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Climate Linkages in Four Dimensions



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The Aspen Global Change Institute

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“Learning from Regions: A Comparative Appraisal of
Climate, Water, and Human Interactions in the Colorado and
Columbia River Systems”

Climate Linkages in Four Dimensions

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Climate Linkages

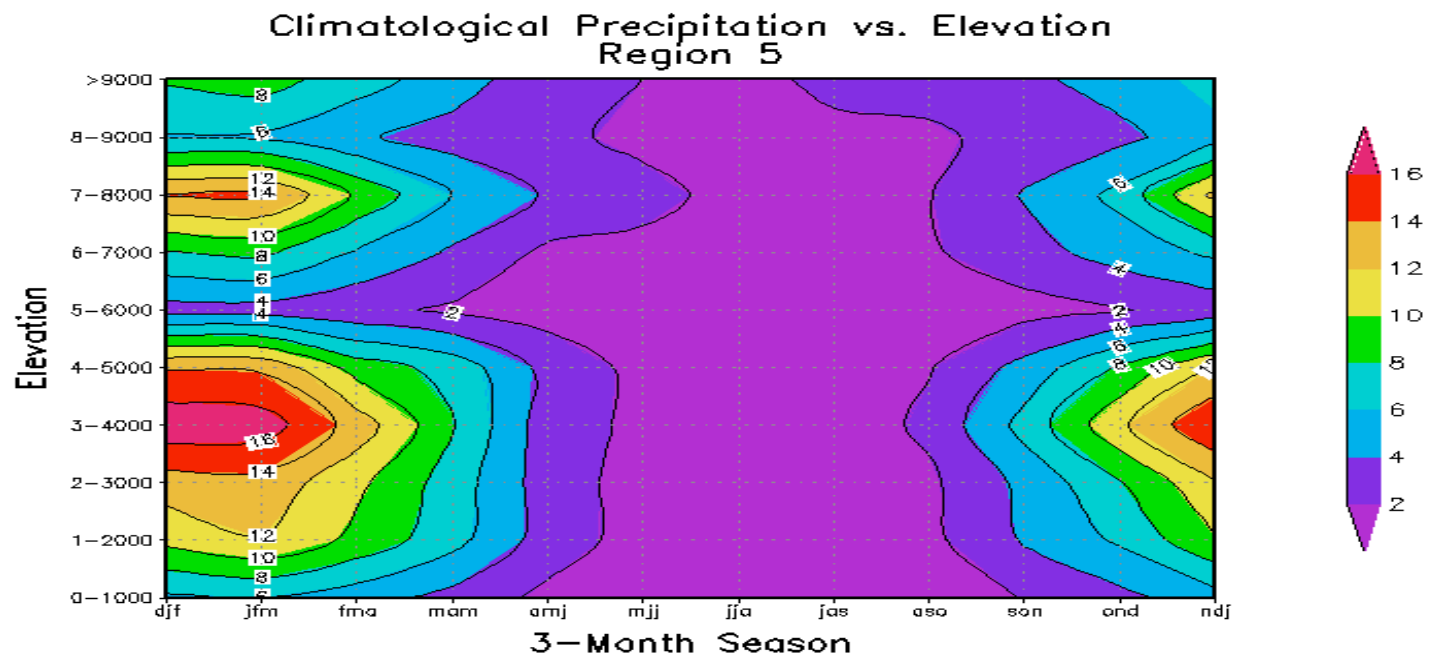
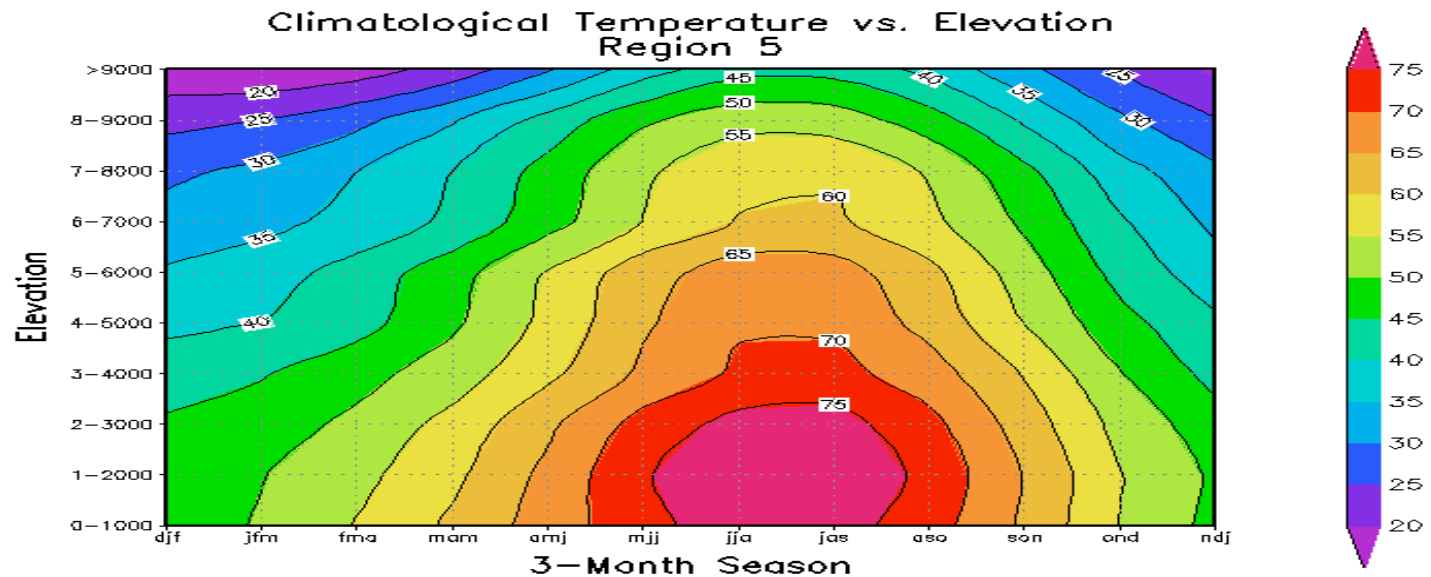
To gain a more integrative perspective of climatic variations in the high topographic relief regions of the western United States, one needs to:

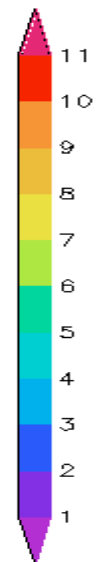
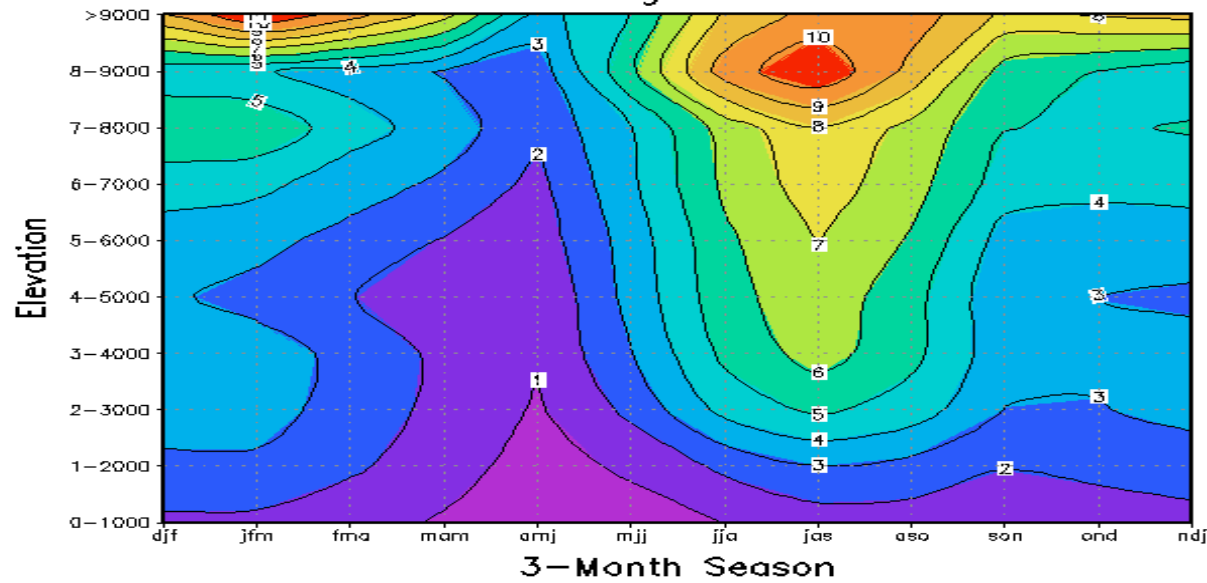
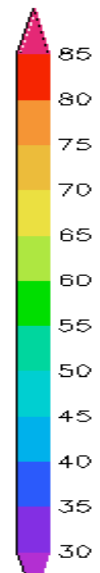
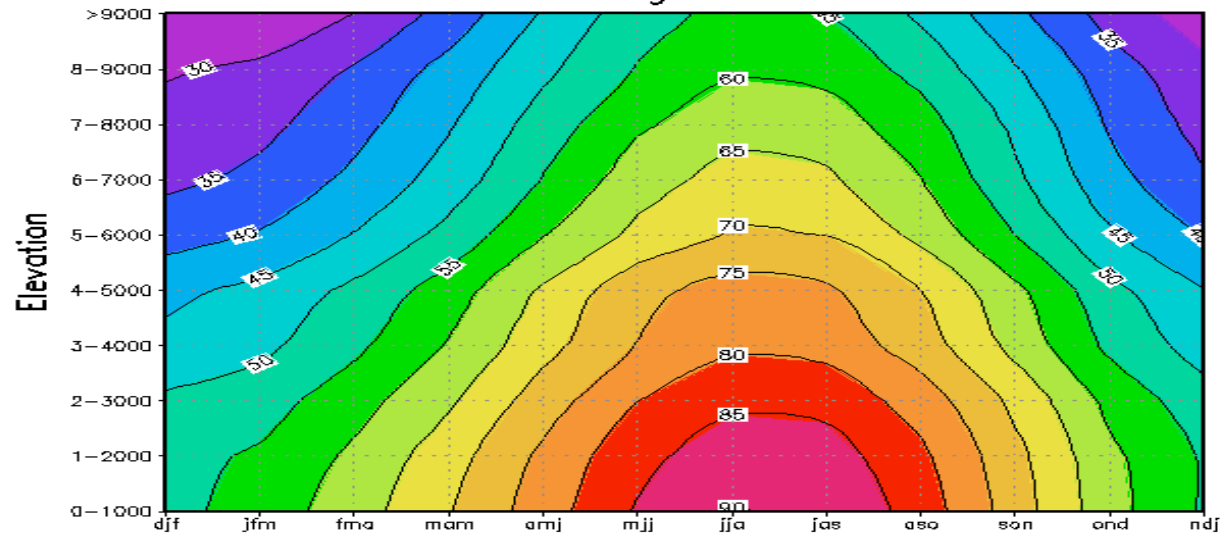
Address changes in the vertical dimension and in time.

What are the changes in surface temperature and precipitation in high relief areas of the West in relation to ground elevation? Is the magnitude of the changes variable with respect to height?

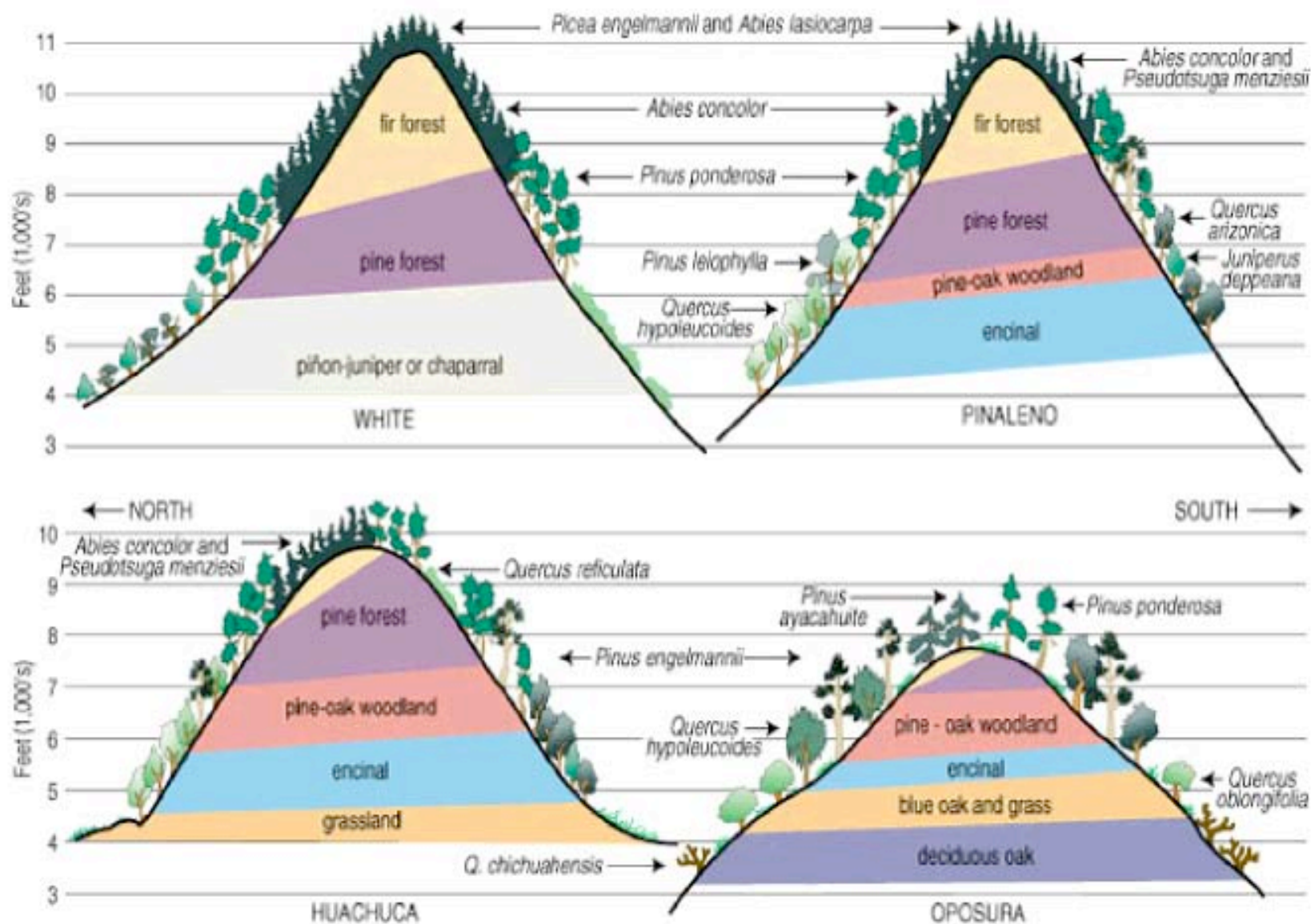
Address changes in the horizontal dimension and in time.

