GeoConvention 2015
GEOSCIENCE
new horizons
Telus Convention Centre • 4-8 May 2015 • Calgary, AB Canada

A method for converted wave receiver statics correction in the CRG domain

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Summary

A method for receiver statics correction of converted waves (PS-waves) is proposed here. It is based on the observation that the static time delay on PS-wave events between two adjacent receivers, after the source statics correction has been applied, should correspond mostly to the differential receiver statics. The statics surface consistent model provides the theoretical framework. Adjacent Common Receiver Gathers (CRG) are crosscorrelated to obtain their time delay, namely their differential receiver statics. Stacking of PS-waves it is not required, therefore the method does not depend on Vc (stacking velocity for converted wave), neither does it assume a simplified stacking model such as asymptotic binning. Tests on synthetic data illustrate the resulting statics.

Introduction

The statics correction aims to overcome the delay caused by the near surface layer (NSL) on seismic waves reflected at deeper layers. Since *S*-waves propagate more slowly than *P*-waves and are not affected by the water table, the statics correction becomes more critical and difficult to obtain.

S-waves correspond to the receiver statics correction in converted wave (PS-wave). Several methods proposed for this statics correction can be grouped into two main approaches: methods that require a Near Surface Layer (NSL) velocity model (datum statics) and methods based on the surface consistent model, analogous to the P-wave residual statics (Cox, 1999).

The methods based on the NSL velocity model appear less accurate than what is required and the picking of events is challenging (Schafer, 1993). The methods based on the surface consistent model are more popular (Harrison 1992, Cary and Eaton 1992) since they show the capability for short wavelength statics resolution. However the calculation is frequently cumbersome and laborious and requires PS-wave reflections stacking.

An alternative approach to obtain a receiver statics correction for PS data is proposed in tthis abstract. It is carried out on surface receiver gathers using data without NMO correction, based on the principle that all the PS-wave events of a common receiver gather are affected by the same S-wave static. Techniques for conventional seismic data statics using prestack data in the surface domains Common Receiver Gather (CRG) and Common Shot Gather (CSG) are presented by Disher and Naquin (1970) and Cox (1999). The method principles and a test with synthetic data are presented in the following sections.

Theory

The statics correction can be described by the surface consistent model, established by the following equation (Taner et al., 1974):

$$T_{ijk}=R_i+S_j+G_k+ M_k h_{ij}^2 \qquad (1)$$

where

R_i= receiver statics at the ith receiver position.

S_j= Source statics at jth source position.

G_k= arbitrary time shift for kth CDP gather.

M_k= residual NMO component at kth CDP gather, and h_{ij}= source to receiver distance.

The method proposed is based on the assumption that all the *PS*-wave events of a common receiver gather are affected by the same *S*-wave statics. Then, in principle, it would be possible to obtain the differential delay time between receivers from the delay time of each trace with the corresponding trace of the adjacent receiver. Thus it would be required to use traces organized by Common Receiver Gathers (CRG), namely traces recorded at the same receiver, generated by many sources.

The *PS*-wave events involved are illustrated in Figure 1. Two adjacent receivers have a different near surface delay, which is common to all the traces of the same pair of CRGs, no matter the source. This delay should be detected by a method such as crosscorrelation (e.g. Li, 1999), applied to *PS*-wave reflections. We assume that the source statics (obtained from the *PP*-wave processing) have been already applied. It is possible to assume that G_k (geology delay) is small, since the distance between reflections is small.

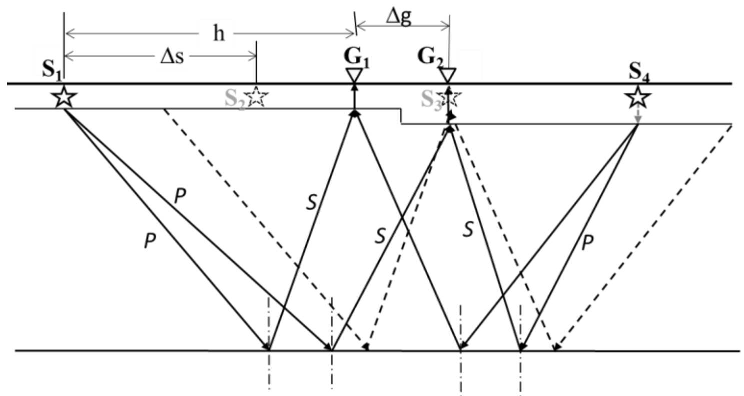


Figure 1. The PS-wave events that arrive at two adjacent receivers (G1 and G2) with a differential time delay δR (statics) between them, illustrated by raypaths. The events generated by different sources (S1 and S4) should have the same differential delay δR . However there is an additional delay generated by the different offset h. The dashed rays, however, have the same offset, and interpolation is proposed to obtain them.

