Seasonality of microseisms from 6C ground motions

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Motivation & Method

A single 6C (3C translation + 3C rotation) seismometer provides the feasibility of estimating the azimuth of ambient seismic noise sources, which allows us to locate microseismic noise sources and in particular to better understand the **mechanism of microseismic Love waves**. In addition, recent studies (Tang et al., 2023a,b) have shown that the amplitude characteristics of 6C can extract the azimuthal-dependent phase velocity of surface waves, making it possible to study **azimuthal anisotropy** using **seasonal ambient seismic noise sources**.

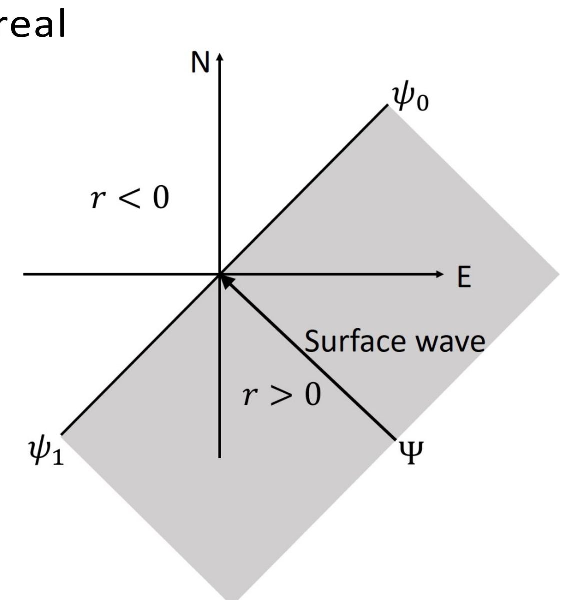
1.1 Backazimuth Ψ estimation from single 6C point observation

Grid Search in azimuth domain to estimate the real backazimuth.

(1) $\Omega_T(\psi) = \Omega_E \cos(\psi) - \Omega_N \sin(\psi)$; $\psi \in (0, 2\pi)$

(2) $r(\psi) = \dfrac{\sum_{i=1}^{N}(A_{z_i} - \overline{A_z})(\Omega_{T_i} - \overline{\Omega_T})}{\sqrt{(\sum_{i=1}^{N}(A_{z_i} - \overline{A_z})^2)(\sum_{i=1}^{N}(\Omega_{T_i} - \overline{\Omega_T})^2)}}$

$$\min\left(\frac{\partial r(\psi)}{\partial \psi}\right)\Bigg|_{\psi=\psi 1} \quad ; \max\left(\frac{\partial r(\psi)}{\partial \psi}\right)\Bigg|_{\psi=\psi 0}$$



Rayleigh waves: where Ψ is the estimated backazimuth, Ω_T represents the transverse rotational velocity (rad/s), A_z represents the vertical acceleration (m/s^2), r is the correlation coefficient between A_z and Ω_T.
Love waves: A_z, Ω_T, Ω_E and Ω_N are replaced by Ω_z, A_T, A_E and A_N respectively.

