Mapping of noise sources areas and trialling of noise correlation methods in the marine environment, offshore Ireland

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Introduction

In seismology, a microseism is defined as a faint earth tremor caused by natural phenomena. The term is most commonly used to refer to the dominant background seismic noise signals on Earth, which are caused by pressure fluctuations beneath ocean waves.

The generation mechanism for OGM and their subsequent propagation to continental regions has led to their use as a proxy for sea-state characteristics and for climate change studies.

Also many modern seismological methods make use of OGM signals. For example, the Earth's crust and upper mantle can be imaged using ambient noise tomography; analysis of the geometric dispersion of surface waves and spectral ratio techniques can provide information on velocity structure; and cross-correlation techniques can be used to monitor seismic velocity changes.

For many of these applications an understanding of the source distribution is necessary to properly interpret the results.

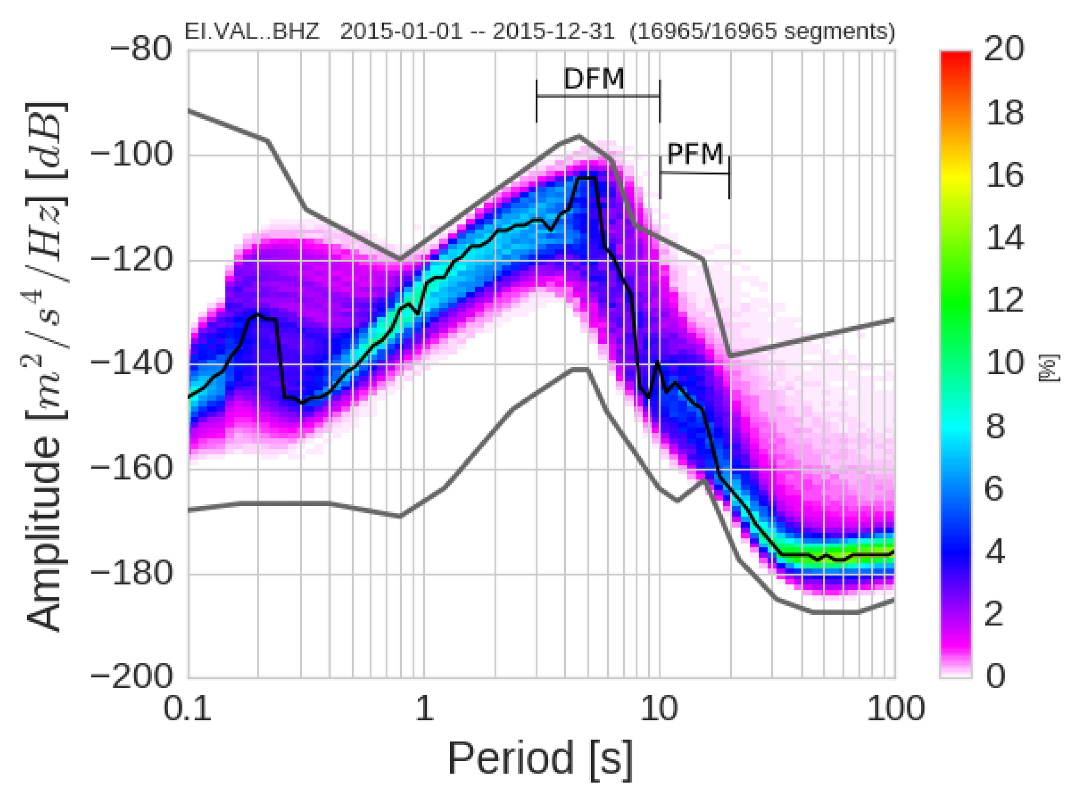
Ocean Generated Microseisms (OGM)

OGM can be recorded globally, by means of a broadband seismograph. Dominant microseism signals from the oceans are linked to characteristic ocean swell periods, and thus occur between approximately 3 to 30 seconds

Typically spectra display two peaks corresponding to the primary frequency microseisms (PFM) and double frequency (3-10s) microseisms (DFM).

PFM occur between 10 and 20 seconds and are generated in shallow water when ocean waves interact with the sea-floor. The resulting seismic waves have the same frequencies, as the causative ocean waves.

DFM occur between 3 and 10 seconds and are much more energetic. These are generated beneath counter-propagating ocean wave trains. This type of OGM generation does not depend on water depth and results in seismic waves at twice the frequency of the causative ocean wave trains.

