DANISH METEOROLOGICAL INSTITUTE

——— TECHNICAL REPORT ———

99-1

Verification Report for the 1997-1998 Slippery Road Season

Maryanne Kmit
Bent Hansen Sass

DMI

COPENHAGEN 1999

ISSN-Nr. 0906-897X

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 detailed description of the RCM, see Bent Hansen Sass's article, ref [1].

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. 1997–1998 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. There was one such situation in the morning hours 15 April 1998: In the late evening on 14 April 1998 in eastern Jutland, 2m temperatures were between $3 - 4^\circ$ C, there were rain showers and gentle to fresh southerlies to southeasterlies. In the early morning 15 April 1998, the skies cleared, the 2m temperature fell to below zero, and the winds died down and were from south-southwest. At 03 UTC the wet roads began to freeze, making for dangerous traffic conditions. Slippery roads in Jutland, which weren't forecasted the previous evening, (the RCM makes 5 hour forecasts), resulted in several car accidents. The RCM forecasts made that morning predicted the slippery road conditions.

As an experiment we tried running a 9 hour forecast and found that the RCM depends so much on atmospheric cloud cover data when it calculates its road surface temperature, that increasing the RCM forecast length cannot be considered until HIRLAM's small scale cloud cover is improved. Work will be done to improve HIRLAM's small scale cloud cover during 1999.

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 $+3°$ C are included. All Danish road stations are included, except for stations 1508 (Øresunds-broen) and 4007 (Zarthmannsvej) because they reported erroneous road observations throughout the season. Icelandic stations are evaluated separately, in Section 6.

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.a. 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 -0.10 at 5 hours, while for the linear trend forecasts it is -0.45. The mae for Ts for the RCM is 0.81, for lt, 1.3.

Figure 1.b. 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).

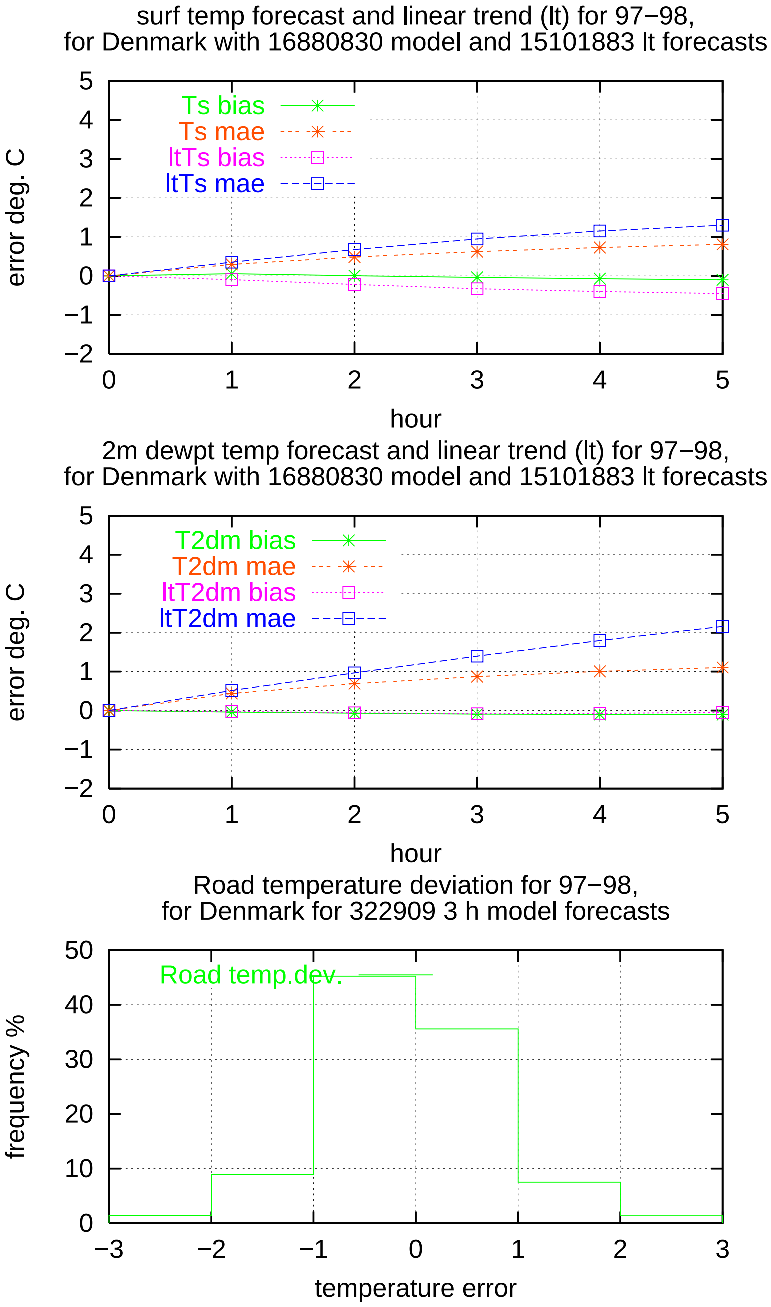

Figure 1: Verification of Ts and T2dm for the RCM and for linear trend for the 1997-1998 season for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

Again the RCM outperforms the linear trend forecast. Here the bias for T2dm for the RCM is -0.10 (for lt, -0.04) and for mae for T2dm: RCM, 1.1; lt, 2.2.

Figure 1.c. shows the error frequencies (%) of Ts for 3 hour forecasted values for the entire 1997−1998 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. 81% of the forecasts are within 1° C of the observed values. This is a satisfactory result in that it complies with the minimum value of 80% specified in the result contract for the RCM. Figure 1.c. indicates that the model tends to underestimate Ts. Absolute errors above 2° C occur in 2.8% 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 1997−1998 version of the RCM system relative to the 1996−1997 season is in the HIRLAM input data. RCM specific input files are no longer used; ordinary model level files are instead used as input and the model level data is interpolated to station positions.

An additional difference between the two seasons is in the road station list. It has in general been adjusted at the beginning of the season and remained unchanged for the remainder of the season. However throughout this season the station list was updated (roughly 9 times). These station list updates included the addition of Bornholm (17 December 1997) and Iceland (9 January 1998). All stations are included in the verification runs shown in Figure 1 as soon as they appear in the list (aside from the two error-prone stations, 1508 and 4007, mentioned above).

Operational irregularities for the 1997−1998 season are listed in Appendix 2.

3. 1996–1997 Season Verification

For the sake of comparison, results of a seasonal verification run for 1996–1997 are shown in Figure 2. The results are very similar to those from the 1997–1998 season.

Figure 2.a. shows for Ts the average mae and bias for the RCM and linear trend forecasts (lt). The bias for Ts for the RCM is −0.06 at 5 hours, while for the linear trend forecasts it is −0.73. The mae for Ts for the RCM is 0.78, for lt, 1.1.

Figure 2.b. shows for T2dm the average mae and bias for the RCM and linear trend forecasts. Here the bias for T2dm for the RCM is −0.27 (for lt, −0.05) and for mae for T2dm: RCM, 1.1; lt, 2.2.

Figure 2.c. shows the error frequencies (%) of Ts for 3 hour forecasted values for the entire 1996–1997 season for all stations. 82% of the forecasts are within 1° C of the observed values. This Figure also indicates that the model tends to underestimate Ts. Absolute errors above 2° C occur in 2.8% of the forecasts. There are no absolute prediction errors larger than 3° C.

The overall impression is that the model predicts satisfactorily both Ts and T2dm, making better predictions than the linear trend forecasts. The verification results for the 1996–1997 are very similar to those from 1997–1998 in spite of differing weather situations in the two seasons, [2–6].

4. Monthly Verification Averaged for All Counties

Results of monthly verification runs averaged over all counties are shown in Figures 3–9, corresponding to October 1997-April 1998. 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

