RAYLEIGH WAVE TOMOGRAPHY BENEATH EASTERN ASIA.
THE QUEST FOR RESOLUTION

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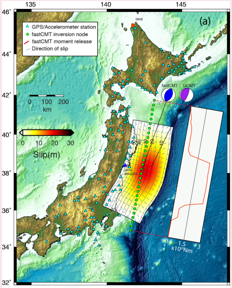
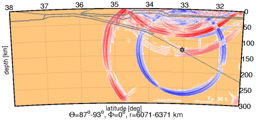
Seismological seminar, NCU, Zhongli, 2016/05/06

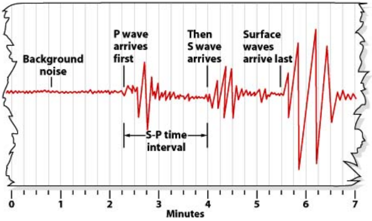
Source



Propagation



Data



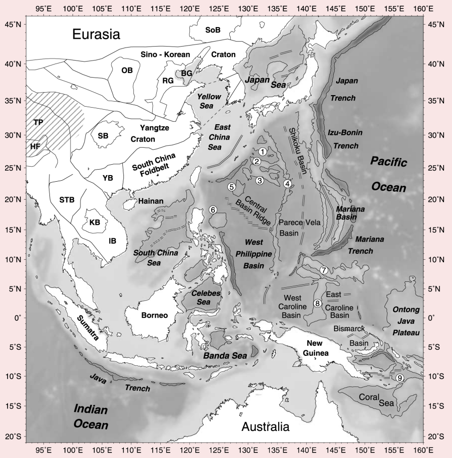
Problem

Like trying to solve:

$$A + B = 2 \quad (1)$$

Motivation

What kind of resolution can we achieve?

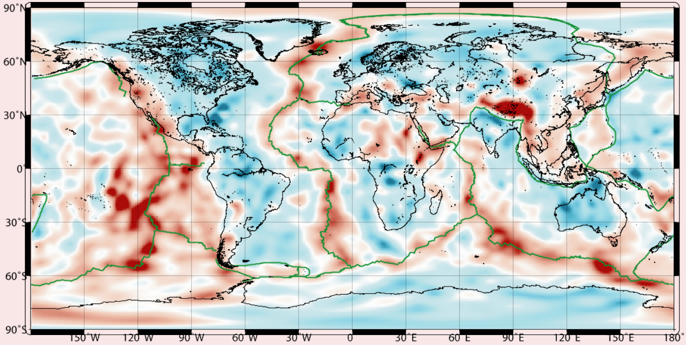


East Asia

- Cratons
- Subductions
- Plates/microplates
- Passive margins

Global models

Large scale models

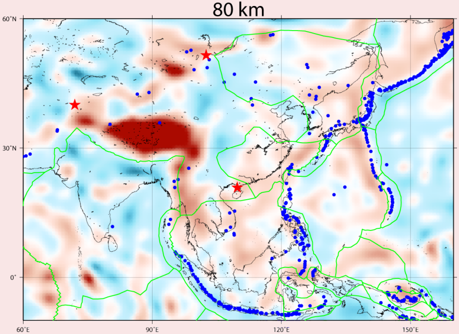


Resolution

- Large scale anomalies.
- Even resolution.
- Deep investigations.

Global models

Regional scale models



Resolution

- Large and intermediate scale anomalies.
- Even resolution.
- Deep investigations.

Problem

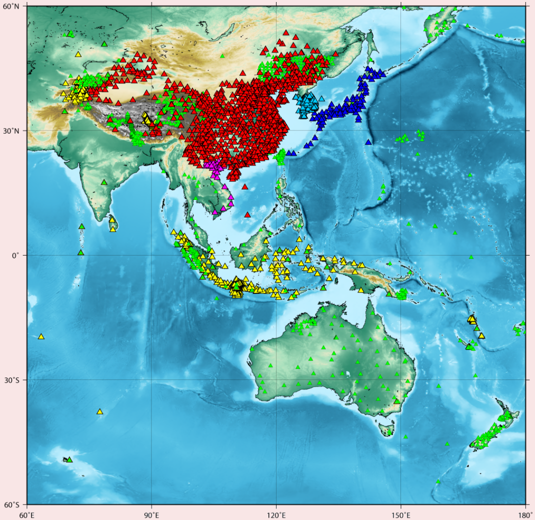
Legendre, C. P., Zhao, L., & Chen, Q. F. (2015)b.

Upper-mantle shear-wave structure under East and Southeast Asia from Automated Multimode Inversion of waveforms,

Geophysical Journal International.

Volume 203, Issue (1), pages 707–719, October 2015

Seismic stations in Eastern Asia



- Very dense networks
- Permanent + temporary
- Continent well covered

Local investigations

Local tomography?

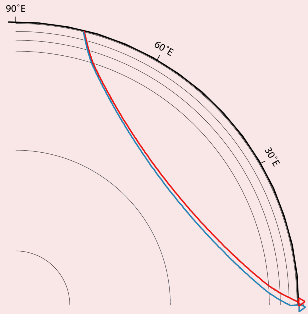
- Local earthquakes – uneven.
- Station distribution – uneven.
- Lack of deep information.
- Isotropic inversions.

