Geophysical Research Abstracts
Vol. 17, EGU2015-1108-1, 2015
EGU General Assembly 2015

Copula-based estimation of large-scale water storage changes: exploiting the dependence structure between hydrological and GRACE data

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Data from the Gravity Recovery and Climate Experiment (GRACE) has significantly improved our knowledge of the terrestrial water cycle. With the availability of GRACE data from 2002, we are now able to even perform climate change studies with respect to water storage variations. However, as GRACE is already after its lifetime, we have to find methods for filling the gaps of both past data and also until the launch of GRACE Follow On.

In this study, we therefore analyze the potential of Copula based methods for simulating GRACE data from other hydrological data sources. The method exploits linear and non-linear relationships between two or more variables by fitting a theoretical Copula function into an empirical bivariate or multivariate distribution function. Finally, new data, which is then consistent with the previously derived dependence structure, can be simulated by evaluating the conditional distribution function which given by the theoretical Copula.

First, we want to analyze the applicability of the proposed method to spherical harmonic data from GRACE. As the approach involves several drawings of random data, we are interested if this random nature has any impact on the results. We therefore generate filtered out of unfiltered GRACE coefficients, based on the previously derived dependence structure. The comparison between this simulated and the filtered data shows very good agreement with negligible differences in both the spatial and spectral domain.

We also want to evaluate if copula based methods are able to estimate reliable water storage changes from independent hydrological data. Therefore, we derive the dependence structure between filtered water storage changes from GRACE and global gridded precipitation data from the Global Precipitation Climatology Centre GPCC. Based on the fitted theoretical Copula, we then simulate water storage changes from precipitation data. The Copula based estimates are compared with filtered GRACE data in both the spectral and spatial domain. We also perform a catchment-based analysis between area-aggregated time-series of simulated and GRACE-derived water storage change. The analysis shows that our estimates and the original filtered GRACE data are in very good agreement. Thus, we conclude that the proposed method is indeed able to fill the missing months in the GRACE-dataset and to even extend the time-series until the launch of GRACE Follow On.