

Hydrol. Earth Syst. Sci. Discuss., referee comment RC1
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Comment on hess-2021-433

Anonymous Referee #1

Referee comment on "Trends and variability in snowmelt in China under climate change" by Yong Yang et al., Hydrol. Earth Syst. Sci. Discuss.,
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Interactive Comment on "Trends and variability of snowmelt in China under climate change" by Yang et al.

The manuscript presents a country-wide assessment on present and future changes of snowmelt in China. To this end, a simplified temperature-index model is used that simulates several snow properties including snowmelt, snowfall, and snow sublimation. The model is forced with high resolution temperature and precipitation datasets as well as datasets that are needed for the model parametrization, which include PDD, snow density and snow/rain threshold temperatures. The model outputs, snowmelt, snow depth, snow water equivalent, and snow cover extent, are validated on equivalent station-based or grid-based observation datasets. Finally, the model is forced with temperature and precipitation data for 5 CMIP5 models under 3 different RCPs are selected to project future changes of snowmelt in China. The manuscript is well structured and generally well written. However, there are some issues with the grammar in this manuscript since most of the manuscript has been written in a past tense, whereas I would expect that some sections of the manuscript could have been written in a present tense or future tense. The topic the manuscript covers is very interesting. The assessments presented in this paper are novel as well, but I have several major and minor comments that need to be addressed.

General Comments

- My first general comment is on the grammar that has been used while writing the manuscript. Most of the manuscript is written in a past tense. That is fine in some sections, such as the Abstract, but insufficient in those sections where a present or future tense is warranted.
- To compare future snowmelt with present snowmelt I think it would be more beneficial to use climate "reference" periods instead of comparing future decadal values with the mean values of an entire historical period since the entire period reflects different

climatological characteristics. For example, since the late 1970s/early 1980s the global warming accelerated (Hartmann et al., 2013; doi:10.1017/CBO9781107415324.008), which might have had a different impact on the snow climatology than before the late 1970s. Therefore, I would like to suggest using 1981-2010 as an historical "reference period" and to use 2010-2039, 2040-2069, and 2070-2099 as near-future, mid-future, and far-future "reference" periods, respectively. That might give a better representative view on future snowmelt changes.

- Section 2.2.2 L108: Why did the authors use observational air temperature data from 824 stations, whereas they already mentioned before that they would like to use a high-resolution air temperature dataset to force the model. What is the added value of the observational air temperature data? What is the bias between the observational air temperature data and the high-resolution dataset of Peng et al., 2019 and to what is the difference between PDDs retrieved from the high-resolution dataset and PDDs retrieved from the observational data? Please elaborate on this.
- Section 2.2.4; L135-136: Why did the authors only select these five CMIP5 models? Are the climate conditions in these models representative for the full range of possible conditions in terms of climate change (e.g. cold-dry, warm-wet)? What are the consequences for choosing these models for the outcomes of this study? And finally, it would be beneficial to show a few figures on the projected temperature and precipitation changes in China to put the projected changes of snowmelt in a better context.
- Section 3.1.3; L178: How are the PDDs measured? Or where do the data come from? Why not just simply say that when the temperature is above 0 snow starts to melt and the PDD starts to count? What are the temperature thresholds?
- Section 3.1.3; Table 1: The results that are presented here are strange. According to the authors the NSE and R^2 are both 1.0, which means perfect. I doubt whether this is the case since the MAE and RMSE indicate there are errors. If the MAE and RMSE were 0 I could have imagined that the R^2 or NSE are equal to 1 or close to 1, however that is not the case. Therefore, I guess something must have gone wrong in the calculations of R^2 and NSE and urge the authors to address this point.
- Section 4.1.1; L260: NSE = 0.2 is considered to be an unsatisfactory evaluation score, so why did the authors decide to use this value as a threshold? Is there a reason why at several stations the outcomes are unsatisfactory? And maybe the authors can elaborate more on their choice to use the NSE as an evaluation criterion for snowfall. It is more usual to use NSE as an evaluation index for snowmelt runoff or discharge. For the evaluation criteria, please also check Moriasi et al., 2007: <https://pubag.nal.usda.gov/download/9298/PDF>
- Section 4.1.2; L269 / Section 4.1.3; L282-283 / Section 4.1.4; L294: The simulated output reported by the model of the authors is on monthly basis, based on monthly mean values. Then it would be more appropriate and representative to compare the simulated snow depth with the monthly means of the observed snow depth instead of selecting the last day of each month. That is not representative. Besides, most likely comparing the simulated values with the observed monthly means will improve the outcomes of the authors presented later in the manuscript.

