POTENTIALS OF HIGH RESOLUTION TERRASAR-X IMAGES IN INSAR PROCESSING FOR EARTH DEFORMATION AND ENVIRONMENTAL STUDIES

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Abstract

Accurate determination of topography and surface deformation became one of the crucial tasks in Earth and environmental sciences. InSAR technology based on radar images which can be acquired during both day and night and in all weather conditions, is a very powerful tool for land movement detection and hazard monitoring. Although radar images from satellites available up to now were used in many researches, their resolution (app.20m) was not sufficient for small, local phenomenon monitoring. The new high resolution radar TerraSAR-X can overcome this restriction. This article shows potentials of TerraSAR-X radar images used in InSAR processing in comparison with lower resolution products used for researches concerning land deformation (i.e. earthquakes). Moreover, the utility of high resolution radar images for environmental science is studied. Finally the planned research on soil erosion using InSAR technology is presented.

Keywords

InSAR, TerraSAR-X, land deformation, soil erosion

1 INTRODUCTION

TerraSAR-X is the first public-private satellite with SAR (synthetic aperture radar) instrument onboard which allows to gain the resolution of around 1m for recorded satellite images. The satellite was launched on 15th of June 2007 and since that time it has been delivering images of very significant importance for scientific community observing the Earth surface. This is the first civil satellite which achieved the resolution which is standard resolution for optical remote sensing instruments for almost 10 years. The radar is operating on the X-band (2.8-3.4 cm wavelength) which implies bigger decorrelation between two SAR acquisitions used for InSAR, because of shorter wavelengths are backscattered more easily from smaller particles. This limitation was eliminated due to shorter repeat cycle (11 days) in comparison with other satellites like ENVISAT or ERS-2 (35 days) and enhanced spatial resolution, which is the main advantage of the system[8]. Satellite microwave systems are widely used for InSAR (interferometric aperture radar) applications giving an opportunity to generate deformation maps with a centimeter or millimeter accuracy. TerraSAR-X as an active remote sensing system allows to obtain images during the day and night, in almost all weather conditions. These advantages together with the possibility to obtain images in different polarization modes, with different incidence angles and 11 days repeat cycle are giving many opportunities for Earth scientists investigating different environmental processes. This article presents potentials of TerraSAR-X radar images used in InSAR processing in comparison with lower resolution products of ESA such as images from Envisat and ERS-2 satellites.

2 MAIN OBJECTIVES

TerraSAR-X products are relatively new products that can be useful not only in the discipline of geodesy or geology but other disciplines concerned with environmental studies. The main objective of this study is to present abilities of TerraSAR-X InSAR technology, and its unquestionable importance for Earth surveys such as land deformations caused by earthquakes and land subsidence. Finally the possibilities of usage within the discipline of environmental sciences will be discussed.

3 DATA SELECTION AND FACTORS AFFECTING INSAR RESULTS

TerraSAR-X is giving an opportunity to choose between various modes of image acquisition, each with different spatial resolution, size of the scene and a possibility to choose polarization mode. Product's characteristics are shown in Tab. 1.

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	SpotLight (SL)	HighResoution SL	StripMap (SM)	ScanSAR (SC)
Scene size	10x10km	5x10km	50x30km	150x100km
Azimuth resolution	2m	1.1m	3.3m	16m
Range resolution	1.2m	1.2m	1.2m	1.2m

Tab. 1 *Characteristic of TerraSAR-X products*

Images obtained in each acquisition mode can be purchased with different level of processing. The first product which can be obtained by user in relatively short time and can be used for InSAR processing is SSC (Single Look Slant Range Complex) corresponding Envisat SLC data. Such images are complex images holding the information about both amplitude of the image and its phase. This is "single look" product which contains speckles but within some processing steps these images can be used successfully for interferometric processing. All of the data are distributed with precise orbit information. Data selection, although cumbersome, is the crucial step in InSAR processing in order to obtain reliable results.