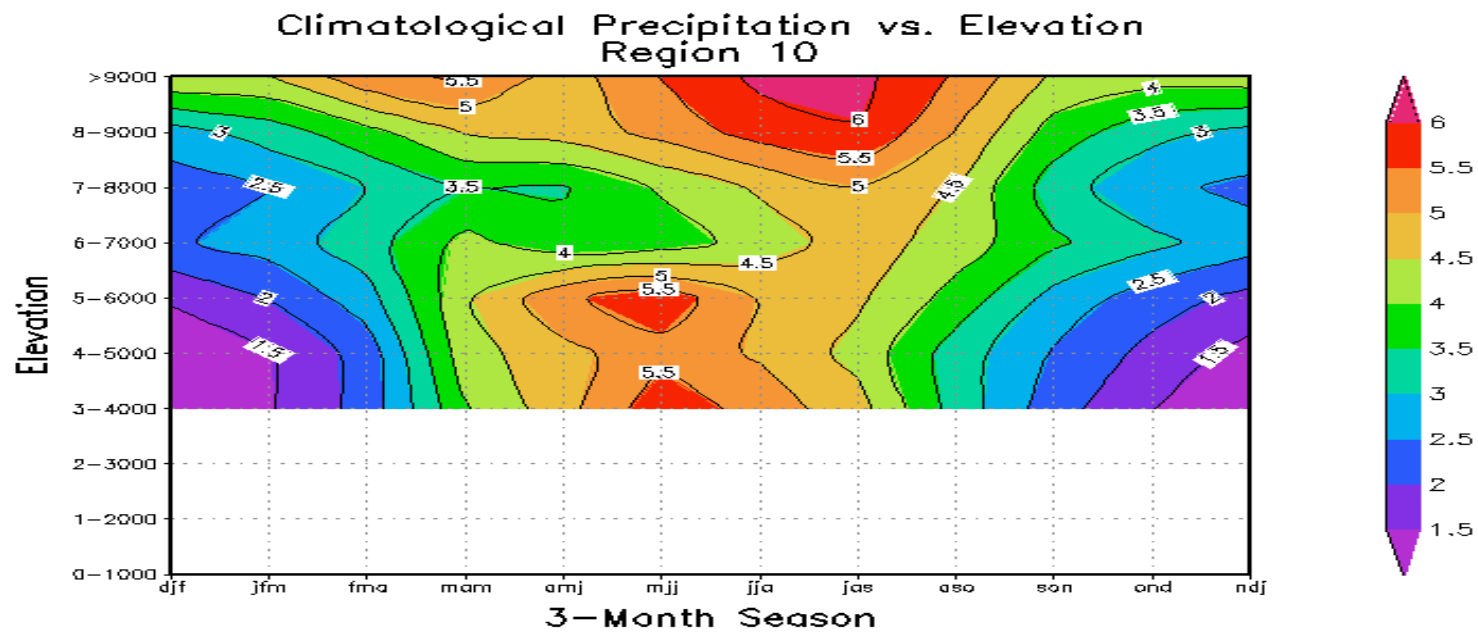
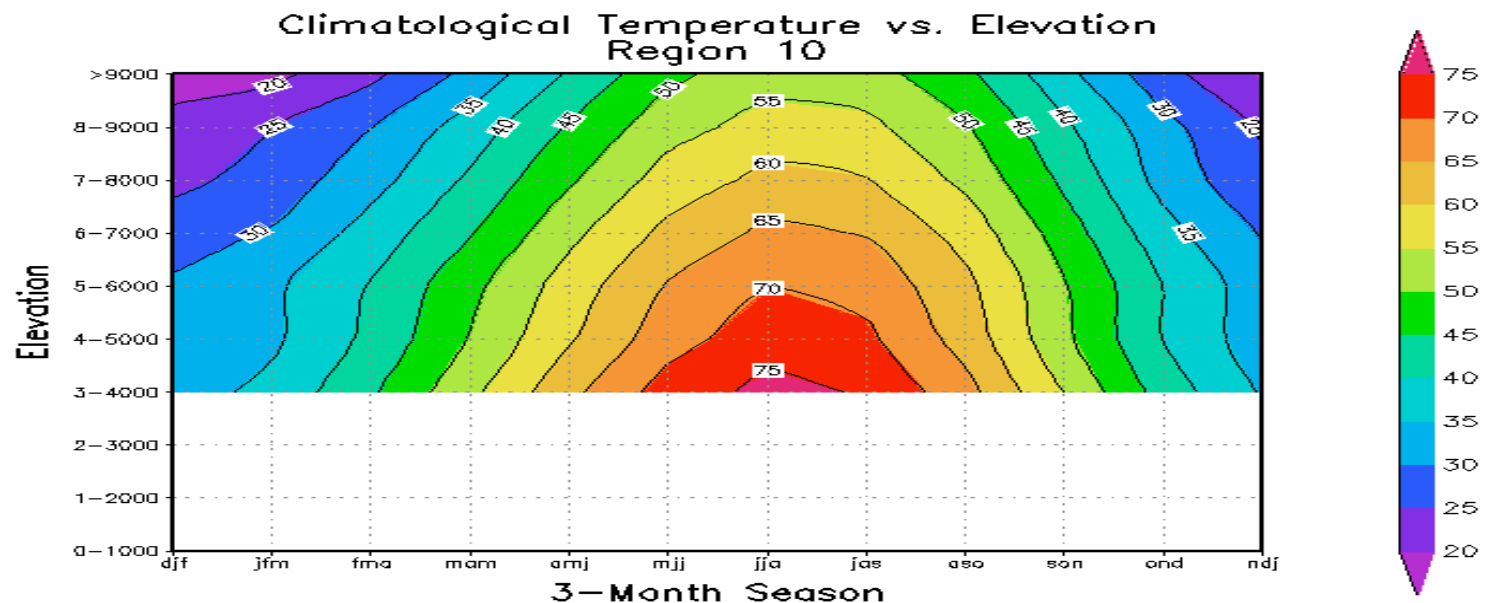
Are there north-south and east-west differences in the temporal behavior of the temperature and precipitation fields in West?



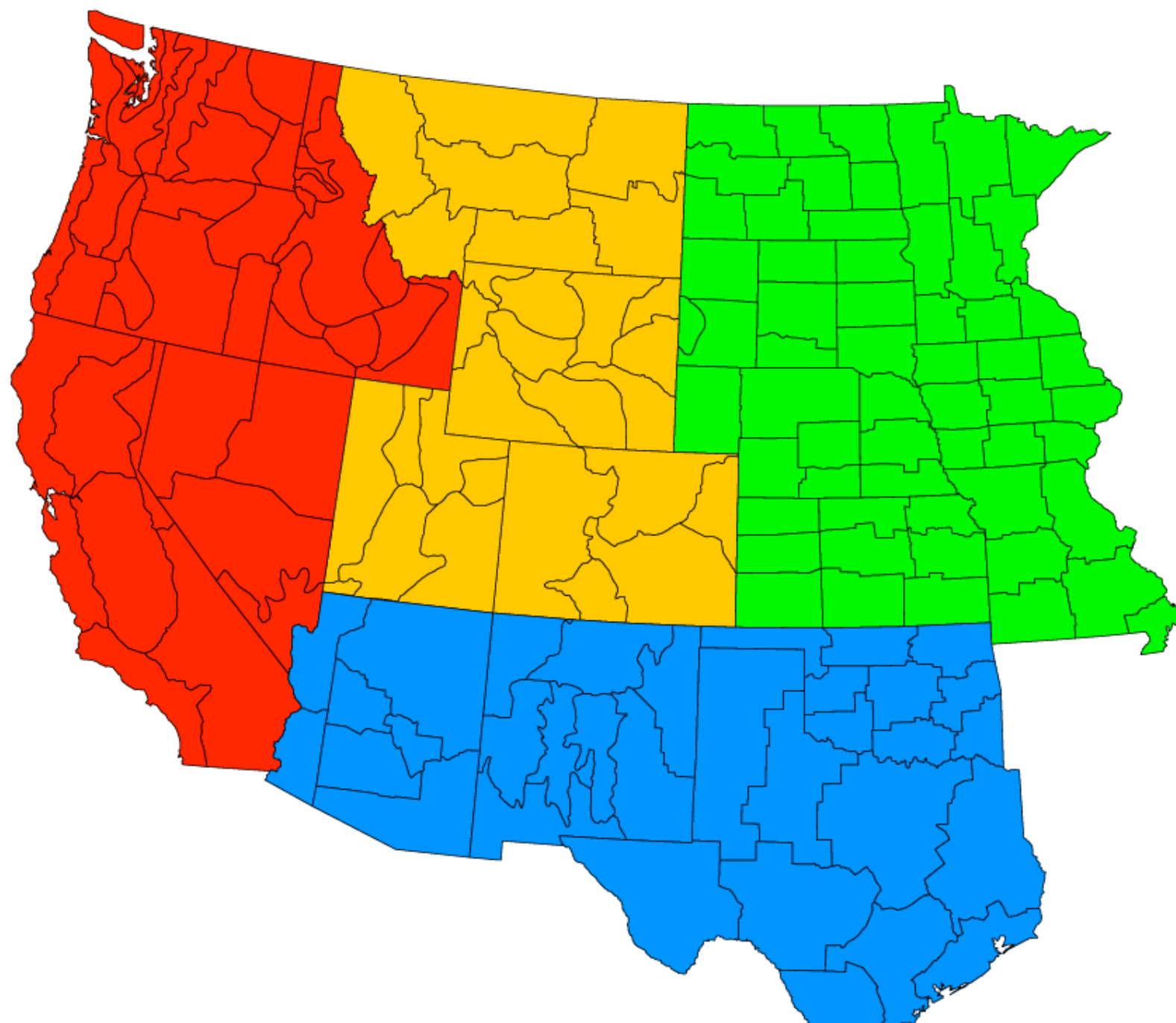


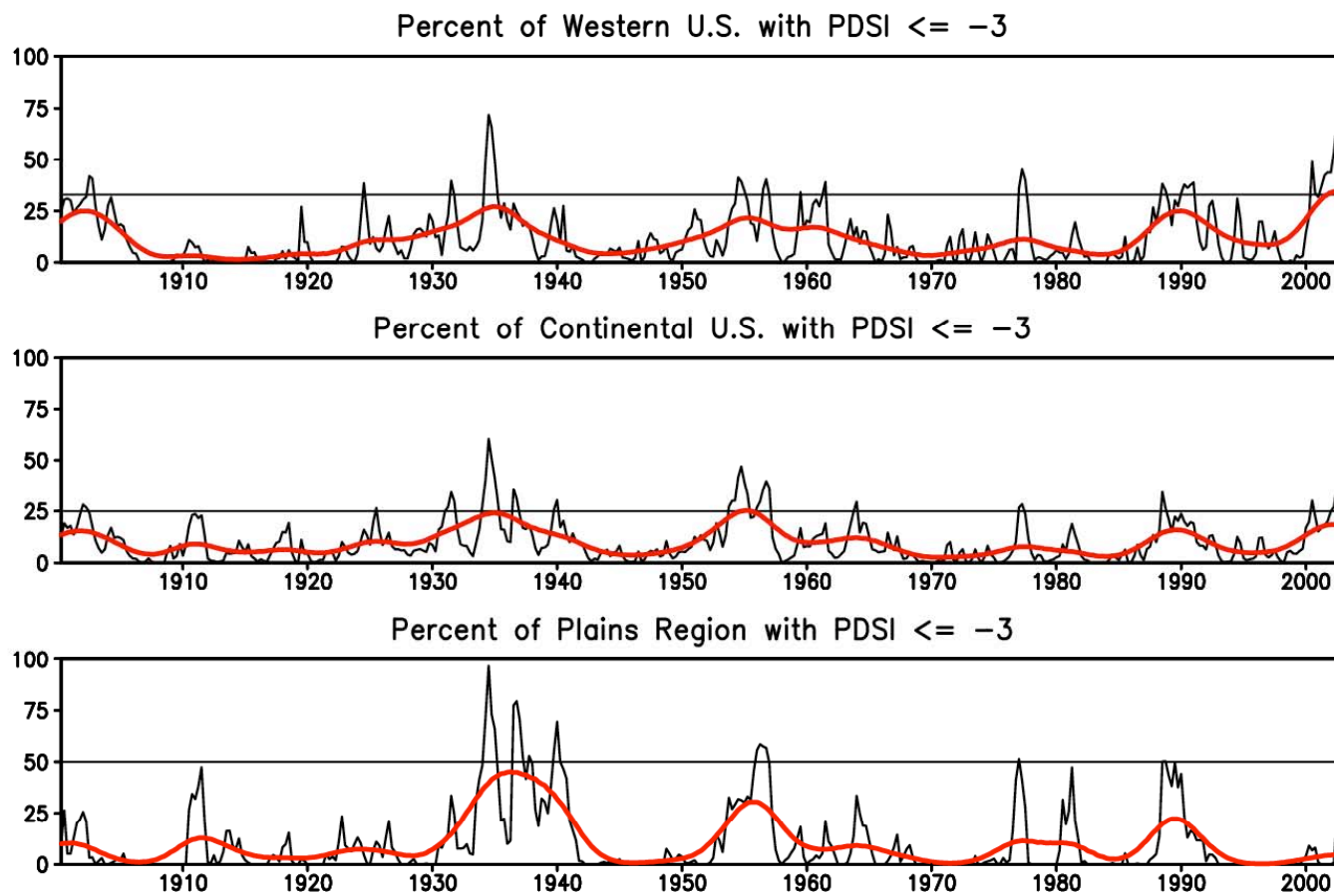
Cross-section of three Sky Islands “stacked” biotic communities varying with latitude. The Oposura Mts. in Mexico is more representative of Sierra Madre communities.

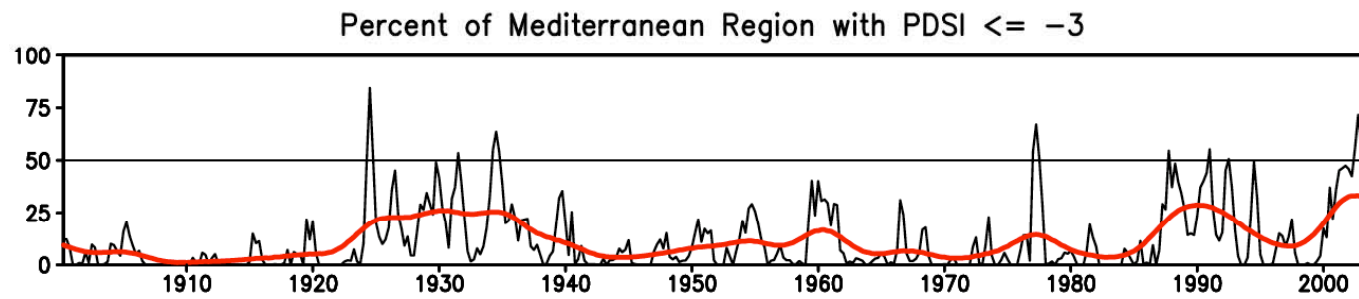
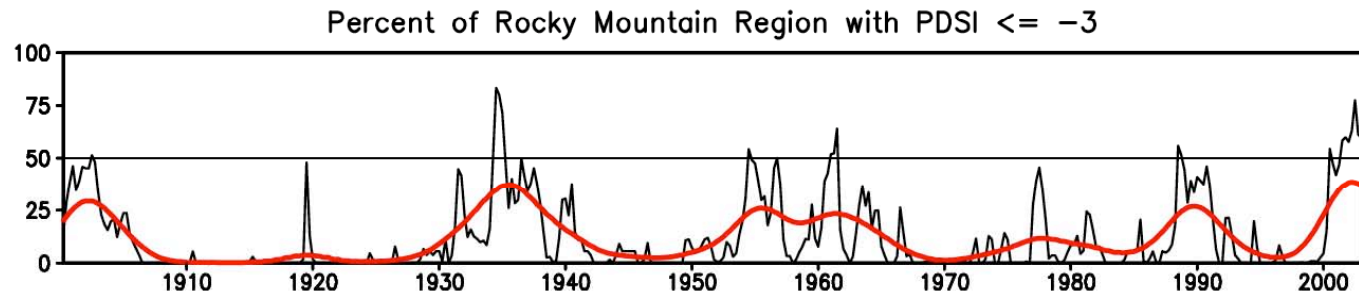
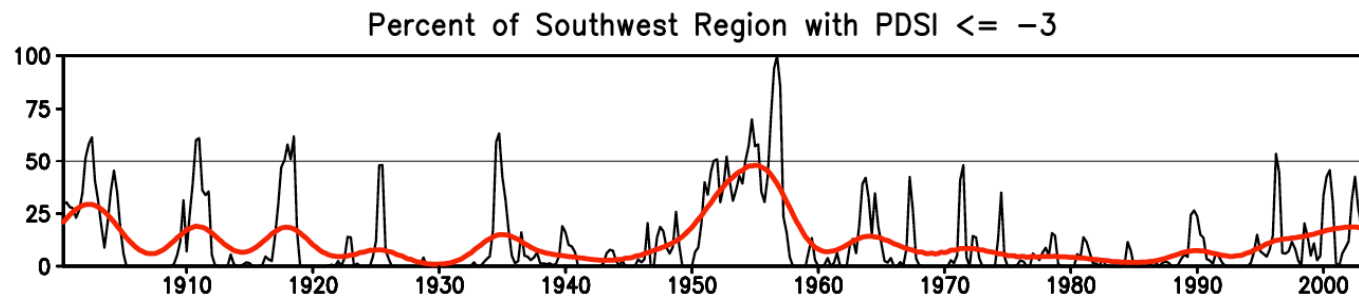




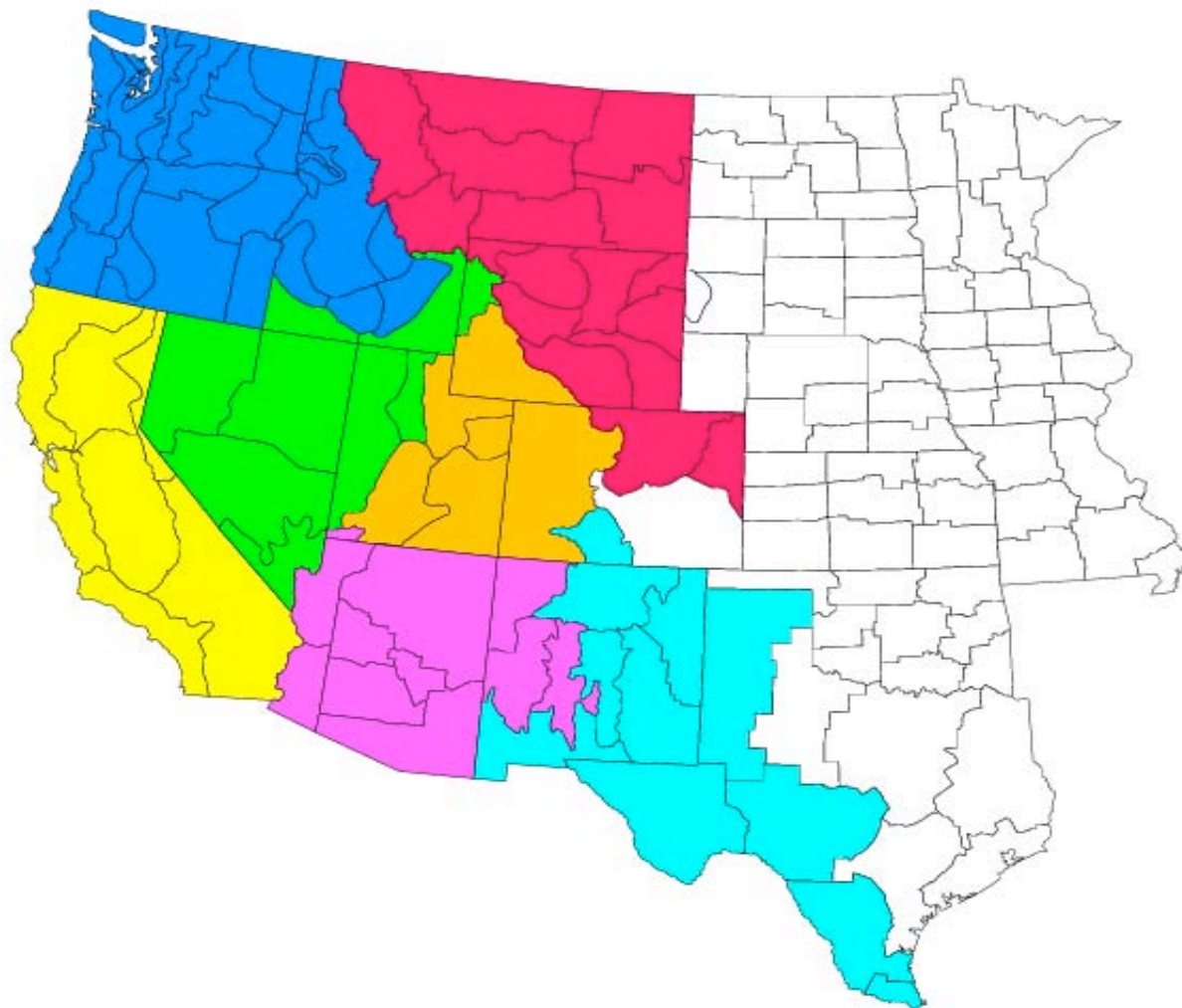
***CHANGES IN REGIONAL CLIMATE
OVER TIME***



