Land Surface Deformation in Northern Taiwan Determined by Radar Interferometry

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Abstract

Taiwan is located at the convergent zone between Eurasia plate and Philippine Sea plate. Because the convergence between these two plates is still active, land surface deformation in Taiwan is very rapid; this island is threatened with geological hazards. Besides, the northern Taiwan is highly populated, and this population is mainly concentrated in some metropolitan areas. The natural hazard mitigation, especially in and around the metropolitan areas, is thus an urgent and important issue for habitants on this island. This research applies the Differential Interferometry Synthetic Aperture Radar technique to observe the land surface deformations in some potential hazard areas in northern Taiwan, including Taipei, Taoyuan and Ilan cities. The SAR images used in this study are all acquired by ENVISAT satellite, which is launched by the European Space Agency in 2002. Our interferometric results reveal that the surface deformation in the urban areas are much clear than that in mountainous and rural areas. In some areas juxtaposed against the fault zones some clear deformations are also clearly observed. Application of Radar Interferometry can efficiently observe the land surface deformation, and further imply to interpret and predict the underground tectonics and potential natural hazard.

Introduction

The Taiwan Island is young, as revealed by its dense seismic activities and rapid surface deformation. The habitation of this island is thus threatened with highly geological hazards. For example, the Chi-Chi earthquake occurred at September 21, 1999, and its unanticipated effects on population and infrastructure frightened all people who live in Taiwan island. The northern Taiwan is highly populated, and this population is mainly concentrated in some metropolitan areas. If there is a destructive earthquake happened in these areas, it must be certainly causing huge damages to northern Taiwan society. To realize the surface deformation pattern in these metropolitan areas will help us to proceed the mitigation of geological hazard.

Geological background

The northern Taiwan is highly populated, and this population is mainly concentrated in some metropolitan areas, involving Taipei, Taoyuan and Ilan cities. Besides, the northern region of Taiwan is situated at the position where Philippine Sea

plate subducts downward to the western margin of Eurasia plate. Therefore, the northern Taiwan is affected by Ryukyu subduction zone. In Taipei area, the Taipei basin is based by the Tertiary basement, a tectonic basin, and it is filled with the Quaternary sediments, and the Pleistocene igneous rock (Andesite). It is bounded by Shanjiao normal fault and Linkou tableland on the west, and the Tatun volcano groups on the north. Taoyuan area was composed with Pleistocene gravels, sand and mud, and belonged to the front of western foothill belt. In addition, there are many anticlines and reverse faults developing here. The Taoyuan Tableland is formed two sets uplift horst displacement model due to the effect of compressive stress toward northwest (Teng et al., 2003) and the average altitude is about 200 m to 300 m. In Ilan area, the Lanyang Plain is the westernmost extension of the Okinawa Trough, which is opening as a back-arc basin, and there are active fault zones on both the southern and northwestern flanks of this plain. As the foregoing conditions, there are many structures controlling the surface deformation in these metropolitan areas. For this reason, monitoring these potential hazard regions is thus an urgent and important work.

Methology and data used

In this research, we applied the DInSAR (Differential Interferometry Synthetic Aperture Radar) technique with the two-pass approach cooperating the DIAPASON and SNAPHU software in this research. In case that, a spatial displacement occurred between two different SAR images acquired at different time, we can calculate the displacement amount by using the interferometric technique from radar. The images used are all acquired by ENVISAT Satellite, developed by European Space Agency (ESA) and carried the C-band ($\lambda \approx 5.6$) SAR instruments to observe the surface of earth. It works at the altitude around 785 km with repeat orbit of 35 days. For the ENVISAT C-band radar, therefore, each cycle of fringes in the interferogram corresponds to above 2.8 cm of displacement in the direction of radar line of sight. In order to remove the topographic effects from the interferograms, we used the Shuttle Radar Topography Mission (SRTM) global digital elevation model (DEM) in this study.

ENVISAT ASAR images are acquired from 2003 to 2006 in northern Taiwan area. We chose the shorter baseline difference pairs for our surface deformation research. In order to take the curvature of earth and the topographic phases away, we used the SRTM DEM and the precise orbit data from the Delft University, Netherland. Therefore, we can correct the inaccuracy of interferometric signals causing by orbital uncertainty and topography and promote the qualities of result. According to the baseline difference smaller than 300 m, there are nine SAR images we selected in this

research and all of them come from ENVISAT descending orbit (track: 461, frame: 3105). We plan to observe the long-term surface changes continuously in past three years and try to deduce the relation of deformation pattern in northern Taiwan. Therefore, We made the interferometric processes by twelve image pairs chose as Figure 3. By the way, the dense vegetation and the precipitous topography will bring about the poor coherence of image pairs, further diminishing the qualities of interferometric patterns. In Taiwan, many cases using D-InSAR technique are made of demonstrating the surface deformation in the urban areas successfully. The qualities of interferometric phases in the urban areas are more distinct than the qualities in the rural areas. This study focuses on the metropolitan areas, Taipei, Taoyuan and Ilan. Investigating these areas not only promotes the qualities of interferometric phases but also achieves the goal mitigating the geological hazards in the metropolitan areas.

