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A Two-Phase Automatic Converted-Wave Statics Correction Method

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SUMMARY

In this paper we propose a two-phase automatic converted-wave statics correction method. Seed statics are estimated by maximizing the low-frequency components of the original broadband data stacking power using a genetic optimization algorithm. The resulting statics solution is more robust in the presence of cycle skipping. With seed statics as the initial values, the coordinate descent method is then used to maximize the stacking power of the original broadband data, as well as the spatial coherency of the common converted point stack. We demonstrate our automatic method on an OBC PS dataset with good success.

Introduction

Shear information in multicomponent seismic data has a potential to dramatically improve standard interpretation workflows, such as lithology analysis, fracture detection, image below gas clouds, etc. (Caldwell 1999; Stewart et al., 2003). Estimating accurate shear-wave statics is one of the most challenging problems when processing converted wave seismic data. Shear wave statics are two to ten times greater than the corresponding P-wave statics, and S-wave velocities are not influenced by the water table (Cary et. al., 1993; Li et al., 2012). P-wave and S-wave static are hence mostly independent and applying a simple scaling to the known P-wave statics cannot provide satisfying results.

There are two categories of S-wave statics correction methods: model driven and data driven. For model driven methods, the shear wave velocity model has to be derived first by methods such as surface wave inversion, refraction wave inversion, or from uphole information (Schafer, 1991). For data driven methods, the goal is to maximize the stacking power, with or without resorting to pilot traces (Schafer, 1991; Cary et. al., 1993). One of the main benefits of data driven methods is the possibility of automation. Shear wave statics magnitude makes cross correlation based approaches less efficient on converted waves than P-wave data, due to potential cycle skipping. Visual control of the common converted point stack coherency is still required to assess the quality of the solution, compromising the possibility to carry out S-wave statics correction in a totally hands-off manner.

In this abstract we present a novel two-phase automatic converted-wave statics correction method. In the first phase, an initial statics solution is derived from the low-frequency component of the data by maximizing stacking power with a genetic optimization method. In the second phase, the final static solution is then refined using the broad band data, by maximizing stacking power with a fast local optimization technique. We demonstrate our method on a marine OBC PS dataset with promising results.

Workflow of the Automatic S-Wave Statics Correction Method

The workflow of our proposed two-phase automatic method is shown in Figure 1. Seed statics are estimated in the first phase, which contains two steps: low-frequency components of the original broadband data are filtered out, and then a genetic algorithm (Sun Y. et. al., 2013) is used to align these low-frequency components while maximizing the coherency of a common converted point stack. The statics obtained are named “seed statics.” The second phase uses the seed statics as the initial values and a coordinate descent method (Nocedal et. al., 1999) is applied to further maximize the stacking power on the original broadband dataset, while maximizing the coherency of common converted point stack. In our two-phase method, Seed Statics Phase is the most important. Utilizing the low-frequency component of the data allows deriving an automatic solution which is less sensitive to cycle skipping while being close enough to the actual solution to allow using a local optimization algorithm in the second phase. By using the heuristic algorithm, intensive human-machine interaction is avoided, so the whole workflow can be done in a completely automated manner.

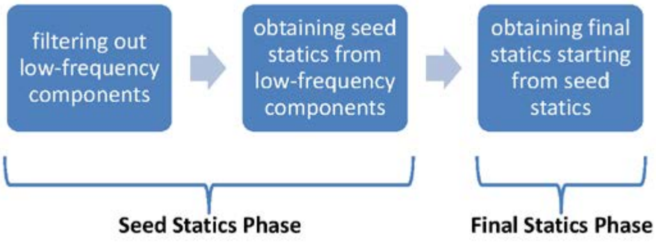

Figure 1 *The workflow of our two-phase automatic S-wave statics correction method.*

Field Data Example

In this abstract we use an OBC PS dataset to demonstrate our proposed automatic method. It contains one 10 km long receiver cable and two source lines located on each side of the cable. 200 receivers are on the cable with 50 m interval distance. Source side statics, or P-wave statics, are obtained by refraction tomography and have been applied to the dataset, and as a result the only outstanding statics issue for the dataset is the S-wave statics, or receiver side statics. The dataset is common-conversion-point (CCP) binned, and the original image after CCP stacking is shown in Figure 2. Due to our focus, only signals up to 1 s are shown in the image. Our events of interest are around 0.4 s, which are clearly discontinuous. The origin of these S-wave statics in this dataset is due to the combined effect of severe lateral velocity variations and low-velocity-layer thickness variations below the seabed.