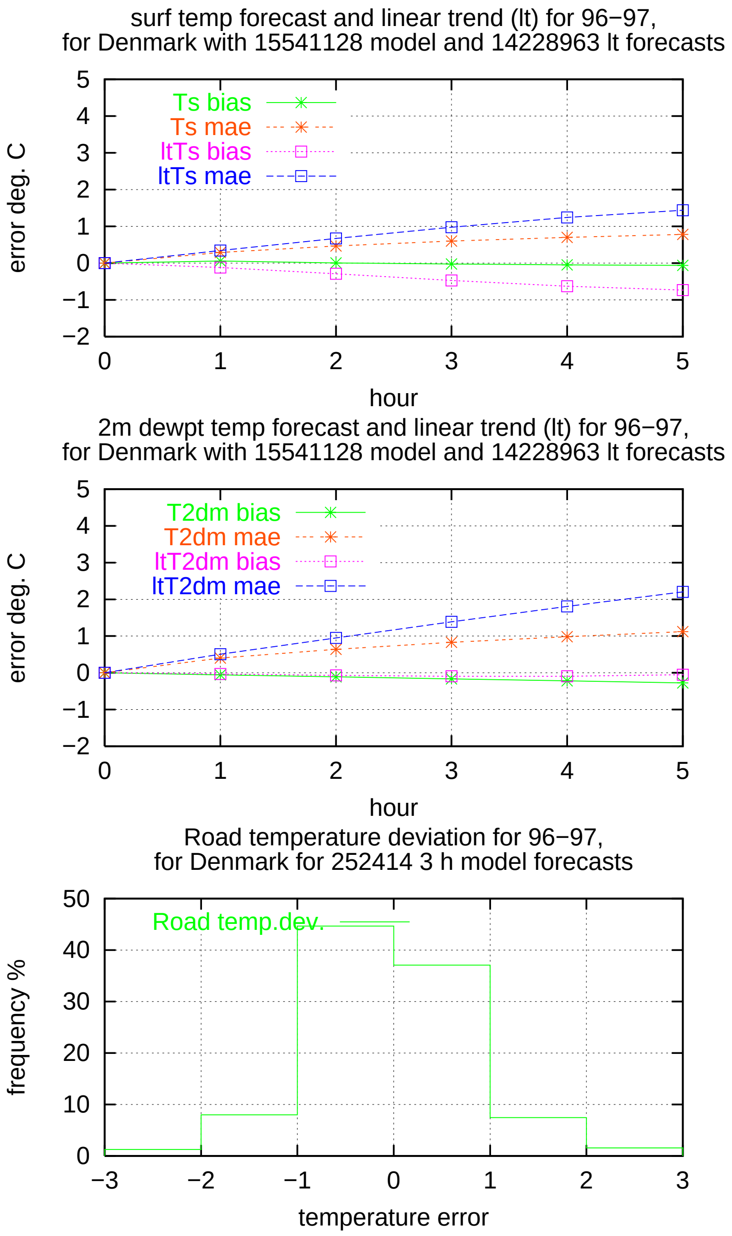

Figure 2: Verification of Ts and T2dm for the RCM and for linear trend for the 1996-1997 season for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

of the monthly runs. In February (Figure 7) and April (Figure 9) the RCM tends to overestimate Ts. However, the RCM predicts both Ts and T2dm much better than linear trend.

In November (Figure 4), December (Figure 5) and January (Figure 6) the RCM has a marked tendency towards underestimating Ts, as seen from Figures 5.c., 6.c. and 7.c., in than it has a significantly higher error frequency between -1 and $0°$ C that between 0 and $1°$ C. For December it is especially pronounced that the RCM tends to underestimate Ts. In Figure 5.c 54% of the forecasted temperatures lie between -1.0 and 0.0 degrees from the observed values and 30% between 0.0 and -1.0 degrees from the observed values. This underestimation of Ts for November, December and January is also reflected in the negative bias in Figures 5.a., 6.a. and 7.a.

In October (Figure 3.c.) and March (Figure 8.c.) the error frequencies are distributed quite symmetrically around a temperature error of 0. Figures 3.a., 3.b., 8.a., and 8.b., also demonstrate the superiority of the RCM over linear trend for both Ts and T2dm.

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

Results of verification runs January, February, March and April for Bornholm and Jutland are shown in Figures 10–17, respectively. In the case of both counties, the Ts bias for the RCM is positive, see Figures 10.a.-17.a. In particular for Bornholm, in February (Figure 11.c.), where the Ts error frequency between 0 and 1 degrees is 60.8%, and for April (Figure 13.c.), where the error frequency between 0 and 1 degrees is 66.5%. In Figures 10.b.-17.b. the superiority of the RCM is again demonstrated for every month and for both groups of stations.

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

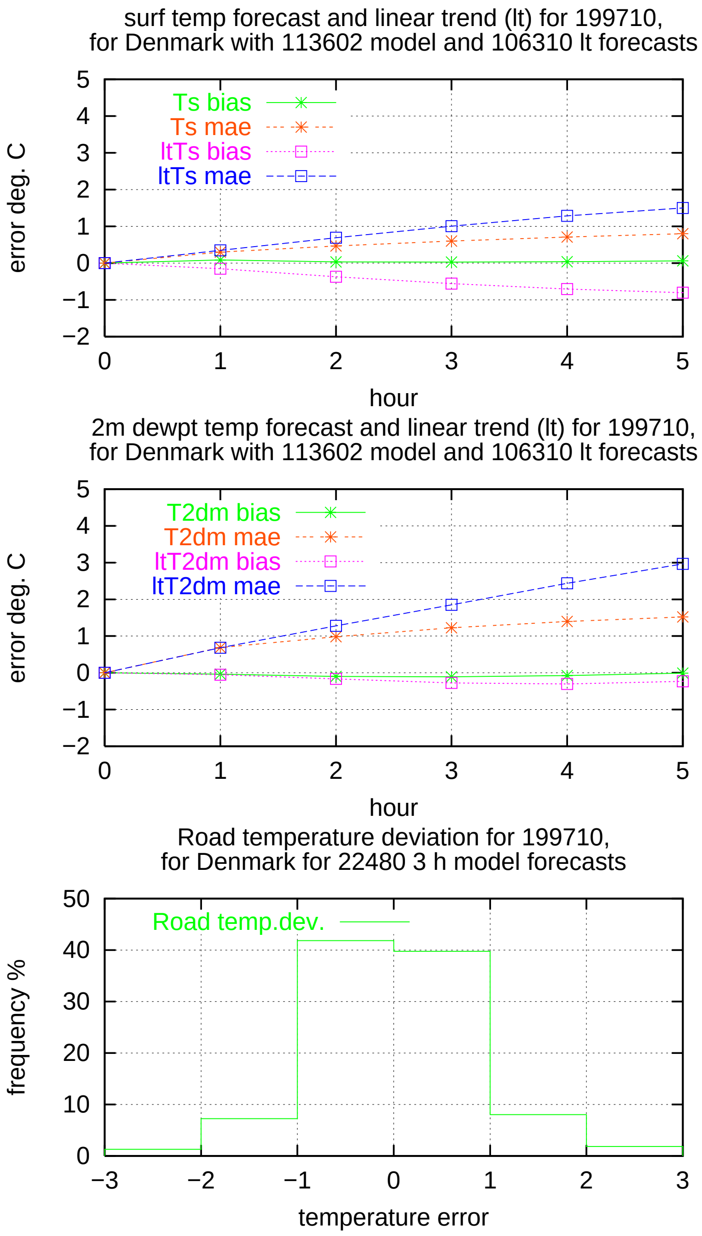

Figure 3: Verification of Ts and T2dm for the RCM and for linear trend for October 1997 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

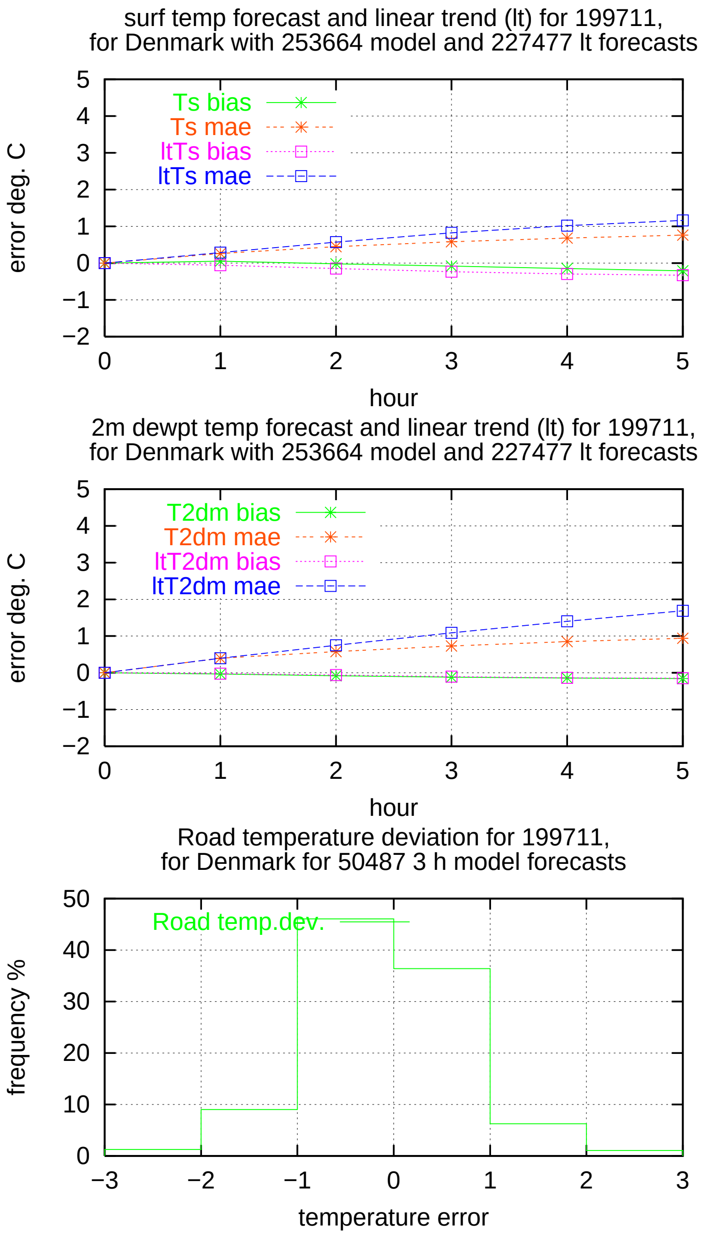

Figure 4: Verification of Ts and T2dm for the RCM and for linear trend for November 1997 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

