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Monitoring land subsidence in the southern part of the lower Liaohe plain, China with a multi-track PS-InSAR technique

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ABSTRACT

The lower Liaohe plain is one of the most important industrial zones in Liaoning Province, China, and activities here include oil and gas exploration, aquaculture and salt production. Heavy land use may have contributed to the different magnitudes of land deformation in this region, and this has been detrimental to the environment and economic construction projects in this zone. In this paper, we employ the permanent scatterer interferometry (PSI) technique with L-band ALOS/PALSAR imagery data to monitor the annual land subsidence and produce accumulative time-series maps for the years of 2007 to 2011. The unwrapped grid size was tested in order to recover the maximum deformation. InSAR results from two adjacent tracks were merged by considering the offset over the overlapped area. A PS standard deviation of 0.91 cm/year was achieved in the vertical direction, according to calculation from two independent PS results. Three kinds of land subsidence were analyzed quantitatively over the oil fields, coastal zones, and salt production areas. Some severe land subsidence regions were verified by field investigations.

1. Introduction

The lower Liaohe plain is 23,470 km^2 in size and is located in the middle of Liaoning Province, China. This region is one of the most important industrial zones in northeast China for activities such as oil and gas exploration, aquaculture, and salt production. While the abundant resources have contributed greatly to the local economy, uncontrolled resource exploitation has caused severe environmental problems such as land subsidence and increases in aridity. Field survey results showed that maximum land subsidence occurred in the Dongguo Marsh Field (Fig. 1) of Panshan country and the extent of subsidence was more than 2.5 m; consequently, a pumping station had to be abandoned and serious impacts on marsh plants and aquaculture facilities have also occurred. Government reports estimate the associated industrial facility loss amount at 136.68 million RMB yuan, the marsh production loss amount at 22.4 million RMB yuan, and the aquaculture loss amount at 21.14 million RMB yuan (Shenyang Institute of Geology and Mineral Resources, 2009). Moreover, the wetland nature reserve is becoming more degraded year by year, and this has seriously affected the habitat and reproduction of precious wildlife.

However, up until now, there has been no large-scale high-precision monitoring work conducted in this area; only some local leveling measurements have been taken. Unfortunately, the present leveling data set is not very reliable because of too few historical measurements and incomplete records. In order to investigate the scope, magnitude, distribution, and temporal change of land subsidence in lower Liaohe plain and the possible causes, synthetic aperture radar interferometry (InSAR) would be ideal technology to employ. This technology represents one of the most advanced topography analysis methods, and it has been used successfully in monitoring studies of land subsidence in a number of cities (Zhao et al., 2009, 2011, 2013a, 2013b; Zhu et al., 2013; Zhang et al., 2014; Zhao et al., 2014; Carnec and Fabriol, 1999; Fielding et al., 1998). To overcome of the limitations of using InSAR in areas of heavy vegetation, the permanent scatterers (PS) InSAR technique (Ferretti et al., 2001) was employed here. Specifically, this research obtained deformation data for the lower Liaohe plain by using the archived Advanced Observing Satellite Phased Array type L-band SAR (ALOS/PALSAR) data. StaMPS (Hooper et al., 2013) parameters such as the unwrap_grid_size were analyzed in order to obtain large gradient deformation information, and the PS results from two adjacent tracks were merged into a large coverage deformation map. Then, the land subsidence results were analyzed to determine their different causes. Section 2 presents an overview of the study area. Section 3 presents the methodology involved. Section 4 and Section 5 present the results

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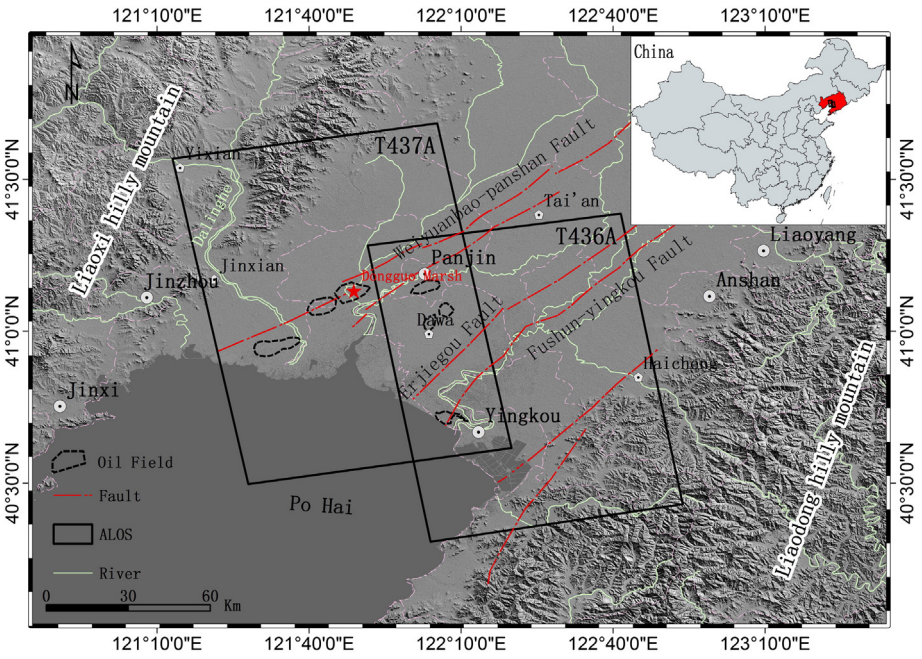

