2D inversion of DAS surface wave data

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CMC Containment & Monitoring Institute

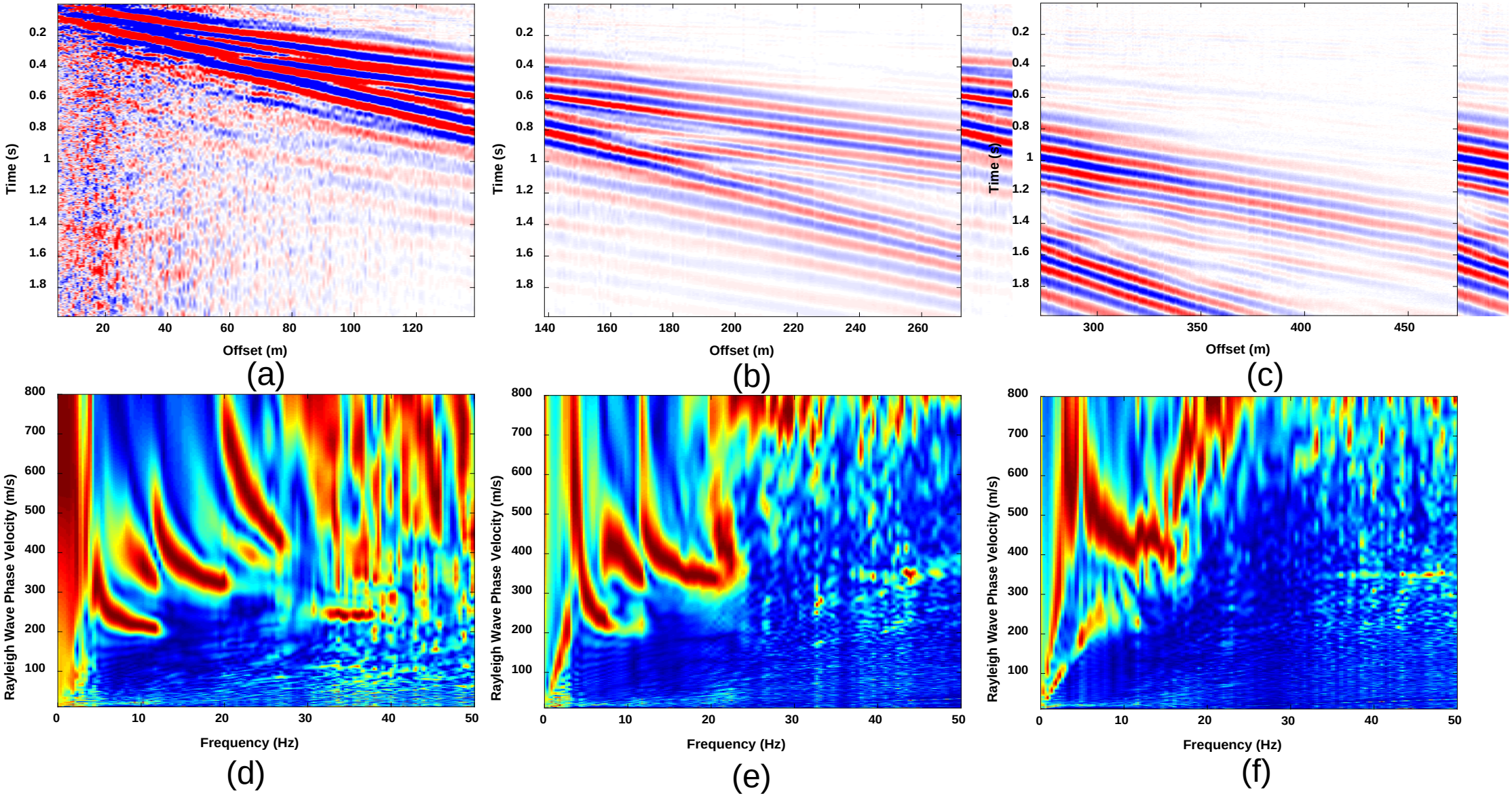
Introduction

Multi-offset MASW

Surface-wave FWI

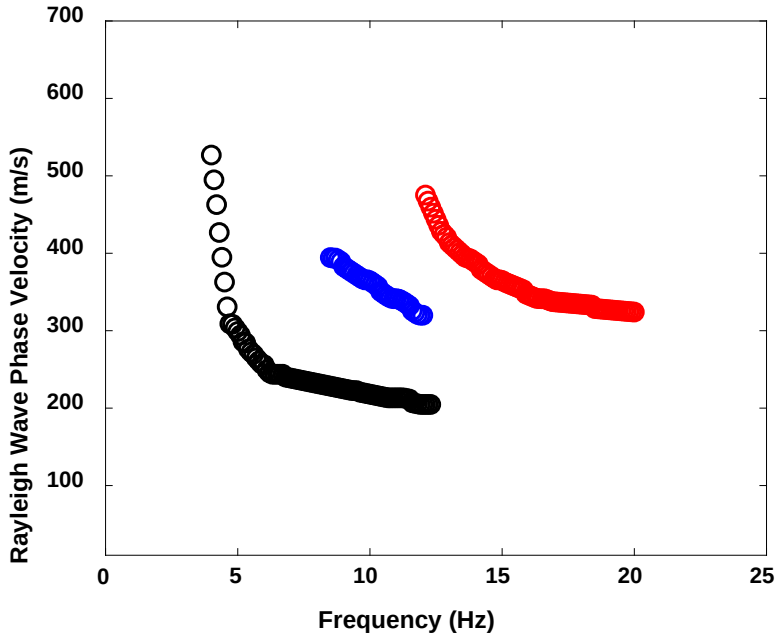
DAS data inversion

MO-MASW


Time (s)
Offset (m)
(a)
(b)
(c)
Rayleigh Wave Phase Velocity (m/s)
Frequency (Hz)
(d)
(e)
(f)

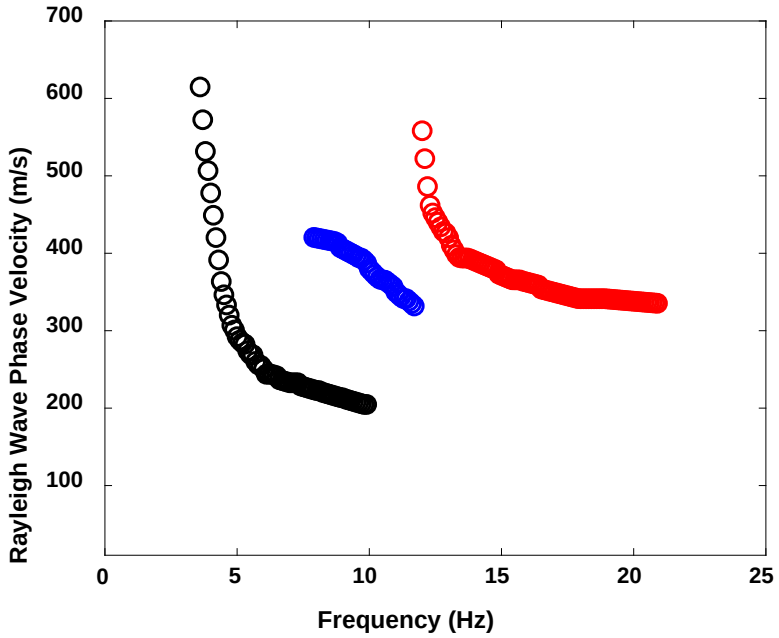
MO-MASW

Offset range 1



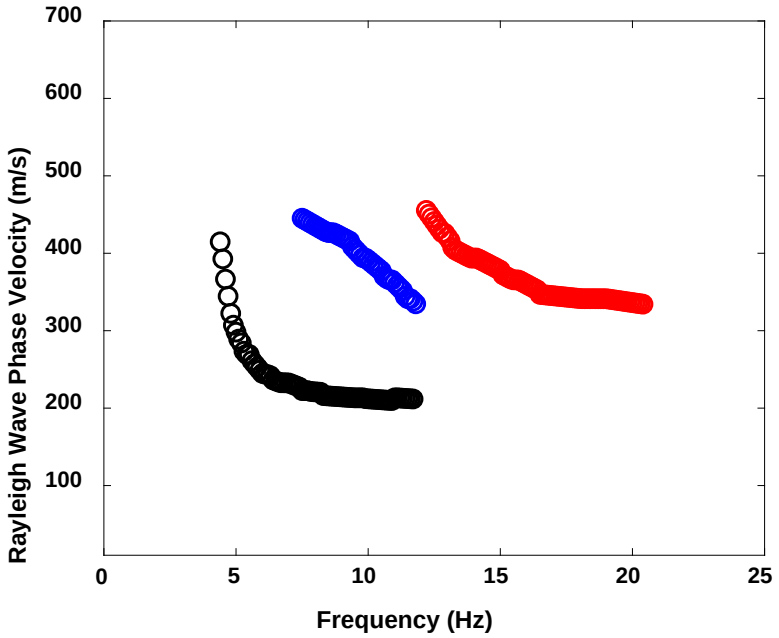
(a)

Offset range 2



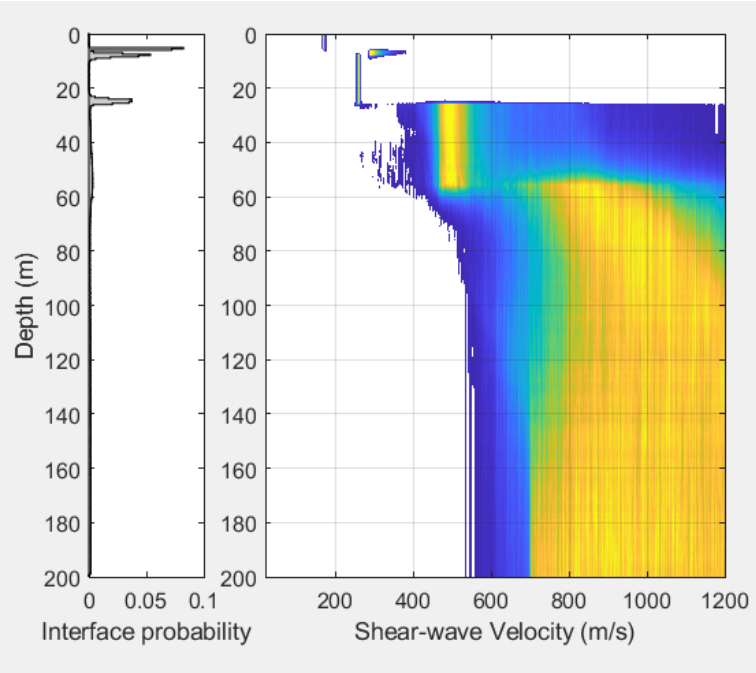
(b)

