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Chehalis Basin: Extreme Precipitation Projections

Guillaume Mauger, Climate Impacts Group, UW

PURPOSE

The purpose of this technical memo is to characterize the spatial distribution of projected increases in extreme precipitation in the Chehalis basin for use in the Chehalis Basin Board's planning as part of the Local Actions Program (LAP). The spatial distribution characterization provided in this memo responds to the Technical Advisory Group's (TAG) request for refined model assumptions that could be used to estimate a reasonable upper range of predicted increases in late-century flood flows throughout the Chehalis Basin for preliminary planning purposes. The TAG's request, in turn, was generated by the Chehalis Basin Board's desire to understand how a 50 percent increase in flood flows in 2080 would differ from the 26 percent increase assumed in the draft SEPA EIS for the proposed flood retention facility/airport levee improvement project.

BACKGROUND

Precipitation projections were obtained from the recent ensemble of simulations developed by Cliff Mass in UW's Atmospheric Sciences department (projections are described in Mauger and Won, 2019 and Lorente-Plazas et al., 2018). These simulations were implemented at an hourly time step, at a spatial resolution of 12 km, spanning the years 1970-2099. Projections were developed for the following 12 global climate models (GCMs), all driven by the high-end RCP 8.5 greenhouse gas scenario (Taylor et al., 2012; Van Vuuren et al., 2011): ACCESS1-0, ACCESS1-3, bcc-csm1-1, CanESM2, CCSM4, CSIRO-Mk3-6-0, FGOALS-g2, GFDL-CM3, GISS-E2-H, MIROC5, MRI-CGCM3, and NorESM1-M.

Since all projections are based on the same greenhouse gas scenario, the results presented here do not reflect uncertainties in future greenhouse gas emissions. As such, the range among projections described below provides an estimate of the model uncertainty, related to physical process understanding and model accuracy.

APPROACH

We analyzed projections for three durations (6-hr, 12-hr, and 24-hr) and four return intervals (2-, 10-, 25-, and 100-year events). Following the approach used in the draft SEPA EIS, projected changes are assessed by evaluating the percent change for 2016-2060 ("mid-century") and 2055-2099 ("late-century") relative to 1970-2015 ("historical").

Precipitation statistics are summarized for the entire Chehalis Basin as well as the following sub-basins or mainstem river locations:

- Upper Chehalis River at proposed dam location
- Upper Chehalis River at Doty
- Elk Creek
- South Fork Chehalis River
- Chehalis River Near Adna
- North Fork Newaukum River
- South Fork Newaukum River
- Mainstem Newaukum River
- Skookumchuck River at Dam
- Skookumchuck River at Mouth
- Lincoln Creek
- Chehalis River at Grand Mound
- Scatter Creek
- Black River
- Chehalis River at Porter
- Satsop River
- Chehalis River at Satsop River
- Wynoochee River
- Chehalis River below Wishkah River
- Wishkah River
- Hoquiam River
- Humptulips River

Finally, we compare projected changes in precipitation to projected changes in streamflow based on hydrologic modeling of the GFDL-CM3 climate model projection, developed by Watershed Science & Engineering (WSE, 2019).

RESULTS

Results for all models, time periods, durations, and return intervals are summarized in a spreadsheet that accompanies this technical memo. Our analysis of the results indicates that there is no systematic difference between the results for different precipitation durations. As a result, this memo focuses on the average change across all durations.

Although there does appear to be a systematic increase in the projected change in precipitation at higher return intervals (e.g., the change in the 100-year precipitation is generally greater than the change in the 2-year precipitation), we chose to also average over all return intervals for two reasons: First, changes in streamflow extremes are heavily influenced by antecedent conditions, which means that changes in the 100-year precipitation may not be a reliable predictor of changes in the 100-year flow. This is supported by the comparison with the hydrologic modeling results shown in Table 1 and Figure 1 which show greater variability than the precipitation statistics. Second, the statistics of the 100-year precipitation are extrapolations and are subject to far greater uncertainty than those for more frequent events (e.g., 2-year), and are therefore less reliable.

