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TOWARDS AN OPERATIONAL 1KM LIMITED AREA MODEL BY USING VARIABLE RESOLUTION

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1. INTRODUCTION

The Met Office uses a single non-hydrostatic model code for its operational NWP and climate modelling, the Unified Model (UM), (Davies et al, 2005). Several configurations are run routinely; global model at various resolutions and limited-area models for different regions. The current North Atlantic and Europe (NAE) model is run with a horizontal resolution of 12km. A 4km version of the model over the UK is operational and the hope is that we can increase the operational resolution towards 1km in the future. A 1.5km resolution model is available "on-demand" if the forecasters think the synoptic situation warrants this. One problem with these set-ups is that they require Lateral Boundary Conditions (LBC's) and these files can take up a lot of disk space and also slow down the generating model depending on the systems I/O. One way to get round this is to embed a high resolution area inside a lower resolution model thus getting the benefits of higher resolution without the cost in terms of extra LBC file generation. This talk will outline the tests that have been carried out so far and the performance of the model on a test case.

2. THE CURRENT MODEL CONFIGURATION

2.1 *Dynamical core*

The scheme is detailed in Davies et al. 2005 but the main features are listed below.

The main features of the scheme are:

- Two time level semi-implicit Semi-Lagrangian scheme
- Non-hydrostatic model with height as the vertical co-ordinate.
- Charney-Philips grid staggering in the vertical, i.e. potential temperature is on the same levels as the vertical velocity including top and bottom boundaries where vertical velocity is zero.
- C grid staggering in the horizontal, i.e. u-component is east-west staggered from temperatures and v-component north-south staggered.

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2.2 *Parametrizations*

Whereas most UM configurations use the same dynamics, there are currently a number of different physical parametrization versions available. The model is using the physics generally being used in the latest UM climate model, HadGEM1

This consists of:

- Edward-Slingo radiation scheme with non-spherical ice (Edwards and Slingo, 1996).
- Large scale precipitation with prognostic ice microphysics.
- Vertical gradient area large-scale cloud scheme.
- Convection with CAPE closure, momentum transports and convective anvils.
- Boundary-layer scheme which is non-local in unstable regimes and includes BL entrainment (Lock et al, 1999).
- Gravity-wave drag scheme which includes flow blocking.
- GLOBE orography dataset.
- MOSES (Met Office Surface Exchange Scheme) surface hydrology and soil model scheme (Cox et al, 1999).

2.3 *Physics Coupling*

In the model, the slow physics are performed in parallel whereas the fast physics (boundary layer and convection) operate sequentially. The increments from the cloud scheme, large-scale precipitation, radiation and gravity-wave drag are calculated at time level n and interpolated to departure points. For the boundary layer and convection, the calculations are made at the arrival points from the estimates to time-level n+1 but the exchange coefficients in the boundary layer scheme are calculated using (balanced) time level n fields.

3. VARIABLE RESOLUTION LIMITED AREA MODEL (LAM) RUNS

With the new model being non-hydrostatic it has the capability to run acceptably at much higher resolution (of the order of 1km). Indeed the model has been run at a regular resolution of 50m in research mode.

The same underlying computer code is used for limited area runs as for the global model but a number of the code options in the dynamics and parameters inside the physics parameterizations are changed to give more realistic local values. The model is run with a one-way coupling. For very high resolution LAM runs we create the Lateral Boundary Conditions (LBC'S) for these runs by reconfiguring from lower resolution LAM runs. In the case of a 1km LAM we nest it inside a 4km grid inside a 12km grid.

This means that we need two LBC files and these can be large in terms of size and their generation can slow down the output from the generating model.

