Inner core structure behind the PKP core phase triplication

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AGU paper nr.: DI33A-2607

Questions?

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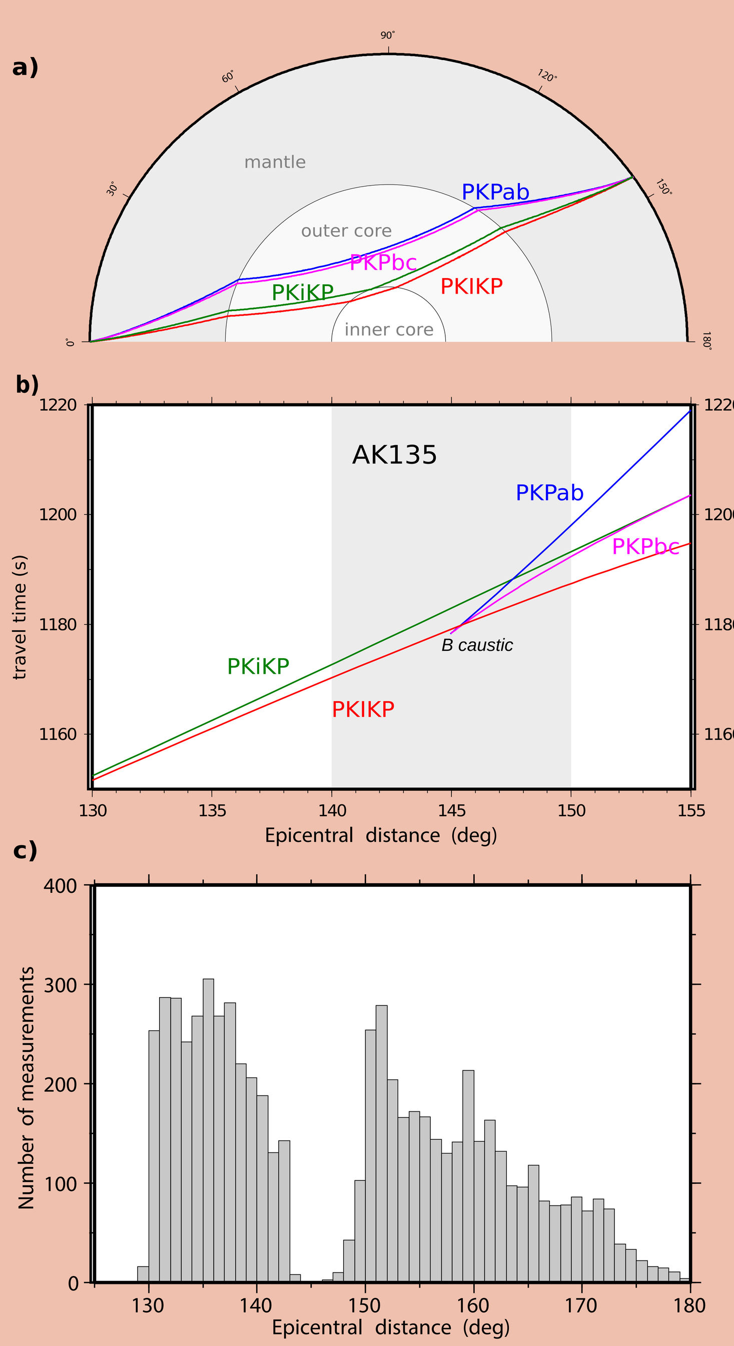
Inner Core structure



The inner core plays an important role in the dynamics of the Earth's interior and knowledge of its detailed structure places constraints on the Earth's thermal and dynamical evolution. Body waves, and especially (differential) travel times of PKIKP waves (figure 1a,b) are particularly suitable for studying the inner core's velocity structure. However, between epicentral distances of ~140-150°, a 'measurement gap' (figure 1c) exists because of multiple core phases arriving approximately simultaneously and the existence of strong precursors to PKPbc at the B caustic of the core phase triplication. In this study, we show how to bridge this gap using vespagram analysis of seismograms, and that an increase in polar velocity with depth is needed in order to explain the data.

[Blom et al., Geophys. J. Int., 2015]

Figure 1. (a) ray paths of compressional core phases. PKIKP traverses the inner core. (b) travel time curves for the same core phases (study range shaded grey). (c) histogram of PKIKP data compiled from previous work. The epicentral distance range 140-150° is heavily undersampled.

