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Forecasted flow and temperature changes in fish-bearing streams of the Hood Canal and Strait of Juan de Fuca

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Forecasted Flow and Temperature Changes in Fish-bearing Streams of the Hood Canal and Strait of Juan de Fuca

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1. Introduction and Objectives

In recent years, concern has grown over the potential impacts climate change might have on freshwater resources and subsistence fishery populations throughout the Pacific Northwest. The Port Gamble S'Klallam (PGST) and Jamestown S'Klallam (JKST) tribes in Northwest Washington State rely heavily on salmon and steelhead populations for subsistence and for local tribal economies. The Big Quilcene River and Tarboo Creek watersheds (Figure 1) contain critical salmon and steelhead spawning habitat that will potentially be negatively impacted by climate variability and change. While some regional hydrologic modeling studies have been carried out in Western Washington, few fine-scaled watershed models have been applied to assess the potential changes to streamflow and stream temperature under climate change scenarios for these areas.

This project aims to provide hydrology projections through the end of the 21st Century under a range of climate change scenarios. Results ultimately will be used to produce and update existing fish habitat vulnerability assessments for the PGST and JKST tribes in Northwest Washington State. This project is a crucial first step to help the JKST and PGST tribes better understand how to guide their fisheries managers, help protect critical habitat in these ecosystems, and better adapt to the potential changes under a variety of climate scenarios.

Presented and discussed here are preliminary streamflow and stream temperature forecast results for the high-relief and mountainous Big Quilcene River watershed and the relatively low-lying and smaller Tarboo Creek watershed. Topography and watershed relief play an important role in western Washington hydrology and we contrast the forecasted impacts of climate change on the two watersheds as an example of how climate impacts may vary within a similar geographic region. Funding was provided by the Bureau of Indian Affairs and North Pacific Landscape Conservation Cooperative.

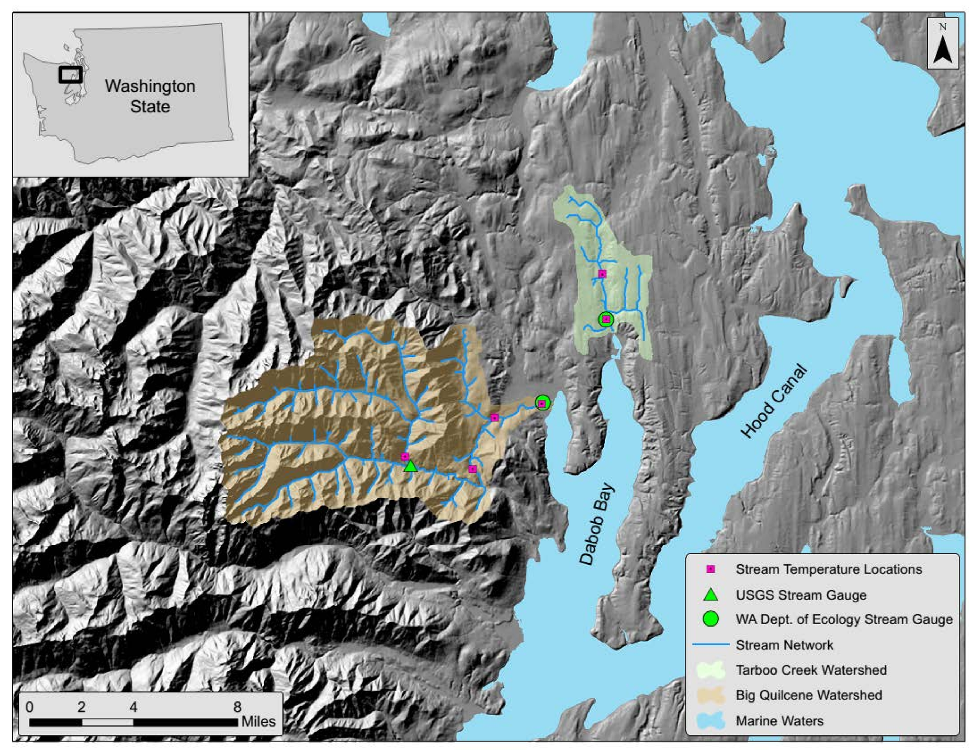


Figure 1. Location of the Big Quilcene River and Tarboo Creek watersheds in northwestern Washington State, USA , and the historical stream flow and temperature monitoring sites.

