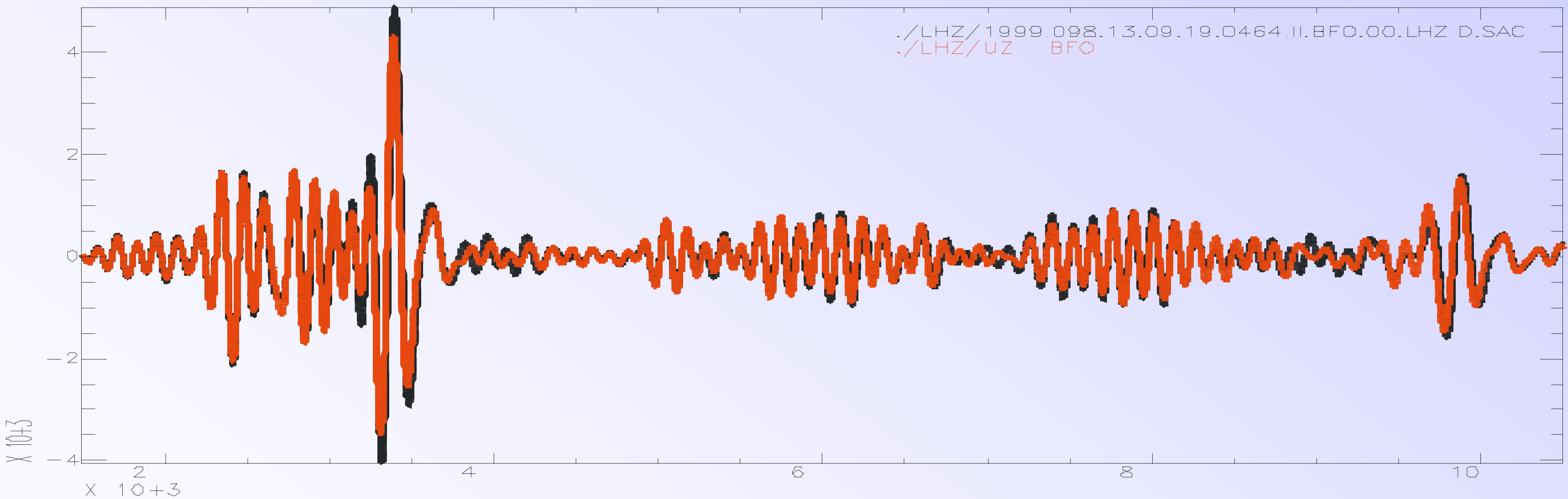
A SPICE benchmark for global tomographic methods
and
Test of Global tomographic models

Yilong Qin, Yann Capdeville, Valerie Maupin, Jean-Paul Montagner

Lapo Boschi and Thorsten Becker



Supported by ***SPICE****- Seismic Wave Propagation and Imaging in Complex Media: A European Network*

Part I

Why we do the Benchmark?

Factors affecting the results of seismic tomography

- Approximation of forward computation
- Ray coverage
- Correlation length
- grid size
- Damping coefficients
- How the different datasets are weighted?
- Sensitivity kernel is 1D, 2D or 3D
- Selection of starting reference model?

Multi-solution of seismic inversion

Part I

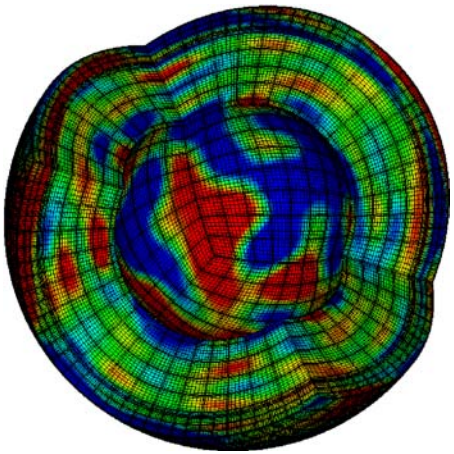
- **Objectives of Benchmark**

1. understand the resolving properties of specific imaging algorithms
2. how current imaging techniques are limited by approximations in theory and by the data quality and coverage.

• Procedure of Benchmark

1.Preliminary Benchmark: To make sure that the computation precision, acquisition geometry, data format, sampling rate are good for tomography test

- Minimum period 50s
- Simple isotropic model
- No topography, ocean, ellipticity



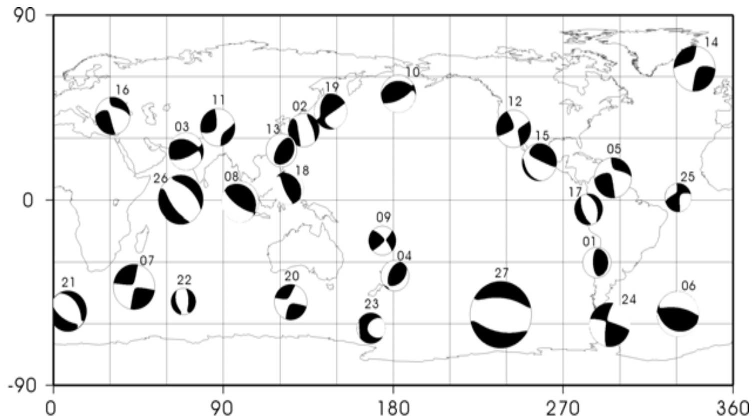
2. Benchmark

- Minimum period 32s
- Complex anisotropic model (designed by *Valerie Maupin*)
- With gravity, topography, ocean, ellipticity
- Constant Moho interface
- Use spectral element method (SEM)

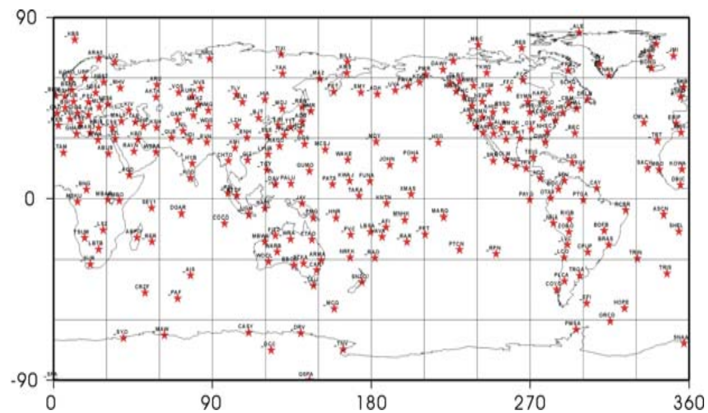
3. Procedure

Build model —**SEM**→ synthetic seismograms —tomography→ 3D image

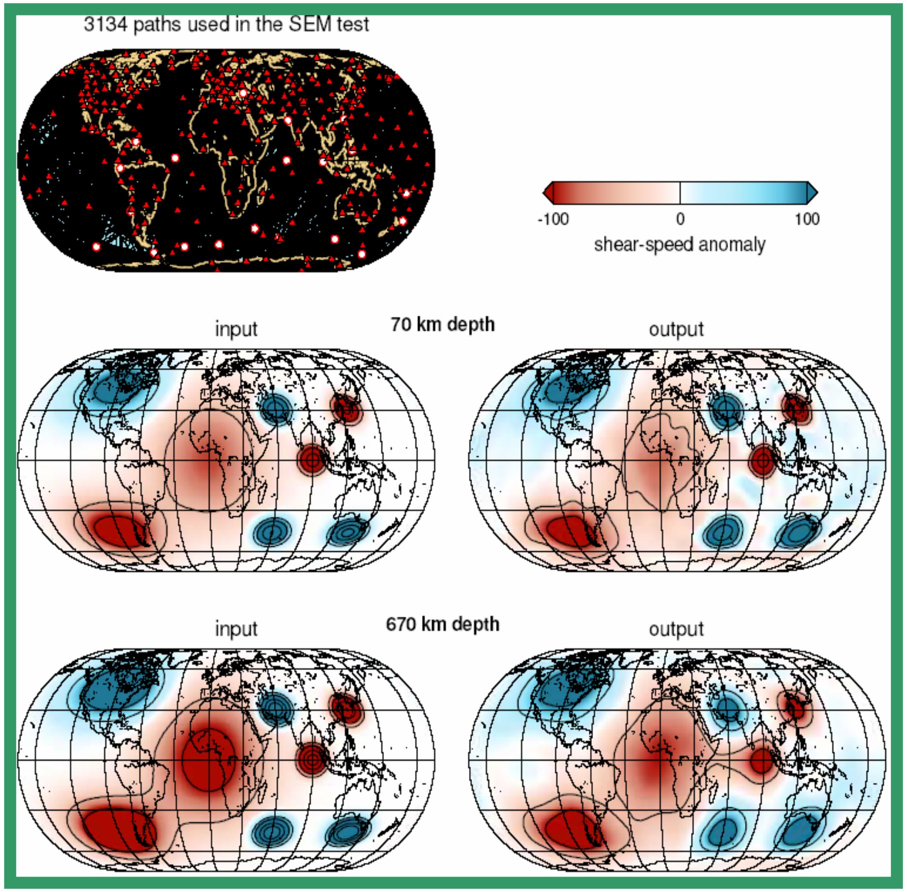
Source and station distribution of preliminary benchmark



