Inner core anisotropy measured using new ultra-polar PKIKP arrivals and corrected for raypath geometry.

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Introduction

The inner core is one of the most challenging regions of the Earth to study: high seismic attenuation, mantle structure and poor data sampling all influence seismic interpretations of inner core structure.

When the velocity of a seismic wave differs depending on the direction of wave propagation through a medium this is called anisotropy. Anisotropy was first observed in the inner core by Poupinet et al. (1983) and is thought to be caused by the orientation and shape of HCP or BCC iron in the inner core. This is related to how the inner core grew and formed.

The main difficulty with measuring the anisotropy in the inner core is the poor spatial sampling, It is difficult to measure anisotropy reliably due to a lack of polar paths (phases that travel near parallel to Earth's axis of rotation).

To overcome this poor sampling we have collected the largest known data set of ultra-polar (ζ<20) paths to better resolve the Anisotropy in the inner core.

Results

- Anisotropy in the inner core varies between the western and eastern hemispheres
- Overall inner core anisotropy is 2.1%-2.5%, while the western hemisphere has an anisotropy of 3.6% and the eastern hemisphere 1.1%
- Anisotropy Increases with depth
- No 'inner most inner core' is required by the data
- When measuring fractional travel time (Panel B) care must be taken to allow ray path considerations

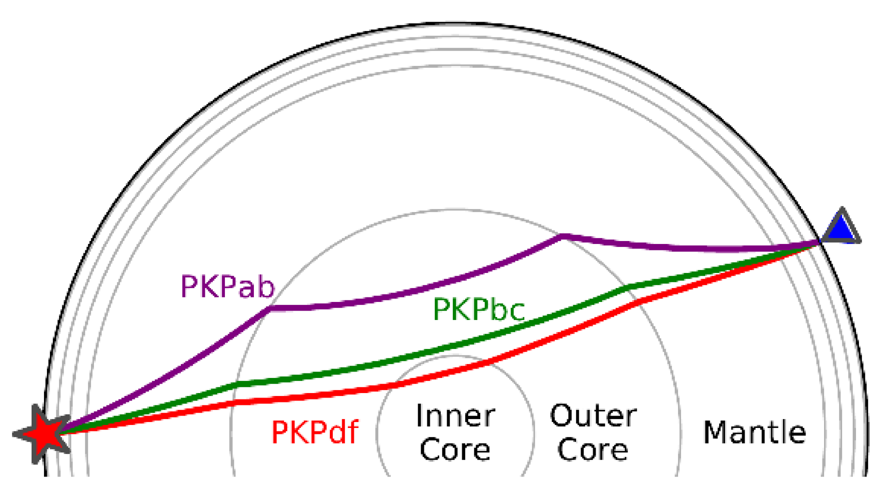
Conclusion

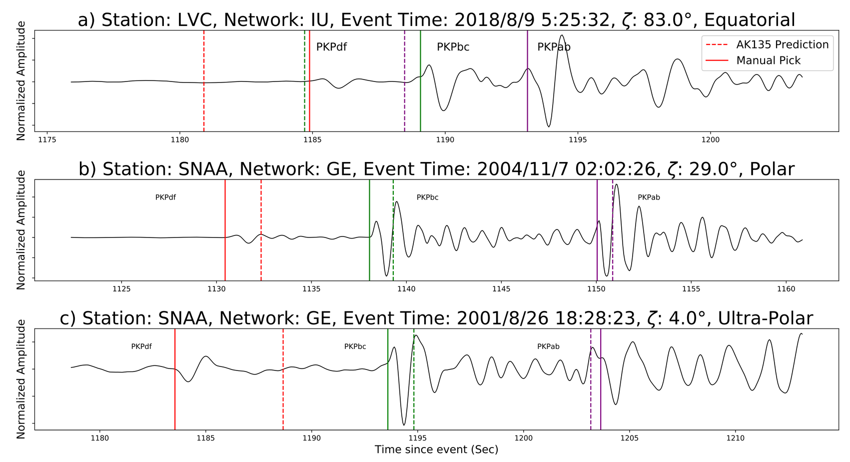
- Our method of measuring anisotropy resolves for the changes in raypath within the inner core
- Our measured values of anisotropy are lower than other estimates and in better agreement with normal mode observations

Methodology

1. We collected a data set of 2081 high quality seismograms to measure differential velocity using the methodology of Irving and Deuss 2011.

