Temporal change in crustal deformation related to volcanic activity of Iwo-jima observed by PALSAR/InSAR

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Abstract
An increase of volcanic activity of Iwo-jima was observed in August of 2006. We applied InSAR to PALSAR data for detection of crustal deformation in Iwo-jima. A slant-range change representing subsidence of several centimeters throughout Motoyama was detected on the interferogram showing crustal deformation until August of 2006. Shortening of the slant-range throughout the island was found in the period between August and November, and it indicates the inflation of the deep source. In the period between November and February of 2007 that volcanic activity was highest, the blockwise uplift of Motoyama was found. It suggests that the magma which had pooled in shallow depth was pushed up by the magma that ascended from deep magma chamber, and its magma would intrude along the outside of the magma which had pooled in shallow depth. It seems that progress of its intrusion has been complicated temporally and spatially.

Keywords: PALSAR, InSAR, crustal deformation, Iwo-jima, volcano

1. INTRODUCTION

Iwo-jima is a caldera volcano which is part of the Izu-Ogasawara arc (Fig. 1). An extremely high uplift which often exceeds 1m in a year characterizes its volcanic activity. In August of 2006, subsidence which had continued from 2003 rapidly changed to uplift (Fig. 2), and an increase of seismicity was also observed simultaneously.
To gather information about such an increase of the volcanic activity, emergent observations and high frequent observations have been carried out by cooperation between Coordinating Committee for Prediction of Volcanic Eruption and JAXA. We applied interferometric synthetic aperture radar (InSAR) to these data, and detected the temporal change of crustal deformation related to an increase of the volcanic activity. In this paper, we present obtained crustal deformations and the model of magma movements which is inferred from them. To explain the results simply, we divided the period as shown in Fig. 2.

2. INSAR PROCESSING

InSAR can detect a change in a slant-range between the satellite and the earth surface due to crustal deformation. It corresponds to an inner product of a displacement vector and a unit vector of line-of-sight direction. Line-of-sight directions are shown in each interferogram. We used 2-pass differential InSAR method to remove topographic component, and 10m-mesh DEM generated by Hokkaido-chizu co., ltd. was used to apply this method. Finally, interferograms were adjusted to displacements observed by GPS to correct the remains of orbital component. Since the reference site of their GPS displacements is Haha-jima, final results which are shown in this paper is a slant-range change with respect to Haha-jima GPS site.

3. CRUSTAL DEFORMATION IN QUIET PERIOD AND 1ST STAGE

Fig. 3(a) shows interferogram showing crustal deformation in the quiet period. Slant-range extension representing slight subsidence is found throughout Motoyama. On the other hand, slant-range shortening throughout the island suggesting an inflation of volcano is found on the interferogram of 1st stage (Fig. 3(b)). Its wavelength is relatively long, and a contraction pattern with the wavelength of several km is superposed on it. Contraction pattern in Motoyama seems to appear independently of volcanic activity from previous research [1]. From the wavelength of the inflation pattern, we suspect that the depth of the inflation source is deeper than 2km and shallower than 10km.

4. CRUSTAL DEFORMATION IN 2ND STAGE

In 2nd stage, the acceleration of the uplift and further increase of the seismicity were observed. PALSAR observations were carried out from the ascending and the descending orbits in this stage, and changes of slant-range for two directions were obtained (Fig. 3(c)-(e)). Slant-range change in this stage is 4 times larger than that of 1st stage. Especially the characteristic fringe pattern is found along the Asodai Fault which is located in the west coast area. Cracks were found on roads crossing the fault in this period, and therefore it must be the fringe pattern showing dislocation of the fault. To see crustal deformation in detail, we derived 2-D displacement map using the method of [3] (Figs. 4). Quasi-vertical component inclines 10 degree to the south from vertical, and quasi-EW component is almost equal to absolute EW component. Along the Asodai Fault, sharp contrast corresponding to approximately 5cm deformation in the vertical component is found on the map of quasi-vertical component, and its contrast

