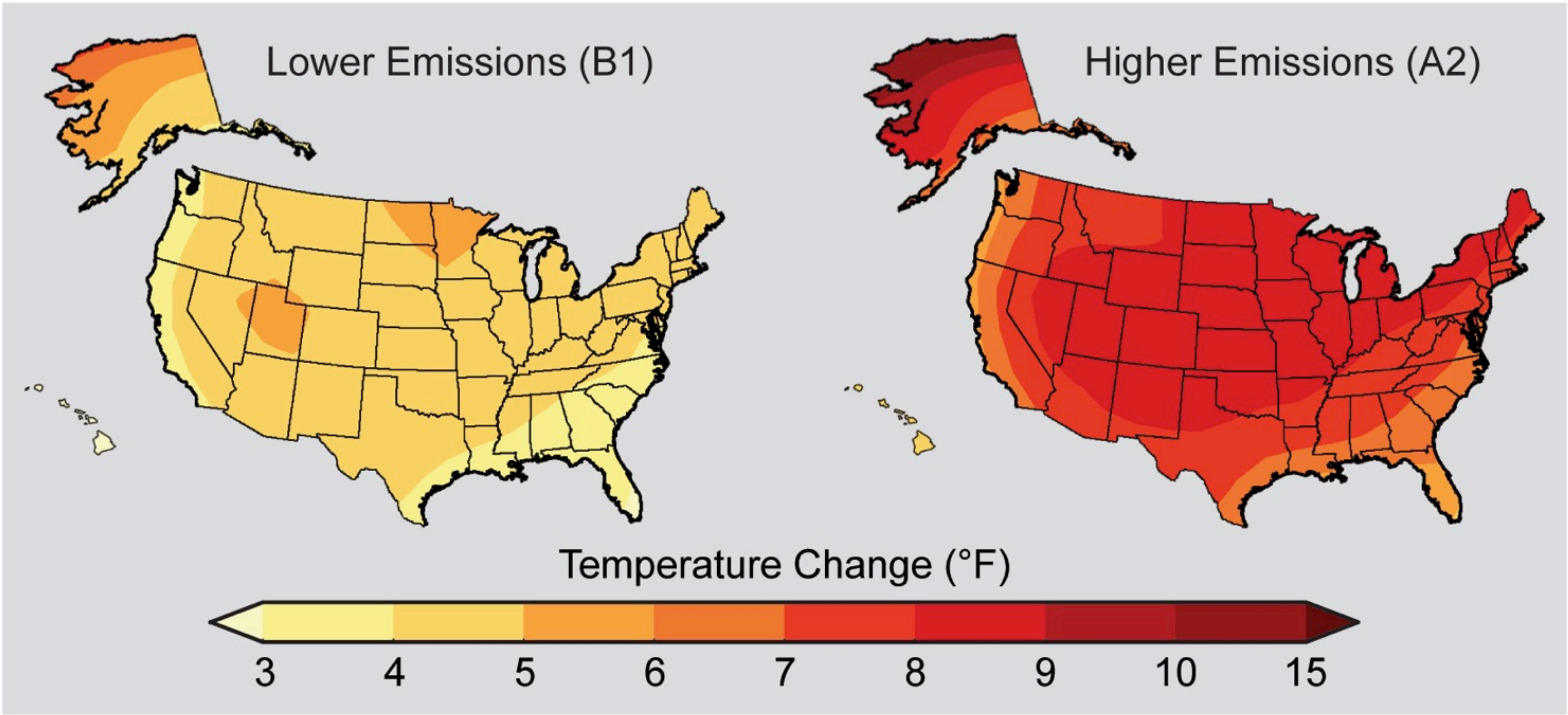
Extreme weather: Some extreme weather and climate events have increased in recent decades, and new and stronger evidence confirms that many of these increases are related to human activities.



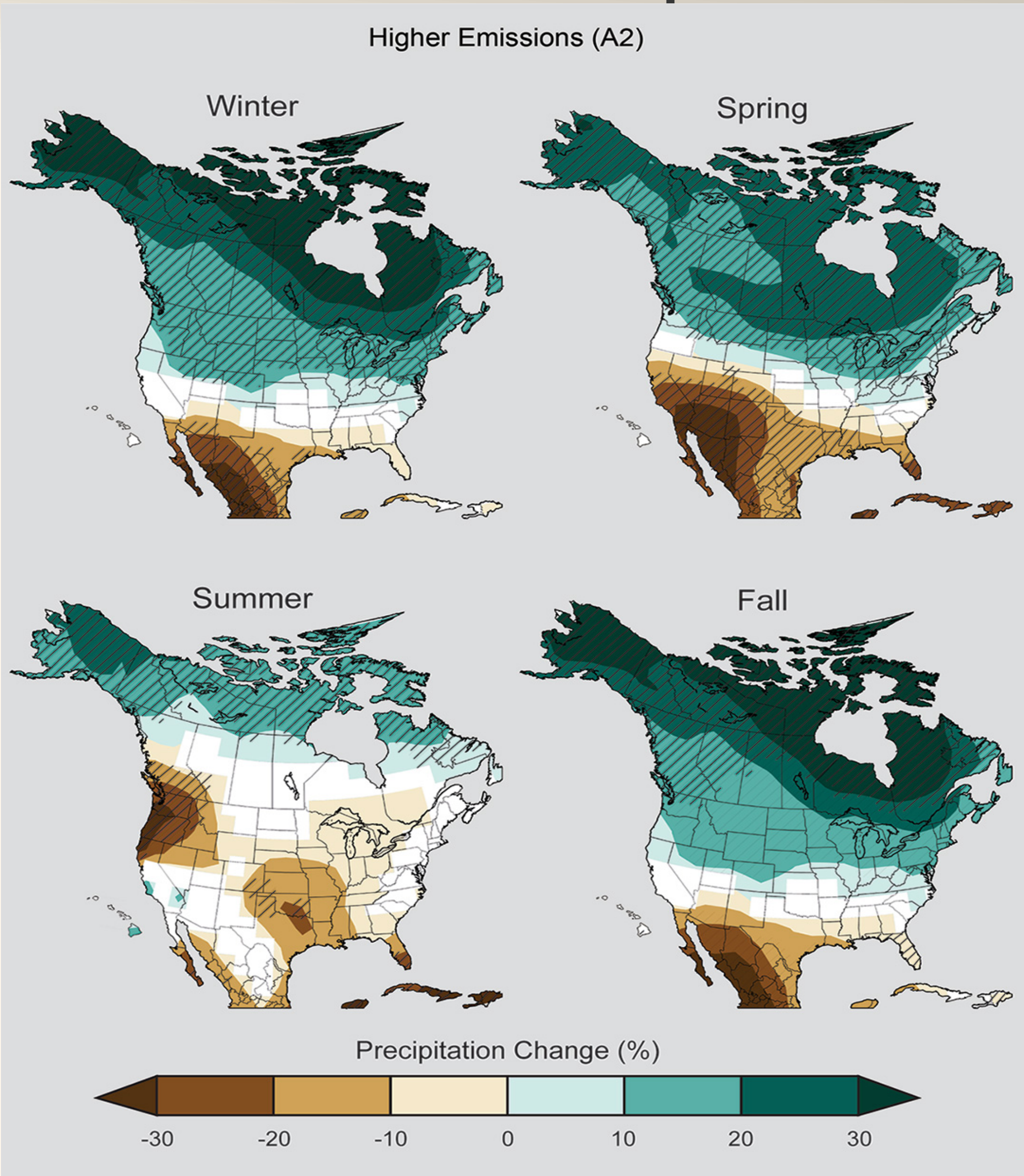
Observed Change in Very Heavy Precipitation

NCA 2014 Report Findings

Future climate: Human-induced climate change is projected to continue, and it will accelerate significantly if global emissions of heat-trapping gases continue to increase.



