Recent Subsidence Rates in the Mekong Delta derived from Sentinel-1 SAR-Interferometry

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MOTIVATION

Land subsidence in coastal areas increases the vulnerability to flooding, salinization of water resources and permanent inundation. For the Mekong Delta (MD), whose mean elevation is less than 2 m above sea level, subsidence rates of up to several centimeters per year have been reported (Erban et al., 2014). This leads, in combination with the progressive sea level rise, to a growing risk for the resident population, infrastructure and economy. Precise monitoring of the subsidence rate is necessary for hazard analyses as well as planning and assessment of counter-measures.

Here, we present recent land subsidence rates in the Mekong Delta derived from Sentinel-1 based SAR-Interferometry. On that basis, we reconsider drivers of the subsidence (e.g. Minderhoud et al., 2017).

METHODS

We use 174 Sentinel-1 scenes acquired between 2016 and 2019 in a descending orbit and 88 Sentinel-1 scenes acquired between 2017 and 2019 in an ascending orbit. The Persistent Scatterer (PS) Interferometry Technique is applied for the purpose of two different studies:

Study 1: Delta-wide estimation of subsidence rates and comparison with geological data.

- Application of the common StaMPS approach (Hooper et al., 2012) to estimate the subsidence rates of PS.
- Comparison of subsidence rates from descending and ascending orbits and comparison with the maximum aquifer drawdown rate and the regional geomorphology.

Study 2: Examination of differential subsidence rates between infrastructure with different foundation depths and adjacent ground points in Can Tho City.

- Application of a multi-stack small baseline approach (Schenk, 2015) to estimate the subsidence rate and the height of PS.
- PS position correction as a function of the estimated height.
- Selection of PS on buildings and ground surface using polygons covering the buildings respectively their surroundings and a lower and upper height threshold.

RESULTS

Delta-wide Subsidence Rates

The estimated subsidence rates in the MD between 2016 and 2020 (Figure 1a) are up to 6 cm/yr and feature mainly three different spatial characteristics: (i) interconnected areas of little to no subsidence, (ii) isolated urban hot-spots with high subsidence rates and (iii) larger regions with increased subsidence rates covering urban as well as rural areas. The subsidence rates are characterized by shorter-scale patterns as those estimated in Erban et al. (2014) for the period 2006-2010. The differences between estimated subsidence rates from descending and ascending orbits between 2017 and 2020 (Figure 1b) are between -15 and 15 mm/yr and in large part spatially correlated. The subsidence rates partly correlate with the modeled aquifer drawdown in the Middle Pleistocene and other aquifers between 1990 and 2016 in Minderhoud et al. (2017) (Figure 1c), however the subsidence rates exhibit shorter-wave patterns. There is no significant correlation between the subsidence rates and the geomorphology in the MD (Figure 1d).

