GC Spectral Decompostion for a More Accurate Image*

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General Statement

When seismic data is decomposed into individual frequency components, as is done in spectral decomposition, some subsurface features, such as channels, can be distinguished at certain frequency components. There are several ways of performing spectral decomposition of seismic data in terms of the mathematical method adopted, such as short-time Fourier transform (STFT), continuous wavelet transform (CWT), S-transform, etc. Each method has its own strengths and weaknesses.

Seismic Uncertainty

Seismic data, especially 3-D seismic data, are critical and indispensable in many cases. However, its significance and degree of trustworthiness vary among geoscientists, especially geologists. The disparity could be greater if the target area has good drilling coverage. This is because the seismic data is a collection of subsurface events, which include reflections, diffractions and refractions, as well as noise and other factors unrelated to subsurface geology. Though spectral decomposition of seismic data may reveal and enhance geological features, it can also introduce artifacts and uncertainty.

The author's article Effective Ways to Eliminate Side-Lobe Effects, Search and Discovery Article #41667, explained the most significant artifact, the so-called side-lobe effects, which are the extra events caused by the algorithm employed rather than by the subsurface geological features. In that article, a new method was introduced to suppress these artifacts. The essential idea was to use a wavelet extracted from the acquired seismic data itself to do the decomposition, which is data-adaptive, because the extracted wavelet is different in different datasets and in different areas. The results show better images due to largely reduced artifacts.

The subsequent research and applications indicated that a single wavelet used to do spectral decomposition is often not adequate, because the wavelet can and often does change spatially, even in the same dataset, as seen in Figure 1, where the space-varying wavelets extracted from seismic data in Taranaki Basin, New Zealand are shown.

Improvement through Space-Varying Wavelets

The extracted wavelets have the same location of inline and crossline as that of the seismic data volume because at each inline/crossline location, a single wavelet will be extracted. Figure 1 is actually a time-slice view of these extracted wavelets. Using these space-varying wavelets instead of a single wavelet to do the decomposition makes noticeable improvements, as seen in Figure 2, where time slices from the 30 Hz frequency volumes after spectral decomposition were performed using a single wavelet (Figure 2a) and space-varying wavelets (Figure 2b) are shown, respectively. They look quite similar, especially in the east area, right beside the roughly north-south fault. However, noticeably cleaner images of several meandering channels in the west area in the right image can be easily discerned. Note that the color bar and the scale bar are the same for both Figure 2a and Figure 2b for comparison. Figure 3 is a close up of the southwest corner (indicated with a rectangle in Figure 2) where the channels are located. The improvements are believed to be the result of further reduced artifacts compared with the result obtained using a single wavelet. In this case, we see a big overall change of seismic data characteristics between the west and east side of the fault. A single wavelet is clearly not able to represent the whole dataset. A space-varying wavelet is more appropriate. At each inline/crossline location, a single wavelet is extracted using seismic data around the location. Eventually, there are the same number of wavelets being extracted as the number of traces in the seismic dataset. Furthermore, only a small portion of the seismic data in the time interval of interest is selected.

Obviously, the space-varying wavelets bring out geological aspects that may not be seen with the use of a single wavelet. Because the space-varying wavelets are extracted in a time and range of interest, it will carry the information within that range and is of interest to us. Therefore, these extracted space-varying wavelets themselves will reflect subsurface geology in that time range and are potentially interpretable.

Comparing Figure 1 with Figure 2, it can be seen that the two images look similar; for example, compare the north-south big fault and the block of data in the west and east. Further investigations are needed to explore this benefit in more detail.

