11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

AN LES-LIKE STABILIZATION OF THE SPECTRAL ELEMENT SOLUTION OF THE EULER EQUATIONS FOR ATMOSPHERIC FLOWS

Simone Marras and Francis X. Giraldo

Naval Postgraduate School, Dept. of Applied Mathematics
833 Dyer Road, Bldg. 232, Spanagel 249A Monterey, CA 93943-5216 U.S.A.
smarras1@nps.edu; fxgirald@nps.edu

Key words: *Spectral element method; Euler equations; LES; stabilization; non-hydrostatic atmospheric flow*

The solution of the Euler equations by the spectral element method (SEM) is subject to oscillatory behavior if the high-frequency modes are not damped in some way. In this analysis, we extend to high order spectral elements and to low-Mach number flows the recent work by Nazarov and Hoffman [1], where an LES-like physical diffusion acts both as a localized and controlled numerical stabilization for finite elements and as a turbulence model for compressible flows. In the framework of high-order SEM for the solution of the low-Mach number flows, this approach is a possible physics-based alternative to the variational multiscale stabilization (VMS) method that the authors successfully applied to the SEM solution of the advection diffusion equation [2] in the context of atmospheric flows. Like for VMS, stabilization is obtained by means of a residual-based term that is added to the inviscid Euler equations. Unlike VMS, however, this extra term is based on purely physical –rather than numerical– assumptions, in that it is related to the viscous component of the stress tensor of the Navier-Stokes equations.
The method is tested with pseudo and fully 3D simulations of idealized nonhydrostatic atmospheric flows and is verified against data from the literature. This work represents a step toward the implementation of a stabilized, high order, spectral element LES model within the *Nonhydrostatic Unified Model of the Atmosphere* [3, 4] developed by the authors.

REFERENCES

[1] M. Nazarov and J. Hoffman, *Residual-based artificial viscosity for simulation of turbulent compressible flow using adaptive finite element methods.* IJNMF **71**, 2013

[2] S. Marras, J.F. Kelly, F.X. Giraldo, and M. Vazquez, *Variational multiscale stabilization of high-order spectral elements for the advection-diffusion equation.* JCP **231**, 2012

[3] J.F. Kelly, F.X. Giraldo, *Continuous and discontinuous Galerkin methods for a scalable three-dimensional nonhydrostatic atmospheric model: Limited-area mode.* JCP **231**, 2012

[4] F.X. Giraldo, J.F. Kelly, E. Constantinescu, *Implicit-explicit formulations of a three-dimensional nonhydrostatic unified model of the atmosphere (NUMA).* SISC **35**, 2013