Seismic wave Propagation and Imaging in Complex media: a European network

EBRU BOZDAĞ
Early Stage Researcher

Host Institution: Utrecht University
Place of Origin: Istanbul, Turkey
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Project: Testing and Improving Tomographic Models Using Numerical 3D Wave Propagation

Task Groups: TG Planetary Scale

Cooperation: Oxford University

Universiteit Utrecht

SPICE

Assessment of the tomographic mantle models using SEM seismograms

Ebru Bozdağ
Jeannot Trampert

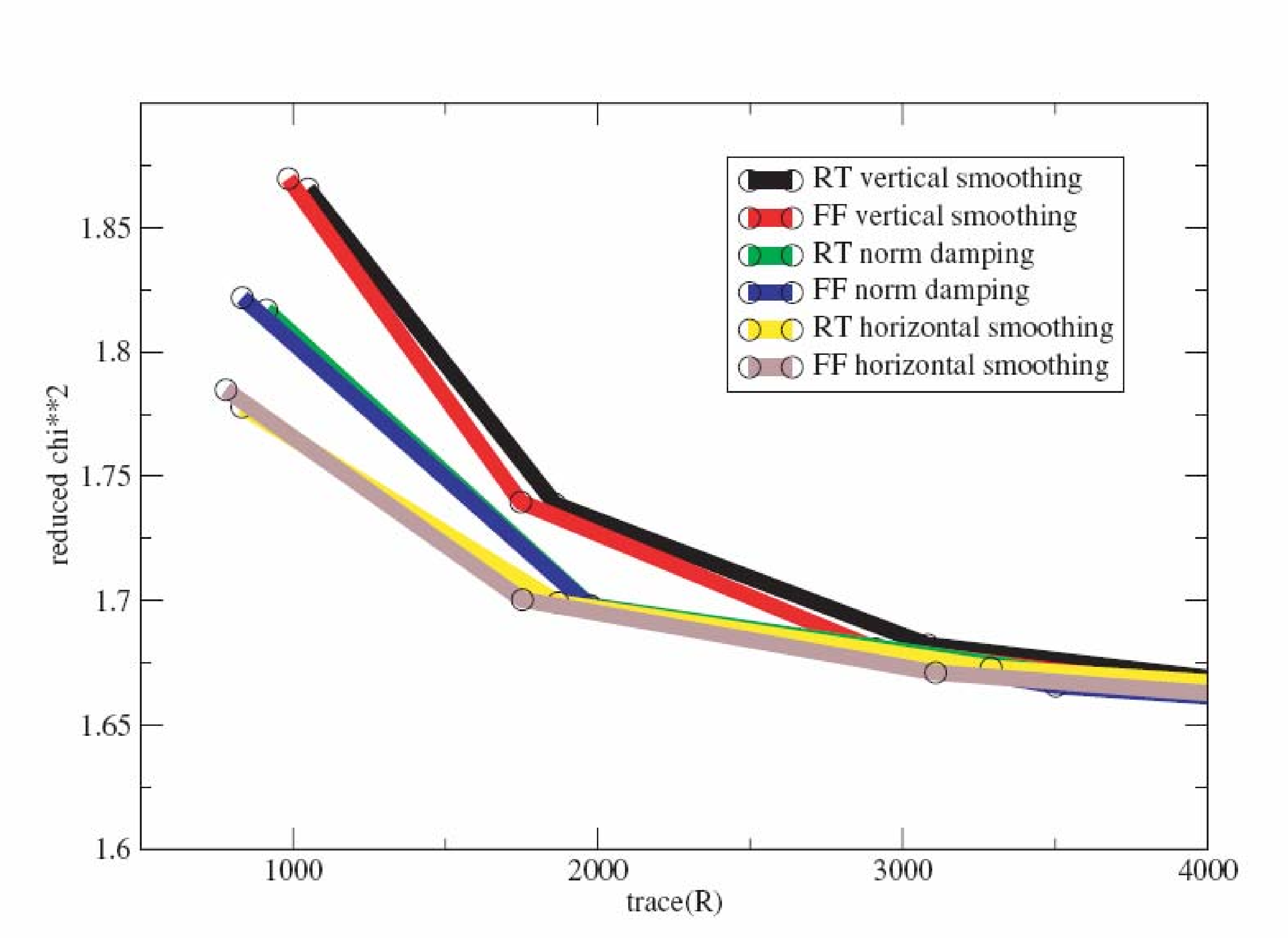
Utrecht University, Utrecht, the Netherlands

Importance of damping in inversion

$$\mathbf{m}=(\mathbf{A}^{\mathrm{T}}\mathbf{C}_d^{-1}\mathbf{A}+\gamma\mathbf{D})^{-1}\mathbf{A}^{\mathrm{T}}\mathbf{C}_d^{-1}\mathbf{d}$$

