

Hydrogeological effects on terrestrial gravity measurements

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For the 20 last years, terrestrial and satellite gravity measurements have reached such a precision that they allow for identification of the signatures from water storage fluctuations. In particular, hydrogeological effects induce significant time-correlated signature in the gravity time series. Gravity response to rainfall is a complex function of the local geologic and climatic conditions, e.g., rock porosity, vegetation, evaporation, and runoff rates. The gravity signal combines contributions from many geophysical processes, source separation being a major challenge. At the local scale and short-term, the associated gravimetric signatures often exceed the tectonic and GIA effects, and monitoring gravity changes is a source of information on local groundwater mass balance, and contributes to model calibrations. Main characteristics of the aquifer can then be inferred by combining continuous gravity, geophysical and hydrogeological measurements.

In Membach, Belgium, a superconducting gravimeter has monitored gravity continuously for more than 24 years. This long time series, together with 300 repeated absolute gravity measurements and environmental monitoring, has provided valuable information on the instrumental, metrological, hydrogeological and geophysical points of view. This has allowed separating the signal sources and monitoring partial saturation dynamics, convective precipitation and evapotranspiration at a scale of up to 1 km², for signals smaller than 1 nm/s², equivalent to 2.5 mm of water.

Based on this experience, another superconducting gravimeter was installed in 2014 in the karst zone of Rochefort, Belgium. In a karst area, where the vadose zone is usually thicker than in other contexts; combining gravity measurements at the surface and inside accessible caves is a way to separate the contribution from the unsaturated zone lying between the two instruments, from the saturated zone underneath the cave, and the common mode effects from the atmosphere or other regional processes.

Those experiments contribute to the assessment of the terrestrial hydrological cycle, which is a major challenge of the geosciences associated with key societal issues: availability of freshwater, mitigation of flood hazards, or measurement of evapotranspiration.

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