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Discussions

Interactive comment on "Linking baseflow separation and groundwater storage dynamics in an alpine basin (Dammagletscher, Switzerland)" *by* F. Kobierska et al.

Anonymous Referee #1

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This study is presenting a conceptual model of groundwater flow contributions to streamflow in the forefield of a glacier. Although the model presents an interesting data set and conceptualization of the different aquifer or reservoir dynamics and interactions hypothesized for shallow groundwater flow dynamics it is omitting and over-simplifying several hydrologic components that influence streamflow and groundwater flow over the active summer melt period to a degree that it is questionable whether the processes included in the two groundwater reservoir model are producing the right answer for the right reason. Dynamics such as changes in the active layer depth of the forefield (defining the active or drainable aquifer thickness), the unknown subsurface contribution of

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flow from the upslope dead ice body and diurnal snow and glacier melt contributions (how were those estimated in the model?) are unsatisfactorily considered. Thus, I recommend major revisions of this manuscript to address these shortcomings of the study.

Specific comments:

The active layer depth within the forefield of the glacier is typically increasing over the summer season. It is unlikely that flow occurred in the frozen glacial deposits early in the summer season. How was this dynamic increase in the active layer depth or active thickness of the aquifer considered in the model? Because of that freeze-thaw dynamic at the beginning of the summer season flows should be entirely dominated by melt contributions before the active layer depth is large enough that greater groundwater flow contributions occur. This is contrasting the dynamics described on page 12202 (last paragraph).

The dead ice body located upslope of the forefield will continuously contribute flow to the forefield aquifer and stream. The rate at which the dead ice body is contributing flow depends on the summer air temperature. How was this flow contribution considered in the model?

Page 12189, Lines 15-16: I would like to see a little bit more information on the use of electrical conductivity for estimating groundwater flow contributions. What is meant by "seasonal envelopes"?

Page 12189, lines 27-28: What are the two benchmark models mentioned?

Page 12189: The mixing model is assuming a time-varying input of groundwater. However, it is not clear to me whether the authors assume that the electric conductivity remains constant over time in order to define the groundwater end-member or whether it is changing values contemporaneously to the change in groundwater contributions.

Page 12190, line 17: Over which period was the annual air temperature estimated.

HESSD

11, C5339–C5344, 2014

Where was the temperature measured? What is the mean summer temperature?

Page 12191, lines 9 ff.: I would mention that depth to the groundwater table were measured in piezometers instead of “two in groundwater tubes”.

Page 12191: What was the length of the piezometers and to which depth were they installed in the forefield?

Page 12191, lines 25-29: Please add references to this section to corroborate your statement.

Page 12192, line 3: Please explain what you mean by “passive aquifer”.

Page 12192, line 6: What was the overall range of groundwater level change and stage measured? What is the accuracy of the Hobo U20 pressure transducer?

Page 12192, Lines 20-21: You assumed a snow density of 0.3. Snow density can vary greatly (0.05 – 0.7) depending on the climatic conditions and the moisture content of the precipitation contributing to snow. How did you decide for this value? Why didn’t you determine the snow density from one or several snow cores or snow pits?

Page 12192, Lines 22: How was snow depth measured at the AWS?

Page 12193, line 2: Do you mean water temperature here?

Page 12193, line 11: How did you derive the different EC zones? Please explain the method/approach used.

Page 12195, line 18: How are the two groundwater reservoirs connected? Is there percolation/exfiltration between the two reservoirs? Do both reservoirs contribute to streamflow or is only the fast reservoir contributing to streamflow in the summer? I see that some of these points are clarified in section 3.2.3, however, I would suggest stating those key assumptions earlier on.

Page 12195, line 19: It is important to mention here that the slow reservoir, although

HESSD

11, C5339–C5344, 2014

remaining constant (or full – constant is a bit confusing here!), is still contributing to streamflow at a constant rate. The current wording gives the impression that the slow reservoir is not contributing to streamflow during the summer at all.

Page 12196, lines 6-8: Did you measure electric conductivity in the stream throughout the winter? This would have provided an indirect way to quantify flow in the winter using the EC-based mixing model.

Page 12196: Equation 5 states how the integral water level was estimated based on all available groundwater level measurements. How was the initial groundwater storage estimated? Did you use any of the geophysical data (e.g. the estimated average aquifer depth of 10 m) to determine the groundwater storage size? Also you mention that only piezometers far away from the stream were used to estimate the integral water level. Was the water table measured in near-stream areas always near the soil surface or why were those piezometers not included in the estimate?

