Land subsidence as revealed by PS-InSAR observations in the Antwerp area (Belgium): first steps towards the understanding and modelling

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PS-InSAR observations using multi-sensor radar data acquired by ERS 1-2, ENVISAT ASAR, and Sentinel-1A satellite sensors operating in C-band, have shown various land subsidence rates in different zones of the Antwerp area along the Scheldt River and in the harbor zone during the 1992 to 2021 period[1]. The LOS velocity values calculated from different radar datasets collected over Antwerp City Centre are ranged between -0.96 - +1.14 mm/year (ERS 1-2), -2.21 - +1.11 mm/year (ENVISAT), and -3.31 - +3.87 mm/year (Sentinel-1A). Moreover, the LOS velocity values for Antwerp Harbor are -4.38 - +1.02, -4.06 - +1.65, and -9.46 - +3.86 which are more significant than their corresponding ranges in the Antwerp City Centre. Groundwater is intensively pumped from the sandy Vlaanderen Formation (Holocene), Lillo and Poederlee Formations (Pliocene), and Berchem Formation (Miocene). However, in this area, land subsidence can be attributed to four potentially complementary consolidation processes:

- natural consolidation of the Holocene estuarine sediments,
- additional consolidation in the saturated Holocene estuarine sediments due to the backfill overload (8 m thick embankments) along the harbor docks,
- saturated-unsaturated consolidation of the backfill materials,
- consolidation of the most compressible layers, probably in the Boom Formation (Paleocene) and in the Asse clay of the Maldegem Formation (Eocene) due to pore pressure decrease induced by groundwater pumping in the different Cenozoic aquifers.

Indeed, several of these processes could be added to produce the actual observed land subsidence. Geomechanical and hydrogeological data were being collected in the frame of the BESLSPO BRAIN project: "monitoring LAnd SUbsidence caused by Groundwater exploitation through gEOdetic measurements (LASUGEO)". For consolidation of estuarine sediments induced by the backfill overload, the rapid increase of total stress should be equilibrated by an increase of both water pore pressure and effective stress. This later, inducing land subsidence, will progressively increase as the water overpressure can be dissipated mostly laterally through groundwater flow. A coupled approach including a 3D groundwater flow model and 1D geomechanical models will be needed for a detailed analysis[2,3,4]. First, local models will probably be needed in specific zones to understand in details the ongoing consolidation processes. Then a large 3D groundwater flow model will be considered over the Antwerp area including all the complex boundary conditions with the Scheldt River and the harbor docks to provide realistic transient water pressure conditions to numerous 1D geomechanical models in the area.

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