Computing pseudo-shear-wave data using PP and PS-wave traveltime interferometry in the rayparameter domain

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Abstract

The kinematics of converted-waves is one the features that complicates the processing of multicomponent data. The asymmetry of the converted-wave raypath prevents us from using an important part of the methods developed for P-wave processing. To accommodate the issue of asymmetric raypath Grechka and Tsvankin (2002) and Grechka and Dewangan (2003) proposed what they named the PP+PS=SS method. Their goal was to generate pseudo-shear-wave data by convolution and correlation of PP and PS-wave data. By taking advantage of the shared raypath between PS and PP data in the space domain they were able to retrieve the kinematics of pure shear-wave data. Here, we propose moving the data to the plane-wave domain, where the shared features of PS and PP are more evident. Although the P and S-leg of converted-wave events may follow different raypath angles, they share the same rayparameter following Snell's law. Recently, Tao and Sen (2013) developed a mathematical framework for doing interferometry in the plane-wave domain. They showed how the cross correlation-type reciprocity equation holds for data in the rayparameter domain. Hence, data with shared rayparameters can be cross correlated to compute redatumed data. In this work I will be using seismic interferometry in the plane-wave domain to extend the PP+PS=SS method to this framework. Access to the rayparameter values will be achieved by the τ-p transform and cross correlation and convolution of PS and PP data will be performed to reconstruct the kinematics of pure S-wave data.

Interferometry in the plane-wave domain

- ***τ-p* Transform pair:**

Forward τ-p Transform / **Inverse τ-p Transform**

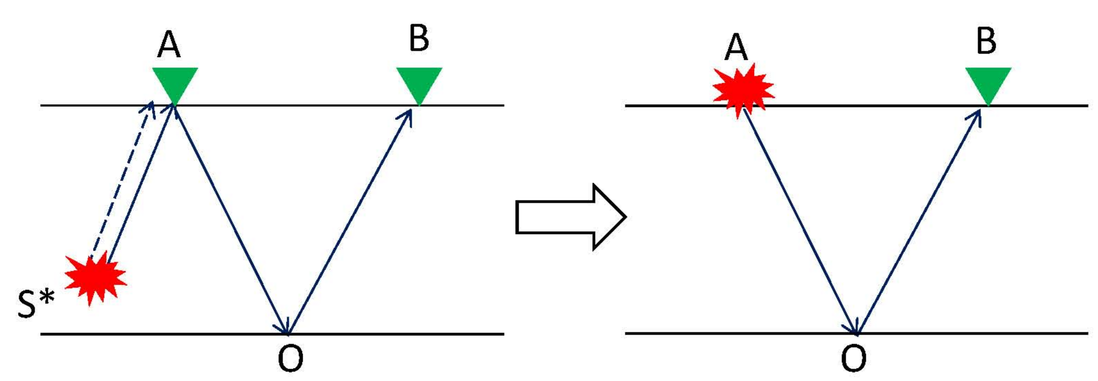
$$\hat{D}(x_s|p_r,\omega) = \int D(x_s|x_r,\omega)e^{i\omega p_r x_r}dx_r, \qquad D(x_s|x_r,\omega) = \omega^2 \int \hat{D}(x_s|p_r,\omega)e^{-i\omega p_r x_r}dp_r.$$

- ***Reciprocity equation of the correlation type in ω-x domain (without amplitude terms):***

$$Im\left[D(x_B|x_A,\omega)\right] \approx \int D(x|x_A,\omega)D(x|x_B,\omega)^* dx.$$

- ***Reciprocity equation of the correlation type in ω-p domain:***

$$Im\left[D(x_B|x_A,\omega)\right] \approx \omega^2 \int \hat{D}(x_B|p,\omega)^* \hat{D}(x_A|p,\omega)dp.$$



Cross correlation of events that share parts of the same raypath leads to the cancelation of the shared part redatuming the source to a new location.

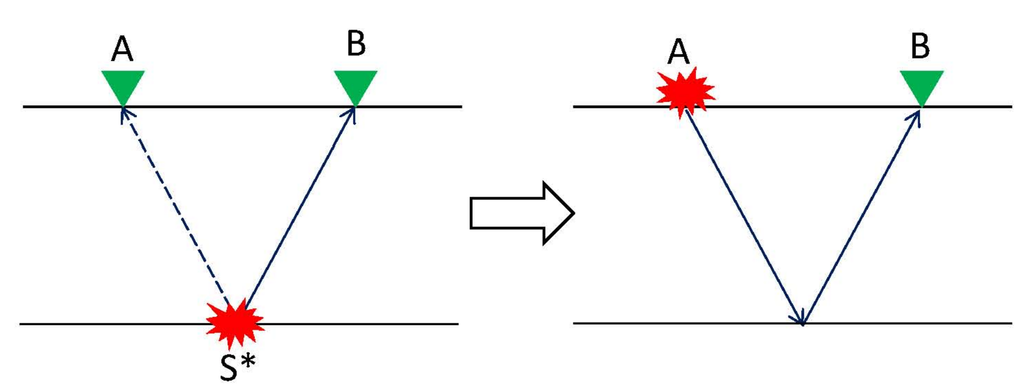
Convolution-type Interferometry in the plane-wave domain

