Answers to J. Schöber

We would like to thank J. Schöber for the thorough review and constructive comments which resulted in an improved manuscript. In the following you find the responses to the reviewers' questions one by one:

> **Bold: comment of the reviewer**
> Red: Answer of the authors
> *Italic: Changes to the initial manuscript*

Specific comments:

1) There is a large potential for applications of the resulting gridded SWE-maps (examples in chapter 5). However, it remains sometimes difficult to assess the accuracy of the presented SWE-maps. The authors put a lot of effort in comparing the different resulting SWE-maps (map110 vs. map203). However, the whole article would benefit from detailed comparisons of model results with measured data. First of all, I suggest to cite results from Jonas et al. (2009; e.g. table 3) in order to get an idea of the general accuracy of the SWE estimates (e.g. in the introduction or methods section). Some of the stations, from which snow depth is used for the preparation of the maps and which also provides measurements of SWE (e.g. one of the locations where bi-monthly density and SWE are available), could be used for comparison with the estimated SWE (e.g. in a figure comparably to Fig.7 but plotting estimated SWE and observed SWE).

For the evaluation of the homogenisation approach using quantile mapping it is not crucial what the accuracy of the used SWE maps is. As the focus of this work was to illustrate that the method is able to adjust map110 to map203 the validation of the input SWE is kept to a minimum. We agree with the reviewer that for applications of such datasets it would be interesting to get an idea of the accuracy of the SWE maps. It is however not useful to compare the SWE estimates from this work with the data set from Jonas et al. (2009). The large data set used by Jonas et al. (2009) contains a many high SWE values. This results in a higher RMSE that is expected with the data used in this work. Therefore we decided to not include the magnitude of the RMSE that was presented by Jonas et al. (2009). A Figure that compares measured SWE with estimated SWE can be found in Jonas et al. (2009, Fig. 6b). In this Figure it can be seen that estimated SWE compare well with observed SWE.

2) After reading the article two times I am still not sure if the data which is used in 4.4.1 are SWE estimates or observations of SWE. However, I am quite sure that a comparison between estimated and observed SWE on the point-scale will emphasize the quality of the SWE data which is used for the interpolation of the maps.

We thank the reviewer to point out this uncertainty. For a better overview we summarised all grids and data in Table 2 and hope to clarify this point.

Table 2. Grid, number of stations used to produce grid, available data period and role in the study (c: used for calibration, v: used for validation.

Grid	*Stations*	*Period*	*Role in the study*
map110	*110 (d110)*	*1971-2009*	*c*
map203	*203 (d203)*	*2001-2009*	*c/v*
map.cal	*-*	*2001-2009*	*-*
	23 (d23)	*1989-2009*	*v*
map203⁻	*203-4*	*2001-2009*	*c/v*
map.cal⁻		*2001-2009*	*v*

The statistical scores in section 4.4.1 are calculated for *map110* and *map.cal* using *map203* as a reference. The validation on the point-scale is done in section 4.1 (Fig. 3) where SWE estimates are compared to snow depth measurements which have been converted into SWE. We hope this is clearer in the revised manuscript.

3) For the resulting gridded SWE-maps comparisons with spatial distributed data such as satellite-based snow cover data would be preferable. This is not a demand since the authors have already put a lot work in this study. However, to strengthen the value of the presented results, e.g. MODIS snow cover data or NOAA-AVHRR data could be used for a spatial evaluation of the gridded SWE maps. The authors cite several applications of satellite data for snow hydrology in the introduction. According to the description on page 4244, line 25, the work by Foppa et al. (2005, 2007) provides realtime snow cover maps for Switzerland which are based on snow depth measurements and satellite data. Zappa (2008; Objective quantitative spatial verification of distributed snow cover simulations – an experiment for entire Switzerland. Hydrolog. Sci. J., 53(1):179-191.) applies several functions for the spatial evaluation of modelled SWE based on satellite snow cover data. Such comparisons would be beneficial for quantifying uncertainties related to the placement of the snow borderline (page 4262, line 28-29) but do not allow to evaluate the accuracy of SWE. For the latter case MODIS fractional snow cover data would be a good choice since binary snow cover data may not be accurate in vegetated areas.

