An overview of climate change impacts on streamflow for the Blue Mountains

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The diagram illustrates the average annual temperature and precipitation for the Pacific Northwest. The historical variability is shown in blue, with 2020s, 2040s, and 2090s shifts in mean precipitation represented by different colored bars. The source of the data is the Climate Impacts Group, University of Washington.
Snowpacks have gotten smaller, are melting earlier...

...and are projected to continue to diminish.
Snow at risk in a warming climate

22% Oregon Cascades
12% Washington Cascades
61% Olympic Range
<3% Pacific Northwest study area

(Nolin and Daly, 2006)
How could hydrographs change in the future?

- Total precip (wet/dry year)
- Timing and type or precip
  - Timing of snowmelt

Magnitude

Timing
How could hydrographs change in the future?

- **Total precip (wet/dry year)**
  - Magnitude

- **Timing and type or precip; Timing of snowmelt**
  - Timing

- **Water use by vegetation (ET)**
  - Abstraction
How could hydrographs change in the future?

- **Total precip (wet/dry year)**
  - Magnitude
  - Timing of snowmelt

- **Water use by vegetation (ET)**
  - Abstraction
  - Timing

- **Drainage Efficiency**
  - Recession
Surface runoff vs. Spring-fed

Western Cascades
surface runoff = high drainage efficiency

High Cascades
spring-fed = low drainage efficiency
Snow vs. rain

- Snowmelt-dominated (N. Santiam)
- Rain-dominated (Luckiamute)
Our “bottom up” approach

We need to know (at the landscape scale)

1) Whether precipitation is rain or snow

2) When water actually enters the ground (recharge)

3) How long does it take for recharge to become streamflow (discharge)

From these we can identify places where streamflow will be more or less likely to change due to changes in precipitation and temperature.
Predicted sensitivity of summer streamflow in Oregon and Washington

High sensitivity due to relatively late snowmelt

High sensitivity due to relatively low drainage efficiency (deep groundwater)

Magnitude
\[
\frac{\partial Q(t_r)}{\partial Q_o} = e^{-kt_r}
\]

Timing
\[
\frac{\partial Q(t_r)}{\partial t_r} = Q_o ke^{-kt_r}
\]
Predicted sensitivity of summer streamflow in Oregon and Washington

Magnitude

$$\frac{\partial Q(t_r)}{\partial Q_o} = e^{-kt_r}$$

Timing

$$\frac{\partial Q(t_r)}{\partial t_r} = Q_o ke^{-kt_r}$$

Moderate sensitivity to changes in both magnitude and timing

Safeeq et al, in review
Predicted sensitivity of summer streamflow in Oregon and Washington

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\[
\frac{\partial Q(t_r)}{\partial Q_o} = e^{-kt_r}
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**Timing**

\[
\frac{\partial Q(t_r)}{\partial t_r} = Q_o ke^{-kt_r}
\]

Safeeq et al, in review
The pieces of the puzzle for the Blue Mountains
Take home messages

• Blue Mountains are moderately sensitive to projected climate changes compared with other regions in OR and WA

• Summer streamflow sensitivity highest in parts of the Blues with combination of:
  - Late melting snowpacks (which will melt earlier)
  - Moderately low drainage efficiencies (lots of memory)
1) Identify controls on current peak flows across landscape

2) Use empirical model to improve prediction and generate map of classes of peak flow drivers

3) To predict FUTURE sensitivity to peak flow change, perturb climate-related peak flow drivers in model (i.e., definition of susceptibility rain on snow)

4) Re-map and show which areas change under warmer climate
We can predict the increase in 2- and 25-yr peakflows with change from current moderate and low flood risk snow cover to high flood risk under warmer climate.
1) Select unregulated basins and extract key controls from historical streamflow record

2) Develop empirical model to predict drainage efficiency ($k$)

3) Determine dominant type of recharge (snow or rain)

4) Use gridded precipitation, SWE and temperature data (CIG) to extract magnitude ($I_M$, $I_R$) and timing ($t_M$, $t_R$) of recharge

5) Use derived variables to solve equations from conceptual model