Source-model simultaneous FWI

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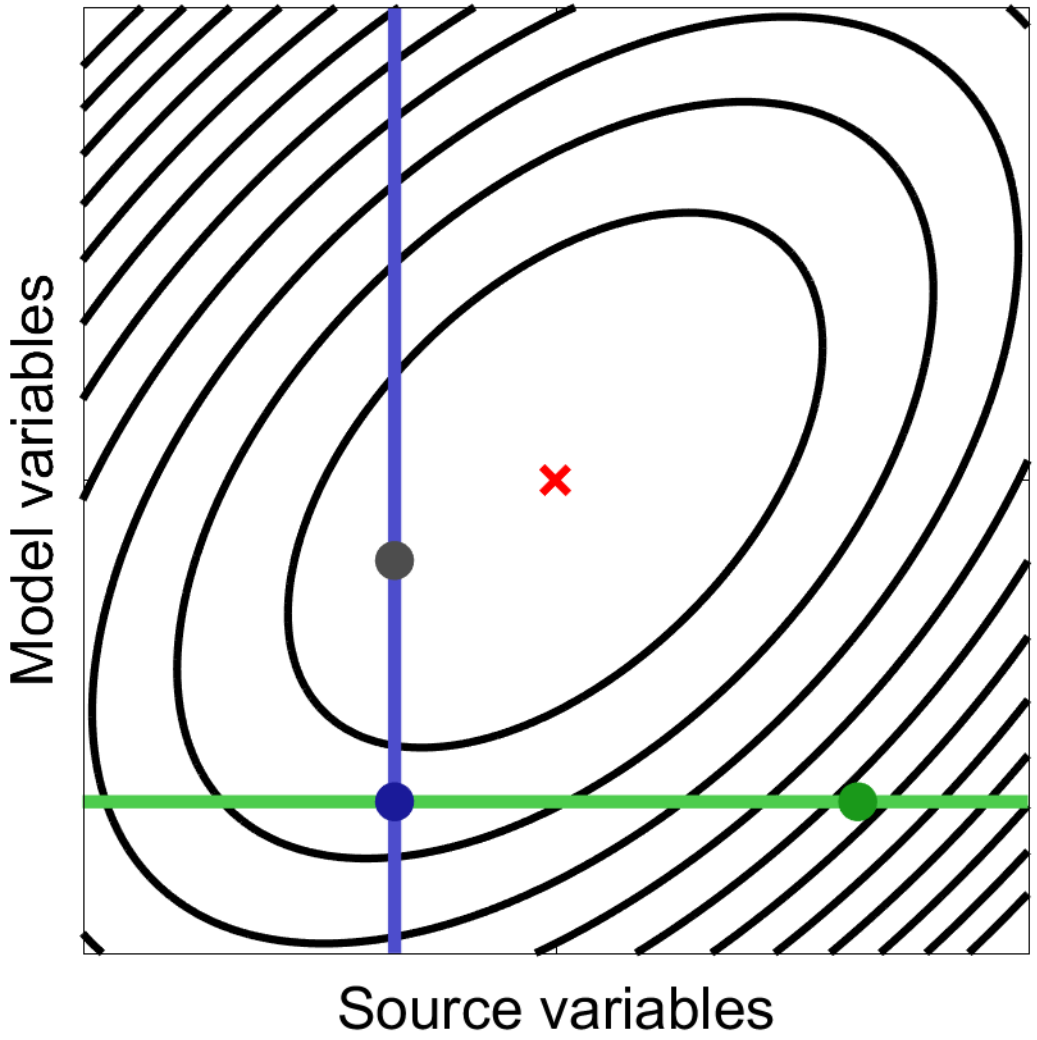
Sequential and simultaneous inversion

- In some applications, we want to recover seismic moment tensors at unknown locations (e.g. microseismic events)
- It may be useful to use the same data to improve the subsurface model
- When both these classes of variables are desired, we need to decide on either sequential or simultaneous inversion

Sequential inversion

- In sequential inversion, we first invert for one set of variables, then the other
- This can introduce significant uncertainty if the estimates strongly influence each other
- It can be effective and efficient otherwise



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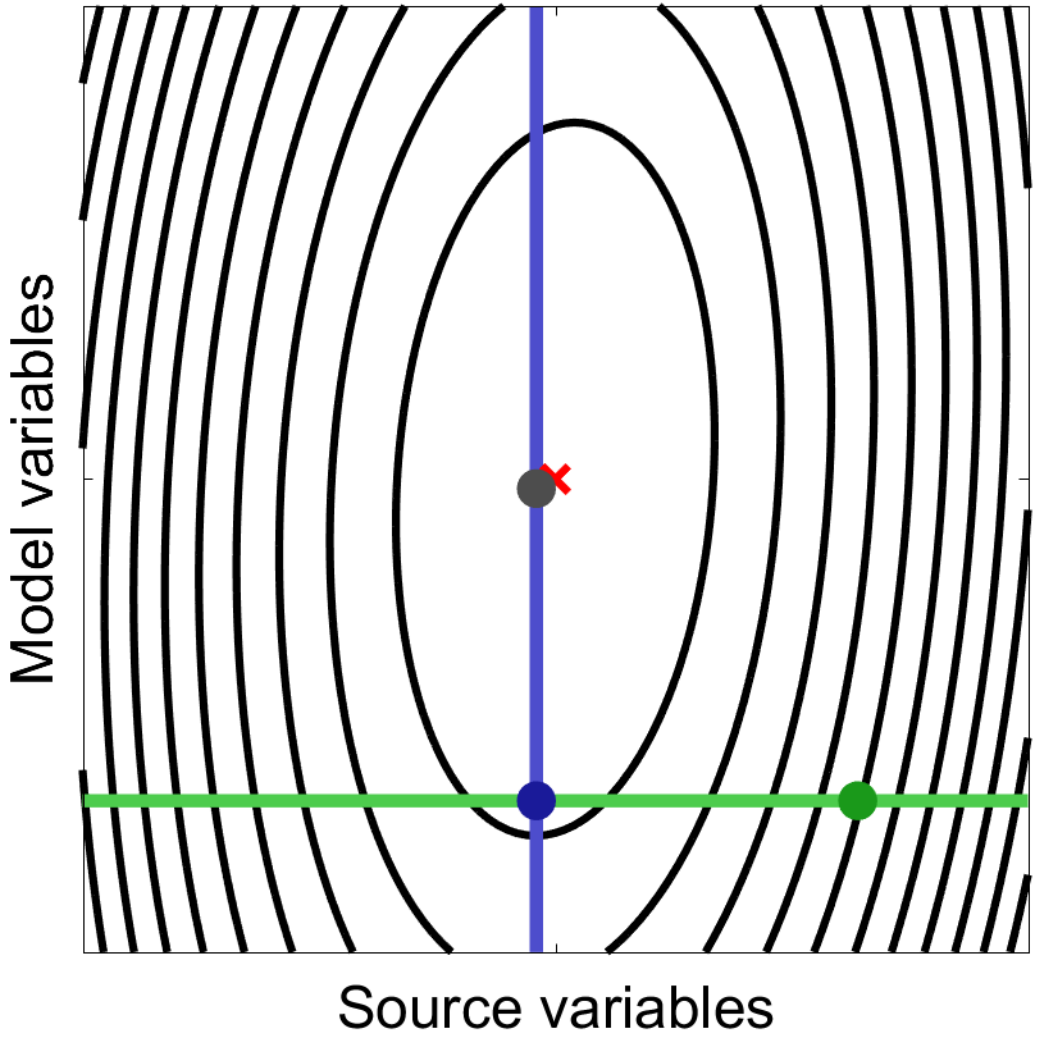
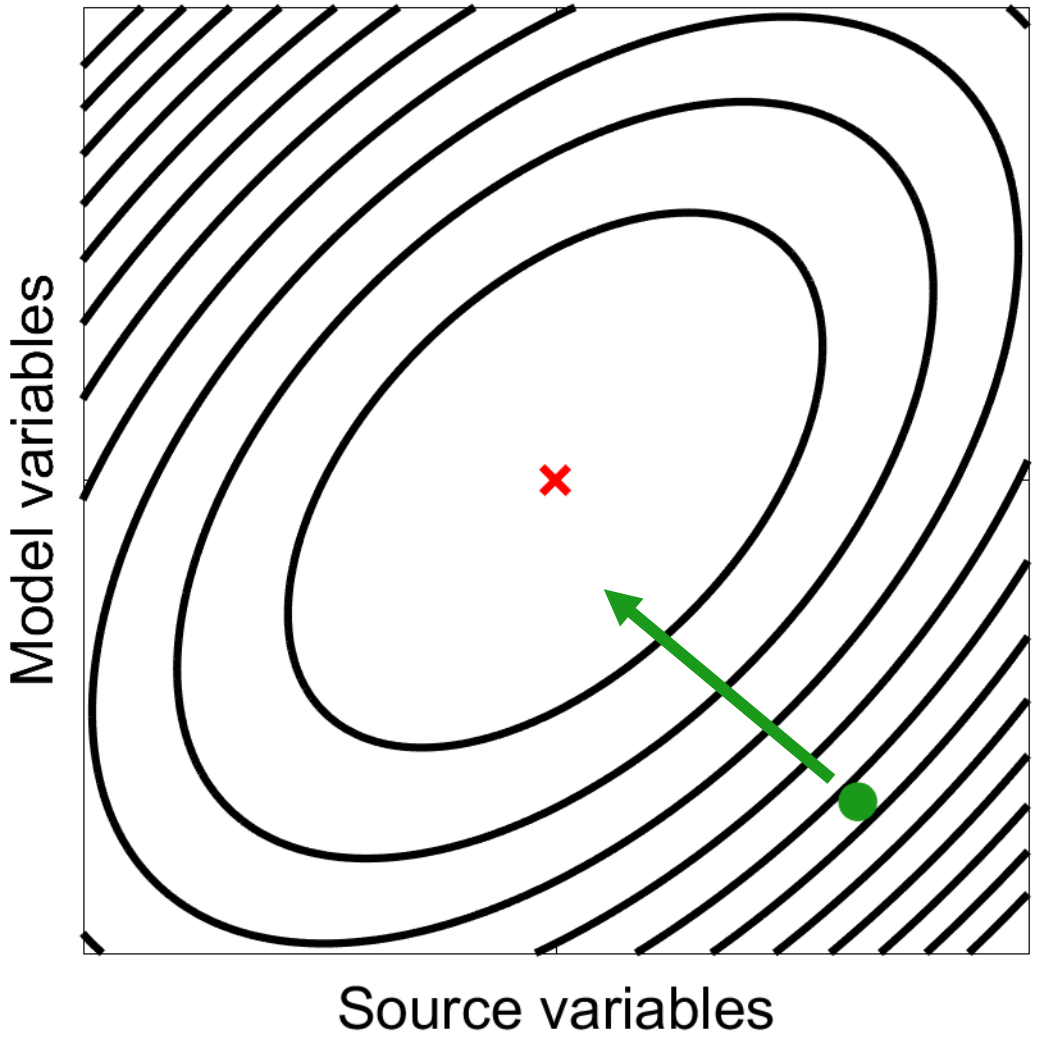