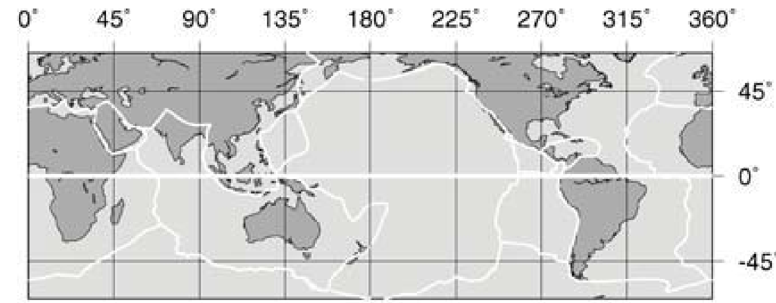
- Regularization is needed to make the inversion stable.
- Damping factor (γ) controls the smoothness of the models.
- Choice of γ depends on subjective observations.

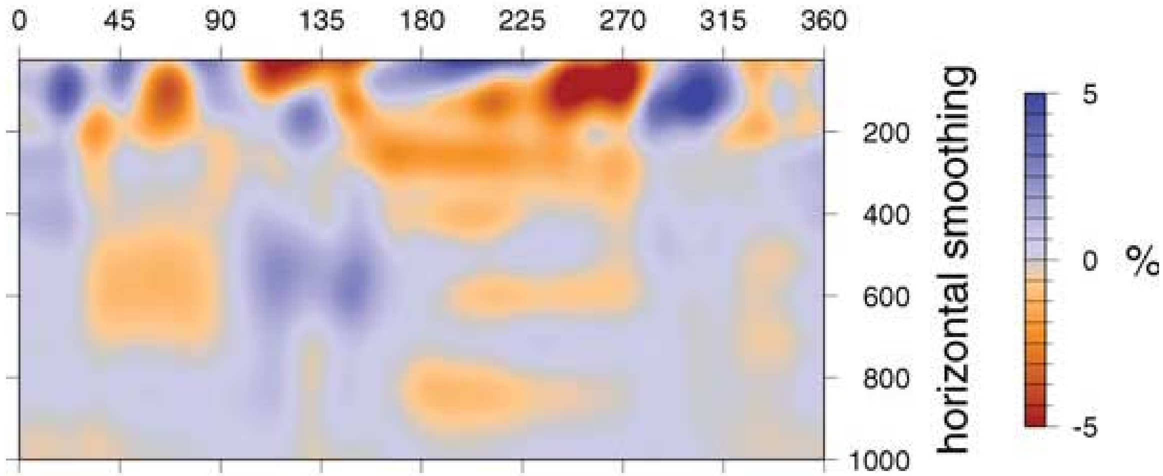
Sample trade-off curves



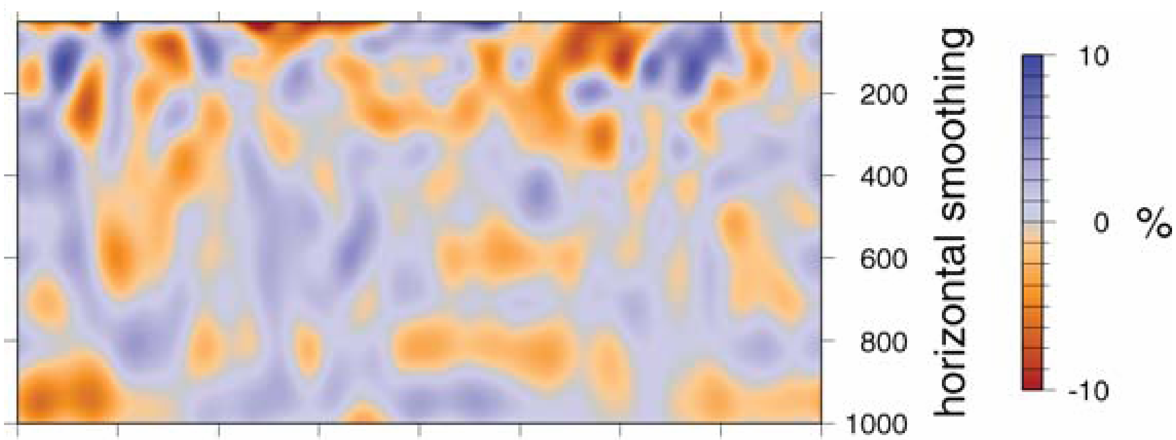
Trampert & Spetzler (2006)

Cross-sections along the equator of the mantle models from Trampert & Spetzler (2006)





