RAYLEIGH-WAVE ANALYSES BENEATH EASTERN ASIA.
THE QUEST FOR RESOLUTION

Legendre, Cédric [1]

[1] *Institute of Earth Sciences*
Academia Sinica

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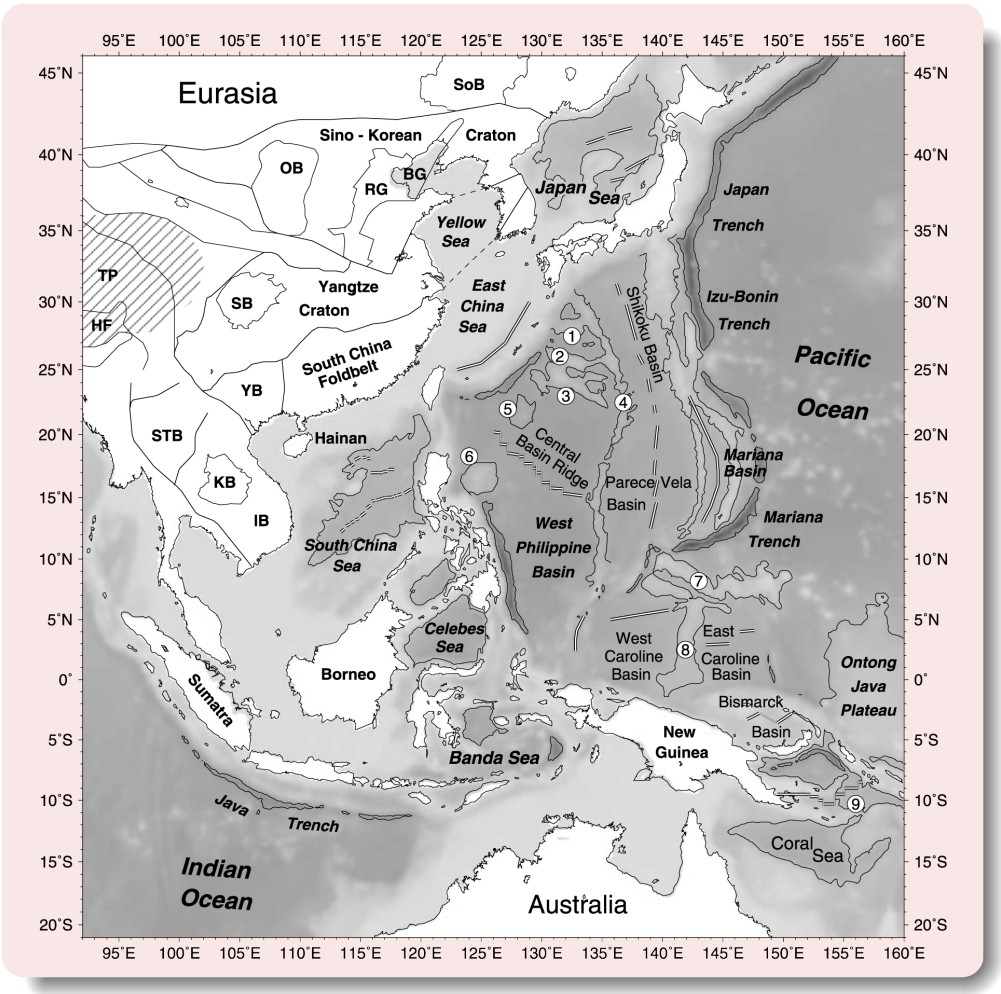
Motivation

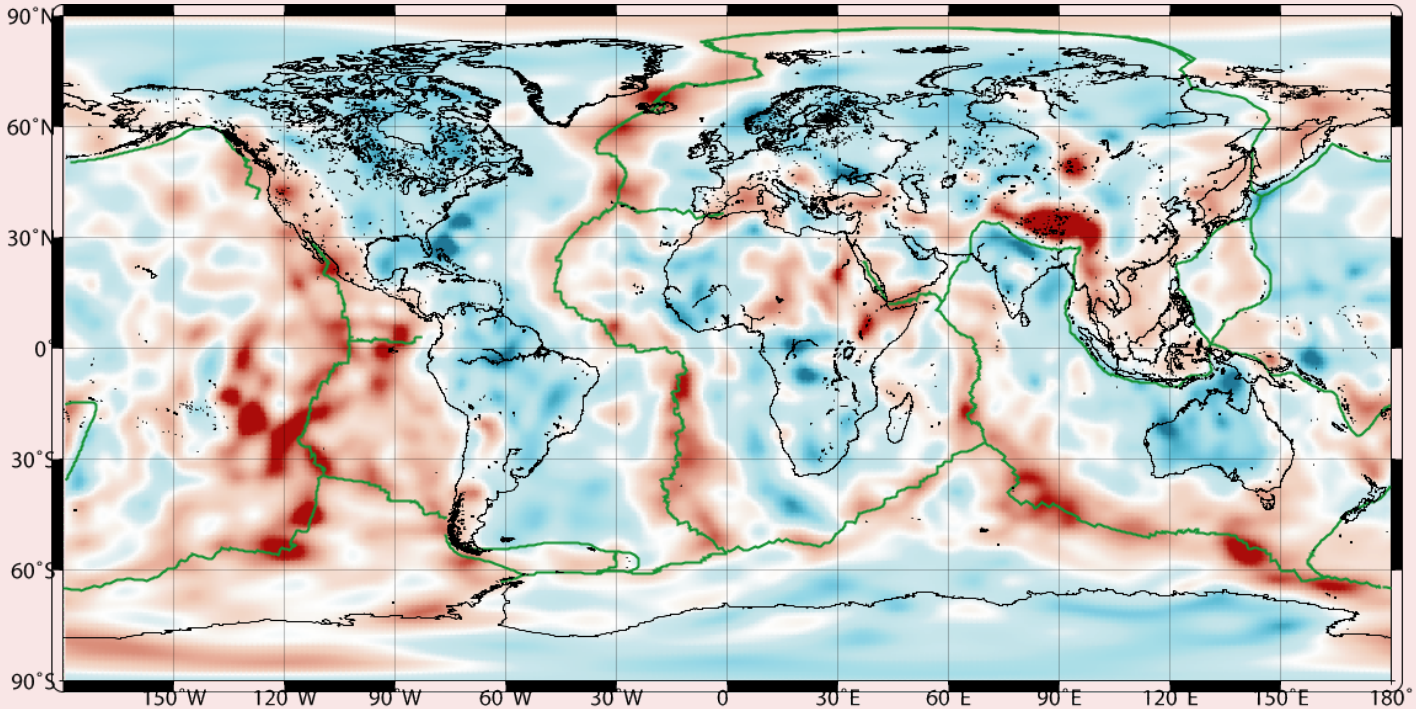
What kind of resolution can we achieve?



East Asia

- Cratons
- Subductions
- Plates/microplates
- Passive margins

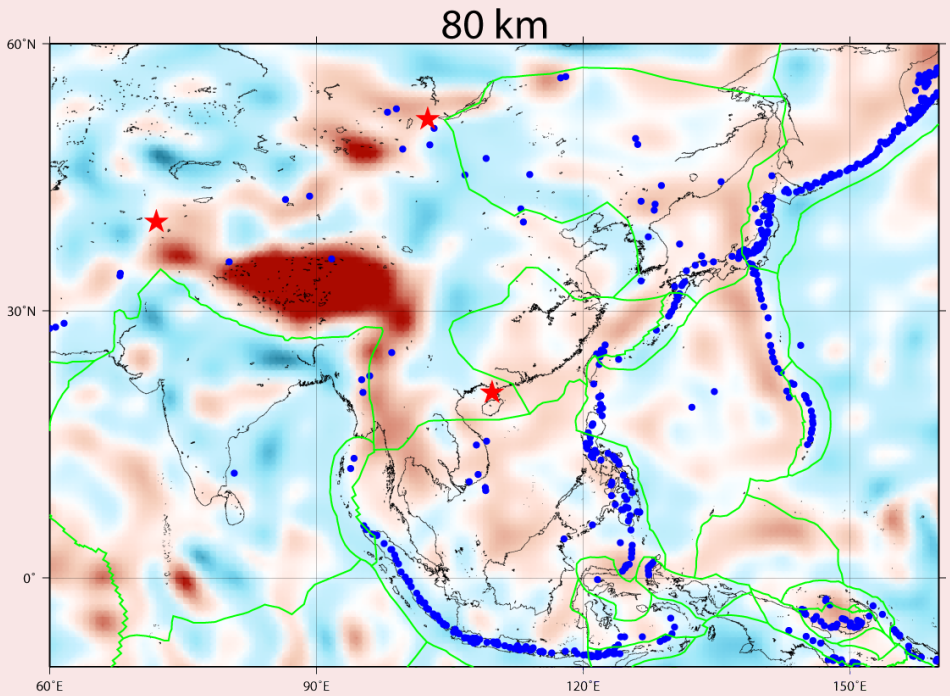
Large scale models



Resolution

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

Regional scale models

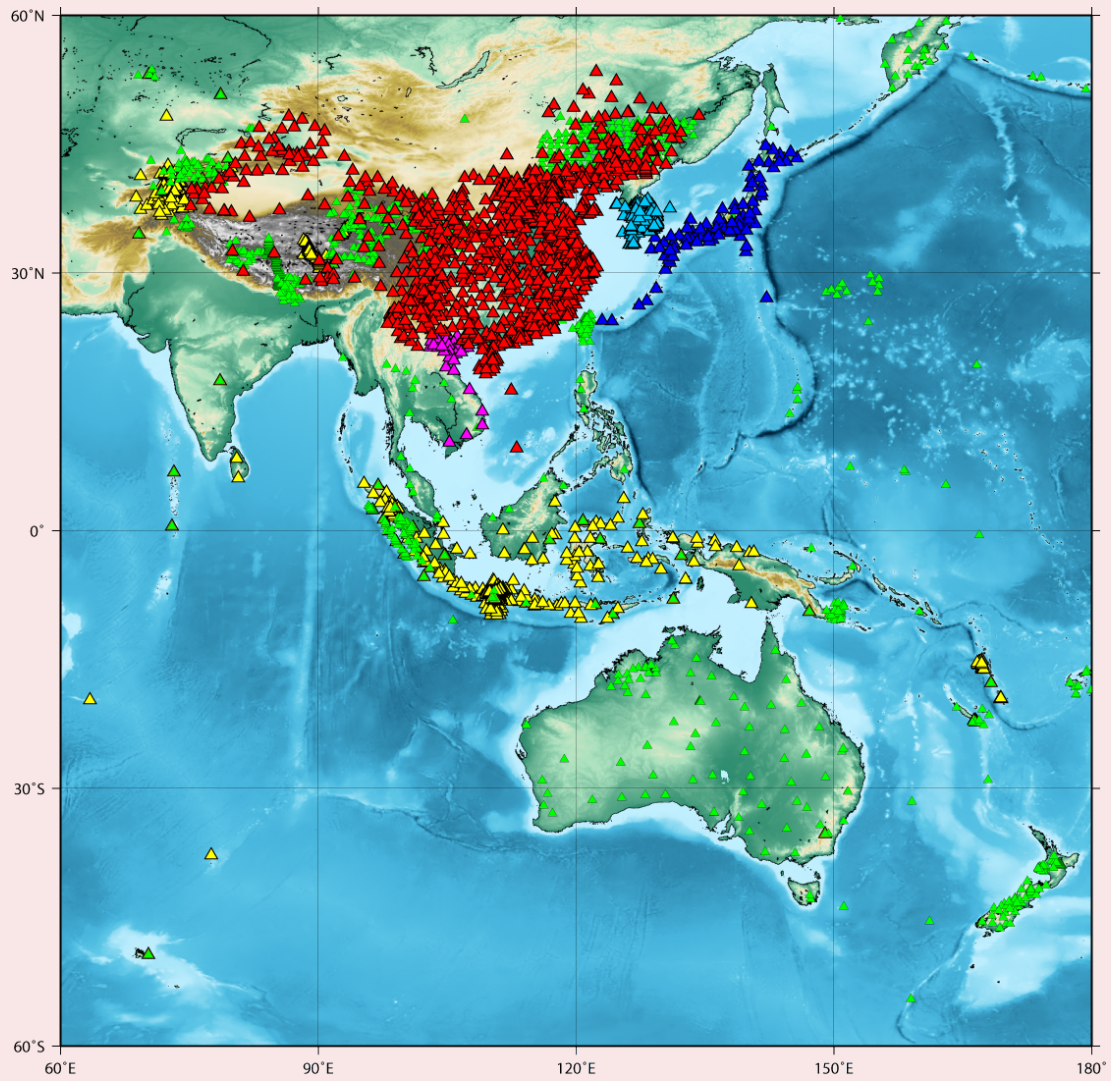


Resolution

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

Seismic stations

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.

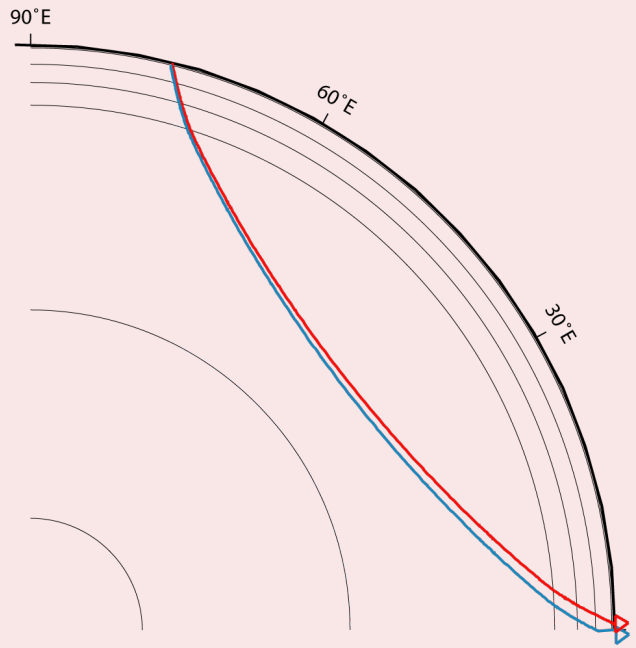
Rayleigh-wave dispersion curves

We will focus on two regions:

- Eastern China.
- East China Sea.

