Responses to Reviewer Comments for Manuscript EGUSPHERE-2023-2604

Responses to Anonymous Referee #1

Addressed Comments for Publication to

The Cryosphere

by

Ange Haddjeri,

Matthieu Baron,

Matthieu Lafaysse,

Louis Le Toumelin,

César Deschamps-Berger,

Vincent Vionnet,

Simon Gascoin,

Matthieu Vernay,

and Marie Dumont

Dear Masashi Niwano,

Please find enclosed the detailed responses to Anonymous Referee #1 for the manuscript entitled ‘Exploring the sensitivity to precipitation, blowing snow, and horizontal resolution of the spatial distribution of simulated snow cover’ with manuscript number EGUSPHERE-2023-2604. We would like to thank you and the reviewers for the valuable comments which help improving the quality of our manuscript. In this revision, we have carefully addressed the reviewers’ comments. A summary of the main modifications and a detailed point-by-point response to the comments from Reviewer #1 (following the reviewers’ order in the decision letter) are given below.

Sincerely,

Ange HADDJERI,
Matthieu BARON,
Matthieu LAFAYSSE,
Louis LE TOUMELIN,
César DESCHAMPS-BERGER,
Vincent VIONNET,
Simon GASCOIN,
Matthieu VERNAY,
and Marie DUMONT

Note: To enhance the legibility of this response letter, all the editor’s and reviewers’ comments are typeset in boxes. Rephrased or added sentences are typeset in color. The respective parts in the manuscript are highlighted to indicate changes.

Authors' Response to Reviewer 1

General Comments. This paper has carried out the validation of simulated snow cover distribution in alpine areas using a combination of state-of-the-art techniques. Also, some concerns I had while reading are already explained in the discussion chapter. In my opinion, there are no problems with publishing the paper in TC. I have summarized some of the concerns in the minor comments below. This is not a requirement for acceptance. Please use them as a reference to improve the content in the revised draft.

Response:

Thank you for your positive assessment of our manuscript and your recommendation for publication in TC. We appreciate your time and valuable feedback.

We carefully considered the minor comments you have outlined and addressed them bellow.

Authors' Response to minor comments

Comment 1

Fig. 5: In case of "with transport", there are some areas with locally large snow depths. This is probably a depression or downwind slope, but are these localized areas of high snow cover consistent with those observed by the satellite? If it has also been confirmed at visual level or already verified by Baron et al (2023) etc., it would be good to have a mention of this. In section 4.3.3 (L626-635), it is written that the simulation shows a larger snow depth in the depression, it would be good to write whether the large snow depth area is consistent with the satellite as well.

Response: Thank you for the comment.

The fair localization of snow accumulation is demonstrated in Sect.5.6 of Baron et al., 2024 using Pearson correlation. First, the analysis of our simulations' spatial patterns shows that the accumulation zones correspond to the areas sheltered from the wind and ablation zones to the most exposed zones, in line with the theory. The main modeled accumulation zones are well located in high-observed snow height areas (e.g. Figure 4). However, the reciprocal is not exact: many areas of high observed snow accumulation are not present in the simulations. Indeed, the 2 m high-resolution image shows a complexity of spatial variability (mainly caused by the high-resolution topography) that is only approached in the 250 m simulation. Even in the Pléiades observation aggregated to 250 m, the impact of the sub-mesh topography can be felt and these sub-mesh accumulation zones are not simulated. (see discussion 6.6)

We added a sentence describing the consistency between simulated snow accumulation and the observation. We also added observation to simulations scatter plots (Fig. 14) and Pearson correlation coefficient (Tables 1 & 2) which helps demonstrate this consistency.

Added Fig. 14, Table 1 & 2

L299-L302 It can be observed that the primary areas of model snow accumulation are located in regions of high observed snow height. However, the opposite is not true, many areas with high observed snow accumulation are not present in the simulations. Additional maps for the 13 May 2019 comparing resolutions can be found in Appendix Fig. C1

Comment 2

3.1.1 Figure 6: Figure 6 shows the results of the bias and other validation results. Also, I thought it would be easier to visualize the degree of agreement if there was a scatter diagram from the snow depth data at each location, with the snow depth from the satellite on the horizontal axis and the simulation snow depth on the vertical axis.

