Azimuth Moveout (AMO) for data regularization and interpolation. Application to shallow resource plays in Western Canada

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Introduction

Azimuth Moveout (AMO) is a wave-equation correct binning algorithm that accurately handles dipping geological strata and variable velocitites. AMO is a partial pre-stack migration operator, and can be effectively applied to interpolate and regularize seismic data. The operator (Biondi et al., 1998) is strictly derived from the wave equation and therefore carries the correct kinematic, phase and amplitude transformation. The dipping events are moved correctly when transforming or interpolating the data, in a manner that is consistent with the wave equation, and thus diffractions are better preserved than after normal or flex binning. This property sets AMO apart as a seismic interpolator from more conventional ones. Dipping events are especially important for migration, because they determine the increase in image resolution after 3-D prestack or poststack migration. Biondo and Chemingui (1994) show how AMO preserves the dipping events after stack, in comparison with the industry standard sequence of NMO, DMO and stack.

Traditionally, AMO was designed to address the marine acquisition shortcomings, and regularize the data. Recent focus by exploration and production companies to exploit shallow resource plays has demanded new research into utilizing existing 3D data for mapping the shallow reservoirs. The land examples provided in this paper demonstrate the success of applying AMO to conventional land 3D data.

Azimuth Moveout Theory

AMO transforms data with a vector offset **h1** into equivalent data with vector offset **h2** where the vector offset represents the directional segment between a seismic source and a receiver. In other words AMO can transform a trace recorded with a source and receiver positioned at $x_{s1},y_{s1},x_{g1},y_{g1}$ into a trace recorded with a source and receiver positioned at $x_{s2},y_{s2},x_{g2},y_{g2}$. AMO can be applied to reduce the data size of a 3-D prestack dataset by coherently stacking traces with similar absolute offsets and azimuths, or it can be applied to interpolate missing offsets and regularize the geometry of the output dataset. The resulting 3-D prestack dataset can be used as input to Kirchhoff 3-D prestack migration or to other wave-equation 3-D prestack migration algorithms. The main applications of AMO as a wave-equation corrrect binning operator used to regularize and interpolate data:

1. Marine data imaging:
2. Use AMO to arrange data in common azimuth format for 3-D prestack wave-equation migration.
3. Marine and Land data imaging:
4. Use AMO to reduce data volume input to 3-D PSDM (partial stacking).
5. Fill acquisition gaps and balance input data (interpolation).

The application of AMO to land data before full-prestack migration can be motivated by increasing the signal to noise ratio. Applying AMO before partial stacking improves the accuracy of partial stacking compared with conventional methods based on interpolations and binning. The main advantage of applying partial stacking after AMO, instead of global stacking after DMO, is a gain in robustness with respect to velocity variations. Partial stacking is less sensitive than global stacking to velocity variations because it averages reflections recorded with similar geometries and thus with similar propagation paths in the subsurface. Velocity variations affect those propagation paths similarly and thus do not degrade the coherency of partial stacks as much as of global stacks that average reflections with very different geometries. In areas with complex geology (e.g. steeply dipping reflectors) the conventional route of DMO followed by global stacking and poststack migration yields suboptimal results even in presence of a velocity function varying only with depth because of NMO velocity conflicts (Hawkins et al., 1995; Rietveld et al., 1997). In these cases partial stacks are more robust than global stacks, and furthermore, partial stacks after AMO are more robust than partial stacks after DMO (Biondi, 1998). When the velocity varies laterally, the advantages of partial stacking over global stacking are even greater than in v(z) media. However, in presence of severe velocity variations the sampling of the AMO binning cannot be too coarse. The kinematics of the AMO operator are exact only for constant velocity. Therefore, in the presence of severe velocity variations the average of the reflections must be kept localized in offset and azimuth to avoid the degradation of the coherency in the stack.

When the spatial sampling of the data is irregular the application of partial stacking before migration can also improve the quality of the images compared with direct prestack migration of the raw data (Chemingui and Biondi, 1996). In this case AMO works as an accurate interpolator before migration.

True-amplitude imaging

True-amplitude imaging is necessary when the amplitudes of the seismic image are used as input for an estimation of the petrophysical properties of the reservoir rocks. Prestack imaging and AMO can be necessary for true-amplitude imaging even in presence of very simple velocity functions and subsurface structure. In these cases it is important to image as accurately as possible all the components of the wavefield. Even diffractions from a sand channel embedded in a perfectly flat geology must be properly focused.

AMO Application Examples

Figure 1 shows an example of AMO interpolation for Gulf of Mexico marine data, where missing offsets are filled in during the wave-eqaution binning process. Figure 2 shows a time slice through the same Gulf of Mexico data after NMO and stacking of a standard binned and AMO binned dataset. Notice how the AMO stack has a higher signal to noise ratio and the diffractions around the salt dome are better preserved. Some steeper events have more coherency after AMO and stack.

