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Multidomain Denoise - A Robust and Efficient Method of Suppressing Incoherent Noise

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Summary

We present a method of noise attenuation performed in a small cuboid of seismic data moving within a larger block of local gathers. Noise contents are detected by comparing the frequency spectrum of a sliding time window against a local median amplitude with respect to a soft threshold. This approach replaces a preceding work flow which involved repeated sorting into different domains. This simultaneous implementation significantly improves both robustness and efficiency of the method. Further improvements may be achieved by either protecting strong signals or reducing the signal leakage in the noise model while performing an adaptive subtraction.

Introduction

Seismic data often contains various types of noise. Conventional towed streamer marine seismic data may be contaminated with swell noise, seismic interference (SI), monotonic noise, spikes, random noise and many other types of noise. Some noisy contents remain consistent from shot to shot, whereas some other noisy elements may appear only occasionally. Similarly, some noise elements may be consistent with the receiver location, midpoint location or the recording channel. Various methods have been proposed for dealing with this broad range of noise types. In the recent years, the advent of broadband processing has heightened the ever increasing demand for a higher signal-to-noise ratio, partly because the deghosting operation involves a significant amplification in the vicinity of the notch frequencies, particularly the deep notch at 0 Hz. Moreover, an ideal inverse-Q operation may involve significant amplification of high frequency signals, which are often accompanied with significant amounts of noise.

Method

The method described in this paper is a modification of the Time-Frequency Peak Filtering (TFPF) algorithm (Arnold et. al., 1993; Boashash & Mesbah, 2004). Conventional T-F trim method involves a normalization of frequency domain amplitudes which stand well above the local median amplitudes. This normalization process is performed over a desired number of frequency bands for each time window. In our approach, we use a soft threshold, meaning that not only will amplitudes above the given threshold receive a downscaling correction, but the amplitudes marginally below that threshold will also be treated with a milder correction. This variation helps reduce the artefacts corresponding to a step-shape transition between the scaled and unscaled frequency contents. It is worth mentioning that as well as the median amplitude we could use alternative central values, for example a trimmed mean or even the minimum. Furthermore, the correction scalar can be raised to a time and frequency dependent power. Therefore, not only can the loud elements be further suppressed using a large power, but it also would be possible to use a negative power to boost the weak elements falling well below the central value. The latter option is less helpful because there is a risk of boosting unreliable data.

Figure 1 shows a schematic diagram of our simultaneous multidomain denoising method. We load a number of adjacent shot gathers into the computer’s memory. Processing starts with half a window transition zone above the user-defined top horizon time, e.g. the water bottom reflection time. First, every new trace read into the memory is divided into a number of overlapping segments. Then all those segments, except the ones situated entirely below the given bottom time, will be transformed into the frequency domain. Then an amplitude representation of each frequency band is calculated and saved. The width of those overlapping bands can be wider than a sample size suggested by the temporal length of those trace segments. For every trace in the middle gather, the amplitude of each frequency band is compared against the median value obtained from a number of adjacent traces, and corrected accordingly, with regards to a threshold ratio. The threshold values can vary with respect to both time and frequency. In order to speed up this process, we can take into account only a subset of those local traces. Furthermore, we reuse the same statistics while still pacing within the same neighbourhood.

Figure 2 shows a real data example contaminated by strong noise contents. Using the method explained in this paper we managed to enhance the signal-to-noise ratio significantly. We applied a low frequency denoising pass targeting the swell noise, followed by a secondary pass aiming at some monotonic noise from an unknown source, appearing as sharp spikes at about 100 Hz and 200 Hz.

Further applications of multidomain denoising was investigated in a number of transformed domains. For example, seismic interference (SI) noise, originated from other source vessels operating in the same area, may appear at any time in some shot gathers, but the noise characteristics are not distinct enough from the signal to make it detectable. After a τ-p transformation however, SI noise could appear not only in different times, but also different ray parameters than the signal, allowing a more successful denoising. A case of SI noise contamination is presented in Figure 3. It can be seen that the SI noise is condensed into a different zone than the desired signal, making the noise more anomalous and therefore more detectable when compared against the less contaminated traces in a common-slowness view.

