ESASGD 2016

ISBN: 978-604-76-1171-3

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INTERNATIONAL CONFERENCES ON EARTH SCIENCES
AND SUSTAINABLE GEO-RESOURCES DEVELOPMENT

Hanoi University of Mining and Geology

Proceedings of the ESASGD 2016

Hanoi, November 12-15, 2016

Session: Geoinformatics for Natural Resources, Hazards and Sustainability (GIS IDEAS 2016)

ISBN:978-604-76-1171-3

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ESASGD 2016

GIS-IDEAS 2016

International Conference on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS)

Application of the InSAR technology for determining changes in surface topography

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Abstract

In recent years, the Synthetic Aperture Radar Interferometry (InSAR) is widely applied and it provides reliable results for determining Digital Elevation Model, and vertical and horizontal land deformation. All these applications are based on the analysis of the phase difference between two pairs of Radar interferometry. To determine the surface deformation, we can use 2 or 3 images to form two pairs of interference, one is used to determine topographic phase, while the other for determining phase containing topography and topography deformation. Topography deformation will be determined by removing the topographic phase in the pair containing deformation. This paper introduces InSAR technique in determining surface subsidence and experimental result in Hanoi city with TeraSAR- X images has identified areas of North Thang Long Industrial subsidence (-41mm/ year) during the period 2012 to 2013.
Keywords: INSA, Radar interferometry, surface subsidence

1. Introduction

In the past years, the determination of the topographical surface changes is measured by leveling and calculating the height valueswith some monitoring period. Such monitoring is only applied for local works without determining the changes in large areas. In recent years, Synthetic Aperture Radar (SAR) is developed with the advantages of allowing the collection of high -resolution images and from three images collected from SAR techniques , we can identify the changes of topographical surfaces based on the use of phase information of the signal of Radar .

By analyzing the height of the topography we can determine that the baseline is the distance between two times recording images and that the interference of the two images can be used to calculate the height of the terrain . In other cases such defined land surface deformation may use 2 or 3 images to form two pairs of interference , including a pair for determining interference topography while the another pair for determining interferogram containing topography and topography deformation. Topography deformation will be determined by removing the interference pattern topography or minimized to the extent not substantially interfering in the pair contains deformation.

In the world, there are many scientific research projects about Radar data applications to the issues of digital elevation model DEM and topography deformation. In Vietnam, there have been some studies such as: "Applied research methods in monitoring INSAR differential land subsidence due to groundwater exploitation " of the Institute of Geography in 2008-2009 ; "Science-based research and suggesting forecasting solutions to land

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subsidence in Hanoi by interferometry radar techniques " , code : DTDL.2012 - T/28 of the Institute of Geology - Academy of Vietnam science ...

2. InSAR

InSAR is a signal processing technique that combine two images recorded at two different time at the same region to form interference phase. These interference phases include topographical phase, reference phase and fluctuation phase. So to identify the topographic change, we need to find the ways to separate the fluctuation phase. There are several methods to separate the fluctuation phase (also known as terrain shifting phase) such as the Two-pass, Three or Four-pass method. Two-pass method uses 1 DEM and 1 pair of image interference (the time before and the time after fluctuations), Three-pass method is a method using 3 images at three different periods,that two images are used to create a pair of interference for the DEM. Four-pass method uses 4 photos at 4 different times. In the experiments we used differential InSAR Three-pass method.

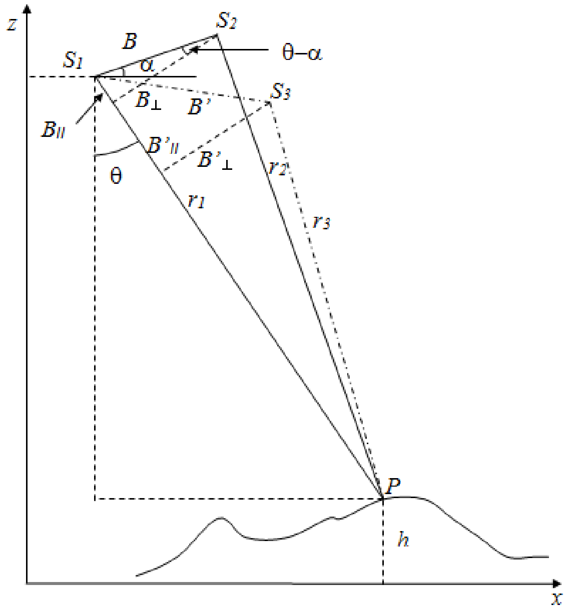

Fig. 1. The differential Three-pass InSAR methods

Three -pass method was first introduced by Zebker and his partners (1994). In figure 1 S1 , S2 , S3 are the three points of time collecting images of radar satellite. From these 3 images we can create 2 pairs of interferometer . Supposing that there is only one pair of interferometer affected by terrain shifting, for example, the ϕ1-2 phase is the interference phase containing only terrain factors and the ϕ1-3 phase contains the change of terrain.

