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Combining controlled-source seismology and local earthquake data to derive a consistent three-dimensional model of the crust: Application to the Alpine region

Michael Wagner (1), Edi Kissling (2), Stephan Husen (1), and Domenico Giardini (1)
(1) Swiss Seismological Service, ETH Zurich, Switzerland, (2) Institute of Geophysics, ETH Zurich, Switzerland

Crustal models of the Earth are important for various seismic applications. In many regions a lot of different seismic models are existing. Based on the underlying method all these models have their individual strengths and drawbacks. Controlled-source seismology (CSS), for example, is especially suitable for detecting and imaging seismic interfaces showing a strong contrast in seismic velocity, such as the crust-mantle boundary (Moho). However, due to the setup of the method (i.e. source-receiver geometry, resulting ray paths, ...), CSS provides information on seismic velocities limited to only relatively small volumes. In contrast, local earthquake tomography (LET) can provide 3D images of seismic velocities of the lithosphere with a spatial resolution up to a few tens of kilometers. The parameterization of LET models, in combination with less certain phase identification in 3D cases, however, prevent tomographic imaging of first order velocity discontinuities.

Several attempts have already been proposed to get a model satisfying data from both CSS and LET methods. In these approaches CSS data is used in a starting model and, thus, included in the inversion process of the coupled hypocenter-velocity model problem. The resulting models show improved resolution of near-surface structures, but imaging of sharp first order discontinuities (e.g. Moho) is still not possible. This restriction of not knowing the Moho precisely is a serious limitation.

Our newly developed approach of combining CSS and LET data takes into account the above-mentioned strengths of the individual seismic methods by combining them and, therefore, trying to eliminate the drawbacks of each other method. We focus on the greater Alpine region which is, due to many available CSS and LET information, the preferred region for such a study. Our crustal model includes a well-defined Moho, as constrained by CSS and LET data, as well as 3D variations in seismic velocities, as constrained mainly by LET data and in localized volumes complemented by CSS information. The model clearly shows three Moho surfaces, being Europe, Liguria and Adria, as well as major tectonic structures like suture zones and the high-velocity Ivrea body. Such a model can then be used, for example, for calculating travel times of Moho reflected phases (PmP) and, thus, improve regional earthquake hypocenter location by using not only first arriving phases, but also secondary ones.