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Long Time Steps for Advection: MPDATA with implicit time stepping

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Semi-Lagrangian advection schemes are accurate and efficient and retain accuracy and stability even for large Courant numbers but are not conservative. Flux-form semi-Lagrangian is conservative and in principle can be used to achieve large Courant numbers. However this is complicated and would be prohibitively expensive on grids that are not logically rectangular.

Strong winds or updrafts can lead to localised violations of Courant number restrictions which can cause a model with explicit Eulerian advection to crash. Schemes are needed that remain stable in the presence of large Courant numbers. However accuracy in the presence of localised large Courant numbers may not be so crucial.

Implicit time stepping for advection is not popular in atmospheric science because of the cost of the global matrix solution and the phase errors for large Courant numbers. However implicit advection is simple to implement (once appropriate matrix solvers are available) and is conservative on any grid structure and can exploit improvements in solver efficiency and parallelisation. This talk will describe an implicit version of the MPDATA advection scheme and show results of linear advection test cases. To optimise accuracy and efficiency, implicit time stepping is only used locally where needed. This makes the matrix inversion problem local rather than global. With implicit time stepping MPDATA retains positivity, smooth solutions and accuracy in space and time.