



Climate Change in the Southwest United States



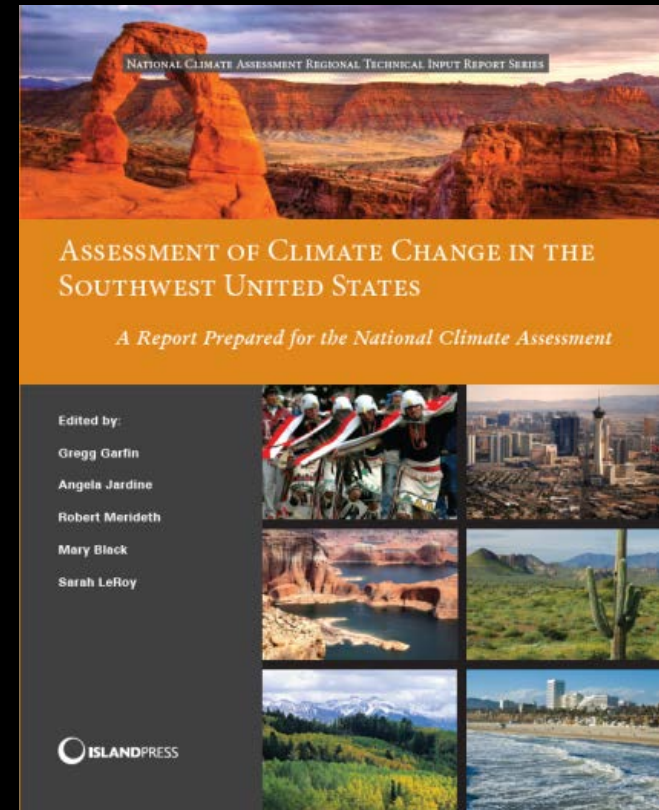
WESTCAS Fall Conference
October 31, 2013
Tucson, Arizona

Gregg Garfin, The University of Arizona

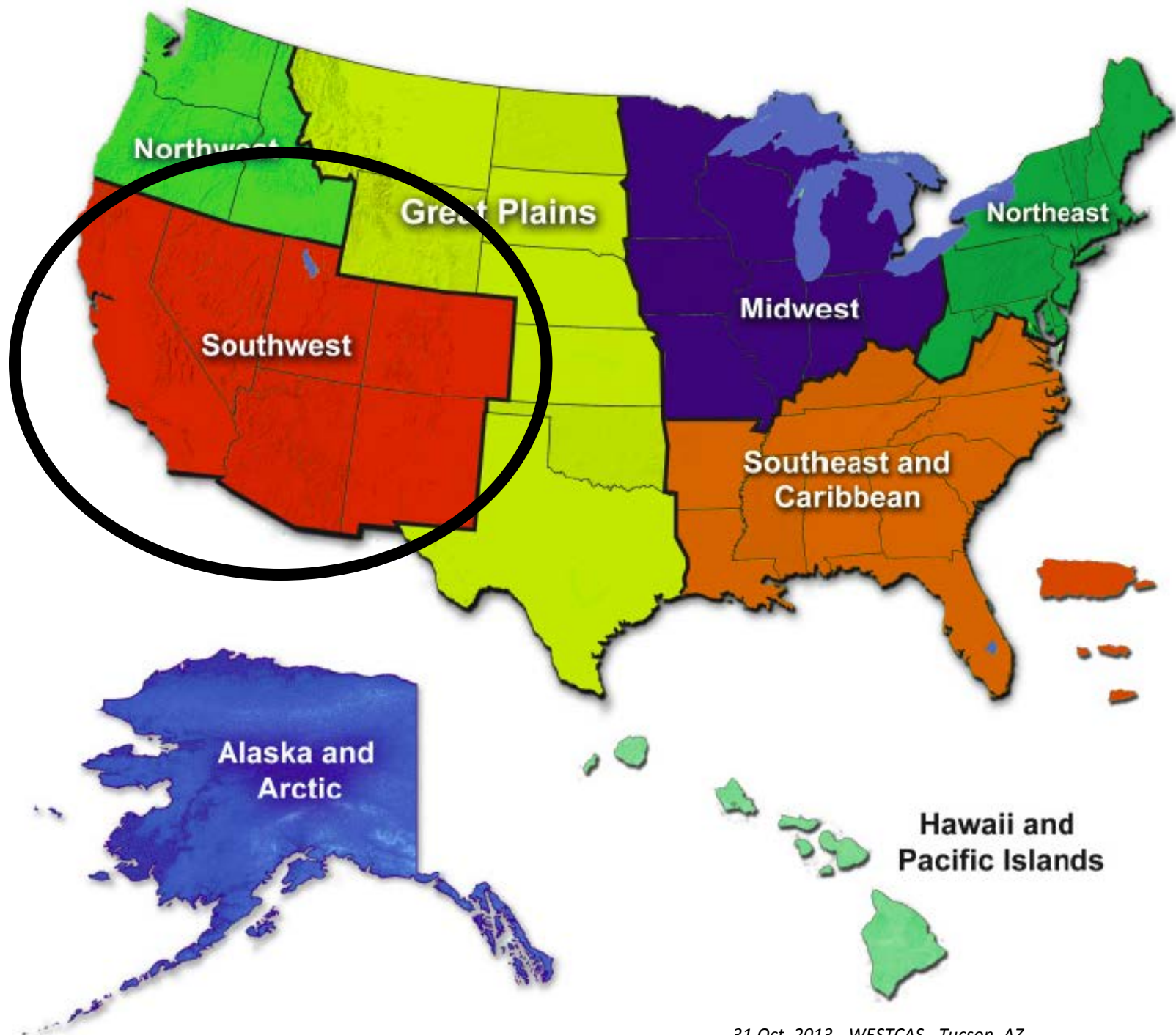


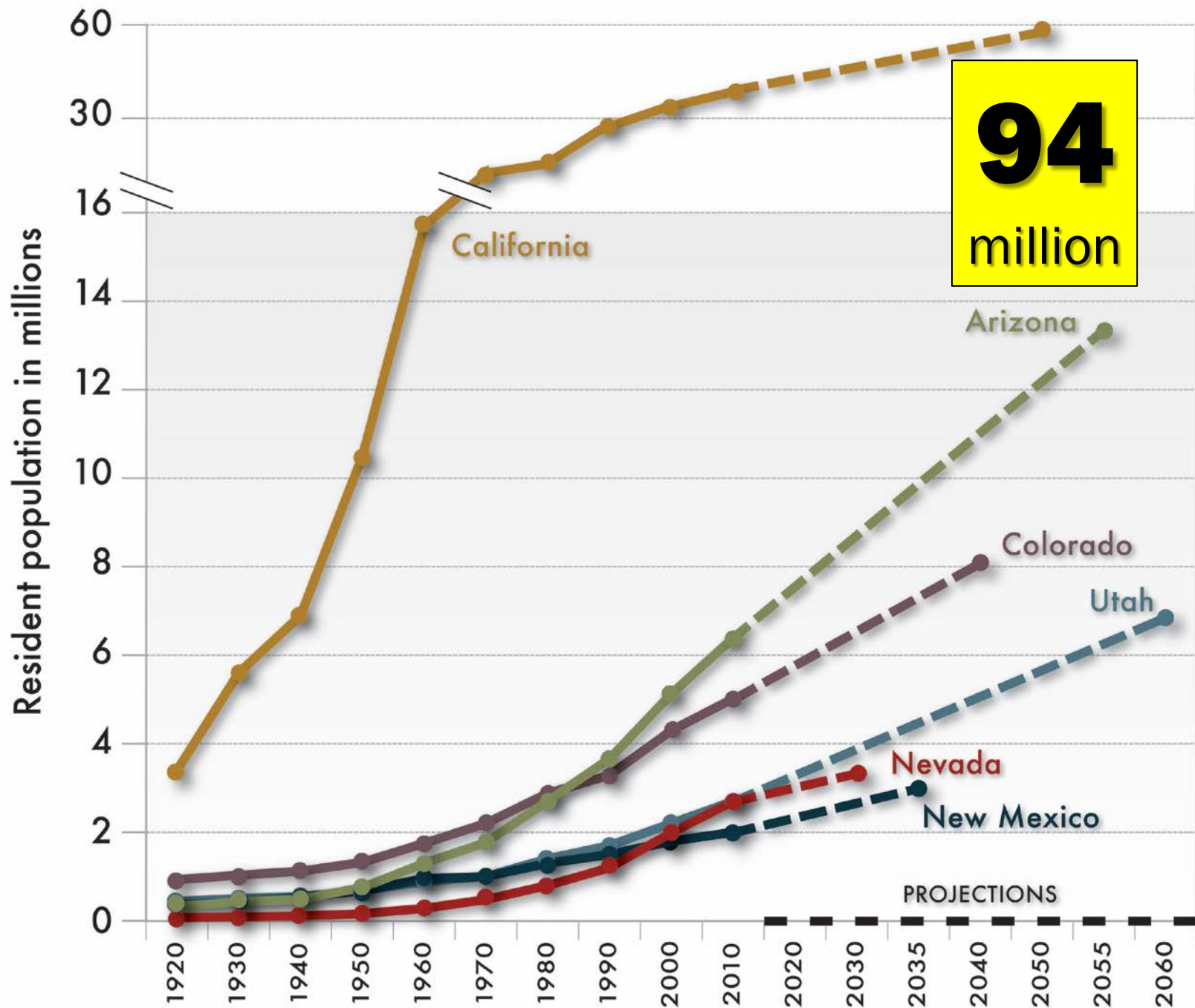
Overview of the talk

- Climate
- Impacts
- Choices
- Where to get information



<http://www.swcarr.arizona.edu>





50%



2013 | REPORT CARD for **america's** INFRASTRUCTURE

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

Every 4 years, the American Society of Civil Engineers releases a Report Card for America's Infrastructure that depicts the condition and performance of the nation's infrastructure in the familiar form of a school report card by assigning letter grades to each type of infrastructure.

CATEGORIES

STATES

NEWS

CHARTS & FIGURES

AVIATION



BRIDGES



DAMS



DRINKING WATER



ENERGY



HAZARDOUS WASTE



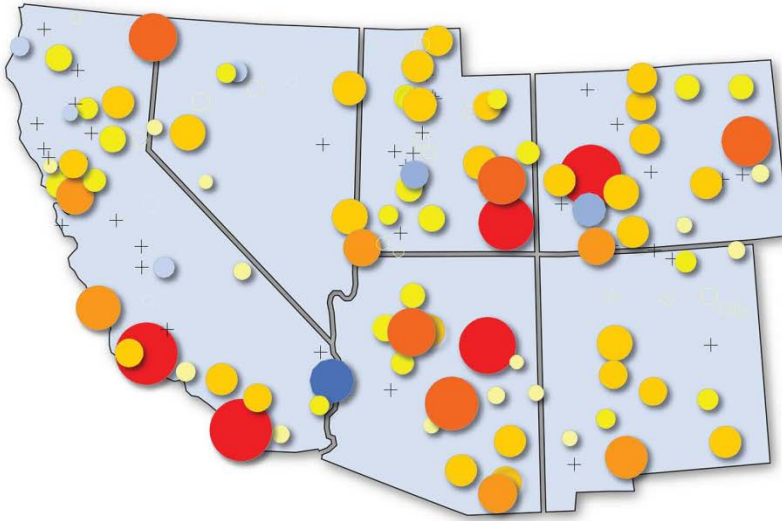
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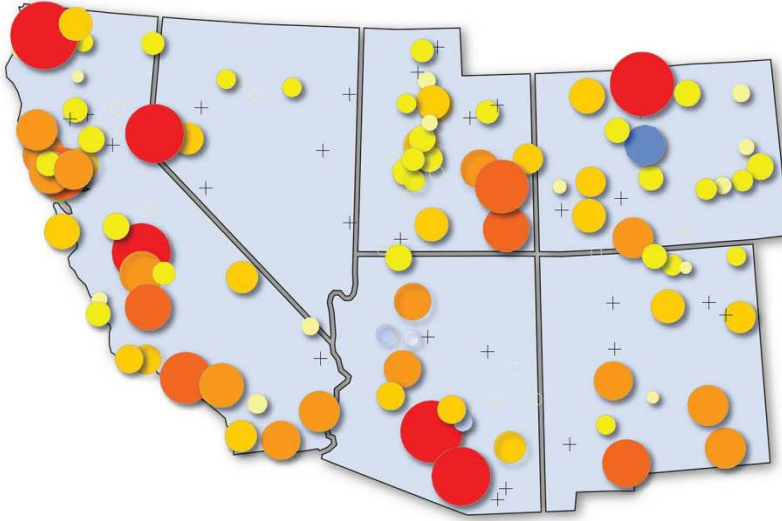
**Observed
Changes**

Temperature

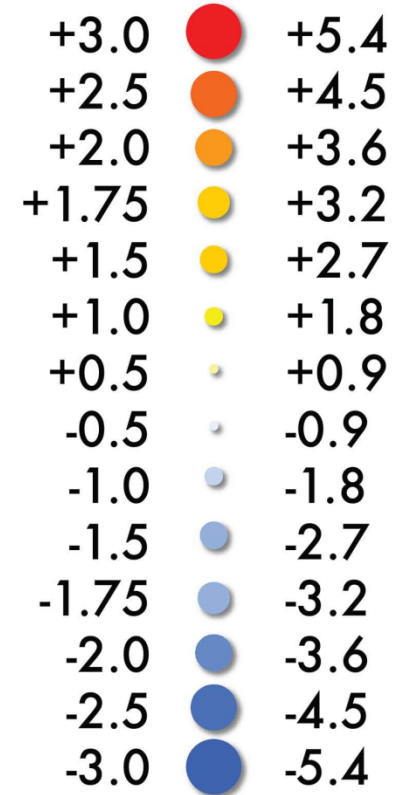
TMAX Trend



TMIN Trend



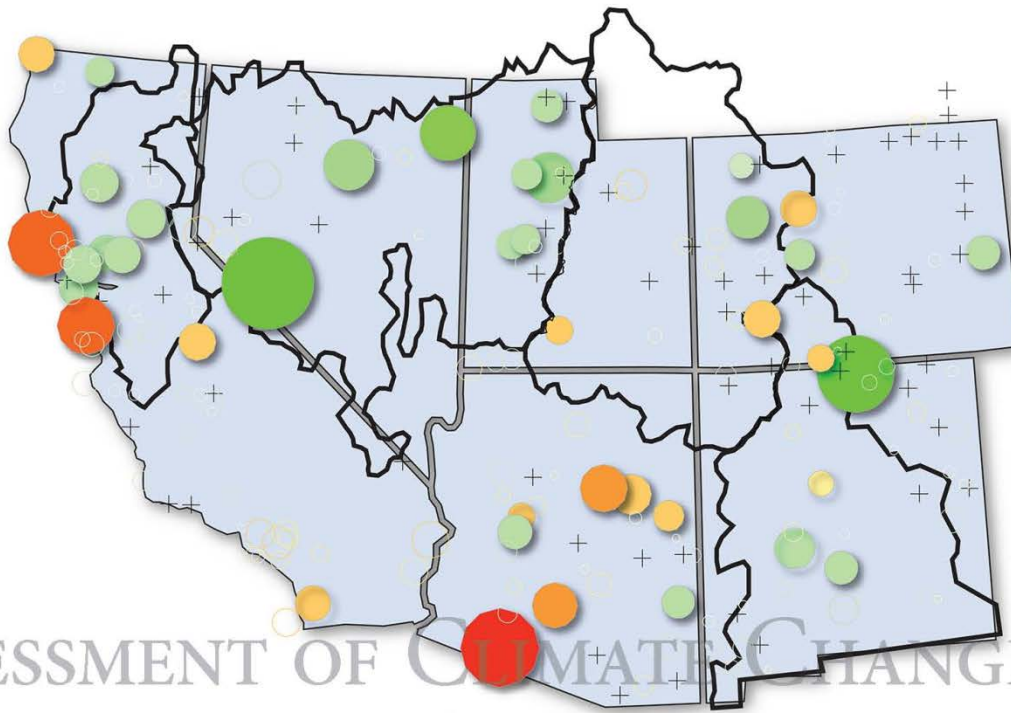
Total Change in °C



Total Change in °F

Precipitation

PPT Trend



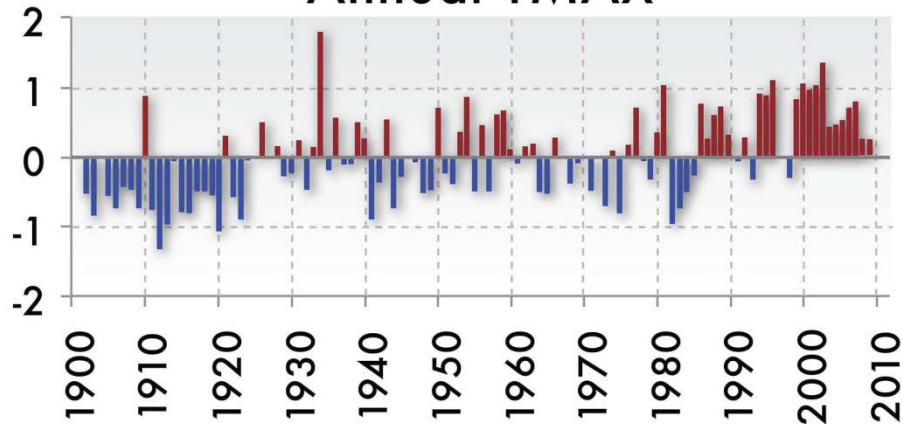
Total Change as a Percentage
(%) of Climatology



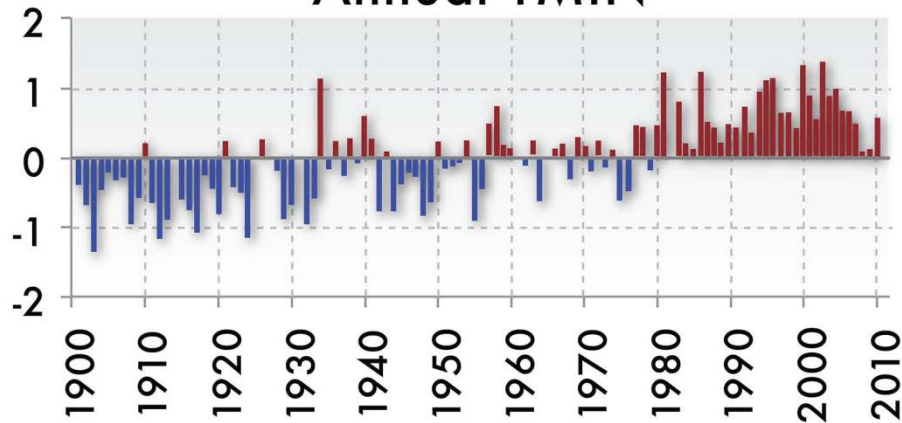
ASSESSMENT OF CLIMATE CHANGE
www.swcarr.arizona.edu

