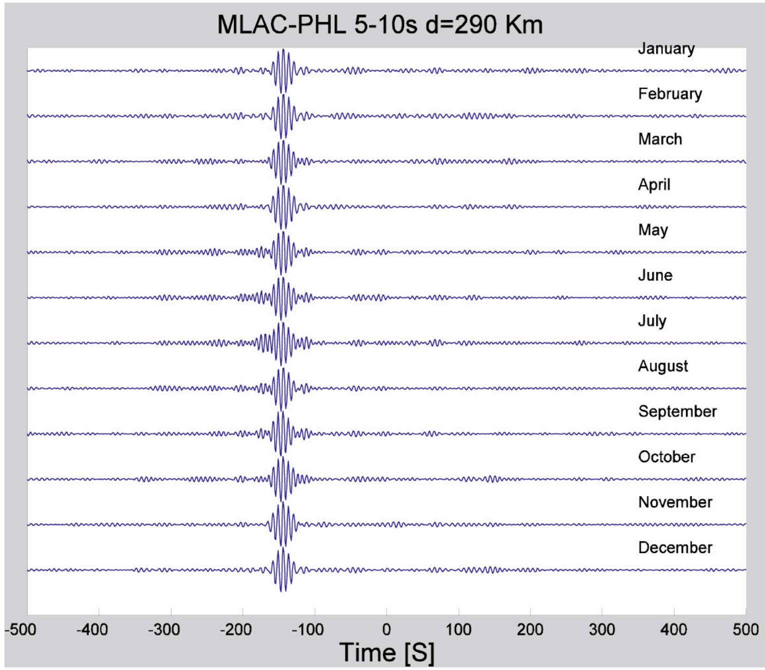
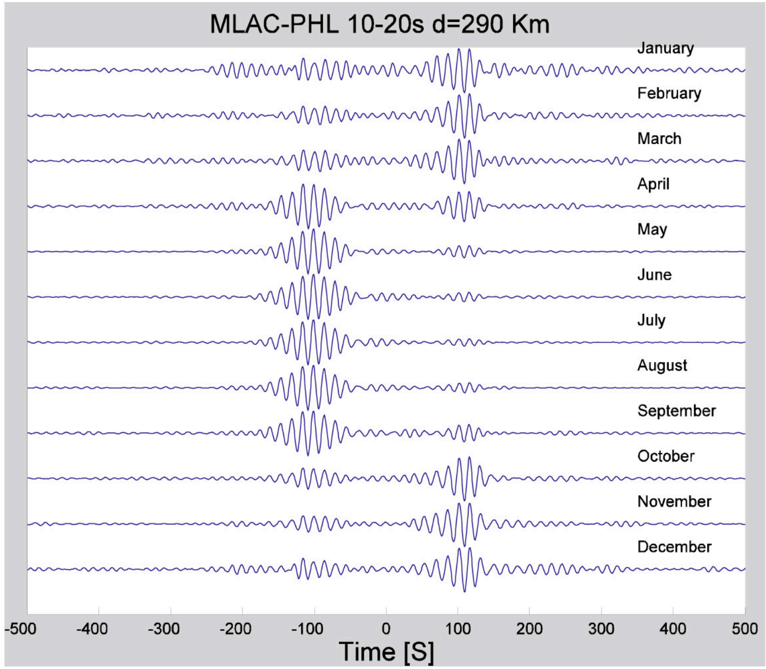
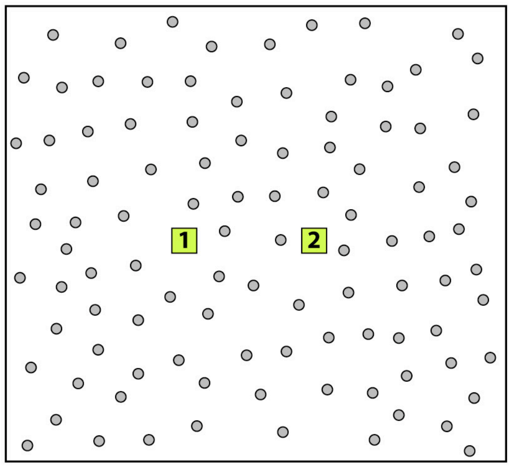
Tracking the origin of the seismic noise



