Investigating the accuracy of Green's function estimates from Z-Z and Z-R correlations

Dylan Mikesell, Kasper van Wijk, Matt Haney, Vera Schulte-Pelkum, Josh Stachnik, Thomas Blum, Roel Snieder & Haruo Sato

3rd QUEST Workshop

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Correlation of Rayleigh waves

Aki's SPAC (1957)

$$\phi_{ij}(\mathbf{x},\mathbf{x}',\omega) = \begin{bmatrix} \phi_{zz} & & \\ & \phi_{rr} & \\ & & \phi_{tt} \end{bmatrix}$$

Correlation of Rayleigh waves

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$$\phi_{ij}(\mathbf{x},\mathbf{x}^{'},\omega) = \begin{bmatrix} \phi_{zz} & & \\ & \phi_{rr} & \\ & & \phi_{tt} \end{bmatrix}$$

Nakahara (2006)

$$G_{ij}(\mathbf{x},\mathbf{x}^{'},t) \propto \mathscr{F}\left(\phi_{ij}(\mathbf{x},\mathbf{x}^{'},\omega)\right)$$

Is noise really isotropic?

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The seismic noise wavefield is not diffuse

Francesco Mulargia[a)]
Dipartimento di Fisica, Settore di Geofisica, Università di Bologna, Bologna, Italy

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the latter for azimuthal isotropy and spatial homogeneity. This procedure is then applied to the seismic noise recorded at 65 sites covering a wide variety of environmental and subsoil conditions. Considering the instantaneous oscillation vector measured at single triaxial stations, the hypothesis of azimuthal isotropy is rejected in all cases with high confidence, which makes the spatial homogeneity test unnecessary and leads directly to conclude that the seismic noise wavefield is not diffuse. However,

Isotropic noise

$$\phi_{ij}(r = |\mathbf{x} - \mathbf{x}^{'}|, \omega) = \begin{bmatrix} \phi_{zz} & & \\ & \phi_{rr} & \\ & & \phi_{tt} \end{bmatrix}$$

$$\phi_{ij} \approx P^{R}(\omega) \times \sum_{m=0}^{\infty} J_m\left(\frac{\omega_0}{c} r\right) \mathrm{Re}[\gamma_m^{ij}]$$

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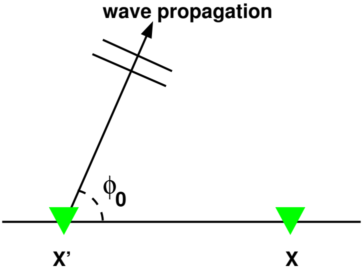
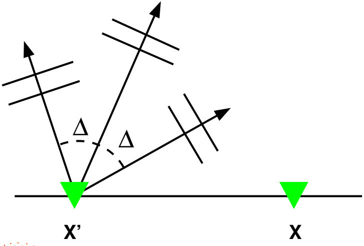
$$p(\theta) = constant = 1$$

Anisotropic noise

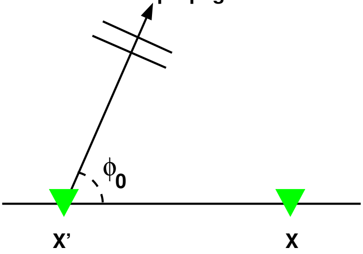




$$\gamma_m^{zz} = \frac{1}{2\pi}\int_0^{2\pi} \exp[-im(\theta-\psi)]d\theta$$

$$\gamma_m^{zz} = \frac{1}{2\Delta}\int_{\phi_0-\Delta}^{\phi_0+\Delta} \exp[-im(\theta-\psi)]d\theta$$

