Reflection FWI with a Poor Starting Model

Mike Warner & Gang Yao

Inverting synthetic data is easy if . . .

- Unrealistic accurate starting model
- Unrealistic low frequencies
- Unrealistic long offsets
- Unrealistic compute effort
- Perfect physics during inversion

Can we invert with . . .

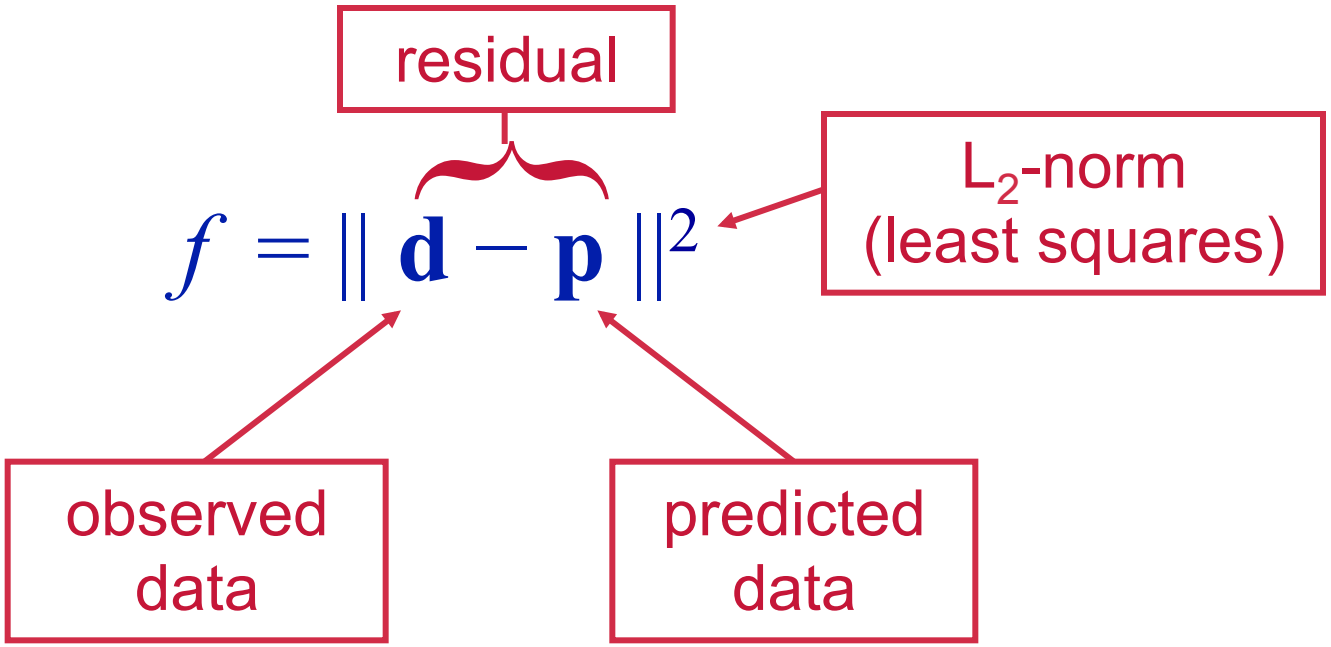
- No knowledge of true model
- No data below 4 Hz
- Only reflections
- Maximum offset $\approx$ target depth
- Realistic compute in 3D
- Imperfect physics