Phase terrain can be collected by subtracting two interference phases which are created from 3 images from 3 different times.

$$\phi_{1-2} = -\frac{4\pi}{\lambda} B\sin(\theta-\alpha) = -\frac{4\pi}{\lambda} B_{II} \qquad (1)$$

$$\phi_{1-3} = -\frac{4\pi}{\lambda} B'\sin(\theta-\alpha') + \frac{4\pi}{\lambda}\Delta r = -\frac{4\pi}{\lambda}(B'_{II} - \Delta r) \qquad (2)$$

Where:

$\phi_{1-2} = \Phi_1 - \Phi_2$ Terrain phase

$\phi_{1-3} = \Phi_1 - \Phi_3$ denotes changing phase (Phase between two times, includding terrain phase and change phase)

α is the inclination of baseline *B* Terr

α′ is the inclination of baseline *B′*

B_{II} is the component of B parallel to look direction

B'_{II} is the component of B' parallel to the look direction.
Δr is a component of displacement parallel to the radar line.
If $\Delta\phi$ is the change phase of topography, we will have:

$$\Delta\phi = \phi_{1-3} - \left(\frac{B'_{II}}{B_{II}}\right)\phi_{1-2} \tag{3}$$

Then we have the relation between the change phase $\Delta\phi$ and the change of distance Δr as follows:

$$\Delta r = \frac{\lambda}{4\pi}\Delta\phi = \left(\frac{\lambda}{2}\right)\left(\frac{\Delta\phi}{2\pi}\right) \tag{4}$$

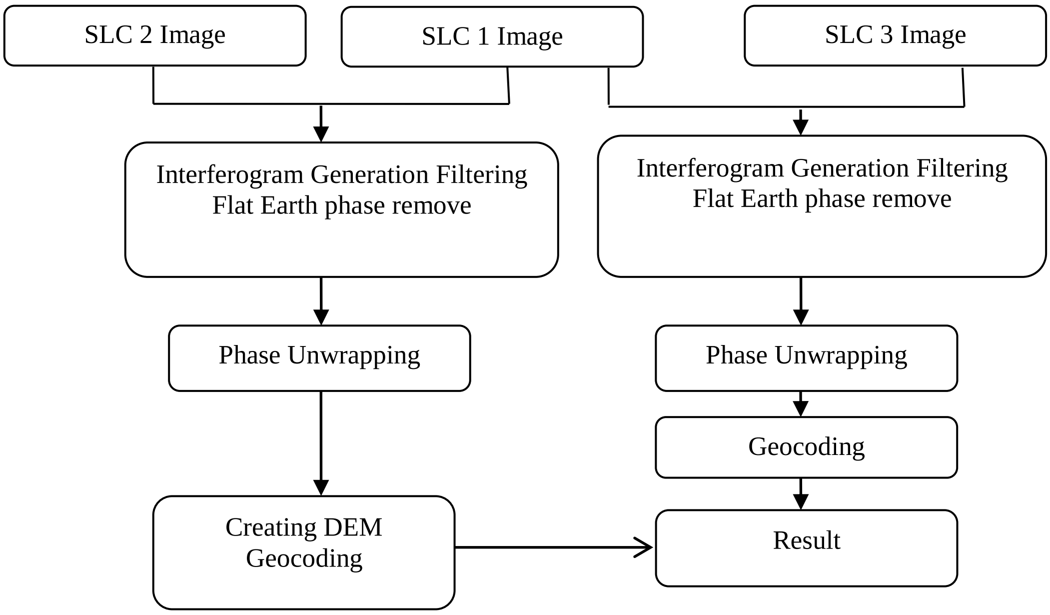

Fig. 2. Diagram of the technical process to determine the changes in topography

The combination of two SAR images can form SAR interferometry to provide information about the third dimension (height) of an object and to measure the movement of an object in different times.

Phase flattening is the step for removing the flat phase(the phase of ellipsoid) and noise filtering is the requirement for easier phase unwrapping.

Phase Unwrapping: As the height of the terrain increases, the phase also increases steadily. Since phase values are periodic functions of 2π, they automatically get wrapped after reaching 2π, which is not a desirable situation. Phase unwrapping is a technique that permits retrieving the unwrapped phase from the wrapped phase, which for the InSAR, is a necessary step for the generation of DEM.

3. Experimental results

3.1. About the scope of the study

Located slightly to the northwest of the center of the Red River delta, Hanoi is between 20° 53' to 21° 23' north latitude and 105° 44 ' to 106° 02' east longitude, bordered by the provinces of Thai Nguyen, Vinh Phuc to the north; Ha Nam, Hoa Binh to the south, Bac Giang, Bac Ninh and Hung Yen provinces to the east; Hoa Binh and Phu Tho to the west.