Rayleigh-wave dispersion curves

We will focus on two regions:

- Eastern Tibet.
- Japan Sea.

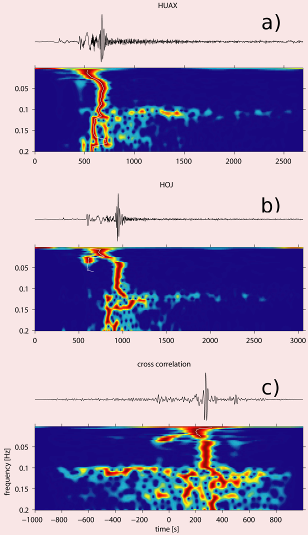
Path



Theory

- Inter-station distance < epicentral distance.
- Path similarity.
- Differences in waveform = structure between the stations.

Cross-correlation



Theory

The cross-correlation is then transferred into the frequency domain, and its complex phase $\zeta(\omega)$ is used to calculate the phase-velocity C(ω) following:

$$C(\omega) = \frac{\omega(\Delta_1 - \Delta_2)}{\zeta(\omega)}, \tag{2}$$

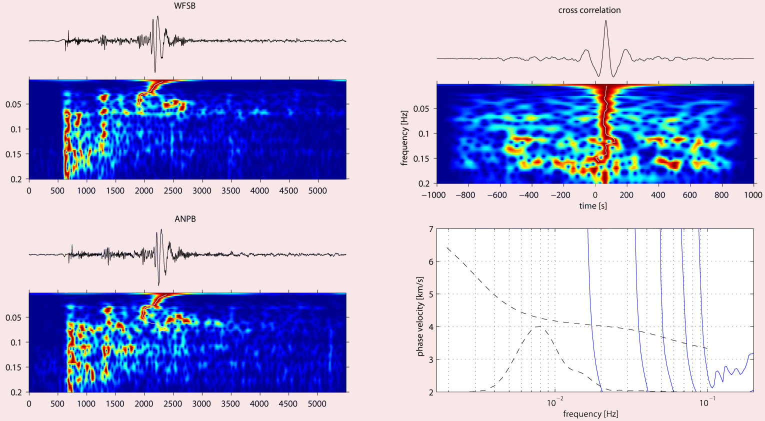
with

$$\zeta(\omega) = \arctan\left\{\frac{Im[\Phi(\omega)]}{Re[\Phi(\omega)]}\right\} + 2n\pi, \tag{3}$$

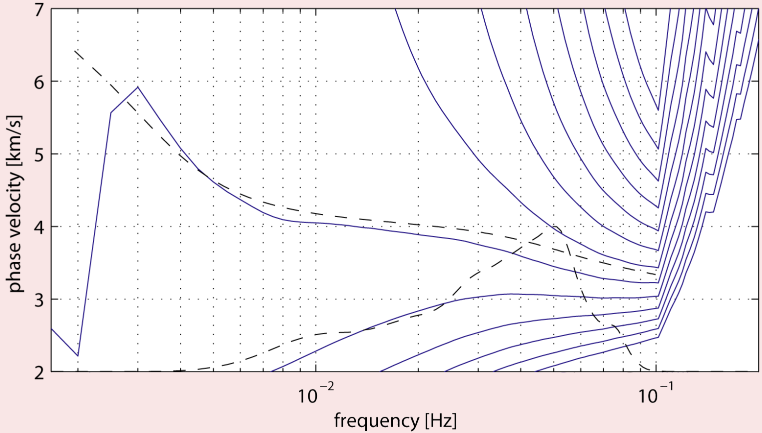
$\Phi(\omega)$ is the transformed cross-correlation between the surface waves recorded at the two stations with epicentral distances Δ_1 and Δ_2.

