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Coupling between P- and S-wave velocities in earthquake location and seismic tomography

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The use of S-wave arrivals does not only provide important constraints on hypocenter locations but also on composition and physical parameters of the crust. For example, the P- to S-wave velocity ratio (Vp/Vs ratio) is proportional to the Poisson's ratio, and as such it provides important constraints on composition and mechanical properties of the rock volume under study. Because S-wave arrivals are secondary arrivals, their arrival times are more difficult to pick than P-wave arrivals, which often yields S-wave data sets of lower quality and quantity. As a consequence, hypocenter locations or tomographic images can usually not be determined by using S-wave arrivals alone. In order to overcome this limitation, P- and S-wave arrivals can be used jointly and or interdependently in earthquake location and in seismic tomography. For example, P- and S-wave arrivals are often inverted simultaneously for P-velocities and P-to-S-wave velocity ratios. This approach, however, may lead to biased P-to-S-wave velocity ratios due to the lower number of S-wave arrivals, compared to the number of P-wave arrivals. In this study we investigate the coupling between P- and S-wave velocities in earthquake location and seismic tomography by using local earthquake data from Alaska. Our data set encompasses 4811 well-locatable earthquakes with a least eight P- and eight S-wave observations. The large number of P- and S-wave arrivals per earthquake allow us to invert each data set separately as well as simultaneously for P- and S-wave velocities. For each inversion we compute the corresponding Vp/Vs ratios from the derived P- and S-wave velocity models. Our results indicate a significantly larger variability in depth for Vp/Vs ratios computed from separate both well-constrained inversions for P- and S-wave velocities. Moreover, we observe systematically different Vp/Vs ratios in the lower crust and in the underlying mantle wedge whether P- and S-wave arrivals are inverted simultanously or separately. Although the inverse problem for the combined inversion is even better constrained due to common hypocenter parameters, Vp/Vs ratios derived from separate inversions for P- and S-wave velocities are more consistent with physical and petrographic models for the Alaska subduction zone. We therefore think that Vp/Vs ratios derived from combined inversions for P- and S-wave velocities are less realistic and may show a systematic bias. As a consequence, hypocenter locations computed by inverting jointly P- and S-wave arrivals may also show a systematic bias, particular in focal depth.