The contribution of land subsidence to the increasing coastal flooding hazard in Miami Beach

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Introduction

South Florida is one of the most vulnerable areas to Sea Level Rise (SLR) due to its low elevation, large population concentration, and economic importance. Recently, the city of Miami has been identified as the economically most vulnerable city to SLR in the world (US National climate assessment). Heretofore, the effect of SLR has felt mostly in low-lying coastal communities, such as the City of Miami Beach. A recent flooding hazard study of Miami Beach have shown a significant increase in flooding frequency after 2006, in which the flooding frequency increased by 400% compare with flooding events during the previous decade (Wdowinski et al., 2016). This study attributed the flooding frequency increase to a decadal-scale accelerating rates of SLR. However, some of the increased flooding frequency might have caused due to local land subsidence, because some of the low elevation sections of the city were built on reclaimed swamps. In this study we evaluate the contribution of land subsidence to the increasing flooding hazard in Miami Beach using Interferometric Synthetic Aperture Radar (InSAR) observations.

Flooding in Miami Beach

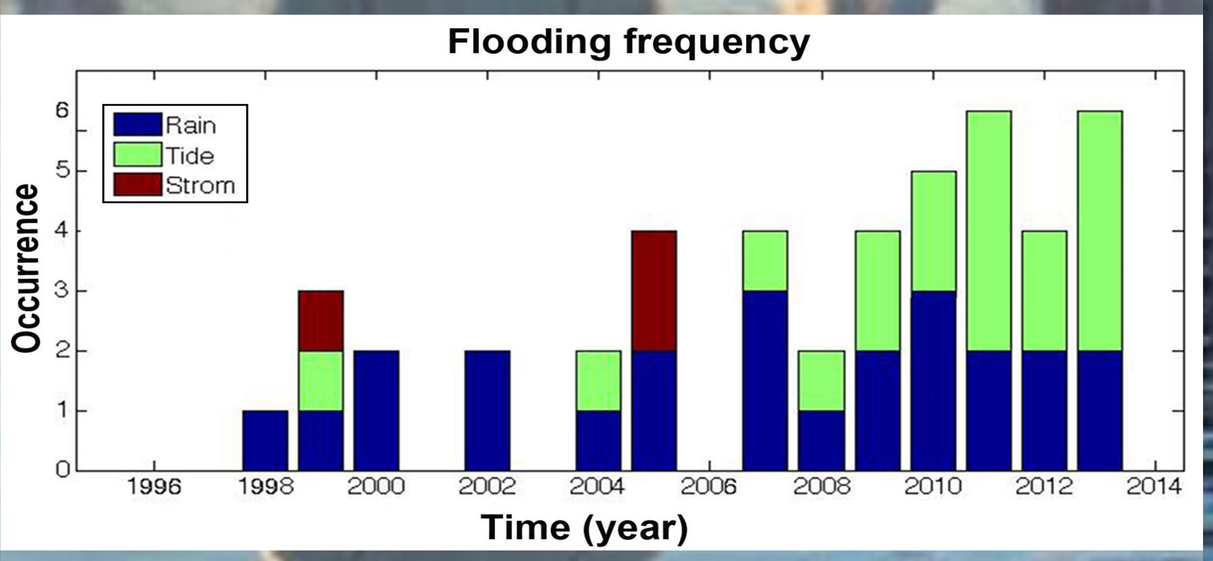


Figure 1. Flooding frequency in Miami Beach based on a cross reference analysis using tide gauge, rain gauge, insurance claim, media reports, and photo documentation records (Wdowinski et al., 2016).

