CONTINUOUS MONITORING OF LANDSLIDES AREA CAUSED BY IWATE-MIYAGI NAIRIKU EARTHQUAKE IN 2008 USING ALOS IMAGES

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ABSTRACT:

The Iwate-Miyagi Nairiku earthquake struck inland area in northern Japan on June 14, 2008. This earthquake triggered landslides in mountainous area. The landslides changed land coverage from forest to bare soil. Aftermath of the disaster occurrence, many satellites observed target area to identify the damage. In this study, we report on long-term observation for damaged area using ALOS satellite after the earthquake occurrence. The landslide on north of the Aratozawa-dam lake is the largest one by this earthquake. The landslide area is identified by PALSAR single polarization intensity image. Sediments by the landslide were deposited into the dam lake and they caused rise of water level immediately after the earthquake. Temporal change of water level is observed by PALSAR single polarization intensity images. Normalized difference calculation from two of AVNIR-2 band 3 data is helpful to extract temporal change of landslide area. Pan-sharpen image of AVNIR-2 and PRISM is effective to extract small scale change on the damaged area. Satellite remote sensing data is records of reconstruction process and secondary damage for time span of several years.

1. INTRODUCTION

An earthquake hit inland area of Iwate and Miyagi prefectures in Northern Honsyu, Japan at 8:43 AM (JST) on June 14, 2008. Magnitude as determined by the Japan Meteorological Agency was Mj 7.2. The earthquake was named Iwate-Miyagi Nairiku Earthquake. The epicenter was located at 39.03 N, 140.88 E, on the south of the inland part of Iwate prefecture. Seismic intensity by Japanese meteorological agency was 6-plus in Oushu city, Iwate and Kurihara city, Miyagi. The earthquake caused massive landslides on mountainous area. Landslides expanded around Mt Kurikoma, in Oou mountain range. Seventeen people were died and 6 people were missing by this earthquake and most of the victims were killed by the landslides. The landslides caused dam up of rivers, collapse of artificial dams and closure of roads.

Immediately after the earthquake, ALOS (Advanced Land Observing Satellite) and other satellites had been observed the damaged area for the disaster assessment. Landslide areas caused by this earthquake were interpreted from aerial photograph (Kisanuki et al., 2008). We previously reported about agricultural damages observed by ALOS data (Yonezawa et al., 2009; Yonezawa and Kato, 2009). Increase of surface scattering component on the landslide area from before to after the earthquake was found from analysis of PALSAR full polarimetric data (Watanabe et al., in printing).

After the earthquake, reconstruction and recovery processes started on the damaged area. The damaged area should be monitored to avoid secondary landslide by rainfall and snow cover melting. There are few studies about the continuous monitoring of damaged area using satellite imagery after a disaster. In this study, we report on continuous observation for typical damaged areas using ALOS data through 2008 to 2009. ALOS has two optical sensors, PRISM and AVNIR-2, and one synthetic aperture radar, PALSAR. All of these three sensor data were analyzed in this study.

2. STUDY AREA

The main land coverage of the damaged area was forest. Many landslides were caused by this earthquake in mountainous area. Most of the landslides expanded approximately 25 km by 38 km region. The largest sediment disaster caused by this earthquake was the landslide on north of Aratozawa-dam lake, in Kurihara-shi, Miyagi prefecture. This landslide area expanded approximately 0.9 km by 1.3 km. Several large scale landslides occurred on south east side slope for Mt Kurikoma. On Dozou-sawa, a mudflow with 1.5 million sediments destroyed forest area through a valley (Kisanuki et al., 2008). The second largest landslide occurred at upstream of Ubuzume-gawa. Another landslide concentrated area was upstream of Ichihazama-river, on south slope of Mt Kurikoma. Several landslides triggered formation of landslide dams. The largest landslide dam by this earthquake was formed on upstream of Yabitsu-dam. The images observing these damages are examined.

