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Nature of inner-core temporal changes and a precise estimate of differential inner-core rotation rate

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Temporal changes of the inner core over several years have been well observed by different studies, especially those using high-quality repeating earthquakes (i.e., doublets). The phenomenon has commonly been interpreted as the differential rotation of the inner core shifting its interior heterogeneities. However, an alternative interpretation, the rapid growing or shrinking at the inner core boundary (ICB), is favored by some studies. On the other hand, estimates of the inner-core rotation rate vary by an order of magnitude.

In this study, we used high-quality doublets from our previous systematic global search and analyzed the temporal changes (in terms of arrival times and waveforms) of inner core waves (both the refractive PKIKP and the reflective PKiKP) at the distance range between 128° and 142°. Using SKP (or PP) phase as a reference to eliminate possible clock errors, we found that the temporal changes are mostly from the PKIKP arrivals and always start before the onset of the late-arriving PKiKP. The observation is consistent with the proposal of differential rotation and rules out the ICB as the sole source of the temporal changes.

On the other hand, we discovered compelling evidence of the differential rotation. Stations AAK and KZA in Kyrgyzstan are virtually the same distance to the doublets along the South Sandwich Islands (SSI) and hence are referred to as twin stations by us. The fortuitous geometry captures the underlying local structures, which have complex lateral velocity gradients. The yearly temporal change from different doublets also varies a lot, but surprisingly, it strongly correlates with the underlying velocity gradient, providing unequivocal evidence for the rotation of the inner core. The rotation rate could be accurately determined as 0.127° ± 0.006° per year at 95% confidence level in 1991-2010. In other words, when the lapse of a doublet is about 6.3 years, the inner core structure sampled by the earlier event to AAK is captured by its later repeater to KZA, which agrees very well with the real data.

We believe that the above results largely resolve the debates on the origin of the temporal changes of the inner core and provide the most precise estimation of the differential rotation rate for the 1991-2010 time period.