NCA 2014: Impacts on the Southwest



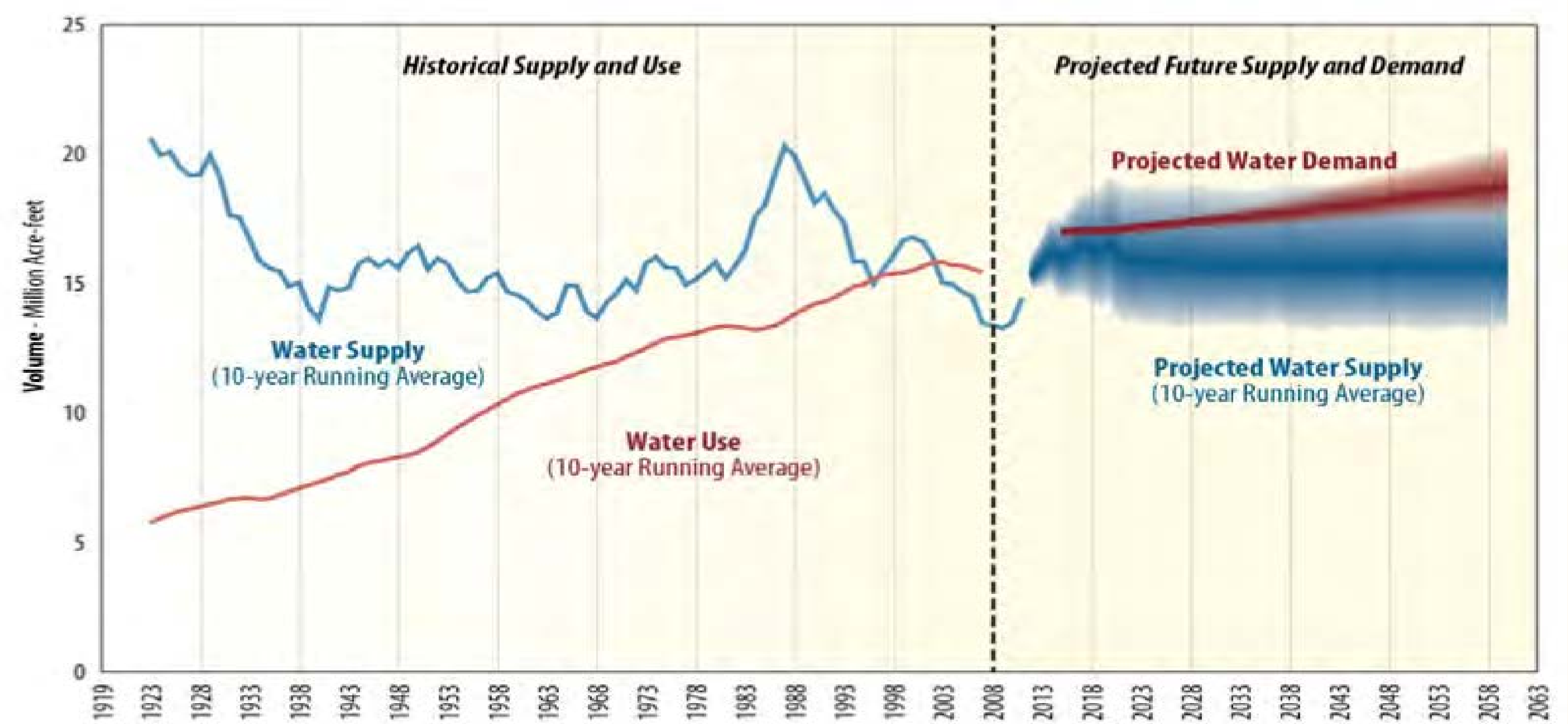
Projected Precipitation by Season (CMIP 5)

The Southwestern US is expected
to get dryer as well as warmer…

The wet areas will get wetter,
The dry areas will get drier…
But the seasonal effects are different.

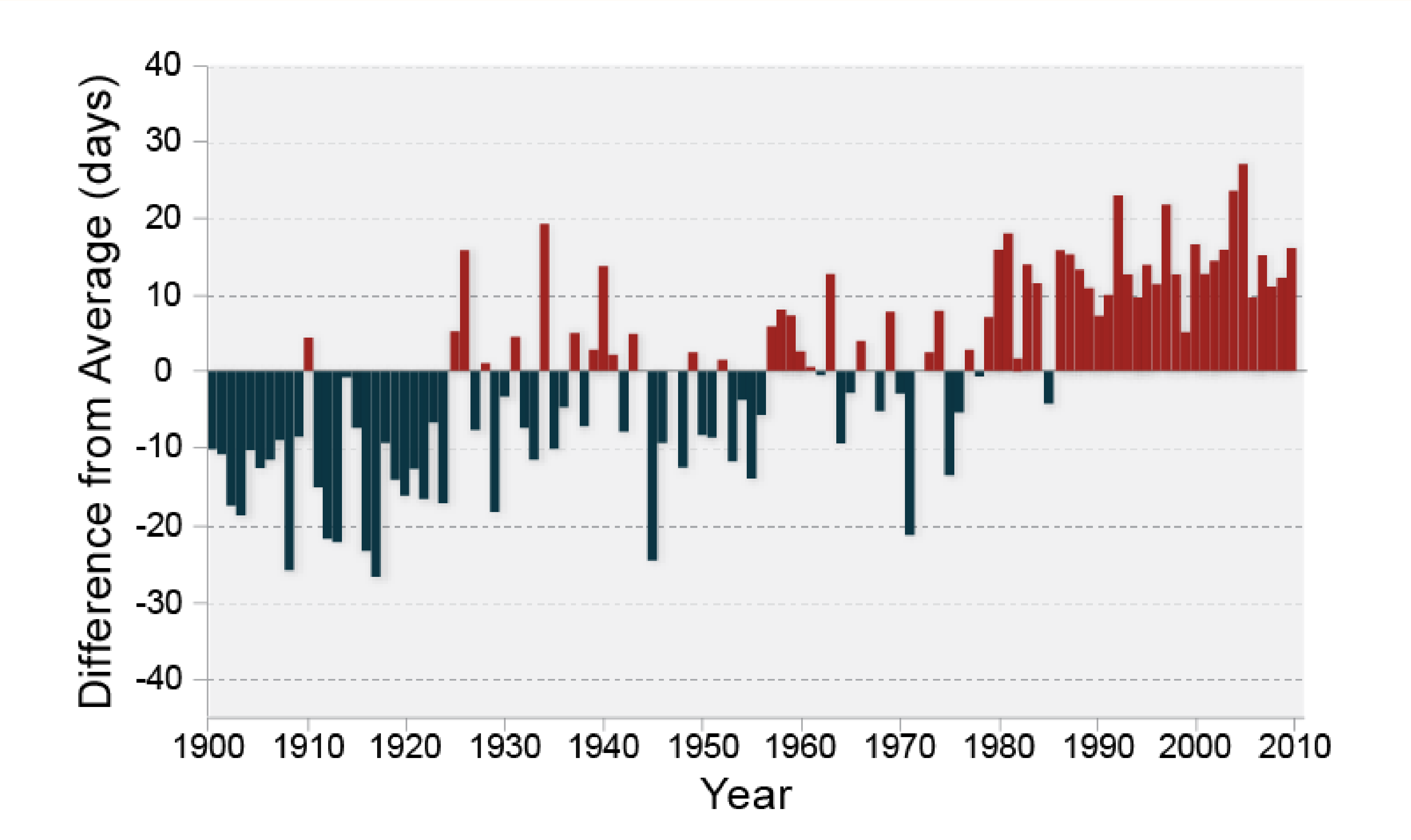
NCA 2014: Reduced Snowpack and Streamflows