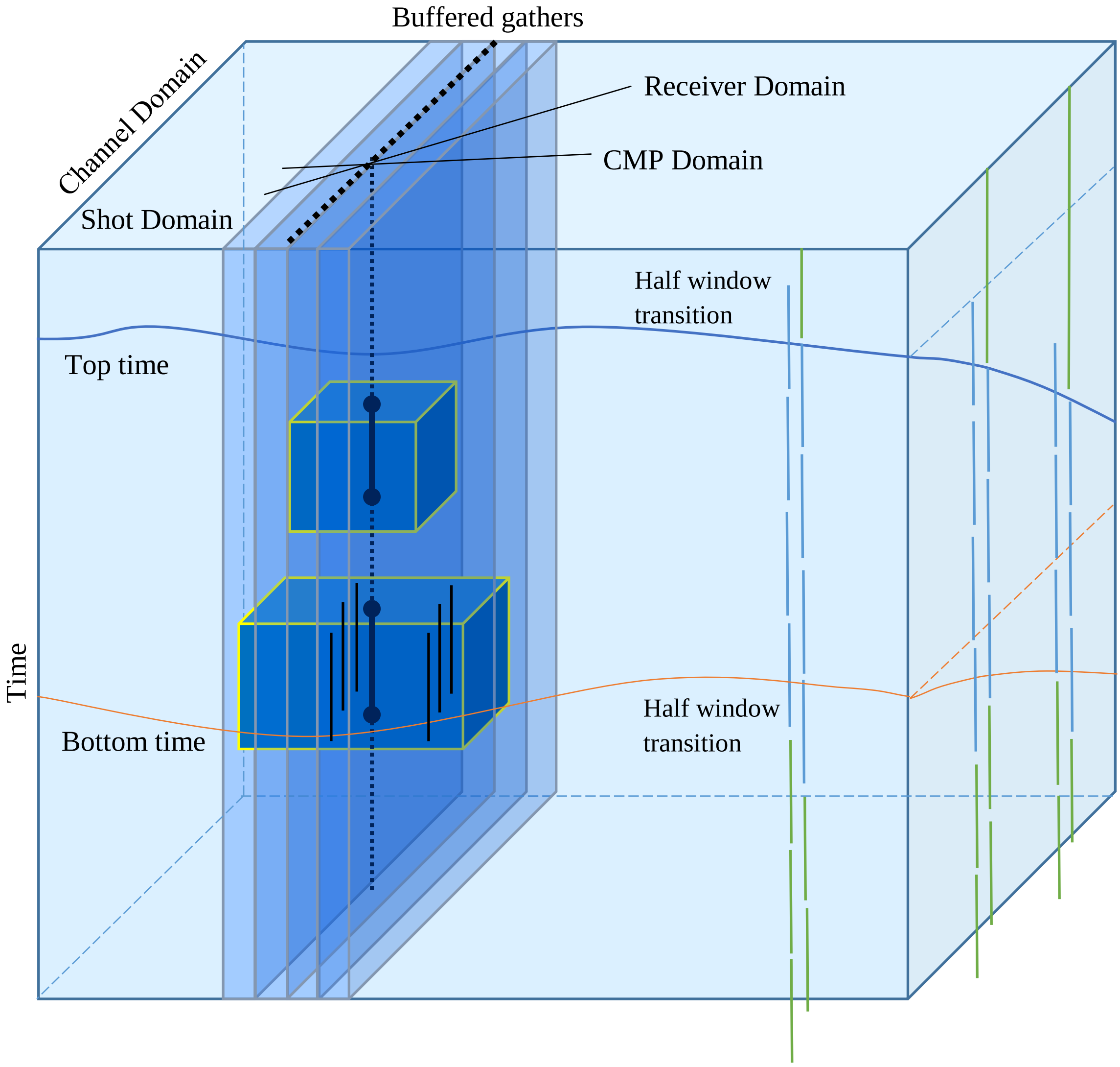

Figure 1 *A schematic diagram demonstrating how the denoising process is performed in a multi-domain cuboid. The size of the local cuboid can be time variant.*

Conclusions

Considerable signal-to-noise enhancement can be achieved by normalizing the frequency spectrum of a moving time window, with reference to a statistical representation of adjacent traces in a shot gather. Since a noise feature appearing consistent in one domain is likely to be inconsistent in other domains, further noise attenuation may be achieved by repeating the denoising process in various domains. However, a simultaneous multidomain approach presents a number of advantages over the cascaded approach. Firstly, eliminating the need for several rounds of sorting and denoising, this approach is highly efficient. Secondly, since the local representation becomes more stable and valid by including more neighbouring traces from the other directions, the noise detection aspect of this process becomes less ambiguous, so that a tighter threshold can be used while the chance of damaging the signal is not increased.

