Streamflow Projection Uncertainties in the Major Watersheds of British Columbia, Canada

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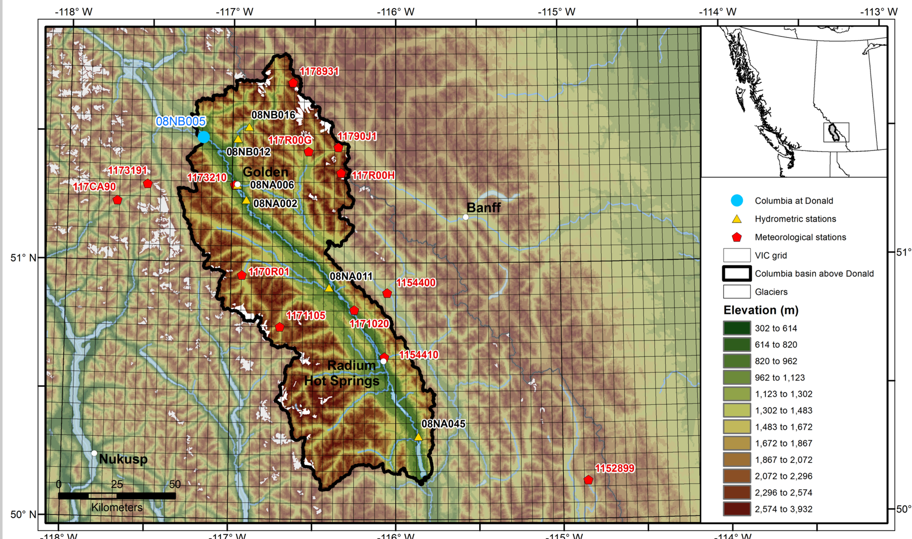
1. Introduction



The Columbia river above Donald is a steep mountainous watershed that ranges from ~300 m to ~4000 m in elevation and covers an area of 9710 km^2. Its glaciers are integral to sustaining late-summer and early-fall streamflow throughout the greater Columbia basin, a river heavily used for hydro electric power. Mountainous, glaciated basins are difficult to model under the current climate as many hydrologic models do not adequately represent the underlying processes. Projections of future change in streamflow are hampered by challenges to downscaling coarse GCM data, especially at high elevations where limited observations exist. By comparing projections from two hydrologic models driven by two downscaling techniques, we hope to see how the results from these two modelling chains compare, and if they agree or disagree.

