Climate Surprise: Unexpected Impacts of Global Warming on the Northwest

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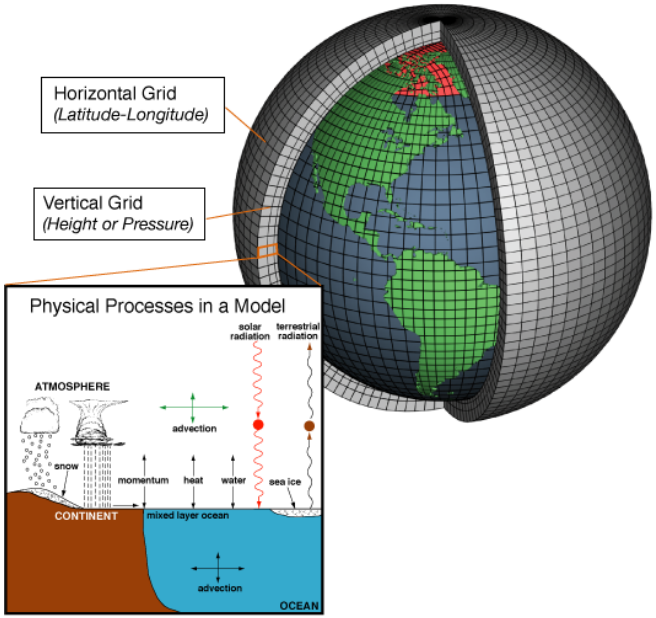
University of Washington

The planetary threat of global warming is well understood, based on solid science and the most sophisticated models we possess



The basic physics has been known for a long time

Svante Arrhenius 1896

On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground

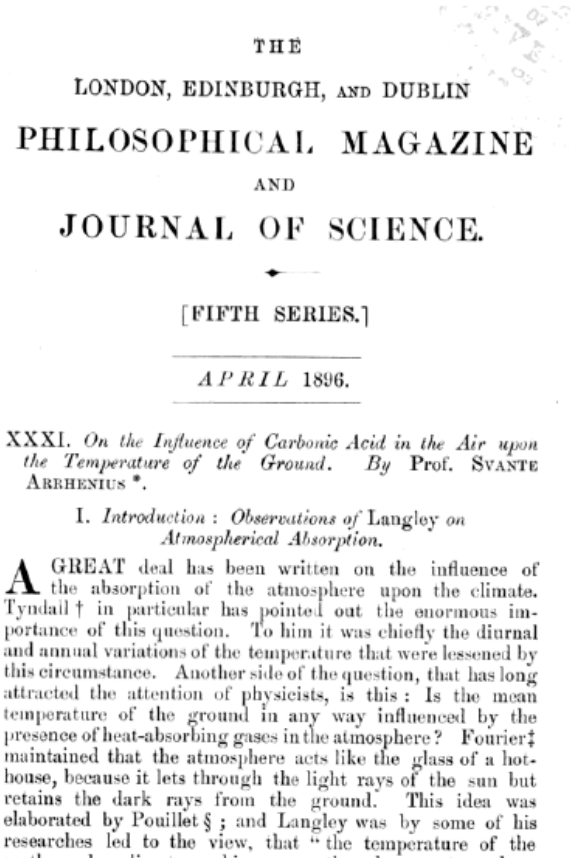
Svante Arrhenius

Philosophical Magazine and Journal of Science
Series 5, Volume 41, April 1896, pages 237-276.

This photocopy was prepared by Robert A. Rohde for Global Warming Art (http://www.globalwarmingart.com/) from original printed material that is now in the public domain.

Arrhenius's paper is the first to quantify the contribution of carbon dioxide to the greenhouse effect (Sections I-IV) and to speculate about whether variations in the atmospheric concentration of carbon dioxide have contributed to long-term variations in climate (Section V). Throughout this paper, Arrhenius refers to carbon dioxide as "carbonic acid" in accordance with the convention at the time he was writing.

Contrary to some misunderstandings, Arrhenius does not explicitly



THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

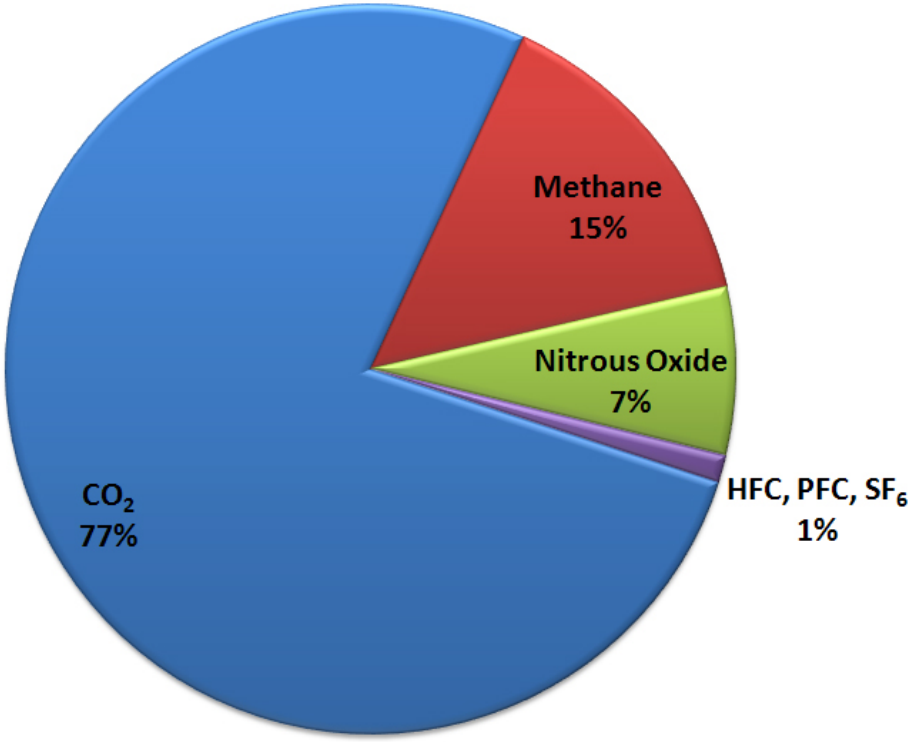
XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

I. *Introduction : Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this : Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet § ; and Langley was by some of his researches led to the view, that " the temperature of the

Greenhouse gases warm the planet

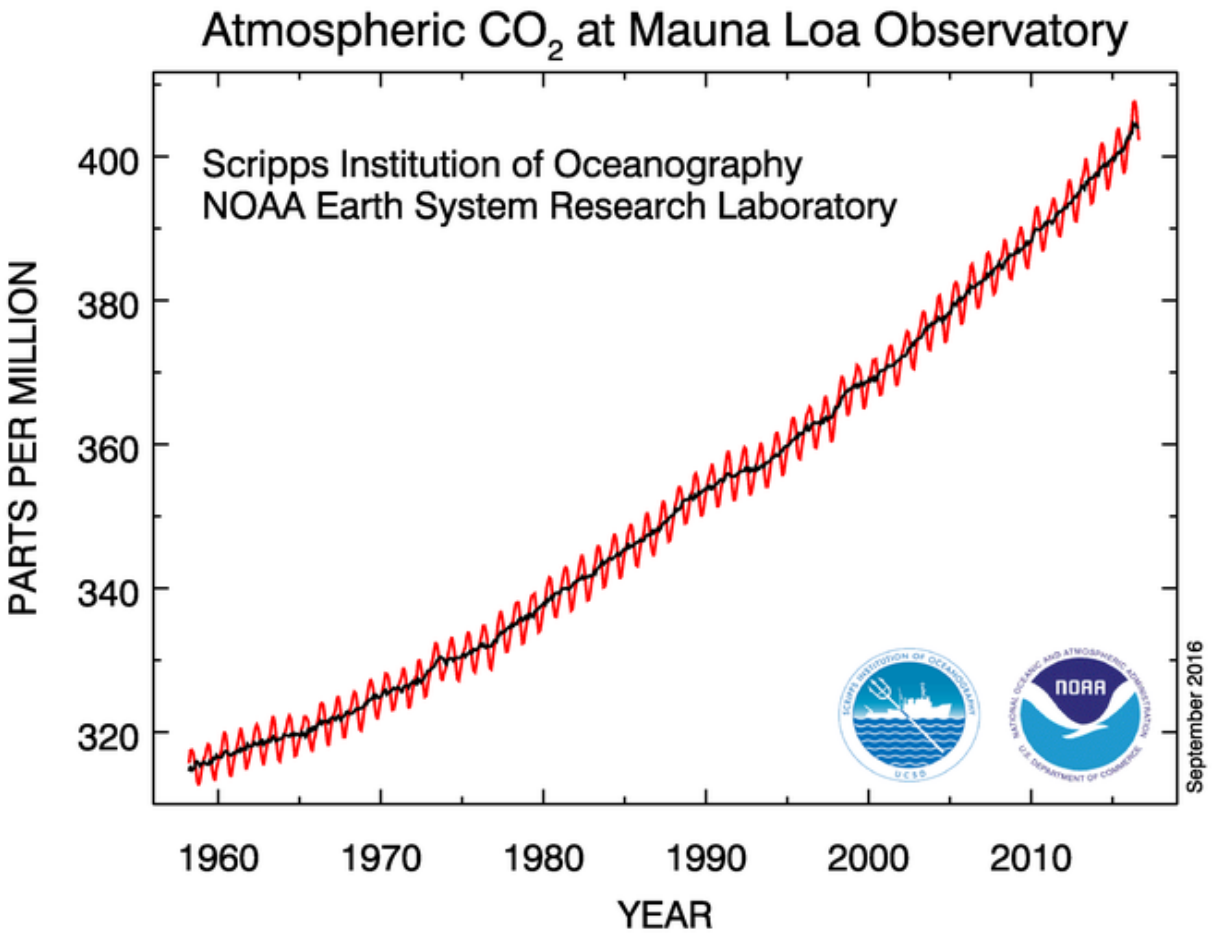
- Carbon Dioxide
- Water Vapor
- Methane
- Nitrous Oxide
- … and others



