Consideration of Surface Information Extraction Method for Disaster Prevention using ALOS PALSAR Interferometry

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Abstract

The first object of this study is to consider ground surface displacements that occurred due to Philippine Sea Plate movements in the adjacent area of Huatung Valley in Taiwan. In order to clarify the activity of Crustal Deformation in this area, we have previously performed repeat-pass Differential SAR Interferometry (D-InSAR) to estimate and then evaluate the displacement values by geodesic levering measurements. According to these previous results using successful ENVISAT/ASAR data. The displacement values ranged between -1.5 cm and +2.8 cm, which coincide on the active fault area. In order to confirm these obtained results, we are expecting to acquire and more detail processing of L-band ALOS/PALSAR interferograms.

The second object of this study is aiming to apply the Triherence method developed by ENVISAT/ASAR data to generate the stable phase points to extract the small hazardous area of landslides. According to previous results, varying of stable phase point number that indicates the tiny deformation caused by the existence of landslide precursor. We plan to develop new Triherence method using ALOS/PALSAR data to apply landslide areas in Taiwan, Malaysia and Japan.

Finally, we plan compare with GPS displacements at the hazardous areas. This is the step to obtain ground surface hazardous map by comparing several geophysical data such as Earthquake Epicenters, GPS surveys, EDM surveys and Seismic Exploration survey. Using above related Earth's Surface Deformation Information, we plan to extract effective and useful information for disaster prevention and mitigation.

Keywords: Disaster prevention, SAR Interferometry, Triherence

1. APPLICATION AND VALIDATION USING ALOS/PALSAR DISASTER MONITORING METHOD

1. 1 Background

Repeat-pass SAR interferometry is a technique to retrieve the land surface change, if any land surface changes have been occurred, between any two satellite observations. If we could acquire useful SAR data, which could be utilized for the environmental change detection and extraction of crustal movement, small land surface changes, or surface motion can be detected in targeted areas. Several SAR systems, including RADARSAT/SAR, ENVISAT/ASAR and many others, have been used to detect disasters in the last several decades. If we are able to apply capable SAR data, like ALOS/PALSAR data in the near future for this purpose, more useful information related to the crustal movement can be obtained. Because SAR data and the repeat-pass SAR interferometry have became promised technique in the field of Geoscience and Environmental analysis. Monitoring the crustal movement is significant to avoid and minimized the disaster area and the extent of damaged areas.

1.2 Repeat-Pass Interferometry

SAR interferometry has been developed in last several decades. In this method, two interferograms made from three passes or observations separated by

Then the phases of corresponding pixels are differenced, and altitude formation is deduced from some simple computation and image co-registration.

However, very small changes, or surface motions can be extracted using the repeat-pass SAR interferometry. In 2001, we generated first interferogram by JERS-1/SAR between the specific periods along Huatung Valley. It was realized that the fringe patterns matching almost over the valley. Recently two new interferograms using ENVISAT/ASAR over the same area were generated. Interestingly, these new interferograms are also overlapped over the same area. Consequently, there is possibility to perform a repeat-pass SAR interferogram analysis by using these products along Huatung Valley.

1.3 Geophysical and Satellite data used

ASTER/VNIR satellite data were used in order to confirm the topographic and land surface characteristics. Seismic Refraction Survey was also carried out parallel to the satellite data acquisitions. Sub-surface structure in the northern part of the Huatung Valley was clearly acquired and the results indicate that the reflected wave velocities were calculated 4.4km/sec and 5.7km/sec in the upper and lower layers, respectively. Also the direct wave velocities of 4.4km/sec and 4.5km/sec were obtained,

Four successful ENVISAT/ASAR data were acquired along the geophysical survey, these data were obtained at 24 July 2004, 6 November 2004, 4 June 2005, and 17 September 2005. Two interferograms were generated using these four combination data.

GPS and EDM data were measured and calculated since 1996 at the area of Shoufeng, Mizhang and Yuemei stations in the northern Huatung valley. The results indicate that the displacements are approximately 4cm/year.