2. Climate Inputs

Due to a lack of spatially distributed long-term historical weather observations in the study area, we applied publically available statistically derived gridded surface data developed by Livneh et al. (2013; Figure 2) to calibrate the model.

Future simulations were forced with downscaled climate projections developed using the multivariate adaptive constructed analogs method (MACA; Abatzoglou and Brown, 2012). The MACA downscaled data incorporates 20 general circulation models (GCMs) of the CMIP5 using RCP4.5 and RCP8.5 forcing scenarios and uses the Livneh meteorological grids for the training dataset. For this project, 10 GCMs suitable for the Pacific Northwest were used as future climate forcings (Rupp et. al., 2013). Bias corrections that were applied to the Livneh historical meteorology were also applied to the MACA future climate grids to maintain internal consistency.

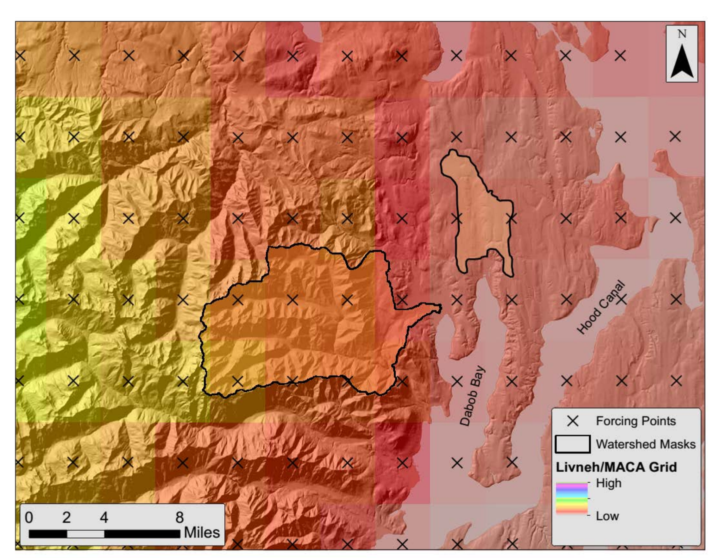


Figure 2. Meteorological forcings.

3. Modeling Tools

Distributed Hydrology Soil Vegetation Model

The DHSVM, developed at the University of Washington and Pacific Northwest National Laboratory, uses meteorological and spatially distributed physical data to simulate a water and energy balance at the pixel scale of a digital elevation model (Figure 3; Wigmosta et al., 1994). The model predicts snowpack evolution, evapotranspiration, soil infiltration and storage, saturated subsurface flow, and surface runoff, for each pixel over a user-defined time step. For this project, we elected to use a grid spacing of 50m and a 3-hour timestep.

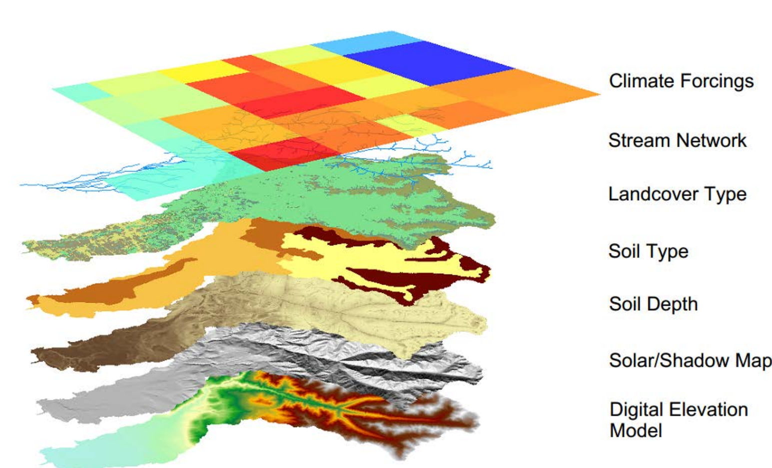


Figure 3. Input grids for the DHSVM.

