Climate Change in Washington: Past and Future

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Climate Science in the Public Interest

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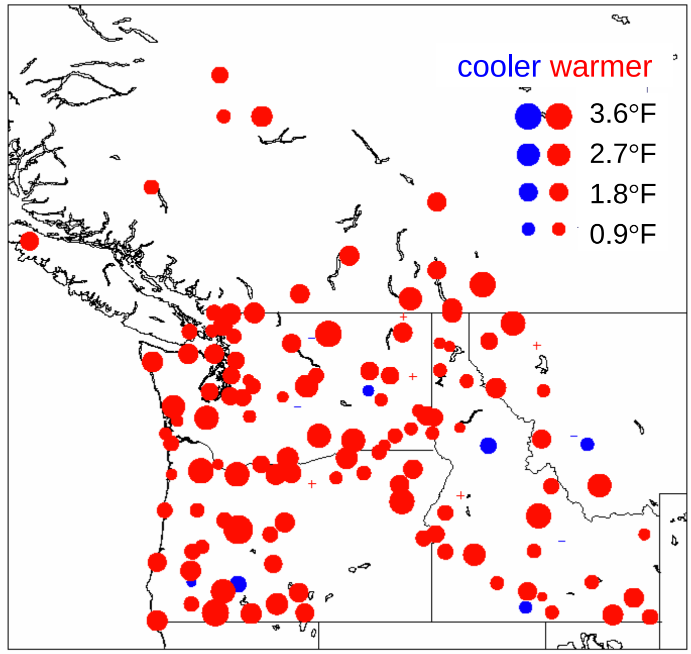
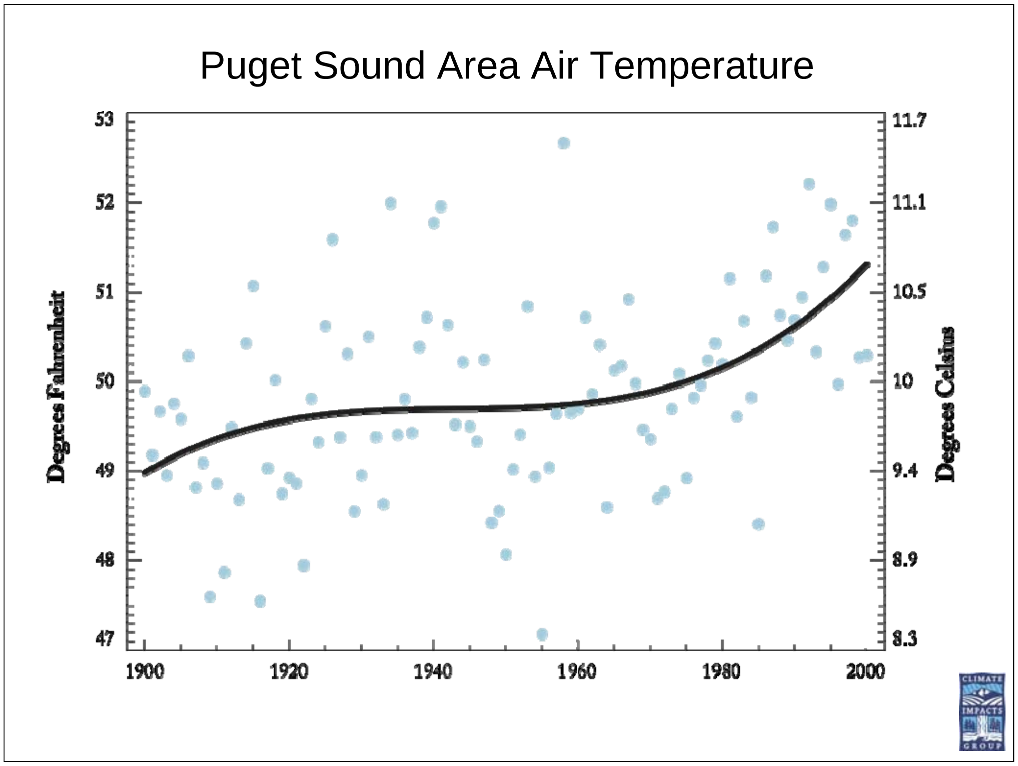
The Future Ain't What It Used to Be: Preparing for Climate Disruption

