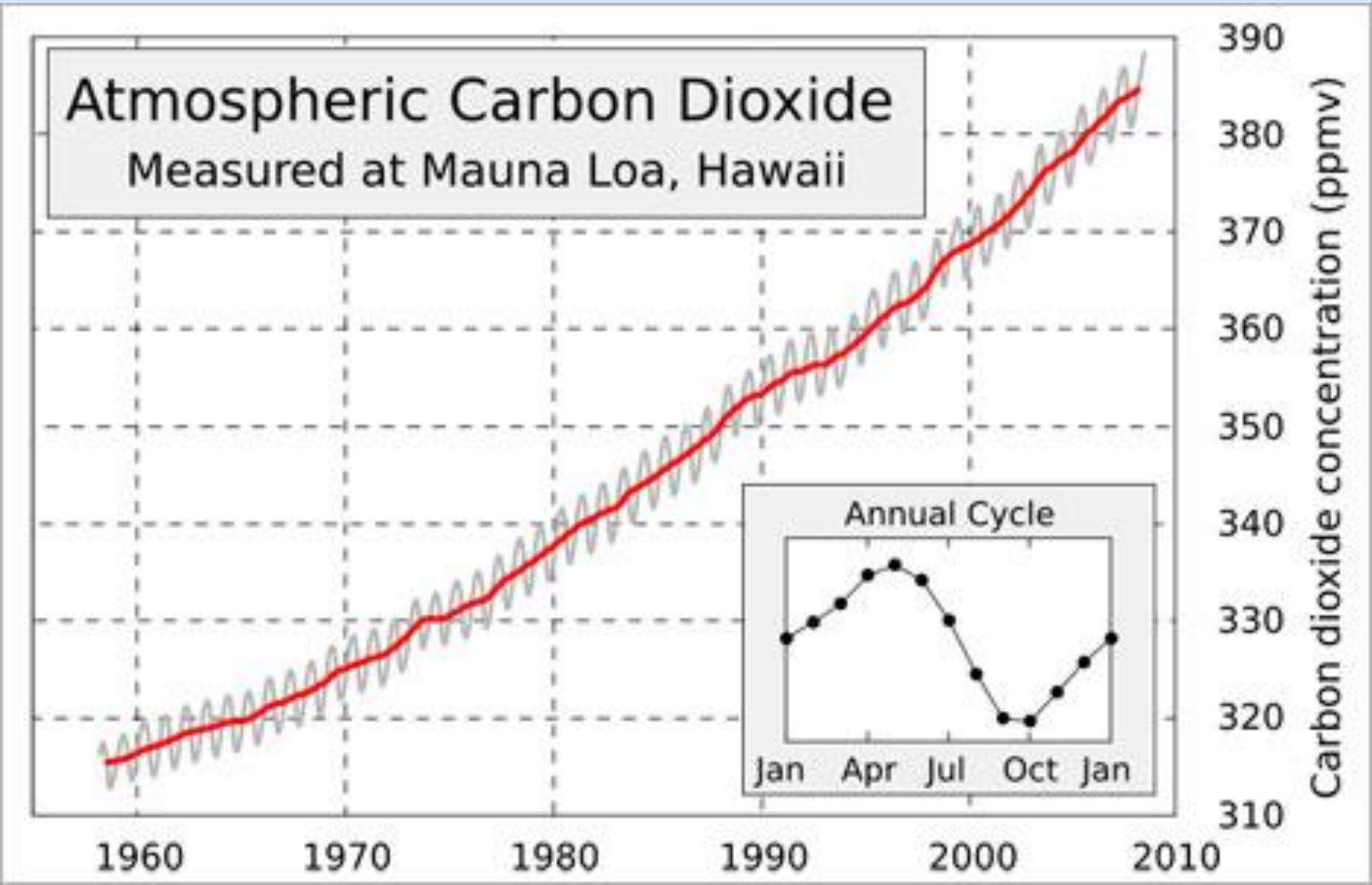
Global Climate Change and Impacts on the Pacific Northwest

Tom Ackerman
Professor, Department of Atmospheric Sciences
Director, Joint Institute for the Study of the Atmosphere and Ocean

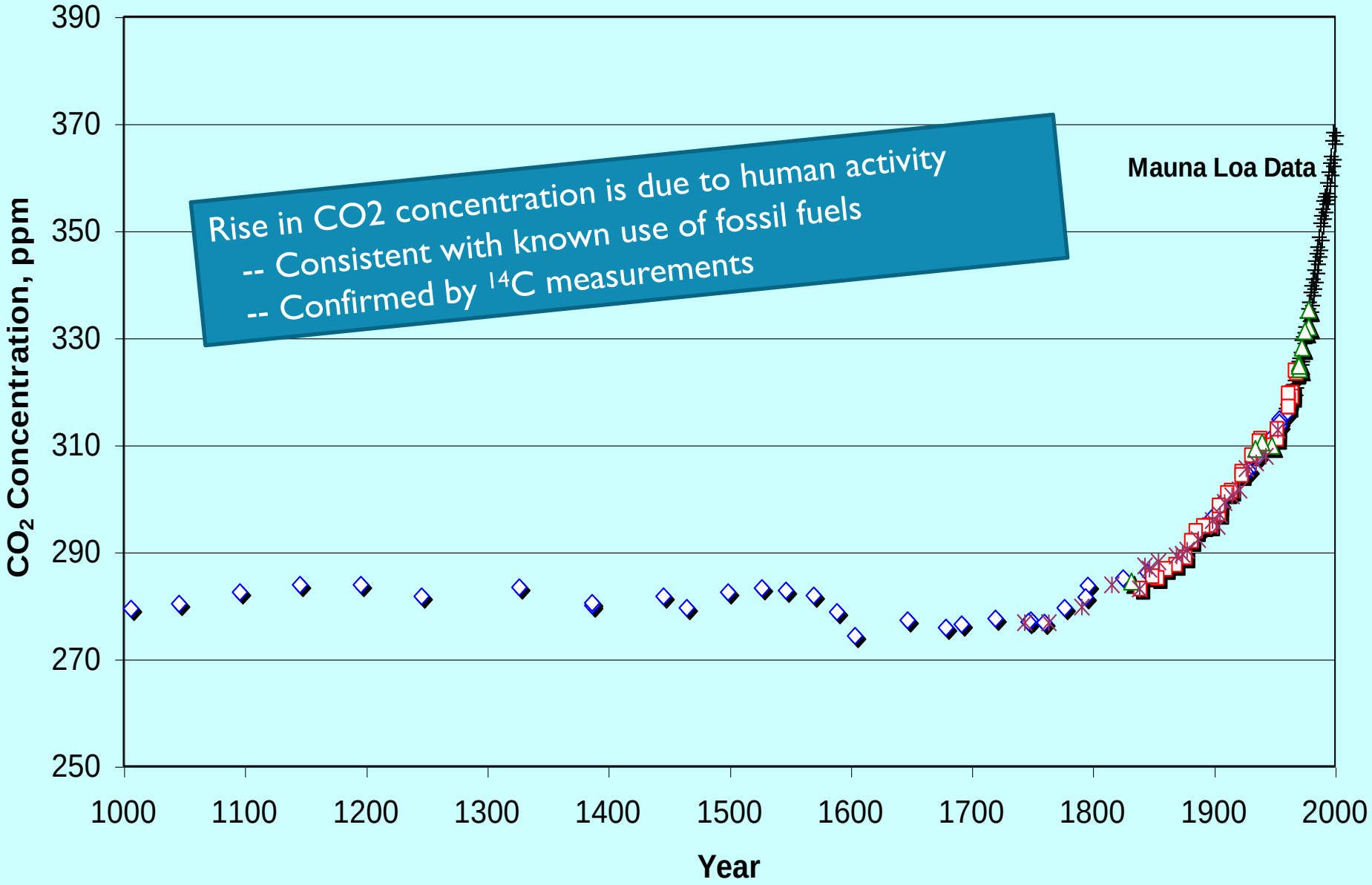
COLLEGE of the ENVIRONMENT
UNIVERSITY of WASHINGTON

