The Future of the West: Adapting to a Warmer World

The Climate and Deserts Workshop

Aquarius Casino Resort, Laughlin, NV, April 9, 2008

Gregg Garfin

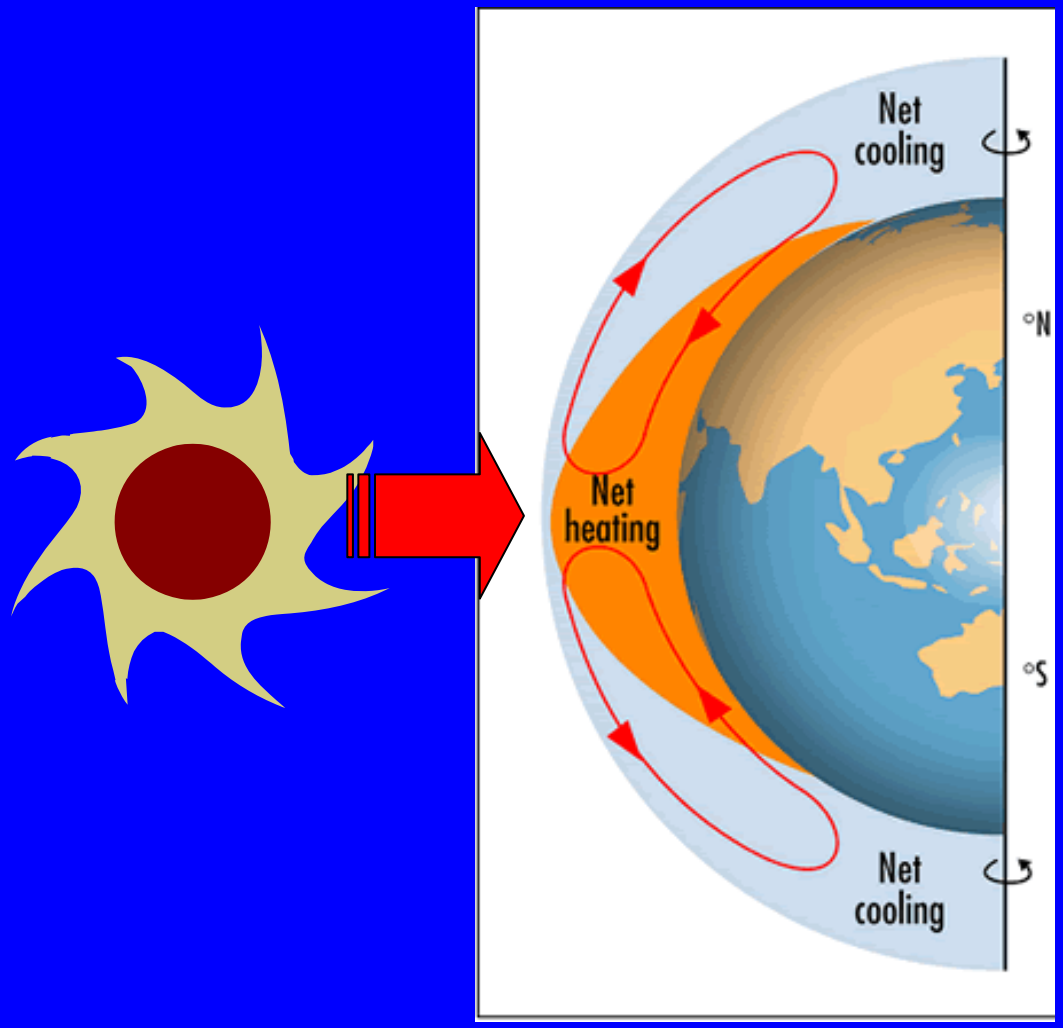
INSTITUTE FOR THE STUDY OF PLANET EARTH

CLIMAS
Climate Assessment Project for the Southwest

RISA
Regional Integrated Sciences and Assessments
Building Bridges Between Climate Sciences and Society

Lisa J. Graumlich,
Professor and Director
School of Natural Resources

Global Energy Balance



From http://www.bom.gov.au

Roadmap

- What is the scientific consensus?
- What is the evidence for impacts now?
- Is the Southwest vulnerable?
- Some thoughts on adaptation

Intergovernmental Panel on Climate Change (IPCC)

- Established by WMO and UNEP in 1988 to advise governments on climate change
- 4th in a series of assessments by 1000 scientists from 74 countries
- Scenarios of future emissions drive forecasts
- Error estimates, likelihood and confidence are of great concern

Likelihood, Confidence

Specific outcomes, statistical analyses

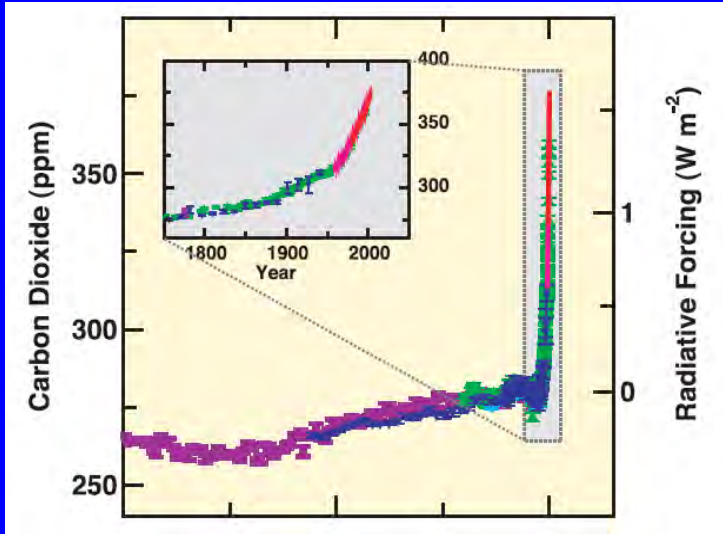
- Virtually certain > 99% probability of occurrence
- Extremely likely > 95%
- Very likely > 90%
- Likely > 66%
- More likely than not > 50%
- Very unlikely < 10%,
- Extremely unlikely < 5%

Correctness of underlying data, models

- Very high confidence: At least a 9 out of 10 chance of being correct
- High confidence: About an 8 out of 10 chance
- Medium confidence: About a 5 out of 10 chance
- Low confidence: About a 2 out of 10 chance
- Very low confidence: Less than a 1 out of 10 chance

IPCC 4th Assessment Report

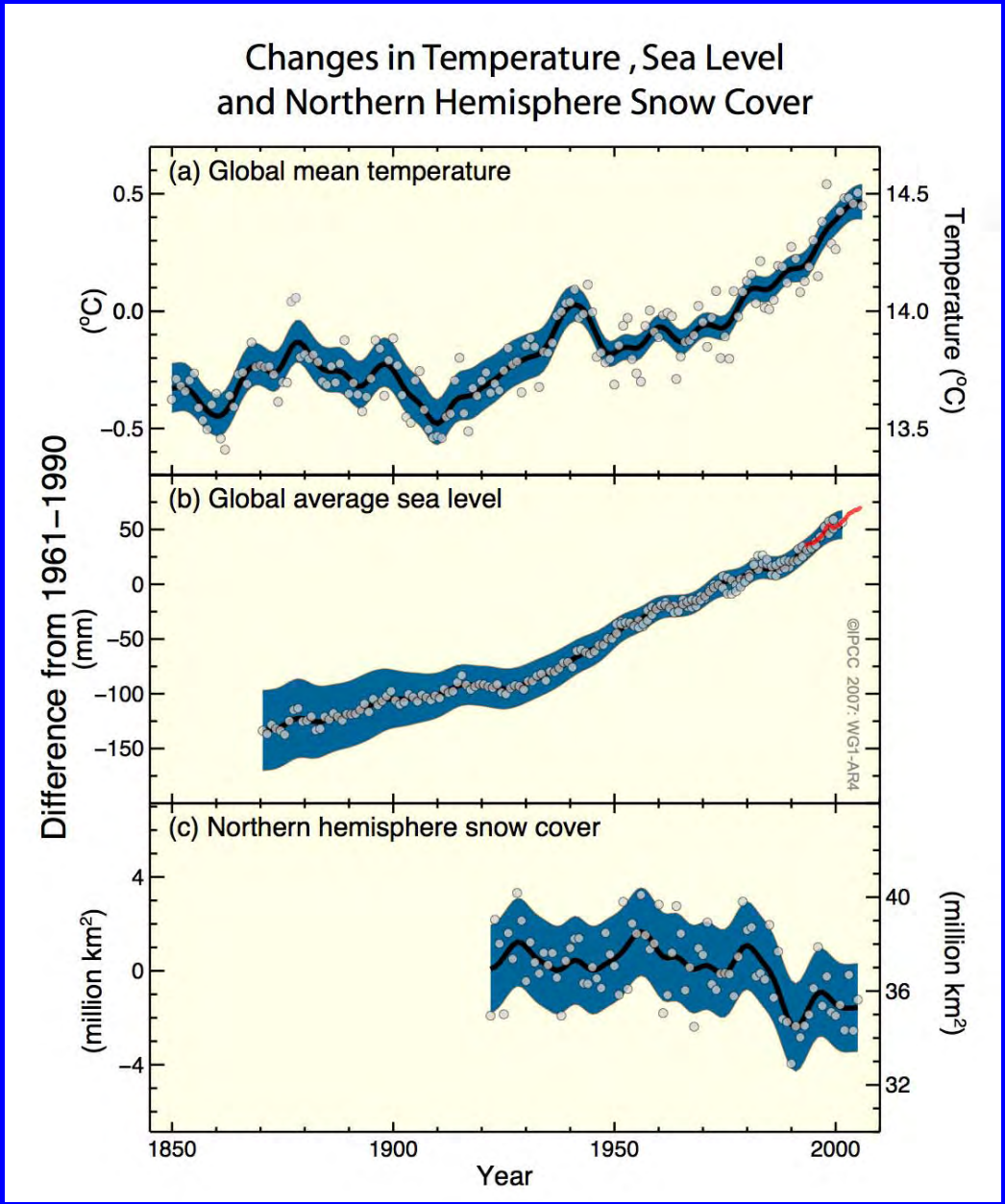
- Global atmospheric concentrations of CO_2, CH_4, and NO_x have increased markedly as a result of human activities since 1750
- They now far exceed pre-industrial values from ice cores spanning many thousands of years
- Primarily due to fossil fuel use, land use change, agriculture



http://www.ipcc.ch

IPCC 4th AR

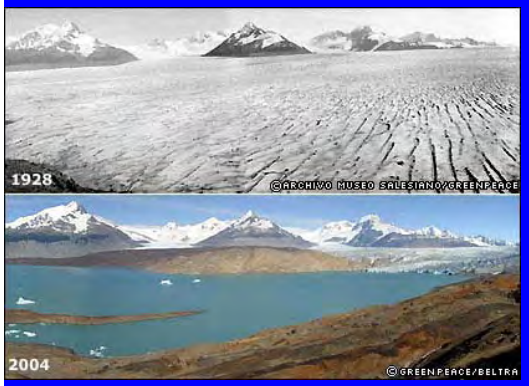
- Warming of the climate system is **unequivocal**
- This warmth is unusual in at least the last 1300 years

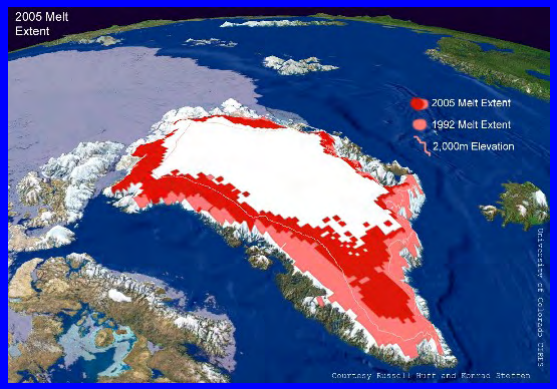


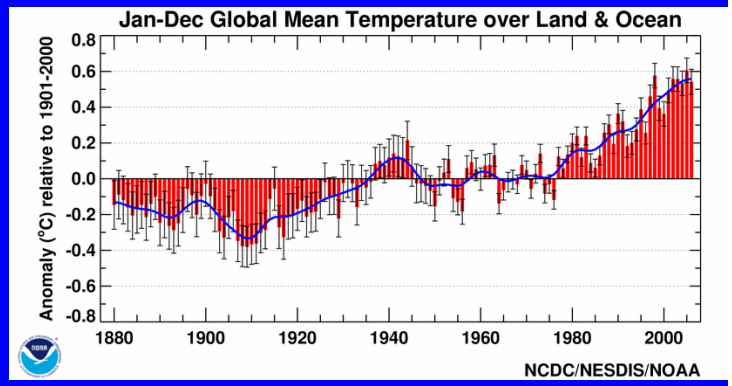
http://www.ipcc.ch

IPCC 4th Assessment Report

- **Warming since the mid-20th century is very likely due to observed increase in GHG concentrations**
- **Forcing from human activity is likely to have contributed to changes in wind patterns**