RBM Stream Temperature Model

The RBM framework (Yearsley, 2009, 2012) makes use of disaggregated hydrologic and meteorological output from the DHSVM hydrology model to predict stream temperature along each stream segments within the watershed at sub-daily timesteps (figure 4). DHSVM version 3.1.2 allows for the effects of riparian vegetation shading to be incorporated into stream temperature predictions as well.

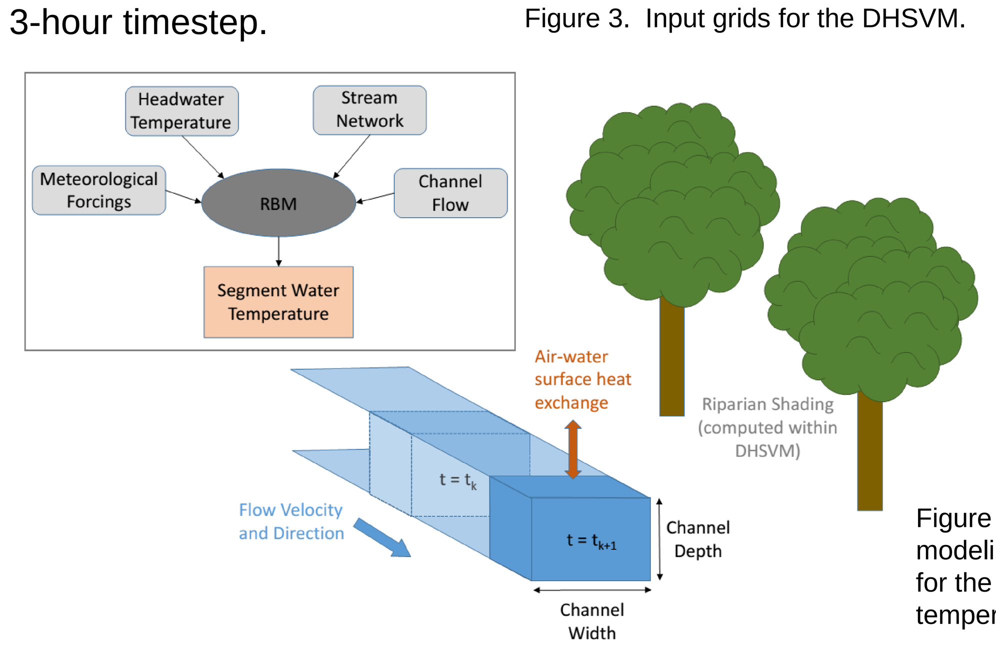
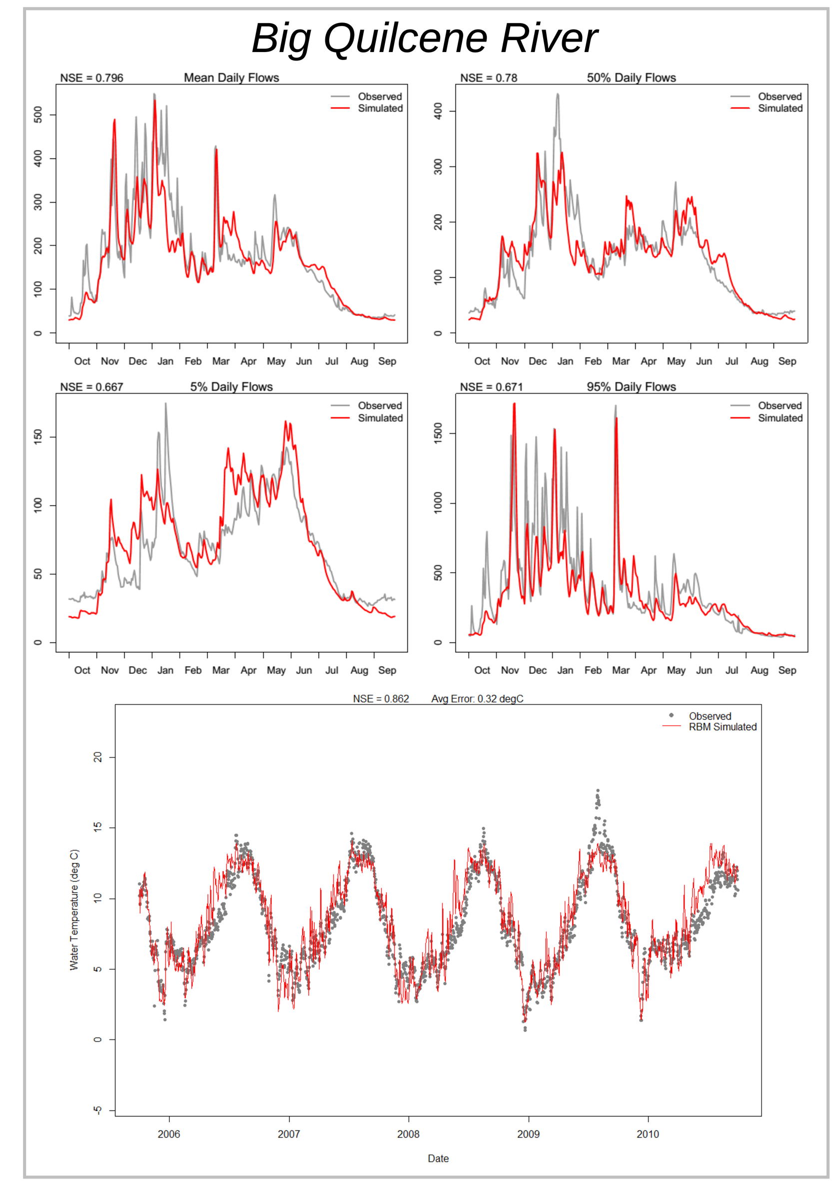


