GIS based approach to Predicting Road Surface Temperatures

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1. Introduction

Treatment of transport networks of the winter period is a key responsibility of maintenance teams whether in the private or public sector. With tightening budgets and increasing statutory requirements, maintenance teams are looking to improve the treatment of networks by improving ice prediction techniques. Improved forecasting techniques leads to financial savings, reduction in environmental damage and degradation of road surfaces and reduces potential litigation cases.

The use of Network Forecasting has become a principal component in helping a highway engineer to make an informed decision on whether to grit a route on a given night. Traditionally this network forecast has relied on a thermal survey of the road network as a main input to a forecast model. Although recording actual surface temperatures thermal mapping is expensive and requires repeating to achieve a representative set of climate scenarios. Recent work in the field has seen a move away from thermal mapping to better categorise and model local climate conditions. Work by Thornes et al (2005) has described the use of GIS in this field yet the technique described still requires some form of manual survey – in the form of measuring sky view Factor and thermal mapping – as an input to their model. This paper outlines a GIS desktop based approach to surveying a route and the results of integration into Aerospace and Marine International’s GRIP (Geographical Road Ice Predictor) model in recent trials held across the county of Hampshire as to the effectiveness of the methods used.

Ice prediction models have been developed in many countries where a temperate climate results in marginal temperatures - when temperatures are at or below freezing and a gritting run would be advised- at night. A variety of techniques have been developed with the aim of better predicting ice on road networks across the world.

Network forecasting models can be broken down into two key concept areas:

1. Temporal component that consists of a standard road weather prediction model. This uses forecast meteorological data to produce a *Road Surface Temperature* (RST) forecast curve.
2. Spatial component that uses geographical attribute data to modify the forecast curve on a site-specific basis.

1.1 Temporal Component

Thornes' (1984) model uses a zero-dimensional energy balance approach. The model uses standard 3-hourly forecast meteorological data to produce the 24-h RST forecast curve. This forecast is provided to the winter maintenance engineer at midday so that early decisions can be made regarding the salting of the road network. In the model a forecast for a particular night may be marginal with regard to temperatures – i.e. just below freezing. Should the surface receive an input of moisture, the forecast site will need salting, however, large sections of the road network will not. A sensitivity test of the model is described in Thornes and Shao (1991) and the temporal forecasting ability of the model is covered in Parmenter and Thornes (1986). Both studies indicated that Thornes' 1984 model has significant forecasting ability and compares favourably with other road weather models. The model used in this research is Davy's (2000) GRIP model which produces a forecast at higher frequencies – three instances per hour – and at finer resolutions - 100m spacing along a network.

1.2 Spatial Component

Davy (2000) first introduced a spatial component into the weather model by replacing geographical constants with variables. This work was further explored by Chapman et al. (2001b) who also added a spatial component to the Thornes (1984) model. In the original models, latitude, land use, and road construction were all constant. In Davy's GRIP model and the revised model described in Chapman and Thornes (2006), these variables along with altitude and traffic are parameterised.

2. Ice Prediction Forecasts

The aim of this research is to replace more traditional ice prediction techniques – in particular the surveying aspect used in these techniques - with a desktop model. By modelling the road network - and the surrounding area (a Road Canopy Model) - in 3D using a variety of new and well established GIS techniques this research has dispensed with the need for thermal mapping and sky view surveys as described in previous work by Chapman and Thornes.

Working with Hampshire County Council (HCC) provided an ideal opportunity to develop, test and refine the modelling technique and monitor the results in terms of forecast accuracy in a live trial. Using the inputs from the GIS model the forecaster was able to provide 20 minute updates via an internet mapping service to HCC, and predicted road surface temperatures to the highway managers – upon which they were able to make informed decision on whether to grit a route. An example of a forecast map from the night of the ninth and morning of the tenth of December is shown in figures 1a and 1b.

