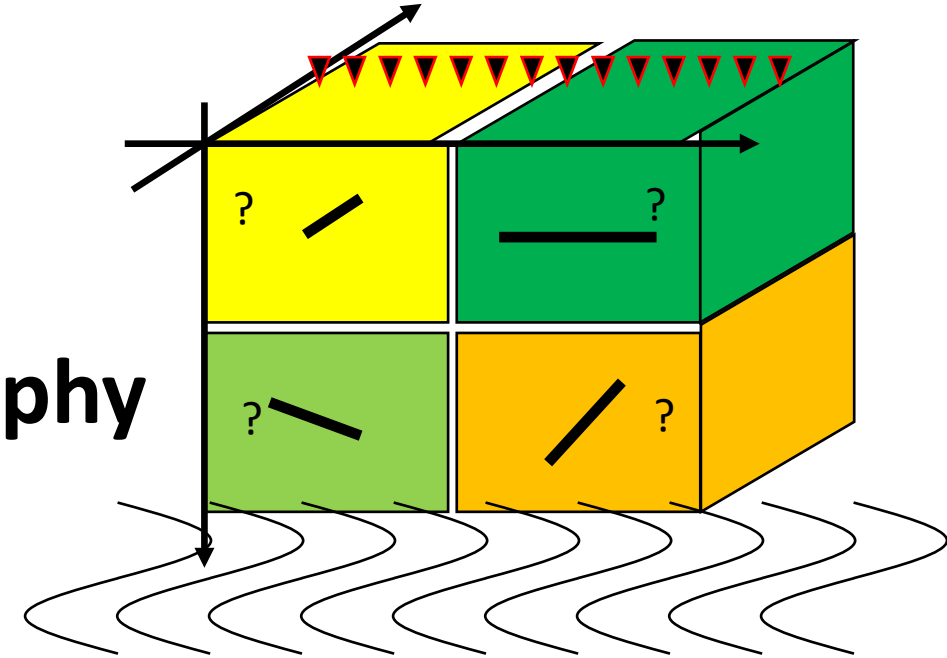
On the limitations of finite-frequency XKS-splitting tomography



Georg Rümpker and Ayoub Kaviani

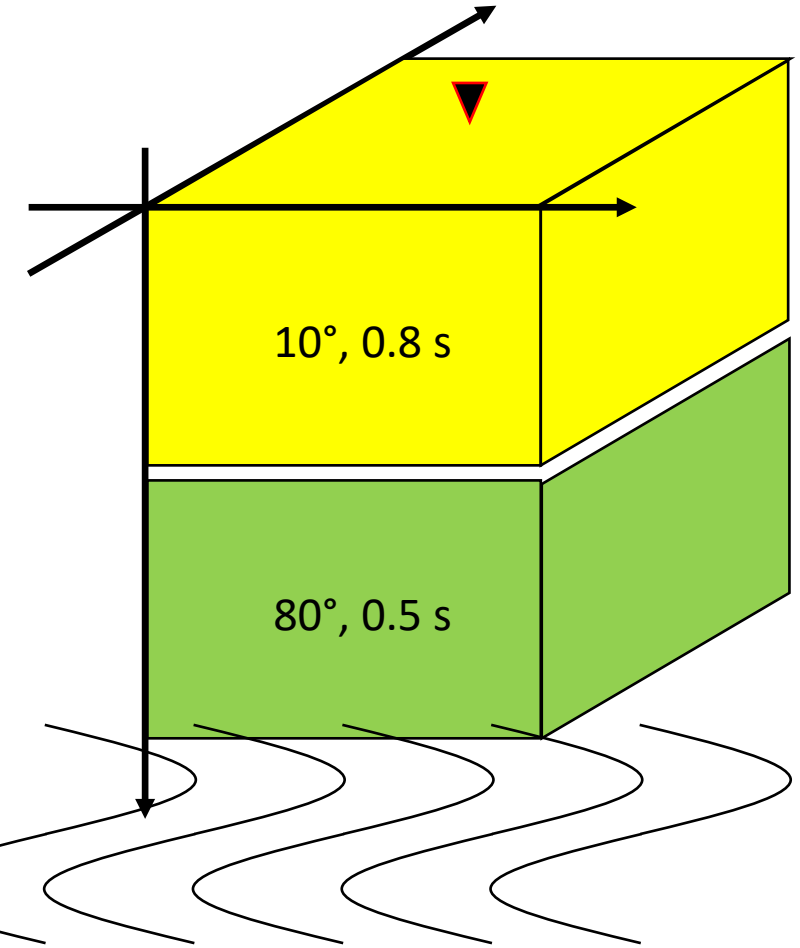
Institute of Geosciences
Goethe-University Frankfurt
Germany

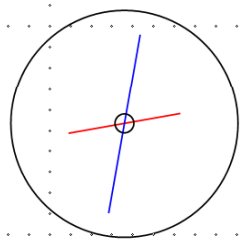
rumpker@geophysik.uni-frankfurt.de

Motivation

- Can tomographic schemes **uniquely** resolve the anisotropic structure of the upper mantle?
- To test this, we compare **finite-frequency waveforms** for relatively simple, canonical models of upper-mantle anisotropy.
- The models are characterized by up to four zones of different anisotropic properties (with orthorhombic symmetry).

