

The Estimation of PS Wave Statics By Using SCDCC + Stack Power Method

Aimin Xue *

Petrol Sound Geoservices.

8, MacEwan Ridge Close, N.W., Calgary, Alberta T3K3A7, Canada.

aiminx@telus.net

ABSTRACT

Summary

The conventional residual statics estimation methods have been used for PP wave statics estimation effectively for years. However, they are not straightly forwarded to PS waves. They often fail in the cycle skips if the large values of the receiver statics exist during the statics estimation.

I suggest a new method that combines the surface consistent difference of cross-correlation (SCDCC) with the stack power method to get the large residual statics. The synthetic data has been used for showing the examples in the paper. In the example, the statics larger than 130 ms wag with the period of a half maximal offset have been estimated. The seismic data processing showed that the combination, SCDCC + stack power, are more powerful and economical to estimate the PS wave statics. It can also straightly be used to estimate the large statics of PP wave data.

Introduction

Unlike PP data, PS data are often with smaller S/N ratio and larger receiver statics. The receiver statics of PS waves are commonly two to ten times greater than those of PP waves for the same locations (Tatham and McCormack, 1991). Additionally, if the P wave sources are used, the converted S wave data are with the noises that associate with PP waves, PS waves, ground rolls and some others. The data qualities of PS waves are poor, normally, comparing to those of PP waves. It is difficult to get the reliable statics for this kind of data by using conventional residual statics algorithms. They often produce numerous cycle skips when attempting to resolve the problem of larger statics (Cary, 1993).

Many methods have been suggested to estimate the large residual statics. Tomography method that associates with first break picking has been developed to inverse the near surface velocities and estimate the time changes for ray traveling in the replace velocities and the inversed velocities (Chang et al., 2002). It limits to the unreliable first break picking for PS data. Conventional stack power method (Ronen and Claerbout, 1985) working in CMP domain obtains the statics by searching the maximum of stack powers. The cross-correlation between the pre-stack trace and the post-stacked trace (pilot trace) is carried

out instead of costly searching the stack power of global maximum. It often fails in the statics larger than a seismic wave cycle, which is common for PS waves. The method of stack power in frequency domain (Normark, 1993) improves the solution of statics problem in some cases, but still suffers the lacking of data with high reliability of lower frequencies. Cary and Eaton (1993) suggested a method for obtaining the large statics by optimizing the trace-to-trace coherence of the common-receiver-point (CRP) stack. The method is successful in the flat data but fail in the structural data. It is also limited to the low quality of the CRP stack data. There are some other methods that associate with the simulated annealing algorithm (Vasudevan, et al., 1991) and the local optimization algorithm (Wang et al., 1997) for estimating the large statics. The high costs of computation may hesitate the practice of geophysical production.

In the paper, I suggest a new method to resolve the problem of large statics with the period smaller than a half maximal shot-receiver offset. It is the combination of the difference of cross-correlation (DCC) and the conventional stack power (STKPW) algorithms. DCC estimates the statics by optimizing the coherence receiver-to-receiver and shot-to-shot in CMP domain and the coherence cdp-to-cdp in shot or receiver domain. The advantage of DCC is to get the statics without the pilot traces. It avoids the problem of cycle skips if the assumption is true that the time-shift is not larger than a seismic wave cycle between the neighbor traces. For most of the data, the assumption is quit reasonable. The time-shift estimated may not be accurate for the traces because of the noises. Therefore, the statistics are needed at the shots, the receivers and the CMP's. When DCC job is done, STKPW is used to do the rests of work for the fidelity of statics. To example the method, synthetic data are used in the paper.

Surface consistent difference of cross-correlation (SCDCC)

The new method consists of two steps to get the large statics where, in the first step, the raw statics with very large time-shifts are estimated, and in the second step, the rests of statics smaller than a wave cycle are estimated. The estimation is executed by cross-correlating the trace in question against a neighbor trace for the first step or a pilot trace for the second step. The time-shift that fit the surface consistent model for a given seismic data can be expressed (Ronen and Claerbout, 1985) as

$$\Delta T_i = S(s_i) + G(g_i) + Y(y_i) + R(y_i)h_i^2, \quad \dots \dots (1)$$

ΔT_i is the total time anomaly, $S(s_i)$ is the shot component; $G(g_i)$ is the receiver component; $Y(y_i)$ is the CMP component and $R(y_i)$ is the residual normal moveout coefficient with offset h ; i is the trace number. Generally, one can only consider the shot component $S(s_i)$, the receiver component $G(g_i)$ and the CMP component $Y(y_i)$.