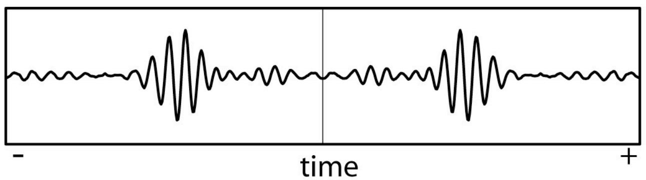


Tracking the origin of the seismic noise

Isotropic distribution of sources: symmetric cross-correlation

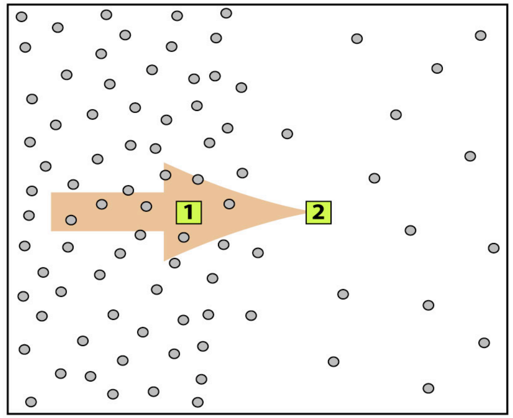


cross-corrleation 1-2

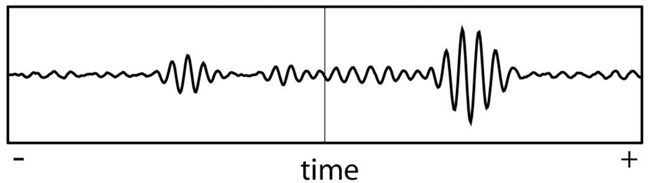


time

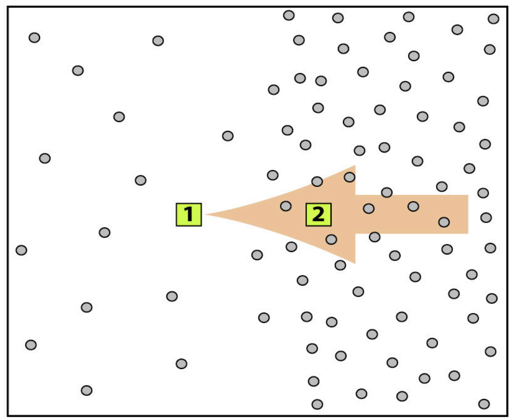
Anisotropic distribution of sources: asymmetric cross-correlation



