New constraints on inner core structure from differential waveform analysis of PKP core phases at global scale

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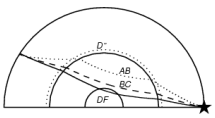
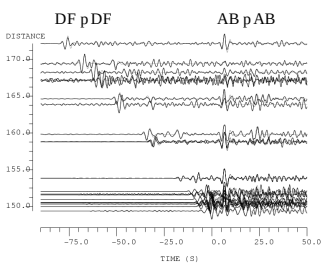
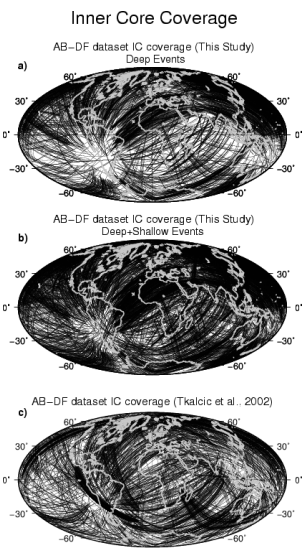


Abstract:
An extension of our previously developed Simulated Annealing algorithm to analyze body waves is presented. It allows us to resolve the interference between the different PKP phases and their corresponding depth phases (pPKP and sPKP), which makes possible to process shallow earthquakes previously discarded, and thus to improve the sampling of the deep Earth. The introduction of shallow event data confirms the hemispherical pattern of the inner core anisotropy and the increase of the inner core quality factor with depth. An anti-correlation is found in the upper 300 km of the inner core between differential travel time residuals and amplitude ratios. This anti-correlation can only be explained by a high attenuation of fast rays inside the inner core. Relative amplitude ratios and waveforms of core phases are also analyzed in order to detect inner core discontinuities below the inner core boundary. We demonstrate that relative amplitude ratios are highly sensitive to velocity discontinuities inside the inner core. Consequently the absence, at global scale, of both marked features on DF/AB amplitude ratios at large epicentral distances and secondary DF arrivals on stacked waveforms exclude the presence of a discontinuity in the inner core at global scale. Unfortunately, the low number of polar data does not allow to reach a signal to noise ratio good enough to perform such an analysis for anisotropic ray paths.

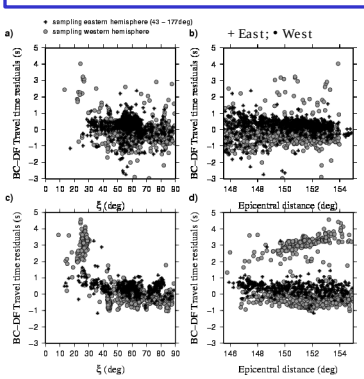
Data processing and data set:
The data processing method is described in previous papers (Garcia et al., 2004; Garcia et al., 2006). The outputs of the inversion are the PKP waveforms, differential travel times, amplitudes and attenuations for each trace. The final data set includes 1802 and 1247 PKP records respectively for deep and shallow earthquakes after careful data selection based on objective error estimates. Data are filtered in the 0.3-1.5 Hz range.

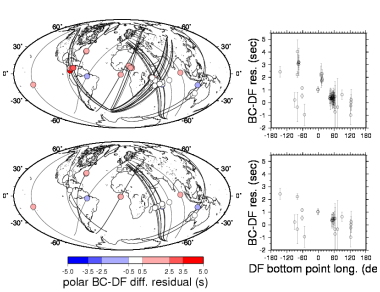




Examples of data fit for a shallow quake (54 km deep). Waveforms are aligned on AB phase

Traveltimes, core structure and anisotropy:
The BC-DF differential travel times present an hemispherical pattern, and some polar paths present fast DF rays, as in previous studies (see the comparison with Tkalcic et al., 2002 data set). In our data set, these anomalous polar paths are restricted to events from the south sandwich subduction zone to northern stations.