27 Events distribution



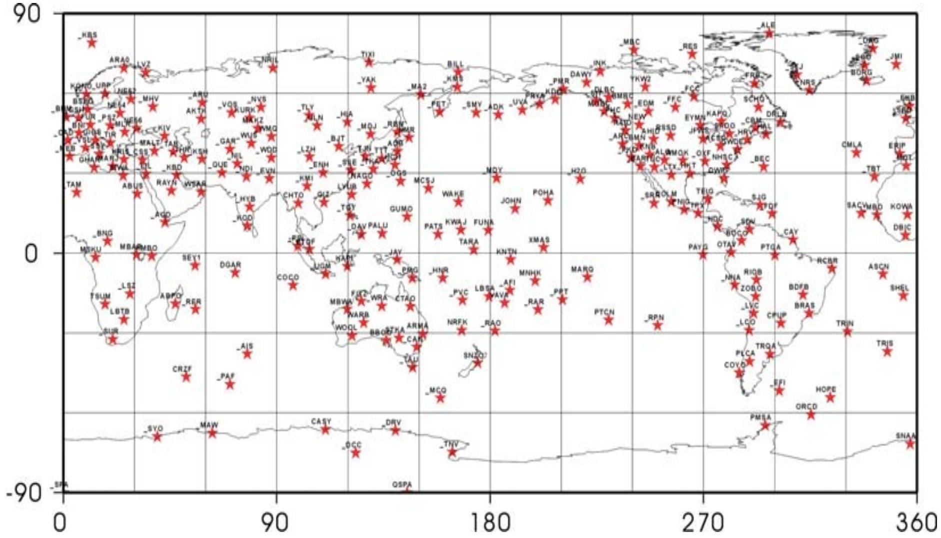
256 stations distribution



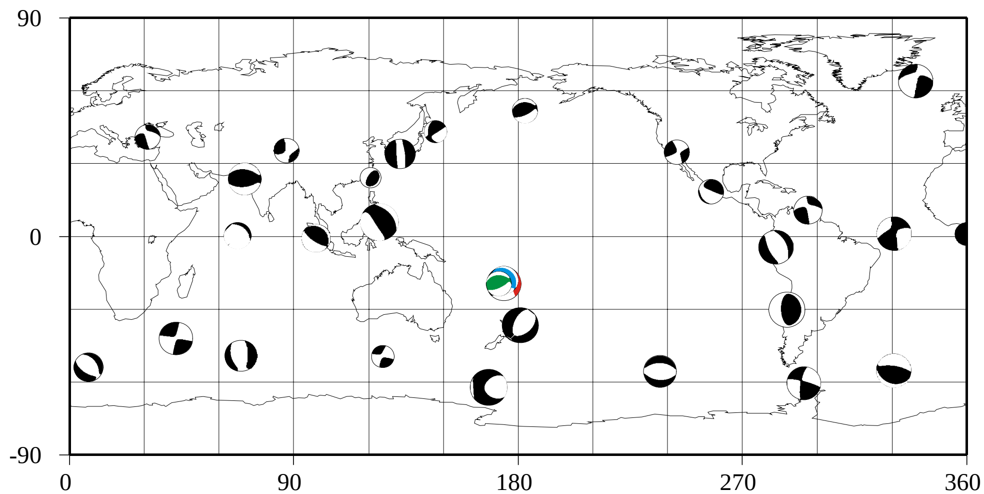
Inversion results using Automated Multi-mode inversion of surface and S waveforms by Sergei Lebedev (Lebedev, et al., 2005).

Preliminary Benchmark

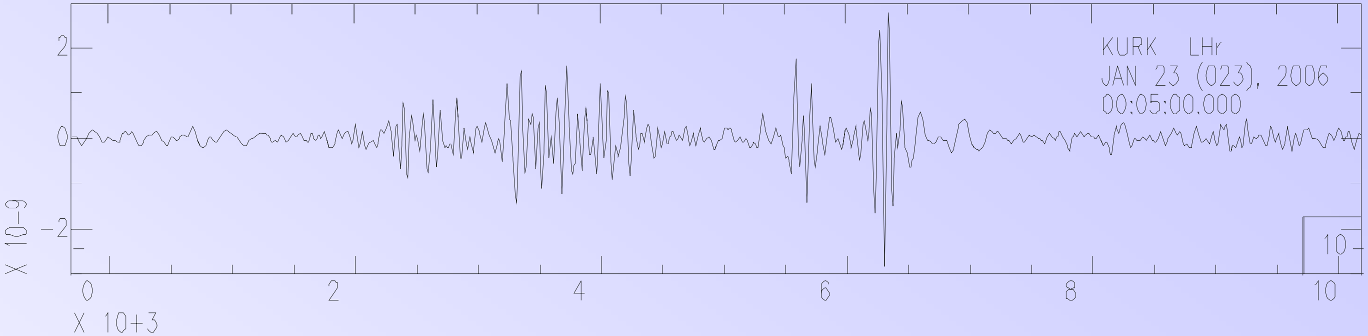
Source and station distribution of second benchmark



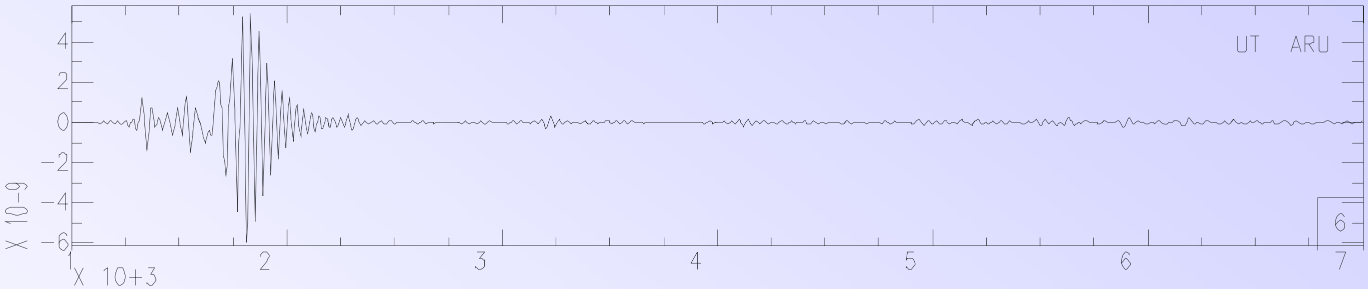
256 stations distribution



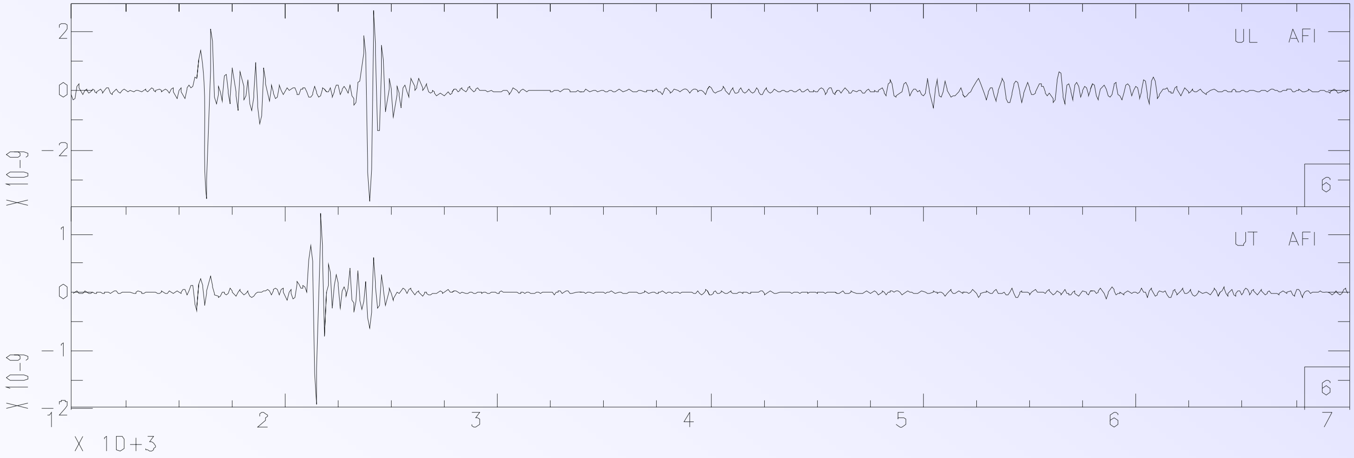
29 Events distribution (magnitude is more homogeneous)



strong scattering



Oscillatory nature of Love wave for continental path



impulsive nature of surface wave for ocean path

Some interesting propagation effect of synthetic dataset

Inversion of Second Benchmark dataset

1. **Automated multimode Inverison (AMI)** ***(****Sergei Lebedev****)***

2. **Phase-velocity measurement + regionalization+depth inversion** ***(already know the input model)***

(1). use Roller-Coaster method to calculate the phase velocity for each source-receiver path (Beucler, et al., 2003)

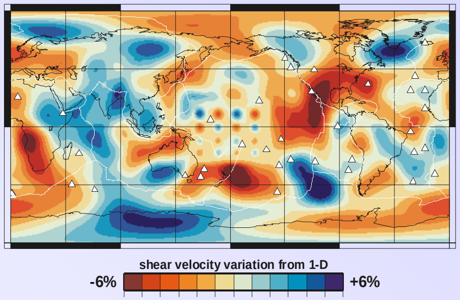
(2). use CLASH method to calculate the anisotropic phase velocity distribution for different period (Beucler and Montagner, 2006)

(3). 1D Depth inversion (11 periods from 45s to 315s)