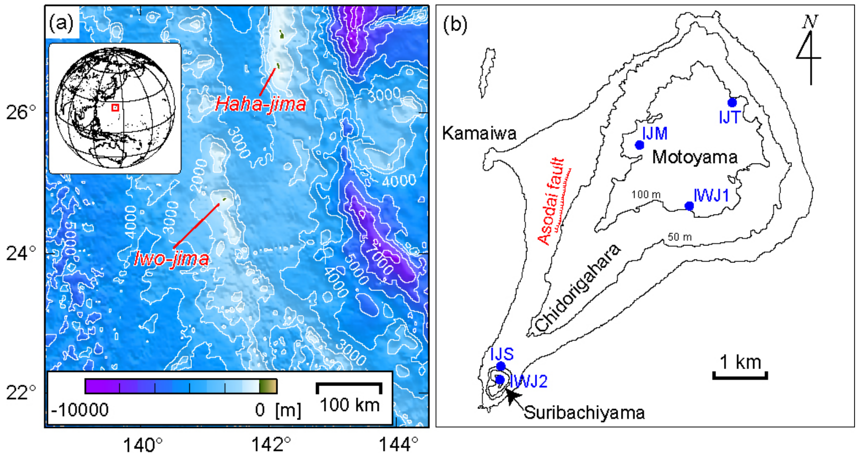

Figure 1. (a) Bathymetric map around Iwo-jima described from ETOPO2. Contours indicate depth at 1,000m intervals. (b) Map of Iwo-jima. Blue circles show GPS sites. Red curve shows the Asodai Fault.

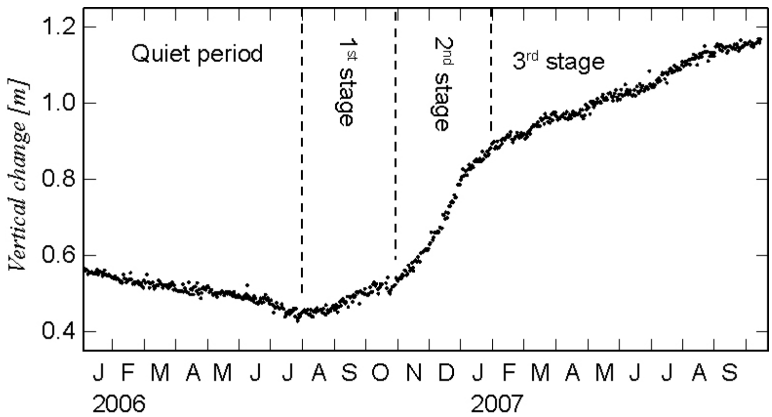

Figure 2. Time series depicting vertical movement of IWJ1 relative to Haha-jima

turns to the east at the south end of the fault along the fault zone (Fig. 4(a)). It seems that Motoyama has been uplifted blockwise. The map of quasi-EW component shows that the west side of the Asodai Fault has moved to the west, and it might relate to blockwise uplift of Motoyama.

5. TEMPORAL CHANGE OF CRUSTAL DEFORMATION in 2ND AND 3RD STAGE

The uplift of Motoyama decelerated in the end of 2nd stage, and is continuing in constant speed in 3rd stage (Fig. 2). Fig. 3(d)-(i) show interferograms which have been generated from the descending data observed in 2nd and 3rd stages. Deformation along the Asodai Fault is found in all interferograms, though its amount is different. Fig. 5(a) shows the temporal change of the deformation across the fault calculated from comparison of slant-range changes at two points shown by red line of Fig. 3(d). It has decelerated in the end of 2nd stage and is continuing in constant speed in 3rd stage, and its pattern is similar to that of the uplift of Motoyama. From this pattern, we think that this is not deformation such as landslide triggered by an increase of volcanic activity but deformation which directly related to it. Fig. 5(b) and (c) show the temporal change of the slant-range at the north and south coasts which are calculated from comparison of slant-range changes at two points shown by green and blue lines of Fig. 3(d). Although the temporal change pattern continuing in constant speed in 3rd stage is the same at the north and southeast coasts and the Asodai Fault, those in 2nd stage are different. It means that the sources which caused each deformation are different.

6. A MODEL OF MAGMA MOVEMENTS INFERRED FROM PALSAR/InSAR

The gravity and the geomagnetic surveys suggested that the magma which was shaped like a funnel (Shallow Magma) had pooled in 1~2km depth just under Motoyama [4],[5]. The source of the inflation in 1st stage was deeper than its depth, and it indicates that the inflation of a deeper magma chamber has occurred (Fig. 6(a)). In 2nd stage, we think that the magma has ascended to the bottom of Shallow Magma and that Shallow Magma has been pushed up by the ascending magma. The blockwise uplift of Motoyama can be explained by its scenario (Fig. 6(b)). The magma that ascended to the bottom of Shallow