Specific Comments

- Abstract; L11: 1 km corresponds to 30 arcseconds or 0.5 arcminute. The latter has also been used in the dataset description for the high-resolution temperature and precipitation datasets by Peng et al., 2019.
- Abstract; L16: I recommend the authors to use $m^3/year$ instead of m^3 to make clear

that the authors talk about the mean annual snowmelt instead of the total snowmelt volumes within a period.

- Abstract; L20: From the abstract I cannot derive what "third level" stands for. Also, from the manuscript it is not clear what authors mean with "third level". Therefore, I would like to suggest using "subbasin" instead of "third level".
- Introduction; L39: What do the authors mean with slower snowmelt rates? Please rephrase to increase the clarity of the sentence.
- Introduction; L63: Do the authors mean the crop sowing season, crop harvesting season, or the entire crop season with "crop planting season"? I would like to recommend using one of the above-mentioned terms.
- Introduction; L65: Recently a new paper has been published on the Asian water towers by Immerzeel et al., 2020 (<https://doi.org/10.1038/s41586-019-1822-y>).
- Introduction; L76: Here and throughout the manuscript, please check and see my point at Abstract; L11.
- 2 Data Collection: Since a significant number of datasets is used in this study and the reader can get lost in all the numbers and details, I would like to suggest adding a table that includes the information of the datasets used, such as the variables (e.g., snow density), the source, the measurement periods, and the number of stations, etc.
- Section 2.2.1; L100: NetCDF is a data format, data cannot be obtained from NetCDF but are supplied in a NetCDF format. As I understand via the links the data were obtained from Peng et al., 2019, so please refer to them. Also, the link to the precipitation datasets did not work.
- Section 2.2; L102: CRU timeseries are supplied on a 0.5 degree grid, not at a 30 arcseconds grids. Please correct.
- Section 2.2; L103: I miss a reference to the WorldClim dataset. Also, more information on this dataset would be beneficial. For instance, what is spatial resolution of this dataset?
- Section 2.2; L102-104: I would split up the sentence into two parts to increase the readability.
- Section 2.2; L104: The observations are collected from 1951 to 2016, but is the latter year not supposed to be 2017?
- Section 2.2.2; L114: Is this about the critical temperature defining whether precipitation falls as snow or rain? That there are different threshold makes sense, but it would be good to map this as well for the readers convenience.
- Section 2.2.2; L116: I think in this context there are more recent data available as well. For example, see Jennings et al. (2018; <https://doi.org/10.1038/s41467-018-03629-7>) on the spatial variation of the rain-snow temperature threshold across the Northern Hemisphere.
- Section 2.2.2; L117: Were the threshold temperatures spatially interpolated? If so, via IDW or another method?
- Section 2.2.3; L120: Are there no other observations of snowfall data from a later period?
- Section 2.2.3; L125: Please validate the spatial resolution of the dataset.
- Section 2.2.3; L129: How is snow cover derived from snow depth?
- Section 3.1; L151: Does the PDD represent the mean monthly accumulated positive air temperature?
- Section 3.1.1; L159: The threshold temperatures are described, but not presented as a main result, which makes it difficult to imagine what the numbers are. Is it possible for the authors to present those numbers by means of a table or figure, either in the manuscript or the supplementary information?
- Section 3.1.2; L160-168: The authors use a method to calculate DDF based on the density of snow and water. The density of snow is based on observations. The question is, however, how do the authors calculate the future DDF. Do they authors assume the snow density to be constant over time?
- Section 3.1.2; L164: The snow density is variable since it is observed, but the density of water is constant, so please note it here for the readers.

