Constraining attenuation from ambient seismic noise

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QUEST meeting
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Spectraseis
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SEVENTH FRAMEWORK PROGRAMME
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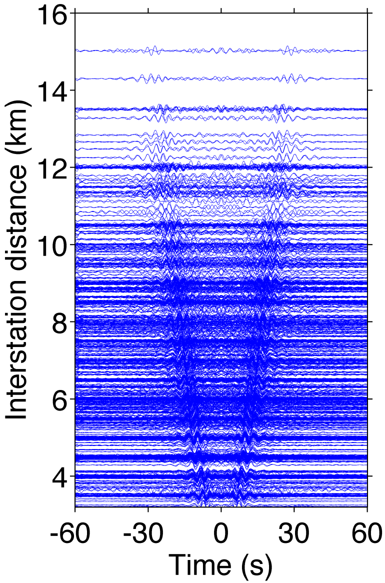
The challenge: attenuation



Cross-correlation

Normalized cross-correlation:

$$C_{x_1 x_2}(\omega) \equiv \frac{U(\mathbf{x_1}, \omega) U^*(\mathbf{x_2}, \omega)}{\left|U(\mathbf{x_1}, \omega)\right| \left|U(\mathbf{x_2}, \omega)\right|}$$

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Averaged complex coherency:

$$\bar{\rho}(\omega, r = |\mathbf{x_2} - \mathbf{x_1}|) \equiv \sum_{azimuth} \sum_{time} C_{x_1 x_2}(\omega)$$

Bessel function fit

$$\Re[\bar{\rho}(\omega, r)] = J_0\left(\frac{\omega r}{c(\omega)}\right)$$

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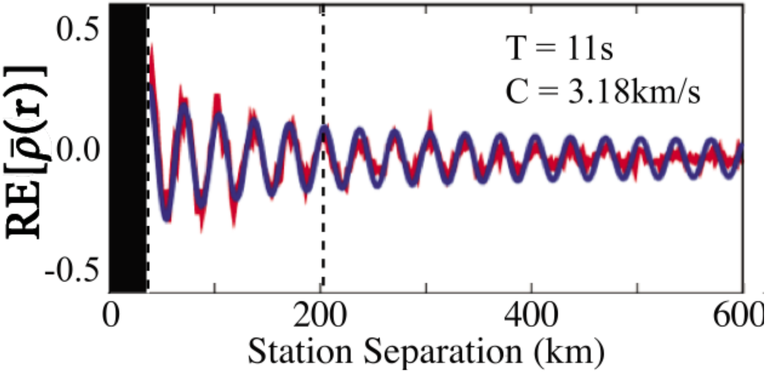

Lawrence and Prieto (2011), Journal of Geophysical Research

Damped Bessel function fit

$$\Re[\bar{\rho}(\omega, r)] = J_0\left(\frac{\omega r}{c(\omega)}\right) e^{-\alpha(\omega) r}$$

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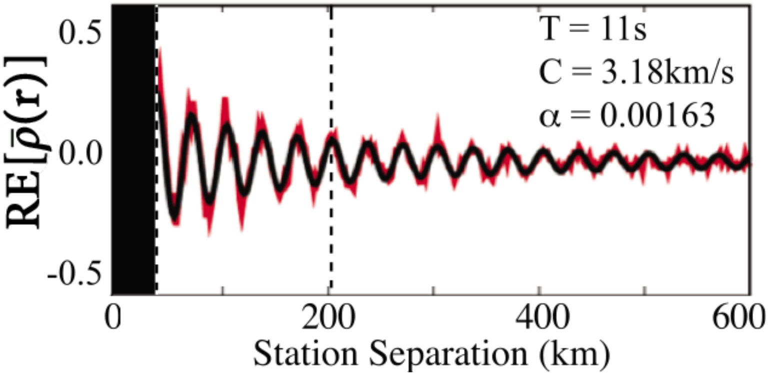
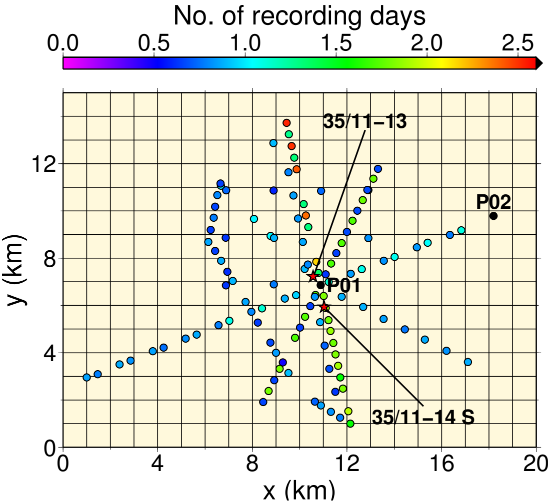