Dispersion curve

Bad curve

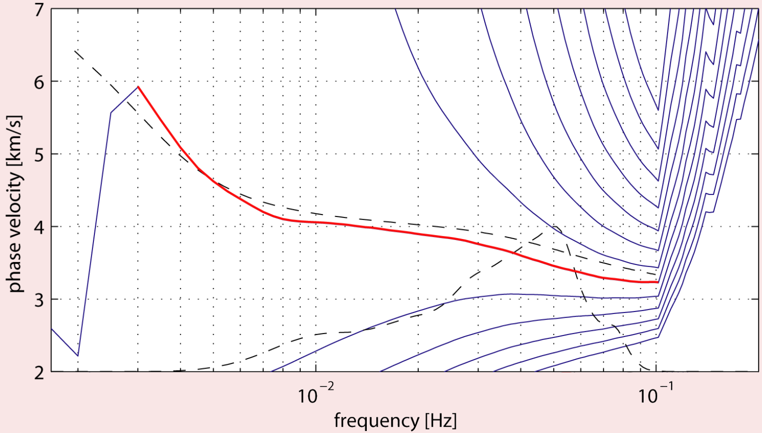


Selection

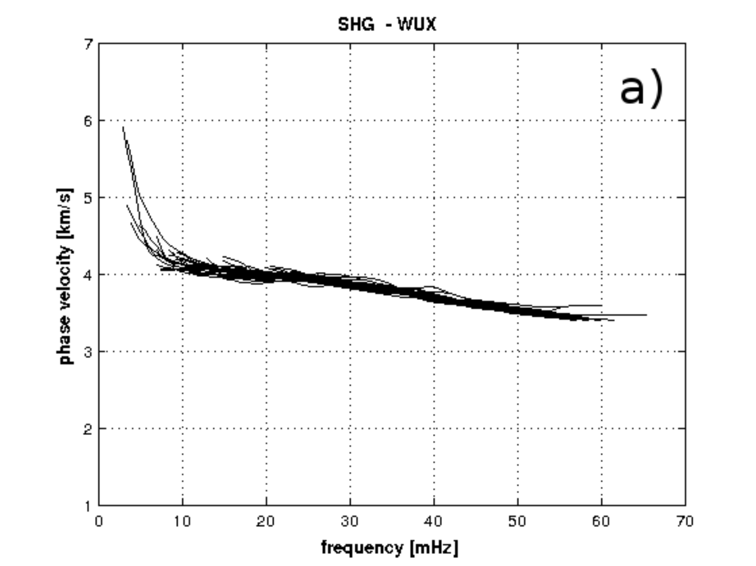


Dispersion curve

Selected

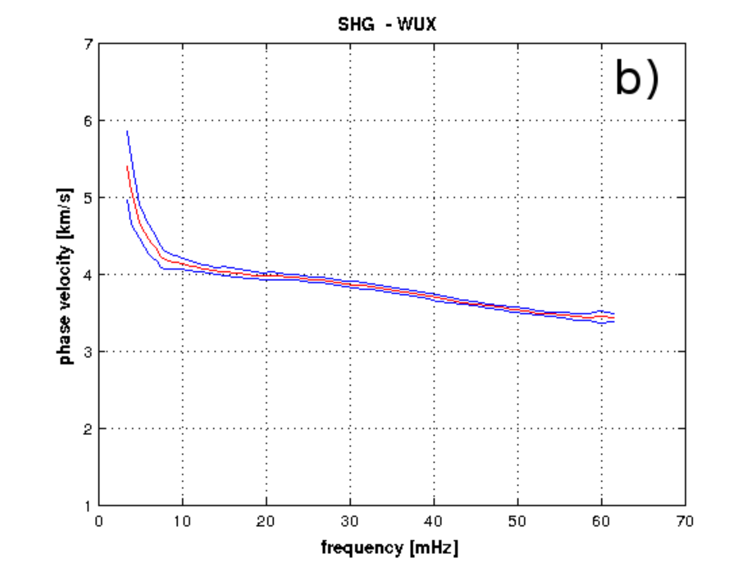


Summation


SHG - WUX
a)
phase velocity [km/s]
frequency [mHz]
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70

Individual measurements

Averaging



Inversion for both isotropic and anisotropic (2ψ and 4ψ)

At each point of the model, the total velocity anomaly can be parameterized with 5 coefficients: one coefficient δC_{iso} for the isotropic phase-velocity variation, 2 coefficients $A_{2\psi}$ and $B_{2\psi}$ for the 2ψ-anomaly, and 2 coefficients $A_{4\psi}$ and $B_{4\psi}$ for the 4ψ-anomaly:

$$\delta C = \delta C_{iso} + A_{2\psi} * cos(2\psi) + B_{2\psi} * sin(2\psi) + A_{4\psi} * cos(4\psi) + B_{4\psi} * sin(4\psi). \quad (4)$$

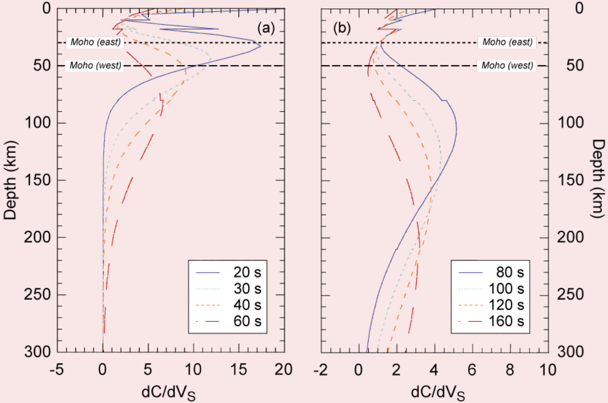
The amplitudes of azimuthal velocity variation (Λ) and the directions of fast propagation (Θ) of the 2ψ- and 4ψ-anisotropy are then given by:

$$\begin{cases} \Lambda_{2\psi} = \sqrt{A_{2\psi}^2 + B_{2\psi}^2} \\ \Theta_{2\psi} = \frac{1}{2}\, arctan(\frac{B_{2\psi}}{A_{2\psi}}) \end{cases} \quad and \quad \begin{cases} \Lambda_{4\psi} = \sqrt{A_{4\psi}^2 + B_{4\psi}^2} \\ \Theta_{4\psi} = \frac{1}{4}\, arctan(\frac{B_{4\psi}}{A_{4\psi}}) \end{cases} . \quad (5)$$

Each dispersion curve yields the average phase velocity along the path linking the two stations as a function of period, and the total average velocity anomaly along this path may be written as the integral of local anomalies at each grid knot sampled by the given path,

$$\delta \bar{C}_i = \int_{\varphi} \int_{\theta} K_i(\varphi, \theta)\, \delta C(\varphi, \theta)\, d\theta\, d\varphi\ , \quad (6)$$

Sensitivity



- Frequency dependancy.
- Here we focus on frequency, but can be linked to depth.

