Modeling land subsidence caused by groundwater pressure variations and revealed by geodetic InSAR measurements (case study in the Leuven area)

In the framework of the LASUGEO project: « monitoring Land Subsidence caused by Groundwater exploitation through gEOdetic measurements »

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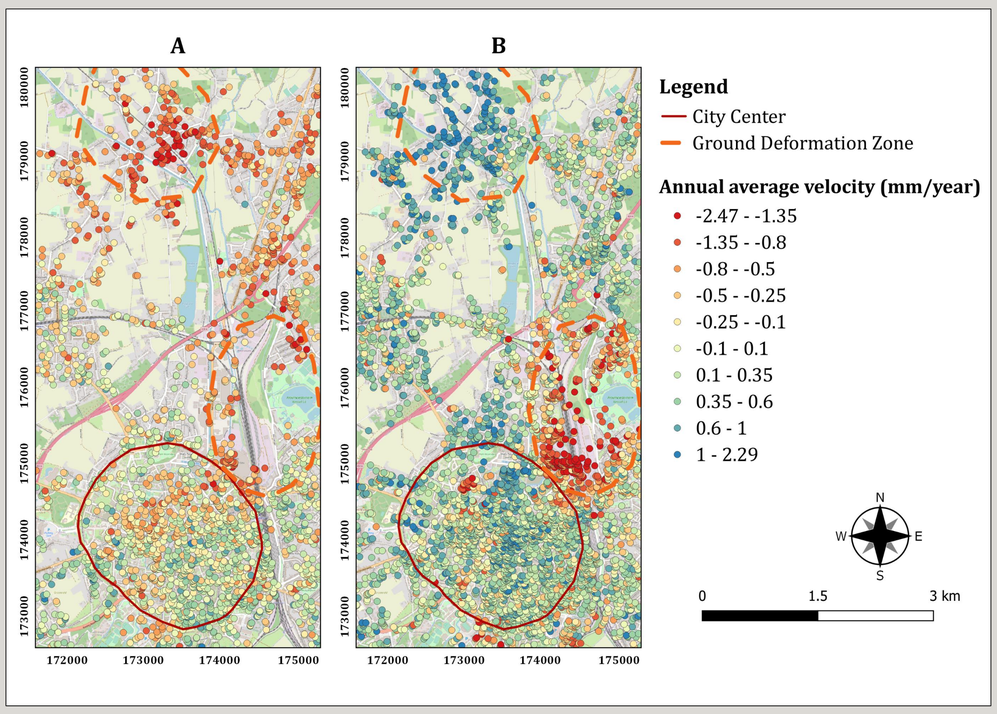
ABSTRACT

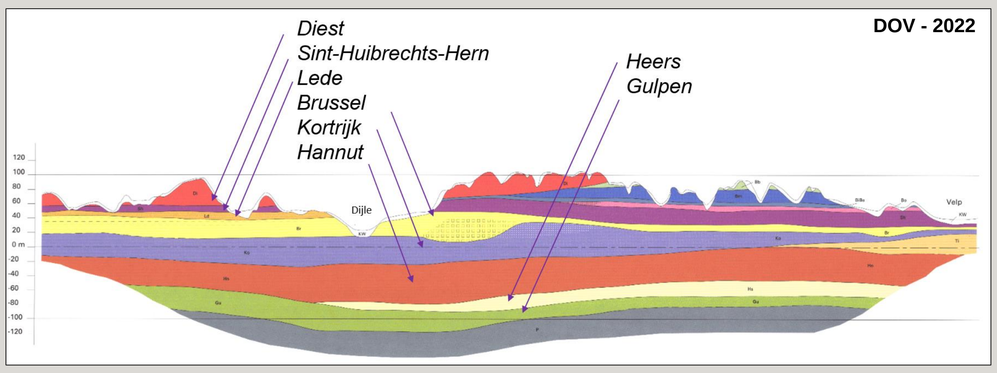
Using the Synthetic Aperture Radar Interferometry (InSAR) technique on data acquired by satellite ERS 1/2, ENVISAT and Sentinel-1A, from 1992 to 2022, localized vertical ground motion have been detected throughout Belgium. One of the assumption to explain vertical ground motion is anthropic groundwater pressure variation in specific layers of the underground. A general methodology is developed to identify consolidation and elastic rebound processes occurring in confined and unconfined conditions using 3D regional groundwater flow models coupled with 1D geomechanical models. The case study of the Leuven area is presented in this poster.

