Climate change and stream flow: Barriers and opportunities

Preliminary project report to

Washington State Department of Ecology

STATE OF WASHINGTON
WATER RESEARCH CENTER

UNIVERSITY of WASHINGTON

CLIMATE IMPACTS GROUP

WASHINGTON STATE UNIVERSITY

DEPARTMENT OF ECOLOGY
State of Washington

Project Team

- Jonathan Yoder (lead) Washington State University (WSU) & State of WA Water Research Center
- Crystal Raymond (co-lead) University of Washington (UW) Climate Impacts Group
- Reetwika Basu WSU School of Economic Sciences
- Suhina Deol WSU School of Economic Sciences
- Alexander Fremier WSU School of Environment
- Kairon Garcia WSU School of Economic Sciences
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- Julie Padowski WSU School of Environment & Center for Env. Research, Ed. & Outreach
- Matt Rogers UW Climate Impacts Group
- Amanda Stahl WSU School of Environment

Big thanks to lots of people

- Numerous experts from Washington State and throughout the West provided perspectives on important topic areas and critical needs. It's a list too long to include.
- Special thanks to Dave Christensen for his leadership on this project.

Context

- This report is the product of a preliminary effort toward a long-term goal of understanding climate-induced stream flow changes and impacts on fish, and the institutional context for mitigation and adaptation.
- The project was carried out over about 3 months – very quick turnaround for academics!
- Although this preliminary report is brief and relatively narrow in focus, a great deal of background information was collected and remains available for future work.

Report Contents and presenters

- Projected climate effects on streamflow and water temperature
  - **Dr. Crystal Raymond**, UW CIG
- projected climate impacts on salmonids
  - **Dr. Alex Fremier**, WSU SoE
- Washington State law and policy barriers to streamflow management
  - **Dr. Jonathan Yoder**, WSU, WRC
- Western States' policy responses to climate-induced stream flow change
  - **Yoder**

Link to report:
https://apps.ecology.wa.gov/publications/SummaryPages/2211029.html

Climate Change Impacts on Summer Streamflow and Temperature

Crystal Raymond,
Guillaume Mauger,
Matt Rogers

Climate Impacts Group
University of Washington

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EARTHLAB
UNIVERSITY of WASHINGTON

For water resources in a changing climate, three most important points for changes in low flows.

1. More precipitation in winter, less in summer.
2. More winter precipitation as rain, less as snow.
3. Earlier snowmelt and runoff.

Seasonal changes in the amount and timing of natural streamflows.

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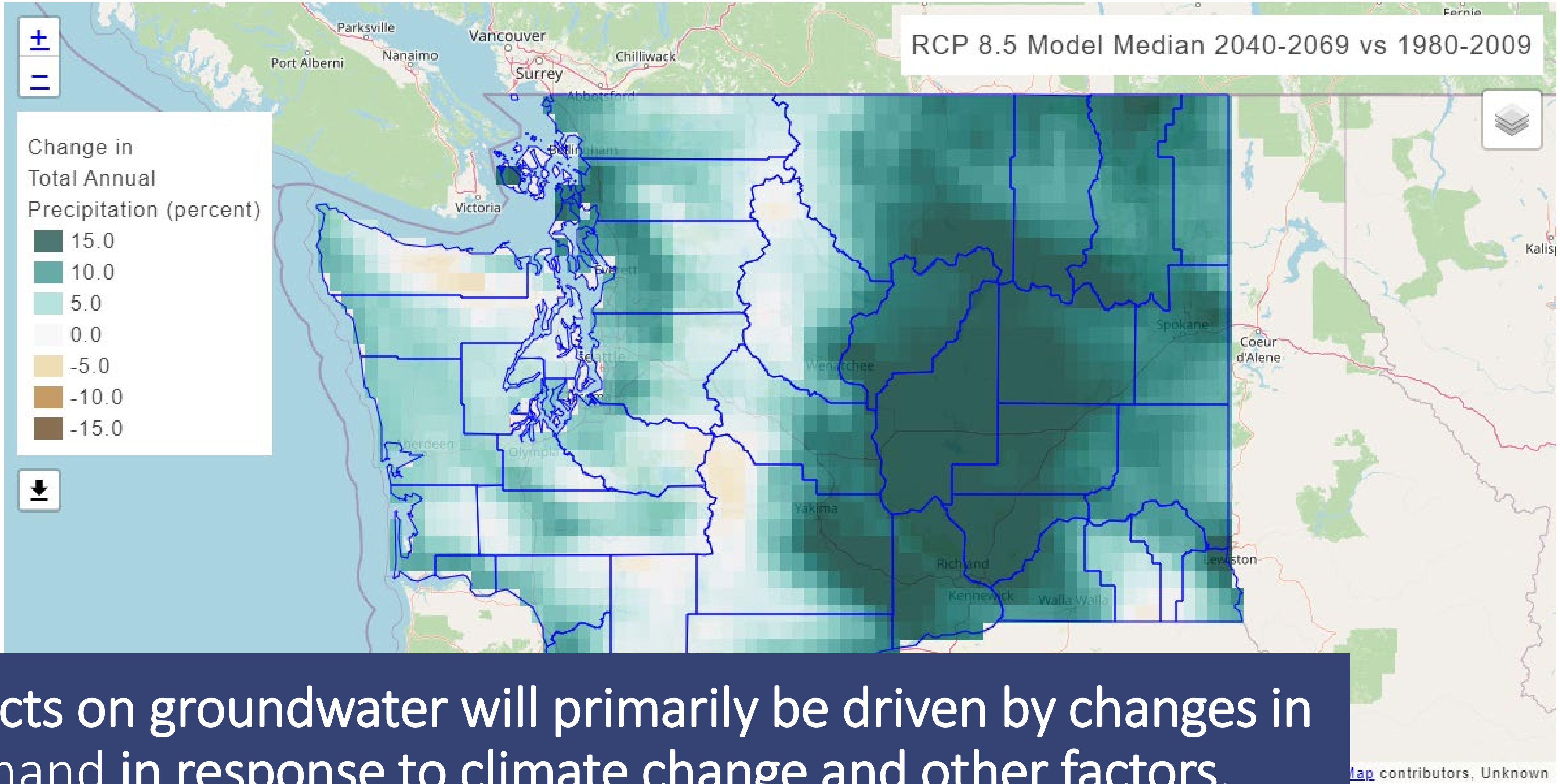
Little change is expected in annual precipitation, and variability from one year to the next will continue to be high.

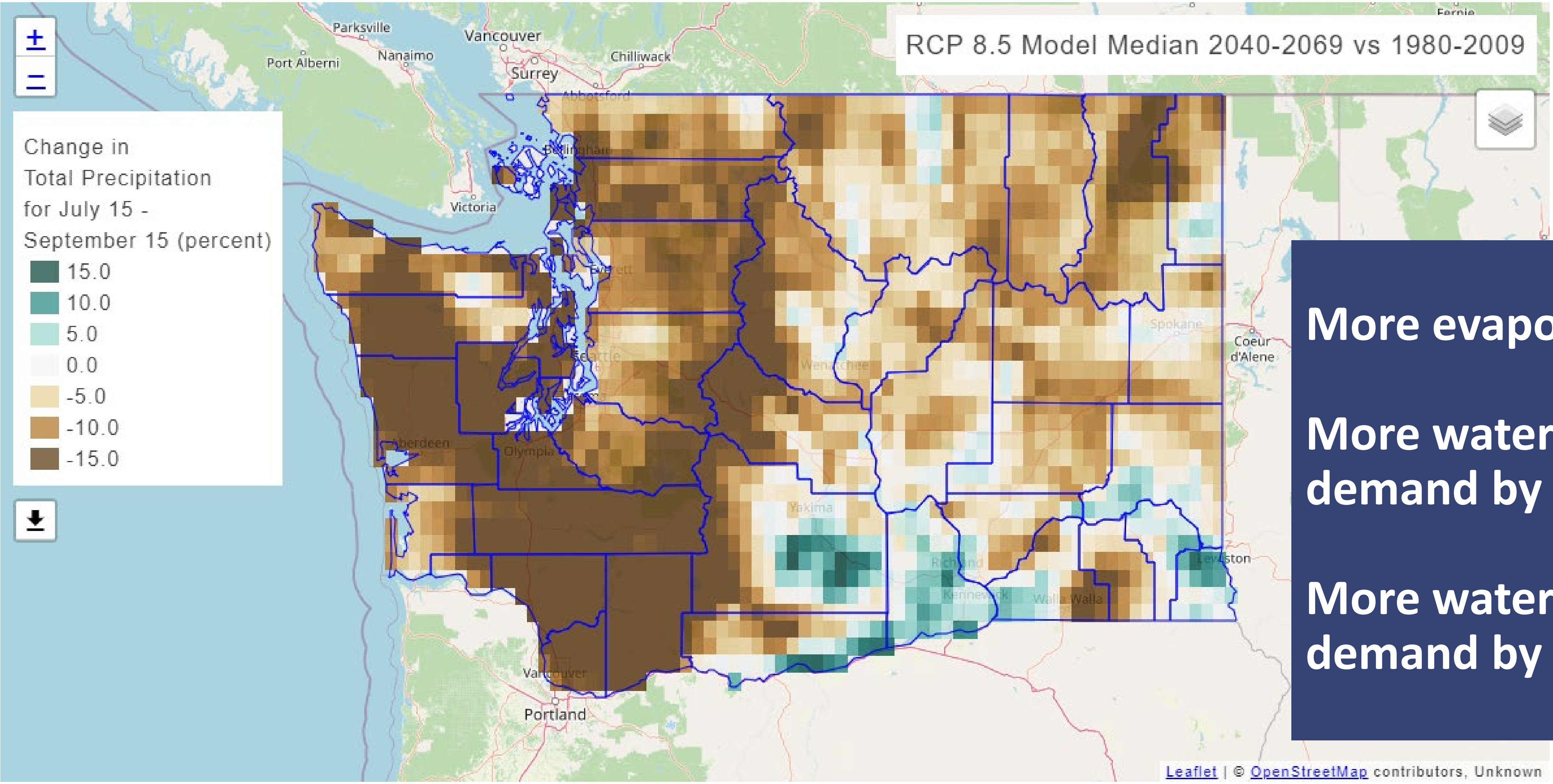


Effects on groundwater will primarily be driven by changes in demand in response to climate change and other factors.

Map contributors, Unknown

Snover et al. 2013

Summer precipitation is expected to decrease by 6% for a low scenario and 8% for a high scenario; some models project decreases of up to 30%.

