Applications of non-oscillatory schemes and adaptive grids to problems with flow reversals (P. Saucez, A. Vande Wouwer and W.E. Schiesser)

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Physical systems in which convection is a predominant phenomenon are commonplace in science and engineering. These systems are generally difficult to analyze because they exhibit steep moving fronts and even discontinuities that must be resolved with good accuracy if small-scale spatial features are to be observed and understood.

In this study, several upwind approximations of the spatial operators, including classical finite differences and flux limiters, are compared to centered nonoscillatory schemes such as the Nessayahu-Tadmor central scheme. These schemes are used on fixed uniform spatial grids as well as on nonuniform adaptive grids. Specifically, an adaptive mesh refinement algorithm based on the equidistribution principle and spatial regularization is used.

These numerical tools are applied to a variety of application examples from heat and mass transfer and reaction kinetics, in which flow reversals can take place and knowledge of the local propagation direction and speed is particularly important. Two situations are considered:

(a) change in the overall fluid flow velocity (such as in reverse-flow reactors, which are used to achieve autothermal operation with high reaction temperature and ambient feed temperature in spite of low adiabatic temperature rise); (b) reflection at the boundaries of the spatial domain (such as in the classical Sod's shock-tube problem).

Several variations of these examples are discussed, depending on the model parameters and the selection of different numerical methods.