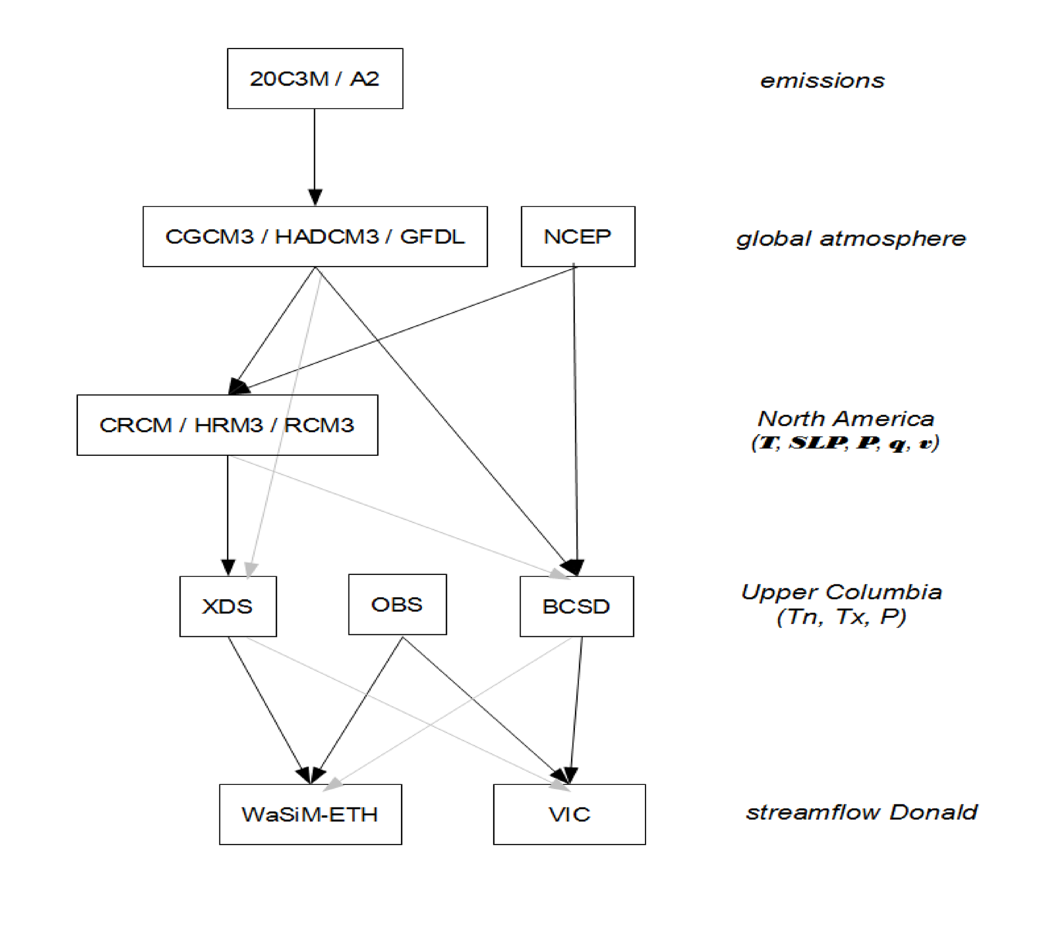
2. Methods

Two different model chains were applied.

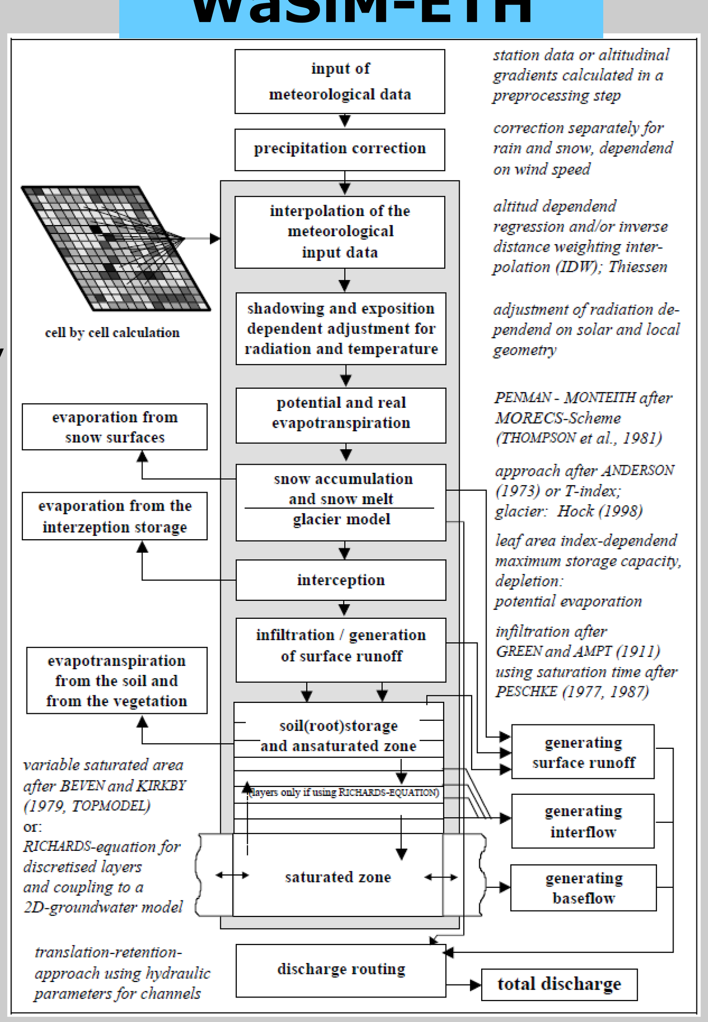
Method (1) - three Regional Climate Models (RCMs) were used to dynamically downscale, three Global Climate Models (GCMs), these RCMs were then downscaled statistically to climate station locations using the Expanded Downscaling (XDS) method (Bürger, 1996). XDS is based on daily GCM data. These climate fields were then interpolated internally via lapse rate regression and inverse distance weighting and used to drive the Water Balance Simulation Model (WaSiM) run at a 500 m resolution. WaSiM is a physically based, distributed hydrologic model that represents glaciers explicitly (Schulla, 1997; Schulla and Jasper, 2007).