Normally, the statics estimated by using *equation (1)* are values that make the stack power reach a local maximum if stack power method is employed. The

changes in stack power due to the static perturbation are estimated by resolving a nonlinear equation system. Commonly, Gauss-Seidel iterative algorithm is used. Based on the assumption of random distribution of the statics in CMP domain, the average of statics is small. Hence, the time-shift can be found for every trace by the cross-correlation between the trace and its pilot. Each pilot trace is built by stacking the CMP gather except the trace itself. The method is powerful when the time-shift between the trace and its pilot smaller than a seismic wave cycle. For PS waves, it is common for the time shift between the receiver trace and its pilot larger than a wave cycle, and the cross-correlation is not always successful. In this case, I suggest that one can optimise the coherence trace-by-trace by the cross-correlations. The cycle skip problem will be overcome if the time-shift between the two neighbours is smaller than a seismic wave cycle. We can use the idea to *equation (1)* and get an equation for obtaining the statics of each single component as

$$\Delta t_i = \frac{1}{N} \left\{ \sum_{j=1}^{i-1} [-j\Delta_j] + \sum_{j=i}^{N-1} [(N-j)\Delta_j] \right\}, \quad (2)$$

where N is the ACCP fold (CMP fold for PP waves), j is the sorted trace sequence number in the gather and Δ_j is the time-shift between trace j and trace $j+1$, Δt_i is the statics for trace i . In fact, Δt_i obtained from *equation (2)* is based on the difference of cross-correlations trace by trace. *Equation (1) and (2)*, the limitation for the time-shift between the neighbours and the assumption of the small statics average at ACCP domain (CMP domain in PP waves) are the foundations of the surface consistent difference of cross-correlations (SCDCC).

To get the reliable statics, one needs to execute several Gauss-Seidel iterations and does the statistics of the statics at the shots, the receivers and the ACCP's (CMP's for PP data). If the data are flat, the estimation for the statics of the ACCP component can be ignored. If the statics of the shot component have been found or borrowed from the PP data processing, only the statics of the receiver component should be estimated.

The statics estimation by using of stack power method

The statics estimated by SCDCC may not be accurate enough for the final statics corrections for some data. In this case, the stack power method is needed to improve the solution after applying the statics estimated by SCDCC. The iterations for Gauss-Seidel solution may be executed several times. Normally, the better solution of the nonlinear equation associates with the larger numbers of the iteration. However, the payment for the computer cost should be considered. One has to balance the computer cost and the accuracy of Gauss-Seidel solution. For noise data, things get complicated and it is not always successful for increasing the iteration to get better Gauss-Seidel solution. In this way, the super trace may be selected since it does improve the solution for many cases. It is constructed by stacking the trace and its neighbors.

Synthetic data examples

The synthetic data are used to examine SCDCC and the stack power process routine. The input and estimated statics for the shot component and the receiver component are shown in *fig. 1* and *fig. 2*. In the model, the maximal period of the statics is up to 750 m and the maximal shot-receiver offset is 1500 m. The experiences tell us that the estimated statics will include regional anomalies if the period of statics larger than a half of the maximal shot-receiver offset. The shot statics are equal to a half of the receiver statics at the same positions, which is not true for PP data but is true for PS data in some cases. The stack section before the statics corrections are very bad (*fig. 3a*). One can't get the initial pilot traces if one uses conventional stack power method to estimate the statics for this data. During the processing, 13 iterations for Gauss-Seidel solution are used, 5 for SCDCC and 8 for STKPW. The estimated statics match the input one very well (*fig. 1, 2*), even the maximal waging value up to 135 ms for the receiver statics. The stack image after the statics corrections (*fig. 3b*) is good comparing to the stack image before the statics corrections (*fig. 3a*).

The stack sections for noise data are shown in *fig. 4*. The iterations are same to those above. The different noise levels give the different estimation resolutions of the statics. *Fig. 4a* shows that the method can work at the maximal random noise amplitude up to 3 times of the maximal signal amplitude without a significantly influence on the statics estimation. *Fig. 4b* shows that the large influence comes if the maximal amplitude of noises goes up to 5 times of the maximal signal amplitude. The more folds of seismic data can reduce the noise influence. It can be seen from the middle parts of the stack section in *fig. 4b*.