Trend Contrast

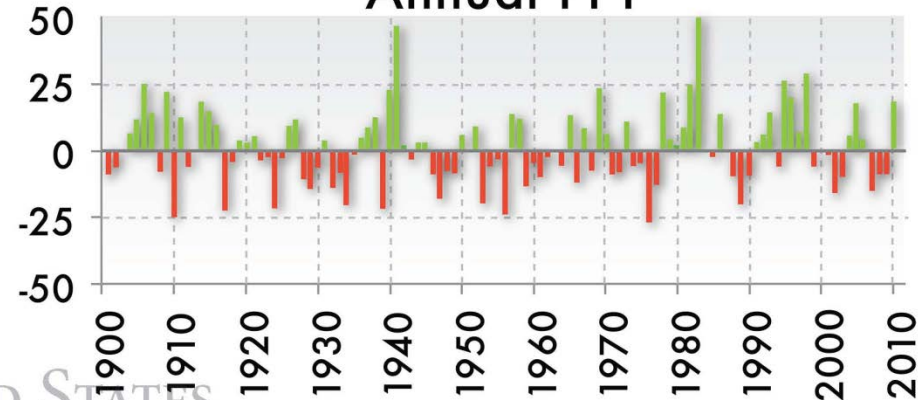
Annual TMAX



Annual TMIN



Annual PPT



D STATES

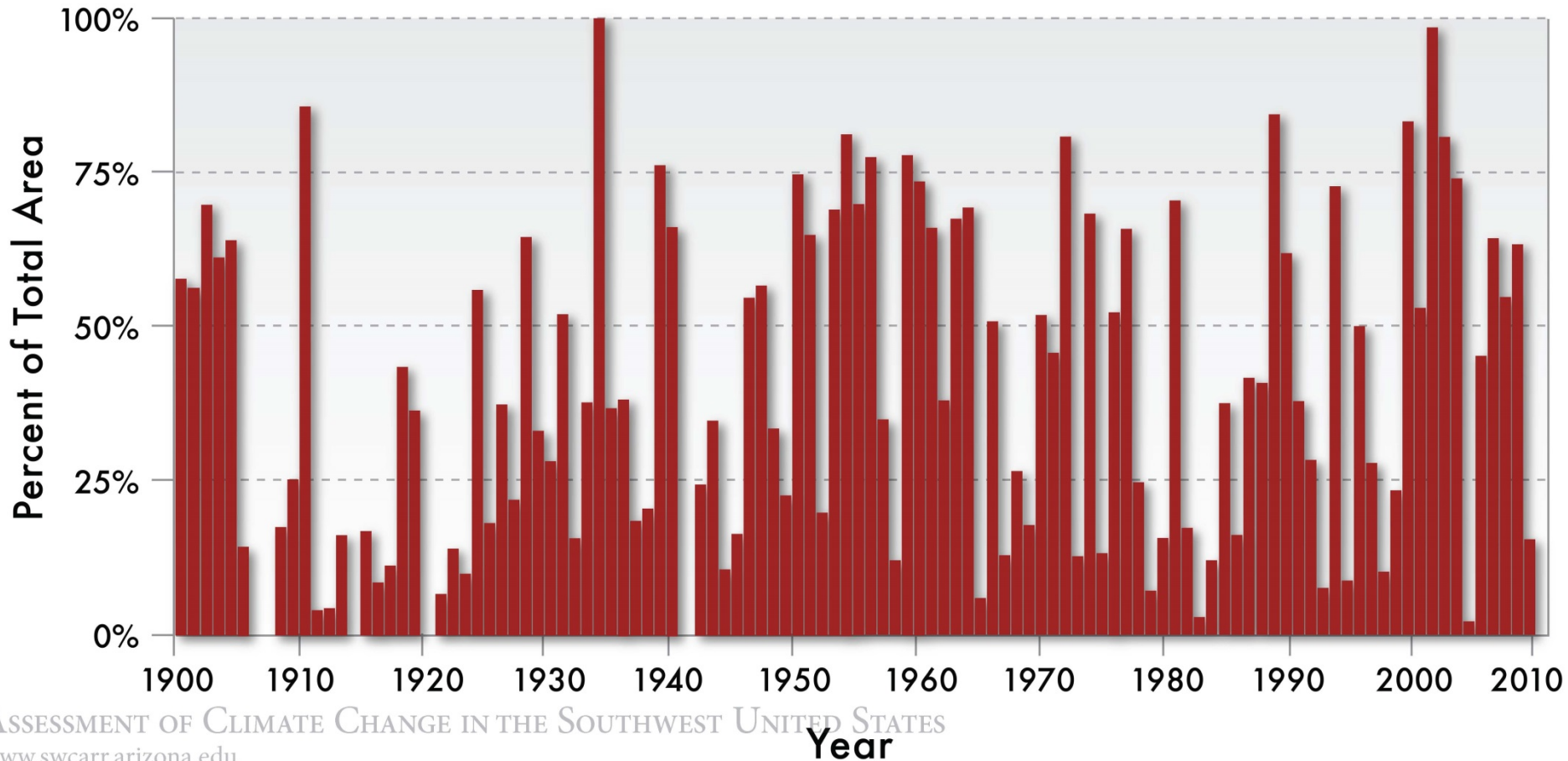


Lake Mead



Drought Area: 2nd Highest

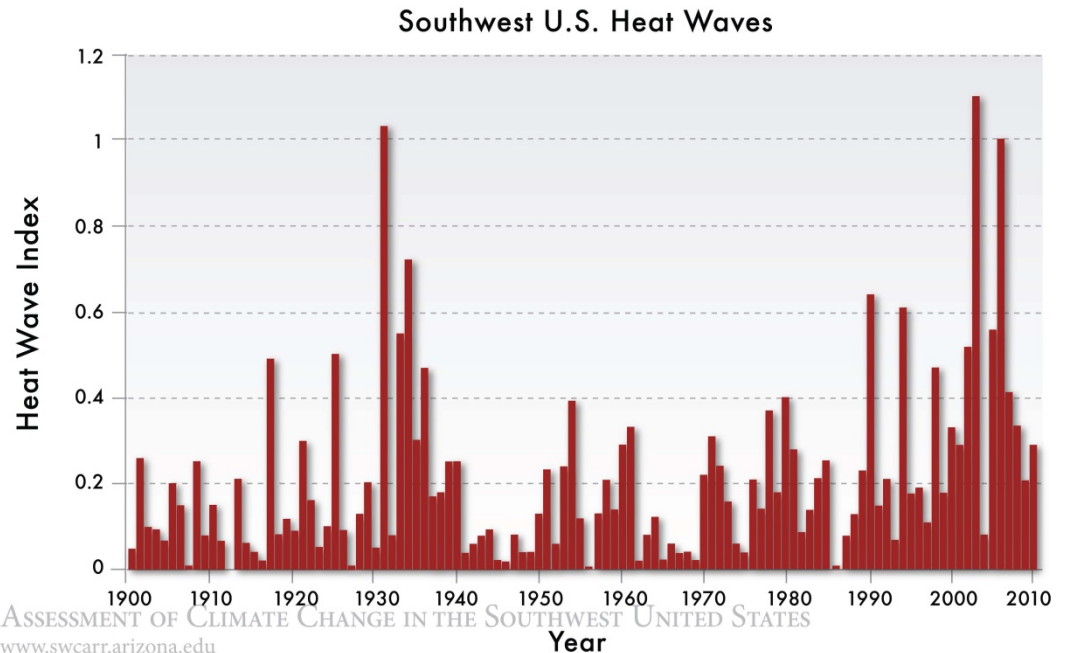
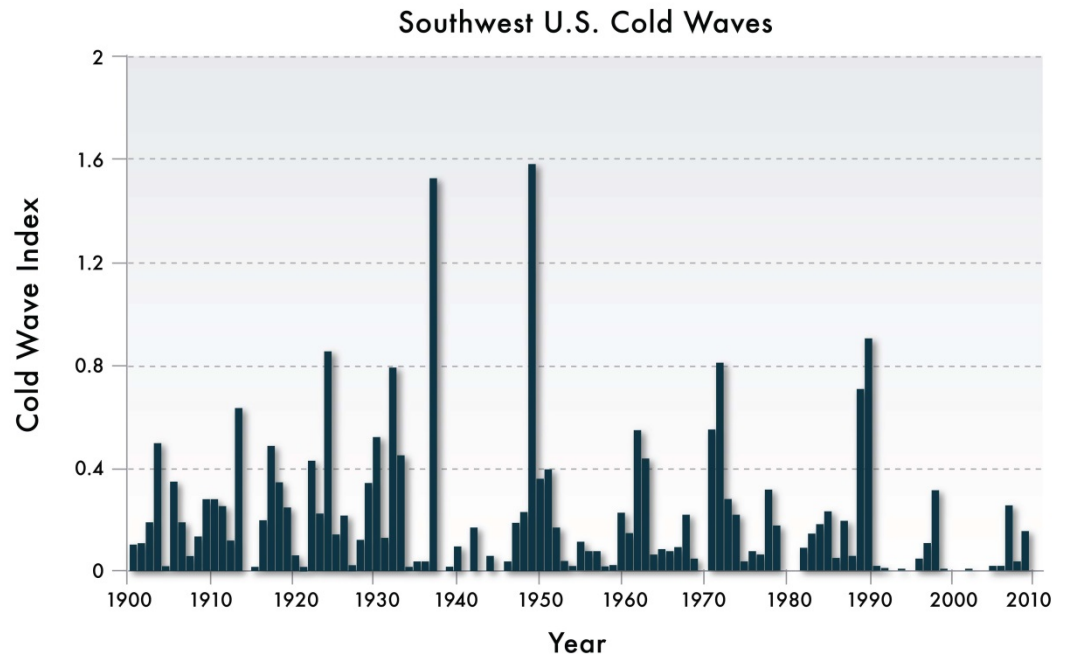
Percent of Area < -1 PDSI (1901-2010)



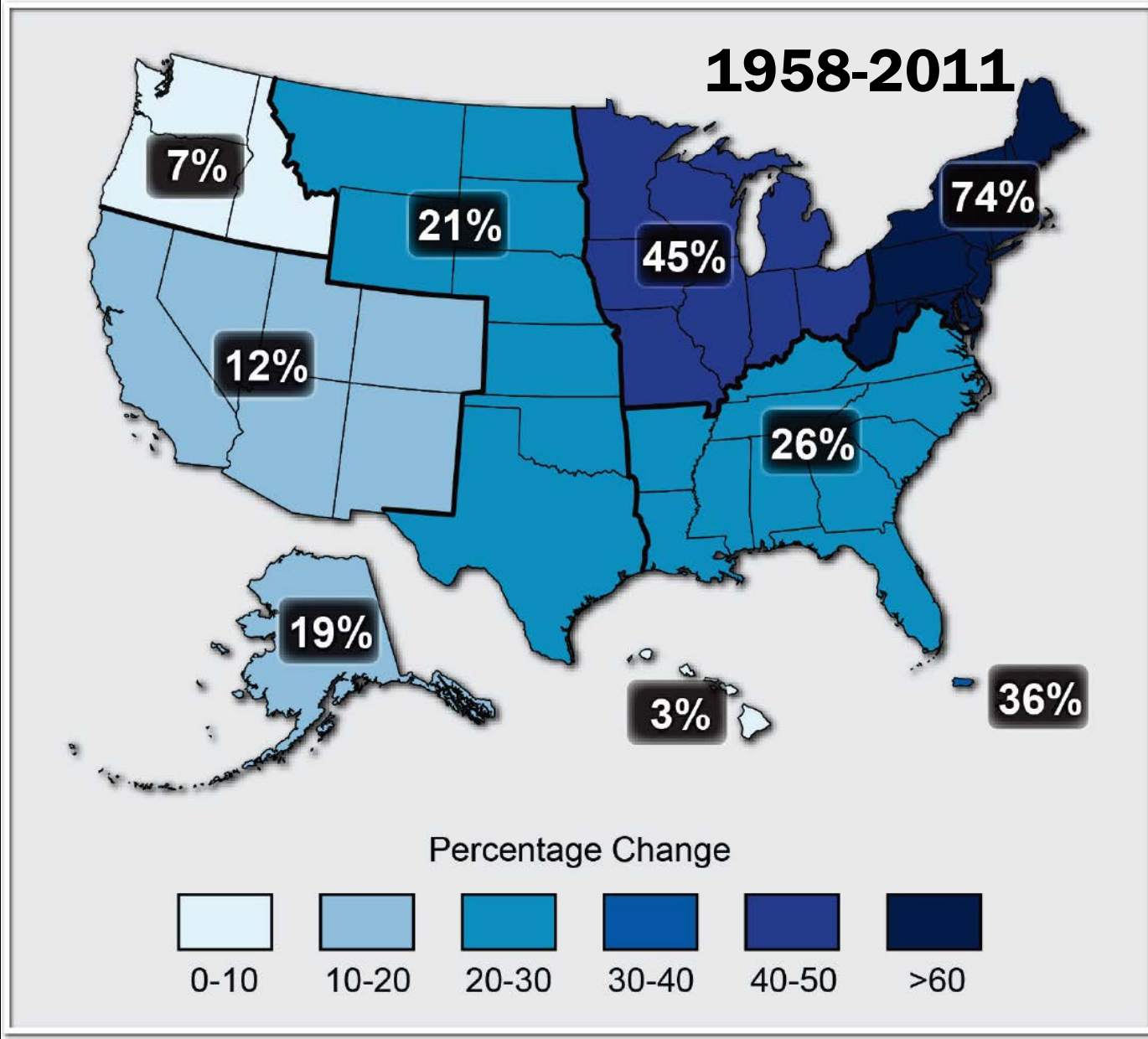
ASSESSMENT OF CLIMATE CHANGE IN THE SOUTHWEST UNITED STATES
www.swcarr.arizona.edu