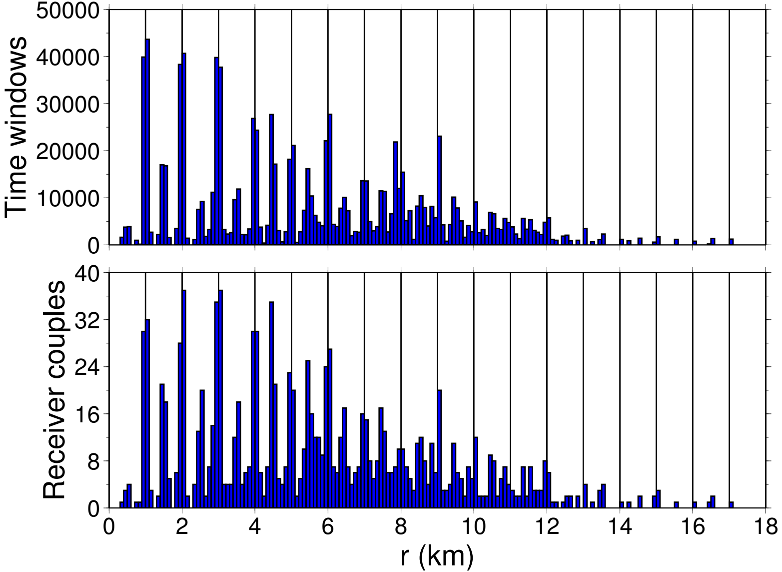
Lawrence and Prieto (2011), Journal of Geophysical Research

Offshore data set

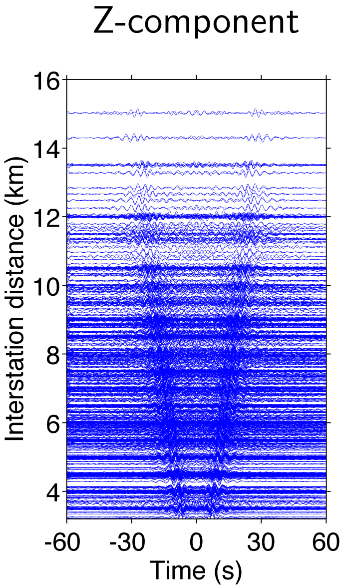


- offshore survey.
- 4-component data
- 16 BBOBS.
- nominal station interval 500 m
- different lines deployed successively
- water depth of 360 m
- Z and P data only