- Section 3.1.4; L200: Do the authors have a reference to this sublimation method? Or is this a method the authors developed their own? If so, is this method considered to be valid?
- Section 3.2; L216-L218: I don't consider this as a good argument, since many hydrological models use the same methods, the authors also use. The models require temperature and precipitation data + several GIS data as an input, which are mostly available.
- Section 3.3; L233: Does n refer to the number of samples within a dataset?
- Section 4.1.1; L254-255: Please indicate this info in the data section.
- Section 4.1.2; L268: How is the snow depth calculated from the snow accumulation and snow density?
- Section 4.1.2; L270-271: Please indicate this info in the data section.
- Section 4.1.4; L295-296: An alternative solution for dealing with scale differences is to conservatively remap the outcomes to the 25km grid to compare simulated values with observed values. Did the authors consider using a conservative remapping technique to compare the simulated values with the observed values?
- Section 4.1.4; L298: Here as well as in the other sections where validation outcomes are presented it would be beneficial to add the observed and simulated values as well.
- Section 4.1.4; 299-306: I consider this argumentation as insufficient. Firstly, that the microwave remote sensing data have a spatial resolution of 25 km does not mean that relatively small glaciers are not recorded. At least, I think the authors should be able to substantiate why this is the case (e.g. by means of scientific literature) and whether it is a common problem for microwave remote sensing data. Secondly, since the authors decided to use the last day as a monthly observational representative the chance is very likely that the snow water equivalent on that particular day is 0, whereas the mean monthly snow water equivalent would have been different. This might explain as well why there is a discrepancy between the observed data and the simulated data. To my opinion, the authors need to elaborate more on this point.
- Section 4.2.1; L333: Here and throughout the manuscript, many readers have most likely no idea where most of the geographical areas are located. Therefore, I would like to recommend adding those locations to a map or to give an indication where these areas are located, such as West China or via some lat-lon coordinate.
- Section 4.2.2; L358-359: I think this is a result of global warming that combined, causes a larger fraction of rainfall relative to snowfall during summertime and an earlier onset of snowmelt during spring.
- Section 4.2.2; L359: Can the authors support their finding by indicating the increase in temperature that is measured in the regions?
- Section 4.3.1; L362: What are third-level basins? Are these basins of a third order? How are these defined? Is not better to mention them as subbasins?
- Section 4.3.1; L366: Due to heavy rainfall and low snowmelt?
- Section 4.3.2; Line 386: I guess it should be Section 4.3.2 instead of 4.2.2
- Section 4.3.2; L391: Is it Southeastern China or the southeastern part of the Tibetan Plateau?
- Section 4.3.2; L408: Is it significant or not significant. Considering the way how the sentence is phrased I would say non-significant. Please check and rephrase if necessary.
- Section 5.1; L454-465: What are the big differences and why are the results of this paper different/better/worse than the results in the other studies?
- Section 5.1; L468: The authors indicate their self that they should have used another method. What can the authors do to improve their results?
- Section 5.1; L466-479: What could be a potential reason for the under-performing snow depth? Could undercatch be a reason?
- Section 5.1; L484-487: I think point 2 and 3 are related to each other. Due to the complex terrain and harsh climate conditions, the number of stations is limited, and the distribution is sparse.
- Section 5.2; L502: Is there a specific reason for the higher correlation during

wintertime? Is the variability of winter precipitation larger than the variability of spring precipitation?

- Section 5.2; L523: Are the annual precipitation increases related to the changes in monsoon rainfalls or to changes in the westerly driven precipitation?
- Section 5.2; L524: High elevations are more sensitive to warming --> Elevation-dependent warming. I am not sure what the authors mean with "tolerate", but I guess it should be opposite.
- Section 5.3.2; L550-551: What are the authors trying to say with the high levels of precipitation in this region? As far I know most of the precipitation falls here during the East Asian summer monsoon, which is in summer, whereas the snowmelt season is in spring. That means the high levels of precipitation cannot be a good explanation for the snowmelt runoff ratios in this region.
- Section 5.3.3; L565: I think the authors cannot simply state that in some months all the runoff is contributed by snowmelt, since the authors have not considered the contribution of glacier meltwater to total runoff. For this reason, the authors need to elaborate more on this point, or I recommend them to rephrase the sentence.

