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Joint refraction and reflection travel-time tomography of multichannel and wide-angle seismic data

Slaven Begovic (1), Adrià Meléndez (2), César Ranero (3), and Valentí Sallarès (2)

(1) Institut de Ciencies del Mar, Barcelona, Spain (begovic@icm.csic.es), (2) Institut de Ciencies del Mar, Barcelona, Spain, (3) ICREA at Barcelona Center for Subsurface Imaging (BCSI), Institut de Ciencies del Mar (CSIC), Barcelona, Spain

Both near-vertical multichannel (MCS) and wide-angle (WAS) seismic data are sensitive to same properties of sampled model, but commonly they are interpreted and modeled using different approaches. Traditional MCS images provide good information on position and geometry of reflectors especially in shallow, commonly sedimentary layers, but have limited or no refracted waves, which severely hampers the retrieval of velocity information. Compared to MCS data, conventional wide-angle seismic (WAS) travel-time tomography uses sparse data (generally stations are spaced by several kilometers). While it has refractions that allow retrieving velocity information, the data sparsity makes it difficult to define velocity and the geometry of geologic boundaries (reflectors) with the appropriate resolution, especially at the shallowest crustal levels. A well-known strategy to overcome these limitations is to combine MCS and WAS data into a common inversion strategy. However, the number of available codes that can jointly invert for both types of data is limited.

We have adapted the well-known and widely-used joint refraction and reflection travel-time tomography code tomo2d (Korenaga et al, 2000), and its 3D version tomo3d (Meléndez et al, 2015), to implement streamer data and multichannel acquisition geometries. This allows performing joint travel-time tomographic inversion based on refracted and reflected phases from both WAS and MCS data sets.

We show with a series of synthetic tests following a layer-stripping strategy that combining these two data sets into joint travel-time tomographic method the drawbacks of each data set are notably reduced.
First, we have tested traditional travel-time inversion scheme using only WAS data (refracted and reflected phases) with typical acquisition geometry with one ocean bottom seismometer (OBS) each 10 km. Second, we have jointly inverted WAS refracted and reflected phases with only streamer (MCS) reflection travel-times. And at the end we have performed joint inversion of combined refracted and reflected phases from both data sets. MCS data set (synthetic) has been produced for a 8 km-long streamer and refracted phases used for the streamer have been downward continued (projected on the seafloor). Taking advantage of high redundancy of MCS data, the definition of geometry of reflectors and velocity of uppermost layers are much improved. Additionally, long-offset wide-angle refracted phases minimize velocity-depth trade-off of reflection travel-time inversion.
As a result, the obtained models have increased accuracy in both velocity and reflector's geometry as compared to the independent inversion of each data set. This is further corroborated by performing a statistical parameter uncertainty analysis to explore the effects of unknown initial model and data noise in the linearized inversion scheme.