Automatic InSAR processing and Introduction of its application studies

Tomonori Deguchi
Earth Remote Sensing Analysis Center (ERSDAC)
3-12-1 Kachidoki Chuo-ku Tokyu, Japan
deguchi@ersdac.or.jp

Abstruct: InSAR is an effective technology to detect and measure the magnitude of ground surface displacement caused by earthquake, volcanic activity, land subsidence, landslide and others. Automatic InSAR processing software "auto_insar" was developed for the purpose to remove difficulties involved in applying InSAR and to promote data use of ALOS/PALSAR by ERSDAC which will be launched in December 2005. The software automatically generates the interferogram of earth surface displacement out of two Single-Look Complexes (SLC) and Digital Elevation Model (DEM) within 2 hours.

In this study, some phase anomalies were extracted around Taal volcano and Mak-Ban geothermal area, which are located 70 km to the southeast from Manila, Republic of the Philippines. This study also includes the application to extract land subsidence around Hanoi where ACRS is held.

Keywords: InSAR, auto_insar.

1. Introduction

It is not easy to grasp the whole picture in the wake of a huge disaster,and it goes without saying that remote sensing can be utilized effectively to observe the damages. InSAR is already established as an useful technology to detect and measure the magnitude of ground surface displacement caused by earthquake, volcanic activity, land subsidence, landslide and others. However, it takes a great deal of time to process data, and above anything, it is difficult to anticipate whether the process succeeds or not until the final product comes out. Normally, in case of using commercial software, registration of images and baseline estimation will be done manually repeating trial and error, and in addition, a filter incorporated in such software doesn't work effectively. In other words, manual analysis takes time and quite inefficient. These facts keep InSAR users from expanding. To counter the situation, automatic InSAR processing software "auto_insar" was developed to make InSAR application much easier and to promote data use of ALOS/PALSAR that is planned to be launched in December 2005. The software automatically generates the interferogram of surface displacement based on two SLCs and DEM within 2 hours. DEM could be generated out of ASTER L4A, SRTM and others. "Auto_insar" has a function to produce mosaic images of ASTER L4A and SRTM.

In addition to InSAR processing, the software can automatically correct "foreshortening" of radar image. Since foreshortening becomes larger as incidence angle gets smaller, foreshortening corrected SAR images are more suitable for interpretation.

In this study, some phase anomalies were extracted around Taal volcano and Mak-Ban geothermal area, which are located 70 km to the southeast from Manila, Republic of the Philippines. Taal volcano has not exploded since huge eruption in 1977. Deformation indicating non-active state of the volcano was captured inside the crater. An aggregate geothermal capacity maintained in Mak-Ban geothermal field is over 420 MW. InSAR analysis also led to extract land subsidence, whose causal relation with the geothermal production is being pointed out. Another analysis includes land subsidence around Hanoi, where ACRS is held.

2. Development of "auto_insar"

Fig.1 shows the flow of InSAR processing. SLC and DEM were used as input data. Mosaic of ASTER Level 4 or SRTM was used to produce DEM that covers SLC completely. A series of process shown below initiates in that order, by merely designating two SLCs and DEM data. Final interferogram will be produced in about 2 hours.

(1) Format conversion
(2) Registration between Master and Slave
(3) Resampling of Slave
(4) SAR image simulation
(5) Registration between Master and DEM
(6) Resampling of DEM
(7) Removal of orbit fringe and topographical fringe

(8) Filtering
(9) Phase unwrapping
(10) Correction of foreshortening
(11) Map projection

