Authors' reply to interactive comment posted by Anonymous Referee #1 regarding the HESS Discussion paper "Simulating cold-region hydrology in an intensively drained agricultural watershed in Manitoba, Canada, using the Cold Regions Hydrological Model"

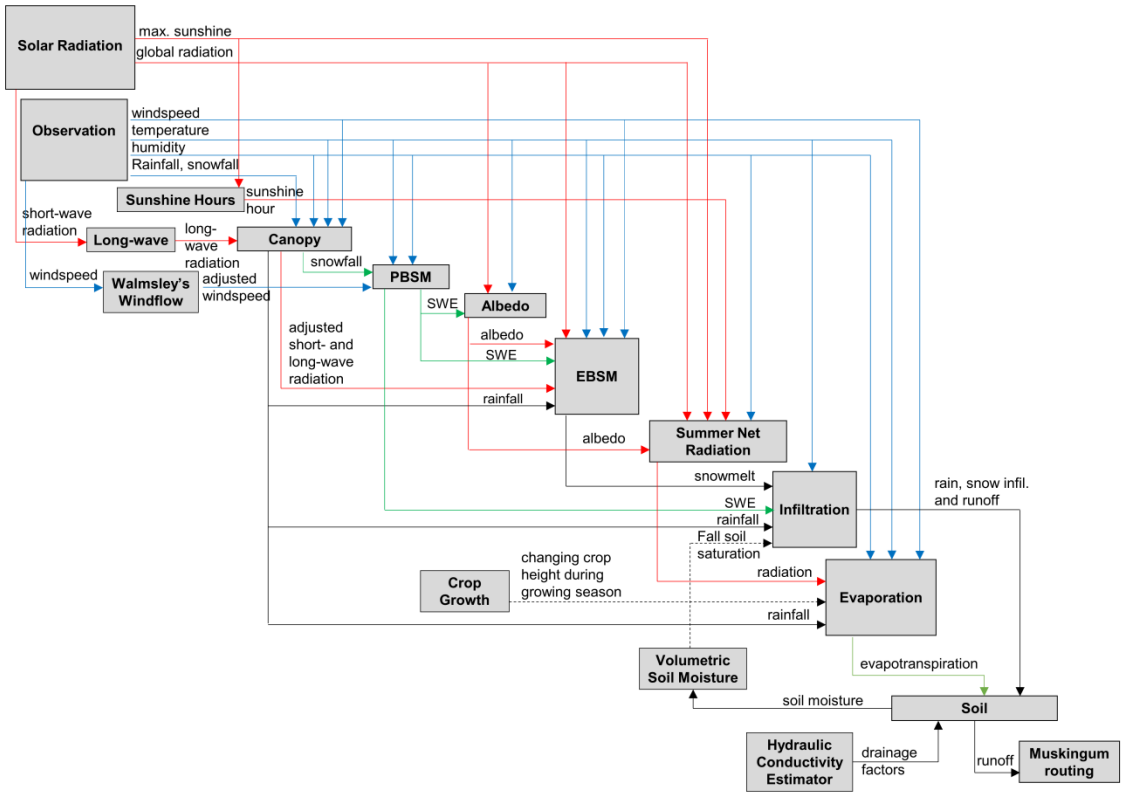
Dear Reviewer,

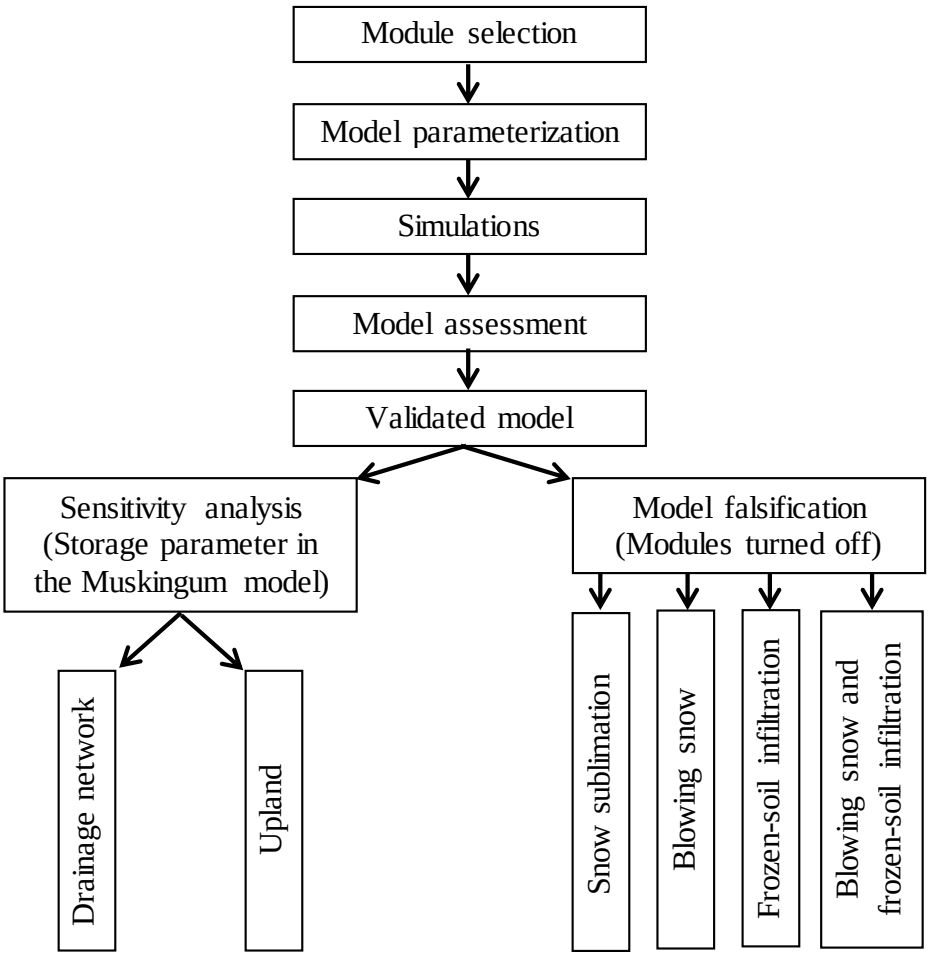
We appreciate your comments and suggestions to strengthen the manuscript. Please find below the answers to your comments.

General comments

Reviewer: *The manuscript could be improved by providing clearer description of the modeling framework. Also, Discussion section may need to be revised to be more organized. My suggestion would be major revision.*

Authors: Model framework and a process chart describing the analysis workflow have been included in the supplemental material of the revised manuscript as per reviewers' suggestion. The discussion section has also been modified to improve flow.





