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Heterogeneous cloud-supercomputing framework for daily seismic noise source inversion

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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 have previously implemented a combined cloud - HPC infrastructure for production of ambient source maps with high temporal resolution. It covers the entire European continent and the North Atlantic, and is based on seismic data provided by the ORFEUS infrastructure. The solution is based on the Application-as-a-Service concept and includes (1) acquisition of data from distributed ORFEUS data archives, (2) noise source mapping, (3) workflow management, and (4) front-end Web interface to end users.

We present the new results of this ongoing project conducted with support of the Swiss National Supercomputing Centre (CSCS). Our recent goal has been transitioning from mapping the seismic noise sources towards modeling them based on our new method for near real-time finite-frequency ambient seismic noise source inversion. To invert for the power spectral density of the noise source distribution of the secondary microseisms we efficiently forward model global cross-correlation wavefields for any noise distribution. Subsequently, a gradient-based iterative inversion method employing finite-frequency sensitivity kernels is implemented to reduce the misfit between synthetic and observed cross correlations.

During this research we encountered substantial challenges related to the large data volumes and high computational complexity of involved algorithms. We handle these problems by using the CSCS massively parallel heterogeneous supercomputer "Piz Daint". We also apply various specialized numeric techniques which include: (1) using precomputed Green's functions databases generated offline with Axisem and efficiently extracted with Instaseis package and (2) our previously developed high performance package for massive cross correlation of seismograms using GPU accelerators. Furthermore, due to the inherent restrictions of supercomputers, some crucial components of the processing pipeline including the data acquisition and workflow management are deployed on the OpenStack cloud environment. The resulting solution combines the specific advantages of the supercomputer and cloud platforms thus providing a viable distributed platform for the large-scale modeling of seismic noise sources.