$\rightarrow$ velocity update at all scale lengths

$\rightarrow$ improved RTM

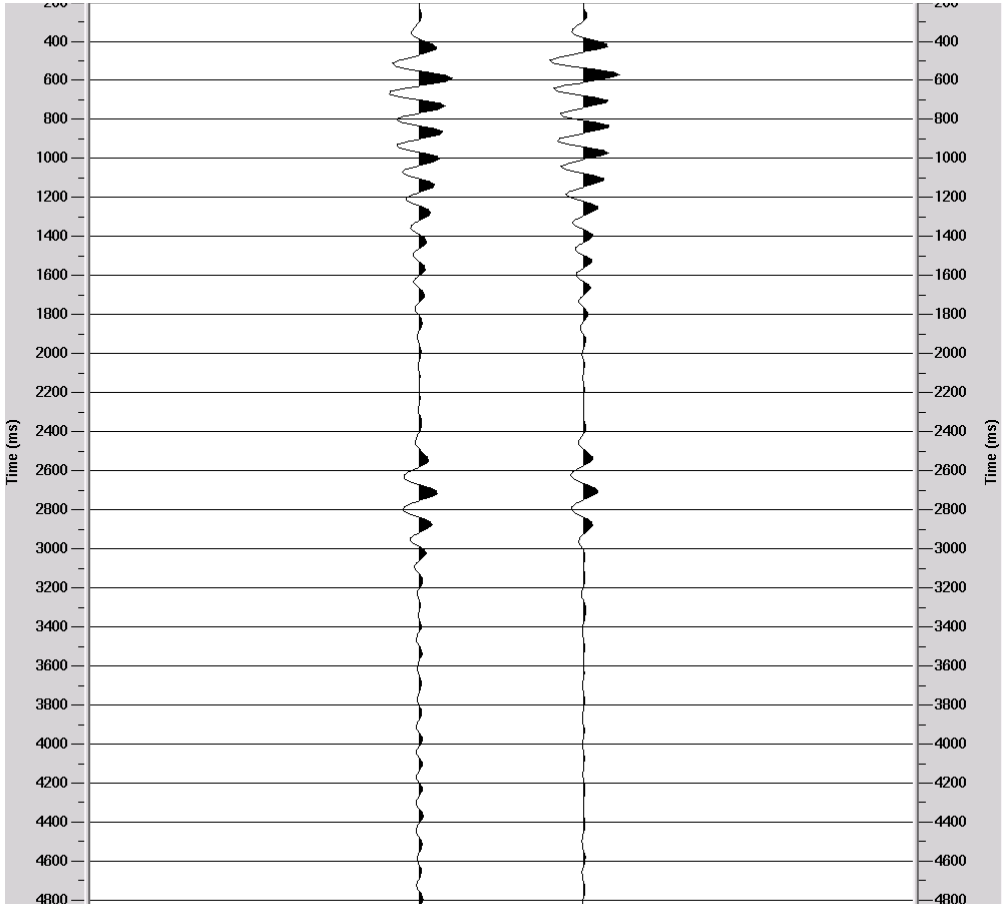
Cycle skipping during FWI

Conventional FWI minimises the functional f



subtraction of oscillating signals causes cycle skipping

Cycle skipping during FWI



predicted observed

