Investigating Soil Saturation Changes through Geophysical Data
Gravimetric and Seismological Perspectives

Anita Thea Saraswati[1,2], Thomas Lecocq[1], Marnik Vanclooster[2]

[1] Seismology - Gravimetry, Royal Observatory of Belgium, Brussels, Belgium; [2] Earth and Life Institute, UCLouvain, Louvain-la-Neuve, Belgium

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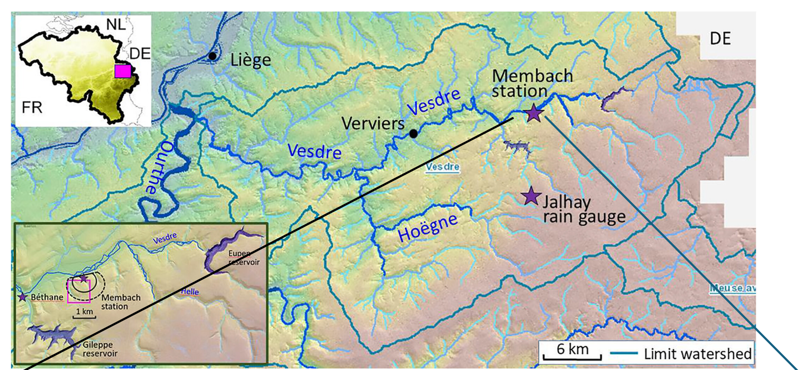
Context

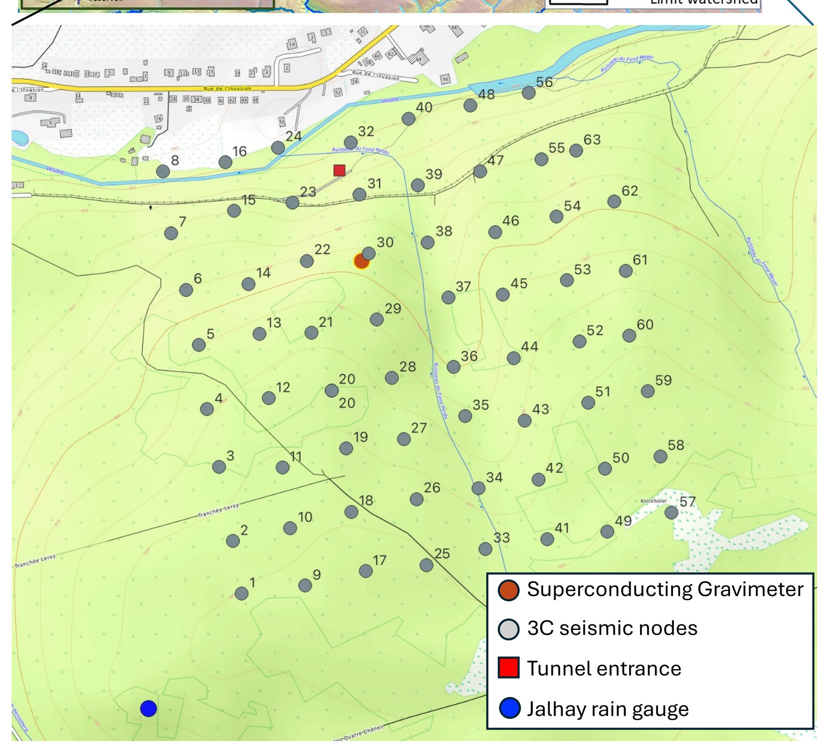
The water cycle exerts a significant influence on geophysical signals. Through an extensive hydrogeophysical investigation at the geodynamic station in Membach, Belgium, we aim to estimate hydrological variations in the surrounding area. Our focus is on integrating gravity and ambient seismic noise measurements to develop a detailed hydrological numerical model at a local scale.

