# A new trend toward seismic metamaterials: the METAFORET project

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## Abstract

Why should complex wave physics be limited to experiments at very small scales? As waves obey similar propagation equations whatever their origin, why are there so few observations of the effects of advanced wave physics at the geophysics scale, for example? Of course, the answers to these deliberately provocative questions are multiple. What can be achieved in terms of wave manipulation and control at the laboratory scale turns out to be very tedious, if not impossible, at larger scales, where the deployment of numerous autonomous sensors is often another practical limitation.

In recent years, however, wide areas of the sciences involved with large-scale data have been through a technological revolution. Indeed, Earth sciences, and especially geophysics, can now benefit from continuous data acquisition on very dense arrays of seismometers, with sometimes more than 10,000 sensors. These sensor deployments were nearly unconceivable only 10 years ago, and up to very recently, they were limited to vastly expensive geophysics experiments that could only be funded by the oil & gas industries. However, the technology has now progressed and academic institutions can now obtain experimental data using thousands of seismic sensors at an affordable cost.

The present project aims to fill this gap in terms of large-scale wave manipulation with a multidisciplinary approach devised by a team composed of physicists, geophysicists and engineers who share a common interest in wave propagation in complex media. In practice, we aim to experimentally test two geophysics configurations from which metamaterial physics - inducing seismic cloaking and/or seismic protection - can be demonstrated. For example, the first configuration deals with the interaction between a surface wave and a natural forest. Each tree within the forest can react as a resonator that traps a small part of the seismic waves propagating at the Earth surface. The collective behavior of the trees when arranged in a dense forest is then analogous to the physics observed at a very small scale in optical metamaterials. In the second experimental configuration, we aim to show that a particular spatial distribution (deduced from a geometric transform) of long and thin vertical inclusions in the ground (concrete columns) surrounding a structure can create a special seismic lens that diverts surface waves away from the inner region leaving the protected object almost untouched.

In conjunction with numerical and theoretical investigations, the primary goal of this project is thus to achieve two ambitious and novel experiments where ~1000 seismic sensors will cover a ~120 m square grid with 4-m inter-element spacing that is to be set up on the two seismic metamaterials we wish to demonstrate. This spatial density of sensors is essential in order to accurately measure the dispersion curves both outside and inside the medium. To be comprehensive, both an active vibrometer and/or seismic ambient noise will be used as a controlled source or sources of opportunity. The comparison between the dispersion curves in these different areas will hopefully confirm the metamaterial behavior of the two geophysical configurations (either natural trees or buried concrete columns), with potential applications to seismic protection and seismic cloaking in civil engineering.