Vertically-varying reference model (an arbitrary example)

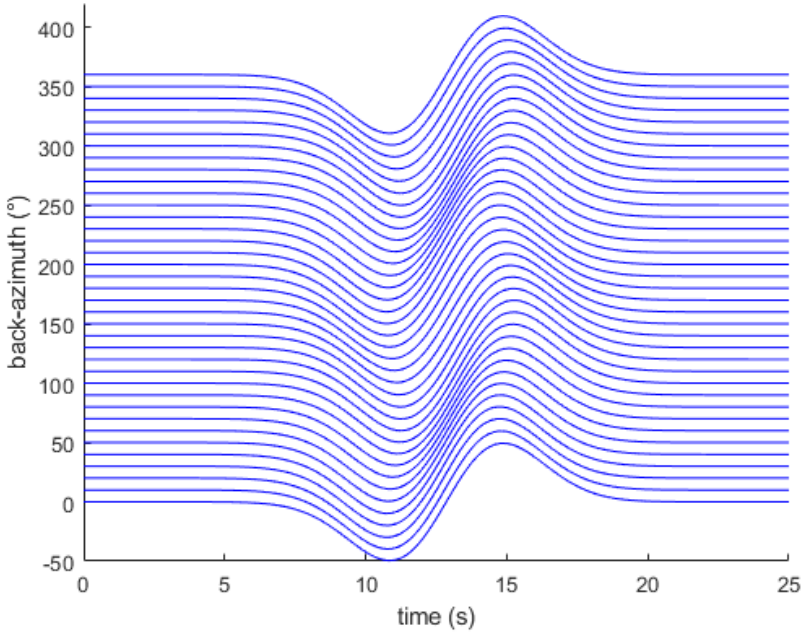




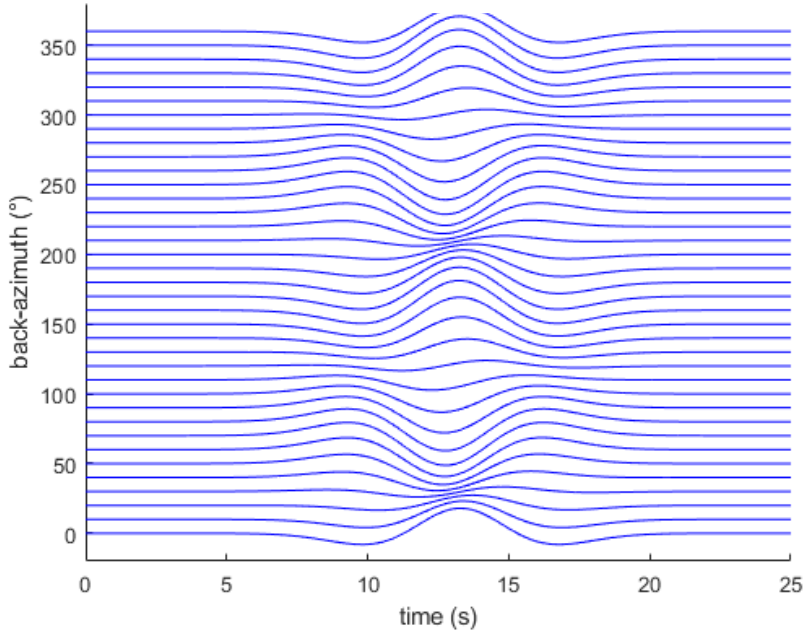
- Upper layer (blue bar) – fast axis: 10°, delay time 0.8 s
- Lower layer (red bar) – fast axis 80°, delay time 0.5 s

Waveforms (dominant period 8 s) as function of BAZ(°)

