Connecting FWI and LSRTM through variable restriction

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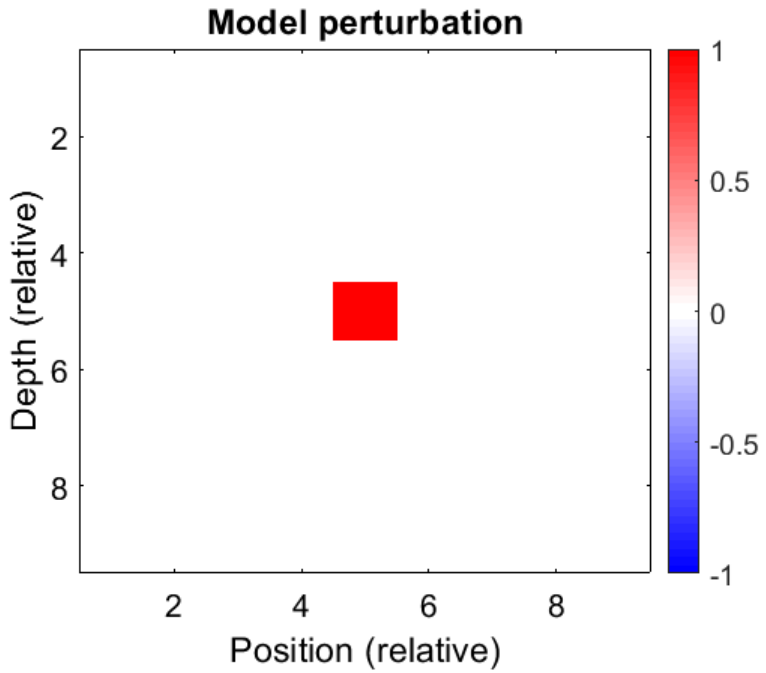
Introduction

- Full waveform inversion (FWI) seeks the model which best describes the data
- Most FWI approaches choose a subset of subsurface properties to invert
- Least squares migration (LSM) seeks a reflectivity model
- Usually, LSM invokes a high frequency approximation in the forward modeling

Can FWI be formulated to solve a LSM-type problem?

Variables in conventional FWI

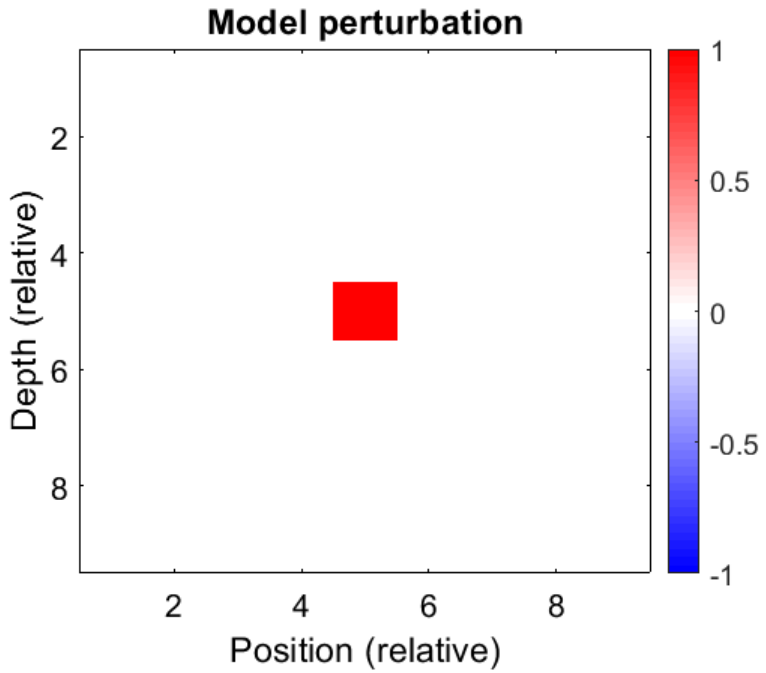
Conventional FWI minimizes an objective with respect to delta-like variables



The effects of changes in these variables can be estimated by looking at radiation patterns

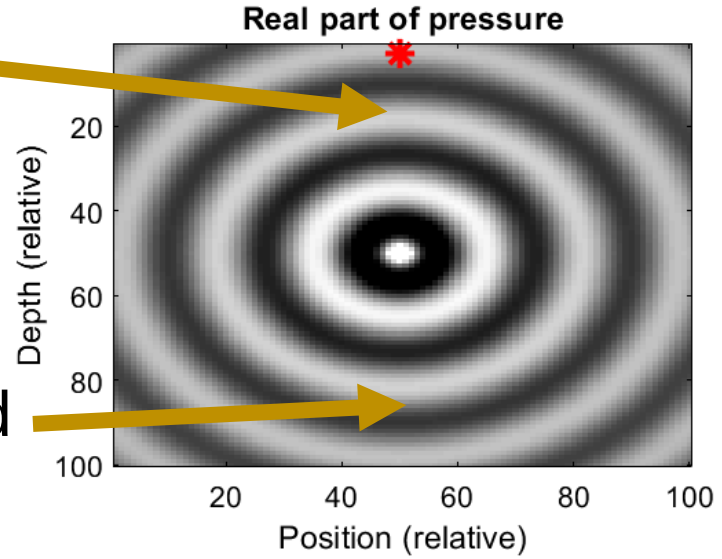
Variables in conventional FWI

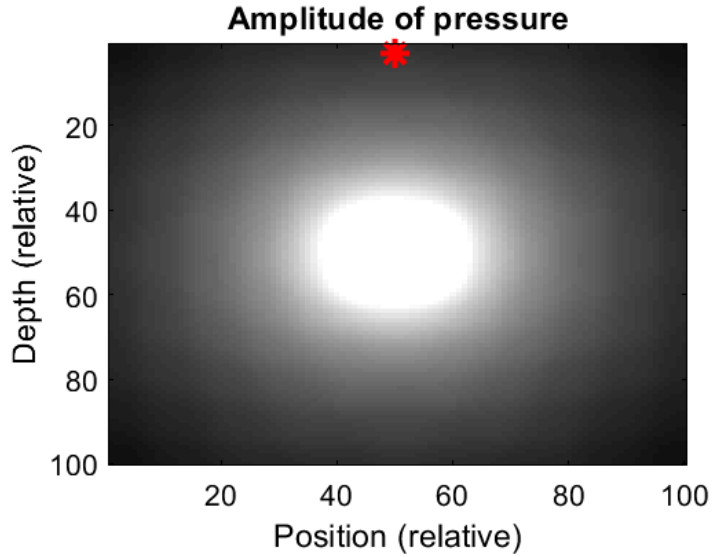
Conventional FWI minimizes an objective with respect to delta-like variables



