Wave-Equation Migration of Land Data

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Summary

Prestack shot-domain wave-equation depth migration can produce better quality images than Kirchhoff methods (Albertin et al., 2001). Most wave-equation migrations based on downward continuation, however, are restricted to seismic data which is regularly and densely sampled in space, datumed to a planar surface, and has no significant anisotropic effects. This prevents application of wave-equation migration to most land data, and in particular to areas with rugged topography. Here we describe how to overcome these limitations. Migration from surface in anisotropic media and data regularization are necessary steps to remove these restrictions. Their effectiveness is demonstrated by comparing Kirchhoff and wave-equation migrations on a synthetic data example simulating conditions in the Canadian Rockies, and on real data examples from the fold and thrust belt area of the Alberta foothills. The focus is on examples rather than on theoretical analysis, but necessary theory, in particular the modifications to standard wave-equation migration method, is explained in full.

Wavefield extrapolation

Prestack wave-equation depth migration requires separate extrapolation of the source signature and trace data acquired at the receivers. Many algorithms have been proposed for more accurate and efficient wavefield extrapolation. The implicit finite-difference scheme (Claerbout, 1985) appears to be most suitable when strong velocity contrasts dominant the subsurface. Phase shift methods (Gazdag, 1978; Gazdag and Sguazzero, 1984) are best when wide angle propagations are dominant. The explicit scheme (Holberg, 1988; Hale, 1991) is more easily modified for anisotropic media with nonvertical sysmemetry axes. If computational speed is an issue, implicit finite difference is best, explicit is the next, and phase shift is worst. We believe, therefore, that an implementation should offer implicit, mixed phase-shift, and explicit methods, the particular choice in any one circumstance depending upon the characteristics of the data.

Migration from topography

Nonflat surface topography introduces a problem for wave-equation migration since downward continuation schemes have to start at a flat interface. Here we propose to migrate the seismic data directly from the acquisition surface, eliminating any datuming or elevation static corrections before migration. Starting with a zero wavefield at a depth just above the highest surface point, wavefield extrapolation is carried out through downward continuation. At every depth level, data is added if receivers exist until a datum below the lowest surface point is reached. Extrapolated wavefields above the surface must be eliminated at each depth level. The only additional computation over conventional wave-equation migration is the elimination of the extrapolated wavefield above the surface.

Data regularization

Real acquisitions are never perfectly regular. Wave-equation migration requires regular data. Here we propose to regularize the traces from a cluster of nearby recorded traces using polynomial interpolation. Steeply dipping events are positioned properly provided they are not spatially aliased. This suggests that the data regularization is best performed after NMO correction. Polynomial interpolation has a number of attributes which make it well suited to regularize most prestack data: (1) It is accurate up to about 90% of the aliasing dip limits; (2) It adapts to every output trace by accurately compensating for boundaries and missing or dead traces; (3) It can interpolate to an output grid of any size and orientation, not just some discrete subdivision of the input grid; (4) Input and output traces are identical wherever the input and output fall exactly on top of each other; (5) It can be used not just for trace samples, but also to interpolate surface elevations; (6) The regularized volume has a natural appearance, free from artifacts or worminess. The main effect, apart from the repositioning, is that of a mild random noise attenuator.

Examples

The synthetic example has a complex velocity model simulating conditions in the Canadian Rockies (see figure). Steep thrust fault planes, complicated folds, large elevation changes (around 1600 m), and complex surface velocities present serious imaging challenges (Gray and Marfurt, 1995). This velocity model was used to generate 278 synthetic shot records. 8 s of data was recorded at a sample interval of 4 ms. Each shot has 480 receivers with offsets ranging from 15 to 3600 m on both sides of the shot points. The shot and receiver spacing is 90 m and 15 m, respectively. The figure compares the wave-equation migration stack with the Kirchhoff migration stack. Both wave-equation and Kirchhoff migration are migrated from the acquisition surface, and both produce reasonable results. On closer inspection, however, we see that the wave-equation migration is significantly better at imaging the large basin near the center of the section and the horizons below the basin. On the Kirchhoff section we can see discontinuities and vertical shifts in horizons below the basin. In the talk, both 2D and 3D real data examples from the fold and thrust belt area of the Alberta foothills will be presented.

