DANISH METEOROLOGICAL INSTITUTE

TECHNICAL REPORT

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Verification Report for the 1998-1999 Slippery Road Season

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DMI

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1. Introduction

The Road Conditions Model (RCM) is a vitally important operational product. It is therefore relevant to evaluate the performance of the RCM. In addition, users of the system have voiced interest in gaining access to a verification report after each slippery road season. For a verification report for the seasons 96-97 and 97-98, see [3]. For a detailed description of the RCM, see Bent Hansen Sass's article, ref [1], [2].

Briefly, the RCM system uses as input observations from weather stations and road stations along with results from the DMI weather prediction model HIRLAM, (HIgh Resolution Limited Area Model), to produce five hour forecasts every hour. The data assimilation produces a model state at the forecast initial time and atmospheric (HIRLAM) input data which are modified by observations. These data force the RCM during the forecast. For a description of the operational system see the manuals on DMI's intranet

`http://intranet.dmi.min.dk/~hirlam/road/roadmain.html`

2. 1998−1999 Season Verification

A season is considered to extend from October through April. The reason for the season's extent is that slippery road situations can occur both in October and well into April. Verification of the surface temperature and the dew point temperature for the entire season has been made. All analysis times are included, however only forecasts where both the observed and forecasted road surface temperatures lie between -3 and $+3^\circ$ C are included. All Danish road stations are included.

Verification results for the RCM and for linear trend forecasts are presented in Figure 1. In a linear trend forecast, one assumes that the temperature tendency that existed an hour ago also holds for the remainder of the forecast. The results demonstrate the superiority of the RCM over a simple linear trend forecast.

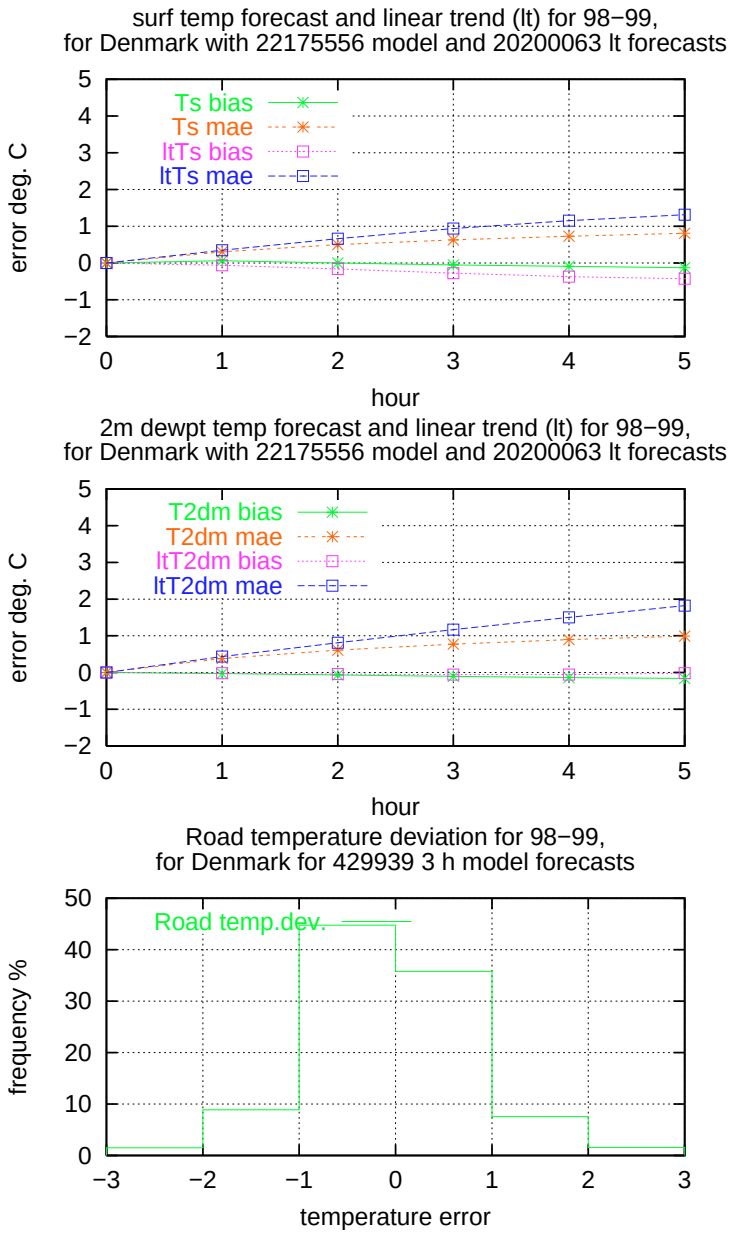

Figure 1: Verification of Ts and T2dm for the RCM and for linear trend for the 1998-1999 season for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

Figure 1a. shows for surface temperature (Ts) the average mean absolute error (mae) and mean error (bias) for the RCM and linear trend forecasts (indicated by 'ltTs bias' and 'ltTs mae' in the symbol legends). The bias for Ts for the RCM is -0.13 at 5 hours, while for the linear trend forecasts it is -0.43. The mae for Ts for the RCM is 0.81, for lt, 1.32.

Figure 1b. shows for the 2m dewpoint temperature (T2dm) the average mean absolute error (mae) and mean error (bias) for the RCM and linear trend forecasts (indicated by 'ltT2dm bias' and 'ltT2dm mae' in the symbol legends). Here the bias for T2dm for the RCM is -0.16 (for lt, -0.02) and for mae for T2dm: RCM, 0.90; lt, 1.82.

Figure 1c. shows the error frequencies (%) of Ts for 3 hour forecasted values for the entire $1998-1999$ season for all stations for the RCM. Again all analysis times are included, but only forecasts for which both the observed and forecasted temperatures lie between -3 and $+3$ ° C are included. The frequencies are divided into 1 ° C intervals, where the two extreme intervals represent errors with absolute values larger than 2 ° C. 80.52% of the forecasts are within 1 ° C of the observed values. This complies with the minimum value of 80% specified in the result contract for the RCM.

Figure 1c. indicates that the model tends to underestimate Ts. Absolute errors above 2 ° C occur in 3.1% of the forecasts. All the 3h forecasts are included in the Figure; in other words, there are no errors larger than $\pm 3°$ C.

The main change in the $1998-1999$ version of the RCM system relative to the $1997-1998$ season is in the HIRLAM input data.(see section 3 below) An additional difference between the two seasons is in the road station list. Throughout the season the station list was updated 8 times. The changes are included as soon as changes appear in the databasefile. All stations are included in the verification runs shown in Figure 1 as soon as they appear in the list. Operational irregularities for the $1998-1999$ season are listed in Appendix 2.

3. Comparison of the last 3 seasons

Table 1 shows the verification scores for the last three seasons, that is bias and mae for T_s, ltT_s, T_{2dm} and ltT_{2dm}. There has been no improvement.

For surface temperature the bias has changed from -0.06 to -0.13 and the mae is increased from 0.78 to 0.81. The trend in the dew point temperature prediction is somewhat different because the mae has decreased from 1.12 to 0.99 while a negative bias is more pronounced, becoming -0.16 compared to -0.10 degrees in the previous season.

There may be several factors influencing the marginally worse verification scores for the road surface temperature prediction in the 1998-99 season compared to the 1997-98 season.