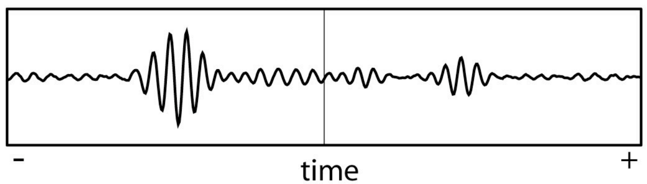
cross-corrleation 1-2



time

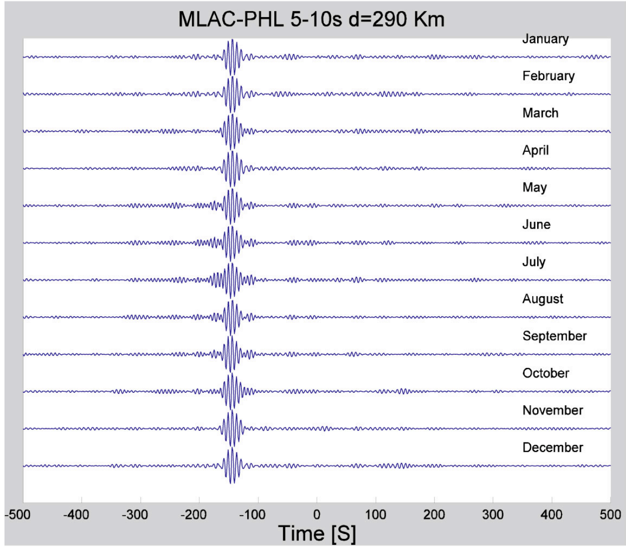


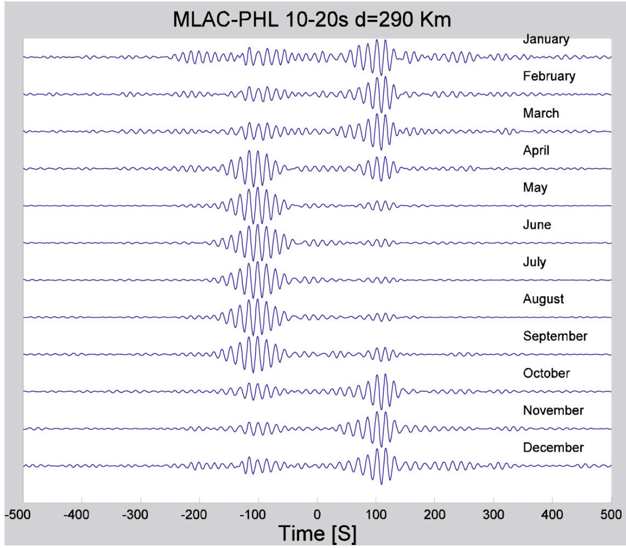
cross-corrleation 1-2

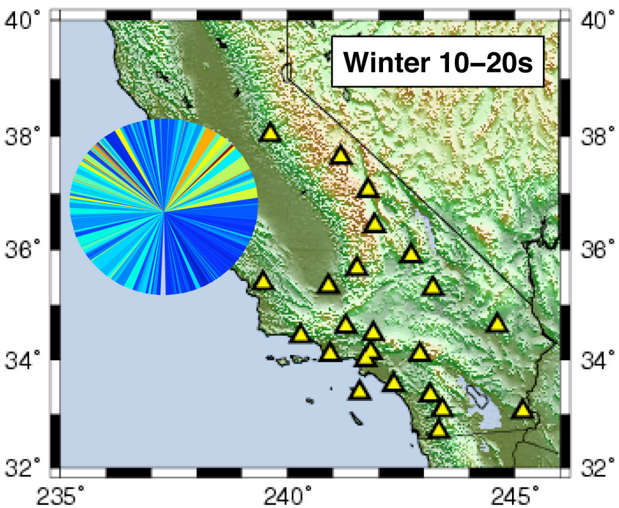


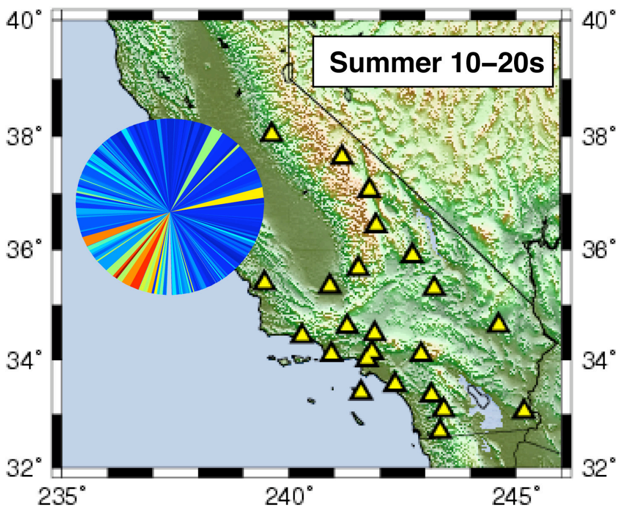
time

Tracking the origin of the seismic noise



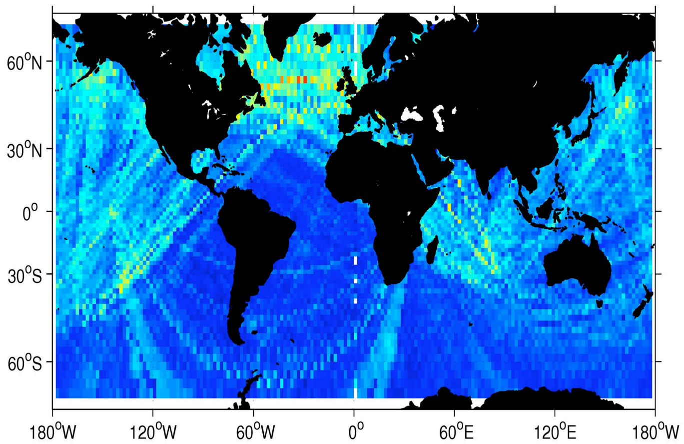




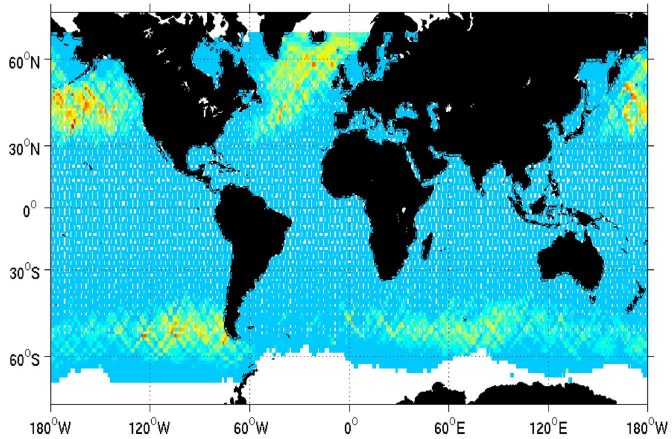


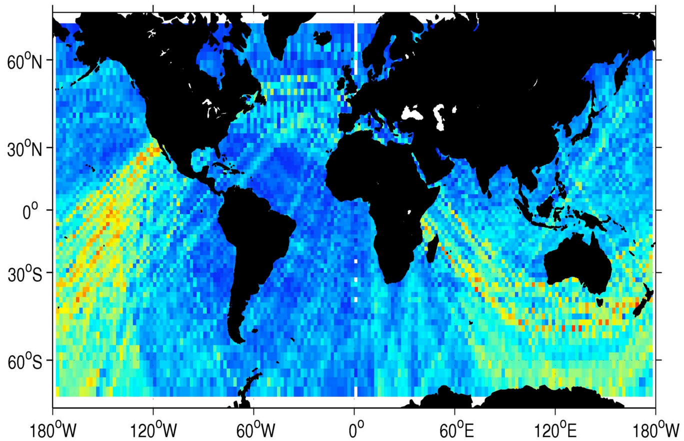
