

Fast RTM with multiples and source estimation

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Main messages

Demonstrate how *linearized* inversion

- can be carried out *efficiently*
- modelling errors can be *mitigated*

by *sparsity-promotion accelerated by rerandomization*

Demonstrate how *surface-related multiples* can be

- *imaged* by including the *upgoing* wavefield as an *areal* source
- used to estimate the *source function on the fly*

Disclaimer

Assume that

- *receiver-side ghost* has been *removed by processing*
- we have access to *kinematically correct background* velocity models

Results are on *synthetic* 2D ... Will keep you posted on 3D & field data.

'Ideal' imaging vs inversion

[w/ primaries only]

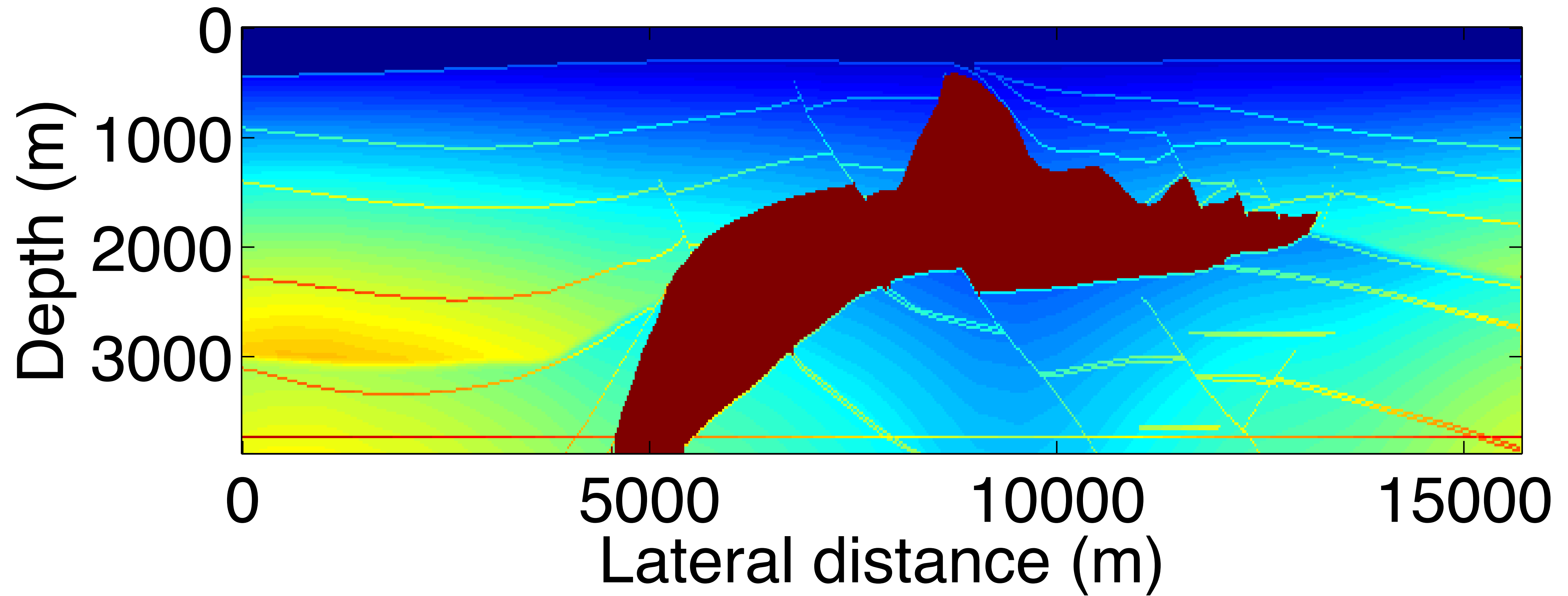
What are the *advantages* of iterative *inversion* over single-pass RTM *imaging*?

Can *sparsity*-promoting inversion be carried out *efficiently*?

How does *rerandomized* inversion handle *mundane* modelling *errors*?

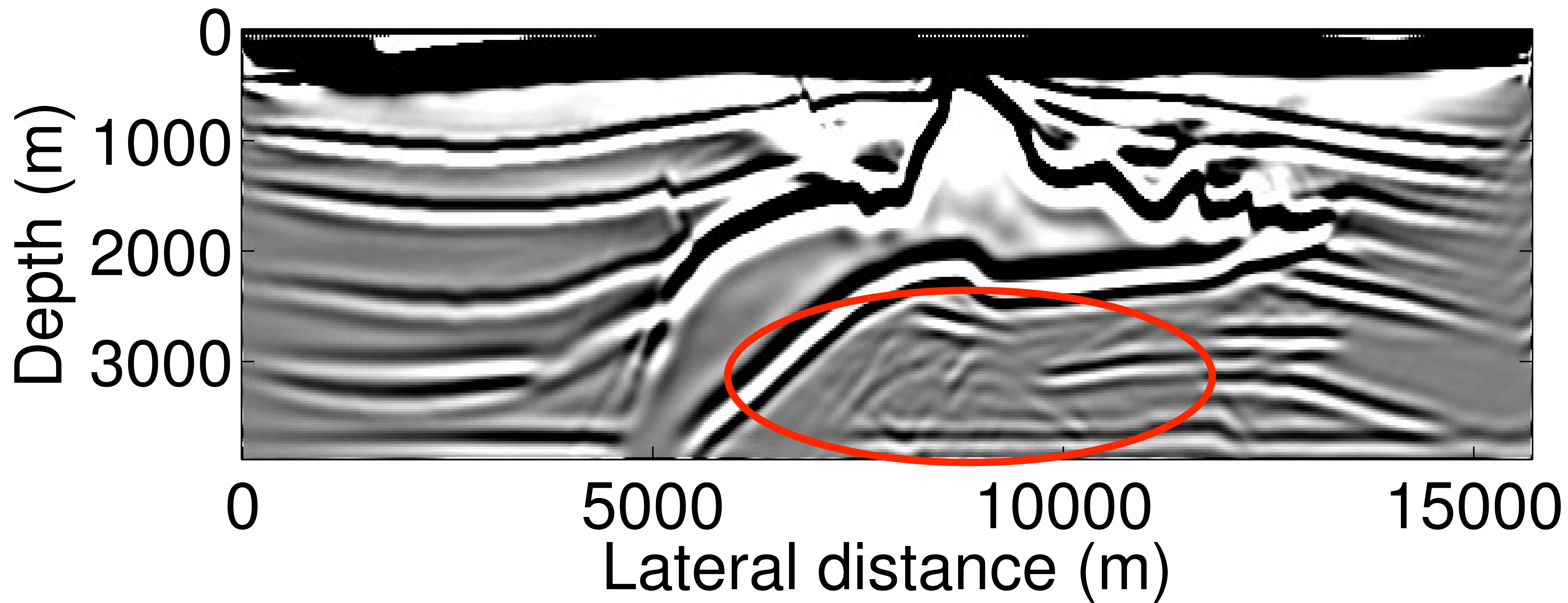
True model

[given source function (5Hz Ricker) & absorbing BC @ surface]



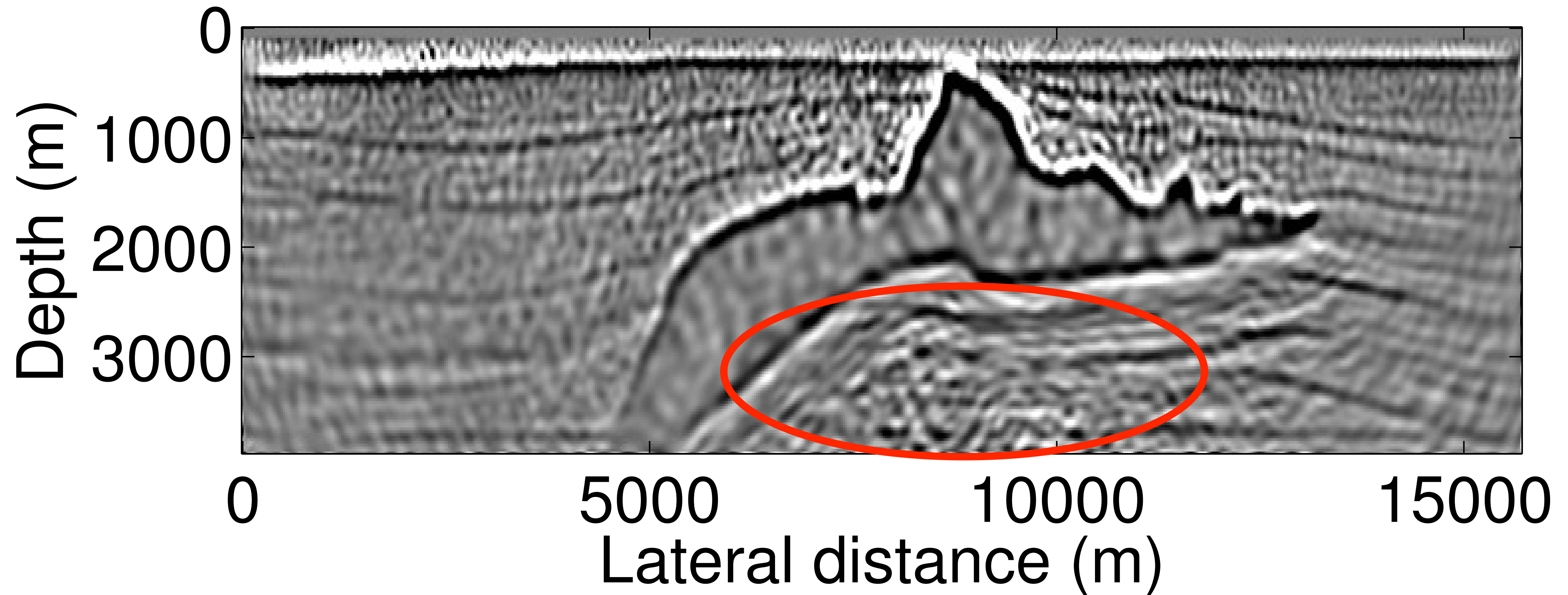
RTM

[w/ modeling errors and w/ all sources & frequencies]



