Land subsidence contribution to coastal flooding hazard in southeast Florida – An update

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Abstract

The current study updates the results of our TISOL 2020 paper describing geodetic measurement efforts in southeast Florida to monitor local subsidence and evaluates its contribution to coastal flooding hazards. Over the past three years, we established a Global Navigation Satellite System (GNSS) monitoring network in Miami-Dade County, acquired and processed the GNSS data, and continued Interferometric Synthetic Aperture Radar (InSAR) monitoring using Sentinel-1 observations. The GNSS observations spanning over a period of 2.35 years revealed that all four stations have subsided at rates of 1.7-5.8 mm/yr. InSAR time series analysis of the Sentinel-1 data acquired during 2016-2021 indicates a shift in subsidence pattern with respect to the 1993-1999 ERS-1/2 results. The Sentinel-1 results show mostly localized subsidence associated with recent large building constructions, whereas the ERS-1/2 results show mainly pockets of subsidence in the western section of the city, where the city was built over reclaimed wetlands. The one exception in the ERS-1/2 results was localized subsidence in the eastern part of the city of a 12-story condominium building, the Champlain Tower South in Surfside, which collapsed in 2021 and attracted worldwide attention.

Background

Florida coastal communities are periodically subjected to flooding events, which are induced by heavy rain, high tide, and storm surge. Over the past decades, several coastal communities have experienced a significant increase in flooding frequency, causing significant disturbance to property, commerce, and overall quality of life (Wdowinski et al., 2016). In the current study, we measure land subsidence along the urban section of the Miami-Dade coastline using precise geodetic observations. These measurements are used to evaluate the contribution of land subsidence to the increased coastal flooding hazards along the coast of Mami-Dade County.

Methods

The project aims at monitoring land subsidence along the urban section of the Miami-Dade coastline using two advanced geodetic measurement techniques, GNSS and InSAR. Precise GNSS measurements require the installation of continuous GNSS units in subsiding coastal areas and monitoring the movements over a period of at least 3-4 years. InSAR uses space-borne radar observations acquired over a period of 5+ years to detect small movements of the Earth's surface. In this project, we installed four GNSS units along the urban section of the Miami-Dade shoreline and processed InSAR data acquired by the Sentinel-1 satellite constellation. By using both measuring techniques, we obtain

detailed temporal information on subsidence processes in the four GNSS station locations and high spatial coverage of land subsidence along most of the urban sections of the Miami-Dade County coastline.

Results

Data processing of our four GNSS stations was conducted by the Nevada Geodesy Lab (NGL - http://geodesy.unr.edu/) and presented in the International Terrestrial Reference Frame 2014 (ITRF14). Here we focus on the vertical (Up) component, in which negative values represent subsidence. A visual presentation of the four stations' vertical movements during the 2.35 years (February 2020 – June 2022) measurement period is presented in Figure 1. The time series show three main features, long-term trend, seasonal component, and high-frequency variability (noise). The rates of subsidence were estimated using the MIDAS algorithm (Blewitt et al., 2018). The calculated subsidence rates show that all stations are subjected to subsidence at rates of 1.7-5.8 mm/yr.

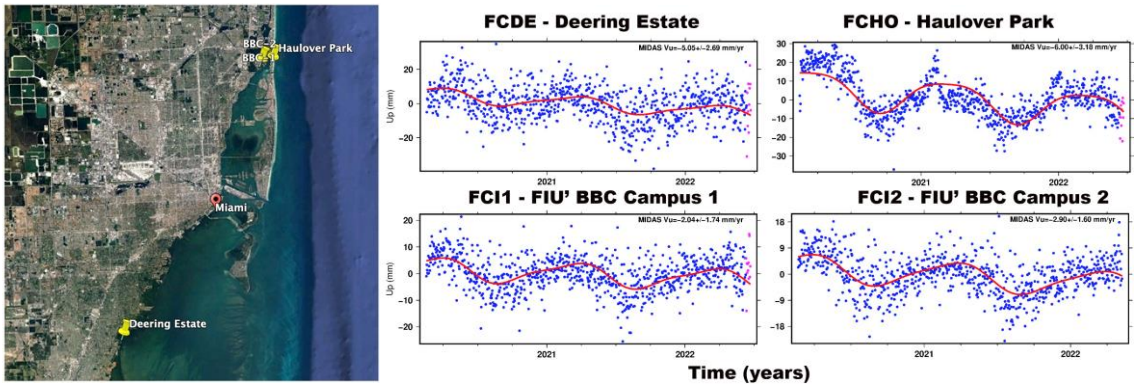

Figure 1 (Left) Location of the four GNSS sites constructed along the coast of the urban section of Miami-Dade County. (Left) Subsidence time series of all four GNSS stations.

InSAR time series processing of the Sentinel-1 data (2016-2021) indicated that mostly localized subsidence was associated with recent large building constructions. This subsidence pattern differs from measurements obtained by ERS-1/2 data (1993-1999) indicating that subsidence occurred mainly in pockets in the western section of the city, where the city was built over reclaimed wetlands. The one exception in the ERS-1/2 results was localized subsidence in the eastern part of the city of a 12-story condominium building, the Champlain Tower South, which collapsed in 2021 and attracted worldwide attention.

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