Application of supergrouping to land seismic data in desert environment

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Summary

We apply supergrouping of land data after moveout corrections and prove that it can address noise issues caused by extreme near-surface scattering present in a desert environment. We demonstrate how supergrouping enhances pre-stack single-sensor data as well as data previously group-formed in the field. Improved statics, velocity estimation, and deconvolution operators obtained with supergrouping all lead to better images. Imaging of supergrouped data also has a clear advantage at least in simple structural settings.

Introduction

The near surface gives rise to strong surface waves and wavefield scattering. Simple source and receiver arrays can usually mitigate these effects to a level acceptable for reliable processing and imaging of reflected data. A desert environment often has a challenging type of near surface where strong acoustic contrasts and heterogeneities such as karsts give rise to a high degree of elastic scattering of surface and subsurface arrivals, thus creating an incredibly complex wavefield. This is most apparent on single-sensor data as well as data acquired with small source/receiver arrays. In many complex areas, even large source and receiver arrays may still result in poor signal to noise ratio on recorded data. Unusual problems require unusual treatment. Neklyudov et al. (2015) introduced smart supergrouping to mitigate these problems. They acknowledge upfront the need for larger apertures of source and receiver arrays to make supergrouping in processing more effective. To preserve higher frequencies when dealing with larger arrays and sampling intervals, Neklyudov et al. (2015) introduced common-offset summation in the poorly sampled direction and a weighted stack with complex coefficients. Here we take a different approach.

Supergrouping after NMO

Group forming in the field is limited by logistics and cost, in seismic processing we can be more flexible. So let us examine supergrouping after applying normal moveout (NMO) corrections. Preliminary velocity information is almost always available so it makes perfect sense to use this a priori information. Intuitively it is clear that reflections after NMO will be better aligned and make signal summation more straightforward. What would be the noise reduction properties of such arrays? Let us examine this in detail. Figure 1 shows the moveout of a reflection event and groundroll as well as their apparent velocities with offset. Based on moveout differences, conventional group forming with a five-element array and 50 m spacing will effectively suppress groundroll starting from 3 Hz. It will damage frequencies of the signal above 15 Hz due to the large sampling interval (Figure 2). If we apply NMO, then moveout and apparent velocities will transform as shown on Figures 1b and 1d. A linear noise event with constant velocity becomes curved with an apparent velocity varying between 500 and 600 m/s after NMO correction is applied,

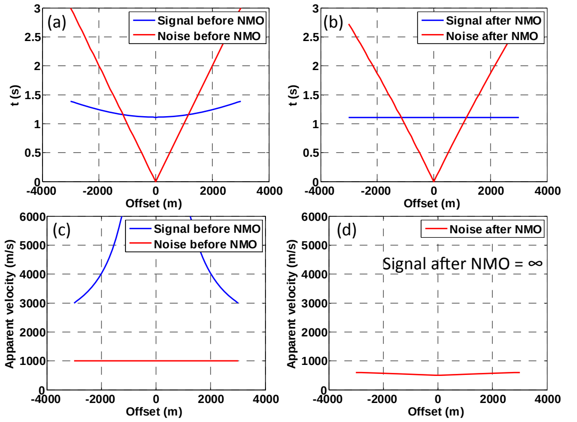

Figure 1. Moveout (top) and apparent velocity (bottom) before (a,b) and after (c,d) applying NMO. Signal is reflection (Vnmo=3,600 m/s), while linear noise is a groundroll with 1,000 m/s.

