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Mantle convection on modern supercomputers

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Mantle convection is the cause for plate tectonics, the formation of mountains and oceans, and the main driving mechanism behind earthquakes. The convection process is modeled by a system of partial differential equations describing the conservation of mass, momentum and energy. Characteristic to mantle flow is the vast disparity of length scales from global to microscopic, turning mantle convection simulations into a challenging application for high-performance computing.

As system size and technical complexity of the simulations continue to increase, design and implementation of simulation models for next generation large-scale architectures demand an interdisciplinary co-design. Here we report about recent advances of the TERRA-NEO project, which is part of the high visibility SPPEXA program, and a joint effort of four research groups in computer sciences, mathematics and geophysical application under the leadership of FAU Erlangen. TERRA-NEO develops algorithms for future HPC infrastructures, focusing on high computational efficiency and resilience in next generation mantle convection models. We present software that can resolve the Earth's mantle with up to 10^{12} grid points and scales efficiently to massively parallel hardware with more than 50,000 processors. We use our simulations to explore the dynamic regime of mantle convection assessing the impact of small scale processes on global mantle flow.