Use of a high resolution mesoscale model to prepare site specific road temperature forecasts

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ABSTRACT

The UK Met Office has a suite of numerical weather prediction models known as the *Unified Model*. Whilst utilising the same physics, the model can be operated within different domains. The highest resolution of these models is known as the *Mesoscale Model*. Its domain is the British Isles and adjacent parts of Northwest Europe, and it has a grid length of approximately 15 Kilometres.

On a much smaller scale, the site specific forecasts of road surface temperature are produced using a one dimensional heat balance model of the road surface. Input required by this model is three hourly forecast values of air temperature, dewpoint, wind speed, cloud amount, cloud height and precipitation. In the past, these forecast parameters have been provided by a human forecaster. However, this is time consuming and limits the number of road temperature forecasts that can be produced.

During the winter of 1994-95, the Met. Office implemented a scheme to drive the road temperature model directly from the mesoscale model. Dedicated input parameters required by the road temperature model are produced directly by the mesoscale for each required location (approximately 270 locations around the UK). Fast communications ensure that this can take place very quickly.

The human forecaster, released from the more mundane task of typing in numbers, now has more time in which to think. The job of the forecaster now becomes one of quality control. Account must be taken of effects which the mesoscale model cannot handle (such as small scale frost hollows or atypical exposure of the site). This combined mesoscale/human forecaster mix has proved to be very powerful.

Verification for the winter of 1994-95 showed a 3% improvement in frost prediction accuracy compared to previous winters. Nationwide, the successful frost predictions improved to 88%. The previous three winters, using human forecaster input only had averaged 85%.

Future developments planned for the near future include the use of Kalman filters on the mesoscale input. This technique is used to remove persistent biases and arrive at a mean error in predicted road surface temperature of close to zero.

1. Introduction

The Met. Office first became involved with ice prediction forecasts in 1983, and has routinely provided ice prediction forecasts for all parts of the UK since 1987. Forecasts of road surface temperature and road state are produced using a one dimensional heat balance model of the road surface. The Met. Office road surface temperature model has been described by Rayer (1987) and a comparison between various road temperature models was given by Thornes and Shao (1991).

In its basic form, a road temperature model requires three hourly inputs of air temperature, dewpoint, wind speed, cloud amount, cloud height and precipitation. A typical data input is given at figure 1. The model is designed to produce *site specific* forecasts at a number of spot locations. This requires detailed local knowledge from forecasters, to take accounts of highly localised effects (such as frost hollows or heat islands). This process has given good results, typically with frost prediction accuracy of around 85%, over a number of years. However, it has two main drawbacks:

- It is very labour intensive, which means that the number of ice prediction forecasts that can be produced is limited.
- Using three hourly input can artificially smooth the output, thus masking sudden rises or falls in road temperature (which can be very important).

Model Input - Met. Office Model

	Start Date	Time	Runs
Site: A24 Beare Green	02 Feb 95	1200	1

Temps	
Surface	5.2
Depth	2.3

Realistic

Input

	1200		1500		1800		2100		0000		0300		0600		0900		1200
Air Temp	3.2		3.0		1.8		0.7		0.3		0.0		-0.2		-0.1		2.9
Dew Point	1.2		1.2		1.2		0.7		0.3		0.0		-0.2		-0.2		0.7
Wind Speed		12		10		6		4		3		4		2		7	
Cloud Cover		88		24		22		11		00		00		00		24	
Cloud Type		L		M		L		L		-		-		-		M	
Precipitation		Y		-		-		-		-		-		-		-	

Enter Start Date for model run as dd mmm yy, eg 23 Dec 90

Figure 1.

During the late 1980s demand for ice prediction forecasts grew by over 500%. Despite upgrading to the most powerful PCs which were available at the time, it became very difficult to satisfy demand. Therefore, a method to speed up production needed to be found. It was also decided that accuracy of the forecasts needed to increase (rather than decrease) with increased automation.

2. The Mesoscale Model

The Met. Office has a suite of Numerical Weather Prediction models known as the *Unified Model.* The models all use the same physics but cover different domains and/or timescales. The working of the Unified Model was described by Cullen (1993).