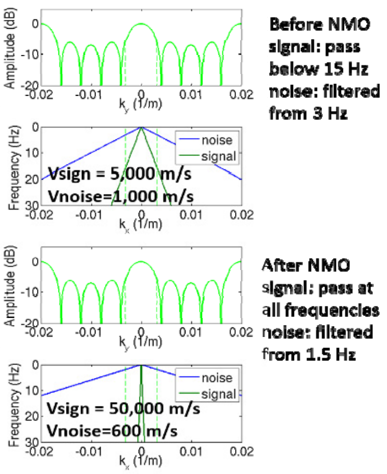

Figure 2. Array response for data a) before and b) after NMO application. The array consists of 5 elements with 50 m spacing.

whereas signal acquires an infinite apparent velocity. Simulating the array response for moved out data, we observe that not only signal is all pass for the entire frequency band, but also groundroll is now filtered from 1.5 Hz instead of 3 Hz. We conclude that arrays with NMO corrections are good at preserving signal and more efficient in suppressing noise. Let us examine applications of supergrouping to various datasets from Saudi Arabia.

Reflection imaging: Land 3D dataset 1

Here we examine application of supergrouping to particularly challenging seismic data from a difficult imaging area. 3D legacy data were acquired in an orthogonal layout with a 120 x 60 m shot grid and a 60 x 240 m receiver grid. Despite using 72 geophone arrays and 5-vibrator source groups for noise attenuation, raw data (Figure 3a) show little sign of reflections. Supergrouping with a preliminary NMO function confirms that reflections are hidden behind back scattered arrivals caused by the near surface (Figure 3b). Application of supergrouping early in the processing sequence is highly beneficial for velocity analysis and noise identification. Another approach is to apply supergrouping later in the sequence so that surface-consistent processing and residual statics can be derived on non-grouped data. Figures 4 and 5 confirm that processed CDP or PSDM gathers can be significantly enhanced and may lead to a better velocity model. In particular using image gathers from Figure 5 for reflection tomography can bring significant uplift. Even without revising the velocity model we can obtain a better migrated image using supergrouped data as shown in Figure 6. These improvements are particularly evident in the shallow section and areas without steep dips.

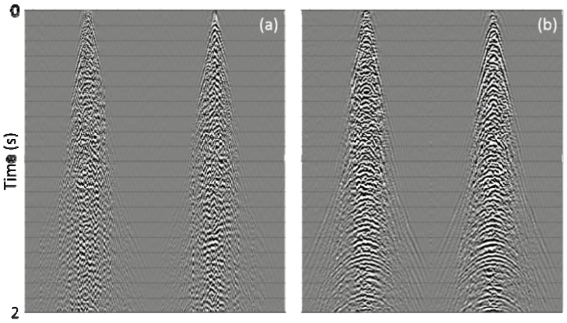

Figure 3. Raw shot gathers without (a) and with (b) supergrouping.

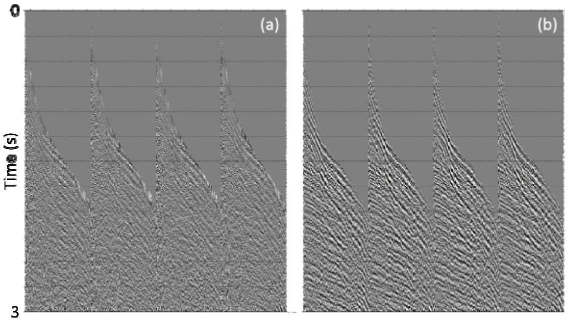

Figure 4. Processed CDP gathers before (a) and after (b) supergrouping.

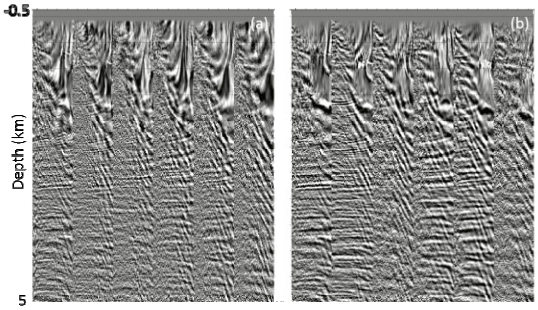

Figure 5. PSDM gathers obtained for data without (a) and with (b) supergrouping.