Offset range 3

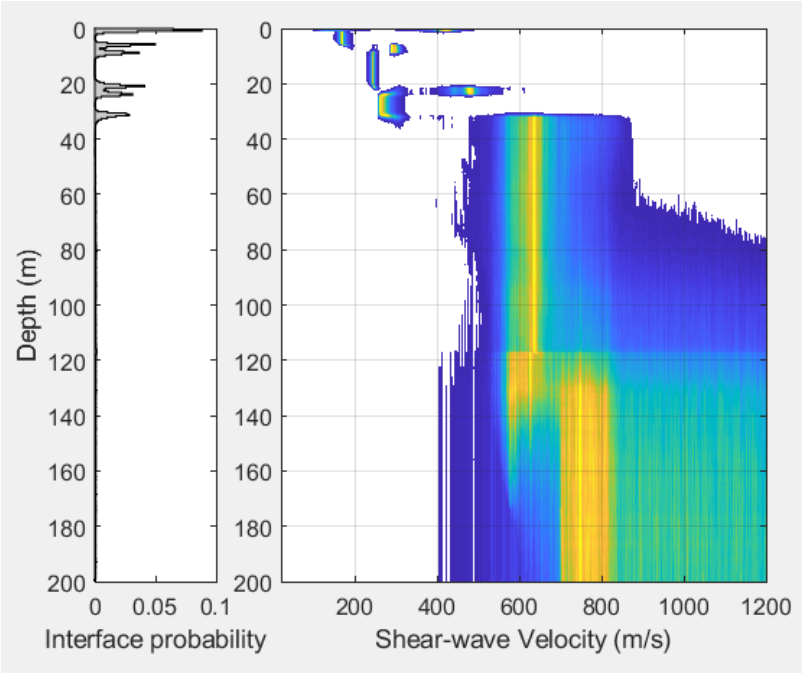


(c)

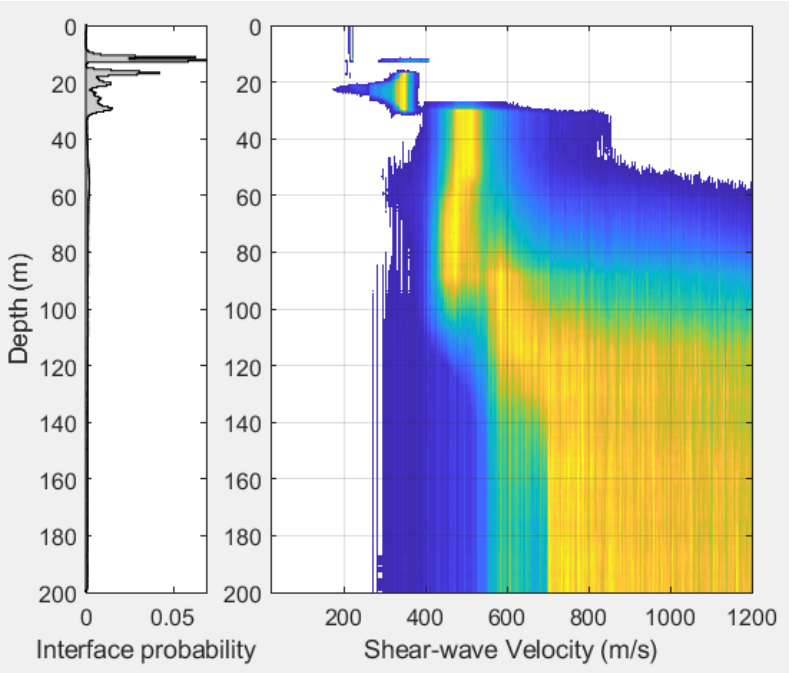
MO-MASW


Depth (m)
0
20
40
60
80
100
120
140
160
180
200
0
0.05
0.1
Interface probability
200
400
600
800
1000
1200
Shear-wave Velocity (m/s)

(a)

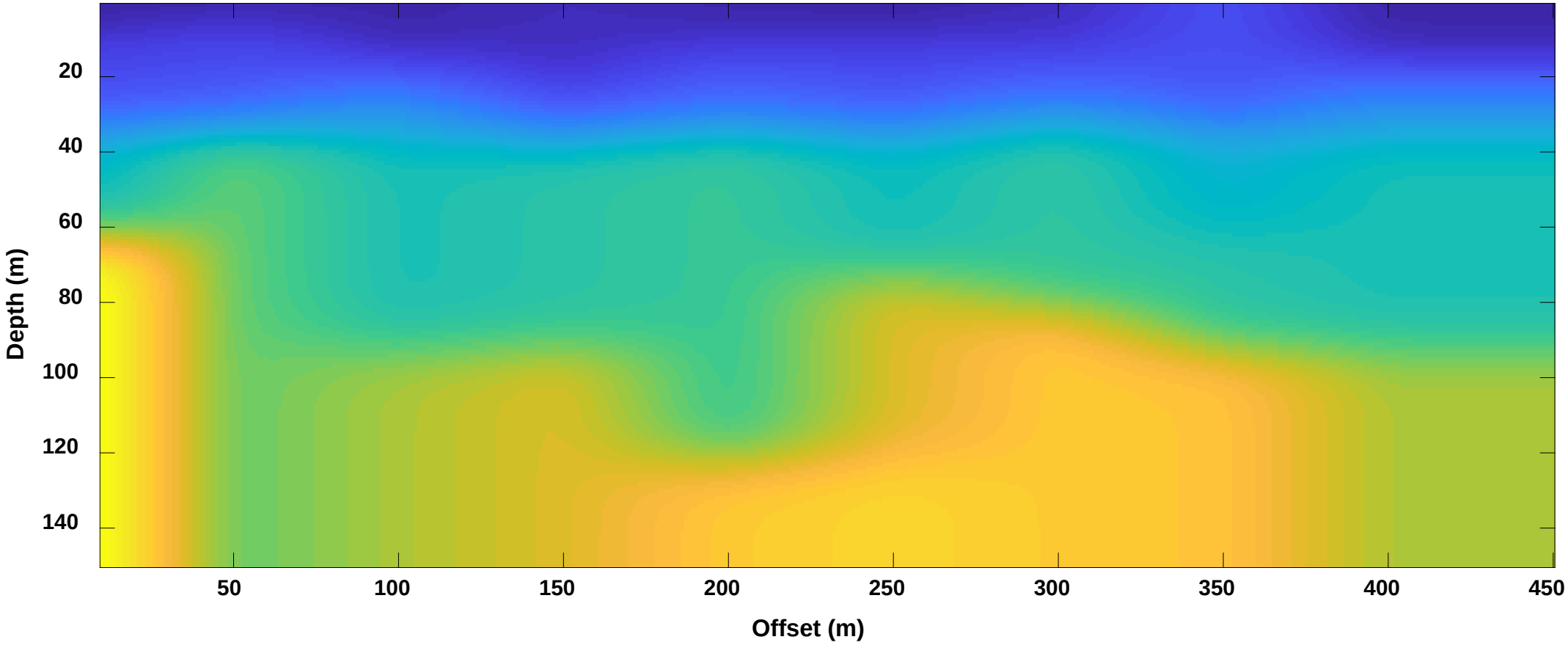

Depth (m)
0
20
40
60
80
100
120
140
160
180
200
0
0.05
0.1
Interface probability
200
400
600
800
1000
1200
Shear-wave Velocity (m/s)

(b)


Depth (m)
0
20
40
60
80
100
120
140
160
180
200
0
0.05
Interface probability
200
400
600
800
1000
1200
Shear-wave Velocity (m/s)

(c)

MO-MASW


Depth (m)
20
40
60
80
100
120
140
50
100
150
200
250
300
350
400
450
Offset (m)

Summary

- Hard to deal with complex lateral variations, due to its assumption.
- Limited vertical resolution ability, velocity structure beyond 100 m depth is not reliable.
- The picking accuracy influences the inversion result greatly.
- Provide reasonable near-surface velocity range, but difficult to resolve near-surface structures.