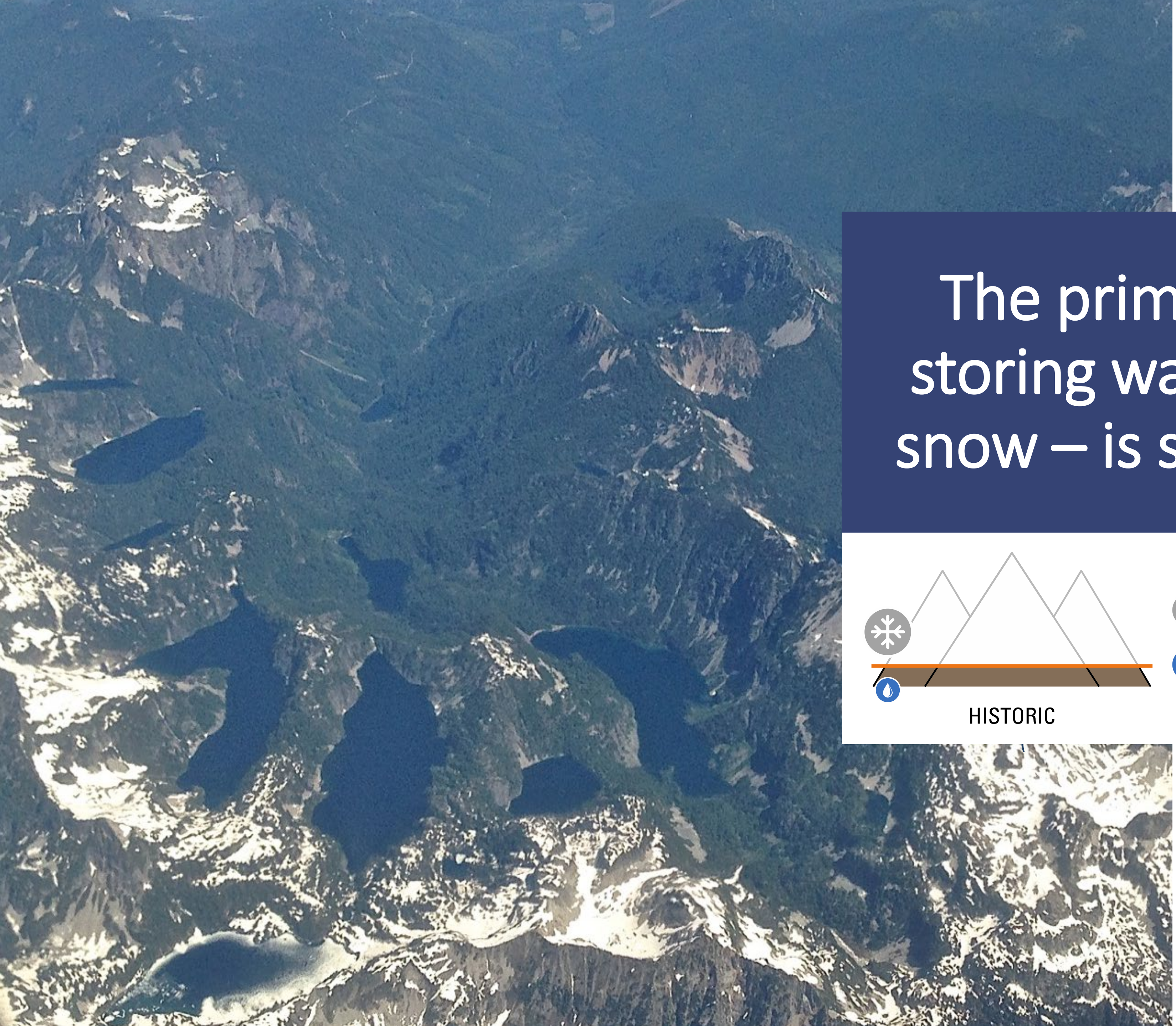


More evaporation

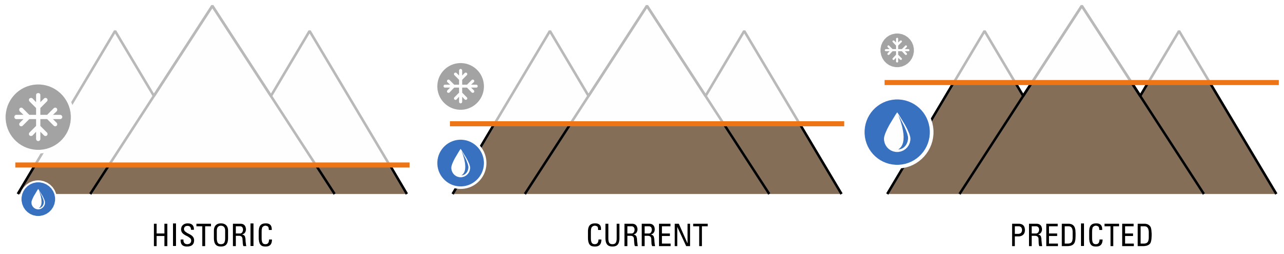
More water demand by plants

More water demand by people

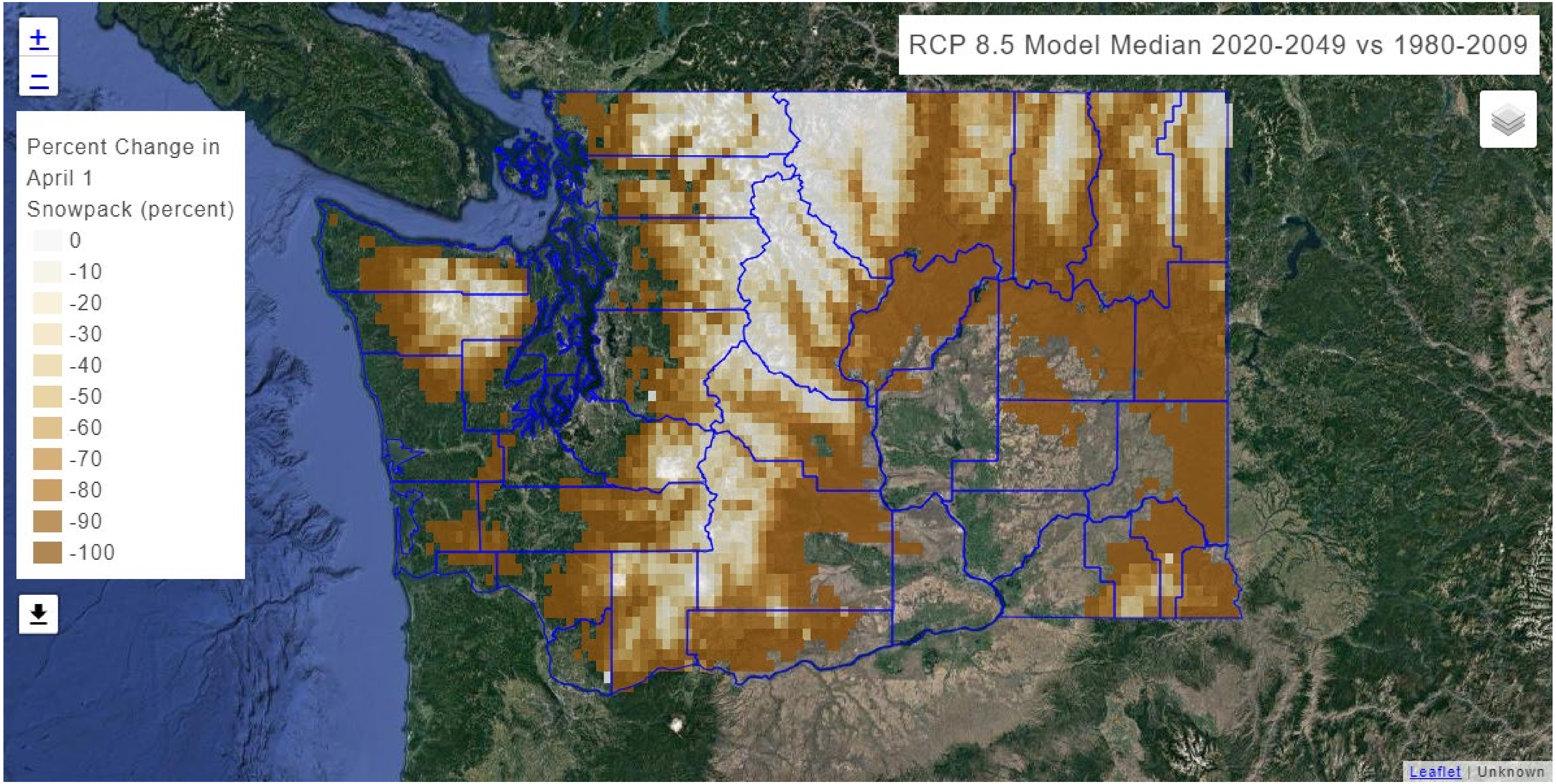
Snover et al. 2013



The primary mechanism for storing water in Washington – snow – is sensitive to warming.

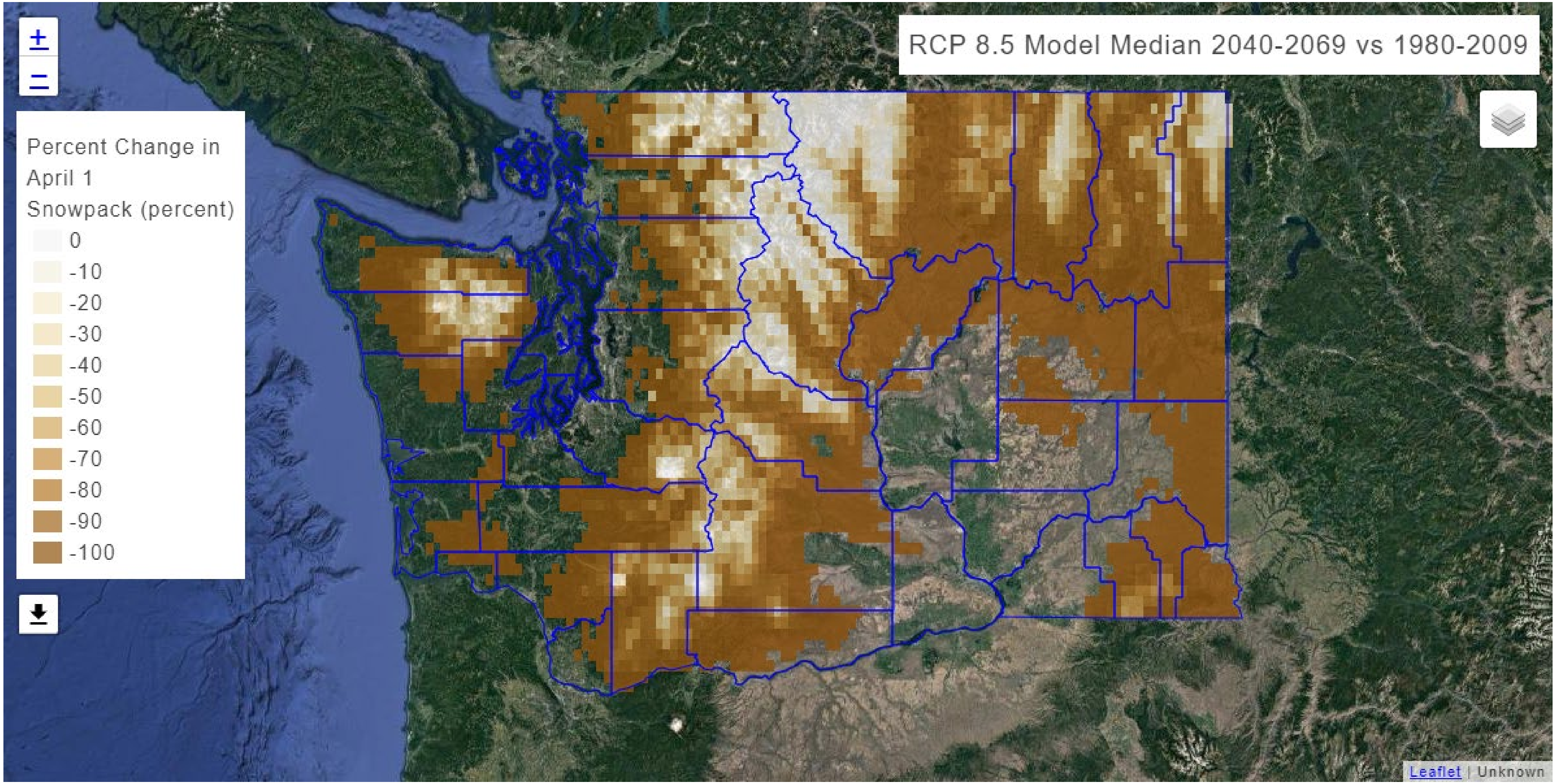


Cascade snowpack declined 25% between mid-century and 2006 and is expected to continue to decline with warming.



