Source wavefield estimation in VSP full waveform inversion

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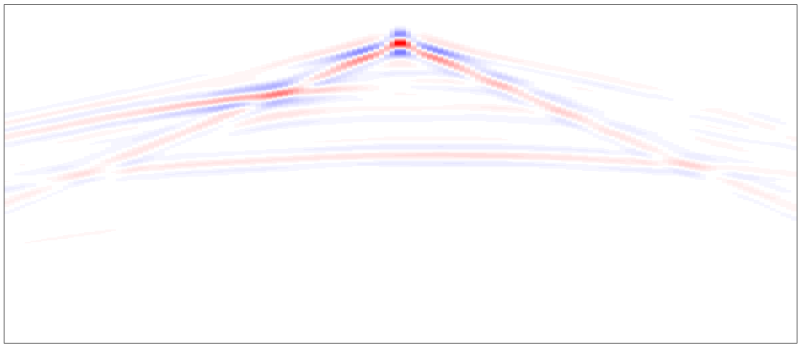
Full waveform inversion

Earth subsurface

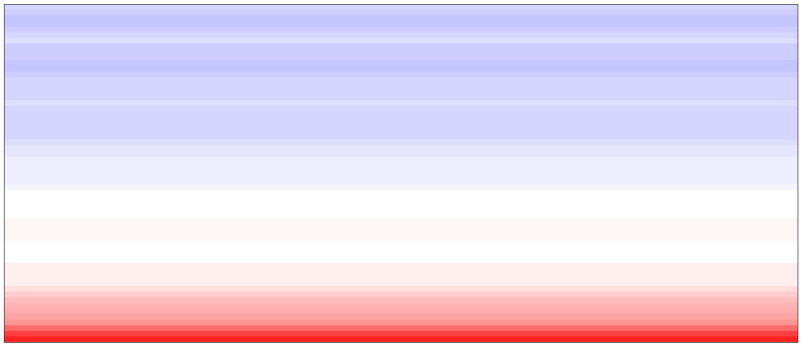
?

Seismic survey

Measured data

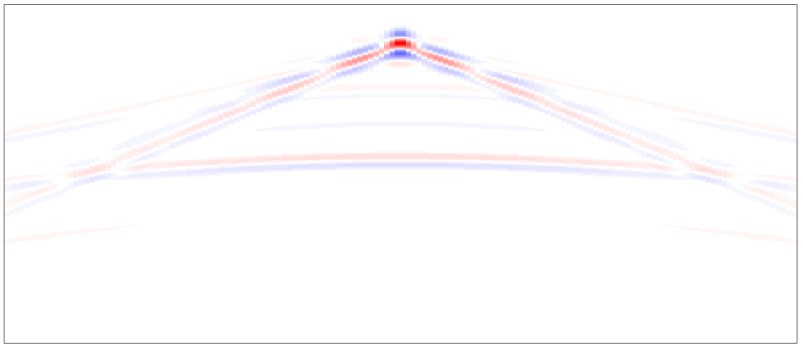


Prior model



Numerical simulation

Simulated data



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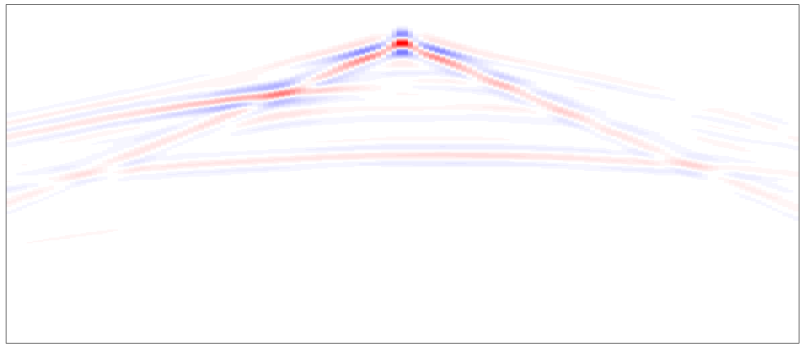
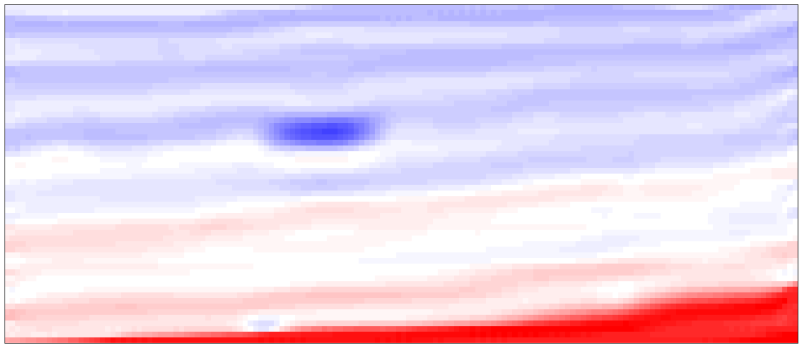