Principle

Path

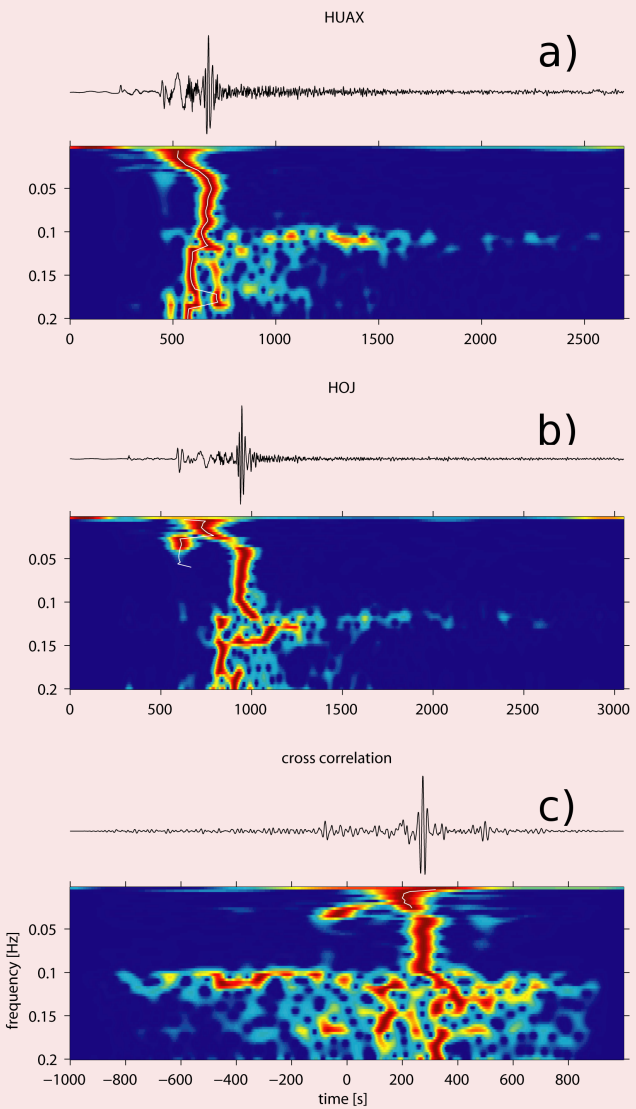


Theory

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

Phase velocity dispersion curves

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:

$$C(\omega) = \frac{\omega(\Delta_1 - \Delta_2)}{\zeta(\omega)}, \qquad (1)$$

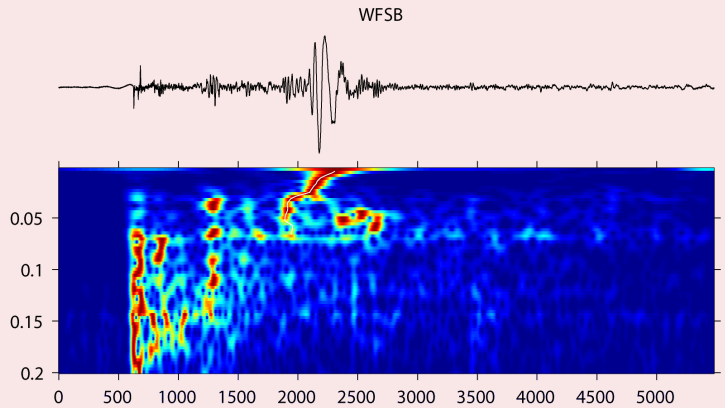
with

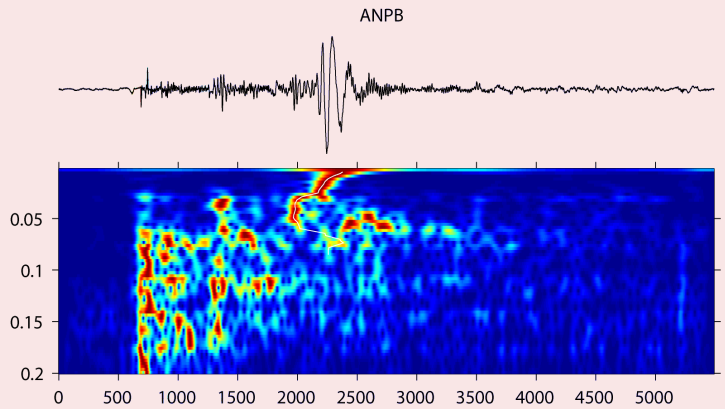
$$\zeta(\omega) = \arctan\left\{ \frac{Im[\Phi(\omega)]}{Re[\Phi(\omega)]} \right\} + 2n\pi, \qquad (2)$$

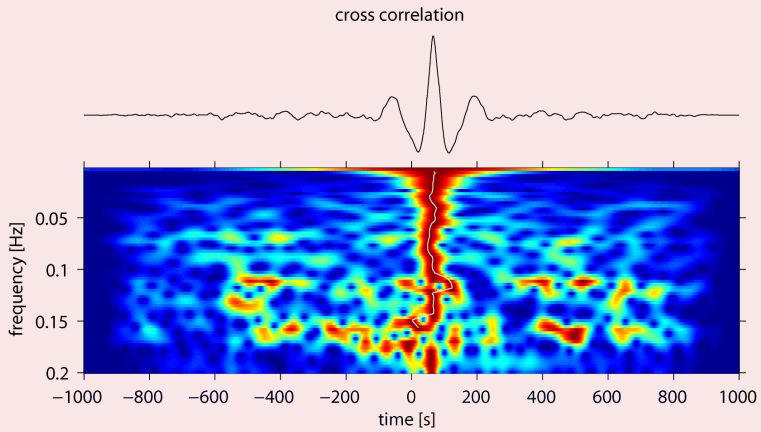
$\Phi(\omega)$ is the transformed cross-correlation between the surface waves recorded at the two stations with epicentral distances Δ_1 and Δ_2.

