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Seasonal changes in groundwater storage estimated by absolute ground gravity and MRS surveys in West Africa

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Important and fast groundwater storage changes occur in tropical monsoon regions in response to seasonal rainfall and subsequent surface water redistribution. In West Africa, one main goal of the GHYRAF experiment (Gravity and Hydrology in Africa, 2008-2010) is to compare absolute gravimetric measurements with dense hydrological surveys to better estimate and model water storage changes at various time scales.

Magnetic Resonance Sounding (MRS) is a non-invasive geophysical method having a signal directly related to groundwater quantity. In SW Niger, MRS surveys were performed concurrently with gravimetric (FG5) measurements for monitoring seasonal changes in groundwater storage. Water table levels were recorded on a 4-piezometers profile ($\sim$500 m) near a temporary pond (area $\sim$2 ha) fed by sandy gullies. The volume of water drained from the pond to the phreatic aquifer was computed to be $\sim$100,000 m3/yr. Large piezometric fluctuations (3-6 m) occurred in response to indirect recharge through the pond during the 2008 rainy season (July-Sept.), with stronger water table fluctuations recorded near the pond.

Absolute gravimetric (FG5) measurements were performed at a distance of 150 m from the pond, in order to minimize the influence of 2D effects on gravimetric records. The increase in absolute gravity measured between two dates (July-Sept.) was 8.7 $\pm$ 2.6 μGal; for the same period, the measured water table rise was +3.0 m. Considering these values, a first estimate of the groundwater storage increase is 0.2 m, corresponding to a porosity filled up by the water table rise of $\sim$7%. Repeated MRS surveys were performed at the same location for different dates (three soundings in Sept., one in Dec.). The MRS water content was 13%, with little variation in space ($\pm$3%) along the piezometric profile. In response to a 3 metres drop in the water table (Sept- Dec), there was no significant recorded change in the MRS water content and/or in the estimated MRS water table depth.

MRS and absolute gravimetry are two independent methods that could be sensitive to changes in groundwater reserves. However, because MRS is integrative of the whole saturated thickness of the aquifer (here, a few tens of metres), it was shown to be comparatively less sensitive to groundwater storage fluctuations occurring at the water table. These methods provide complementary data on aquifer characteristics, MRS being useful for quantifying lateral changes in aquifer properties, whereas gravimetric measurements helped in characterizing groundwater recharge and porosity. Both methods bring pieces of information that could be used to better constrain transient groundwater modelling at site scale.