Implicit Large Eddy Simulations using MPDATA based integrators

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ABSTRACT

The paper documents recent developments of numerical models based on the Non-oscillatory Forward-in-Time (NFT) integrators build on the Multidimensional Positive Definite Advection Transport Algorithm (MPDATA) [1]. The advocated algorithms are fully multidimensional, rigorously sign preserving, nonlinearly stable and exploit MPDATA properties for Implicit Large Eddy Simulation (ILES) of turbulent engineering and environmental flows. The models admit several systems of partial differential equations, including those applicable to classical compressible [2] and incompressible flows as well as anelastic and pseudo-incompressible soundproof systems [3,4]. The solution of the elliptic Poisson equation, implied by the soundproof mass-continuity constraint, employs a robust non-symmetric Krylov-subspace solver.

The ability of ILES numerical discretizations to economically substitute for explicit subgrid-scale turbulence models is examined for a range of challenging problems. High resolution computations of canonical flows past obstacles are followed by a quantitative analysis that confirms suitability of the approach for accurate simulation of wave phenomena and thermal convection. A study is reported next that addresses a complex problem of sound and blast waves propagating in a turbulent, strongly-stratified orographic flow. The problem blends large- and small-amplitude hyperbolic and dispersive wave dynamics, in the spirit of the secondary-application-models [2], with the anelastic equations employed to generate a fully developed atmospheric flow constituting extreme ambient conditions for simulation of acoustic phenomena with the compressible equations of gas dynamics. The flow parameters are specified purposely to generate a highly complex natural flow, combining physical phenomena of violent gravity wave breaking in the lee of the hill, critical level in the stratosphere aloft where wave absorption proceeds via small scale overturning and turbulence, and imposing a flow excess perturbation to mimic a volcano eruption.

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