STORM

Atmosphere – Ocean – Solid Earth Coupling:
Seismic Tools to Explore and Monitor the Oceans

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TEAM

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Other partnering organizations:
Fundação Gaspar Frutuoso
IPMA - Instituto Português do Mar e da Atmosfera

SPACE-EARTH INTERACTIONS

Background

In this exploratory collaborative project, we propose to explore innovative seismology-based tools to observe the oceans, in parallel with state-of-the-art meteorological reanalysis, bringing together knowledge from atmospheric, ocean and solid earth science.
In this exploratory project, we propose to use unique ocean and land-based seismic datasets, collected in and around the North Atlantic, both on the seafloor, ocean islands and margins, in order to study ocean processes and the internal structure of the Earth. Our workplan aims at proving concepts that, if successful, can later be applied to larger datasets and/or be used for operational/monitoring purposes.
The project is structured around three main tasks:
1) Using seismic data to image ocean storms, assessing its results against meteorological reanalysis;
2) Evaluating the impact of the steep topography of ocean islands on the microseismic wavefield, with impact on imaging the sub-surface;
3) Using OBS data as a proxy for ocean bottom currents.
The aims of the project are relevant for the mission of the Azores International Research (AIR) Center, in particular for understanding climate change, ocean processes and imaging sub-surface georesources in oceanic domains.

Approach/Methodology

The project benefits from the collaboration between a strong Applied Mathematics team at the University of Texas, Austin (UT Austin) and Earth Sciences researchers in Portugal. Inverse problems are perhaps the most popular mathematical approaches for enabling predictive scientific simulations that integrate observational data, simulations and/or models. For inverse problems that serve as a basis for discovery and decision-making, the uncertainty in their solutions must be quantified. Indeed, assessing the uncertainty of inverse solutions is a key component of seismological problems, where we often find a range of solutions that can fit the complex and often noisy observed data similarly well.
The UT Austin team is highly skilled on rigorous and scalable uncertainty quantification (UQ) methods for large-scale inverse problems in the Bayesian framework.
These methods aim to provide not only solutions to an inverse problem but also to characterize the uncertainty associated with each solution. The Portuguese team encompasses experts in Seismology (seismic sources, Earth structure and wave propagation, seismic networks and instrumentation, ocean bottom seismology development), Physical Oceanography and Atmospheric Modelling, and will provide the relevant physical and observational knowledge on the project to tackle. The project uses existing data from IDL, IPMA and the Univ. of Azores and new deep ocean data to be obtained by IPMA.

Implementation Challenges

The main challenged that we found were not scientific, but rather administrative, namely caused by the short duration of the project and by the rigid administrative procedures of the institutions. Namely:
• The project envisioned the hiring of 1-hr PhD students and post-docs. At Austin, the hiring of students can only be done at the beginning of academic semesters, which was not synchronized with the project starting date. In Portugal, the hiring of post-docs was paused for several months due to changes in regulations. The delay in the hiring of human resources caused a substantial delay in the execution of the workplan.
• In addition, when we could finally hire, we could only establish short-duration contracts, because the final date of the project could not be extended until we had executed the budget, which in turn was dependent on executing the hirings. In the end, this resulted in us not being able to hire the best candidates, as we could only offer very short-duration contracts, which could only be later extended.
• Finally, IPMA had considerable difficulty in performing the field work that was foreseen, both due to administrative difficulties in the acquisition of instrumentation and to the execution of field work in light of the current COVID-19 pandemic.

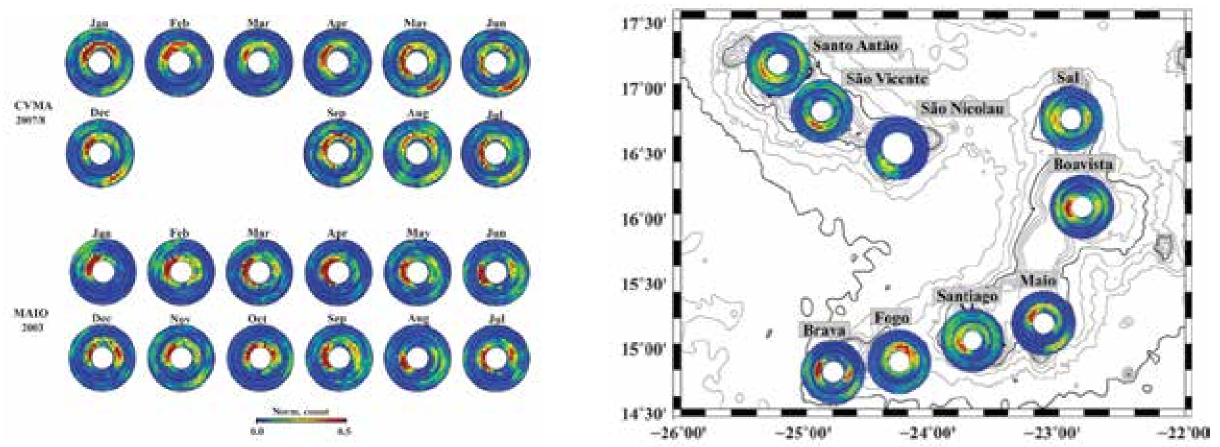
Main Findings

• Demonstrate how ocean bottom seismic data is influenced by the water layer (oceans) and suggest analysis procedures that allow to image the Earth's internal structure in spite of the water layer.
• Image sources of seismic noise, which are related to ocean storms, by using data recorded in the Cape Verde archipelago, central Atlantic.
• Develop empirical transfer functions that allow to image ocean storms using seismic data recorded on land.
• Develop machine learning method (i.e. deep neural network and recurrent neural networks) to construct empirical functions

Expected Impact

This project proposes to explore innovative seismology-based tools to observe the oceans, in parallel with state-of-the-art meteorological reanalysis, bringing together knowledge from atmospheric, ocean, solid earth science, and applied mathematics.
The expected impacts are to obtain improved observations of atmospheric, oceanic and solid Earth structure, which in turn allow for a better understanding of the dynamics of these Earth spheres, using seismic data.

The main goals of the project are to:
1) Use seismic data to image ocean storms, assessing the results against meteorological reanalysis;
2) Evaluate the impact of the steep topography of ocean islands on the microseismic wavefield, with impact on imaging the sub-surface;
3) Using OBS data as a proxy for ocean bottom currents.



Project Highlights

• Map identifying the oceanic sources of seismic noise in the Cape Verde archipelago, central Atlantic.
• New empirical transfer functions that allow to predict ocean activity at a given location in the ocean given seismic data recorded on a point on land.
• Documentation of the effect of the oceans in seismic data recording in the ocean bottom.
• Preliminary success of developing machine learning method (deep neural network and recurrent neural networks) on some historical data. We are currently working on improving the ocean storm imaging using machine learning techniques.

UTAustin Portugal
FCT Fundação para a Ciência e a Tecnologia
TEXAS The University of Texas at Austin

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