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Monitoring water storage variations in the vadose zone with gravimeters – quantifying the influence of observatory buildings

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Time-lapse ground-based measurements of gravity have been shown to be sensitive to water storage variations in the surroundings of the gravimeter. They thus have the potential to serve as an integrative observation of storage changes in the vadose zone. However, in almost all cases of continuous gravity measurements, the gravimeter is located within a building which seals the soil beneath it from natural hydrological processes like infiltration and evapotranspiration. As water storage changes in close vicinity of the gravimeter have the strongest influence on the measured signal, it is important to understand the hydrology in the unsaturated soil zone just beneath the impervious building. For this reason, TDR soil moisture sensors were installed in several vertical profiles up to a depth of 2 m underneath the planned new gravimeter building at the Geodetic Observatory Wettzell (southeast Germany).
In this study, we assess the influence of the observatory building on infiltration and subsurface flow patterns and thus the damping effect on gravimeter data in a two-way approach. Firstly, soil moisture time series of sensors outside of the building area are correlated with corresponding sensors of the same depth beneath the building. The resulting correlation coefficients, time lags and signal to noise relationships are used to find out how and where infiltrating water moves laterally beneath the building and towards its centre. Secondly, a physically based hydrological model (HYDRUS) with high discretization in space and time is set up for the 20 by 20 m area around and beneath the gravimeter building. The simulated spatial distribution of soil moisture in combination with the observed point data help to identify where and to what extent water storage changes and thus mass transport occurs beneath the building and how much this differs to the dynamics of the surroundings. This allows to define the umbrella space, i.e. the volume of the vadose zone where no mass transport occurs below the building, as a function of building geometry, soil type, surface and subsurface topography.

This, in turn, leads to an improved determination of the damping effect of observatory buildings on gravimeter observations, increasing accuracy and value of gravimeters as instruments suitable for assessing local water storage variations in the vadose zone.