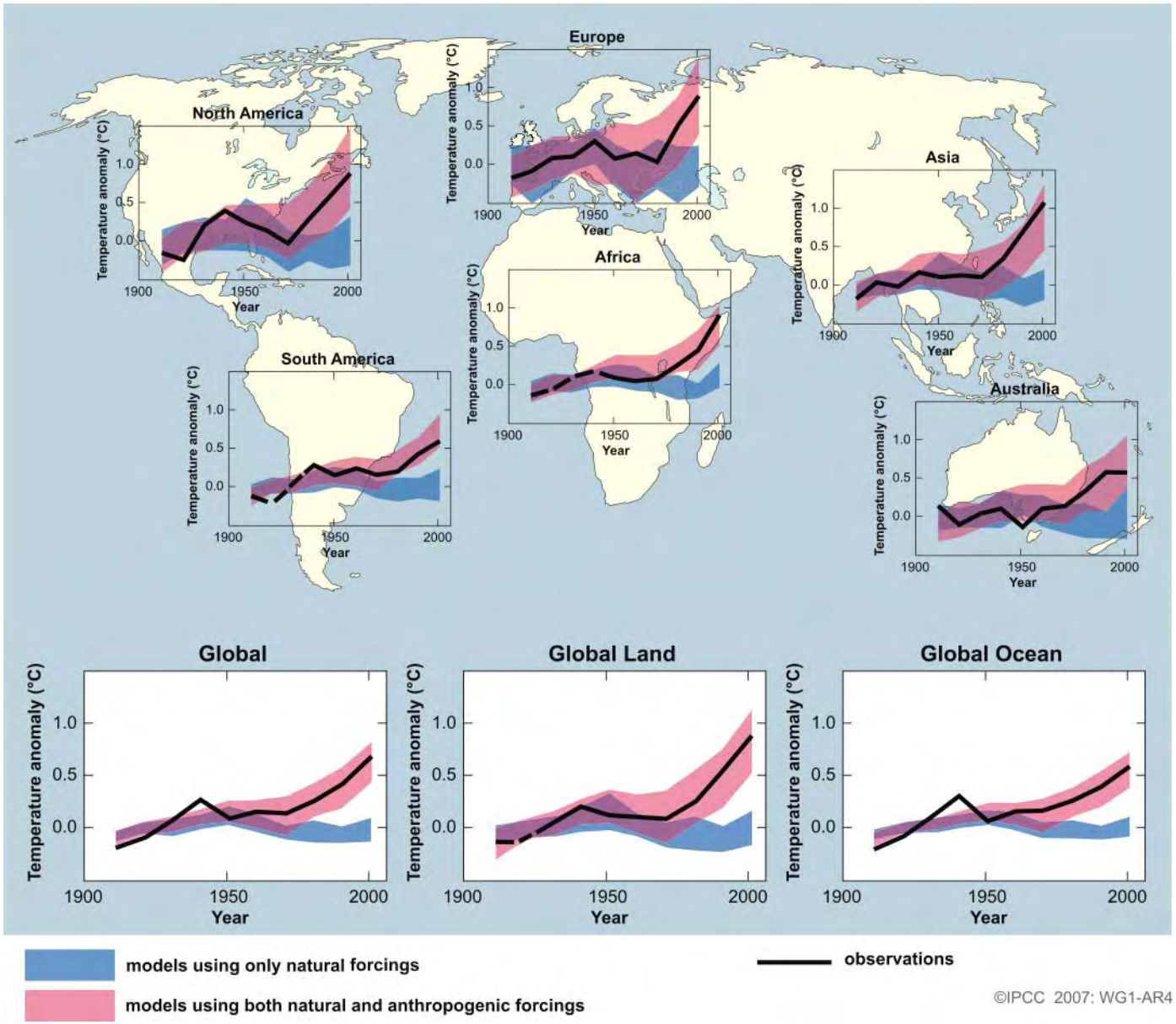






http://www.ipcc.ch

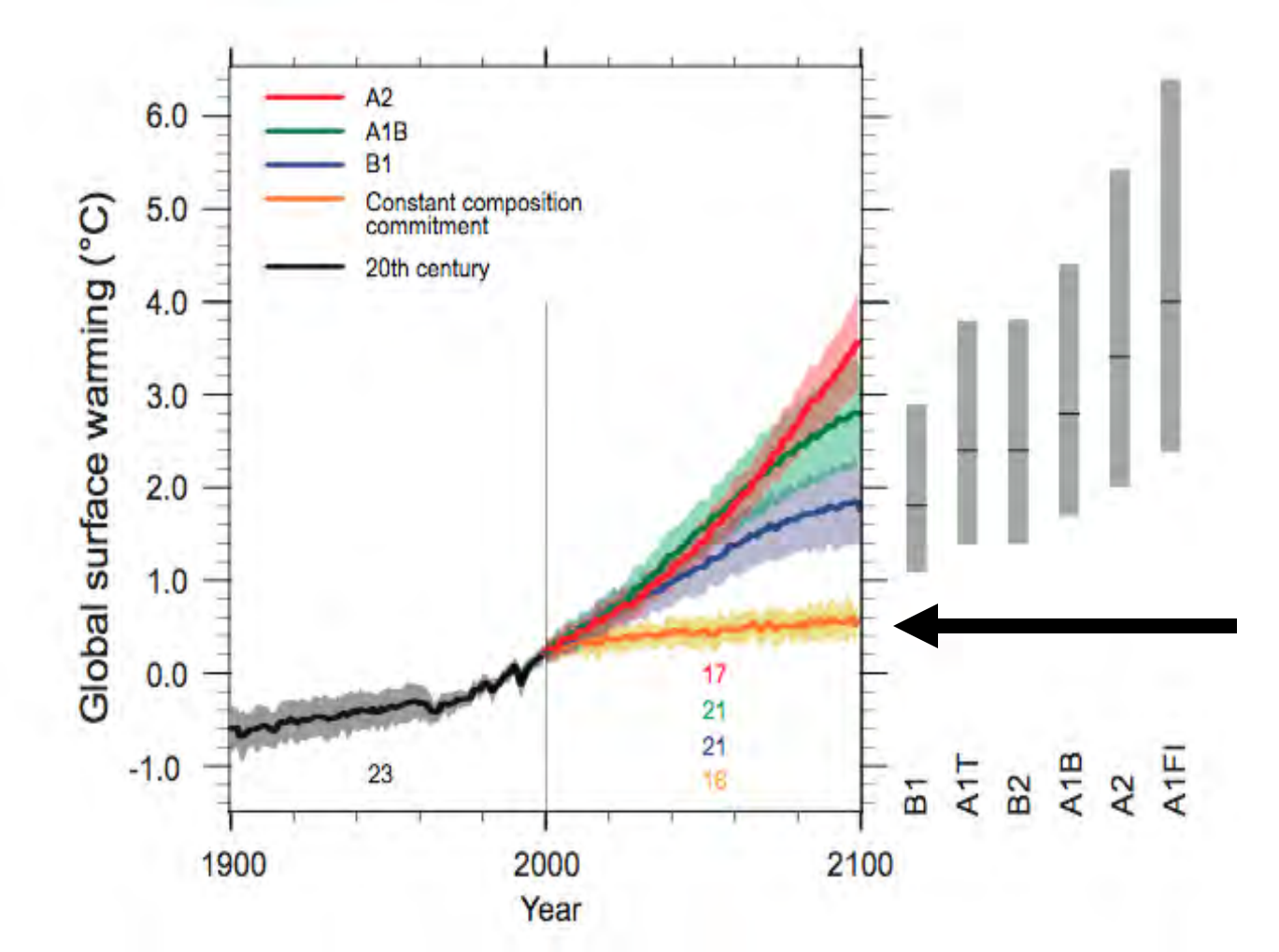
Attribution: *Very Likely* human-caused increase GHG



FAQ 9.2, Figure 1

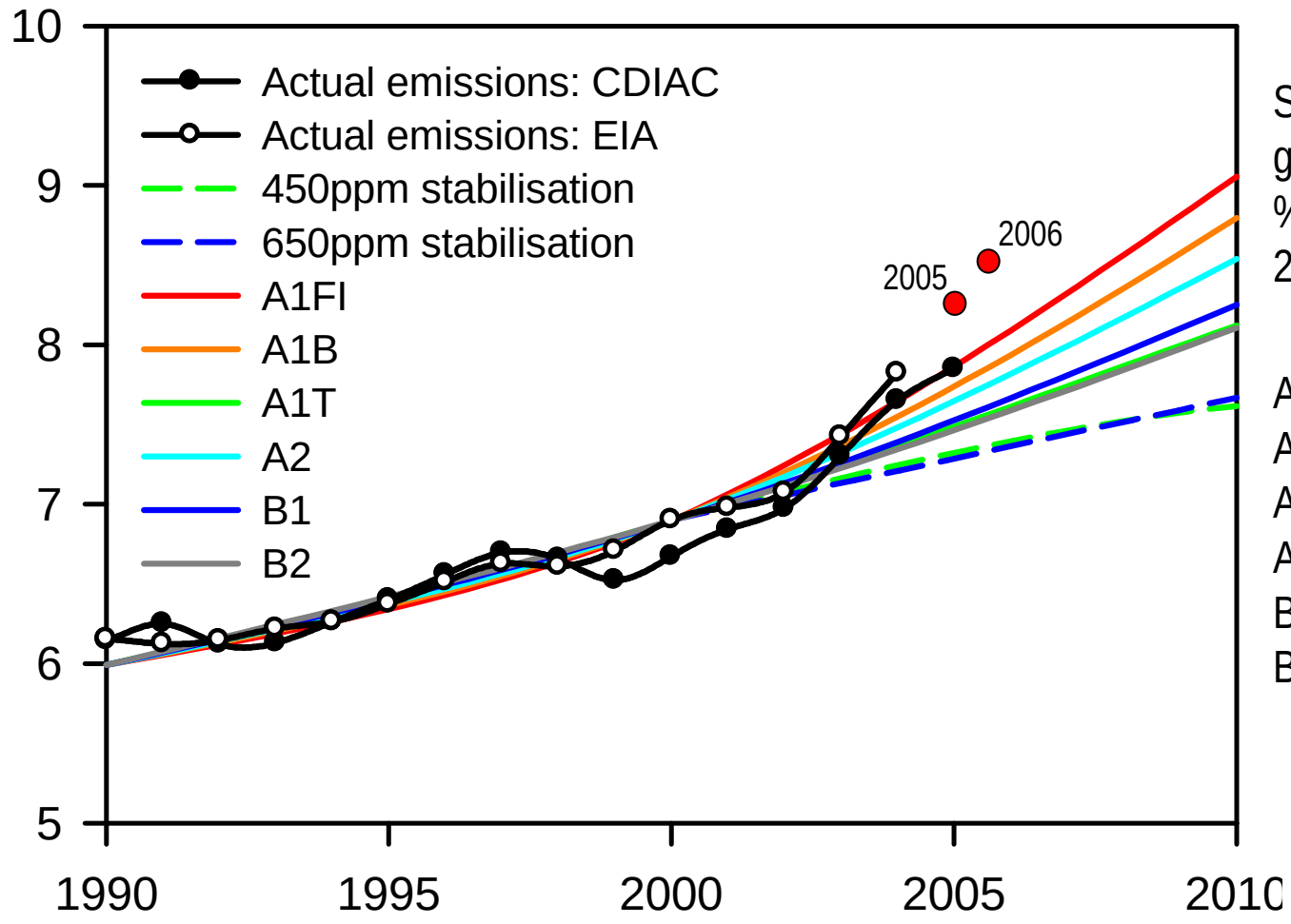
IPCC 4th Assessment Report

Best estimate for low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and for high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C).



http://www.ipcc.ch

Trajectory of Global Fossil Fuel Emissions



SRES (2000) growth rates in % y^{-1} for 2000-2010:

A1B: 2.42
A1FI: 2.71
A1T: 1.63
A2: 2.13
B1: 1.79
B2: 1.61

Raupach et al. 2007, PNAS

Joellen Russell, UA Geosciences

IPCC 4th Assessment Report

- Warming is expected to be greatest over land and at most high latitudes
- Sea ice and snow cover are projected to decrease
- It is very likely that hot extremes, heat waves, and heavy precipitation events will become more frequent

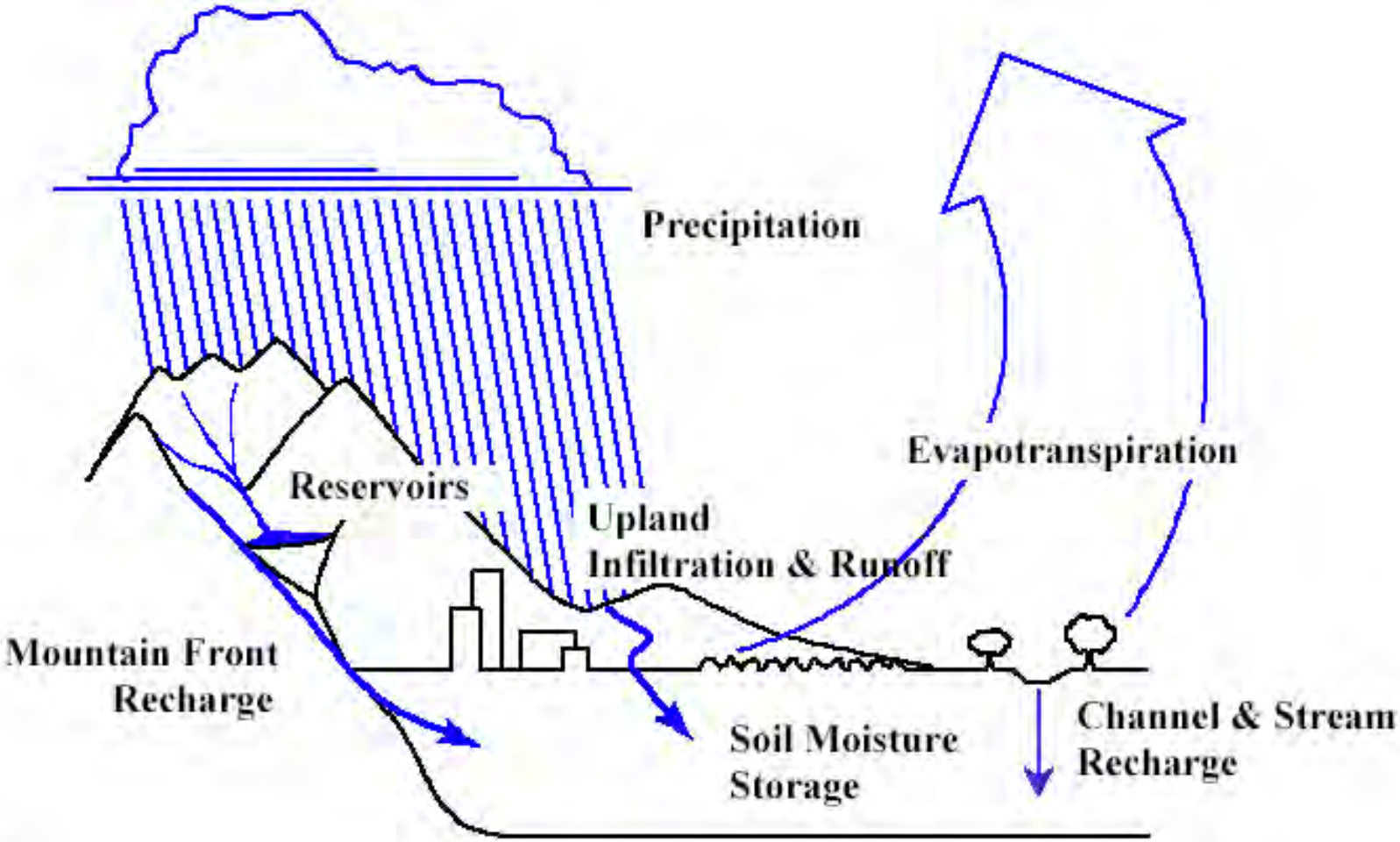
http://www.ipcc.ch

IPCC 4th Assessment Report

- Storm tracks are projected to move poleward
- Warming and sea level rise would continue for centuries due to the timescales associated with climate processes
  - Even if GHG concentrations were to be stabilized

http://www.ipcc.ch

Changes in the Drivers



Recharge = Precipitation – Evapotranspiration – Runoff – ΔSoil Moisture

Roadmap

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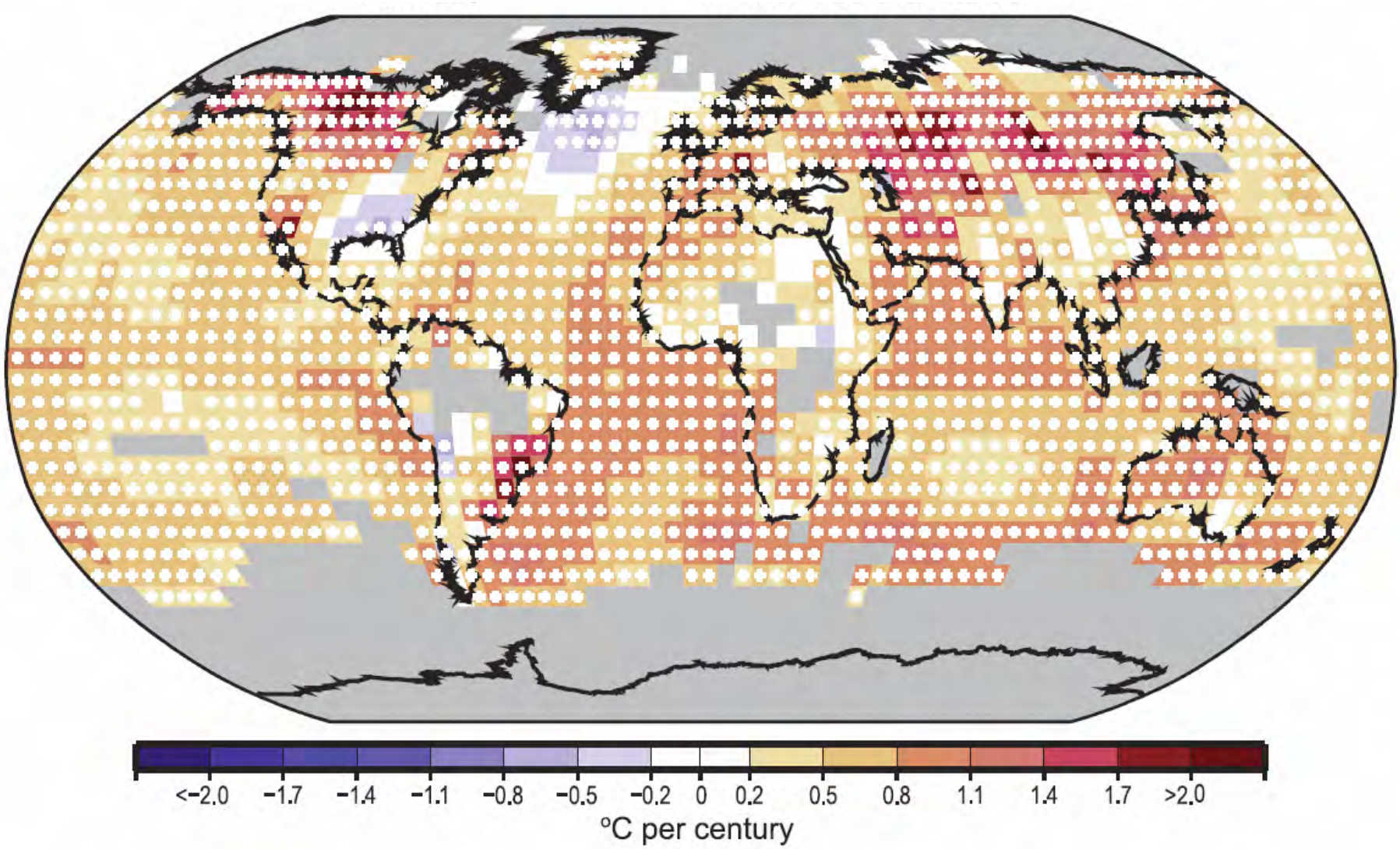
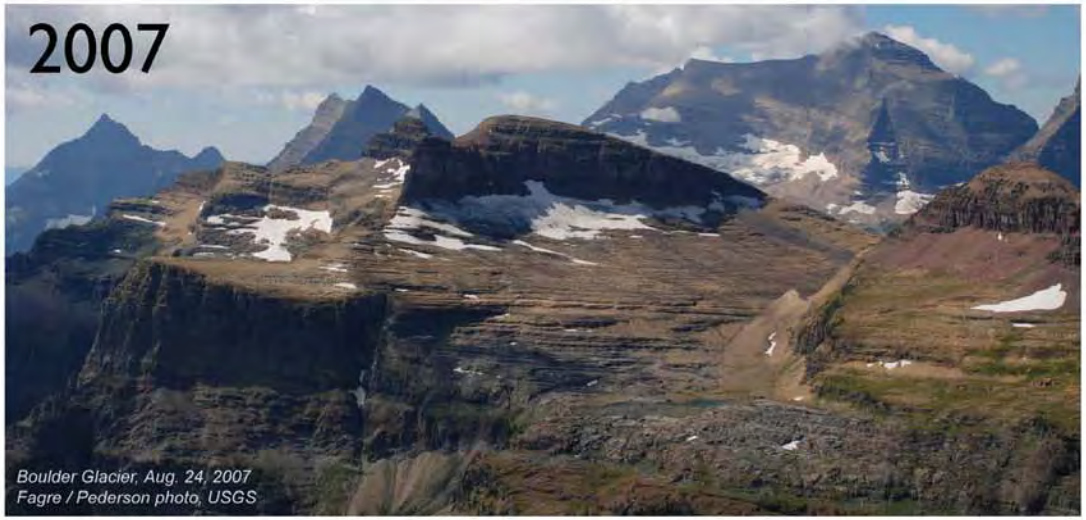
- What is the evidence for impacts now?
- Is the Southwest vulnerable?
- Some thoughts on adaptation?

