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 2.8%, while the western hemisphere has an anisotropy of 3.5% and the eastern hemisphere 0.9%
- Anisotropy Increases with depth
- No clear 'inner most inner core' as proposed by other research
- When measuring fractional velocity, *dv/v*, (Panel B) care must be taken to allow raypath considerations

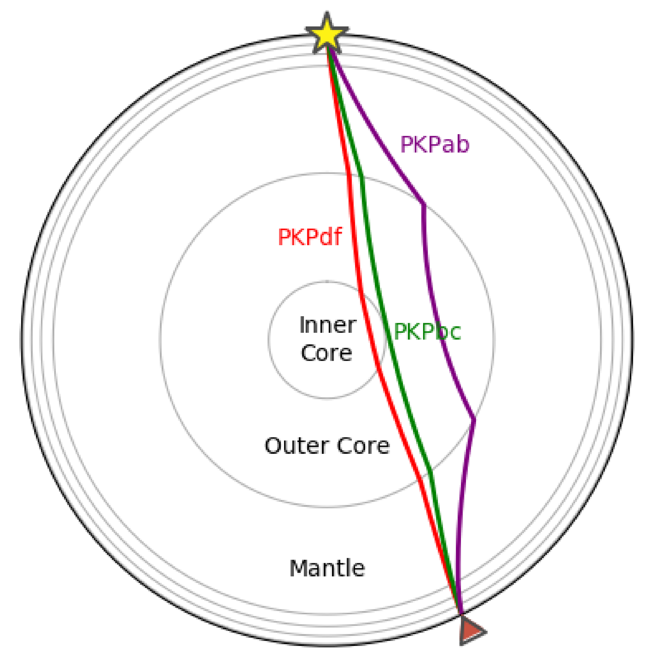
Conclusion

- Our method of measuring anisotropy solves 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

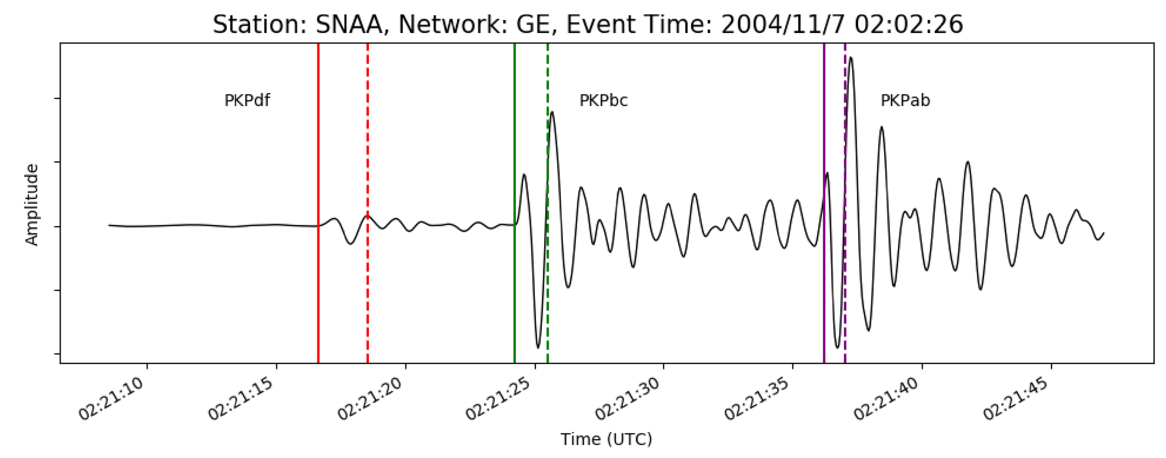
1. We collected a data set of 1840 high quality seismograms to measure differential velocity using the methodology of Irving and Deuss 2011. Panel A shows an example of a seismogram and the paths of the PKPdf, PKPbc and PKPab phases.