Research objectives:

- Investigate the correlations between the geophysics and hydrological observations in Membach.
- Understand the influence of water saturation in relative seismic velocity changes

Site overview



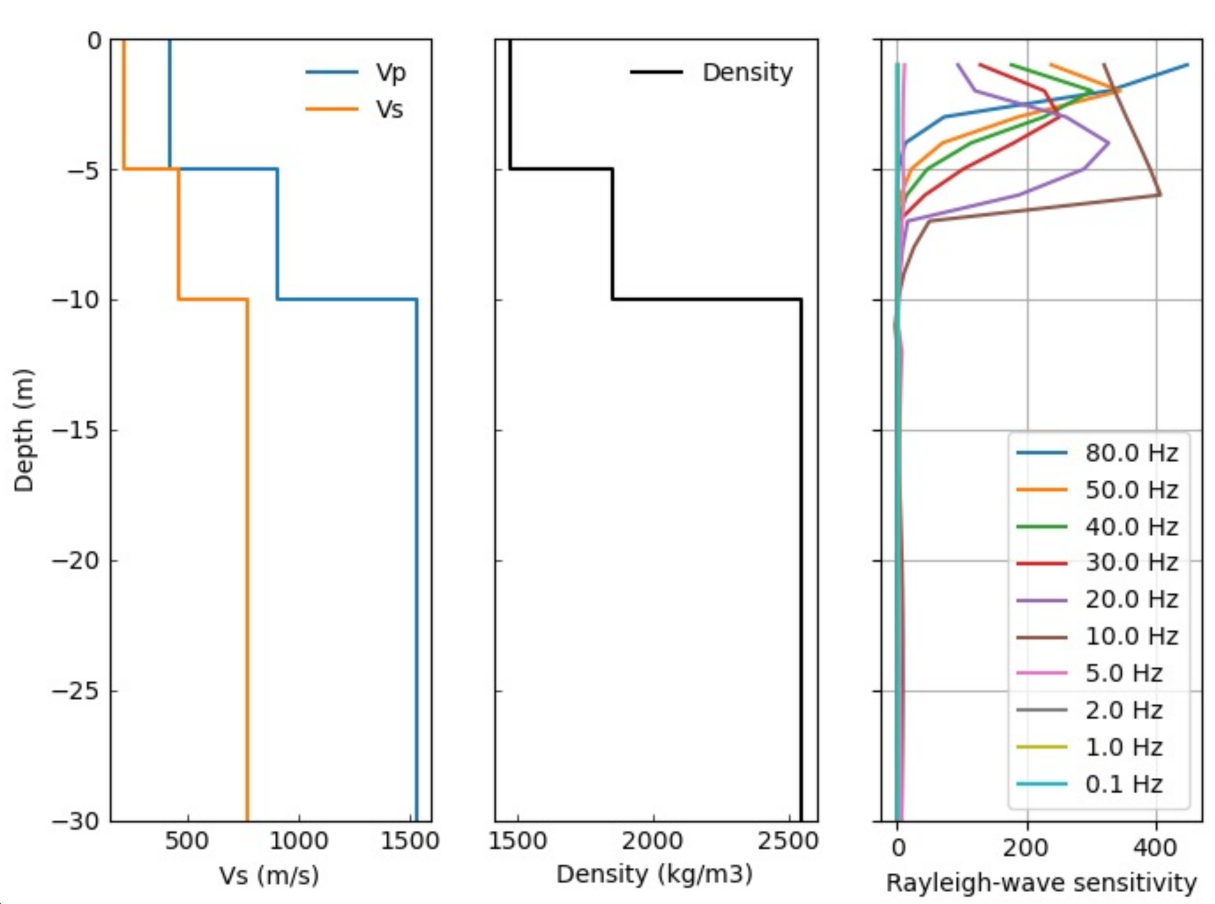


Membach geophysical station

- No presence of aquifer around the station (Van Camp et al., 2006)
- The thickness of the weathered zone covering the bedrock varies between 0 and 10 m
- The area is covered by primarily a deciduous forest canopy and hilly terrain