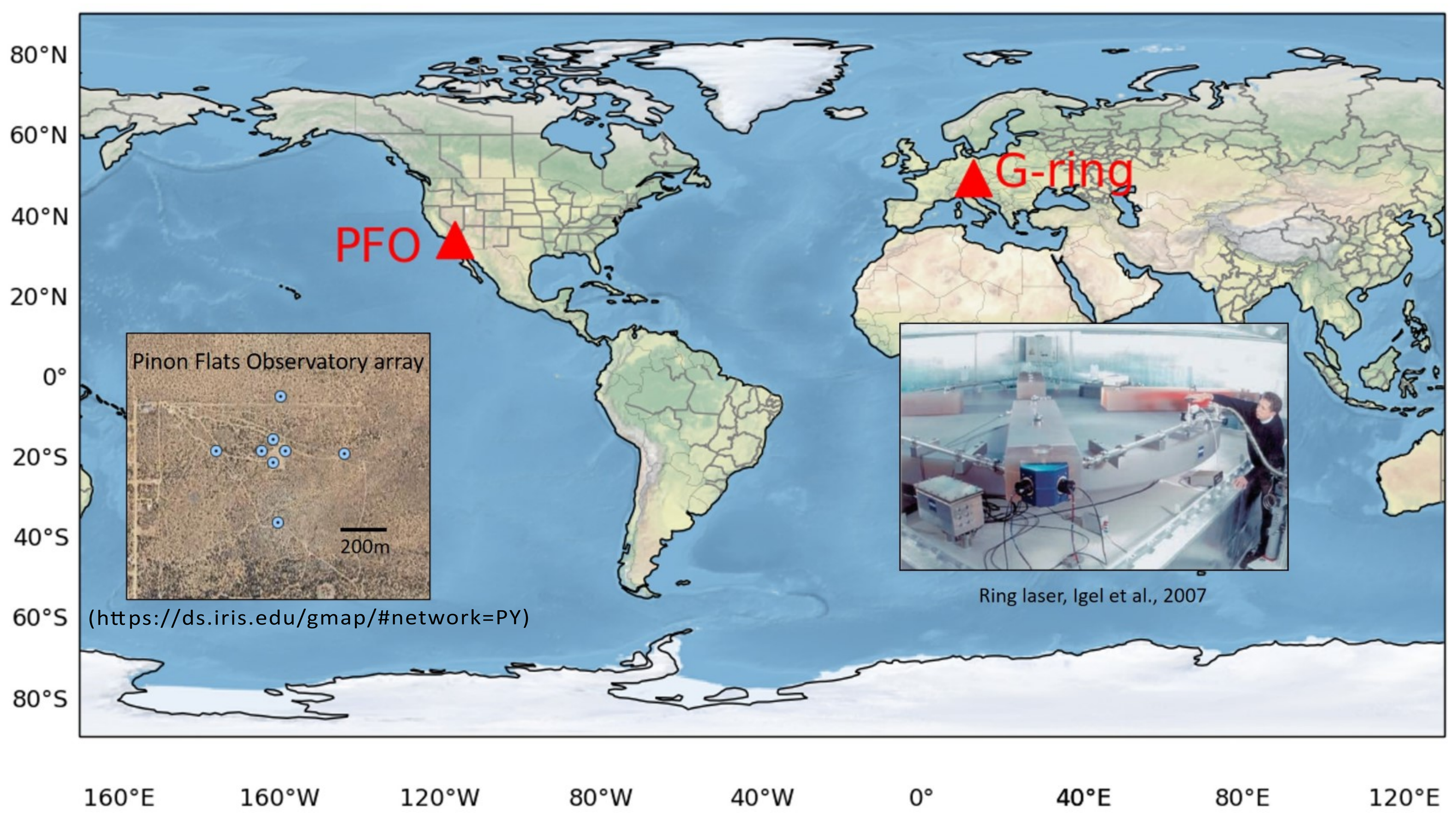
1.2 Azimuthal anisotropy from 6C observations

$$\frac{A_z}{\Omega_T} = v_R(\psi) = a_0 + a_1\cos(2\psi) + a_2\sin(2\psi) + a_3\cos(4\psi) + a_4\sin(4\psi)$$

Rayleigh waves: where Ω_T represents the transverse rotational velocity (rad/s), A_z represents the vertical acceleration (m/s^2), v_R is the phase velocity, a1-a4 represent the integral coefficient of elastic parameters.
Love waves: A_z and Ω_T are replaced by A_T and $2\Omega_z$ (Tang et al., 2023a,b).

