Interactive comment on "Future projections of High Atlas snowpack and runoff under climate change" *by* Alexandre Tuel et al.

Anonymous Referee #2

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Future projections of High Atlas snowpack and runoff under climate change Tuel et al. 2020: https://doi.org/10.5194/hess-2020-622

General comment

Tuel et al. simulate the snow cover of part of the High Atlas mountains in Marocco (headwater catchments of the Oum-Er-Rbia watershed) using downscaled and bias corrected climate model data (data from three GCMs and two RCPs). Furthermore, they use a statistical runoff coefficient model to estimated changes in runoff. They concluded that decreases in precipitation in combination with increases in temperatures will diminish snowpacks and reduce runoff. 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 analytical approaches and the text that need

to be addressed before it can be considered for publication at HESS. It needs to become more clear what are the new findings of this study that extend already existing knowledge, I think.

Major comments

Comment 1: Language

Although I am not a native English speaker myself, I find that the language of the manuscript needs to be improved. I came across numerous sentences and expression that I think need improvement (see specific comments). In my opinion, a language check will improve the manuscript. Furthermore, make sure to use a space to separate the unit from the number.

Comment 1: Structure text

A restructuring of the text can increase its comprehensibility. I think, it would be helpful to separate Results and Discussion. First present results with subsections on snow simulations and runoff coefficient model and then discuss results in a next step (maybe again use same subsection, e.g. 'snow simulations' and 'runoff coefficient model'.

Comment 3: Introduction

I miss a clear line of argumentation here that then leads to your aims/goals. Please restructure and rephrase so that the literature and numbers presented are easier to understand (see also specific comments). I think the main sentence is in Page 2 Line 39-40. This is your main motivation, right?

Comment 3: Data

This section was a bit confusing for me. You present so many different data sets with different time frames, observed, simulated, station-based, satellite-based,..Often I did not understand what you use the individual data sets for. Please support the reader by e.g. an overview scheme and/or table that illustrates what data sets you use, what

time frame and what for. As far as I understood, historic data sets are mostly used for the runoff coefficient model? While reading I also was not sure what data is from Tuel et al. 2020b and what is new in this study. I suggest to extend the scheme in Fig. 4. Also you present results from your comparison of the satellite-based data sets in the data section. Please consider moving this in the result section.

Comment 4: Study area

You use several different domains in your manuscript. What is your snow domain (Page 6 Line 162)? What the model domain and how do the Oum-Er-Rbia watershed and the seven sub-basins fit into this? Please clarify. Add more information on the sub-basins (area, elevation,...).

Comment 5: Snow model calibration

With annual cycles (Page 6 Line 161) you refer to mean average annual cycles for the time frames you state (i.e. 1995-2005 and 2000-2011)? If yes, why do you use NSE values of average annual cycles that only partly overlap? Didn't you mention that the inter-annual variability is very high? Isn't it important to use the exact same time periods? I never saw this approach before, I think. Please explain in more detail why you use average annual cycles of snow fraction here. Furthermore, please provide more information on the calibration routine (how many runs, what NSE values did you get, what optimization algorithm,...).

Comment 6: Statistical Runoff Coefficient Model

What is the motivation to use this approach here? Please explain. What are e.g. the disadvantages compared to hydrological models, which seem predestined to investigate changes in runoff. You state that your covariates only explain 30 % of the inter-annaul variability. What about the other 70 %? Later you use this two covariates to estimates future runoff. Please justify. Why should the relationships you established for the historic time frame hold under future conditions? Don't you show that climatic

changes with fundametally alter the hydrological cycle in the region? Why do you think RH is so important in this model?

Specific comments

Page 1 Line 1-8: Large parts of the abstract are introduction. Please provide more information on your model set up and results (!) here.

Page 1 Line 11-12: What results have important implications!?

Page 1 Line 16: "1000m": Please use space between unit and number. Check your manuscript.

Page 2 LIne 26: "station snow data series": Pleas rephrase. They simulate snow for one station and use the observations from there to calibrate and validate?

Page 2 LIne 27: "somewhat less sensitive": Please rephrase.

Page 2 Line 27: "Atlas" > "High Atlas"? In general, I was a bit confused by the different term 'High Atlas', "Atlas", "Middle Atlas". Is there any difference?

Page 2 Line 34-37: With only 12 years of data no proper trend analysis can be conducted, I think. It is not very surprising that no significant trends can be found. You also states this in the following that there is a strong inter-annual variability. Maybe only inform the reader here about the strong inter-annual variability and do not discuss the results of the trend analysis from Marchane et al., 2015, as they do not seam to contain relevant information.

Page 2 Line 34: "coefficient of annual variants (0.25)": What does this coefficient mean? Where does it come from?