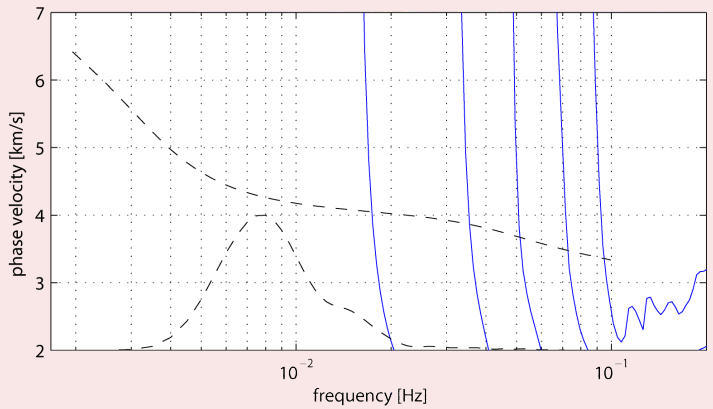
Dispersion curve

Bad curve



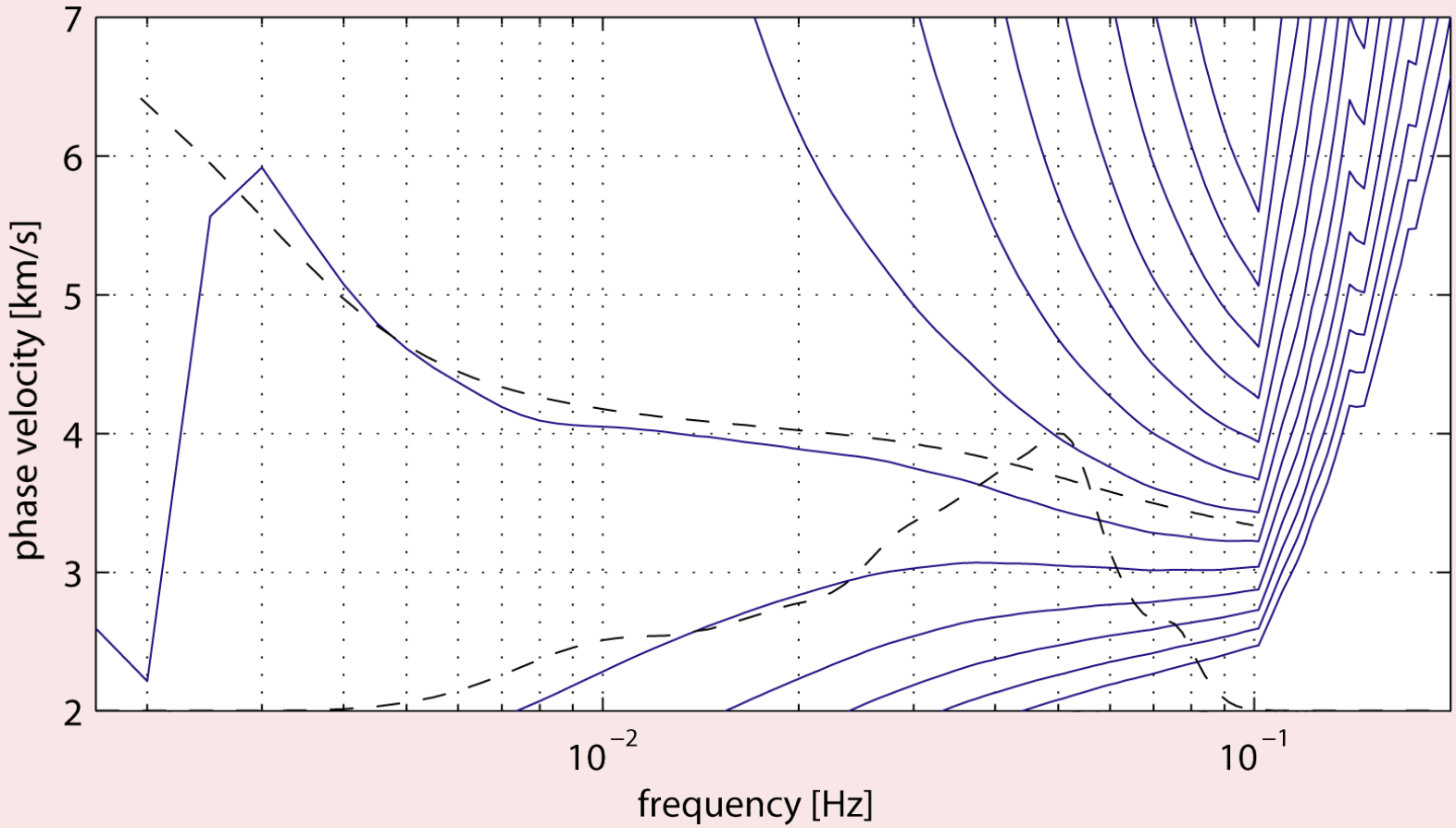






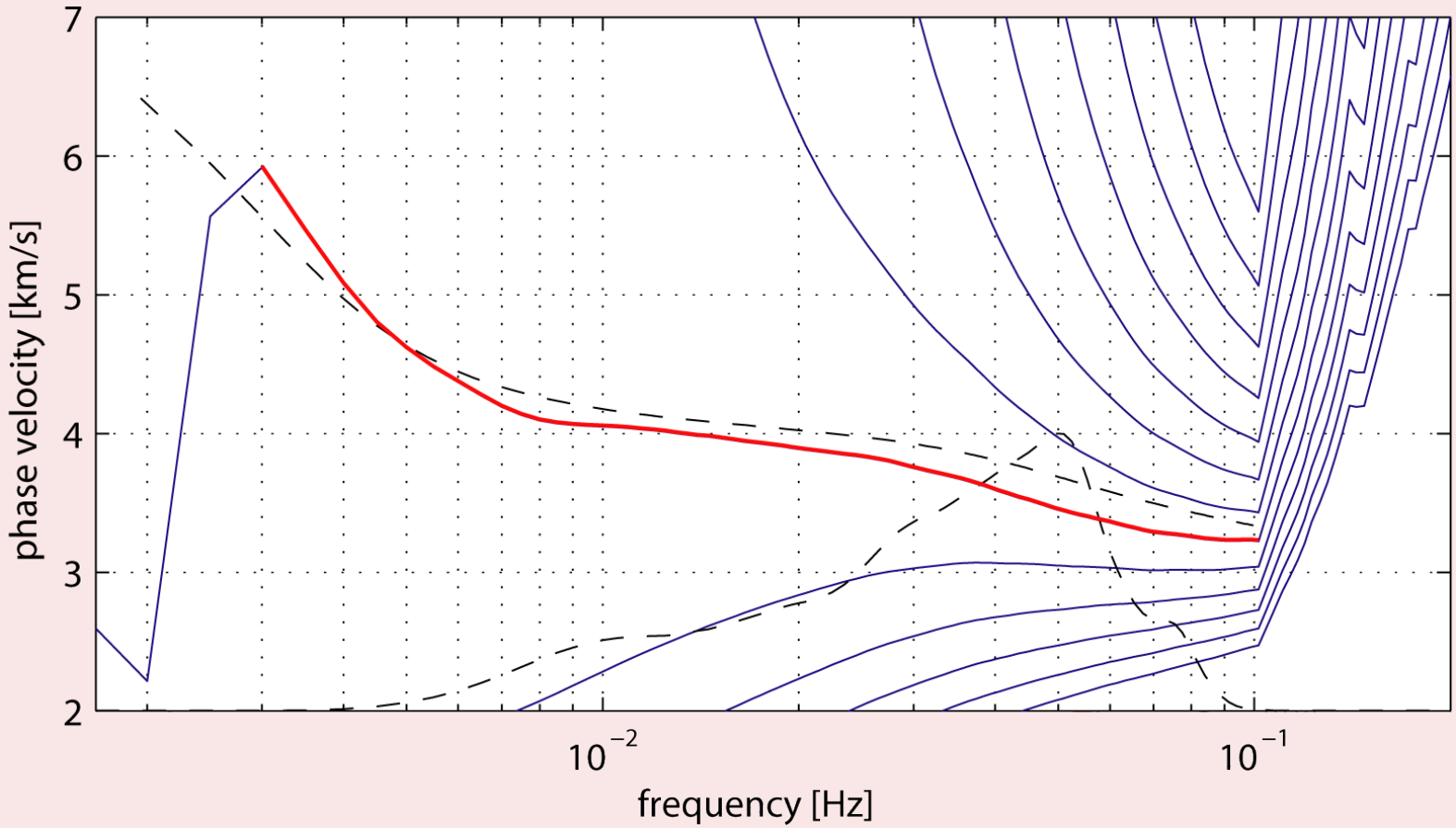
Dispersion curve

Selection

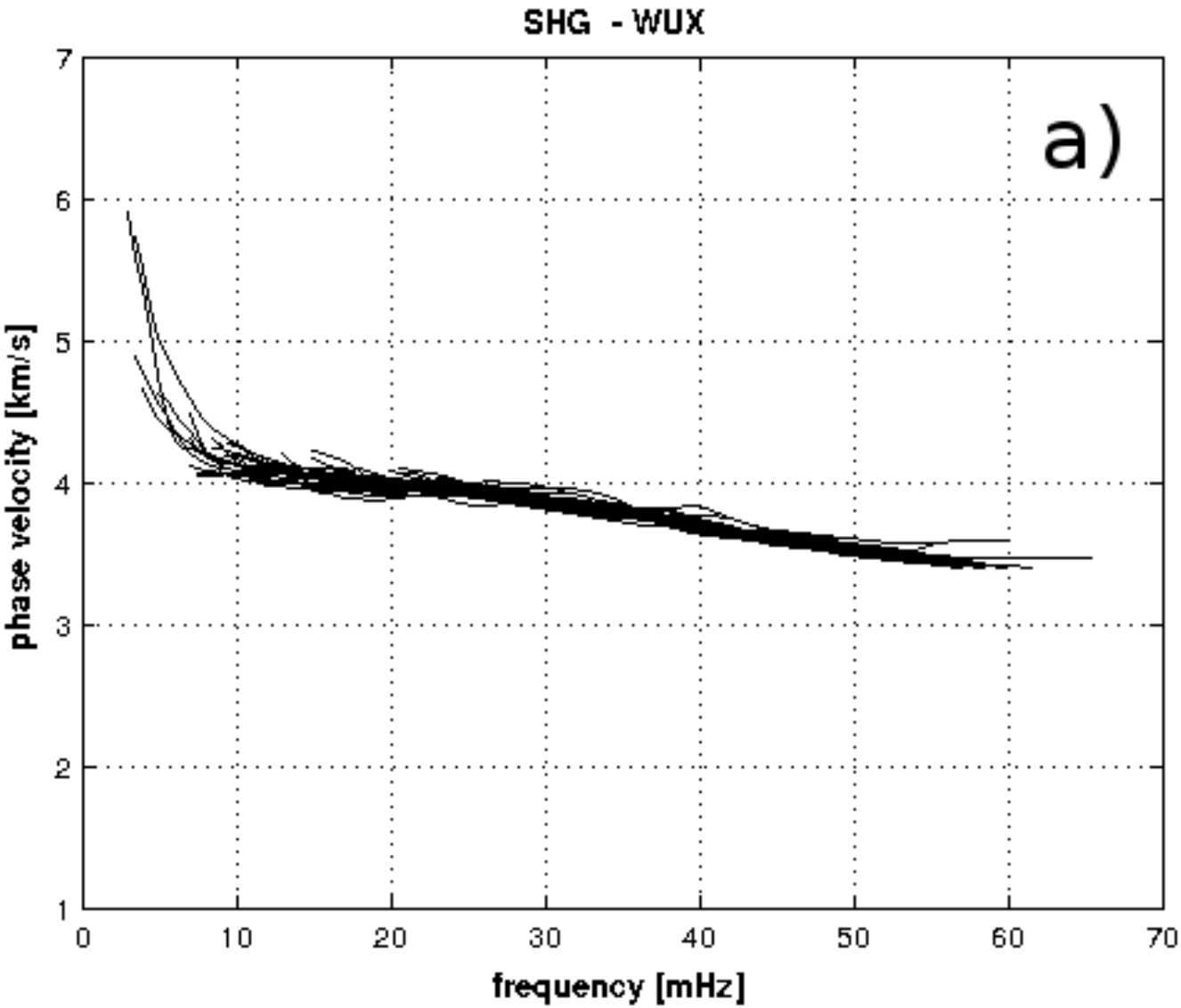


Dispersion curve

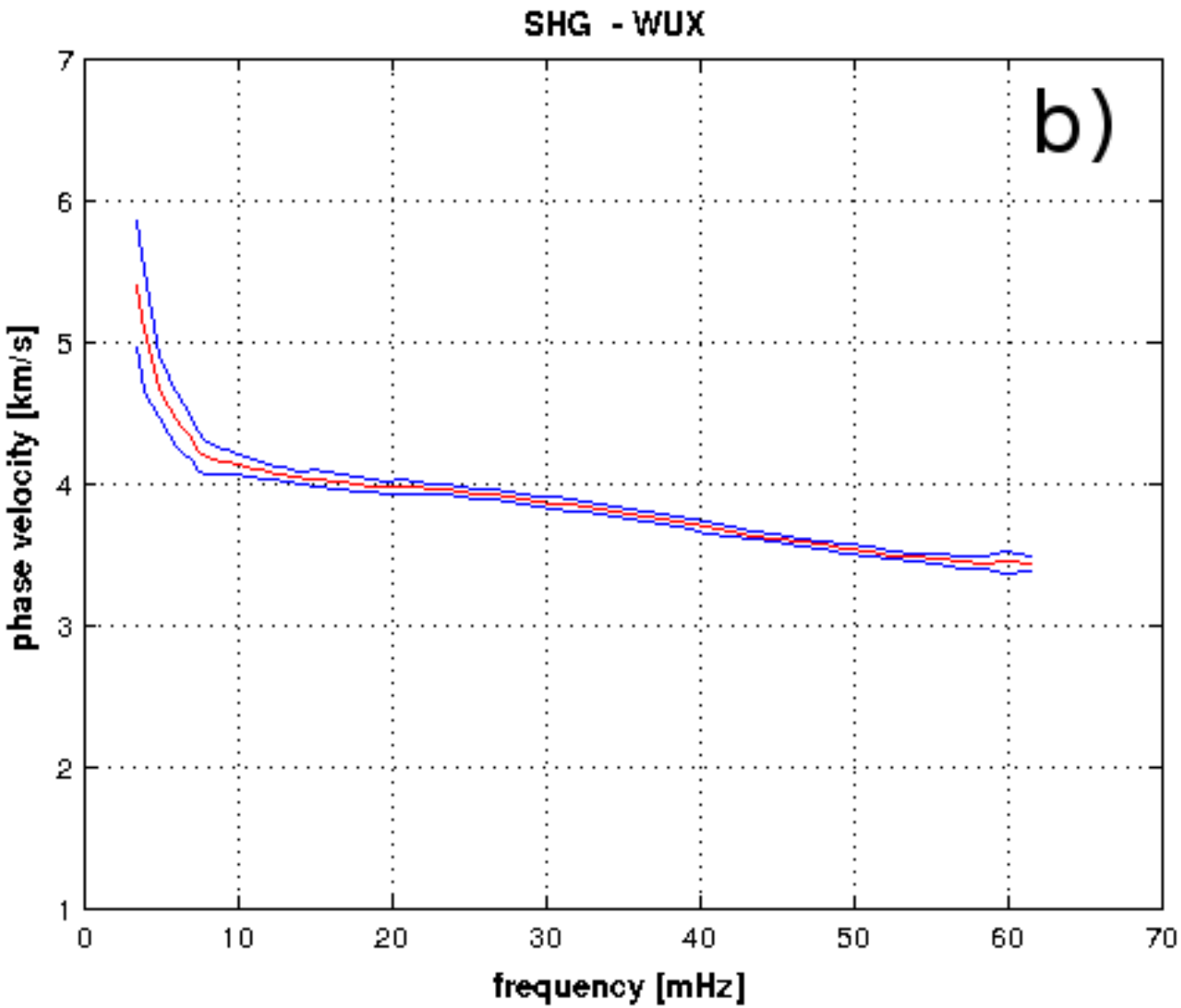
Selected



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

Averaging


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

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:

$$\delta C = \delta C_{iso} + A_{2\psi} * cos(2\psi) + B_{2\psi} * sin(2\psi) + A_{4\psi} * cos(4\psi) + B_{4\psi} * sin(4\psi). \quad (3)$$

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

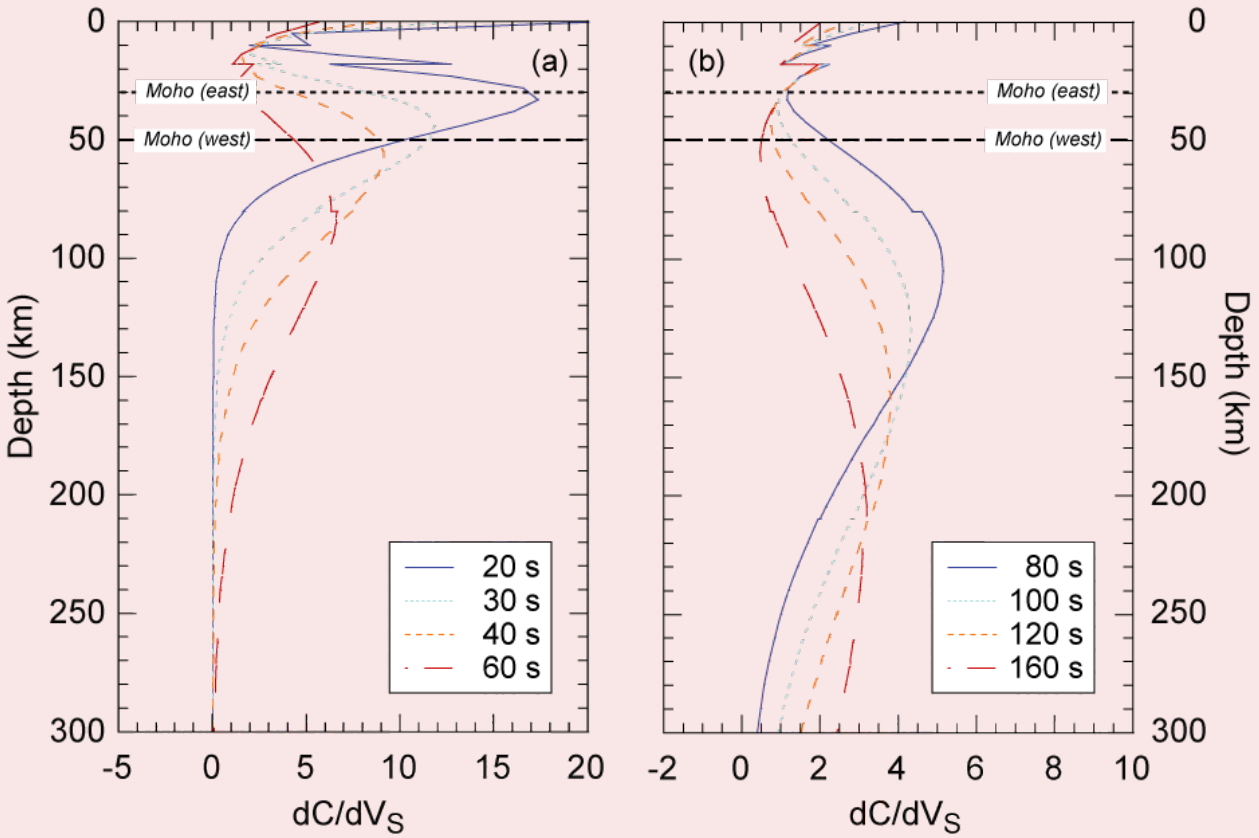
$$\begin{cases} \Lambda_{2\psi} = \sqrt{A_{2\psi}^2 + B_{2\psi}^2} \\ \Theta_{2\psi} = \frac{1}{2}\ arctan(\frac{B_{2\psi}}{A_{2\psi}}) \end{cases} \quad and \quad \begin{cases} \Lambda_{4\psi} = \sqrt{A_{4\psi}^2 + B_{4\psi}^2} \\ \Theta_{4\psi} = \frac{1}{4}\ arctan(\frac{B_{4\psi}}{A_{4\psi}}) \end{cases}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

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,

$$\delta \bar{C}_i = \int_\varphi \int_\theta K_i(\varphi, \theta)\ \delta C(\varphi, \theta)\ d\theta\ d\varphi\ , \quad (5)$$

Phase velocity kernels

Sensitivity



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

Applications

Why?

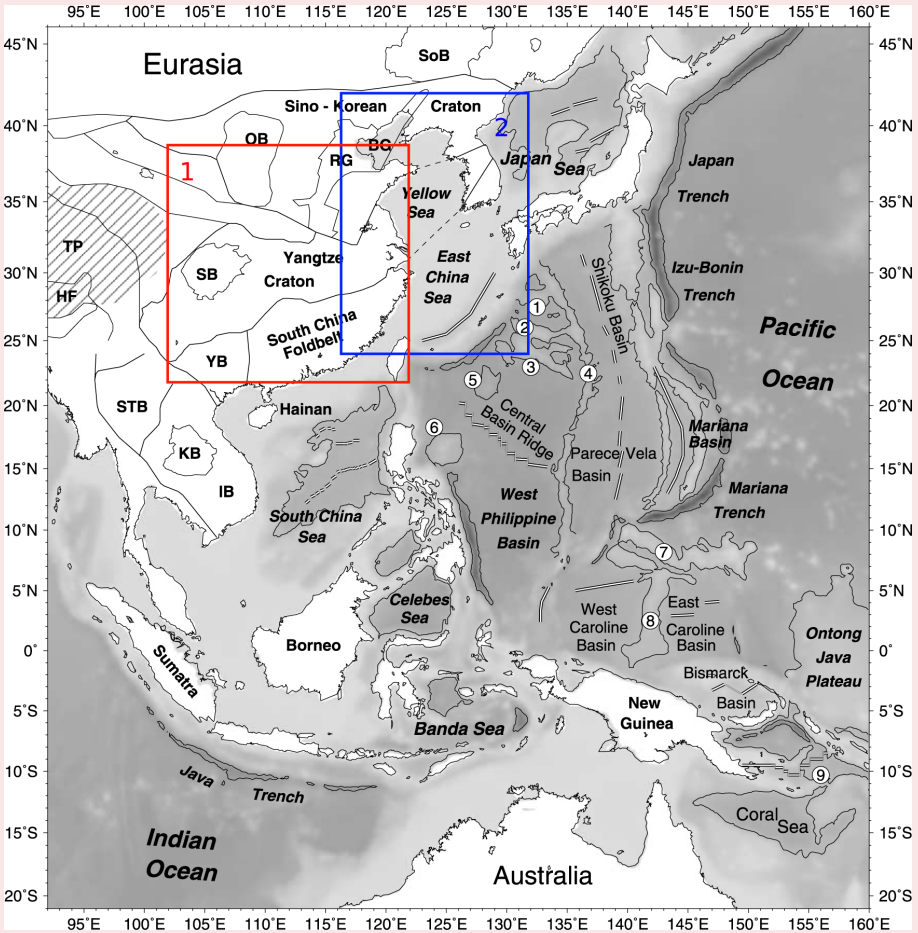
- Many information from isotropic model.
- More can be obtained from anisotropy.
- Local scale.