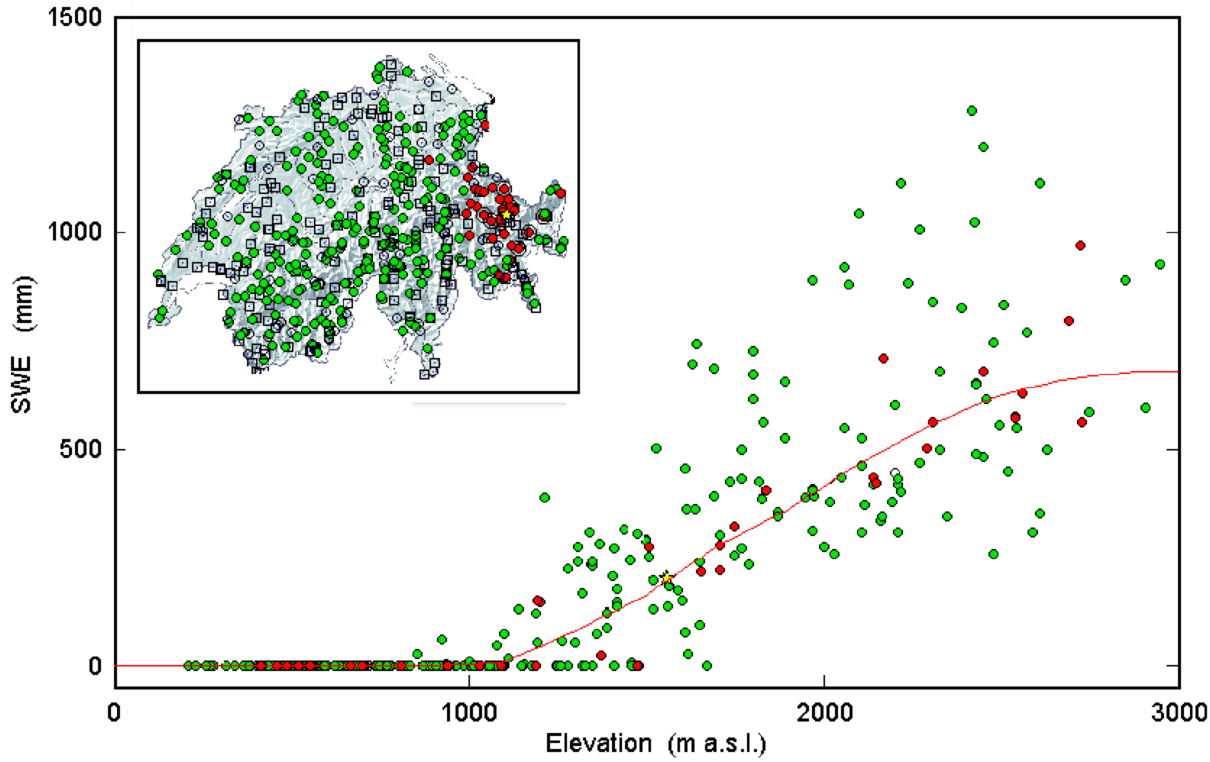
The snow model used in this study is a further development of the work by Foppa et al. (2005,2007) and the snow density model presented by Jonas et al. (2009). This model is also used operationally, where SCA data from NOAHH-AVHRR are used. For this application no SCA data are used as they are not available on a daily basis for the period of 40 years. Further such optical data have gaps due to cloudy days. The comparison of a binary SCA product with our quantitative SWE product cannot validate the estimation of SWE values. As stated before the scope of this work is not the validation of the SWE data. We would like to consider such approaches to validate spatial structures of SWE in future work.

4) The model presented by Jonas et al. (2009) is designed for a monthly resolution. The according description in the method section lacks details from the enhanced version of the model which is mentioned. Does the enhanced version include daily resolution regressions parameters? How can settling and melt be distinguished if only HS is used?

Based on snow depth measurements the non-linear regression curve is estimated for each day. For the conversion of snow depth to SWE monthly parameters are used. In addition settling and melt of the snow cover are implemented similar to the concepts presented in Martinec and Rango (1991). This reference is now included in the methods section.

5) A non-linear trend of SWE over elevation is the basis for the mapping of SWE. How does the trend of SWE over elevation look like? Is it influenced by the station elevations? SWE generally increases with elevation but does the used function/ chosen resolution of the maps account on the often observed decrease of SWE in the ridge zone?

