Measuring Land subsidence in Ha Noi city by means of Radar Interfeometry technique

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Key words: Risk management, Land subsidence, Envisat, ERS-1/2, Dinsar, Insar

SUMMARY

In the past 10 years, the speed at which Hanoi has been urbanized is so fast that it has brought some bad influences on the environment. One of such problems is the collapse of the land in some area of the city, resulting from the under-water exploition (according to the research of the Institute of Hanoi Technological architecture, the number of water-exploiting factories has been much increased in the recent years: the 80s: 300.000 m3/day; the 90s: 390.000 m3/day; 2004: 553.400 m3/day). This phenomenon has brought a great danger to the properties and life of many citizens as well as many facilities. As a result, it is high time to investigate the speed and size of the collapse in the process of city scheme and development.

In order to detect the subsidence, although many traditional methods such as precise levelling and GPS techniques can be identified very accurately. In spite of the fact that those results are reflected in some individual points ,it does not reflect the level of subsidence in the area of the entire surface. Moreover, they are costly and time consuming. Recently, a new method has been applied successfully in some developed countries (USA, Italy, Canada, Japan...) in detecting subsidence with very high accuracy (some millimeter), this method is Differential Interferometric Synthetic Aperture Radar (DInSAR). The substance of this method is based on the interfering characteristic of the Radar image pairs taken in different time periods of the same area, to measure the degree of differential interferogram which is the basis to measure the degree of subsidence of study areas.

Therefore the objective of this paper is the experiment using a technology (DInSAR) to detect the degree and scale of subsidence in Hanoi due to groundwater exploitation.

SUMMARY

Nghiên cứu ứng dụng kỹ thuật InSAR vi phân trong quan trắc sụt lún đất khu vực đô thị Hà Nội

Trong 10 năm gần đây, tốc độ đô thị hóa của Hà Nội đã diễn ra quá nhanh và đã để lại những hậu quả về môi trường. Một trong vấn các vấn đề đó là hiện tượng sụt lún của mặt đất trên nhiều khu vực của thành phố do việc khai thác nước ngầm gây ra (Theo báo cáo của Viện Kỹ thuật xây dựng Hà Nội thì khối lượng của các nhà máy khai thác nước ngày càng tăng trong những năm gần đây: Thập niên 80: 300.000m3/day; Thập kỷ 90: 390.000m3/day; Năm 2004: 553.400 m3/ngày). Hiện tượng này gây nguy hiểm đến tài sản và tính mạng của người dân cũng như các công trình xây dựng. Vì vậy việc nghiên cứu tốc độ và quy mô của các khu vực sụt lún là rất quan trọng trong việc quy hoạch và phát triển đô thị.

Để phát hiện sụt lún, có các phương pháp truyền thống như là quan trắc lún bằng đo thủy chuẩn hay đo GPS. Các phương pháp này cho kết quả rất chính xác. Tuy nhiên những kết quả đó chỉ được phản ánh trong cá nhân một số điểm, không phản ánh được mức độ sụt lún trên toàn bộ bề mặt, rất tốn kém và mất thời gian. Gần đây, một phương pháp mới đã được áp dụng thành công ở một số quốc gia tiên tiến (Mỹ, Ý, Canada, Nhật Bản ...) trong phát hiện sụt lún với độ chính xác rất cao (cỡ millimeter), phương pháp này là Differential Interferometric Synthetic Aperture Radar (DInSAR). Cơ sở của phương pháp này là dựa trên các đặc tính của các cặp ảnh Radar được chụp trong các thời điểm khác nhau của cùng một khu vực và đo độ lệch pha giữa 2 thời điểm đó. Đây chính là nguyên lý cơ bản để xác định độ trồi lún của khu vực nghiên cứu.

Do đó, mục tiêu của bài báo này là thử nghiệm sử dụng công nghệ DInSAR để phát hiện mức độ và quy mô của sụt lún tại Hà Nội do khai thác nước ngầm.

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1. INTRODUCTION

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In order to detect the subsidence, although many traditional methods such as precise levelling and GPS techniques can be identified very accurately. In spite of the fact that those results are reflected in some individual points ,it does not reflect the level of subsidence in the area of the entire surface, they are costly and time consuming. Recently, a new method has been applied successfully in some developed countries (USA, Italy, Canada, Japan...) in detecting subsidence with very high accuracy (some millimeter), this method is Differential Interferometric Synthetic Aperture Radar (DInSAR). The substance of this method is based on the interfering characteristic of the Radar image pairs taken in different time periods of the same area, to measure the degree of differential interferogram which is the basis for measure the degree of subsidence of study areas.

