A full waveform inversion approach based on dilatation and rotation of scatter points and PP/PS wave separation

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Outline

- Introduction and motivation
- Forward problem using elastic scattering
- Inverse problem using migration/inversion
- Numerical experiments
- Conclusions

Introduction and motivation

- Perform the P and S wave separation using migration imaging conditions
- Reduce the uncertainty of inversion by avoiding co-location of P- and S-waves images
- Taking into account the formulation of Tarantola's (1986) strategies for our inversion problem
- Establish a framework for elastic waveform migration and inversion

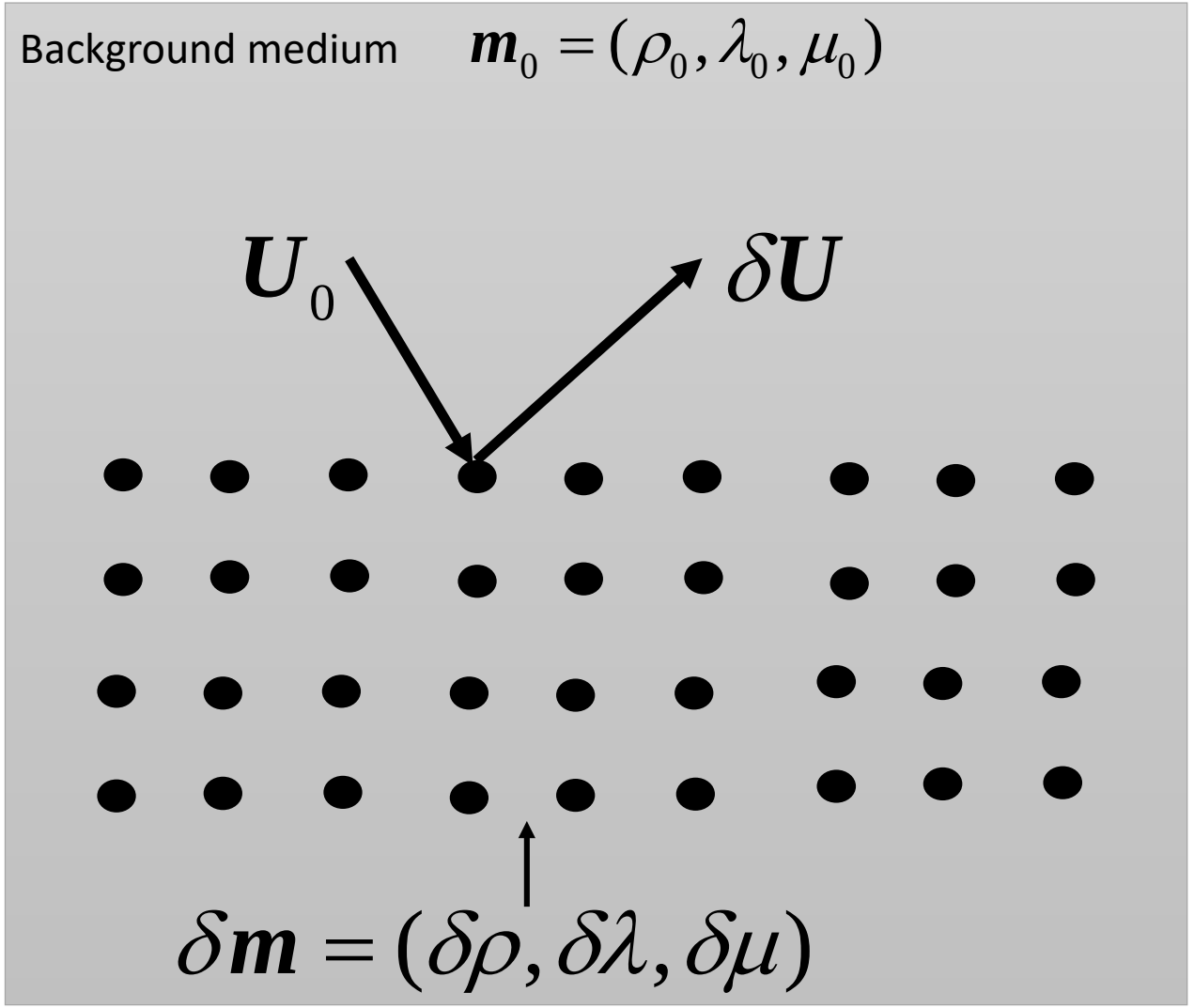
Forward problem (Elastic scattering)

$$\boldsymbol{U} = \boldsymbol{U}_0 + \delta\boldsymbol{U}$$

$\boldsymbol{U}_0$: Incident wave

$\delta\boldsymbol{U}$: Scattered wave

$\boldsymbol{m}$: Model

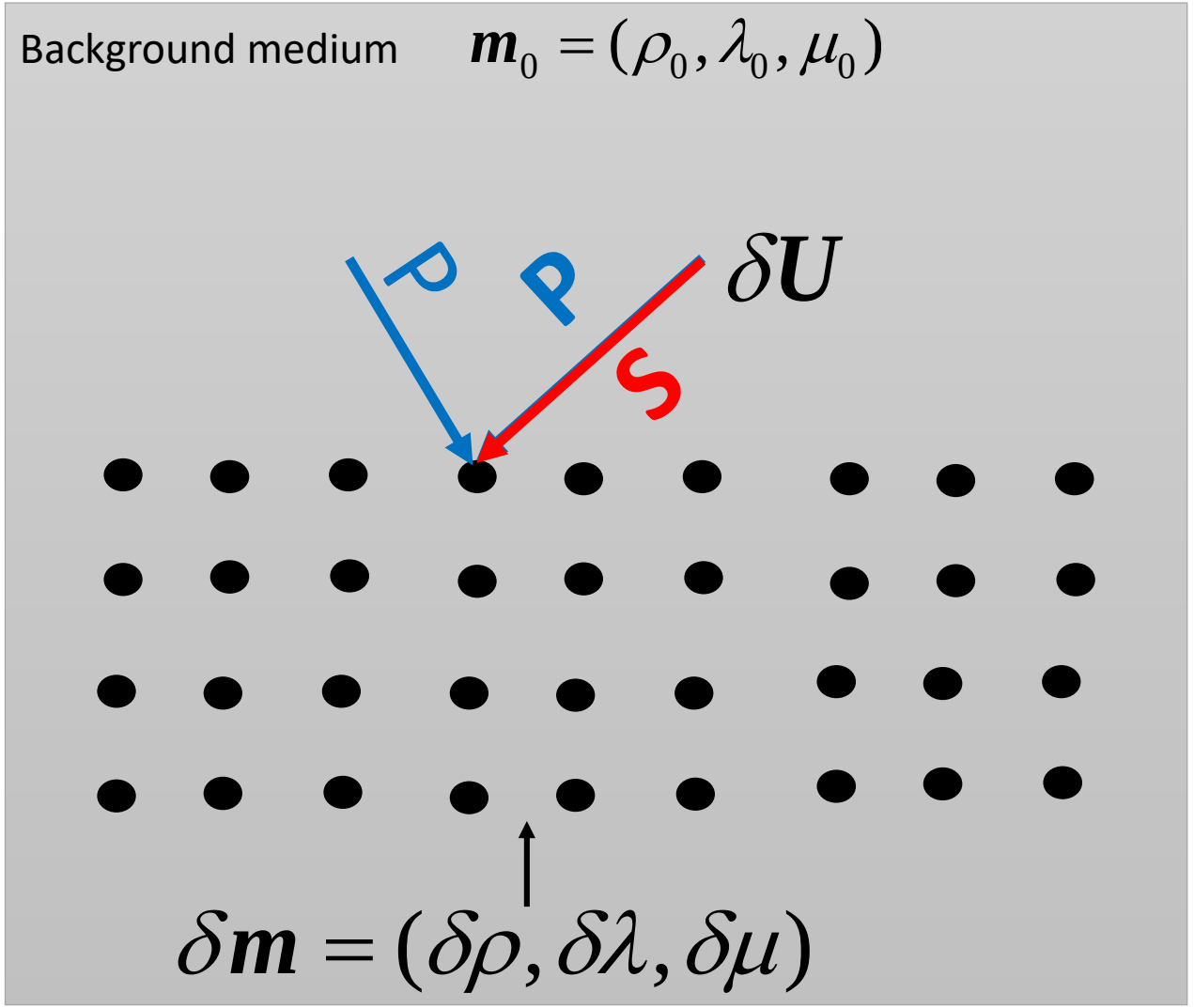


Inverse problem (Two scenarios for Migration plus inversion)