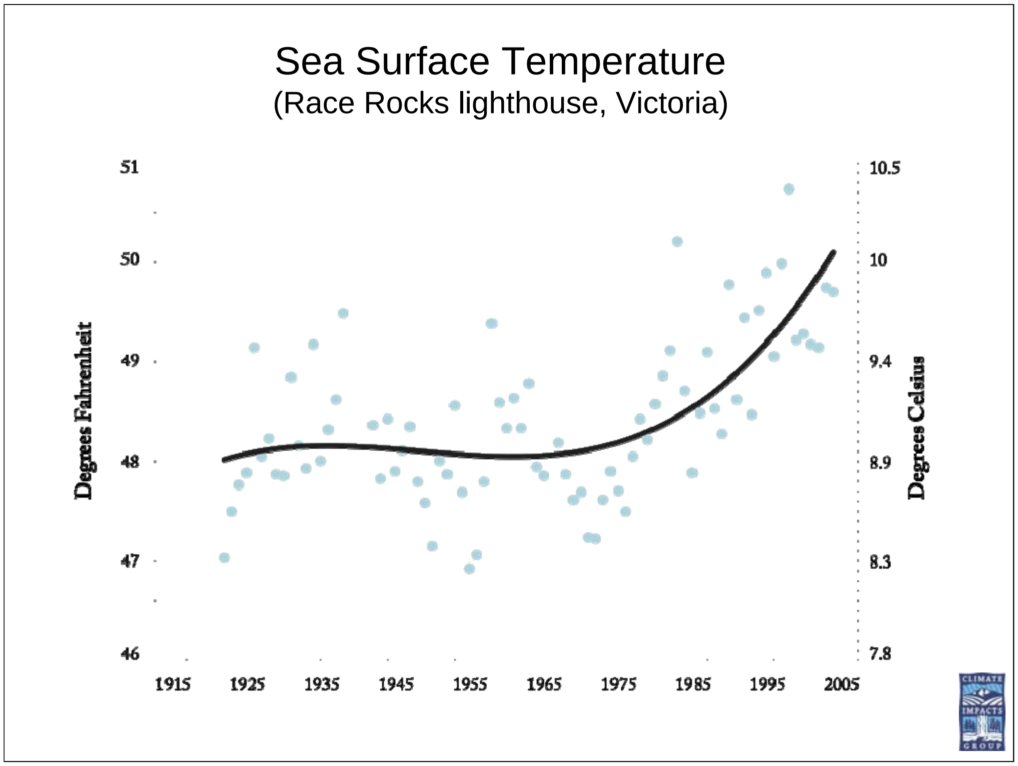
Temperature trends (°F per century) since 1920



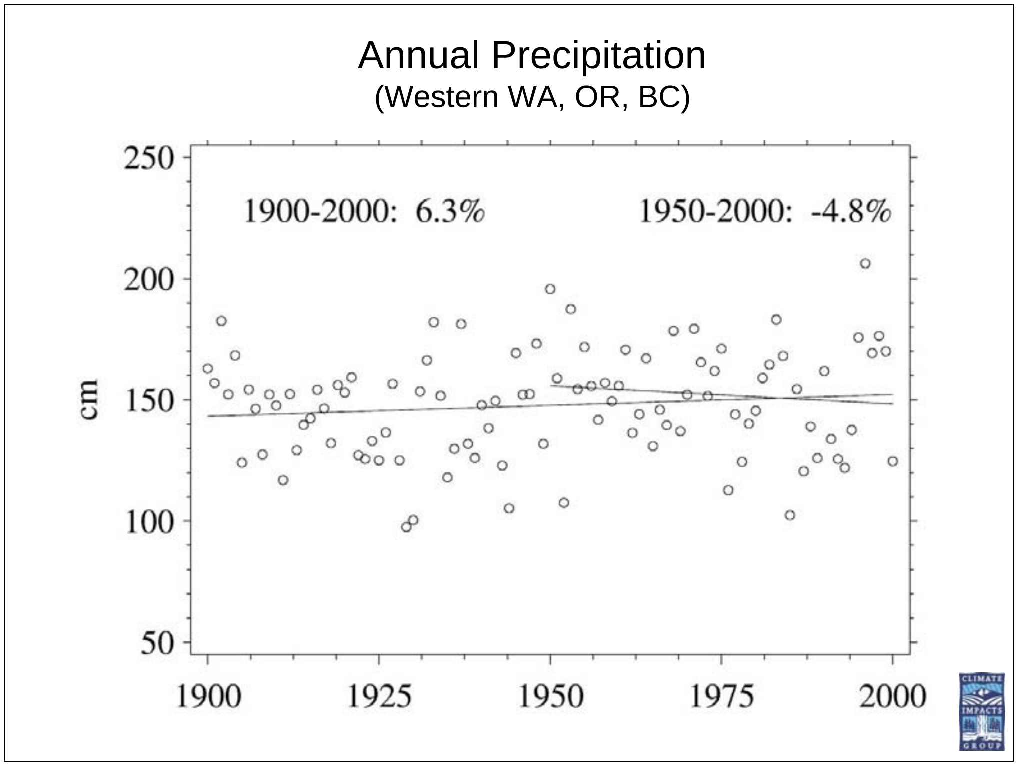
Each dot represents a station with data going back at least to 1920, size of dot shows magnitude of linear trend. Open circles are negative trends - not many of those. Most trends in the 1-3°F range. The regional average (using appropriate area-weighting) is 1.5 ° F/century. These data have been quality-controlled and corrected by the National Climate Data Center. This includes removing the “urban warming” effect, which is statistically estimated and is very small.



The temperature at each of the Puget Sound-area stations shown in the previous figure has been averaged to produce a single value for each year, and then a third-order (cubic) polynomial has been fitted to the data (black curve). Most of the 20th century warming (1.7F) occurred since 1960, and none of the years since 1986 has had a temperature below the 20th century mean.



Corroborating evidence of the regional warming comes from the measurements of sea surface temperature at Race Rocks lighthouse near Victoria, BC. The warming rate since 1970 is over 2°F and the shape of the curve is similar. Note too that the average temperature is somewhat lower and the interannual variability is much lower.