InSAR measures relative changes in phase between two image acquisitions over the same area for a specified time span[4]. Accuracy is on the order of fractions of a wavelength which for TerraSAR-X (2.4-3.75cm) can give the measurements of ground movements on the millimeter scale. However, the use of InSAR relies on accounting for any changes in the radar phase over the monitoring interval due to factors other than the change in the slant range distance. In particular, the radar phase will be affected by changes in the reflectivity (and the relative location) of the ground (temporal decorrelation), by changes in the viewing perspective (baseline decorrelation), and by changes in the atmosphere.In the worst cases, these factors will prevent the determination of ground movement from the interferogram phase.

Temporal decorrelation - Changes in the reflection coefficient are generally due to variation in the soil moisture content or the vegetation. Each pixel in a SAR image is formed by the coherent sum of the backscatter from thousands of cells on the scale of the radar wavelength. Since X-band is short wavelength, easily backscattered from small particles, it is dependent on small changes in vegetation. The impact of mentioned factors is limited by 11 days repeat cycle and enhanced spatial resolution (signal scattering is nearly elementary scattering , surface scattering, not volume scattering)[7].

Baseline decorrelation - Variation in the phase occurs with different viewing geometries, since the relative locations of the scattering cells depend on the viewing position. The different viewing geometries are denoted by the satellite baseline, or the difference in orbit position from one satellite pass to the next. Choosing the pair of images for a study user should take into account the topography of area under study, as well as the availability of precise DEM which can be subtracted from interferogram in order to remove the effect of topography. For TerraSAR-X interferometric processing it is not sufficient to use DEM such as DTED level 2. It might be very effective to use more precise DEM for example from laser scanning measurements.

Atmospheric effect – microwaves are less dependent of weather conditions than optical waves, nevertheless atmospheric effects should be also taken into account while choosing data for a specific study. Alternatively, the variation due to atmospheric effects can be isolated from multiple interferograms using PSInSAR methods.

Depending on the area of study, concerning the topography, soil moisture and surface roughness[2] user should also make decision on polarization mode and incidence angle (in order to prevent layover, shadowing or foreshortening for very steep slopes).

Although TerraSAR-X images with its potential seem to have less restrictions for image selection, above factors should be taken into account in order to increase the possibility of obtaining detailed and reliable results.

4 EXAMPLES OF DIFFERENTIAL INTERFEROMETRY ON LAND

4.1 Earthquakes

The utility of InSAR technology for earthquakes studies was proved many times with various researches for example Bam earthquake in Iran 2003, California earthquake in USA 1999, Izmit earthquake –Turkey 1999, Zarand earthquake –Iran 2005 and finally the latest earthquakes in China,Sichuan in May 2008. These events were usually big quakes with mean magnitude M 7.0. Nevertheless there were several attempts to observe small earthquakes using InSAR technology i.e. Flawnskin earthquake which occurred in USA ,on 4th December 1992.The example shown in the Fig.1 is the resulting interferogram from Bam earthquake (26th December 2003). Interferogram was processed with

DORIS software developed by The Delft Institute of Earth Observation and Space Systems of Delft University of Technology. We can interpret app. 70 cm of horizontal deformation, where the source of deformation is the main rupture localized in the center of the image (city Bam).The accuracy of obtained results was highly dependent on the characteristic of processed images from ASAR Envisat instrument. Interferogram covers the area of approximately 100x100km.The ground resolution is 20 meters in both azimuth and range direction, there are large baselines between two image acquisitions (around 500m), lower signal-to-noise ratio, and quite long temporal baseline (for topographic pair time span was almost 6 months). These obstacles seem to be possible to be restricted for TerraSAR-X satellite. High resolution images from TerraSAR-X can provide more reliable and accurate results in such studies because of some main reasons, such as:

- shorter temporal baseline causing better coherence between image acquisitions
- higher resolution resulting in better coherence which can be a problem especially for highly damaged areas
- more accurate DEM could be produced from two SAR images with 5m horizontal and vertical accuracy[1]. The influence of topography on interferogram could be subtracted
- existence of an acquisition tube for TerraSAR-X leads to a majority of baselines below 300 m and thus a suitability of most of interferograms[3]. More possible interferograms for the area of interest.