Simultaneous inversion

- In simultaneous inversion, we invert all sets of variables at once
- This can improve results if the variables strongly influence each other



FWI for model and source terms

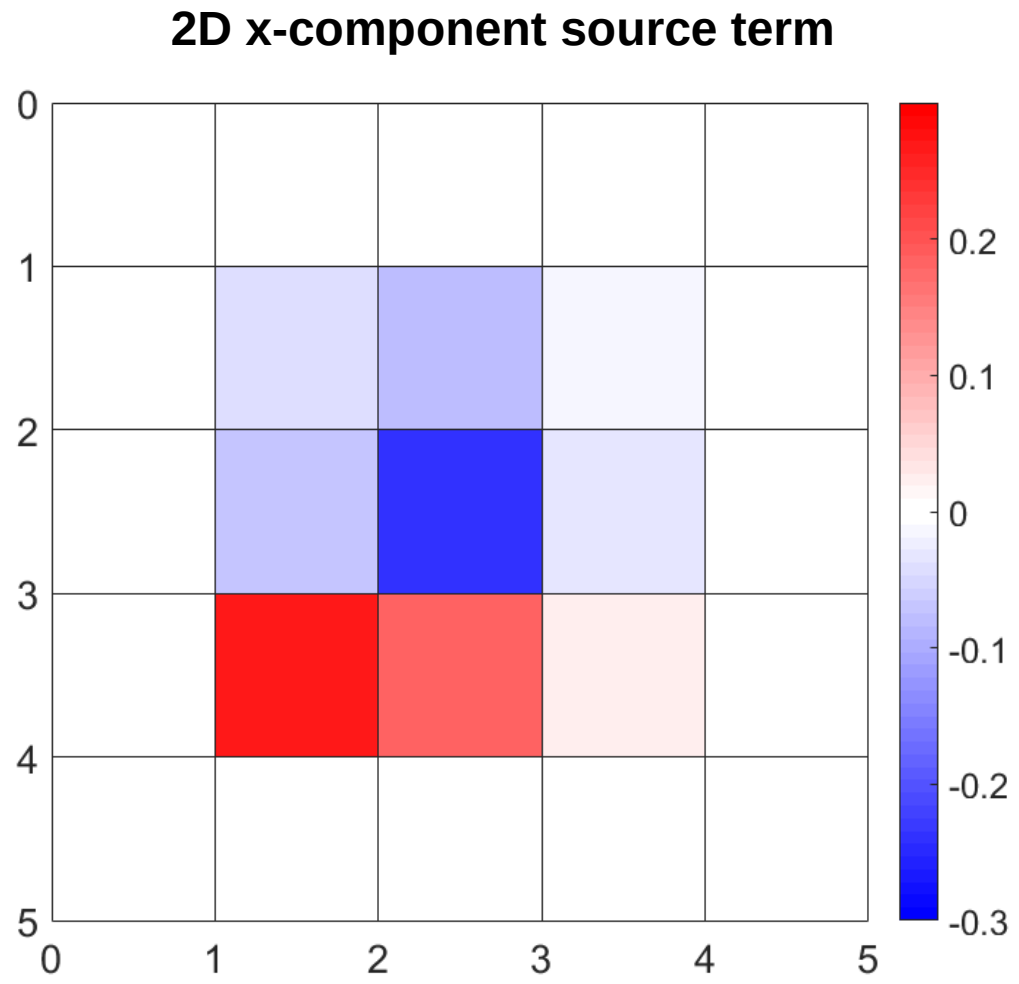
- FWI gradient uses same wave propagations for both model and source terms
- Per iteration cost of simultaneous FWI is about the same as in model-only FWI
- Naïve parameterizations introduce problems

Parameterizing source terms

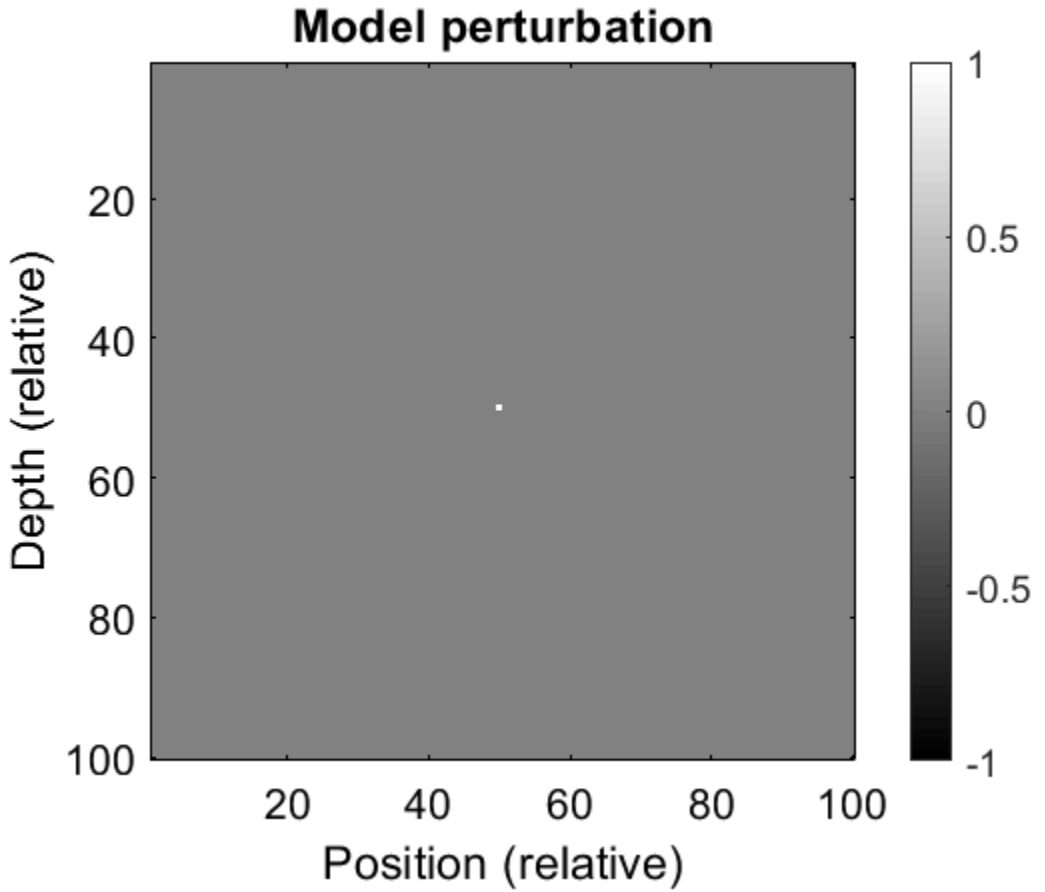
- A source term can be define at each point in space, at each frequency or time, for each source
- With this many variables, FWI becomes very poorly conditioned, nonlinear, and difficult to solve
- To make the problem manageable, we assume point sources and known frequency dependence, but arbitrary moment tensors and event locations
- We define our variables as x and z location, M_{zz}, M_{xx}, and M_{zx} for each source