One problem with going to higher and higher resolution is the increase in cost of the models. If we compare the cost of the model over exactly the same area then we find that for example a 2km resolution model would be 8 times more expensive than a 4km model ($\Delta x^2 \Delta t$) and 1km would be 64 times as expensive. If we had a region of high resolution embedded in the domain then this cost increase would not be quite so prohibitive (although still large). If we have a quarter of the domain at 1km resolution, a blending region and then the rest of the domain at 4km then the increase in cost is roughly 27 times

The proposed solution is to use a variable resolution LAM. Côté et al (1998) used this technique within a global model. With only one set of LBC's being generated by the higher resolution model, the domain of the variable resolution LAM is generated as follows. In each horizontal direction the high resolution area in the centre of the LAM domain is set up first. Then the ratio of grid sizes in the expansion area is decided and then expansion area is then generated, Finally the area with the larger grid separation is set up.

An example of such a grid is shown below.

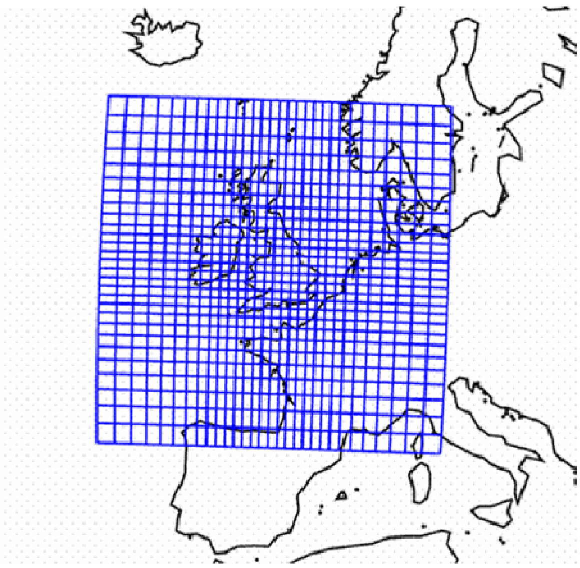

Figure 1, A variable resolution grid centred over the UK.

For example let us assume we want a low resolution of 4km, a high resolution of 1 km and a 50% expansion ratio. The 50% expansion ratio shows that we need 3.4 boxes in the expansion area. We round this up to 4 and then find the actual expansion ratio of $\sqrt{2}$. In practice the expansion ratio is between 5 and 10%.

Initial tests with the variable resolution code have shown that results comparable to that of a doubly nested mesh are possible and that finer detail than is available from a lower resolution model is possible.

Also with improvements in the coding of the variable resolution code the cost increase in the model has been kept down.

5. AN EXAMPLE – Typhoon Nabi over Japan

A case study has been made with the Typhoon of the 5th September 2005 which passed to the west of Kyushu Island. Results are due to Junichi Ishida.

The rainfall rates shown are for 10 hours into the run.

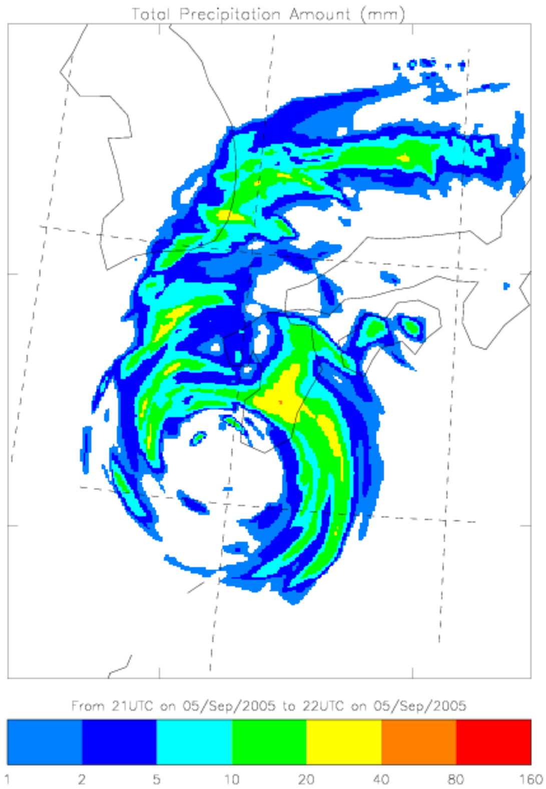

Figure 2, A regular 4km grid result for rainfall

Two regions of enhanced resolution were tried. The results of this are shown in the following two figures. Variable resolution grid 1 has the variable resolution area centred on the southern Island, while variable resolution grid 2 is centred on the initial eye of the typhoon. In both cases the rain band round the eye of the typhoon is slightly better than that in the regular 4km run above.