Inverted model



Numerical simulation

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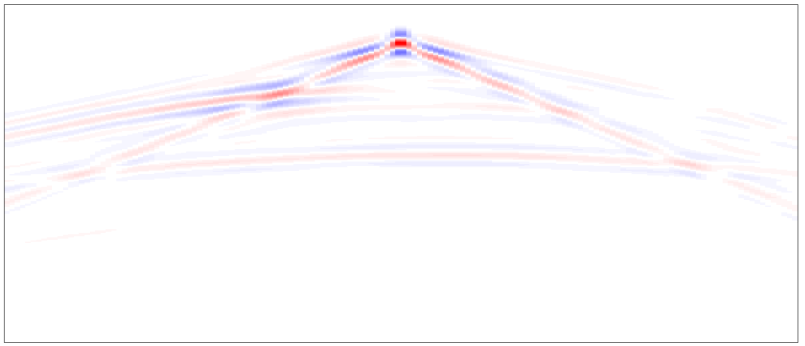
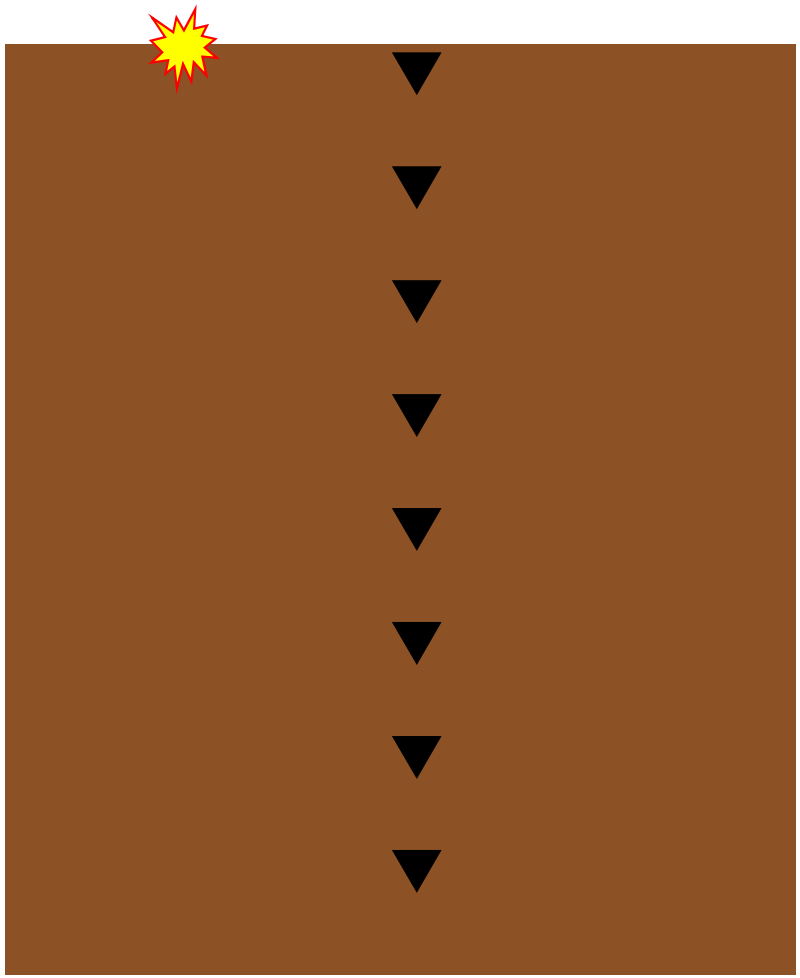
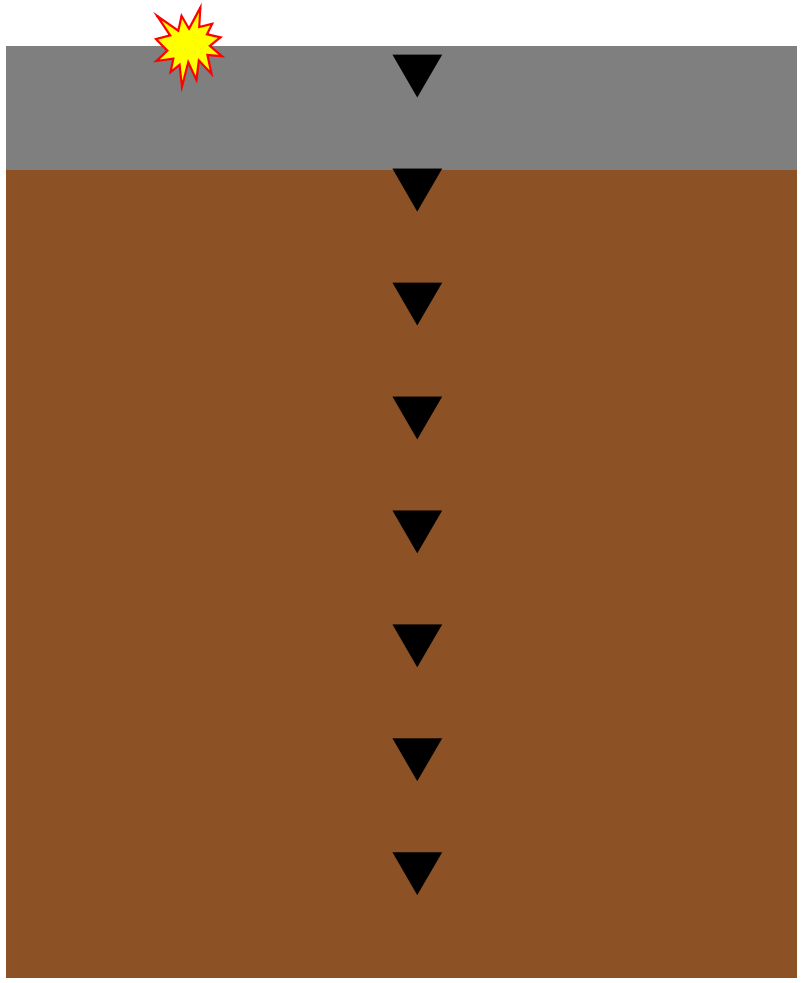


Vertical seismic profiles

- Walkaway VSP surveys offer high-quality coverage near the well
- This type of survey is well suited for monitoring
- The transmission raypaths available in VSP surveys allow for long-scale model features to be recovered in inversion