A



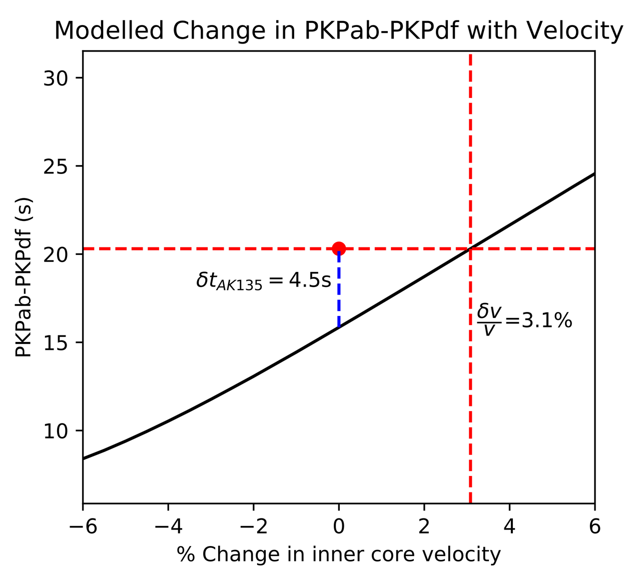


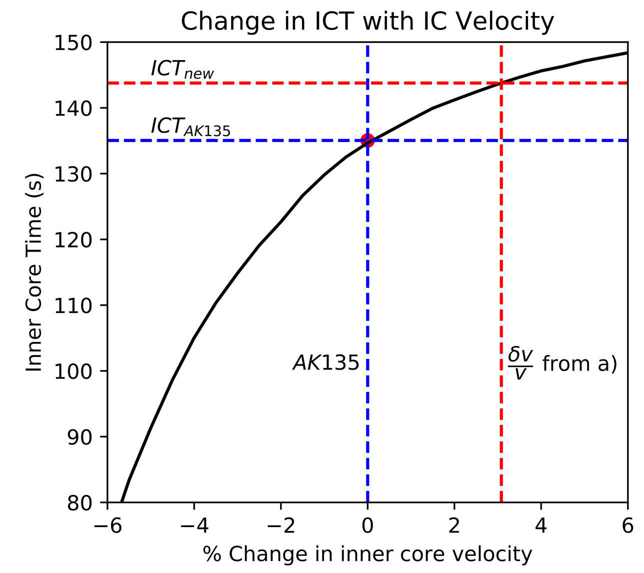
Raypaths and Arrival Times

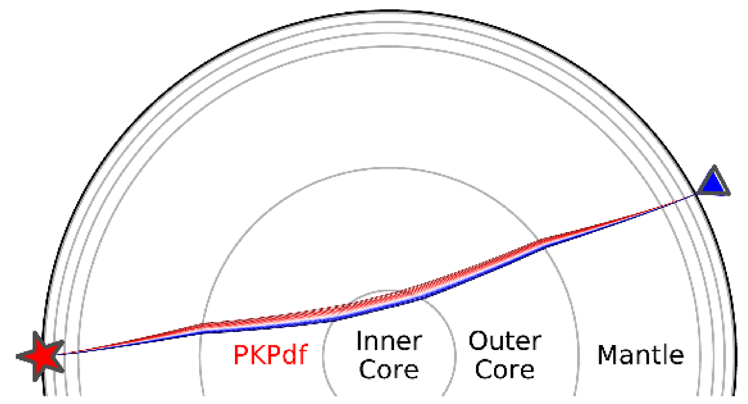
- We use differential arrival times to measure the fractional velocity of the inner core
- After inspecting 116000 seismograms by eye a high quality data set of 2081 seismograms was collected providing measurements of the arrival times of PKPdf, PKPab and PKPbc phases (raypaths shown on the furthest left figure). This is now the largest dataset of it's kind and still growing.
- We then calculate the differential arrival time between the PKPdf phase, which samples the inner core, and the PKPab and PKPbc phases which sample the outer core and mantle.

2. We found that when there is positive velocity anomaly the PKPdf phase travels deeper through the inner core and spends more time in the inner core (Panel B) and we designed a method to take this into account.

