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Interactive Comment

Interactive comment on "Modelling of snow processes in catchment hydrology by means of downscaled WRF meteorological data fields" *by* K. Förster et al.

K. Förster et al.

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We would like to thank Anonymous Referee #3 for a detailed review of the manuscript. The comments and suggestions will help us to improve our manuscript. Please find our detailed response below.

General comments:

> *"Overall the paper deals with an interesting question, because data availability is often the bottleneck for modeling.*

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I generally agree with the other referees, in particular it is essential to mention that WRF precipitation is not used to run the models in the abstract. Moreover there should be more specific information given, e.g. about how the calibration of the models was done. Also it was not clear if the measured precipitation is corrected for systematic errors like undercatch.

Overall I suggest to focus revision on the calibration of the models and giving more specific information about them, e.g. if they use different thresholds to divide between rain and snow. This makes results hard to compare. Also the degree-day method should be explained better regarding the use of a fixed or variable degree-day factor. Finally, if there are snow height measurements available, they could be used to evaluate snow cover development for the point scale modeling.

The specific comments may help to provide missing information and if these deficits can be eliminated the paper meets the requirements of the journal."

Reply: In the abstract we will mention that we also consider observed precipitation for snowmelt simulations. As explained earlier, we will also involve WRF precipitation in order to more clearly and consistently show the applicability of downscaled meteorological fields.

We will also rewrite the text with respect to calibration. In this context, the different ways in which the models separate rain and snow will also be explained briefly. More emphasis will also be put on how the degree-day factor has been considered. Since snow depth observations are available to some extent, a comparison with modelled SWE will be included.

Specific comments:

"P4067: Line 8pp: Regarding which climatological parameters?"

This statement refers to mean annual precipitation depth and temperature. As explained in our response to Anonymous Referee #1, we will delete this statement since it is not relevant.

> *"P4067: Line 21pp: What is the range in altitude in the Sieber catchment? Are rain gauges representing the topography of the catchment?"*

The altitudinal range of the Sieber catchment covers 340 m to 920 m, which will be included in the improved text. The rain gauges represent the general topography of the catchment. We will provide a map including all stations, displaying that the surrounding stations represent the altitudinal range of the catchment.

> *"P4068: Line 3pp: Is there a reference? Or derived through own data analysis?"*

This value is derived through own analysis. Mean daily values of discharge are available from 1930 onward, in the form of mean daily values. Rather than to limit these to 2008, we will extend the time period to 2013.

> *"P4068: Line 10pp: Why are just 2 years considered in the study? How well are the meteorological values modeled for the other seasons?"*

We agree that a long-term evaluation would be of great value. Depending on the computer hardware, WRF applications run 3 up to 20 days in order to simulate the meteorological fields of one single winter season. The 3 day estimate refers to high performance computing with 24 cores whereas the 20 days would be necessary to run the model on a computer with 4 cores. We will add the information regarding computing time in order to show the limitations of this approach. Unfortunately, due to required

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computing power it is not possible to downscale a greater number of winter seasons under the present conditions.

We configured the model only for the winter seasons mentioned in the text. Hence, a continuous run is not available and the study focuses on melt events. We tested the applicability of downscaled meteorological fields for two winter seasons in order to show the principle applicability of this approach. Instead of using long-term simulations we focused on running different snowmelt models at the point and the catchment scale to compensate the use of short periods of time to evaluate the applicability of downscaled meteorological fields.

We see the WRF application of longer time series as an opportunity for future research, a point of view we will add to the concluding remarks.

However, we carried out simulation runs for a third winter season, as suggested. The point scale results are depicted in Fig. 1. In contrast to the Taylor plots in the manuscript, the herein displayed results are based on modelled precipitation. Since we will revise our manuscript to include modelled precipitation input, as announced, the updated manuscript will be considerably more extensive than the current version. Hence, we believe that providing all additional plots including a discussion for the additional winter season would go beyond the scope of this study, since the evaluation of the additional winter season does not provide further insight. The already discussed results, based on two winter seasons, represent sufficiently different conditions to prove the main research question.

We see this as a realistic compromise between conciseness and completeness.

> *"P4071: Line 26 pp: Please mention more about the used degree day method. Is the degree-day factor changing over the season or is a fixed factor used over the whole period?"*

We use time-independent degree-day values in order to consider the basic

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temperature-index method. However, we provide a lookup table for PANTA RHEI simulations including various land use classes for catchment scale applications. This will be outlined more precisely.

> *"P4074: Line 6 pp: Please clarify more how the calibration was done. Why did you calibrate with meteorological data from 1971 to 2000 but precipitation from 2002 to 2008? Why to use measured meteorological data if the model is driven by WRF data?"*

We carried out two calibration steps. For the first calibration period, only daily meteorological time series are available. This first calibration procedure accounts for the calibration of the water balance components of the hydrological model (e.g., soil model, evapotranspiration). The subsequent shorter period enables the calibration of flood peaks since hourly precipitation time series were considered. We will describe the calibration procedure in a more detailed manner.

> *"P4074: Line 8pp: Why don't you use another year (representing more average conditions) for calibration instead of one included in the study? Especially since you are just modeling 2 years."*

The basic idea was to make optimal use of the short periods of time. Therefore, we decided to use the first winter season for calibration while the second winter season is seen as validation period. Since both seasons differ in terms of meteorological conditions, this modelling experiment can be seen as a differential split sample test. We will clarify this.

