Recent spatial pattern of land subsidence in Shanghai retrieved by Sentinel-1A MT-InSAR analysis

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Abstract

Due to large-scale infrastructure construction and land reclamation, the problem of land subsidence in coastal cities is becoming more and more serious, which will have a major impact on urban public safety. In order to detect land subsidence, many coastal cities have established leveling networks and GPS networks, but due to cost constraints, the resolution is relatively insufficient. In recent years, InSAR technology has been widely used to monitor urban land subsidence due to its low cost and high precision. In this paper, by exploiting a set of 33 SAR images acquired by the Sentinel-1A from July 2015 to August 2017, coherent point targets as long as land subsidence velocity maps and time series are identified by using the Small Baseline Subset (SBAS) algorithm in Shanghai. And by focusing on the land subsidence trend in high-rise buildings in urban areas and coastal areas, we found that the settlement in the coastal area is still significant, and the high-rise buildings in the area along the Huangpu River also have a settlement of up to 2 cm/y.

Keywords:land subsidence; high-rise buildings; subway; Small Baseline Subset; Shanghai

1. Introduction

Nowadays, according to the World Urbanization Prospects updated by United Nations Department of Economic and Social Affairs in 2016, about 10% of the world population (about 634 million) live in coastal zones below 10m elevation. There are 37 mega-cities in the world with more than ten million people, of which 25 are located in the coastal zones, such as 37.9 million people in Tokyo, 31.7 million people in Jakarta and 23.4 million people in Shanghai. However, coastal zones are highly threatened by land subsidence. Shanghai is one of biggest cities in coastal zones in China, where land subsidence is potential hazard. In this paper, we study the recent spatial pattern of land subsidence in Shanghai retrieved by Sentinel-1A MT-InSAR analysis and proposed some useful tips for the Urban Construction Management.

2. Data and Methodology

2.1 Study area

Shanghai is located at the Yangtze River estuary, surrounded by East China Sea, Hangzhou Bay, Jiangsu and Zhejiang provinces. The biggest city in China is an important center of economy, transportation, science and technology, industry and finance and trade. About 133 km2 of the region in Shanghai is land reclamation area, the largest reclamation project in the world.

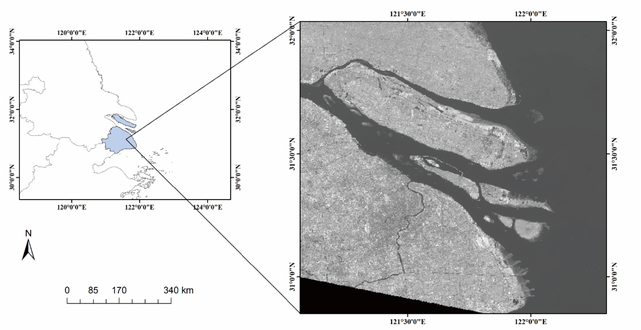

Figure1.Map of study area in Shanghai. The right image is band 6 of Landsat 8, the projected coordinate system is WGS84 UTM 51N.

2.2 SAR and TM data

In this paper, we used two sets of satellite images. The first data set is composed of 33 SAR images acquired by the Sentinel-1A from July 2015 to August 2017 (ascending passes, VV polarization, with a side-looking angle of about 39˚and a satellite heading angle of about 348˚). The second data set is Landsat optical satellite data which were collected every five years in winter with the resolution of 30 m from 1990 to 2018.

2.3 InSAR Time Series

The Small Baseline Subsets (SBAS) is used to obtain land subsidence data in the study area. SBAS relies on a Least Squares algorithm (LS). The LS is a algorithm of inverting the time series of surface deformation using multiple interferometric SAR images. This algorithm can overcome the problem of incoherence and atmospheric disturbance.

3. High-precision land subsidence retrieved with SBAS

In this paper, the line-of-sight deformation rate and cumulative deformation are obtained from 2015 to 2017 in Shanghai with the SBAS method. Sentinel-1A data were processed by the SBAS toolbox implemented within the commercial ENVI's SARScape modules from EXELIS VIS Information Solutions with the coherence threshold of 0.35 and the maximum temporal baseline set to 180 days. After data processing, the vertical deformation rates of Shanghai are acquired. The result in Figure2 shows that most land subsidence in Shanghai occurred near the coast area, especially in land reclamation Areas. In the central city, subsidence areas are densely located along subway lines and the settlement in the coastal area is still significant, and the high-rise buildings in the area along the Huangpu River also have a subsidence of up to 2 cm/y.

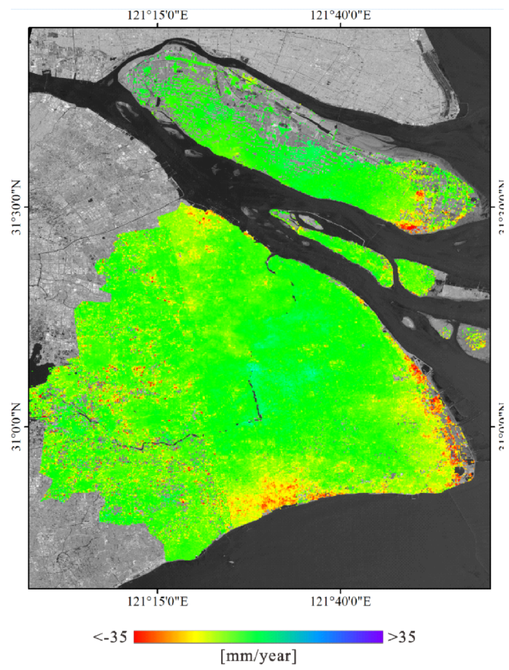

Figure2.Map of annual ground deformation velocity in Shanghai.