Fewer Cold Waves

More Heat Waves



Percentage Change in Very Heavy Precipitation



Conifer Forest Mortality

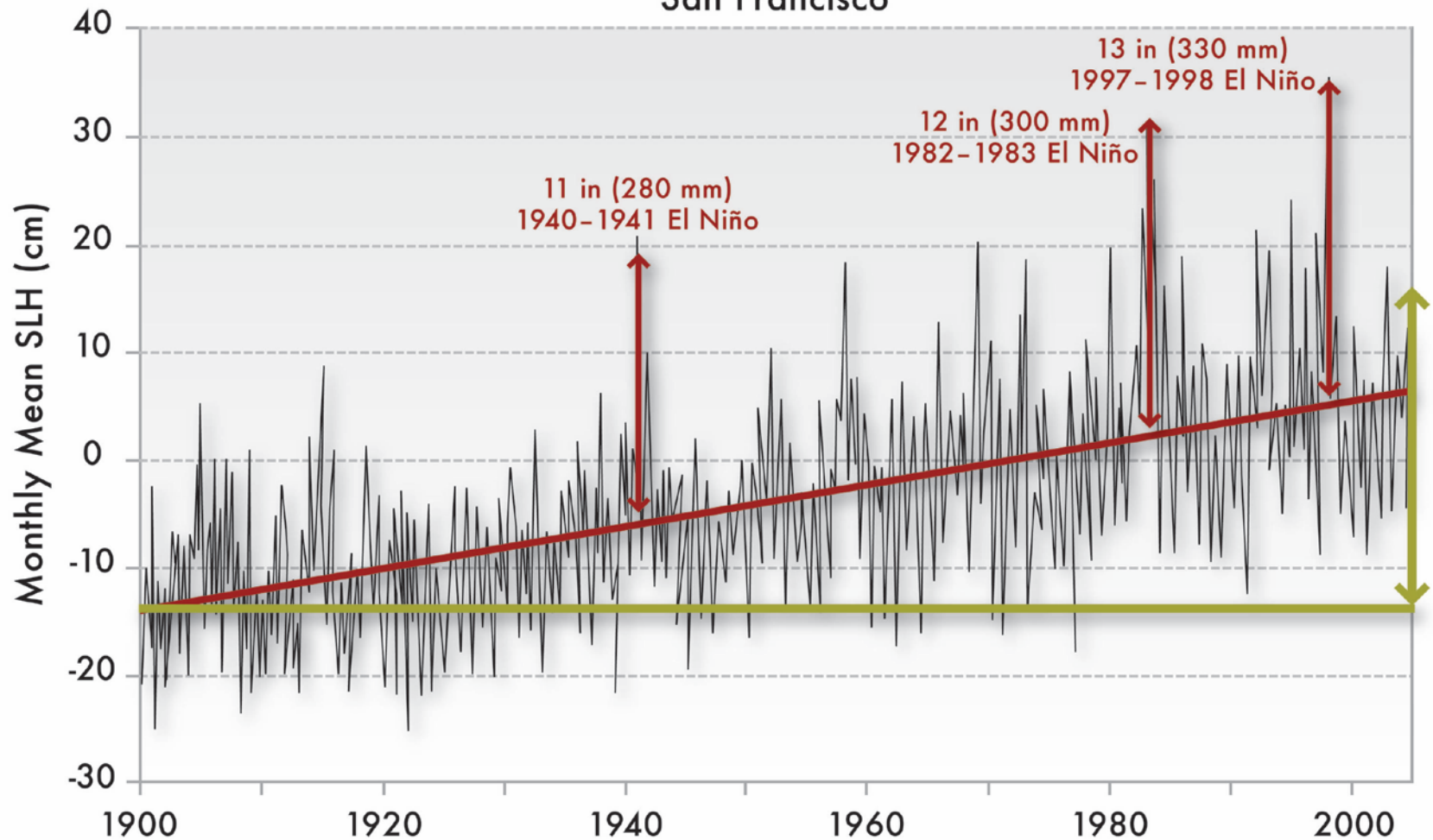


Photo: Jemez Mountains
Craig Allen, USGS



Horseshoe 2 Fire Chiricahua Mountains, 2011

San Francisco



Annual Variability



Short-term sea level
increases

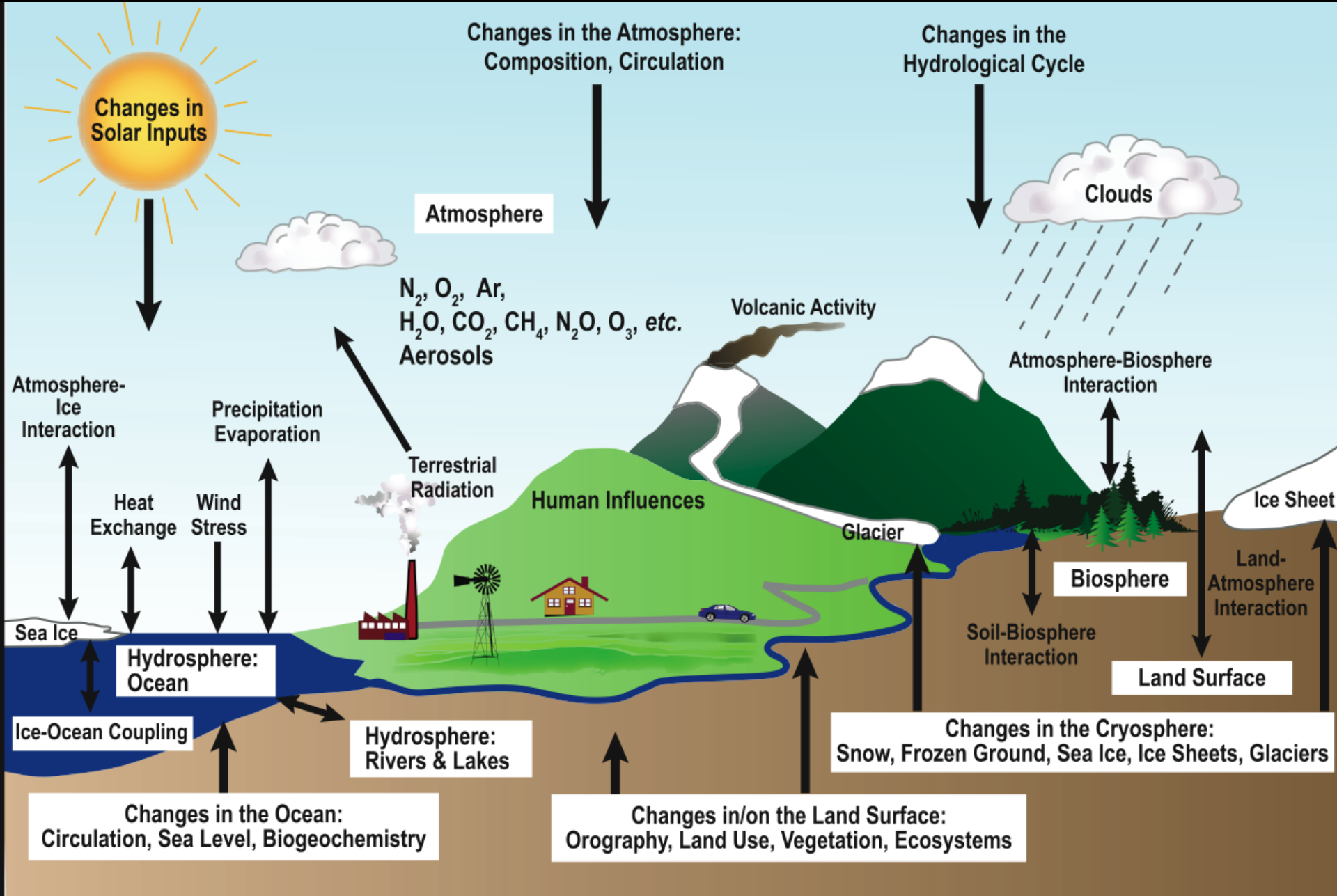


Long-term average rise in sea level at the
San Francisco/Golden Gate tide gauge



Difference 7-8 inches of sea-level rise
along the California coastline has made

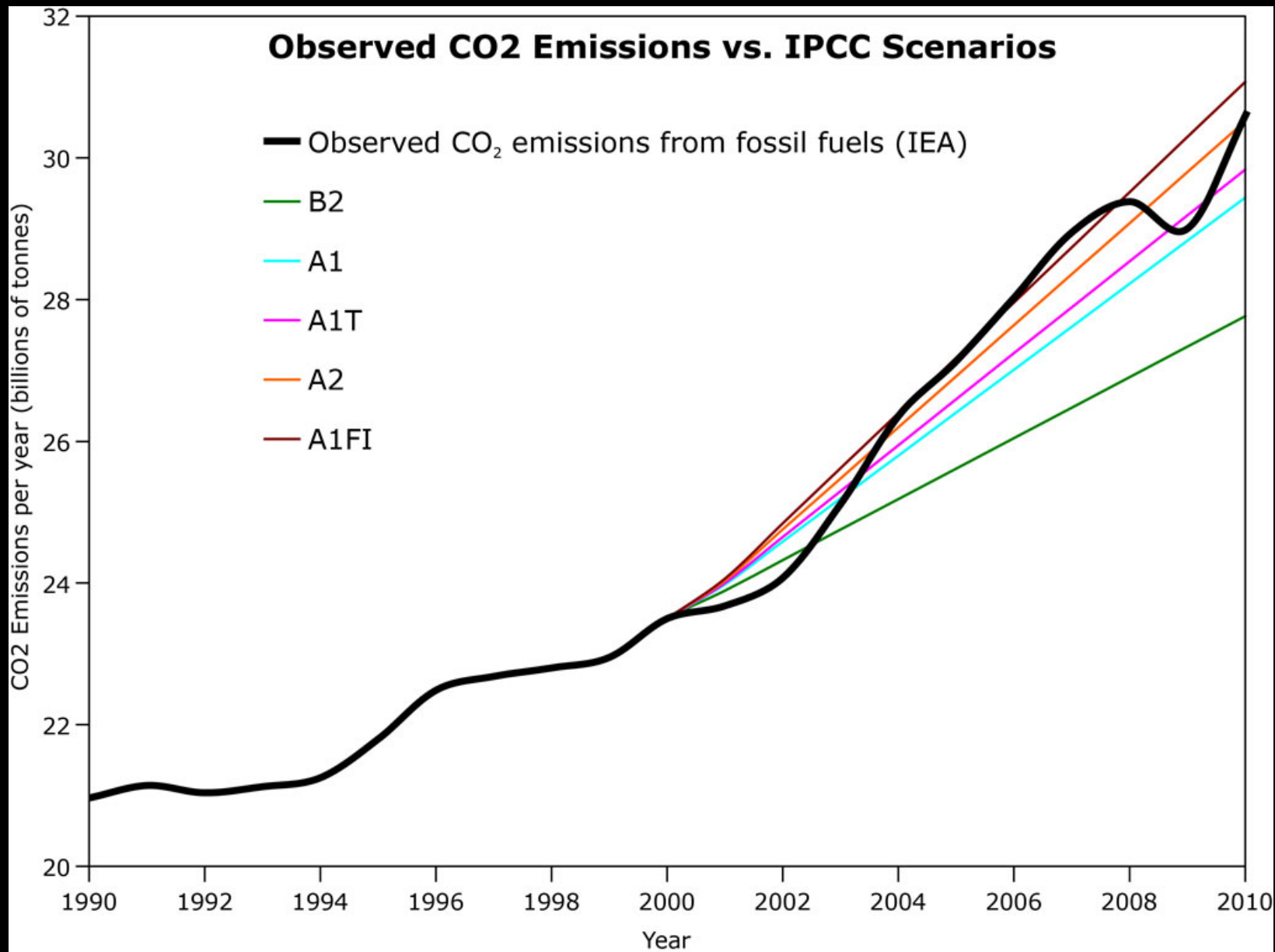




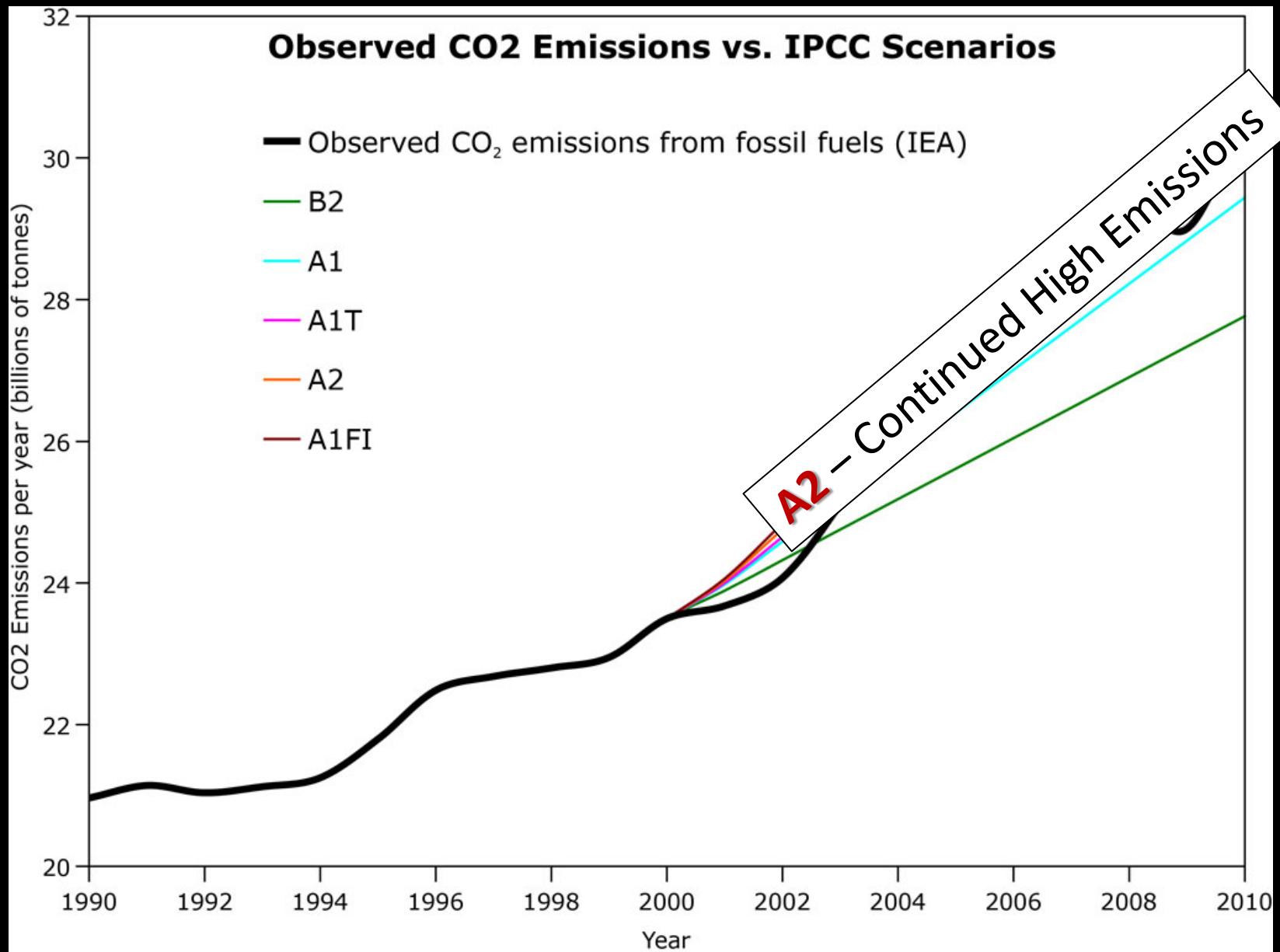
The Climate System





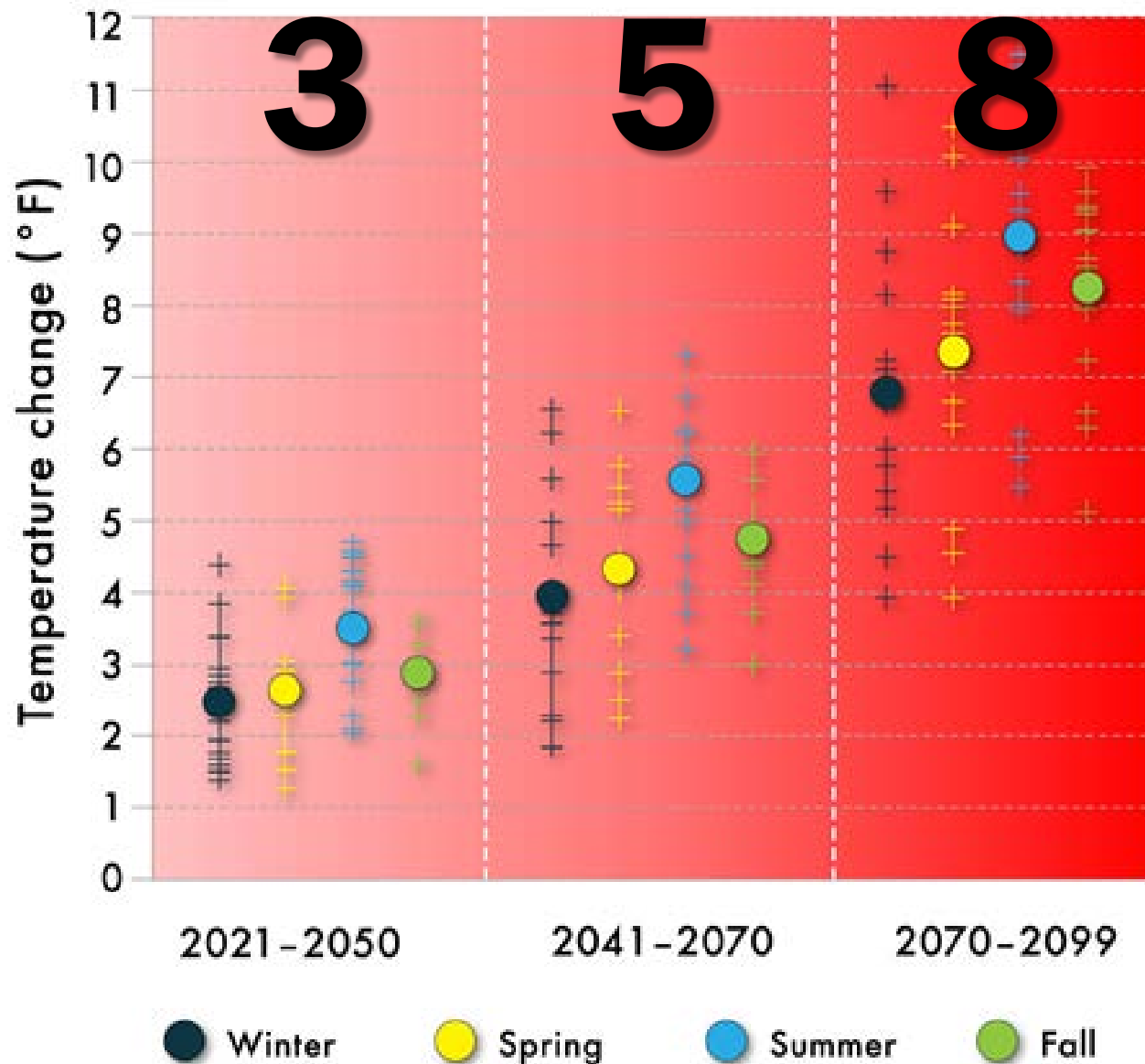


<http://www.skepticalscience.com/iea-co2-emissions-update-2010.html>



<http://www.skepticalscience.com/iea-co2-emissions-update-2010.html>

Average Annual Temperature



**High
emissions
A2**

Tucson

69°F



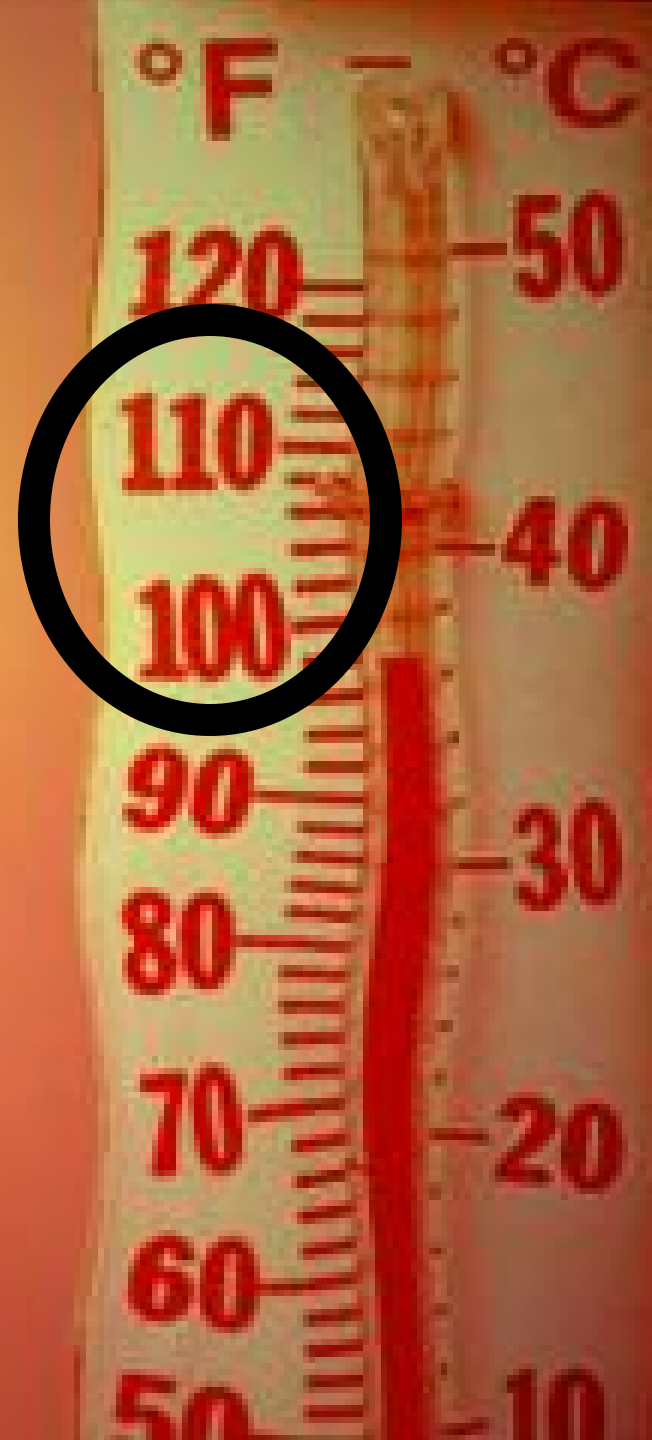
Yuma

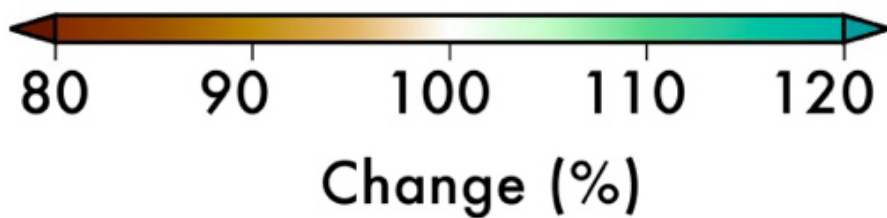
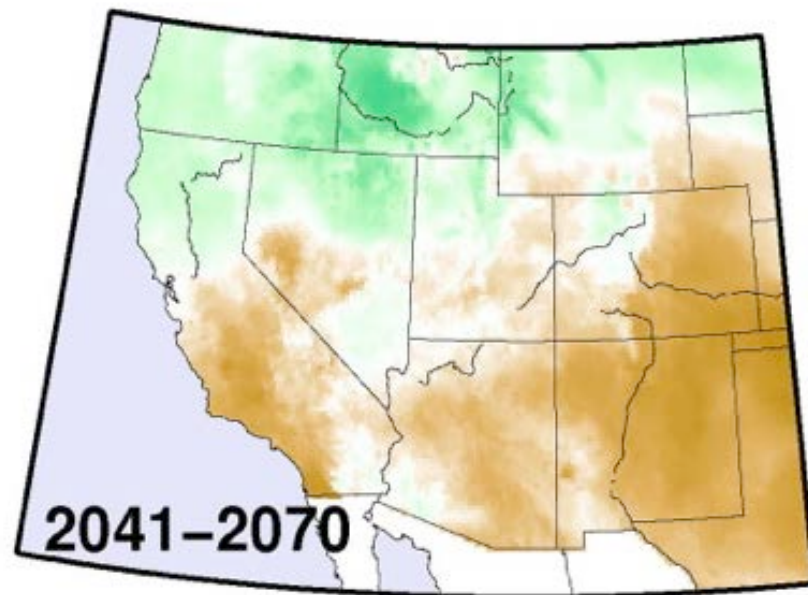
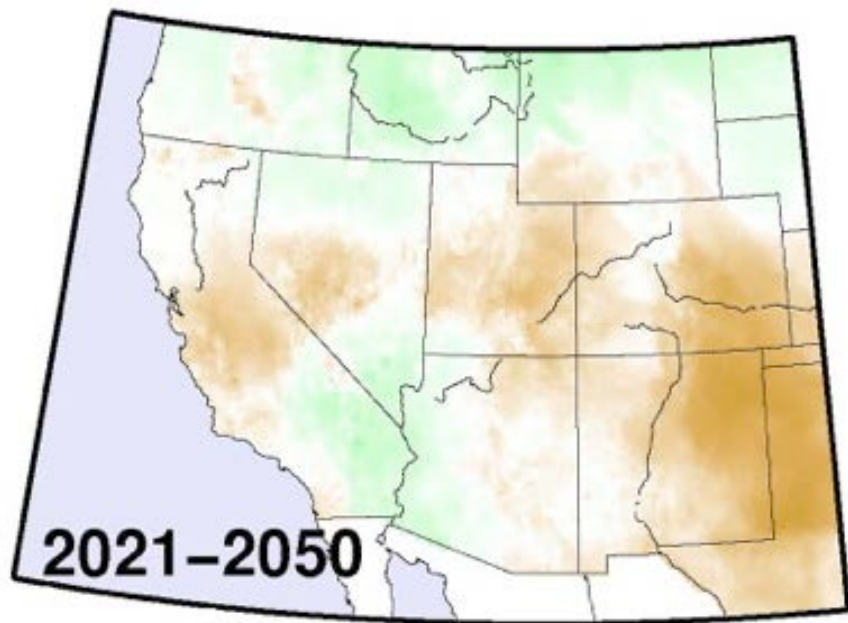
76°F



