SLIM Seismic Laboratory for Imaging and Modeling

SINBAD

Shallow-water sparsity-promoting LS-RTM with surface-related multiples

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SEG International Exposition and 87th Annual Meeting, Houston, Texas, 24-29 September 2017

UBC

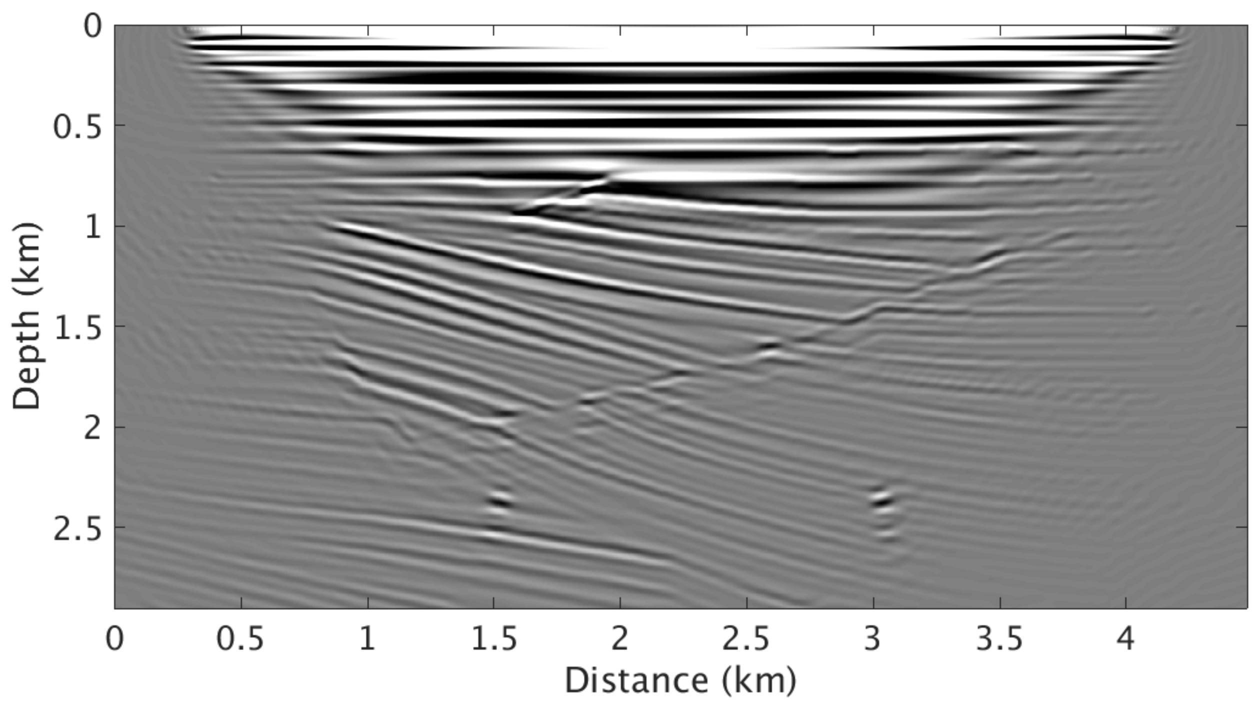
In the SRME relation, multiples are expressed as the multi-dimensional convolution between the vertical derivative of the surface-free Green's function and the down-going receiver wavefield. This relation leads to the methods that separate the surface-related multiples and primaries. Instead of trivially imaging separated multiple, we introduced the SRME relation into wave equation by areal source injection, which costs nothing extra to involve multiples into the forward wavefields. The related image contains the phantoms components from cross-correlation between different-orders of events. Especially in shallow water, due to the strong magnitudes of multiples and their overlap with primaries, the artifacts contain strong phantoms not only of ocean bottom but also subsurface layer interfaces. We use sparsity-promoting inversions where the nicely curved structure of the subsurface models is detected to help cleaning up the phantoms. We reduce the costs by combining randomized source subsampling with linearized Bregman method and get cleaned image with one data pass.

