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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Estimating glacier and snowmelt contributions to stream flow in a Central Andes catchment in Chile using natural tracers" *by* M. Rodriguez et al.

Anonymous Referee #3

Received and published: 23 August 2014

I think this is an interesting study and the paper is well written. The study improves our understanding of spatiotemporal flow dynamics and runoff generation in snow- and glacier-dominated watersheds. I think that the science is good and the paper is generally well written. My only concern with this paper is the lack of clarity on which data sources, time periods or explanatory variables have been used in the various hydrograph separation methods. This information has been repeatedly less clearly stated or simply omitted. In addition, the authors point out that the Bayesian hydrograph separation approach has the main advantage of providing more accurate uncertainty estimates on the relative contributions to streamflow. Yet a thorough uncertainty anal-

ysis as discussed in both the introduction and discussion has not been performed or presented in this study. It would be interesting to see how uncertainty such as the change in snow isotopic signature with elevation or the non-conservative behavior in the concentration of cations and anions is influencing the estimated snowmelt and glacier melt contributions. The errors associated with both uncertainty sources could be propagated through the various hydrograph separation methods and plotted as error bars in figures 10 and 11. I think such analysis would provide a valuable addition to the understanding of the various water sources and their spatio-temporal contributions to streamflow in snow- or glacier dominated hydrologic systems.

Specific comments: Introduction:

The authors mention the advances of using Bayesian approaches in hydrograph separations because they provide a better means to assess statistical and model uncertainty in the results. Yet uncertainty was only marginally addressed in the actual presentation of results (only on page 8972). I would like to see a more thorough analysis and presentation of the uncertainty associated with spatial and temporal variability in the isotopic and constituent concentrations and the various models used for the hydrograph separation.

Study area: Please add information on the percent glacier cover in the Juncal watershed and the spatio-temporal variability of snow in the watershed (e.g. Over what period does the snow melt? Are there areas where snow lasts over the summer?)

Page 8956, line 1: Why not use the chemical symbols (e.g. Mg) instead of element names as was done in the previous paragraph?

Page 8956, line 10 ff.: I am assuming snow samples were taken along the road to estimate the change in snow isotopic composition with elevation. How was the spatial variability considered in the hydrograph separations? Including an uncertainty analysis that is estimating the effect of spatial variability in isotopic signals on the estimated source water contributions as done by Laudon et al. 2002 (Oxygen 18 fractionation

during snowmelt. . ., WRR), Taylor et al. 2002 (How isotopic fractionation of snowmelt affects hydrograph separation, HP), or Dahlke et al. 2013 (Isotopic investigation of runoff generation in. . ., HP).

Methodology:

Page 8958: Why not just used “RMSE” and “bias” instead of “BRB” and “RRRMSE”?

Page 8959, line 16-20: Please explain how rotating the coordinate system helps to clarify the dynamic behavior of the hydrologic system.

Results:

Page 8962: The results section needs an introductory sentence or two that is outlining the results section.

Page 8963: I don’t see: the apparent seasonal difference in the observed δD vs. δ18O graph shown in Figure 5. If there is indeed a significant difference in the isotope signal between the three seasons then this could be easily proven with a two sample t-test for example.

Page 8964, lines 3-5. It is unclear whether the DGA data were projected onto the U space of the UChile data or vice verso or whether an independent U space was created from both data sets. Was the entire data set used to create the PCA or was the PCA conducted for the different seasons distinguished earlier?

I would like to see a table or box-whisker plot summarizing the observed concentrations at the various sampling points incl. the number of samples that were collected.

Page 8964, lines 10 ff.: Which elements were contributed most to the PCA among the 6 listed in line 10? Figure 6 does not really indicate which element (e.g. K or Mg) contributed most to the PCA besides the isotope signals. Thus I would suggest adding a biplot or 3D plot of the first two/three principle components as well as the orthonormal principal component coefficients. In addition, the authors should add a pareto diagram

showing how much each principal component explains the variance observed in the data.

