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GEO-DEEP 9300: Introduction to surface wave tomography

Valerie Maupin

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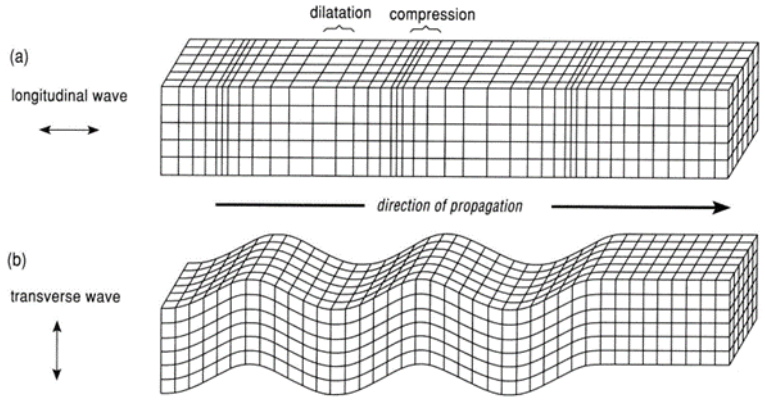
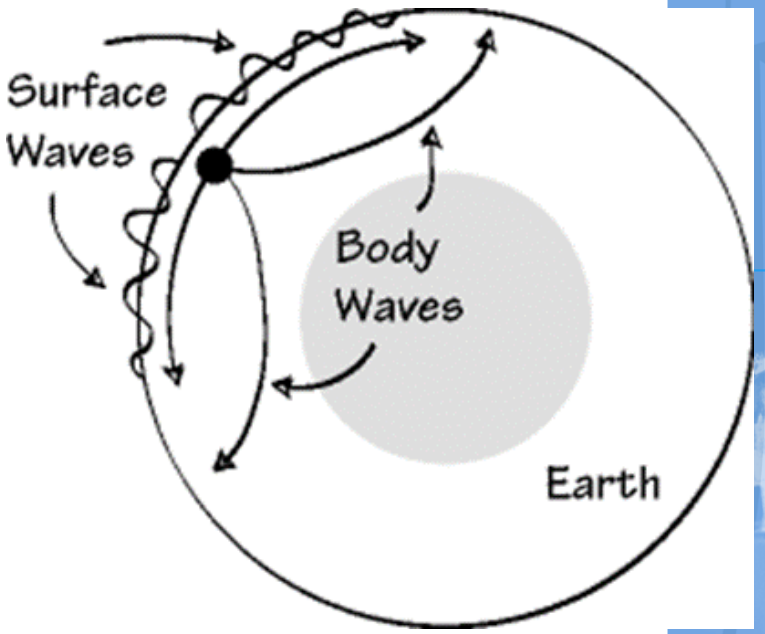
Body wave and surface wave tomography

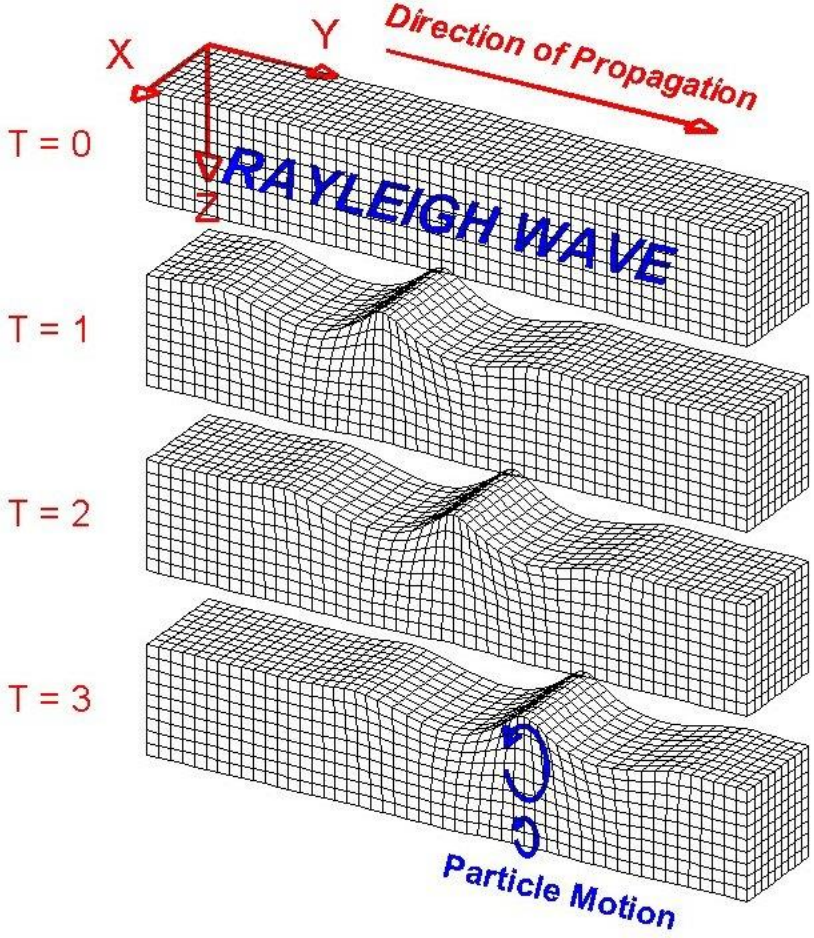
P and S waves

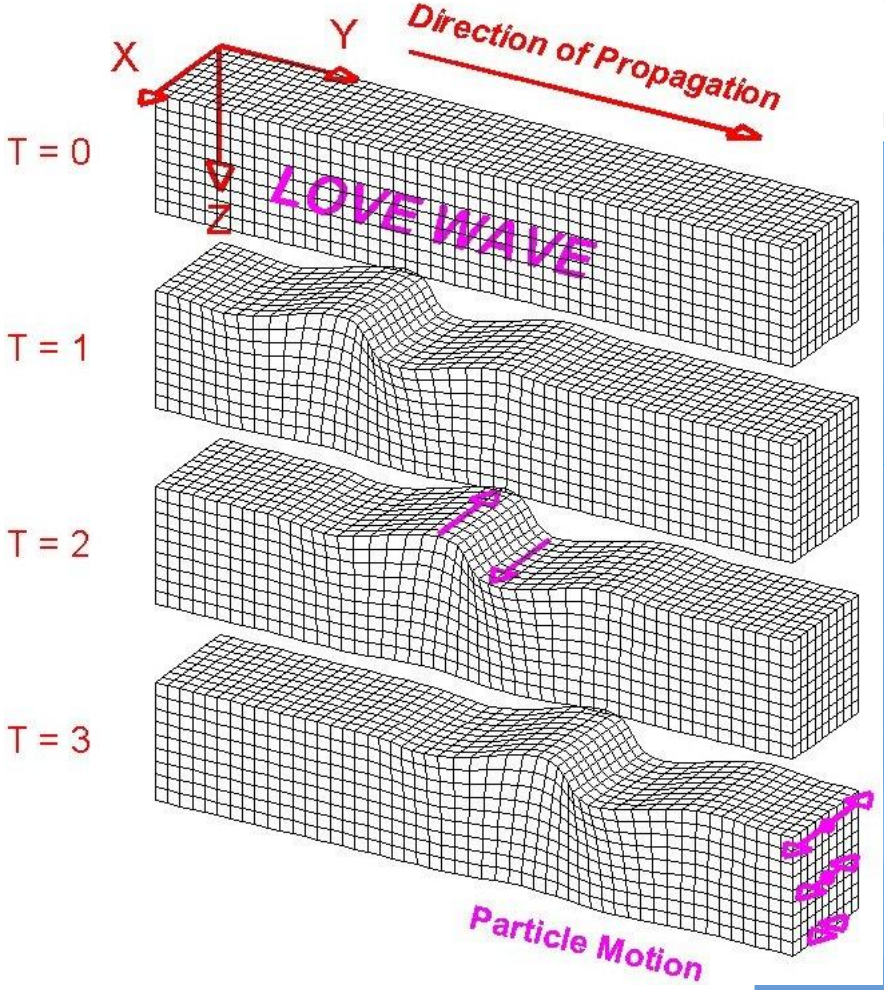




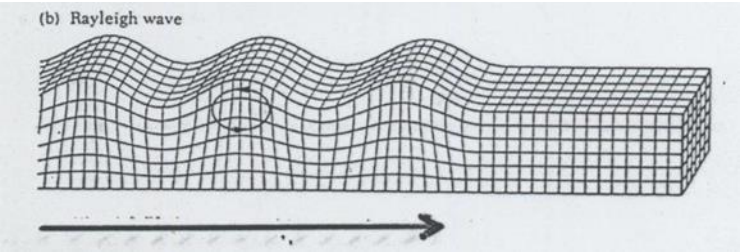
Surface waves summary

Source for figures and animations:
http://web.ics.purdue.edu/~braile/edumod/waves/WaveDemo.htm