After the earthquake, roads on the damaged region were closed by landslides. The reconstruction of these damages has been progressed, however, several roads have been still closed at two years past the earthquake occurrence. We carried out ground survey on this region for several times.
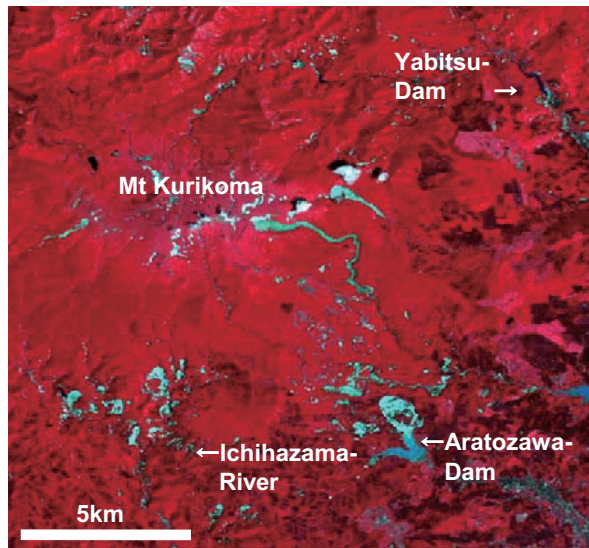
Figure 1   AVNIR-2 image obtained on 2 July, 2008 for damaged area by the Iwate-Miyagi Nairiku earthquake. R:band4, G:band3, B:band2.

3.   DATA AND DATA ANALYSIS

Immediately after the earthquake, imageries of which cloud coverage was less than 10% were obtained on 2 July 2008 by PRISM and AVNIR-2.

AVNIR-2 images obtained on 17 September 2008, 4 December 2008, 8 December 2008, 18 April 2008, 17 May 2009 and 17 October 2009 were also used for visual interpretation. From November 2009 to May 2010, target area was covered by cloud when ALOS observed.   Two AVNIR-2 images obtained different time were compared to detect temporal change.   For change detection, normalized difference was calculated from band 3 of two images.   Wave length of Band 3 on AVNIR-2 is 0.61~0.69μm, and bare soil area showed higher reflectance than forest area.   Band 3 showed the largest difference at the area where land cover change from forest to bare soil is found between before and after the earthquake image in all four bands. PRISM imageries that cloud effect was small were obtained on 1 March 2007, 15 November 2007 and 17 May 2008. Simultaneously observed PRISM and AVNIR-2 images were pan-sharpened by modified HSI conversion method.

PALSAR had been observed target area for many times with single polarization, dual polarization and full polarization mode. The data obtained before the earthquake with same orbit and off-nadir angle were compared with the data after the earthquake.   The Level1.0 single and dual polarizatoin data was processed to intensity imagery by JAXA SIGMA SAR software.

4.   RESULTS AND DISCUSSION

4.1   Landslide on Aratozawa-dam

Sediments by the landslide on Aratozawa-dam were deposited in the dam lake and caused big rise of water level.   After the earthquake, water in the dam has been drained for boring survey.   Total sediment was 4.17 million m^3 and a recovery task force decided to remove a part of them.

Deforestation caused by the landslide is observed by AVNIR-2 images.   This landslide caused landform deformation and it