$\gamma = 0.01$



$\gamma = 0.0001$

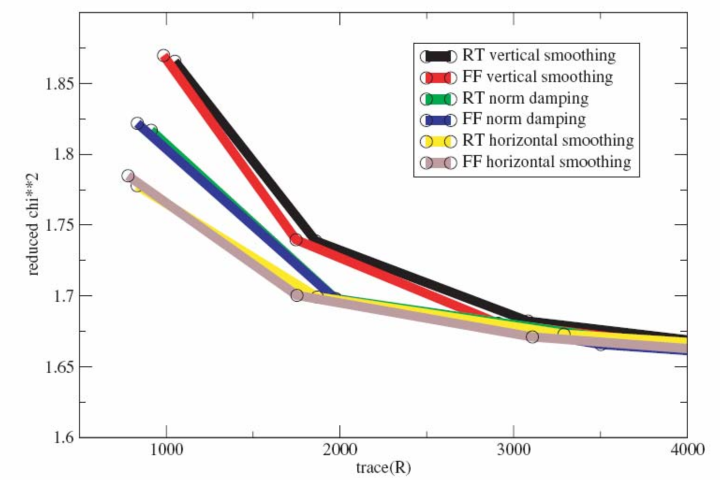
The objective

- Investigate the effect of varying levels of damping on tomographic mantle models.

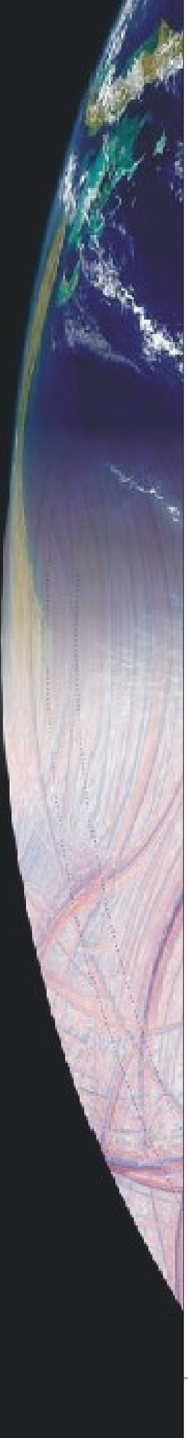
- Check the agreement between real and SEM (Komatitsch & Tromp 2002) seismograms.

Synthetic seismograms using SEM

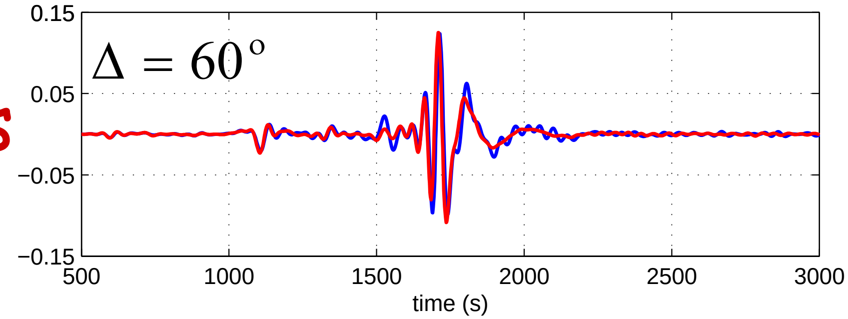
- Crust2.0 (Bassin et al. 2000)
- Four mantle models (Trampert & Spetzler 2006)
  - $\gamma = 0.01$
  - $\gamma = 0.001$
  - $\gamma = 0.0001$
  - $\gamma = 0.00001$