Figure 4. Conceptual modeling framework for the RBM stream temperature model.

4. Calibration Results



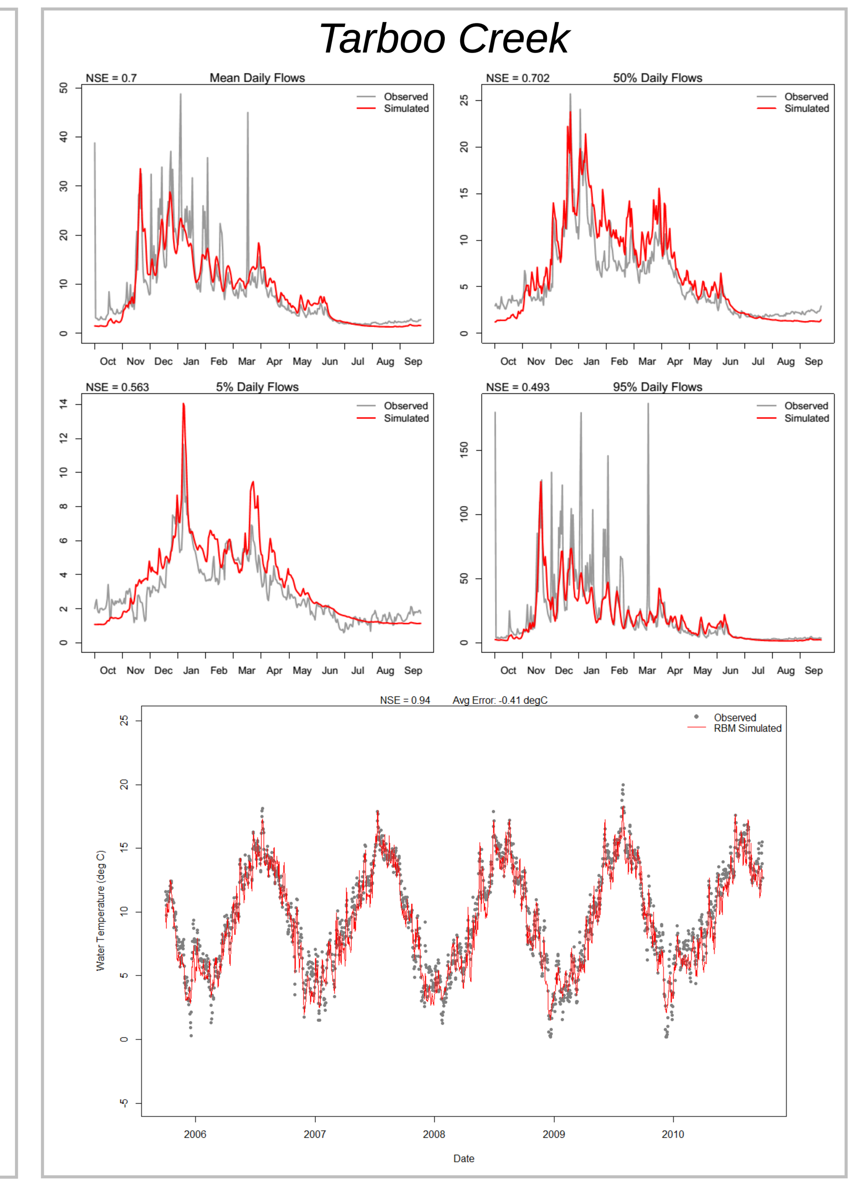


Figure 5. Left plots (Big Quilcene River). Calibration results for the Big Quilcene River at the WA Dept. of Ecology stream gauge near the river mouth for mean, 50th percentile, 5th percentile, and 95th percentile daily flows for water years 2003-2010. Also shown at the bottom of the figure box are the preliminary calibration results for stream temperatures at the WA Dept. of Ecology gauge location for water years 2006-2010.

