Effect of topography of volcanoes on seismic wave propagation

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Characteristic earthquakes with the various features occur in and around volcanoes. By analyzing those seismic signals, the information about magma systems or hydrothermal systems which are considered as sources of volcanic seismic signals can be obtained.

A seismic waveform inversion is one of the techniques which are used to analyze the characteristic seismic waveforms observed in volcanoes. This is the technique of determining source mechanisms of seismic signals by comparing the seismograms which are calculated theoretically with the observed seismograms. When we analyze the seismic waveforms observed in volcanic areas, we need to be cautious of the following point. In a volcano, seismic waveforms are variously influenced according to the velocity structure and the topography of the volcanic edifice. These influences are manifested in amplification, attenuation, or phase changes of the waveforms. In case when we calculate synthetic seismograms necessary for the waveform analysis, we have to take such effects due to velocity structure or topographic feature into consideration.

Although the waveform inversion method has so far been used in analysing waveforms observed in various volcanoes, such as Sakurajima, Kilauea, Mt. Iwate, etc. the theoretical seismigrams used in the analyses are calculated by having assumed one dimensional structure (velocity and density are functions of depth only) and no topography, in many cases. In our research, we focus on evaluating the influence of topographic feature on seismic wave propagation. We compute theoretical seismograms using 3D finite-difference-method assuming two cases. In one case, we take the topographic feature of a volcanic edifice into consideration and in other case, we do not. By comparing seismograms for two cases, we quantitatively evaluate the influence of topography on the wave propagation. We mainly use simplified imaginary topography of volcanic edifices in order to see the effect clearly. The topography of an actual volcano is also used.

The effects of topography on the seismic wave propagation through the volcanic edifice vary depending on wave length of the seismic signal under consideration or on the relative location between sources and receivers. For example, when the source depth is very shallow and thus the source is located above seismic stations, the effect of topography cannot be disregard no matter what wavelength. On the other hand, the effect might be omitted when source is deep enough and the wavelength of the seismic signals is much longer than the typical length scale of the volcanic edifice. When wavelength is short, sufficiently accurate waveforms may be obtained by a simple elevation correction.

In this research, effects of topography on the waveforms for various wavelength and for various source locations are evaluated. As a real topography, we use that of Miyake-jima which last erupted in 2000. The effect of the change in topography due to the formation of summit crater during the volcanic activity will be discussed.