Special focus on two regions

- East China Sea.
- Eastern China.

Two regions

Eastern China and East-China Sea



Differences

- One "wild" (East China Sea).
- All the stations at the periphery.

- One well studied region (Eastern China).
- Stations evenly distributed.

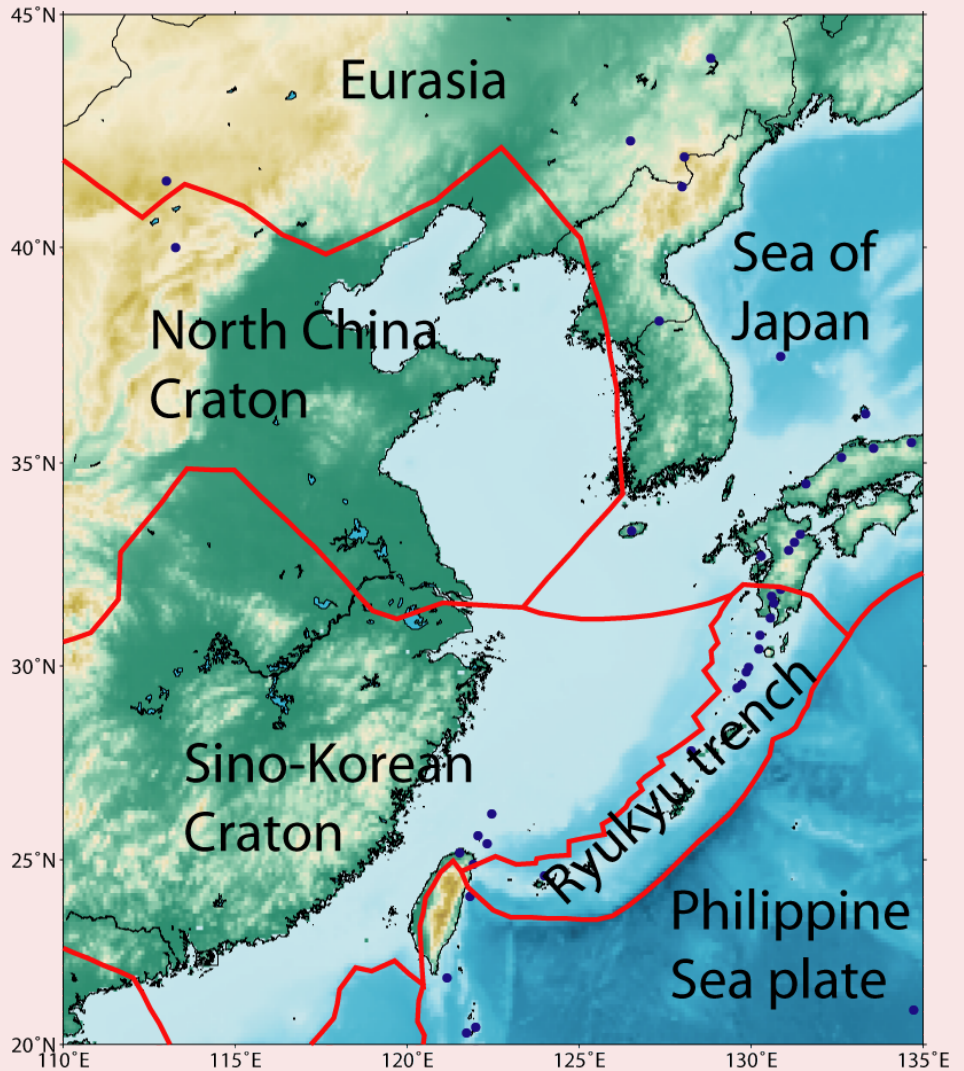
East China Sea

1st region

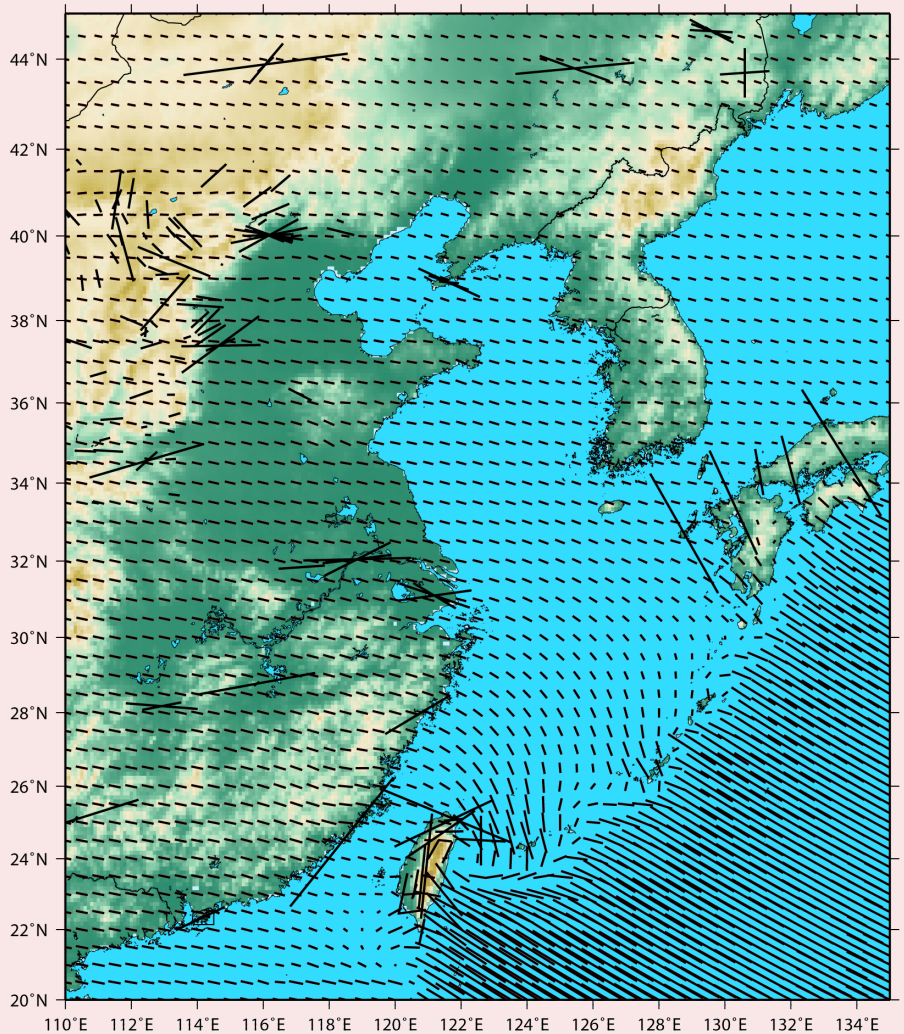
Legendre, C. P., Chen, Q. F., & Zhao, L. (2014).
Lithospheric structure beneath the East China Sea revealed by Rayleigh-wave phase velocities.
Journal of Asian Earth Sciences
In press (Available online 16 September 2014)

Tectonic setting

Geological units

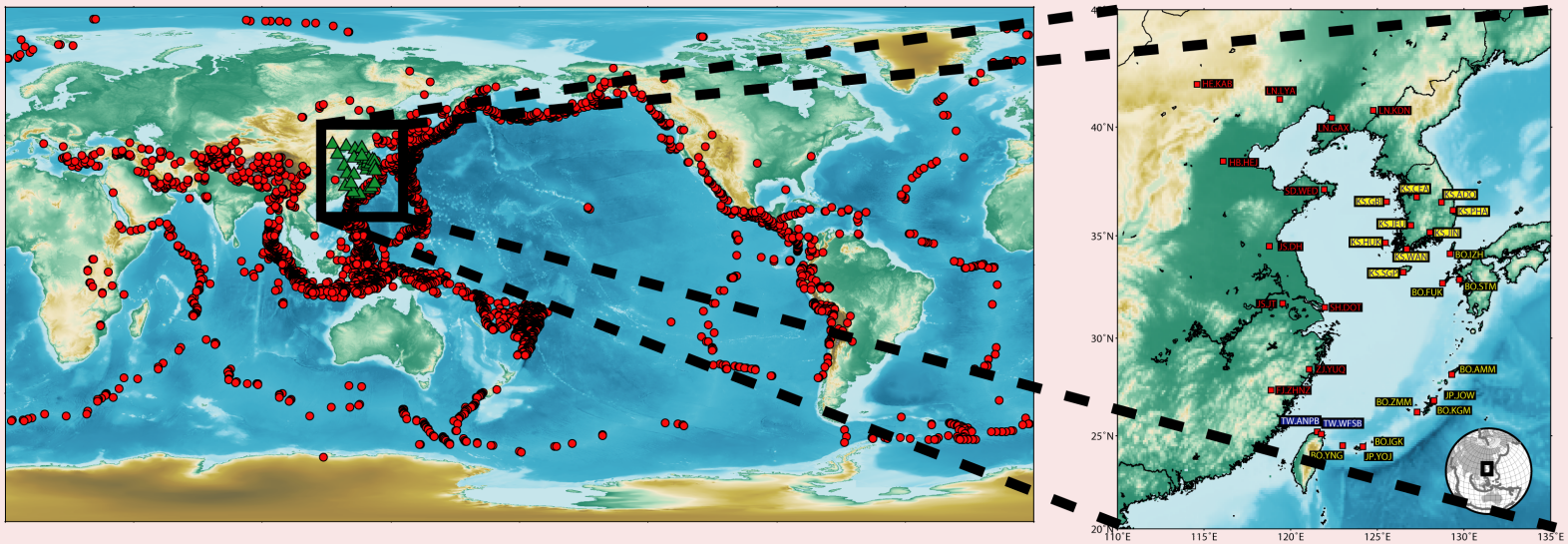


APM + SKS



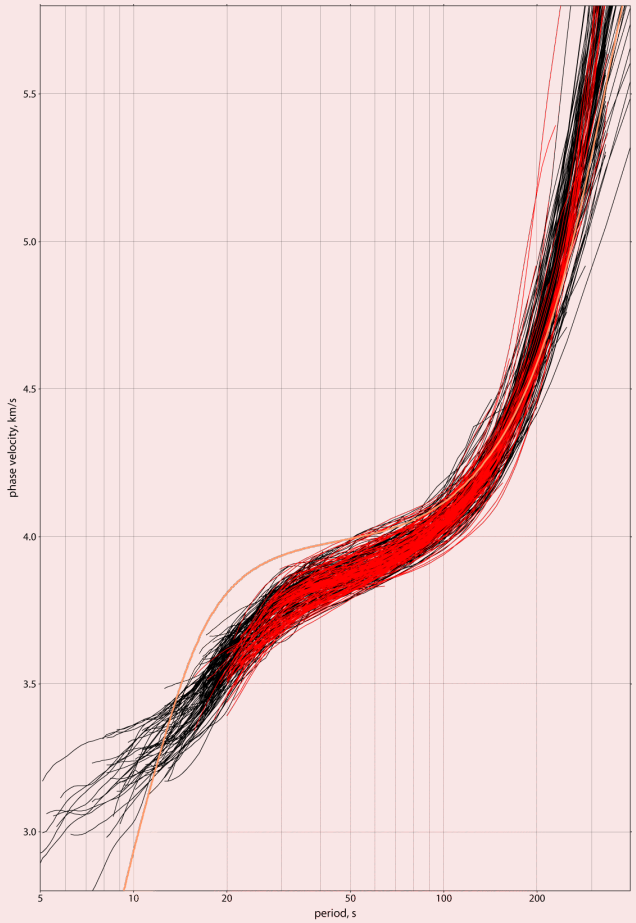
Seismic stations and events

Seismic stations in Easte China Sea and seimic events



- 32 seismic stations.
- 6891 global earthquakes.