radial components



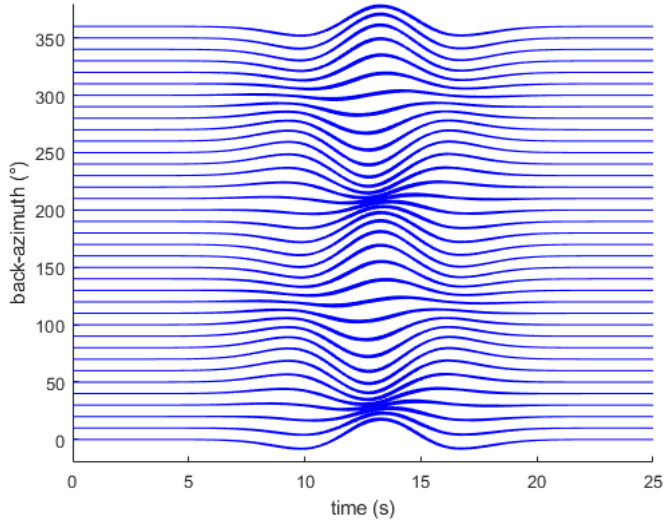
transverse components



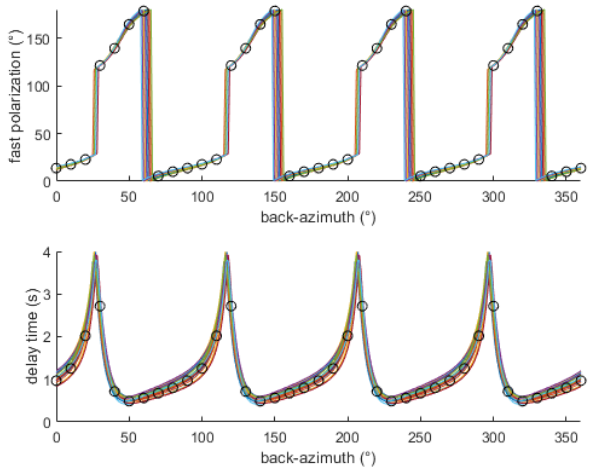
- Can we (uniquely) infer the corresponding anisotropic parameters from waveform inversion?
- Should we use **waveforms**, **splitting parameters** or **splitting intensities**?