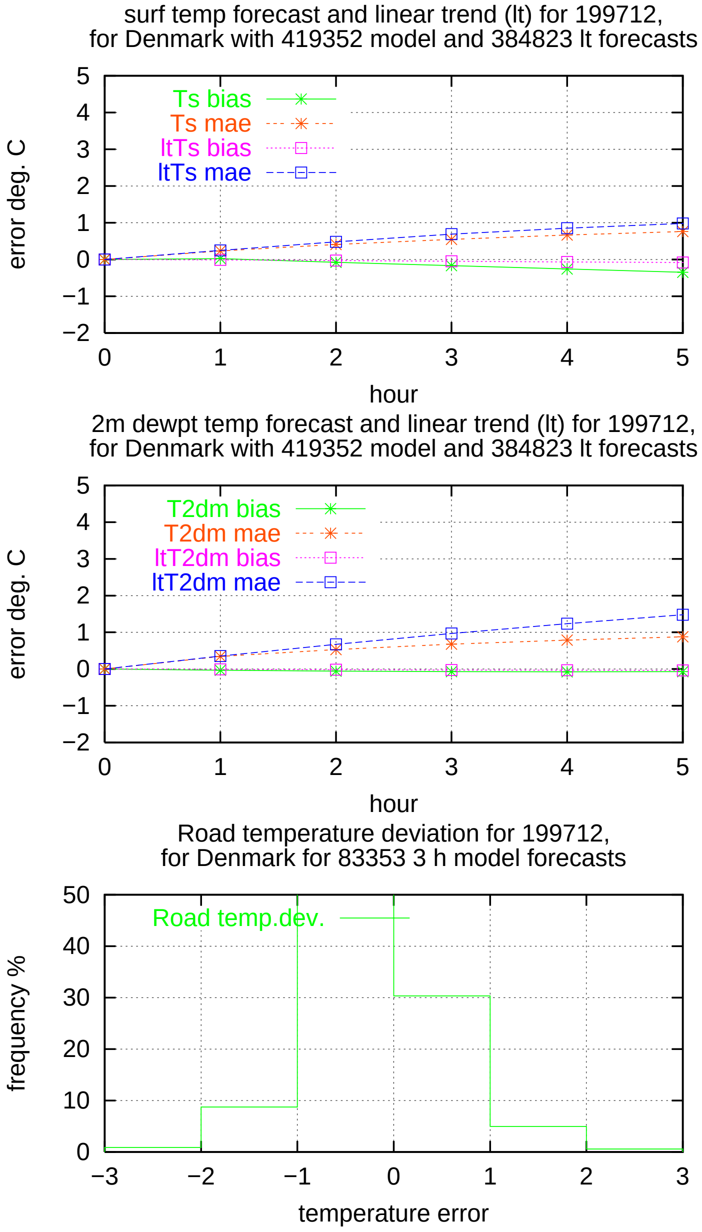

Figure 5: Verification of Ts and T2dm for the RCM and for linear trend for December 1997 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

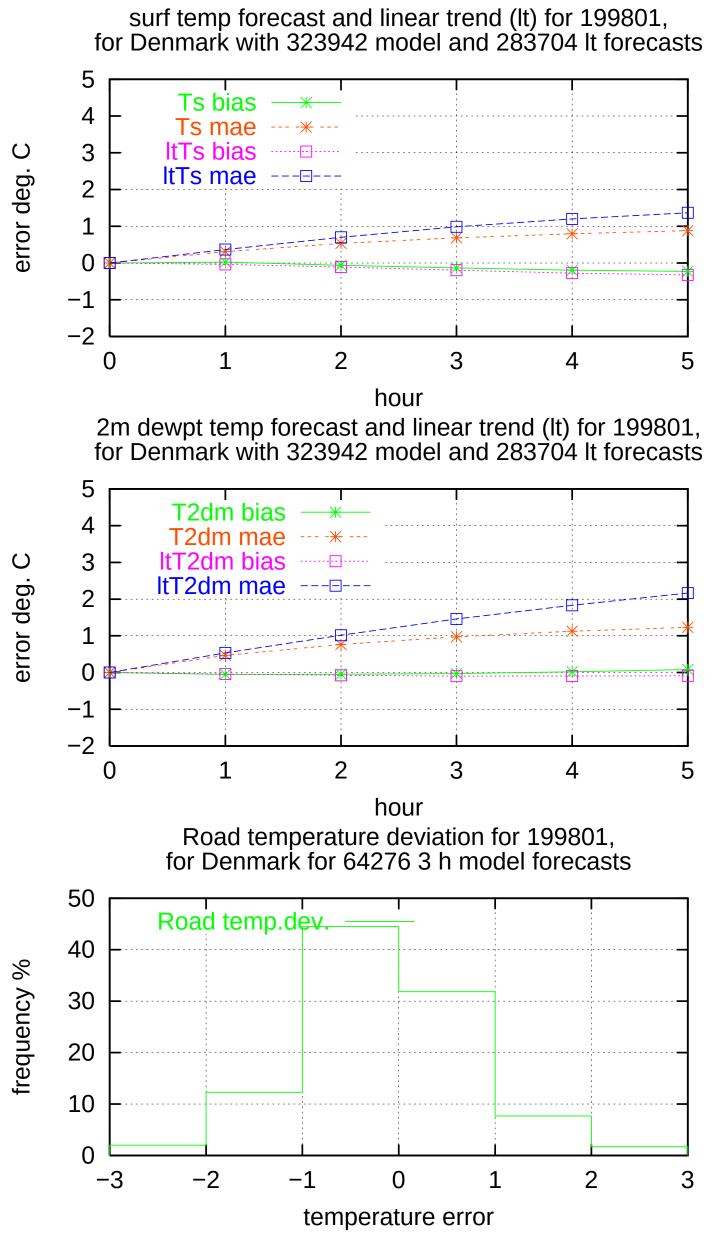

Figure 6: Verification of Ts and T2dm for the RCM and for linear trend for January 1998 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

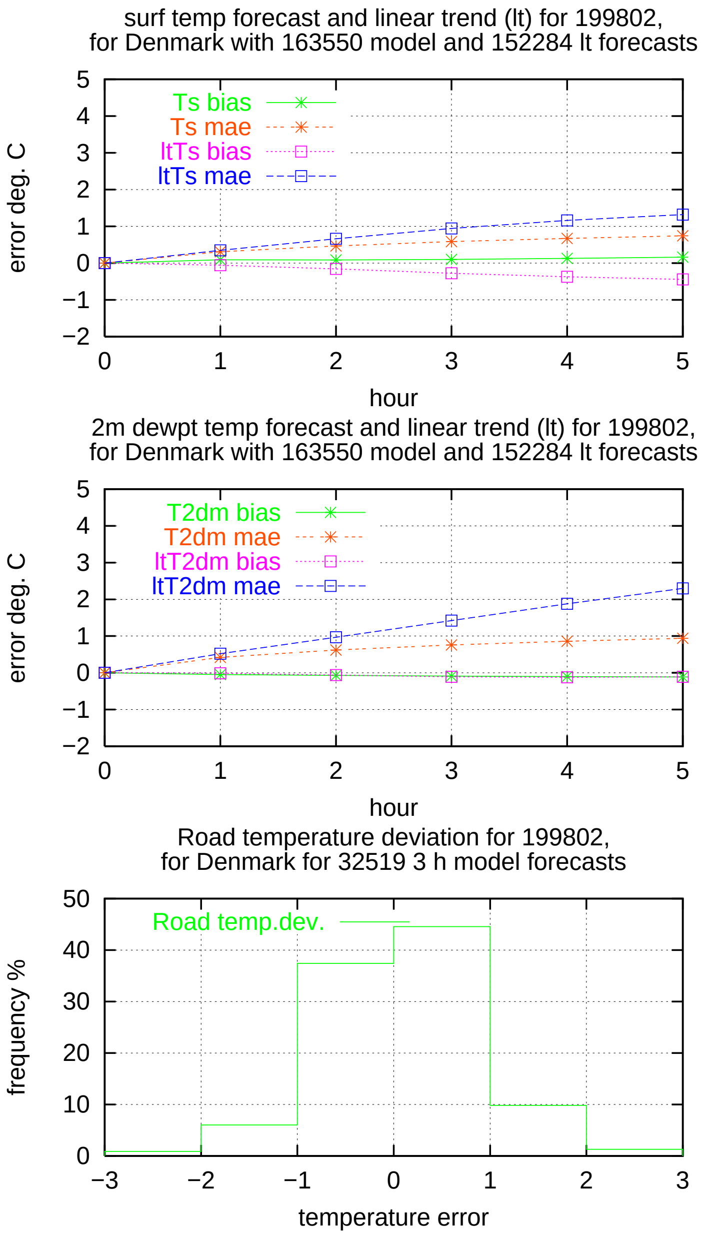

Figure 7: Verification of Ts and T2dm for the RCM and for linear trend for February 1998 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

