Full Waveform Inversion in the data and image space

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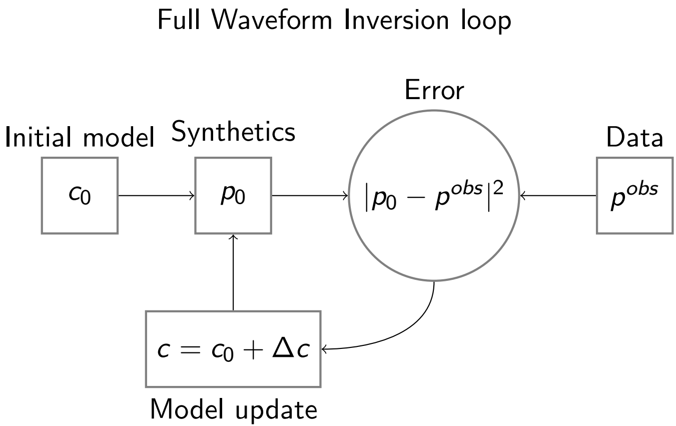
Overview

Introduction



Introduction

Full Waveform Inversion (FWI) minimization the least-squares error w.r.t. velocity (Tarantola, 1984)

$$e_l = |p - p^{obs}|^2 \quad (1)$$

Linearization leads to a Newton-Raphson Scheme where the first iteration is

$$\mathbf{J}^T[p_0 - p^{obs}] = \mathbf{J}^T\mathbf{J}\Delta c \quad (2)$$

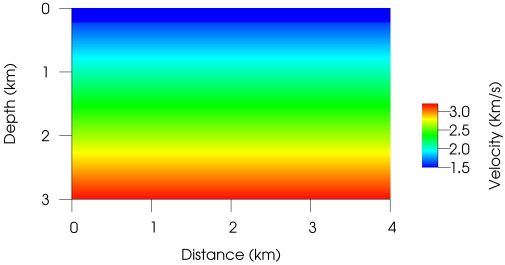
where **J** is the Jacobi operator and the Born approximation is

$$\Delta p = p_0 - p^{obs} = \mathbf{J}\Delta c \quad (3)$$

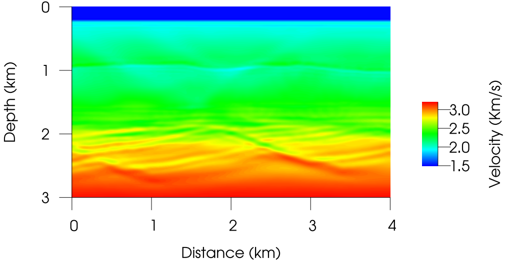
$$\Delta c \approx \alpha \nabla_c e_l = \alpha \mathbf{J}^T[p_0 - p^{obs}] \quad (4)$$

