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Advanced 3D Land Internal Mutiple Modeling and Subtraction, a WAZ Oman Case Study

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SUMMARY

In this Oman land case study we propose a new internal multiple attenuation methodology using a wave equation based multiple modeling technique followed by a 3D adaptive subtraction technique.
The first step consists in modeling the multiple wavefield for a variety of multiples generators, for any multiple orders. The modeling is performed in sub-windows selected on the reflectivity series, around the suspected or identified generators. All multiple ray paths for all orders and all periodicities are generated without precise identification of the multiple generators.
The generated multiple wavefields are then simultaneously subtracted from the total wavefield using a 3D least square adaptive subtraction technique. Subtraction in the Common Offset vector (COV) domain allows flexibility for testing, production and quality control, as well as optimum efficiency, as each COV volume is subtracted from its multiples content as if it was a stacked volume. It is also a domain that allows efficient data handling for large modern datasets like wide azimuth (WAZ) surveys. The results on complex narrow azimuth and WAZ Oman land datasets are encouraging. The method is accurate, efficient, yet primary wavefield preserving and integrates well in the seismic processing workflow.

Introduction

Internal multiple attenuation presents a major problem to both the geologist and the geophysicist. For the geologist the amount of noise can often be such that accurate interpretation of the primary seismic wavefield is impossible, making seismic data unusable. For the geophysicist internal multiples are hard to distinguish from the primaries and more difficult to deal with than surface related multiples. Internal multiples have a dispersed character that creates a curtain of noise often stronger than primaries and where move-out discrimination or deconvolution techniques usuallyfail.
If strong reflectors generating internal multiples are present and identified in the subsurface, re-datuming the wavefield of all shot points and receivers to the generators is possible, thus making each reflector a new buried surface from which the Surface Related Multiple Elimination (SRME) process can be engaged (Berkhout,1992 & Jakubowicsz,1998). However in the Middle East onshore data it is not always possible to identify clearly the generators of internal multiples given the large number of possible candidates.
In certain areas of Oman it is common to have shallow carbonate sequences with strong reflectivity, and high velocity contrasts, overlying lower reflectivity clastic series with weak impedance contrasts and lower velocities. This geologic sequence yields a heavy contamination of the lower unit by energetic interbed multiples generated in the upper unit. These multiples may have the same, or higher apparent velocity, than the primaries offering no opportunity to remove them by move-out discrimination methods such as the High Resolution Radon (Hugonnet & al,2008). Similarly prediction methods (e.g. gapped deconvolution) have proved unsatisfactory. Historically these unwanted multiples have been removed by surgical 3D FK filtering after flattening of the suspected multiple generators. This method has remained in service for many years but has several strong limitations, in addition to the well known FK artifacts. It depends on the interpretation of one or a few horizons. Its implicit assumption is that multiples travel vertically between conformable layers. So it isn't applicable to pre stack data. Hence a new methodology was required to overcome the failings of this 3D FK approach. The new methodology is independent of horizon interpretation and applicable to pre imaged data and all geometries including Wide Azimuth (WAZ) surveys.

3D Interbed Multiple Modeling (IMM)

The new methodology uses the wavefield extrapolation method developed by Pica and Delmas (2008). It is very flexible and works with different surface geometries e.g. Cross-spreads, receiver or source gathers. It is particularly well suited for modern WAZ geometries in which a receiver location is sampled by a very dense wavefield of source locations. An estimate of the overburden reflectivity is extracted from a processed migrated volume and subdivided in small time sub-windows. Each time sub-window defines an area of down-going or up-going reflections (see Figure 1).

