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# *Surface Deformation Caused by Shallow Magmatic Activity at Okmok Volcano Detected by GPS Campaigns 2000-2002 (Extended Abstract)*

YOUSUKE MIYAGI[1], JEFF FREYMUELLER[2], FUMIAKI KIMATA[3], TOSHIYA SATO[4] and DOERTE MANN[2]

[1]Institute of Seismology and Volcanology, Graduate School of Science, Hokkaido University, N10W8 Kita-ku Sapporo
[2]Geophysical Institute, University of Alaska, Fairbanks. Fairbanks, Alaska 99775-7320
[3]Research Center for Seismology and Volcanology, Graduate School of Environmental Studies, Nagoya University, Furou-cho Chigusa-ku Nagoya
[4]Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, Aoba-ku Sendai

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## 1. Introduction

Okmok volcano is located on Umnak Island in the eastern Aleutian Arc. This volcano is a large shield type volcano composed of a 10 km wide caldera and there are several cones within the caldera. It had erupted more than 10 times during 20th century (Miller *et al.*, 1998) and the latest eruption occurred in February 1997, in which massive lava flow and abundant ash plume were produced from active vent, which is located at southern part of the caldera floor. Its eruption may be directly connected to the catastrophic accidents, because a lot of aircrafts fly over this volcano. However there had so far been no geodetic data except for the data from remote sensing technique. With financial support from IARC/NASDA and logistical support from AVO, we had carried out GPS campaigns in 2000, 2001 and 2002 and we could establish a dense GPS network and detect a significant surface deformation of Okmok caldera, which indicated remarkable inflation.

## 2. InSAR Measurement

Significant surface deformation associated with the latest eruption in 1997 has been measured by SAR Interferometry. Several results using InSAR for Okmok volcano have reported (Lu *et al.*, 1998, Lu *et al.*, 2000, Mann *et al.*, 2002). In Lu *et al.*, [1998] and Lu *et al.*, [2000], they detected pre-eruptive inflation, co-eruptive deflation and post-eruptive inflation. They observed ~18 cm of uplift between 1992 and 1995, and more than 140 cm of subsidence between October 1995 and September 1997, that was including the period of 1997 eruption, and ~10 cm of uplift between September 1997 and 1998. These deformations centered in the almost same location at the approximate caldera

Fig1

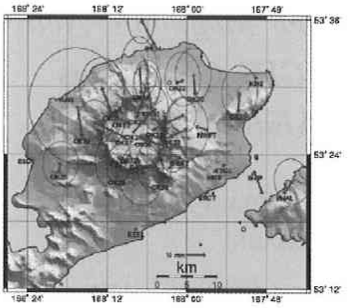

Fig2

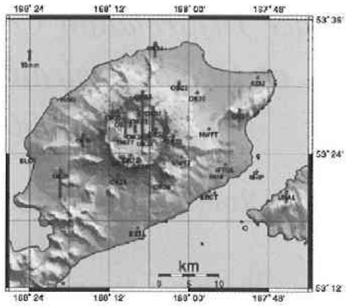

Fig3

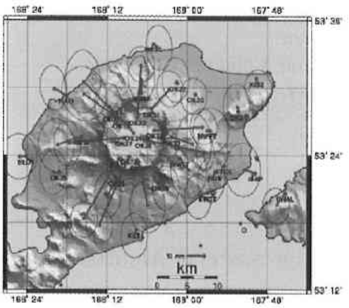

Fig4

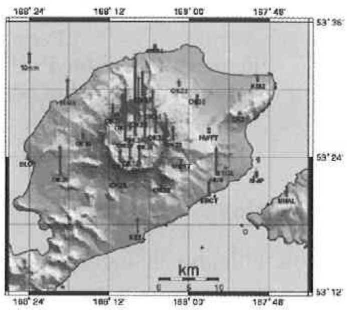

Fig5

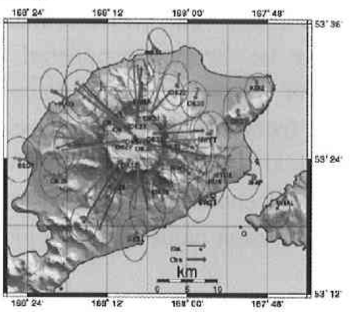

Fig6

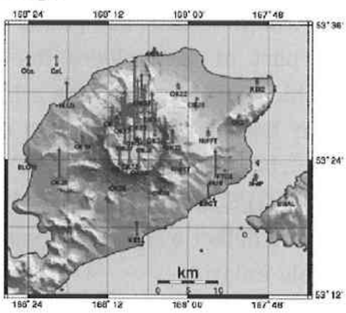

Fig 1. Horizontal displacements during 2000-2001 with 95% error ellipses.