Snowpack and streamflow amounts are projected to decline in parts of the Southwest, decreasing surface water supply reliability for cities, agriculture, and ecosystems.



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

NCA 2014: Longer Frost-Free Season Increases Stress on Crops; Higher temperatures increase water demand

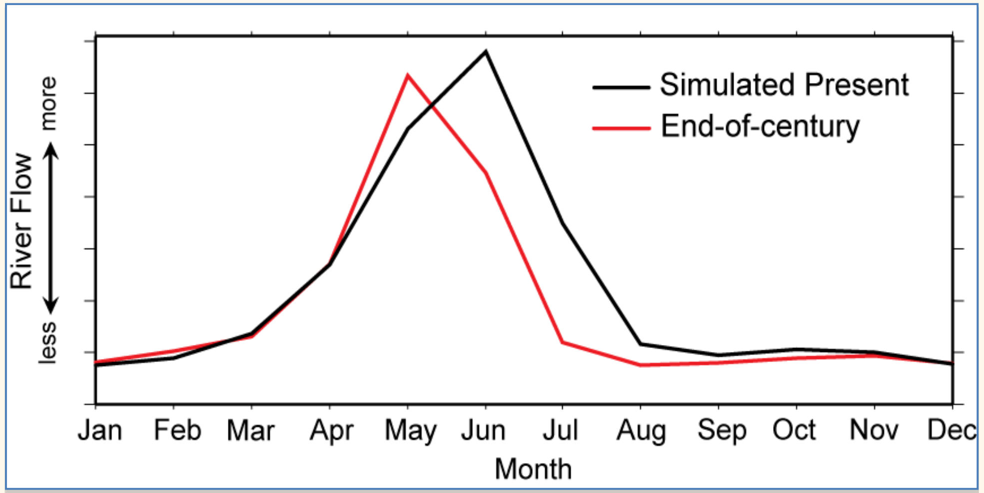


NCA 2014: Ecosystems, Biodiversity and Ecosystem Services

1. Climate change impacts on ecosystems reduce their ability to improve water quality and regulate water flows
2. Climate change, combined with other stressors, is overwhelming the capacity of ecosystems to buffer the impacts from extreme events like fires, floods and storms
3. Landscapes and seascapes are changing rapidly, and species, including many iconic species, may disappear from regions where they have been prevalent….

Impacts of Climate Change on Water Cycle

- Less supply/storage from snow melt
  - Higher % of precipitation as rain vs snow
  - Earlier melt and peak flows
- Loss of reservoir storage
  - Evaporation and sedimentation
  - Dam operating constraints (e.g., flood control)
- More extreme events, both floods and droughts
- Serious implications for aquatic ecosystems, including water quality
- Higher ET
- Cascading effects



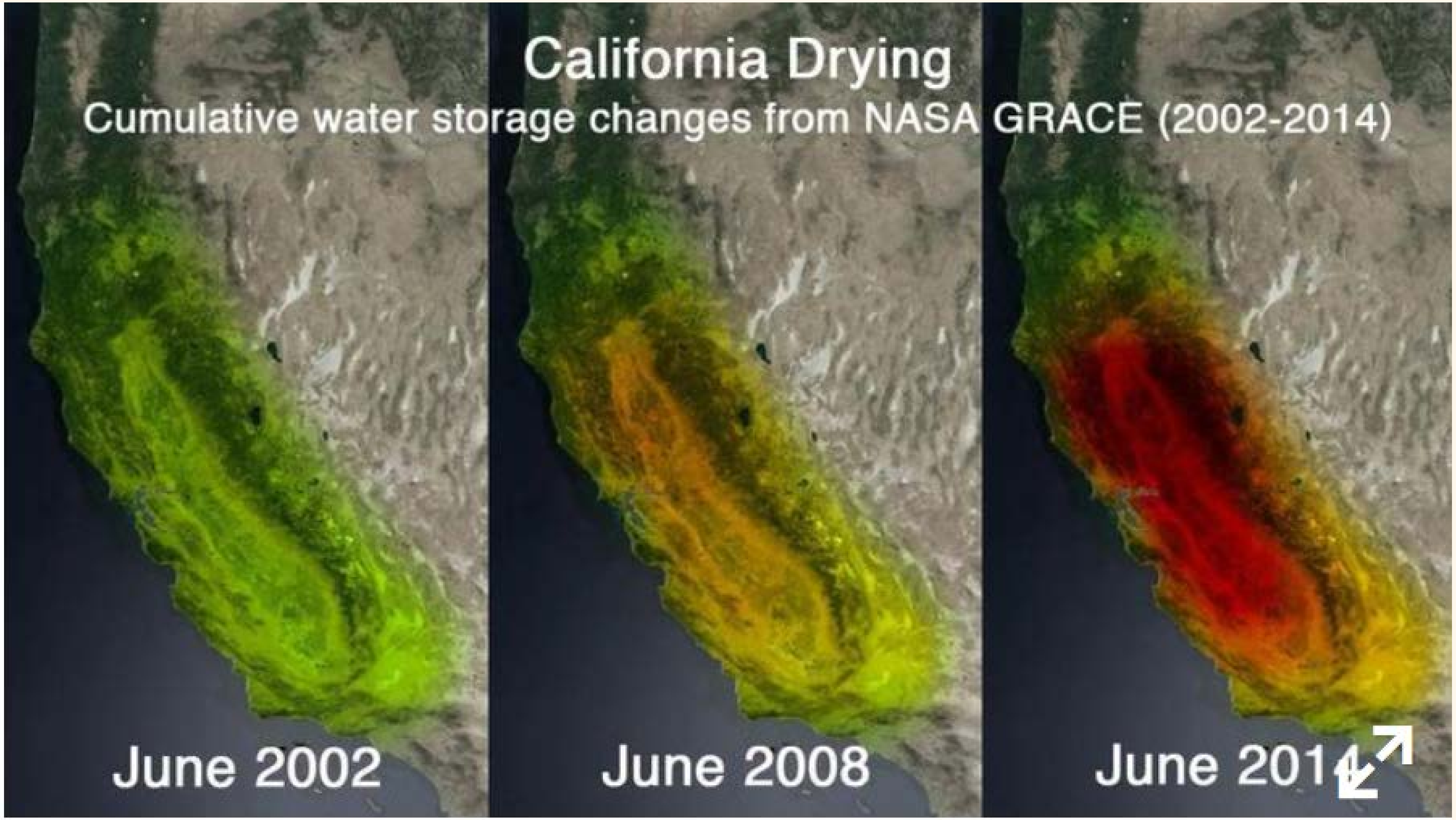
Groundwater – the hidden source

Arizona Daily Star

Impacts of climate change and drought on groundwater supply and use can be substantial, and have significant implications for river flows and riparian habitat... Groundwater levels are rarely managed to support environmental objectives