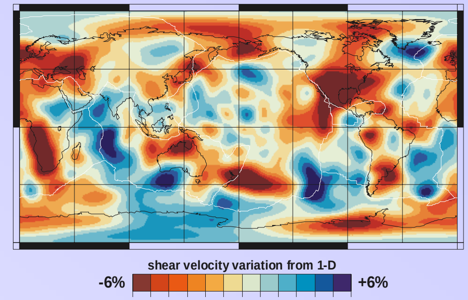
Input models

Output model of AMI by *Sergei Lebedev (only isotropic)*

70km

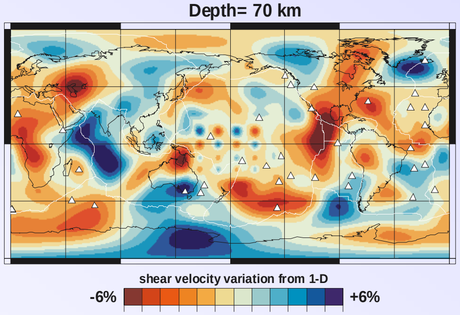


Depth= 70 km

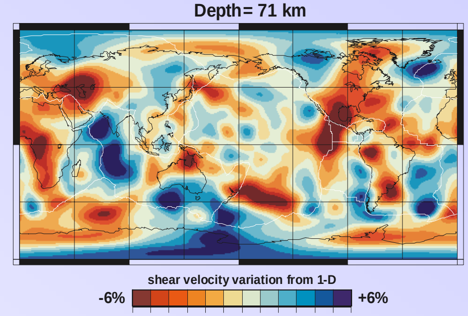


Depth= 71 km

160km

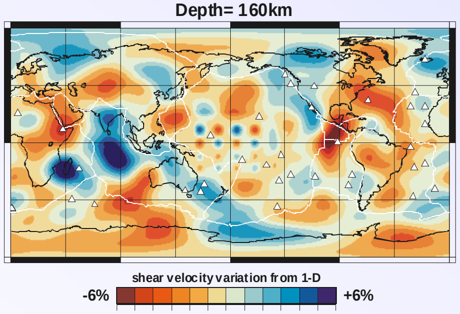


Depth= 160km

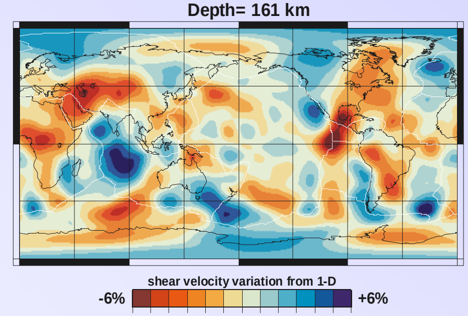


Depth= 161 km

300km

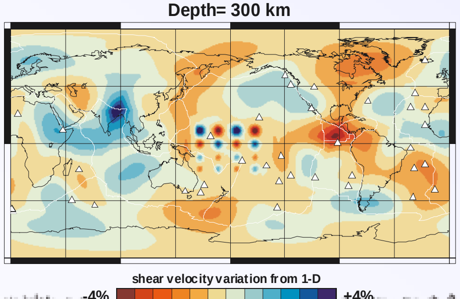


Depth= 300 km

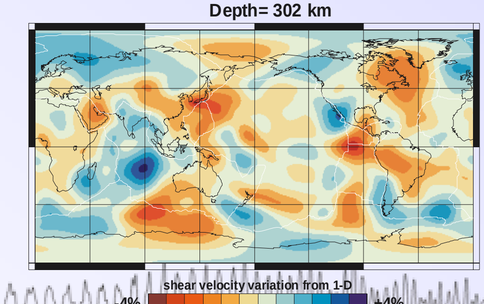


Depth= 302 km

520km



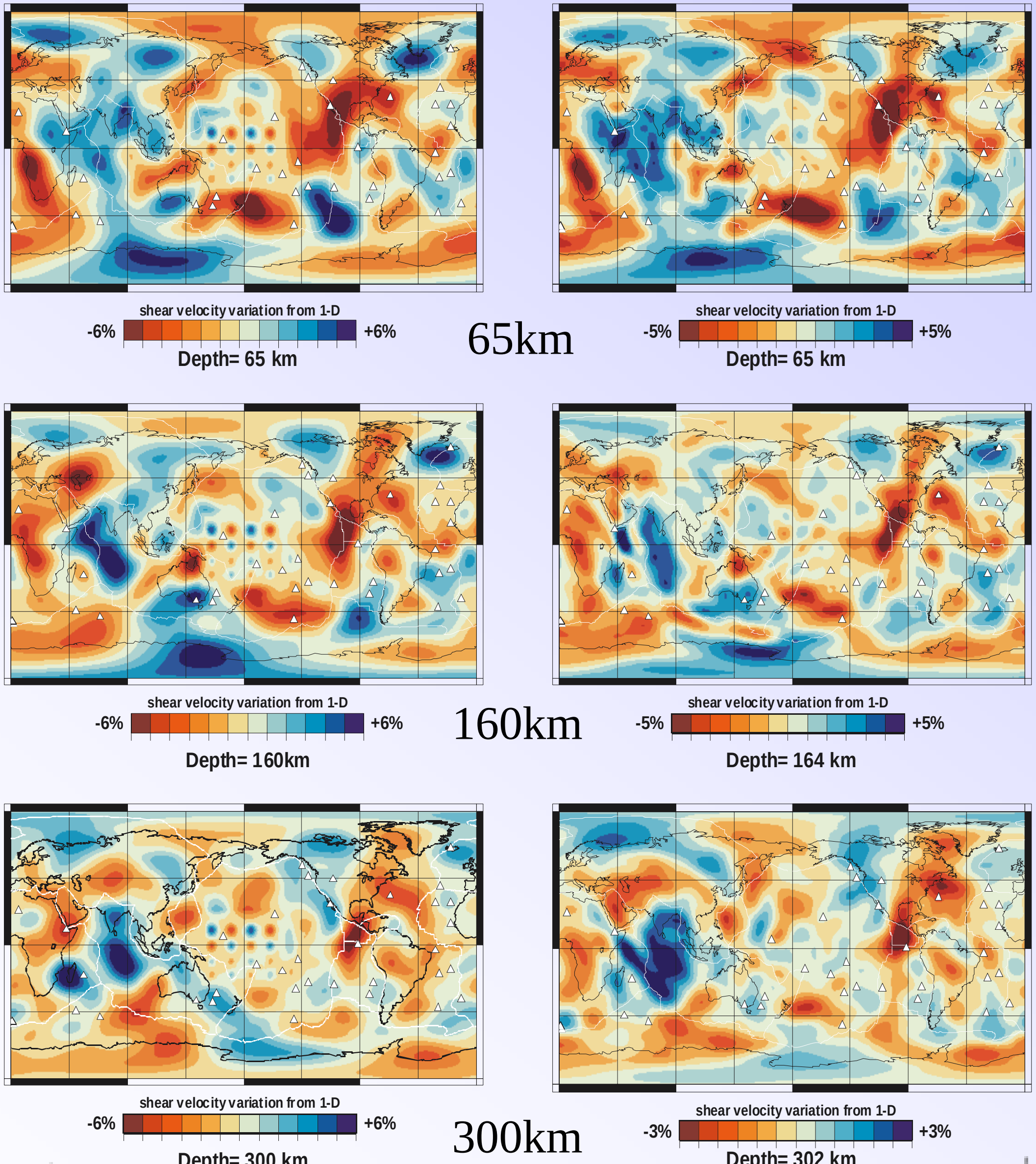
Depth= 520 km

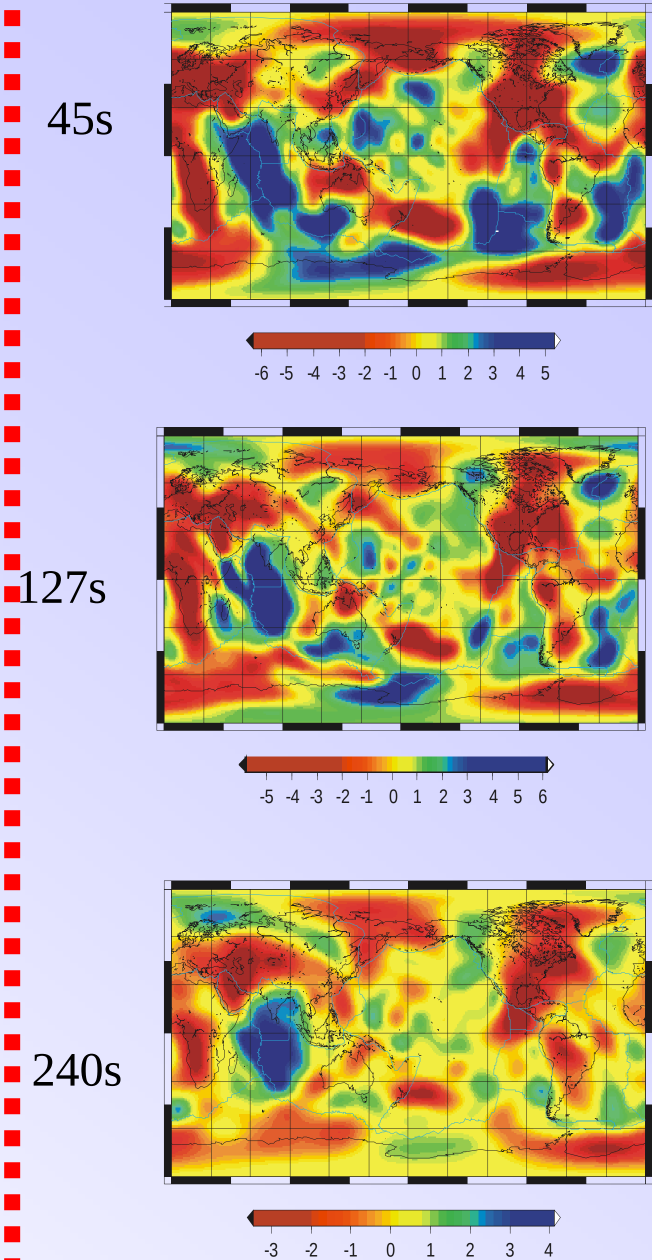


Depth= 520 km

Input model

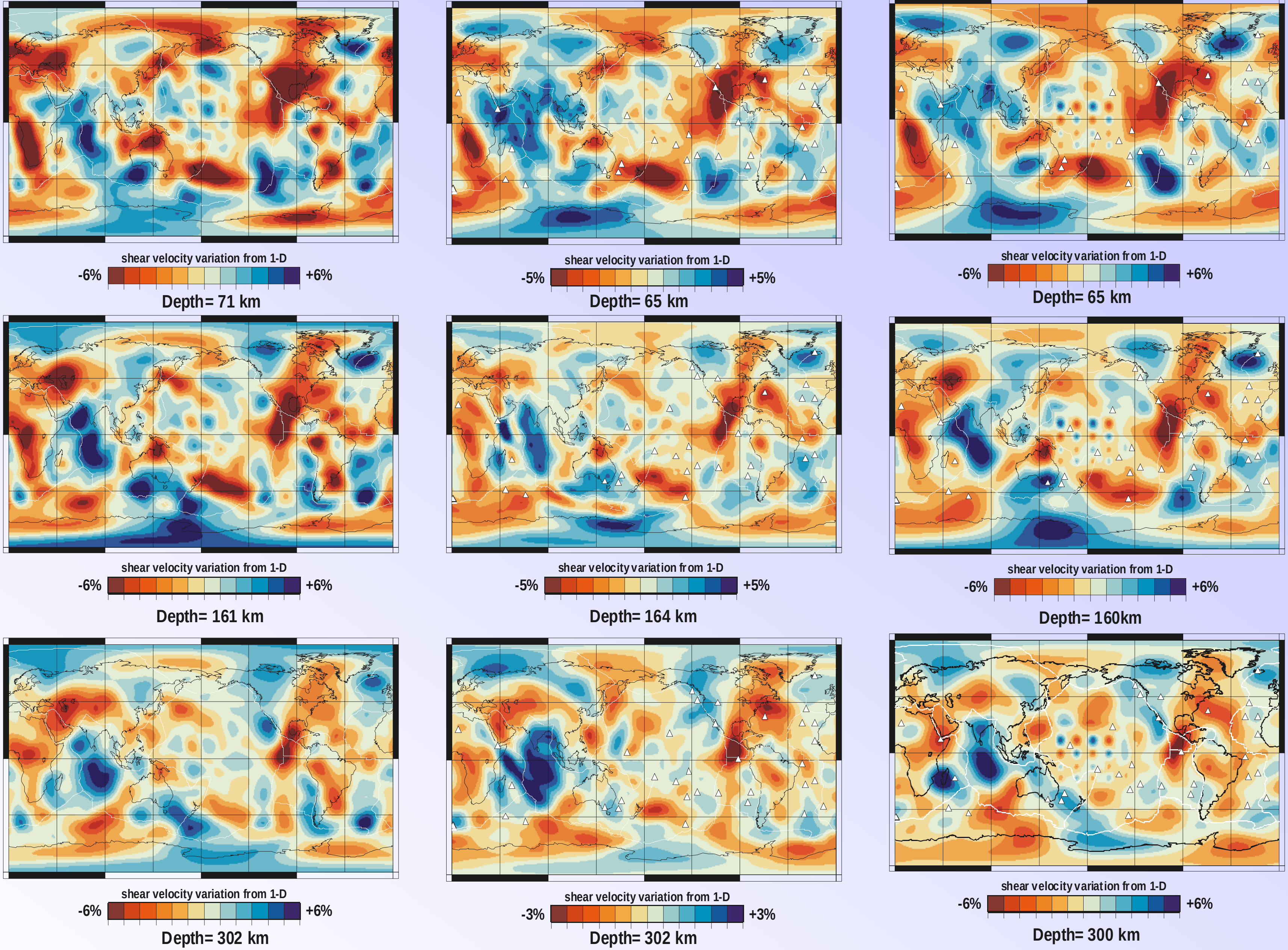