20 best-fitting anisotropic models derived from different observables

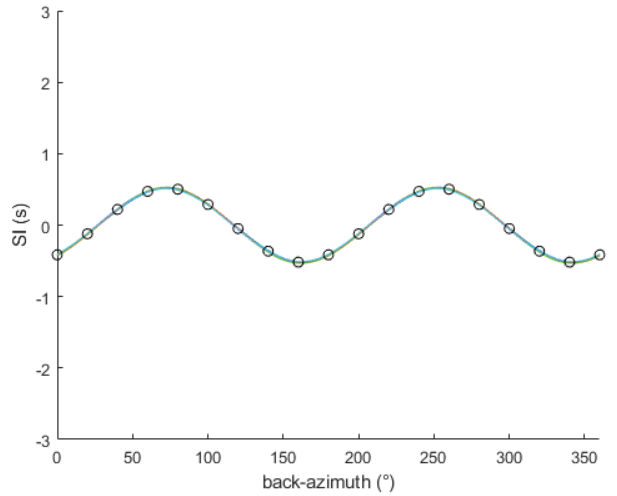
20 best-fitting waveforms



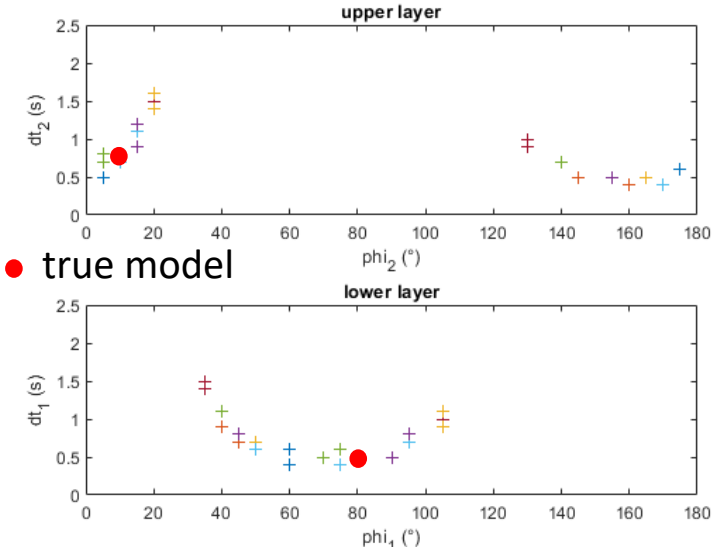
20 best-fitting splitting-parameters



20 best-fitting splitting intensities

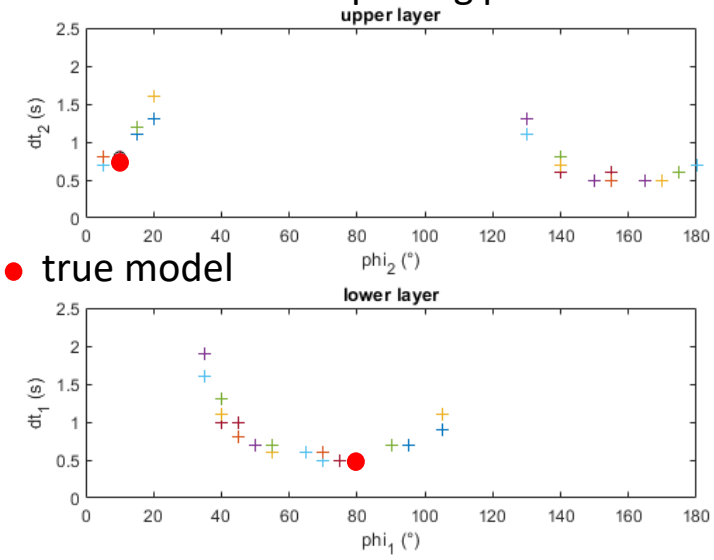


20 models from waveforms



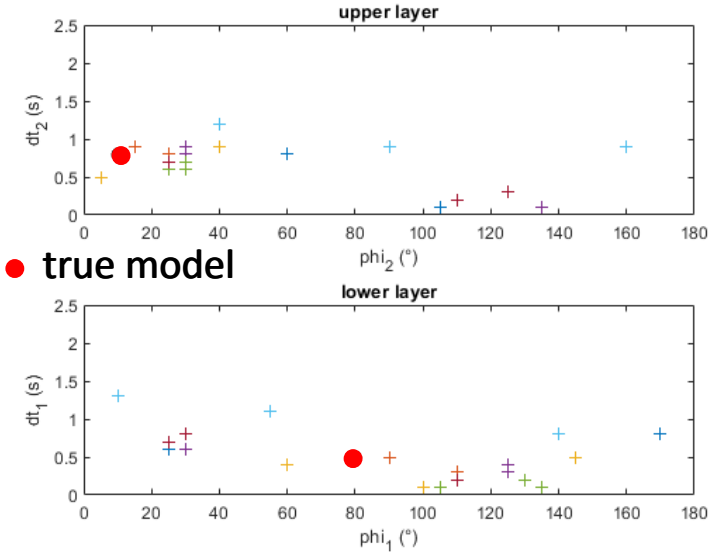
● true model

20 models from splitting parameters



● true model

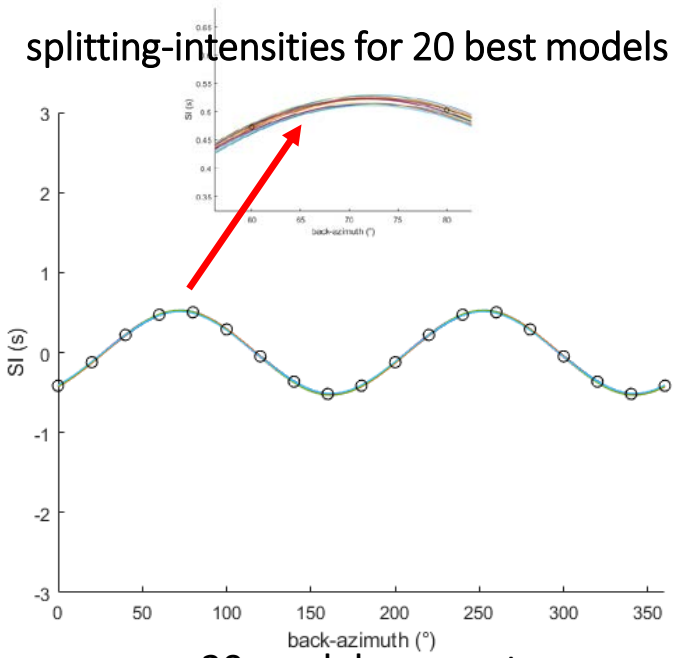
20 models from splitting intensities



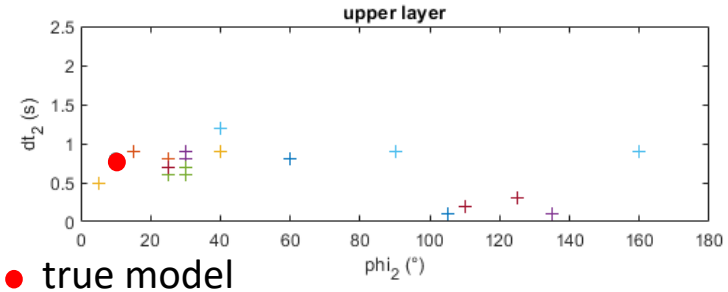
● true model

Splitting intensities – corresponding models and waveforms

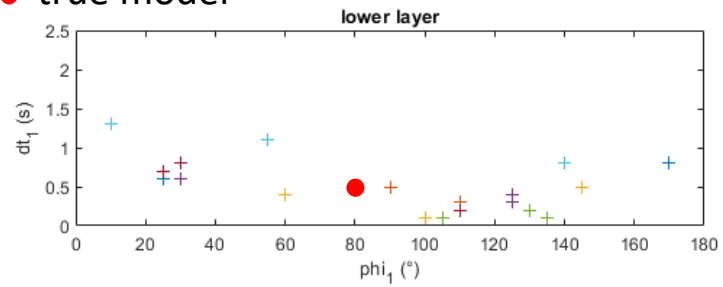
splitting-intensities for 20 best models