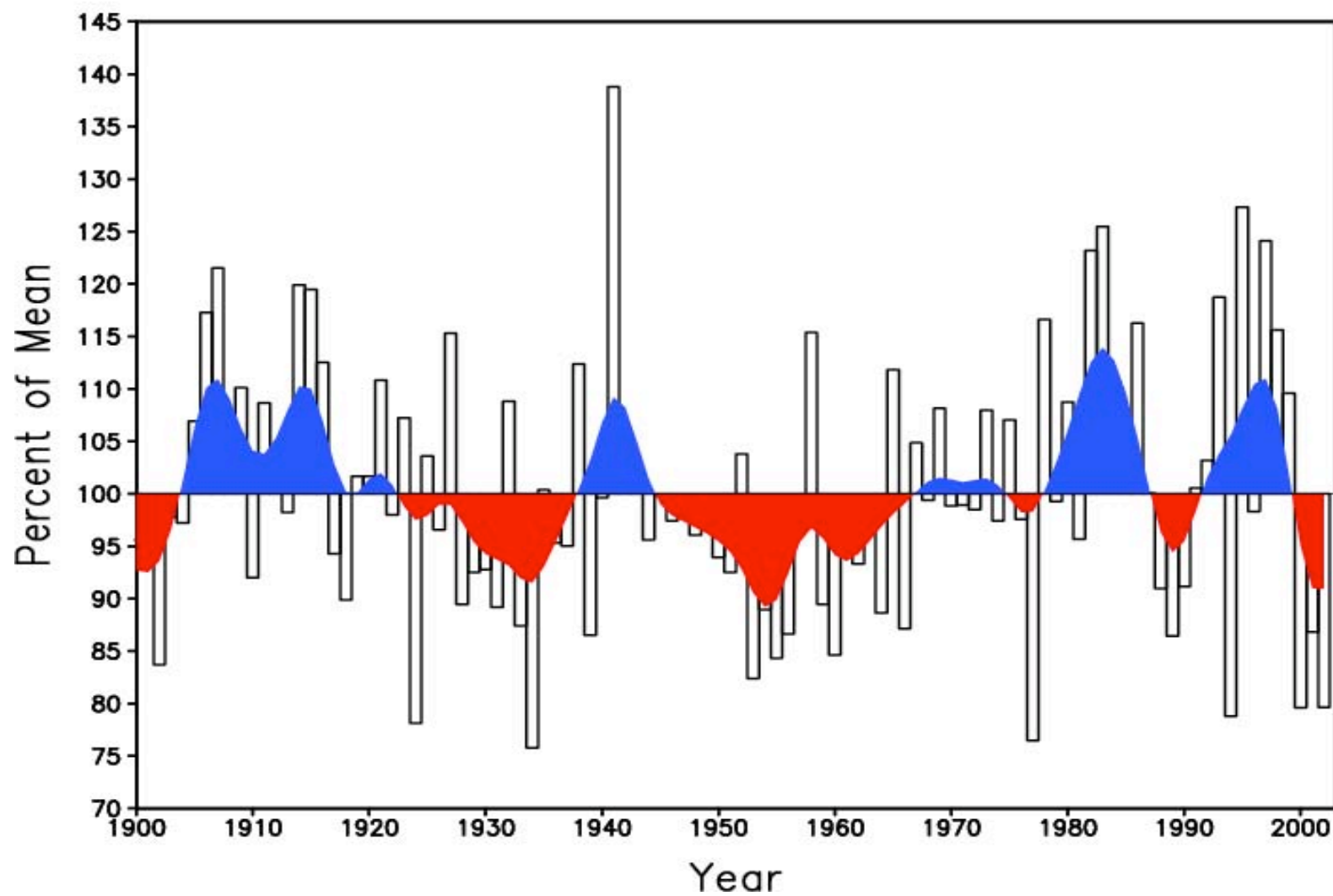




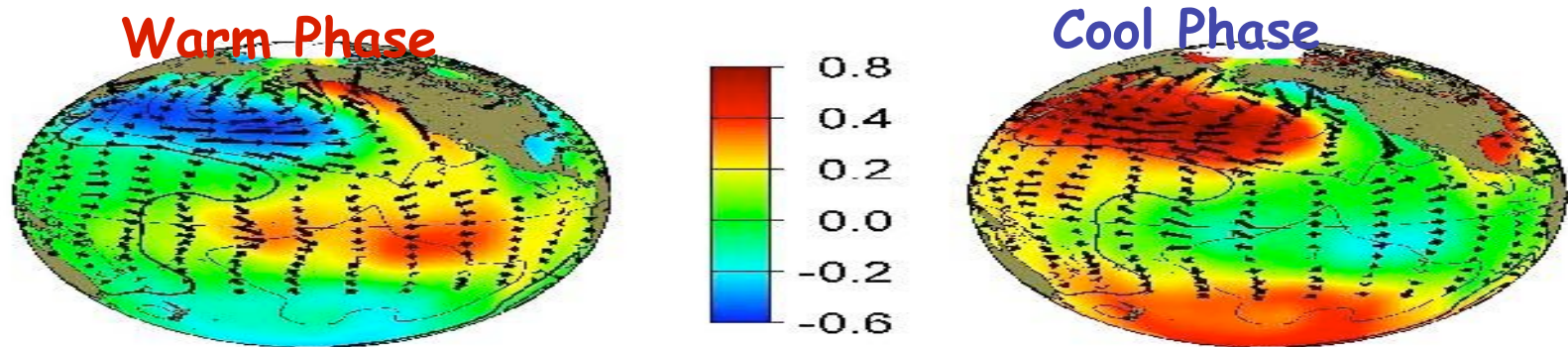
Western River Boundaries



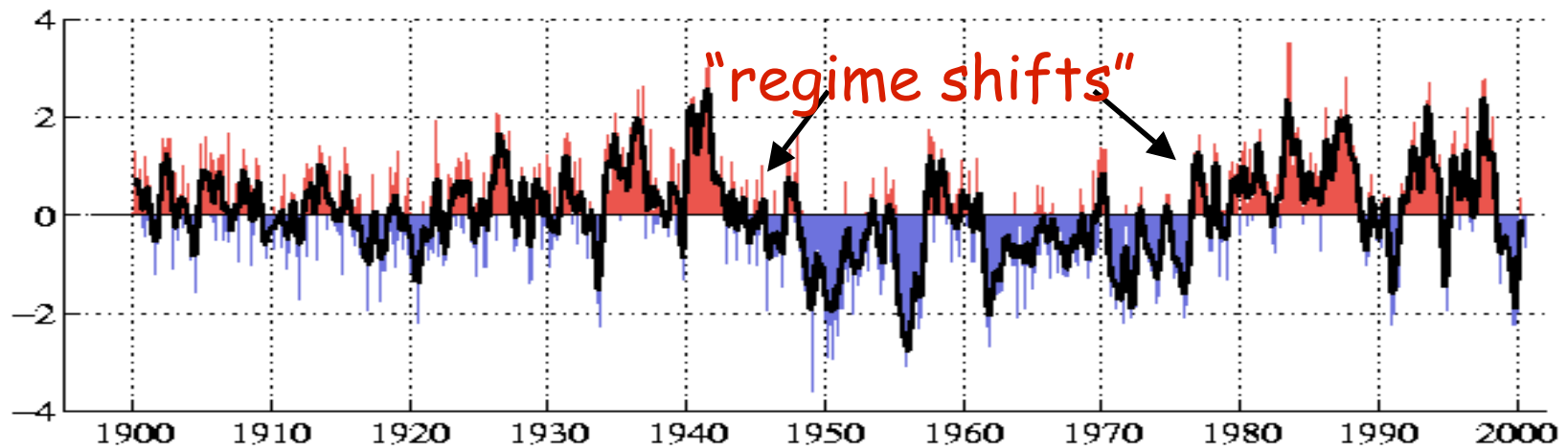
Seven Western Rivers Index
October–September: 1900–2002



Pacific Decadal Oscillation

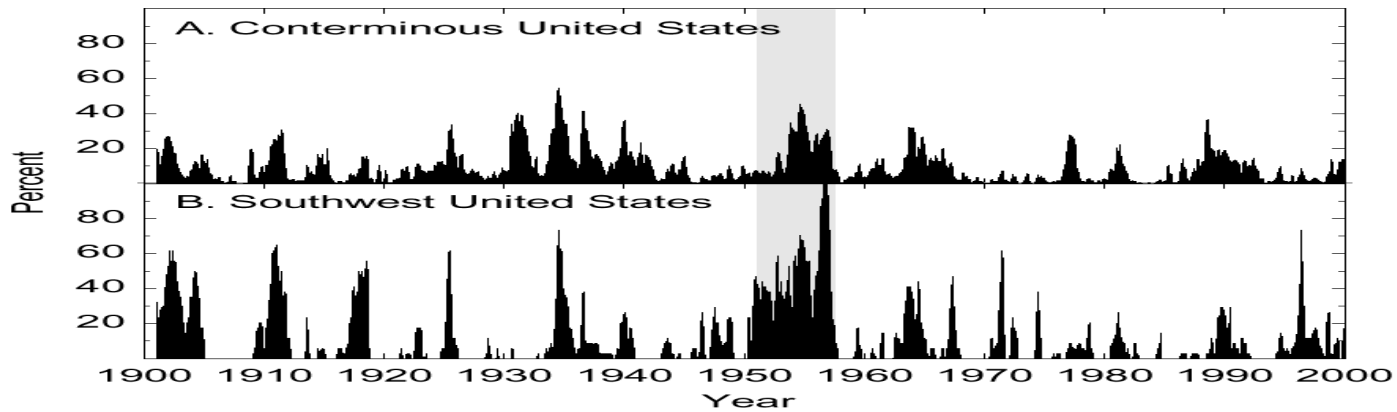


Monthly Values for the PDO Index, 1900-2000

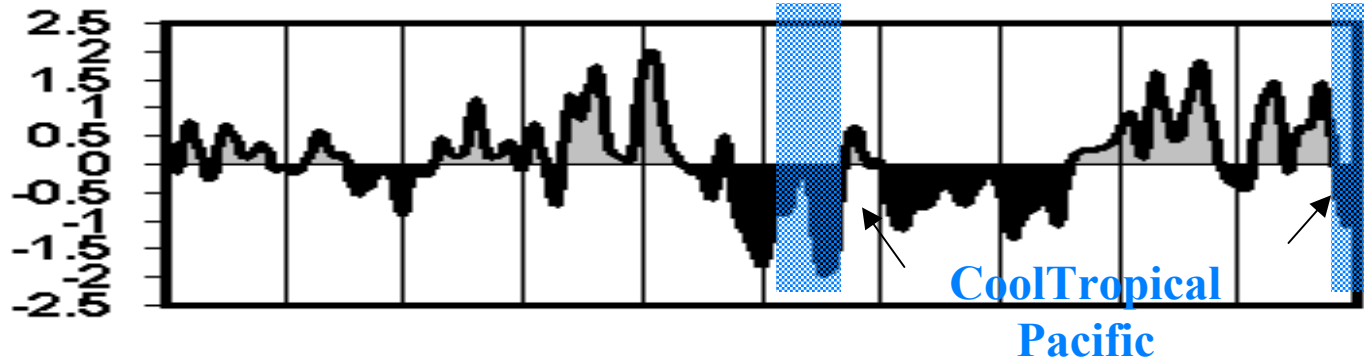


Ongoing shifts in Tropical Pacific & North Atlantic Ocean temperatures may foretell persistence of disastrous, multiyear droughts across the North American continent

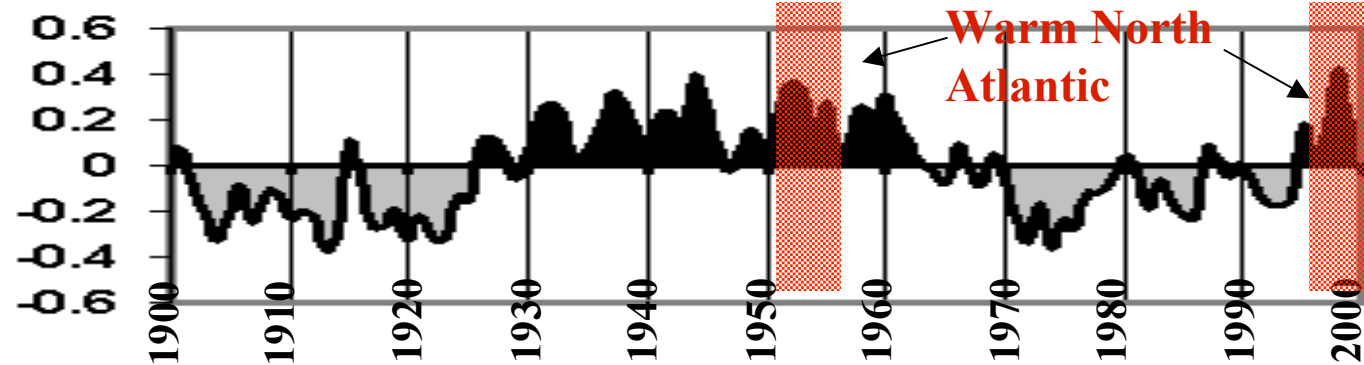
Percent Area in severe drought(PDSI<-0.3)



PDO Index

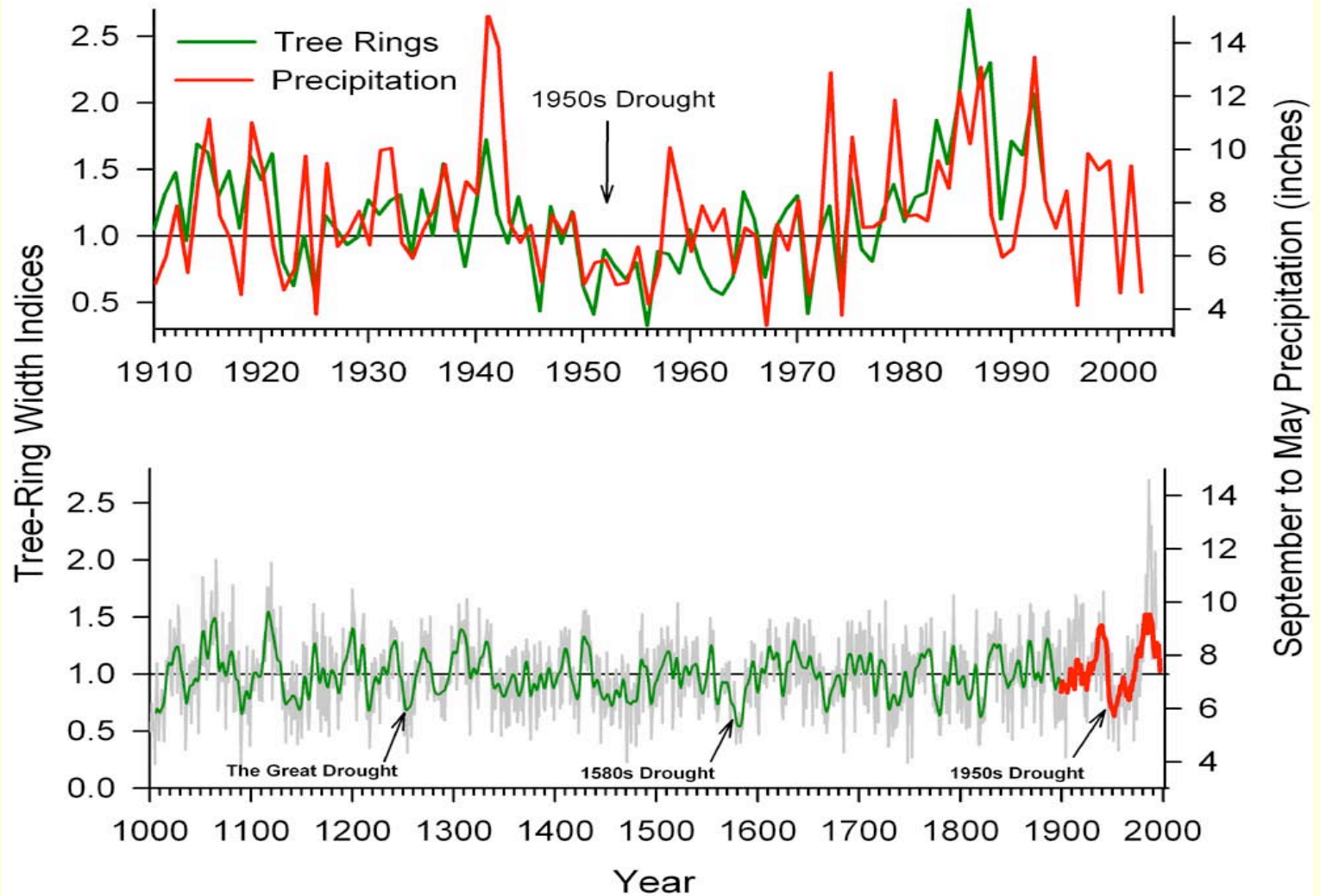


North Atlantic SSTA (°C)