Page 8965, line 4: Please provide a short description of what the Hooper approach is.

Page 8965, line 9: A more quantitative analysis of the residuals for normality is needed to make this statement. Please see my comment on Figure 7 for details.

Page 8965, lines 15-17: A 3D plot showing the sample value cloud and first principle components would be more meaningful especially if including the orthonormal principal component coefficients and labels for the various water sources considered in the PCA.

Page 8966: Was the MPCA model created for the entire time period for which data was available or for one or many of the seasonal time periods distinguished in Figure 3. Please clarify.

Page 8966, lines 22-23: Were the studies of Ragletti and Pellicotti (2012) and Liu et al. (2004) performed in the same watershed (Juncal)? If not how can the spring and summer data collected in these studies be used as prior information in the Bayesian model?

Page 8967, lines 2-3: How were glacier and snowmelt sources split into surface and baseflow components? Please specify the methodological approach for this.

Page 8967, line 6: What is reacted water? Please define.

Page 8967, lines 12-14: How was the Bayesian model informed using soil water signatures? Please state the data source and prior information build based on the soil water signature.

Page 8967, lines 15 ff.: Please support your isotopic model with statistical proof on significant differences observed in the snowmelt, soil water, glacier melt and streamflow isotopic signatures.

Page 8968, lines 4-5: “the amount of poorly and highly soil. . .” Awkward phrasing.

Page 8968, line 9: Please specify which “relative contributions” you are quantifying in this final results section. The current wording does not make this aspect clear.

Figures and Tables:

Figure 4: The various sampling locations are impossible to distinguish. Please consider either combining all water sources into one symbol or change the scale of each piper diagram to zoom into the diagram to allow a better differentiation of the various water sources. Otherwise this plot does not add much value to the study.

Figure 5: I don’t agree with the apparent seasonal difference in the observed δD vs. δ18O graph shown in Figure 5. If there is indeed a significant difference in the isotope signal between the three seasons then this could be easily proven with a two sample t-test for example. All three seasons clearly cluster within the same value range. Please also increase the line width of the dotted line which is hard to see.

Figure 6: It is not clear from the caption or the actual graphs what this figure is supposed to indicate. One can see the RMSE and bias I assume from the MPCA for different elements used in the MPCA. It would be helpful if a more detailed explanation was added to the caption.

Figure 7: In order for the reader to judge whether residuals are i.i.d. and randomly distributed it would be helpful to add trendlines to the point clouds. In addition, the authors could perform the Lillifors test to assess the normality in the residuals.

Figure 8: An actual 3-D plot of the first three principal components including the orthonormal principal component coefficients would actually be a better representation of this figure. As in Figure 4 the symbols are nearly indistinguishable and need to be revised.

Figure 9: For which season or time period is data shown in this plot? Please indicate in the figure caption.

Figure 10: Please add information regarding the data and model source and time

period in the caption. Was UChile or DGA data used for this plot? Is the graph showing the entire period for which observations were available? Plots F and G are hard to read since the legend is covering parts of the graph. I would suggest moving the legend into the dark grey shaded area. In addition, instead of showing the separated flow components in units m3/s I would plot percentages since you use percentages in the text and they are easier to interpret for the reader. One could add a second y-axis label on the right side of the graphs showing the percentages while the left graph will state flow rates.

Figure 11: See my comment in Figure 10 regarding y-axis label.

Figure 12: Although being a conceptual graph this figure needs a legend that is explaining the various symbols.

Minor comments: Page 8952, line 18: Change “season” to “seasons”. Page 8952, line 18: Change “primary” to “primarily”. Page 8953, line 25: Insert “it” before “is accepted”. Page 8954, line 3: Replace “giving” with “providing”. Page 8955, line 1: Replace “site” with “side”. Page 8968, line 12: Delete “with” before “nearly”> Page 8973, line 1: Replace “respect” with “compared”. Figure 10: Please correct “shows” to plural since you are referring in both instances to two plots.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 8949, 2014.