Methods - from seismograms to vespagrams

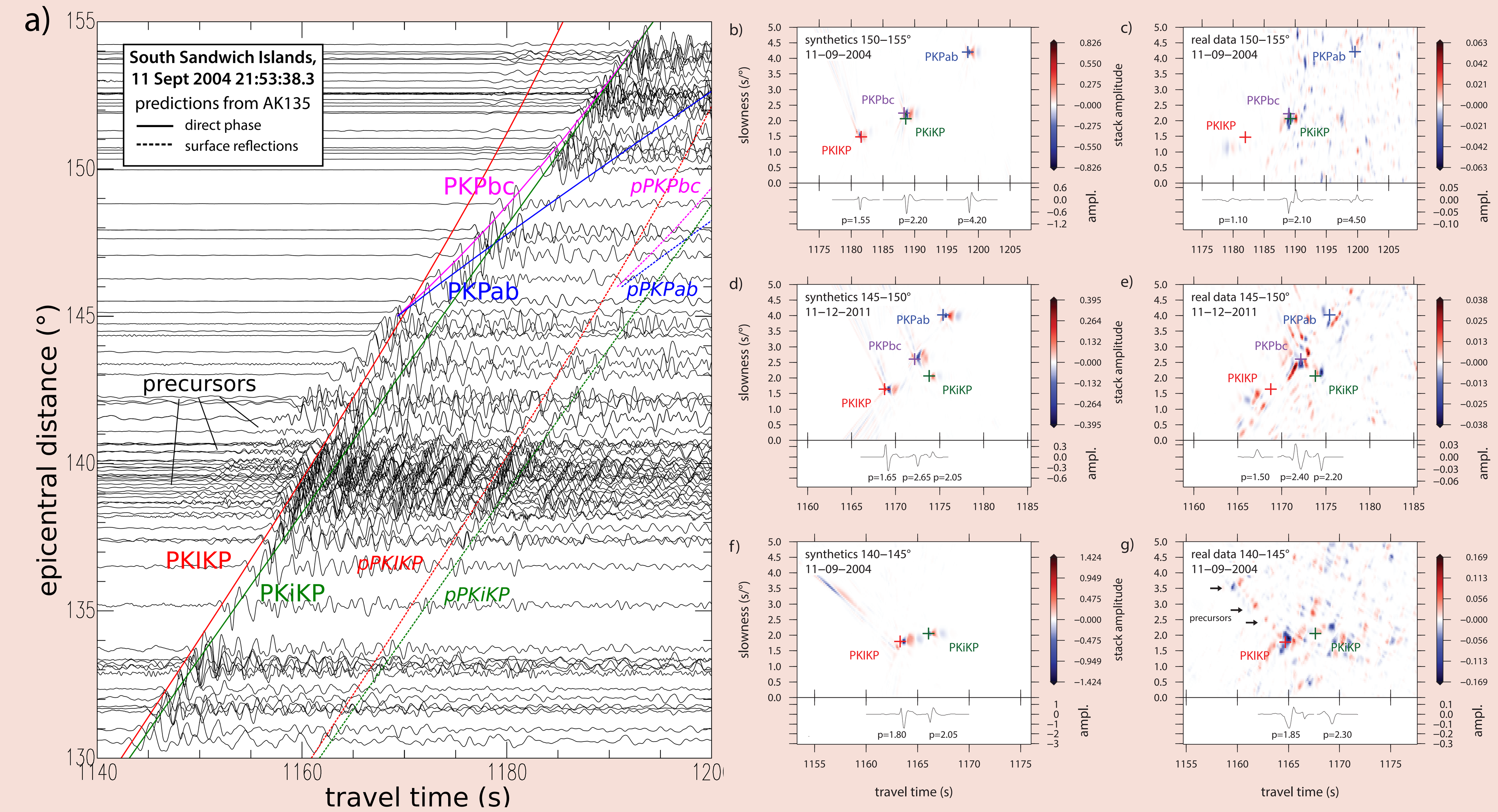