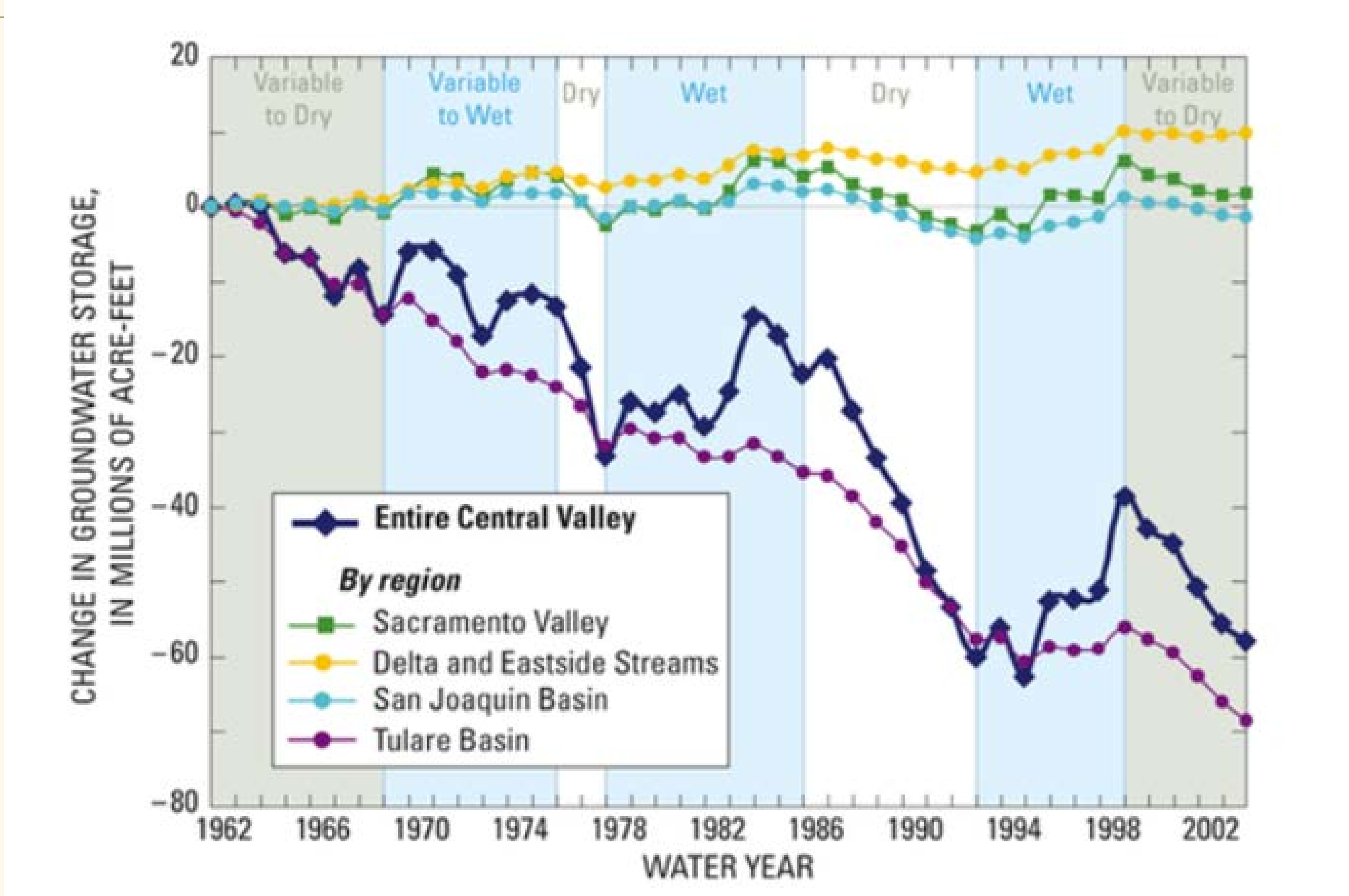
Effects of climate change on groundwater use?

When surface water is scarce, groundwater pumping rates increase…

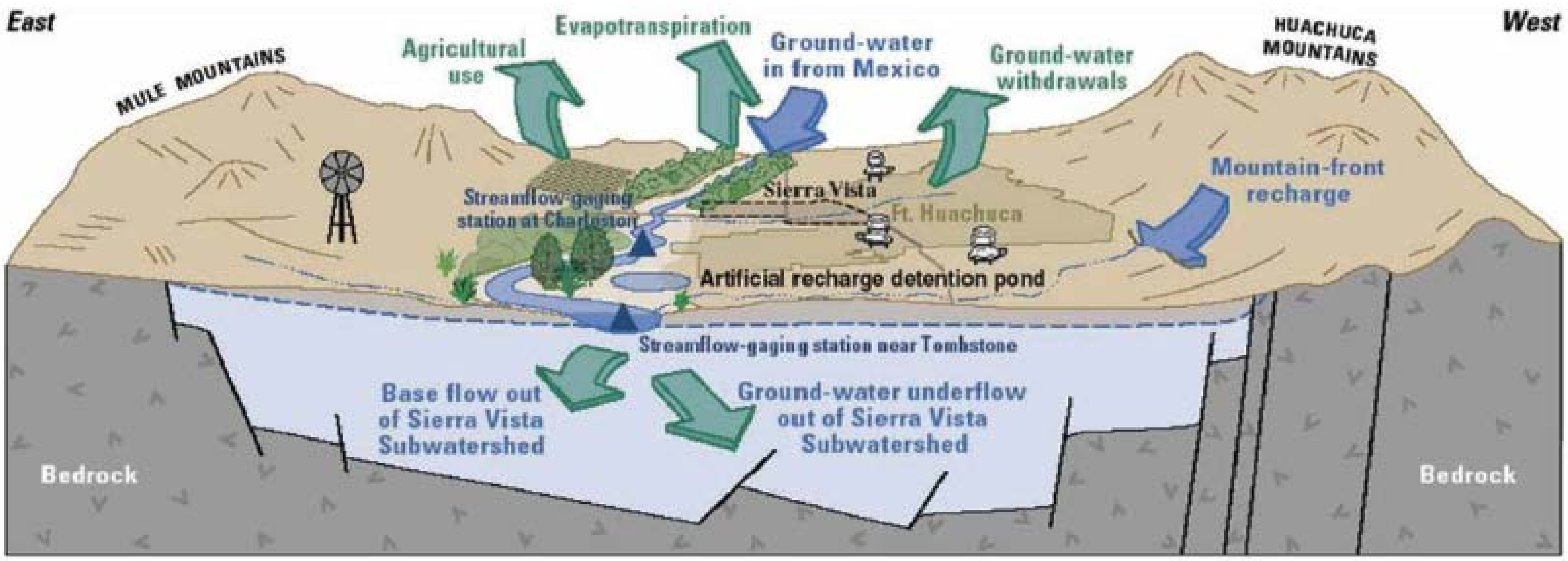


This series of satellite images reflects the huge loss of groundwater in California. (UC Irvine, NASA)

