Relation between 2016 Kumamoto Earthquake-induced landslide surface deformation and 3-D surface deformation detected by Pixel Offset method using InSAR image

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2016 Kumamoto Earthquake triggered many slope failures. In the previous study the authors have produced SAR (Synthetic Aperture Radar) interferometry image from ALOS-2/PALSAR-2 data observed on 15 and 29 Apr 2016, next, applied 2.5-D analysis on the image, then, detected EW component and Up-down component of surface deformation by the earthquake. And they investigated the relation between slope aspect of the failures and direction of surface deformation by the earthquake, and found the coincidence between them. However, 2.5-D analysis could not yield 3-D deformation by the earthquake. This study applied Pixel Offset method on the image and revealed the 3-D deformation, then, tried to investigate the relation between slope aspect and 3-D deformation. In this study result of the investigation will be shown in the latter half of the poster and in the previous half, the authors discuss the image dependent on the look number and window size set in calculating Pixel Offset method.

Keywords: earthquake, slope failure, landslide, SAR, Pixel Offset

Detection of slope deformation by using InSAR analysis - A case of Shikoku Mountains and Asahi Mountains

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Preface: In the SAR interferograms throughout Japan produced by Geospatial Information Authority (GSI) of Japan using the ALOS-2 data of JAXA, many phase changes indicating the slope deformation of ca. several centimeters can be confirmed. There are many reports that such phase change detects the creep phenomenon of slopes such as landslide blocks (e.g. Squarzoni et al., 2003; Une et al., 2008; Delacourt et al., 2009; Sato et al., 2012), but not all slope deformations are detected due to the observation performance of satellites. Therefore, in order to establish a method of slope deformation monitoring using SAR interference analysis in the future, it is important to accumulate information on the relationship between the observation condition of SAR, the topography / geological condition, the land cover condition, and the surface displacement in the field for observed phase change.
In this presentation, we report the characteristics of phase changes detected by InSAR and of the surface displacement observed by field survey in the Shikoku Mountains (Kochi Prefecture) and Asahi Mountains (Yamagata Prefecture).

Result: Field surveys were conducted on Shikoku Mountains from 9 to 11 March 2016 and Asahi Mountains from 14 to 16 November 2016.
(1) Shikoku Mountains: Among the 4 surveyed sites, clear surface displacements were identified at two sites (SK-1 site: Okushiraga Valley in Motoyama Town, SK-2 site: Tebako Valley in Ino Town).
At the SK-1 site, the SAR interferogram (October 2014 - October 2015) detected a variation of ca. 8 cm away from the satellite. As a result of field survey, a relatively new some open cracks were found in the concrete retaining wall at the side of the forest road which is in contact with the phase change area, and it is indicating that deformation of the slope block harmonized with the phase change type occurred.
(2) Asahi Mountains: Among the 5 surveyed sites, clear surface displacements were identified at two sites (AS-1 site: Tsukinuno area in Oe Town, AS-2 site: Kamikonuma area in Nishikawa Town). At the AS-1 site, a wide range phase changes were continuously detected in SAR interferograms of a multiple periods, including the period from September 2014 to June 2015. At the concrete pavement section of the forest road crossing the phase change area, a step and opening crack harmonious with the direction of the displacement indicated by the phase change was found. The AS-2 site is a landslide countermeasure site, and phase change was detected in SAR interferograms at multiple periods including the period from January to April 2016. In the field, clear vertical and right-lateral displacements harmonious with the direction of phase change were identified in the asphalt road and the side irrigation channel crossing the edge of phase change area located on the side cliff of the landslide block (Figure). In this point, there are at least three repair traces of road. There is a high possibility that the latest repair was done within 2016 and it is the displacement caused by the displacement detected by the SAR interferograms.

Summary and Challenges: There were no artificial structures at the edge of the phase change at the sites where the phase change occurred but the surface displacement was not identified in the field. Conversely, if the deformation indicated by the phase change is certain, it shows that InSAR can detect and monitor deformations that humans can not recognize on the ground. However, it cannot be judged whether or not the surface displacement identified at the site was caused by the deformation detected by

InSAR in the post-survey like this time. For that reason, we would like to examine the verification using the constantly deformation observation at the site in the future.