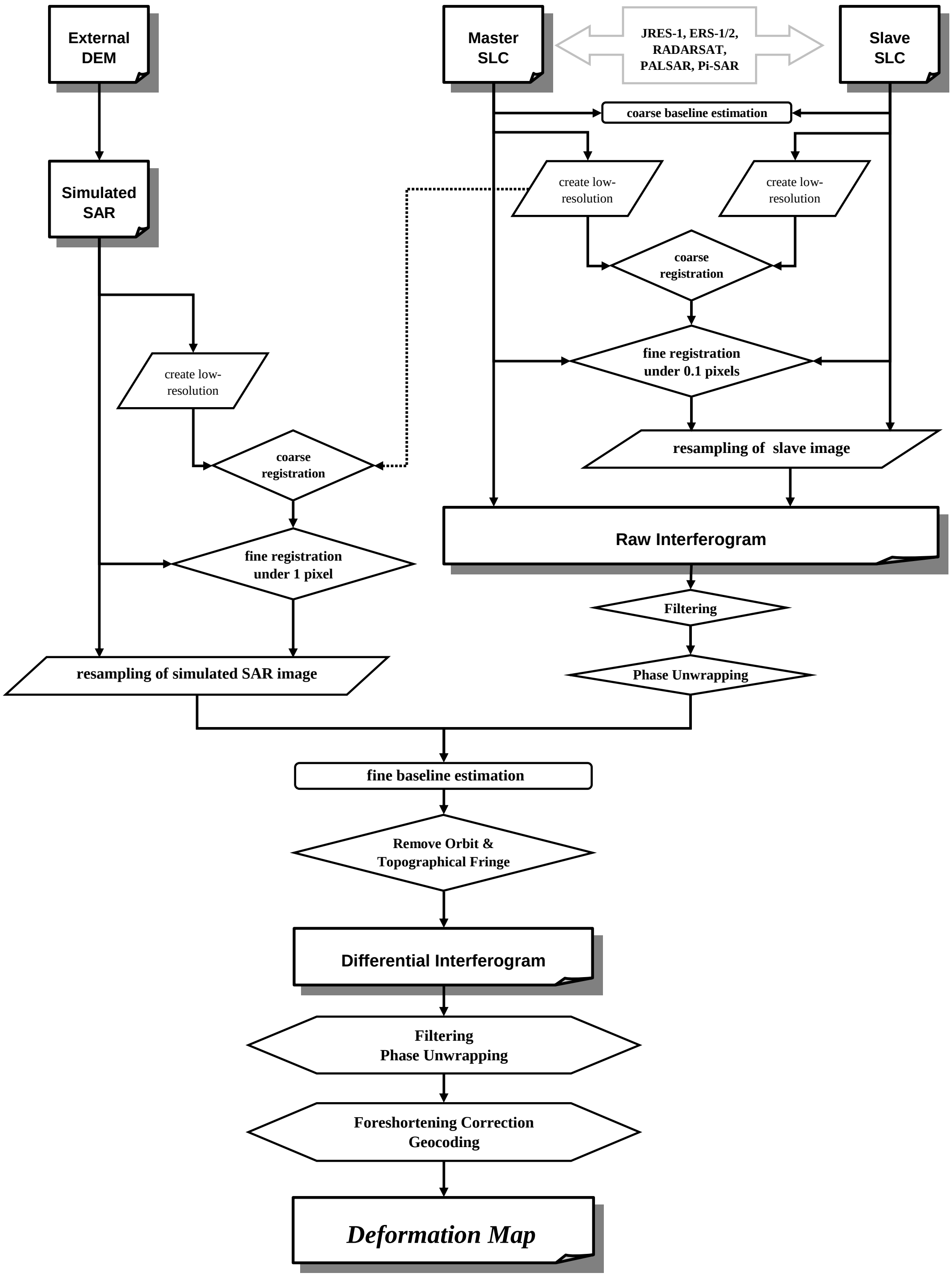


Fig.1 Flowchart of InSAR processing

Especially important factors for effective processing are detailed as follows.

1) Format conversion

In the process, SLCs and DEM data will be converted to a prescribed format of “auto_insar” and important header information will be recorded as a text file. The software can import SLC recorded by CEOS format only at the moment. However, it should be improved in the future to be able to import other format data, especially ALOS/PALSAR data (VEXCEL format).