Change in GW Storage, 1962-2002, CA (from USGS, 2009)



Changes in Partitioning of Precipitation



Simulated annual water budget for a ground-water-flow model — Values are in acre-feet per year

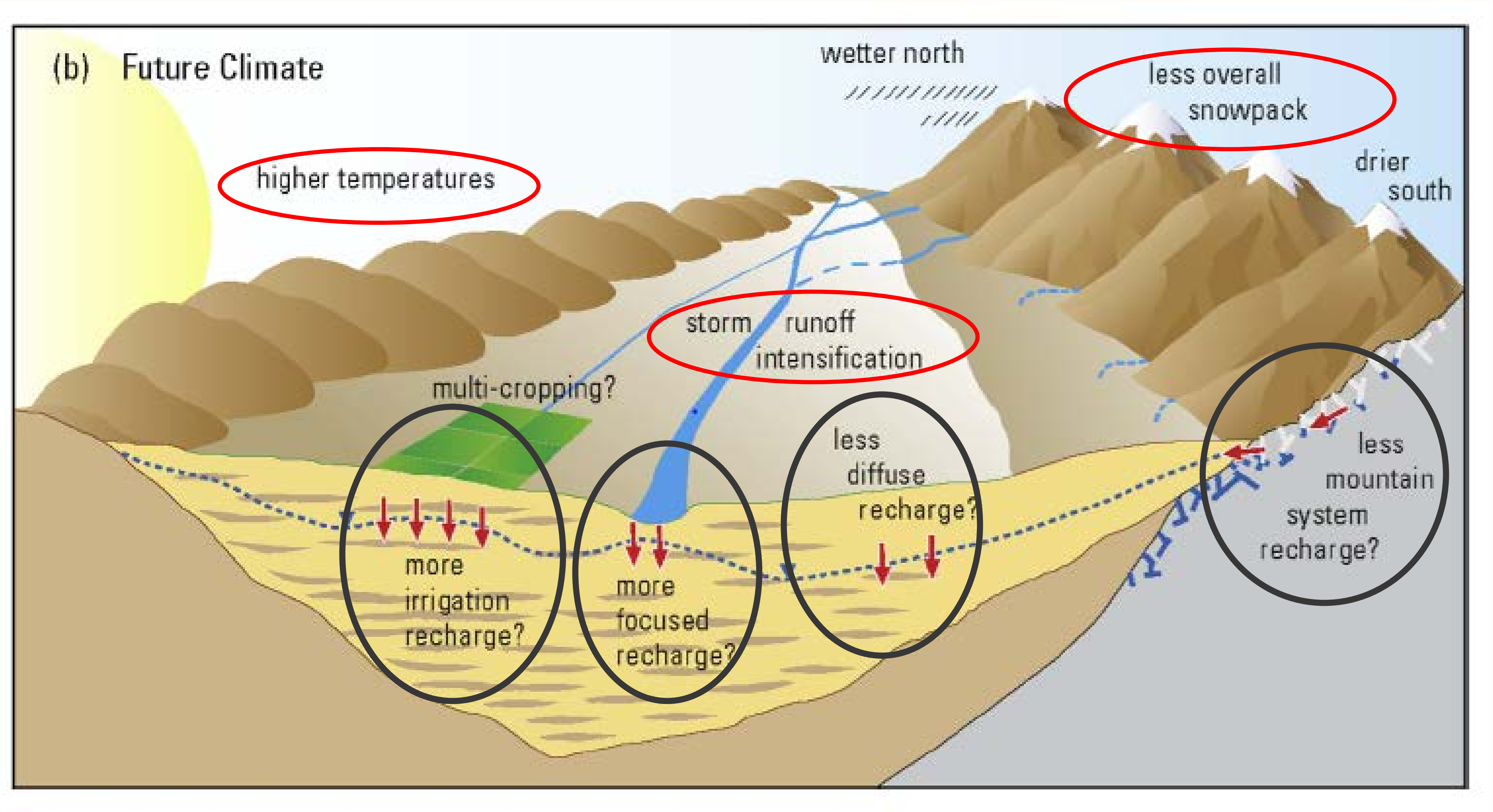
Climate Impacts on Groundwater Recharge depend on…

- Basin structure, depth to water
- Aquifer recharge type: diffuse vs. focused, mountain front recharge, agricultural and municipal return flows
- Groundwater/surface water interactions
- Temperature, ET
- Intensity and seasonality of precipitation
- Degree of snowpack dominance
- Changes in land use and technology
- Changes in vegetation

Includes material from Meixner et al., 2015, Journal of Hydrology

Illustration of four recharge mechanisms under future climate

Meixner et al., 2015, Journal of Hydrology



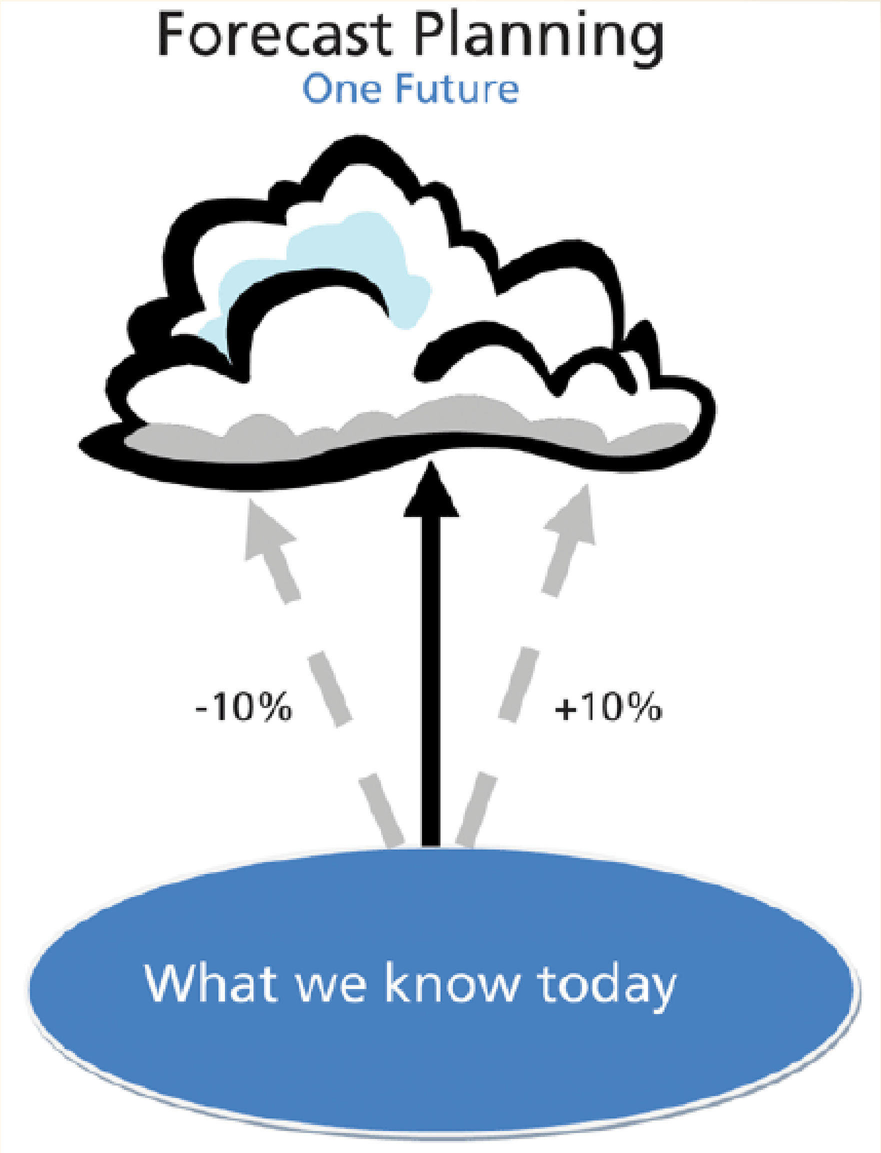
Why are projections uncertain?