Apparent origin of the noise

Average sea wave height

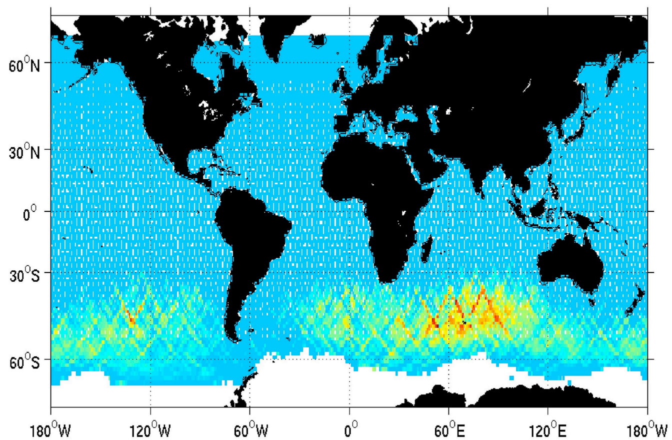


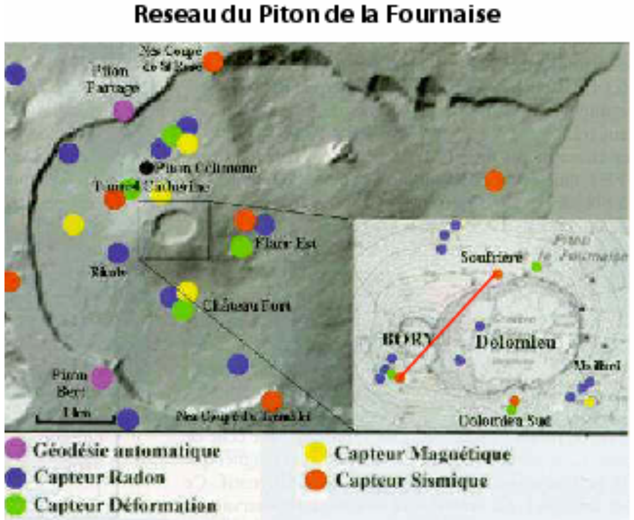
winter

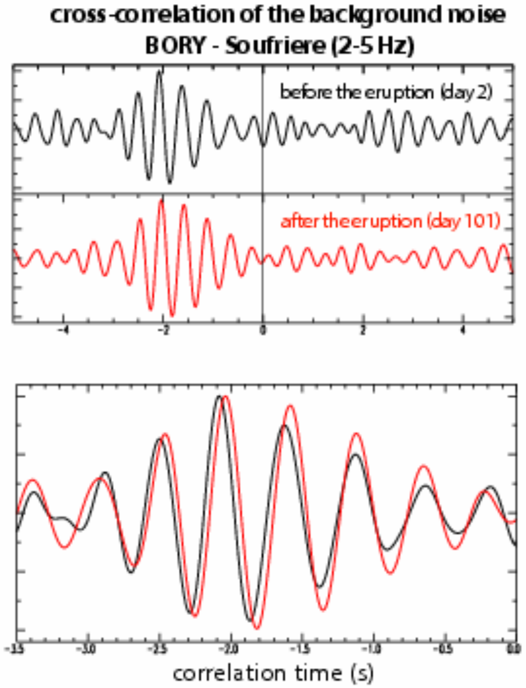


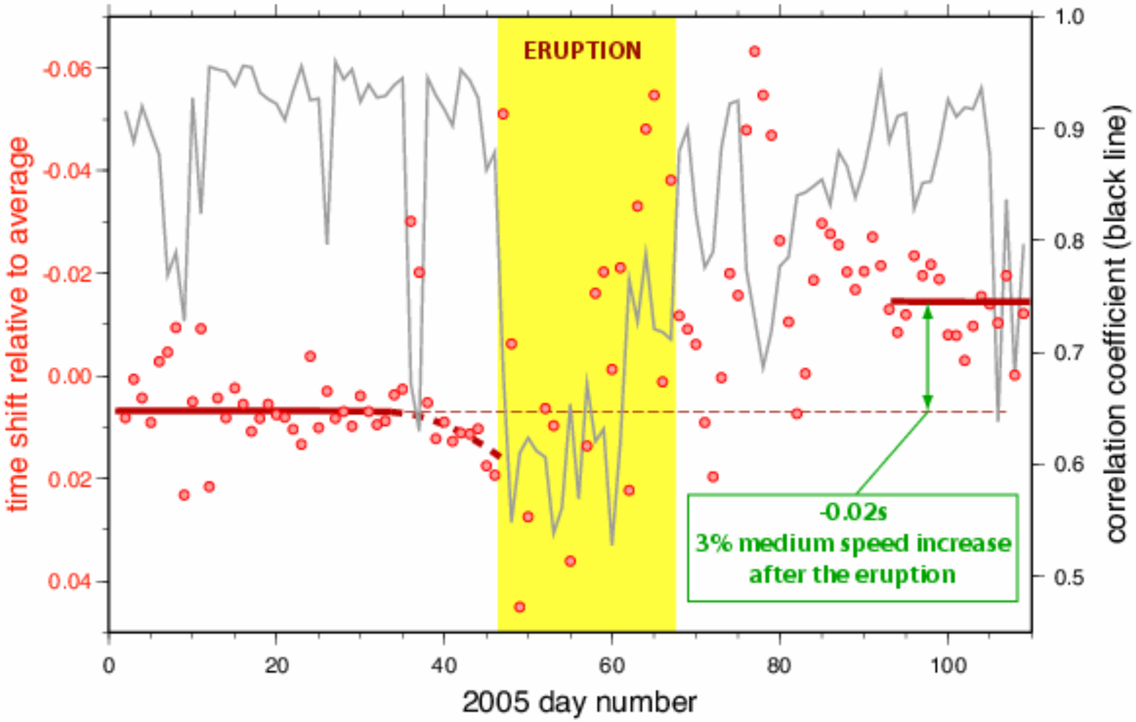


summer



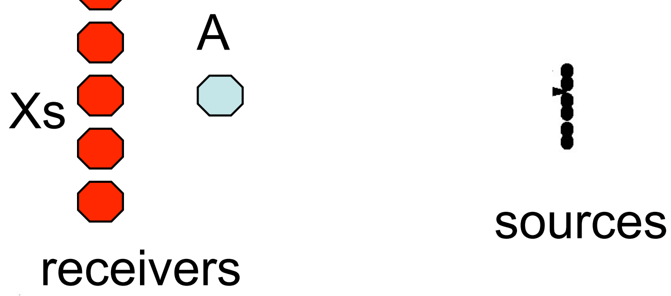

Reseau du Piton de la Fournaise
Soufriere
BORY
Dolomieu
Géodésie automatique
Capteur Radon
Capteur Déformation
Capteur Magnétique
Capteur Sismique

