Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2020-73-RC1, 2020
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Earth System Dynamics Discussions

Interactive comment on "Seasonal discharge response to temperature-driven changes in evaporation and snow processes" *by* Joost Buitink et al.

Anonymous Referee #1

Received and published: 26 October 2020

General comment

Buitnik et al. simulate the Rhine River Basin for two 10-year time slices (1980s and 2000s) using the dS2 model and ERA5 data (0.25x0.25). An additional soil moisture model was added in order to attain values of actual evapotranspiration. ERA5 data was interpolated to a 4x4 km grid using bilinear interpolation. They assess changes in discharge between the two time slices and attribute differences in runoff to differences in precipitation, evapotranspiration and snowmelt. In general, it is an interesting study and has the potential to become a valuable contribution to hydrological research. However, I see several major issues regarding the analysis and the text that need to be

addressed before it can be considered for publication.

Major comments

Comment 1: Structure text

One major issue I see is that sections in the manuscript are mixed up or even missing. Often, model and method description are located in the result section. The results section is mixed with the discussion. In general, the manuscript lacks important details. I think a more detailed method description, where each step of the analysis conducted is described, needs to be added. Furthermore, model set-up and model components need to be described better. This is crucial to understand you experiments. Please provide more information on the dS2 model and the snow routine. An additional section 'study area and data' could be good to better introduce the Rhine Basin. In my opinion, large parts of the supplementary material can be moved into the actual manuscript.

Comment 2: Swapping variables

I still have troubles to understand your approach of swapping forcing variables in order to attribute changes. You try to asses the contribution of the three factors: 1) changes in precipitation, 2) changes in snowmelt due to changes in temperature and 3) changes in evapotranspiration due to changes in temperature. If I understand correctly, you swap individual forcing variables (temperature or precipitation, respectively) between the two 10-year time slices. You run the 1980s with temperature data from the 2000s, for example. So the temperature in the first week of August 2005 becomes the temperature in the first week of 1985, right?

This seems to be a very rough approach and I am not sure if this is a good idea. Also the performance of this approach seems quite poor. For parts of the year you can not at all explain variations or even expect an opposite trend (in February, for example, strong overestimation and in March even an opposite trend). The three factors you investigate do not really explain the variations in discharge, I think.

All variations that you can not explain, you attribute to 'interactions'. To me, these 'interactions' are not clear. I do not know what you have in mind here. Can you explain more detailed?

It looks like that a model only using the factor 'changes in precipitation' alone would explain changes in discharge better than the approach with the three factors (Fig. 2e). Please check.

What about changes in evapotranspiration due to changes in precipitation? What about changes in snowmelt due to changes in precipitation?

Comment 3: Attribution

In the abstract you write that variation can be 'explained by the changes induced by snow (11%), evaporation (19%) and precipitation (18%), while 52% was driven by combination of these variables." This bases on results presented in Fig. 2 panels e, f and g, I assume. How do you calculate those percentage values? In February and April, for example, you have a negative variation in discharge between the two 10-year slices of around 1000 m^3/s. This variations can be explained by variation in rainfall to 90-100%, right?

Comment 4: Evapotranspiration

Are you using evaporation or evaporation + transpiration = evapotranspiration? You mention the Penman-Monteith equation to get potential evaporation. Isn't it reference evapotranspiration you get? Do you calculate this? Or is it ERA5 data directly? You show a map of the potential evaporation (Fig. 1c). Can you also show a map of the calculated actual evaporation? Please give more information on the soil hydraulic data used. If I understand correctly, you assume one value of the rootzone depth for the entire basin? Is this value also constant over time? What about vegetation cover?

Comment 5: Temperature 'scenarios'

In my opinion, the different approaches you use need to be explained better. Your

swapping approach and the temperature 'scenarios'. Please explain in the method section. In those temperature 'scenarios', you simple add e.g. 2 °C to the hourly temperature time series? This again seems a very simple approach. In what way do those increases influence your model components and does this reflect 'real-world' processes? In Fig. 5 b your results indicate that increasing temperatures will rise evaporation in winter, in turn, decreasing discharges. According to my knowledge, evapotranspiration does barely play any role in winter (low radiation, low temperatures, no plants). All studies I know hint at an increase in discharge in winter, e.g. due to liquid instead of solid precipitation. Can you check this and maybe show your simulated evapotranspiration values for winter for this temperature 'scenarios'? Your model shows a linear response of evapotranspiration to temperature. How is evapotranspiration affected by changes in temperatures in the first place? Isn't it an input to your model?