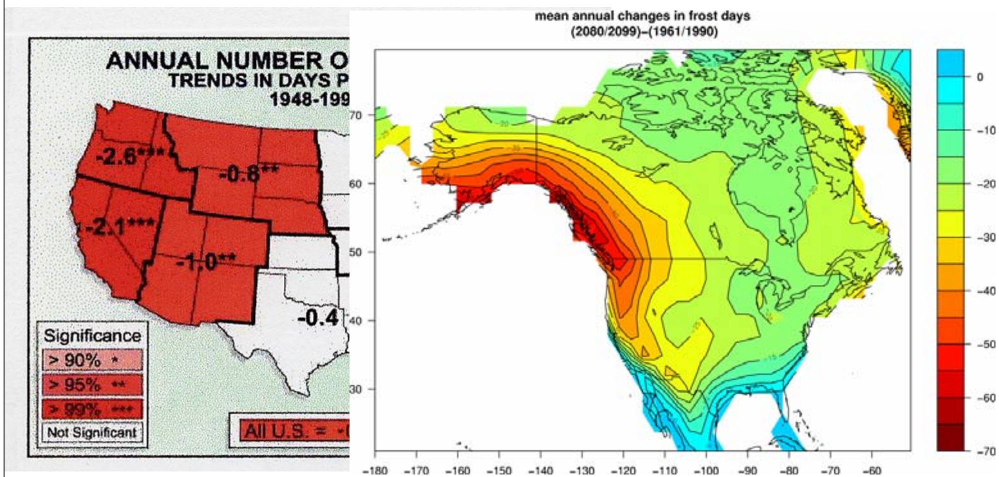


In contrast to temperature, which has shown very strong and statistically significant trends since mid-century, precipitation in this region has fluctuated on interannual and interdecadal timescales but with no persistent trend. Trends since about 1920 or 1930 are rather positive, trends since 1945-55 somewhat negative.

Climate change is more than just averages

- frost days decreasing
- snowfall decreasing
- precipitation intensity...

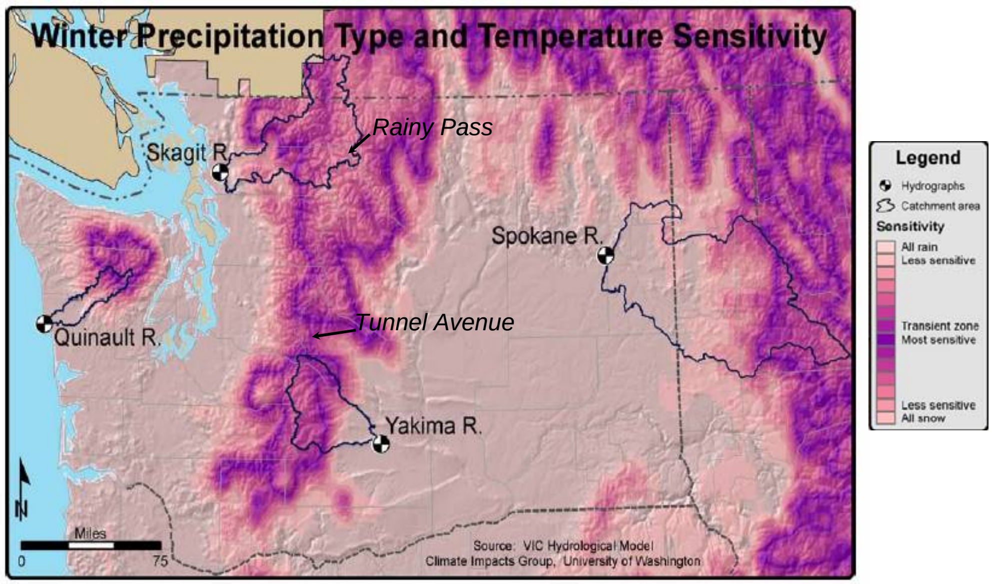
Large decline observed in frost days in the late 20th century…



…and predicted by a global climate model

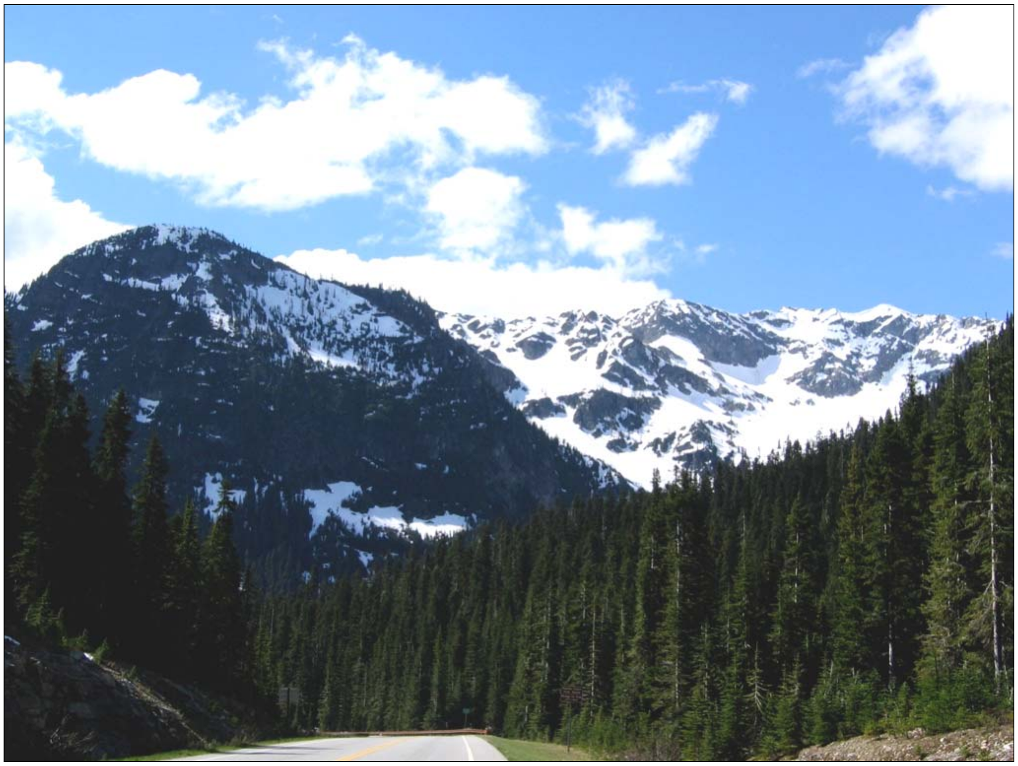
Observed trend in number of frost days has been larger in the Northwest than anywhere else in the country, almost 2 weeks since 1948. Western declines in frost days are almost entirely due to earlier spring. The PCM predicts future declines in frost days on the order of two *months* by late 21st century.

