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Translation, Strain and Rotation: New Approaches to Seismic Processing and Inversion

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Translation, Strain and Rotation: New Approaches to Seismic Processing and Inversion

What is the task?

➡ We try to produce realistic tomographic images of the Earth's interior using seismic information (full waveform inversion).

What kind of information do we have?

rotational ground motions	**translational ground motions**	**dynamic strain**
(new observable)	(standard observable)	(new observable)
3 components	3 components	6 components
$\frac{1}{2}\nabla \times \boldsymbol{u}(\boldsymbol{x}^r, t)$	$\boldsymbol{u}(\boldsymbol{x}^r, t)$	$\frac{1}{2}(\partial_i u_j + \partial_j u_i)$

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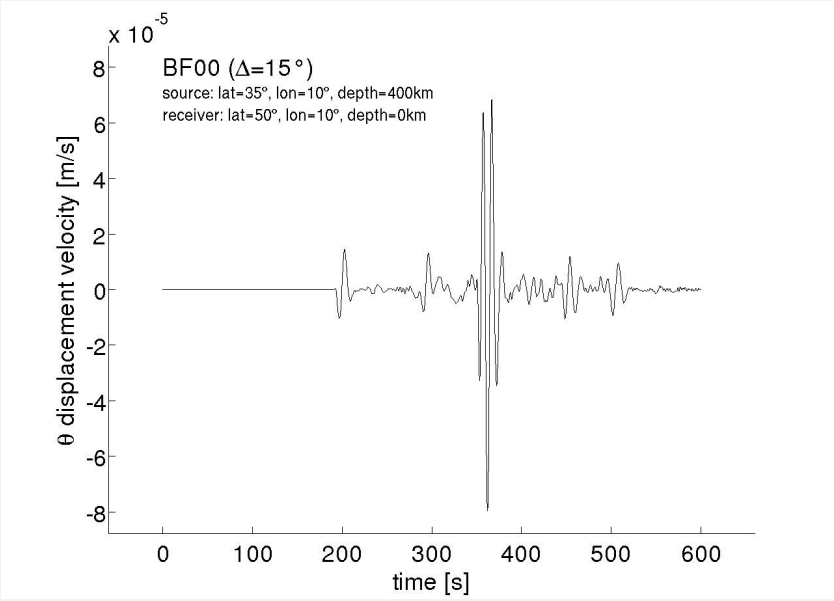
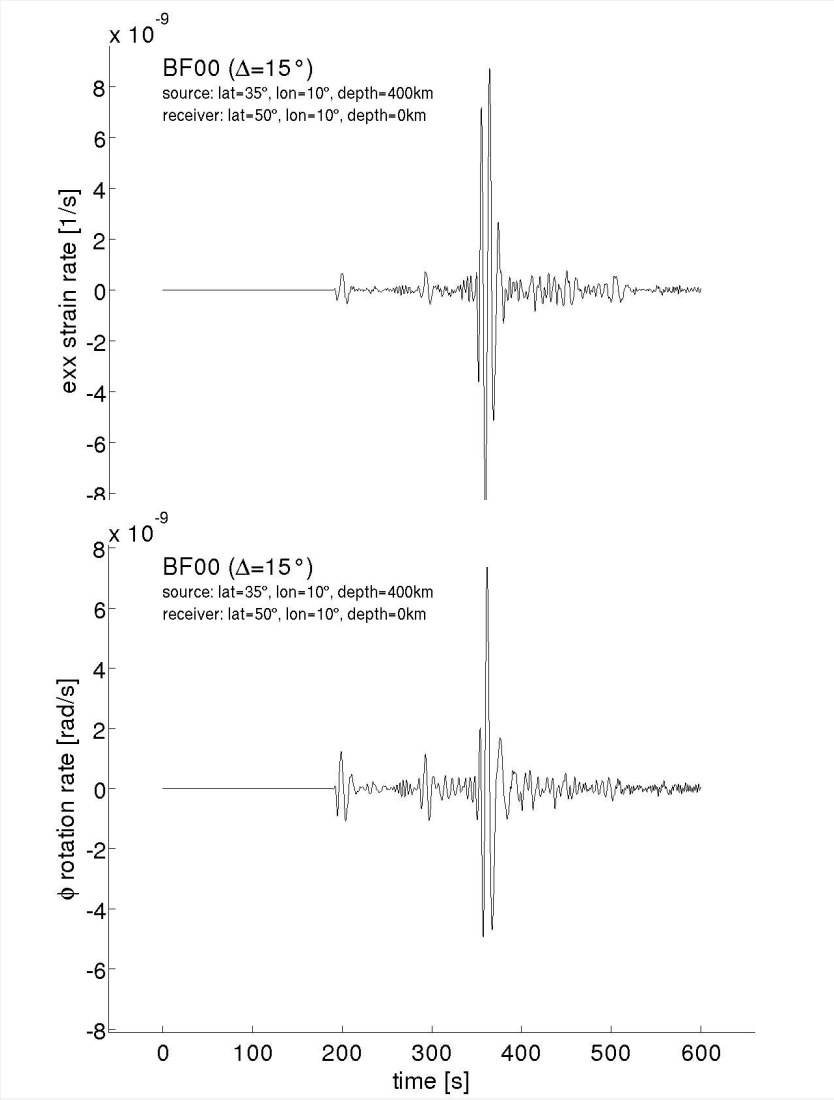
THESIS

