EMS Annual Meeting Abstracts
Vol. 16, EMS2019-202, 2019

Heavy rainfall estimates from underground gravity measurements

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Estimation of rainfall amounts produced by convective storms is challenging due to the very high spatial variability of such type of precipitation. In this study we explore the use of underground gravity monitoring to estimate heavy rainfall at a spatial scale of a few hundred meters.

Superconducting gravimeters produce gravity measurements with a precision of 1 nm/s^2 at 1-minute time step. When performed underground, these measurements are directly affected by rainfall. Water mass increase at the ground level due to precipitation tends to reduce underground gravity. Rainfall amounts can be derived from these gravity variations.

The superconducting gravimeters used in this study are installed in Membach (Belgium) and Walferdange (Luxembourg), 48 m and 80 m underneath the surface, respectively. The gravimeters integrate soil water in a radius of several hundred meters. The two gravimeters are located at 85 and 54 km from a C-band weather radar located in Wideumont (Belgium). Gravimeter data at 1-min time step and radar data at 5-min time step are available for the 15-year observation period 2003-2017.

The comparison of radar reflectivity and gravity time series shows that short-duration intense rainfall events produce a rapid decrease of the underground measured gravity. Precipitation amounts derived from gravity measurements and from radar observations are further compared for more than 500 events with very intense precipitation over short durations.

We show that a superconducting gravimeter is a valuable source of in-situ observations for the verification of rainfall estimates derived from weather radars. The two main benefits are the spatial scale at which precipitation is captured and the interesting property that gravity measurements are directly influenced by water mass at ground no matter the type of precipitation: hail or rain.