First of all the natural variability of the weather conditions is considerable from year to year. The season 1998-99 is known to be a season with strongly varying weather conditions. This is reflected in objective verification scores for the HIRLAM model giving somewhat poorer verification scores in the 1998-99 season as compared to the previous season (demonstrated in DMI HIRLAM verification reports ref. [4]). It is further noted that the difference in behaviour between the two seasons is similar for 'linear trend' and the RCM prediction (the mae of road temperature is increased and the dew point temperature mae has decreased).

The HIRLAM forecast model was modified on 23 February 1999 with regard to the description of turbulence, cloud and precipitation processes. Although the new HIRLAM version is considered to be better than the old version in most respects there is not reason to believe that the corresponding influence on the road conditions model from this modification is very significant, because the cloud cover computation method inside the road model has not been changed.

An additional change in HIRLAM data, however, has occurred as a result of new 'climate' data at the surface. During the first period after the operational change (from 23

February to 15 March 1999) some surface data used in HIRLAM were inaccurate. As a result, too low temperatures at a height of 2 metres were produced by the HIRLAM system (input to the RCM).

Also it should be noted that the number of road stations has increased during the last three years. This also may influence somewhat the verification scores. In addition some new road sensors have been installed. However, an investigation of the impact of the new sensor indicates that the scores are not affected by the new equipment.

4. Monthly Verification Averaged for All Counties

Results of monthly verification runs averaged over all counties are shown in Figures 2−8, corresponding to October 1998-April 1999. The Figures show that the RCM forecasts road conditions better than linear trend. In addition, the Figures demonstrate that the tendency towards underestimating Ts seen for the seasonal average is not seen in all

	96/97	97/98	98/99
$T_s \pm 1$	81.8	80.8	80.5
T_s bias	-0.06	-0.10	-0.13
ltT_s bias	-0.73	-0.45	-0.43
T_s mae	0.78	0.81	0.81
ltT_s mae	1.44	1.30	1.32
T_{2dm} bias	-0.27	-0.10	-0.16
ltT_{2dm} bias	-0.05	-0.04	-0.02
T_{2dm} mae	1.12	1.11	0.99
ltT_{2dm} mae	2.21	2.16	1.82

Table 1: shows the trend for the last three seasons. $T_s \pm 1$ is the percentage of forecast with an error lower than ± 1 ° C. Forecast and observations are only included if they lie between -3 and +3 ° C

of the monthly runs. In October (Figure 2) the RCM tends to overestimate Ts. This tendency was also present in the seasons 96-97 and 97-98. However, the RCM predicts both Ts and T2dm better than linear trend. The reason to overestimation in October can be due to fewer observations in the start and the end of the season so the data material is usually much smaller in these months. It appears that in months with a large data material the bias is negativ.

In November (Figure 3), January (Figure 5), March (Figure 7) and April (Figure 8), the RCM has a marked tendency towards underestimating T_s, as seen by Figures 3c, 5c, 7c and 8c, in than it has a significantly higher error frequency between -1 and 0 ° C than between 0 and 1 ° C. This underestimation of T_s is also reflected in the negative bias in Figures 3a, 5a, 7a and 8a.

In December (Figure 4c) and February (Figure 6c) the error frequencies are distributed quite symmetrically around a temperature of 0. Figures 5a, 5b, 8a and 8b, also demonstrate the superiority of the RCM over linear trend for both T_s and T_{2dm}.

5. Verification for Bornholm and Northern Jutland for January, February, March, April

Results of verification runs for January, February, March and April for Bornholm and Northern Jutland are shown in Figures 9−12 and 13−16, respectively. In Figures 9-16 the superiority of the RCM is again demonstrated for every month and for both groups of stations.

As also noted in the verification report for the season 97/98 ref. [3], the overall impression is that the model is better able to make predictions of Ts and Td2m for Northern Jutland than for Bornholm, given that the positive Ts bias is more pronounced for Bornholm.

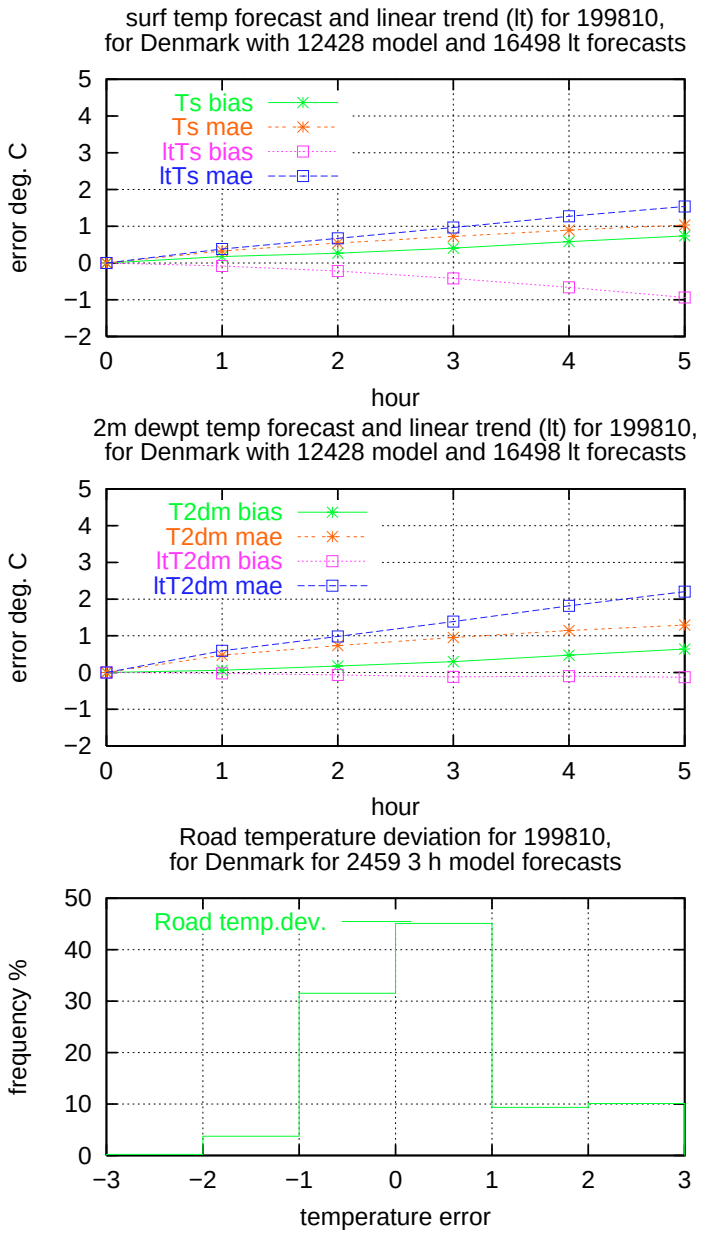

Figure 2: Verification of Ts and T2dm for the RCM and for linear trend for October 1998 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

