Support for Inner Core Super-Rotation from High-Quality Waveform Doublets

Xiaodong Song, Yingchun Li, Xinlei Sun • University of Illinois at Urbana-Champaign
Jian Zhang, Paul G. Richards, Felix Waldhauser • Lamont-Doherty Earth Observatory of Columbia University

Differential inner core rotation was inferred from temporal change of travel times through the inner core (Song and Richards, 1996). However, claims of such a travel-time change have been challenged and reinterpreted as artifacts of systematic event mislocations, mantle heterogeneity, and other causes (e.g., Souriau, 1998). Waveform doublets potentially can provide much stronger proof of temporal change in travel times through the inner core (Li and Richards, 2003). The high similarity of the whole waveforms in a waveform doublet ensures that the two events indeed occur at the same location and sample the same Earth structure. The waveform similarity also allows measurements of relative time shifts with high precision.

We have recently found 18 high-quality waveform doublets with time separation of up to 35 years in the South Sandwich Islands (SSI) region, for which the seismic signals that have traversed the inner core as PKP(DF) show a consistent temporal change of travel times at up to 58 stations in and near Alaska, and a dissimilarity of PKP(DF) coda (Zhang et al., 2005). Using waveform doublets avoids artifacts of earthquake mislocations and the contamination of small-scale heterogeneities. Our new results greatly strengthen the original claim of seismological evidence for inner core super-rotation.

The figure overlays waveforms of the SSI doublets in order of increasing time separation, most of which were recorded at the GSN station at College Alaska (COL/COLA). We see that the waveforms of the PKP branches that do not traverse the inner core, PKP(BC) and PKP(AB) at College station and Beaver Creek array stations (BC01 and BC04), are highly similar. The high similarity of BC and AB signals in our doublets is due to propagation paths outside the inner core that sample the same heterogeneities. Observed differences in DF give information on changes in the inner core.

Our basic observations are that when signals from these high-quality waveform doublets are aligned on the BC phase, the DF phases for event pairs with time separation of less than 4 years overlap with each other rather well; but the DF phase of the later event arrives consistently earlier than that of the earlier event for doublets separated by more than 4 years, and the DF phase is seen to arrive progressively earlier as the time separation increases. The temporal change of the DF travel times is about 0.09 s per decade with standard error of 0.005 s. We also see that the waveforms of the DF coda become dissimilar when the time separation is larger than 7-10 years. The DF coda is presumably caused by scattering within a complex anisotropic heterogeneous structure. Thus, the observed breakdown of waveform similarity provides new and powerful evidence for motion of the inner core.