Figure courtesy Jerry Meehl, NCAR.

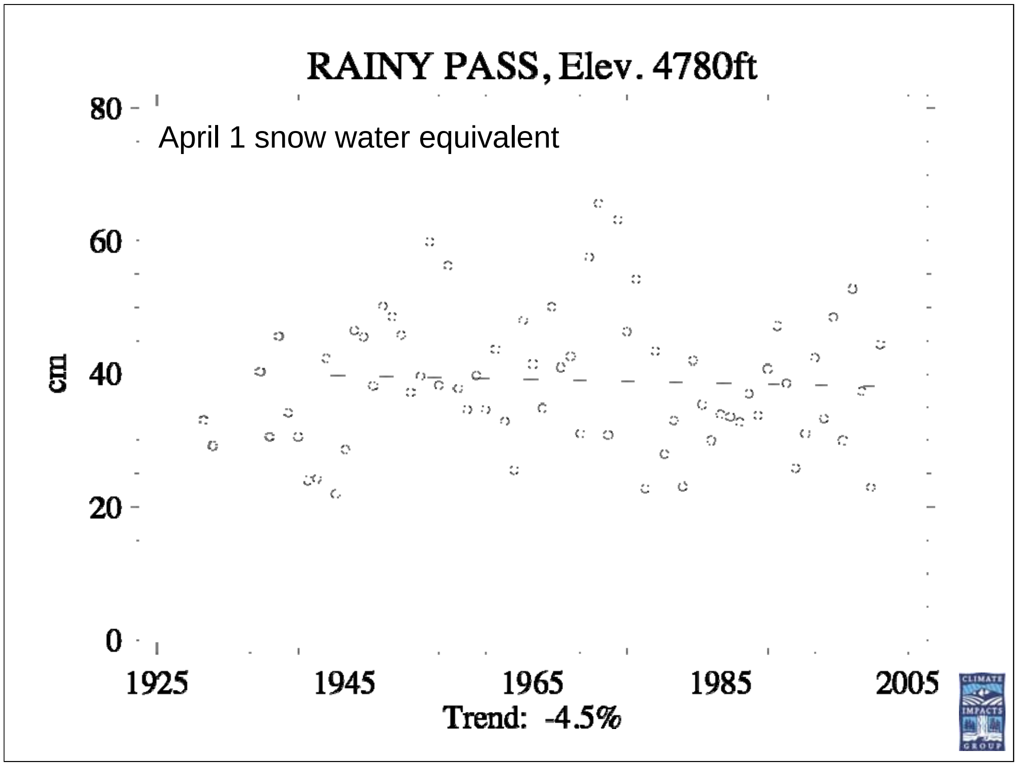


This figure shows that most of Washington's mountainous areas are sensitive to temperature, with a mean winter temperature just below freezing (deep purple areas). High elevations are so cold that they are not sensitive to modest increases in temperature (a few °C); low elevation areas are so warm that they rarely get snow. I will shortly show graphs of long-term records at a high-elevation location (Rainy Pass) and a moderate-elevation, temperature-sensitive location (Tunnel Avenue).

