Azimuth Moveout – a promising application for pre-stack data

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2005 CSEG National Convention

Introduction

It is often found that the offset and azimuth distribution in 3D seismic surveys, both land and marine are sub-optimal, for reasons that vary from practical considerations to economics. Modification of azimuth and offset distributions of data during processing could prove to be an effective method for optimum imaging of 3-D datasets. Azimuth moveout is a partial prestack migration process which rotates the azimuth and modifies the offset distribution of the data during processing (Biondi et al 1998), without the need for detailed a priori assumptions about the velocity function or geology.

Potential applications for the process include the following:

1. One important application of AMO is its ability to reduce the amount of 3-D prestack data, without losing any information by coherently stacking traces with similar azimuths and offsets. Since the kinematics of 3D data depend on azimuths and offsets, the data need to be processed with AMO before stacking, for maximizing coherency among the traces that are averaged. This data reduction would make compute intensive processes like 3D prestack time migration for example, more economical to use.

2. Regularisation of sparse and irregular geometries: Wide-azimuth 3-D surveys need an even range of source to receiver offsets at all azimuths and these need to be sampled adequately in space and time. However, in practice, offset and azimuth distribution could vary from bin to bin or could be uniform in say the inline direction and vary in the crossline direction. Significant offset and azimuth irregularities can occur in multi-streamer marine marine surveys (Chemingui and Baumstein, 2000). If not corrected, these irregularities can cause amplitude artifacts and positioning errors in the final image. Neglecting azimuth variations results in incorrect computation of travel times which enter in to various calculations during imaging, affecting both positioning and amplitude. After correction with AMO, the data has the necessary regularisation and can be processed using any wave extrapolation methods including finite-differencing and wave equation domain techniques.

3. AMO serves to be employed for a 'wave-equation' interpolation of 3D data to overcome spatial aliasing problems or correct for uneven coverage.

The Azimuth Moveout process

Azimith moveout is a partial migration operator, that rotates the offset and modifies the offset of 3-D prestack data. The AMO operator essentially may be considered as a cascade of an imaging operator acting on a data with a given offset and azimuth, followed by a forward modelling operator that reconstructs data at a different offset and azimuth (Chemingui and Biondi, 1995).

Prestack migration operator could be used for defining AMO, but the present formulation has been derived from DMO. The reasons for doing this include: 1. Under the constant velocity assumption, DMO is velocity independent, and since it is applied to NMO corrected data, the first order effects of velocity variations are removed, 2. DMO can be formulated to act on data with constant offset and azimuth and so AMO derivation can be effected in a straightforward way.

The AMO operator is derived by starting with the Fourier domain formulation of DMO (Hale,1984) and inverse DMO (Ronen,1987). Since the AMO application will be unevenly sampled data, instead of the Fourier domain formulation, a time-space formulation is resorted to. The impulse response of the time-space AMO is a skewed saddle surface – its width and dips are dependent on the values of absolute offsets and azimuths, i.e. difference in azimuths between input and output data.

The spatial extent of this saddle increases with the amount of azimuth rotation and offset continuation applied to the data. For small azimuth rotation and offset continuation the AMO operator is compact. In such a case it would be inexpensive to apply. Thus the spatial extent of operator is maximum for 90 degree rotation and vanishes for offsets and azimuths approaching zero.

For example, a land dataset, with a wide range of azimuths and offsets can be reduced to small set of data-cubes with constant offset and azimuth. Then each of these common-offset cubes can be migrated independently with a 3D prestack migration. The migrated cubes can be stacked together to form the final image.

Real data applications

AMO was run on different 3D data volumes and the effectiveness of the process was evaluated by computing coherence volumes and comparing time slices before and after the process.

Figure1 shows an inline from a 3D land data set from central Alberta. Notice the gaps in the data in the shallow zones before AMO. After AMO application the gaps are filled up and signal-to-noise ratio is also somewhat better.

Figure 2 shows a pair of coherence time slices at 1760 ms. Notice the focusing of the edges of the N-S channel in the lower middle part of the section, which does not show up at all before AMO processing.

Figure 3 is another pair of coherence time slices (at 320 ms) from a different 3D volume from southern Alberta. Notice the missing data along the receiver lines before AMO processing is filled up after AMO processing. At least two fault trends can now be seen starting from the left, one running downwards and the other going to the right.

Figure 4 shows another comparison of two coherence slices (1324 ms) from before and after AMO processing.

Conclusions

The effective offset and azimuth of 3-D prestack data can be modified during the processing flow, by applying an AMO operator (partial migration operator) to the prestack data. The method addresses proper handling of irregular geometry and therefore allows for reliable AVO analysis of migrated data.