Fast inversion

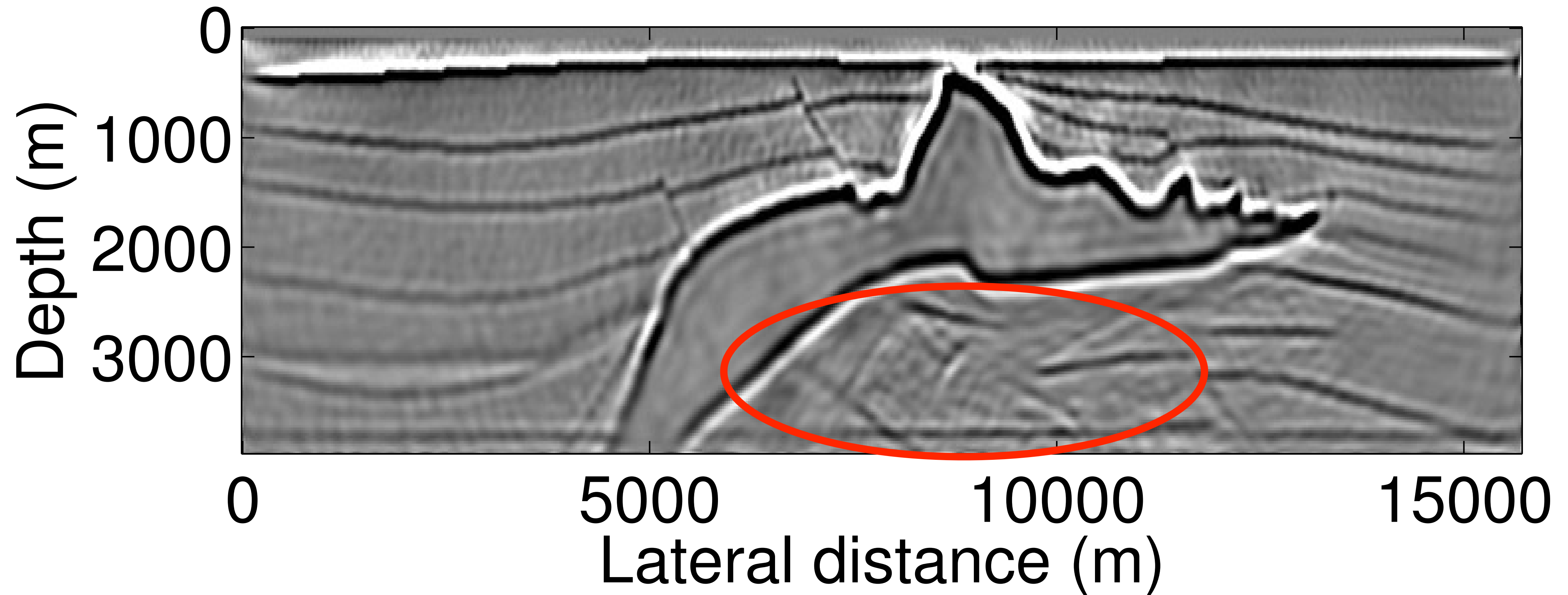
[w/ modeling errors and w/o **rerandomization**]



~1.45X the simulation cost of a single RTM with all data

Fast inversion

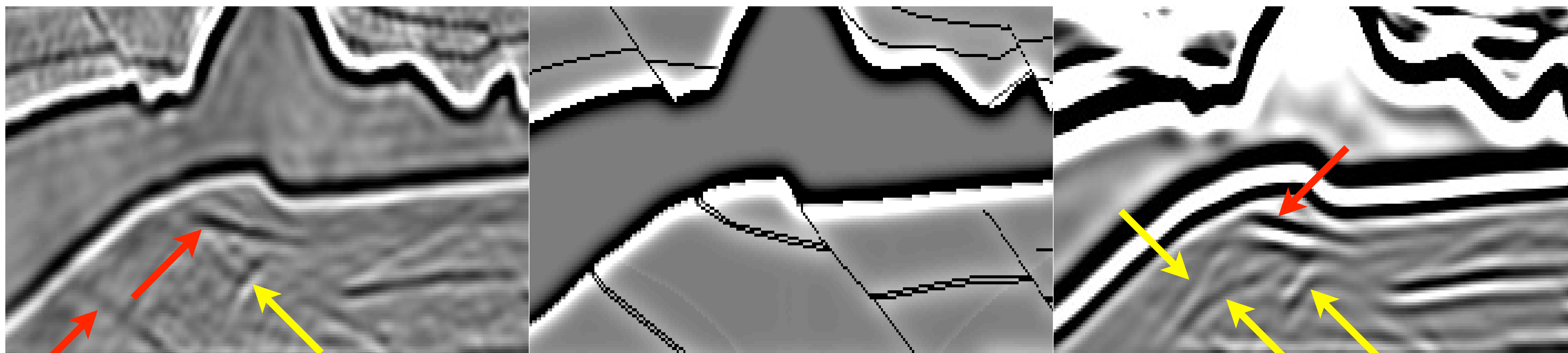
[w/ modeling errors and **w/ rerandomization**]



~1.45X the simulation cost of a single RTM with all data

Details

[red arrow: true reflector; yellow arrow: artifacts]



Fast inversion

True perturbation

RTM

Imaging vs inversion

What are the *advantages* of iterative *inversion* over single-pass RTM *imaging*?

- ▶ restoration of amplitudes for complex geology
- ▶ correction for the source & improved spatial resolution
- ▶ possibility to image cheaply by working with *randomized* subsets of data

Can *sparsity*-promoting inversion be carried out *efficiently*?

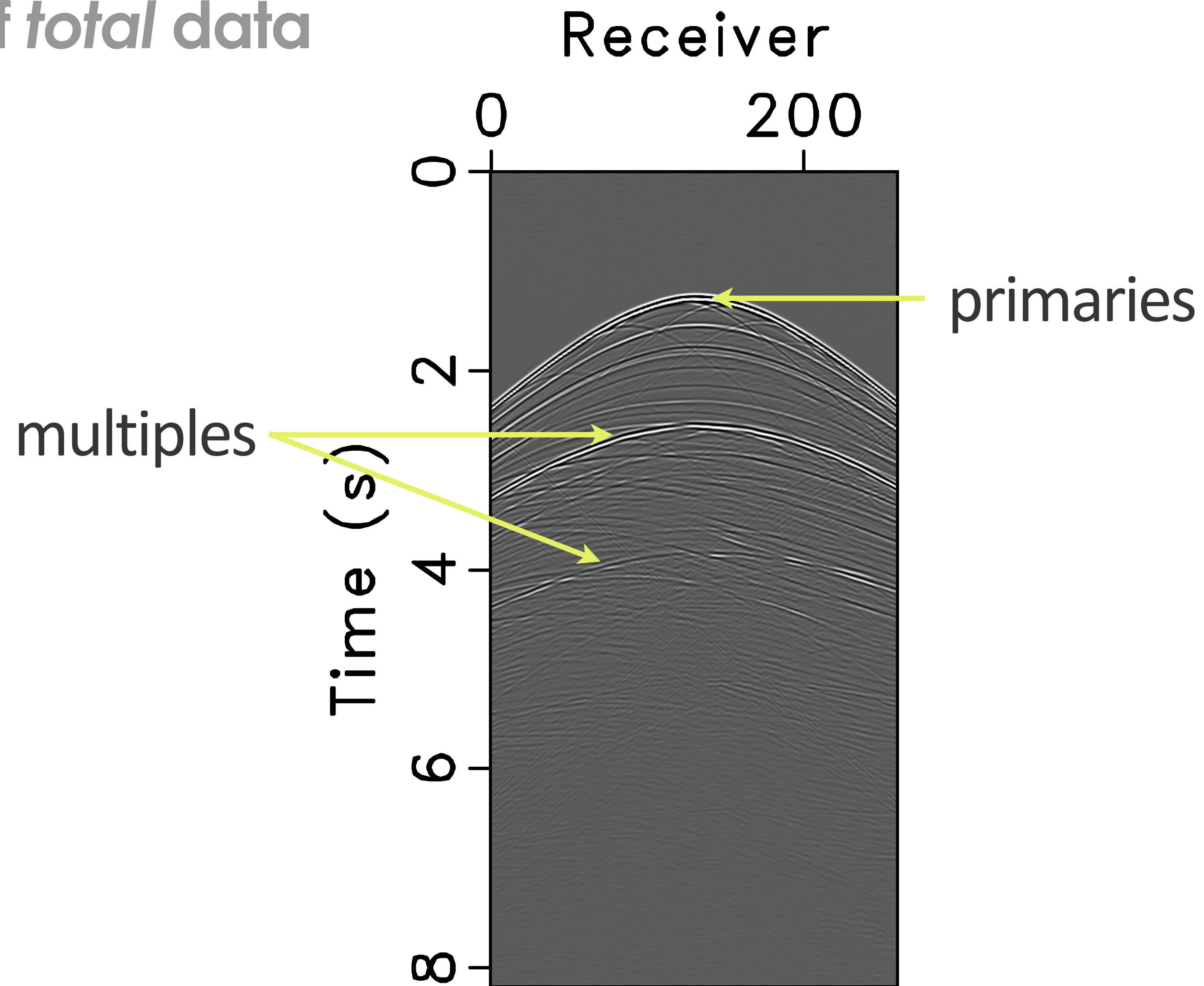
- ▶ yes by combining simultaneous sourcing w/ rerandomization

How does *randomized* inversion handle *mundane* modelling errors?

- ▶ rerandomization cancels noise buildup on the model & *accelerates* convergence

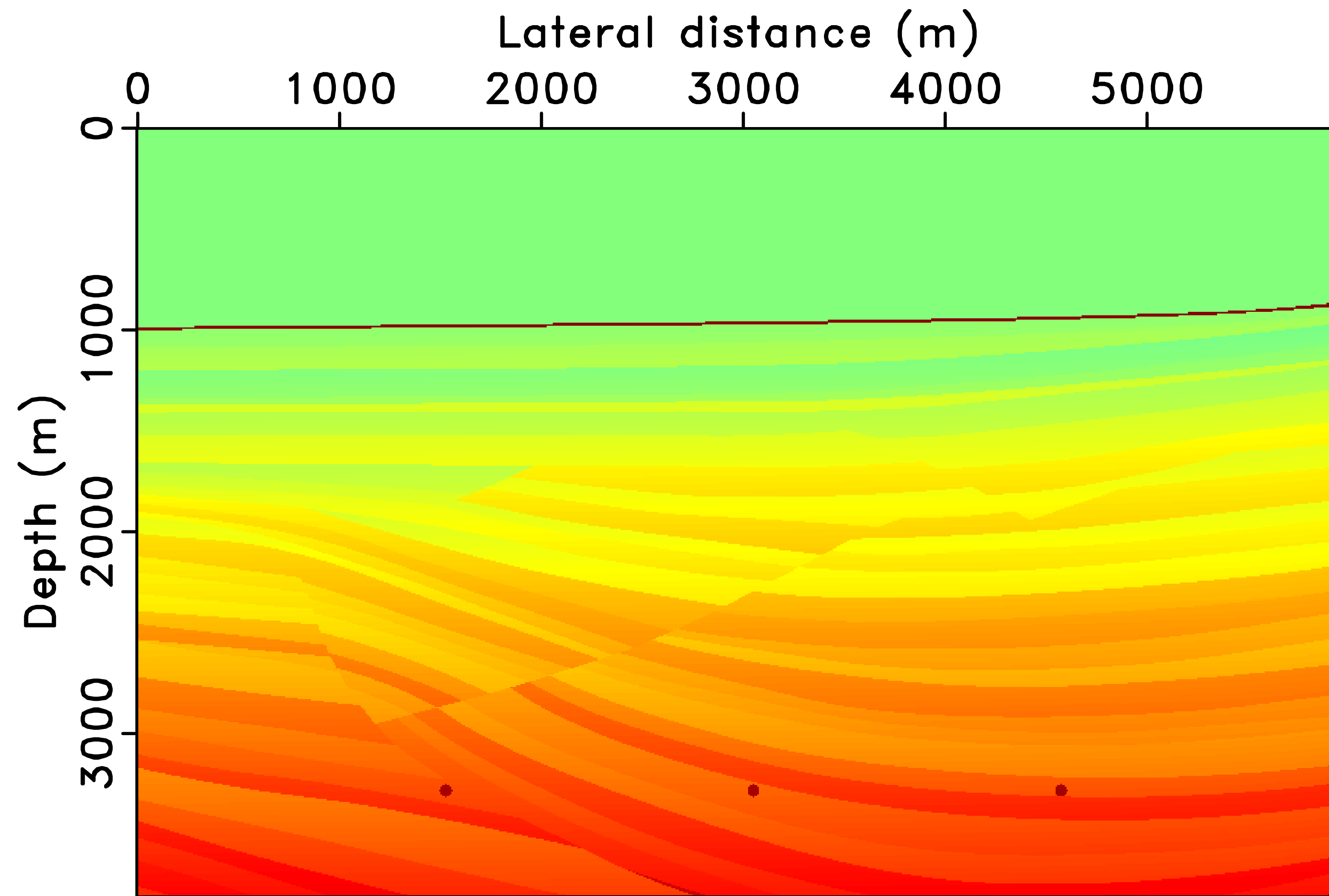
Can *surface*-related multiples be *ignored*?