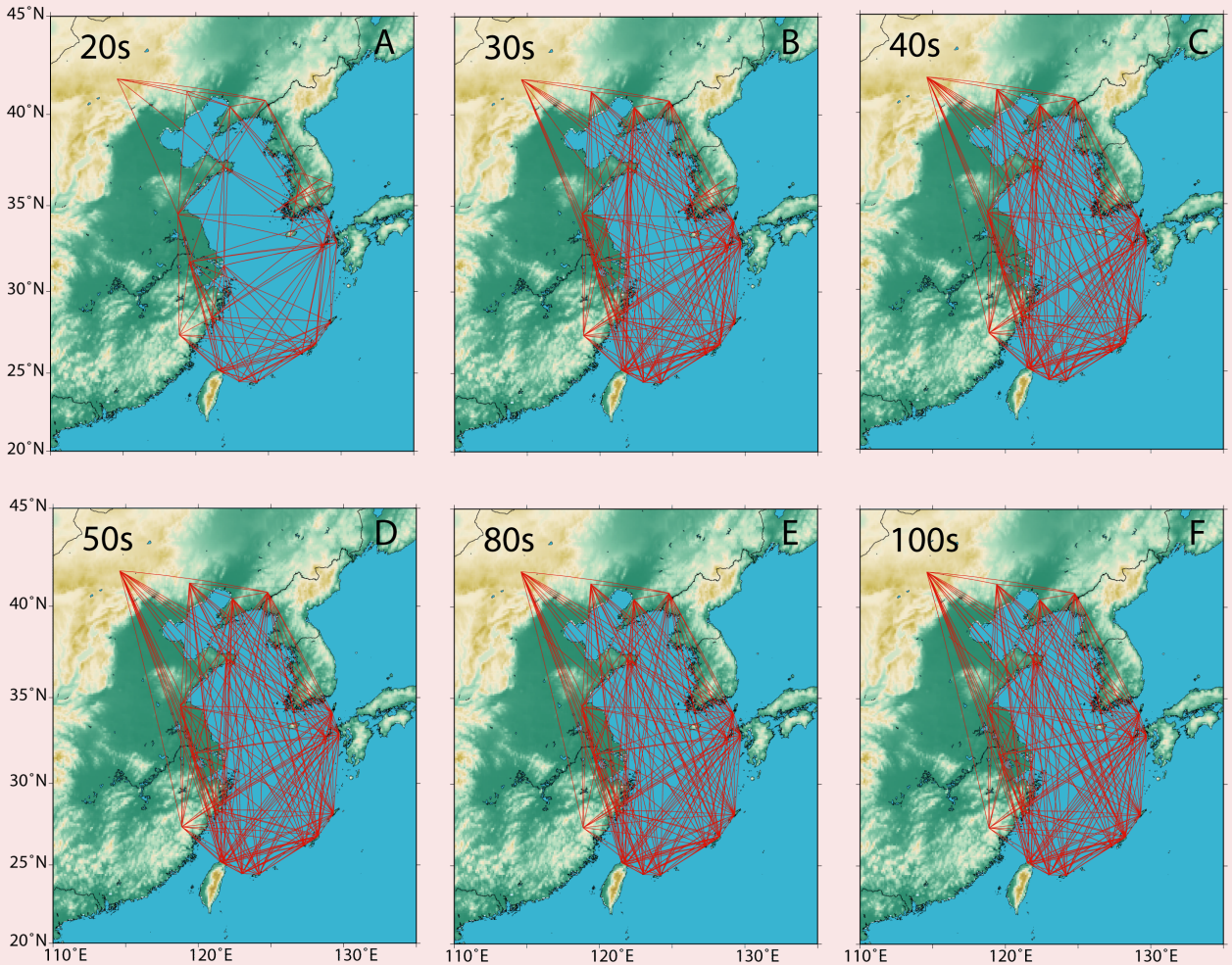
All individual measurements



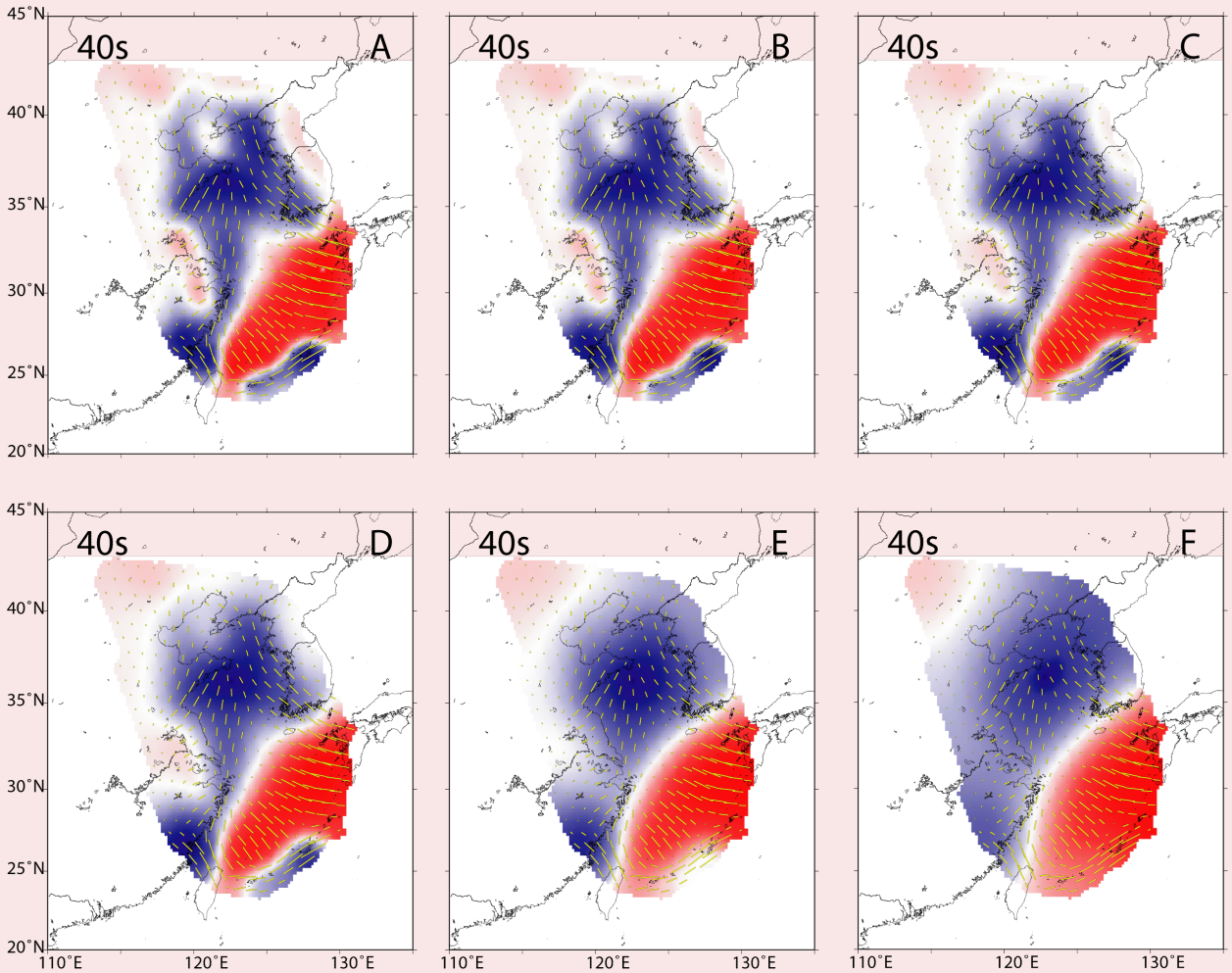
- 373 individual curves.
- Sample the whole region.
- Even distribution.