Introduction

Initial model A

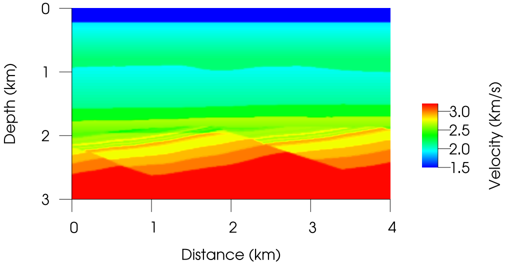


FWI

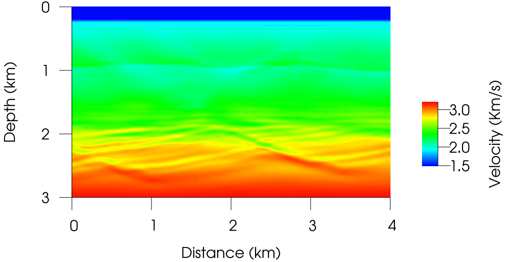


Introduction

Exact model

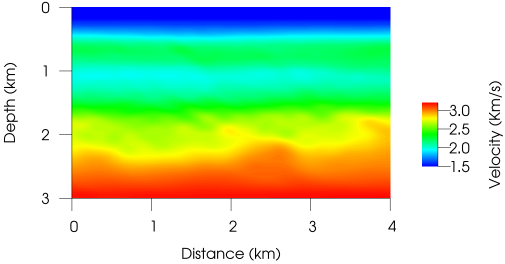


FWI

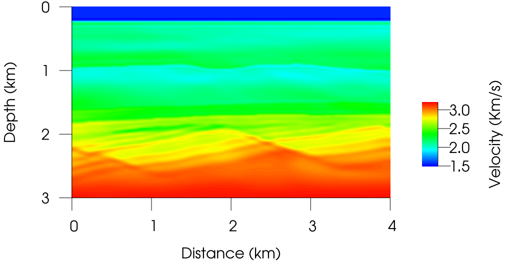


Introduction

Initial model B

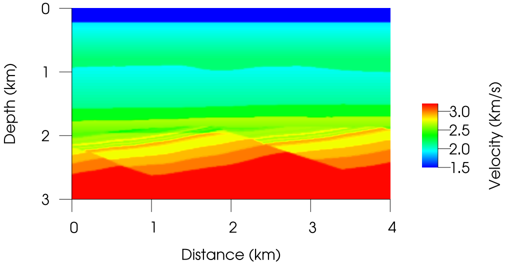


FWI

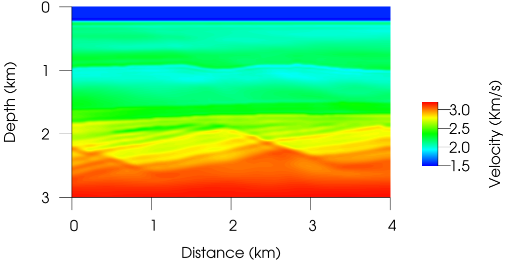


Introduction

Exact model



FWI



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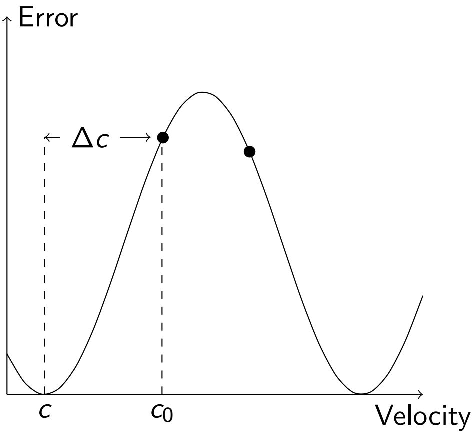


Initial models for FWI

Born approximation holds (Beydoun and Tarantola, 1988)

$$\Delta T < \frac{1}{2f_0} \tag{5}$$

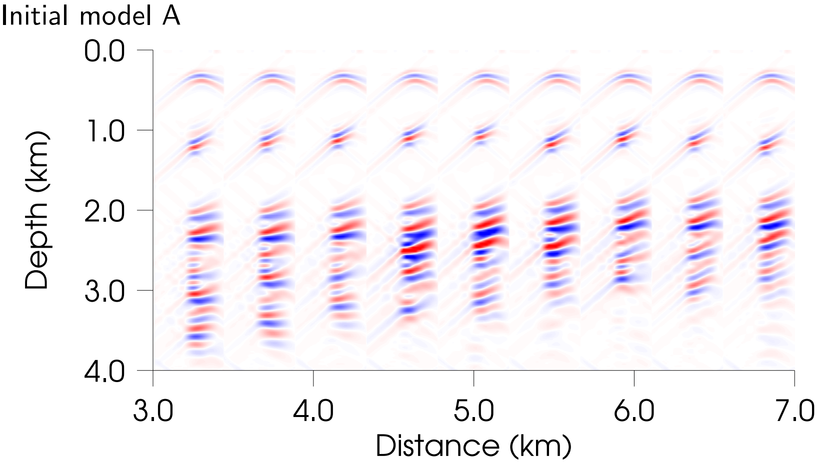
- Δt : Traveltime error between model and data
- f_0: Dominant frequency

or (Pratt et al. 2008)

$$\frac{\Delta T}{T} < \frac{1}{N_\lambda} \tag{6}$$

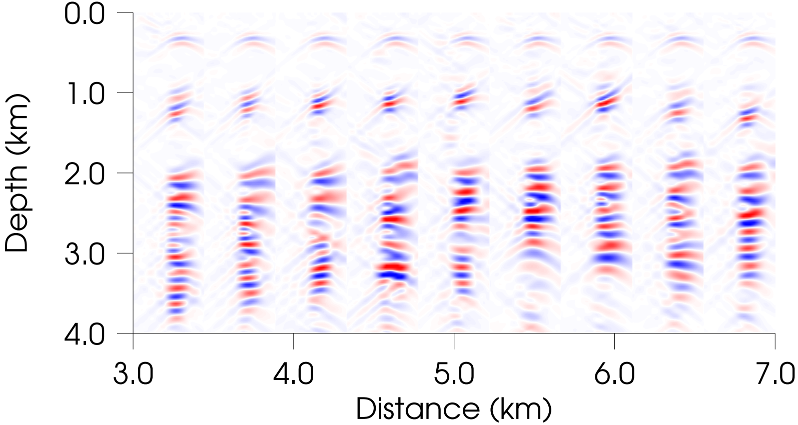
- N_λ : No of wavelengths
- T : Record time

