

CLIMATE CHANGE AND HYDROPOWER IN THE NORTHWEST

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Climate Science
in the Public Interest

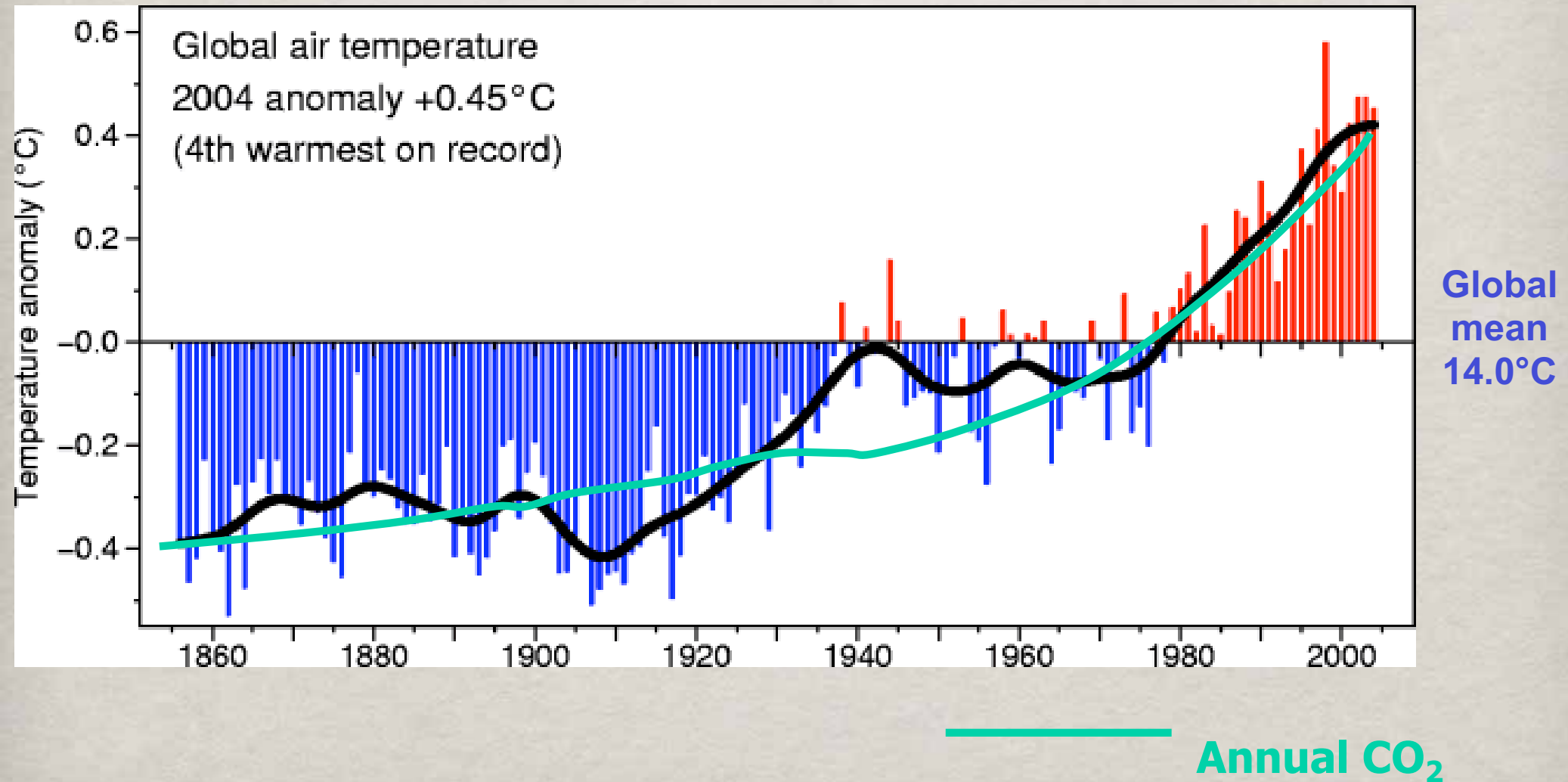
What we know (high confidence)

- Earth's climate is changing
- Humans are involved and the pattern is unlike natural changes
- Global average temperature is likely to increase substantially during this century
- We know this through peer-reviewed research and assessments (IPCC, NAS,...)

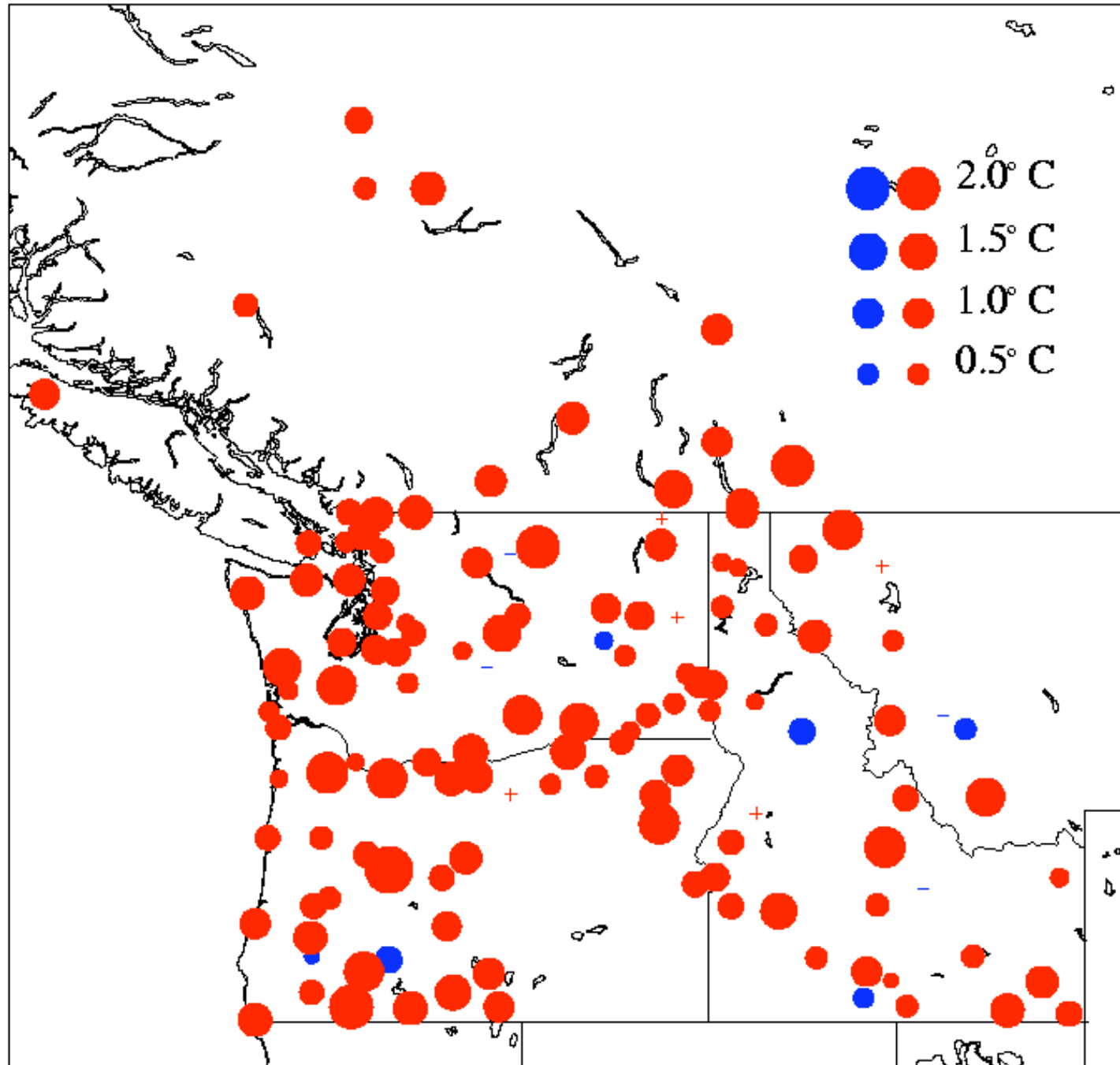
OUTLINE

- ☀ How we know that global climate is changing and that humans are involved
- ☀ Observed and projected changes of relevance to the Northwest's hydropower

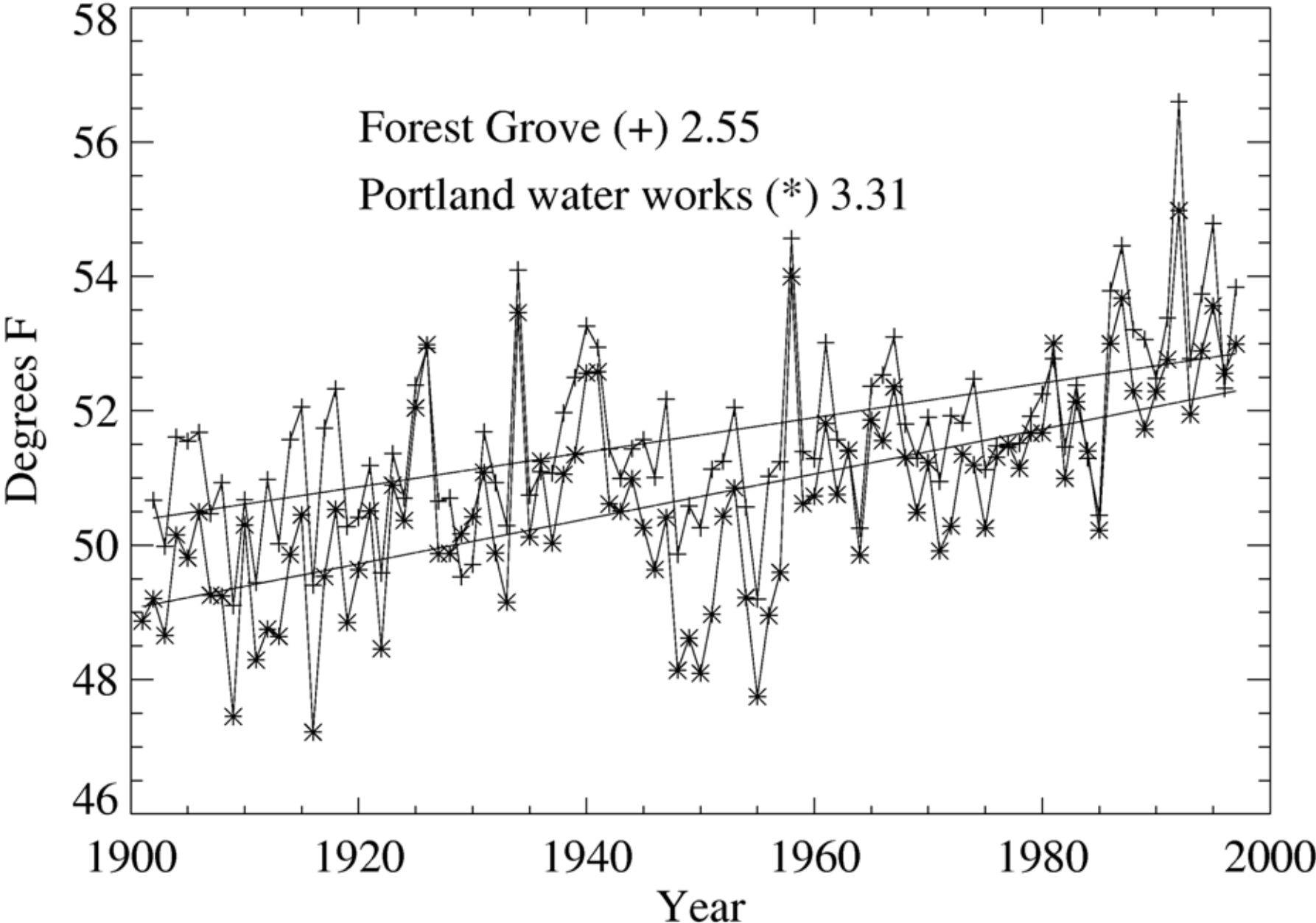
Variations of the Earth's surface temperature



