ALOS-2 polarimetric SAR observation of Hokkaido-Iburi-Tobu earthquake 2018

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Abstract: This paper reports prompt space-borne ALOS-2 SAR observation results of Hokkaido-Iburi-Tobu earthquake on 2018/09/06. Emphasis is placed on quick survey for disaster monitoring using fully polarimetric data. On 2018/09/08, ALOS-2 has acquired data over the disaster area. By comparison of the previous data (2017/08/26) before the earthquake, damaged areas by landslides are clearly detected. The analysis is based on the scattering power decomposition, which retrieves scattering mechanism change from bare soil surface caused by landslide and serves to identify the landslide location. The decomposition and anisotropy images are presented to show the effectiveness of fully polarimetric SAR sensing from space.

Keywords: polarimetric synthetic aperture radar, scattering power decomposition, disaster monitoring, landslide detection

Classification: Sensing

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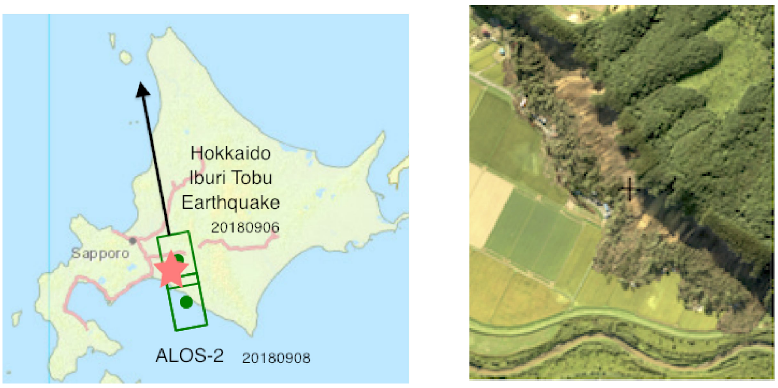
1 Introduction

Hokkaido-Iburi-Tobu earthquake occurred on 2018/09/06 with a magnitude of 6.7 and seismic intensity of 7 [1]. This earthquake destroyed everything for daily life and caused devastating damages, including tremendous landslides of 13.4 km^2 around Atsuma-cho area. Advanced Land Observing Satellite 2 (ALOS-2) was observing the situation on 2018/09/08. ALOS-2/PALSAR-2 is Japanese space-borne synthetic aperture radar (SAR) at L-band developed by JAXA, and has been operating for disaster monitoring [2, 3]. Among various SAR systems and their applications [4], L-band SAR has advantages of penetration of clouds and also penetration into forests, leading to excellent operating capability in all weather condition at anytime for monitoring the earth-cover. Since the data acquisition mode was fully polarimetric, it became possible to retrieve scattering mechanism from the imaging scene, to compare the previous data set on 2017/08/26, and to investigate the difference in this area. Fig. 1 shows the earthquake location and ALOS-2 observation area. This paper reports the prompt imaging results due to the earthquake event.

2 Quad Pol. Data by ALOS-2

The acquired data numbers by ALOS-2 are ALOS2176020840-170826 and ALOS2231910840-180908. The specifications of the data are: off-nadir angle = 28°, Center latitude = 42.34°, Center Longitude = 142.2°, 8950 × 22187 pixels with range pixel size ∼6 m and azimuth pixel size ∼3 m, in the ascending orbit with right direction looking. The data covers approximately 50 km (range) by 70 km (azimuth) as shown in Fig. 1(a). Fig. 1(b) is one of the landslide areas, which has frequently appeared on TV news.



(a) The earthquake epicenter and ALOS-2 data acquisition

(b) Landslide example which frequently appeared on TV.

Fig. 1. Hokkaido-Iburi-Tobu earthquake

3 Decomposition images

We used the time series data sets for polarimetric imaging and change detection based on the four-component scattering power decomposition [5]. The scattering

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power decomposition yields surface scattering power *Ps*, double bounce scattering power *Pd*, volume scattering power *Pv*, and helix scattering power *Ph*. These powers are color-coded to create a full color image which is comprehensive to everybody.

