Geophysical Research Abstracts
Vol. 14, EGU2012-5168, 2012
EGU General Assembly 2012

Development of Lagrangian vertical coordinate for UM ENDGame dynamical core

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Some theoretical reasons and results from numerical atmospheric models support the hypothesis that Lagrangian conservation properties and related properties of a numerical model dynamical core can be improved by the use of a Lagrangian or quasi-Lagrangian vertical coordinate (LVC). This may lead to improved accuracy for long range forecasts and improved physical realism for climate simulations. In this research we implement the LVC in ENDGame, the next generation dynamical core of the atmospheric Unified Model (UM), currently being developed by the Met Office. Since Lagrangian surfaces fold over time, locations of coordinate surfaces need to be reinitialised and values of atmospheric fields remapped to new surface levels. Some of desirable properties of remapping schemes are conservation of total mass, energy and entropy, as well as preservation of balance.

Firstly, we implemented LVC formulation in 1D version of the ENDGame dynamical core, based on the compressible Euler equations. The vertical advection terms are no longer calculated for the implicit time scheme used here, thus reducing the numerical cost. The eigenvalues of numerically calculated normal modes for both idealised hydrostatic initial state and some real sounding profiles indicate stability of 1D LVC formulation. Next, we tested various remapping strategies and methods. Some strategies focus on conservation properties through choice of remapped quantities (total model mass, energy and entropy) while others on preserving balance (separately remapping hydrostatic balance and non-hydrostatic part). We implement various remapping methods, like piecewise polynomial (parabolic, PPM, and quartic, PQM) and piecewise spline (PSM) methods. Mass is conserved due to exact evaluation of cell averages between old and new coordinate levels. Depending on the choice of remapped quantity, either total energy or entropy can be conserved together with the mass, but apparently not both of them. We also explore the influence of boundary conditions (BC) on polynomial reconstruction in remapping schemes and subsequently prognostic values in lower- and uppermost model layers. Further research addresses the frequency of remapping in dependance of space- and timescales of Lagrangian surfaces folding. In addition, the choice of new model levels is investigated, leading towards the full 3D model version.