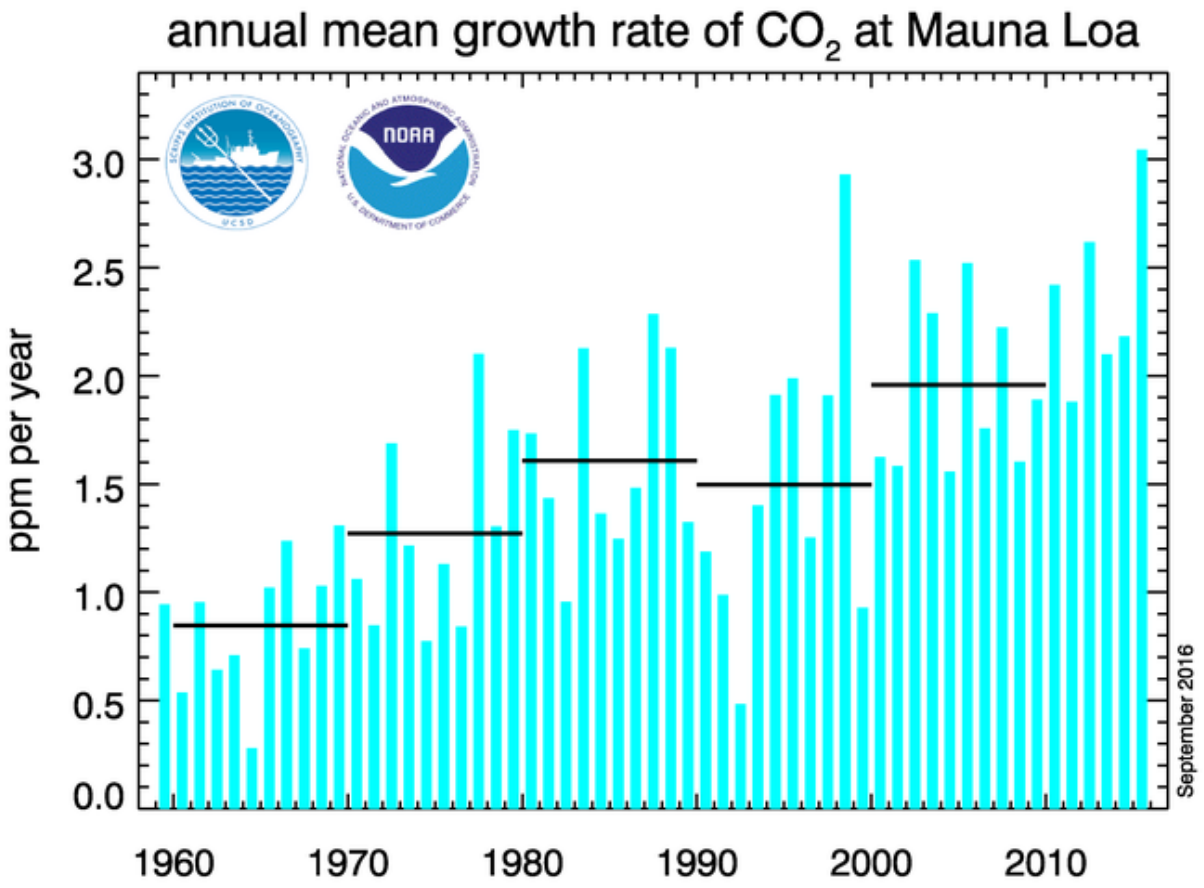
Greenhouse Gas Emissions

Greenhouse Gas Concentrations are Increasing Rapidly

CO2



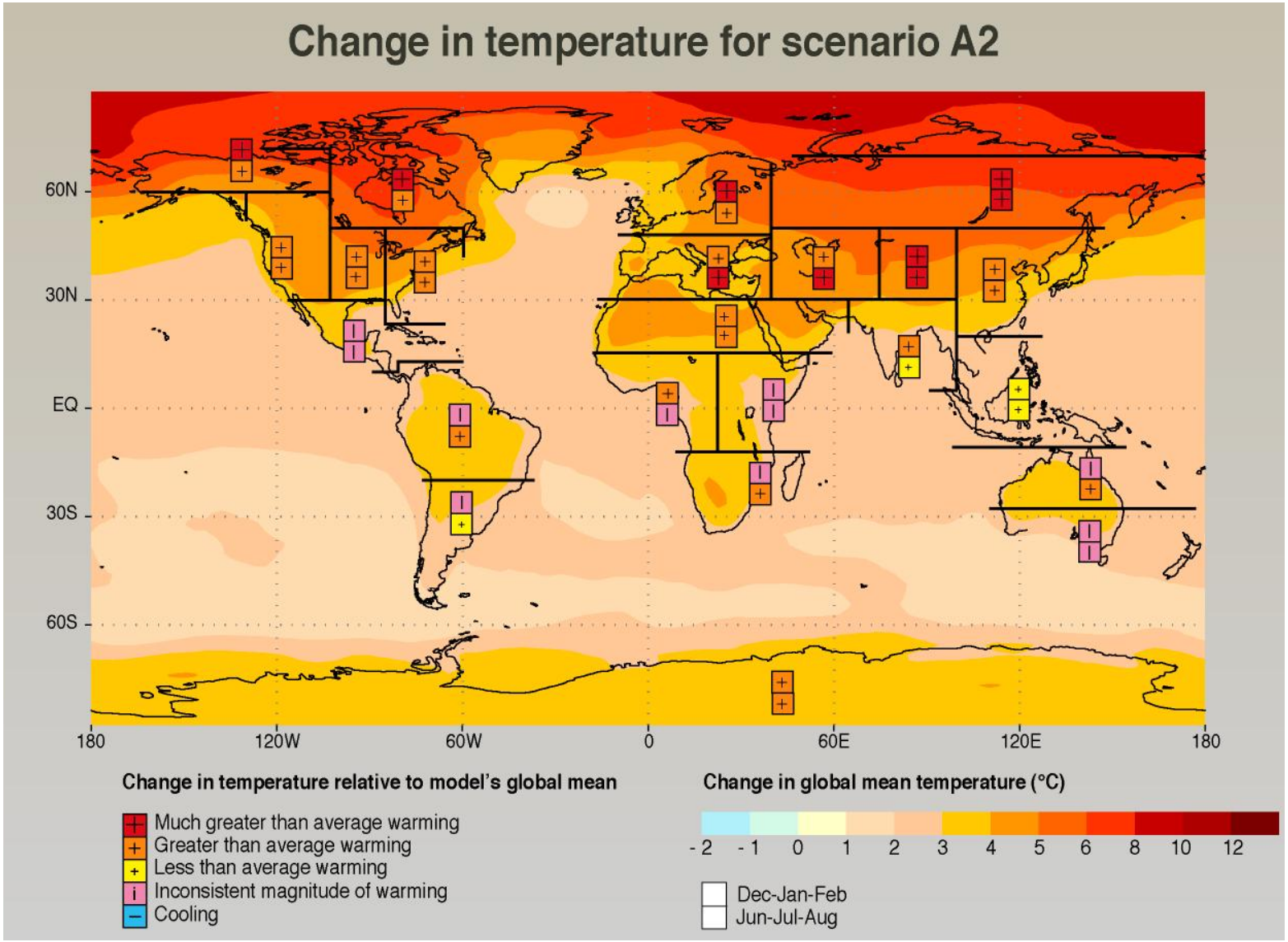
Surprise: The annual growth rate of CO2 is increasing



The central tool for predicting the impacts of increasing greenhouse gases is global climate modeling

- Sophisticated computer simulations based on the physics of the atmosphere and ocean.
- Atmospheric parts are **nearly identical to weather prediction models**, which are tested every day, but with atmospheric gases varying in time.

Climate Model Output for 2100



Surprise?

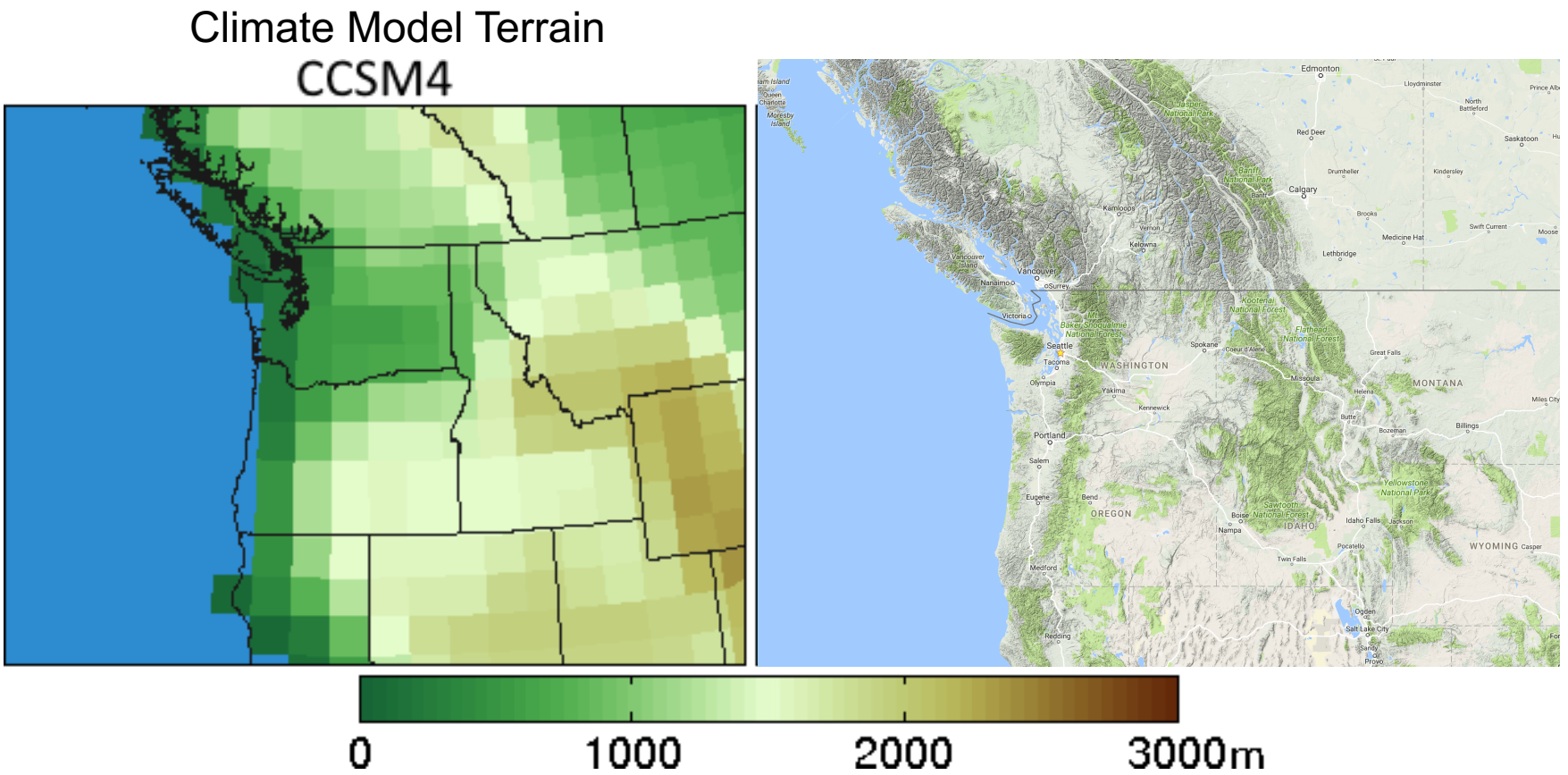
Global Warming is NOT Globally Uniform

- Arctic warms quickly for a number of reasons, including the melting of sea ice.
- Continents warm up more than oceans.
- **Eastern oceans warm up less than western oceans**.

But are there special surprises for our region?

- Local terrain has major impacts on weather/climate
- The nearby Pacific also has profound impacts.
- Our general location (midlatitudes, western North America) has unique weather/climate patterns.

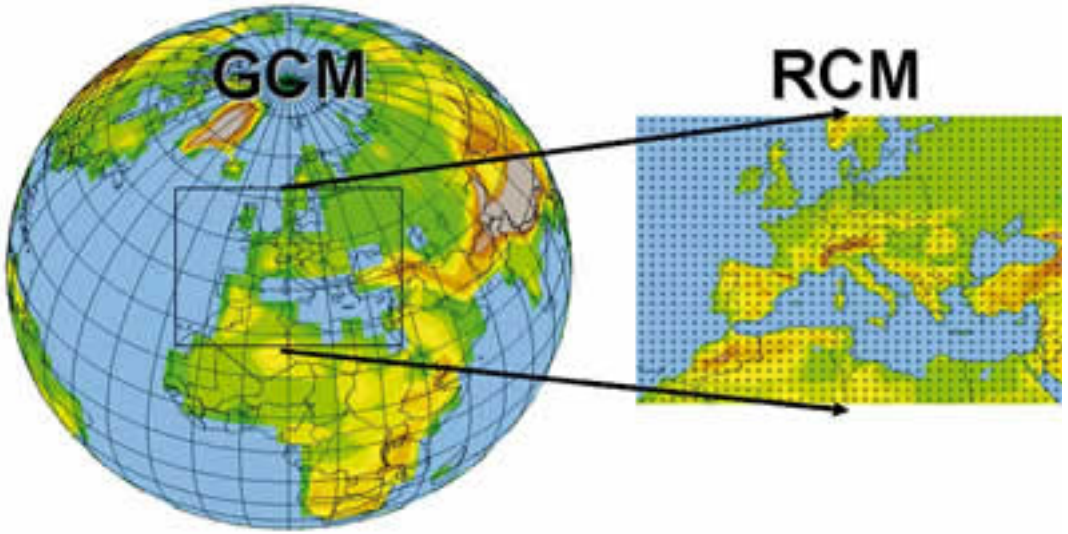
Problem: Global climate models are too coarse to simulate the effects of critical Northwest terrain



A new technology is being used to solve the resolution issue:

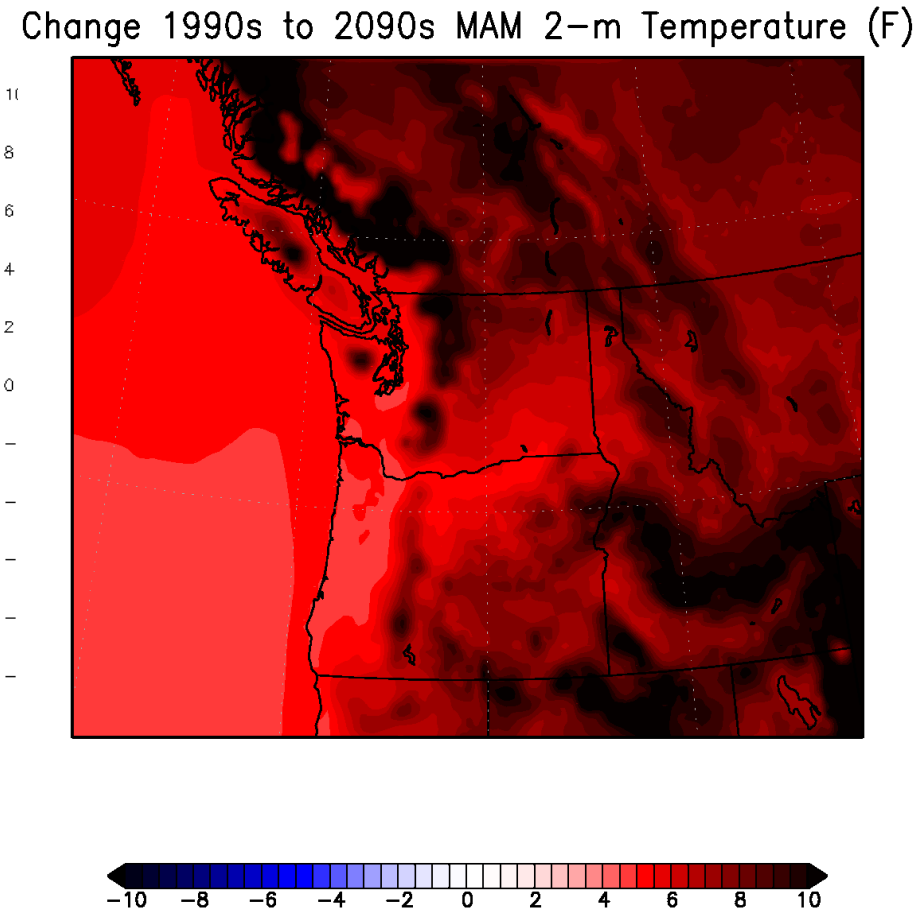
Regional Climate Modeling

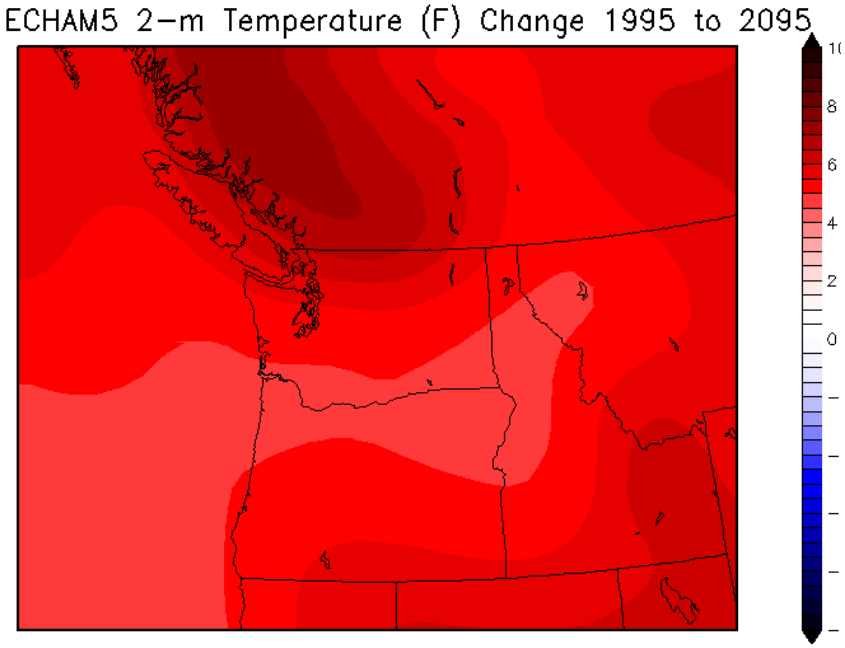
Running **regional high-resolution weather forecasting** models for long periods, driven by global climate models