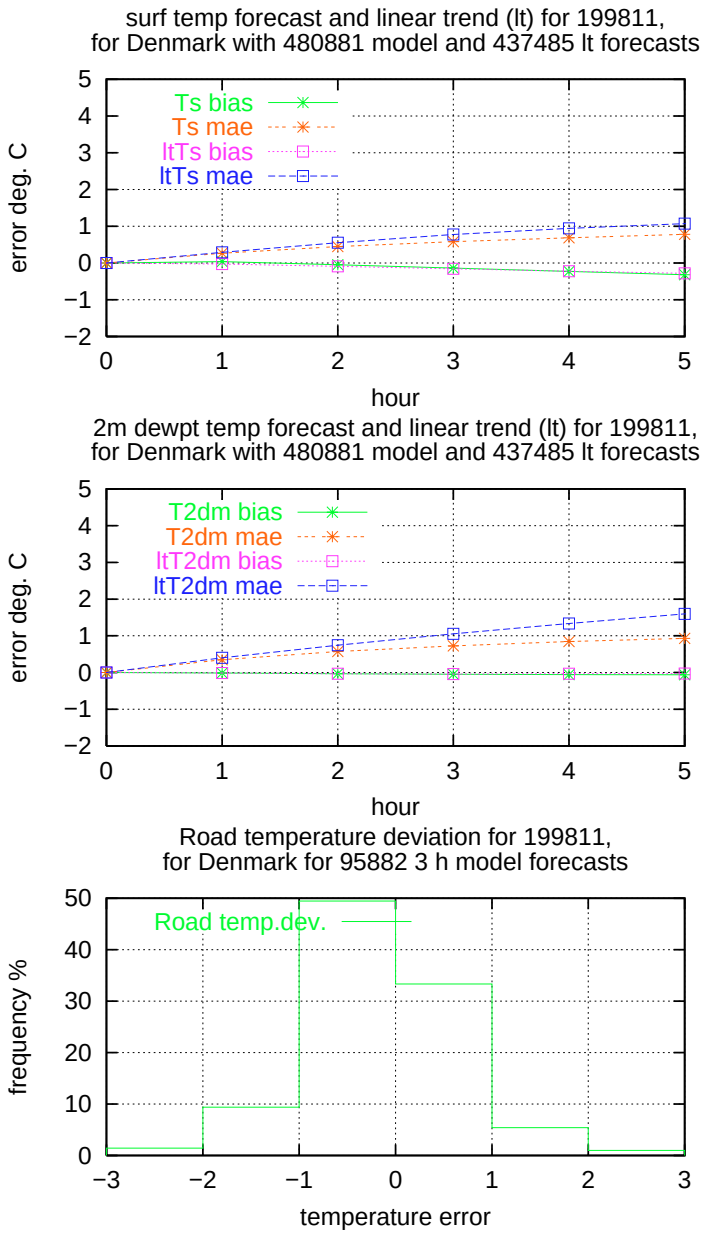

Figure 3: Verification of Ts and T2dm for the RCM and for linear trend for November 1998 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

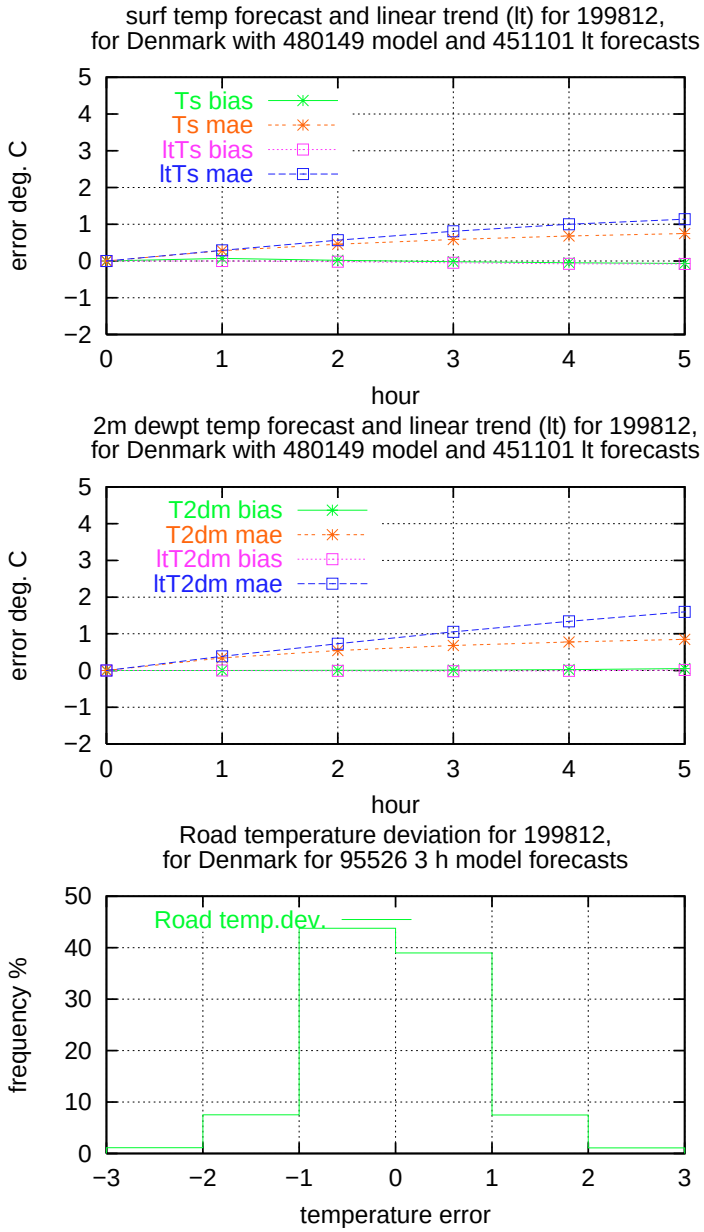

Figure 4: Verification of Ts and T2dm for the RCM and for linear trend for December 1998 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

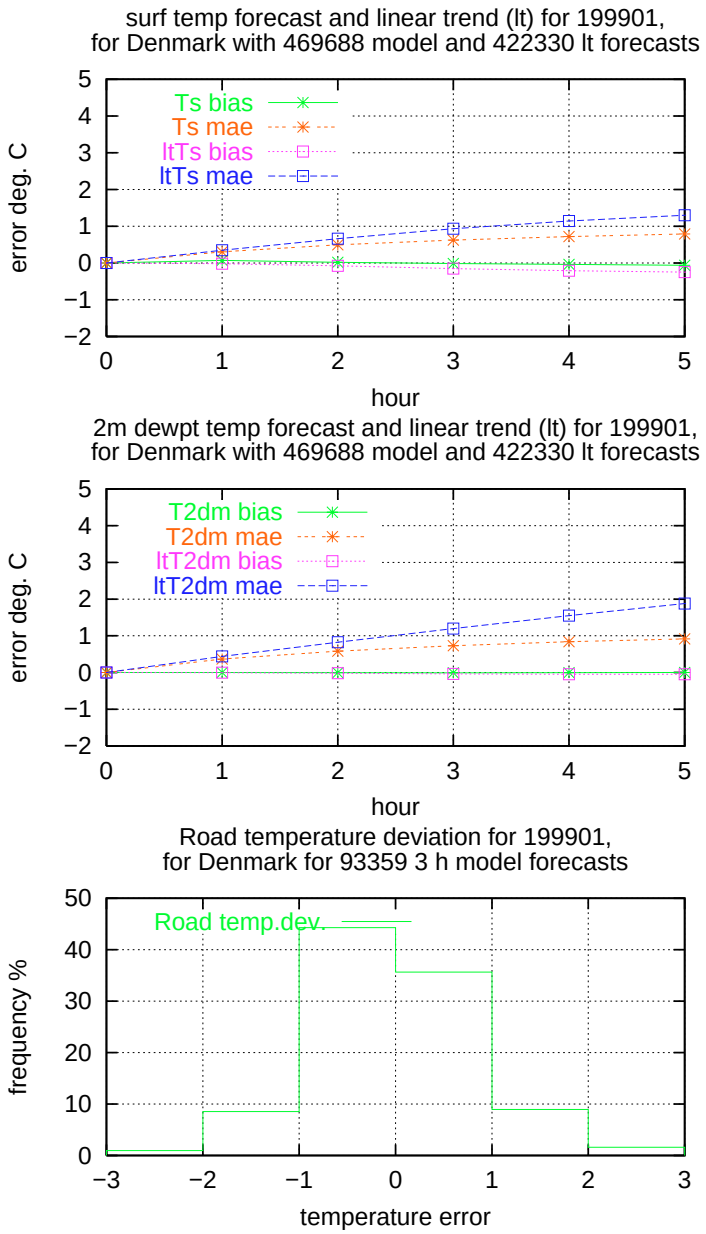

Figure 5: Verification of Ts and T2dm for the RCM and for linear trend for January 1999 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