We could assume that the NMO effect ($M_k h_{ij}^2$ in Eq. (1)) is negligible taking into account the short distance between the reflections. However the numerical experiments showed a meaninful effect related to the NMO. It can be considered a pervasive issue, taking into account that the distance between sources is usually larger and more irregular than the distance between receivers. An interpolation method to obtain the same offsets was used to overcome this delay, applying the τ-*p* transform. The traces with the same offset to the adjacent CRG are illustrated by the dashed lines in Fig. 1.

The differential delay time corresponding to two traces of adjacent receivers with the same offset can be found from the crosscorrelation:

$$C^h{}_{j,j+1}(\tau) = \sum_t \frac{D^h{}_j(t) D^h{}_{j+1}(t+\tau)}{\sqrt{\sum_t D^h{}_j(t)^2 \sum_t D^h{}_{j+1}(t)^2}} \qquad (2)$$

Where $D^h{}_j$ is the trace with offset h, and receiver location j, and τ is the time delay.

The differential delay time between two receivers then would be the summation of the delay between same offset traces, according to:

$$\delta R_j = max \sum_h C^h{}_{j,j+1}(\tau) \qquad (3)$$

Finally the statics correction relative to a datum defined by the receiver m is

$$R_i = \sum_{j=m}^{i} \delta R_j \quad (4)$$

Test on synthetic data

A test of this method on a synthetic model is now described. The data was generated using a Finite Difference elastic modeling method. Fig. 2 illustrates the S-wave velocity model. The surface, where sources and receivers are located, is assumed to be flat and 75 m deep. Receivers are separated by 5 m and sources are spaced at 20 m intervals. The *S*-wave velocity in the near-surface layer has a gradual increase with depth, with five lateral zones as shown in the close-up of Fig. 2 (b).

Figure 3 shows the crosscorrelation results for each receiver location, namely the summation along all the offsets (last part of Eqn. (3)).The differential receiver statics (the maximum of Fig. 3(a)) is in Fig. 3(b) (red crosses).Notice that the picks can be nicely related to the lateral velocity variations of the near surface in Fig. 2(b). Fig. 3(b) also shows the receiver statics calculation according to Eqn. (4) in the blue line, assuming as a datum the first receiver of the left hand side (m=1 in Eqn. (4)). Figure 4 shows the application of the receiver statics correction to shot gathers. The continuity of the events has been improved after the application of the receiver statics (Fig. 4(b)).

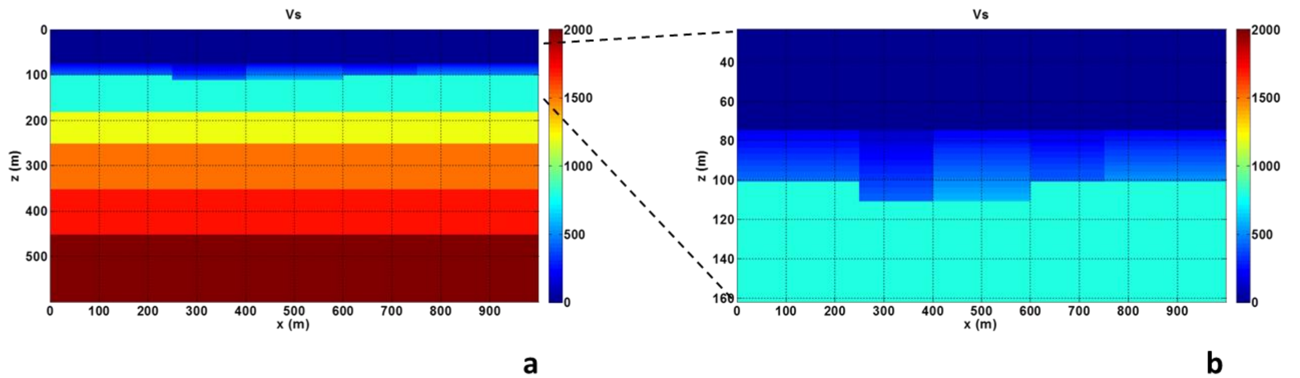


Figure 2. Synthetic model: (a) S-wave velocity model. The free surface is at z=75 m. (b) A close-up of the near surface. Notice the lateral velocity variation in five zones and a depth velocity gradient.

