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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Impacts of climate and forest changes on streamflow and water balance in a mountainous headwater stream in Southern Alberta" *by* V. Mahat and A. Anderson

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We thank you for your helpful comments on our paper. Please find below our response to the comments.

Comment: Before providing comments, I would like to clarify that I am not a hydrologist, but more of a civil/river engineer. I am therefore unfamiliar with the models and procedures used in the study, but have done my best to try and understand the process. I should also make clear that this is the ïňĄrst paper I have ever refereed. Please consider this background when reading my comments. Water scarcity in the oldman

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catchment and much of southern Alberta is a very important issue. I applaud the two authors for attempting to quantify how climate change may affect the region such that proper measure can be taken. I am also impressed at the amount of work done in this paper. I believe the paper is relevant, but would like to see some changes prior to it being published.

General comments: As I understand it, precipitation of the region is driven by the so called "pineapple express". I would love to see a short section describing the hydrology of the region which could validate whether or not the GCM is able to capture the relevant processes. This "pineapple express" is a relatively thin ribbon of moist air and I am not sure if the GCM grid of 200 km2? (the actual GCM grid size is not clariïňĄed in the paper) is able to capture this phenomenon.

Reply: Pineapple Express, Alberta Clipper, Colorado Low and other common names phenomenon that affect the extreme weather patterns in western Canada and NW USA; however, for this study we are not focused on the weather that causes the extremes but rather the climate patterns that will affect monthly runoff. The daily climate data used in our study is stochastically generated data based on monthly climate outputs from the GCMs, so this process may very well capture these patterns to some extent. Because we are focused on monthly changes we did not evaluate the effectives of our methods to capture the extreme events, only the general statistics of climate for the reference time period. Evaluations of changes to extreme weather patterns and effect on the hydrology would likely use different methods than presented in this study.

Hydrology of the region is given in section 2; we will add additional detail in the revised manuscript and the GCM grid size.

Comment: There is also the affects of the PaciïňĄc Decadal Oscillations that may or may not affect future precipitation in the region. I am not sure if the GCM is able to capture that. Certainly the climate station used with only 32 years of data will not be able to pick up this PaciïňĄc Decadal Oscillations phenomenon.

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Reply: There is no doubt that Global Climate Models integrate a variety of equations to describe the atmosphere and oceans to help project the future climate as well as reconstruct the past. It is also true that multi-decadal pattern of sea surface temperature shifts are seen in the models; however, it is not clear that whether or not GCMs depict the exact PDO. Mantua et al. (1997) state that no one is certain about how PDO works; it is not possible to say with great confidence that PDO shift change persist for 20 or 30 years. A more in-depth look into GCMs may help to learn more about this phenomenon, and we believe climate scientists are working on this. If this is accomplished, definitely climate prediction into the future will be an accurate measure.

Our objective here is to use the GCM outputs in the hydrological model. We know that there is lots of uncertainty in the climate projection resulted due to the model not able to capture the PDO or many other phenomenon. We also agree that the 32 years of data we used in this study will not be able to pick up this PaciïňĄc Decadal Oscillations phenomenon because each phase of the PDO typically lasts from 15 to 30 years or more (Mantua et al., 1997). However, a full uncertainty analysis of the GCM is outside of the scope, but we will add discussion about the climate model uncertainty in the revised manuscript, including the issue of PDO and other ocean temperature processes.

Comment: The methodology seems to make sense, but as the other two referees pointed out, it would be nice to have more detail in this section.

Reply: This was noted by other reviews, we will expand the methodology section describing GLUE approach, and how forest change was considered.

Comment: There is some repetition in the text that could be removed to save space and make it more readable.

Reply: We will check and remove the repetitions.

Comment: SpeciïňĄc Comments: ABSTRACT: DeïňĄning stream ïňĆow in mm must

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be a hydrologist thing, but I ïňĄnd it confusing. Also without providing a mean ïňĆow, an increase or decrease of x mm is not helpful. P8504 Line14 - You mention the decrease in June, which is when typical high ïňĆows occur. Perhaps in the abstract you should talk about the ïňĆow decrease in July and August when irrigation is occurring and reduced river ïňĆows could impact agriculture production.

Reply: Millimeters is a common unit used in hydrology. Defining streamflow data to millimeters enables the data to be directly comparable to precipitation, and since mm is presented as per unit area, flow data of two watersheds with different sizes can be compared directly. We will provide the mean flow in the revised manuscript. Our result shows maximum flow decreased in the June; however flow also decreased in July and August. Following your suggestion we will add discussion of the ïňĆow decrease in July and August when irrigation is occurring and reduced river ïňĆows could impact agriculture production in the revised manuscript.