Synthetic velocity, strain- and rotation rate seismograms calculated by a spectral element code (SES3D by Fichtner,A.):

- Earth model: AK135
- Epicentral distance: 15°
- Cutoff periods: 10s-100s





General concept of sensitivity kernels:

$$\nabla_m \chi \, \delta \boldsymbol{m} = \int_G K_m(\boldsymbol{x}) \, \delta \boldsymbol{m}(\boldsymbol{x}) \, d^3 \boldsymbol{x}$$

χ : Observable (translation, rotation, strain, ...)

$\boldsymbol{m}$: Model parameters (Vp, Vs, ...)

K : Sensitivity kernel

➡ Compute sensitivity kernels for translation-, strain- and rotation seismograms

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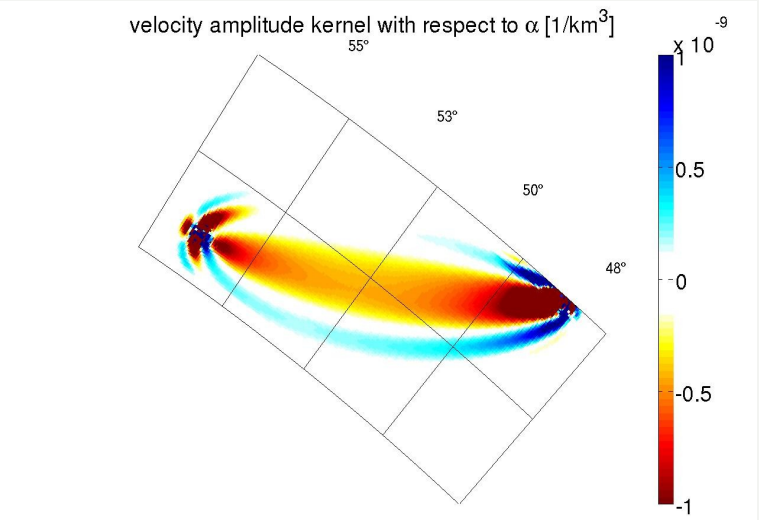