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2. TWO - PASS DINSAR TECHNIQUE

2.1 Fundamental theory

A conventional SAR only measures the location of a target in a two-dimensional coordinate system. However, the development of interferometric SAR (InSAR) technique has enabled us to measure the three dimension information(Rosen et al. 2000). The conventional antenna transmits the radar pulse and radar echoes from terrain are received by both the conventional and an additional antenna. Through combining the received signals from the two antennas, phase difference can be obtained. This phase difference contains the information about the angle from which the radar echo returned and can be converted into an altitude by combining with the distance information. The major difference between the SAR interfermetry and stereoscopy is that InSAR technique uses the phase difference to obtain a topographic height of the image point.

In case the two statistics are acquired in different time by two flights covering the same region, the interferometric measurement contains two kinds of phase information, terrain altitude and radial motion or displacement. We call it repeat-track interferometry and the basic idea of differential interferometric processing is to separate only displacement information from the total phase.

The amount of displacement can be acquired by removing the topography related phase. According to the methods subtracting this topography phase, there are three kinds of common methods in differential interferometry, 2-pass, 3-pass, and 4-pass. In case of 2-pass, the simulated topography phase is generated from a conventional DEM and 3-pass or 4-pass using an independent interferometric pair without phase component of topography change. 2-pass method has been developed by Massonnet and others, and 2-pass method became one of the most common methods in differential interferometry. In this study, we aimed to monitor the landslide by 2-Pass DInSAR technique.

2.2 Two-pass interferometry

Tow-pass differential interferometry (2-pass DInSAR) is based on an interferometric image pair and a Digital Elevation Model (DEM). The DEM may either be given in a map projection, or in the slant range-azimuth geometry of the SAR image.

The basic idea of 2-pass DInSAR is that a reference interferogram which has the phase coressponding to suface topography is simulated from the DEM is transformed from its original coordinate system to the reference SAR image coordinate. This is done in two steps. First, the geometric transformation is done based on the avaiable information on the geometry of the DEM and the SAR image geometry used. In the same step the SAR image intensity is simulated based on the simulated local pixel resolution and incidence angle. Inaccurate DEM coordinates, orbit data, and small errors in the calculation of the geometry. In the next step the offsets between the real and simulated image intensities are estimated and used to accurately register transformed DEM to the SAR image geometry.

Base on the reference SAR geometry, the interferometric baseline model, the transformed height map, and the unwrapped interferometric phase corresponding exclusively to topography is calculted. This also be called topographic phase and may either be subtracted from the complex interferogram (resulting in a complex differential interferogram) or unwrapped phase (result in the unwrapped differential phase). Figure 1 shows the flowchart of 2-pass DInSAR process.

Subtracting the latter from the reference interferogram can reveal differential, which are a result of SAR range changes of any displaced point on the differential interferogram to the next. In the differential interferogram, each fringe is directly proportional to the SAR wavelength, which is about 5.6 cm for ERS, ENVISAT, RADASAT (C-band) and 23.5 cm for JERS-1 (X-band) single phase cycle. Suface displacement away from the satellite look direction causes an increase in path (translating to phase) difference. Since the signal travels from SAR antenna to the target and back again, the measured displacement is twice the unit of wavelength. This means in differential interferometry one fringe cycle -Π to Π or one wavelength corresponds to a displacement relative to SAR antenna of only half wavelength (2.8 cm and 11.7 cm each).

There are ENVISAT, JERS, and RADASAT that InSAR technology can be applied. In this reaserch, SAR images used for this study are ENVISAT, which have information given in Table 1, baseline information is showed in Figure 2 and SRTM DEM is showed in Figure 3.