Surface Wave FWI

Model 1: True models

Source spacing: 50 m

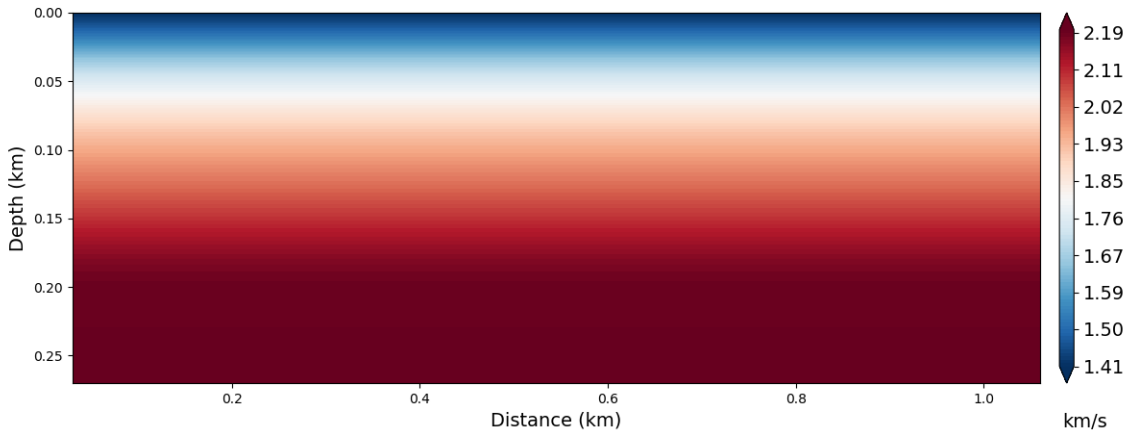
Receiver spacing: 5 m

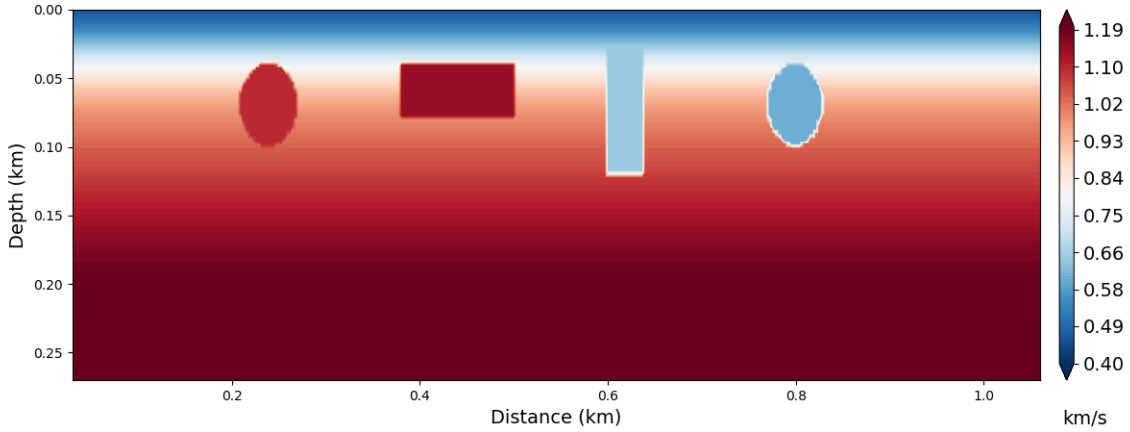
Source wavelet: 10 Hz Ricker wavelet

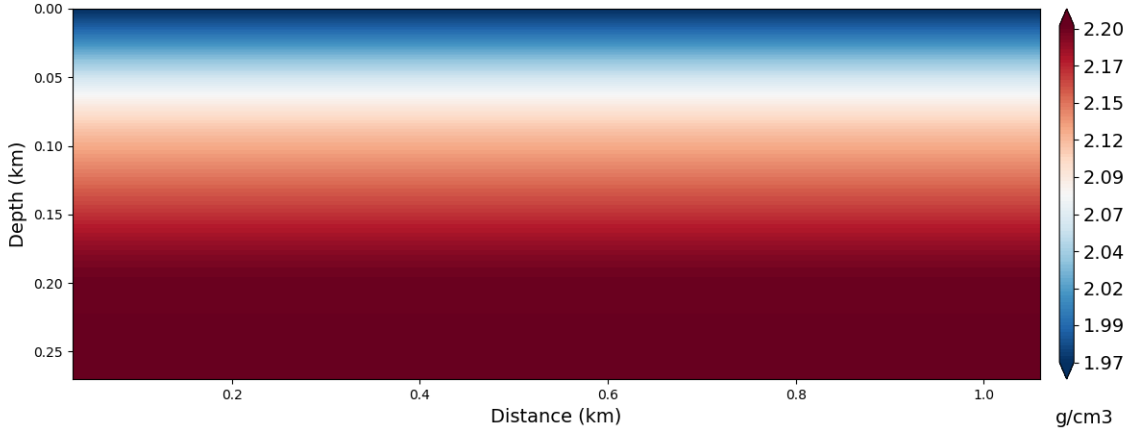
Vp

Vs

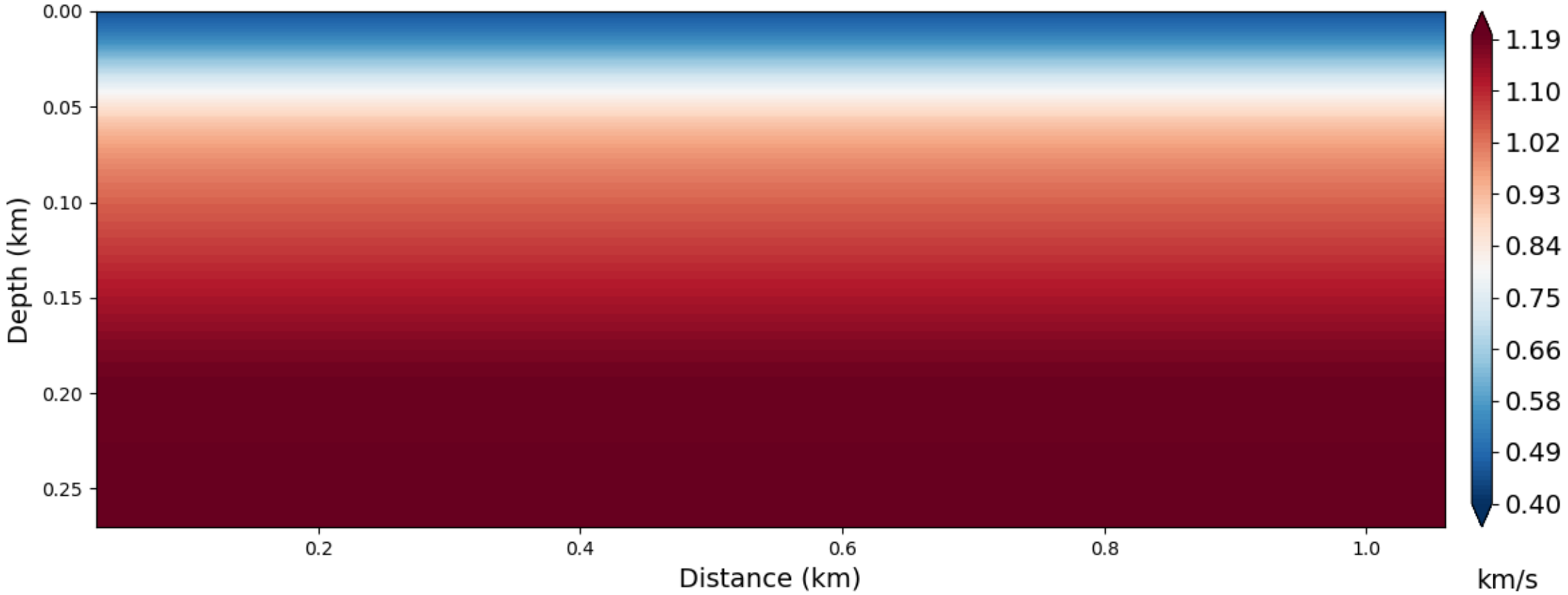
Density



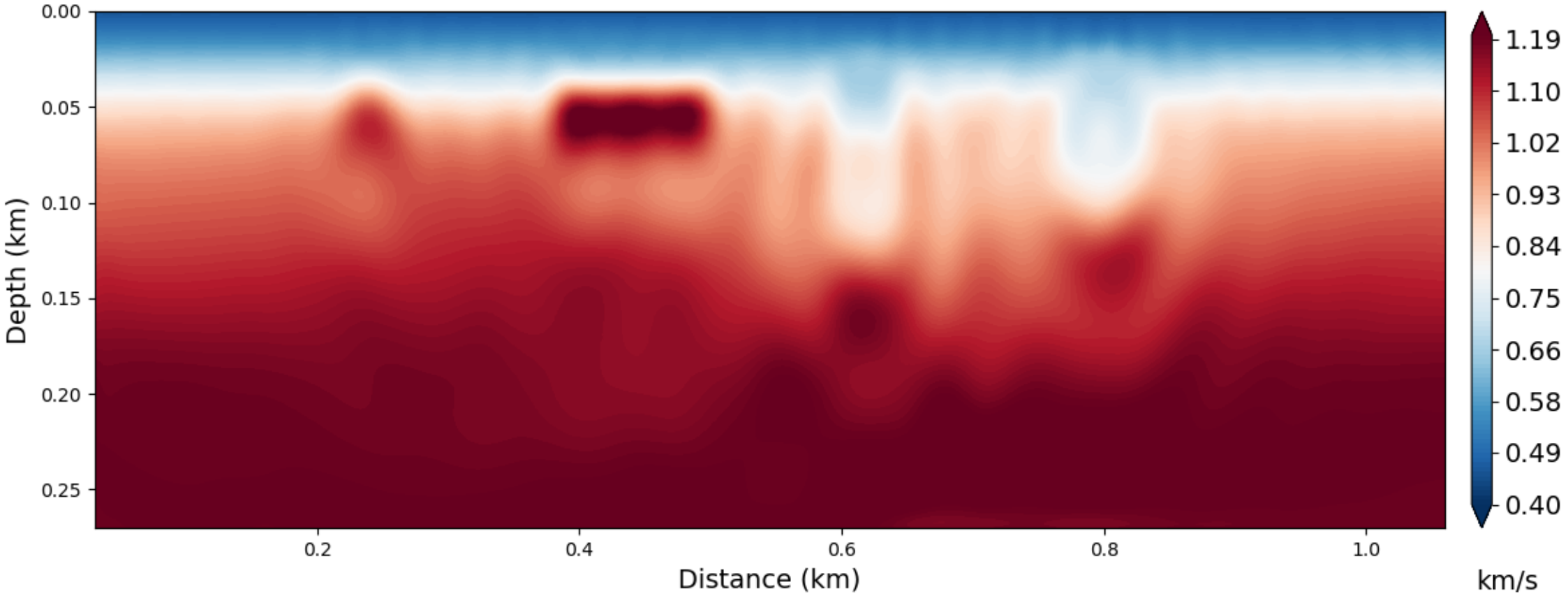




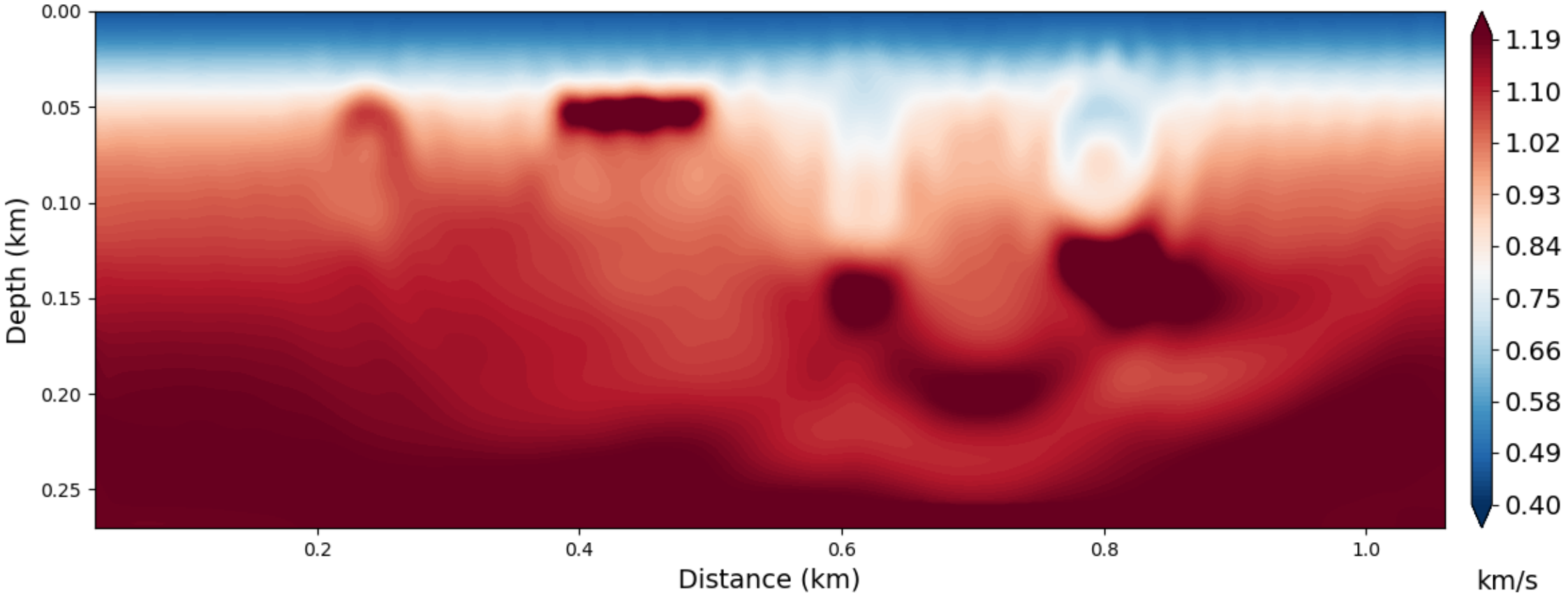
Model 1: Vs initial model



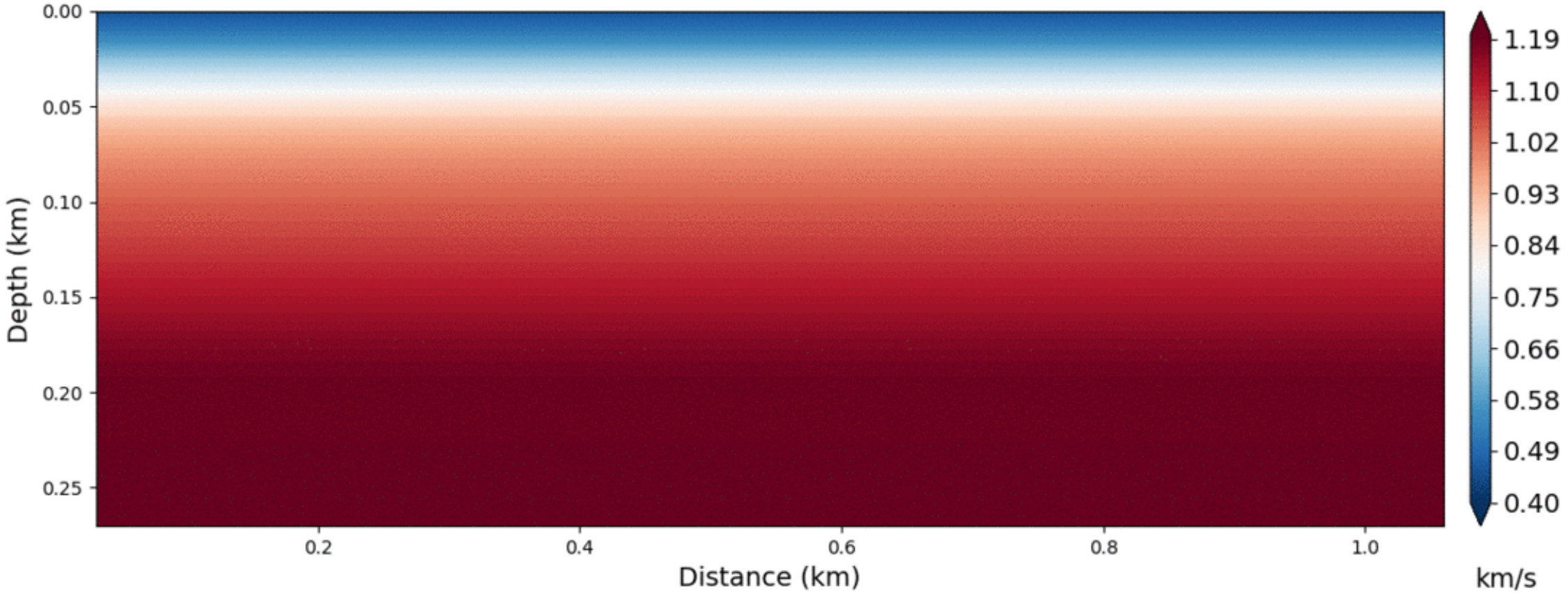
FWI: WD misfit function result



