STT54-P01 Room:Convention Hall Time:May 25 18:15-19:30

Examination of InSAR tropospheric delay correction with JRA-55 reanalysis data

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Interferometric Synthetic Aperture Radar (InSAR) phase signal contains not only surface deformations but also propagation delays due to Earth's atmosphere, which is the principal limiting factor for InSAR application of small deformation with amplitude of a few centimeters or less. The atmospheric propagation delay is caused by the difference of refractive index between in atmosphere and in vacuum, and can be divided into the ionospheric delay and the tropospheric delay (Doin et al., 2009). Bevis et al. (1992) showed that the tropospheric delay consists of the hydrostatic delay due to dry gases and the wet delay due to water vapor. In the case of InSAR, the hydrostatic delay can be negligible and therefore the principal source of the tropospheric delay is due to the heterogeneity of water vapor in time and in space (Zebker et al., 1997). Previous studies proposed correction methods which used GNSS delay data or numerical weather model outputs. However, it is still insignificant for detecting small surface deformation.

Jolivet et al. (2014) showed that reanalysis data like ECMWF Interim Re-Analysis (ERA-Interim) data is useful to mitigate topography-correlated tropospheric delay from InSAR data. However, previous studies used only one of the model data as a case study and didn't apply the correction to other areas.

In this study we examined an effect of the tropospheric delay correction with Japanese 55-year reanalysis (JRA-55) data that is designed to produce a high-quality homogeneous climate dataset covering the last half century (Kobayashi et al., 2015). The horizontal resolution of JRA-55 is TL319 (approximately 60 km) and has 60 vertical layers. JRA-55 data are available every six hours. Pressure, temperature and specific humidity are interpolated to the SAR acquisition time and then used to calculate refractive index. We used the calculation method proposed by Jolivet et al. (2014) to estimate the tropospheric delay in the zenith direction and then converted to the line-of sight direction with a simple trigonometric function. In addition, we estimated the tropospheric delay with ERA-Interim data for comparison. SAR data used were derived from ALOS/PALSAR around Nagoya prefecture (Path-Frame: 411-690). We used the GAMMA software to generate interferograms and the 10 m-mesh digital ellipsoidal height model generated by the GeoSpatial Information Authority of Japan to remove the topographic fringe. To avoid the spatial decorrelation, interferometric pairs with the perpendicular baseline of less 3000 m were generated. As a result, 309 interferograms were generated from 28 SAR single-look complex images. Although some of interferograms have long-wavelength phase variations that may be caused by orbital estimation error or ionospheric disturbance, we didn't apply polynomial fitting to remove it because of the difficulty to determine whether that variation are due to the tropospheric delay or not.

In consequence of the tropospheric delay correction with JRA-55 and ERA-Interim data, the averaged standard deviation of all interferograms slightly reduced from 1.26716 cm to 1.25231 cm by JRA-55 and slightly increased to 1.26797 cm by ERA-Interim. We further examined the correction effect when dividing the estimated delay into the hydrostatic component and the wet component. In JRA-55, the averaged standard deviation slightly reduced to 1.26053 cm and 1.2659 cm by applying the hydrostatic and wet delay correction, respectively. On the other hand, in ERA-Interim, the averaged standard deviation slightly reduced to 1.26223 cm and 1.2659 cm by applying the hydrostatic delay correction and increased to 1.28106 cm by applying the wet delay correction. These results indicate that one of the factors of correction failure by ERA-Interim would be due to the low reproducibility of the actual wet delay.

In the presentation, we will report correction effects of JRA-55 and ERA-Interim, and discuss the difference of these effects.

Keywords: InSAR, tropospheric delay, reanalysis data, JRA-55, ERA-Interim

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PALSAR-2/InSAR analysis using RINC

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Advanced Land Observing Satellite-2 (ALOS-2) was launched on 24 May 2014, and distribution of PALSAR-2 (SAR sensor onboard on ALOS-2) data was began in 25 Nov. 2014. On the other hand, we are developing InSAR tools, named RINC, for researching on advanced SAR analysis techniques using PALSAR-2 and other SAR data (e.g., Ozawa, 2014). In this presentation, we introduce some case studies of PALSAR-2/InSAR analysis using RINC.

PALSAR-2 has three observation modes; stripmap, ScanSAR, and Spotlight. In InSAR analysis using stripmap mode data, high coherence was obtained for most pairs and topographic and orbital phase components could be removed by simulation based on orbit data included in images. Then we applied PALSAR-2/InSAR analysis to the Kuchinoerabujima (volcanic island) and the Ontake volcano and detected phase differences which may be due to surface deformation around the crater. In Ogasawara-Iwoto, obvious crustal deformation associated with volcanic activity was obtained. For the Northern Nagano Earthquake occurred on 22 Nov. 2014, we applied PALSAR-2/InSAR and detected crustal deformation associated with the earthquake.