Global versus regional climate models

Regional climate model

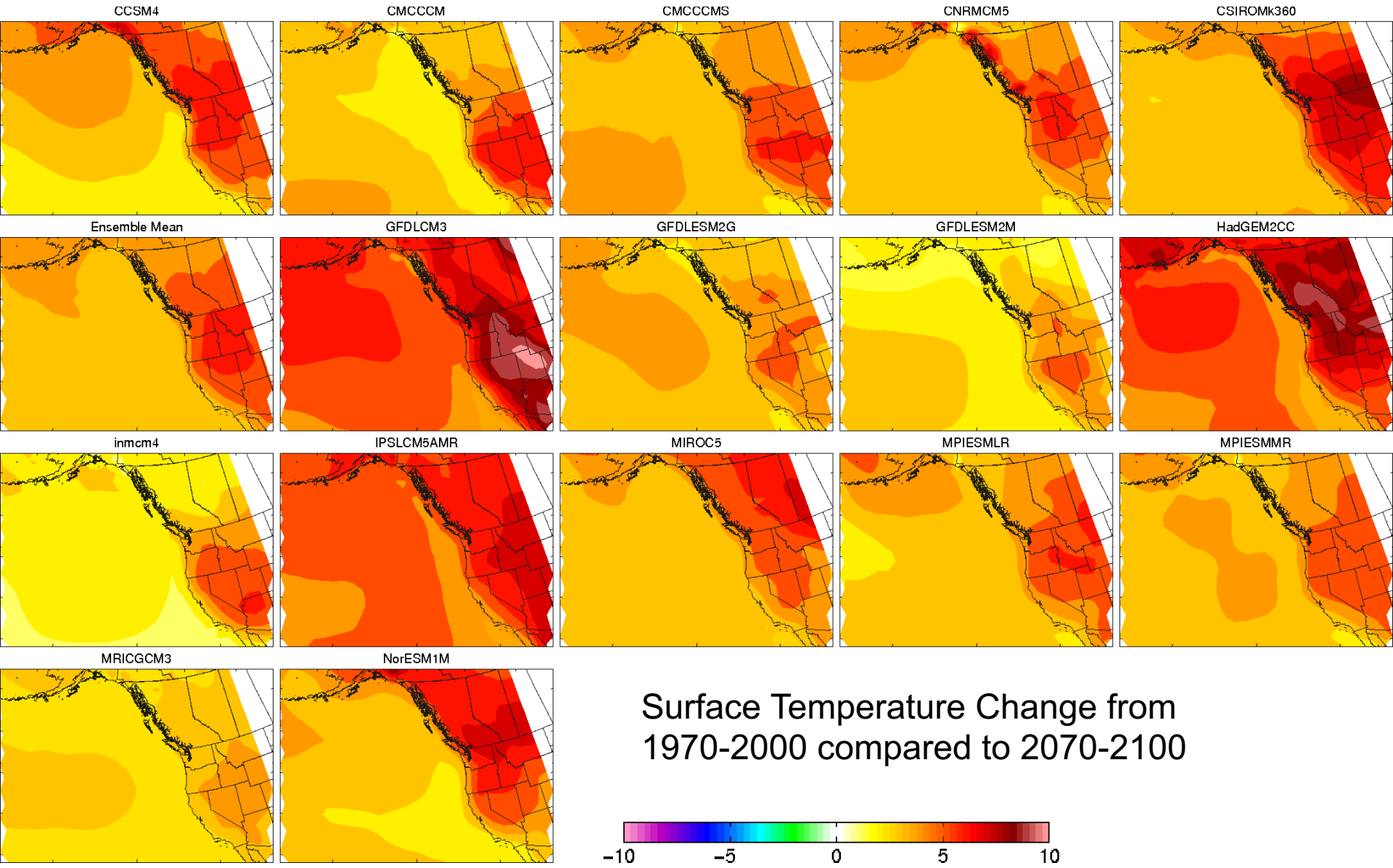




Global model

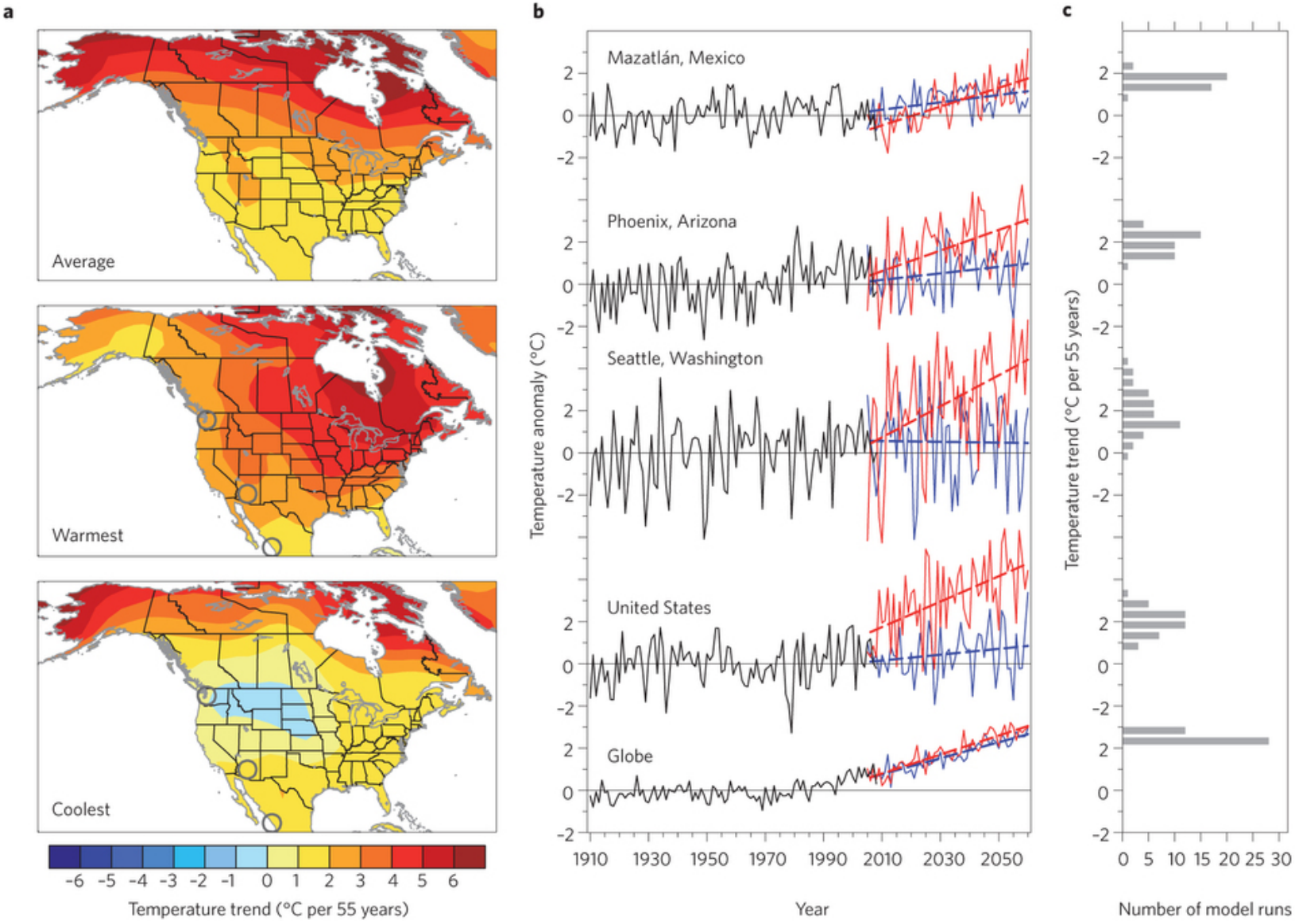
But there is another issue with global climate models …

They don't necessarily agree. There is uncertainty



Surface Temperature Change from 1970-2000 compared to 2070-2100

Considering a large ensemble of forecasts



So how do we do this right?

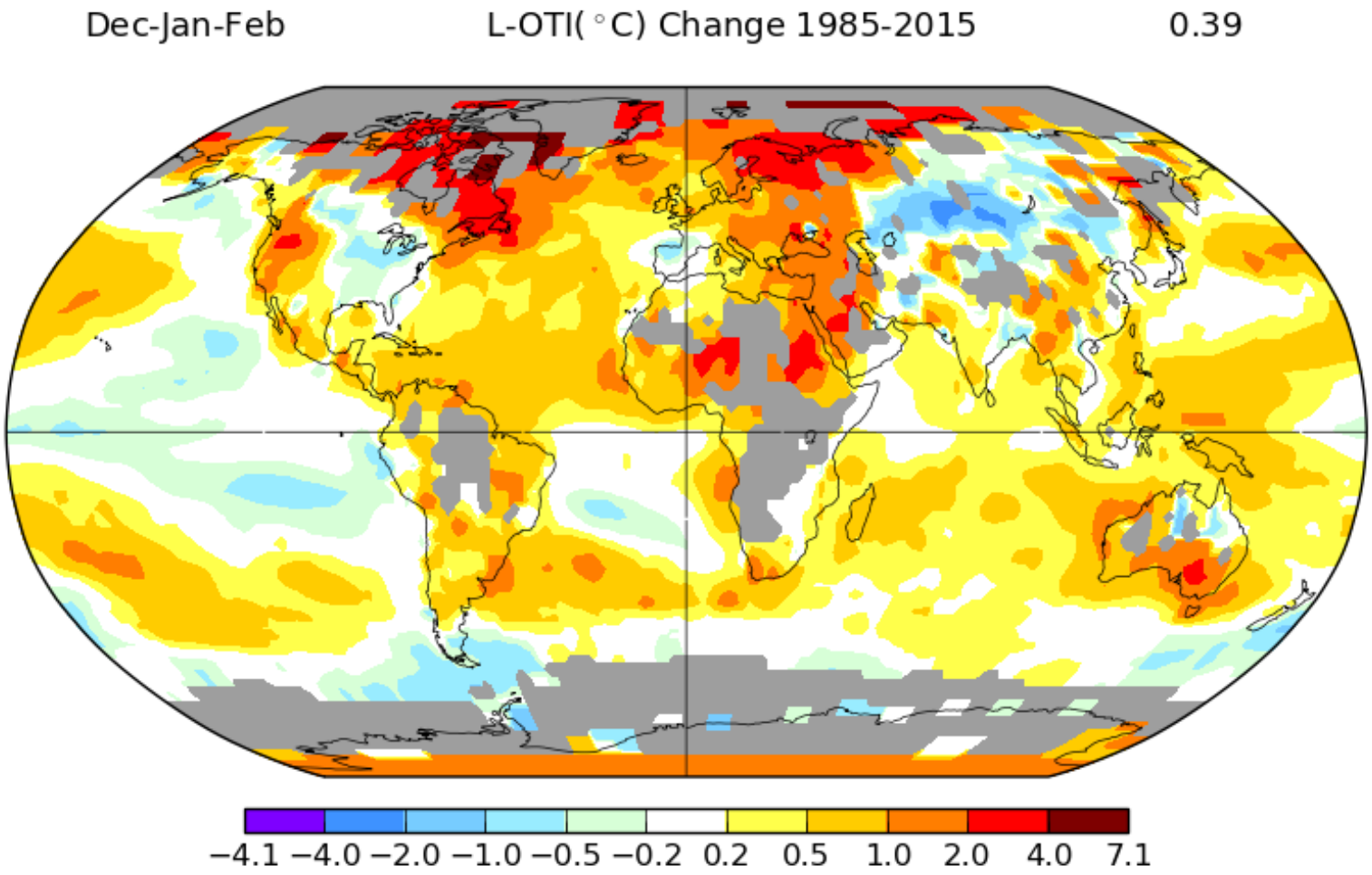
- Use a large collection of global climate simulations that span the uncertainty.
- Run regional climate models for each to secure the local implications.
- Use sophisticated statistical corrections to remove biases using contemporary periods.
- Find common elements in forecasts
- Starting to do all this at the University of Washington.

So based on what we have completed so far, what are the potential surprises?

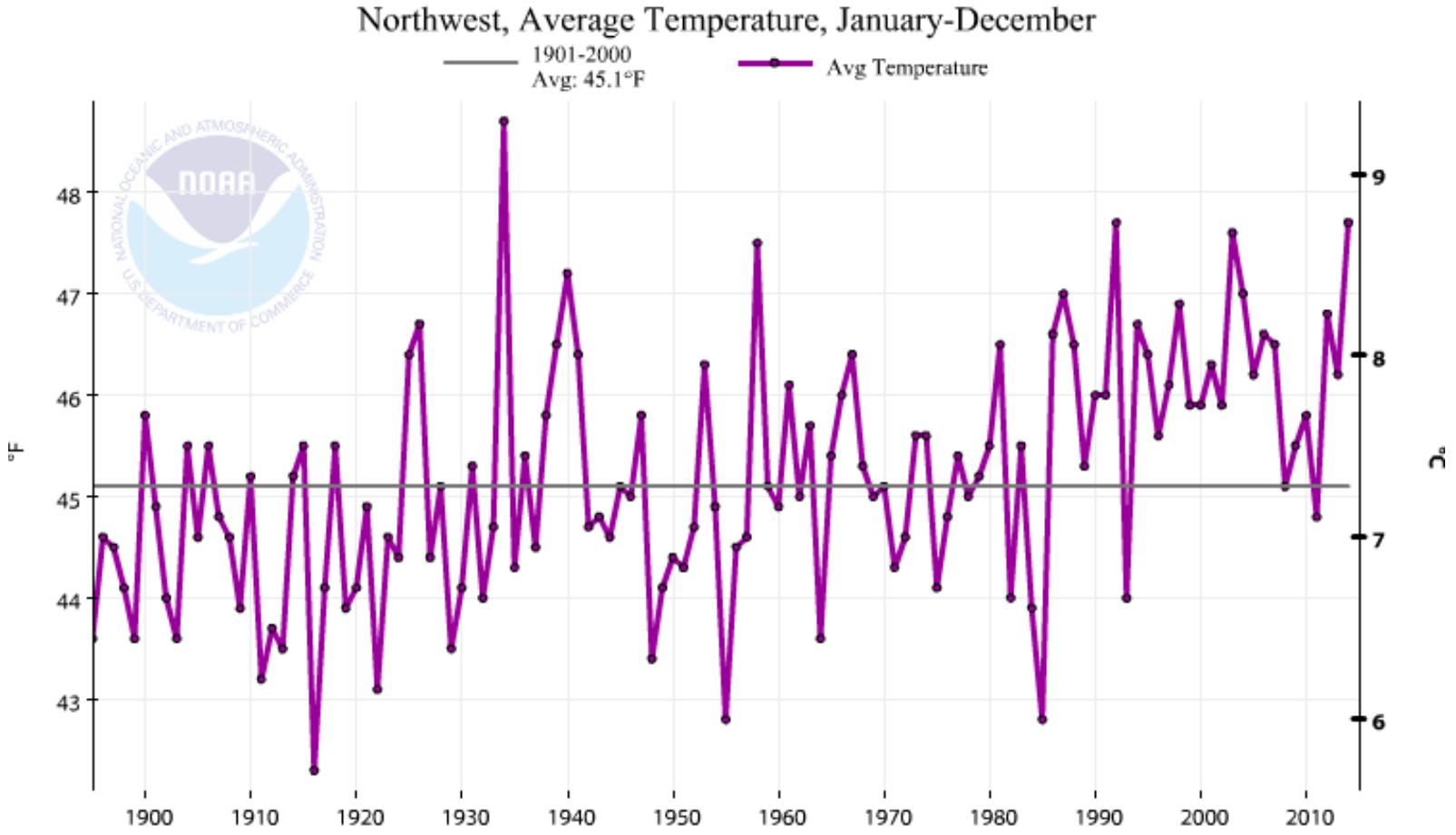
Local Global Warming Surprises

1. **Temperature Surprises**
   - The warming in our area has been relatively slow so far because of the Pacific Ocean
   - Warming will not be spatially uniform.
   - Warming rate will increase over time, with the most profound effect later in the century.
   - There will be warming “hot spots” where snow melts

SuperSurprise: the Eastern Pacific has not warmed during the past 30 years.