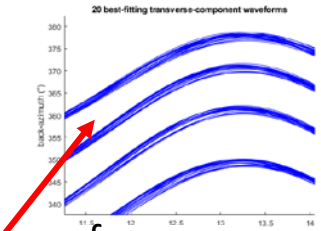
20 model parameters



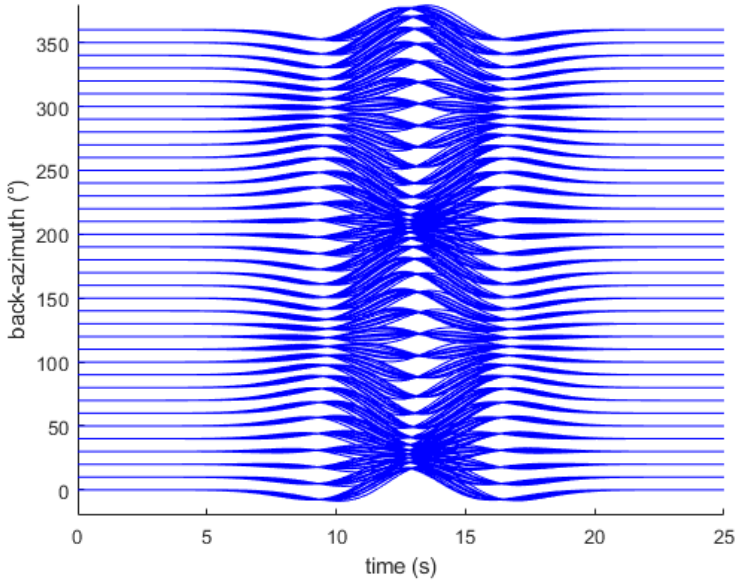
- true model



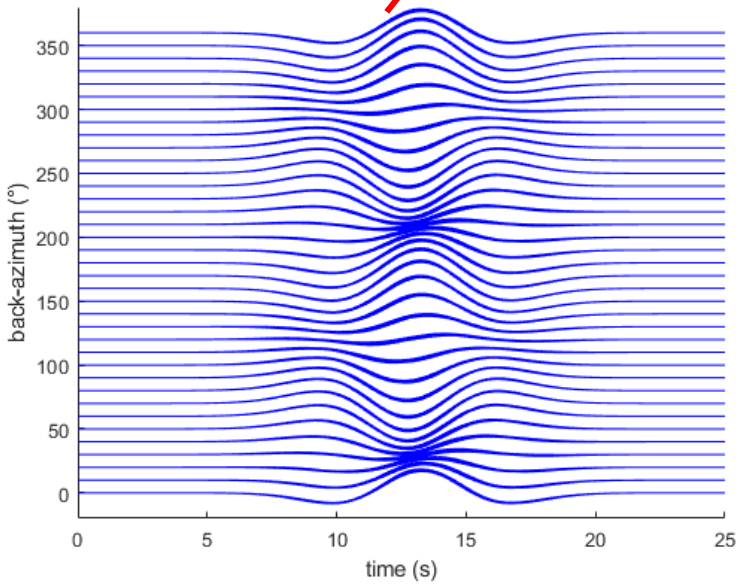
- Waveforms for models derived from splitting intensities **do not match** the waveforms for the reference model



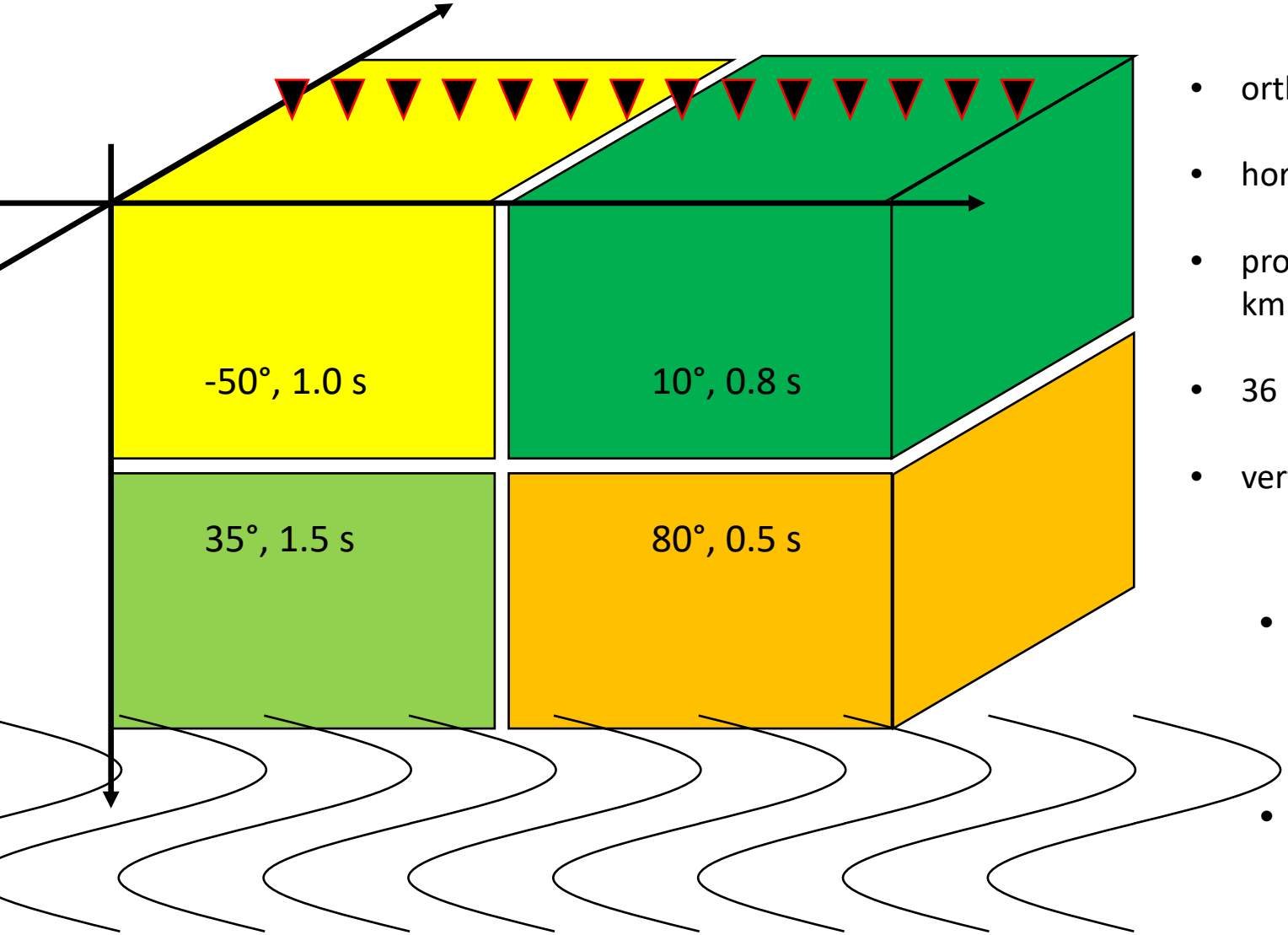
waveforms for best-fitting splitting intensities



