

Stability and numerical study of Parareal and MGRIT applied to the shallow water equations on the rotating sphere

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In this work, we study the temporal parallelization of the shallow water equations on the rotating sphere, in the context of atmospheric circulation modeling, using Parareal and MGRIT. Due to the well-known stability and convergence issues of predictor-corrector iterative parallel-in-time methods when applied to relatively simple hyperbolic problems, their application to complex advection-dominated equations, such as those arising in fluid dynamics, remains limited. The goal of this work is to obtain analytical and numerical indications of whether operational atmospheric circulation models can be successfully parallelized in time, and how the performance of the temporal parallelization can be improved. For that, we consider Parareal and MGRIT combined with time integration schemes that are used operationally in atmospheric modeling due to their improved stability properties in serial integration: namely a semi-Lagrangian semi-implicit method (SL-SI-SETTLS) and an implicit-explicit (IMEX) scheme. Linear stability analyses and numerical simulations indicate that Parareal and MGRIT perform poorly with SL-SI-SETTLS, while better results are obtained using IMEX. Our results also show that level-dependent artificial hyperviscosity, applied only on the coarse discretization levels, can provide stable and convergent simulations while keeping an accurate discretization on the fine level. This work is based on a joint work (<https://doi.org/10.1016/j.jcp.2023.112591>) with Pedro S. Peixoto (University of São Paulo) and Martin Schreiber (Université Grenoble Alpes).