Other advantage of TerraSAR-X for such studies is almost immediate availability of data which are in the case of emergency accessible within only a few hours upon reception. Following the recent earthquake in China (12 May, 2008) the system can support rescue teams with valuable geo-information needed for example in case of sudden earthquake.

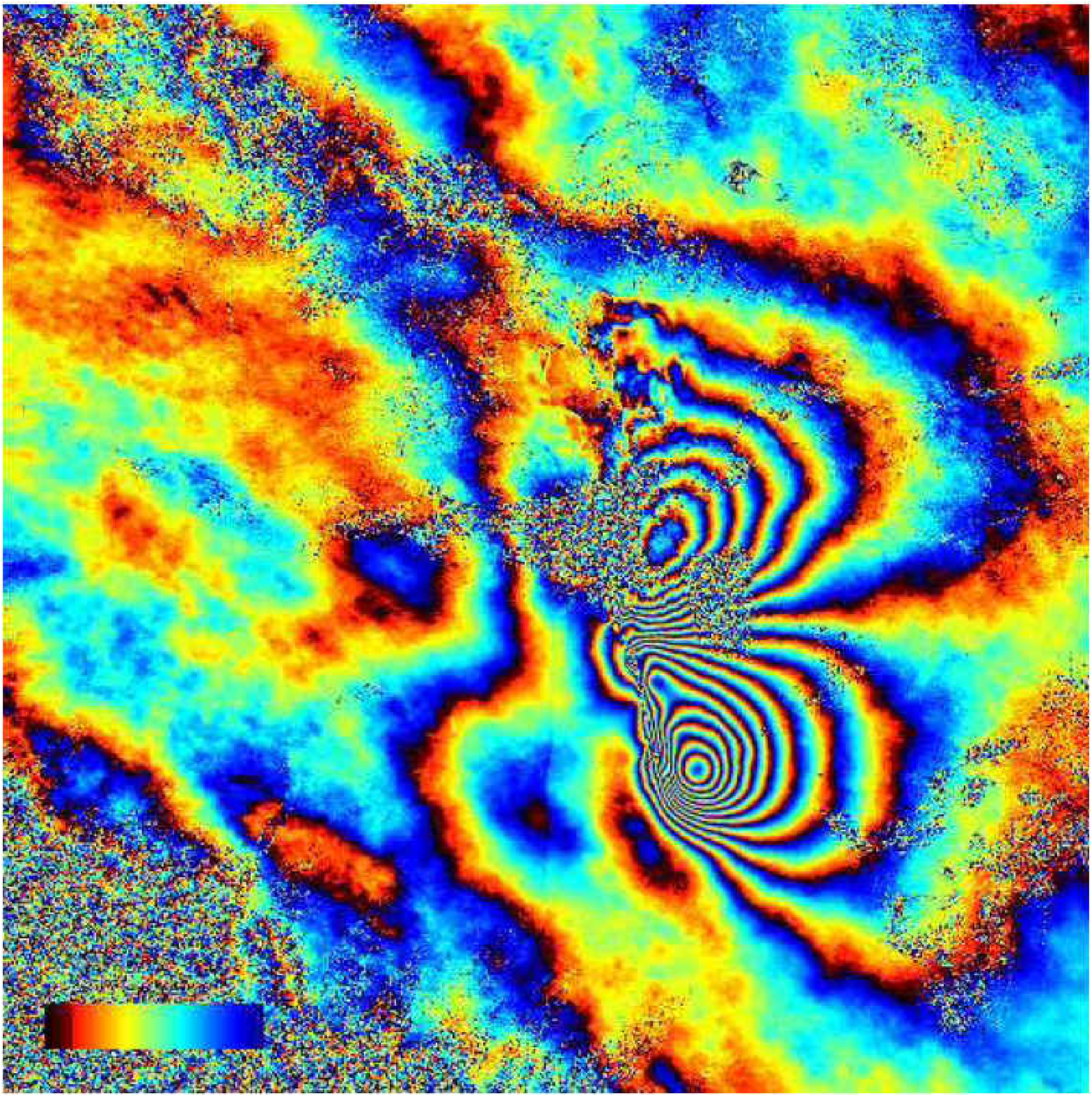

Fig. 1 *Resulting interferogram for Bam earthquake (26th December 2003) processed from two ASAR Envisat images of resolution app. 20m.*

4.2 Land subsidence

The most important restrictions for land subsidence monitoring are location, orientation and geometry of slopes. Up to now satellites' look direction was generally either east or west, for ascending or descending orbits respectively. These SAR systems are, therefore, sensitive to movement along slopes facing either east or west, and almost insensitive to movements in a north or south direction. Moreover for steeper slopes and big incidence angles the SAR image may suffer from layover or shadowing effect.