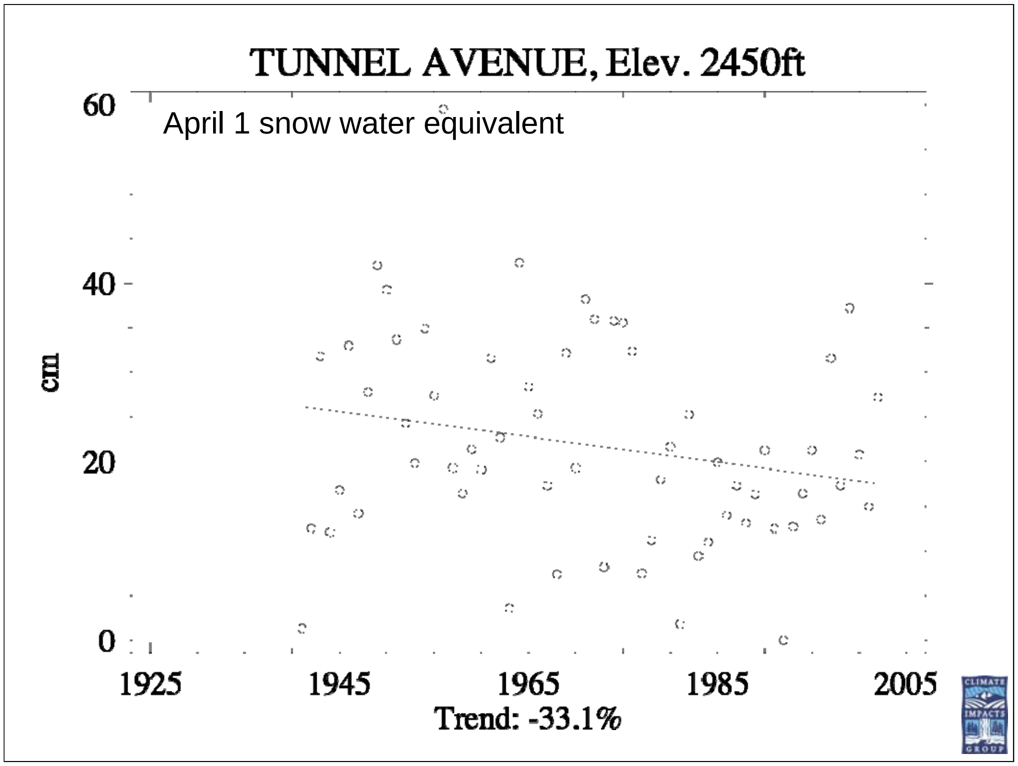
Here’s a photo of Rainy Pass



View from Rainy Pass



These records of “snow water equivalent” are maintained by the US Department of Agriculture’s Natural Resources Conservation Service. In common with many locations above 4500 feet in the Cascades, Rainy Pass shows no significant long-term change, and in fact the year-to-year variations are almost entirely due to fluctuations in precipitation.

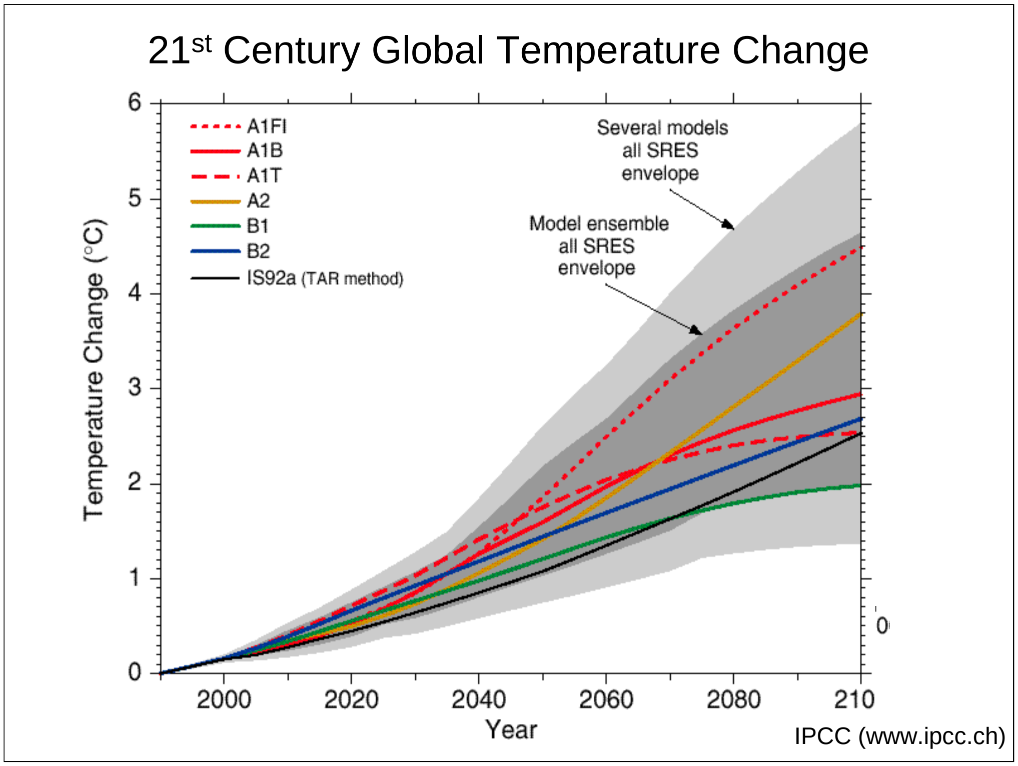


At Tunnel Avenue, by contrast, there has been a substantial long-term decline (more so if the line is drawn beginning in 1950 or 1955). The year-to-year fluctuations are strongly correlated with temperature as well as precipitation, and the long-term decline is mostly related to temperature.

What about the future?