Sampling with offset



Green's function gathers



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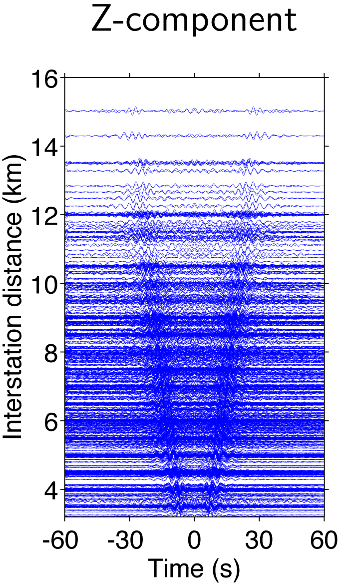
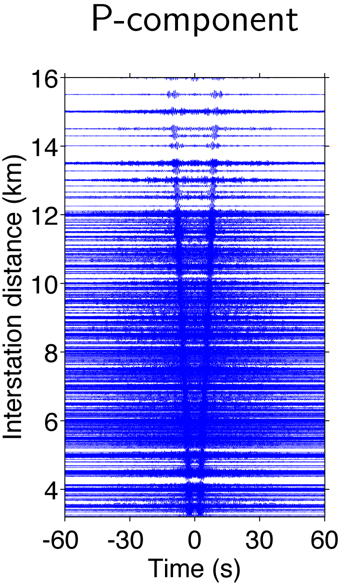
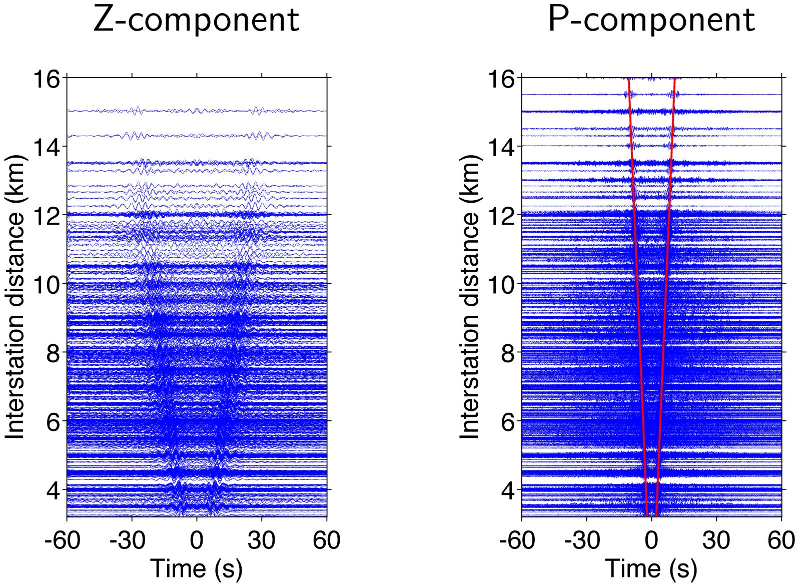
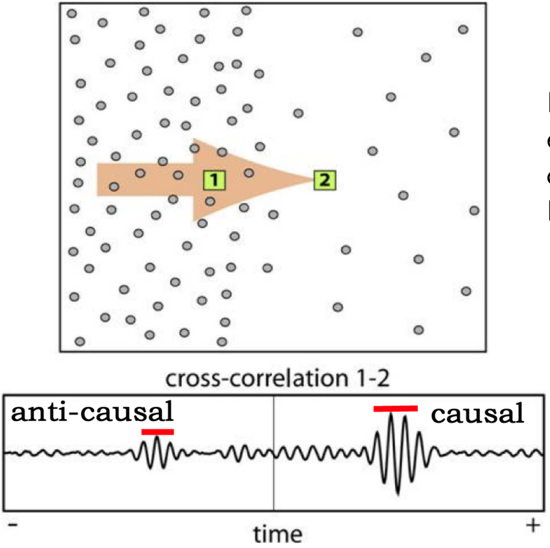




