Review of: High-Resolution Snow Water Equivalent Estimation: A Data-Driven Method for Localized Downscaling of Climate Data, Zakeri et al., EGUsphere, 2024.

General comment

This study by Zakeri et al. presents a method for downscaling Snow Water Equivalent (SWE) to 500 m, from a low resolution SWE dataset and low resolution climate reanalysis data. The model is trained using a high-resolution SWE dataset (SWE reanalysis from UCLA) and low resolution climate data. The downscaling algorithm uses a K-nearest neighbors method, for which parameters are determined through sensitivity analysis and optimization. Results are shown in two mountainous regions of the Western United States, in California and Colorado, and compared to other SWE spatial datasets.

The paper is interesting for the snow and hydrology community as it offers a new method to produce useful spatial SWE datasets over large areas, without using physical modelling of the snowpack which can be computationally expensive. The method is quite clearly exposed.

However, the paper generally lacks a solid discussion of the results. Results and metrics of comparison are exposed in the result section but are not further discussed since the Discussion and Conclusion section is more a summary. A dedicated Discussion section would be welcome, in particular to convince the reader of the quality of the evaluated method against other methods, provide more physically-based explanations of differences (e.g. can the chosen method explain certain biases?), provide a critical point of view on the benefits and limitations of the method, etc.

Specific comments

1. Introduction

Bales et al. (2006) is cited three times (l. 33), more references (particularly more recent ones) could be used in the beginning of the introduction. You could also provide a few more references about physically-based snow models (l. 34).

l. 61: specify “spatial snow patterns” (or do you also mean temporal patterns?)

2. Methodology

l. 85-86: “physical models are computationally expensive”. This assertion is not true by itself, see several recent publications where physical snow models are being applied over large domains, e.g. Mower et al. (2024). Please specify in a few words what makes them too computationally expensive for the application (domain, resolution, solved processes...?), or what computational benefit your method offers.

l. 92: “climatic variables”. Perhaps rather say “meteorological variables”.

l. 94-95: “not subject to significant temporal variations within the specified regions”. Note that terrain shading depends on the sun position, so varies throughout the year.

l. 97: “SWE is also affected by conditions in the preceding periods”. This sentence is a bit unclear: do you mean SWE conditions? Meteorological conditions? Please clarify "preceding periods" too.

l. 98-99: “These intervals consider climate variables such as minimum temperature, maximum temperature, precipitation, and surface downwelling shortwave radiation”. The use of “such as” makes it unclear whether it is an exhaustive list of considered variables. This section needs more justification of why and how these specific variables were chosen, and why other meteorological variables were discarded.

L. 143: The reference HR-SWE is not an actual "observation", so please simply use reference instead of observation.

l. 147: please provide the units (days?).

3. Study Areas, Datasets, and Parameters

Fig. 2: Maybe a better colour than blue can be chosen for visibility of the numbers on the map.

Section 3.1: you could add a few words on the snow climatology of these two regions.

l. 175: A bit more details (one or two sentences) on what this dataset is based would be appreciated for the reader’s understanding.

l. 180: Please don't use "such as" if it is the exhaustive list of considered variables.

l. 227-228: it would be interesting to discuss the relative weights of each variables from a physical perspective.

4. Evaluation Approach

l. 240: Please stick to mm as SWE unit, which corresponds to the standard unit kg/m^2. Potentially m for high values, but cm introduces confusion.

l. 246-250, Table 3: It is probably unnecessary to define very common metrics like mean difference, correlation and RMSE.

5. Results

Why aren't in-situ SNOTEL SWE measurements not shown? Metrics of comparison to these point measurements could be presented and compared to metrics of the other products.

See the general comment about a more in-depth discussion of the results.

References

Mower, R., Gutmann, E. D., Liston, G. E., Lundquist, J., and Rasmussen, S.: Parallel SnowModel (v1.0): a parallel implementation of a distributed snow-evolution modeling system (SnowModel), Geosci. Model Dev., 17, 4135–4154, https://doi.org/10.5194/gmd-17-4135-2024, 2024.