Average Annual Temperature - 1981-2010 - Data: NCDC

- **Longer Heat Waves**
- **Fewer Cold Nights**
- **More Hot Days**





A2 High Emissions Scenario

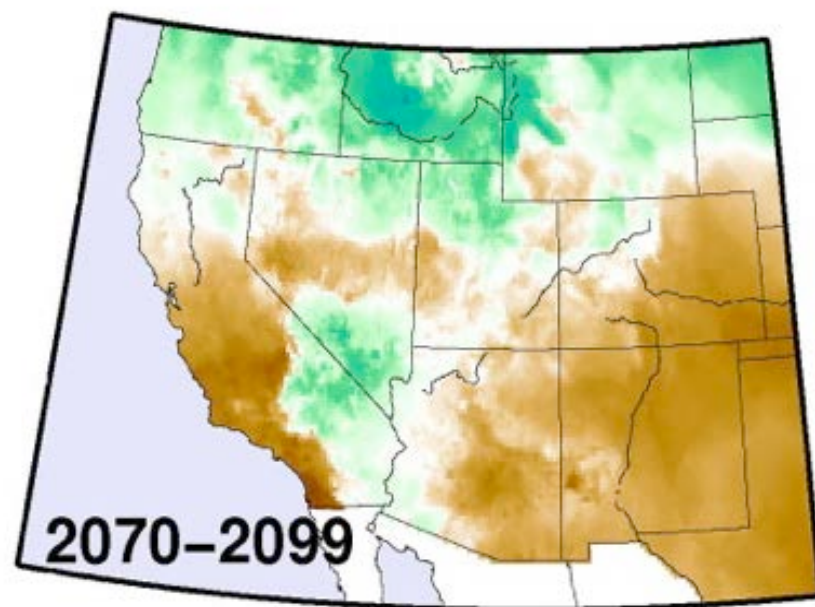




Photo: Daniel Griffin, University of Arizona

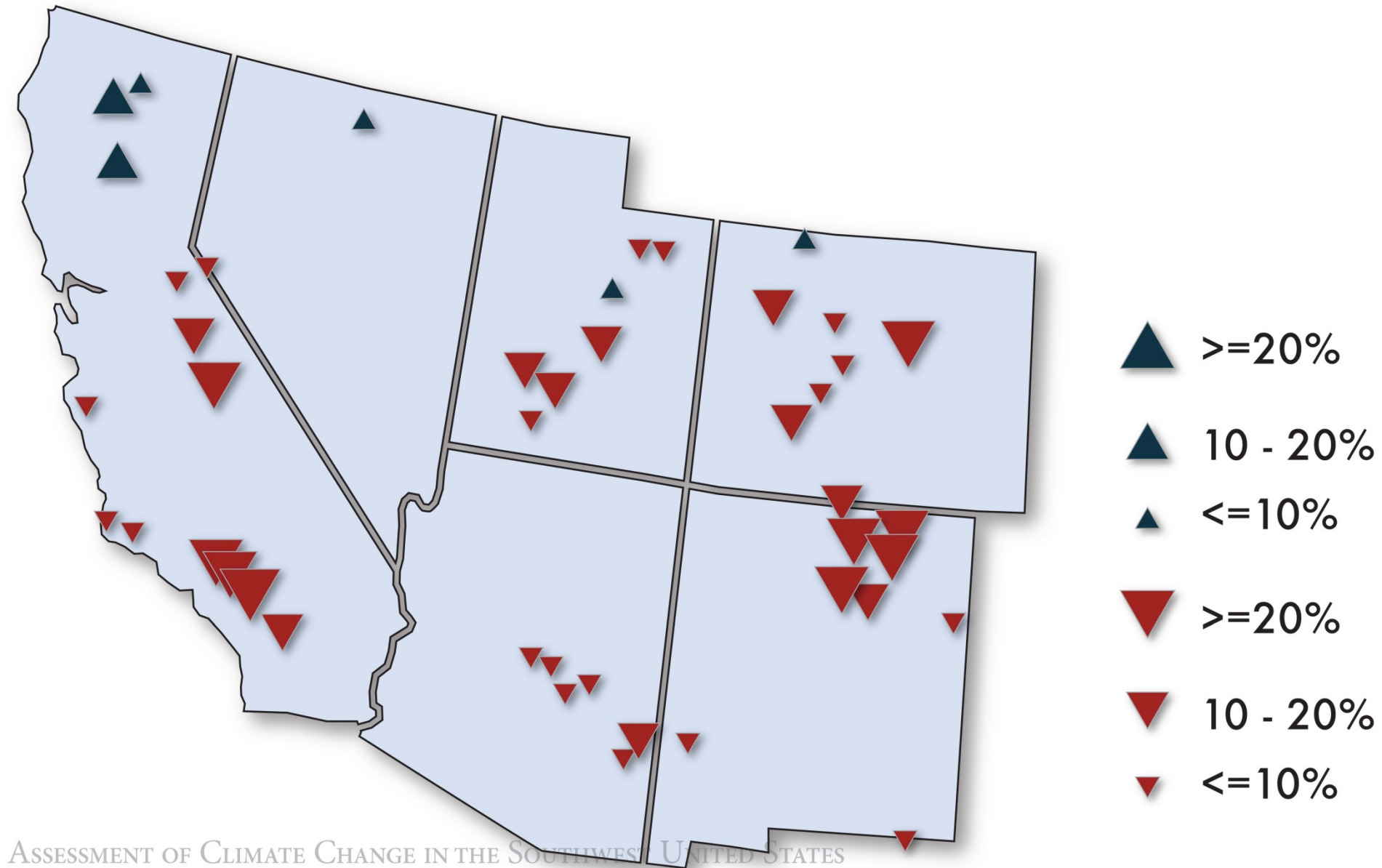
Impacts

Less Snow
Less Runoff
Less Soil Moisture



A2 High Emissions Scenario

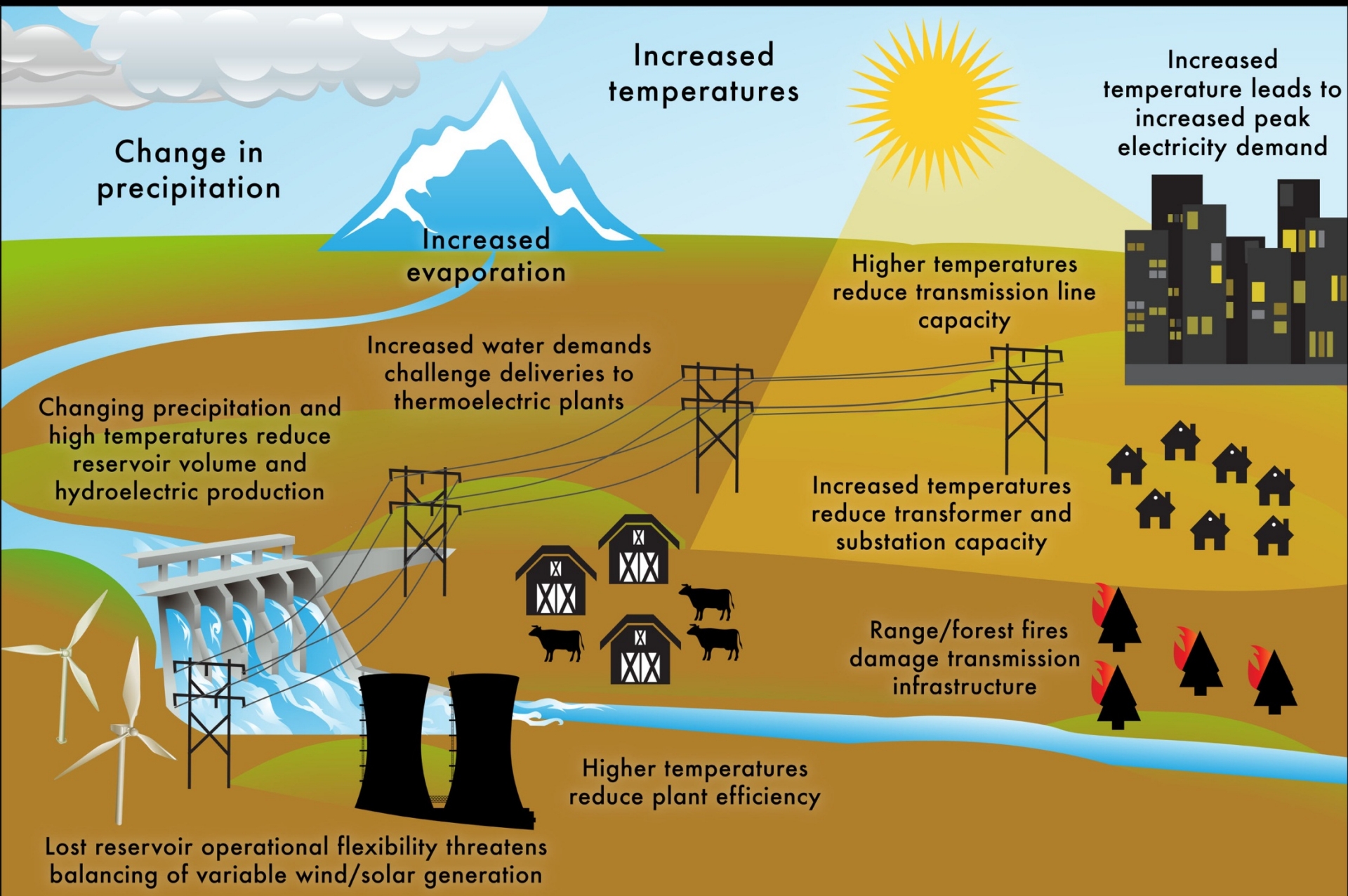
Streamflow % Change : 2050s vs. 1990s





 Federal Advisory
Committee
**Draft Climate
Assessment Report**
Now Available







Salt Lake City



Denver



Las Vegas



Albuquerque



Phoenix



Los Angeles

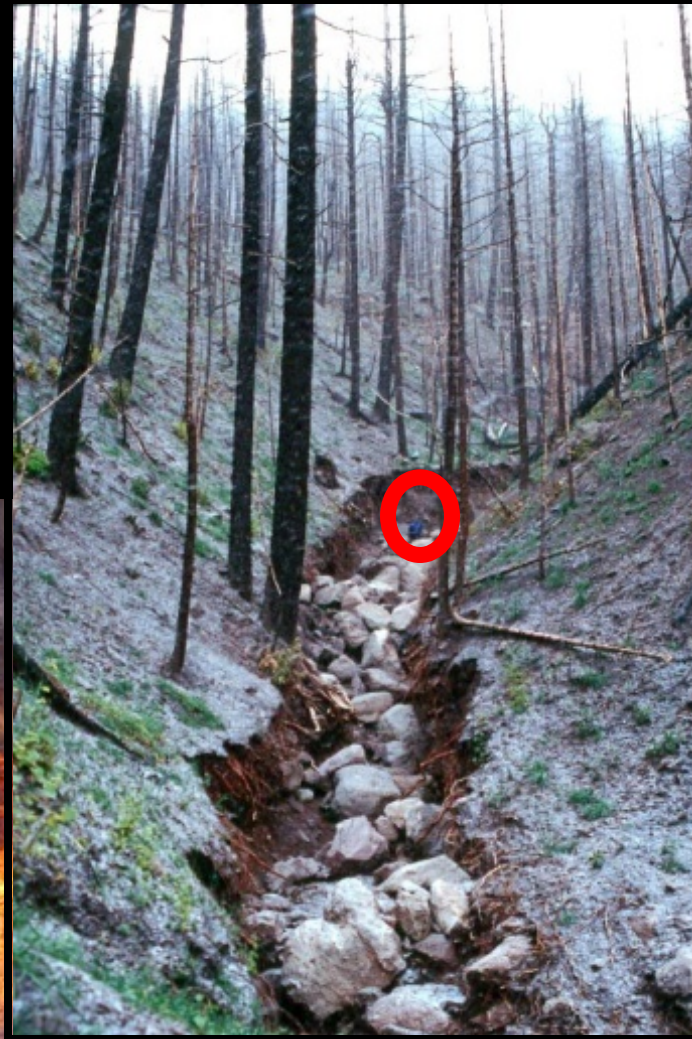
Waldo Canyon Fire Colorado Springs, CO - 2012



Intersecting Challenges

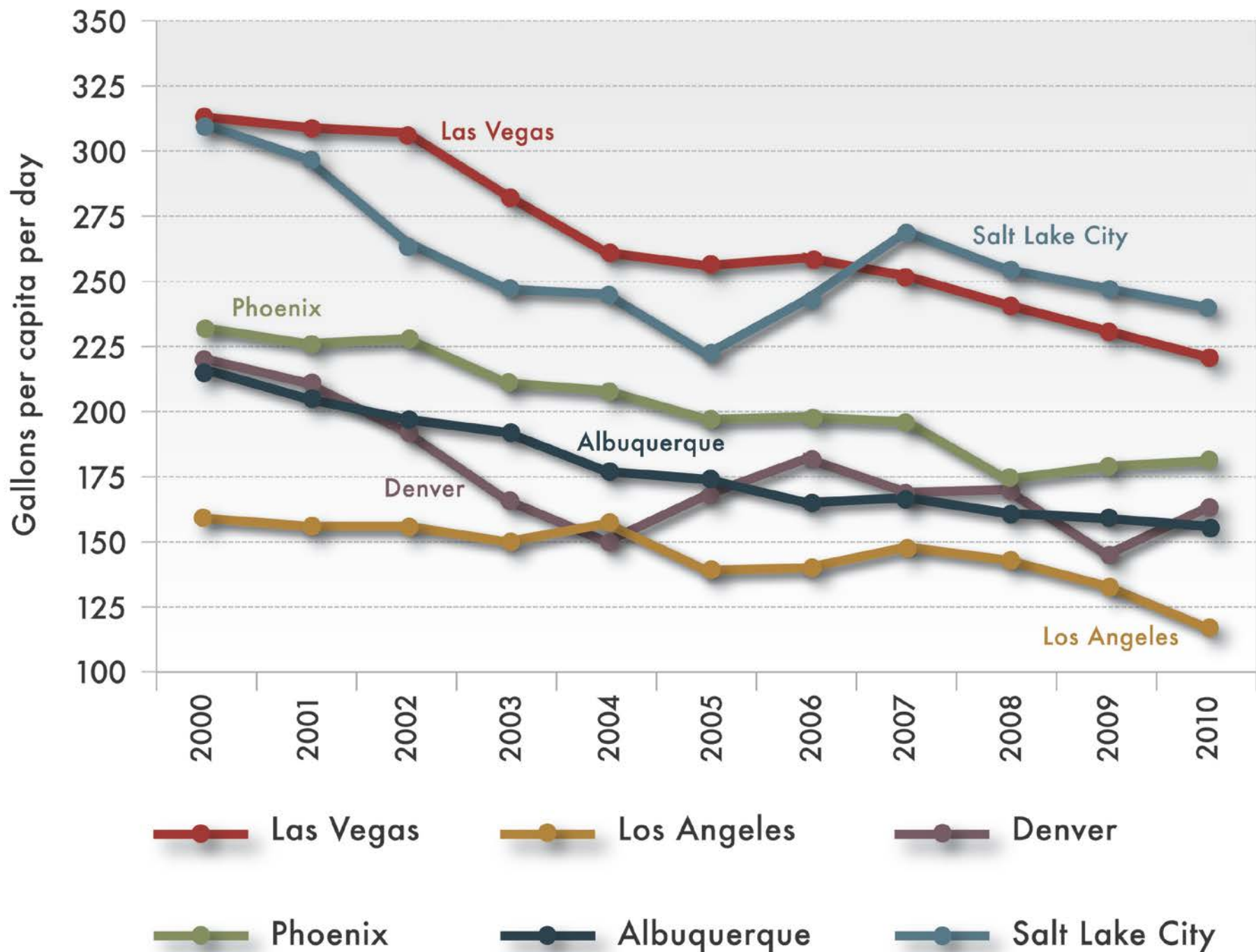
Erosion

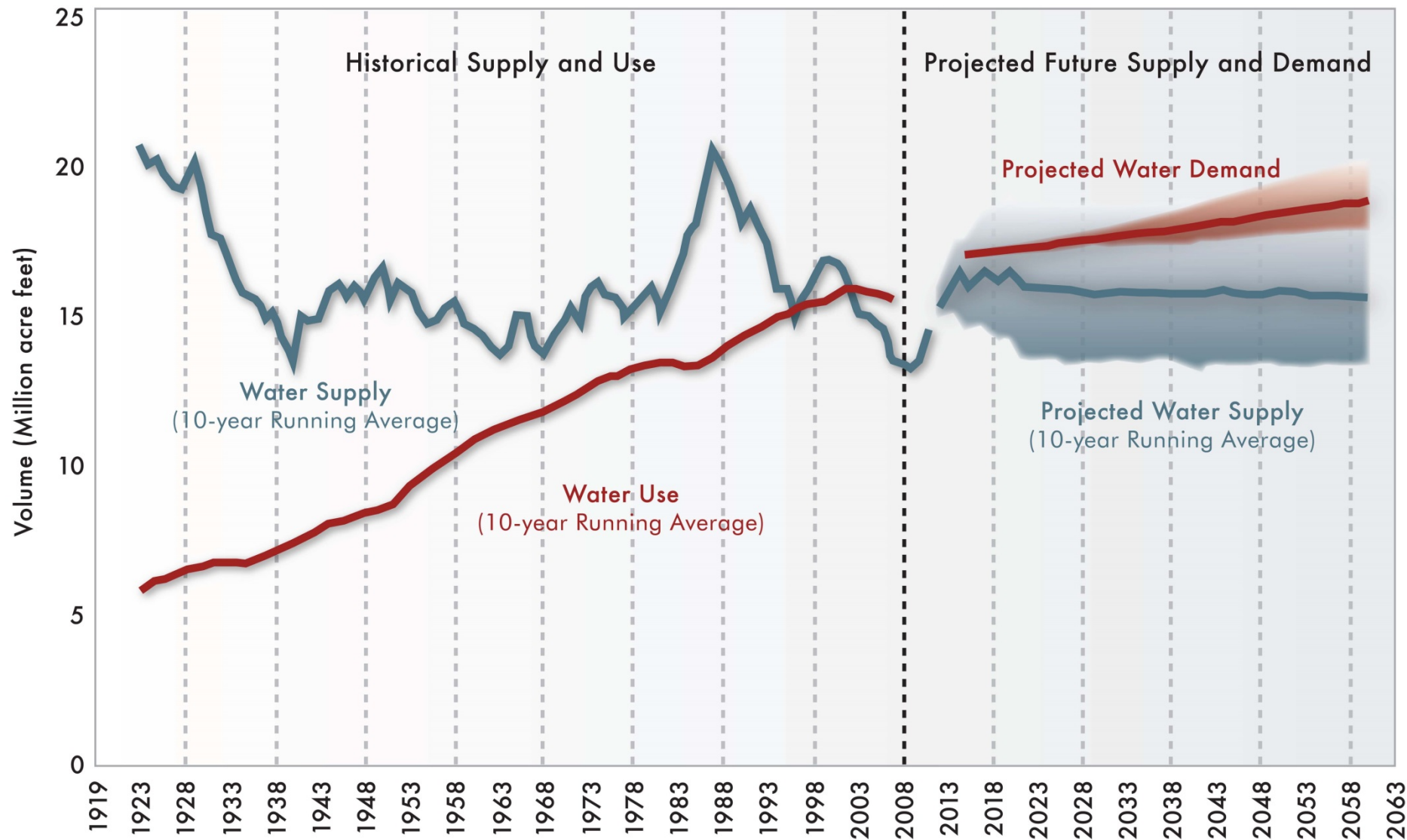
Fire



Mortality







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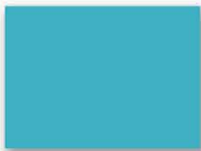


Chapter 10 – Water

San Francisco International Airport



Oakland International Airport



Areas potentially exposed to an approximate 16-inch sea-level rise assuming no flood protection from existing dikes and levees



Areas potentially exposed to an approximate 55-inch sea-level rise assuming no flood protection from existing dikes and levees

Highways Power plants Infrastructure

choices



CALIFORNIA ADAPTATION PLANNING GUIDE



PLANNING FOR ADAPTIVE COMMUNITIES

RECLAMATION

Managing Water in the West

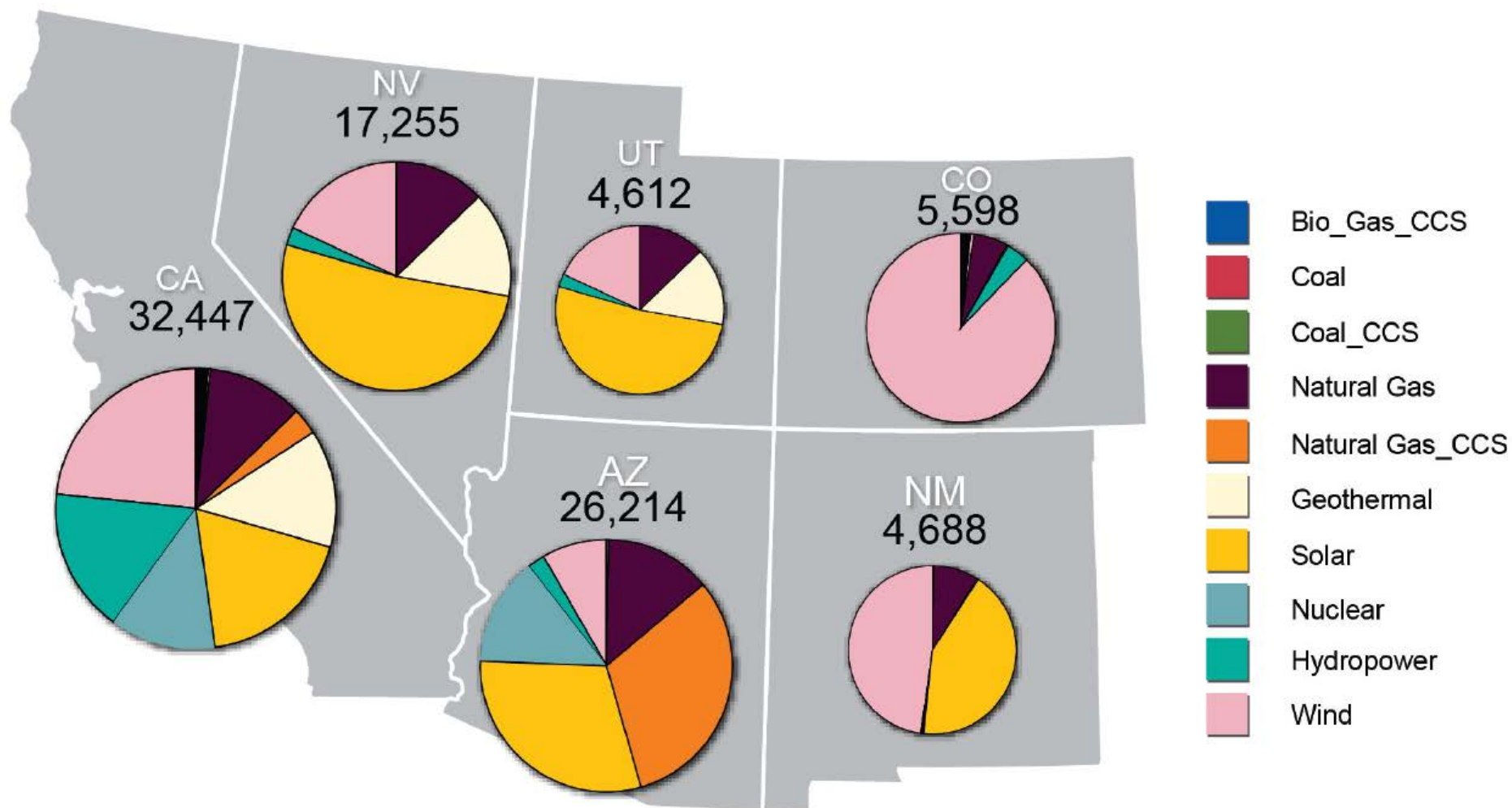
Colorado River Basin Water Supply and Demand Study

Executive Summary – Pre-Production Copy



If drastic reductions in GHGs are required, studies have found that it is more practical and less costly to reduce emissions in the electricity sector and electrify as much of other sectors as possible.





