Sensitivity of Columbia Basin Runoff to Long-Term Changes in Multi-Model CMIP5 Precipitation Simulations

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Abstract

In this study, we used precipitation elasticity index of streamflow, \( e_p \), to reflect on the sensitivity of streamflow to changes in future precipitation. We estimated precipitation elasticity of streamflow from (1) simulated streamflow by the VIC model using observed precipitation for the current climate (1963-2003); (2) simulated streamflow by the VIC model using simulated precipitation from 10 GCM - CMIPS dataset for the future climate (2010-2099) including two different pathways (RCP4.5 and RCP8.5) and two different downscaled products (BCSD and MACA). The hydrological model was calibrated at 1.16 latitude-longitude resolution and the simulated streamflow was routed to the subbasin outlets of interest i.e. Hungry Horse subbasin. We used hydrological model simulations from 19063-2003 and calculated streamflow sensitivities and precipitation elasticity for the same period using observed climate (case 1) and simulated climate (case 2). The runoff sensitivity to long-term changes (e.g., 30-year) average annual changes in precipitation is calculated based on the elasticity of streamflow for three different 30 year blocks (2010-40, 2040-70 and 2070-99), which are of importance to reservoir management in the Columbia River basin. These two cases and different periods are compared to assess the effects of forcing by different climate models and different pathways on the precipitation elasticity of streamflow.

Preticpitation Elasticity of Streamflow

Following Sankarasubramanian et al. (2001), we used a non-parametric estimator for precipitation elasticity of streamflow (Eq. 1)

\[
e_p = \text{median} \left( \frac{Q_i - Q_{obs}}{P_i - P_{obs}} \right) \tag{1}
\]

In the second part of our study, the multiple model outputs from 10 GCMs are combined using a weighted averaging method. In this method, the inverse of the error variance of each model’s output for each model cell is used to estimate the weight for that cell.

Study Area: Hungry Horse Subbasin (Columbia River)

In this study we selected Hungry Horse subbasin located in the Eastern Columbia River Basin as a test-bed since the performance of the hydrological model for calibration and validation period is good (KGE-M of 0.92 and 0.84 respectively). The abbreviation, KGE, stands for Kling and Gupta metric (Gupta and Kling, 2011)

Results: VIC model runs using BCSD and MACA forcing

Results: Precipitation Elasticity of Streamflow and P-Seasonality

Table 1: Legend for Precipitation Seasonality in Fig.6

<table>
<thead>
<tr>
<th>Season</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.19</td>
<td>Precipitation is equally spread throughout the year</td>
</tr>
<tr>
<td>0.20 - 0.30</td>
<td>Precipitation is equally spread throughout the year, but with a definite wetter season</td>
</tr>
<tr>
<td>0.40 - 0.50</td>
<td>Rather seasonal with a short dry season</td>
</tr>
<tr>
<td>0.50 - 0.70</td>
<td>Seasonal</td>
</tr>
<tr>
<td>0.80 - 0.89</td>
<td>Markedly seasonal with a long dry season</td>
</tr>
<tr>
<td>1.00 - 1.19</td>
<td>Most precipitation in less than three months</td>
</tr>
<tr>
<td>&gt;1.20</td>
<td>Extreme seasonality, i.e. almost all precipitation occurs in 1-2 months</td>
</tr>
</tbody>
</table>

Conclusion

- We found significant differences in simulated discharges, precipitation seasonality and precipitation elasticity of streamflow using BCSD and MACA datasets.
- The ranges in precipitation elasticity of streamflow using BCSD forcing are higher than those for MACA showing the uncertainty in downscaled forcing.
- We used precipitation elasticity of streamflow to assess the climate change impacts on streamflow. However, other processes are also important in streamflow generation and temperature and PET elasticity of streamflow should also be considered to explain the changes in streamflow dynamics.
- We used January period in our precipitation elasticity calculations. However, the period October-September should also be studied as Fu et al (2007) found better performance in elasticity estimation due to the higher correlation between \( Q \) and \( P \) for the generic hydrological year definition i.e. the period from October to September as compared to Jan-Dec.

References


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