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Creating virtual receivers by inter-source seismic Interferometry

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Outline

- Introduction
- Inter-source seismic interferometry
- Numerical example 1
- Numerical example 2
- Conclusion

Introduction

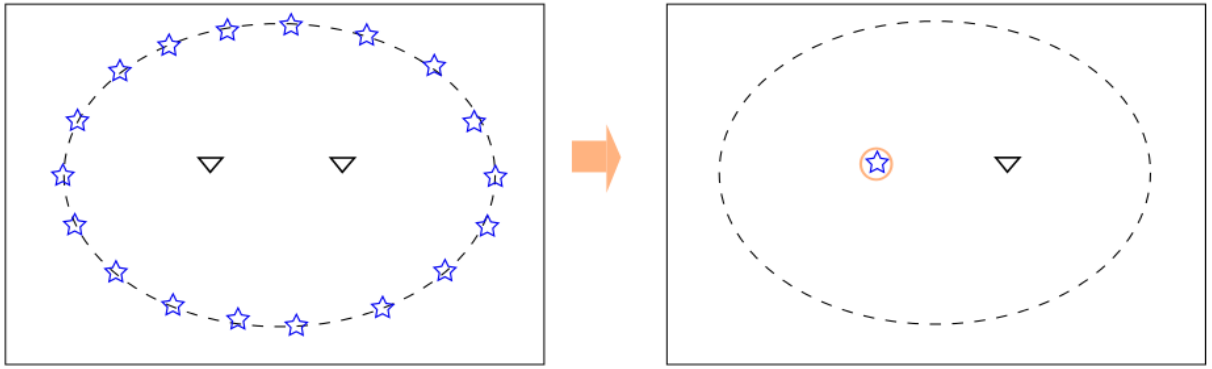
•What is seismic interferometry (SI)?

- Generating new seismic responses from existing observations obtained at different locations.

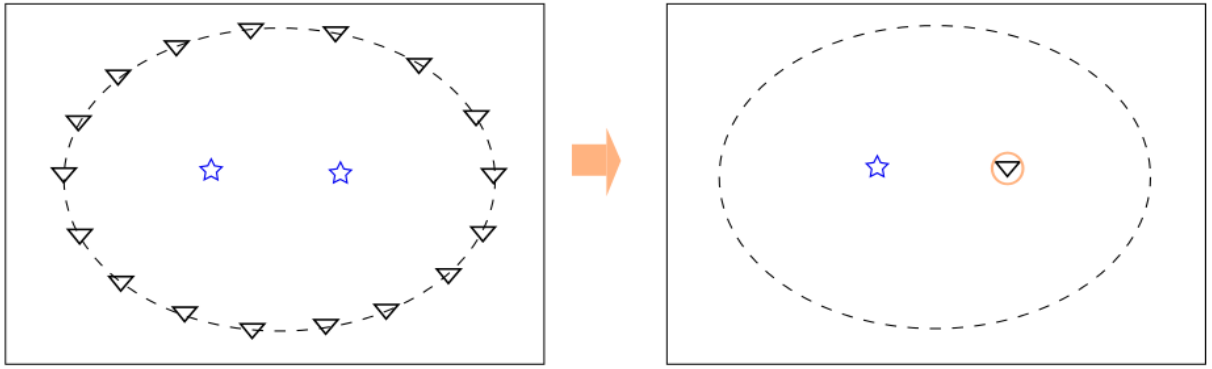
- Implementation methods: crosscorrelation (CC), deconvolution, multi-dimensional deconvolution (MDD) and cross-coherence.