2) Registration of images

FFT oversampling method developed by Tobita et al. (1999) is used for the registration between Master and Slave or Master and DEM data. More generally used template matching (area-based matching using correlation) searches a point of maximum correlation coefficient by pixel in order to identify tiepoints. On the other hand, FFT oversampling method interpolates correlation coefficient matrix based on FFT to identify tiepoints by subpixel. Then, bad tiepoints will be excluded until RMS errors get smaller than 0.1 and 1.0 pixel for MASTER/Slave and Master/DEM, respectively. And calculate affine transformation coefficient based on the residual tiepoints. It is not efficient to use original image from the beginning of the registration process. After generating averaged 10x10 pixel image, coarse offset value of the two images will be calculated. Since this offset value is not accurate enough, FFT oversampling method should be applied to estimate offset value by pixel. In this way, searching tiepoints around coarse offset reduces the risk of mismatch, and above all, the effective processing becomes reality. This automatic processing enables to extract tiepoints of over 100 and calculated affine transformation enables to resample Slave and DEM.

3) Interferogram Filter

Various noises get mixed in an interferogram after InSAR processing, which makes phase error per pixel quite large. Spatial baseline, temporal baseline, change of land use and meteorological factors (moisture in the atmosphere etc.) are considerable causes for the noise. Adaptive windows that is based on moving average and the filter developed by Goldstein et al. (1998) (hereinafter called GW filter) are often used as filters. GW filter utilizes two-dimensional window Fourier transform. Conversion into frequency domain leads to emphasize phase that stands out in the window. Other than GW filter, "auto_insar" accommodates improved GW filter and the one based on least squares method. These filters were developed for the purpose to extract local phase anomaly.

4) Correction of foreshortening and map projection

SAR image that reflects nothing but topographic effect will be simulated using DEM in order to remove topographical fringe from the interferogram. Since foreshortening value is calculated in the process of simulation and registration between Master and DEM, foreshortening value of each pixel of Master image can be estimated and its correction becomes possible. In addition, resampling of Master and interferogram to correspond with DEM leads to improve the accuracy of geometric position. This correction is important for JERS-1/SAR data because it doesn't carry GPS. By referring to DEM whose geometric position is quite accurate, GIS and data fusion using OPS, SAR, DEM and others become reality.

3. Case study

1) Geothermal field and volcano study in Philippines

Fig.2 shows the studied areas, Mak-Ban geothermal field and Taal volcano, which are located 70 km to the southeast from Manila, Republic of the Philippines. Philippines is the world's second largest productor of geothermal energy for power generation. In 1998, the contribution of geothermal energy to total energy requirements is 21.52%[11]. Mak-Ban area is one of six geothermal fields producting electric power in Philippines. Since geothermal production at Mak-Ban area began in 1979, an aggregate geothermal capacity of over 420 MWe is currently maintained in this field, making the second largest operating geothermal field in the Philippines[12], [13], [14].

In this study, the land subsidence around the production area of Mak-Ban geothermal field was detected using JERS-1/SAR data. Approximately 16 cm of subsidence is estimated to have occurred

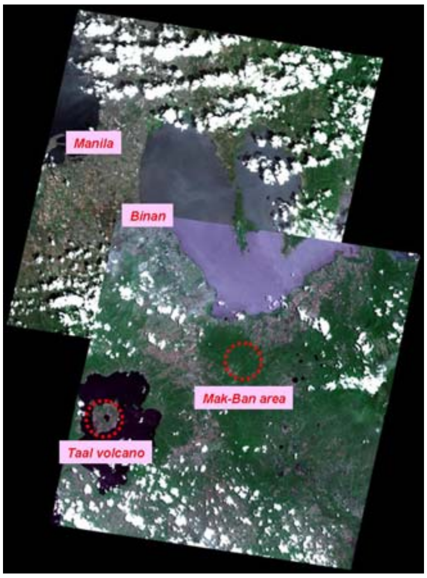


Fig.2 ASTER images with the studied areas in Philippines

from 1995/2/24 to 1998/10/6 (Fig.3 and 4). Precision leveling survey proposed by J. A. P. Protacio et al. shows that land subsidence of approximately 56.5 cm occurred from 1981 to 1999. Another phase anomaly, which indicates huge subsidence, was clearly detected in the southern part of Manila and Binan area. Because there are no references about these displacements, the cause of them is unclear.