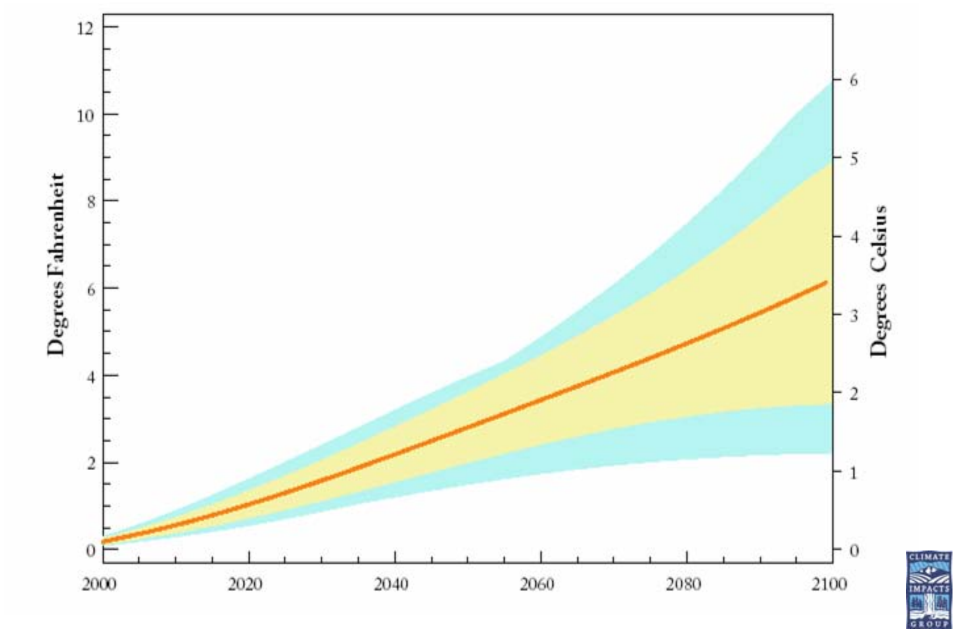
David Horsey's view of future climate change...



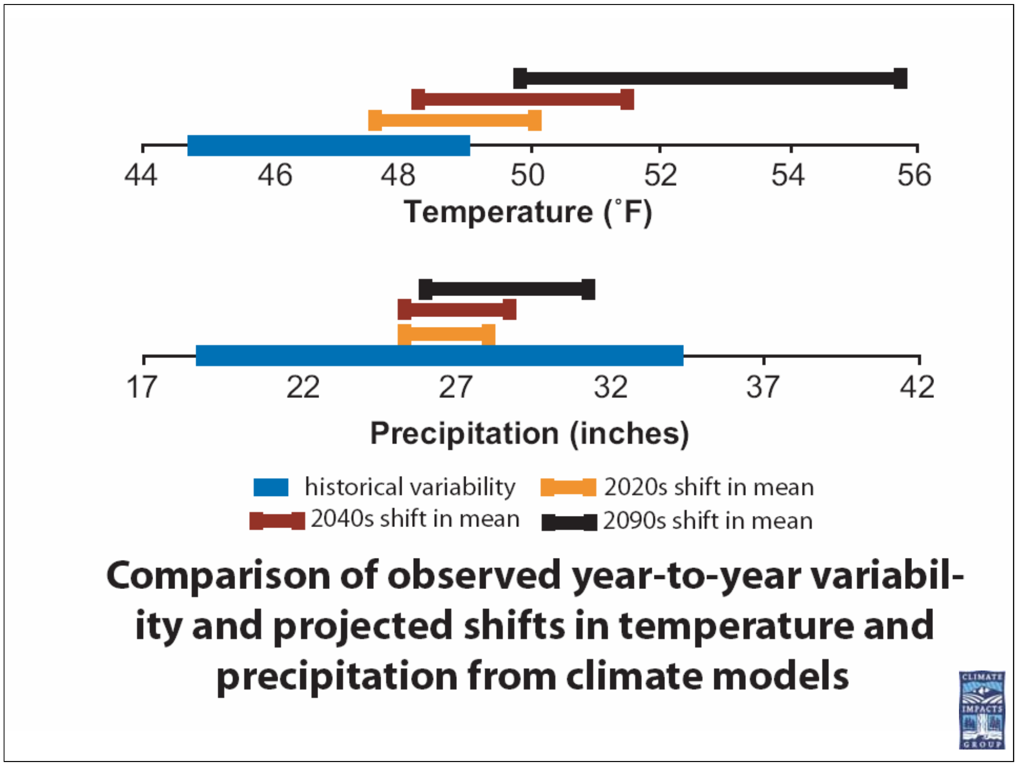
The IPCC came up with a range of future scenarios of CO_2 emissions, leading to a wide range of projected temperature changes. At the top end (5.8°C) you have to assume extreme growth in CO_2 emissions combined with very high sensitivity of climate to greenhouse gases, more than what is consistent with the observed 20th century warming. Likewise, the low end is probably also unrealistic without significant policy efforts.

The warming continues beyond 2100.

