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Mapping the Moho with seismic surface waves: Sensitivity, resolution, and recommended inversion strategies

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Seismic surface waves have been used to study the Earth's crust since the early days of modern seismology. In the last decade, surface-wave crustal imaging has been rejuvenated by the emergence of new, array techniques (ambient-noise and teleseismic interferometry). The strong sensitivity of both Rayleigh and Love waves to the Moho is evident from a mere visual inspection of their dispersion curves or waveforms. Yet, strong trade-offs between the Moho depth and crustal and mantle structure in surface-wave inversions have prompted doubts regarding their capacity to resolve the Moho. Although the Moho depth has been an inversion parameter in numerous surface-wave studies, the resolution of Moho properties yielded by a surface-wave inversion is still somewhat uncertain and controversial.

We use model-space mapping in order to elucidate surface waves' sensitivity to the Moho depth and the resolution of their inversion for it. If seismic wavespeeds within the crust and upper mantle are known, then Moho-depth variations of a few kilometres produce large (over 1 per cent) perturbations in phase velocities. However, in inversions of surface-wave data with no a priori information (wavespeeds not known), strong Moho-depth/shear-speed trade-offs will mask about 90 per cent of the Moho-depth signal, with remaining phase-velocity perturbations 0.1-0.2 per cent only. In order to resolve the Moho with surface waves alone, errors in the data must thus be small (up to 0.2 per cent for resolving continental Moho). If the errors are larger, Moho-depth resolution is not warranted and depends on error distribution with period, with errors that persist over broad period ranges particularly damaging.

An effective strategy for the inversion of surface-wave data alone for the Moho depth is to, first, constrain the crustal and upper-mantle structure by inversion in a broad period range and then determine the Moho depth in inversion in a narrow period range most sensitive to it, with the first-step results used as reference. We illustrate this strategy with an application to data from the Kaapvaal Craton. Prior information on crustal and mantle structure reduces the trade-offs and thus enables resolving the Moho depth with noisier data; such information should be sought and used whenever available (as has been done, explicitly or implicitly, in many previous studies). Joint analysis or inversion of surface-wave and other data (receiver functions, topography, gravity) can reduce uncertainties further and facilitate Moho mapping. Alone or as a part of multi-disciplinary datasets, surface-wave data offer unique sensitivity to the crustal and upper-mantle structure and are becoming increasingly important in the seismic imaging of the crust and the Moho.

Reference

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