THE ANALYSIS OF SURFACE DEFORMATION BASEED ON TWO-PASS AND THREE-PASS D-INSAR

Qu Ning-ning, Zhu Guang , Zhao Xi-an, Jing Chang-feng

College of Geomatics, Beijing University of Civil Engineering and Architecture Beijing, 100044,China

d-z-ning-ning@163.com, zhuguang@bucea.edu.cn, zhaoxian@bucea.edu.cn, *jingchangfeng*@bucea.edu.cn

1. INTRODUCTION

The Synthetic Aperture Radar Interferometry (InSAR) reaches the precision of cm-level or even mm-level in height. D-InSAR is widely used in many domains such as co-seismic displace, volcanic deformation, glacial movement, land subsidence and so on. Gabriel et al. presented the capability of D-InSAR in detecting the centimeter level deformation at the first time in 1989. The deformation of imperial valley irrigation in the southeast of California was analysed based on the L-band SeaSat SAR data. The co-seismic deformation field of American Landers' earthquake in 1992 was acquired from ERS-1 SAR data by Massonnet et al. The result in D-InSAR was compared with the result of traditional instrument. These results were quite consistent. The research results published in NATURE caused the international earthquake's shock. The paper introduces the application in deformation analysis, based on the two-pass and three-pass differential methods using ENVISAT/ASAR radar data. The deformation fields obtained by two different differential methods have been compared with traditional methods.

2. THE PRINCIPLE D-INSAR

The interferometric phase generated by InSAR may be represented as

$$\phi = \phi_t + \phi_d + \phi_a + \phi_f + \phi_n \tag{1}$$

where ϕ_t , ϕ_d , ϕ_a , ϕ_f and ϕ_n are the topographic phase, surface deformation phase, atmospheric effect phase, ellipsoid reference phase and noise phase, respectively. Three different approaches are used in getting surface deformation from the interferogram phase : (1) two-pass method using two SAR images plus external DEM; (2) three-pass method using three SAR images; (3) four-pass method using four SAR images.

2.1 The Principle of Two-pass D-InSAR

Firstly the external DEM is converted into radar coordinates. Then it is adjusted by the baseline parameters of the SAR pair, so that the DEM and topographic phases have the same scale. Finally the topographic phase simulated from DEM is subtracted from the interferogram phase , shown in Fig. 1. The ground points are observed from satellites at $S_1$and S_2. The surface deformation, or shift of ground point has happened, when the satellite runs up to S_2. The interferometric phase during two observations is represented as

$$\phi_{12} = -\frac{4\pi}{\lambda}(R_1 - R_2) = \phi_d + \phi_t \tag{2}$$

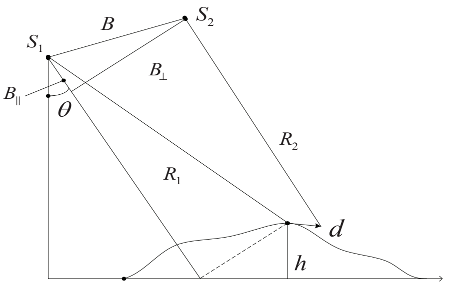

Figure. 1 two-pass differential interferometry

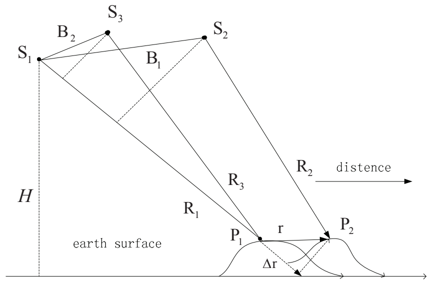

Figure. 2 three-pass differential interferometry

where R_1 ,R_2 are the distance between the satellite and ground point. λ is the radar wavelength. ϕ_d , ϕ_t are the deformation phase and topographic phase respectively. The topographic phase is represented as.