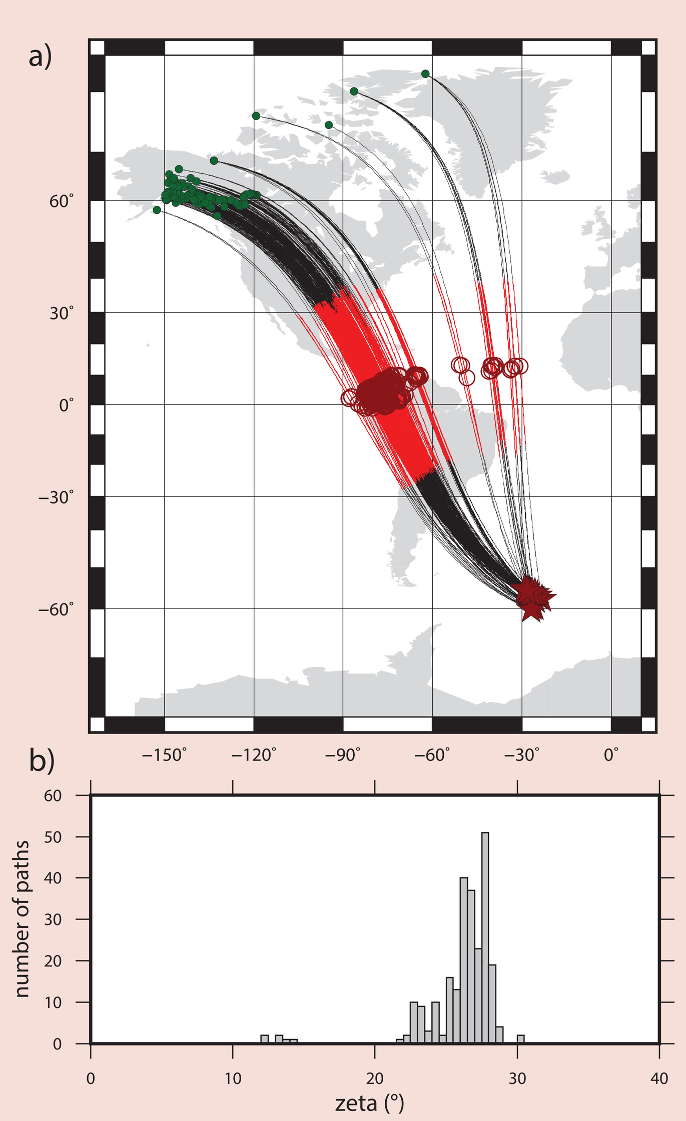