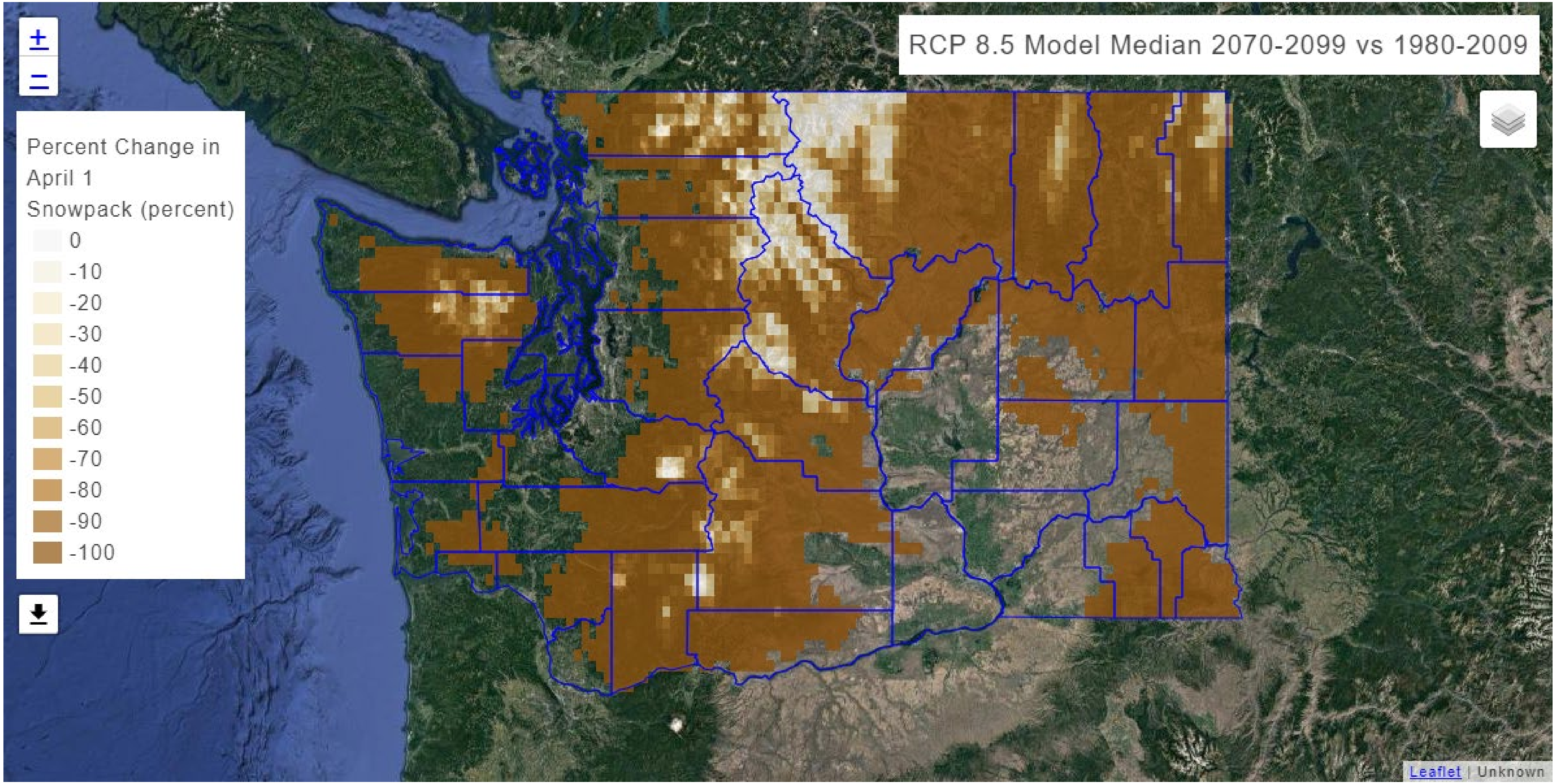
Chegwidden, O. S., B. Nijssen, D. E. Rupp, P. W. Mote, 2017: Hydrologic Response of the Columbia River System to Climate Change.

Snowpack will decline fastest in the low-elevation foothills of the Olympic and Cascade mountains.



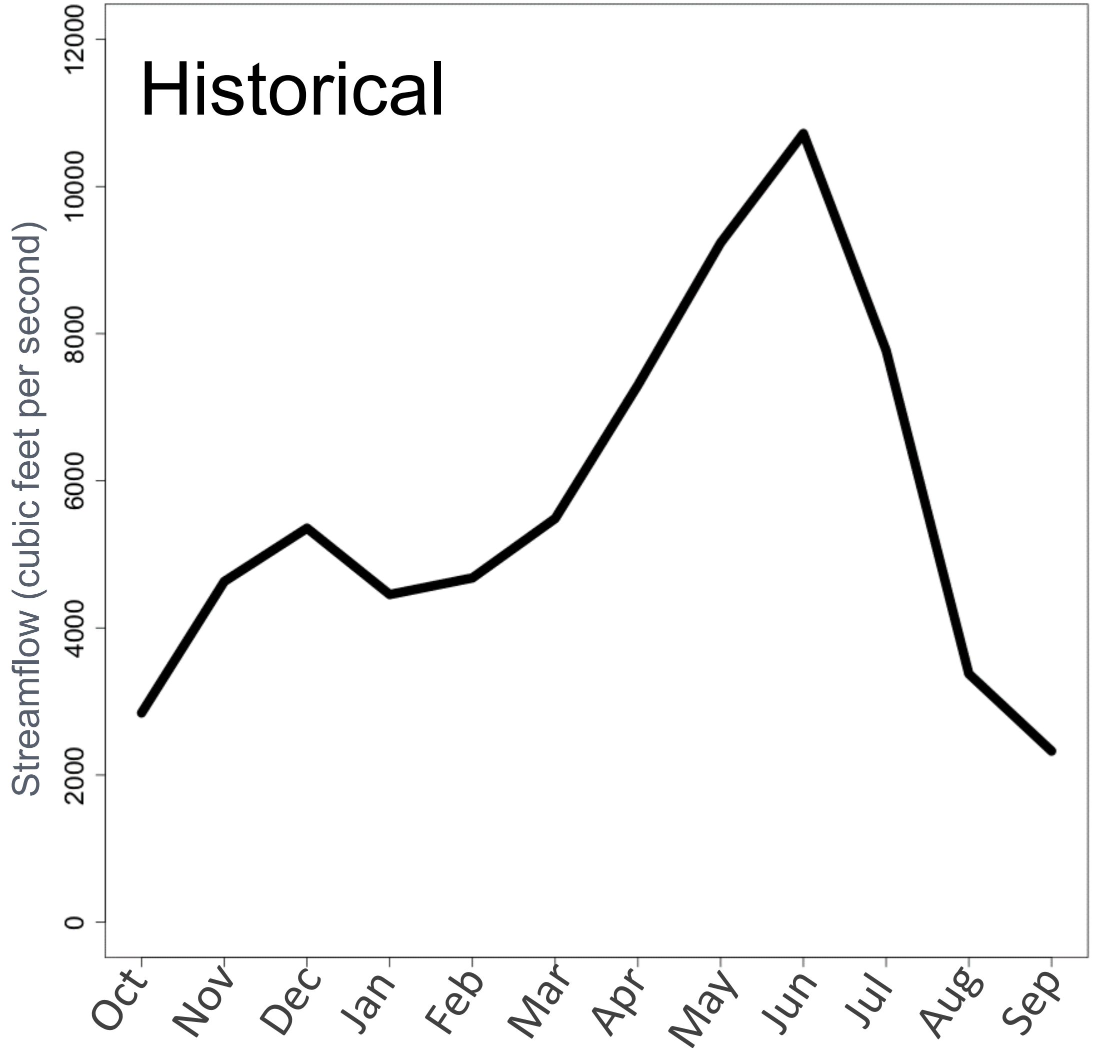
Chegwidden, O. S., B. Nijssen, D. E. Rupp, P. W. Mote, 2017: Hydrologic Response of the Columbia River System to Climate Change.

By the end of the century, 2080s (2070-2099) snowpack is expected to be 56% to 70% less than what it was in the 20th century.



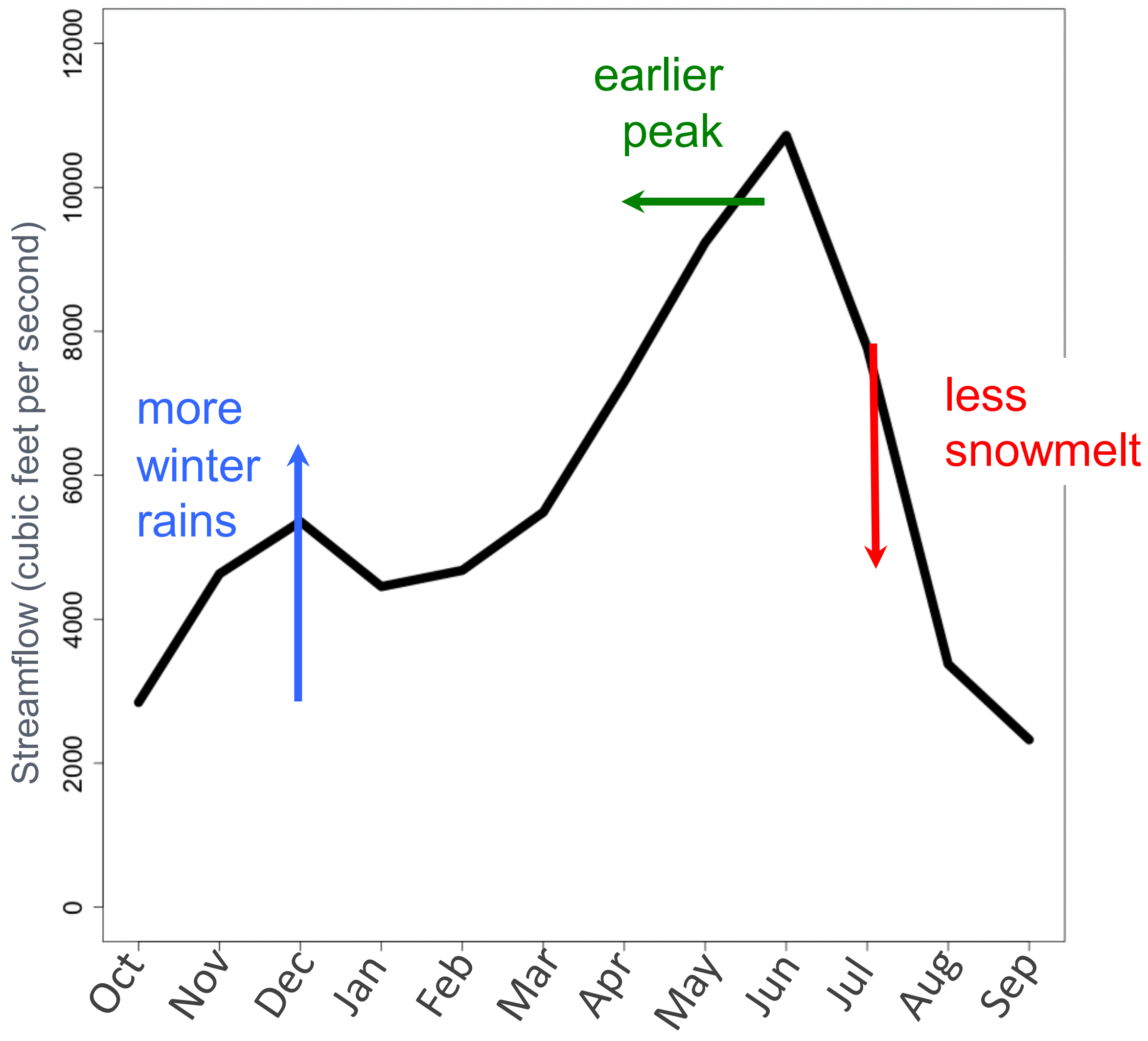
Chegwidden, O. S., B. Nijssen, D. E. Rupp, P. W. Mote, 2017: Hydrologic Response of the Columbia River System to Climate Change.

Changes in snowpack will have considerable effects on _natural_ streamflow timing.