3.2. Result

Three images are acquired on 10/04/2012, 26/06/2012 and 04/30/2013 from German satellite TeraSAR- X (2007) were selected for processing by SARscape 4.3 software.

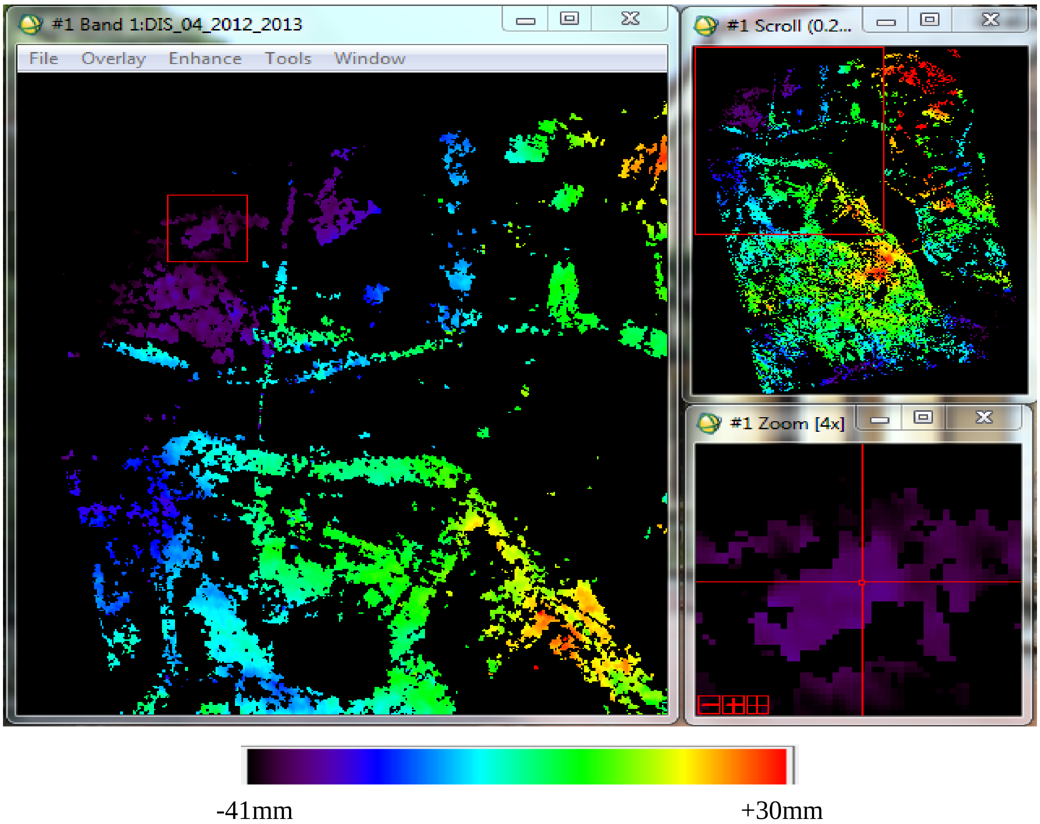

Fig. 3. The result of subsidence detection from three images of Terra SAR X

Some areas are black and no value because of the lost coherence between images, some well-correlated areas show that the experimental results of Hanoi indicate the minor change in the surface eg subsidence (-41mm / year) of the North Thang Long Industrial zone (Fig 4) in the period of 2012 to 2013.