Observations of 6C Ground Motions

(1) PFO: Array-Derived Rotation (ADR) **(2) G-ring: Rotational seismometer**



Seasonal Microseismic Noise Sources

3.1 PFO: Array-Derived Rotation

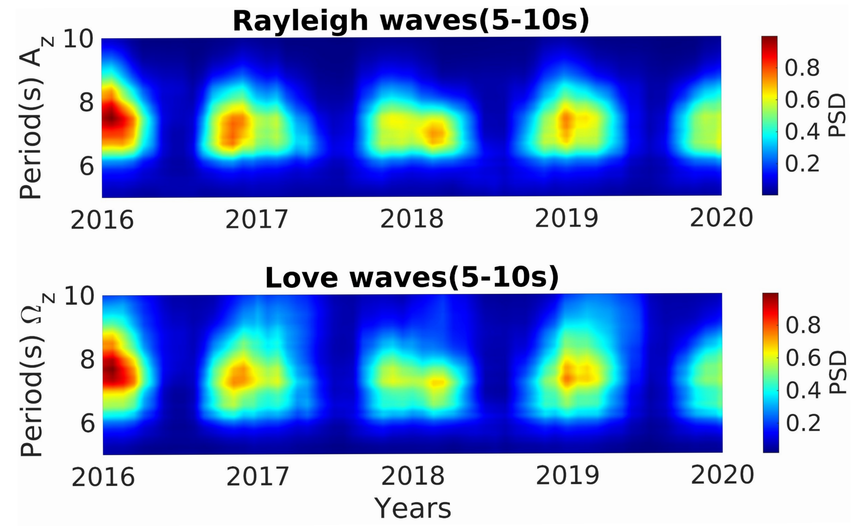


Figure 1. PSD of secondary microseisms at the PFO array.

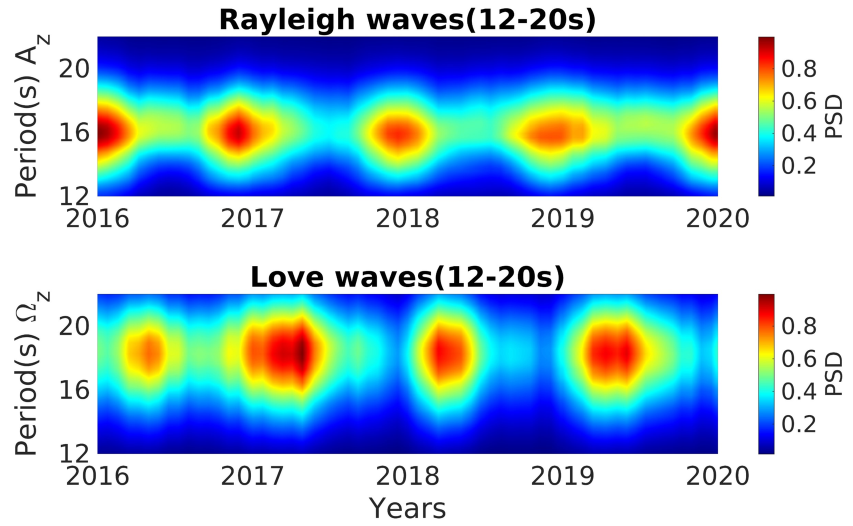


Figure 2. PSD of primary microseisms at the PFO array.