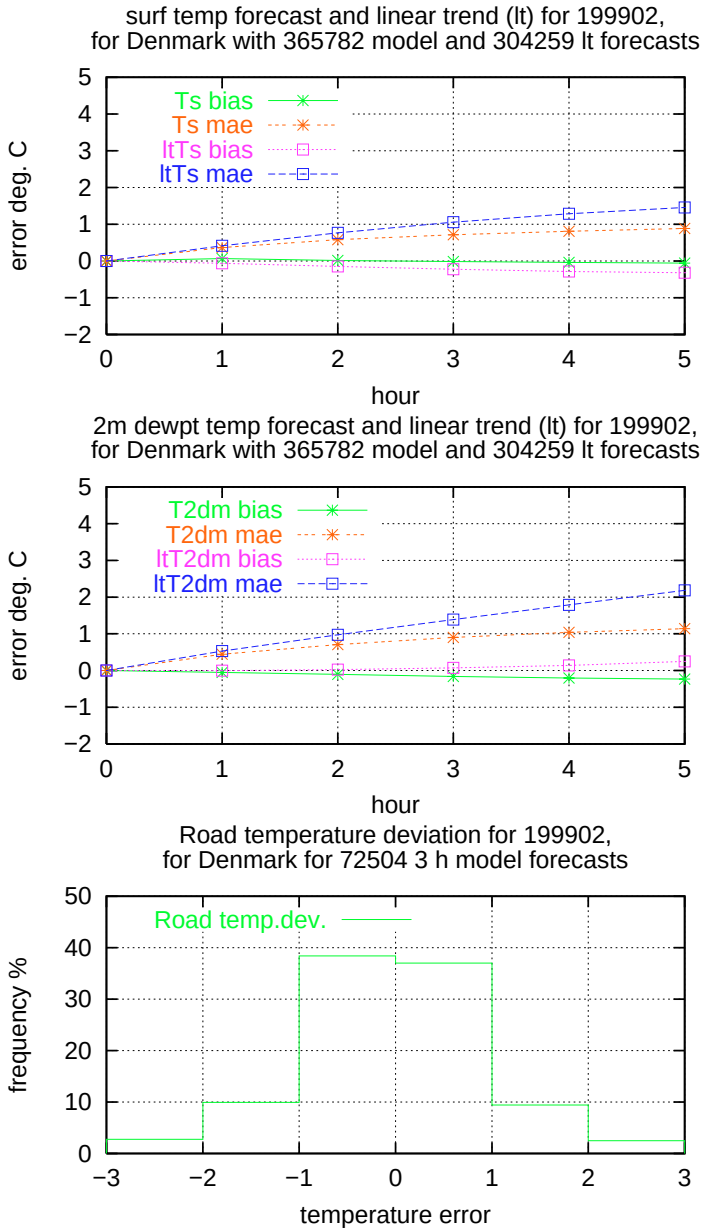

Figure 6: Verification of Ts and T2dm for the RCM and for linear trend for February 1999 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

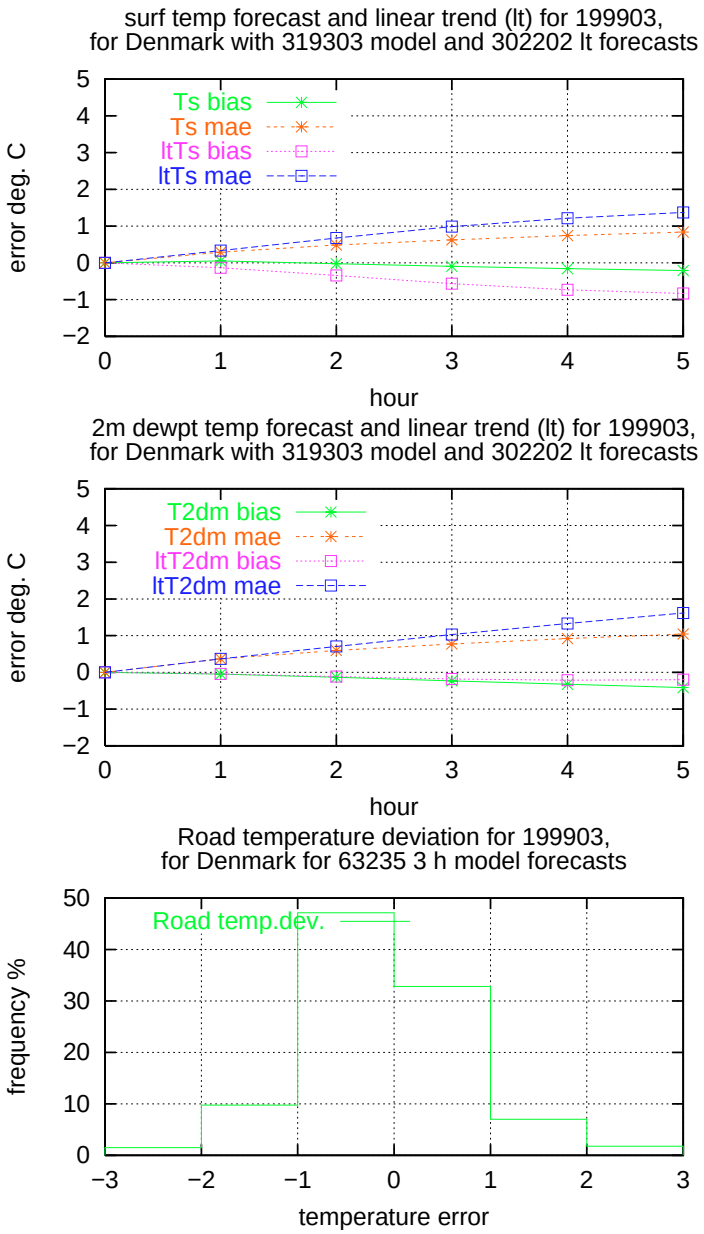

Figure 7: Verification of Ts and T2dm for the RCM and for linear trend for March 1999 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