Initial models for FWI



Initial models for FWI

Initial model B



Initial models for FWI

Jian-Bing et al. (2009) for

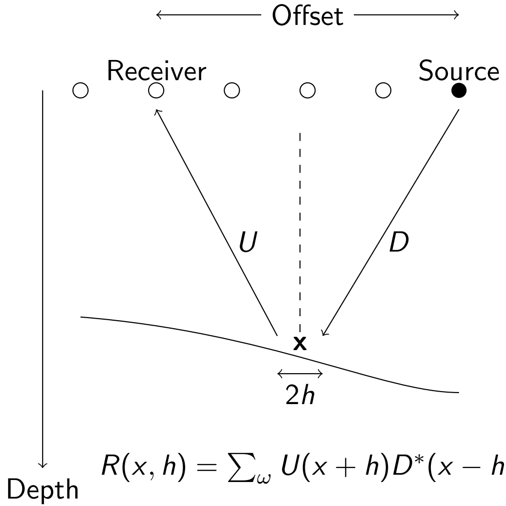
$$(\omega/c_0)^2 I < 1, \tag{7}$$

$$I = \max \left| \int g(x_r, \omega, x) \frac{\Delta c(x)}{c_0(x)} d^3x \right|. \tag{8}$$

g is the acoustic Green's function.
Give max frequencies $\approx 1 - 10Hz$ for both model A and B

WEMVA

Wave Equation Migration Velocity Analysis (WEMVA)



$R(x, h) = \sum_{\omega} U(x+h) D^*(x-h)$

WEMVA

Minimize e_s w.r.t c

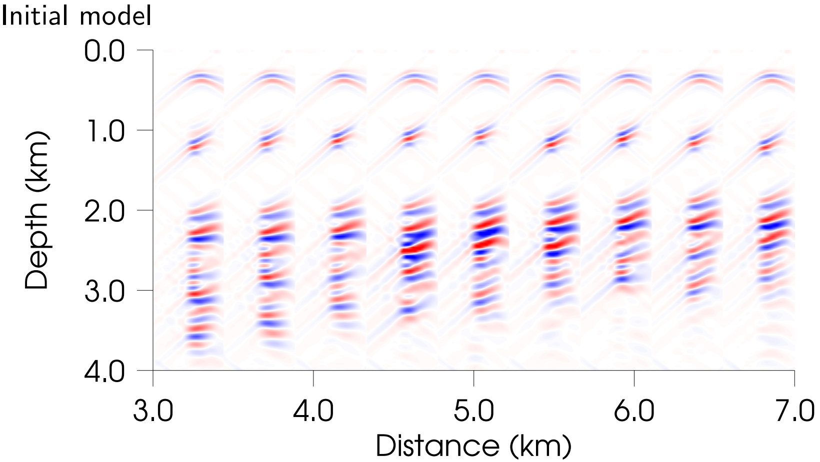
$$e_s = \sum_x \sum_h h^2 \left[\frac{\partial R(\mathbf{x}, \mathbf{h})}{\partial z} \right]^2, \tag{9}$$

Iterative solution

$$\begin{aligned} c &= c_0 + \Delta c \\ \Delta c &\approx \alpha \nabla_c e_s \end{aligned} \tag{10}$$

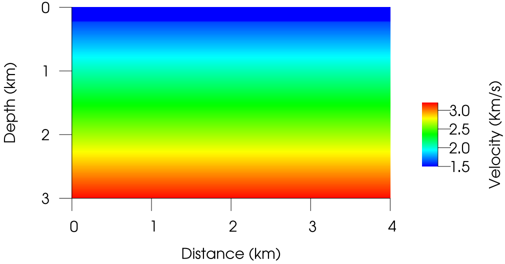
- e_s is mainly sensitive to travel-time
- Low resolution
- Relies on the Born Approximation