Method (2) - three GCMs were statistically downscaled using the Bias Corrected Spatial Disaggregation (BCSD) technique (Wood et al. 2002; Wood et al. 2004; Salathé 2005). BCSD is based on monthly GCM data. Downscaled gridded climate fields at 1/16° resolution were used to drive the Variable Infiltration Capacity (VIC) model. VIC is a spatially-distributed macro-scale hydrologic model (Liang et al. 1994 and 1996). In this application, glaciers are represented very simply by adding excess snow water equivalent to the snow state of specific grid cells (Schnorbus et al. 2010).

Model Flow



WaSiM-ETH



Calibrated manually.

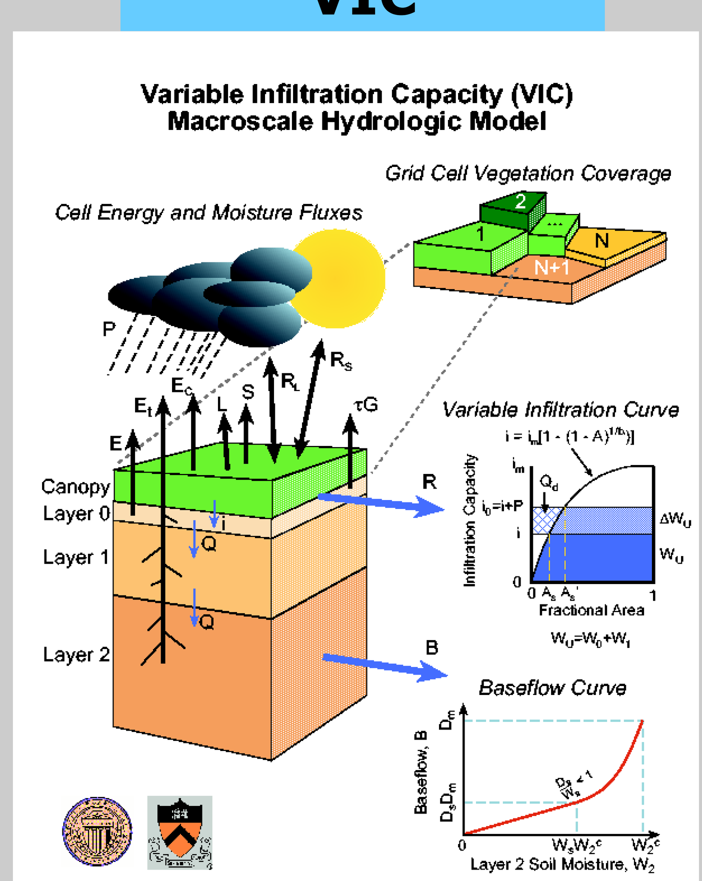
Calibration

- 1980 to 1997
- Nash-Sutcliffe Efficiency (NSE) = 94.4%
- Mean Volume Error (MVE) = 5.5%

Validation

- NSE = 95.0%
- MVE = -3.5%

VIC



Calibrated with the Multi-Objective Complex Evolution method (Yapo et al. 1998).

Calibration

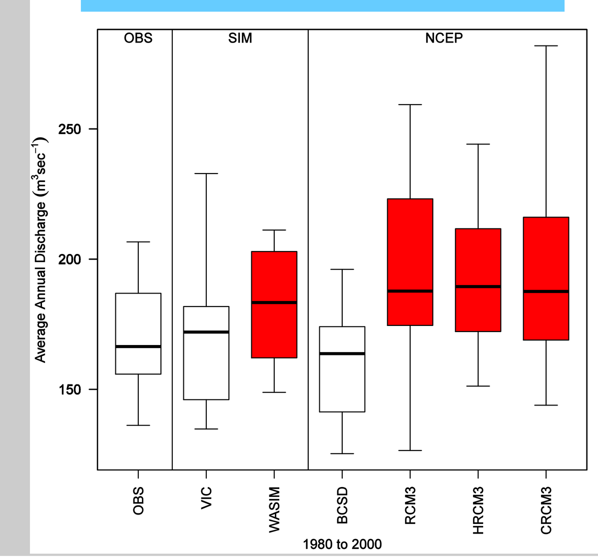
- 1990 to 1994
- Nash-Sutcliffe Efficiency (NSE) - 94%
- Mean Volume Error (MVE) - 2%