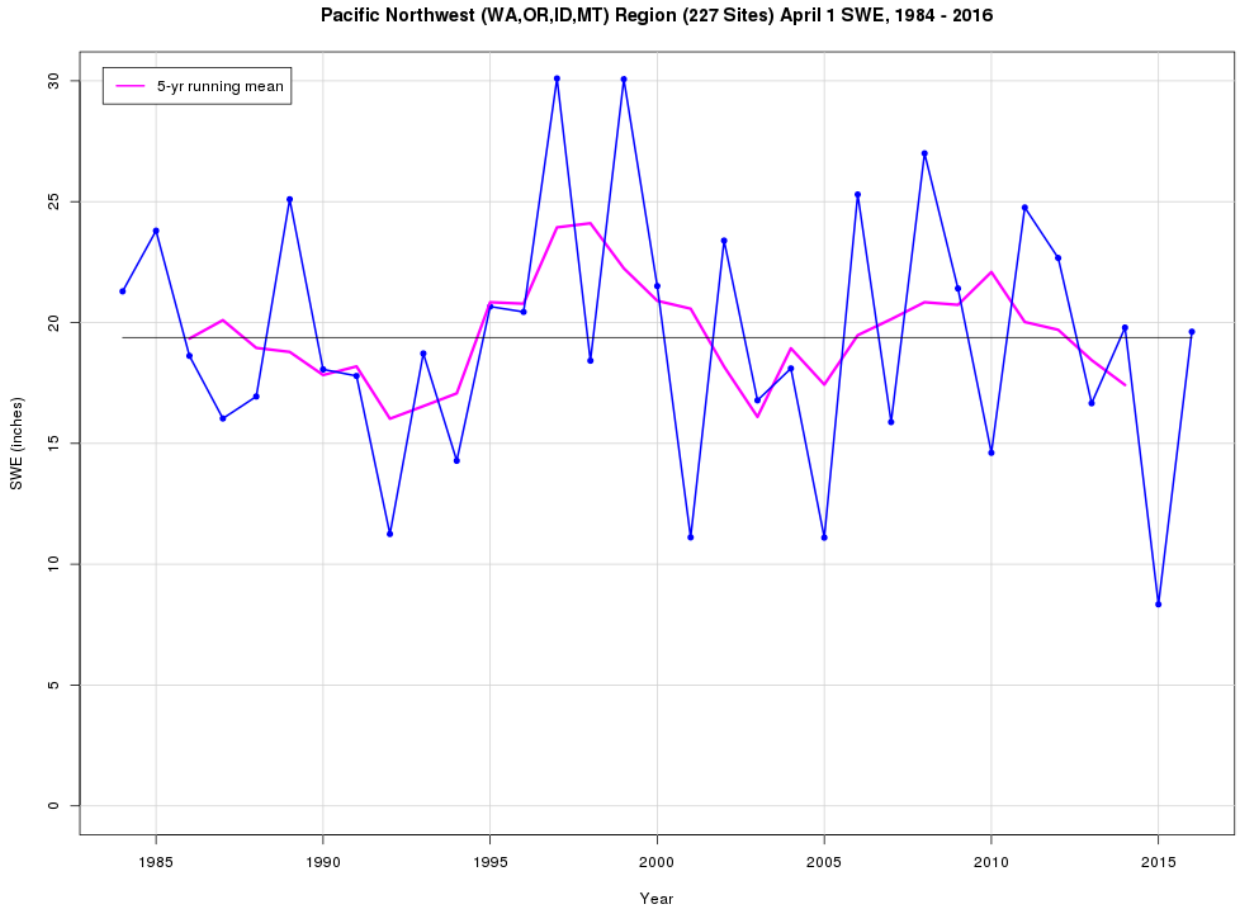
NOAA temperature observations over the NW



Mainly Natural

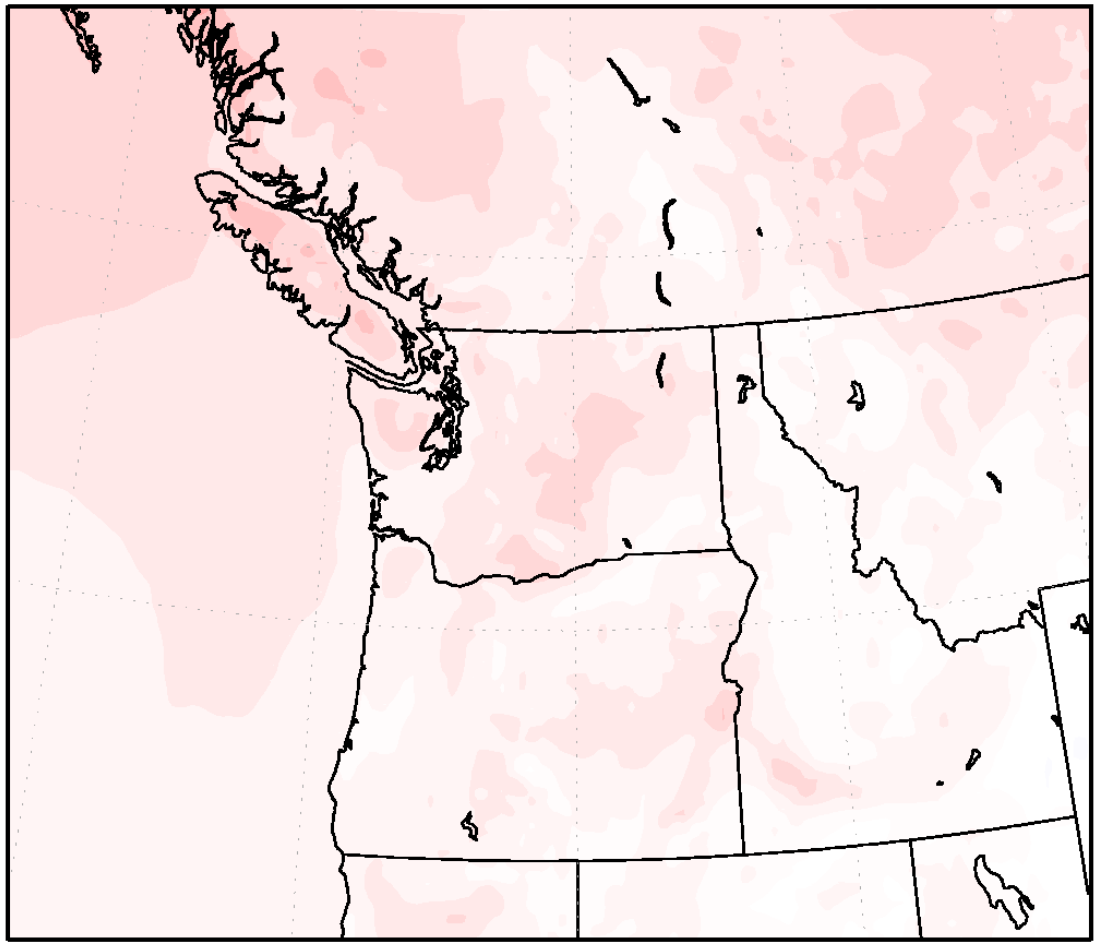
Natural & Anthropogenic

Without Pacific warming, our mountain snowpack has not changed much over 30 yr

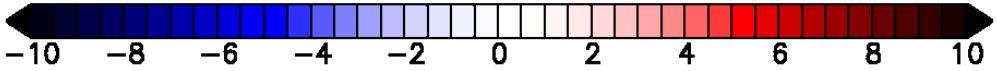


But the future projected by regional climate simulations is very different….

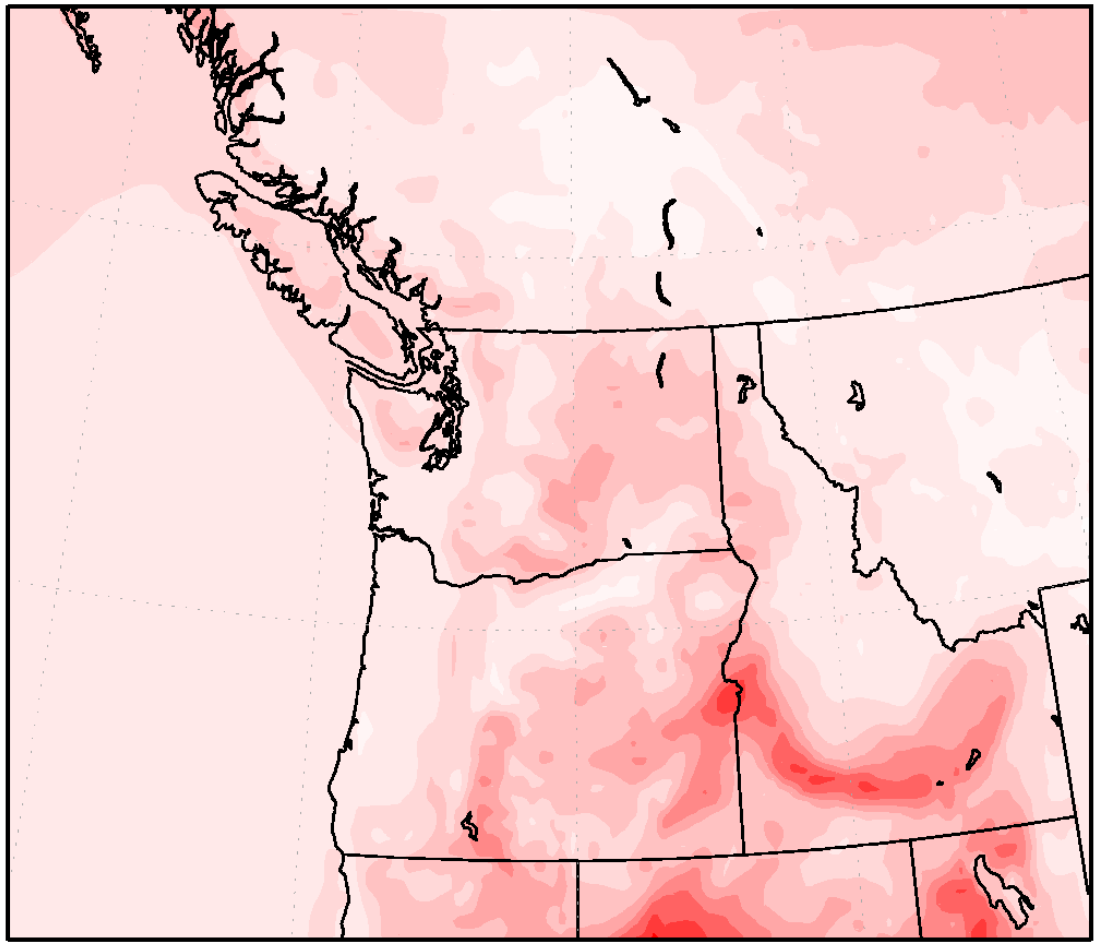
Change 1990s to 2020s DJF 2-m Temperature (F)



Change in Winter Surface Air Temperatures (F)

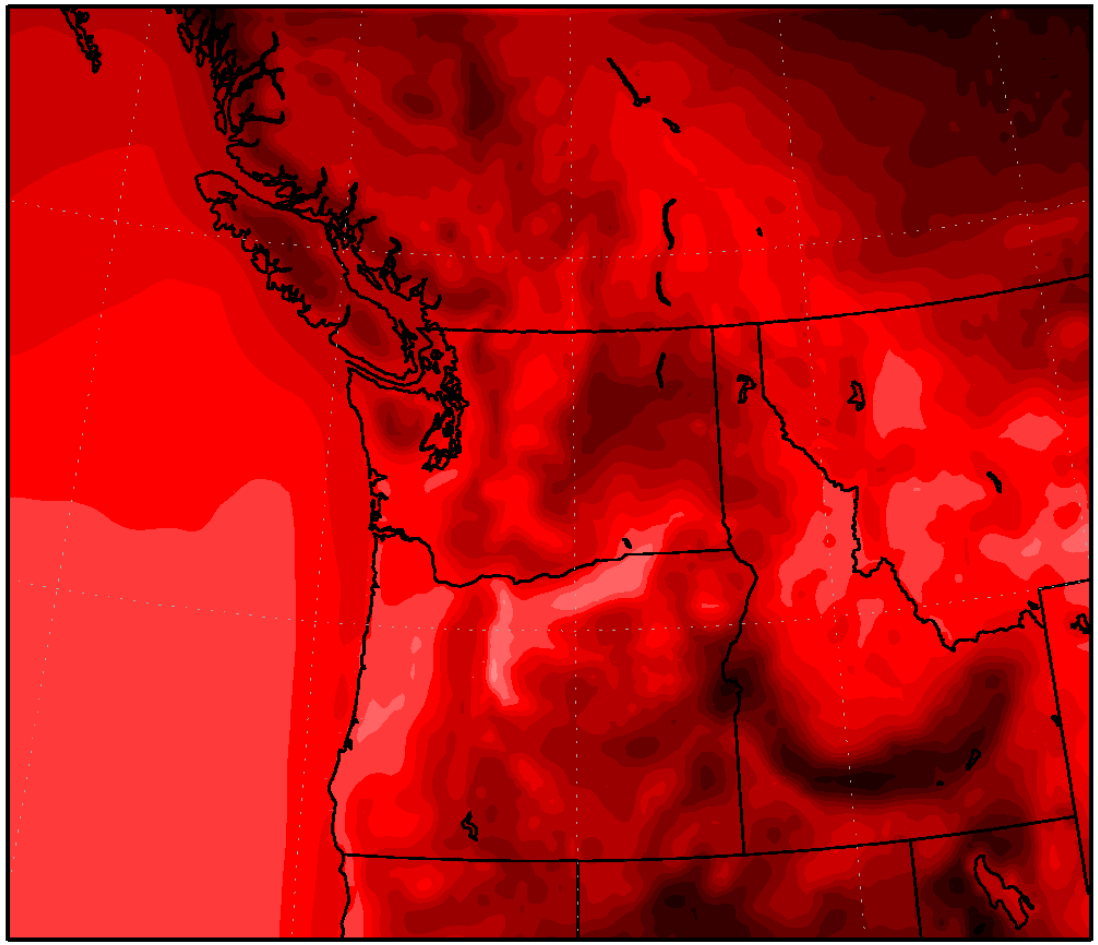


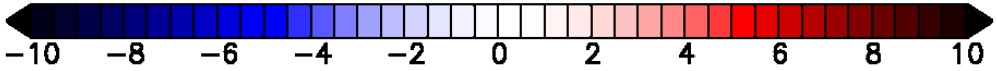
Change 1990s to 2050s DJF 2-m Temperature (F)