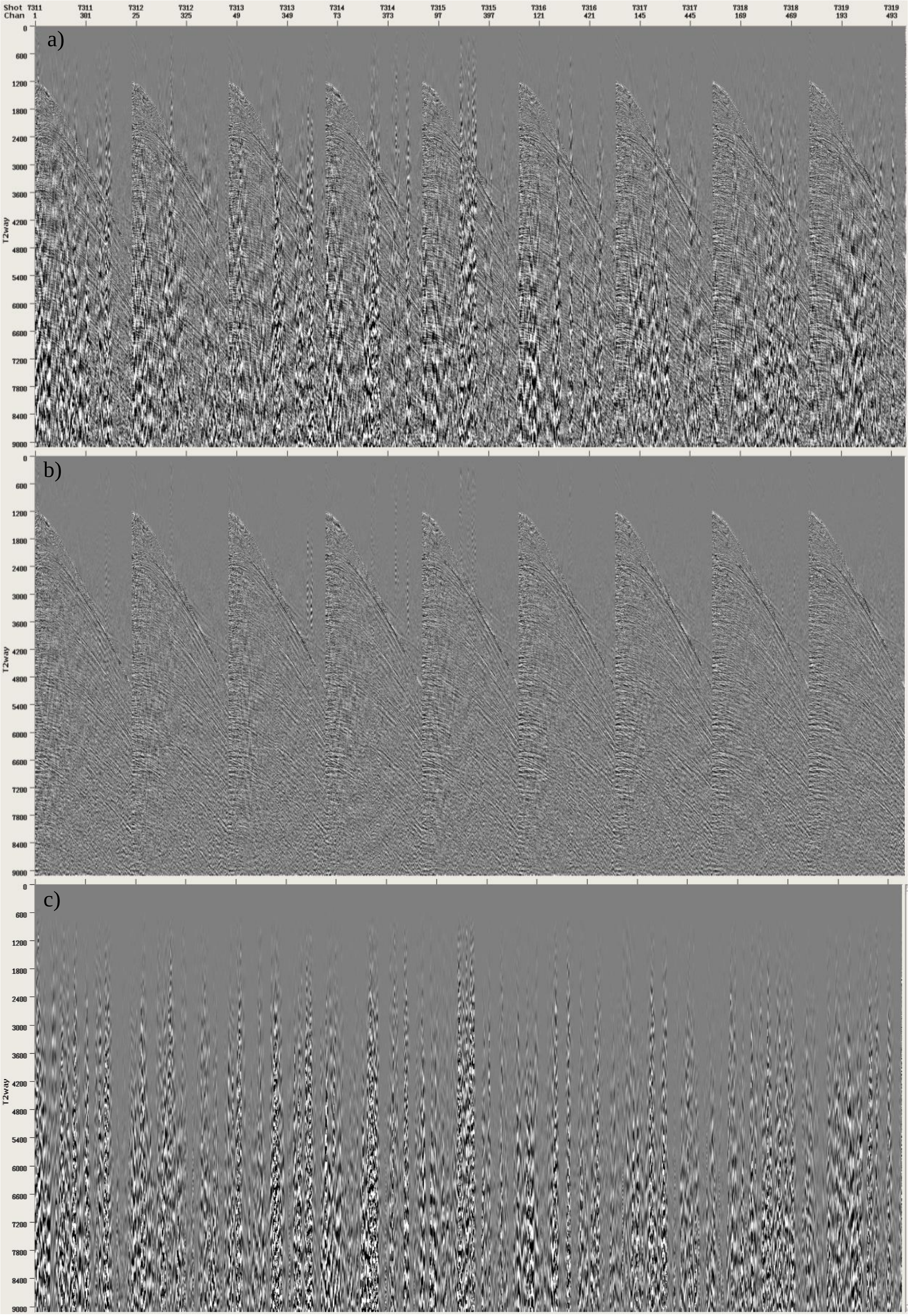

Figure 2 *A number of shot gathers with swell noise contamination, a) before, and b) after the application of our multidomain denoising method. The difference (c) shows no visible leakage of the seismic signal.*