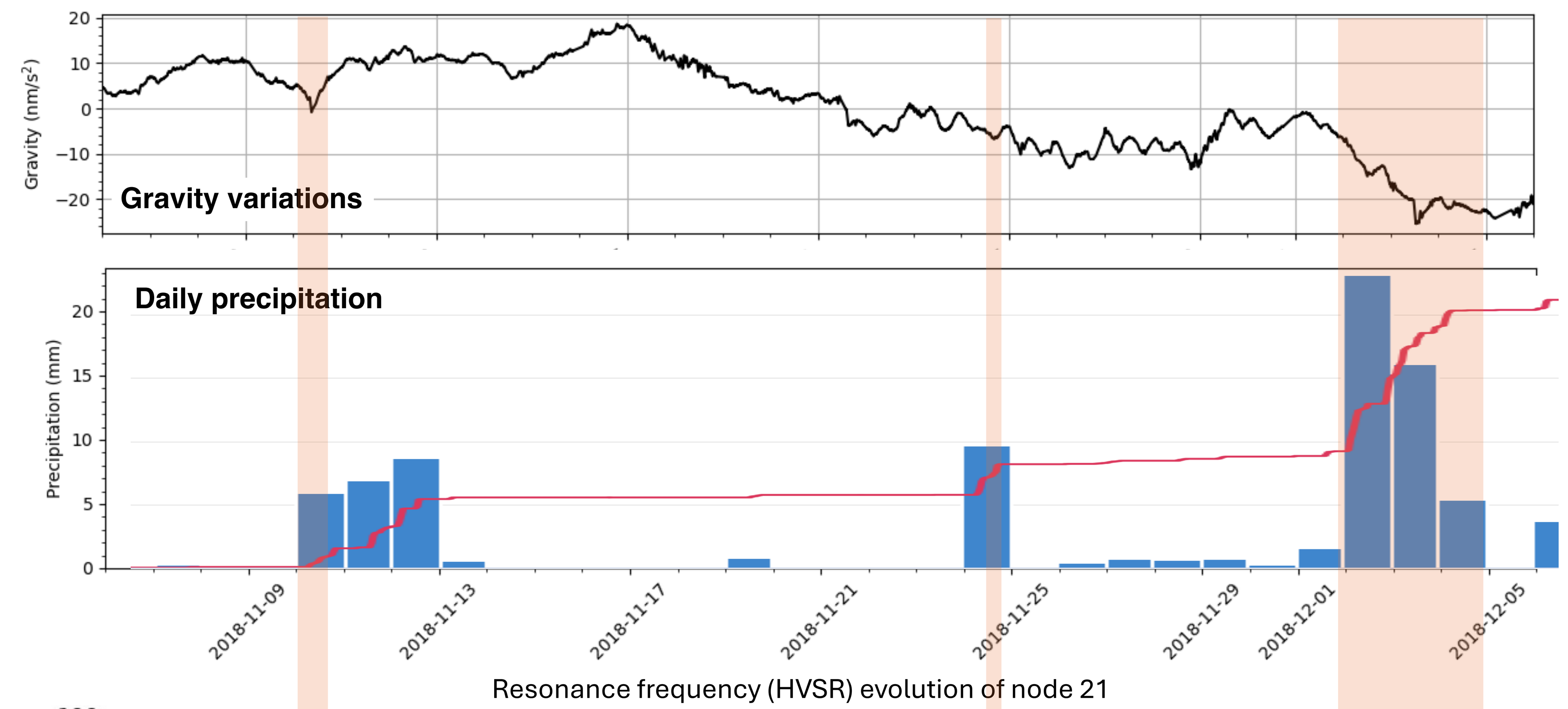
- **The Supraconducting Gravimeter (SG):**
  - Installed at the end of a 130 m long tunnel excavated in low-porosity argillaceous sandstone, 48.5 m below the surface (since 1995)

- **Ambient seismic measurements:**
  - 63 ground 3-C nodes deployed in winter 2018 (Nov – Dec 2018) in the frame of the LARGE-MEM project