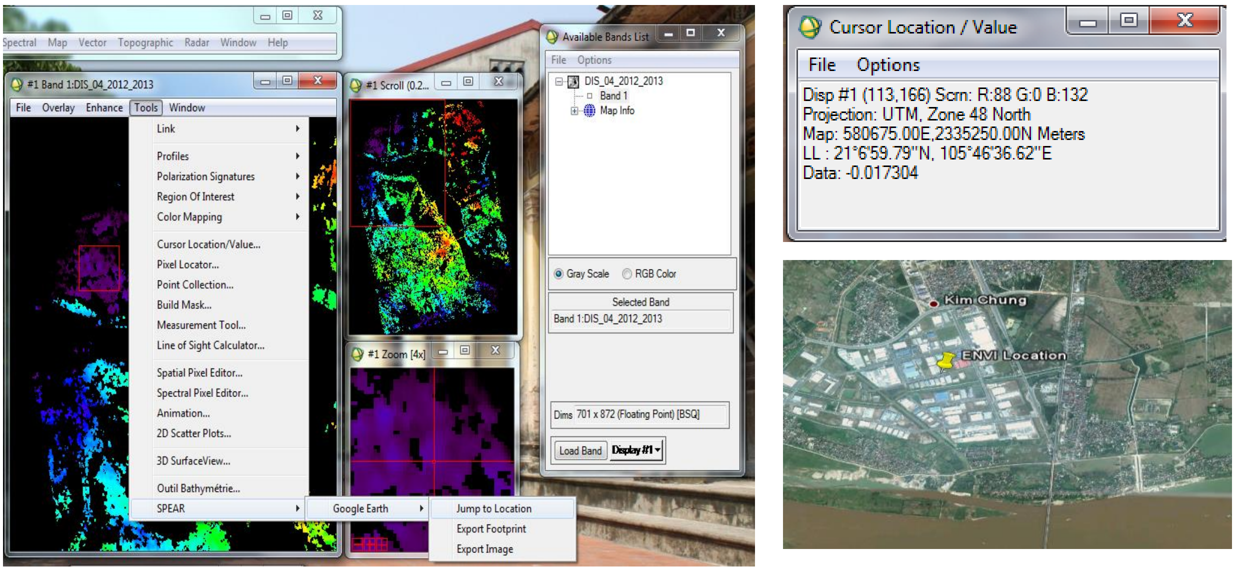

Fig. 4. Export changes in the terrain surface to Google Earth

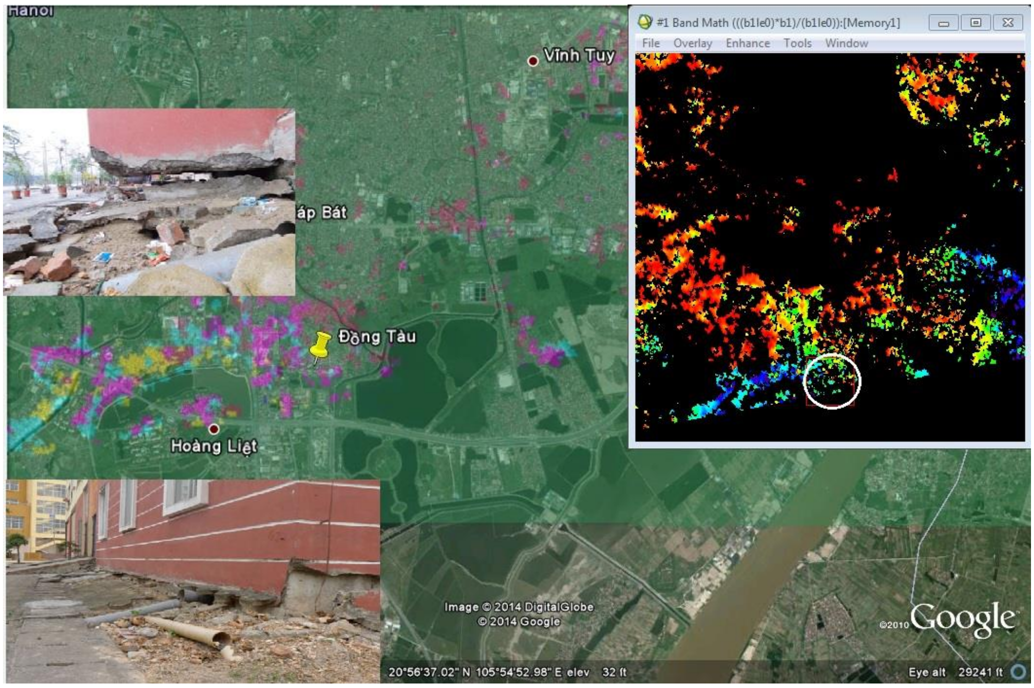

Fig. 5. Dong Tau subsidence 14mm in 2012-2013

In our experimental works, we compared our results to the result of Hanoi subsidence in the period of 2007-2011 of our colleague Vu Khac Dang. We found that the location of subsidence of Hanoi region in 2012- 2013 is relatively similar to the prediction that Dang Vu Khac has given out in his research.

The previous research in this area mainly used satellite images from JERS-1(Tran. V. A et al, 2007) and ENVISAT showed the advantages of InSAR in identifying the terrain surface deformation. The experimental results proved the use of X band to determine the terrain surface deformation.

X band with the wavelength from 2.4 - 3.8 cm in InSAR can show the detail of the terrain more accurately than those from the long-wavelength because they can be easily lost the correlation between the images. Thus it is necessary to select the relatively identical images on the conditions (atmospheric, time, ...)

4. Conclusion

InSAR has brought about the important possibilities for determining changes in surface topography. Preliminary results obtained after being processed shows the possibility of using X band. However, the success of the technique depends on various factors such as SAR sensor, baseline, correlation, interpretation open phase problem... The paper points out result in the minor change of Hanoi terrain surface, eg subsidence (-41mm / year) of the Bac Thang Long industrial park area in the period of 2012 to 2013, the results are expected to contribute to the management bodies and social organizations.

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