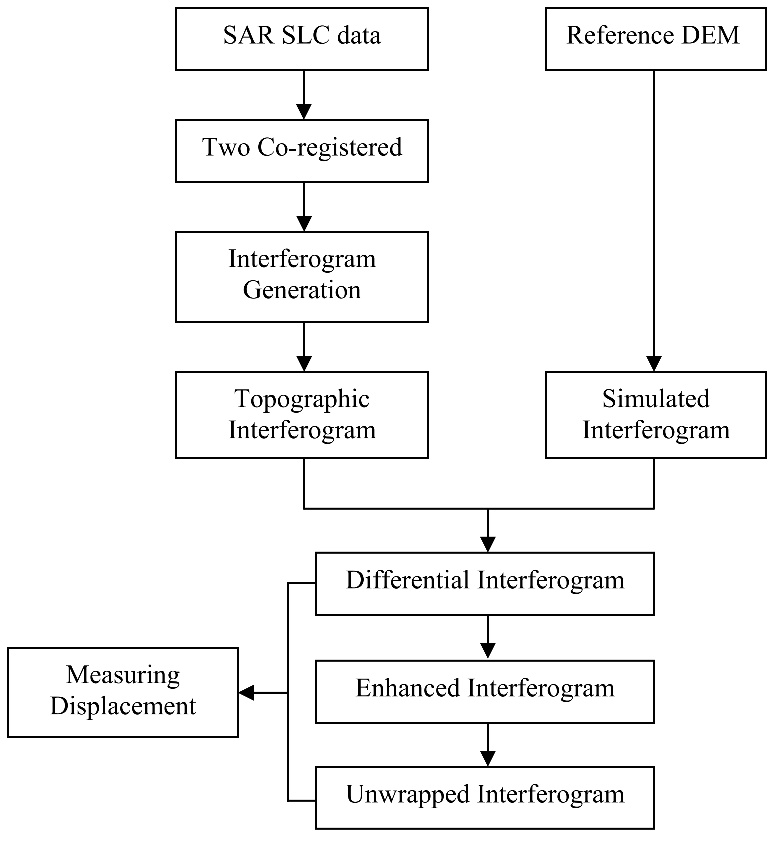


Figure 1. Flow chart of two-pass DInSAR

3. ESTIMATION OF SUBSIDENCE IN HANOI AREA

3.1 Study area

The study area is in Ha Noi City, which is a mega city with more than 6 million people, with near 340 000 ha. Hanoi city is a plain which has an altitude of 10 metres. There is no point in using Interfere Sar record to set up DEM. Therefor, in this Pilot Project, studying and applying different Radar are main methods to consider depression area in Hanoi .

Many area wrote in introduction which witnessed depression- almost in Hanoi, such as: Mai Dich, Phap Van, Ha Dinh, Thanh Cong, Ngo Si Lien. So, main area of research is Hanoi. It is located at $105^0 44'$ west longitude, $105^0 54'$ eastern longitude, $20^0 57'$ south latitude, $21^0 07'$ eastern latitude and lies ~ 50 km^2 inland at 10 m average altitude. The topographic variation is approximately 15 m in the study area.

To measure the displacement, we generated six interferograms for each region from ENVISAT satellite images between 2003 and 2008, and acquired simulated phase by a conventional DEM (Figure 3) from NASA Shuttle Radar Topography Mission (SRTM). In case of Eurasia, it has the 90m resolution and 9m vertical error (Farr et al. 2007). Through differential interferometry, we subtracted the simulated interferogram from original interferogram and finally generated displacement images for estimating landslide of research area. The satellite image area subjected to analysis is shown in Figure 3.

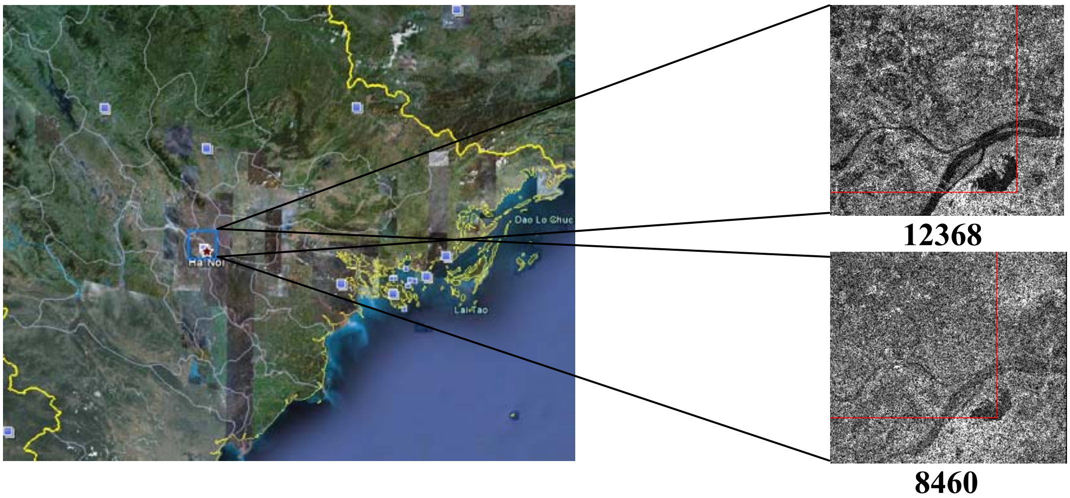


Figure 1. The satellite image of Ha Noi (Google Earth)