Page 2 Line 34: "potential long-term climate trends will be difficult to detect in such short-term series": Yes, I agree. long-term climate trends can not be determined with short time series I would recommend to rephrase to something like "A sufficient length of the time series is needed..." I still think that it is not a good idea to base your line of

argumentation here on the study analyzing 12 years of data.

Page 2 Line 36: "developed" > "assessed"?

Page 2 Line 46: "anthropogenic warming" > "global warming"?

Page 2 Line 46: "quantify the sensitivity [...] to large-scale meteo": You estimate changes in runoff.

Page 2 Line 54: Refer to the map (Fig. 1) here.

Page 2 Line 54: "4 km^3"; Where is this number from?

Page 3 Line 62-63: Are the 'plains' below 1000? The sentence is a bit difficult to read. Please rephrase. Do the 'plains' play any role anyway? As far as I understood you only simulate the high-head watersheds (snow domain)?

Page 3 Line 62-63: Rephrase sentence. I would present this information more neutral and remove 'precipitation is spares'. Stick to the numbers: basin average 400 mm, lowland plains 250 mm and mountains 800 mm.

Page 3 Line 68: At this point you did not introduce the data yet.

Page 3 Line 71: "somewhat persistent snowpack is not uncommon": This is a quite strange formulation. Please rephrase.

Page 3 Line 72: "rapid": What does it mean here? Are melt rates higher than in other mountain regions?

Page 3 Line 76: "seven stations": Please include table with information on stations: location, elevation,..

Page 3 Line 77: "discard": How much of the data is left after this step?

Page 3 Line 78: "daily discharge measurements": Any quality check conducted?

Page 3 Line 82: Provide average elevation and area for each sub-basin.

Page 3 Line 82: "remove the contribution...": Why do you do this? Is this a common approach?

Page 3 Line 88: What is the spatial resolution of TRMM?

Page 4 Line 110: due to cloud cover?

Page 4 Line 116: "consider" > "use"?

Page 6 Line 155: I think you should introduce this modeling domain and its characteristics in the section on study area already.

Page 6 Line 158: Why 0.8? Where is this equation from? Is this your approach?

Page 6 Line 180-183: Move to discussion?

Figure 5: What time frame do you compare here? Add elevation ranges to figures (header) directly. What fraction of the simulation are do those elevation ranges cover? Do you simulate the whole watershed or only the 'snow domain' or the seven sub-basin? Add also a legend to indicate what lines represent.

Page 8 Line 213: Where can I see 'elevation gradients' in Fig. 6?

Figure 6: Add sub-basins to map. Use grayscale? for background map. Maybe also add river network? Add figure headlines, so readers does not have to scan through the caption to find out what is shown.

Page 8 Line 215: What is a narrow band? Can you quantify?

Figure 9: What additional information do we get from Fig. 9? Why do you normalize in this way?

Page 8 Line 224-226: This sentence sound complicated. You want to point at two signals, right: total precipitation is getting less and in addition solid fraction is reduced. Both results in less snow accumulation.

Page 8 Line 228: Why do you use MCM here? Can you change to mm?

Page 8 Line 231-232: Please rephrase.

Page 8 Line 236: This section on sublimation loss contains intersting information, but somehow comes out of nowhere and I have troubles to connect it to previous parts. Please add information on your analysis on sublimation losses in your method section.

Page 9 Line 253: "may not increase very significantly": Rephrase. Maybe to "remain largely unchanged"?

Page 9 Line 277-280: This part of the discussion is confusing me. It mixes up a lot: groundwater, infiltration, evaporation, runoff concentration processes - all things you do not directly investigate in your study...

Page 9 Line 284: "The impact of decreasing RH largely dominates over that of declining snow fraction": Where can I see this. Don't they have the same effect on RCs? How robust are these findings? How much uncertainty is in your runoff estimates?

Page 10 Line 303: "Final chapter"? What final chapter?

Page 10 Line 304: "Unsurprisingly" > remove

Page 10 Line 306: "substantial mitigation of emissions": Where is this? What RCP?

Page 10 Line 308: "for much of these trends": How much? Can you quantify? How much is the contribution of changes in precipitation and how much from rising temperatures?

Page 10 Line 308: "larger snow fraction leads to less runoff": More snow results in less runoff? Do you mean lower runoff coefficients? (This is not a surprise, as you also explain). Maybe also take a look at: https://www.nature.com/articles/nclimate3225

Page 10 Line 311: remove "believed". This word is more used in the context of religion, I think.

Page 10 Line 314: Where do you show that rain-on-snow events increase? At all

elevatins? Please provide more details

Page 10 Line 317-319: Where do you show this in you analysis?

Data availability: This is not sufficient. Please provide more information on where to get the different data sets you used.

Acknowledgements: You provide information on funding here. Please do so in 'Funding information'. Acknowledge here the data providers etc.