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Interactive comment on "A statistical approach to refining snow water equivalent climatologies in Alpine terrain" *by* S. Jörg-Hess et al.

Anonymous Referee #3

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The authors present a procedure to create gridded observational SWE datasets for a time series in the climatology range. The set of methods includes the conversion of measured values of snow depths to SWE, the spatial interpolation of these values using a DEM, and the refinement or correction of a dataset with low station density using a dataset with higher station density and a quantile mapping approach. The datasets are compared to each other and examples for their application are given.

General Comments

The presented work is generally of high value for the scientific community as long-term, high-quality gridded maps of SWE could be used in many applications e.g. atmospheric and hydrological modeling, or flood and avalanche forecasting. There is generally still a lack in spatially distributed observations of SWE or snow depths. The manuscript is

overall of very high quality and well structured and presented. The presented examples of applying the SWE datasets are well chosen and illustrate the need for such data. I first state some major points of criticism followed by some more specific suggestions and remarks. In total, I would classify the clarification of these issues as moderate revisions. However, as this is not a possible choice in this journal format, I will hit the "major revisions" button when submitting this review, but this should be seen as well doable "major" complements and corrections.

The following remarks are stated directly to the authors: When analyzing the resulting maps after applying the stated procedures, you use map203 as the reference dataset. You probably did this, because there is no other independent dataset available that you could use to validate your methods of interpolation and remapping. However, this is a bit unsatisfying, as the reader simply has no clue of the quality of the resulting maps. You tried to overcome this with the leave-one-out procedure, but this is still not enough for the gridded datasets. The measurement stations used as basis for the gridded fields are usually located in flat and accessible terrain and do not represent other locations such as very steep slopes, different expositions, wind-exposed ridges, ... (but these locations cover large parts of the presented terrain). The used interpolation method produces a nice elevation-dependent field with some regional differences induced by the horizontal distance weight, but cannot account for processes like e.g. wind-blown snow over crests, large northern oriented shaded faces vs. southern exposed terrain. On the one hand, the stations do not cover these areas, and on the other hand, the interpolation method does not account for additional terrain parameters such as slope or exposition. The problem might be a bit "smoothed out" with the presented 1 km resolution, but in the high alpine parts of the catchment, these processes and the corresponding variability play a role also at the presented scale. This leads me to the next remark: why or how did you confine the 1 km resolution? Have you also produced maps with a finer resolution and evaluated these results? These issues result in the following suggestions: It would be highly useful to have a reference dataset to validate the produced maps at least for some years or dates. This could be data of airborne

laser scans for a limited area within the catchment and of course limited to single years. You could also use snow coverage at certain dates derived from satellite-based sensors such as Landsat ETM+ and compare these to the coverage in your maps. Even if this approach is not able to validate the amounts of SWE, this would give you insights in the performance of your interpolation methods. At least point out these issues and uncertainties and try to elaborate further validation in future work.

I would highly appreciate if you would add a spatial validation of the presented distributed model PREVAH in section 5.1 besides the catchment averaged SWE. This could demonstrate impressively the value of the spatially distributed SWE maps!

Specific Comments

The following specific suggestions and comments are referenced in line numbers.

P. 4243, L. 15 What "long-range model forecasts" do you mean here? Hydrological models (discharge forecasts), atmospheric models (weather or climate simulations), or others? Please specify!

P. 4243, L. 25 Additionally, gridded SWE maps are of high value not only for hydrological model calibration, but to validate and develop these models. Particularly, distributed hydrological models with a focus on snow that include specific processes e.g. lateral snow transport would highly benefit from these validation datasets.

Such models are presented e.g. in these publications:

Garen, D.C., and D. Marks (2005), Spatially distributed energy balance snowmelt modelling in a mountainous river basin: Estimation of meteorological inputs and verification of model results, J. Hydrol., 315, 126– 153, doi:10.1016/j.jhydrol.2005.03.026

Lehning, M., H. Löwe, M. Ryser, and N. Raderschall (2008), Inhomogeneous precipitation distribution and snow transport in steep terrain, Water Resour. Res., 44, W07404, doi:10.1029/2007WR006545

Liston, G., and K. Elder (2006), A distributed snow-evolution modeling system (SnowModel), J. Hydrometeorol., 7, 1259–1276, doi:10.1175/JHM548.1

Strasser, U., M. Bernhardt, M. Weber, G. E. Liston, and W. Mauser (2008), Is snow sublimation important in the alpine water balance?, Cryosphere, 2, 53–66, doi:10.5194/tc-2–53-2008

Warscher, M., U. Strasser, G. Kraller, T. Marke, H. Franz, and H. Kunstmann (2013), Performance of complex snow cover descriptions in a distributed hydrological model system: A case study for the high Alpine terrain of the Berchtesgaden Alps, Water Resour. Res., 49, 2619-2637, doi:10.1002/wrcr.20219

P. 4244, L.16-18 "The spatial patterns of the snow depth calculated with this model agree well with the precipitation maps of the Alps contained in FOEN (2010), which are based on a different approach." Either skip this sentence or explain the methodical differences in creating these two maps. I guess that both are created by a more or less refined or extended regression with height calculation, so the matching patterns are really no surprise and don't tell anything about their quality (neither of the precipitation map, nor of the snow depth product).