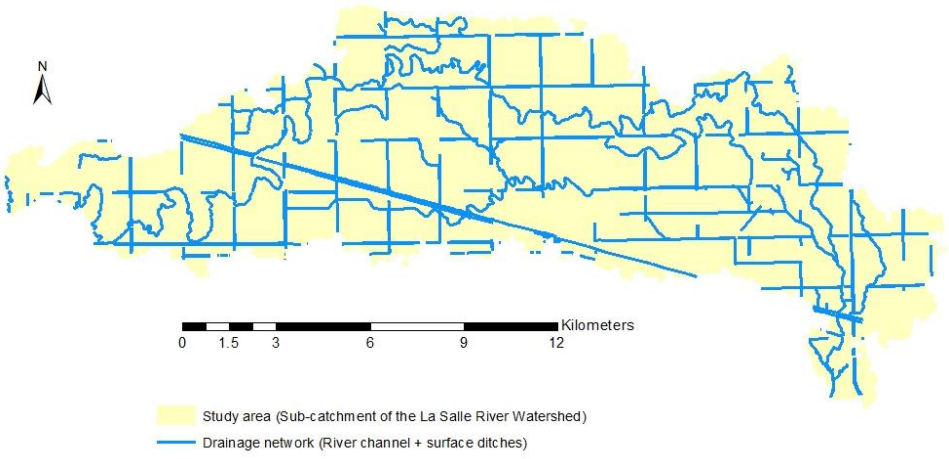

Specific comments

1. Reviewer: *Line 120-121: The study area is a sub-catchment of the La Salle River watershed, so it is shown in Fig. 1b right? Maybe the authors can revise this sentence to make it clearer. Also, what is the importance of this sub-catchment to the watershed? Is data coverage limited in other sub-catchments (in other words, why not study the whole watershed)?.*
   Authors: Only the sub-catchment was used in the present study due to weather data availability in an hourly time-step, which was required to force some physically-based processes in CRHM, such as the energy balance snowmelt model. This information has been included in the revised manuscript.