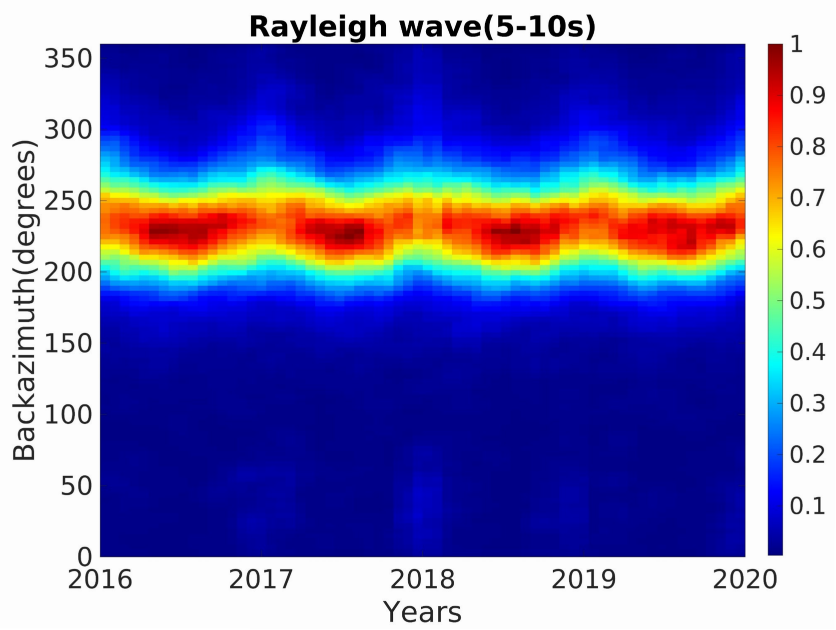


Figure 3. Seasonal variation in secondary Rayleigh waves from the PFO array.

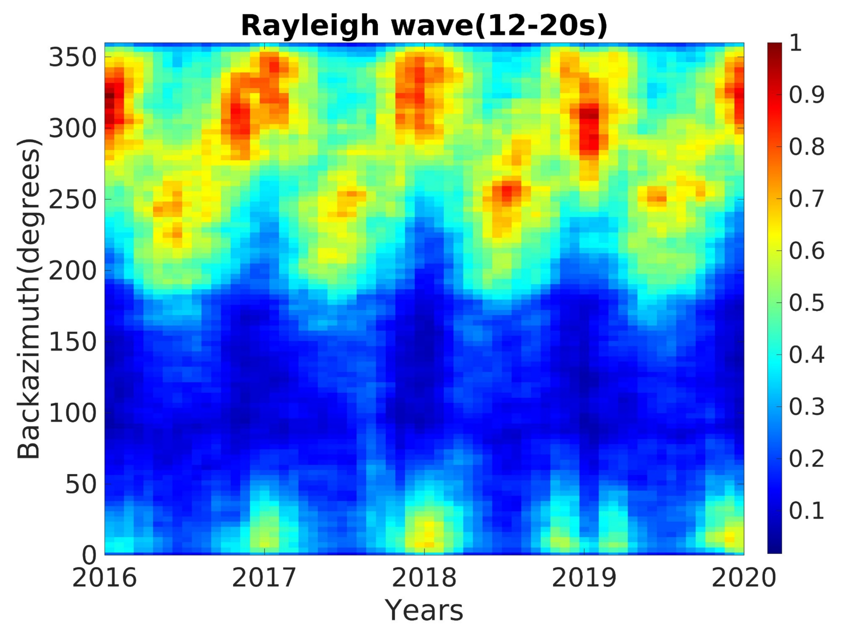


Figure 4. Seasonal variation in primary Rayleigh waves from the PFO array.

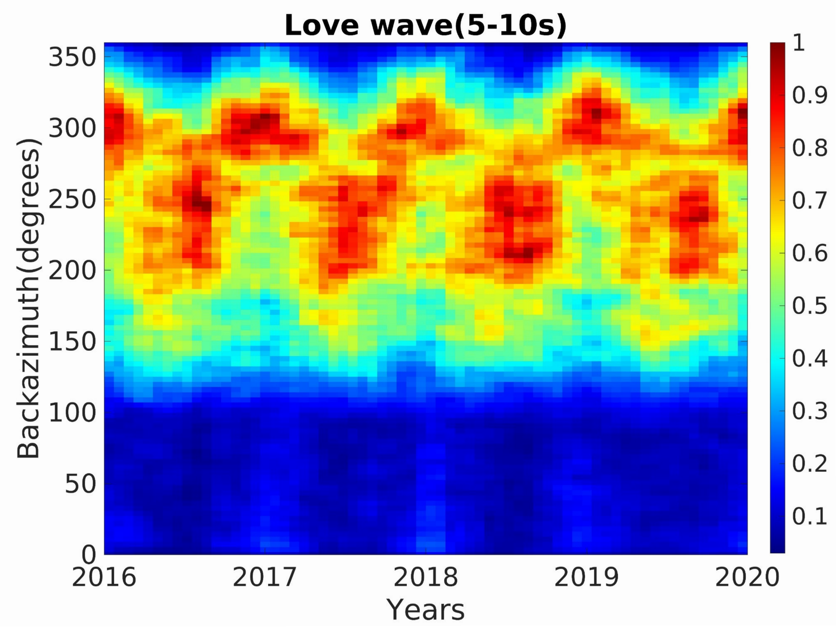


Figure 5. Seasonal variation in secondary Love waves from the PFO array.