Annual Temperature Trends 1901-2005



http://www.ipcc.ch

Alpine glacier retreat, Glacier NP



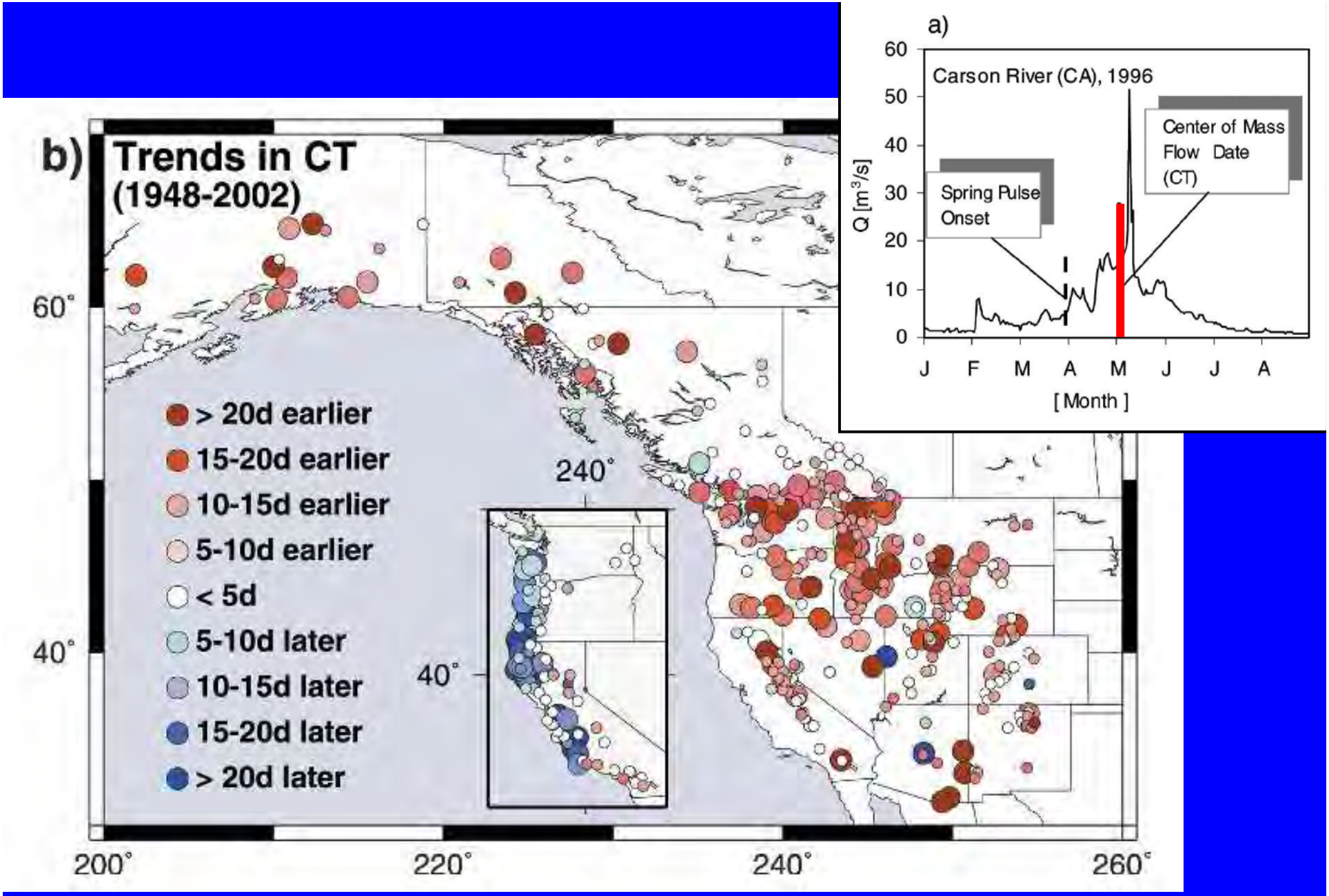
Lisa Graumlich, UA
School of
Natural Resources

Warming in the Western US

Abrupt or rapid ecosystem changes, attributable to temperature change, are occurring now:

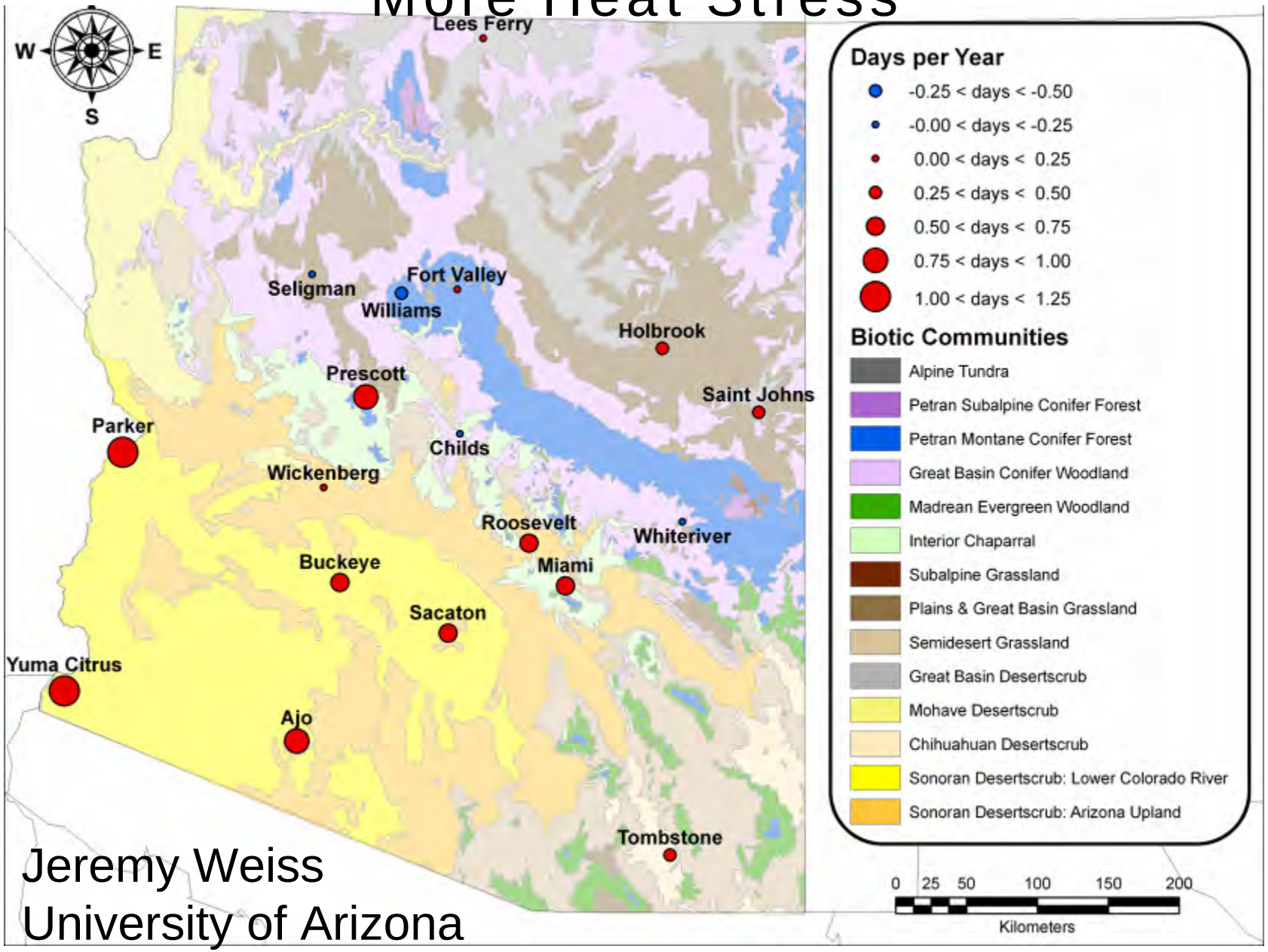
- snowpack decline
- increased wildfire
- ecological impacts

Lisa Graumlich, UA School of Natural Resources



Stewart et al. 2005 Journal of Climate

Longer Frost-Free Season = More Heat Stress



Jeremy Weiss
University of Arizona

Conventional wisdom: Drought = wildfire

1988: 1.4M acres in Yellowstone

2000: 1.1M acres in Montana

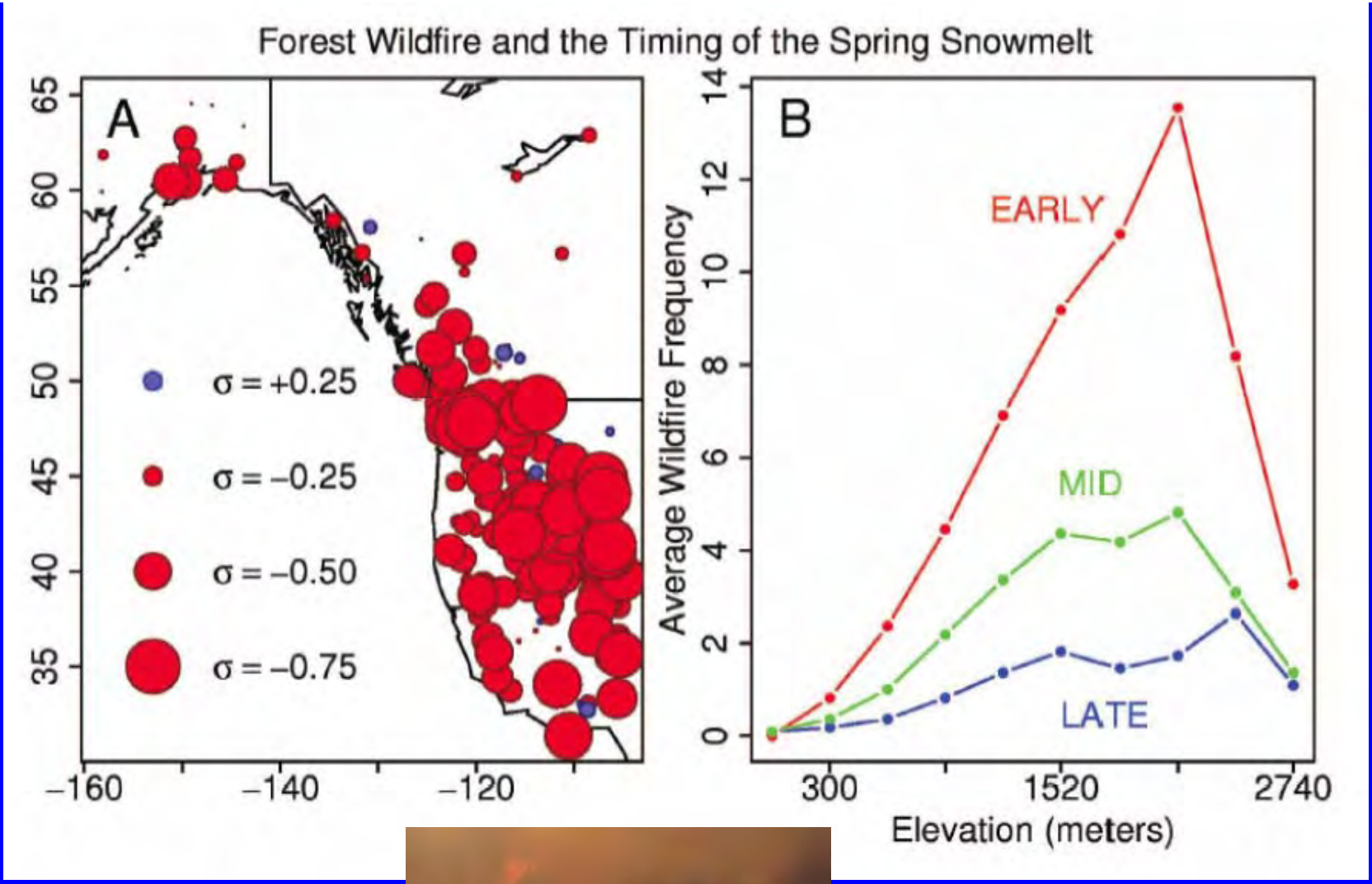
Lisa Graumlich, UA School of Natural Resources

Warmer temperatures also increase wildfire

- 1116 records of fire in Western US
- 6x increase in area burned since 1986
- Higher spring and summer temperatures plus earlier snow melt

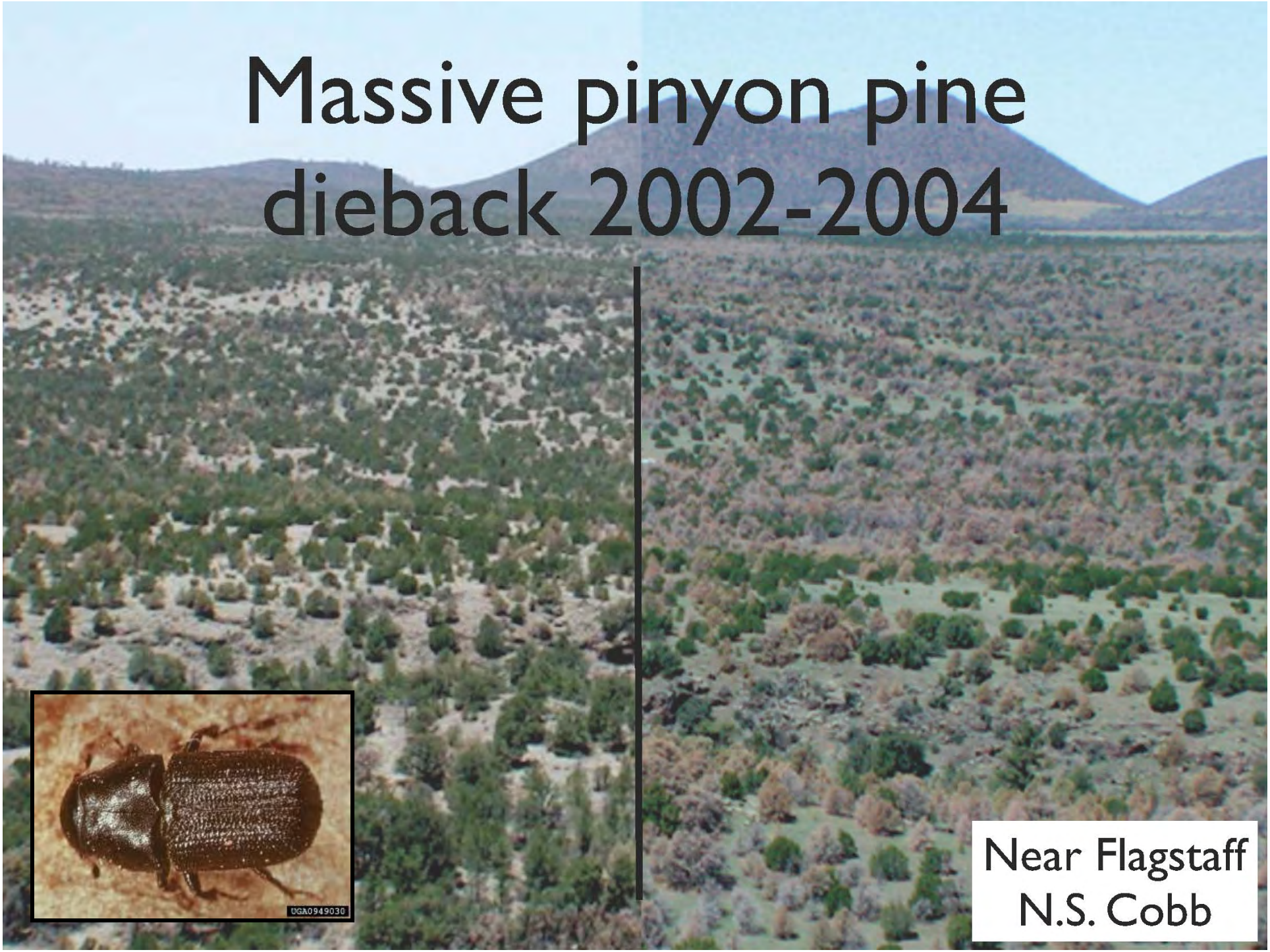
--Westerling, Swetnam et al. 2006; see also McKenzie et al. 2004