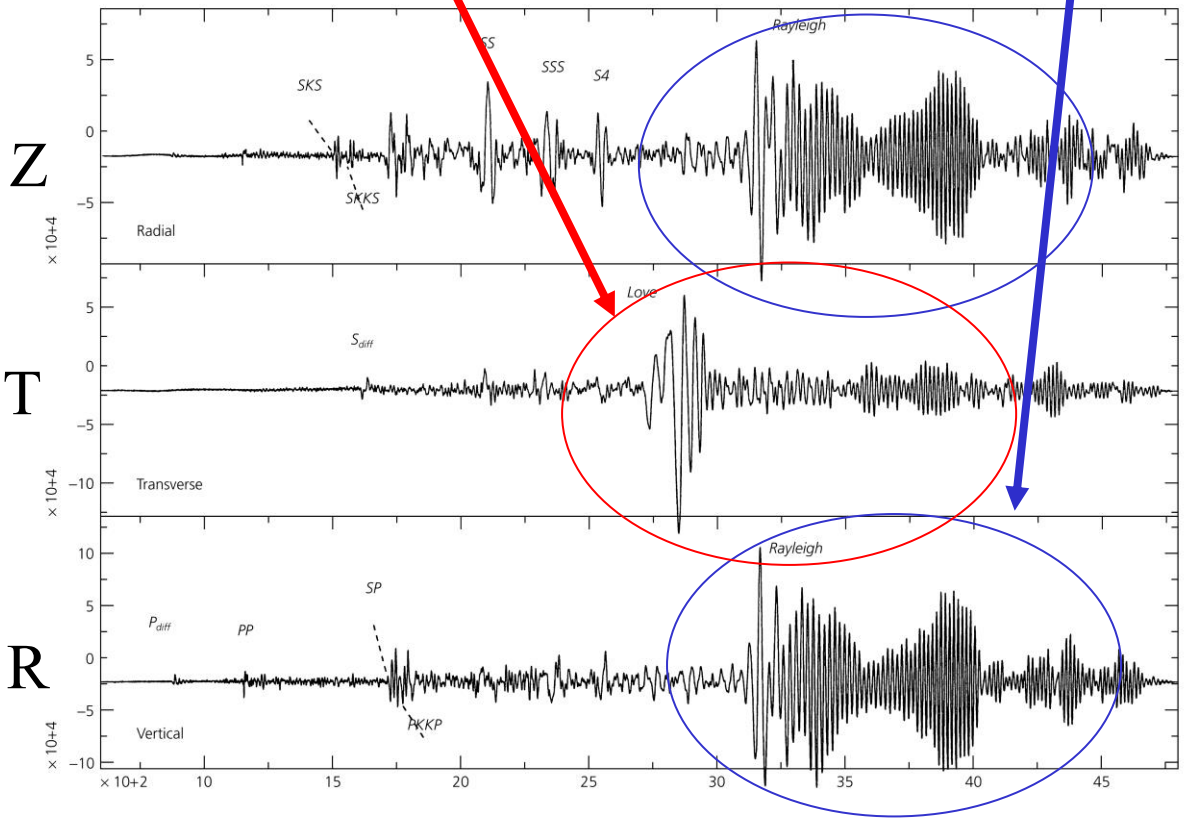
Rayleigh wave



Although they are called surface waves, they do not propagate only along the surface, but have a penetration depth.

Love **Rayleigh**

Figure 2.7-1: Seismograms recorded at a distance of 110°, showing surface waves.



Large earthquakes generate Rayleigh waves propagating for hours around the Earth

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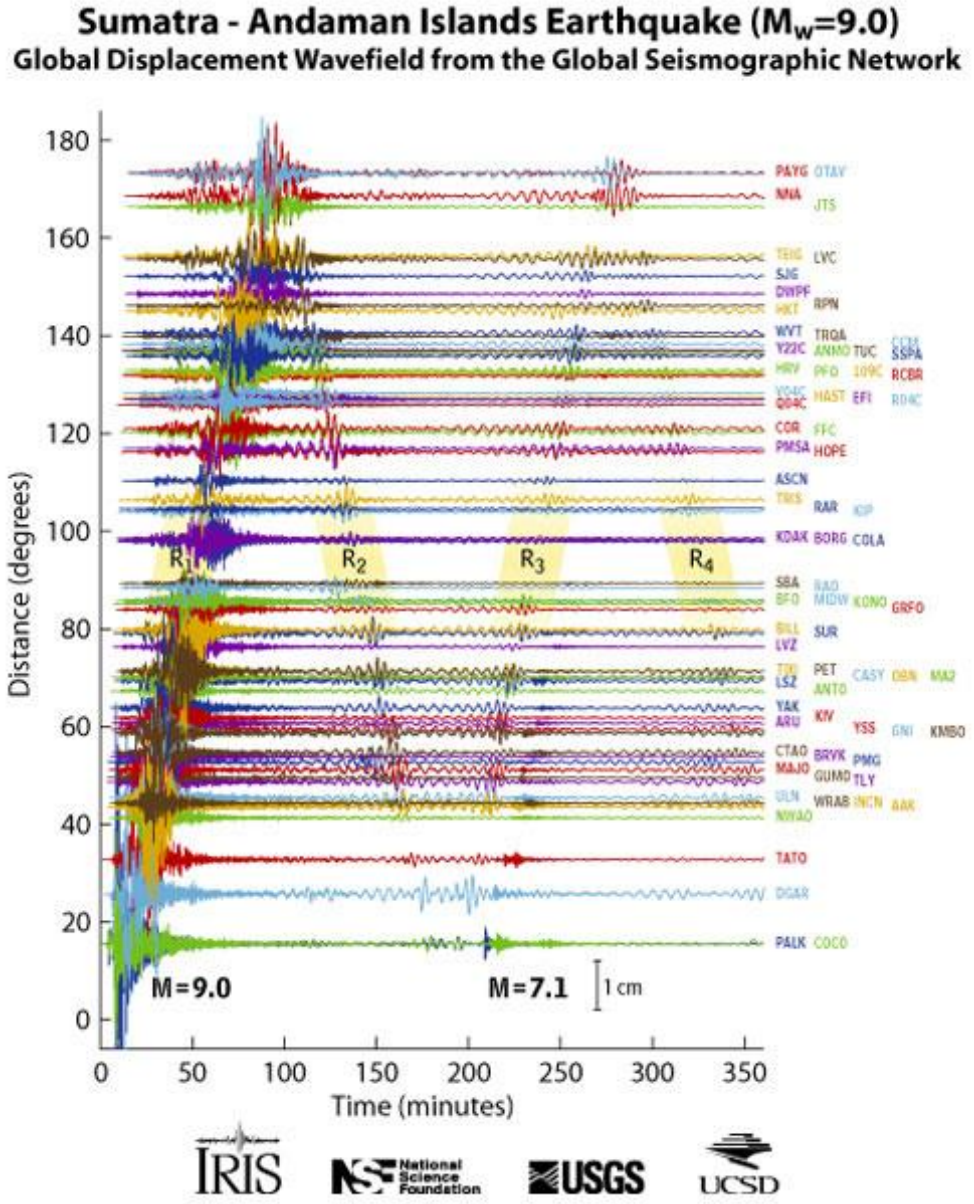
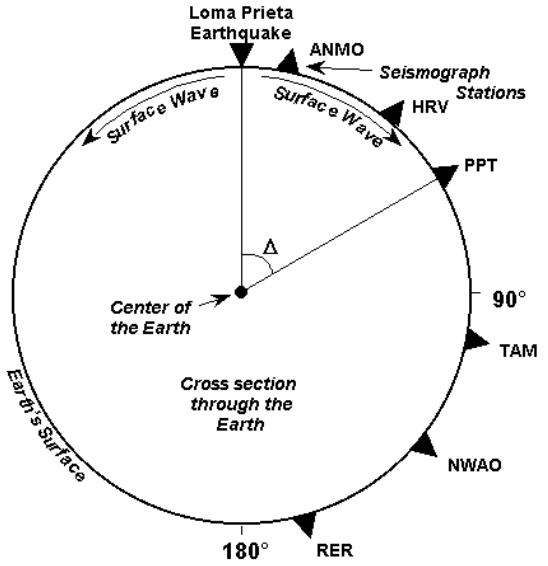
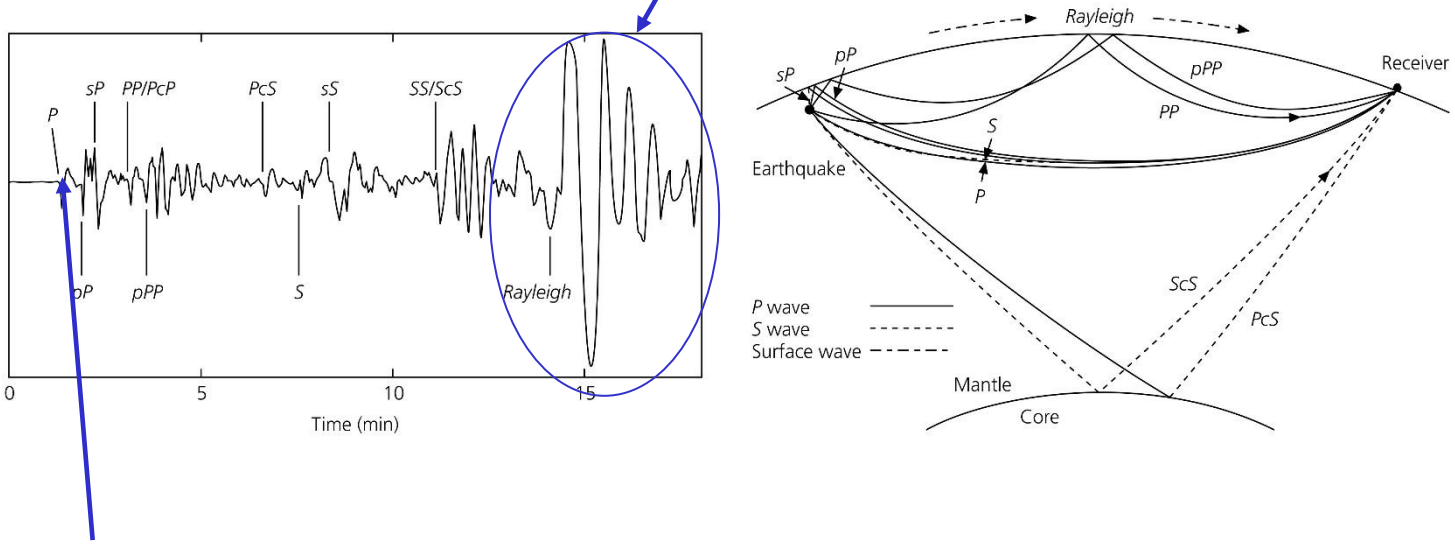