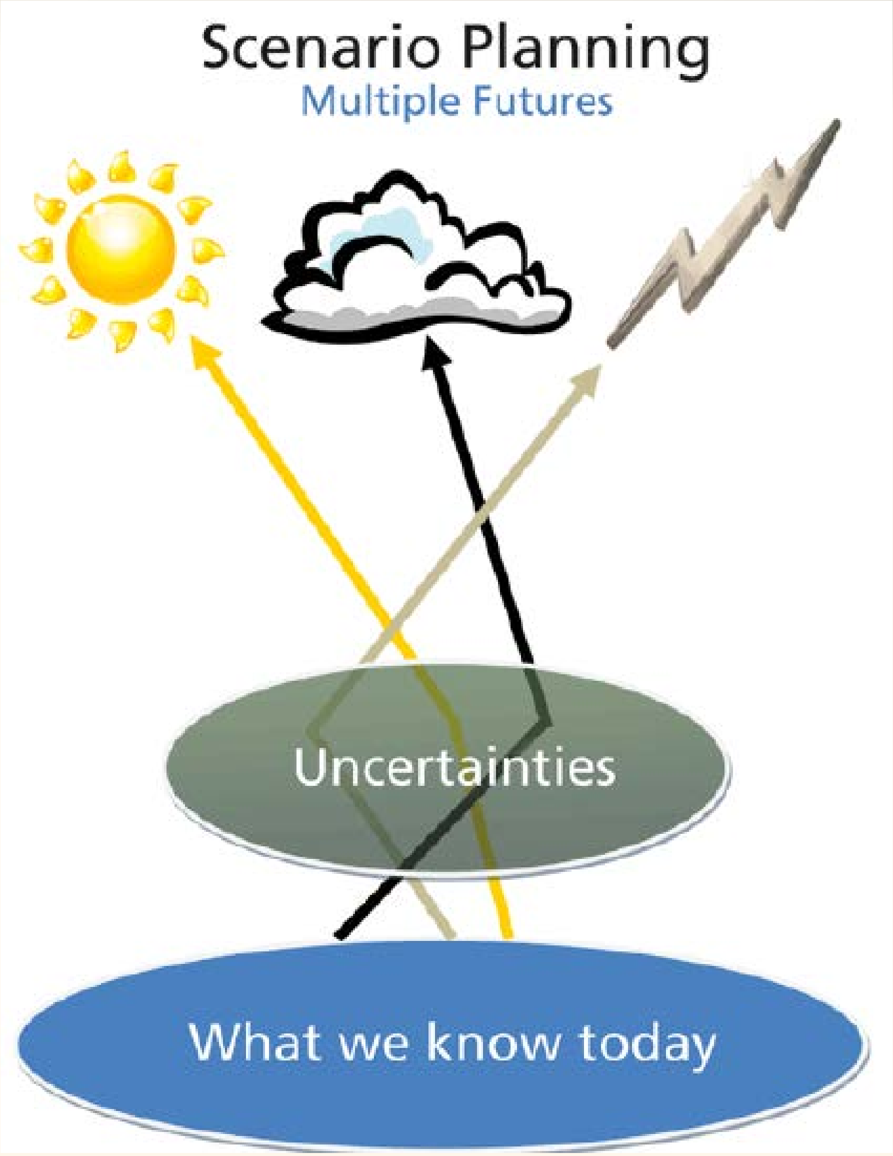
HUMAN — We don't know what future emissions from human activities will be

SCIENTIFIC — We don't know how sensitive the planet is, and our ability to simulate the climate system is limited and incomplete, particularly at the local to regional scale

NATURAL — Continuous natural variations in climate make it difficult to predict conditions over shorter time scales

Why use Scenario Planning?