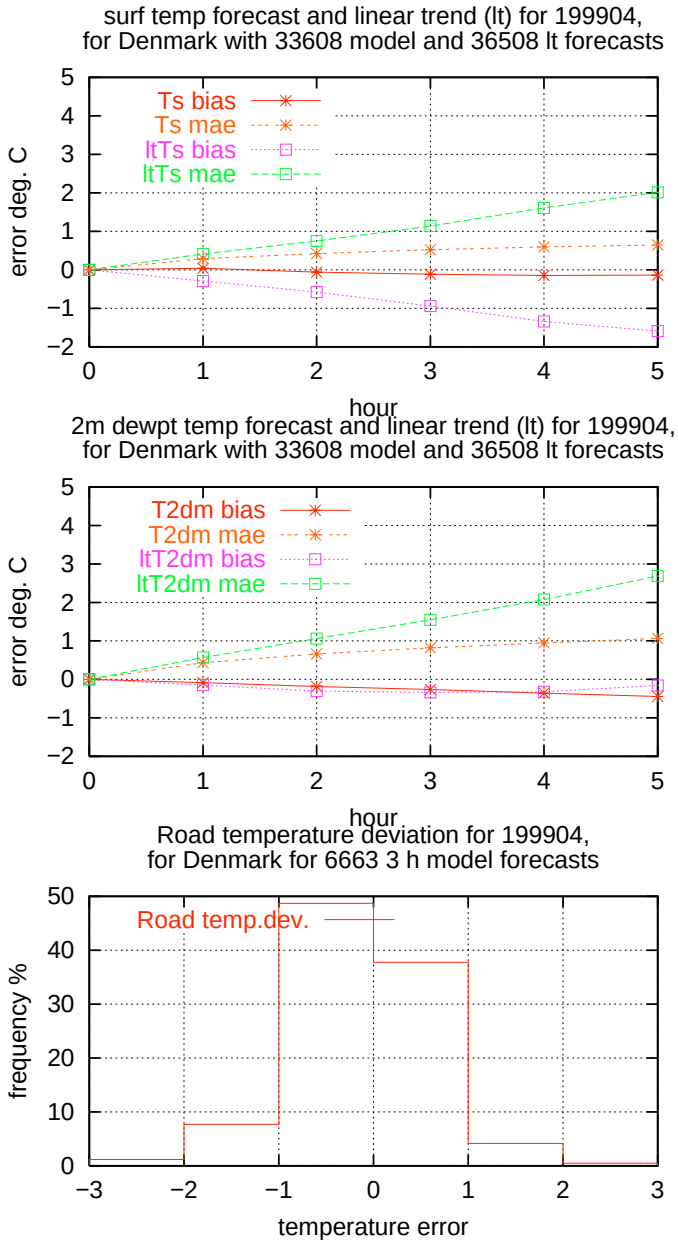

Figure 8: Verification of Ts and T2dm for the RCM and for linear trend for April 1999 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

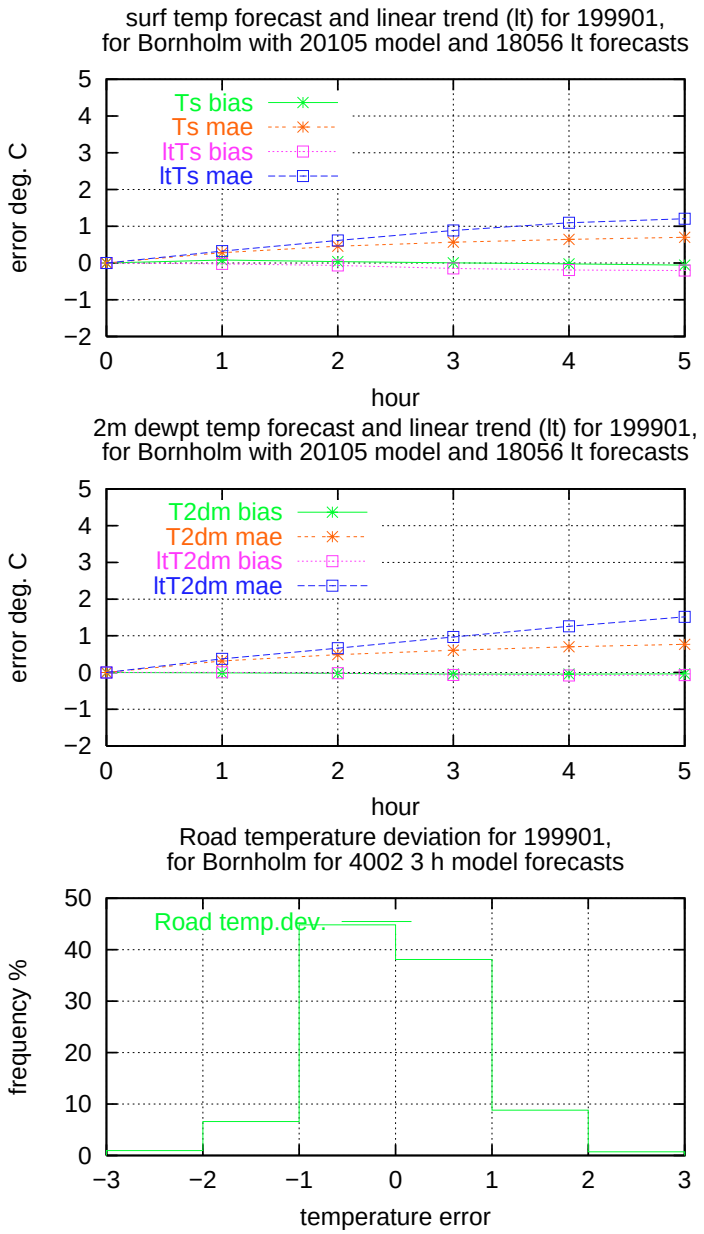

Figure 9: Verification of Ts and T2dm for the RCM and for linear trend for January 1999 for stations in Bornholm. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

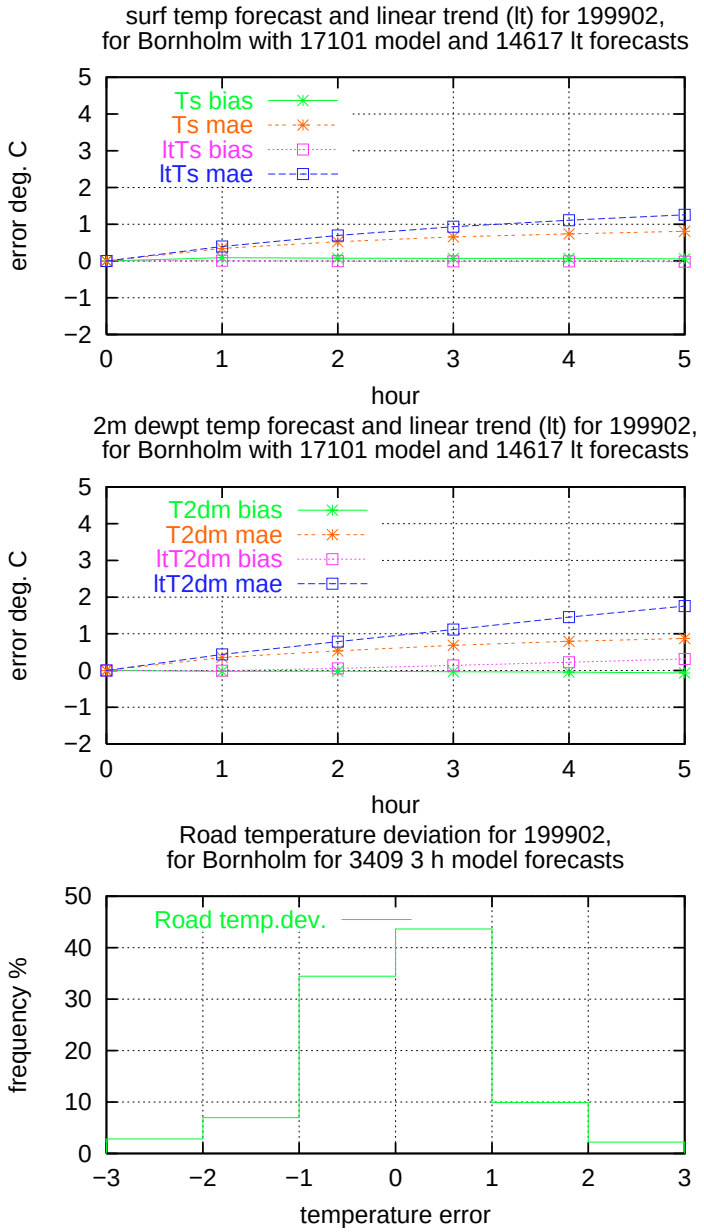

Figure 10: Verification of Ts and T2dm for the RCM and for linear trend for February 1999 for stations in Bornholm. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