A shot-gather of *total* data

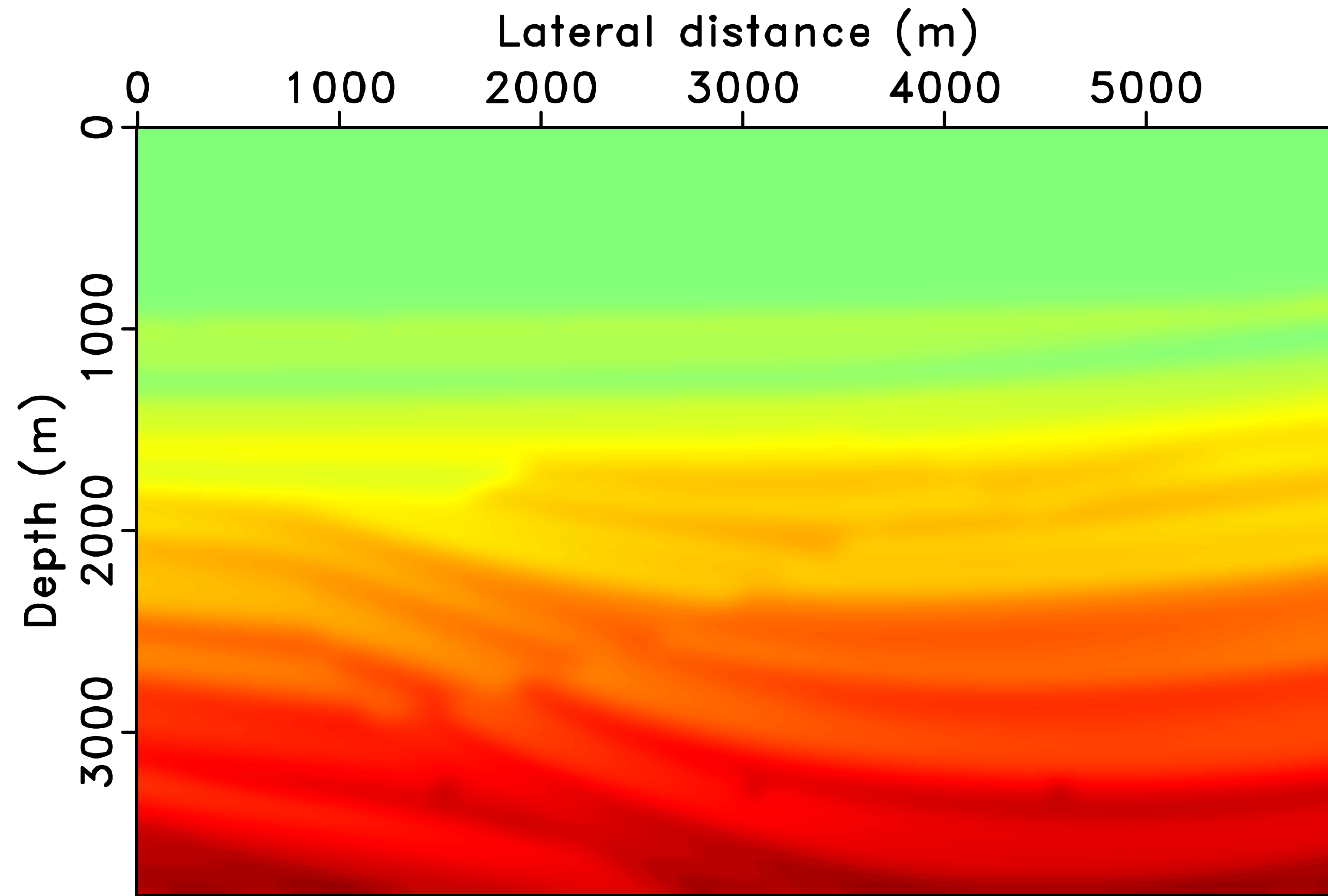


True model

[given source function (15 Hz Ricker) & multiples are predicted by SRME relation]

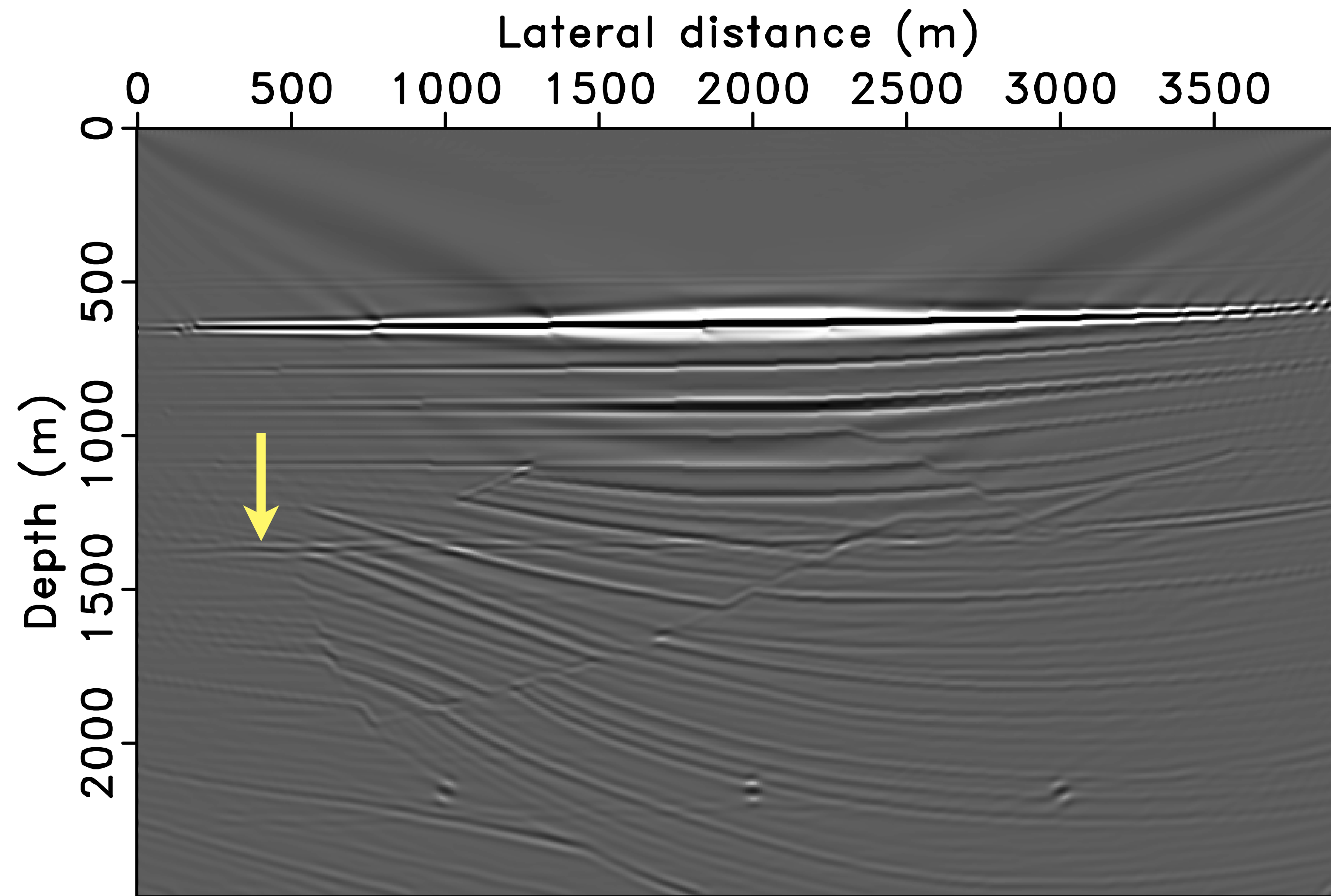


Background model



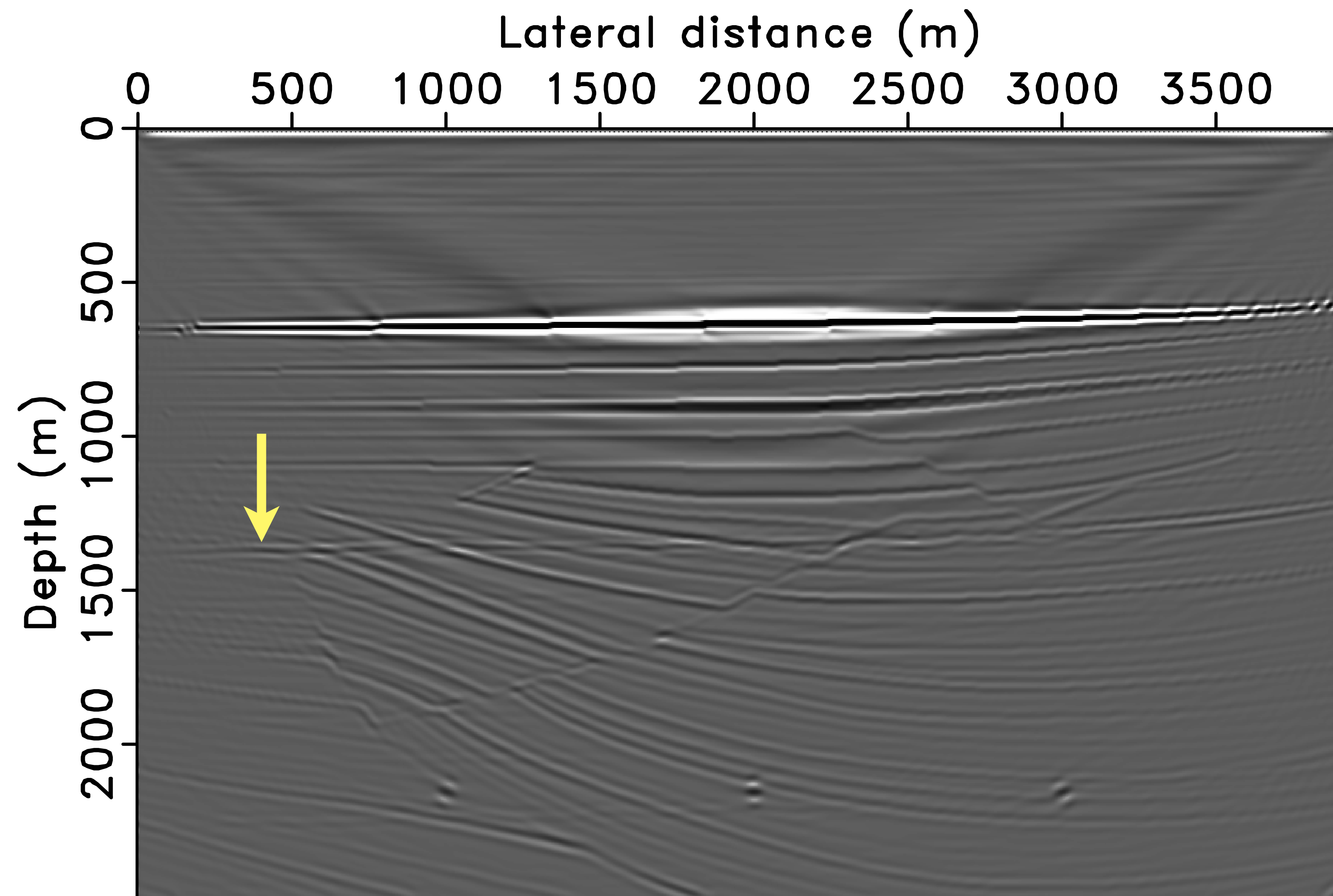
Conventional RTM image

[w/ *primary* imaging operator – multiples are ignored]



