A Study of Detection of Landslide Disasters due to the Pakistan Earthquake using ALOS data

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Abstract – On October 29, 2008, magnitude 6.4 earthquake occurred in a area of western Pakistan. One of the Japanese earth observation satellite, Advanced Land Observing Satellite (ALOS), observed this area by all onboard sensors, AVNIR-2, PRISM, and PALSAR. By optical imagery, AVNIR-2 and PRISM imagery, huge landslide (rock slide) and landslide dam were confirmed by visual interpretation. And also this landslide can be confirmed by PALSAR imagery. Using optical imagery and PALSAR data, the amount of deformation of landslide was analyzed. Especially, PALSAR DInSAR analysis performed well to detect landslide movement that cannot detect by optical imagery. However, some landslides was not detected clearly by PALSAR DInSAR analysis. Through these analyses, the applicability of ALOS data for landslide detection is discussed in this paper. And using both optical imagery and PALSAR DInSAR imagery, landslide disasters of the 2008 Pakistan earthquake is evaluated.

Keywords: Pakistan, Earthquake, ALOS, DInSAR, Landslide

1. INTRODUCTION

On October 29, 2008, magnitude 6.4 earthquake occurred in north-western Pakistan. One of the Japanese earth observation satellite, ALOS, observed earthquake affected area by its onboard sensors, AVNIR-2, PRISM, and PALSAR. In order to understand applicability of each sensor for landslide detection, several analytical methods were applied. In this paper, especially, applicability of DInSAR analysis and landslides due to earthquake was evaluated.

1.1 Overview of ALOS

ALOS (Ichitsubo et al., 2003; Matsumoto et al., 2003; Tadono et al., 2004) is one of the Japanese earth observation satellites which had launched on 24 January 2006. ALOS stands for "Advanced Land Observation Satellite". ALOS carries two optical sensors, AVNIR-2 and PRISM, and L-band active micro wave synthetic aperture radar, PALSAR. AVNIR-2, Advanced Visible and Near Infrared Radiometer type 2, is a multi-spectral sensor with 10 m spatial resolution. PRISM, Panchromatic Remote sensing Instrument for Stereo Mapping, is a panchromatic sensor with 2.5 m spatial resolution. And it has three telescopes fixed to different observation angle, forward, nadir, and backward, in order to generate 3-D terrain model. PALSAR, Phased Array type L-band Synthetic Aperture Radar, is active microwave radar sensor which has cloud free, day-and-night observation, and interferometry capacity. Objectives of ALOS mission are cartography, regional observation, disaster monitoring, resource surveying, and technology development for future mission. ALOS have been contributing to some disaster monitoring activities and frameworks (i.e. International Charter Space & Major Disasters, Sentinel Asia, etc.), and it has been observing effective date and imagery for domestic and international disaster activities.

1.2 Overview of 2008 Pakistan earthquake

On October 29, 2008, magnitude 6.4 earthquake occurred in north-western Pakistan. Based on the report of USGS (USGS Website, 2008), earthquake epicentre was located at 30.656°N and 67.361°E, 60km north-east of Quetta,, Pakistan. Figure 1 shows the location map of the earthquake. By this earthquake, one hundred sixty-six people killed, 370 injured and several villages destroyed in Balochistan. Several villages destroyed by landslides in the Ziarat area. A total of 3,487 homes destroyed and an additional 4,125 homes damaged in the Harnai area, Pishin and Ziarat. Felt (VI) at Quetta. Felt strongly in Bolan, Kalat and Qila Saifullah; and at Loralai, Mach, Mastung, Muslimbagh, and Surab. Felt (III) at Kandahar, Afghanistan.

Figure 1. Location map of the 2008 Pakistan earthquake. (A red star mark shows earthquake epicentre.)

2. METHODS

In this research, both optical and SAR data was used. In order to analyse each data, several methods were applied. Offset tracking for optical imagery was used to analyse deformation amount of landslide. And differential SAR interferometry, DInSAR, was also used to analyse deformation amount of landslide. Moreover, normalized sigma-naught index, NDSI, was proposed to detect landslide area.

2.1 Offset Tracking for Optical Imagery

In order to detect landslide deformation from optical imagery, offset tracking method was applied. Two optical images were used for analyses, and SSDA (Sequential Similarity Detection Algorithm) method was used to search conjugate points between a pair of images. In SSDA method, similarity of pixel value of a pair of images is decided by residual error. And conjugate point can be determined by the coordinate of minimum residual correlation of specified area. SSDA as expressed by following equation.

$$S_{ij} = \sum_{u=1}^{m}\sum_{v=1}^{l}\left|f(u,v) - t(u,v)\right| \qquad (1)$$

where S_{ij} = residual error

i, j = coordinate of image pixel
$f(u, v)$ = pixel value of image1
$t(u, v)$ = pixel value of image2