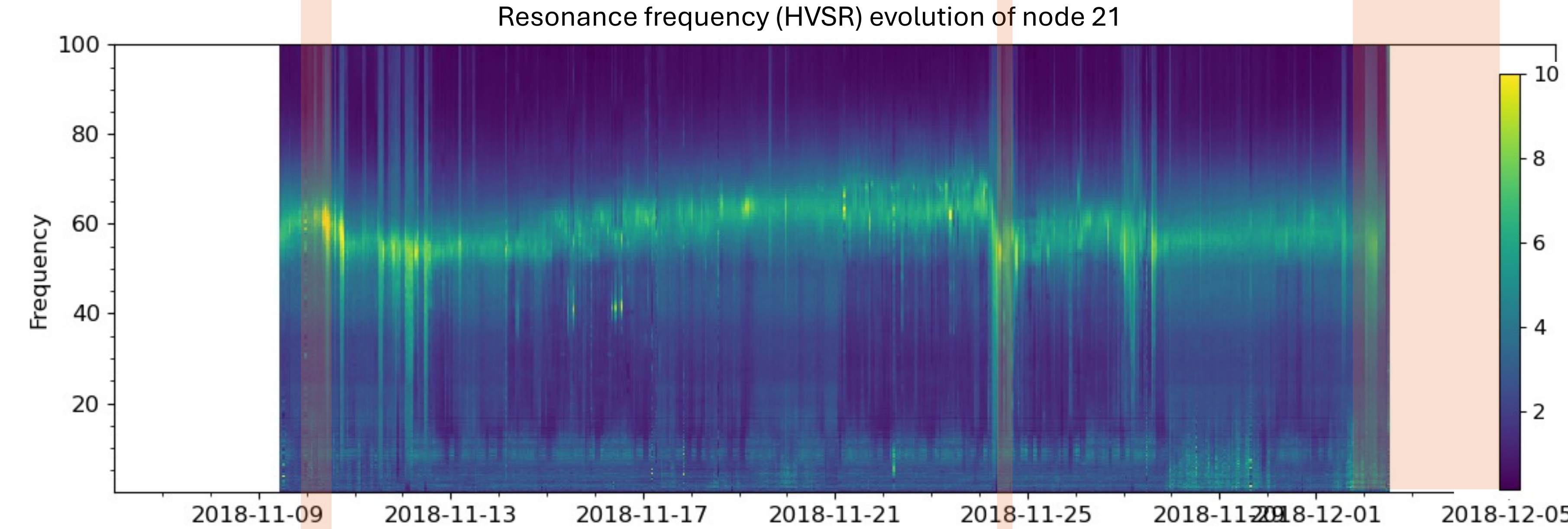
- Scheme of 1D profile around the Membach geophysical station.
- P-wave and S-wave velocity (V_P and V_S) and density profiles, estimated from geoelectric tomography results in Van Camp et al. (2006).
- The Rayleigh-wave sensitivity kernel at various frequencies computed using CPS software by Hermann (2013). The sensitivity is derived from the partial derivative of R-waves phase velocity with respect to the S-wave velocity (∂_C/∂_B)