All projections analyzed show a similar spatial pattern of change, in which changes in upper basin tributaries (e.g., Skookumchuck) are larger than changes in the lower basin tributaries (e.g., Wishkah). Within the upper basin, projected increases are somewhat lower for the Chehalis River above Doty, South Fork Chehalis River, and Newaukum River than for the Skookumchuck River or Scatter Creek. Elk Creek and Lincoln Creek show slightly higher projected increases.

Table 1. Projected change, averaged over both durations and return intervals, for each site. Results are shown for the average and maximum among the 12 climate model projections, as well as for the GFDL model, which was the focus of the 2019 flood study used in the draft SEPA EIS. A final column shows the streamflow projections obtained from WSE for comparison; these are also based on the GFDL model. All changes are expressed as a percent change for late-century (2055-2099) relative to historical (1970-2015).

	Precipitation			Streamflow
	Avg. of all 12 Models	Max. of all 12 Models	GFDL	GFDL
CHEHALIS AT DAM	+19%	+46%	+42%	
CHEHALIS NEAR DOTY	+20%	+49%	+46%	+53%
ELK CREEK	+24%	+67%	+58%	
SF CHEHALIS	+19%	+46%	+42%	+42%
CHEHALIS AT ADNA	+21%	+54%	+49%	
NF NEWAUKUM AT SF	+23%	+51%	+48%	+76%
SF NEWAUKUM AT NF	+22%	+53%	+50%	+56%
NEWAUKUM RIVER	+23%	+51%	+48%	+71%
SKOOKUMCHUCK AT DAM	+21%	+58%	+57%	+53%
SKOOKUMCHUCK AT MOUTH	+24%	+59%	+55%	+69%
LINCOLN CREEK	+28%	+63%	+54%	
CHEHALIS AT GRAND MOUND	+23%	+54%	+50%	+66%
SCATTER CREEK	+26%	+60%	+55%	
BLACK RIVER	+26%	+56%	+47%	
CHEHALIS AT PORTER	+24%	+54%	+48%	+65%
SATSOP RIVER	+20%	+41%	+29%	+41%
CHEHALIS AT SATSOP	+23%	+49%	+43%	+55%
WYNOOCHEE	+19%	+41%	+27%	+19%
CHEHALIS US WISHKAH	+23%	+47%	+42%	+49%
WISHKAH RIVER	+18%	+40%	+27%	
HOQUIAM RIVER	+18%	+37%	+27%	
HUMPTULIPS	+19%	+38%	+25%	+18%
CHEHALIS ENTIRE BASIN	+22%	+43%	+38%	

