

This is a preliminary point-by-point response prepared for the discussion stage to summarize our current position and planned revisions. A complete and finalized response, including the corresponding manuscript changes and finalized additional analyses, will be provided together with the revised manuscript.

This manuscript presents a novel, observation-constrained global reconstruction of active root-zone water storage (aSr_z) and demonstrates its value for diagnosing ecosystem water access and its decoupling from bulk terrestrial water storage. The conceptual advance from static storage capacity to a dynamic, ecosystem-mobilized state is significant, and the multi-constraint hybrid modeling framework is well designed. However, the dependence of aSr_z on the 2001–2020 baseline, the limited direct validation, and the interpretation of monthly versus interannual coupling with TWSA require further clarification.

Response: We thank the referee for the positive assessment of the manuscript and for recognizing the conceptual contribution of the framework. We agree that several aspects of the interpretation and evaluation can be strengthened. These points will be addressed through the manuscript revisions outlined below.

1. The manuscript introduces active root-zone storage (aSr_z) as a time-varying, ecosystem-accessible component of subsurface water, which is a meaningful advance over static root-zone storage capacity (Sr) estimates. However, the definition of aSr_z relative to the observed minimum over 2001–2020 makes the absolute magnitude strongly dependent on the specific hydroclimatic window sampled. The authors acknowledge this in Sect. 3.4, but the sensitivity analysis (Fig. S1) should be more explicitly integrated into the main text, and the implications for regions where the record lacks a pronounced dry-down should be quantified more rigorously.

Response: We agree that the dependence of aSr_z magnitude on the finite reference period should be quantified more explicitly and integrated more directly into the main text.

Planned revision: We will move the reference-window sensitivity analysis from the Supplement to the Appendix so that the evidence supporting the finite-period definition of aSr_z is available within the main article. The main text will summarize the key result and refer directly to the Appendix, while Sect. 3.4 will discuss the remaining limitation associated with the sampled hydroclimatic period.

Additional analysis: We will quantify how rapidly aSr_z converges with increasing reference-window length and examine whether this convergence is related to magnitude of the most negative precipitation and P-PET anomalies contained within each window. We will summarize these relationships globally and across major hydroclimatic regions.

2. aSr_z is a latent diagnostic with no direct observational counterpart, and the evaluation relies primarily on functional consistency with independent root-zone soil moisture products (Fig. A2). While the comparison with GLEAM, ml, and ERA5-Land is useful, correlations are lower in high-latitude and dry regions, precisely where the reconstruction is most uncertain. The authors should provide additional process-based validation, for example by testing whether aSr_z buffers ET during meteorological drought or sustains canopy activity through dry-down periods, as suggested in Sect. 3.4.

Response: We agree that comparison with independent root-zone soil moisture products provides only a partial evaluation of the functional interpretation of aSr_z. Because aSr_z is intended to represent storage actively accessed by ecosystems, its functional interpretation can be tested against vegetation activity during periods when contemporaneous meteorological water supply becomes limiting.

Planned revision: We will expand the evaluation section and Appendix to distinguish more clearly between (i) consistency with independent estimates of root-zone wetness and (ii) functional consistency with ecosystem activity observed from remotely sensed products. The new functional evaluation will be summarized in the main text, with the detailed spatial analyses provided in the Appendix.

Additional analysis: We will evaluate whether antecedent aSr_z is associated with the maintenance of ecosystem activity during dry conditions using GPP products that were not used as model training targets. Specifically, we will examine the relationship between current and previous-month aSr_z and GPP anomalies after accounting for contemporaneous meteorological conditions, LAI, and previous-month GPP. We will further stratify this analysis by meteorological drought or dry-down conditions and by hydroclimatic regime, with particular attention to high-latitude and dry regions where the root-zone soil-moisture comparison shows weaker agreement.