Temperature trends (°C per century), since 1920



Annual average temperature



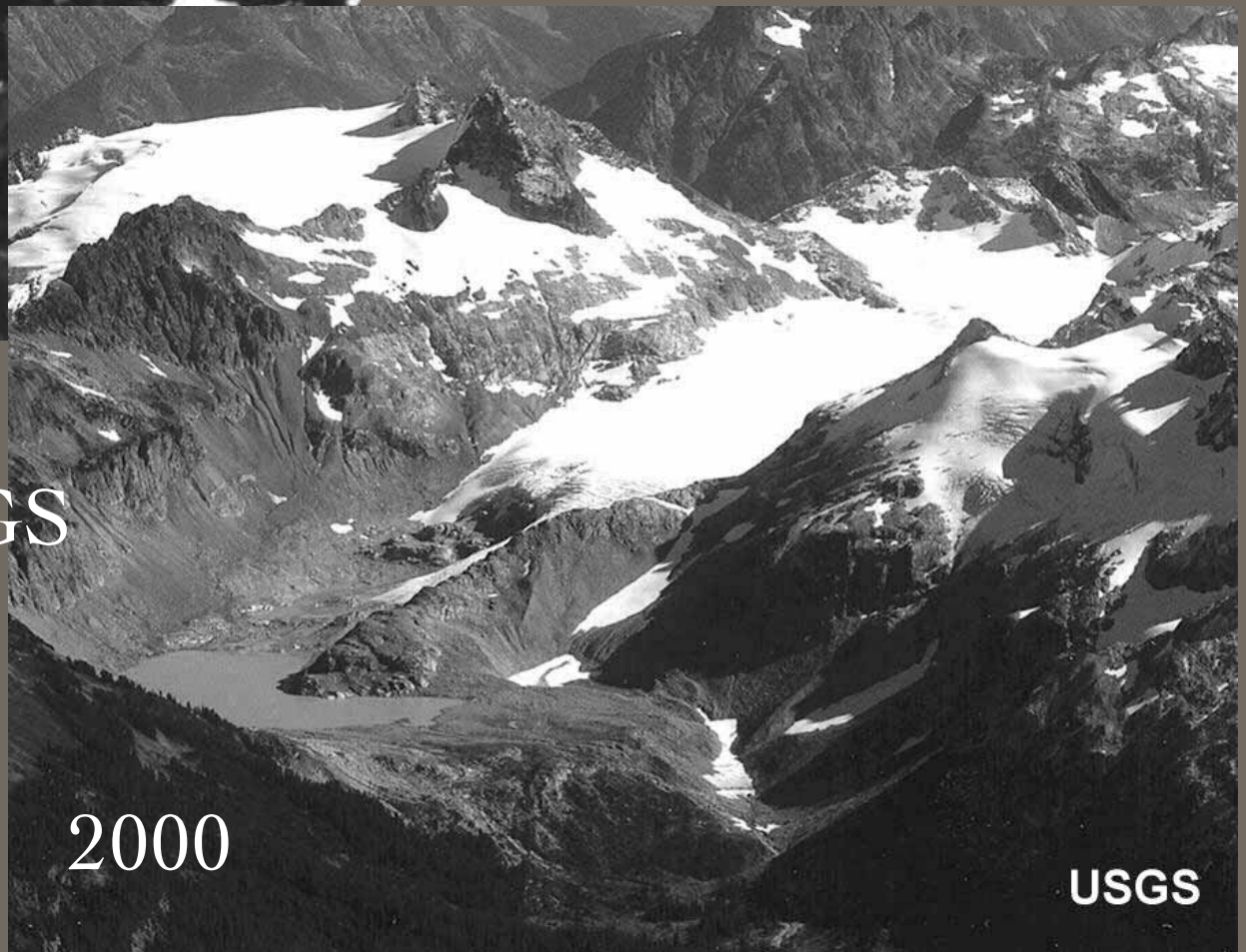
OTHER EVIDENCE OF WARMING

- ☀ Receding glaciers
- ☀ Thinning and retreat of Arctic sea ice
- ☀ Collapse of ice shelves
- ☀ Changes in phenological indicators and species ranges

The South Cascade
glacier retreated
dramatically in the
20th century



1928



2000

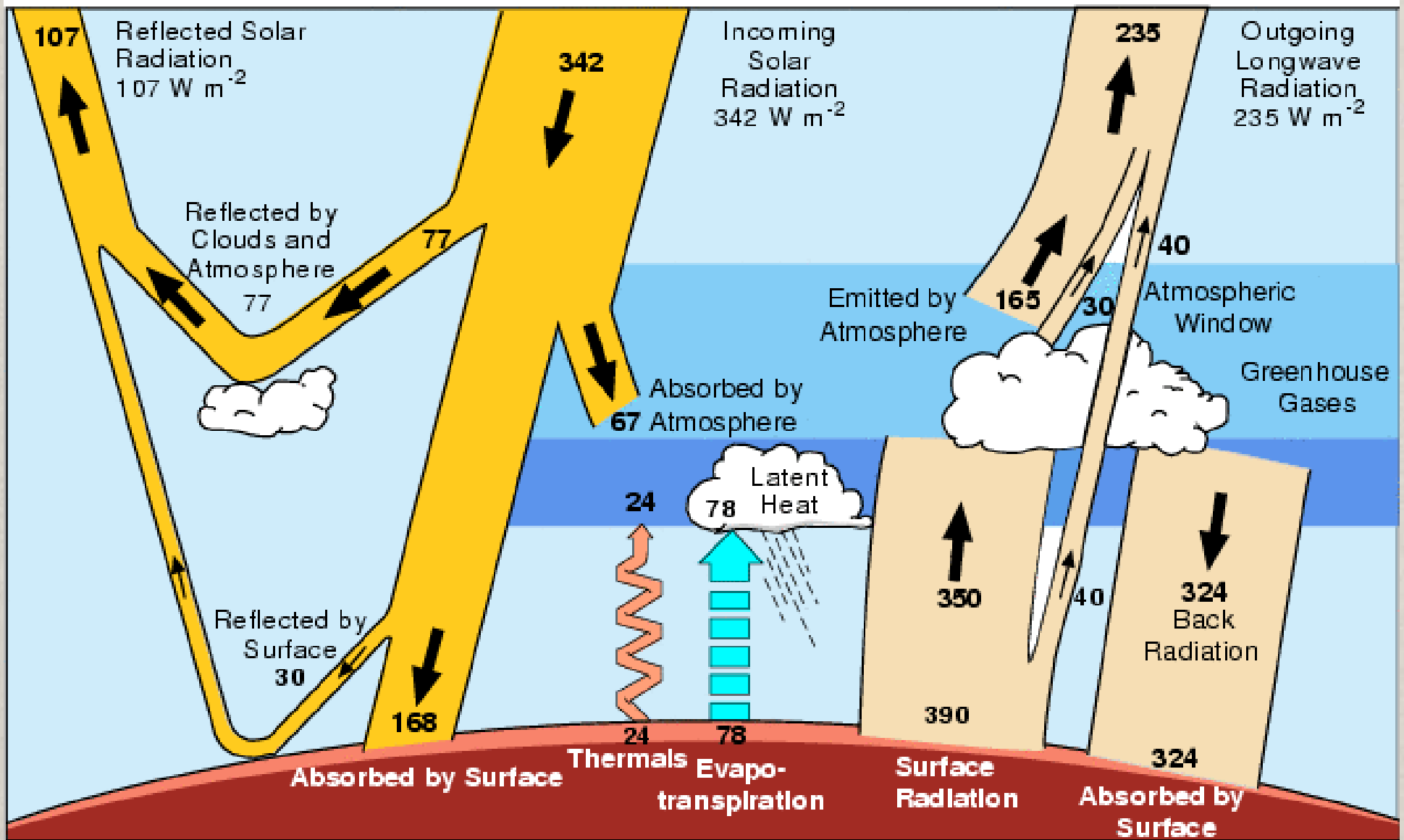
USGS

Courtesy of the USGS
glacier group

HOW DO WE KNOW IT'S NOT NATURAL?

