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Intra Array Statics (IAS) in the Cross-spread Domain

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SUMMARY

Demand for higher signal to noise ratio in seismic data is rapidly increasing. In land data ground roll noise has always been a major problem. Coarse spatial sampling makes this kind of noise considerably difficult to attenuate because of aliasing. High density single sensor recording naturally solves the sampling problem. Digital array forming may then be needed for cost reduction or for signal to noise ratio enhancement. To increase the temporal processing bandwidth, Intra Array Statics (IAS) must be applied prior to digital array forming. Here, three methods for estimating intra array statics are proposed and real data examples are shown.

Introduction

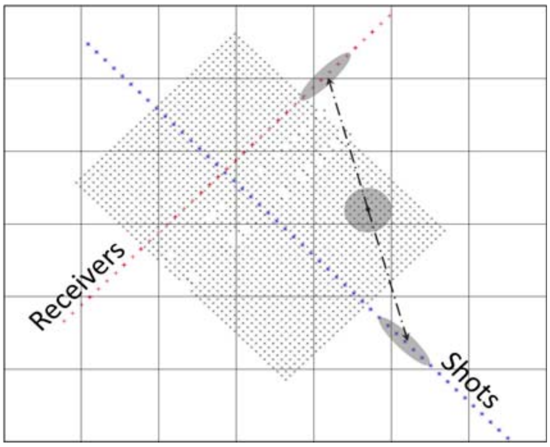

Figure 1: *Cross-spread geometry of the Timimoun dataset. In this cross spread, there are 960 receiver stations acquiring data from 1250 shots. Some stations have been dropped from the figure for visual clarity. The figure also shows method 3's radial mixing zone (exaggerated) for one trace. Traces inside the grey circle are stacked to create the corresponding pilot trace. Grey ellipses show contributing shot and receiver stations.*

Single sensor recording is becoming more and more popular as it makes it possible to properly sample coherent noise such as groundroll. Proper sampling of groundroll facilitates its accurate modeling and hence removal but is not the only advantage provided by single sensor recording. Within a receiver group perturbations in amplitude and phase due to topography or weathering effects can be present. Single sensor recording makes it possible to correct for these effects. Digital array forming without prior intra array statics decreases the temporal bandwidth of the signal as it acts as a high cut filter on the data.

In this abstract, three methods for deriving Intra Array Statics (IAS) prior to array forming are discussed. Using first break information, all three methods derive and apply statics in the cross-spread domain.

The cross-spread geometry (Figures 1 and 2) is an attractive domain for statics calculation as it provides great redundancy in information; it roughly provides NS.NR measurements for NS+NR unknowns, where NS is the number of shots and NR is the number of receivers in the cross-spread.

The first method of this paper is based on first break arrival time picking and decomposition which makes it a risky approach as first break picking and QC can be difficult to perform on noisy single sensor data. The second and the third approaches have been developed to overcome this problem. These two methods are based on cross-correlation functions. The second method is a two-pass approach; Refractions within neighboring traces are cross-correlated, time shifts are then used to derive IAS. The third method is very similar to the second one however, it is a single pass approach in which cross-correlations are done against pilot traces and statics are then surface consistently decomposed within each cross-spread.

To illustrate these methods, we use one cross-spread from the Timimoun dataset. This dataset was the result of an acquisition field test performed in Algeria at the initiative of TOTAL to assess the benefits of point receiver recording for enhancing the resolution and signal to noise ratio of land seismic surveys (Mougenot, 2008). A finely sampled point receiver line was simultaneously recorded with the regular 3D receiver spread during the Irharen 3D dataset that was being acquired in 2006 on the Timimoun block on behalf of TOTAL, SONATRACH and CEPSA. The cross-spread contains 1250 shots and 960 receivers creating approximately 1.2 million traces. Shot and receiver spacing's are both 6.25m. The geometry of this cross-spread is shown in Figure 1, and, its data in Figure 2.

Method 1:
IAS via first break arrival time decomposition

In this method, first break arrival times are automatically picked ignoring offsets less than 800m and after application of a constant velocity (4000 m/s) linear move-out. As single sensor data is noisy, spectral first break data cleaning is performed prior to picking. Our picking program also enhances first breaks internally: For each trace, nearby first breaks are stacked after applying measured time shifts estimated via cross correlations between a trace and its neighbors. Even with such clean first breaks it is nevertheless difficult to stay on the same phase of the first breaks during the picking to

