POSTER Nº

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Using common information in compressive time-lapse full-waveform inversion

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Time-lapse seismic inversion

Aim
Obtain timelapse velocity models and difference

Challenges
Nonrepeatability in acquisition geometry
Weak 4D signal below noise level
Expensive baseline/monitor acquisitions

Approach
Use random subsets of data
Inversion with modified Gauss-Newton
Joint inversion with the joint recovery model (JRM)

Sparsity-promoting Gauss-Newton

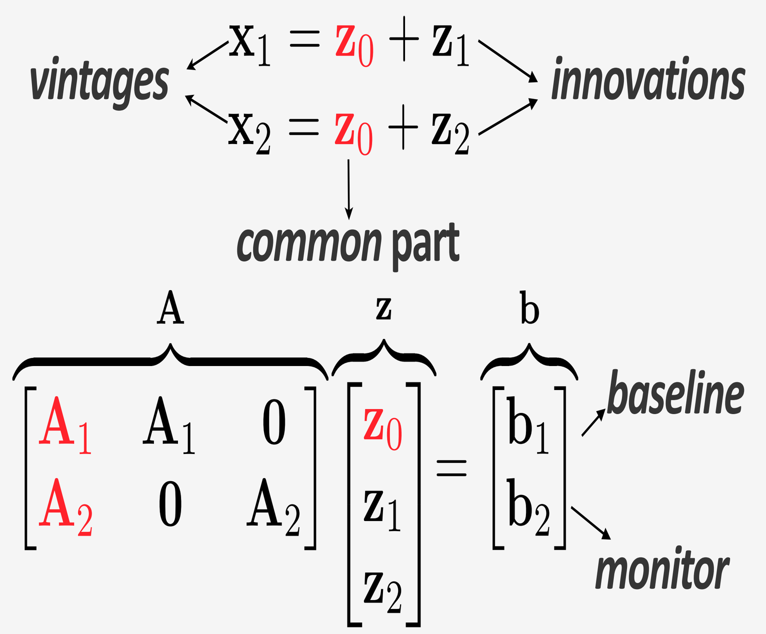
$$\underset{\delta \mathbf{m}_i}{\text{minimize}} \ \frac{1}{2}\|\mathbf{D}_i - \mathcal{F}(\mathbf{m}_i^k; q_i) - \nabla\mathcal{F}(\mathbf{m}_i^k; q_i)\mathbf{C}^T\mathbf{x}_i\|_2^2 \quad \text{s.t} \quad \|\mathbf{x}_i\|_1 < \tau_i$$

$\mathbf{D}$: observed data
$\mathcal{F}$: forward modelling kernel
$\mathbf{m}$: model parameters
$\nabla\mathcal{F}$: Jacobian
q : source function
$\mathbf{C}$: curvelet transform
$\delta\mathbf{m}$: model update

$$\delta\mathbf{m}_i = \mathbf{C}^T\mathbf{x}_i$$

$$\mathbf{m}_i^{k+1} = \mathbf{m}_i^k + \delta\mathbf{m}_i$$

Inversion with JRM



Goal: Compute baseline, monitor, and difference from common component and innovations w.r.t. the common component

$$\tilde{\mathbf{z}} = \underset{\mathbf{z}}{\arg\min} \ \frac{1}{2}\|\mathbf{b} - \mathbf{A}\mathbf{z}\|_2^2 \quad \text{s.t.} \quad \|\mathbf{z}\|_1 < \tau$$

$$\mathbf{A}_i = \nabla\mathcal{F}(\mathbf{m}_i^k; \bar{q}_i)\mathbf{C}^T$$

$$\mathbf{b}_i = \bar{\mathbf{D}}_i - \mathcal{F}(\mathbf{m}_i^k; \bar{q}_i)$$

$$\delta\mathbf{m}_i = \mathbf{C}^T(\tilde{\mathbf{z}}_0 + \tilde{\mathbf{z}}_i)$$

$$\mathbf{m}_i^{k+1} = \mathbf{m}_i^k + \delta\mathbf{m}_i$$

Modeling parameters
38 shots (150m spacing)
113 receivers (50m spacing)
Different acquisition geometry
Ricker wavelet @ 12Hz

