

Climate Impacts Science Primer: How do scientists project future climates and their impact on resources in Washington State (WA) and the Pacific Northwest (PNW)?

1. Estimate future atmospheric greenhouse gas concentrations and other climate drivers.

Q1 - What do scientists have to know before they can project future climate?

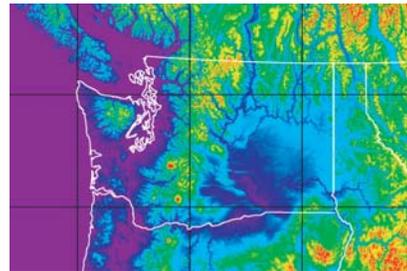
See Climate Impacts Science Questions for answers to Q1-Q9

2. Use global climate models (CMs) to project future climate at a global scale

*Q2 - How does a CM work?
Q3 - Why is there so much uncertainty in projected climate changes?
Q4 - Why can I believe climate change projections if it's impossible to forecast weather beyond two weeks?
Q5 - Which CM climate projections are most trusted? Which are less certain?*

3. Downscale CM results to project the future climate of WA and the PNW

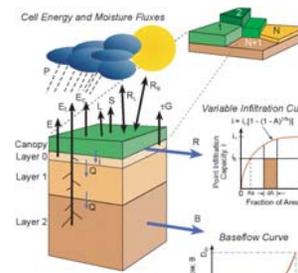
*Q6 - What factors control WA and PNW climate?
Q7 - How do scientists "downscale" CM results to a region like WA?*



WA topography with typical GCM grid resolution (~150 miles)

4. Use regional hydrology models to project future snowpack, streamflow, and soil moisture

Q8 - How do scientists project climate change impacts on the water cycle?



VIC hydrology model

5. Use resource management models or empirical relationships to understand implications for WA and PNW resources

Q9 - How do scientists project impacts on natural resources?



Salmon in Lake Washington

Climate Impacts Science Questions

Q1: What do scientists have to know before they can project future climate?

Before scientists can project future climate, they need to constrain how important climate drivers are likely to change over time. Human socio-economic and political choices influence two important climate drivers: atmospheric greenhouse gas concentrations and atmospheric particle concentrations. The climate of the 21st century will depend on both natural climate drivers and the cumulative impacts of human climate drivers. By making a range of assumptions about future development, global population, and per capita energy consumption, scientists have developed scenarios for future greenhouse gas and particle emissions. These emission scenarios can be put into climate models to project future climate changes (see Q2).

Q2: How does a global Climate Model (CM) work?

A CM is a computer program that solves a series of scientifically established equations to “model” the interactions between major components of the climate system including the atmosphere, the ocean, the land surface, ice sheets, and the biosphere. The relatively coarse resolution of CMs (~150 miles in the horizontal, ~0.6 miles in the vertical, ~½ hour) means some physical processes must be simplified. Most of the uncertainty and differences between CMs comes from the simplification of unresolved processes such as cloud evolution and mixing processes in the atmosphere and ocean. Using a number of CM projections (an “ensemble”) identifies a range of possible outcomes, and eliminates biases from a single model. When many independently formulated CMs produce similar projections of future climate, scientists have increased confidence in CM results.

Q3: Why is there so much uncertainty in projected climate changes?

Roughly speaking, uncertainty in climate change projections comes from two sources: uncertainty in future climate drivers (see Q1) and uncertainty in modeling how the climate system works (see Q2). According to IPCC scientists, uncertainty in emissions and in modeling how the climate system works contribute about equally to known uncertainty in future climate change projections. With improved understanding of the climate system, some of the uncertainty in future model projections could be reduced. However, even if scientists had perfect models of the climate system, uncertainty in future socio-economic and political decisions and their influence on human climate drivers will always remain.

Q4: Why can I believe climate change projections if it's impossible to forecast weather beyond two weeks?