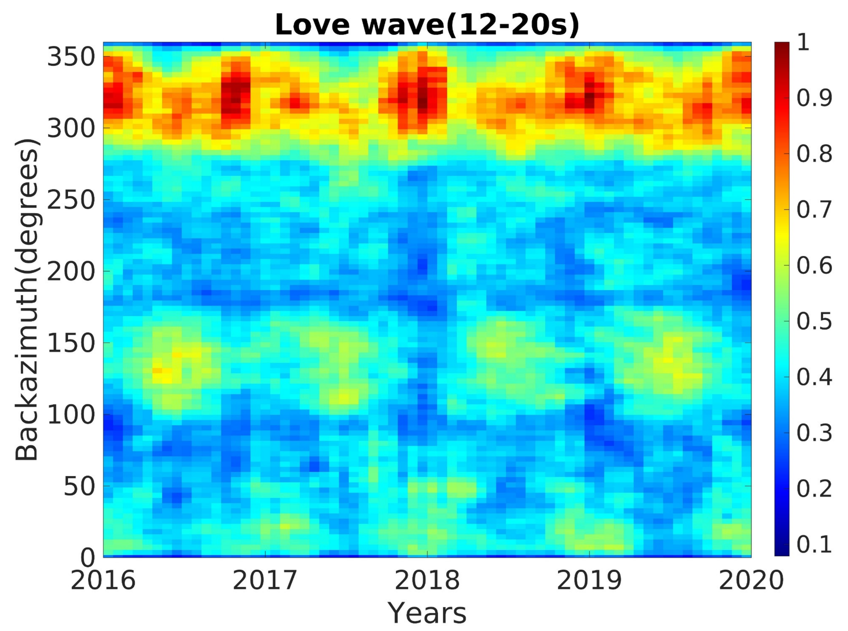


Figure 6. Seasonal variation in primary Love waves from the PFO array.

3.2 G-ring: Rotational seismometer

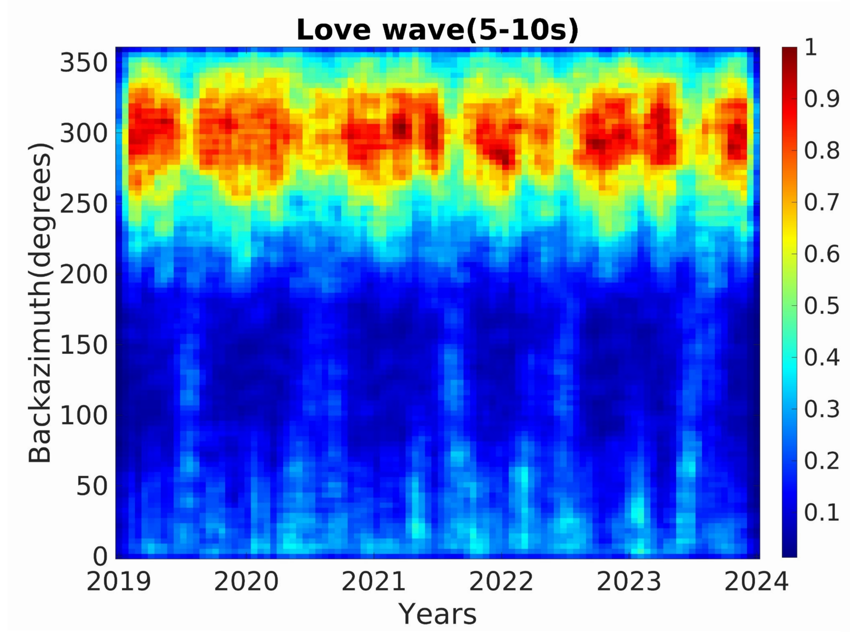


Figure 7. Seasonal variation in secondary Love waves from the G-ring seismometer.

