KIRCHHOFF PRE-STACK DEPTH SCALAR MIGRATION USING THE PREVAILING-FREQUENCY APPROXIMATION OF THE COUPLING RAY THEORY

Václav Bucha
Department of Geophysics, Faculty of Mathematics and Physics, Charles University,
Ke Karlovu 3, 121 16 Praha 2, Czech Republic

It is known that the isotropic ray theory assumes equal velocities of both S wave polarizations and the anisotropic ray theory assumes both S wave polarizations strictly decoupled (e.g. Bulant & Klimeš, 2002). Coupling ray theory proposed by Coates & Chapman (1990) provides a continuous transition between the isotropic and anisotropic ray theories and solves the problematic behaviour of S wave polarizations in inhomogeneous weakly anisotropic velocity models. The coupling ray theory provides more accurate polarizations and travel times of S waves in inhomogeneous weakly anisotropic models than the anisotropic ray theory. There are many more or less accurate approximations of the coupling ray theory.

We test the application of the prevailing-frequency approximation of the coupling ray theory (Klimeš & Bulant, 2016) to 3-D ray-based Kirchhoff pre-stack depth scalar migration and compute migrated sections in two simple velocity models composed of two layers separated by a curved interface. The upper layer is inhomogeneous, anisotropic and the bottom layer is homogeneous, isotropic. The first model has weak anisotropy (QI) and the second model has approximately four times stronger anisotropy (QI4).

Ray-theory software package ANRAY (Gajewski & Pšenčík, 1990) and packages MODEL, CRT, FORMS (Červený, Klimeš & Pšenčík, 1988; Bulant, 1996; Bucha & Bulant, 2022) do not offer the possibility to calculate coupling ray-theory S waves in models with interfaces. In order to compute recorded wave field in an inhomogeneous weakly anisotropic model with interface, we used the Fourier pseudospectral method (Tessmer, 1995). We apply scalar imaging for the complete wave field in a single-layer velocity model with the same anisotropy as in the upper layer of the velocity model used to calculate the recorded wave field. Under the scalar migration, we understand the migration of just a single component of the complete recorded elastic wave field. For migration we utilize the MODEL, CRT, FORMS and DATA software packages (Červený, Klimeš & Pšenčík 1988; Bulant 1996; Bucha & Bulant 2022).

We migrate reflected PP, converted PS1 and PS2 elementary waves without the separation of the recorded complete wave field into P and S waves. For migration of the S-wave part we use the prevailing-frequency approximation of the coupling ray theory and for comparison we apply the anisotropic-ray-theory approximation. The differences in migrated images due to different S wave polarizations between the coupling ray theory and anisotropic ray theory are visible. Calculations using the prevailing-frequency approximation of the coupling ray theory are without problems in both models. On the other hand, for the anisotropic-ray-theory approximation in the model with weaker anisotropy (QI), we have to use limitation of Green function maxima, otherwise the migrated sections are wrong.

In spite of complex recorded wave fields, without decomposition, the migrated interfaces for the vertical component of the PP reflected wave, radial and transversal components of PS1 and PS2 converted waves are relatively good in all stacked migrated sections, with exception of spurious interface images close to the correct ones (please see two examples in Figures 1 and 2).

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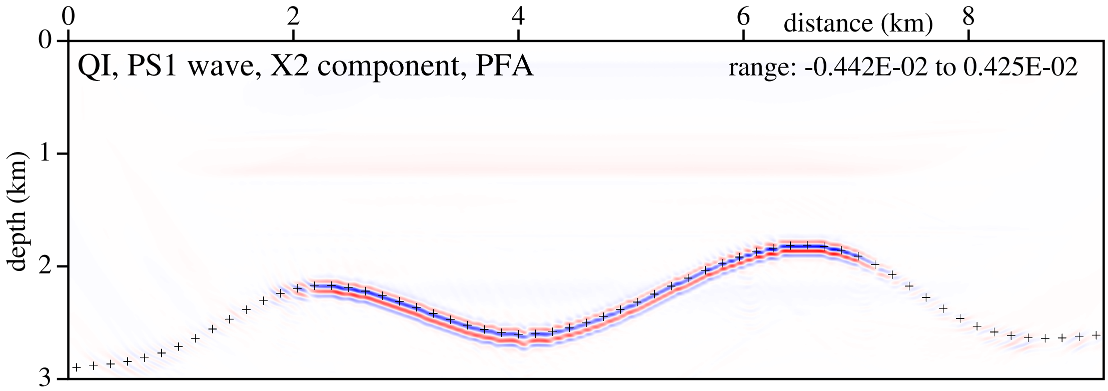

Figure 1. Stacked section migrated in the weakly anisotropic velocity model QI without interface. The transversal (X2) component of the PS1 converted wave is considered. Prevailing-frequency approximation (PFA) is used for calculation of the S-wave part of the converted PS1 wave. The elastic moduli in the single-layer velocity model for migration are the same as in the upper layer of the velocity model used to calculate the recorded wave field. 81×240 common-shot prestack depth migrated sections, corresponding to 81 profile lines and 240 sources along each profile line, have been stacked. The crosses denote the interface in the velocity model used to compute the recorded wave field. The top image of the interface is correct, the false image is slightly shifted downwards.

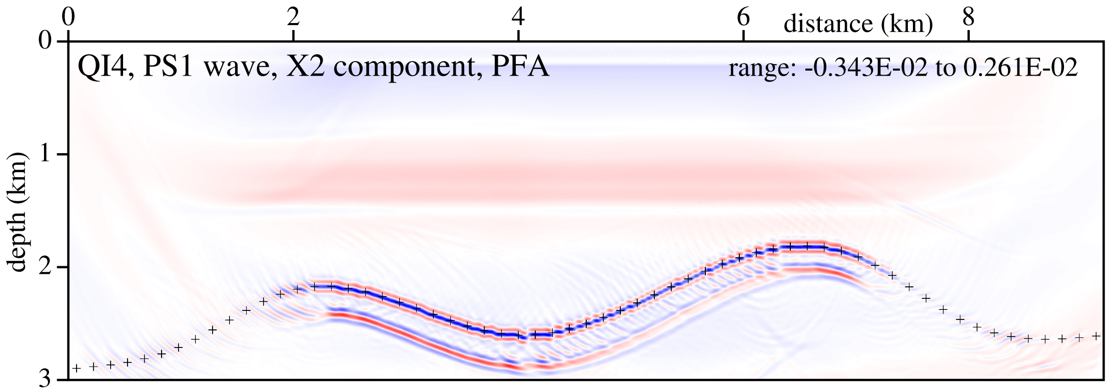

Figure 2. Stacked section migrated in the anisotropic velocity model QI4 without interface. The transversal (X2) component of the PS1 converted wave is considered. Prevailing-frequency approximation (PFA) is used for calculation of the S-wave part of the converted PS1 wave. The elastic moduli in the single-layer velocity model for migration are the same as in the upper layer of the velocity model used to calculate the recorded wave field. 81×240 common-shot prestack depth migrated sections, corresponding to 81 profile lines and 240 sources along each profile line, have been stacked. The crosses denote the interface in the velocity model used to compute the recorded wave field. The top image of the interface is correct, the false image is displaced downwards.

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