Inter-source SI & Inter-receiver SI

- Inter-receiver SI



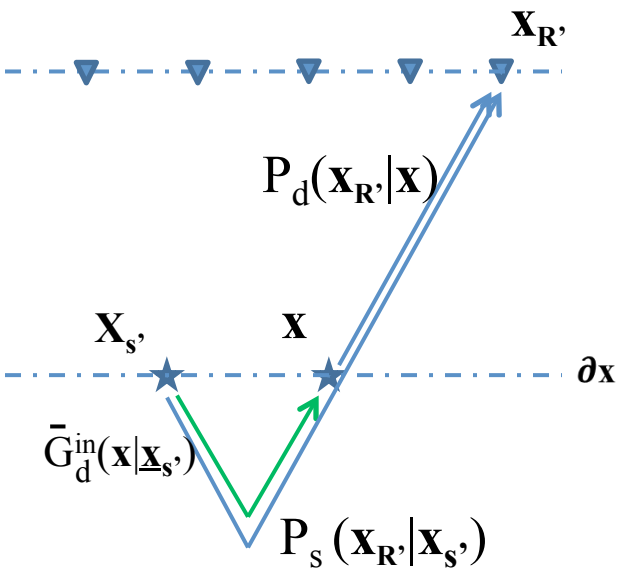
- Inter-source SI



Inter-source SI by multidimensional deconvolution (MDD)

Rayleigh's reciprocity theorem:

$$\int_D (P_A Q_B - V_{i,A} F_{i,B} - P_B Q_A + V_{i,B} F_{i,A}) d^3\mathbf{x} = \oint_{\partial D} (P_A V_{i,B} - P_B V_{i,A}) n_i d^2\mathbf{x} \quad ①$$



- Defintion of states A and B
- P=P^{out} + P^{in}
- High frequency approximation
- Source-receiver reciprocity

$$P^{in}(\mathbf{x}_{R'}|\underline{\mathbf{x}}_{S'}) = P^{out}(\mathbf{x}_{R'}|\underline{\mathbf{x}})\bar{G}_d^{in}(\mathbf{x}|\underline{\mathbf{x}}_{S'}) \quad ②$$

$$P_r(\mathbf{x}_{R'}|\mathbf{x}_{S'}) = P_d(\mathbf{x}_{R'}|\mathbf{x})\bar{G}_{MDD}^{in}(\mathbf{x}|\underline{\mathbf{x}}_{S'}) \quad ③$$

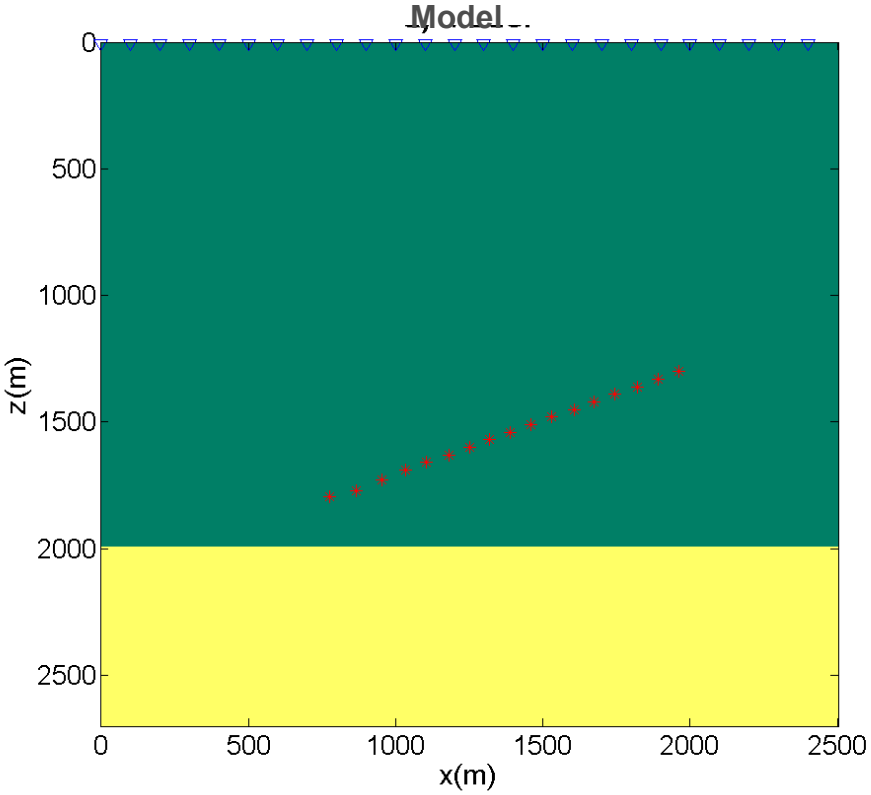
Inter-source SI by multidimensional deconvolution (MDD)