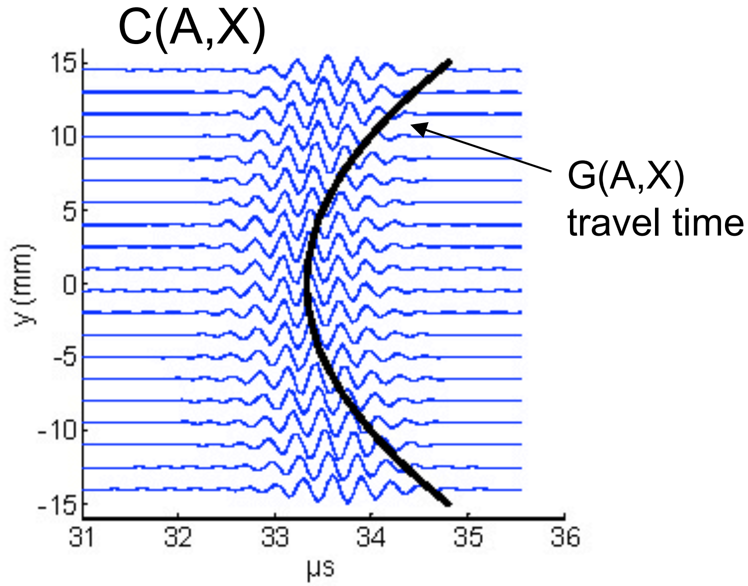

cross-correlation of the background noise
BORY - Soufriere (2-5 Hz)
before the eruption (day 2)
after the eruption (day 101)
correlation time (s)


ERUPTION
-0.02s
3% medium speed increase
after the eruption
time shift relative to average
correlation coefficient (black line)
2005 day number

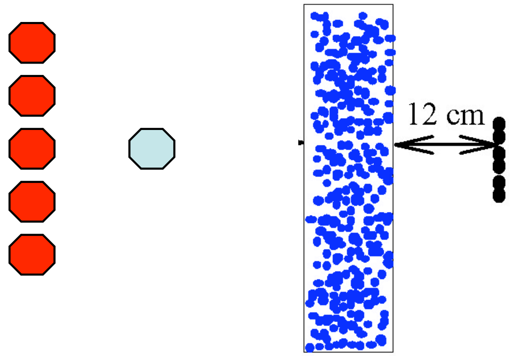
Importance of scattering: a simple laboratory experiment with a few sources

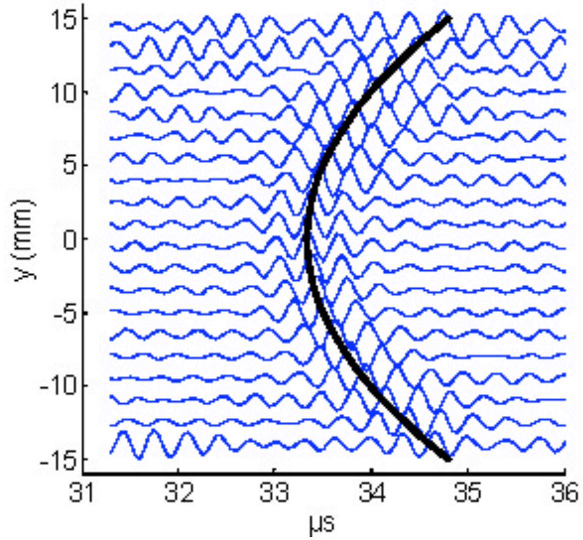
Correlations in water





Correlations in presence of scattering





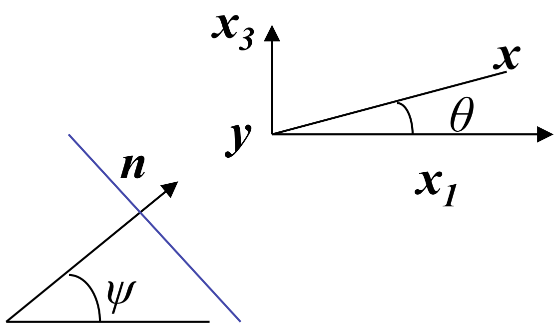
THE 2D SCALAR CASE

$$G_{22} = \frac{1}{i4\rho}\frac{H_0^{(2)}(kr)}{\beta^2},$$

$$H^{(2)}{}_n(kr) = J_n(kr) - iY_n(kr)$$

$$G_{22}(\mathbf{x},\mathbf{y},t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} G_{22}(\mathbf{x},\mathbf{y},\omega)\exp(\mathbf{i}\omega t)d\omega = \frac{1}{2\pi\mu}\frac{H(t-r/\beta)}{\sqrt{t^2 - r^2/\beta^2}}$$

Illumination by plane waves



Azimuthal average over ψ leads to

$$\left\langle v(\mathbf{y},\omega)v^*(\mathbf{x},\omega)\right\rangle = \left|F(\omega)\right|^2 \frac{1}{2\pi}\int_0^{2\pi}\exp(\mathbf{i}kr\cos[\psi-\theta])d\psi = \left|F(\omega)\right|^2 J_0(kr)$$

SPAC method ➔ k ➔ C

$$\left\langle v(\mathbf{y},\omega)v^*(\mathbf{x},\omega)\right\rangle = E_{SH}J_0(kr) = -4\mu E_{SH}\,\mathrm{Im}\left[G_{22}(\mathbf{x},\mathbf{y},\omega)\right]$$

A isotropic distribution of plane waves in an homogeneous body : the local approach
THE 2D SCALAR CASE

SH waves in a homogeneous elastic medium

Propagation takes place in the x_1-x_3 plane. Therefore, the antiplane (out-of-plane) displacement $v(\mathbf{x},t)$ fulfils the wave equation

$$\frac{\partial^2 v}{\partial x_1^2} + \frac{\partial^2 v}{\partial x_3^2} = \frac{1}{\beta^2}\frac{\partial^2 v}{\partial t^2}$$

Keiiti Aki

where β = shear wave velocity and t = time.

