Climate Change Impacts on Mountain Water Resource in the Pacific Northwest

Alexander Foss¹, Nicholas Ness², Wenlong Feng²

Department of Geography, University of Idaho, Moscow, ID

1. Department of Chemistry, University of Idaho, Moscow, ID

Introduction

Mountain precipitation and snowpack are the primary water supply of streams in the Pacific Northwest. Variation in snowpack melt timing and quantity decides the annual time series of streamflow. Climate factors always strongly affect not only mountain precipitation and snowpack but also the water usage. Since the increase in the green house gases emission, the global warming is inevitably intensified in the 21st century, its impacts become more and more obvious. This chapter shows the information of climate change impacts on orographic precipitation, mountain snowpack, snow melting and water usage, in order to reveal the possible changes in the mountain water resource.

Declining orographic precipitation and mountain snowpack

- Mountain precipitation is usually enlarged by the orographic enhancement.
- The decreasing trend in streamflow from 1948 to 2005 is at least partially accounted for the decline in orographic precipitation enhancement.
- Orographic enhancement strongly positive correlates with the low tropospheric (700hPa height) zonal wind (easterly) speed.
- Global warming leads to the decrease trend in 700hPa level wind speed in the PNW.
- Snowier wintertrees reduces the orographic precipitation.

Variations in Snowpack melt timing and quantity

- Snowfall rates affected by aerosols: aerosols causing less precipitation downstream from pollution source.
- Less snowpack, less runoff, less stream flow.
- Snowmelt rates: Black carbon aerosols mining in with precipitation.
- Higher temperature for the entire West. Connected domains indicate the areas where the percentage from a VIC simulation of which annual variations in precipitation were removed at each grid point by constraining annual precipitation to be the same each year.

Fig. 1. Location and Effects of lower-quartile annual precipitation and streamflow and VIC precipitation data points and HydroClime Data Network/VMR data for snow course locations (white dot) and streamflow sites (light blue dot) in the PNW.

Fig. 2. Correlation of 1960–2012 November to March 700hPa zonal wind (left) and April 1960–2012 700hPa zonal wind (right) with annual streamflow and snow water equivalent (SWE) for the western United States, Canada and Northern Mexico. Significant trends for the period 1950–1990 are shown by thick black lines. Lower-quartile annual precipitation and streamflow are shown by open boxes. The grey line indicates the 10th and 90th percentiles and the grey area indicates significant trends.

Fig. 3. Trends in November to March snow water equivalent (SWE) from 1960–1990. The dashed line shows the temperature for the entire U.S. Connected domains indicate the areas where the percentage from a VIC simulation of which annual variations in precipitation were removed at each grid point by constraining annual precipitation to be the same each year.

Fig. 4. Projected increases in November to March snow water equivalent (SWE) for the Pacific Northwest for the period 1950–2005 under the scenarios of A1B, A2, B1 and B2. The gray area indicates significant trends.

Fig. 5. Linear trends in 1 Apr snow water equivalent (SWE) relative to the starting value for the period 1950–1990 for snow course locations in the PNW.

Fig. 6. Linear trends in 1 Apr snow water equivalent (SWE) relative to the starting value for the period 1950–1990, with negative trends shown by red arrows and positive trends shown by blue arrows.

Fig. 7. Projected climate change impacts on streamflow timing in the Northeast. The plot shows monthly mean streamflow of historical record (black), historical record plus current climate change projection (red), and historical record plus future climate change projection (blue). The dots indicate the period 1950–2005 and the line with arrows indicate the projection under the A1B scenario in 2020s (blue line). The dashed line indicates the future climate change projection with the 50th percentile and the solid line indicates the future climate change projection with the 95th percentile.

Impacts of climate change on water storage and uses

Four main uses of water resources

- Municipal
- Agriculture
- Electricity generation
- Industry/Commercial

Fig. 8. Thermoelectric-power withdrawals, by State, 2005

Thermoelectric-power withdrawals, by State, 2005

References


Conclusion

- Global warming will cause slower westerlies which will reduce the orographic precipitation enhancement. Higher temperature in winter will also reduce the snowpack accumulation in the mountain area. These will lead to the decline in water supply of streams in the PNW.
- Snowier wintertrees will reduce the snowpack accumulation in summer, and result in reducing streamflow in spring and early summer.

- The winter content of snowpack (snow water equivalent) is strongly affected by the temperature and precipitation in winter (Nov–Mar). From 1930 to 1950, SWE losses caused by temperature increases are less than SWE gains from precipitation increase in most mountain areas in the PNW. But a significant SWE decline trend is overwhelming in our region after 1950.
- Global warming in the future will decrease snowpack accumulation in winter, and then will reduce streamflow in spring and early summer.

- Agriculture
  - Increased probability of drought
  - Increased evapotranspiration
  - Larger volumes of water required to prevent crop loss
  - Longer growing seasons would require more water

- Electricity generation
  - Increased demand for municipal irrigation
  - Production may be slowed due to limited water supply

- Industry/Commercial
  - Reduced inflow cause less power to be produced
  - More water will be used for thermoelectric power
  - More water will be used for thermoelectric power

- Municipal
  - Mostly non-consumptive
  - Some demand with increased population

- Agriculture
  - Preparation of products
  - Preparation of products
  - Preparation of products
  - Preparation of products

- Electricity generation
  - Preparation of products
  - Preparation of products
  - Preparation of products
  - Preparation of products

- Industry/Commercial
  - Preparation of products
  - Preparation of products
  - Preparation of products
  - Preparation of products

- Municipal
  - Preparation of products
  - Preparation of products
  - Preparation of products
  - Preparation of products