Polarisation anisotropy for Australian paths

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Abstract. Rayleigh and Love joint waveform inversions are performed for selected Australian paths. To establish an anisotropic upper mantle model beneath Australia, a transversely isotropic medium with a vertical symmetry axis (TIV) is introduced. When the joint waveform inversion converges, the general pattern of the polarisation anisotropy is similar from two different starting models. However, it can be difficult to reach a plausible SH wavespeed model for some of paths using the TIV assumption. This is mainly due to the strong sensitivity of the Love wave inversion to staring model and to the difficulty of assuming a simple TIV behaviour for the Australian continent.

1 Introduction

Recent regional studies of Rayleigh waveform inversion over the Australian continent (van der Hilst et al., 1998 and Debayle & Kennett, 2000) confirm that the strong lateral contrast of the SV wavespeed between the eastern younger belt and the western cratons could reach more than 10 percent. For the SH wavespeed profile, a regional P and S wave study by Kaiho & Kennett (2000) reveals that in the western Archean cratons there are very fast SH wavespeed anomalies which could reach around 8 percent faster than the reference model *ak135*.

Such strong SV and SH wavespeed contrasts across the continent imply that we observe both seismic heterogeneity and anisotropy simultaneously. To establish a more accurate model of the seismic wavespeed beneath the Australian continent, we should add information on anisotropic structure to the current images. In other words, it is likely that the degree of the lateral contrast of the shear wavespeed over the continent could be modified by introducing new information on upper mantle anisotropy, because of the trade off between seismic heterogeneity and anisotropy.

In this paper, we try to retrieve polarisation anisotropy for the selected Australian paths with Rayleigh and Love joint waveform inversion technique based on the TIV assumption.

2 Data

We use surface wave data recorded by the three-component broadband seismometers at two permanent stations: NWAO (IRIS) at Narrogin placed on the Archean craton in southwestern Australia and CAN (GEOSCOPE) at Canberra on the younger eastern belt in the southeastern part of the continent. Seven events (figure 1) are selected, having favourable source mechanisms which are not too close to the nodes of both Love and Rayleigh waves. Their focal depths range from 30 km to 160km.

To effectively isolate the major portion of the fundamental and several higher mode waves, we apply a bandpass filter between 50 second and 100 second to the data. The lower limit (50 s) is based on the observations that the shapes of the surface wave envelop clearly change for periods of 35 to 45 second. The upper limit (100 s) is mainly due to the noise level on the horizontal components.

3 Starting models

We introduce two different starting models. The first model comprises a crustal structure derived from the 3SMAC model (Nataf and Ricard, 1996) and a common upper mantle starting model based on the PREM (Dziewonski and Anderson, 1981). All the discontinuities below the Moho are smoothed and the upper mantle anisotropy is removed.

The second starting model (AU3) was proposed

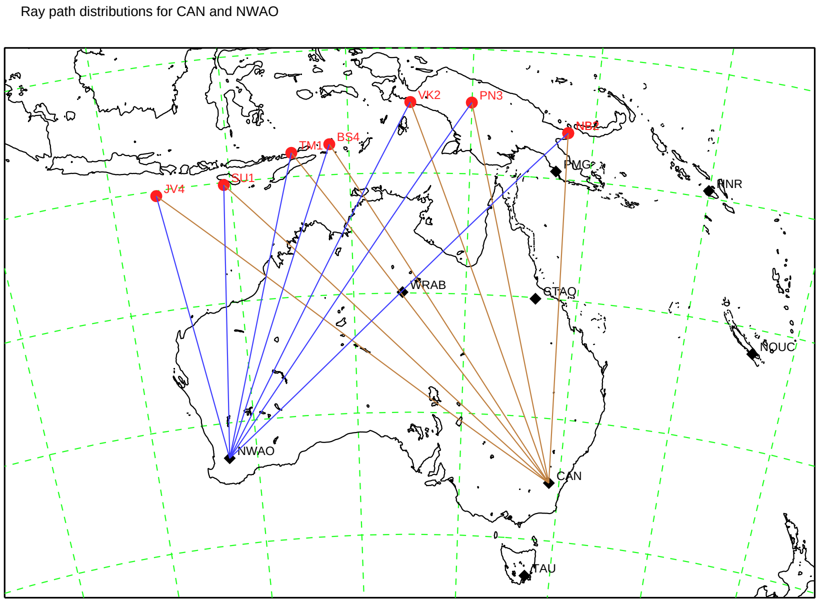

Figure 1: Ray path distributions from 7 events to the permanent stations CAN and NWAO.

by Gaherty & Jordan (1995). The model AU3 has a simple crustal structure and high shear velocities throughout the upper 350 km of the mantle without low-velocity zone in the isotropically averaged shear velocities. Moreover, AU3 contains polarisation anisotropy in the upper mantle from the Moho depth of 54 km down to the Lehmann discontinuity at the depth of about 250 km. We also apply smoothing all the discontinuities in AU3 model below the Moho depth.

4 Rayleigh and Love waveform inversion

We aim to construct an anisotropic 1-D model for each path. For that purpose, a 1-D transversely isotropic waveform inversion technique, which is an extension of the first stage of the Cara and Lévêque (1987) method, is applied to simultaneously process the fundamental Love and Rayleigh wave portions and several overtones for the vertical and tangential components.

