Interbed Multiples Attenuation Using 3D Complex Wavelet Transform

Introduction

Multiples are challenges for seismic data processing and imaging. Interbed multiples are even much worse challenges for land seismic data. A lot of methods have been developed to attenuate multiples in both data and image domains (Moore, I., and R. Bisley, 2006). Multi-dimensional wavelet transform recently has been applied to seismic data processing such de-spike, linear noise attenuation, de-blending, and signal enhancement (Yu et al., 2017). We extend three dimensional complex wavelet transform to attenuate multiples including interbed multiples. We first review complex wavelet transform. Then the principle of proposed method is introduced. Next, the proposed method is applied to 3D field data examples.

Principle of multiple attenuation using 3D complex wavelet transform

Multi-dimensional complex wavelet transform (Yu et al., 2002; Yu and Whitcombe, 2008) transform seismic data from time-space domain into orientation and scale domain while the local features of original data are still kept, which creates new domains of signal processing in seismic data processing production. Figures 1 and 2 show that a 2D shot gather is decomposed into 6 orientations and each orientation is decomposed into 7 scales. The complex wavelet transform has been successfully applied to de-blending, separating up-down going VSP wavefields, enhancing OBN’s vertical component (Yu et al., 2012, 2017) according to hydrophone component. In above applications, we take advantages of orientation-scale domain because different types of wavefields show different features in the domain of orientation and scale. To attenuate noise or enhance signals, we apply filter in the orientation-scale domain according to attributes of different wavefields and then inverse transform into time/depth-space domain.

**Figure 1** A shot gather (most left) is decomposed into 6 orientation by using 2D complex wavelet transform. Orientations from left second to right panels are: -75, -45, -15, 15, 45, 75 degree. These figures demonstrate the orientation’s distribution of shot gather.

**Figure 2** Orientation 15 in Figure 1 is decomposed into 7 scales. The most left panel is the re-plot of orientation 15. The scales from left second to right panels are: 1, 2, 3, 4, 5, 6, and 7. The scale 1 has highest frequency band.
We have extended the 3D wavelet transform’s applications to attenuate multiples based on common image gathers from 3D prestack depth/time migration. Supposing prestack migration is performed using the velocities for primary wavefields, the primary events within common image gathers are aligned flat while multiples including inter-beds are not fully aligned. Therefore, we first perform partial stack by optimizing for primaries. Then, 3D complex wavelet transforms are carried out on for 3D individual offset and the partial stack respectively. Next, in the orientation and scale domain, the individual offset volume is filtered according to the transform of partial stack. Thus, multiples are attenuated and the primaries are enhanced. The filtered volumes are inversely transformed back into time/depth-space domain for each offset respectively. This technical flow is shown in Figure 3.

We use $F_{offset}(z,x,y)$ to express offset volume from prestack migration and its 3D CWT is defined as

$$D_{offset}(z,x,y,s,\alpha,ri) = 3DCWT(F_{offset}(z,x,y))$$

(1).

where $s$ and $\alpha$ stand scale and orientation respectively and $ri$ is for real and imaginary parties. The partial stack and its 3D CWT are as:

$$Q_{stack}(z,x,y,s,\alpha,ri) = 3DCWT(F_{stack}(z,x,y))$$

(2),

where: $F_{stack}(z,x,y) = \sum_{offset=off1}^{offset=off2} F_{offset}(z,x,y)$

(3).

The filter in the orientation and scale domain is briefly described as:

$$D'_{offset}(z,x,y,s,\alpha,ri) = D_{offset}(z,x,y,s,\alpha,ri) \cap Q_{stack}(z,x,y,s,\alpha,ri)$$

(4).

The inverse 3D CWT is obtained by

$$P_{offset}(z,x,y) = 3DICWT(D'_{offset}(z,x,y,s,\alpha,ri))$$

(5).

![Figure 3 Technical flow for multiple attenuation using 3D complex wavelet transform.](image)

**Field Examples**

The proposed multiple attenuation method has been validated using synthetic data and applied several field 3D projects worldwide. We also compared the proposed method with traditional multiple attenuation methods such as Radon transform filtering eigenvector filtering. We here show examples of field data from western China, for short, referring as Project A. The major challenges for Project A are that the interested zones in deeper part are contaminated by the interbed multiples which are

---

82nd EAGE Annual Conference & Exhibition
generated by the overlying igneous rock layers with very high velocity. Almost horizontally flatten layers for both interested zones and multiples generated layers lead to fail for the traditional methods. The project covers 317 spare KM and has maximum offset as 8.0 km with 100 m increment. Figure 4 and Figure 5 show the stacks of one line located at middle and one gather within the line. Figure 4A, 4B, and 4C compare stacks from raw PSDM, processed by the proposed method and by Radon filtering respectively. The multiples are generated by layers at depth 4500 m and reflected multiple times within layers. The multiples are mixed with primary image from underneath layers, and can be clearly observed as a stripe of certain width, which make it very difficult to interpret. Figure 4B shows the multiples are effectively suppressed and the image of interested zones from 5500~7500 m changed into clear and simple. The Radon filtering stack show in Figure 4C has much more weak result comparing with the proposed method. Figure 5A, 5B and 5C show the common image gathers from raw PSDM, processed by the proposed method and Radon filtering respectively. The raw gather clearly shows multiples after depth 4000 m since the events curve downward at far offsets while multiples and primaries are aligned in near offsets up to 2000 m. By comparing gathers, the proposed method attenuates multiples significantly better than traditional methods, especially for near offsets. Overall, the new method also keeps dynamic features of wavefields. After multiple attenuation, structure features are clearly revealed and the ratio of signal over noise is also improved significantly.

**Conclusions**

We have developed an innovative method to attenuate multiples using 3D complex wavelet transform based on common image gathers from 3D prestack depth/time migration. The proposed method has been tested using synthetic data sets and applied to 3D field data sets. The results demonstrate that the new method attenuates multiples and reserves image gets recovered significantly better than traditional methods, especially for near offsets. As well known, 3D complex wavelet transform requires highly computational power. We also optimize the algorithms and software structure to achieve production scale for large 3D data volumes. For further work, we will apply the new method to marine seismic processing and expect good results as to land data.

**References**


Figure 4 Stack from PSDM located at middle of the Project. (A), Raw stack; (B), Stack processed by the proposed method and (C) by Radon filtering.

Figure 5 One common image gather located in the line from Figure 4. (A) Raw gather; (B) Processed by the proposed method and (C) Processed by Radon filtering.