Preliminary results & discussion

Twelve interferograms have been carried on applying the Diapason and SNAPHU software. These interferograms revealed the surface information of the northern Taiwan from November 22, 2003 to October 7, 2006. In the longest time interval interferogram, we can observe the long-term accumulative displacement. The displacement amount in Taipei Basin is mainly increasing from east to west; moreover, we found out two distinct fringes adjacent to the Shanjiao normal fault. In general, the deformation amount approximately increases form east portion of Taipei Basin to the west portion. In the central of the basin, there are a few fragmentary fringes of interferogram. In Taoyuan area, we discovered that the displacement rate is slightly smaller than in Taipei area, and the phase signals here is quite complicated. There is clearly a deformed center at the Pader area, and we also noticed the variation in Hukou area. In Ilan area, two distinct deformed centers emerged from both northern and southern portions of the Lanyang Plain.

The surface deformation caused by human activity is generally very local and unsteady (Chang et al., 2004), and the tectonic motion usually brings about quite regional deformation. Therefore, we inferred that there are human activities causing local surface deformation in the central Taipei Basin (in Taipei), the Pader area (in Taoyuan) and the Lanyang Plain (in Ilan). In addition, the large-scale fringes in Taipei and Taoyuan are inferred that they were causing by some active structures, like faults and folds. In the future, we will keep on doing the research focusing on these particular surface deformation areas, in order to interpret the occurred events in these areas. Furthermore, we will compare our results with other geodetic techniques to demonstrate them, so that we can suggest doing the precaution against the potential

geological hazard supported by our research.

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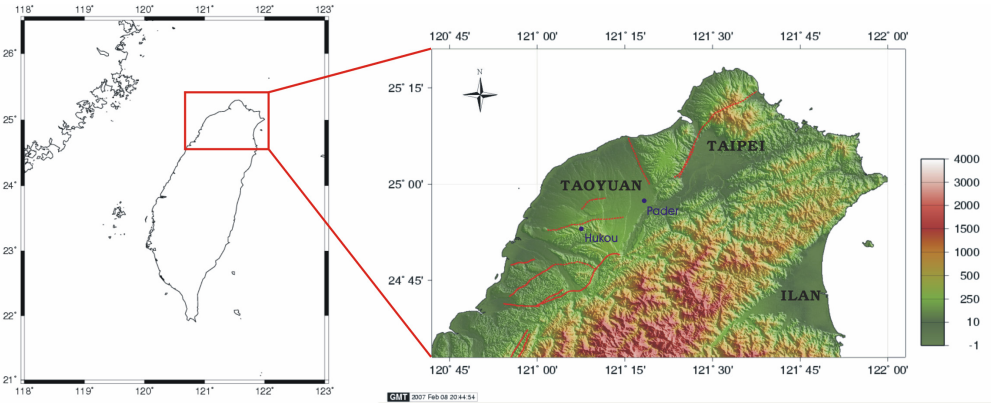

Figure 1. The digital elevation model (DEM) of the northern Taiwan, including the three metropolitan areas, Taipei, Taoyuan and Ilan.

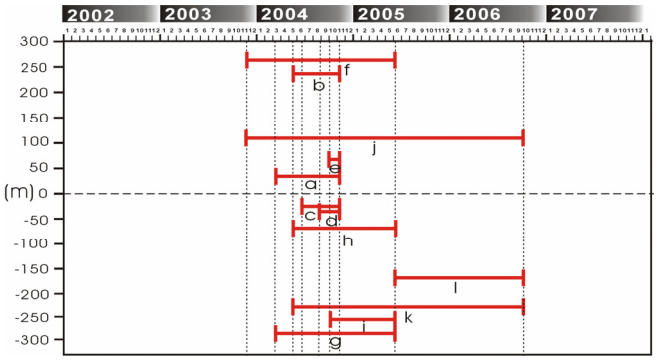

Figure 3. The interferometric image pairs selected from 2003 to 2006 in this study. Vertical axle shows the perpendicular baseline difference of each image pairs.