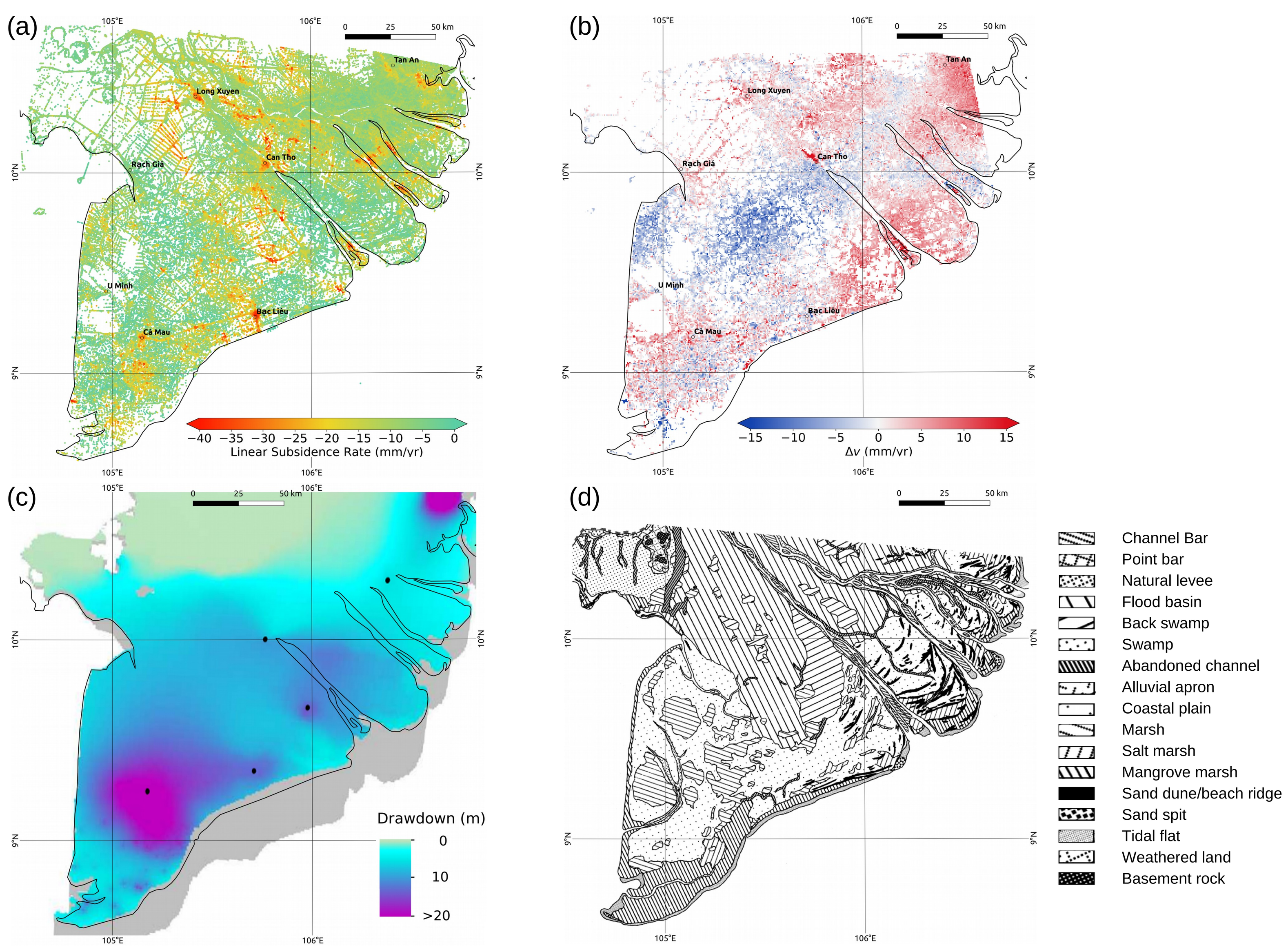

Figure 1: (a) Estimated subsidence rate in the MD based on Sentinel-1 data from 2016 – 2020 acquired in a descending orbit, (b) difference between estimated subsidence rates based on data from 2017-2020 acquired in a descending orbit and an ascending orbit, (c) modeled head drawdown in the Middle Pleistocene aquifer between 1990-2015 from Minderhoud et al. (2017), (d) geomorphological map of the MD based on Nguyen et al. (2000).

Subsidence Rates in Can Tho City

The selection of PS on buildings and the adjacent ground is exemplary shown in Figure 2. PS located in the inner polygon and having an estimated height of more than 10 m are selected as house PS. PS located in the outer polygon and having a height of less than 2 m are selected as ground PS. We compare the median estimated subsidence rate of building PS and adjacent ground PS for a number of houses in Can Tho in Figure 3a. The house PS are characterized by lower absolute subsidence rates than the ground PS in all but one case. The differences are up to 34 mm/yr. The differences are plotted over the piling depth of the respective houses in Figure 3b. No significant trend can be identified in this Figure.

