Authors’ response to interactive comment by Reviewer #2 Giacomo Bertoldi

Black text: Reviewer comment

Blue text: Authors’ response

In attach some specific comments of Valentina Premier Ph.D. working with me.

We thank the reviewer for her valuable comments and suggestions that will help us improve our manuscript. Below we reply to each of them and explain how we will incorporate them into the manuscript.

The paper applies some modifications on the snow routine of the HBV model. Main results are that an increasing complexity does not lead to increasing performance. The most positively influencing modification is the use of an exponential snowmelt function and of a seasonally variable degree-day factor.

Some comments follow:

- Line 15-17: “However, [...] support tool” This sentence is not really clear to me. In general, I would restructure the abstract making clear from the beginning that the investigations are performed among snow routines based on temperature-index methods only.

With this sentence we wanted to point out that the implications of the decisions on which model structure to use for a given application are not always adequately addressed. We will rephrase the sentence to clarify this point. Additionally, we will revise the abstract to clarify that the study builds on temperature-index methods.

- Line 34: “... often triggered by raising temperature”. Is the main triggering source induced by air temperature or by incoming solar radiation, which is well represented by temperature?

Incoming solar radiation is indeed an important driver behind snowmelt, perhaps the most important one for open areas. This parameter is also strongly correlated with air temperature. Nevertheless, there are fluctuations in temperature that cannot be explained by incoming solar radiation alone, but by other processes such as lateral energy transfers, among others. For instance, snow also melts in locations with very little direct sunlight by the effect of temperature alone, such as under the canopy. We will, however, clarify the text to be more specific here. This will include referring to the important contribution of incoming solar radiation and its correlation with temperature.

- Line 64-66: “Regarding the proportionality constant ...” Is the constant catchment defined? Are there studies which take into account of the spatial variability (e.g. different altitude, topography, etc?)

Yes, since we only use a single vegetation zone per catchment (see paragraph starting at line 117), the proportionality constant is catchment-defined. By defining different vegetation zones this parameter could take into account e.g. aspect, forested areas vs bare ground, etc. This would however come at the cost of having additional free parameters for calibration and make this study overly-complex. Other studies have indeed focused on the use of a spatially-variable proportionality constant (see e.g. He et al 2014). We will clarify this in the manuscript.

- Line 66-67: ".. one for temperature and another for net radiation". Doesn't this belong to the hybrid methods?

Yes, the reviewer is correct. We will list this approach under hybrid methods.

- Line 115 Formula (3) Is T the daily average temperature? Some formulations take into account the cumulated temperature which exceeds the threshold, measured for example with 1 hour time step. Would these different formulation affect the results?

Yes, T refers to the daily average temperature, as it is common practice in degree-day approaches. Considering the approach mentioned by the reviewer is an interesting alternative, which might produce a somewhat increased simulated snowmelt, since the daily temperature pattern might allow for snowmelt during some hours, even if the daily average temperature is below the threshold for snowmelt. This, however, is beyond the scope of our study, since it is limited to simulations at a daily resolution.

- Section 2.2.1 Has the formula (5) been evaluated by using the available temperature data for the studied catchment?

As mentioned in the manuscript, this equation is derived from the analysis of observational temperature data throughout the year from a large number of stations situated at different elevations (Rolland, 2003). We did not evaluate this equation here again since the temperature driving data we use in this study were either from a gridded data product based on the interpolation of station measurements (Switzerland) or single station measurements (Czechia). Based on these data, it is not possible to properly evaluate the equation. We did, however, check a sample year from a Swiss catchment for which we obtained the lapse rate from the gridded data product and fitted a constant and sinusoidal lapse rate parameter (Figure 1).

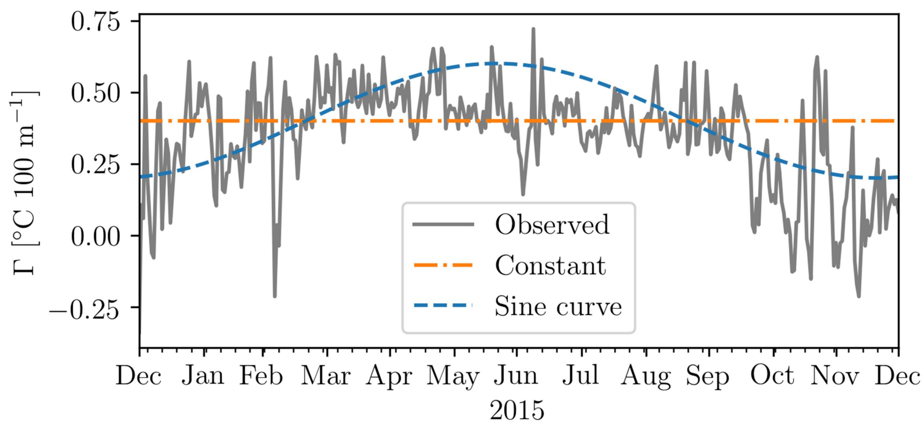

Figure 1. Comparison between the temperature lapse rate as described by a constant and sinusoidal parameters and the observed values from a gridded temperature data product.

- Paragraph 2.2.5 What is the threshold used in the model as the maximum liquid water content retained in the pores (maximum water retention capacity)?

We set the maximum liquid water content retained in the pores as a free parameter for calibration and restricted the range between 0 and 0.2 following Seibert (1999).

- Section Results. I would plot the performance vs size of the catchment and altitude (also for a fixed configuration, given the high number of variable components).

The reviewer makes a good suggestion. Actually, we expected to observe some relationship between these parameters and model performance and we tested this. We even tested other parameters such as yearly snowmelt contribution to runoff (we mention it briefly in the manuscript, lines 362-364). Nevertheless, we did not find any clear relationships for our case study.

References

He, Z. H., Parajka, J., Tian, F. Q. and Blöschl, G. (2014). Estimating degree-day factors from MODIS for snowmelt runoff modeling. *Hydrol. Earth Syst. Sci., 18,* 4773-8789.

Rolland, C. (2003). Spatial and seasonal variations of air temperature lapse rates in Alpine regions. *Journal of climate*, *16*(7), 1032-1046.

Seibert, J. (1999). Regionalisation of parameters for a conceptual rainfall-runoff model. *Agricultural and forest meteorology*, *98*, 279-293.