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Interactive comment

Interactive comment on "Assimilation of citizen science data in snowpack modeling using a new snow dataset: Community Snow Observations" *by* Ryan L. Crumley et al.

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DUE January 25th, 2021 Reviewer Comments and Responses

Reviewer #1:

The reviewer's comments are preceded by: Comment The authors responses are preceded by: Response

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Comment:

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Discussion paper

The article is interesting and innovative. The use of data measured by the community is a contribution to the simulation of snow distribution and a way of bringing the community closer to snow science and hydrology. The scientific quality of the article is good; however, the article could improve the analysis on some topics described below.

First, despite mentioning that the distribution of snow by the wind is important, the article does not present results or analysis in this regard. Snowmodel allows you to export the results of wind redistribution. Showing these results would be a contribution to the analysis and discussion.

Response:

SnowTran-3d does allow for variables to be exported for analysis, and these variables include: snow depth (m), saltation transport (m), suspension transport (m), sublimation (m), snow redistribution at the time step (m), summed sublimation (m), and summed blowing snow transport (m). During the calibration of SnowModel for the domain, before measurements were assimilated, we tested the results of SnowModel simulations with SnowTran-3d turned off and with SnowTran-3d turned on. These initial results showed that simulations using SnowTran-3d were consistently outperforming those without it, according to various calibration metrics at the Upper Tsaina SNOTEL location. At this point we determined that we should use SnowTran-3d for all simulations, both for the no assimilation case and the CSO assimilation case.

The wind related variables exported by SnowTran-3d would not be altered by the data assimilation process, since SnowAssim only modifies the precipitation inputs and snowmelt factors, not the wind speed fields or wind direction fields. Additionally, the snow depth variable was exported and analyzed extensively throughout the manuscript, playing a key role in our methodology, validation, and final results. The authors believe that our analysis of the snow depth distributions in the manuscript are sufficient and the decision to use SnowTran-3d as a parameter tested in the calibration was prudent.

Comment:

Also, a comparison simulation without wind redistribution (Windtrans off) would be a way to measure the improvement of using this tool.

Response:

See the answer above regarding the calibration workflow when we tested results with and without SnowTran-3d. See also Appendix A on line 605 which shows that SnowTran3d was tested before assimilation. The authors believe that any further exploration of the SnowTrand-3d sub-model results lies outside the scope of this manuscript, as our research questions are not directly related to the effects of CSO measurement assimilation on wind transportation processes.

Comment:

Secondly, the assimilation in Snowmodel is highly dependent on swe point location, in addition to timing. It is important to consider in the analysis where the data used are located. And if they agree in time and place with the validation dataset. If the SWE data used for assimilation are located close to the validation point. Logically the result will be very similar to the validation point measure since the model corrects the precipitation or fusion to obtain a value close to the given one. For this reason, it is important to know how close the CSO data is to the field work data. If these two data are very close in time and location it does not make sense to use the field work data for validation.

Response:

The authors agree that it is necessary to be aware of the location of the CSO measurements in space and time in comparison to the validation datasets location in space and time. We provide the following explanation to clarify the location and timing of the CSO measurements assimilated.

First, the time-series analysis validation metrics were quantified for all days of the water year in both years at the Upper Tsaina SNOTEL location. The CSO measurements that were assimilated in 2017 range in distance from 4.1 km to 30.5 km away from the SNOTEL station location. The CSO measurements that were assimilated in 2018 range in distance from 2.1 km to 17.4 km away from the SNOTEL station location. These distances mean the CSO measurements used in the assimilation do not coincide with the SNOTEL grid cell location and should be included in the section 6.1 time-series validation.

Secondly, the 2018 fieldwork measurements (co-located snow depth and SWE) were used to validate the model results with assimilation. As noted in lines 478-479 in section 6.3, "we separated those [2018 fieldwork] measurement sites used in the assimilation scheme from the validation set when creating Table 3." Due to this, we think the fieldwork measurements and analysis should be included in the section 6.3 fieldwork results.

Thirdly, the remote sensing datasets were collected on April 29th in 2017 and April 7th/8th in 2018. These validation datasets are essentially a spatial snapshot of snow depth from a single day in both water years. In water year 2017, there were a total of 9 CSO measurements submitted on April 29th, the same day as the remote sensing dataset collection. For the presented results in Section 6.2 from the highest performing (Best) simulation with assimilation and the median performing (Median) simulation with assimilation, none of these 9 CSO measurements from April 29th were used. For water year 2018, the remote sensing dataset was collected on April 8th and the measurements were not assimilated in time until at least April 15th (see the experimental design outlined in Section 5 lines 354 to 369 which states that we selected the CSO measurements for assimilation that were collected on or after April 15th of each water year). Due to all of these factors, the remote sensing dataset validation should be included in section 6.2.