$$\boldsymbol{U} = \boldsymbol{U}_0 + \delta\boldsymbol{U}$$

$\boldsymbol{U}_0$: Incident wave

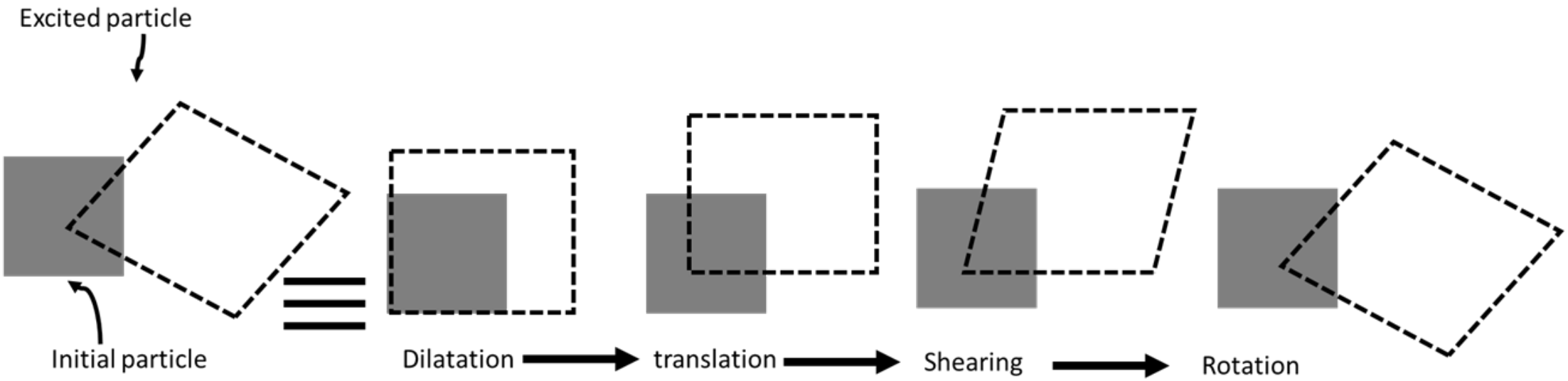
$\delta\boldsymbol{U}$: Scattered wave



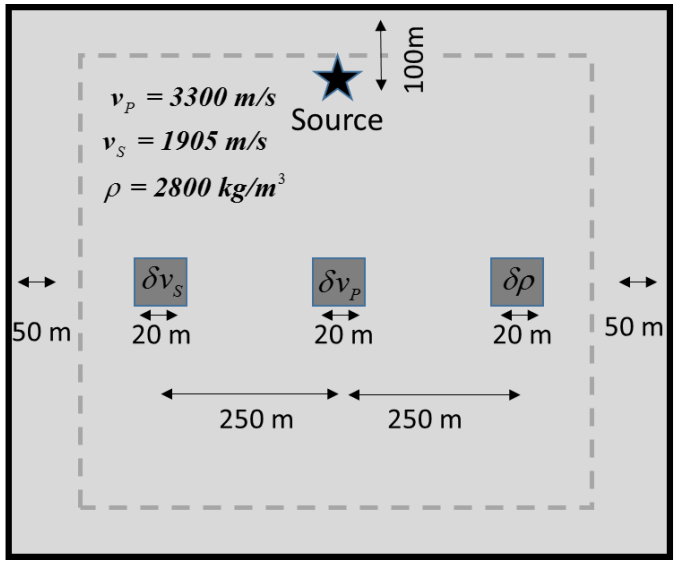
Elastic waves inversion

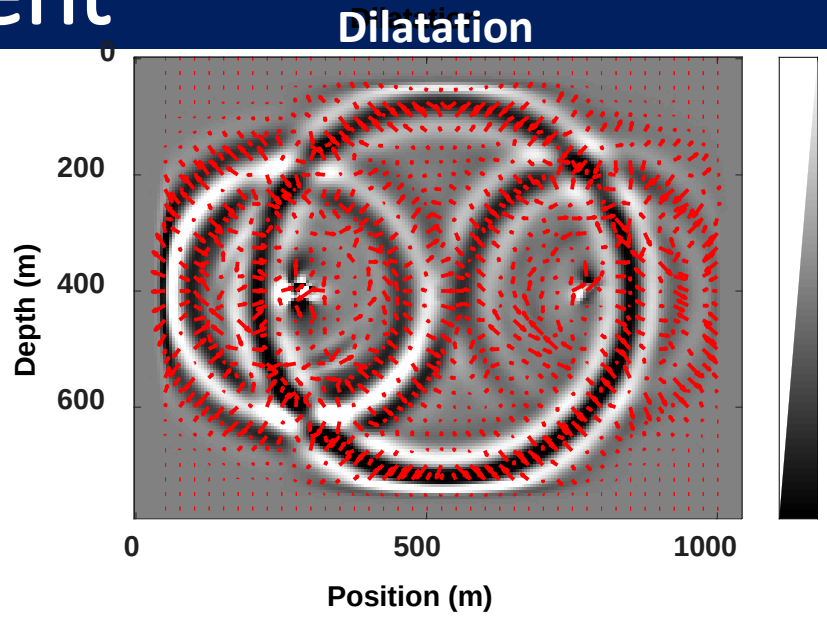
$$\rho_0 \partial_t^2 \delta \boldsymbol{U} - \left(\lambda_0 + 2\mu_0\right)\left(\nabla\nabla \bullet \delta \boldsymbol{U}\right) + \mu_0\left(\nabla \times \nabla \times \delta \boldsymbol{U}\right) = \boldsymbol{f(U_0, \delta m)}$$

Acceleration term **Dilatation term** **Rotation term** **Perturbation**



Elastic waves and sensitivity experiment





P-to-P scattering

$$S^{PP} = \frac{2\delta\mu}{\lambda_0 + 2\mu_0}\cos^2\theta^{PP} + \frac{\delta\lambda}{\lambda_0 + 2\mu_0} + \frac{\delta\rho}{\rho_0}\cos\theta^{PP}$$