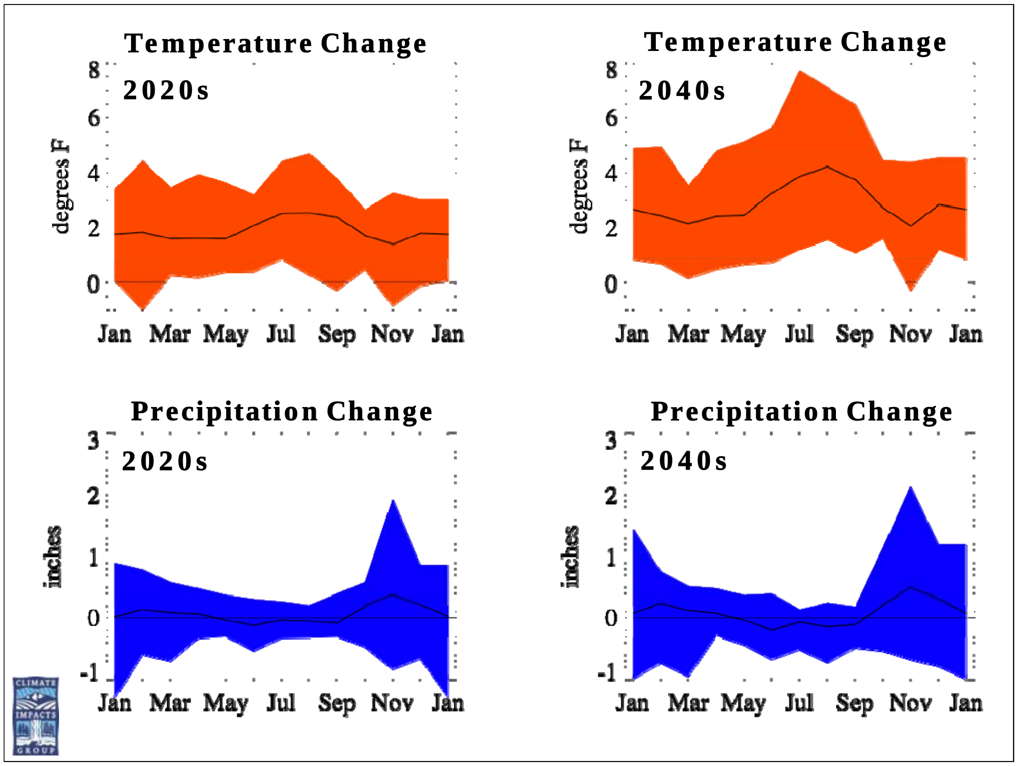
21st Century PNW Temperature Change



Sampling of ten climate models’ simulations of the A2 and B1 scenarios (see previous slide) for Northwest warming. The two scenarios are indistinguishable before about 2040.

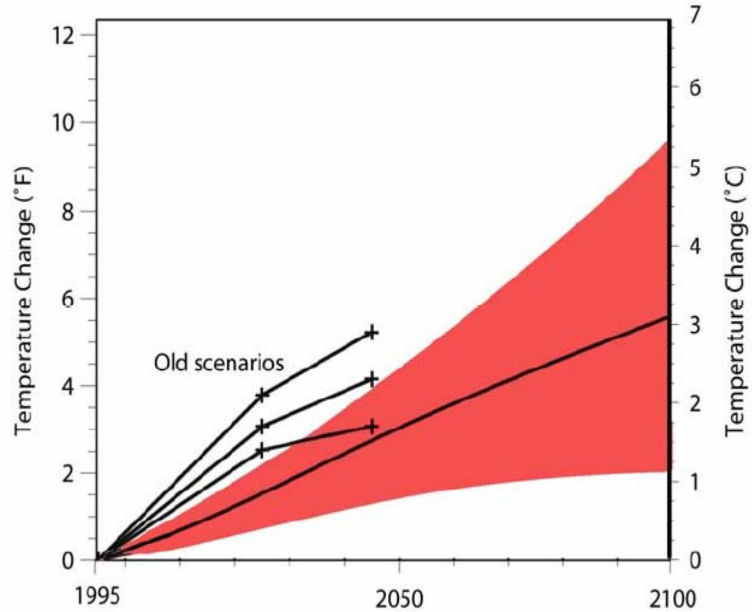


The horizontal bars show the range in expected shifts in average temperature (top) and precipitation (bottom) for the "2020s" (actually a 30-year mean, 2010-2039), 2040s and 2080s. For comparison, the blue bar shows the observed 20th century variability, actually the +/- 2 standard deviations. Note that predicted changes in temperature slide well outside observed variability, whereas predicted changes in precipitation are quite small compared with 20th century variability.

