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Spatio-temporal analysis of surface displacements in N'Djamena, Chad derived by Persistent Scatter-Interferometric Synthetic Aperture Radar (PS-InSAR) and Small BAseline Subset (SBAS) techniques

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High-resolution characterisation of land deformation and its spatio-temporal response to external triggering mechanisms is an important step towards improving geological hazard forecasting and management. The work presented here is part of the ResEau-Tchad project (www.reseau-tchad.org), with a focus on the city of N'Djamena. The extraction of groundwater to sustain this rapidly growing capital city has increased the pressure on water supply and urban sanitation infrastructures which are failing to meet the current water demand. In this study we exploit Synthetic-Aperture Radar (SAR) data acquired by the Sentinel-1 satellite to investigate the temporal variability and spatial extent of land deformation to assist in the development of a sustainable water management program in N'Djamena city.

The objectives of the work are: 1) to analyse the recent evolution of land deformation using two multi-temporal differential interferometry techniques, SBAS and PS-InSAR; and, 2) to investigate the land deformation mechanism in order to identify the factors triggering surface movements. The PS-InSAR and SBAS techniques are implemented on SAR images obtained in both ascending and descending orbits from April 2015 to May 2021 to generate high resolution deformation measurements representing the total displacement observed at the surface. While the pattern of displacement indicated by the two datasets is similar, the average velocity values obtained with PS-InSAR tend to be noisier than the ones derived using the SBAS technique, particularly when the SBAS time-series shows non-linear deformation trends.

Characterisation of the subsidence areas by means of statistical analyses are implemented to reveal the surface deformation patterns which are related to different geo-mechanical processes. The integration of the spatio-temporal distribution of PS and SBAS InSAR results with geological, hydrological, and hydrogeological data, along with subsurface lithological modelling shows a relationship between vertical displacements, clay sediments, and surface water accumulation.

These areas are located mostly in the surroundings of the urban area. The city centre is observed to be mostly stable, which might be the result of the removal of the surface water through the city drainage system. Investigation of the relationship between vertical displacements and seasonal groundwater fluctuations or effects due to the groundwater withdrawal is limited due to the temporally sparse piezometric dataset; however, the recent deformation rates appear to be correlated with the groundwater level trend at some locations.