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Volcanic earthquakes and tremors within a system of interacting volcanoes: Klyuchevskoy volcanic group in Kamchatka, Russia

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The Klyuchevskoy volcanic group (KVG) located in Kamchatka, Russia is one of the largest and most active clusters of subduction-zone volcanoes in the world, and is composed of 13 closely located stratovolcanoes. The 4,750-m-high Klyuchevskoy volcano is the most prominent of this cluster, and has had a mean eruptive rate of 1 m3/s over the past 10 kyr. Bezymianny and Tolbachik volcanoes have also produced strong eruptions over recent decades. In addition, two other very active volcanoes, Shiveluch and Kizimen, are respectively located north and south of KVG. The group is located in a unique tectonic setting, above the edge of the Pacific plate at the Kamchatka–Aleutian junction where the Hawaii–Emperor Seamount chain is subducted. Geodynamic models that have been proposed to explain the exceptional activity of the KVG include fluid being released from the thick, highly hydrated Hawaii–Emperor Seamount crust, mantle flow around the corner of the Pacific plate, and recent detachment of a portion of the subducting slab.

The KVG activity is characterized by abundant seismic tremors, mostly co-eruptive and by volcanic earthquakes more easily detected during inter-eruptive periods. Overall, this seismicity characterize the stress evolution and its transfer between different parts of the large volcanic system. In this study, we use the catalog of volcanic earthquakes developed by the Kamchatka Branch of the Geophysical Survey, Russian Academy of Sciences and additionally develop methods for detecting long-period tremors and earthquakes. Seismovolcanic tremors are detected, classified and located with an approach that exploits the coherence of tremor signals across a network that is estimated from the array covariance matrix. The method is applied to four and a half years of continuous seismic data recorded by 19 permanent seismic stations in the vicinity of the KVG. As a result, we identify seven episodes of tremors associated with different periods of activity of four volcanoes: Tolbachik, Klyuchevskoy, Shiveluch, and Kizimen. For strongest tremor episodes associated with eruptions of Klyuchevskoy and Tolbachik we observe evolution in the depth distribution of their sources. During the same period, we detent long period volcanic earthquakes based on a template matching method and find two distinct groups of long-period sources: events that occurred just below the active volcanoes, and deep long-period events at depths of $\sim$30 km in the vicinity of a deep magmatic reservoir. We report systematic increases of the long-period seismicity levels prior to volcanic eruptions with the initial activation of the deep long-period sources that reflects pressurization of the deep reservoir and consequent transfer of the activity/stress towards the surface. The observed spatio-temporal evolution of earthquakes and tremors support a model in which different volcanoes are interacting via a system of magmatic reservoirs located within the crust and in the uppermost mantle.