Naturalized flows in the Yakima basin, Washington (without the influence of dams); Elsner et al. 2010

Many watersheds are expected to have higher winter flows, earlier peaks, and lower summer flows.



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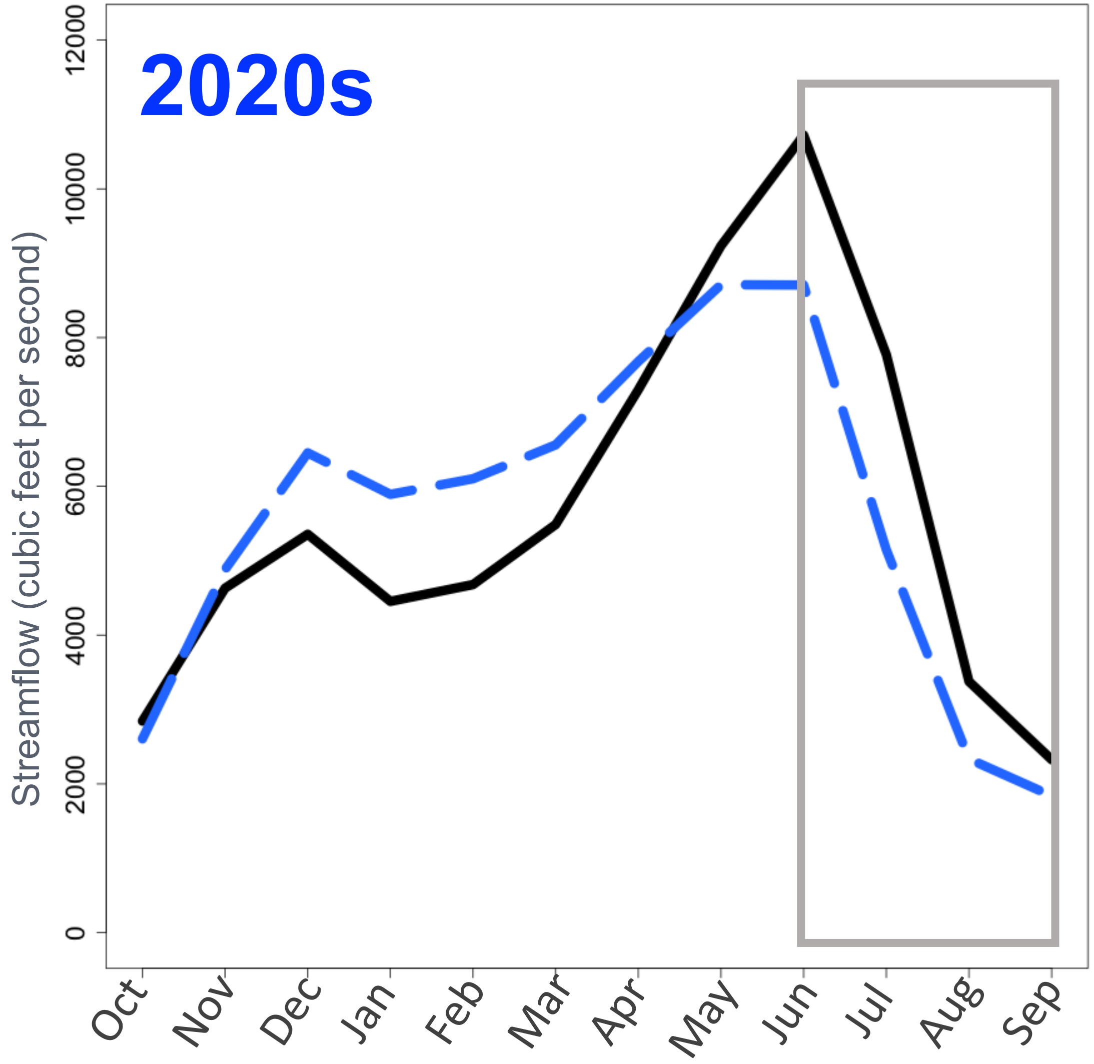

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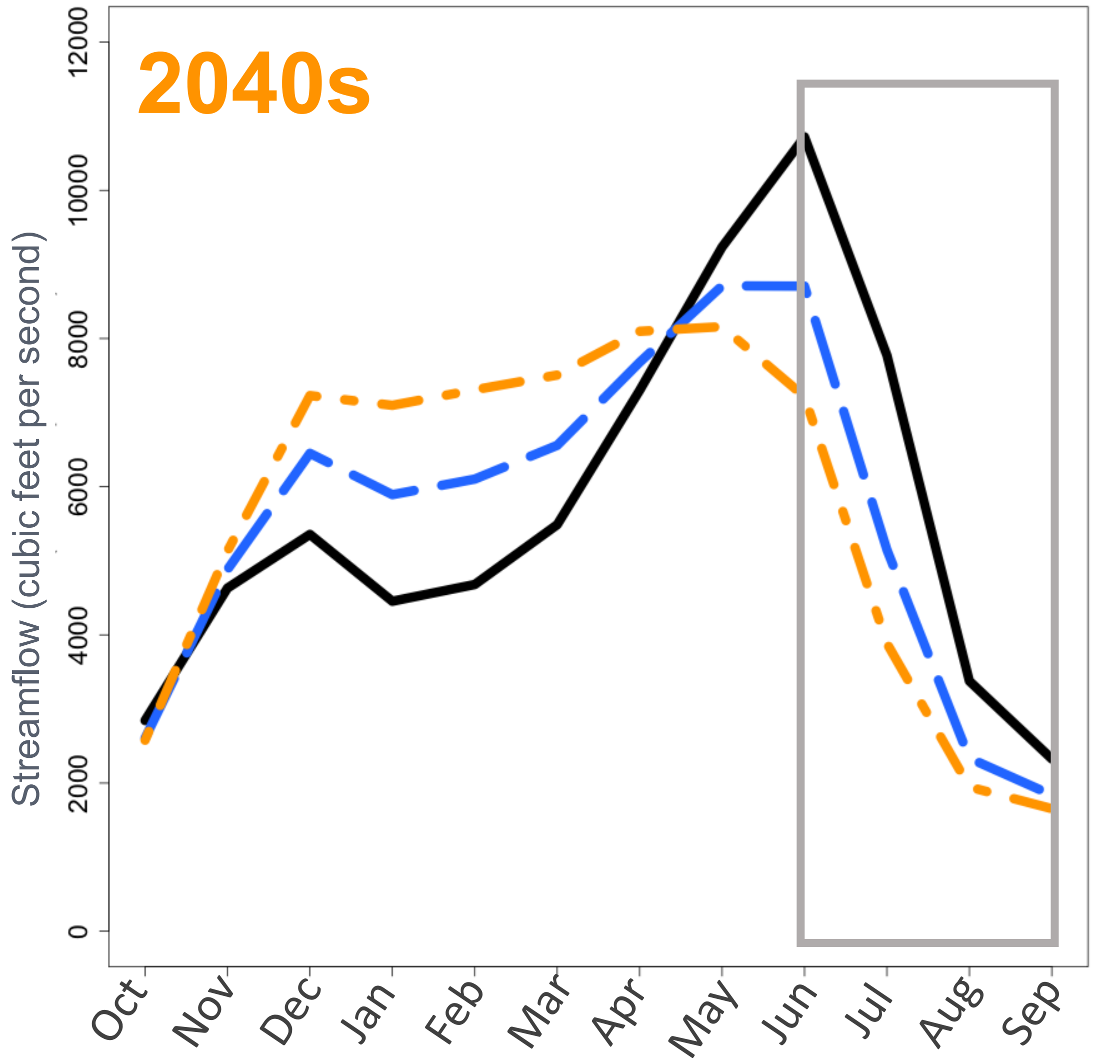

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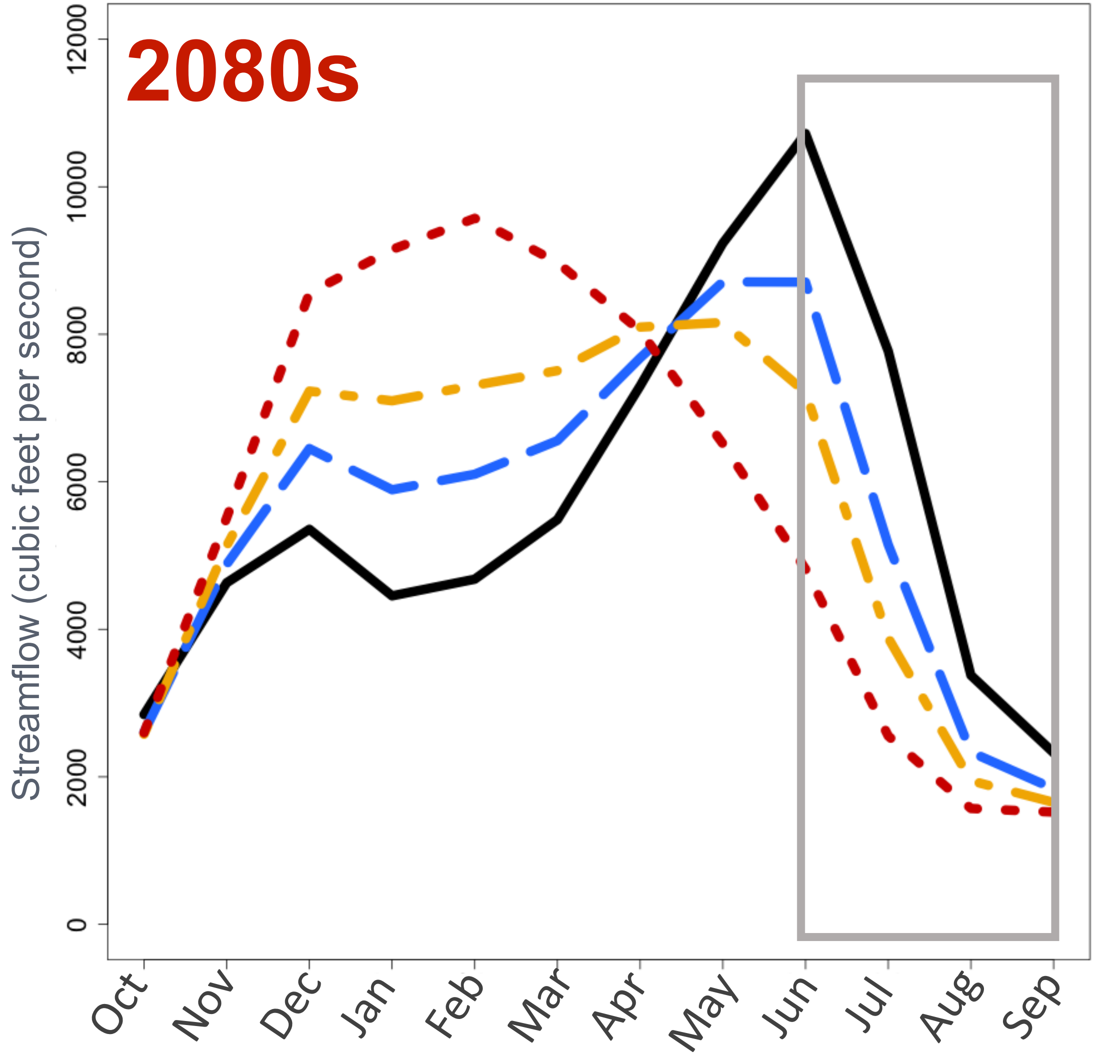
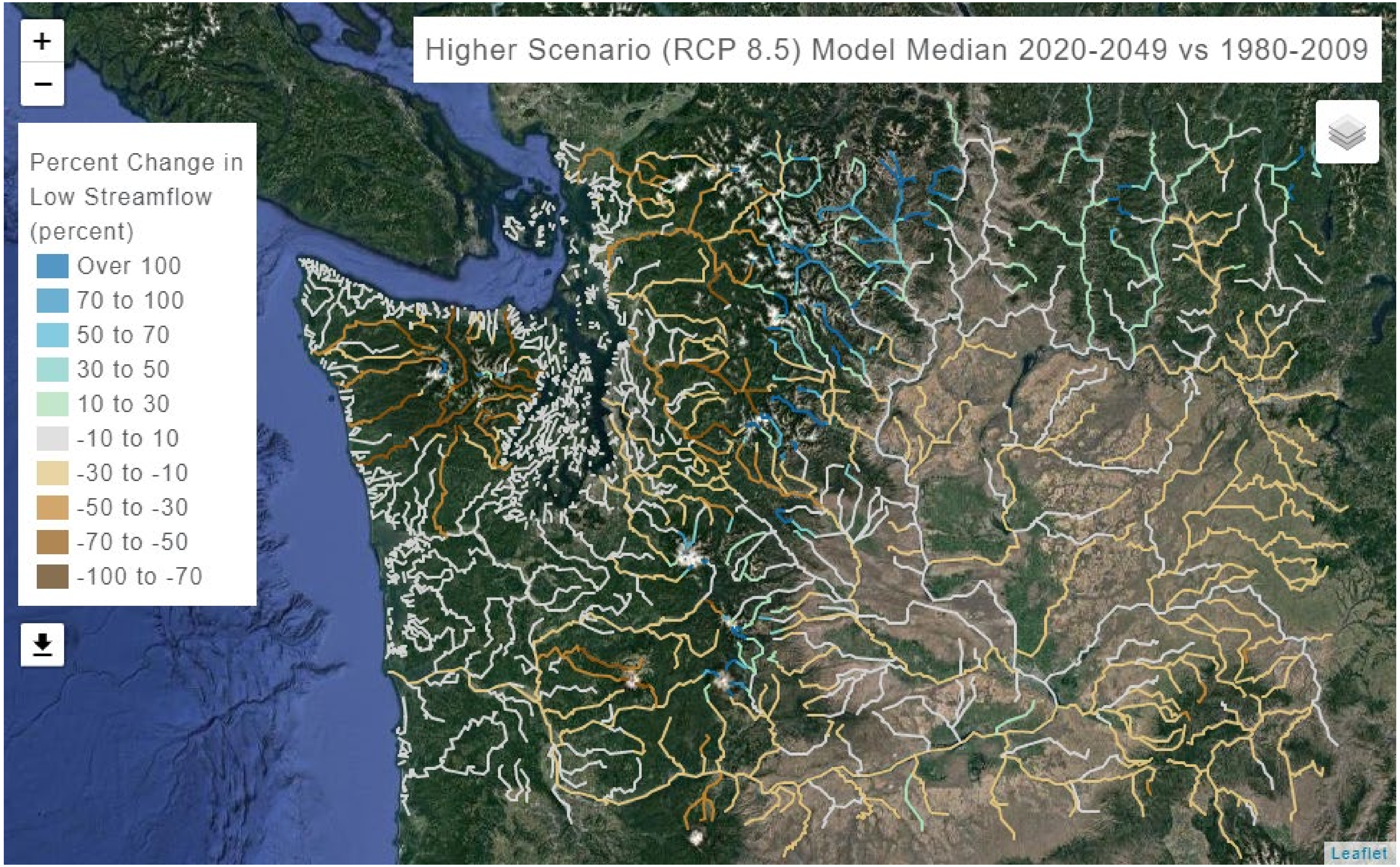


