Effect of the water layer on seismic noise cross-correlation across the Northeast Atlantic, from Madeira and Canaries to the Atlas-Gibraltar zone

Graça Silveira, Joana Carvalho, Juan Pinzón, Susana Custódio, Carlos Corela, Luís Matias

EGU2020-18561

Introduction

In the framework of project SIGHT (SeIsmic and Geochemical constraints on the Madeira HoTspot system) we want to obtain a 3D model of SV-wave velocities of the crust and upper mantle of the Northeast Atlantic area encompassing Madeira and Canary Islands to the Atlas-Gibraltar zone, using seismic noise cross-correlations in the period range 2-100 s.

Geological setting

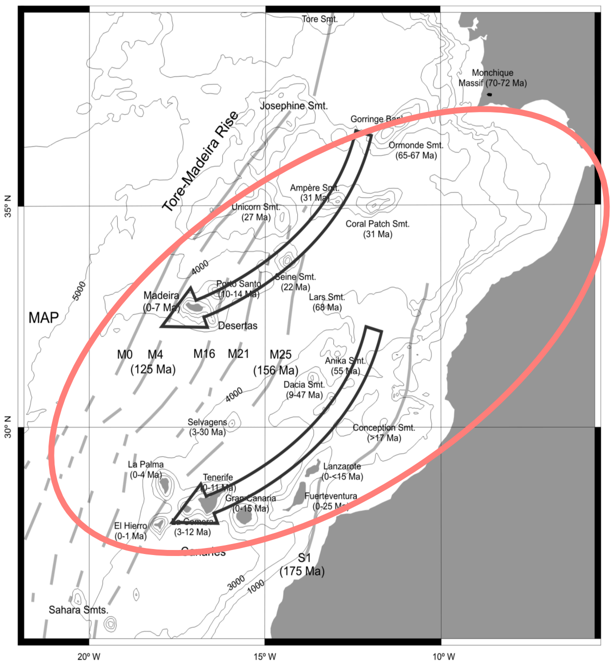


Figure adapted from Geldmacher & Hoernle, 2000

Region of raised seafloors that develops to the NNE (the 1400 km long Tore-Madeira Rise);

Youngest dated eruption occurred 6-7ka ago;

Intraplate active volcanic archipelago;

Lies over a large (2500 x 4500 km) upper mantle anomaly extending down to depths of 500 km – Hoernle et al. 1995 global study.

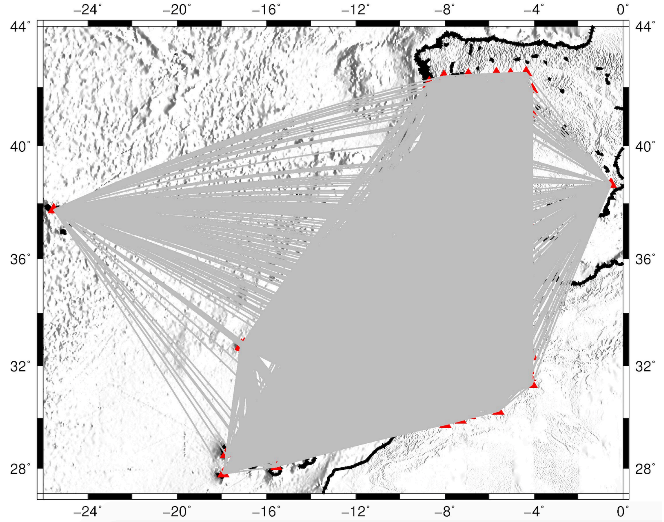
Key questions

- Is Madeira´s volcanism fed by a deep-seated mantle plume?
- Do the Madeira and Canary hotspots have a common or distinct origin?
- What is the lithospheric nature of the corridor between the Canaries and the Atlas-Gibraltar?

Addressed with

SKS Anisotropy; P and S Receiver Functions; H/V polarization analysis; **Ambient Seismic Noise Tomography.**

What's the problem?



Good azimuthal coverage;

Most of the interstation **paths cross the ocean**.

