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Temporal changes in volcanic feeding systems inferred from time-dependent seismic tomography (case studies for the Nevado del Ruiz and Mt. Spurr active volcanoes)

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Active volcanoes are some of the most dynamic systems among geological structures. During activity episodes, physical properties beneath volcanoes may considerably change for years, months and even days. Seismic tomography is one of geophysical tools that helps revealing such temporal changes. However, as the result of tomography inversions are sensitive to the existing ray coverage, it is not always possible to separate the actual variations of seismic parameters from changes caused by different data distributions in different time periods. To overcome this problem, we have developed an algorithm of repeated tomography that is based on selection of data with similar distributions. The algorithm workflow presumes a series of synthetic tests that verify the stability of revealing the temporal variations of actual seismic parameters. This scheme has been implemented for several active volcanoes.

The first example is Nevado del Ruiz in Colombia that remains in the active state of intensive degassing since 2010. Beneath the volcano edifice, we have detected an anomaly of high Vp/Vs ratio that possibly represents a shallow magma reservoir saturated with fluids. According to the results of repeated tomography, in the period from 2010 to 2014, this anomaly decreased the volume and amplitude, which represents gradual escape of fluids from the magma reservoir. In 2015-2016, this anomaly increased again that is explained by income of a new portion of fluid-rich magma from deeper sources. Such periodic “breathing” of magma reservoir seems to be in agreement with the regime of degassing and magma dome emplacement.

Similar study has been performed for the Mount Spurr in Alaska. We explored the seismic structure beneath the volcano in three time windows: 1996-2001, 2002-2004 and 2005-2012. During the observation period, the major unrests of the volcano occurred in 1997 and 2004-2006. Similarly as in the case on Nevado del Ruiz, in all time windows, we observed a large anomaly with high Vp/Vs ratio located right beneath the volcano. In episode 2, in respect to the episode 1, we observed a considerable ascent of the anomaly: in 1996-2001, the upper limit of the anomaly was observed at $\sim$5 km depth below surface, whereas in 2002-2004 it was approximately at 3 km depth. In the following episode (2005-2012), the shape of the anomaly remained unchanged, whereas slight decrease of Vp/Vs was detected. We propose that these changes represent the fluid migration in the magma system that affects the partial melting and degassing processes in the plumbing system beneath the volcano and controls the eruption activity phases of Mt. Spurr.

The repeated tomography studies performed for Mt. Spurr, Nevado del Ruiz and other active volcanoes have revealed considerable changes of seismic velocities occurred within a few years. These temporal variations can be caused by fluid migration, which, in turn, affects the processes of melting/crystallization and degassing. All these factors control the occurrence of volcanic eruptions. This study has been supported by RSF Grant 14-17-00430 and RFBR Grant 16-05-00477.