Modelling the coupled influence of climate and glacier change on discharge

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HYDROLOGY

Introduction

Glacier melt is an important source of freshwater in mountain regions around the world. Future projections of hydrological change in high mountain regions need to consider the effect of global warming on stream discharge

- directly through a change in hydroclimatic variables and
- indirectly through land cover change, i.e. the retreat of the glacier.

Generalized effects of climate warming on stream discharge:

Short-term: increase in the meltwater contribution to streamflow

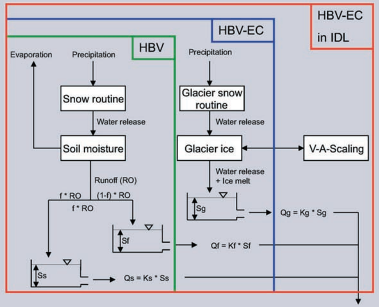
Long-term: decrease in streamflow as a result of the declined glacier coverage

Objectives

- To investigate the long-term response of discharge from glacierized catchments to climate change
- To consider and compare uncertainties from
  - climate model, scenario, and downscaling method
  - glacier mass balance and hydrological models
- To assess how future discharge changes depend on catchment glacier coverage

Model

Semi-distributed rainfall runoff model HBV coupled with a mass balance and a glacier response model - i.e. based on an empirical volume-area scaling relation glaciers are re-scaled every decade (Stahl et al., 2008).



Modelling Approach

Multi-Criteria Calibration (1985-2004)

0 500 1000 1500 2000 2500

Discharge: Modified Nash Suttcliffe efficiency

Snow: Mean absolute error of SWE at snow pillow stations

Snow: Mean error of SWE at snow courses for April/May/June

Snowline: Mean error of elevation estimated from flight surveys

→ **20 best parameter sets**

Future ensemble projection (2000-2100)

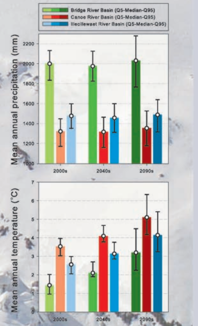
2 Transient climate scenarios (B1/A2)

2 Different GCMs (CGCM3/CM2.1)

10 Downscaling realizations to local conditions with TreeGen

20 Model parameter sets

→ **800 members**

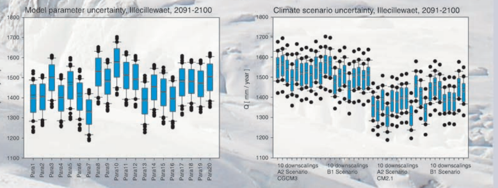


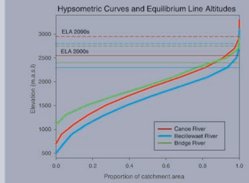
Modelling Uncertainty

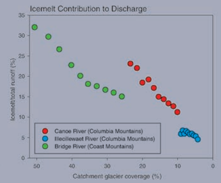
Nash Suttcliffe efficiencies for discharge calibration and validation are mostly >0.8.

Errors of SWE simulations vary with month and snow pillow/course site. Often overestimated for lower elevations.

Simulated snowlines are within survey uncertainty of 100m.







Conclusions

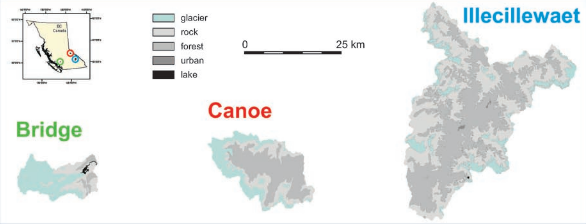
Without data to constrain the glacier mass balance, the uncertainty from the coupled glacio-hydrological model (parameters) is similar to the uncertainty from GCM and downscaling (climate).

While icemelt decreases in all basins over the scenario period, seasonal changes and the effect on total discharge differ in the three catchments - though with large uncertainties.

Transient coupled simulations may be used to derive regional estimates of the relation between icemelt contribution to discharge and catchment glacier coverage.

Projected Changes

Future changes were simulated for three catchments with similar glacier surface area but varying basin size, climate, glacier type, and other catchment characteristics.



Total area / Glacier area (according to LandSat images in 1990s):

Bridge	Canoe	Illecillewaet
150 km² / 90 km² (60%)	300 km² / 80 km² (25%)	1150 km² / 110 km² (10%)

Glacier Area

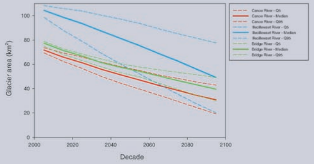
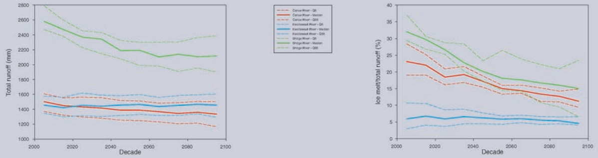
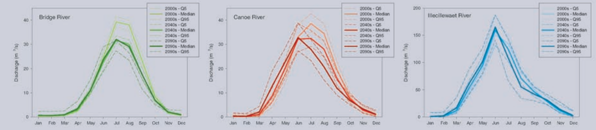


Photo Credit: Dr. Dan McCarthy, Brock University

Total Runoff and Icemelt Contribution



Hydrologic Regimes



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Stahl, K., R.D. Moore, J.M. Shea, D. Hutchinson and A.J. Cannon (2008): Coupled modelling of glacier and streamflow response to future climate scenarios, Water Resour. Res., 44, W02422, doi: 10.1029/2007WR005956.