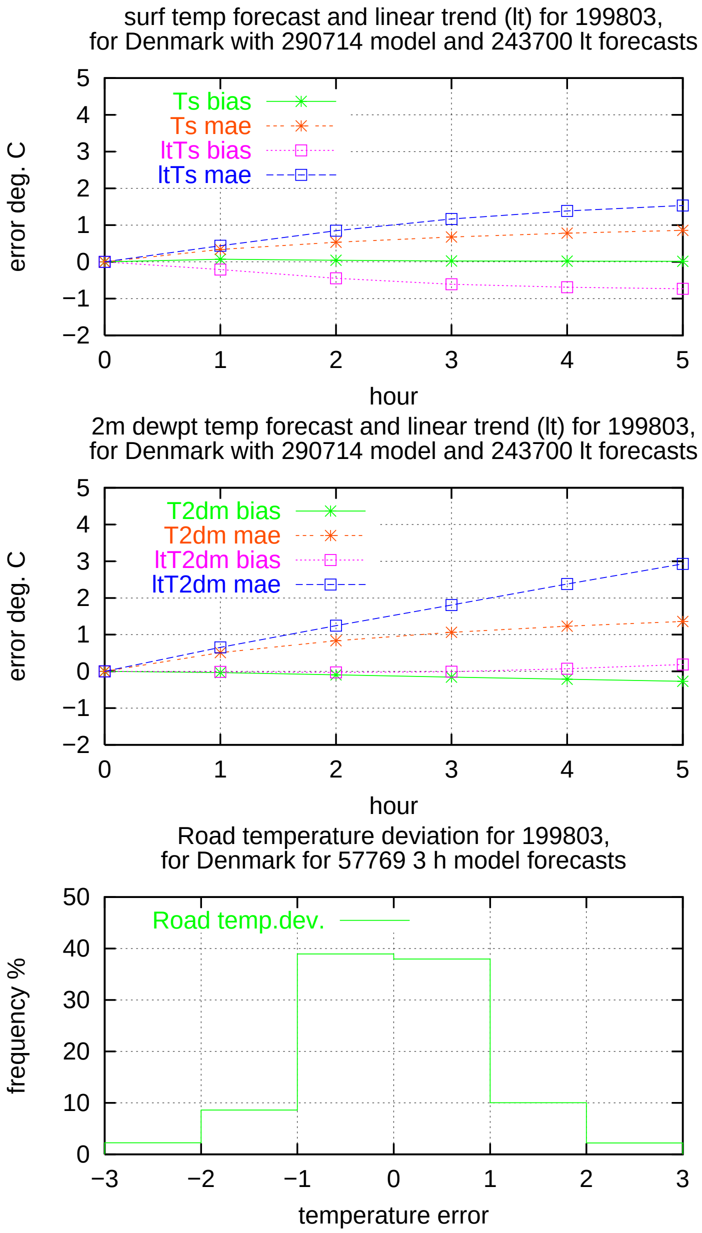

Figure 8: Verification of Ts and T2dm for the RCM and for linear trend for March 1998 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

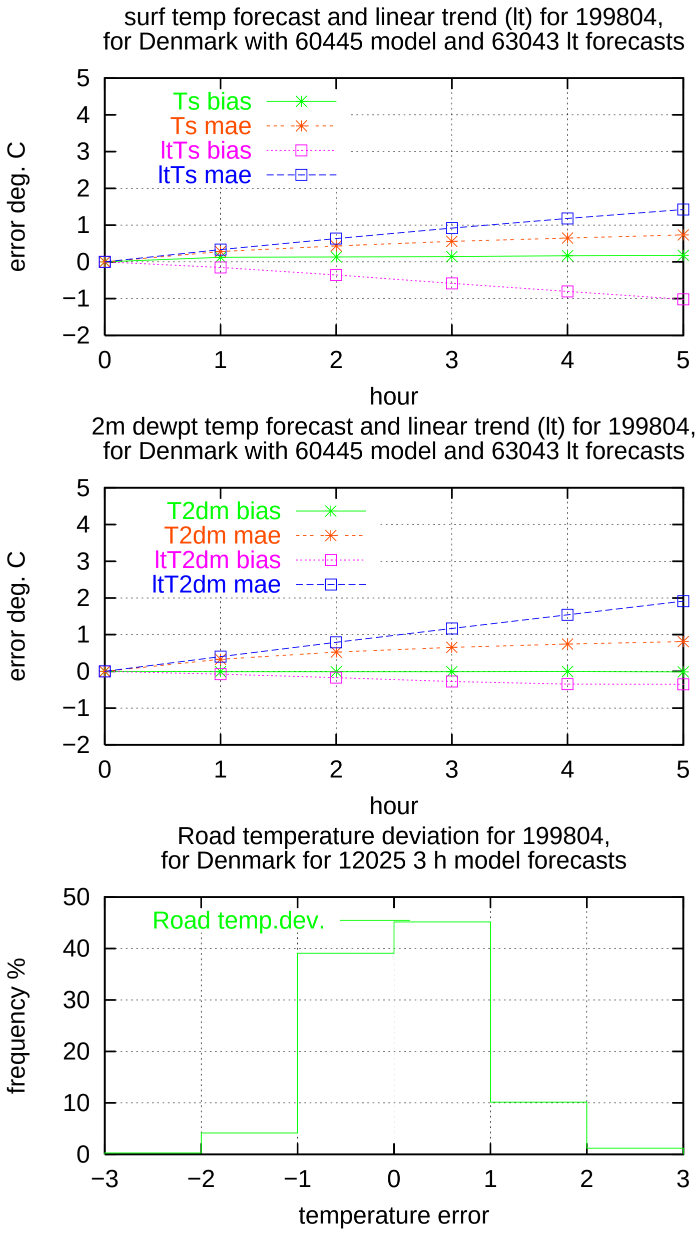

Figure 9: Verification of Ts and T2dm for the RCM and for linear trend for April 1998 for all Danish stations. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

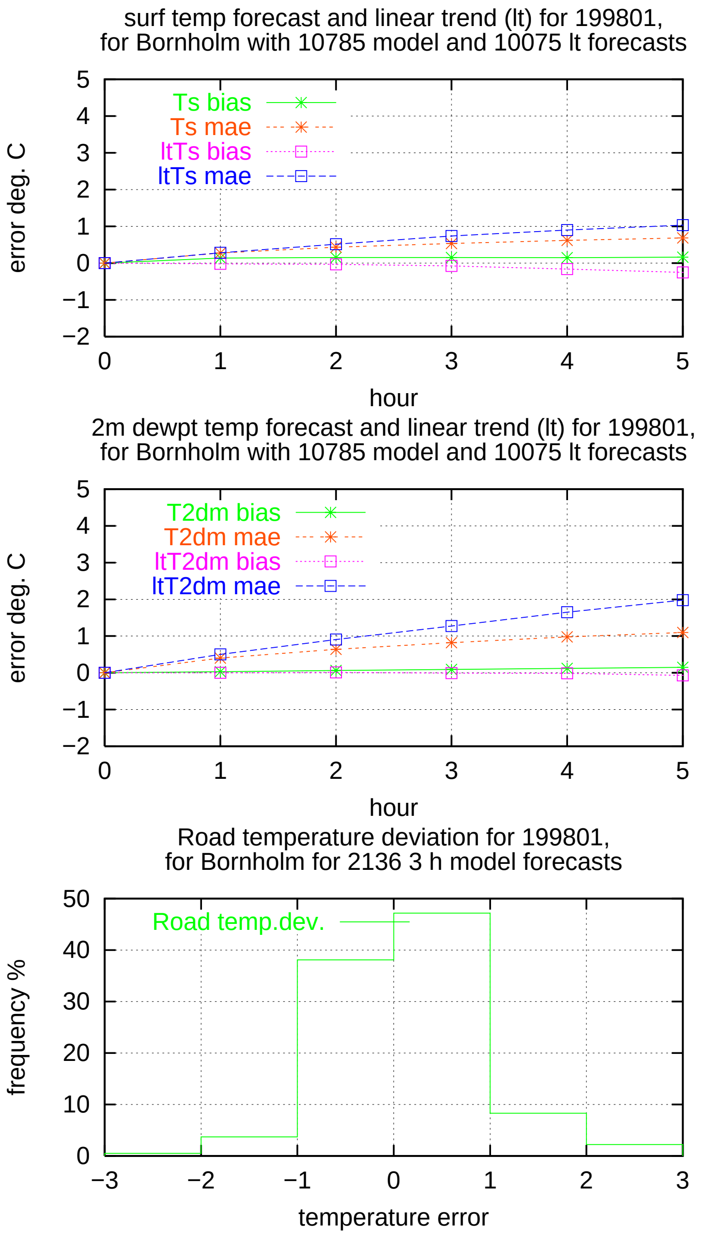

Figure 10: Verification of Ts and T2dm for the RCM and for linear trend for January 1998 for stations in Bornholm. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