2. Reviewer: *Line 144: The stream gauge is located 80 meters downstream of a dam. As a result, streamflow will be significantly affected by human operations of the dam. The authors may need to explain how they introduce anthropogenic impacts into their modeling framework and how they evaluate their model performance from this perspective.*

Authors: During the time period of study the operation of the dam was used to maintain a minimum water level during the summer months (i.e. no stop-logs are added or removed). Therefore, stream discharge is not significantly affected by human operations of the dam. This information has been added to the revised manuscript.

3. Reviewer: *Line 174: DEM of 90 m resolution is a little bit coarse for modeling a small subcatchment of 189 km2. Based on Fig. 1, the watercourse is not very detailed. It would be helpful if the authors can show the drainage network they generated and used in the modeling framework.*
   Authors: The best available DEM was used at the time of model setup. However, besides the watercourse, and maybe even more influential for stream discharge, is the presence of surface drainage ditches (thus the title of the manuscript). A major effort was made in order to incorporate surface drainage ditches into the representation of the drainage network used in this study. As detailed in the manuscript, the DEM-derived stream network was augmented using recent aerial photography, LiDAR, and a ground based inventory of ditches and culverts, resulting in a much more detailed drainage network. This detailed network is shown in Fig. 1b. For a clear assessment of the drainage network, a supplemental figure has been added to show in more detail the drainage ditches included as a HRU in CRHM and used in the calculation of parameters such as distance from upland HRUs to stream. This figure is reproduced below for convenience.