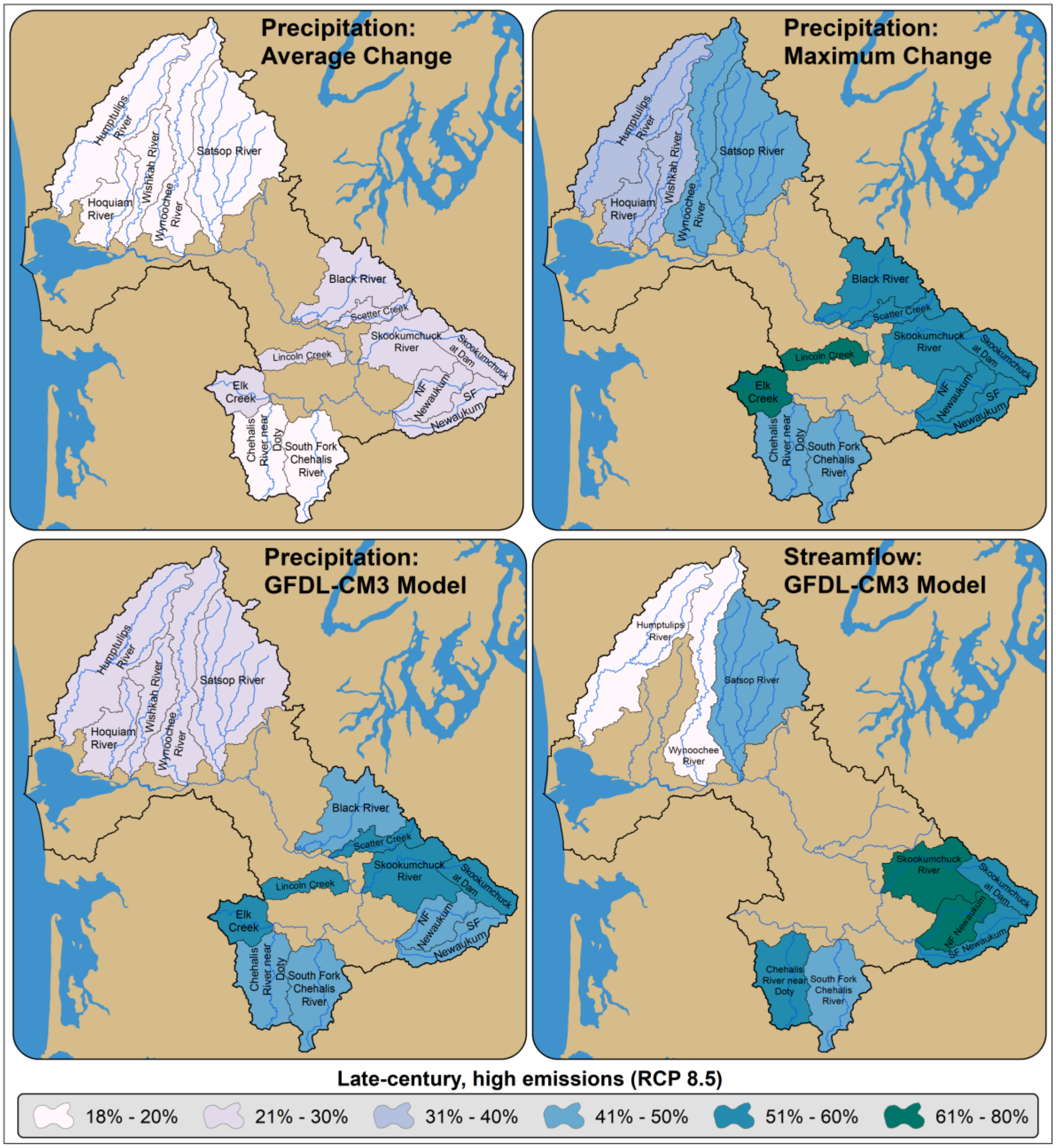

Figure 1. Projected change, averaged over both durations and return intervals, for each site. Only upstream basins are included so as to focus on differences among source watersheds. Results are shown for the average (top left) and maximum (top right) among the 12 climate model projections, as well as for the GFDL model (bottom left), which was the focus of the 2019 flood study used in the draft SEPA EIS. A final map shows the streamflow projections obtained from WSE for comparison (bottom right); these are also based on the GFDL model. All changes are expressed as a percent change for late-century (2055-2099) relative to historical (1970-2015)

CONCLUSIONS

We analyzed precipitation projections from the new ensemble of regional climate model projections produced by UW's Cliff Mass. These are based on the same methods used to develop the projections for the Draft SEPA EIS, and were chosen because research indicates regional climate models are needed to accurately estimate changes in heavy rainfall events.

The results of our analysis show that there are distinct variations in projected precipitation increases across the Chehalis basin and that the differences are relatively consistent among all of the climate models evaluated. This suggests that spatially distributed scaling factors should be used to characterize future flows across the Chehalis basin, as opposed to a single uniform scaling factor across all basins.

We recommend basing the spatially distributed scaling factors on the maximum change projected among the 12 climate models, after averaging over return intervals and durations (Figure 2). We note that the averaging reduces the potential for anomalies in these projections, while using the maximum projection among all of the models ensures that a high-end future flow scenario is considered. Results using these high-end scalars can be considered as a complement to the results with the 26% scaling, as used for the draft SEPA DEIS. The 26% increase is comparable to the average projection among the 12 models evaluated here (Figure 1, top left).

The primary argument against using the maximum increase from the 12-models is that it could exaggerate the change on the mainstem Chehalis River by aggregating the maximum projections on all tributaries. We nonetheless recommend using the 12-model maximum because (a) the results are not very different from those for the GFDL model, and (b) using the maximum ensures that a high-end projection is considered for each sub-basin, whereas the same would not be true if using the GFDL projection alone.

Due to the spatial resolution of the regional climate model, smaller basins were not evaluated in this analysis. We recommend applying scalars to these basins as shown in Figure 2. These were developed based on the spatial distribution shown in Table 1 and Figure 1 above.