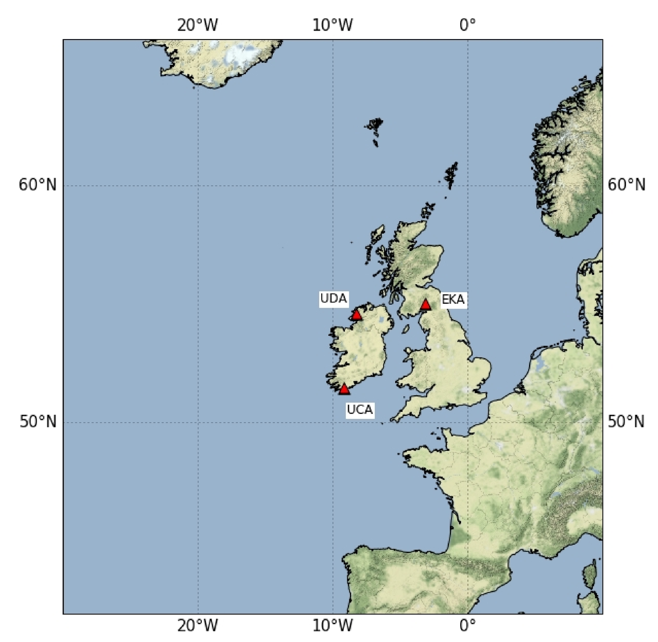


Microseism Source Distribution Observed from Ireland

Ireland has a highly energetic ocean wave climate and is close to major source regions for both PFM and DFM.

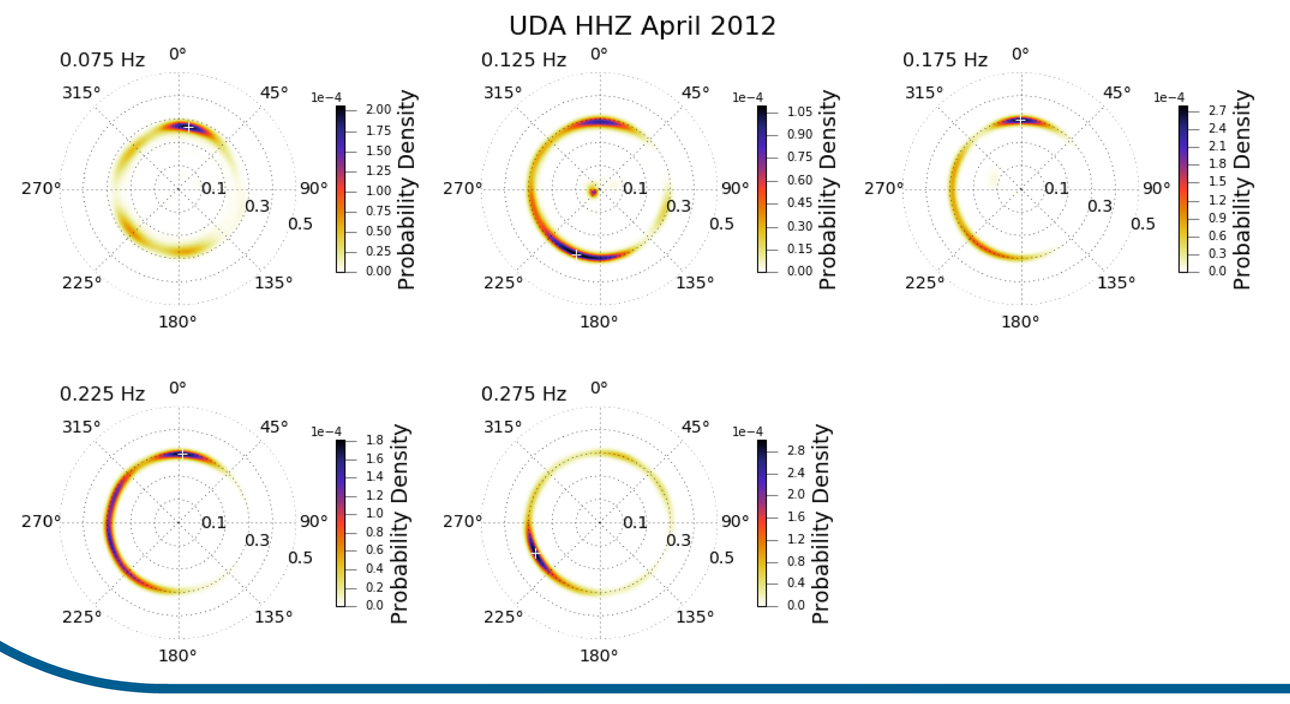
The region is also the subject of ambient noise interferometry and noise correlation studies. As such it is important to have an understanding of the source distribution observed from the region.

Similarly the source distribution is important for wave height quantification using land based seismic data where the proximity of ocean buoys to OGM source regions needs to be understood.



