# Waveform analysis of infrasound pulses observed before the phreatomagmatic explosion on October 23, 2015

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A phreatomagmatic explosion is hazardous because it scatters ballistic projectiles and pyroclastic flows around the crater. Therefore, society demands to predict its occurrence. To attempt this, it is necessary to understand the mechanisms of the explosion itself and also related processes progressing beneath the crater before an occurrence of the explosion. In this study, we analyze infrasound pulses of Aso volcano, which were observed several days before explosions in 2015.

At Nakadake 1st crater of Aso volcano in Japan, phreatomagmatic explosions occurred in the early morning of October 23, 2015. Before the occurrence of explosions, tones of infrasound pulses were observed around the crater. These pulses started to appear three days before the explosions. In the beginning, the maximum amplitude of the pulses was 1 Pa at 200 m distance: however, it gradually increased and reached to 60 Pa at 10 hrs before the explosion. The occurrence frequency of the pulses, which was initially small about once every two minutes, increased with each passing day. It consequently reached 20 pulses per min four hrs before the explosion. The waveform of the infrasound pulses of Aso volcano quite resembles that often observed at Stromboli volcano. The pressure increased over ~0.1 s. After reaching the positive pressure peak, the pressure decreased in a short time to be a negative phase. The maximum amplitude of negative pressure was about 50-60% of the positive peak. After that, it returned to the original state while vibrating the pressure for ~1 s. The dominant frequency of the infrasound pulses was about 3-12 Hz.

We analyzed the waveform of the infrasound pulses using a model of Vergniolle and Brandeis (1996): Their model was proposed to interpret mechanism of infrasound radiation for Strombolian explosions. In the model, the size of a large bubble changes with time (the radius of a bubble oscillates) at the surface of the magma in the conduit, which induces the perturbation of the air pressure. The bubble shape surrounding by a fluid (magma) is assumed to be composed of a hemisphere and a cylinder in the upper and lower parts. The overpressure of gas inside the bubbles causes a change of the radius. Given the surrounding fluid density, viscosity, and the thickness of the bubble's membrane at equilibrium, we solve the model equations of motion of the bubble's radius by the fourth-order Runge-Kutta method. We set the density of the surrounding fluid as 1000-3000 kg/$m^3$ (5 patterns), the viscosity as $10^{-3}$-$10^3$ Pa s (7 patterns), and the bubble film thickness as 1-10 cm (4 patterns). By iterating to minimize the residual between the observed and calculated waveforms, we could estimate three parameters; the radius of the hemispherical part, the length of the cylinder, and the gas overpressure inside the bubble. We applied this method to an initial part of the infrasound pulse, from the onset to the maximum negative pressure.

The result for the pulse at 22:41:07 on October 22 is as follows. The residual was minimized when the fluid density, viscosity, and the film thickness are 2000 kg/$m^3$, $10^3$ Pa s, and 10 cm, respectively. At this case, the estimated radius and the length of the bubble are 0.21 m and 11 m, respectively (the volume is 1.5 $m^3$). The gas overpressure inside the bubble is $1.2\times10^6$ Pa. The size of bubble's radius might be confined by the size of the conduit. For time variation of the bubble's film thickness, it is gradually decrease. It indicates that bursting of the bubble occurred when the strength of the film thickness becomes below the critical value.

By applying the same method to all other infrasound pulses observed before the occurrences of explosions, it would be possible to reveal time variations of such parameters of each pulse (size, inner pressure, and the surrounding conditions of the bubble). This gives us a clue to understand the environmental conditions that might control processes leading to a phreatomagmatic explosion.

Keywords: Aso volcano, infrasound pulse