Fig. 2 shows decomposition image over Atsuma-cho area, Hokkaido, using a special RGB color-coding [6] with Red for *Ps*, Green for *Pv*, and Blue for *Pd*. The reason of using this color-coding is to enhance the contrast and to attract attention to the bare soil surface caused by landslide induced by the earthquake. This color-coding enhances the surface scattering by bare soil surface distinctively from other objects and serves to identify the landslide location. Fig. 2 is a movie file comparing with "before" and "after" the earthquake. It is possible to find the changes by color, i.e., by our eye inspection. It is seen in Fig. 2 that Red areas are spread all over the scene due to the earthquake.

Red color areas in Fig. 2 are characterized by the surface scattering power *Ps* dominant due to bare soil surface scattering. The *Ps* has increased significantly (up to 6 dB) in the landslide areas. Since bare soil surface reflects the surface scattering power in omni-direction, it is rather easily picked up by SAR and recognized by color in the decomposition image.

In addition, small mountain ridge moved to the left direction by this earthquake. We can recognize the ridge movement (indicated by a small pink arrow) at the lower left of the 6-th and 7-th images of Fig. 2. Movie image has advantage of showing the movement.

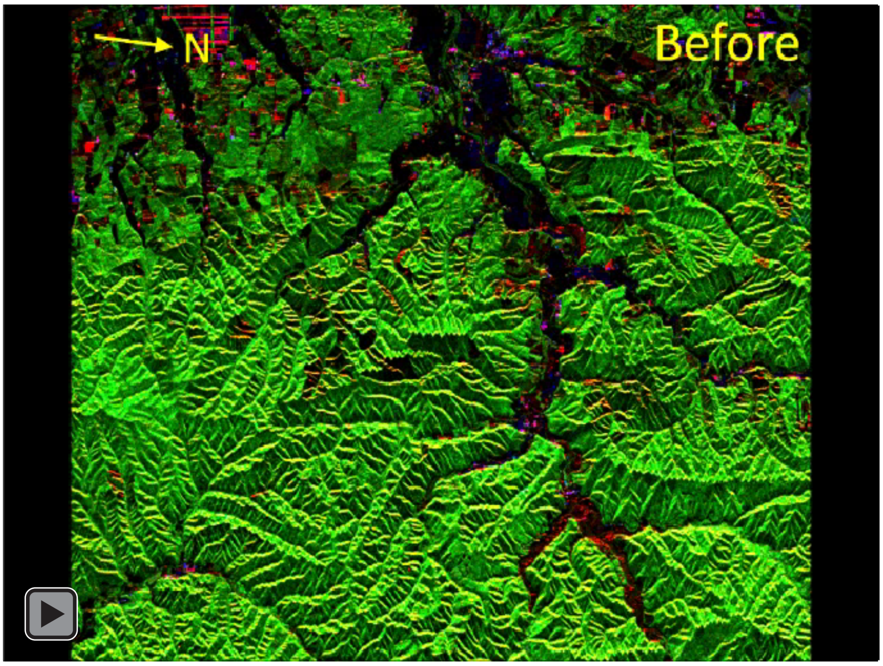

Fig. 2. Scattering power decomposition images before and after the earthquake of Atsuma-cho, Hokkaido. RGB color-coding with R(*Ps*), G(*Pv*) and B(*Pd*).

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4 Change detection

As can be seen in Fig. 2, it is possible to identify the location where color (scattering mechanism) has changed. These changed areas are caused by the earthquake. Some areas have increasing Ps, whereas other areas have decreasing tendency. At the same time, there are also areas with increasing or decreasing Pv. In this section, we try to pick up these areas as much as possible using some polarimetric information.

Fully polarimetric data provides the total power TP, which is the most fundamental radar quantity, accounting for all polarimetric combination (HH, HV, VV) powers.

$$TP = |S_{HH}|^2 + 2|S_{HV}|^2 + |S_{VV}|^2. \tag{1}$$

where S_{HH}, S_{HV}, and S_{VV} are elements of scattering matrix [S]. This value is invariant with respect to change of polarization basis. In the four-component scattering power decomposition [5], it can be also represented as a sum of the surface scattering power Ps, the volume scattering power Pv, the double bounce scattering power Pd, and the helix scattering power Ph.

$$TP = P_s + P_d + P_v + P_h. \tag{2}$$

We can define the following normalized “Anisotropy parameter A” for change detection,

$$A(TP) = \frac{TP^a - TP^b}{TP^a + TP^b}, \tag{3}$$

where the superscript “a” shows “after” the event while “b” means “before” the event. This value falls in the range $[-1, 1]$ and indicates how the total power is changed. This normalized value can be a good indicator for monitoring of disaster area.

