# Monochromatic-hybrid events associated with volcanic activity: a case study at Kuchinoerabujima volcano since 2019

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Monochromatic event (MNC), also known as T-type, N-type, LP-event, Tornillo, is a volcanic earthquake characterized by waveforms signatures of damped harmonic oscillations. The MNC has been observed at plenty of volcanoes worldwide, especially with hydrothermal systems. Some physical models have been proposed to explain the sinusoidal waveform signatures of the MNC with a fluid-filled resonator. However, there are still considerable challenges linking the excitation of such harmonic seismic events and volcanic activity.
Kuchinoerabujima volcano has had several eruptive activities since August 3, 2014 (the 2014 eruption), the first eruption since 1980. The present study examines the MNCs at Kuchinoerabujima (Iguchi, 2007; Triastuty et al., 2009) to reveal the relation between the MNC and volcanic activities. We focus on the period from September 2019 to December 2021, which includes an eruptive period in early 2020. Some MNCs in this period have hybrid characteristics (Iguchi, 2007), which have superpositions of high-frequency signals (> 5 Hz) on sinusoidal oscillation. We also focus on the aspects of the hybrid events.

The figure shows daily earthquakes numbers, seismic energy of MNC ($E_{mnc}$), temporal changes of cumulative $E_{mnc}$, the fundamental peak mode of MNC ($f_0$), and daily SO2 emission amount (by JMA). We adopt short period ground velocity data at FDKL operated by Sakurajima Volcano Research Center, DPRI, Kyoto University. The gray color corresponds to the 2020 eruption period reported by JMA. The time history of the $E_{mnc}$ cumulative shows an acceleration of MNC activity since January 2020. The daily average rate of $E_{mnc}$ from January 2020 to April 2020 (Period 1) is $3.8\times10^3$ J/day. In the following period (from May 2020 to September 2020: Period 2), the rate decreased to $8.9\times10^2$ J/day. The rate of $5.2\times10^2$ J/day in the latest period from October 2020 (Period 3) is almost the same as before Period 1. This MNC activity sequence correlates well with the temporal changes of SO2 emission amount, suggesting that the MNC seismicity is related to volcanic gas emissions.

The MNC events can be divided into two groups in terms of $f_0$. The events with $f_0$ of <4.5 Hz (Group LF) continuously occurred in Period 1. The average $E_{mnc}$ of each event of Group LF is $1.6\times10^3$ J. This value is more significant than $6.6\times10^2$ J of events with $f_0$ of >4.5 Hz (Group HF). Therefore, Group LF played a role in the MNC activity correlating the SO2 discharges. The $f_0$ value in Group LF sequentially decreases from 3 Hz to 2.5 Hz before and including the 2020 eruptive period. In Periods 2 and 3, the $f_0$ of Group LF gradually increases and reaches 4 Hz on November 2021. Most events in Periods 2 and 3 are classified into Group HF. The maximum $f_0$ increases from 15 Hz to 20 Hz in Periods 2 and 3. Previous studies reported temporal changes of quality factor $Q$ of sinusoidal oscillation as well as $f_0$ (Molina et al., 2004). The maximum $Q$ values decrease from 300 to 200 in the entire period.

Orange and blue plots in the figure correspond to the hybrid MNCs. High-frequency signals superposed in the coda of the MNCs with orange plots in Periods 1 and 2. On the other hand, the events with blue color in Period 3 have the onset dominated by high-frequency signals, followed by sinusoidal oscillations. Assuming that shear fractures excite the high-frequency signals, a possible interpretation about the temporal evolution of the hybrid MNC is as follows: in Periods 1 and 2, oscillations of the MNCs trigger

 

shear fractures in the vicinity of the source region. On the other hand, the hybrid MNCs in Period 3 begin with shear fracture. This fracture triggers gas escapes in the crack, which induces following sinusoidal oscillation. Based on the above hypothesis, the oscillation amplitude of the hybrid MNC and shear fracture scale are expected to correlate. We will evaluate this expected relation from seismic records.

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