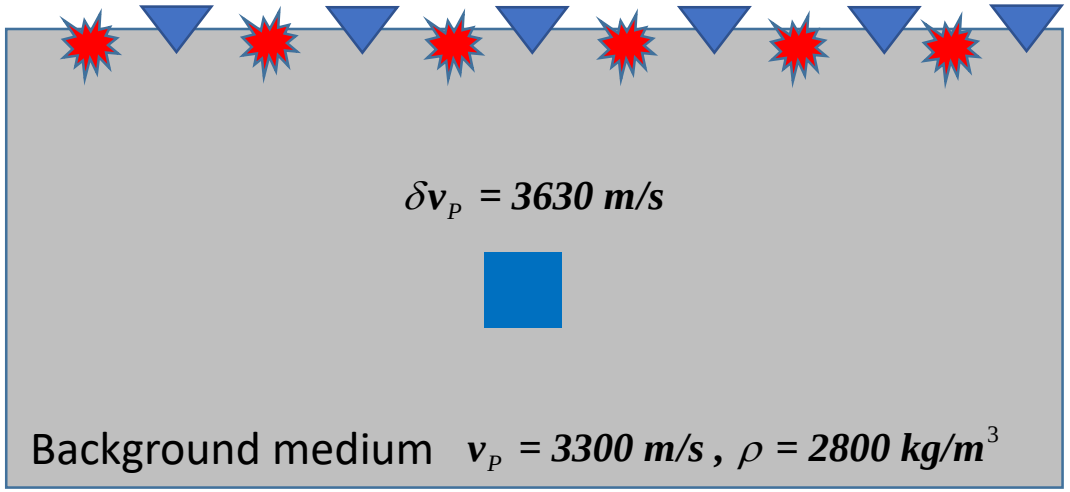
P-to-S scattering

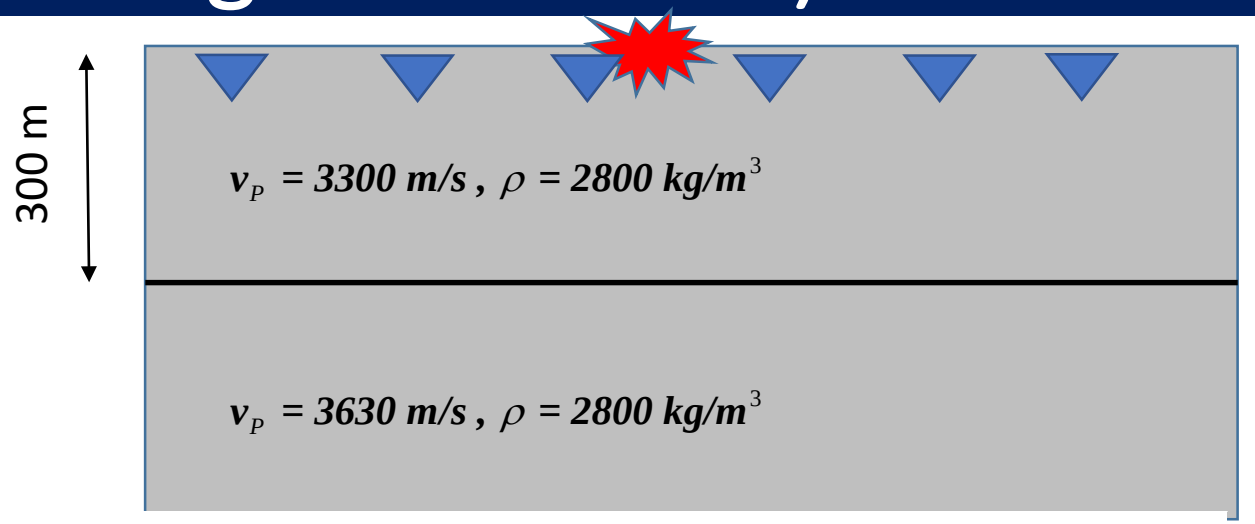
$$S^{PS} = \frac{\delta\mu}{\mu_0}\frac{v_S}{v_P}\sin 2\theta^{PS} + \frac{\delta\rho}{\rho_0}\sin\theta^{PS}$$

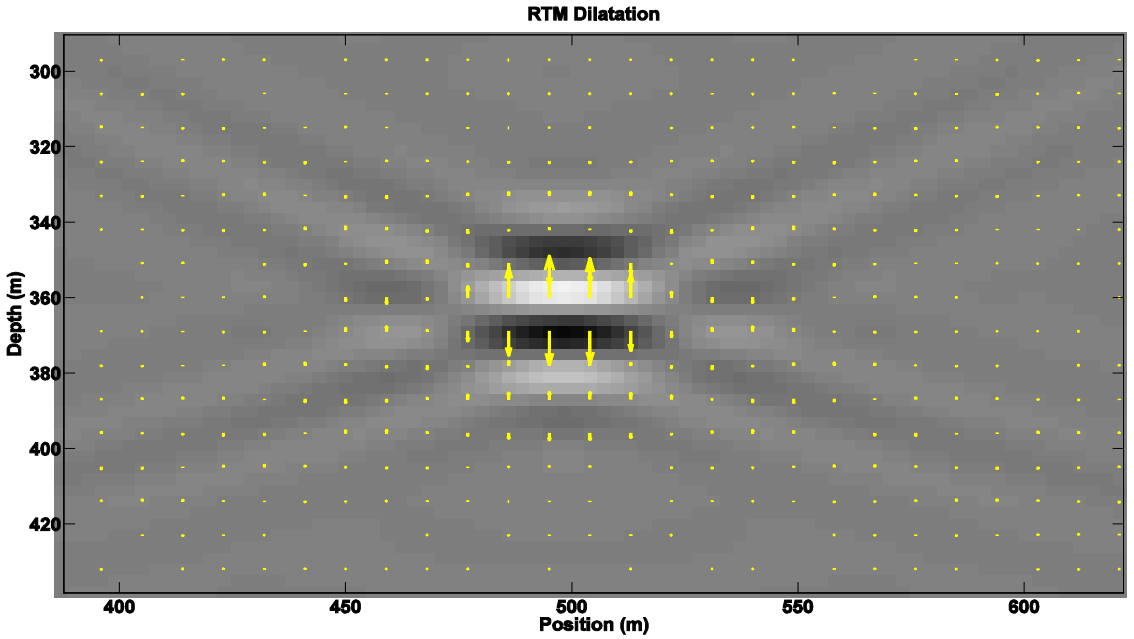
Opening angles

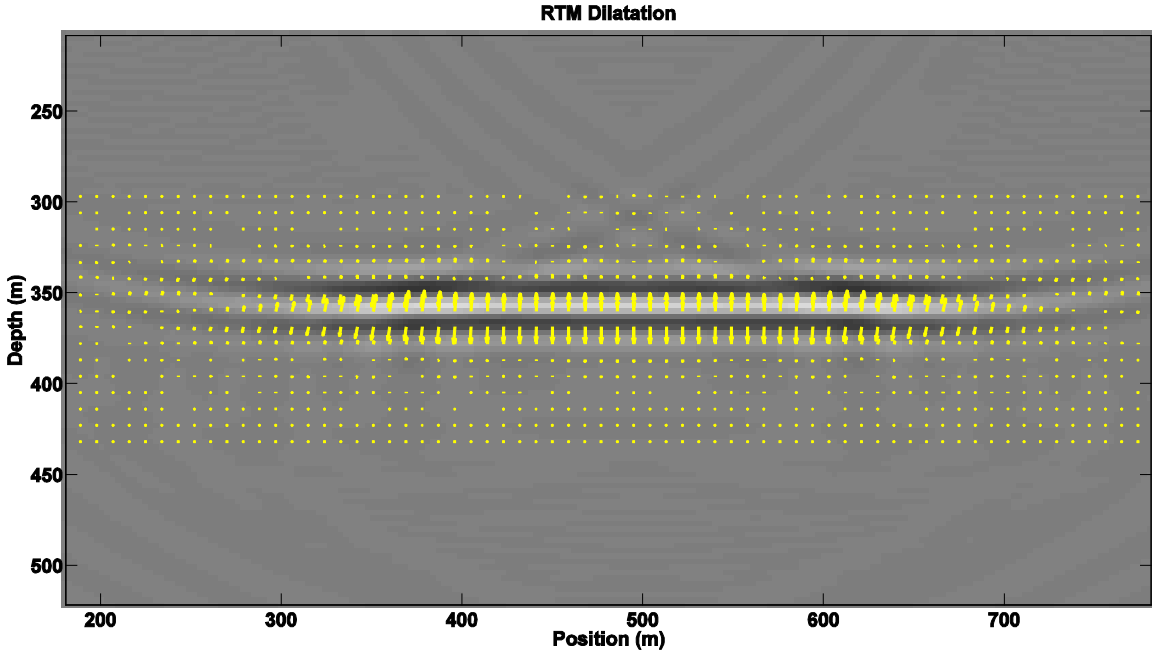
Beylkin and Burridge (1990)