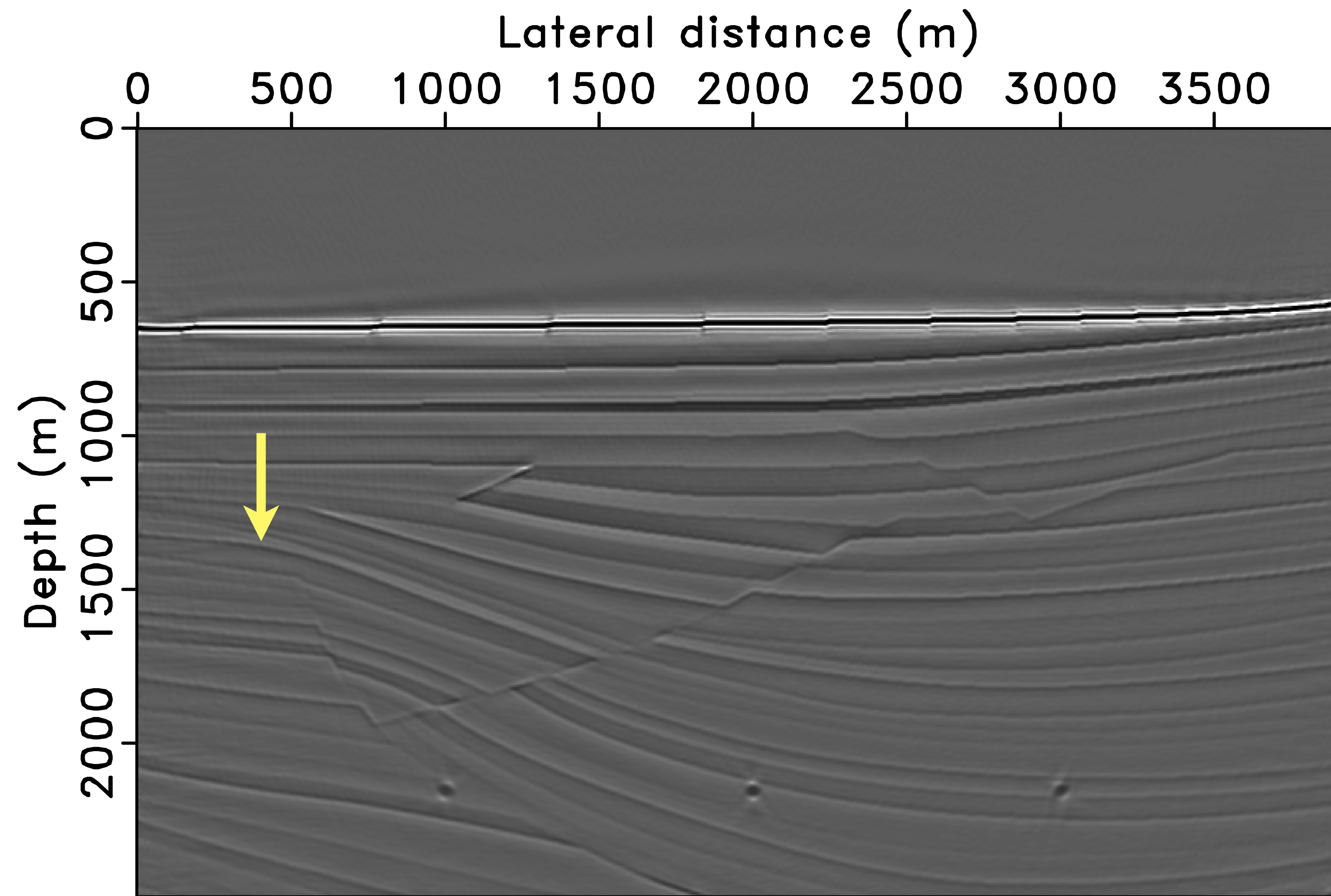
RTM image w/ *total* data

[*multiples* are accounted for by including *total* data as *areal* source]



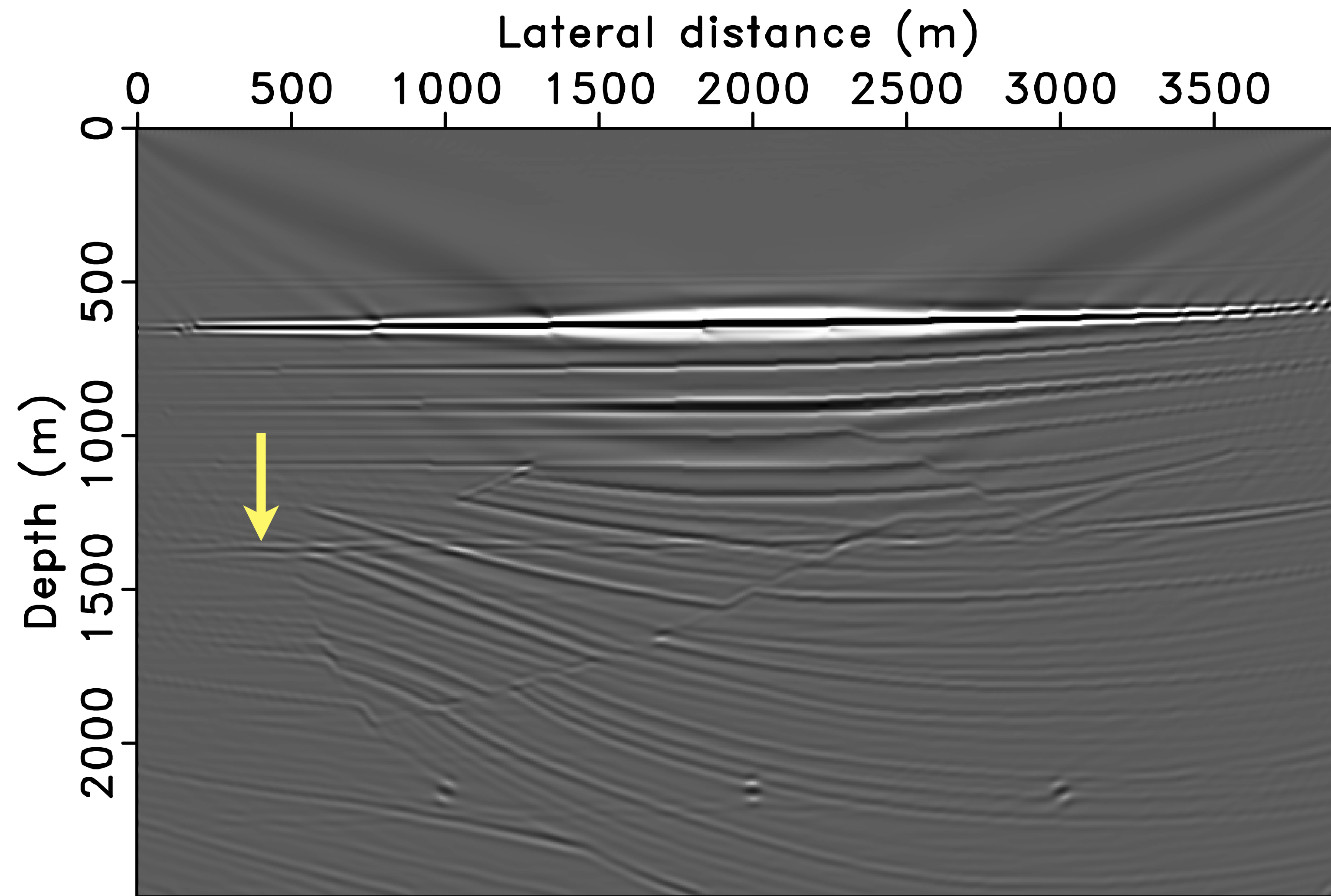
Fast inversion w/ sparsity promotion

[15 freq., 8 sim. src., ~300 iter., **simulation cost ~1 RTM w/ all data**]



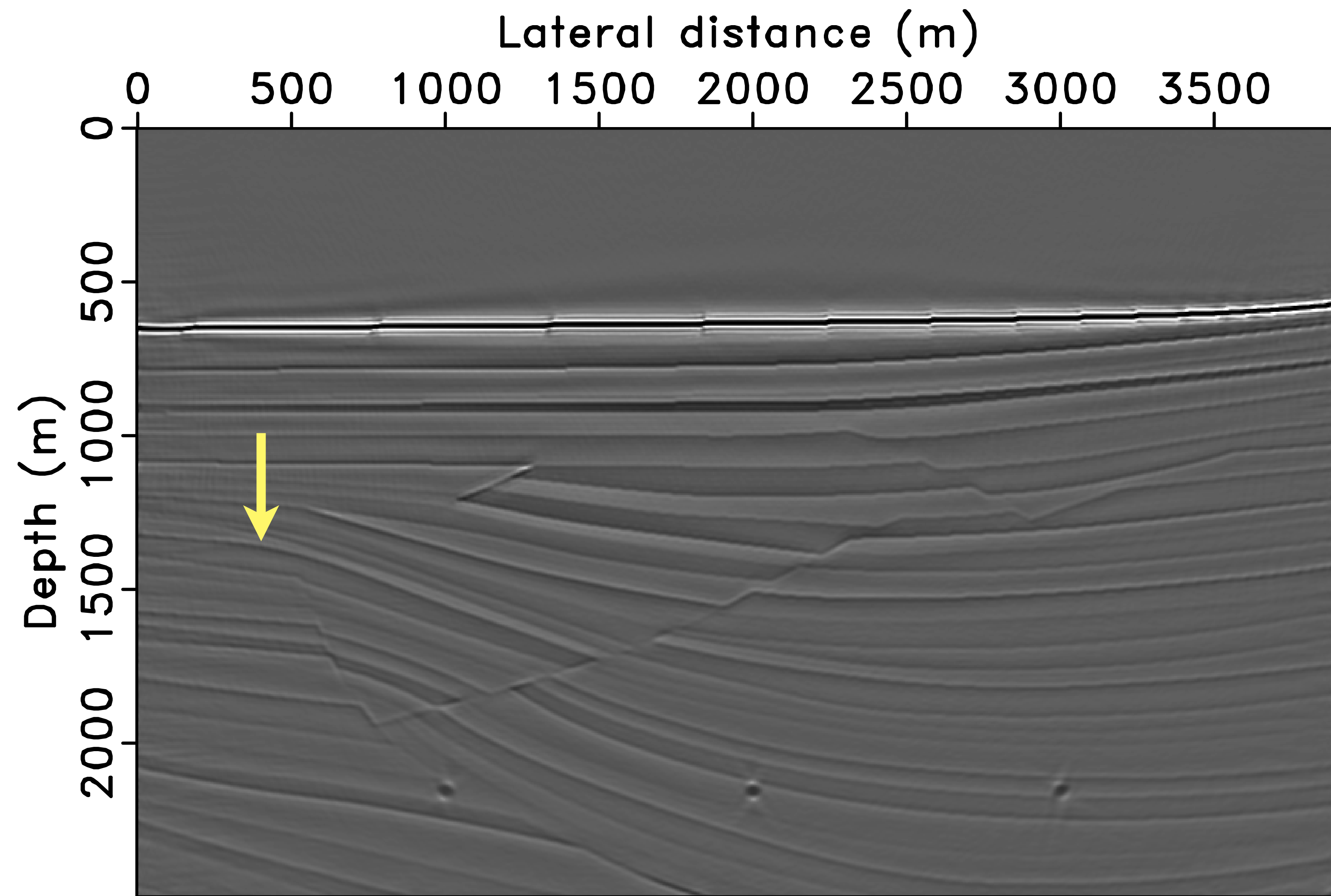
Conventional RTM image

[w/ *primary* imaging operator – multiples are ignored]



