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TOWARDS AN OPERATIONAL 1KM MODEL

Andrew J. Malcolm*
Met Office, Exeter, United Kingdom
and
Nigel M. Roberts
Met Office, Joint Centre for Mesoscale Meteorology, Reading, United Kingdom

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 UK mesoscale model is run with a horizontal resolution of 12km. A 4km version of the model is undergoing pre-operational trials and the hope is that we can increase the resolution towards 1km in the future. This talk will outline the tests that have been carried out so far and the performance of the model on a test case. With the increase in resolution will come a change in the way forecasts are verified and a methodology is described in this paper (may not appear in the talk due to time constraints).

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.

- *corresponding author address:* Andrew J. Malcolm, Met Office, Fitzroy Road, Exeter, Devon, EX1 3PB, United Kingdom;
 e-mail: andy.malcolm@metoffice.gov.uk

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. 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). Results from a stand-alone version of the model showed that we could get good results at 1km resolution (Malcolm et al, 2001).

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.

At 4km and 1km we have introduce prognostic rain into the models, while at 1km we turn off the convection scheme.

4. DATA ASSIMILATION

Currently the 12km mesoscale model uses 3D-VAR with MOPS (cloud + latent heat nudging). The pseudo-operational 4km model currently uses no data assimilation but the plan is to introduce similar data assimilation to that used in the 12km model by the end of the year.

Currently the data assimilation technique for the 1km model is under investigation. The short-term possibilities include not using VAR but just MOPS and latent heat nudging, or reconfiguring the 4km increments to 1km and inserting using the IAU or even not using any data assimilation at all.

5. AN EXAMPLE – THE BOSCASTLE STORM

Several test cases have been run for a number of severe convective events. The most high profile of these was the "Boscastle flood" event from 16th August 2004. This is a case where there was highly localised rainfall from a slow-moving thunderstorm which caused severe flooding and damage to the village of Boscastle in Cornwall. 24 hour rainfall amounts of 200 mm were measured by rain gauges, while less than 10km away readings of less than 10mm were recorded. (See Figure 1).

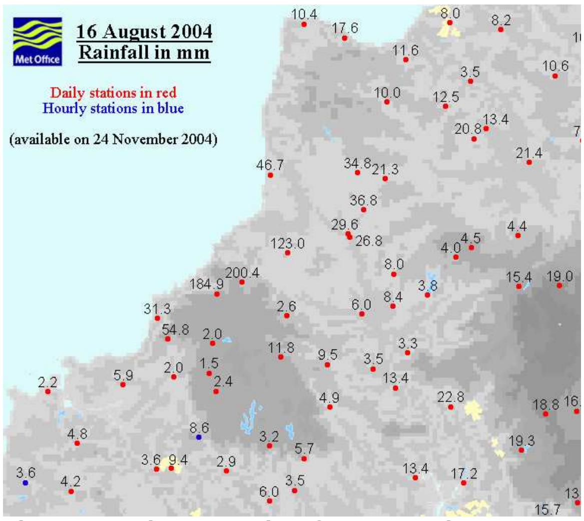

Figure 1, Rain Gauge data for Boscastle area

Figure 2(a) shows 6-hour rainfall accumulations over the period of the event. The 12km model missed the position and ferocity of the rainfall. Subsequent tests with the 4km and 1km models should let us see what effect the higher resolution would have

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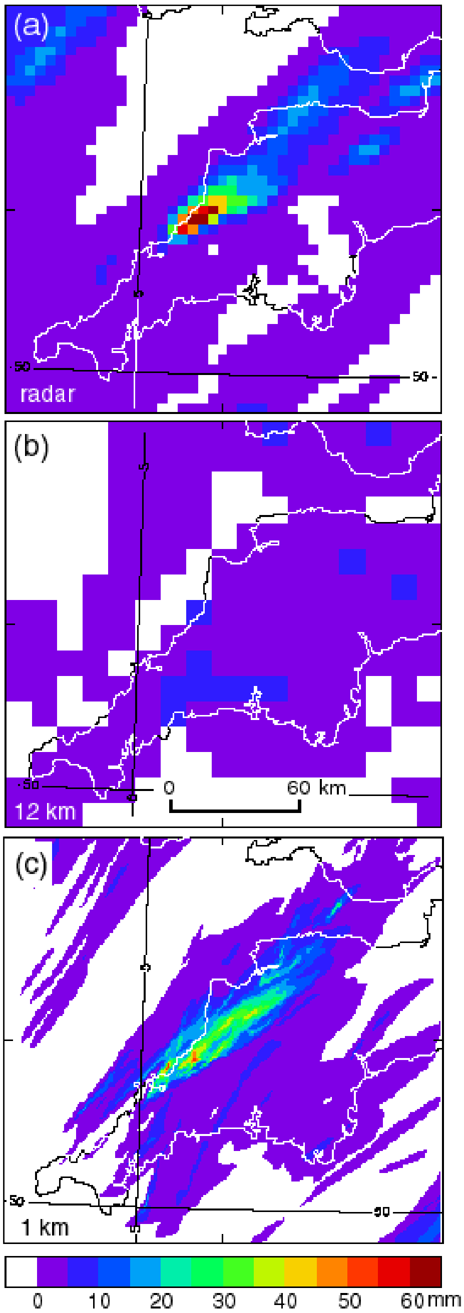