Additionally, the remote sensing datasets are distinct, in both form and collection method, from the CSO measurements. All of the analysis in section 6.2 is aggregated to the entire spatial domain of the RS datasets, not at a single point like a CSO measurement location. This fact is why these datasets are important to include in the validation, because they can show the effects of assimilation throughout a complex and variable mountainous terrain.

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Comment:

Finally, the article should include a comparison between the data used: RS, CSO and field work data. The objective is to check if the data are consistent with each other and if they are very similar in time and location.

Response:

In our submitted manuscript, we did not find it necessary to include analysis comparing the remote sensing datasets, the CSO measurements, and the fieldwork measurements. This is primarily because there is not a single day of measurements that would work to make this comparison between all datasets.

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Comment:

Also, the article should include a comparison between the densities estimated to convert the CSO data to snow water equivalent and the densities measured in the field work.

Response:

The authors agree with the reviewer that comparing the SWE values measured at the 2018 fieldwork sites to the SWE values estimated by Hill et al. (2019) would add clarity to the results and quantify the uncertainty that is added when converting the CSO snow depth measurements to SWE. See the following sentences that will be added to section 6.3 Fieldwork Results:

“Additionally, we can use the co-located snow depth and SWE measurements at the fieldwork sites to quantify the uncertainty that is added to the model during the snow depth to SWE conversion. By converting the fieldwork snow depth values to SWE using the Hill et al. (2019) method, we can compare the measured SWE to the approximated SWE values. The fieldwork measurement RMSE in SWE is 10.5 cm and the Bias in SWE is 0.6 cm when using the Hill method for all fieldwork sites.”

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Comment:

Some specific comments:

1) Figure 1 and 3 should be next to each other or join them to be able to compare the distribution of the data used for assimilation and validation

Response:

The authors are amenable to combining figures 1 and 3 if the editor or the production design team thinks it’s a better use of space or would be easier for the readers to understand. We note that they include different types of data that are introduced in different sections of the manuscript, so keeping them separate may be easier for readers.

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Comment:

2) Point 3.2.5 Snow depth to snow water equivalent conversion. Add the uncertainty in the snow density estimation.

Response:

We changed the following sentence in section 3.2.5 of the submitted manuscript to include the bias and RMSE from Hill et al. 2019.

“Second, it was found to outperform other bulk density methods such as Sturm et al. (2010) and Jonas et al. (2009) when tested against a wide variety of snow pillow and snow course datasets, with an overall bias of 2 mm and RMSE in SWE of 6 cm (Hill et al., 2019).”

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Comment:

3) Point 6 why the Sugarloaf Mountain station is not used to validate the results?

Response:

We used temperature data from the Sugarloaf SNOTEL station to calculate local lapse rates for the calibration analysis. Since the station does not have snow water equivalence measurements (stated in line 256), we did not use the data for any other purpose. This point could be made more clearly, and we suggest adding the following sentence to the manuscript section 3.4.1.:

“The SLS station data was used to create local temperature lapse rates for the calibration and the UTS station data is used in the manuscript results section to create the SWE time series analysis.”

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Comment:

4) Point 6.2 The location or spatial distribution of CSO measurement used for the assimilation is as important as the number and should be and it should be analyzed here or elsewhere.

Response:

We specifically did not include the spatial distribution of CSO measurements in the research questions of this manuscript. In order to address questions about the spatial representativeness of CSO measurements, we think more extensive fieldwork measurement campaigns or coordinated CSO campaigns would be required. We think that taking regular measurements within a study area across 1) multiple elevational gradients, 2) a broad array of land cover types, 3) a representative sample of slope angles, and/or 4) a representative sample of aspects would help untangle these multiple landscape controls on the spatial distribution of the snowpack. The research design of the current study was not set up to incorporate this type of analysis, however we absolutely agree with the reviewer that this is an interesting and important question moving forward. We conducted some initial spatial analysis of the CSO measurement locations and metric ranking results, and this initial analysis was messy and complex. We note that the CSO modeling team has set up experiments in other locations in the continental U.S to address these various spatial distribution of CSO measurements questions. These include study areas where more measurements have been taken per water year and more SNOTEL stations exist for validation purposes.

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