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Simultaneous waveform analyses of seismic and acoustic signals accompanying explosive volcanic eruptions

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Multi-parameter observations at active volcanoes have become popular recently. Especially, seismo-acoustic observations have been conducted at many active volcanoes. When explosive eruptions occur, both seismic and acoustic signals at a wide frequency range are observed. These signals reflect complex physical conditions in the volcanic conduit and at the vent. By conducting waveform analyses of these seismo-acoustic signals, various types of valuable information are obtained.

For example, waveform analyses of the broadband seismic signals observed during the 2004 Mt.Asama eruptions reveal source mechanisms dominated by the vertical single-force component at the source region. Complicated source-time histories of the vertical single force component reflect the vertical reaction force due to the jet recoil and the acceleration and deceleration of the mass in the conduit.

Even though some of the seismic signals associated with summit eruptions are similar to each other, acoustic signals are totally different from event to event. This observation indicates that a one-to-one correspondence between the physical process in the conduit and the physical process outside the conduit does not hold. This also means that the analyses of the acoustic signals will bring us new information of the physical processes associated with explosive eruptions.

Well known examples of waveform analyses of acoustic signals accompanying eruptions are obtained at Stromboli, Italy and Pavlof volcano, Alaska. Both analyses are based on the forward modeling of the synthetic waveform, and thus are different from waveform inversion techniques used in the analyses of seismic waveforms. Then, what kind of conditions is required to perform the waveform inversion of the acoustic waveforms?

By the waveform inversions of seismic signals, both geometrical information of the source and the source-time histories are obtained owing to the fact that the seismic wave propagation is linear phenomena and thus observed seismic waveforms are represented by the convolution of the Green's functions and appropriate source-time functions. In contrast to this, propagation of acoustic signals is not necessarily linear phenomena when the amplitude of the acoustic signals is large. Only when the amplitude of the signal is small enough so that the wave propagation can be regarded as linear phenomena, waveform inversion analyses similar to the analyses of the seismic signals can be applicable to the acoustic signals to obtain the source-time history. When monopole source is assumed, the source-time history of the mass acceleration of the source will be obtained.

Before conducting waveform analyses of the acoustic signals, appropriate Green's functions have to be calculated. The calculation of the Green's functions requires numerical approach when realistic topography and layered structures of the atmosphere are taken into consideration.

Directivity of the source of acoustic signals corresponds to the geometrical information of the seismic source. The simplest geometry of acoustic sources will be an isotropic source. One of the simplest anisotropic source geometry will be realized when a lid capping the top of the pressurized conduit breaks irregularly and the high pressure volcanic gas is emitted anisotropically.