Acknowledgement

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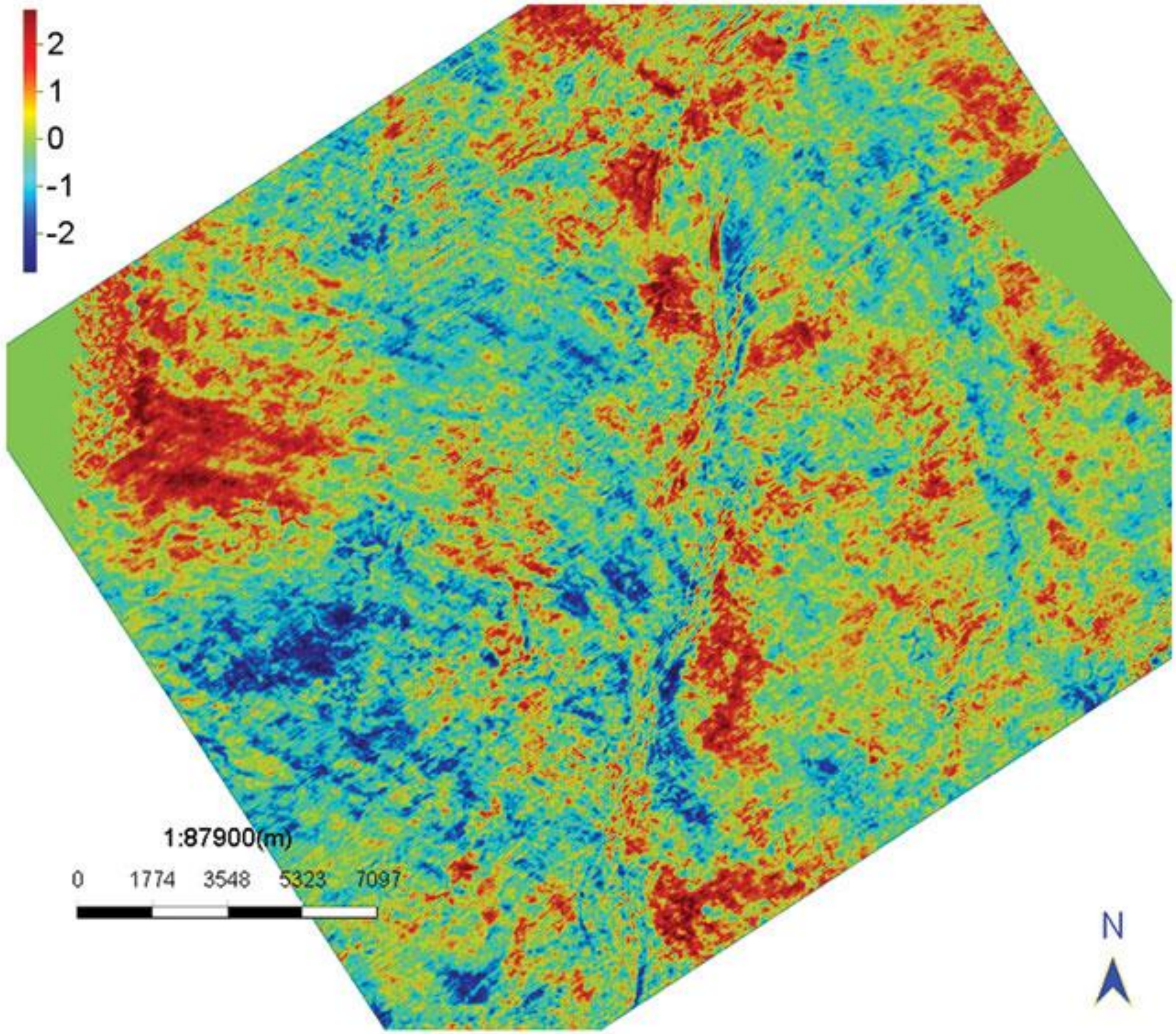

Figure 1. Map view of the extracted space – varying wavelets from seismic data in Taranaki Basin, New Zealand.

