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Ground-based gravimetry as a tool to monitor the non-saturated zone of karst aquifers

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The aim of this study is to understand the water storage variations in a karst system using absolute and relative gravimetry.

The studied karst system located on the Larzac Plateau (South of France) is a unary karst where water input is exclusively rainfall and draining occurs at the Durzon perennial spring in a karstic valley. Because the entire Larzac Plateau is drained by a few karstic springs, it constitutes a significant water resource. Our basis assumption is that water storage in the non-saturated zone (epikarst and infiltration zone) has a significant effect on surface gravity through Newtonian attraction.

Gravity on the karst aquifer is hence being monitored since January 2006 using three complimentary methods:

1. monthly absolute gravity measurements done at three sites

2. vertical differential relative gravity measurements between the surface and 60 m depth performed three times a year in a cave

3. relative gravity surveying covering the karst system recharge area measured twice a year, during wet and dry periods

Hydrological monitoring consists of continuous surface and underground rainfall recordings, pressure head variations in bore holes and underground natural caves and

hourly Durzon spring flow.

The gravity measurements are corrected for regional scale gravity using global water storage models in order to obtain gravity variations related exclusively to local karst water storage.

Based on two years of observations, absolute gravity variations exhibit an important seasonal component (10-15 μgal (1μgal =10^{-8} m.s^{-2}) corresponding to a variation of equivalent water height of $\sim$24-36 cm). Mass balance considerations linking rainfall, evapotranspiration and spring discharge as well as lumped modeling provide a framework for the understanding of observed gravity variations.

We find that the time variations of the surface to 60m depth gravity differences are of the same order as those seen by absolute gravity. This indeed proves that absolute gravity is an effective way to monitor water storage in the non-saturated zone.

The comparison between the gravity fields obtained from surveying during wet and dry periods over the karst recharge area shows areal water storage variations ranging from 0 to 60 cm of water between the considered periods. A first order interpretation linking the degree of karstification and geomorphological considerations is shown.