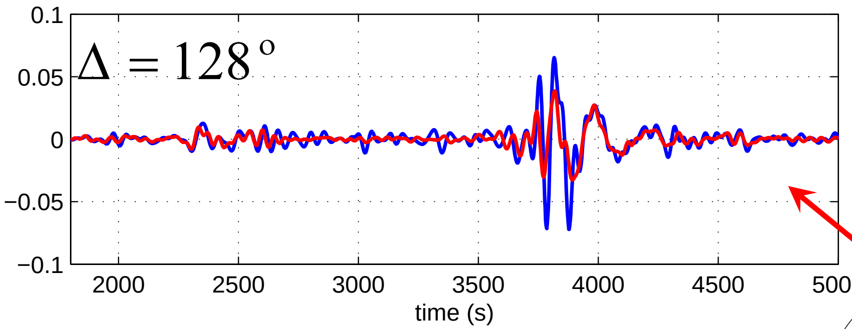


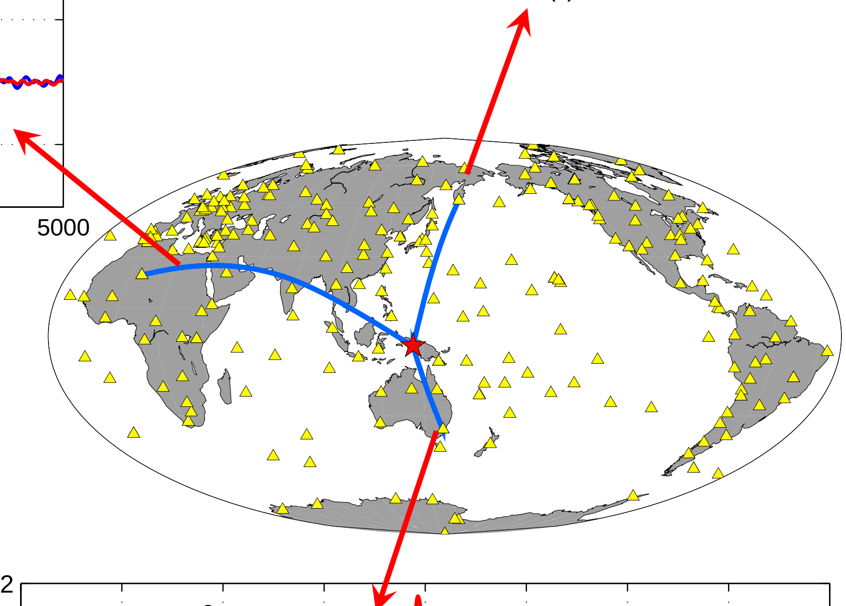
- PREM (Dziewonski & Anderson 1981)