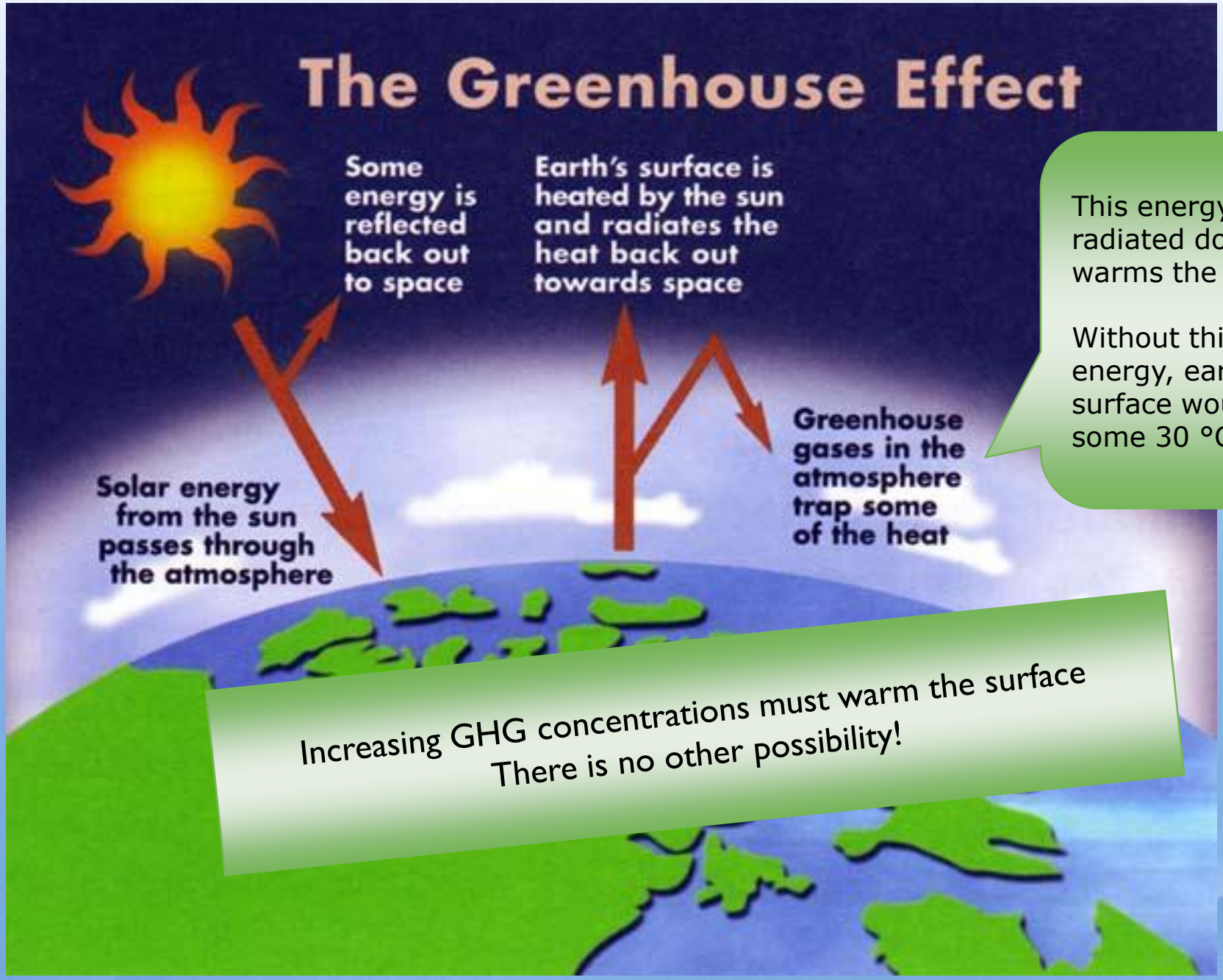
JISAO

Increasing GHG Concentration



Antarctic Ice Core Data

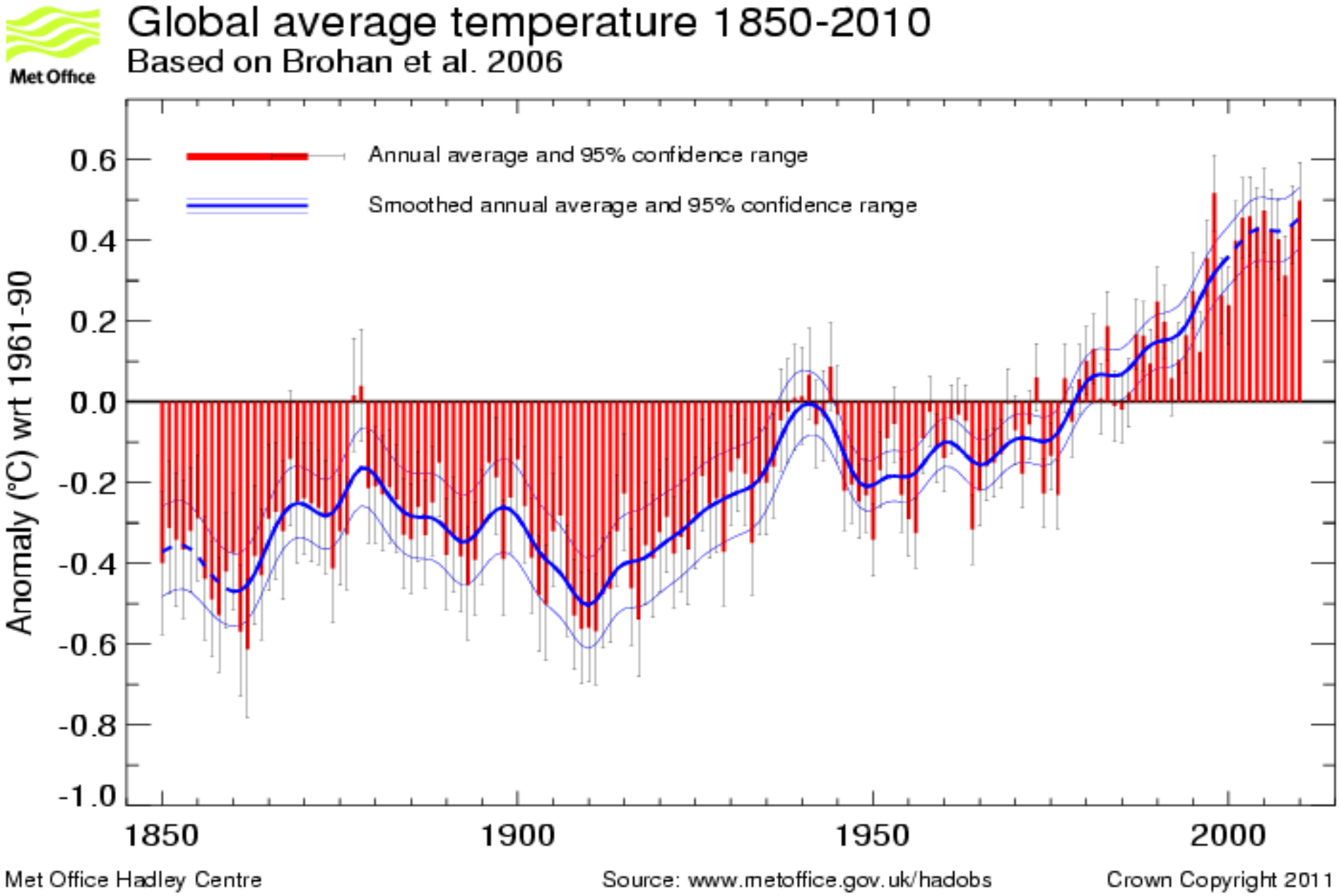




This energy is radiated down and warms the surface

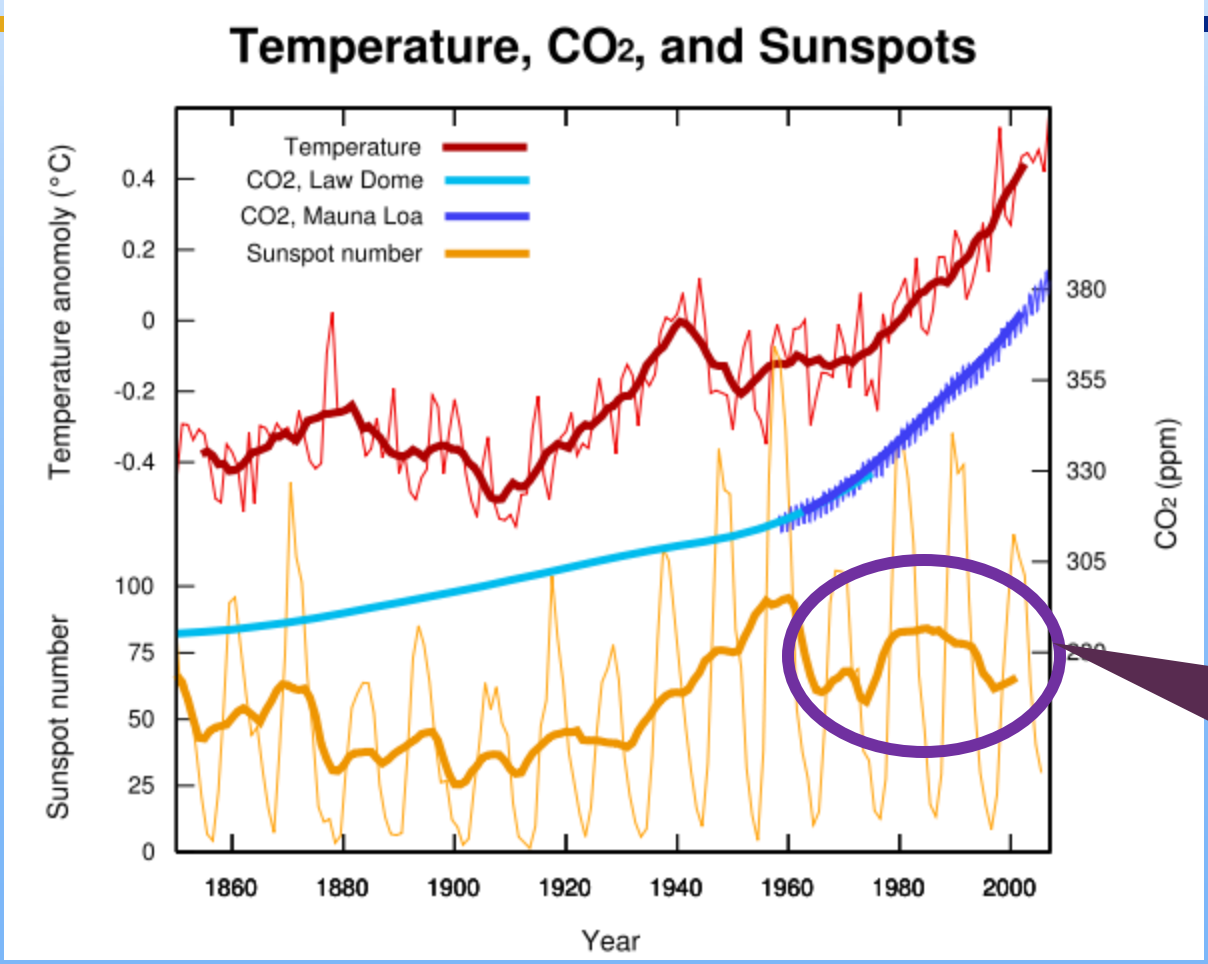
Without this energy, earth surface would be some 30 °C colder

Increasing GHG concentrations must warm the surface
There is no other possibility!



Anomaly scale is arbitrary: difference from1961-1990 average

Recent warming is not due to solar variability



Irradiance also measured by satellite since ~1975

Solar irradiance changes are roughly proportional to sunspot number

Graph from Stanford Solar Center, Stanford U.

Global climate change

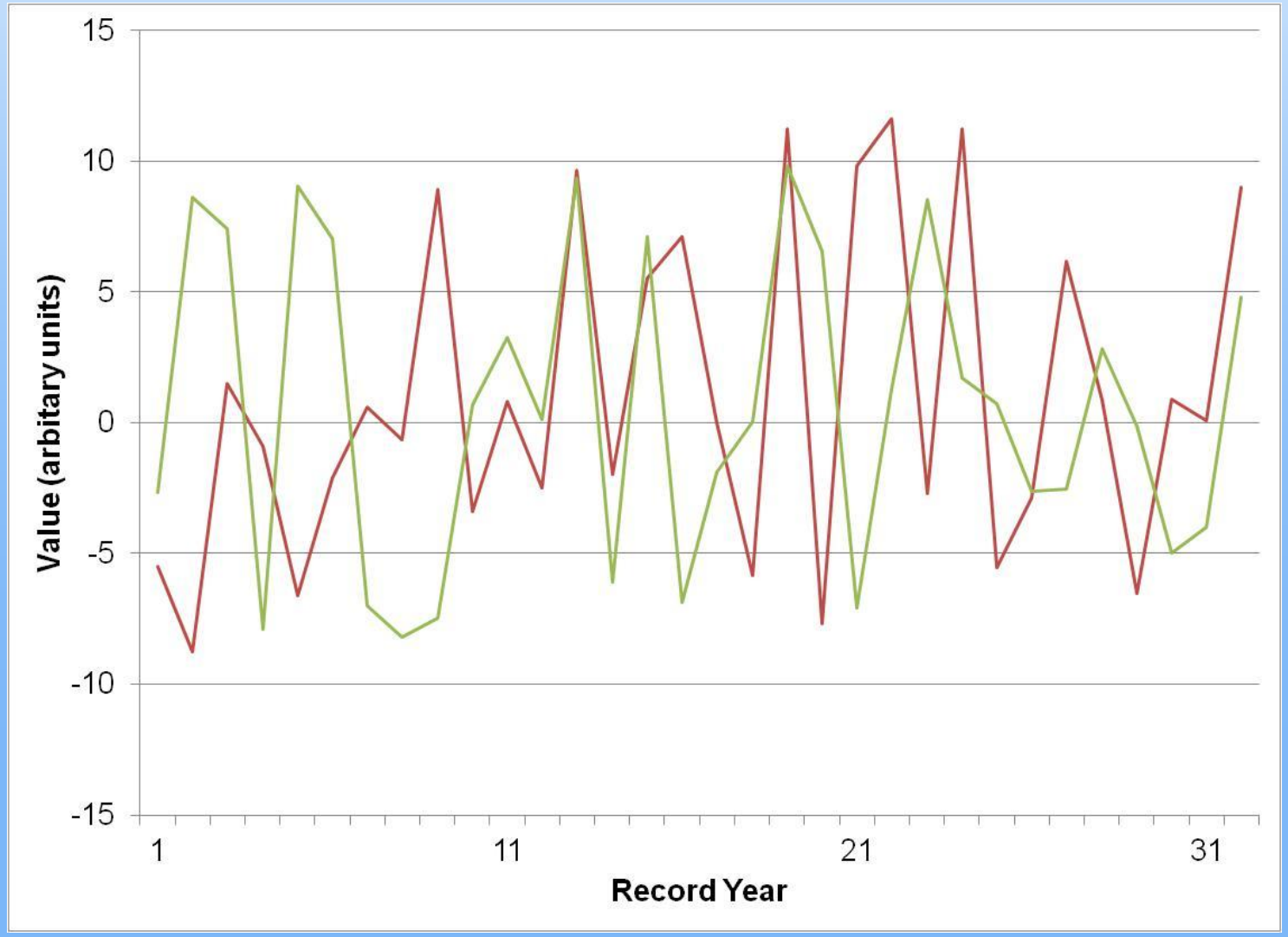
- CO2 (and other greenhouse gas concentrations) are rising in our atmosphere
- An increase in GHG's must cause surface temperature to rise
- Surface temperatures have risen in the last century
- That rise is consistent with our understanding of the physics and models of climate

What about the future?