Figure 2. 12 to 18 UTC 16/08/04. (a) Rainfall accumulations from radar. (b) Accumulations from a 12km forecast starting at 00UTC. (c) Accumulations from a 1km forecast starting at 00UTC.

The Met Office operational mesoscale (12km) model failed to predict the storms from even very short lead times. Figure 2(b) shows the inadequate accumulations produced from one of those forecasts. However, simulations run at 4 and 1km (after the event) were much more successful. A 1km forecast is shown in Figure 2(c). There was no additional data assimilation at the higher resolutions; they were spun up from a 12km analysis. The 1km forecast was significantly better as it was able to produce significant rainfall totals over the area they occurred. This is an encouraging result, as it shows that a more detailed representation of local effects can produce a better forecast, even without additional data assimilation. However, it is only one case and appropriate verification of a larger number of events is necessary. That work is ongoing, as is the investigation of data assimilation methods at high resolution.

5. SCALE SELECTIVE VERIFICATION

A principle reason for developing the 1km model is to achieve a forecast system that is capable of predicting convective storms to a level of accuracy that is useful for providing useful warnings of flash floods. This means that, in terms of the verification of such a system, we want to know how accurately the model is able forecast precipitation over areas the size of susceptible river catchments or urban areas. It is therefore not helpful to continue with the traditional approach of verifying at the grid scale or observation points because it does not provide information on the scales we are interested in, and in addition, the unpredictable nature of such small scales limits the value of such results. For that reason we have used a scale-selective verification method for evaluating precipitation forecasts.

5.1. Method

The approach is to compare the forecast fraction of occurrences of a rainfall event (e.g. accumulation >16mm) with that seen by radar over a variety of scales. For every grid square, we compute the fraction of surrounding points within a given area that exceed a particular accumulation threshold over a given period and compare with fractions derived from radar in the same way. These fractions (or probabilities) can be compared over different spatial scales by changing the size of the sampling area. For the purposes of verification, squares of different sizes are used to compute fractions for different spatial scales. Verification scores that deal with probabilities (e.g. Brier skill scores) can be used to compare the fractions.

5.2 Scores from the Boscastle case study

Figure 3 shows curves from a variation on the Brier skill score for comparison of fractions (termed the Fractions Skill Score) from the grid scale to 400km for a threshold of 4mm over the same period as shown in Figure 2. (As well as curves for the 12km and 1km forecasts, there is also a curve for the 4km forecast run from the same time). The Fractions Skill score has a range of 0 to 1; 0 for a complete forecast mismatch, 1 for a perfect forecast**.**

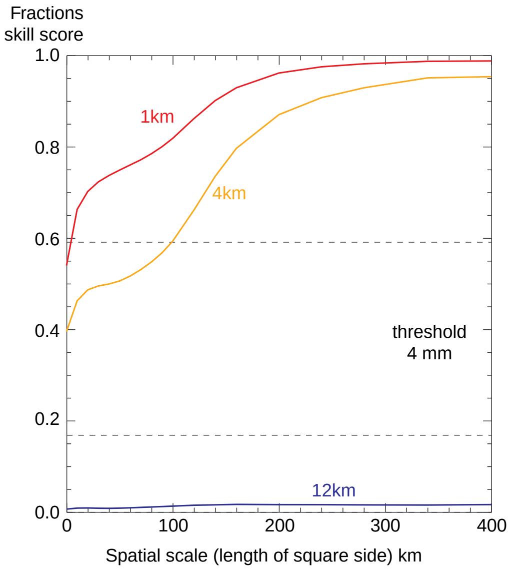

Figure 3. Fractions skill scores for an accumulation threshold of 4mm over the period shown in Figure 1 against spatial scale for 12, 4 and 1km forecasts.

