Introduction

Seismic oceanography (SO) is a multidisciplinary research field that uses common marine multichannel seismic reflection data to imaging sub-mesoscale oceanic processes hardly detected by sparse direct measurements as represented by conventional oceanographic sampling techniques.

Why the Madeira abyssal plain?

The Mediterranean outflow waters (MOW) have high influence in the mixing layers of the Madeira abyssal plain (MAP).

The MOW is characterized by warm and high-salinity water masses, which reach the MAF in buoyancy between ~500 to 1500 meters depth creating an anomaly dividing the North Atlantic Water from the North Atlantic Deep Water (NADW).

The three seismic sections acquired by the Portuguese Task Force for the Extension of the Continental Shelf in the Madeira Abyssal Plain (MAP), covering 300km and ~1000km apart from each other, and dating from 2006, were processed to enhance the amplitudes of the water column (Azevedo, L. et al., 2021). The conductivity-temperature-depth (CTD) data was acquired from Poseidon research vessel campaigns (Waniek, 2007a & 2007b; Müller, 2008; Müller & Schulz-Bull, 2003).

Characterizing the ocean with acoustic waves

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Seismic oceanography allows studying the ocean by taking snapshots of the water layers.

We detected thermohaline staircases in the Madeira abyssal plain and correlated with three seismic sections.

Temperature and Salinity measurements

This salinity gradient anomaly is auspicious for developing double-diffusive mixing (Radko, 2013; van der Boog, C. et al., 2021), in particular thermohaline staircases formed by mixing of the MOW with NADW, between ~1600 to 2000m deep.

Thermohaline staircases

Thermohaline staircases are regular, relatively homogeneous, horizontal structures, that spread laterally in well-defined layers. Those layers are formed by different mixing gradients of heat and salt, they are also observed in vertical temperature and salinity profiles as step-like variations.

Correspondence between seismic reflections and thermohaline staircases

We found horizontal reflections on the three seismic sections (between ~1200m to ~1900m) which correspond to thermohaline staircases depths. By integrating the seismic images with the direct measurements, it is noted that those reflections correspond to the staircases. When there is a jump of the properties, there is a reflection associated to it.

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References

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Plain Oceanographic Mapping of The Ocean: Coupled Earth Observations with Acoustic Waves (EMEPC/P/CR_002/2015/001) project. Further measurements of temperature and salinity were collected by Poseidon research vessel, we greatly appreciate Thomas Müller and Luiz Waniek for their efforts in collecting and sharing valuable data.

Figure 1: a) Multichannel Seismic acquisition diagram; b) Final stacked image of the ocean acquired 2D line.

Figure 2: Data location, CTD profiles (dots), Seismic sections (black lines).

Figure 3: Temperature (a) and Salinity (b) vertical plots and its correspondence in depth to the different water masses.

Figure 4: Conservative temperature of the CTD profiles which show step-like features. Red dots correspond to salt finger pronounced depths computed with Turner Angle between -90° and density ratio between 1-2.

Figure 5: Vertical plots of T and S between 1000 and 2000m with thermohaline staircases plotted against seismic reflections, highlighted colours capturing the salt finger pronounced depths of the profiles.

Figure 6: Shows that the staircases seen on the vertical profiles are corresponding to the reflections on the seismic which is a good validation to use the seismic images to infer the lateral continuity of those structures.