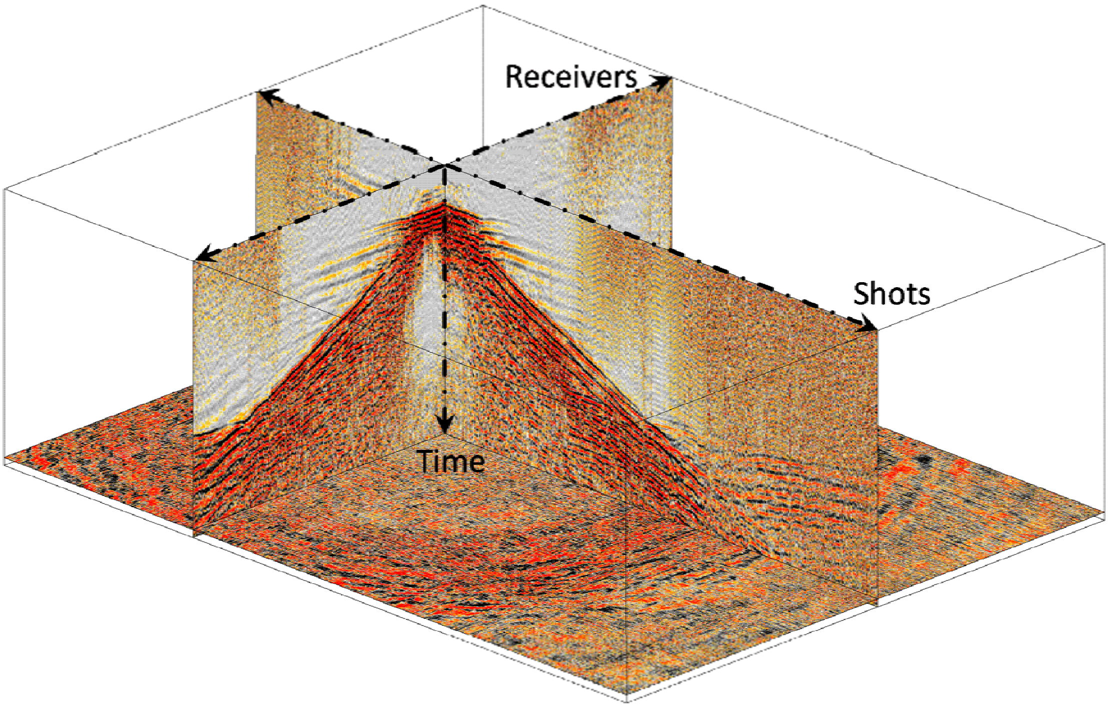

Figure 2: *Three dimensional view of the cross spread data (LMO applied).*
In Method 2: Within each shot, refraction arrival profile is obtained by integrating time shifts along the receiver direction. For each receiver, the time difference between the obtained profile and its smoothed version is an estimate for the receiver static needed on that shot. Averaging estimates across all shots gives the receiver static we are looking for. In Method 3: each trace of the cross spread is correlated against its static free version obtained by radial mixing of neighboring traces.

make surface consistent judgments. Another factor such judgments can not be made that the refracted arrival data belong to different refractors; shallow refractors when sources and receiver are near to the crossing of shot and receiver lines, and deep refractors when shots are far from the receiver line. Therefore a method to eliminate local slopes from the first breaks as well as cycle-skips on each common shot record was implemented.

During cycle-skip removal, travel times of the first breaks are derived on each common shot along the receiver direction, a threshold based cycle-skip editing is done and results are integrated. Resulting travel times on this shot are then smoothed along the receiver direction and the difference between unsmoothed and smoothed travel times are taken as residual (refraction) statics profile at this shot. The alpha trimmed mean (across shots) of these residual statics values gives us the required receiver line statics profile.

After the derived receiver line statics are applied to the original first break times, a similar procedure is applied in the other direction (to common receivers picks) to obtain the statics profile for the shot line.

Method 2:
Two-pass IAS without pilot traces

First, linear move out is applied and traces are truncated in time such that the refraction energy is dominant. The process is then applied in two passes:

In the first pass, common shot gathers of the cross-spread data are considered with receiver statics being the output of the process. For a given shot gather geometrically consecutive traces are correlated to one another and relative time shifts are picked.

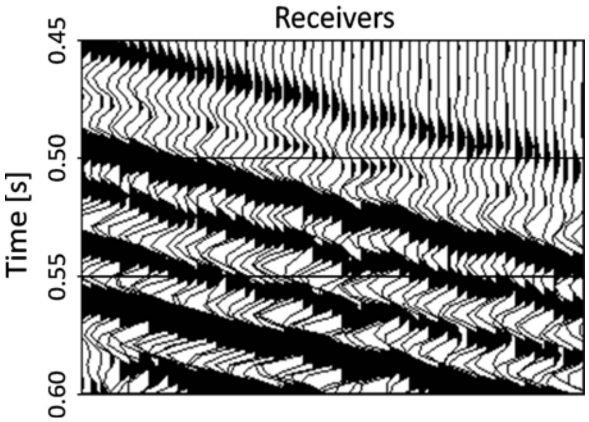

Figure 3: *A selected part of an input shot (4000 m/s LMO applied) before applying method 3's IAS.*