Applications

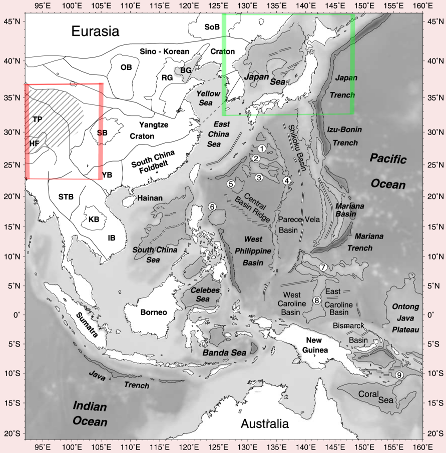
Why?

- Many information from isotropic model.
- More can be obtained from anisotropy.
- Local scale.

Special focus on two regions

- Eastern Tibet.
- East See.

Eastern Tibet and Sea of Japan



Differences

- One well studied region (Tibet).
- Stations evenly distributed.

- One "wild" (Sea of Japan).
- All the stations at the periphery.

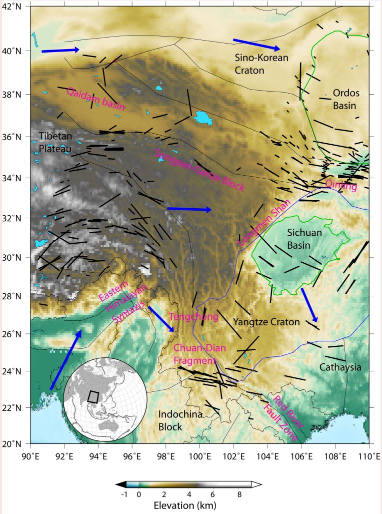
Eastern Tibet

1st region

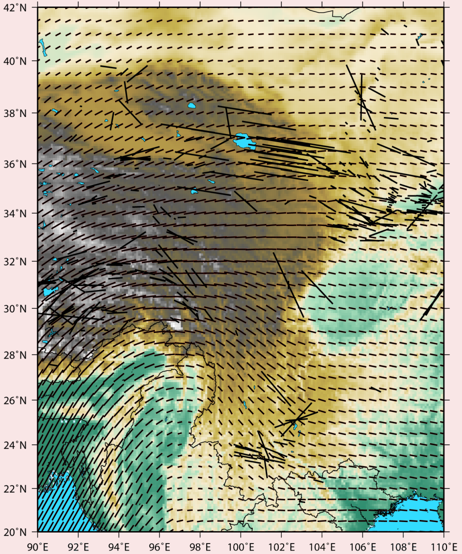
Legendre, C. P., Deschamps, F., & Zhao, L., & Chen, Q. F. (2015)c.
Rayleigh-wave dispersion reveals crust-mantle decoupling beneath eastern Tibet.
Scientific Reports
Vol. 5, p. 16644(1–5).

Tectonic setting

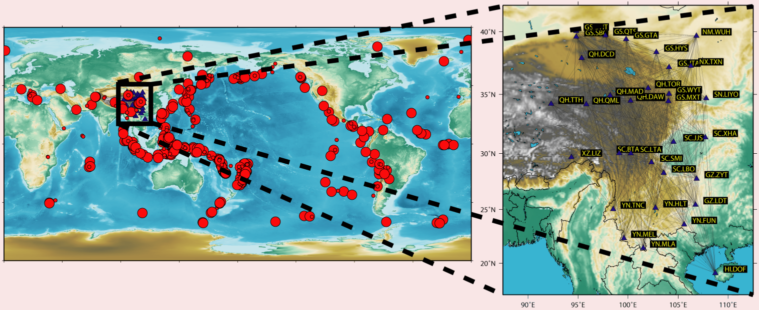
Geological units



APM + SKS



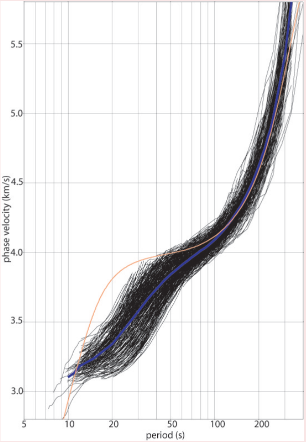
Seismic stations in Eastern Tibet and seimic events



- 32 seismic stations.
- 467 global earthquakes.

