Seismic imaging and multiple removal via model order reduction

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We introduce a novel framework for imaging and removal of multiples from seismic data based on model order reduction. The reduced order model (ROM) is an orthogonal projection of the wave equation propagator (Green's function) on the subspace of discretely sampled time domain wavefield snapshots. Even though neither the propagator nor the wavefields are known in the bulk, the projection can be computed just from the knowledge of the seismic data using the block Cholesky factorization. Once the ROM is computed, its use is twofold.

First, the projected propagator can be backprojected to obtain an image. ROM computation implicitly orthogonalizes the wavefield snapshots. This highly nonlinear procedure differentiates our approach from the conventional linear migration methods (Kirchhoff, RTM). It allows to resolve the reflectors independently of the knowledge of the kinematics and to untangle the nonlinear interactions between the reflectors. As a consequence,
the resulting images are almost completely free from the multiple reflection artifacts.

Second, the ROM computed from the original seismic data can be used to generate the Born data set, i.e. the data that the measurements would produce if the propagation of waves in the unknown medium obeyed Born approximation instead of the full wave equation. Obviously, such data only contains primary reflections and the multiples are removed. Consecutively, existing linear imaging and inversion techniques can be applied to Born data to obtain reconstructions in a direct, non-iterative manner.