We attempted to apply InSAR analysis to ScanSAR mode data (490km swath), and obtained fringes in the whole image, although coherence was low. Phase gap among swaths was negligible. However phase difference with long wavelength was remained in the differential interferogram. We attempted to apply InSAR analysis to spotlight mode images for Ogasawara-Iwoto, and high coherence could be obtained. However, artificial phase gap was obtained. These are severe problems on detection of surface deformation, and then its resolution is necessary.

Keywords: PALSAR-2, InSAR, RINC, Kuchinoerabujima, Ontake, the northern Nagano Earthquake

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Usefulness of long-term monitoring of volcanic eruptions by synthetic aperture radar

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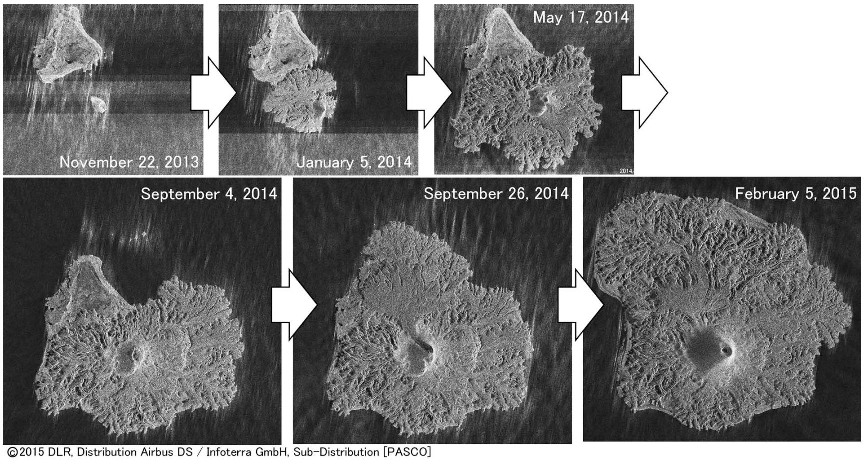
Nishinoshima is desert island located in about 1000km south from Tokyo. In November 20, 2013, a new eruption was confirmed in the southeast about 500m of the location of Nishinoshima Island, and integrated with the Nishinoshima Island in December 26, 2013, and most of Nishinoshima Island covered by lava in October, 2014. Like these, the active eruption with overflow of lava is also continuing now. However, because Nishinoshima Island is about 130km far from the nearest inhabited islands Ogasawara, it is difficult to observe all the time by eyesight and observation machinery. Although it is possible to monitor from the sky by an aircraft, the aircraft fault is also concerned with the eruption.

The authors, for the purpose of precisely recording the development form of volcanic island, and long term observed using a synthetic aperture radar satellites can be safely and periodically observed.

Keywords: Synthetic aperture radar, Volcano monitoring



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A spatial filter adaptive to slope size applied to differential SAR interferograms for landslide detection

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Differential interferometric SAR (DInSAR) is the technique to measure small surface deformation induced between acquisition times by measuring ground surface several times from satellite. Since it employs microwave, it can observe ground surface of dozens of kilometers square under cloud or volcanic smoke. Thus, DInSAR has been used for the ground subsidence and volcano monitoring.

In the DInSAR image, surface deformation is appeared as an interferometric fringe. On the other hand, the fringe caused by the change of atomospheric water vapor distribution between SAR acquisitions also appears frequently in the image. The fringe caused by the atomospheric effect not only hinders image interpretation but also makes an error in the estimation of surface displacement. In order to make a proper interpretation of local fringes caused by landslide and analyze them quantitatively, it is necessary to remove the fringe caused by the atomospheric effect.

We propose a spatial filter for DinSAR image which suppresses the fringes caused by the atomospheric effect while preserving those caused by landslide as clear as possible. The proposed filter is based on high-pass filter in the spatial frequency domain. The scale of the fringe caused by the atomospheric effect ranges, in general, from several hundred meters to several kilometers, while those caused by landslide is restricted by landslide itself whose size ranges, in general, from dozens meters to several hundred meters in Japan. Using this difference of the scale between the two fringes, one can suppresses the fringes caused by the atomospheric effect efficiently while preserving those caused by landslide.