Page 12197, line 6: How did you estimate the residual water storage volume?

Page 12198, line 4: What are the remaining years? Please add time period in parentheses.

Page 12198, line 22 ff.: Why do you keep the groundwater exfiltration rate constant in equation 3 instead of keeping the end-members constant (e.g. low EC for melt runoff, high EC for groundwater) and use a simple 2-component hydrograph separation to estimate groundwater contributions to streamflow? If you measured EC in the streamwater, snow/glacier melt and groundwater over time one doesn't have to know the groundwater flow rate to determine the contribution to streamflow in Equation 3.

Page 12199, lines 4-5: Unclear wording. I don't think "compensate" is the right word here.

Page 12201, lines 13-16: This part is confusing. Just state that you estimated the groundwater contribution from the slow reservoir from the baseflow recession and that

HESSD

11, C5339–C5344, 2014

this storage is linearly draining at a rate of 0.07 m3/s and that this value was used to define the constant exfiltration rate. There are two many terms introduced that are describing the same hydrologic component (e.g. exfiltration rate, baseflowmax). Try to reduce the number of terms for the sake of consistency.

Page 12202: It would be interesting to see a figure comparing the hydrographs of observed flows versus PEC and PGW.

Page 12202, lines 20-21: The authors state that the modeled stream width is a function of groundwater exfiltration and that this is suggesting that the mixing component is well parameterized. Where is the data shown that is supporting this conclusion? I don't see estimated stream width in either a table or figure. Is the modeled stream width supposed to range between 5 and 14 m as stated in line 14 (same page)? Even though braided rivers are "hard" to measure one could have attempted to provide a comparison to field measurements. There are always spots where braided rivers have confluences where one could measure stream width and depth. This is otherwise a far-fetched statement.

Page 12205, line 1. The authors state that the piezometers were "empty" by the end of the season. How deep were the piezometers? Are you sure you didn't just see empty piezometers because they were not installed deep enough?

Page 12205, lines 17 ff.: I would add that this deeper reservoir has an "active" volume of 1000m by 400m by 1.7m. The authors should mention in the site description whether permafrost exists in the forefield and how active layer depth changes over the season. Forefields of glaciers are typically characterized by several dead ice bodies or saturated moraine or glacial till material that is frozen during the winter. Thus during the spring snowmelt, runoff occurs on top of frozen and supersaturated soils. The hydrogeological description provided in section 5.2 however implies that the moraine deposits in the forefield of the Damma glacier remain unsaturated for most of the time except for the summer melt season. This should be discussed. Page 12206, line 12

HESSD

11, C5339–C5344, 2014

ff.: Rainwater has an EC of 6.05 μS/cm. If rainfall occurred during times when the groundwater reservoir was "half-empty" the infiltrating rainwater would quickly mix with the groundwater body in the aquifer causing a dilution of the 15.1 μS/cm groundwater while at the same time contributing to streamflow. Since contribution of groundwater to streamflow is delayed how would this "dilution" of the groundwater EC-values influence the uncertainty of the model?

Page 12207, line 5 ff.: This statement is simply not true. There are several energy-balance based hydrologic models that work satisfactorily with available meteorological data (see references below for a few examples).

G. Jost, R. D. Moore, B. Menounos, and R. Wheate. 2012. Quantifying the contribution of glacier runoff to streamflow in the upper Columbia River Basin, Canada. HESS, 16, 849–860. Reijmer, C. H. and R. Hock, 2008. A distributed energy balance model including a multi-layer sub-surface snow model. Journal of Glaciology. 54, No. 184, 61-72. Hock, R. and B. Holmgren, 2005. A distributed energy balance model for complex topography and its application to Storglaciären, Sweden. Journal of Glaciology 51(172), 25-36. Hock, R., 1999. A distributed temperature index ice and snow melt model including potential direct solar radiation. Journal of Glaciology 45(149), 101-111.

Figure 5: Is the reservoir depth plotted in Figure 5 showing the reservoir depth of the slow, the fast or both reservoirs? When is the reservoir considered to be full? Please indicate with a threshold.

Minor comments: Page 12190, line 10: Insert "the" after "a small piece of". Page 12192, line 21: Replace "Cumulated" with "cumulative". Page 12198, line 5: Suggest using "EC data" instead of just "EC". Page 12206, line 10: replace "a" with "of" before "four". General: Please use the term "piezometer" instead of "tubes". I find the word "tubes" very unspecific.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 12187, 2014.