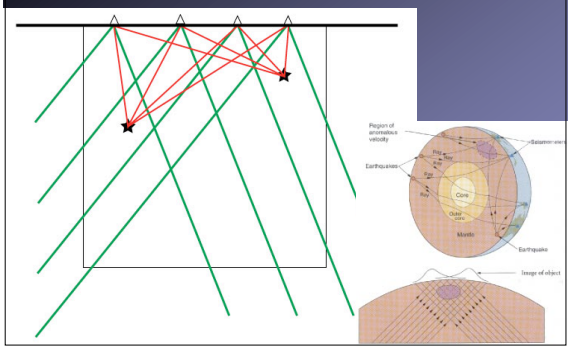
Lecture 7

Seismic tomography

Tomography



Tomographic approaches

1. Local earthquake tomography (LET)
2. Regional earthquake tomography
3. Teleseismic tomography
4. Global tomography

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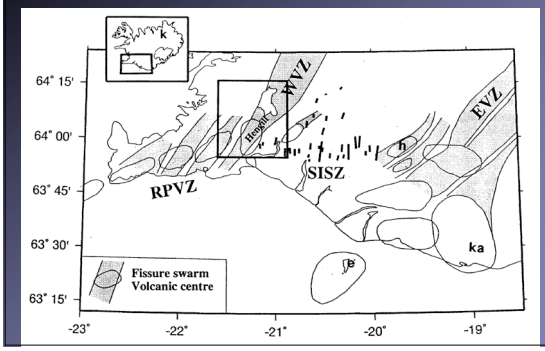
Local earthquake tomography



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Local earthquake tomography

- Divide volume of interest into grid
- Stations should cover the surface
- Earthquakes should fill the volume of interest
- Trilinear interpolation of velocity between grid nodes
- Iterative inversion for improved locations and velocity model

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Local earthquake tomography

- Earthquake locations and velocity structure both unknown
- Iterative inversion for improved locations and velocity model

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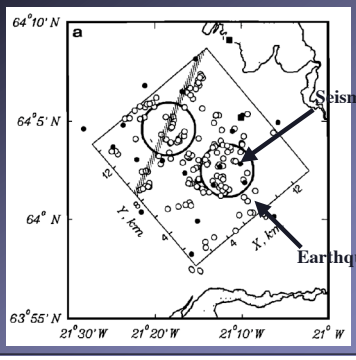
Hengill, Iceland

Local-earthquake tomography



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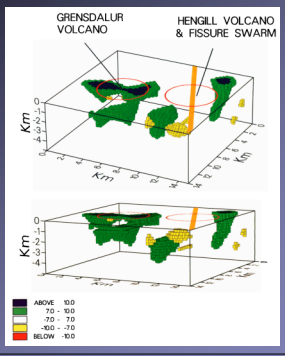
Local-earthquake tomography



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2. Regional earthquake tomography

Regional earthquake tomography

Problems

1. Locations of earthquakes not known
2. Structure between earthquakes and study volume not known

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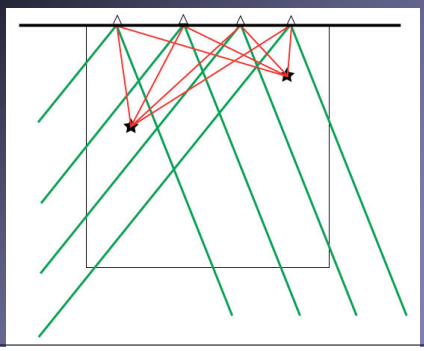
Regional earthquake tomography



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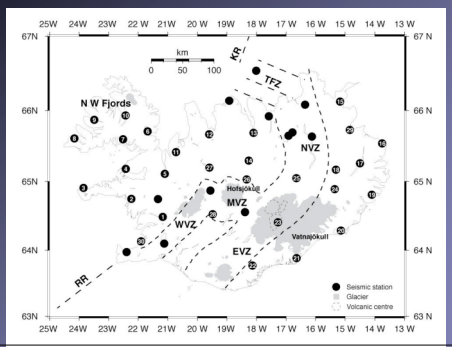
3. Teleseismic tomography

Iceland tomography network



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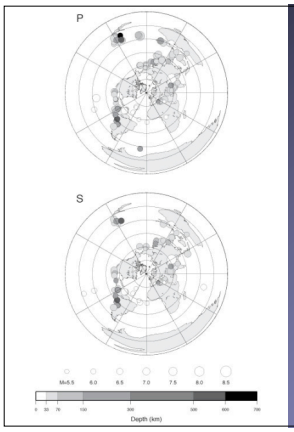
Fieldwork photos