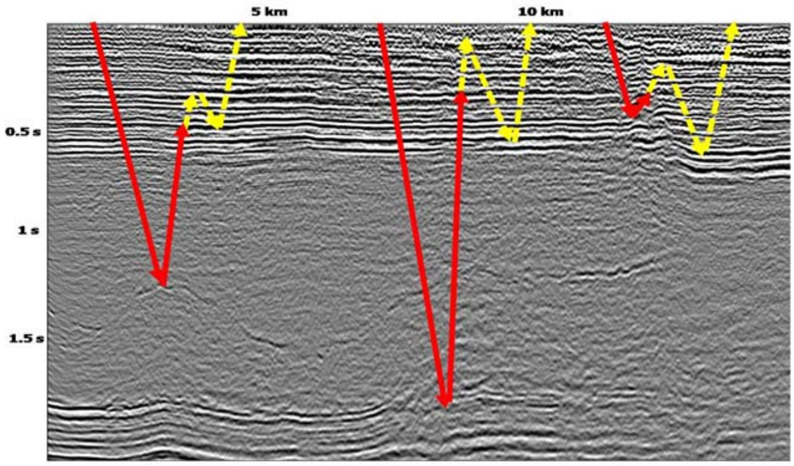

Figure 1. *Three examples of modeled interbed multiples. The red part of the ray is obtained after backward extrapolation of the input data. The yellow (dashed) corresponds to the wavefield extrapolation.*

The windows are combined together, without overlap, such that all possible multiple ray paths are modeled. The size is carefully chosen to be complementary to the previously applied predictive deconvolution which addresses the short period multiples (Gulunay & Benjamin 2008). The input gathers for the modeling are subject to strong de-noising and coherency enhancement after application of high frequency surface consistent static corrections. This is typically achieved using 3D FX projection filtering (Soubaras 2000) combined with radial trace mixing (Gulunay & Benjamin 2008). In the Oman case study example 6 sub-windows are used. This results in 15 possible sub-window combinations. Figure 2 shows some of the multiple models generated from a WAZ 3D dataset. The strength and density of the modeled multiples vary a lot depending on the presence/absence of strong reflectors in each sub window.

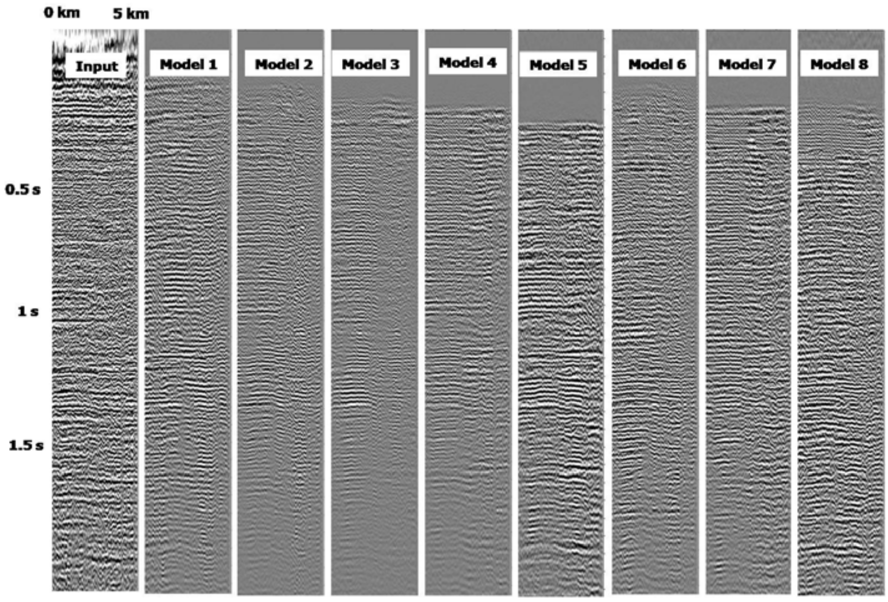

Figure 2*. Eight multiple models generated from 8 sub-window combinations on a 3D WAZ Common Offset Vector (COV) tile.*

3D Adaptive Subtraction

A 3D adaptive subtraction software has been developed allowing simultaneous subtraction of numerous interbed multiple models. The adaptive subtraction is performed in 2 passes. The first pass performs a global amplitude adaptation in which each model is adapted separately to the input data, the second pass performs a simultaneous 3D least-squares adaption and subtraction of the globally adapted models from the original input data. 3D operators can be derived and averaged before application. This process can be run on different frequency bands. The subtraction window can also be guided by horizon interpretation, if desired.