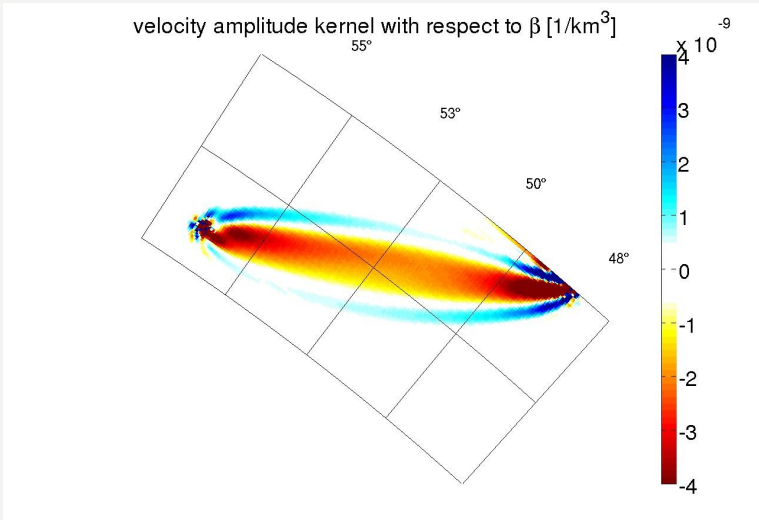

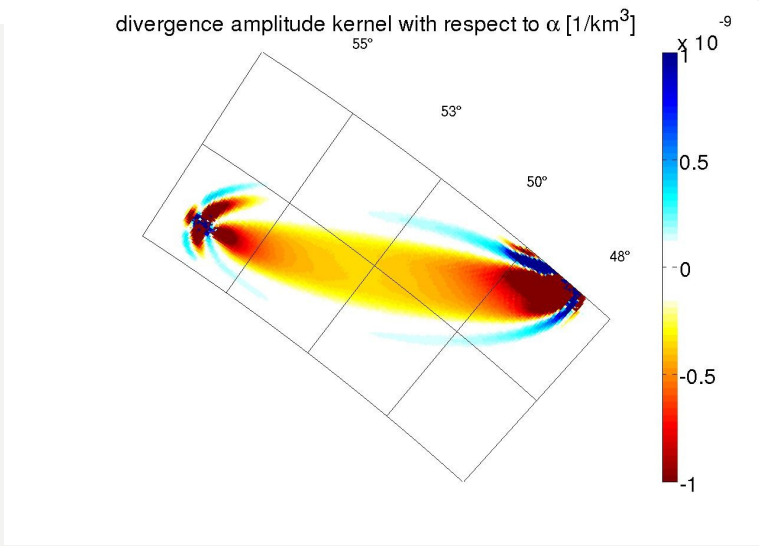

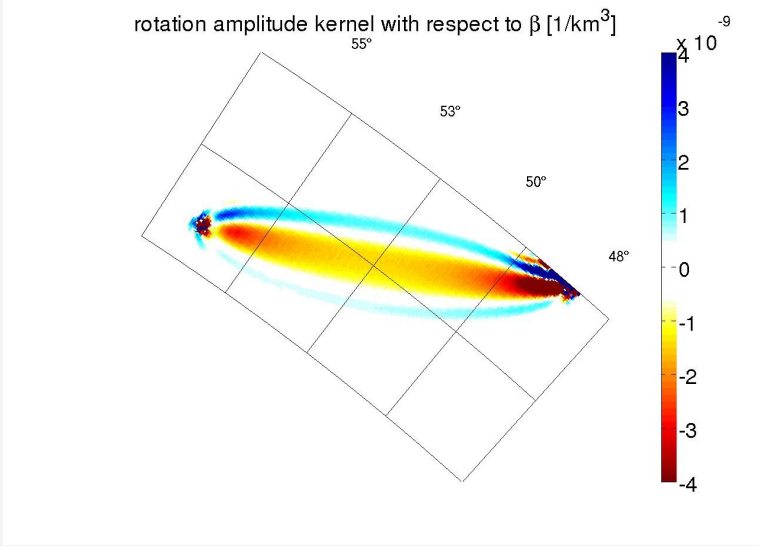

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Challenge: define new physical observables that are related to strain and rotation providing structural information

Motivation: plane S or P wave in a homogeneous and isotropic medium:

Rotation

$$\frac{|\dot{\boldsymbol{u}}(\boldsymbol{x}^r)|}{|\nabla \times \boldsymbol{u}(\boldsymbol{x}^r)|} = \beta$$

Definition: apparent S wave speed

$$\beta_a(\boldsymbol{x}^r) \stackrel{\text{def}}{=} \frac{\|\dot{\boldsymbol{u}}(\boldsymbol{x}^r)\|_2}{\|\nabla \times \boldsymbol{u}(\boldsymbol{x}^r)\|_2}$$

