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High temporal resolution mapping of seismic noise sources using heterogeneous supercomputers

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Time- and space-dependent distribution of seismic noise sources is becoming a key ingredient of modern real-time monitoring of various geo-systems. Significant interest in seismic noise source maps with high temporal resolution (days) is expected to come from a number of domains, including natural resources exploration, analysis of active earthquake fault zones and volcanoes, as well as geothermal and hydrocarbon reservoir monitoring. Currently, knowledge of noise sources is insufficient for high-resolution subsurface monitoring applications. Near-real-time seismic data, as well as advanced imaging methods to constrain seismic noise sources have recently become available. These methods are based on the massive cross-correlation of seismic noise records from all available seismic stations in the region of interest and are therefore very computationally intensive. Heterogeneous massively parallel supercomputing systems introduced in the recent years combine conventional multi-core CPU with GPU accelerators and provide an opportunity for manifold increase and computing performance. Therefore, these systems represent an efficient platform for implementation of a noise source mapping solution.

We present the first results of an ongoing research project conducted in collaboration with the Swiss National Supercomputing Centre (CSCS). The project aims at building a service that provides seismic noise source maps for Central Europe with high temporal resolution (days to few weeks depending on frequency and data availability). The service is hosted on the CSCS computing infrastructure; all computationally intensive processing is performed on the massively parallel heterogeneous supercomputer "Piz Daint". The solution architecture is based on the Application-as-a-Service concept in order to provide the interested external researchers the regular access to the noise source maps. The solution architecture includes the following sub-systems: (1) data acquisition responsible for collecting, on a periodic basis, raw seismic records from the European seismic networks, (2) high-performance noise source mapping application responsible for generation of source maps using cross-correlation of seismic records, (3) back-end infrastructure for the coordination of various tasks and computations, (4) front-end Web interface providing the service to the end-users and (5) data repository. The noise mapping application is composed of four principal modules: (1) pre-processing of raw data, (2) massive cross-correlation, (3) post-processing of correlation data based on computation of logarithmic energy ratio and (4) generation of source maps from post-processed data. Implementation of the solution posed various challenges, in particular, selection of data sources and transfer protocols, automation and monitoring of daily data downloads, ensuring the required data processing performance, design of a general service oriented architecture for coordination of various sub-systems, and engineering an appropriate data storage solution. The present pilot version of the service implements noise source maps for Switzerland. Extension of the solution to Central Europe is planned for the next project phase.