Technical Comments

- Introduction; L38: "contribute" instead of "contributes"
- Introduction; L39: here and throughout the manuscript: "an earlier onset of snowmelt" instead of "earlier snowmelt times"
- Introduction; L44: "operations" instead of "operation"
- Introduction; L45: here and throughout the manuscript: "physically-based" instead of "physically based"
- Introduction; L46: I would use "simplified" instead of "simpler"
- Introduction; L52: "variations of air temperature and that the snowmelt" instead of "variations of air temperature that the snowmelt"
- Introduction; L61: "snowmelt" instead of "snow meltwater"
- Introduction; L64: "Snowmelt is also an important hydrological process on the Tibetan Plateau" instead of "Snow melting is also an important hydrological process in the Tibetan Plateau"
- Introduction; L65: "and is considered as the Asian water towers" instead of "and considered as the asian water towers".
- Introduction; L65: "Further, snowmelt is an important" instead of "Snowmelt is also an important"
- Introduction; L77: "considers" instead of "considered"
- Introduction; L78: "are" instead of "were"
- Introduction; L79: "China as well as in its three main" instead of "China and in its three main"
- Introduction; L80: "during 1951-2017" instead of "in the 1951-2017 period"
- Section 2.2; L102: "temperature" instead of "temperatures"
- Section 2.2.3; L119: I recommend merging the two sentences here into one. For example: "The observational snowfall (snow depth) data used to validate the model were collected from 475 (557) meteorological stations in China (Fig.1d (1a)) during the 1961-1979 (1951-2009) period and were provided by the China Meteorological Administration"
- Section 2.2.3; L123: "from" instead of "from by"
- Section 2.2.4; L139-142: This sentence is long and, particularly, the first part of the sentence needs to be rephrased to increase its readability and clarity.
- Section 3.1.2; L164: "mm °C⁻¹ day⁻¹" instead of "cm °C⁻¹ day⁻¹"

- Section 3.1.4; L193: "methods" instead of "method"
- Section 3.3; L240: "where the β sign reflects whether a trend is negative or positive" instead of "where β sign reflects data trend reflection"
- Section 4.1.1; L259: I guess the authors made a mistake here. I guess it should be 57.5%.
- Section 4.1.1; L260: "accounting for 60.0%" can be removed.
- Section 4.2.1; L316: repeated word, i.e., "the area with with"
- Section 4.2.1; L322: "Plateau becomes the main region of snowmelt until May. In summer, there is no snowfall in most of China and snowmelt" instead of "Plateau became the main region of snowmelt until May. In summer, there was no snowfall in most of China and snowmelt"
- Section 4.2.2; L346: "In Southeast China" instead of "Southeast China"
- Section 4.2.2; L355: "but" instead of "while"
- Section 4.2.2; L356: "might imply" instead of "implied"
- Section 4.2.2; L357: "at the Tibetan" instead of "in the Tibetan"
- Section 4.4.1; L415: "are shown" instead of "were shown"
- Section 4.4.1; L425: "17.1% (24.7%, 42.8%), respectively, compared to the historical period." Instead of "17.1% (24.7%, 42.8%) compared to the historical period."
- Section 4.4.2; L445-449: Very long sentence. I think it is better to split up the sentence in two parts.
- Section 5.2; L498: "grid cells" instead of "grids"
- Section 5.2; L513: "freezing point" instead of "freezing"
- Section 5.3.1; L546: "and therefore introduce agricultural risks Northern Xinjiang." Instead of "and changes in the snowmelt amount and timing may bring agricultural risks in the Northern Xinjiang."
- Section 5.3.3; L565: "contributes to runoff" instead of "contributes runoff"