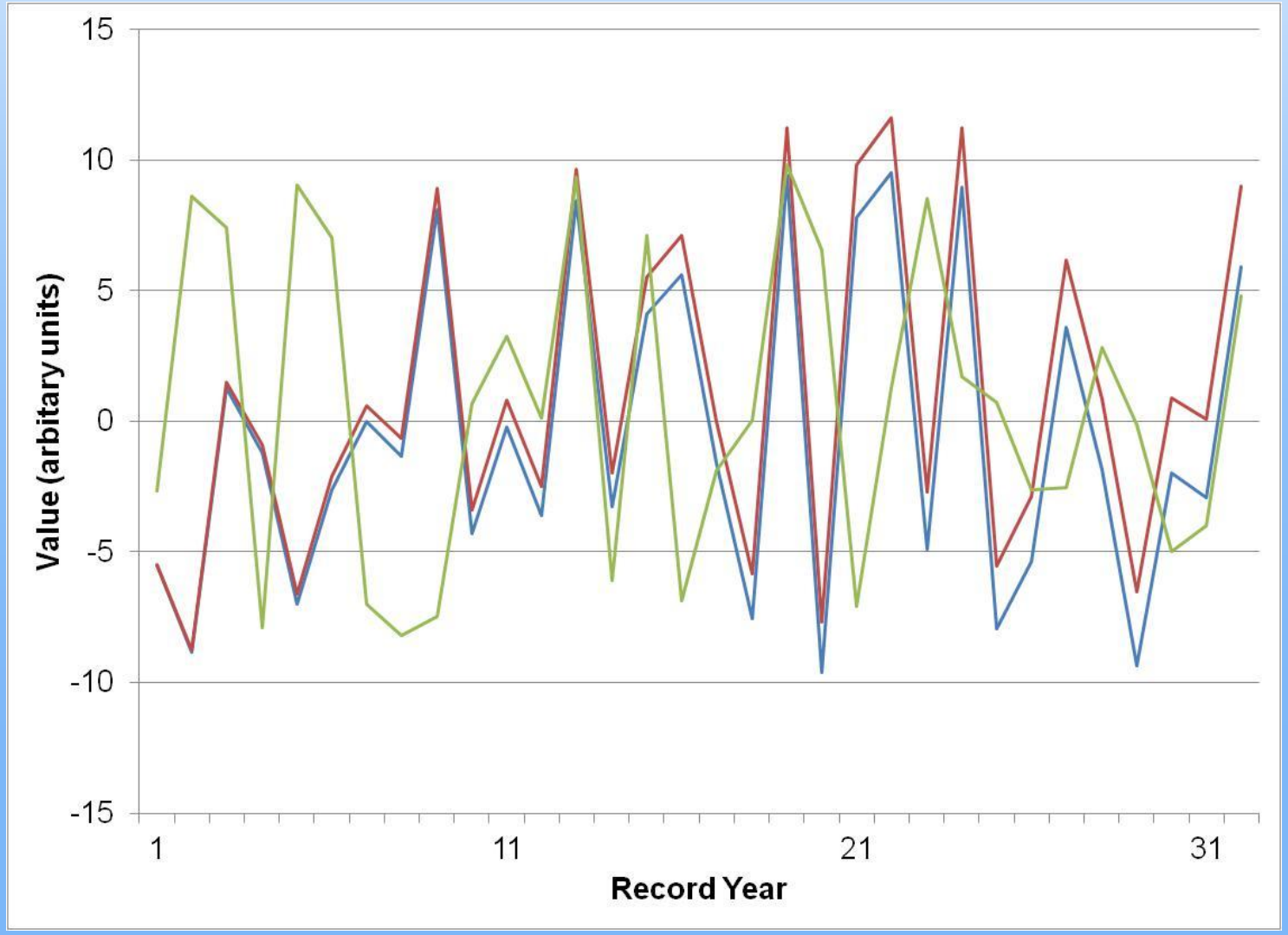
- Human activity will continue to add GHGs to the atmosphere
- The result will be a warmer world
- The extent of that warming is uncertain to a factor of 2 or so (but it will be warmer!)
- We are still working to reduce that uncertainty but it will never go away completely