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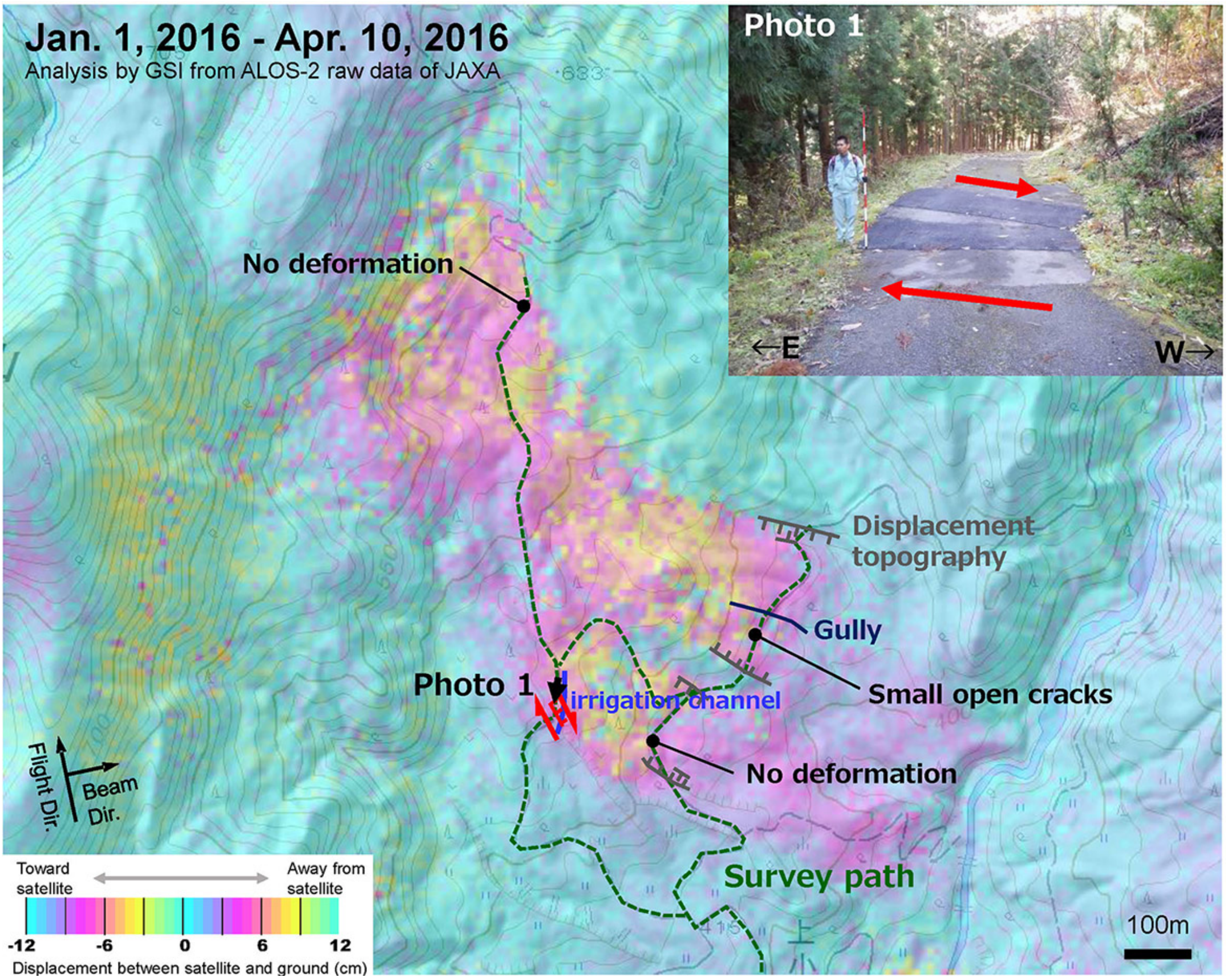
Keywords: InSAR analysis, slope deformation, landslide, surface displacement



The relationship between source faults and distribution of landslide induced by inland earthquakes in Japan - a preliminary report

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In recent years, a series of strong inland earthquakes triggered a large number of landslides in Japan. These landslides caused serious damage to the focal areas and their surroundings. Clarifying the distribution and dimensions of landslides induced by inland earthquakes may provide basic information which helps us to grasp the landslide prone area around active faults. In this study, we investigated the relationship between the distance to the source faults and the characteristics of the distribution and dimensions of landslides induced by recent inland earthquakes in Japan.
We collected the information about landslides that were induced by recent earthquakes (Magnitude larger than 6.5, and intensity larger than 5+ in JMA scale) since the great earthquake of Kobe, in 1995 based on available literature. To clarify the relationship between landslide distribution and earthquake source fault, we analyzed the occurrence and distribution of the landslides in terms of the shortest distance from the projected line of earthquake source fault to the center of the landslide source area. We summarized the characteristics of landslides with regard to the types of faults (normal fault, reverse fault and strike-slip fault), and we concerned whether the landslides are on the hanging or footwall side in the cases of normal and reverse faults.
The results show that in the cases of reverse fault earthquakes, landslides are concentrated on the hanging wall side compared to footwall side cases. Sizes of landslides on the hanging wall side are comparatively large. In the case of strike-slip fault earthquakes, no clear difference was confirmed between the both sides of the earthquake source fault.
In summary, there are differences in the characteristics of the distribution and dimensions of landslides induced by dip-slip fault earthquake and those by strike-slip fault earthquake. We will discuss about the landslide susceptibility around active faults by specifying the concentration areas and the geological conditions of landslides induced by inland earthquakes in the further work.

Keywords: Inland earthquake, Landslide, Earthquake source fault

Analysis of relationships between strike of rock discontinuities and formation position of linear depressions using finite element method

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Linear depression is formed on mountain slopes under the constraints of topography, geology and stress field. Therefore, investigating linear depression is important for understanding mountain development. In this presentation, in order to estimate the formation position of the linear depressions, a simple model of the mountain was created and three dimensional finite element analysis was performed. The software used for the analysis is Abaqus student edition 2016 (Simula).
An idealized mountain model is set where the main ridgeline is sandwiched between valleys. The rock discontinuity plane is set in the direction perpendicular to and parallel to the ridgeline direction. Furthermore, in order to deform the mountain body, compression is applied in the direction perpendicular to and parallel to the ridgeline direction. The physical property of the mountain body is assumed to be an isotropic linear elastic body.
As a result, when the discontinuity plane is parallel to the ridgeline, the forming position of the linear depressions varies depending on the compression direction. When the compression direction is parallel to the ridgeline, opening deformation occurred at the discontinuous surface near the ridgeline. On the other hand, when the compression direction is perpendicular to the ridgeline, vertical deformation occurs along the discontinuous surface at the lower part of the slope. In addition, when the discontinuous surface is perpendicular to the ridgeline, noticeable deformation cannot be observed in the discontinuous surface regardless of the compression direction.
These results are consistent with the tendency of the strike of the linear depressions to coincide with the ridgeline and the direction of the joint. These consequences also support the fact that the linear depressions are formed all over the slope of the mountainous region.

Keywords: FEA, Linear depressions, Rock discontinuity, Mountain gravitational deformation