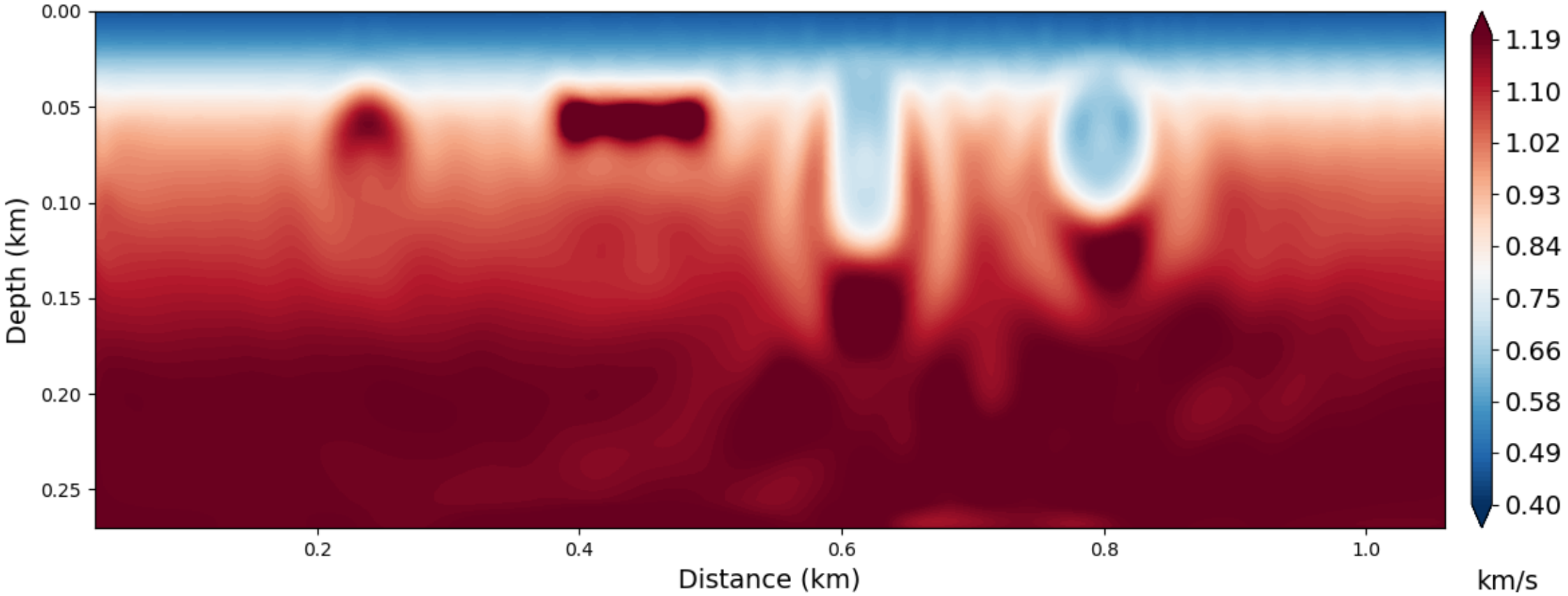
FWI: ED misfit function result



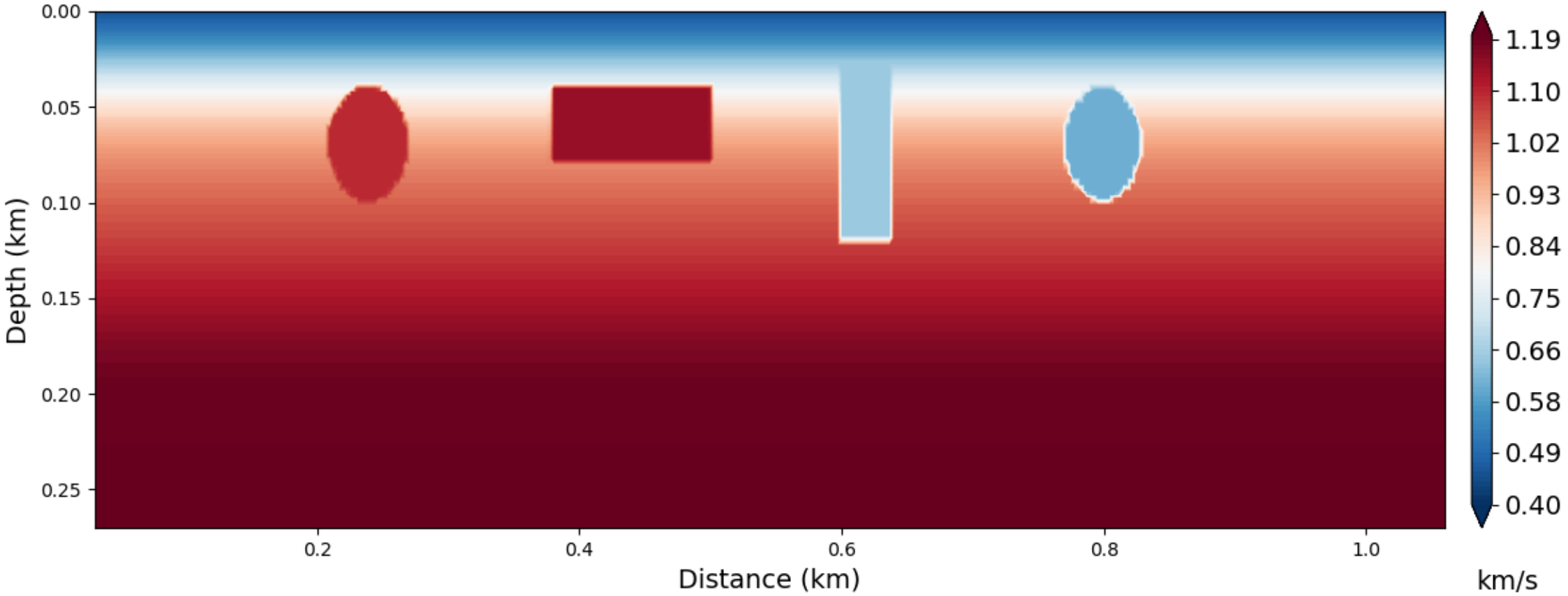
FWI: ED+WD

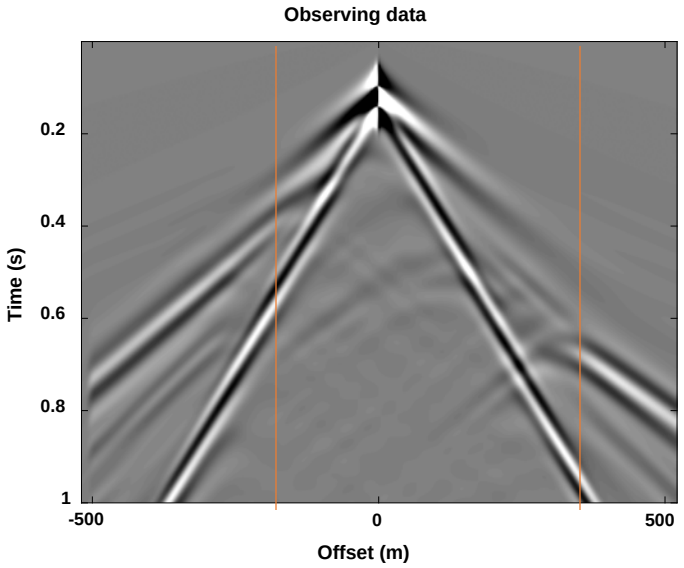

0.00
0.05
0.10
0.15
0.20
0.25
Depth (km)
0.2
0.4
0.6
0.8
1.0
Distance (km)
1.19
1.10
1.02
0.93
0.84
0.75
0.66
0.58
0.49
0.40
km/s

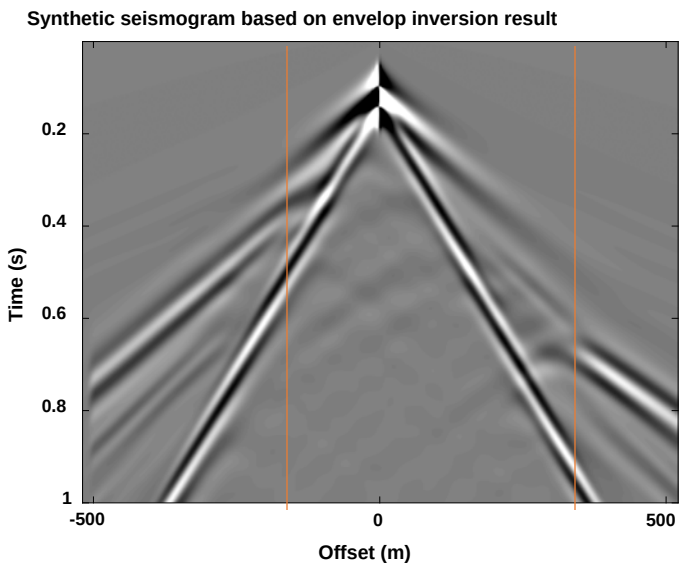
FWI: ED+WD

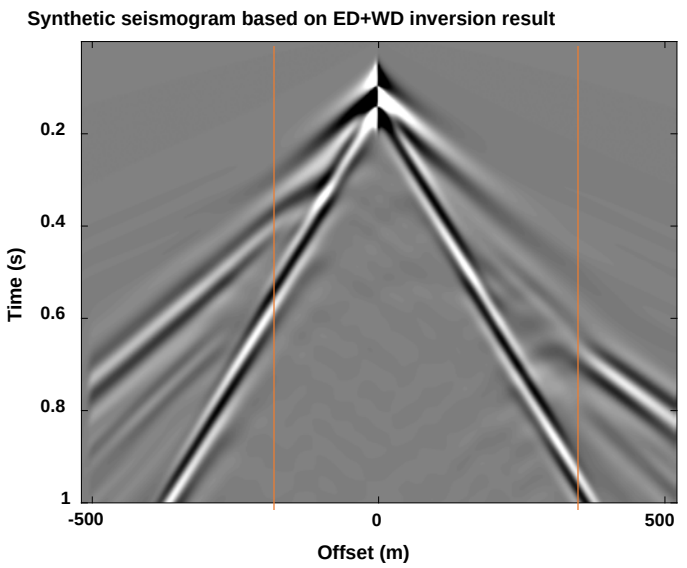

0.00
0.05
0.10
0.15
0.20
0.25
Depth (km)
0.2
0.4
0.6
0.8
1.0
Distance (km)
1.19
1.10
1.02
0.93
0.84
0.75
0.66
0.58
0.49
0.40
km/s