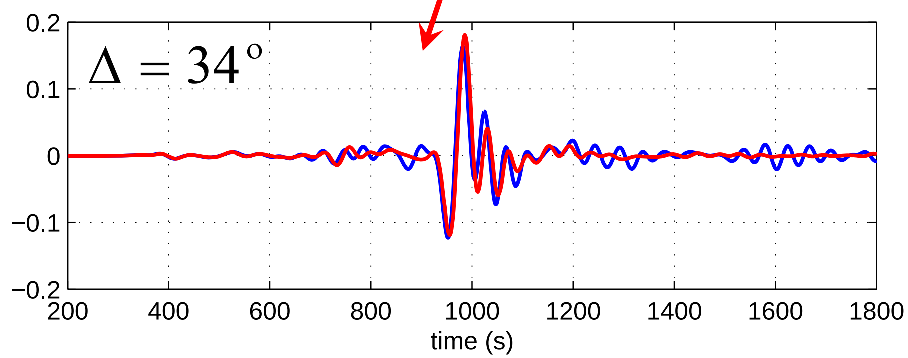


Comparison of real - SEM seismograms







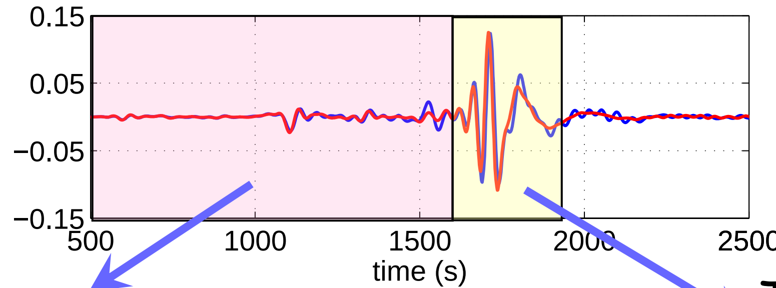


★ Irian-Jaya (2004) M_w=7

Blue: real seismograms

Red: SEM seismograms

Measuring time shifts as a function of frequency



Windowing the body waves

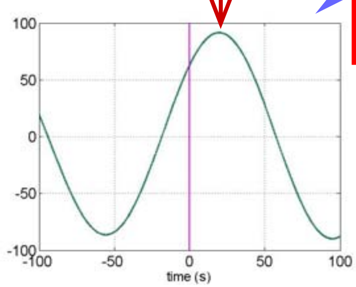
↓

Cross-correlation of the seismograms

↓

Narrowband filter at desired periods 250 s – 40 s

↓



→ $dt_{body}(\omega)$

Time-variable filter to extract the 0^{th} mode Rayleigh waves

↓