appears on PALSAR intensity images.   Figure 2 shows PALSAR intensity images for Aratozawa-dam from descending orbit with off-nadir angle of 34.3 degree.   Figure 2 (e) was
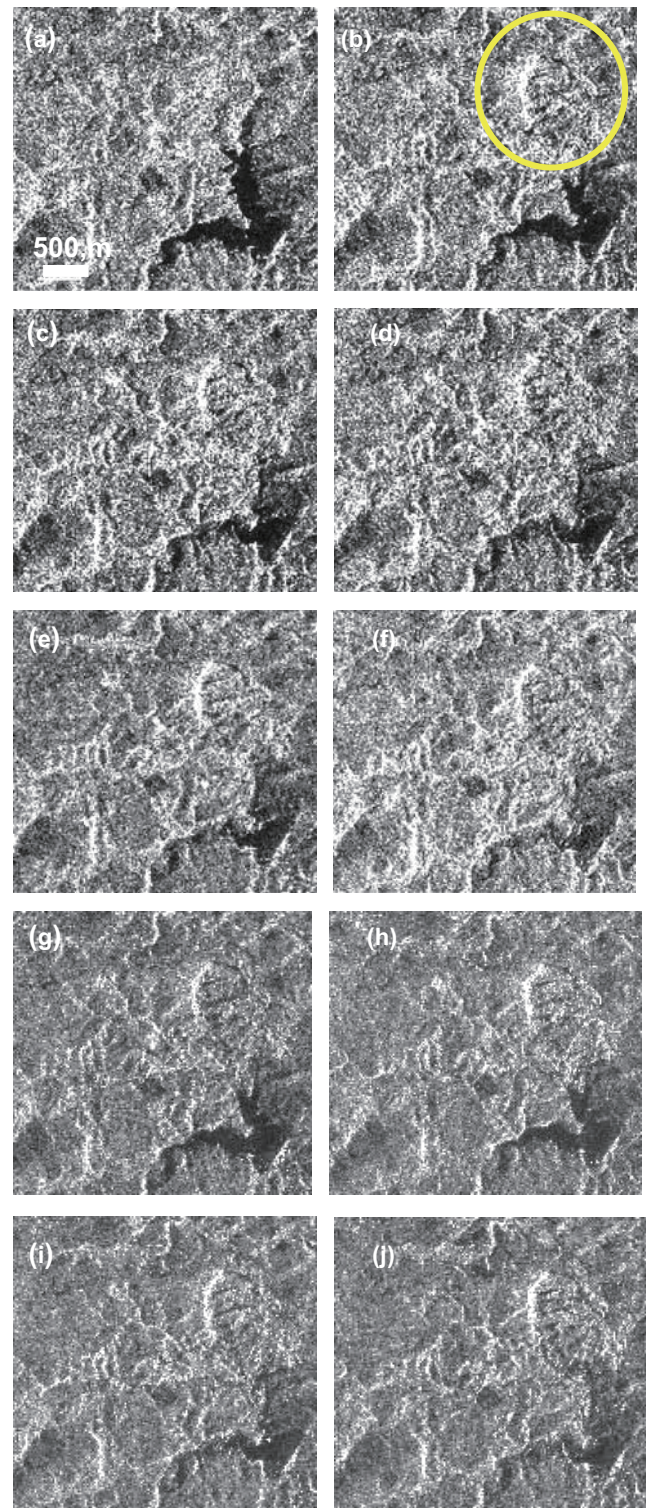

Figure 2. PALSAR intensity images for Aratozawa-dam with off-nadir angle 34.3 degree, descending orbit. (a) 17 October, 2006, (b) 2 July, 2008, (c) 17 September, 2008, (d) 4 December, 2008, (e) 1 December, 2008, (f) 16 January, 2009, (g) 3 June, 2009, (h) 19 July, 2009, (i) 3 September, 2009, (j) 4 December, 2009. A yellow circle denotes massive landslide area.

obtained by dual polarization mode. Other images were obtained by single polarization mode. Yellow circle denotes landslide area caused by the earthquake.

Temporal changes of water level were observed PALSAR images obtained after the earthquake. Decrease of the water level is observed on September 2008 image. Increase of water level is found at April 2009. Decrease appears again in the image obtained on September 2009. The water level had been low on December 2009.

4.2 Landslide on south-east slope of Mt Kurikoma

The landslides on south-east slope of Mt Kurikoma are clearly detected by comparison of the images before and after the earthquake. AVNIR-2 images clearly reveal the landslide areas. The damaged areas are observed by PALSAR image obtained by single, dual and analysis result of full polarization data (Watanabe et al., in printing; Yonezawa et al., 2008). On single polarization intensity images, landslide on Komanoyu-Spa area is detected as landform deformation. However, it is difficult to detect the whole of the landslide damages due to fore shortening effect. Land cover change area is detected using dual and full polarization data as scattering mechanism change. There are few AVNIR-2 images observing this area after the earthquake because of effect of the cloud. There are many PALSAR data obtained after the earthquake, however, it is difficult to extract the change process clearly. Spatial resolution of PALSAR data is insufficient for the detection of tiny change.

4.3 Landslide on Upstream of Ichihazama-river

There are many landslides caused by this earthquake on upstream of Ichihazama-river. The road to this area has been closed and ground survey has not been carried out. Normalized difference of band 3 from 2 July 2008 and 17 May 2009 data which were both taken after the earthquake is calculated and shown in figure 3. The area where the normalized difference is low appeared as black colour and this area corresponds to landslides occurred at immediately after the earthquake. High normalized difference area is shown in white and it means large increase of pixel value with temporal change. Several areas possible to be interpreted as expand of bare soil from July 2008 to May 2009, about eleven month after the earthquake. And one of the possible reasons for this change is sediment flow from landslide area. Normalized difference of band 3 data makes clear different area between two data and it is helpful to estimate the change of landslide area.