Fig 2. Vertical displacements during 2000-2001.

Fig 3. Horizontal displacements during 2001-2002 with 95% error ellipses.

Fig 4. Vertical displacements during 2001-2002.

Fig 5. Comparison between horizontal displacements observed during 2001-2002 and calculated displacements from best fitting Mogi source, which is located 3.65 km depth beneath ★ in the figure.

Fig 6. Comparison between vertical displacements observed during 2001-2002 and calculated displacements from best fitting Mogi source, which is same as above.

center. In Mann *et al.*, [2002], they reported the results of advanced modeling for above deformations at Okmok volcano. According to their model, all deformations could be explained by a couple of Mogi sources (Mogi, 1958) and rectangular dislocation source (Okada, 1985). The horizontal positions of every best fitting main Mogi sources were well constrained at the approximate center of the caldera.

## 3. GPS (Global Positioning System) Measurement

In 2000, we set up and surveyed 24 GPS sites on and around the Okmok caldera. In 2001 and 2002, we resurveyed existent sites and added several new GPS stations. Consequently, we established a well-distributed GPS network composed of 33 sites. We set up a local reference station nearby our base camp, and recorded the data throughout our campaign in each year. For analysis of the acquired GPS data, we used Bernese GPS software Version 4.2 with IGS precise orbit. We first decided the coordinate of the station FTGL as a local reference station relative to FAIR that was IGS station in Fairbanks, and then we decided the coordinate of other sites relative to FTGL each year. As a result, we could detect significant deformation with several remarkable features. Roughly speaking, both horizontal and vertical displacements during 2000-2002 show an inflation of Okmok caldera as we expected from InSAR data after 1997 eruption. In particular, the inflation rate during 2001-2002 was much larger in magnitude than the one during 2000-2001. The horizontal displacements during 2001-2002 (Fig. 3) show much more purely radial pattern, and the vertical displacements during 2001-2002 (Fig. 4) show a clearer tendency of uplift than for the period 2000-2001 (Fig. 1, Fig. 2).

## 4. Discussion

We will compare our GPS data acquired during 2000-2002 to the InSAR data acquired during 1997-2000. In Mann *et al.,* [2002], they reported ~7 cm/year of uplift at the caldera center between 1997 and 2000. As results from our GPS campaigns, we detected ~3 cm/year of uplift during 2000-2001 and ~8 cm/year of uplift during 2001-2002 at the site located close to the caldera center. The uplift for the period 2001-2002 was consistent with the one detected by InSAR measurements, on the other hand the uplift for the period 2000-2001 was not significant and not consistent with InSAR. This possibly means that the uplift lasting after 1997 eruption was suspended during 2000-2001 and then it was resumed with similar rate as before suspension. We suppose a possibility as a reason of this suspension that other magmatic activities occurred in this period instead of regular inflating activity, for example like a lateral magma transport from the source to active vent (Mann *et al.*, 2002). We modeled the observed deformation during 2001-2002 using a Mogi source as a magma chamber. The best fitting Mogi source was inferred the location of 3.65 km depth beneath the approximate center of the caldera. And its volume increasing rate was estimated ~0.0046 $km^3$/year, assuming that the source strength is completely affected from the volume change without pressure change in the source. It can explain both horizontal and vertical displacement well, especially inside caldera (Fig. 5, Fig. 6). Mann *et al.,* [2002] also inferred a Mogi source, and its location and volume increasing rate were quite consistent with our results.

## 5. Conclusions

Using the data from repeated GPS campaigns in 2000, 2001 and 2002, we detected significant deformation that indicated an inflation of Okmok caldera, and change of inflation rate. The uplift showing inside the caldera during 2001-2002 is very similar to the uplift measured by InSAR during 1997-2000. However the deformation during 2000-2001 is much smaller than for the period 2001-2002. The results from the GPS data during 2000-2001 indicate that the source seems to suspend its inflation for this period. We modeled the observed displacements during 2001-2002 using Mogi source. Compared with model, we could assume an inflating magma chamber located 3.65 km depth beneath the approximate center of the caldera and estimate ~0.0046 $km^3$ of volume change. This location and volume change rate of the best fitting source are quite consistent with the best fitting source modeled from InSAR data for the period 1997-1998. We need next GPS campaign to investigate the volume change rate, and we hope to combine the GPS data with InSAR data for the same period.

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