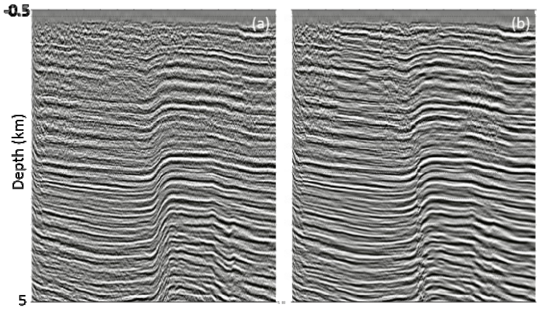

Figure 6. PSDM images obtained for data a) without and b) with supergrouping.

Reflection imaging: Land 3D dataset 2

Another challenging 3D seismic dataset from a different area has noise issues exacerbated by very irregular receiver geometry due to acquisition in an urban area (Figure 7a). Here we choose to apply combined source-receiver supergrouping (Figure 7b) to produce a symmetric array. This was done for two reasons. First, we can make smaller supergroups using only the directions with finer spatial sampling (<= 50 m) for both source and receivers. Second, this enables pre-stack algorithms requiring uniform treatment of different azimuth to be applied. Supergrouping helps to enhance the data and application after NMO makes better job at preserving higher frequencies particularly in the shallow section (Figures 7c, 7d and 7e). Such pre-stack enhancement has a strong impact on the stack, greatly improving images of the crest of the structure and general event continuity (Figure 8) as well as volumetric continuity attribute based on plane-wave destruction (Figure 9).

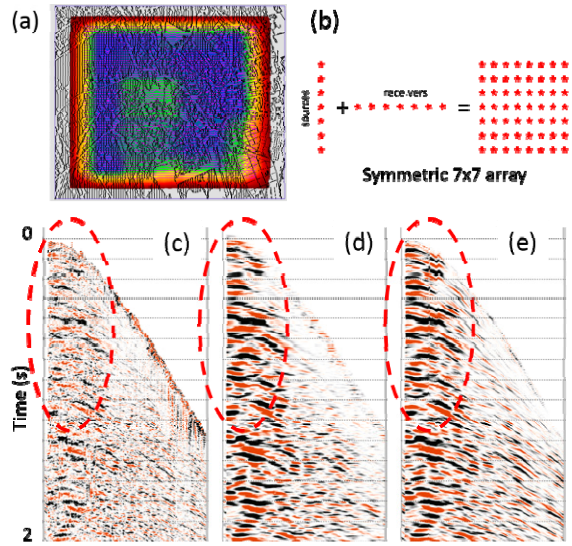

Figure 7. Supergrouping results showing a) the fold diagram, b) the receiver geometry and associated shot gathers including the c) raw data, d) supergrouped data before NMO, and e) supergrouped data after NMO.

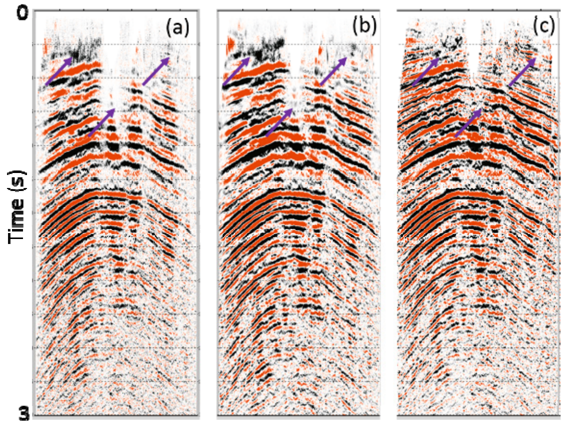

Figure 8. CDP stack along one of the lines after a) no supergrouping, b) supergrouping before NMO, and c) supergrouping after NMO.