Output model from CLASH





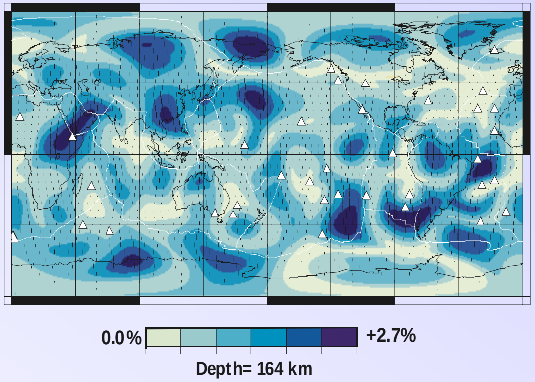
Phase velocity

Comparison inversion results of CLASH and input models

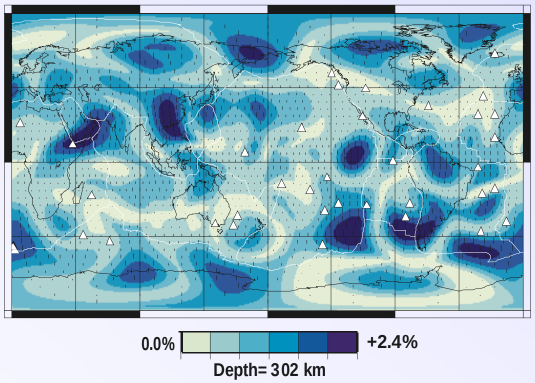


AMI CLASH Input model

Comparison of inversion between AMI and CLASH

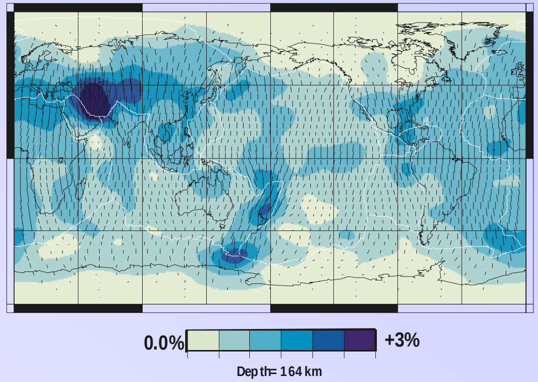


164km

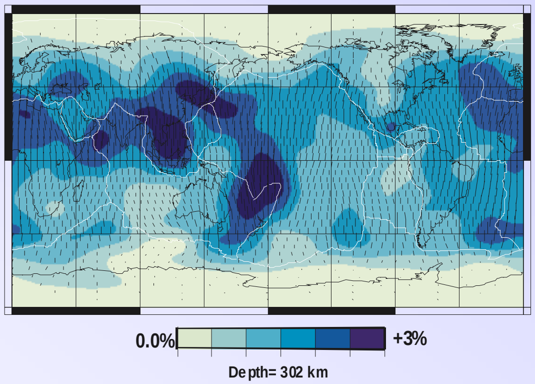


302km

Input model

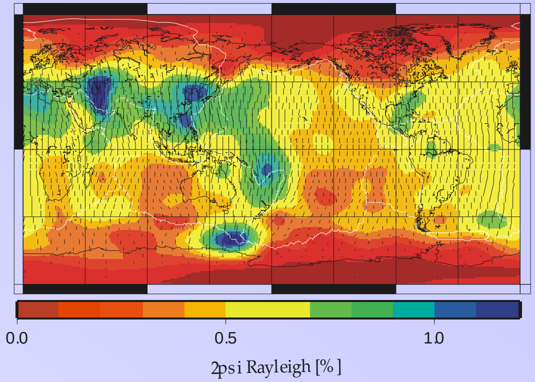


164km

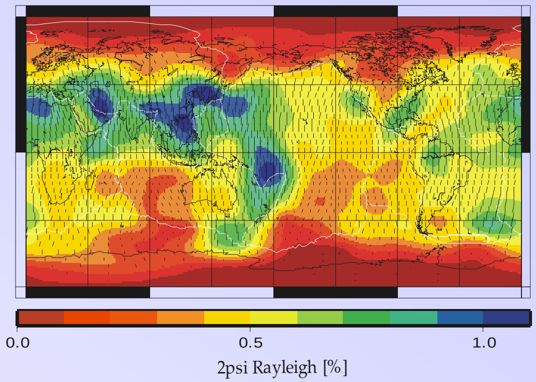


302km

Inversion results



156s



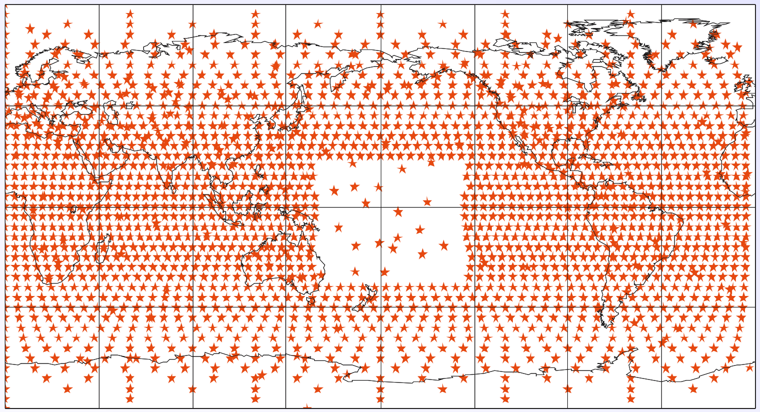
192s

Phase velocity of CLASH

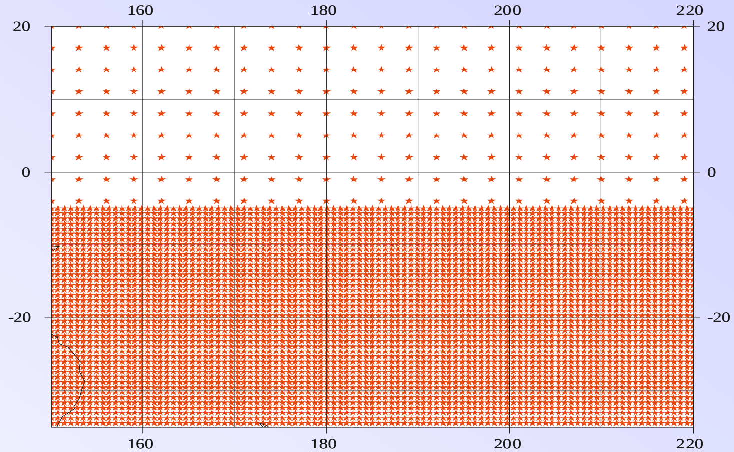
Comparison of Azimuthal anisotropy (only CLASH results)