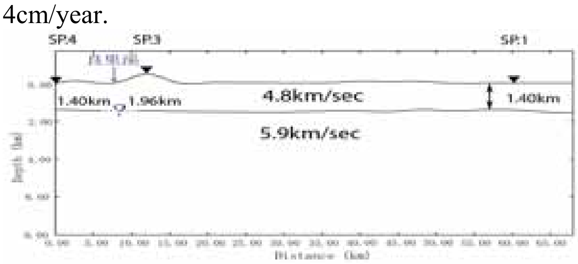

Fig. 1.1 Sub-surface structure along the Valley

1.4 Results and Discussion

Lineaments extracted from the optical image, have been collected. It was confirmed based on the interpretation that there exist active faults in north part of Huatung valley. The locations of the lineaments are clearly matched with most of the active faults in the Coastal Range. As for distribution of lineaments, we have manually extracted lineaments existing in mountain range. Lineaments are concentrated in the mountain areas, some of them are matched with the specific faults. Statistical lineament analysis is under processing. Interferometric analysis, a repeat-pass interferometric approach was applied in order to evaluate the continuous crustal movement, which has been confirmed by many actual geophysical measurements. Recently, expected fine results were not obtained from our repeat-pass interferometric analysis yet because of the relatively poor fringe quality of one of the interferograms. According to the second result (Fig.ure1.2), the displacement values seem to be better than the first results. But, in 2006 result, you can easily find the distribution of each displacement with less topographic effects in the entire target area.

We have recognized this difference come from the quality of phase images. The first phase image was different quality phase and the second was the same quality. That comes the difference between the results. We can recognize a variety of distribution of displacement patterns individually. These are the range of -2.8cm to +2.8cm. We are now searching the combination of ENVISAT/ASAR new archived data and the ALOS/PALSAR data to compare with ENVISAT/ASAR result. Precise quantitative crustal movement values will be reported in the future presentation. As for the plate motion, according to the recent research results, the estimated displacement value is approximately 7.4cm per year (Seno et al, 1994). In addition, Dahan Institute of Technology has observing the distances between the Central Mountains and the Coastal Mountains since 1996 using Electronic Distance Meter (EDM) at the area of Shoufeng located in the northern Huatung Valley.

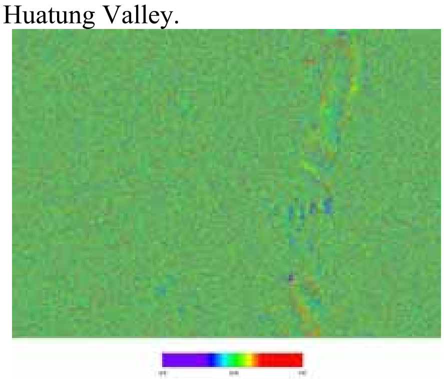

Figure. 1.2 Acquired displacement values

2. APPLICATION AND VALIDATION USING ALOS/PALSAR TRIHERENCE METHOD

2.1 Introduction

Landslides can often be preceded by some more subtle movements (of the order of 10 cm). Under this assumption, satellite-based techniques can be very useful if they can detect these small movements of the ground surface. SAR interferometry is known to produce very accurate estimates of ground surface movements in open areas where the surface structure remains constant from scene to scene. In forested areas, the relative movement of tree branches and tree trunks cause that the origins (scattering centres) do not stay constant from scene to scene. Still, forests have some patches (very low-density forest or openings within forest) that could be relatively stable. These stable patches could ideally be used for a land surface monitoring technique aimed at an early warning of potential landslides, especially by averaging SAR data pixels to get reliable phase information to identify stable pixels or patches. Identification of a drop in phase stability, by analyzing phase distribution within an averaging window, can be used as an alert trigger.

SAR interferometry (InSAR) and differential interferometry (D-InSAR) have been often used to monitor ground stability in the context of earthquakes [1], subsidence [2] and, landslides [3]. Techniques like Permanent Scatterers (PS) [4] or Interferometric Point Target Analysis (IPTA) [5], based on the coherent response from targets stable over long time period have found a large and positive echo for monitoring landslide prone areas. If the analysis of phase stability is based on coherence between two images there is a possibility that pure chance causes some areas (in large SAR scenes) identified as stable. If three images are used this chance is reduced. This observation led to the development of a tool called Triherence [7] and [8].

The objective of this project is to analyze the phase stability on coherence between three repeat pass images, called Triherence here after, using ALOS PALSAR data. In particular, the effects of improved signal-to-noise ratio and orbit control (compared to JERS-1) and a more suitable wavelength (compared to Envisat/ASAR) are evaluated. In the following sections, the principle of interferometric Triherence is first introduced and then, past experimental results using Envisat ASAR (C-band) data are reviewed. The characteristics of ALOS/Palsar and the systematic acquisition plan are discussed from the point of view of land stability monitoring using Triherence. Test sites are also presented.