Hydrological induced signals



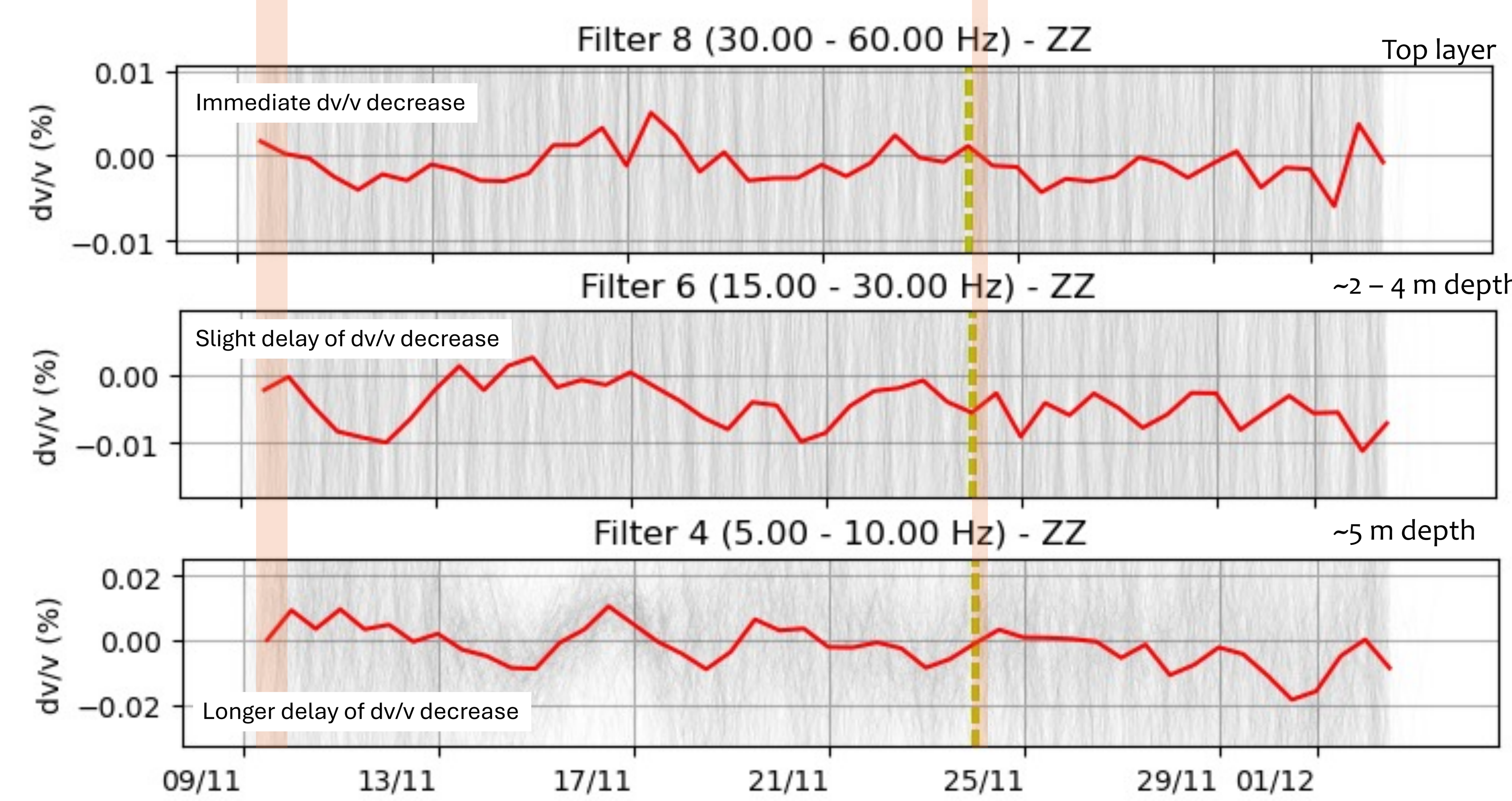
Gravity residuals and precipitation variations

- Gravity residuals: gravity corrected from tides and atmosphere
- The gravity residuals decrease while soil saturation increases (hydrological changes occur above the gravimeter)
- Increase in gravity variations days after rainfall
  - Water drains to a deeper layer (below the gravimeter)
- Gravity variations provide insight into total water storage changes in the area



Seismic velocity changes:

- During and shortly after the rainfall:
  - Increase in HVSR amplitude at 50 – 70 Hz
  - Saturation changes of the top soil layer (~60 cm)
- Decrease in f_0 caused by the decrease of the shear-wave velocity due to water infiltration
- Possible cause: shallow water infiltration? Run-off?



- The relative velocity variations (dv/v) is computed based on MWCS (Moving Window Cross-Spectrum) in MSNoise (Lecocq et al., 2017)
- Delayed decrease in dv/v after rainfall events
  - Higher frequency range has smaller dv/v amplitude changes
  - Lower frequency band → deeper water storage
- Seismic velocity changes provides insight of the infiltration time and the depth of the water storage

Discussion and Perspectives

- Soil moisture changes influence the geophysical measurements at the Membach station
- Further modellings and detailed processes are needed to quantify water storage changes that influence the geophysical observables
- Detailed petrophysical parameters need to be investigated in order to obtain a better parameterization

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email: anita.saraswati@oma.be

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