Acknowledgements: The author is grateful to the personnel involved in AMO processing of the data at Arcis Corporation and to Arcis Corporation for the support, permission to use the data examples, and to publish this paper.

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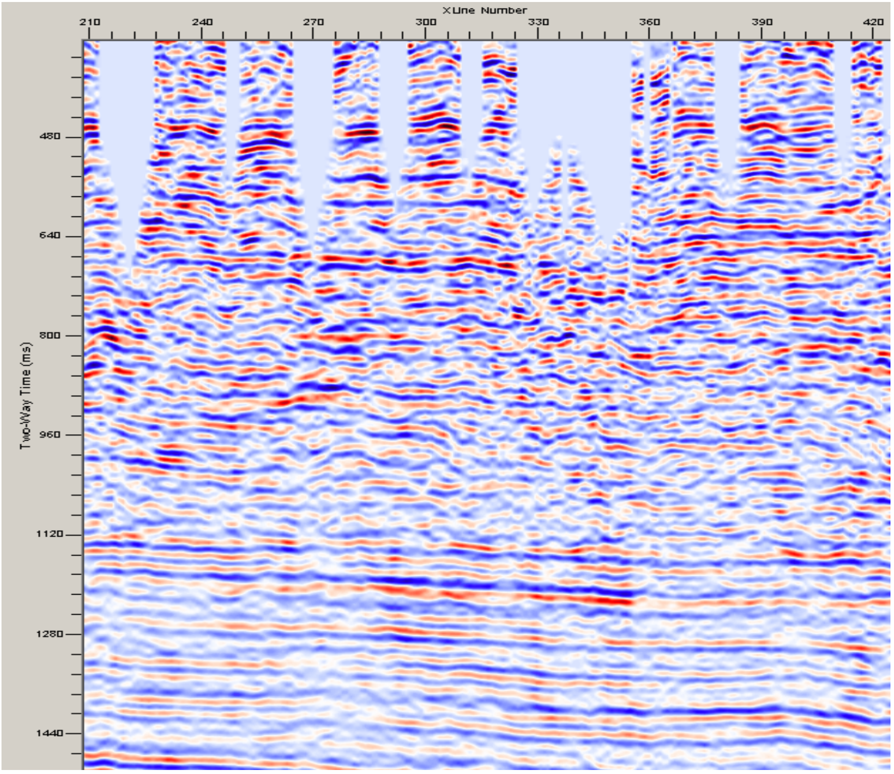
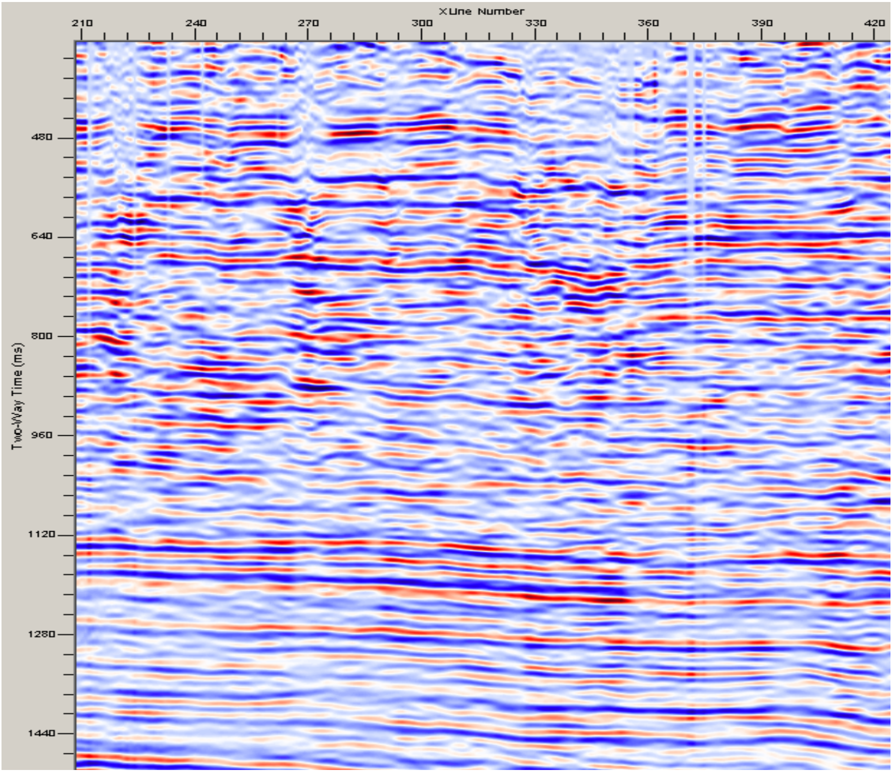
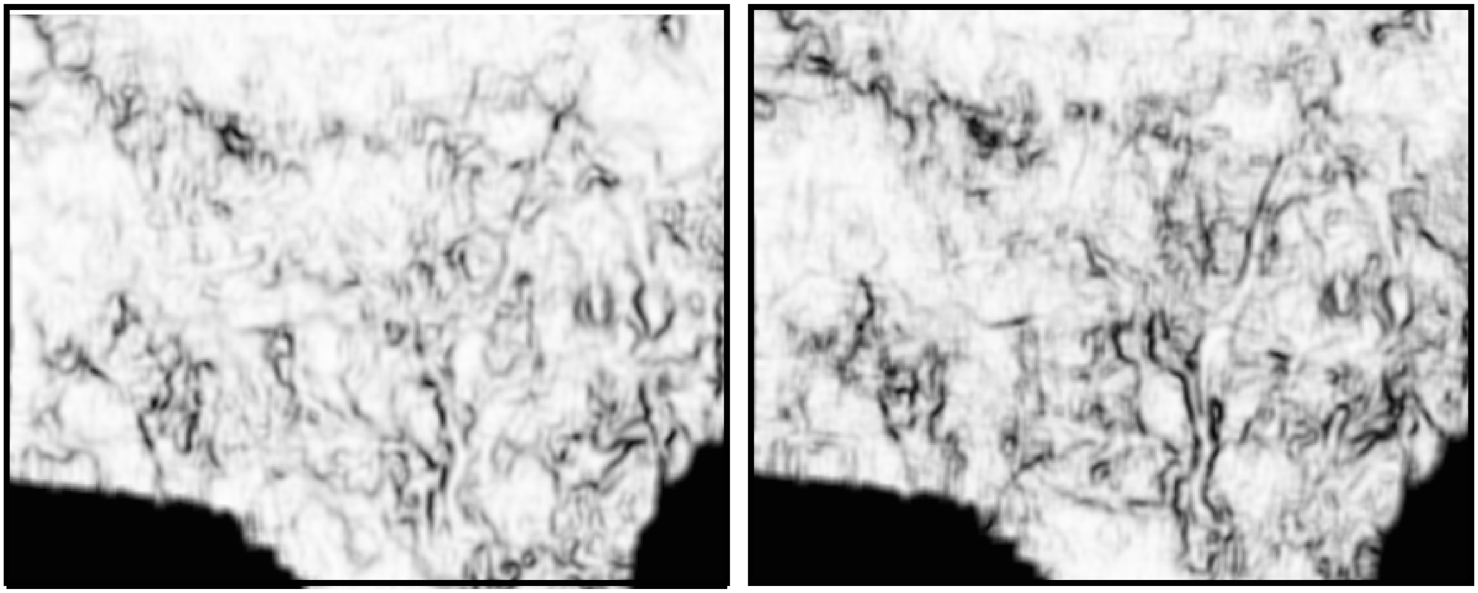