Lisa Graumlich, UA School of Natural Resources



Courtesy of Tom Swetnam, UA LTRR

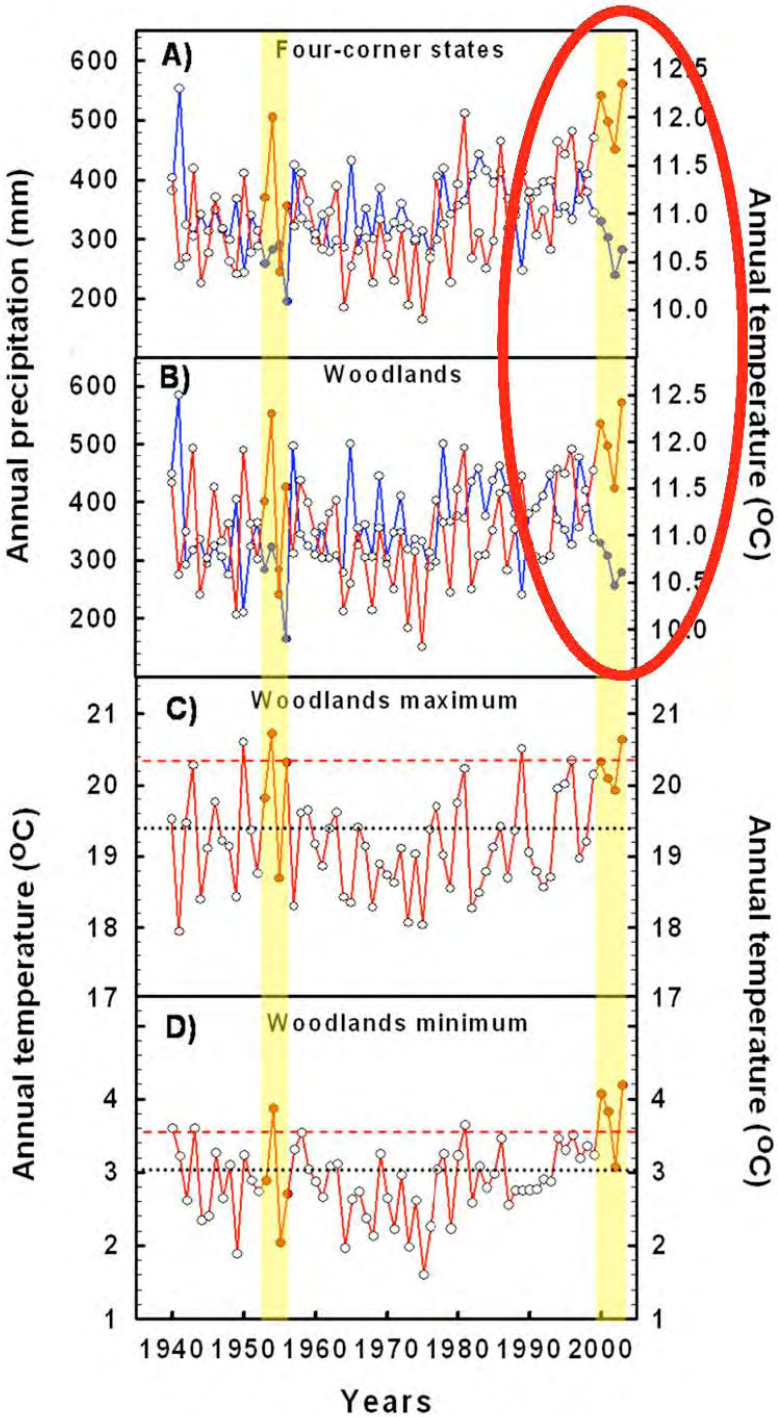
Massive pinyon pine dieback 2002-2004



Pinyon-Juniper die back

Photo: Craig Allen, USGS

Breshears et al. PNAS 2005

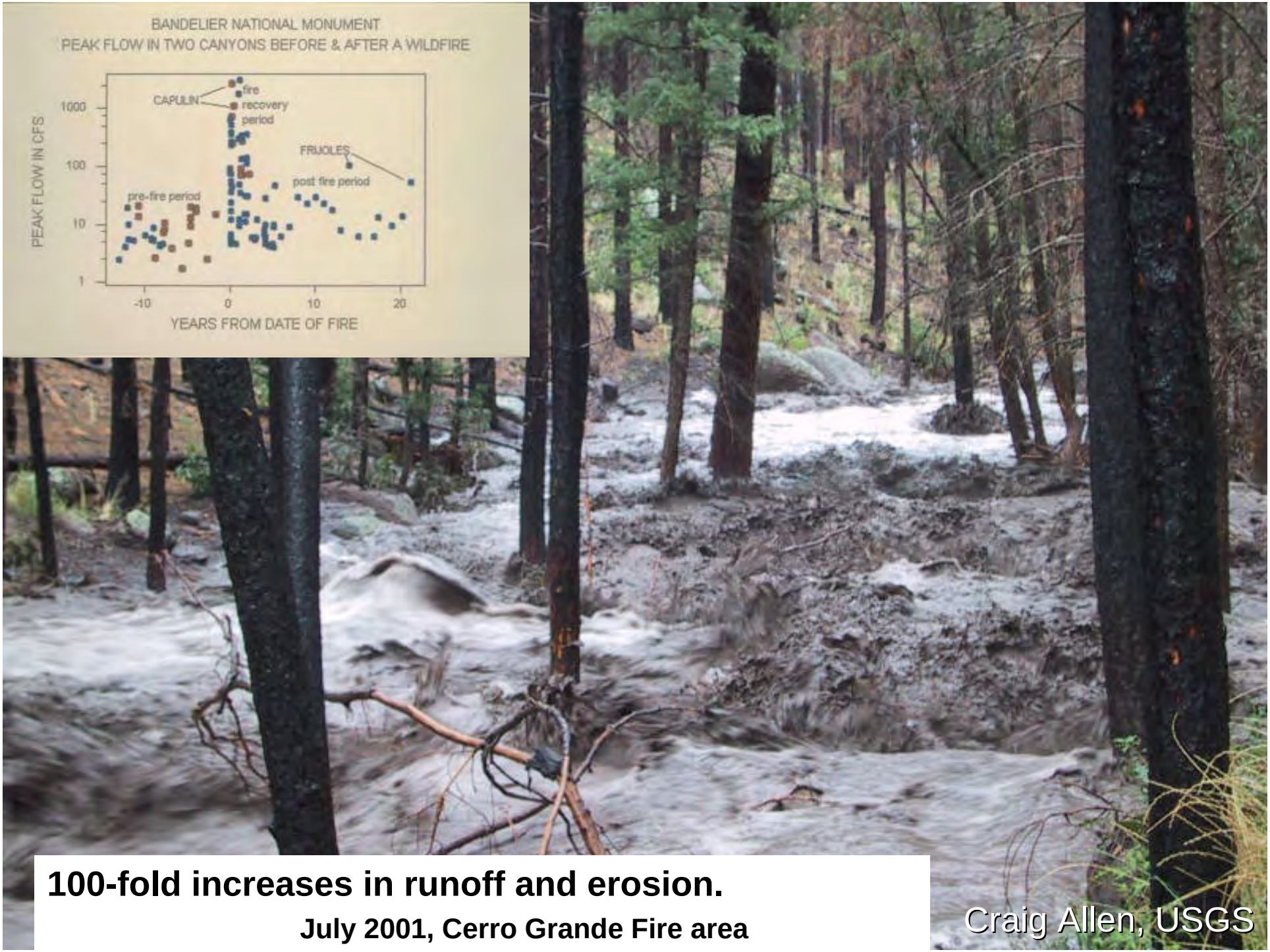


Global change-type drought ?

- 40-80% pinyon pine mortality over 2.5M acres
- prolonged high temperature increased vulnerability to bark beetle

--Breshears et al. 2005

Lisa Graumlich, UA School of Natural Resources



100-fold increases in runoff and erosion.