cannot “pick” the arrival time of a surface wave

Figure 1.1-3: Example of seismogram, showing accompanying ray paths.



“pick” the arrival time of P wave

Rayleigh waves with oceanic and continental paths can show very long wavetrains

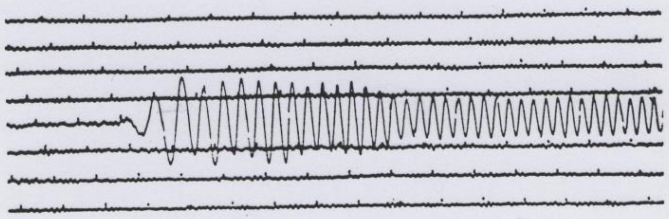


Figure 8.13 Example of Rayleigh wave dispersion for an oceanic path (WWSSN long-period record at Atlanta, Georgia).

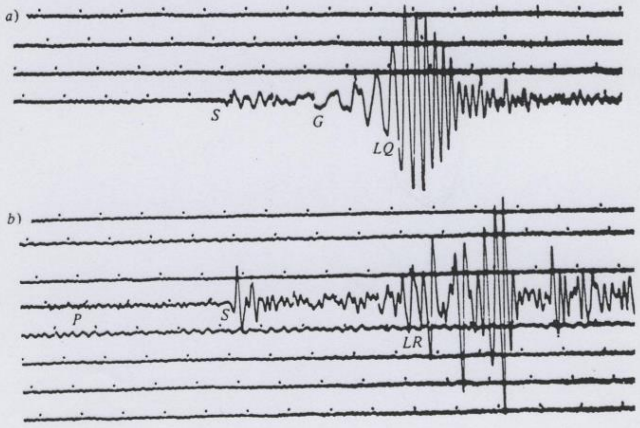


Figure 8.12 WWSSN long-period records for Baja California events at Atlanta, Georgia, epicentral distance 3000 km: a) transverse component; b) radial component. after Kennett (83).

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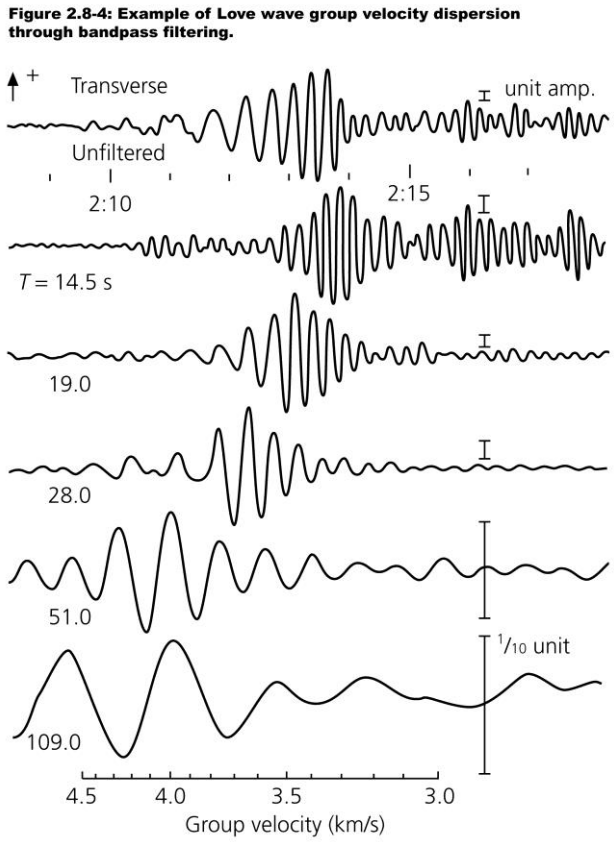
The different periods have different velocities. This is called “dispersion”



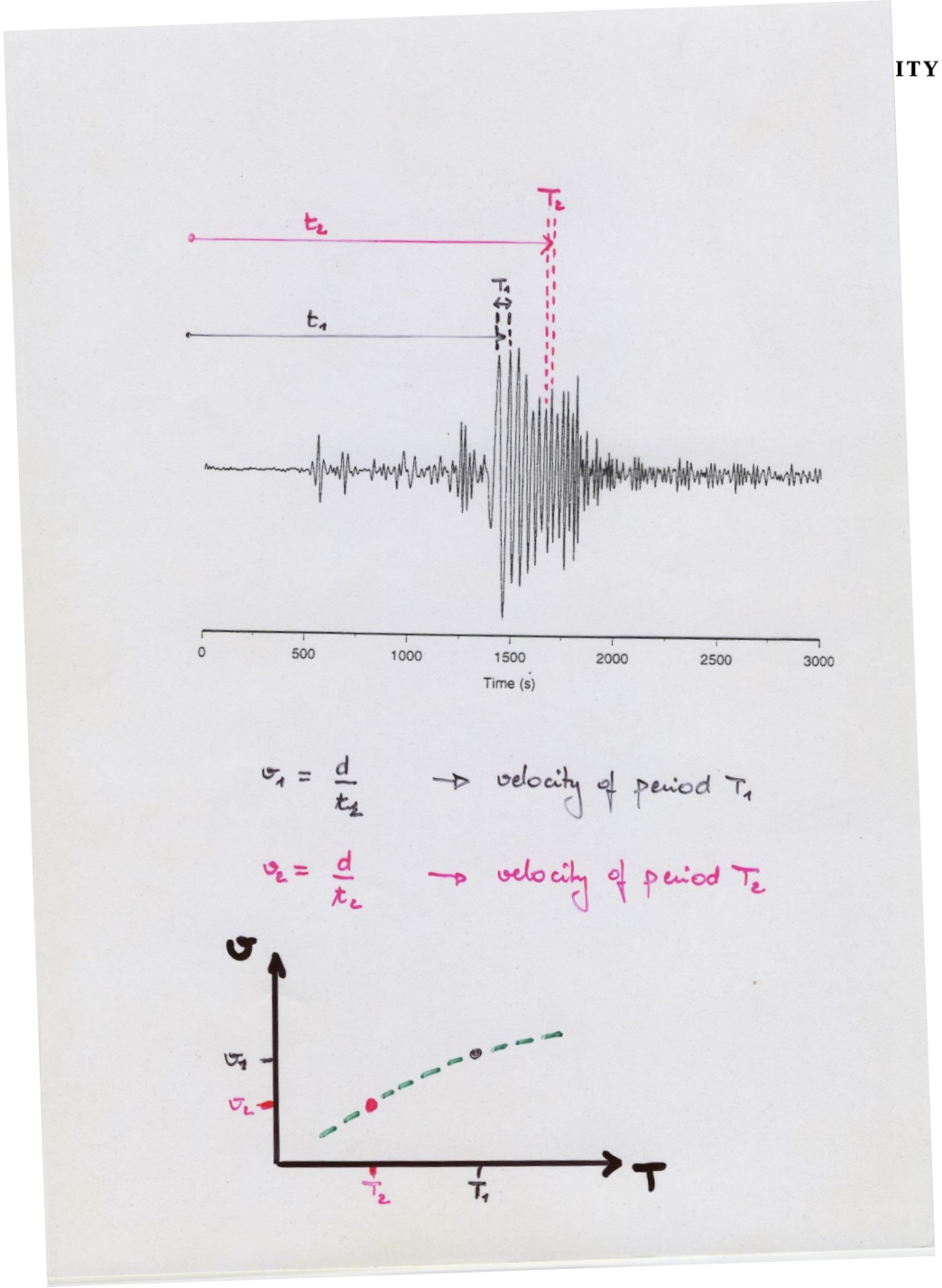
Full record

Filtered records

Note the periods vary here from 14.5 to 109.0 seconds

How to measure the velocities as a function of period

Very schematically!