Modified Gauss-Newton
Assume good starting model
Draw randomly selected shots @ every iteration
Started inversion @ 3Hz to 20Hz
8 frequencies per band
10 Gauss-Newton subproblems
10 iterations per subproblem

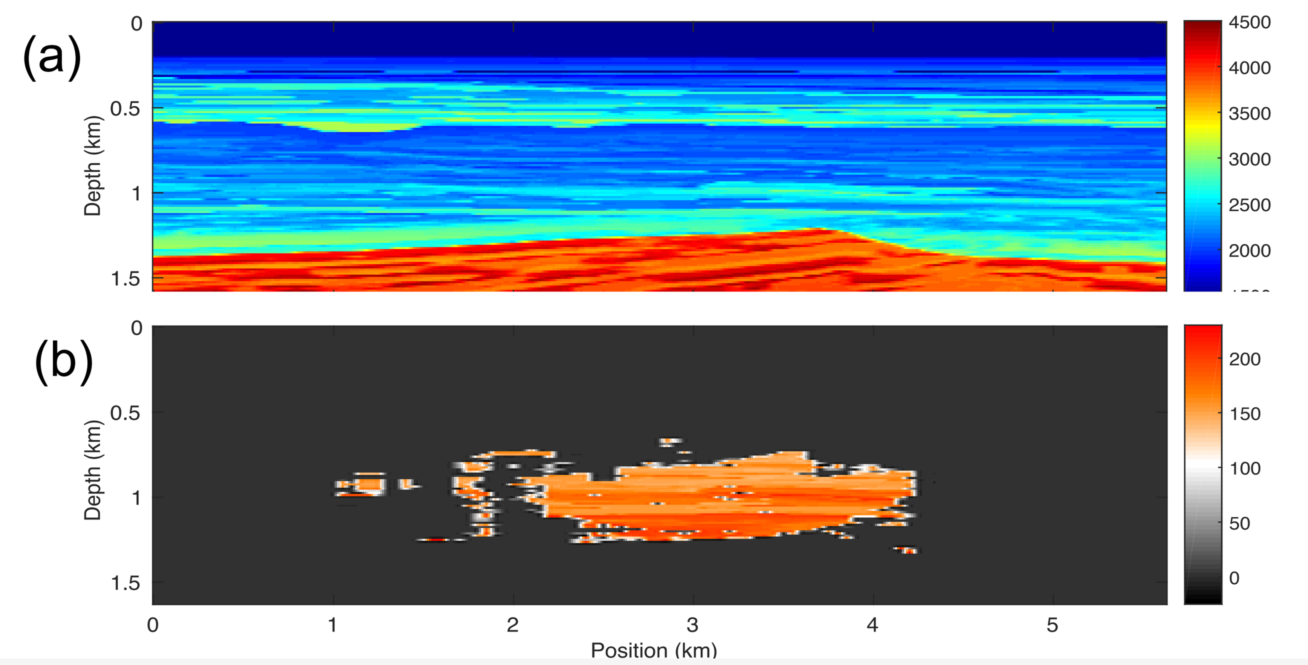