Third Benchmark (going on)

- use Moho topograhy
- Array surface-wave tomography (spacing 70km)
- Increase global station density
- 2D crustal velocity
- Variation of azimuthal anisotropy
- Minimum period 32s



Global station coverage (spacing 500km)



Station coverage for array

Part II

Test of Global tomographic model

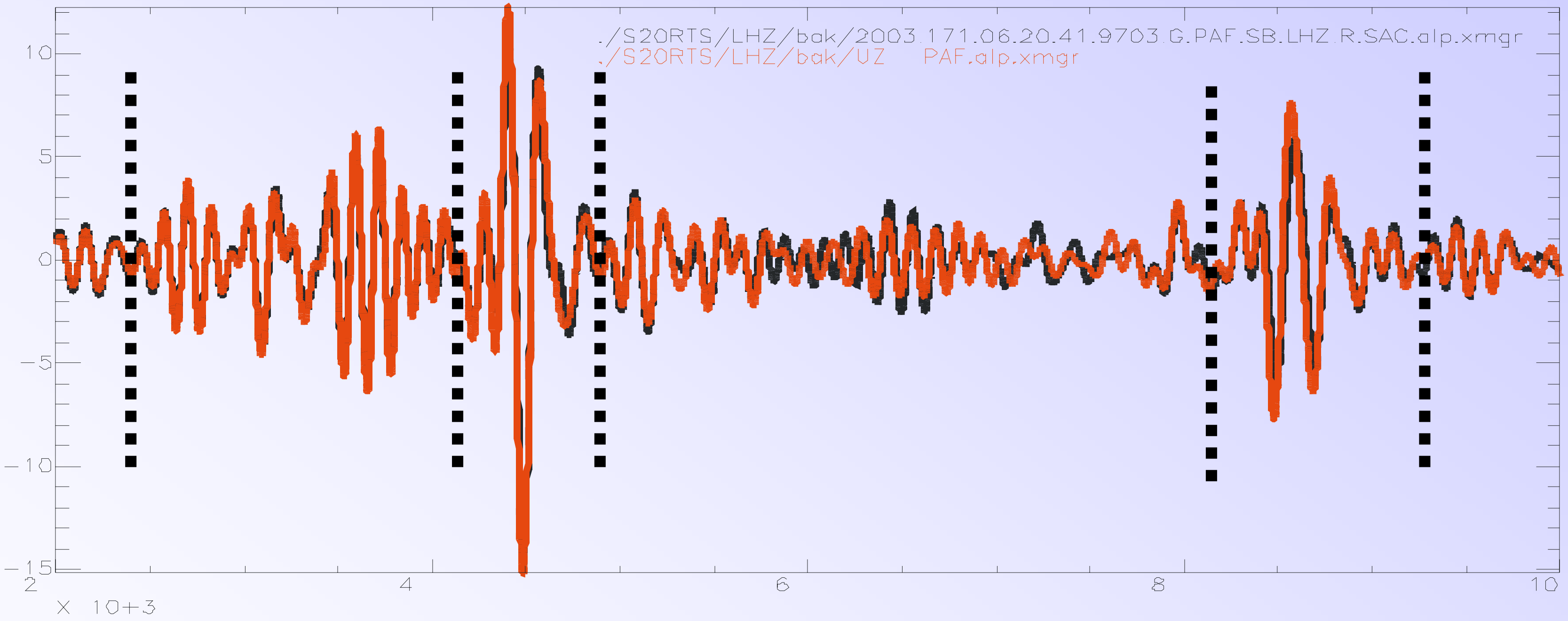
Yilong Qin, Yann Capdeville, Jean-Paul Montangner,
Lapo Boschi and Thorsten Becker

Data are not to be used to create a model, but, instead, to falsify models.

Albert Tarantola (Nature, 2006)

Objectives

- how well different tomographic models can explain the overtones and fundamental modes of surface waves.



Correlation coefficients: x1= 0.9817 R1= 0.9791 X2= 0.7715 R2= 0.9075

Configuration of Test

- Minimum period is 100s
- Use Deep events with magnitude (Mw) is about 7
- The duration of events is less than 20s
- Length of traces is 10500s (Include R2, L2)
- Three components (LHZ, LHR,LHT)
- Currently tested model: S20RTS, SAW24B16, SB4L18, Smean and Princeton-05

Currently tested models

- **S20RTS**: ***derived by inverting Rayleigh wave dispersion , body-wave Travel time, and normal-mode Splitting data***

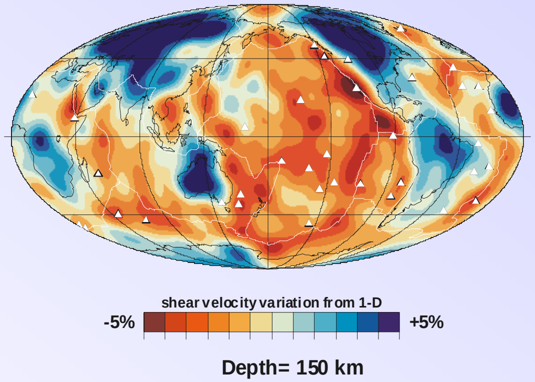
- **SAW24B16: *derived with handpicked transverse component waveforms,***

- **SB4L18: *Scripps "high-resolution" model. Derived from surface wave phase velocity, free oscillation structure coefficients and long-period body wave absolute and differential travel times.***

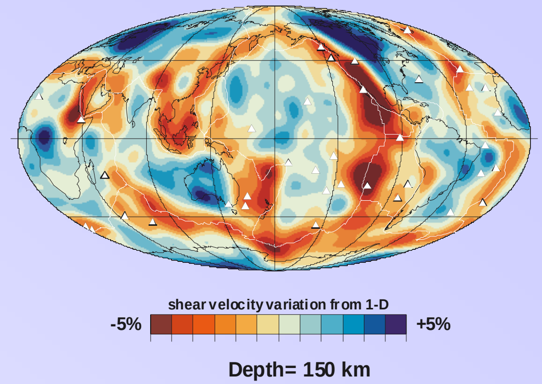
- **Smean: *average of S20RTS, SAW24B16, and SB4L18***

- **Princeton-05: *derived using finite-frequency tomography of body waves***

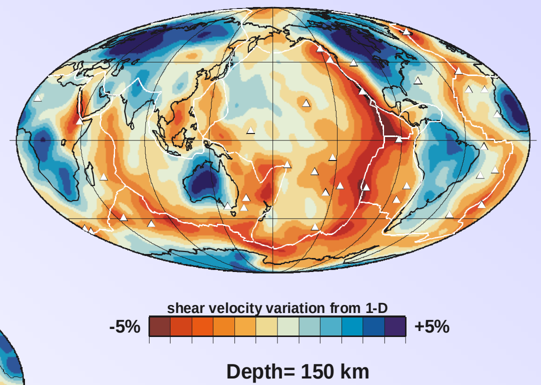
Comparison of different models at depth of 150km



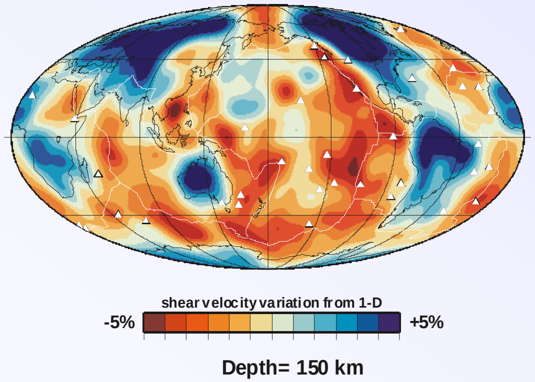
S20RTS



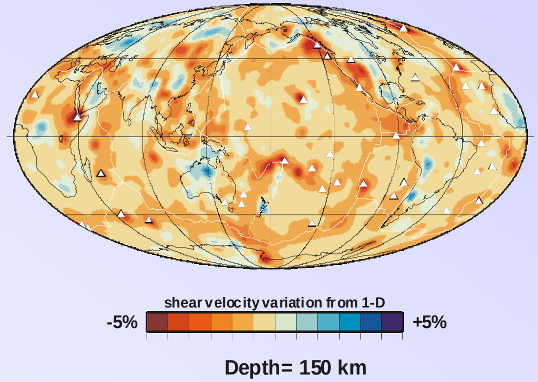
SAW24B16



Smean model



SB4L18

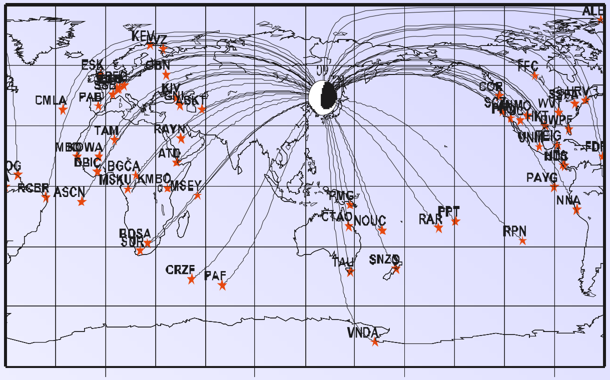


Princeton-05

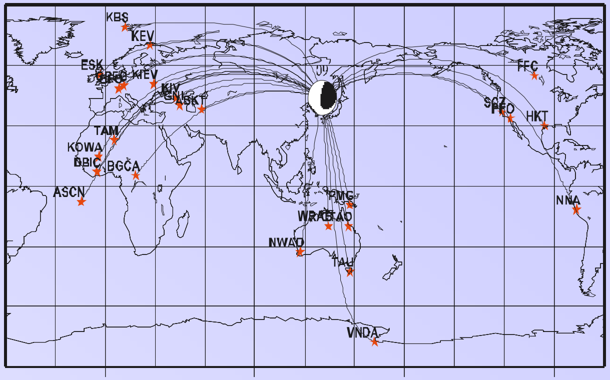
Numerical computation

- Coupling SEM method (Capdeville et al., 2003)
- Average CRUST2.0 for anti-aliasing
- 1D anisotropic PREM model as reference model
- incoporate the Moho topography
- The variation of Vp and density is scaled to perturbations of Vs by factor 0.5 and 0.4