Migration and Inversion (scattering vs reflection)

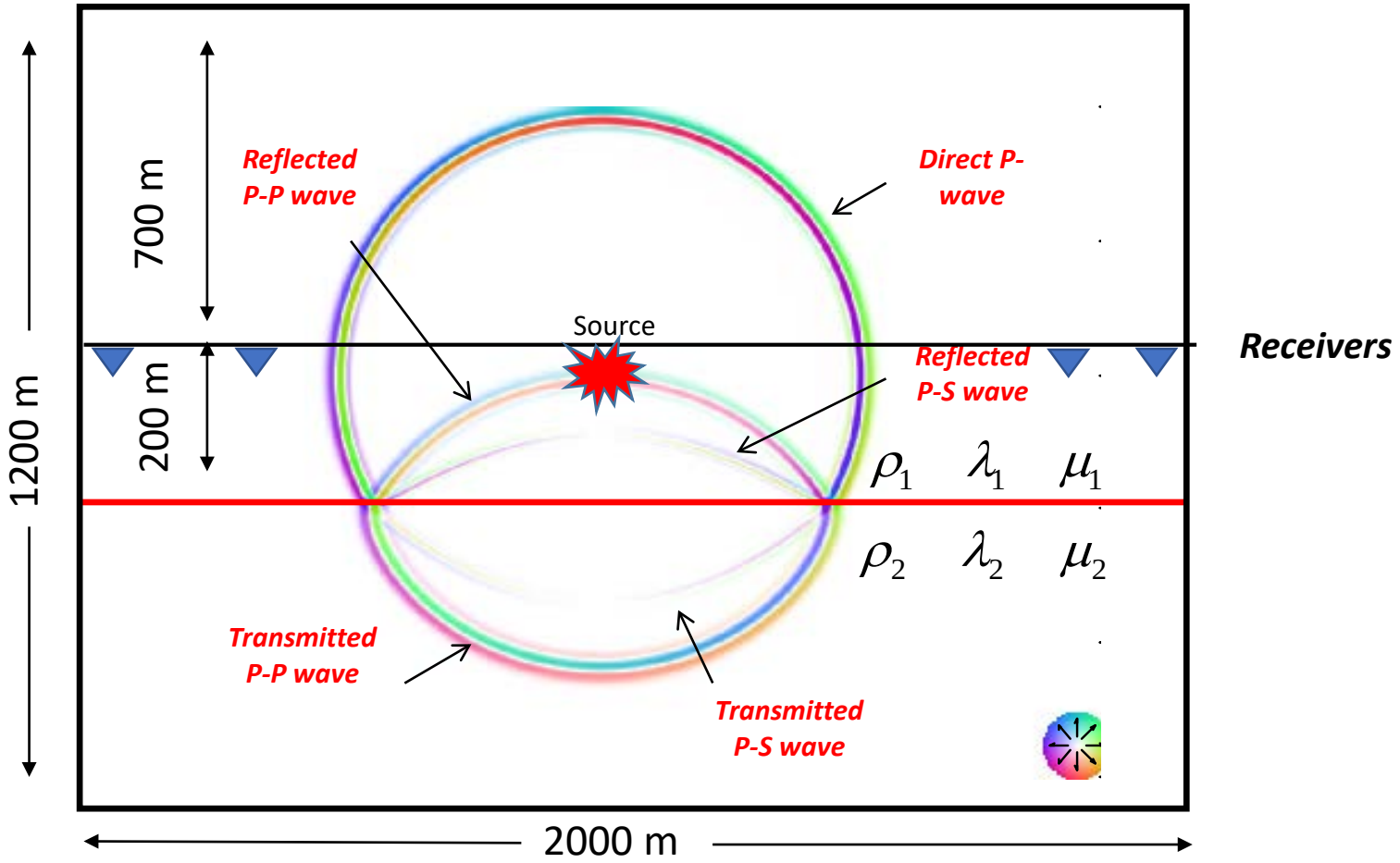








PP and PS modeling

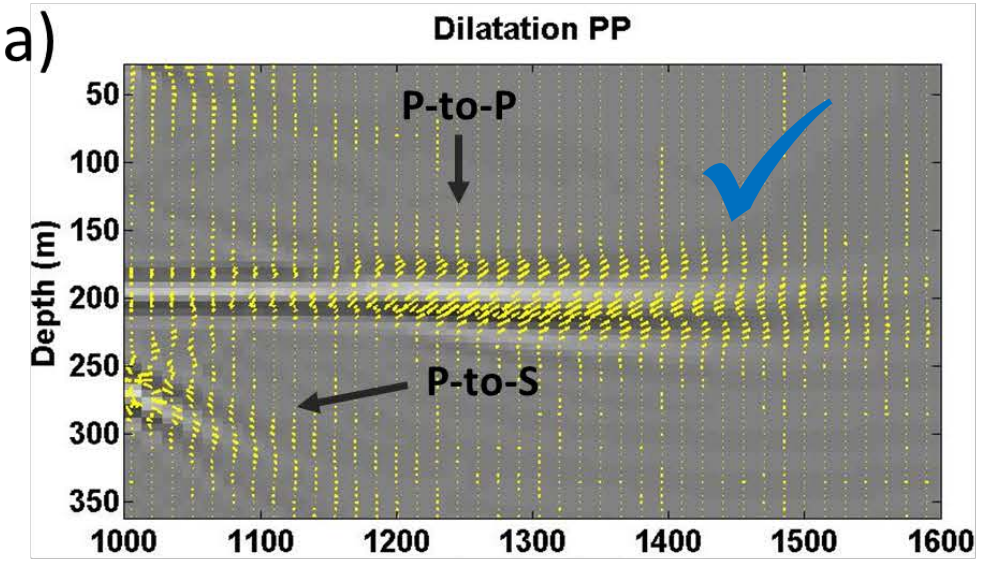


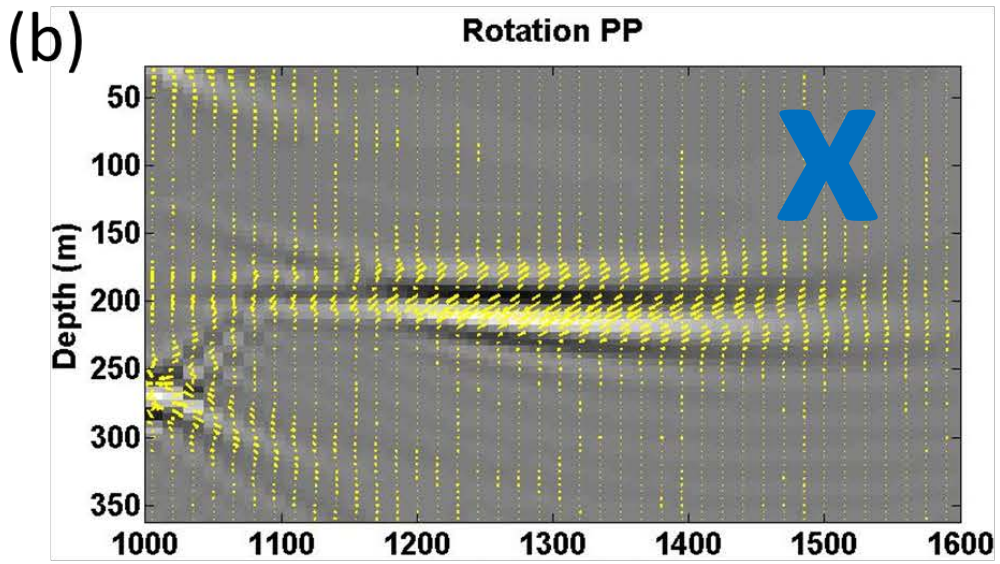
Color scale shows the particle displacement direction. The matlab code of Manning (2008) is used here.