Green’s function gathers

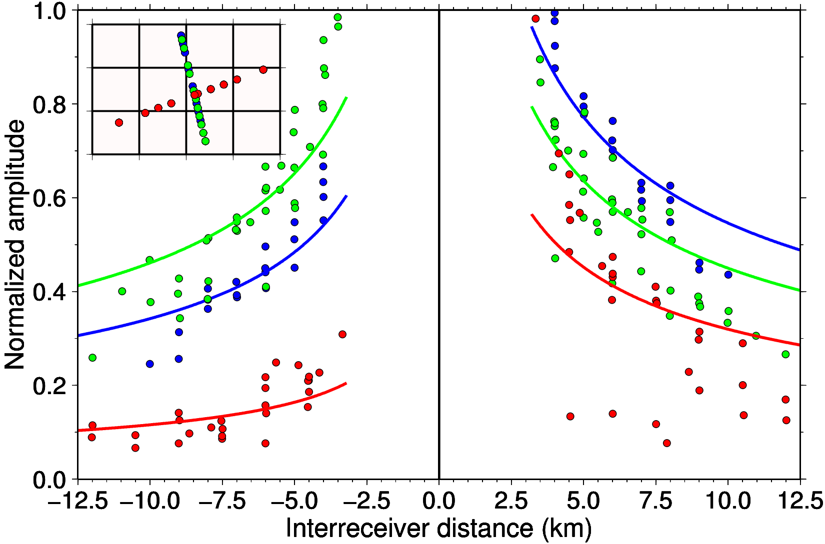


Relation to source distribution

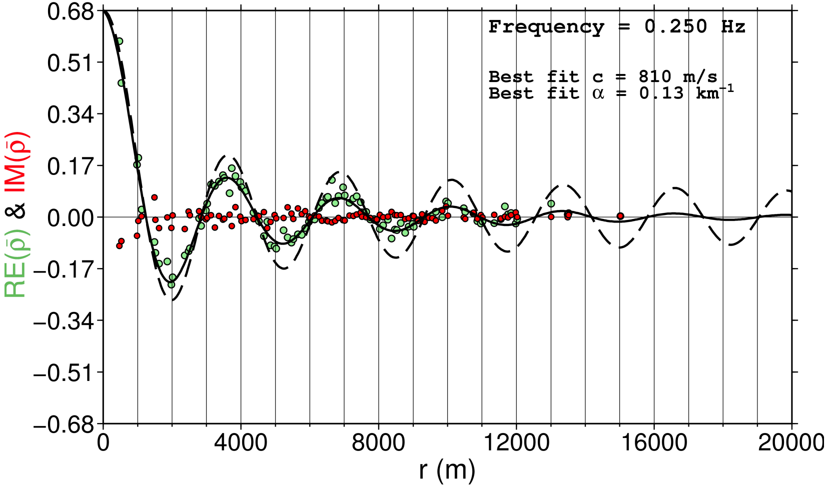


Modified from Stehly et al. (2006), Journal of Geophysical Research

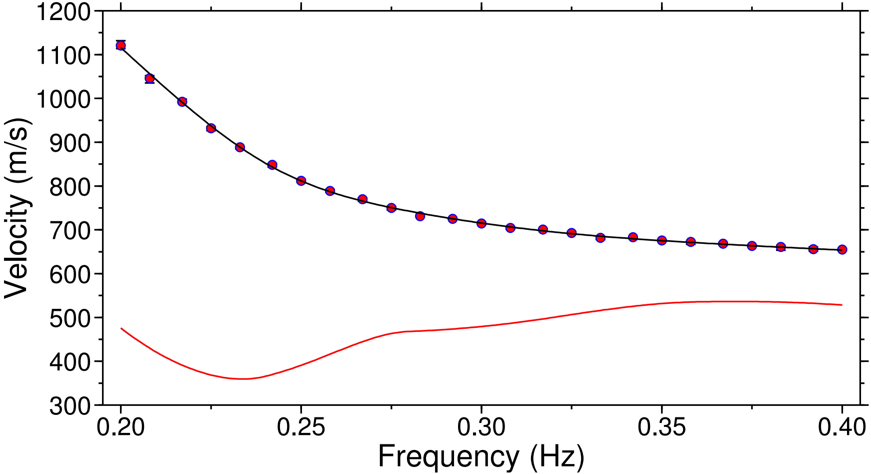
Decay in time-domain



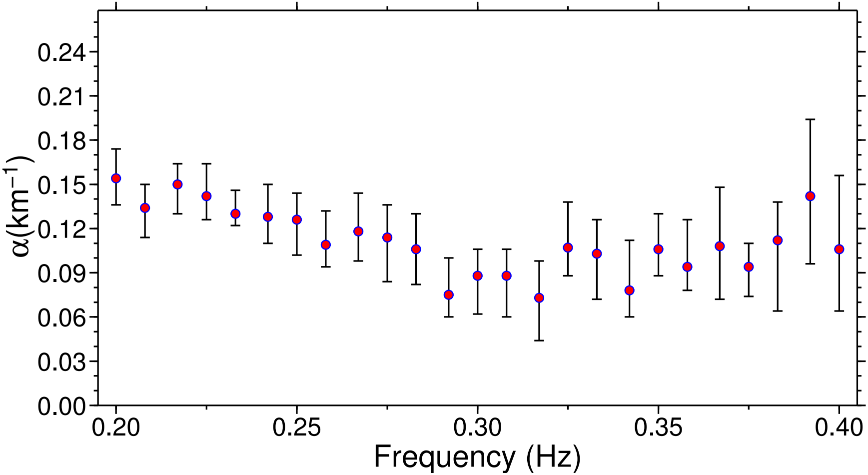
