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Forward and adjoint spectral-element simulations of seismic wave propagation using hardware accelerators

Daniel Peter (1,2), Brice Videau (3), Kevin Pouget (4), and Dimitri Komatitsch (5)

(1) ETH Zurich, Institute of Geophysics, Department of Earth Sciences, Zurich, Switzerland (daniel.peter@erdw.ethz.ch), (2) USI Lugano, Institute of Computational Science, Lugano, Switzerland , (3) CNRS, LIG - Equipe NANOSIM, Grenoble, France, (4) University of Grenoble, LIG - Equipe NANOSIM, Grenoble, France, (5) CNRS, Laboratory of Mechanics and Acoustics, Marseille, France

Improving the resolution of tomographic images is crucial to answer important questions on the nature of Earth's subsurface structure and internal processes. Seismic tomography is the most prominent approach where seismic signals from ground-motion records are used to infer physical properties of internal structures such as compressional- and shear-wave speeds, anisotropy and attenuation. Recent advances in regional- and global-scale seismic inversions move towards full-waveform inversions which require accurate simulations of seismic wave propagation in complex 3D media, providing access to the full 3D seismic wavefields. However, these numerical simulations are computationally very expensive and need high-performance computing (HPC) facilities for further improving the current state of knowledge.

During recent years, many-core architectures such as graphics processing units (GPUs) have been added to available large HPC systems. Such GPU-accelerated computing together with advances in multi-core central processing units (CPUs) can greatly accelerate scientific applications. There are mainly two possible choices of language support for GPU cards, the CUDA programming environment and OpenCL language standard. CUDA software development targets NVIDIA graphic cards while OpenCL was adopted mainly by AMD graphic cards. In order to employ such hardware accelerators for seismic wave propagation simulations, we incorporated a code generation tool BOAST into an existing spectral-element code package SPECFEM3D_GLOBE. This allows us to use meta-programming of computational kernels and generate optimized source code for both CUDA and OpenCL languages, running simulations on either CUDA or OpenCL hardware accelerators. We show here applications of forward and adjoint seismic wave propagation on CUDA/OpenCL GPUs, validating results and comparing performances for different simulations and hardware usages.