best-fitting waveforms



Laterally and vertically-varying anisotropic medium

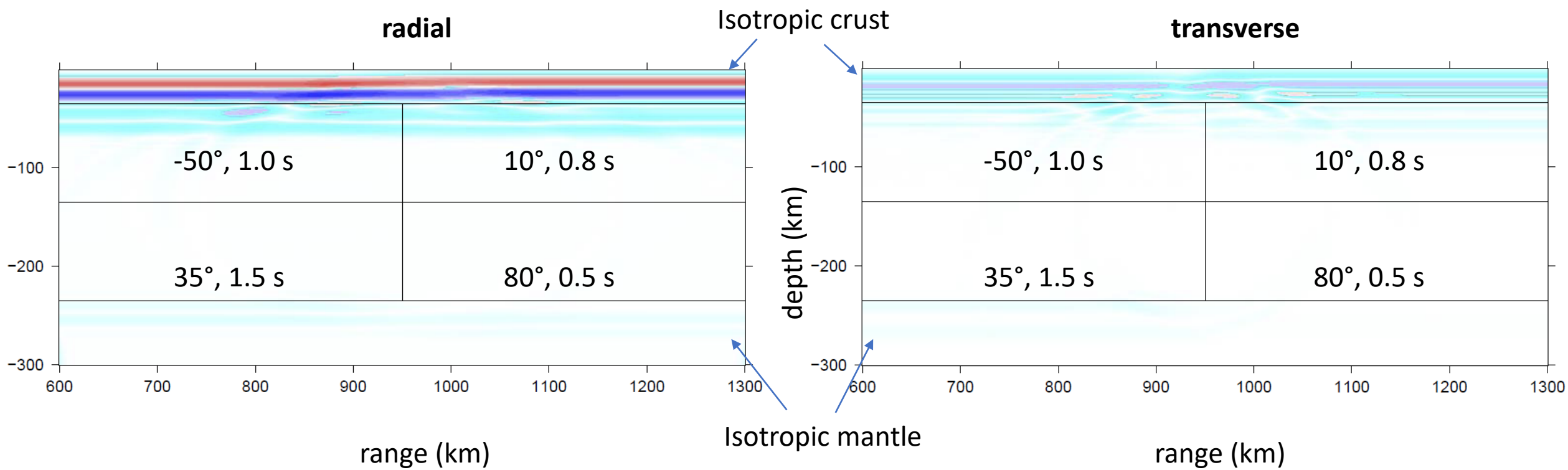


- orthorhombic symmetry
- horizontal a-c axes, b axis vertical
- profile with 30 receiver positions, 20 km spacing
- 36 back-azimuths: [0°: 10°: 350°]
- vertically-incident XKS-wavefronts

- Our previous modeling shows that 2-layer anisotropy cannot be resolved uniquely – even if waveforms are used!
- Here we show that **strong lateral variations are also not resolvable**, if combined with vertical variations of anisotropy.