True model

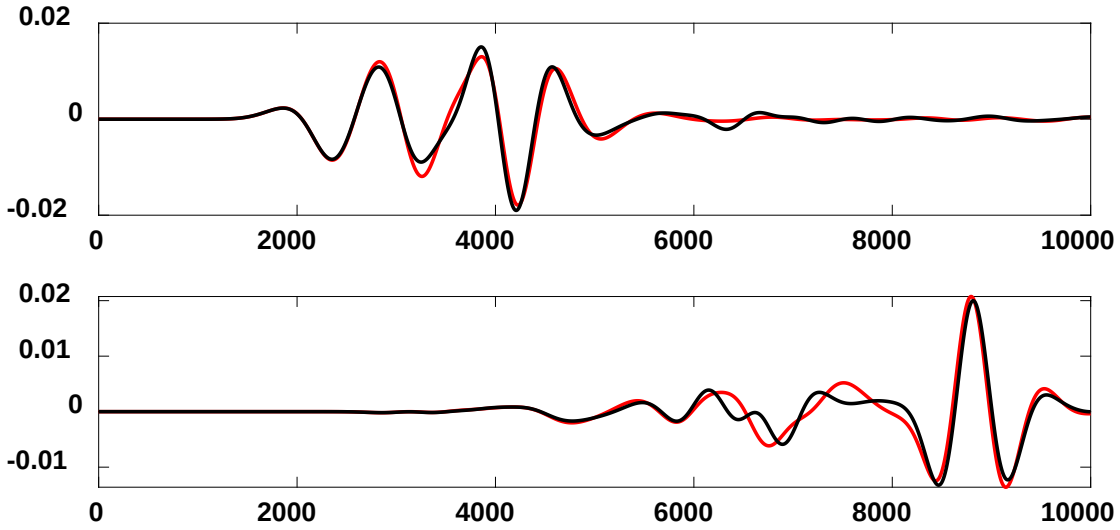

0.00
0.05
0.10
0.15
0.20
0.25
Depth (km)
0.2
0.4
0.6
0.8
1.0
Distance (km)
1.19
1.10
1.02
0.93
0.84
0.75
0.66
0.58
0.49
0.40
km/s



