Site specific road surface temperature forecast improvements by use of radiation measurements

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INTRODUCTION

A road surface temperature forecast with high accuracy is an essential tool within a road weather information system (RWIS). Today the Swedish RWIS consists of more than 660 outstations. These stations represent different kinds of microclimates and local climates such as bridges, frost hollows, shaded road sections, hills etc. To be able to produce a road surface temperature forecast that the maintenance crew could use to take preventive action it must be designed to be site specific. In recent years research and development of forecast models have been focused on the fact that site specific conditions must be included in a model to produce high quality results (Bogren 2000, Chapman 2000, Maisey et al. 2000).

BACKGROUND

The present model for road surface temperature (RST) forecast, which is in use today in the Swedish RWIS, calculates the RST individually for each field station where the local conditions are considered. From the model a 4-hour forecast is given each 30 minutes in steps of 1 hour. The model algorithms are built around three different principles which are combined, 1- a numerical energy balance calculation, 2 - calculation of RST by means of a statistical module using site specific constants and 3 –computation of RST using a linear trend model.

Depending on time of the day and prevailing weather conditions the relevant module is chosen, individually or in combination. The different ways of establishing a route for the forecast calculation is determined by a complex network of criteria where the previous trends in relation to the normalized signature is the most important parameter. It has been possible to develop these individual and site-specific empirical criteria for the filed stations since RWIS data has been stored for every winter during the last 20 years.

The input data for this forecast model is delivered from the field station itself and also from external data such as an air temperature and cloud forecast which the Swedish Meteorological and Hydrological Institute (SMHI) produce. A cloud forecast is decisive for the calculation of the radiation balance and in the present model it is determined using empirical formulae derived from an extensive data set presented by Nielsen et al. (1981) combined with observations from the Swedish test site at Surte. The cloud forecast, which is used in the calculation of the net radiation, is a forecast that gives the effective cloudiness i.e. clouds height, type and amount is integrated for a 1 km grid.

However studies and evaluations of the present RST-model output have shown that the cloud forecast is a weak link in the calculation. This means that an error in the cloud forecast has a considerable impact on the accuracy of the RST forecast result. In the present study the use of radiation measurements at the field station has been tested. An idea is that by use of the measured radiation in combination with the other RWIS-data the present prevailing weather situation can be determined. It is also possible to use the measured radiation as an input to the model that is matched with the cloud forecast.

METHODS

In this study the RST forecast calculations for two stations (stations 1520 and 1417) outside Göteborg in SW Sweden have been analysed with regard of the effect of radiation measurements as input to the model. Actual radiation has been measured at station 1520 while at station 1417, which is located close to Säve airport cloud observations on an hourly basis have been performed as reference. The distance between the stations is 8 km. In this study data from the 23 January – 12 February 2001 have been used. This period is characterised by relatively large fluctuation in type of weather and temperatures, Figure 1.