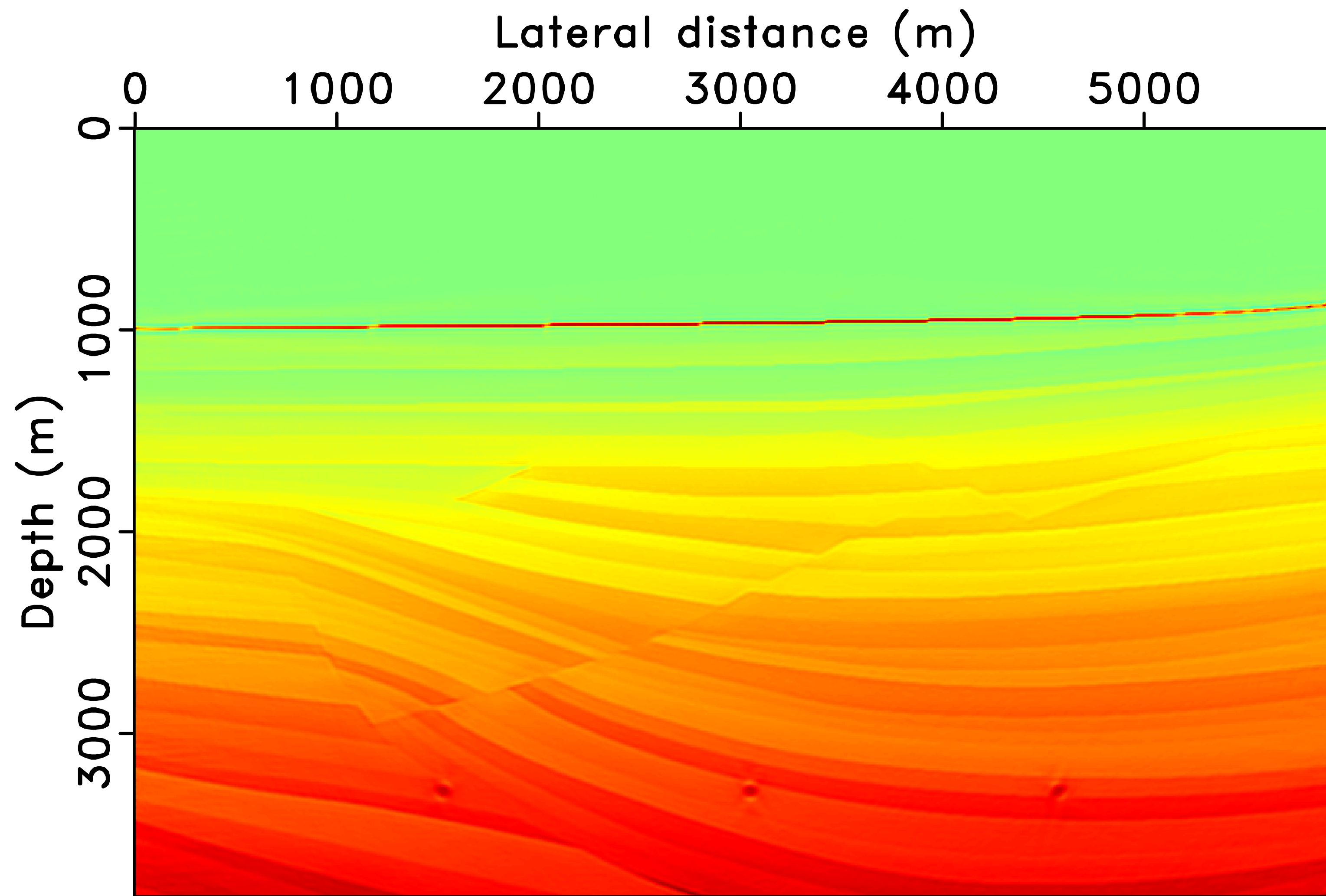
Fast inversion w/ sparsity promotion

[15 freq., 8 sim. src., ~300 iter., **simulation cost ~1 RTM w/ all data**]

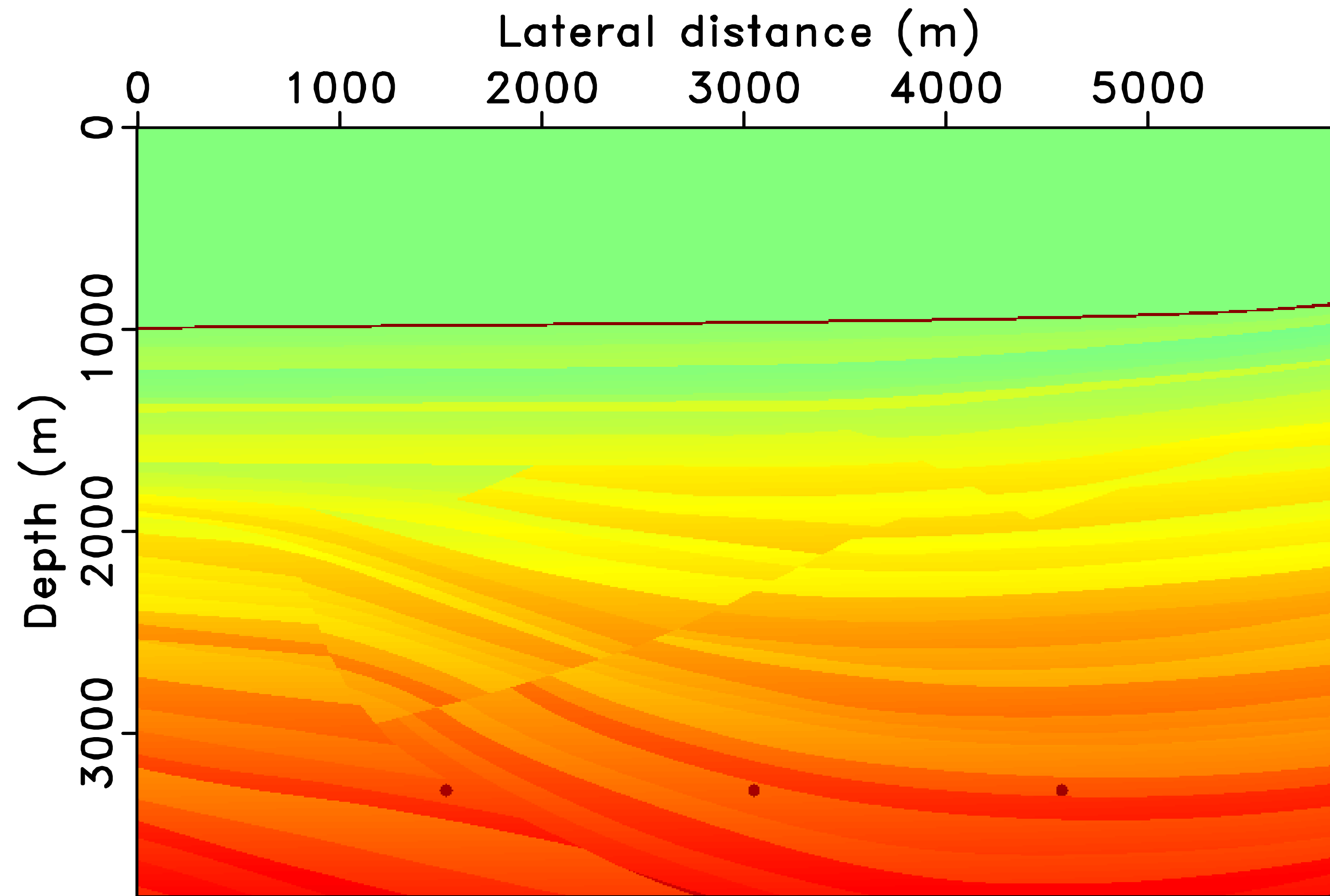


True-amplitude inversion

[adding inversion result back to smooth model]