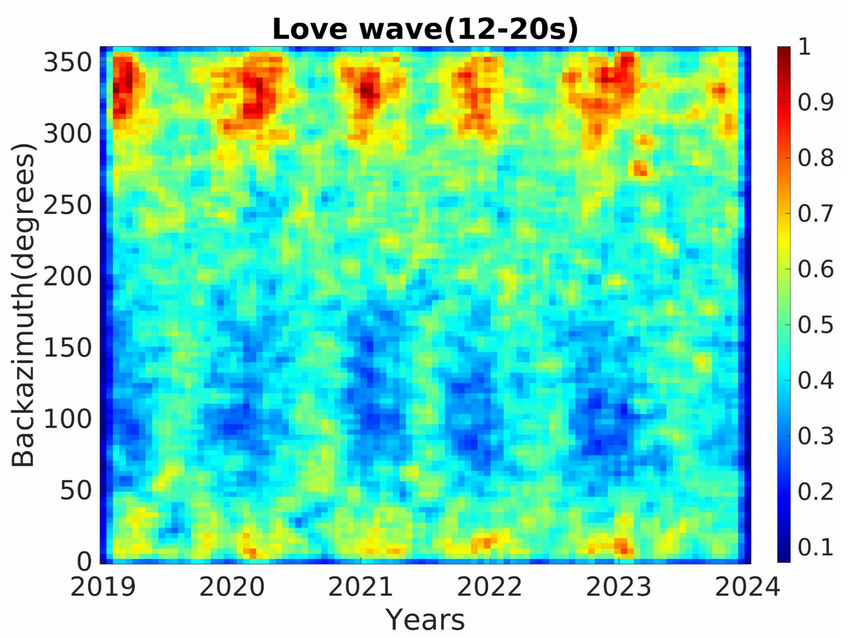


Figure 8. Seasonal variation in primary Love waves from the G-ring seismometer.

Seasonality of Ocean Waves & Microseismic noise

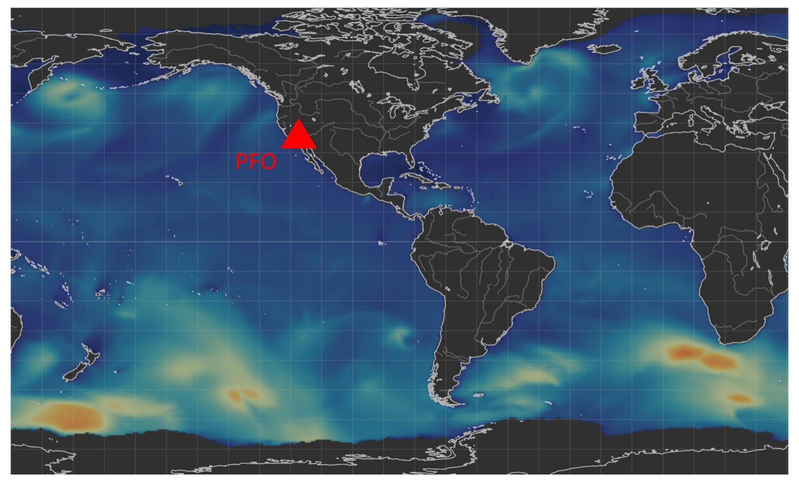


Figure 9a. Ocean wave height on 11.06.2019.
(earth.nullschool.net/)

