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Monitoring of subsidence with UAVSAR on Sherman Island in California's Sacramento–San Joaquin Delta

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ABSTRACT

Sherman Island, the westernmost island in the Sacramento–San Joaquin Delta in California, plays a crucial role in maintaining the water flux between saline ocean water from the San Francisco Bay to its west and the rest of the Delta to its east. Land elevation below mean sea level and continuous subsidence over the past century has made this island a high priority area for investigations of subsidence and restoration in the Delta. This study reports the results of successful application of Interferometric Synthetic Aperture Radar (InSAR) data and technique to measure subsidence in the Delta, which is a coherence-challenged non-urban area. We carried out a time-series interferometric analysis of Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) L-band (23.8 cm) data, collected from July 2009–August 2014, to assess both the spatial and temporal variation of subsidence on Sherman Island. We report both large-scale (island-wide) subsidence trends and small-scale (levee/farm scale) subsidence features in Sherman Island. Assuming the subsidence is linear during the five years of UAVSAR data acquisition, subsidence rates across the island range from 0–5 cm/yr, with an average of 1.3 ± 0.2 cm/yr. We estimate our systematic uncertainty to be 0.3 cm/yr. Overall, the central region in the island has subsided at a faster rate than the rest of the island. We find our results to be consistent with previous measurements of subsidence rates at electric transmission line towers scattered throughout the island. The results of this study provide insights into several factors influencing subsidence, including soil type, water table depth, land use, land elevation and the location and time of levee repairs. Subsidence monitoring on Sherman Island is essential for maintaining a reliable water supply for the state of California and for protecting the Delta ecosystem.

1. Introduction

The Sacramento–San Joaquin Delta (from here on referred to as the 'Delta') is located east of San Francisco Bay, at the confluence of two of the largest rivers in the state of California: Sacramento River which joins the Delta from the north and San Joaquin River which joins from the south. The Delta itself occupies ~39 km east to west and ~77 km north to south (Fig. 1) (Lund et al., 2010). It is bordered by the cities of Sacramento on the northeast, Antioch on the west, Tracy on the south-west and Manteca (near Stockton) on the southeast. The tidal marshland and reclaimed land that make up the Delta are distributed among ~70 major islands and tracts surrounded by about 1700 km of levees or embankments. The Delta plays a critical hydrological role as the main freshwater supply for California and collects runoff from almost 40% of the state's land area. It is a hub of various state, federal and local water systems and provides water to about two-thirds of California's residents (Burton & Cutter, 2008; Delta Science Plan, 2013; Suddeth, Mount, & Lund, 2010). Moreover, it is also a complex estuary ecosystem and a biodiversity hotspot that provides home to nearly 750 animal and plant species, some of which are threatened or endangered (United States Environmental Protection Agency [USEPA], 2011).

In the late 1800s and early 1900s, the tidal marshlands that constituted the Delta were reclaimed and converted into farmland (Mount & Twiss, 2005). 'Reclamation' refers to the drainage of existing tidal marshlands and construction of levees/embankments, channel networks and drainage ditches to assist in making the region suitable for agriculture. The conversion of tidal marshlands into farmland initiated the process of subsidence in the Delta. As a result of this ongoing subsidence over the past century, current mean island elevations throughout the Delta are below mean sea level, with some islands being as low as eight meters below sea level (Fig. 2) (California Department of Water Resources [CA DWR], 2007b; Deverel & Rojstaczer, 1996; Mount & Twiss, 2005).

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Fig. 1. The Sacramento and San Joaquin Rivers join east of the San Francisco Bay in northern California, forming the Delta. The westernmost island in the Delta, Sherman Island, is the focus of this study (outlined in red). Cities forming the boundaries of the Delta are cited in the text and their locations are depicted in this figure.

The factors causing subsidence of the Delta land surface have changed over the years. In the early 1900s, controlled firing/burning of the surface soil was a common practice in the preparation of potato fields and led to lowering of surface levels (Cosby, 1941). Later, this factor was superseded by conversion of larger tracts of land into farms, accompanied by drainage of the organic-rich soils in order to lower water tables for growing crops. These drained organic soils were more susceptible to oxidation and consolidation/compaction, which are currently the dominant causes of subsidence in this area (Deverel & Rojstaczer, 1996; Deverel & Leighton, 2010). Oxidation refers to the microbial oxidation of organic matter in the soil that constitutes the Delta. The rate of oxidation depends on the content of organic matter in the soil. Other factors that can also contribute to subsidence include shrinkage, anaerobic decomposition, wind erosion, resource withdrawal, dissolution of soil organic matter and direct harvest of soils. Organic matter content and farming practices/water resources management directly contribute to the variation in subsidence throughout the Delta.

Sherman Island is the westernmost island in the Sacramento–San Joaquin Delta and its geographic location makes it critical for controlling the flux of seawater into the Delta (Fig. 1) (Fischer, Miyamoto, Nguyen, & Whipple, 2011). This island was one of the first in the Delta to be reclaimed during the period 1868–1879 (URS, 2009). This island is primarily used as pasture area, although agricultural farming, primarily of corn, grains, and alfalfa, is also carried out in the central and northeastern parts of the island (Fig. 3C) (CA DWR, 2007a; National Resources Conservation Service Soils [NRCSS], 1985). Land surface elevations measured with LiDAR across Sherman island vary from 1 m to −5 m relative to the sea level (levee elevations are higher than the