List of all changes

- We have rewritten the abstract to better summarize the different parts of our study, and have clarified several confusing sentences.
- Throughout the manuscript, we have clarified our usage of the term “snow processes” as it was not always clear what processes we were referring to. Additionally, other confusing sentences have been clarified as well.
- We added a brief description and the equations of the snow module of the dS2 model, as this helps to understand the results.
- We improved the structure of the manuscript by moving text to their appropriate sections (from results to methods and discussion).
- We added a figure in the supplement, which shows the melt rate from snow and ice, to support the claims made in the main manuscript.

We would like to thank Anonymous Referee #1 (AR1) to write this review. Below, we will reply to the points made by AR1, with the comments from AR1 in black, and our response in blue.

General comment

The manuscript considerably improved compared to the other version I saw. The text is structured better and the model set-up explained better. In the following, some more minor issues that should be addressed before it is considered for publication. When specifying line numbers, I refer to the marked-up manuscript.

Thank you for reading and reviewing our improved version of the manuscript. We understand the issues raised, and comment with our solutions below.

Specific comments:

- Structure text: Even though the structure of the text is better now, one more revision is necessary, in my opinion. There still are some elements in the result section that should be moved to the method part. Please discuss your results in the 'Discussion'. Still almost all the discussion is in the result section. Add sub-section to the discussion (preferably the same that you use in the results).

  Thanks for this suggestion. We have moved the relevant paragraphs from the results to either the methods or the discussion. We do believe however, that some interpretation of the results is necessary to understand the results and the following analyses.

- Line 8: Please explain (what you mean by combination of these variables.

  Here we refer to the interaction between e.g. precipitation and temperature. If temperature drops below 0°C, precipitation will fall as snow, and will hence have a different effect on the resulting discharge. We have revised the abstract to clarify this.

- Line 19-20: Suggestions:: write directly 'less precipitation and lower snowmelt rates' and remove 'potentially higher snowmelt rates' and 'surprisingly'.

  We have clarified the sentence, and move the reference to Musselman et al. (2017) to the discussion.

- Line 61: expected > potential

  Thanks for the suggestion, we have changed this.

- Fig. 1: You detect less precipitation in the second time window. How do you explain this? Before you mention the intensification of the hydrological cycle. Should this cause more precipitation? Or is it just decadal variability?

  We attribute this to decadal variation, as periods of 10 years are to short to make qualitative assessments about changes in climate.

- Line 125 ff: The model does not include lakes or reservoirs, as far as I understood. This should be mentioned here and discussed later, as this is important for low flow situations.

  This is correct. We already discuss this in the discussion section, but we added this to the initial model description as well.

- Line 139: You run in hourly resolution, right? How does this work when you have a degree-day approach? What glaciers do you simulate? How does the model know that there is ice to simulate in a pixel? In case the snow and glacier modules are new, their implementation should be explained a bit better, I think.

We do indeed run the model on a hourly timestep, and the snow module is corrected for this. This means that the melt factors are defined as $\mathrm{mm\ ^{\circ}C^{-1}h^{-1}}$. We defined several pixels as glacier pixels, which are therefore fixed in space. These pixels also receive the glacier melt factors.

- Line 156: Please provide references of other studies using this swapping approach and discuss (dis-)advantages better.

  To our knowledge, this approach has not yet been applied yet. We have added a statement about the pros and cons of this method.

- Line 171: Please explain better what you mean by 'interaction between the three forcing components. This is an important point of your study and should be explained in more detail, I think.

  We have added a description of what we mean with the interactions, including the temperature-precipitation example.

- Line 180: You add 0.5 ° to you hourly temperature time series? If yes, please discuss possible shortcomings of this approach.

  This is correct, and we have added a downside of this approach.

- Line 198-199: This information needs to be in the method section.

  Thanks for the suggestion, we have moved it to the method section.

- Fig. 3: How do you determine that differences are significant? Significant differences in median values?

  We compare the discharge values from the 1980s with discharge values from the 2010s, grouped per month. We perform an independent t-test using these two groups of data, to determine the p-value for each month.

- LIne 205-209: Move this information to the section on data and methods. Do not introduce new data of validation approaches in the result section.