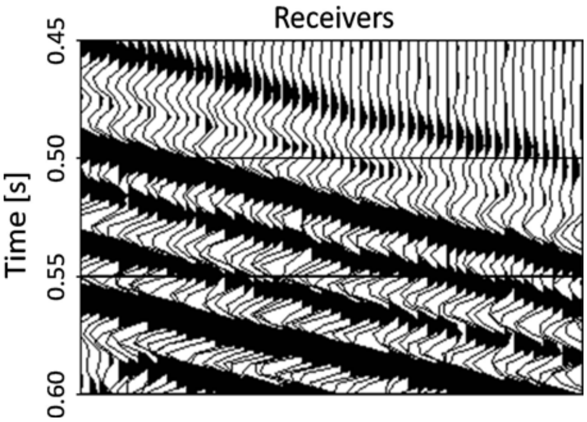

Figure 4: *A selected part of an input shot (4000 m/s LMO applied) after applying method 3's IAS.*

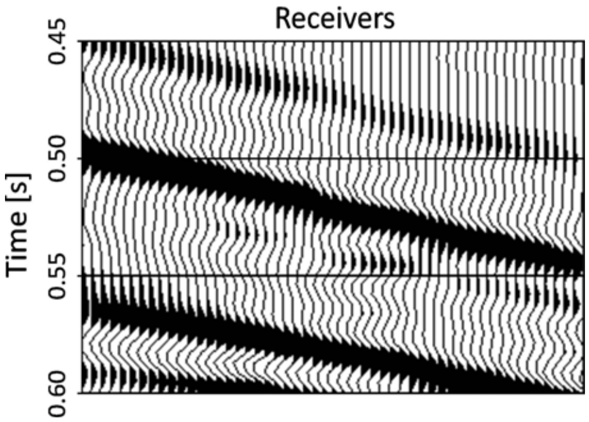

Figure 5: *A selected part of an input shot (4000 m/s LMO applied) after radial mixing (Pilot traces).*

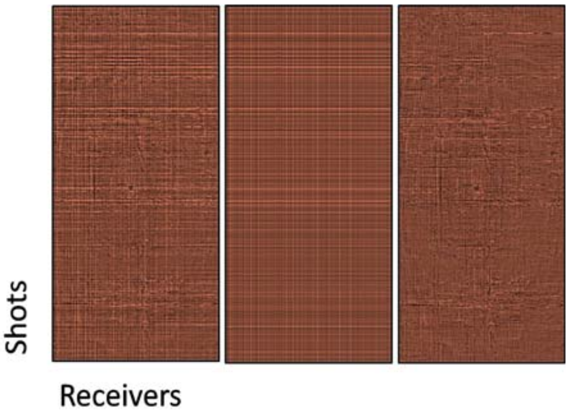

Figure 6: *Method 3's two dimensional statics arrays. Left: Picked time shifts against pilot traces. Middle: Sum of shot and receiver statics after SC decomposition. Right: difference.*

Refraction arrival times for a given shot can then be calculated by integrating the picked relative time shifts. The travel time profile so calculated contains variations related to refractor velocity changes, topography or weathering layer anomalies. To remove the high spatial frequency component related to intra array statics, a smoothed version of the profile is created. For each receiver in the shot gather, the time difference between the raw and the smoothed profiles gives the receiver static, but there are many shot gathers to use and therefore many statics estimates for each receiver. Averaging time shifts across all shots for each receiver gives the receiver static profile (Figure 2).

In the second pass the same procedure explained earlier is similarly performed on common receiver gathers of the cross-spread, resulting with the shot statics profile. Finally the derived shot and receiver statics are applied to the traces of the cross-spread and the process is repeated again for the following cross-spreads.

Method 3:
Single-pass IAS with pilot traces

Again in this approach linear move out is first applied and traces are truncated in time such that refraction energy is dominant. As processing is performed in the cross-spread domain; traces' midpoint coordinates directly define shot and receiver neighborhoods (Figures 1 and 2). Radial mixing of traces (Gulunay & Benjamin, 2008) according to their midpoint coordinates removes bumps from the refracting arrivals giving an assumed statics free version of the input traces i.e. the pilot traces (Figure 5). Obviously the mixing radius should be kept to the same spatial extent of the arrays to be formed so that we do not correct for any statics having a longer wavelength.

Using cross correlation functions, time shifts between input and pilot traces are picked and then surface consistently decomposed via the DRM method (Gulunay, 1985). Surface consistent decomposition within each cross-spread removes anomalous time shifts related to cross-correlation miss-picks (Figure 6).

The approach we use in this third method has been applied successfully in the processing of a large high-density project (Seeni et al, 2009; Gulunay et al, 2009). In this project IAS has been independently derived for each cross-spread, variation from one cross-spread to the next has been found to be minor reflecting the robustness of the approach. Results of method 3 applied to the Timimoun dataset are shown in Figures 3, 4 and 5. Notice that long spatial frequency components are purposefully left on the data. Also the figures show that the method naturally handles complex multiple refraction arrivals.

Conclusions

We have presented three methods for deriving intra array statics, all of which are derived and applied in the cross-spread domain. Methods 2 and 3 easily accommodate for any complex near surface effect avoiding all the troubles of first break picking. Method 3, i.e. deriving IAS in a single pass using pilot traces proved to be the most robust approach. This method has been tested intensively in the production processing of a large high-density dataset and proved to be very successful.

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