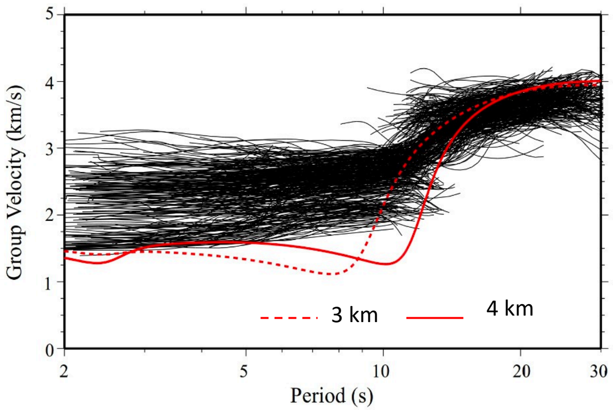
What is the:

- Effect of the water and sediments in the Empirical Green Functions (EGF) and in the dispersion curves for paths crossing the ocean for short periods?
- Impact on retrieving single mode dispersion curves?

Dispersion measurements in an oceanic environment – going on study*

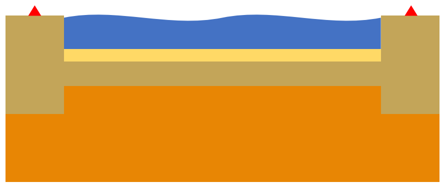
Fundamental mode group velocities using:
S-transform (Ventosa et al., 2017)
Velocity range1.5 - 4.5 km/s;
Maximum frequency range 0.3 -0.5 Hz

Compared with synthetic fundamental mode group velocities in laterally varying media (Herrmann, 2013)



Black - measurements; Red- synthetics

Synthetic scenario

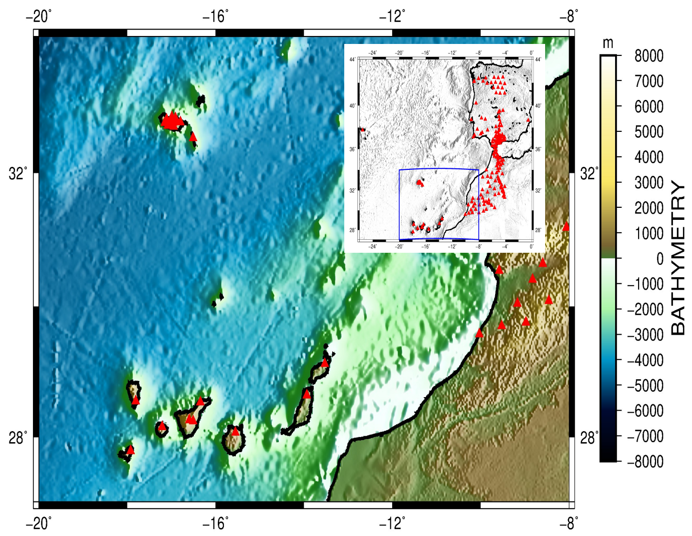


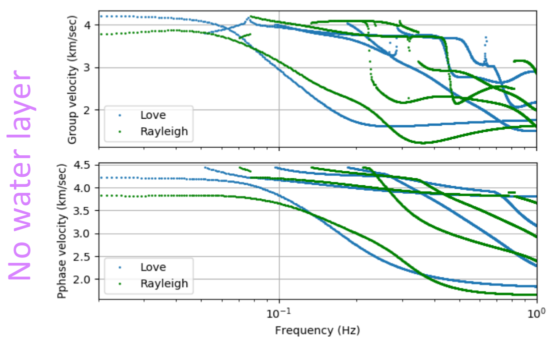
Land
Lodge and Helffrich (2006), Vinnik et al. (2012)