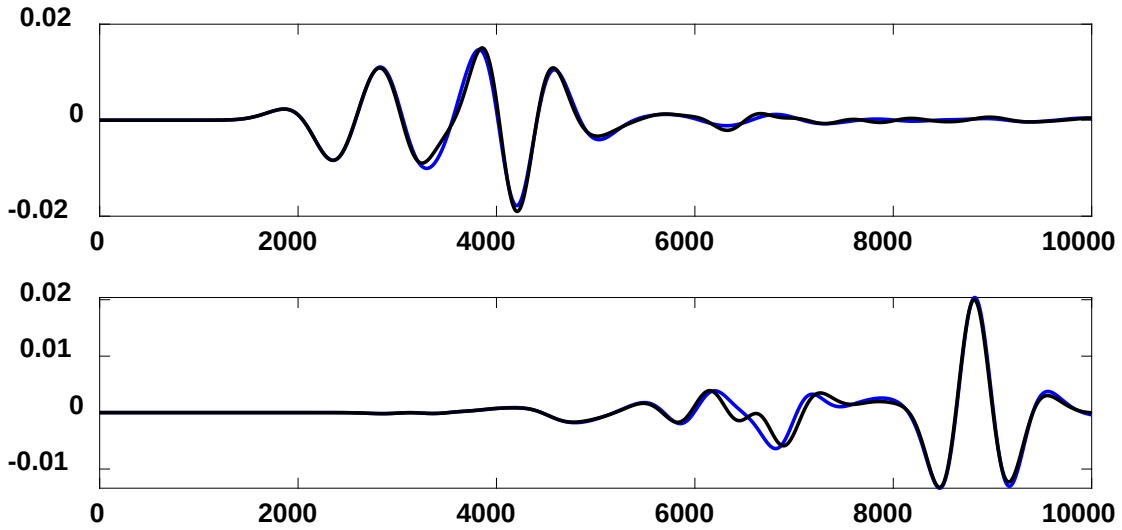




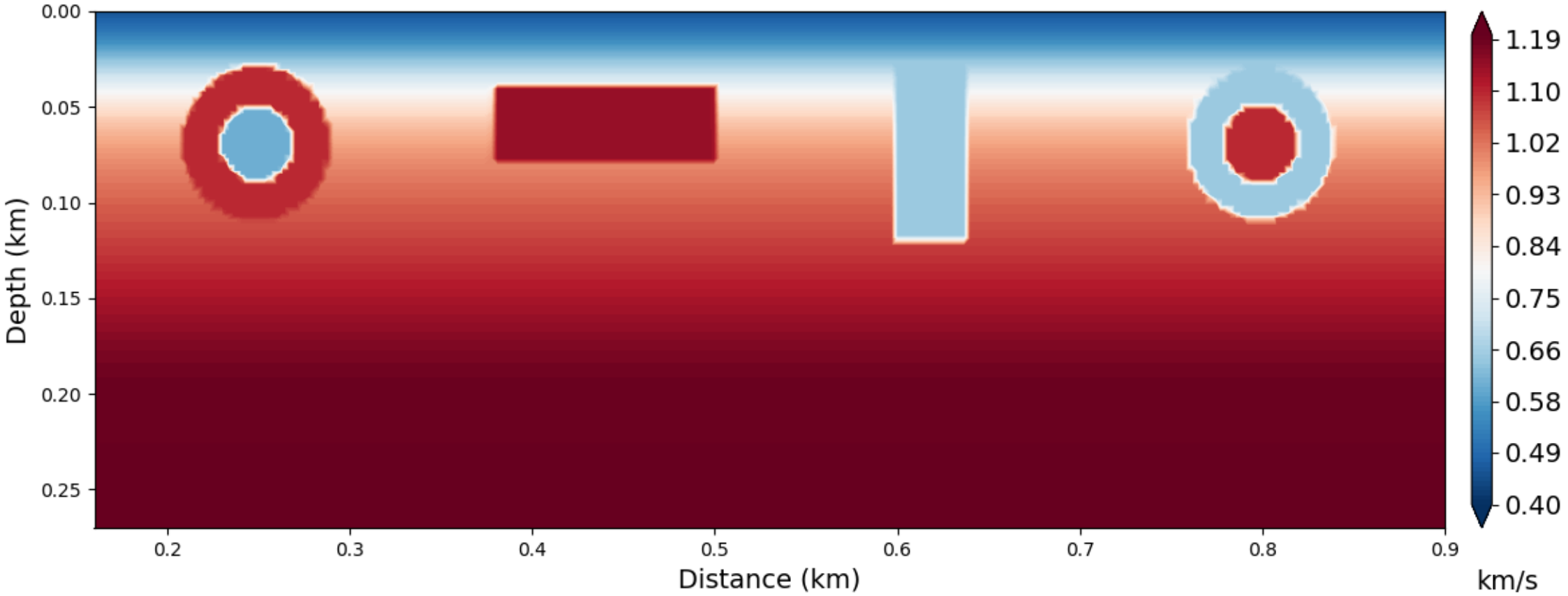
ED FWI



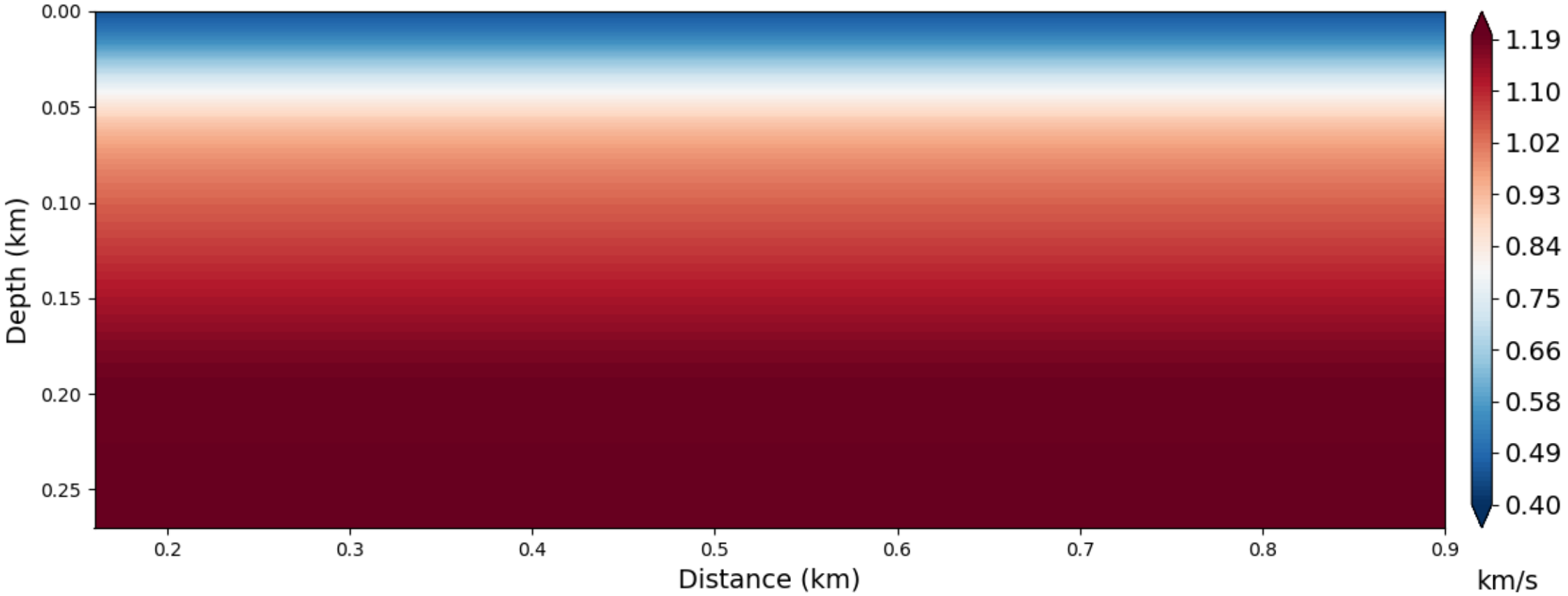
ED+WD FWI



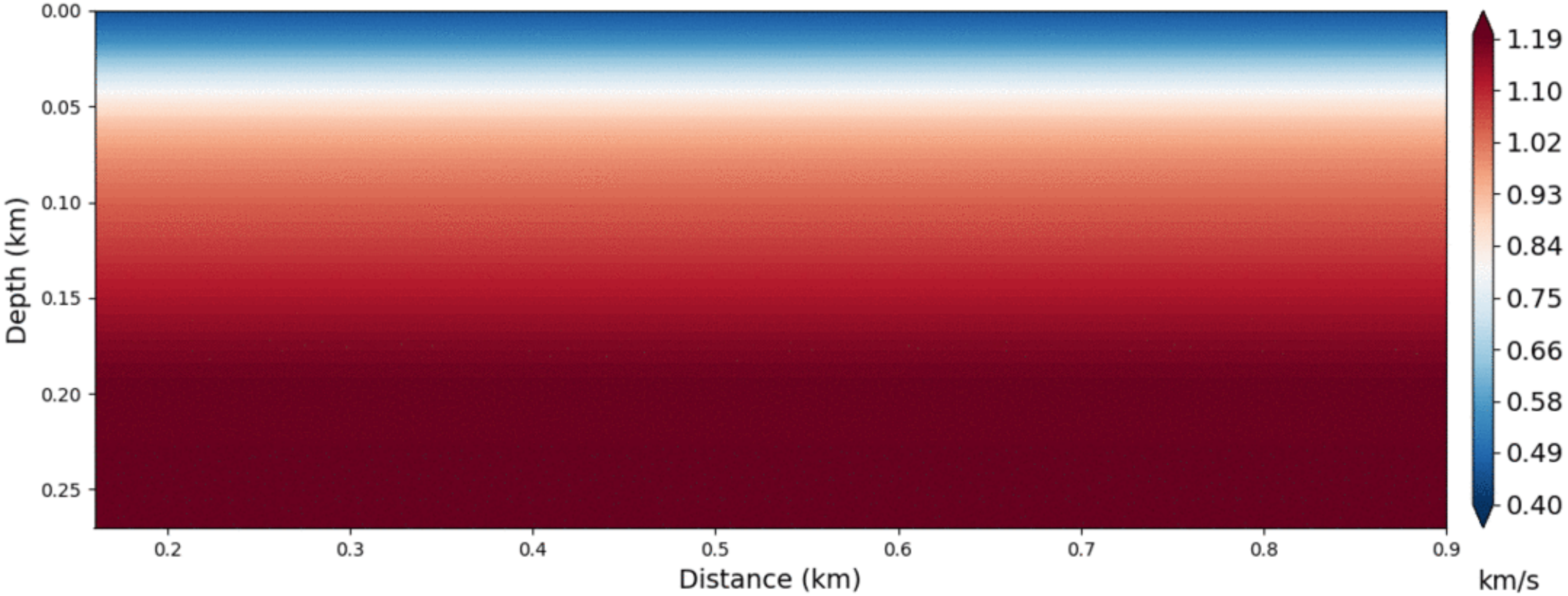
Model 2: True Vs model



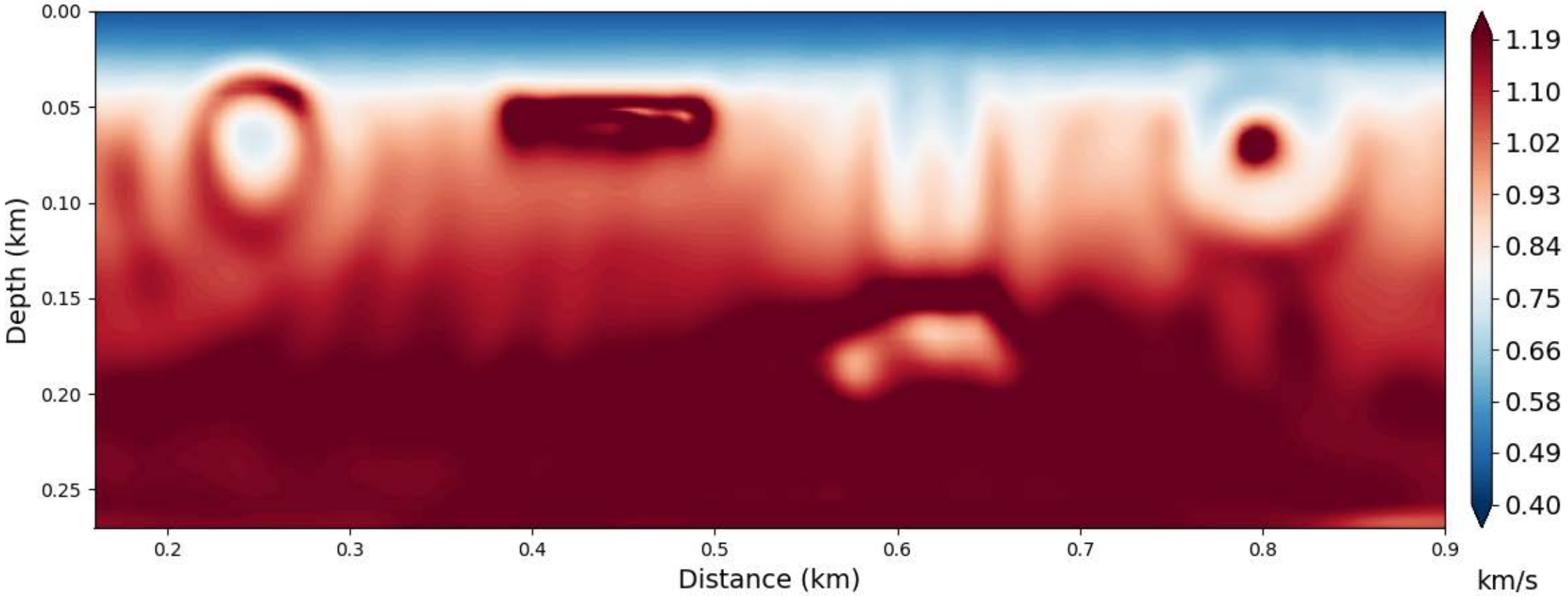
Model 2: Initial model



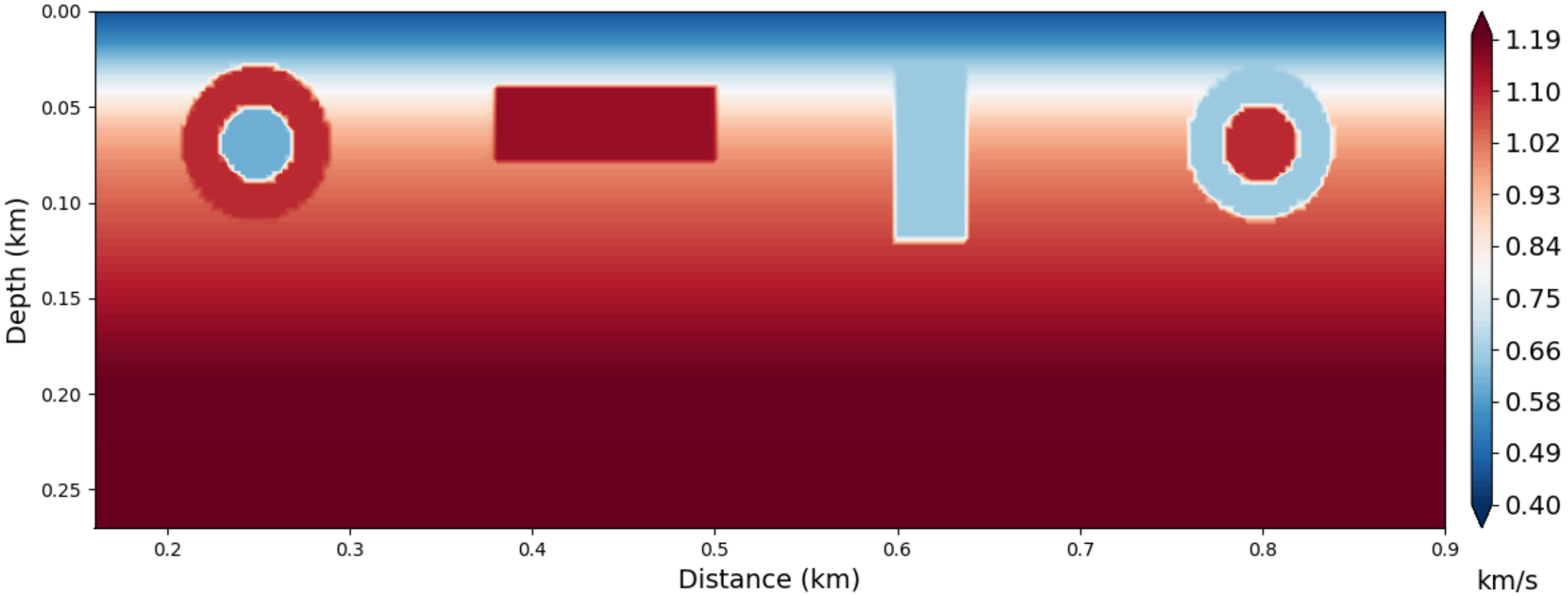
FWI result


0.00
0.05
0.10
0.15
0.20
0.25
Depth (km)
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Distance (km)
1.19
1.10
1.02
0.93
0.84
0.75
0.66
0.58
0.49
0.40
km/s

FWI result

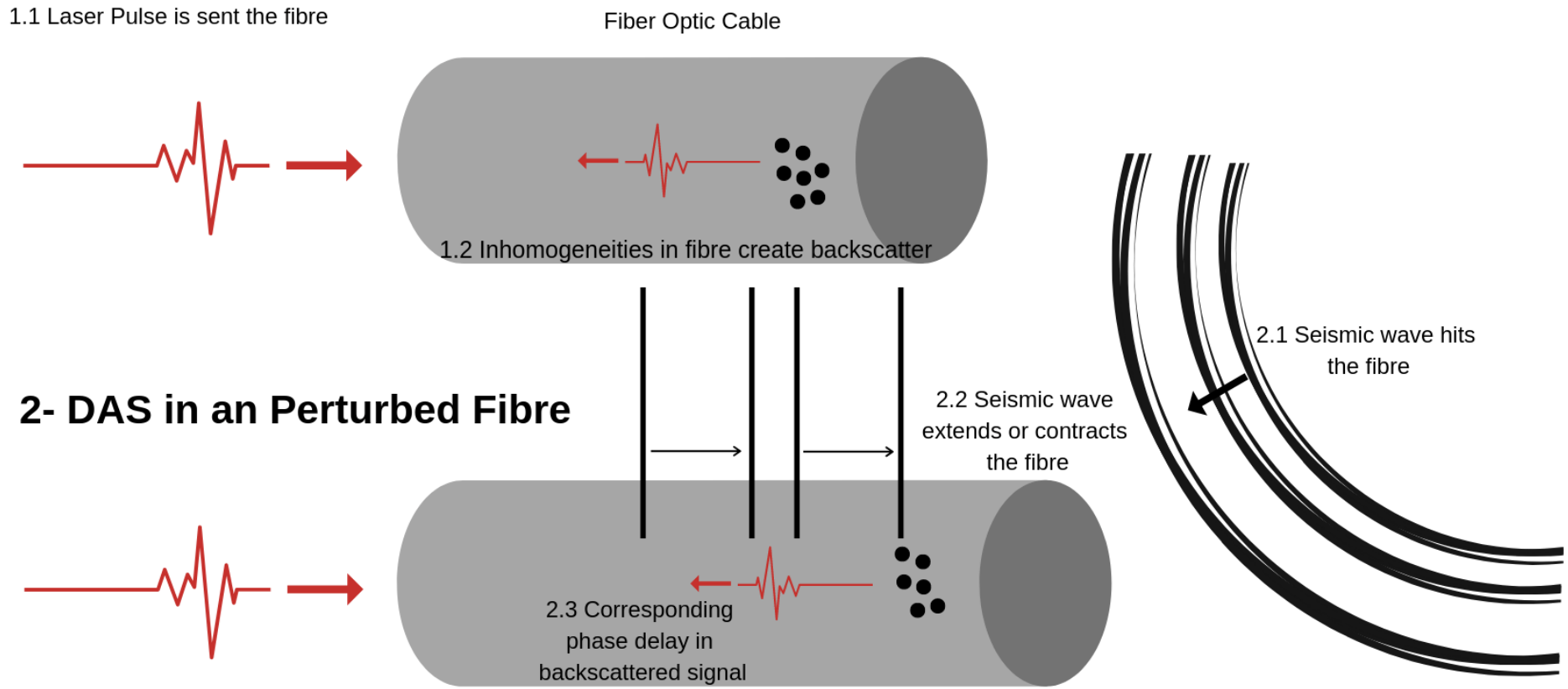

0.00
0.05
0.10
0.15
0.20
0.25
Depth (km)
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Distance (km)
1.19
1.10
1.02
0.93
0.84
0.75
0.66
0.58
0.49
0.40
km/s