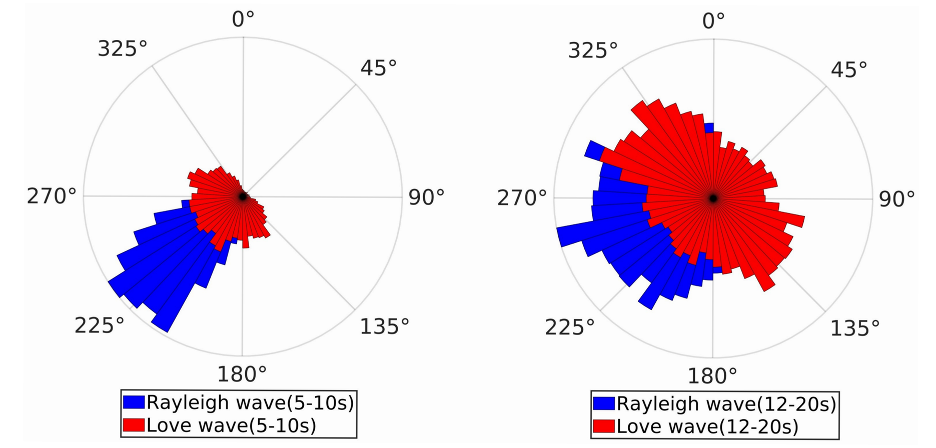


Figure 9c. PFO: microseismic noise in Summer.2019.

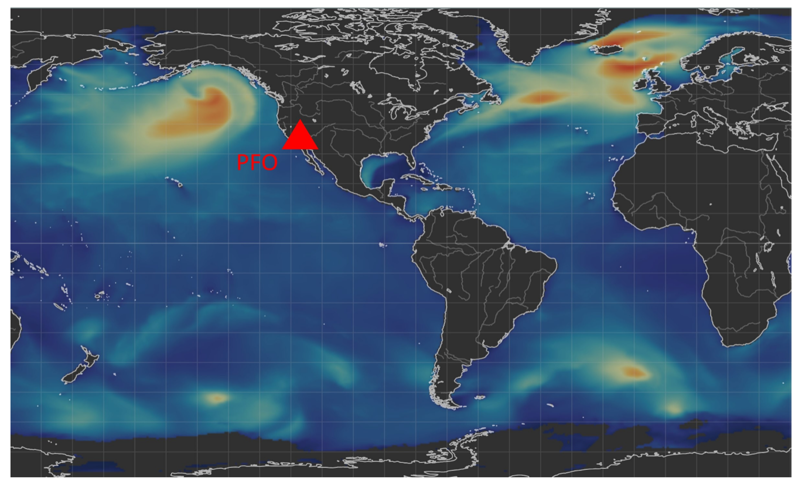


Figure 9b. Ocean wave height on 11.12.2019.

