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An assessment of various discretizations of the energy equation in compressible flows

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Nonlinear instabilities are one of the major problems in turbulence simulations. One reason behind this problem is the accumulation of aliasing errors produced by the discrete evaluation of the convective term. This can be improved by preserving the quadratic invariants in a discrete sense [1, 2]. However, another source of instabilities is the error due to an incorrect evolution of thermodynamic variables, such as entropy. An appropriate discretization of the energy equation is needed to address this issue.

A systematic analysis of the preservation properties of different discretizations of the compressible Euler equations is reported, which includes some of the most common approaches used in the literature [3], together with some new formulations. Two main factors that characterize each formulation have been identified and studied: one is the choice of the energy equation to be directly discretized; the other is the particular splitting of the convective terms, chosen among the kinetic energy preserving (KEP) forms. The energy equations analyzed in this paper are total and internal energy, entropy, enthalpy and speed of sound. All the cases examined are locally conservative and KEP, since this is considered an essential condition for a robust simulation. The differences among the formulations have been theoretically investigated through the study of the discrete evolution equations induced by the chosen energy variable, showing which quantities may be preserved. Both two-dimensional and three-dimensional tests have been performed to assess the advantages and disadvantages of the various options in different cases.

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