$$\phi_t = \frac{4\pi}{\lambda} \frac{B_\perp h}{R_1 \sin\theta} \tag{3}$$

Here has $$\phi_d = \phi_{12} - \phi_t$$

After the ϕ_d phase is unwrapped, The absolute phase ϕ_{abs} is given. The surface deformation Δr is expressed as.

$$\Delta r = \frac{\lambda}{4\pi} \phi_{abs} \tag{4}$$

2.2 The Principle of Three-pass D-InSAR

The three-pass differential method uses three SAR images to form two interferograms. One interferogram (pair one) contains only the topography information, while the other (pair two) implicates the topographic and deformation message. The scales both pair one and pair two are adjusted to the same based on the satellite baseline. Then the pair one interferogram phase is subtracted from the interferogram phase of pair two, shown in Fig. 2.

When ground points are observed from satellite at S_1， S_2， S_3, the target point shifted from P_1 to P_2. The interferometric phase (pair one) during observations at S_1 and S_2 is expressed as follows

$$\phi_{12} = -\frac{4\pi}{\lambda}(R_1 - R_2) \tag{5}$$

where R_1， R_2， R_3 are the distance between the satellite and the target point. λ is the radar wavelength. Δr is the displacement between point P_1 and P_2. Pair two interferometric phase observed at S_1 and S_3 is expressed as follows

$$\phi_{13} = -\frac{4\pi}{\lambda}(R_1 - R_3) + \frac{4\pi}{\lambda}\Delta r \tag{6}$$

The height of P_2 is implicated in the interferometric phase. The deformation phase is given by

$$\phi_{defo} = \phi_{13} - \phi_{12} .$$

After the deformation phase is unwrapped, the surface deformation Δr is given as follow

$$\Delta r = \frac{\lambda}{4\pi} \phi_{defo} \tag{7}$$

At last, the Δr is geocoded.