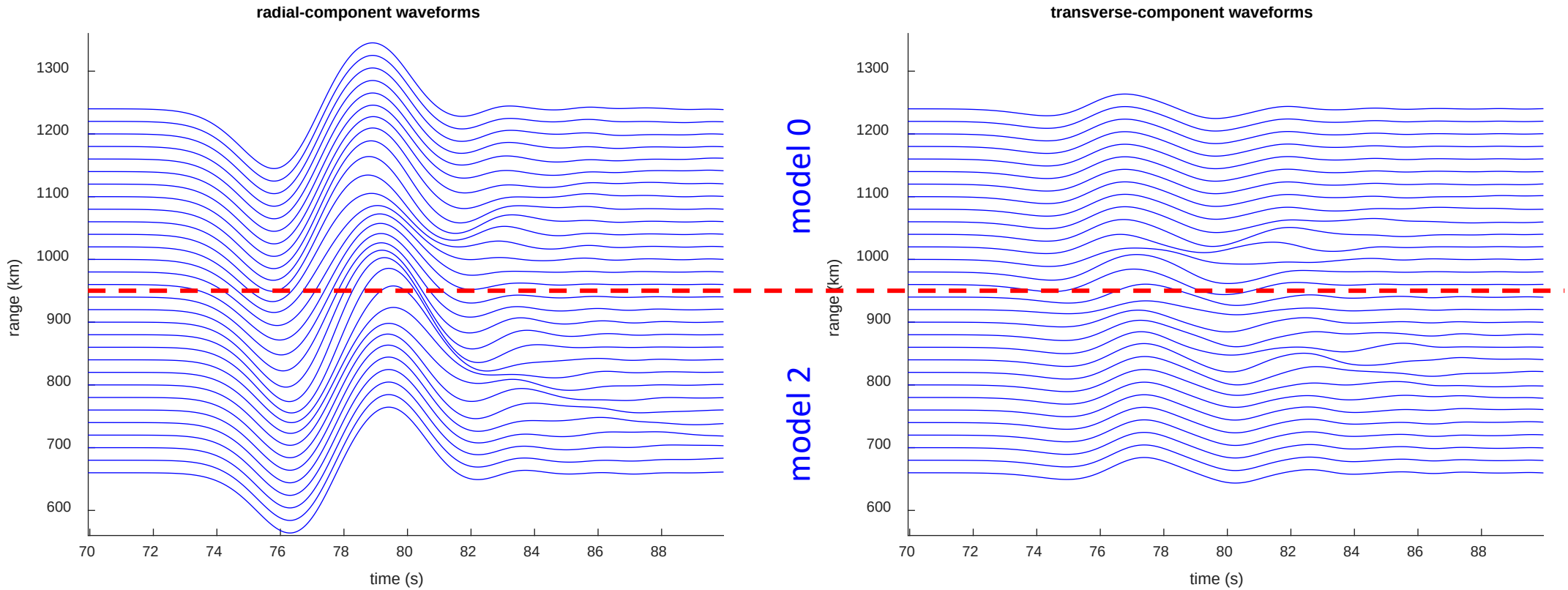
Finite-difference wavefronts

BAZ=90°, timeframe=29



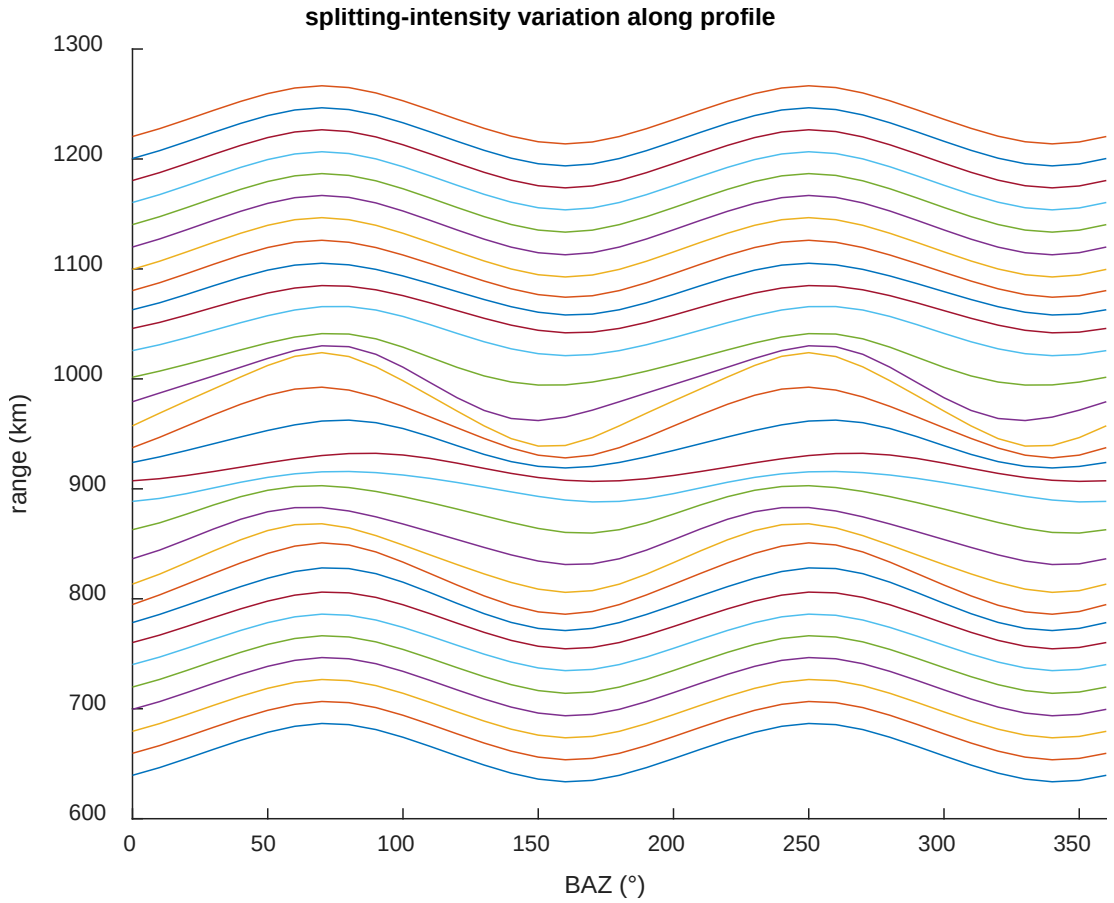
Radial and transverse-component waveforms along profile