Iceland tomography

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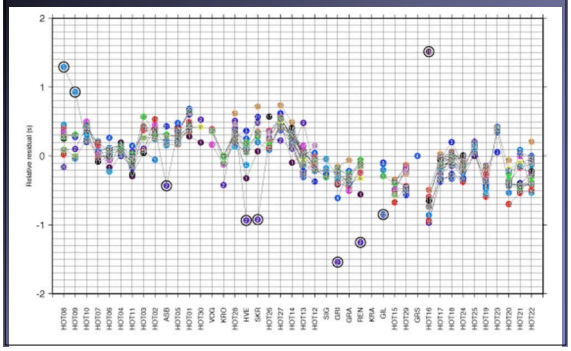
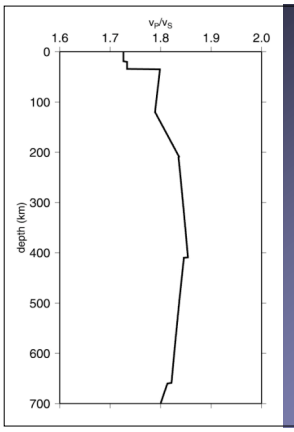
Iceland tomography





Iceland tomography starting model

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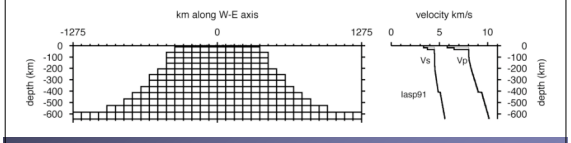
Iceland tomography model



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Inversion is linear because locations of earthquakes not solved for

Assumed planar waves impinge on base of study volume

Thus, damped least squares can be used

Measures of quality

1. Hit-count
2. Resolution
3. Volume metric
4. Retrieval of theoretical structures

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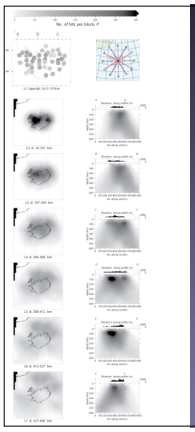

Iceland tomography P "hit-count"

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Resolution

$$\hat{\mathbf{m}} = \mathbf{Rm}$$

where

$\hat{\mathbf{m}}$ = the "true" Earth model

m = the inversion Earth model result

R = the resolution matrix

- Describes the uncertainty in the model as function of data uncertainty and resolution information

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Resolution

- Data uncertainty: estimated from data variance after inversion
- Resolution: Geometric considerations
- What is needed to maximise resolution is crossing rays
- The diagonal elements of **R** give a measure of resolution of a single block
- The spread of values along a single column gives a measure of the "volume averaging"

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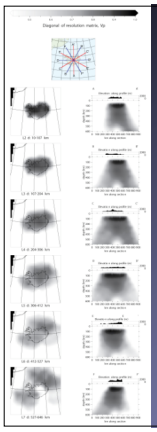

Iceland tomography resolution

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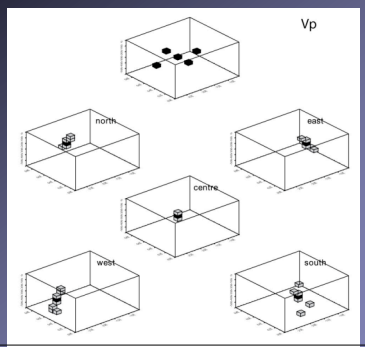
Iceland tomography: “volume metrics”



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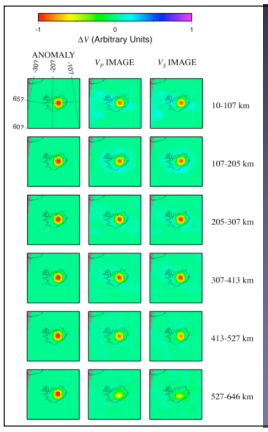

Theoretical Icelandic plume

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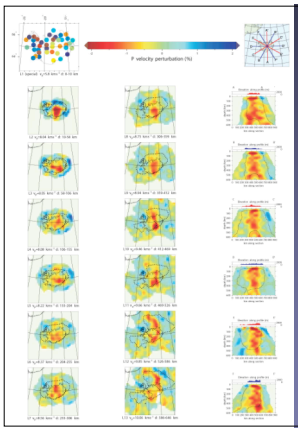