−10 −8 −6 −4 −2 0 2 4 6 8 10

Change 1990s to 2090s DJF 2-m Temperature (F)

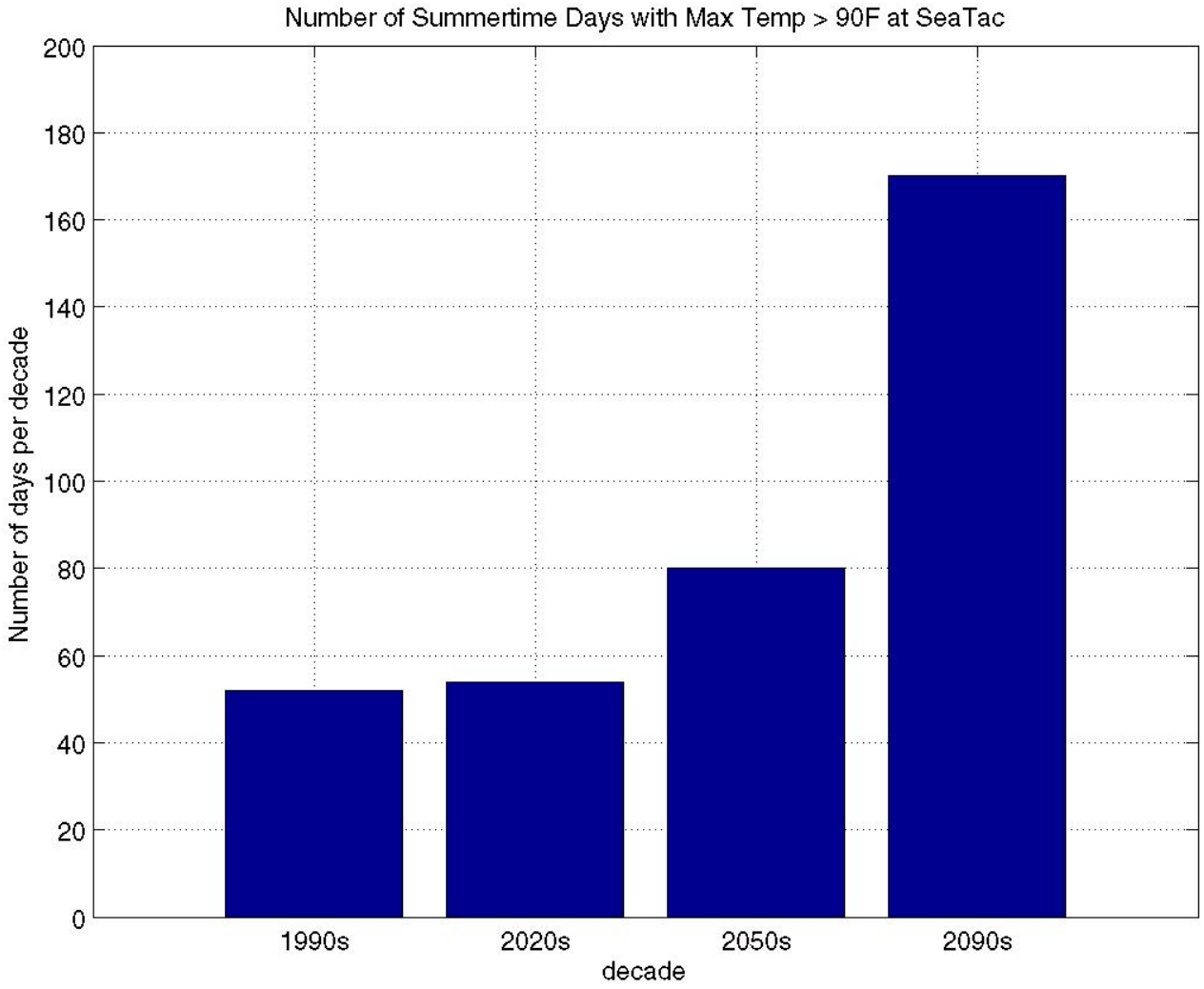




Why local hot spots?

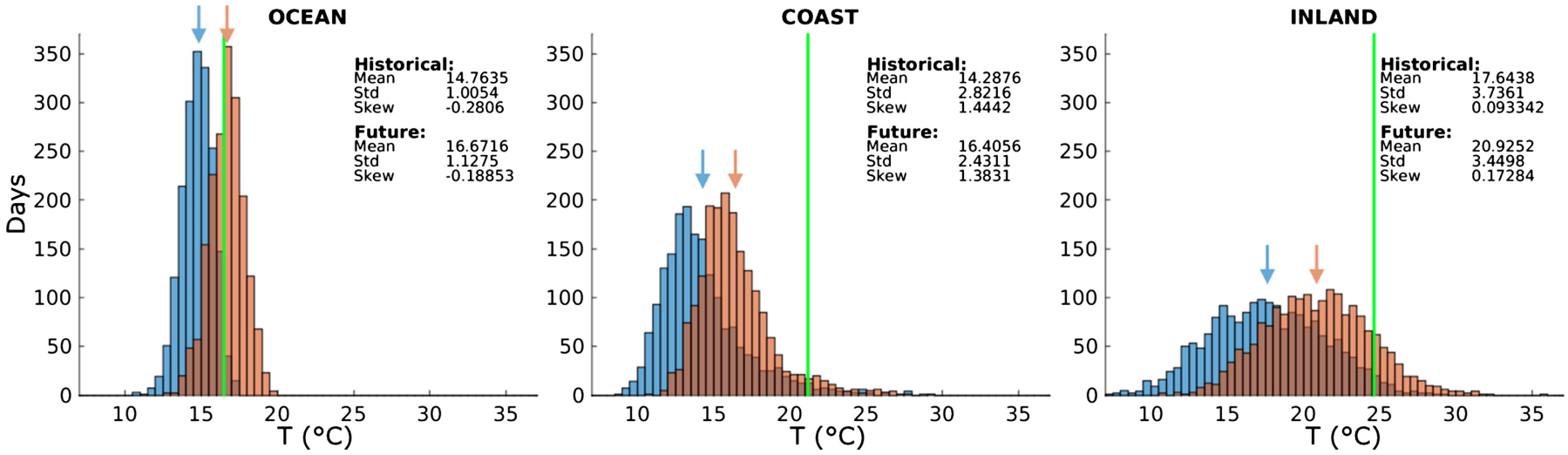
Regions of melting snow on terrain

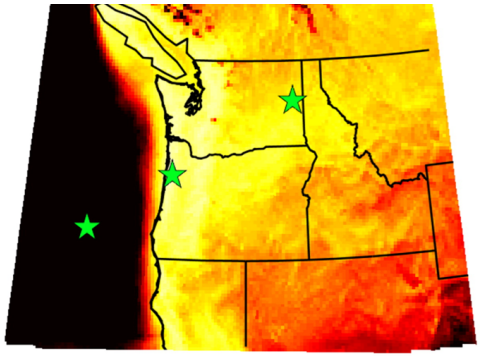
Warming rate increases over time



Forecast: Seattle Times in 2070 will have lots of these ads:

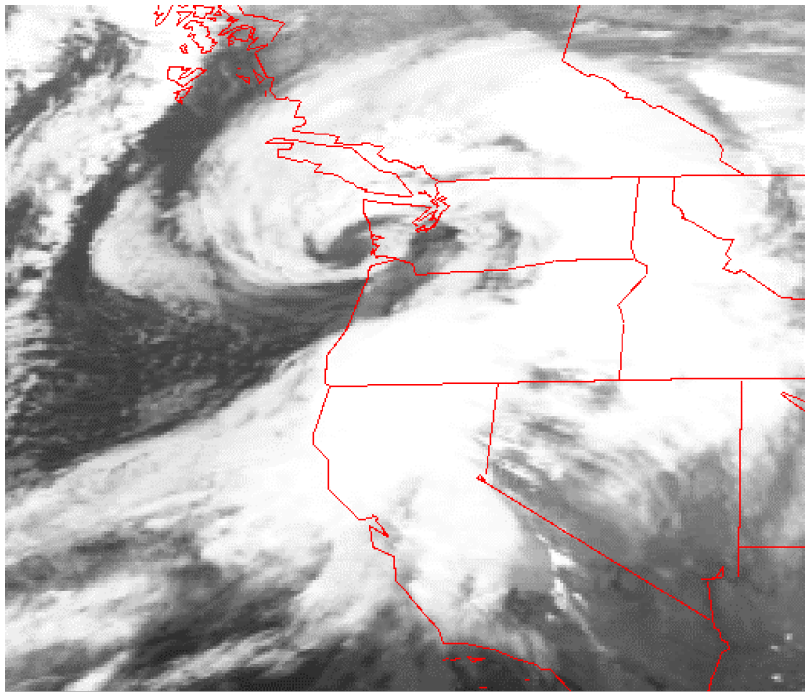
Surprise: Global Warming will bring more extreme hot days inland than at the coast





Windstorm Surprises

- Will there be more of them?
- Will they become more intense?



The Inauguration Day Storm
1993

Scientists say as climate changes, odds increase for deadly storms

by KING 5 News

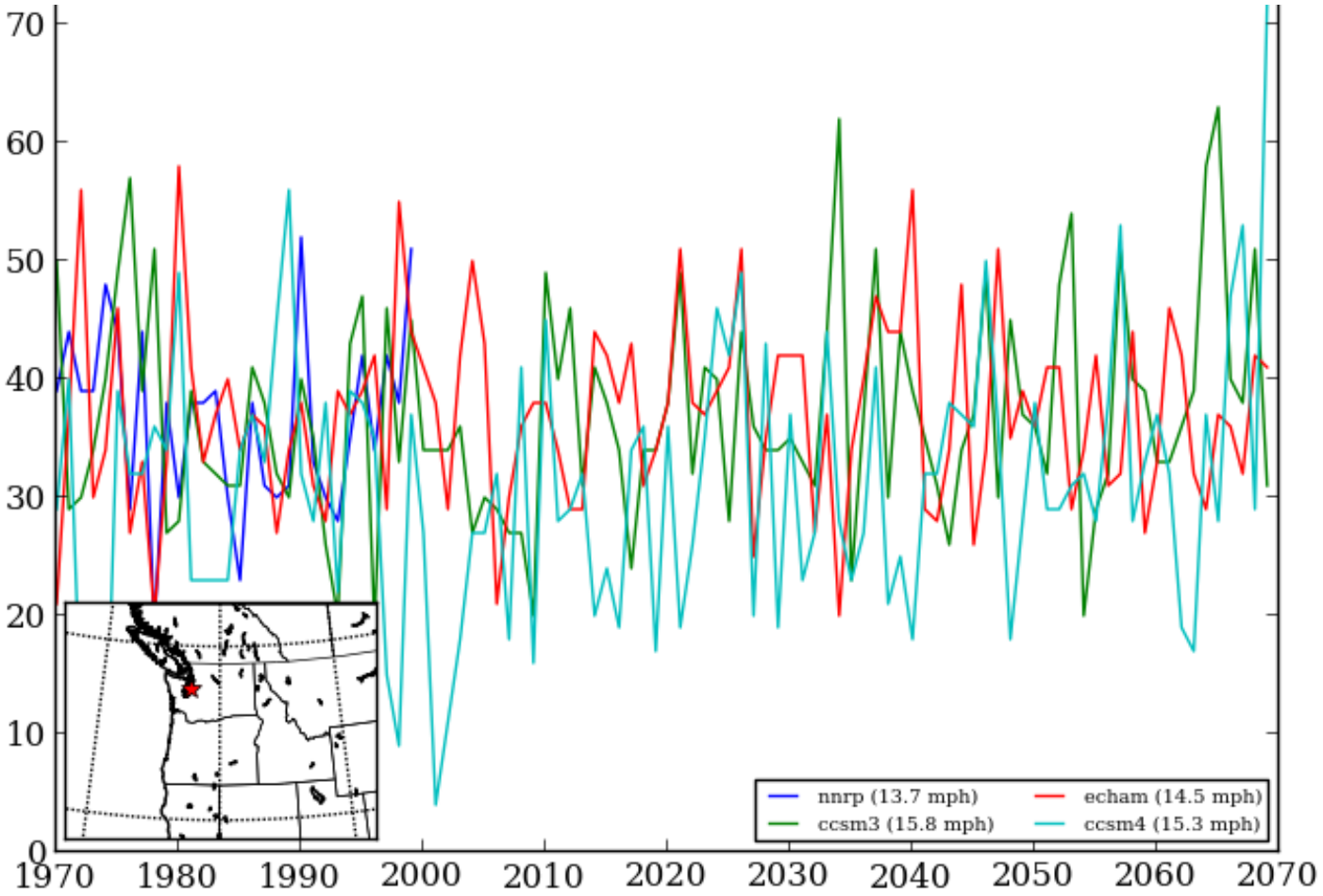
Posted on November 12, 2013 at 6:03 PM
Updated Tuesday, Nov 12 at 6:20 PM

SEATTLE - Members of an international conservation group say it's time to prepare for more intense, more frequent and more damaging storms in Puget Sound