The Figure below is an example of the non-linear trend with elevation for an arbitrary day with the available snow depth data at the green and red points. For the 'regional' non-linear trend only the stations coloured in red are used. We hope the additional information in the text also clarifies this point. All points (red and green) would be used to determine the global (Swiss wide) trend of SWE with elevation.



In this model the trend over elevation is not based on a function and no assumptions are made. We use the real variability of the data with elevation. The trend of SWE over elevation is determined using median values calculated for overlapping elevation windows. If the decrease of SWE in the ridge zone is observed in the data this can be also seen in the non-linear elevation trend in the model.

Technical corrections:
6) The methods and results sections need some revisions. Several descriptions of methods are spread over the results section (e.g. 4.3, 4.3.1) Therefore it is hard to follow the line of argumentation in the results section.
The authors should move the first sentence from chapter 4 to chapter 3.3.
The assumption that map203 is used as reference data should be mentioned in 3.3.
The cross validation and the comparison with station data (Fig.3) should be explained in section 3.3. This may also clarify one of my points of criticism from above.
The methods in the revised version of the manuscript are summarised in section 3.3 with the suggestion of the reviewer. Section 3.3 now reads as follows:

3.3 Validation methods
In this study, map203 is assumed to contain more accurate gridded snow information because it is based on more snow measurements that also cover higher elevations. Therefore map203 is considered as the reference data set.
In a first step SWE estimates are compared to measured snow depth that is converted into SWE over the period 2001-2009. At each measurement station, SWE was estimated with the associated station (SWE_{orig}) and without ($SWE_{loo\text{-}cv}$). The altitude was adjusted to the station altitude by subtracting the day-specific SWE gradient from the modelled SWE values. “Orig” and “loo-cv” were compared to identify the uncertainty of the model and the impact of individual stations on the mapping results. Estimated SWE is validated taking into consideration the mean error (ME), the mean absolute error (MAE), the squared correlation coefficient (R^2) and the root mean squared error (RMSE). In order to ensure that small fluctuations in SWE are preserved, R^2 is calculated with the seasonal trend removed. Therefore the first-order differences with a lag of one year are used (Wilks, 2006; Foppa et al., 2007; Saloranta, 2012).

After implementing the quantile mapping (section 4.3), which is performed according to the results from comparing map203 with map110 (section 4.2), map.cal was validated. First the calibration was tested for the nine overlapping years with a cross-calibration approach. By dividing the data set into a training period (eight years) and a calibration period (one independent year), each year can be calibrated independently with the remaining eight years. The relation obtained between the quantiles of the two data sets was then applied to the 39 available years of map110.
For the validation of the spatial and temporal consistence "independent" stations are used (Table 2).The temporal validation outside the calibration period is done by comparing the calibrated maps with "independent" measurements from d23 (Fig. 1) during the test period (1989-2000) and the calibration period (2001-2009). Most of these 23 stations are located between 1500 and 2000 m a.s.l. and three stations are located around 2200 m a.s.l. The spatial consistence is tested with a grid that removes four stations (Stations with the black outline in Fig. 1) before estimating SWE (map203^{-}). These four stations are then used to validate map203^{-} and the therewith calibrated grid map.cal^{-}.