Cross-correlation of the seismograms

↓

Measure the phase $d\phi$ of the cross-correlation

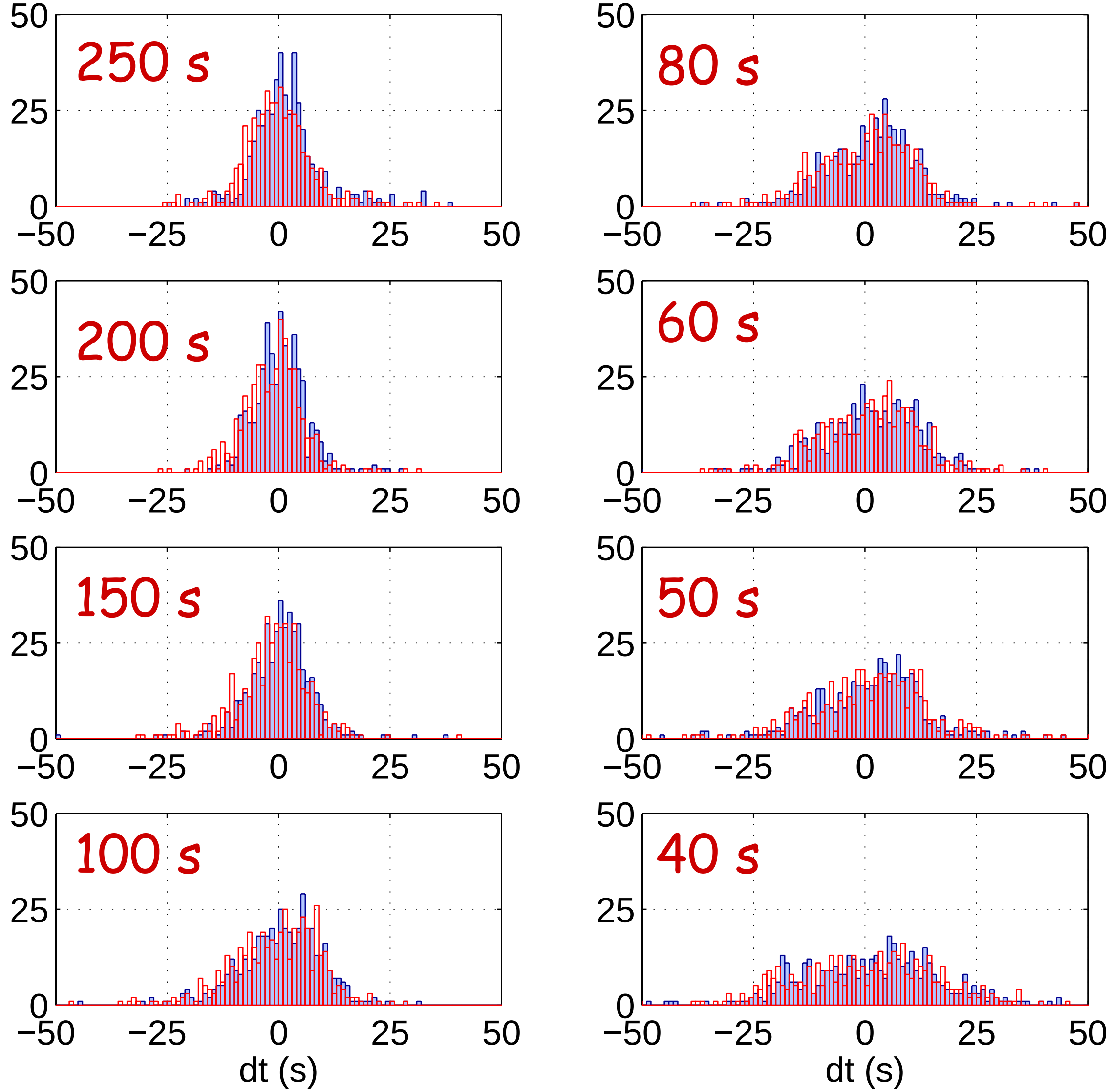
↓

Unwrap the phase

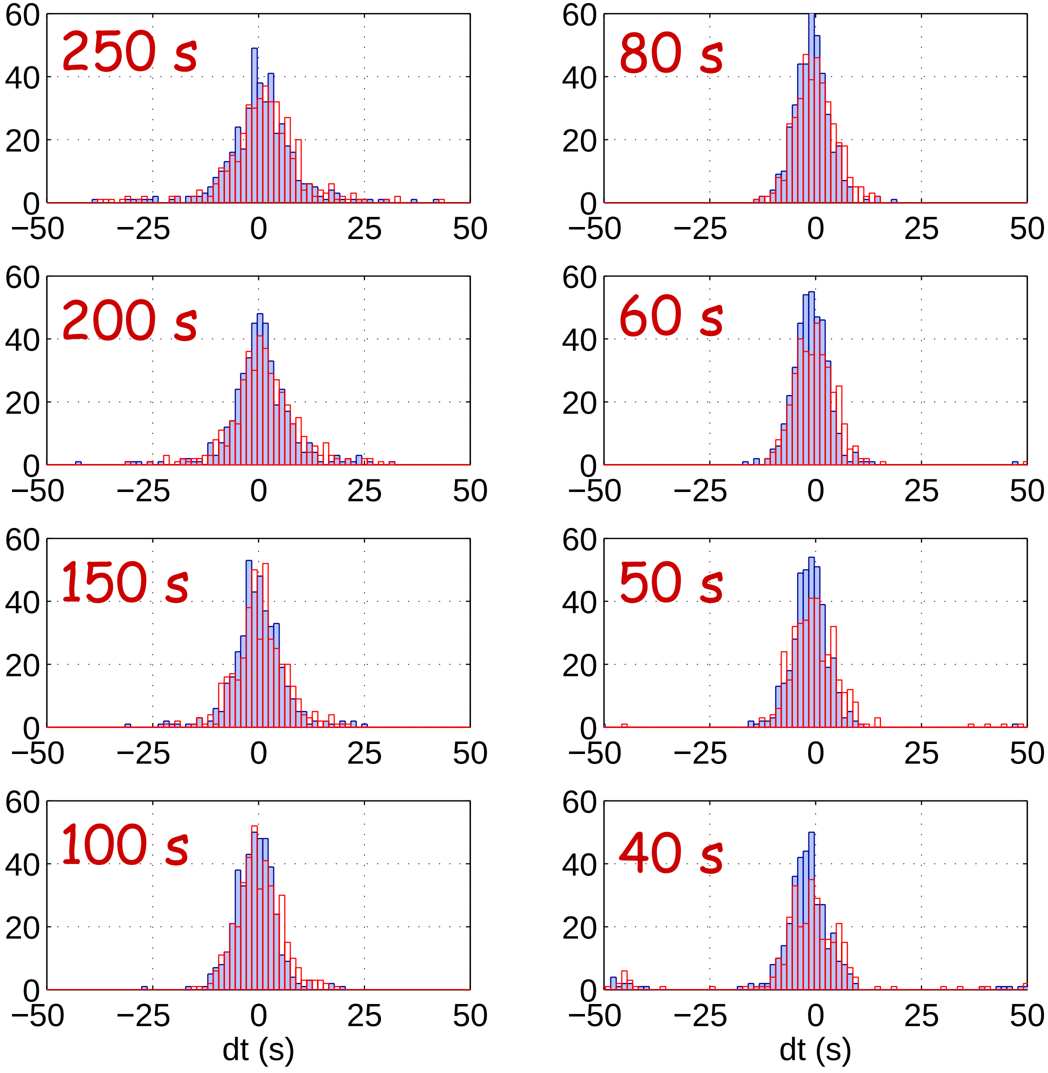
↓

$$dt_{Rayleigh}(\omega) = \frac{d\phi(\omega)}{\omega}$$

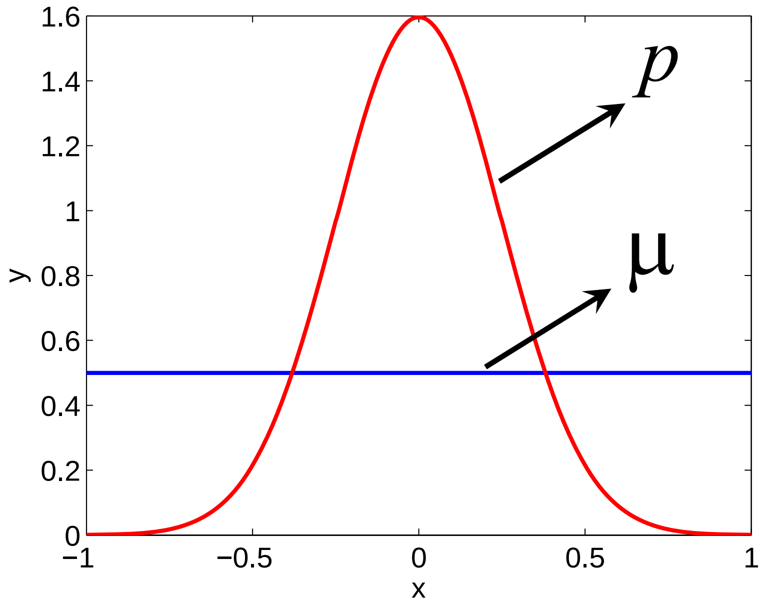
Time shift histograms from Rayleigh waves for the mantle models γ = 0.001 (blue bars) and γ = 0.00001 (red bars).



Time shift histograms from body waves for the mantle models γ = 0.01 (blue bars) and γ = 0.00001 (red bars).