Response: Thank you for the comment.

Initially, we chose to use the graphs summarised in Figs. 6, 8, and 10 to get straight to the point and reduce the number of graphs. At the request of both reviewers, we have added the different scatter plots for the Pléiades observation in Fig. 14, E1, E2, E3. Those figures allow for a visualization of the degree of pixel-to-pixel agreement between observations and simulations. Additionally, quantification of this agreement is added using Pearson correlation coefficients computed in Tables 1 and 2. It is important to remember that direct pixel-to-pixel evaluations are extremely challenging from this kind of spatialized model and are generally not promoted in the literature (Vionnet et al., 2021; Sharma, Gerber and Lehning, 2021; Quéno et al., 2023). However, we agree that these diagnostics help to provide a fair overview of the limitations of currently available snow modeling systems.

Added scatter plot Fig. 14, E1, E2, E3, Tables 1 and 2 and discussion of Pearson correlation coefficient.

Comment 3

L392-395 As the result of Figure 9, the difference between years states that 2018-19 showed wide spatial variability, but what are the differences between these two years in terms of characteristics of the weather conditions? For example, was it a windier winter in 2018-19?

Response: Thank you for the comment.

The S2M (SAFRAN–SURFEX/ISBA–Crocus–MEPRA) meteorological and snow cover reanalysis from 1958 to 2021 (Vernay et al., 2022) can be used to estimate the 3 simulation years chosen (2017-2018, 2018-2019, 2019-2020) in term of inter-annual variability. The reanalysis shows that the 3 years chosen capture most of the inter-annual variability found in air temperature, total precipitation, and fraction of solid precipitation. Looking at the yearly solid precipitation of the Safran forcing shows the 2018-2019 season was low on solid precipitation with 21% less snowfall compared to 2017-2018. Wind speed is not evaluated in this study but we can compare the wind statistics for the 3 years. In Table 1 and Figure 1 we can see different statistics of the wind used in our simulations. For the 3 years, the mean, median, and 10% quantile are similar. On the 90 and 99% quantile, we see the 2017-2018 and 2018-2019 years are similar. The 2019-2020 values are slightly higher so we can say the 2019-2020 year was a winder year, not 2018-2019. The exact causes of the increase in variance in Fig. 9 in 2018-2019 not precisely determined by our analysis is not increased wind. We note that we observe an earlier SMOD for this season at all altitude bands, consistent with a smaller snow accumulation and a smaller amount of solid precipitations.

L426-L429 Analysis of wind speed and direction over the three simulation years indicates that the values remained consistent. Examination of the yearly solid precipitation of the SAFRAN forcing reveals that the 2018-2019 season had 21% less snowfall compared to 2017-2018. This result is consistent with a smaller amount of solid precipitation leading to a reduced amount of snow accumulation and the observed earlier SMOD for the 2018-2019 snow season.

	2017-2018	2018-2019	2019-2020
Mean wind speed (m/s)	1.86	1.88	1.93
Median wind speed (m/s)	1.36	1.37	1.37
Quantile 10% (m/s)	0.43	0.43	0.42
Quantile 90% (m/s)	3.94	4.01	4.14
Quantile 99% (m/s)	7.71	7.72	8.38