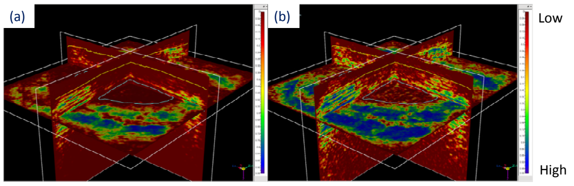

Figure 9. Continuity attribute for a processed volume a) without and b) with supergrouping. Higher values correspond to better event continuity.

Reflection imaging: Single-sensor 2D dataset

Now let us examine a single-sensor single-source 2D dataset with 10 m inline source and receiver sampling. Figure 10a shows shot gathers after mute revealing an extreme degree of near-surface scattering which completely obscures the reflections. After applying NMO and 1x7 receiver supergrouping we start to observe some hints of reflections (Figure 10b) albeit very weak. Figure 11 proves that a stack of supergrouped data provides far superior image compared to stacking the single-sensor data directly. Here we took a different strategy and applied supergrouping early in a sequence so that surface-consistent deconvolution operators and residual statics are estimated based on pre-stack data enhanced via supergrouping.

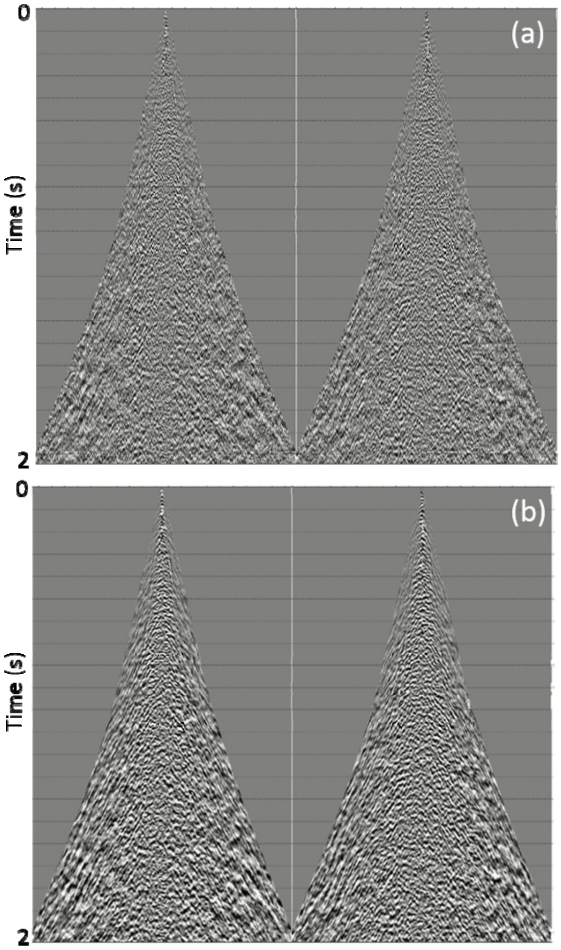

Figure 10. Shot gathers a) before and b) after supergrouping is applied (AGC applied for display purposes).

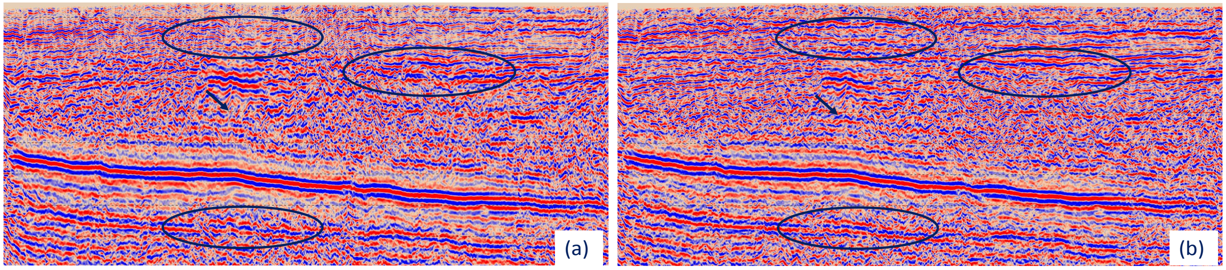

Figure 11. CDP stacks obtained with a) single-sensor and b) supergrouped data.