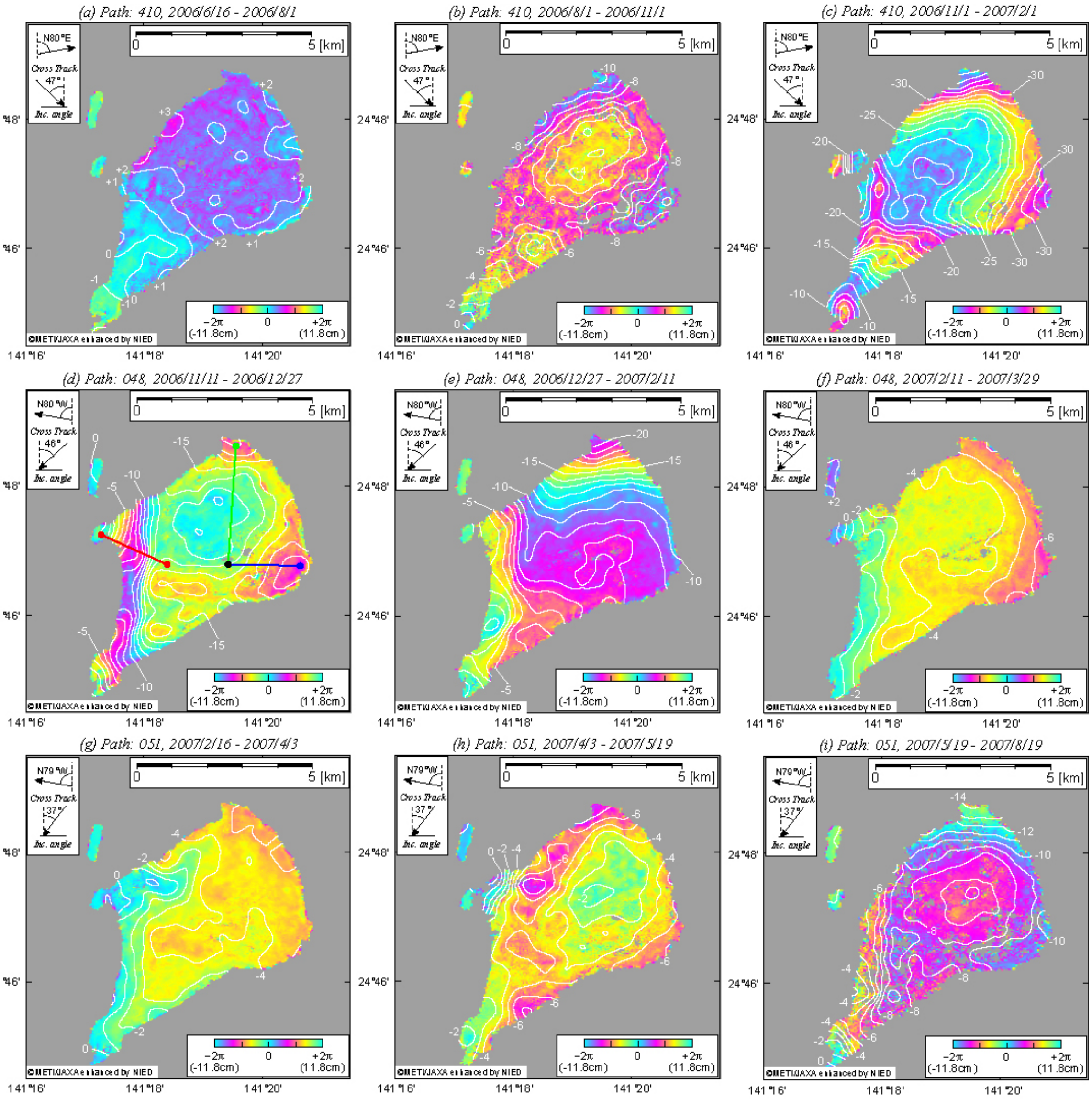

Figure 3. Interferograms generated from PALSAR data. Observed dates are shown in the upper of each figure. Contour lines represent slant-range change at 2cm intervals.