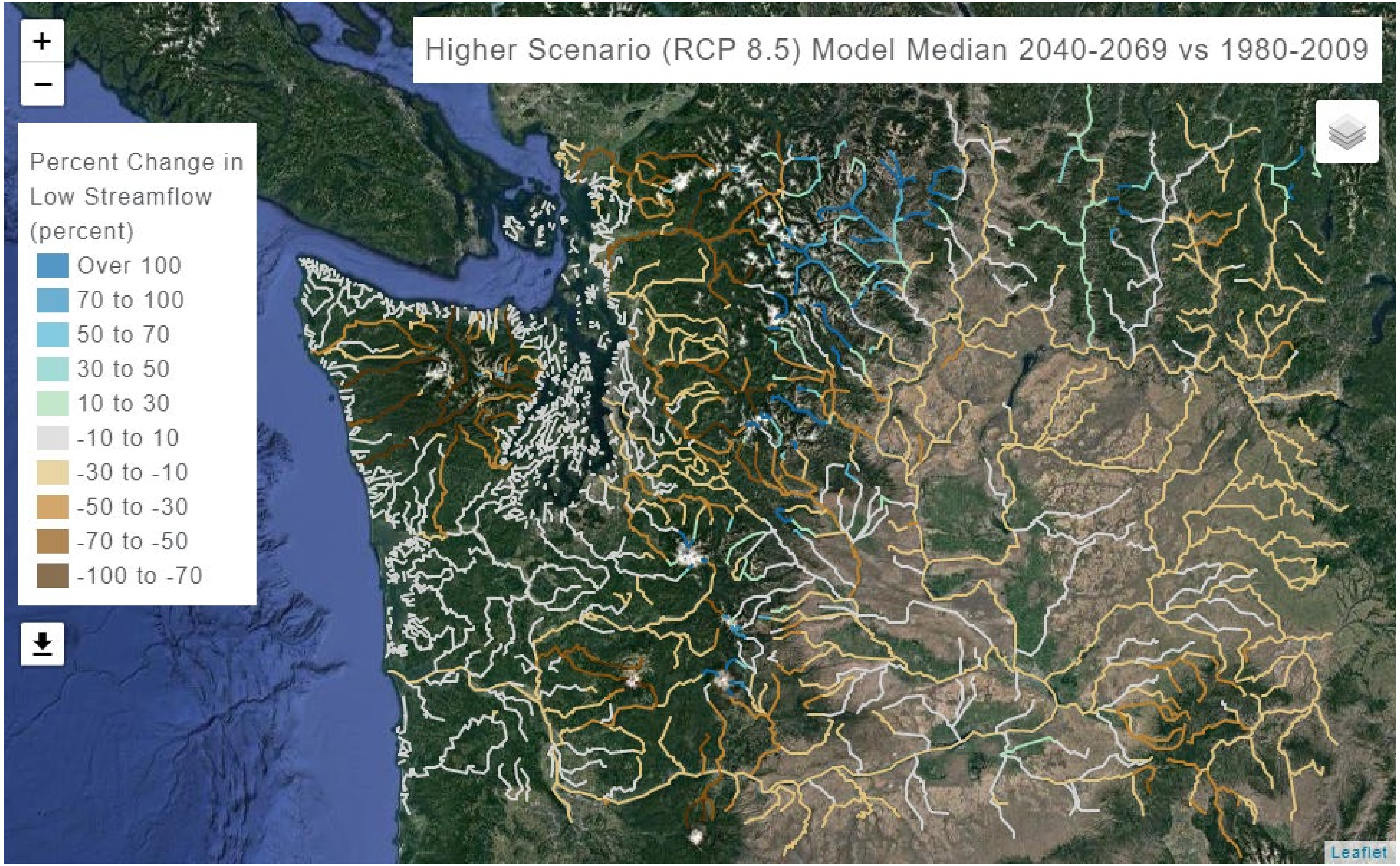
Naturalized flows in the Yakima basin, Washington (without the influence of dams); Elsner et al. 2010

Natural summer low flows (7Q2) are expected to be decrease in volume (less water) throughout much of the state.



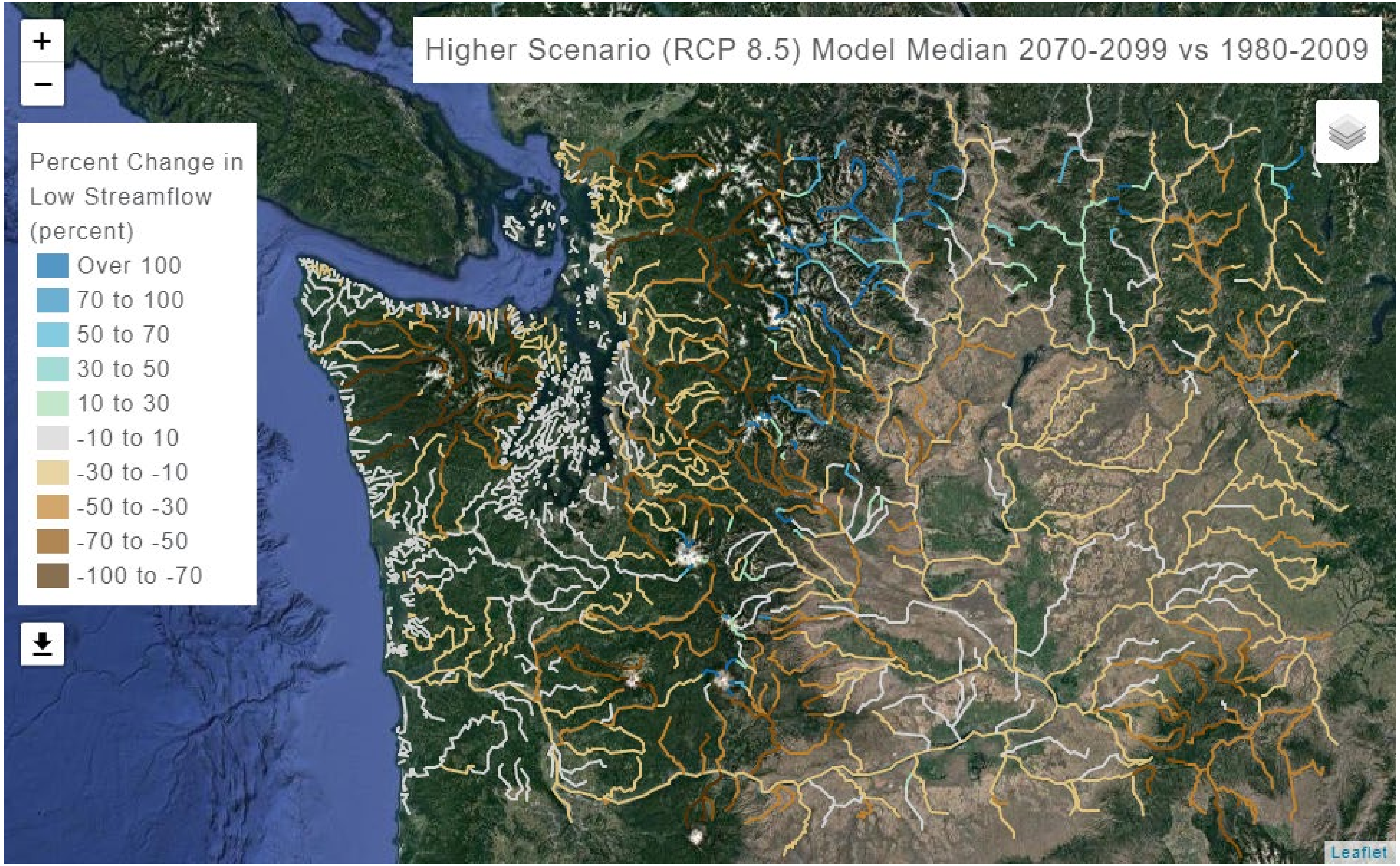
Chegwidden, O. S., B. Nijssen, D. E. Rupp, P. W. Mote, 2017: Hydrologic Response of the Columbia River System to Climate Change.

Declines in natural summer flows (7Q2) will be first and most substantial on the west slopes of the Olympic and Cascade Mountains.



Chegwidden, O. S., B. Nijssen, D. E. Rupp, P. W. Mote, 2017: Hydrologic Response of the Columbia River System to Climate Change.