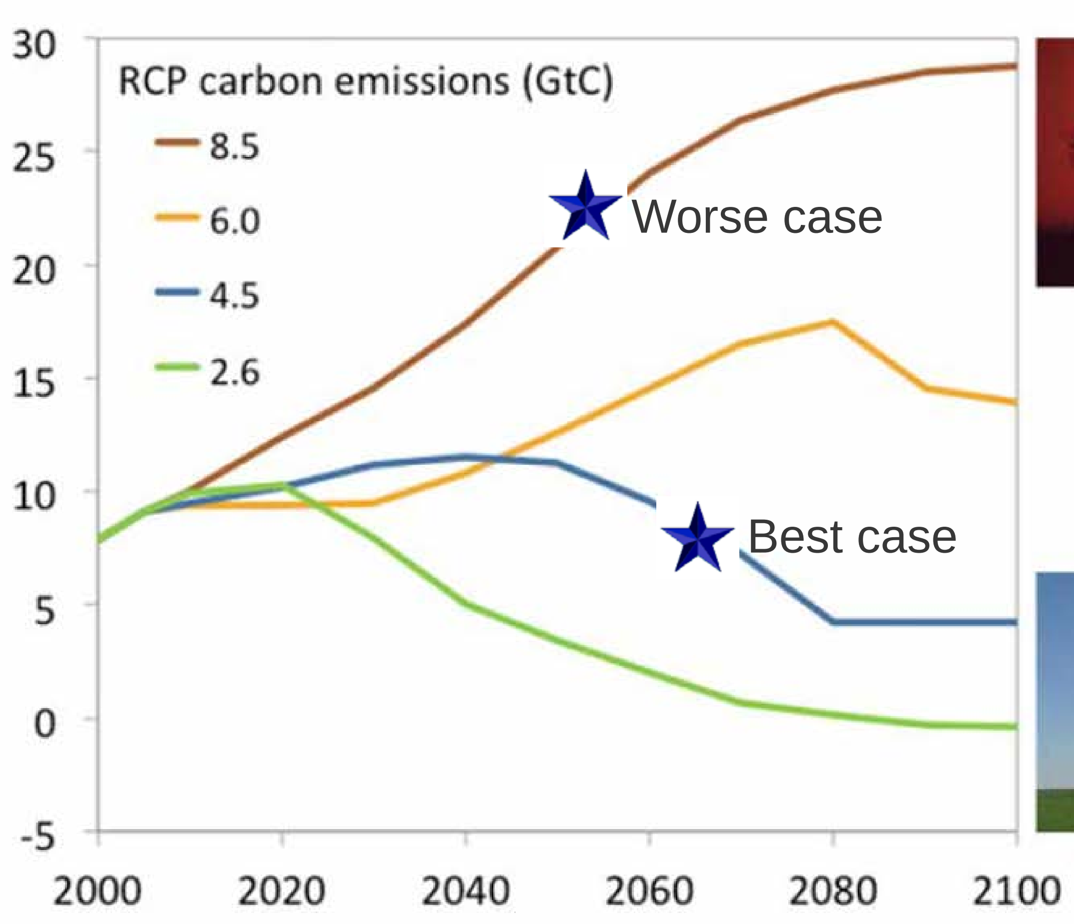


Source: Global Business Network Weeks et al 2011

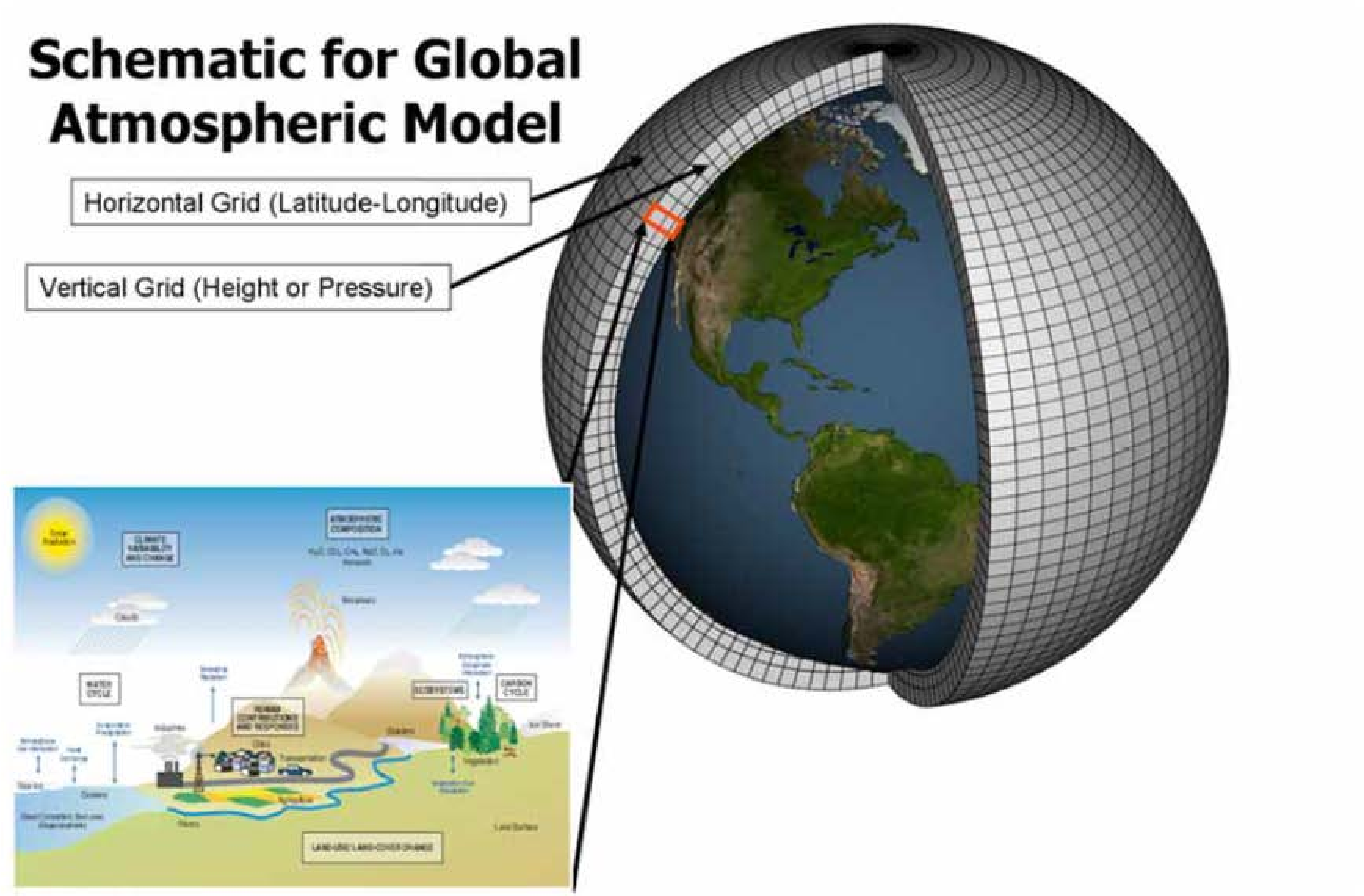
Emissions
Scenarios
From IPCC
Fourth Assessment