A



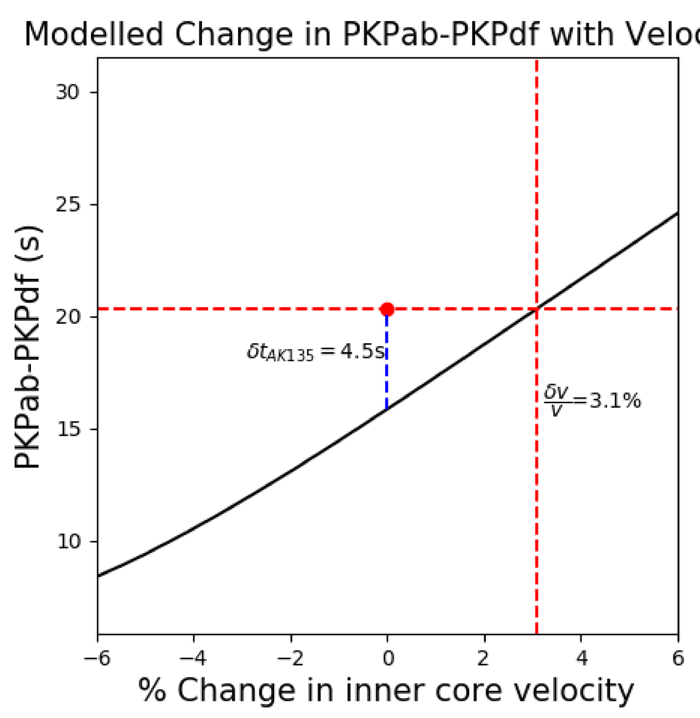
Raypaths and Arrival Times

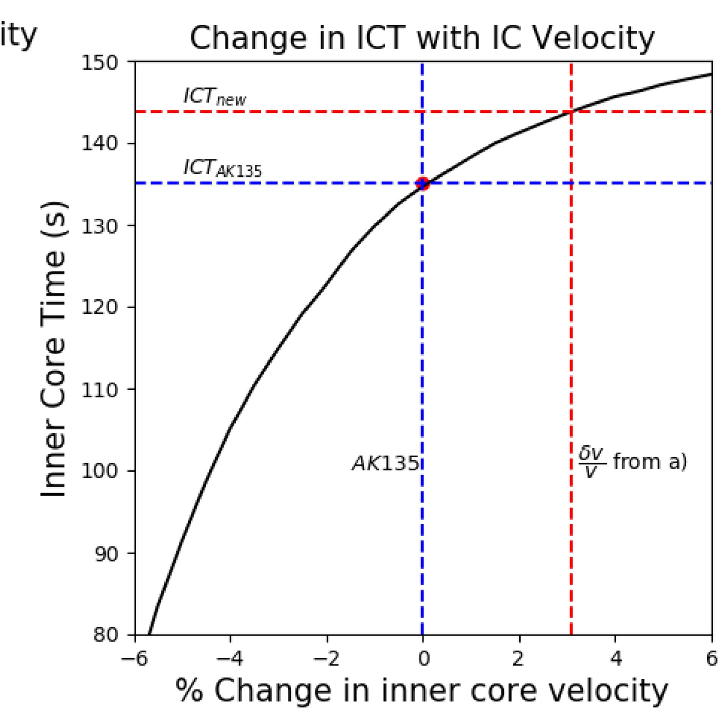
- We use differential arrival times to measure the fractional velocity of the inner core
- After inspecting 85000 seismograms by eye a high quality dataset of 1840 was collected providing measurements of the arrival times of PKPdf, PKPab and PKPbc phases (raypaths shown on the left figure)
- We can then 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





