Multiples: towards a toolbox perspective on assumptions, challenges and options (an Invited Presentation)

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Introduction

All seismic methods make assumptions; when the assumptions are satisfied, methods are effective, and when assumptions are violated, the methods can have difficulty and can fail. Seismic challenges arise when the assumptions behind the algorithm are violated. The three links provided at the end of this Abstract provide: (1) a more extensive and detailed version of this Abstract with a context, motivation and perspective (and the references cited within this abstract) and (2) the various types of assumptions behind seismic processing algorithms.

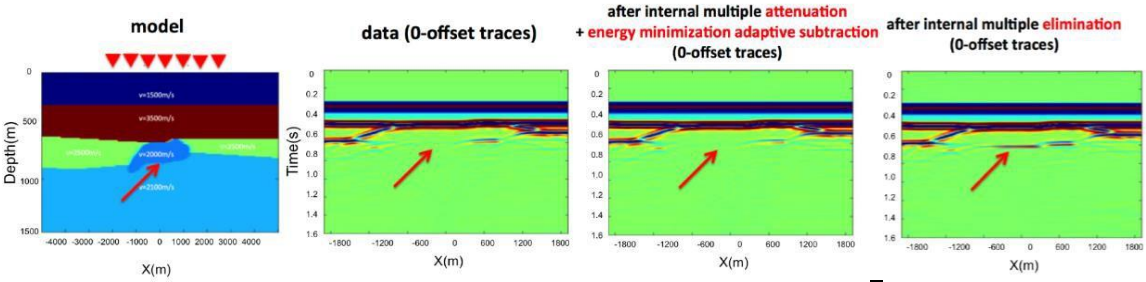
They are all important. For example, a seismic processing method is not an isolated entity, but rather a link in a sequence of processing steps. All the earlier steps in the chain, are important assumptions, prerequisites and requirements for the effectiveness of later steps.

A critically important assumption for a given link in the chain is the need for subsurface information. The industry trend to deep and complex offshore and onshore plays made the need for adequate subsurface information increasingly difficult or impossible to satisfy, and that inability remains the situation today. That reality drove the interest in developing methods that did not need to know, to estimate or to determine subsurface information.

Removing the need for subsurface information.

G. Berkhout (1985) and E. Verschuur (1991), pioneered and developed **SRME**, an algorithm that provided an approximate prediction of the phase and amplitude of free surface multiples, without subsurface information, and independent of earth model type. To address the approximate nature of its prediction it called upon an energy minimization adaptive subtraction to remove the multiples. It is the method of choice for removing free surface multiples that are isolated and not proximal to, or interfering with, other events.

The inverse scattering series (ISS) free surface multiple elimination (**ISS FSME)** (Carvalho et al. 1992) algorithm and the ISS internal multiple attenuation **(ISS IMA)** (Weglein et al. 2003) and ISS internal multiple elimination (ISS IME) (Zou et al. 2019) algorithms taken together, represent the high water mark of current multiple removal capability. They remove all multiples, and can automatically accommodate specular and non-specular reflectors, including curved reflectors, diffractive reflectors, and pinch-outs, without (knowing, estimating or determining) any subsurface information, or any knowledge of the generators of the multiples. **They are the only methods with that set of capabilities.** The ISS FSME is the method of choice when a free surface multiple is proximal to or interfering with another event, Chao Ma et al (2018). SRME for FS multiples and ISS IMA have become industry standards for the following two reasons – they do not require any subsurface information or interpreter intervention. Figure 1 (from Zou et al., 2019) shows a comparison of **ISS IMA** and **ISS IME** for a model where the base salt primary interferes with an internal multiple generated at the water bottom. The **ISS** IMA plus adaptive damaged the base salt primary, whereas the ISS IME removed the internal multiple without damaging the base salt primary.



Marchenko-based methods towards internal multiple removal have received substantial and positive interest over the recent years. There are various approaches within the Marchenko portfolio, each with a different set of features and requirements that may suit a given multiple contamination problem, if their assumptions are met.

From two different and important representative Marchenko approaches presented at the recent SEG/KOC Workshop on Multiples Dec. 3-5, 2019, by Wapenaar et al. (2019) and Dukalski et al (2019), we understand that when a full re-datuming of source and receivers is part of the method, a smooth migration like velocity model is needed. Alternatively, when the method is performed from the seismic experiment recording surface, a virtual boundary defining the multiple generating formations and target ones is required. Although the boundary is virtual, it is required to reside beneath a known and well located physical reflector, requiring prior knowledge and information about the subsurface. This requirement can be loosely interpreted as a generalized form of the Jakubowicz (1998) method and relates to early internal multiple removal concepts by Berkhout. For any choice of virtual boundary, certain multiples will be removable and others will not. The paper by Zhang et al. (2019) is an advance within the Marchenko umbrella, that does not require a virtual surface, showed encouraging results, and explicitly points out several assumptions made in the method. Among the assumptions pointed out is that the data and the multiples are assumed to arise from a reflectivity model of the subsurface, a specular reflection model, valid for planar reflectors and will not accommodate curved and diffractive multiple generators. Another assumption is that later-arriving primaries are coming from deeper depths. We know that shallow primary events can have a longer arrival time than a deeper primary, especially at far offset ranges. In such cases, the method assumption is not met, leading to a need of complementary methods to help address the internal multiple contamination issue at far offset. The distinct ISS methods for eliminating free surface multiples, and for attenuating or eliminating internal multiples make none of the assumptions described above for Marchenko methods.

Many factors go into deciding the appropriate toolbox choice for a given play. No method is the cost-effective choice under all circumstances. When a method like, e.g., Radon de-multiple, (that assumes a one-D earth, and requires sufficient move-out differences and a velocity model) is effective, it can be the cost-effective toolbox choice. We encourage collaborative research to understand under what circumstances, e.g., the Marchenko approaches and ISS methods might be the indicated and appropriate toolbox choice for removing multiples. In our view, the function of research is to increase the options in the seismic tool box, providing: (1) effectiveness under a broader set of circumstances, and (2) a guide for when a particular method would be the cost-effective and appropriate choice.

For dealing with onshore challenges, Weglein (2013) proposed a three-pronged strategy. The development of new onshore preprocessing and processing methods that do not need near surface information would be an important step and advance towards realizing that strategy. In this presentation we will cover: (1) a recent advance in the removal of the need for near surface information, (Weglein 2020a) and (2) a new and first multi-D ISS algorithm for eliminating *higher order* internal multiples (Weglein 2020b).

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An extended and more detailed version of this 2020 EAGE Abstract, including references, is available in the two links below
http://www.mosrp.uh.edu/news/m-osrp-news-2020-eage-workshop-on-multiples-invited-talk
https://bit.ly/3byirFZ

Also relevant for context and perspective is the video below of the key-note address that Weglein presented at the 2019 SEG/KOC workshop on Multiples in Kuwait
"A New Perspective on Removing and Using Multiples", Pre-recorded keynote address for the SEG/KOC Workshop Seismic Multiples – the Challenges and Way Forward. (https://youtu.be/sD89_418h1A)