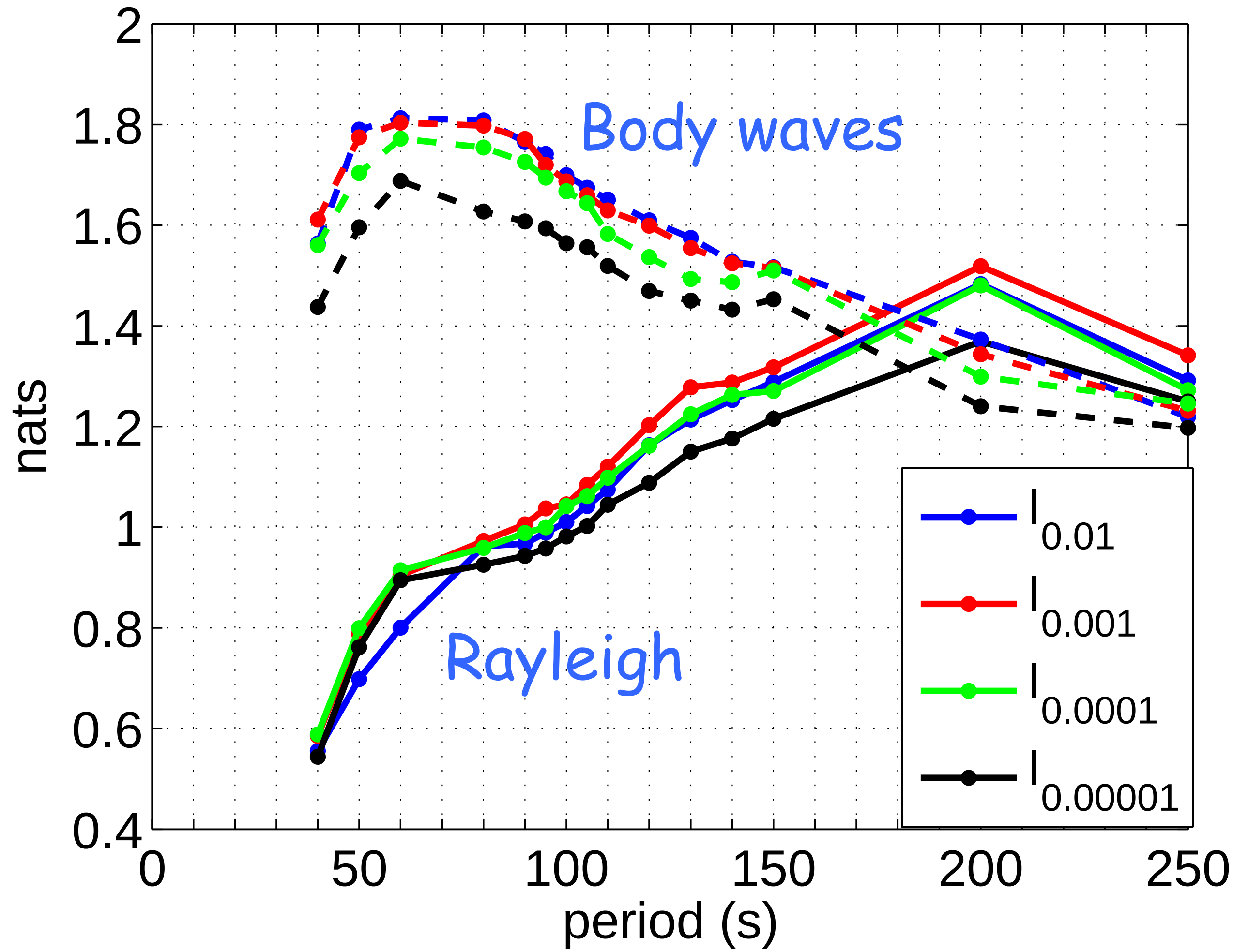
Information content in a probability density function

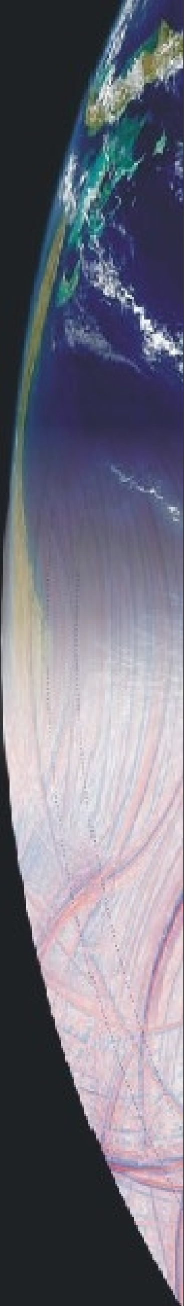


$$I_i = \int_{-\infty}^{\infty} p_i(m) \log\left(\frac{p_i(m)}{\mu(m)}\right) dm$$ (Shannon 1948)