Draft 2013 National Climate Assessment Chapter 20: Southwest

Federal Advisory Committee

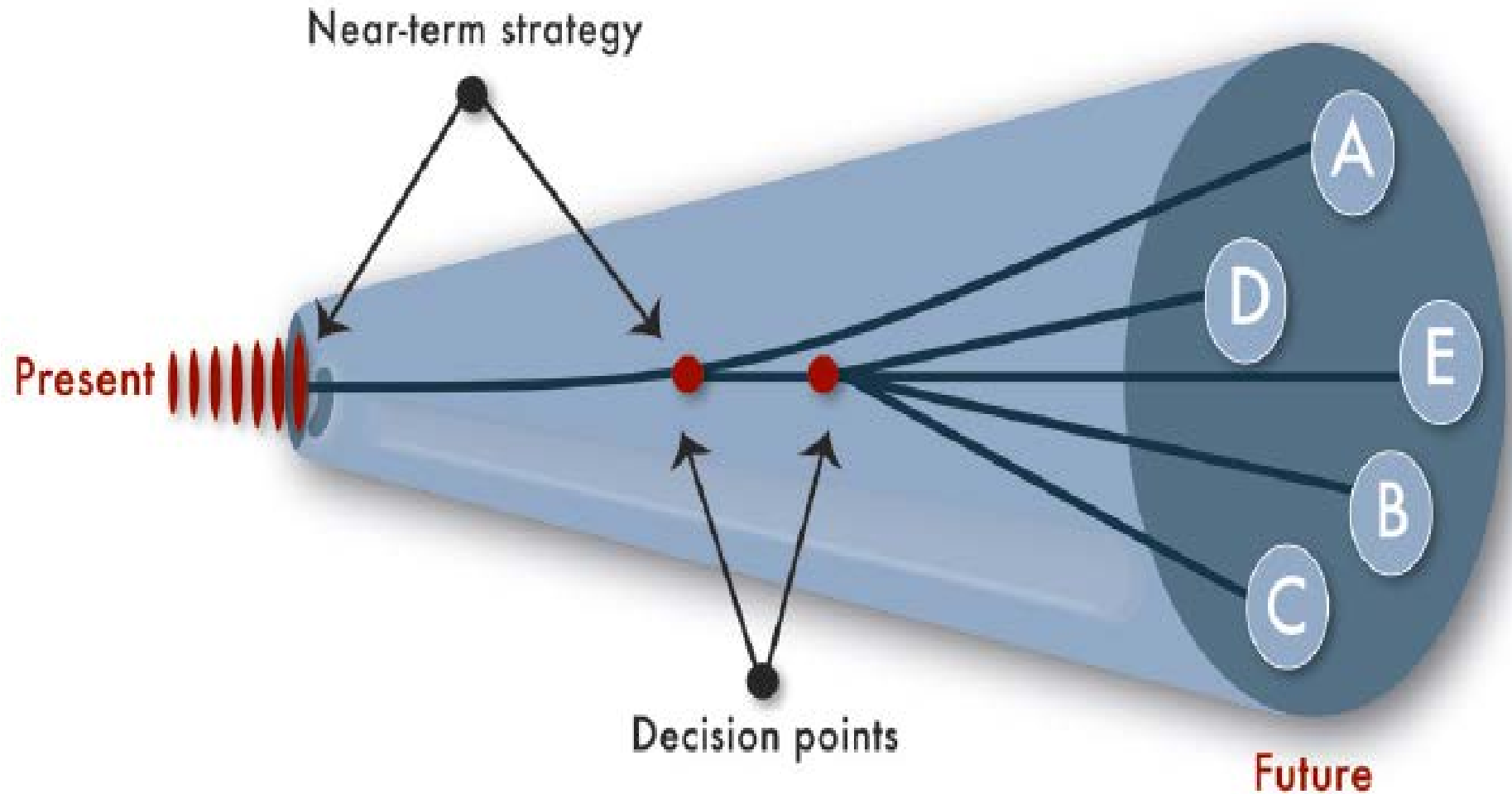
Draft Climate Assessment Report

Now Available

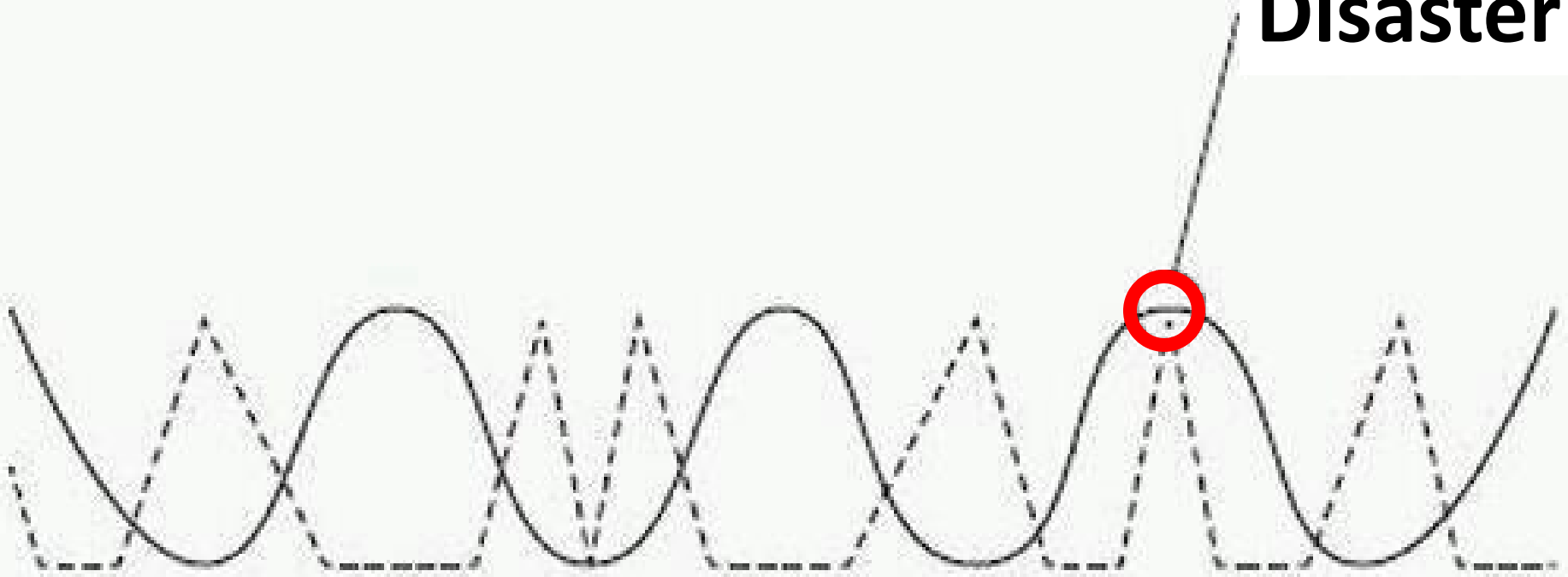
Supply and Demand Strategies

- Conservation
- New dams
- Desalination
- Retirement of lawns
- Groundwater banking
- Direct potable reuse

The Cone of Uncertainty



Disaster



—————

Have to Pee

- - - - -

Have to Sneeze



Assessment of Climate Change in the Southwest U.S.

Assessment of Climate Change in the Southwest United States speaks broadly and clearly about climate and its effects on the people and landscapes of Arizona, California, Colorado, Nevada, New Mexico, Utah, the U.S.– Mexico border region, and the lands of Native Nations.

A landmark study in terms of its coverage and analysis (and a synthesis of knowledge from some 120 contributing experts), the book offers decision makers and stakeholders a substantial basis from which to make informed choices that will affect the well-being of the region's inhabitants in the decades to come.

[Read More](#)

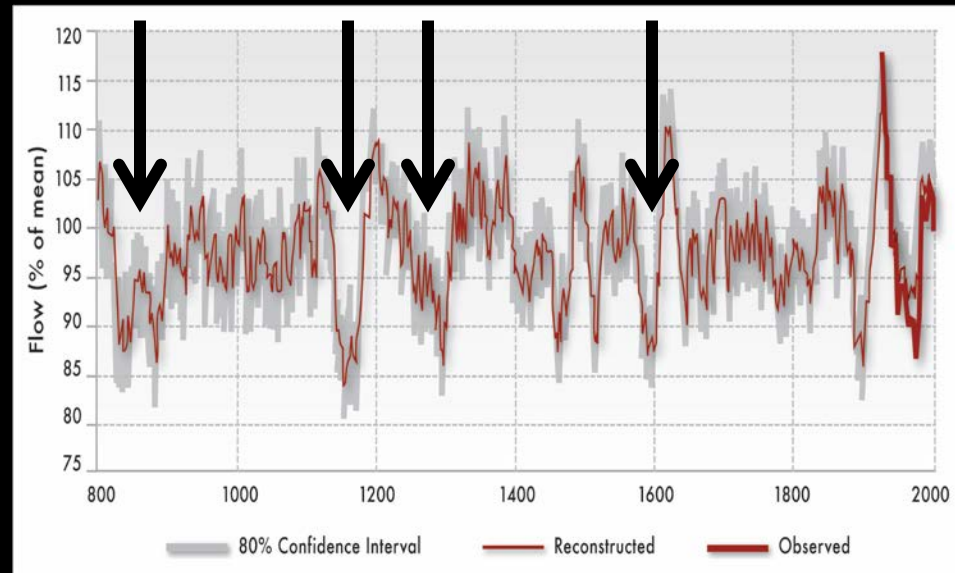
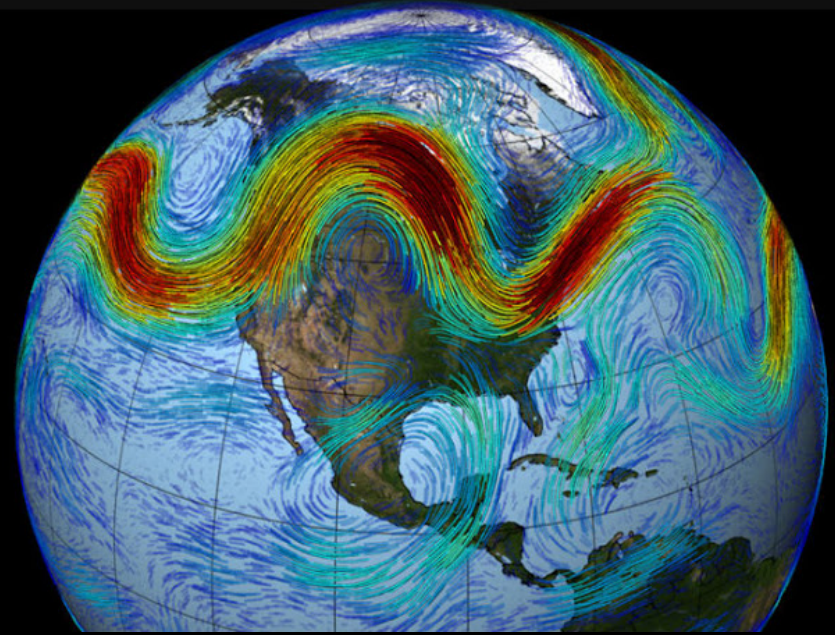
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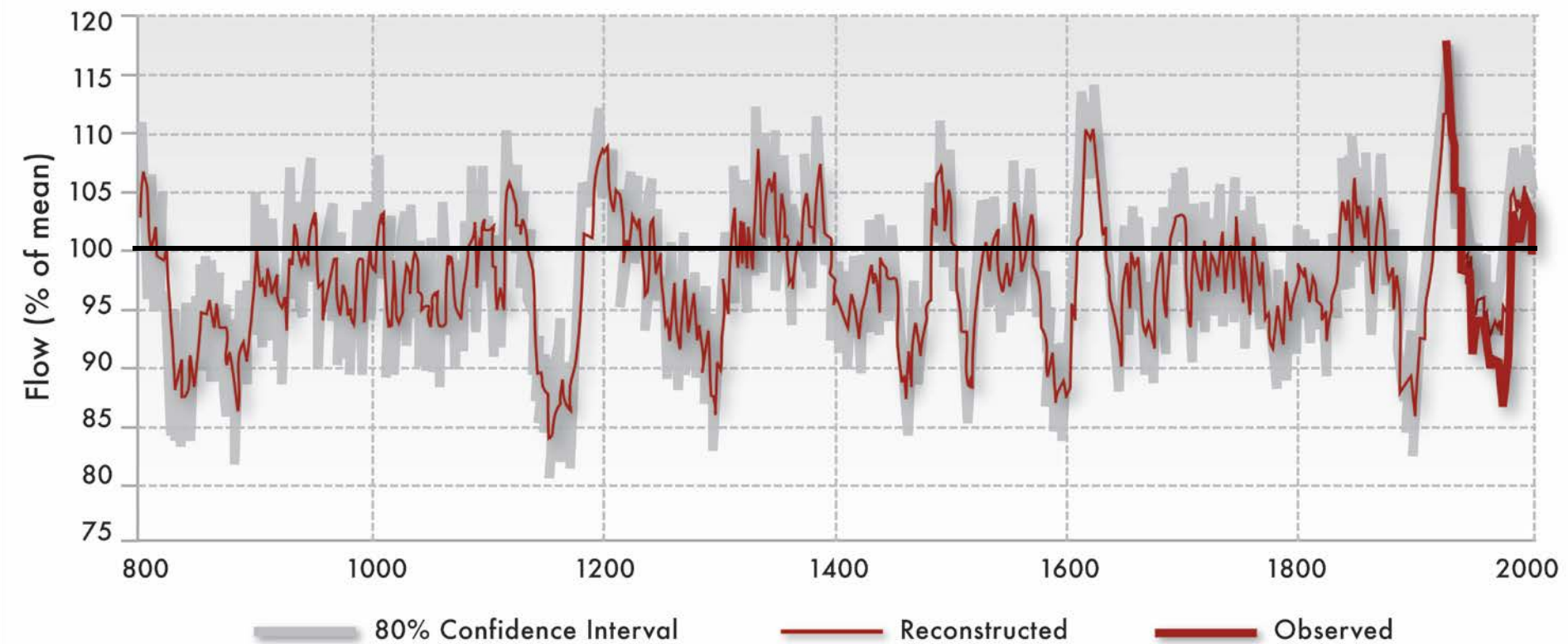


<http://globalchange.gov/>

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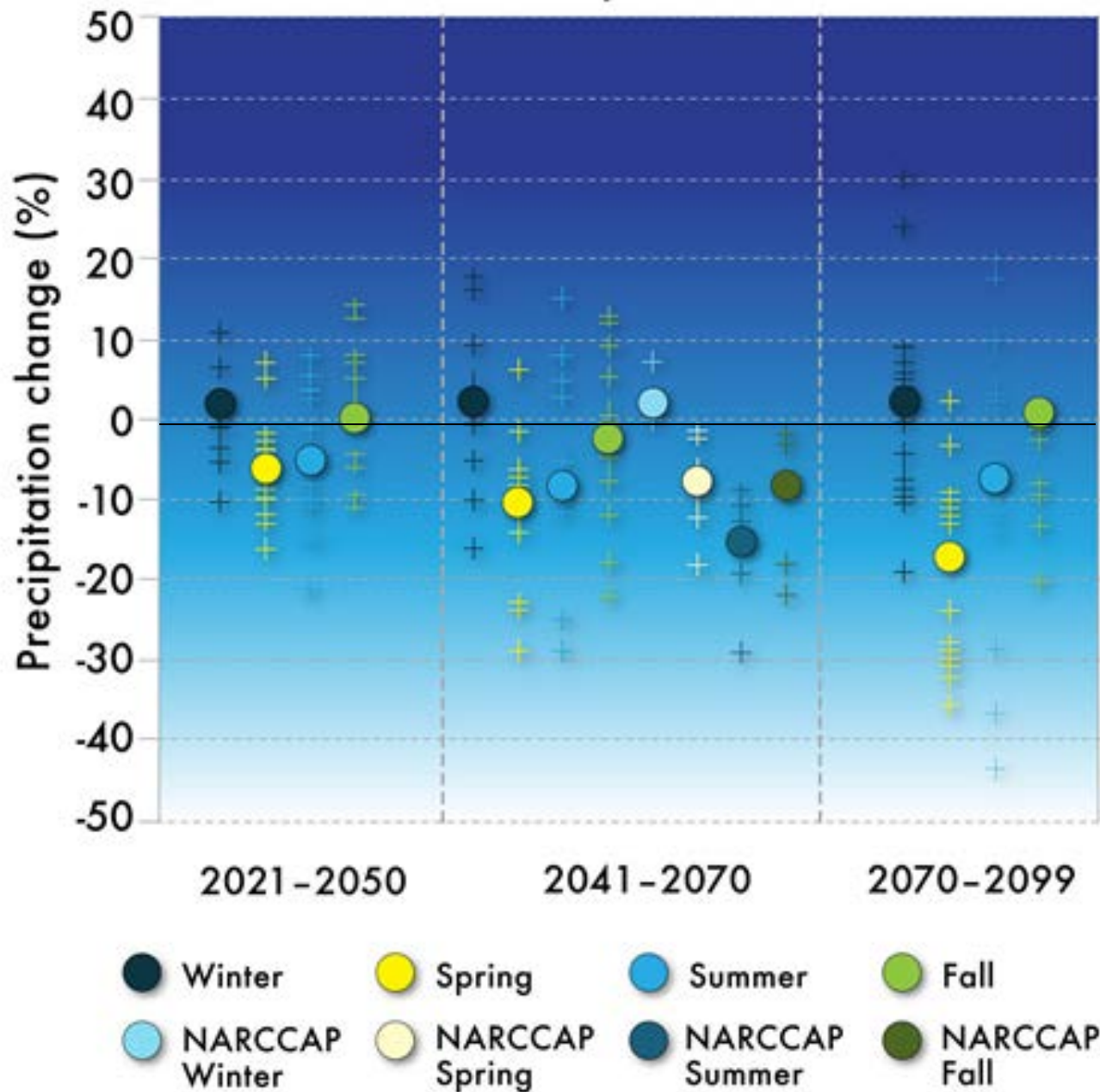
Tipping Points





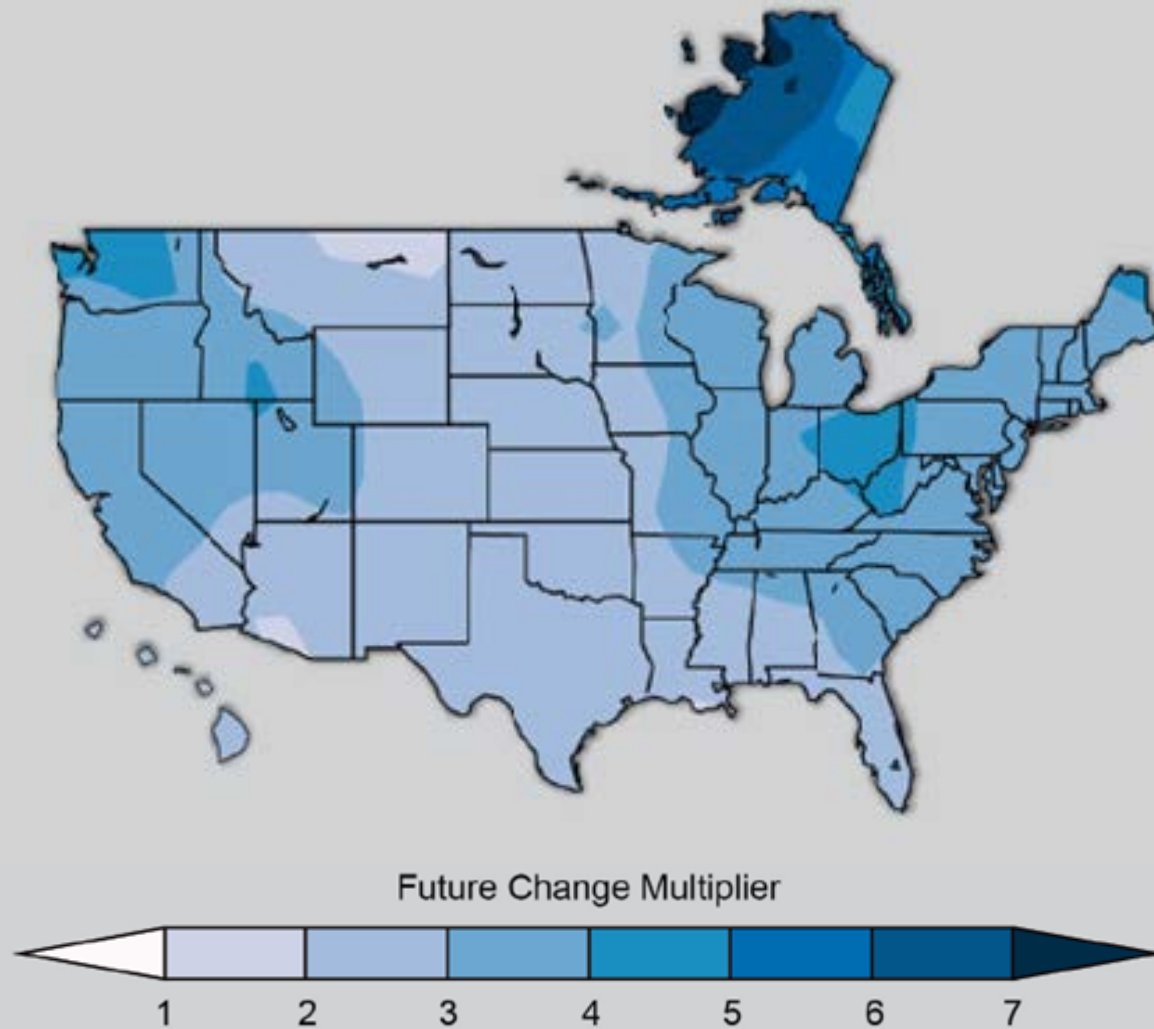
Colorado River Streamflow 762-2005

Precipitation



**High
emissions
A2**

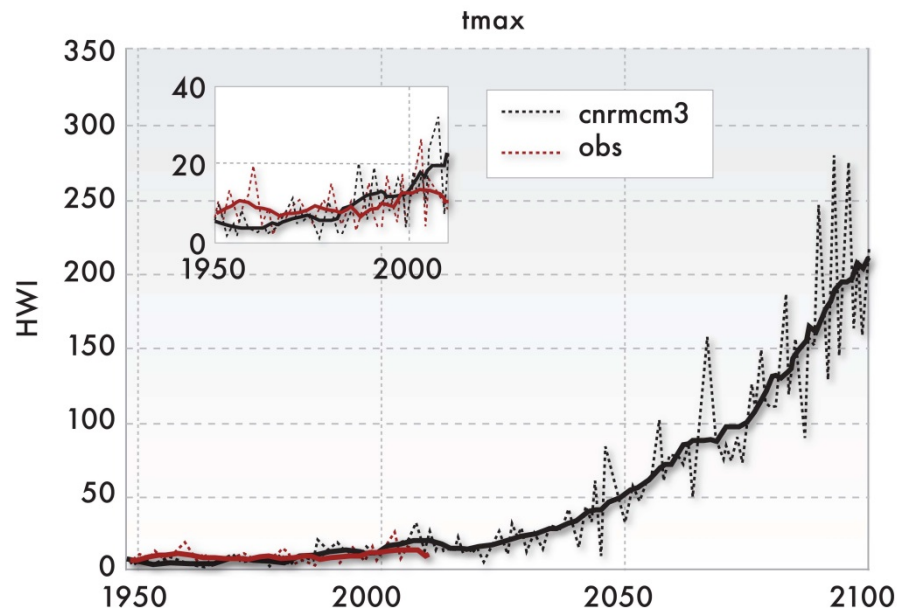
High Pathway (RCP 8.5)



