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.

We implement the LVC formulation in the full 3D version of the ENDGame dynamical core, based on the compressible Euler equations. Because of the variable r (height of Lagrangian surfaces) there is an additional prognostic equation in the LVC formulation, and also additional computation and storage costs. However, the absence of vertical advection and explicit calculation of the vertical component of departure points result in overall reduced running time when compared with the height-based ENDGame. Next, we test different remapping strategies, some of them focusing on conservation properties while others on preserving hydrostatic balance. As expected, remapping mass and energy leads to better conservation of total energy, while remapping mass and entropy favours entropy rather than energy. Various remapping methods (e.g. piecewise polynomial or spline methods) are also implemented, with slightly different results regarding conservation of mass, energy and entropy. Finally, we discuss choices of target levels for remapping and show comparison with the height-based ENDGame dynamical core.