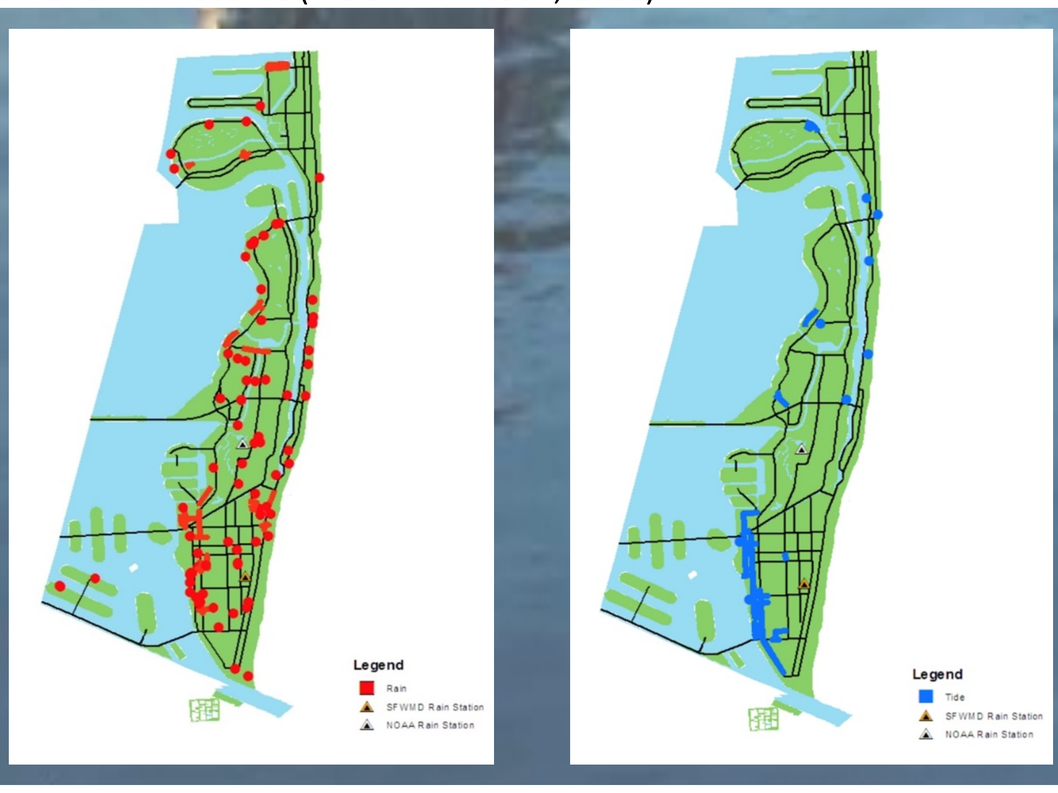
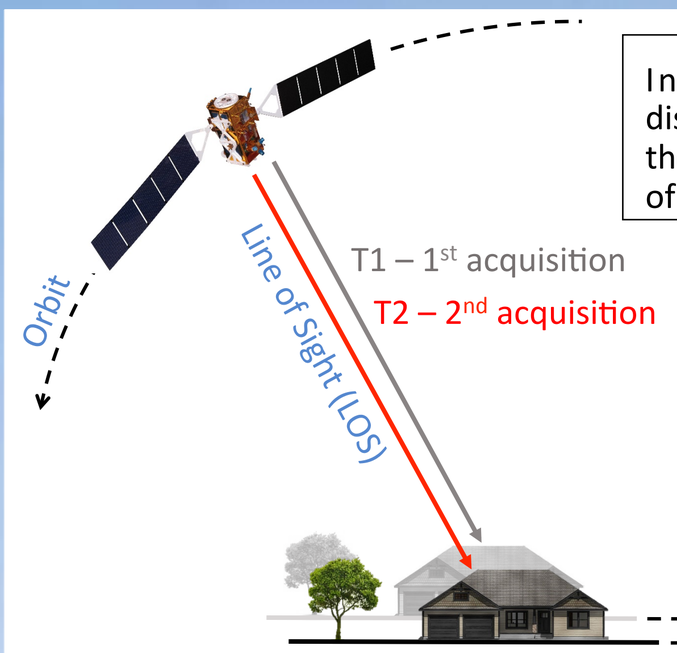
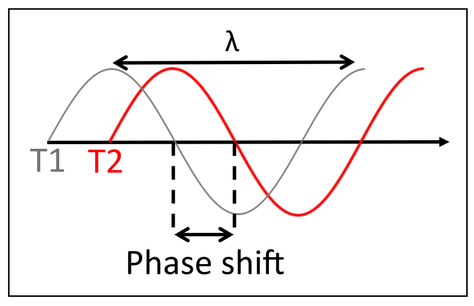


Figure 2. Location of the flooding events in Miami Beach caused by rain (A) and tide (B) during the period 1993-2013. Most of the tide flooding occurred in the western part of the city.

What is InSAR?

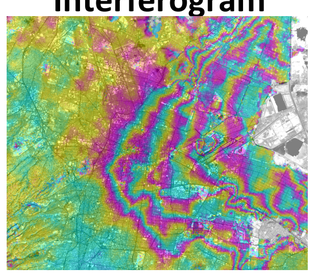


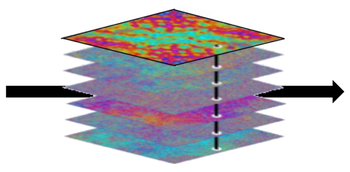
InSAR measures changes in distance between the satellite and the ground along the satellite Line of Sight



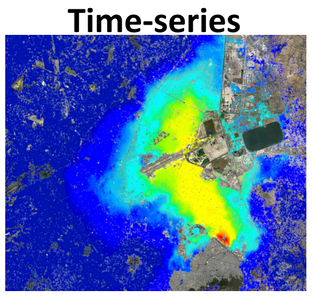
Interferograms are generated by differencing the phases of two SAR images acquired over the same place at different times.

Interferogram





Time-series



Inverting many interferograms, it is possible to extract the displacement through time and perform time-series analyses.