Northwest Windstorms

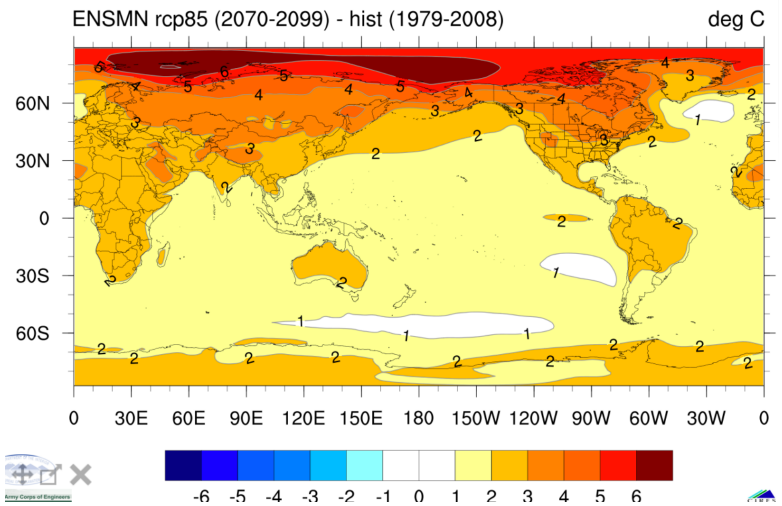
- **The answer appears to be no**. No increasing trend.
- UW investigated this issue for Seattle City Light

Number of times per year winds exceed a high-wind threshold (DJF) at Seattle for several simulations



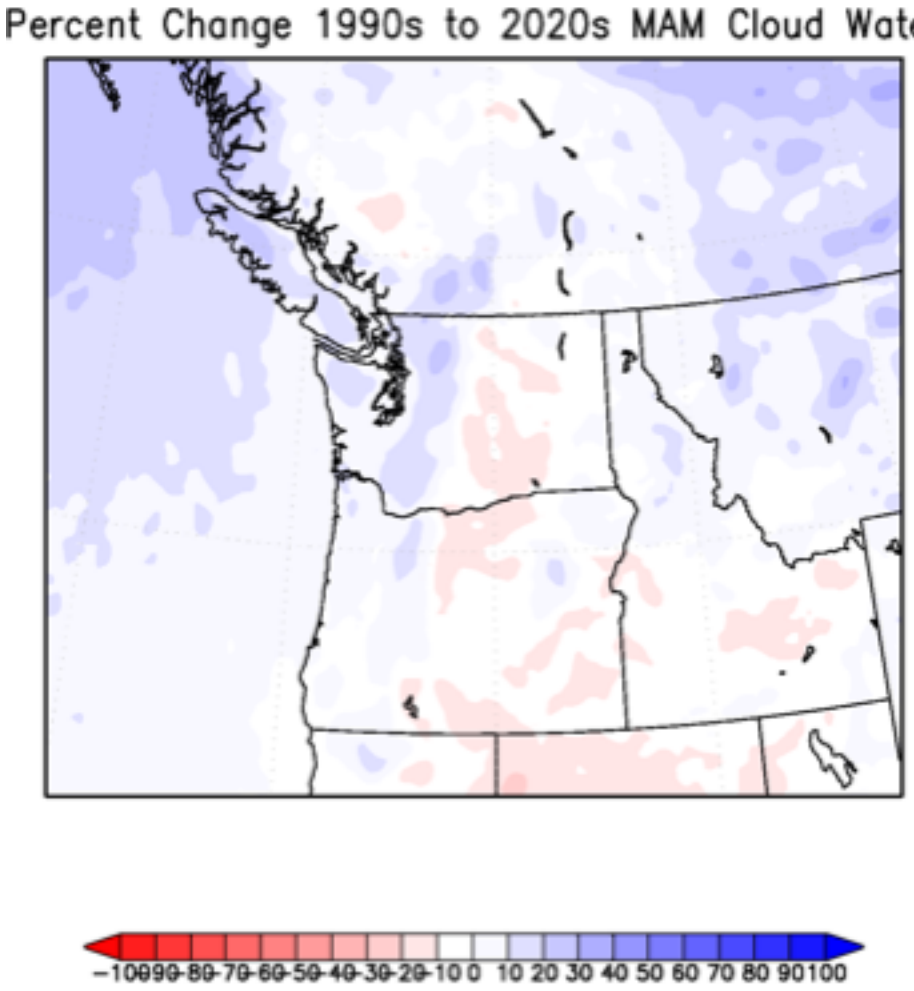
Why no increase?

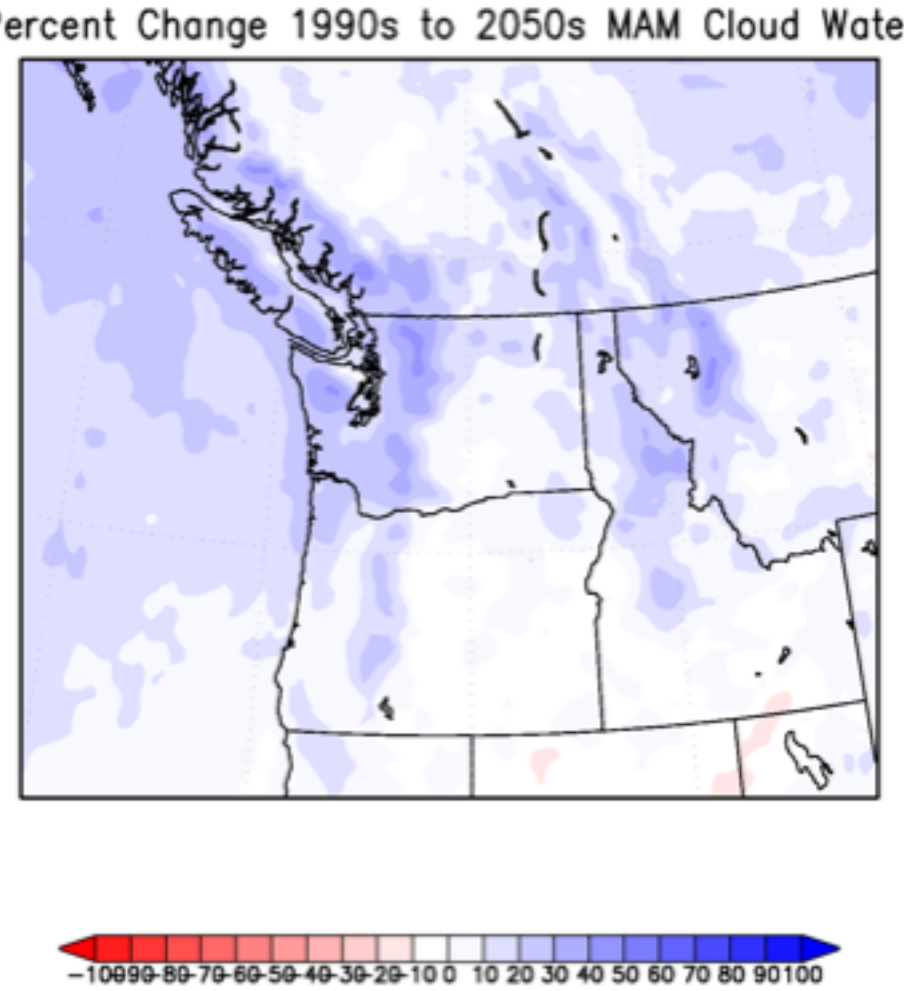
- Low level temperature gradients weaken as Arctic warms.
- This temperature gradient is the energy source for storms.
- Warming in the tropical upper troposphere compensates for low level weakening.



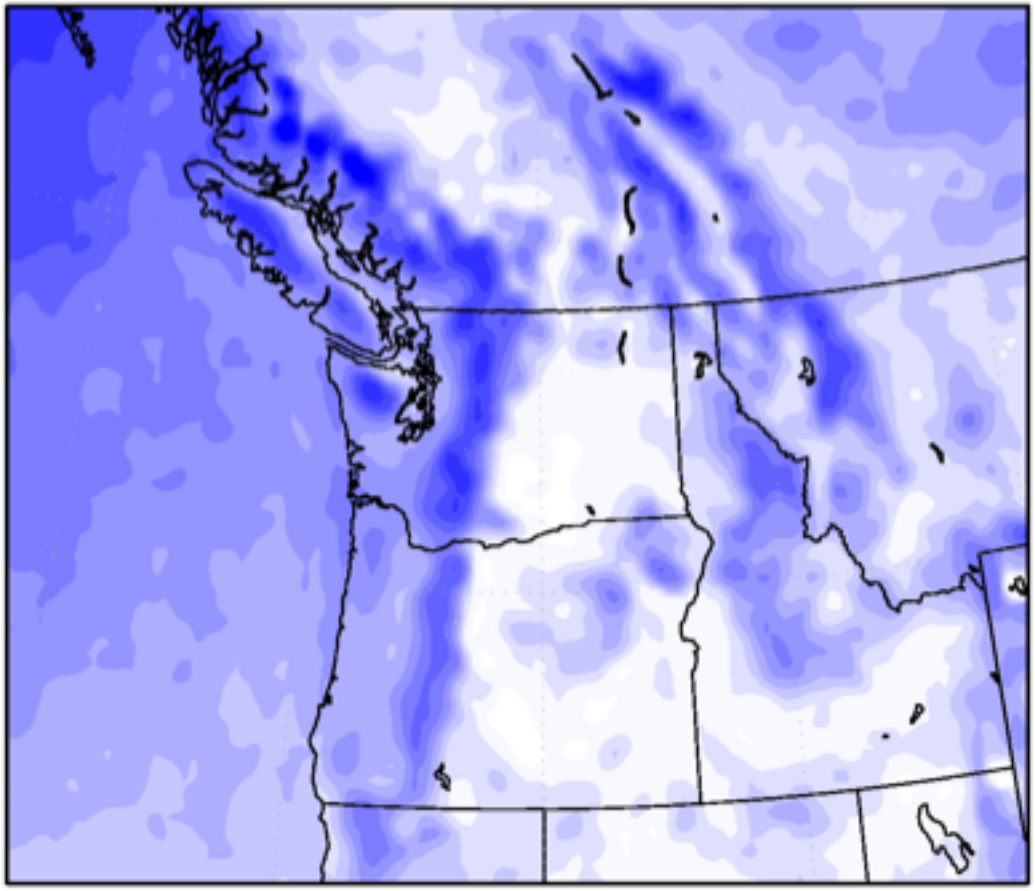
Surprise! More Low Clouds in Spring!

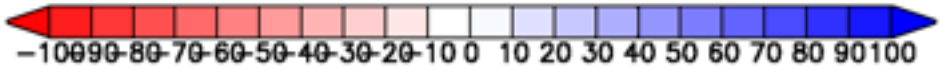
March-April-May Changes





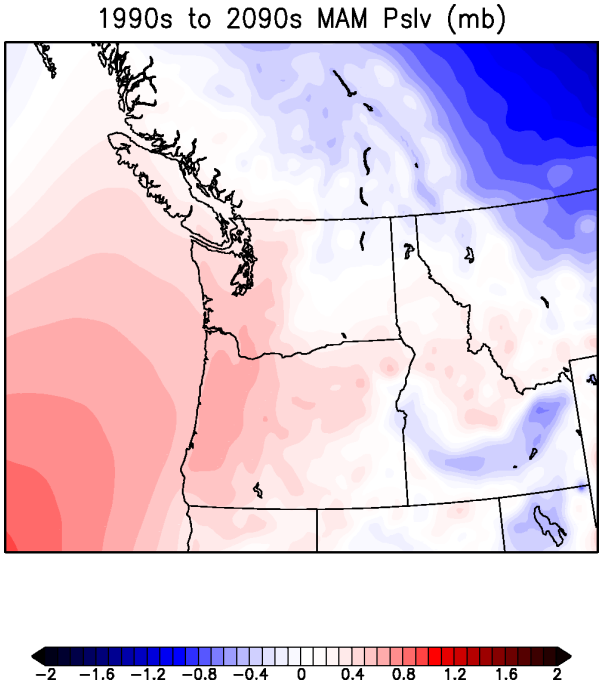
Percent Change 1990s to 2090s MAM Cloud Water





Why more clouds in spring?

- The interior of the continent warms up more/faster than over the eastern Pacific.
- Warmer air is associated with lower pressure.
- Higher pressure offshore under global warming
- Enhanced onshore pressure difference pushes marine air inland.



Drought?

Drought?

Pacific Northwest's 'Wet Drought' Possible Sign of Future

Published: *April 28th, 2015*

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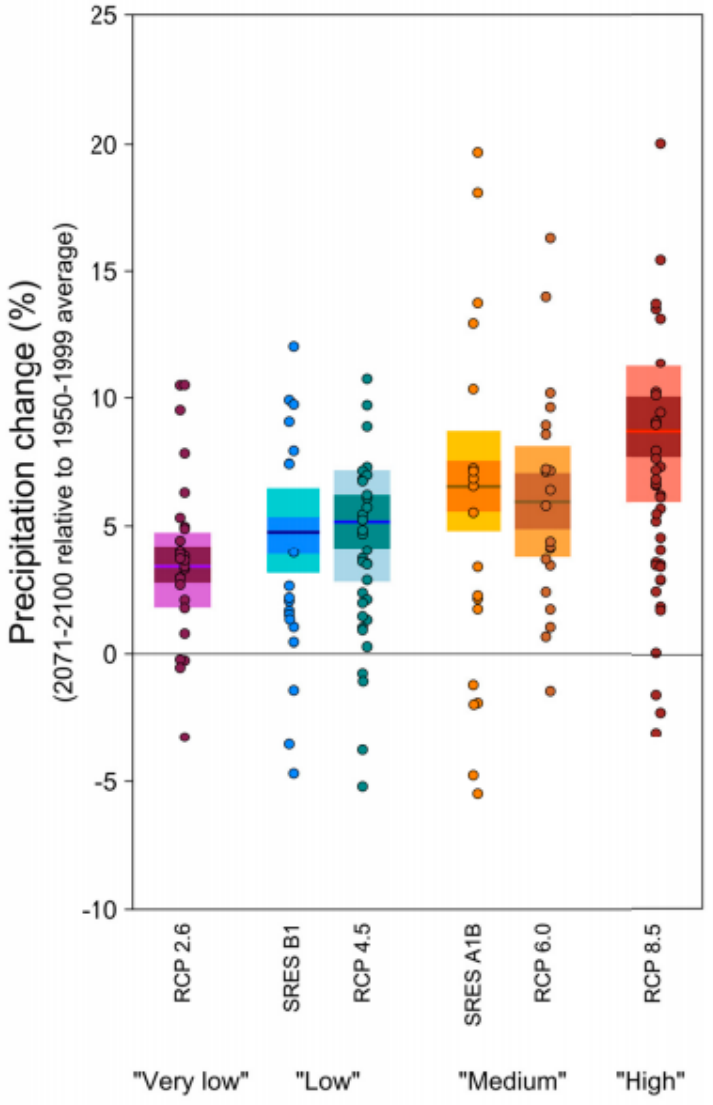
By Andrea Thompson