Figure 1: Reference models (a) Baseline (b) Time-lapse

Time-lapse

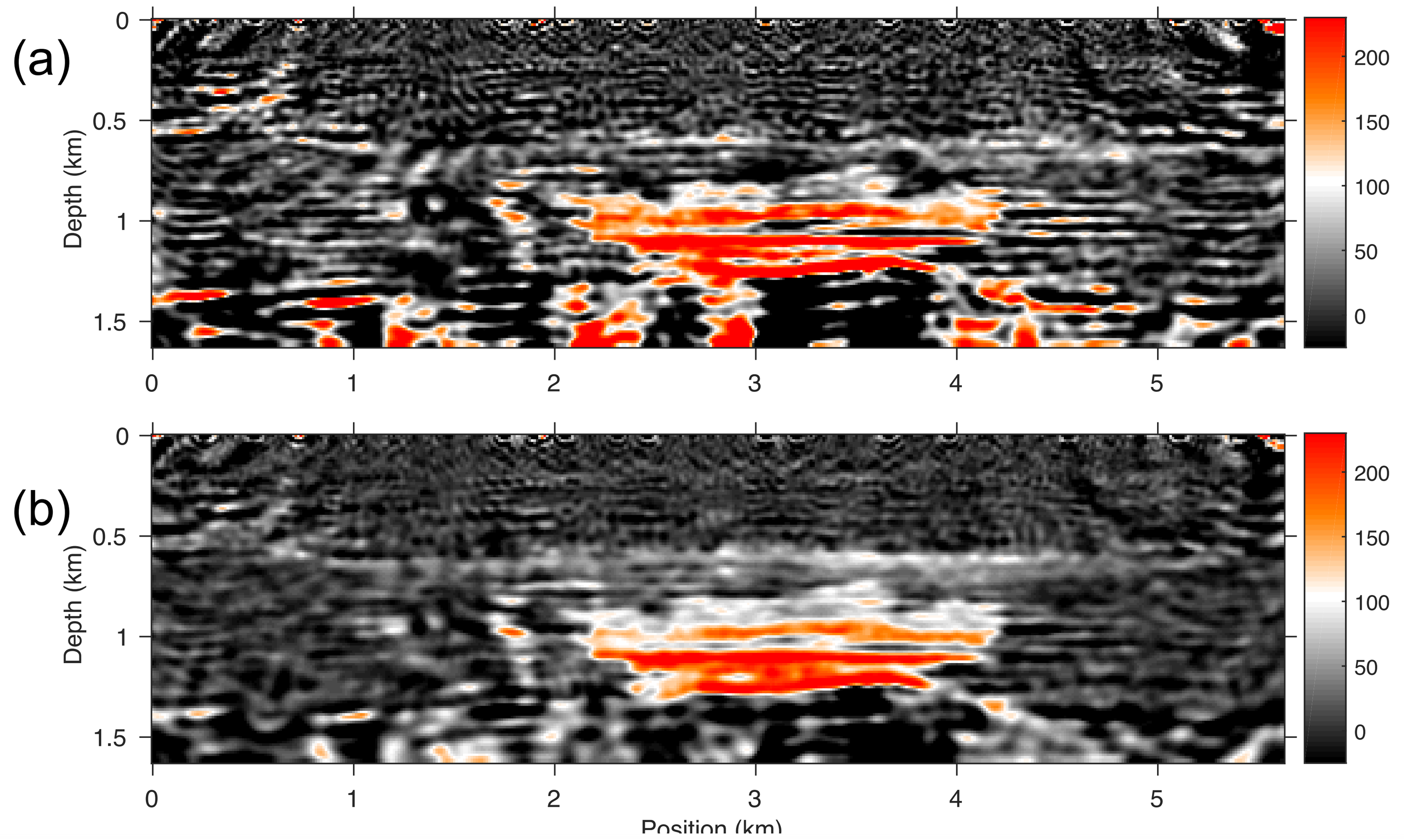


Figure 2: Time-lapse inversion results obtained by subtracting monitor from baseline
(a) Independent inversion
SNR = -4.5dB
(b) Joint inversion
SNR = 1.4dB

Time-lapse (zoom)