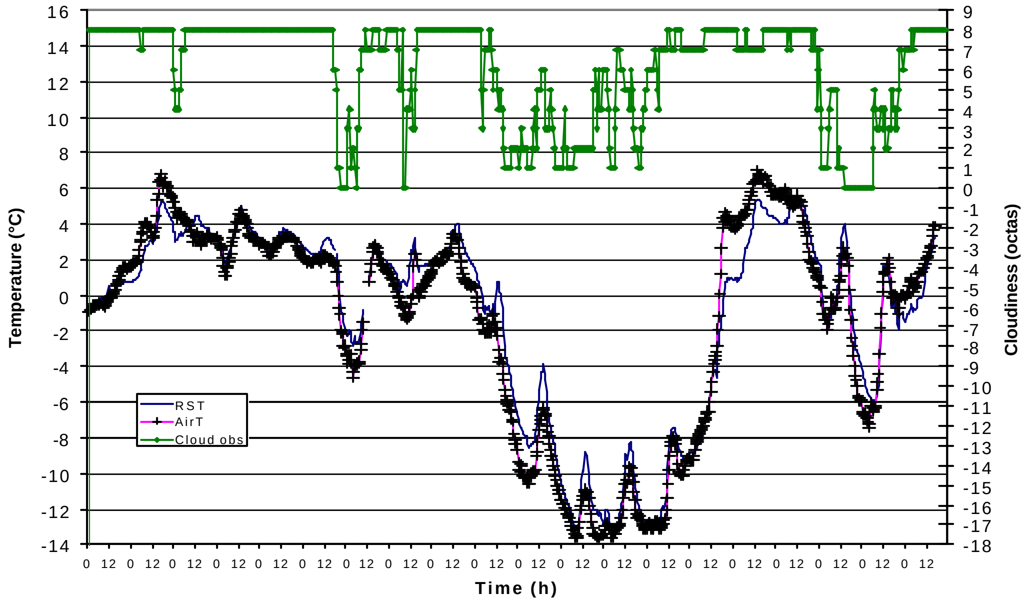


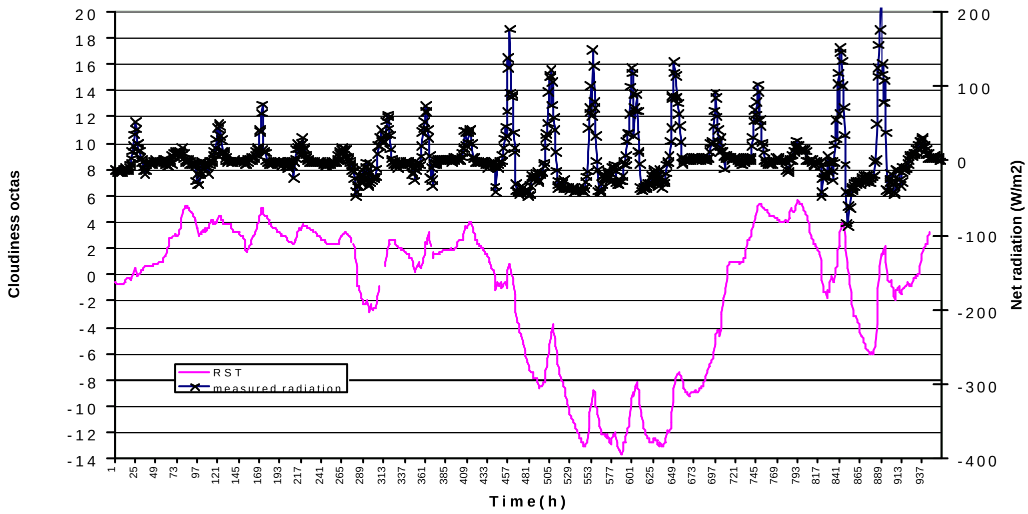
Figure 1. Recorded air temperature and road surface temperature at station 1520 together with observed cloudiness, 23 January – 11 February 2001.

The test of the model has been performed by analysing the result from the model runs forced by different input. Two different modes have been used for the test: Mode 1 – input with cloud forecast and calculated radiation as the model works today, Mode 2 – input based on measured radiation which is also transformed and used as cloud forecast.

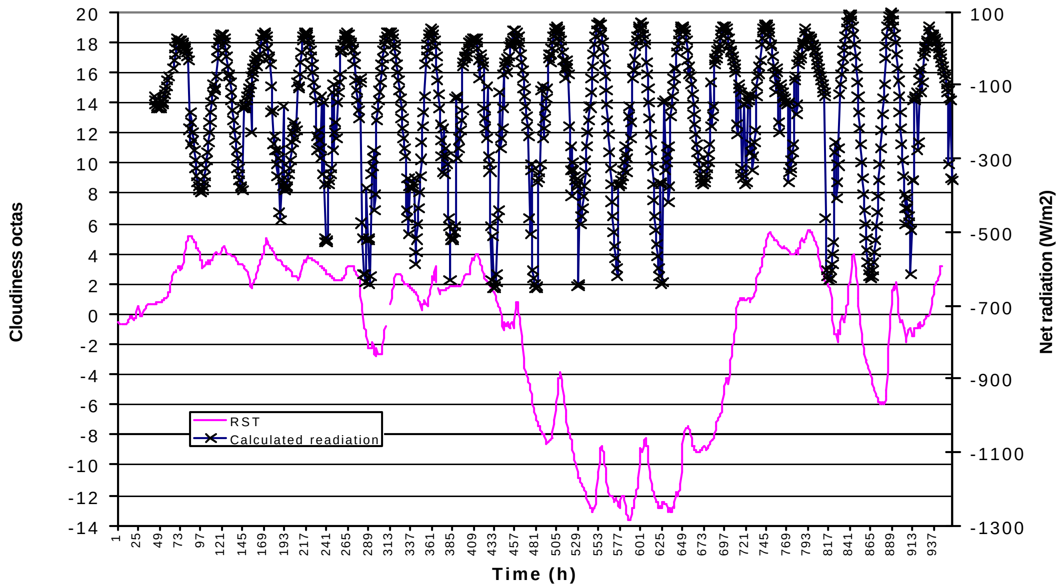
Using times series it is possible to get a survey of the different calculation where rapid changes in weather and temperature can be compared with the model output. The difference between calculated forecast and measured RST is also analysed by means of frequency of absolute error and mean error. The correlation between calculated and measured values are also used for the evaluation of the different modes in which the model is run.

RESULTS

The analysis of the result shows that the choice of input parameters has a significant impact on the output. It is obvious that the radiation data is of great importance. Comparing the measured radiation data and the calculated data with observed RST and cloudiness it can be concluded that the calculated data which is used today is too crude. The sensitivity for rapid changes in cloudiness and hence radiation that affects the RST increases by use of the measured radiation data, figure 2. In the figures it is seen that the measured values are in the same magnitude as the variation in observed RST.



a)



b)

Figure 2. Comparison of a) measured radiation, b) calculated radiation and RST at station 1520, 31 January – 8 February 2001.

The advantage with the measured radiation is that it is more sensitive for variations in solar elevation and changes in cloudiness which is not the case with the calculated radiation.