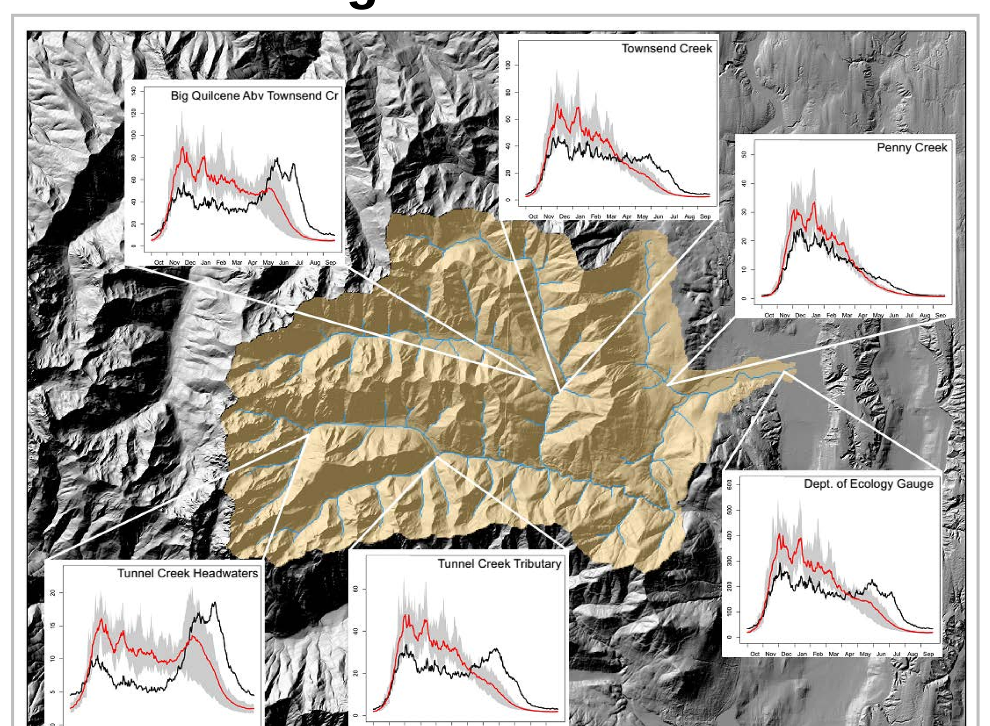
Figure 6. Right plots (Tarboo Creek). Calibration results for Tarboo Creek at the WA Dept. of Ecology stream gauge near the river mouth for mean daily, 50th percentile, 5th percentile, and 95th percentile daily flows for water years 2004-2010. Also shown at the bottom of the figure box are the preliminary calibration results for stream temperatures at the WA Dept. of Ecology gauge location for water years 2006-2010.