The graph supports the subjective impression that the 1km model was significantly better at all scales than the 12km model. Even over the largest scales 12km model was poor, but this is because of a bias caused by under-prediction at the 4mm threshold.

Verification can be performed with the bias removed by choosing a percentile value as the threshold (giving a different accumulation threshold for each forecast), in order to compare just the spatial accuracy. The curves in Figure 4 reveal that the 1km model had a more accurate spatial distribution at all scales up to 240km. This also agrees with the subjective impression given by Figure 2, in which we see that the 12km model produced the general area of higher accumulations in the wrong place without sufficient structure.

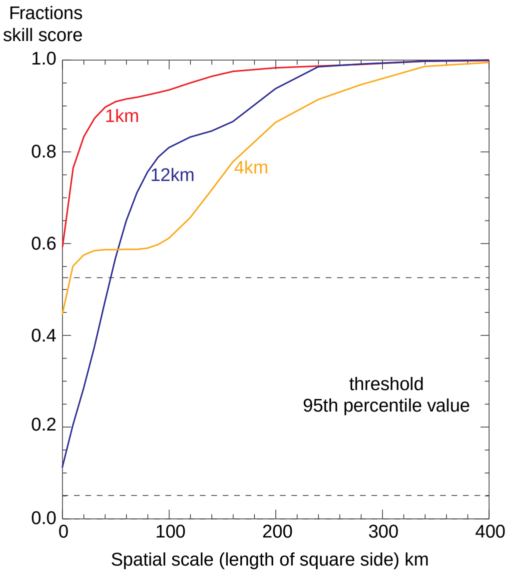

Figure 4. Fractions skill scores for a frequency threshold of the 95th percentile value over the period shown in Figure 3 against spatial scale for 12, 4 and 1km forecasts.

5.3 More general scores

An example in which the 1km model was clearly better has been used to demonstrate the verification approach. More representative results from 16 forecasts over 4 convective events (not including the Boscastle storm) are shown in Figure 5.

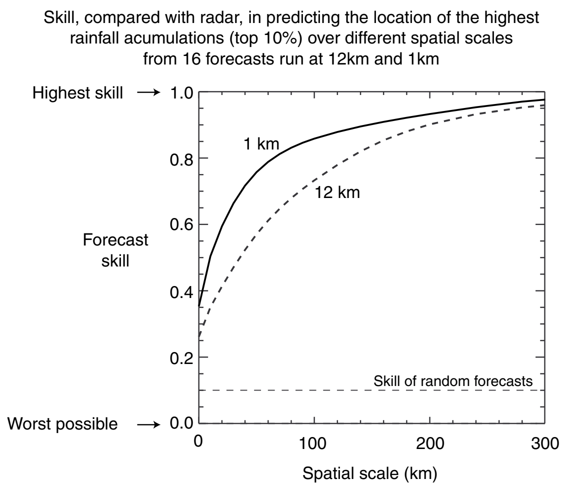

Figure 5. Fractions skill scores for 6-hour precipitation accumulations using a frequency threshold of the 90th percentile value. (Spatial scale of 0km is really 5km.)

Again we see that the 1km forecasts (no additional data assimilation) were more skilful over all scales, with the greatest difference being at intermediate scales between ~20 and ~100 km. However, this is still a small sample and more test cases are being examined. (Lean et al 2005)

6. SUMMARY

The implementation of the non-hydrostatic UM has allowed the possibility of going to higher resolutions. The implementation of a pseudo-operational 4km 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.

Appropriate verification of precipitation forecasts from new high-resolution NWP models (< 5 km) is essential. It is not sensible to verify raw model output on a grid point by grid point basis, because we should not expect skill at that scale. We need to be able to assess the accuracy of forecasts over different spatial scales (as a human observer would). A simple method has been developed to perform a scale selective verification of precipitation forecasts.

Results from 1km forecasts of several convective events have been encouraging. The 1km model was more skilful than the operational 12km model on scales that matter, even without additional data assimilation. Further testing is ongoing. The next major hurdle is the development and testing of high resolution data assimilation techniques. Further work is also needed to compare the verification approach with others such as the use of wavelets (Casati 2004).

7. REFERENCES

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