P-wave tomography beneath Greenland and surrounding regions

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Greenland is a stable land mass and has preserved ~4 billion years of Earth’s history. In the vicinity of the island, there are the Mid-Atlantic Ridge, the Iceland and Jan Mayen hotspot volcanos, and a geothermal area of western Svalbard, which indicate importance of these regions for understanding the global-scale tectonics. The Greenland Ice Sheet Monitoring Network (GLISN), initiated in 2009, is an international project for seismic observation in these regions, and currently is operating 35 seismic stations. The purpose of this work is to study the detailed 3-D P-wave velocity (Vp) structure beneath Greenland and surrounding regions using the latest data recorded by the GLISN network. We use a method of regional tomography to investigate the 3-D crust and upper mantle structure, and apply a global tomography method to study the deep structure from the mantle-transition zone to the core-mantle boundary.

In the regional tomography, we used the method of Zhao et al. (1994, 2012) to simultaneously invert both P-wave arrival-time data from local events and P-wave relative travel-time residuals from teleseismic events recorded at 34 GLISN stations. We used 1,508 P-wave arrival time data from 934 local earthquakes extracted from the ISC-EHB catalog. For teleseismic events, we integrated two sets of arrival-time data. The first data set was selected from the EHB catalog, which includes 35,871 arrival times from 5,399 teleseismic events. The second data set was newly picked from seismograms by ourselves using the cross-correlation technique (Liu & Zhao, 2016), which includes 7,573 relative travel-time residuals from 347 events.

In the global tomography, we used a multi-scale tomography method (Zhao et al., 2017), which sets 3-D grid nodes densely in the target area. We inverted ~5.8 million arrival times of P, pP and PP waves from 16,257 earthquakes extracted from the EHB catalog, which were recorded at 12,549 stations in the world. Since the grid intervals in the longitudinal direction depend on the latitude in the polar regions, we applied the coordinate transformation that moves the target area to the equator in both the regional and global tomographic studies.

Our results reveal the following features.

(1) A remarkable low-Vp anomaly elongated in the NW-SE direction is revealed at depths <= 250 km beneath the center of Greenland, which may reflect the residual heat when the plate with Greenland passed over the Iceland plume at ~80–20 Ma. Although previous studies have suggested this feature, our results first show that the low-Vp zone is within the Greenlandic lithosphere and its spatial distribution agrees very well with the high crustal heat-flow regions.

(2) The Iceland plume has been considered to be a single plume, but it could be a composite of a plume rising from a depth of 1,500 km beneath Iceland and a plume rising from the core-mantle boundary beneath Greenland. Here the latter one is called the “Greenland plume”. We deem that, after the two plumes are joined together in the mantle transition zone, they supply magmas to the active volcanoes in Iceland, Jan Mayen, and Svalbard.

(3) A high-Vp anomaly is imaged at depths <= 500 km off the northeast coast of Greenland. Iceland and Jan Mayen volcanoes are located south of the high-Vp anomaly, while Svalbard is located to the north. There is no volcano in Svalbard but it exhibits a high heat flow. The high-Vp body is also located at the bend of the Mid-Atlantic Ridge, suggesting that it might be an obstacle for plume flow to provide sufficient magma to Svalbard, and it might have caused changes in the plate-spreading direction at the Mid-Atlantic Ridge.

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