$$I_{gain} = I_i - I_j$$

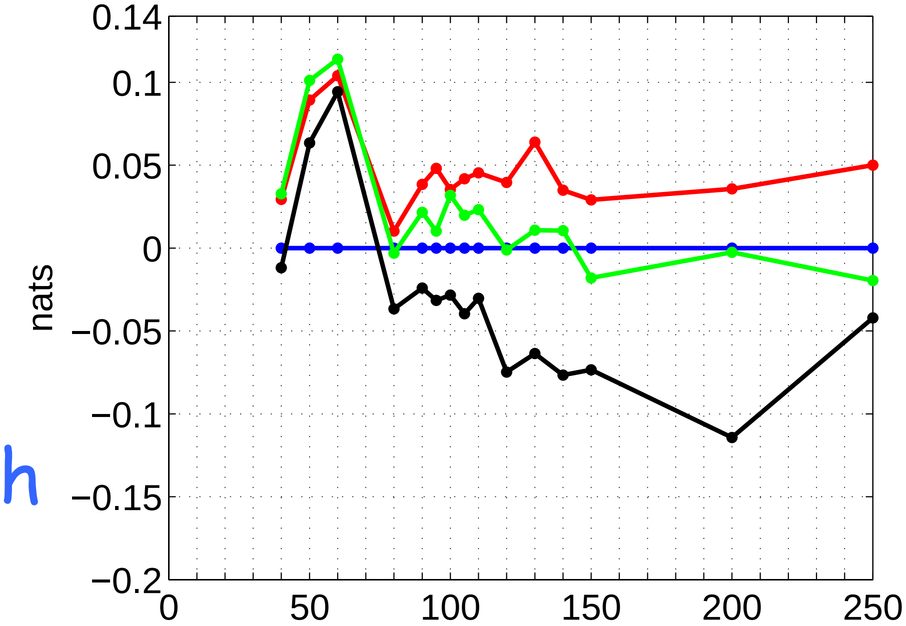
Information content



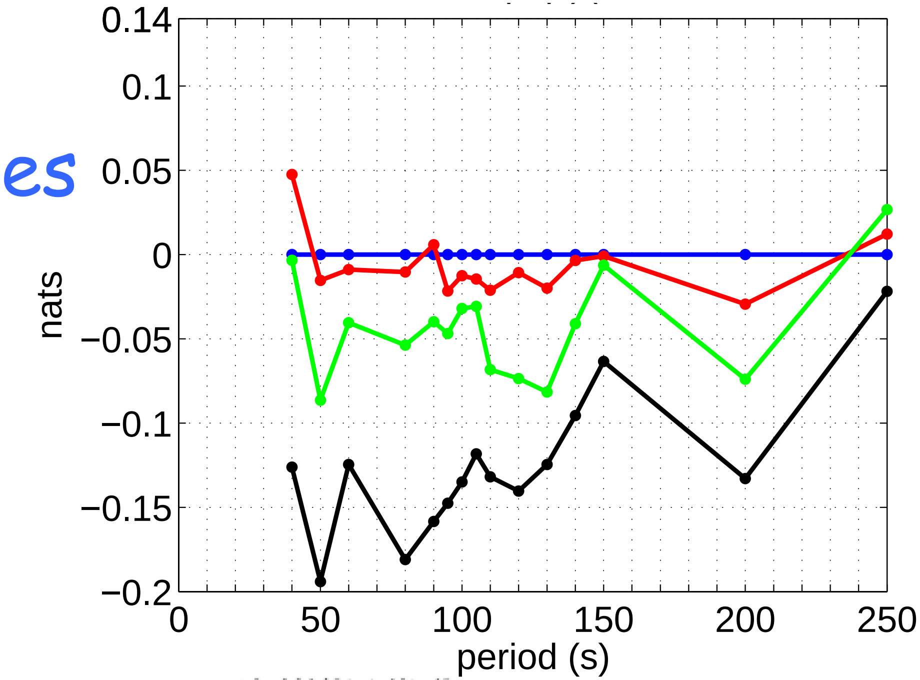


Information gain with respect to smoothest model

Rayleigh



Body waves



$I_{0.01} - I_{0.01}$

$I_{0.001} - I_{0.01}$

$I_{0.0001} - I_{0.01}$

$I_{0.00001} - I_{0.01}$

Conclusions

- For Rayleigh waves, the match between real and SEM seismograms is much better at long periods.
- The difference between the models is not large.
- For Rayleigh waves, problems at short periods might be due to the crustal model.
- Increase the number of paths!