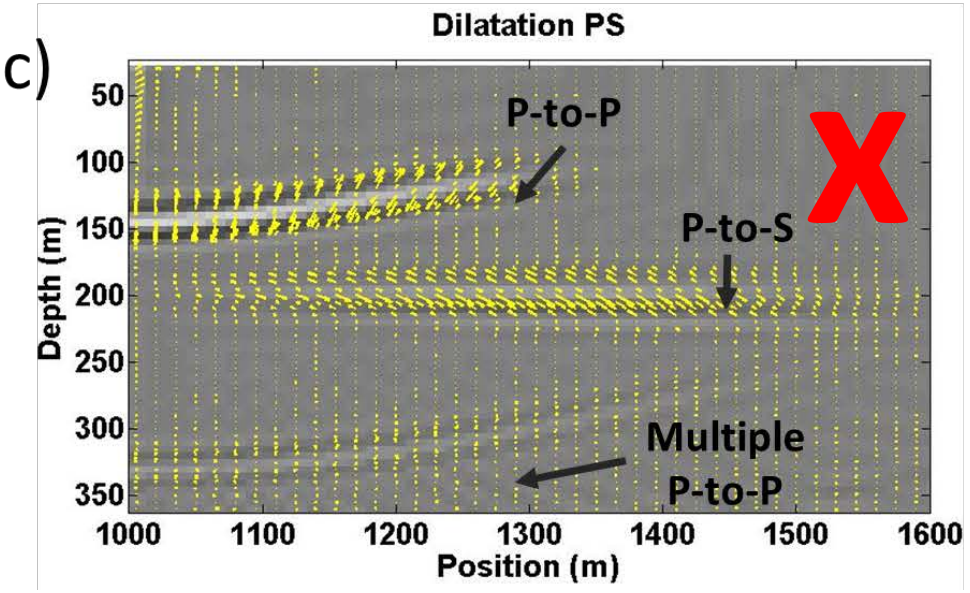
PP and PS wavefield migration and inversion

