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Pushing the limits of gravity field recovery from high-low satellite-to-satellite tracking - a combination of 10 years of data of the satellite pseudo-constellation CHAMP, GRACE and GOCE.

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For a long time, the primary sources for the observation of time varying gravity from space have been SLR and the GRACE mission where the latter is based on the concept of ultra-precise low-low satellite-to-satellite tracking. Meanwhile, time-variable gravity signals were also successfully derived from the high-low satellite-to-satellite tracking mission CHAMP (Weigelt et al. 2013, JGR:Solid Earth, doi:10.1002/jgrb.50283). This single-satellite solution allows for the derivation of only the strongest annual hydrological signals on the continents, e.g. in the Amazon, and ice-melting in Greenland and is limited to large scales due to its higher noise level. A natural approach to overcome this limitation is to combine the observations of several satellites. Here, we form a pseudo-constellation which - with the exception of the two GRACE satellites - is a loose one and was not designed as such. We present the methodology and the results of combining gravity field estimates based on kinematic orbits from the four satellites of the three missions CHAMP, GRACE and GOCE within the frame of a Kalman filter forming a time series over a span of ten years. The gain compared to the CHAMP-only solution is about half an order of magnitude in terms of degree-RMS, an increased spatial resolution with approximately 750km placing the solutions on the level of the early GRACE solutions and a decreased error level allowing now to clearly identify the hydrology-induced mass changes in Africa, East-Asia and Australia which have been erroneous in the CHAMP-only solution. We demonstrate the quality of the solutions by comparing to (1) K-Band based GRACE solutions, (2) GNSS loading time-series and (3) hydro-meteorological estimation of water storage changes and derive mass estimates for various regions of the world. We also demonstrate that remarkably this combined solution starts to indicate mass change patterns related to glacial isostatic adjustment (GIA).