Fig. 1. Location map of the southern part of the lower Liaohe plain, which is superimposed on a shaded relief map of Liaohe. The study area is mainly located in the plain area. Irregular polygons represent the distribution of oil fields in the research region, the red and green lines represent the faults and rivers, respectively, and black rectangles demarcate the coverage of the two adjacent ALOS/PALSAR ascending tracks numbered 436 and 437. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

and land subsidence analysis work, respectively, and concluding remarks are given in Section 6.

2. Study area

Fig. 1 shows the location of the southern part of the lower Liaohe plain administrative district, which includes Liaoyang, Anshan, Yingkou, Panjin, and Jinzhou municipalities. The total area of this region is about 12,620 km^2, and it is approximately 118 km along W-E direction and 107 km along N-S direction. The mountainous regions of Liaodong and Liaoxi are located to the east and west of this plain, respectively. The plain elevation ranges from 10 m to 50 m. Weiyuanbao-Panshan, Liaozhong-Dawa, Erjiegou, and Fushun-Yingkou faults cut through this plain in northeast-east directions. The Liaohe, Raoyang, Dalinghe, and

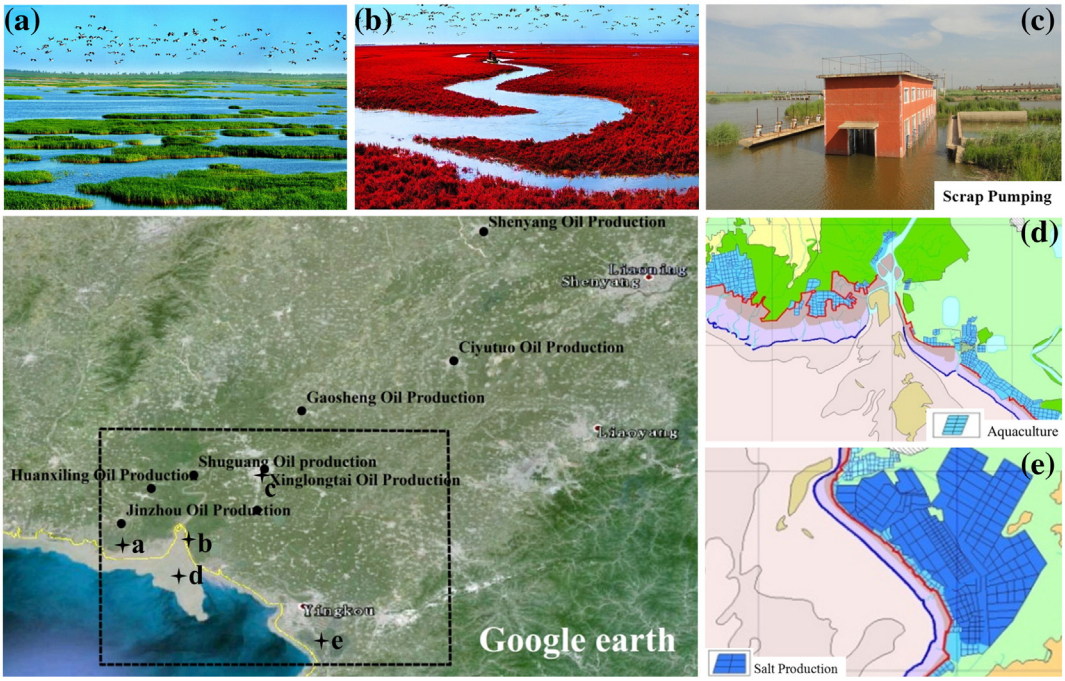

Fig. 2. The lower left panel Google Earth image shows the distribution of oil production bases in the lower Liaohe plain. The study region is demarcated by the black rectangle. (a) Marshes; (b) "Red Beach"which is a wetland nature reserve. The picture of (b) is a natural-color image, and it is a natural phenomenon for the marsh to turn from green to red in autumn; (c) abandoned pumping station in the Dongguo Marsh Field, Panjin; (d) and (e) are Landsat ETM+ images that represent the aquaculture field and the salt production zone, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)