Phase and group velocities

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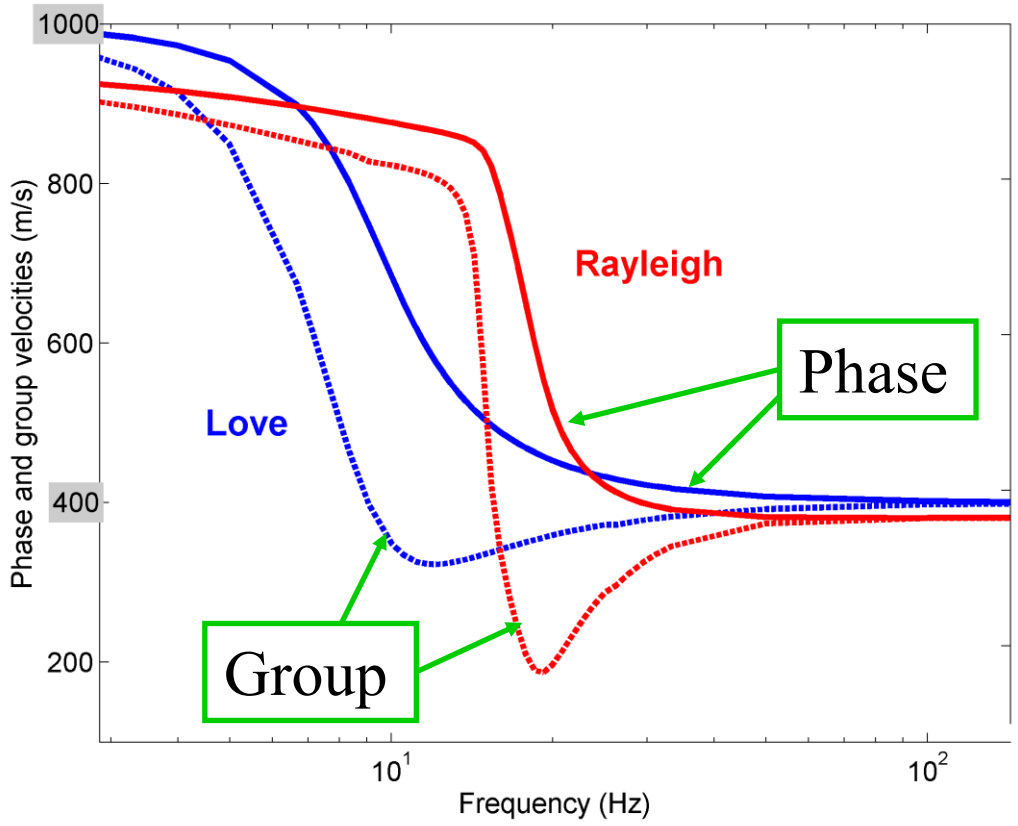
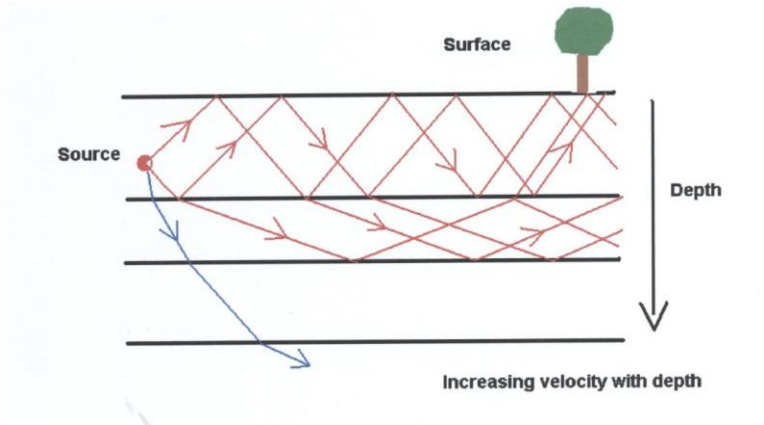
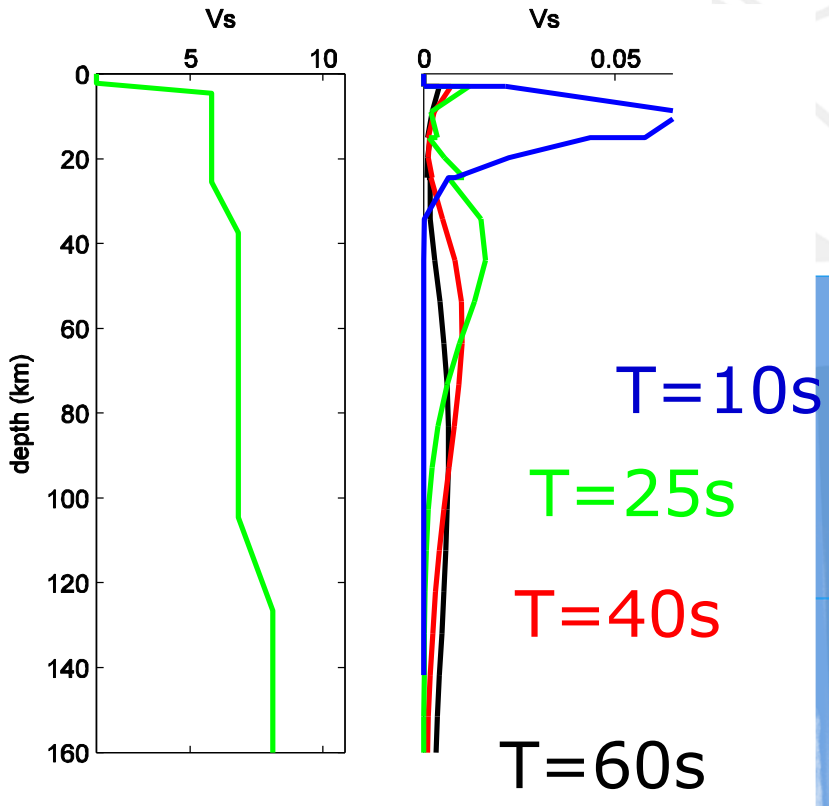
Surface waves have two types of velocities (velocity of individual peaks and velocity of the envelope) that are measured differently.





Surface waves are trapped waves.

They have a horizontal wavelength and a related penetration depth. For mantle studies, wavelength is typically 40 to 250 km and penetration depth 20 to 140 km. This means they are only sensitive to large-scale features.



Depending on their wavelength, surface waves are trapped in the mantle, crust, sediments, near-surface…

How to use them for imaging the lithosphere?

Principle of surface wave tomography

Illustrate one methodology among others

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How to use them for imaging the lithosphere?

Principle of surface wave tomography

- For each path, measure velocity as a function of period
- For each period, combine the velocities along all the paths to a 2D map of the velocity at each period (TOMOGRAPHY)
- At each location on the map, gather the velocity as a function of period
- Transform this to S/wave velocity as a function of depth for this location
- Gather all the depth profiles into a 3D model

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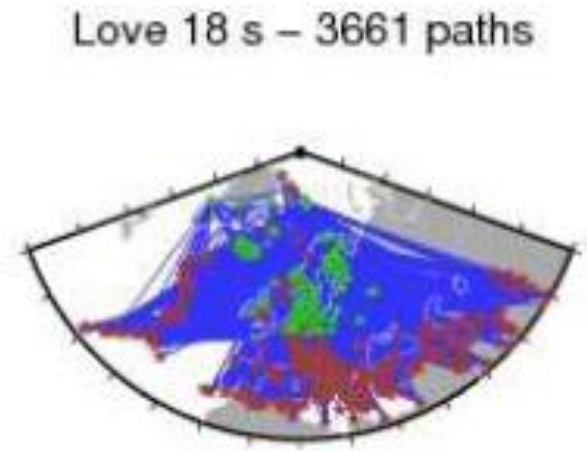