WEMVA

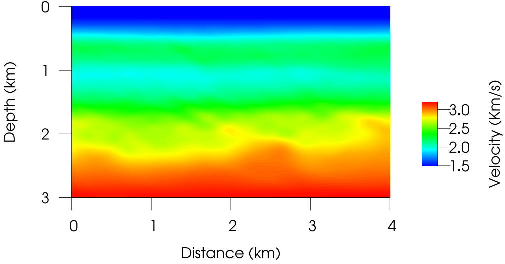


WEMVA

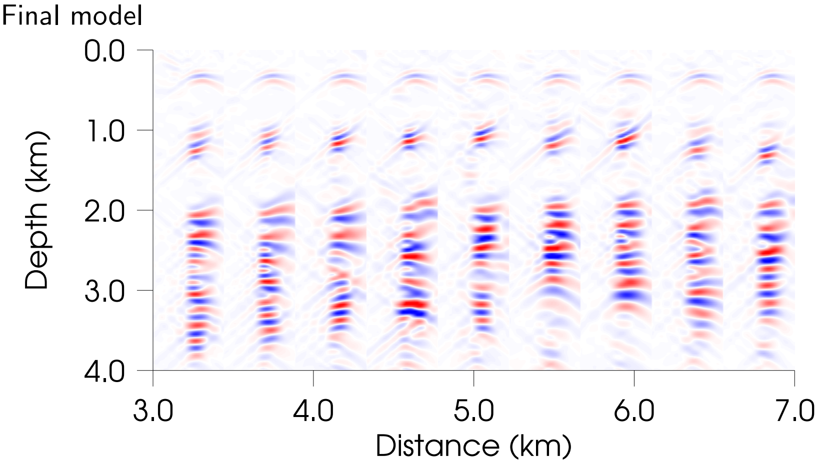
Initial model



WEMVA 25 iterations

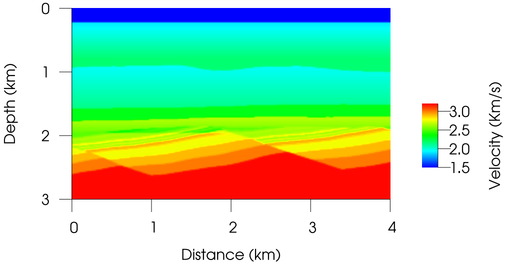


WEMVA



WEMVA

Exact model



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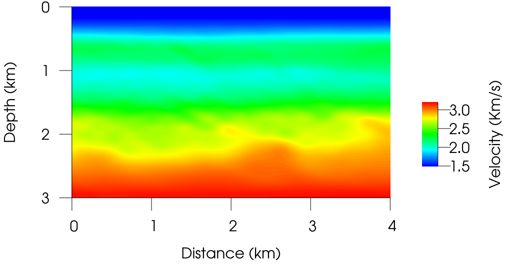
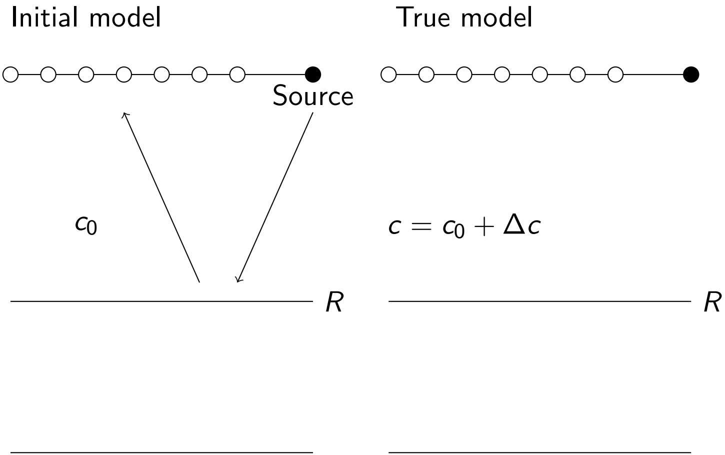
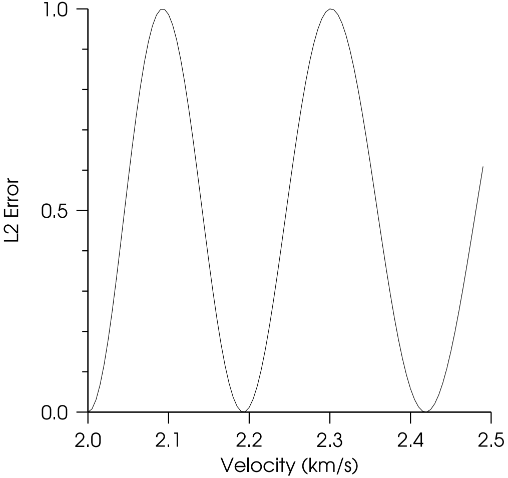


