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Visualization of seismic wave propagation around Aomori Prefecture, northern Japan

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In seismology, travel-time curves have been the most fundamental tool to understand the propagation of seismic waves. However, some complex velocity structures of the real earth produce the triplication or discontinuity of curves, which makes it difficult, especially for the general public, to grasp the nature of wave propagation. In order to improve these circumstances, we tried to visualize the spatiotemporal variation of seismic wave energy distribution. We used the seismograms obtained from an earthquake with magnitude 6.2 which occurred eastern off of Aomori Prefecture on August 14, 2001. Both borehole stations including Hi-net and the Seismic Observation System of Aomori Prefecture, and surface stations of KiK-net and K-net, were individually utilized to animate the seismic wave propagation in the following way. To deal with the seismograms of ground velocity, we integrated the acceleration data from the KiK-net and the K-net stations, and filtered out the low frequency noise. Then we transformed all the seismograms into envelopes, smoothed them by taking a moving average, and resampled the amplitude at a rate of one sample per second. Finally we used the Generic Mapping Tool (GMT) software to obtain contour map in logarithmic amplitude scale. The snapshots thus obtained for each time slice were combined together to produce the animation, which were written in SWF format for the purpose of opening to public via Internet.

From the animation we have noticed the following characteristics of ground motion that may not be found from the traditional travel time analysis. As for the spatial distribution of noise level at the origin time of the earthquake, stations in plains have higher amplitude than in stations in mountain areas. After the arrival of P wave, the wave front spreads almost concentrically in the animation from the borehole data set, while the wave front is distorted for the case of the surface data set. The most interesting feature of wave propagation is the delay of wave front when it passes the Lake Towada. A low velocity zone that exists in the upper mantle beneath this active volcano probably causes this delay. Main part of S wave also exhibits higher amplitude in plains than in mountains. Since this characteristic is more evident for the surface data set than the borehole one, we interpret that amplification due to surface layers with low velocity is generally large in plains. After the lapse time exceeds twice the S-wave travel time at the Japan Sea, seismic wave energy is distributed homogeneously in space. This phenomenon can be explained by the scattering of seismic waves. Even at these time windows, however, the amplitude level is again higher in plain than in mountains. This indicates the longer duration of seismic motion in plains than in mountains. This fact is explained by trapping of seismic wave energy in the sedimentary surface layers in plains. At sufficiently large lapse times, the seismic wave energy returns to the ordinary noise level. In the case of this event, this stage appears after 22 minutes, which is much longer than expected from the well-known empirical formulas to define the F-P magnitude of an earthquake.

The characteristics of wave propagation seen in the animation is quite consistent with our knowledge of wave front expansion, the existence of low velocity zone beneath the Lake Towada, and surface topography. Although we need more case study to delineate the general feature of wave propagation, we regard the visualization by means of animation is an excellent tool not only for the seismologist to confirm the existing knowledge and to find new subject of study, but for the general public to be more conscious to seismic wave propagation and the earth's structure.