Slowness Anomalies of PKP Phases Recorded in Alaska: Implications for Inner Core Anisotropy

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The Eielson, Alaska seismic array (ILAR) is well situated to record PKP(DF) waves from earthquakes occurring in the South Sandwich Islands (SSI) region. Such ray paths are nearly aligned with Earth’s rotation axis and are useful for constraining models of inner core anisotropy. The many previous studies of PKP(DF) waves traversing the SSI-Alaska corridor generally find waves that arrive several seconds fast, with highly attenuated and often complicated shapes. Simple laterally homogeneous models of inner core anisotropy cannot explain these observations, and it may be the case that mantle heterogeneities are biasing the SSI-Alaska PKP(DF) waves. In this study, we take advantage of the small-aperture of ILAR to make independent measurements of differential PKP(DF) - PKP(BC) travel times and differential PKP(DF) - PKP(BC) horizontal slowness vectors for 37 SSI earthquakes that occurred from 1996-2004. Anomalies in slowness (ray parameter and backazimuth) of a phase reflect heterogeneous Earth structure in a manner complementary to travel time anomalies. We find a mean differential travel time residual of 3.3 s, a mean differential ray parameter of 2.0 s/deg, and that PKP(DF) waves arrive from a backazimuth rotated approximately 25 counterclockwise relative to corresponding PKP(BC) waves. We use a niching genetic algorithm to generate a suite of nearly 10,000 radial Earth models that are consistent with both the differential travel times and differential ray parameters. These isotropic models represent a 2D slice through a 3D cylindrically anisotropic model of the inner core, making an angle of approximately 25° with respect to Earth’s rotation axis. Our modeling indicates that (1) mantle heterogeneities are not responsible for the properties of PKP(DF) from SSI-ILAR, (2) the lower several hundred kilometers of the outer core has a slightly lower velocity, and/or velocity gradient, than current reference models, and (3) the outer inner core along this path is nearly isotropic with a transition to strong anisotropy (8%) occurring at a radius of 600-900 km.

(Left) The Eielson array (ILAR) consists of 19 short-period, vertical component seismometers deployed with an effective aperture of about 10 km. The reference point for forming array beams is element 14 and is indicated by the circle. The solid lines represent contours (50 km increments) of the surface of the subducting Aleutian slab (Gudmundsson & Sambridge, 1998). (Right) Epicenters for the earthquakes used in this study, with plate boundaries from Bird (2003). The differential travel time residuals are defined as $dt = (\text{PKP(BC)} - \text{PKP(DF)})_{\text{obs}} - (\text{PKP(BC)} - \text{PKP(DF)})_{\text{theo}}$, and AK135 is used to calculate the theoretical times. The earthquakes occurred between 1996 and 2004 and each has a magnitude of at least 5.5 $M_w$.