Harmonic tremor during the 2011 Shinmoe-dake eruption (2)

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Although various models regarding harmonic tremors have been proposed [e.g., Kubotera, 1974; Chouet, 1988; Julian, 1994; Ripepe and Gordeev, 1999; Johnson and Lees, 2000; Hellweg, 2000; Lesage et al., 2006; Liao et al., 2018], the source mechanism of harmonic tremor remains poorly understood. Previous researches analyzing or modeling a harmonic tremor mainly focused on amplitude spectrum characteristics [e.g., Schlindwein et al., 1995; Kedar et al., 1996; Hellweg, 2000; Maryanto et al., 2008]. To construct a source model of a harmonic tremor in a rigorous manner, it is desirable to confirm a similarity not only in amplitude spectrum but also in phase spectrum between observations and synthetics calculated by the model. If we observe a harmonic tremor near its source region, the effect of wave propagation is relatively weaker than that of source and the spectra among plural stations near the source exhibit the same set of frequency peaks as with the 2011 Shinmoe-dake eruption [Natsume et al., 2019]. The near-field signal seems to be analogical with data obtained in an experimental setting. A common way to analyze a time-series is to study its phase portrait. Phase portraits show the relationship between two different state variables of a dynamic system [e.g., Strogatz, 1994]. Assuming that the near-field signal represents only a linear transformation of a certain variable of the source dynamics, an analysis of a phase portrait is a dominant tool to examine consistency of qualitative features between the observed signals and theoretically predicted time sequences.

Takeo [2019] proposes that harmonic tremors are excited by a non-linear instability that arises when viscous fluid flows through a partially constricted flexible channel, and develops a simple lumped-parameter model of the process. This model employs the same basic framework with Bertram and Pedley's model [Bertram and Pedley, 1981], but the following points are different with the previous model. The first point is that it configures "control space" in each section and employs an integral form of momentum conservation law in each section instead of Euler's equation. The advantage of this formulation is that the contribution from nonstationary changes inside the control space also takes account in the formulation. Changing only the reservoir pressure (Po) of this model, Takeo [2019] succeeds in simulating a harmonic tremor which has the same topological characteristics (phase portrait) with the largest observed harmonic tremor occurred at 6:08 on February 3rd in several portions of time series. This formulation includes several geometrical and dynamical parameters to keep a generality of the model. In this paper, I set up other configuration of parameters and search other trajectories of self-sustained oscillations. When the length of the constricted flexible channel is fifth of the upstream tube length, another self-sustained oscillation appears. The phase portrait of this oscillation has a different qualitative feature with the previous simulation, resembling with that of the harmonic tremor occurred at 20:43 on February 2nd as shown in Figure 1. This result suggests that this model has wide spectrum of capability in simulating observed harmonic tremors and in understanding the source mechanism of harmonic tremor.

Keywords: volcanic tremor, non-linear oscillation

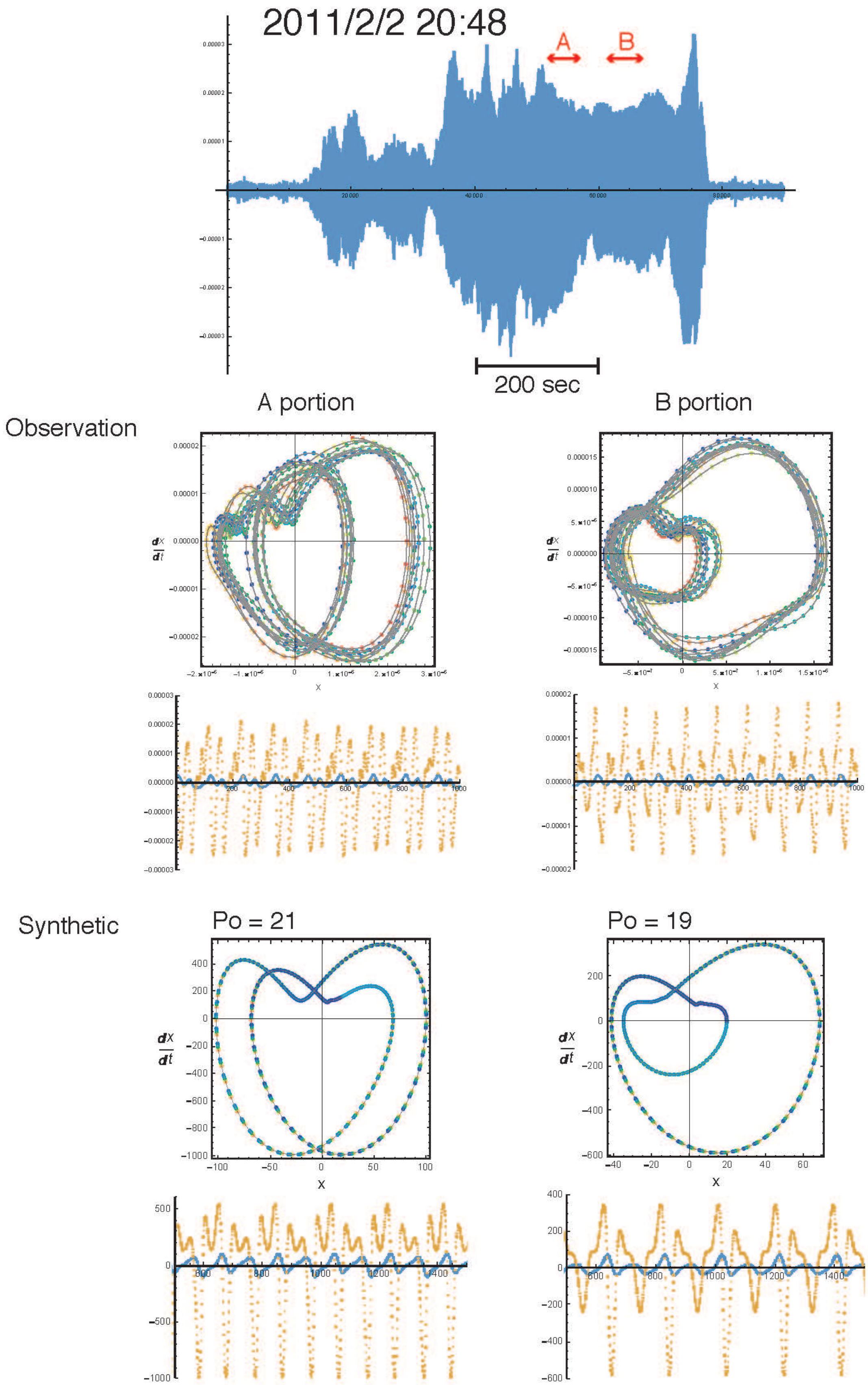
2011/2/2 20:48
A
B
200 sec
A portion
B portion
Observation
Synthetic
Po = 21
Po = 19

Figure 1