2.2 Interferometric Triherence

In a pair of SAR images, acquired in interferometric conditions, indicator of phase stability can be derived like the classical interferometric phase coherence γ [6]:

$$\gamma = \frac{\langle p_1 p_2^* \rangle}{\sqrt{\langle p_1 p_1^* \rangle \langle p_2 p_2^* \rangle}} \qquad (1)$$

Here <...> denotes ensemble averaging within an averaging window and * denotes complex conjugate (i.e. if a complex number x = a +b j, then x* = a – b j). Pixels of the scenes of a scene pair are denoted by complex numbers p_1 and p_2. Coherence is defined for two scenes only. If longer period phase stability must be monitored or measured, some other variables have to be used. For this purpose, a measure was adopted [7] and [8] to describe the phase stability between two interferometric pairs (i.e. within a triplet of scenes). This measure η, which is later called triherence, is computed as in:

$$\eta = \frac{\langle (p_1 p_2^*)(p_2 p_3^*) \rangle}{\langle p_2 p_2^* \rangle \sqrt{\langle p_1 p_1^* \rangle \langle p_3 p_3^* \rangle}} \qquad (2)$$

Here p_3 denotes the complex pixel value of the third scene of the triplet. It is assumed that small ground surface movements in such points between scene acquisitions modify or destroy completely the phase stability (Figure 2.1). The upper sub-figure of Figure 2.1 shows a land area that contributes to a single triherence observation. If there is a small movement of one part of the area (sub-area d in Figure 2.1) the phase difference between scattering components from d and the other sub-areas changes. This lowers the triherence in those triplets where a part of the scenes are acquired before the land surface movement and another part after the land surface movement.

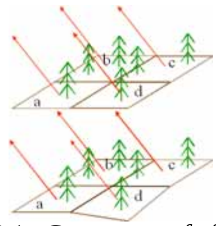

Figure 2.1 Geometry of four-pixel blocks for land surface monitoring: undisturbed (upper) or with a small disturbance in block d (lower).

2.3 Prior experimental results

Tests were performed ([7] and [8]) on ENVISAT ASAR and JERS-1 datasets over two sites in Japan (Tanzawa, close to Tokyo, and Aso-Unsen, in the volcano area in the Southern part of the country). Data pre-processing was realised with VEXCEL FOCUS module, to generate single look complex images from raw data. Repeat pass pairs were selected, with respect to acquisition time and estimated baselines. Accurate baseline computation and image co-registration were realised with VEXCEL PHASE module. Various quantities were then computed for each triplet, using a 7x2 averaging window (Azimuth x Range): interferometric coherence between images 1 and 2, and images 2 and 3; interferometric triherence; interferometric phase of image pairs and triherence.

The presentation of results is limited to the Aso-Unzen test site, where 5 ENVISAT ASAR scenes from 11.03.2005 to 29.07.2005 (Figure 2.2) and 4 JERS-1 scenes from 13.02.1995 to 08.08.1993 were available to generate 3 triplets. SAR images and derived information (*i.e.* triherence images) were ortho rectified using available DEM and VTT in-house software.

Color composites of triherence values were used for a visual evaluation of stability of triherence scatterers over time. The cumulative histogram count was used as a scaling input for displaying triherence layers. Triherence values from 0 to the 98% histogram point were scaled to zero, whereas triherence values over the 98% histogram point were scaled (linear scaling) to values between 129 and 255. Either a Landsat ETM+ mosaic (from the Global Land Cover Facility) or a SAR amplitude image was used as a background to locate high triherence scatterers. The combination of three triherence images finally resulted in a map of the highest triherence scatterers over the study period. Following additive color synthesis principle, it enables to identify the scatterers (as white pixels) that remain stable over the study period. Results from coherence and triherence computations using the ASAR data of the Aso-Unsen study site are shown in Figure 2.2. Coherence between the first and second ASAR scenes (Figure 2.2 a) shows stronger dynamics than coherence between second and third image (Figure 2.2 b). Triherence over this first triplet (from 11.03.2005 to 20.05.2005) tends to summarize efficiently the two coherence layers, by highlighting more clearly stable areas over the time period.