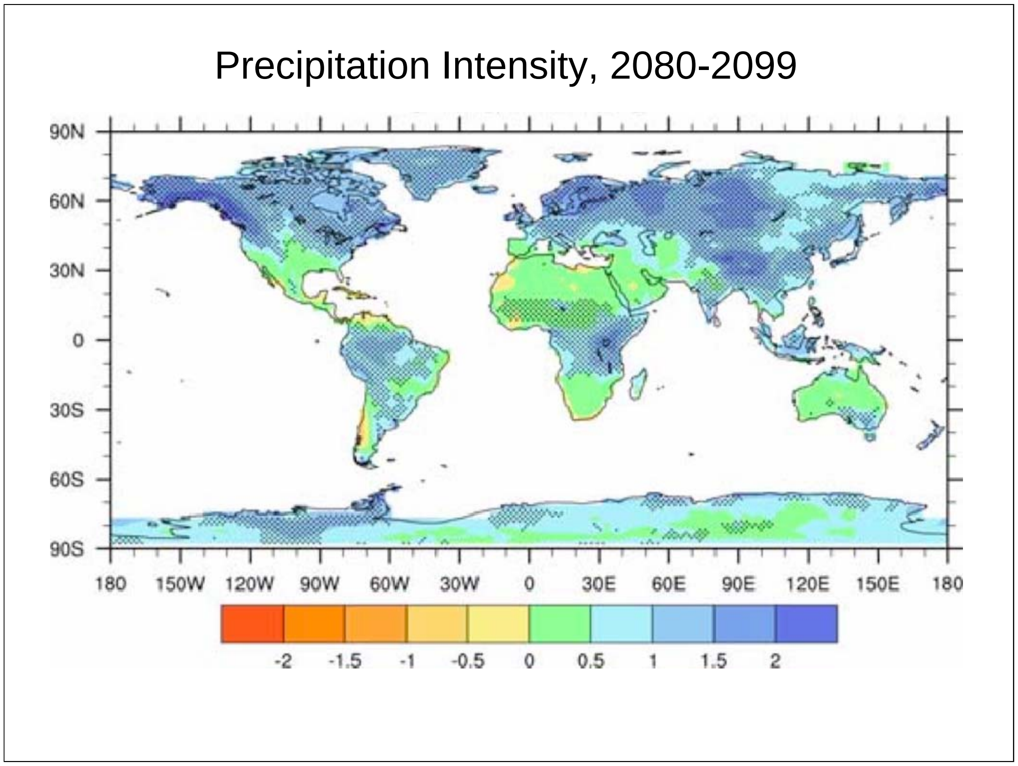


This shows, for each month, the range of projected changes in temperature (top) and precipitation (bottom), along with the means (black). Temperature changes tend to be largest in summer; models are divided about changes in precipitation - some foresee negative changes, some positive in each month. The averages are for slight increases (order of 5%) in winter, decreases (order of 10%) in summer.

Comparison of Old & New Climate Change Scenarios



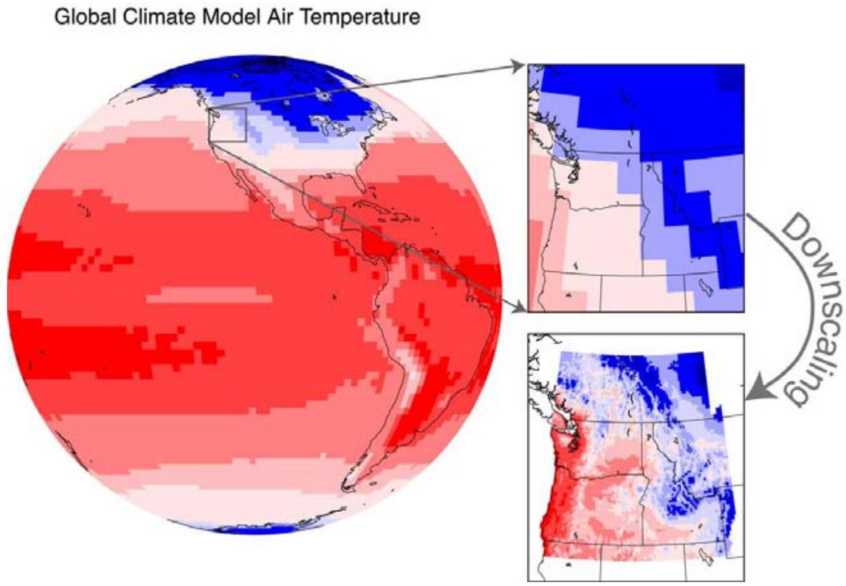
Red plume is the range of PNW changes from the previous diagram. The black lines with + symbols show the range of temperature projections CIG produced several years ago. The primary reason for a reduction in projected temperature change was an improvement in the specification of “baseline” climate, rather than a change in the rate of warming projected by the models globally and regionally. That is, previous results for 21st century climate were compared with a baseline from “control runs” by the climate modeling groups, each of which used a different value of CO_2 for the control run. Although some attempt was made to adjust these baseline values for the different CO_2 values to derive a baseline “1990s” value, the approach left something to be desired. The new model runs all included a simulation of 20th century driven by the observed year-to-year increases in greenhouse gases, and the baseline used here was 1971-2000 from these simulations.



From Meehl et al., GRL 2005. 2080-2099 minus 1980-1999 from 9 models, a1b scenario. Units are standard deviations. Stippling shows where at least 4 of the 9 models have statistically significant increases. Precipitation intensity is defined as precipitation per rainy day (total precipitation divided by number of days of precipitation). The nine models are PCm, CCSM3, GFDL-CM2.0, GFDL-CM2.1, MIROC3.2-hires, MIROC3.2-medres, CNRM-CM3, MRI, and INM.

Full citation: Meehl, G.A., J.M. Arblaster, and C. Tebaldi, 2005: Understanding future patterns of increased precipitation intensity in climate model simulations. GRL, 32, L18719, doi:10.1029/2005GL023680.

Global models must be "downscaled" for regional studies



Global climate models are designed to simulate the large-scale patterns of climate, and they do so quite well (globe, the surface air temperature simulated by the German ECHAM5 model for January 1999). The ECHAM5 model in this simulation had a resolution of approximately 2°longitude by 2°latitude. For smaller-scale studies, however, the graininess of the models is evident (top right) and important features are missing like the east-west contrast across the Cascades. The process of translating these large-scale fields to the fine-scale topography (0.125° by 0.125° in the example shown) is called "downscaling". The next slide shows the two primary approaches to downscaling.

Two downscaling methods used by the Climate Impacts Group

Statistical Downscaling	Downscaling with a Regional Climate Model
• Assumes global climate model captures local temperature and precipitation trends	• Based on MM5 regional weather model
• Quick: Can do many scenarios	• Represents regional weather processes
• Shares uncertainties with global models	• May produce local trends not depicted by global models

Empirical (statistical) downscaling includes “Delta” method, bias correction (Wood), and scaling methods (Salathé) that have been used in all prior CIG work. Regional climate model (dynamical downscaling) work is in collaboration with Cliff Mass. This work is in preliminary stage, and we anticipate results suitable for impacts studies in a year or so.

Summary

- Projected warming: 0.2-1.0°F *per decade*
  (compared to 1.5°F over 20th century)

- More in summer than in winter (?)

- Precipitation: wet season gets wetter, dry season gets drier; year-to-year variability continues