I

INNER CORE ROTATION

Observational evidence of inner core rotation is based on changes in the travel-time of seismic waves. The rotation rate appears to be a few tenths of a degree per year eastward with respect to the mantle.

Early speculations

The inner core with radius of about 1215 km resides concentrically within the much larger fluid outer core, which has a low viscosity (e.g., Poirier, 1998). Patterns of convection within the fluid core associated with the geodynamo are presumed to undergo temporal variations because the Earth's magnetic field is changing on timescales ranging over several orders of magnitude. It is therefore reasonable to speculate (Gubbins, 1981; Anderson, 1983) that the inner core might have a rotation rate somewhat different from that of the rest of the solid Earth, which is dominated by the daily rotation. If such relative rotation could be detected, it would provide information on the energy of convection patterns that maintain the geomagnetic field.

The study of inner core motion relative to the mantle and crust is difficult, because of the remoteness of the inner core (more than 5150 km from the Earth's surface where the nearest observations can be made) and its small size (about 0.7% of the Earth's volume). Also there are intrinsic difficulties in telling whether a spherical object is rotating, unless a marker on or within the object can be identified and tracked if it moves.

First claims, based on seismological observations and implications

The first published claim of observational evidence for inner core rotation, relative to the mantle and crust, was given by Song and Richards (1996). They noted that seismic waves originating in the South Sandwich Islands (in the southernmost South Atlantic) and recorded in Alaska, which had traveled through the inner core, appeared to have traveled systematically faster for earthquakes in the later years during the period from 1967 to 1995, compared to observations of seismic waves from earlier earthquakes in this time period. The rate of travel-time decrease amounted to about 0.01 s per year—a value that was close to the precision of measurement.

More detailed studies by Creager (1997), Song (2000), and Li and Richards (2003), have provided additional support for travel-time change of about this same value, for seismic P-waves crossing the inner core. Figure I7 shows a clear example of *PKIKP* waves (which pass through the inner core) showing a faster arrival for the later earthquake, when the seismograms are aligned on *PKP* waves (which avoid the inner core).

Song and Richards (1996) interpreted the travel-time change as an effect of anisotropy, which causes P-waves to travel with speeds that depend on direction relative to a crystalline axis that rotates with the inner core. Creager (1997) persuasively argued for a more important marker of inner core rotation, namely a lateral gradient of the P wavespeed (increasing from east to west) in the part of the inner core traversed by *PKIKP* waves. He and Song (2000), Richards (2000), and Li and Richards (2003) concluded the observed travel-time changes indicate an eastward rotation of the inner core amounting to a few tenths of a degree per year.

The concept of an inner core rotating fast enough to be detected on a human timescale has attracted numerous investigators since 1996. Dehant *et al.* (2003) describe inner core research in mineral physics, seismology, geomagnetism, and geodesy. The rate of inner core rotation is an indication of the vigor of convection in the outer core, associated with the geodynamo. A nonzero rotation rate can be used to place limits on the outer core's viscosity (Buffett, 1997).

Counterclaims, and additional methods and evidence

Several papers since 1996 have argued that the seismological evidence for inner core rotation is equivocal. Thus, Souriau and Poupinet (in Dehant *et al.*, 2003) claim the reported travel-time changes of *PKIKP* waves on the path between the South Sandwich Islands and Alaska are an artifact of mislocated earthquakes. Early reports of purported changes in the absolute arrival times (not differential times) of *PKIKP* waves were later dismissed as based on inadequate evidence.

Laske and Masters have used normal mode data to study inner core inhomogeneities. Some modes appear to indicate eastward rotation, others westward, and their paper in Dehant *et al.* (2003) concludes the rate is only marginally indicative of a small eastward rotation, about 0.15 degree per year (but alternatively estimated as 0.34 ± 0.13 degree per year if the normal modes likely to be most contaminated by upper mantle structure are excluded). Vidale and Earle (2000) used backscatter from within the inner core, following *PKIKP* waves, to find an eastward rotation of the inner core amounting to a few tenths of a degree per year.

It appears that the strongest claims of evidence for inner core rotation derive from differential traveltimes, for earthquakes separated by several years and which occur at essentially the same location, generating very similar waveforms. The evidence for inner core rotation is still under debate, and consensus on inner core rotation will likely depend on whether examples such as that given in Figure I7 can be accumulated, since waveform doublets avoid artifacts of event mislocation. A report on 18 high-quality doublets with time separation of up to 35 years in the South Sandwich Islands region, observed at up to 58 stations in and near Alaska, provides such an accumulation (see Zhang *et al*., 2005).

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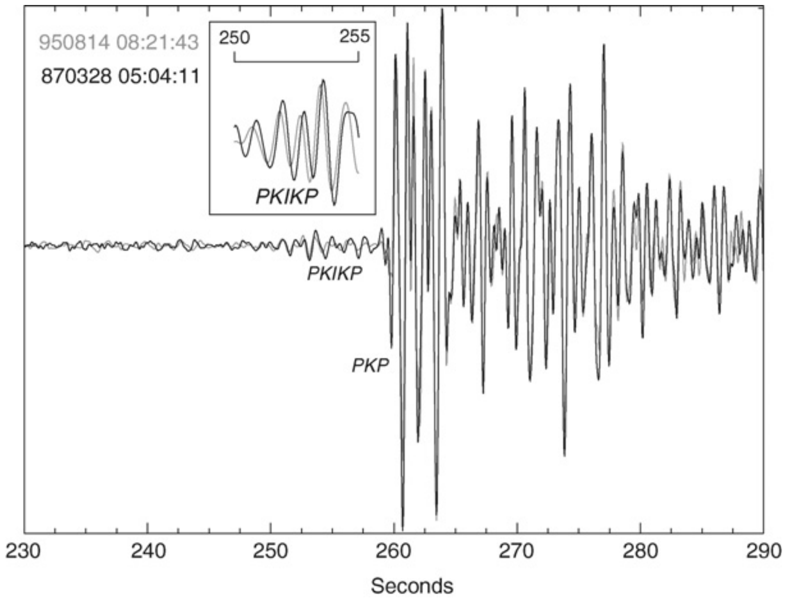

Figure I7 One minute segments of short-period seismograms recorded at College, Alaska, for two earthquakes in the South Sandwich Islands (March 28, 1987 and August 14, 1995). For 30 s following the *PKP* arrival, and for an additional 3 min (not shown here), these seismograms (passed in the band from 0.6 to 3 Hz) show excellent waveform agreement for signals that have traversed the Earth but not via the inner core. For the *PKIKP* waveform, from time 250 to 255 s, an insert shows an expanded view of the narrowband filtered version of the two arrivals (in the passband from 0.8 to 1.5 Hz) that have traversed the inner core. With the two seismograms aligned on the *PKP* phase, it is seen that the *PKIKP* phase of the later event (shown in gray) traveled slightly faster. An explanation is that the inner core rotated during the 8-year period between the earthquakes, in a manner that provided a faster path for the later *PKIKP* signal through the inner core.

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Cross-references

Core Motions
Geodynamo, Energy Sources
Geodynamo
Geomagnetic Spectrum, Temporal
Inner Core Anisotropy
Inner Core Composition
Lehmann, Inge (1888–1993)
Length of Day Variations, Long Term
Inner Core Seismic Velocities