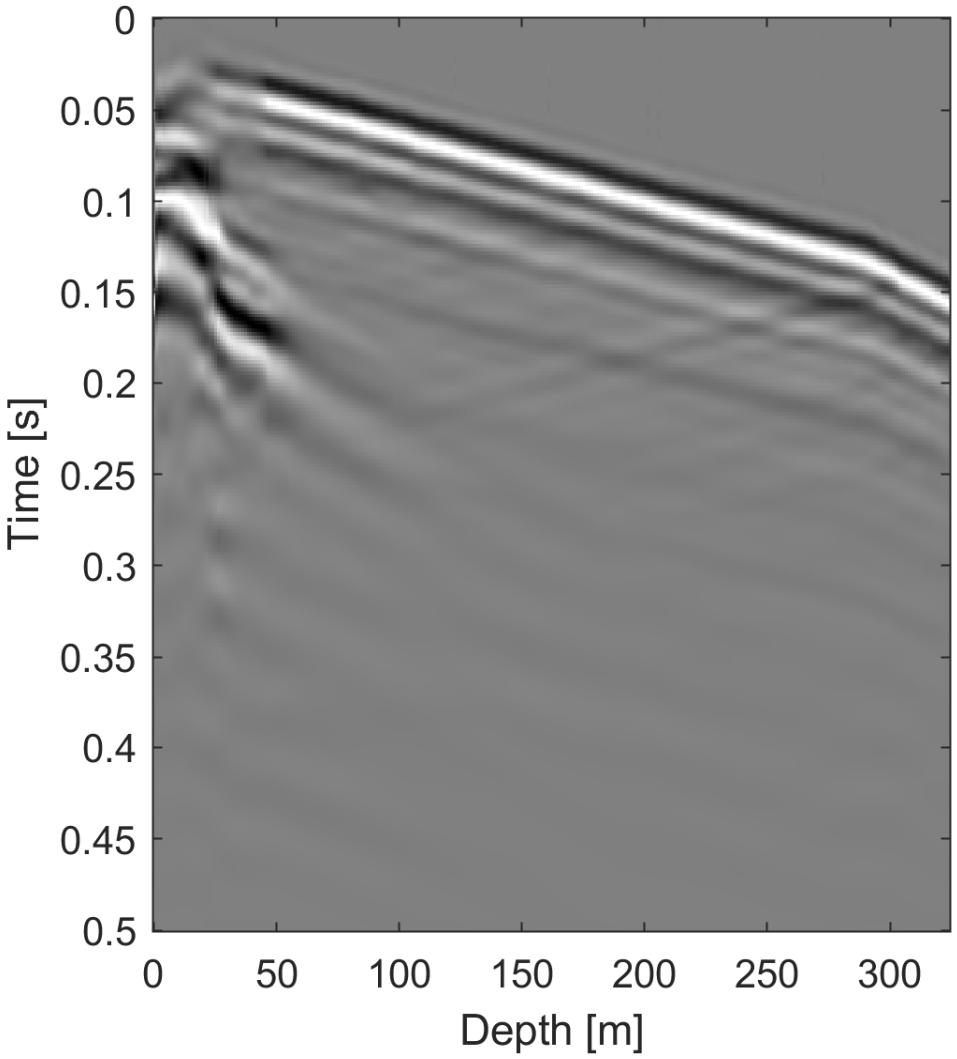
Near surface complications

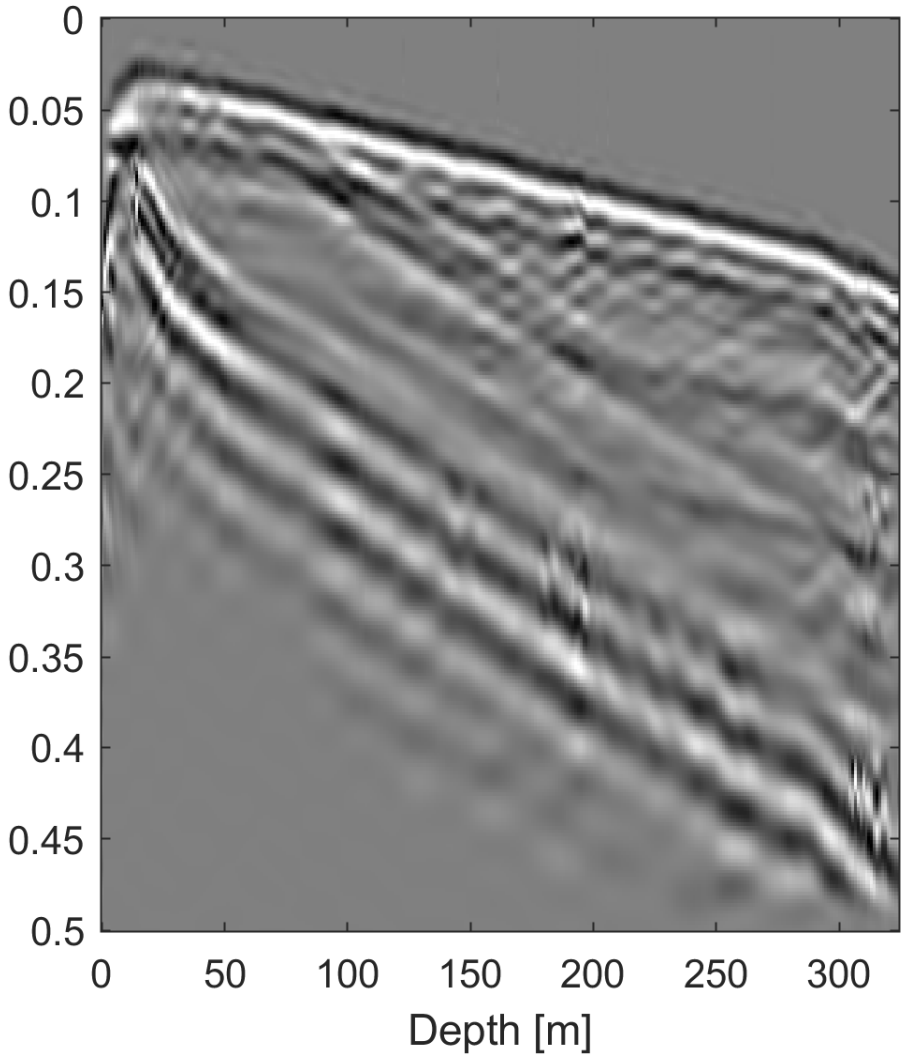


- The near surface presents a challenge for inverting VSP data

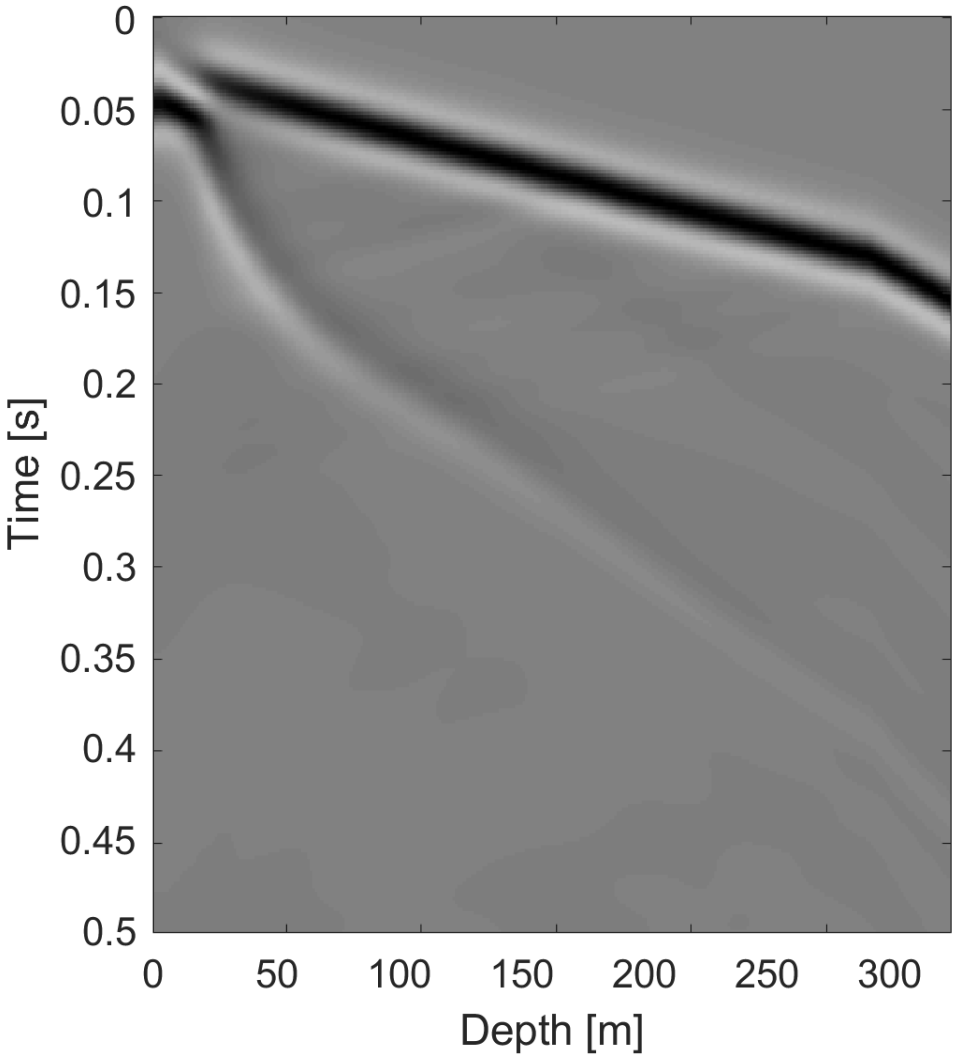
- The near surface is typically
  1) Highly heterogeneous
  2) Very low velocity
  3) Poorly resolved by seismic data

