Dear Vadim Yapiyev,

Thank you very much for your comment, for testing the G3P data set in your study area Yesil river basin, and for sharing your experiences. We highly appreciate application and evaluation cases as yours as they are very important for better knowing the performance of the G3P data set at regional scales and for improving the data set in upcoming versions.

The unexpected behaviour of the G3P-based groundwater storage anomalies (GWSA) that is described in your comment primarily refers to its seasonal dynamics. The corresponding GWSA time series is shown in Ongdas et al. (2025) Figure 7, and for illustrating of our reply, we add here the mean seasonality (climatology) of (total) terrestrial water storage TWS and of all water storage compartments (WSCs) derived from the G3P data set (Güntner et al. 2024) for the Yesil river basin in the figure below.

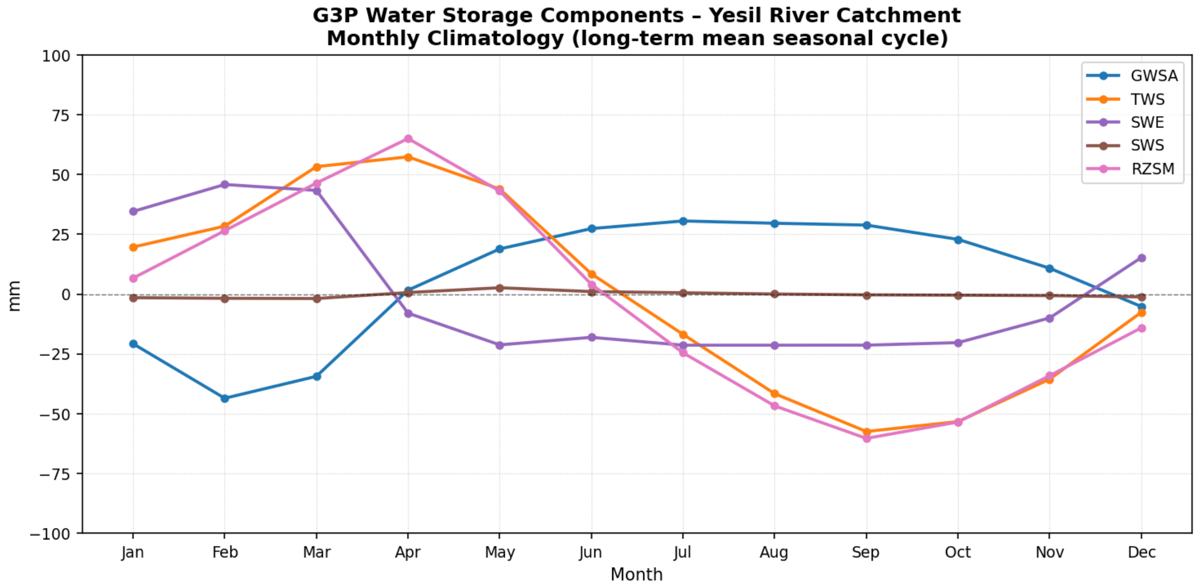

Figure: Seasonality of the G3P water storage compartments in the Yesil river basin, as basin-averages in mm water equivalent, and mean for the period 2003-2022. GWSA: Groundwater storage anomaly, TWS: Terrestrial water storage, SWE: snow water equivalent, SWS: surface water storage, RZSM: root zone soil moisture.

According to the G3P data, the seasonal cycle of TWS closely aligns with the seasonality of soil moisture in the Yesil river basin, both in amplitude and seasonal phase, with its maximum in April. G3P-based snow storage (SWE) peaks in February and March, followed by a quick decline during the snowmelt period towards April. The SWE dynamics are largely within the range of those described in Ongdas et al. (2025), also in terms of the basin-average maximum seasonal SWE of about 65 mm. Surface water storage has a comparatively small contribution, with higher values during the April and May snowmelt season.

As stated by the community comment, GWSA is largely out of phase with TWSA. According to the G3P results, groundwater storage increases in the spring season during the snowmelt period and reaches a plateau of maximum values during the summer season, with a decline in autumn and minimum values in February. As stated in Ongdas et al. (2025), there are no in-situ groundwater observations in the Yesil river basin that could be used for evaluating these G3P results directly. Qualitatively, an increase of groundwater storage during the snowmelt period is reasonable from a process perspective as snowmelt water can recharge the upper aquifers. This is also in line with qualitative descriptions of the groundwater in alluvial aquifers of the Yesil basin given by Ongdas et al. (2025) (page 496) who state that "the regime of alluvial aquifers is linked to river water level, so the highest level is observed in spring (i.e. recharge) and the lowest in autumn-winter". The further increase of GWSA during late spring and its maxima during summer seen in the G3P data could be related to a delayed recharge of aquifers that are at a larger distance from the rivers, and of deeper aquifers. This hypothesis, however, cannot be validated without further knowledge of the hydrogeological characteristics of the study area and without in-situ groundwater observations.

Alternatively, the seasonality of GWSA seen in the G3P data set for the Yesil river basin may also be attributed to uncertainties, errors and a resulting misbalance of the different observation- and partly model-based water storage compartments (WSCs) that go into the G3P subtraction process. As seen in the above figure, TWSA and soil moisture RZSM have a very similar mean seasonality in terms of amplitude and phase. Subtracting RZSM from TWS in the G3P processing chain thus already removes most of the seasonality of TWS. Additionally subtracting the storage anomalies of snow storage (SWE) (positive in the winter season, and negative in the summer period in the absence of a snow cover) may spuriously reduce the resulting GWSA in winter and increase GWSA in summer. The reason for this may either be underestimating the TWS seasonality or overestimating RZSM seasonal dynamics. The first may be due to signal dampening by leakage or filtering of the GRACE/-FO-based TWS. For RZSM, uncertainties of extrapolating the observed near-surface soil moisture to larger soil depths (to a depth of 2m for G3P) are high and may cause an overestimation of RZSM seasonal amplitudes. Also, for aquifers with water tables closer than 2 m below the terrain surface (e.g., in alluvial groundwater bodies close to rivers), groundwater storage is falsely attributed to RZSM in the G3P data (while for deeper groundwater tables, water storage variations in the deeper vadose zone are spuriously attributed to groundwater). The question if and to which extent these errors are relevant for the Yesil river basin as a whole cannot be answered here. Improving the separation process of G3P in combination with indications from in-situ groundwater observations and detailed regional hydrogeological studies can advance the knowledge on groundwater variations.

References:

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