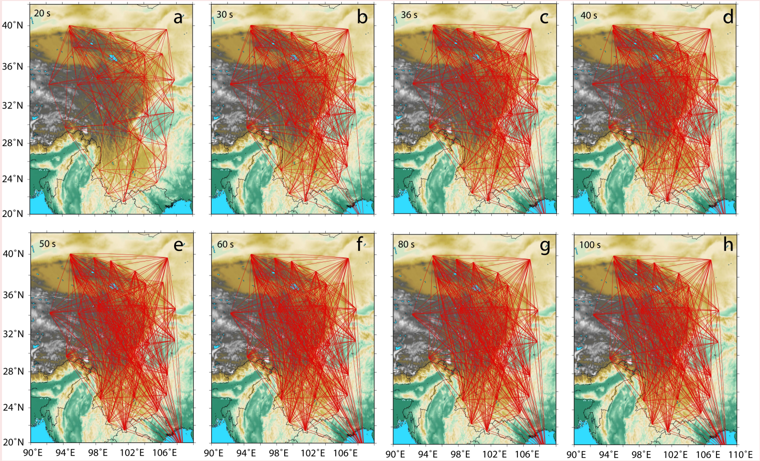
Dispersion curves

All individual measurements



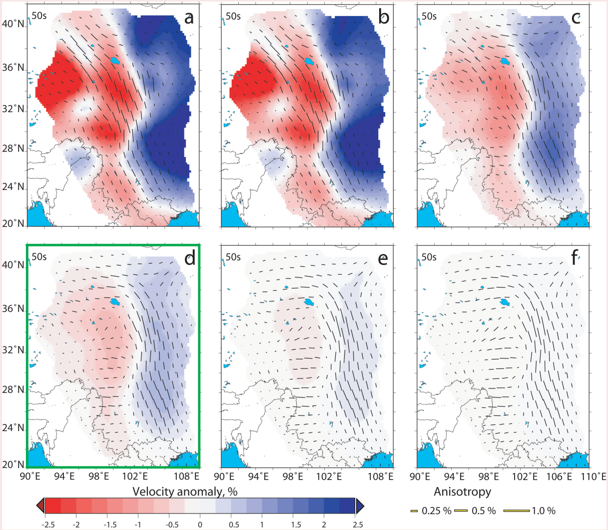
- 531 individual curves.
- Sample the whole region.
- Even distribution.