July 2001, Cerro Grande Fire area

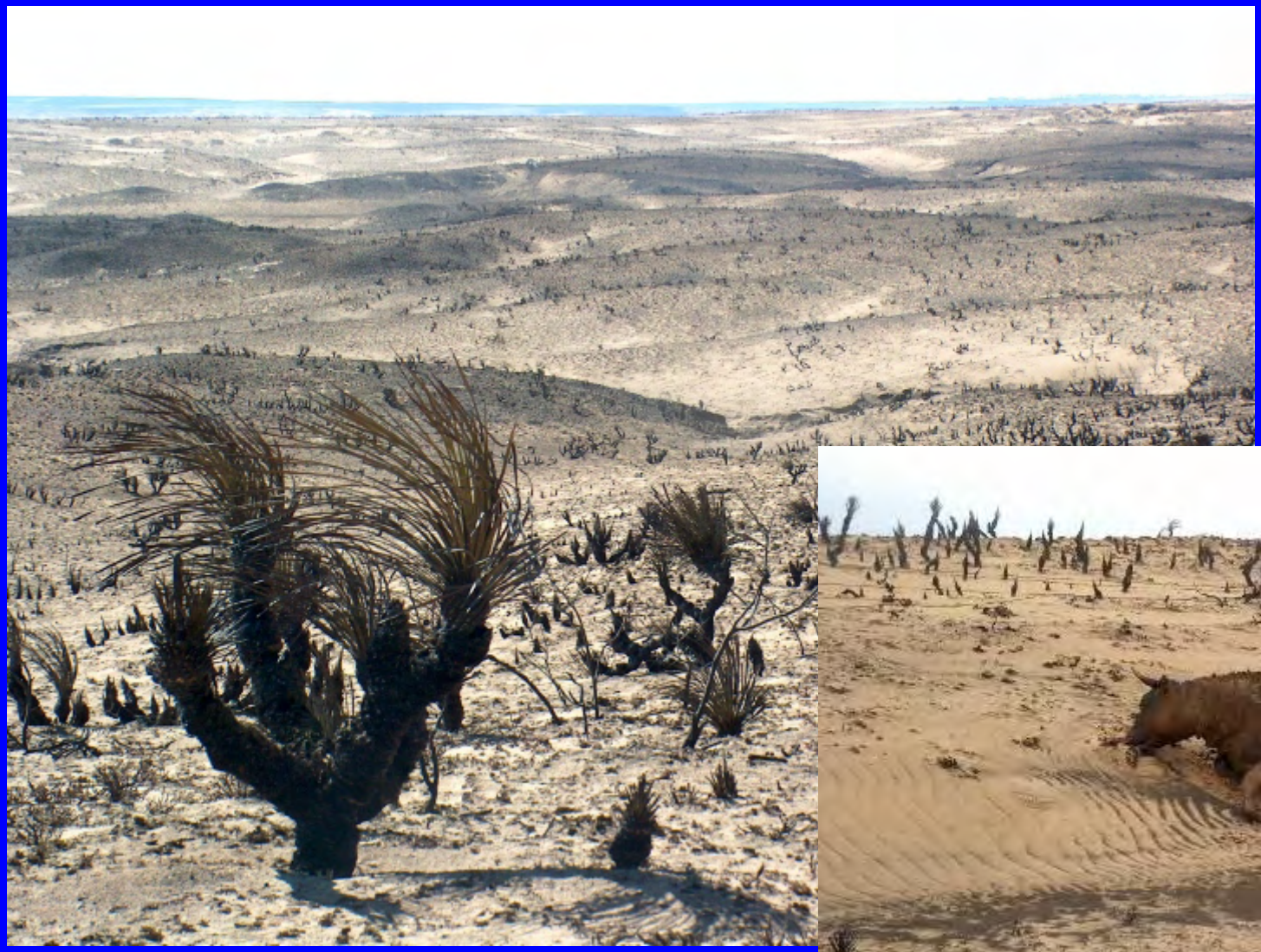
Craig Allen, USGS

Post-fire erosion by water…

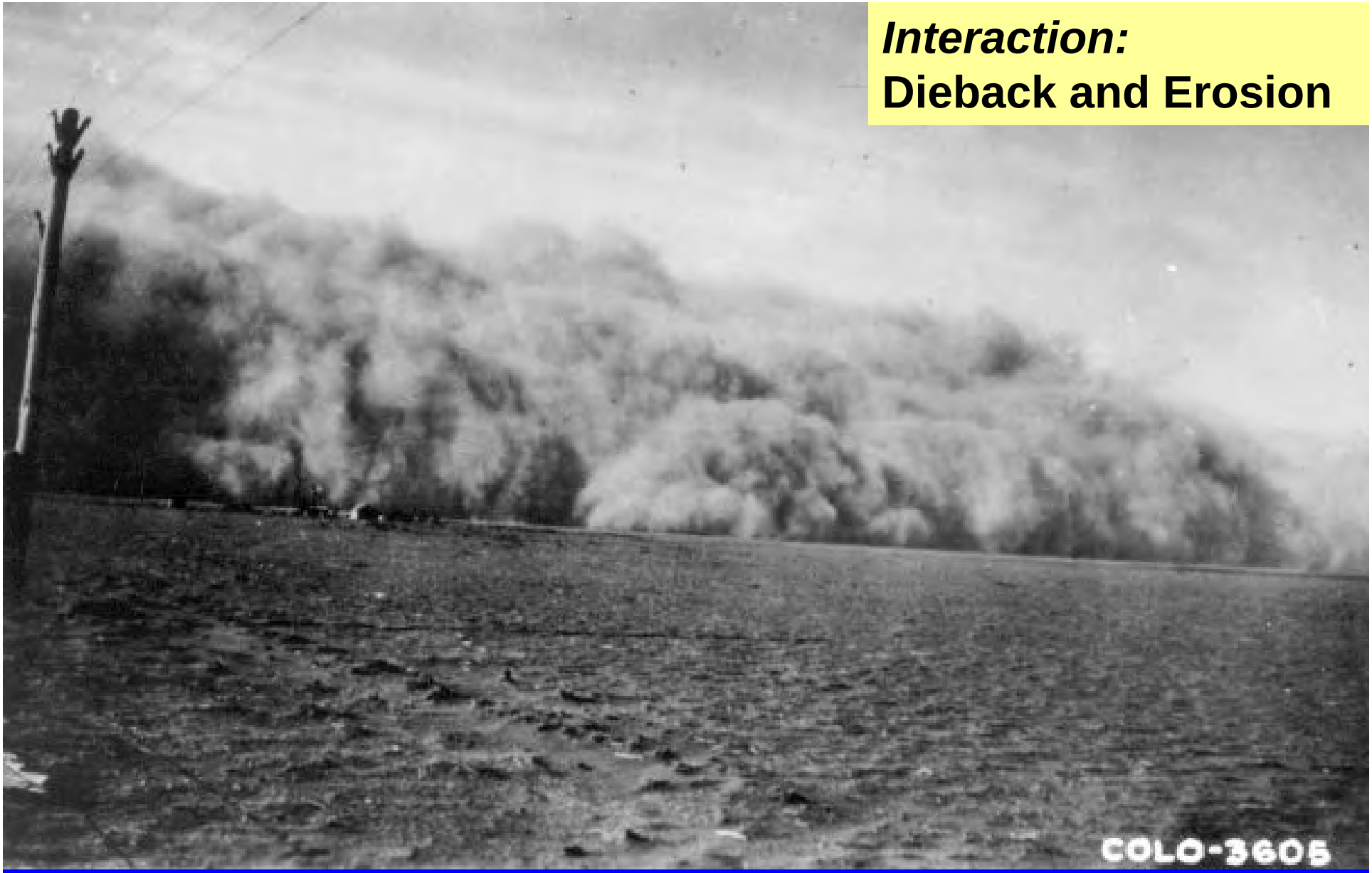
Craig Allen, USGS

2006 TX and OK: 4 million acres

Increased ***wind*** and water erosion risk



Craig Allen, USGS

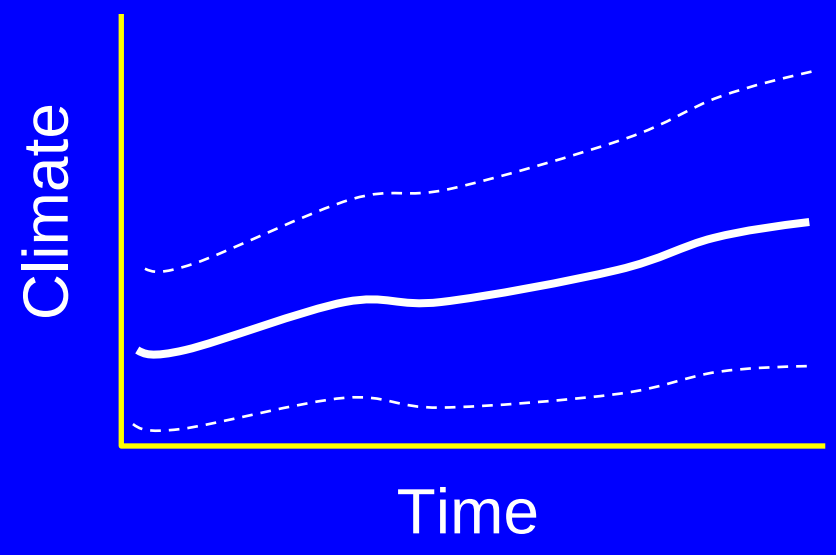


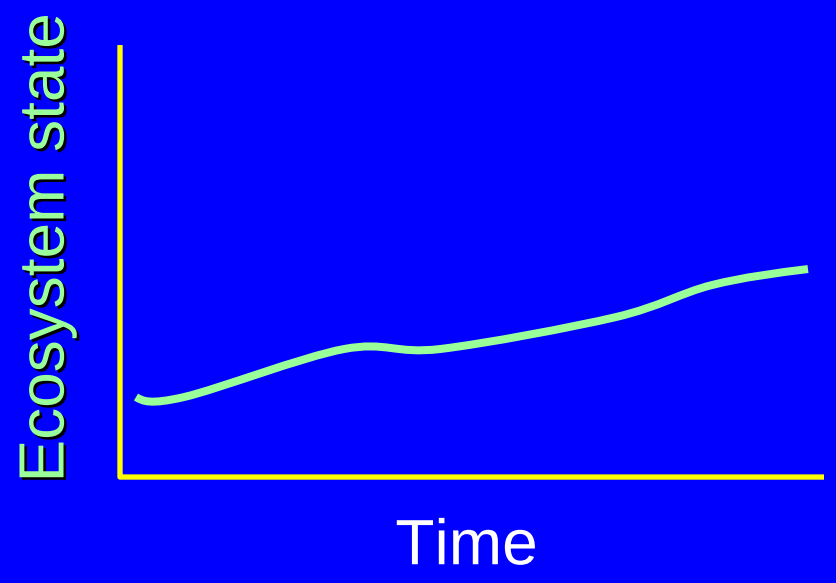
Interaction:
Dieback and Erosion

Drought reduces vegetation cover and increases erosion risk: the Dust Bowl…

C. Allen, USGS

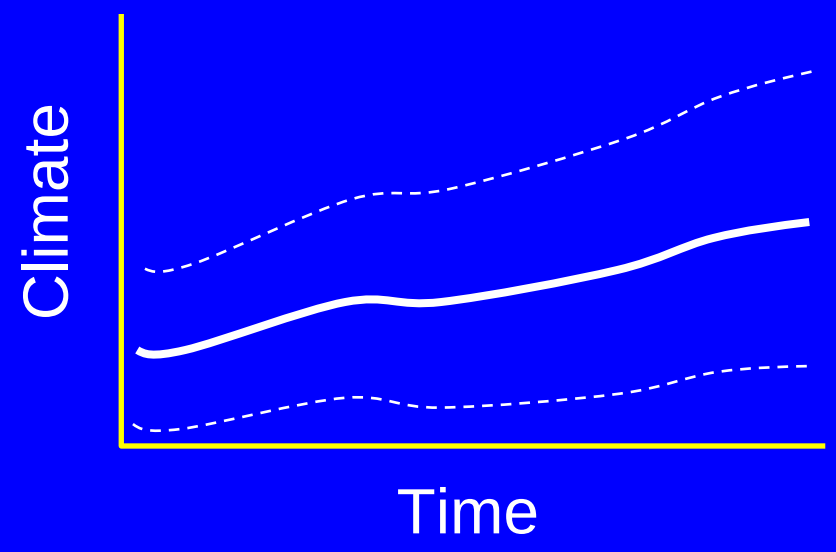
Current thinking often emphasizes gradual changes

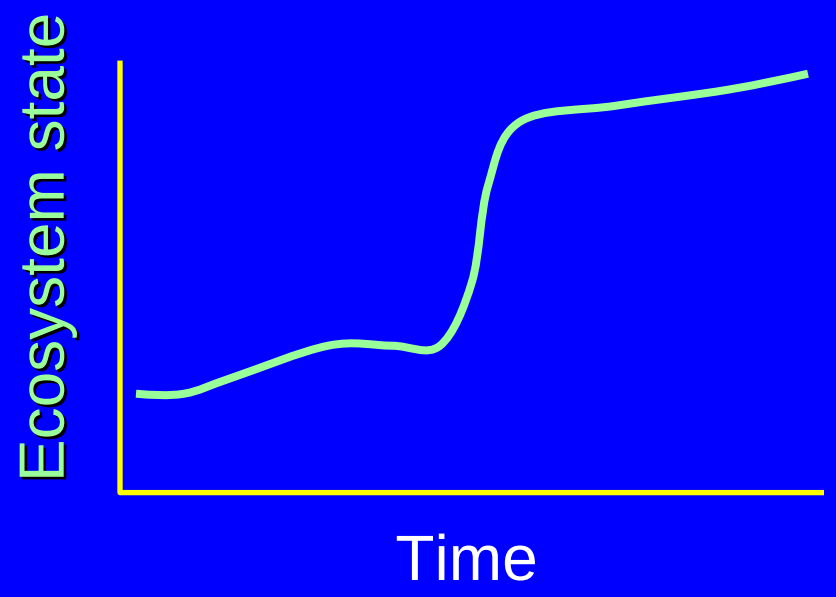




Craig Allen, USGS

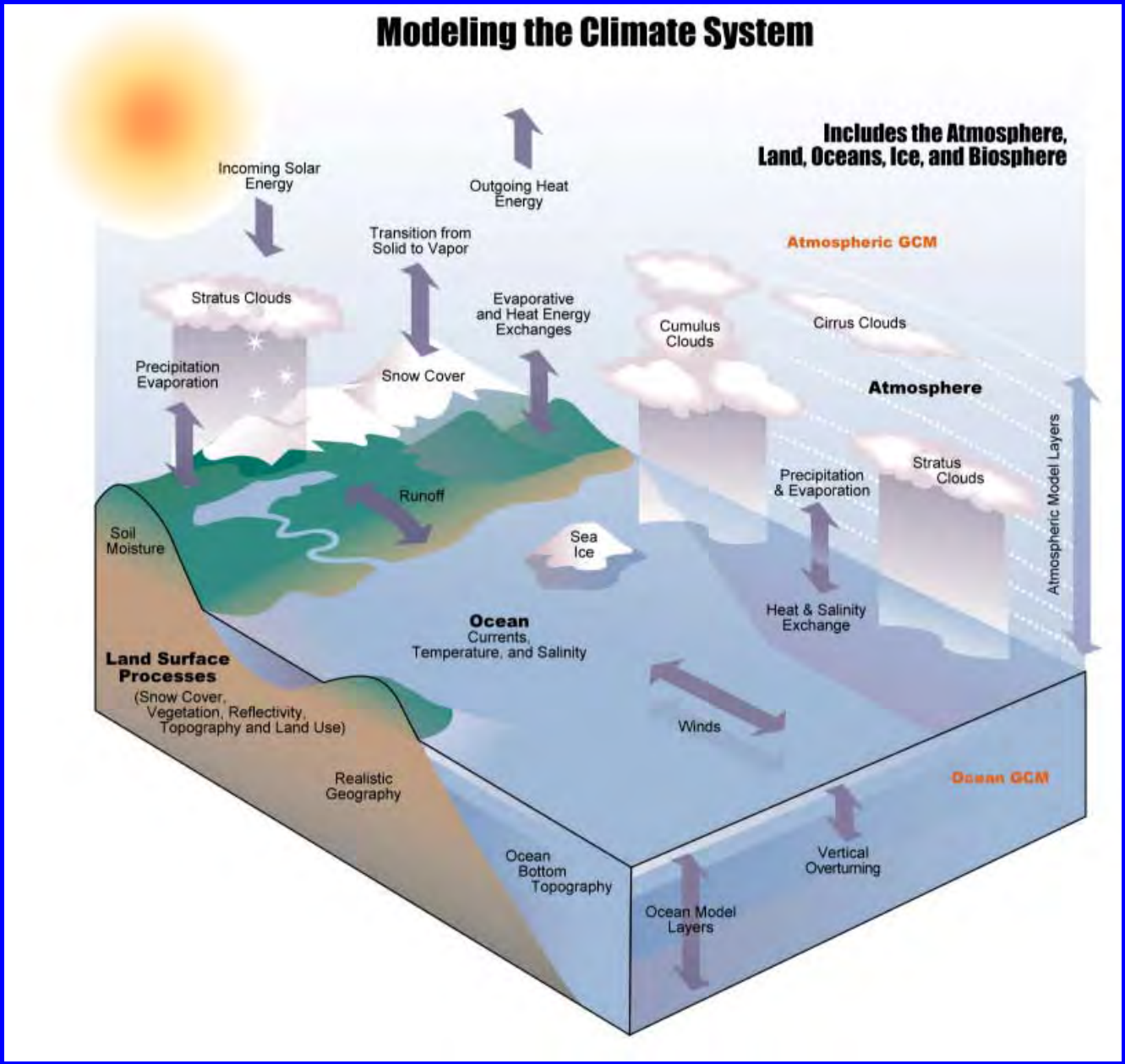
However, gradual climatic change may trigger abrupt ecosystem change (threshold response)





Craig Allen, USGS

Projected Climate Change In the Southwest



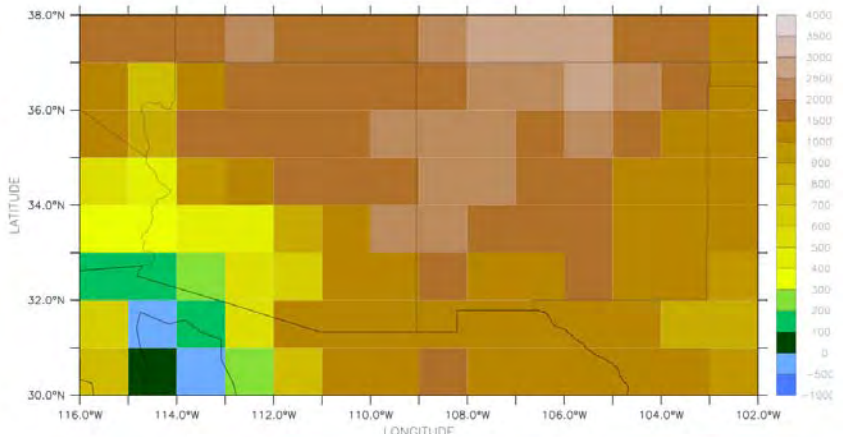
http://www.usgcrp.gov/usgcrp/images/ocp2003/ocpfy2003-fig3-3.htm

What GCMs Can and Can't Do

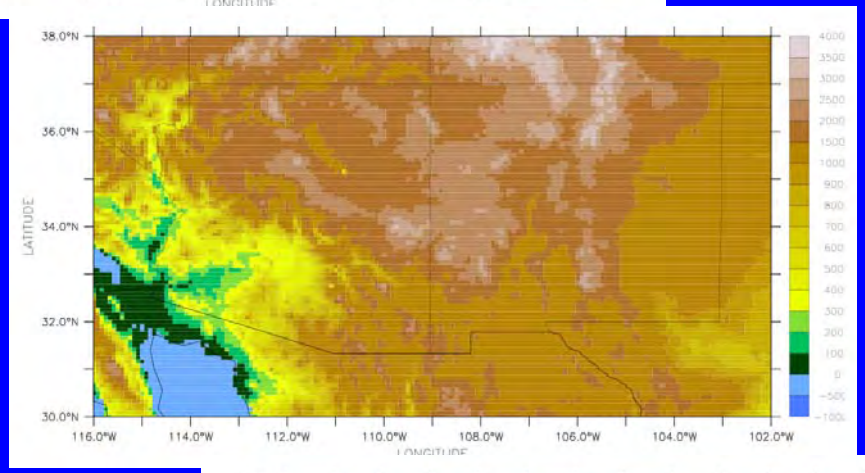
There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes. Confidence in model estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). Over several decades of development, models have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.

IPCC 4th Assessment Report, Chapter 8, *Climate Models and their Evaluation*
http://ipcc-wg1.ucar.edu/wg1/wg1-report.html

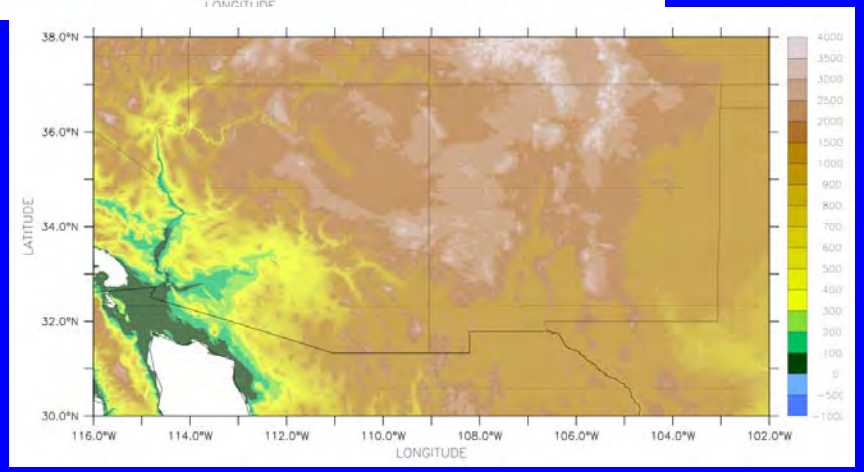
Resolution



1° x1°
(~111 km)