Anisotropic noise



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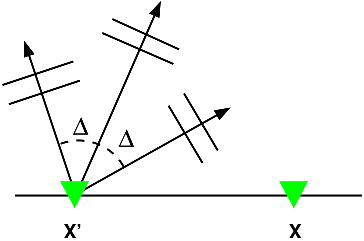
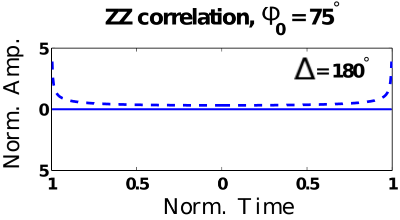
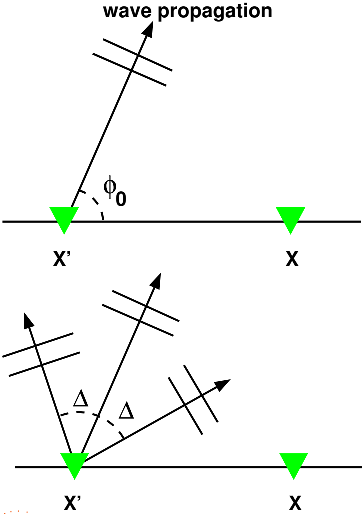
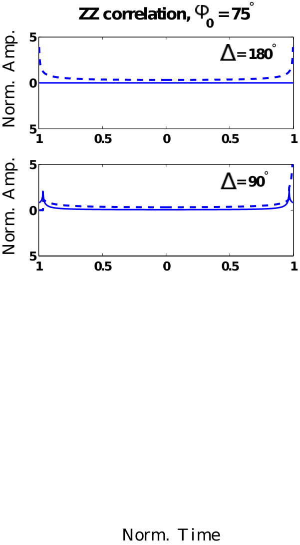


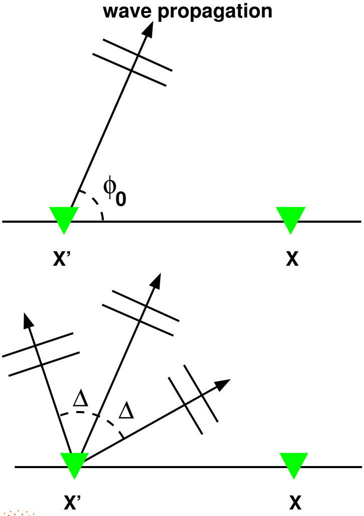


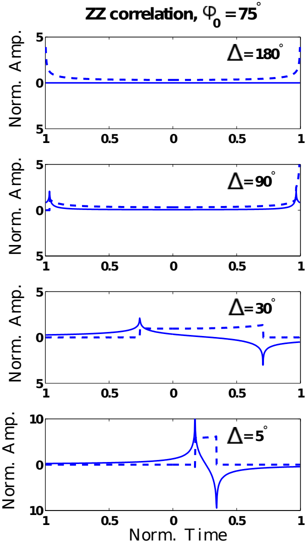
ZZ Artifacts





ZZ Artifacts



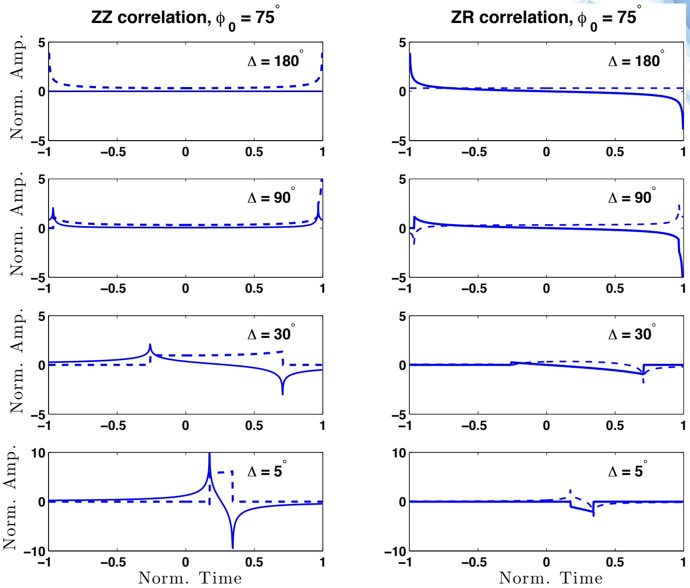


Correlation of Rayleigh waves

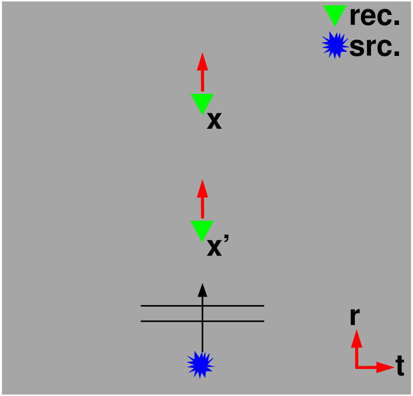
$$\phi_{ij}(|\mathbf{x}-\mathbf{x}^{'}|,\omega) = \begin{bmatrix} \phi_{zz} & \phi_{zr} & 0 \\ \phi_{rz} & \phi_{rr} & 0 \\ 0 & 0 & \phi_{tt} \end{bmatrix}$$

Haney et al., in review G.J.I. (2012)