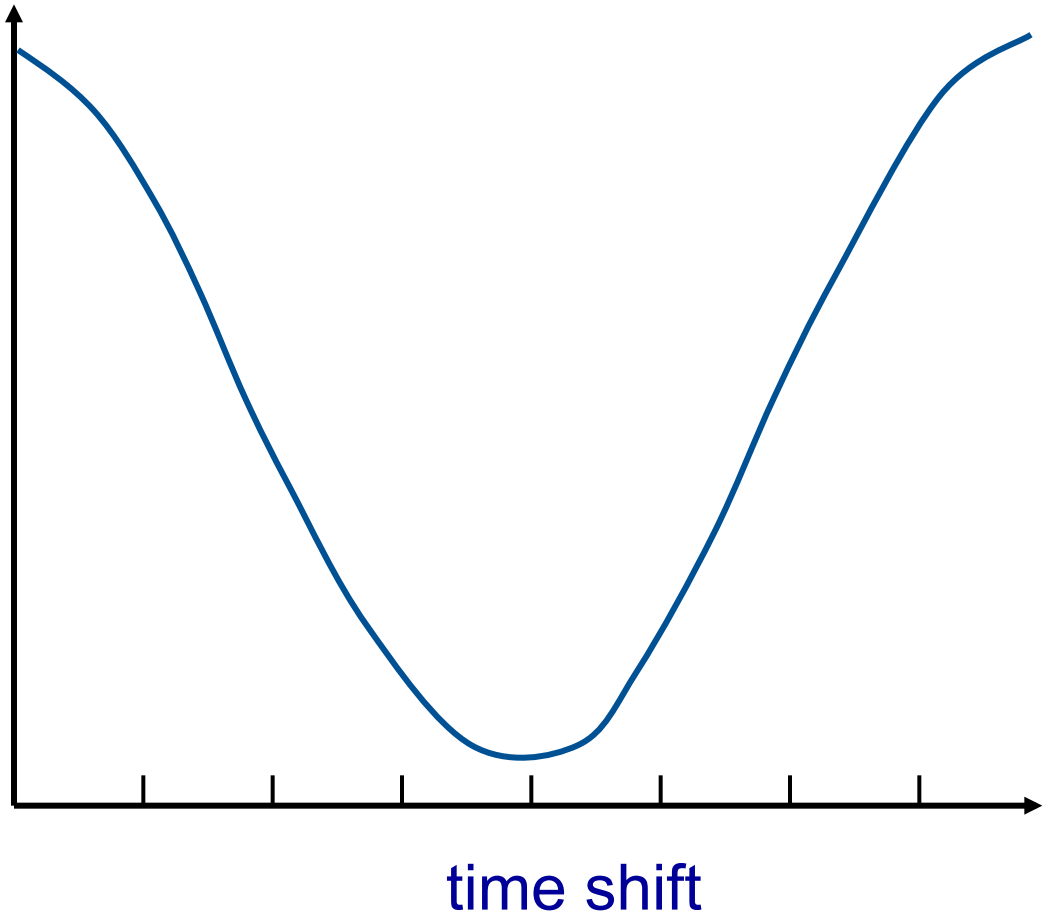
dominant frequency about 7Hz

Cycle skipping during FWI

functional

$$f = \| \mathbf{d} - \mathbf{p} \|^2$$

dominant frequency about 7Hz

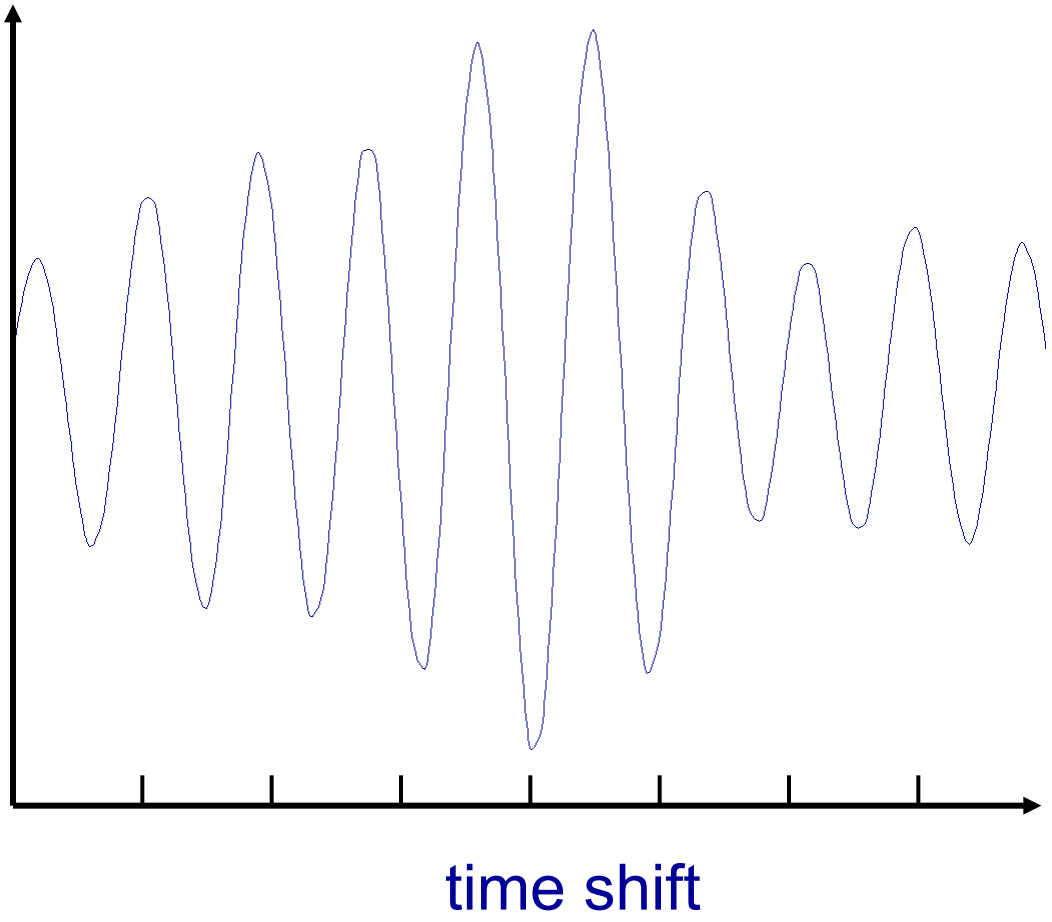


Cycle skipping during FWI

functional

$$f = \| \mathbf{d} - \mathbf{p} \|^2$$