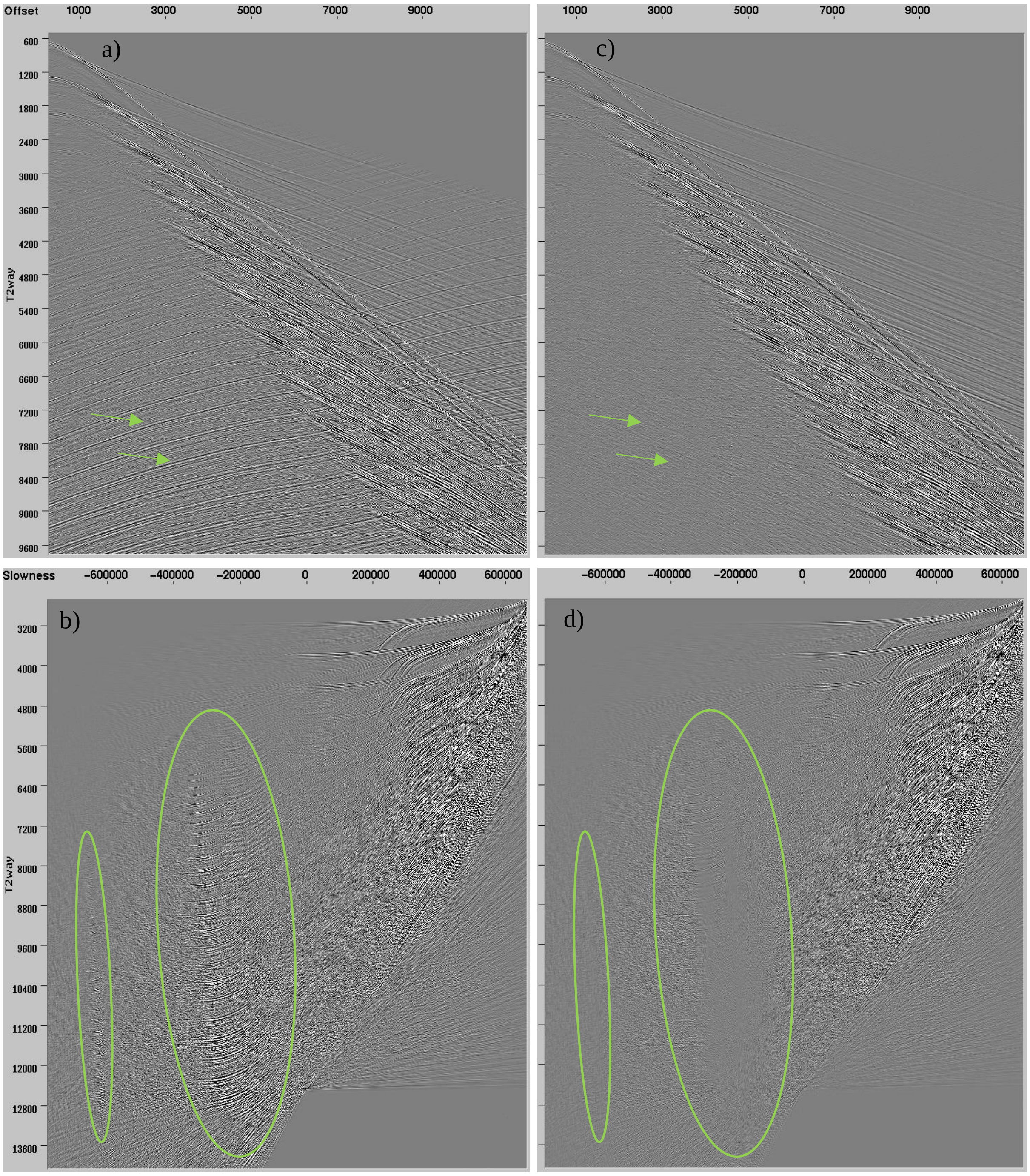

Figure 3 *a) A shot gather contaminated with SI noise. b) After transformation into the τ-p domain. c) and d) same data as a) and b) after the application of multidomain denoising algorithm, comparing every slowness trace against a large number of local traces with similar ray parameters, without sorting the transformed data into the common-p panels.*

References

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