2.2 DInSAR

DInSAR, Differential SAR Interferometry, is a method for extract topographical change information from SAR data (Graham, 1974; Zebker et al., 1986; Li et al., 1990). In DInSAR analysis, difference of phase difference of a pair of SAR data and simulated topographic phase based on reference digital elevation model (DEM) is calculated. Total phase difference is expressed by following equation.

$$\phi_{total} = \phi_{orbit} + \phi_{topography} + \phi_{deformation} + \phi_{noise} \quad (2)$$

where ϕ = phase difference

In order to detect phase difference of deformation, phase difference of both orbit and topography should be subtracted from total phase difference. Phase difference of orbit can be estimate by orbit information. And phase difference of topography can be estimated by reference digital elevation model (DEM) as SRTM, GDEM, and so on. By the estimation of phase difference of both orbit and topography, phase difference of deformation can be detected as following equation, equation 2. By equation 2, surface deformation can be detected with less than half of wave length resolution.

$$\frac{\partial\phi}{\partial D_x} = -\frac{4\pi}{\lambda}\sin\theta \qquad \frac{\partial\phi}{\partial D_y} = -\frac{4\pi}{\lambda}\cos\theta \quad (3)$$

where ϕ = phase difference
D_x, D_y = deformation content
λ = wave length of microwave (23.8 cm by ALOS PALSAR)
θ = local incidence angle

2.3 NDSI

Pixel value of SAR amplitude image can convert to physical value of SAR data that sigma naught. In case of ALOS, pixel value of amplitude image can be converted to sigma naught value as equation 4. Normally, in order to analyse difference of two images, subtraction of sigma naught value is applied. For the comparison purpose, normalized method is proposed as equation 5.

$$\sigma_0 = 10 \cdot \log_{10}\left\langle DN^2 \right\rangle + cf \quad (4)$$

$$\text{NDSI} = \frac{\sigma_0^m - \sigma_0^s}{\sigma_0^m + \sigma_0^s} \quad (5)$$

where σ_0 = sigma naught value
DN = digital number of pixel value
cf = correction factor
m, s = master, slave

3. RESULTS AND DISCUSSION

Earthquake affected area was acquired by ALOS/AVNIR-2, PRISM, and PALSAR. In order to detect landslide due to the 2008 Pakistan earthquake, acquired imagery was compared. And several analytical methods were applied to acquired data in order to understand applicability of each analytical method for landslide detection. In this paper, following data was used which shown in table 2.

Table 2. Utilized data for this study.

Sensor	Observation date	Satellite direction	Pointing / Off-nadir angle
AVNIR-2	2008/09/22 2008/11/07	Descending	0 degrees
PRISM	2008/09/22 2008/11/07	Descending	0 degrees
PALSAR	2008/01/22 2008/12/12	Ascending	34.3 degrees

3.1 Analysis by optical imagery

Figure 2 shows comparison of ALOS/AVNIR-2 and PRISM imagery of pre- and post- earthquake. In figure 2 (b), post-earthquake imagery of PRISM, a sign of landslide (scarp) can be seen. Yellow allow shows the position of scarp in figure 2 (b). This scarp can be seen in figure 2 (d) that post-earthquake imagery of AVNIR-2. And landslide dam can be seen in figure 2 (d). The size of the landslide is approximately 2 km. In order to understand amount of deformation of this landslide, offset tracking method was applied. Figure 3 shows the result of offset tracking analysis. From this result, approximately 50 m deformation was detected.

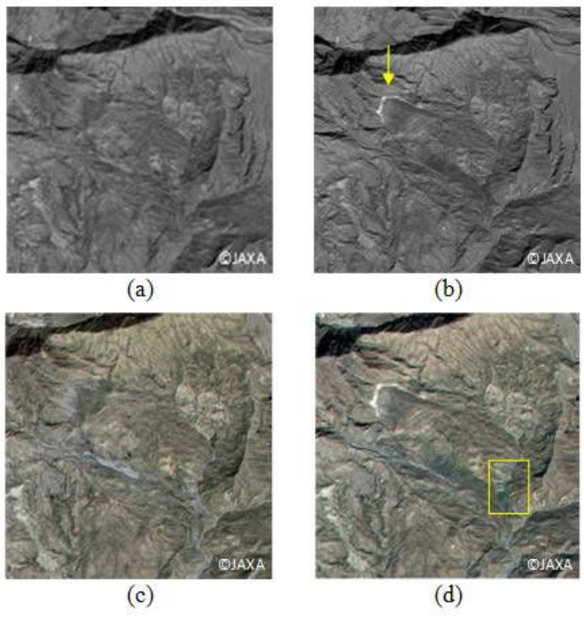

Figure 2. Comparison of optical imagery of pre- and post-earthquake.: (a) pre-earthquake imagery of PRISM, (b) post-

earthquake imagery of PRISM, (c) pre-earthquake imagery of AVNIR-2, (d) post-earthquake imagery of AVNIR-2

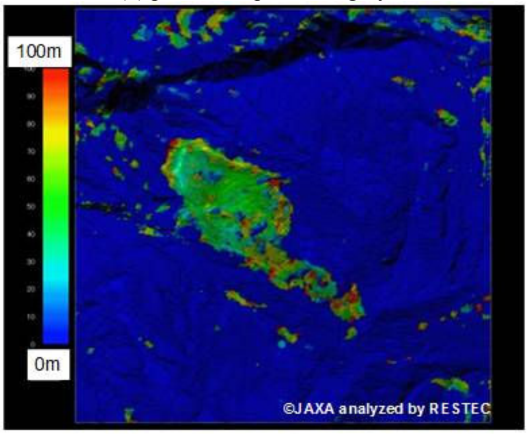

Figure 3. Result of offset tracking analysis of PRISM image.