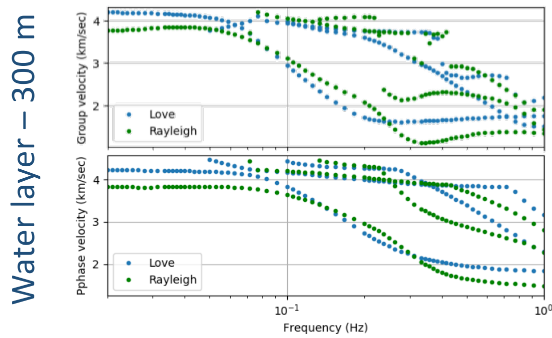
Ocean
Crust to a depth of 20 km - Pim et al. (2008)
Below - Carvalho et al. (2019)

* Carvalho et al. 2020 in prep.
In the Cape Verde region

Fundamental mode and overtones in an oceanic environment

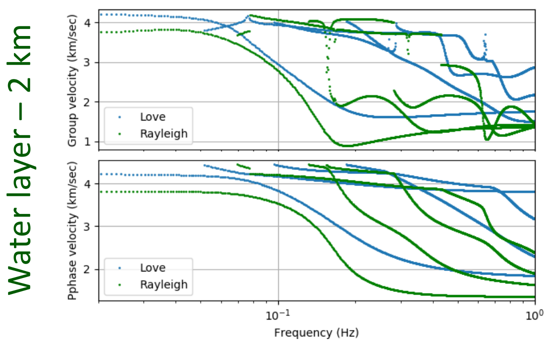


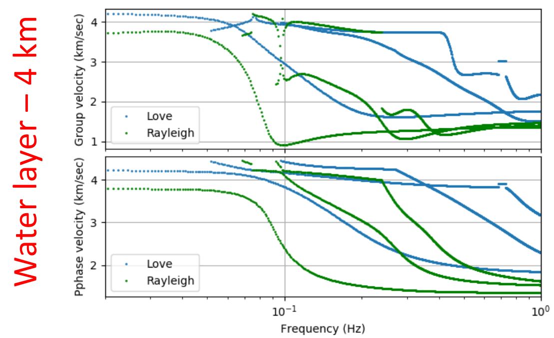


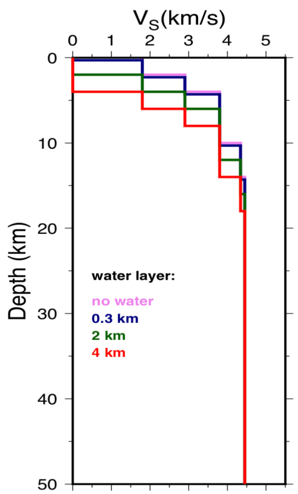


Rayleigh waves → no mode contamination in the short frequency range;
Love waves → contamination in 0.02 – 0.03 Hz.

- Short period measurements - Madeira to Canaries paths;
- Intermediate periods measurements - between islands and continent.







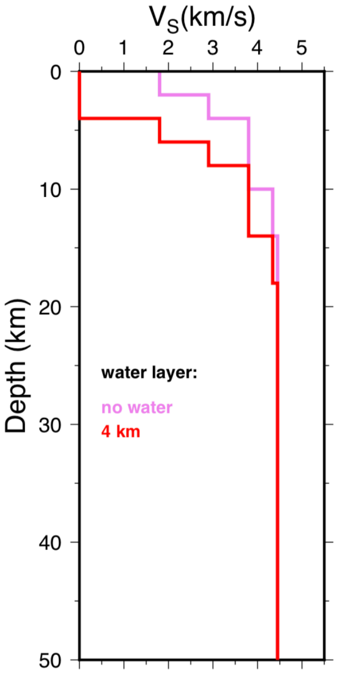
1D model - Vs

. Water
. Sediments
. Three layer crust
. Mantle

Rayleigh waves → mode contamination in the short frequency range;
Airy phase frequency related with water layer thickness;
Love waves → contamination between 0.02 – 0.03 Hz.

