Geophysical Research Abstracts
Vol. 15, EGU2013-5387, 2013
EGU General Assembly 2013

Characterisation of Runoff – Storage Relationships by Satellite-Gravimetry and Remote Sensing

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In hydrological modelling approaches runoff is often conceptualized by a linear relationship with storages of different types (surface, interflow, baseflow) and the related time constants. This approach is motivated by the exponential decrease in runoff for time periods with no input to storage.
Direct measurements of water storage comprising the surface, soil, unsaturated and saturated water storage are mainly point measurements and very scarse compared to heterogeneity scales. Thus they are not suitable for a comparison on large spatial scales. GRACE observations of the time dependent gravity field provide a direct measurement of the monthly state of mass and thus the total monthly water storage in a catchment. This for the first time allows for a direct comparison of monthly runoff and water storage for global scale catchments and thus the investigation of their runoff – storage relationship.

The direct comparison of runoff and storage shows a distinct individual, yet seasonally characteristic and mainly non linear behaviour for different climatic (tropical, boreal) and physiografic (surface, vegetation, soil etc.) conditions. For the Amazon basin just a time lag occurs between runoff and storage, which is caused by the finite transition time between input and hydraulic coupling. Adapting the time lag by a temporal shift leads to a nearly linear relationship with a very high correlation coefficient.
For other tropic basins or for boreal catchments the runoff-storage relationship is much more complex. Supported by the linear behaviour of the Amazon it can be assumed that deviations from the linear behaviour are caused by storage components which are not hydraulically coupled to the drainage system like floods, snow etc. Thus for a more detailed investigation of the runoff-storage relationship the coupled liquid storage components as well as the contributions from the decoupled storages have to be properly quantified.
As boreal catchments are seasonally dominated by snow, the decoupled storage could be quantified by MODIS snow coverage. For this purpose homogenous, large scale conceptual models based on GRACE and MODIS snow coverage are developed. These conceptual approaches lead to high correlations of liquid mass and measured runoff.

The investigations show, that for the investigated large scale catchments the relationship between runoff and hydraulically coupled water storage is by far dominated by a linear behaviour. With a proper description of the liquid mass, the relationship can be fully described by a fit of the unknown mass offset, the hydraulic time constants and the time lags of the hydraulic coupling processes. Hereby the description of the decoupled storages like snow / ice, canopy, surface ponds, soil / unsaturated zones and their input into the hydraulically coupled discharge system is the main challenge, which needs to be addressed and quantified for a proper description of the runoff - storage relationship.

As a consequence GRACE mass storage allows for a direct determination of river runoff for unmanaged catchments provided that there is a sufficient overlap of measured runoff and GRACE data and that the coupled / decoupled water storage components can be partitioned by other means like remote sensing.