- ☼ Basic physics
- ☼ Known patterns of natural variability cannot explain the pattern of warming
- ☼ Heat going into the oceans and land
- ☼ Simulations with climate models cannot reproduce recent warming without rising greenhouse gases

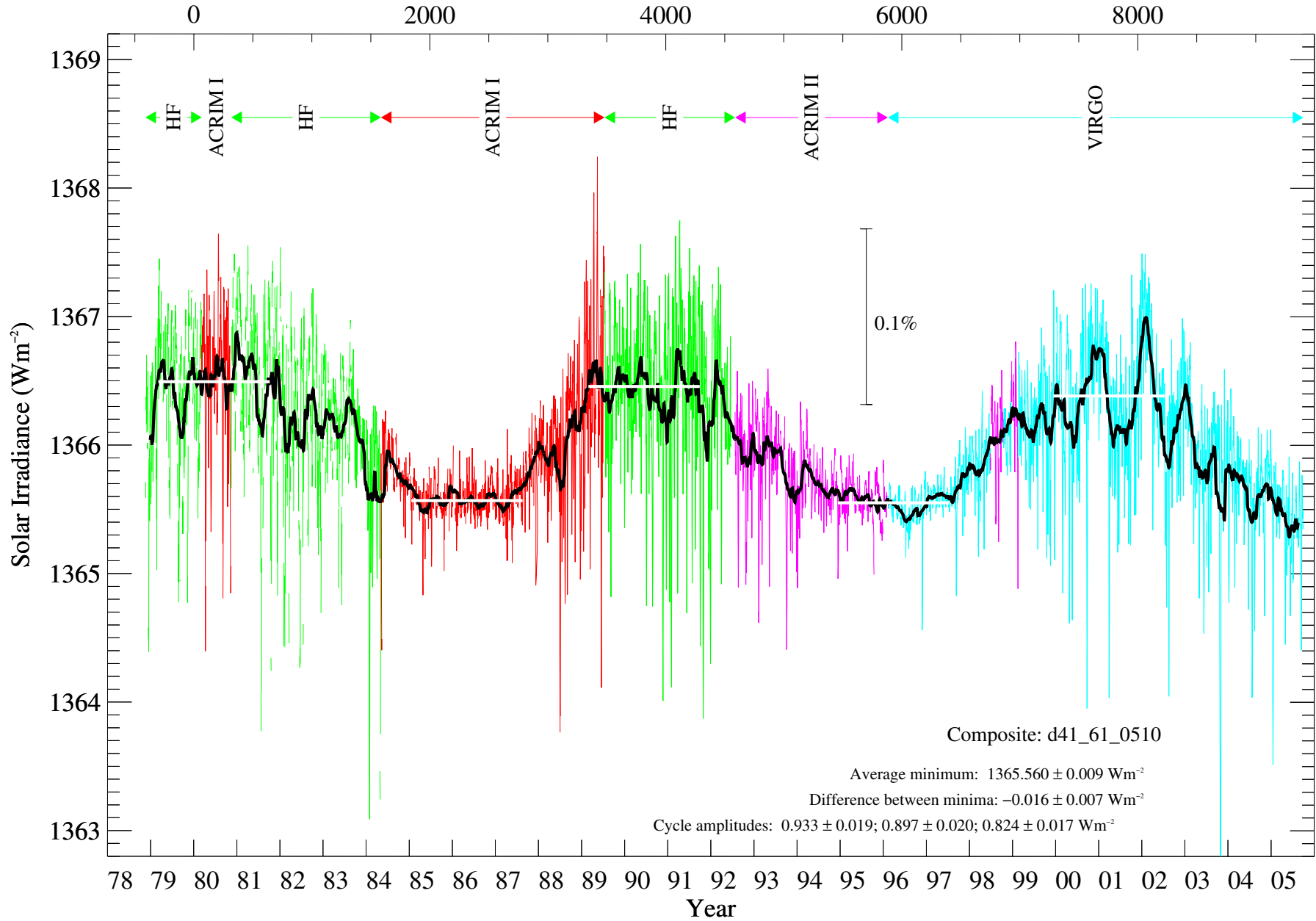
Global Heat Flows



Kiehl and Trenberth 1997

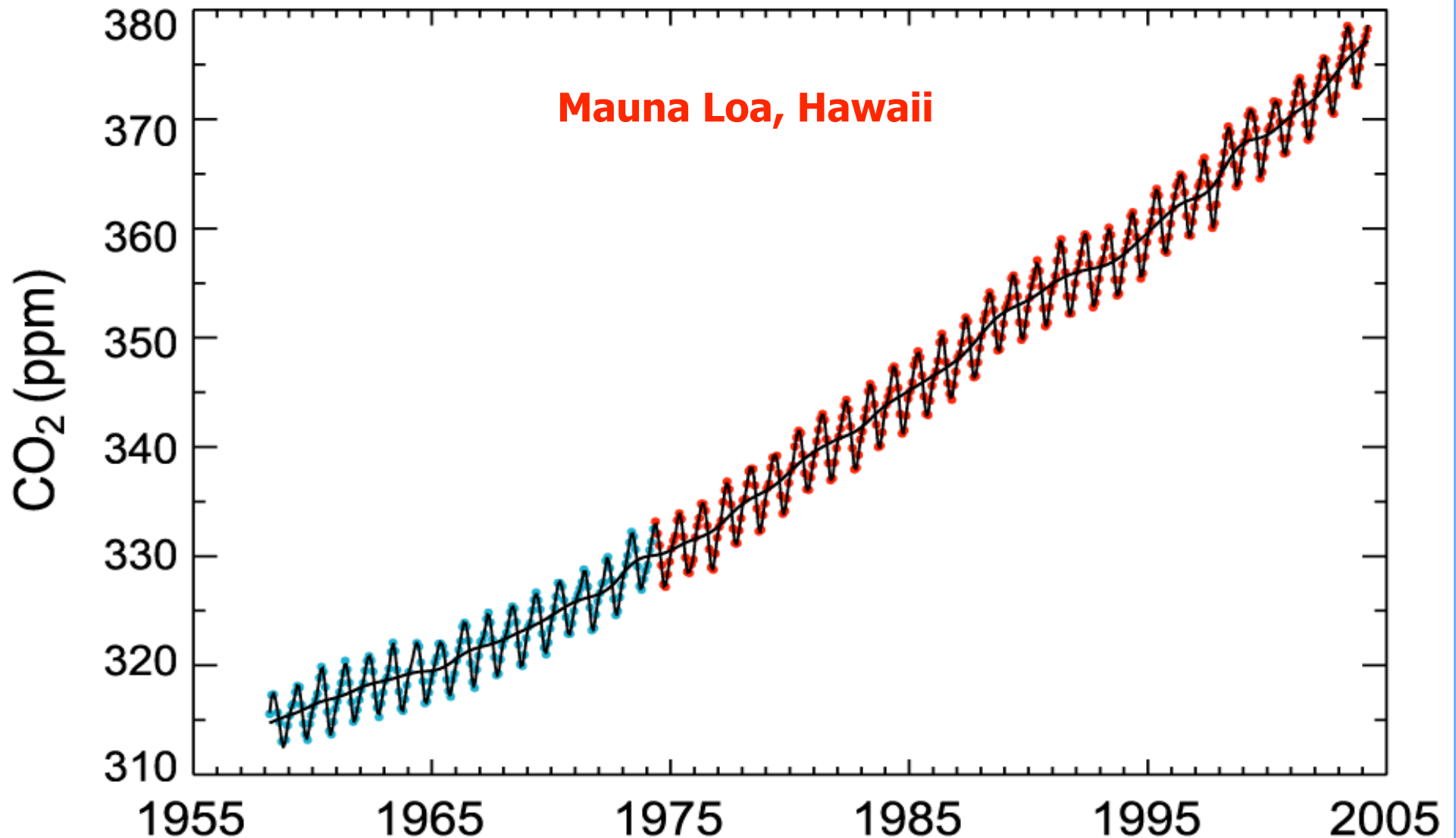
Total Solar Irradiance Data (referred to SARR via ACRIM-II)

Days (Epoch Jan 0, 1980)