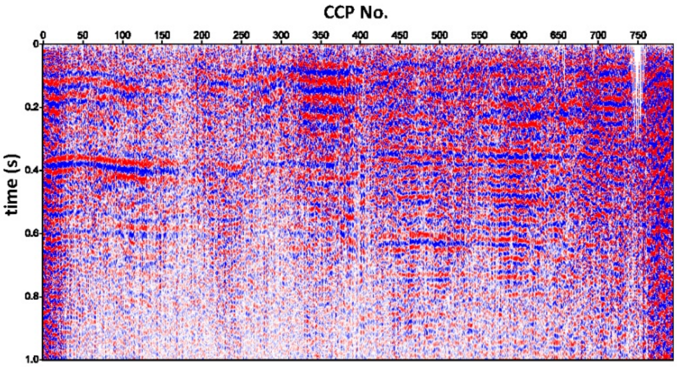

***Figure 2** Original CCP stack with source side statics (P-wave statics) applied, shown only to 1.0 s. Events around 0.4 s are discontinuous.*

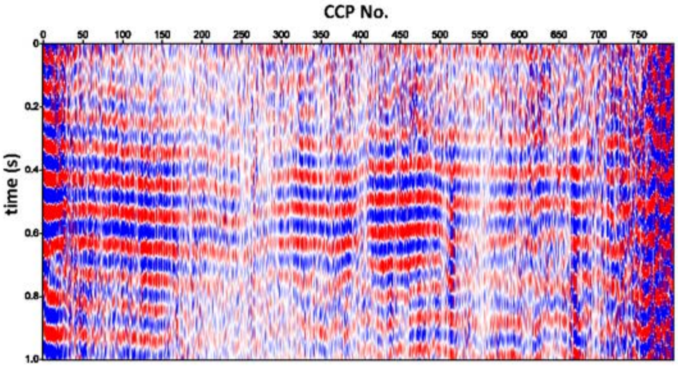

***Figure 3** CCP stack image after low-pass filtering the original data to 10Hz. Although events are still broken, their continuity is much easier to identify than Figure 2.*

The original dataset contains frequency components up to 50 Hz. The spatial coherency of the CCP stack displayed in Figure 2 is poor, with only the P-wave statics applied. Possible cycle skipped reflectors are also visible in Figure 2 in the neighbourhood of CCP 200. The original data is first low-pass filtered to only 10 Hz, and the corresponding CCP stack image is shown in Figure 3. It can be clearly observed that although these low-frequency reflectors are still broken, their continuity is much easier to identify. Next a heuristic optimization algorithm, which is similar to Sun Y. et al. (2013), is used to automatically align these low-frequency components to obtain the seed statics. The result is shown in Figure 4. The local coherence of the CCP stack is accounted for by performing this alignment step in a small sliding lateral window. Figure 5 shows the low-frequency CCP stack with the seed statics applied. The obtained seed statics are then applied to the original broadband data, and the corresponding CCP stack section is shown in Figure 6. Compared with Figure 2, events of interest are already better aligned, and more importantly the overall event structure around 0.4 s, which is an anticline, can be retrieved clearly. This structure is also in good agreement with the PP image (not shown in this abstract). Using these seed statics as initial values, coordinate descent method (Nocedal et. al., 1999), which belongs to line search family, is used on the broadband data to further maximize the stacking power. The final aligned broadband CCP stack image is shown in Figure 7. The image quality is improved considerably compared to Figure 2, and a lot of events between 0.30 s and 0.80 s that cannot be observed before are now visible. The final S-wave statics are shown in Figure 8. Generally speaking, these statics contain combined information of both long-wavelength statics and residual statics. The smoothed statics curve from Figure 8 will be the long-wavelength contribution, while the rest of the fluctuations are residual statics.

