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Separation of River Network Storage from Total Drainable Storage on Global Scales using the Phasing of GRACE and/or Runoff

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Investigations of the Runoff - Storage relationship using GRACE mass deviations have shown that for hydraulically coupled storage compartments the R-S relationship is linear once the observed phase shift between GRACE and river runoff is adapted (Riegger & Tourian. 2014). The respective hydraulic time constant and the assumption of proportionality allows to quantify the total "Drainable" storage (i.e. the volume freely draining with gravity) from river runoff. Even though the consideration of the phase shift or time lag between runoff and total storage in numerical models leads to a description of the system behavior with high accuracy (Riegger & Tourian 2014), the reason for its occurrence is not understood in detail so far. A possible reason for the observed phase shift might be found in a non negligible river network storage. Opposite to storages, which drain in parallel (like overland and groundwater flow) and are leading to a superposition of the signals, a sequence of storages leads to a temporal delay or a phase shift. In order to investigate such a phasing effect a system of Cascaded Storages for the Catchment and River Network is set up with different hydraulic time constants and mathematically solved by piecewise analytical solutions.
Tests of the scheme with synthetic recharge time series (in order to avoid impacts of noise) show, that a parameter estimation either versus mass deviation or runoff reproduces the time constants individually for both, the Catchment and the River Network in a unique way with high accuracy. Opposite to this, the description of a system (showing a phase shift) by one single storage leads to considerable errors in the time constant of the total system and thus in total Drainable Storage volume.

The application of the Cascaded Storage approach to the Amazon catchment shows very good agreements of calculated and measured Total Mass and River Runoff simultaneously (Nash-Sutcliff for signal > 0.96, for monthly residual >0.72). Both, the phase shift between GRACE and river runoff and the signal amplitudes are reproduced very well. The calculated River Network mass highly correlates with the observed Flood area from the "Global Inundation Extent from Multi-Satellites" data set (GIEMS) and corresponds to the Flood volumes determined by Papa et al. (2013). It can be concluded that a non negligible River Network in a cascade of storages describes and explains the observed phasings and allows for a separate quantification of the storage volumes in the Catchment and in the River Network.

References:
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Riegger, J., and M. J. Tourian (2014), Characterization of runoff-storage relationships by satellite gravimetry and remote sensing. Water Resour. Res., 50, doi:10.1002/2013WR013847.