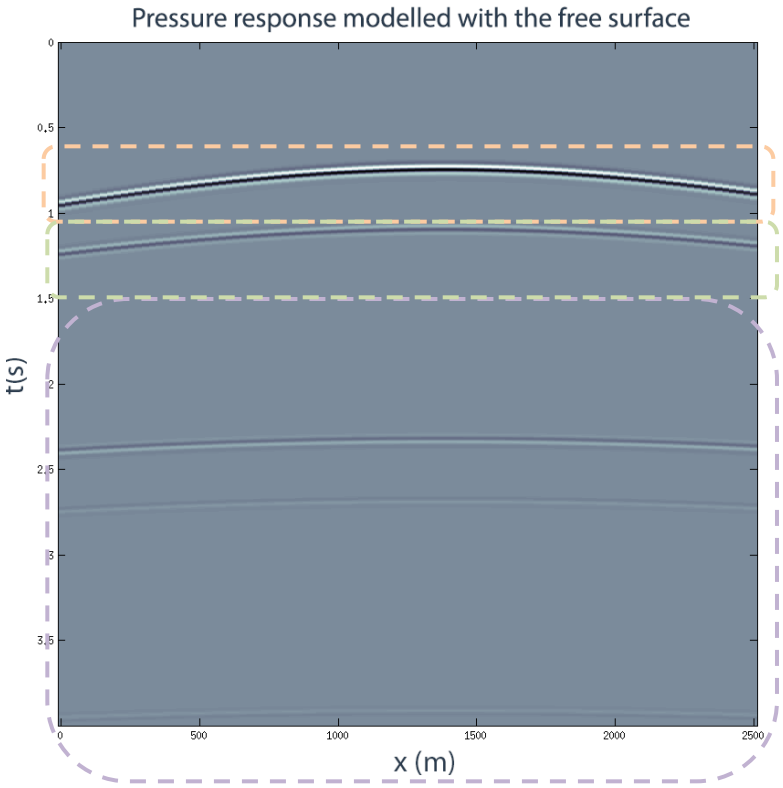
② in matrix form: $$\mathbf{G}^{in} = \mathbf{G}^{out}\bar{\mathbf{G}}_{MDD} \quad ④$$

Normal equation: $$\mathbf{G}^{out\dagger}\mathbf{G}^{in} = \mathbf{G}^{out\dagger}\mathbf{G}^{out}\bar{\mathbf{G}}_{MDD} \quad ⑤$$

$$\Rightarrow \bar{\mathbf{G}}_{MDD} = \left[\mathbf{G}^{out\dagger}\mathbf{G}^{out} + \varepsilon^2\mathbf{I}\right]^{-1}\mathbf{G}^{out\dagger}\mathbf{G}^{in} \quad ⑥$$