Iceland tomography Vp result

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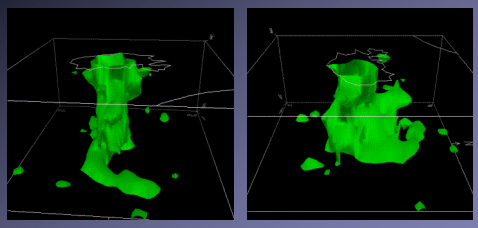
Teleseismic tomography



Looking south looking west

ΔVp > 0.5%

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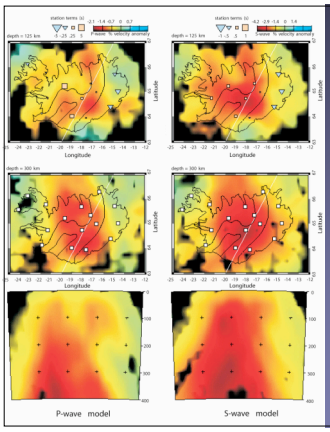

Iceland tomography

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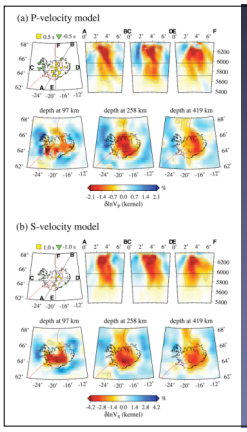

Iceland tomography "banana doughnut"

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Whole mantle tomography

- Earth is a sphere
- Outer core is fairly homogenous because liquid
- Extremely long wavelengths–structures of the order of 1000 km in size best that can be achieved

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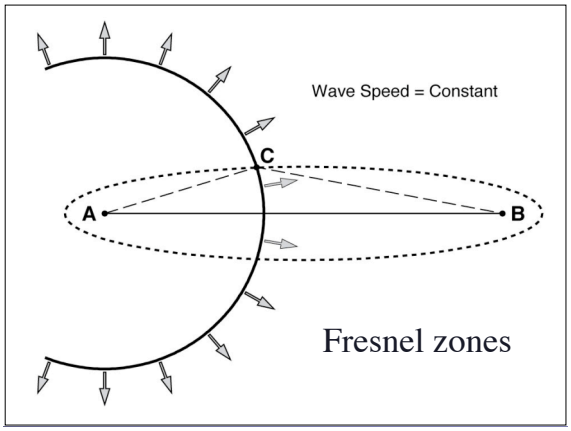

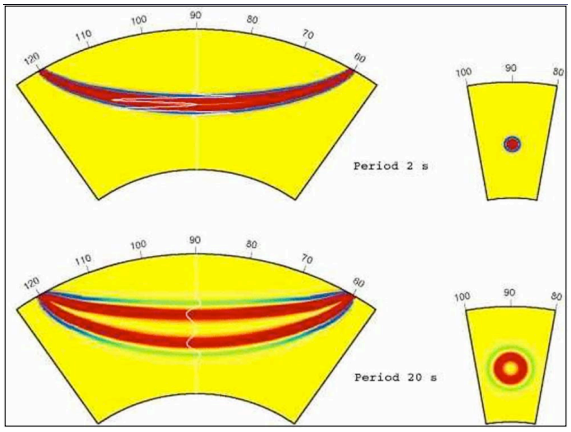

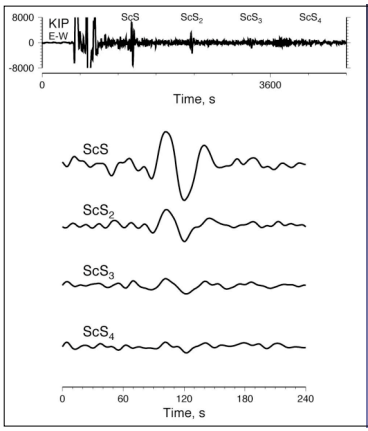

Hawaii ScS_n

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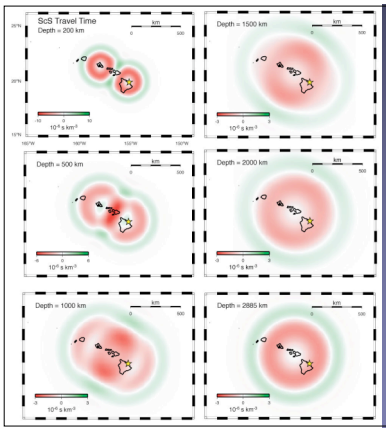