4.4 Landslide on Yabitsu-dam

A landslide dam was generated on upstream of Yabitsu-dam, Iwate prefecture. Figure 4 shows pan-sharpen image of AVNIR-2 and PRISM data for before the earthquake (1 March, 2007) and after the earthquake (2 July, 2008 and 4 December, 2008). PRISM image was not acquired on 17 May, 2009, therefore AVNIR-2 image is shown in figure 4. By comparison of before and after the earthquake image, landslide area and landslide dam are easily interpreted. Pan-sharpen image of AVNIR-2 and PRISM is useful for visual interpretation.

For temporal change detection after the earthquake, normalized difference is computed from band 3 data of AVNIR-2. The normalized difference computed from 2 July, 2008 and 17 May,
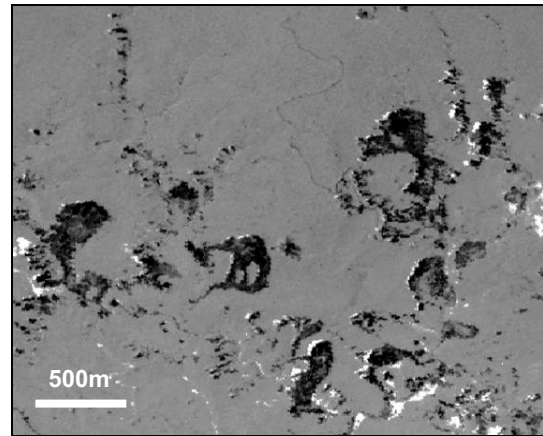

Figure 3. Normalized difference image from 2 July 2008 and 17 May 2009 data on Upstream of Ichihazama-river area.

2009 data is shown in figure 5. Several high value areas reveal cloud effect. Large cloud coverage area is excluded for figure 5. The high normalized difference areas that not related with cloud are surrounded by yellow circles. One of the possible reasons for the high normalized difference is land surface change as expanding of bare soil area. Especially, artificial meandering pattern is found in a circle denoted "a". This pattern is explained as caused by construction of new load.

5. CONCLUSION

In this study, ALOS PRISM, AVNIR-2 and PALSAR data is demonstrated for usefulness to assess the landslide areas after the Iwate-Miyagi Nairiku earthquake. The normalized difference of band 3 from two data both obtained after the earthquake is helpful to estimate the temporal change on after the earthquake. Visual interpretation of pan-sharpen image of PRISM and AVNIR-2 is effective to confirm the area that has possibility for the temporal change. There are many overcast days through a year on the target areas, then few clear image is acquired through one year. Massive landform deformation and water level change on the dam lake are detected by PALSAR intensity images. It is difficult to detect tiny change because of spatial resolution of PALSAR data.

Satellite images will be a record of reconstruction process for time span of several years. It is also expected to observe unstable slopes and sediments. Satellite remote sensing has advantage to observe large area continuously. Assessment of damaged area after the disaster is expected for satellite remote sensing.