3. 6, the comparison between aSr_z and TWSA is an interesting contribution, but the interpretation of monthly versus interannual correlations could be strengthened. The monthly correlation is dominated by the shared seasonal cycle, which may inflate apparent coupling. The authors should consider decomposing the monthly signal into seasonal and residual components, or at least clearly separating the seasonal cycle from anomalous variability, to better isolate the timescales at which TWSA carries information on ecosystem-accessible storage.

Response: We agree. We will explicitly separate the seasonal and anomalous components in the revised analysis.

Planned revision: We will revise Sect. 2.3, Sect. 3.3, and Fig. 6 to distinguish seasonal, deseasonalized monthly-anomaly, and interannual coupling. The revised interpretation will treat seasonal coupling, deseasonalized monthly-anomaly coupling, and interannual coupling separately.

Additional analysis: We will decompose both aSr_z and TWSA into their climatological seasonal cycles and deseasonalized monthly anomalies. At each grid cell, we will calculate: (i) the correlation between the 12-month climatological seasonal cycles of aSr_z and TWSA; (ii) the correlation between deseasonalized monthly anomalies, obtained by removing the corresponding calendar-month climatology from each time series; and (iii) the interannual correlation between annual means, as in the current analysis. We will compare these components across hydroclimatic regimes and vegetation classes to determine whether the strong coupling currently seen at monthly resolution primarily reflects shared seasonality or also extends to anomalous variability.

4. 4, the trend analysis reports nearly balanced positive and negative trends with only ~6% of grid cells significant at $p < 0.05$. While this is expected for a 20-year record, the regional narratives (e.g., declining aSr_z in Europe and the Amazon margins, increasing in the Sahel and southeastern US) would benefit from a more explicit attribution to specific drivers, such as changes in precipitation seasonality, snowmelt timing, or groundwater withdrawal. The divergence from TWSA trends in regions like the southeastern US is noted but not fully explained.

Response: We agree that the regional interpretation of aSr_z trends should be linked more explicitly to the hydroclimatic drivers analyzed in this study. We will focus the attribution on processes that can be evaluated directly from the available data, including precipitation, PET, climatic water balance, precipitation seasonality, and snow conditions.

Planned revision: We will revise Sect. 3.2 to connect the regional aSr_z trends more explicitly to corresponding changes in precipitation, PET, climatic water balance, and, where relevant, snow conditions.

Additional analysis: We will compare regional aSr_z trends with changes in precipitation, PET, P-PET, precipitation seasonality, and, where relevant, snow timing. These relationships will be summarized for the regions highlighted in the manuscript, including Europe, the Amazon margins, the Sahel, and the southeastern United States. Where aSr_z and TWSA trends diverge, we will quantify the divergence and examine its relationship with storage components represented in TWSA but not in the active reservoir. Specific mechanisms that cannot be resolved from the present analysis will be discussed as possible contributors.

5. The turnover time τ (Fig. 5) is a useful diagnostic, but its interpretation as a storage-to-outflow timescale should be more carefully distinguished from tracer-based transit times. The authors correctly note this distinction, but the ecological implications of shortening versus lengthening τ could be developed further, particularly regarding how changes in τ relate to drought resilience and recovery timescales across different biomes..

Response: We agree that the interpretation of τ should be sharpened. We also agree that the ecological implications of changes in τ deserve further examination.

Planned revision: We will revise Sect. 2.2 and Sect. 3.2 to define τ consistently as a characteristic cycling timescale of the active reservoir, and explicitly distinguish it from tracer-based transit time, water age, or residence-time distributions. We will also distinguish changes in τ caused by changes in aSr_z from those caused by ET. The ecological interpretation will be discussed separately across major vegetation and hydroclimatic regimes.

Additional analysis: We will examine whether differences in τ , and particularly changes in τ , are associated with ecosystem response to drought across vegetation classes. Using the functional analyses introduced in response to Comment 2, we will test whether ecosystems with different active-reservoir timescales show systematic differences in GPP decline and recovery under comparable meteorological drought conditions. We will also separate the contributions of changes in aSr_z and ET to changes in τ , so that any ecological relationship can be interpreted in terms of whether the active reservoir is becoming smaller, ET is increasing, or both.