1. InSAR measurements

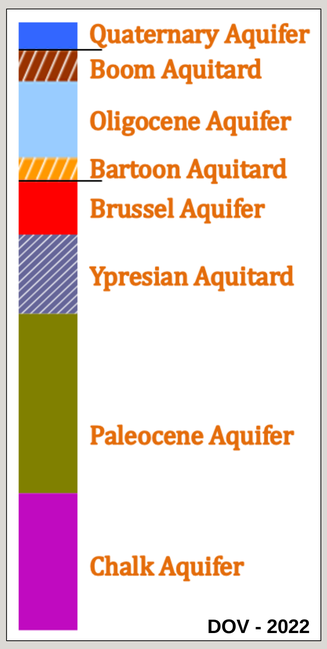


→ Identification of the two ground deformation zones located North of Leuven using InSAR data from the ERS1/2 (**A**) and ENVISAT (**B**) satellites

2. Geology & hydrogeology



→ Geological cross section of the Leuven area.

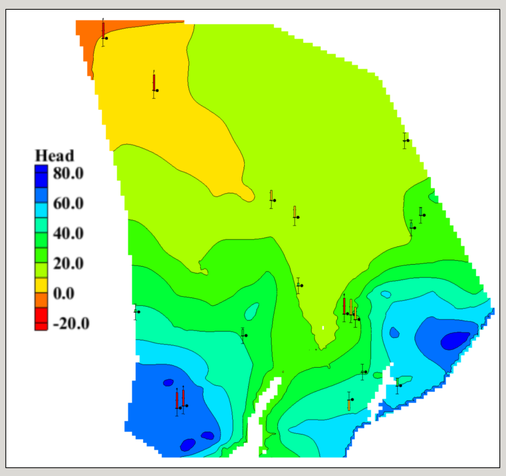


→ The city of Leuven lays on, from top to bottom, the Quaternary Aquifer, the Brussel Aquifer, the Ypresian Aquitard, the Paleocene Aquifer and the Chalk Aquifer

→ The Paleocene aquifer contains the two sandy formations of Hannut and Heers. The base of the Hannut Formation is clayey. This aquifer is divided into 3 layers in the numerical model

→ In the North of Leuven, the lithology becomes more complex. 3 hydrogeological formations appear as indicated between black lines on the left. They contain mostly clay and are counted as a single layer.

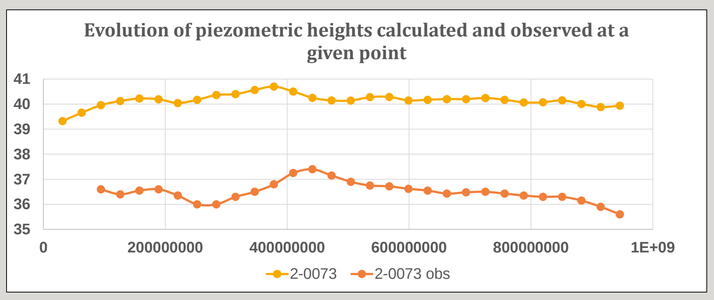
3. Steady state & transient groundwater flow models



→ The transient model covers the period between 1990 and 2020

→ It integrates the temporal variation of the recharge and the pumping rates

→ It was calibrated using the piezometric heads in each aquifer



4. First geomechanical approach

Geological formations	Thickness (m)	Volume compressibility α (Pa^{-1})	Variation of the groundwater level needed in one single layer to reproduce the whole observed subsidence (m)
Gent	17.2	1.00E-07	1.1
Brussel	17.6	1.00E-09	(112.3)
Kortrijk	24.7	1.00E-07	8
Hannut	51.7	1.00E-08	3.8
Heers	9.7	1.00E-09	(203.9)
Gulpen	46.1	1.00E-10	(428.7)

→ Using InSAR mean maximum value of ENVISAT over 8 year (2003-2010), a total subsidence of 19.76 mm is observed in a specific point

→ Above, the calculation to reproduce the total subsidence in only one formation shows that the study should focus on the Formation of Kortrijk, Hannut and Gent.

Future Works

1. → Use of 1D geomechanical models, using the SUB package of MODFLOW, to evaluate the compaction in each layer of the transient model
2. → Application of the same methodology to a rebound case in Brussels
3. → Development of guidelines

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