Mapping multi-mode surface wave phase speeds in North America using mode-branch waveforms decomposed by linear Radon transform

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The use of higher-mode surface waves is inevitable for further enhancement of vertical resolution of tomography model since they are much more sensitive to the deep structure of the Earth's upper mantle than the fundamental modes. However, measuring the multi-mode phase speeds is not a straightforward issue since wavetrains of different modes overlap each other in a seismogram.

We have developed the two-step array-based method for higher-mode analysis, which consists of (1) multi-mode phase speed measurements based of a classical *f-k* analysis using a long-range linear array with several-thousand kilometers (e.g., Nolet, 1975, GRL) and (2) modal waveform decomposition for the centroid location of the linear array using the linear Radon transform (e.g. Luo *et al.*, 2015, GJI).

We have previously applied the method to a large data set of seismograms observed at Transportable Array stations of USArray and employed the average phase speeds of linear array to map phase speed distributions in North America (Matsuzawa and Yoshizawa, SSJ Fall Meeting 2018; AGU Fall Meeting 2018). We could obtain phase speed maps of the fundamental-mode and the first four higher-mode surface waves. Although the large-scale anomalies (i.e., fast phase speeds in cratons in the stable eastern U.S., slow phase speeds in the tectonically-active western U.S.) can be identified, the lateral resolution of the phase speed maps were insufficient compared to inter-station/array based tomography models. This suggests that the small-scale tectonic features have been blurred and averaged out due to the direct use of long linear array (2000–4000 km) with relatively large measurement errors.

In this study, we apply the inter-station dispersion analysis with nonlinear waveform fitting (Hamada and Yoshizawa, 2015, GJI) to the decomposed modal waveforms of the fundamental-mode surface waves derived from method using the centroids of the linear array as imaginary stations.The lateral resolution of resultant phase speed maps has been improved up to about 2.0 degrees owing to the relatively shorter inter-station (inter-centroid) distances used in the inversions.We can find typical small-scale tectonic features in the inland region of eastern and central US. Average phase speeds along each short ray path (several-hundred kilometers) have been measured stably without interference by overtones, which is likely to be of help in improving the accuracy of the resultant tomography maps.

The decomposed modal waveforms of the higher modes as well as the fundamental mode can be applied to the secondary dispersion analyses such as the inter-station dispersion measurements as done in this study and/or a 2-D beamforming analysis, which can be expected to enhance both the lateral and vertical resolutions of surface wave tomography models.

Keywords: Surface wave, Higher mode, Array-based analysis, Tomography, North America