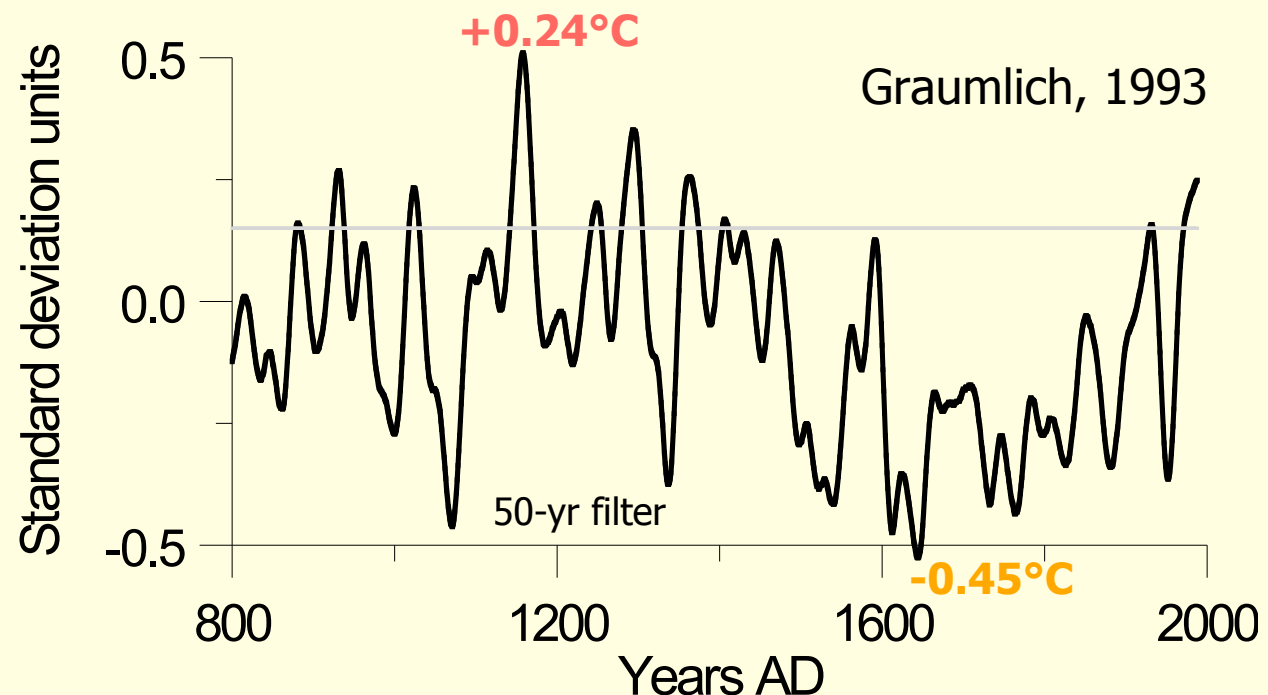


How bad can “bad” get?

Tree-Ring Reconstruction of Precipitation for the Southwest



Sierra Climate Estimated From Tree Rings – summer temperature.

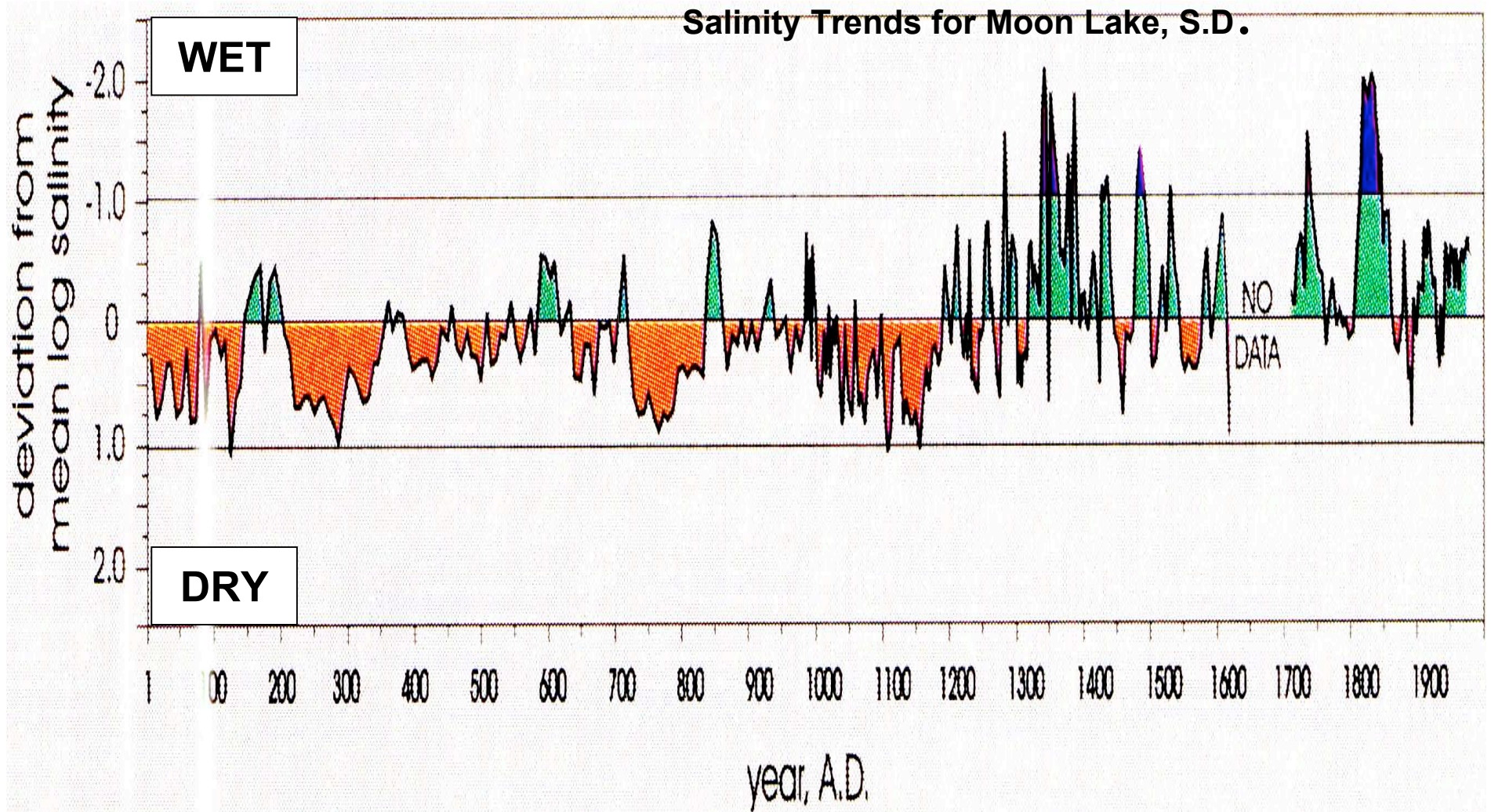


Numbers show deviation from 1928-1988 mean.

Warmer - earlier thaw, more evaporative loss?

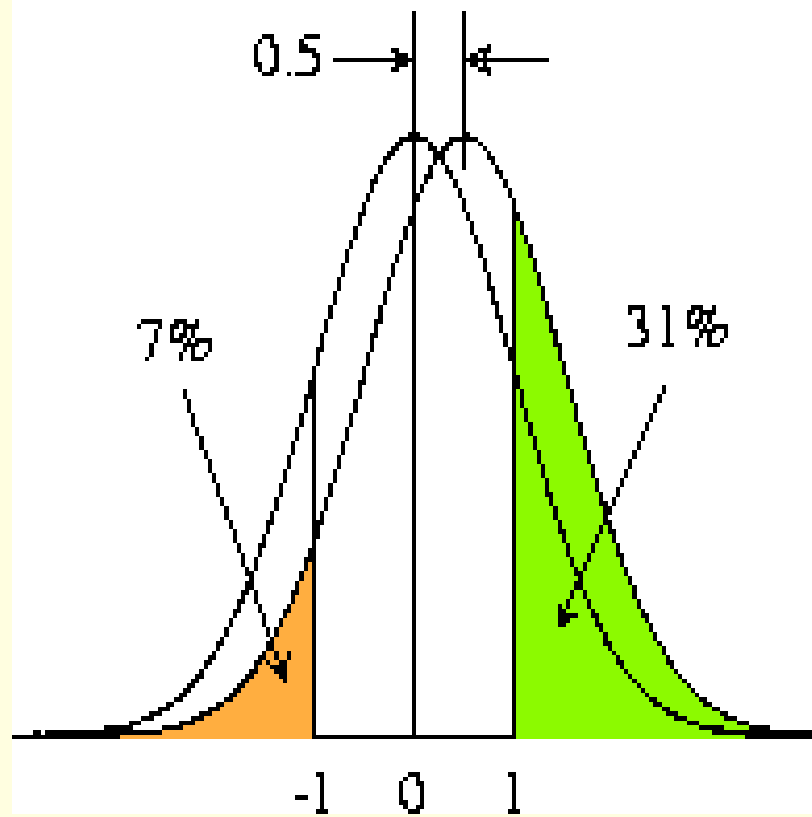
Changing dynamics of riverine systems?

Paleo records suggest dry periods have been common in central North America in the past

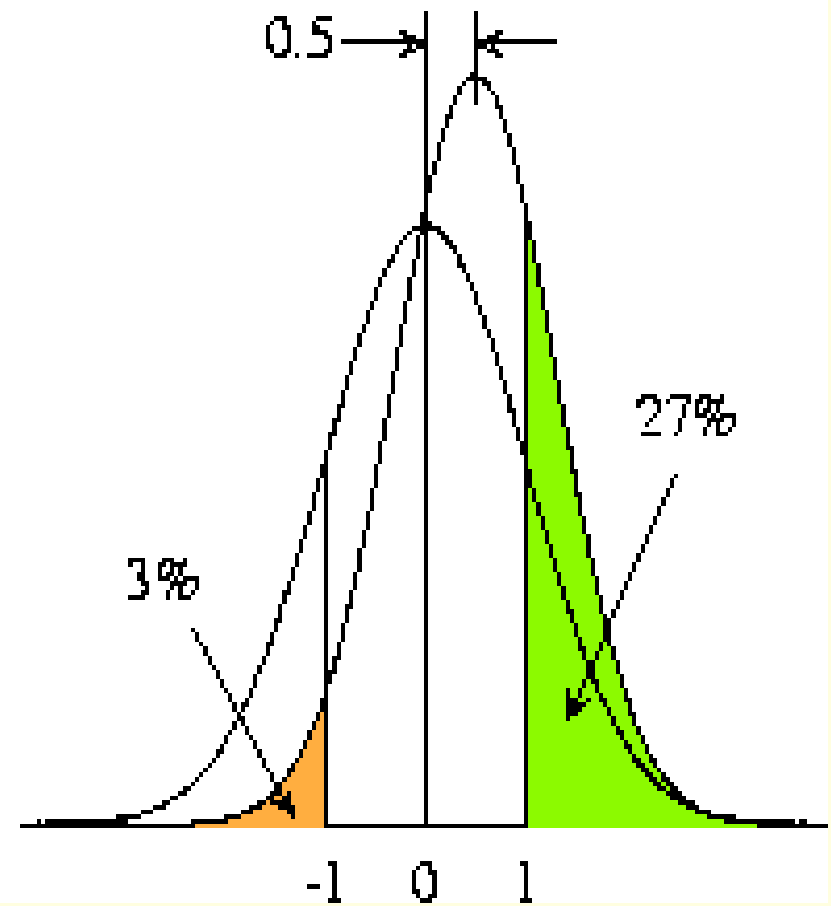


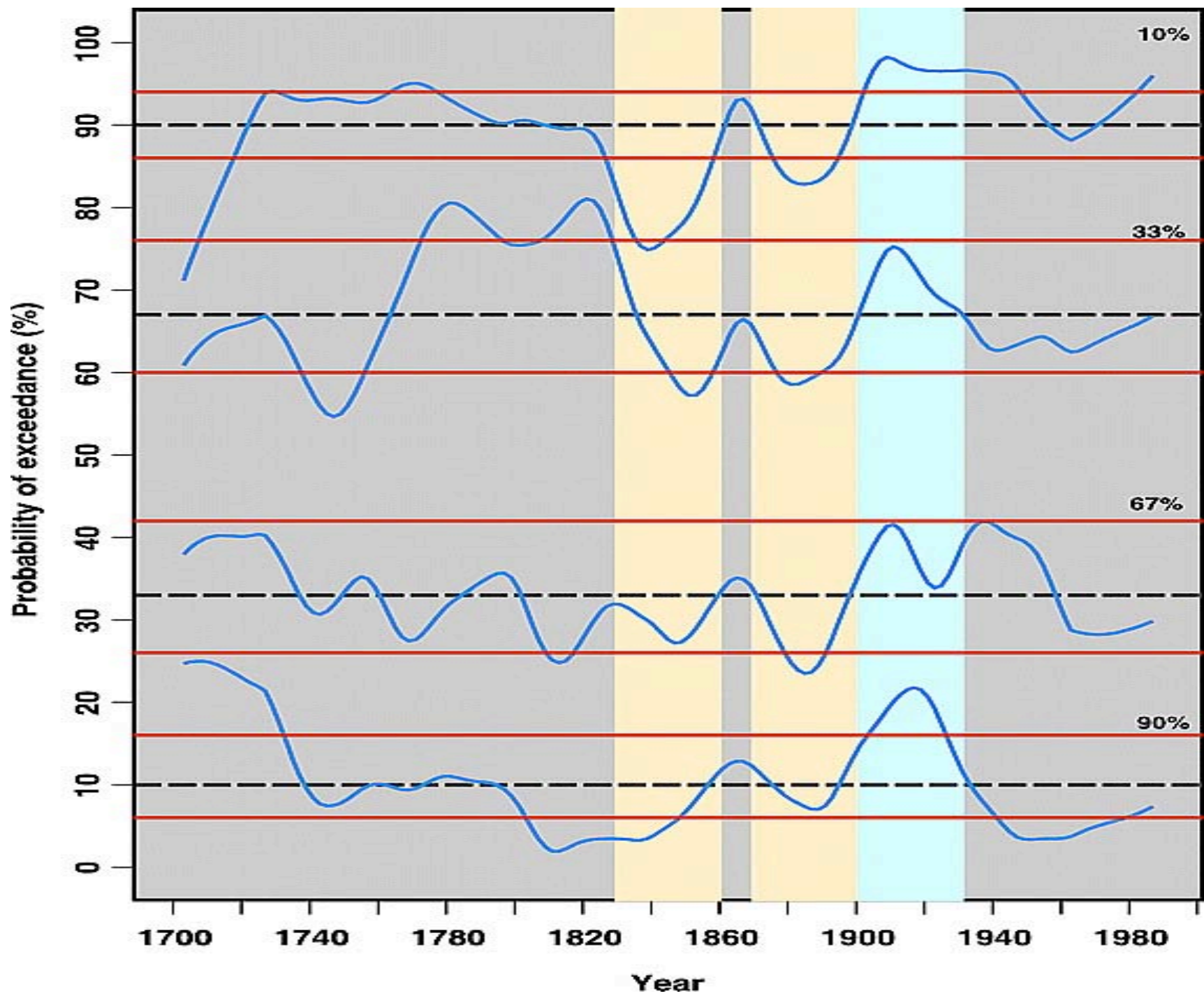
Effect of changing probability distributions on event frequency