True model


0.00
0.05
0.10
0.15
0.20
0.25
Depth (km)
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Distance (km)
1.19
1.10
1.02
0.93
0.84
0.75
0.66
0.58
0.49
0.40
km/s

DAS data inversion

1- DAS in an Unperturbed Fibre



2- DAS in an Perturbed Fibre

https://motionsignaltechnologies.com/what-is-das-and-what-is-it-measuring/

Data conversion

Strain

Gauge length

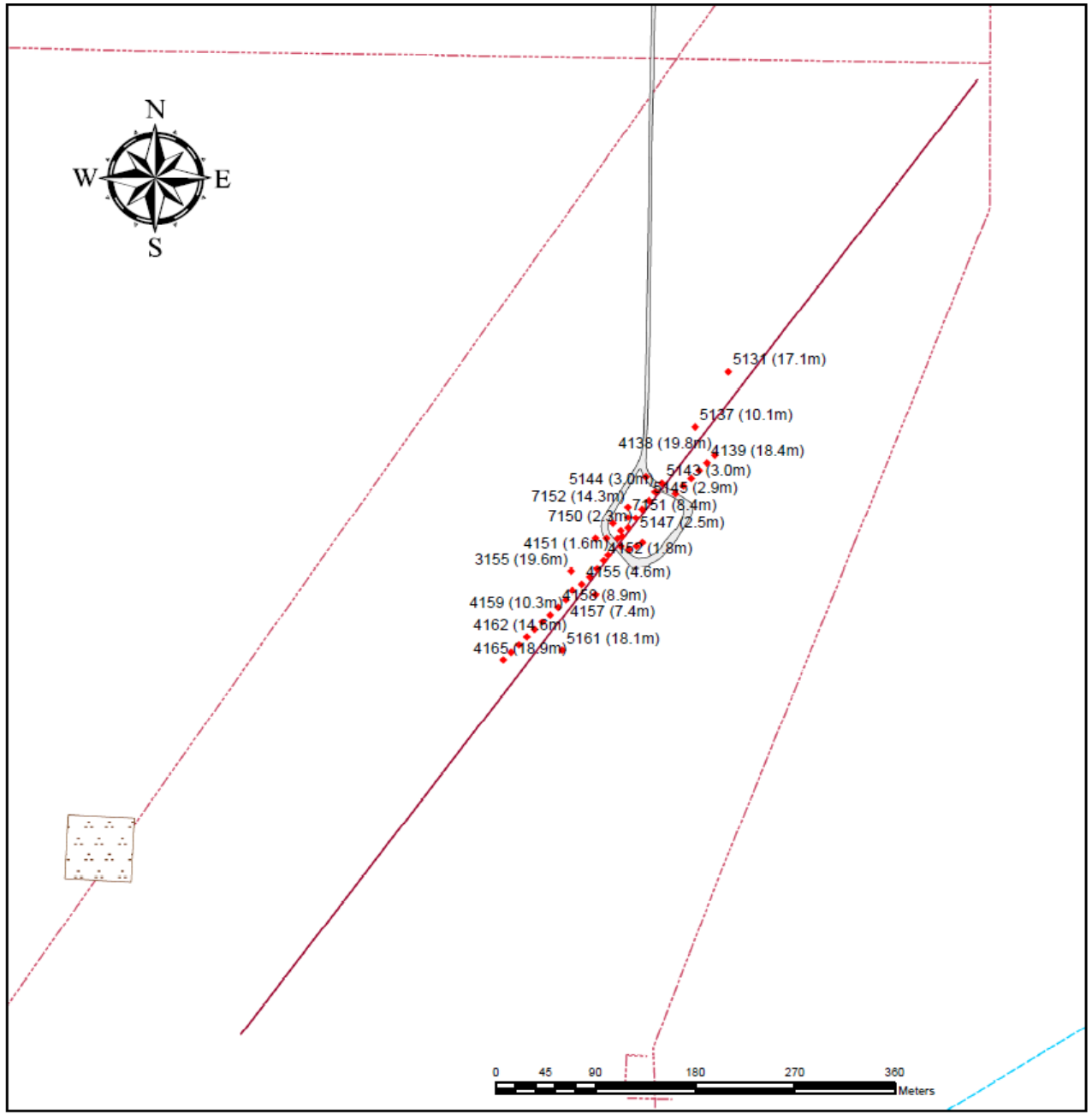
$$\epsilon'(r) = \frac{1}{L_g}\left(u\left(r + \frac{L_g}{2}\right) - u\left(r - \frac{L_g}{2}\right)\right). \tag{1}$$

Displacement

$$\begin{pmatrix} \epsilon'_1 \\ \epsilon'_2 \\ \vdots \\ \epsilon'_N \end{pmatrix} = \begin{pmatrix} -1 & 1 & & & \\ & -1 & 1 & & \\ & & \ddots & \ddots & \\ & & & -1 & 1 \end{pmatrix} \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_M \end{pmatrix} \tag{2}$$