Additionally, to help constrain the least square subtraction process, an estimate of the primary reflections can be introduced leading to a better preservation of the amplitude of the primary wavefield.

For 3D WAZ land surveys, the common offset vector (COV) volume (Cary 1999 & Vermeer 2007), with limited offset and azimuth range, has been found to be the optimum volume for this process. Nevertheless the process may be run on any other well spatially sampled gather such as receiver gathers or cross spreads.

Figure 3 shows multiple attenuation results on a Common Mid Point (CMP) gather extracted from an Oman land dataset. The strong interbed multiples,without move out discrimination from the primaries at short and long offsets, could be efficiently attenuated by the IMM/3D Adaptive Subtraction technique. Subsequent to this, further multiple interferences could be modeled and removed using 3D hi-resolution Radon anti-multiple (Hugonnet et al 2008).

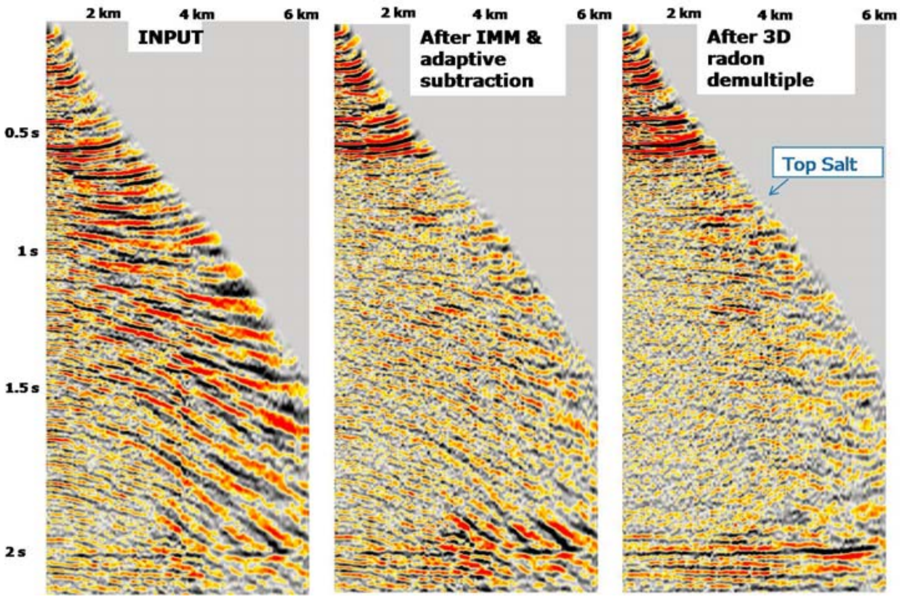

Figure 3. *A CMP gather from the line shown in Figure 5 after IMM & 3D Hi-res Radon*

Fig 4 & 5 show the impact of the IMM/Adaptive Subtraction process on stack sections extracted from two different Oman datasets. In these examples, the multiples generated by the horizontal and highly reflective shallow section (above 0.6s) were masking the lower reflective and structured primaries beneath. In both cases, the IMM/ Adaptive Subtraction technique managed to attenuate these multiples in such a way that the continuity and clarity of the structured primaries where enhanced.