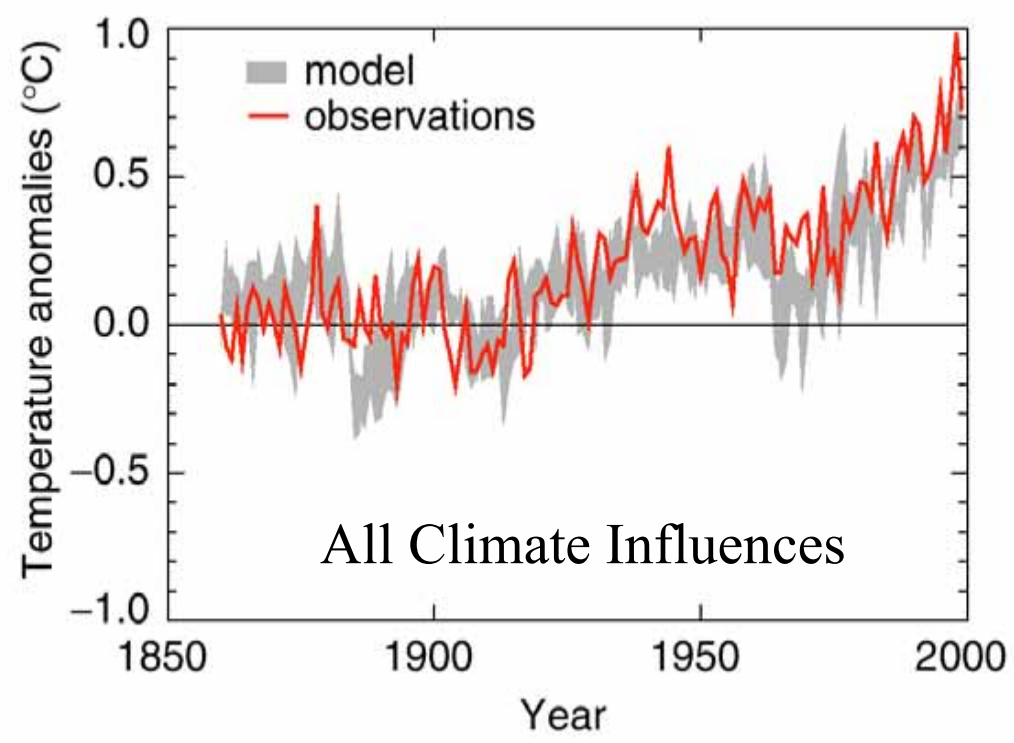
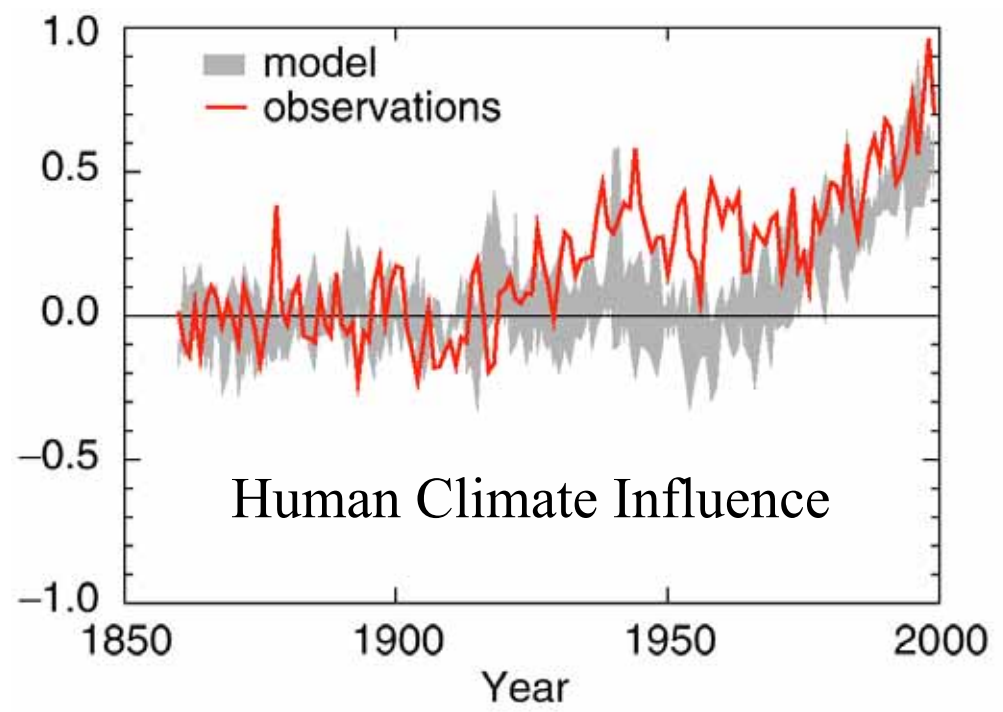
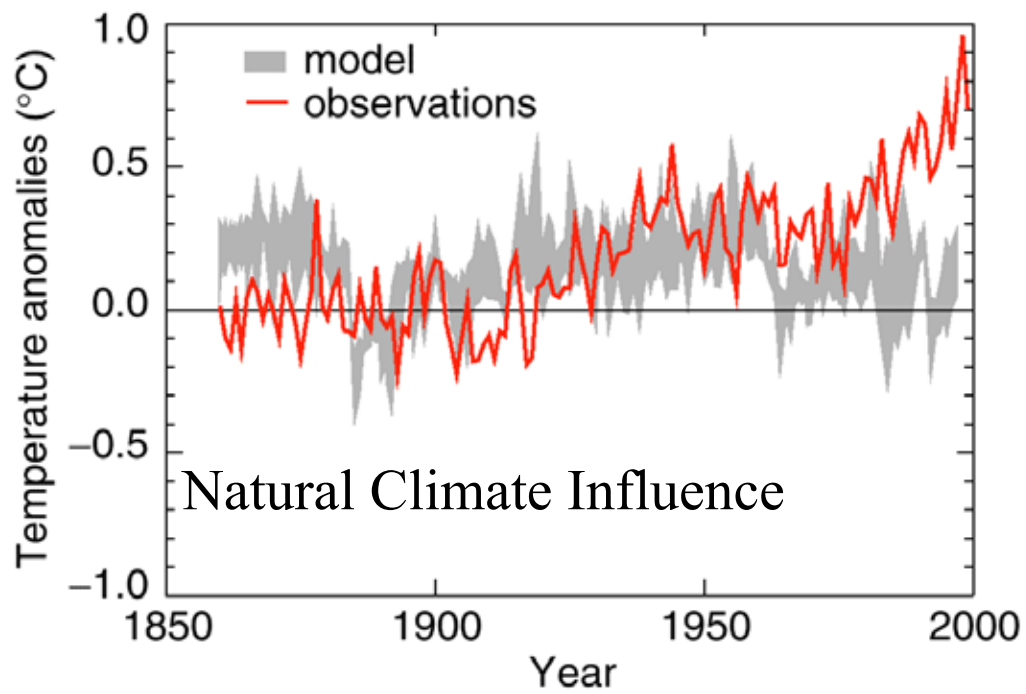


from: C. Fröhlich, Space Science Reviews, 94, pp.15–24, 2000, with composite (vers d41_61_0510), ACRIM-II/III (vers II:101001) and VIRGO 6_001_0510 data (Oct 07, 2005)

Changing atmospheric composition: CO₂



Data from Climate Monitoring and Diagnostics Lab., NOAA. Data prior to 1973 from C. Keeling, Scripps Inst. Oceanogr.

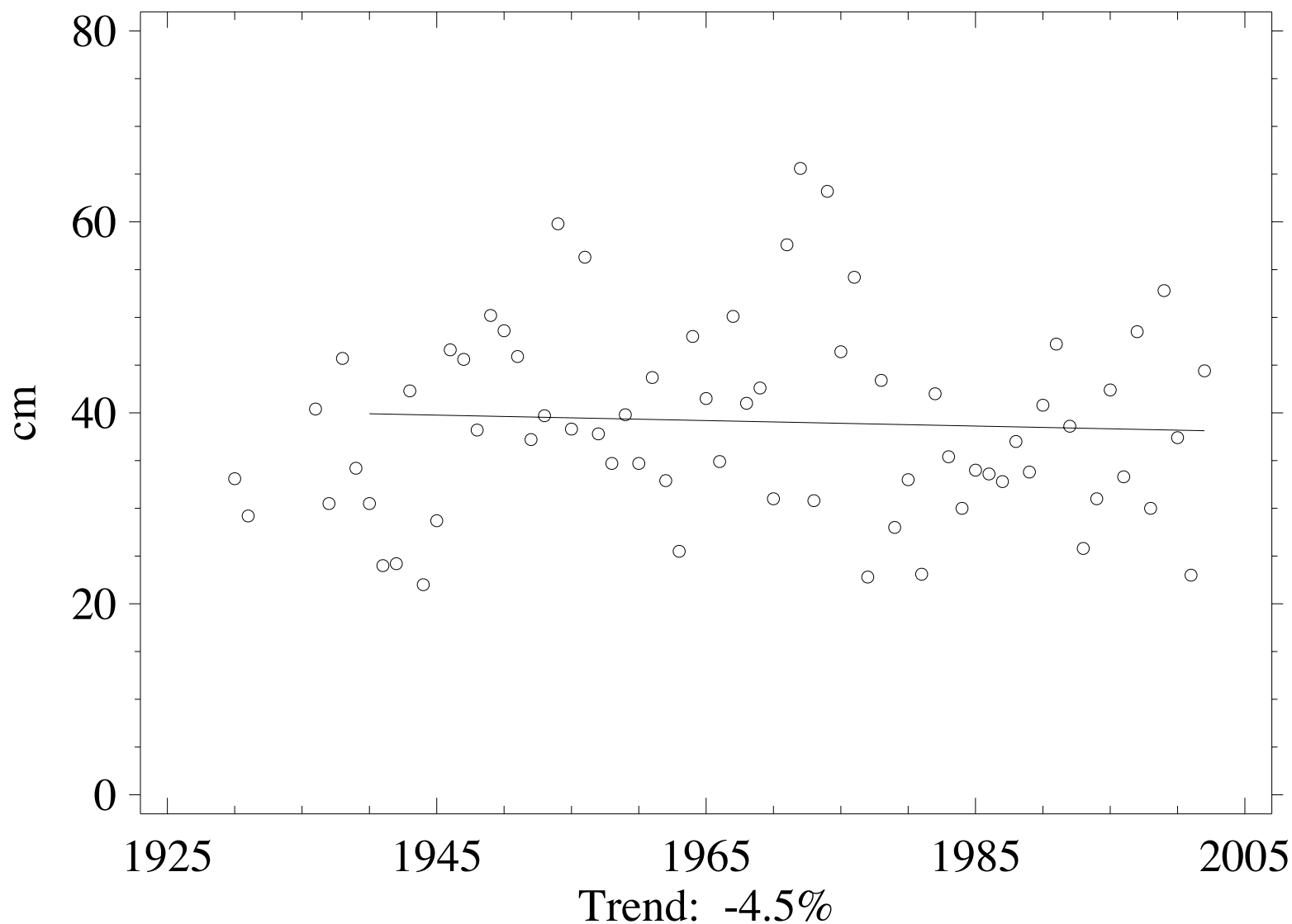


HYDRO RESOURCES IMPLICATIONS

- ☀ Warming has already caused a reduction in Northwest snowpack and a consequent shift in flow from summer to winter
- ☀ Continued shifts in timing of flow are very likely

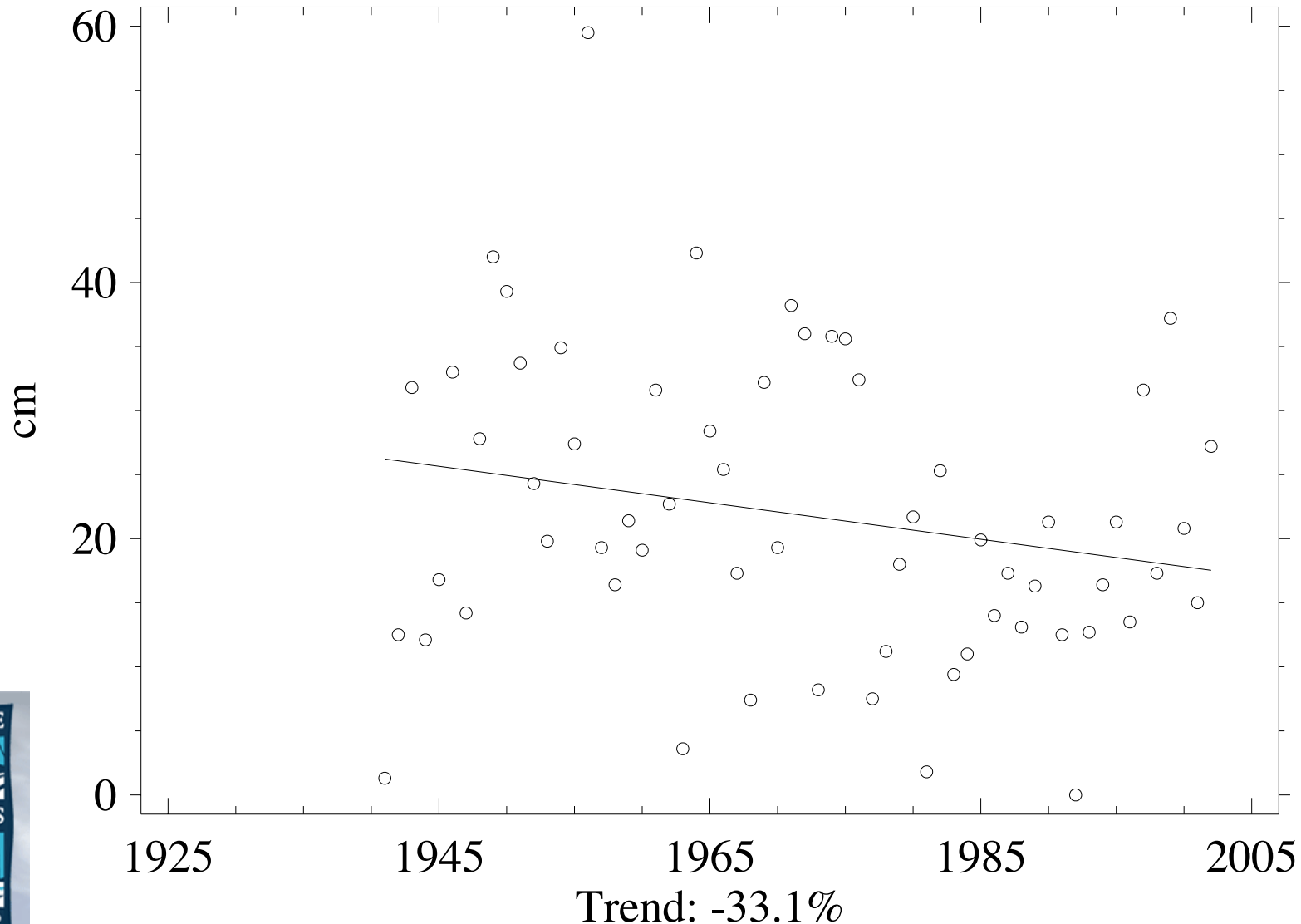
April 1 snowpack: no decline at high elevations