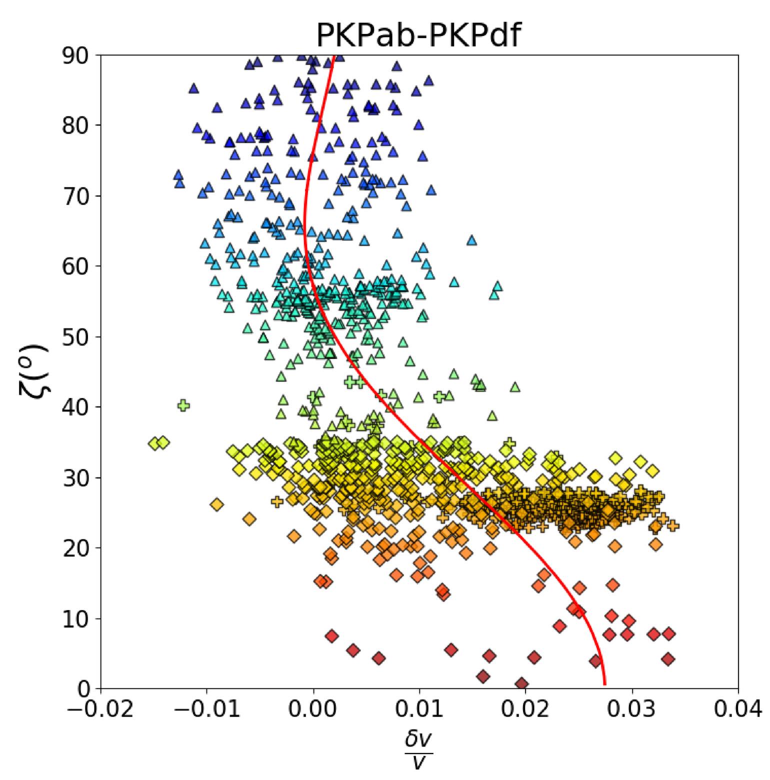
Raypath Corrections

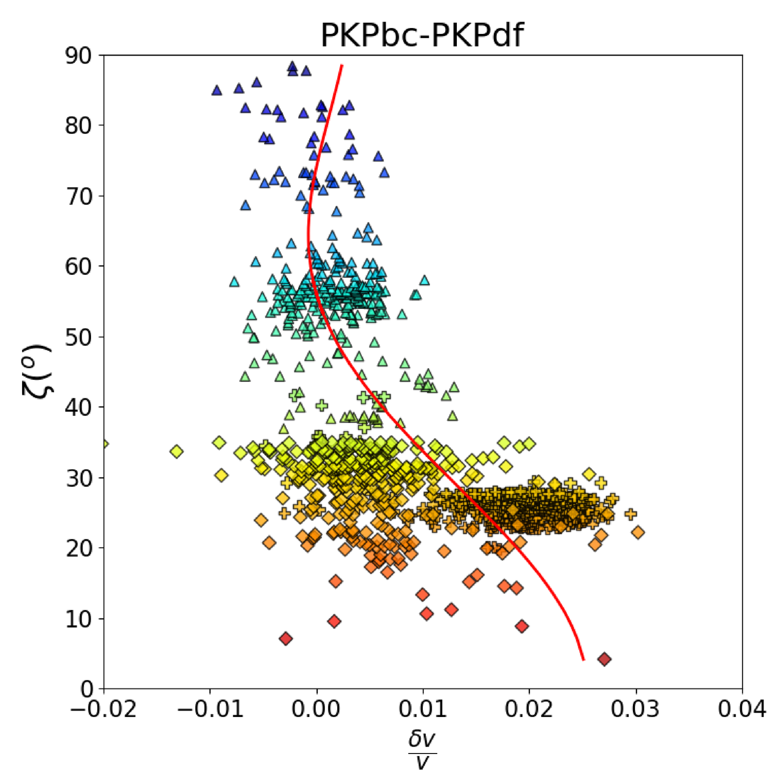
- Eqn. 1 (Creager 1999) shows how we can calculate fractional travel time from differential arrivals.
- *t* is the time spent by the PKPdf ray in the inner core. We found that if you do not allow raypaths to vary with velocity anomalies then you underestimate *t*, thus amplifying the anomaly by as much as 10%.
- To take this into account we solve for *dv/v* directly by finding the necessary % change in the inner core velocity in the *AK135*. This allows the TauP toolkit to adjust the traveled raypath.

$$\frac{\delta t}{t} = \frac{(\mathrm{PKP_{bc}} - \mathrm{PKP_{df}})_{\mathrm{data}} - (\mathrm{PKP_{bc}} - \mathrm{PKP_{df}})_{\mathrm{AK135}}}{t} \qquad (1)$$