Strain

$$\frac{|\dot{\boldsymbol{u}}(\boldsymbol{x}^r)|}{|\nabla \cdot \boldsymbol{u}(\boldsymbol{x}^r)|} = \alpha$$

Definition: apparent P wave speed

$$\alpha_a(\boldsymbol{x}^r) \stackrel{\text{def}}{=} \frac{\|\dot{\boldsymbol{u}}(\boldsymbol{x}^r)\|_2}{\|\nabla \cdot \boldsymbol{u}(\boldsymbol{x}^r)\|_2}$$

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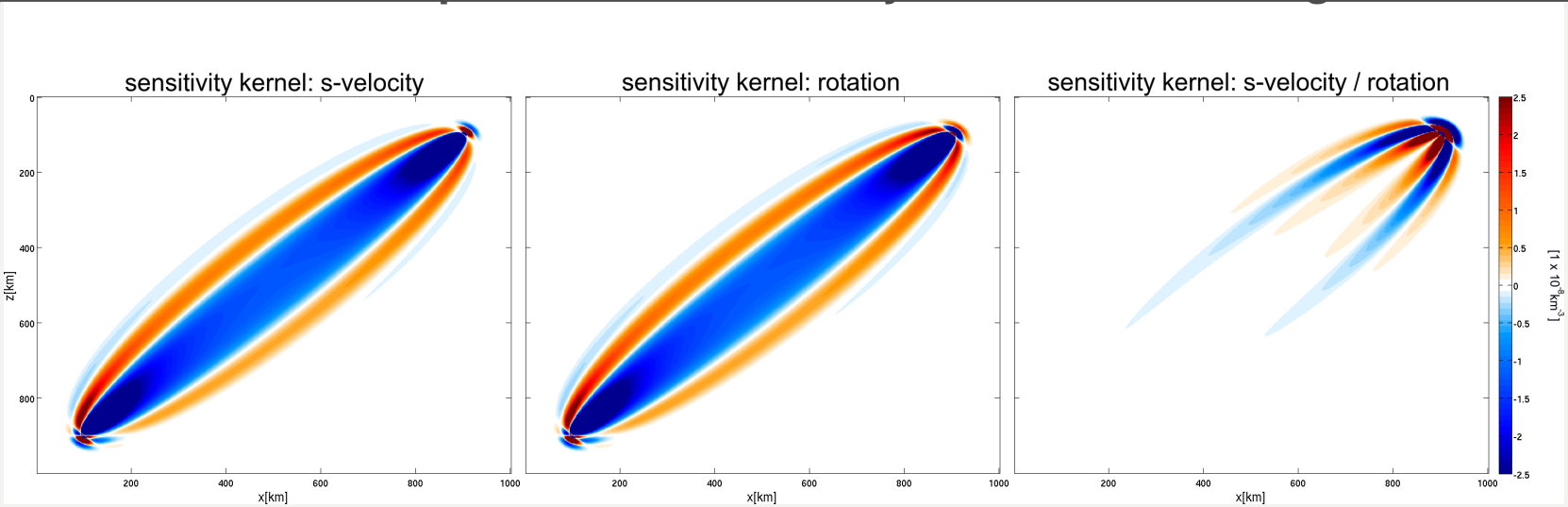
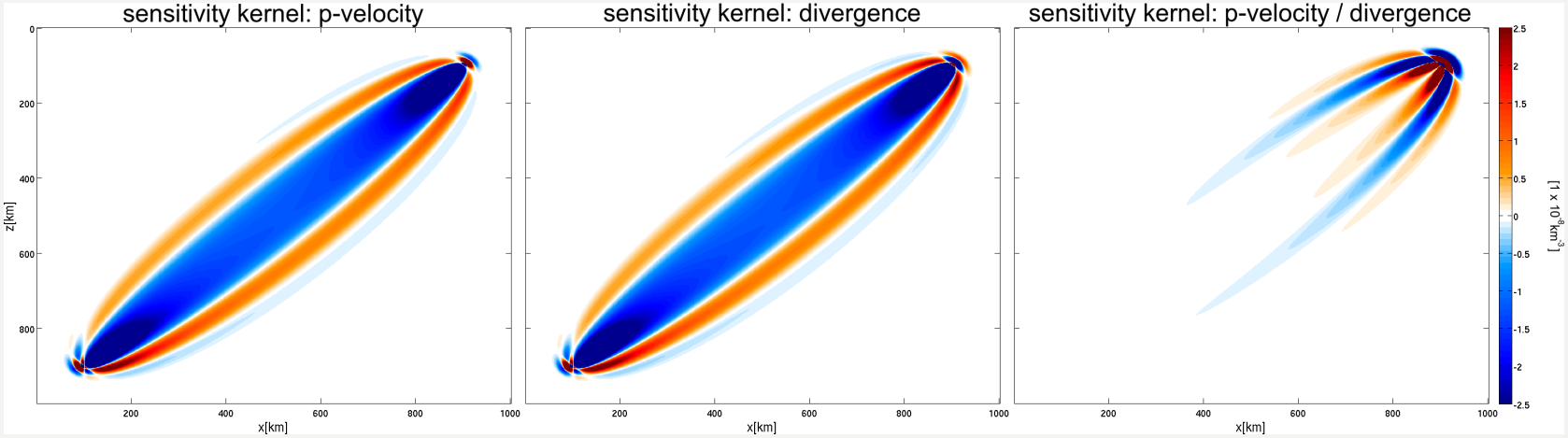
THESIS

