Geophysical Research Abstracts
Vol. 16, EGU2014-12407, 2014
EGU General Assembly 2014

A high-resolution ambient seismic noise model for Europe

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In the past several years, geological energy technologies receive growing attention and have been initiated in or close to urban areas. Some of these technologies involve injecting fluids into the subsurface (e.g., oil and gas development, waste disposal, and geothermal energy development) and have been found or suspected to cause small to moderate sized earthquakes. These earthquakes, which may have gone unnoticed in the past when they occurred in remote sparsely populated areas, are now posing a considerable risk for the public acceptance of these technologies in urban areas. The permanent termination of the EGS project in Basel, Switzerland after a number of induced ML$\sim$3 (minor) earthquakes in 2006 is one prominent example.

It is therefore essential to the future development and success of these geological energy technologies to develop strategies for managing induced seismicity and keeping the size of induced earthquake at a level that is acceptable to all stakeholders. Most guidelines and recommendations on induced seismicity published since the 1970ies conclude that an indispensable component of such a strategy is the establishment of seismic monitoring in an early stage of a project. This is because an appropriate seismic monitoring is the only way to detect and locate induced microearthquakes with sufficient certainty to develop an understanding of the seismic and geomechanical response of the reservoir to the geotechnical operation. In addition, seismic monitoring lays the foundation for the establishment of advanced traffic light systems and is therefore an important confidence building measure towards the local population and authorities. Due to this development an increasing number of seismic monitoring networks are being installed in densely populated areas with strongly heterogeneous, and unfavorable ambient noise conditions. This poses a major challenge on the network design process, which aims to find the sensor geometry that optimizes the measurement precision (i.e. earthquake location), while considering this extremely complex boundary condition.

To solve this problem I have developed a high-resolution ambient seismic noise model for Europe. The model is based on land-use data derived from satellite imagery by the EU-project CORINE in a resolution of 100x100m. The the CORINE data consists of several land-use classes, which, besides others, contain: industrial areas, mines, urban fabric, agricultural areas, permanent corps, forests and open spaces. Additionally, open GIS data for highways, and major and minor roads and railway lines were included from the OpenStreetMap project (www.openstreetmap.org). This data was divided into three classes that represent good, intermediate and bad ambient conditions of the corresponding land-use class based on expert judgment. To account for noise propagation away from its source a smoothing operator was applied to individual land-use noise-fields. Finally, the noise-fields were stacked to obtain an European map of ambient noise conditions. A calibration of this map with data of existing seismic stations Europe allowed me to estimate the expected noise level in actual ground motion units for the three ambient noise condition classes of the map.

The result is a high-resolution ambient seismic noise map, that allows the network designer to make educated predictions on the expected noise level for arbitrary location in Europe. The ambient noise model was successfully tested in several network optimization projects in Switzerland and surrounding countries and will hopefully be a valuable contribution to improving the data quality of microseismic monitoring networks in Europe.