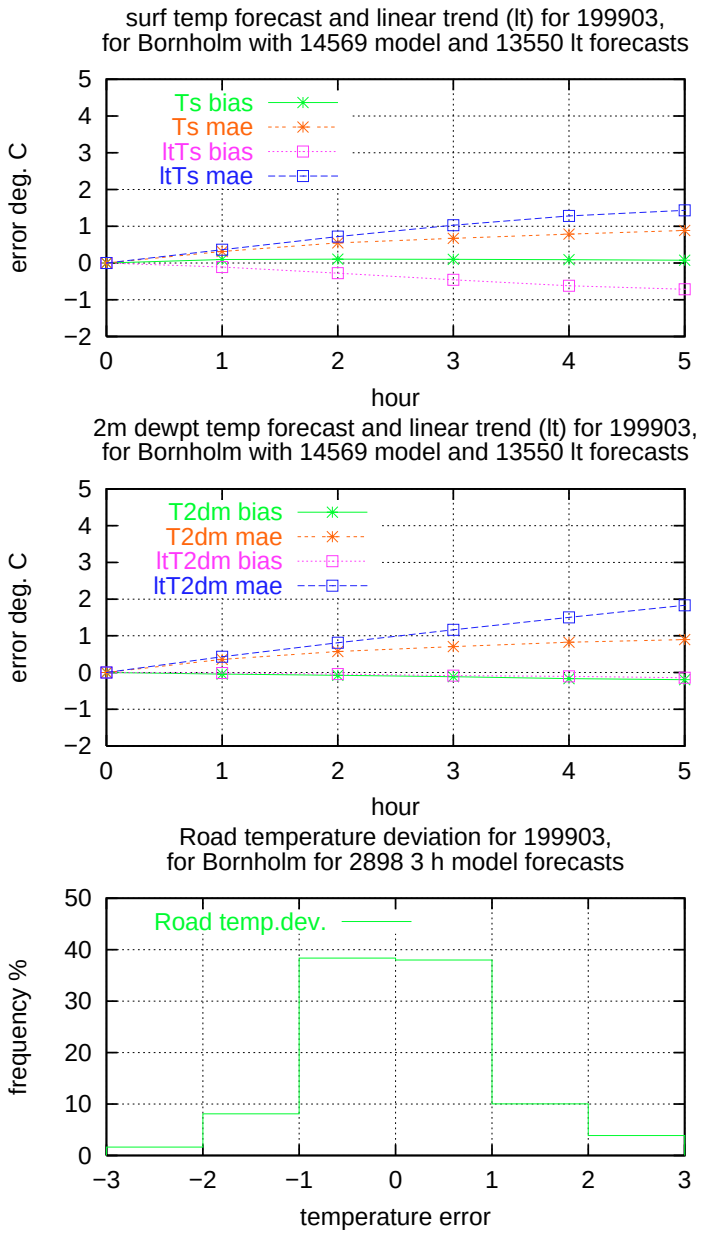

Figure 11: Verification of Ts and T2dm for the RCM and for linear trend for March 1999 for stations in Bornholm. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

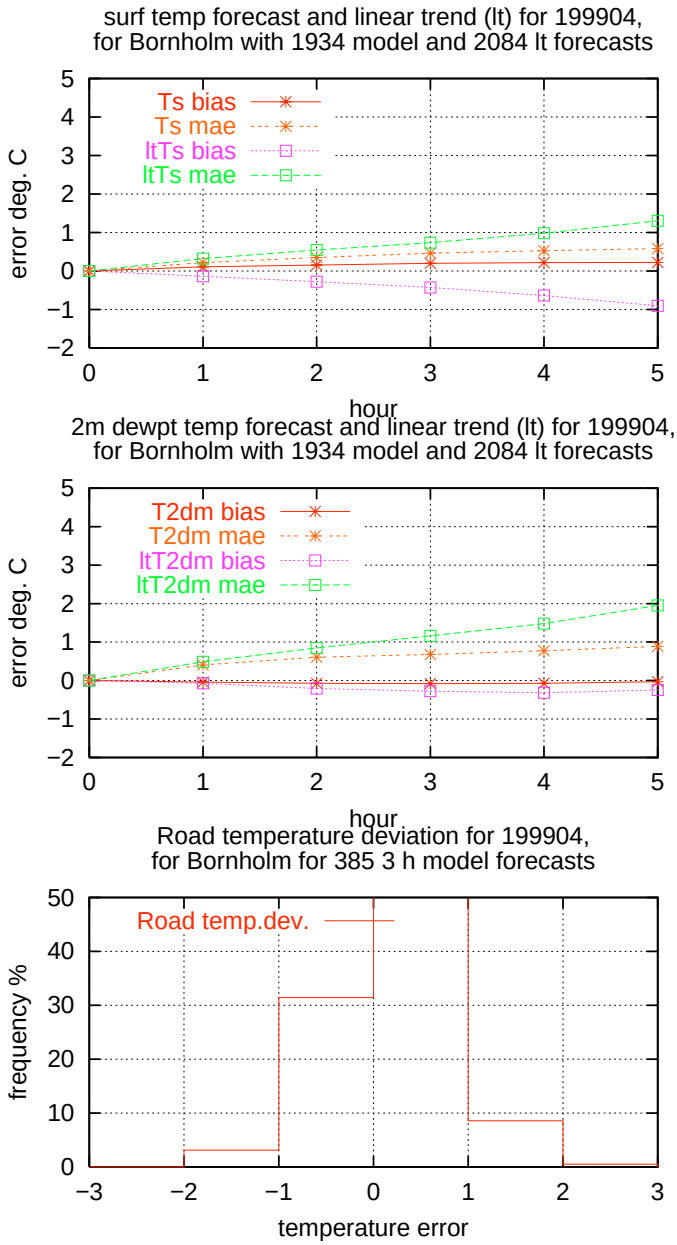

Figure 12: Verification of Ts and T2dm for the RCM and for linear trend for April 1999 for stations in Bornholm. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