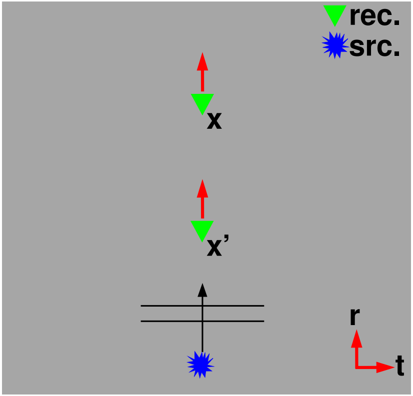
ZZ vs. ZR Artifacts

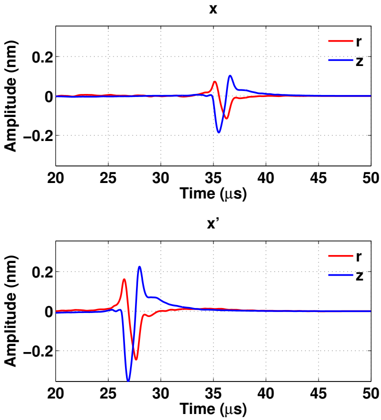


Rayleigh waves

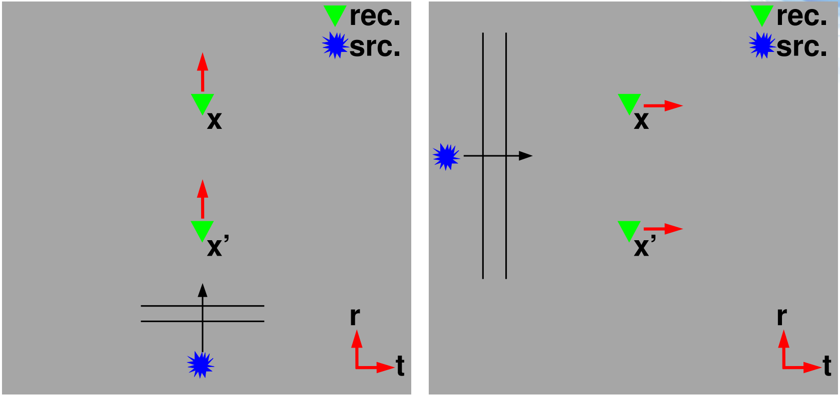


Rayleigh waves

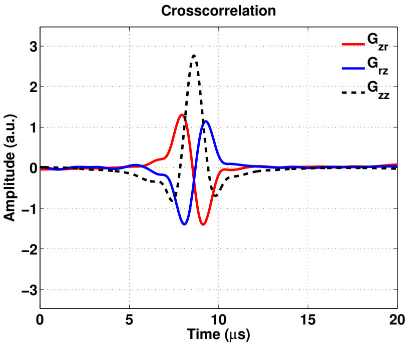




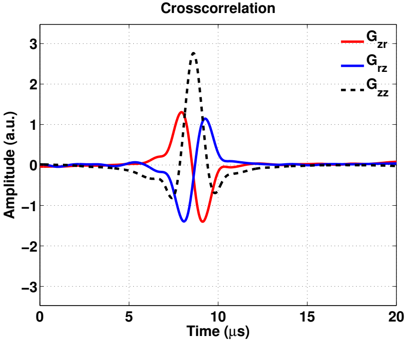
Rayleigh waves

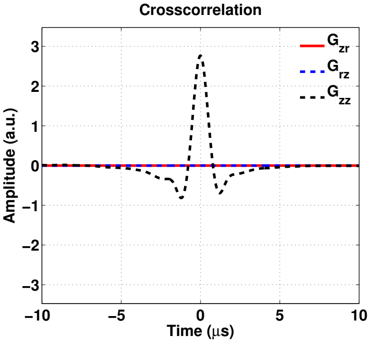


Multicomponent correlations

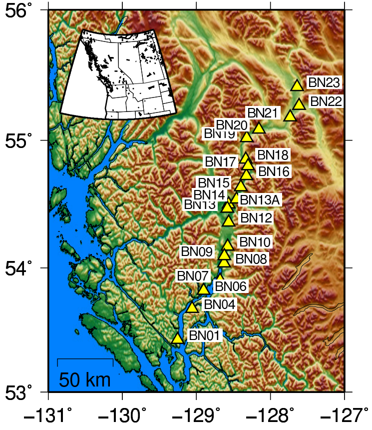


Multicomponent correlations



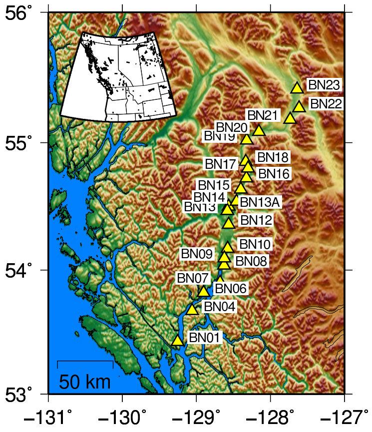


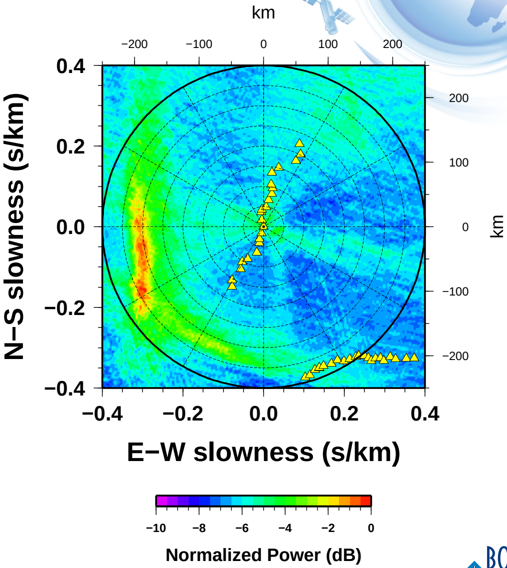
