EGU General Assembly 2021

EGU21-2217, updated on 27 May 2022
https://doi.org/10.5194/egusphere-egu21-2217
EGU General Assembly 2021

Analysis of the interannual variability in satellite gravity solutions : impact of climate modes on water mass displacements across continents and oceans

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The acquisition of time-lapse satellite gravity measurements during the GRACE and GRACE Follow On (FO) missions revolutionized our understanding of the Earth system, through the accurate quantification of the mass transport at global and regional scales. Largely related to the water cycle, along with some geophysical signals, decadal trends and seasonal cycles dominate the mass transport signals, constituting about 80 % of the total variability measured during GRACE (FO) missions. We focus here on the interannual variability, constituting the remaining 20 % of the signal, once linear trends and seasonal signals have been removed. Empirical orthogonal functions (EOFs) highlight the most prominent signals, including short-lived signals triggered by major earthquakes, interannual oscillations in the water cycle driven by the El Nino Southern Oscillation (ENSO) and significant decadal variability, potentially related to the Pacific Decadal Oscillation (PDO). The interpretation of such signals remains however limited due to the arbitrary nature of the statistical decomposition in eigen values. To overcome these limitations, we performed a LASSO (Least Absolute Shrinkage and Selection Operator) regression of eight climate indices, including ENSO, PDO, NPGO (North Pacific Gyre Oscillation), NAO (North Atlantic Oscillation), AO (Arctic Oscillation), AMO (Atlantic Multidecadal Oscillation), SAM (Southern Annular Mode) and IOD (Indian Ocean Dipole). The LASSO regularization, coupled with a cross-validation, proves to be remarkably successful in the automatic selection of relevant predictors of the climate variability for any geographical location in the world. As expected, ENSO and PDO impact the global water cycle both on land and in the ocean. The NPGO is also a major actor of the global climate, showing similarities with the PDO in the North Pacific. AO is generally favored over NAO, especially in the Mediteranean Sea and North Atlantic. SAM has a preponderant influence on the interannual variability of ocean bottom pressures in the Southern Ocean, and, in association with ENSO, modulates the interannual variability of ice mass loss in West Antarctica. AMO has a strong influence on the interannual water cycle along the Amazon river, due to the exchange of moisture in tropical regions. IOD has little to no impact on the interannual water cycle. All together, climate modes generate changes in the water mass distribution of about 100 mm for land, 50 mm for shallow seas and 15 mm for oceans. Climate modes account for a secondary but significant portion of the total interannual variability (at maximum 60% for shallow seas, 50 % for land and 40% for oceans). While such processes are insufficient to fully explain the complex nature of the

interannual variability of water mass transport on a global scale, climate modes can be used to correct the GRACE (FO) measurements for a significant part of the natural climate variability and uncover smaller signals masked by such water mass transports.