We assume a TIV medium specified by the two best-resolved parameters β_v and $\xi = (\beta_h/\beta_v)^2$. The Rayleigh and Love joint inversion is then conducted in the region from the upper crust to the bottom of the transition zone for constructing a 1-D TIV model. For an adequate scaling of the seismograms, we also invert for the shear wave quality factor Q_β parameterised as $\log Q_\beta$ and the scalar seismic moment of the source $\log M_0$. The resulting TIV model is expected to reconcile inconsistent one-dimensional models from separate isotropic inversions of Rayleigh and Love waveforms.

5 Results and discussion

For 14 selected paths crossing the continent (figure 1), Rayleigh and Love joint surface waveform inversions are performed with two different starting models; 3SMAC crustal correction applied to isotropic smoothed *prem* and AU3. When the joint waveform inversion converges, the general pattern of the polarisation anisotropy is similar from two different starting models (figure 2). The difference between the two ξ solutions in their maximum amplitudes and in its shallow parts could come from that of their parameterisation in the crust. In the 3SMAC plus *prem* case (the upper two figures), a joint inversion iteratively renews the structure from the top of the upper crust (depth of 12 km) to the bottom of the transition zone. On the other hand, a joint inversion starting from AU3 (the lower two figures) modifies the structure below the Moho depth (54 km), because the AU3 has a one-layer crustal model above the Moho.

For the majority of the paths, however, it is often difficult to obtain a comparable level of fit to the waveforms of both Rayleigh and Love in a joint inversion with the TIV assumption. In particular, the Love wave inversion can tend to converge to an implausible solution or not converge at all. Thus, it may not be possible to find a satisfactory SH wavespeed profile using a single starting model even

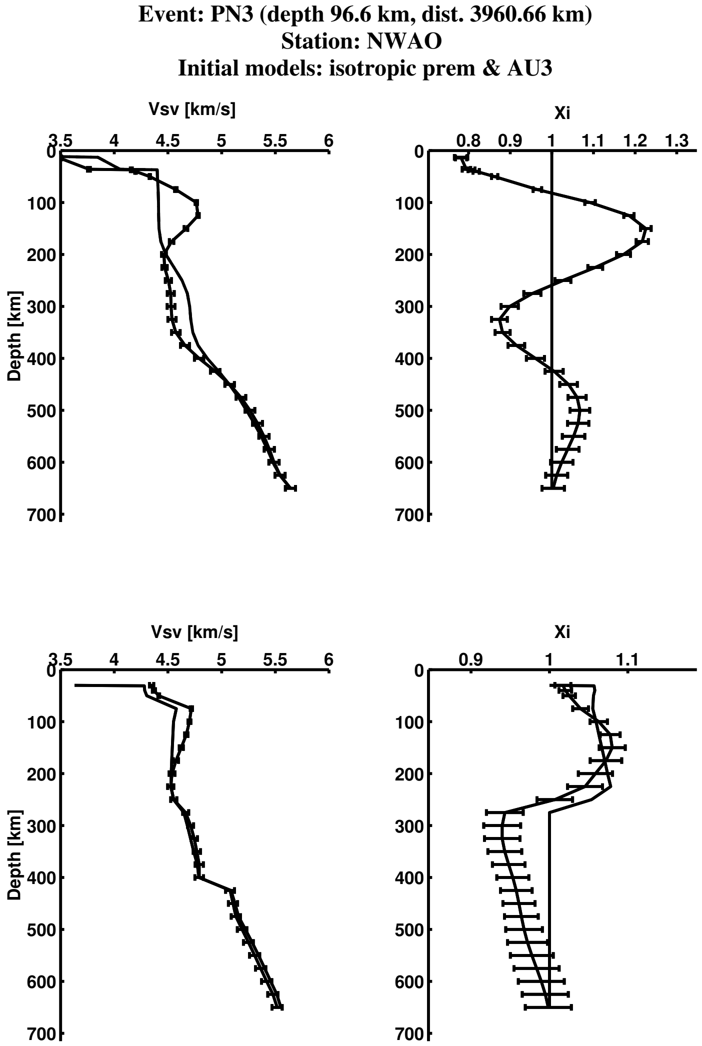

Figure 2: Two 1-D anisotropic models for the path from Papua New Guinea to NWAO. The upper two figures illustrate a starting model (3SMAC plus isotropic *prem*) and the final converged models of β_v and ξ. The lower two figures indicate the final iteration and its starting model AU3.

with a robust approach such as Cara & Lévêque method.

Such difficulties of obtaining reasonable SH wavespeed profiles are due to several reasons. First, the Love inversion has a larger sensitivity to starting model than the Rayleigh inversion. It is quite possible that SH wavespeed profiles in Australia are much faster than both starting models, so that the resulting SH wavespeed model from the joint inversion could depend highly on its starting model. Second, azimuthal variations of the surface wavespeed are not taken into account in our inversion. Debayle & Kennett (2000) report Rayleigh wave azimuthal anisotropy across Australia up to three percent. In addition, it is possible that azimuthal anisotropy of Love waves could reach the same degree as that of Rayleigh waves; therefore it may not be possible to assume TIV effective media.

6 Reference

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