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Discussions

Interactive comment on "GRACE storage-streamflow hystereses reveal the dynamics of regional watersheds" *by* E. A. Sproles et al.

Anonymous Referee #2

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General comments:

In its exploration of the use of GRACE gravity data for improved understanding of the hydrology of regional watersheds this paper presents intriguing results and points a way forward to further applications of this approach. To that extent it appears to merit publication.

This paper can be viewed within the general context of an increasing attention for changes of water storage in a watershed as the driver of streamflow. The classical rainfall-runoff models of hydrology avoid the obvious fact that streamflow is driven by

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storage in the watershed and not by precipitation as such, but the intermediate storage change step was skipped because there were no adequate means to observe storage changes in most regional watersheds. New observation techniques such as GRACE allow closer consideration of storage.

The prognostic ability demonstrated in this paper of the GRACE signal to predict seasonal runoff is impressive and indicates a potential for the use of GRACE results to enhance the reliability of seasonal water supply predictions.

Specific comments

The distinction between soil moisture and groundwater appears rather arbitrary and requires more scrutiny. It might be preferable to combine the two as subsurface moisture storage because for much of these watersheds soil moisture changes on a monthly time step are likely to be closely linked to groundwater storage changes. The groundwater storage includes water storage in the capillary fringe above the water table and the top of the capillary fringe is likely to be above the 2000 mm below ground level over much of the time and space of the analysis. Thus it is possible that the soil moisture changes as estimated in this paper include much of the groundwater storage changes. That may be one of the reasons why the modeled groundwater storage changes appear to be small and have almost no correlation with the observation well records.

Fig 7. The almost total lack of correlation between the groundwater levels and TWSA serve to underline the questionable assumption that GWSA can be estimated from TWSA – SWE – SM. Likely the problem lies both in the uncertainty of the SM estimates and the high variability of groundwater dynamics across the whole basin from low to very high elevations. It is also likely that the groundwater observations are practically all for valley bottoms and do not represent the GW storage at higher elevations and on steep slopes. By contrast the TWSA is dominated by high-elevation snow.

The paper should include plots, analysis and discussion of the changes of SWE and SM (or of SWE and SM+GW). These are just as critical an aspect of the components of the TWSA as the estimated groundwater changes. One would expect that the SWE can be validated fairly well on the basis of various point observations, at least much better than SM.

It would be intriguing to attempt a water balance for the watersheds by including precipitation estimates. Since evaporation is relatively minor during the winter months P – TWSA $\sim$ Q for the winter and this would provide a test of the consistency of these components with the conservation of mass. However, this perhaps such analysis lies outside the scope of the present paper.

Technical comments:

P. 12029 L 22. Topography is clearly a major watershed descriptor apart from climate and geology, as also implied in this paper by the contrast between the steep slopes of the Upper Columbia basin and the relative flatness of the Snake River watershed.

P 12033 LL 16-18. This characterization of aquifer storage capacity of the two watersheds is rather off-hand, and without any further explanation and references. The “well-developed soils” of the Snake River basin are perhaps relevant to soil moisture storage but not to aquifer storage which depends on the nature of the underlying subsoil and bedrock. Do the Snake River basalts in fact have much effective porosity at the water table (see also p. 12041, L 25)? The results shown later in the paper for groundwater storage changes in the Snake River watershed suggest very low groundwater storage capacity.

P 12035 LL 20-25. In view of all the uncertainties in measuring or estimating regional soil moisture, as summarized in the introduction to this paper, these GLDAS-derived estimates of soil moisture are surely highly tentative at best. This would appear to be a very uncertain foundation for estimating changes of groundwater storage. The error estimate for SM is not adequately estimated on the basis of the “monthly standard deviation” (p. 12036, L 11) because there are likely large biases in the GLDAS model algorithms.

P 12036, L 17 Insert “error” as in “individual ERROR components”.

p. 12039 L 13. hardly "dramatic" since this is an obvious consequence of snow accumulation.

p. 12041, L 25. It is not obvious that the basalt provides excellent aquifer storage. The basalts provide excellent transmissivity for groundwater flow and discharge, but that is not the same as storage and in fact would go to counteract large changes of groundwater storage, as indeed is suggested by the analysis results of this paper (see Fig 2e).

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Interactive Comment