Numerical example 1

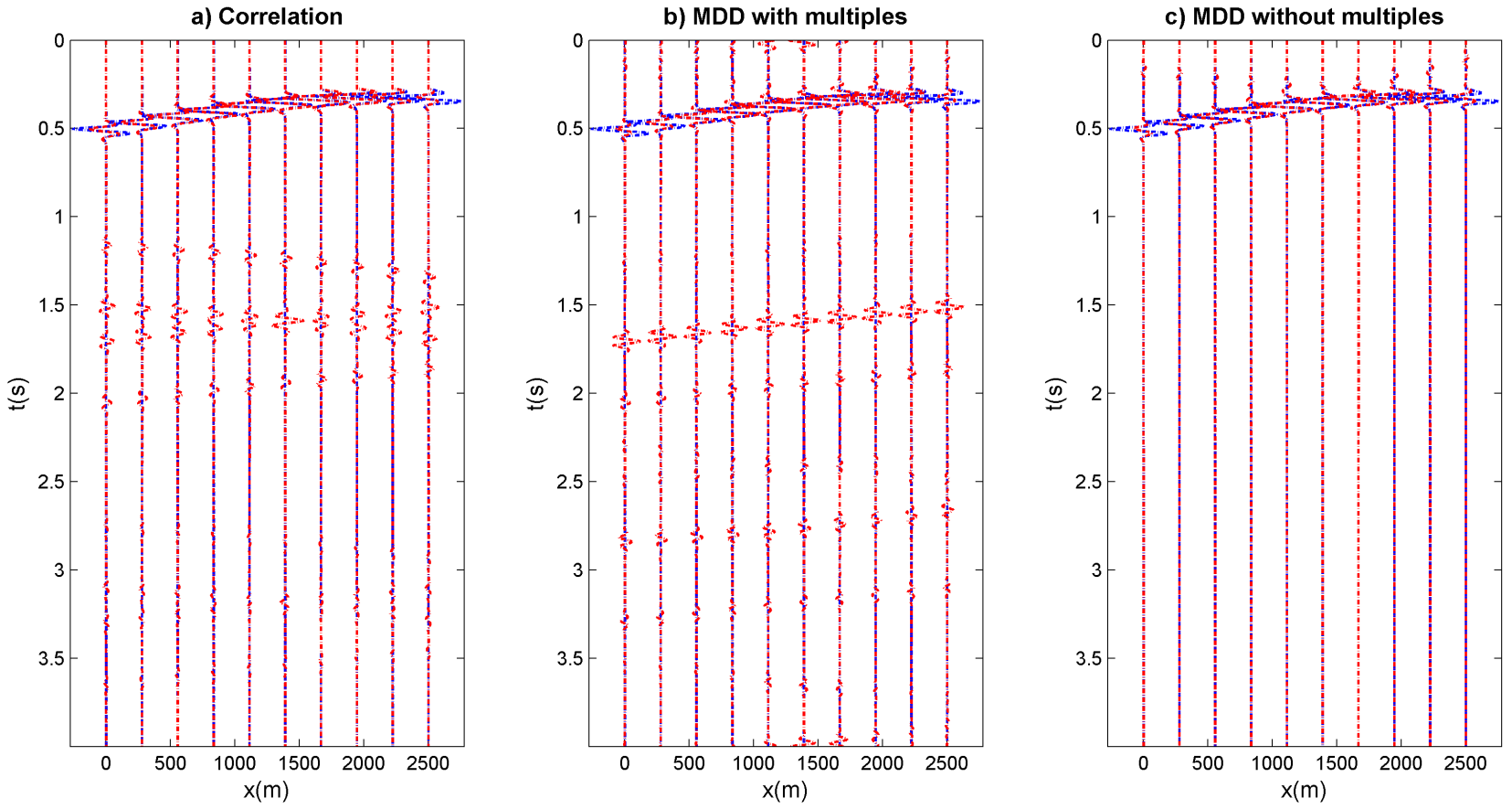




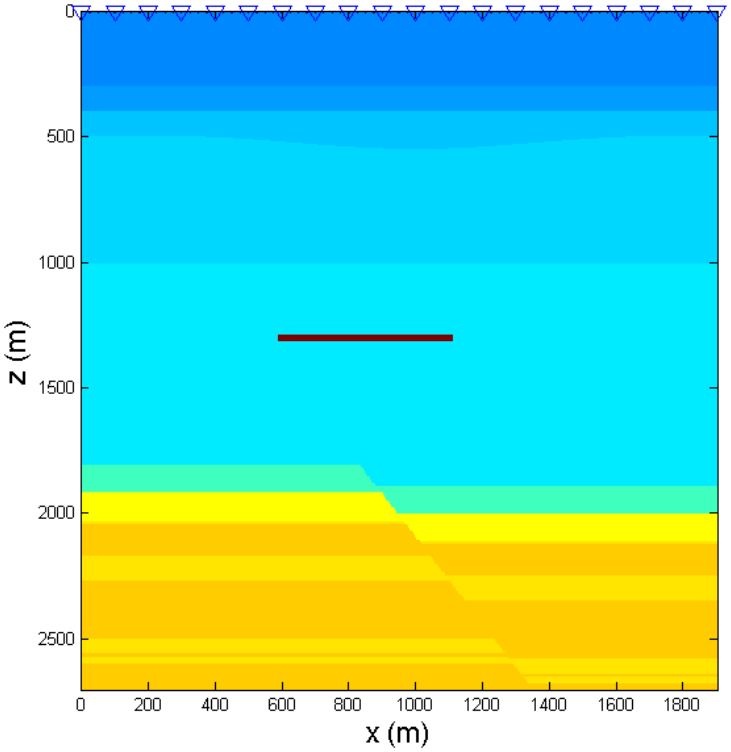
nsrc=51, nrcv=101, dsrc~30, drcv=25,

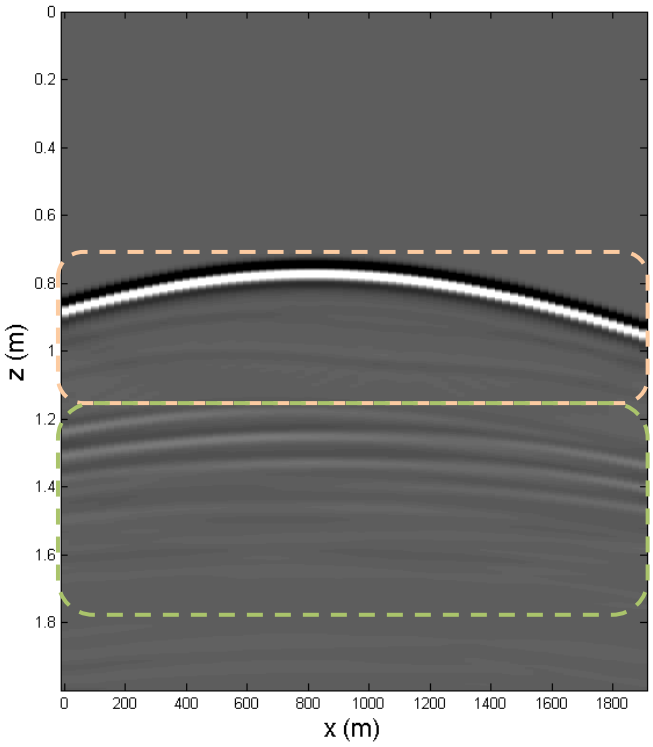
ns=2ms, t=4s, 15 Hz Ricker,

Numerical example 1



Numerical example 2



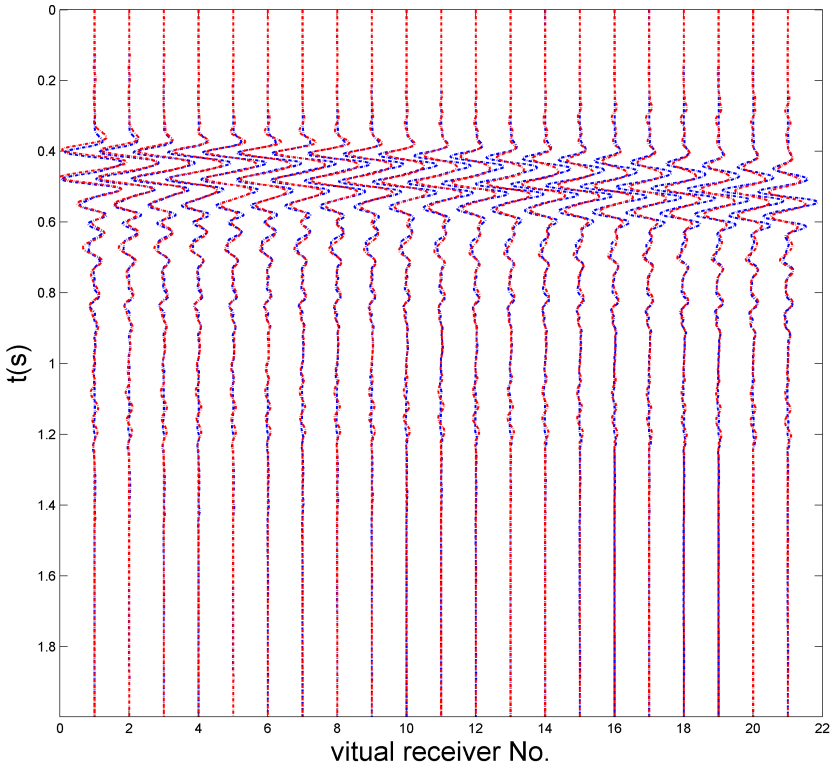


nsrc=21, nrcv=77, dsrc=25, drcv=25,