A typical harmonic, homogeneous plane wave can be written as

$$v(\mathbf{x},\omega,t) = F(\omega,\psi)\exp(-\mathrm{i}\frac{\omega}{\beta}x_j n_j)\exp(\mathrm{i}\omega t)$$

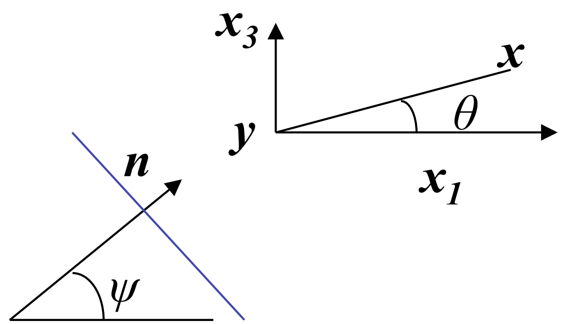
where, $F(\omega, \psi)$ = complex waveform, ω=circular frequency, $\mathbf{x}^T = (x_1, x_3)$ = Cartesian coordinates

$x1 = r\cos\theta =$, $x3 = r\sin\theta =$, with r, θ = polar coordinates

nj = direction cosines ($n1 = \cos\psi$, $n3 = \sin\psi$)

Consider the auto-correlation of the motion, evaluated at positions **x** and **y**, respectively. For simplicity assume **y** at the origin:

$$n_j x_j = r n_j \gamma_j = r\cos[\psi - \theta]$$

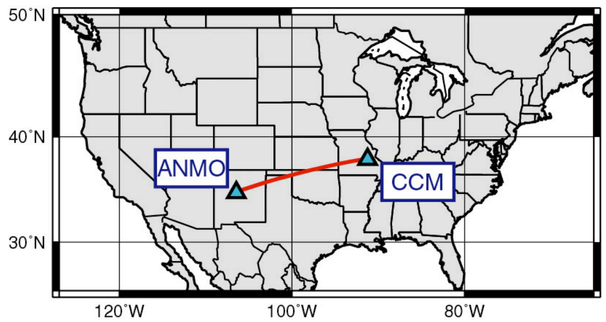


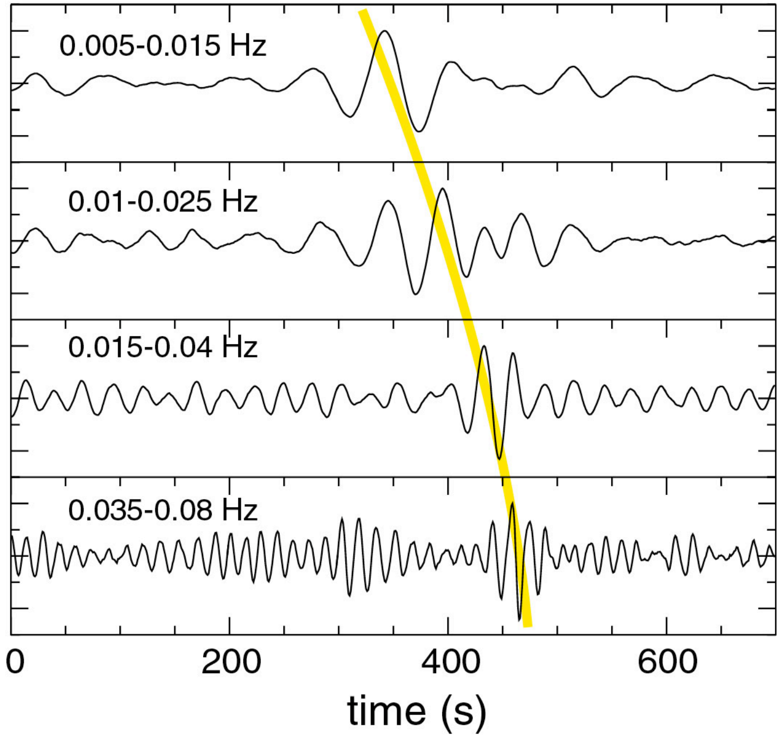
$$v(\mathbf{y},\omega)v^*(\mathbf{x},\omega) = F(\omega,\psi)F^*(\omega,\psi)\exp(\mathbf{i}kr\cos[\psi-\theta])$$

Cross-correlations of seismic noise: ANMO - CCM

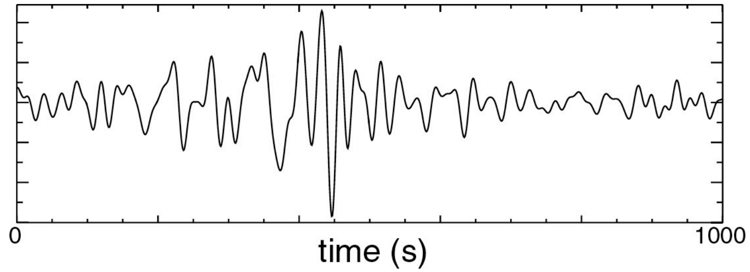
(from Shapiro and Campillo, GRL, 2004)