Model parameterization

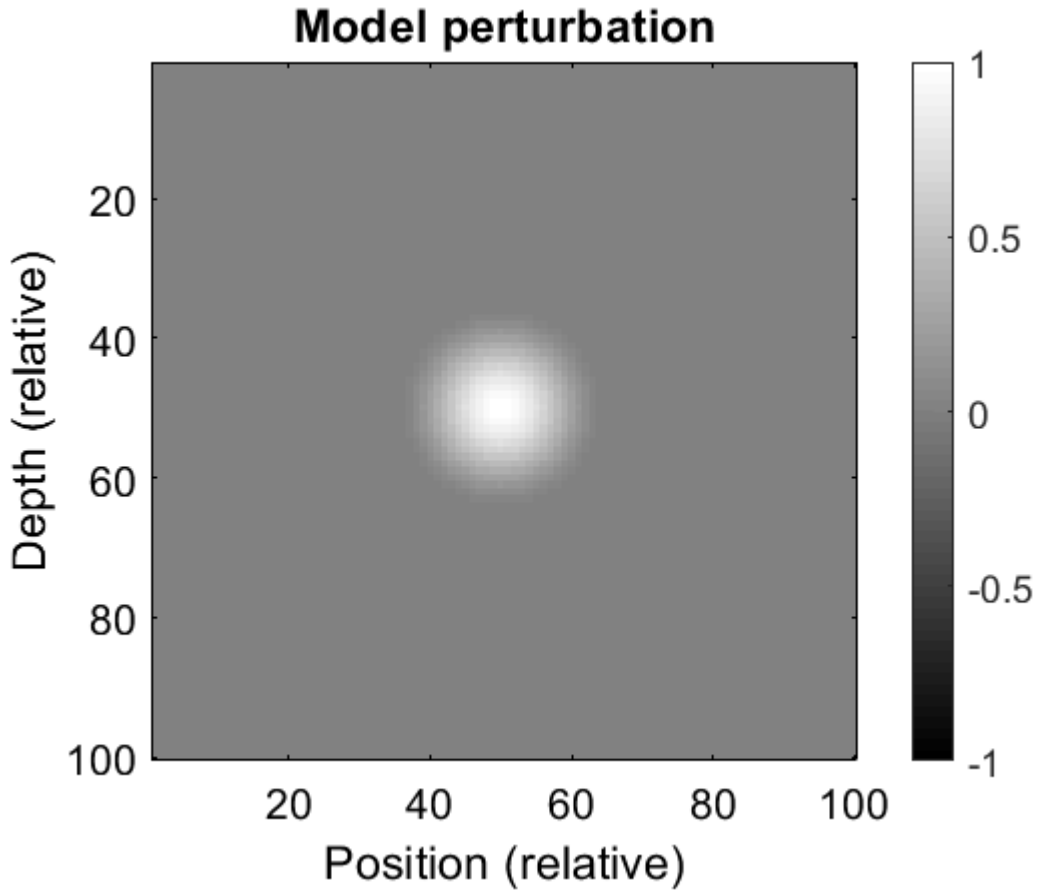
- Finite-difference modeling of seismic point sources uses multiple finite difference grid cells (i.e. point sources are represented by a 2x2 or 3x3 square of cells)
- Model changes which alter specific parts of the source can have far more impact on the inversion result than model changes which modify propagating waves
- This can lead to artifact-dominated models