- ***Reciprocity equation of the convolution type in ω-x domain (without amplitude terms)***

$$D(x_B|x_A,\omega) \approx \int D(x|x_A,\omega)D(x|x_B,\omega)dx.$$

- ***Reciprocity equation of the convolution type in ω-p domain:***

$$D(x_B|x_A,\omega) \approx 2\pi\omega^3 \int \hat{D}(x_A|p,\omega)\hat{D}(x_B|-p,\omega)dp$$

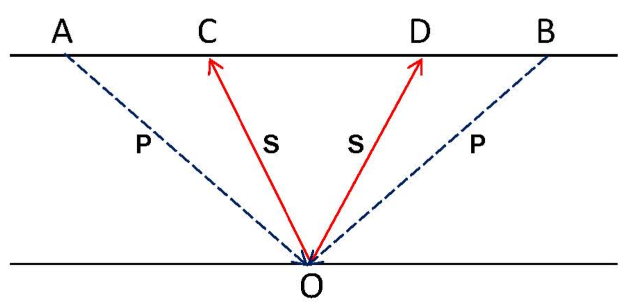


Convolution of events with the same rayparameter value returns events with larger traveltime. The figure shows how reflection times can be computed from one way times.

PP+PS=SS method

- ***SS traveltime reconstruction from PP and PS traveltimes***

$$t_{SS}(C,D) = t_{PS}(A,D) - t_{PP}(A,B) + t_{PS}(B,C)$$

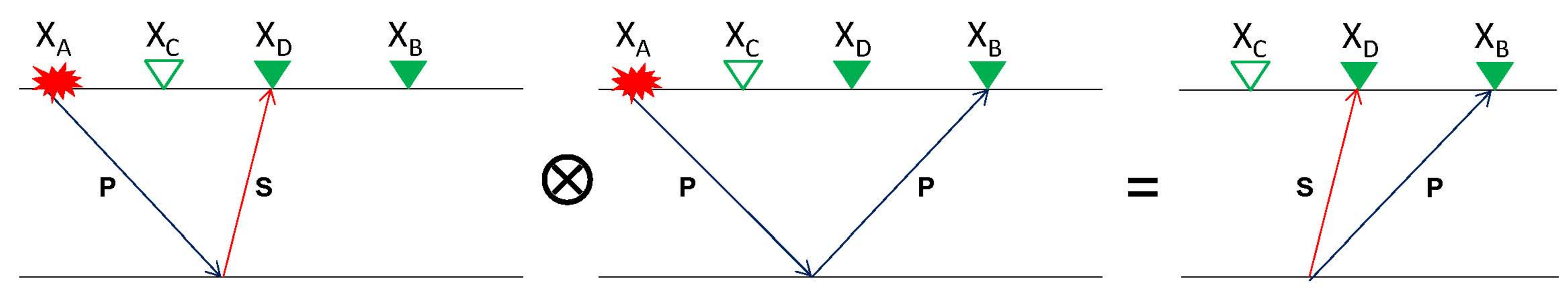


- ***Integral form of the reconstructions of SS traveltimes***

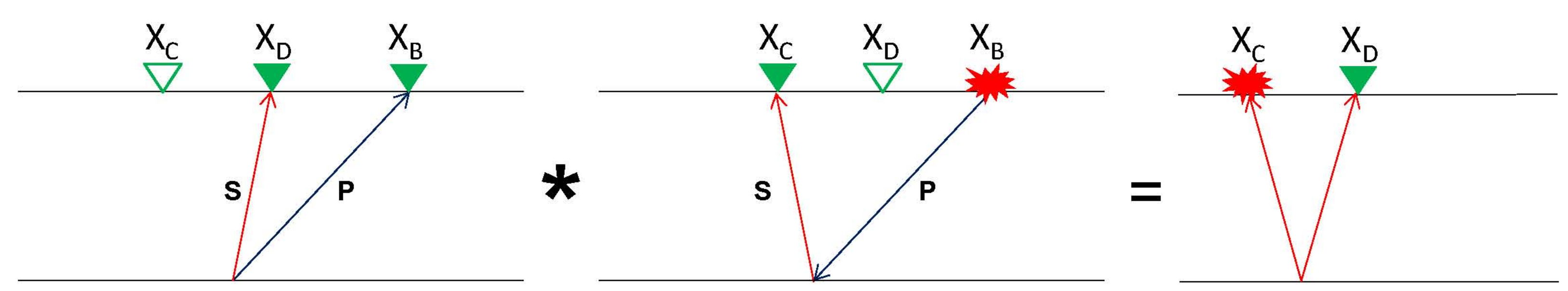
$$D_{\Psi S}(x_C|x_D,\omega) = \int\int D_{PS}(x_A|x_D,\omega)D_{PP}(x_A|x_B,\omega)^* dx_A D_{PS}(x_B|x_C,\omega)dx_B$$