However, in general, the scale of landslides differs depending on locations. In addition, the shape of landslides is also various and anisotropic. Thus, when detecting a fringe caused by an unknown landslide from DInSAR images, it is difficult to set the appropriate maximal size to be filtered. One needs to adjust the frequency through try and error. To avoid this, the proposed filter is adapted to the size of ground slopes by assuming that the size of landslides is restricted by its underlying ground slope. When filtering, the maximal size is decided based on the size of the slope. Thus, the fringes caused by landslide are preserved adaptively while suppressing those caused by the atomospheric effect.

The procedure of the proposed method is as follows. The slope is defined by the slope orientation angle in this research. In the image of the orientation angle calculated from DEM, pixels with similar values are merged and regarded as the identical slope. The merging is performed by the region growing method. By applying the two-dimensional Fourier transform to the binary image of the detected slope area, the power spectrum is generated. The spectrum is normalized to be a window function and applied to the spectrum generated from DInSAR image of the corresponding area. In this way, the filter is adaptively applied to each slope area. The filtered spectrum of the DInSAR image is transformed to the spatial domain, generating the filtered DInSAR image of the corresponding slope area. By applying the procedure to neighboring slopes, the filter is applied to whole the DInSAR image. In this research, the maximal size of the slope is defined so that the maximal size to be filtered is restricted.

The proposed method was evaluated applying to the DInSAR image of landslide area in Nagano and Yamagata prefecture, Japan. We compared two filters; high-pass filter and proposed filter. By the high-pass filter, the fringes caused by the atomospheric effect are better suppressed, as the maximal spatial frequency to be filtered is high, while the fringes caused by landslide become small and weak. The best spatial frequency is difficult to decide. On the other hand, the proposed method also suppresses the fringes caused by the atomospheric effect while preserving those caused by landslide.

Keywords: Differential SAR interferometry, landslide, spatial filter

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Monitoring of Sakurajima Volcano using X-band and L-band SAR

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Sakurajima volcano is located in southwestern part of Japan, and currently one of the most active volcanoes in Japan. Eruptive activities from a Showa-crater have activated since 2009, and many explosive eruptions have occurred and lava dome growth was found in January 2015. In previous studies, regional and local deformation were detected by GPS, tiltmeter, and leveling [Iguchi et al., 2013; Yamamoto et al., 2013]. To understand current condition and future unrest of Sakurajima, periodic monitoring is required. Although it is generally difficult to make a field observation in dangerous active volcanoes, a satellite remote sensing can make observations of even ongoing volcanoes periodically. Especially, Synthetic Aperture Radar (SAR) sensor is well-suited for monitoring active volcanoes because it can penetrate ash clouds and can observe targets like an active vent. Moreover, SAR data are applicable to use a Differential Interferometric SAR (DInSAR) technique to detect crustal movement associated with the magmatic activities. In this study, we used COSMO-SkyMed (CSK) data through JAXA-ASI co-operative research and ALOS-2/PALSAR-2 data. And we tried DInSAR/PSInSAR processing.

We have been monitoring on Sakurajima volcano using CSK data acquired between 2010 and 2014 from both ascending and descending orbits. From amplitude images, we detected apparent changes of backscattering intensity probably due to an enlargement of the Showa-crater. Because enough coherence could be given by only short-term pairs and the crustal movement on Sakurajima is small, it was hard to detect signals from the DInSAR processing. Then we tried PSInSAR processing using StaMPS software [Hooper et al., 2007]. The results show 1cm/year uplift in north part of Sakurajima volcano between 2012 and 2014, and it corresponds to results from leveling survey. ALOS-2/PALSAR-2 launched in May 2014, and the data have been acquired from both ascending and descending orbits since September 2014. We will introduce the latest result using ALOS-2/PALSAR-2 data.

Keywords: Synthetic Aperture Radar, Sakurajima, Monitoring, InSAR, PSInSAR, Deformation

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Spatial distribution of permafrost in the northern Tien Shan, Central Asia

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Tien Shan Mountains in the arid and semi-arid regions of Central Asia, with their water resources in the form of mountain glaciers and permafrost, are known as the water towers of Central Asia. Although it is necessary to investigate the current level of these mountain glaciers and permafrost to estimate the amount of water stored (Sorg et al., 2012), the spatial distribution of permafrost is not well known in the northern Tien Shan. We clarify the current state of mountain permafrost in the Kyrgyz Ala-Too Range using the distribution, classification, and motion of rock glaciers as indicators of mountain permafrost.