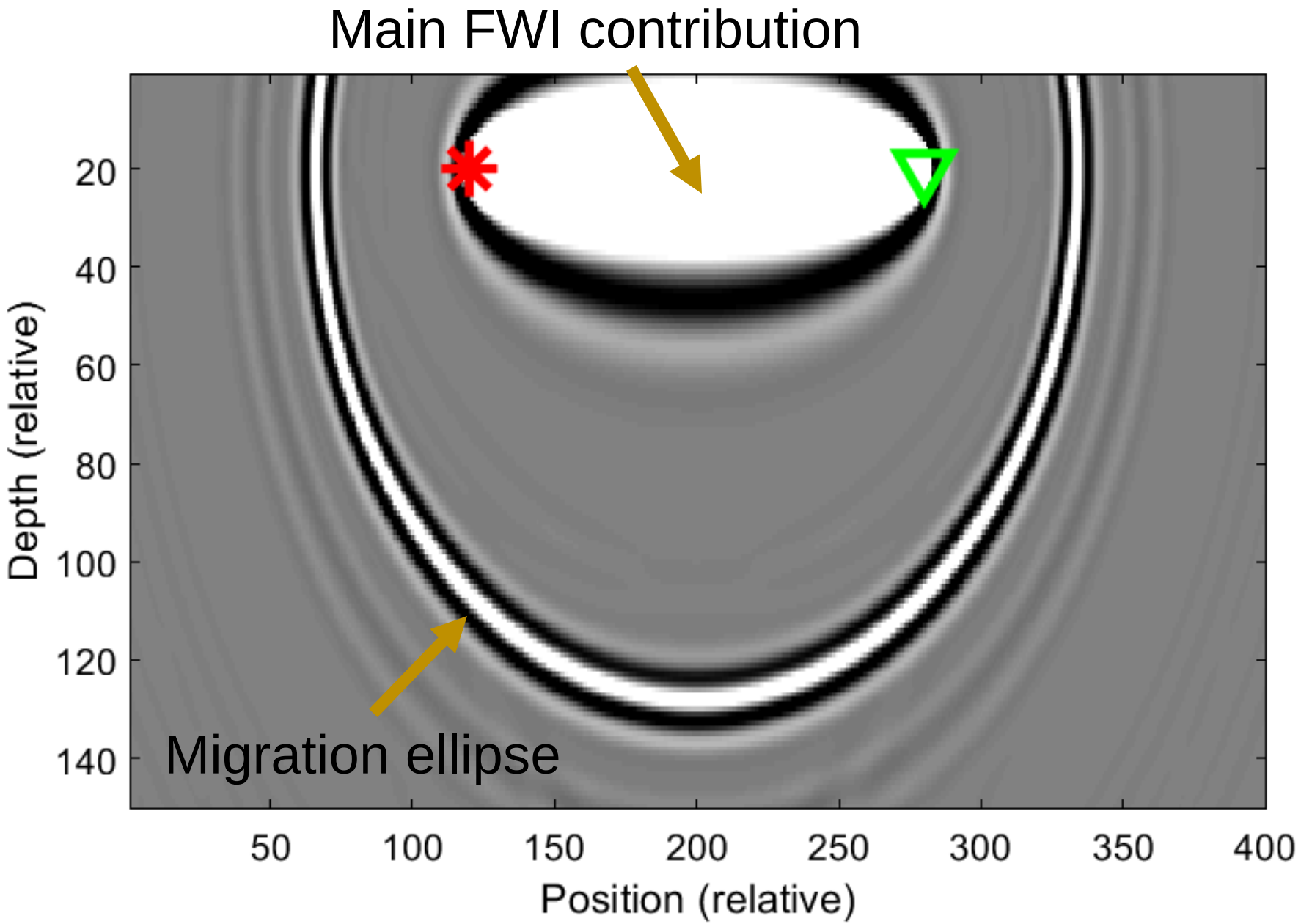
Reflected energy

Transmitted energy





Conventional FWI gradient



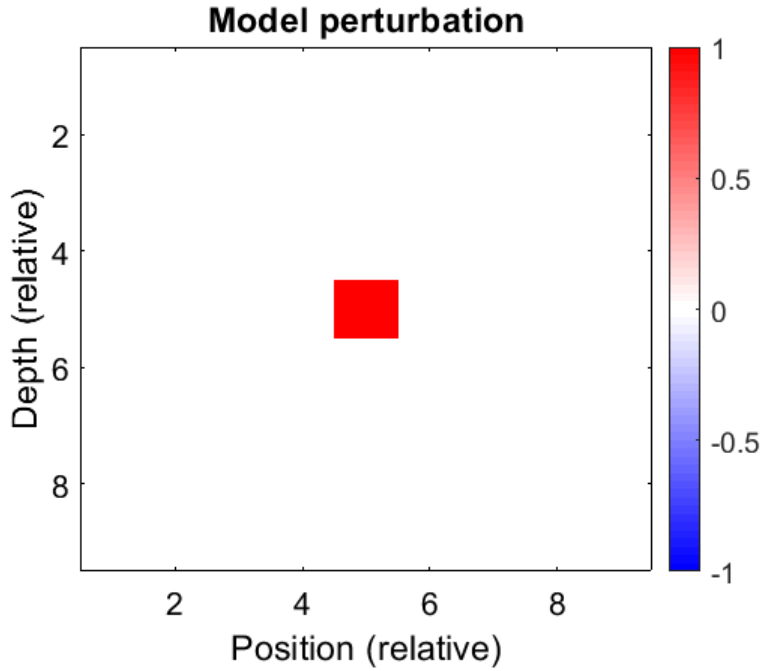
Focusing on reflectors

- Long wavelength velocity changes do not introduce reflections
- These changes can be prioritised in FWI

How can we formulate FWI to specifically recover reflectors?