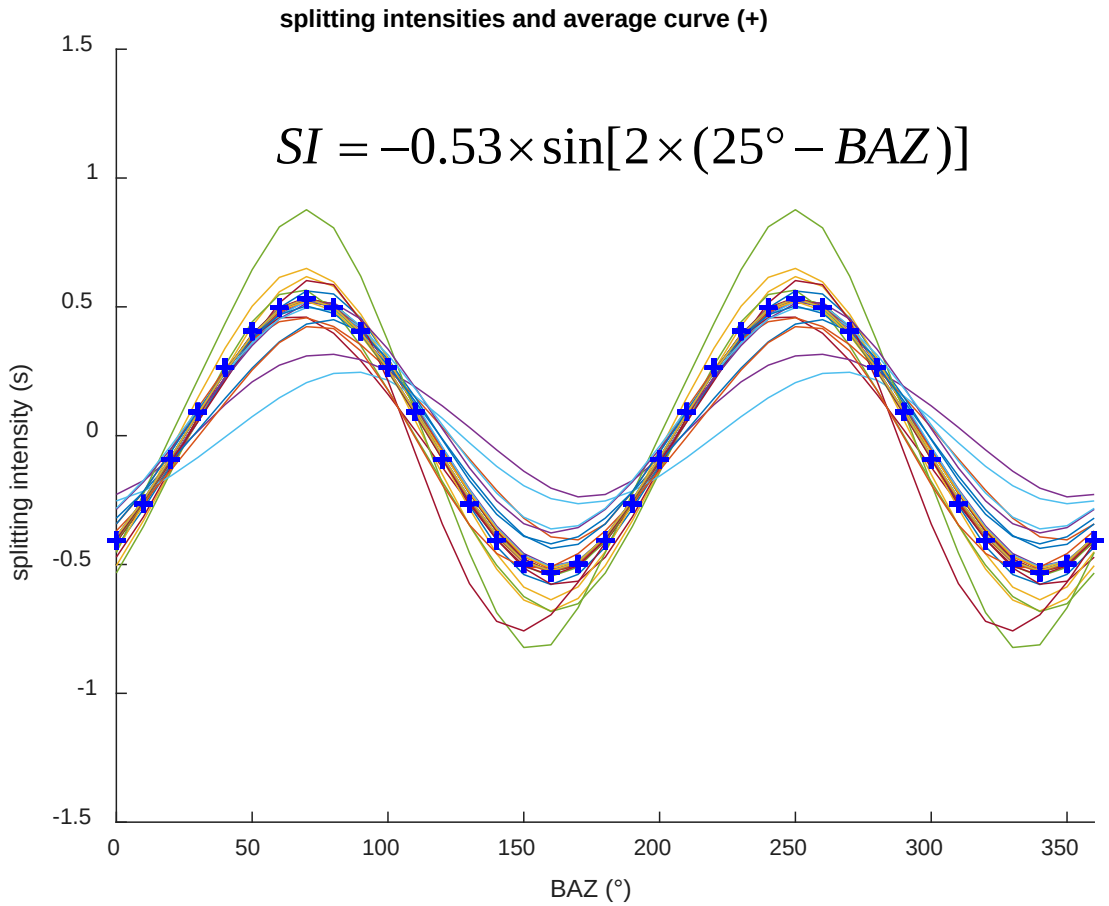
BAZ=90°



- Waveforms exhibit only minor variations along the profile.

Splitting intensities along profile





- Splitting intensities exhibit only minor variations along the profile and can be explained by single-layer anisotropy.

Conclusions

- Waveforms for significantly different anisotropic models, often, are indistinguishable.
- Generally, it is not possible to uniquely resolve the eight anisotropic parameters (a-axis orientation and strength of anisotropy in four zones) of a given model, even with complete waveforms and backazimuthal coverage.
- Splitting intensities do not allow for a complete description of waveform characteristics in vertically- and/or laterally-varying anisotropic media.
- We conclude that finite-frequency XKS-splitting tomography, alone, is not suited to resolve the anisotropic structures of the upper mantle and that combinations of methods based on e.g. receiver-function splitting or surface waves are required.