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Lessons learned for hydrogravimetry: the superconducting gravimeter observatories at Concepción (Chile) and Sutherland (South Africa)

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Superconducting gravimeters (SGs) continuously measure temporal variations of the Earth's gravity with very high precision. As SGs are sensitive to water mass changes in their surroundings, they potentially provide unique measurements of total water storage variations (the sum of variations in snow, soil and groundwater storage) at scales of several hundreds of meters. However, other geophysical signals by mass attraction and loading effects (e.g., tides, atmosphere, ocean, regional and global hydrology) have to be adequately removed from SG observations. In addition, the local settings of SG deployment (e.g., topographic position and near-field observatory infrastructure) are important controls on SG is sensitivity to the hydrological signal of interest.

In this study, we evaluate the hydrological value of SGs for two sites in contrasting climate regions, i.e. (1) the Geodetic Observatory TIGO in the Coast Range of Southern Chile in Concepción, and (2) the South African Geodynamic Observatory Sutherland (SAGOS) in the semidesert Karoo region. At both sites, gravimetric as well as independent hydro-meteorological observations are available for several years. We remove large-scale atmospheric, oceanic and hydrological gravity effects by an ensemble approach using several global models. For the highly seasonal sub-humid climate at TIGO, the residual gravity signals had a larger seasonal amplitude (300-400 nm/s2) and a later annual phase than the gravimetric signal estimated from near-surface soil moisture observations in previous analyses. The gravity observations alluded to important and delayed water storage variations in the deeper (20 meter) unsaturated zone. This has been corroborated by soil moisture observations in deeper soil horizons, monitoring of the groundwater level, and hydrological modelling. At the semi-arid site SAGOS, water storage variations are considerably smaller, as are variations of SG residuals (amplitudes smaller than 20 nm/s2). While some short-term effects of rainfall events are visible in the SG residuals, a comprehensive hydrological interpretation of the SG data at SAGOS is limited by the position of the SGs in a sub-surface observatory with disturbed and natural soil both below and above the SG level.

Based on the experiences from both SG sites, we conclude on the particular requirements for the deployment of SGs for hydrological applications and point to the new generation of iGrav SGs in field enclosures as a hydrological monitoring device.