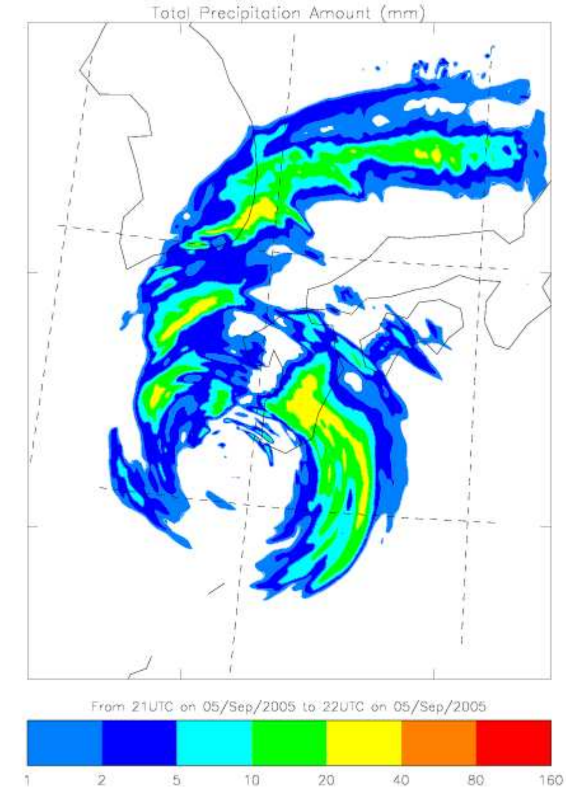

Figure 3, Result with enhanced grid 1 for rainfall.

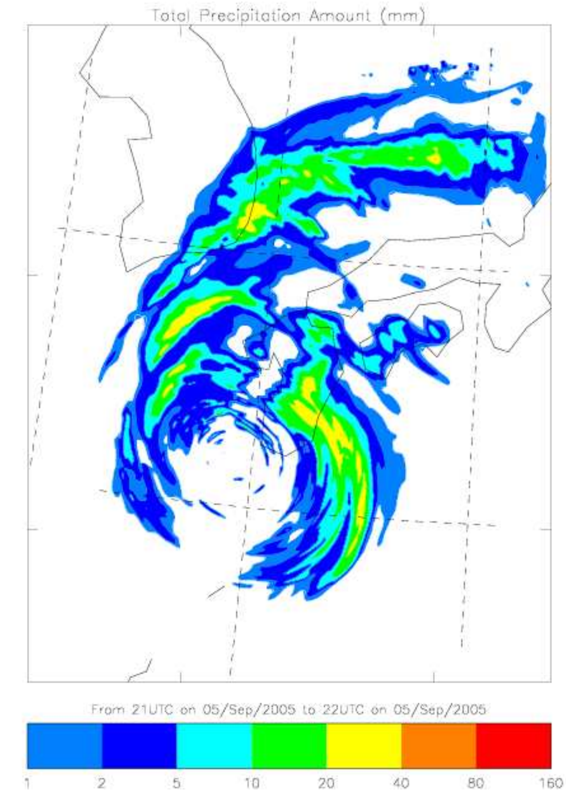

Figure 4, Result with enhanced grid 2 for rainfall.

6. SUMMARY

The implementation of the non-hydrostatic UM has allowed the possibility of going to higher resolutions. The implementation of an operational 4km model and an on-demand 1.5km model is showing a number of areas (e.g. data assimilation) where further work is needed before it can go fully operational.

The 1km version of the model is currently being tested and is showing reasonable results but there is still much work to be done. Computer power required for routine operations may not be available until the end of the decade, which allows time for further research. However the current solution of running a model without data assimilation allows testing to start now.

Variable resolution offers the option to run at higher resolutions without the large increase in computer power required by high resolution regular grids.

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