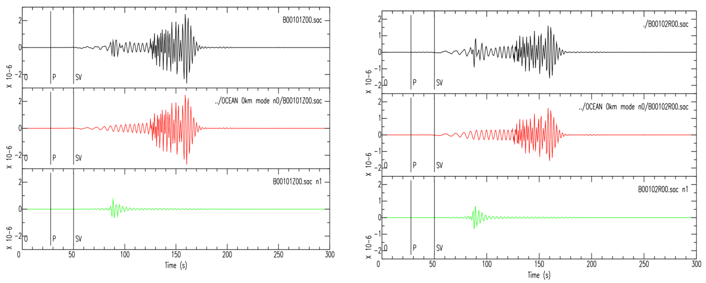
Synthetic seismograms in oceanic paths – radial versus vertical components

Computed by normal mode summation (Herrmann, 2013);
Source → vertical force;
Δ = 200 Km

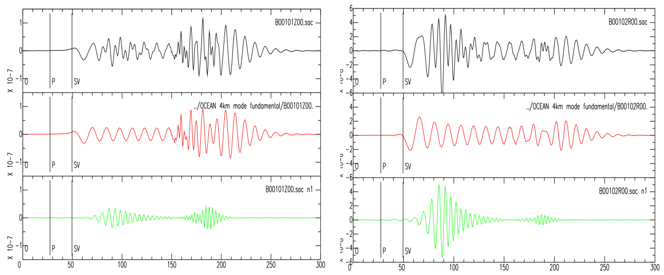


. Water (0 or 4 km)
. Sediments
. Three layer crust
. Mantle

No water



Water layer thickness – 4 km



— complete seismogram; — fundamental mode seismogram; — 1st overtone seismogram

Presence of a water layer → has impact on the fundamental mode;
first overtone dominate in the radial component.

Conclusions

The influence of the water layer on both vertical and radial synthetic Rayleigh waves, as well as on higher-mode conversion and on the group velocities dispersion measurements cannot be neglected;

Although the fundamental mode dominates, the presence of the first overtones at short periods (typically below 8 seconds) show that specifying a given velocity range when retrieving group velocity can result in a mixture of modes.

At short periods, the water has a dominant effect on ocean-continent laterally varying media.

References

Carvalho, J., Bonadio, R., Silveira, G., Lebedev, S., Mata, J., Arroucau, P., ... & Celli, N. L. (2019). Evidence for high temperature in the upper mantle beneath Cape Verde archipelago from Rayleigh-wave phase-velocity measurements. Tectonophysics, 770, 228225.

Carvalho J., Silveira G., Stutzmann, E., Kiselev S., Custódio, S., Mata, J. and Ramalho R. (2020). Seismic imaging of the Cape Verde crust and uppermost mantle with ambient seismic noise measurements. (in preparation).

Geldmacher, J., & Hoernle, K. (2000). The 72 Ma geochemical evolution of the Madeira hotspot (eastern North Atlantic): recycling of Paleozoic (≤ 500 Ma) oceanic lithosphere. Earth and Planetary Science Letters, *183*(1-2), 73-92.

Herrmann, R. B. (2013). Computer programs in seismology: An evolving tool for instruction and research. Seismological Research Letters, 84(6), 1081-1088.

Hoernle, K. A. J., Zhang, Y. S., & Graham, D. (1995). Seismic and geochemical evidence for large-scale mantle upwelling beneath the eastern Atlantic and western and central Europe. Nature, 374(6517), 34-39.

Lodge, A., & Helffrich, G. (2006). Depleted swell root beneath the Cape Verde Islands. Geology, 34(6), 449-452.

Pim, J., Peirce, C., Watts, A. B., Grevemeyer, I., & Krabbenhöft, A. (2008). Crustal structure and origin of the Cape Verde Rise. Earth and Planetary Science Letters, 272(1-2), 422-428.

Ventosa, S., Schimmel, M., & Stutzmann, E. (2017). Extracting surface waves, hum and normal modes: time-scale phase-weighted stack and beyond. Geophysical Journal International, 211(1), 30-44.

Vinnik, L., Silveira, G., Kiselev, S., Farra, V., Weber, M., & Stutzmann, E. (2012). Cape Verde hotspot from the upper crust to the top of the lower mantle. Earth and Planetary Science Letters, 319, 259-268.