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Volcanic subsidence triggered by the 2011 Tohoku earthquake in Japan: Hot and weak material hypothesis

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With spaceborne interferometric synthetic aperture radar (InSAR) analysis, we found that the 2011 Mw 9.0 Tohoku earthquake in Japan (March 11, 2011) has triggered unprecedented subsidence of multiple volcanoes. Similar phenomenon has been reported for the 2010 Mw 8.8 Maule earthquake (Pritchard et al., 2013). We used SAR data acquired before and after the mainshock by ALOS (PALSAR). By removing long wave-length phase trend from InSAR images, we obtained the localized subsidence signals at five active volcanoes: Mt. Akitakoma, Mt. Kurikoma, Mt. Zao, Mt. Azuma, and Mt. Nasu. All of them belong to the volcanic front of Northeast Japan. The subsidence areas exhibit elliptic shape elongated in the North-South direction – perpendicular to the principal axis of the extensional stress change due to the Tohoku earthquake. Major axis of the ellipse reaches 15 - 20 km, and the amount of subsidence is up to 15 cm (Mt. Azuma). GPS data from two volcanoes also indicate surface subsidence consistent with the satellite radar observations. Furthermore, the GPS data show that the subsidence occurred immediately after the earthquake. A common feature of the five volcanoes is their high geothermal activity. The areas of high geothermal gradient and high thermal water temperature are in good agreement with the area of subsidence detected by InSAR. Also, the Late Cenozoic calderas cluster around the subsidence regions, which implies that hot plutonic bodies once intruded are still hot and highly deformable even now. According to numerical modelling, the observed subsidence can be explained by the co-seismic response of fluid-filled ellipsoid beneath each volcano. We confirmed that the surface subsidence is also caused by the ellipsoid filled with elastic body of low shear strength. We further checked that an ellipsoid is more effective to cause the subsidence than a sphere when the ellipsoid is elongated perpendicular to the tension axis of the imposed stress.

References:
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