The surface consistent DCC is cheaper than conventional stack power method. It does not need to stack the gathers to build the pilot traces. If the data are not very noisy, 3 to 5 iterations are quit enough. After SCDCC process, the stack power routine does also not need to run many times of the iteration too, because the most of job has been done by SCDCC.

Conclusion

The new approach to the large statics problems has been suggested. It combines two methods, SCDCC method and stack power method, together to resolve the nonlinear equation problems. The formal is for getting the raw statics with the large amplitudes, and the later is for making the fidelity of the statics. Synthetic data of PS waves has been used to show the example. For PP wave data, the method is straightly forwarded.

References

- Cary, P. W., and Eaton, D. W., 1993, A simple method for resolving large converted-wave (P-SV) statics. *Geophysics*, 58, 429-433.
- Chang, X., Liu, Y., Wang, W., Li, F., and Chen, J., 2002, 3-D tomographic statics correction: *Geophysics*, 67, 1275-1281.
- Normark, E., 1993, Residual statics estimation by stack power maximization in the frequency domain: *Geophysical Prospecting*, 41, 551-563.
- Ronen, J., and Claerbout, J. F., 1985, Surface-consistent residual estimation by stack-power maximization: *Geophysics*, 50, 2759-2767.
- Tatham, R. H., and McCormack, M. D., 1991, multicomponent seismology in petroleum exploration: *Soc. Expl. Geophys.*
- Vasudevan, K., Wilson, W. G., and Laidlow, W. G., 1991, Simulated annealing statics computation using an order based energy function: *Geophysics*, 56, 1831-1839.
- Wang, B., Cheng, S. W., Pann, K., and Deng, H. L., 1997, Estimating large statics by a simplified stacking power approach using local optimization: 67th intern. Mtg: Soc. of Geophys., 1066-1069.

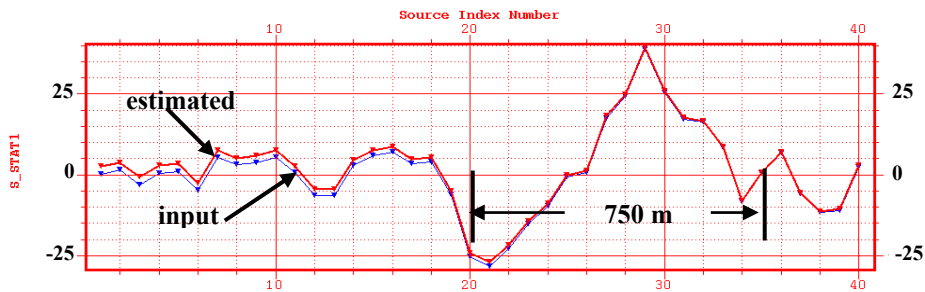


Fig. 1. The statics for the shot component: The maximal statics period is up to 750 meter. The maximal statics is 40 ms and the minimal statics is -28 ms.

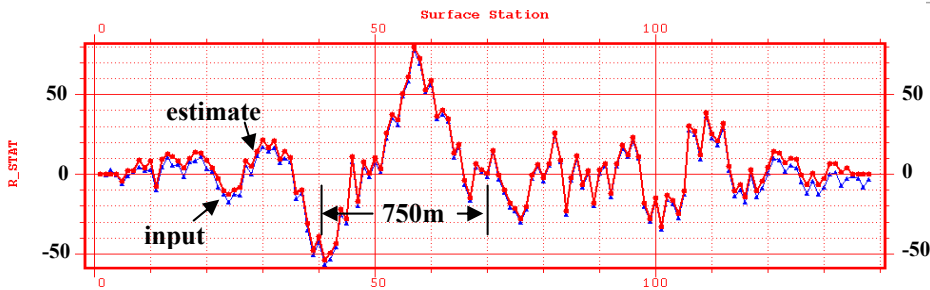


Fig. 2. The statics for the receiver component: The maximal statics period is up to 750 meter. The maximal statics is 80 ms and the minimal statics is -55 ms.

