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**Geoscientific
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Interactive comment on "A pragmatic approach for the downscaling and bias correction of regional climate simulations – evaluation in hydrological modeling" *by* T. Marke et al.

Anonymous Referee #1

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General comments: The paper addresses a key issue currently discussed in the hydrological and meteorological modeling community of using coarse scale climate model results for hydrological modeling. Addressing these issues is particularly important in the context of climate impact research but also of more general interest with respect to applying suitable and simply applicable downscaling methods. The presented paper therefore addresses a relevant scientific question suitable for publication in GMD. Downscaling of climate variables to hydrological relevant scales and coupling of meteorological and hydrological models is an ongoing research issue. Particular focus is often given to downscaling of precipitation. However, the applicability of many complex methods is limited by a large computational demand or the need for additional

data. Thus simple and easily applicable downscaling techniques are needed. While the basic concept of the approach is not new, the paper provides a valuable extension of a previously published approach. The approach is pragmatic and easily transferable to other regions if sufficient knowledge of small scale patterns of climate variables is available and is therefore worth publishing. The evaluation of the approach to other meteorological parameters and with respect to their effects on hydrological model outputs is a new aspect of this paper. The advance in model science is sufficiently substantial, particularly with respect to quantifying the effects downscaling methods upon hydrological model outputs is relevant and interesting, the methods and assumptions valid and mostly clearly outlined. Some comments given in the review should be noted. Observation based extrapolation to small scale patterns form the reference data set to analyze the downscaling approach. However, an error analysis of the small scale patterns for instance through cross-validation is not provided. This would however be important to quantify the attainable accuracy of the downscaling approach and to provide statistical evidence for the quality of the downscaling method which goes beyond the (very helpful and well described) analysis of the effects upon the hydrological model. The quality of the observation based model results (Fig. 5a) however is indirect evidence, that the quality of the meteorological input data used in the observation based model runs is quite high. The results are traceable and the method is sufficiently well described to reproduce similar results. Some comments are made in the review, address aspects recommended for a more thorough evaluation of the methods. Credits to related work are given in a proper form, they are complete and cited in the text. The original contribution can be clearly identified. A short overview/review of frequently used downscaling methods to clarify the need for a new method would be helpful however. The title clearly reflect the contents of the paper The abstract provides a concise and complete summary. The overall presentation is well structured and clear. The paper needs a language review by a native speaker to check for more precise wording, grammar and more concise sentences. The mathematical formulae, symbols, abbreviations, and units are correctly defined and used. All parts of the paper are necessary.

The number and quality of references is appropriate, as is the amount and quality of supplementary material.

Additional comments with reference to the text: Page 47, Line 4: "A clear need has been identiïňĄed to develop appropriate methods to overcome the scale mismatch between RCMs and impact models in order to permit the investigation of climate change impacts at the regional to local scale" Provide evidence for this statement, either by a placing a citation or by putting this statement in the context of a given task (e.g. GLOWA) which requires climate models on the one hand side and regional, high resolution data on the other side

Page 47, Line 7: It is unclear what you mean with "currently found limitations in the spatial resolution“, Who found these limitations currently, or is the current finding due to the application, which goes beyond the original applications intended for RCMs. The word currently is not helpful in the given context. Do you refer to the previous sentence, which talks about the scale mismatch?

Page 47, Line 8: Biases are only defined against a reference. I suggest: . . .biases in the simulation as (e.g. . . .) compared to measured values.

Page 47, Line 12: Suggestion to rephrase: Their studies reveal biases which largely depend on the chosen RCM, geographical region and the observation-based meteorological reference data.

Page 47, Line 21: Suggestion to rephrase: The current study addresses the need to develop simple and pragmatic downscaling techniques, which is applicable for a range of meteorological parameters required for hydrologic modeling. It is based on a pragmatic downscaling approach for precipitation developed by Früh et al (2006).

This sentence is the key sentence with respect to the purpose of this paper. The statement or purpose should be more precise and more clearly phrased. "Addressing" is a rather weak word. It would be clearer if you use words such as develop, evaluate,

investigate. What precisely do you want to show in this paper?

Page 47, Line 25: here you start explain the methodological approach used in this paper. However, if the purpose of the paper would be more precisely stated in the previous sentence, the following paragraph would allow you to more generally set the stage for your methodological approach. To my understanding, your ultimate goal is to show the relevance and importance of an improved downscaling technique used in a process based hydro-meteorological model chain. Thus the line of reasoning is that high quality meteorological input data are a needed prerequisite for process based models, since these models are not calibrated but parameterized. Thus errors in the input data cannot be compensated by a calibration procedure and the model performance is very strongly affected by the quality of the input data, which needs therefore high quality meteorological input data, without bias and - for spatially distributed models – with valid spatial patterns appropriate for the spatial resolution of the hydrological model. Such a general statement sets the stage to select the models which are suitable for this endeavor.

