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Out-of-plane reflections – are they evidence for deep subducted lithosphere?

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Subduction zones form dominant tectonic features on the Earth and have complex three-dimensional structures. Tomographic inversions for P- and S-wave seismic velocities in the Earth's mantle give impressive images of slabs descending into the deep Earth. However, direct observations of deep slabs are scarce but necessary to make statements concerning physical parameters, structural differences within the slab and its behavior with depth. The main objective of this study is to investigate the geometry, physical parameters and structural differences of subducted lithosphere by investigating seismic P-wave arrivals that reflect off the base of the slab using seismic array techniques. The great circle paths of the source-receiver combinations used do not intersect the slab and serve as reference. We focus on the North pacific region by using earthquakes from Japan, the Philippines and the Hindukush recorded at North American networks (e.g. USArray, Alaska and Canada). The data cover a period from 2000-2012 with a minimum magnitude of 5.6 Mw and depths below 100 km. We are looking for reflections from the slab region that would arrive at the stations with deviating backazimuths. Information on slowness, backazimuth and travel time of the observed out-of-plane arrivals is used to backtrace the wave to its scattering location and to map seismic heterogeneities associated with subduction zones. The reflection points give an idea for the 3D structures within the mantle. Assuming only single scattering in the backtracing algorithm, most out-of-plane signals have to travel as P*P and only a few as S*P phases, due to their timing. Taking into account the radiation pattern of each event in direction of the great circle path and towards the calculated reflection point, it is possible to compare the polarities of the out-of-plane signals with P and/or PP. Furthermore, we analyze the out-of-plane waveforms in the beam trace of the observed slowness and backazimuth by cross-correlating them with great circle path phases and applying a systematic frequency analysis. Since the backtracing results are used for the further analysis of the signals, it is important to know how robust the backtracing routine is. We therefore analyze synthetic seismograms for 3D models with and without slab like heterogeneities. The result helps us to understand the depth dependent thermal behavior of sinking lithosphere, its internal structure and the extent to which it is seismically visible.