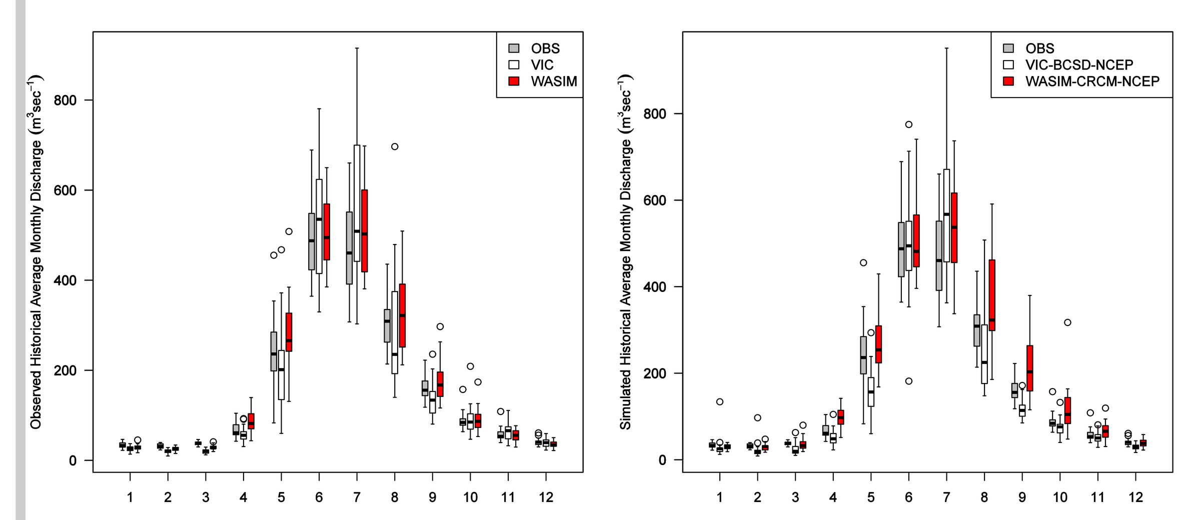
Validation

- NSE = 91%
- MVE = -1%

3. Results

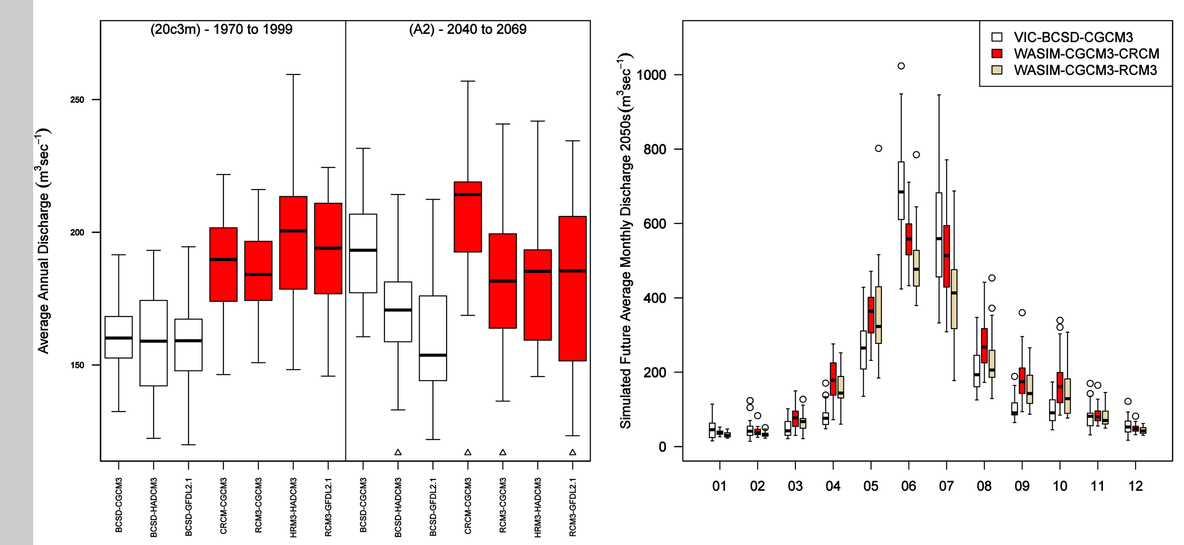
Historical

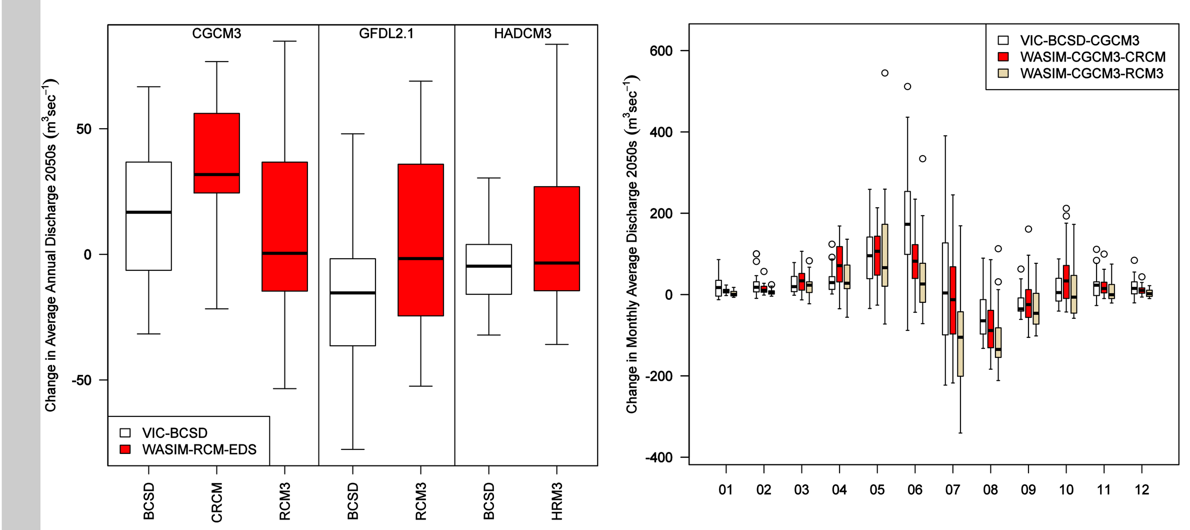




- Mean annual discharge from VIC is similar to OBS flow, but the range for this 20-year period is better captured by WaSiM.
- Median monthly historical flows from WaSiM, in Apr, May, Aug and Sep, are greater than those for OBS or VIC.
- Median monthly flows from NCEP-RCM-XDS-WaSiM are greater than those for OBS or NCEP-BCSD-VIC in Aug and Sept.
- NCEP-RCM-XDS-WaSiM response depends on the RCM applied.
- Differences between the hydrologic responses combine the effect of the downscaling method and hydrologic model.

Future





- Annually, little change is projected in median flow by the WaSiM model chain, except for increases projected by CGCM3-CRCM-XDS-WaSiM. CGCM3-BCSD-VIC also projects increases. The only median annual decrease is projected by GFDL-BCSD-VIC.
- Median monthly flows are projected to increase Apr-Jun and decrease Jul-Sep by both methods, decreases are projected to be somewhat larger for CGCM3-RCM3-XDS-WaSiM, than by CGCM3-BCSD-VIC or CGCM3-CRCM-XDS-WaSiM. Again, for the WaSiM modelling chain responses differ by RCM, under the same GCM.

4. Conclusions and Future Work

The two approaches, when starting from the same GCM, did not agree in the direction or magnitude of change annually. But did more so on a monthly basis. Even when using the same GCM, projections from the WaSiM model chain, differ by RCM, suggesting the dynamical downscaling of the RCM plays a major role in the projection of future flows. Although, the statistical downscaling (XDS) and hydrologic model (WaSiM) contribute to these differences also. Different representation of glaciers by the two hydrologic models could also play a role.

It can not be shown decisively if the different results are driven primarily by the downscaling approach or the hydrologic model set up. To test this, future work includes downscaling the selected RCMs with BCSD and running their output through VIC and downscaling the selected GCMs with EDS and running this through WaSiM. Along with swapping inputs to hydrologic models, i.e. GCM-RCM-EDS to VIC and GCM-BCSD to WaSiM. Additionally, the forcing variables: temperature and precipitation, need to be analyzed to establish their influence on changes.

5. References

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