Coherency for a single frequency



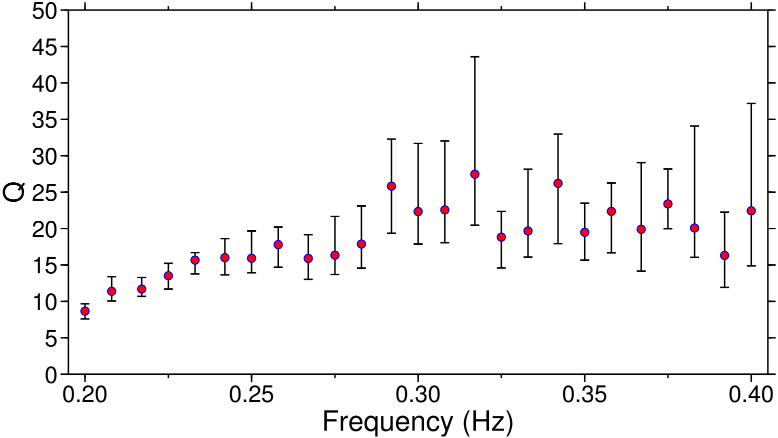
Phase and group velocities



Attenuation coefficients

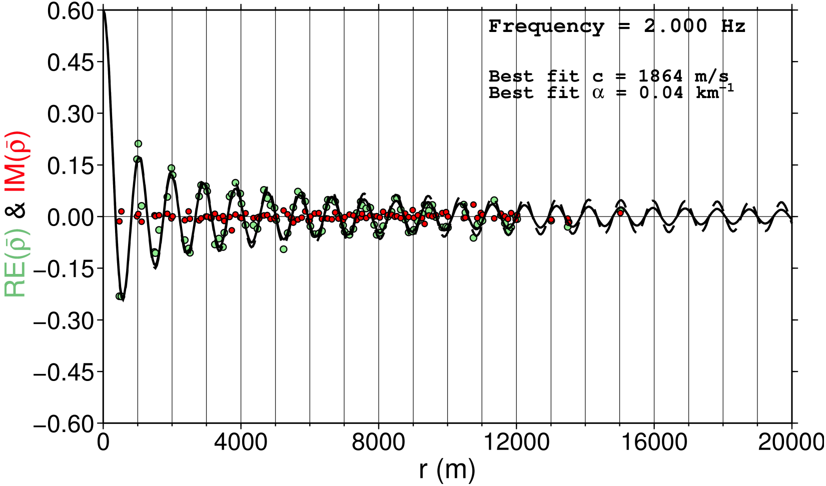


Quality factors

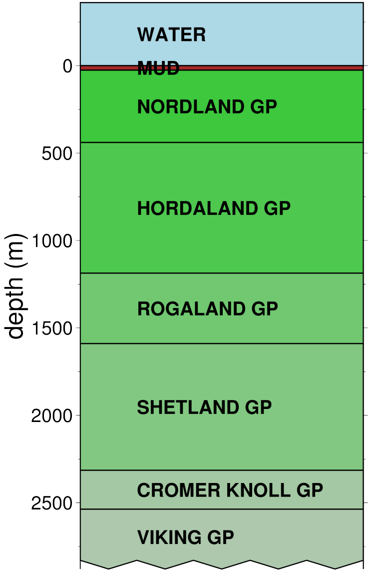


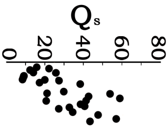
$$Q(\omega) = \left(\frac{\omega}{2\alpha(\omega)U(\omega)}\right)$$