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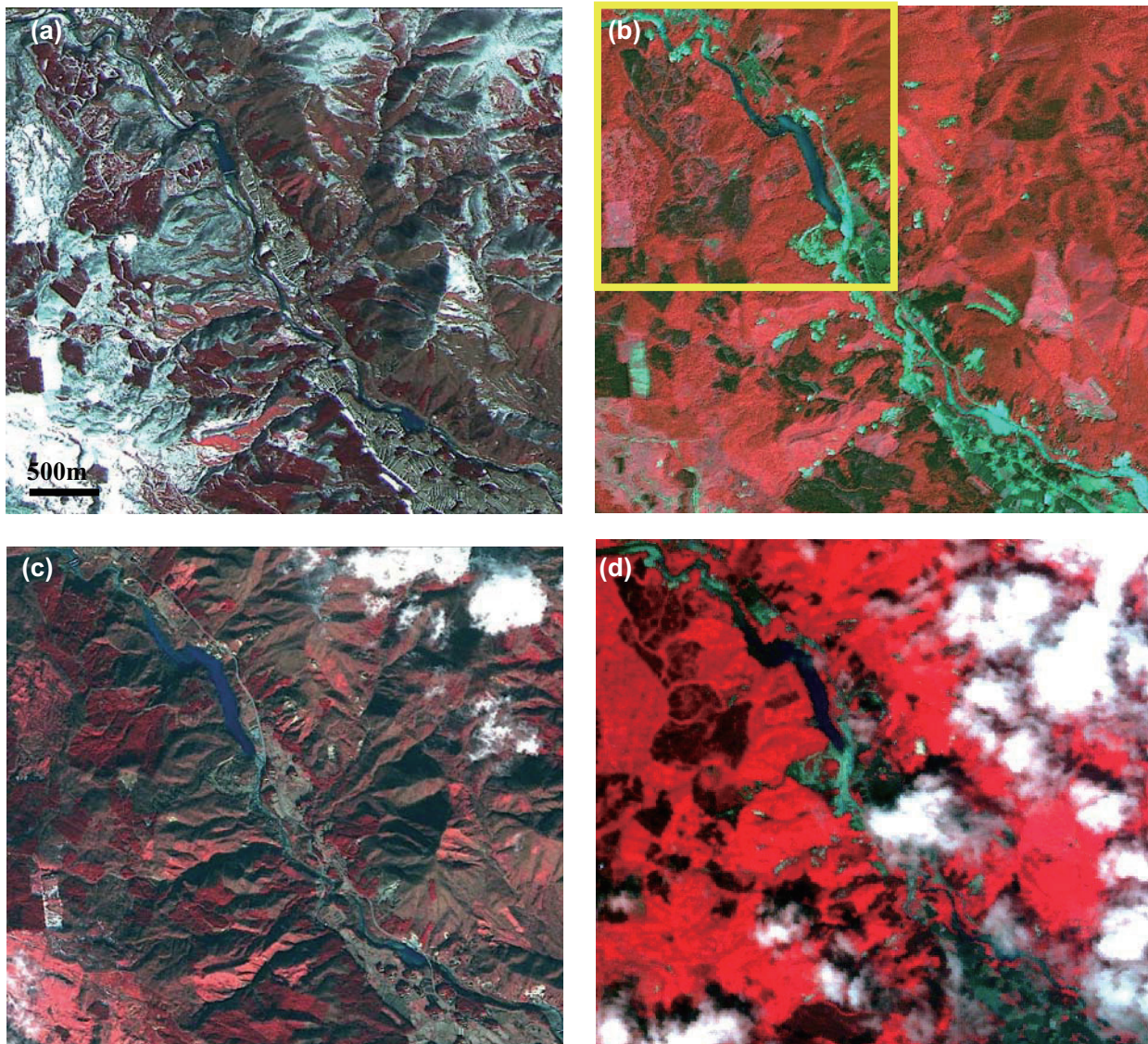
Figure 4. (a), (b), (c) : Pan-sharpen image of AVNIR-2 and PRISM for landslide on upstream of Yabitsu-dam, obtained on (a) 1 March, 2007, (b) 2 July, 2008 and (c) 4 December, 2008. (d) : AVNIR-2 image for same area obtained on 17 May 2009. Yellow square indicates the area shown in figure 5.

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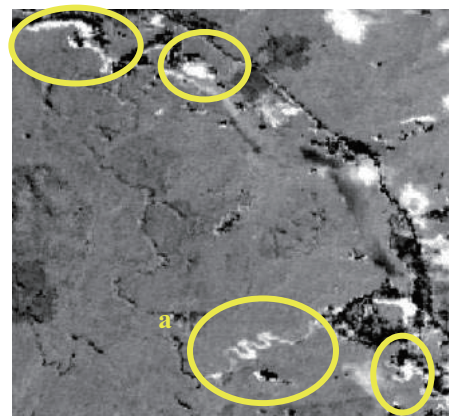
Figure 5. Normalized difference image from 2 July 2008 and 17 May 2009 data on upstream of Yabitsu-dam area. Large changes between two images of which is independent from cloud are yellow circled.