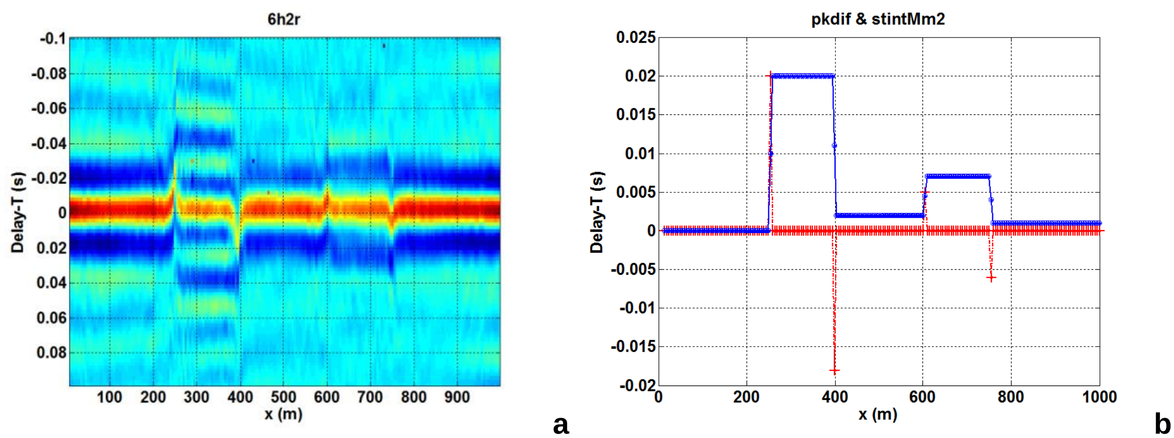
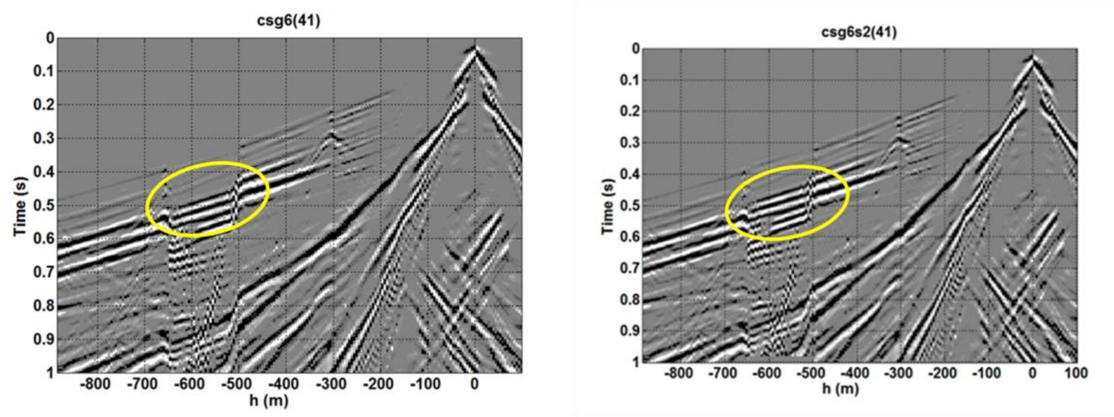


Figure 3. (a) Stacked crosscorrelations for each receiver. Notice the time delay at the limit between the lateral zones of Fig. 2. (b) Differential delay δR after the result of Fig. 3(a) according to Eqn. 3, shown by red crosses. and statics calculated from the differential according to Eqn. (4) shown by the blue line with dots.



a b

Figure 4. Seismic data in the source domain after the application of the receiver statics correction of Fig. 3(b). (a) Before statics, (b) after receiver statics application. Notice the improved continuity of the events.

Conclusions

- We proposed a method for *PS*-wave receiver statics correction based on CRGs without stacking *PS* reflections.
- The method yielded promising results when it was applied it to synthetic data. These test results also confirm the working assumptions, namely that there are coherent *PS*-waves in CRG data, which yield meaningful information about the receiver statics time delay.
- The method can provide short wavelength receiver statics, is automatic and does not require Vc (stacking velocity for PS-wave). It can be applied more easily to complex geological settings.

Acknowledgements

We thank the sponsors of CREWES for their support. We also gratefully acknowledge support from NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 379744-08. CREWES staff contributed greatly, specially Rolf Maier, Kevin Hall and Helen Isaac.

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