

The Cryosphere Discuss., referee comment RC2
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Comment on tc-2021-225

Anonymous Referee #2

Referee comment on "Propagating information from snow observations with CrocO ensemble data assimilation system: a 10-years case study over a snow depth observation network" by Bertrand Cluzet et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2021-225-RC2>, 2021

Major comments

In the paper titled "Propagating information from snow observations with CrocO ensemble data assimilation system: a 10-years case study over a snow depth observation network" Bertrand Cluzet et al. assimilated snow depth observations from an in-situ network of 295 stations covering the French Alps, Pyrenees, and Andorra over the period 2009–2019. They attempted to demonstrate how in-situ observations of snow depth can help contain intermediate and large-scale modeling errors by means of data assimilation. However, while the results of snow depth data assimilation are closer to observations than the non-operational open-loop counterpart (open-loop), which does not use data assimilation, they are not as good as the operational deterministic snow cover modeling system (oper). It is natural that the results of snow depth data assimilation are better than those of open-loop, but it is necessary to show that snow data assimilation outperforms oper. Moreover, I believe that snow depth data assimilation not only improves the reproducibility of the same snow depth but also affects other parameters of the snow model such as snow water equivalent, snow density, snow surface temperature, and water and energy balances above the snow; hence, I would like to see the discussion on the impact and verification of these factors. The procedure of the data assimilation method is difficult to understand, especially the need to clarify the control variables and the analysis variables. Overall, the paper is not accepted in the current form and needs to be revised in accordance with the following comments. My main concerns are as follows:

(1) Although the method of data assimilation has already been published in papers such as Cluzet et al. (2020, 2021), I feel that it is necessary to describe the flowchart of data assimilation and to clarify what the control variables and analysis values are, so that the data assimilation method can be understood to some extent from this study independently. I feel that since there is a limit to the extent of explanation that can be

expressed only in text, I would really like to see a flowchart of data assimilation. I think that data assimilation can be corrected for other elements of the model using cross-covariance and error covariance with snow depth. It should be clarified whether snow depth is the only control variable. Furthermore, the authors conducted two types of experiments for data assimilation using particle filters, but I did not understand the difference between rlocal and klocal. Please explain this in detail

(2) I would like to see an explanation of the difference between Oper and open-loop as a reference. I would also like to see a more detailed explanation of the SAFRAN massif, with expanded abbreviation, and the convincing data provided by SAFRAN to the snow model.

(3) Advantage of data assimilation is that by assimilating snow depth data, the information is correlated to other factors such as snow water content and precipitation, which will improve the accuracy of model estimation other than direct snow depth improvement. If you have observational data on snow density, snow surface temperature and snow water content, please add a discussion on whether the assimilation of snow depth affects other model parameters.

(4) I feel that there is a lack of literature in the introduction. As a pioneering work in satellite data assimilation, I feel it is necessary to mention the data assimilation study of MODIS snow cover and AMSR-E snow water content by Andreadis and Lettenmaier (2006).

Andreadis, K. M.; Lettenmaier, D. P. Assimilating remotely sensed snow observations into a macroscale hydrology model. *Adv. Water Resour.* 2006, 29, 872–886.

Line 42–43: "Their potential to improve local simulations is unambiguous as demonstrated by many studies." After this sentence, please consider adding references such as Liston and Heimstra (2008) and Suzuki et al. (2015).

Liston, G. E.; Hiemstra, C. A. Simple data assimilation system for complex snow distributions (SnowAssim) *J. Hydrometeorol.* **2008**, 9, 989–1004.

Suzuki, K.; Liston, G. E.; Matsuo, K. Estimation of continental-basin-scale sublimation in the Lena River Basin, Siberia. *Adv. Meteorol.* **2015**, 2015.

Line 61–62: "These variants are used in a localised framework, in which only observations coming from a certain radius around the considered location are assimilated." After this, please consider adding references such as Zupanski (2021).

Zupanski, M. The Maximum Likelihood Ensemble Filter with State Space Localization. *Mon. Weather Rev.* 2021.

(5) Line 389: There are two reasons why the operational run could not be beaten by the assimilation in terms of RMSE.

Line 454–455: In other words: the assimilation can not beat the open-loop in the most densely observed areas (e.g. in the Northern Alps, 455 where the observation density is similar to the studies of Magnusson et al. (2014) and Winstral et al. (2019)) because the open-loop performance is already high there.

In the above two sentences, the verb "beat" is used, but I feel it is not appropriate. I would like to see this correction with more appropriate words.

Line 267–269: The text needs to be revised and made more readable.

(6) The results of data assimilation in Fig. 6 should be shown in the form of Table 1 with numerical values. Moreover, there is no data for oper in RMSE and SS in Fig. 6; please resolve this.