A SIMPLE MODEL OF CLIMATE VARIABILITY

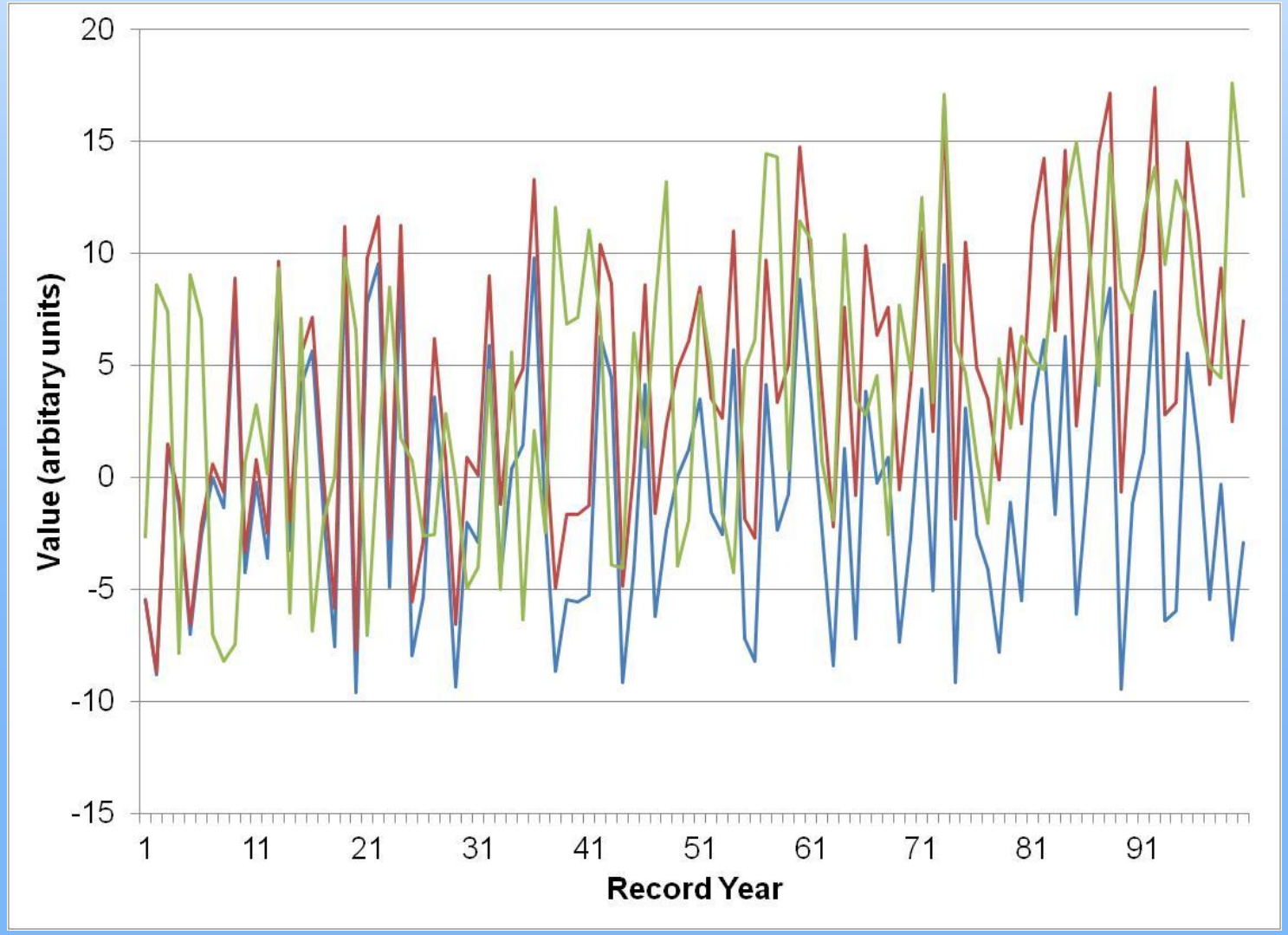
Climate variability



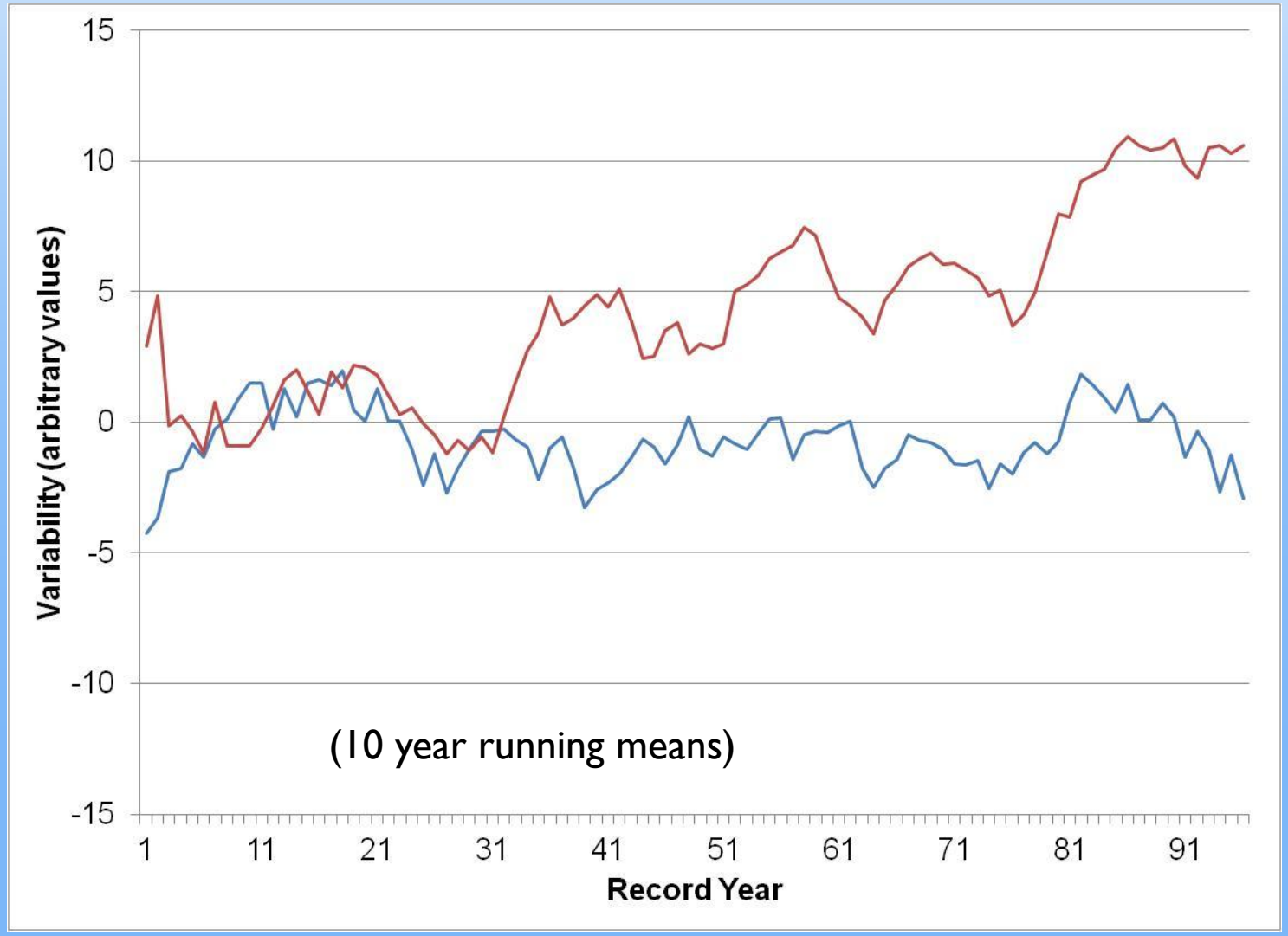
Climate variability



Climate variability and change



Climate variability and change

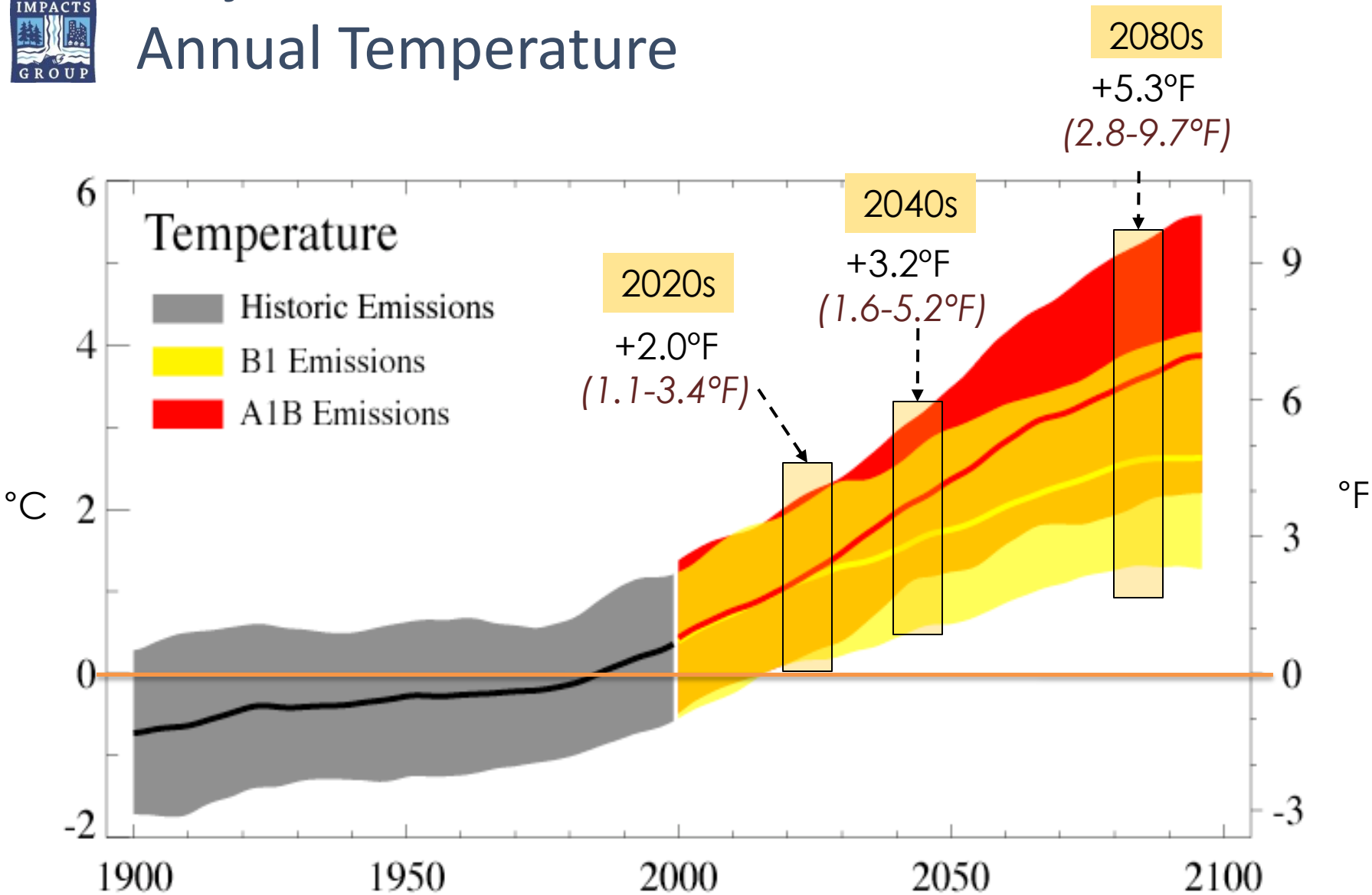


What does this mean?

- It takes time to find the climate signal in the midst of climate variability
- Averaging helps some but need to average on decadal time scale
  - Probably little observable signal in the USA for the next 20-30 years
- Will climate variability change with a warming climate?
  - Probably!

CLIMATE CHANGE IN THE PACIFIC NORTHWEST

Projected Increases in PNW Annual Temperature

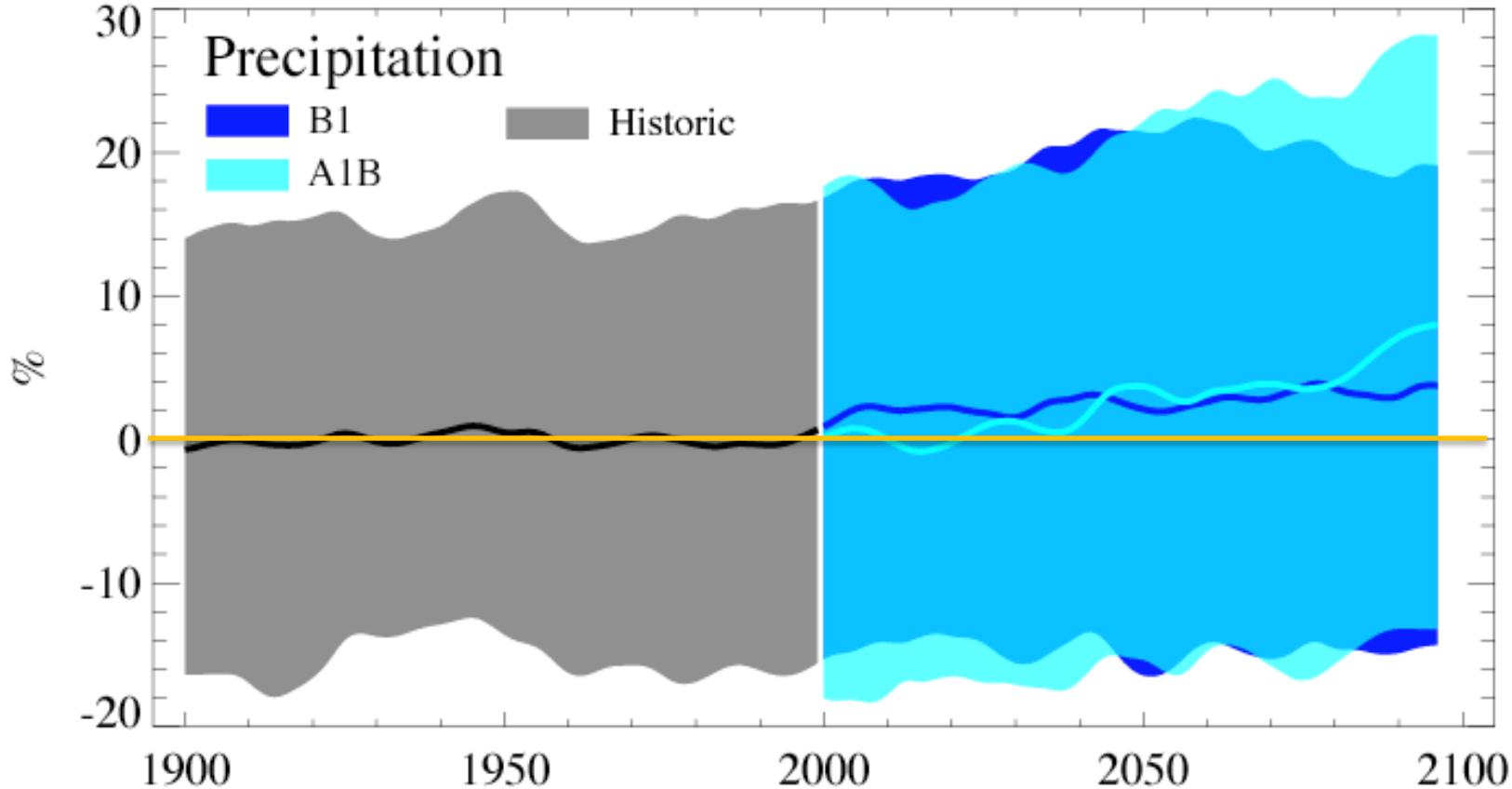


Mote and Salathé, 2009

** Relative to 1970-1999 average*

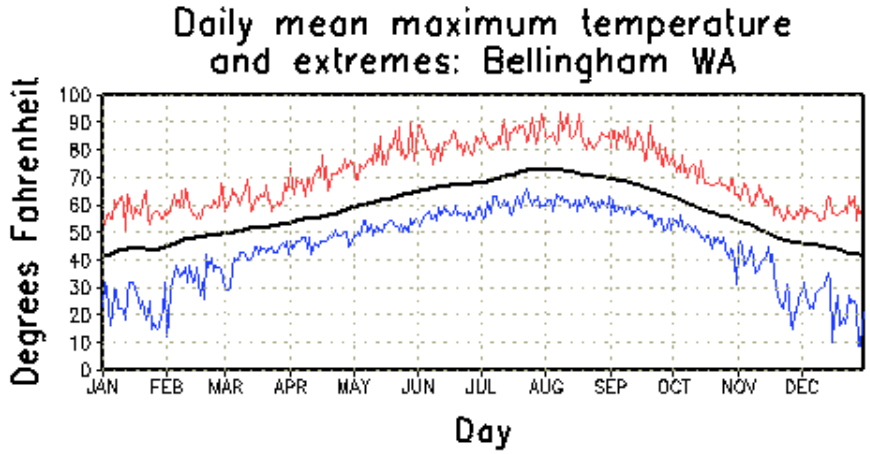
Projected Changes in Annual Precipitation

