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Waveform Tomography Applied to Long Streamer MCS Data from the Scotian Slope

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Detailed velocity models of the earth subsurface can be obtained through waveform tomography, a method that relies on using information from the full wavefield. Such models can be of significantly higher resolution than the corresponding models formed by more generic traveltime tomography methods, which are constrained only by the wave arrival times. However, to derive the detailed subsurface velocity, the waveform method is sensitive to modelling low-frequency refracted waves that have long paths through target structures. Thus field examples primarily have focused on the analysis of long-offset wide-angle datasets collected using autonomous receivers, in which refractions arrive at earlier times than reflections and there is a significant separation between the two wave arrivals. MCS datasets with shorter offsets typically lack these important features, which result in methodological problems (e.g. Hicks and Pratt, 2001), even though they benefit from a high density of raypaths and uniformity of receiver and shot properties.

Modern marine seismic acquisition using long streamers now offers both the ability to record refracted waves at far offsets arriving ahead of the seafloor reflection, and the ability to do this at great density using uniform sources. In this study, we use 2D MCS data acquired with a 9-km-long streamer by ION GX-Technology over the Nova Scotia Slope in water depths of $\sim$1600 m. We show that the refracted arrivals, although restricted to receivers between offsets of 7.5 and 9 km, provide sufficient information to successfully invert for a high-resolution velocity field. Using a frequency domain acoustic code (Pratt, 1999) over frequencies from 8 Hz to 24 Hz on two crossing profiles (45 and 20 km long), we detail how the limited refracted waves can constrain the velocity field above the depth of the turning waves ($\sim$1.5 km below seafloor). Several important features are resolved by the waveform velocity model that are not present in the initial travel-time model. In particular, a high velocity layer due to gas hydrates is imaged along the entire profile even where a characteristic BSR is not visible. The velocity increase in the gas hydrate layer is very small (< 100 m/s). In addition, a strong velocity increase of $\sim$ 300 m/s exists below a deeper, gently dipping reflector along which discontinuous low-velocity zones, probably related to gas, are present. Velocity models are consistent at the crossing point between the two profiles. The depth limitation of the detailed MCS waveform tomography imaging could be extended by even longer streamers (e.g. 15 km) or by joint inversion with OBS data.