A seismic array is a system of seismometers distributed in space in such a way as to increase the sensitivity to OGM detection. The data from a seismic array is obtained using special digital signal processing techniques such as beamforming, which enhance the signal-to-noise ratio (SNR). Arrays are extremely useful tools as it is possible to determine the velocity (and hence the phase) and the back-azimuth (BAZ) of signals observed on the seismometers.

The velocity allows the phase (seismic wave-type) of the signals to be determined. Data from an array in Donegal (UDA) is displayed below. The majority of the signal occurs near 0.3 s/km meaning it relates to surface waves (R_g and possibly L_g) however some body waves are also present (most obvious at 0.125 Hz below 0.1 s/km).

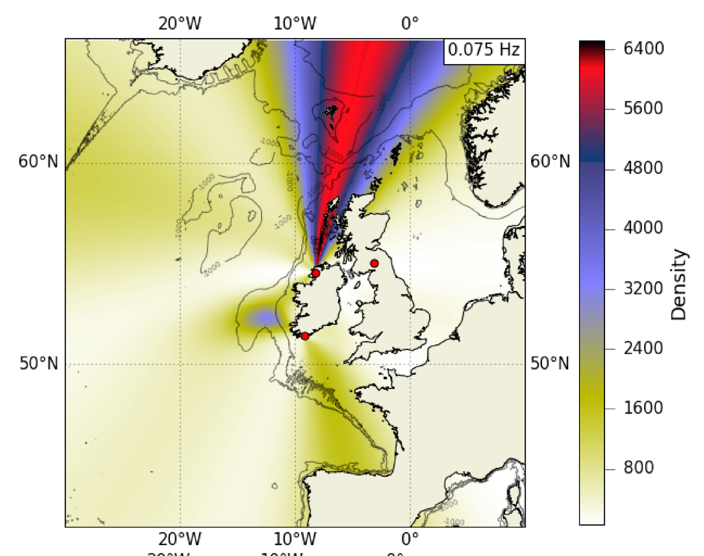


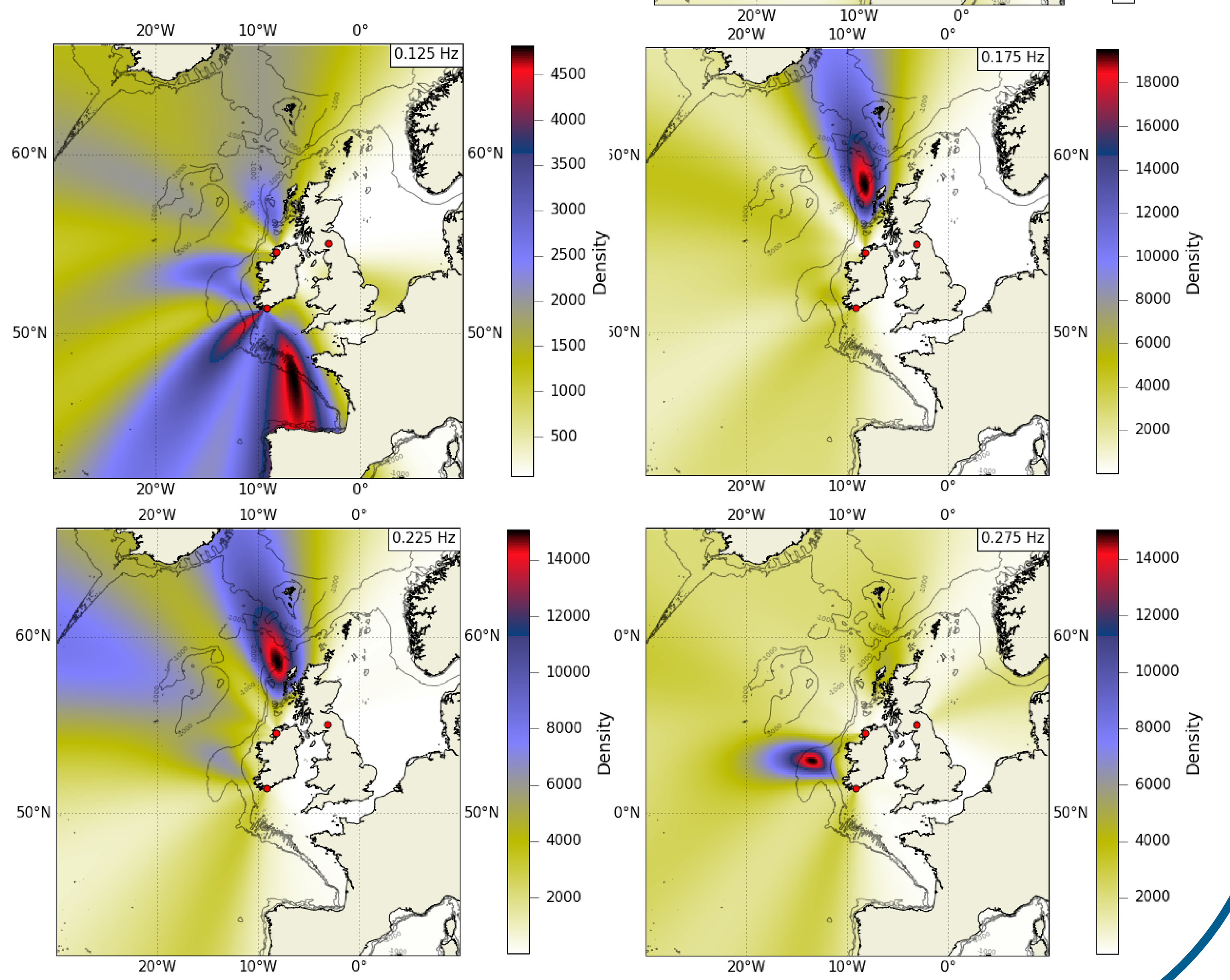
Three such arrays (UDA, UCA and EKA) are used here to determine the source locations for OGM signals observed on the arrays.