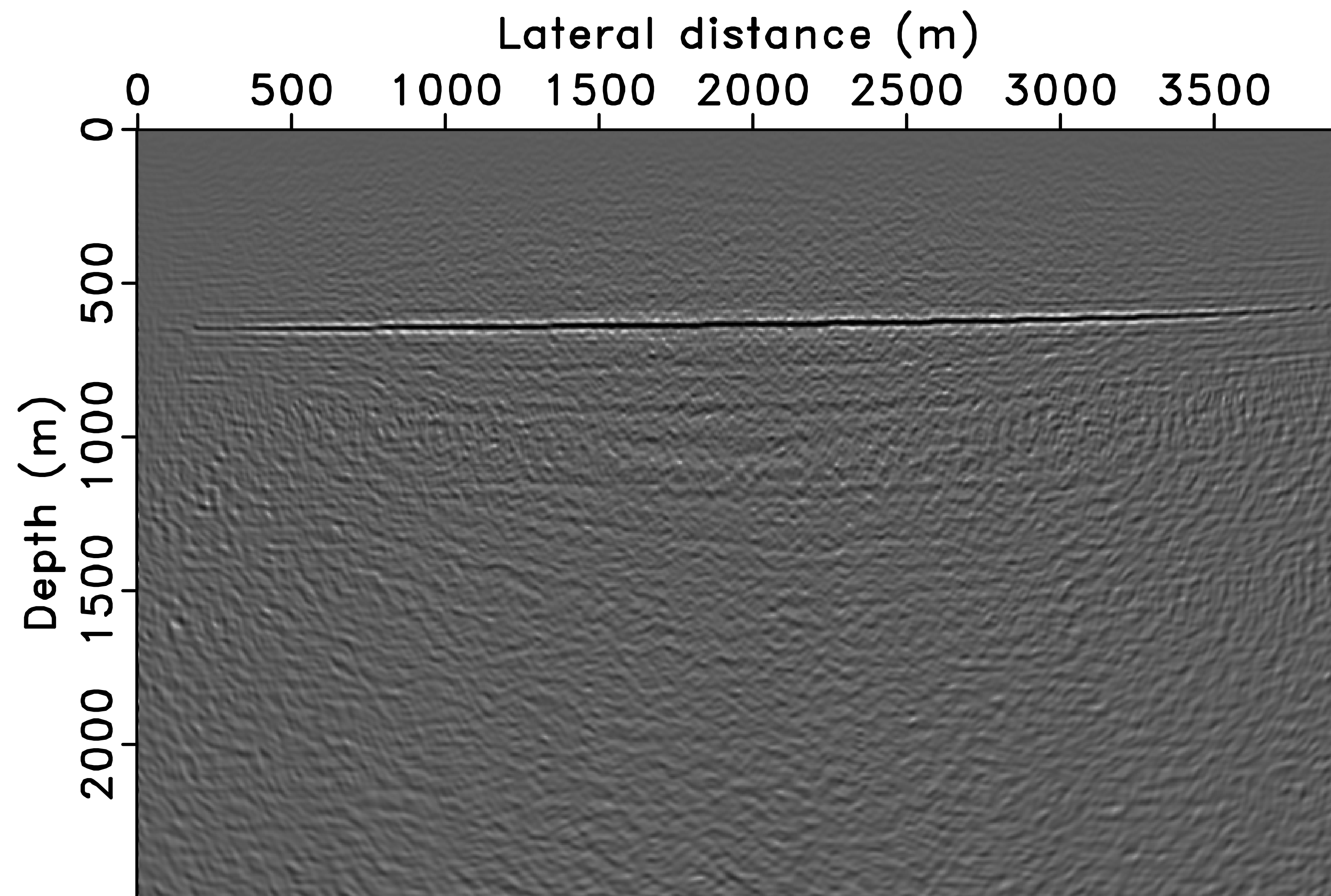


True model



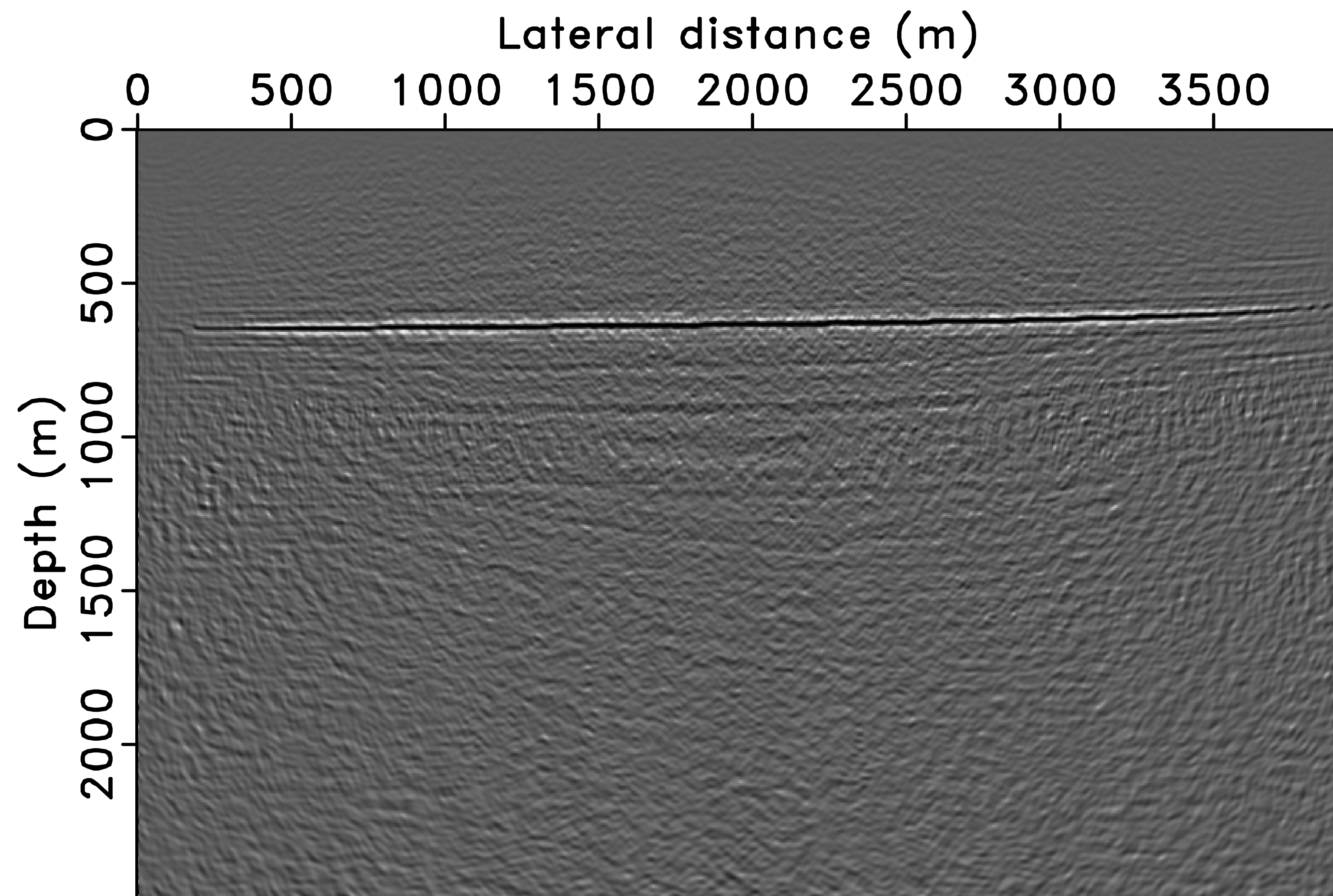
Inversion with L2 solver

[15 freq., 8 sim. src., 10 iter., no rerandomization]



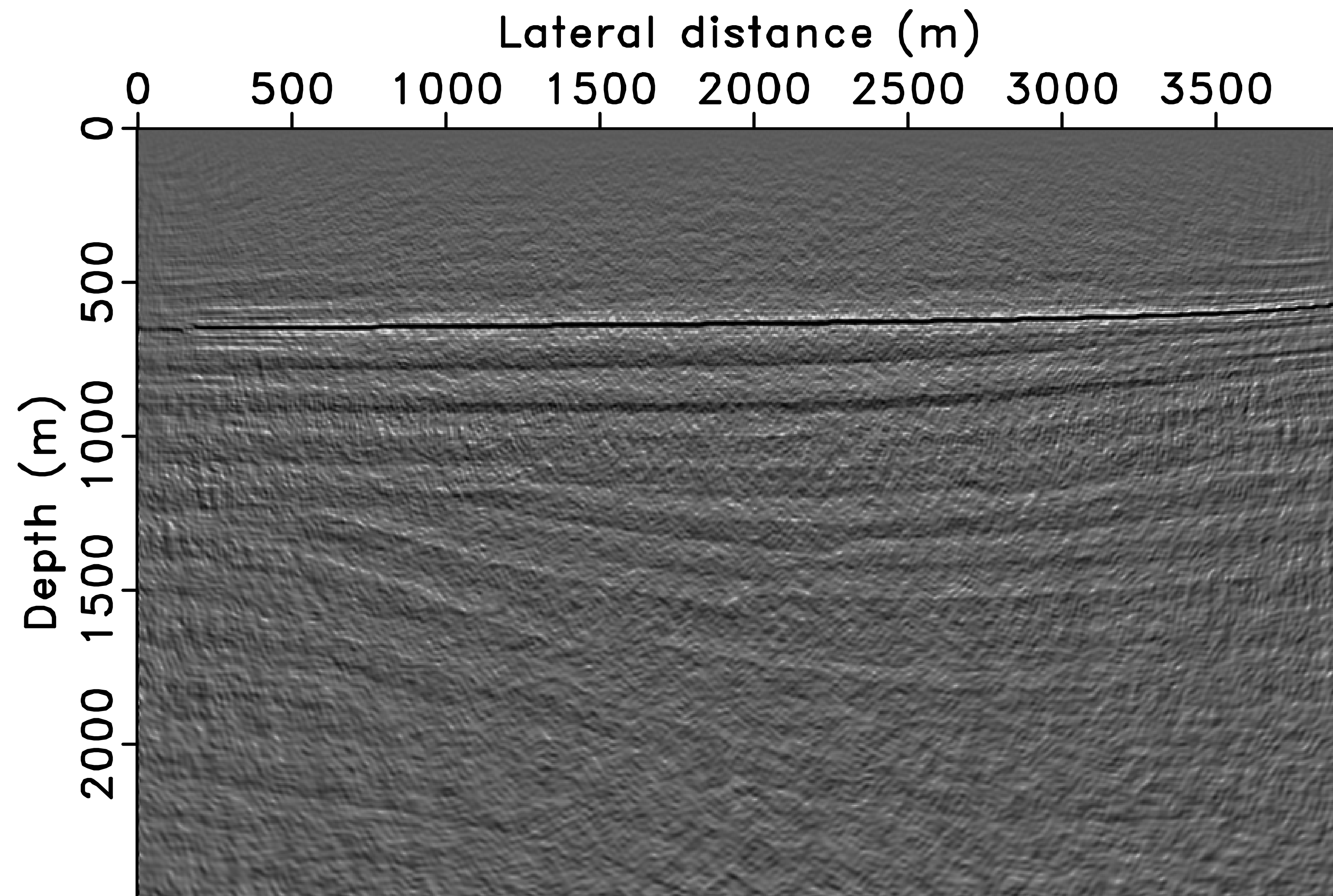
Inversion with L2 solver

[15 freq., 8 sim. src., 20 iter., no rerandomization]



Inversion with L2 solver

[15 freq., 8 sim. src., ~300 iter., **simulation cost ~1 RTM w. all data**, no rerandomization]



Imaging vs inversion w/ multiples

What is the impact if we ignore surface-related multiples?

- ▶ major because of the occurrence of coherent noise

What are the advantages of inversion over RTM imaging?

- ▶ remove cross terms from *areal* source

Are there more potential challenges?