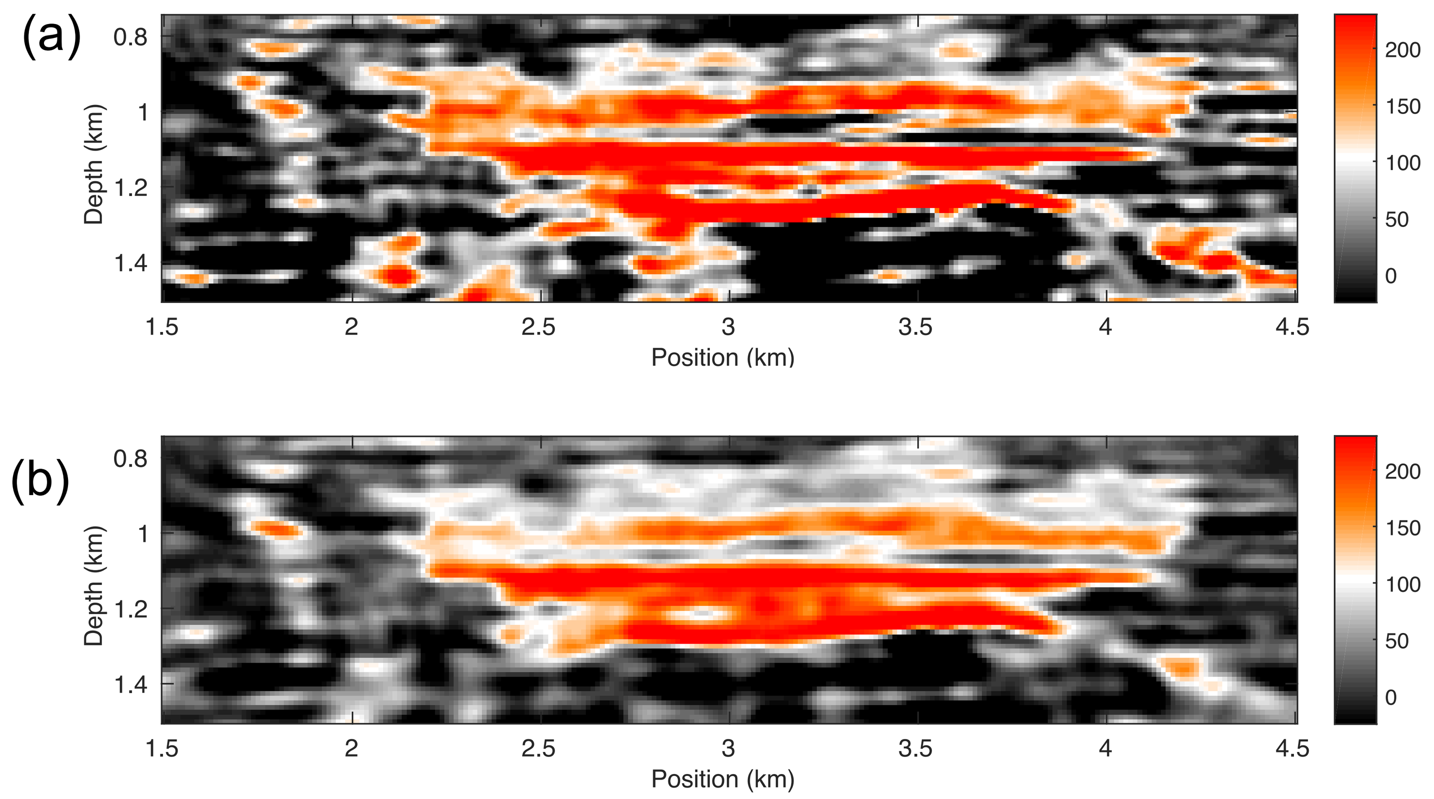
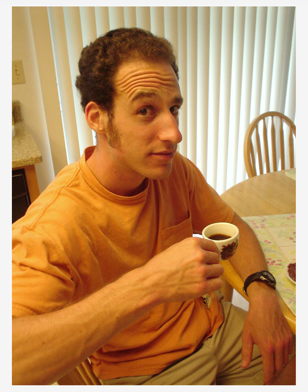


Figure 3: Zoom of time-lapse inversion result in Figure 2
(a) Independent inversion
SNR = -0.7dB
(b) Joint inversion
SNR = 3.6dB

Conclusions

- With random subsampled time-lapse data, we can perform 4D FWI using a modified Gauss-Newton inversion
- Significant attenuation of artifacts in the time-lapse difference model obtained from joint inversion with JRM, giving improved signal to noise
- We propose using the models from JRM for subsequent migration
- The key is in exploiting the shared information during inversion of time-lapse data



† John "Ernie" Esser (May 19th 1980 - March 8th 2015)

We would like to recognize the extraordinary contributions Ernie Esser made to the scientific accomplishments of this paper. Unfortunately, Ernie was not able to see the final product.. We will miss him dearly.

Acknowledgements

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References

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