  We have fixed this, and the validation procedure is now explained in the method section.

- Line 210: Please explain why you use this catchment.

  This catchment was selected as the data is of high quality and at a high temporal resolution, which matches the model timestep. We have added this information to the manuscript.

- Line 240: 'ice' Glacier melt during March and May? Can you check whether it really is snow + ice or only snowmelt?

  It was slightly wrong written: it is a combination of more melt from the glaciers (due to the increased average temperatures), and more direct runoff as more precipitation is falling as rain in stead of snow.

- Fig. 4: To me it is confusing why there are two ylab next to panel d. Please move to correct panels.

  We use two labels as the two panels (e and f) use different units (cm and mm, respectively), similarly to panel d. We have clarified this in the caption.

- Line 246-249: I do not understand this explanation. Why are 'storage conditions' different between the months of March and April?

  We have improved the explanation of this, as the references to the periods were confusing

- Fig. 3: Please provide an explanation for the almost sinusoidal variation in your result figures.

  This sinusoidal variation is largely driven by the change in precipitation, which is simply due to the differences between the decades.

– Line 267-269: How is it possible that you get opposite results in your experiments for Jan-Feb with regard to changes in snowmelt contribution. I am surprised as well. Please explain better

An explanation has been added to describe the cause of this increase.

– Line 269 and Line 351: 'snow processes': Please specify what you mean by snow processes. Is it accumulation, snowmelt rates, timing,...

We have added more explicit descriptions of snow processes where necessary.

– Line 285: Move to discussion. Please do not discuss you results in the result section. Discuss in Discussion.

This paragraph describes the results shown in Fig. 6b, but requires some explanation to understand the results.

– Line 297: 'Over these periods of 10 years, most interannual variability is average out'

We have added a statement about the remaining present decadal variation.

– Line 348: I still have troubles to understand how you get to this number of 19% for precipitation. Please explain in the method section.

It is taken directly from Fig. 3f ($0.45 - 0.26$), where the mean values of panel e are presented. The way the contribution of each forcing variable is calculated is shown in Equation 11.

– Line 351: It sounds like there is more snowmelt with higher temperatures in Sep-Oct. Is this what you want to say? Isn't it the opposite? Higher temperatures result in a reduction of snow accumulation and a reduced build up of a snow cover. Rainfall is liquid instead of solid and hence more runoff?

This is indeed correct, and we have clarified this (more liquid precipitation, but enhanced melt from the glaciers).

– Line 264: Where do you snow enhanced snowmelt in you study? I do not see a figure depicting changes in snowmelt (rates) in you study.

Assuming you refer to Line 364, we have clarified this sentence. Additionally, we have added timeseries to show the melt rates for both snow and glaciers in the supplement (where also timeseries of the snowpack and -cover can be found).

We want to thank Anonymous Referee #2 (AR2) for taking the time to review the improved version of the manuscript. The comments from AR2 are presented in black, and our response in blue.

Comments

- I do not think the increase in discharge due to increased snow melt (processes) is a major conclusion. Suggesting that it partially offsets reductions in discharge is misleading. It seems that if you added up the increases during colder parts of the year with the decreases during warmer parts, they would equal 0 and changes in snow melt (processes) would not have much impact?

  This is correct when taking the yearly average value. Our conclusion that this is the case refers, however, to specific periods. We will clarify this.

- Abstract: This is still confusing to understand what was done in this study. I highly recommend using the term snowmelt throughout the paper as a simple and consistent replacement for "snow processes" or "snow dynamics".

  We have rewritten the abstract to more clearly describe the two experiments, and replaced the term "snow processes" with "snowfall and melt from snow and ice," as both are important.

- L1-6: "... how temperature-driven changes in evaporation and snow processes influence the discharge". Fourth sentence: "... observed changes could be explained by the changes induced by snow, evaporation and precipitation". I would try to make these sentences consistent. Mention specifically in the first sentence which parameters influenced discharge. Further, there are many snow processes, I would just mention the ones in your model that effect discharge (i.e. snowmelt (including glacier melt)). I am confused with attributing some changes in discharge to snow and precipitation. Snow is precipitation, so is it included in precipitation? Or do you mean liquid precipitation?