RAINY PASS, Elev. 4780ft



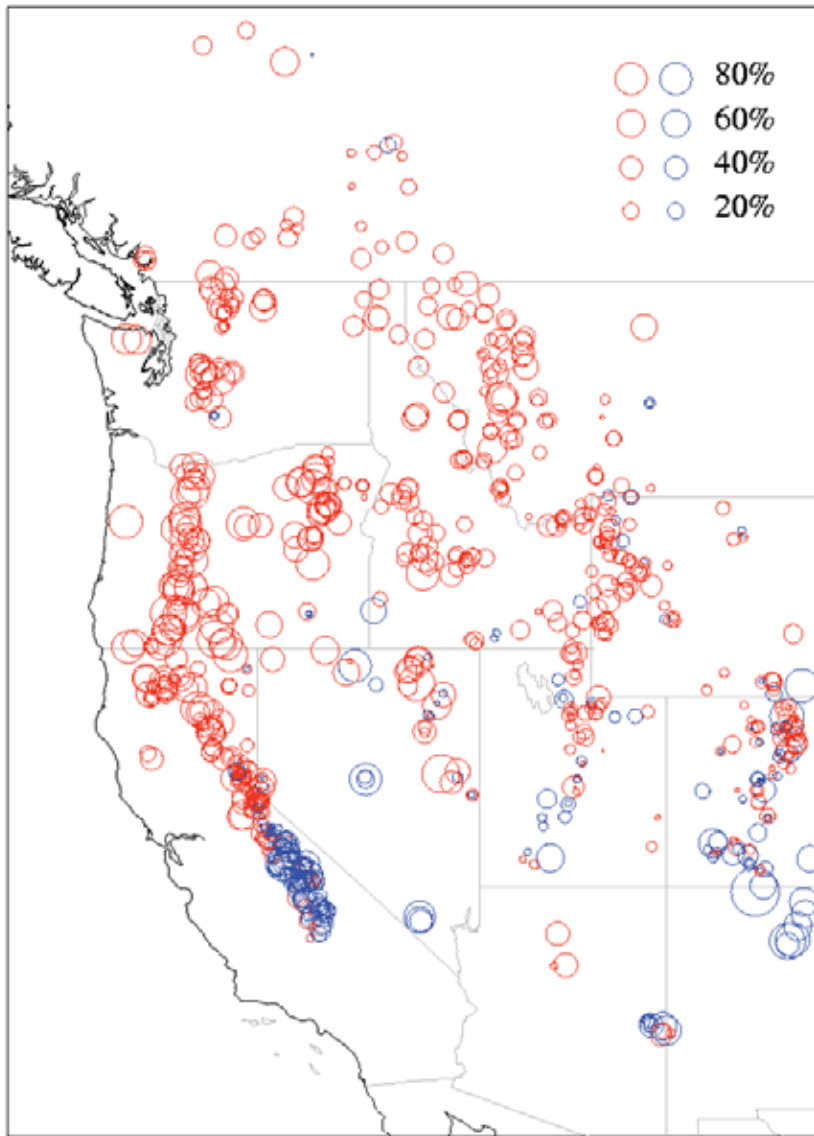
...but large declines at low elevations

TUNNEL AVENUE, Elev. 2450ft

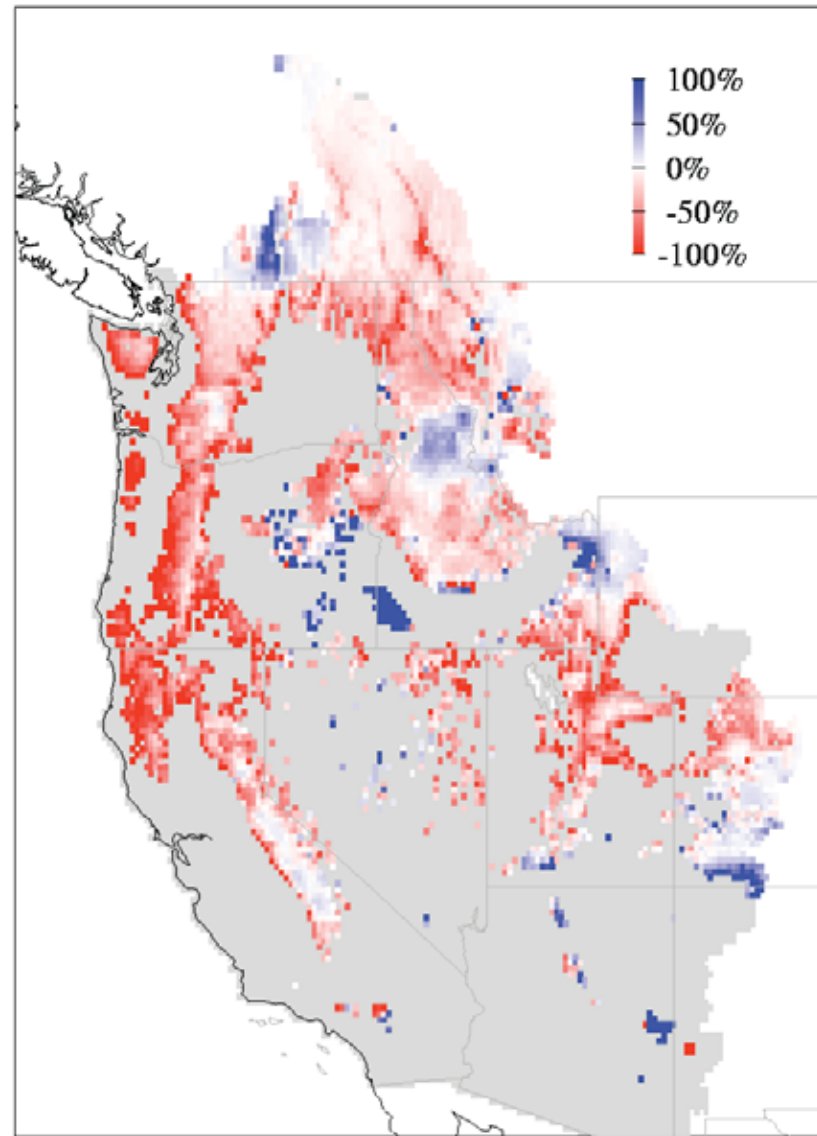


Declining April 1 snowpack, 1950-1997

a. Observations

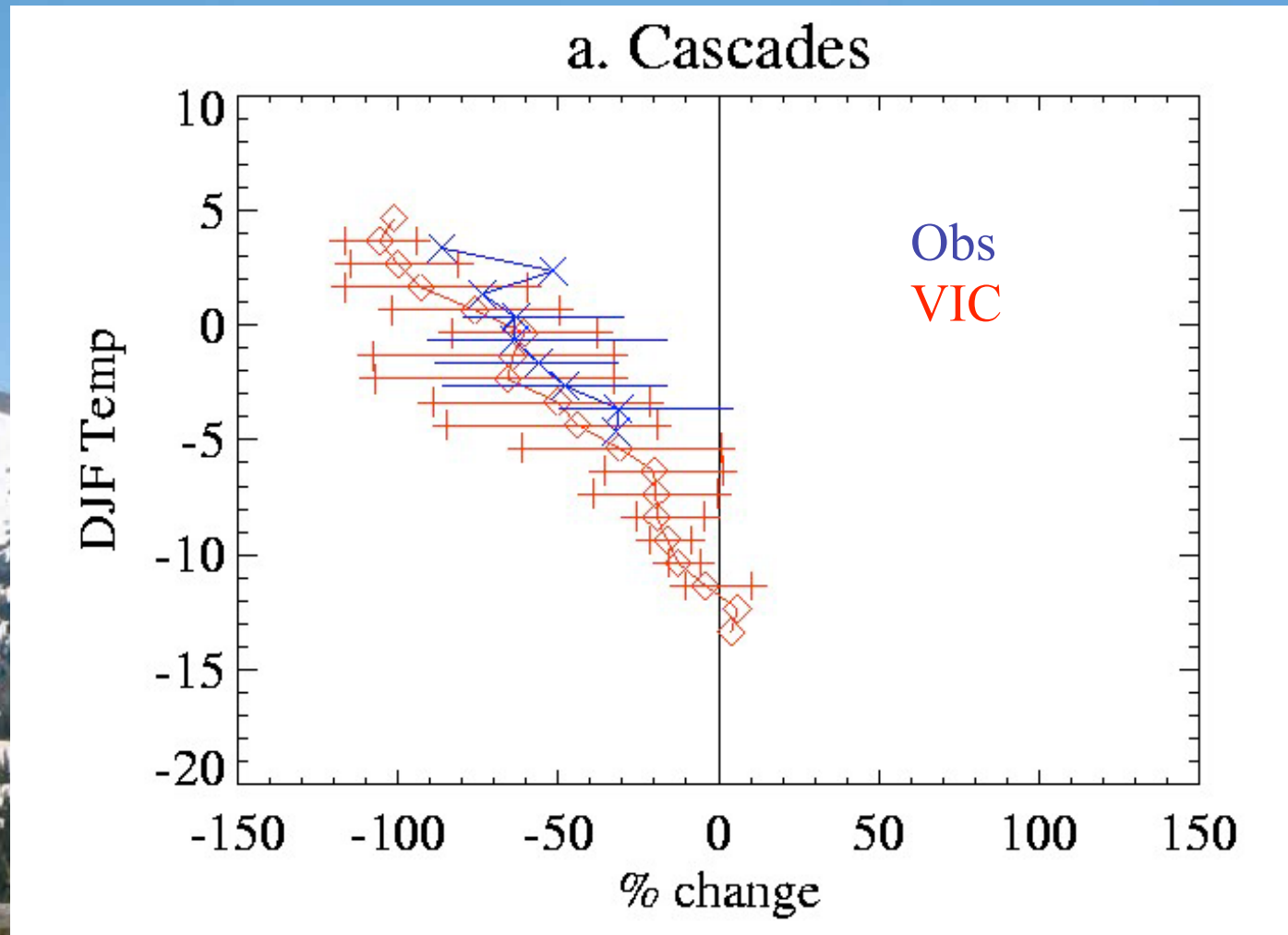