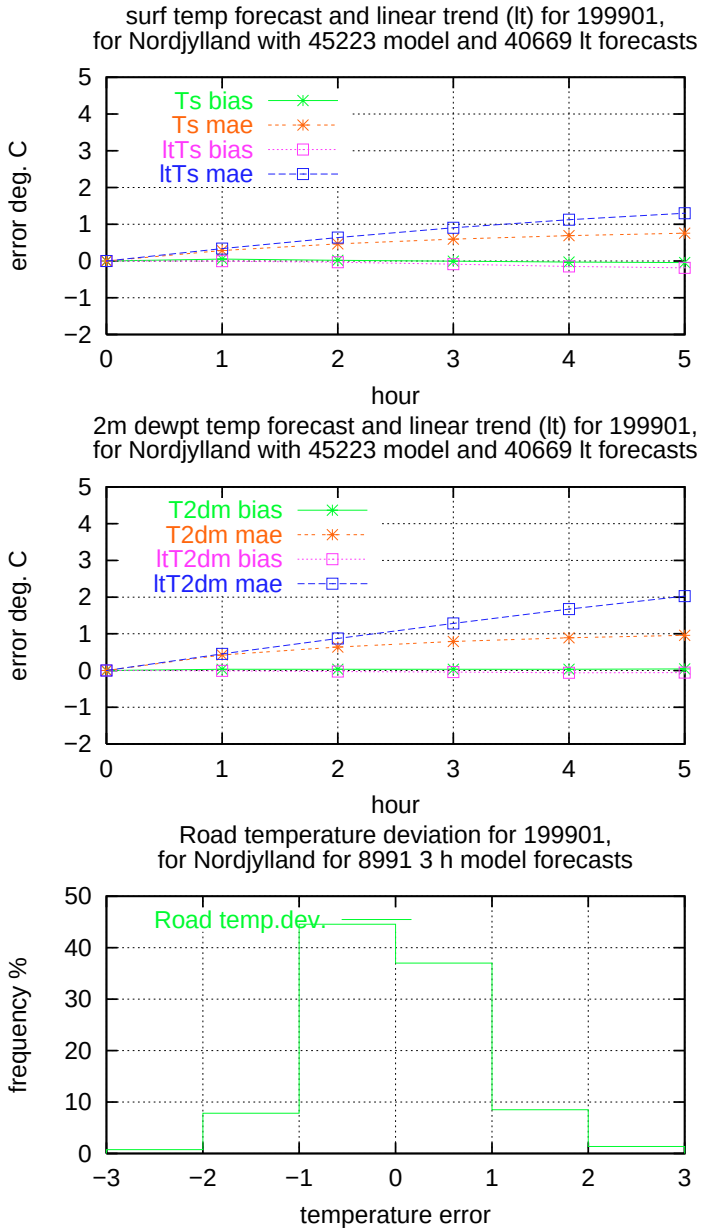

Figure 13: Verification of Ts and T2dm for the RCM and for linear trend for January 1999 for stations in Northern Jutland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

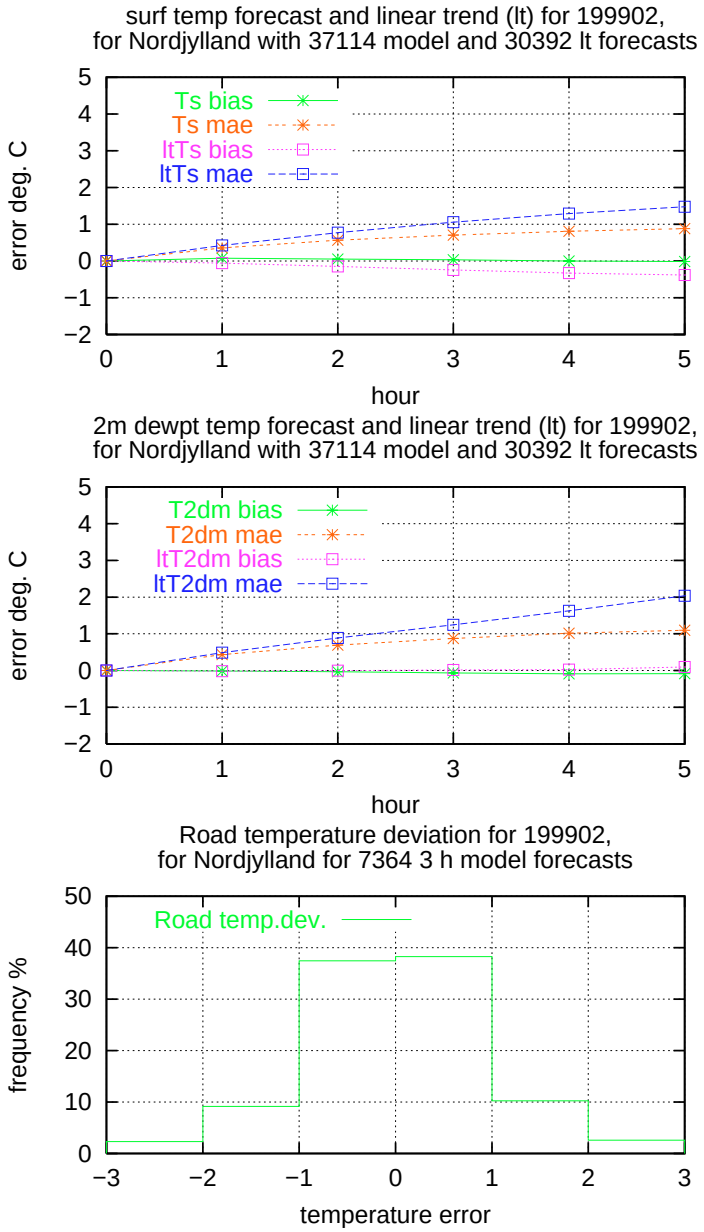

Figure 14: Verification of Ts and T2dm for the RCM and for linear trend for February 1999 for stations in Northern Jutland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

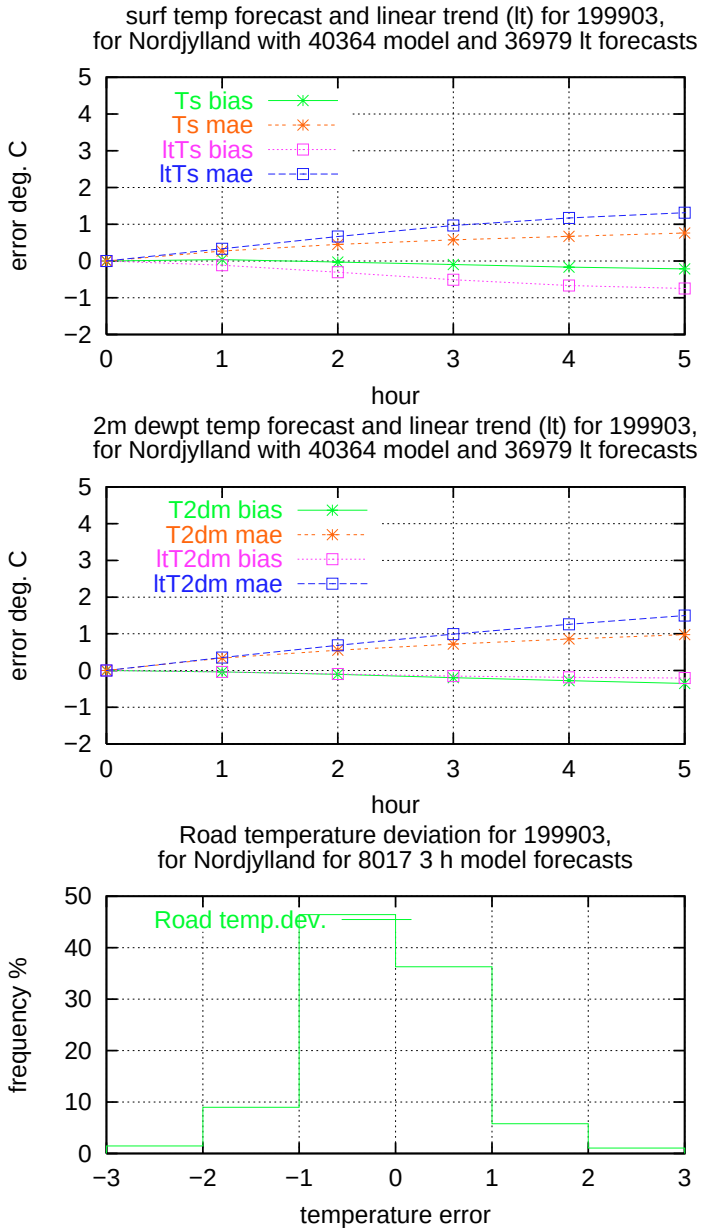

Figure 15: Verification of Ts and T2dm for the RCM and for linear trend for March 1999 for stations in Northern Jutland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