3. Comparing our measurements of *dv/v* to the angle ζ allows us to measure Anisotropy.

C





Measuring Anisotropy

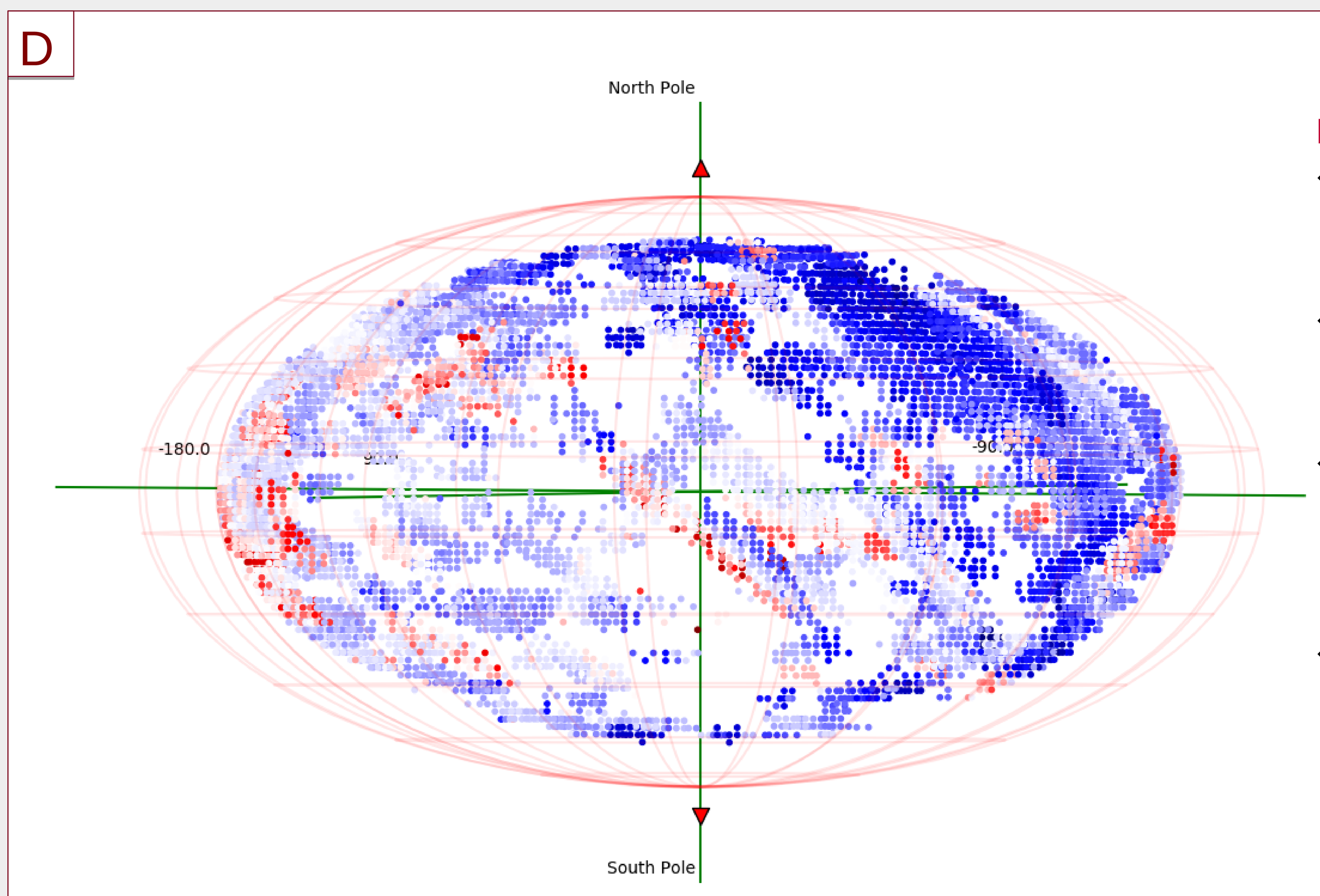
- Using eqn. 2 (Creager 1999) anisotropy can be measured by comparing *dv/v* with the raypath angle ζ.
- Paths with a ζ = 90 are equatorial and paths with ζ = 0 are polar (traveling parallel to the Earth's rotation axis).
- Previous research had struggled to find high quality seismograms with a ζ < 20 (ultra-polar paths)
- However, new seismic stations in the antarctic have now made it possible to measure >38 ultra-polar differential arrival times.
- By fitting the function defined by eqn. 1 we can then estimate anisotropy for the inner core

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

Future Steps

- 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
- The voxelization shown in Panel D is the first step to combining separate data types in a 3D framework.

D



Lateral anisotropy variations

- Measuring anisotropy in the inner core is hampered by the poor body wave sampling. We attempt to quantify this sampling by splitting the inner core into separate voxels.
- Every voxel represents a volume of the inner core and is used to collect information from raypaths which pass within a distance threshold of that voxel.
- This allows us to say that for any random point in the inner core there is on average a PKPdf raypath from our data set that travelled within 49km of that point. (with the worst sampled areas having distance of 190km)
- We can then plot the voxels as a function of raypath properties (such as this plot) which is the difference between polar and equatorial velocity.

References
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