As expected, most of the long-term coherent points are located in urban areas. High scattering points are also identified in natural areas and may correspond to open areas in forests or isolated buildings (Figure 2.3, left). Comparison of the successive triherence images shows that seasonal effects of vegetation on the highest scatterers in vegetated areas are quite high. Seasonal variations have mainly two consequences: 1) there are very few stable points in natural areas and 2) nonpersistence of triherence scatterers over time.

Color composite (triplets 1, 2 and 3 in RGB combination) of samples of high-triherence points are shown on a Landsat ETM+ image (Figure 2.3, left) and on a black-and-white ASAR amplitude image scaled between values 0 and 128 (Figure 2.3, right). Most of the stable triherence scatterers (white dots) are in agricultural areas and villages in the valley areas around Mount Aso. The areas around higher peaks of the mountain have only very few of such stable scatterers. As these areas are dominated by low vegetation or open rock surfaces, the lack of stable points is surprising.

One possible reason why C-band and even L-band SAR data (wavelength 23 cm) looses phase coherence over a few months is related to stability of the ground in the volcanic area. If there are even small earthquakes between image acquisitions, these may cause erosion on steep slopes, which leads to movements of a few centimeters. This destroys the phase stability. Rain-induced erosion can also be a reason for lack of phase stability. Another reason could be some changes in soil moisture conditions in grass-covered areas. Further understanding of the distribution of high-triherence points would require better knowledge about the ground conditions in and around those points where high-triherence points were observed.

Numbers of points with high and stable triherence were found both in agricultural/urban areas and on mountain slopes. However, those points were surprisingly rare on the slopes of Mt. Aso, mainly covered by low vegetation. The main foreseen explanation for the lack of stable triherence points could be erosion and minor earthquake activity in this active volcanic area.

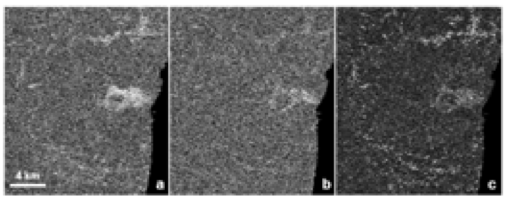

Figure 2.2 Interferometric coherence between the first and last two scenes in a triplet (a, b) and interferometric triherence over the whole triplet. ASAR data in Mt. Aso area.

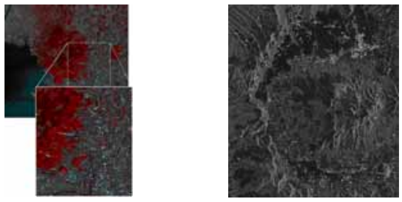

Figure 2.3 High-triherence points in Kumamoto urban area (left) and in the Mt. Aso area (right).

Even very low earthquake activity can cause small erosion on steep slopes, which can then destroy the phase stability of SAR images. Another potential explanation is changes in soil moisture conditions. Further research is required to better understand the mechanisms that produce high-triherence points on one hand and the mechanisms that prevent these points on the high slopes of mountains in the study sites.

REFERENCES

[1] Wegmüller U. and Werner C. 1995. SAR interferometric signatures of forest, IEEE Transactions on Geoscience and Remote Sensing, Vol. 33, No. 5, September 1995, pp. 1153-1161.

[2] Henry, J-B., Rauste, Y., Louhisuo, M., and Häme, T. 2006. NIED-VTT Joint research project Triherence 2005, Final report, version 1.0, VTT Technical Research Centre of Finland, January 2006, unpublished project report, 35 p.

[3] Rauste, Y., Louhisuo, M., Henry, J-B. Kuzuoka, S., Morohoshi, T., Häme, T. 2006. Interferometric triherence for ground movements monitoring, Proceedings of IEEE International Conference on Geoscience and Remote Sensing Symposium IGARSS 2006, Denver, Colorado, USA, 31.7.-4.8.2006, p. 1883-1885.

[4] A.Iwashita and M. Qong, “Disaster area extraction4algorithm development using repeat-pass SAR interferometry,” Proc. IGARSS05, Korea, July, 2005.

[5] A. Iwashita, M. Kudo H. Baba, T. Morohoshi, “Study of ground surface displacement estimation using ALOS/PALSAR D-InSAR Interferometry,” Proc. IGARSS07, Barcelona, July, 2007.