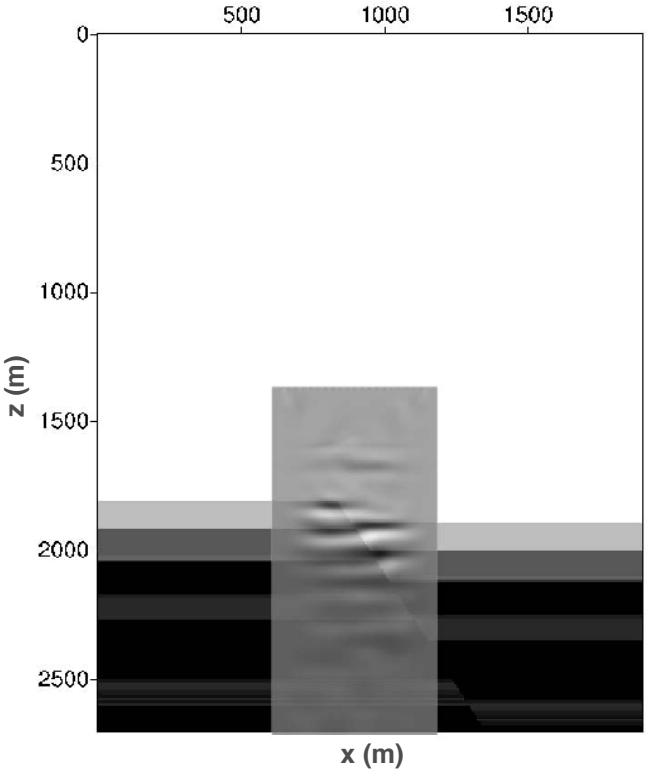
ns=2ms, t=2s, 15 Hz Ricker,

Numerical example 2

Trace comparison



Migrated image



Conclusions

- Derived a formula for inter-source SI by MDD to turn borehole sources into virtual receivers;
- Investigated the theory with numerical examples;
- The retrieved virtual receiver responses can be used for deep imaging which does not depend on the accuracy of the overburden model.
- The direct wave approximation seems adequate for local imaging around the borehole.

Acknowlegement

- The Drilling and Well Center for Improved Recovery
- ROSE consortium

DrillWell

DRILLING AND WELL CENTRE
FOR IMPROVED RECOVERY

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Thank you!