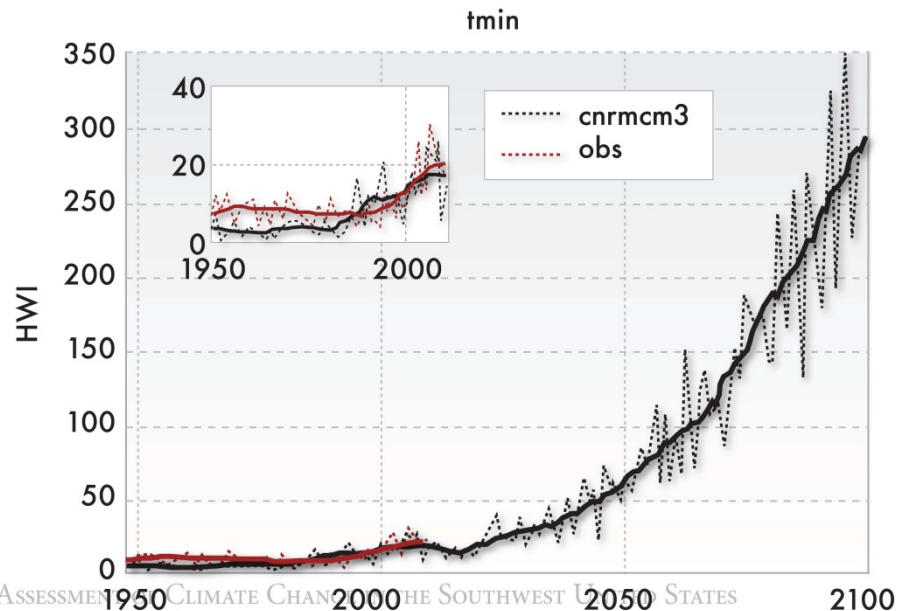
Heat Waves

- More frequent
- Longer
- More intense

a) Observed and projected daytime Heat Wave Index



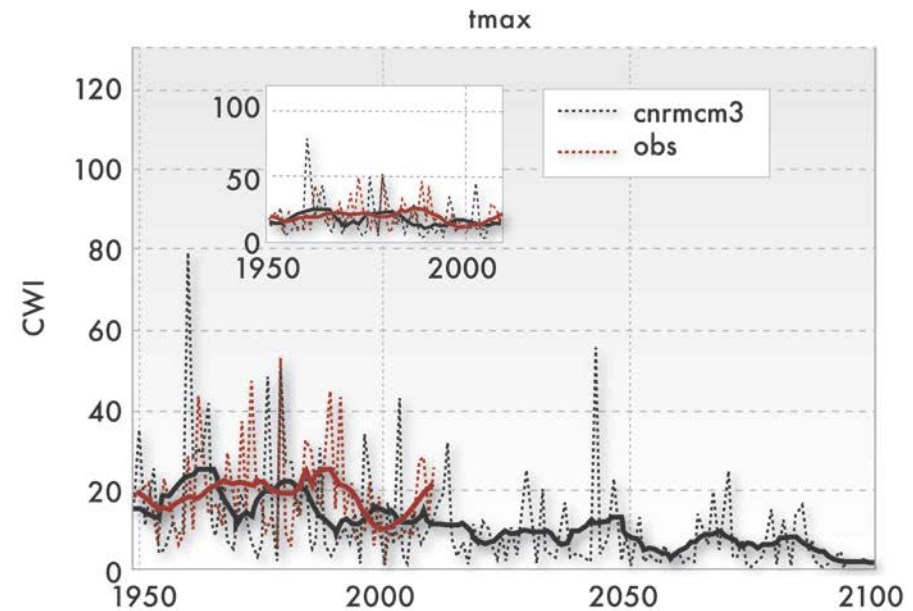
b) Observed and projected nighttime Heat Wave Index



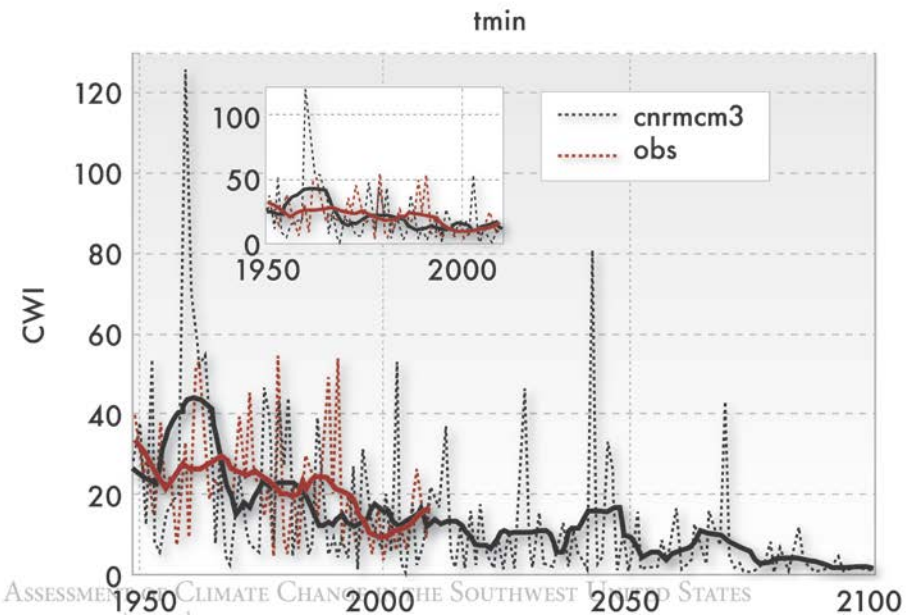
Cold Spells

- Less frequent
- Just as cold

a) Observed and projected daytime Cold Spell Index

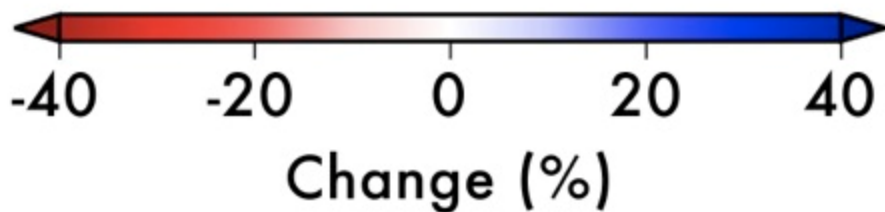


b) Observed and projected nighttime Cold Spell Index

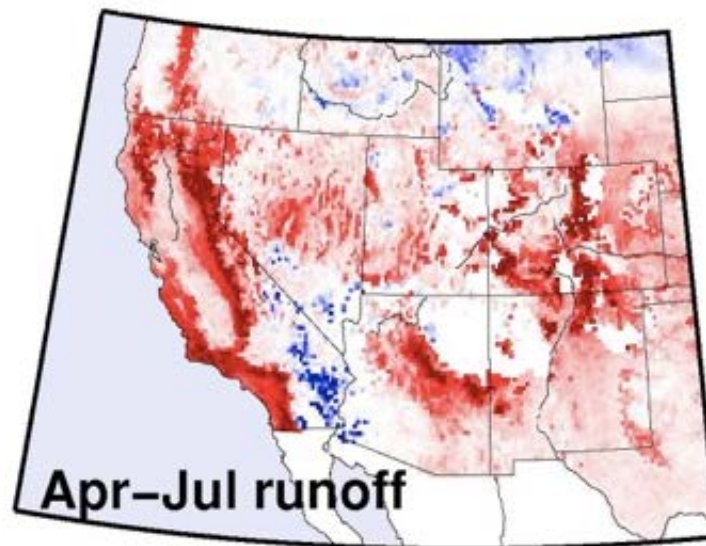
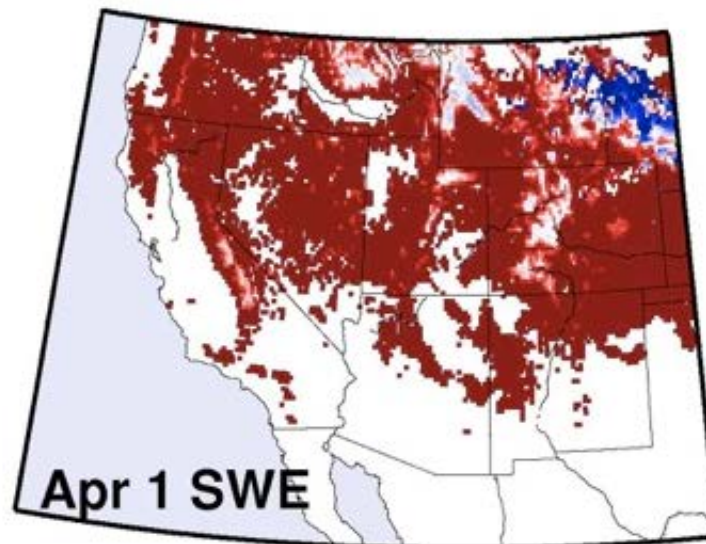


Less Snow
Less Runoff
Less Soil Moisture

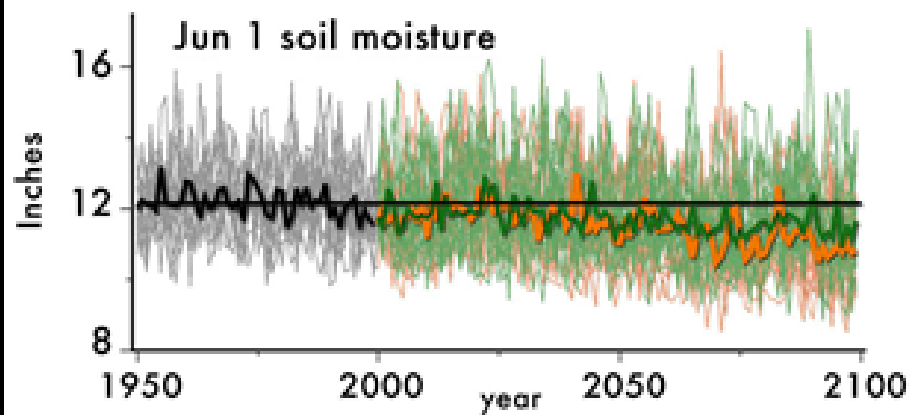
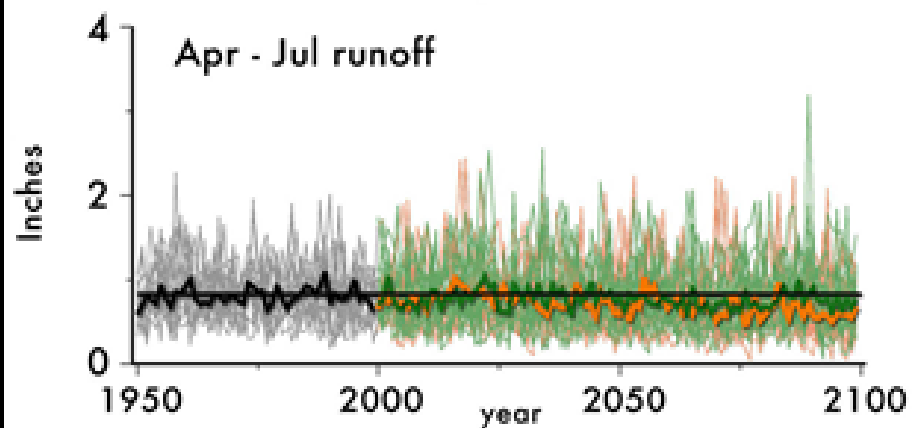
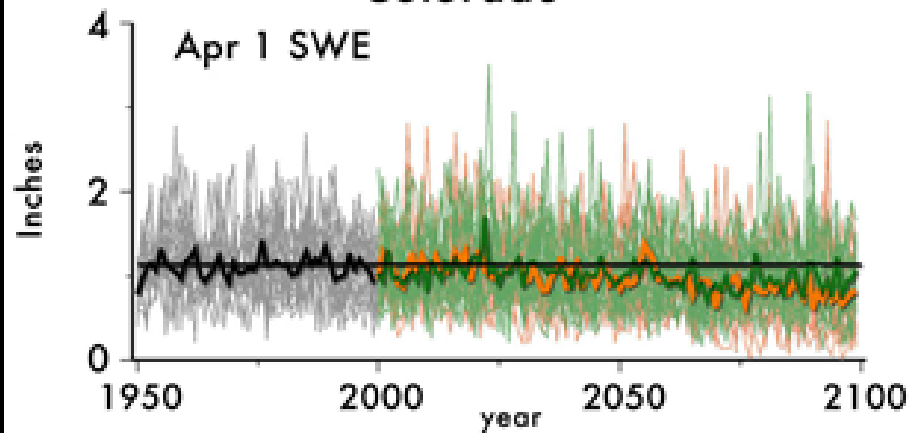
A2 High Emissions Scenario



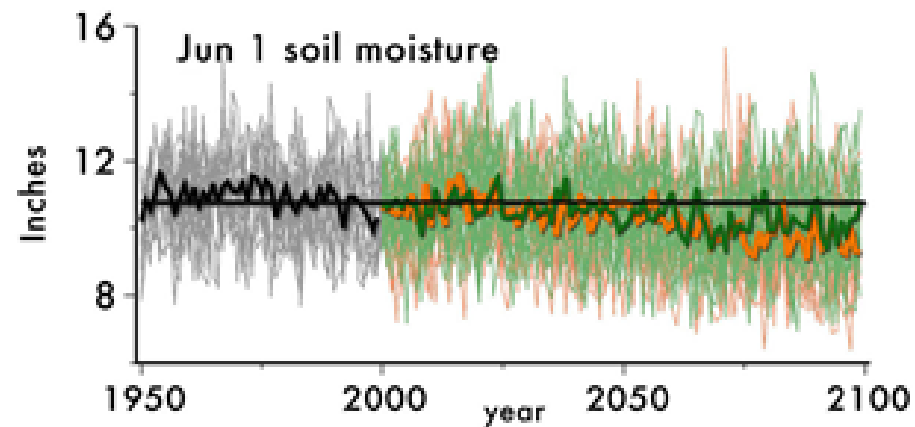
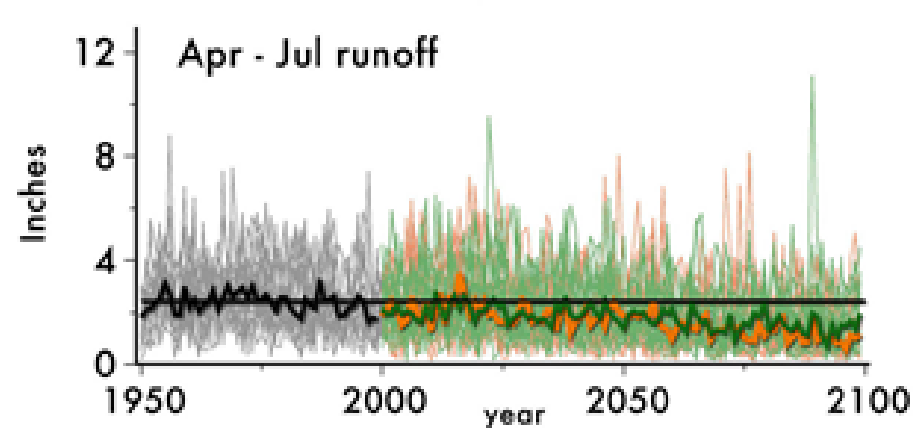
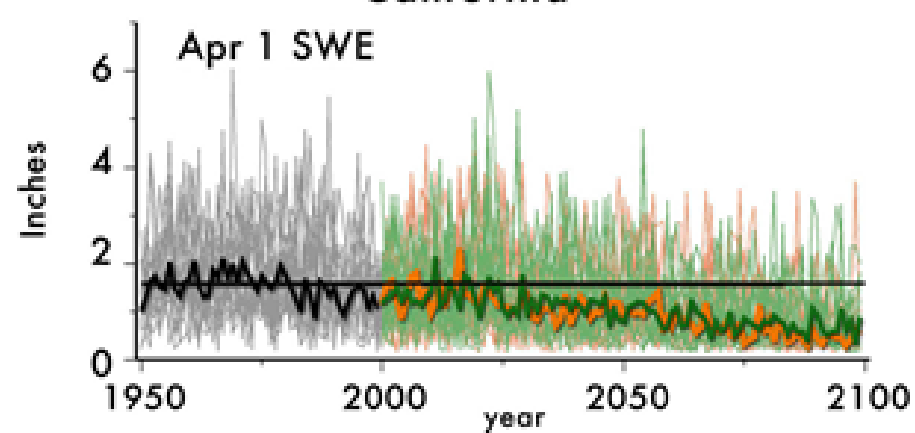
High emission scenario
2041–2070



Colorado

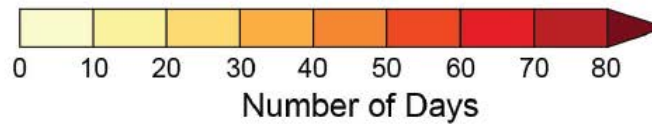
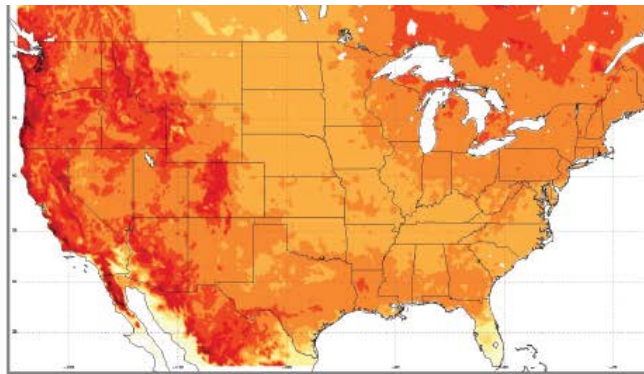


California

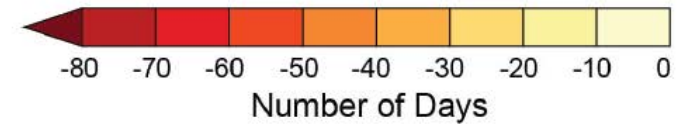
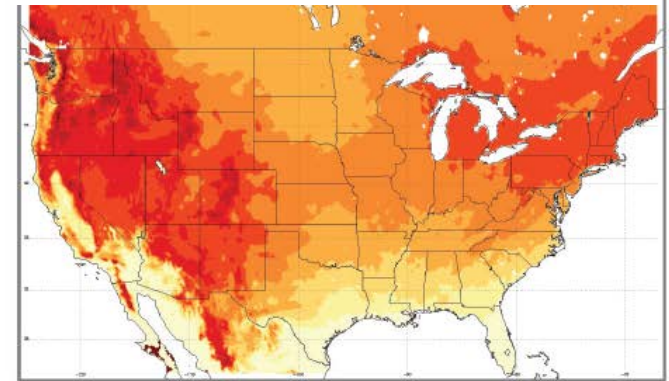


High emissions A2

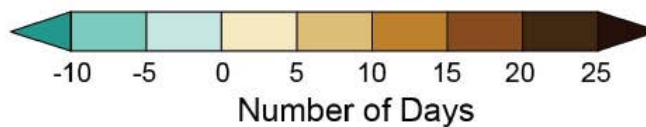
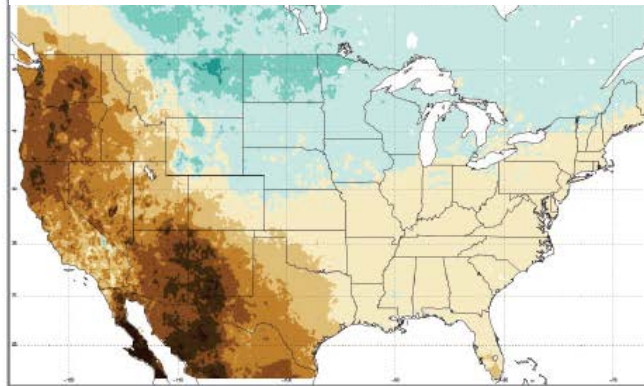
Frost-free Season



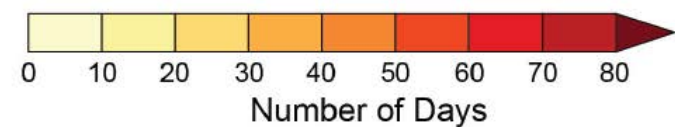
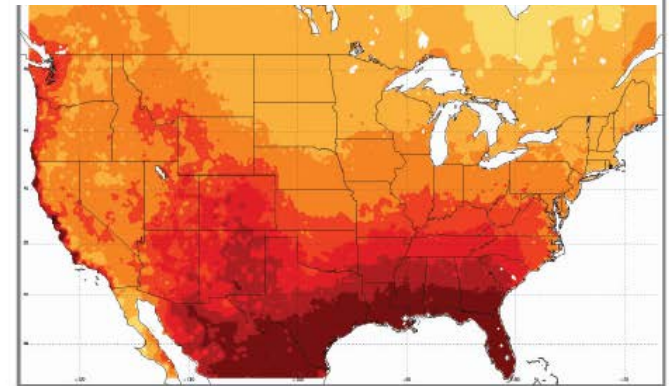
Freeze Days



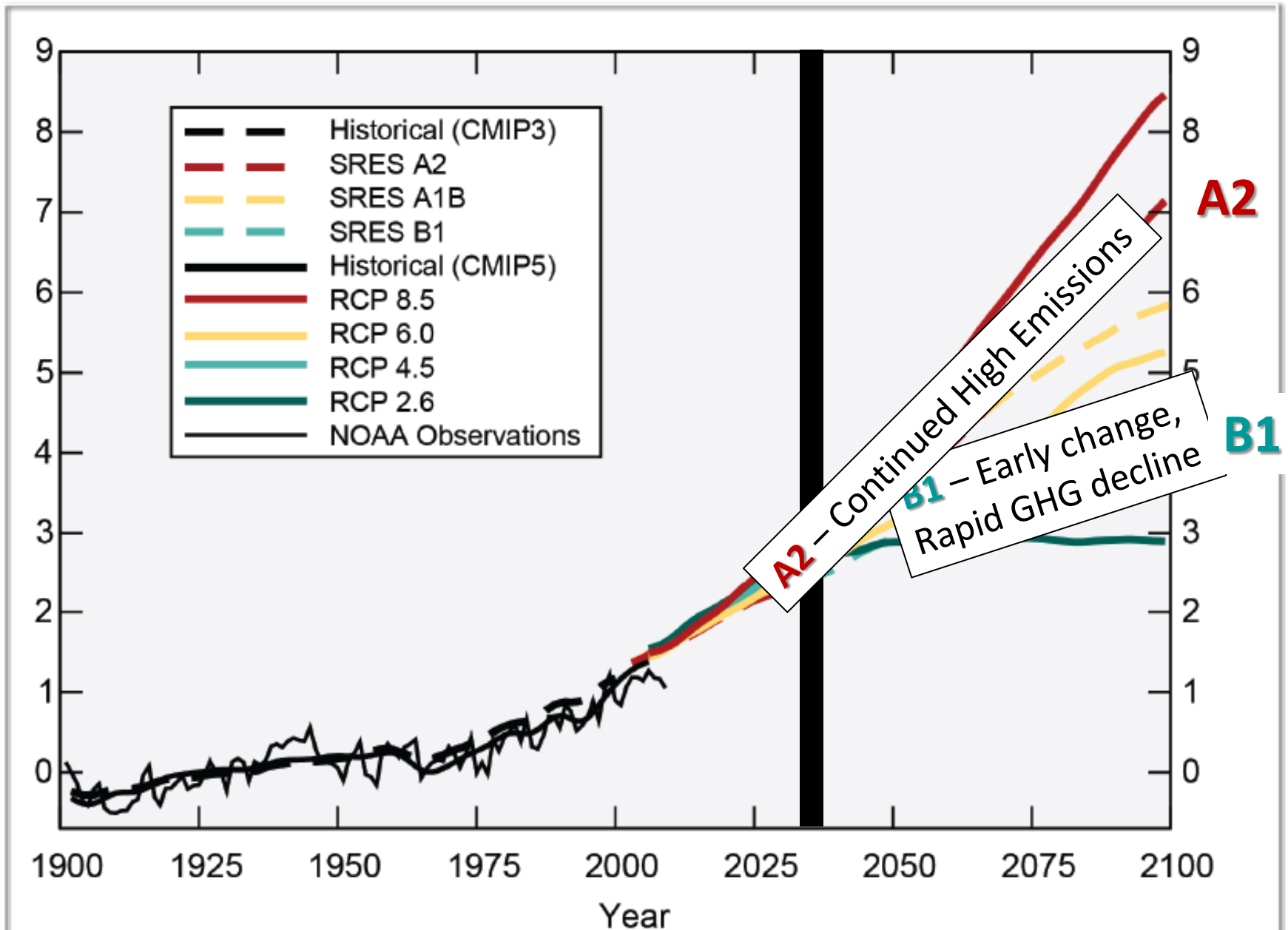
Dry Days



Hot Nights



Average Global Temperature Projections



Adapted from: Draft National Climate Assessment, 2013

Summary Points

Climate Change and the West

Provides one more source of variability. “Old” variability continues.