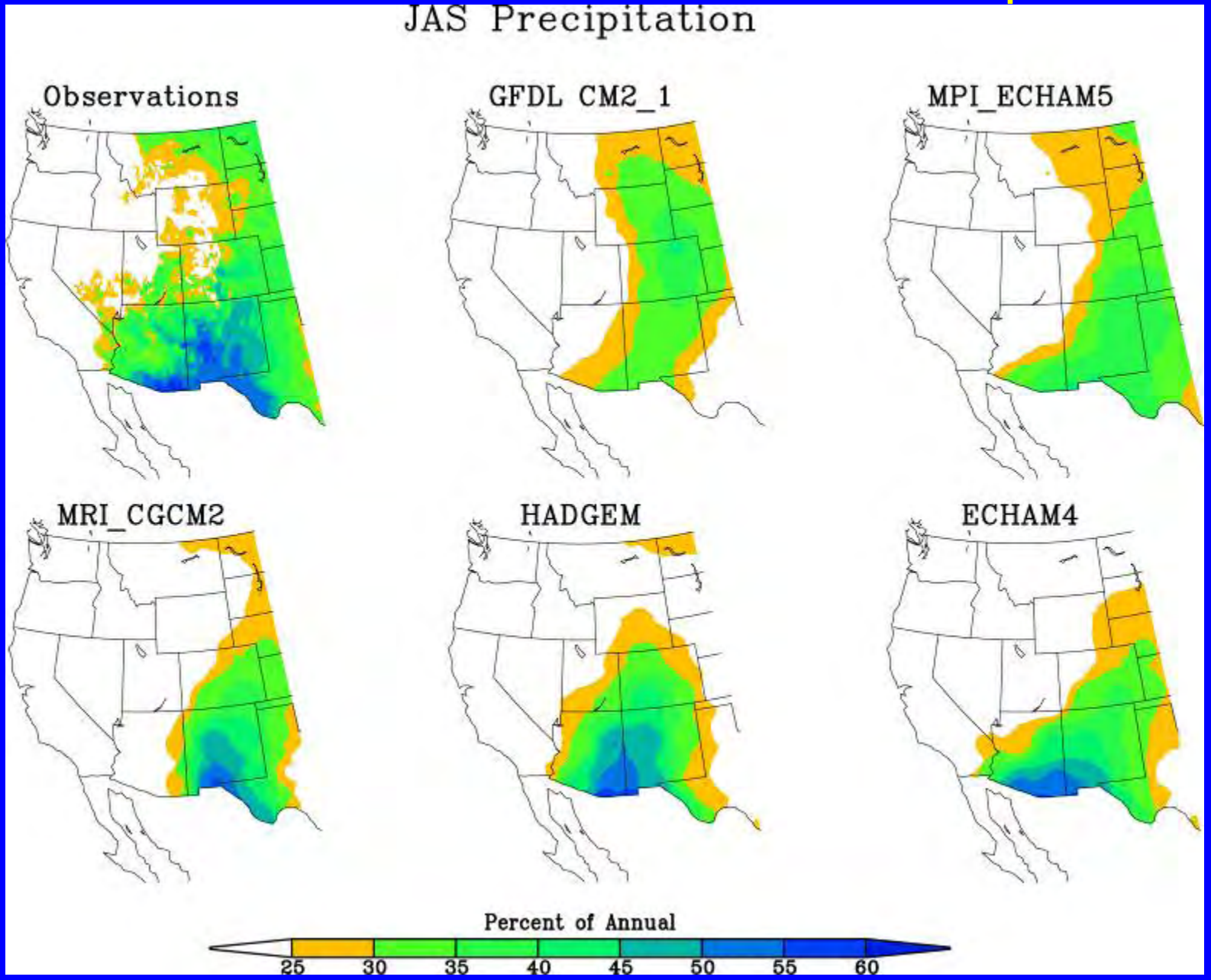
1/12° x1/12°
(~10 km)



1/120° x1/120°
(~1 km)

J. Russell, UA Geosciences

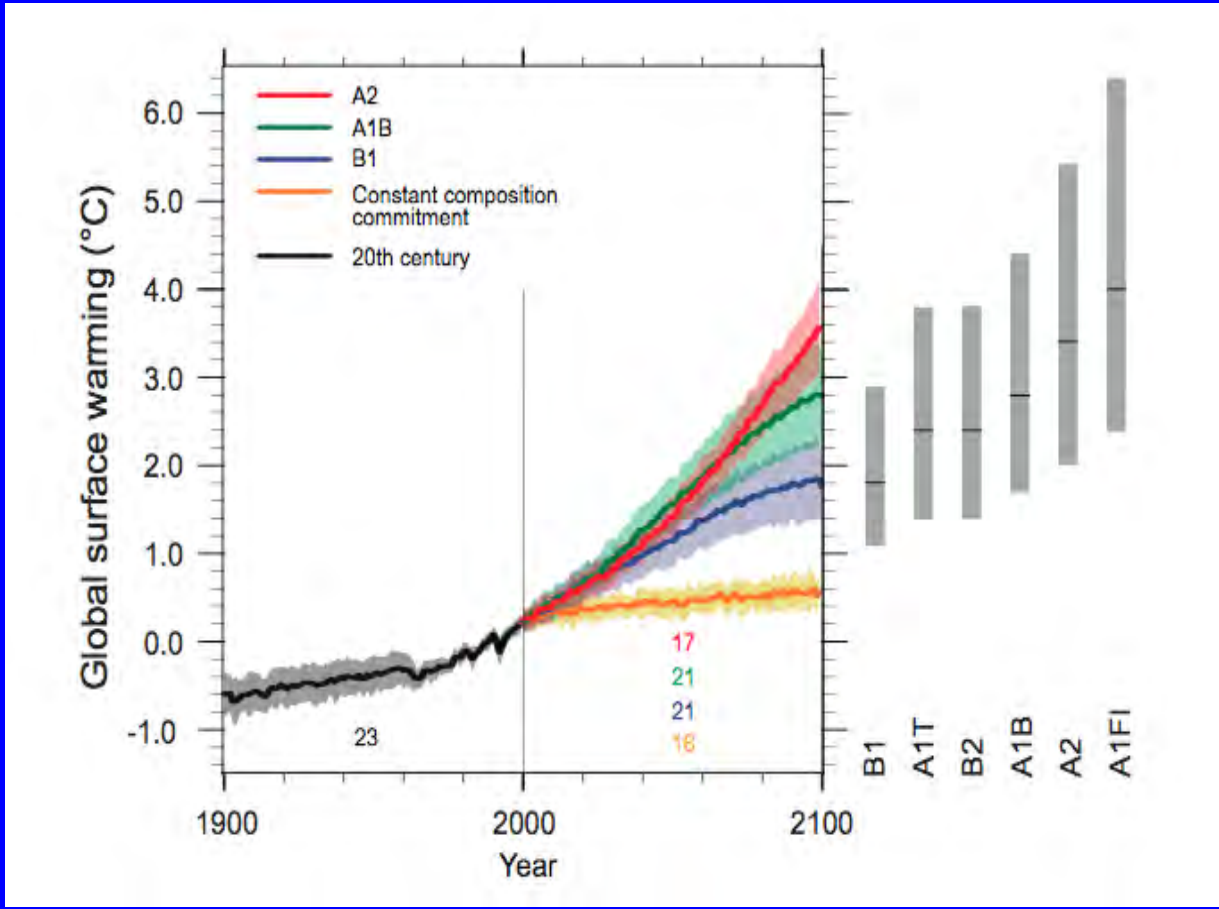
Summer Monsoon % Annual Precipitation



J. Eischeid (NOAA) and G. Garfin (UA/ISPE) -- unpublished

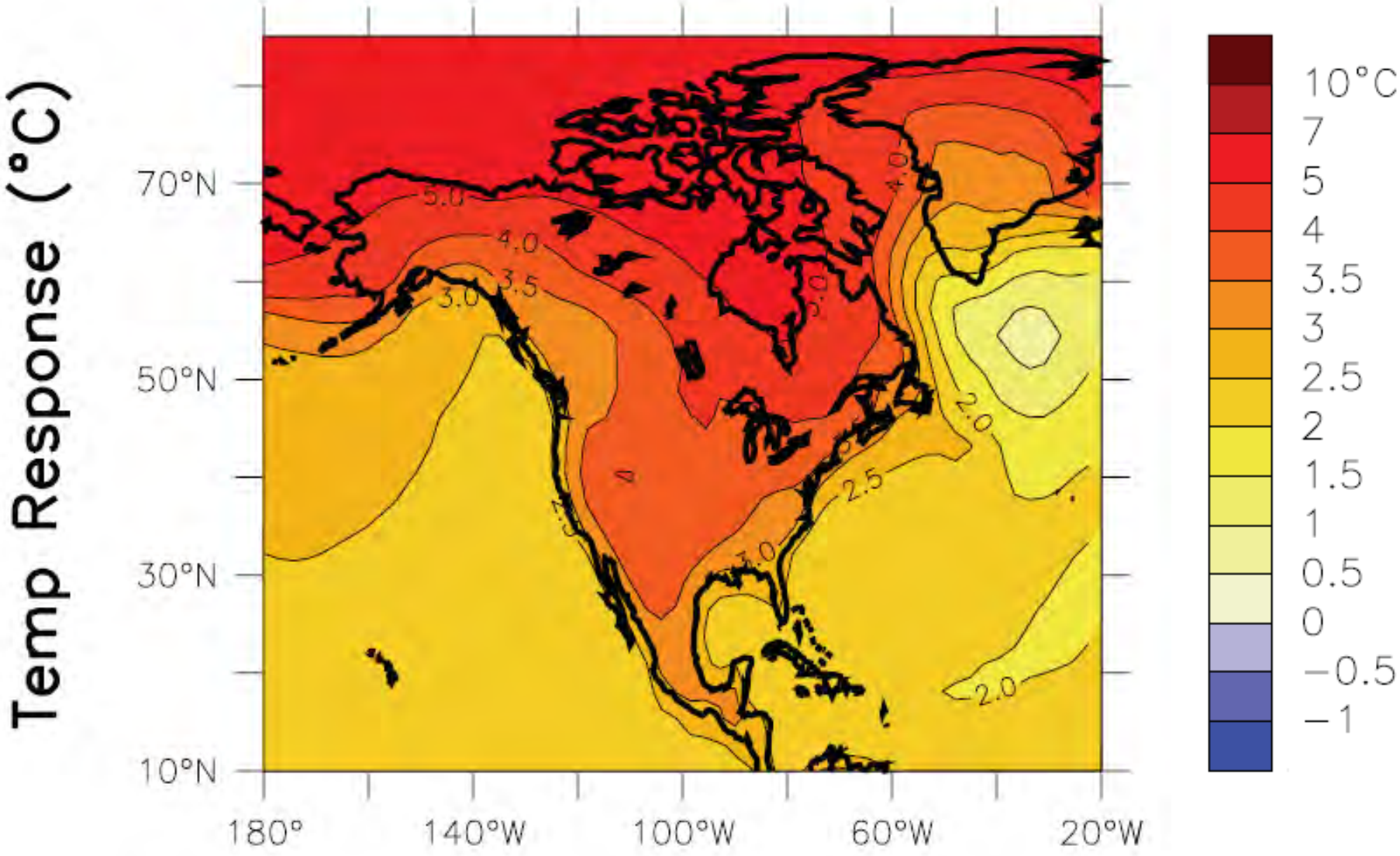
Emissions Scenarios

Best estimate for low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and for high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C).



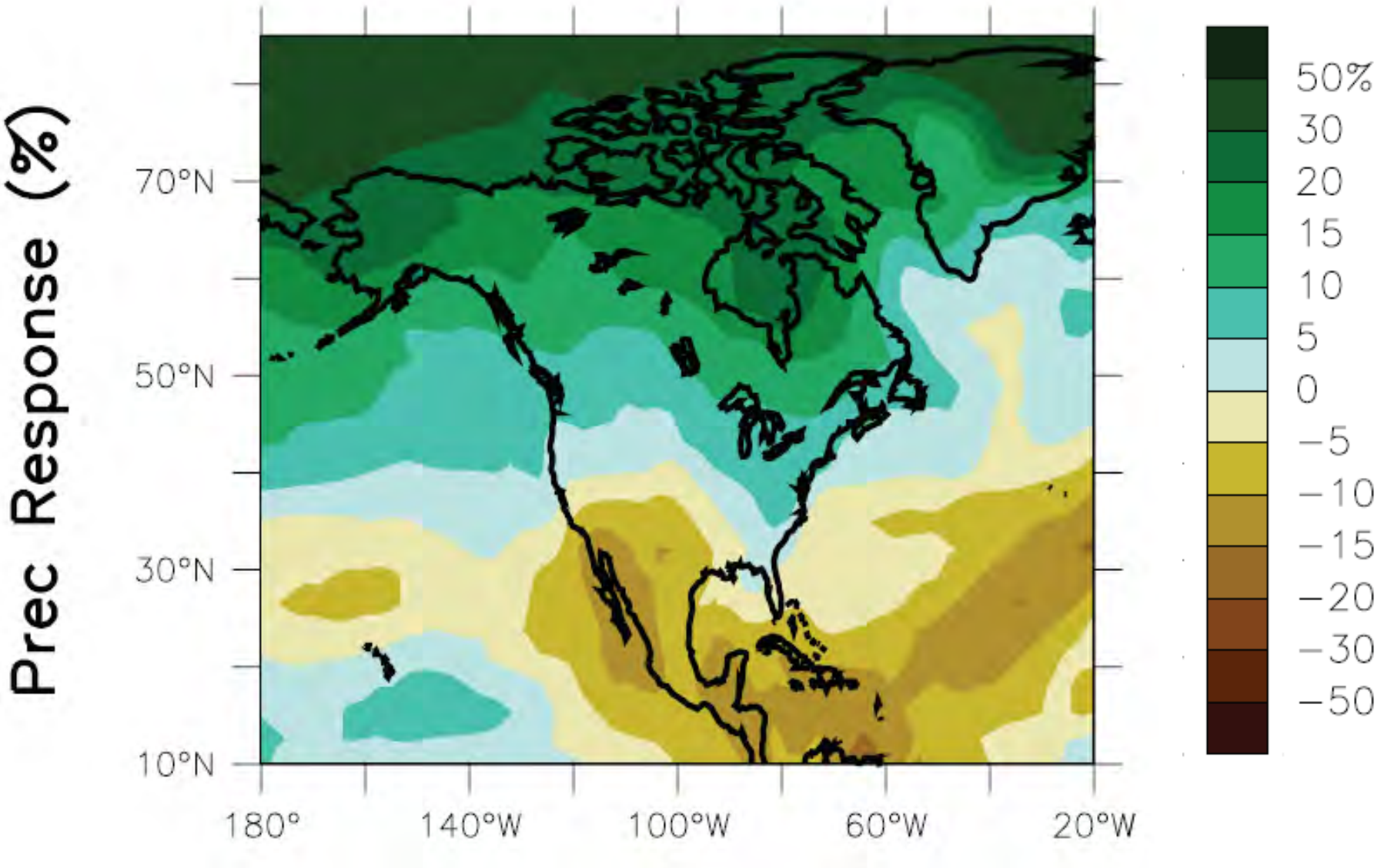
http://www.ipcc.ch

Annual Temperature: End of 21st Century



IPCC 4th Assessment: Working Group I, Chapter 11, Regional Projections

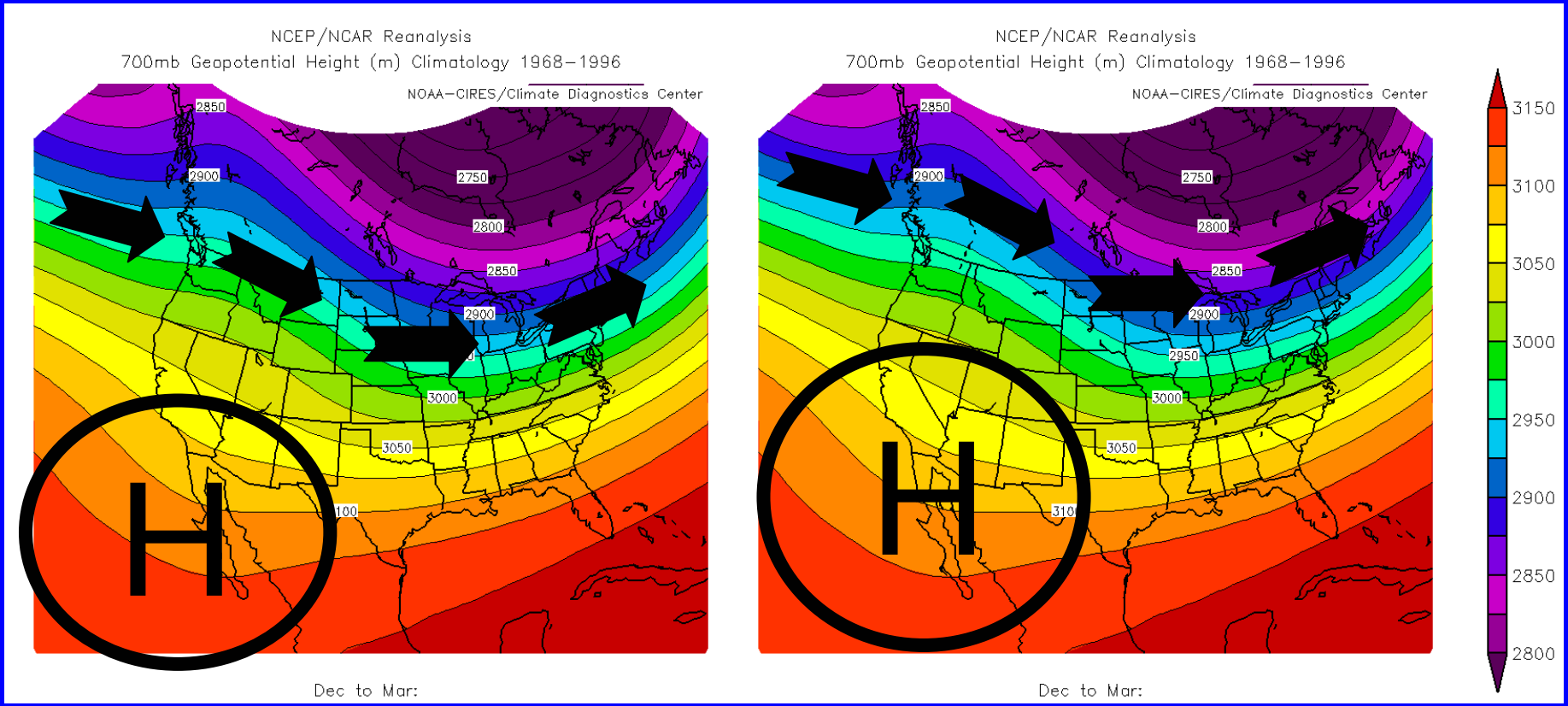
Annual Precipitation: End of 21st Century