InSAR study of Miami Beach

We analyzed 23 ERS-1/2 images acquired during the period 1993-2005 using InSAR time-series techniques. Preliminary results yield localized subsidence at a rate of 2-3 mm/yr, mostly along the western section of the city. The subsiding areas correlate well with the areas that were built on reclaimed swamps.

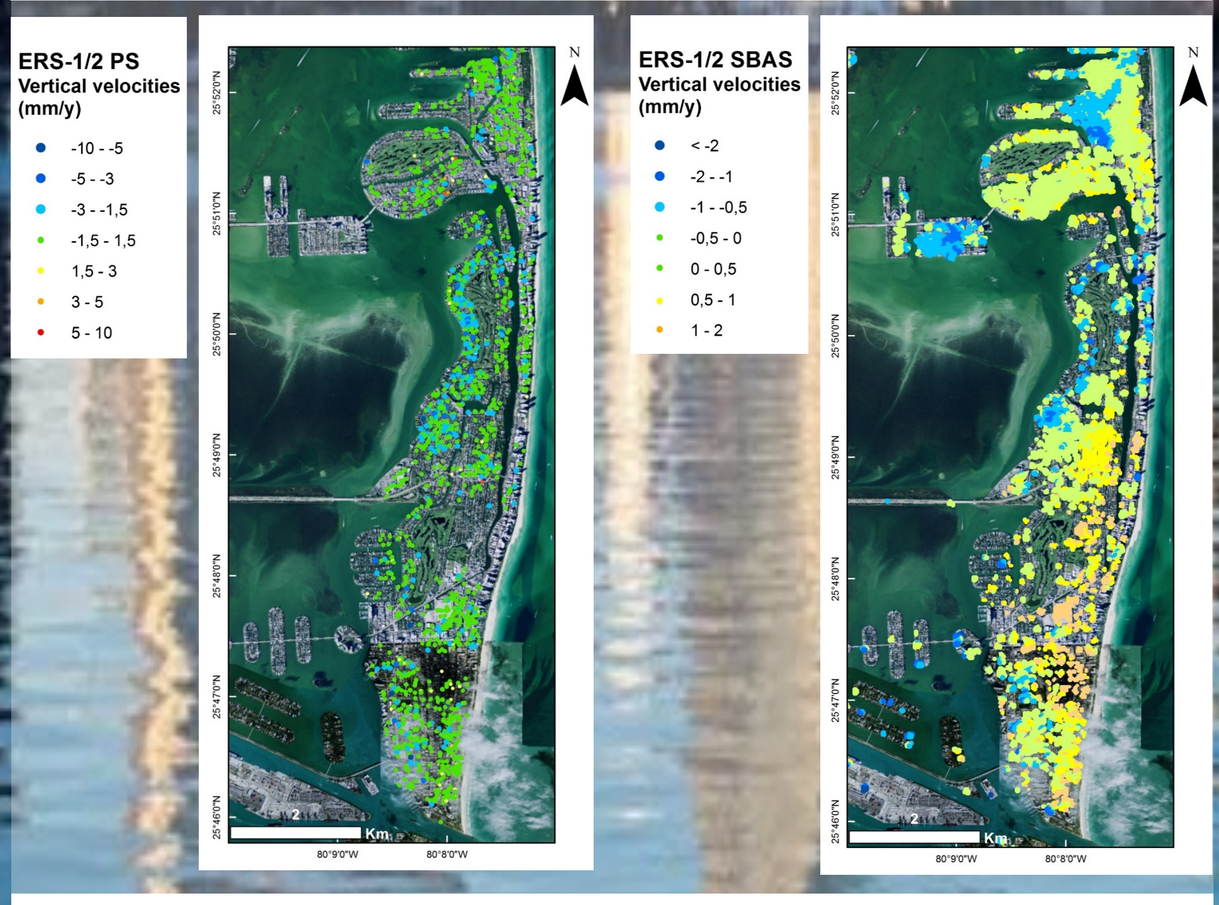


Figure 3. Velocity maps obtained with PS (left) and SBAS (right) techniques. The color scale indicates the value of the velocity for each point. Negative values, in blue, mean ground settlement while positive values, in red, are uplift. For the SBAS results, each point represents the mean velocity calculated for a 20x20 m square. The results show a good correlation between the subsiding areas and some of the tide flooded areas (Figure 2) in the western part of the city.

Conclusions

- Preliminary InSAR results detected localized subsidence, up to -3 mm/yr, mainly in reclaimed land located along the western side of Miami Beach.
- Although the detected subsidence velocities are quite low, their effect on the flooding hazard is significant, because houses originally built on higher ground have subsided since the city was built, about 80 years ago, by 16-24 cm down to flooding hazard zones.
- The combined effect of subsidence and SLR further expose the subsiding areas to higher flooding hazard than the rest of the city.

References

- Wdowinski, S., R. Bray, B. P. Kirtman, Z. Wu (2016). Increasing flooding hazard in coastal communities due to rising sea level: Case study of Miami Beach, Florida. Ocean & Coastal Management, 126:1.