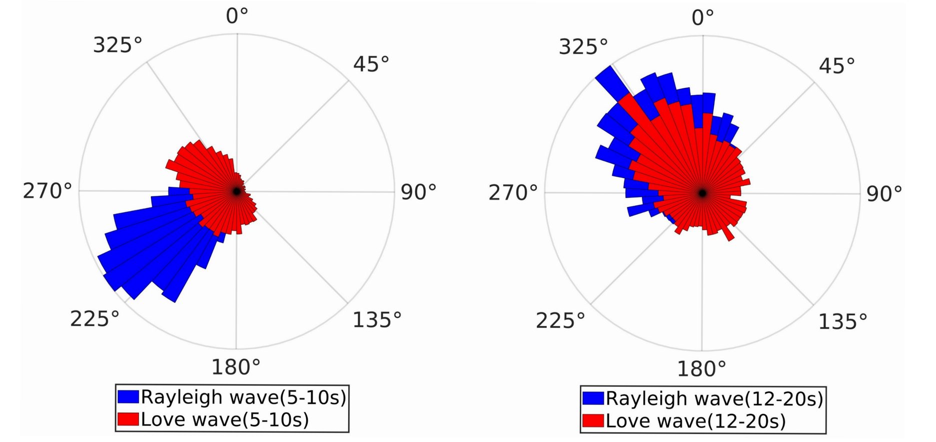
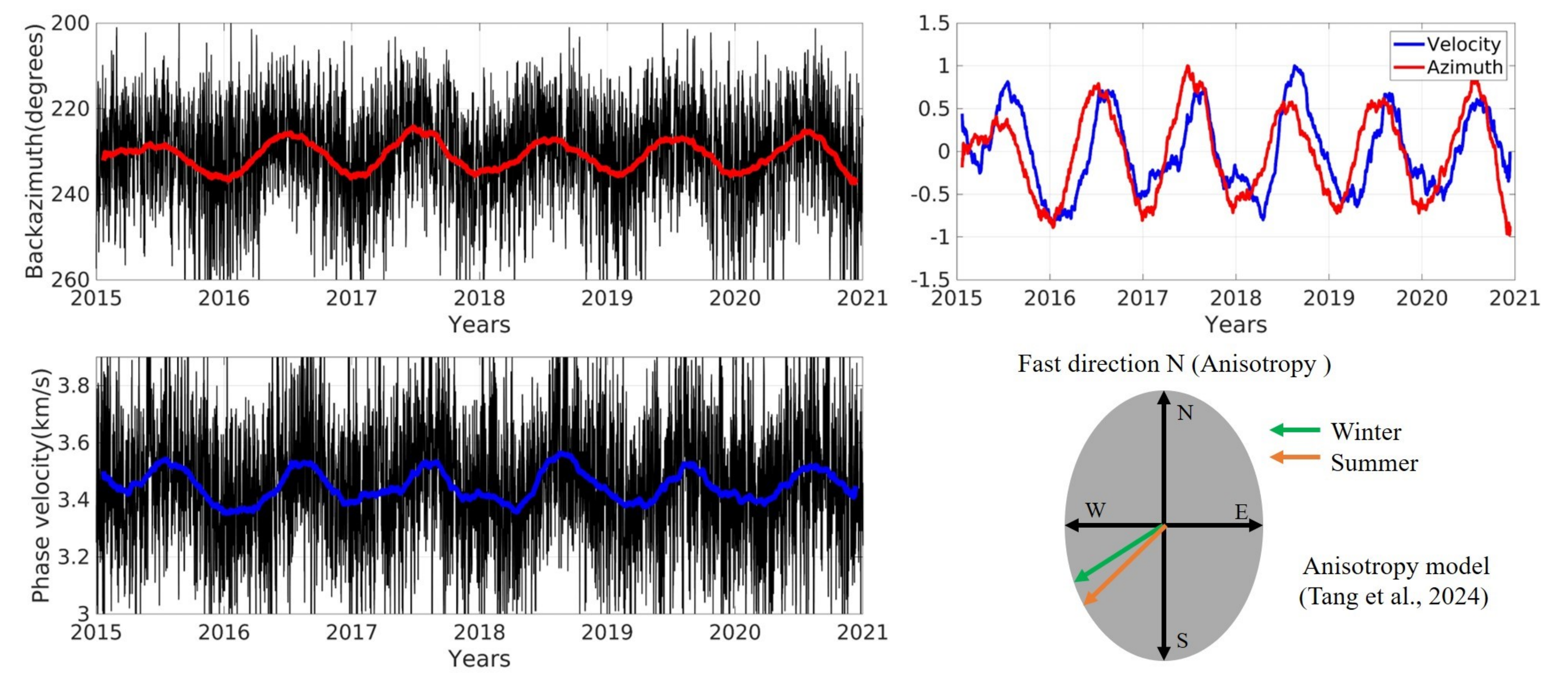


Figure 9d. PFO: microseismic noise in Winter.2019.

Seasonality of Local Seismic Velocity

PFO: Secondary Microseismic Rayleigh waves



Conclusion & Outlook

(1) Microseismic noise sources (primary and secondary) show significant seasonal azimuth variation which can be obtained from a single 6C rotational seismometer or ADR-based small seismic array.
(2) The azimuth difference between microseimic Rayleigh waves and microseismic Love waves provides new insights on the generation mechanism of Love waves.
(3) Seasonal azimuth variation in microseismic noise sources can provide constraints on the local seismic anisotropy.
(4) We expect the rapid development of portable broadband rotational seismometers to conduct rotational observations on the Earth or other planets.

References & Acknowledgments

[1] Tang, L., Igel, H., & Montagner, J. P. (2023). Single-point dispersion measurement of surface waves combining translation, rotation and strain in weakly anisotropic media: theory. GJI.
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