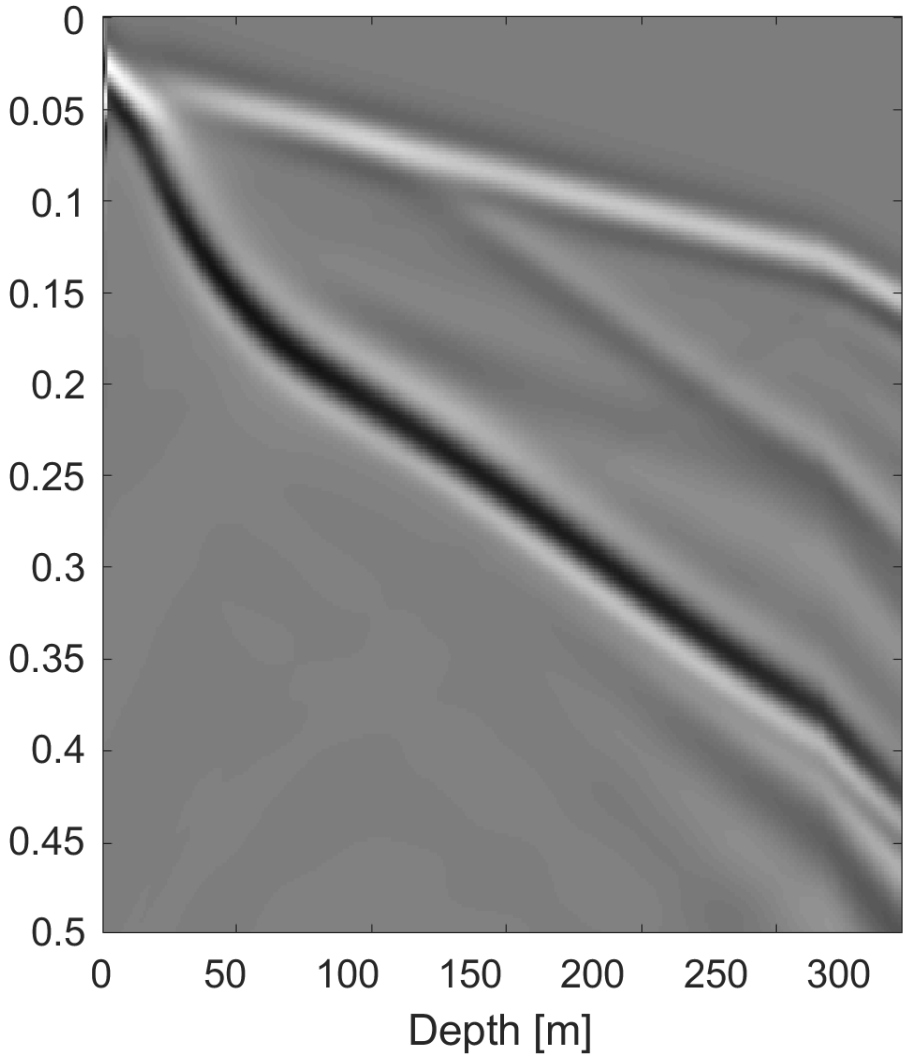
Near surface complications



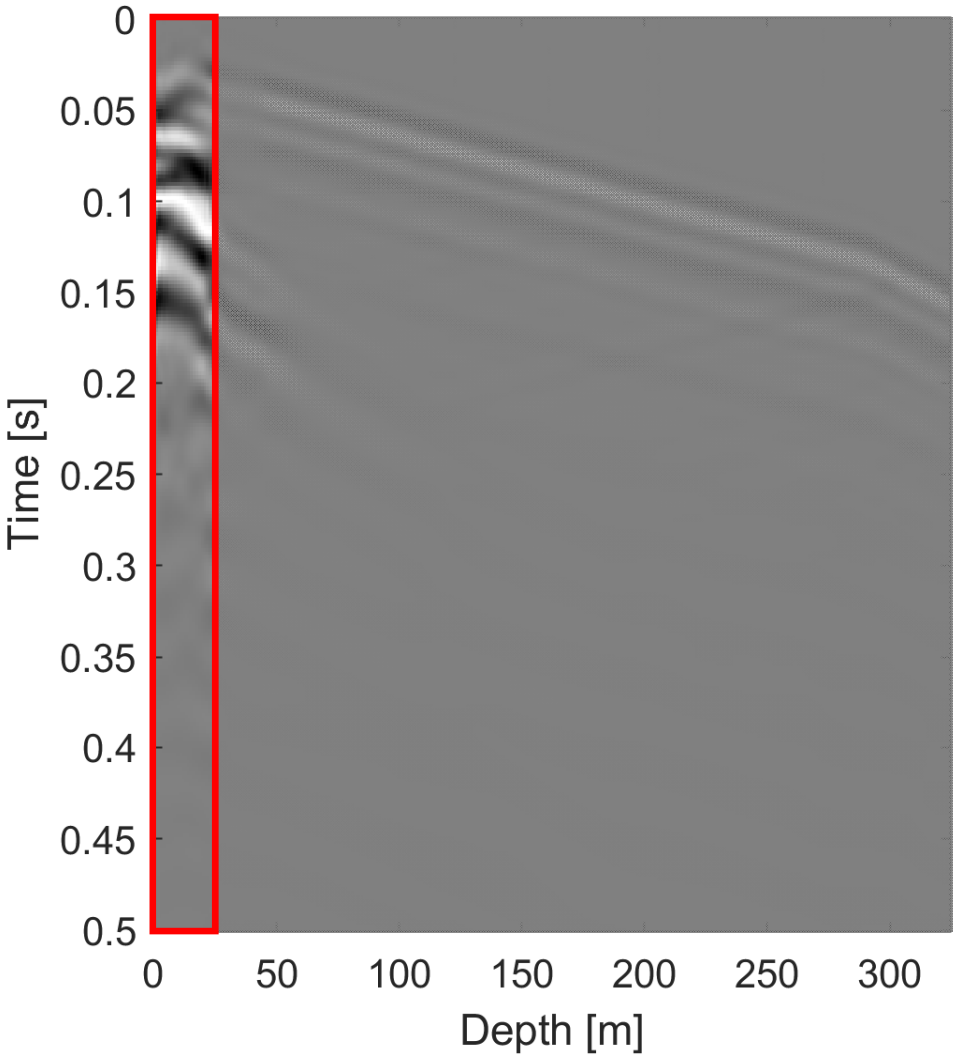


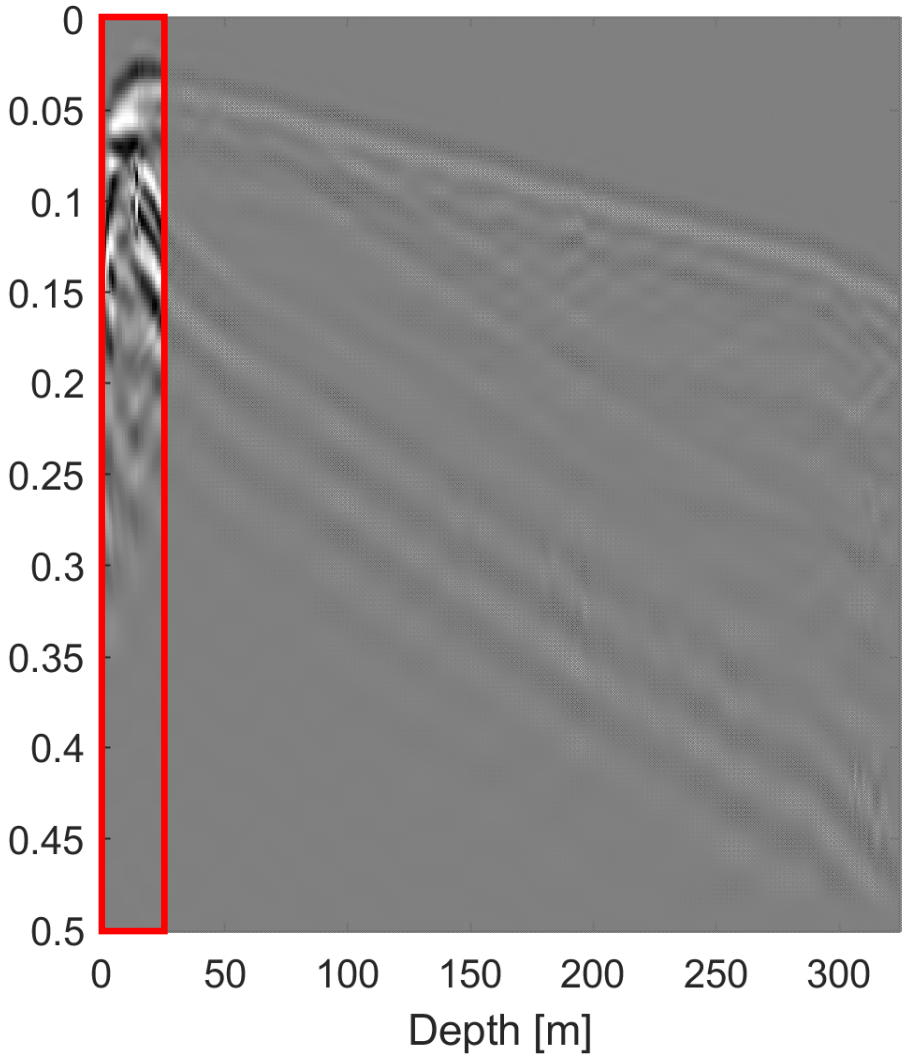
Near surface complications



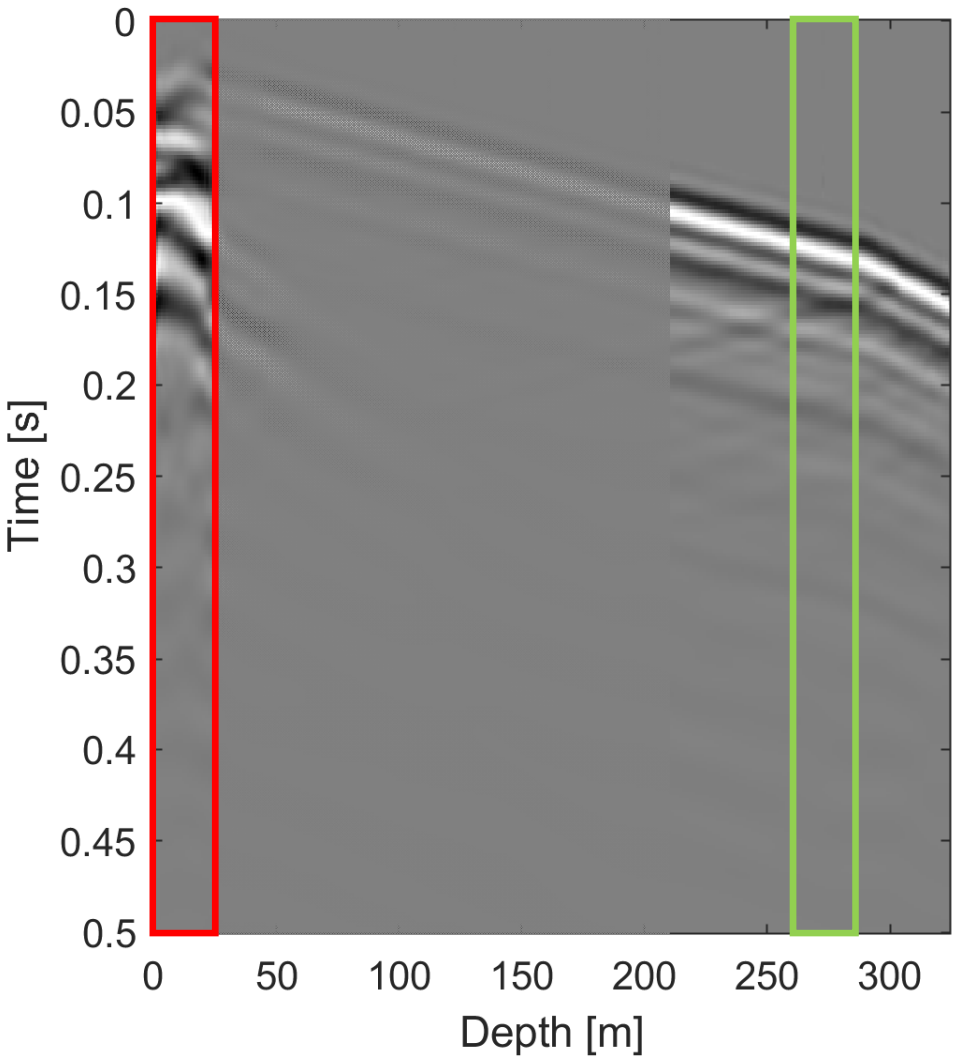


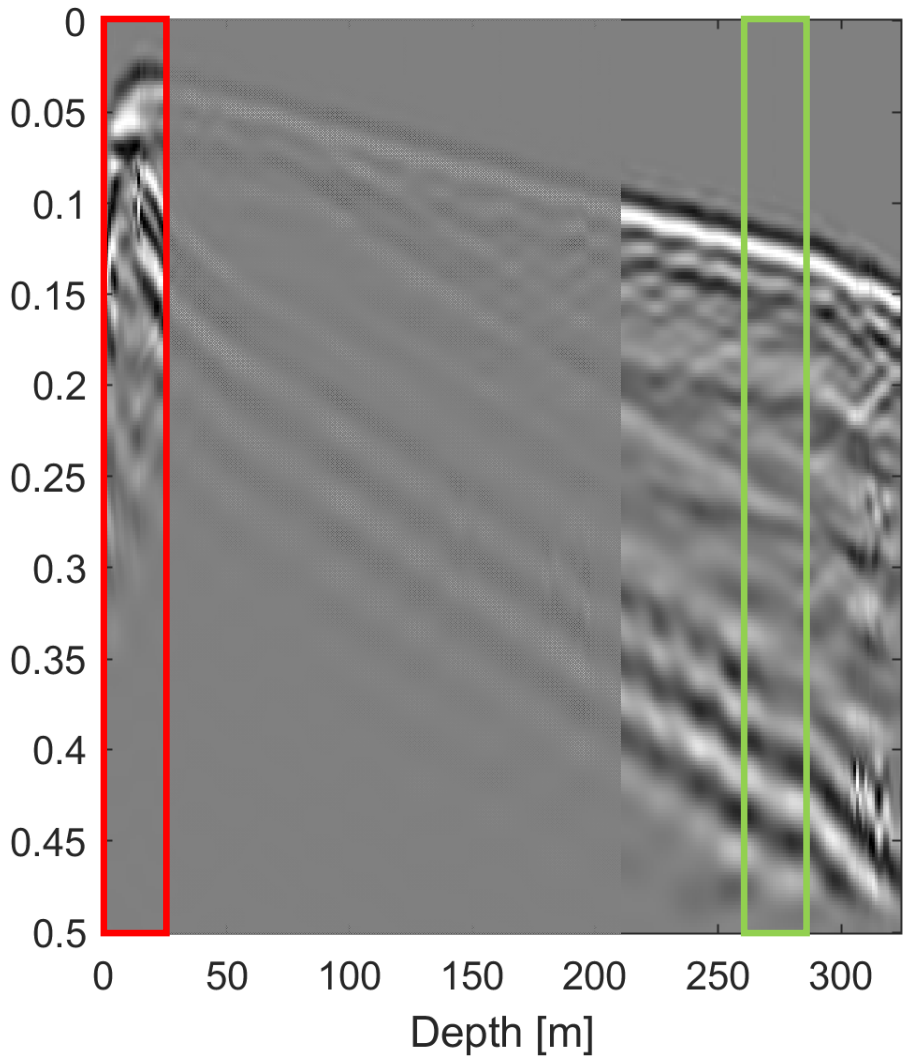