TerraSAR-X again is facing these problems. Changeable incidence angle from 20-55 degrees and the possibility to acquire images in both right and left direction from the sensor provide more data which can be used for interferometric processing. An additional advantage of employing this system for land subsidence monitoring is that the temporal decorrelation is minimal over the short timeframe between acquisitions which is very significant feature especially for fast and sudden changes on the slope.

4.3 Environmental studies

Remote sensing methods are very often employed in environmental studies. The main advantages of TerraSAR-X in this discipline, similarly with other SAR systems like ERS-2, Envisat, RADARSAT etc. are big spatial coverage, independency on weather conditions, as well as night and day possible acquisitions. For the X-band used by TerraSAR-X the penetration depth in any type of material is lower than for lower frequencies (C/L-band). This feature can be an advantage while considering evaluating land coverage with TerraSAR-X images, flood mapping or identification of burned areas. There are many applications of InSAR in environmental researches, starting with small deformations caused by mining industry[6],as well as wetlands, ice and snow coverage monitoring. One of the limitations for using SAR data in environmental studies was the resolution of images. Up to now SAR images with the resolution of app. 20m couldn't provide accurate results for monitoring small, local phenomenon. Additionally, long temporal baseline for some areas was making the interferometric processing impossible. Moreover, TerraSAR-X data are provided with precise orbit information reducing the effort for baseline estimation, and baseline error itself.

One of the applications of radar interferometry for environmental studies is currently under development in the Institute of Geodesy and Geoinformatics at Wroclaw University of Environmental and Life Sciences. Basically, we are trying to develop a method of soil erosion monitoring and its quantity evaluation for the area of The Trzebnickie Hills located in western Poland. Appearance of loess soils in this region is giving high probability of water erosion which in consequence can cause soil degradation. TerraSAR-X images with resolution of 1m can provide valuable information on local surface changes caused by erosion process. Coherence of images should be secured by one repeat cycle temporal baseline (11 days). Additionally the thickness of loess layer is more than 2-3 m, which is giving a chance for good correlation between image acquisitions (homogenous material should give similar backscatter). The area chosen for this study is located in agricultural region to the south of the town Trzebnica. Images from single track of TerraSAR-X should be sufficient to cover the whole area of interest. Images from Google Earth shown below (Fig.2 and Fig.3) present the area under research. Characteristic "shadows" or "stains" easily recognizable especially at the fields is the effect of soil erosion, particularly loess denudation.

Fig. 2   The area of research is located to the south of Trzebnica

Fig. 3 *Magnification of the area marked in Fig 2. shows typical "stains" proving the occurrence of loess denudation.*

The objective of this study is to support other, currently available methods, for soil erosion monitoring using remote sensing data. The potentials of TerraSAR-X in the application of detecting small changes caused by erosion will be executed. Results will be compared with existing field measurements, additional field surveys will be performed. This study is supposed to provide information on utility of TerraSAR-X for local phenomenon monitoring, especially in the terms of soil erosion.

5 CONCLUSIONS

. This article presents some arguments proving the utility of TerraSAR-X images for both Earth and environmental studies. High accuracy of these images together with other innovations according to older systems (Envisat, ERS, Radarsat, JERS) allows to use TerraSAR-X images in much wider range. Additionally very high geometric quality of images, short time of obtaining data from image providers and high independency on weather conditions make the system useful for environment protection, hazards management and hydrology[5]. Subsequent studies on the potential of TerraSAR-X images for water erosion monitoring should also provide good results in following months.

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