Preliminary Calibration Results Summary

Streamflow was well captured by the model with daily Nash-Sutcliffe efficiency scores (NSE) generally above 0.6 indicating a good model fit. Model skill was best for mean and median daily flows but still good for 5th and 95th percentile daily flows in the Big Quilcene River. The Tarboo Creek model performed less well for 5th and 95th percentile flows, however, and the model generally underestimates peak storm event flows in both watersheds with the current setup. Average monthly streamflow results (not shown) show that the model also does well at longer time-steps with NSE scores of 0.85 and 0.93 for Big Quilcene River and Tarboo Creek respectively. Not shown are calibration results for the Big Quilcene River at the USGS stream gauge higher up in the watershed. Model skill was similar to that at the Ecology gauge shown in figure 5 indicating good model skill throughout the watershed.

Preliminary stream temperature calibration results show that the RBM stream temperature predictions match well with the observations near the mouths of these two streams. Further work is needed to improve model skill at other stream temperature observation locations to ensure the model is accurately simulating the spatial variability of stream temperatures.

5. Forecasting Results



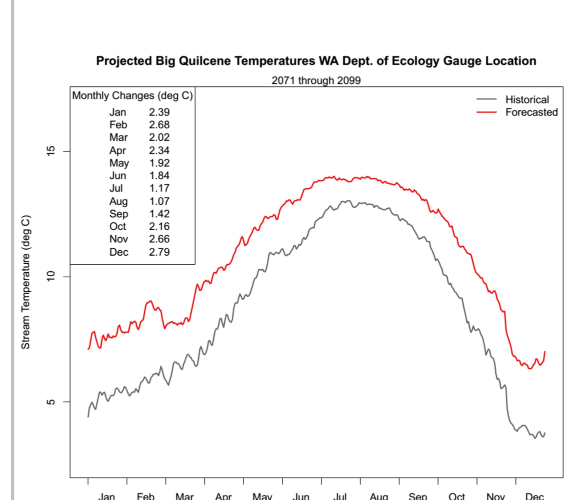
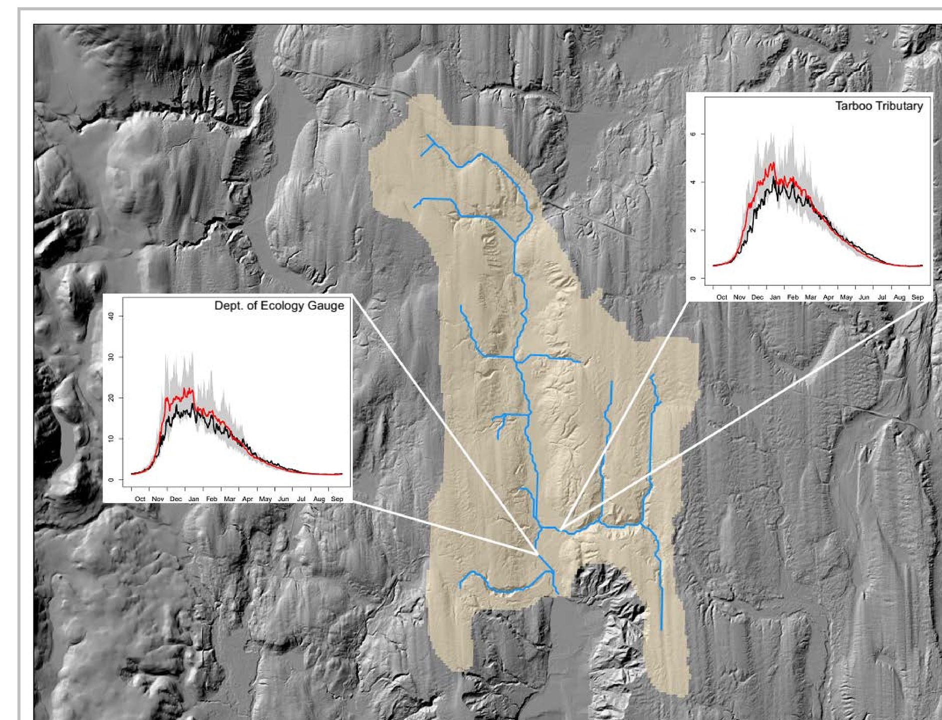