  The three variables we changed in the first experiment are evaporation, temperature (affecting only snowfall, and melt from snow and ice), and precipitation. Since the focus of our manuscript is on effect of temperature changes, we focus on evaporation, snowfall and melt. Precipitation input is defined as total precipitation, the model divides between rain and snow based on the temperature timeseries. We have clarified this in the newest version of the manuscript.

- L6: Changes in precipitation explained more of observed changes in discharge than changes in snow or evaporation, but in the title and throughout the paper you focus on evaporation and snow processes. Why are changes in precipitation left out of the title and not mentioned throughout the paper when changes in snow processes and evaporation are?

  The focus of the paper is on temperature driven changes in evaporation and snowfall and melt. When comparing two decades, changes in precipitation become indeed very important. However, our results show that in this decadal comparison the temperature driven changes are larger (26%) than the precipitation driven changes (19%). We have clarified this in the next version of the manuscript.

- L7: Higher temperatures led to earlier snowmelt (faster winter snowmelt rates) and less available snowpack to melt later in spring, when it historically melts.

  Thanks for this suggestion, we have clarified the sentence.

- L16: Need a reference for "potentially higher snowmelt rates". Perhaps you are talking about an increase in winter snowmelt rates? ("Melt trends portend widespread declines in snow water resources")

  Higher temperatures means that more energy is available to melting. We have rewritten this section and moved the confusing reference to Musselman et al. (2017) to the discussion.

- L17-18: This new sentence comes off out of place without additional context.

We decided to remove this sentence, as we cover this work in the discussion.

- L20: “Water towers” were defined earlier “Mountains of the world, water towers for humanity: Typology, mapping, and global significance”. Also, add “to” between important and have.

  Thanks for this correction, we have fixed it.

- L26: Wouldn’t only melted snow affect discharge?

  Whether precipitation falls as rain or snow also affects discharge. Here we wanted to explain the term “snow processes” but we understand this is still confusing.

- L50: I am more of a fan of using the term “snowmelt” compared to “snow processes”

  We understand the ambiguity of the term “snow processes” and we will therefore replace this term in the text with the exact processes we refer to (snowfall, snowmelt and melt from glaciers).

- L64: Delete “upstream of the basin”.

  Thanks for the correction.

- L149-150: How do you separate temperature effects on ET or snow processes? Wouldn’t changing the temperature affect both processes at the same time? Are you only changing temperature during the winter/summer and attributing that to only affecting snow/ET?

  The model uses separate inputs for evaporation and temperature (for snowfall and melt). This way, we provided time-series where only the evaporation is changed, and timeseries where only the temperature is changed. This is also how we setup the increased temperature experiment.

- L244: What do you mean by snow and evaporation are threshold processes?

  Snowfall and melt are dependent on temperature, where temperature acts as a threshold to “activate” these processes. Evaporation is dependent on (amongst others) soil moisture, where insufficient soil moisture acts as a threshold to reduce actual evaporation. We have clarified this in the newest version of the manuscript.

- L246: add “periods” between ‘the’ and ‘during’

  We have fixed this.

- L248: “Partially offset” seems like a stretch for the Jan-Feb period. The black line barely deviates from the orange line.

  There is a small deviation, yet it is still present. We will rephrase this sentence.

- L266: Switch “changed” to “change”

  Thanks for the correction, we have fixed this.

- L324: Can you differentiate between snow melt and ice melt?

  We have added average melt rates for snow and ice in the supplement, to better depict how higher temperatures affect melt from snow and ice.

- L330-331: Can this be explained with your data? Yes, the blue line in Fig. 5a is often barely above the dashed black line, but I would not rely on it too much. This statement is misleading if you cannot differentiate between snow and glacier melt and presents a potential false hope.

We defined the term snow processes to include snowfall, snowmelt and melt from glaciers. Despite it being a small change (for the majority of the year, both the purple line is slightly above the dashed black line, and the brown line is slightly above the orange line), it still slightly offsets the negative change induced by the enhanced evaporation. We understand the ambiguity around the snow processes term, and this will hopefully be fixed by explicitly stating which processes we refer to.