Novel Solution-Adaptive Schemes for Shallow Atmosphere Simulation

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Summary

This research investigates novel solution-adaptive methods for the shallow atmosphere model. Emphasis is given to accurate schemes that are both robust and cost-efficient when implemented in modern parallel computers. Successful design of these solution algorithms is likely to have a positive impact in the development of global models for climate simulation. One solution scheme in development utilizes spherical harmonics (spectral method) on an arbitrarily distributed set of points on the sphere. In contrast, a second scheme uses element-wise discontinuous basis functions.

The shallow-atmosphere equations on a rotating sphere are very convenient for testing new solution schemes for global atmospheric flows. Despite their simplicity, they retain major difficulties found in the solution of advanced atmospheric models. The equations represent momentum transport in a viscous fluid undergoing an incompressible flow on the surface of a sphere. Therefore this is a system of nonlinear, hyperbolic, time dependent equations. In view of the spherical shape of the domain, no boundary conditions are needed whereas initial field data need to be provided. Time-dependent solutions are sought for the velocity and atmosphere height fields. The latter has two components, namely, the height of the Earth landscape (orography field) above the reference sphere (sea line), and the height of fluid (atmosphere) above the mountains.

The purpose of this research is to develop novel solution-adaptive methods for solving the shallow-atmosphere model that are accurate, cost-efficient, and suitable for large-scale simulation in parallel computers. One approach we are investigating utilizes an adaptive spectral method based on spherical harmonics [1].

We have introduced arbitrary non-uniform point distributions on the surface of the sphere that adapt to the orography field and obtained preliminary short-term solutions for an atmospheric pulse rotating around the Earth (figure 1). Further work will be carried on to determine the new adaptive scheme accuracy and cost-efficiency.

In contrast to the spectral method, a second adaptive approach has been conceived wherein the approximation of the solution takes place by discontinous basis functions. In addition, the method utilizes a flux-preserving weak formulation that takes advantage of arbitrary unstructured meshes. This method will be implemented and tested against the spectral method.

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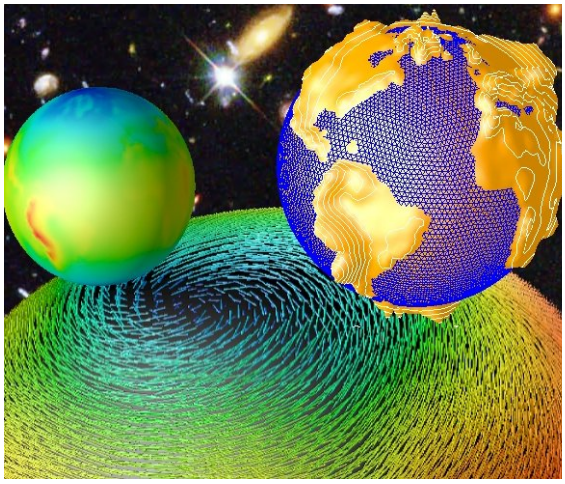

Figure 1. ***Geopotential (left) and velocity vector (bottom) fields calculated for the shallow atmosphere model on the sphere with Earth orography (right).***