Near surface complications





Near surface complications



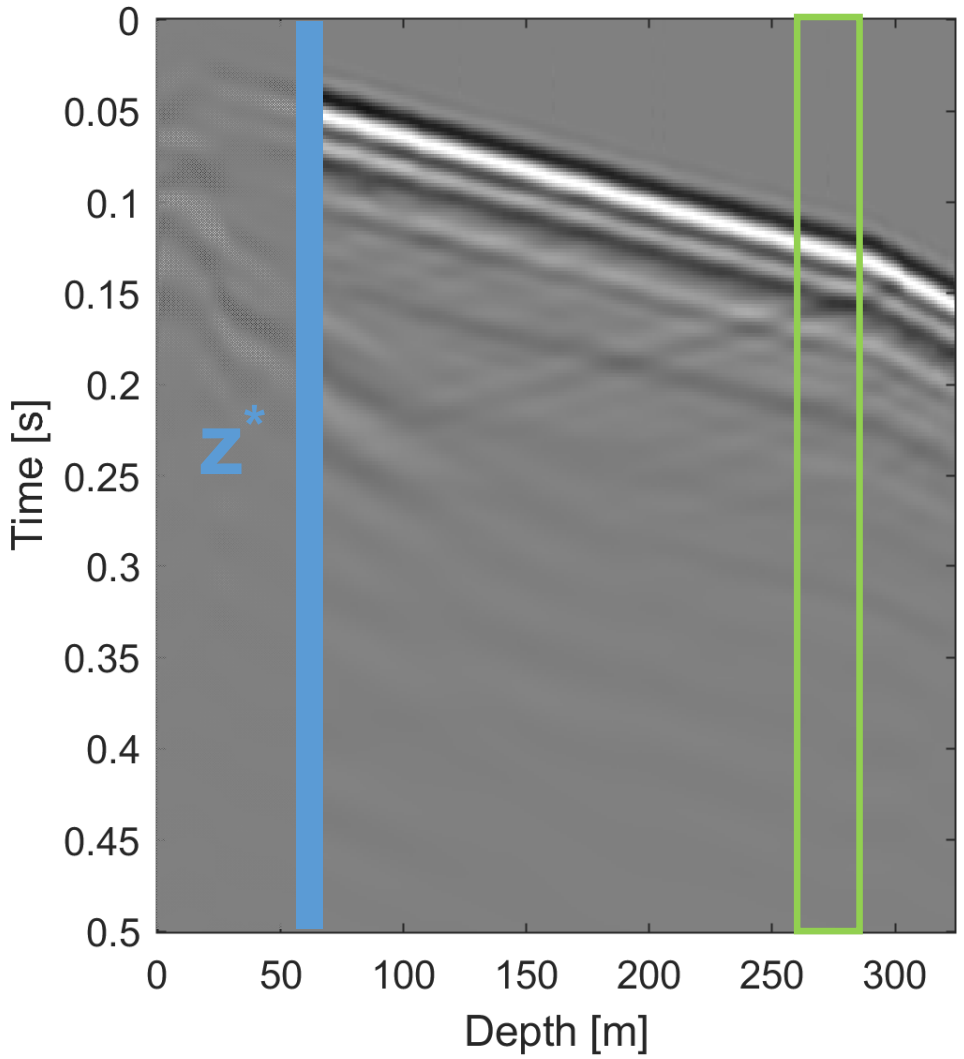


Near surface complications

How can we account for the effects of the near surface on our observed data without needing to explicitly characterize it?

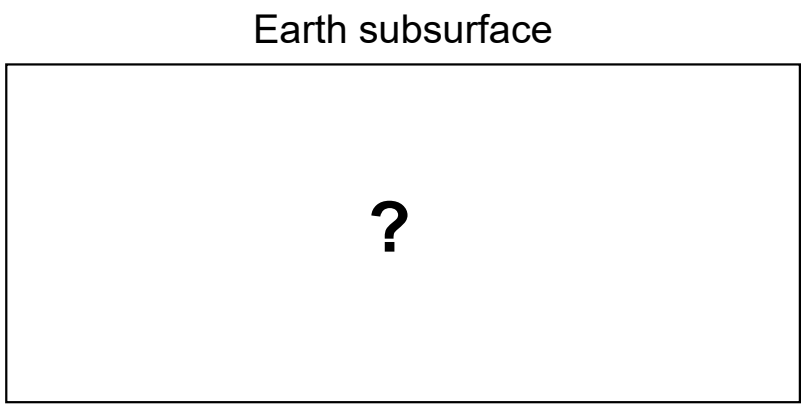
Effective sources

- Interaction with the near-surface changes the downgoing wavefield
- We learn about the **target** through the interaction of the wavefield and medium at the target depth
- Knowing the **wavefield** at z^* would eliminate need for near-surface modeling