SRME

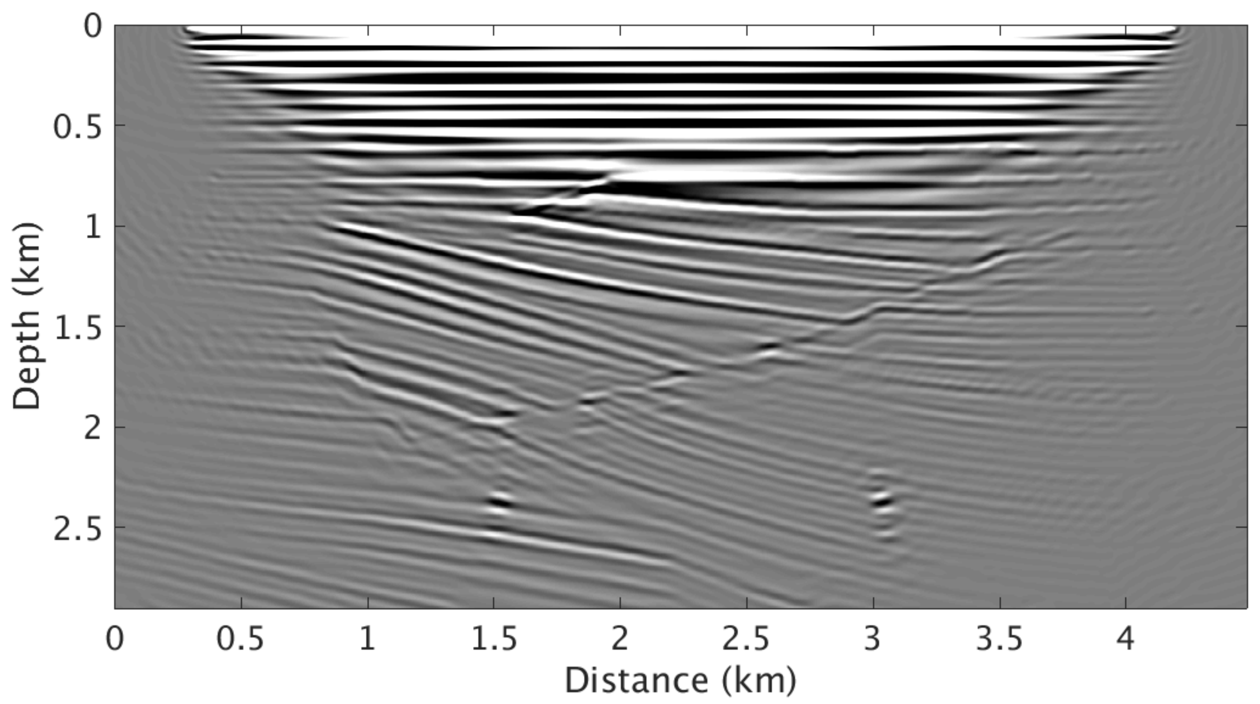
In frequency domain, SRME relates the vertical derivative of the surface-free Green's function and the downgoing wavefield to the total upgoing wavefield: $\mathcal{P}_i = \mathcal{G}_i(\mathcal{Q}_i + \mathcal{R}_i\mathcal{P}_i)$

Areal source

By combining the SRME relation and the linearized forward Born modelling together, we effectually replace the expensive multi-dimensional convolutions in SRME by an areal source injection into Born modelling in time domain. Density strong interface is involved in multiples generation. Only velocity perturbation is inverted $\mathbf{P} \approx \nabla \mathbf{F_m}[\mathbf{m}_0, \rho_0; \mathbf{Q} - \mathbf{P}]\delta\mathbf{m}.$