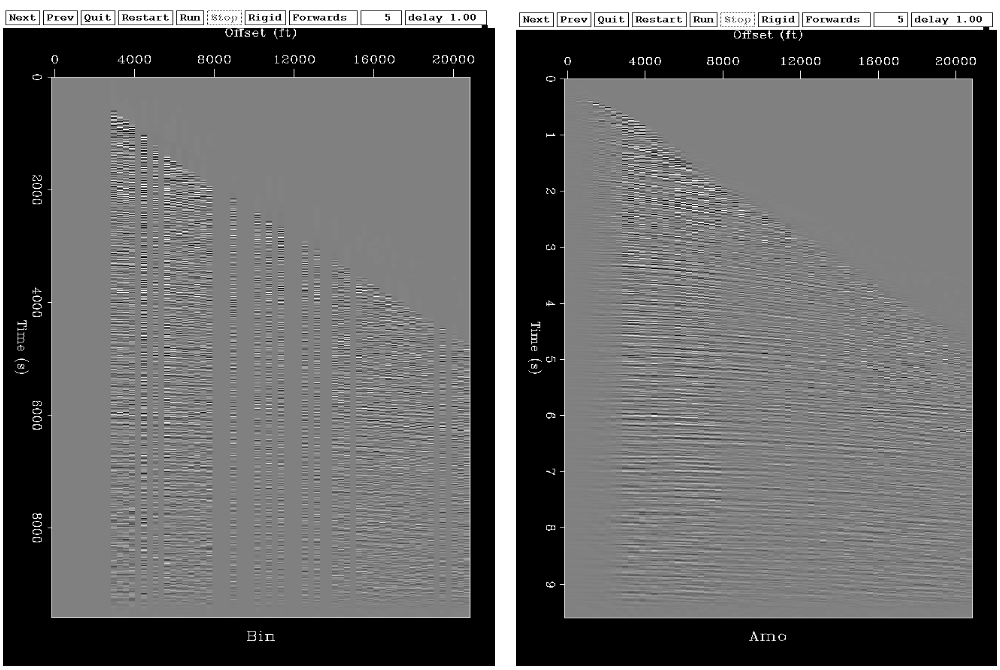


Figure 1: Offset gather after AMO interpolation.