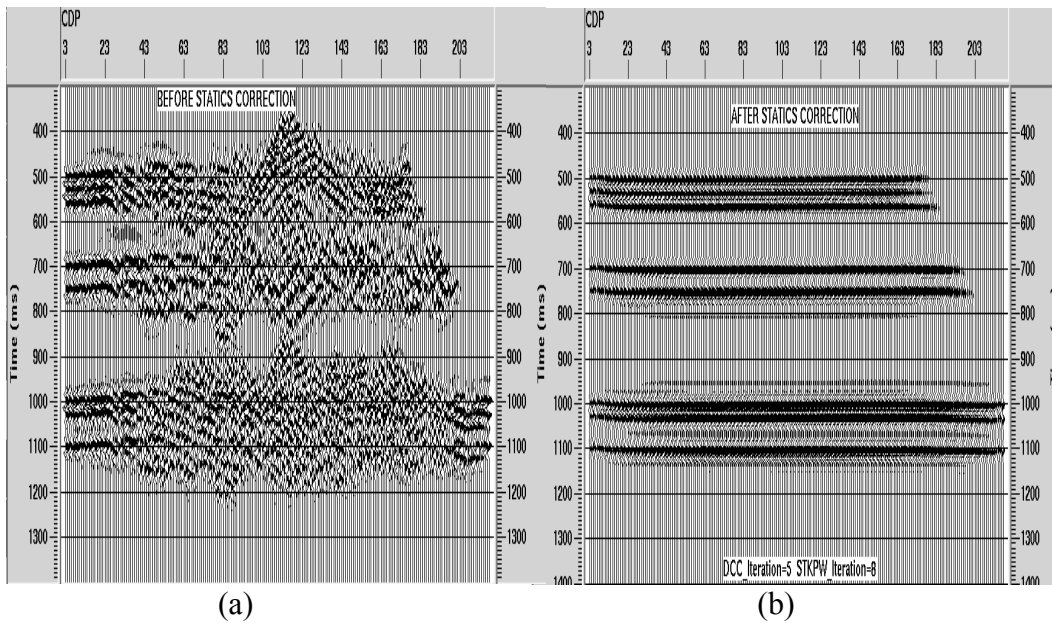


Fig. 3. The ACCP stack sections: (a) before statics correction, (b) after statics correction. The statics input and estimated are showed in fig. 1 and 2.

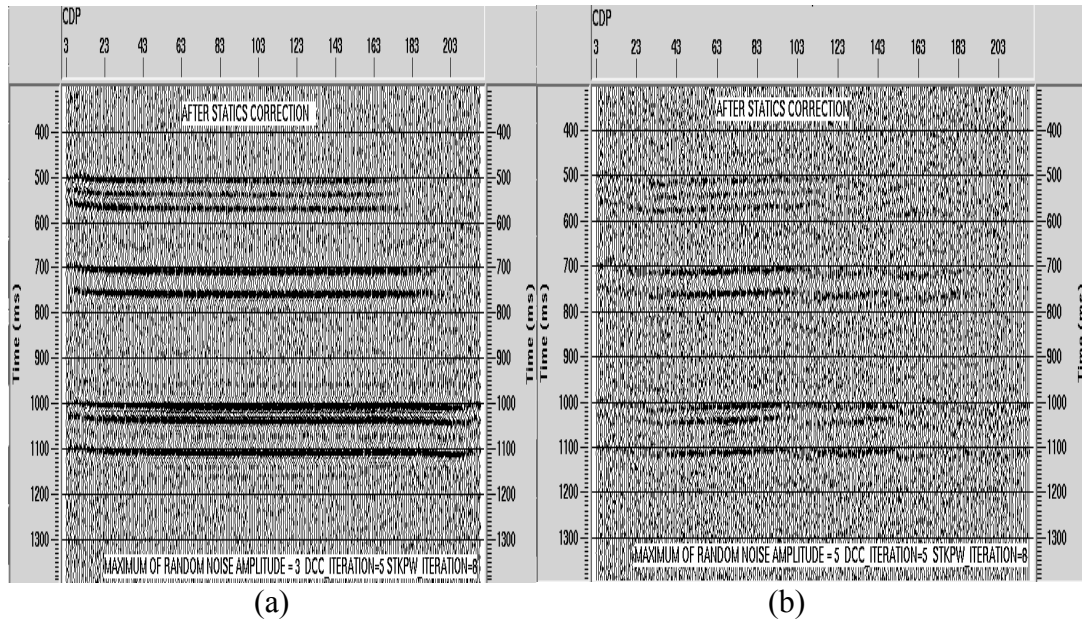


Fig. 4. The ACCP stack sections after statics corrections for synthetic data with random noises: (a) The maximal noise amplitude is 3, (b) The maximal noise amplitude is 5, and the maximal signal amplitude is 1.