RTM image of total data

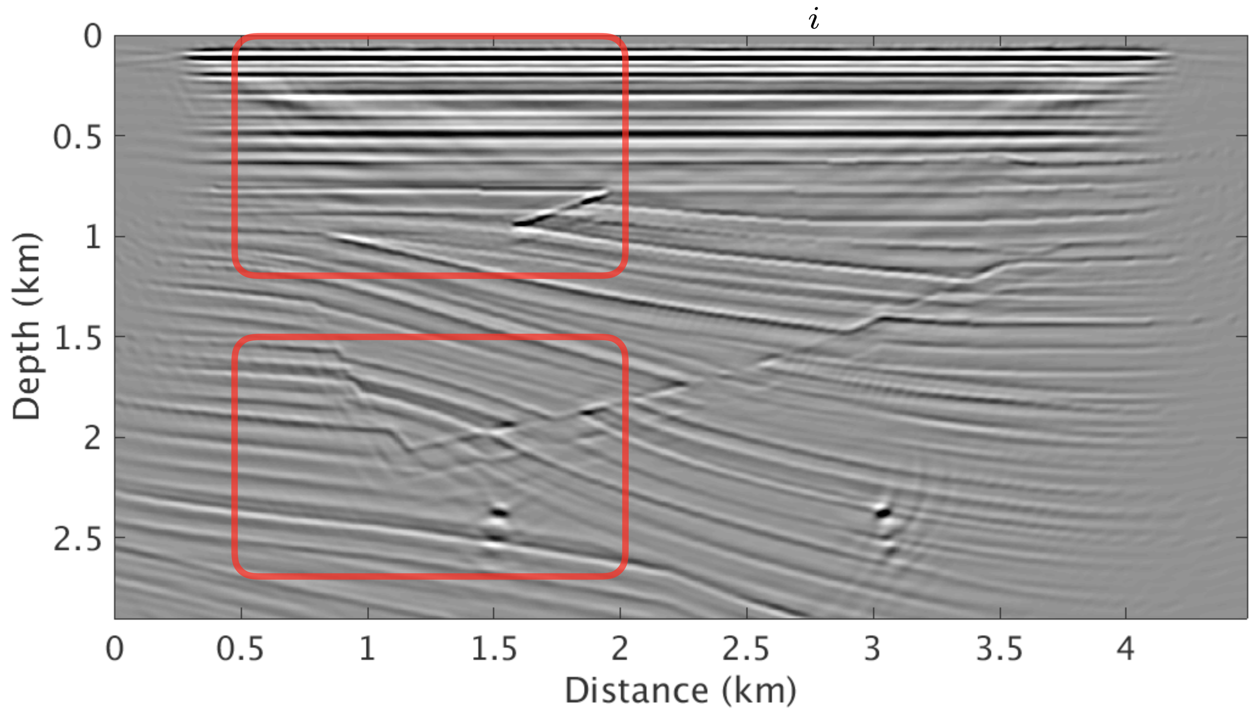


RTM image of total data w/ areal source

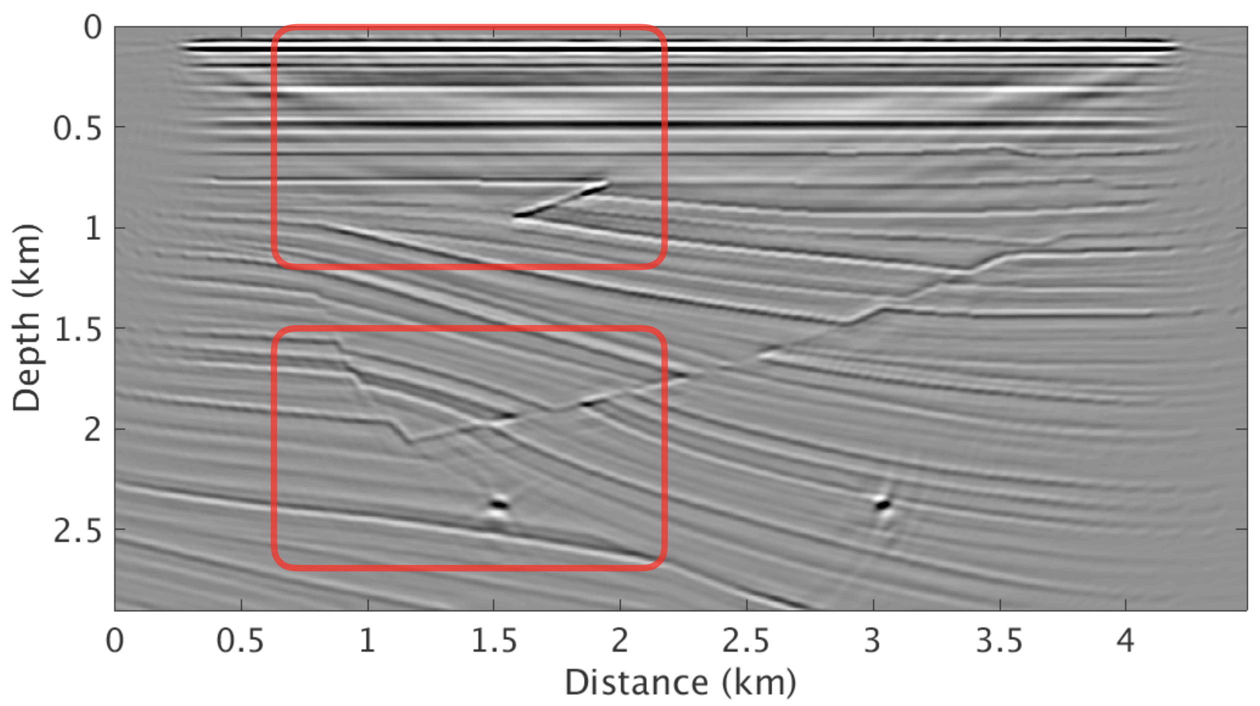
Sparsity-promoting inversion

To suppress the artifacts, we detect the curved structure of model perturbation, which is sparse in Curvelet domain and leads to sparsity-promoting LS-RTM. Considering of the large scale of this over-determined ill-posed problem, and the goal of pursuing sparse solution, we use the linearized Bregman method with source subsampling. The images are obtained by solving

$$\min_{\mathbf{x}} \lambda\|\mathbf{x}\|_1 + \frac{1}{2}\|\mathbf{x}\|_2^2$$
$$\text{subject to} \sum_i \|\nabla\mathbf{F}_i(\mathbf{m}_0, \rho_0, \mathbf{Q}_i - \mathbf{P}_i)\mathbf{C}^T\mathbf{x} - \mathbf{P}_i\|_2 \leq \sigma,$$