- ▶ we need to know the source

Imaging vs inversion

[w/ multiples & source estimation]

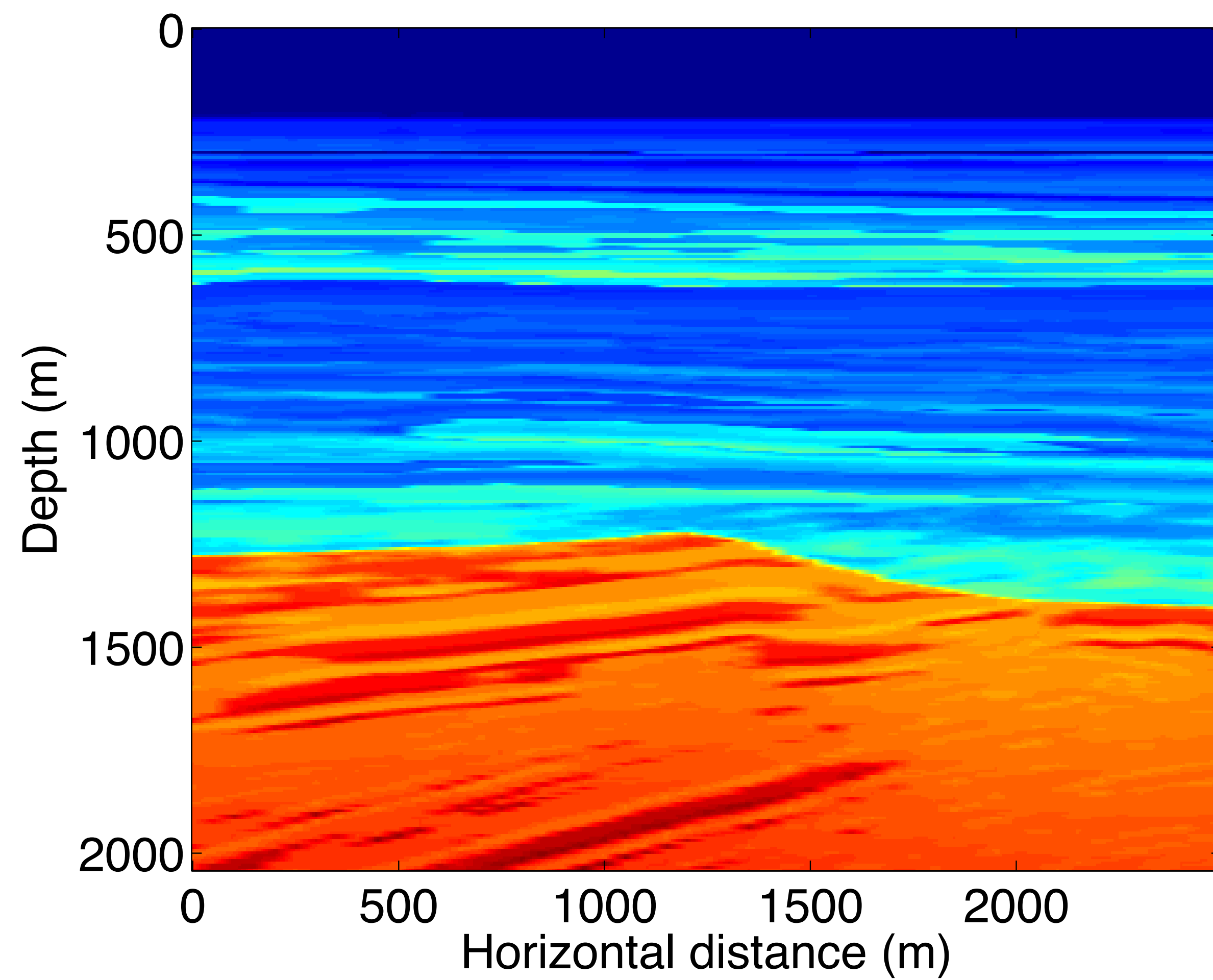
Do surface related multiples help with source estimation?

Can we estimate the source during inversion w/ sufficient accuracy?

Does this improve the image?

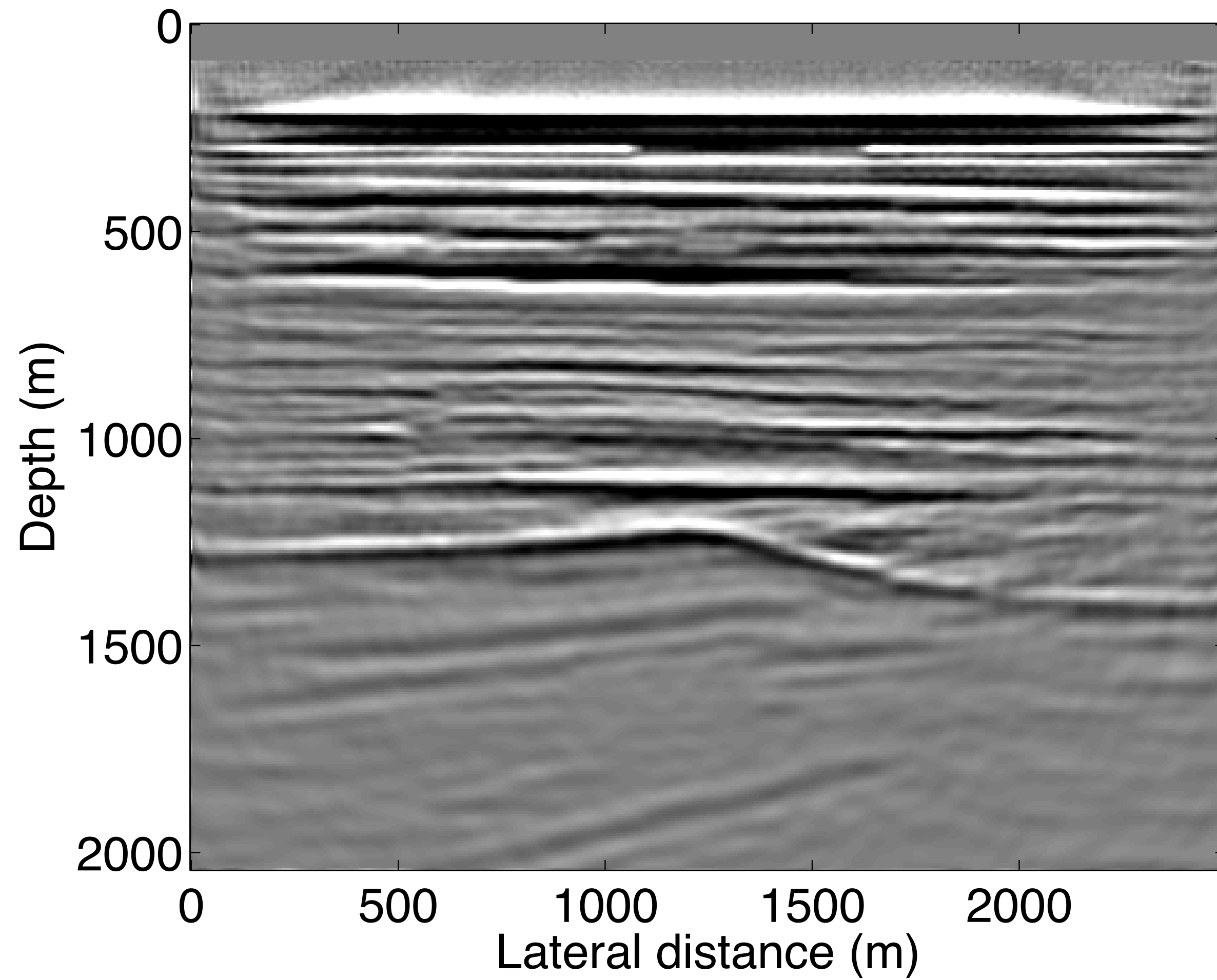
True model

[source function unknown]



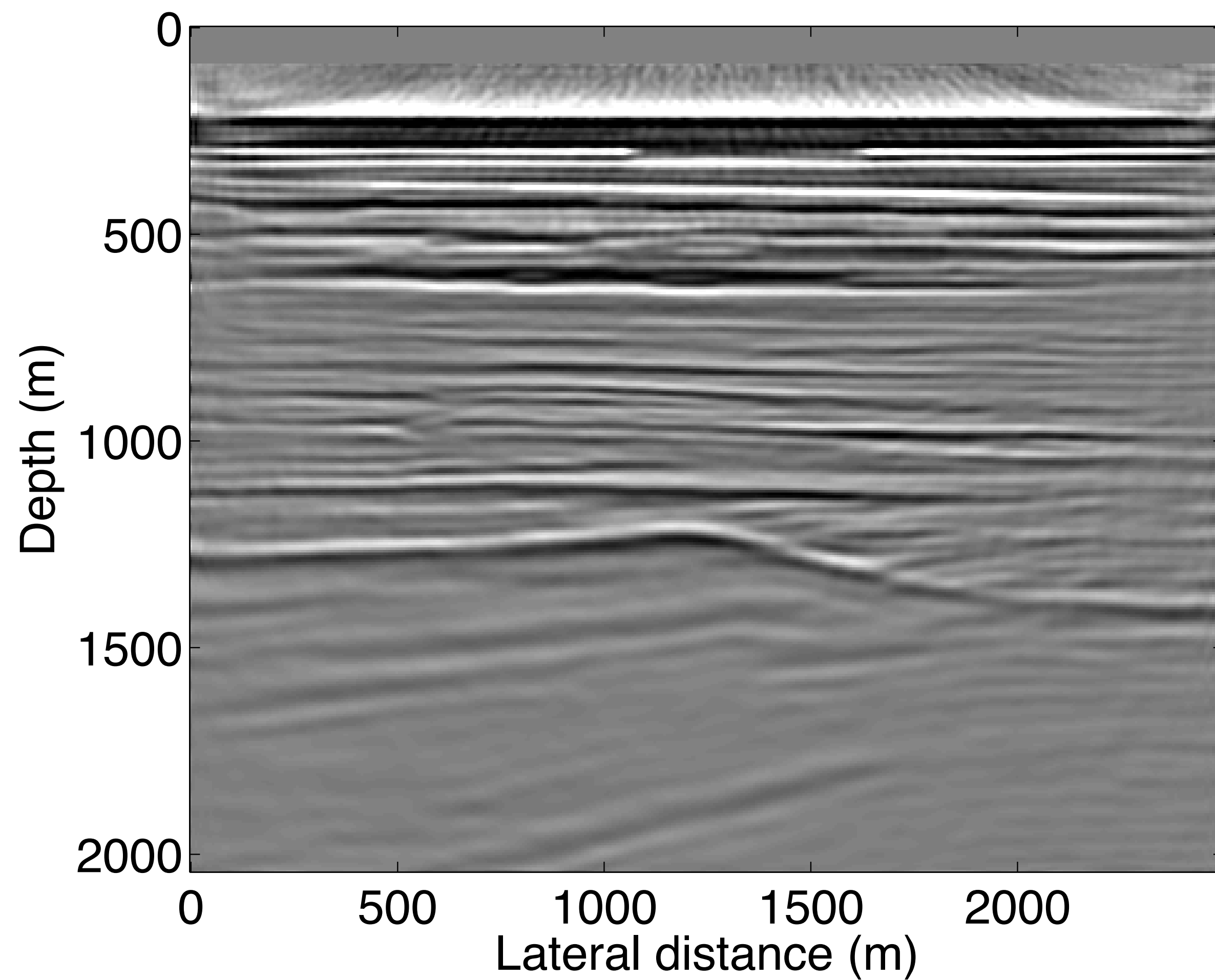
Inversion with source estimation

[with rerandomization, *primary* data, initial wavelet guess simply an impulse at $t=0$]