RCP = Representative
Concentration Pathway

Future Scenarios



Global Climate Models



Downscaling Options

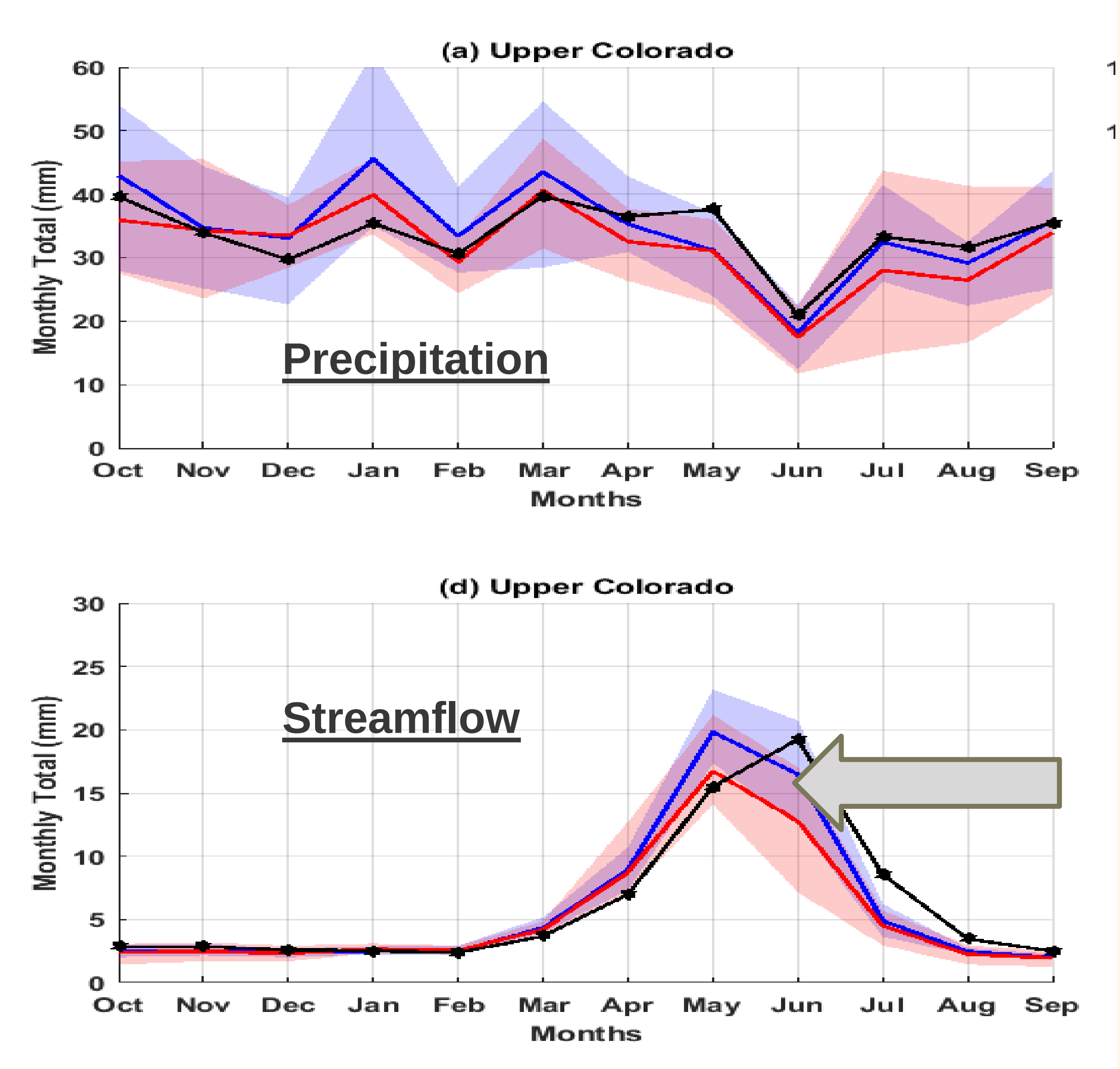
DYNAMIC

- Many variables
- Computationally expensive
- Require additional bias correction
- Can be used even if observations lacking
- Don’t need to assume stationarity at scale of resolved processes

STATISTICAL

- Often limited to T,P
- More computationally affordable
- Incorporate bias correction into model
- Limited by available observations
- Assume GCM-OBS relationship holds in the future

Downscaled CMIP3 Projected Absolute Changes in Upper Colorado River Precipitation and Streamlow: 2041-2070 minus 1971-2000



Blue = Statistical DS CMIP 3
Red = Dynamical DS CMIP 3

Blue line = Mean of Statistical DS
Red line = Mean of Dynamical DS

Black line = Observed 1971-2000

Bias Corrected Statistical Downscaling (BCSD) vs. NARCCAP + UA Weather Research and Forecasting Regional Climate Models

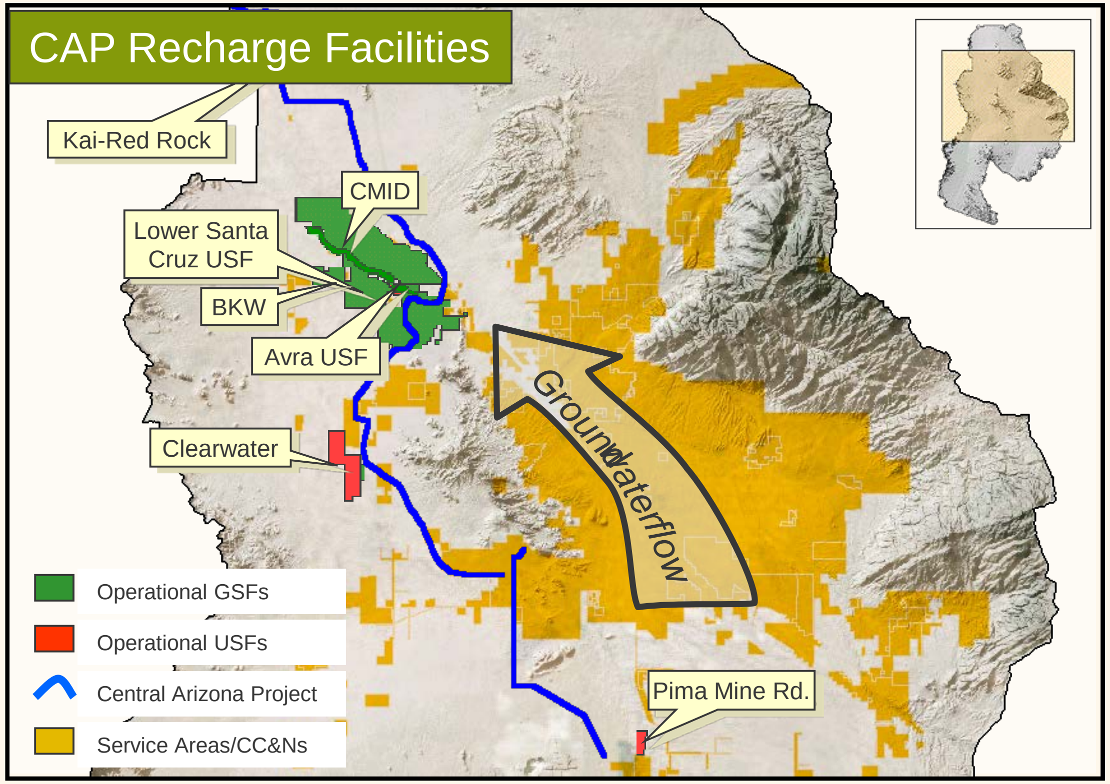
Mukharjee et al. (in preparation)

Summary of Upper Colorado Basin Projected Impacts – Castro et al., UA

- Dynamically downscaled streamflow is closer to observations in the historical period.
- Both statistical and dynamical downscaling show a shift of the peak hydrograph to an earlier period.
- Dynamical downscaling projects lower peak streamflow than statistical downscaling, on the order of 10-20% additional decline in the mid 21^{st} century.

Renewable supply use and local impacts: moving beyond a basin-wide balance

- Physical access to renewable supplies varies
- Unmet infrastructure needs
- Lack of protection for environmental resources
- Need for local area management

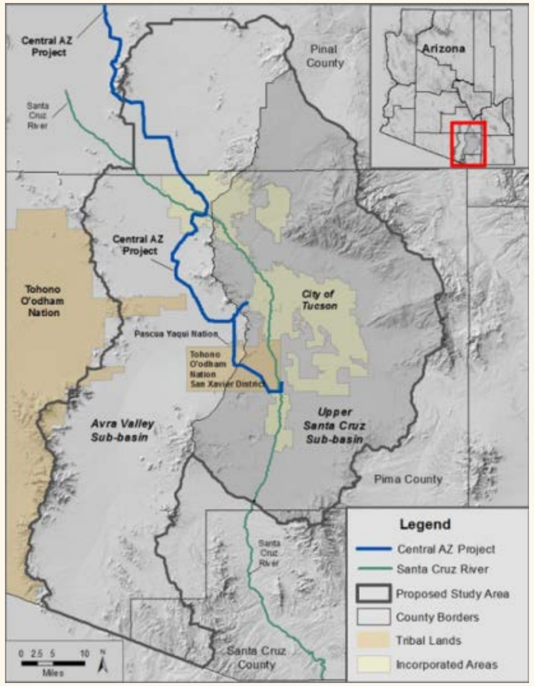


Tucson AMA – Seasholes (CAP)

Lower Santa Cruz River Basin Study

Important contributions:

- Considers alternative scenarios and management options through regional scale modelling
- Considers impacts of climate change on both supply and demand
- Considers both local and imported (CAP) supplies
- Uses dynamical downscaling (first Basin Study) as a primary source of future projections; risk based strategy
- Explicitly considers environmental impacts and options



Indicators of a Warming World: Data since 1850 (left) and 1940 (right) show clear trends for each indicator (NOAA-NCDC)