(a) shift of PDF only

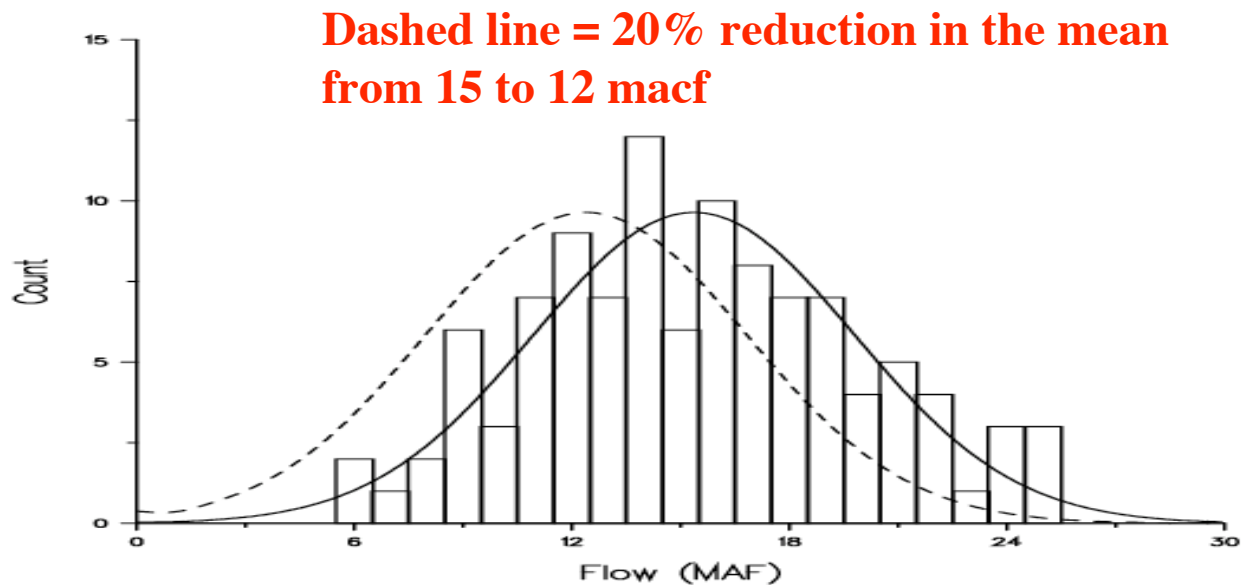


(b) shift with change of spread

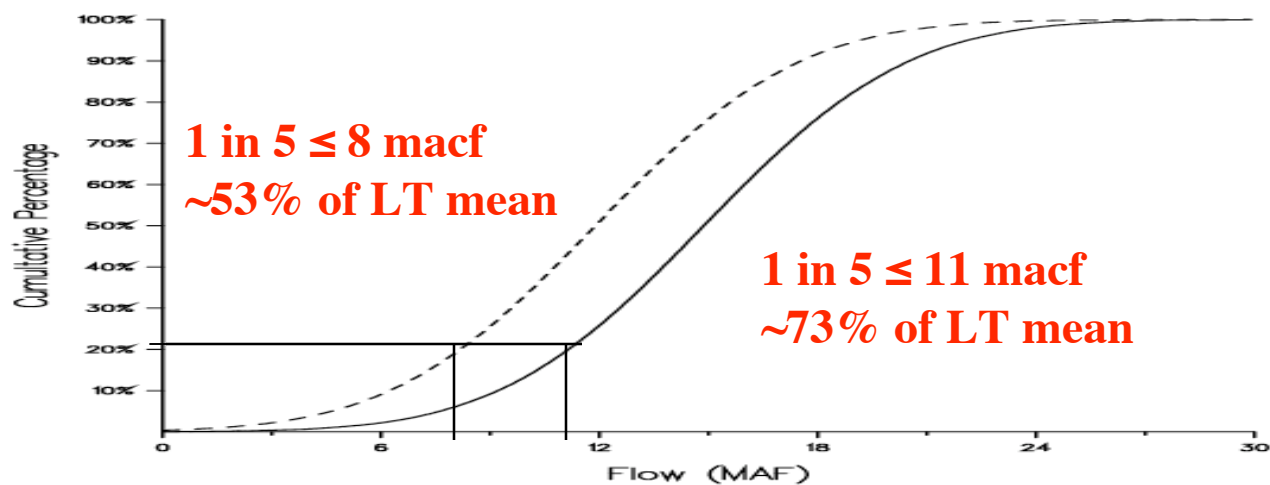


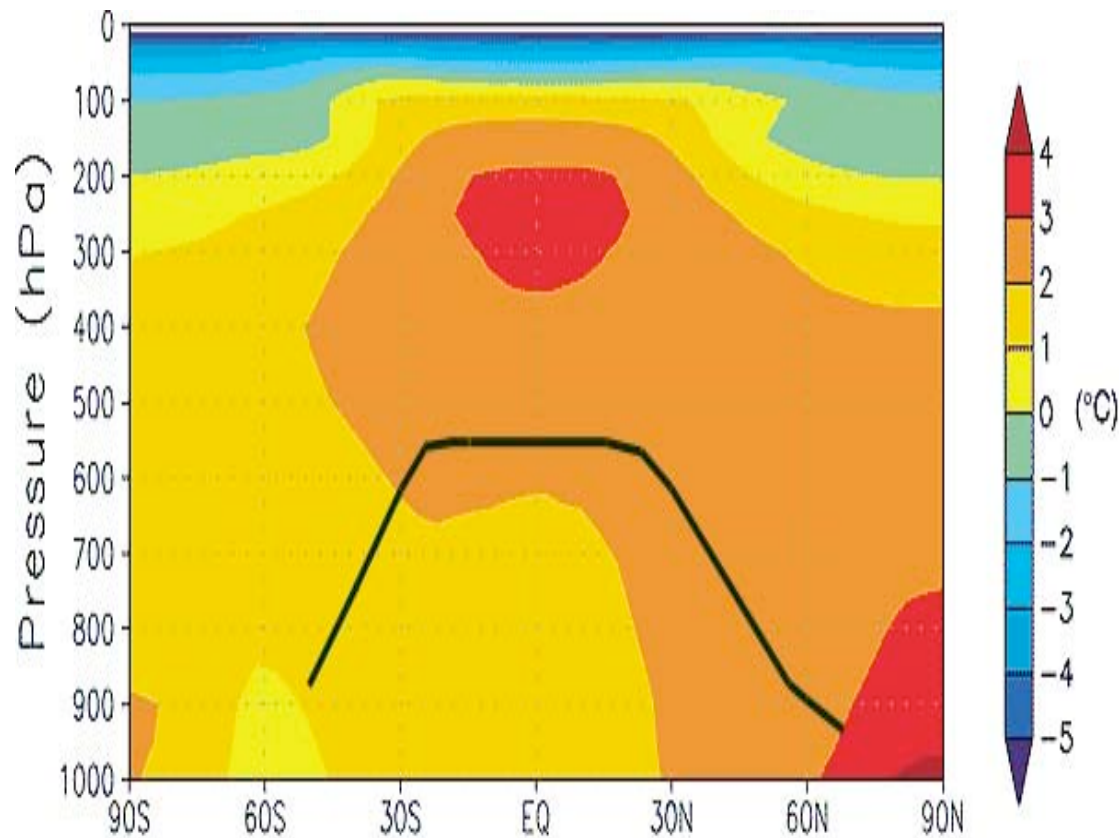


Distribution of Annual
Lees Ferry Streamflow (MAF)



Cumulative Distribution of Annual
Lees Ferry Streamflow (MAF)

