Urban land subsidence detection in Mexico using Sentinel 1 InSAR time series

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Abstract

Land subsidence is a natural or human-induced process that has increased in magnitude and exposure in Mexico over the past 30 years. As a result, urban infrastructure may be damaged and affected by a reduction of its design efficacy, causing either aesthetic or structural damage. Land subsidence can also indirectly increase the exposure of urban infrastructure to damage due to other natural phenomena such as flooding and earthquakes. Characterization of urban land subsidence in Mexico has mainly been limited to several large metropolitan areas, but there is no country-wide assessment of exposure to ground subsidence. This research showcases a methodology to assess the total land subsidence throughout Mexico affecting all urban populated areas and households.

We used Interferometric Synthetic Aperture Radar (InSAR) tools to assess land subsidence throughout Mexico. In our methodology, we use Single Look Complex (SLC) scenes from ESA's Sentinel 1 A/B sensors and the Small BAseline Subset (SBAS) algorithm to reduce spatial and temporal decorrelation. The dataset comprises 4,611 from 2018 to 2019. These scenes were acquired using 12 adjoining descending orbits of Sentinel-1 covering an area of ~ 1.7 million km2 or ~85% of the Mexican territory susceptible to ground subsidence associated with groundwater extraction. To implement the InSAR-SBAS analysis, we divide the total study area into 40 sub-areas. The SLCs are processed on a high-performance computer using the JPL/Caltech InSAR Scientific Computing Environment (ISCE) software and the Miami InSAR Time Series-software in Python (MintPy) to compute the unwrapped interferograms and deformation time series, respectively. In the InSAR-SBAS methodology, we use DInSAR interferograms with 20 and 60 looks along azimuth and range directions to obtain a pixel size of ~ 300 x 300 m2. To improve the quality of our results, we also correct tropospheric errors using the empirical correlation between troposphere and topography and keep only high-quality deformation pixels or pixels with temporal coherences higher than 0.7. Finally, the resulting average velocity maps are projected from the line of sight (dlos) component into vertical (dv) using each pixel incidence angle and assuming that the horizontal velocity components are negligible. We then overlap the National Mexican 2020 census (INEGI, 2020) urban Áreas Geoestadísticas Básicas (AGEBs) over the vertical velocity fields to compute the total urban areas, population, and households exposed to land subsidence in Mexico.

We find that 1,567 urban localities in Mexico are exposed to land subsidence velocities faster than -25 mm/year (Figure 1). These urban localities cover an area of more than 5,900 km2 exposing 28.9 million people and 9.4 million households. These localities are mainly located along the Mexican Volcanic Belt, the central North-South Mexican Basin and Range province, and along coastal plains. The higher exposure to subsidence in these regions can be a consequence of human and natural factors. These geologic provinces include the larger urban areas in Mexico with high water demand, but on the other hand, have been developed over compressible sediments and, in some cases, within an extensional tectonic regime.

Monitoring land subsidence on a country-scale is necessary for city managers and policymakers to implement better strategies for water management, land use, and natural hazards mitigation. According to our results, the fastest subsiding area is within the Mexico City metropolitan area with velocities up to 420 mm/year.

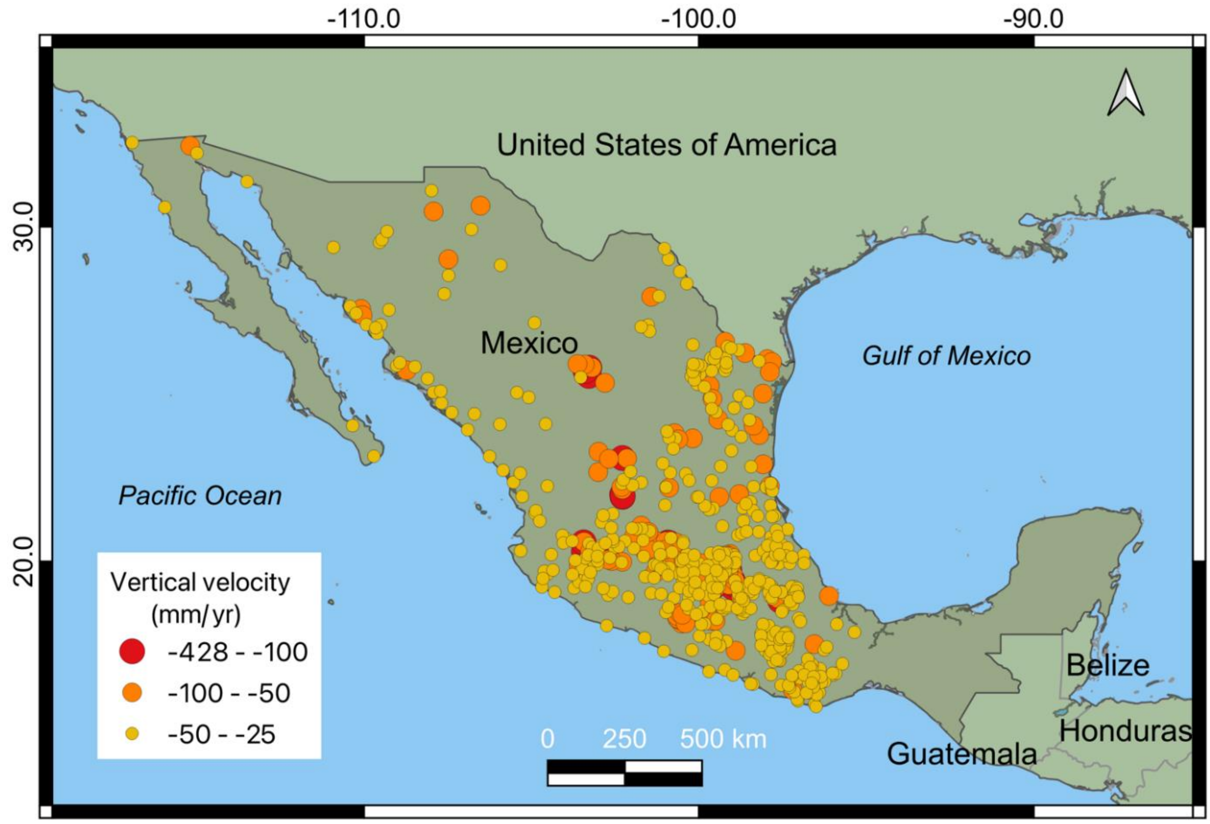

Figure 1 Urban localities in Mexico with land subsidence higher than 25 mm/year