Path coverage

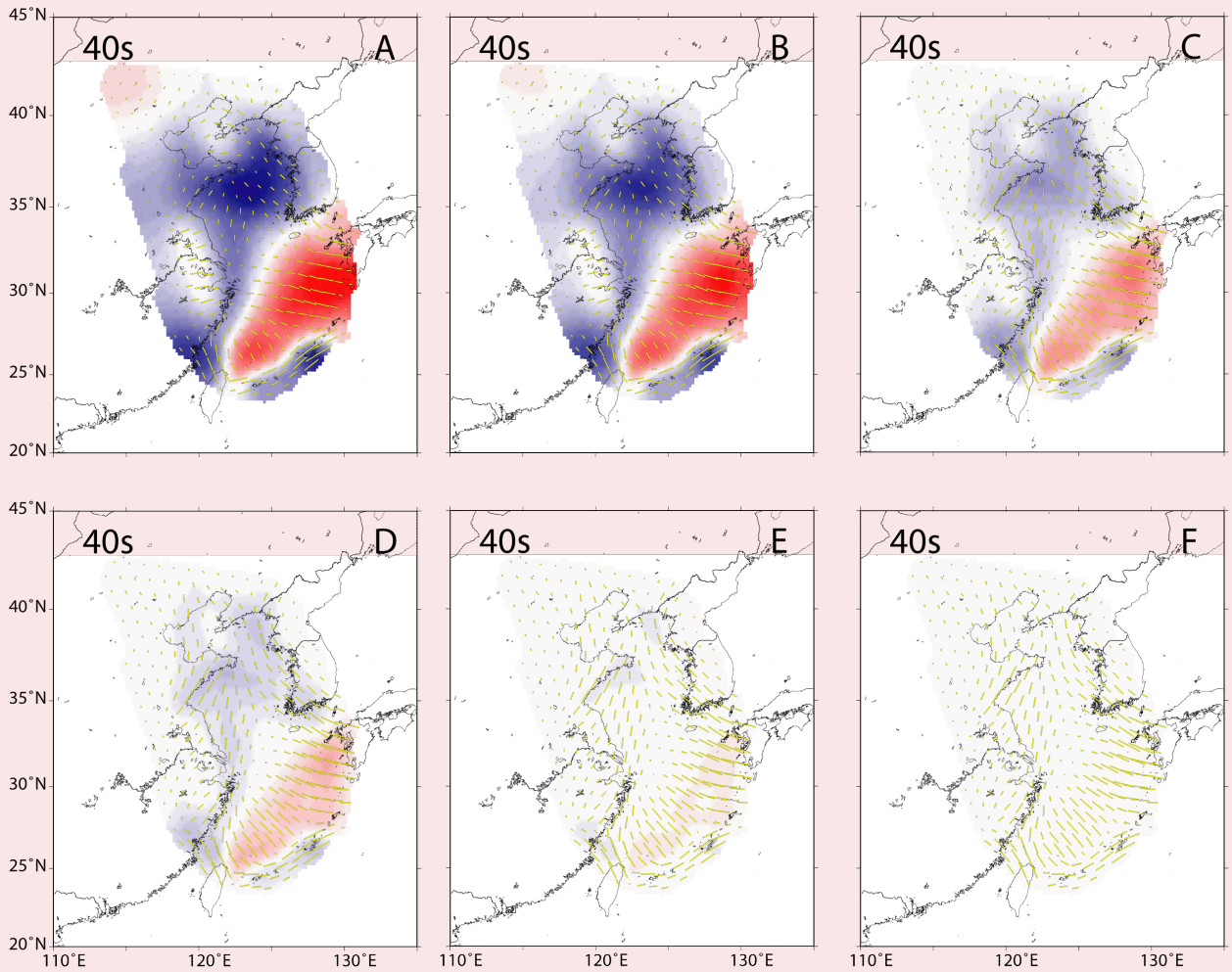
For various periods



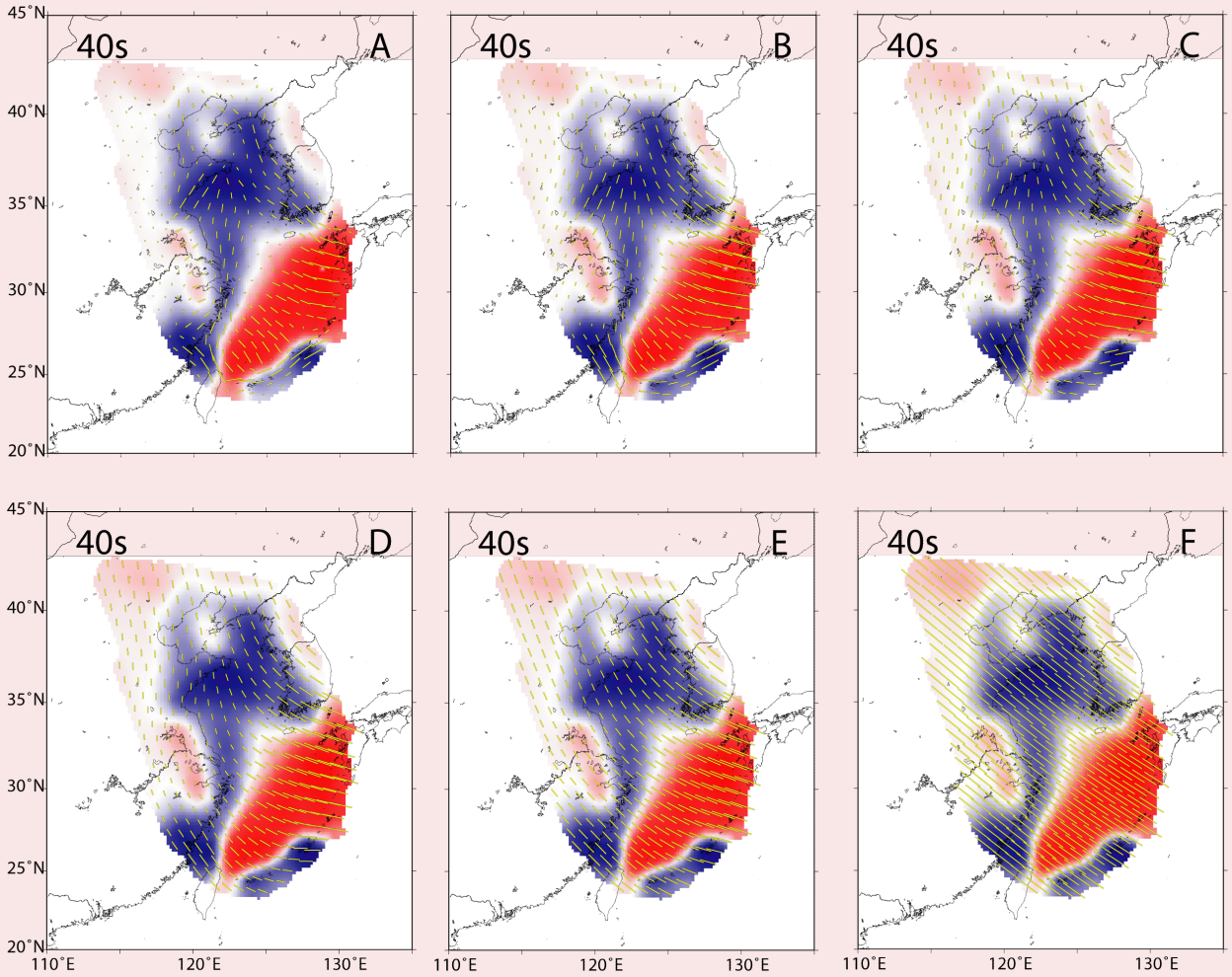
Isotropic smoothing



Isotropic damping

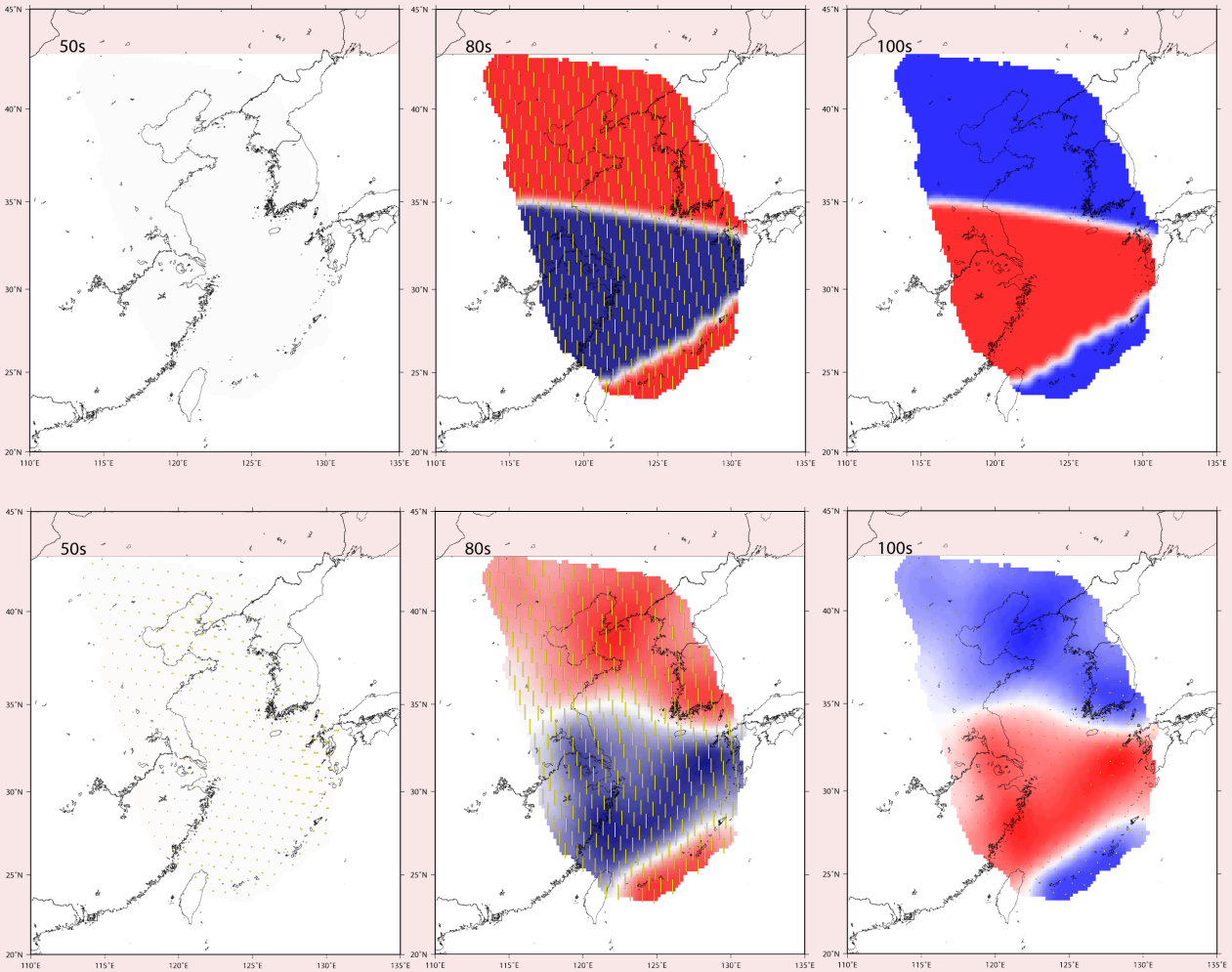


Anisotropic smoothing

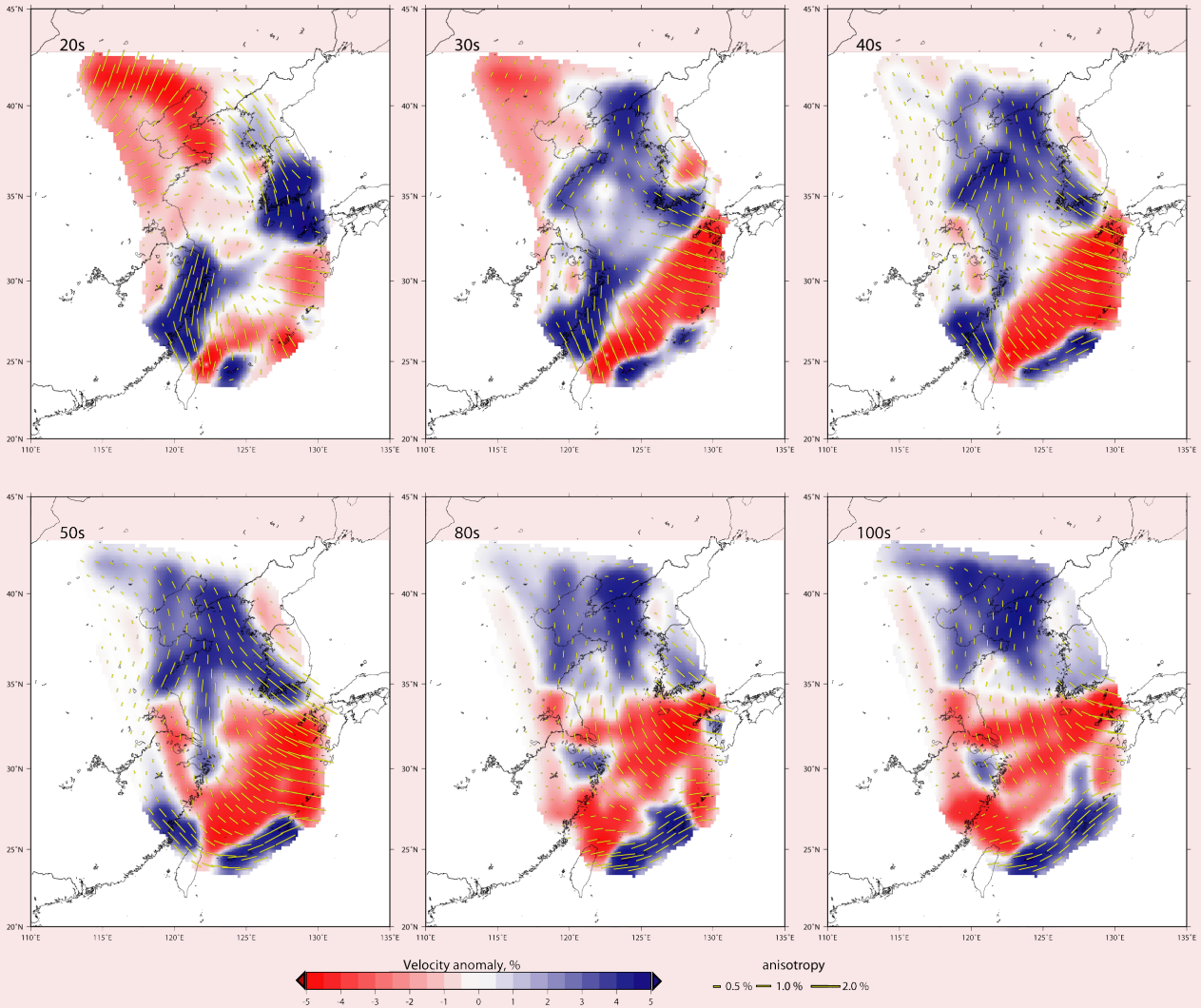


Resolution tests

For both isotropic and anisotropic variations



Period of 20 –100 sec



Discussions

Interpretation

- Undeformed passive margin.
- Crustal deformation in the southern part.
- Subduction in the South.

Conclusions

East China Sea

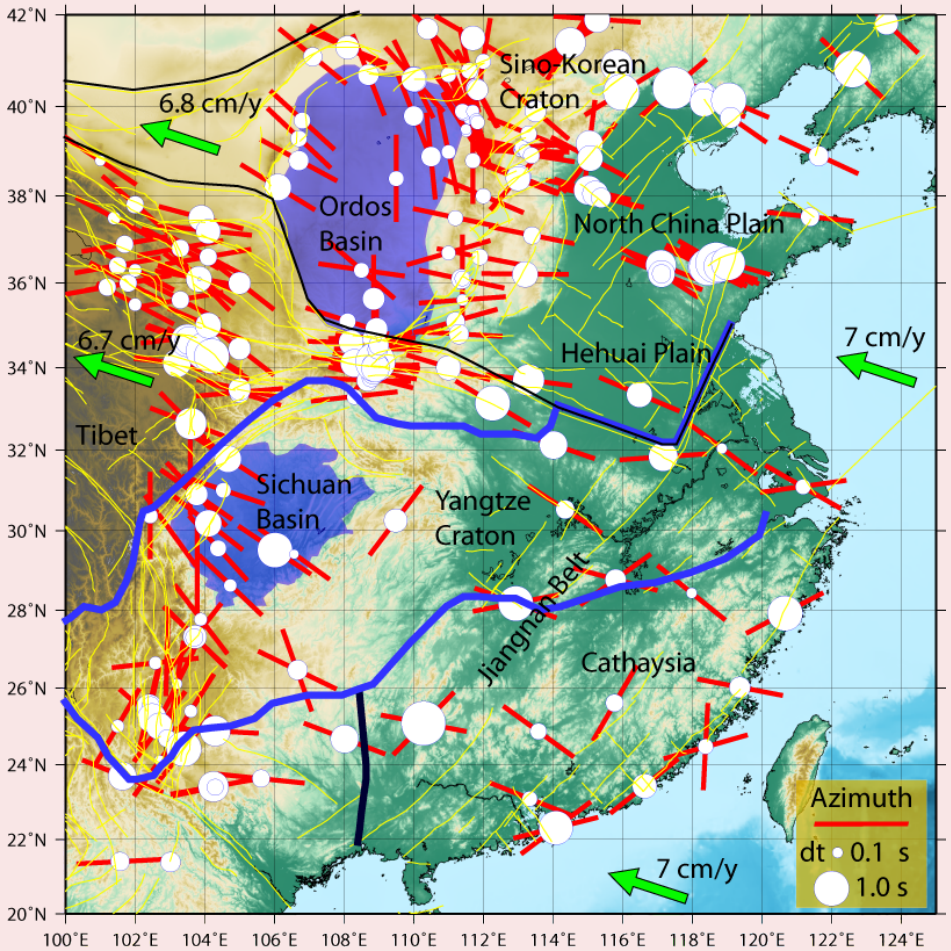
- Stable continental crust in the North.
- Oceanic crustal deformation.
- Evidence for a subduction.

Eastern China

2nd region

Legendre, C. P., Deschamps, F., Zhao, L., Lebedev, S., & Chen, Q. F. (2014).
Anisotropic Rayleigh wave phase velocity maps of eastern China.
Journal of Geophysical Research: Solid Earth.
Volume 119, Issue 6, pages 4802–4820, June 2014

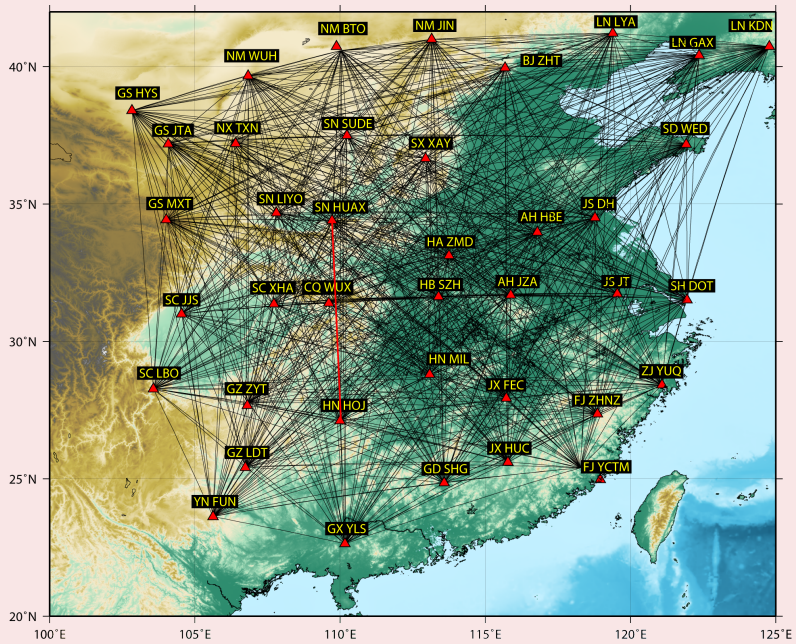
Geological units



- Cratons, basins, faults, uplifted blocks, ...

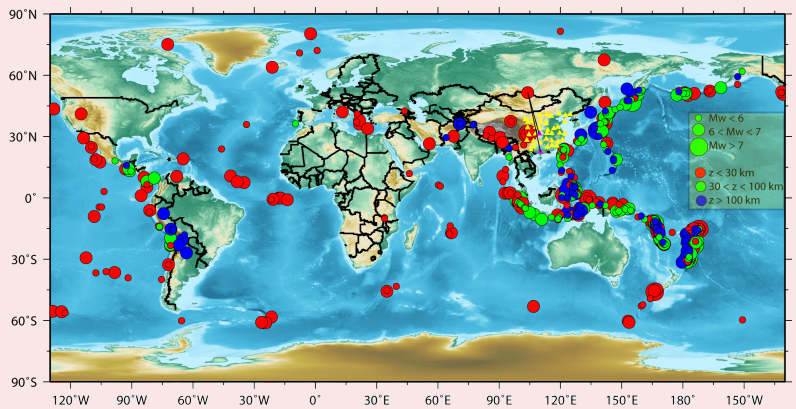
Seismic stations and events

Seismic stations in Eastern China



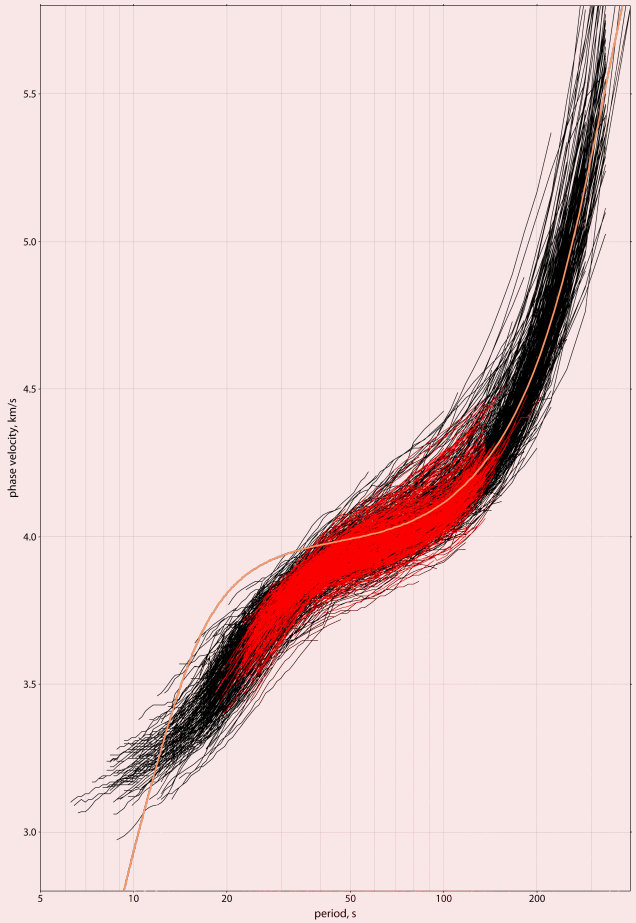
- 32 seismic stations.