In a similar way, we can define the anisotropy parameter A for each scattering power,

$$A(P_s) = \frac{P_s^a - P_s^b}{P_s^a + P_s^b}, \quad A(P_d) = \frac{P_d^a - P_d^b}{P_d^a + P_d^b},$$
$$A(P_v) = \frac{P_v^a - P_v^b}{P_v^a + P_v^b}, \quad A(P_h) = \frac{P_h^a - P_h^b}{P_h^a + P_h^b} \tag{4}$$

$$A(S_{HH}) = \frac{|S_{HH}^a|^2 - |S_{HH}^b|^2}{|S_{HH}^a|^2 + |S_{HH}^b|^2}, \quad A(S_{HV}) = \frac{|S_{HV}^a|^2 - |S_{HV}^b|^2}{|S_{HV}^a|^2 + |S_{HV}^b|^2},$$
$$A(S_{VV}) = \frac{|S_{VV}^a|^2 - |S_{VV}^b|^2}{|S_{VV}^a|^2 + |S_{VV}^b|^2}. \tag{5}$$

By this notation, it is possible to examine the change of scattering mechanisms or of polarimetric channel power. Since these values are normalized in $[-1, 1]$, a simple addition of these parameters may cancel out in some cases. Rather, the magnitude sum of these parameters would yield the change profoundly. Therefore the following parameter may be suitable for the change detection purpose.

$$TA = |A(P_s)| + |A(P_d)| + |A(P_v)| + |A(P_h)| \tag{6}$$

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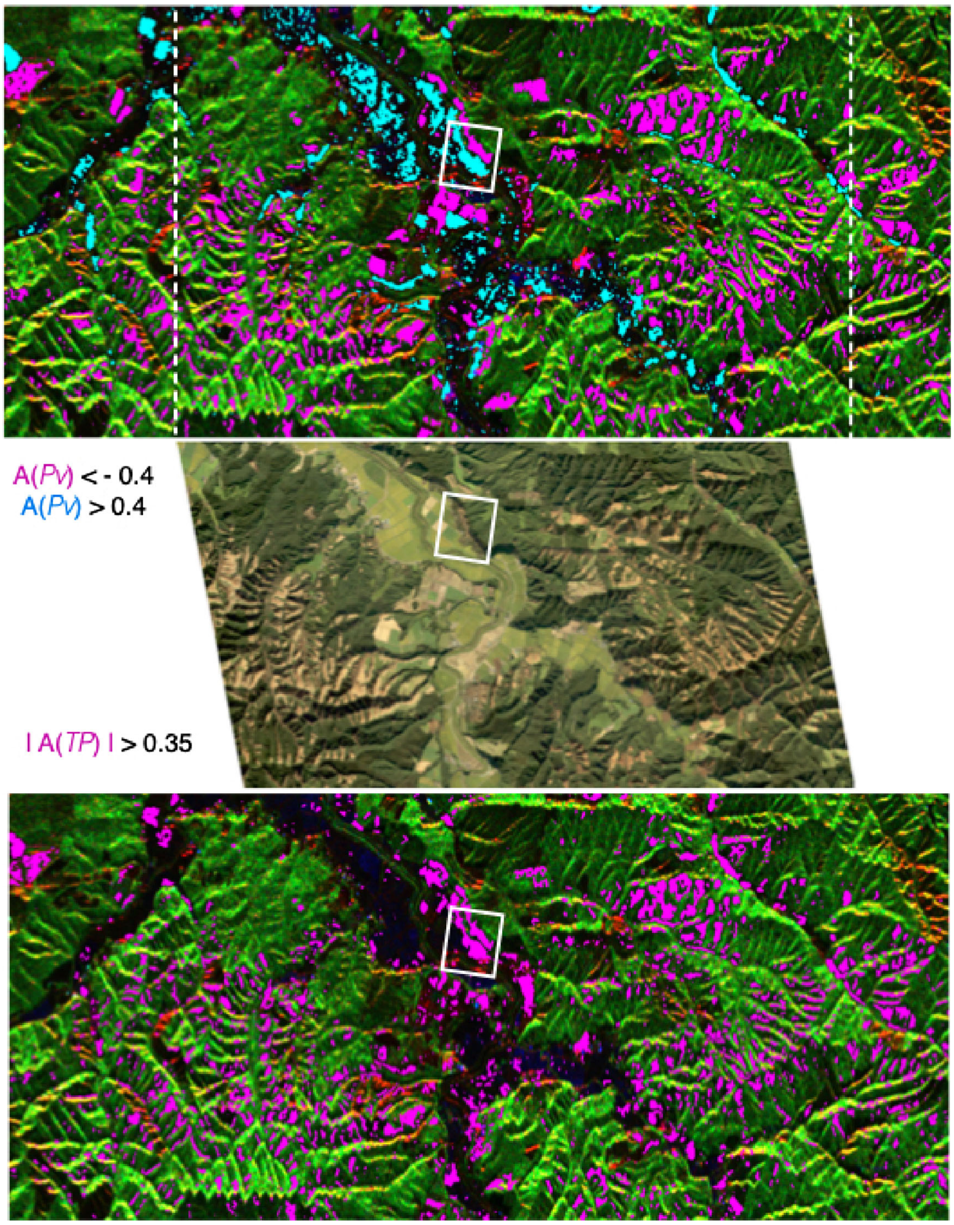