3.2 Analysis by SAR imagery

Figure 4 and 5 shows result of comparison of SAR images and analyses. In figure 4, site-1, large scale deformation could be confirmed as well as optical imagery. Especially, landslide area was detected clearly by NDSI analysis. However, landslide deformation wasn't detected by DInSAR analysis because the amount of landslide deformation is very large that confirmed by offset tracking analysis of PRISM imagery. This result shows the importance of application of NDSI analysis with DInSAR analysis. In figure 5 landslide area and its deformation couldn't be confirmed by image interpretation and NDSI analysis. However, phase change with half cycles, approximately 6 cm deformation, was detected by DInSAR analysis. In these cases, applicability of DInSAR analysis was confirmed because it is difficult to identify landslides by image interpretation or NDSI analysis. This result shows the importance of application of DInSAR analysis for the landslide detection. From the analysis of SAR, importance of application of several analytical methods for landslide detection was confirmed.

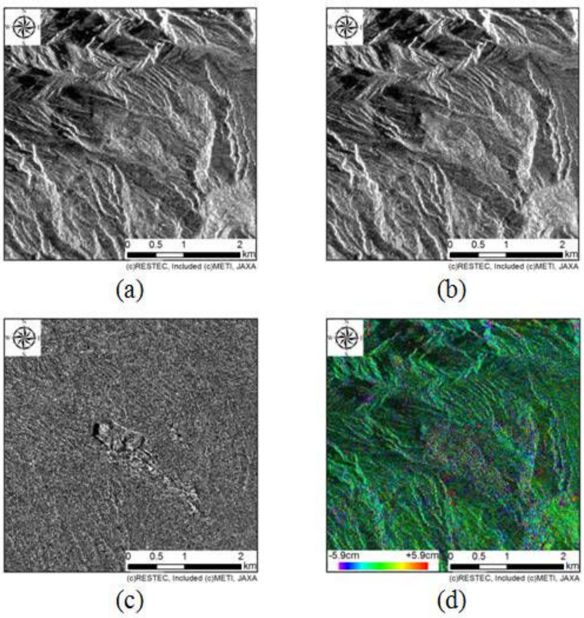

Figure 4. Comparison of SAR imagery and analytical imagery of site-1. : (a), (b) PALSAR imagery of pre- and post-earthquake, (c) result of NDSI, (d) result of DInSAR

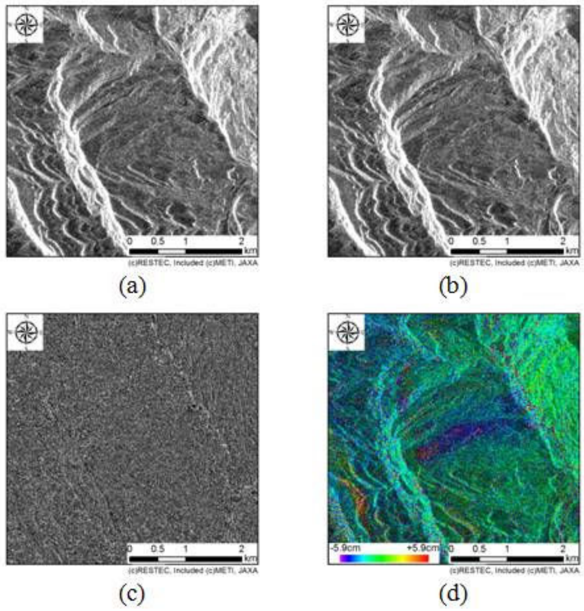

Figure 5. Comparison of SAR imagery and analytical imagery of site-3. : (a), (b) PALSAR imagery of pre- and post-earthquake, (c) result of NDSI, (d) result of DInSAR

4. CONCLUSIONS

Landslide disaster due to the 2008 Pakistan earthquake was analysed using ALOS AVNIR-2, PRISM, and PALSAR data. From AVNIR-2 and PRISM imagery, landslide scarp was interpreted. And landslide deformation was detected by offset tracking analysis of PRISM data. However, this landslide wasn't detected by DInSAR analysis. But, landslide area was detected by NDSI imagery. On the other hand, a few landslides deformation were detected by DInSAR which couldn't be identified by optical and SAR imagery. From this result, importance of utilization of several analytical methods for landslide detection was confirmed.

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