3.2. SAR data and reference DEM.

N^0	Sensor	Date	Orbit
1	ENVISAT_ASAR	13-Oct-2003	8460
2	ENVISAT_ASAR	17-Nov-2003	8961
3	ENVISAT_ASAR	19-Jul-2004	12468
4	ENVISAT_ASAR	05-Apr-2004	10965
5	ENVISAT_ASAR	22-Sep-2004	13406
6	ENVISAT_ASAR	22-Nov-2007	29502

Table 1: SAR satellite data used in this study

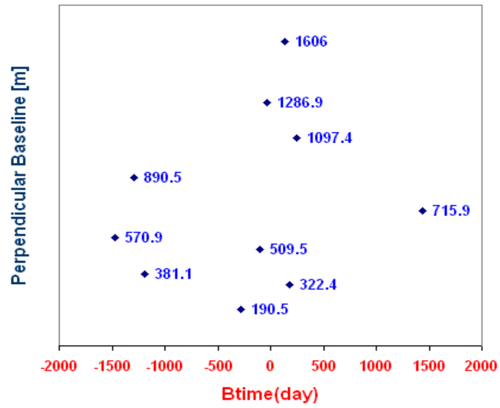


Figure 2. Baseline distribution for HaNoi City data Set

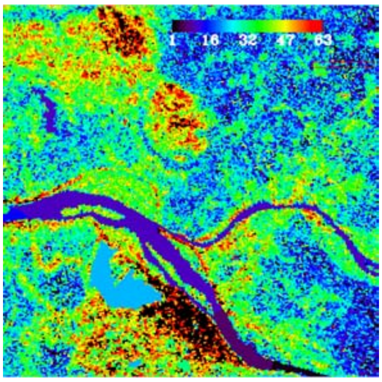


Figure 3. The DEM of Ha Noi

4. RESULTS

4.1. Select SAR images for DInSAR processing.

Data may be useful for DINSAR studying

No	Master	Slave	Master(y/m/d)	Salve(y/m/d)	Bperp(m)	Btime(days)
1	12468	8460	2004/06/19	2003/11/13	190.5	-280
2	12468	29502	2004/06/19	2007/11/22	-381.1	1190

Table 2. Two pairs for DInSAR processing

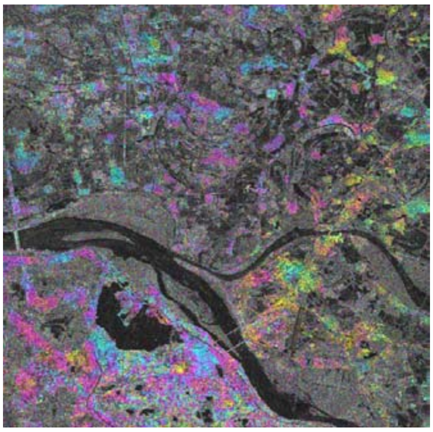
	
Interferogram: 12468-8460(12468 Amplitude image background)	Interferogram: 12468-29502 (12468 Amplitude image background)

Figure 4. Interferograms

4.2. DInSAR results and interpretation

(12468-8460)

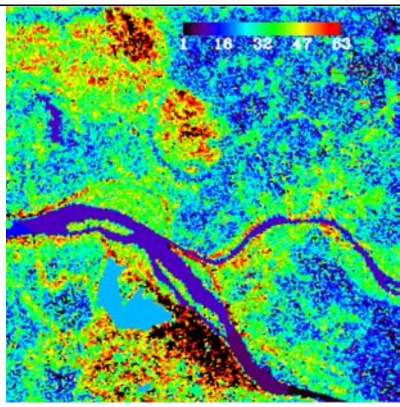
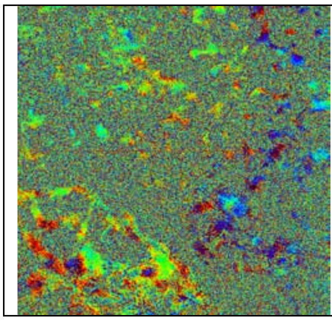
	
