42th Seminar on Modeling
May 9th 2017

Dynamico-FE: A Structure-Preserving Hydrostatic Dynamical Core

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It is well known that the inviscid, adiabatic equations of atmospheric motion constitute a non-canonical Hamiltonian system, and therefore possess many important conserved quantities such as as mass, potential vorticity and total energy. In addition, there are also key mimetic properties (such as curl grad = 0) of the underlying continuous vector calculus. Ideally, a dynamical core should have similar properties.

A general approach to deriving such structure-preserving numerical schemes has been developed through a combination of Hamiltonian methods and mimetic discretizations. Beyond these structure-preserving properties, modern dynamical cores must be efficient on a wide range of computational architectures, and should be able to efficiently leverage the increasing parallelism of modern machines. This is achieved through the selection of a particular class of mimetic discretizations: structured grid, tensor product mimetic Galerkin methods.

This talk will discuss Dynamico-FE, a new structure-preserving hydrostatic atmospheric dynamical core built using these techniques, and show results from a standard set of test cases on both the plane and the sphere. It will also briefly discuss the Themis software framework (used to construct this code), which is designed specifically for tensor product Galerkin methods on structured grids.

High performance climate modeling: the DYNAMICO atmospheric flow solver

Thomas Dubos
Professor, École Polytechnique

Climate models simulate atmospheric flows interacting with many physical processes. Because they address long time scales, from centuries to millennia, they need to be efficient, but not at the expense of certain desirable properties, especially conservation of total mass and energy. Most of my talk will explain the design principles behind DYNAMICO, a highly scalable unstructured-mesh energy-conserving finite volume/mimetic finite difference atmospheric flow solver and potential successor of LMD-Z, a structured-mesh (longitude-latitude) solver currently operational as part of IPSL-CM, the Earth System Model developed by Institut Pierre Simon Laplace (IPSL).

Specifically, the design of DYNAMICO leverages the variational structure of the equations of motion and their Hamiltonian formulation, so that the conservation of energy requires only that the discrete grad and div operators be compatible, i.e. that a discrete integration by parts formula holds. At the implementation level, performance is achieved by combining a simple memory layout allowing vectorization, mixed MPI/OpenMP parallelism and using the asynchronous parallel I/O server XIOS.

Tuesday, May 9th 9:30 AM (coffee offered, talks at 10 AM)
Maison de la Simulation, Digiteo building (565), room 34

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