In addition, a small phase anomaly which exhibits subsidence corresponded to 10 cm is extracted inside the crater of Tall volcano. This deformation indicates non-active state of the volcano, which has not been exploded since 1977. Moreover, a fringe appears in parallel to north - south direction, the deformation that the ground of Taal island is tilted downward at the eastern edge was caught.

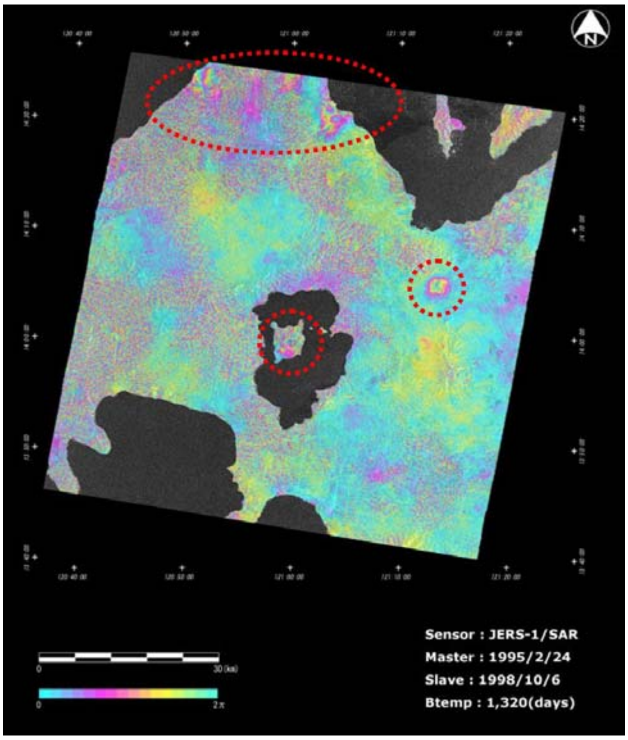
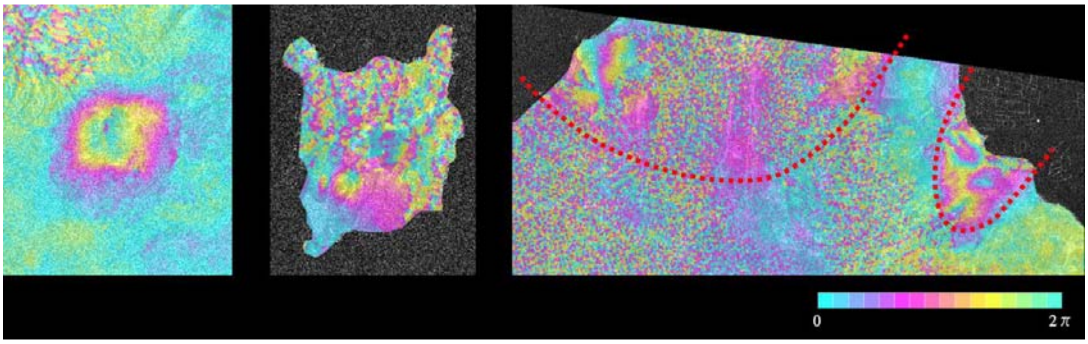


Fig.3 Interferogram (1995/2/24 – 1998/10/6)



(a)Mak-Ban **(b)Taal volcano** **(c)Southern part of Manila and Binan**

Fig.4 The enlargement of interferogram

2) Case study of Hanoi in Vietnam

People of Hanoi highly depend on underground water resource and the extraction increases year by year, giving rise to the risk of land subsidence. Extraction of groundwater in Hanoi started in 1909 for domestic and industrial uses. The extraction back in those days was about 40,000 m^3/day. In 1975, it increased to 150,000 m^3/day, and 400,000 m^3/day in 1997. It is estimated that it will be bloated to over 1,000,000 m^3/day by 2020. N. V. Dan and N. T. Dzung show that land subsidence had occurred in most urban areas and the suburbs from 1988 to 1995 by level measurement. The highest land subsidence areas are at the center and south of Hanoi (Giang Vo, Thanh Cong and Phap Van) with 20-44 mm/year[15], [16].

