Evidence for over pressured fluids within the subducting Philippine sea plate inferred from anomalous vp/vs ratios

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In this study we investigate the seismic structure of the Philippine Sea plate in southwest Japan in terms of interval vp/vs ratios, geometry and anisotropy of the subducting oceanic crust, using 9700 receiver functions from 21 broadband stations of F-NET and J-array sited in the Shikoku, Chugoku, Kii peninsula and Kinki regions. The Moho conversions corresponding to the subducting plate are very pronounced between 4-6s with their corresponding free surface multiples close to 15 and 19s. At most of the stations the Moho conversion is preceded by a negative phase corresponding to the top of the dehydrated oceanic slab. The free surface reflection of this phase can also be traced close to 10s. To parameterize the seismic structure beneath each station, we adapt the nearest neighborhood algorithm approach (Sambridge, GJI, 1999) in conjunction with the efficient forward modelling scheme of Frederisksen and Bostock (GJI, 2000). The forward modeling uses a ray theoretical approach capable of modeling dipping anisotropic media. The travel time equation of Diebold (Geophysics, 1987) is used to synthesize the effects of dipping planar media, by using analytic expressions involving the depth and the vertical slowness within a layer. The displacement seismogram is then constructed by combining the travel times and amplitudes of all the phases and segments. Anisotropy is modeled with a hexagonal axis of symmetry with an arbitrarily oriented axis of symmetry using the formulation of Farra et al., (GJI, 1991). The suite of models that best explain the azimuthal variations of the radial and transverse receiver functions in a multidimensional parameter space are obtained in a Monte Carlo mode by searching among parameters that have previously produced low misfits with observed data. Since the ray theoretical approach to generate synthetics is more sensitive to travel times of phases compared to their amplitudes, the misfit function is based on the correlation coefficient between synthetic and real traces, with a weighting factor assigned to the P, SV and SH traces.

In the present study, a slab model in which a dipping anisotropic layer embedded in an isotropic mantle and overlain by an isotropic crust is used to parameterize the medium beneath a station. The model consists of P and S velocities in each layer, strike and dip of the top and bottom of the subducted crust and the plunge and azimuth of anisotropy within this layer. To obtain tighter constraints on the vp/vs ratios, the multiples are also included in the inversion, albeit an exponential increase in the computation time. The modeling reveals significant complexity in the nature of the top and bottom of the subducted oceanic crust along different segments of the subduction zone, suggestive of a highly complicated nature of the slab whose thickness is close to 7km. Interestingly, the modeling results for stations close to the trench indicate very anomalous vp/vs ratios (greater than 2.2) providing clear evidences for highly over pressured fluids within the subducting oceanic plate. These results are similar to those recently reported from the Cascadia subduction zone, where the anomalously high vp/vs values have been interpreted in terms of pervasive presence of water trapped in fluid form by a sealed (impervious) plate boundary, resulting in pore pressures near lithostatic values (Audet et al., Nature 2009). Interestingly, these regions of high vp/vs ratios coincide with the occurrence of Low Frequency Earthquakes that have a bearing on the generation of mega-thrust earthquakes in subduction zones. As a continuation of this study, it is intended to model the dense Hi-net data from SW Japan for a detailed understanding of the nature of the fluids in this subduction zone and its relation to seismogenesis.