B







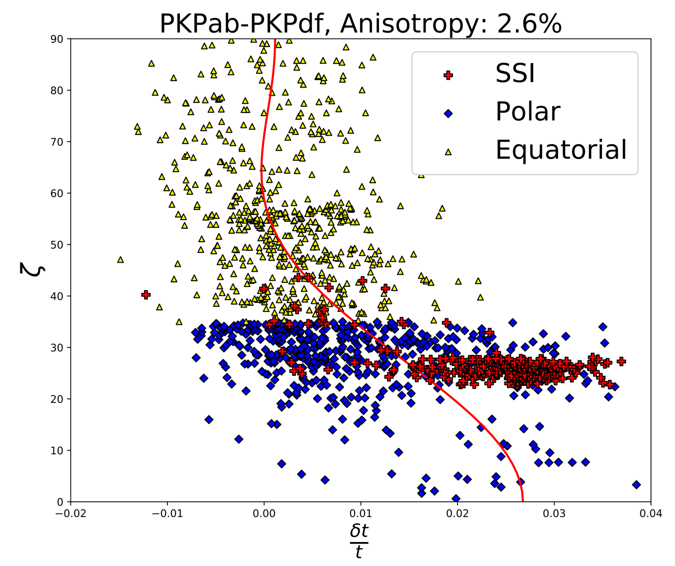
Raypath Corrections

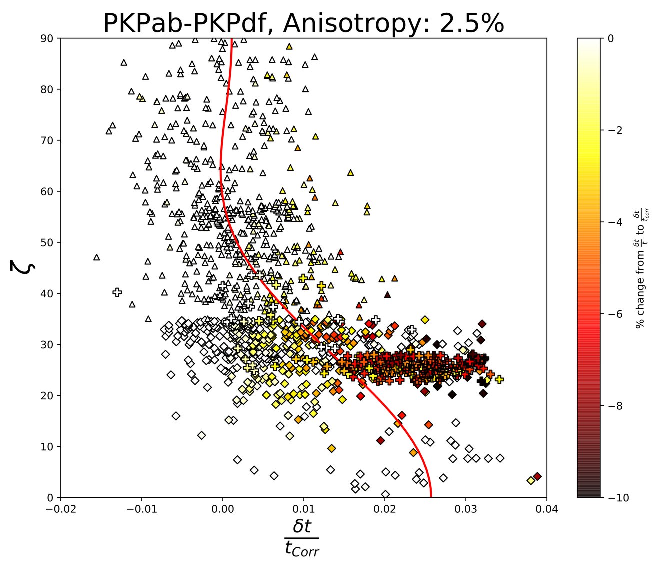
- Eqn. 1 (Creager 1999) shows how we can calculate residual travel time from differential arrivals.
- You then normalize δt by t, the time spent by the PKPdf ray in the inner core. We found that if you do not allow raypaths to vary with velocity anomalies then you get an inaccurate raypath and estimate for t, which can amplify the $\frac{\delta t}{t}$ anomaly by as much as 15%.
- We remodel each raypath, finding the necessary % change in inner core velocity to account for its anomaly. From this we calculate a new raypath taken through the inner core use this to calculate $\frac{\delta t}{t_{Corr}}$.

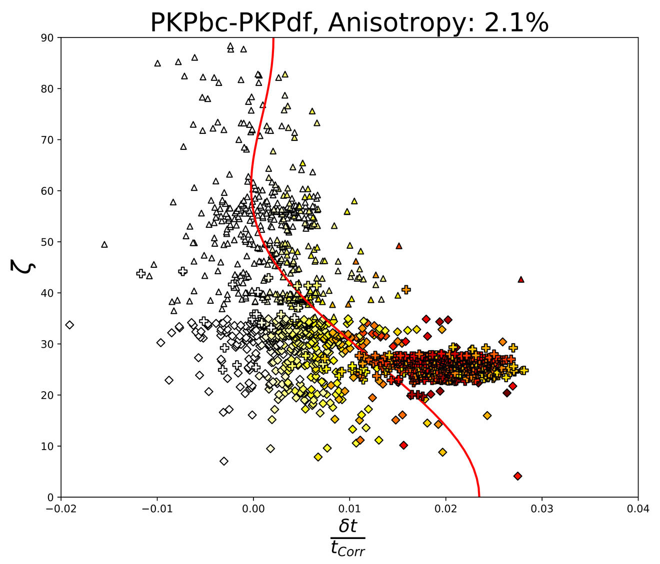
$$\delta t = (t_{PKPbc} - t_{PKPdf})_{data} - (t_{PKPbc} - t_{PKPdf})_{AK135} \qquad (1)$$

