Lateral heterogeneity in the lowermost outer core (F layer) of the Earth revealed by seismic analyses

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We have determined seismic velocity structures of the lowermost outer core (F layer) beneath Northeast Pacific and Australia (Ohtaki and Kaneshima, 2015; Ohtaki et al., 2018), and found that the F layer is seismologically heterogeneous. These structures were obtained using a combination of two observations. First one is differential traveltimes between waves that reflect at the inner core boundary (ICB) and that graze the boundary; the second is dispersion (frequency dependence of velocity) of the grazing wave.

Our results show a somewhat strange velocity profile in the F layer beneath Australia, which has a lower-velocity-gradient layer than that of the Preliminary Reference Earth Model (PREM; Dziewonski and Anderson, 1981) on the ICB, and a higher-gradient layer just above the layer. Recent advance in high pressure research enables seismologists to translate lateral seismic velocity variation to relative chemical abundance in the outer core condition. Based on the results of Ichikawa and Tsuchiya (e.g., 2018), we showed light-element enrichment there. This result suggests that lighter fluid exists beneath Australia in the lowermost part of the liquid core, although the outer core is low-viscosity fluid.

The solid inner core of the Earth has quasi-hemispherical structure (e.g., Tanaka and Hamaguchi, 1997). As the origin of this hemispherical structure, uneven growth of the inner core has been proposed (e.g., Aubert et al., 2008; Alboussière et al., 2010; Monnereau et al., 2010). When the liquid in the outer core solidifies at the inner core surface, excess light element is partitioned to residue because the solid inner core is poorer in light elements compared with the liquid outer core. Thus, the uneven growth of the inner core is tied with an uneven release of the light elements to the F layer, which may be related to our results of the heterogeneous F layer. Then, a question arises: this heterogeneity has hemispherical structure like the inner core or local one?

We have not answered it yet because the survey areas of the above studies are restricted. Furthermore, other studies focusing F-layer velocity are not so many. Souriau (2015) determined lateral variations of velocity in the lower outer core using traveltimes of waves that turn there, and suggested that heterogeneity in F has degree-one feature. We also determined the seismic structure of the F layer beneath Antarctica using amplitude ratios between waves that turn just above the inner core and that get into the inner core. Although the resolution and reliability of structure obtained using amplitude ratios is lower than those using the method of our recent papers, the structure beneath Antarctica has a much lower velocity gradient in the F layer compared with PREM. Such a lower gradient is close to the model beneath Australia.

In this paper, we will show the summary of the heterogeneous F-layer structures of velocity and chemical abundance at this stage.

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