Event I



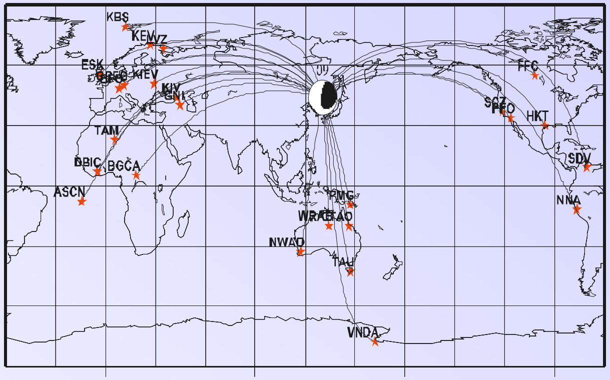
LHZ



LHR

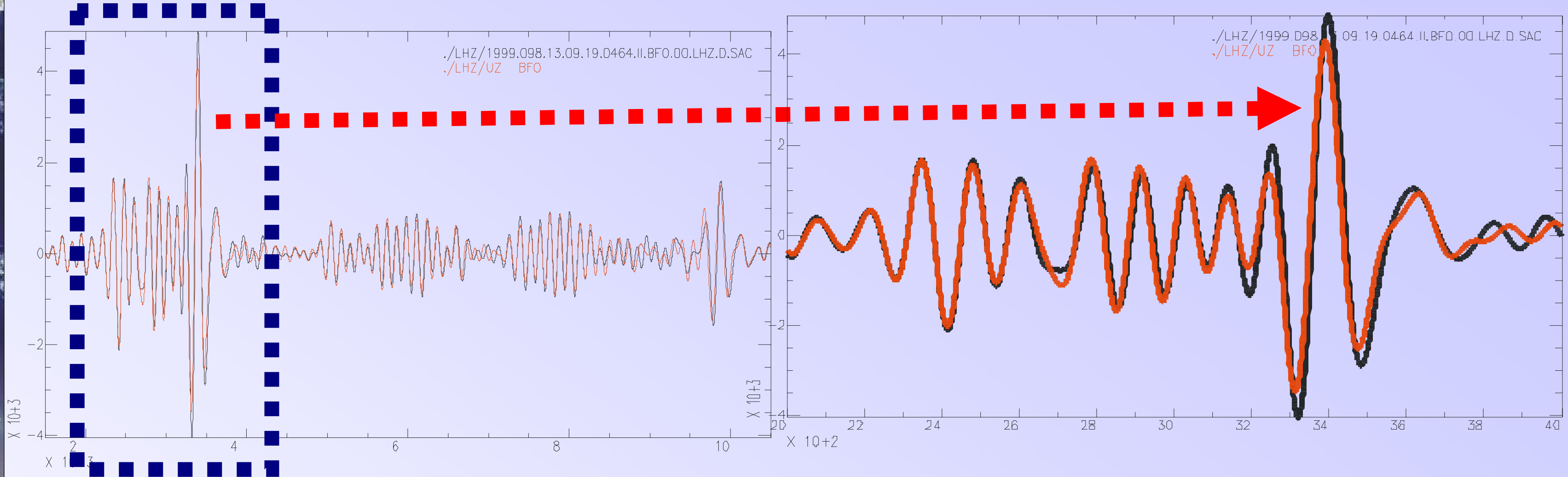
China.Russia Border event

Depth=645km

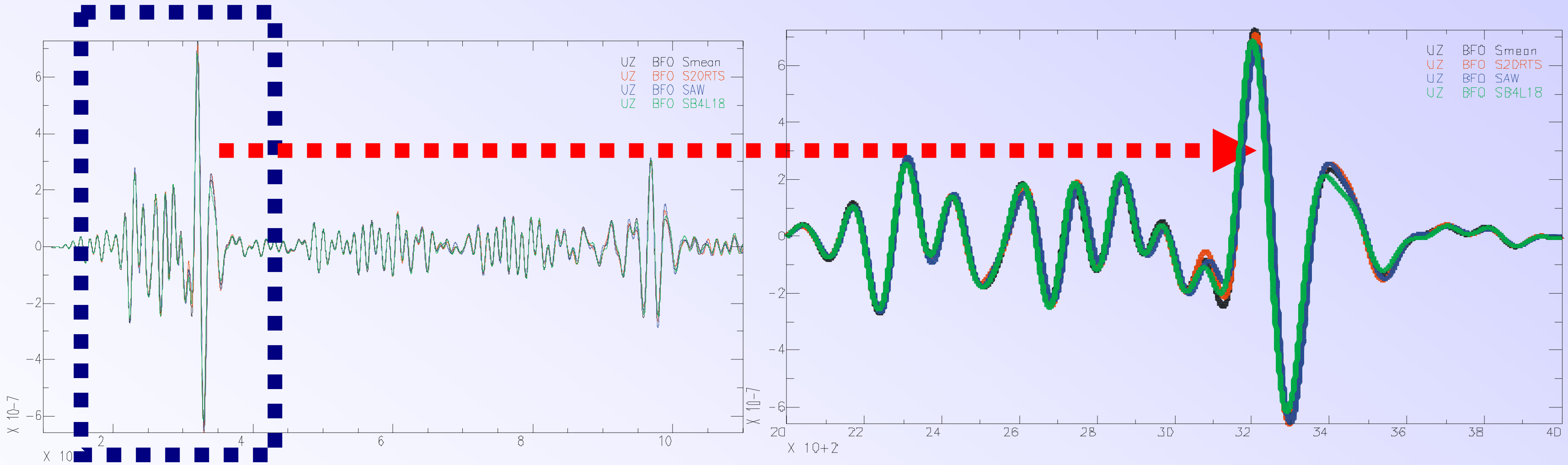


LHT

Path coverage for different component

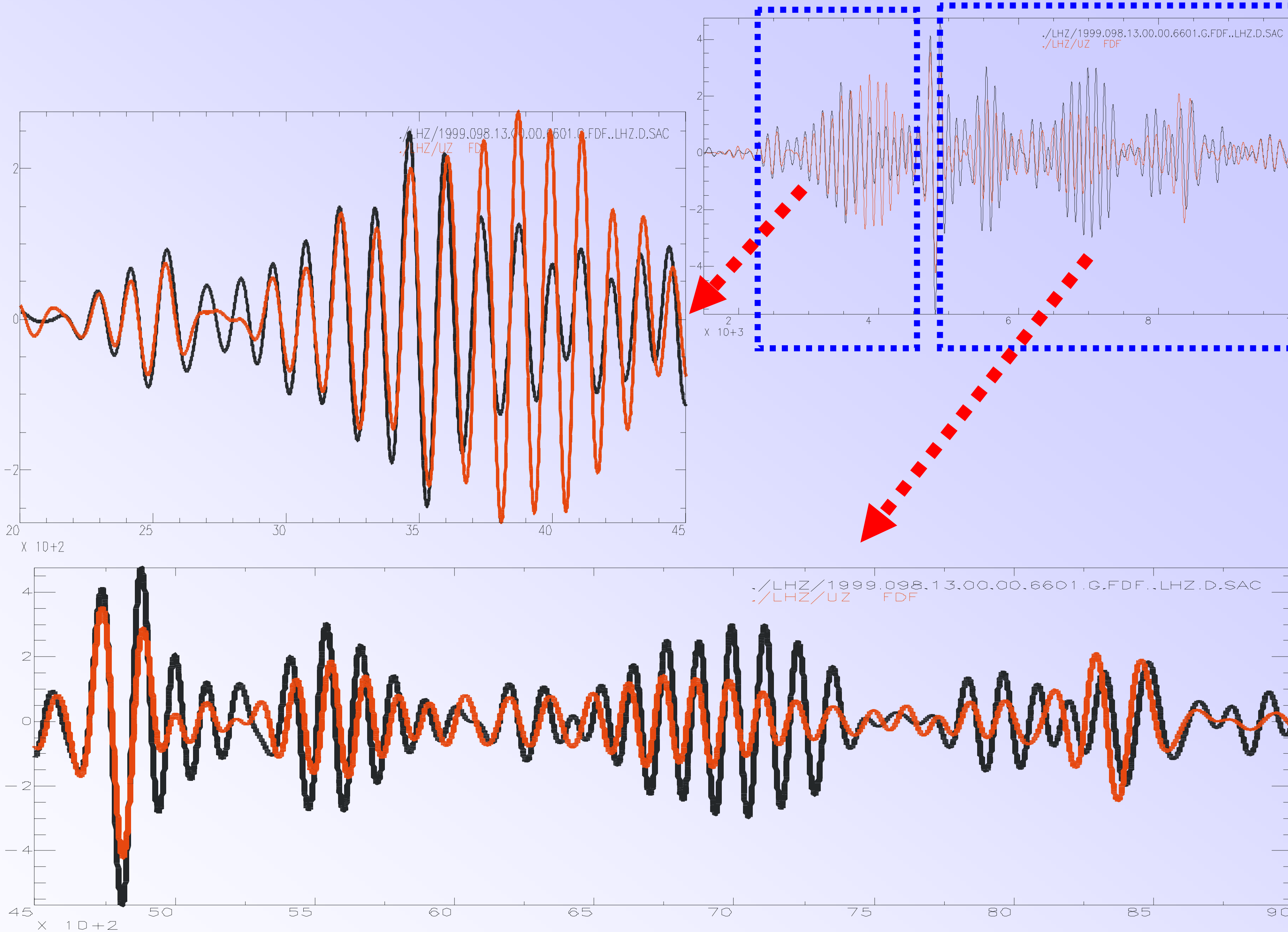


Comparison between observation and synthetics of model Smean



Synthetics comparison for Smean, S20RTS, SAW20RTS and SB4L18

Event: China.Border Station:BFO



One Bad waveform fitting for Smean model (event: China.Border)

	Smean	S20RTS	SAW24B16	SB4L18	Princeton-05	PREM
X1	0.956	0.949	0.910	0.942	0.911	0.825
R1	0.918	0.943	0.927	0.889	0.865	0.770
X2	0.864	0.850	0.833	0.837	0.736	0.705
R2	0.808	0.842	0.820	0.806	0.220	0.530

LHZ : 59 traces

	Smean	S20RTS	SAW24B16	SB4L18	Princeton-05	PREM
G1	0.964	0.964	0.948	0.965	0.939	0.912
L1	0.968	0.956	0.943	0.945	0.872	0.793
G2	0.890	0.888	0.870	0.877	0.756	0.735
L2	0.915	0.799	0.842	0.888	0.5684	0.416

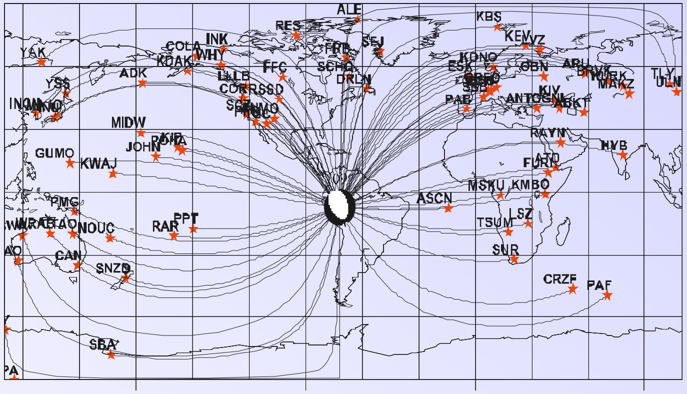
LHT :total 25 traces

	Smean	S20RTS	SAW24B16	SB4L18	Princeton-05	PREM
X1	0.911	0.906	0.899	0.896	0.881	0.832
R1	0.900	0.917	0.914	0.868	0.866	0.788