Ray method based computation of sensitivity kernels in a homogeneous medium:





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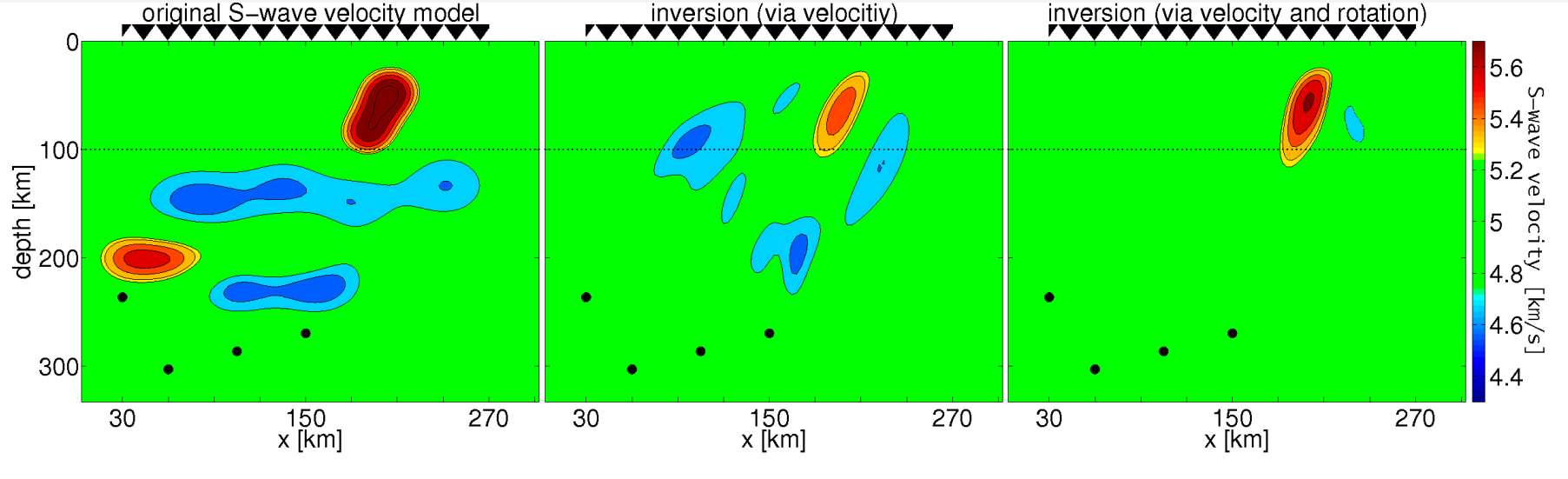
Ray method based synthetic inversion example:



- The apparent S wave speed may be used to increase the vertical resolution in regional tomography for local structures!
- Rotational ground motion measurements have the potential to complement standard tomographic methods.