dominant frequency about 7Hz

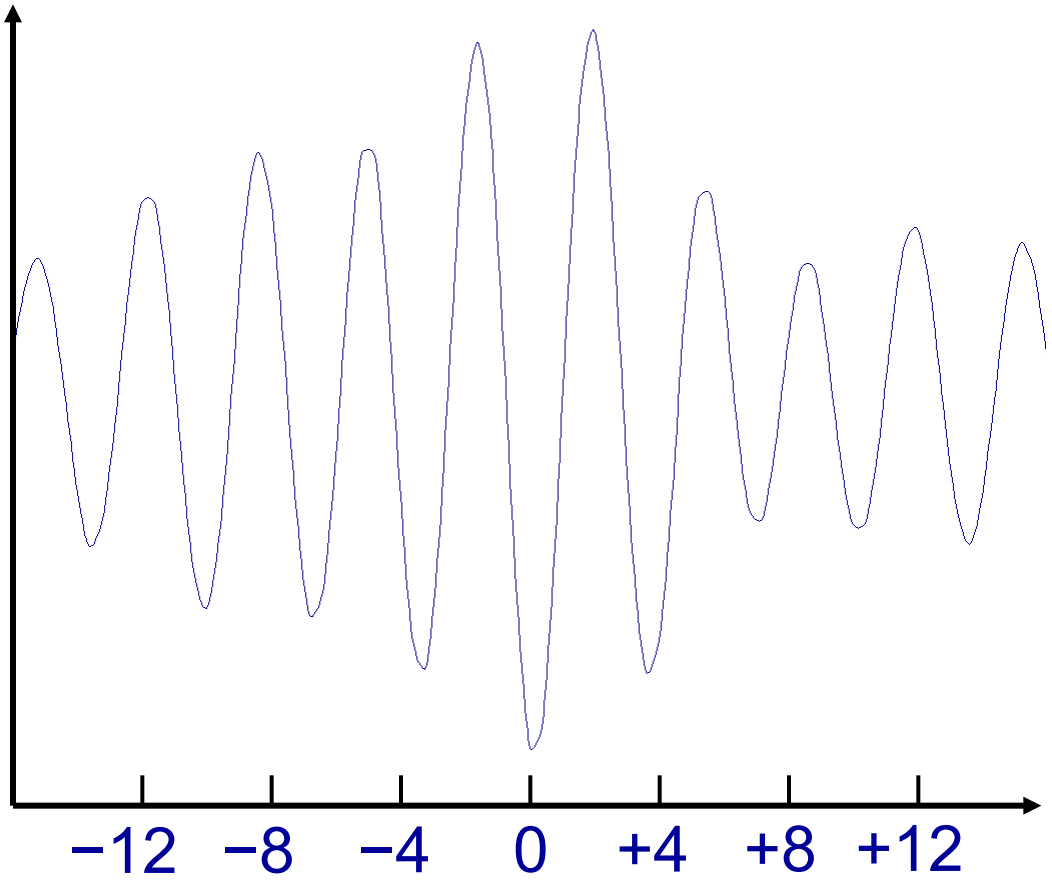


Cycle skipping during FWI

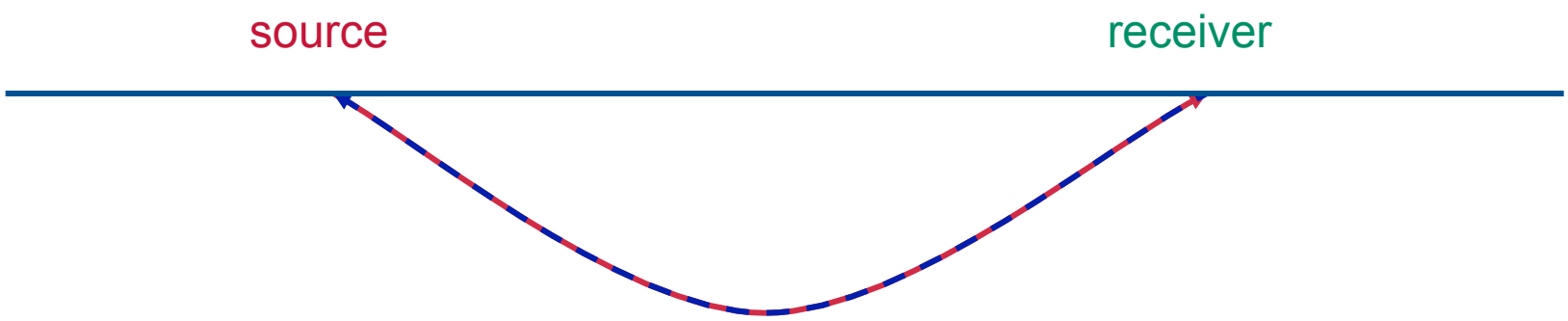
functional

$$f = \| \mathbf{d} - \mathbf{p} \|^2$$

dominant frequency about 7Hz



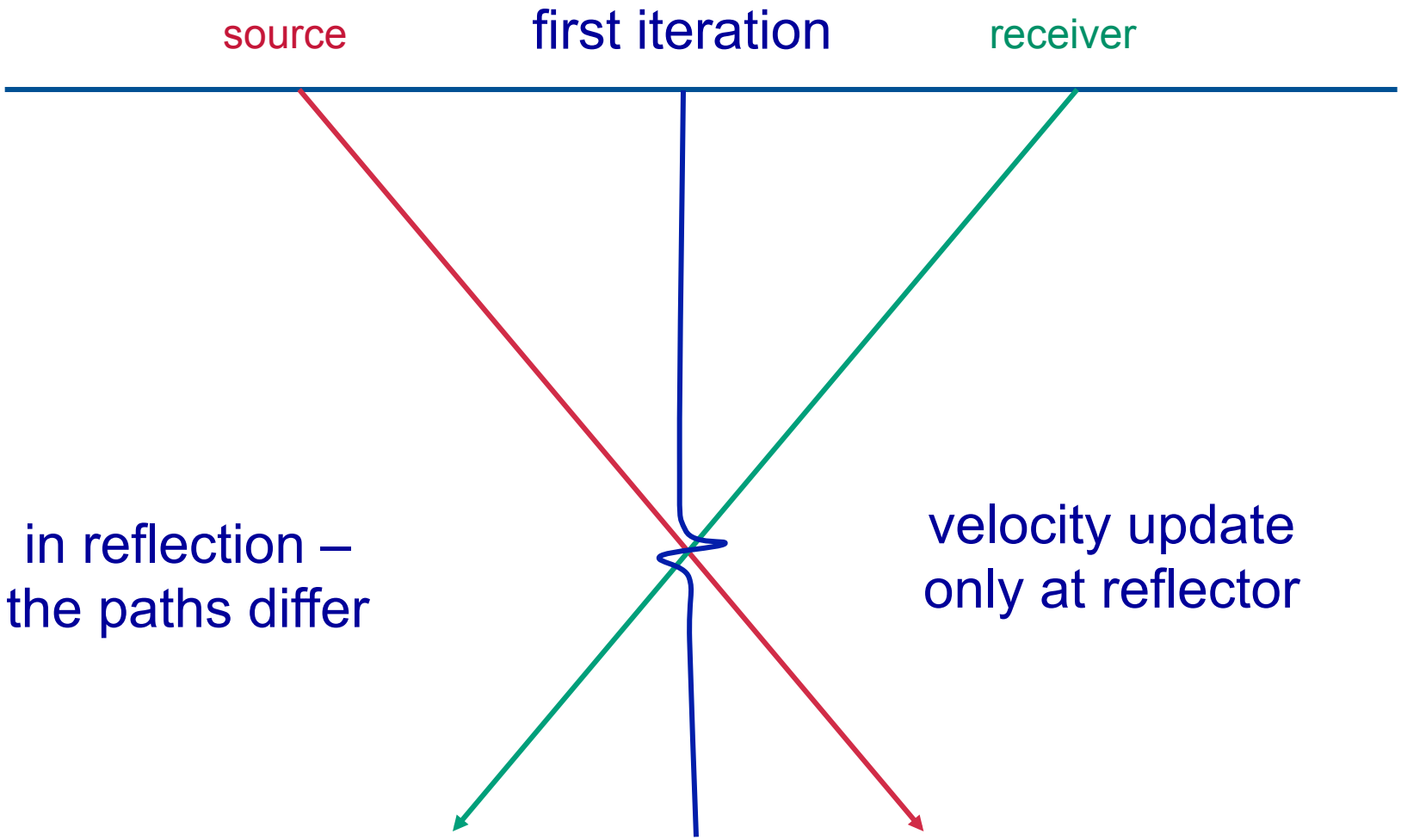
Conventional FWI – refraction