Attenuation of seawater?

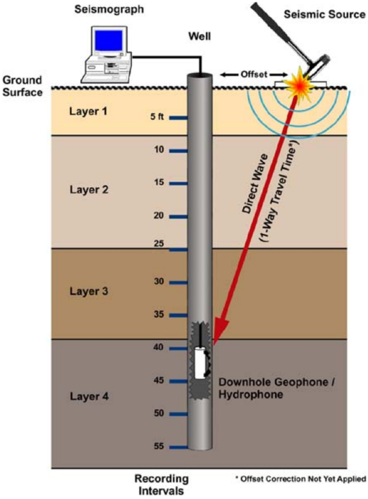


Interpretation





Reid et al. (2001), SEG Expanded Abstract.



Conclusions

- stable Green's functions
- reasonable fit to damped Bessel functions
- 1-D estimate of phase velocities
- reasonable quality factors
- first order comparison with geology

Acknowledgements

- QUEST Initial Training Network.
- Statoil and especially Peter Hanssen.
- Julie Verbeke, Sacha Bussat, Clotaire Michel and Steve Della Mora.

THANK YOU

References

Bussat, S., and S. Kugler, 2011, Offshore ambient-noise surface-wave tomography above 0.1 Hz and its applications: The Leading Edge, **30**, 514–524.

Lawrence, J. F., and G. A. Prieto, 2011, Attenuation tomography of the western united states from ambient seismic noise: Journal of Geophysical Research, **116**.

Reid, F. J. L., P. H. Nguyen, C. MacBeth, and R. A. Clark, 2001, Q estimates from north sea vsps: SEG Technical Program Expanded Abstracts, **20**, 440–443.

Stehly, L., M. Campillo, and N. M. Shapiro, 2006, A study of the seismic noise from its long-range correlation properties: Journal of Geophysical Research, **111**.

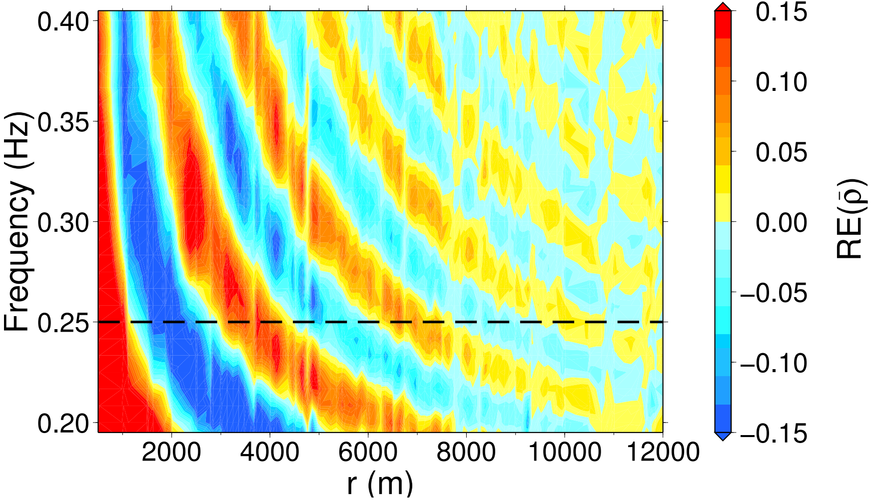
Processing sequence

1. synchronous periods selected
2. shorter time windows with 75% overlap
3. time windows are detrended
4. Fourier transformation
5. whitening of the amplitude spectra
6. cross-correlation
7. time averaging
8. time domain: inverse Fourier transformation
9. frequency domain: azimuthal averaging

