Curl-free pressure gradients over orography in a solution of the fully compressible Euler equations with long time-steps

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14th February 2014

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Long, stable and accurate time-steps are important for models of the atmosphere to enable efficient weather and climate predictions. This has motivated the use of semi-implicit, semi-Lagrangian models. However semi-Lagrangian techniques appears not to be ideal for the next generation of models for modern computers. Some new numerical methods are presented that enable long, stable time-steps without the non-local communication of semi-Lagrangian. Sub time-stepping is used for advection and acoustic and gravity waves are treated implicitly without the need for mean and perturbation variables.

In addition, a new technique for modelling flow over orography using terrain following layers is introduced which guarantees curl-free gradients implying that the pressure gradient term is not a spurious source of vorticity. This mimetic property leads to better hydrostatic balance and better energy conservation.

Results with large Courant numbers and strong stratification are presented which demonstrates the validity of the sub-cycling of advection and the implicit treatment of gravity waves.