Rank deficient

DAS data geometry



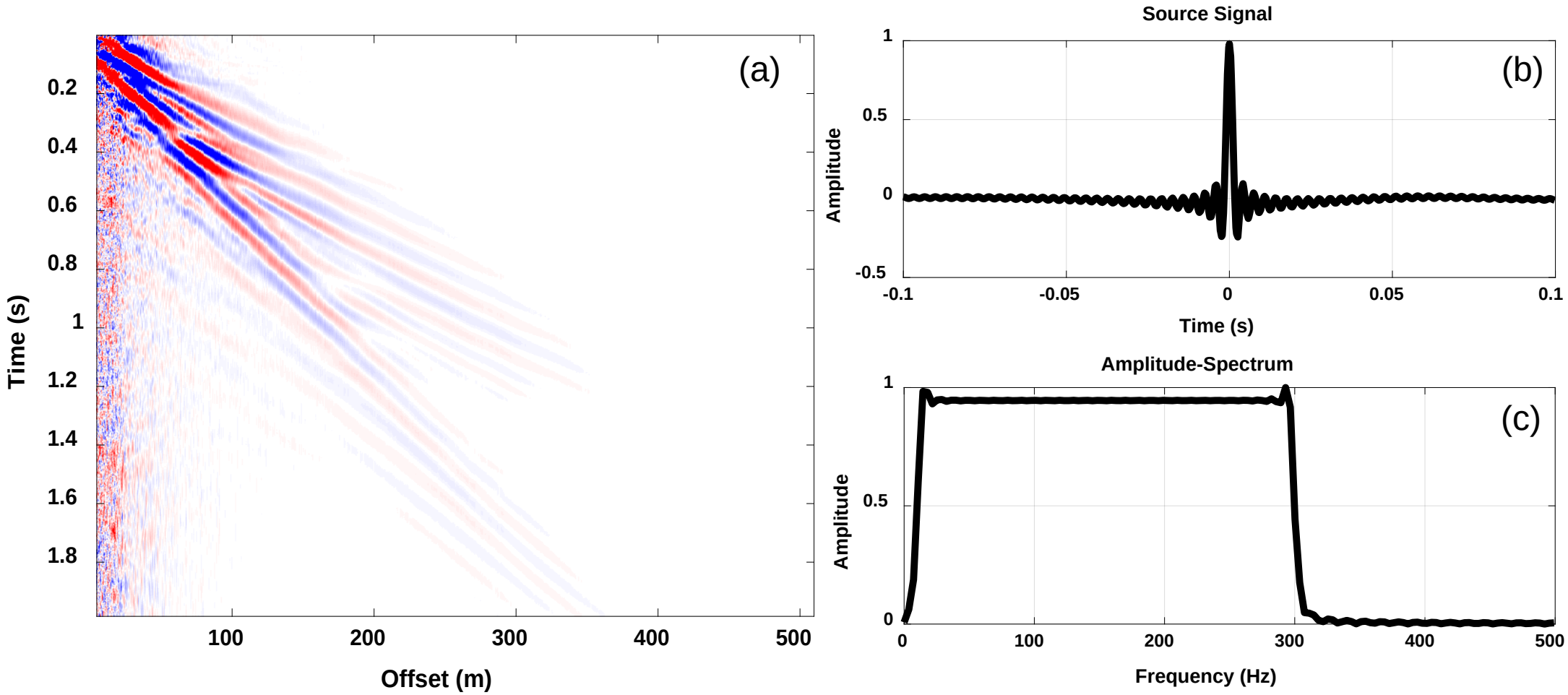
Source type: IVI Enviro Vibe

Source frequency range: 1 Hz to 150 Hz

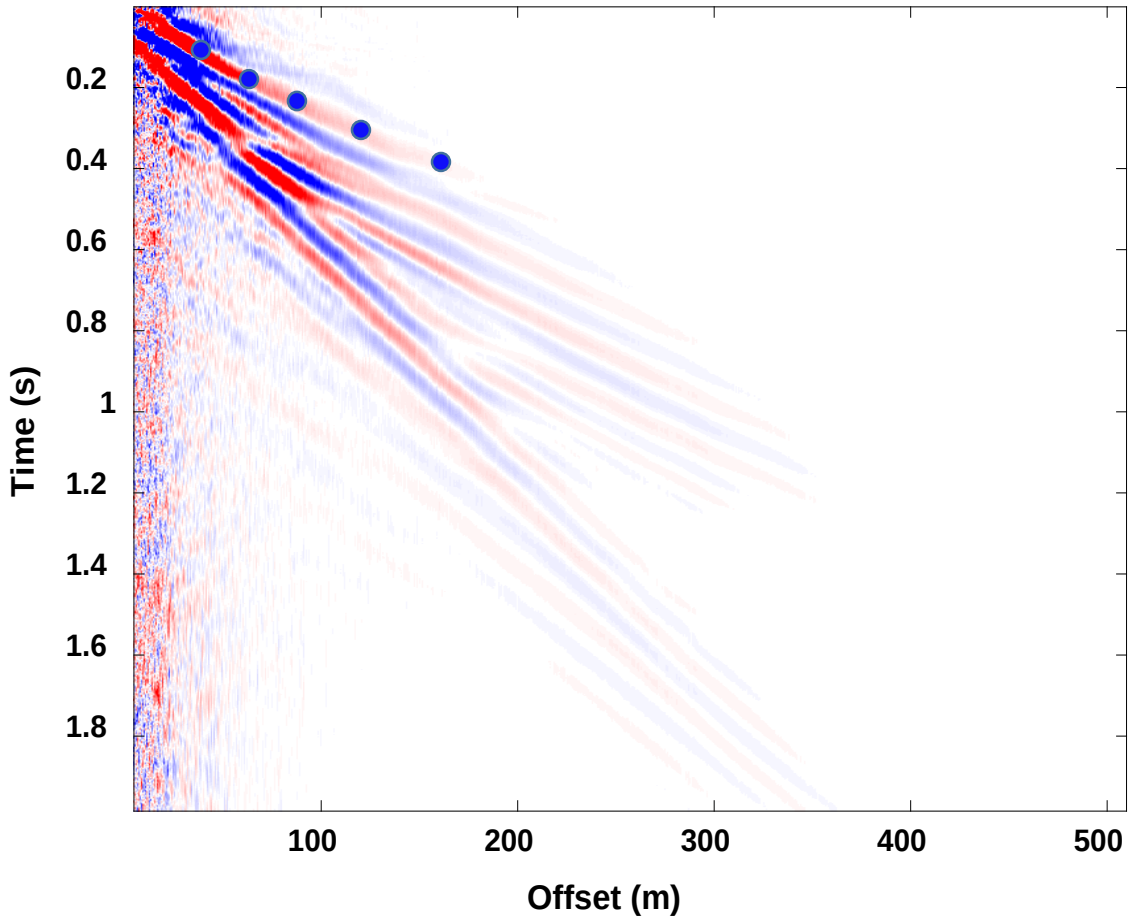
Sensor spacing: 0.67 m

Gauge length: 10 m

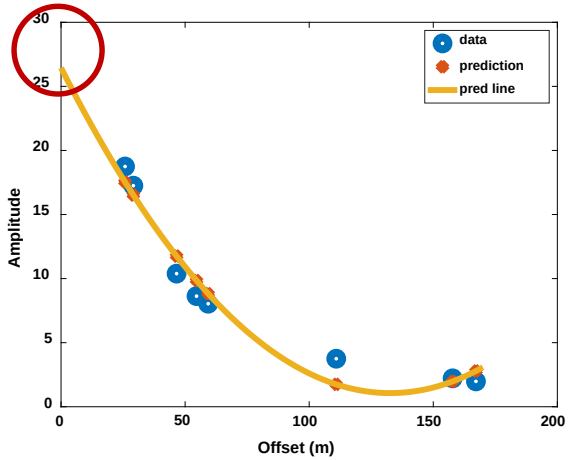
Wavelet


(a)
Time (s)
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
100
200
300
400
500
Offset (m)
Source Signal
(b)
Amplitude
1
0.5
0
-0.5
-0.1
-0.05
0
0.05
0.1
Time (s)
Amplitude-Spectrum
(c)
Amplitude
1
0.5
0
0
100
200
300
400
500
Frequency (Hz)

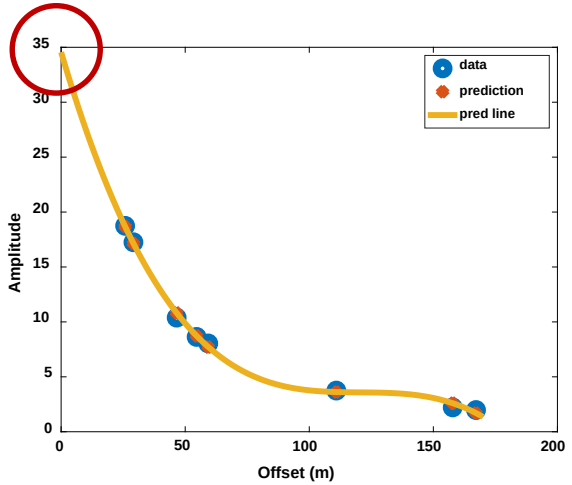
Wavelet amplitude



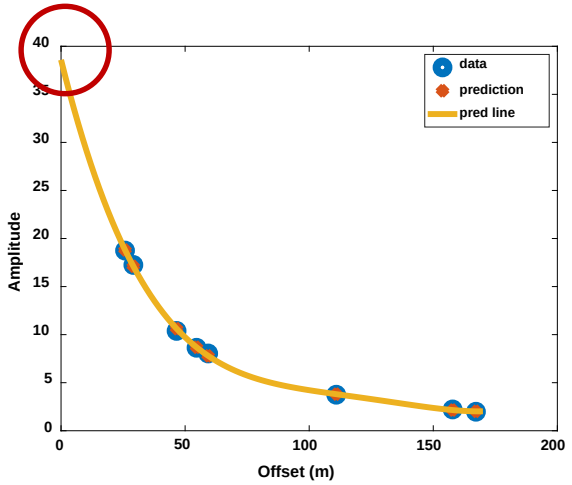
Order=2



Order=3



Order=4



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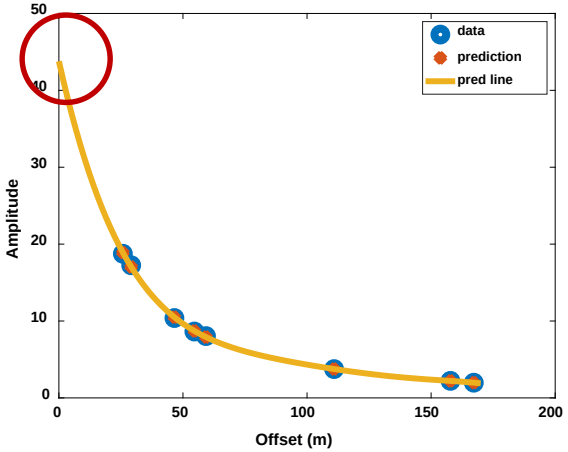
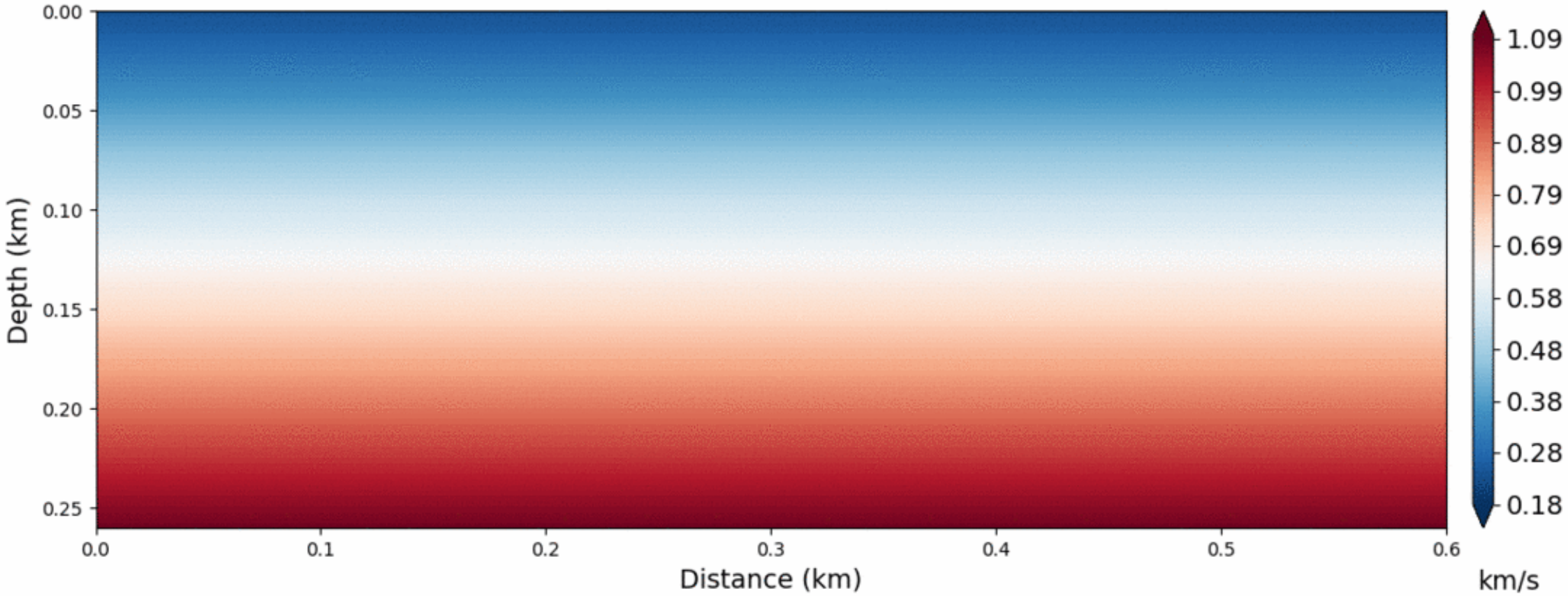
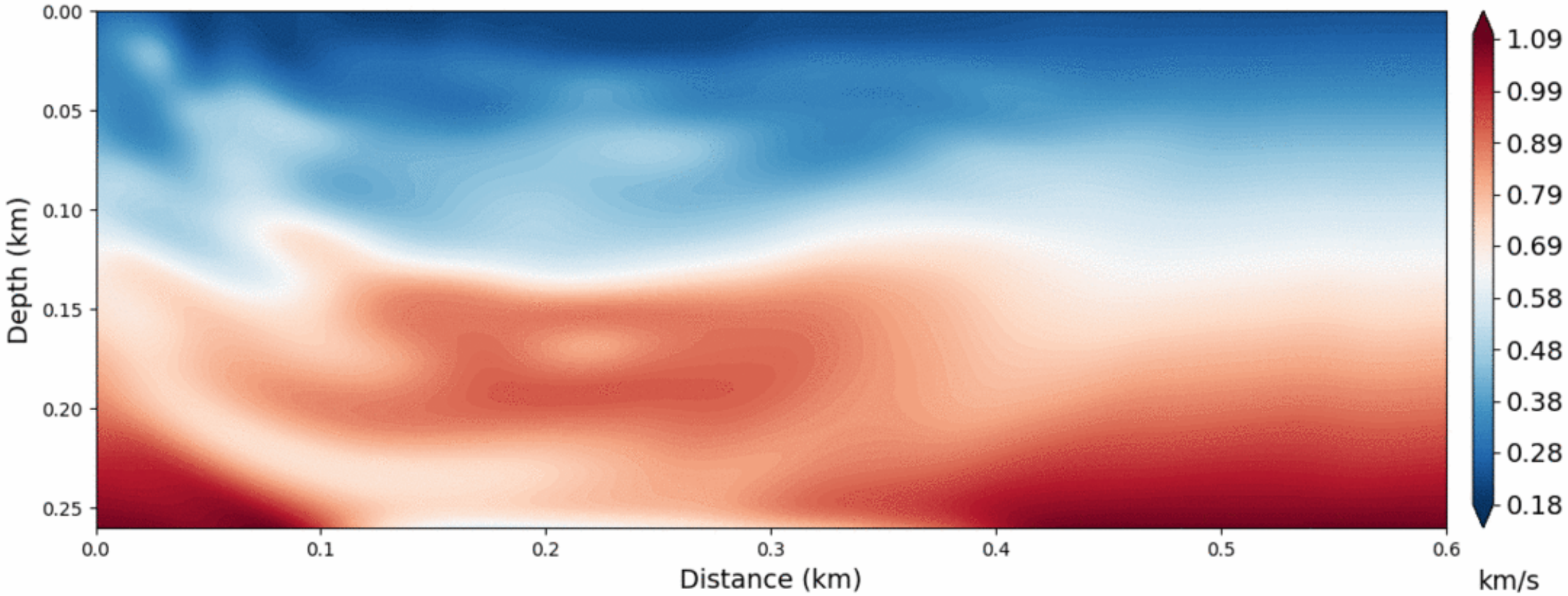


FWI: ED


0.00
0.05
0.10
0.15
0.20
0.25
Depth (km)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Distance (km)
1.09
0.99
0.89
0.79
0.69
0.58
0.48
0.38
0.28
0.18
km/s

FWI: ED+WD


0.00
0.05
0.10
0.15
0.20
0.25
Depth (km)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Distance (km)
1.09
0.99
0.89
0.79
0.69
0.58
0.48
0.38
0.28
0.18
km/s

Conclusions

I. Surface-wave FWI shows better resolution ability in both vertical and lateral directions.

II. Combined misfit and frequency decreasing multi-scale approach can help improve the resolution of inversion result.

III. DAS data inversion requires data transform, and DAS data simulation may help improve the inversion results.

IV. Attenuation related inversion, and gauge length study will be considered in the following work.

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Compute Canada

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CREWES sponsors

CaMI Field Research Station

SEG

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