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A stability analysis of finite-volume advection schemes permitting long time steps

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Finite-volume schemes developed in the meteorological community that permit long time-steps are considered. These include Eulerian flux-form schemes as well as fully two-dimensional and cascade cell-integrated semi-Lagrangian (CISL) schemes. A one and two-dimensional Von Neumann stability analysis of these finite-volume advection schemes is given. Contrary to previous analysis, no simplifications in terms of reducing the formal order of the schemes, which makes the analysis mathematically less complex, have been applied. An inter-scheme comparison of both dissipation and dispersion properties is given. The main finding is that the dissipation and dispersion properties of Eulerian flux-form schemes are sensitive to the choice of inner and outer operators applied in the scheme that can lead to increased numerical damping for large Courant numbers. This spurious dependence on the integer value of the Courant number disappears if the inner and outer operators are identical in which case, under the assumptions used in the stability analysis, the Eulerian flux-form scheme becomes identical to the cascade scheme. To explain these properties a conceptual interpretation of the flux-based Eulerian schemes is provided. Of the two CISL schemes the cascade scheme has superior stability properties.