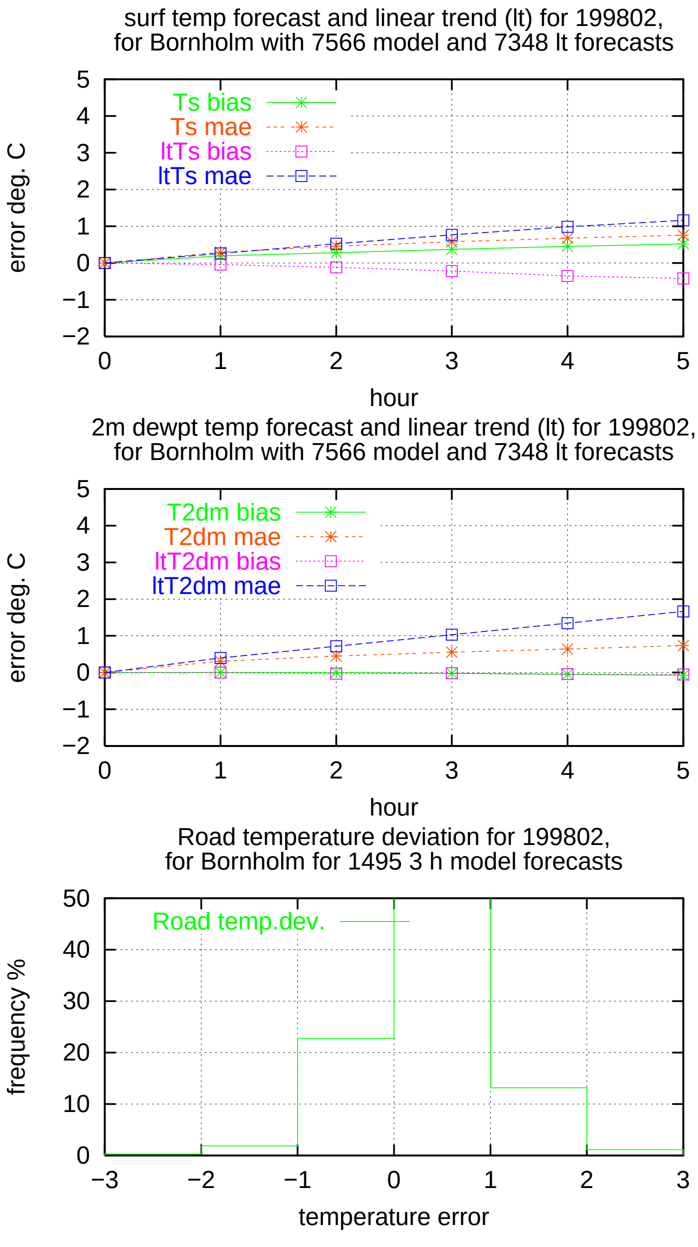

Figure 11: Verification of Ts and T2dm for the RCM and for linear trend for February 1998 for stations in Bornholm. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

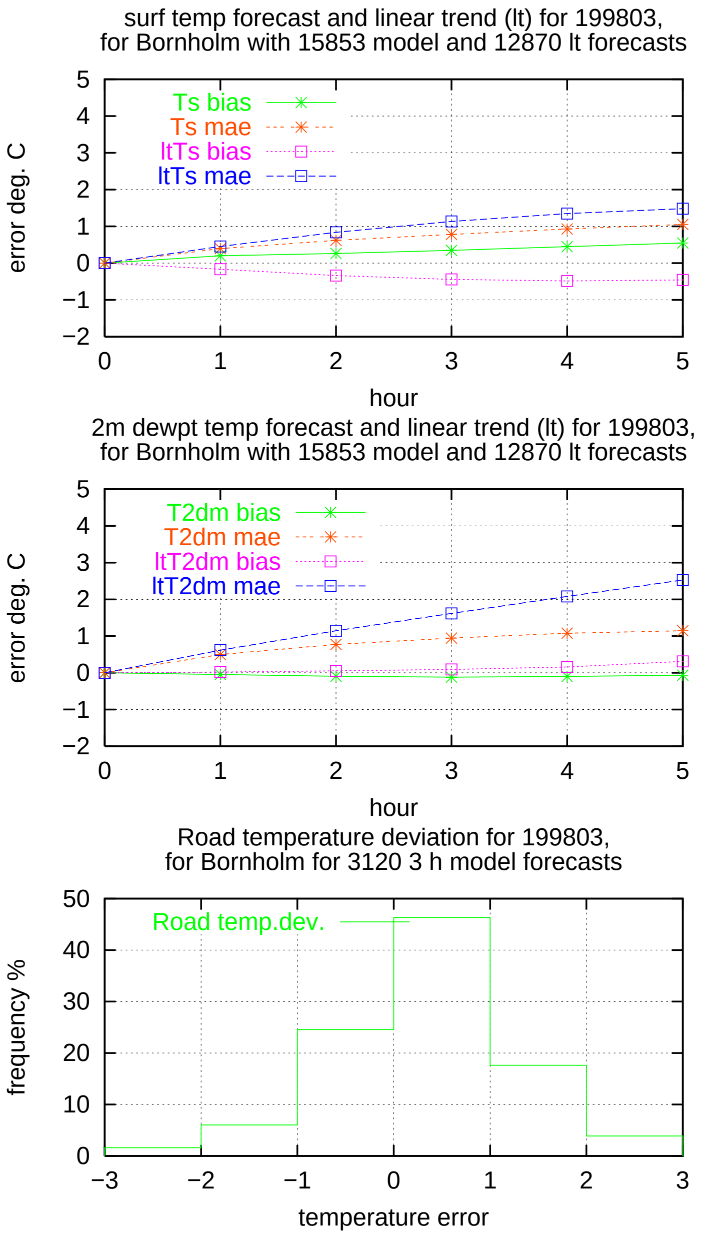

Figure 12: Verification of Ts and T2dm for the RCM and for linear trend for March 1998 for stations in Bornholm. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

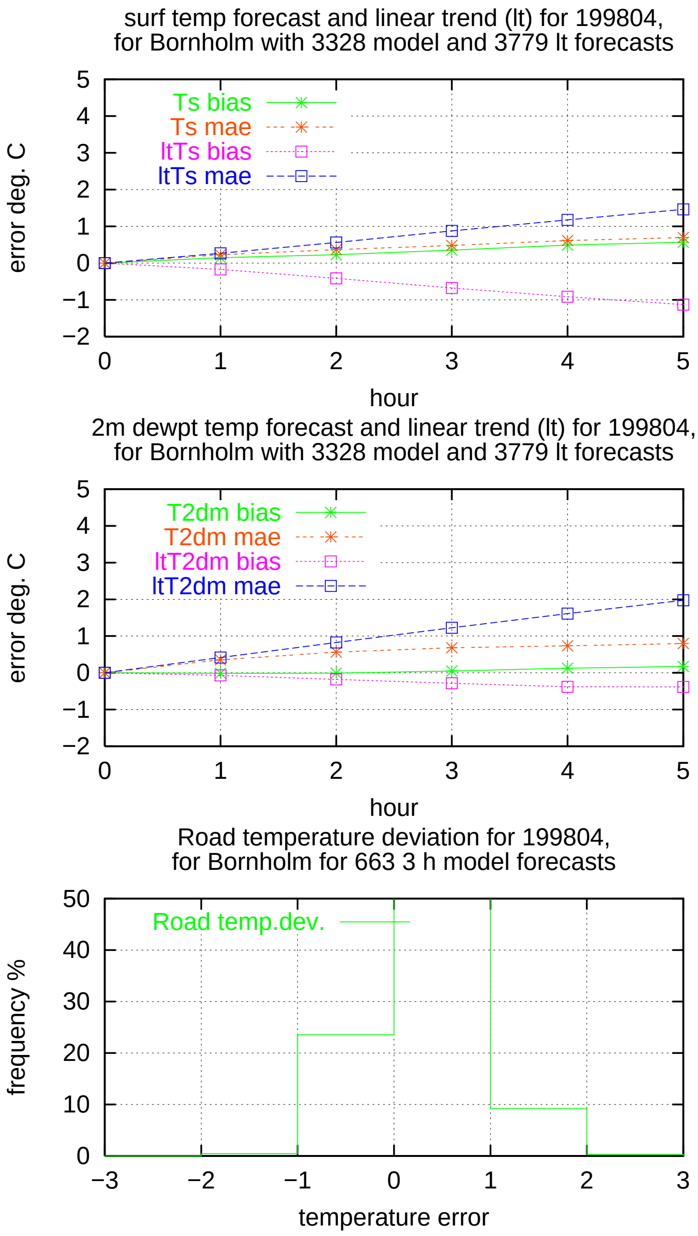

Figure 13: Verification of Ts and T2dm for the RCM and for linear trend for April 1998 for stations in Bornholm. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