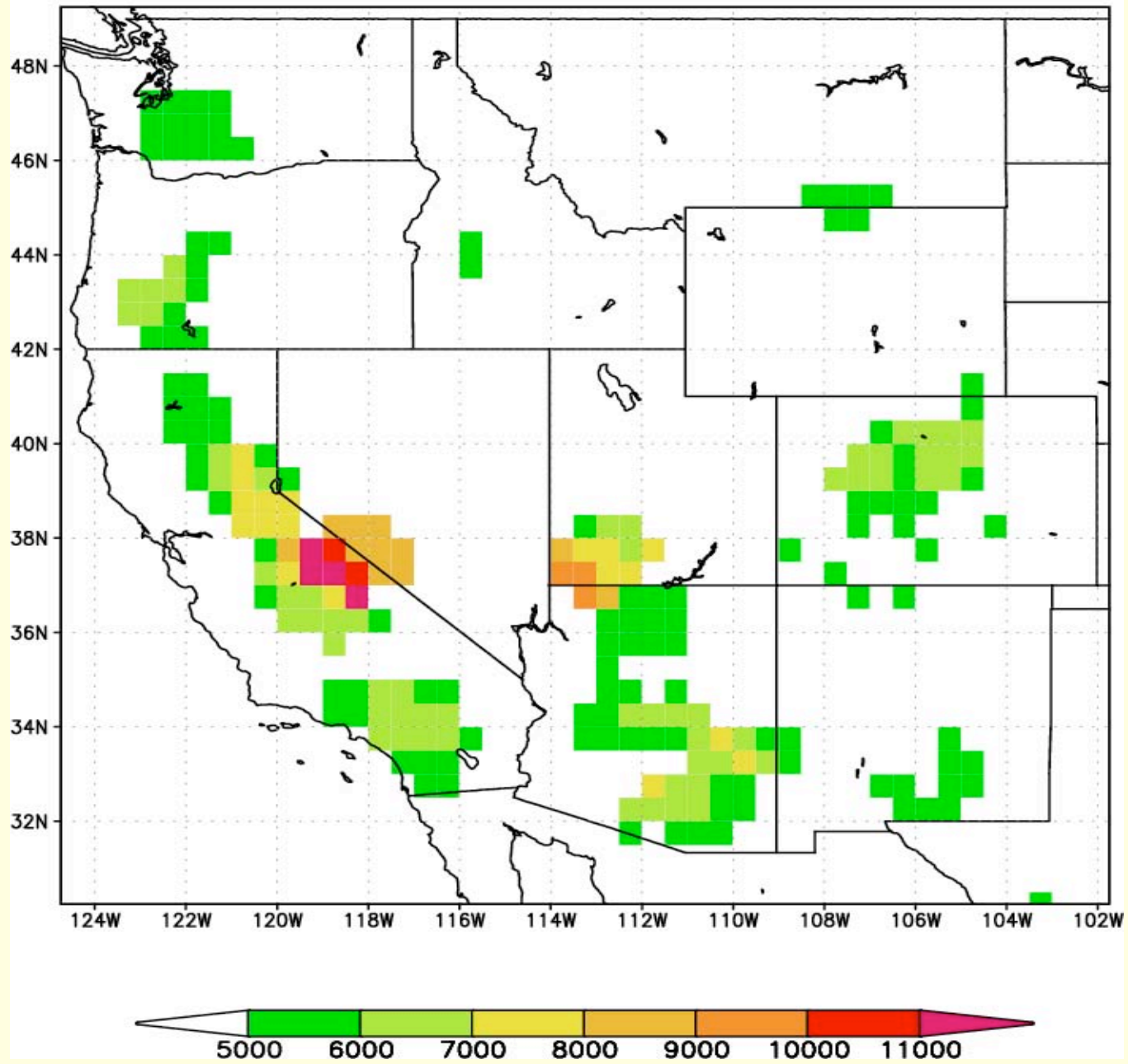


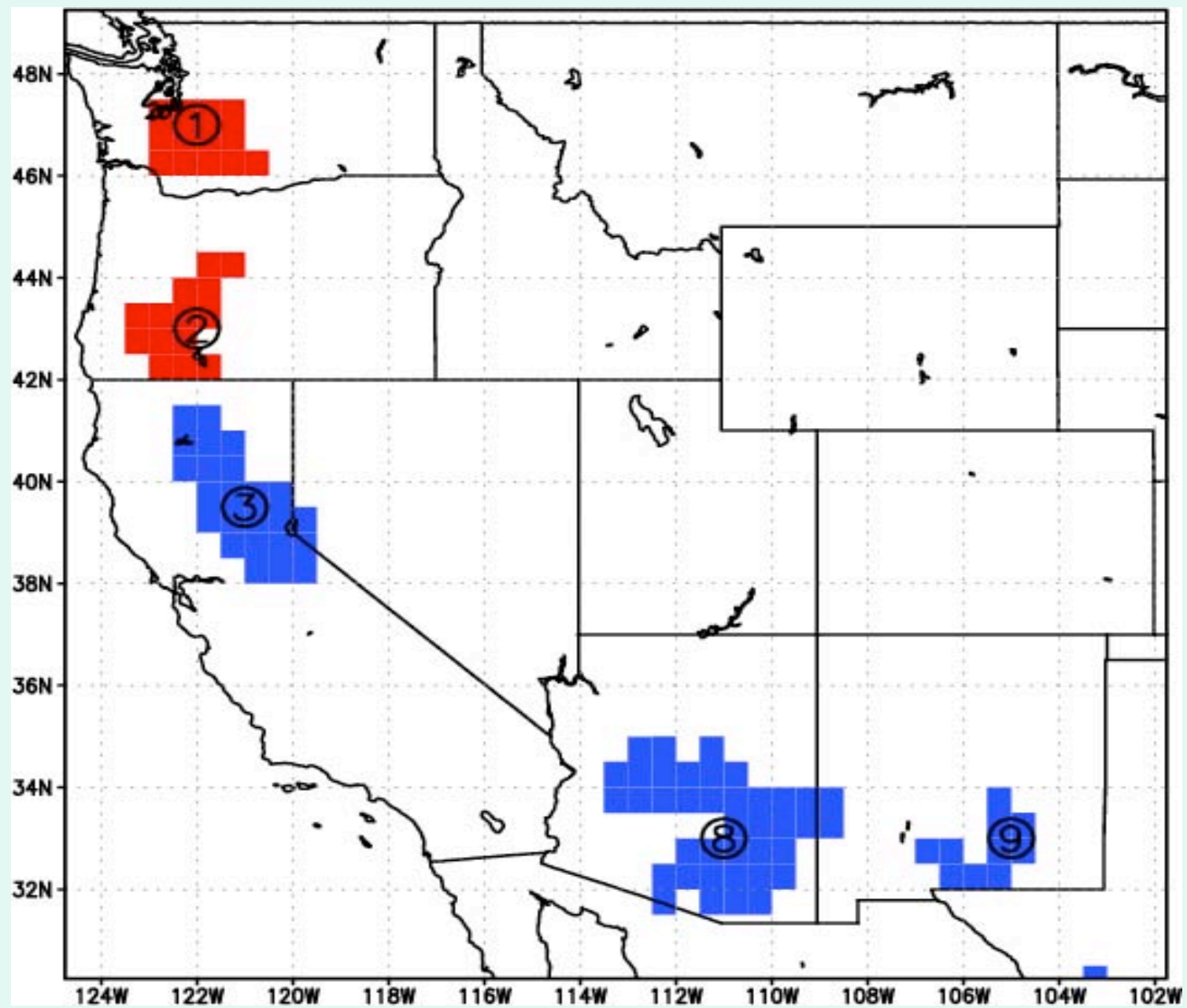


IPCC 2001: Zonal mean temperature change

**From: IPCC (2001), p. 544
2xCO₂ CMIP2 averages**

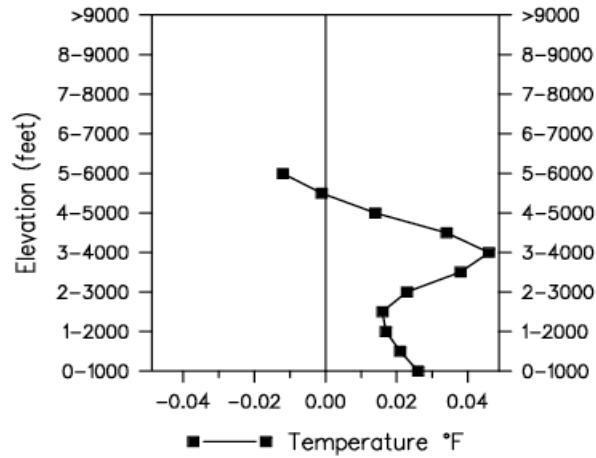
Elevation Range



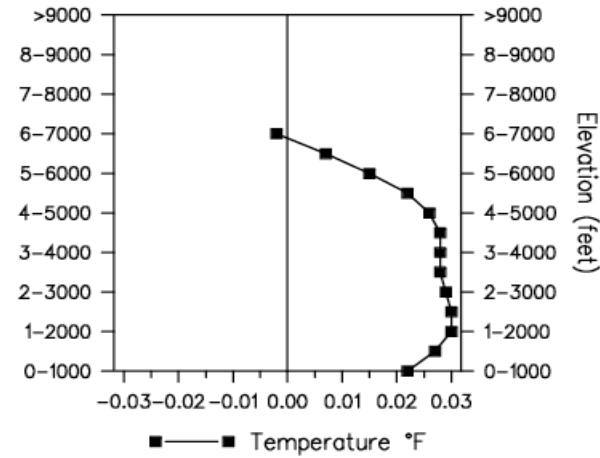


50yr Annual Temperature Trends by Elevation

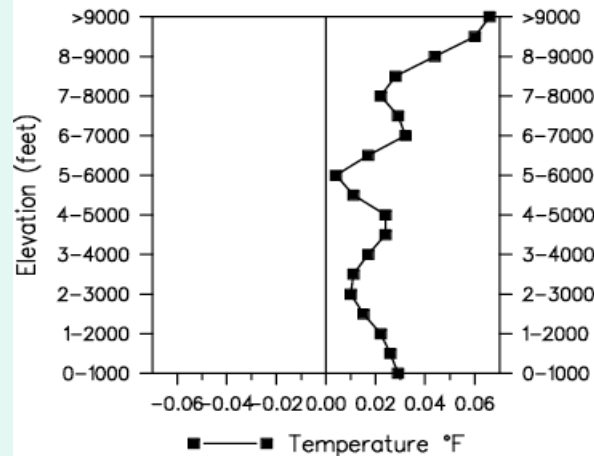
Region 1



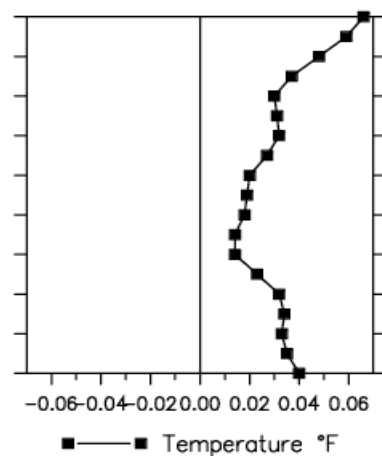
Region 2



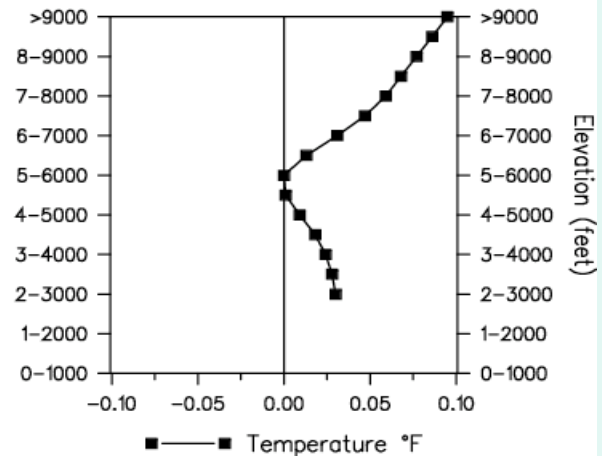
Region 3



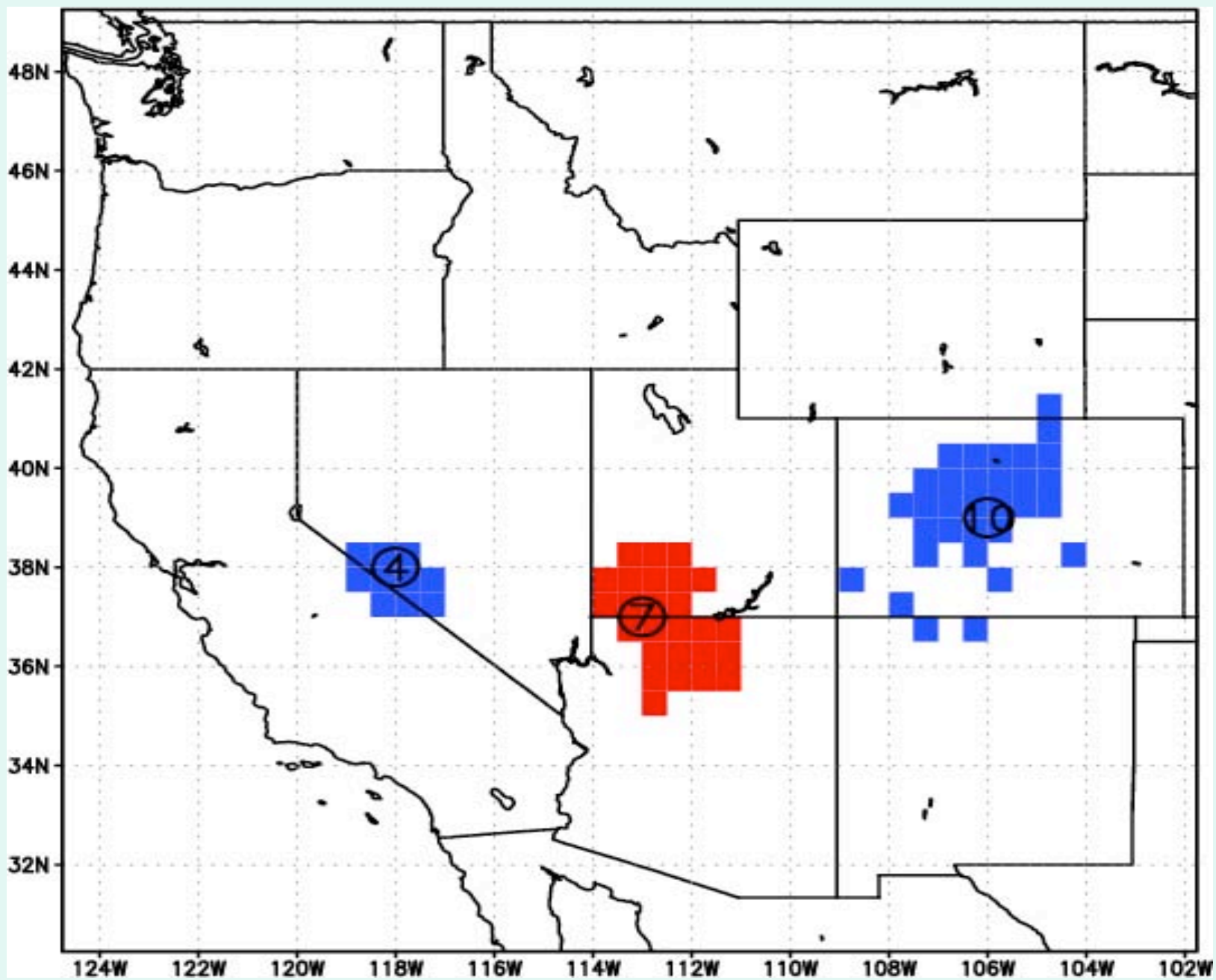
Region 8



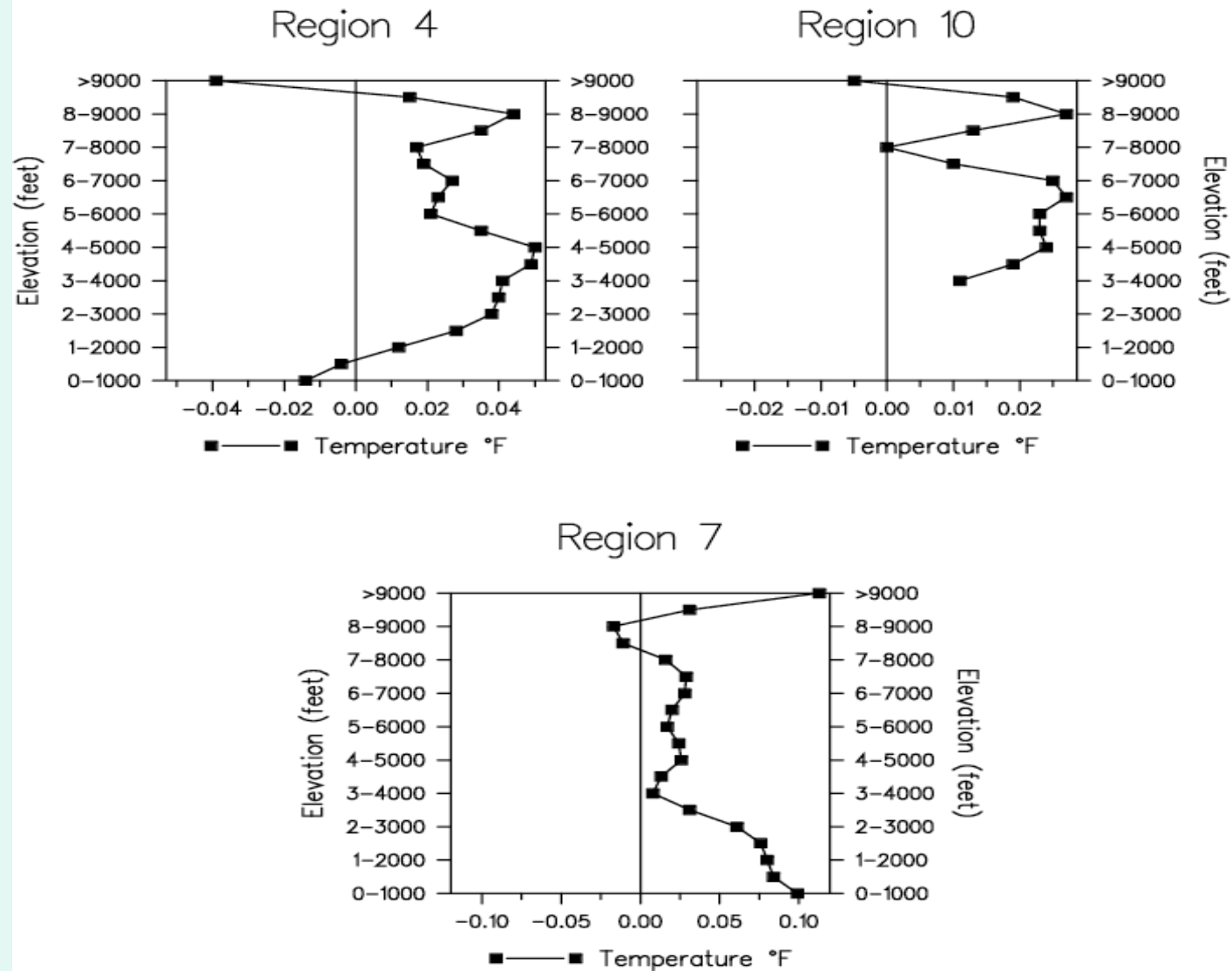
Region 9



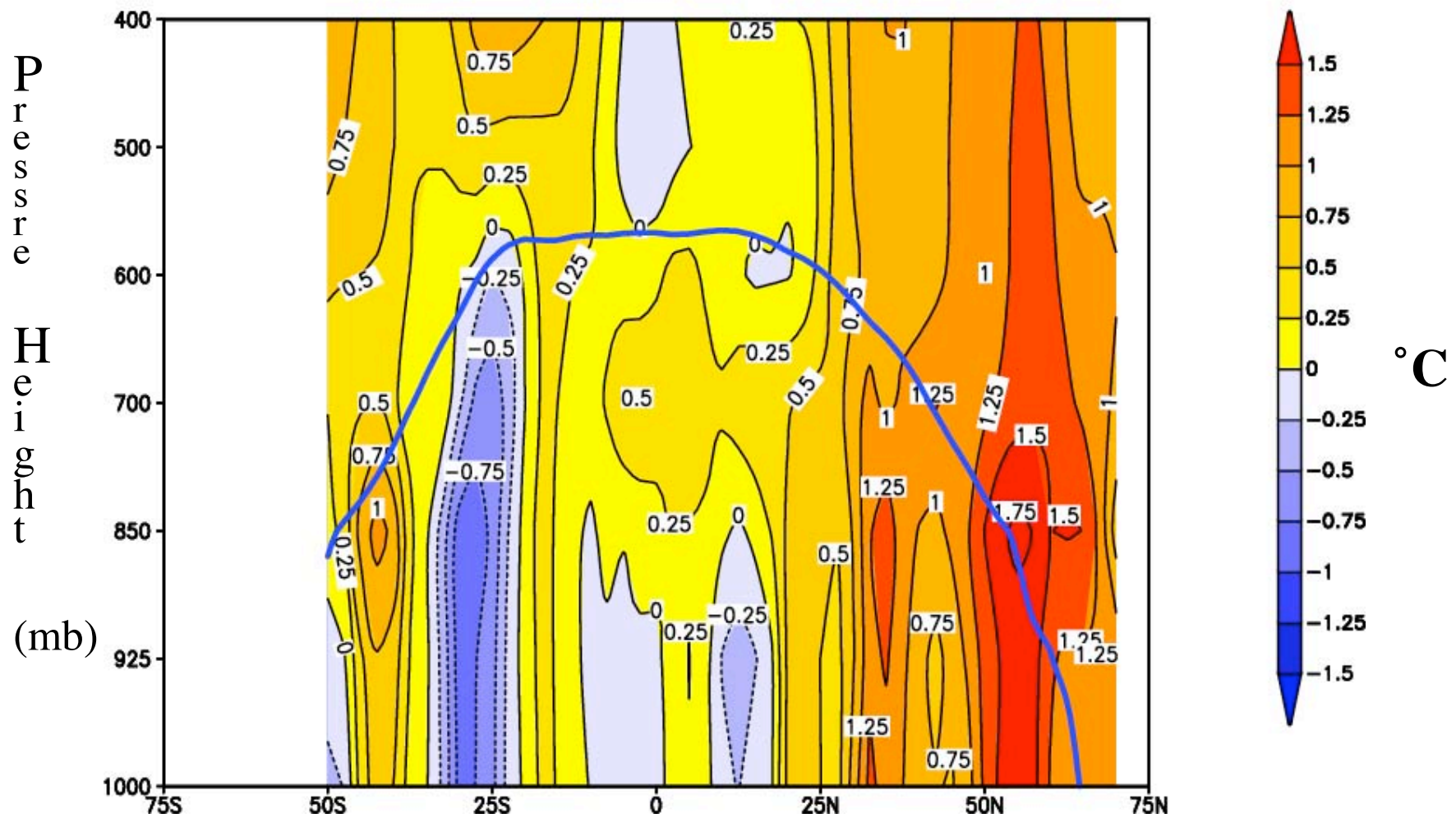
Linear Trends in °F/year

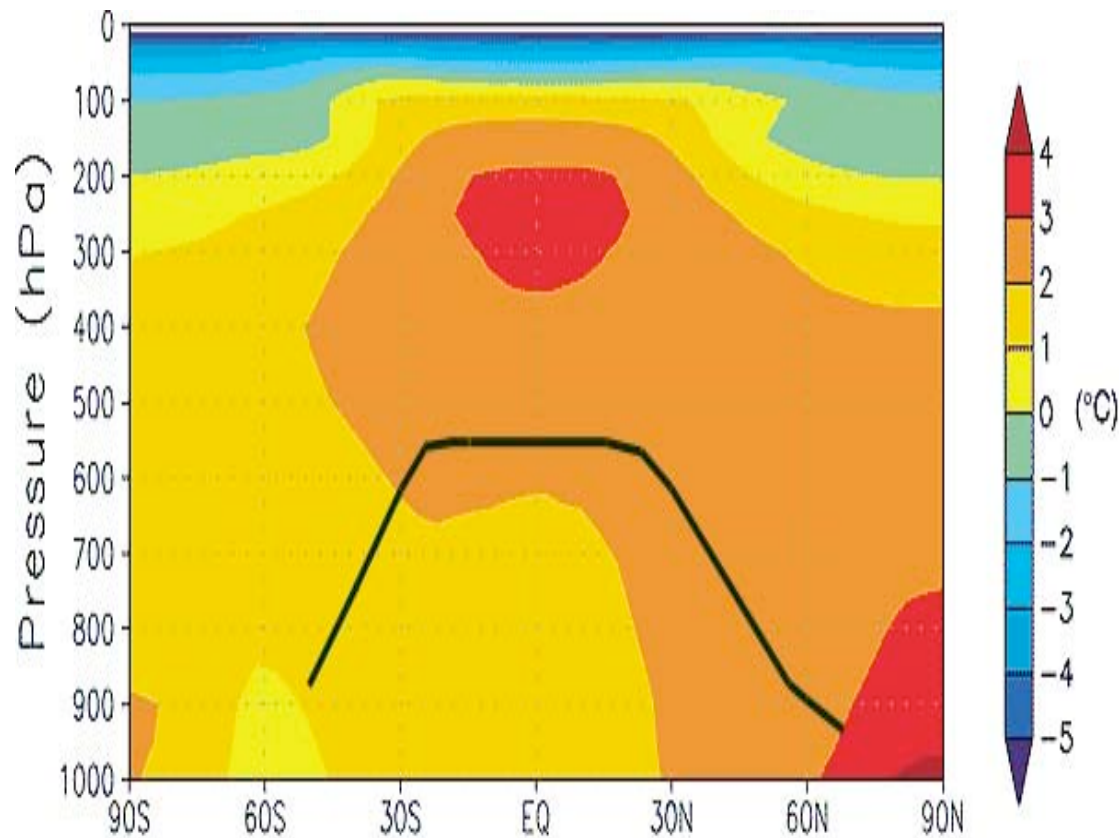


50yr Annual Temperature Trends by Elevation



Change in Annual Temperature over the American Cordillera for the Period 1970–2000

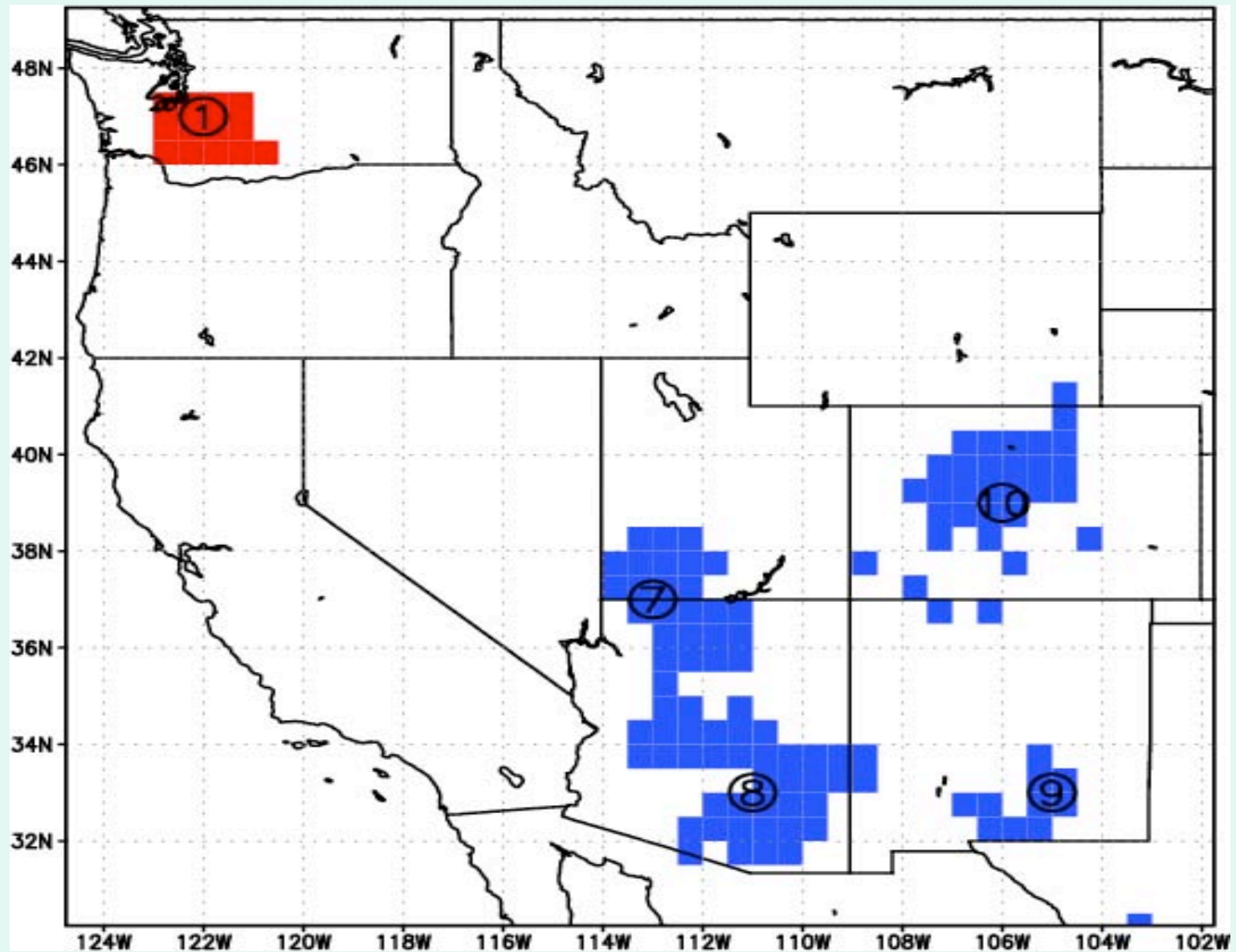




**IPCC 2001:
Zonal mean
temperature change**

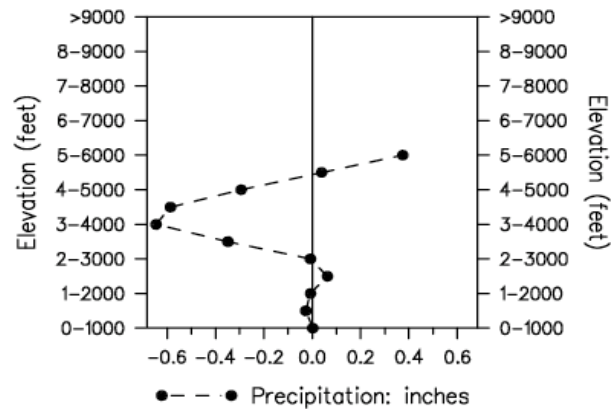
**From: IPCC (2001), p. 544
2xCO₂ CMIP2 averages**

