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Parallel-in-time Integration of an Acoustic-Advection System

D. Ruprecht and R. Krause
Università della Svizzera italiana, Institute of Computational Science, Lugano, Switzerland (daniel.ruprecht@usi.ch)

Numerical weather prediction is one of the most demanding applications in high performance computing and the list of the fastest computers worldwide (www.top500.org) contains several super computer systems operated by weather services or meteorological research centers. One reason for the large computational cost of integrating meteorological models is the large range of scales in atmospheric flows, ranging from planetary or synoptic scale features with time scales of hours, days or even weeks down to sound waves, limiting the size of employable time steps to the order of seconds.

As the growth of the frequency of individual processors ceased over the last years because of fundamental physical problems, gains in computational power are achieved by a massive increase of the numbers of nodes and cores in HPC systems. This, however, requires increasing levels of concurrency in software in order to fully exploit all available CPUs.

Parallelization by domain decomposition is by now a standard feature of codes solving meteorological equations, like for example WRF or COSMO. This strategy can scale very well to a large number of nodes or cores, but nevertheless the achievable run time reduction saturates at some point where the sub domains become too small. Although the spatial resolution of NWP-codes is increasing, thereby allowing spatial parallelization to scale to a higher number of cores, the much more rapidly growing number of cores in HPC systems will very likely require additional directions of parallelization in the near future.

One possible approach is the introduction of parallel-in-time integration schemes. A promising algorithm in this field is the so-called "Parareal", introduced in [1]. Over the last years it has received much attention, including detailed analysis of its properties as well as the application to a range of very different problems. Although the original version turned out to have difficulties in dealing with hyperbolic problems, a recently introduced modification ([2], [3]) was successfully applied to hyperbolic problems in structural dynamics.

The presentation will introduce "Parareal" and investigate the performance of the modified version when applied to meteorologically relevant test problems, like a two-dimensional acoustic-advection system with a sound speed that is about thirty times larger than the advection velocity. Also, the use of "Parareal" in a hybrid space-time parallelization using nodes for spatial sub domains and the cores inside a node for time-integration is discussed.

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