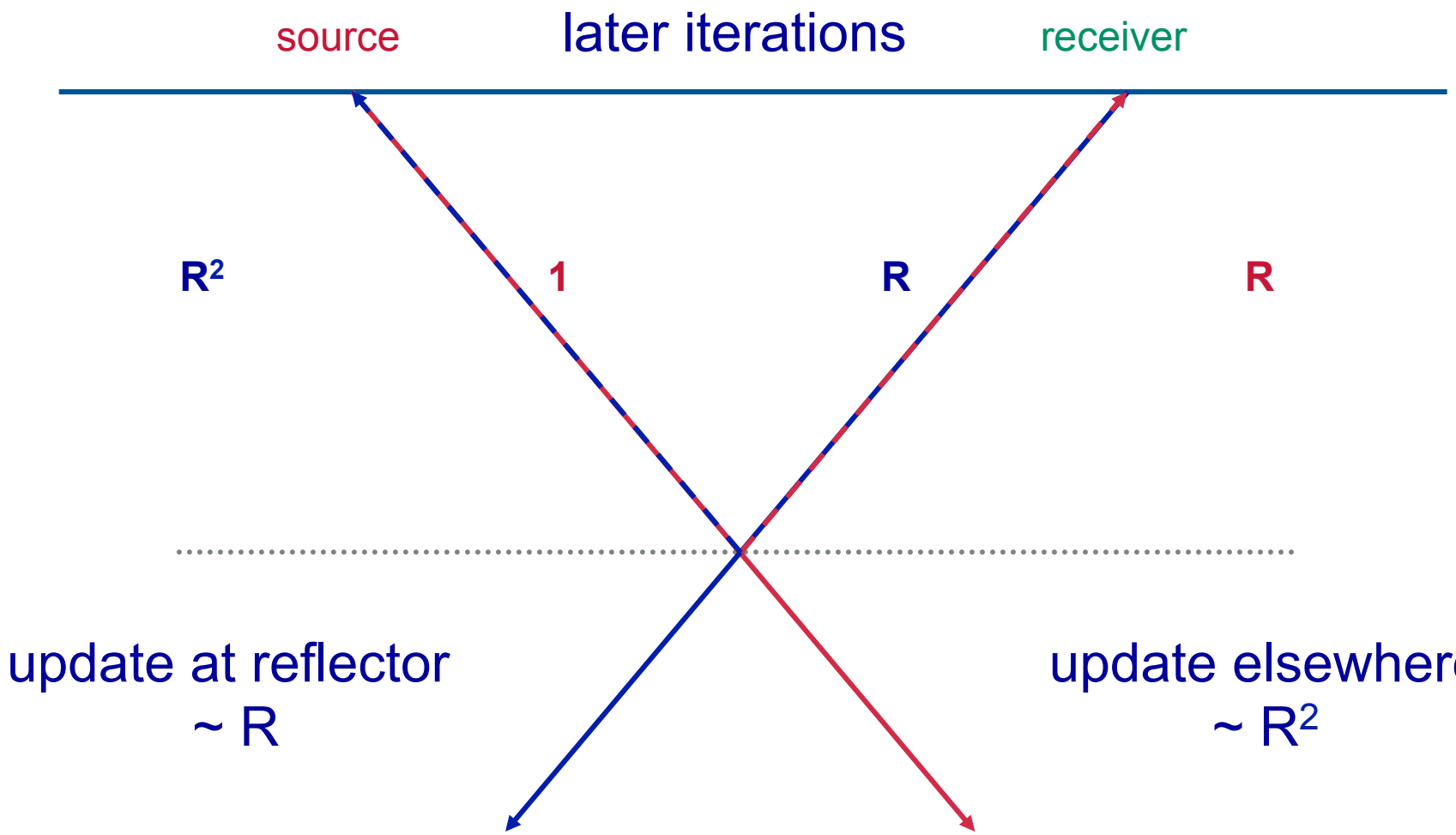
velocity update
everywhere

in transmission – forward and residual follow same path

Conventional FWI – reflection



Conventional FWI



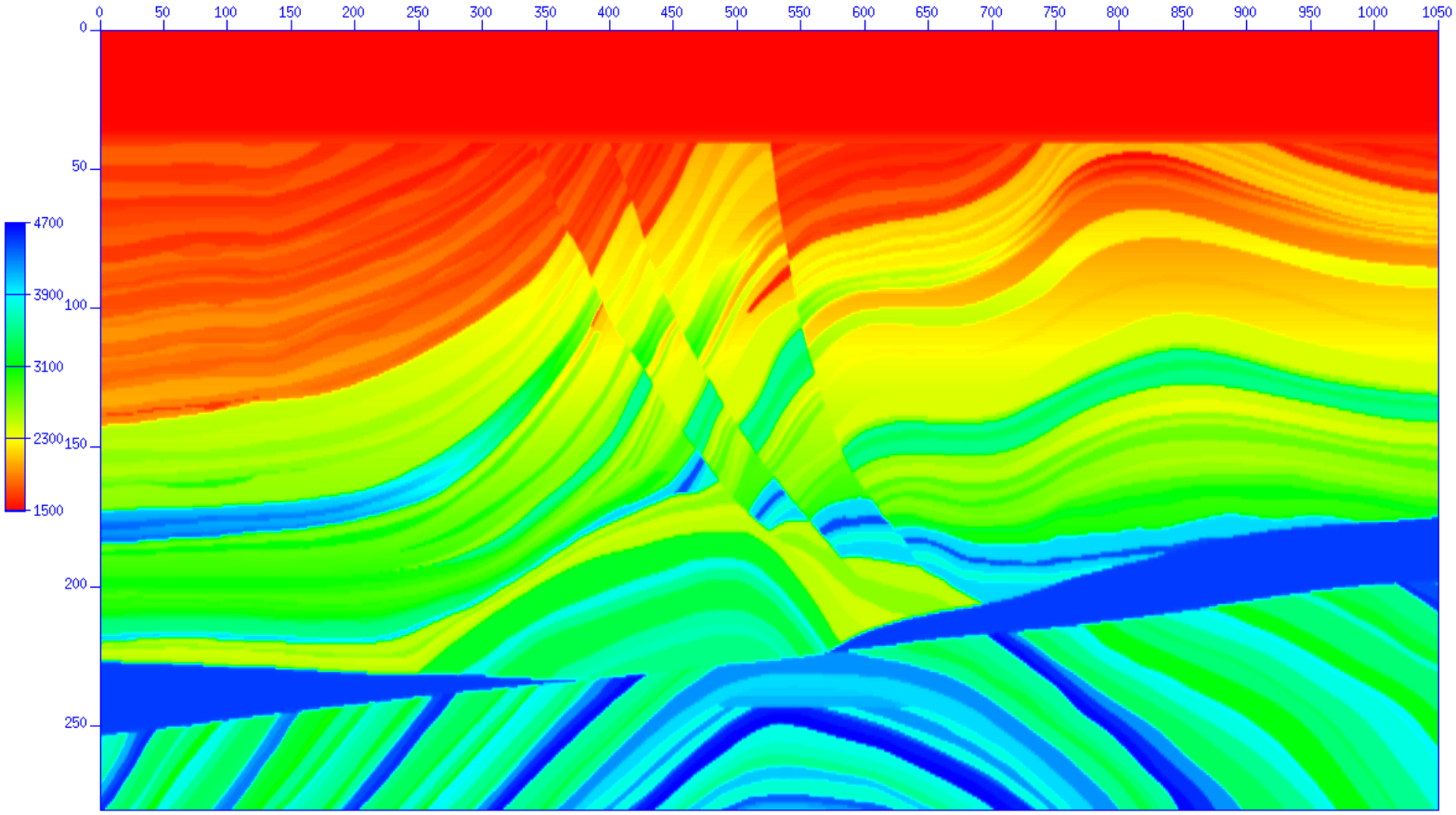
Reflection FWI

To make reflection FWI update the macro model we need to:

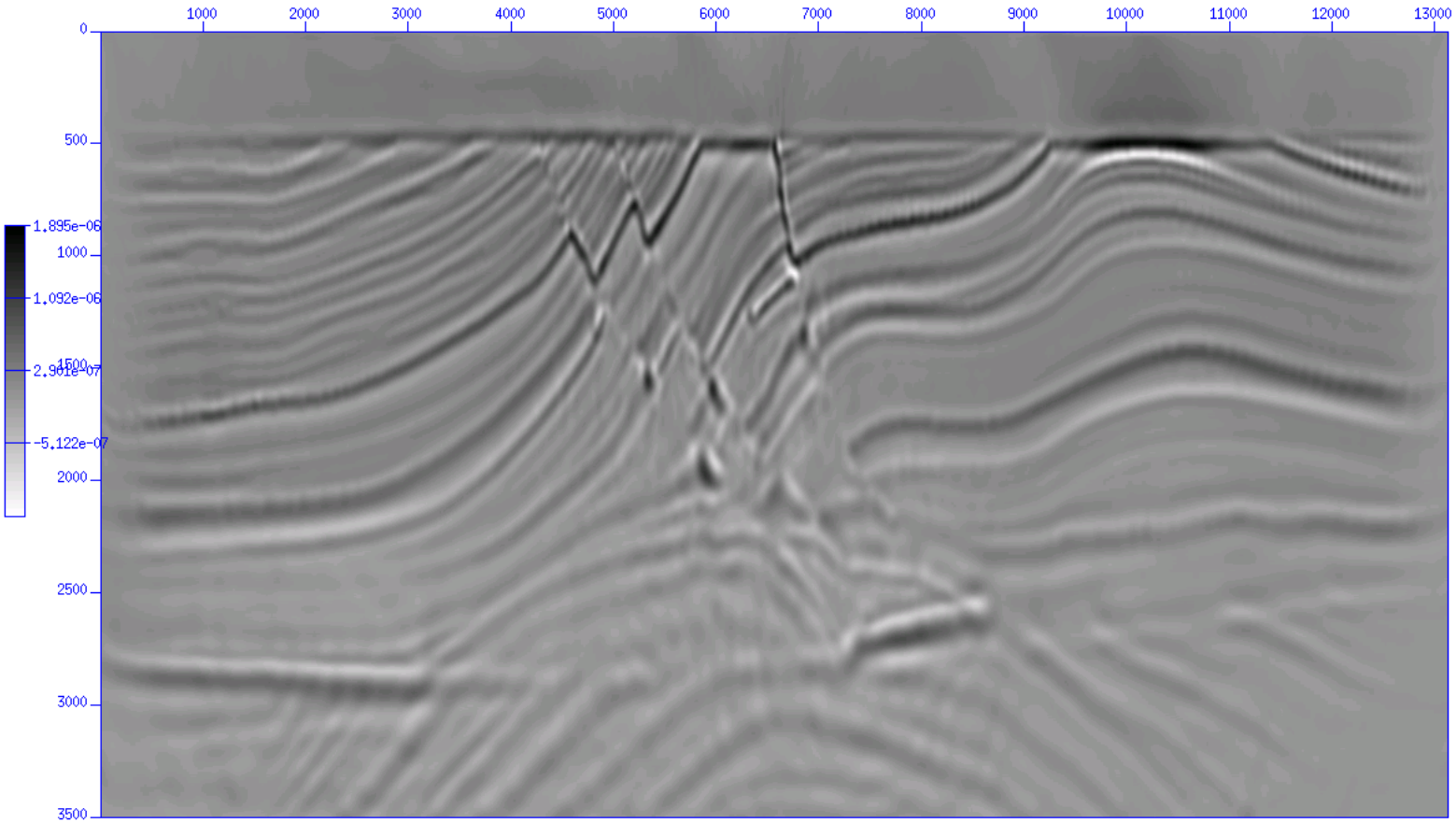
- cross correlate waves travelling in opposite directions
- avoid cross-correlating waves travelling in the same direction

- the latter is least-squares RTM
- the former is least-squares FWI
- we need to interleave these

Inverting Marmousi is easy . . .