Comment 6: Validation, Calibration

Why do you use two point measurements of this small pre-Alpine catchment to validate? Isn't there hundreds of snow gauges? Where is this snow gauge exactly? At what elevation? You compare the simulated snow in your 4x4km cell with the point measurement? Why do you simulate in an hourly resolution? Why not daily? For the routing? Can't you use daily data for calibration and validation (even if you initially run hourly)? At the end you aggregate to monthly values anyway. I still do not see the use of the hourly temporal resolution.

Further comments

Page 1 Line 6: "Increased temperature scenarios show that seasonal changes in snow-dynamics could offset a fairly constant negative change in relative runoff induced by evaporation, but not during the melt season."

I do not understand. What seasonal changes are you talking about? Where can I see this? What figure?

Page 2 Line 14: "higher snowmelt rates"

Lower snowmelt rates? https://www.nature.com/articles/nclimate3225

Page 2 Line 48: "high spatial and temporal resolutions ensure that small scale variability is accounted for."

I do not see how you account for small scale variability. The basic input data is very course (30x30 km) and only interpolated linearly to a 4 km grid. Strong spatial variability over short distances in the Alps, for example, is not captured.

Page 2 Line 54: "representative"

I do not get why it is 'representative'. Representative for other large river basin in Europe? Which ones? As you mention, it is a very heterogeneous basin, so this large heterogeneous basin actually is not representative for any sub-region in the basin, as they do not have this heterogeneity. Please check this again. Maybe I just don't get it. Page 2 Line 54: "north"

Northern Europe is roughly north of the southern coast of the Baltic Sea. It is more Central Europe, I think. Page 3 Line 63: "bilinear interpolation"

Why do yo use bilinear interpolation? Are there other ways to better address the spatial variability in the basin? Why do you interpolate on a 4x4 grid?

Page 3 Line 72: "yearly average precipitation sums decreasing from 1146 mm to 1066 mm"

How does this go along with mentioned 'intensification of the hydrological cycle'? Is this only decadal variability or a long-term trend? Can you compare to other 10-year slices?

Page 4 Figure 1: "climatic changes"

I am not sure weather it is appropriate here to call in climatic changes. You only com-

pare to 10-year time slices only twenty years apart. Usually climatic changes are assessed over longer time periods comparing at least 30-year time slices. Particularly precipitation is subject to strong decadal variability. I don't think it is appropriate to attribute the differences in precipitation that you show to climate change.

Page 4 Line 92: "Given that dS2 is not calibrated on these variables, and the difference in spatial scale of the input data, this shows that dS2 is able to correctly simulate evaporation and snow processes."

This validation using only two point measurements does not really convince me. Are there other ways to better assess the performance in space? Maybe MODIS snow cover maps?

Page 6 Line 121: "confirming our hypothesis"

Your hypothesis was a linear response of discharge to temperature change?

Page 6 Line 132: "increased snowmelt"

Isn't it more liquid instead of solid precipitation?

Page 7 Figure 4: " Panel a shows the yearly average discharge under a 2.5° C "

Just for me to understand. First, you simulate the 1980s with your normal input data. Then you add 2.5°C on the temperature time series and re-run the model? So the increase in temperature strongly increases (linearly) the evaporation and hence discharge decreases? Does it makes sense that this effect is the same throughout the year?

Page 7 Line 133: "glaciers in the Alps"

There are glaciers in your model?

Page 8 Line 38: "As expected, the majority of the basin is controlled by the change induced by a change in evaporation (84–97%). As a result, the mean discharge is reduced by $\pm$18%."

Do you think that his is only in you model or is this effect the same in the 'real-world'? Any seasonal differences?

Page 8 Line 146: "interannual variability"

What about decadal variabilities?

Page 8 Line 147: "effect of different temperatures"

Also strong differences in precipitation between the two time slices!

Page 8 Line 149: "downscaling method"

A linear interpolation is better than downscaling? Isn't the simple bilinear interpolation you use adding a lot of errors and uncertainties throughout the basin?

Page 8 Line 159: "With higher temperatures, increased melt from glaciers and snow packs can offset the discharge reduction from enhanced evaporation over the majority of the year."

Where can I see this in your result figures? Please explain better what you mean by 'snow driven changes'.

Page 9 Line 168: "Enhanced melt will offset the negative trend caused by the increased evaporation, until the frozen water storages are depleted."

Where do you show this in your study?

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