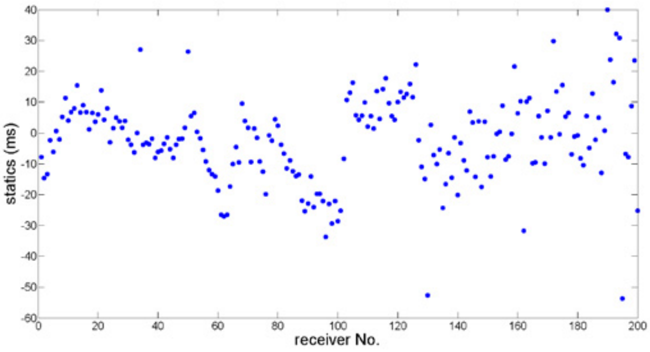

Figure 4 *The receiver seed statics obtained after the Seed Statics Phase.*

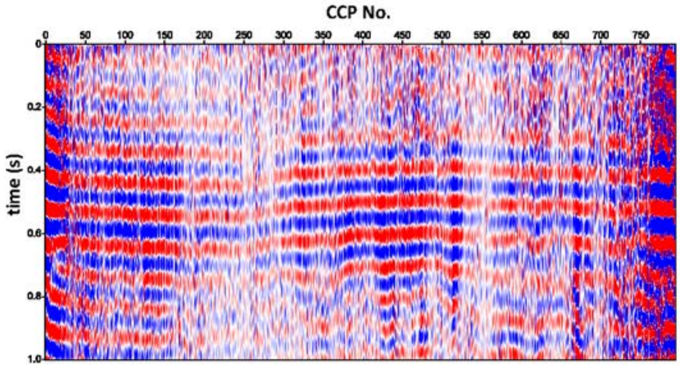

Figure 5 *The aligned low-frequency CCP stack, corresponding to Figure 3.*

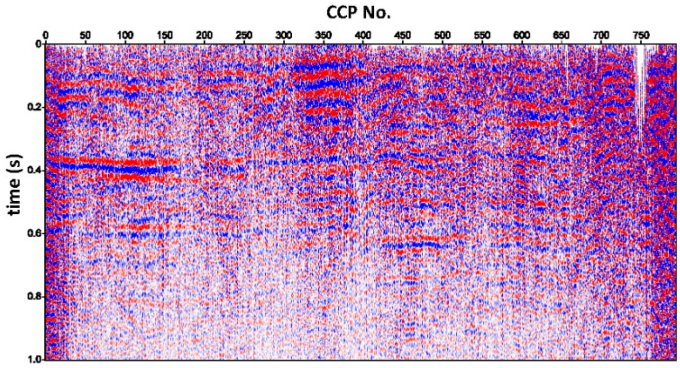

Figure 6 *The image after applying seed statics onto the original broadband dataset. The anticline structure around 0.4 s can be observed.*

Conclusions

In this paper we proposed a two-phase automatic converted-wave statics correction method. Seed statics are estimated by a genetic algorithm from the low-frequency components of the original broadband data, and then they are applied back to the original data. With seed statics as the initial values, coordinate descent method is used to process the original broadband data. We have demonstrated our automatic method on an OBC PS dataset with good success.

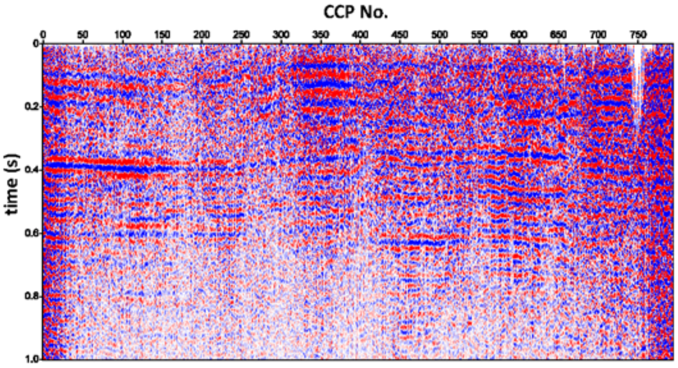

***Figure** 7 The final aligned broadband image with the final S-wave statics shown in Figure 8.*

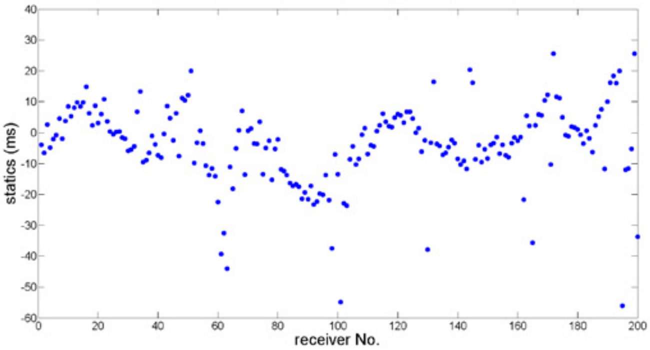

***Figure 8** The final receiver statics (S-wave statics) statics obtained by our method.*

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