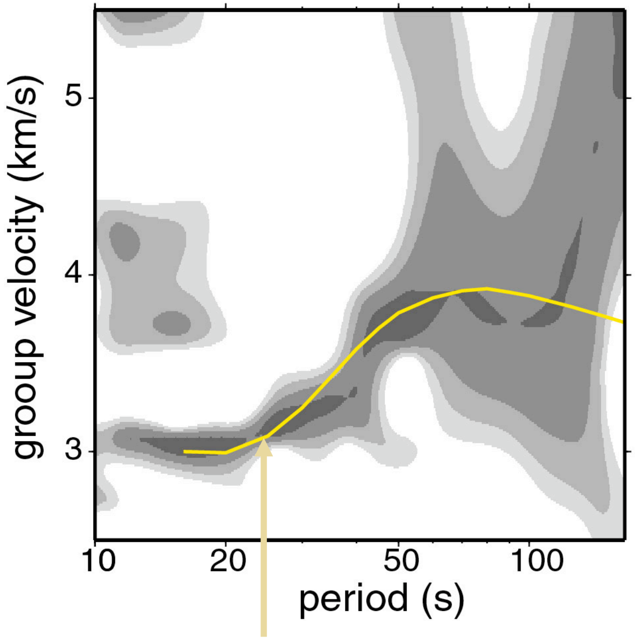
30 days of vertical motion



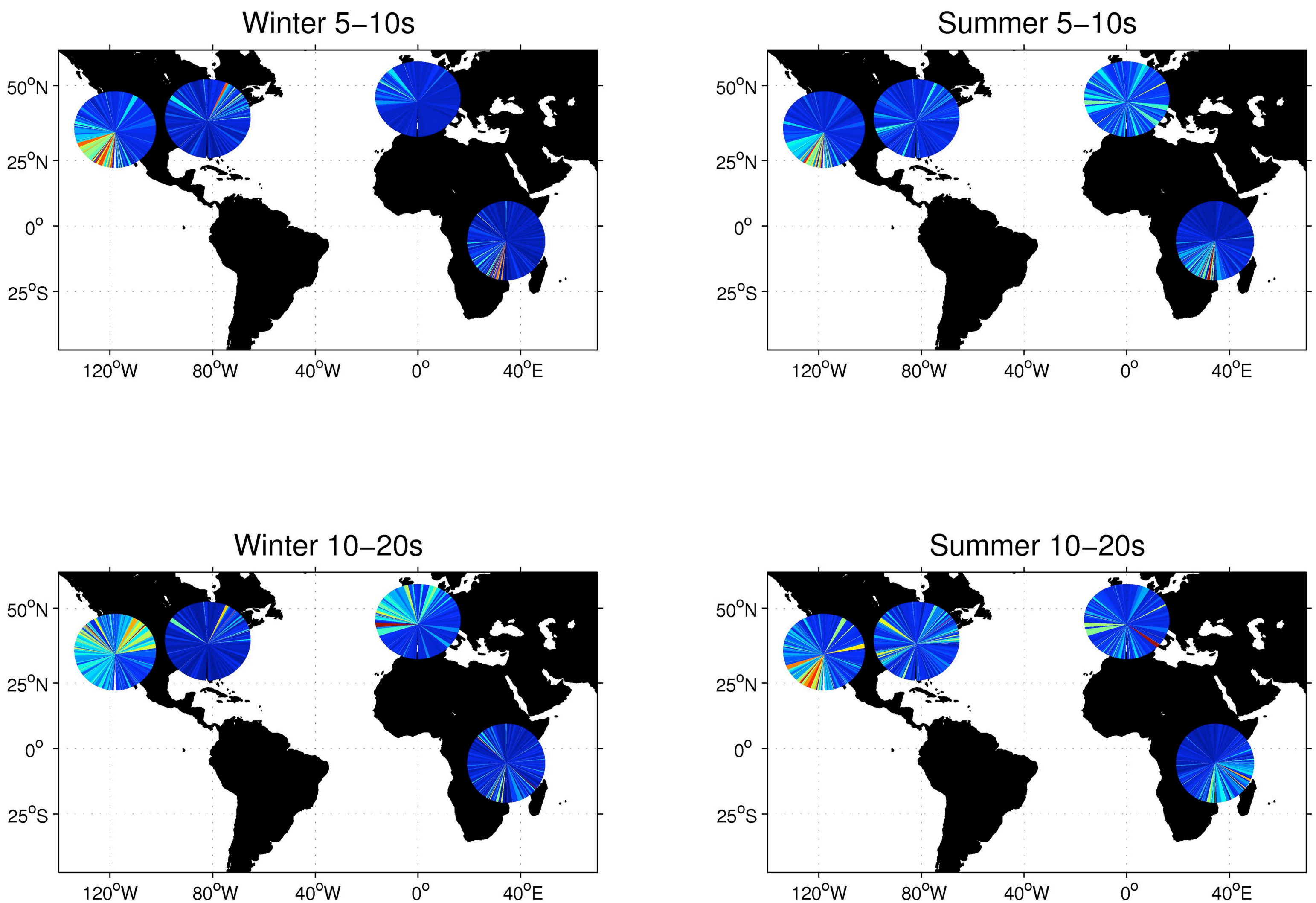


Dispersion analysis



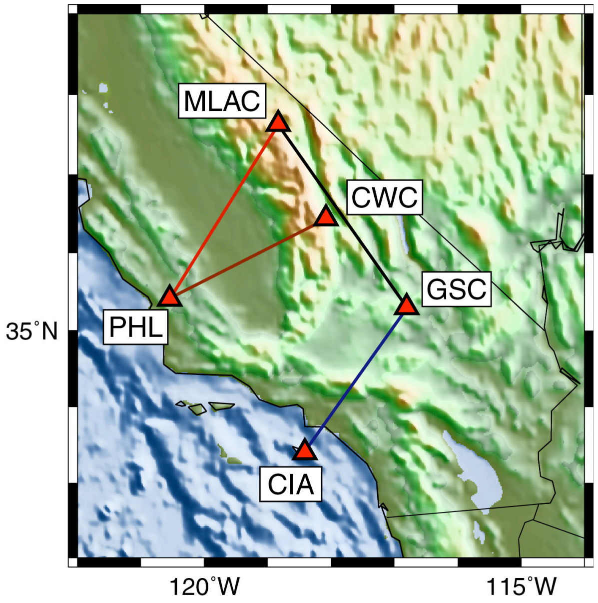


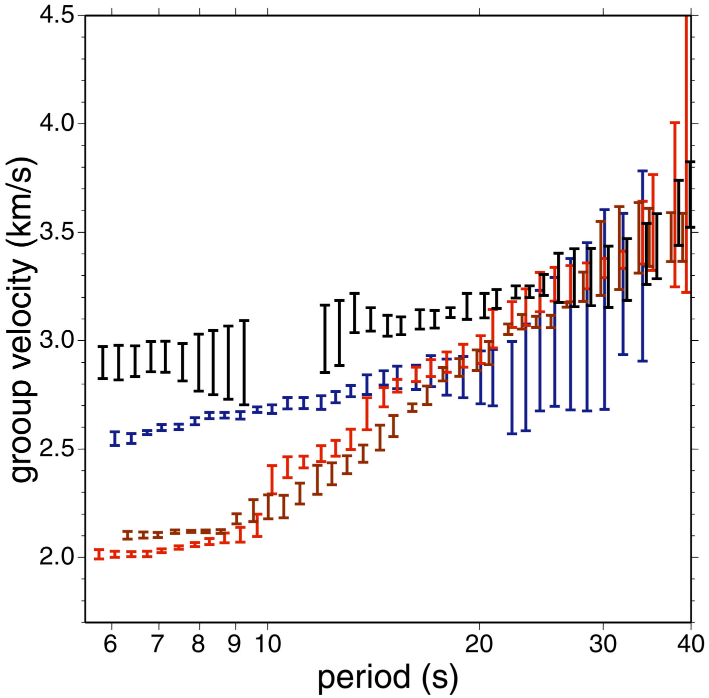
global model by Ritzwoller et al. 2002



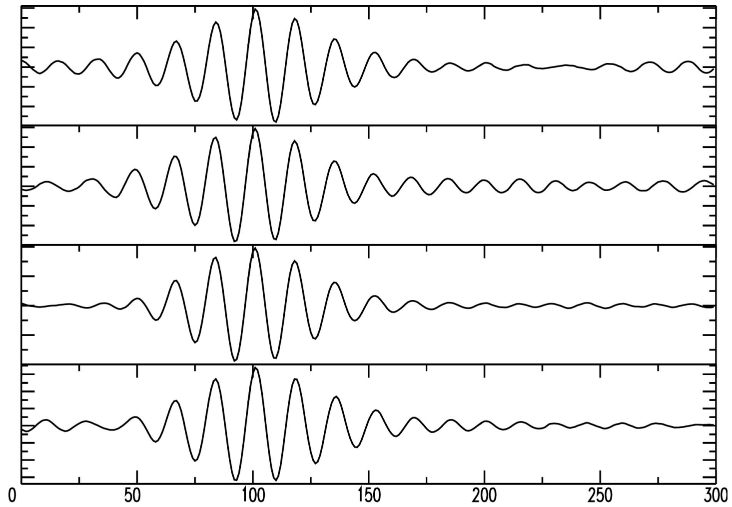
Winter 5–10s
Summer 5–10s
Winter 10–20s
Summer 10–20s
50°N
25°N
0°
25°S
120°W
80°W
40°W
0°
40°E