For various periods

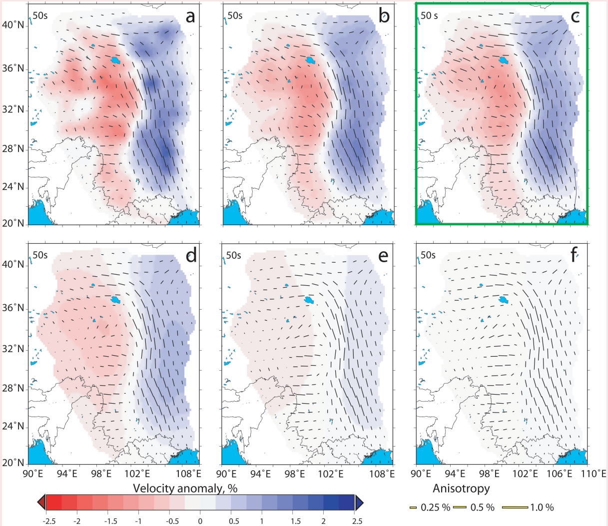


Parameters

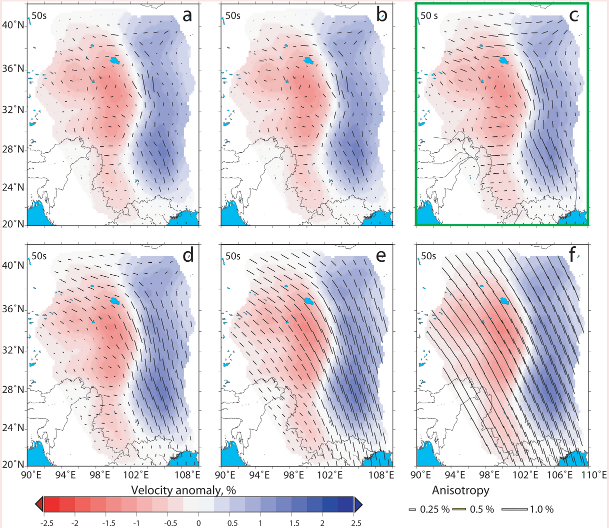
Isotropic damping



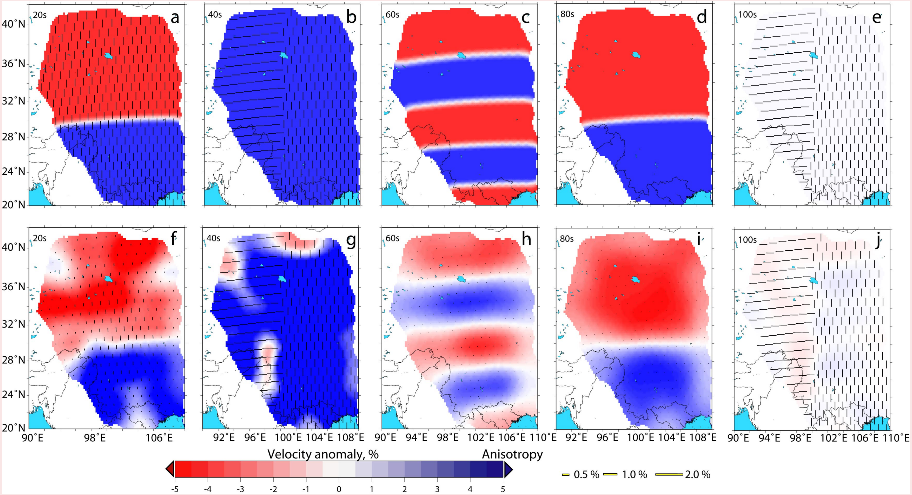
Isotropic smoothing



Anisotropic smoothing

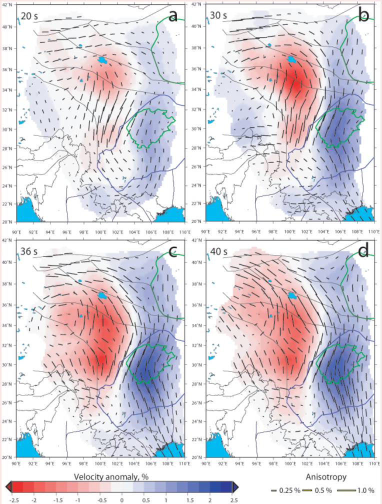


For both isotropic and anisotropic variations

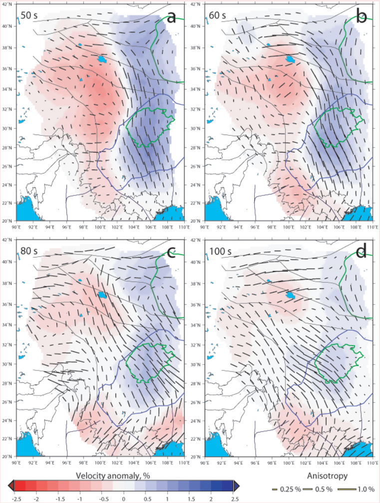


Models

20-40 s

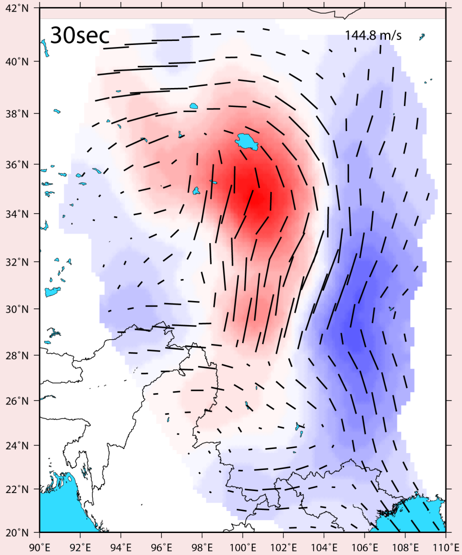


50-100 s



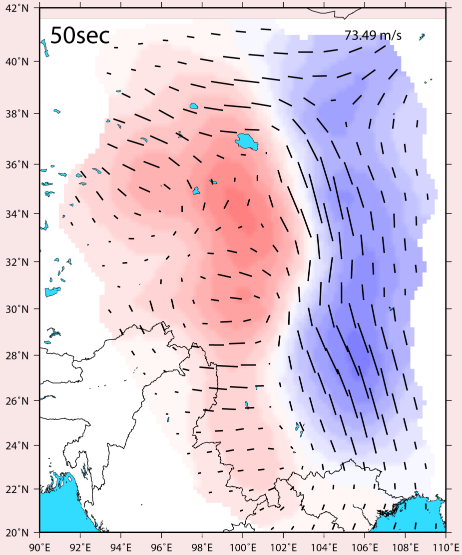
Models

Period of 30 sec



- Slow velocities beneath Tibet.
- Fast velocities beneath cratons.
- Rotation of the anisotropy.

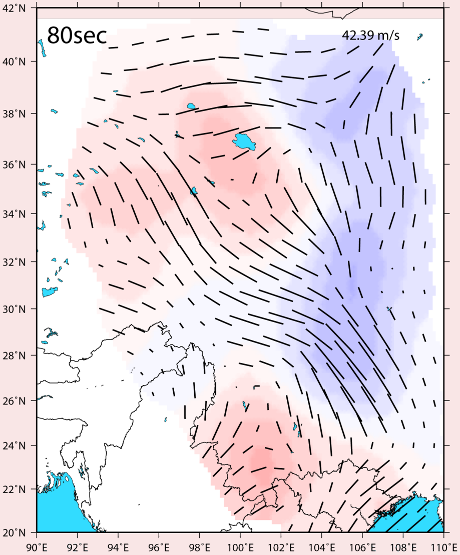
Period of 50 sec



- Slow velocities beneath Tibet.
- Fast velocities beneath cratons.
- Rotation of the anisotropy.

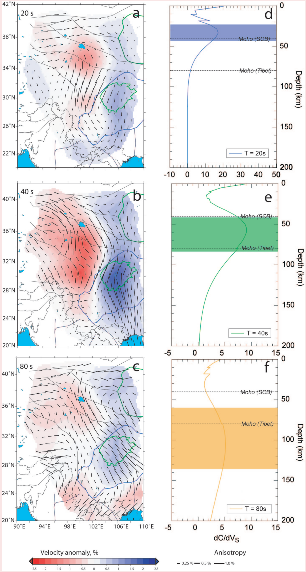
Models

Period of 80 sec



- Lithospheric depth.
- E/W velocity dichotomy.
- Anisotropy close to the APM.

