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Monitoring water storage changes using absolute gravity measurements, neutron probes and piezometer data in West Africa: advances in specific yield and recharge estimation

B. Hector (1), L. Séguis (2), M. Descloîtres (3,4), J. Hinderer (1), M. Wubda (3), B. Luck (1), and N. Le Moigne (5)

(1) IPGS-EOST, CNRS/UdS, UMR 7516, 5 rue René Descartes, 67084 Strasbourg Cedex, France, (2) HydroSciences Montpellier, UM2, Place E. Bataillon, F-34095, Montpellier CEDEX 5, France, (3) Institut de Recherche pour le Développement (IRD), 08 BP 841 Cotonou, BENIN, (4) LTHE, Domaine universitaire, BP 53, 38041 Grenoble Cedex 09, France, (5) Géosciences Montpellier, UMR CNRS/UM2 5243, Université Montpellier II, Montpellier, France

Advances in water storage monitoring are crucial to characterize the spatial variability of hydrological processes. Classical water storage investigation methods often involve point measurements (piezometers, neutron probes, humidity sensors...), which may be irrelevant in heterogeneous mediums. Over the past few years, there has been an increasing interest in the use of gravimeters for hydrological studies. Water mass redistribution leads to variations in the Earth's gravity field which can be measured by gravimetry. In the framework of the GHYRAF (Gravity and Hydrology in Africa) project, 3 years of repeated absolute gravity measurements using FG5#206 from Micro-g Solutions Inc. have been undertaken at Nalohou, a Sudanian site in northern Benin. Hydrological monitoring is carried out within the long-term observing system AMMA-Catch (an observatory of RBV, the French critical zone exploration network). Seasonal gravity variations in link with the hydrological cycle can reach 11 μgal at this site, equivalent to a 26cm thick infinite layer of water. The vadose zone and a shallow unconfined aquifer in weathered metamorphic rocks are responsible for most of the water storage variations. For the first time in the climatic context of the West African monsoon, gravity data are compared to the time evolution of the water storages deduced from neutron probes and water-table variations. The approach is two-fold: first, total storage variations are estimated from neutron probe-derived moisture through the whole vertical profile (surface to groundwater) monitored at the gravimetric site and uniformly extended according to the topography. Results show a very good fit with gravity data, enlightening the fact that absolute gravimeters are sensitive to total water storage variations from the soil surface to the aquifer. The second approach introduces a spatial variability: it was undertaken to check a structural model for specific yield of the aquifer, based on magnetic resonance soundings (MRS) and spatialized with resistivity data (TDEM). We distinguish the soil moisture variations estimated by neutron probes in the vadose zone and the groundwater storage variations calculated from water-table observations and specific yield estimations. This experiment allows discussing specific yield values obtained by different methods and gravimeters contribution to recharge estimation. This hydro-geophysical experiment shows that time-lapse gravity data can effectively be used as an integrative tool to monitor the long-term water storage variations in tropical West Africa. In a close future, gravimetric measurements could become a calibration variable in hydrological modeling as streamflow discharge do today.