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Crustal Changes Preceding Earthquake Swarm Activity in the Eastern Izu Peninsula, Observed by Seismic Noise Correlations

Tomotake Ueno[1*], Tatsuhiko Saito[1], Kazushige Obara[1], Katsuhiko Shiomi[1], Bogdan Enescu[1], Hisanori Kimura[1]

[1]NIED

Seismic swarm activity has repeatedly occurred in the eastern Izu peninsula region, central Japan. Anomalous ground tilt changes have been often recorded just before the start of the swarm activity and the ground tilt deformation was interpreted as dike intrusion at depth (e.g., Okada et al., 2000). On 17 December 2009, earthquake swarm activity started again in the area. The center of the swarm located 1-2 km north of the Hi-net N.ITOH station and the hypocenters of the early events were at 8-9 km depth. The activity migrated in the following hours towards shallower depths. Some stations near the earthquake swarm epicentral area recorded ground tilt deformation before the start of the earthquake swarm. From the ground tilt changes, a preliminary dike intrusion model was proposed by the National Research Institute for Earth Science and Disaster Prevention. The center of the dike located around 5 km and subsequently migrated to around 2 km depth.
Temporal changes of the seismic noise auto-correlation function (ACF) were recently reported in relation to remarkable seismic activity (e.g., Ohmi et al., 2008; Wegler et al., 2009; Maeda et al., 2009) and interpreted as tiny changes of the subsurface structure. In this study, we analyze in detail the temporal changes of ACFs preceding the 2009 earthquake swarm in the eastern Izu peninsula.
Data processing consists in cutting the continuous waveforms recorded at Hi-net stations in the eastern Izu peninsula in one-hour length segments, removing the mean and trend, 1-3 Hz band-pass filtering, one-bit normalization, and auto-correlation. The obtained, one-hour length ACFs were averaged for one-day time windows, with an incremental time-shift of one hour, using bootstrapping techniques. To make the ACF temporal changes more clear, we subtracted from our averaged ACFs a reference auto-correlation function. The reference ACF is obtained by first stacking one-hour length ACF for each day of February 2009, when the ACF pattern is very stable, and then averaging the one-day ACFs for the whole month. We mainly focused on the ACFs variations on 15, 16 and 17 December 2009. The ACF hourly changes before the swarm were compared with the ground tilt time series.
A clear ACF change appeared at a lag time of 10-15 s, from the evening of 16 December 2009, at the closest station N.ITOH. Precursory ground tilt change was recorded at the same station, simultaneously. The ACF and ground tilt changes were also observed at the Hi-net N.ITHH station, which is located about 5 km away from the seismic swarm area, although the change of ACF was obscure.
The temporal changes of ACF and ground tilt at the two Hi-net stations were observed for the same period of time. The wave packet of ACF at the lag time of 10-15 s was interpreted as a reflection phase from the depth of 30 km, in the case of a P-wave propagating at 6 km/s, or the depth of 15 km, in the case of an S-wave propagating at 3 km/s. This suggests that the structural change of the wavefield as a source of the temporal change of ACF is in the crust at least. Since these depths were deeper than the depth of the dike model inferred from ground tilt measurements, the relationship between the dike intrusion and the temporal change of ACF is not

straightforward. An earthquake (M1.0) occurred at the depth of 10 km in the earthquake swarm region on 16 December, at 22:45, about half-day before the start of the swarm. This event could represent an early signature of magma ascent. Hence, the temporal change of ACF might reflect the structural change caused by magma migration from the deeper part of the crust. We are now testing whether the seismic noise ACF method is valid as a monitoring tool for remarkable inland earthquake activity and volcanic eruptions.

Keywords: auto-correlation function, Izu, earthquake swarm, ground tilt preceding seismic activity, dike intrusion