Investigating the Antarctic subglacial liquid water layer using the ellipticity of Rayleigh waves from polarization analysis of seismic noise

A. Berbellini, M. Schimmel, A.M.G. Ferreira, A. Morelli

SUMMARY

We investigate the seismic structure of the uppermost ice and crustal layers beneath the Concordia station (Antarctica) using a new method based on the inversion of ellipticity of Rayleigh waves from ambient noise by degree-of-polarization analysis (DOP). We apply this technique to 1 month of continuous noise recordings in the period band 2–10 Hz, and complement such analyses with measurement of Rayleigh wave ellipticity on earthquake data (in the period band 10–50 Hz). Results show no evidence of a liquid water layer beneath the ice directly beneath the station confirming the results from previous studies. To further validate this result we perform a synthetic test demonstrating that this technique is able to resolve a thin (>100 m) liquid water layer beneath the ice (3.5 km). Since DOP is a completely single-station technique, it can be used when a dense seismic array is not available. It can also be used to monitor possible transients in the shear wave velocity in a wide range of geological settings such as volcanoes, fault zones and glaciers.

METHOD

1. Identification at each time and frequency of the ellipse which best fits the ground motion (Fig. 1a).
2. Separation of the portions of waveform where the polarization changes (Fig. 1b).
3. Selection of the ellipse polarized on a horizontal plane with an orthogonal to the Earth surface (Fig. 2).

VALIDATION

We simulate synthetic ambient noise generated by a storm in Northern Atlantic:
1. We stack synthetics computed at Parma station (Northern Italy) from 300 random, vertical, instantaneous source model Prem (Fig. 3).
2. We add synthetic Love waves generated by 200 horizontal, random, double couple sources at the same location.
3. We add white noise with a signal-to-noise ratio equal to 7.5.

RESULTS

Fig. 7: ellipticity measurements from both ambient noise (black) and earthquakes data (red) and theoretical ellipticity from CRUST1.0 (green). Fig. 8a measured ellipticity (black) and theoretical ellipticity from best fitting model (red). Fig. 8b best fitting vs profile (red) compared to profile from model CRUST10. Fig. 8c zoom of the top 6 km.

SENSITIVITY TEST

We test the capability to resolve a hypothetic liquid layer beneath the ice using ellipticity. We select 5 different models with fixed thickness and different Vs (Fig. 6a). We then calculate the theoretical curves from each model (Fig. 6b). We then assume that a liquid water layer is present, we choose 5 different thickness (Fig. 6c) and compute the theoretical ellipticity curves (Fig. 6d).

NEXT PROJECT

Fig. 12: Ellipticity variations at different periods measured from ambient noise using DOP-E on 1 year of data before and after the Ugilsa earthquake Mw 6.3 (Italy) (red vertical line). Bottom: number of measurements available.

DOWNLOAD

The DOP-E code to measure ellipticity from ambient noise is free to download here: https://github.com/A.Berbellini/DOP-E 

Contact: andrea.berbellini@ingv.it