Local and regional responses do not have to be the same as global scale.

Temp – Strongest consensus among the various climate elements

Temp – All show warming, amounts differ modestly among projections.

Precip – Sign, amounts, seasonality, frequency all matter.

Precip – Character of precipitation can be as important as amount.

Precip – More consensus for T than P, but some precip progress

Precipitation change – more winter, less spring, summer, autumn?

Precipitation change – Annual increase north / decrease south

More floods (winter) & droughts (summer) possible

Temperature is a hydrologic element – has significant implications

Temperature change is under way, began without our noticing.

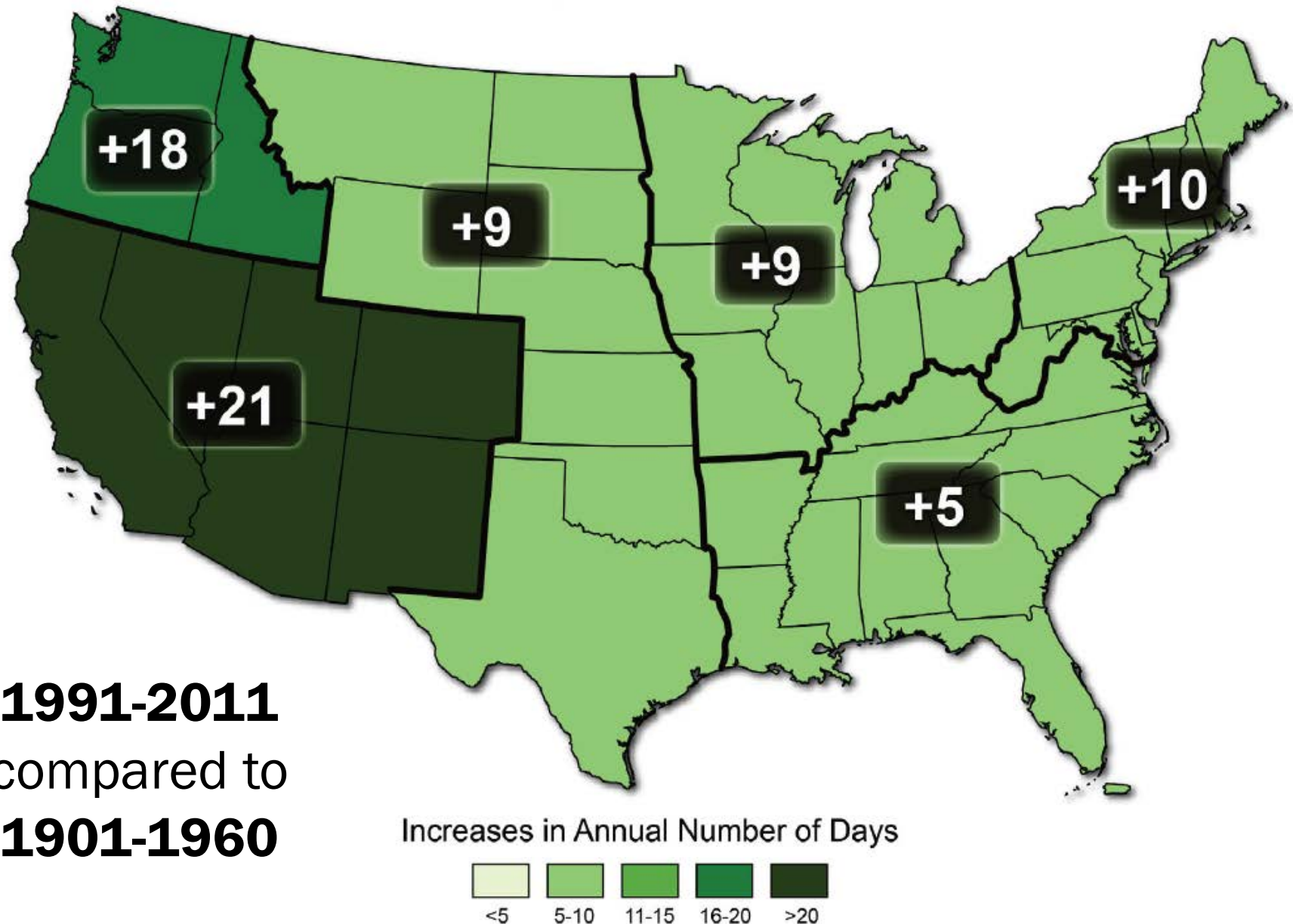
Western Mountains seem particularly vulnerable to climate change

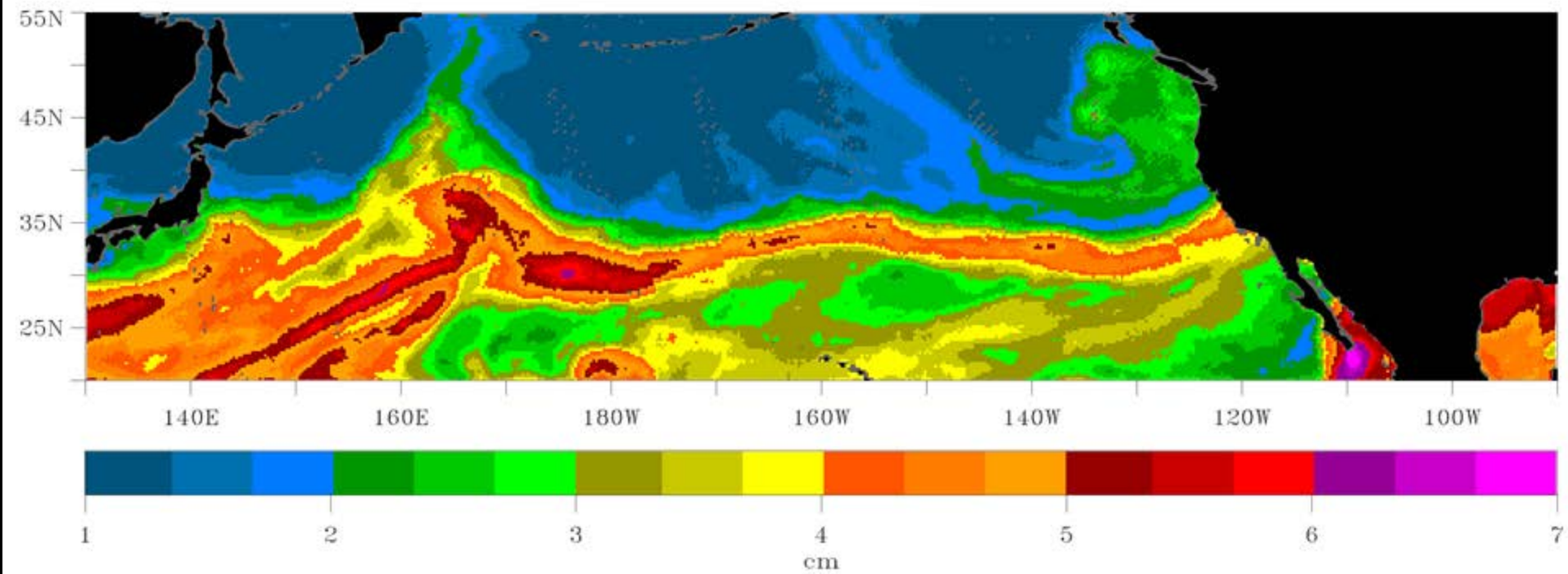
System still has “unrealized warming;” earth radiation not in balance

Choice: Adaptation versus mitigation

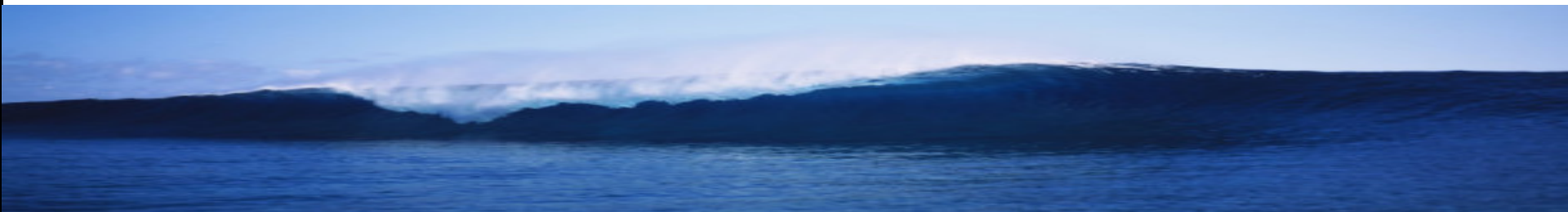
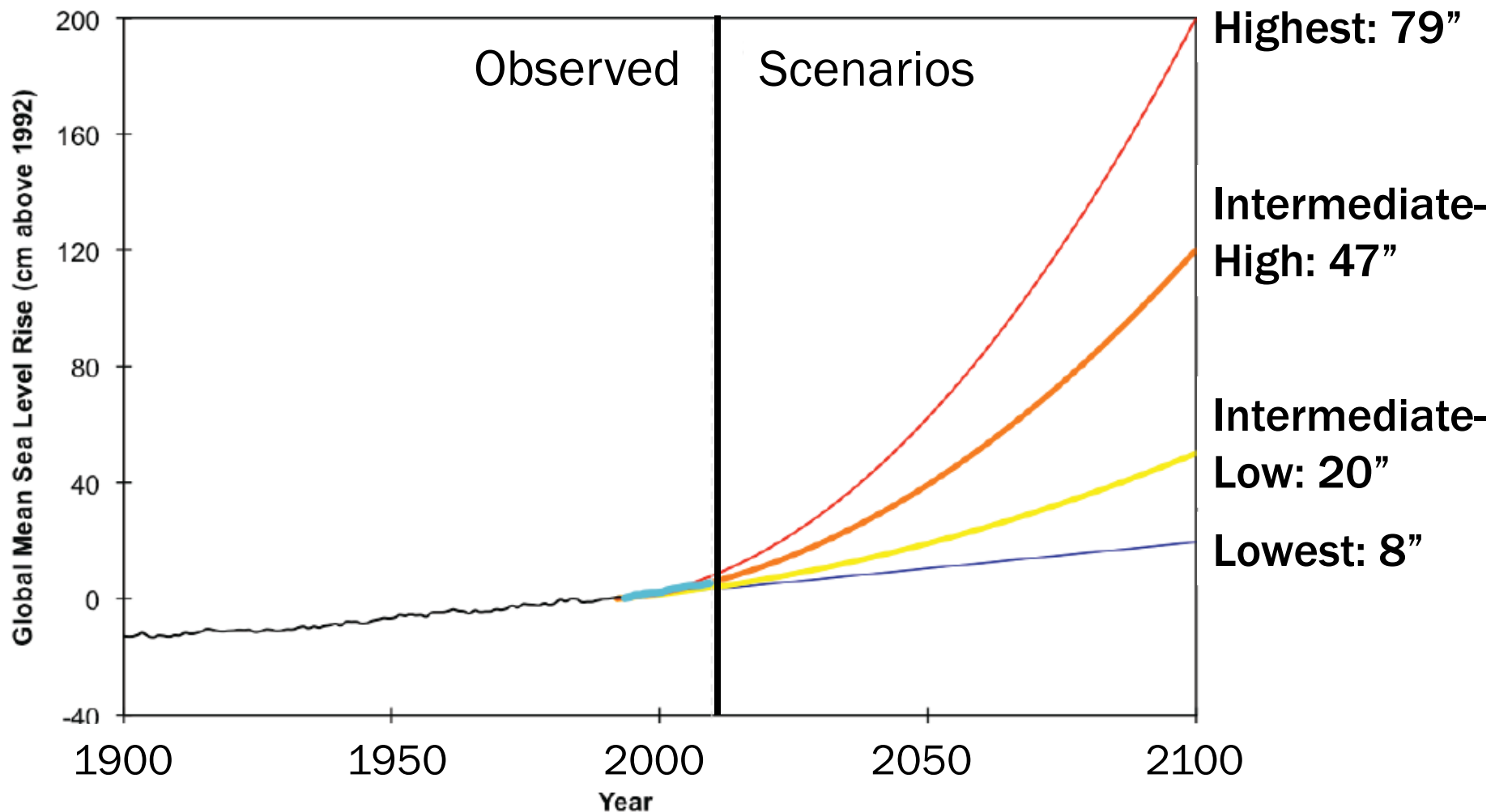
“Managing the unavoidable and avoiding the unmanageable”

Observed Changes in Frost-Free Season





Atmospheric Rivers



Parris et al., 2012 Global Sea Level Rise Scenarios for the United States National Climate Assessment

Adaptation

Supports

Undermines

Mitigation

Supports

- **Forest fuel management**
 - reduces fire risk
 - maintains watershed health
 - decreases **C** releases

- **Compact *coastal* urban design**
 - reduces transportation emissions
 - greater UHI effect
 - floodplain development

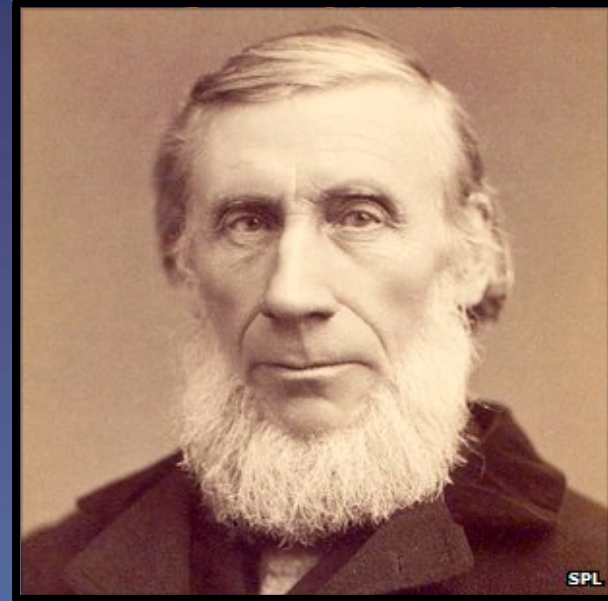
Undermines

- **Seawater desalinization**
 - increases water security
 - very energy-intensive

Business as usual...

The Science of Climate Change

The Greenhouse Effect

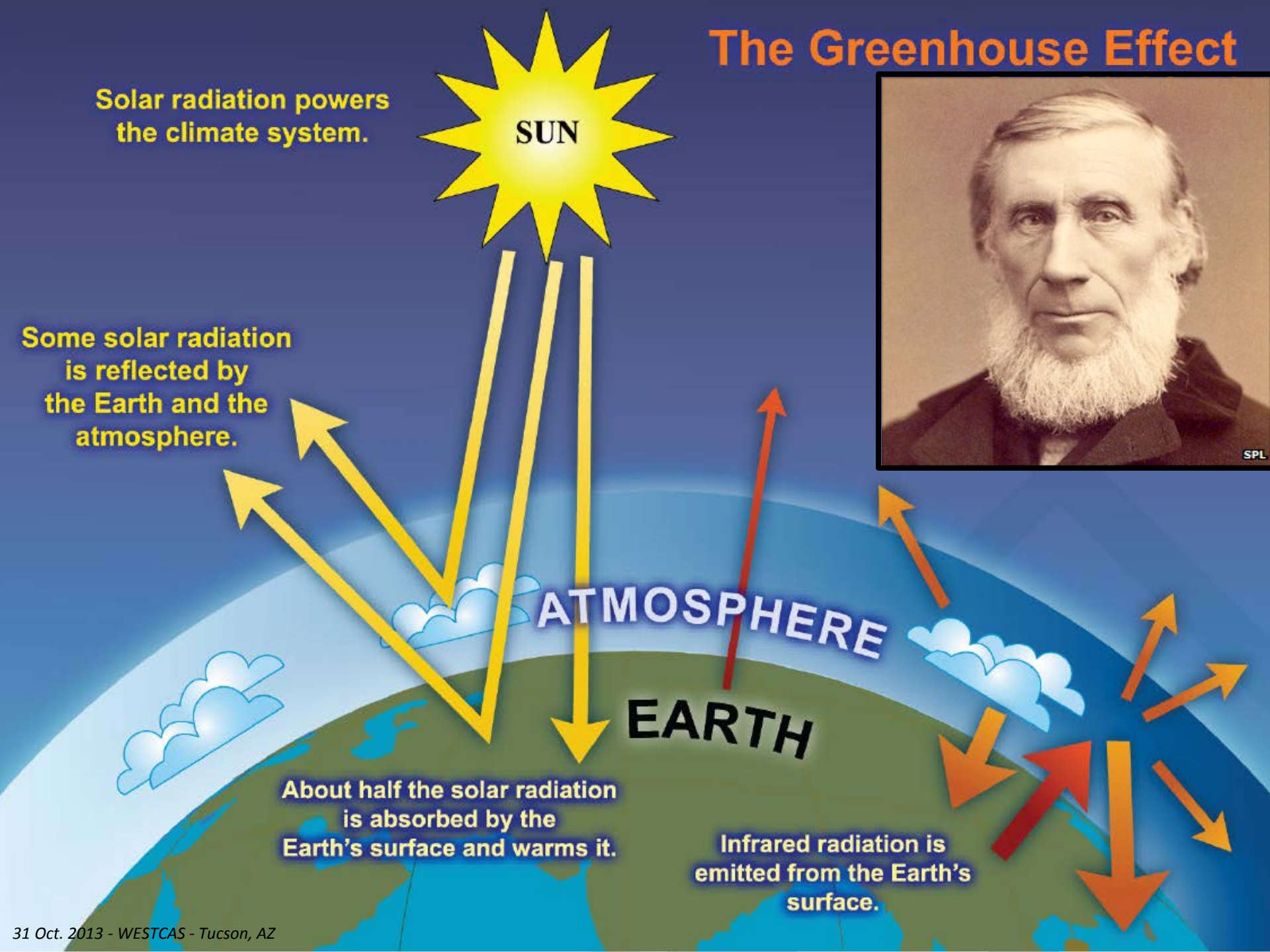


Solar radiation powers the climate system.