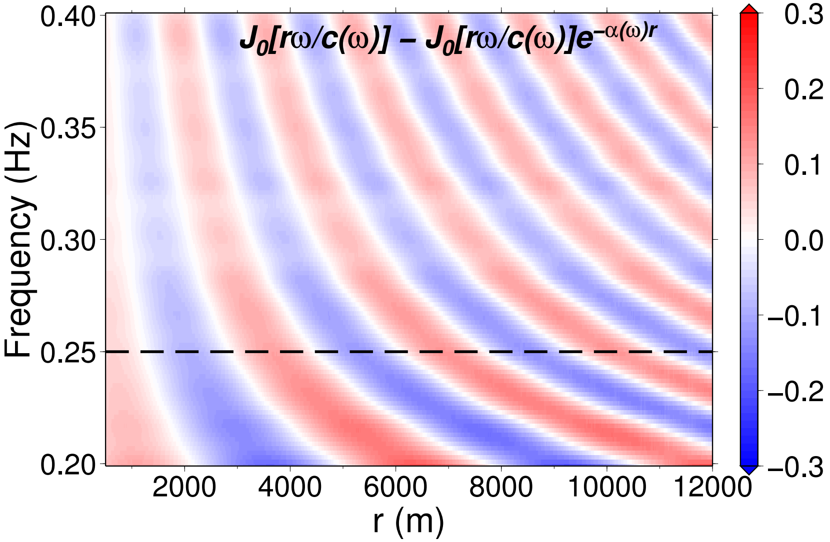
$$\frac{U(\mathbf{x_1},\omega)U^*(\mathbf{x_2},\omega)}{|U(\mathbf{x_1},\omega)|\,|U(\mathbf{x_2},\omega)|}$$