Correlation-type reciprocity equation

Convolution-type reciprocity equation



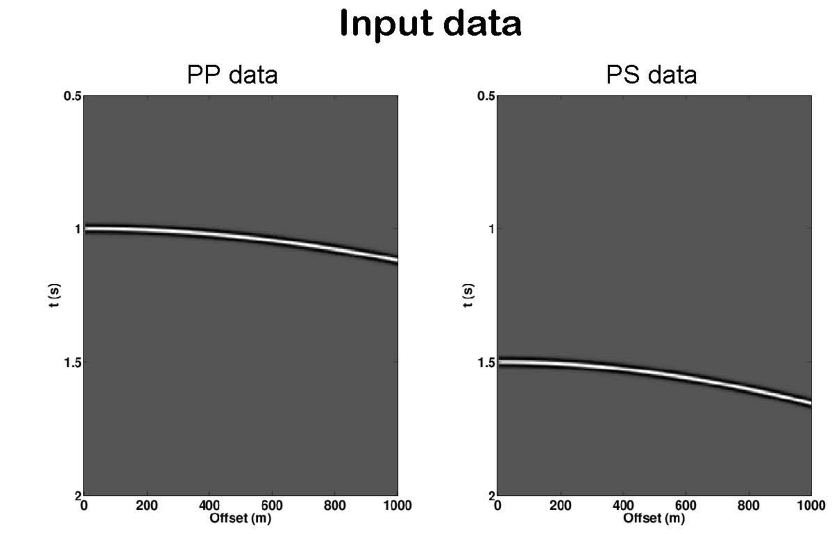
Cross correlation part of the SS traveltime computation



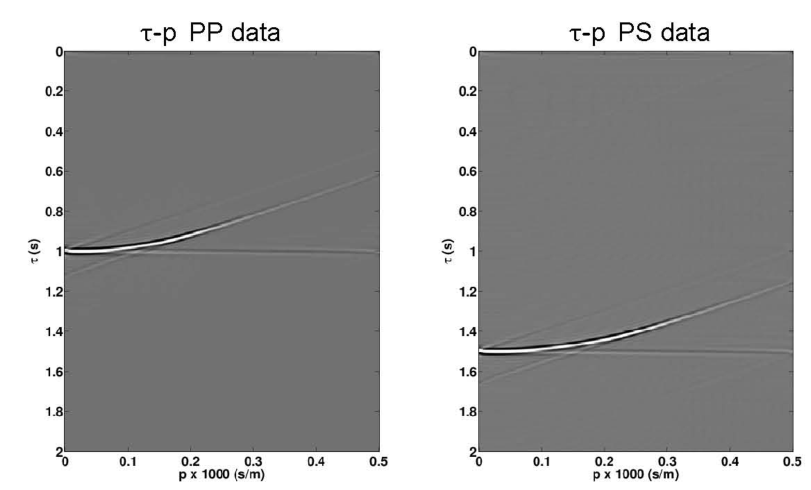
Convolution part of the SS traveltime computation

- ***Synthetic data test:***

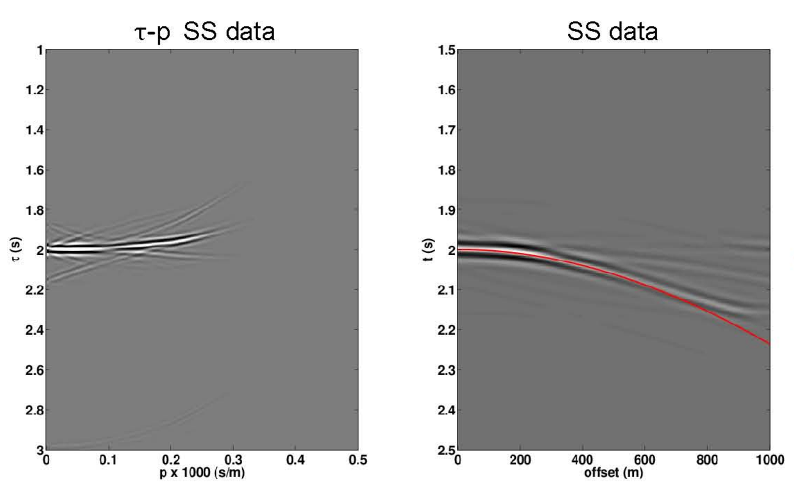
Input data



Transformed data



Pseudo SS-data



Pseudo-SS shot gather
(red line indicates raytraced SS-traveltimes)

Conclusions

The PP+PS=SS method in the plane-wave domain appears to be able to retrieve the kinematics of pure S-wave reflections given PP and PS data. This may be useful to simplify the processing and analysis of converted-wave data.

For this method to be successful, the algorithm used for the *τ-p* transformation must be relatively free of artifacts. The PP+PS=SS method relies on the use of cross correlations and convolutions that predict new events from pre-existing ones. Hence, it is important that the input to this process only contain the events we need in the reconstruction. Otherwise, unphysical events or crosstalk will be present in the output data. Alternative ways of getting access to the rayparameter domain should be considered. Using a radial transform instead of a *τ-p* transform might alleviate the introduction of artifacts into the data, since it is an artifact-free, exactly invertible transform.