Meteorologists model the evolution of individual weather systems and provide weather forecasts at specific times. Climate scientists project the statistics of weather events over longer periods of time (e.g., a season, a decade, or a century). An example of the difference between a weather and a climate forecast follows: A climate projection would state that Januaries in the 2020's will be 3-4 ° F warmer and 4-11% wetter on average than the 1990s while a weather forecast would tell you there is a 70% chance of rain on Friday with a predicted high temperature of 50-55 ° F.

The differences between weather forecasts and climate change projections lead to predictability on different timescales. The sensitivity of weather systems to small changes in initial conditions means that it will never be possible to predict the weather beyond ~2 weeks. The predictability of climate depends on well-understood interactions between the atmosphere and the land surface, oceans, and ice sheets. When climate scientists can identify changes in these interactions (e.g., due to a change in a climate driver such as atmospheric greenhouse gas concentrations), they can project climate changes on long timescales.

Q5: Which CM projections are most trusted? Which are less certain?

Confidence in CM climate projections comes from both comparing CM simulations of past climate to historical climate observations and CM inter-comparison studies. Most CMs can reproduce observed warming trends in the 20th century global surface air temperature when driven by natural climate drivers (e.g., volcanoes, solar radiation) and human-caused increases in greenhouse gases and atmospheric particles. However, agreement between present day climate in CMs and observations decreases for key meteorological variables in the following order: temperature, sea level pressure, and precipitation. Model inter-comparison studies also show that CMs are more consistent in their temperature projections than in their precipitation projections. CMs do not simulate localized climate effects (e.g., the impacts of small-scale topography such as the Cascade Mountains or water bodies such as Puget Sound). CMs also have trouble with the representation of important modes of climate variability such as the El Niño-Southern Oscillation (ENSO).

Climate Impacts Science Questions Continued

Q6: What factors control Washington state climate?

Latitude, proximity to the large water bodies, and mountain ranges all have large influences on Washington and PNW climate. Season-to-season and decade-to-decade changes in Pacific Ocean temperatures have important controls on Washington and PNW climate variability.

Q7: How do scientists “downscale” CM results to a region like Washington state?

Raw CM output has very coarse resolution (~150 miles) and should not be used directly at a regional scale. To project climate changes in Washington or across the PNW, CM results must be downscaled to a regional level where finer scale influences of topography and water bodies can be resolved. The “delta” method and regional scale atmospheric climate models are two methods used to downscale global climate model results. The “delta” method applies changes from the CM simulations to the historic record of climate. For example, for a 2020 scenario, all the Januaries in the historical record might have their monthly total precipitation multiplied by 1.04 and their monthly average temperature increased by 3.4 °F. This method assumes that only the mean temperature and precipitation, not the variability, change in future climates. High-resolution regional models that are forced by lower-resolution CM output can be run to estimate the fine-scale impacts of climate change. Unlike CMs, regional models include features such as the Cascade Mountain Range and Puget Sound.

Q8: How do scientists project climate change impacts on the water cycle?

After regional scale projections of future climate are obtained (see Q2 and Q7), hydrologic models can be used to project changes in the water cycle. For example, most of the CIG research to date has used the delta downscaling method and the Variable Infiltration Capacity (VIC) hydrology model to estimate the influence of climate change on streamflows. Changes in the water cycle are identified by comparing hydrologic simulations forced by the observed climate and a climate with perturbed temperature and precipitation (see Q7).

Q9: How do scientists project impacts on natural resources?

After identifying potential changes in regional temperature and precipitation (Q7) and the water cycle (Q8), resource management models and empirical methods can be used to understand the impact of climate change on specific resources. For example, the Northwest Power and Conservation Council (NWPCC) recently used altered streamflow scenarios to drive a water management model and estimate the impacts of climate change on hydropower operations. For resources such as forestry and fisheries where quantitative models do not exist or are being developed, empirical methods can be used to estimate the impact of climate change. In other words, we can use observations of how past climate fluctuations have affected the resource to project the impact of future climate changes.