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Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment

Title of the research project: Probing the Earth's crust through ambient noise tomography

Principal Investigator: Papazachos Costas

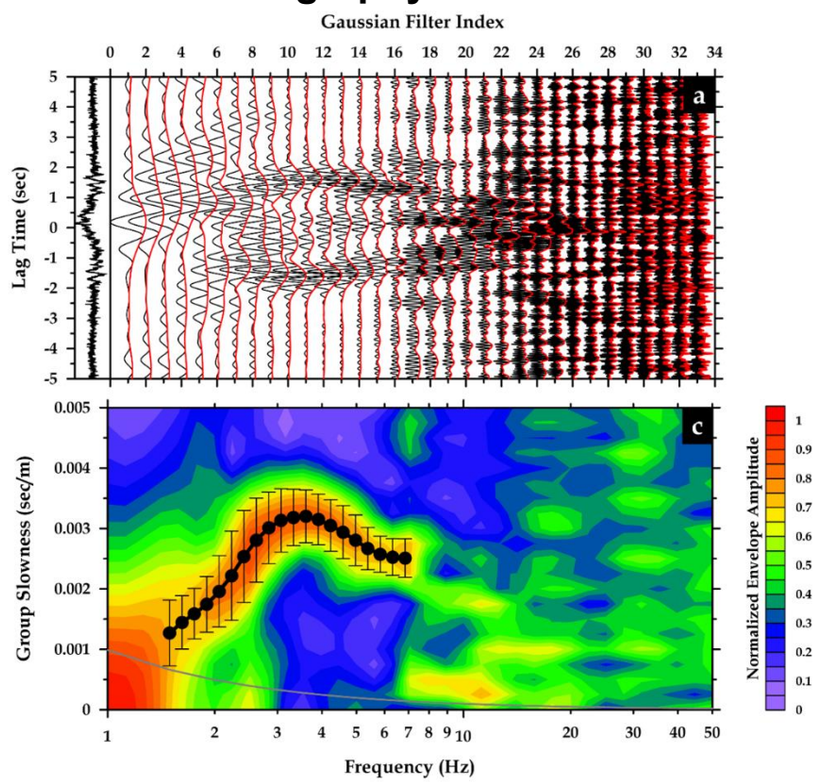
Reader-friendly title: PROTECTANT

Scientific Area: Natural Sciences

Institution and Country: Greece

Host Institution: Aristotle University of Thessaloniki

Collaborating Institution(s): University of Potsdam, Institute of Earth & Environmental Science



Example of multiple filter analysis on an ambient noise records: (Top) Band-pass traces from cross-correlation of ambient noise from 2 recording stations. (Bottom) RMS normalized envelope amplitude distribution of band-pass traces against frequency and Rayleigh wave group slowness, after stacking positive and negative envelopes, allowing the recovery of the Rayleigh wave dispersion curve (black line)

Budget: 200000 €

Duration: 36 Months

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Research Project Synopsis

The proposed research project focuses on the use of ambient noise for the study of the sub-surface structure of the uppermost crust (scale from a few dozen meters to about one kilometer). The basic method to be employed is the Ambient Noise Tomography in one (1D) and three (3D) dimensions, and its combination with independent information, obtained either from the same noise data (HVSR ratios, Rayleigh wave ellipticity) or by independent data (active geophysical methods, reference models), in order to extract information about the sub-surface geophysical structure (e.g. seismic velocities, anisotropy).

The project studies two main targets and applications:

a) The use of ambient noise tomography in urban environments, for the generation of three-dimensional (3D) Vs velocity models. The tomographic inversion will be initially based on the independent inversion, and at the final stage on the joint inversion of Rayleigh and Love waves, coupled with information from HVSR and Rayleigh wave ellipticity curves, in order to create a 3D imaging tool for urban areas. For the inversion, the geophysical model will be appropriately adapted (e.g. introduction of spatially smooth transverse anisotropy and model normalization constraints), employing appropriate inversion methods (linearized and Monte-Carlo).

b) b) Comparison of different techniques for one-dimensional inversion of ambient noise data and their calibration/verification, using a new 1D-reference model database that has recently been presented for the area of Greece. The main objective is to evaluate the reliability of the methods and to formulate suggestions that will allow the reduction of the uncertainty and non-uniqueness of 1D noise data interpretations.

