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New challenges for Urban Engineering Seismology

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ESR3.5 - Past experiments and data available on meta-materials
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In the framework of the ITN URBASIS project, two sets of data are available for all ESRs:

1- **The METAFORET experiment** (Oct. 2016) was designed to demonstrate that complex wave physics phenomena classically observed at the meso- and microscales in acoustics and in optics also apply at the geophysics scale. In particular, the experiment showed that a dense forest of trees can behave as a locally resonant metamaterial for seismic surface waves. The dense arrangement of trees anchored into the ground creates anomalous dispersion curves for surface waves, which highlight a large frequency band-gap around one resonant frequency of the trees, at ~45 Hz. This demonstration was carried out through the deployment of a dense seismic array of ~1000 autonomous geophones providing seismic recordings under vibrating source excitation at the transition between an open field and a forest. Additional geophysical equipment was also deployed (e.g., ground-penetrating radar, velocimeters on trees) to provide essential complementary measurements. Insights and interpretations on the observed seismic wavefield, including the attenuation length, the intensity ratio between the field and the forest and the surface wave polarization, were validated with 2D numerical simulations of trees over a layered halfspace.

References:

● Lott M., Roux P., Garambois S., Guéguen P., Colombi A. 2020. Evidence of metamaterial physics at the geophysics scale : the METAFORET experiment, Geophysical Journal International, 220(2) : 1330–1339, doi : 10.1093/gji/ggz528

● Roux P., Bindi D., Boxberger T., Colombi A., Cotton F., Douste-Bacque I., Garambois S., Guéguen P., Hillers G., Hollis D., Lecocq T., Pon-daven I. 2018. Toward Seismic Metamaterials : The METAFORET Project, Seismological Resesearch letters, 89(2A):582-593. doi : 10.1785/0220170196

2- **The METACity-Quito experiment** conducted in Quito (Ecuador) in August 2018 was to validate the Meta-City concept on an urban scale. Originally called site–city interaction, the interactions between soil and structures, structures and soil, and between structures contribute to the modification of urban seismic ground motion. This may affect the lateral variability of the ground motion observed in relation to earthquake damage, the characterization of site effects in urban areas, and also the response of civil engineering structures designed without consideration of the immediate urban environment. The network was deployed on 6 August 2018 in a specific area of the city of Quito (Ecuador). Forty-two stations were installed in total. The network covers an area of approximately 200 × 150 m2, with an interstation distance of 50 m, approximately. There are 12 free-field, ground-level stations in La Carolina park, 12 urban-field stations along the main avenue crossing the network (Los Shyris Avenue), 8 urban-field sta- tions in parallel and perpendicular secondary streets (Portugal, Luxemburgo, and Holanda Str.), and finally 10 stations at the top of buildings facing the park. Different 24-bit acquisition systems were connected to three-component sensors. The instruments consist of broadband and medium band velocimetric sensors, accelerometers, microelectromechanical systems accelerometers, and geophones. The dataset was prepared by the Réseau Sismologique et Geodésique Français (RESIF) datacenter at ISTerre (Grenoble, France) following the Federation of Digital Seismic Networks (FDSN) recommendations for the metadata (station description, instrumental response) before dissemination. The acquisitions were made at 200 or 250 Hz depending on the possibilities of each acquisition system.

References:

● Guéguen P., Mercerat E.D., Singaucho J.C., Aubert C., Barros J.G., Bonilla F., Crispstyani M., Douste-Bacqué I., Langlaude P., Mercier S., Pacheco D., Pernoud M., Perrault M., Pondaven I., Wolyniec D. 2019. METACity-Quito : A semi-dense urban seismic network deployed to analyze the concept of meta-material for the future design of seismic-proof cities, Seismological Research Letters 90 (6) : 2318- 2326. doi : 10.1785/0220190044

Future experiments (November 2021 if funded):

The META-WT project is designed to perform a 4-weeks seismic experiment in Germany with a dense seismic array of ~400 three-component geophones that will cover (1) a 2.5km x 2.5km wind farm area in Brandenburg, Germany, with almost 200 wind turbines (WTs) and a wellstudied subsurface structure and (2) a 20-km long radial line from the center of the wind farm with one geophone every ½ kilometer. The objective is to capture the spatio-temporal seismic wave-field signature of the wind farm from continuous recordings of ambient noise. Due to the dense interstation distance and proposed geometry the experiment allows for analyzing both smallscale wave field characteristics at an unprecedented spatial resolution and the longer distance radiation pattern of the wind farm.

WTs can act as both active and passive structures for seismic waves. We thus aim to study: (1) the seismic wavefield scattered by the WTs under continuous ambient noise excitation (e.g., ocean-related seismic noise below 0.5 Hz, mainly originating from the surrounding seas); (2) the WT self-generated vibrations transmitted to the ground as seismic noise (0.5-10 Hz), according to the local meteorological conditions; The measurement of the seismic wavefield at both small scale inside (~250 m) and larger scale outside (<20km) of the wind farm is a key issue to understand the role played by the WTs described as a field of heavy mass coupled resonators on the prediction of the seismic noise generated by wind farms in the farmfield (more than several tens of kilometres).