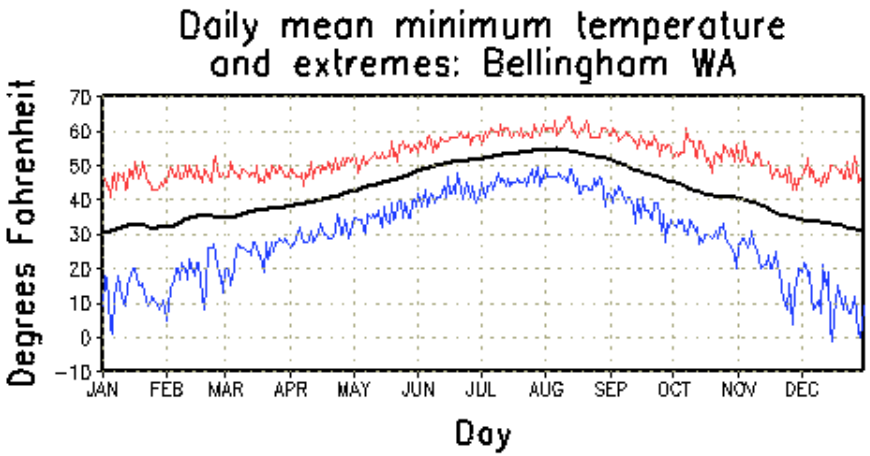
** Relative to 1970-1999 average*

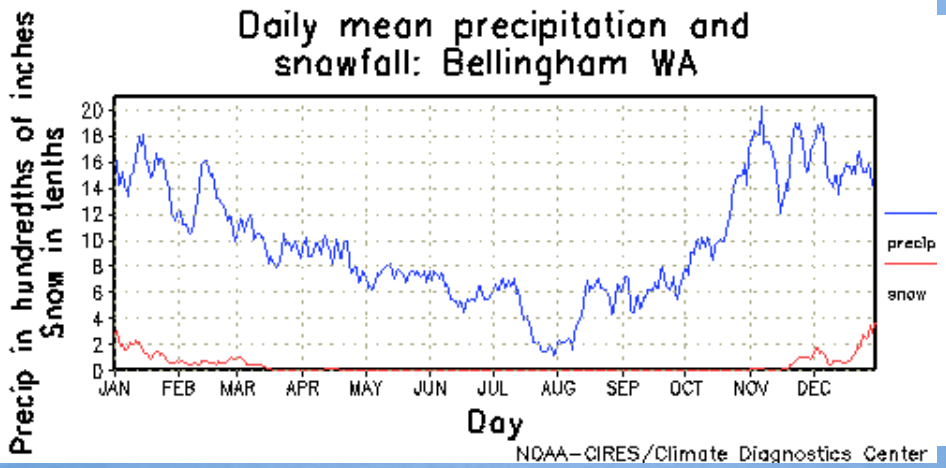


Changes in annual precipitation averaged over all models are small (+1-2%) but some models show large seasonal changes, especially toward *wetter autumns and winters* and *drier summers*.

Mote and Salathé, 2009

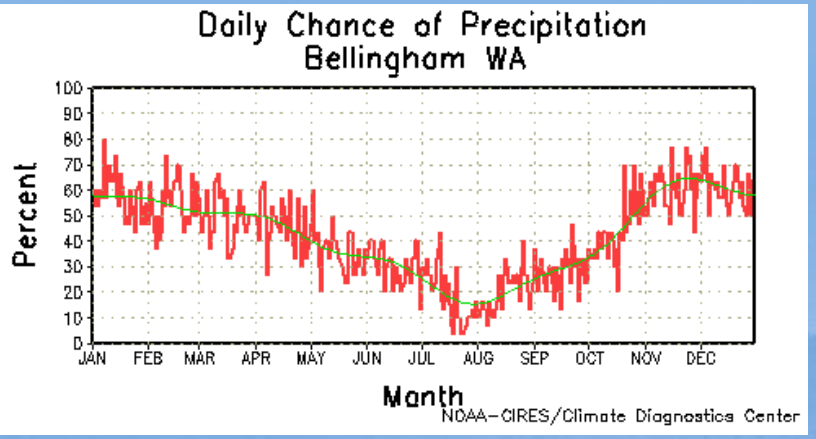






Climatological averages
1961-1990

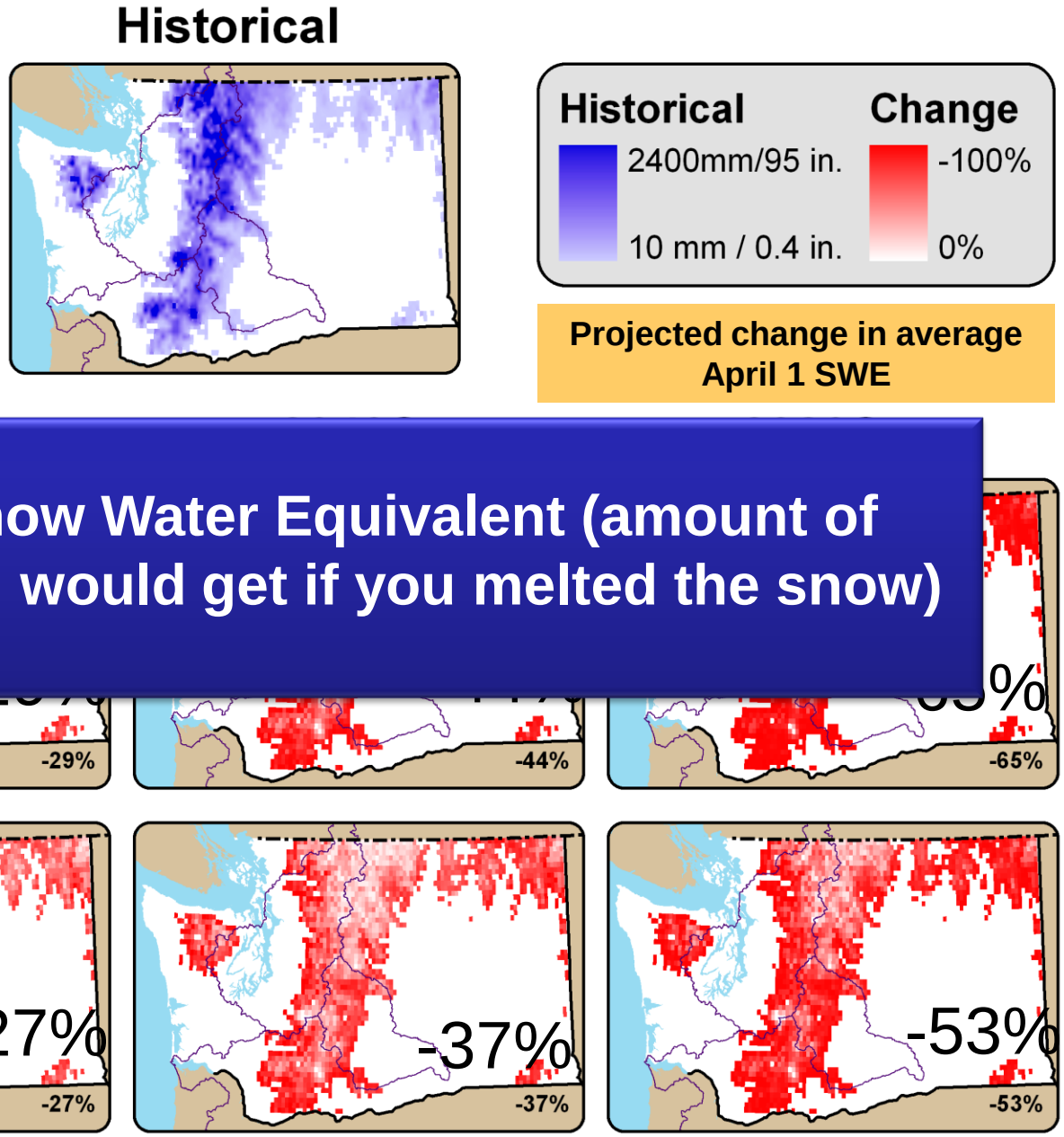
Bellingham
Lat=48.5N Lon=122.3W
Elevation=59 feet



PNW Hydrologic Change

- The PNW is reliant on winter snowpack accumulation to meet growing, and often competing, water needs
- PNW snowpack is extremely sensitive to warming
  - *the Olympic Mountains and Washington and Oregon Cascades have the highest fraction of warm snow (precipitation falling between 0°C and -3°C) in the continental U.S. (Mote et al. 2007, HESS)*
- Hydrologic impacts are the "rock in the pond", affecting a wide range of issues directly and indirectly

Key Impact: Loss of April 1 Snow Cover



SWE = Snow Water Equivalent (amount of water you would get if you melted the snow)

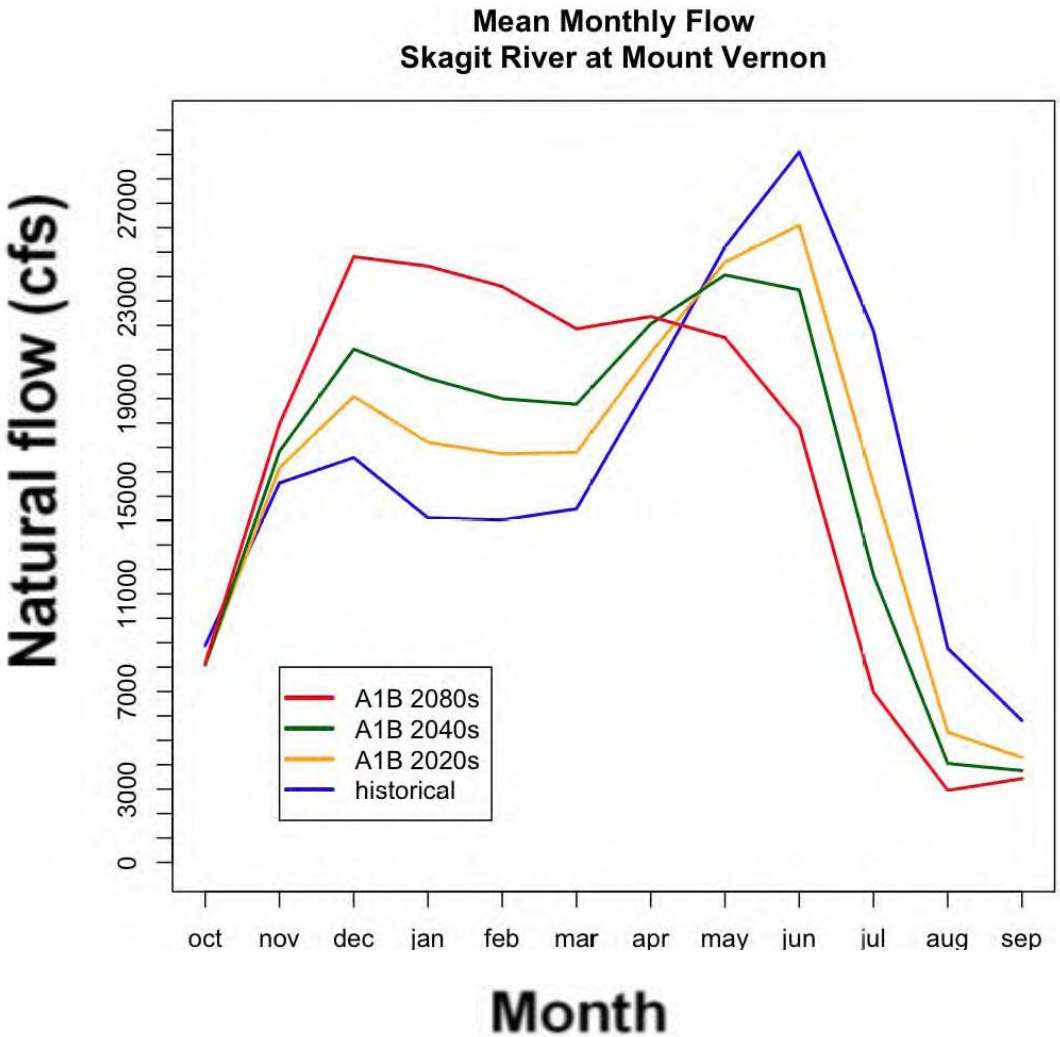
Why? Spring snowpack is projected to decline as more winter precipitation falls as rain rather than snow, *especially in warmer mid-elevation basins.* Also, snowpack will melt earlier with warmer spring temperatures

