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Evaluating the Role of Rivers in Basin Scale Terrestrial Water Storage Variations Using Ensemble Hydrological Simulations Validated by GRACE and Gauged Discharge in Global Rivers

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Terrestrial hydrological processes play a significant role in the climate system, primarily through the exchange of water and energy at the land surface, and terrestrial water storage (TWS), i.e., the sum of soil moisture, groundwater, snow and ice, water in biomass, and surface water in lakes, reservoirs, wetlands and river channels, is a fundamental component of it. Among TWS components, river storage plays a significant role through the transport of freshwater to the ocean, which affects the water balance of the oceans and forms a part of the hydrological circulation on the Earth linking continents and oceans. However, most of the previous studies related with TWS implicitly assumed that soil moisture and snow water equivalent are the only major TWS components. It is still not clear how significant river storage would contribute to the total TWS variations in global river basins under different climates. In the present study, we evaluated the role of rivers in total TWS variations in 29 basins globally and estimated the basin-wide temporal variability and interactions of three major TWS components, i.e., soil moisture, snow water and river storage as well. The contribution of individual storage components to total TWS is investigated by using ensemble hydrological simulations with river routing. The observed Gravity Recovery And Climate Experiment (GRACE) TWS data are used to validate model simulations. It is found TWS simulations are more accurate when river storage is taken into account except for dry basins. Rivers play different roles in various climatic regions as indicated by two new indices quantifying the significance of each TWS component and their interactions. River storage, which effectively includes downslope movement of shallow groundwater, explains up to 73% of TWS variations in Amazon. It also acts as “buffer” which smoothes TWS seasonal variations particularly in snow-dominated basins. Neglecting river storage may lead to mismatch in the amplitude and phase of TWS seasonal variations compared to the GRACE observations.