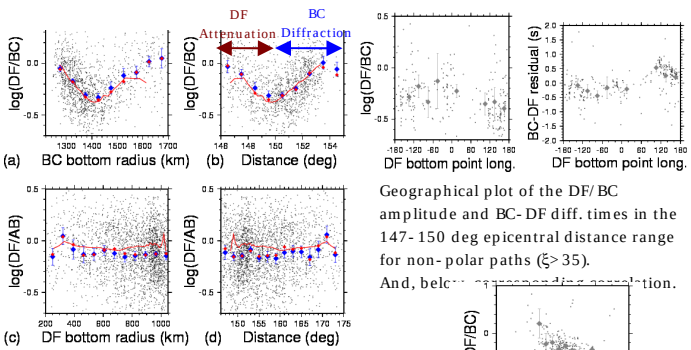




Polar (ξ<35)BC-DF data set with (top) and without (bottom) South Sandwich Islands events.

(a, b) our data set; (c,d) Tkalcic et al., 2002 data set

Relative amplitudes:
The DF/BC amplitude ratios clearly exhibit the finite frequency effects of BC diffraction at the inner core boundary. DF/BC, DF/AB amplitude ratios and t* attenuation parameters are adjusted by trial and error to an average inner core attenuation model through waveform modelling with "Full wave theory" software. A good fit is obtained for a 3 layer model (non-unique) with Q going from 285 in the first 250 km, to 330 down to 550 km radius and 100 000 below. In the epicentral distance range not influenced by BC diffraction (150-220 km IC depth), differential travel times and attenuation are anti-correlated presenting a East (West) hemisphere with fast (slow) velocities and strong (weak) attenuation.



Scatter plot of the results, with median and average (diamonds) computations. The red line presents the fit by the IC attenuation model through the inversion of "Full wave theory" synthetics.

Geographical plot of the DF/BC amplitude and BC-DF diff. times in the 147-150 deg epicentral distance range for non-polar paths (ξ>35).
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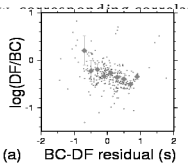
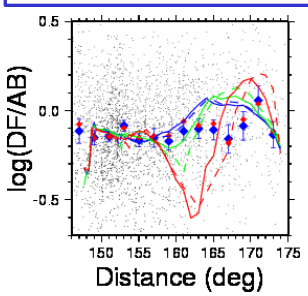
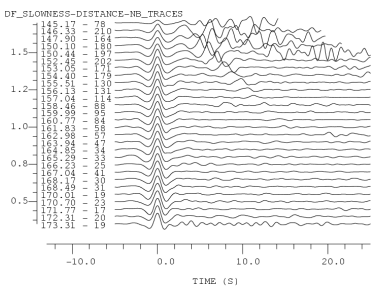


Constraints on an inner core discontinuity:
The effect of an IC low velocity zone at 650km radius on DF/AB amplitude ratios is computed. A small velocity decrease (<-0.3%) creates a signifcant shadow zone demonstrating that DF/AB amplitude ratios are very sensitive to the IC velocity structure. Such a shadow is not observed in our data. Moreover, deconvolved PKP records have been aligned on PKPdf and stacked in ray parameter bins, in order to detect any coherent secondary arrival due to an IC discontinuity. Result is negative.



DF/AB amplitude ratios fit by another IC attenuation model with Q varying from 100 to 1000 until 650km radius and 1000 below (blue line), and same model with an IC low velocity zone of -0.1%, -0.3%, -0.5%, -1%and -1.5% (from blue to red) at 650km radius.



Stack of PKP waveform after deconvolution and alignment on PKPdf phase in various PKPdf ray parameter bins. Equivalent epicentral distance and number of traces in each stack are also given.

Conclusions and prospect:
The data set presented here confirms previous results on the inner core velocity and attenuation structure. The addition of relative amplitude data and deconvolved waveforms is proven to be very efficient at detecting possible inner core discontinuities. Our data set excludes the presence of an IC discontinuity at global scale. However, the low number of polar data does not allow us to conclude both on the IC anisotropic structure and on IC velocity discontinuities related to anisotropy variations.
Future studies will have to incoporate more polar data.

References:
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- Garcia, R., Chevrot, S., Weber, M., 2004. Nonlinear waveform anddelay time analysis of triplicated core phases. Geophys. J. Int. 109,doi:10.1029/2003JB002429
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