From the time series it can bee seen that the model run with input from measured radiation (mode - 2) gives a more smooth and even forecast than when the calculated radiation and forecasted cloudiness (mode - 1) is used, figure 3.

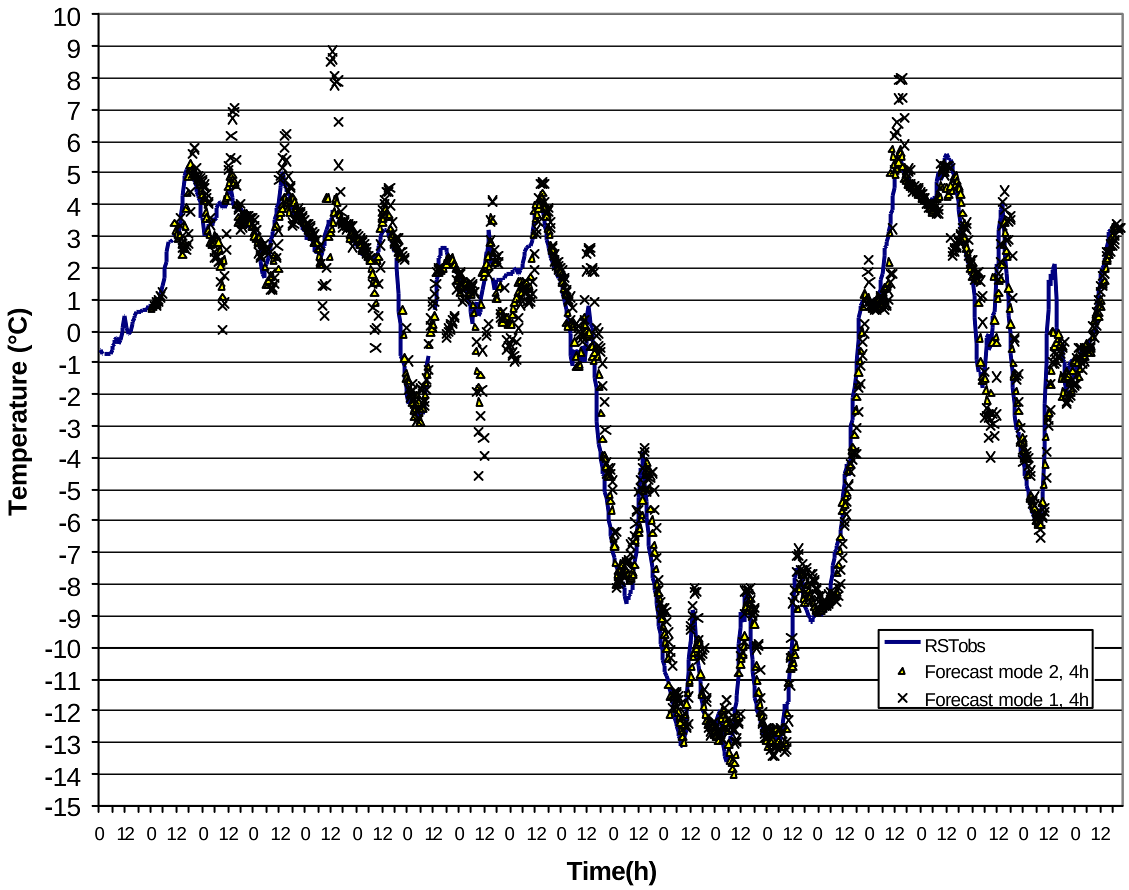


Figure 3. Result from mode - 1, forecasted cloudiness and calculated radiation and from mode – 2, RST forecast based on measured radiation.

An advantage that can be seen is that there are less errors with an absolute error larger than 0,5°C for the runs with mode - 2 than for mode - 1. Table 1 shows that for station 1417 there is an increase in hit rate from 57% to 65% in the error less than 1,0°C interval for the 4 hour forecast.

Table 1. Results showing the "hit rate" for different intervals for the 4 hour RST forecast.

Station Mode	**Frequency (%) in different 0,5°C intervals**				
	-0,5	**-1,0**	**-1,5**	**-2,0**	**-2,5**
1417:1	36	57	72	81	87
1520:1	44	66	78	87	91
1417:2	43	65	78	86	90
1520:2	45	67	80	89	92

The correlation between RST forecast and observed is quite high. The correlation is well above 0,95 for all runs and all forecast steps.

By use of the measured radiation the mean absolute error is improved. For the 2 hour forecast the mean absolute error improves from 0,74°C to 0,70°C for station 1417 and from 0,63°C to 0,60°C for station 1520. The 4 hour forecast increases from 1,16°C to 1,04°C for station1417 and from 1,06°C to 0,96°C for station 1520.

CONCLUSION

The results from this study shows that it is possible to improve the performance of the existing RST forecast model that is used today in the Swedish RWIS by use of radiation measurements. One possible way to do this practically is to use some sort of master station concept where a few well selected stations are equipped with radiation sensors. These master stations can be used as data providers for a set of stations. It is also important that

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