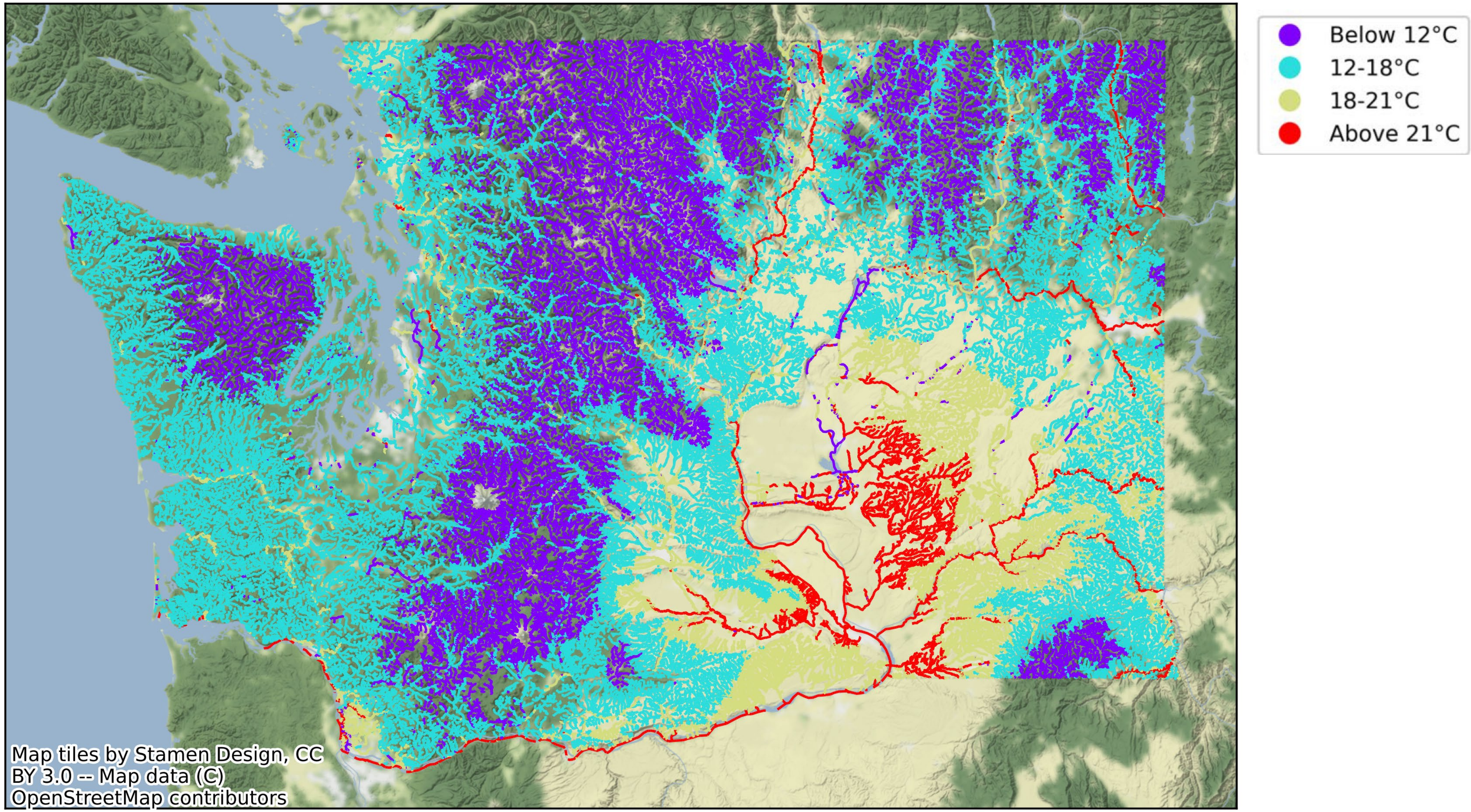
Declines in natural summer low flows (7Q2) will be more substantial across the state by the end of the century for a high climate scenario.



Chegwidden, O. S., B. Nijssen, D. E. Rupp, P. W. Mote, 2017: Hydrologic Response of the Columbia River System to Climate Change.

Earlier snowmelt, lower summer flows, and higher air temperatures will combine to raise natural stream temperatures in summer.

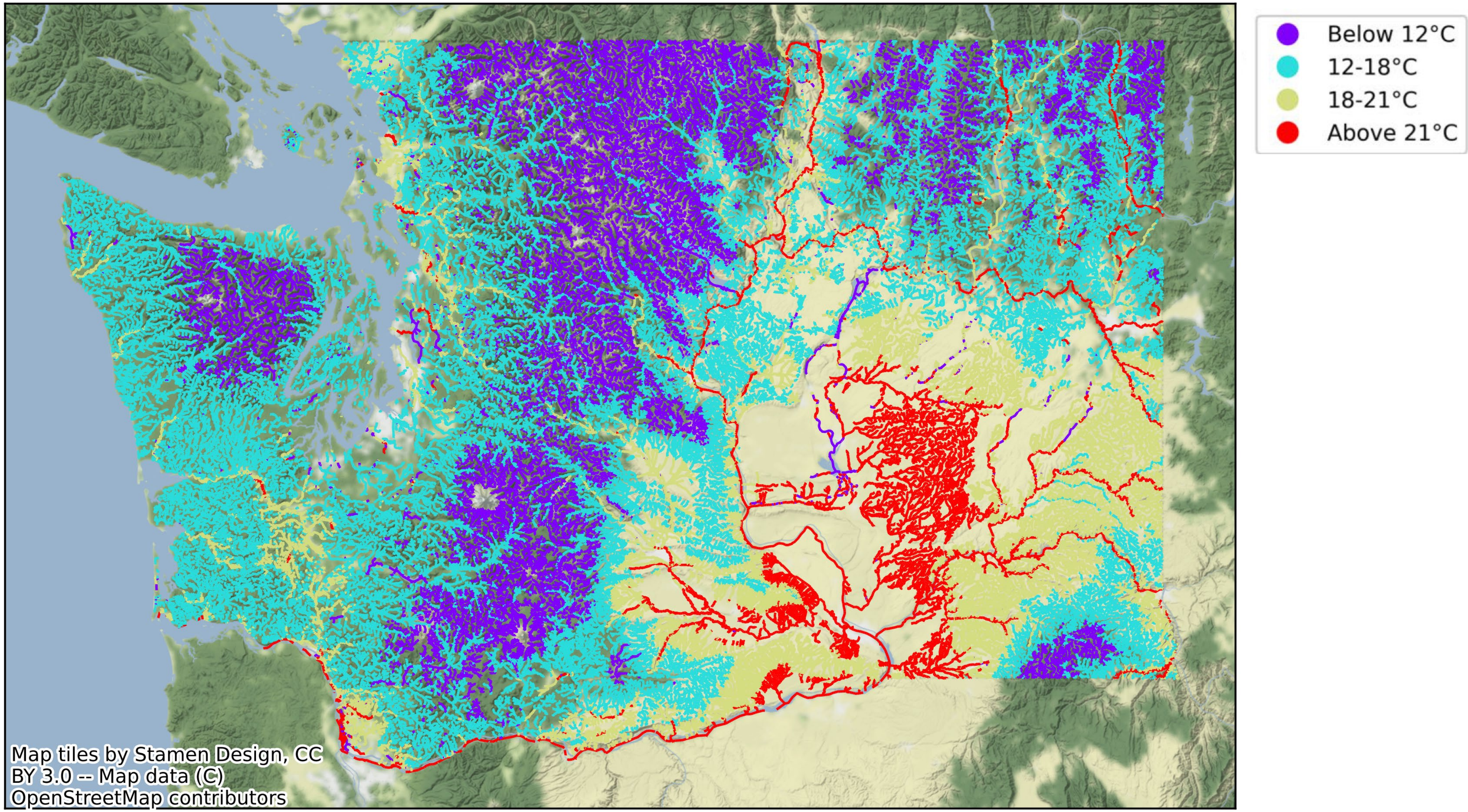
Mean August Stream Temperature 2040s



Isaak, D., et al. 2017. The NorWeST summer stream temperature model and scenarios for the western U.S

By the 2080s, temperatures not suitable for salmon habitat will expand in the Columbia Plateau and include low-elevations in the Cascades.

Mean August Stream Temperature 2080s



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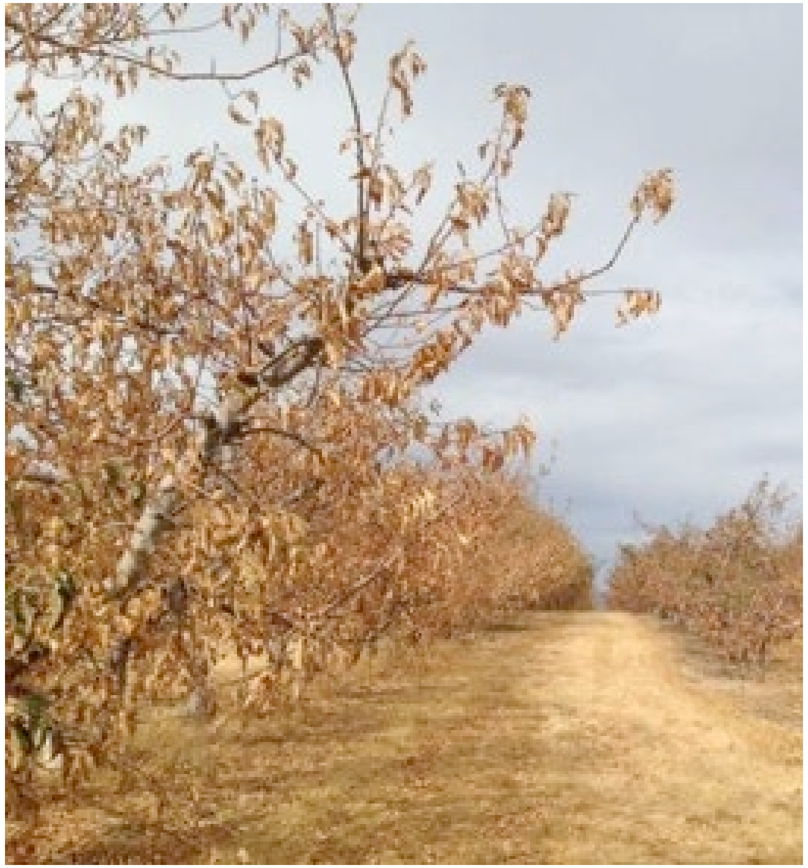

Uncertainties & Challenges

- Low periods of streamflow are critical for water resources and aquatic species, yet hardest to model.
- Uncertainties remain in the magnitude of change, especially tributaries.
- Natural flows are useful, and water storage, withdrawals, and land use will simultaneously drive change.

