Response to Reviewer # 3 major and minor comments

We thank the Reviewer for the careful review of our manuscript and useful suggestions to further improve the analysis.

1. My first assessment was similar to that of the previous reviewers: what has been modelled for the Fraser River has been modelled and reported many times before: changes in mean flow, regime, snow-rain ratio, etc. Abstract and conclusion provide little new information and the international reader doesn't know what knowledge gain to transfer to other regions. In this context we should remember that HESS has the same requirements for special issue papers as for regular contributions. Manuscripts submitted as type 'research articles' should 'clearly advance our understanding', ms type 'cutting edge-case study' needs to provide all data to serve others as testbed e.g. for models (from the HESS website). The current manuscript is perhaps in-between.

1. We agree that there are many different studies reporting changes in mean flow and snow- to rain- dominated regime changes in the FRB. However, most of these studies have examined future hydroclimatic changes on monthly and annual time scale focusing spring and summer seasons. By contrast, there has been relatively little work quantifying cold season, daily time scale flow variability and regime transitions in the FRB. These research goals require the use of a large model ensemble, an effective downscaling and bias-correction method (BCCAQ2) that can account variability at daily time scale, and a robust snowmelt detection algorithm. Furthermore, our determination of snowmelt-dominant categories carried out at fine spatial scale, is an original contribution in a hydroclimatic modelling context for any basin worldwide to study projected runoff regime transition. This study is therefore not a routine effort and represents a significant advance over what has appeared in the published literature. Nevertheless, we are strongly motivated by all the Reviewers' comments to better emphasize the novel methodology and key research results of this study in the revised manuscript.

Regarding the Reviewer's comment on "what knowledge gain to transfer to other regions", we agree that we have not paid sufficient attention to what this particular regional study can teach us about other similar regions in the world. As mentioned in our response to the other reviewers, the specific physical setting of the FRB can teach us a great deal about hydroclimatic change in a mid-latitude mountainous basin with strong maritime influences. In our revised manuscript, we better distinguish projected changes in the FRB that are fairly universal from those that are case-specific.

2. A symptomatic indicator is the start of Section 5 "..overall question...how...precipitation phase and variability will modulate the FRB's runoff variability and flow regimes". Instead of this case study view, the science question should be how cold climate hydrology transitions to temperate climate hydrology - the FRM just happens to be considered the case that is used for illustration. However, with the running model at hand and gauging from the responses given already there is potential to focus on a particular process or phenomenon that is not yet well understood and is still specific to cold regions transitioning to temperate climate.

2. Thank you for providing this comment on the scientific focus of our study. While our geographic region of focus is the FRB, we have made clear in the revised manuscript that the overall context of the work is indeed just the type of hydrologic transition that the Reviewer

identifies. We agree with the Reviewer that the application of the CMIP5-VIC ensemble over the FRB specifically permits us to make a detailed analysis of the processes responsible for this transition.

3. Some of the analyses on the variability and pulses etc. that are presented here stand out and may provide a nice starting point. They are the ones that could be made the sole focus, analysed more specifically and quantitatively to make this an original contribution specifically dealing with features of the transition from seasonal snow to more rainfall-runoff dominated flow dynamics. It would have been very interesting, for example, to see the analysis on the daily to weekly variability expanded more systematically to scale and quantities - e.g. will this cause more floods? The rather abstract mm values could be interpreted within exceedance probabilities or so to make sense of them. This should not only be discussed as a by-product but analysed and demonstrated. Such a focus would require a thorough analysis and discussion of how the downscaling and bias-correction affect the results - are they able to reproduce and project daily to weekly joint warm and moist events in winter such as for example the atmospheric rivers that are mentioned? I am a little skeptic how an analogues procedure will still be concurrent with the climate model projection trends at daily scale then. But this could be analysed.

3. The Reviewer should be made aware that the present work is the first of two papers analyzing the same set of CMIP5-VIC simulations. This point is now mentioned explicitly in Section 2 of the revised manuscript. The present paper deals with features of the transition from seasonal snow to a hybrid snowmelt/rainfall runoff regime, with special attention to the changes in snowmelt dynamics and daily runoff variability. Our upcoming paper (Curry et al., in preparation) addresses the point raised by the Reviewer, namely the consequences of these changes for river discharge at the main outlet to the FRB at Hope, BC, including a formal flood frequency (extreme value) analysis for the 21st century. The methodological question raised by the Reviewer "how the downscaling and bias-correction affect the extreme value analysis" is also addressed in this forthcoming work.

As discussed in our response to the other reviewers, in the revised manuscript we have conducted additional analysis to address the issue raised by the Reviewer, namely "features of the transition from seasonal snow to more rainfall-runoff dominated flow dynamics". The new analysis has allowed us to determine the rate of change of runoff variability and mean with respect to the amount of warming in the Coast Mountains, Interior Plateau and Rocky Mountains subregions of the FRB. We also employed a multivariate linear regression model to decompose the cold season runoff monthly variability into separate contributions from precipitation and air temperature. This procedure allows us to determine the contribution of each key climatic driver to the simulated runoff variability at individual gridcells. These additional analyses, combined with existing results in the paper addressing changes in snow dominant categories and daily runoff variability, both heighten the impact of the present work and provide a foundation for our forthcoming work on streamflow extremes in the FRB.

4. Another option may indeed be to focus on key features of river flow variability that are important for salmon.

4. As discussed in the Response to Reviewer #2, point 1, the question of impacts on the salmon population is beyond the scope of this study. However, in the revised manuscript we do mention possible links between hydrological changes in the FRB and salmon migration for the benefit of future researchers.

5. In any case, a clear focus and message will be required that will make readers remember more than 'again a general shift from snow to more rain dominated regime in winter'. The necessary revisions may be too substantial to be considered the same paper, but it could perhaps be resubmitted with a more focused title and content to the same Special Issue.

5. As mentioned in the response to Reviewers 1 & 2, the Conclusion of our revised manuscript now provides a clear take-home message that better highlights the novel aspects of our work. The additional analysis we have conducted not only provides readers with a clearer notion of the mechanisms behind hydrologic change in the FRB, but also points out commonalities with other mid-latitude basins that are likely susceptible to the same climatic drivers.

<u>Minor comments:</u>

6. Figure 7 - good start of this and illustrative, but is the absolute amount of the variability (scale) really so relevant? For readers who don't know the river.

The units for all the three panels in Figure 7 are kept same to keep results consistent and comparable. The values in panel b and c are daily and 7-day standard deviations. Same units allow readers to clearly see changes in variability, which would be obscured using the Coefficient of Variation (CV) with a changing mean.

7. Figure 6 - right panels should perhaps use another color scheme. I found the same to be confusing.

In our revised manuscript, we have changed the color scheme for all three right panels in Figure 6.