Page 47, Line: 27: rephrase: “It is composed of” instead of “It is composed by”

Page 48, Line 1: skip the word uncalibrated in this context. It is not needed here and it implies, that PROMET is usually calibrated, while you are using the uncalibrated version. Adjectives such as process-based or distributed are possibly more suitable here. Also, the high demand for meteorological input data, as stated in the next sentence, is understandable, if the process based modeling approach is mentioned here.

Page 48, line 2: Rephrase: The hydrological model has relatively high requirements with respect to the meteorological input data

Page 48, line 12: rephrase: The complex topography is characterized by a large gradient of altitude reaching from 287 m a.m.s.l. at the discharge gauge of the watershed at Achleiten up to 4049 m a.m.s.l. at Piz Bernina in the Alpine headwaters. This altitudinal gradient leads to strong meteorological gradients.

Page 47, line 22: skip “itself”, The Danube leaves the watershed at one location, but it crosses the watershed in a direction, what do you mean to say here? Is the flow direction of the Danube relevant in this context?

Page 59, Fig 1: Delete the word “test” in the heading

Page 60, Fig 2: Delete the word “current” in the heading

Page 61, Fig 3: The figure obviously includes the topography, neither this nor the scale is mentioned in the heading. Heading incomplete

Page 49, Line 15: In the current setup, MM5 resolves the atmosphere with 29 layers up to a top lid pressure of 100 hPa with an enhanced resolution in the boundary layer The word resolves is unfit here. This sentence seems to be a direct transfer from the German sentence structure and use of words. Suggestion: In the current MM5 setup 29 layers are distinguished with the top layer set at a pressure of 100 hPa and an enhanced vertical resolution in the boundary layer However, it is unclear, what enhanced resolution in the boundary layer means precisely. Is it defined by a pressure gradient or height above ground ?

Page 49, Line 27: “The latter” reference is ambiguous. Replace with Hydrological modeling is carried out . . . Shouldn’t PROMET be translated as (Processes of Radiation, Mass and Energy Transfer) since there is more than one process it should be a plural

Page 50, Line 7: heading is not precise Suggestion: use Downscaling approach

Page 50, Line 10: replace “in alpine-scale complex terrain” with “in a complex, alpine terrain” and “The general concept behind” with “The general concept of” By the way: What is alpine-scale?

Page 50 Line 10: The general concept behind the approach, however, allows for its application in downscaling of temperature, wind speed and air humidity as well. Isn’t the purpose of the paper to produce proof of this? Thus the sentence should be rephrases e.g. as: The general concepts of the approaches, however, should be applicable also

for application in downscaling of temperature, wind speed and air humidity as well. Use plural, since the previous sentence speaks of two approaches. Same in the following sentence! If this is not intended, then refer to one specific approach here, which is either the correcting for the sub-grid variability or the bias correction, or define the approach as one approach which consists of two parts in the first sentence of this paragraph.

Page 50, line 17: rephrase: . . . , the subgrid-scale variability is estimated with respect to the RCM grid

Page 50, line 22: ..and is generated by the meteorological preprocessor in the hydrological model PROMET as described in detail by Mauser and Bach (2009). The quality of the meteorological preprocessor in PROMET defines the subgrid-scale variability and thus the quality of the subgrid-scale patterns. Since this is a key component of the approach it is important to spend a few words on the methodology of the preprocessor in order to understand its validity and suitability to generate spatial patterns. Also, it would be necessary to assess the quality of the preprocessor either by referring to previous study results or by using a suitable evaluation method of the preprosessor quality e.g. by providing error estimates generated from omitting individual measurement sites and estimating their values using the PROMET preprocessor.

Page 50, line 23: Unclear: The mean monthly conditions are aggregated from 1 $\times$ 1 km Obviously, you refer to the mean monthly patterns generated from hourly maps of meterological parameters derived from the PROMET preprocessor. This is not necessarily clear here

Page 50, line 24: Unclear: This is done in such way that every raster element of the aggregated observed climatology Xobs (m) holds the area weighted mean value of all overlapping ïňĄne grid cells of xobs (m) Do you mean: The upscaling to the RCM grid is done by calculating the area weighted mean of all high resolution grid cells xobs (m) which are completely or partially within the respective coarse resolution cell Xobs (m).

Page 50, line 26: rephrase: The coarse grid cells Xobs (m) are subsequently bilinearly interpolated to generate the high resolution grid. The individual cells of the resulting grid are denotes here as: xobs bil (m)

Page 51, line 1: rephrase: A downscaling function Fvari (m) is finally calculated as

Page 51, line 2: explain in more detail or more precisely. Why are the mass and energy budgets imposed by the RCM conserved? The main reasoning seems to be, that the downscaling function derived from the observed data are applied for the data generated from the RCM. This however is not mentioned, but merely implied.