> *"P4074: Line 17 p: It would be interesting to have a plot of the other meteorological time series as well"*

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It is possible to provide such plots for humidity, wind speed and radiation components. We are considering providing an additional plot, including these variables or at least performance measures.

> *"P4074: Line 20pp: FIGURE 4: Is the measured data compensated for errors like wind error? How does data from different stations look like? Are there some stations representing the modeled data?"*

The observed precipitation time series are not corrected with respect to systematic errors. We will add this information.

> *"P4076: Line 1pp: FIGURE 6: Is snow height measured at point scale? At the beginning of the event SWE values range from approx. 275 to 375 mm for the different models. So not only runoff for this event is interesting, also if the whole season is represented correctly."*

We wholeheartedly agree with this. As explained in our reply to Anonymous Referee #1, we will provide a plot including the modelled SWE for all models including observed snow depth.

> *"P4077: Line 19pp: Is that a good measure for model performance?"*

In response to this very valid question: it is indeed not a good performance measure. However, this information gains insight to the question if snowmelt processes are generally relevant for the selected sites. This comparison is intended to show the plausibility of results.

> *"P4077: Line 23p: Why weren't more winters used then? If comparing different models in performance, than a comparison or ranking should be possible."*

As previously explained, carrying out further evaluations is limited by computation time. You are right to say that using longer time series would enable a comparison of model performance. We consider your comment a possibility for future research. However, our primary aim was to show that the downscaled meteorological data are suitable to drive snowmelt models at different scales. We agree it is not necessarily possible to compare the models using only data of two winter seasons. We see the application of more than one model as a surrogate for long time-series applied to one model in order to prove our hypothesis.

> *"P4077: It would be interesting to also see whole winter seasons for point observations."*

We will add a plot for the winter season in its entirety including both observed snow depth and modelled SWE.

> *"P4078: Line 26pp: Not all models used the same thresholds to separate rain and snow? How are parameters for the models set? Do comparable parameters differ for the different models?"*

The parameterization of this separation differs. The temperature-index model and the modified Walter model rely on a simple temperature threshold, the Utah Energy Balance model includes two thresholds considering mixed precipitation and ESCIMO is parameterized using a wet-bulb temperature threshold.

> *"P4079: Line 23: It is not clear, how snow and rain are separated."*

We will add a brief description of these parameters in order to clarify this statement.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 4063, 2014.

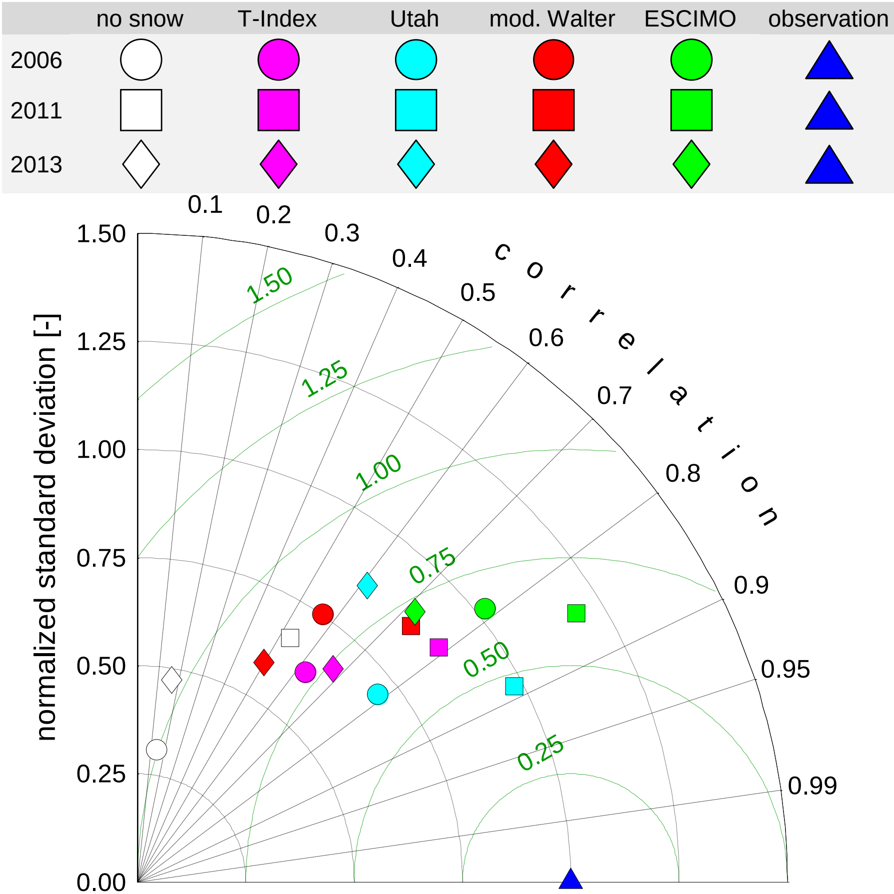

Fig. 1. Taylor plot including point scale simulations for three winter seasons. All simulation runs are based on modelled WRF precipitation.

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