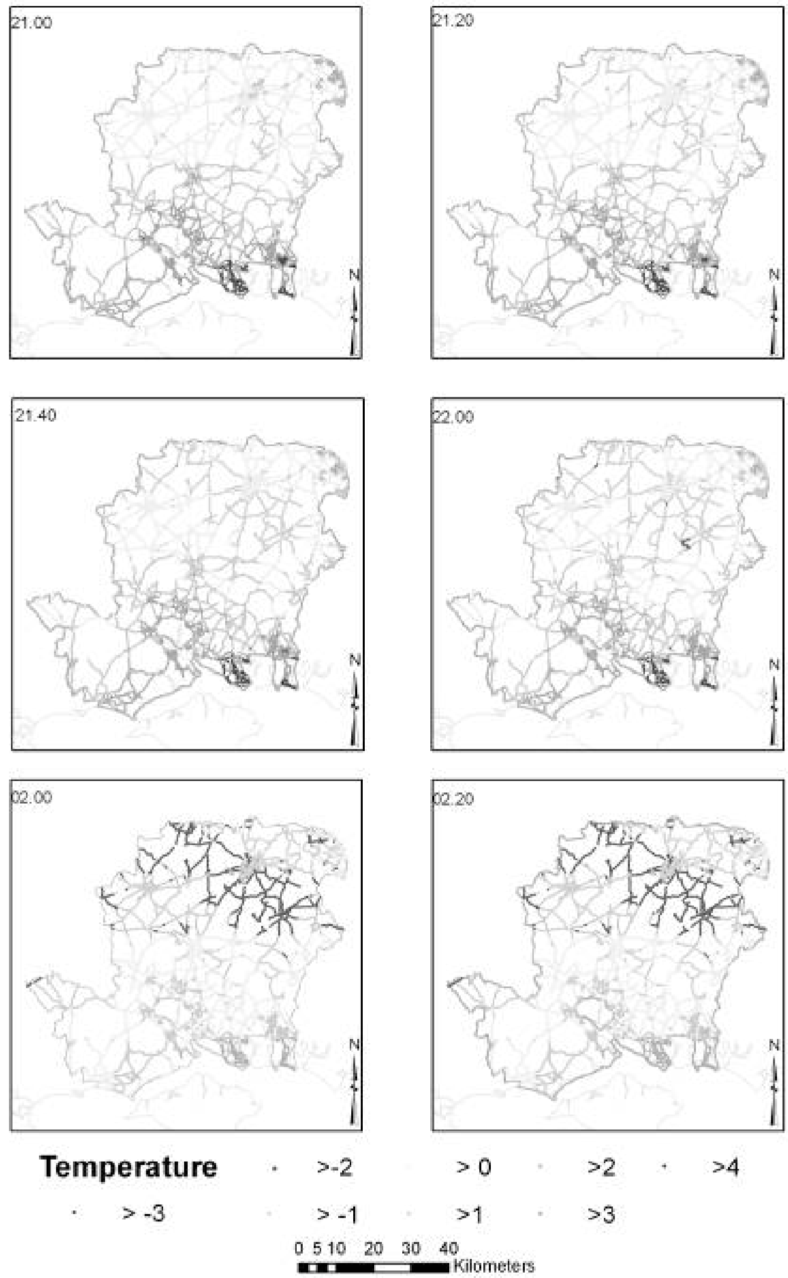

Figure 1a: Network Forecasts for the 9th/10th December 2006

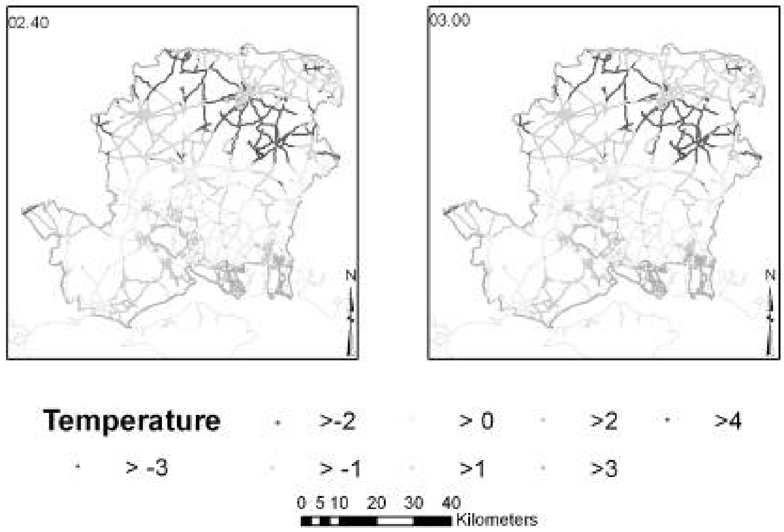

Figure 1b: Network Forecasts for the 9th/10th December 2006

Figure 2 shows minimum forecast RST plotted against actual minimum RST – as recorded by Wootton Weather Station - over a period of 22 nights in November and December 2006. Forecast errors may be divided into two types. Type 1 errors are defined as instances where the RST at monitoring stations falls below 0°C when the temperature was forecast to remain above 0°C. Type 2 errors are defined as instances where RST at monitoring stations remains above zero when the temperature was predicted to fall below 0°C.

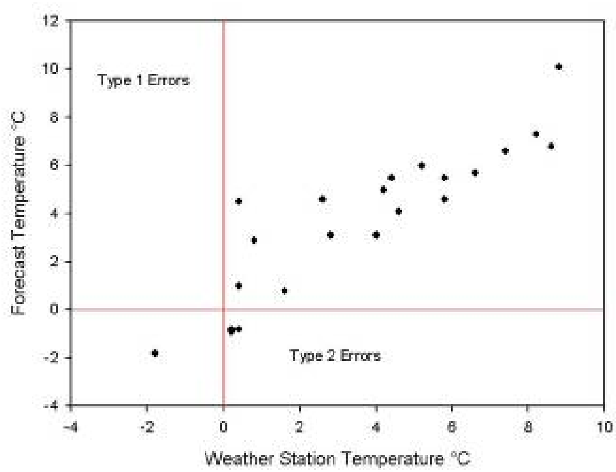

Figure 2: Minimum forecast RST plotted against actual minimum RST

Figure 2 also shows there are no Type 1 errors so far in this trial and only three type 2 errors. The forecast successfully predicted every marginal night from the sample of 22 nights. Current fieldwork will provide a wider range of temperature readings across the network and a larger sample to analyse. This analysis will be reported on in due course.

3. Conclusions and Further Work

The initial results from the Hampshire trials indicate that the GIS techniques used to create the 3D model can enhance, if not replace, the surveying techniques used in previous ice prediction models. The model has saved several unnecessary gritting runs already this season which will, given a continued reduction in unnecessary gritting runs, reduce the environmental impact of gritting, reduce road maintenance needs, reduce accidents caused by over gritting and ultimately save money.

However, the model is not perfect and with the increase in the quality and accessibility of spatial data, coupled with the improvement in GIS techniques and computing power, the accuracy of the model should increase.

Further work is being carried out on the technique outlined in this paper. These include trials in different counties, further validation of results and refinement in techniques. The main area of research focuses on improving the accuracy of the road canopy model and measuring the results of these improvements.

5. Acknowledgements

This work is being carried at as part of an EPSRC funded PhD in conjunction with GeoBureau Ltd, Aerospace and Marine International and Findlay Irvine. The trial is being conducted through Findlay Irvine in conjunction with Hampshire County Council. The author would like to thank all parties for their cooperation and time whilst conducting this research.

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