Seismic events in Eastern China



- 467 global earthquakes.

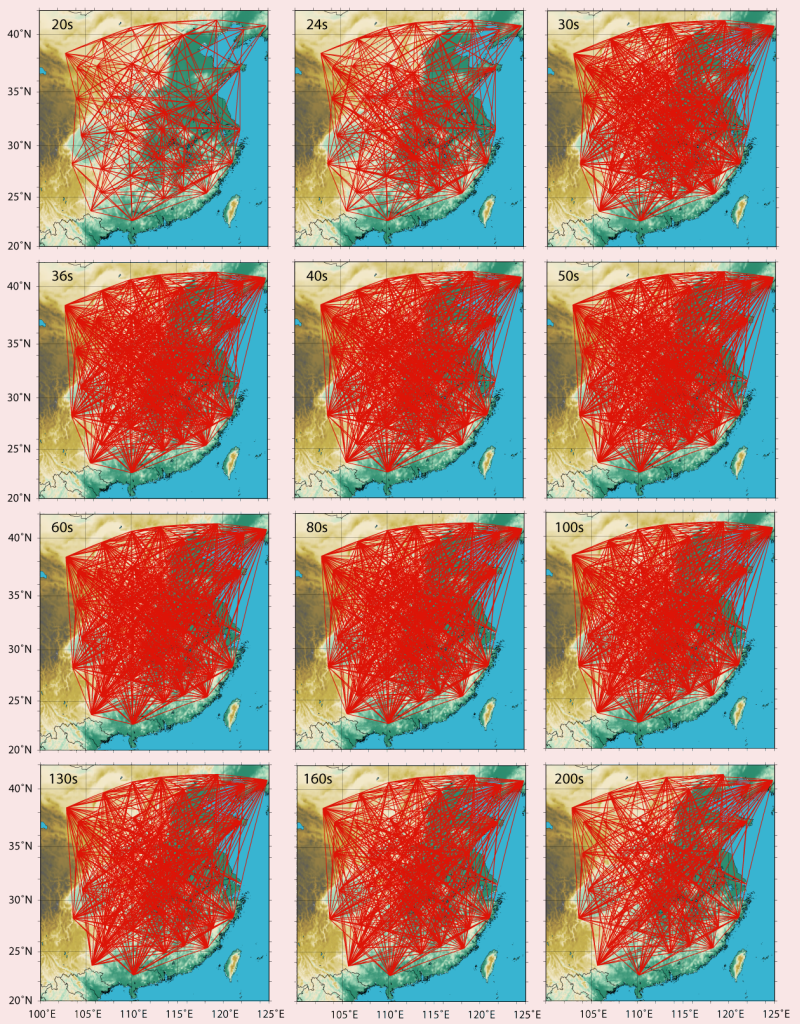
All individual measurements



- 734 individual curves + 599 automated.
- Sample the whole region.
- Even distribution.

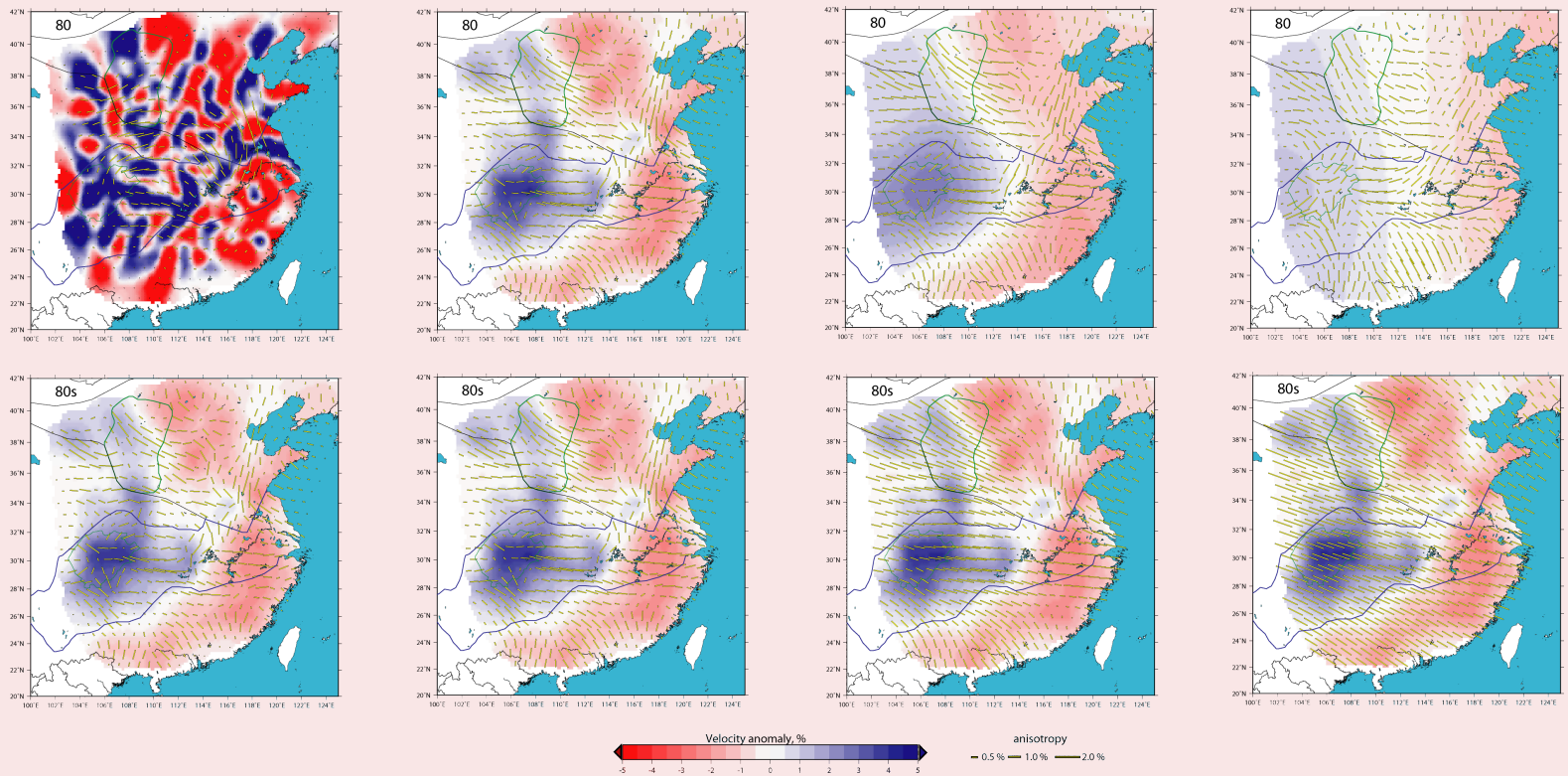
Path coverage

For various periods

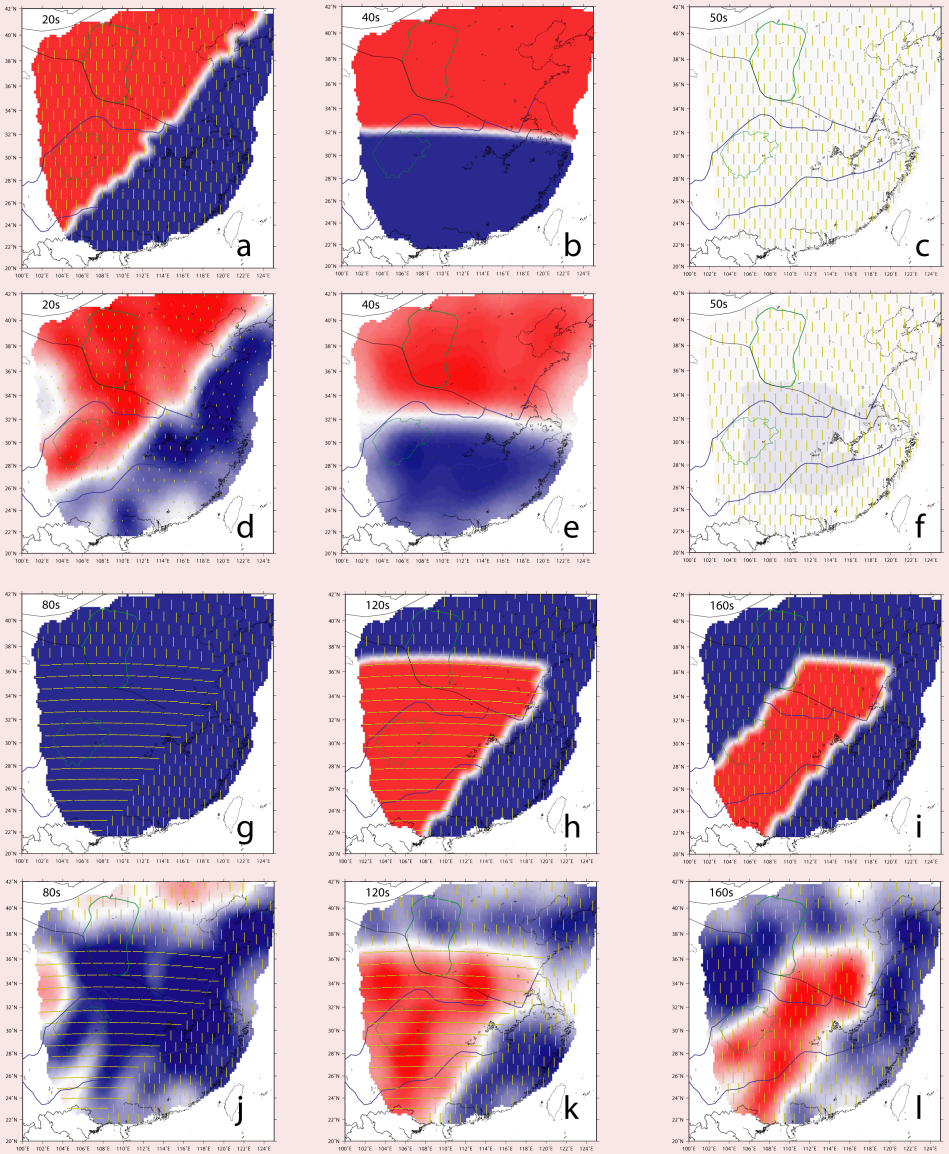


- Good coverage at 20s.
- Excellent coverage at 24-200s.
- Even distribution.

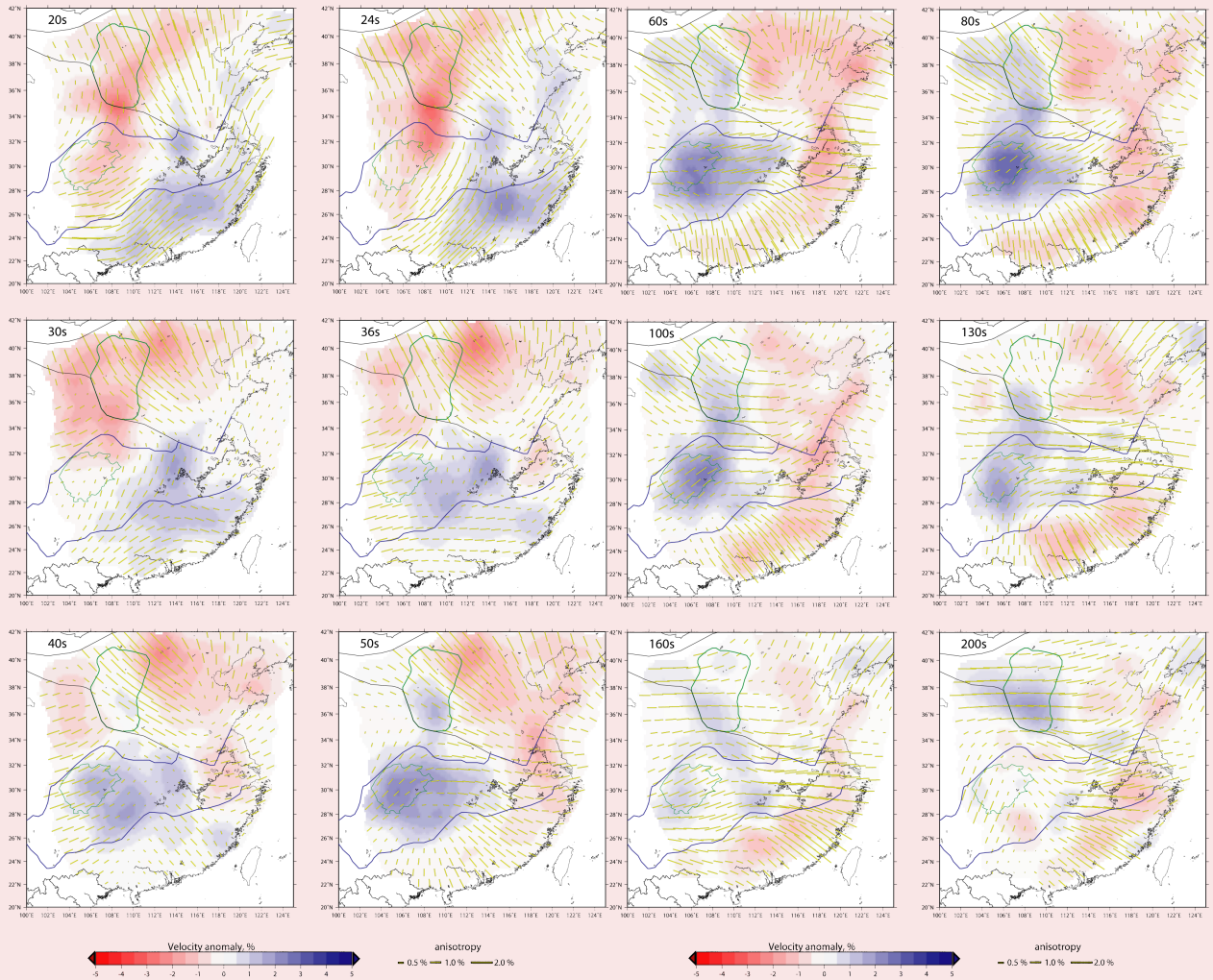
Constraining the inversion



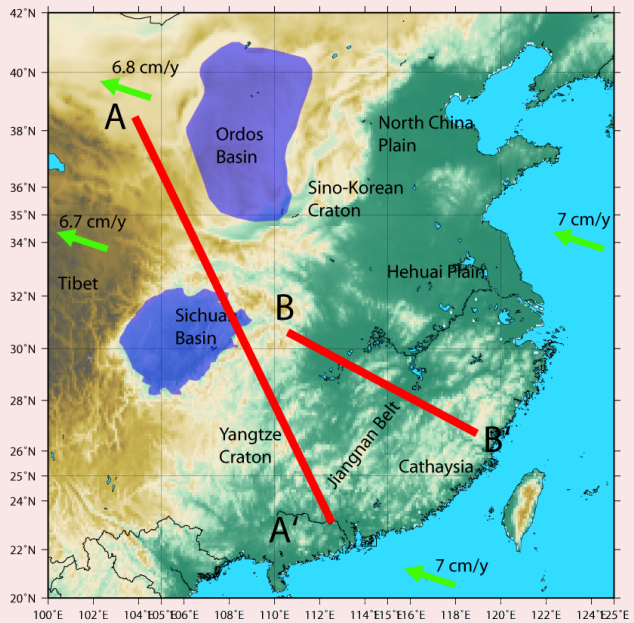
For both isotropic and anisotropic variations