Precipitation Trends

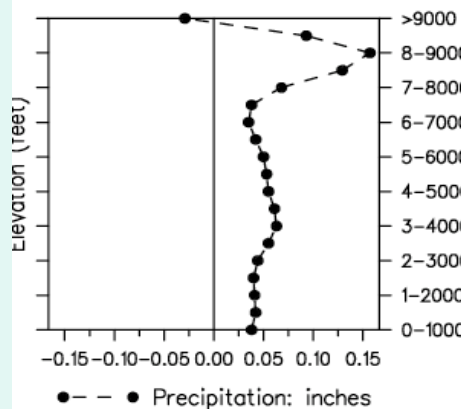


50yr Annual Precipitation Trends by Elevation

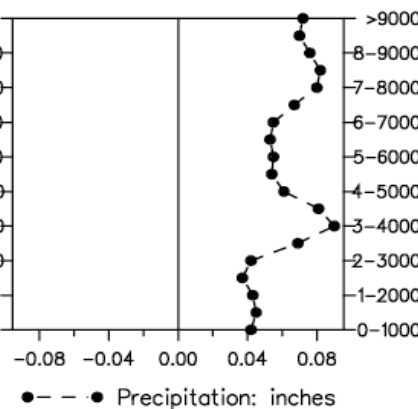
Region 1



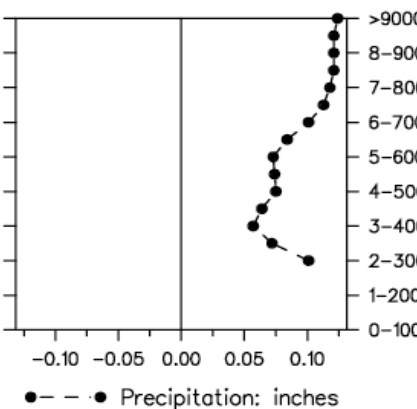
Region 7



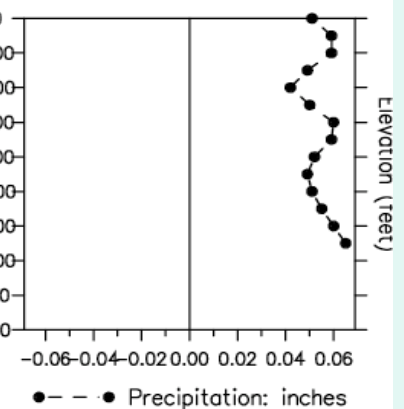
Region 8



Region 9



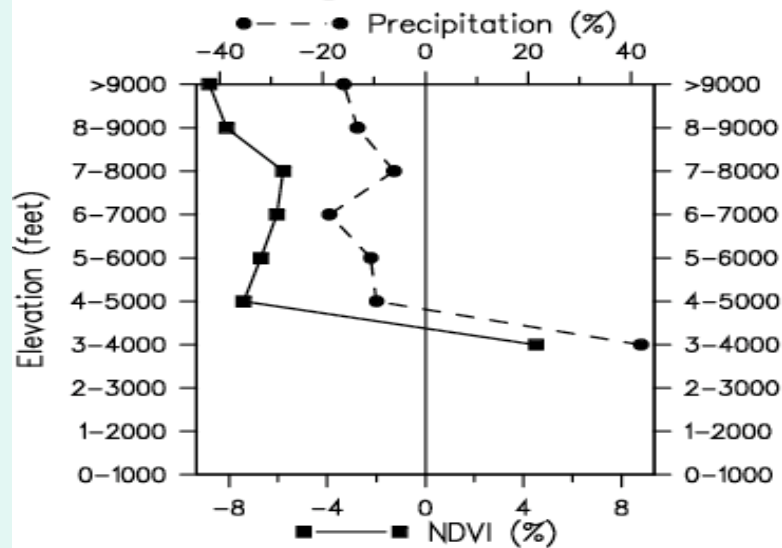
Region 10



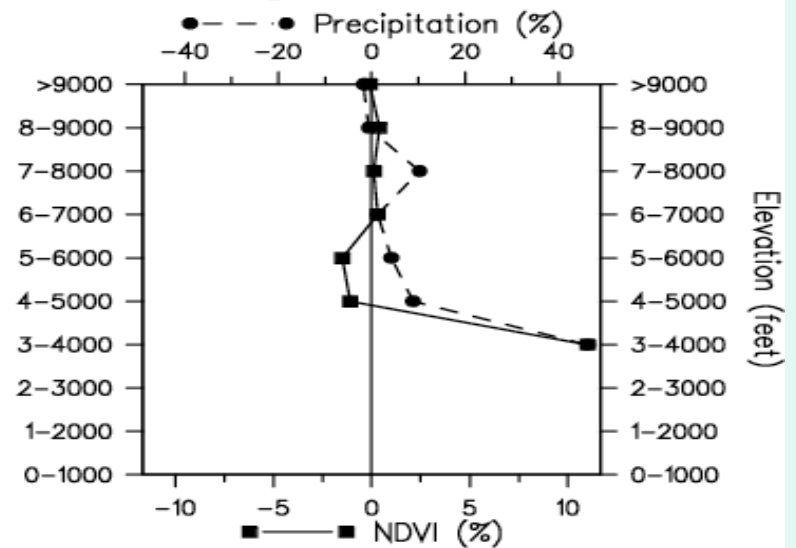
Linear Trends in inches/year

NDVI and Precipitation Trends by Elevation (1981–2000)