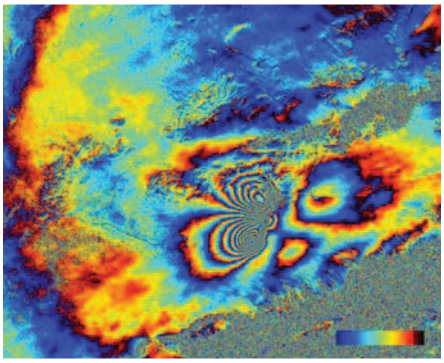

Figure. 3 Interferogram of two-pass differential interferometry

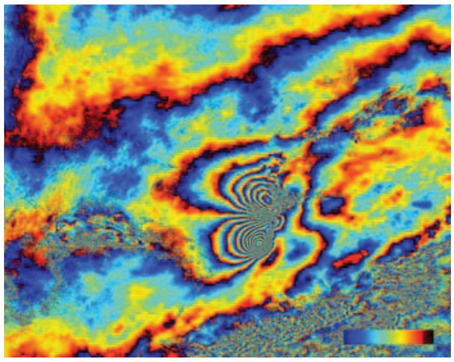

Figure. 4 Interferogram of three-pass differentialinterferometry

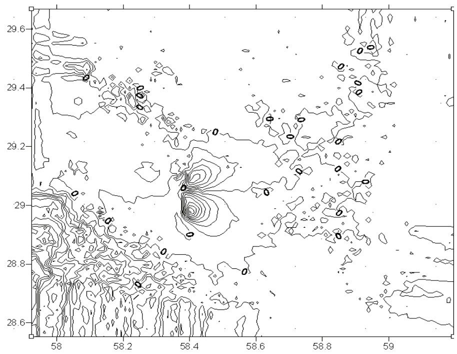

Figure. 5 Isogram of two-pass differential interferometry

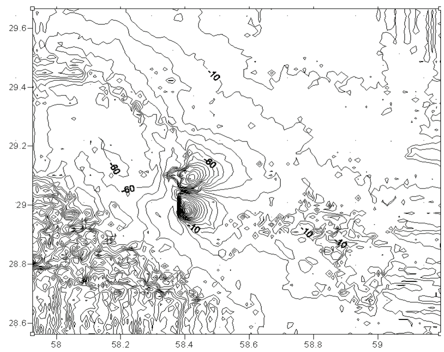

Figure. 6 Isogram of three-pass differential interferometry

3. THE EXPERIMENTS

In our experiment, three track No.120 SAR images from the seven ENVISAT/ASAR radar images covering Bam (provided by ESA) are used. The precise orbit data and SRTM3 DEM are also used in the research. In the two-pass differential method, the master image is the pre-seismic image in orbital No.9192, and the slave is post-seismic image in orbitial No.9693. The interferogram is generated by both images. The topographic phase is simulated by SRTM3 DEM. The interferogram phase is subtracted by the topographic phase, so that the surface deformation is given. In the three-pass differential method, two pre-sesimic images of orbitial No.6687 and 9192 are combined in producing the interferogram (pair one) . The other interferogram (pair two) is given by two images in orbitial No.9192 and 9693. The deformation interferogram comes from the subtraction between pair one and pair two. After the deformation interferogram is unwrapped, the ground deformation can be calculated.

The co-sesimic deformation field (butterfly shapes) is gained by two methods above. Not only the distribution of interference fringes,but also the subsidence tendency shown in the interference fringes are consistent. Shown in Fig. 3 and Fig. 4, a color loop shows the phase change of 2π and represents the surface deformation of 2.8 cm. The approximate deformation values can be got from the numbers of interference fringe. The error values may be existed in the two-pass method because of the external DEM. The affect of temporal decorrelation and the inconsistency is also implicated in the three-dimensional deformation maps and isograms by the two methods. The statistical analysis in isograms can be known that the deformation values in radar line-of-sight (LOS) range are from -16cm to 27cm in two-pass method. In the three-pass differential method, the values in LOS range are between -18cm and 30cm.

4. CONCLUSION

The deformation analysis based on two-pass differential and three-pass differential InSAR is done.The advantage in two-pass differential method is that we don't need to unwrap topographic phase and processing work is less. Some of errors such as the errors from external DEM may be introduced.The main advantage in the three-pass differential method is that the ground information is not needed, and the coregistration is easy. The analytic results by the three-pass differential method is better. The quality of result may be effected in phase unwrapping in two different methods. The deformation fields obtained by two different differential methods have been compared with traditional methods. With the changes in topographic factor, climatic conditions and vegetation types, the coherence effect is different, results may been given. It is not easy that the strong coherence is satisfied in three SAR images in the same time. Therefore, the optimizing methods depend on the purpose of application and the characteristics of studied area.

ACKNOWLEDGEMENTS

This study was supported by The National Natural Science Foundation of China (No.40771178), Key Program of Natural Science Foundation of Beijing (No.KZ200710016007) and Technologic Innovative Group Plan of Beijing (No. PHR 2009 07127).

REFERENCES

[1]Gabriel A K, Goldstein R M and Zebker H A," Maping small elevation changes over large areas: Differential radar interferometrym," J. Geophysical Research, vol. 94, no. B7, pp. 9183-9191, 1989.

[2]Massonnet D, Rossi M, Carmona C, et al, "The displacement field of Landers earthquake mapped by radar interferometry," J. Nature, vol. 364, no. 8, pp. 138-143, 1993.

[3]Zebker H A, Roser P A, Goldstein R M, et al, "On the derivation of coseismic displacement fields using differential radar interfere-ometry-the Landers earthquake,: J. Geophys. Res, vol. 99, 1994.

[4]Bian Lei and Wang Meng, "Study on Doris saftware applied to D-InSAR technology," J. Yancheng Institute of technology Natural Science Edition, vol. 21, no. 3, pp. 6-8, 2008.

[5]Xia Ye, "Bam earthquake: surface deformation measurement using radar Interferometry," J. Acta Seismologica Sinica, vol. 27, no. 4, pp. 423-431, 2005.