Model parameterization

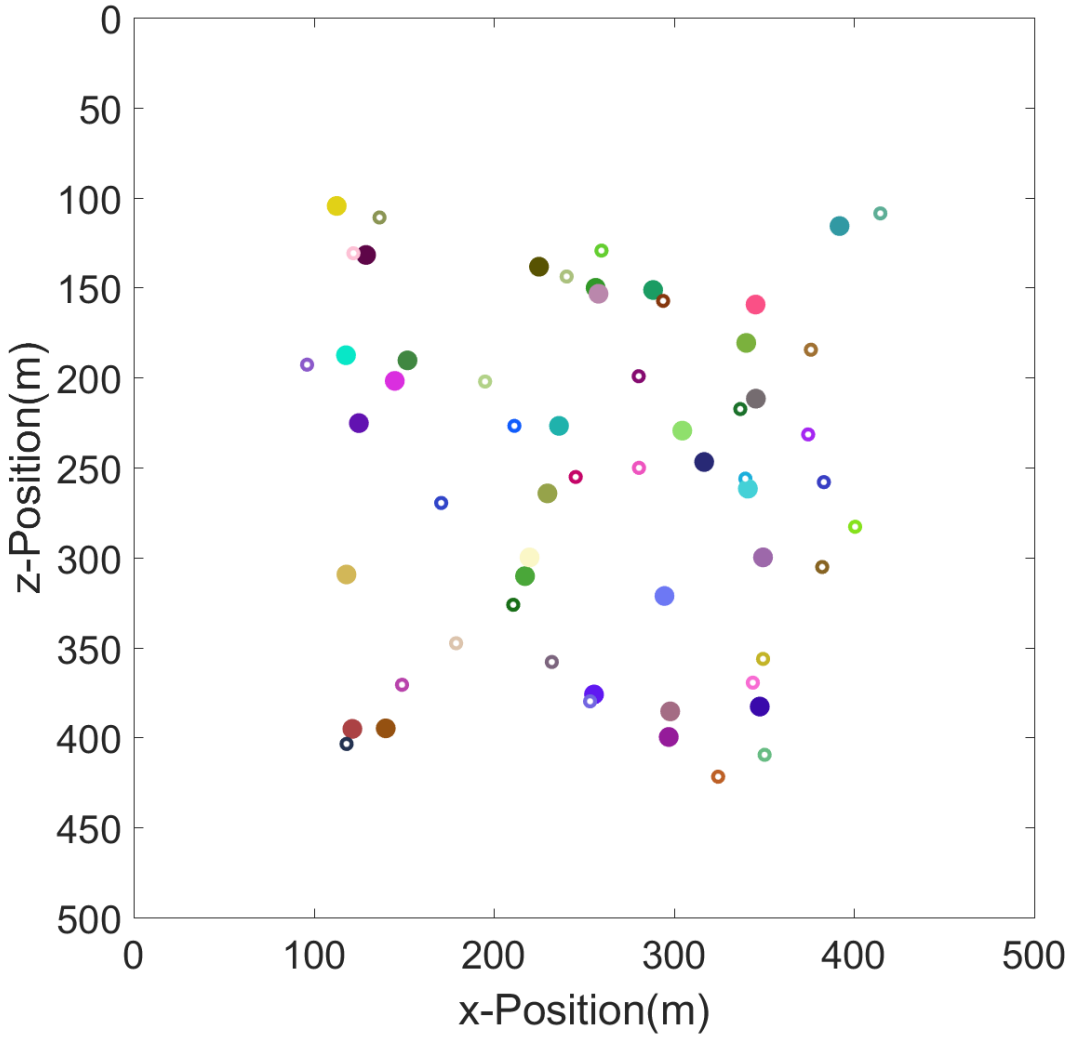


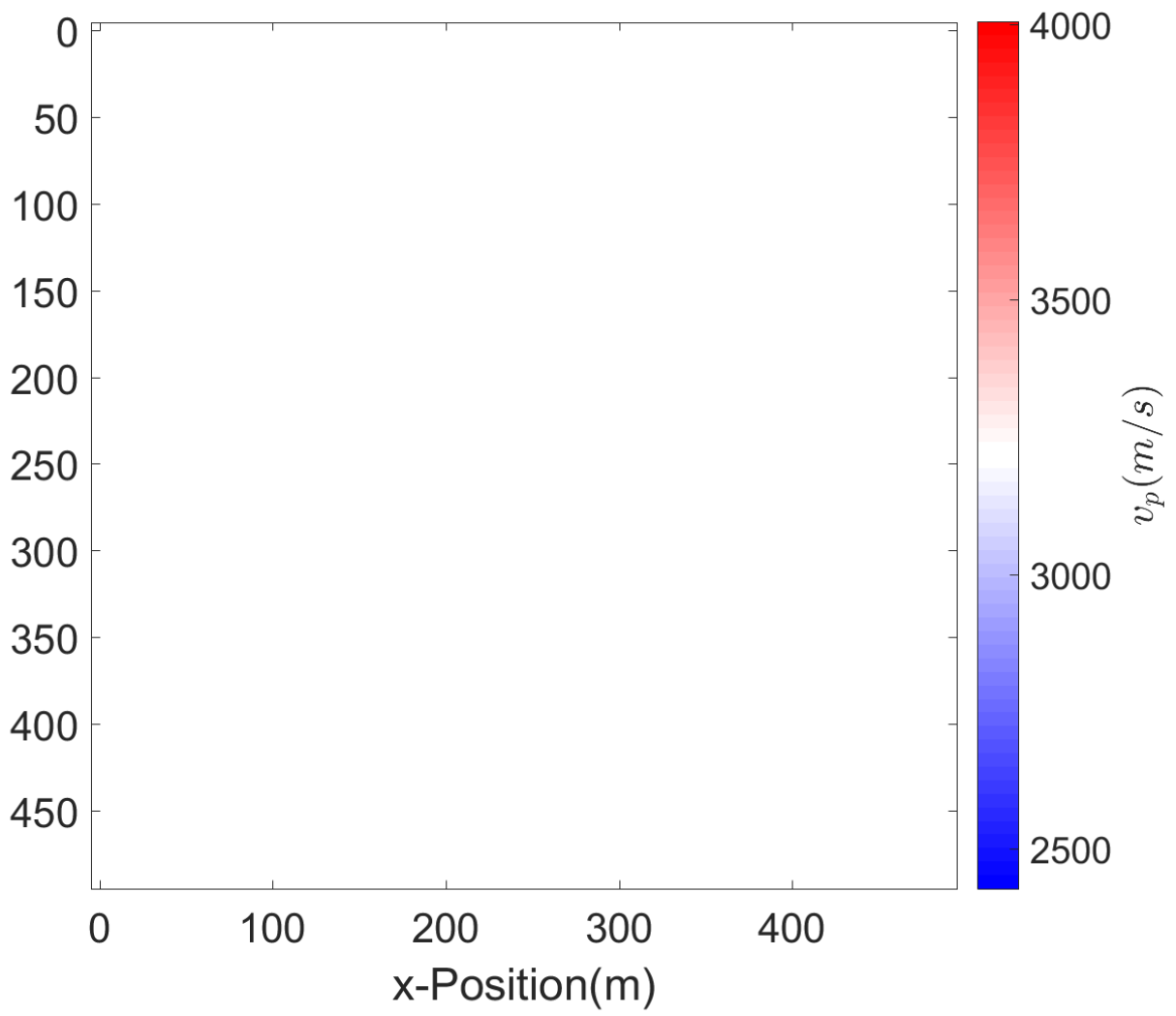
- Conventional FWI parameterization
- Model changes on scales smaller than point-source star – leads to source artifacts



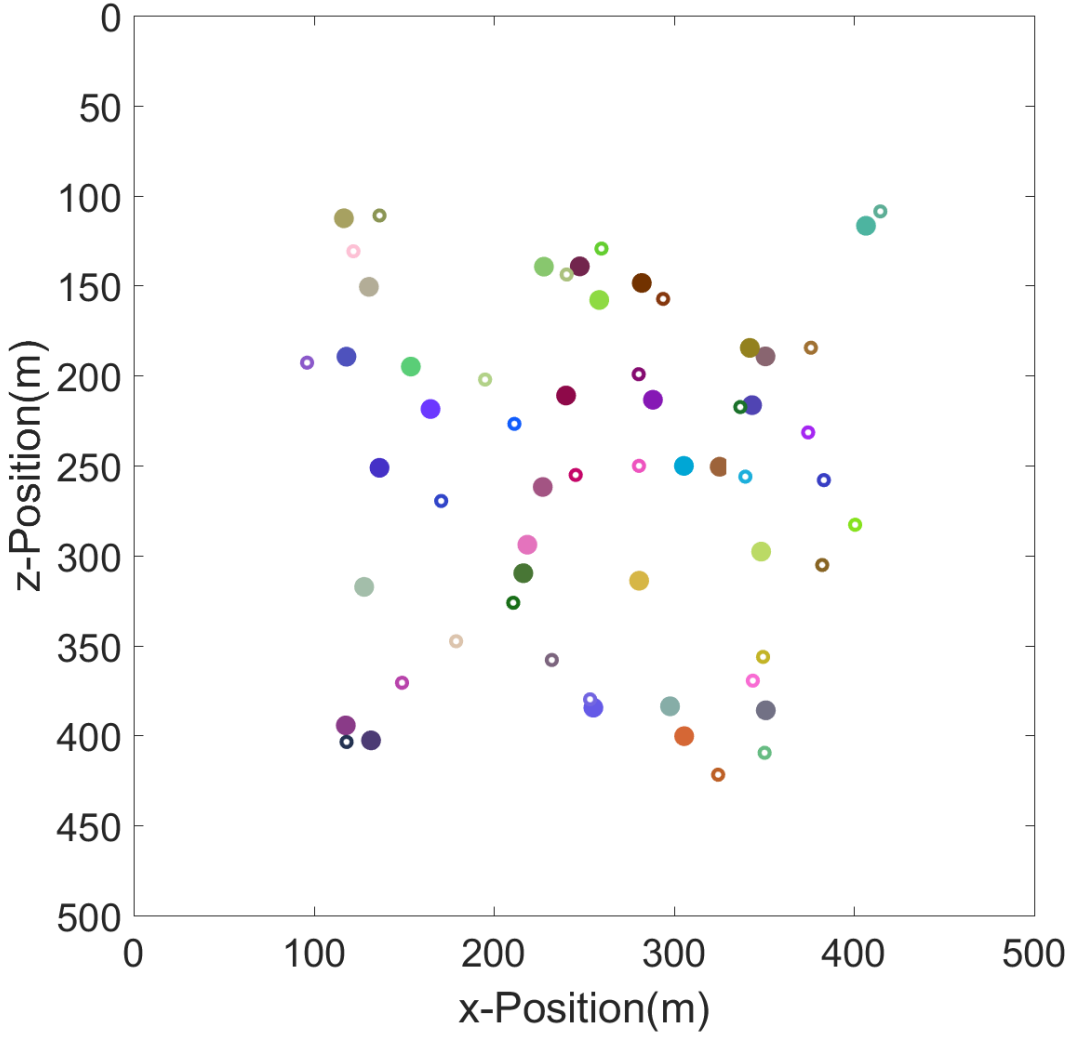
- Gaussian basis function parameterization
- Model changes only on scales larger than point-source stars