Fig.5 shows the studied area. It is detected the land subsidence in the southern part of Hanoi using JERS-1/SAR data. The magnitude of subsidence is estimated 4-5 cm from 1997/4/12 to 1998/9/22 (Fig.6 and 7). Since there are no comparable data such as precision leveling data, the accuracy of its result could not be verified to them, but land subsidence due to the pumping of groundwater was extracted by InSAR analysis.

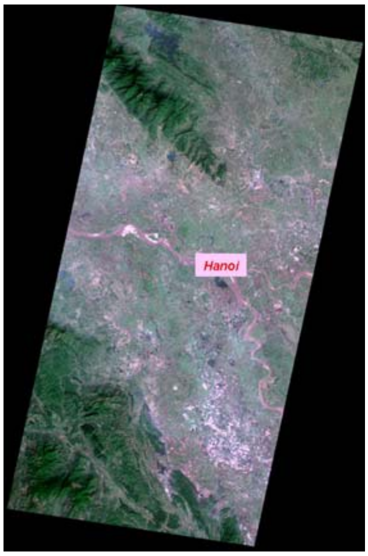
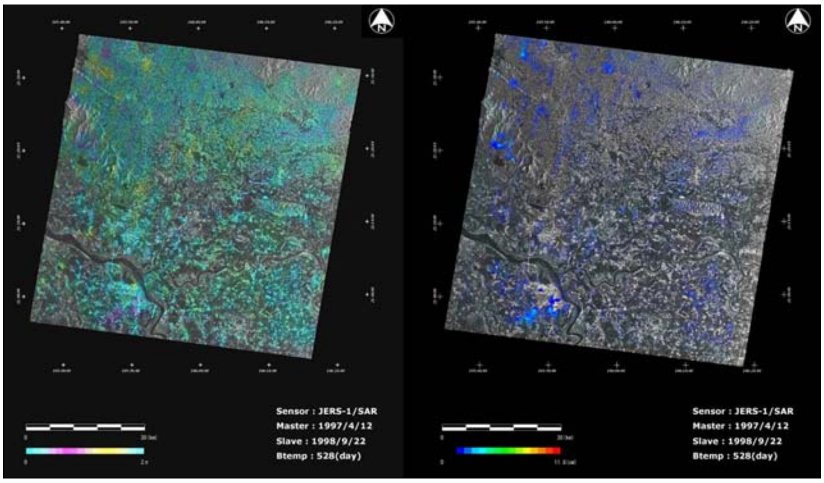


Fig.5 ASTER images with the studied area in Vietnam



(a)Interferogram (1997/4/12 – 1998/9/22) (b) Change map (1997/4/12 – 1998/9/22)

Fig.6 The result of InSAR

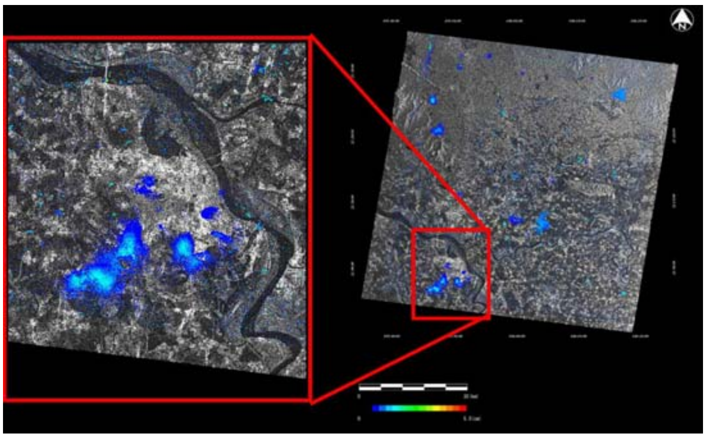


Fig.7 The enlargement of change map

4. Conclusion

In this study, the author developed automatic InSAR processing software “auto_insar” for the purpose to remove difficulties involved in InSAR processing, such as registration of images, baseline estimation, interferogram filtering and others. As a result of analyzing JERS-1/SAR data observed over Philippines and Vietnam using “auto-insar”, surface displacement might have been occurred due to various factors such as the pumping of geothermal fluid, the pumping of groundwater and volcanic activity had been distinctly detected.