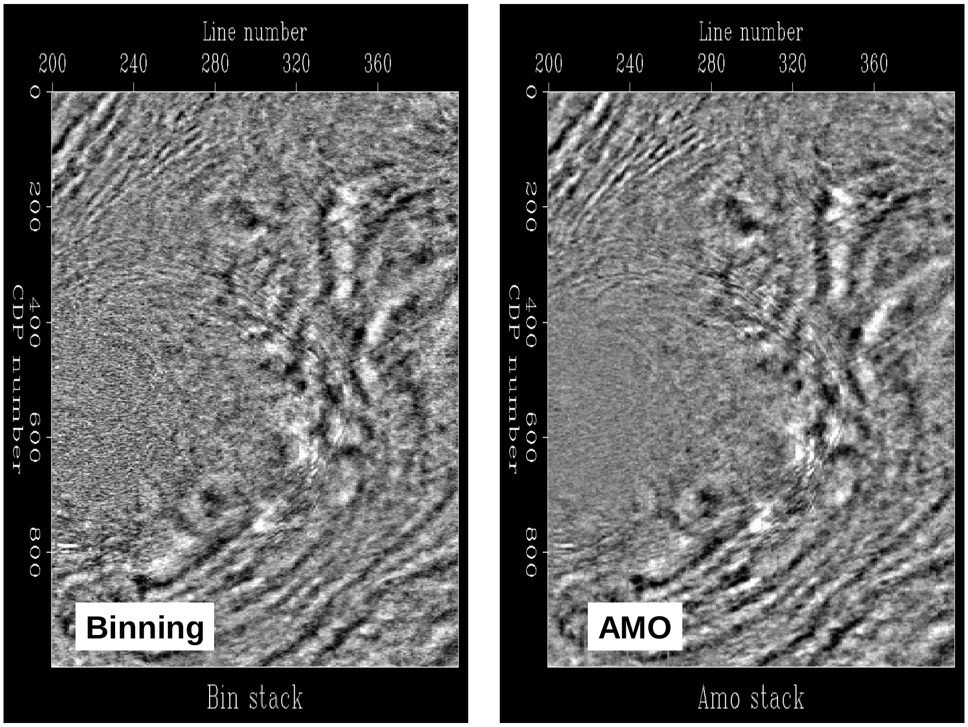
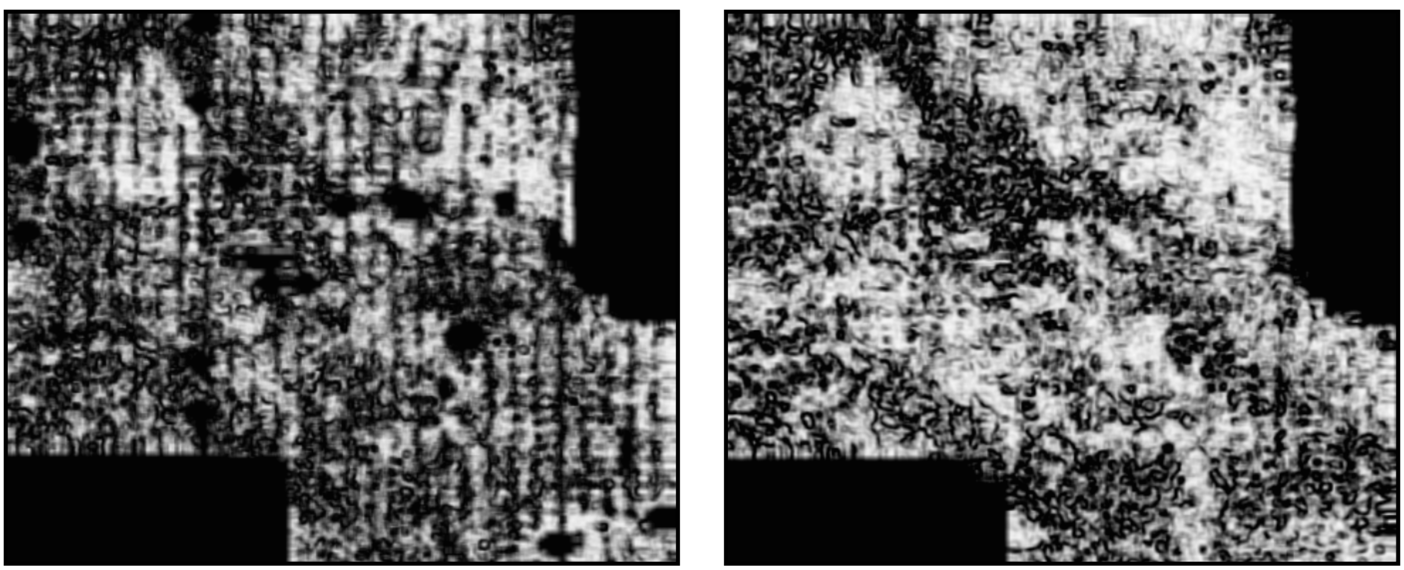


Figure 2: Time slice through stacked data. Comparison of standard binning and AMO.

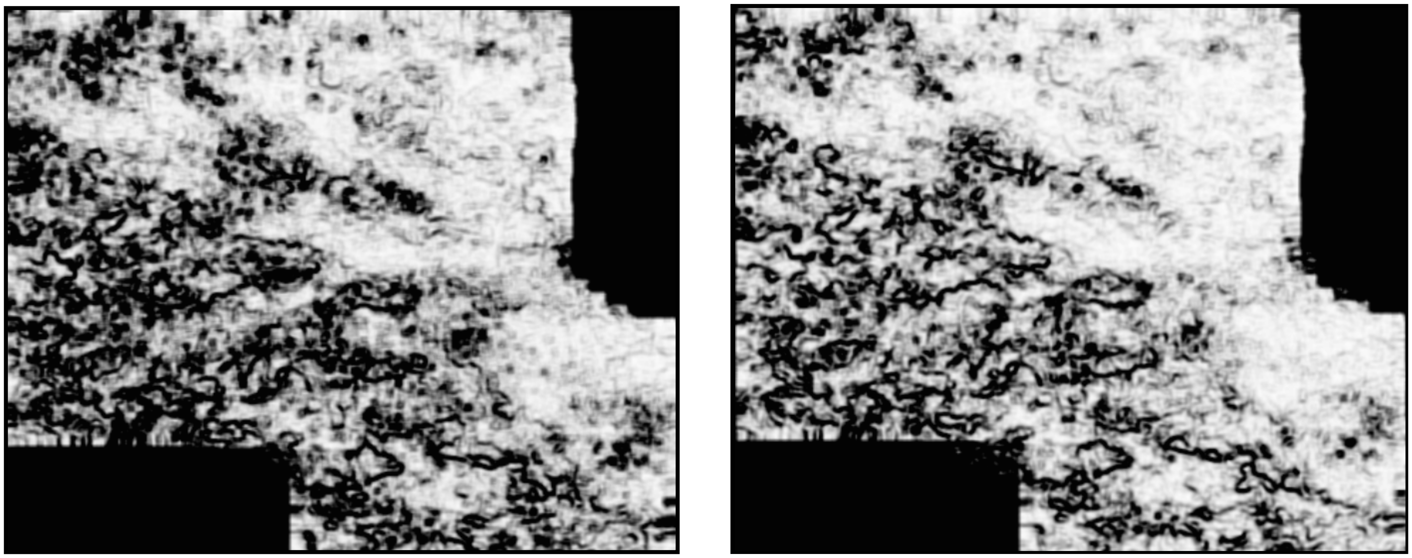


(a) Time slice (320 ms) before AMO

(b) Time slice (320 ms) after AMO

(approx. Edmonton sands interval)

