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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, eastwards with respect to the mantle.

Early Speculations

The inner core with radius 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 time scales 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.

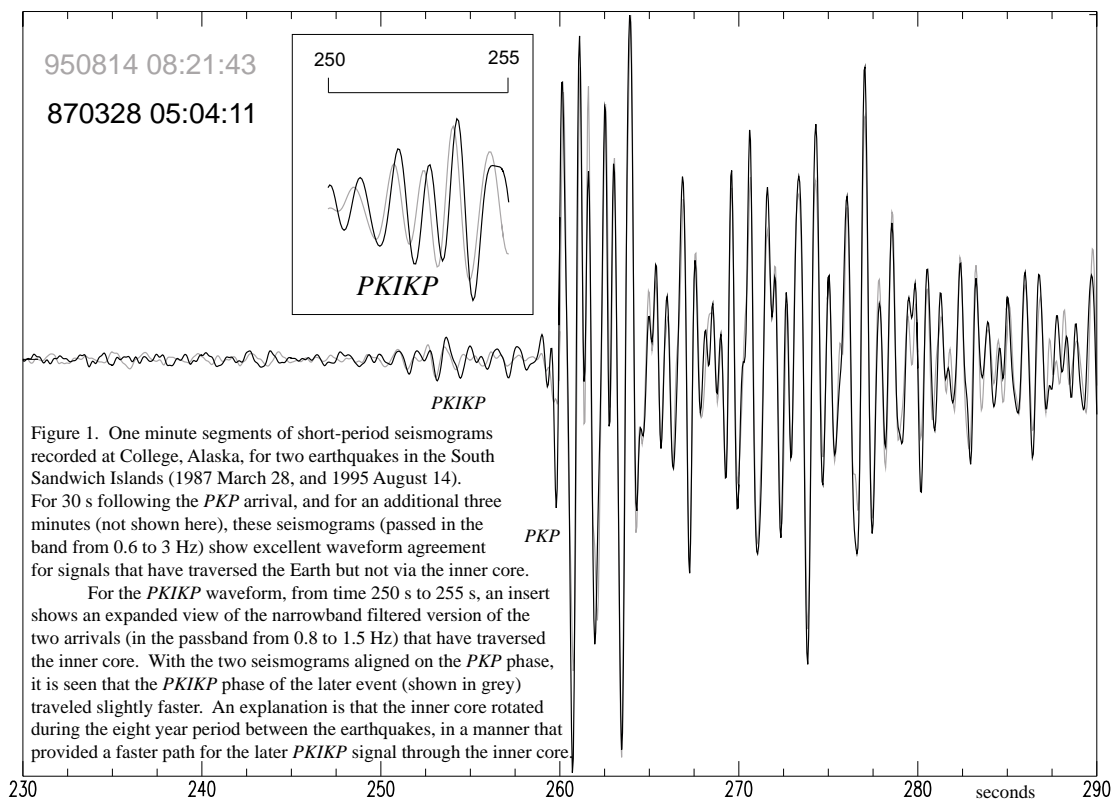
More detailed studies by Creager (1997), Song (2000), and Li and Richards (2003), have provided additional support for travel time change of about this same value, for seismic *P*-waves crossing the inner core. Figure 1 shows a clear example of *PKIKP* waves (which pass through the inner core) showing 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*-wave speed (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 time scale 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 non-zero rotation rate can be used to place limits on the outer core's viscosity (Buffett, 1997).

Comparison of seismograms in Alaska, from two earthquakes at the same place in the South Sandwich Islands but more than eight years apart.



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 *PKIP* waves on the path between the South Sandwich Islands and Alaska are an artefact of mislocated earthquakes. Early reports of purported changes in the absolute arrival times (not differential times) of *PKIP* 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 (1997) used back-scatter 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 travel times, 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 1 can be accumulated, since waveform doublets avoid artefacts 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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Cross references

Core motions

Energy source for the geodynamo

Geodynamo

Geomagnetic temporal spectrum

Inner core anisotropy

Inner core: composition

Lehmann, I.

Length of day variations - long term

Seismic velocities of inner core