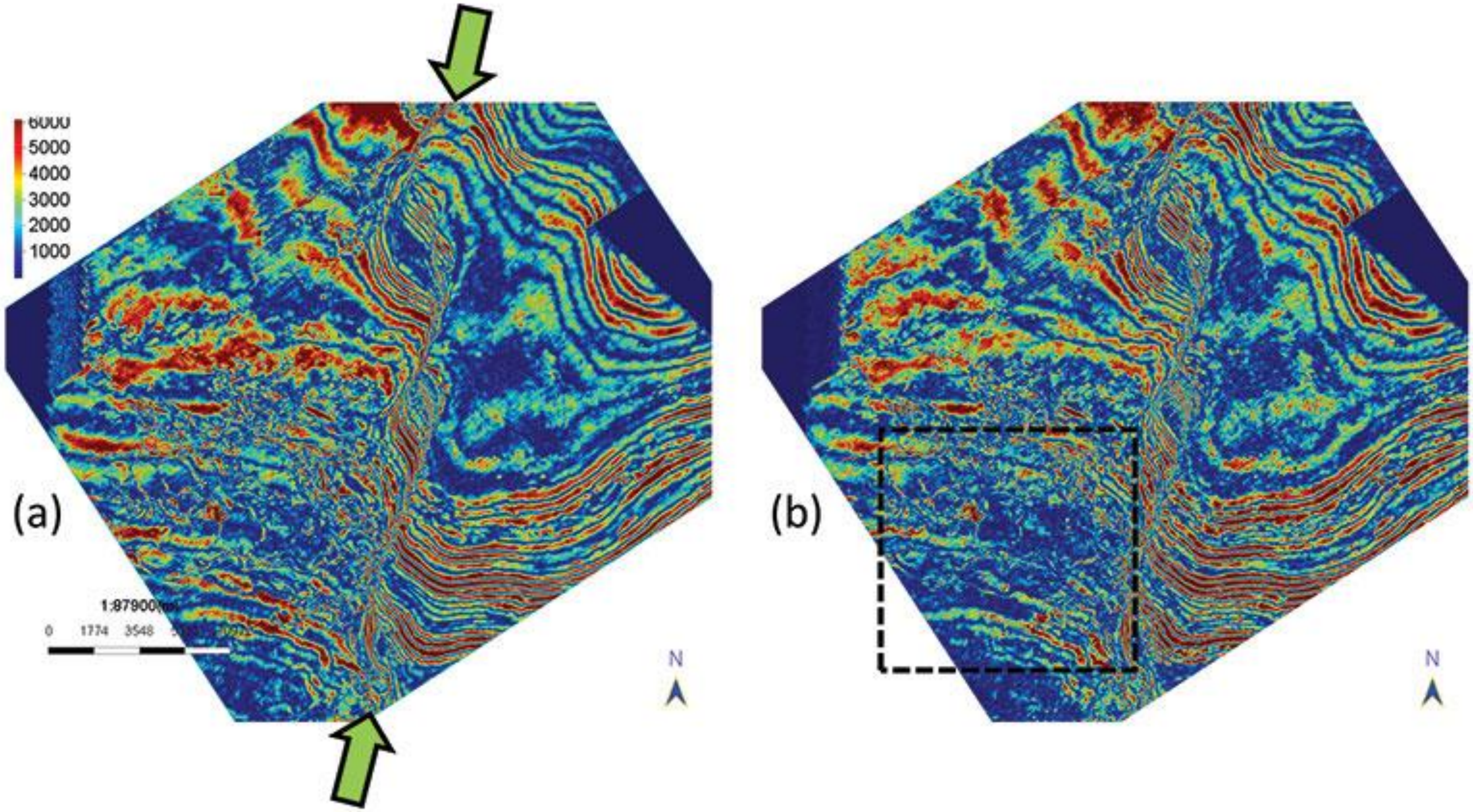

Figure 2. Time slices from 30 Hz frequency volumes obtained with spectral decomposition using (a) a single wavelet, and (b) space-varying wavelets. Notice the overall more distinct image in (b).

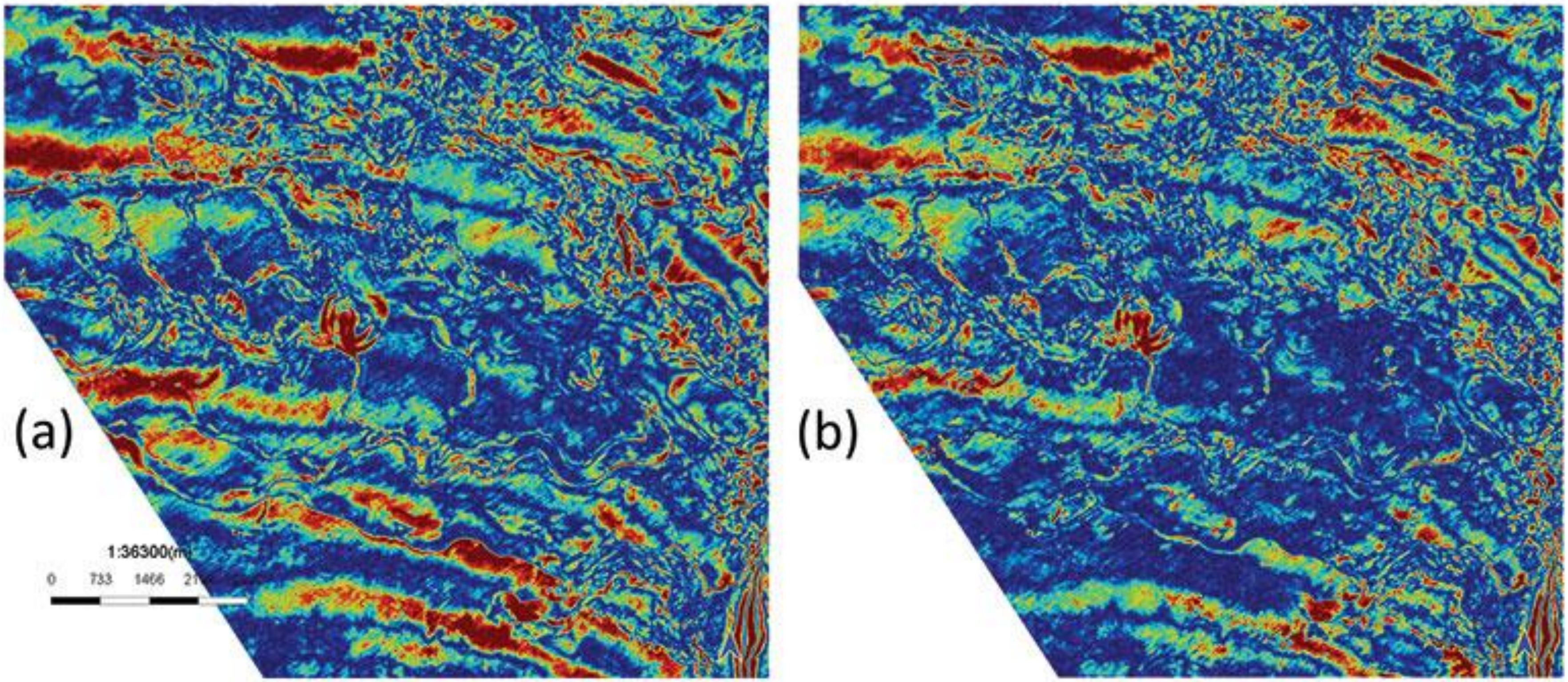

Figure 3. Zoom of a small area as indicated by the dashed rectangle in Figure 2b. Notice the overall clarity of the image in (b).