Detection of rapid land subsidence of civil constructions with TerraSAR-X Interferometry

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1. Introduction

The PSI technique (Persistent Scatterers Interferometry) has been particularly useful for monitoring tiny urban ground displacement, i.e. land subsidence induced by the over-exploitation of groundwater. However, identification and interpretation of PT points are still a challenge for land subsidence resulted from civil constructions (e.g. reclamation) that is characterized by a high deformation rate or involves small-scale ground targets, e.g, single buildings or transportation networks. The new-generation SAR systems, such as TerraSAR-X and Radarsat-2, have enhanced capabilities in terms of high spatial resolution and shorter temporal revisit time, and therefore can offer a potential for monitoring rapid land subsidence in relation to civil infrastructure underground constructions[1, 2].

In this work, the main aim is to evaluate the potential of TerraSAR-X observations for monitoring and detecting land subsidence induced by reclamation activities. A case study was conducted in a large scale reclamation area at the Penny's Bay and its vicinity, Landtau Island, Hong Kong, which provide 280 ha of land for the development of the Hong Kong Disneyland. The reclamation was undertaken in two stages as shown in Figure 1 (a): the Stage 1 Reclamation commenced in May 2000 and was completed in December 2002; the Stage 2 started in 2003 for completion in the year 2008. According to the well-known Terzaghi theory of soil consolidation[3], a rapid reclamation settlement due to consolidation of the alluvial clay deposits and creep within the reclamation fills has been occurring in this area, particularly within the reclaimed land at the Stage 2 Reclamation.

2. Data and methods

A total of 16 TerraSAR-X (TSX) stripmap-mode images acquired between Oct 2008 and July 2009 were utilized in this study, which were programmed and ordered in the framework of the TerraSAR-X General AO project CAL_0390. From the whole set of interferograms formed by all possible pairs of images, only those with a perpendicular component of spatial baseline smaller than 150 m, a temporal baseline shorter than 66 days. By limiting the baselines, the most incoherent interferograms were rejected. In addition, an external DEM data at a spatial resolution of 5 m was used to remove the

topographic phase contribution and co-registered SLC data.

In order to achieve optimal interferometric results, coupled with a limitation of small number of TSX data available, the following key processing steps are emphasized and proposed in this study:
(1) the coregistration procedure assisted with an extended-DEM
(2) the multi-master stacking analysis with small-baseline subset

The DEM-assisted coregistration approach considers the terrain heights in the SLC co-registration and utilizes the imaging geometry information and a-priori information of the topography. It can achieve a higher accuracy of co-registration than that obtained by the so-called cross-correlation coregistration method. In the past PSI analysis need large number of time-series SAR images and was not very successful under these conditions. In this study, for the optimizing the PSI processing in the case of high deformation gradients and non-uniform motion, a multi-master stacking analysis was applied to the subset of interferometric combinations with small baselines.

3. Results and perspectives

Figure 1 (b) shows the line-of-sight deformation velocity between Oct 2008 and July 2009 over the Penny's Bay Disneyland, Hong Kong. A significant settlement bowl on the order of 10-20 cm/yr has been detected with TerraSAR-X interferometry at the Stage 2 reclamation region, with maximum subsidence rate of around 35 cm per year. This can be explained by the quick primary consolidation process of the beneath alluvial deposits due to reclamation fill load which mostly occurs during the initial phase after the reclamation complete [4]. In contrast, a relatively stable pattern has been observed in the Stage 1 Disneyland, which opened for business after 10 year reclamation and building constructions. In particular, a deformation evolution of time series over this area obtained through TerraSAR-X observations illustrates in Figure 2. The validation of the result is ongoing and will be carried out with the geodetic measurements in near future.

The TerraSAR-X SAR system provides high spatial resolution and geometric accuracy imagery which supports well the mapping of the 3-D structure of the civil infrastructures and its deformations. Our preliminary results have demonstrated the applicability and potential of TerraSAR-X data for the detection of quick land subsidence induced by large-scale reclamation constructions in Hong Kong Disneyland. The applicability and capacity of TerraSAR-X interferometry benefits from the high spatial resolution, the shorter repeat cycle of eleven days and the high sensitivity regarding displacement as the result of the shorter radar wavelength.

References

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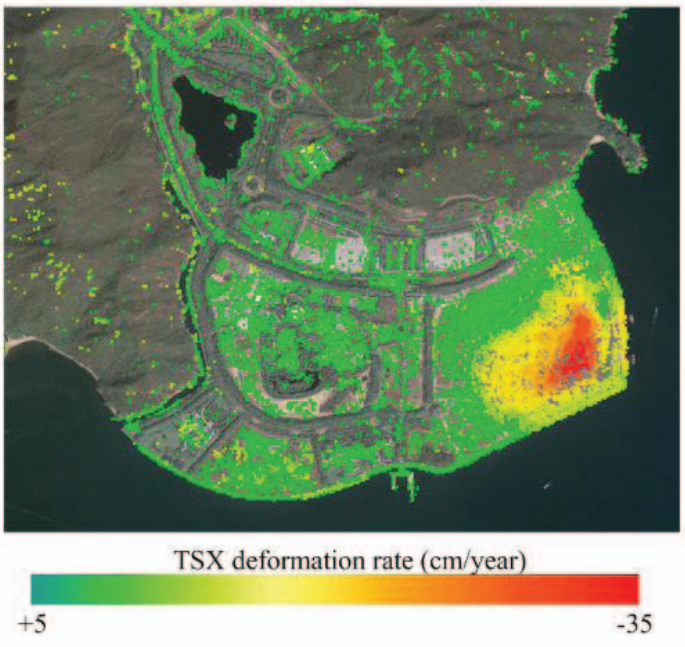
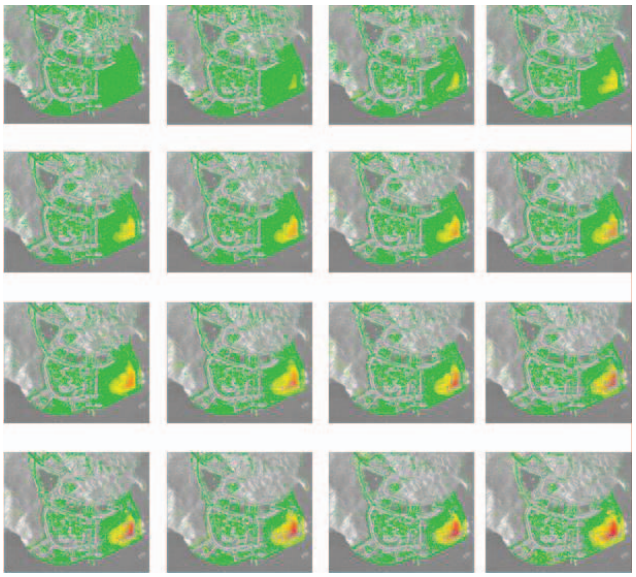


(a)



(b)

Figure 1 (a) Average deformation velocity of this study area obtained TerraSAR Inteferometry (b) Time series deformation evolution over this area obtained through TerraSAR-X observations.