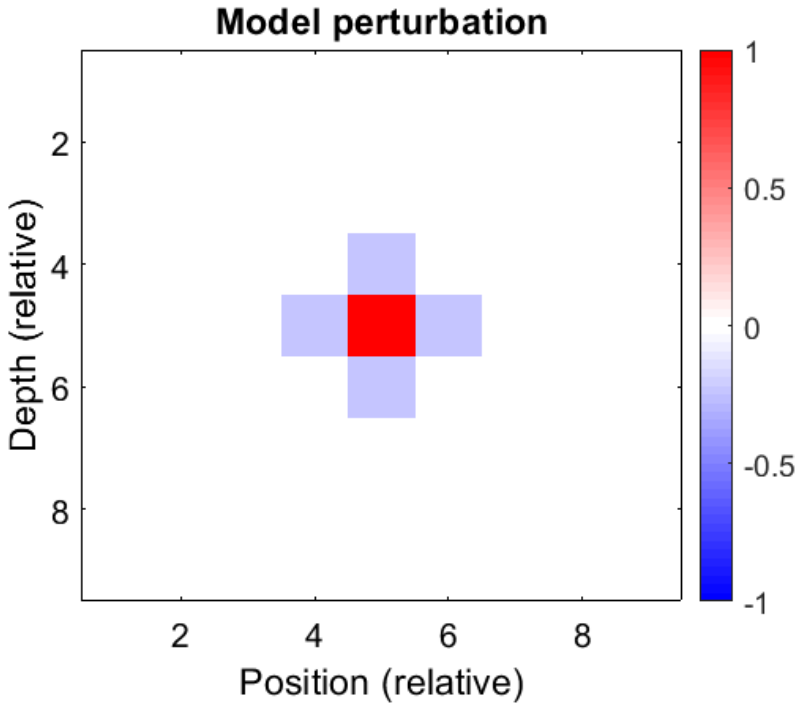
Variable restriction

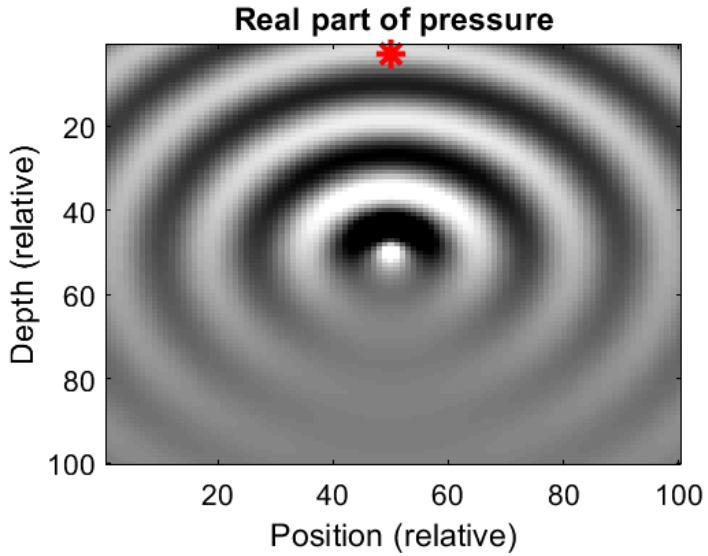
- Variable restriction may help solve this problem
- Variables with sharp velocity contrasts introduce reflections
- Variables with long wavelength features alter travel times