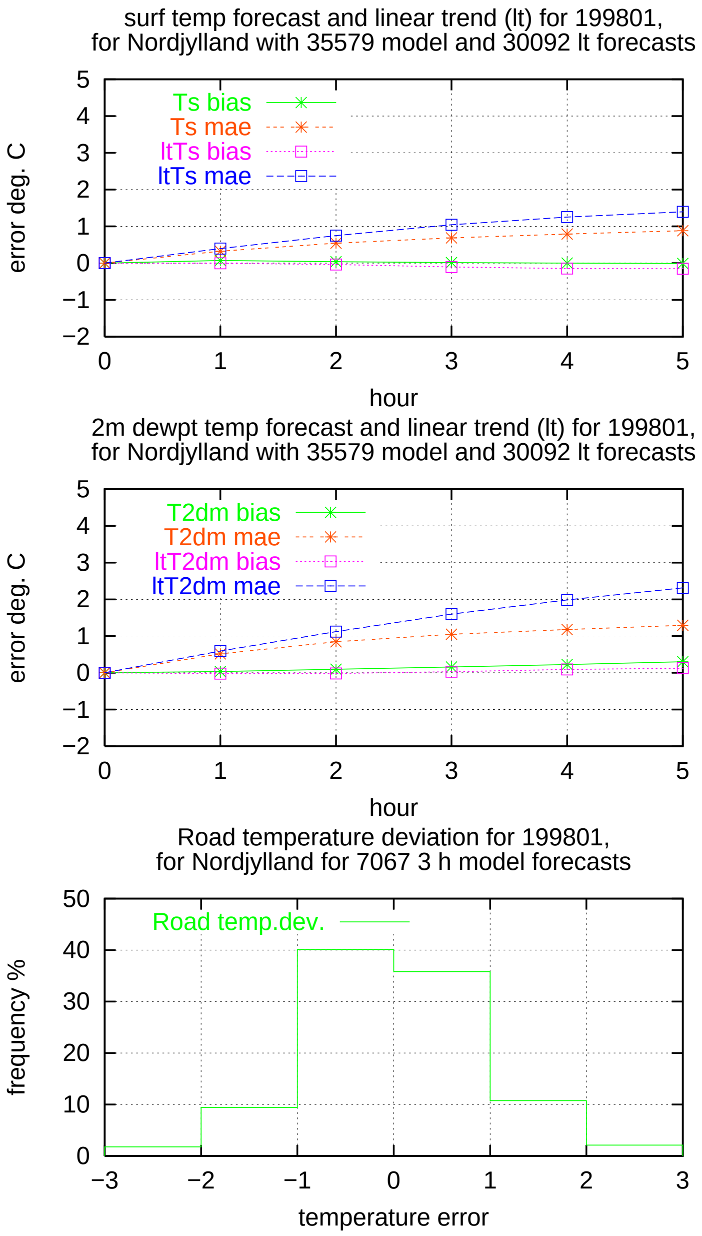

Figure 14: Verification of Ts and T2dm for the RCM and for linear trend for January 1998 for stations in Northern Jutland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

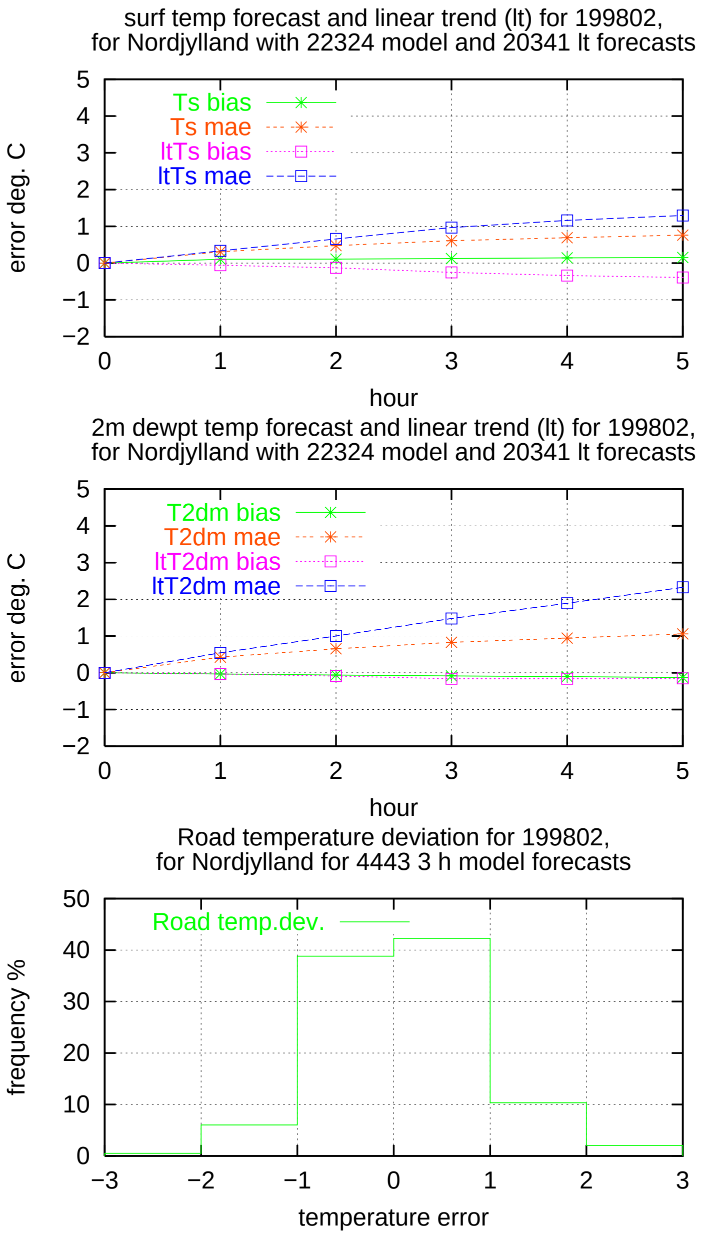

Figure 15: Verification of Ts and T2dm for the RCM and for linear trend for February 1998 for stations in Northern Jutland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

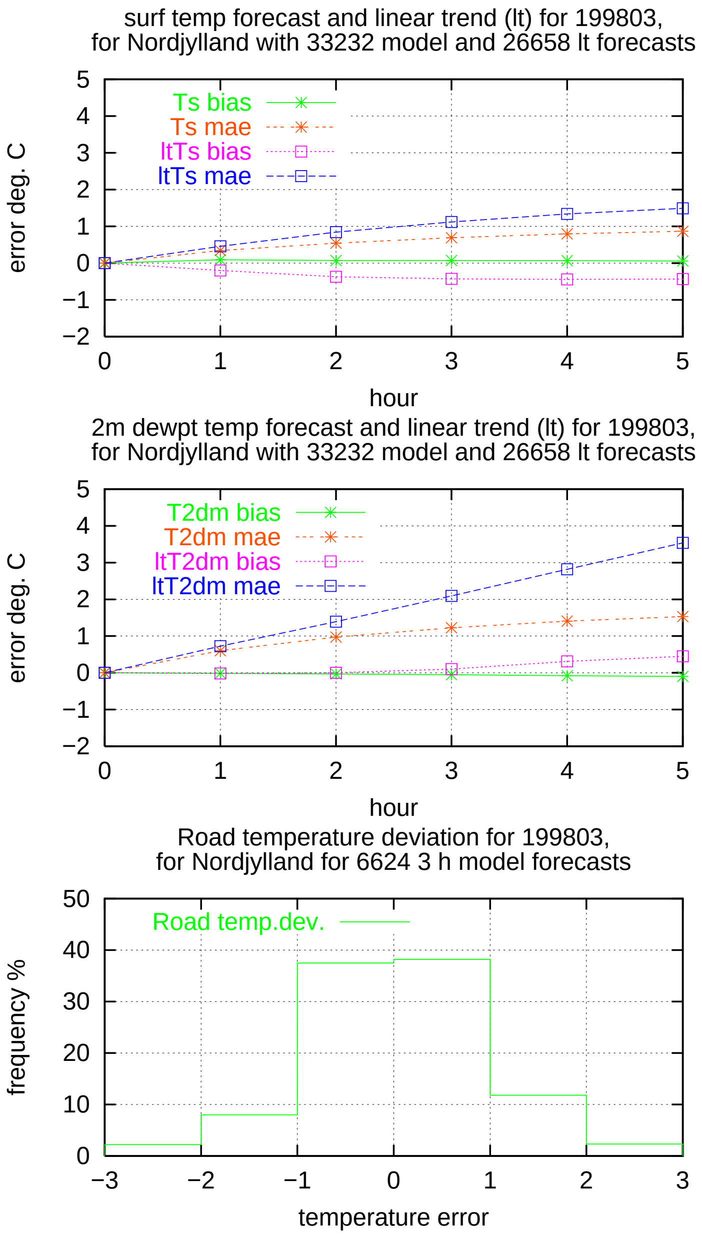

Figure 16: Verification of Ts and T2dm for the RCM and for linear trend for March 1998 for stations in Northern Jutland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