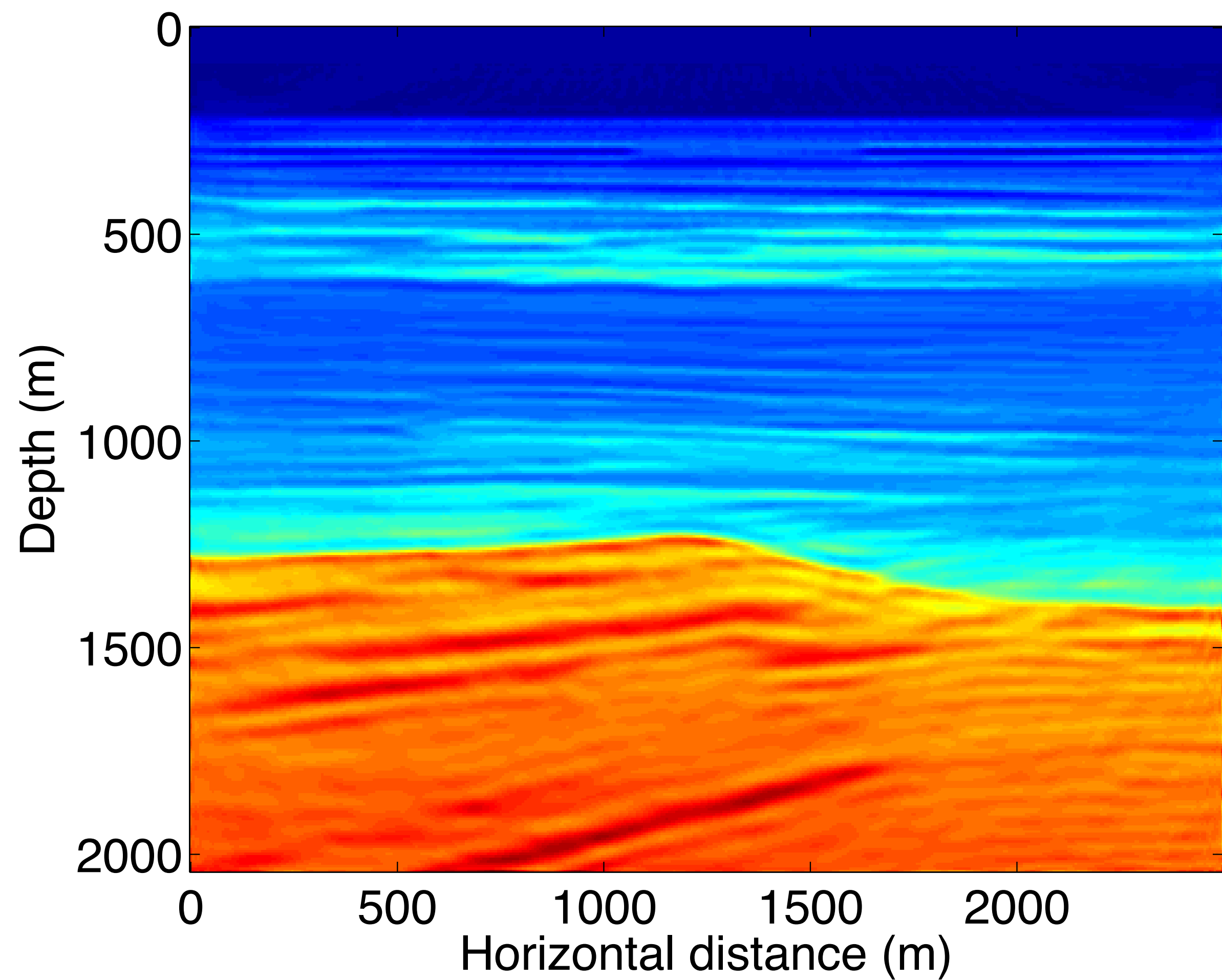


Inversion with source estimation

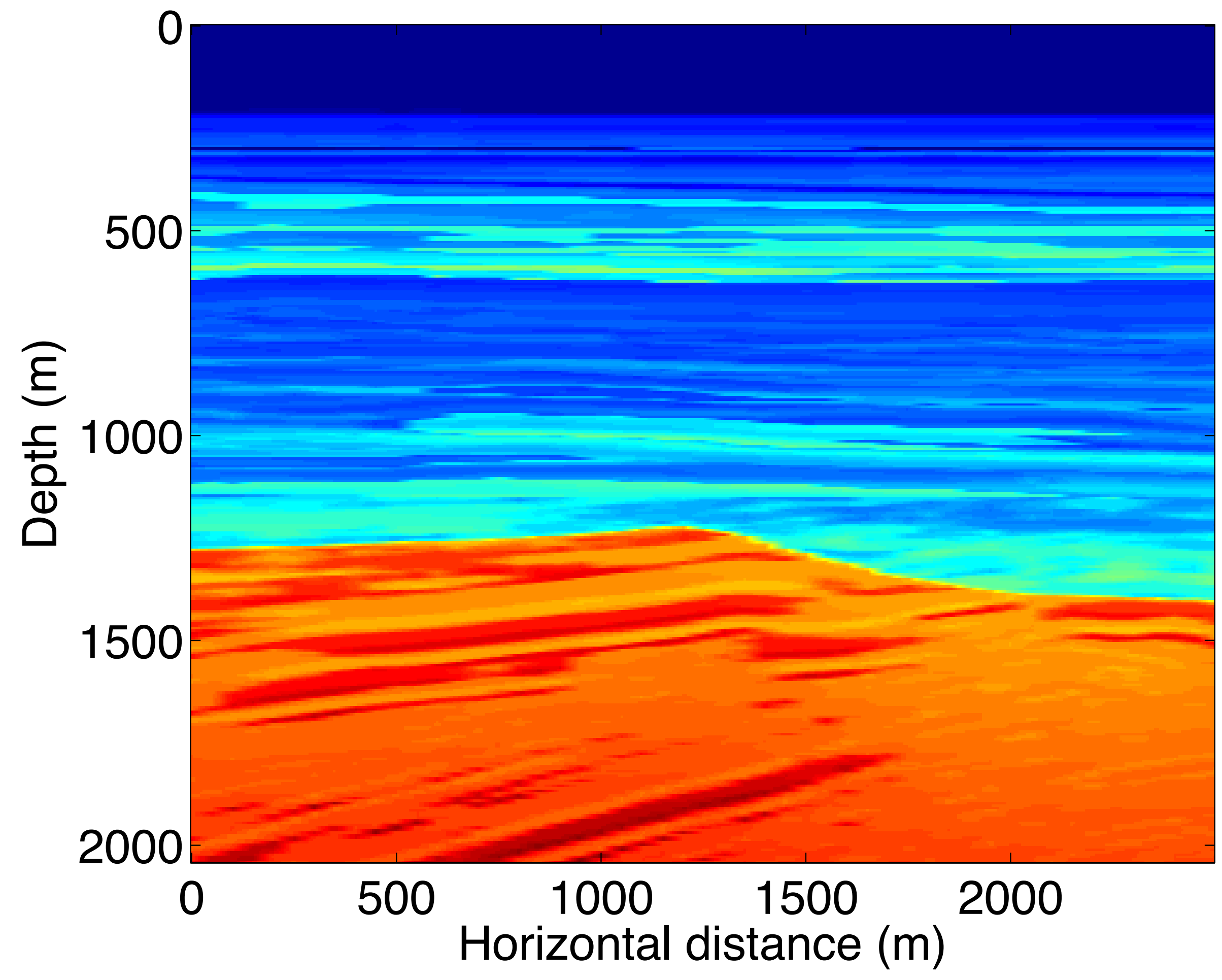
[with rerandomization, *total* data, initial wavelet guess simply an impulse at $t=0$]



REAL true-amplitude inversion w/o knowledge of the true **SOURCE** [adding inversion result w. multiples back to smooth model, *no* rescaling whatsoever]

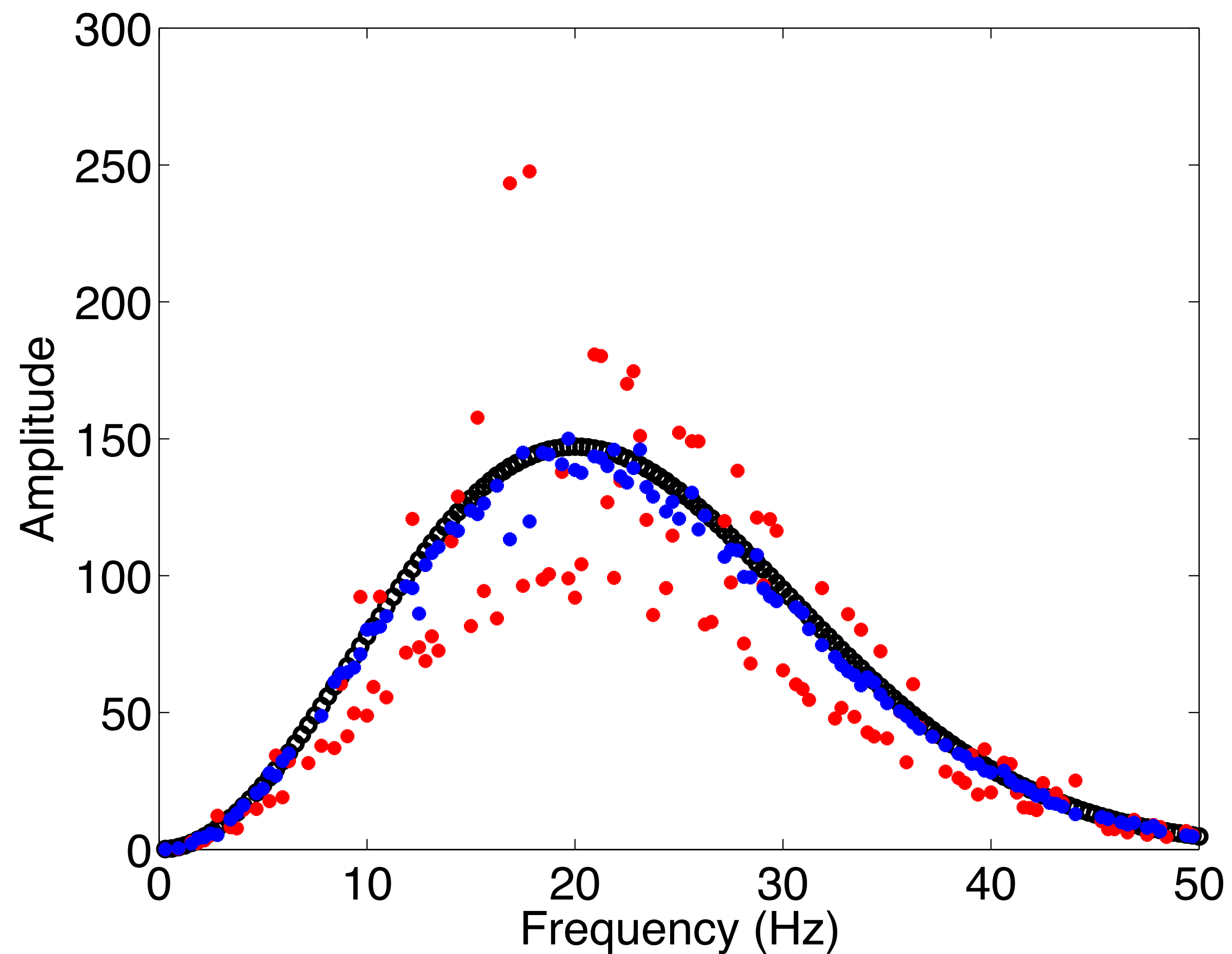


True model



Estimated wavelet: amplitude

[with vs. without using multiples, with rerandomization, with source estimation]



Black: true; Blue: w. multiple; Red: primaries only (rescaled)

Imaging vs inversion

[w\ multiples & source estimation]

Do surface related multiples help with source estimation?

- ▶ yes, because source appears only for the primary data & multiples improve illumination

Can we estimate the source during inversion w/ sufficient accuracy?

- ▶ yes, as long we do this on the fly using variable projection

Does this improve the image?

- ▶ yes

Acknowledgements

Thank you for your attention !

<https://www.slim.eos.ubc.ca/>



SINBAD



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References

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