$$\sum_{azimuth}\sum_{time} C_{x_1x_2}(\omega)$$

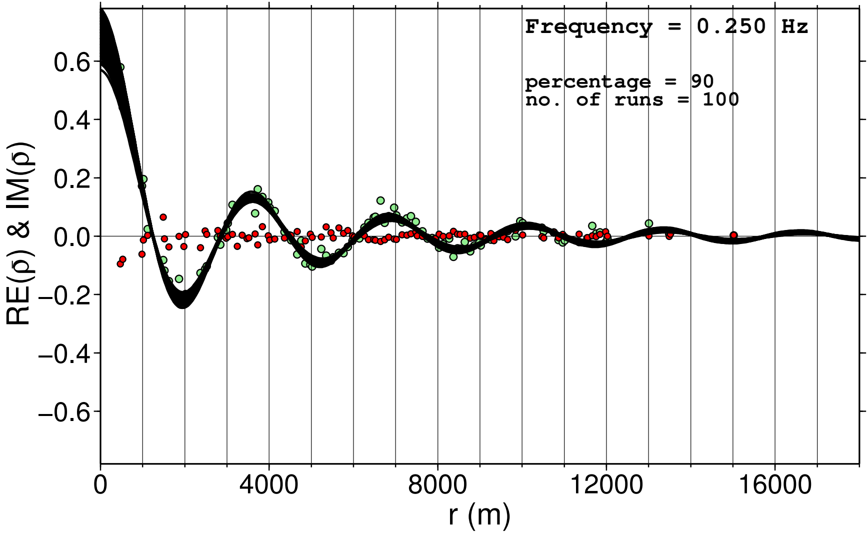
Coherency with frequency



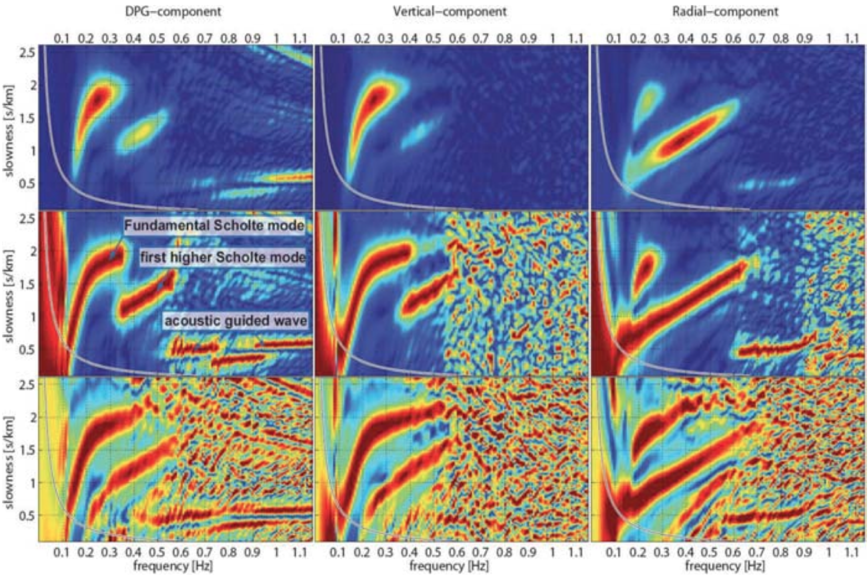
Difference between models



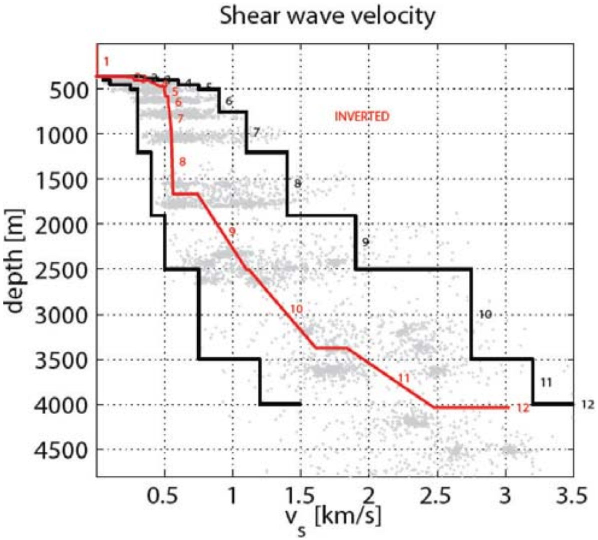
Bootstrapping



Dispersion (Bussat and Kugler, 2011)

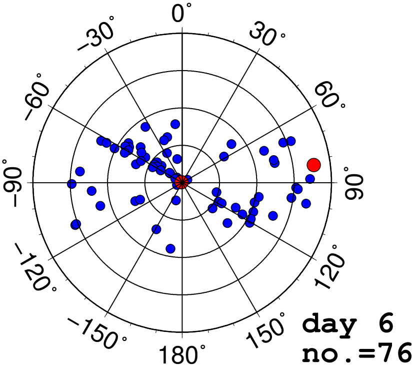


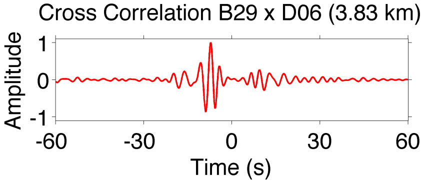
Velocity inversion

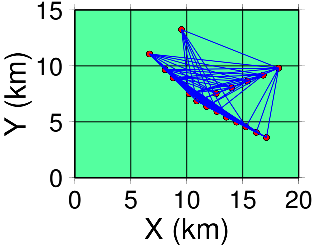


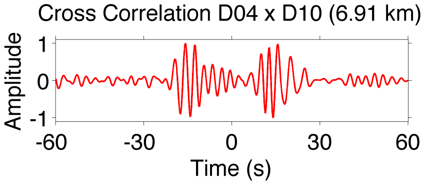
Bussat and Kugler (2011), The Leading Edge

Isotropic wavefield?









Wavefield over time