# Subsidence Evolution of Antwerp Region, Belgium over 77 Years, Using Historical Levelling and GNSS Data and Recent Persistent Scatterers Interferometry Observations

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**Abstract**

A combination of historical levelling surveys, recent Global Navigation Satellite System (GNSS) campaign, and Persistent Scatterers Interferometry (PSI) measurements reveal that the harbour of Antwerp in Belgium has been sinking for the last 77 years. By integrating recently acquired data using PSI and historic databases, this study aims to provide the longest possible time series of data coverage for ground deformation in Antwerp. All data on subsidence in the area is assessed using multiple techniques and has been coherently included in a Geographic Information System (GIS). The long-term impact of ground subsidence on the harbour potentially has both natural and human-caused sources.

The oldest dataset is a map of altitude changes in Belgium, based on a comparison of two first-order levelling surveys conducted in 1946-1948 and between 1976-1980 (Pissart and Lambot, 1989). The iso-displacement map for the entire country was calculated by subtracting the elevation map of the second levelling network from the first. The harbour of Antwerp was crossed by two iso-displacement lines of -20 and -10 mm, representing the overall displacement values over 31 years. This historical data demonstrates that there was a minor sinking in the region likely linked to natural consolidation when the anthropogenic changes in the harbour had not been made.

As the second dataset, three PSI datasets including ERS1/2, Envisat, and Sentinel-1A spanning the area in the periods 1991-2005, 2003-2010, and 2016-2019 respectively were collected and post-processed. The rate of subsidence in the Antwerp harbor and its city centre differs noticeably from one another, based on this data set. The average velocity of PS data in the city centre is 0.002, -0.06, and -0.6 mm/year and in the harbour is -0.83, -2.71, and -1.62 mm/year during the three time spans (Declercq et al., 2021). This study extends Sentinel-1A processing until 2022.

Among the 33 permanent Real-Time Kinematic (RTK) GNSS stations, there are three available stations to monitor the deformation of the region. ANTW (ANTWerp) and ATWR (AnTWeRp) are 70 meters away from each other and both are located within the city centre, and BEZA (BErendrecht-ZAndvliet-Lillo) is in the northeast of harbour. The vertical velocities at the locations of ANTW, ATWR, and BEZA during the periods 2003-2018, 2018-present, and 2010-present, are measured as -0.5, -1.9, and –2.2 mm/year respectively.

First, occurring at a rate of a sub-millimetre per year between 1946 and 1980 as measured in the levelling survey, land subsidence has recently increased substantially, reaching a maximum rate of -7 mm/year observed by the PSI technique. The previous low rate of subsidence as measured by the levelling shows that the natural consolidation of Holocene sediments probably occurred from the beginning. However, this sinking has increased recently, as shown by the most recent PSI and GNSS data. This is probably mostly a man-induced process linked to the consolidation of the constructed backfill and its underlying layer due

to its overpressure, together with the consolidation of the most compressible and less permeable layers (aquitards) due to pore pressure decrease induced by groundwater pumping in the aquifers.

**Keywords** PS-InSAR, Levelling, GNSS, Subsidence, Antwerp

## References

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