Joint Inversion



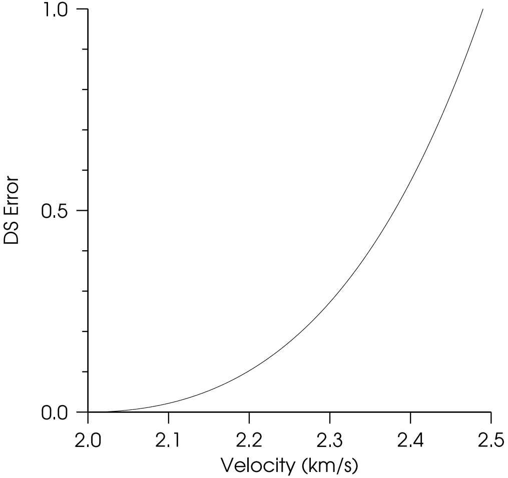
Joint Inversion

L2 Error



Joint Inversion

Differential Semblance Error



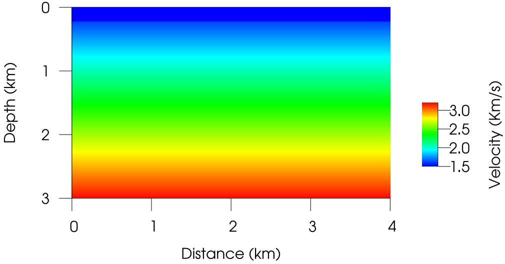
Joint Inversion

$$e = w_I e_I + w_s e_s \tag{11}$$

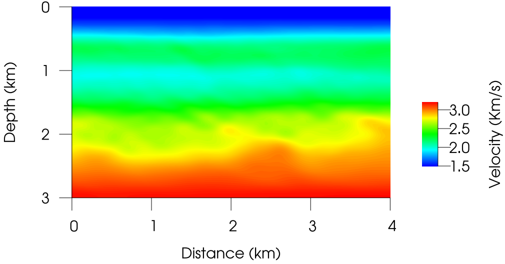
- w_I, w_s: Weights
- e_I: Least-squares Inversion error
- e_s: Differential semblance error

Joint Inversion

Initial model A

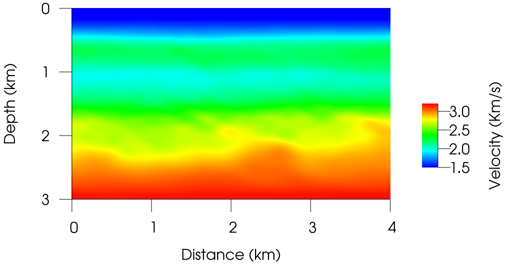


WEMVA after 25 iterations

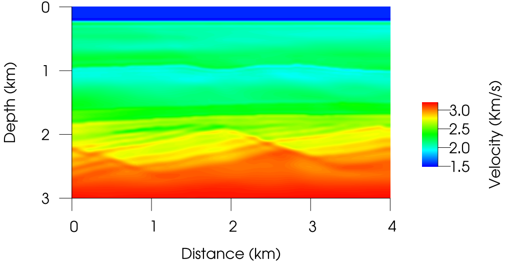


Joint Inversion

WEMVA model

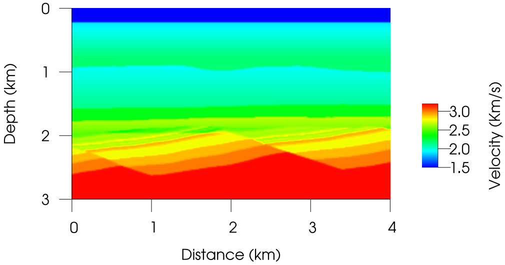


FWI after 25 iterations



Joint Inversion

Exact Model



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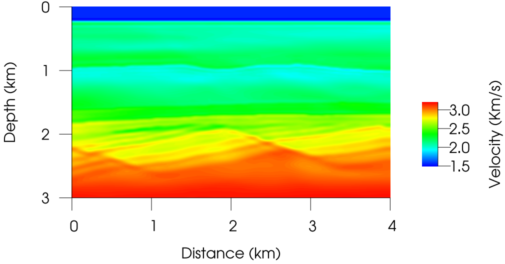

Conclusions

- WEMVA produces low resolution velocity models with reasonable good kinematic properties from simple initial models
- WEMVA velocity models can be used as initial models for FWI to obtain high resolution velocity models

Acknowledgements

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