This result convinces that “auto_insar” makes InSAR processing efficient and facilitates detection and monitoring of surface movement. In view of ALOS/PALSAR to be launched in December 2005 as a successor of JERS-1/SAR, the software should be improved in the future to encourage the data use.

References

[1] Rodriguez E. and J. M. Martin, 1992. Theory and design of Interferometric synthetic aperture radars, *IEE proceedings F*, vol.139, no.2: p.147-159.

[2[Massonnet, D., M. Rossi, C. Carmona F. Adragna, G. Peltzer, K. Feigl and T. Rabaute, 1993. The displacement field of the Landers earthquake mapped by radar interferometry, *Nature*, 364: 138-142.

[3] R. M. Goldstein and C. L. Werner, 1998. Radar interferogram filtering for geophysical applications, *Geophysical Research Letters*, vol.25, no.21: pp.4035-4038.

[4] D. C. Ghiglia and M. D. Pritt, 1998. Two-dimensional Phase Unwrapping : Theory, Algorithm, and Software, *Wiley-Interscience*.

[5] M. Tobita, S. Fujiwara, M. Murakami, H. Nakagawa and Paul A. Rosen, 1999. Accurate Offset Estimation Between Two SLC Images for SAR Interferometry, *Journal of the Geodetic Society of Japan*, vol.45, No.4: pp.297-314.

[6] S. Fujiwara, M. Tobita, M. Murakami, H. Nakagawa and Paul A. Rosen, 1999. Baseline Determination and Correction of Atmospheric Delay Induced by Topography of SAR Interferometry for Precise Change Detection, *Journal of the Geodetic Society of Japan*, vol.45, No.4: pp.315-325.

[7] M. Shimada, 1999. Correction of the Satellite’s State Vector and the Atmospheric Excess Path Delay in the SAR Interferometry – An Application to Surface Deformation Detection -, *Journal of the Geodetic Society of Japan*, vol.45, No.4: pp.327-346.

[8] M. Murakami, M. Tobita, H. Yarai, S. Ozawa, T. Nishimura, H. Nakagawa and S. Fujiwara, 2000. Application of Crustal Deformation Monitoring Using Synthetic Aperture Radar (SAR) for Seismological and Volcanological Studies, *Journal of Geography*, 109(6): 944-956.

[9] **URL:** Interferogram enhancing filter, Proceedings of 2001 ERI Workshop on 'Significance of L-band Interferometric SAR'. Available at: http://www.eri.u-tokyo.ac.jp/KOHO/KYODORIYO/report/2001_insar_ws/b5/.

[10] M. Tobita, 2003. Development of SAR Interferometry Analysis and its Application to Crustal Deformation Study, *Journal of the Geodetic Society of Japan*, vol.49, No.1: pp.1-23.

[11] V. M. Karunungan and R. A. Requejo, 2000. Update on Geothermal Development in the Philippines, *Proceedings World Geothermal Congress 2000*, 247-252.

[12] National Power Corporation and Philippine Geothermal Inc., 2000. Mak-Ban Geothermal Power Plant (Bulalo Geothermal Field) Guide Book.

[13] J. A. P. Protacio, G. U. Golla, G. A. Nordquist, J. Acuna and R. B. S. Andres. Gravity and Elevation Changes in the Bulalo Geothermal Field, Philippines: Independent Checks and Constraints on Numerical Simulation.

[14] G. U. Golla, F. V. Abrigo, B. O. Alarcon, P. A. Molling and J. A. Stimac. The Bulalo Geothermal Field, Philippines: Conceptual Model of A Prolific Geothermal System.

[15] N. V. Dan and N. T. Dzung. Groundwater Pollution in the Hanoi Area, Vietnam.

[16] P. H. Giao and E. Ovaskainen, 2000. Preliminary Assessment of Hanoi Land Subsidence With Reference To Groundwater Development, *Lowland Technology International*, vol.2, No.2: 17-29.