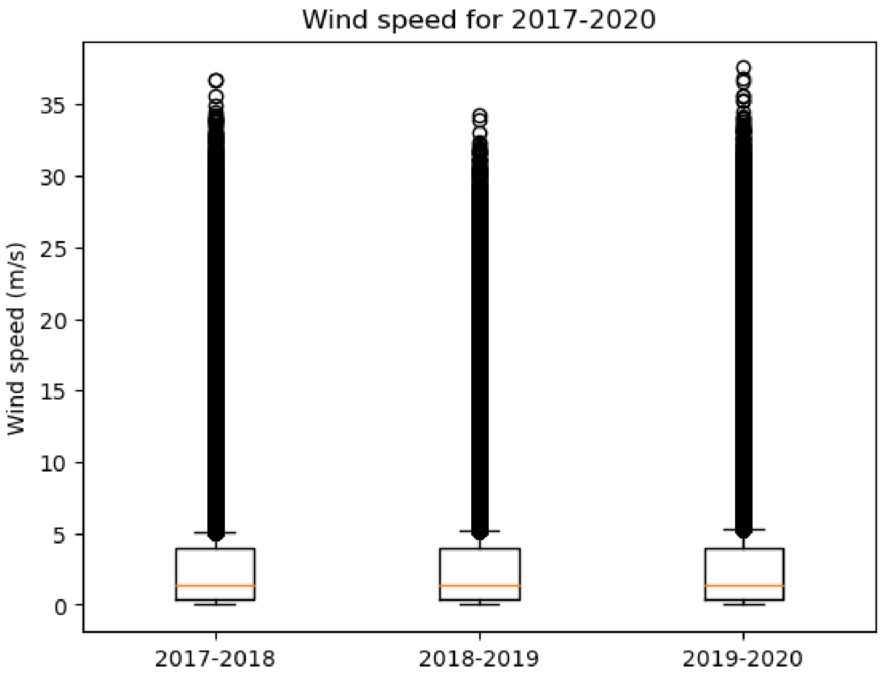

Figure 1: Illustration of the inter-annual wind speed variability for the wind used in our simulations.

Comment 4

Fig. 12: It compares simulation data and satellite data in 2017-2018 and 2018-2019. Comparing these figures, 2017-2018 (a-c) and 2018-2019 (d-f) seems to be the same figure, is it possible that you have misplaced the figures?

Response: Thank you for the comment.

We agree with this comment and apologize for this mistake. We therefore corrected the figure in the new version of the manuscript and checked references to Figure 12 in the manuscript.

The upper panel of Figure 12 (a-b-c) now rightly corresponds to the 2017-2018 year.

References

[1] M. Baron et al. ‘SnowPappus v1.0, a blowing-snow model for large-scale applications of the Crocus snow scheme’. In: *Geoscientific Model Development* 17.3 (2024), pp. 1297–1326.

DOI: `10.5194/gmd-17-1297-2024`. URL: `https://gmd.copernicus.org/articles/17/1297/2024/`.

[2] L. Quéno et al. ‘Snow redistribution in an intermediate-complexity snow hydrology modelling framework’. In: *EGUsphere* 2023 (2023), pp. 1–32. DOI: `10.5194/egusphere-2023-2071`. URL: `https://egusphere.copernicus.org/preprints/2023/egusphere-2023-2071/`.

[3] V. Sharma, F. Gerber and M. Lehning. ‘Introducing CRYOWRF v1.0: Multiscale atmospheric flow simulations with advanced snow cover modelling’. In: *Geoscientific Model Development Discussions* 2021 (2021), pp. 1–46. DOI: `10.5194/gmd-2021-231`. URL: `https://gmd.copernicus.org/preprints/gmd-2021-231/`.

[4] M. Vernay et al. ‘The S2M meteorological and snow cover reanalysis over the French mountainous areas: description and evaluation (1958–2021)’. In: *Earth System Science Data* 14.4 (2022), pp. 1707–1733. DOI: `10.5194/essd-14-1707-2022`. URL: `https://essd.copernicus.org/articles/14/1707/2022/`.

[5] V. Vionnet et al. ‘Multi-scale snowdrift-permitting modelling of mountain snowpack’. In: *The Cryosphere* 15.2 (2021), pp. 743–769. DOI: `10.5194/tc-15-743-2021`. URL: `https://tc.copernicus.org/articles/15/743/2021/`.