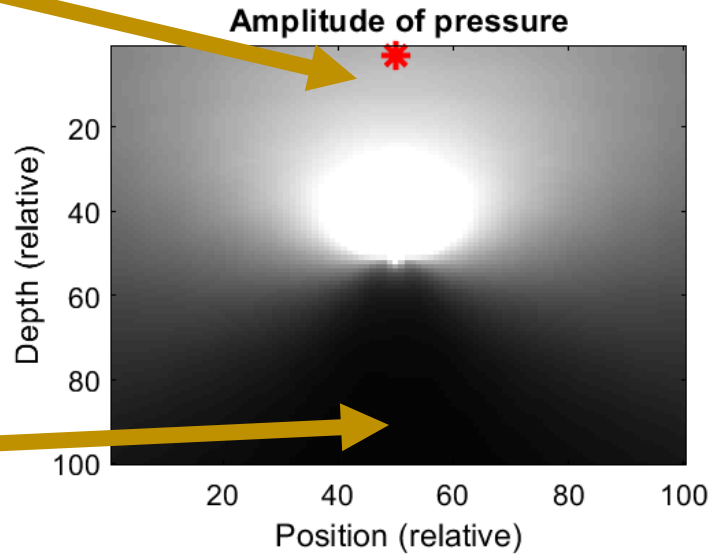
Reflectivity-type parameterization

This variable has sharp contrasts, but limited long wavelength components



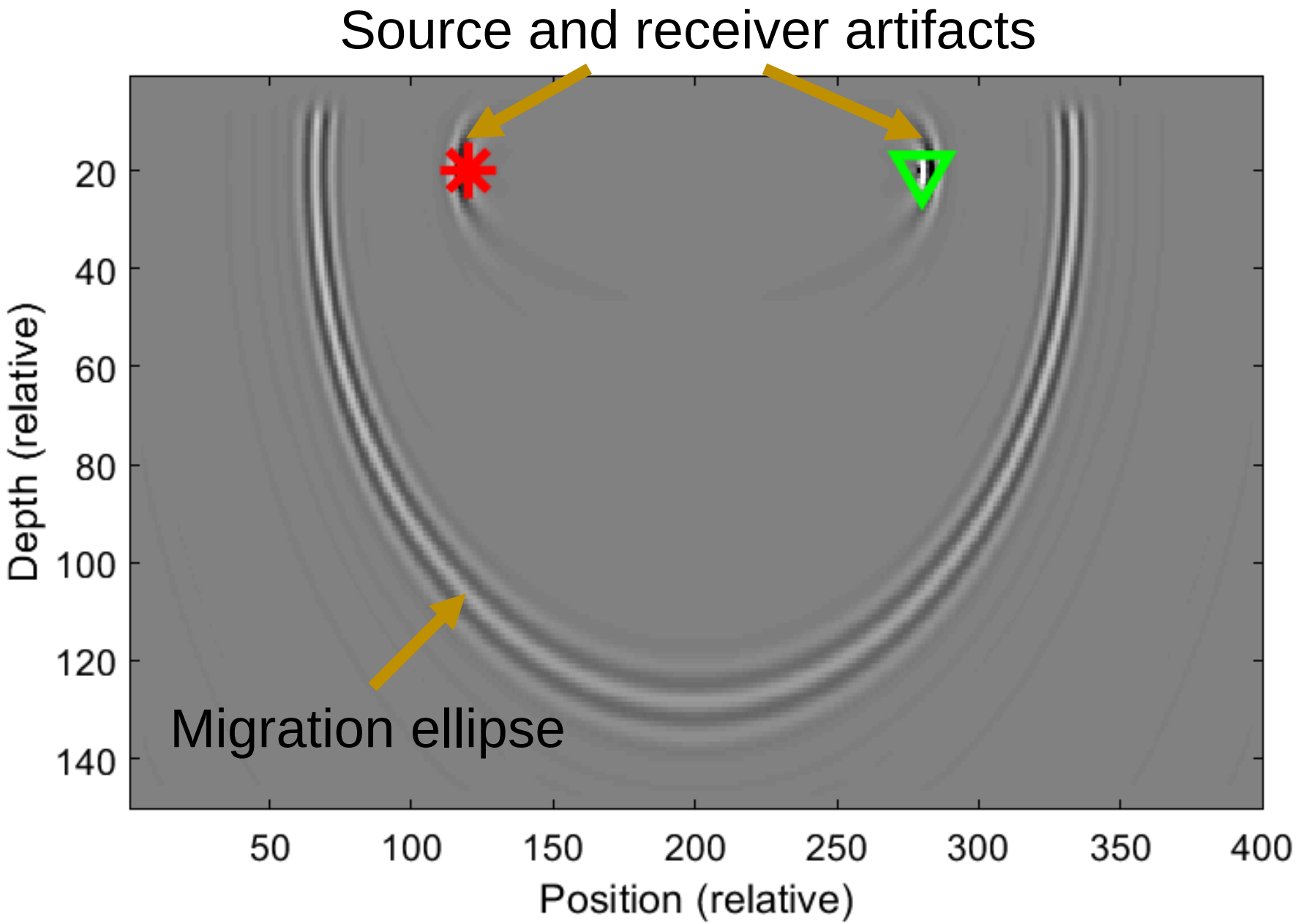


Reflected energy

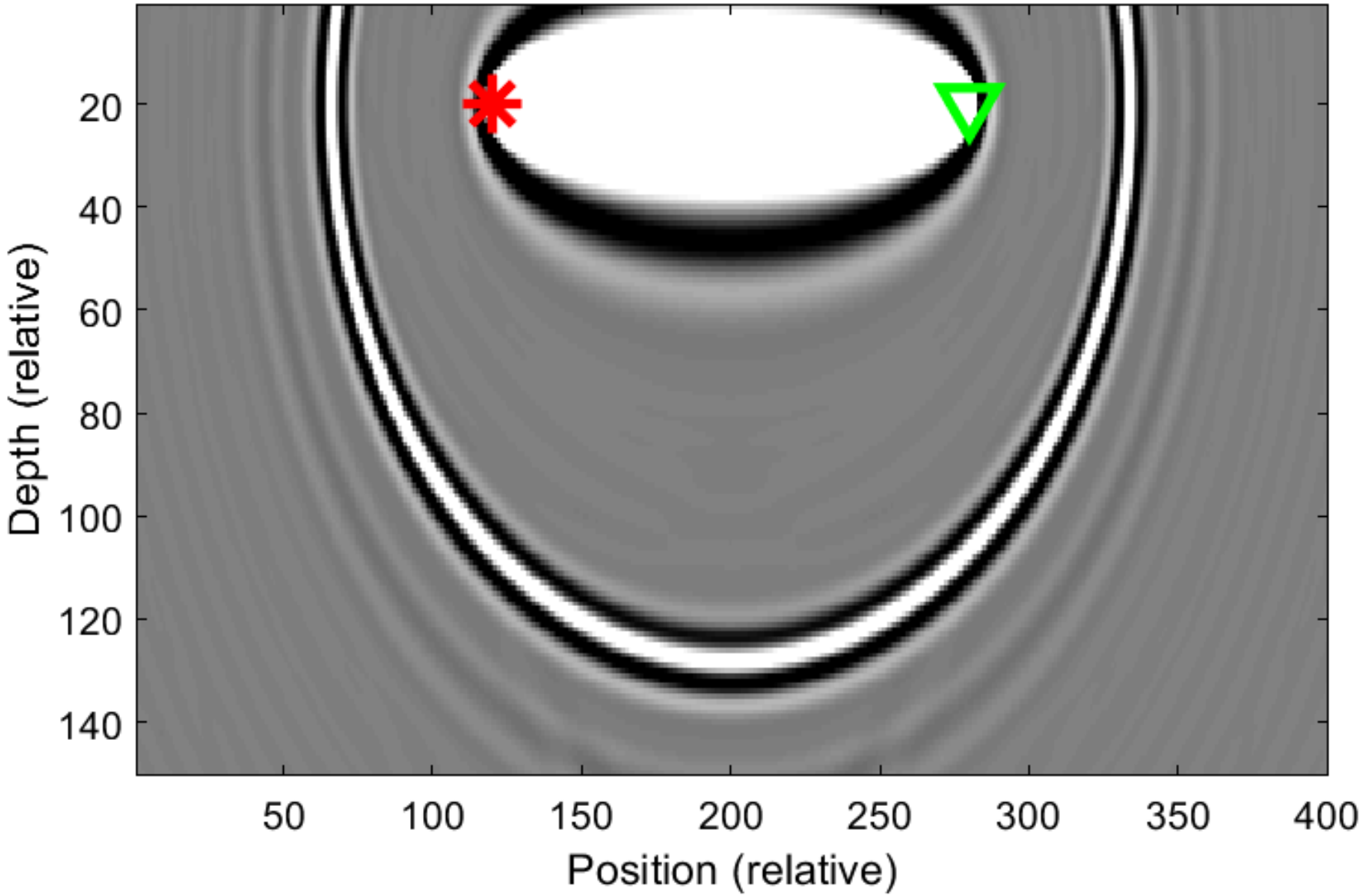


Limited transmission energy

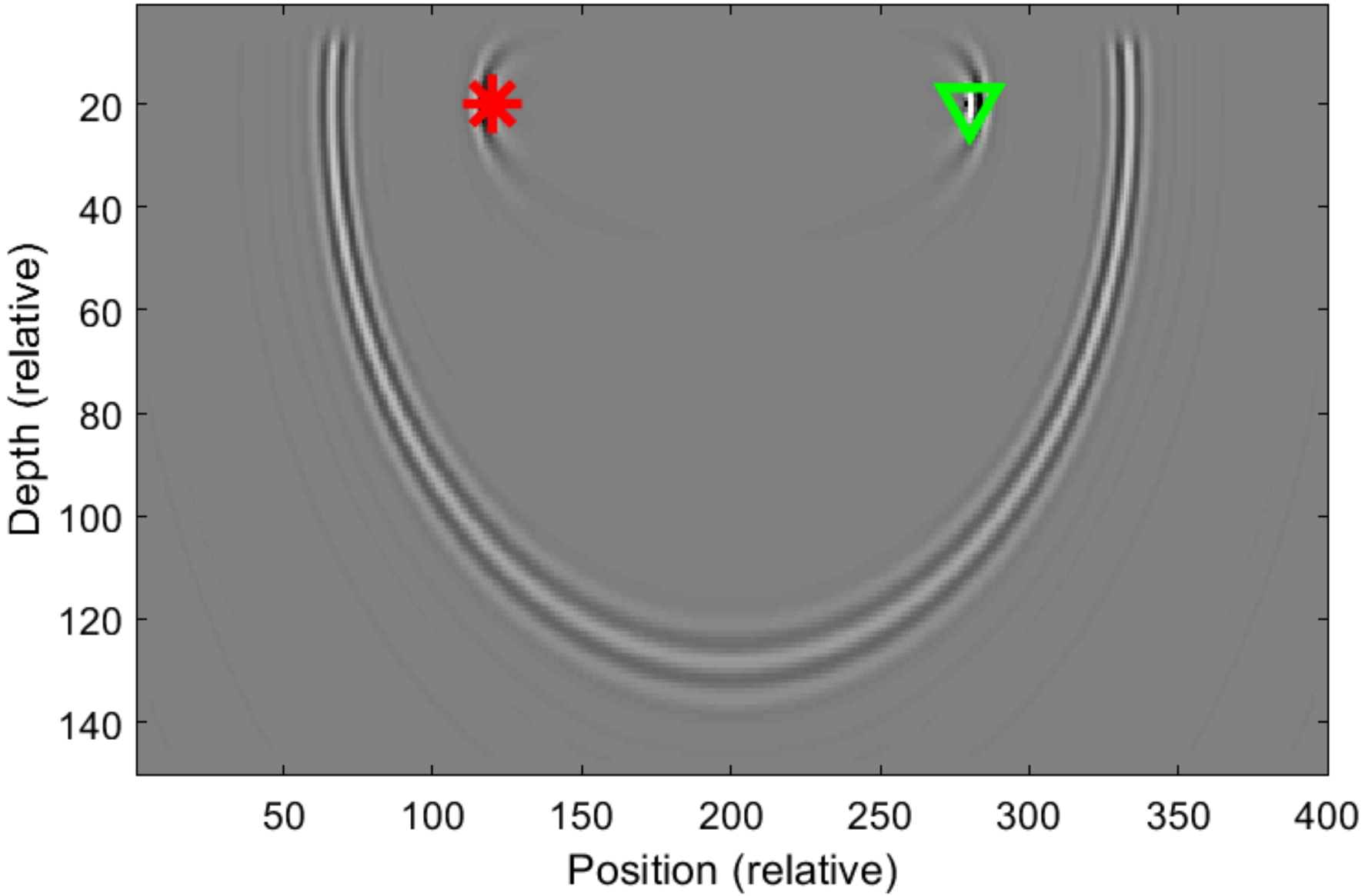
Reflectivity-type gradient



Conventional gradient

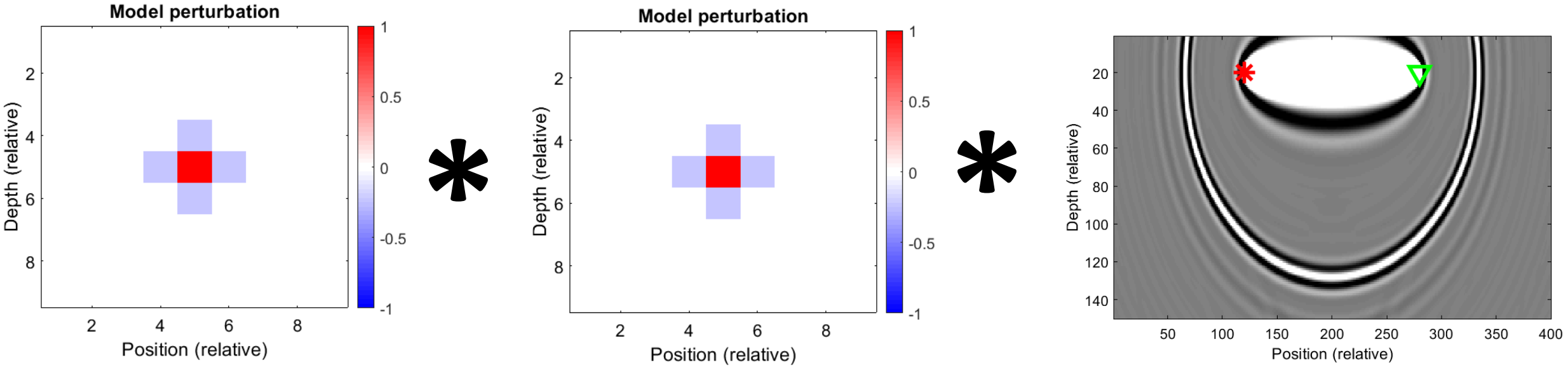