IPCC 4th Assessment: Working Group I, Chapter 11, Regional Projections

Average Winter Jet Stream

Climate Change Winter Jet Stream

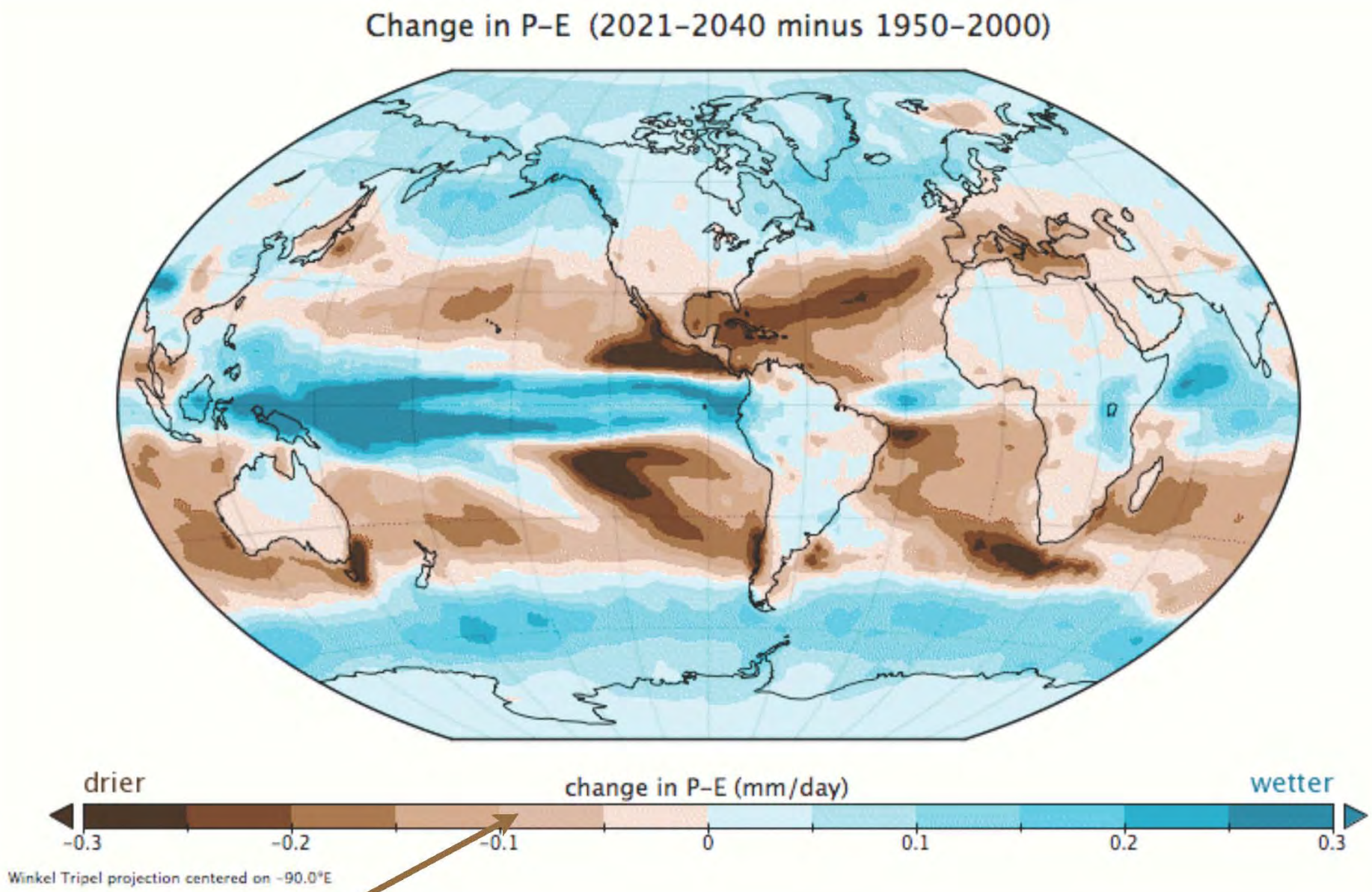


Mike Crimmins, University of Arizona

Dust Bowl Southwest?

- Seager analyzed 19 global climate model results from recent IPCC assessment
- Scenario: rising CO2 until 2050 then slow decline to 720 ppm by 2100
- Result: broad consensus among models that SW will dry significantly in 21st century

★ Arid transition may already be underway

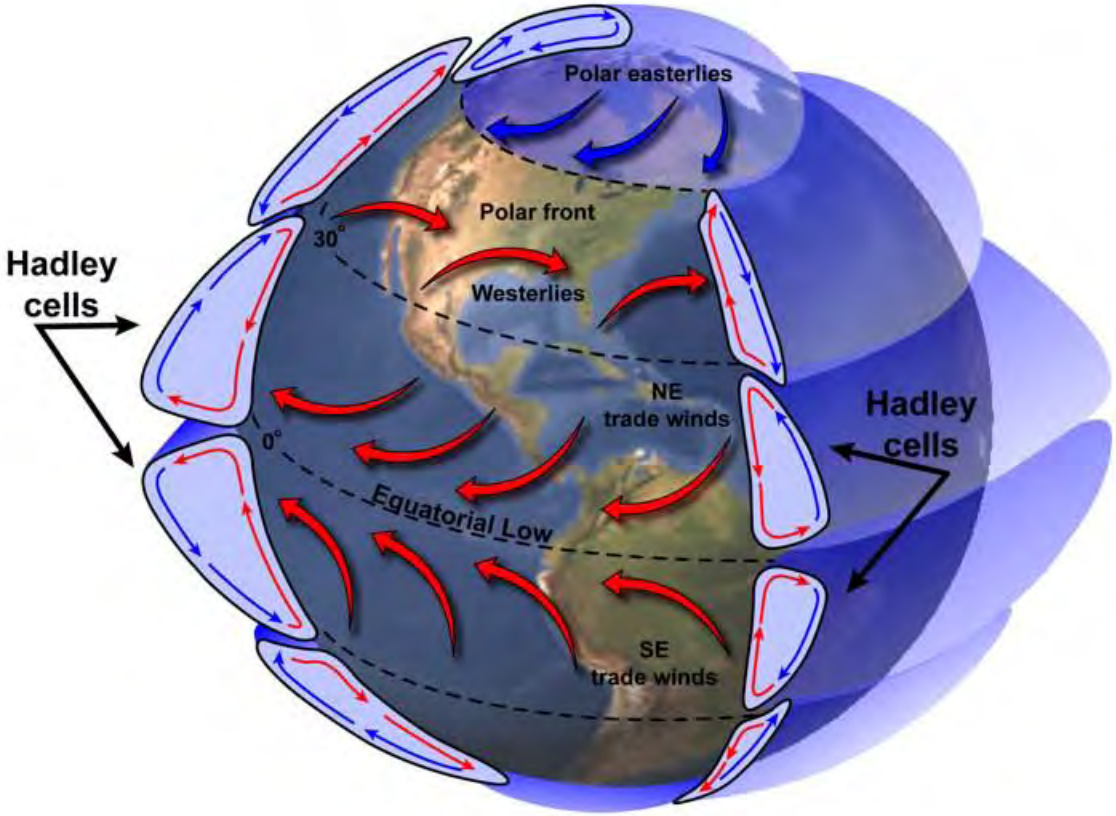


Dust Bowl: 0.09 mm/day

Seager et al 2007

Lisa Graumlich, UA School of Natural Resources

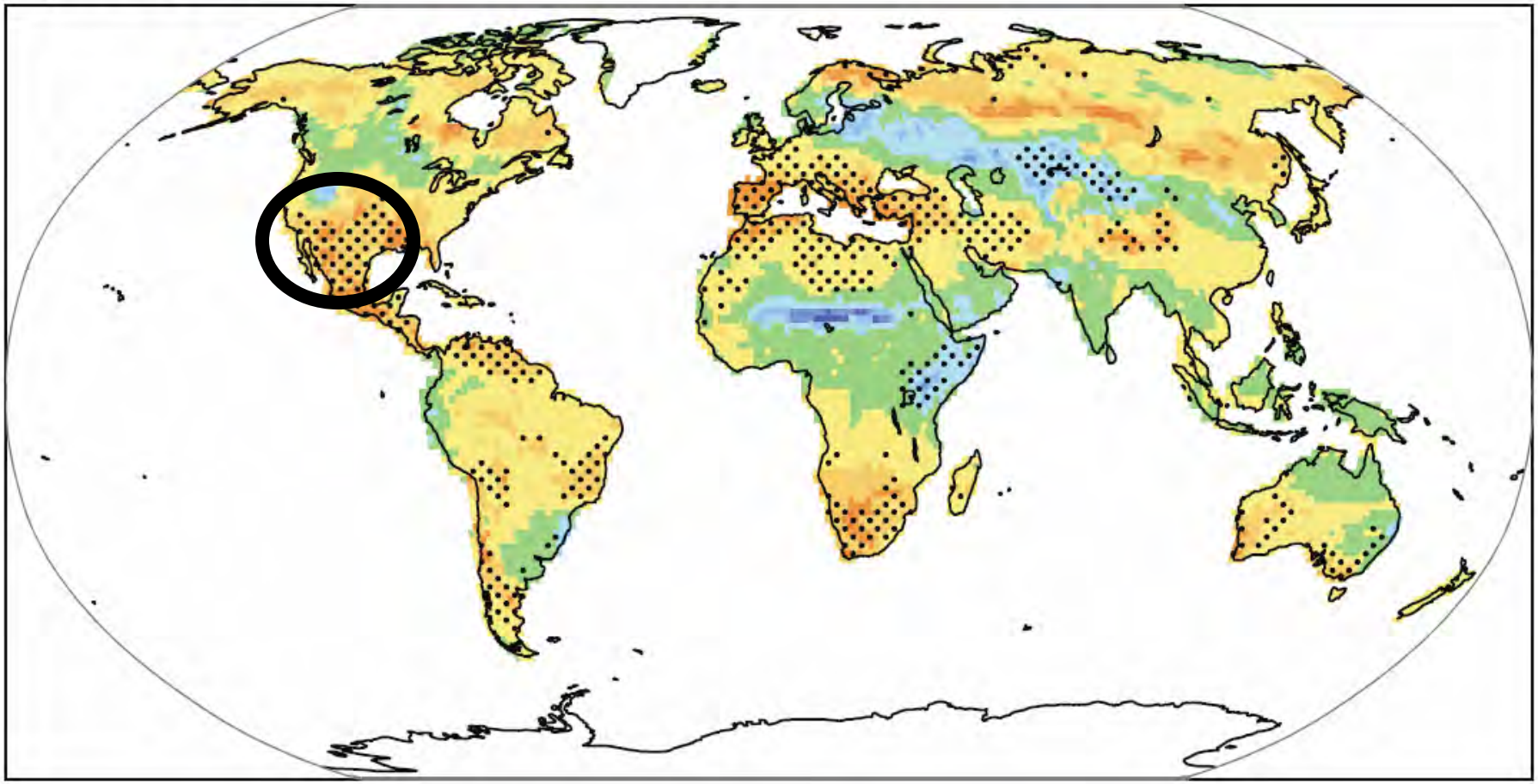
A new climate state?



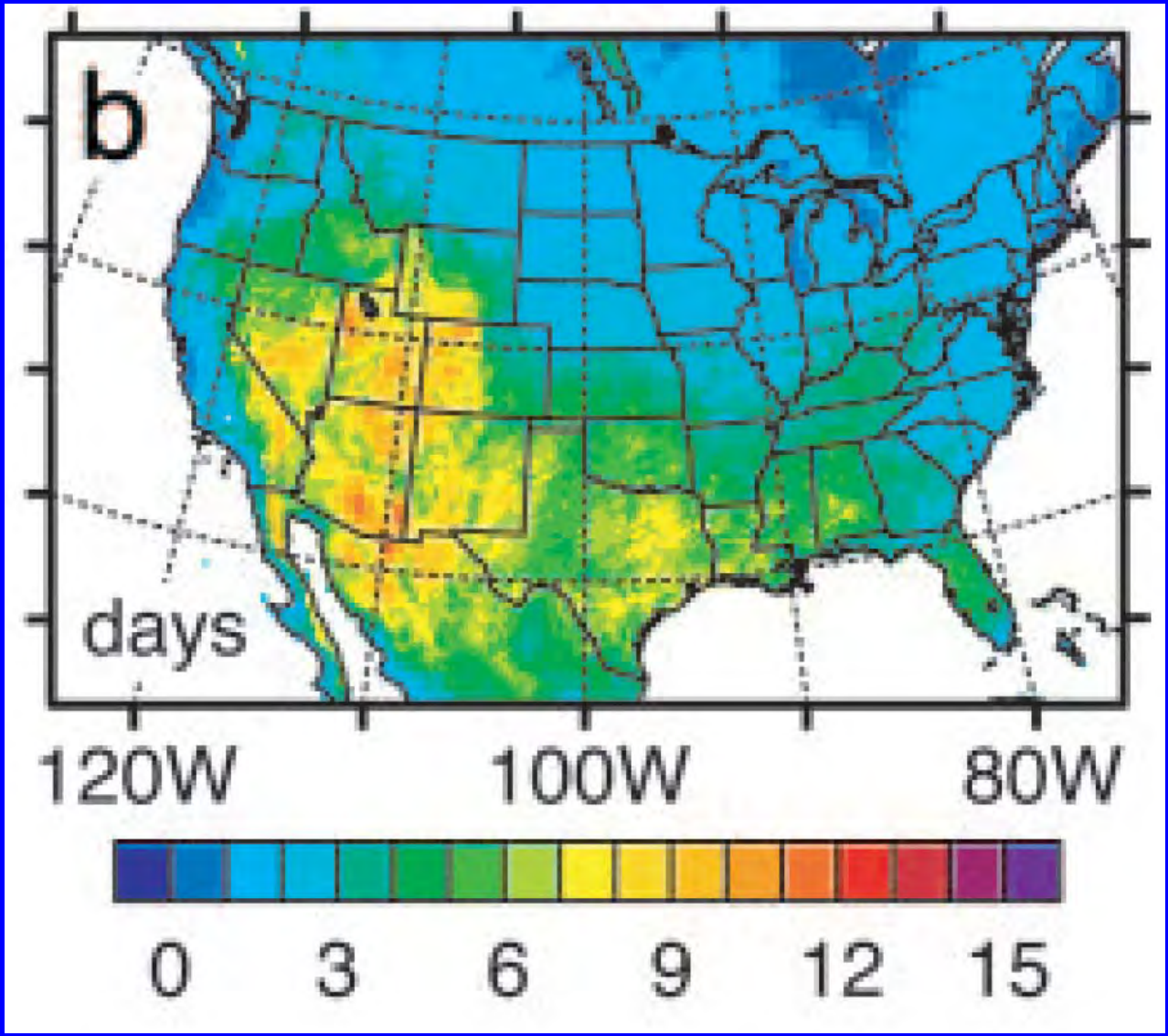
- As planet warms, Hadley cell expands Northward
- Rain-bearing Westerlies shift northward