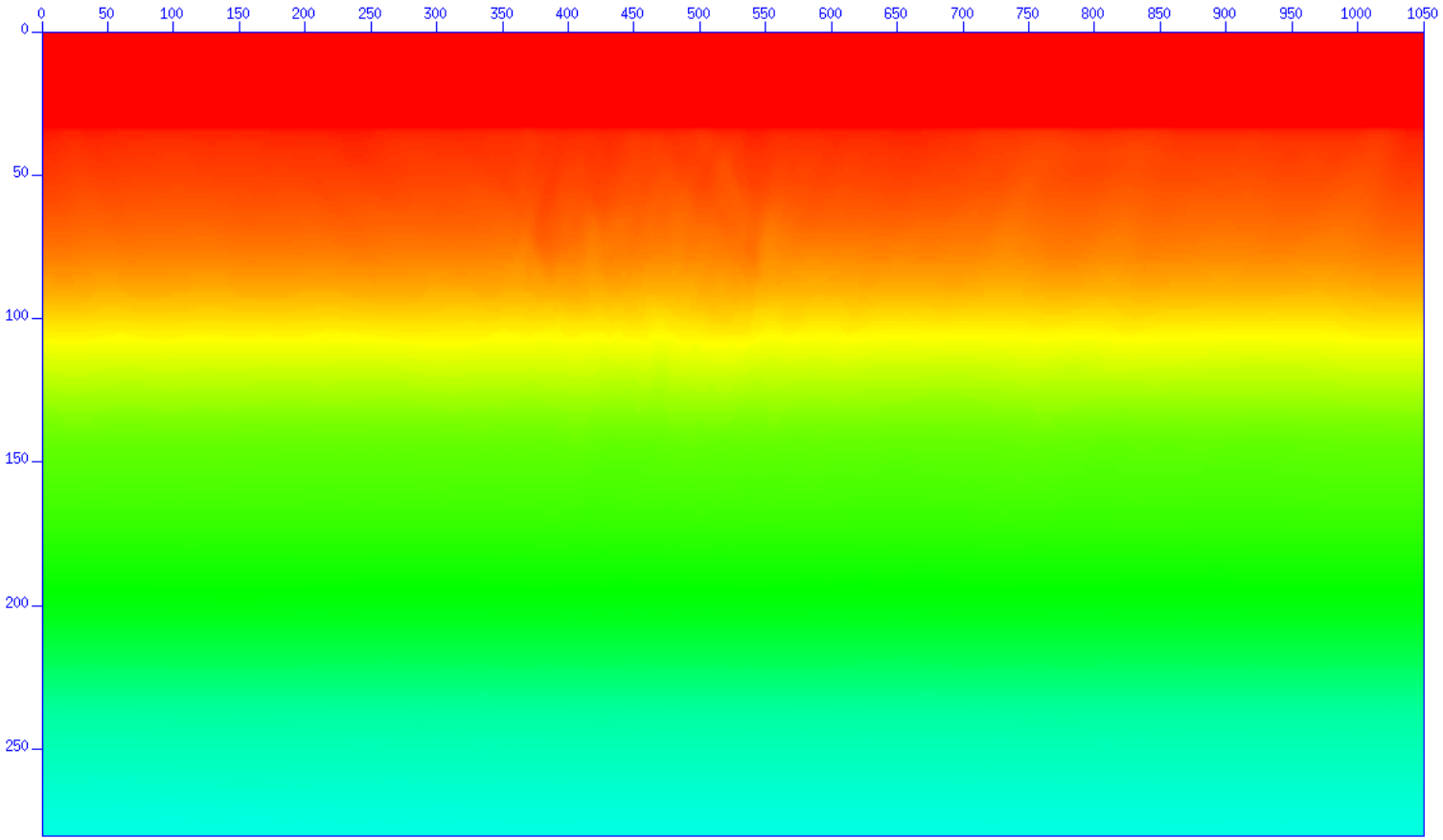
Migrating Marmousi is easy . . .



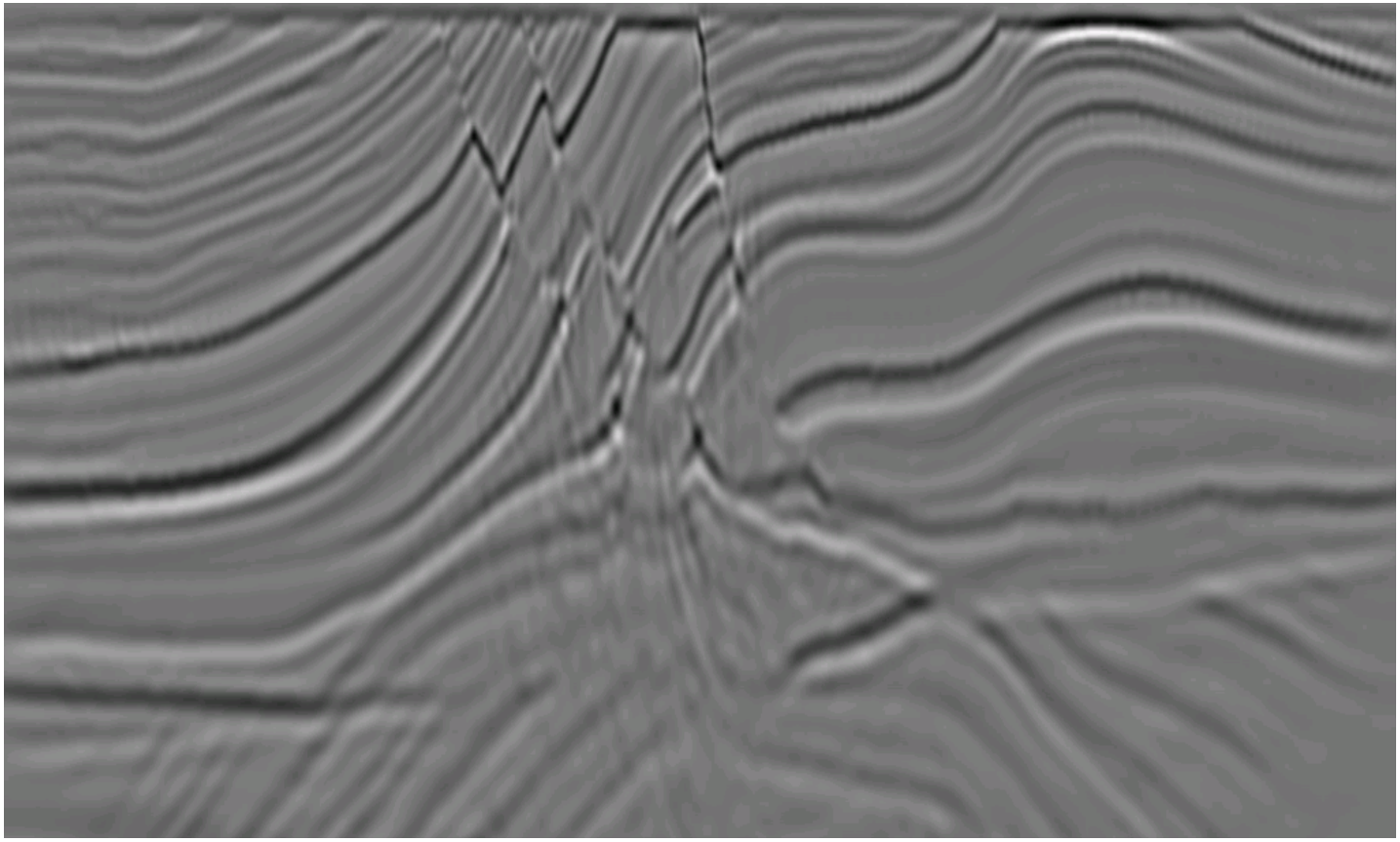
Inverting Marmousi is difficult . . .

