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Informing hydrological models with ground-based time-lapse relative gravimetry: potential and limitations

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Abstract Coupled hydrogeophysical inversion emerges as an attractive option to improve the calibration and predictive capability of hydrological models. Recently, ground-based time-lapse relative gravity (TLRG) measurements have attracted increasing interest because there is a direct relationship between the signal and the change in water mass stored in the subsurface. Thus, no petrophysical relationship is required for coupled hydrogeophysical inversion. Two hydrological events were monitored with TLRG. One was a natural flooding event in the periphery of the Okavango Delta, Botswana, and one was a forced infiltration experiment in Denmark. The natural flooding event caused a spatio-temporally distributed increase in bank storage in an alluvial aquifer. The storage change was measured using both TLRG and traditional piezometers. A groundwater model was conditioned on both the TLRG and piezometer data. Model parameter uncertainty decreased significantly when TLRG data was included in the inversion. The forced infiltration experiment caused changes in unsaturated zone storage, which were monitored using TLRG and ground-penetrating radar. A numerical unsaturated zone model was subsequently conditioned on both data types. Inclusion of TLRG data again led to a significant decrease in parameter uncertainty. Both experiments indicate that TLRG data are useful for hydrological model calibration. However, application of TLRG in hydrology remains challenging, because of limited instrument sensitivity, time changes in gravity due to unmonitored non-hydrological effects, and the requirement of a gravitationally stable reference station. Application of TLRG in hydrology should be combined with other geophysical and/or traditional monitoring methods.

Key words hydrological model calibration; time-lapse gravity; groundwater; vadose zone