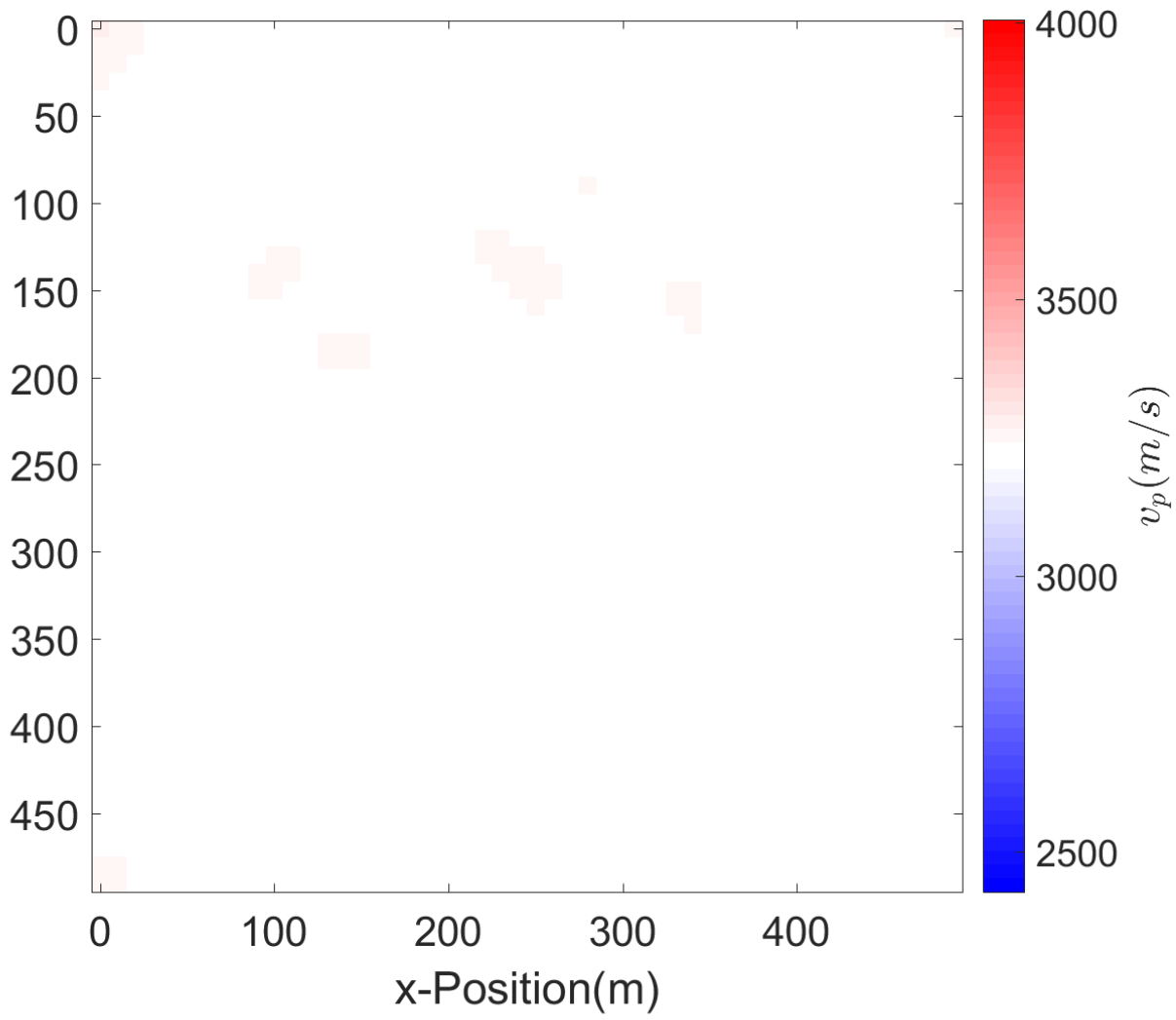
Initial estimate of sources and model



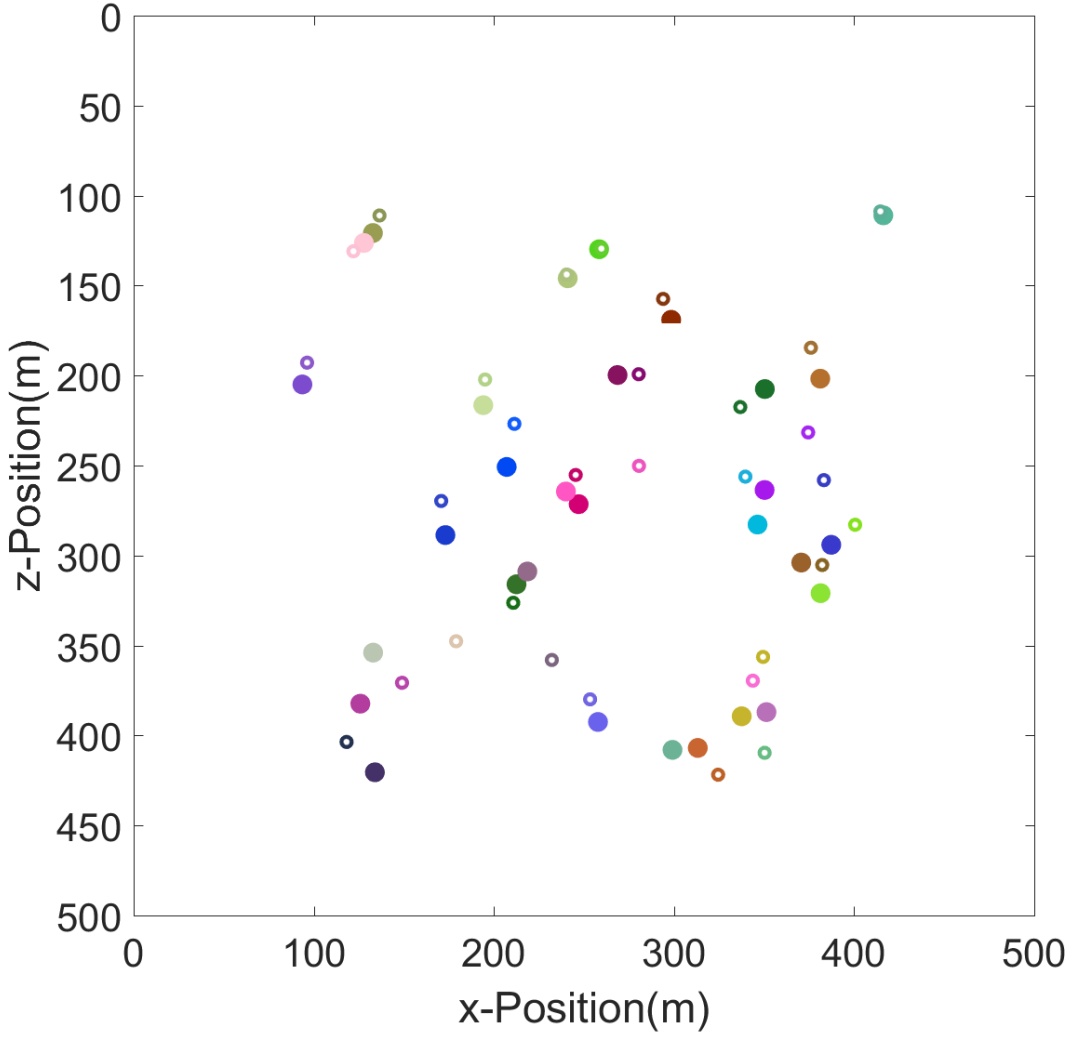


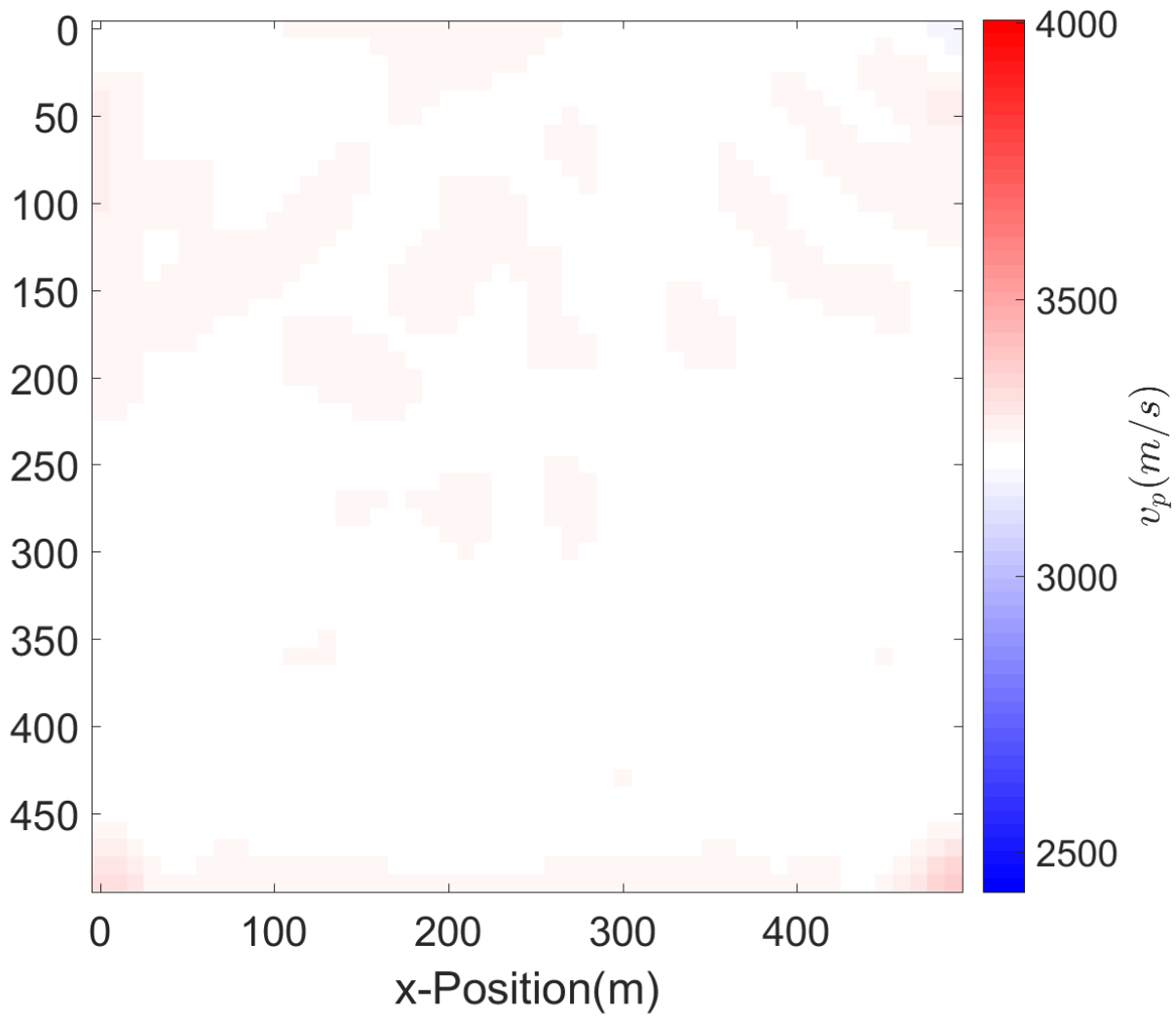
Inversion estimate – 1 iteration



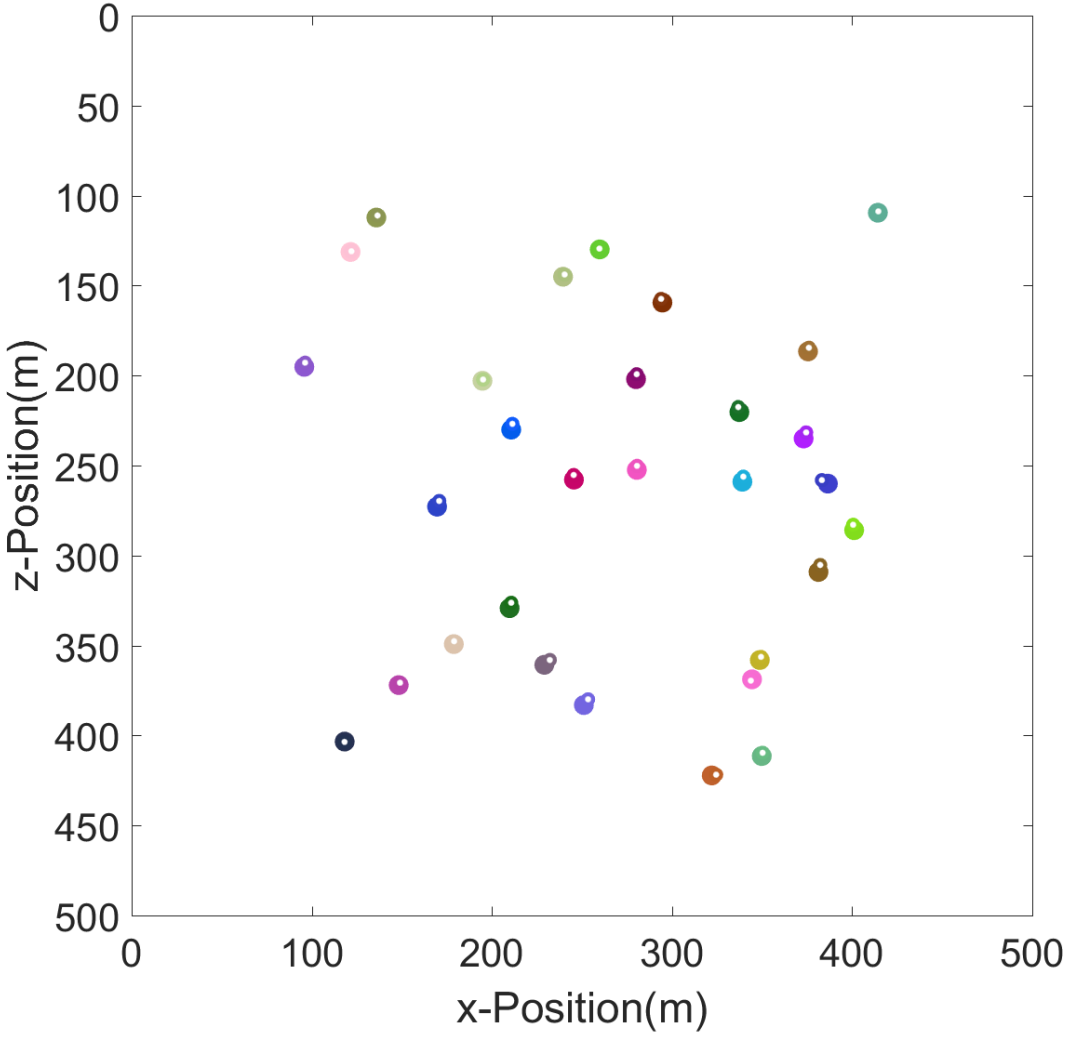


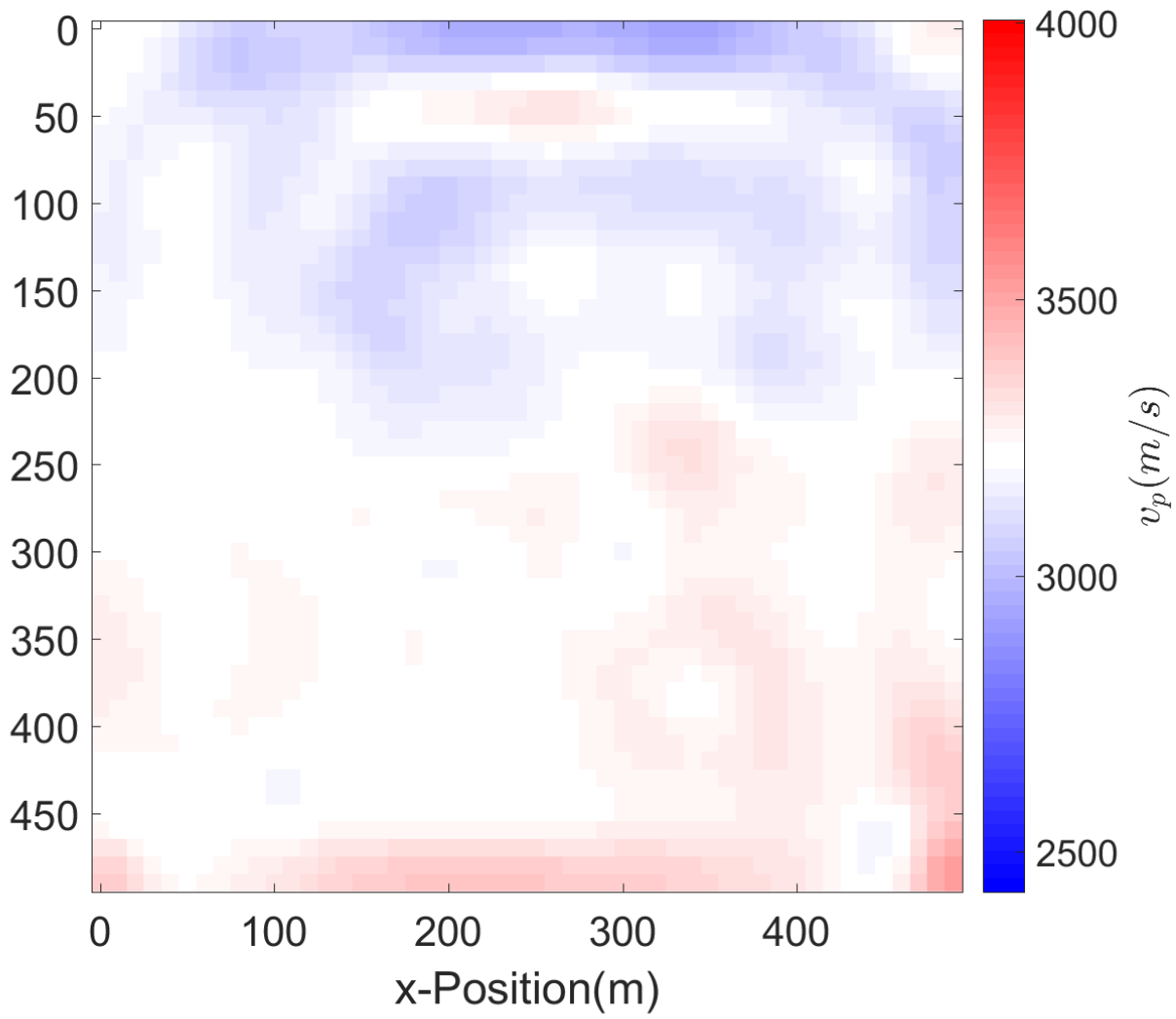