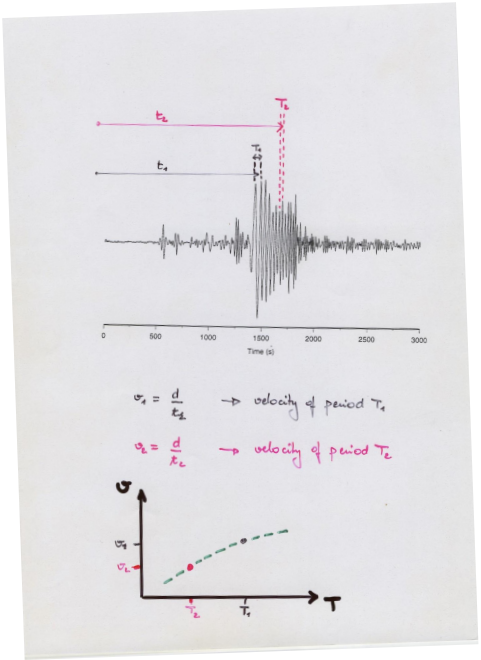

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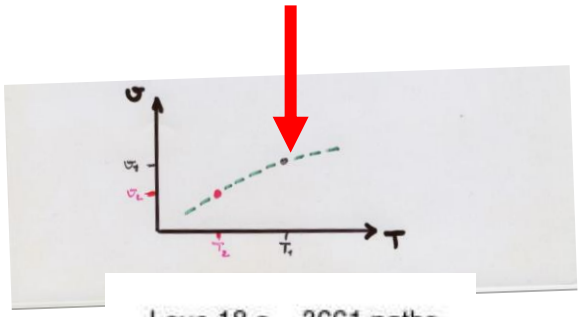

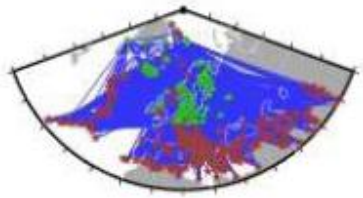

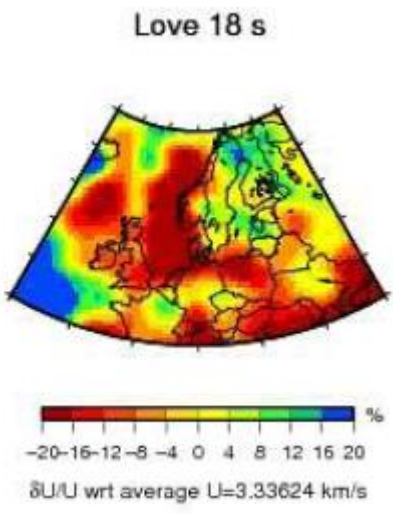

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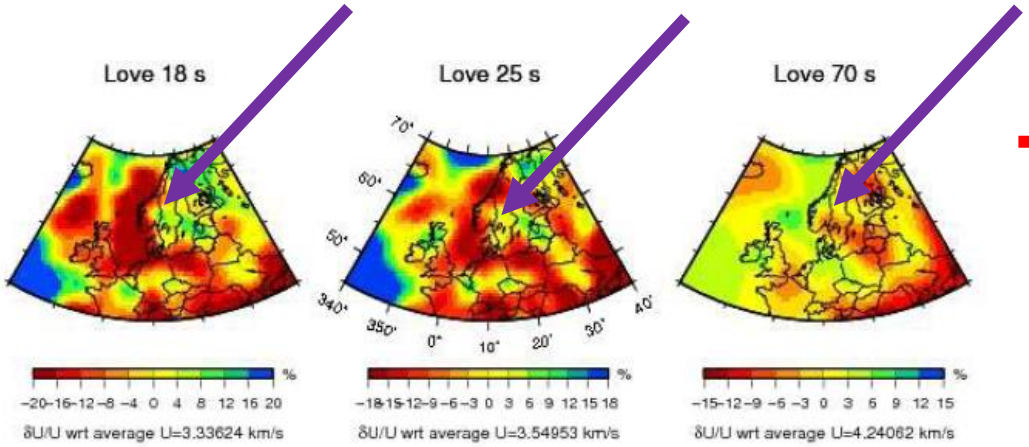

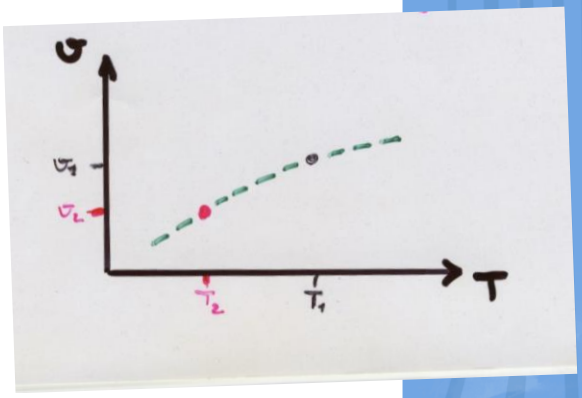

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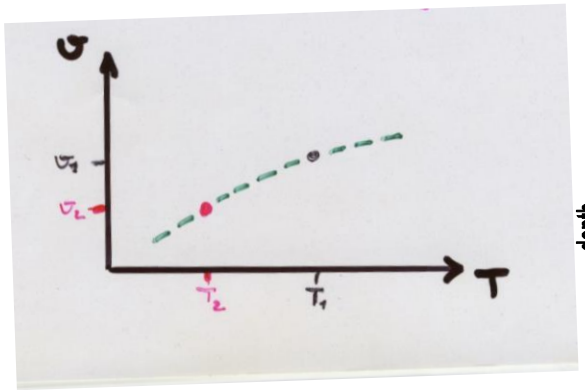

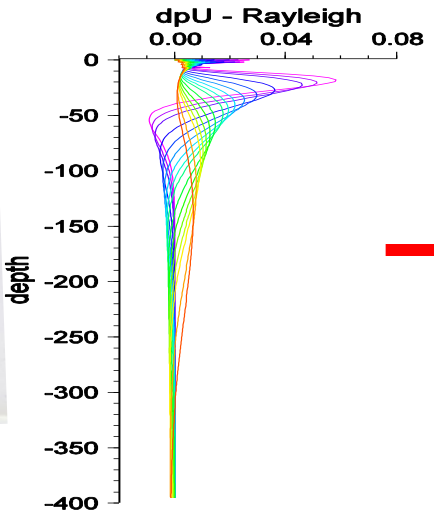

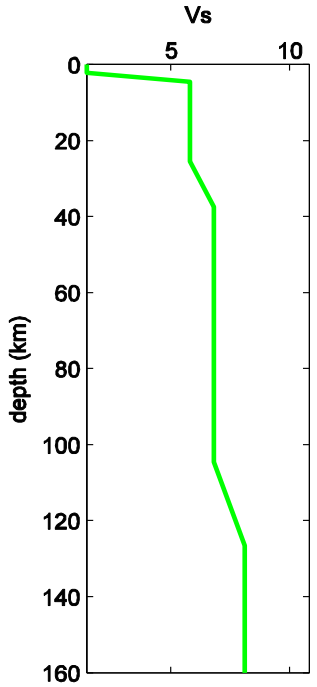

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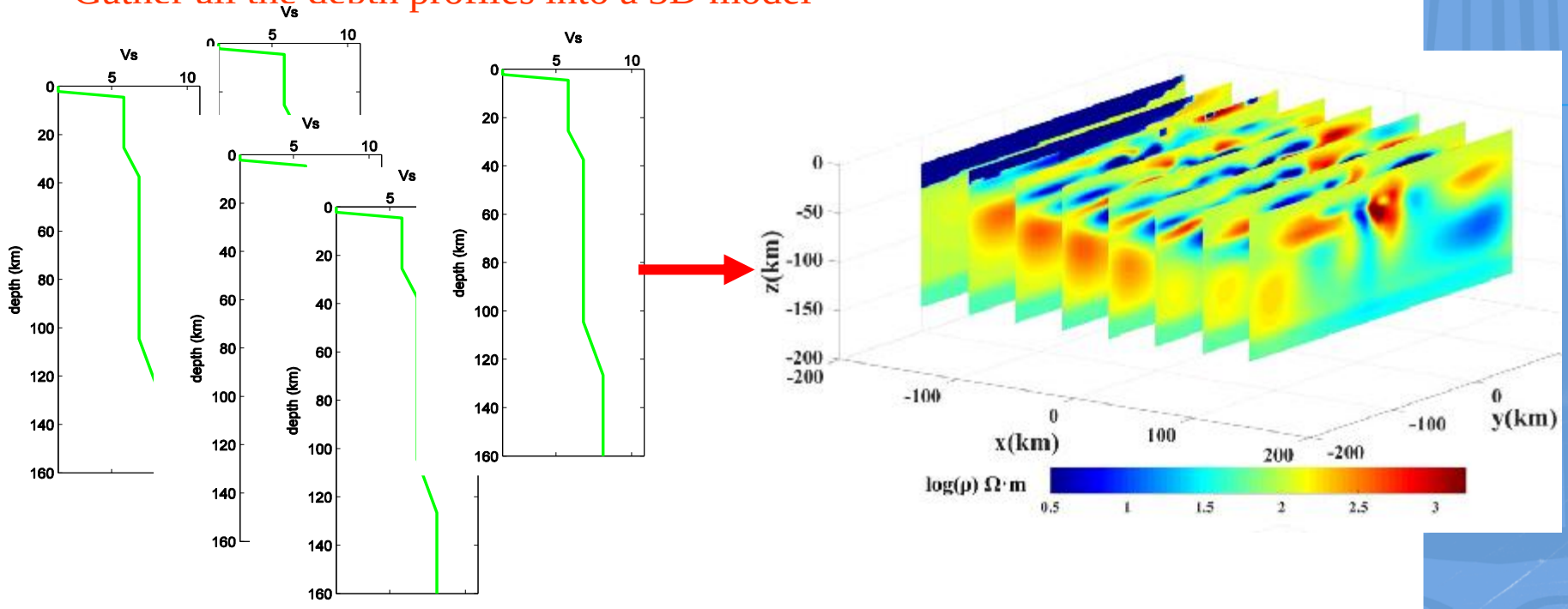