Reflectivity-type gradient



Calculating the gradient

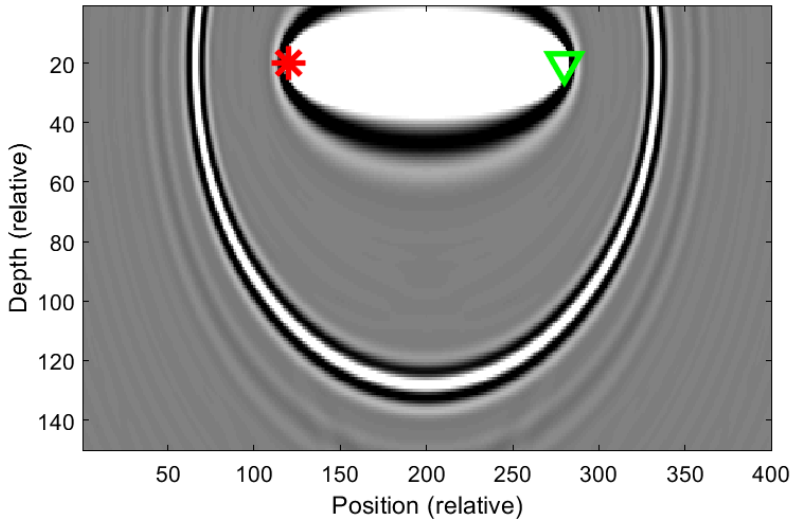
- The reflectivity-type gradient can be calculated by a convolution process
- In effect, this gradient is the result of filtering the conventional one



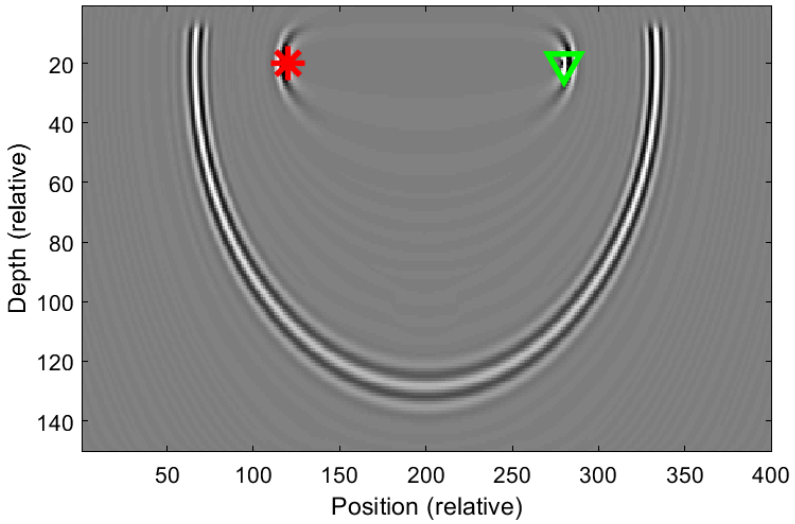
Calculating the gradient

- FWI is an **iterative process**
- Filtering the gradient is not equivalent to filtering after FWI