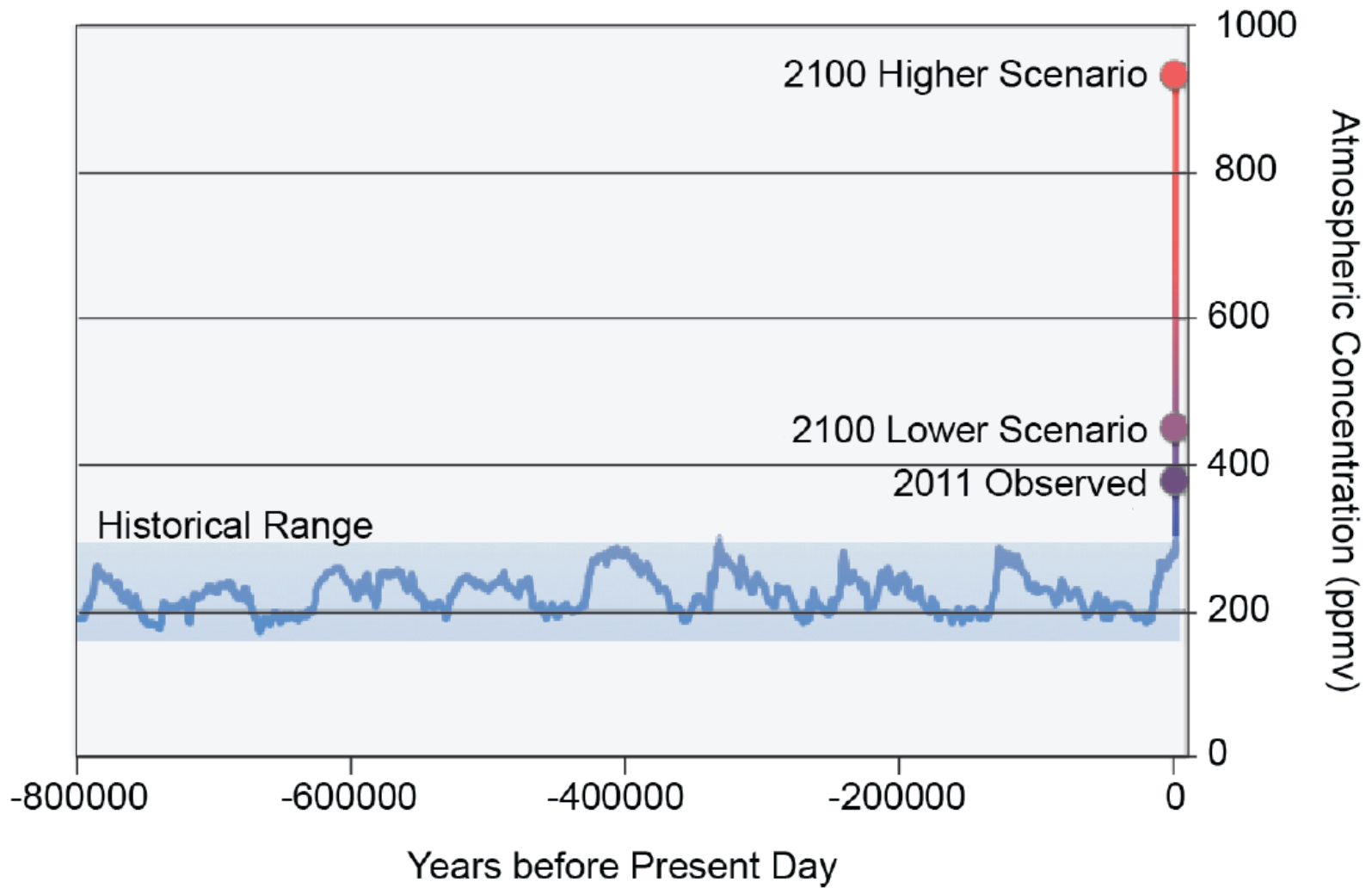
Some solar radiation is reflected by the Earth and the atmosphere.

About half the solar radiation is absorbed by the Earth's surface and warms it.

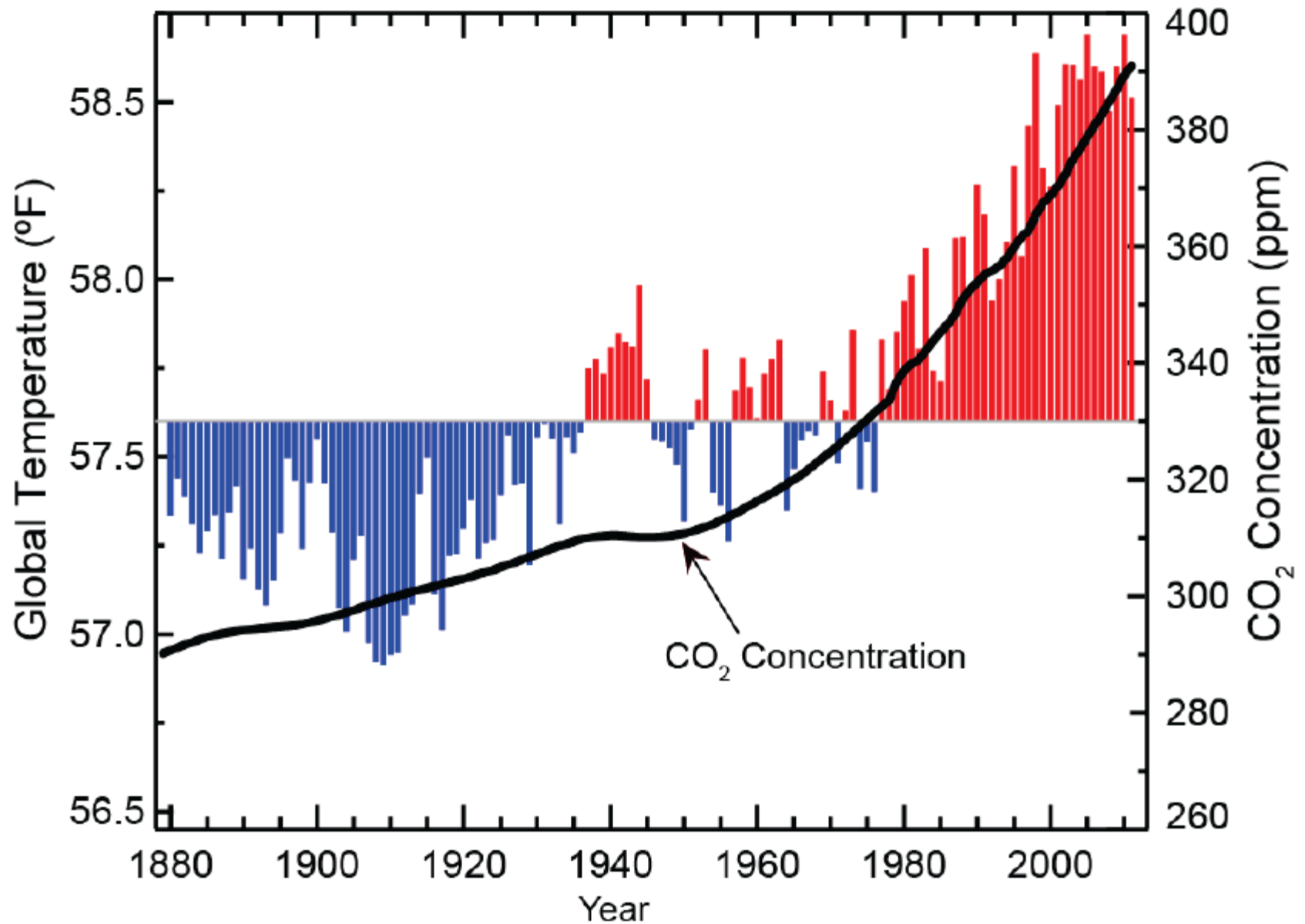
Infrared radiation is emitted from the Earth's surface.

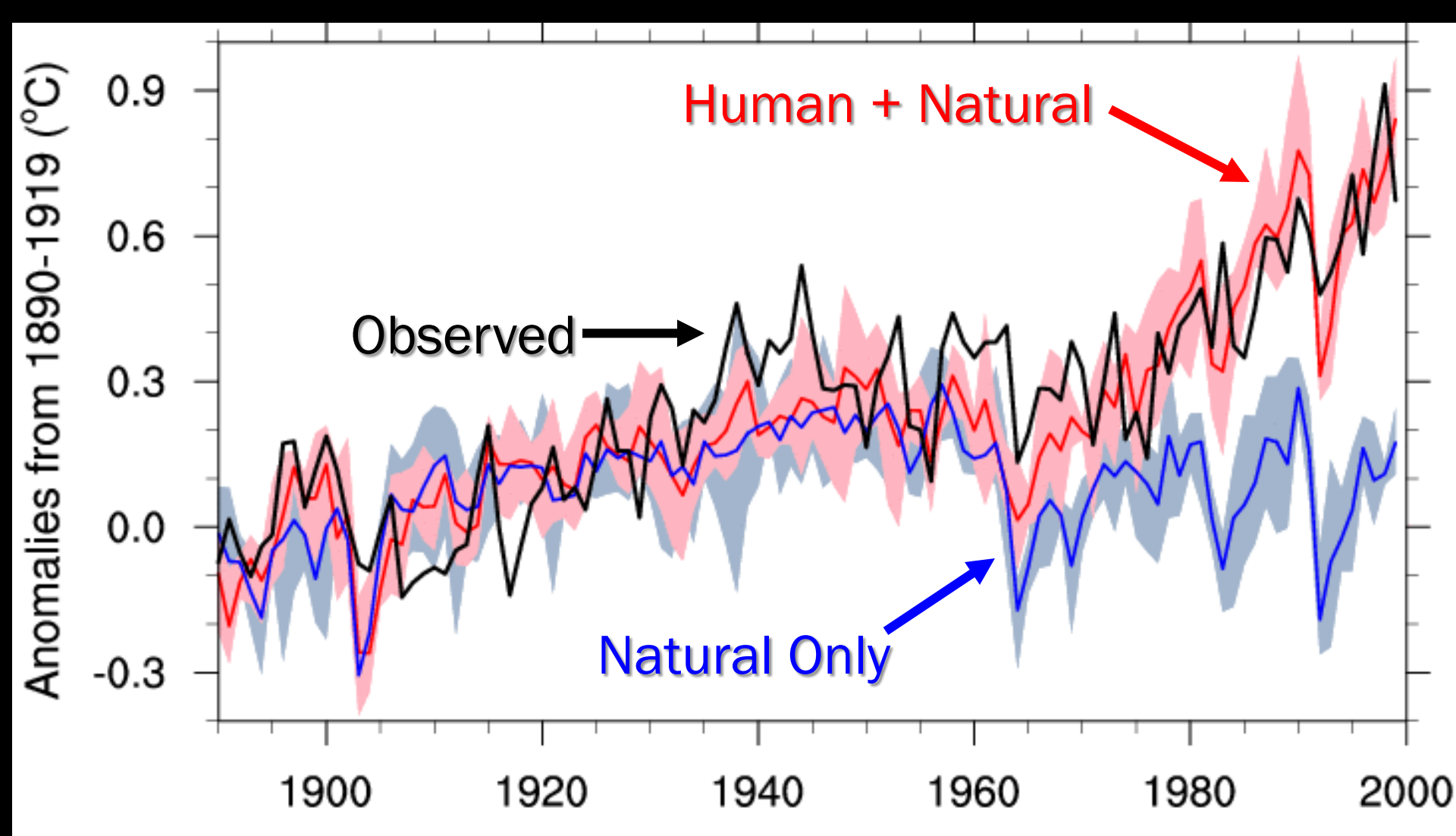


Atmospheric CO₂ Levels



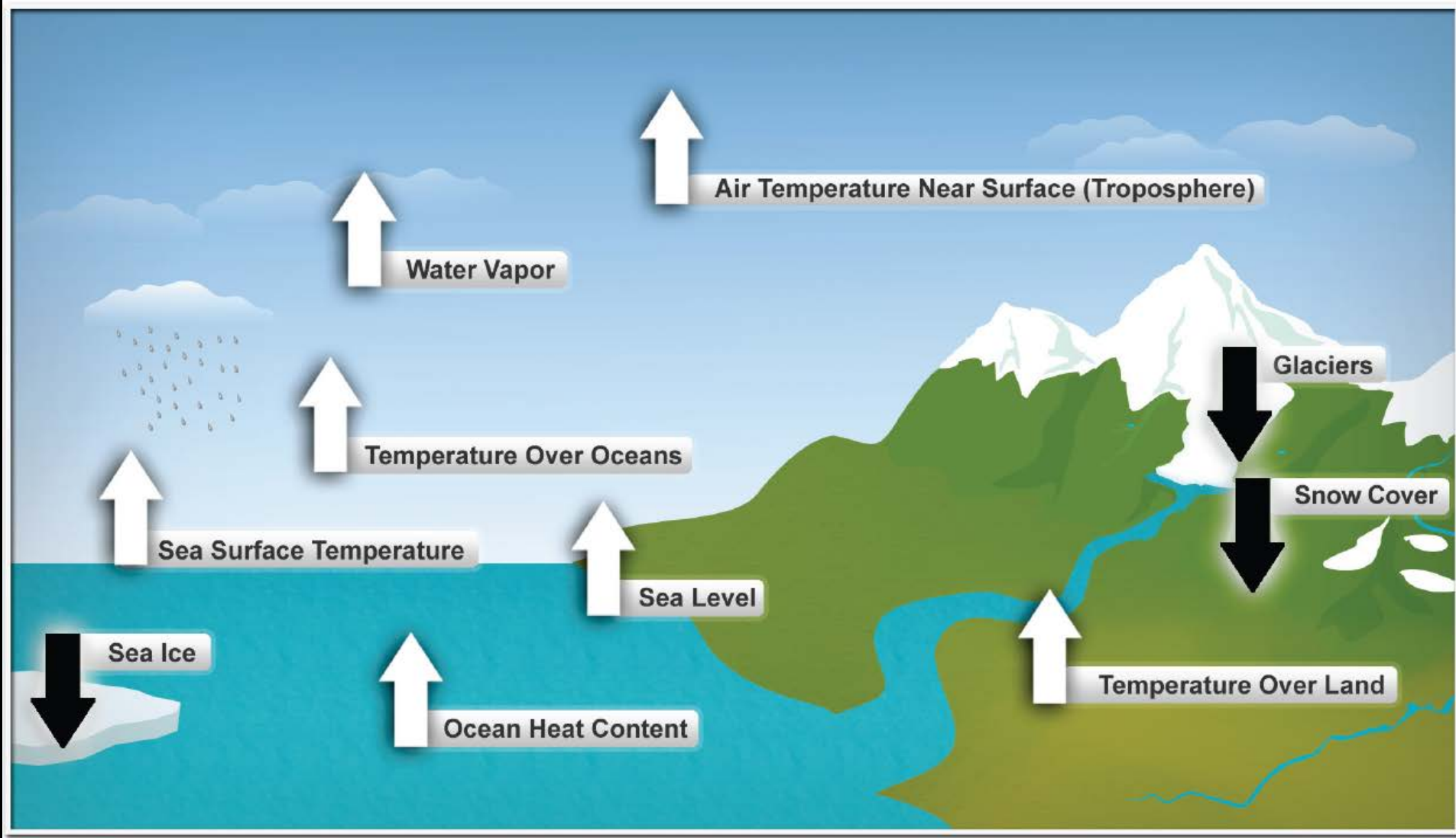
Global Temperature and Carbon Dioxide





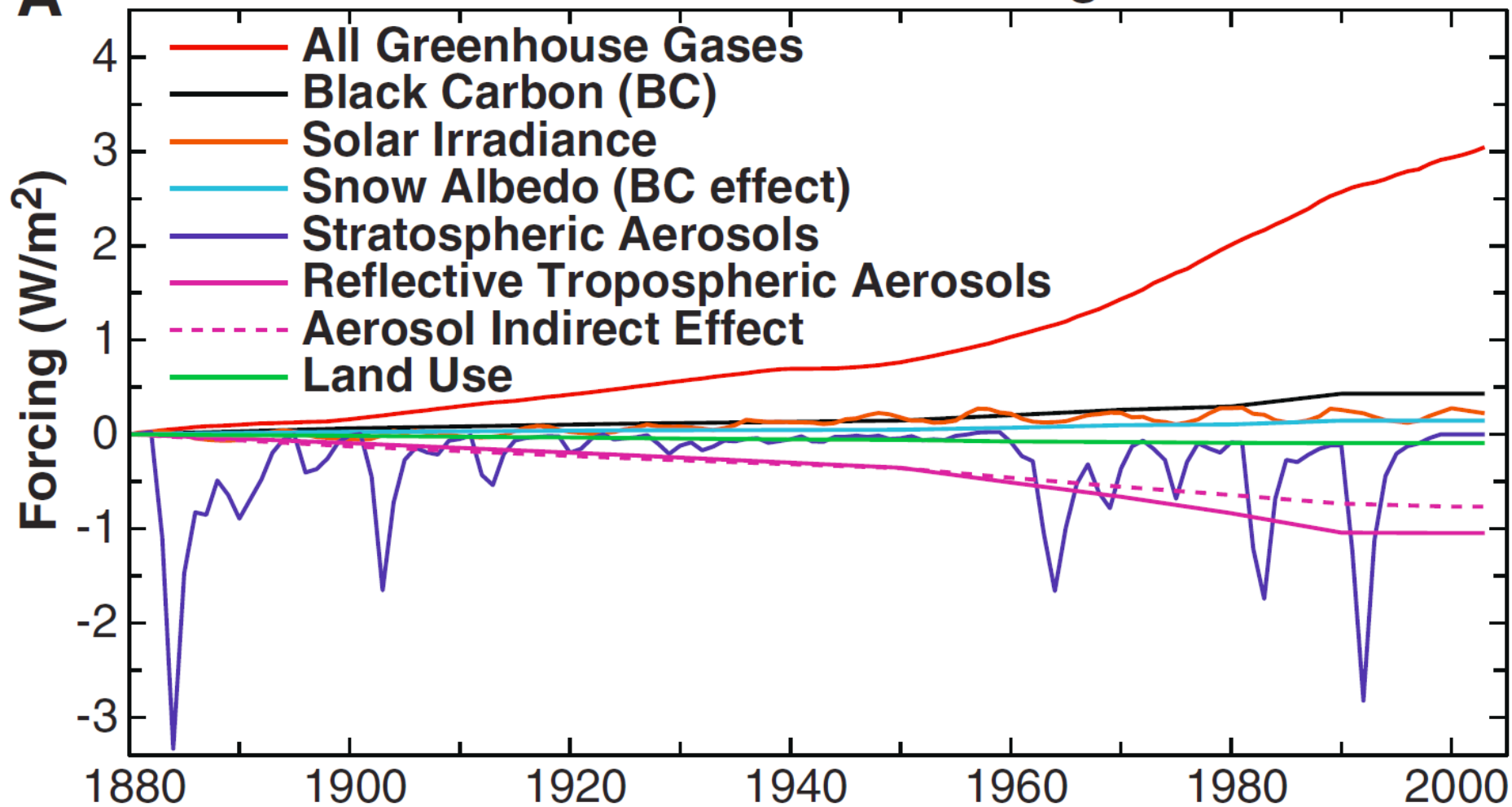
Meehl et al. (2000)

Ten Indicators of a Warming World



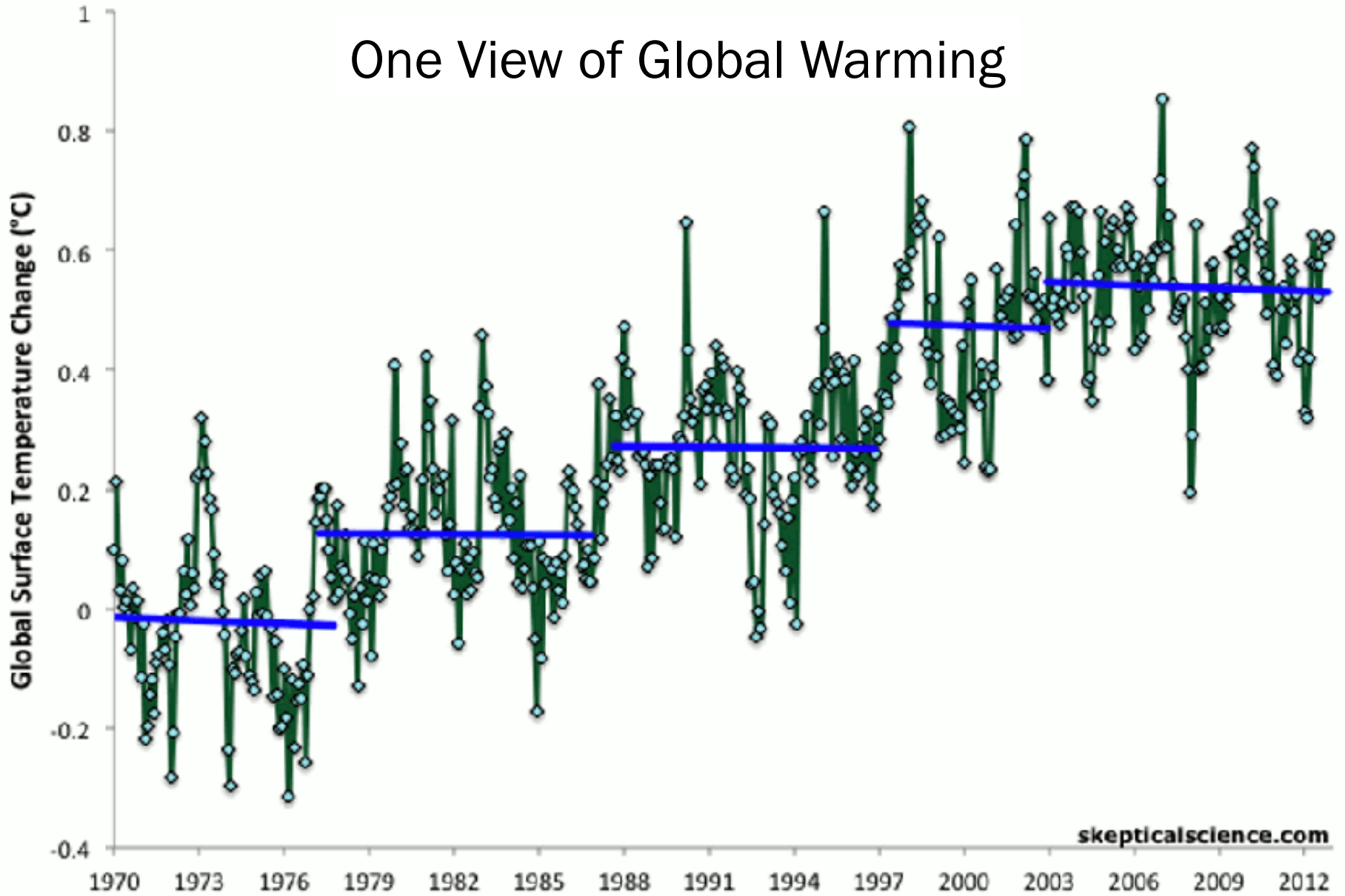
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Global Climate Forcings



Hansen et al., 2005 – Earth's Energy Imbalance

One View of Global Warming



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Another View of Global Warming