Master 12468	SRTM DEM

Figure 5. Master amplitude and DEM



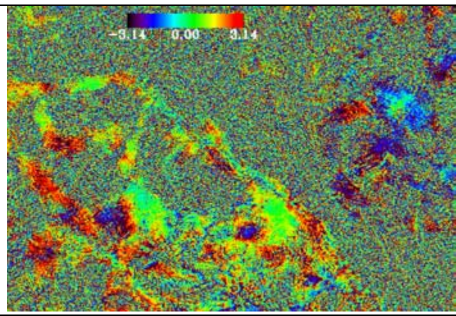


Figure 6. Differential interferogram

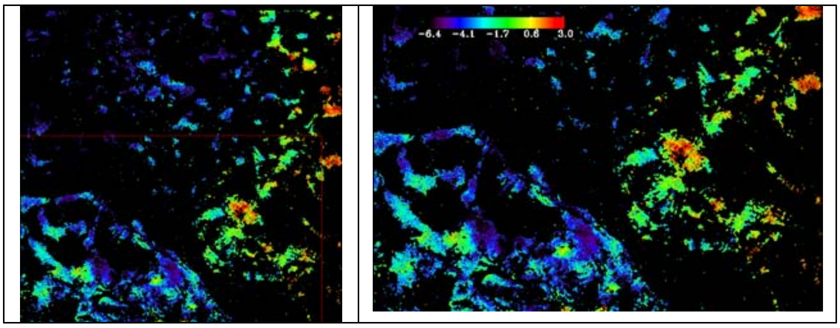
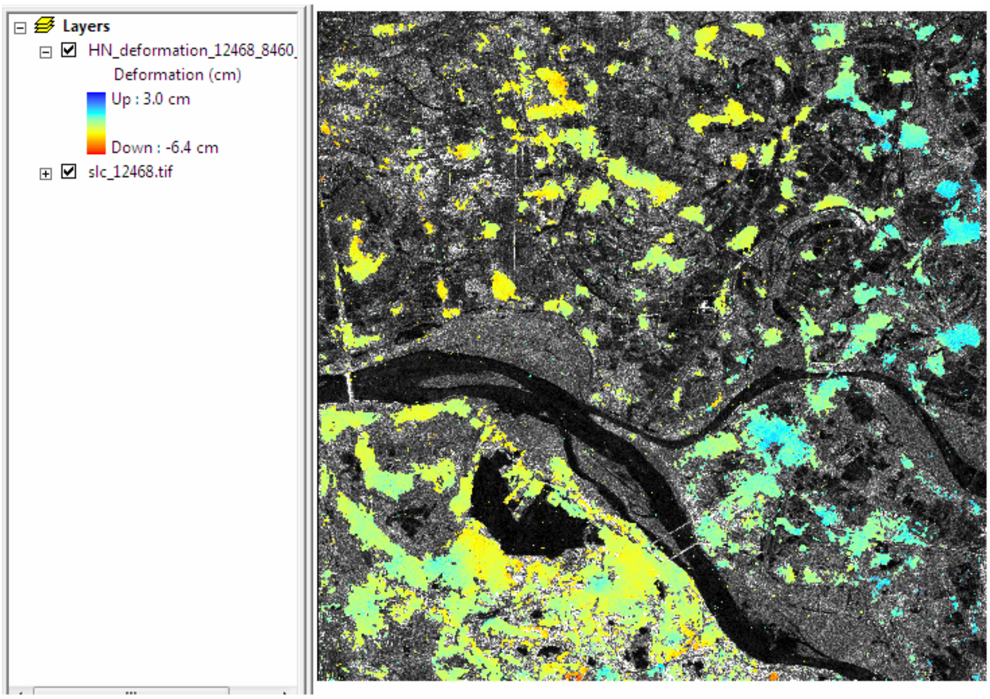


Figure 7. DInSAR subsidence value



5. CONCLUSION

In this study, through two-pass differential interferometry technique, we generated displacement image covering Ha Noi city. We generated 2 interferograms from ENVISAT data and we only can use interferogram made from two SARs image 12468-8460 because of 12468-29502 low coherence.

The subsidence at the geothermal fields has been studied using DInSAR with ENVISAT imagery. The DinSAR results shows the subsidence with the maximum magnitude of 64 mm during 2001 to 2004.

According to the result above, it is easily realized that the subsidence in the investigated area is not the same, some area has the highest subsidence such as Thanh Cong (6cm), the lowest subsidence area is Mai Dich (3cm). This can be explained by the geographic structure such as the level of water exploition in the 2 areas are different.

Moreover, at some areas where there are different Underwater Exploition Stations, the subsidence is different. The area of which geographic structure is weak or in which there are different level of water exploition, will have a higer subsidence than the others where the structure is strong and there is less water exploition.

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BIOGRAPHICAL NOTES

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