Inline before AMO processing



Inline after AMO processing

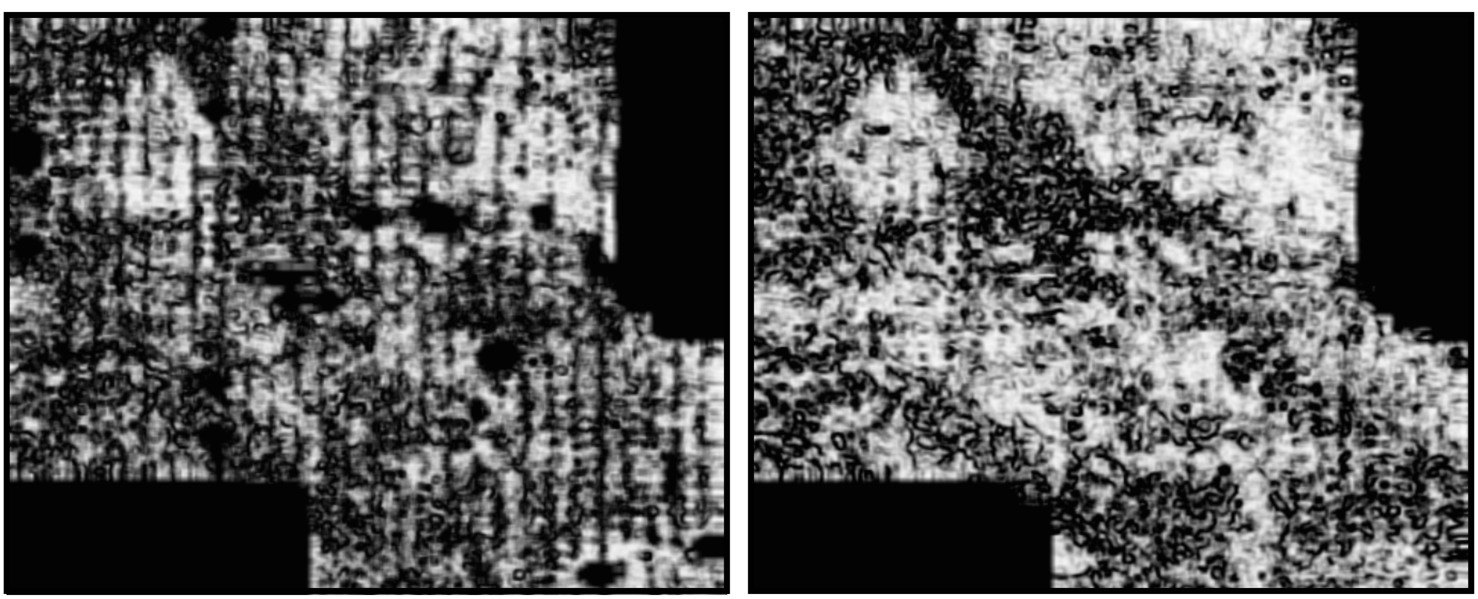
Figure 1



Time slice (1760 ms) before AMO processing

Time slice (1760 ms)after AMO processing

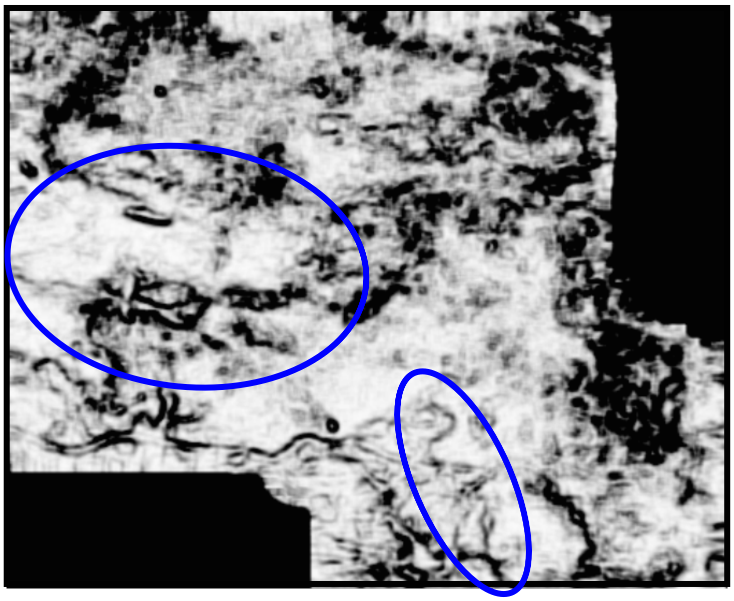
Figure 2



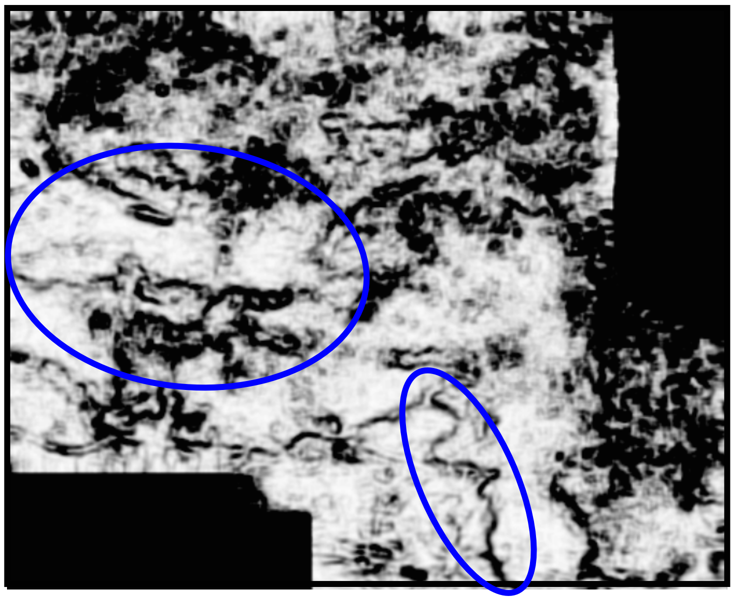
Time slice (320 ms) before AMO processing

Time slice (320 ms)after AMO processing

Figure 3



Time slice (1324 ms) before AMO processing



Time slice (1324 ms)after AMO processing

Figure 4