b. VIC



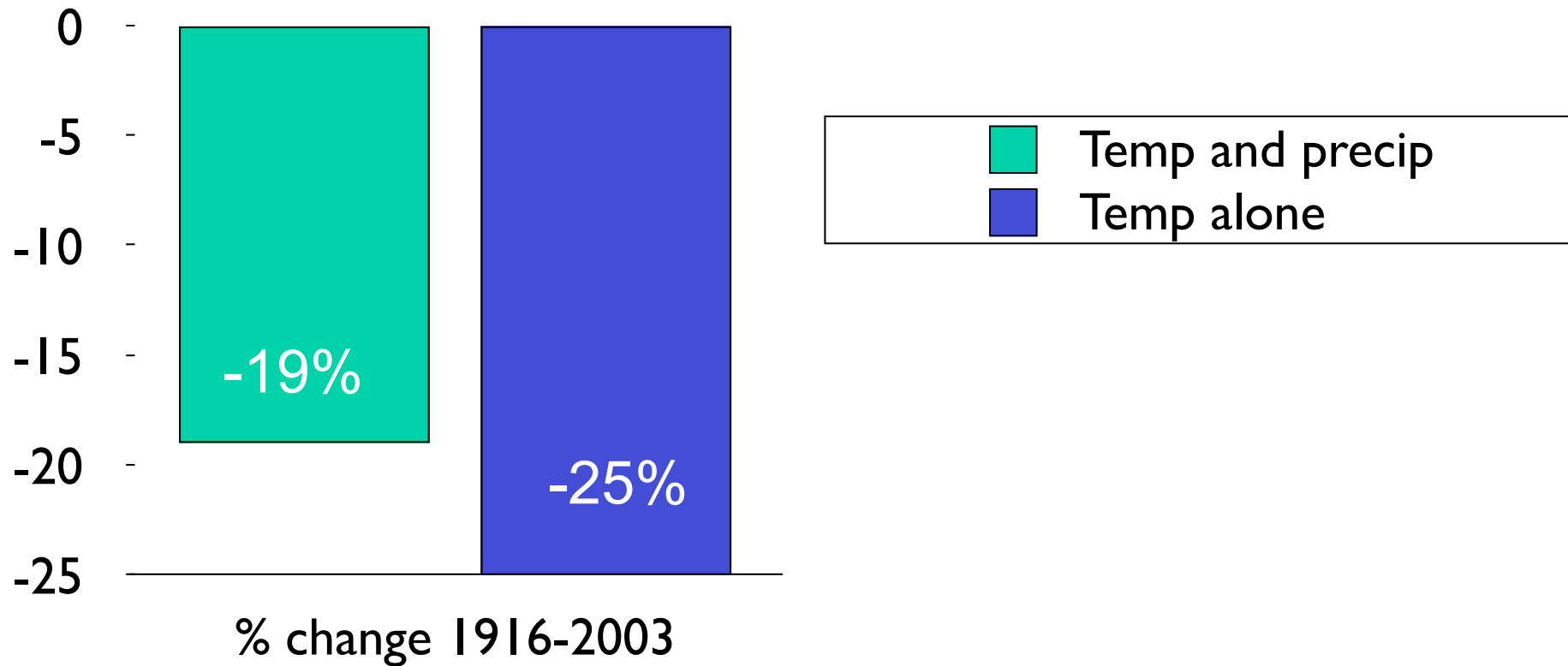
Mote et al., BAMS 2005

1950-1997 relative trends in April 1 SWE vs DJF temperature

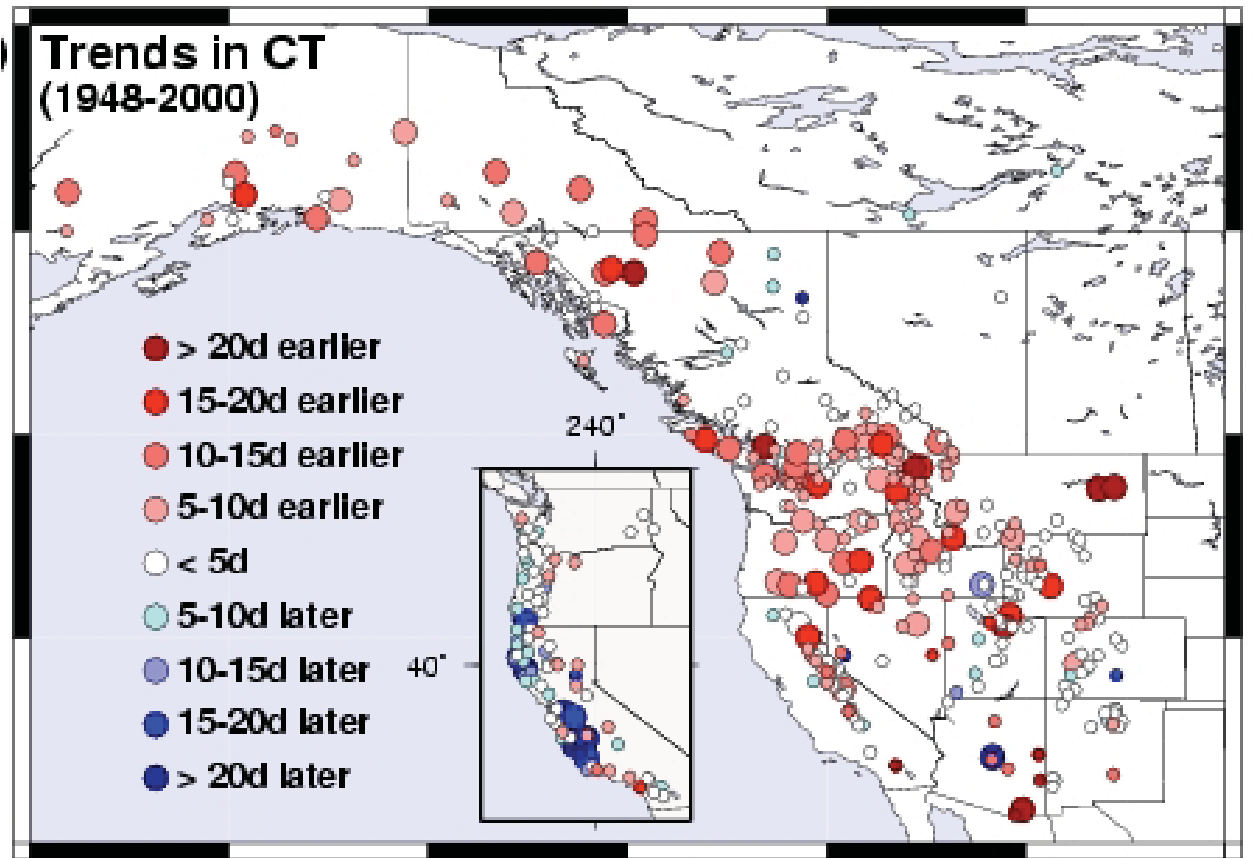
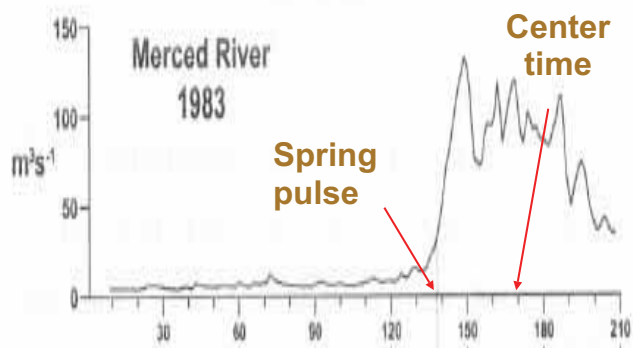
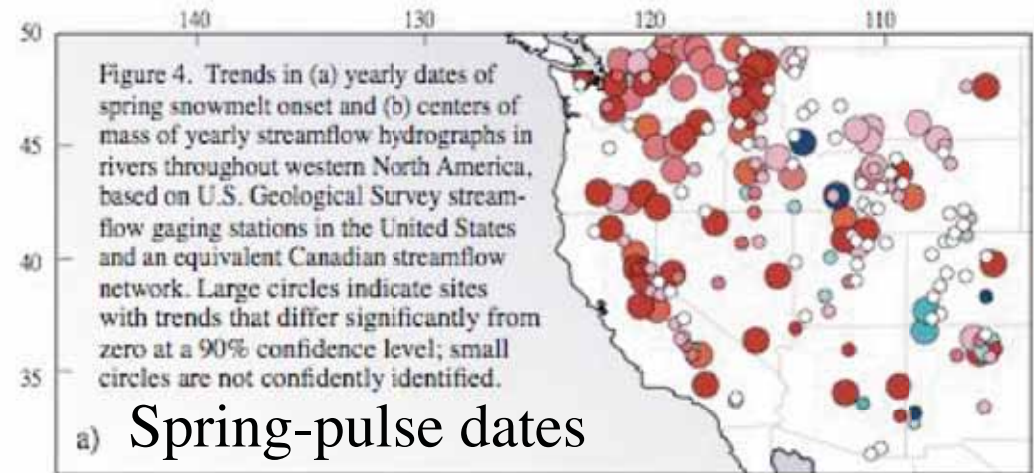


