Further development of new dynamics for the Met Office Unified Model

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1 Model Features

At the Met Office, the Unified Model is used for all NWP activities and climate change studies, from short-range mesoscale to centuries-long climate runs. A new dynamics for the UM (Cullen et al 1997) is expected to become operational for NWP in the spring of 2002 and for climate change from 2004. The main dynamics features are:

1. Non-hydrostatic deep atmosphere equations.
2. Hybrid-height terrain-following vertical coordinate.
3. Charney-Phillips vertical staggering, C-grid horizontal staggering.
4. 2 time-level semi-implicit, semi-Lagrangian predictor-corrector scheme.
5. 3d variable coefficient, iterative elliptic solver.
6. No basic state profile nor vertical separation elliptic problem.

The physics parametrizations are also being upgraded; details of which will appear elsewhere. In pre-operational and climate testing a number of problems have been identified. Below we highlight a few problems that have been rectified.

2 Vertical coordinate flattening

The South East Asian jet was seen to decelerate during the forecast leading to significant errors in this region. The problem resulted from the vertical coordinate transition from terrain-following at the surface to horizontal at an appropriate upper level. The original scheme involved three regions and two interfaces. The lowest region (nominally the boundary layer levels) was fully terrain following. The topmost region had constant height levels (i.e. horizontal in height). In between the layers were gradually flattened linearly between the two interfaces. This resulted in discontinuities in the volume weighting term ($\Delta z/\Delta\eta$) at the interfaces. These discontinuities may be avoided if the lower interface is removed and if the gradual flattening is made quadratic. Starting the flattening process at the first level results in fewer levels being either fully or nearly terrain-following. With this alternative flattening strategy, the South East Asian jet shows no sign of deceleration and the large errors have been eliminated.

3 Idealised test problems

The ability to set up and run various idealised configurations is being built into the latest release of the UM. These include limited-area tests with fixed, forced or open (cyclic) lateral boundaries. This will allow the running of idealised tests over a very wide range of resolution scales (metres to hundreds of kilometres).

4 Excessive drying in tropical lower stratosphere

In climate runs, excessive drying of the tropical lower stratosphere occurred within a month or two and persisted thereafter. Evidence of such drying was also noted in forecast runs but was controlled somewhat in the data assimilation cycles. Changes to the parametrizations (e.g. fall speed of cloud droplets etc) had little effect. Experiments using higher-order interpolation (quintic rather than cubic) in the semi-Lagrangian advection of moisture variables gave a more satisfactory performance. In fact, it was found that the quintic interpolation needed to be applied only in the vertical to give essentially the same performance. We therefore apply quintic interpolation in the vertical on moisture variables in all configurations.

5 Improved conservation under advection

The lack of conservation under semi-Lagrangian advection is widely recognised by users of such schemes. Limiters can be applied to maintain conservation but to work properly we need to know the mass at the arrival point. In our scheme, we use the semi-Lagrangian advection as a predictor step which means that the mass (or in our case the density) at the arrival point (new time-level) is not available. To ensure conservation of a passive tracer we can do the semi-Lagrangian advection step after the correction step. Applying the conservation constraint then does indeed give good conservation. However, for moisture variables we need to do a preliminary semi-Lagrangian step before the correction step to allow for moist effects in the dynamics and we also need to store the increments due to the physics to be used later in the conservative semi-Lagrangian step. If the physics acts on a tracer (e.g. scavenging by precipitation) we need only store the increments due to the physics until application of the conservative semi-Lagrangian advection. To save re-calculating trajectories and departure points we store the departure points for use in the conservative semi-Lagrangian step.

References

[1] Cullen, M.J.P., Davies, T., Mawson, M.H., James, J.A., Coulter, S.C. and Malcolm, A. (1997). An overview of numerical methods for the next generation UK NWP and climate model. *Numerical Methods in Atmospheric and Ocean Modelling*,The Andre J. Robert Memorial Volume, Eds. Charles A. Lin, Rene Laprise and Harold Ritchie. 425-444