Ice prediction models require highly localised input. Therefore, the unified model with the highest resolution needed to be used. The Mesoscale model covers the area of the UK and adjacent parts of Northwest Europe. The separation of the grid points is around 15 kilometres, which is good enough to resolve most major topographic features within the UK. A representation of the topography used within the model domain is given at figure 2. Operationally, the model is run four times a day, based on initial data of 0600, 1200, 1800 and midnight. When first instituted, the mesoscale model only ran up to 18 hours ahead of initial data time. However, road temperature forecasts need to be available for a twenty four hour period from midday on the day of issue. Therefore, to accommodate the needs of the road weather forecasts, the mesoscale forecasts were extended to thirty hours ahead on the 0600 run, and 24 hours ahead on the midday run.

3. The Cheshire Trial winter 1993-94

Before the mesoscale model could be used operationally to produce road weather forecasts, it needed to be tested against existing methods. A trial was set up during the winter of 1993-94 using three ice prediction sites in Cheshire. Operationally, road weather forecasts for Cheshire were produced by Manchester Weather Centre. Ice prediction forecasts had been produced for Cheshire from November 1986 and hence human forecasters had eight years experience of producing the highly localised model input needed for these three sites.

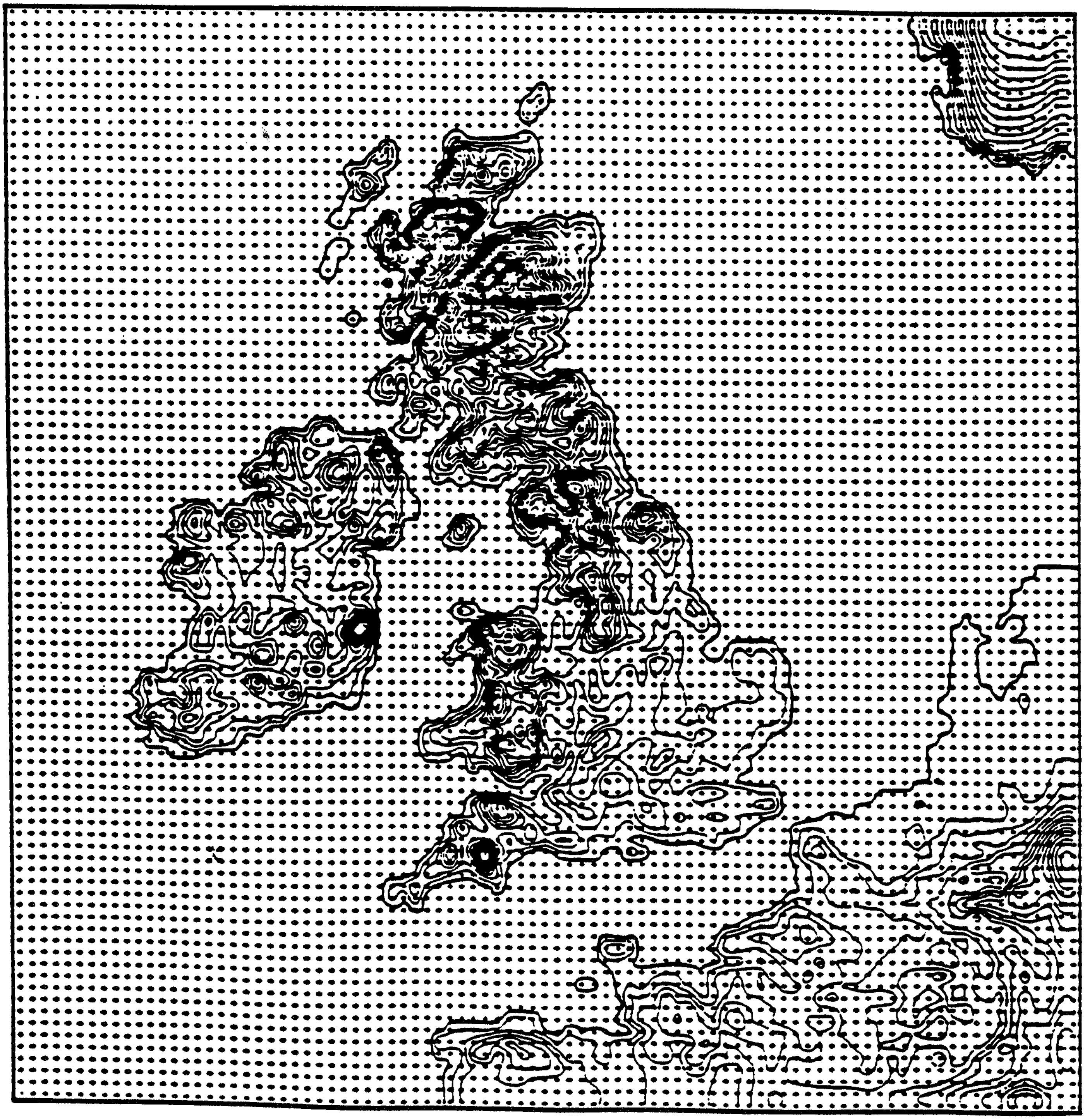
To ensure that the forecasters at Manchester Weather Centre were not unduly influenced by the mesoscale model, additional forecasts for Cheshire were produced by Birmingham Weather Centre. Mesoscale model data was used to produce ice prediction forecasts automatically for the three Cheshire sites. Human forecasters at Birmingham performed basic quality control on the forecasts (such as correcting for synoptic scale errors) but no attempt was made to use local knowledge of the sites (which in any case Birmingham Weather Centre did not possess).