P.4247, L. 18-20 Yes, I agree, but the lake also decreases the natural fluctuations! So I think this is not a reason to look at this large catchment. You could just skip this explanation because it is actually appropriate to investigate just one big catchment if this solely serves as an example for applying the SWE maps. Even if not the focus of this work, it would be very interesting to enhance the analysis to a smaller alpine headwater catchment, where anthropogenic influences are small or not present. I am quite sure you could find such a (small) subbasin within your catchment. The influence of snow on discharge could be investigated more clearly in such a catchment. However, in my point of view, for this manuscript it would be reasonable to just skip the misleading explanation (as stated above).

P. 4248, L. 22-24 How were the optimal filter widths identified?

P. 4249, L. 10 I guess you mean “correction” instead of “calibration”

P. 4250, L. 20 What do you mean by “The data was stratified. . .”? Perhaps just skip this sentence!

P. 4251, L. 2 I don’t understand where these 330 mm RMSE (SWE, HS?) come from. Please explain!

P. 4251, L. 11 “Averaged over all stations, SWEorig outperforms SWEloo-cv (Fig. 3). “ I can’t really detect this in Fig. 3. And: isn’t this an obvious result?

P. 4252, L. 16 As you state here, the uncertainties increase from December to April. Could you please show this or give an error range for spring time values. This increase in uncertainty is actually very important for the following analyses, so please show it! How exactly was the SWE comparison in Fig. 3 done? At a certain point of time? Mean SWE values? Please give some additional explanation.

P. 4252, L. 26 See comment above, what is meant by “stratify” here? The splitting in calibration and validation period?

P. 4253, Sect. 4.3 Please extend this section, as it is a central method of this work, and it is quite hard to understand with these few sentences. You could also think about merging it with the two following sections.

P. 4255, L. 10 and Fig. 7 You can skip this result or at least Fig. 7, because it comes at no surprise, that the calibrated data fits the data you have calibrated it with. This kind of illustrates the major criticism I stated above, that no independent reference dataset is used for validation. I know, it is probably not possible because of the non-existence of such data, but then just state this and remove the figure.

P. 4257, L. 6-7 “. . ., which can generally only be verified against runoff observations.” Physically-based, distributed hydrological models are also verified against other variables, e.g. turbulent fluxes, soil moisture, surface temperature, . . . Regarding snow, hydrological models are often validated using remotely sensed data of snow coverage

(e.g. Landsat ETM+). This is of course a limited approach, because of the missing snow mass information. Additionally, SWE or snow depth values derived from airborne laser scans are used. Your SWE maps are absolutely undoubted very valuable, so either add these validation methods or just skip the statement.

P. 4257, L. 7-10. Please rephrase the sentence, as this may be true for your application and model, but not in general.

P. 4258, Sect. 5.2 If you show this example, please slightly elaborate this section and add some explanation of e.g. the consequences of the anomalies for the reservoir management.

Technical Corrections

P. 4242, L. 1 “Gridded snow water equivalent (SWE) are valuable. . .” I think it is better to write e.g. “Gridded snow water equivalent (SWE) data are valuable. . .” or “. . . datasets are. . .” or “Gridded SWE observation products are. . .”.

P.4242, L. 2 “. . . and verify hydrological models and other models. . .” Just write “hydrological models” or name the other models, e.g. write “verify different model systems, e.g. hydrological, land surface, or atmospheric models. P. 4243, L. 23 “Blöschl” instead of “Bloschl”. Please check also other appearances!

P. 4245, L. 7 Typo, delete one of the two “considerably”

P. 4247, L. 10-12 Please merge the two sentences, e.g. like this:

“Based on daily, gridded SWE maps (d110, d203, and d133), gridded SWE climatology maps (map110, map203, and map133) were produced for Switzerland with the model described in Sect. 3.1. “

P. 4249, L. 8 Delete “the”!

P. 4251, L. 12 “(1 x 1 grid)” add “km”

Interactive comment on The Cryosphere Discuss., 7, 4241, 2013.