Page 51, line 7: As biases in terms of deviations from observed climatological conditions exist in simulations of present-generation RCMs, the quality of the hydrological model results are expected to be compromised by applying uncorrected RCM simulations as meteorological drivers. This is only true if a calibration process does not compensate these biases. This is why a clear statement in the introduction to clarify the basic assumptions and experiment setup (e.g. process based, uncalibrated model) is important.

Page 51, line 18: are these systematic errors accounted for in the measurements? If so, state this with mentioning of the methods used

Page 51, line 20: the country scale is not introduced or relevant in this context. I think you mean generally the large scale of RCM's. Is this correct?

Page 51, line 22: the related shift of mass and energy within a given RCM grid box Shouldn't shift be replaced by redistribution, it is not a shift in the sense of an offset meant here, but mass and energy are conserved and merely redistributed

Page 51, Line 29: rephrase: . . . where the seasonal storage of water in the snowpack controls to a large degree the discharge at the outlet of the watersheds.

Page 52, Line 1: replace shift with redistributing

Page 52, line 17. How do you make sure, that the humidity values after rescaling and redistribution does not exceed the physical viable limits (e.g. more than 100% rel. humidity)

Page 52, line 20 ff: The downscaling of temperature follows a very similar approach, with the difference that the multiplicative correction is substituted by an additive correction term. Provide information on the reasons for this deviation of the general method. If the reasoning is, that a multiplication would not allow a change of the sign at 0 °C, why not use the Kelvin scale instead? Also, both methods are not equivalent. The multiplicative corrections result in a larger value for large input values as compared to small input values. Thus, at large input values of the coarse grid, the spatial variability (expressed here as Max-Min value within the fine scale grid) at the fine grid scale increases in absolute terms as compared small input values. Is this also the case in the observations? If this is so, than a multiplicative stretch indeed does produce a better representation of the spatial patterns and should not be replaced with an additive term, which maintains the same spatial variability throughout the subscale. Page 53, line 6ff: As illustrated, the combined correction of subgrid-scale variability and bias, compared to the correction of subgrid-scale variability alone, remarkably reduces simulated temperature in large parts of the Alpine foreland, whereas temperatures in the southern part of the Alps are slightly increased Rephrase by using a direct reference: such as: As shown in figure 4, the . . . Do you really mean remarkably in the sense of surprisingly or do you mean, significantly, strongly, largely, Also rephrase: remarkably reduces the simulated temperature in large parts of the Alpine foreland, whereas temperatures in the southern part of the Alps slightly increase.

Page 53, line 9: Both approaches reïňĆect altitudinal gradients by increasing temperatures in the Alpine valleys and reducing temperatures in the higher elevated parts of the Alps. Verb "reflect" is not appropriate, also briefly elude of the significance of this. Particularly the snow water storage term should be affected by this.

Page 53, line 12: For the hydrological evaluation of the presented downscaling ap-

proaches, the statistical downscaling of vari and vari&bias is combined with a physically based approach used for the downscaling of surface pressure which is also required as input for the hydrological model. I do not see, why this is important “For the hydrological evaluation of the downscaling approach”. Isn’t the physical based downscaling approach for a variable such as surface pressure due to its simplicity and accuracy the preferred method anyways, irrespective of the application?

Page 53, line 17: rephrase: As recordings of incoming longwave and shortwave radiation are scarce Also, is the scarcity of the data really the main issue here? Or isn’t the fact, that variation along altitudinal gradients – which is a basic prerequisite in the application of the PROMET meteo. preprosessor- is by far less important than variations due to cloud cover? The scarcity of the data would - to my judgement - even warrant the use of a downscaling approach, if this approach would be applicable to the variable at all. Thus the reasoning provided here is not conclusive.

Page 53: line 25: rephrase: To provide a spin-up time for the hydrological model of one year, the period considered in the subsequent evaluation is limited to the years 1972–2000.

Page 54, line 1: the verb “unfold” is inappropriate use, simply shows would be better The rest of the sentence also needs corrections with respect to grammar and wording: Page 54, end of paragraph 4: The offset of the linear regression of modeled vs. observed values assumes the largest value in d, also the gain of the regression deviates the most from the 1:1 line. Is there an explanation for this? This behavior seems to arise from the bias correction

Page 55: Line 9: Rephrase: Compared to a model run using meteorological site measurements instead of meteorological data from a downscaled RCM, the model results obtained with PROMET shows, persistent deviations from the runoff measurements at Achleiten. These differences which cannot be traced back to biases in precipitation, temperature, humidity and wind speed.

Page 55, line 26: rephrase: ... never reproduce exactly the observed temporal evolution

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