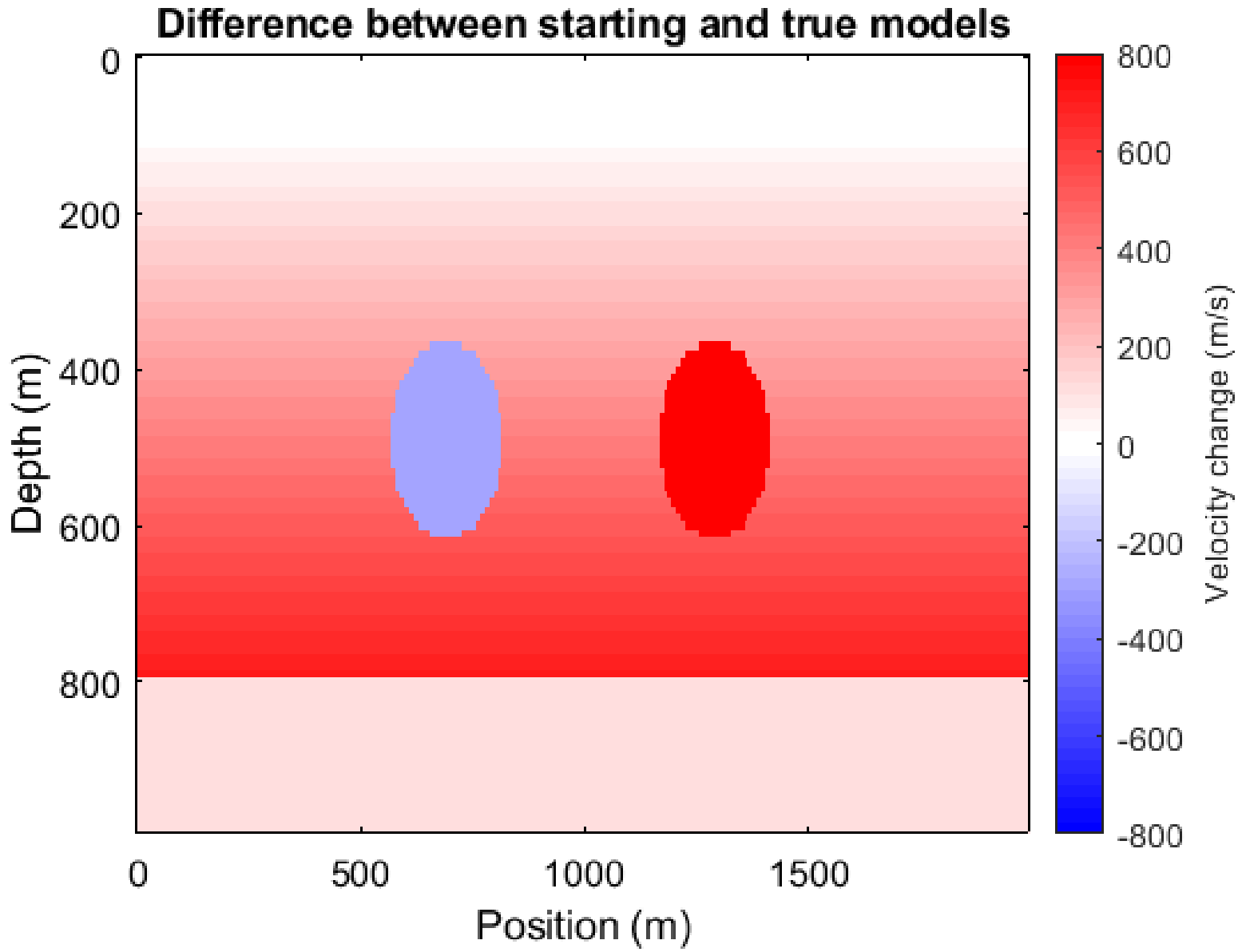
Filter $*$



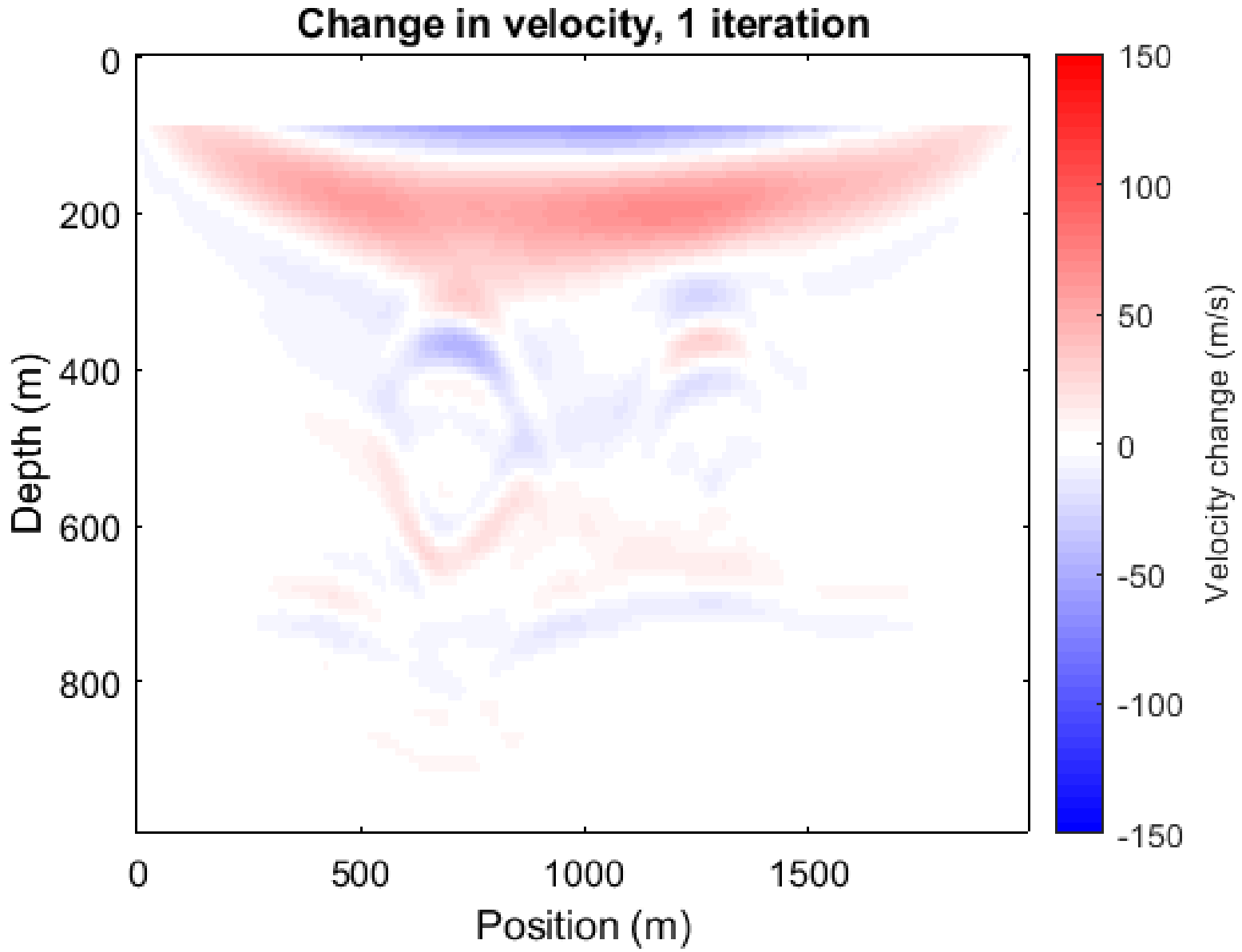
$=$



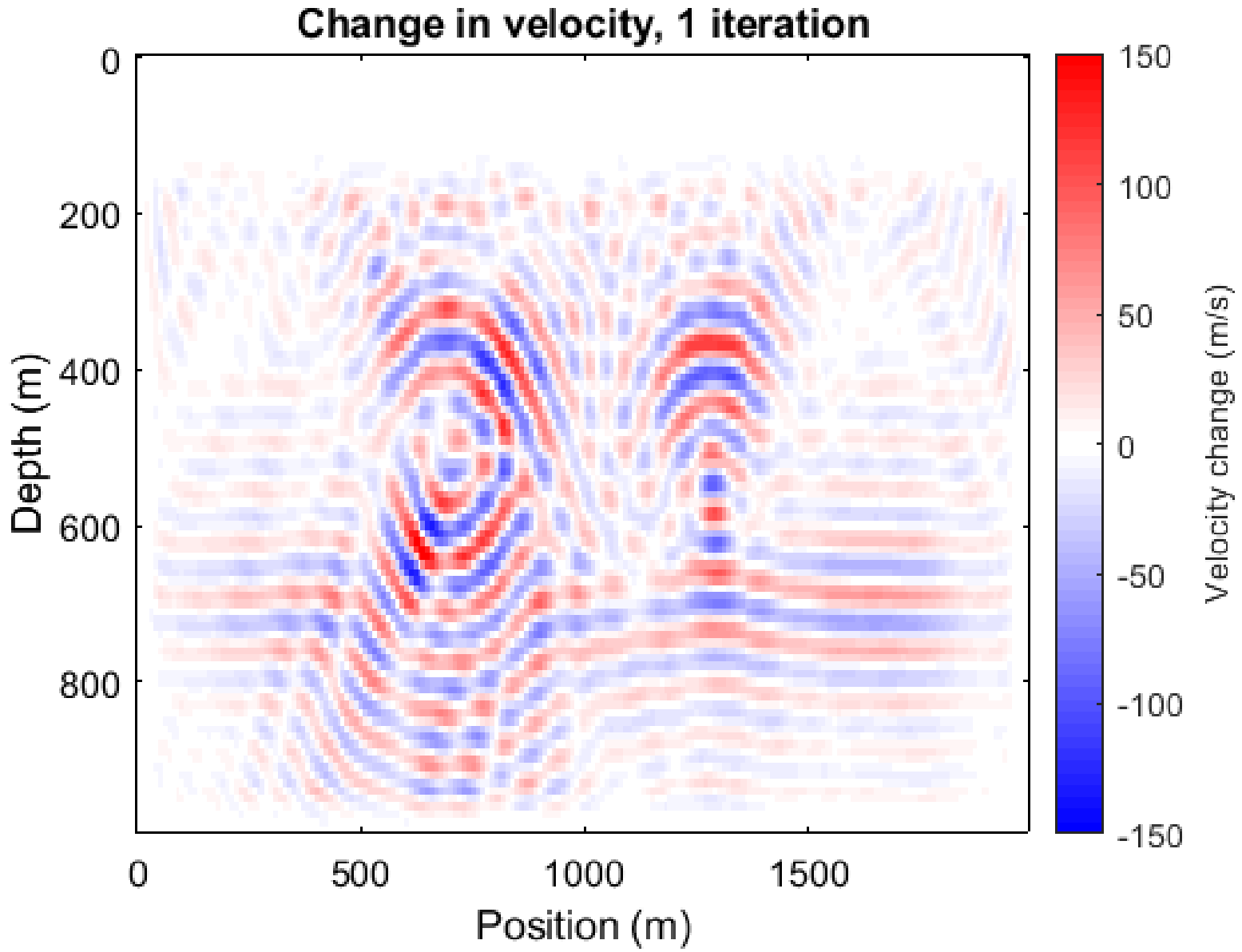
Numerical examples



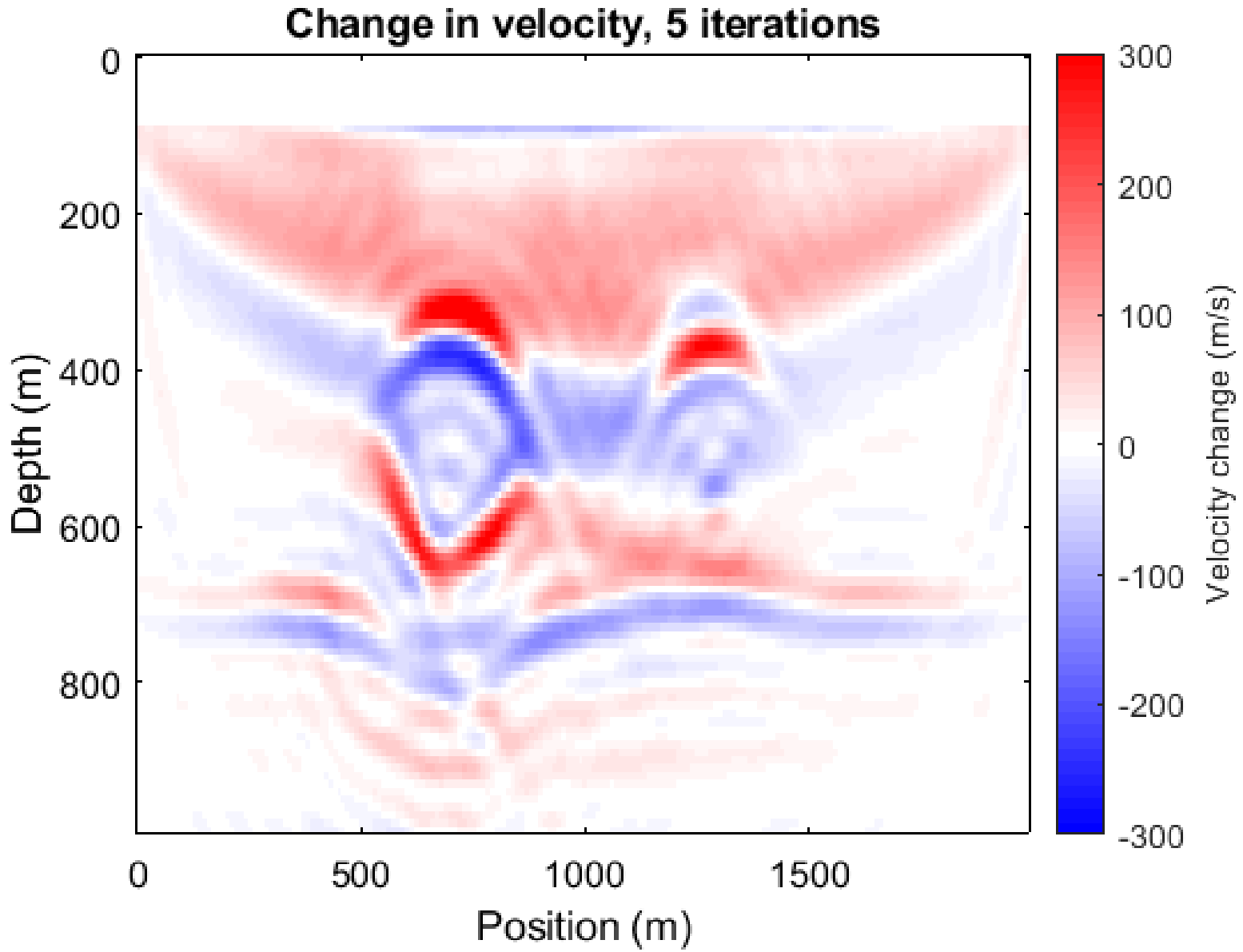
Conventional FWI, one iteration



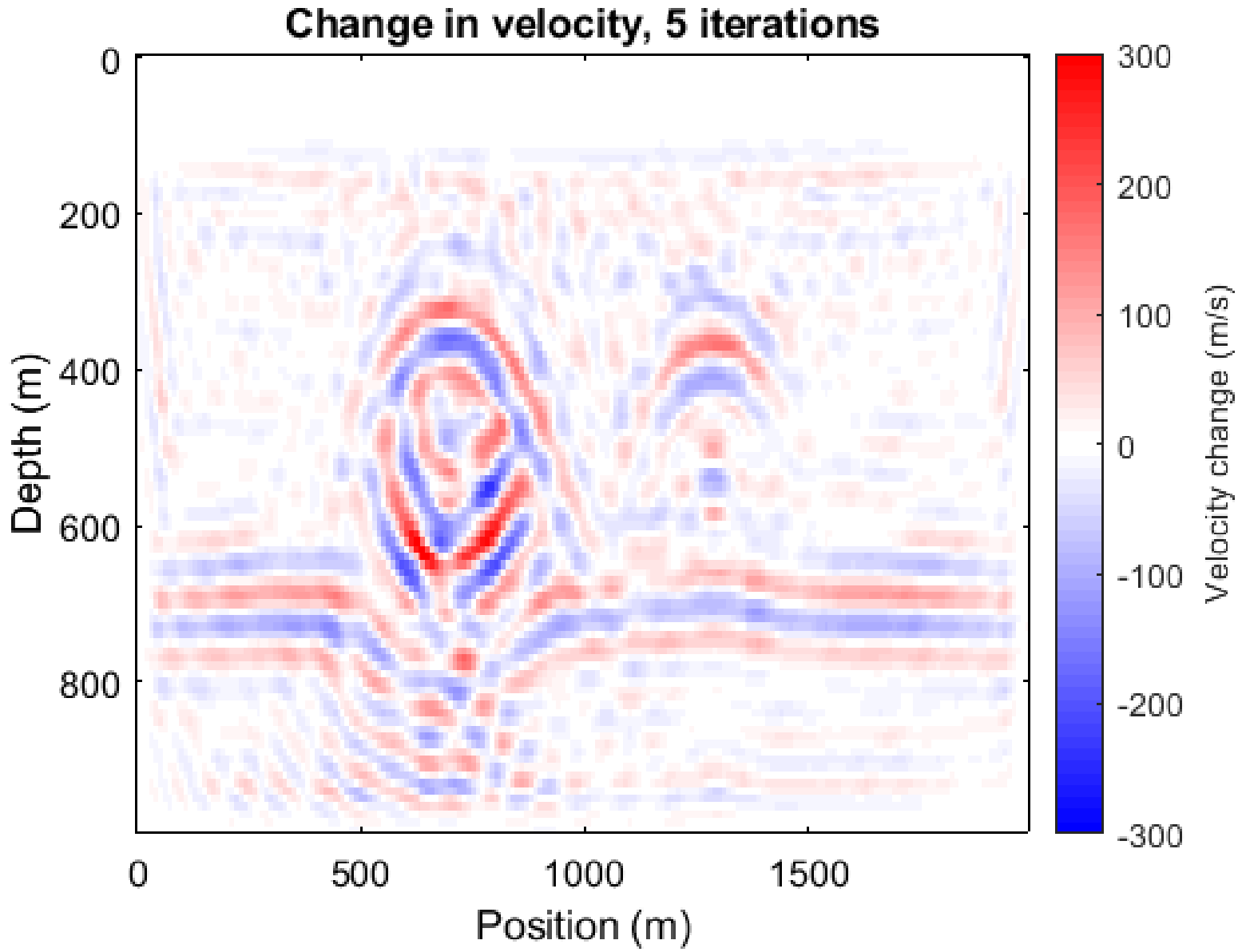
Reflectivity FWI, one iteration



Conventional FWI, five iterations



Reflectivity FWI, five iterations



Current obstacles

- Ringing in gradient term
- Related instability for large numbers of iterations
- Different variables may perform better

Conclusions

- FWI is driven by direct and diving wave energy
- This can hamper the recovery of reflectivity
- Reflectivity can be specifically recovered through variable restriction in FWI
- With restricted variables, FWI can perform a similar role to LSRTM

Acknowledgements

- CREWES sponsors, staff and students
- SEG and CSEGF
- Daniel Trad

CREWES

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Clarifying remarks

Twas brillig and the slithy toves
Did gyre and gimble in the wabe
All mimsy were the borogoves
And the mome raths outgrabe

“Beware the Jabberwock, my son
The jaws that bite, the claws that catch
Beware the Jubjub bird and shun
The frumious Bandersnatch”

He took his vorpal sword in hand
Long time the manxome foe he sought
So rested he by the Tumtum tree
And stood a while in thought

And as in uffish thought he stood
The Jabberwock, with eyes of flame
Came whiffling through the tulgey wood
And burbled as it came

One-two, one-two and through and through
The vorpal blade went snicker-snack
He left it dead, and with its head
He went galumphing back

“And hast thou slain the Jabberwock?
Come to my arms my beamish boy
Oh frabjous day! Callooh! Callay!”
He chortled in his joy

Twas brillig and the slithy toves
Did gyre and gimble in the wabe
All mimsy were the borogoves
And the mome raths outgrabe