PHL - MLAC 290 km

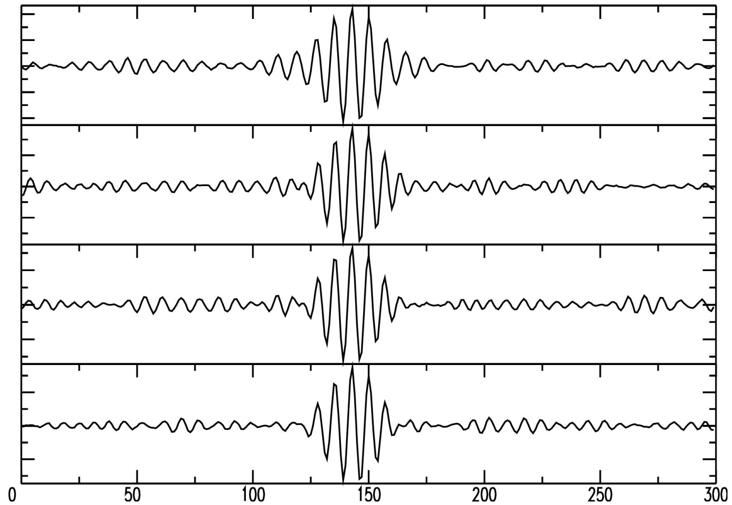




correlations computed over four different three-week periods



band-passed 15 - 30 s



band-passed 5 - 10 s

repetitive measurements provide **uncertainty estimations**

Causality

$$G = \frac{1}{4i\mu} H_0^{(2)}\left(\frac{\omega r}{\beta}\right)$$

$$G = \frac{1}{2\pi\mu} \frac{H\left(t - r/\beta\right)}{\sqrt{t^2 - r^2/\beta^2}}$$