The Climate Impacts Group

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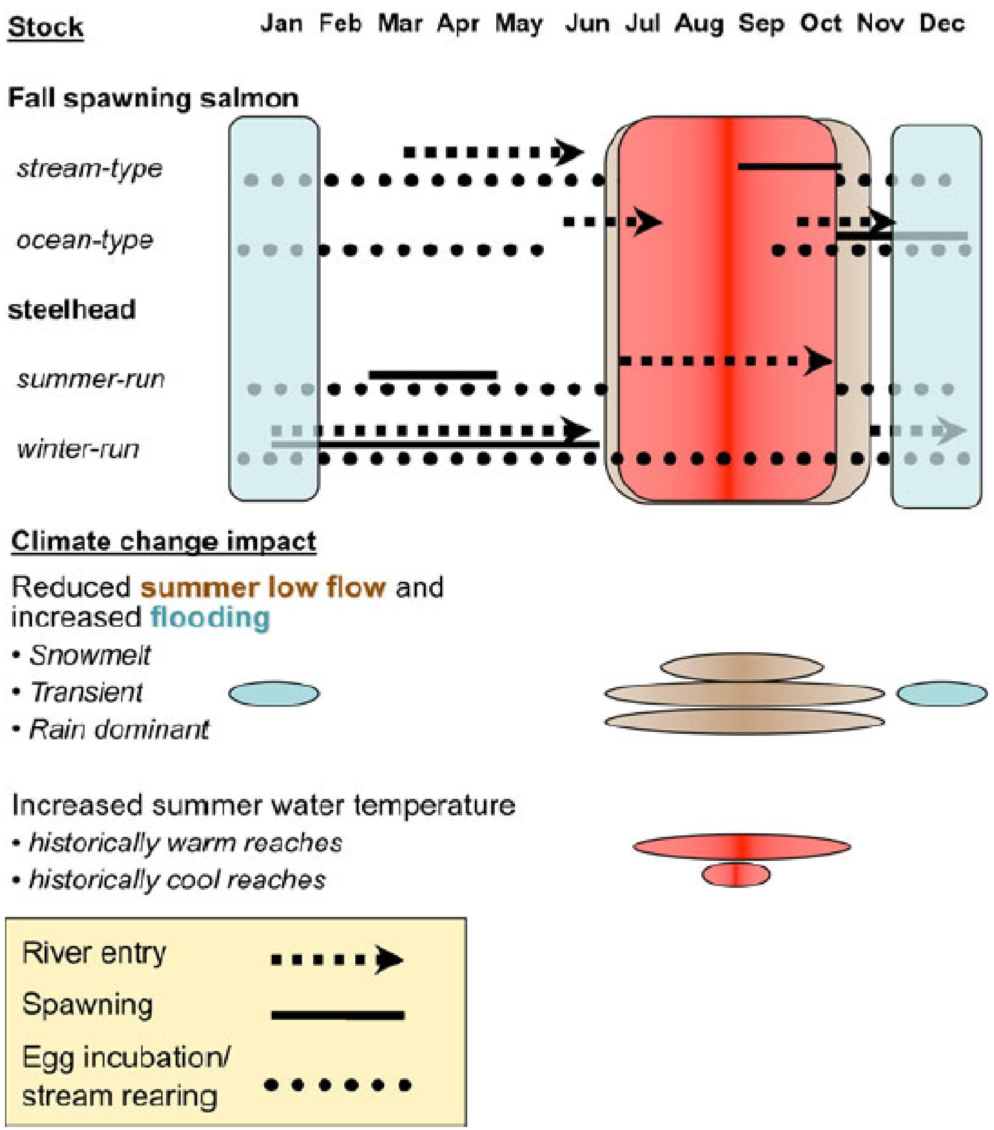
Projected climate impacts on salmonids

Dr. Alex Fremier presenting

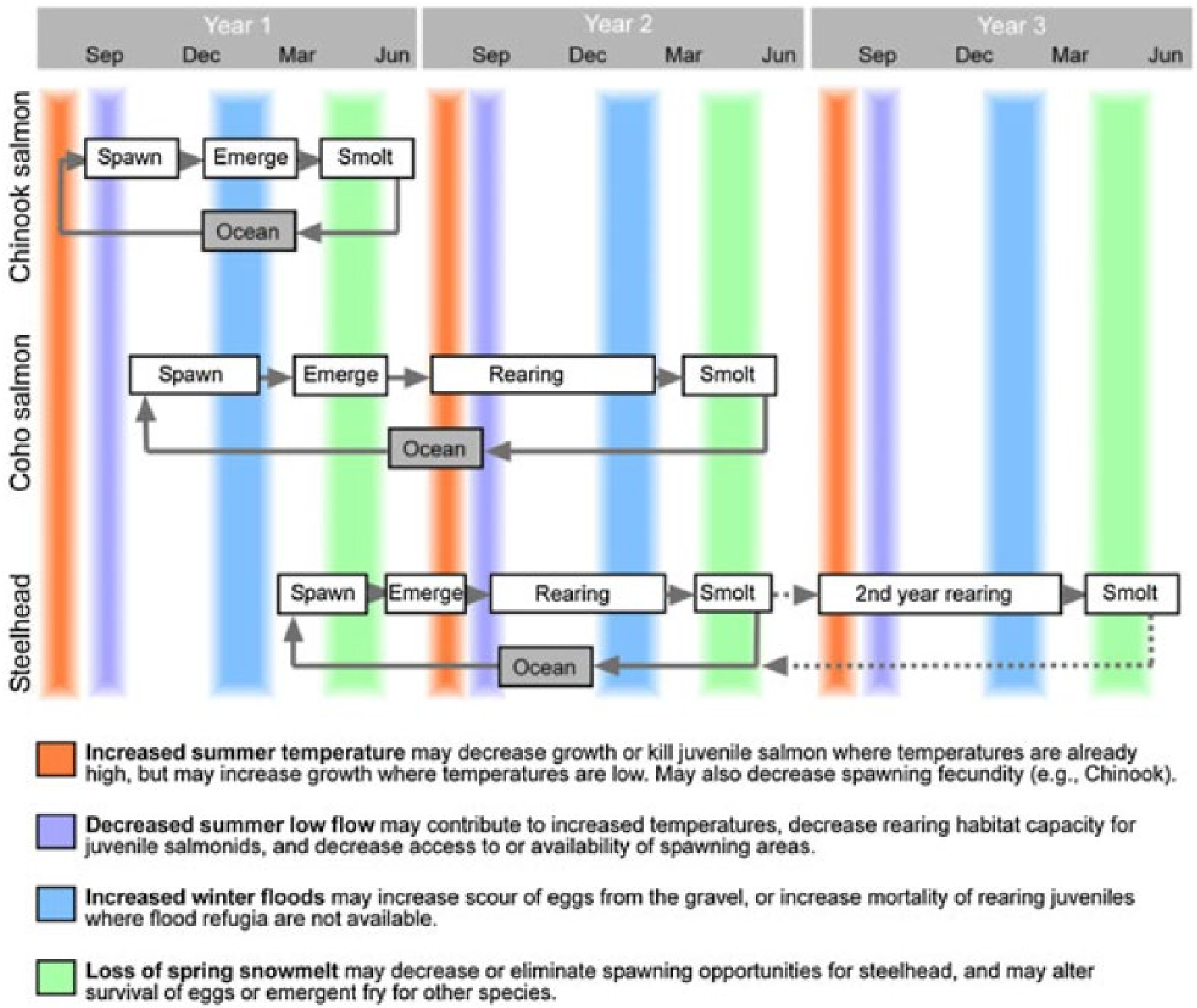
Identifying the key hydrologic parameters influence salmon

- Summer temperatures
- Summer low flow
- Winter high flows (and timing)
- Lower spring flows

Washington State climate change impacts on freshwater habitat for salmon and steelhead



Mantua et al. 2010



Beechie et al. 2013

Climate-Flow-Salmon Modeling

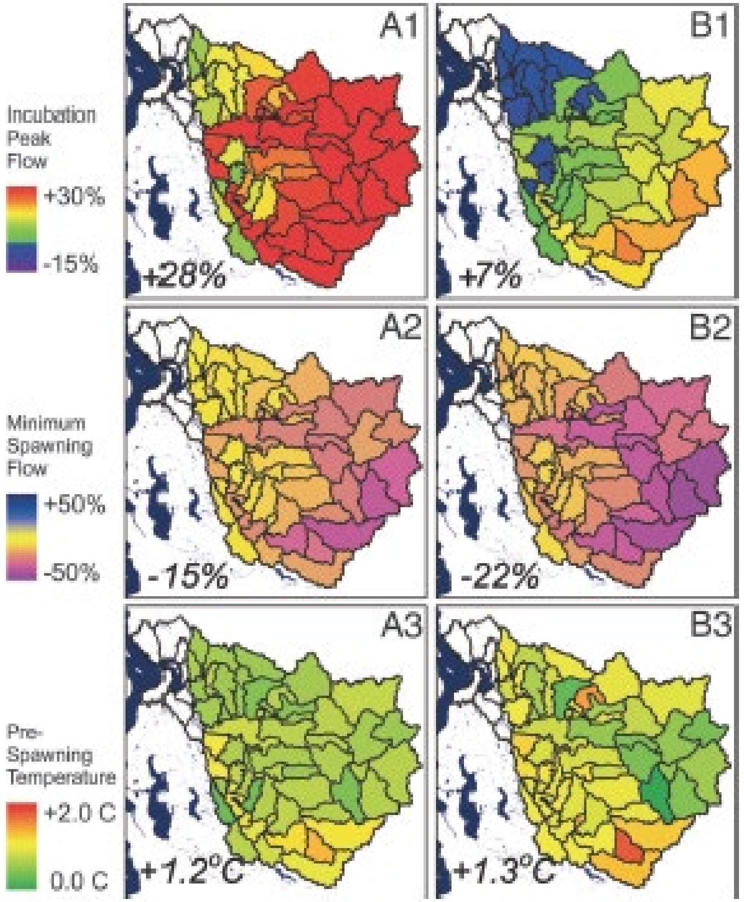


Fig. 3. Climate impacts on three hydrologic variables. (*A1–A3*) The results of the GFDL R30 climate model. (*B1–B3*) The results of the HadCM3 model. (*Top*) Percent change in incubation peak flow. (*Middle*) Percent change in minimum spawning flow. (*Bottom*) Change in prespawning temperature in degrees Celsius. The basin-wide average change is shown in the lower left corner of each figure. Black lines delineate subbasin boundaries. All simulations used the "current" land use scenario.

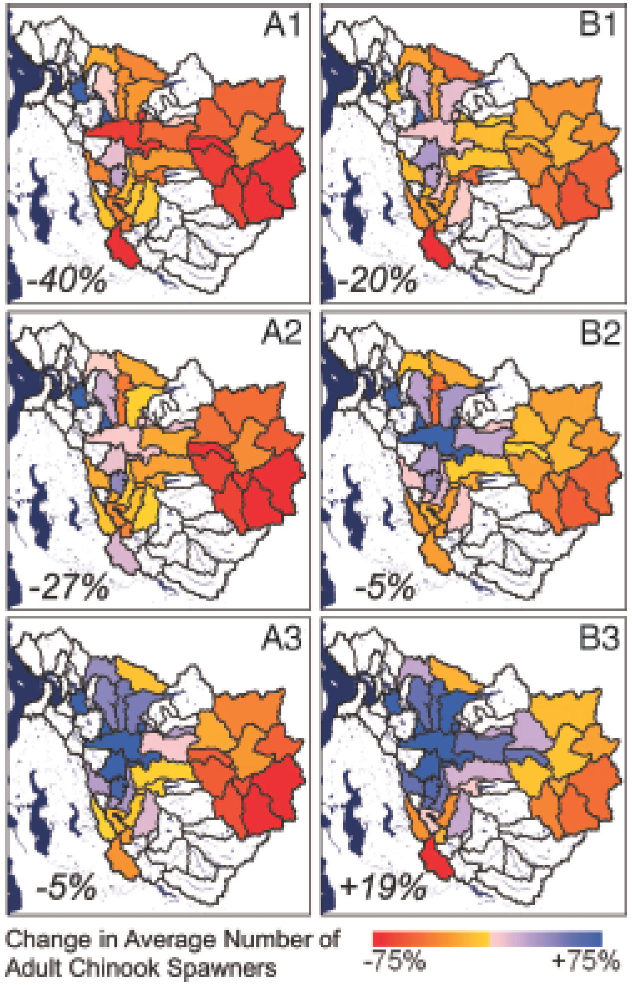
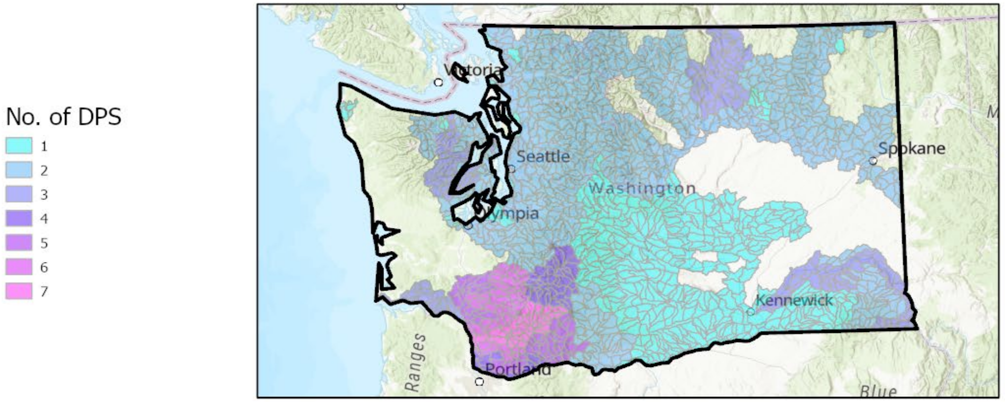


Fig. 5. Change in spawning Chinook salmon abundance between 2000 and 2050 under three future land-use scenarios. (*A1–A3*) The results of the GFDL R30 climate model. (*B1–B3*) The results of the HadCM3 model. (*Top*) Current land-use scenario. (*Middle*) Moderate restoration scenario. (*Bottom*) Full restoration scenario. The basin-wide total change appears in the lower left corner of each figure.