Discussions



- Complex flow.
- Sichuan basin indenter.
- Clockwise rotation in central Tibet.
- Counterclockwise rotation outside Tibet.

Conclusions

Isotropic

- Crustal thickening beneath Tibet.
- Contrast Tibet / surroundings.
- (An)isotropic variation in period (depth).

Anisotropic

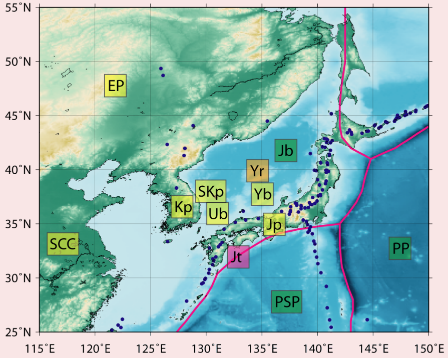
- Flow limited to the crust.
- Clockwise rotation highlighted by the anisotropy.
- (An)isotropic variation in period (depth).

2nd region

Legendre, C. P., Deschamps, F., & Zhao, L., & Chen, Q. F. (2016).
Complex layered deformation within the Crust and lithospheric Mantle beneath the Sea of Japan.
Journal of Asian earth Sciences
in revision.

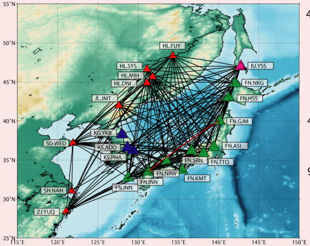
Tectonic setting

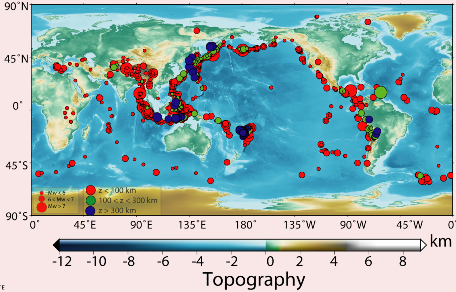
Geological units



- 4 plates: America / Eurasia / Philippine Sea / Pacific.
- Continental and oceanic crust.
- Basins and ridges.

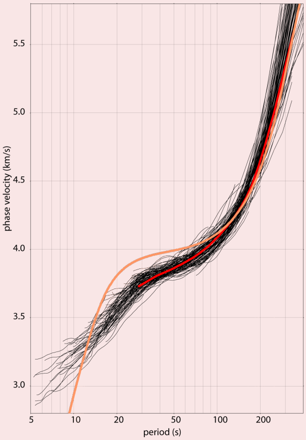
Seismic stations in East China See and seimic events





- 22 seismic stations.
- 1,411 global earthquakes.

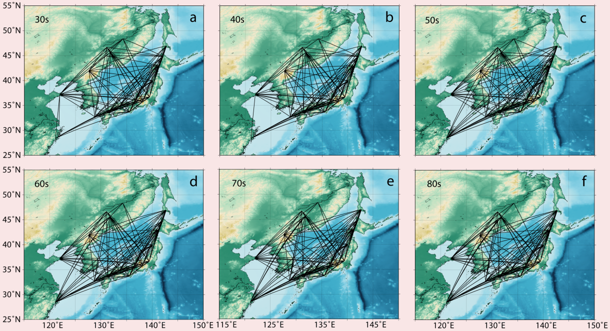
All individual measurements



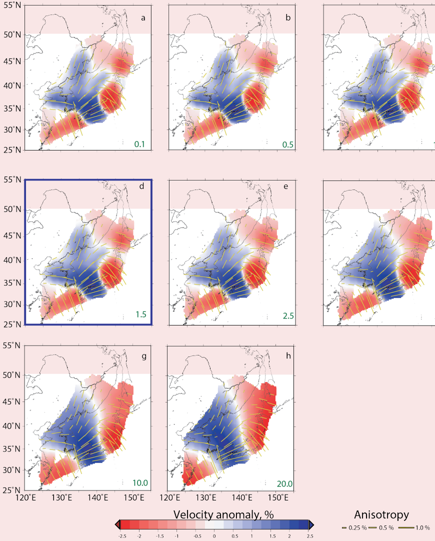
- 231 individual curves.
- Sample the whole region.
- Even distribution.

