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Three-dimensional thermal structure of the lower crust and upper mantle beneath Japan derived from seismological data

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We modeled a three-dimensional thermal structure of the lower crust and upper mantle (to the depths of several tens of kilometers) beneath Japan. The model can be used to infer a viscoelastic property of the crust to conduct numerical simulations for earthquake forecast. Firstly, we estimated temperatures at depths of D90, above which ninety percents of hypocenters are distributed. Secondly, we estimated the temperature distribution below the depth 45 km. Finally, we spatially interpolated the temperature in the other part of the model and obtained a three-dimensional thermal structure of the lower crust and upper mantle. Regions deeper than the upper boundary of the Pacific and Philippine Sea plates (PSP) were excluded from the model. The temperatures on the upper boundary of the PSP were given a priori as a function of depth when it lies shallower than 45 km. A detail process is explained below.
We estimated the temperatures at D90 assuming that the material property of the crust changes from brittle to ductile at D90. We determined D90 using hypocenters reported from the Japan Meteorological Agency (Oct., 2001 to Dec., 2008, M > 1). We calculated brittle strengths at D90 assuming a failure equilibrium predicted by Coulomb theory. The brittle strengths equal the flow strengths at D90 according to the assumption described at the top of this paragraph. We substituted the values of the strengths at D90 and the strain rates deduced from GPS data (Sagiya et al. 2001) into a flow law (Rutter & Brodie, 2004), which describes a relationship among a flow strength, a strain rate and a temperature, to obtain the temperatures at D90.
We took a method of Nakajima and Hasegawa (2008) to estimate the thermal structure at the depths deeper than 45 km. We converted a tomography image of intrinsic attenuation (Nakamura, 2008) to a thermal structure using a relation between an intrinsic attenuation and a temperature of a mantle material (Karato, 1998) and an actual temperature of the mantle just beneath the Moho boundary at two sites as a reference, which was estimated from mantle xenoliths.
We adopted the model of Nakajima et al. (2009) for the geometry of the PSP. Based on the previous studies, we assumed the thermal gradients on the upper boundary of the PSP when it lies shallower than 45 km: 9 degrees/km in the regions near Kyushu, 15 degrees/km around the regions of Nankai to Tonankai, and 7.5 degrees/km in the Kanto regions.
Characteristic features in the resultant models are as follows:
1) The temperatures range from about 320 to 420 degrees C at D90. It is seen that the regions of high temperature correspond to volcanic and geothermal regions.
2) The temperatures at depths of Conrad and Moho boundaries (Katsumata, 2009) take values from 400 to 700 degrees C and values from 600 to 900 degrees C, respectively.
3) The temperatures range from 750 degrees C to 1200 degrees C in the horizontal section at a depth of 45 km. The pattern of the thermal distribution at depth 45 km is quite similar to that at D 90. A characteristic feature observed in the thermal distribution at a depth of 45 km alone are that the temperatures in the northeast Japan are systematically lower than those in the southwest Japan.

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