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A pitfall in using central scheme in atmospheric modeling

Hyperbolic conservation laws are widely used in applied sciences and engineering, such as fluid mechanics, biology and environmental science. However due the inherent complex non-homogeneities and nonlinearities, they are not tractable analytically, but instead, various numerical methods have been proposed for their resolution.

The so-called finite volume methods for conservation laws, that are the state-of-the-art, can be classified into two categories: Godunov-type methods that rely on the detailed or approximate solution of a Riemann problem at each cell or control-volume interface, where the numerical solution is made discontinuous, and central schemes that avoid the Riemann problem all together by averaging between neighboring cells to yield a smooth solution at the cell interfaces and move the discontinuity to the cell center. While central schemes are very attractive because they are very cheap to run and easy to implement, their 2D version can lead to very misleading results when used to simulate wave phenomena, for long integration times. The smoothing of the solution in the direction perpendicular to the direction of the wave-propagation distorts significantly the dispersion characteristics of the waves and induces important deformations in the solution shape and propagation speed.

In this talk, we present such behavior of the central scheme for the case of equatorially trapped waves that are an important component in the dynamics of the tropical climate and the large-scale atmospheric circulation. We provide numerical examples supplemented with a harmonic analysis for the frozen stencil to demonstrate the phenomenon and backup our claims. In order to avoid such disasters we suggest, for such wave problems, use the one-dimensional central scheme compounded through directional splitting.