Lisa Graumlich, UA School of Natural Resources

b) Soil moisture

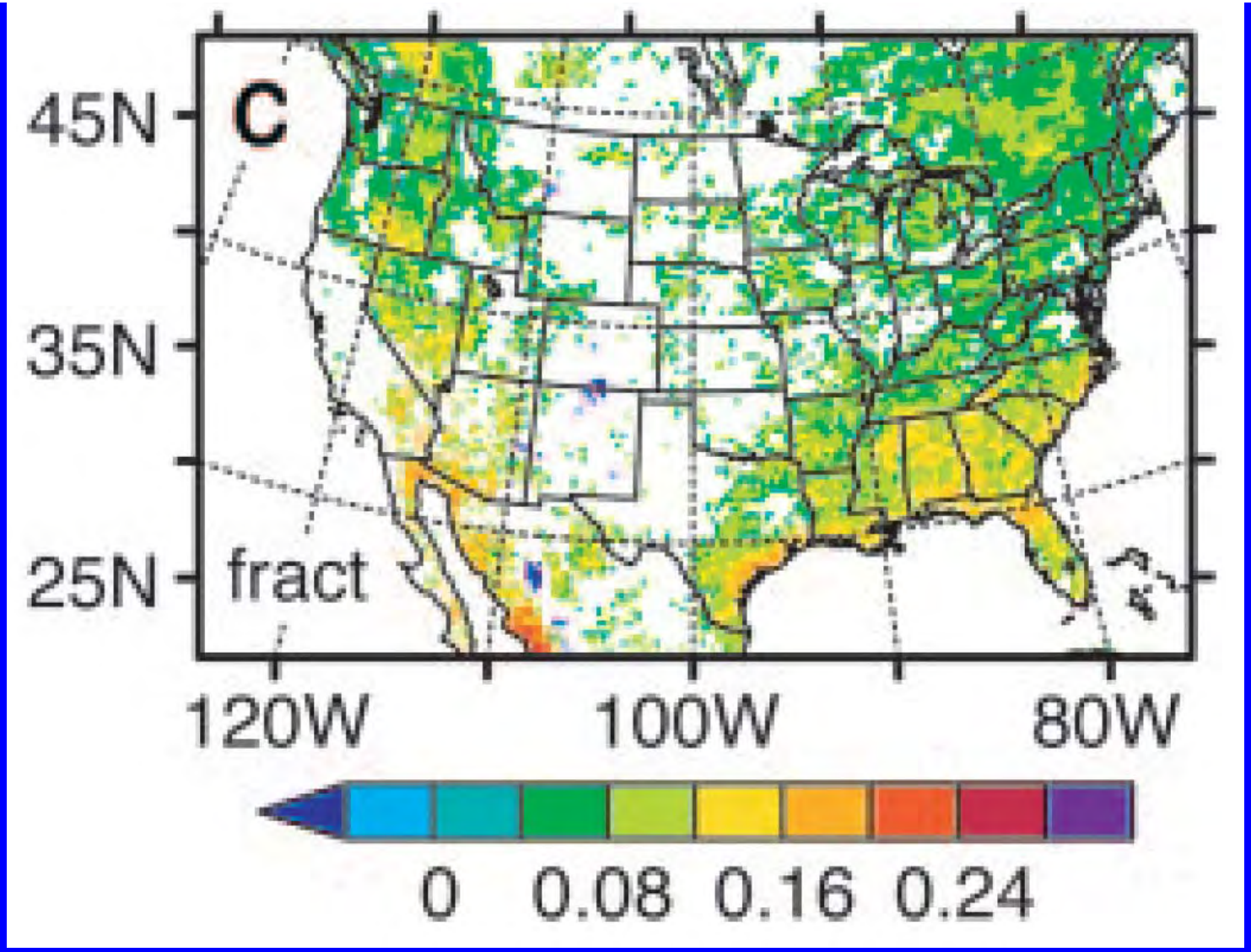


IPCC 4th Assessment: Working Group I



Longer Heat Waves

Diffenbaugh et al., 2005
Proceedings of the National Academy of Science



More Precipitation in Extremes

Diffenbaugh et al., 2005
Proceedings of the National Academy of Science

Ecological Impacts?

Lisa Graumlich, UA School of Natural Resources

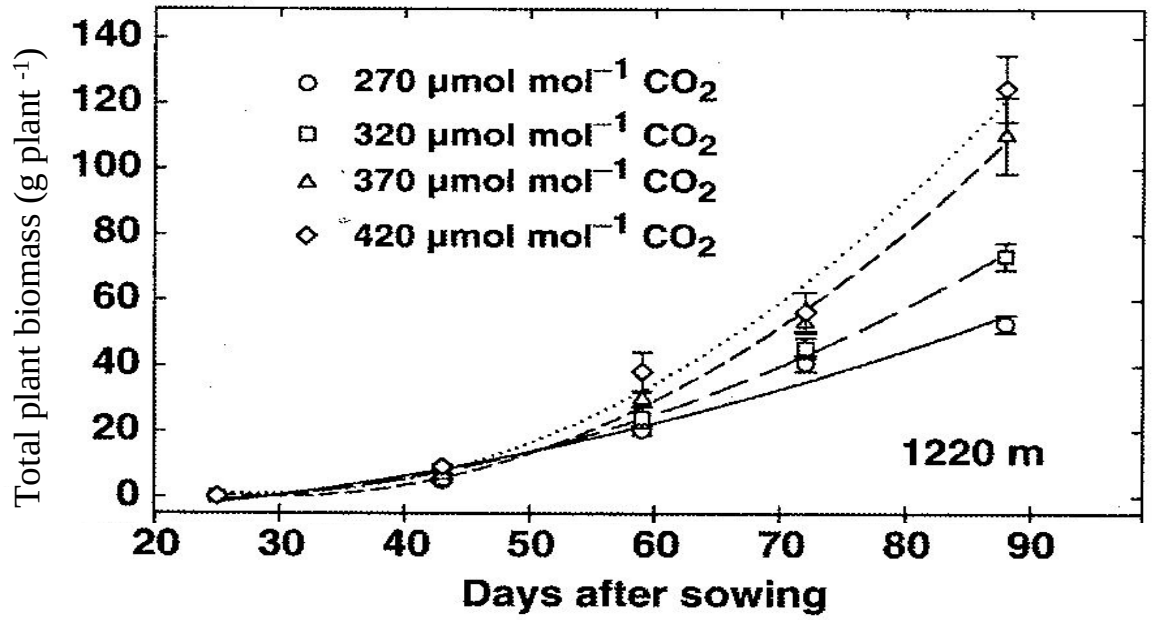


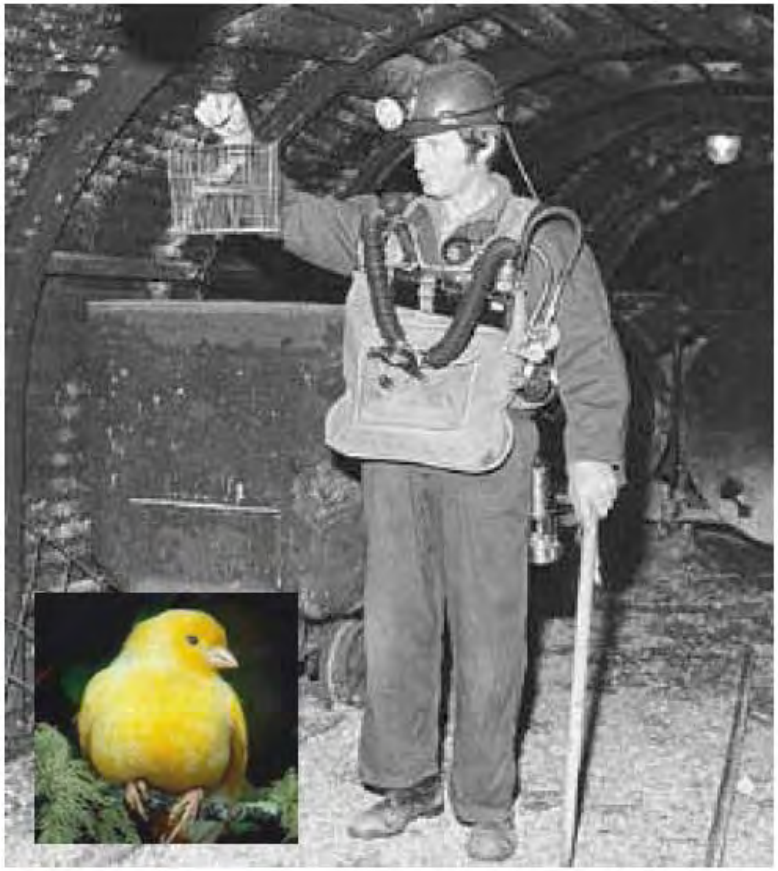
Fig. 1 Total biomass of cheatgrass (*Bromus tectorum* g per plant) over time (days after sowing, DAS) as a function of increasing [CO_2] for three populations collected at different elevations in northern Nevada. Significant [CO_2] differences were observed after 59 DAS. Bars are ± SE.

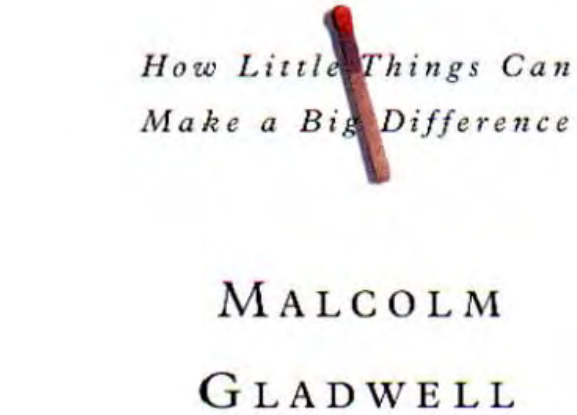
How does this affect composition, processes?

Ziska, Reeves and Blank, 2005. The impact of recent increases in atomospheric CO_2 on biomass production and vegetative retention of cheatgrass (*Bromus tectorum*): implications for fire disturbance. *Global Change Biology* 11: 1325-1332.

Tony Svejcar, USDA

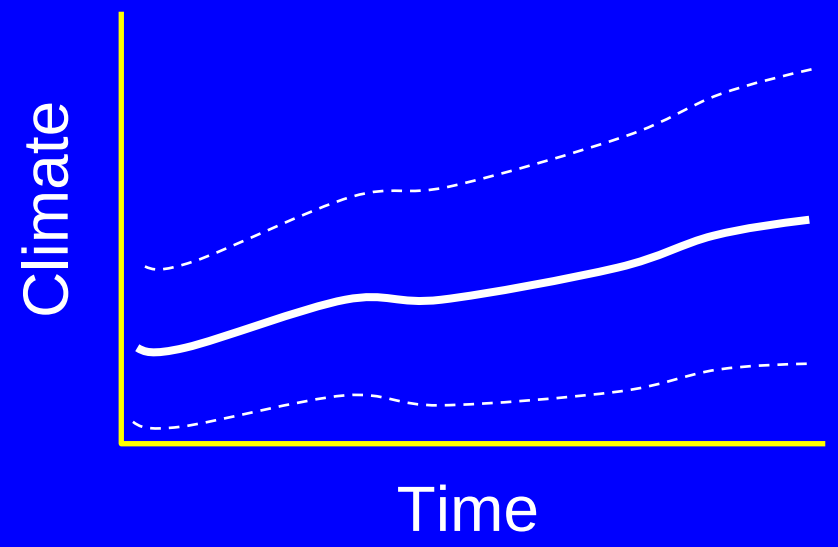
State of science: from canaries to tipping points in a "no analog" world

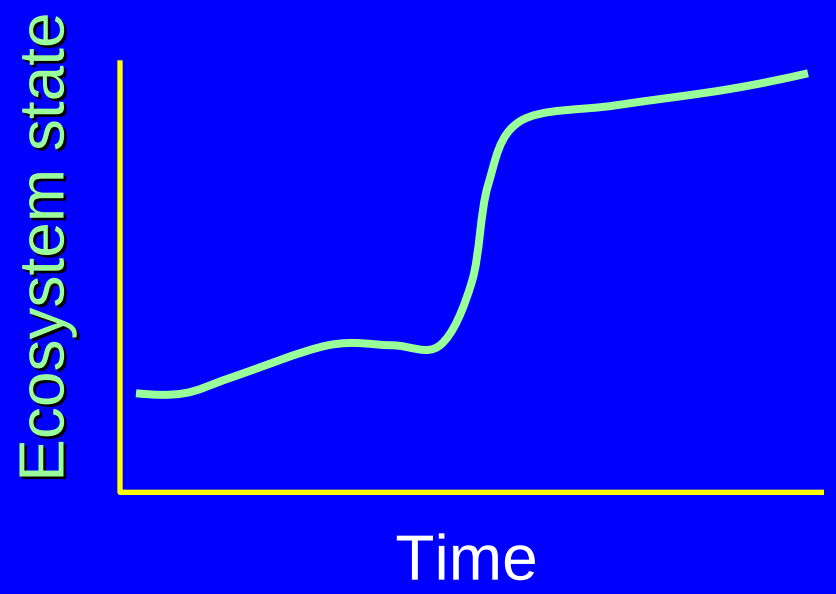




Lisa Graumlich, UA School of Natural Resources

Abrupt ecosystem change

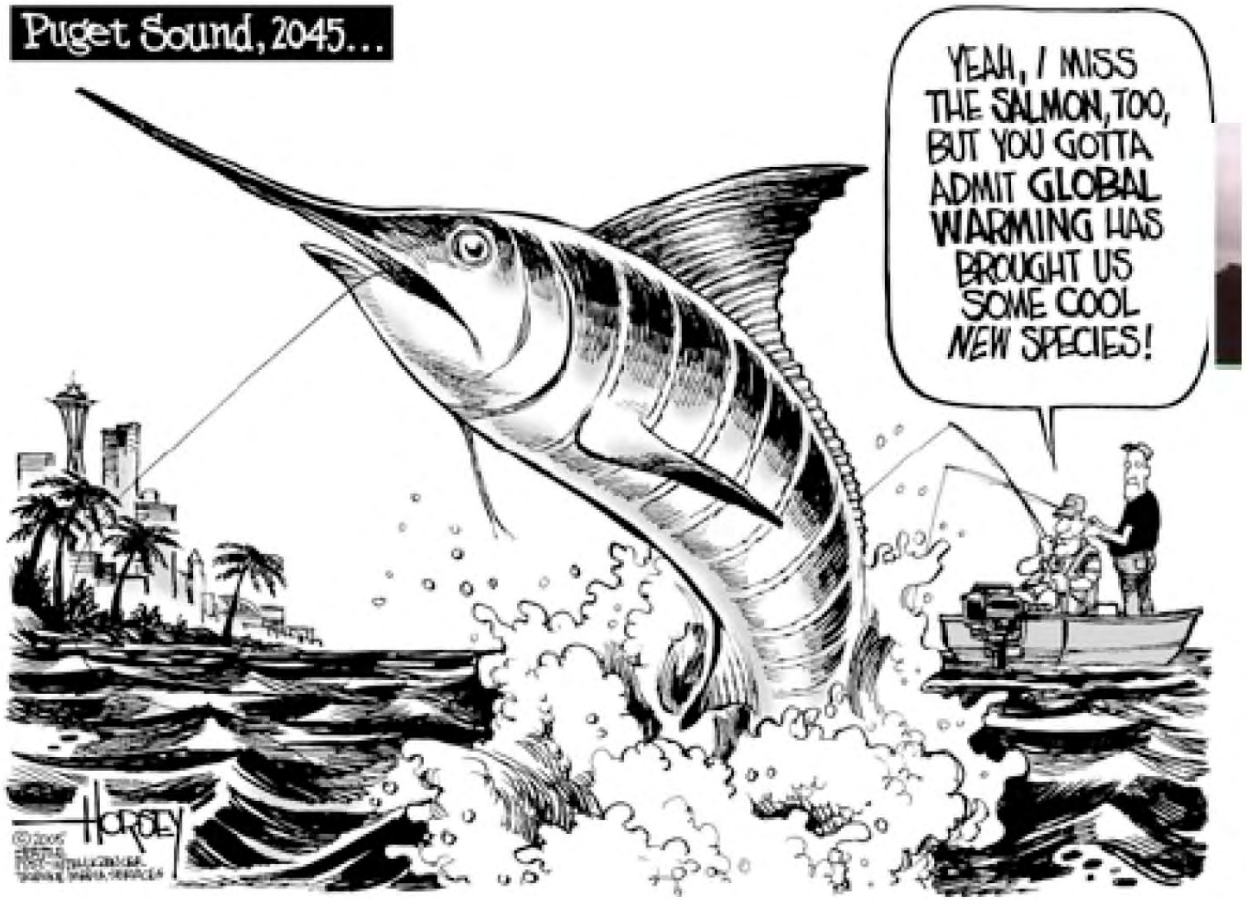




Craig Allen, USGS

Adaptation is the challenge

Who chooses winners and losers?



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