Comment: 1 INTRODUCTION: P8504 Line 23 - "regional" is subjective and not helpful. They are mountains, therefore have high runoff ratios. P8504 Line 18 - Most of your sources are for much larger river basins (eg. missassipi, Missouri, Columbia, North Sask). Is it worthwhile clarifying the differences in applying this proceedure on a small catchment vs a large one? I guess there is a difference when it comes to downscaling.

Reply: We will remove " regional" from the manuscript and also add examples of small basins in the revised manuscript. We agree that smaller watersheds are more prone to error while downscaling compared to larger watersheds. The study of uncertainty in the climate model and downscaling is beyond the scope of this study, but we will discuss the uncertainty in downscaling in the revised manuscript.

Comment: P8506 Line24 - this sentence is not useful. "may" is not deïňĄnitive. I could not see in your methodology how you selected your model?

Reply: We will re-write the sentence and discuss briefly about the selection of model in the revised manuscript.

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Comment: 2 STUDY WATERSHED AND DATA Furthering Cindy's comment. Snowfall data can be very variable, comparing readings or combining the readings for the years available from the other regional climate stations will help strengthen your data.

Reply: Few short term (summer) data are available from other nearby climate stations. These data are not enough for use in the model. However, we will present some comparisons of our derived climate with these short term observed data in the revised manuscript.

Comment: 3 METHODOLOGY You deïňĄne three distinct steps. In order to make your work easily reproducible it would be nice to have several more sub steps included

Reply: We will include more sub-steps in the revised manuscript.

Comment: 3.1 P8509 Line 2 - No clarïïňĄcation on how it was downscaled is given. I am pretty ignorant on the subject and maybe its ïňĄne, but going form 200 km2 to 1 km2 without losing accuracy seems hard to believe.

Reply: We will briefly describe how the climate outputs are downscaled in the revised manuscript. Details are given by Wang et al. (2006, 2011). There is no doubt that there are uncertainties in the downscaled data. But the study focuses only on the watershed hydrology and uncertainty on the hydrological modeling part.

Comment: 3.2 This LARS-WG is pretty amazing.

Reply: Yes, detailed description of the model is available here. http://www.cccsn.ec.gc.ca/index.php?page=lars-wg

Comment: 3.3 P8512 Line 21 – You have a 1500 m elevation difference, is 5 elevation zones (each 300m) enough? P8513 Line 13 – You have over 100 different parameters! This is amazing, I guess you used the monte carlo technique to come up with the best set, but the amount of runs you must have done is daunting. I assume it was automated somehow. Can you provide more info on how this was done? Is it a built in part of the program?

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Reply: There is no definite rule to select the number of elevation bands. We know there is a high chance that increasing number of elevation bands increases the efficiency; however, increasing bands sometime reduces the efficiency (see, Uhlenbrook et al., 1999 paper). So, we selected the default five elevation bands that the HBV-EC because a good efficiency value, E (0.82) was obtained.

We have used 100 parameters sets for the uncertainty analysis. The number of parameters used in calibration was 13. We will describe this in detail in the revised manuscript.

An algorithm in R (it's a program available to use in R) called genoud (Mebane and Sekhon, 2011) was used for the optimization. Genoud combines the evolutionary algorithm methods with a steepest gradient descent algorithm to solve difficult optimization problems. Following the optimization, 10,000 model runs are performed for the catchment using the Latin Hypercube Search (LHS) technique (similar to Monte Carlo technique) until hundred most efficient model parameters that result in NSE values higher than those obtained from the Genoud, minus a threshold, are acquired. These are automatic processes. We will discuss this in detail in the revised manuscript.

Comment: DISCUSSION P8518 line 5 – Some information on the uncertainty of all aspects of the process should be provided so that we can believe your work. In all honesty, because of the inherent uncertainty in the downscaling, I ïňĄnd it hard to believe your results. When combined with all the other similar studies, they make sense, but on its own it makes me uncomfortable.

Reply: We agree that uncertainties in GCM outputs and downscaling exist. We will provide detailed discussion in uncertainty on all aspects of the processes in the revised manuscript. However, the focus of this study remains on the hydrologic modeling and uncertainty in the model parameters while assessing the climate and forest changes impacts of streamflow.

Comment: I closing, I hope at least one of my comments will be useful to you. I enjoyed

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reading your paper and learnt much from it. Thank you for your hard work.

Reply: Your comments are very constructive and useful to us. Thank you very much for taking time to read manuscript and provide comments, they will no-doubt improve the manuscript.

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