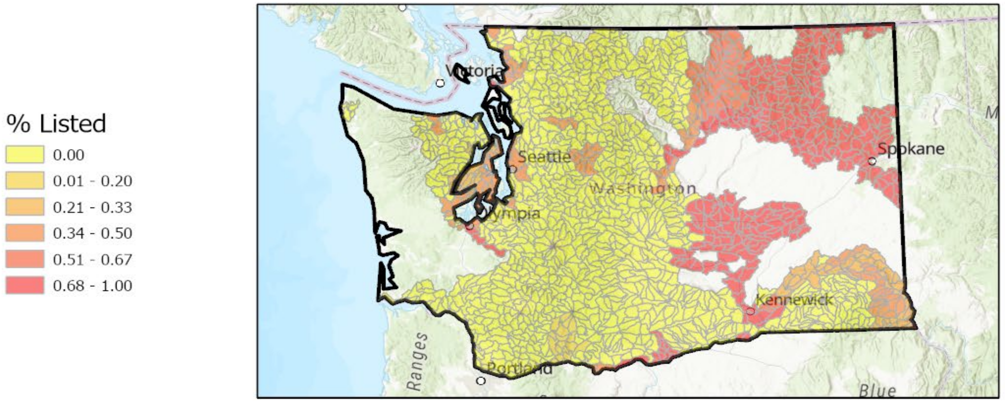
Battin et al. 2007

Describing salmon populations and their status

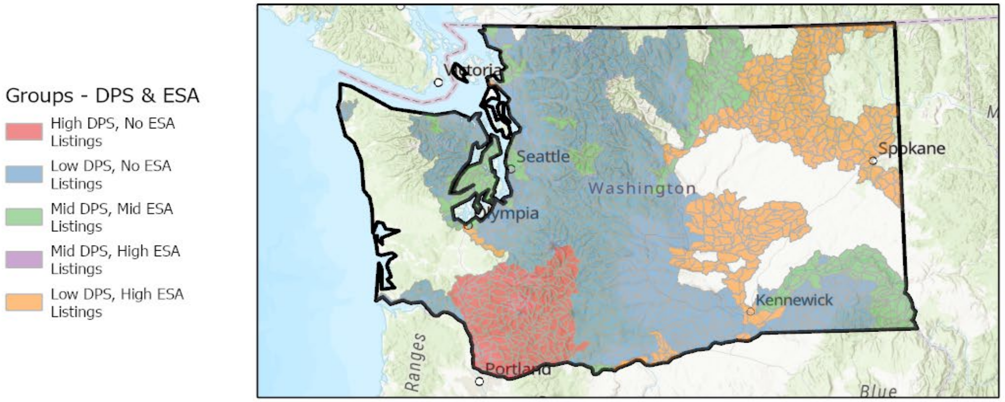
- Spatial description
- Literature review



(Top) the number of Distinct Population Segments (a description of life-history diversity in salmon)



(Middle) The percentage of salmon populations ESA listed

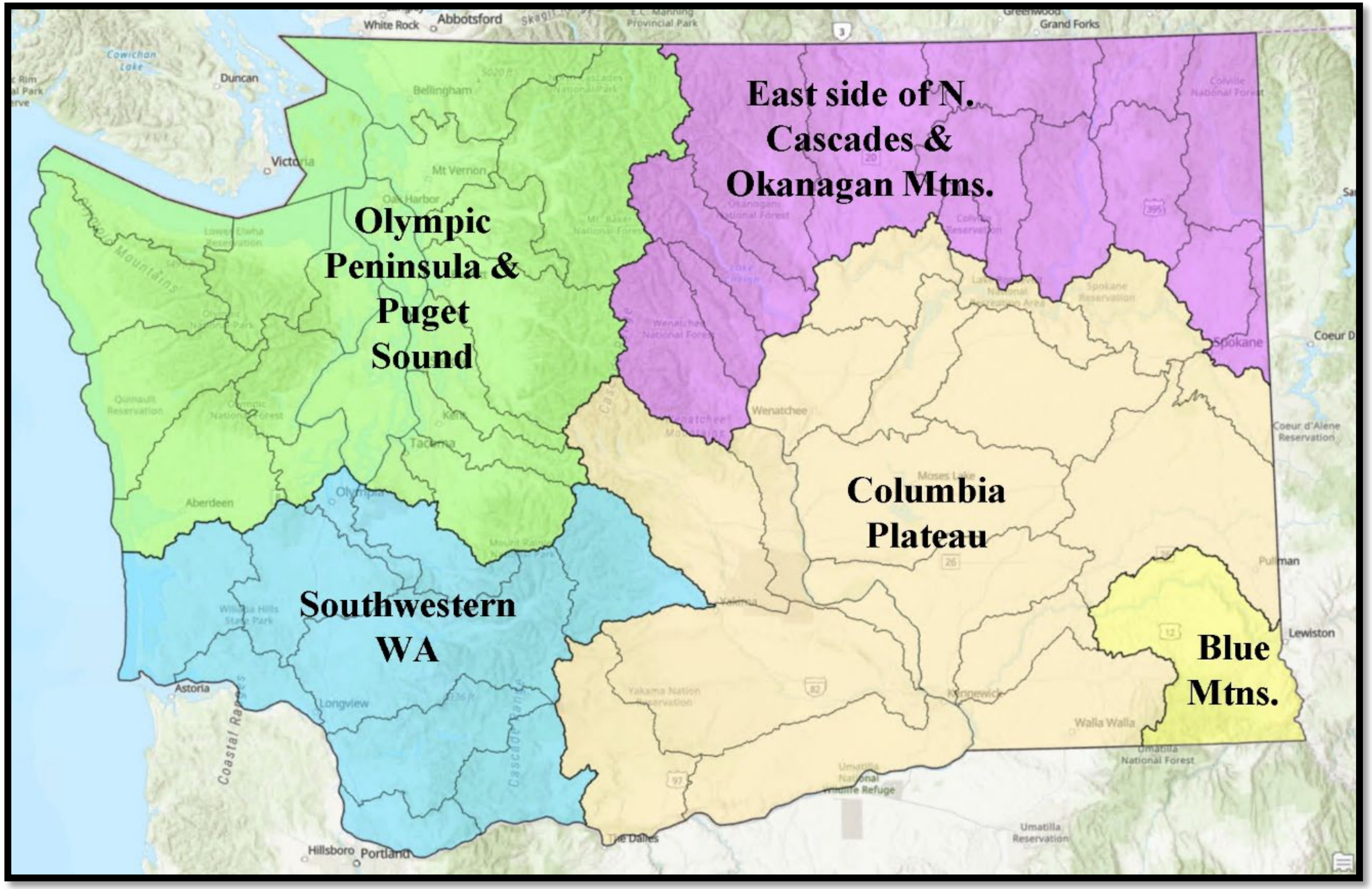


(Bottom) A grouping based on DPS and ESA listing to show areas of both diversity and ESA listing. Much of the state has 1-2 distinct populations and no ESA listings (blue and green) with the SW having high diversity and low ESA, and NW having low diversity with almost all populations having ESA status.

Dunn 2015 NOAA

Characterizing regions with similar climate-salmon histories

- Defined by climate driven changes to stream flow and temperature, and salmon population characteristics (migration distance and status).



Washington law & policy barriers and opportunities

Jonathan Yoder presenting

Washington state law and policy

- Our report contains two sections about policy directly applicable to adaptation management options and barriers
  - An overview of directly relevant law and policy in Washington State
  - An overview of activities being pursued in other western states explicitly in response to projected climate change impacts on streamflow.
- These section are intended to identify law and policy that relate to and/or pose barriers to adaptation. Nothing in the summary is intended as policy prescription.

Washington State law and policy: Existing State authorities and programs

Streamflow as beneficial use. Water Code of 1917 as amended

- Allows acquisition of water rights for streamflow augmentation.
- Allows the state to limit water rights issuance for streamflow protection.

Instream Flow Rules

- The Water Resource Act of 1971 & additional RCWs allows &/or requires the state to issue and enforce Instream Flow Rules (IFRs).
- An IFR is water right that can be the basis for closure of watershed to new rights and to limit use of water rights junior to the IFRs.

Washington State law and policy: Existing State authorities and programs (Cont'd)

WA Trust Water Rights Program (TWRP, 1993 and related)

- WRs can be entered into the TWRP through donation, lease, sale, temporarily or permanently.
- Rights held by Ecology through the TWRP to benefit streamflows and/or groundwater; and maintain their original priority date.
- For temporary transfers into the TWRP, the WR holder avoids risk of relinquishment through nonuse.
- Temporary TWRP holdings may be withdrawn at the discretion of the WR holder, so streamflow benefits through TWRP are indefinite in duration.

Washington State law and policy: Existing State authorities and programs (Cont'd)

Water Rights Adjudication

- Reduces uncertainty about WR validity and extent.
- Provides more certainly about diversion rights that may affect streamflow
- Adjudications are costly, but *ex post* they may
  - reduce regulatory and transaction costs
  - facilitates water transactions for streamflow benefits.
- Tribal treaty reserved rights to streamflow are (most) senior rights generally not quantified in relation to water. Quantification through adjudication may be especially impactful for streamflow.
  - Much of WA remains unadjudicated and few tribal treaty rights are adjudicated.

Washington State law and policy: Existing State authorities and programs (Cont'd)

Water storage

- Water storage allows redistributing water across time and space -- direct physical mitigation of streamflow impacts of climate change.
- Storage infrastructure can have negative consequences on the ecosystem services that streamflow provides (e.g. fish migration).
- Storage infrastructure is expensive.

Water conservation

- Water conservation efforts by municipalities, agriculture and other sectors may benefit streamflow if it leads to reductions in consumptive use, reductions in diversions, and/or increases in return flows.

Judicial case law

Four key WA Supreme Court rulings are especially consequential for streamflow protection

- **Elkhorn** decision (1994): ECY may impose flow requirements for hydropower projects.
- **Postema** (2000): ECY may deny groundwater pumping that may reduce streamflow, and must deny when IFRs are not being met.
- **Swinomish v. Skagit** (2013): *overriding consideration of public interest* (OCPI) cannot be used as a basis for allowing streamflow impairment under an IFR.
- **Foster** (2015): ECY cannot impair streamflow based on OCPI, and only in-kind mitigation (not out-of-kind) may be sufficient.

Approaches by other western states

Many of the legal and administrative developments in Washington State have variants in other Western States. Relevant programs and law within the scope of this project is vast. The examples included in the report are limited and will not discuss in detail here. See report.

- Streamflow as beneficial use
- State and individual streamflow rights
- Water leasing and acquisition programs
- Water measurement and monitoring programs
- Infrastructure and water storage for streamflow

Discussion

- We intend to continue work on this important topic.
- Input especially about broader topics of relevance that are not sufficiently covered are most welcome.