Figure 7. ***Top***: 30-year (2070-2099) daily 50th percentile streamflow projections for select stream segments in the Big Quilcene River watershed. Historical (1951-2010) daily 50th percentile modeled flows are shown in black and projections are in red. The gray area indicates the ensemble range. ***Left***: Daily average stream temperature projections for 2071-2099 at the WA Dept. of Ecology gauge location (red) compared to historical modeled 1981-2010 average daily temperatures (gray). Monthly average changes are indicated in the upper left of the plot area.



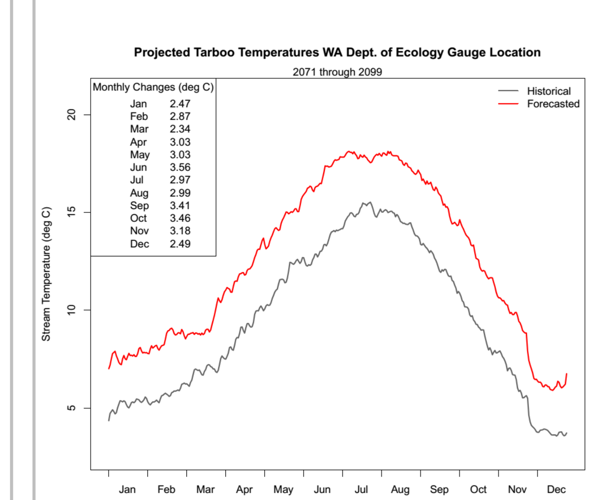


Figure 8. ***Top***: 30-year (2070-2099) daily 50th percentile streamflow projections for select stream segments in the Big Tarboo Creek watershed. Historical (1951-2010) daily 50th percentile modeled flows are shown in black and projections are in red. The gray area indicates the ensemble range. ***Left***: Daily average stream temperature projections for 2071-2099 at the WA Dept. of Ecology gauge location (red) compared to historical modeled 1981-2010 average daily temperatures (gray). Monthly average changes are indicated in the upper left of the plot area.