Fig. 3. Change detection result of Atsuma-cho using anisotropy parameter A(*Pv*) and A(*TP*). Pink and Cyan colored areas represent change detection results of before and after the earthquake. Middle image is a partial aerial photo in GSI website [1]. A small white rectangular area corresponds to Fig. 1(b).

Having defined these parameters (2)–(6) and through many trials to the ALOS-2 data sets, we came to the final criteria that damaged area was well retrieved by $|A(TP)| > 0.35$ and $|A(P_v)| > 0.4$ among others.

Fig. 3 shows the change detection result. Upper image of Fig. 3 is derived by the volume scattering power anisotropy A(*Pv*). The reason why we have chosen A(*Pv*) is such that the volume scattering power is mainly generated by trees in this area, and is lost if landslide occurs. If landslide happens, land-cover changes from trees to bare soil. In this case *Pv* by trees decreases. Considering this scattering mechanism change, we have chosen the criteria for decreasing case as $A(Pv) < -0.4$ after some trials. The corresponding area is colored with Pink. On

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the other hand, Pv increases if trees or vegetation come into the corresponding area. These scattering mechanism changes could be a good indicator for landslide. The criteria for increasing case was chosen as $A(Pv) > 0.4$, and the area is colored with Cyan. By using a median filter with 5×5 window, change detection image is displayed in Fig. 3.

Pink color areas are mostly corresponding to the landslide locations in the upper image of Fig. 3. Using a reference by aerial-photo [1], we can confirm the areas correspond to actual situation. Fig. 1(b) photo area is clearly detected in a small white rectangle in Fig. 3.

Lower image of Fig. 3 can be used for quick monitoring of earthquake using TP magnitude information. If $|A(TP)|$ is employed, any changes can be picked up by the mono-color detection result. Mono-color would be suitable for quick survey. On the other hand, $A(Pv)$ image can be used for the change detection in more detail exhibiting specific scattering mechanism change, i.e., increasing or decreasing. This feature can be recognized, for example, in a small white rectangular area. Although there are lots of polarimetric parameters such as (4), (5) or each decomposition power itself, the volume scattering power Pv and $A(Pv)$ and $A(TP)$ have played the most important role for landslide detection in this earthquake. The key parameter might change according to disaster type, e.g., it was Ps for Tsunami disaster [3] of the great East Japan Earthquake on 2011/03/11.

5 Conclusion

Japanese space-borne sensor "ALOS-2" SAR has acquired fully polarimetric data over Hokkaido-Iburi-Tobu region, where a great earthquake occurred on 2018/09/06 with magnitude of 6.7. Emphasis is placed on quick survey for disaster monitoring using fully polarimetric data. By comparison of the previous data (2017/08/26) before the earthquake, damaged areas by landslides are clearly detected. The scattering power decomposition and power anisotropy method were successfully applied to detect damaged areas. Time series images before and after the earthquake as well as change detection image were presented to show the effectiveness of fully polarimetric SAR sensing from space. It is really important to monitor the earth by fully polarimetric mode routinely.

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