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Hydrology and Earth System Sciences Discussions

Interactive comment on "Uncertainty in the impacts of projected climate change on the hydrology of a subarctic environment: Liard River Basin" *by* R. Thorne

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I thank the reviewer for their helpful comments which certainly permit the enhancement of the manuscript. I have provided a point-by-point response to comments below:

1) The introduction is too general and does not give a good overview of the state of the art. The uncertainty which is emphasized in the title of the manuscript is not only caused by the GCM outputs but also by the hydrological model and its parameters. Internal inconsistencies of the hydrological model are significant sources of errors, which need to be addressed in the introduction.

Internal inconsistencies of a hydrological model are important to investigate and address, however, the purpose of the study was to examine only the uncertainties of climate change scenarios. To avoid the potential effects of uncertainties caused by the hydrological model, parameters were held constant. The manuscript has been rewritten to highlight these points and include more active research.

2) Some more details on the catchment characteristics would be interesting, e.g. which are the main aquifer systems where the water is stored; average precipitation amounts (snow and rain), etc.

The Liard River Basin is a typical mountainous catchment in the Western Cordillera and further details of the basin can be found in Woo and Thorne (2003) and van der Linden and Woo (2003). These details are important hydrologically, however, since everything is held constant to examine the response to the different scenarios, it will not affect the main thrust of the paper.

3) The hydrological model needs to be described in more details. Which melt model is used? How is evapotranspiration calculated? How is the gridded climate data used as input to the semi-distributed model? . Further information about the modeling procedures are discussed in Thorne and Woo (2006) and Woo and Thorne (2006) as cited and are not important to the main thrust of the paper. Analyzes of the changes in evaporation have been removed from the manuscript. If readers require more information about methods and the study area, the listed references are readily accessible in major journals.

4) Calibration of hydrological models against discharge data is a standard approach. However, especially in melt water dominated environments this could lead to significant internal inconsistancies which can have a great impact on the scenario simulations. The uncertainty of the hydrological model needs to be analysed, especially if absolute values (in % p. 3142, lines 25, 26) are given. This could be done by means of Monte-Carlo simulations (e.g. Konz and Seibert, 2010 (JoH)).

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Improving model parameterization is a desirable thing to do, however, as mentioned in Comment #1, the purpose of the study was to examine only the uncertainties of climate change scenarios. To avoid the potential effects of uncertainties caused by the hydrological model, parameters were held constant.

5) Why was only one gauging station used to calibrate the model? According to Burn et al. (2004, Hydrological Sciences Journal) there are 12 stations available in the basin.

In the hydrological model SLURP, calibration is conducted only at the outlet of the basin, where additional hydrometric stations could be used for validation purposes. However, as found in Thorne and Woo (2006), internal basins do not fit properly due to compensatory effect and unfortunately, this is the state of progress for most models. Across the Liard River Basin, the sparse distribution of climate and hydrometric stations and parameter generalization over the large area would preclude exact calibration for all subbasins.

6) It seems that the model has only been calibrated without validation in an independent time period.

It is not the main thrust of the paper to rely on the model to simulate discharge, but to use the simulated discharge as a baseline to give an indication of the uncertainty by the scenarios.

7) Figure 2 does not add additional information.

Figure 2 has been removed as suggested by the reviewer.

8) The author discusses the different sources of errors in the data and methods chapter (pp. 3133 lines 12ff) but does not consider that in the uncertainty analysis.

The main sources of error in the study are from the climate change scenarios, where the parameters and algorithms in the hydrological model have been held constant. These points are now further highlighted in the manuscript.

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9) The discussion of the uncertainties in projected changes in air temperature and precipitation are to long and should be shortened. I suggest showing the spatial variability of the different GCM outputs as one map which shows, on a pixel basis, the standard deviations of the GCMs produced air temperature fields and precipitation fields. The same could be done for 6a.

Figures 4 to 6 have been modified as suggested by the reviewer and merged into two figures, which also includes a reduction in the manuscript.

10) In chapter 6.1 the spatial variability of all components of the hydrological cycle should be discussed rather than only looking into discharge. What about changes in storages of water?

The spatial variability of all components of the hydrological cycle would be too much information for the scope of this paper. The manuscript has been changed to examine only discharge from the basin outlet, temperature and precipitation.

11) Table 1 gives no uncertainty caused by discharge simulations of this hydrological model this is important and needs to be added.

Standard deviations have been added to the average values presented in Table 1.

12) It would be interesting to compare the uncertainty induced by the GCM outputs with the uncertainty caused by the hydrological model parameters. This could be shown in Figure 7.

See Comment 8.

13) pp. 3143, lines 6ff: This is textbook knowledge. I am wondering what can be learned from this study compared to the main other case studies on CC impact assessments already published in literature.

This study uses a well-tested, semi-distributed hydrological model to examine a large, complex, mountainous subarctic environment located in an area influenced by climatic warming. Very little research has been conducted on the hydrological impacts of this environment to warming.

Analyzes have shown that the hydrological impacts are highly dependent on the GCM scenario. Uncertainties between the GCM scenarios are driven by the inconsistencies in projected spatial variability and magnitude of precipitation rather than warming temperatures. Despite these uncertainties, all scenario simulations project that the subarctic nival regime will be preserved in the future but the magnitude of change in river discharge is highly uncertain. Generally, spring freshet will arrive earlier, autumn to spring discharge will increase whereas summer flow will decrease, leading to overall increase in annual discharge. Change in the peak discharge varies between the scenarios but all show an earlier occurrence.

References:

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