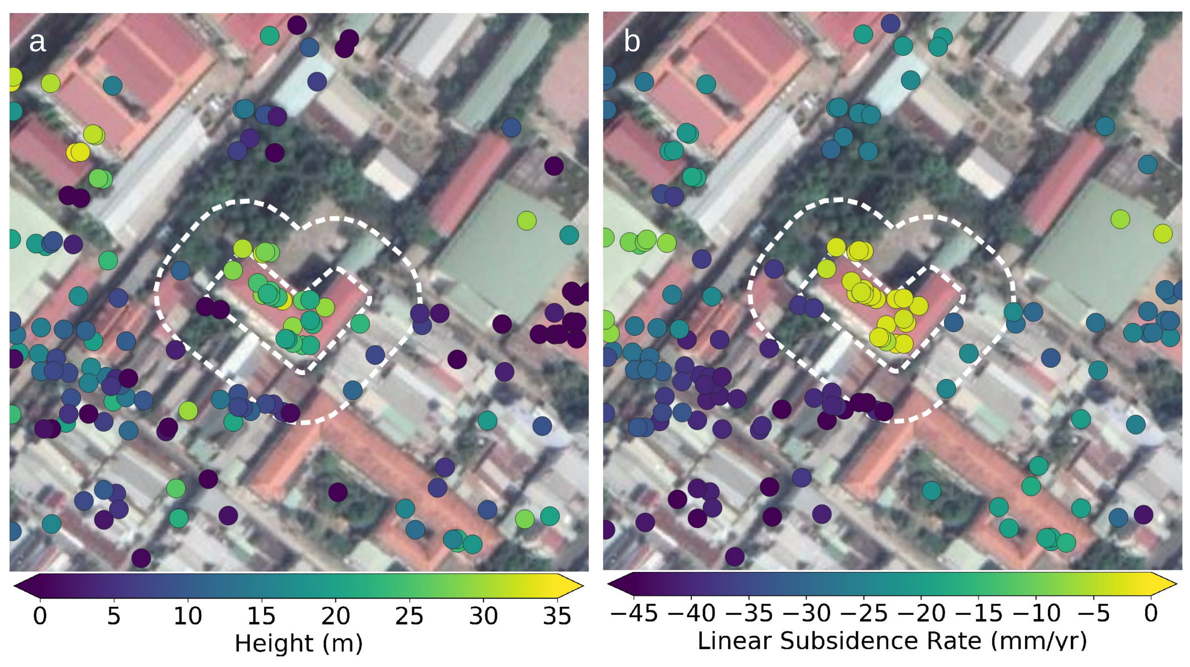

Figure 2: Estimated height (a) and linear subsidence rate (b) of PS in Can Tho City. The selection of house PS and ground PS is carried out using the white polygons in combination with height thresholds. Map data: Google 2020

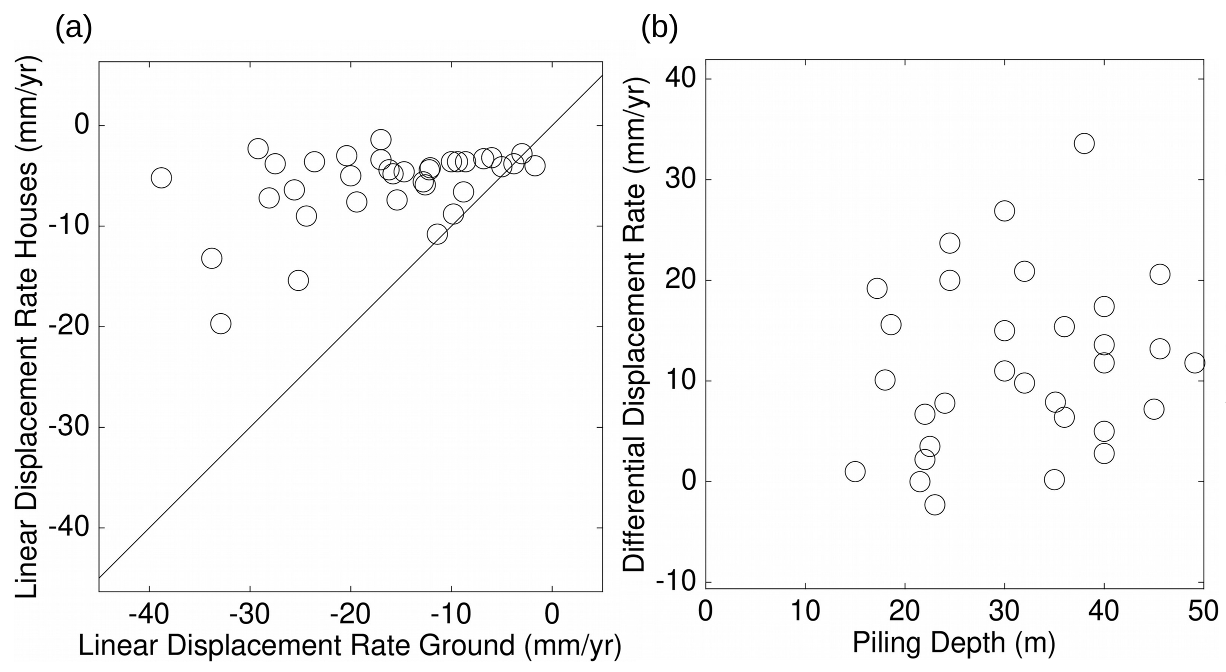

Figure 3: (a): Median linear subsidence rate of ground PS vs. median linear subsidence rate of house PS for a selection of houses in Can Tho City. (b): Differential subsidence rates of house PS and ground PS, plotted over the piling depth of the respective houses.

SYNTHESIS

The estimated subsidence rates exhibit highest values in urban areas. These hot spots are located in different geomorphological units. Since there is also no large-scale correlation between the geomorphology and the subsidence rates, we assume there is no connection between subsidence and the geomorphology. We need additional geological data to examine a possible correlation between the observed subsidence rates and the lithology. The modeled hydraulic head decline in different aquifers is partly correlated with the subsidence rate in the MD, however it does not feature localized hot spots as seen in the subsidence rate. With further detailed data of the ground water aquifer extraction rate, we can investigate the correlation in more detail. Study 2 suggests that a large part of the subsidence in Can Tho City originates from the shallow subsurface as houses with a piled foundation are on average characterized by a lower subsidence rate than the adjacent ground surface. There is no significant correlation between the piling depth and the differential subsidence rates which indicates that parameters like local lithology, local groundwater extraction rate, building age, type of foundation and land use history may also play a role for the local differential subsidence.

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