Detection and location of weak continuous tremor episodes using a seismic array during the 2011 Shinmoedake eruption activity of Kirishima volcano, southwest Japan

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We deployed a seismic array at a site 5 km east of Shinmoedake volcano, in the Kirishima volcanic complex of southwest Japan, five days after the sub-Plinian eruption on 26 January 2011. The 2011 eruptions began as a small phreato-magmatic eruption on 19 January that was followed by the sub-Plinian eruption, with an eruption column reaching an elevation of 2 km. Explosive eruptions started on 28 January and occurred several times during the first half of February. Explosive and non-explosive eruptions mainly occurred between early February and the middle of April, and in late June. The last eruptions occurred from late August to early September 2011. Therefore, it is important to reveal the magmatic process below the volcano for the period from the early stage of the eruptive activity to the last eruption. We report our array analysis for continuous waveform data from the period February to September 2011 to detect coherent waves from the volcano. We estimated slownesses and back azimuths of seismic waves on a sliding 1 min window for the continuous waveform data using the semblance method. We detected several episodes of weak volcanic tremor in the periods in early February, late February to early March, late June, and late August to early September. These periods correspond to explosive and non-explosive eruptions, although there were a few eruptions when no tremor was detected in middle and late March. The weak tremor of each episode continued to several days to and has small amplitude. We successfully estimated the slowness and back azimuths of body waves of nine explosion earthquakes. The P and S wave slowness of the explosion earthquakes are 0.30 and 0.40 s/km, respectively. The slownesses of the weak continuous tremor clustered within the range 0.2-0.8 s/km, consistent with a mix of body and surface waves. A probabilistic approach based on a grid search was used to estimate the source locations of the explosion earthquakes and weak continuous tremor. The sources of the explosion earthquakes were beneath the crater at depths of -0.5-1 km above sea level, while the source of the weak continuous tremor was beneath the northern part of Shinmoedake at depths between 1 km below sea level and 1 km above sea level. This latter region corresponds to a shallow low-resistivity layer, suggesting that hydrothermal processes are more plausible than magmatic processes as the generating mechanism of the weak continuous tremor. The synchronization of weak continuous tremor and eruptions suggests that hydrothermal activity is activated by magma transport during eruptions periods.