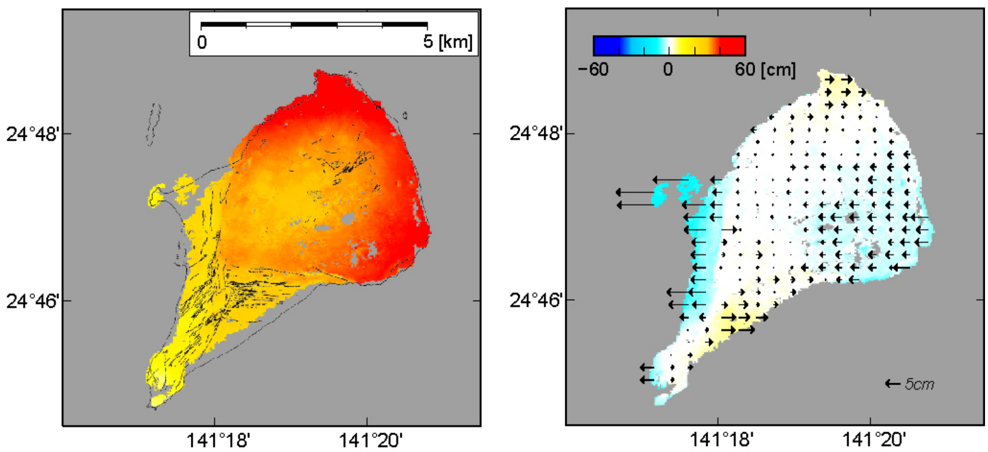

Figure 4. Map of (a) quasi-vertical and (b) quasi-EW components of displacement in 2nd stage.Superposed fault map is from [6].

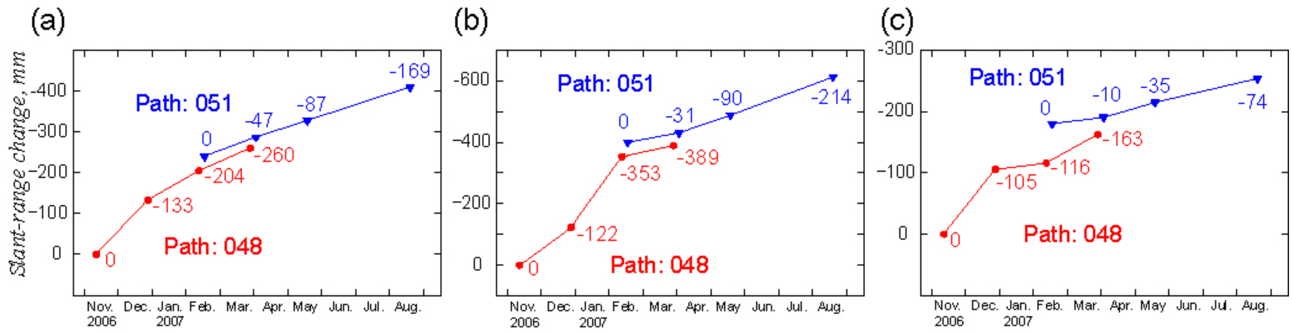

Figure 5. Temporal slant-range change calculated from comparison between two points shown by (a) red (Asodai Fault), (b) green (north coast), and (c) blue (south east coast) lines of Fig. 3(d).

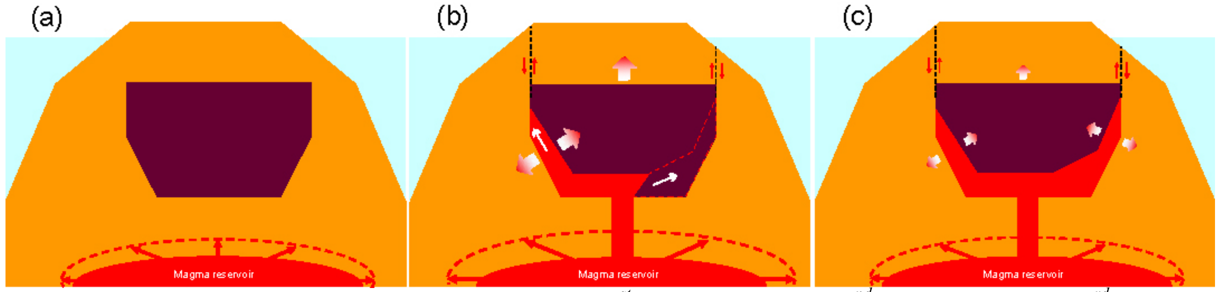

Figure 6. A model of magma movements. (a) Model of 1st stage (b) Model of 2nd stage (c) Model of 3rd stage.

Magma would intrude along the outside of Shallow Magma, and we think that it has caused crustal deformation in the north and the southeast coasts and the Asodai Fault. The difference between temporal change patterns of deformation at the north and southeast coasts and the Asodai Fault in 2nd stage suggests that those intrusions are not uniform temporally and spatially. Deformation continuing in constant speed in 3rd stage suggests that a supply of magma is continuing and that the magma which has pooled along the outside of Shallow Magma is inflating (Fig. 6(c)).

7. SUMMARY

We detected temporal change of crustal deformation related to an increase of volcanic activity in Iwo-jima using PALSAR/InSAR. This is the first result that has mapped temporal change of crustal deformation related to an increase of volcanic activity of Iwo-jima in detail, and is extremely important to understand its mechanism. However its deformation pattern is very complicated, and more detailed investigations and observations will be needed in future work.

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