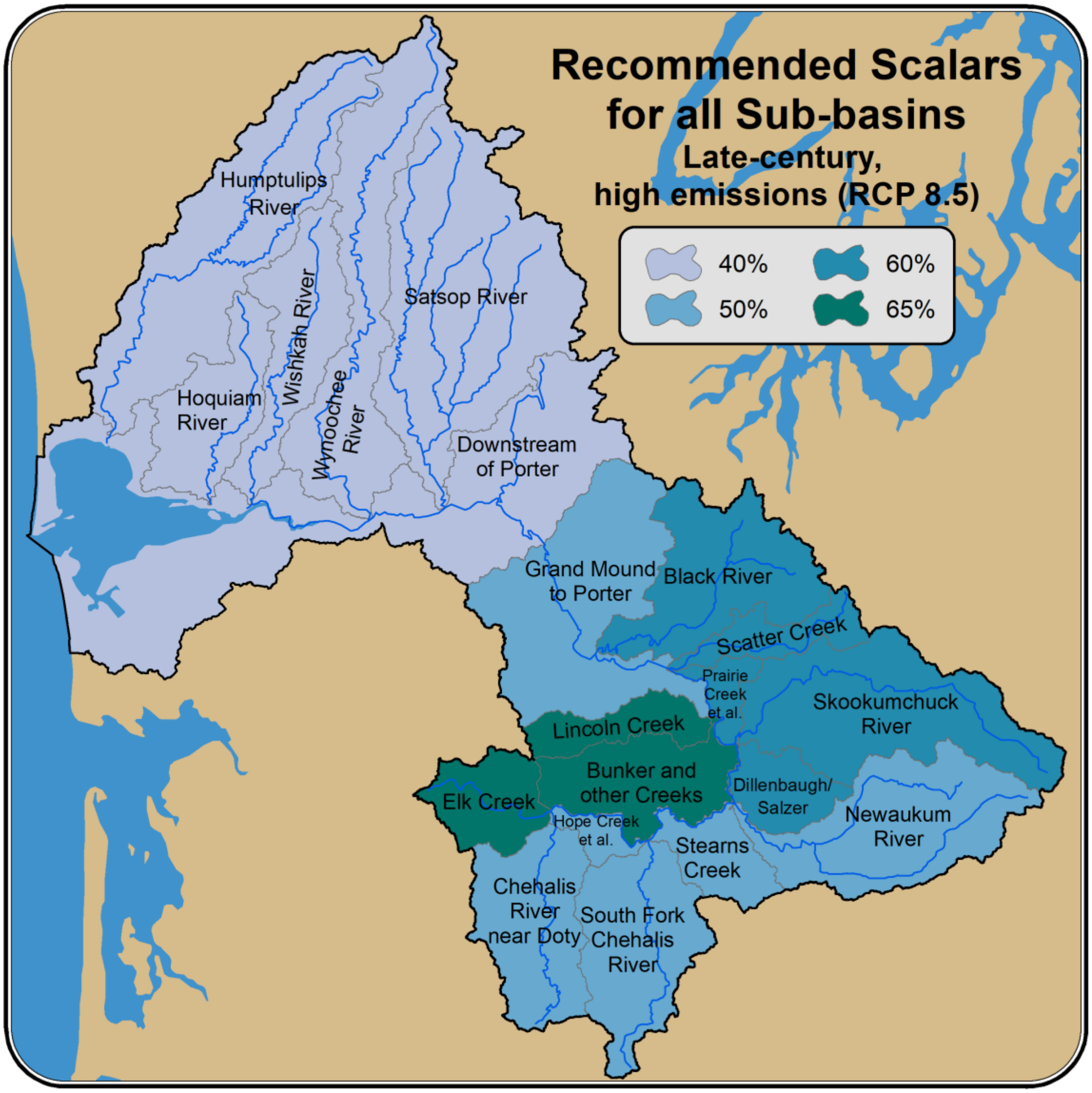

Figure 2. Recommended spatial distribution of scalars representing the high-end projected changes in precipitation for the Chehalis basin. As in Figure 1, all changes are expressed as a percent change for late-century (2055-2099) relative to historical (1970-2015).

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