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Detection of subsurface water storage dynamics with combined gravity - vertical gravity gradient monitoring and hydrological simulation

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Time-lapse ground-based gravimetry is increasingly applied in subsurface hydrology, providing mass balance constraints on water storage dynamics. For a given water content change as e.g. after a precipitation event, the simplest assumption is that of a homogeneous, infinite slab (Bouguer plate) of water column causing the measurable increase in gravitational attraction. For heterogeneous subsurface environments such as karst aquifers at field scale this assumption may not always hold. The gravity signal is depth-integrated and non-unique, hence indistinguishable from a heterogeneous distribution without further information.

Exploiting the different spatial sensitivities of gravity and vertical gravity gradient (VGG) data can shed light on the following questions:

- Is the subsurface water content within the gravimeter's footprint likely to be homogeneous or showing small-scale heterogeneity?
- If not, at which distance are these mass heterogeneities and how large are they?
- Which monitoring set-ups (tripod heights, number of and distance between VGG measurement locations) are likely to detect mass heterogeneity of which spatial characteristics?

One year of monthly vertical gravity gradient surveys has been completed in the geodetic observatory in karstic environment on the Larzac plateau in southern France. We interpret the VGG observations obtained in this field study in the context of further available hydraulic and geophysical data and hydro-gravimetrical simulation. Finally, practical applications in view of detecting near-surface voids and reservoirs of different porosities as well as their storage capacity and seasonal dynamics are evaluated.