The main target of both tasks is to evaluate the performance of environmental noise inversion methods as a reliable tool for the study of the uppermost crust, so that they can be used in various problems of Geosciences and applied Engineering (e.g. urban geology construction work, etc.).

Project originality

The current proposal presents a systematic attempt to contribute to the efficient derivation of reliable subsurface models for the uppermost crust using ambient noise data, since several problems emerge from noise cross-correlations in the surficial structure layers due to the complex wave propagation patterns observed in this heterogeneous part of the structure. The two proposed project targets both serve a long-term goal of the related research, by addressing the fundamental question of how we can improve on the reliability of models from ambient noise inversions (in 1D or 3D). In this direction, we examine within the project two possibilities/extensions:

a) **The joint inversion of all information contained in the noise signal (Rayleigh and Love waves, HVSR and ellipticity), with appropriate model adapting (e.g. smooth anisotropy and/or spatial model constraints) and,**
b) **b) Comparison of results from different "standard" 1D inversion techniques with a reference 1D-model database recently developed for the area of Greece.**

Both proposed approaches serve the same target, i.e. the reduction of the inherit uncertainties in ambient-noise inversion modeling. This constitutes an important step in the effort to achieve the long-term goal to make such techniques a tool that can be reliably employed in everyday engineering practice, besides its use in related geoscience studies. Besides its applied character, the results will also contribute to the better understanding of the nature, waveform content and patterns of ambient noise, which is a major theoretical challenge for geoscientists, since our knowledge is still rather inadequate.

Expected results & Research Project Impact

Despite the extensive use of ambient noise data in a variety of scientific disciplines, especially in the field of Geosciences, the project results are expected to have a clear and distinct contribution to both science and technology. More specifically:

A) Applications that lead to the recovery of full three-dimensional (3D) subsurface models (e.g. of the shear wave velocity) are rather limited. This is especially true for the upper crustal layers, which exhibit the most complex geological structures and the most demanding interpretation due to the presence of complex wave propagation phenomena. In addition, existing studies focus mainly on the study of geological structures outside urban complexes (e.g. volcanoes, landslides, etc.). Therefore, the proposed research is complementary to a limited number of applications in the demanding environment of urban complexes, where the generation of three-dimensional models can have a wide variety of applications.

B) The use of geophysical methods, especially those that exploit ambient noise, remains relatively limited in modern engineering applications, mainly due to the uncertainties/subjectivity that is often involved in their interpretation. The calibration of one-dimensional noise data inversion techniques in selected validation sites of the area of Greece, which exhibit a significant variability and complexity of geological structures, will contribute to the study of the robustness of the ambient noise data inversion. This procedure will highlight the method adapting and automatization developments which are necessary for the method to efficiently work in different geological environments. The results are expected to further boost the application of such methods, e.g. in the case of large-scale projects, where the systematic identification of the local structure is extremely difficult (e.g. gas pipelines), and for which only recently ambient noise data have been systematically employed.

The importance of this funding

The importance of this project funding is the possibility to investigate the capabilities of passive geophysical methods that are based on ambient noise data, in order to generate reliable 3D geophysical subsurface models in various demanding environments, such as urban areas. In addition, the calibration of different techniques that are focusing on the 1D inversion of ambient noise data for the recovery of the local subsurface structure profiles, with respect to a reference database in the broader Greek area, will contribute to the reliable interpretation of the results. Thus, the scientific community of Geoscientists will be encouraged to embrace ambient noise methods for subsurface geophysical/geological structure imaging and benefit from the significant advantages they have to offer, especially in comparison with conventional active geophysical surveys and geotechnical methods.

In particular, the funding will allow:

A) The performance of demanding field measurements both single-site arrays in selected locations in Greece, as well as the application of tomographic techniques in urban complexes and selected non-urban areas

B) The employment of the necessary research staff for the implementation of the research that will support the interpretation of the data

C) The analysis of data for the purposes of the project and the presentation and dissemination of its results

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COMMUNICATION

185 Syggrou Ave. & 2 Sardeon St. 2
171 21, N. Smyrni, Greece
+30 210 64 12 410, 420
communication@elidek.gr
www.elidek.gr