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Hydrology and Earth System Sciences Discussions

# *Interactive comment on* "On the contribution of groundwater storage to interannual streamflow anomalies in the Colorado River basin" *by* E. A. Rosenberg et al.

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"The authors investigate the contribution of groundwater storage to interannual streamflow anomalies in the Colorado River Basin (CRB), using different approaches including satellite estimates. They find that all methods provide similar estimates and that the groundwater component does not play a major role in the interannual variability of the Colorado River Basin. This is an important and useful study that I support. People have wondered about groundwater storage in the CRB at interannual time scales and this study shows that it is not a factor. I have a few comments listed below."



Authors: We thank Dr. Rajagopalan for his feedback and suggestions for improvement.

"1. Several methods are proposed and used in computing the groundwater storage, which can be confusing and a bit overwhelming to the reader. I would suggest if a couple of them could be moved to appendix with description of their results in the text."

Authors: While we agree that the number of methods used in computing groundwater storage can be a bit overwhelming, we feel that moving some of the methodology section to an appendix would gut a key part of the paper, which is intended to look at this issue from several different perspectives. In response to the reviewer's comment, however, we have now added a table summarizing the various groundwater storage computation methods, including the time periods of analysis and sources of data.

"2. The authors should provide a robust discussion on the physical mechanism of the limited role of groundwater storage. Is it due to the subsurface geology? soil type? etc.?"

Authors: The limited role of groundwater storage is most likely due to the subsurface geology of the basin. As described in Sect. 2, the substrate of the Colorado Plateaus aquifer system, which underlies the majority of the Upper Basin, is predominantly sandstone. Since the porosity and hydraulic conductivity of sandstone are relatively low, most groundwater moves along secondary openings such as joints, fractures, and bedding planes. It is therefore largely disconnected from the streamflow generation process, particularly in the central, semiarid rangeland where water tables are very deep. We might expect greater interaction between groundwater and streamflow in headwater sub-basins during the snowmelt season, but here the thinner soil profiles that are typical of mountainous regions would limit this groundwater influence. We have now included a discussion of these mechanisms in Sect. 5.

"3. It is not clear if the authors compute the groundwater component over the entire period of record (1958–2008)? Or do they compute just the climatology?"

Authors: For VIC-SIMGM, time-varying computations of groundwater storage were performed for the entire simulation period, and we have now clarified this point at the end of Section 3.1. For the baseflow recession analysis, both monthly and annual changes in groundwater storage were computed over the respective periods of record for each of the 72 GAGES-II streamflow gages, as described in Section 3.4.

"4. If there is a criticism of this study, it would be that the validation is not done with 'actual' observations. The comparisons and validations are across the methods but not with actual observations. I would like the authors to address this."

Authors: Assuming Dr. Rajagopalan is referring to well observations of water table depth (GRACE data, for example, can be considered observed data as well), we agree that this issue is insufficiently addressed in the current version of the manuscript. As noted in our response to Reviewer #1, direct validation of simulated WTDs with well observations is complicated (and arguably made infeasible) by the relatively coarse spatial resolution of our model implementation (1/8-degree, or roughly 10–15 km). Because of the great spatial variability in WTDs (even over smaller scales), we, like Niu et al. (2007), do not expect our simulated WTDs to be representative of what amount to (nearly) point observations. However, we do expect to be able to validate basin-wide changes in groundwater storage, and hence used water balances, comparisons with GRACE data, and baseflow recession analyses for this purpose. We have now elaborated on this issue in Sect. 3.1.

"5. Does groundwater play a role at decadal or multi-decadal time scales? Also what does it do to the runoff efficiency?"

Authors: Based on the results of our analysis at the interannual level, it is unlikely that groundwater will have much of a modulating influence on streamflow anomalies at decadal scales in the CRB beyond the rather limited interannual signal (obviously interannual variability leads to some decadal variability). A rigorous analysis would be complicated by the small interdecadal sample size that could be drawn from our $\sim$60



year simulation.

With respect to the second question, shallow water tables result in greater values of soil moisture, and hence greater runoff efficiencies, than deeper water tables. Similarly, we expect an uncalibrated VIC-SIMGM implementation to result in greater runoff efficiencies, since the groundwater element also increases soil moisture by volumetric water content (see Fig. 5). However, because of calibration, runoff simulations for our VIC-SIMGM implementation are comparable to those for our VIC implementation, and at least in the model world, the groundwater implementation doesn't result in much of a change in runoff efficiencies – at either interannual or interdecadal time scales. We have now mentioned this point in Sect. 4.1.

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