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ON THE EVALUATION OF SPATIAL AND TEMPORAL NUMERICAL DISSIPATION IN INCOMPRESSIBLE FLOWS

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ABSTRACT

The problem of accurate distinction between physical dissipation and artificial numerical dissipation remains one of the main challenges in Computational Fluid Dynamics. Although energy budgets provide a reliable way to understand flow physics and simulation mechanisms, their value emerges in numerical diagnostics. The arising question is whether we can evaluate the actual numerical, artificial dissipation in a simple and stable manner. It is demonstrated that various discretization schemes, such as the Upwind discretization scheme introduce significant artificial dissipation. Additionally, validation of various benchmark cases has shown that numerical dissipation can rival, or exceed physical dissipation, potentially masking the performance of sub-grid scale models [1].

This work proposes a substantial framework for the evaluation of numerical dissipation in incompressible flows, based on the traditional validation cases, such as the differentially heated cavity case, and Rayleigh-Taylor instability. This is achieved by comparison of global and local energy budgets, which allows for an analysis of the nature of dissipation. Multiple discretization schemes have been observed, with special attention given to symmetry-preserving schemes [2]. The work is further extended by temporal discretization implementation, by assessing the energy- preserving properties of time-integration schemes [3]. Finally, the work focuses on the analysis of the nature of dissipation in Large Eddy Simulations, distinguishing physical, sub-grid scale model and artificial numerical dissipation.

This approach has allowed for a systematic diagnosis of various spatial discretization and temporal integration schemes, establishing itself as a simple, yet coherent tool for simulation analysis. The findings emphasize the necessity of accurately accounting for both spatial and temporal discretization errors to ensure the energy consistency and reliability of incompressible flow simulations, and highlight the significance of accurate distinction between physical and artificial numerical phenomena, essential for advancement of high-fidelity CFD simulations.

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