Figure 3 demonstrates an example from a 3D volume from Winfield Alberta, where coverage in the data is limited based on 3D acquisition parameters. After the application of AMO, the data is more uniform as seen on the coherence slice (Figure 3(b)). Such applications will assume importance in analysis and mapping of shallow resource type plays, where acquisition limitations (cost) impede in the ability to extend the interpretation to very shallow targets.

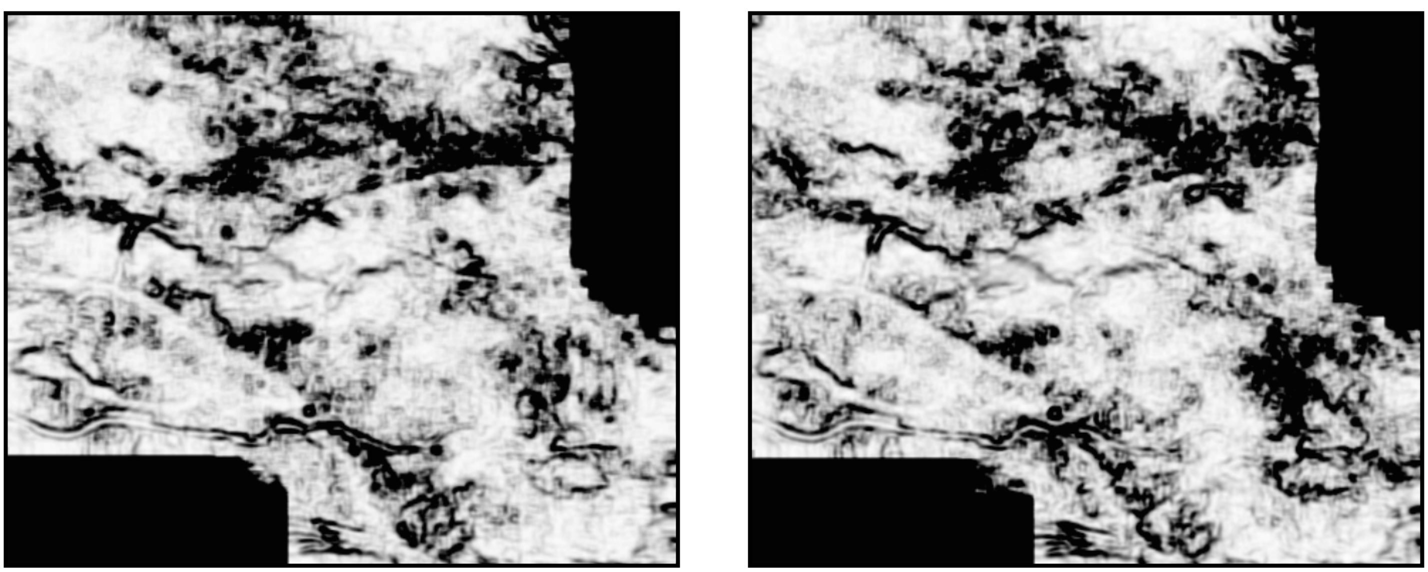


(a) Time slice (830 ms) before AMO

(b) Time slice (830 ms) after AMO

(approx. Lea Park interval)

Figure 4: Comparison of coherence slices from a 3D volume (a) before and (b) after AMO. At this interval coverage is adequate using the natural acquisition parameters for the target zone, however review of the coherence slice after AMO demonstrates the improved resolution of dominant features, while removing any residual footprint effects.



(a) Time slice (1284 ms) before AMO

(b) Time slice (1284 ms) after AMO

(approx. Lower Mannville interval)

Figure 5: Comparison of coherence slices from a 3D volume (a) before and (b) after AMO. At this time interval the original data shows no residual effects of the acquisition footprint and generally identifies the major discontinuity trends. The coherence slice after AMO demonstrates two important observations: firstly, the sharpening of the major discontinuities and refining the minor discontinuities (see bottom right-hand corner), and secondly the AMO process has preserved the general integrity of the geological features without introduction of spurrious or random events.

References

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