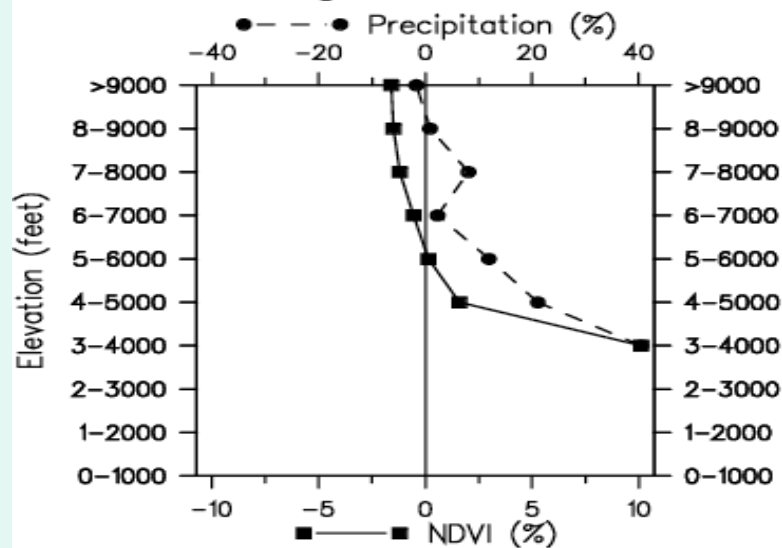
Region 10: MJJ



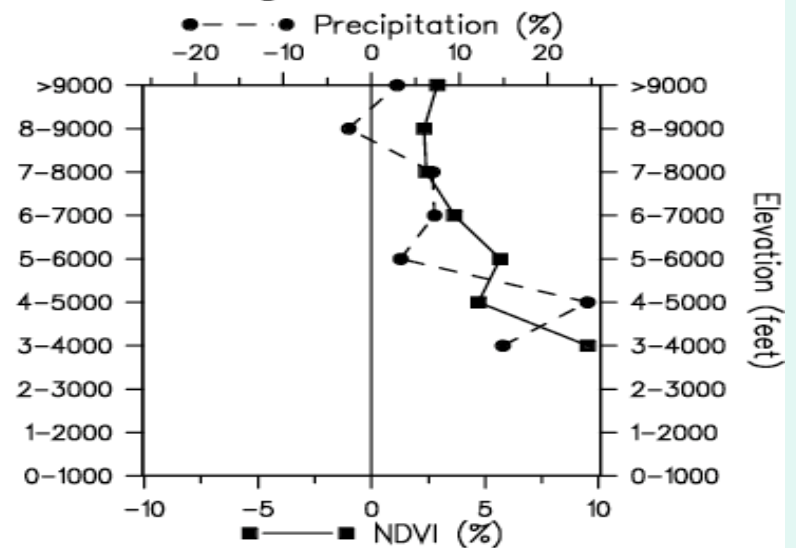
Region 10: JJA



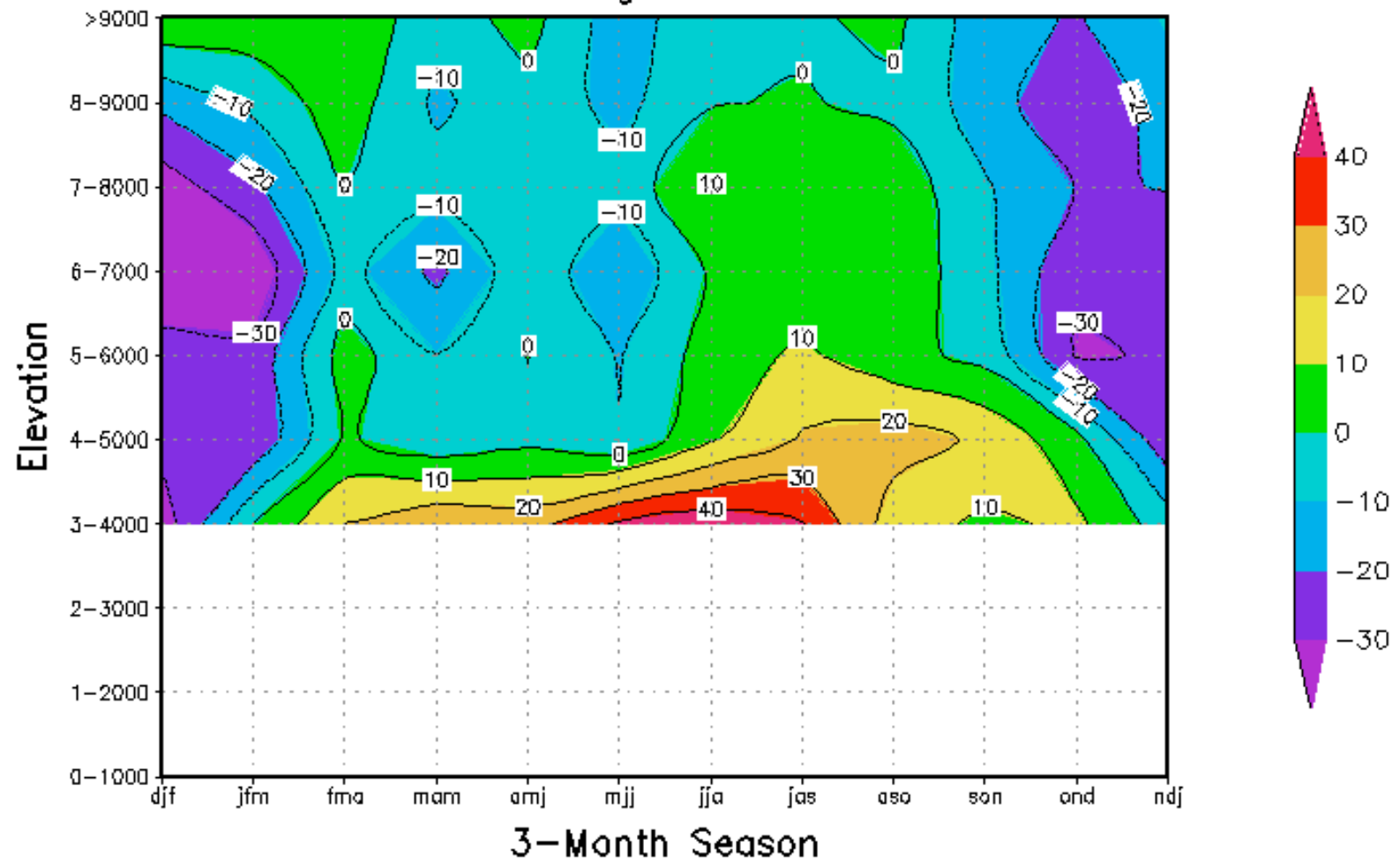
Region 10: JAS



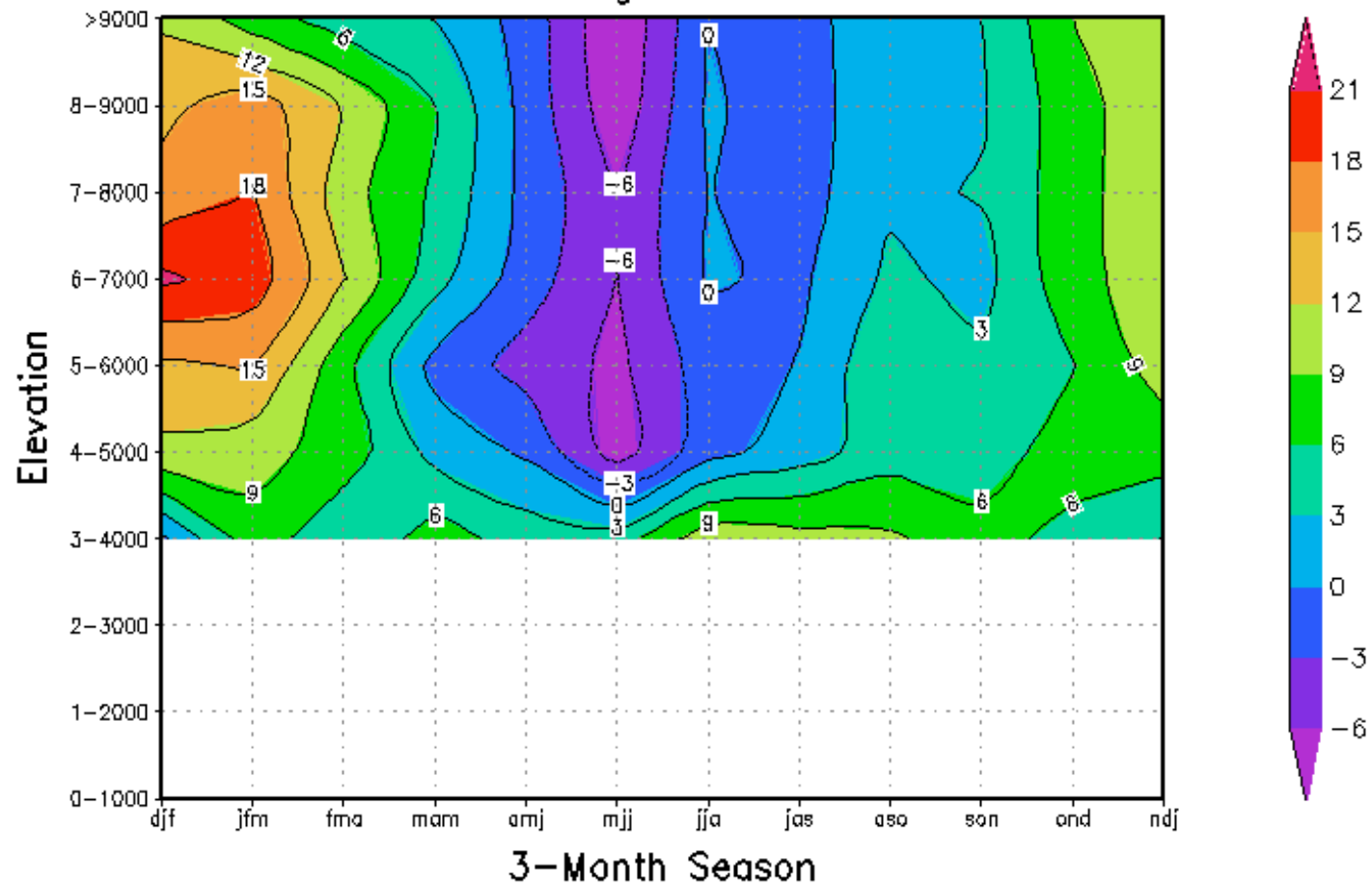
Region 10: ASO



Precipitation Net Change (1980–2000) vs. Elevation Region 10



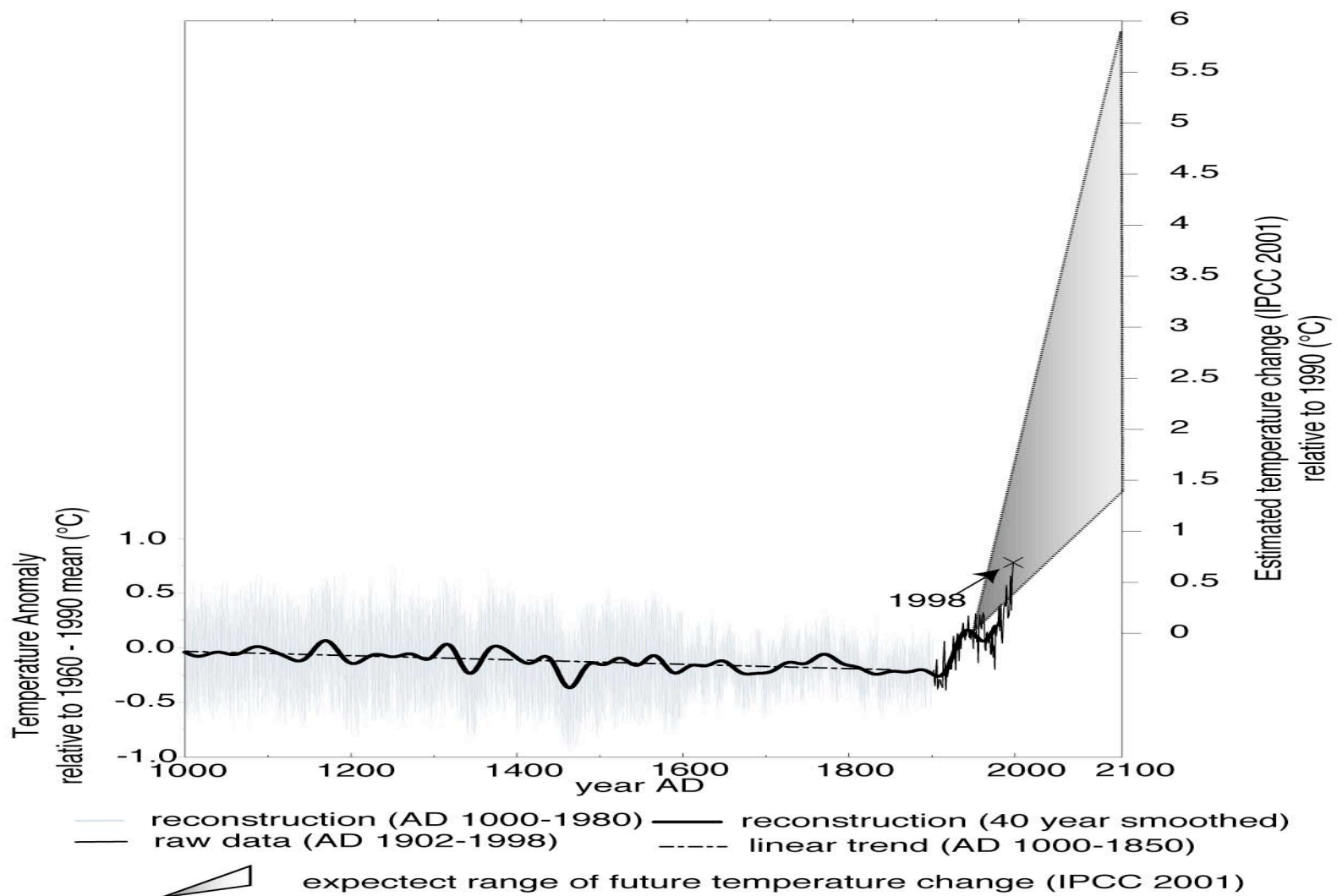
NDVI Net Change (1980–2000) vs. Elevation Region 10



*IT HAS OFTEN BEEN SAID THAT “THE
PAST IS THE KEY TO FUTURE”*

*WE MAY BE ENTERING
“UNCHARTED TERRITORY”*

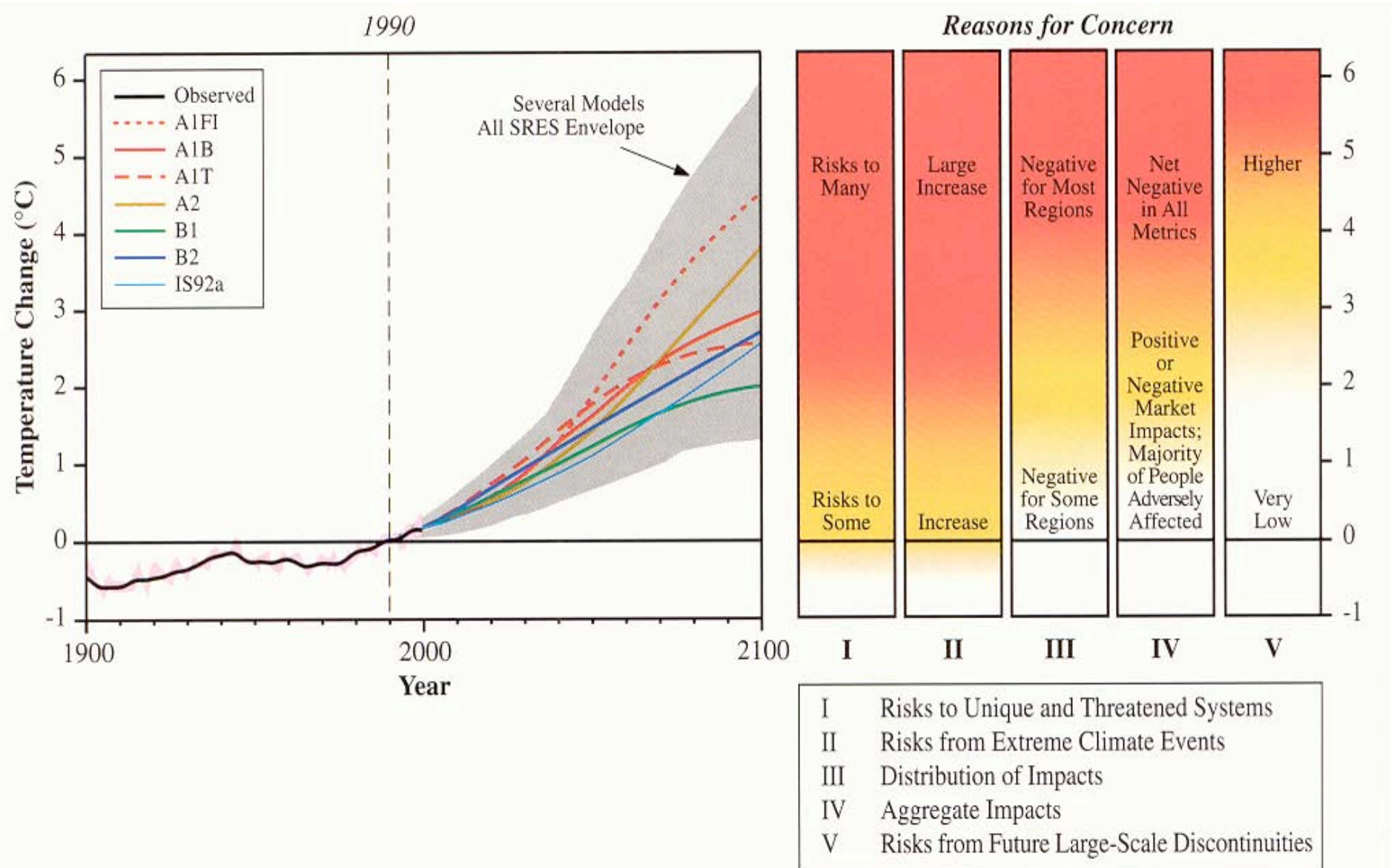
Northern Hemisphere Temperature Extrapolated to the Range of IPCC Estimates



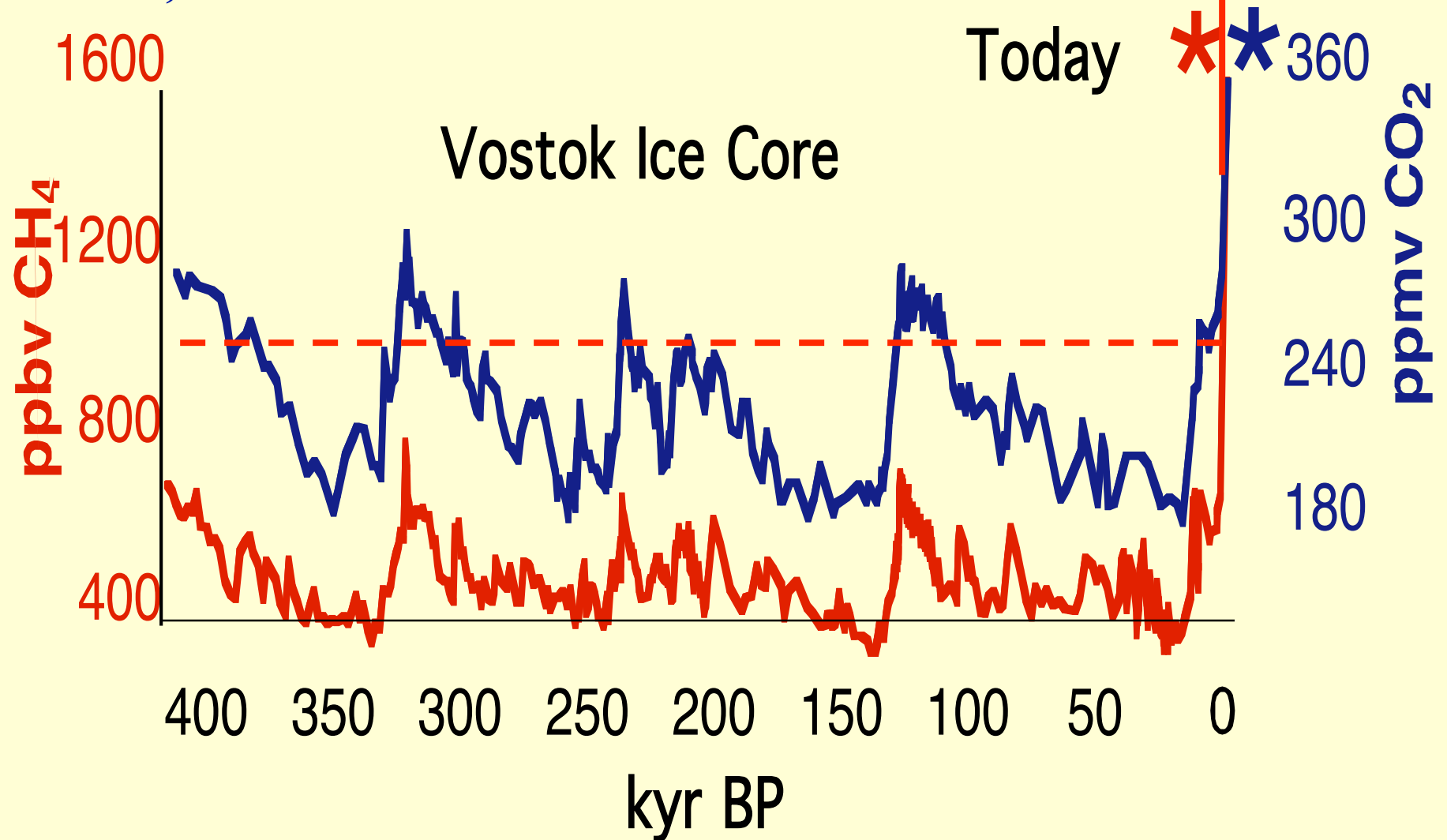
Paleoclimate, Global Change and the Future
 Alverson, Bradley and Pederson eds., 2002

Chapter 1: F. Oldfield, K. Alverson, fig. 1.4, p. 5

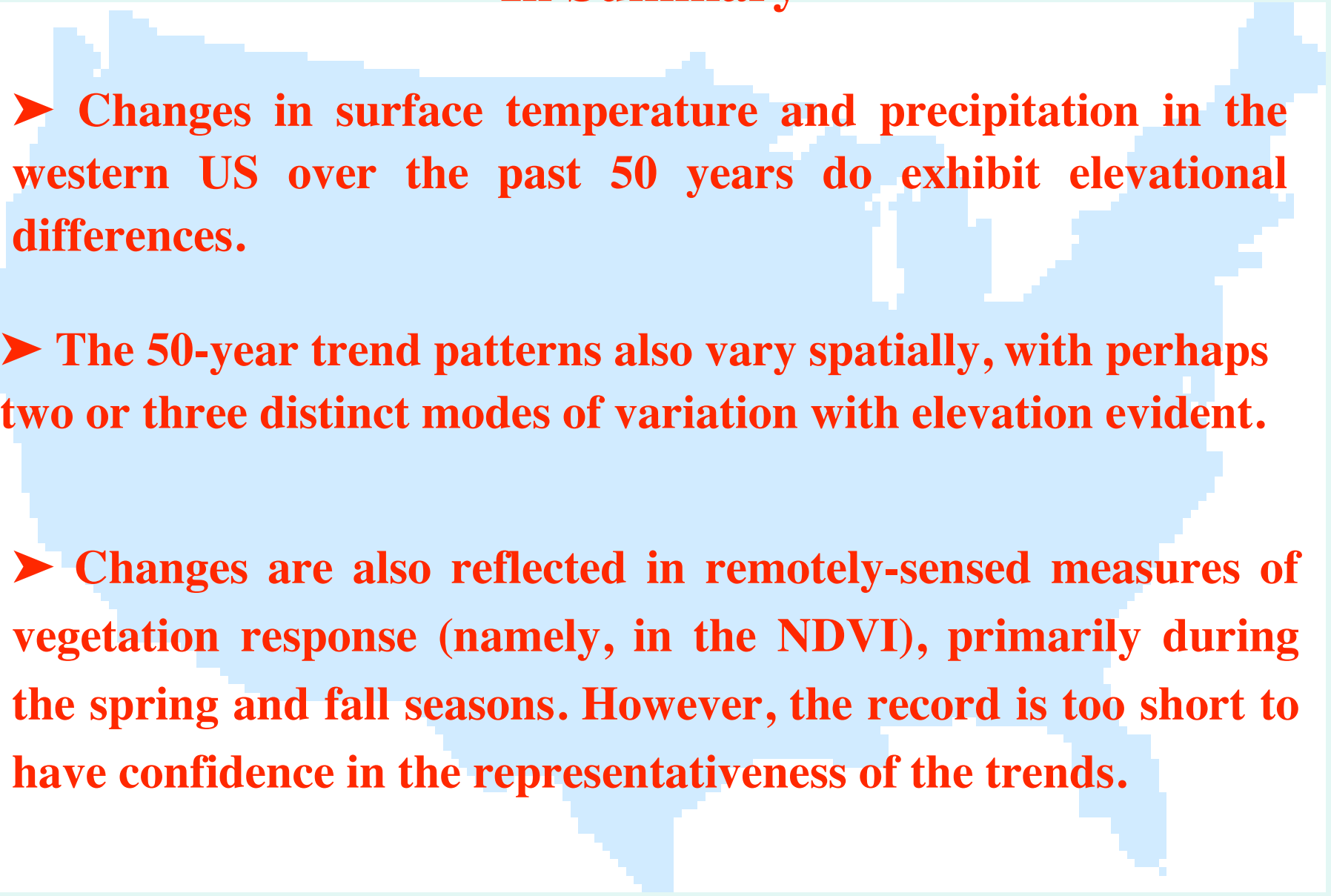
The impact of climate change will amplify with time and the actual rate of global warming



Concentración of methane and carbon dioxide in the atmosphere. Values are based ice cores from Vostok, Antarctic.



In Summary

- 
- **Changes in surface temperature and precipitation in the western US over the past 50 years do exhibit elevational differences.**
 - **The 50-year trend patterns also vary spatially, with perhaps two or three distinct modes of variation with elevation evident.**
 - **Changes are also reflected in remotely-sensed measures of vegetation response (namely, in the NDVI), primarily during the spring and fall seasons. However, the record is too short to have confidence in the representativeness of the trends.**

Summary (Cont.)

- Surface temperatures have risen $\sim 1\text{--}3^{\circ}\text{F}$ ($0.5\text{--}1.5^{\circ}\text{C}$) throughout the elevational ranges of the Western Cordillera during the past 50 years. Precipitation changes are generally more variable, but typically show increases of as much as 10% or more in some of the mountain ranges.
- Considering longer-term climate reconstructions and increasing atmospheric greenhouse gas concentrations, warming trends may be considered robust and likely to continue. In contrast, precipitation trends of the past 50 years may not be representative of future trends.

Summary (Cont.)

- Significant uncertainties remain regarding past and future patterns of climatic changes with elevation, and hence of their impact on physical and biological systems. Changes in relation to greenhouse warming may be amplified with elevation.
- These uncertainties point to the need for continued climate system research on the one hand, but more importantly to start developing the means to mitigate and adapt to some of the possible changes that may be coming our way.