Figure 3. (a) seismograms for an example South Sandwich Islands event (11 September 2004, 21:53:38.3). (b-g) some examples of vespagrams: synthetic (b,d,f) and real data (c,e,g)

Between roughly 140-150°, PKIKP and PKiKP cannot be confidently identified in single seismograms due to multiple phases arriving simultaneously and the strong precursors to PKPbc. To overcome this, the seismograms are gathered into 5° bins per earthquake, and then stacked using the Phase Weighted Stack approach (Schimmel & Paulssen, 1997) at slownesses from 0-5 s/°. Signals that are coherent across traces will add up constructively at the appropriate slowness in the vespagram. Differential travel times of PKiKP-PKIKP can be measured from this.

Data - western polar raypaths



We study the western hemisphere of the Earth's inner core, a region which in previous studies has been observed to be strongly anisotropic, with high velocities in the polar direction. In our study, earthquake data are thus selected to yield polar paths. These paths are defined to travel through the inner core at an angle zeta of <30° with the Earth's rotation axis.

Figure 2. (a) ray paths used in this study. The red stretch is the part of the path travelling through the Inner Core, dark red circles indicate turning points. (b) histogram of raypath angle zeta (angle of the ray path with the Earth's rotation axis at the ray's turning point).

Results - velocity increase with depth

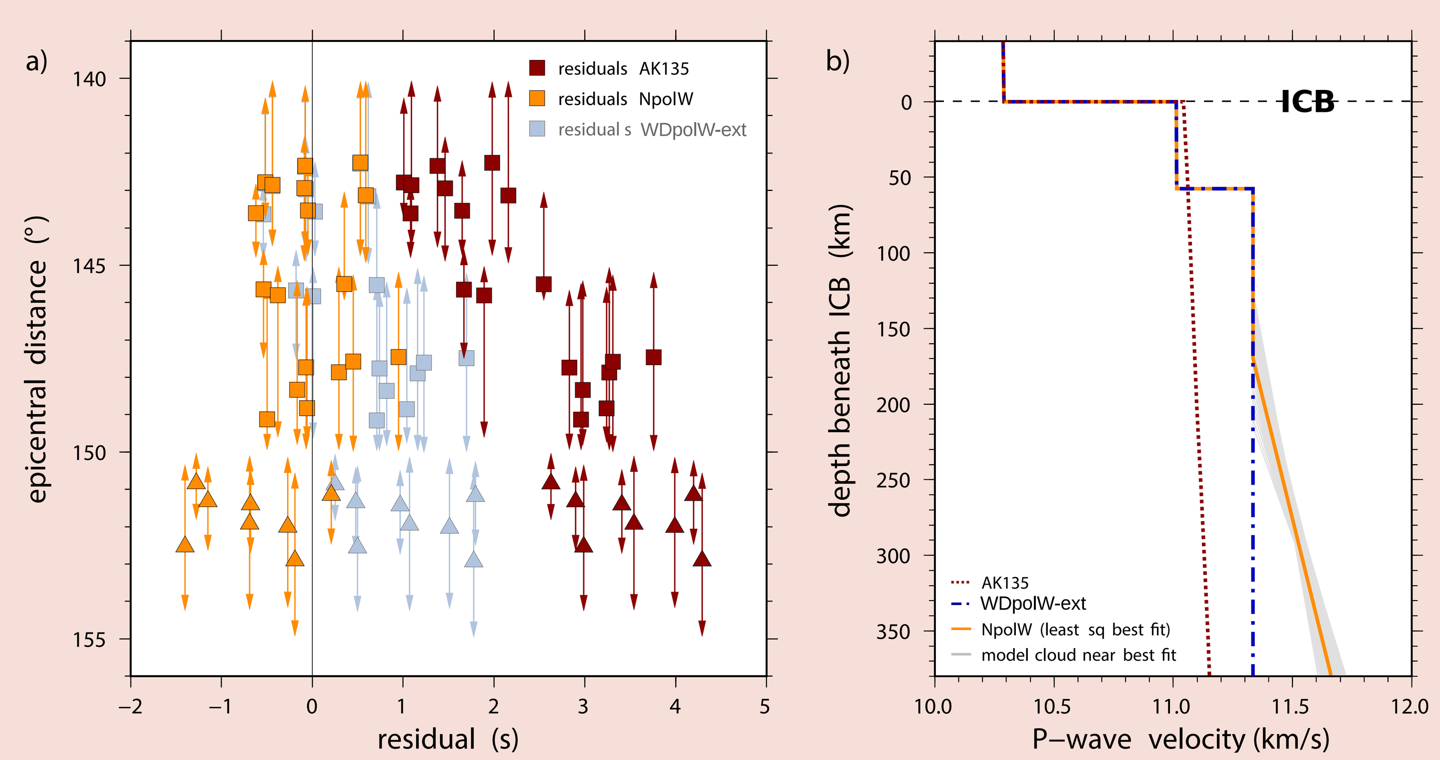


Figure 4. (a) differential travel time residuals of PKiKP-PKIKP with respect to several models. (b) the models for which the differential travel times have been calculated. In order to satisfy the data, an increase in seismic velocity is needed at depths of ~150-350 km. A model cloud around the best fit model (NpolW) indicates the variability of models that have similar fit (residual sum of squares < 0.25 s²).

Differential travel time residuals of PKiKP-PKIKP with respect to AK135 increase gradually with epicentral distance. Even if the seismic velocity at the top of the inner core is corrected according to the findings of Waszek & Deuss (2011, model WDpolW), a trend of increasing residuals is still observed. To minimise the residuals, a model grid search is performed, which indicates that the seismic velocity must increase at depths between ~150-400 km in order to satisfy the data.

Conclusions

- Using vespagrams and Phase Weighted Stacking, it is possible to differentiate between (quasi-)simultaneously arriving core phases.
- The gap of PKIKP measurements at approximately 140-150° can thus be closed.
- PKiKP-PKIKP differential travel times have for the first time been measured up to 150° epicentral distance.
- An increase in polar seismic velocity compared to AK135 between ~150-350 km seems likely. This may be due to an increase in either isotropic velocity, or alternatively polar velocity only and thus an increase in anisotropy. In view of previous work, we prefer the latter explanation.

Selected references:

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Part of this work was funded by the European Research Council under the European Community's Seventh Framework Programme (FP7/2007–2013)/ERC grant scheme number 204995