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Inter-annual displacements induced by hydrological changes in Europe: comparison between hydrological models, GRACE and GPS

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ABSTRACT

Hydrological loading deforms the Earth's crust at various spatial and temporal resolutions. In this study, we compare hydrologically-induced Earth's crust displacements computed for European area using GRACE (Gravity Recovery and Climate Experiment) observations and two hydrological models, namely: GLDAS (Global Land Data Assimilation) and WGHM (WaterGAP Global Hydrological Model), with Earth's crust displacements observed by the GPS (Global Positioning System). For GRACE, we use displacements estimated from RL06 spherical harmonic solution up to degree and order 90, provided by the GFZ (German Research Center for Geosciences) and denoised using DDK3 filter. For the GPS, we utilize solution provided by the NGL (Nevada Geodetic Laboratory). Our study is performed twofold. First, hydrologically-induced displacements are retrieved for the largest river basins in Europe and then, these are estimated for the GPS locations. To estimate the seasonal and inter-annual (changes with periods longer than tropical year or aperiodic) changes, the Singular Spectrum Analysis (SSA) algorithm is used. We demonstrate that the largest seasonal displacements induced by hydrological changes are observed by GRACE for eastern European areas, which is also confirmed by hydrological models. Inter-annual displacements show large variations for GRACE-predicted displacements in southeastern European river basins, as Dnieper, Dniester, Don, Guadiana, Kuban, Tigris and Euphrates, Kura-Ozero Sevan and Volga. These displacements are higher than variations obtained for annual signals, what implies that inter-annual changes are more powerful than other signals. Inter-annual variations are, however, not prominent in GLDAS and WGHM models, proving that they are underestimated in model-predicted displacements (except of Kura-Ozero Sevan as well as Tigris and Euphrates river basins for WGHM). For central and eastern European river basins, smaller inter-annual displacements are observed by GRACE, but it is in agreement with GLDAS and WGHM models which also reveal similar changes. For 107 GPS permanent stations located in river basins used in this study, we compute correlation coefficients between annual, inter-annual and both-combined signals estimated with SSA for GPS displacements and models-/GRACE-predicted displacements. The greatest coefficients (40%-60%) are found for northern and western European river basins for GLDAS and GRACE, while for the WGHM model positive correlation is only found

for inter-annual signals. Root-mean square (RMS) reduction of GPS displacements estimated once these are reduced by inter-annual signals estimated for models-/GRACE-observed displacements is between -20% and 20%. Our study reveals a need of including the hydrology-induced displacements in the analyses of GPS position time series, as their impact is observed for the longest periods, affecting the GPS velocity.