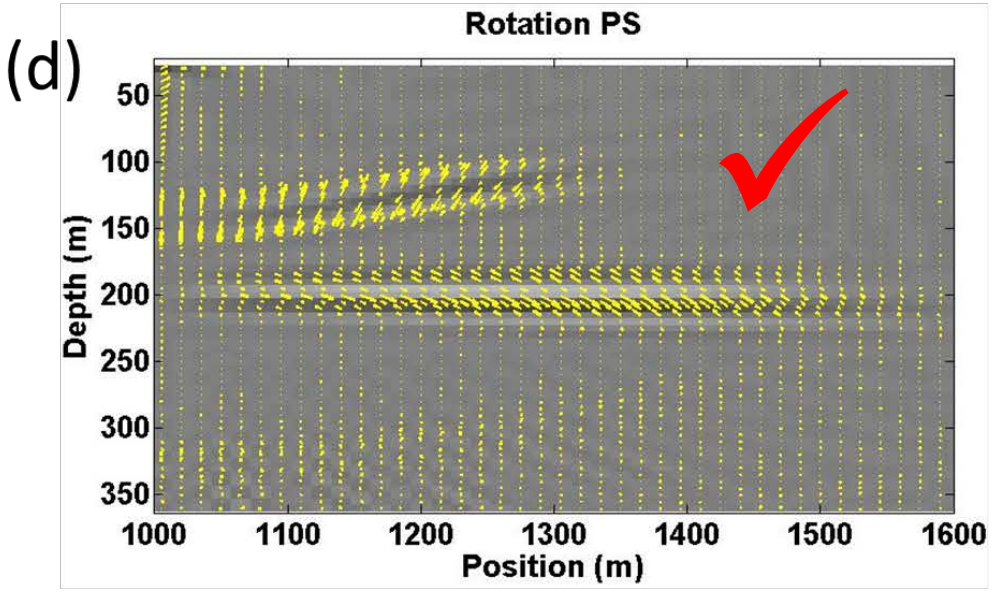
P-to-P migration

P-to-S migration

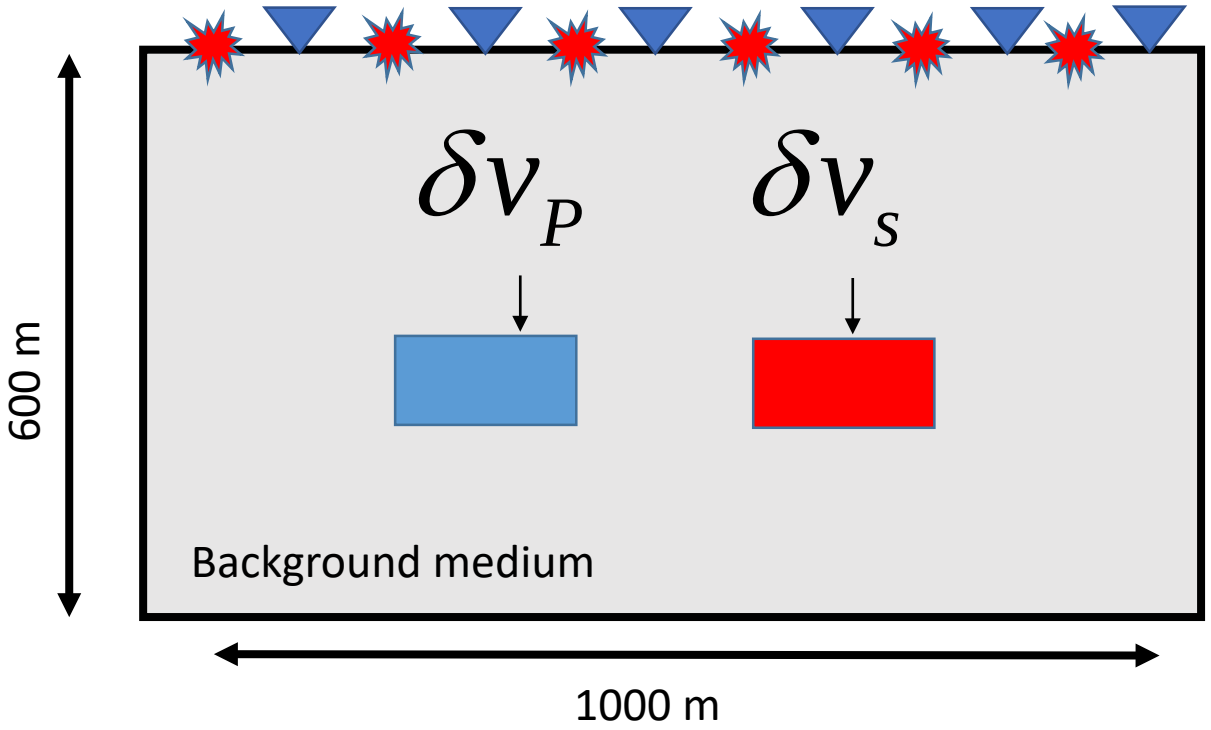






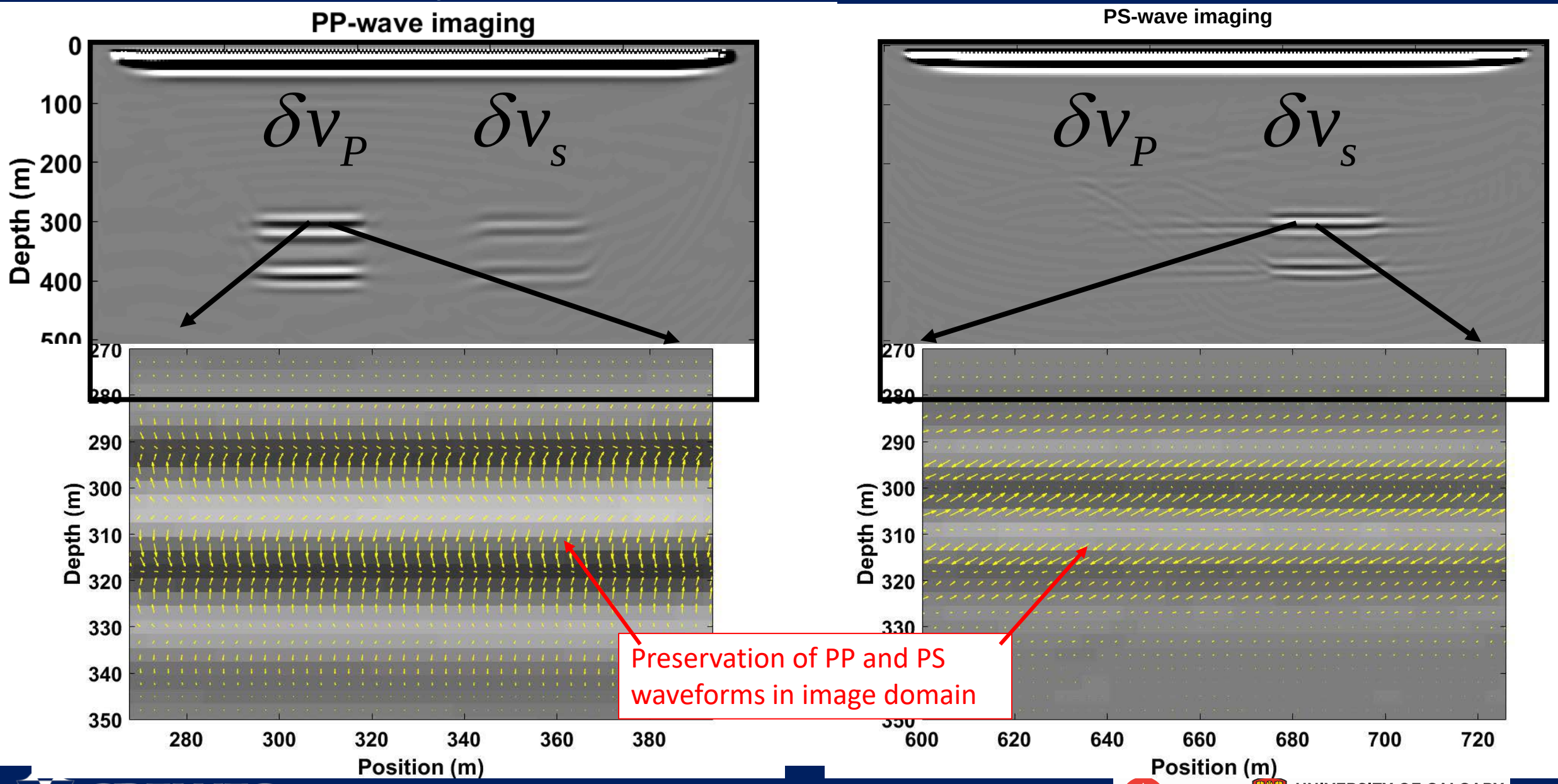


Wavefield sensitivity to Vp and Vs



151 shots records are simulated and migrated/inverted

Numerical examples

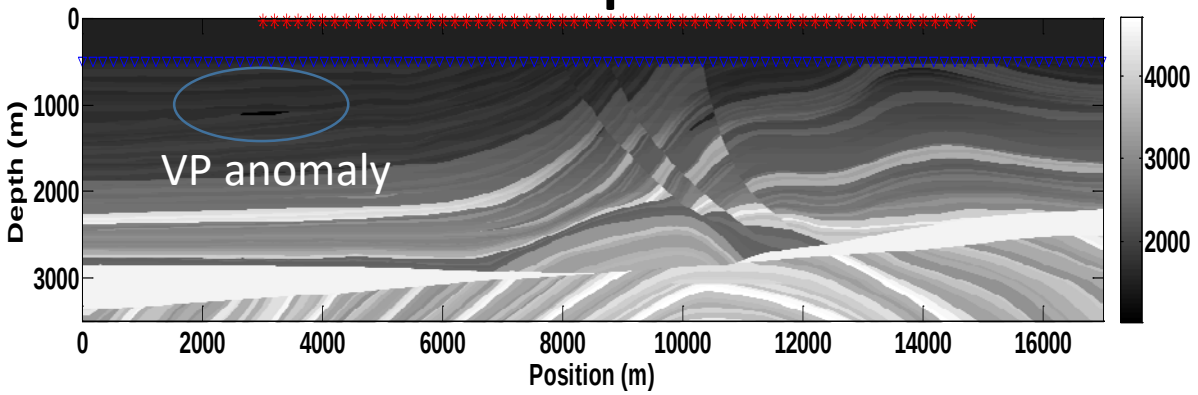


Numerical examples (Preliminarily results)