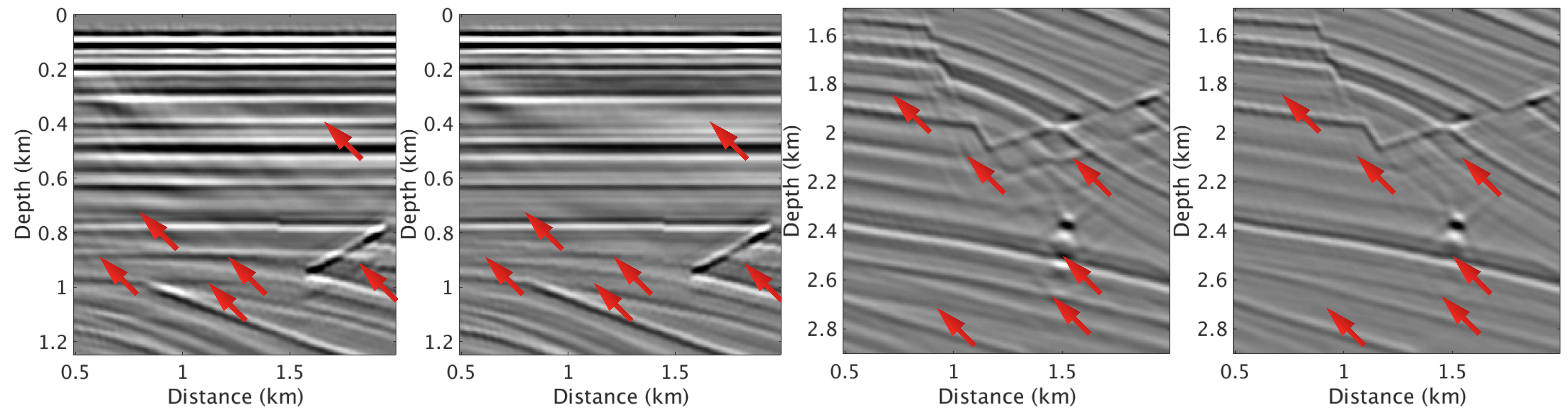


Inversion of total data

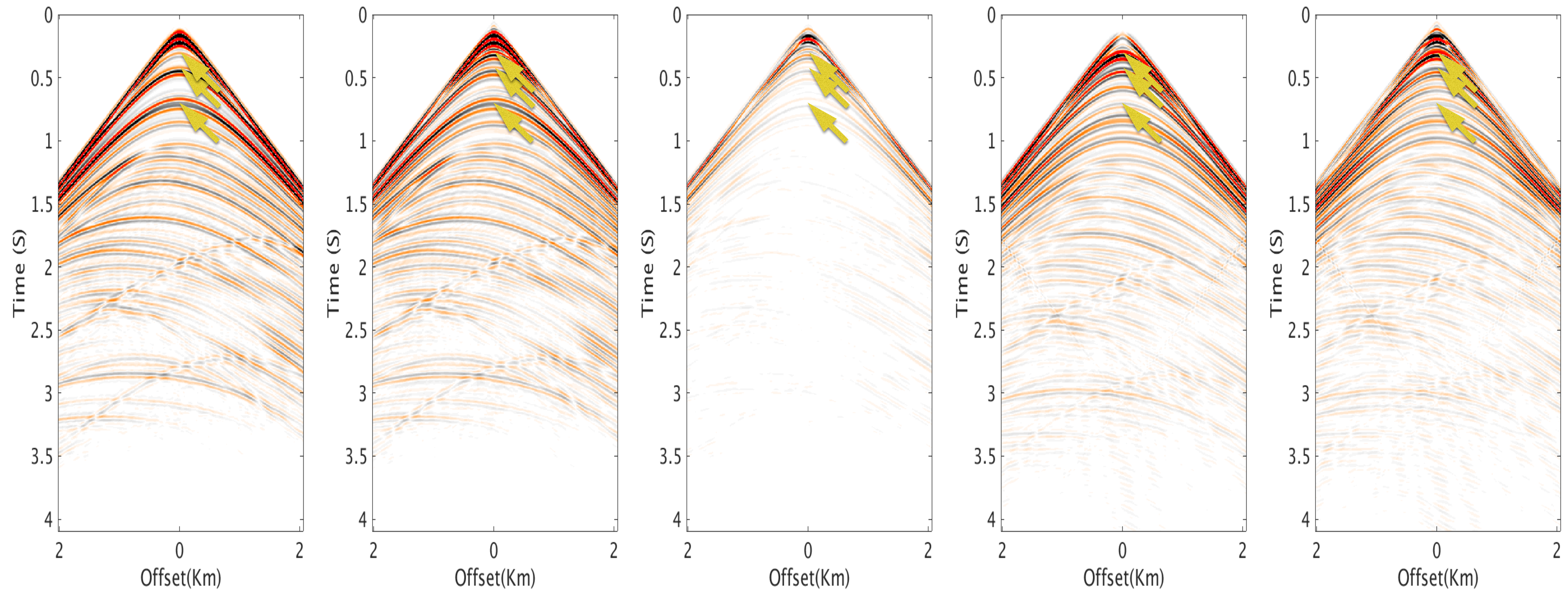


Inversion of total data w/ areal source

Experiments are designed using a part of the Sigsbee2A model. The observed data is generated by iWave with free-surface boundary condition, and inverted according to our method based on Devito with absorbing-surface. We use 5% of the shots per iteration and totally cost one data pass.



(a) zoomed in inversion w/o areal source
(b) zoomed in inversion w/ areal source
(c) zoomed in inversion w/o areal source
(d) zoomed in inversion w/ areal source



(a) true primaries
(b) recovered primaries by the inversion result w/ areal source
(c) errors in recovered primaries
(d) multiples (the difference between (a) and total data)
(e) recovered multiples

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A special mention and thanks to our current sponsors who make our work possible:

Chevron, ConocoPhillips, DownUnder GeoSolutions, HESS, Petrobras, PGS, Schlumberger, Shell, S-Cube, Woodside