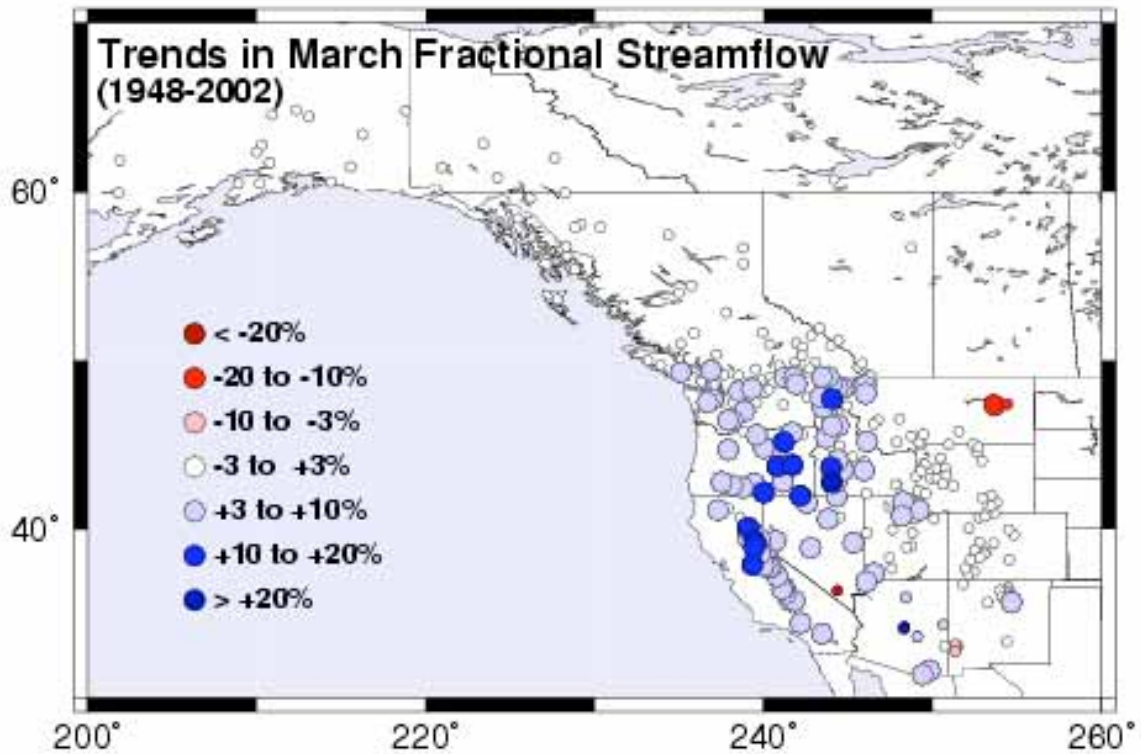
Mote et al., BAMS 2005

Trends in April 1 SWE for the WA and OR Cascades 1916-2003



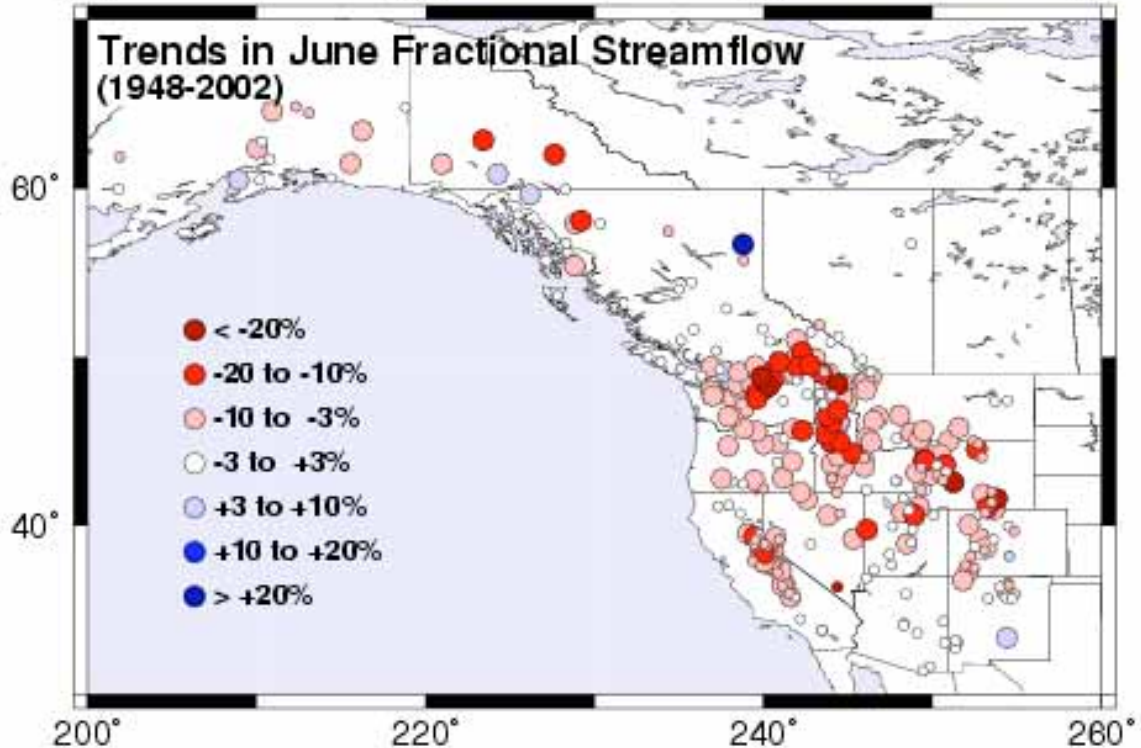
By several measures,
Western snowfed
streamflow has been
arriving earlier in the
year in recent decades





As the West warms,
winter flows rise
and summer flows
drop

Figure by Iris Stewart,
Scripps Inst. of Oceanog.
(UC San Diego)

