Addressing complex internal multiple contamination in the Gulf of Mexico with optimized wave-equation based prediction and post-imaging curvelet matching

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Abstract

We present a feasibility study over a deep-water region from the Gulf of Mexico associated with strong internal multiples beneath the salt and thrusted carbonate formations. The complex contamination pattern precludes the application of conventional attenuation techniques, such as velocity discrimination methods based on parabolic Radon transforms.

The target area in the Gulf of Mexico is structurally complex, with salt bodies and thrusted Cretaceous formations like limestone. Aided by the strong acoustic impedance at the seafloor, we observe a strong and convoluted generation pattern of internal multiples, in some cases with faster apparent velocities than underlying primaries. This type of contamination complexity cannot be solved with velocity or period discrimination methods.

In this work, we employed a wave-equation internal multiple attenuation strategy based on the following steps: 1) Data-driven and data domain modeling using a boundary-based prediction framework composed of multi-dimension convolutions and correlations, guided by interpreted generating formations. 2) Pre-stack depth imaging of the input seismic and predicted internal multiples, as a preconditioning prior to multiple suppression. 3) Internal multiple attenuation using an adaptive matching approach in the curvelet coefficient projection of the imaged data and model.

The internal multiple prediction consisted of a predefined selection of generating formations as input that were simultaneously computed to efficiently and accurately represent the internal multiples observed in this area. The imaging step is needed to better focus the coherent noise and facilitate the adaptive matching process. The subtraction process consisted of a cascaded soft-thresholding matching in the curvelet-transform space.

We applied the proposed workflow to wide-azimuth towed streamer data from deepwater region of the Campeche Basin. The internal multiple modeling process used a simultaneous interface-based prediction approach with four formations as major generators. Combined with a variable aperture and sampling scheme, we captured the 3D effect of the internal multiple in this complex geological environment.

Kirchhoff depth migration (KDM) brought the observed data and predicted internal multiple predictions to the imaging space for adaptive matching and subtraction. The post-imaging subtraction consisted of a soft-thresholding process applied in the curvelet-transform space. The transform represents the recorded data and the multiple model in a multiscale, compact and semi-sparse sense, making it well-suited for this type of multiple contamination. This process enhances similarities present in both datasets (multiples), while isolating components that only exist in one of the datasets (primaries), leading to a more effective internal multiple suppression.

Figure 1 shows KDM images before, after and predicted internal multiples of the proposed workflow. Results show an effective suppression of the strong internal multiple crosstalk, revealing the real structure underneath the complex structural bodies. In this work we proposed an approach to model and suppress internal multiples based on data-driven predictions, followed by a post-imaging curvelet-based suppression process. The example over the Campeche basin clearly shows an effective suppression of the strong crosstalk originating from internal multiples, revealing weak primaries and terminations against major structural bodies.

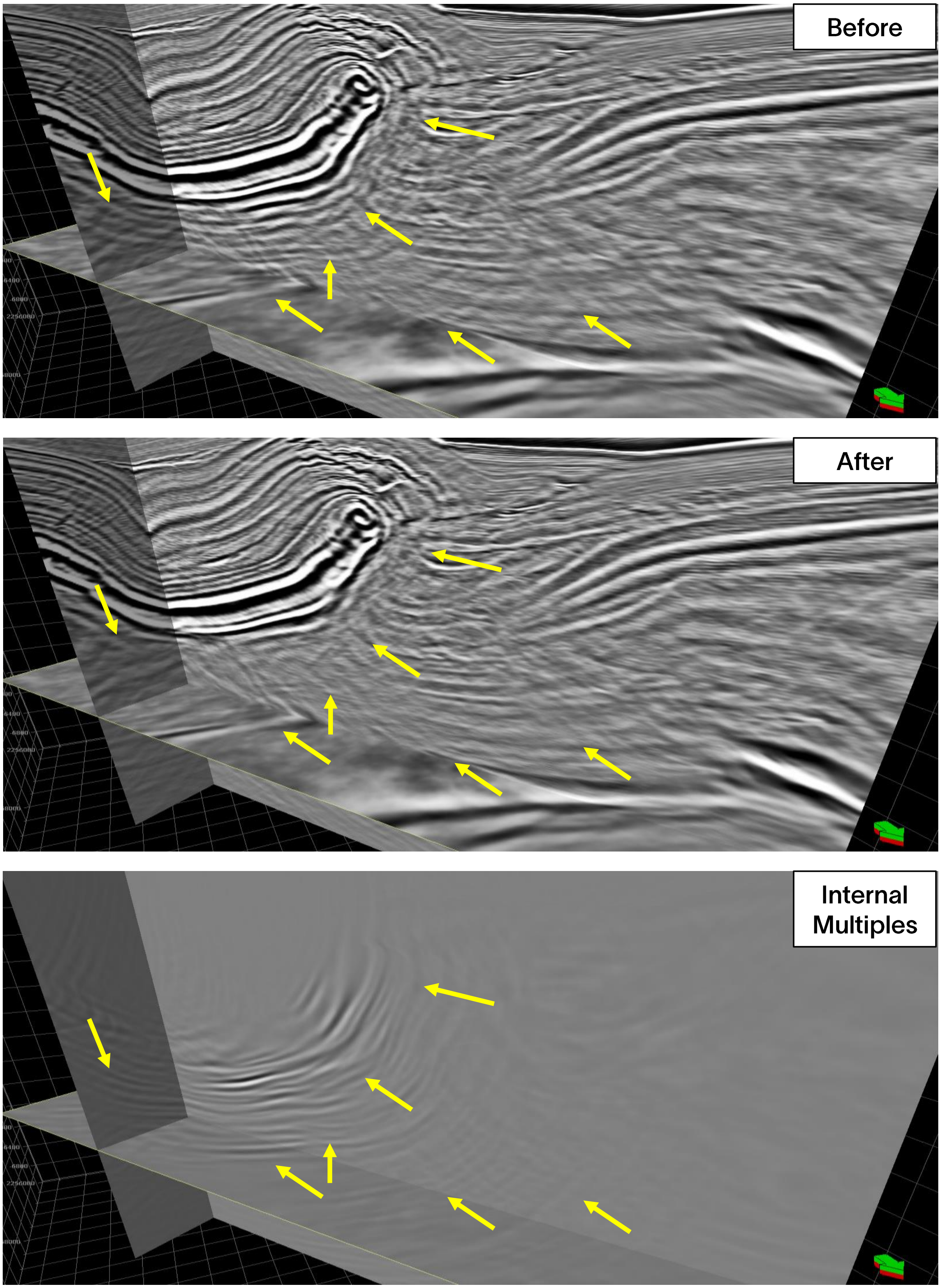

Figure 1: KDM images before (above), after (middle) and model (below) of the internal multiple attenuation process, showing an effective suppression of the crosstalk from internal multiples.