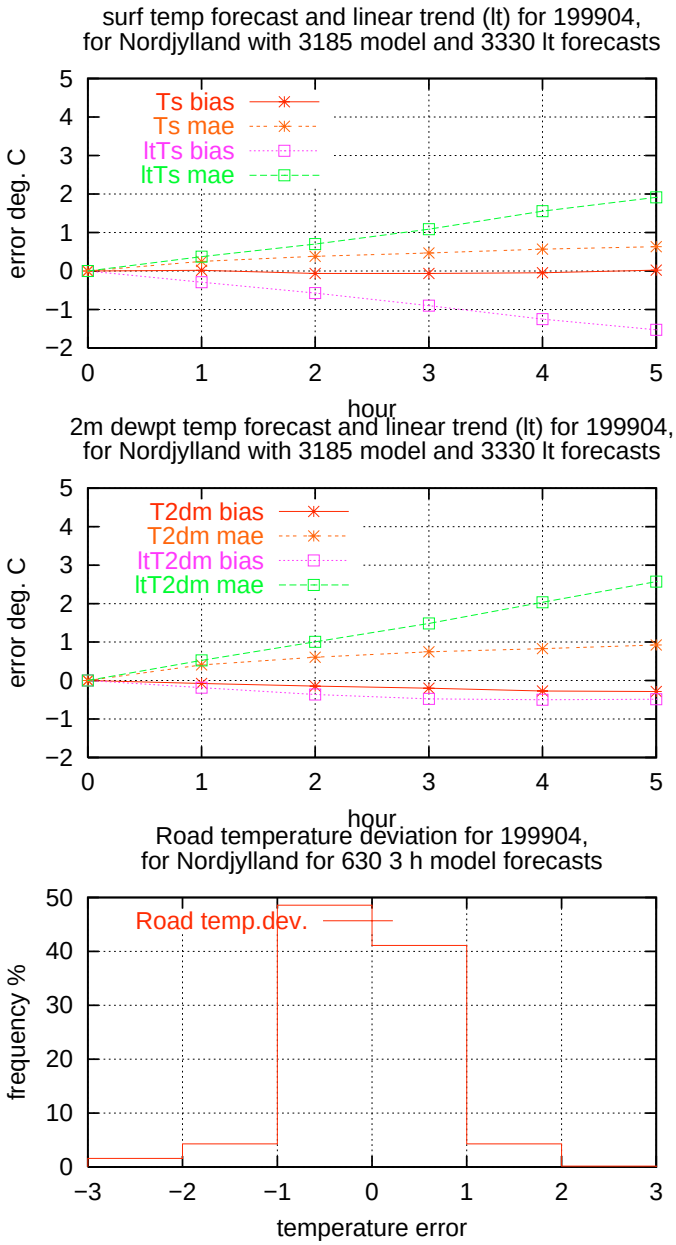

Figure 16: Verification of Ts and T2dm for the RCM and for linear trend for April 1999 for stations in Northern Jutland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

6. Concluding Remarks

There has only been a few changes in the RCM in the last three seasons. This is also indicated in the verification which is almost constant for the last three seasons. There is however a weak tendency to a lower verification score of the surface temperature.

For the season 98/99 the score for three hours surface temperature forcasts in the interval $\pm$ 3 $^\circ$ C with an error lesser than $\pm$ 1 $^\circ$ C is **80.52 %** which complies with the value of 80 % specified in the result contract for RCM. For each month in the season the score in percent is as listed below.

Month	Score
October 98	76.6
November 98	82.8
December 98	82.74
January 99	79.93
February 99	75.4
March 99	79.98
April 99	86.50

There are a number of factors which may have influenced the performance of the RCM during the present season. This has been described in section 3.

It's interesting to note that for individual road stations there can be a large difference in verification score even though they are situated close to each other. As it was seen from North Jutland and Bornholm the difference can also be large from county to county. Also the climatology in HIRLAM data especially from road stations close to the coast can affect the result which is probably the case for Bornholm relative to North Jutland. However the most needed improvement is a better representation of cloud cover as also mentioned in the verification report from 97/98 ref [3].

In the future it seems worthwhile to consider problematic cases, e.g., with difficult atmospheric conditions, in order to get more clear impact of modifications to the RCM system. Several such cases should be considered when testing new methods for predicting the critical weather parameters such as cloud cover and precipitation.

7. References

[1] Sass, B.H., 1997: "A Numerical Forecasting System for the Prediction of Slippery Roads", J.Appl.Meteor., 36, no 6, 801−817.

[2] Sass, B.H., 1992: "A Numerical Model for Prediction of Road Temperature and Ice", J.Appl.Meteor., 31, no 12, 1499−1406.

[3] Kmit, M., 1999: "Verification Report for the 1997-1998 Slippery Road Season", DMI Technical Report 99-1.

[4],Nielsen,W.N and Amstrup B., 1999: "DMI-HIRLAM Verification Report For the first quarter of 1999", Internal Report 99-4.

Appendix 1: Monthly verification now possible on the internet

It is now possible run the verification system on the internet, if you have the proper username and password. The URL is: **http://www.dmi.dk/pub/glatver/** or on DMI's intranet: **http://intranet.dmi.min.dk/cgi-bin/user/kmit/verify.cgi**

Appendix 2: RCM Forecasts can now be viewed from DMI's intranet

It's now possible to view RCM forecasts for each individual road stations. The latest and forecast for the last 24 hours can be viewed. The path on DMI's intranet is:

http://intranet.dmi.min.dk/cgi-bin/cgiwrap/kmit/showroad.pl

Appendix 3: Irregularities in the operation of the system during the season

To make the verification two conditions are required. Observations and model data have to be available. Table 2 shows the percentage of archived forecasts for each month. The table also shows the pertentage of archived forecasts where road data hasn't been available. These forecasts are not used in the verification. For December 98 18 days are missing probably due to data loss. For January 99 and December 98 additional from another source has been used. However, These data have not been possible to retrieve again. Usually the percentage for missing forecast is 1-2In almost all cases the missing forecast is related to computer problems or missing input data from HIRLAM.

Month	Forcast	No forecast	No data
October	98.5	1.5	17.7
November	99.0	1.0	6.6
December	40.1	59.9	16.3
January	83.7	16.3	9.6
February	85.3	14.7	4.0
March	98.3	1.7	2.1
April	98.8	1.2	3.3

Table 2: shows the percentage of archived forecasts, no forecasts and the percentage of archived forecasts where road data has't been available