Sources for both PFM and DFM appear to be located on the continental shelf.

From microseism theory DFM should not be limited to shallow water regions.

Can DFM propagate across the ocean-continent barrier?





Cross-correlation methods require a heterogeneous wavefield (i.e. all frequencies need to be observed from all directions).

This is clearly not the case, how does a non-heterogeneous wavefield effect this type of study?

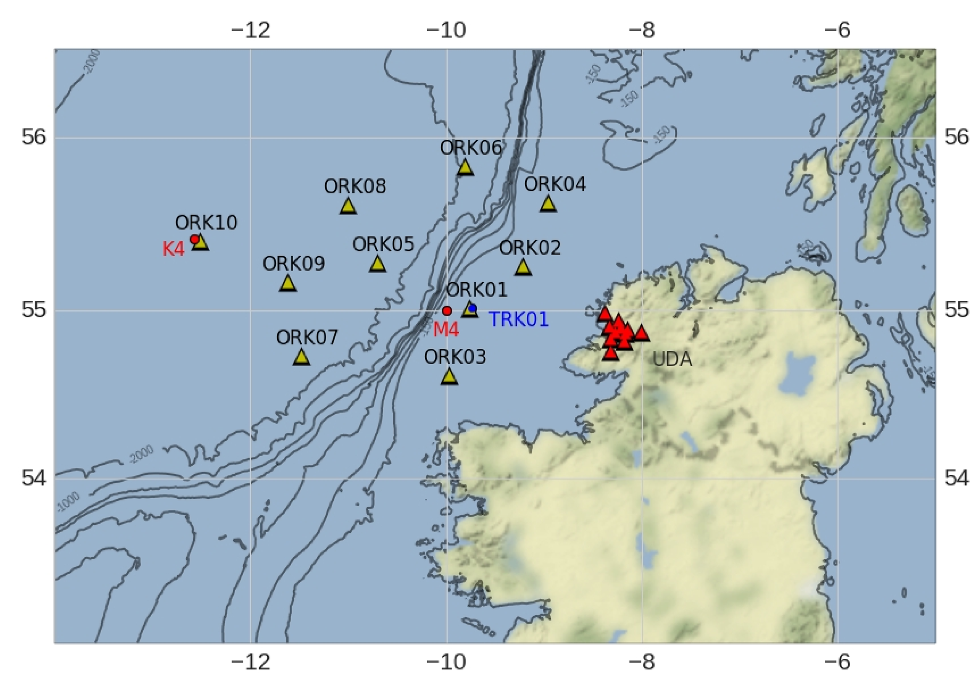
Ocean Bottom Seismic Network:

OGM are generated through non-linear interactions between ocean waves; the acoustic wavefield in the water column; and the seismic wavefield in the crust.

In January 2016 a network of ocean bottom seismometers (OBS) equipped with hydrophones along with a tsunami-meter (high resolution sea-floor pressure meter) were deployed off the coast of Donegal and are capable of recording both acoustic and seismic activity.

Data from a high resolution ocean wave model (made available through collaboration with TechWorks Marine) and in situ ocean buoy measurements (provided by the Marine Institute and UK Met Office) will give detailed information on the ocean wavefield for the duration of the experiment.

Numerical wave propagation models for the acoustic and seismic wavefields constrained by the observational data will aid in understanding the generation of microseisms (in both deep and shallow water regions) and their subsequent propagation toward continental regions.



Summary:

Off-shore OBS networks can greatly improve our understanding of microseism generation and thus provide improved analysis for noise based seismological imaging/monitoring techniques.

Knowledge of the source distribution also allows insight into the effectiveness of a land based ocean wave monitoring system.

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