Duplex Waves Migration Post-processing and Interpretation Guide

Please, also see Introduction to Duplex Wave Migration -Client Guide-

Contents

Raw cube ........................................................................................................................................................... 1
Footprint Removal and Filtering........................................................................................................................ 2
The difference cube........................................................................................................................................... 2
The Geo-bodies Extraction ................................................................................................................................ 3
Using cubes with different processing apertures.............................................................................................. 5
Comparisons with results obtained using other (conventional) techniques .................................................... 6

Raw cube

The results obtained from duplex wave migration (DWM) are used as input data for interpretation. These results are highly contaminated with low, medium and high frequency noise. The intensity of the noise is comparable with the useful signal amplitude.

Fig.1 Example of slice from raw DWM cube with superimposed well trajectories

The shape in 3D space of the signal is the main difference between the noise components and the useful signal:

- the low frequency component of the DWM signal energy response contains information related to the amplitude of the base boundary layer which is characterized by a large-scale, smooth laterally changing heterogeneity;
- the medium frequency component is a noise component attributable to classical 3D footprint effects. The spatial shape of this noise is characterized linear events that are parallel to acquisition receiver lines;
- the high frequency component of the noise is characterized by spatially small events that tend to be very incoherent and asymmetric in shape.

In order to be able to separate the useful signal related to lineal sub-vertical heterogeneities from all the various types of noise mentioned above, it is necessary to post-process the raw DWM data. These post-processing procedures may include:
1. footprint removal, which can be done using specialized procedures or by conventional filtering;
2. conventional or specialized filtering;
3. extraction of signal events from background noise that are based on observations related to the objects shape and spatial size and characteristics.

**Footprint Removal and Filtering**

Due to low signal/noise ratio of DWM images the raw cube may contain considerable amount of footprint hindrances. They may be filtered out using specialized procedures.

![Image](image.png)

**Fig.2a Left to right:** image of the raw DWM cube slice, image of removed footprints, DWM cube slice with removed footprints, highlighted high frequency component of DWM cube with removed footprints.

The raw cube (with or already removed footprints) must be smoothed using filtering procedures. The particular smoothing algorithm and the number of traces for smoothing are selected by scanning and visual analysis. The number of traces for smoothing is determined by the asymptotic point of the ratio between the number of traces and the percentage increment in the difference field.

![Image](image.png)

**Fig.2b** Slice from smoothed cube representing long wave (low frequency) residual after filtration. In this case it also contains footprints (vertically elongated features).

**The difference cube**

Smoothed cube is subtracted from the input (raw) cube to get a difference cube. With the help of this procedure input data is cleaned from low- and medium frequency components. The difference cube is subject to a minimum smoothing before the extraction process begins in order to consolidate the dispersive noise.
Fig. 3 The slice from difference cube: raw cube minus smoothed cube.

The Geo-bodies Extraction

The extraction process consists in extracting stretched amplitude anomalies from the wave field, by separating it from small isometric amplitude anomalies. In this stage, the classification of the wave field is carried out in terms of cubic bodies called voxels. Contiguous stretches and agglomerations of voxels are called geo-bodies.

Fig. 4 Slice from a difference cube (left) and with extracted geo-bodies (right).

A voxel is a cubic geometrical body whose center is a sample of the wave field and its dimensions are determined by the distance between the wave field samples. During the extraction all connected cubic bodies should be removed from the wave field. The connection is determined by the contact type between these voxels.

In case of this example the distance between samples after re-binning in DWM process is 20x20 meters on horizontal and 20 meters on vertical. So each voxel of wave field which put for extraction is a cube with a size of 20x20x20 meters.

Joined volume bodies should be pulled out from a wave field during extraction. Connectivity is determined by the type of voxels contact with each other. Because cube has 6 sites, 12 edges, 8 corners, the strongest connectivity is considered when voxels contact each other only by sites (6). The weakest type of connectivity is when voxels contact each other by sites, edges and corners of cubes (26). The strong type of connectivity is chosen for extraction of linear bodies.

Fig. 5 The type of connections: 6 and 26.
The next most important parameter is the minimum number of connected voxels. This value determines the size of the isometric bodies that should be deleted during the extraction process. Optionally, you can assign the maximum dimension of the selected connected bodies; however, this limitation loses its significance after determining the minimal absolute amplitude value. Since the target anomalies are characterized by, substantially, non-zero amplitudes, they are of limited size. The background values of the wave field fluctuate around zero and the selection of the minimum amplitude value determines the clipping level of the background. The number of connected voxels within this level tends to infinity.

The next important condition for extraction is the preservation of the equal vertical dimension of the cubic body. This is necessary so that the useful bodies that are vertically short but stretched horizontally are not deleted by mistake. These geo-bodies are characterized by having as many voxels that are isometric in plane space as they are elongated vertically. This is why a layer of constant thickness is created around the top of the target interval. Here, we have to emphasize that the exact depths of the upper and lower boundaries of the vertical body are not well defined due to the low vertical resolution that is a characteristic of duplex wave migration imaging.

On the other hand, precisely that property of duplex waves allows to set a layer of equal thickness around target horizon within which from bottom to the top duplex wave amplitudes practically unchangeable. The thickness of this layer should be comparable to thickness of target interval.

![Fig.6 Setting a layer of equal thickness around target horizon within which from bottom to the top duplex wave amplitudes practically unchangeable.](image)

The final parameter combination is achieved by considering two parameters: minimum number of voxels and minimum amplitude value in fractional steps. The fractional steps depend on the layer thickness and on the intensity of the target anomalies. The validation of the final cube is performed by calibrating it with well data.

![Fig.7 Validation of the final cube by calibrating it with the well data. Left and right pictures – different variants of extraction parameters.](image)

As a result of trying pair of parameters: minimal amount of voxels and minimal number of amplitude values with some fracture increment dependent on layer thickness, intensity of target anomalies; the final
set of these parameters is chosen visually. Justification of final cube is confirmed basing on well log data.

**Using cubes with different processing apertures**

DWM processing procedure allows using different kinds of apertures and their offsets. They can be asymmetric, like *left and right apertures*, and more symmetric, like *hexagonal*.

Additionally can be used two different kinds VH and HV of duplex wave ray-paths:

In more details about processing apertures, please, see Processing Manual for DWM -Processor Guide-.

Using of different kinds of apertures, in some cases, allows highlighting systems of fracturing with different orientation and dipping angles.

Summation of the cubes obtained using different kind of apertures usually is done after they are converted into absolute values, to avoid attenuation of anomalies. Such attenuation may be caused: by complex relation of the image phase to the incidence and reflection angles of the twice reflected signal, its shape and frequency, interference, or what else phenomena, which are not yet fully explored due to lack of
binding methods for vertical reflections.

However, the reduction to the absolute values of amplitudes makes it possible to sum cubes obtained using different apertures for the construction of the resulting map.

**Fig. 11** On the left the sum of the absolute amplitudes of all three (above) cubes with applied polygons: blue - cube Hexa, green - the cube Left, red - Right. On the right: the same information is given, but only without the values of the amplitudes of duplex waves.

**Comparisons with results obtained using other (conventional) techniques**

Using results obtained using other (conventional) processing and interpretation techniques allows in many cases to verify and better interpret DWM results. Such comparisons are based on assumption that different processing techniques are differently highlighting the object under study.

**Fig. 12** Examples of structural surface(left), thrust (mid) and erosive (right) surfaces obtained using conventional processing and post-processing techniques and used in comparisons with DWM results.