Inversion estimate – 2 iterations



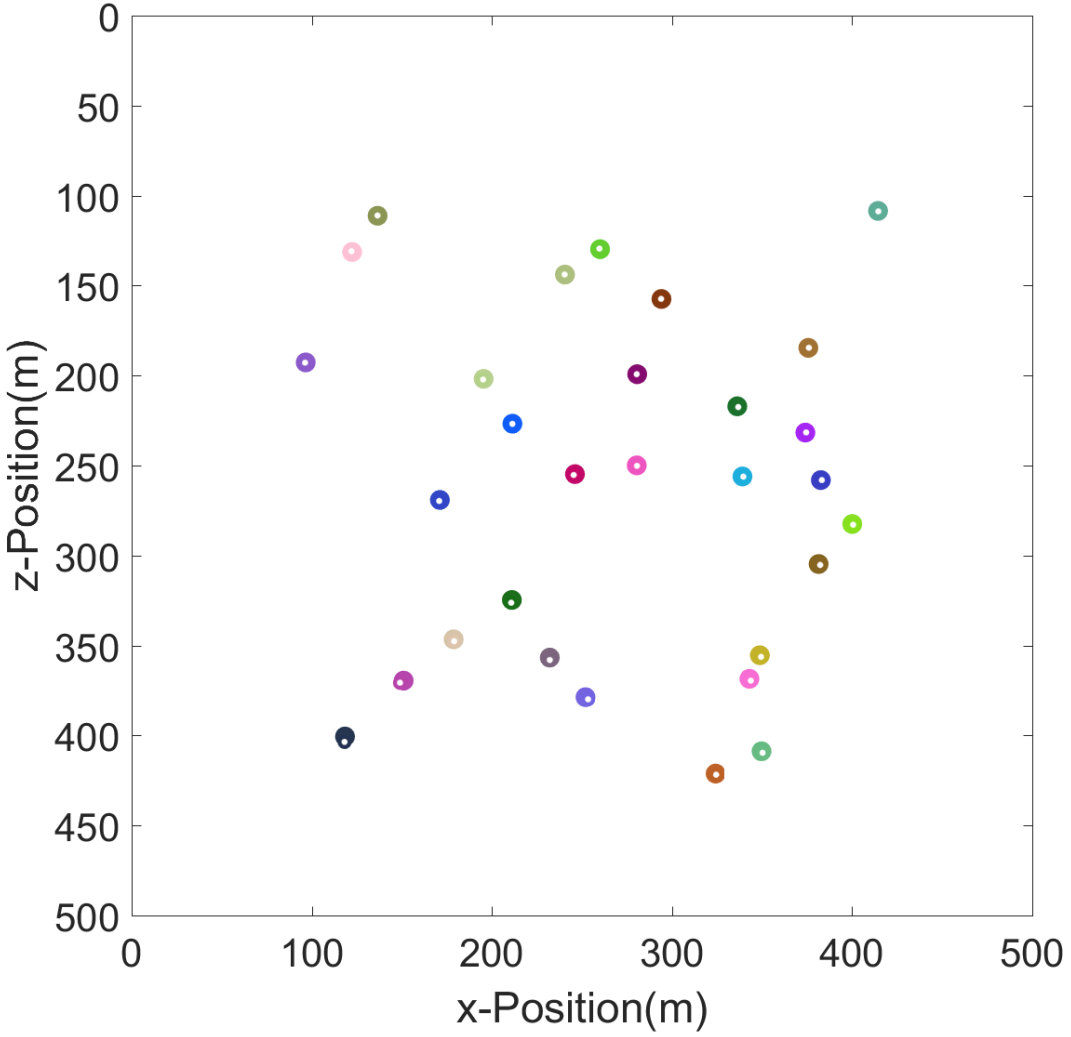


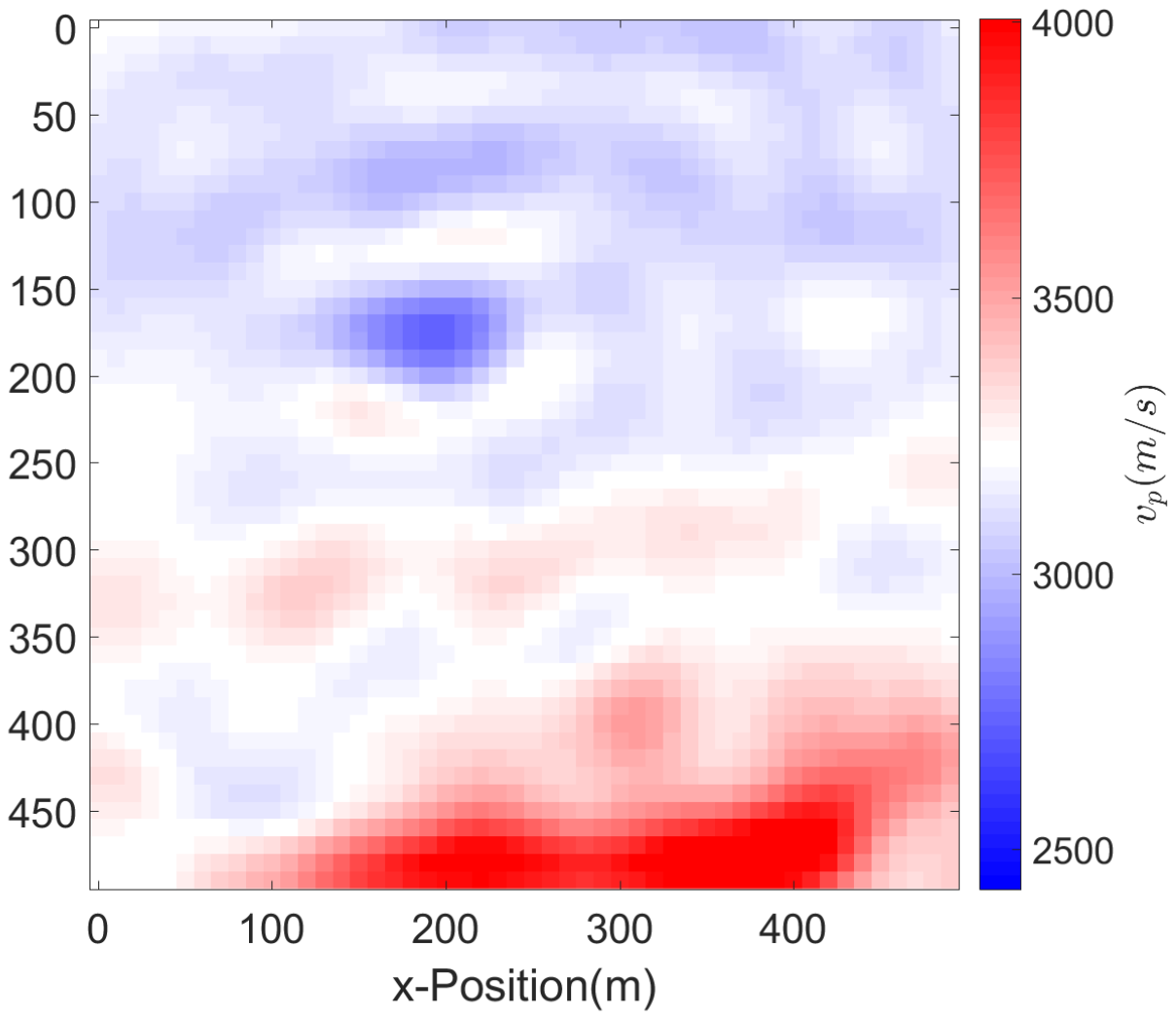
Inversion estimate – 10 iterations





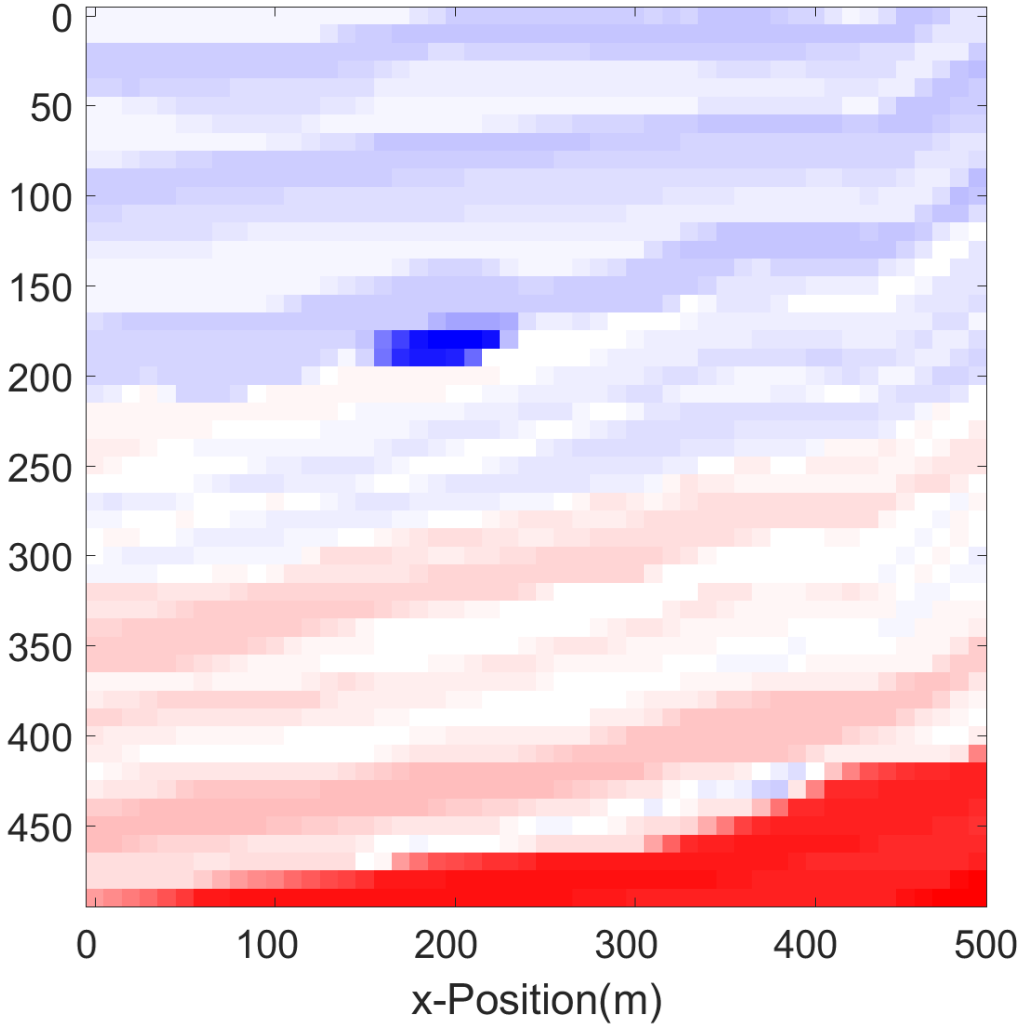
Inversion estimate – 40 iterations



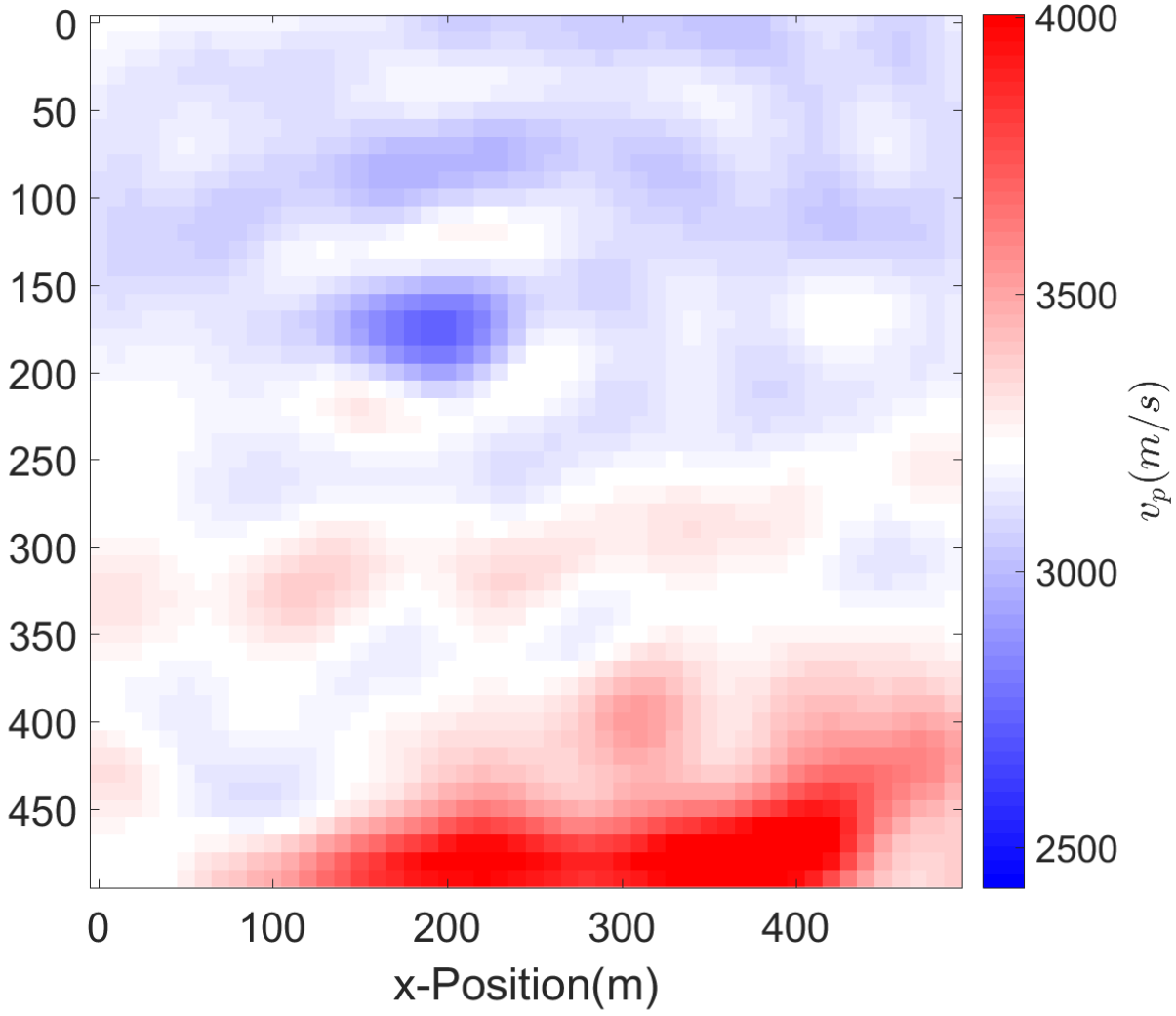


V_P model

True model



Inversion result



Conclusions

- We have developed a FWI approach for simultaneously recovering viscoelastic earth properties, source locations and source mechanisms, and applied it on a simple synthetic 2D problem
- Parameterization plays a key role
- Moment tensor estimation does not seems strongly related to the model estimate
- Simultaneous recovery of long wavelength structure and source locations may be useful

Acknowledgements

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CREWES

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