Follow @AndreaTWeather 2,808 followers

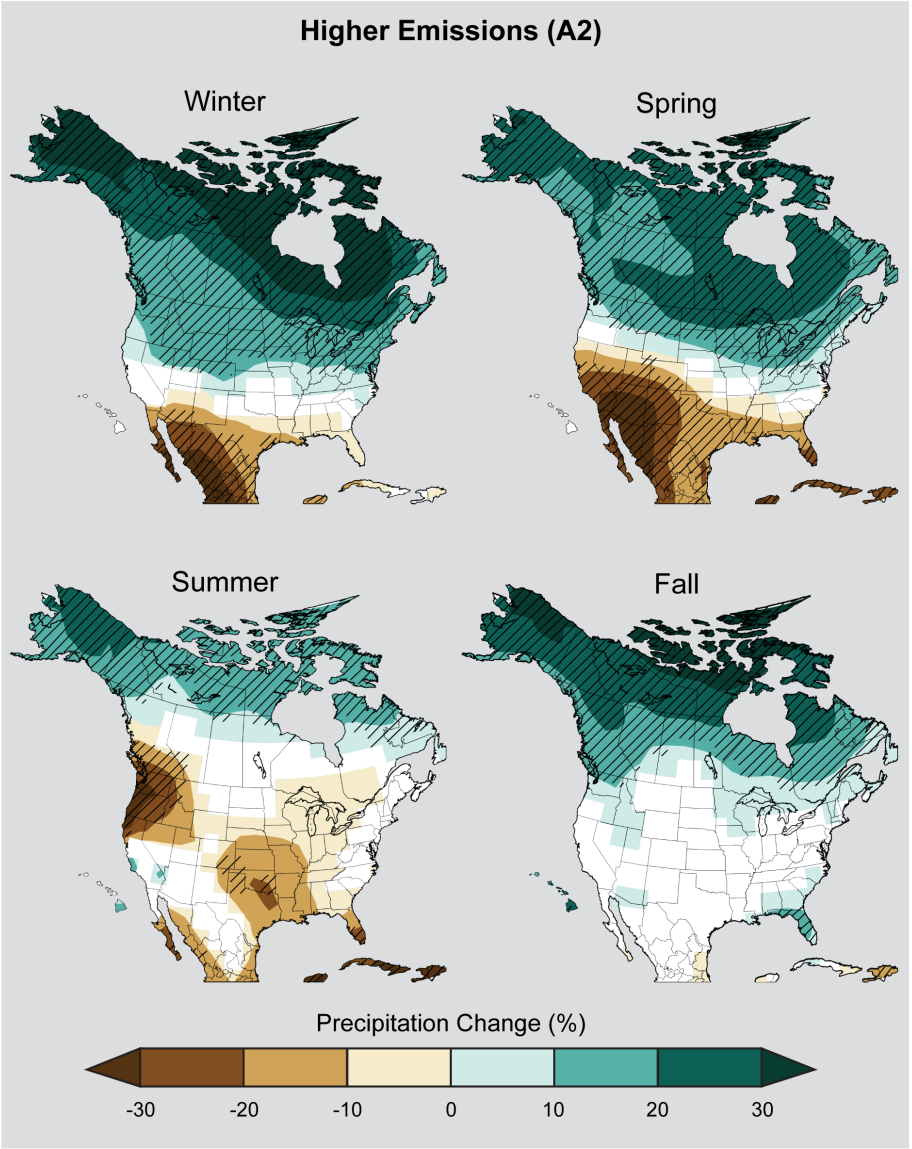
Surprise?

More annual rainfall in the Northwest



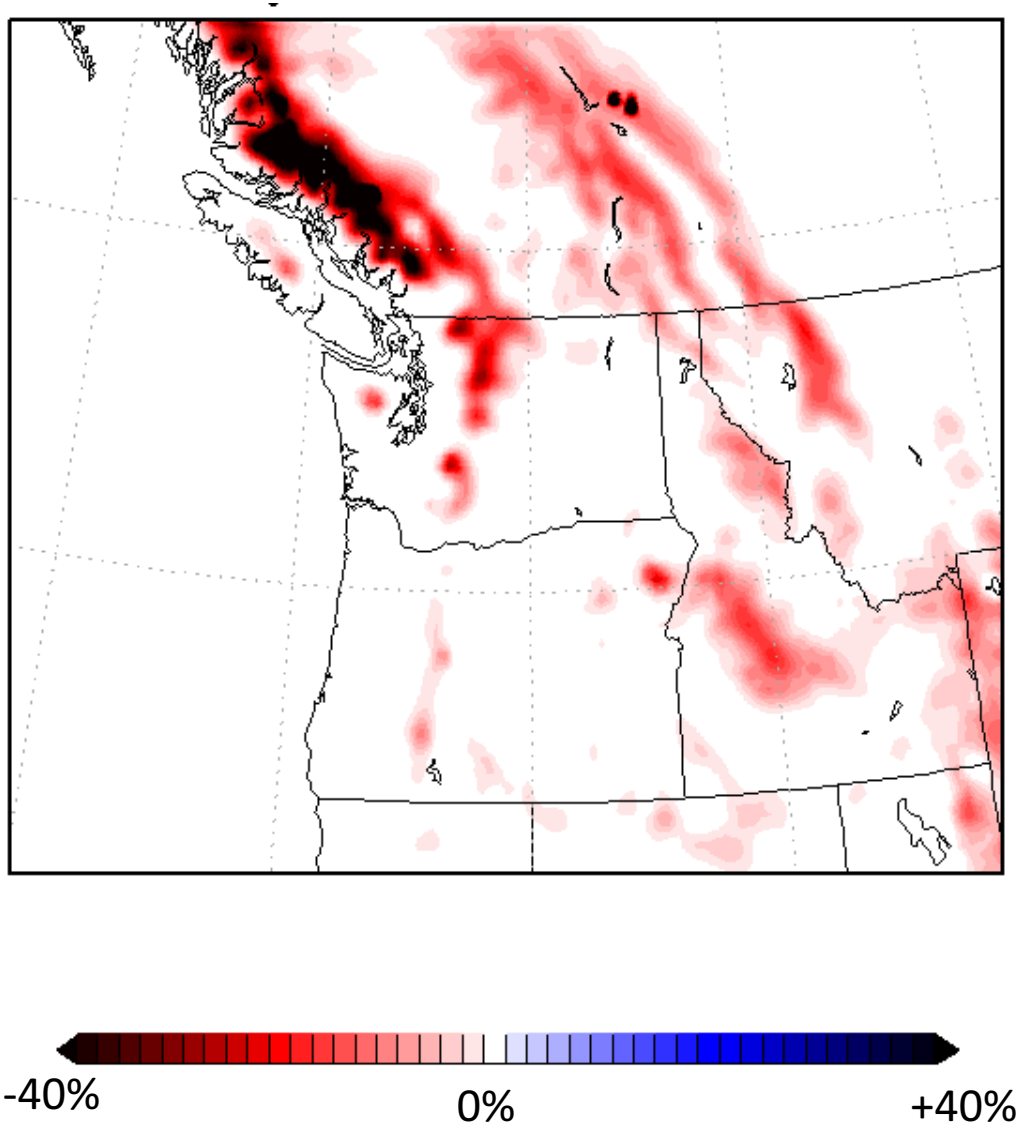
All seasons are wetter except summer—but there isn't much precipitation then anyway

Projected Precipitation Change by Season

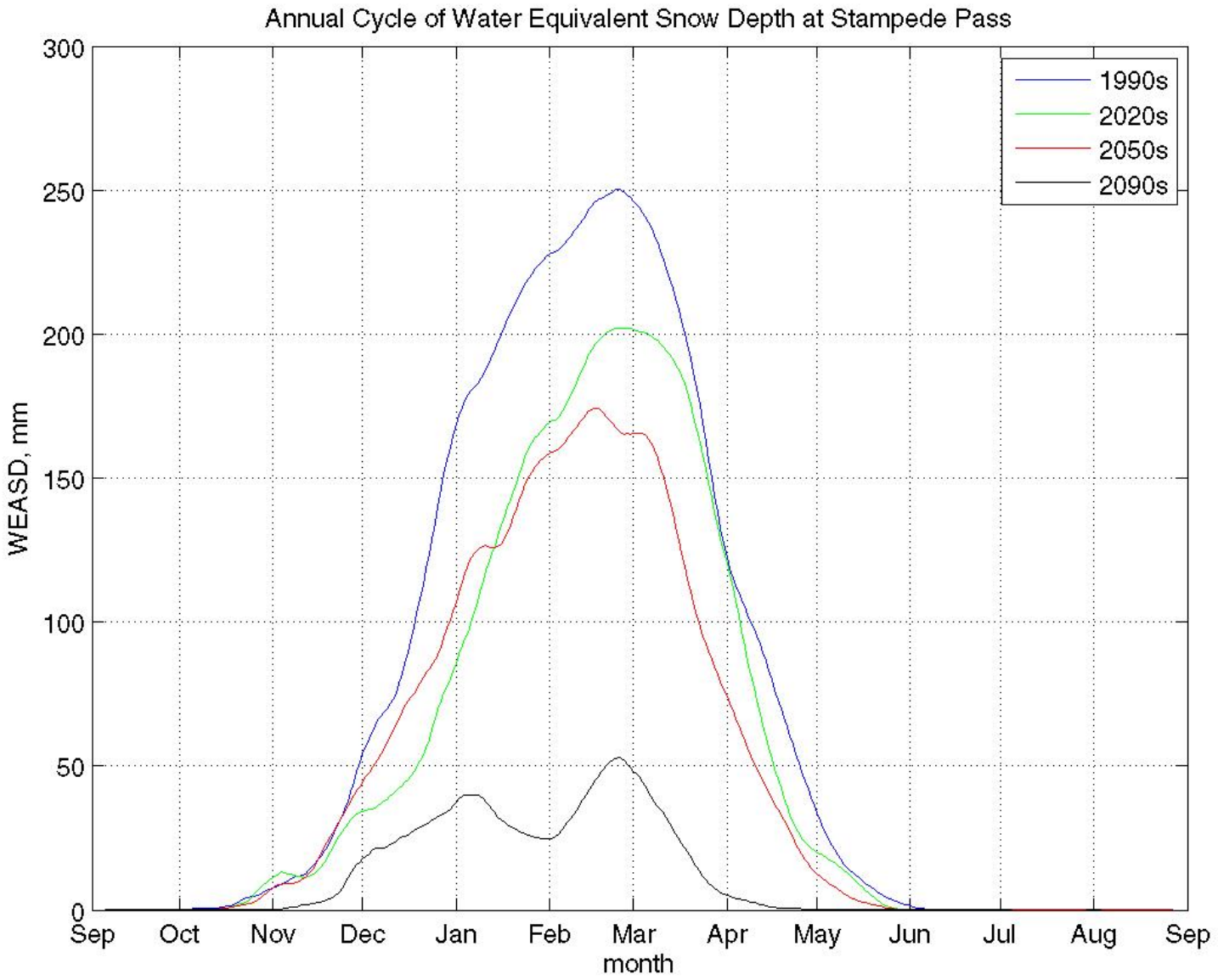


Warming will result in more precipitation falling as rain rather than snow

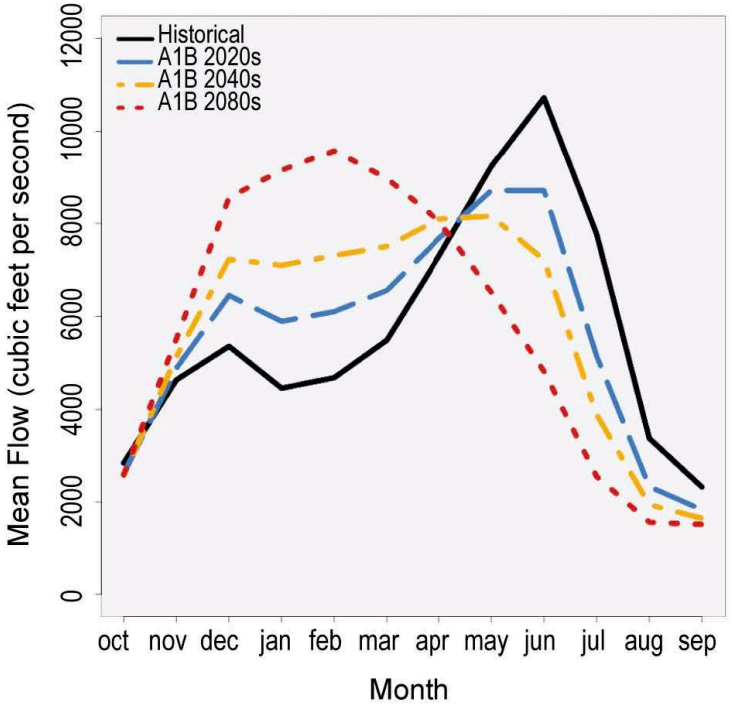
Change in April 1 Snowpack from 1990 to 2090



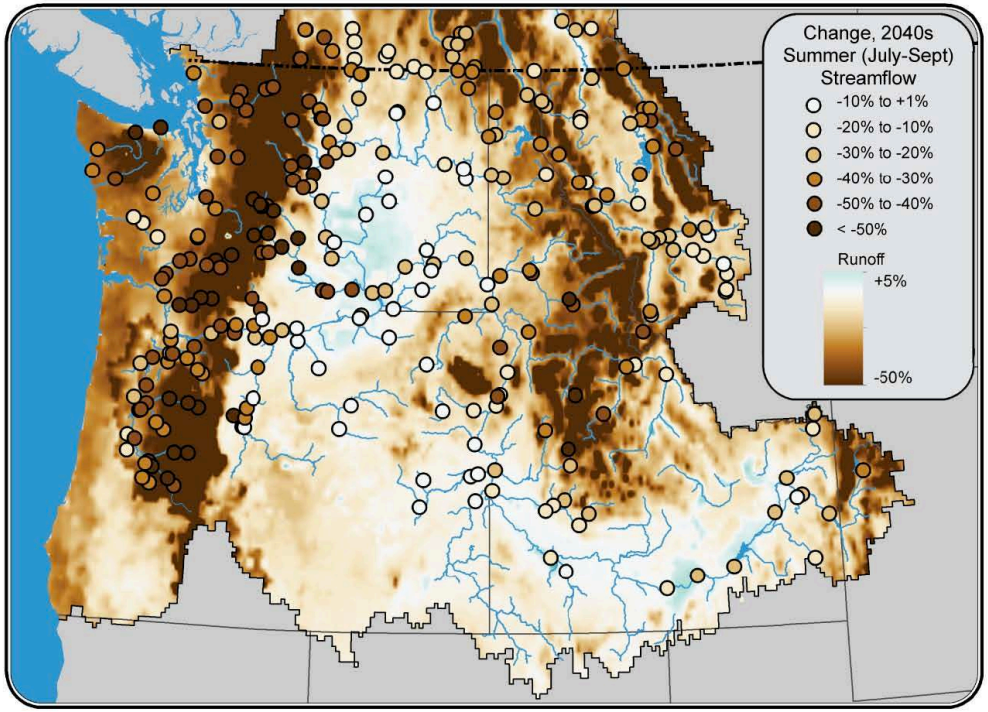
Surprise: Slow drop and then falling off a cliff.