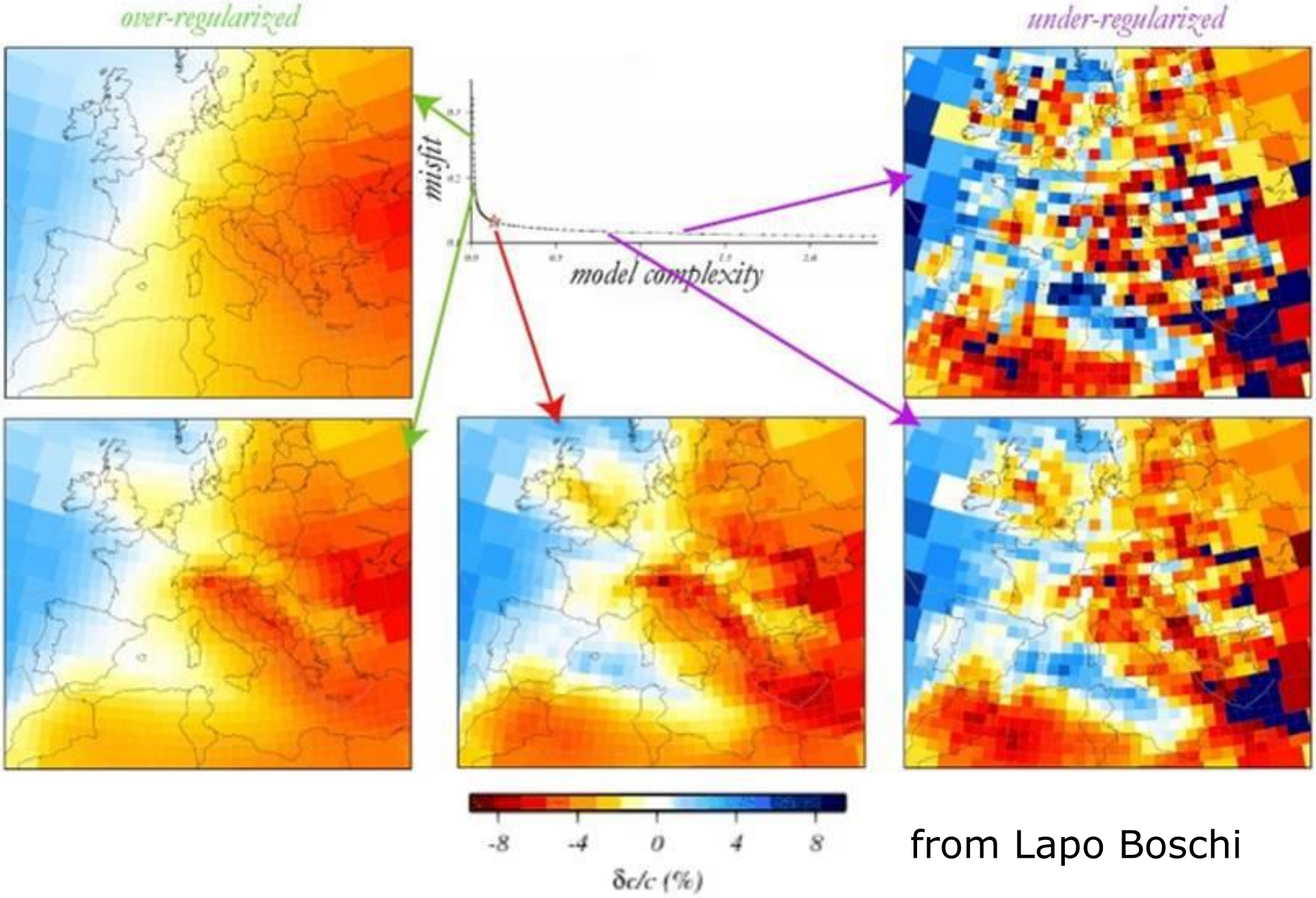
Advantages of surface wave tomography

- Good global coverage
- Coverage in oceanic areas without earthquakes and seismometers
- Give information on S-wave velocity
- Give information on absolute values of velocities

Disadvantages

- Large wavelengths → resolve large-scale features
- Limited depth resolution (OK for the lithosphere)
- Does not distinguish between sharp and smooth depth variations

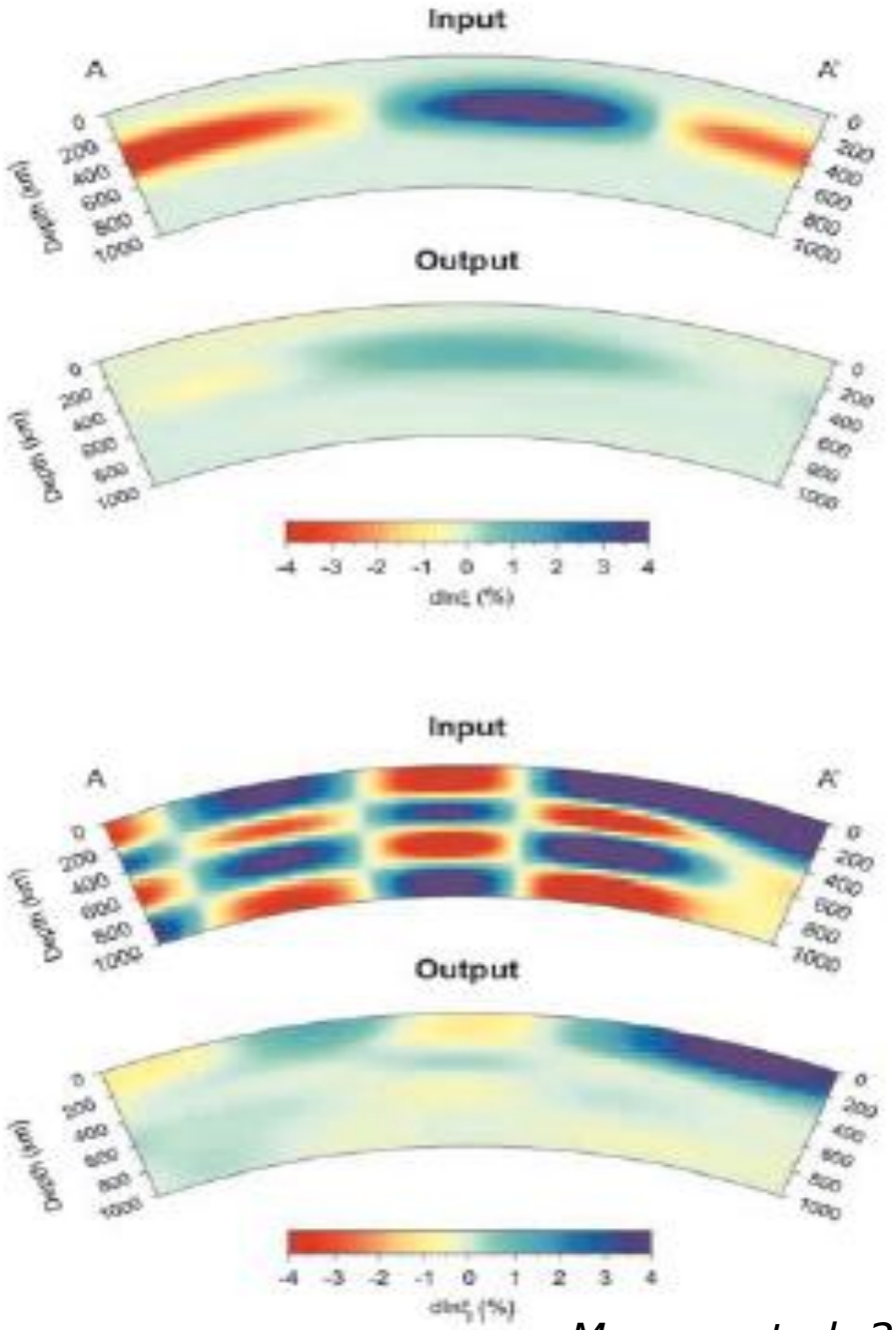
Tomography results are non-unique



from Lapo Boschi

Resolution test

- Prepare a model (input)
- Compute synthetic data in model
- Add realistic noise
- Invert synthetic data with same parameters as real data
- Compare input and inverted models