Figures 12 and 13 clearly demonstrate that better signal-to-noise ratio that is achieved pre-stack translates into better estimates of operators and statics. For example, deconvolution operators derived from the shot gathers are better behaved without extreme trace-to-trace variations likely caused by near-surface noise rather than actual reflection signatures (Figure 12). Likewise, residual shot statics for single-sensor data often reach user-specified bounds of ±16 ms suggesting that pre-stack traces are simply too noisy to determine accurate values based on simple crosscorrelation (Figure 13). Also statics values are cover a narrower range after supergrouping with a smaller standard deviation suggesting the results are more stable. Comparing stack images in Figure 11 clearly validates that these parameter improvements (statics, velocities, etc.) are geologically meaningful: we have better continuity of deep and shallow events as well as a more stable wavelet along the line on the supergrouped data.

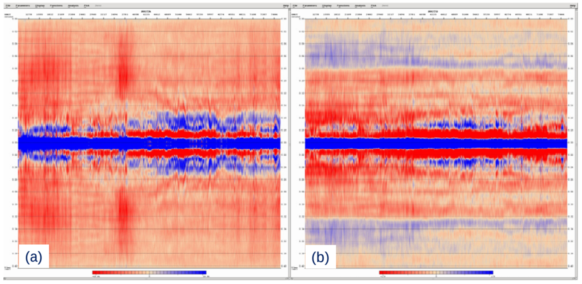

Figure 12. Surface-consistent deconvolution operators from the source side derived from a) single-sensor and b) supergrouped data. Observe more stable response on the right less susceptible to noise.

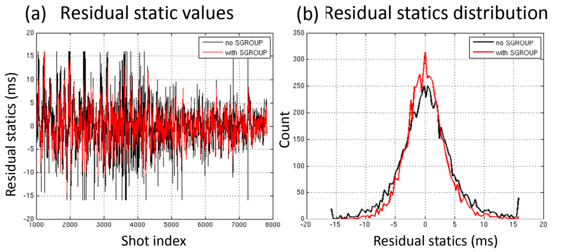

Figure 13. Surface-consistent residual shot statics obtained using single-sensor (black) and supergrouped (red) data showing a) actual values derived for each shot and b) the distribution.

Discussion and Conclusions

We have presented the application of supergrouping to land seismic data from a desert environment. Extreme scattering caused by a complex near surface requires more massive grouping than that done in the field and can often be performed on the data that have already been acquired with source and receiver arrays. To ensure that reflection signal is properly enhanced, we apply supergrouping after NMO corrections. We demonstrate that supergrouping after NMO not only allows to sum the signals without damage, but also possesses better noise-reduction properties. Such drastic measures are justified in areas where there is simple subsurface structure with small dips, but there is considerable near-surface complexity causing backscattered energy which obscures reflected energy. Supergrouping allows more robust evaluation of any processing attributes or parameters derived from pre-stack data. Derivation of these attributes (velocity, statics, deconvolution operators, surface consistent amplitude scalars) usually assumes that input pre-stack data contains a good amount of signal which is often not the case for land data from a desert environment. We have shown that supergrouping can deliver better signal-to-noise in both the pre-stack gathers and post stack images on a series of challenging field datasets.

Acknowledgments

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EDITED REFERENCES

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REFERENCES

Neklyudov, D., A. Bakulin, M. Dmitriev, and P. Golikov, 2015, Enhancement 3D broadband land seismic data with smart super groups for processing and FWI: 77th Annual International Conference and Exhibition, EAGE, Extended Abstracts, P7 06.