

Reply to R3, Anonymous Referee #3

Brief communication: delivering a Digital-Twin-ready snow reanalysis presents a snow water equivalent data product based on satellite observations and snow modelling with a horizontal grid spacing of 1 km and daily temporal resolution. The product is introduced as a contribution to a digital twin of the earth system, intended to support decision makers in water management and risk assessment.

The topic is highly relevant and timely, and the work will undoubtedly be appreciated by both the scientific community and the readership of The Cryosphere. The manuscript is well-written, with a clear presentation of methods, results and discussion. However, there are several aspects that should be addressed to further strengthen the work before it can be considered for publication in The Cryosphere.

Public discussion: We thank R3 for the positive assessment of our work and for the constructive comments. Addressing the points raised below will help us better clarify the scope, interpretation, and limitations of the proposed framework.

My main concern is that the manuscript lacks a reference dataset in the validation. Including a dataset such as ERA5-Land or perhaps the “operational applications of S3M” would greatly enhance the robustness of the validation and strengthen the overall study. Additionally, I am not entirely convinced that the DA_C-SNOW outperforms the open loop based on the results presented in Figure 3 (see comments on L93 and Figure 3).

Public discussion: We thank the Reviewer for this suggestion. We agree that ERA5-Land would provide useful complementary context. However, its spatial resolution of about 9 km is substantially coarser than the 1 km resolution of DTE-SNOW, which limits its suitability as a quantitative benchmark over complex mountain terrain without a dedicated treatment of scale mismatch and spatial representativeness. Given the very limited space available in a Brief Communication, such an intercomparison is beyond the scope of the present manuscript. We will nevertheless clarify this point in the Discussion and better position DTE-SNOW relative to ERA5-Land and other existing snow reanalyses.

Regarding the comparison between open-loop and DA C-SNOW simulations, we refer to our response below, where this point is addressed in more detail.

L26: To me it is not clear what it means that the product is digital-twin-ready. Is there any criteria for this?

Public discussion: Thanks for this comment. In the manuscript, we use this term to indicate that the framework has been designed with characteristics that facilitate its integration within a Digital Twin environment, including spatially explicit and temporally continuous simulations, use of Earth-observation-based forcing and data assimilation, as well as computational scalability over large domains. We will revise the Introduction to explicitly clarify the meaning of this terminology and the characteristics of DTE-SNOW that motivate its use.

L49: The product is presented as it can provide global coverage, however, the use of geostationary MSG data excludes high latitudes, this should be mentioned in the manuscript.

Public discussion: We will revise the manuscript to explicitly mention the limitation associated with MSG coverage and to qualify statements regarding global applicability accordingly.

L90: The authors argue that missing representations of small scale processes occur but have minor impact on the catchment scale. I assume the high spatial resolution of the product has some benefits also on the catchment scale, can this be clarified?

Public discussion: We agree with the Reviewer. Our intended point was that some sub-grid processes remain unresolved even at 1 km, while their effects may partly average out when quantities are integrated over large catchments. This does not imply that spatial resolution is unimportant at the catchment scale. We will revise this passage to better clarify the distinction and the benefits provided by the 1 km resolution.

L93: (DA_ C-SNOW) has whitespace.

Public discussion: We thank the Reviewer for pointing this out. We will correct the typo to “DA_C-SNOW”.

L98: This paragraph describes average errors (bias) based on Figure 3. The figure shows the distribution of the errors which is very good. I miss the description of this information in the text as the spread in the data seems to be very large. I think the errors indicated by boxes and whiskers in Figure 3b reveal significant challenges with the data quality which is not reflected by the bias only.

Public discussion: We agree with the Reviewer that mean bias alone provides only a partial description of model performance and that the spread of the errors shown in Figure 3 contains important additional information. We will expand the Results section to explicitly discuss the distribution and variability of the errors.

Furthermore, Figure 3a suggests that most of the data points included in the verification never have snow in either observations or the products. Would it make sense to filter the data to only include points that are “relevant”, e.g. points that have snow at least once in one of the sources?

Public discussion: We agree and will include this analysis.

Figure 3: Legend says “C-SNOW”, but the caption (and in text) suggests it is “DA_C-SNOW”. Is the figure showing satellite product (C-SNOW) or assimilated (DA_C-SNOW)?

Public discussion: We thank the Reviewer for noticing this inconsistency. The figure shows the model simulation obtained by assimilating C-SNOW retrievals, i.e. DA_C-SNOW, rather than the standalone C-SNOW satellite product. We will correct the legend so that the terminology is consistent between the figure, caption, and main text.