Marone et al, 2007

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Some results and models

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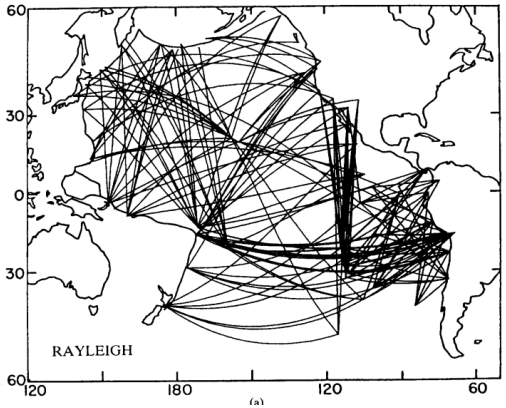
First, a very simple example:

Phase velocity of Rayleigh wave as a function of plate age in the Pacific Ocean



Nishimura and Forsyth, (1989)

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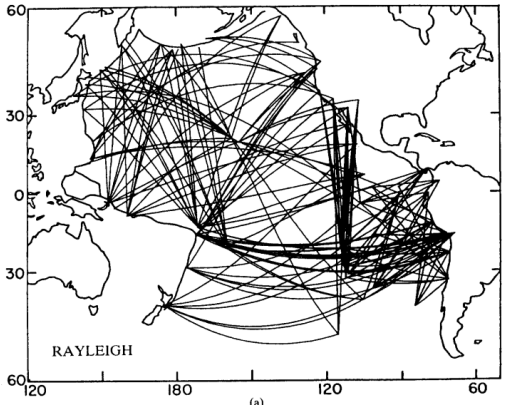

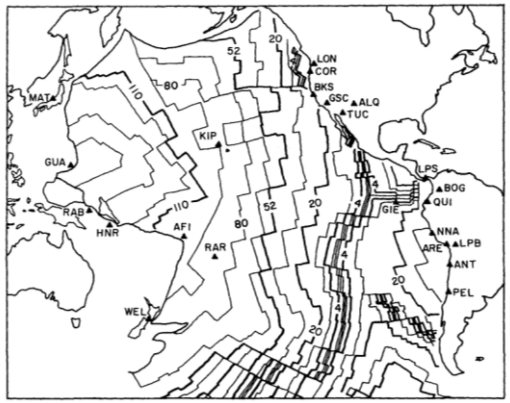

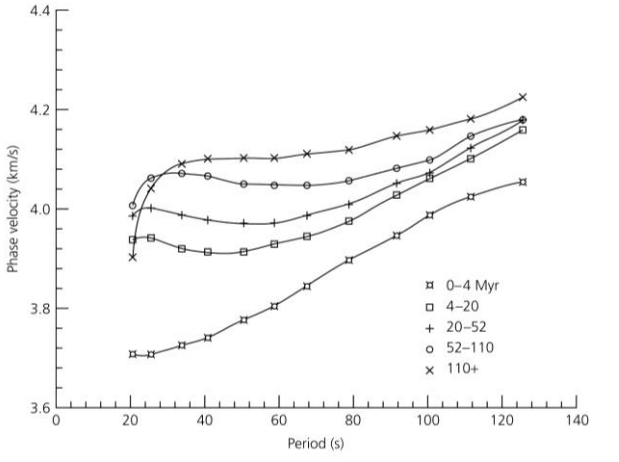

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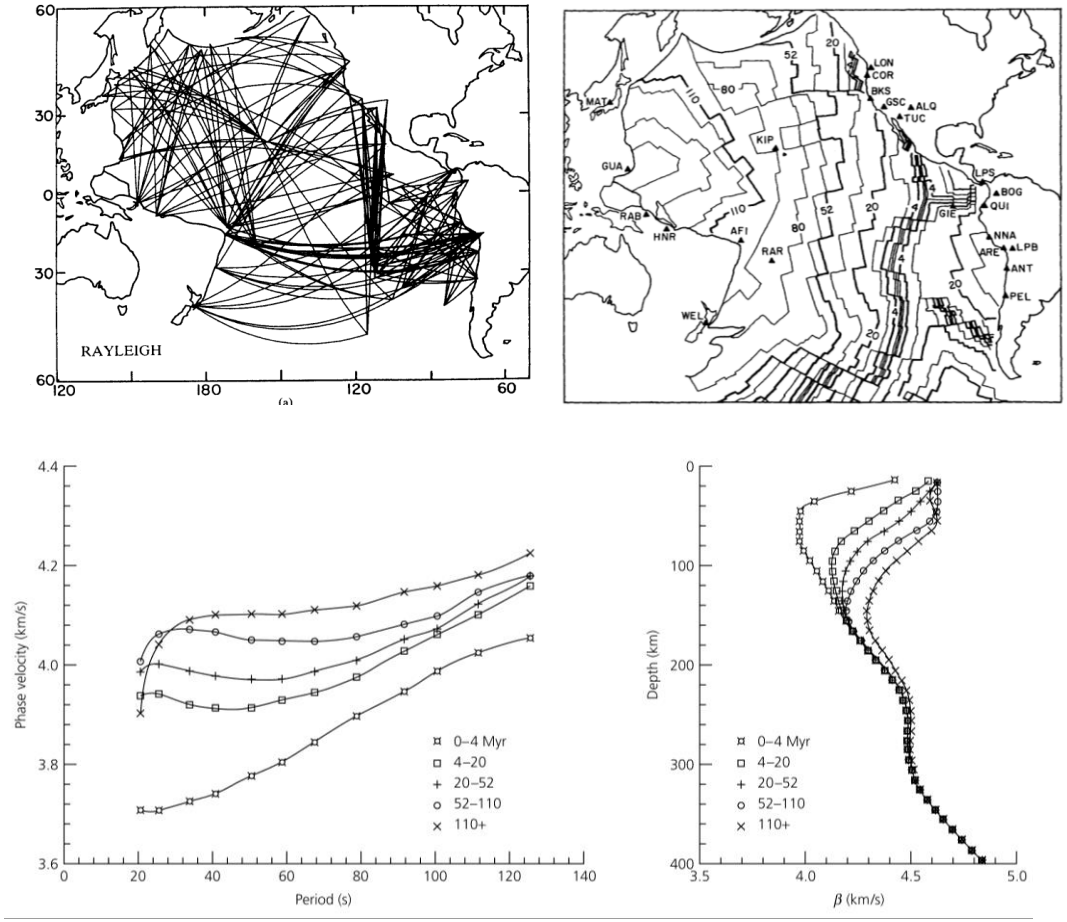
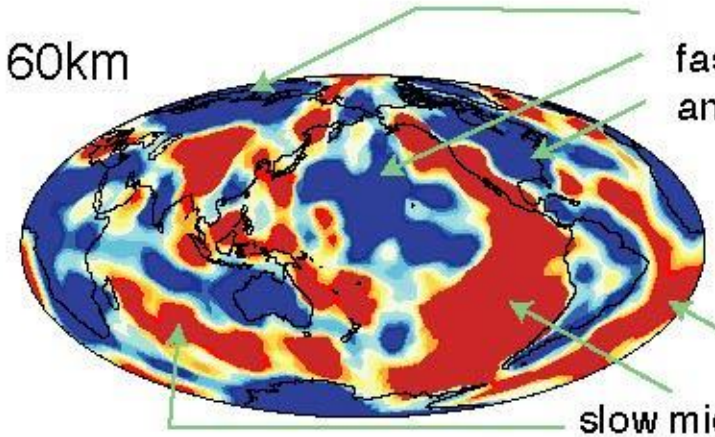
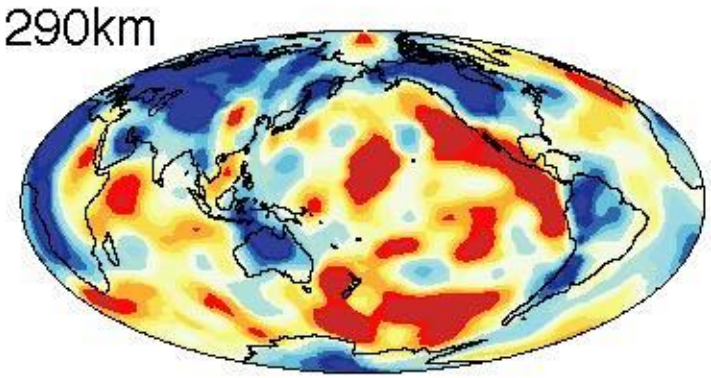