Ambient noise example



van Wijk et al., GRL (2011)

Ambient noise example





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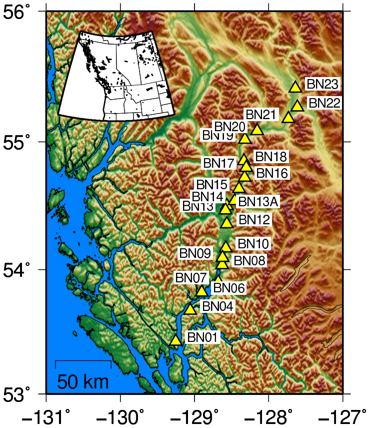
Ambient noise example

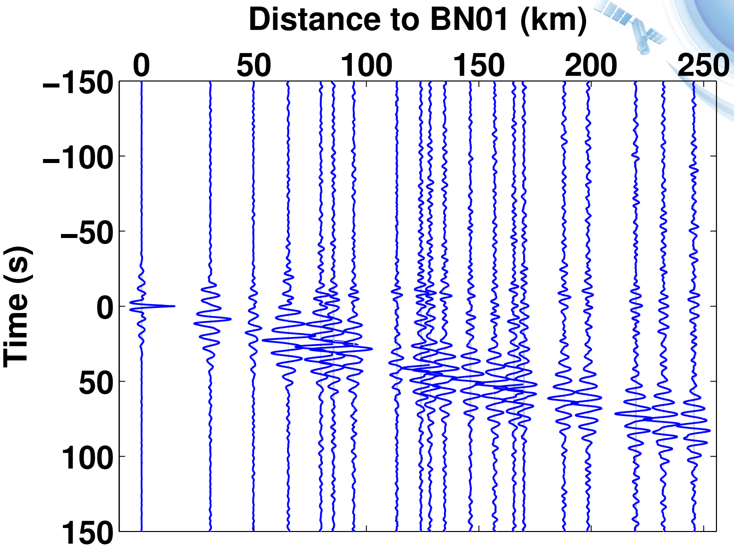


$$G_c(\mathbf{x}, \mathbf{x}', t) \approx G_{zz}(\mathbf{x}, \mathbf{x}', t)$$

$$G_c(\mathbf{x}, \mathbf{x}', t) = \mathscr{H}\left[G_{zr}(\mathbf{x}, \mathbf{x}', t) - G_{rz}(\mathbf{x}, \mathbf{x}', t)\right]$$

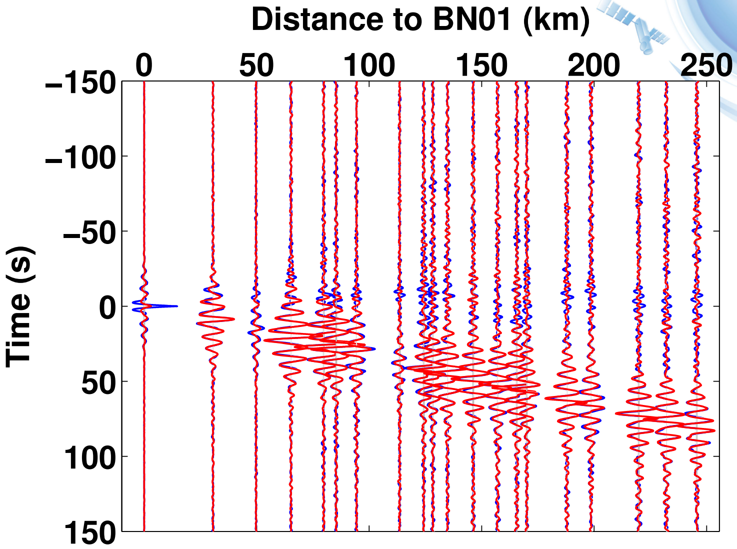
van Wijk et al., GRL (2011)