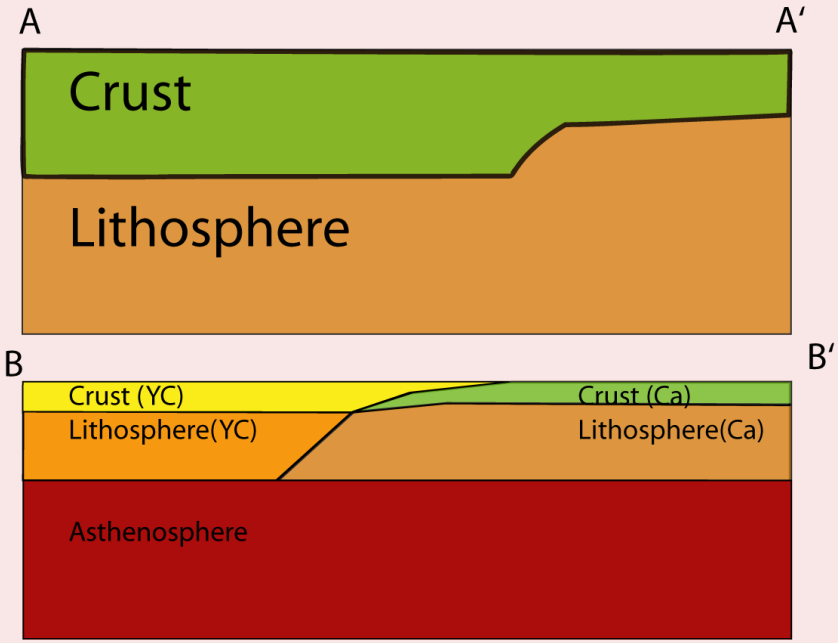


Period of 20 –200 sec



Interpretation





- Crustal thickness.
- Cratonic roots.
- Isotropic and anisotropic variations.

Conclusions

Isotropic

- Crustal thickening towards the west.
- Contrast craton / basins / Cathaysia.
- (An)isotropic variation in period (depth).

Anisotropic

- Less deformation in the craton.
- Difference Cathaysia / Yangtze.
- (An)isotropic variation in period (depth).

Conclusions

Method

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

Improvements

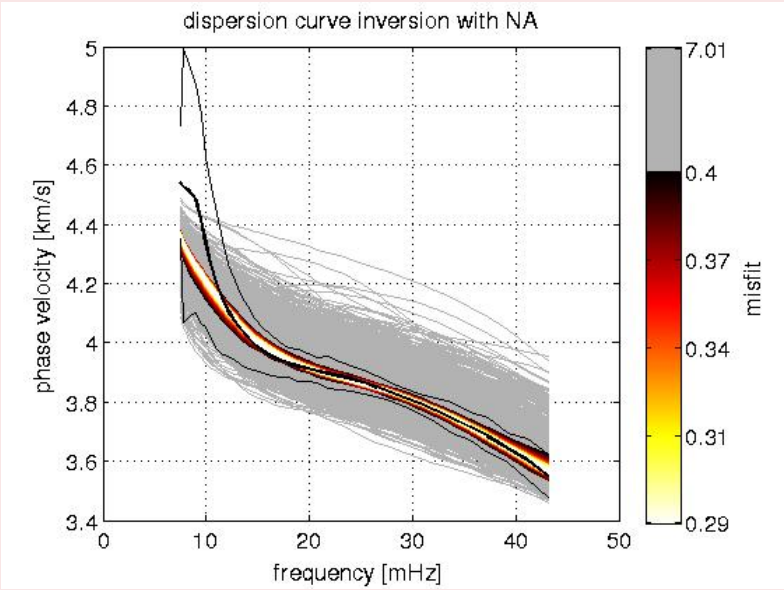
- Using more seismic stations.
- OBS in oceanic regions.
- Inversion for shear-velocity.
- Joint inversion with Receiver Function.

Acknowledgment

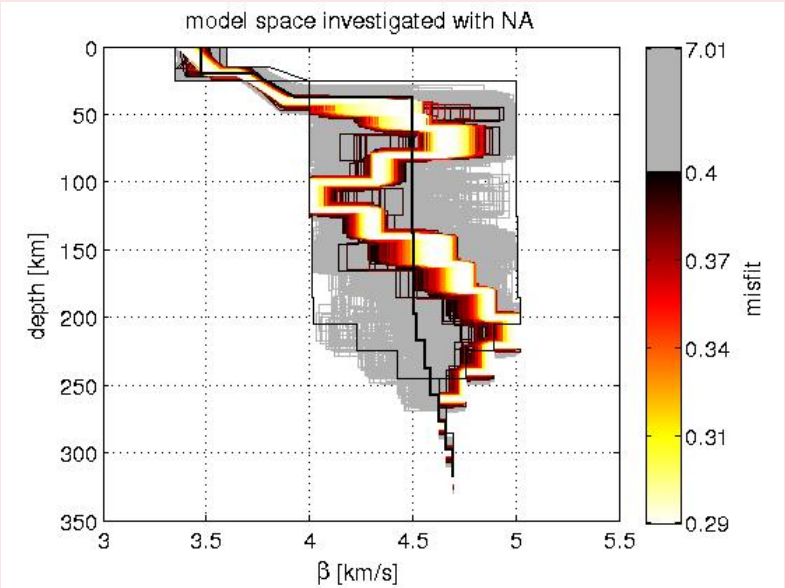
Thank you for your attention !

N/A inversion

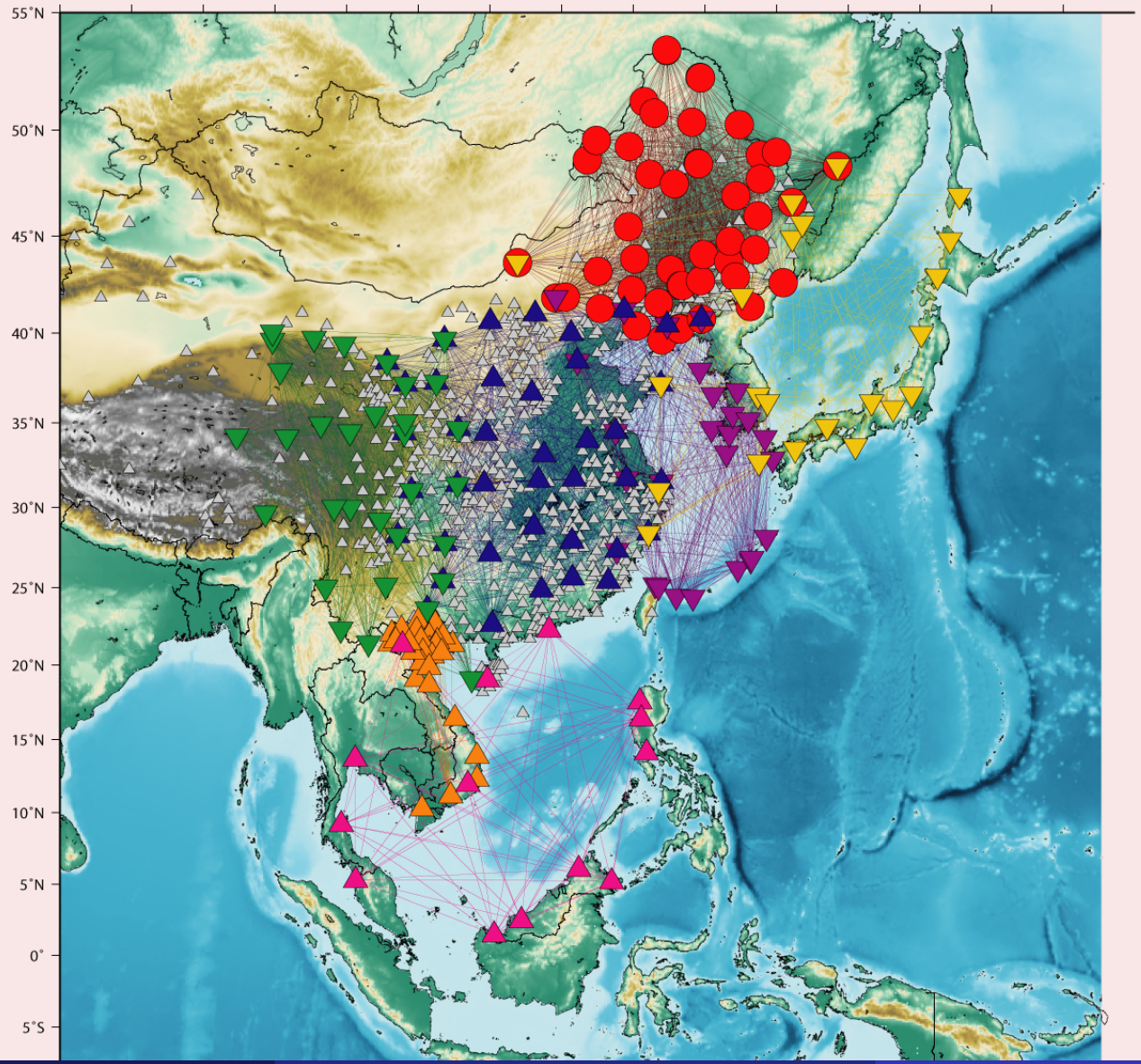
For dispersion curves



Model space

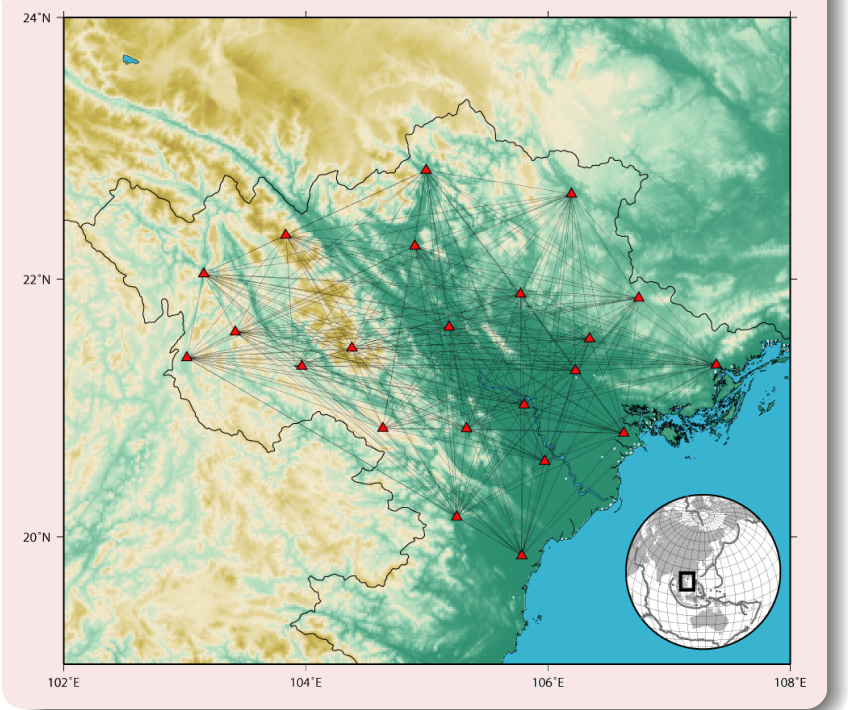


Mainland China and around

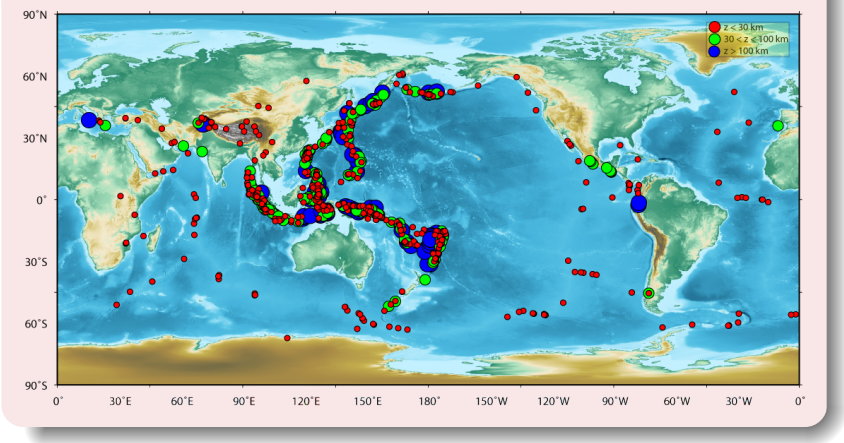


Vietnam

Seismic stations



Earthquakes



Period of 10 – 40 sec