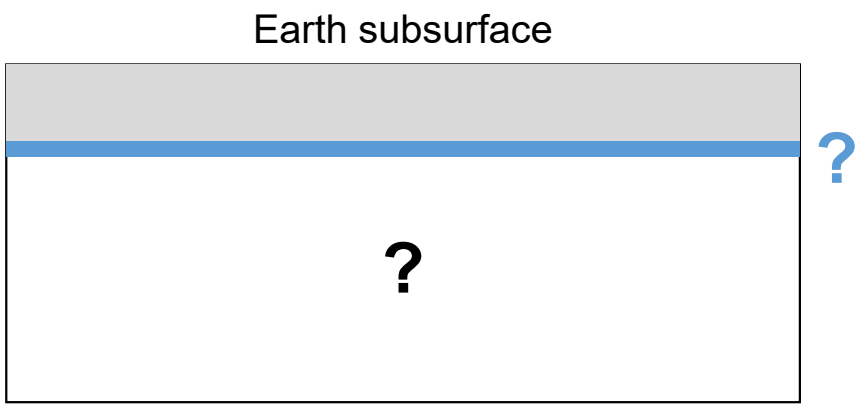


Effective sources

- We can remove the near-surface by including an **effective source**
- This is the source term that generates the same wavefield at depth as propagation through the near-surface
- The effective source becomes another unknown in our inversion

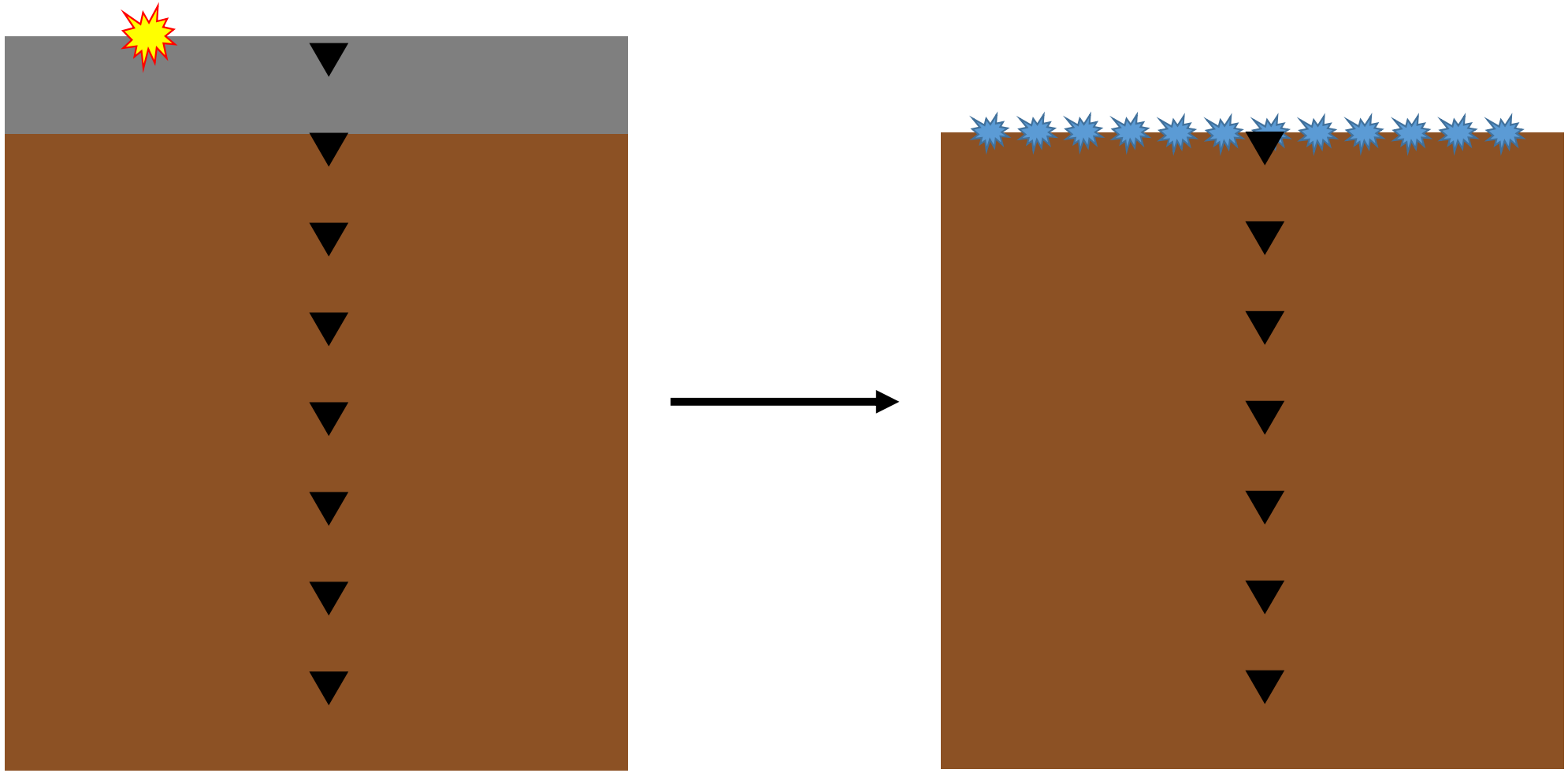


Conventional FWI



Effective sources FWI

Effective sources



FWI for sources and model

FWI for elastic properties:

$$\frac{\mathrm{d}\phi}{\mathrm{d}m} = < \frac{\partial S}{\partial m} u, \kappa >$$