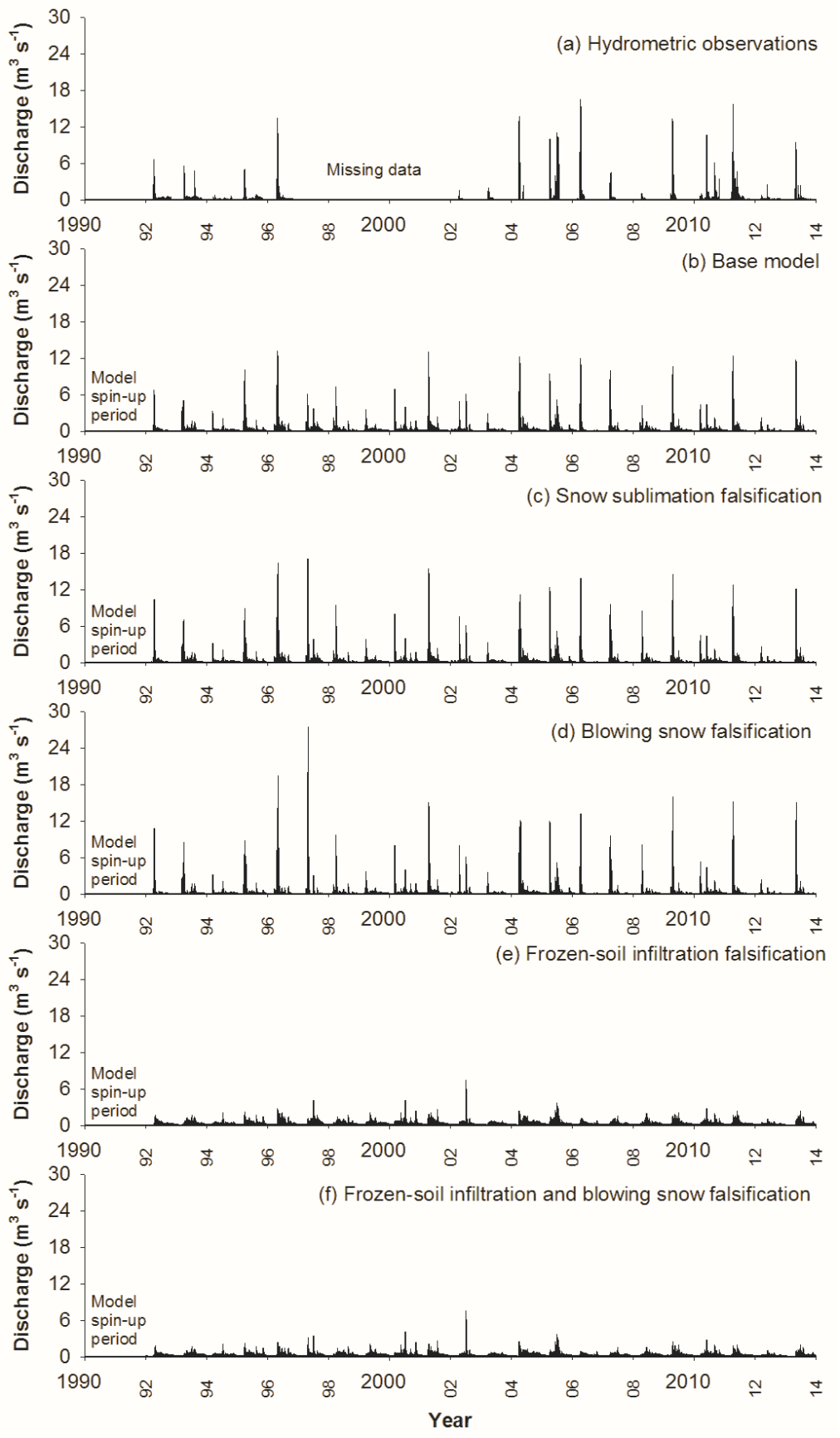



4. Reviewer: *Line 226-232: The model description of CRHM is not clear enough. I understand that there are references of this model, but to make this manuscript a standalone paper, it would be helpful if the authors can provide more information about the main model. Based on description, it seems the model is coupled with SWAT. It would be helpful if the authors can provide a flowchart to explain how their modeling framework works.*

Authors: Some detail was excluded from the original manuscript to reduce text length of the manuscript and because the model detail had been previously described in Pomeroy et al. (2007). The text has been altered to clarify that CRHM was not coupled with SWAT, but the watershed delineation and HRU definition from a previous SWAT model were used to setup CRHM in the present exercise. A flowchart showing the model framework and the workflow used in the analysis have been added as supplemental material in the revised manuscript. The figures have been reproduced in the reply to the general comments above.

5. Reviewer: *Line 434: Typo. Change "asses" to "assess".*
   Authors: Typo corrected.

6. Reviewer: *Figure 11: This figure may need to be revised. I assume there are both simulation and observation lines, but it is hard to distinguish them from each other. Also, legends are missing.*
   Authors: Only one time series is shown per panel. A 6$^{th}$ panel showing the observed hydrograph has been added to increase clarity (figure included below for convenience). This figure is meant for a visual assessment of the overall effect of different model falsifications on stream discharge.


(a) Hydrometric observations
Missing data
(b) Base model
(c) Snow sublimation falsification
(d) Blowing snow falsification
(e) Frozen-soil infiltration falsification
(f) Frozen-soil infiltration and blowing snow falsification
Model spin-up period
Discharge (m3 s-1)
0
6
12
18
24
30
1990
92
94
96
98
2000
02
04
06
08
2010
12
14
Year

7. Reviewer: *Discussion section is long and hard to read. Maybe the author can separate the section into several sub-sections with different topics. Also, the writing needs to be revised to be more concise and focused.*
   Authors: The Discussion section has been separated in sub-sections and some discussion has been removed from the revised manuscript, as suggested.

8. Reviewer: *Line 555-560: The authors discussed the poor model performance in dry years. It could be helpful to provide some references about hydrologic modeling performance in cold regions from previous studies, showing advantages or improvements of the model used in this study.*
   Authors: A new sub-section in the Discussion section of the revised manuscript deals specifically with dry years. Two more studies conducted under drought conditions in the Canadian Prairies have been included and discussed (Fang and Pomeroy, 2008;Fang and Pomeroy, 2007).

References

Fang, X., and Pomeroy, J. W.: Snowmelt runoff sensitivity analysis to drought on the Canadian prairies, Hydrological Processes, 21, 2594-2609, 10.1002/hyp.6796, 2007.

Fang, X., and Pomeroy, J. W.: Drought impacts on Canadian prairie wetland snow hydrology, Hydrological Processes, 22, 2858-2873, 10.1002/hyp.7074, 2008.

Pomeroy, J. W., Gray, D. M., Brown, T., Hedstrom, N. R., Quinton, W. L., Granger, R. J., and Carey, S. K.: The cold regions hydrological model: a platform for basing process representation and model structure on physical evidence, Hydrological Processes, 21, 2650-2667, 10.1002/hyp.6787, 2007.