The trial results are given in table 1. It can be seen that use of the mesoscale model data did produce the increase in accuracy that was sought, as well as speeding the whole production process. The mean errors show that in general the mesoscale model is less pessimistic than a human forecaster. Shotwick Lodge had a mean error of minus 0.17 degrees Celsius when produced by the mesoscale, but minus 0.44 degrees Celsius when produced by a human forecaster. Other measurements of the skill involved in the forecast are *False Alarm Rate* and *Probability of Detection.* The false alarm rate is the ratio of incorrectly forecast frosts to the total number of frosts that were forecast. Ideally, this should be zero. The probability of detection is the ratio of correctly forecast frosts to the total number of frosts that actually occurred. Ideally, this should be 100%. These figures again show that the mesoscale model is less pessimistic, having a false alarm rate a third that of the human forecaster. However, the caution of the human forecaster shows in the probability of detection figures, where a human forecaster is more likely to predict the occurrence of frost.

4. National Implementation winter 1994-95

Following the successful Cheshire trial, the mesoscale model was used operationally to produce all ice prediction forecasts in the winter of 1994-95. The process was semi-automatic, in that mesoscale data was downloaded via a high speed modem link and integrated into the ice prediction software to run the road temperature model for a number of sites. Once the initial model run s had been produced in this automated fashion, it was the human forecaster's job to quality control the graphs. This was accomplished by editing the input to the ice prediction model (if deemed necessary) and then re-running it. Forecaster quality control was necessary to cope with effects at certain sites that cannot adequately be resolved by the mesoscale model. Such effects include:

Figure 2. The mesoscale model domain and orography

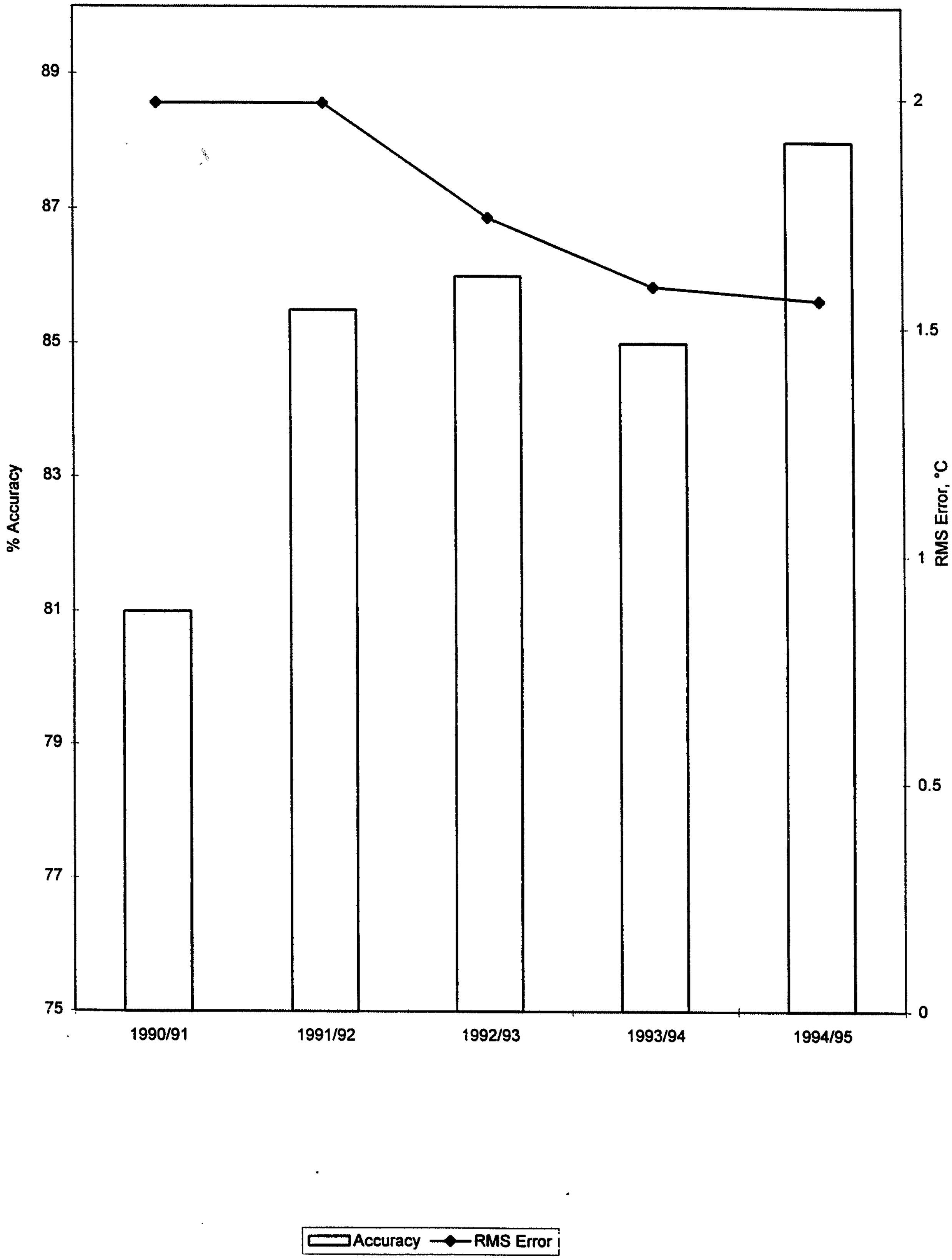


The grid-points are 15km apart and the contour interval is 50m. The bold contour is at zero height and indicates the model coastline

The Cheshire Trial. December 1993 to March 1994

	Forecast temperature mean error (degrees Celsius)	Forecast Temperature RMS error (degrees Celsius)	Accuracy (percent)	False alarm rate (percent)	Probability of detection (percent)
Mesoscale (Birmingham Weather Centre)					
Shotwick Lodge	-0.17	1.28	93%	10%	79%
Bulkeley	0.52	1.69	85%	10%	67%
Siddington	0.31	1.60	83%	10%	64%
Human Forecaster (Manchester Weather Centre)					
Shotwick Lodge	-0.44	1.31	88%	31%	80%
Bulkeley	-0.07	1.52	79%	32%	75%
Siddington	-0.08	1.42	83%	21%	77%

Figure 3. OpenRoad® Verification 1990-1995



- Small scale frost hollows
- Urban heat islands
- Inadequately resolved topography
- Proximity to large rivers or lakes

The results from the winter of 1994-95 are given at figure 3. It was noticeable that after a three year plateau of frost prediction accuracy of around 85% (using human forecasters only), the combined mesoscale/human forecaster accuracy was 88%. Root mean square errors in the predicted minimum road surface temperature also fell, although this effect was less marked as a very definite learning curve has been present each year since the start of ice prediction forecasts.

5. The Future

Having proved itself in the winter of 1994-95, the mesoscale/ human forecaster combination is to be used in the winter of 195/96. However, in order to cope with large workloads it is still necessary to cut down on the amount of human forecaster intervention that is necessary. One way to do this is to use statistical techniques such as *Kalman Filters.* Kalman filters are designed to remove persistent biases from forecast products and arrive at a mean error in predicted road surface temperature of close to zero. They have been described by Aoki (1987) and Young (1984). In the field of ice prediction forecasts they will be most useful in dealing with effects such as traffic, poor exposure of road sensors and poor representation of orography. They will not be of any use for less persistent errors such as synoptic scale timing errors e.g. in cloud clearance. Therefore, quality control by a human forecaster will still be needed, although hopefully at a reduced level to that needed at present.

6. Conclusions

Both the Cheshire trial in 1993-94 and the operational UK wide use in 1994-95 have shown that it is possible to semi-automate the production of ice prediction forecasts, to cope with increased demand, whilst increasing the accuracy of the ice prediction forecasts themselves. Future developments are hoped to increase the accuracy further.

Acknowledgement

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References

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