Elsner et al. 2009

Impacts on Seasonal Streamflow Timing

Historical & Projected 21st Century Flows

Medium (A1B) Scenario



Transient (mixed rain and snow) basins are most sensitive to projected warming

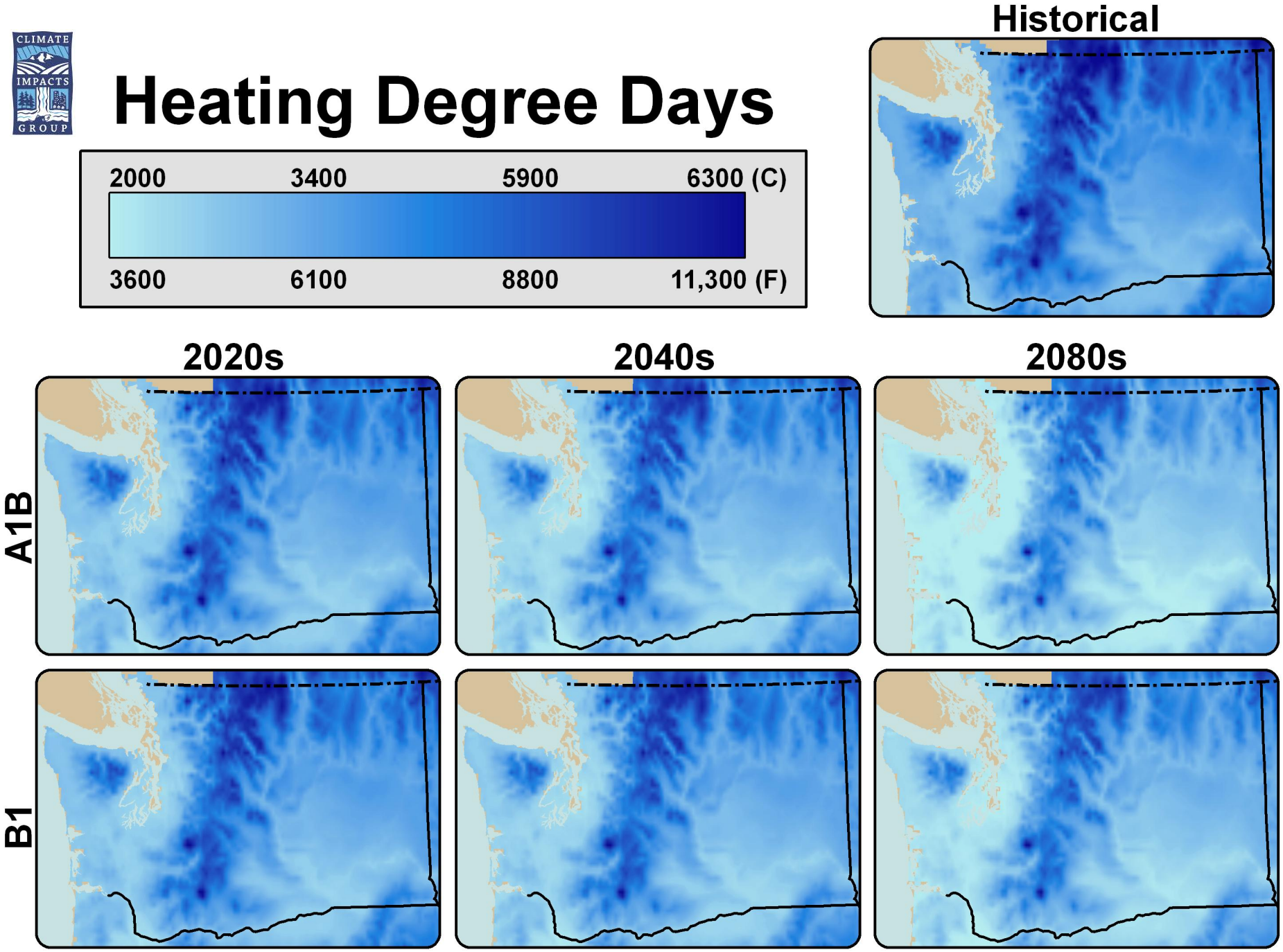
1. Increasing winter flows
2. Earlier, lower peak runoff
3. Lower summer streamflow

Elsner et al. 2009

Hydrology

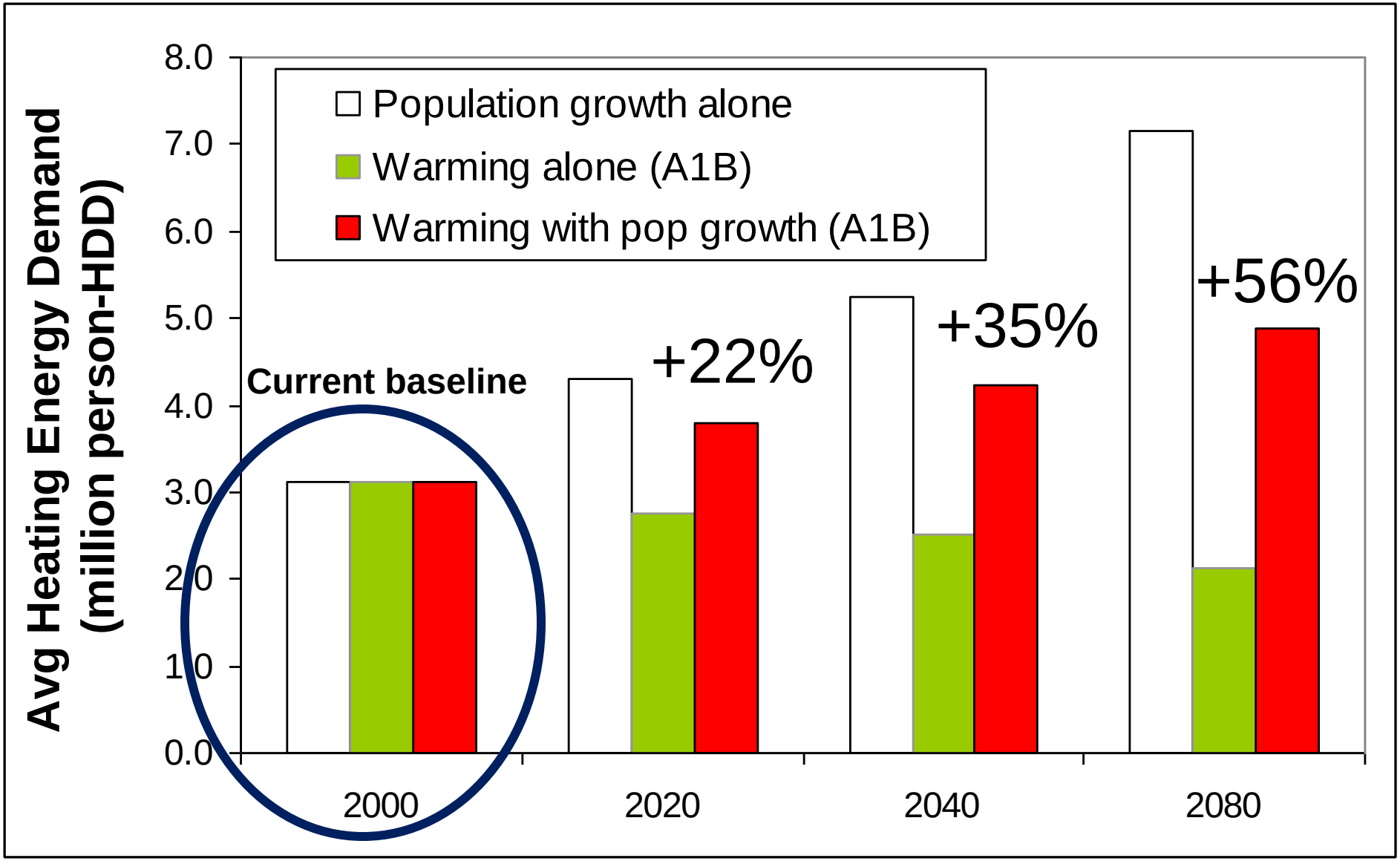
- Projection is for wetter winters and dryer summers
- Competition for water across the state
  - Power generation
  - Agriculture – more demand for irrigation
  - Salmon spawning

