Massiv parallel implementation of a 3D numerical convection model

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Different fluid dynamical systems in geophysics are characterised by a wide range of Prandtl numbers. The Prandtl number measures the ratio of viscous diffusion to thermal diffusion. For example the Earth's core, mainly consisting of molten iron, has probably a Prandtl number between 0.01 - 1. Water fluids are described by values around a Prandtl number about 7 and molten magmas by 100. A common approximation for Earth's mantle in convection models is an infinite Prandtl number. All these systems can potentially be turbulent depending on the value of the Rayleigh number. Besides laboratory experiments, numerical investigations are essential for the research of turbulent thermal convection. In fact, this can be challenging and is limited to available computer resources for two main reasons. (1) It is crucial to choose a spatial grid which is fine enough to ensure a physical correct resolution of small-scale structures like thin thermal and viscous boundary layers or vorticities in the flow. (2) Furthermore, a three dimensional model is required to simulate the strong toroidal flows in fluids with a Prandtl number ≤ 100 (M. Breuer *et al.* (2004)[1]). For these reasons, the resulting problem size is normally not treatable using standard personal computers. Therefore, we parallelised an existing finite Prandtl number convection code[2] (FV discretisation, Jacobi method), particulary with respect to an implementation on massiv parallel architectures. For maximum flexibility we use the Message Passing Interface (MPI) and domain decomposition. The code shows good speedup scaling with large numbers of processors. Finally, we developed a tool to face problemsizes up to 500^3 gridpoints and more. Appropriate simulations with high Rayleigh numbers and a wide range of Prandtl numbers are feasible now.

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[1] **M. Breuer, S. Wessling, J. Schmalzl and U. Hansen** (2004). Effect of inertia in Rayleigh-Bénard convection. *Phys. Rev. E*, **69**, 026302

[2] Code is based on the method described in **R. A. Trompert and U. Hansen** (1996). The application of a finite volume multigrid method to three-dimensional flow problems in highly viscous fluids with a variable viscosity. *Geophys. Astro. Fluid*, **83**, 261-291.