ScS sensitivity volume

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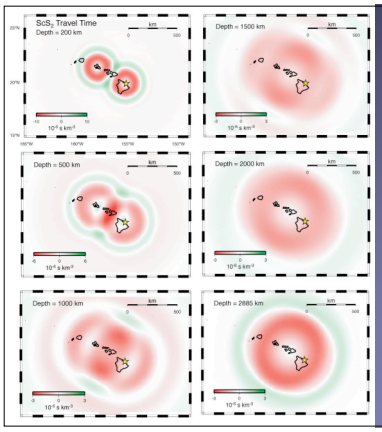

ScS_2 sensitivity volume

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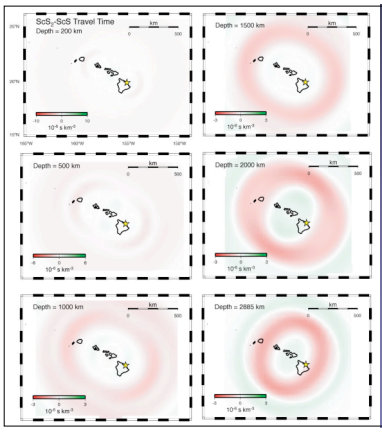

ScS_2-ScS sensitivity volume

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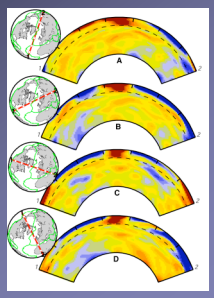
Whole-mantle tomography

- Over 2,000,000 data
  - S-wave arrival times (S, SS, SSS, ScS & SKS)
  - fundamental- & higher-mode Rayleigh-wave phase velocities
  - normal-mode frequencies



Ritsema et al. 1999

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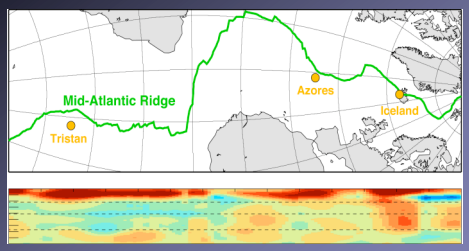
Mantle tomography



Vertical exaggeration x 2

from Ritsema (1999)

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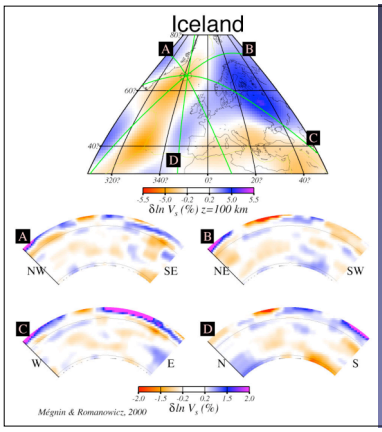

Global surface wave tomography

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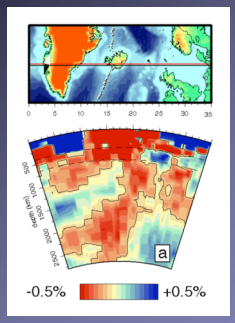

Bijwaard & Spakman (1999)

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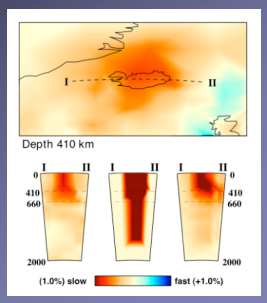
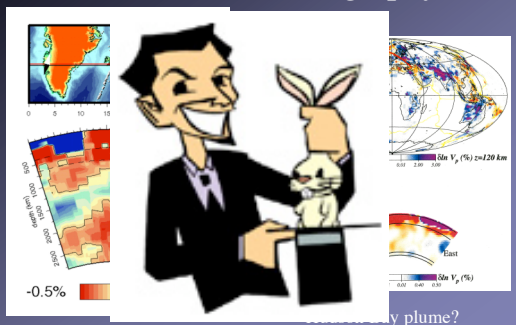
Whole-mantle tomography

The data used by Bijwaard & Spakman have no resolution in the lower mantle



From Foulger et al. (2001) 43

Whole-mantle tomography



Bijwaard & Spakman (1999)

y plume?

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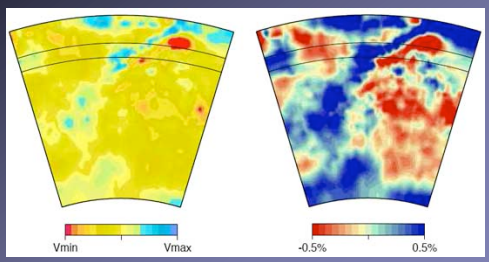
Different color schemes



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