Heating Degree Days

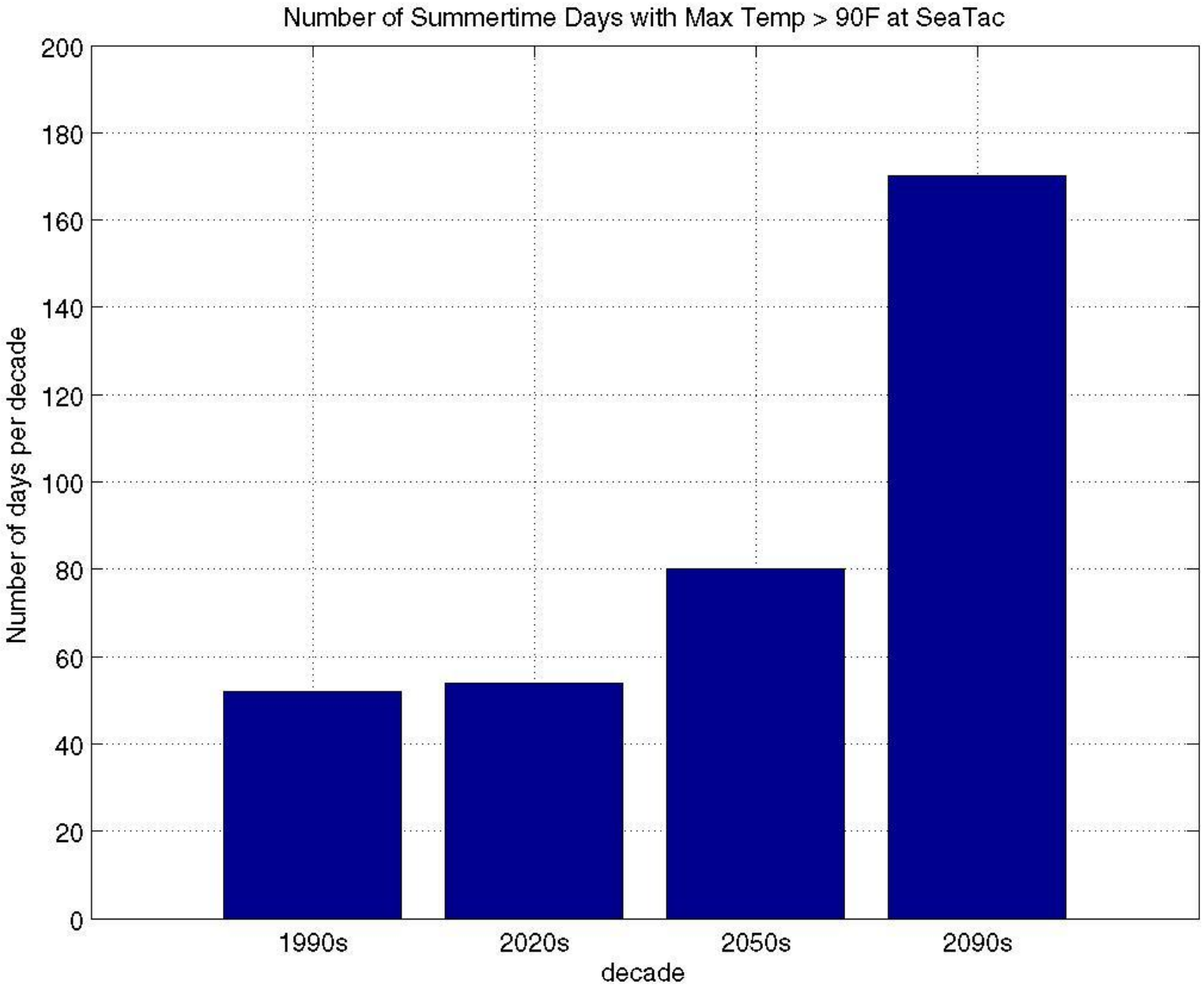


Hamlet et al. 2009

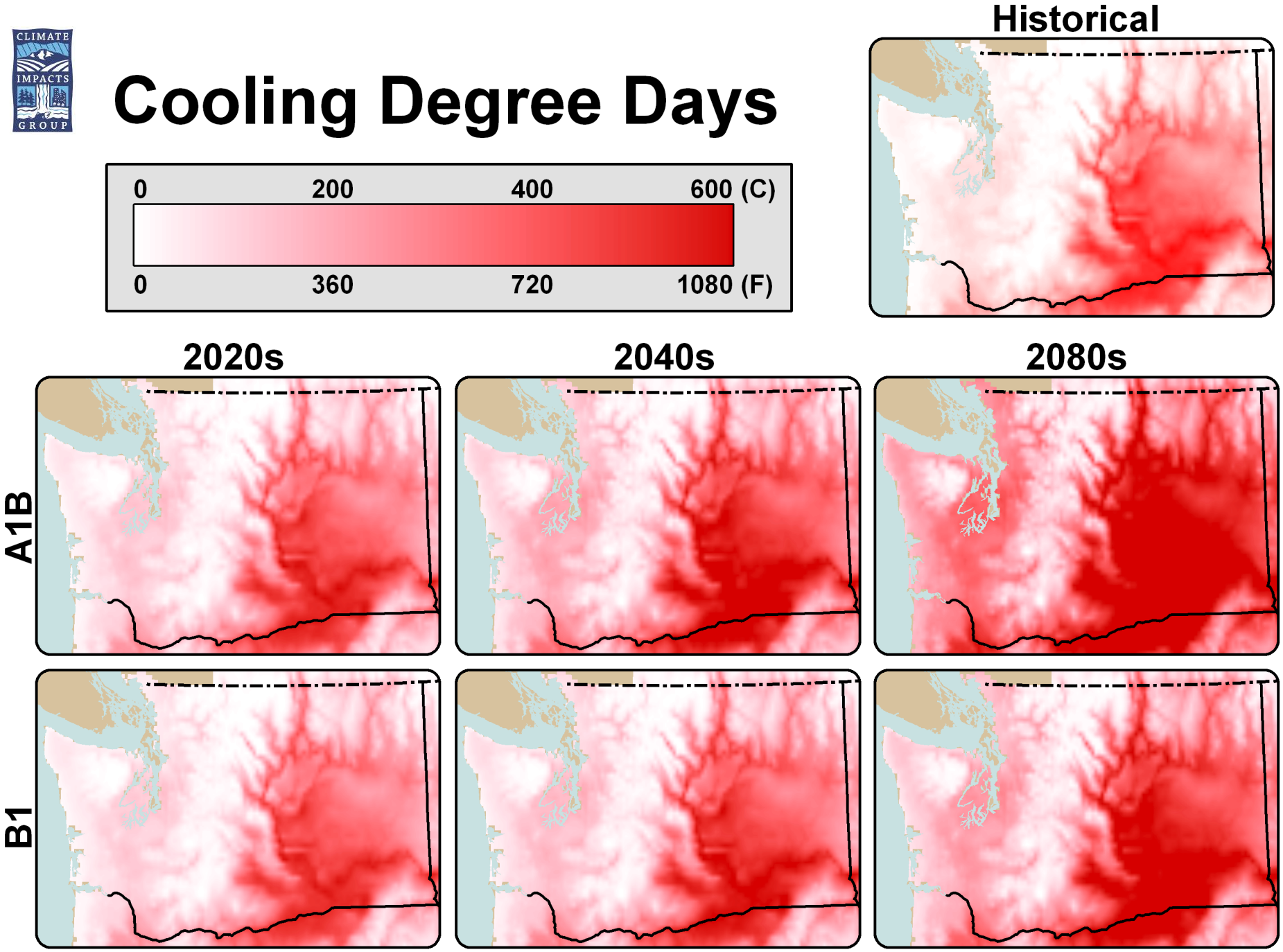
Changes in Heating Energy Demand in WA



Hamlet et al. 2009

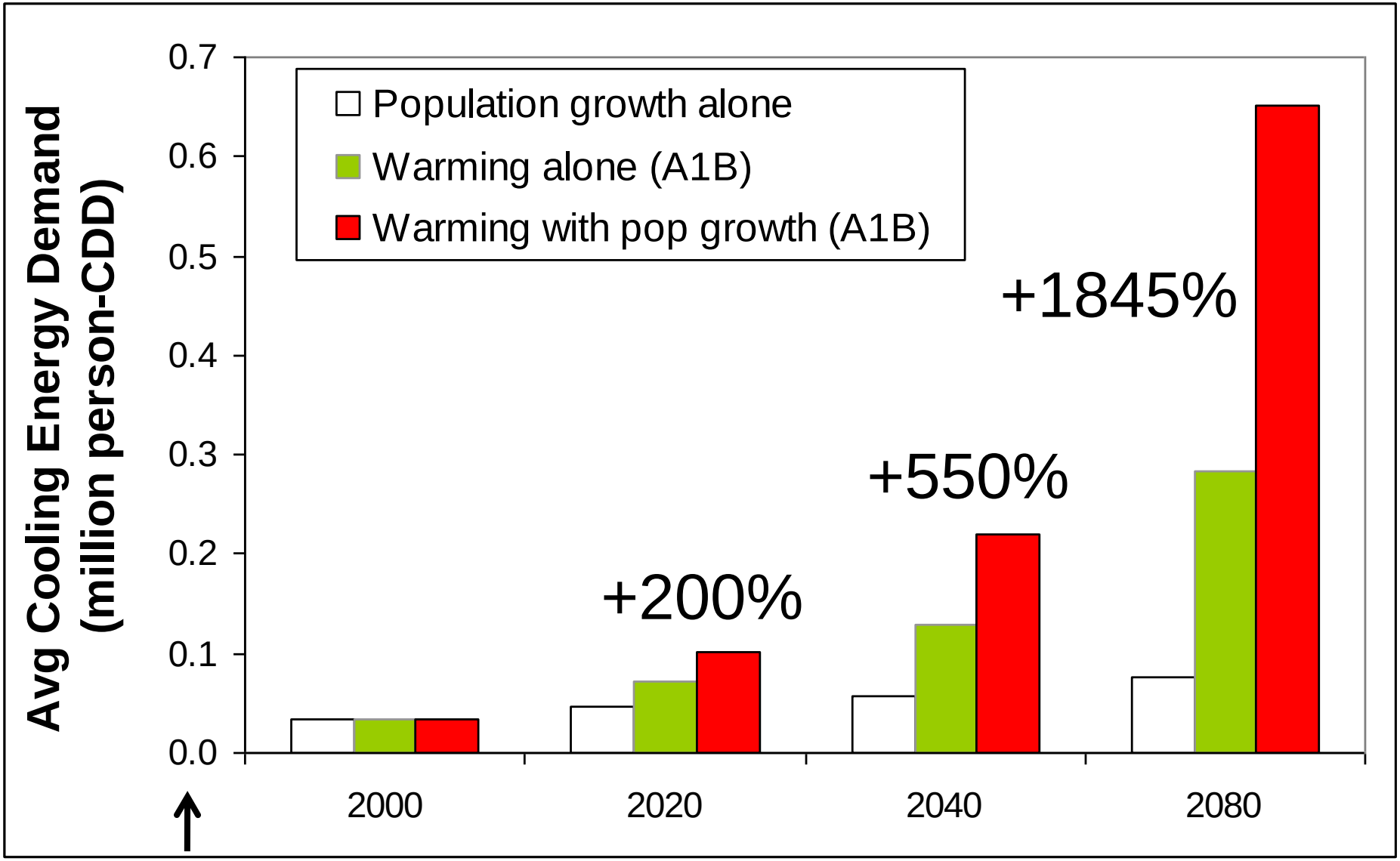

Number of Summertime Days with Max Temp > 90F at SeaTac
Number of days per decade
200
180
160
140
120
100
80
60
40
20
0
1990s
2020s
2050s
2090s
decade

Cooling Degree Days



Hamlet et al. 2009

Changes in Residential Cooling Energy Demand in WA



Scale down by factor of 10 from CDD

Hamlet et al. 2009

Planning considerations

- Increasing competition for summer water
- Transboundary relationships in the Columbia drainage are likely to be impacted – require new agreements?
- Likely result is loss of summer energy production – less energy to ship south and higher prices
- Reduction in winter heating demand but increase in summer cooling demand