4. Reclamation Area Analysis

Based on the ground deformation velocity result acquired in the section 3, we performed a time series analysis of the four sampling points in the reclamation area. It can be seen that the reclamation area still shows a clear trend of settlement in general, and the settlement area is mainly concentrated in the north coastal area and the coastal embankment of Nanhui East Shoal.

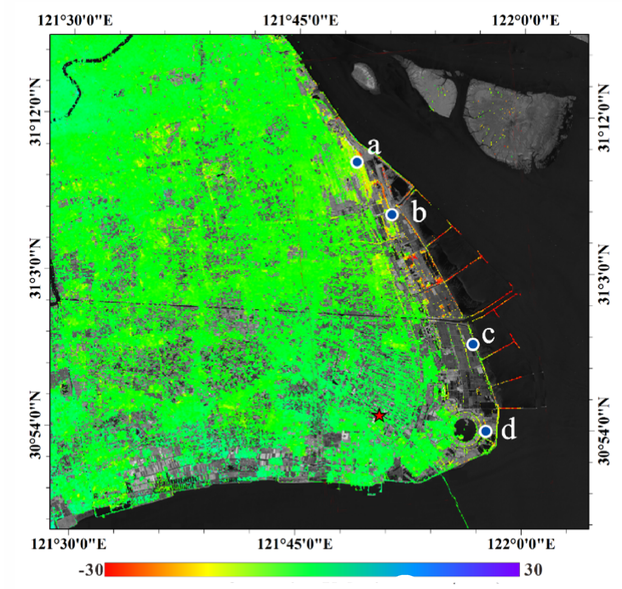

Figure3.Reclamation Area Ground Deformation Velocity(mm/year)

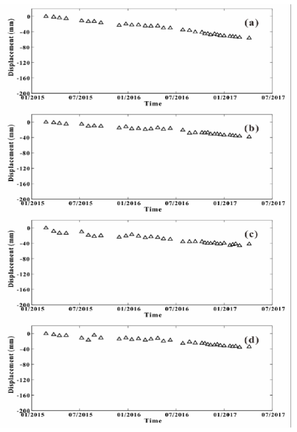

Figure4.Time Series Of Selected Points

5. Central City Analysis

Since frequent human activities and dense covered high-rise buildings in the urban center ,land subsidence is becoming an important factor that threatens public safety. We have studied the deformation trend of the downtown area in Shanghai based on the data obtained in the section 3, the results demonstrate that urban center area in Shanghai is relatively stable in the recent years with respect to the new reclamation area.

With the overlay analysis of Shanghai rail transit route map and Annual mean deformation rate map, we found that most of subsidence areas are located along the urban metro lines, and it is particularly obvious in the areas where multiple metro lines meet. As shown in figure5, obvious settlement funnels occurred in the intersection area of the Line 1, 3, 10, and 11 at the southwest corner of the map and the north part of Line 3 and 10. And the maximum deformation rate reaches 20mm/y.

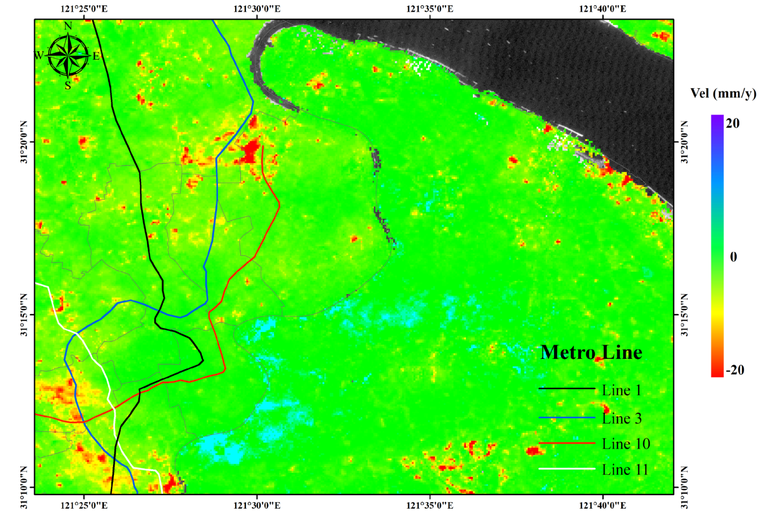

Figure5.Annual ground deformation velocity map of Central city.

6. Discussion and conclusion

1) While Shanghai is very vulnerable to storm surges and urban flooding, the seawall and flood-control dyke are important flood prevention facilities. However, most of these facilities are located in the new reclamation areas along the coast where settlement is significant, which will have a major damage to the flood prevention facilities. Therefore, it is necessary to reinforce and overhaul the areas with obvious settlement.

2) Affected by underground construction projects such as the construction of subways, some obvious settlement areas have also emerged in central city of Shanghai, especially in the areas where underground engineering meets. In the future underground engineering planning, these factors should be taken into consideration to prevent the impact of land subsidence on the public safety of the city.