X2	0.782	0.770	0.759	0.763	0.641	0.551
R2	0.863	0.8716	0.818	0.852	0.185	0.402

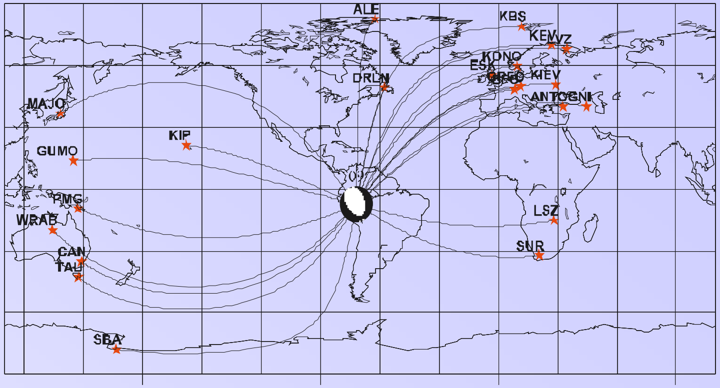
LHR: total 25 traces

Average Correlation coefficients for Event China.Border

Event II



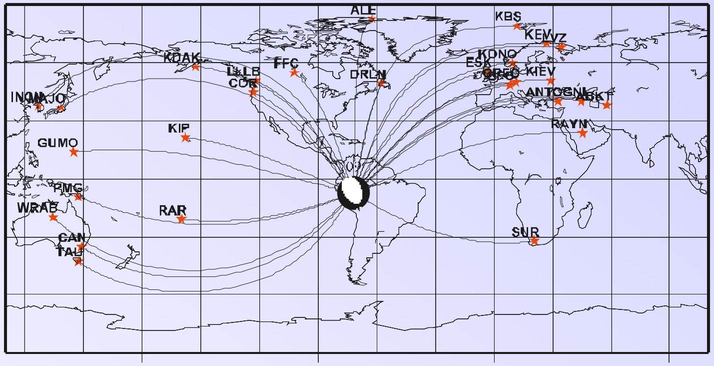
LHZ (76 traces)



LHT (20 traces)

Event: Brazil, 2003

Depth: 556km



LHR (25 traces)

	Smean	S20RTS	SAW24B16	SB4L18	PREM
X1	0.948	0.942	0.935	0.937	0.8334
R1	0.919	0.950	0.934	0.868	0.7430
X2	0.848	0.836	0.783	0.820	0.646
R2	0.797	0.874	0.810	0.784	0.581

76 traces

	Smean	S20RTS	SAW24B16	SB4L18	PREM
X1	0.95	0.953	0.958	0.956	0.9123
R1	0.892	0.928	0.902	0.845	0.7800
X2	0.852	0.859	0.842	0.838	0.6881
R2	0.821	0.861	0.870	0.801	0.5883

25 traces

	Smean	S20RTS	SAW24B16	SB4L18	PREM
X1	0.877	0.872	0.881	0.884	0.828
R1	0.955	0.939	0.917	0.932	0.802
X2	0.762	0.756	0.712	0.725	0.651
R2	0.890	0.893	0.774	0.854	0.454

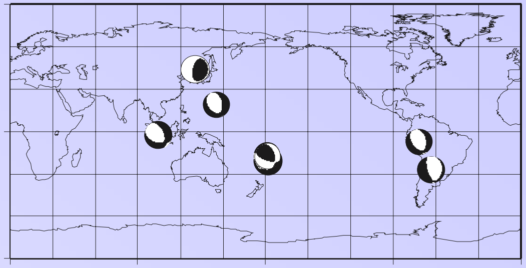
20 traces

Average correlation coefficients

Perspective

1. Try more deep earthquakes

- Magnitude Mw between 7.1 and 7.5
- Source depth >500km
- Duration <20s



Distribution of deep earthqukes
(from Harvard CMT)