Pacific Northwest Sea Level Rise

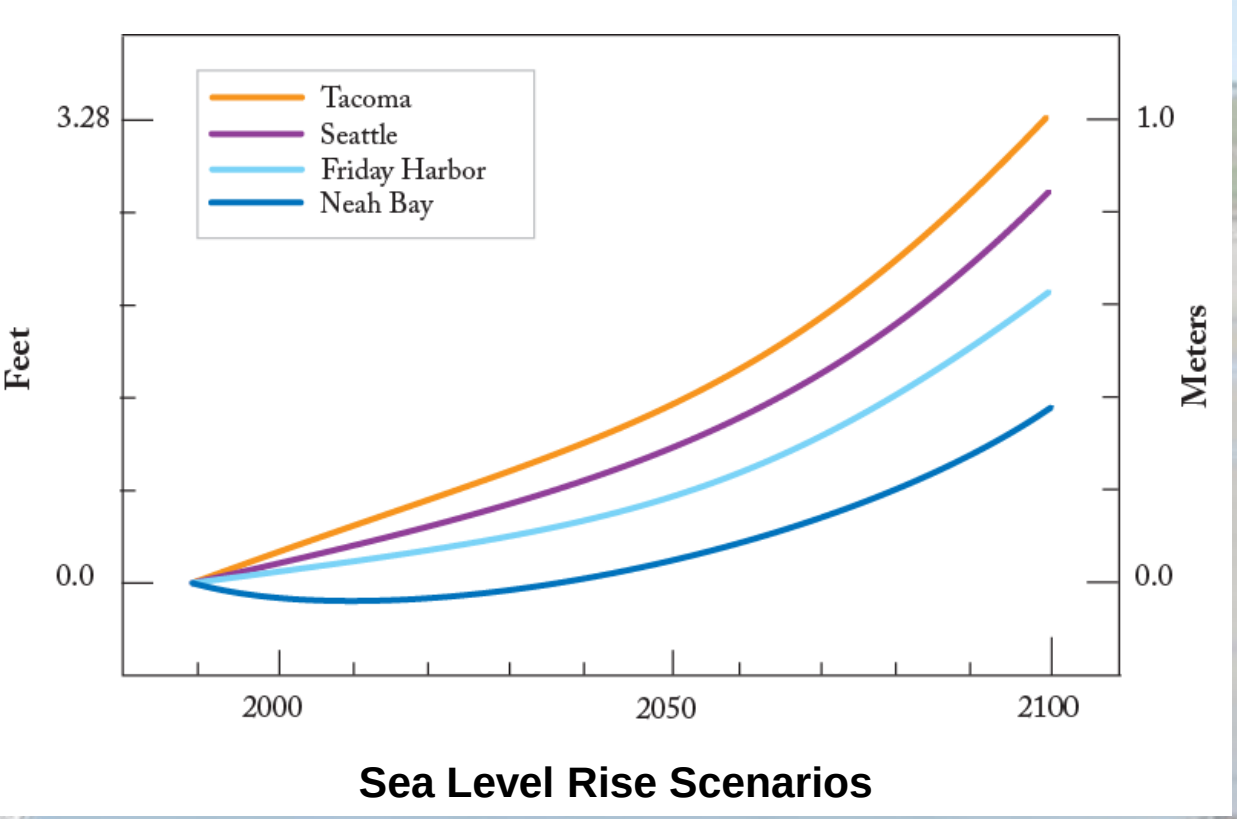


Figure based on 20 inches of SLR (2001 IPCC scenarios) and assumptions about changes in land surface elevation

- Relative sea level rise <u>may</u> be greatest in South Puget Sound (~3.3ft by 2100) and least near Neah Bay (~1.3 ft by 2100)

Sea Level Rise Risks and Benefit

Increased risk of:

- inundation of low-lying areas
- loss of nearshore habitat
- coastal erosion
- bluff landsliding
- salt water intrusion into coastal aquifer

A benefit:

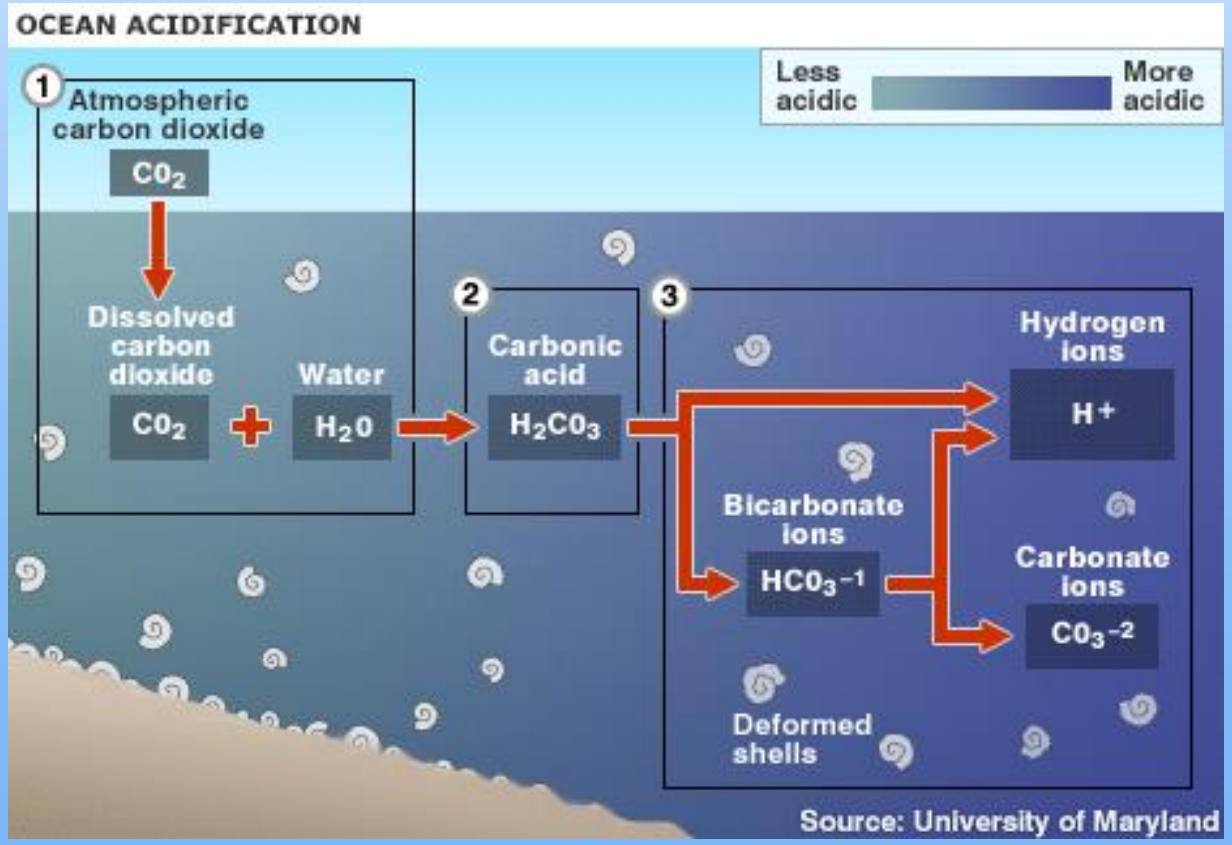
- Improved ferry access at low tide
- Others?

highly ocation not just an sea level.

And then there is the entire issue of melting ice sheets in Greenland and West Antarctica …

Will that happen? We don't know, but don't bet against it!

Ocean acidification

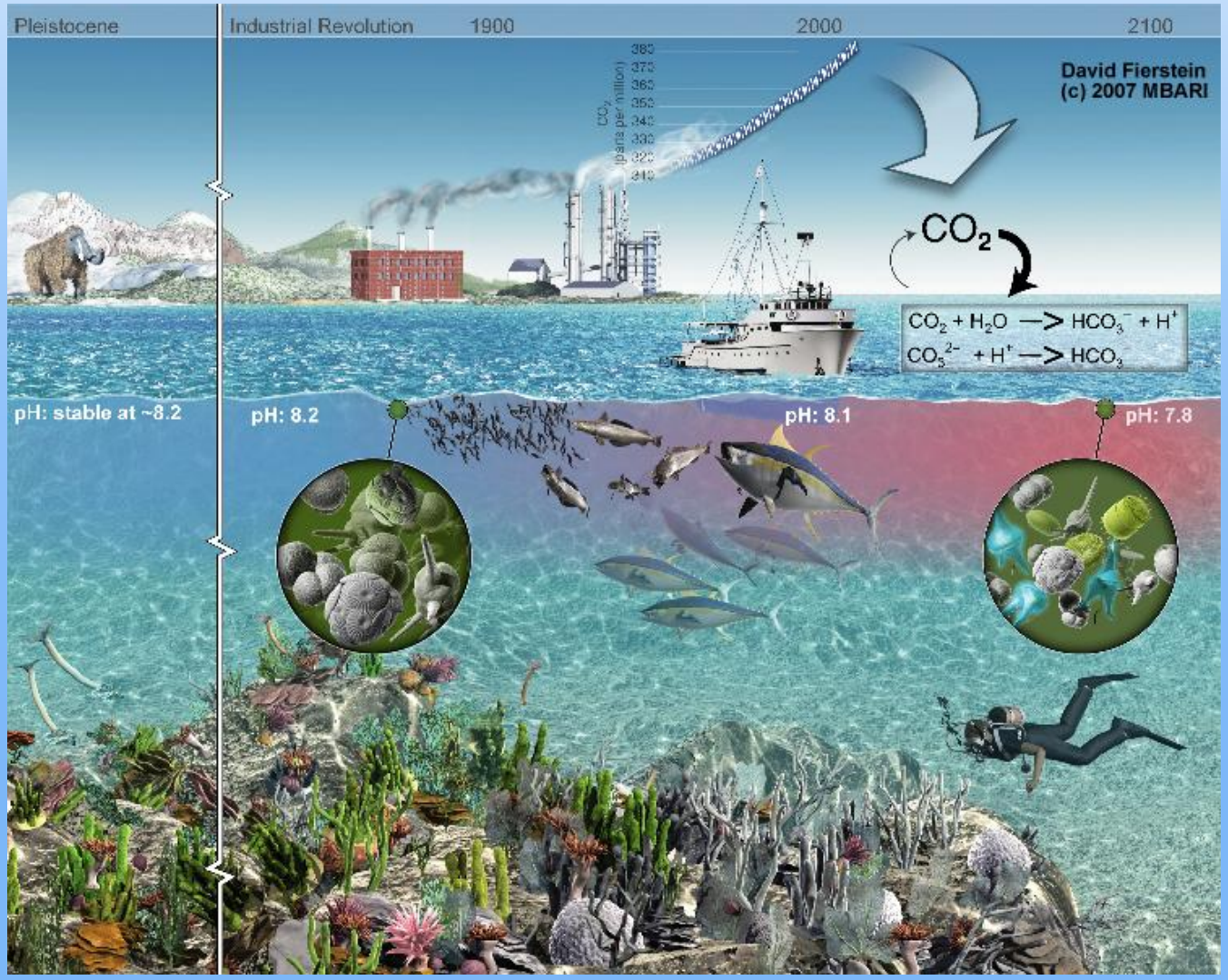


Roughly half of all CO2 emitted from fossil fuel burning ends up in the ocean

Measurable acidification has occurred

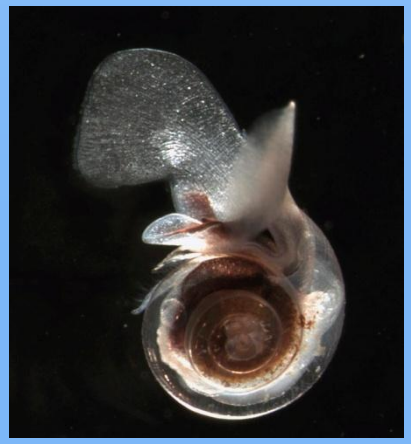
Rate of CO2 uptake by ocean: more than 1 million tons per hour

Effect on sea life



Impacts ability of small organisms to form carbonate shells

Pteropods (prime food for juvenile salmon) are especially vulnerable



What do we know?

- Puget Sound is already suffering from low pH (acidity) and anoxic conditions
- Not sure why – probably related to river discharge of nitrogen and pollutants
- Acidity will increase
- Likely result is further degradation of fish and shellfish in Puget Sound
- Lots to learn about this

Summary

- Hydrology – expect dryer summers and reduced river flow; probably wetter winters
- Temperature – expect warmer climate, with reduced need for heating and increased need for cooling
- Sea level rise – expect at least ½ meter of rise by end of century and could well be more
- Ocean acidification – don't know what to expect but it is likely to be bad
- Extreme events are likely to change
  - Hotter and more intense precipitation

Moving forward

- Needs
  - More and better information about climate change for Pacific Northwest
  - Information needs to be continually updated
- Solution
  - Develop a regional climate modeling consortium
    - UW climate science and hydrology groups
    - Regional users of climate information (transportation, agriculture and aquaculture, ports, health and safety)

Thank you for your attention

Mt. Shuksan, Cascade Range, Washington