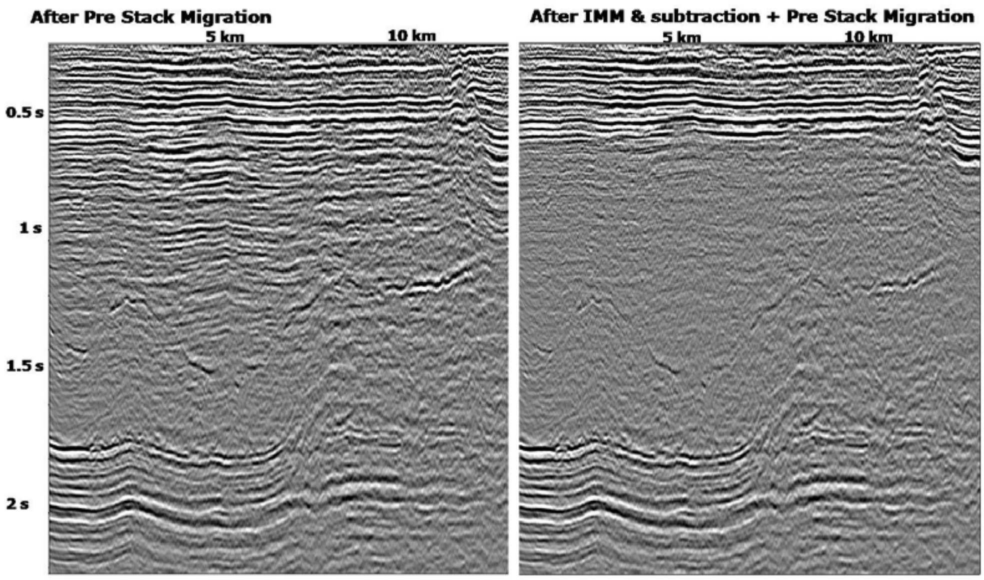

Figure 4*. Impact of IMM and adaptive subtraction on a stack after Pre Stack time migration of a land Narrow Azimuth (NAZ) dataset*

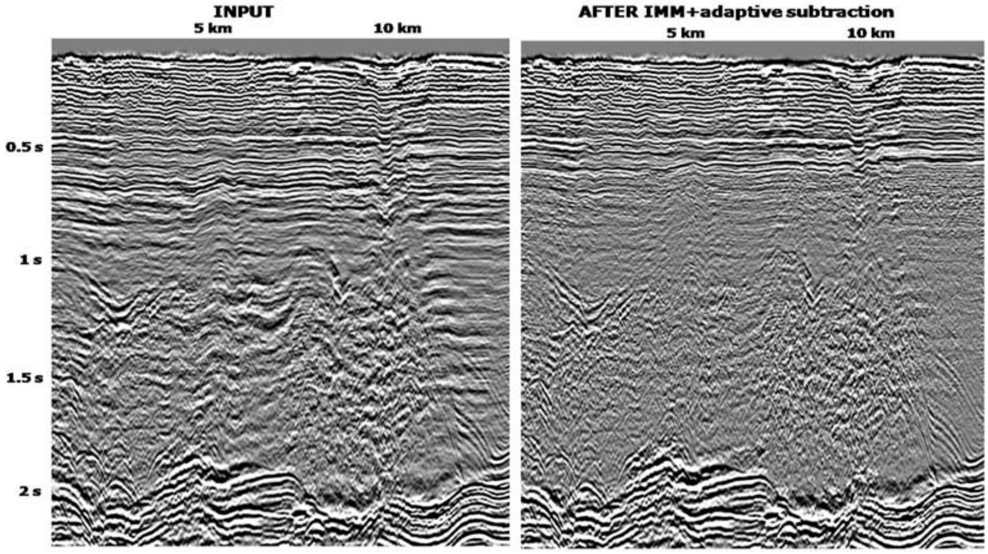

***Figure 5.** Impact of IMM and adaptive subtraction on the stack of WAZ land data set*

The results are sufficiently encouraging to warrant further testing on three production WAZ surveys. The method is fully 3D, accurate, efficient, yet primary wavefield preserving and integrates well in the seismic processing workflow of both modern and vintage (narrow azimuth) seismic surveys.

Conclusion

A new methodology has been described to tackle a difficult, but well known, problem of IM afflicting Land seismic data. Multiples are modeled from de-noised data for a variety of multiples generators, and simultaneously adaptively subtracted, prior to a final pass of 3D HR-radon. Initial results are extremely encouraging. The modeling and subtraction programs can be run on clusters. This makes them fully applicable with a fast turnaround to the huge Oman WAZ datasets.

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