3. We can measure anisotropy by comparing our measurements of fractional travel time to the angle ζ

C







Measuring Anisotropy

- Using eqn. 2 (Creager 1999) anisotropy can be measured by comparing $\frac{\delta t}{t_{Corr}}$ with the raypath angle ζ.
- Paths with a ζ = 90 are equatorial and paths with ζ = 0 are polar (traveling parallel to the Earth's rotation axis).
- Previous research had struggled to find high quality seismograms with a ζ < 20 (ultra-polar paths)
- However, new seismic stations at high latitudes have now made it possible to measure >88 ultra-polar differential travel times.
- By fitting the function defined by eqn. 2 to our data we can measure anisotropy for the inner core

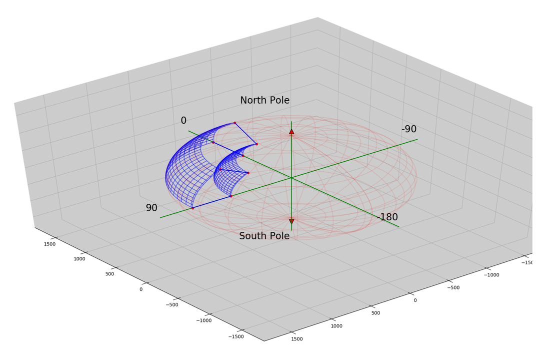
$$\frac{\delta t}{t} = \frac{\delta v}{v} = a + b\cos^2(\zeta) + c\cos^4(\zeta) \quad (2)$$

Future Steps

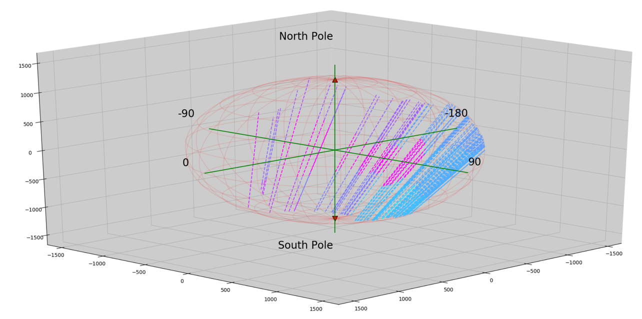
- We have already began to isolate anomalies from the body wave data using an iterative damped least squares inversion method described by Tarantola, A. and B. Valette 1982.
- We will combine body wave and normal mode data from the inner core in a transdimensional inversion
- This will allow the inversion to define the parameterization and produce a best fitting model of anisotropy

D

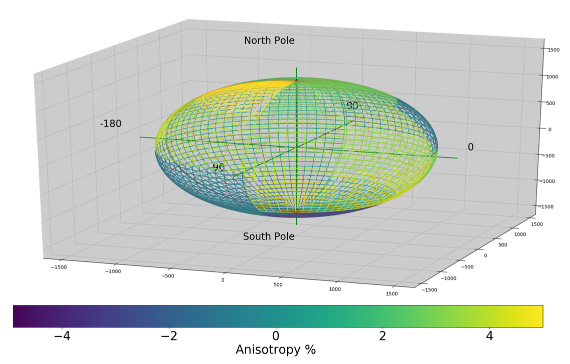
1. Define Model Space



2. Parameterize Data



3. Invert for Anisotropy



Inner Core Anisotropy Inversion

- Until now we have treated the inner core as a single volume with a homogeneous anisotropy
- However, in reality the inner core is heterogeneous with regions of higher and lower anisotropy
- A better approach is to isolate these anomalies within the inner core using a tomographic method
- We define the geometry of our model using radial segments and invert for their anisotropy
- Initial results are promising - but preliminary: we still need to do a thorough null-space and sampling test.

References

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