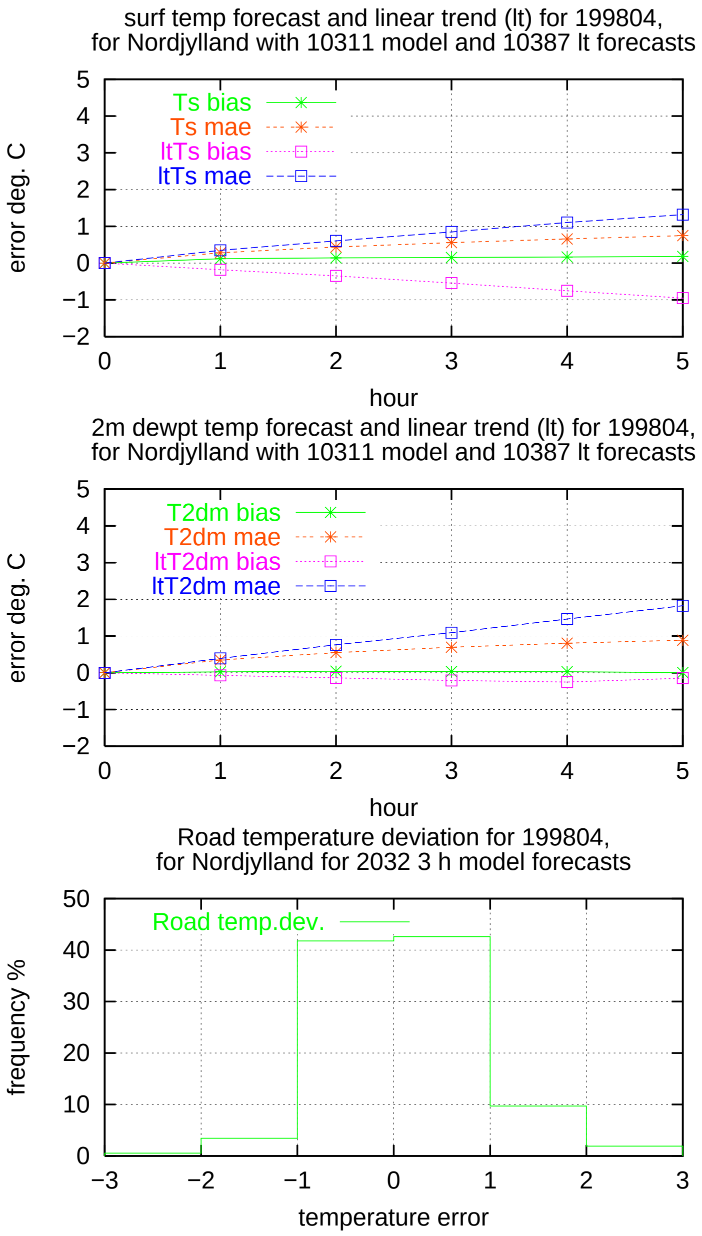

Figure 17: Verification of Ts and T2dm for the RCM and for linear trend for April 1998 for stations in Northern Jutland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

much more pronounced for Bornholm. The positive Ts bias could result from a bias in HIRLAM cloud cover. It could also be due to the interpolation of HIRLAM data for coastal stations or indicate that some local effects are poorly accounted for.

Forecasts for Bornholm are perhaps affected by less accurate cloud cover forecasts. However this is not due to fewer SYNOP observations for Bornholm than for instance Northern Jutland. For SYNOP data for January through April, the six SYNOP stations on Northern Jutland report cloud cover 89% of the time and cloud height 83% of the time, while for Bornholm's three SYNOP stations the reporting frequency is even greater: cloud cover is reported in 90% of the time and cloud height 86%.

6. Monthly Verification for Iceland

Results of monthly verification for Iceland January, February, March and April are shown in Figures 18−21.

In Figures 18.a.-20.a., (January-March), the linear trend forecasts are comparable to the RCM forecasts for Ts. This result is very different from those for Danish stations. However this is not the case for T2dm, (Figures 18.b-20.b.) for which the RCM consistently outperforms linear trend, even more markedly than for instance Bornholm and Northern Jutland. These conflicting results could indicate that road surface temperature measurements are made at too great a depth in the road. In addition, in March (Figure 20.a. and 20.b.) the mean absolute errors in Ts and T2dm at 5h are unusually large. The RCM forecasts are better than the linear trend forecasts for April (Figure 21.a. and 21.b.) for both Ts or T2dm. This difference could be explained by the sun being better able to warm up the road (also at the depth of the sensors) in April. These results require further investigation.

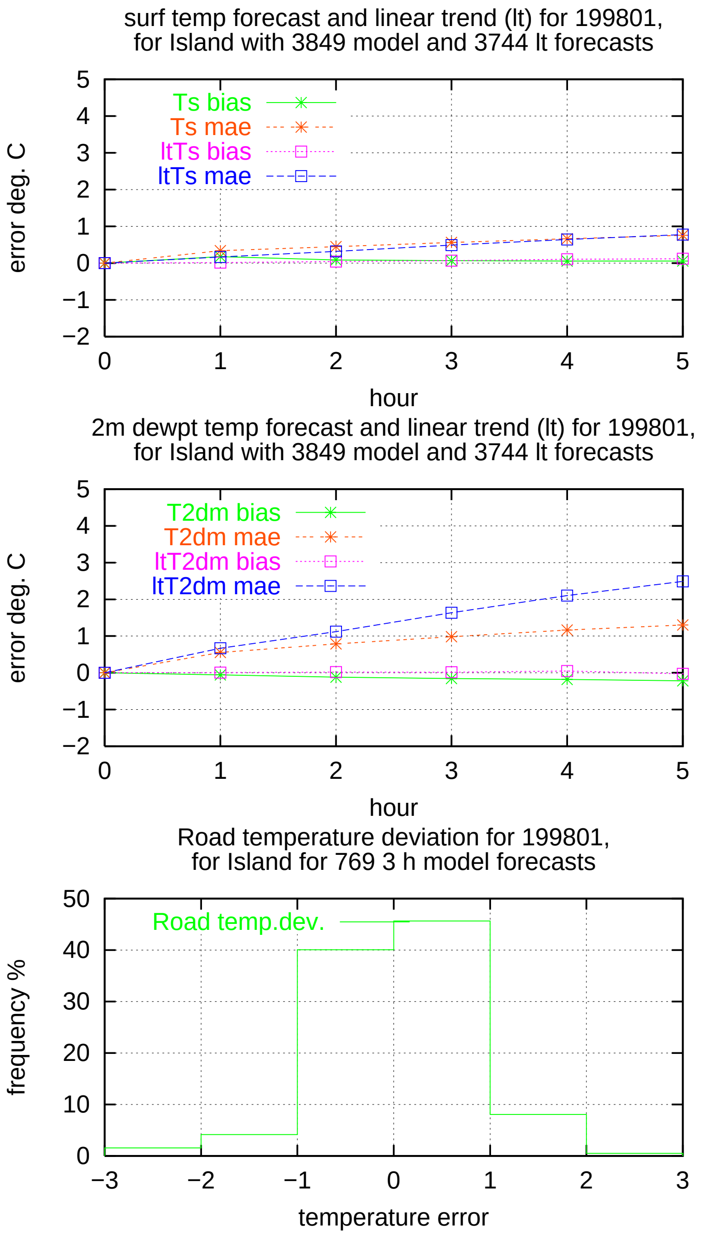

Figure 18: Verification of Ts and T2dm for the RCM and for linear trend for January 1998 for stations in Iceland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

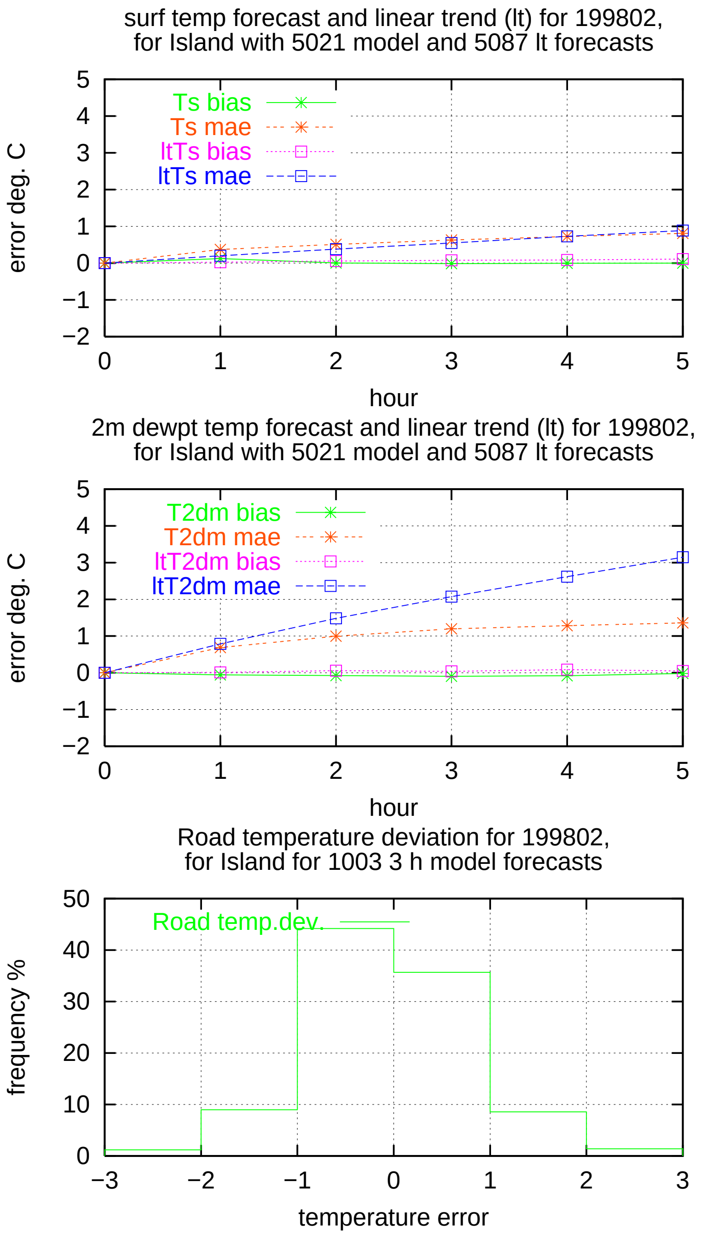

Figure 19: Verification of Ts and T2dm for the RCM and for linear trend for February 1998 for stations in Iceland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