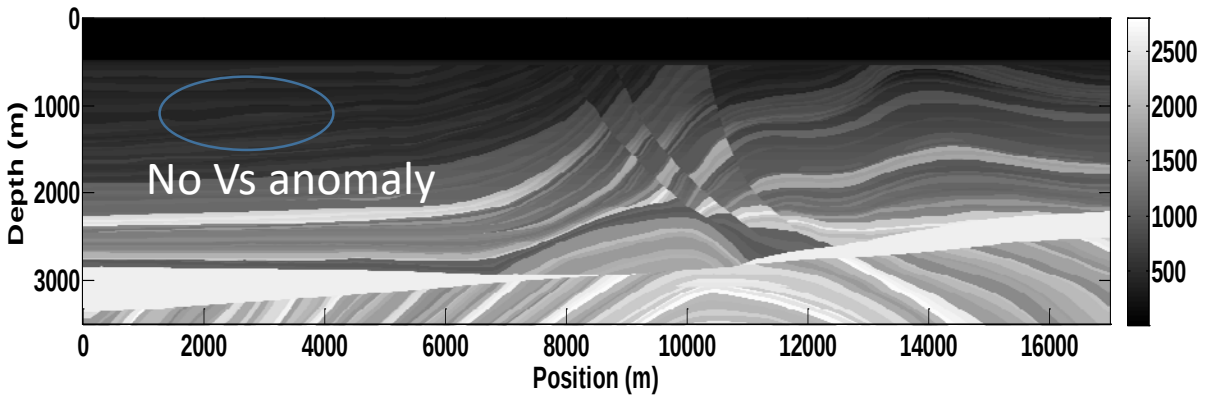
Sensitivity for P- wave impedance

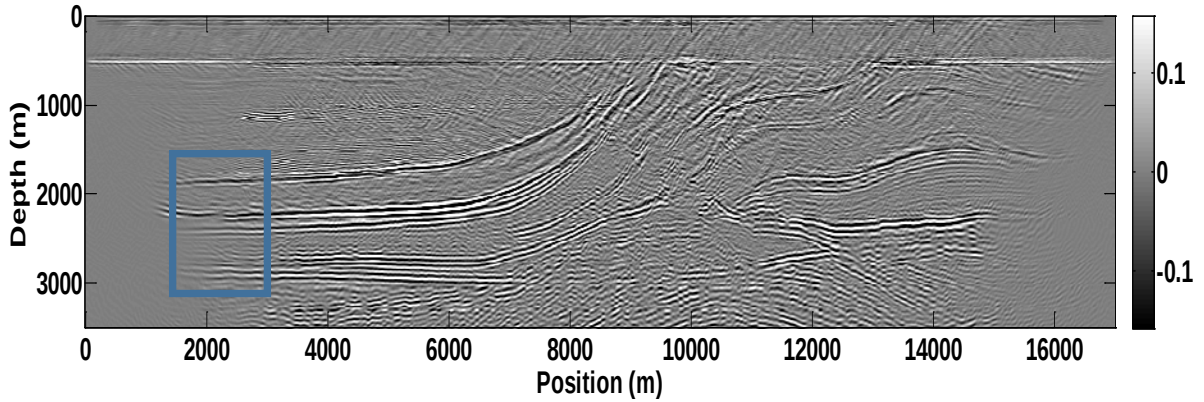
Sensitivity for S- wave impedance

Vp

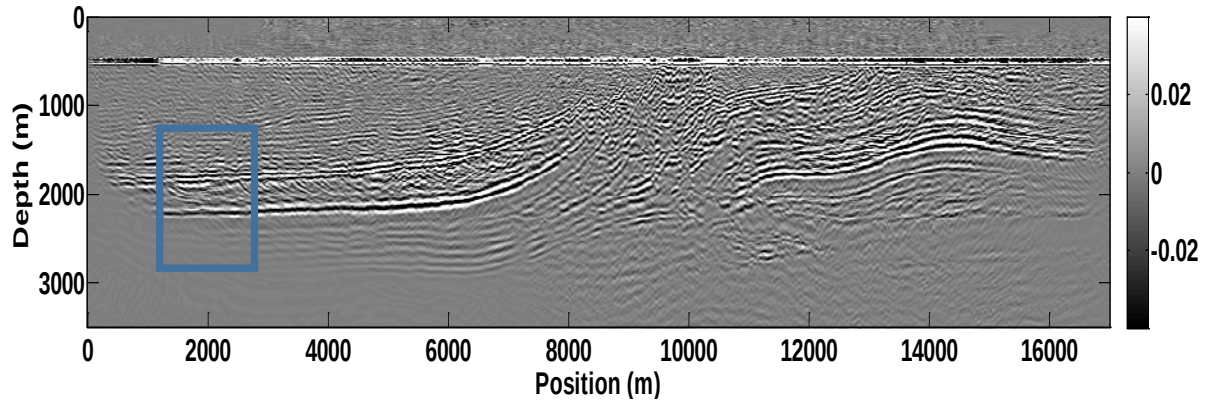


Vs





P-to-P migration and inversion

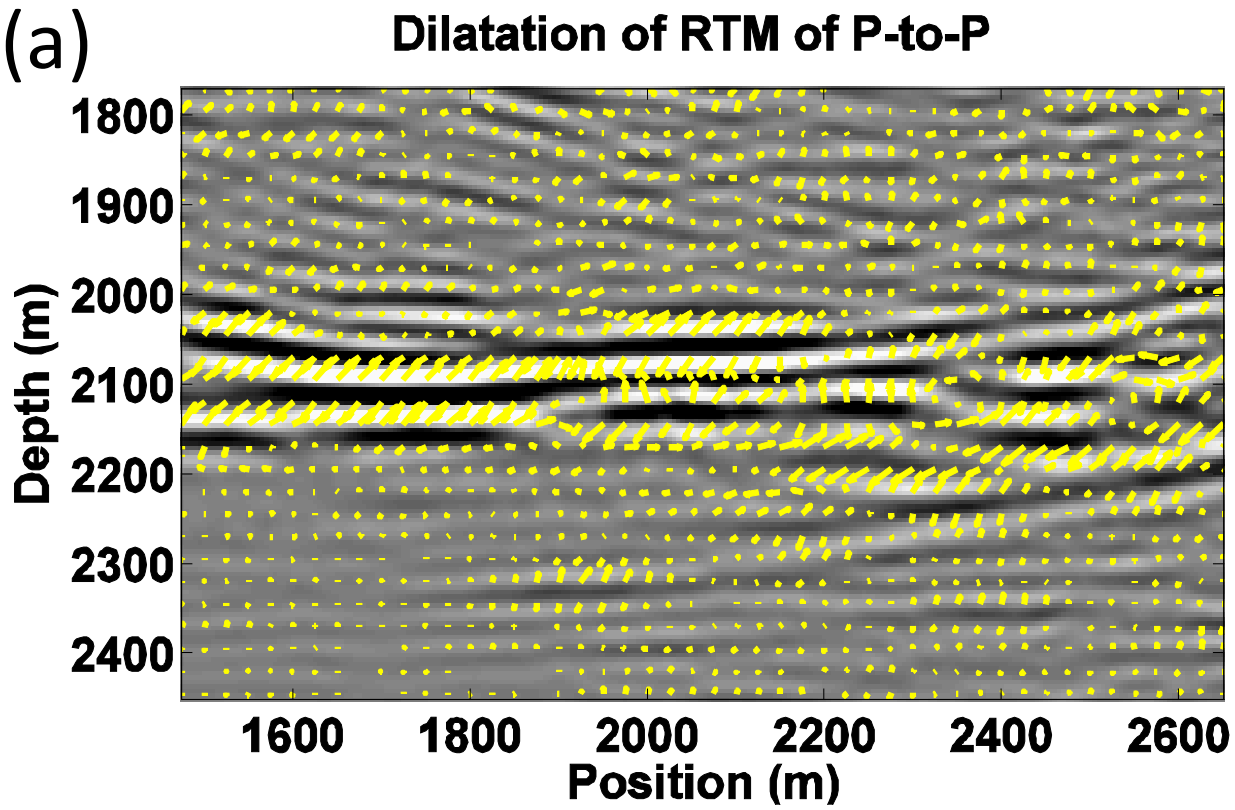


P-to-S migration and inversion

Numerical examples

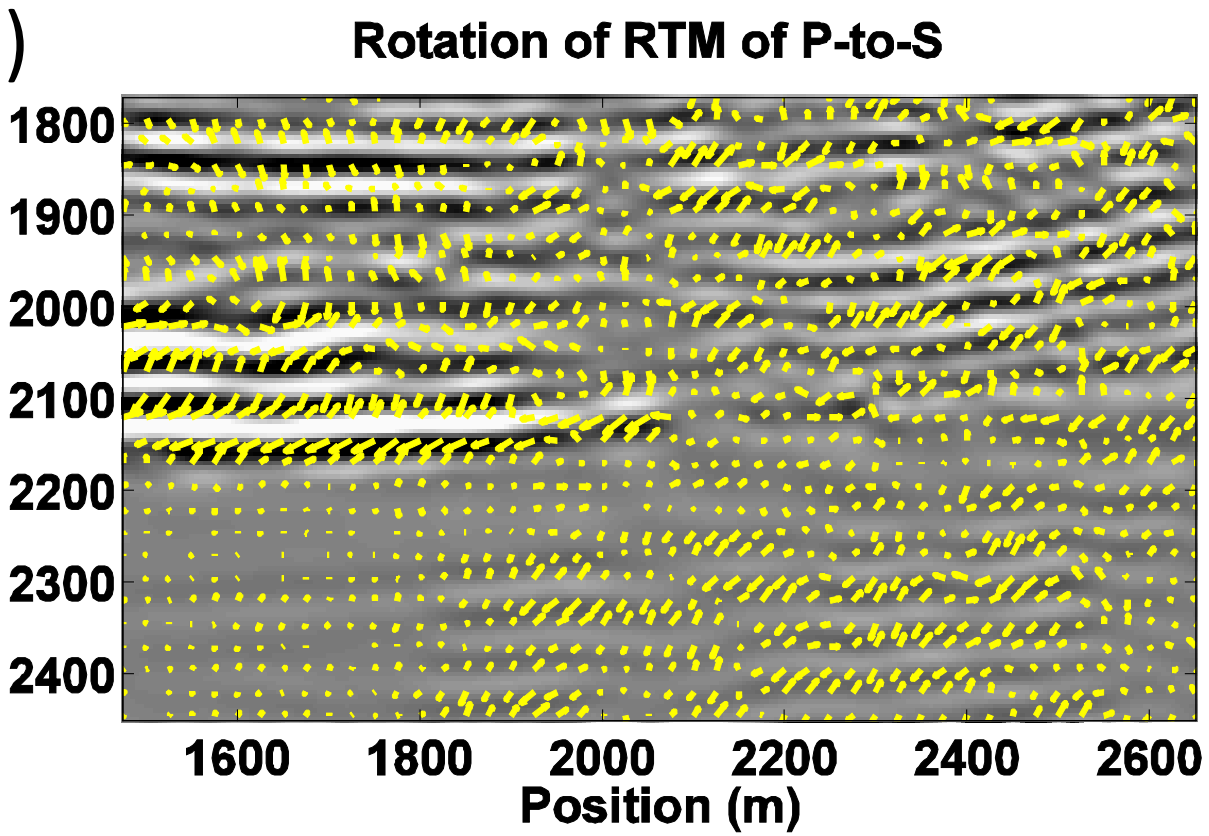
Sensitivity for P- wave impedance

(a)



