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Development of a combined cloud-HPC computing infrastructure for mapping seismic noise sources at the continental scale

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The study of ambient seismic noise sources and their time- and space-dependent distribution is becoming a crucial component of the real-time monitoring of various geosystems, including active fault zones and volcanoes, as well as geothermal and hydrocarbon reservoirs. In this context, we aim to produce ambient noise source maps with high temporal resolution. For this we use advanced source imaging methods based on the massive cross correlation of seismic noise data in the region of interest. We have previously implemented a pilot solution covering Switzerland and based on processing of seismic data provided by the Swiss Seismological Service (SED). The solution architecture is based on the Application-as-a-Service concept and includes the following subsystems: (1) acquisition of data from seismic networks, (2) noise source mapping, (3) workflow management framework for coordination of various tasks and computations, and (4) front-end Web interface providing the service to end users.

We present new results of this ongoing project conducted with support of the Swiss National Supercomputing Center (CSCS). Our recent goal has been to extend this solution to cover the entire European continent based on seismic data provided by the ORFEUS infrastructure. At this stage we address new challenges related to the dramatic increase in data volume, as well as the distributed organization of European seismic networks. These challenges include: (1) more complex data acquisition process involving multiple independent nodes providing seismic data; (2) increase by 2-3 orders of magnitude in computational complexity of massive cross correlation of seismic traces that grows quadratically depending on the number of seismic stations; (3) respective increase in complexity of the processing workflow. We handle the high computational complexity of cross correlation by using the CSCS massively parallel heterogeneous supercomputer "Piz Daint" and our previously implemented high-performance package for noise source mapping using GPU accelerators. However, due to the inherent restrictions of supercomputers, all the other subsystems including the data acquisition, data management, workflow management, and presentation of maps to the end users are deployed on the OpenStack cloud environment, which provides dedicated virtual machines hosting these subsystems. We have successfully resolved challenges related to interfacing between the cloud platform and tightly-coupled software environment on the supercomputer. The resulting solution combines the specific advantages of the HPC and cloud platforms thus providing a viable distributed platform for solving seismological problems requiring both complex computations and sophisticated data and workflow management.