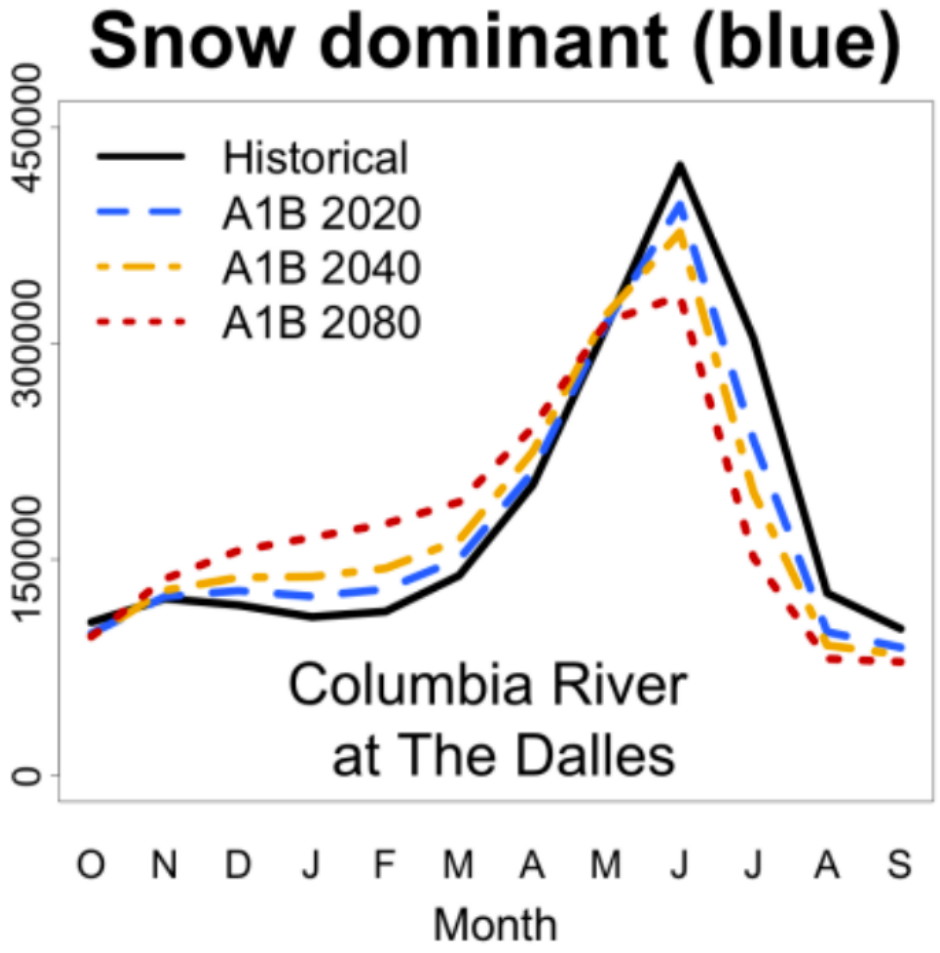
Streamflow will change: generally earlier peaks and less summer flow (except for the Columbia)



Yakima River



Surprise: Columbia streamflow doesn't change much

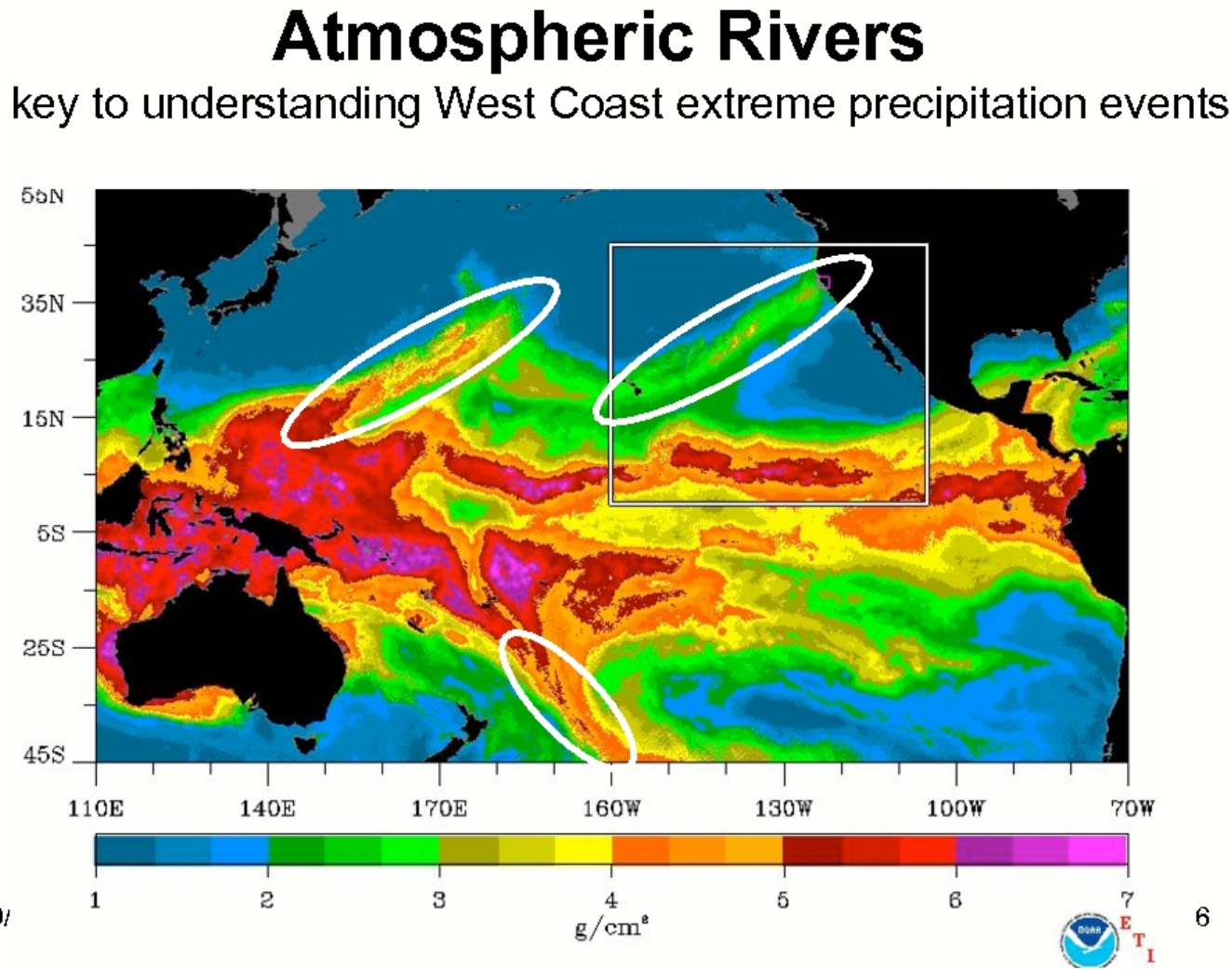


Why?

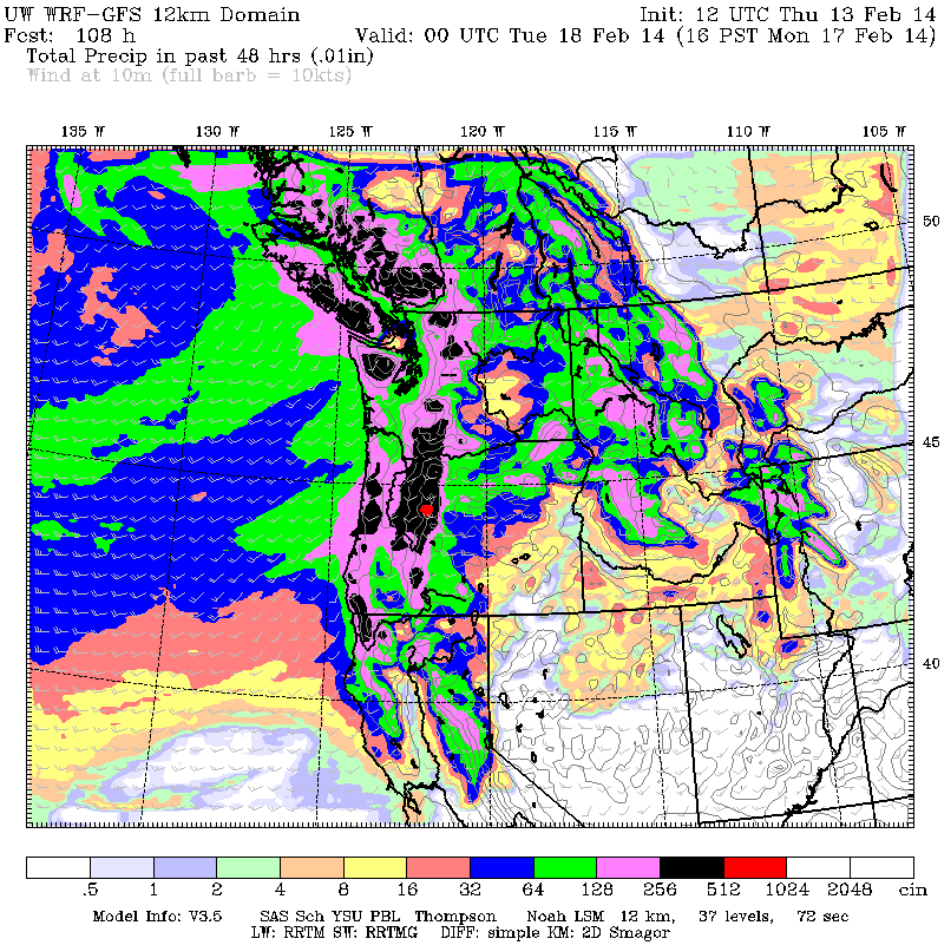
Columbia drains off much higher and wetter terrain

Bad Surprise: more extreme precipitation and flooding

Super Atmospheric Rivers



When atmospheric rivers hit our terrain, intense precipitation falls



Global warming will intensify atmospheric rivers

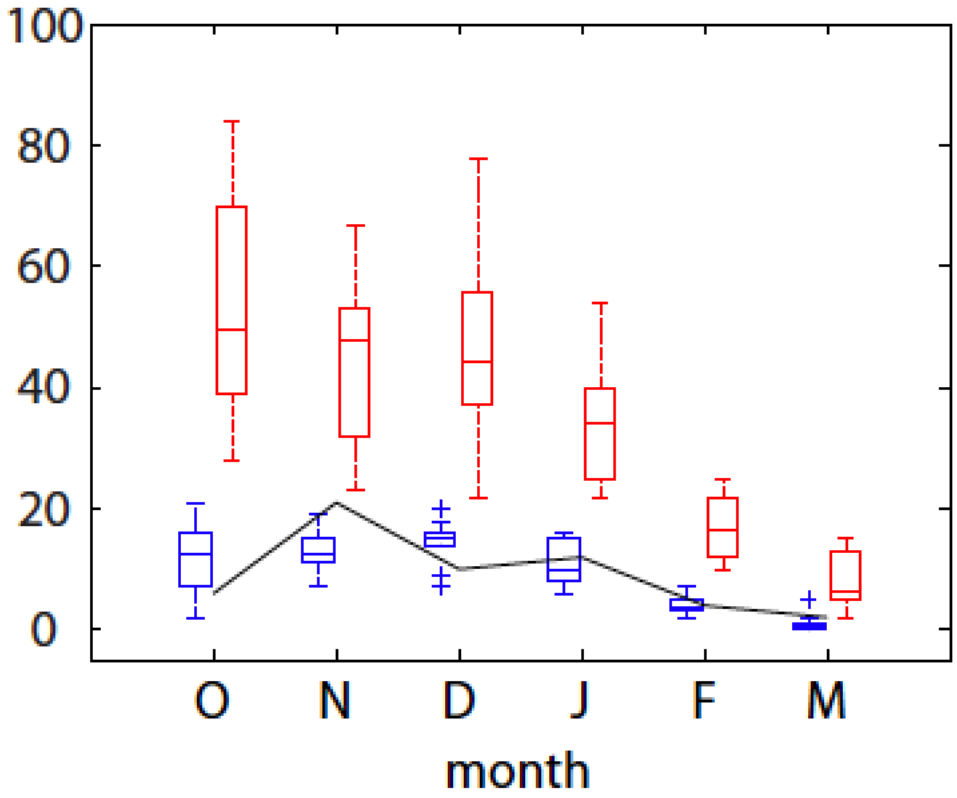
- Warmer air holds more water vapor.
- Examined a large collection of climate model simulations for changes between 1970-2000 to 2070-2100 based on “business as usual” greenhouse gas emissions.
- **Precipitation during extreme atmospheric river days increases by 15-39% .**
- **More flooding.**

More Bad Surprises

- **Snow absorbs rain**. “Origin of Cascade Concrete”
- With less snow, there will be less buffering or storage in the snowpack.
- Thus, heavier rainfall could lead to greater flooding on major rivers.

And even more…

- Heavier precipitation shifts EARLIER in the fall (more in October)



Take Home Messages

- Local terrain and land/water contrasts should greatly modify the impact of global warming on our region.
- Because of the Pacific Ocean, GW impacts have been relatively small **so far**.
- Local impacts from greenhouse gases will accelerate during the next several decades.

Take Home Messages

- Some of the local impacts will be large (heavier rain, less snowpack).
- Improved modeling should provide more robust projections during the next 5 years.
- Greenhouse gas concentrations are rising rapidly and we have done too little to stop it.

The END