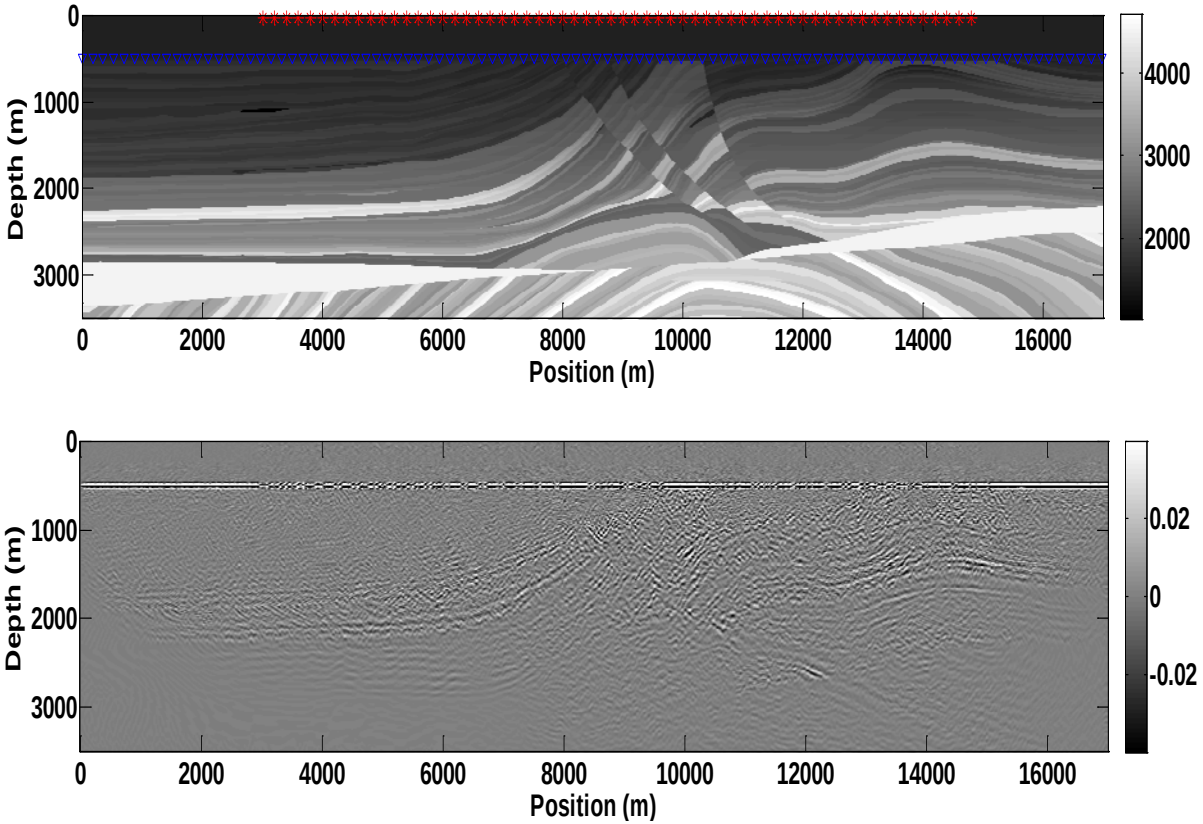
Sensitivity for S- wave impedance

(b)

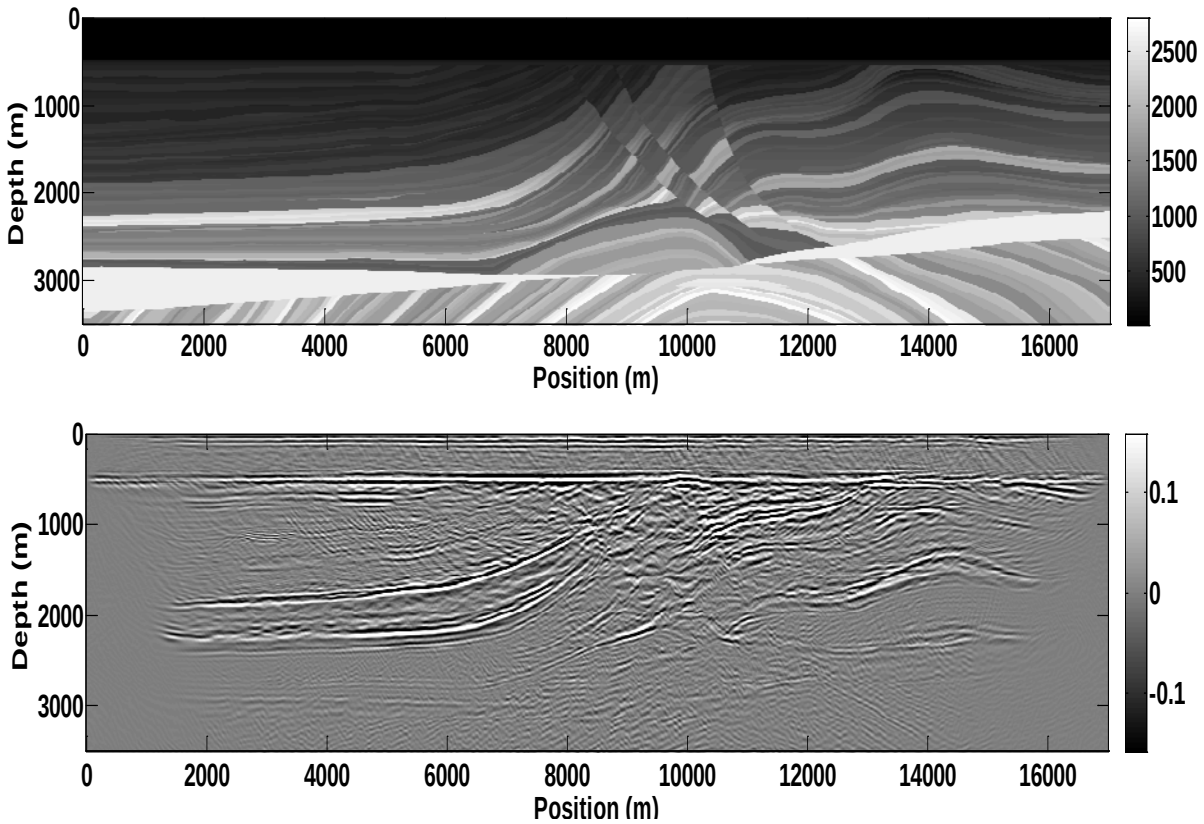


Uncertainty of inversion of colocation of PP and PS

Artifact of P-to-S image on S-wave inversion



Artifact of P-to-P image on S-wave inversion



Conclusion

- ✓ **An FWI inversion strategy is developed by**
  - ✓ **1- Modification of imaging conditions for P- and S- wave separation**
  - ✓ **2- Adaptation of Tarantola's inversion strategy**
  - ✓ **3- Inversion performed after multicomponent migration**
- ✓ **We visualized FWI sensitivity functions using displacement vectors**

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