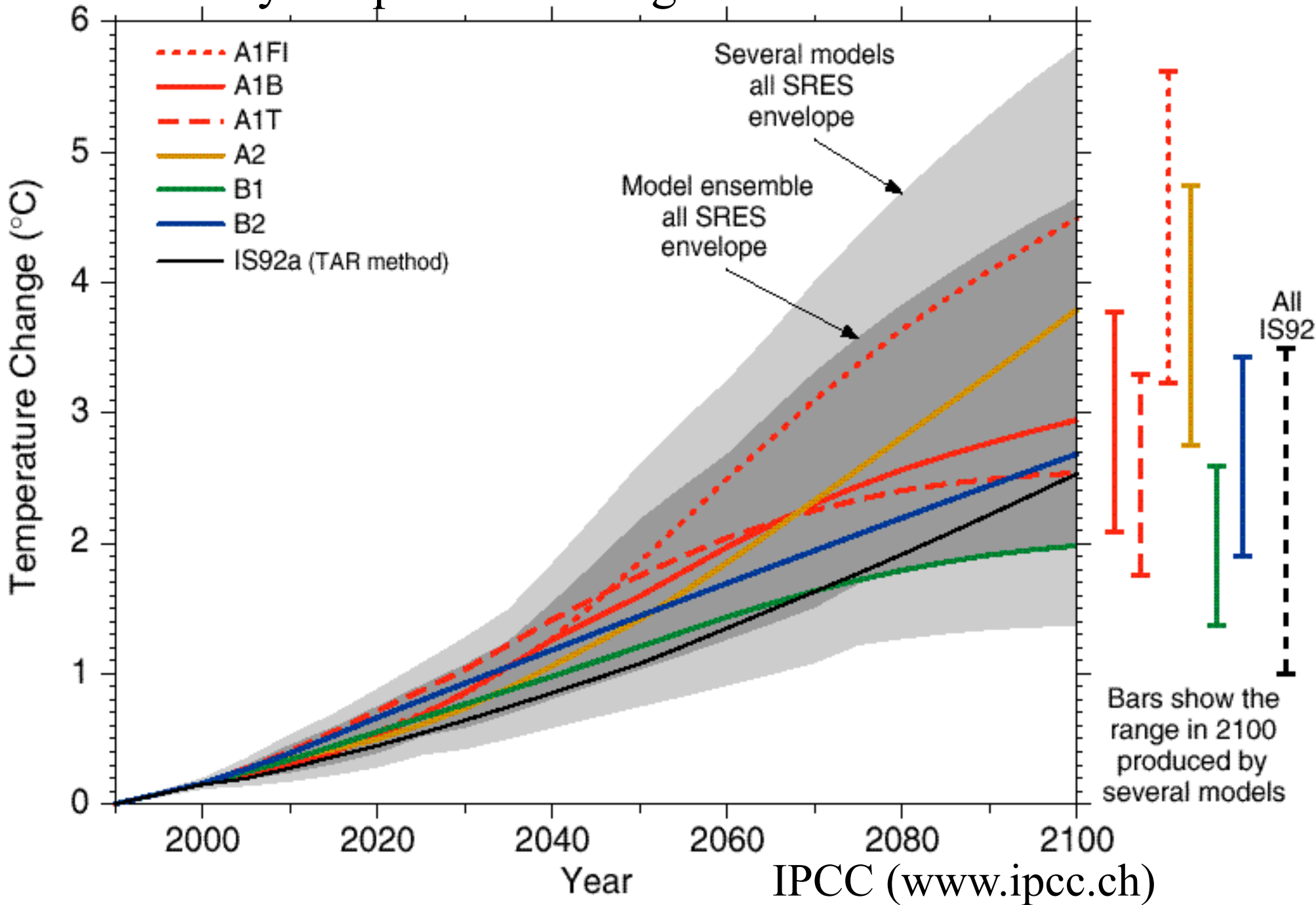


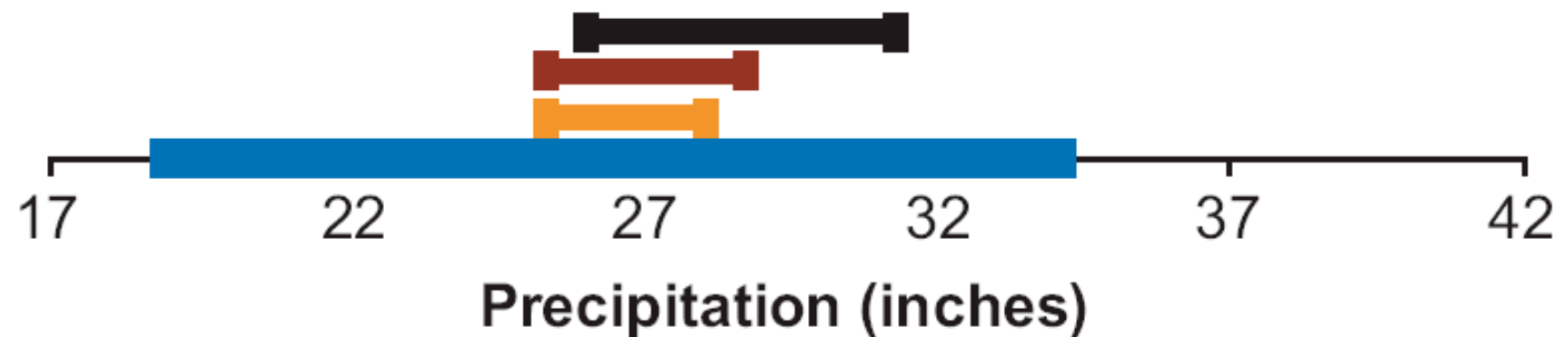
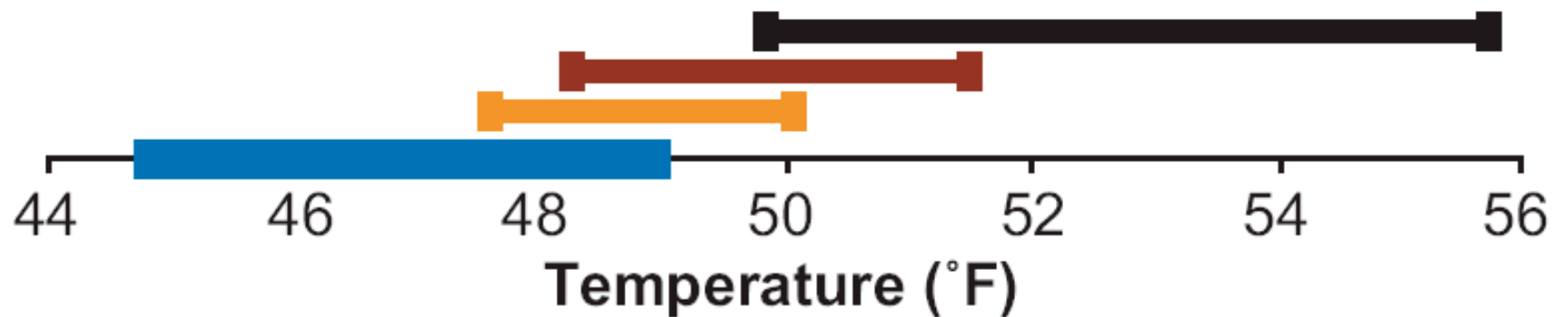
Stewart et al., J Climate 2005

SUMMARY OF OBSERVED CHANGES IN THE NORTHWEST

- ✻ Substantial warming
- ✻ Elevation-dependent loss of snowpack
- ✻ Shift in flow from late spring/summer to winter/early spring

21st century temperature change

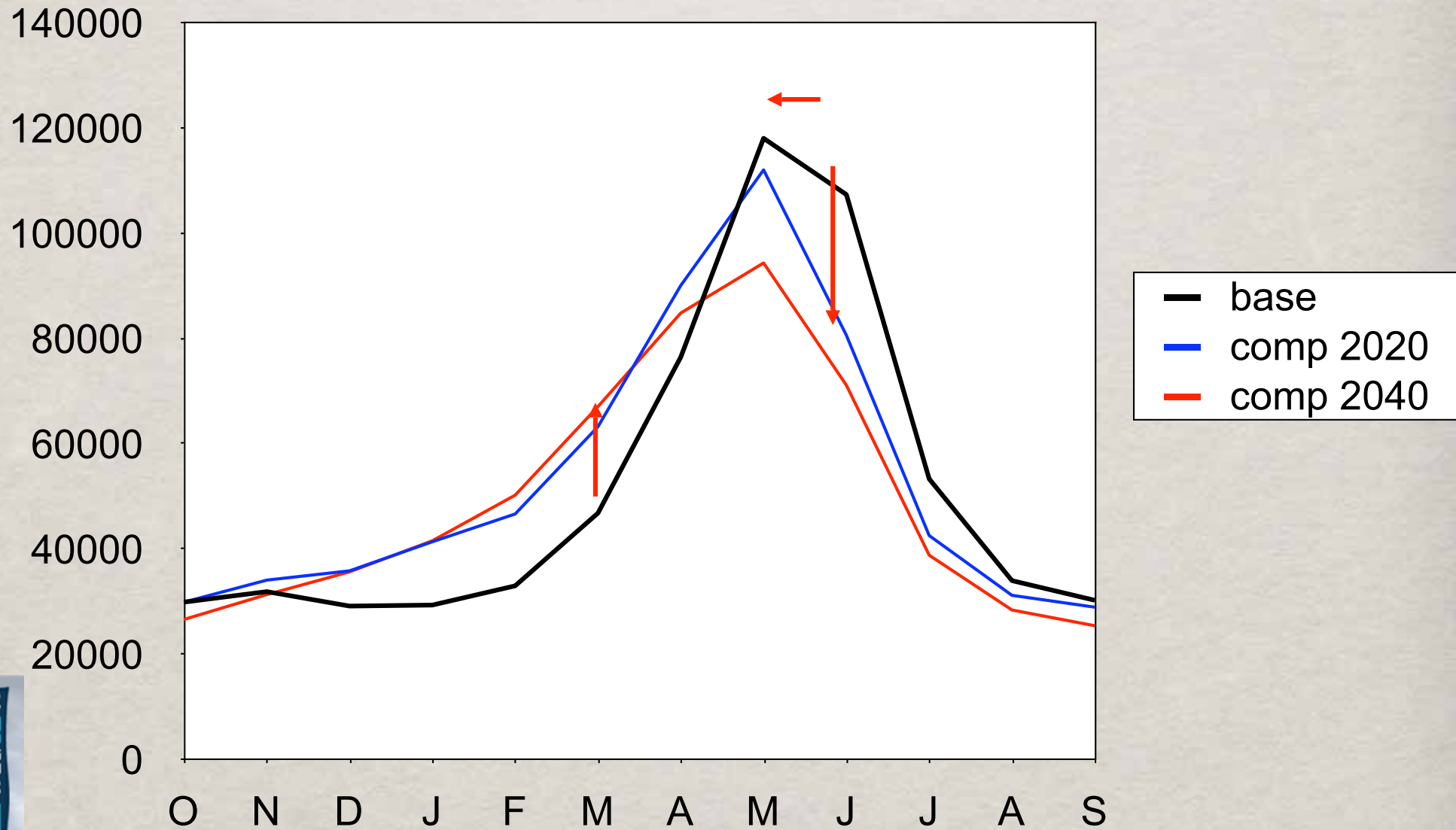




■ historical variability ■ 2020s shift in mean
■ 2040s shift in mean ■ 2090s shift in mean

Comparison of observed year-to-year variability and projected shifts in temperature and precipitation from climate models

Snake River at Ice Harbor



Three changes

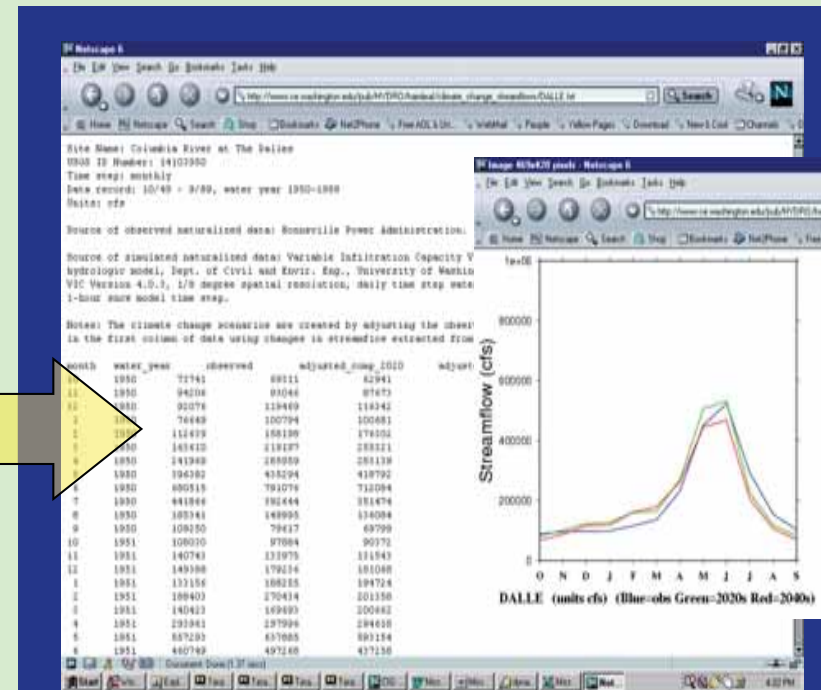
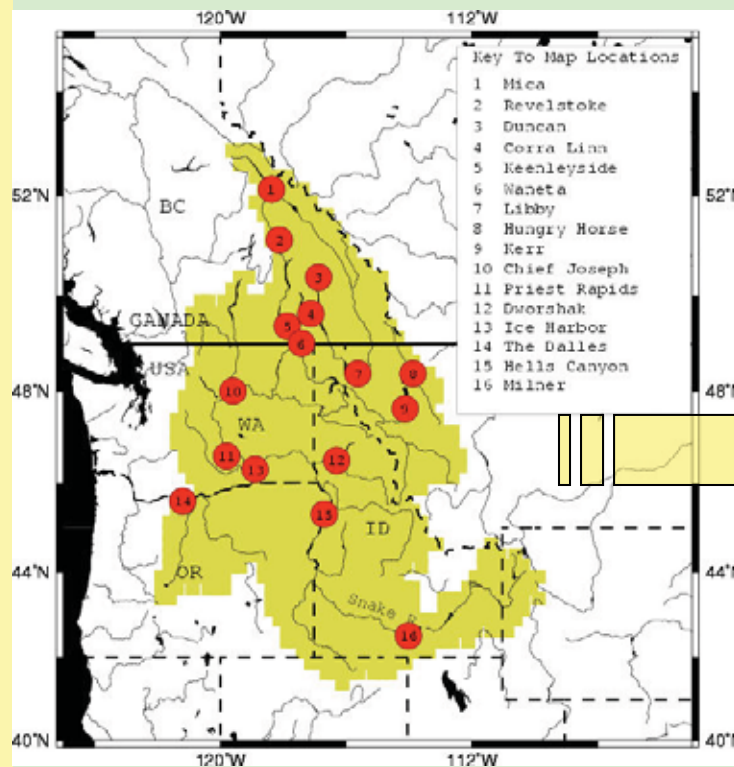
Planning for climate change: water resources in the Columbia basin

Water policy workshops have highlighted the need to inject climate change information into existing river basin planning activities and to provide free access to streamflow scenarios.

Partners:

Northwest Power and Conservation Council

Idaho Dept of Water Resources



CONCLUSIONS

- ☀ Human influence on climate and water resources of the Northwest is emerging
- ☀ Temperature and precipitation changes have different effects