Conclusions

Standard wave-equation depth migration has limitations which make it unsuitable for rugged land data. These limitations can be overcome, however, giving superior results over Kirchhoff migration.

References

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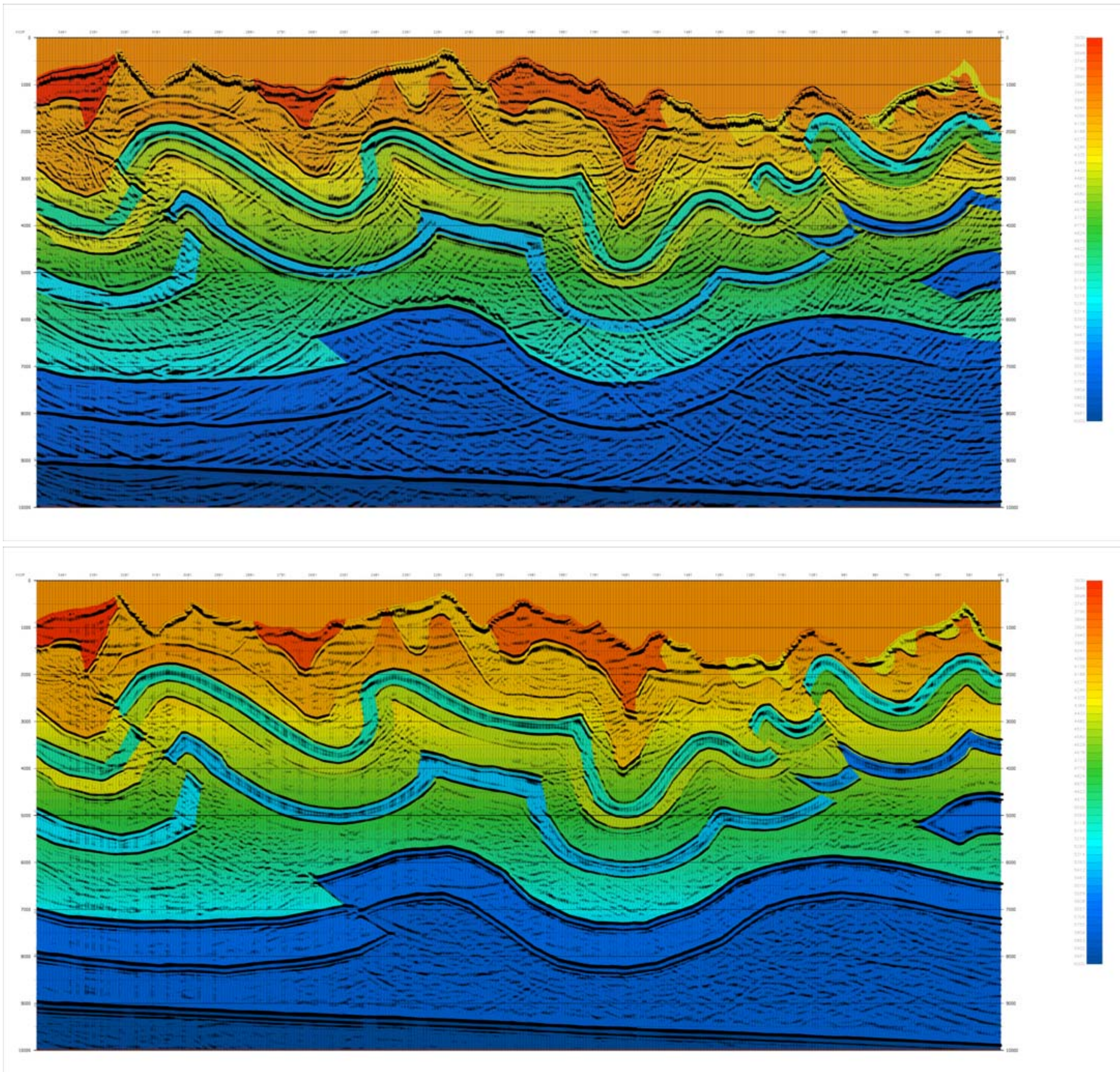

Kirchhoff (top) and wave-equation (bottom) prestack depth migration of a Canadian Rockies model.