We applied DInSAR analysis to rock glaciers which identified by field surveys and interpretation of aerial photographs. We extracted the active and inactive rock glaciers according to the motion of rock glaciers. To validate the detected surface motion on rock glaciers, we conducted GPS measurements on rock glacier in Sokuluk Valley. The average movement was 75cm/yr on the glacier-origin rock glaciers between 2013 and 2014. In addition, ground surface temperature shows that the geothermal conditions were sufficient to maintain mountain permafrost inside rock glaciers at the study site.

The distribution of the active and inactive rock glaciers that confirmed their motion revealed discontinuous permafrost altitudinal zones located above 2900 m a.s.l. in the northern part and above 3400 m in the southern part of the Kyrgyz Ala-Too Range. In addition, we confirmed local subsidence between around 3300-3500 m a.s.l. related to the melting of mountain permafrost inside the rock glaciers during summer by short term DInSAR. Half of the active and inactive rock glaciers are glacier-origin type. We also report the environment conditions of glacier-origin rock glaciers.

Keywords: DInSAR analysis, mountain permafrost, rock glacier, Tien Shan

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Detection of irregular change of ice sheet in north-western Greenland using ALOS/PALSAR data

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Under the situation of ongoing rapid ice sheet melting in Greenland, it is likely that the ice sheet flow velocity is changing there. We applied differential interferometric synthetic aperture radar (DInSAR) to several SAR scenes of north-western Greenland observed by ALOS/PALSAR and the obtained displacement maps had been shown in JpGU2014 as well as maps of the displacement difference obtained by double DInSAR (DDInSAR) technique which means taking the difference between two DInSAR images.

Stable ice flow is a dominant component of surface displacements over ice sheet. Since phase change in a differential SAR interferogram induced by steady surface displacement is canceled out by taking the difference, we can detect irregular surface displacement such as ice sheet flow rate change by DDInSAR.

In order to detect irregular displacement, the DDInSAR technique was applied to an ALOS/PALSAR scene (path-frame: 76-1590) which was observed at three times in series at August 30, October 15, and November 30 in 2007. Two maps of displacement along radar illumination direction have been obtained from the two DInSAR images and a map of displacement difference has been obtained from the DDInSAR image. In the displacement difference map, we found several spots of circular or elliptical shape where displacement differences of 10 to 15 cm were observed. Because the positions of the spots are almost coincident with locations of ponds on the ice sheet near coastal region, these differences seem to be induced by surface displacement of the ponds.

We are going to apply offset tracking technique to the same SAR data to estimate surface flow of the ice sheet and to do further investigation about the displacement differences by combining the surface flow estimated by the technique.

Keywords: Differential Interferometric SAR, ice sheet flow, offset tracking, Greenland

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Ground Deformation around the Domestic and Overseas Active Volcanoes detected by ALOS-2/PALSAR-2

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ALOS-2, was launched on May 24, 2014, has an L-band SAR (PALSAR-2) in the same way as ALOS/PALSAR. PALSAR-2 is of help to understand of a ground surface state, and its interferometric coherence is highly effective for the crustal deformation observation. Furthermore, PALSAR-2, is also very short repeat observation cycle (14days), has a higher resolution sensor than PALSAR. Therefore, higher resolution data can be acquired and we analyzed more frequently and are expected to be useful for disaster prevention and mitigation. After the calibration period of about half a year after the launch, ALOS-2 / PALSAR-2 data has been published on November 25, 2014. Operational plan of ALOS-2 / PALSAR-2 have been focused on the accumulation of the base map at least the first year, but when disasters such as earthquake and volcanic activity occur, has been observed according to circumstances.

We have analyze the ground deformation caused by the earthquake and volcanic activity at domestic and overseas using ALOS-2 / PALSAR-2 data. And then, our analysis results are provided to each department of the JMA, and are used to the study of volcanic activity evaluation and seismic analysis results. In this presentation, we mainly report on the analysis results of around active volcano.

Some of PALSAR data were prepared by the Japan Aerospace Exploration Agency (JAXA) via Coordinating Committee for the Prediction of Volcanic Eruption (CCPVE) as part of the project "ALOS-2 Domestic Demonstration on Disaster Management Application" of the Volcano Working Group. Also, we used some of PALSAR-2 data that are shared within PALSAR Interferometry Consortium to Study our Evolving Land surface (PIXEL). PALSAR-2 data belongs to JAXA. We would like to thank Dr. Ozawa (NIED) for the use of his RINC software. In the process of the InSAR, we used Digital Ellipsoidal Height Model (DEHM) based on "the digital elevation map 10m-mesh" provided by GSI, and Generic Mapping Tools (P.Wessel and W.H.F.Smith, 1999) to prepare illustrations.

Keywords: ALOS-2/PALSAR-2, InSAR, Amplitude image, Active volcano