G_{zz}



Distance to BN01 (km)
0
50
100
150
200
250
Time (s)
−150
−100
−50
0
50
100
150

G_{zz} vs. G_c



Distance to BN01 (km)
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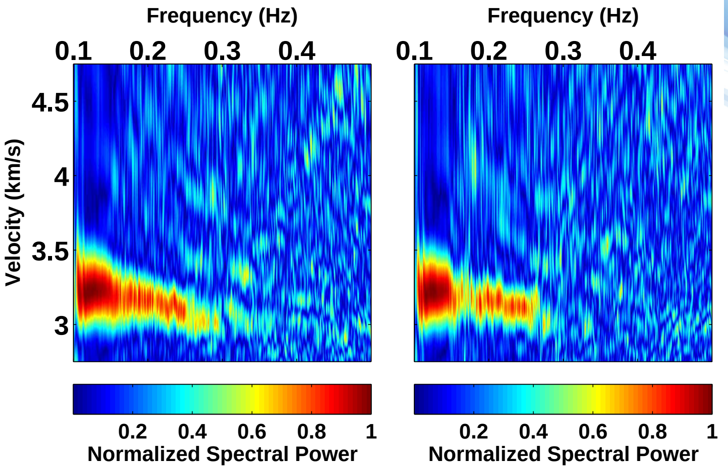
Dispersion comparison



G_c G_{zz}

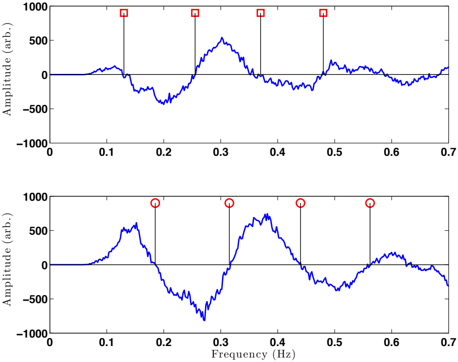
Conclusion

- ϕ_{zr} and ϕ_{rz} are less sensitive to anisotropic Rayleigh wave noise
- G_c has higher $2R$ larger SNR compared G_{zz}

Future Directions

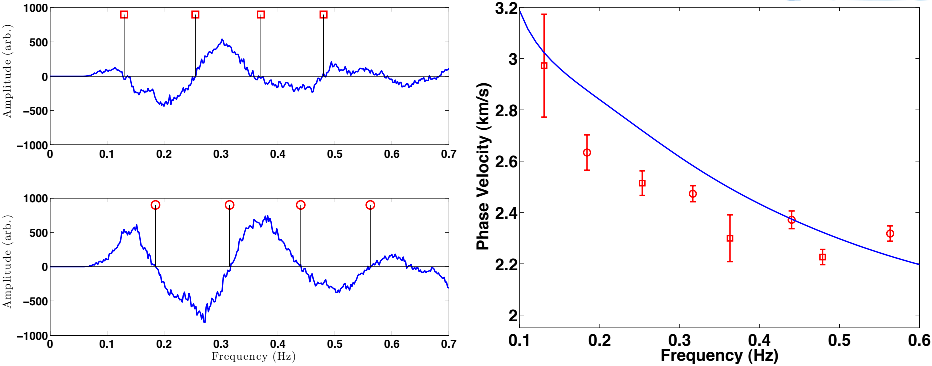
- How does this influence the convergence rate of G?
- Can we use smaller inter-station distances in ANT?
- Do ϕ_{zr} and ϕ_{rz} offer independent phase-velocity dispersion estimates, complimentary to ϕ_{zz} and ϕ_{rr}?

2 station phase-velocity dispersion



$$\phi_{ij} \quad \propto \quad \sum_{m=0}^{\infty} J_m\left(\frac{\omega_0}{c(\omega_0)} r\right)$$

2 station phase-velocity dispersion



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Batholiths comparison