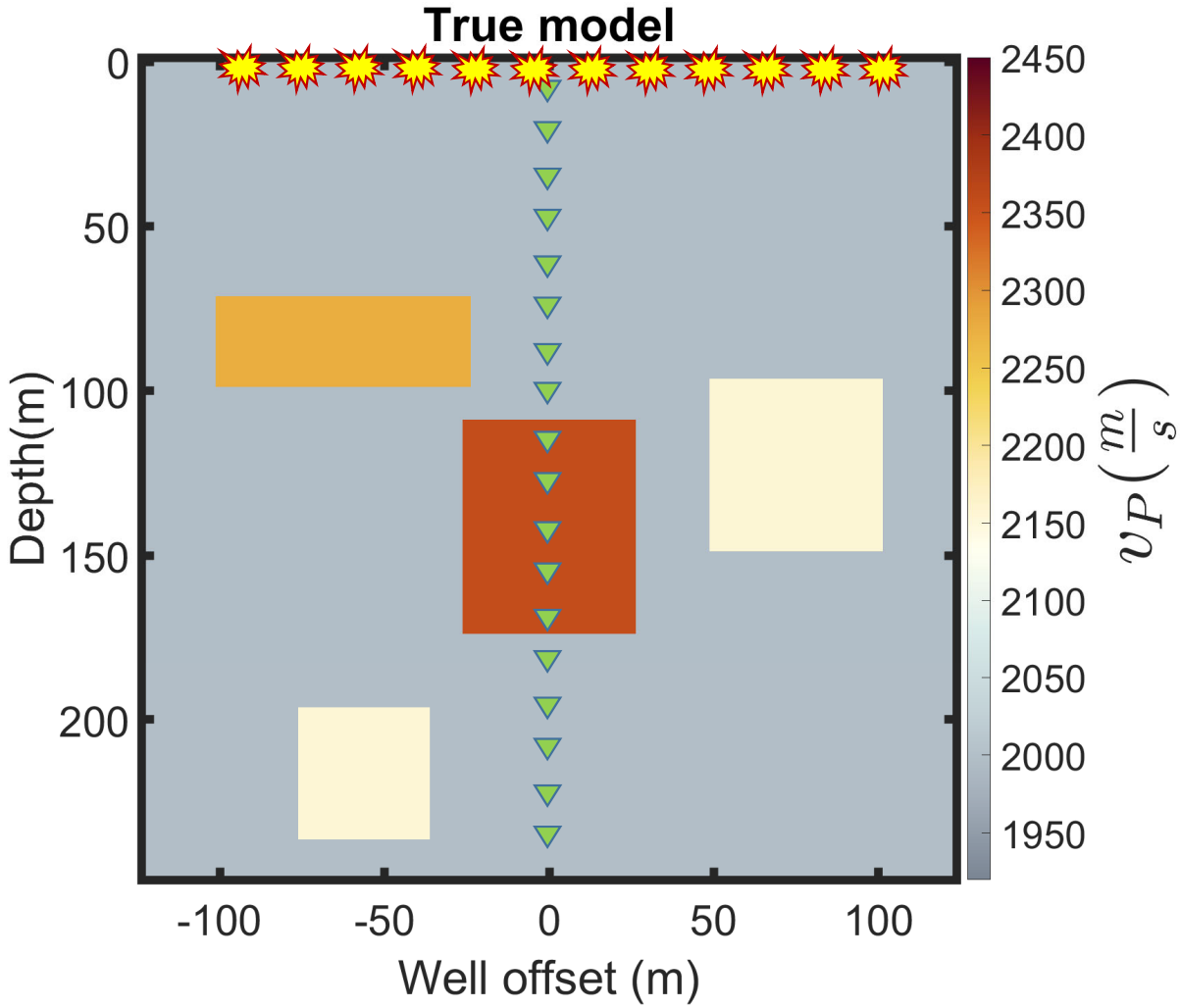
FWI for source term:

$$\frac{\mathrm{d}\phi}{\mathrm{d}f} = \kappa$$

Same per-iteration cost to include effective source

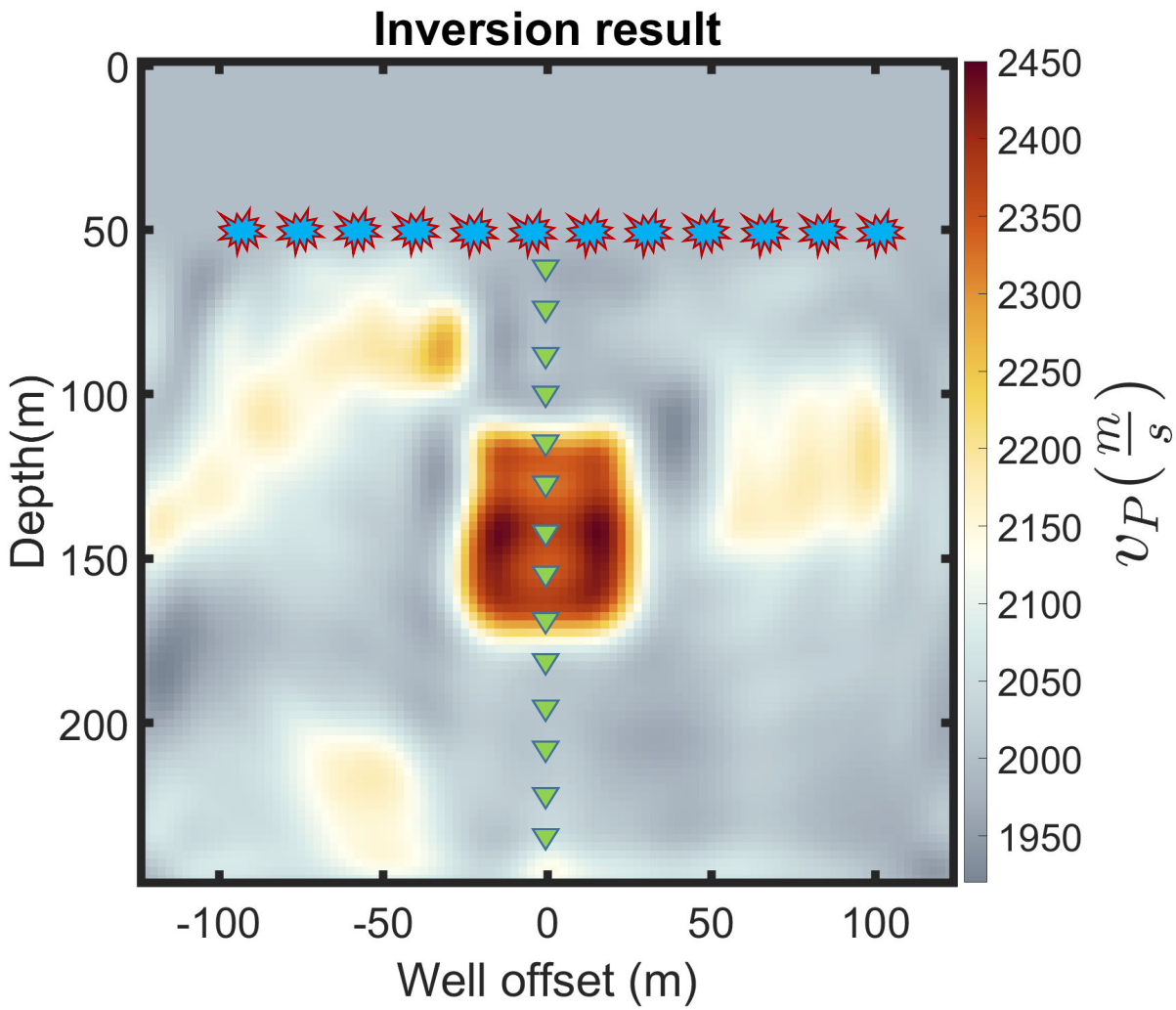
Numerical example

If we replace the **known** sources with an **unknown** effective source at depth, how will the inversion be affected?



Numerical example

In synthetic tests, we can recover an accurate model with effective sources



Conclusions

Vertical seismic profiles provide good data coverage for FWI application

Near-surface issues can be bypassed by considering an effective source FWI

Simultaneous inversion of effective sources and subsurface model can achieve good accuracy

Acknowledgements

- CREWES sponsors, staff and students
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CREWES

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