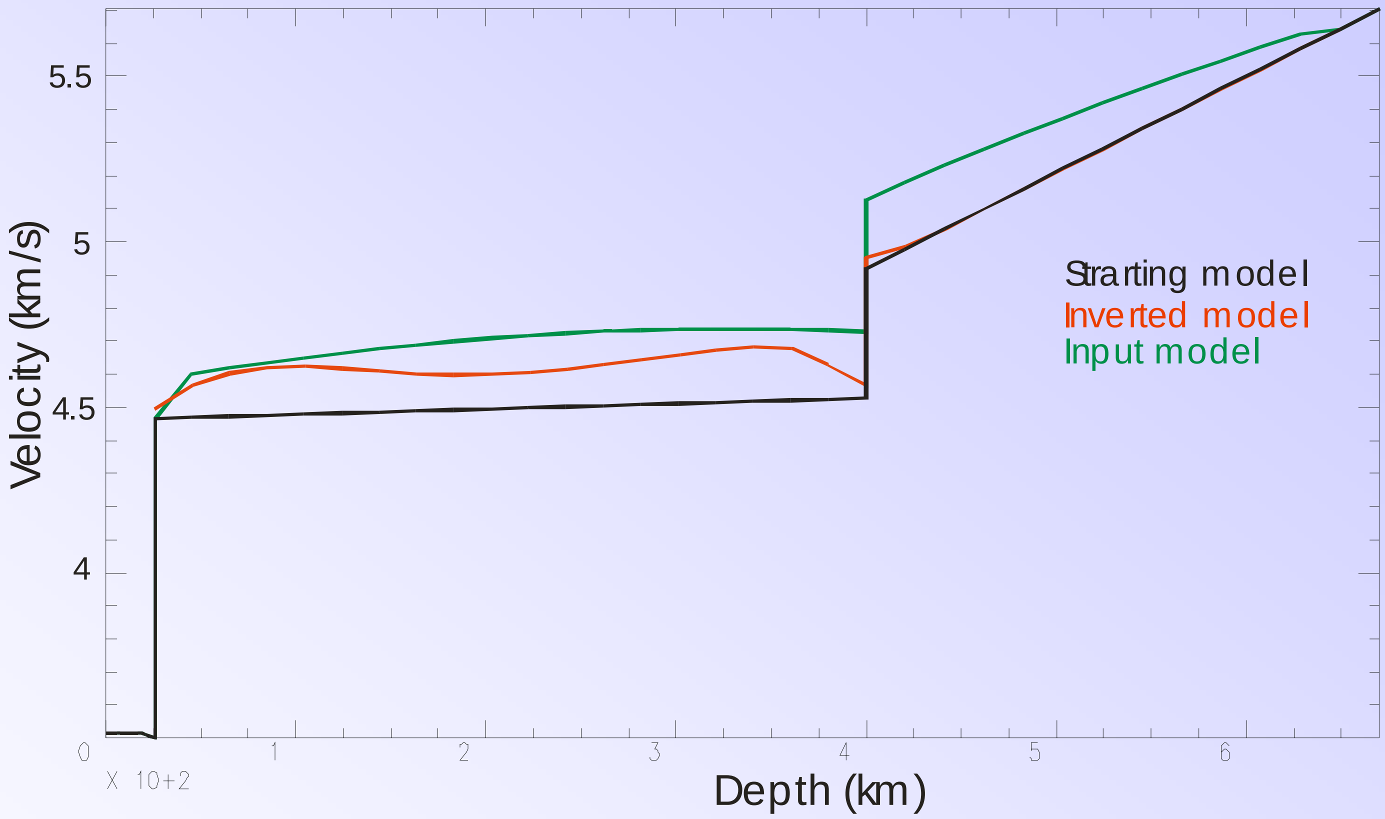
2. Try more models

- geodynamic models
- Recent new models

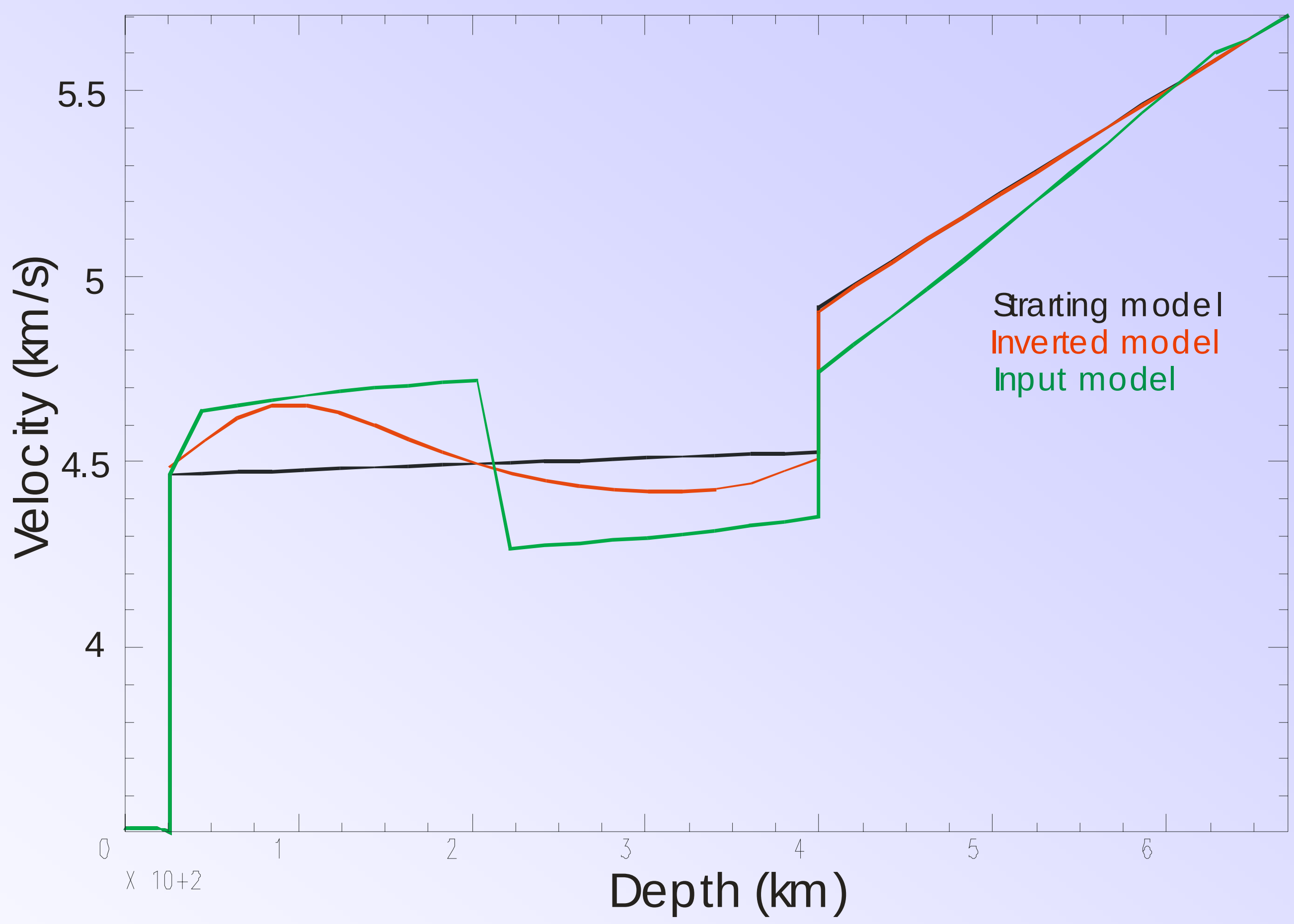
Preliminary Conclusions

- Correlation coefficients of X1 (G1) and R1 (L1) are higher than X2 (G2) and R2 (L2)
- for **Smean, S20RTS, SAW24B16, SB4L18**, the correlation coefficients have no obvious difference
- 3D models have better waveform fitting than anisotropic **PREM**

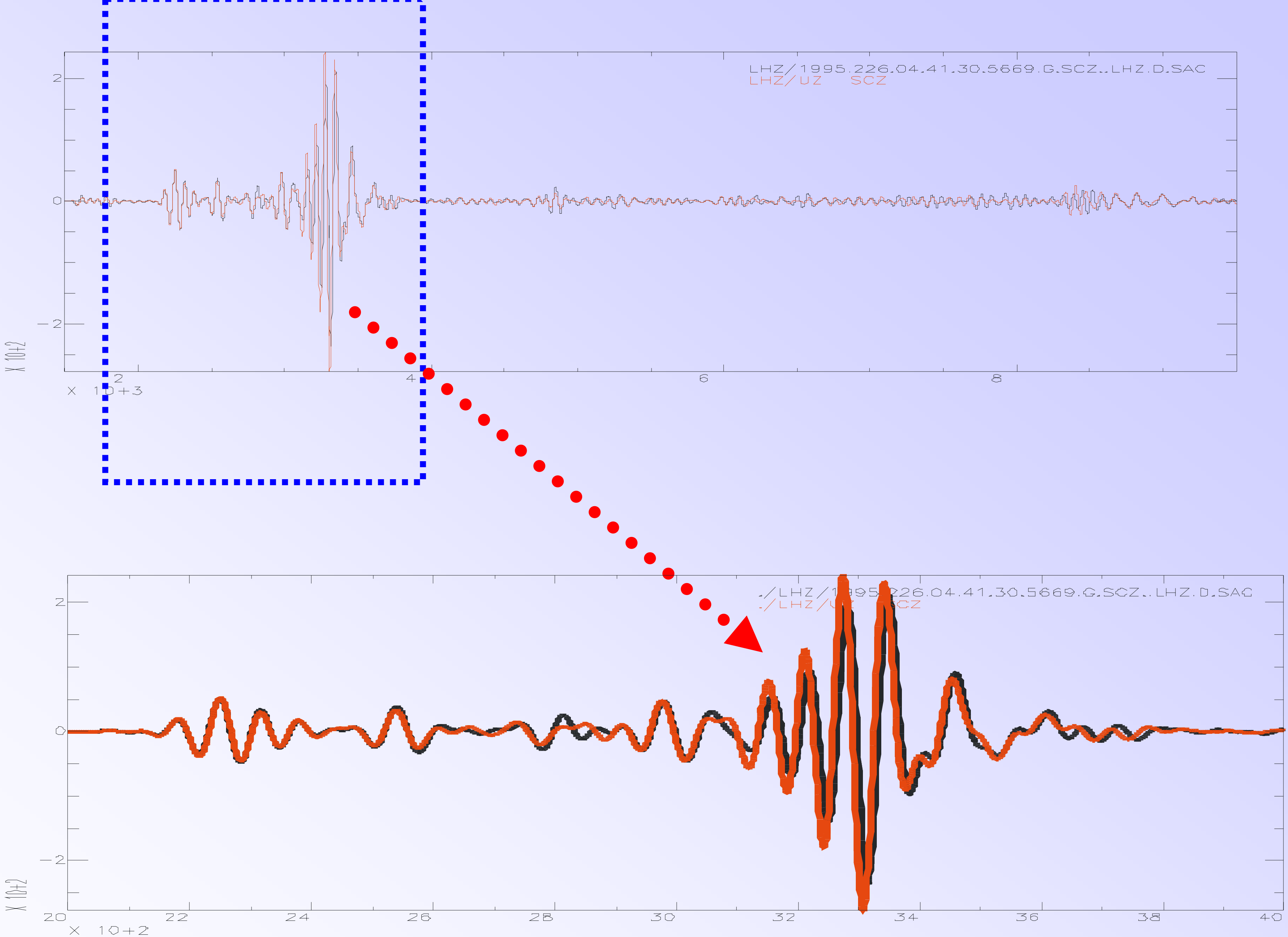
Thanks for your attentions



Depth Inversion using 11 periods: 45s, 55s, 68s, 84s, 103s, 127s, 156s, 192s, 220s, 240s, 273s.



Depth Inversion using 11 periods: 45s, 55s, 68s, 84s, 103s, 127s, 156s, 192s, 220s, 240s, 273s.



Waveform comparison for New.Britain minimum period=50s