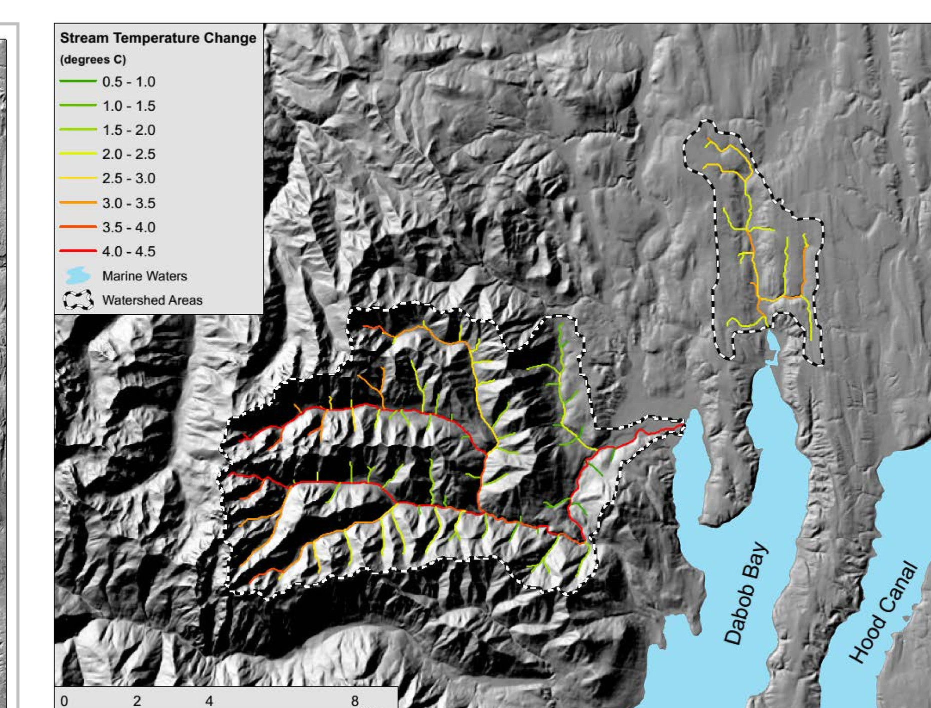


Figure 9. Preliminary average August stream temperature changes by stream segment in the Big Quilcene and Tarboo watersheds for the years 2070-2099 under an RCP 8.5 scenario using the CSIRO-Mk3-6-0 GCM compared to the 1981-2010 modeled historical base period.

Forecasting Results Summary

In the high-relief Big Quilcene watershed, streamflow is projected to increase during the winter months and decrease in the summer as the basin becomes more rain-dominated and the snowpack decreases (Figure 7). Smaller low-elevation tributaries, such as Penny Creek show a similar change to the Tarboo Creek watershed, where winter flows increase but summer flows are not greatly impacted (Figure 8). Preliminary stream temperature forecasts (Figure 9) show that the low-lying Tarboo Creek system has a relatively uniform increase in water temperature. The Big Quilcene and its tributaries in contrast, are projected to warm greatest in the upper reaches and along the main channel with a large amount of variability throughout the watershed.

6. Discussion

Topography plays an important role in not only the hydrology of the Hood Canal area watersheds, but also in the impacts that climate change might have on both streamflow and stream temperatures. High-relief rain-snow watersheds that have historically relied upon snowpack to support spring and summer streamflow are projected to be impacted the greatest by a warming climate. As the atmosphere warms, winter precipitation becomes more rain dominated, reducing the snowpack and subsequently the water storage for later in the spring and summer months. Low elevation stream systems, which are already rain-dominated, are not impacted as much in terms of stream flow. Stream temperatures, however, are likely to increase significantly. A variety of Endangered Species Act fish species use the Big Quilcene and Tarboo stream systems as spawning and rearing habitat which could be threatened with the projected changes, impacting critical tribal cultural and economic resources. Future work will focus on improving stream flow and temperature forecasts so that resource managers can better identify potentially detrimental habitat changes and plan for a changing climate. This project also includes flow and temperature modeling for the Dungeness, Jimmycomelately, Snow, Salmon, Chimacum, Little Quilcene, Dosewallips, Duckabush, Hamma Hamma, and Big Beef watersheds. See climate.pnptc.org for more details.