- No good starting model
- No data below 4 Hz
- Only reflections
- Maximum offset $\approx$ target depth
- Realistic compute in 3D

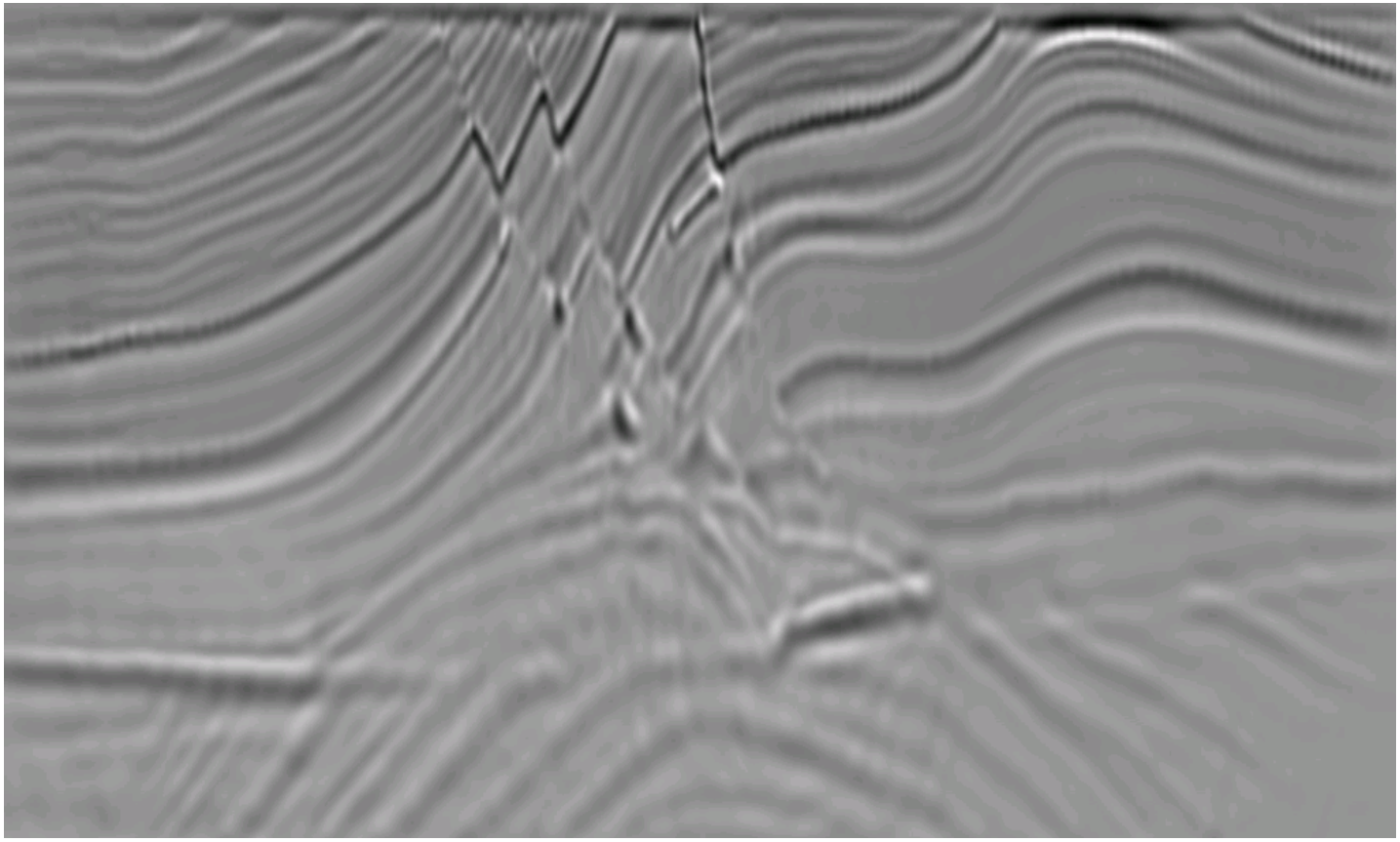
Inverting Marmousi is difficult . . .



Least-squares inverted RTM



Conventional RTM with true model



Conclusions

- interleaving RTM and FWI works when FWI fails
- only 10 iterations per source
- no data below 4 Hz
- only reflections

- add modified functional
- add up-down separation
- add multiples