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Time-domain parallelization for geodynamic modeling

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Modern computational Geodynamics increasingly relies on parallel algorithms to speed up calculations. Currently, parallelization in Geodynamic codes is achieved via spatial decomposition, where the physical computational space (or its associated matrix system) is subdivided into domains that are attributed to one processor or to a set of processors. Such an approach that distributes the computational load is efficient as long as the size of the sub-domains is large enough so that the computational time remains larger than the communication time between processors. However, when the size of the sub-domains becomes too small, the parallel speed-up stagnates, which puts bounds on the maximum performances of the parallel calculations.

This limitation can be overcome using a time-domain parallelization algorithm. This approach, named *parareal*, relies on the use of coarse sequential and fine parallel propagators to predict and to iteratively correct the solution over a given time interval.

Although this method has been successfully used to solve parabolic and hyperbolic equations in various scientific areas, it has never been applied in geodynamic studies, where motions relevant to the Earth and other planetary mantles are that of a convective fluid at infinite Prandtl number. In that case, the time dependence of the mass and momentum equations is only implicit, due to thermal and/or viscous couplings with the explicitly time-dependent energy equation. This requires a number of modifications to the original algorithm.

The performances of this adapted version of the *parareal* algorithm were investigated using theoretical model predictions in good agreement with numerical experiments. I show that under optimum conditions, the parallel speedup increases linearly with the number of processors, and speedups close to 25 were measured, using only few tens of CPUs. This parareal approach can be used alone or combined with any spatial parallel algorithm, allowing significant additional increase in speedup with increasing the number of processors.