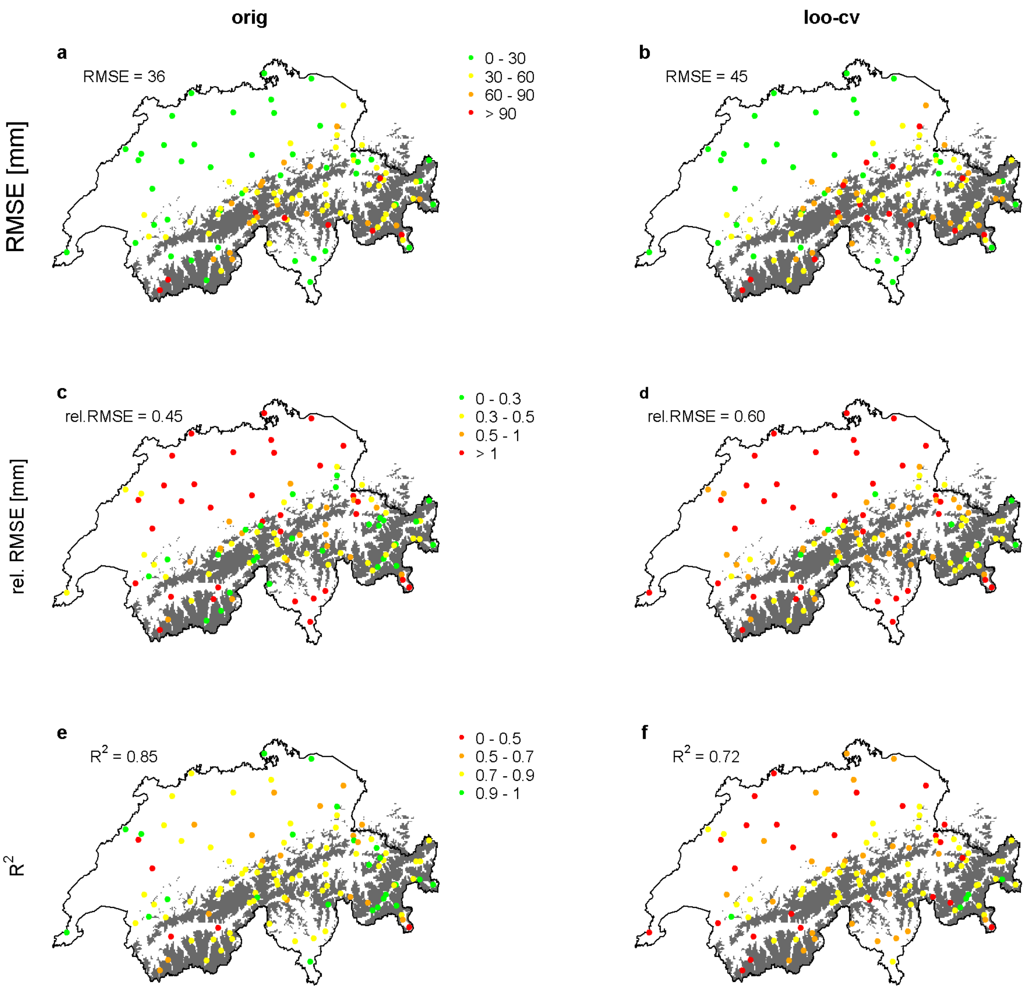
7) Especially in the results section, I would recommend to use fewer abbreviations. For instance, I would not use CP and TP (write out!) in 4.4.1 and 4.4.2 where you first use it and later describe it once again.
We removed many abbreviations and hope we could improve the reading flux.

8) The descriptions of Fig. 15 (actually presented in the conclusions section) should be presented in the results or discussions sections.
Figure 15 and the description are moved to section 3.2 and replaces Figure 2.

Minor corrections:
Page 4245, line 7: considerably x 2, delete one.
OK, one considerably was deleted.

Page 4251, line 11: 1 km x 1 km grid.
Changed to: "1 km by 1 km".

Page 4251, line 20: a relative measure could help.
We decided not to show more than two measures to validate the input dataset as this is not the focus of this work. However we looked at several measures and we will illustrate the relative RMSE to the reviewer and to Christoph Mary who also suggested a relative measure in his short comment. It can be seen, that the relative RMSE is larger in the lowlands, where the RMSE is small due to small snow depths. At higher altitudes where the snow cover is higher, the relative RMSE is smaller.



Page 4252, line 19: "The SWE height trend. . ." ?? Do you mean SWE-elevation?
Yes, changed to:

SWE trend with elevation

Page 4257, line 6: "...which can generally only be verified against runoff." This is not true, rewrite this sentence. There is definitely a lot of work going on with spatial data in hydrological modelling.
We now refer to spatial data that can be verified in hydrological models.

A lot of work is going on in verifying hydrological models against spatial data as remotely sensed data of e.g. snow (Hüsler et al., 2013;Bellinger et al., 2012;Hüsler et al., 2012;Dijk and Renzullo, 2011;Zappa, 2008),evapotranspiration (Kite and Droogers, 2000;Immerzeel and Droogers, 2008) and soil moisture (Bastiaanssen et al., 1998).

Page 4257, line 8: delete "therefore" in this sentence!
We rephrased the sentence.

Page 4257, line 21: "true SWE" is misleading, since it refers to map203 (a model result). Change into, e.g. "likely".
We changed "true" to "likely".

Page 4257, line 24: VS (left), AR (right) is wrong – AR is plotted on the left side of Fig. 12.
Thank you for the correction.

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