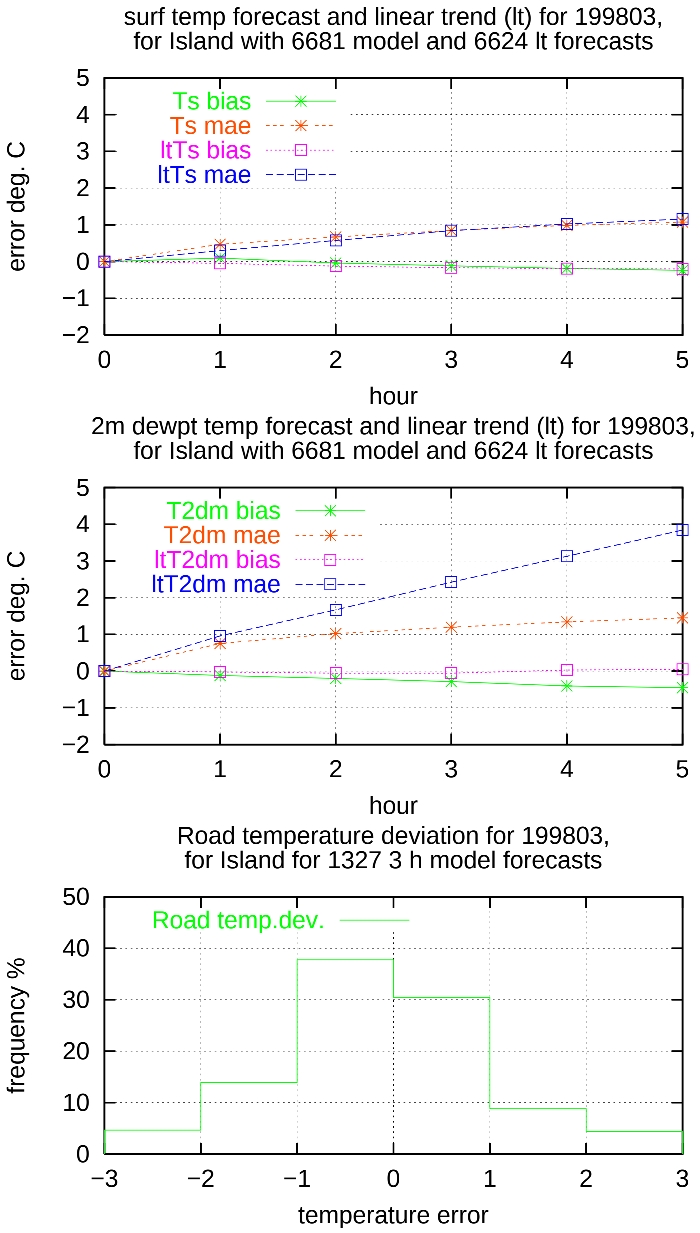

Figure 20: Verification of Ts and T2dm for the RCM and for linear trend for March 1998 for stations in Iceland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

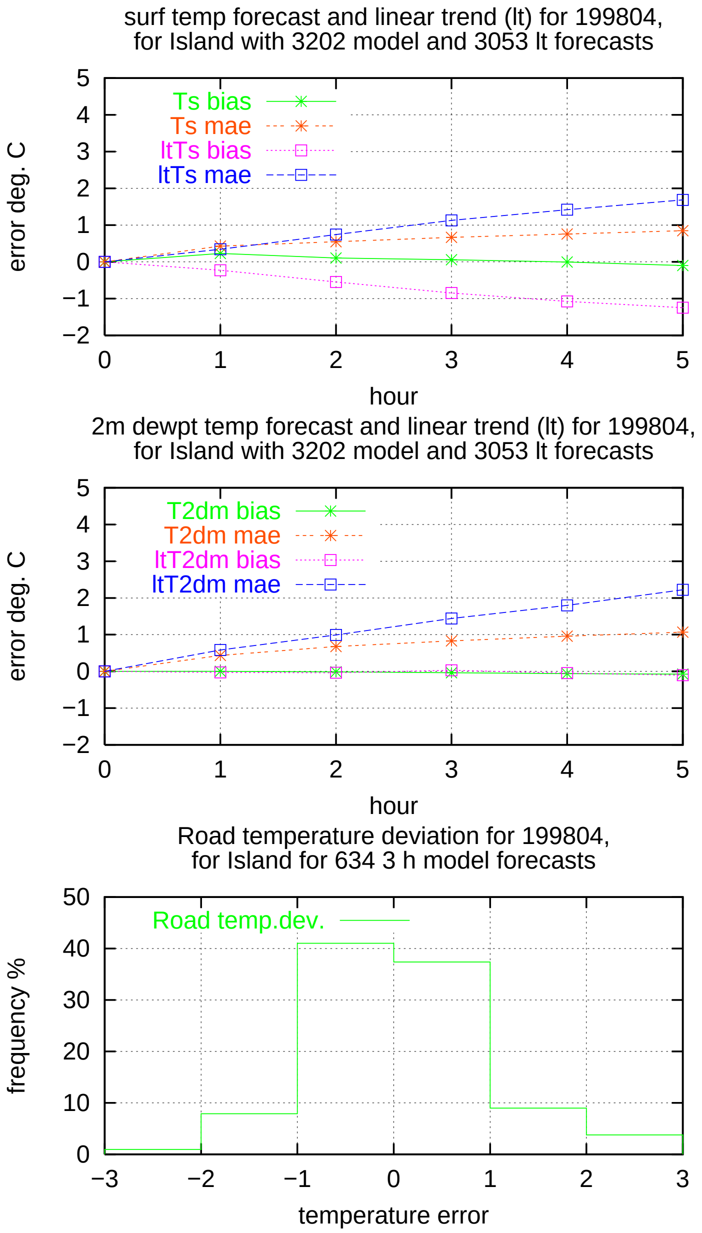

Figure 21: Verification of Ts and T2dm for the RCM and for linear trend for April 1998 for stations in Iceland. a. average mean absolute error (mae) and mean error (bias) in Ts for the RCM and linear trend ('ltTs bias' and 'ltTs mae'), b. mae and bias in T2dm for RCM and linear trend ('ltT2dm bias' and 'ltT2dm mae'), c. error frequencies (%) of Ts for 3 hour RCM forecasted values.

7. Concluding Remarks

The RCM system is remarkably robust, being invariant from year to year in spite of differences in the weather from season to season. The RCM outperforms linear trend both with respect to Ts and T2dm. In addition, for both season verifications, the error frequencies of Ts for 3 hour forecasted values lying between $\pm 1°$ C were over 80%.

The results of the monthly verifications vary a bit from month to month, but throughout the RCM outperforms linear trend, especially in the case of T2dm.

For Bornholm, a positive bias is observed for Ts, especially in February and April. The error frequencies of Ts for 3 hour forecasted values lying between 0 and $1°$ C for these two months are much greater than those lying between -1 and $0°$ C.

In the case of Northern Jutland, there is in general a positive bias for Ts predicted by the RCM. Nevertheless the model is much better at predicting Ts than linear trend.

Future improvements of the RCM depend in large part on better accuracy in the prediction of small scale cloud cover features.

8. 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] Rosenørn, Stig, 1998: "Vintervejret 1997–1998", Vejret, 75, 27–31.

[3] Rosenørn, Stig, 1998: "Forårsvejret 1998", Vejret, 76, 21–25.

[4] Rosenørn, Stig, 1998: "Efterårsvejret 1997", Vejret, 74, 23–27.

[5] Capplen, John and Jørgensen, Bent, ed., 1998: "Månedernes og årets vejr i tekst og figurer", Danmarks Klima 1997, 29–81.

[6] Capplen, John and Jørgensen, Bent, ed., 1997: "Månedernes og årets vejr i tekst og figurer", Danmarks Klima 1996, 51−125.

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: Irregularities in the operation of the system during the season

9 Jan 1998, 15:00−17:00, missing synoptic data resulted in consecutive road program crashes. The RCM ran again 18:00 when a new synop file was made available. Subsequently the absence of atmospheric data (HIRLAM-E) files in grib database (due to a /dataGDB/94 crash) meant the RCM did not run again until 9:00, 12 Jan.

15 Jan 1998, 9:00, no HIRLAM-E files in grib database; due to bad ECMWF boundary files for HIRLAM, affecting the HIRLAM run on the NEC. The RCM had no atmospheric data files available and therefore did not run for several hours.

15 Jan 1998, 16:00, double and 1.5 times normal files in grib database, cause model hangs.

Normal operation resumed after 98011600 HIRLAM run completed and new files are put into the grib database.

21 Jan 1998, changes in ECMWF grib file format caused problems for HIRLAM, which meant that the RCM didn't have HIRLAM-E files to start from for an hour or two.

25 Jan 1998, corrections made to ectrans made program stall, HIRLAM late and the RCM didn't have files to start from for several hours.

28 Jan 1998, bug in corrections made to ectrans caused major problems with HIRLAM and the RCM didn't have HIRLAM files to start from for several hours.

7 Feb 1998, 5:31, problems with V's distribution of BUFR output data.

another run like the above in Feb.

3 Mar 1998, 8:31, ML files for 6z and 18z to 48 in grib database, and therefore used by RCM set-up.

17 March 23z, Wed. 18 00z March, HIRLAM-E files are in the database 2x, resulting in two hangs.

19 March Grib library updated, thereby eliminating RCM hangs when HIRLAM-E files are in the database 2x.