Path coverage

For various periods

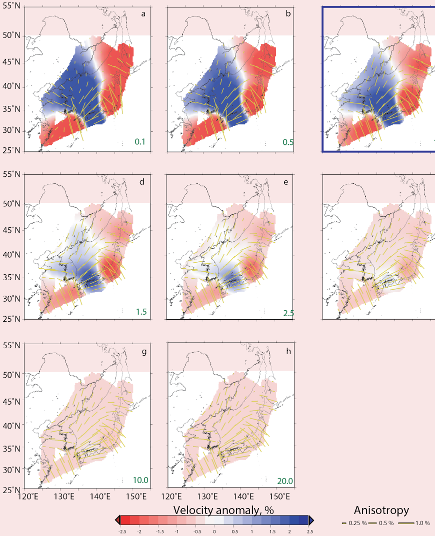


Isotropic smoothing



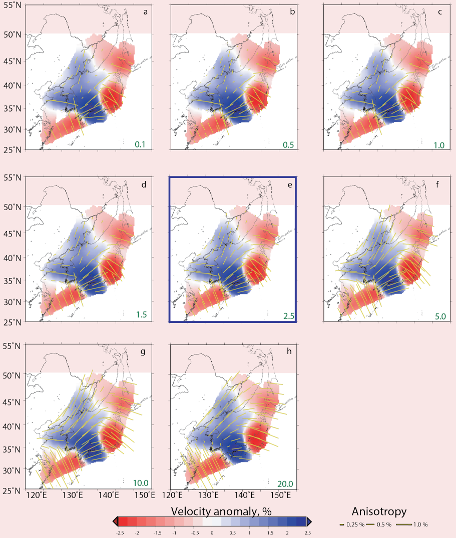
Parameters

Isotropic damping

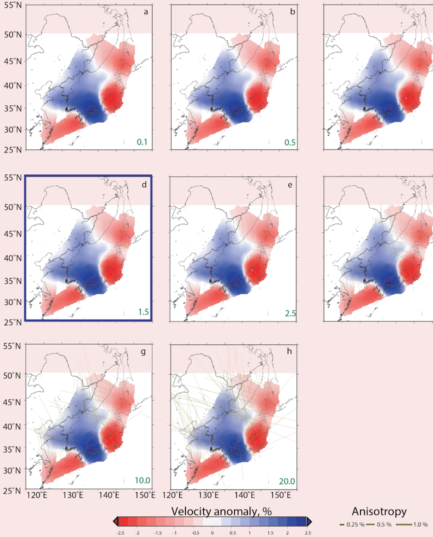


Parameters

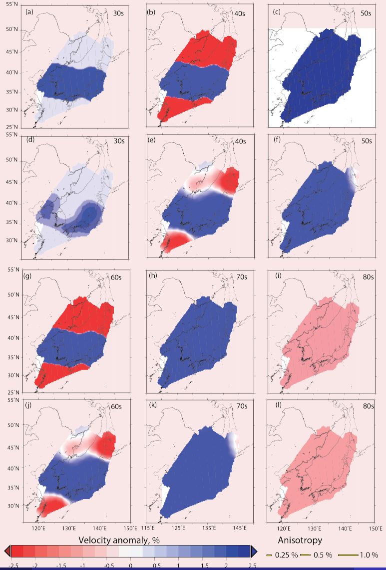
Anisotropic smoothing



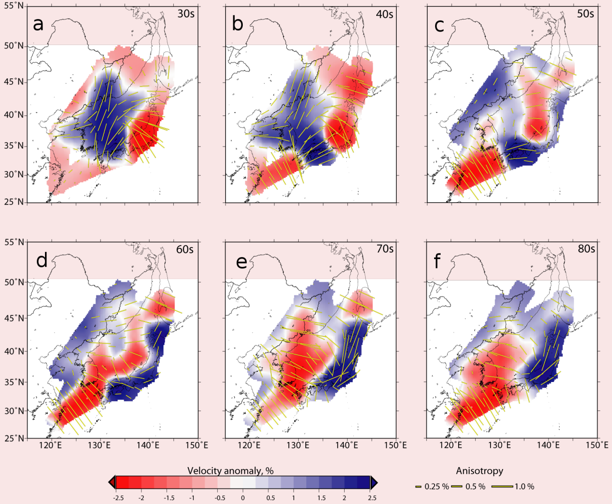
Anisotropic damping



For both isotropic and anisotropic variations

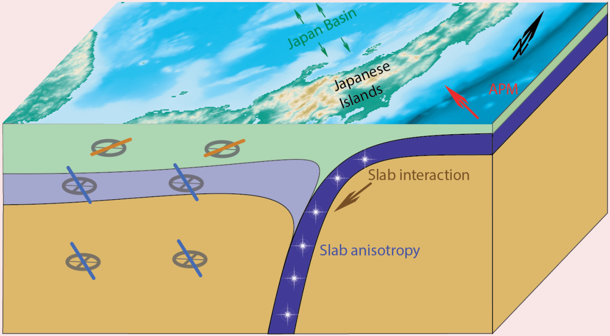


Period of 30 – 80 sec



Discussions

Interpretation



- Crustal and lithospheric deformation.
- Subduction in the east.

Conclusions

See of Japan

- Oceanic crustal deformation.
- Lithorpheric deformation.
- Evidence for a subduction.

Conclusions

Method

- Suitable for oceanic areas.
- Crustal and lithospheric investigations.
- Lateral variations of velocity perturbations.
- Lateral and vertical layering of anisotropy.

Improvements

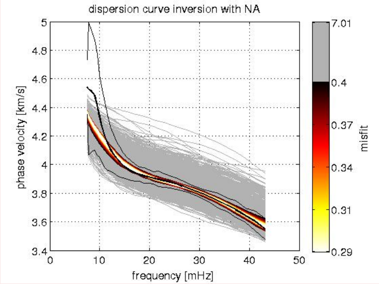
- Using more seismic stations.
- OBS in oceanic regions.
- Inversion for shear-velocity.
- Joint inversion with Receiver Function / SKS / other.

Acknowledgment

Thank you for your attention !

N/A inversion

For dispersion curves



Model space