Understanding the Effects of Climate Change on Water Resources in the Pacific Northwest

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Recession of the Muir Glacier

Aug, 13, 1941

Aug, 31, 2004

Image Credit: National Snow and Ice Data Center, W. O. Field, B. F. Molnia
http://nsidc.org/data/glacier_photo/special_high_res.html
Trends in April 1 SWE 1950-1997

As the West warms, spring flows rise and summer flows drop

Stewart IT, Cayan DR, Dettinger MD, 2005: Changes toward earlier streamflow timing across western North America, J. Climate, 18 (8): 1136-1155
Projections for the Future Using Global Climate Models
Natural AND human influences explain the observations of global warming best.
Hydroclimatology of the Pacific Northwest
Winter climate in the mountains is the key driver of streamflow.

Snowpack functions as a natural reservoir.
Hydrologic Characteristics of PNW Rivers

The graph illustrates the normalized streamflow for different hydrologic characteristics of PNW Rivers.

- **Snow Dominated**
- **Transient Snow**
- **Rain Dominated**

The x-axis represents the months, and the y-axis represents the normalized streamflow.
Effects of the PDO and ENSO on Columbia River Summer Streamflows

PDO

Apr-Sept Flow (cfs)
Temperature warms, precipitation unaltered:

- Streamflow timing is altered
- Annual volume may be somewhat lower due to increased ET

Warming Affects Streamflow Timing
Precipitation Affects Streamflow Volume

Precipitation increases, temperature unaltered:

- Streamflow timing stays about the same
- Annual volume is altered

Black -- Obs
Blue -- 9% increase in precip.
Hydrologic Impacts for the PNW
Schematic of VIC Hydrologic Model and Energy Balance Snow Model

Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model

Canopy Layer 0
Layer 1
Layer 2

Grid Cell Vegetation Coverage

Variable Infiltration Curve

Point Infiltration Capacity, \( i \)

Fraction of Area

Baseflow Curve

incoming shortwave
reflected shortwave
canopy wind profile
Precipitation
Incoming Longwave
Canopy Longwave
Drip Mass Release
Outgoing Longwave
Sensible & Latent Heat

Snow Model

6 km
1/16th Deg.

PNW
USA
The warmest locations that accumulate snowpack are most sensitive to warming.
Simulated Changes in Natural Runoff Timing in the Naches River Basin Associated with 2°C Warming

- Increased winter flow
- Earlier and reduced peak flows
- Reduced summer flow volume
- Reduced late summer low flow
Rain Dominant

Chehalis River

Simulated Basin Avg Runoff (mm)

- Blue: 1950
- Red: plus2c

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Warm Transient Snow

Simulated Basin Avg Runoff (mm)

Hoh River

1950
plus2c

oct  nov  dec  jan  feb  mar  apr  may  jun  jul  aug  sep
Cooler Transient Snow

Simulated Basin Avg Runoff (mm)

Nooksack River

1950

plus2c

oct

nov
dec
jan
feb
mar
apr
may
jun
jul	nov
sep
Snowmelt Dominant

Simulated Basin Avg Runoff (mm)

Skagit River

1950

plus2c
Decadal Climate Variability and Climate Change
Will Global Warming be “Warm and Wet” or “Warm and Dry”? 

Answer: Probably BOTH!
Regionally Averaged Cool Season Precipitation Anomalies

Std Anomalies Relative to 1961-1990

- Red: PNW
- Blue: CA
- Green: CRB
- Gray: GB

Years:
- 1916
- 1920
- 1924
- 1928
- 1932
- 1936
- 1940
- 1944
- 1948
- 1952
- 1956
- 1960
- 1964
- 1968
- 1972
- 1976
- 1980
- 1984
- 1988
- 1992
- 1996
- 2000

Precipitation Anomalies

Values:
- -3
- -2
- -1
- 0
- 1
- 2
- 3
Overview of Some Water Resources
Impact Pathways
Water Supply and Demand

• Changes in the seasonality water supply (e.g. reductions in summer)
• Changes in water demand (e.g. increasing evaporation)
• Changes in drought stress
• Increasing conflicts between water supply and other uses and users of water

Energy Supply and Demand

• Changes in the seasonality and quantity of hydropower resources
• Changes in energy demand
• Increasing conflicts between hydro and other uses and users of water

Instream Flow Augmentation

• Changes in low flow risks
• Changes in the need for releases from storage to reproduce existing streamflow regime.
• Changes in water resources management related to water quality (e.g. to provide dilution flow or to control temperature)
Flood Control and Land Use Planning
• Changes in flood risks
• Changes in flood control evacuation and timing to maintain refill reliability
• Dam safety
• Changes in land use policy

Transboundary Relationships and Agreements
• Differential impacts in different regions (e.g. in Canada and the U.S.)
• Increased conflict over water resources
• Unbalancing of existing agreements

Long-Term Planning, Water Law and Policy
• Water allocation agreements in a non-stationary climate (e.g. water permitting)
• Appropriateness of the historic streamflow record as a legal definition of climate variability
• Need for new planning frameworks in a non-stationary climate
Overview of Some Existing Climate Change Water Planning Studies

• Seattle Water Supply (Wiley 2004)

• White River Basin (Ball 2004)

• Snohomish Basin (Battin et al. 2007)

• Columbia Hydro System (Hamlet et al. 1999; Payne et al. 2004, NWPCC 2005)