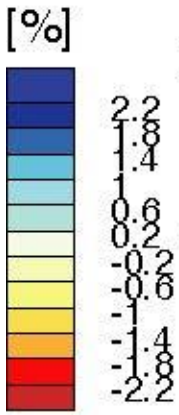
Nishimura and Forsyth, (1989)

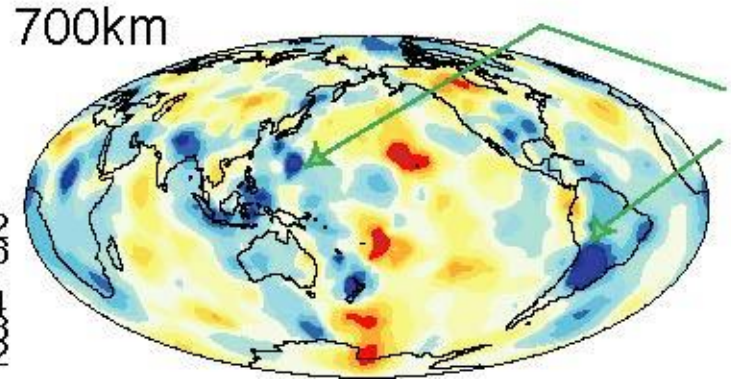
SB4L18-Upper Mantle





the continental plates have fast "keels" at depths at which the oceanic areas are already underlain by the slow asthenosphere

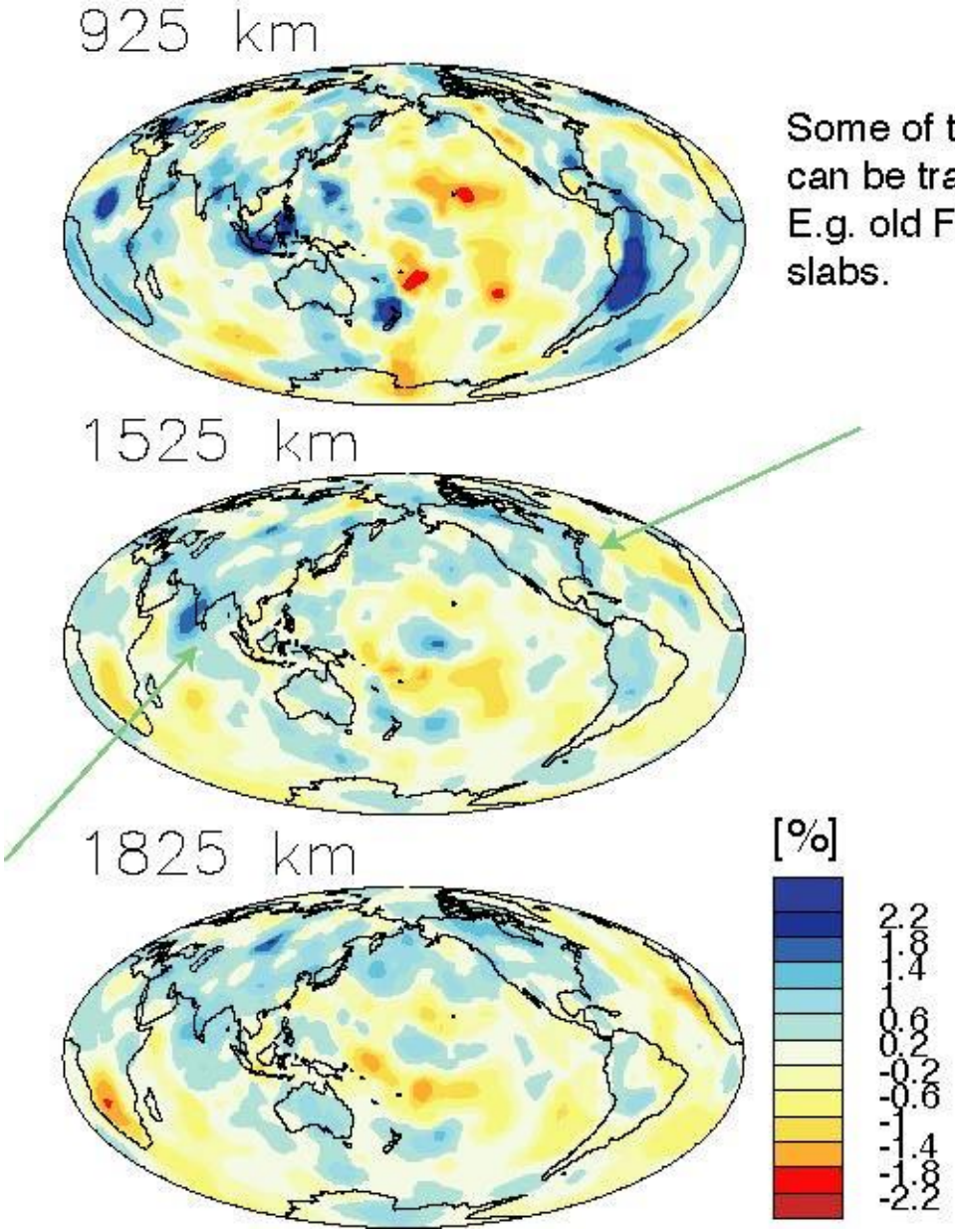




The "cold" subducting slabs show up as seismically fast areas. They pass the 670km discontinuity between upper and lower mantle and penetrate well into the lower mantle.

From Gabi Laske

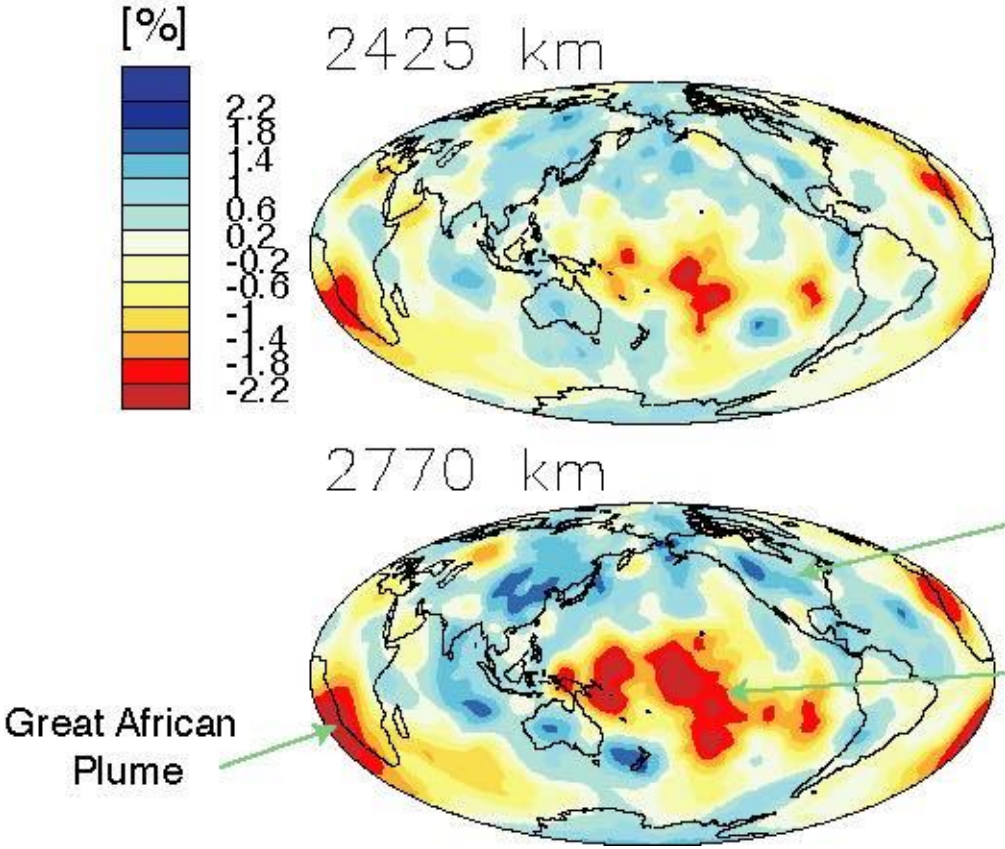
SB4L18-Mid-Mantle



Some of the "cold" subducting slabs can be traced well into the lower mantle. E.g. old Farallon and Tethian subducting slabs.

From Gabi Laske

SB4L18-Lowermost Mantle



The lowermost mantle is dominated by a ring of "fast" material around the Pacific and "slow" material in the Central Pacific and beneath Africa. The fast regions are thought to be the "graveyard of subducting slabs".

From Gabi Laske

Summary

A powerful tool to map the upper part of the mantle and crust

May seem more complex than body-wave tomography

Regularization makes the results non-unique

Lateral variations are small (order of %)

Common interpretation in terms of temperature

Image continental lithosphere/oceanic lithosphere/slabs