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Road Weather Modelling System: Verification for 2005-2007 Road Weather Seasons

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Abstract

For the last two road weather seasons (1 October – 1 May) 2005/2006 and 2006/2007, the scores for the 3 hour forecasts of the road surface temperature with an error of less than ±1ºC is almost 80 and 83%, respectively, based on more than 635 and 259 thousand corresponding forecasts. The overall seasonal averages of the bias and mean absolute error are 0.22ºC and 0.74ºC for the last season. It shows a slightly better performance of the road conditions model compared with the season 2005-2006, where the bias and mean absolute error were 0.31ºC and 0.78ºC, respectively.

Resumé

For de to vejsæsoner (1. October – 1. May) 2005/2006 og 2006/2007 er scoren for forudsagt vejtemperatur henholdsvis 80 og 83%, hvor scoren er defineret som den procentvise antal af 3 timers prognoser for vejtemperatur der har en fejl mindre end ±1ºC. Der indgår henholdsvis 635 og 259 tusinde prognoser i beregningen af scoren for de to sæsoner. For hele sæsonen er bias og middelfejlen henholdsvis 0.22ºC og 0.74ºC for den sidste sæson. Det er en anelse bedre end for sæsonen 2005/2006, hvor bias og middelfejlen var henholdsvis 0.31ºC og 0.78ºC.

1. Introduction

The road weather forecasts done by the Road Weather Model (RWM) system is an important operational product produced by DMI. It is, therefore, relevant after each season evaluate the performance of the Road Conditions Model (RCM: *Sass, 1992; 1997*) in order to continue further development and improvement of the system. In addition, users of the RWM system might have also an interest in gaining access to verification report after each season.

Briefly, the RWM system uses the continuous observations from the synoptic weather stations and road stations of the Danish road network along with the meteorological output from the DMI-HIRLAM (High Resolution Limited Area Model; *Sass et al., 2002*) numerical weather prediction (NWP) model as input to produce 24 hour forecasts every hour. For a description of the RWM operational system see the manual *GlatTerm (2004)*.

For some previous road weather seasons the verification reports are given by *Kmit & Sass (1999)*; *Sass & Petersen (2000)*; *Petersen & Nielsen (2000; 2003)*. Operational irregularities for the 2005-2007 road seasons are listed in Appendix 1 which shows also changes and modifications made in the DMI-HIRLAM and RWM systems, and RCM model.

2. Road Weather Model Verification

2.1. General Approach

A road weather season is considered to have duration from October through April. The reason for such duration is based on a potential possibility that slippery road situations can occur in all these months. After year of 2000, due to recent climatic changes and warmer regional weather conditions, such situations over the Danish road network became rare and less observed (for example, for the last road weather season, only a few forecasts has been done in October 2006 and April 2007).

The verification of the RWM system performance is conducted based on evaluation of the DMI-HIRLAM model (see corresponding quarterly reports at the DMI web-site) and RCM forecasts for key parameters: road surface temperature (Ts), 2m air temperature (Ta) and 2 m dew point temperature (Td), as well as scores reflecting a frequency of good/poor quality forecasts. To make verification two conditions are required, i.e. both the observational data and modeled forecasts have to be available at exact times of observation vs. forecast. If one of these is missing then both are not used in verification. Note, that usually the missing forecasts account for 1-2%. In almost all cases the missing forecasts are related to computer processing and archiving problems (or missing input meteorological data from the DMI-HIRLAM model).

Such verification includes analysis of all times forecasts (i.e. from 01 to 24 hours); however, only forecasts, where both the observed and forecasted Ts are within a range of ±3ºC, are included. Moreover, the major interest is represented by the first six hour forecasts (i.e. the responsible time for the road authorities and representing the time period on a diurnal cycle when the probability of the slippery road conditions is the highest). Note, all road stations (i.e. 386 in total) of the Danish road network are included. In general, the RCM shows a good performance compared with a simple linear trend forecast (assuming that the temperature tendency that existed an hour ago also holds for the remainder of the forecast). The verification of RCM for $Ts, Ta,$ and Td for the road seasons is given by the mean absolute error (MAE), mean error (BIAS), and error frequencies (%) of Ts for 3 hour RCM forecasted values.

2.2. Road Weather Season 2005-2006

2.2.1. MAE and BIAS for Ts

The Figures 1-2 show the bias and mean absolute error, MAE for road surface temperature (Ts) during the first six hour RCM forecasts. As seen at 5 hour RCM forecasts: the highest bias of

0.64ºC is observed in October 2005, and the lowest – 0.03ºC – is observed in February 2006. During the road season, on average, it was 0.31ºC. The highest MAE of 0.91ºC is observed in November 2005 and the lowest – 0.73ºC – is observed in January 2006. During the road season, on average, it was 0.78ºC. The summary of monthly variability for MAEs and BIASes of the *Ts, Ta,* and *Td* temperatures at 5 hour forecasts for the road season 2005-2006 with the corresponding number of the RCM forecasts is given in Table 1.

Month Year		Oct 2005	Nov 2005	Dec 2005	Jan 2006	Feb 2006	Mar 2006
BIAS	**Ts**	0.64	0.50	0.38	0.35	0.03	0.43
	Ta	1.65	0.64	0.25	0.21	–0.25	0.14
	Td	1.91	2.18	0.39	0.25	–0.05	0.43
MAE	**Ts**	0.79	0.91	0.75	0.73	0.75	0.97
	Ta	1.88	1.13	0.74	0.70	0.76	0.81
	Td	0.50	1.02	0.83	0.74	0.87	0.95
RCM forecasts		4273	71760	137505	173149	152042	96479
% of Ts$_{for}$ > ±2ºC		1.12	4.38	2.52	2.80	1.67	6.85

Table 1. Summary of monthly MAEs and BIASes of the road surface temperature (*Ts*), air temperature (*Ta*), and dew point temperature (*Td*) at 5 hour forecasts for the road season 2005-2006 with the corresponding number of the RCM forecasts, and percentage of the *Ts* forecasts higher than ±2ºC.

As seen the percentage of the *Ts* forecasts higher than ±2ºC is low, ranging from 1.12% in October 2005 to 6.85% in March 2006. The bias and mean absolute error for the *Ta* and *Td* temperatures at the height of 2 meters above the ground are given in Appendixes 2-3.
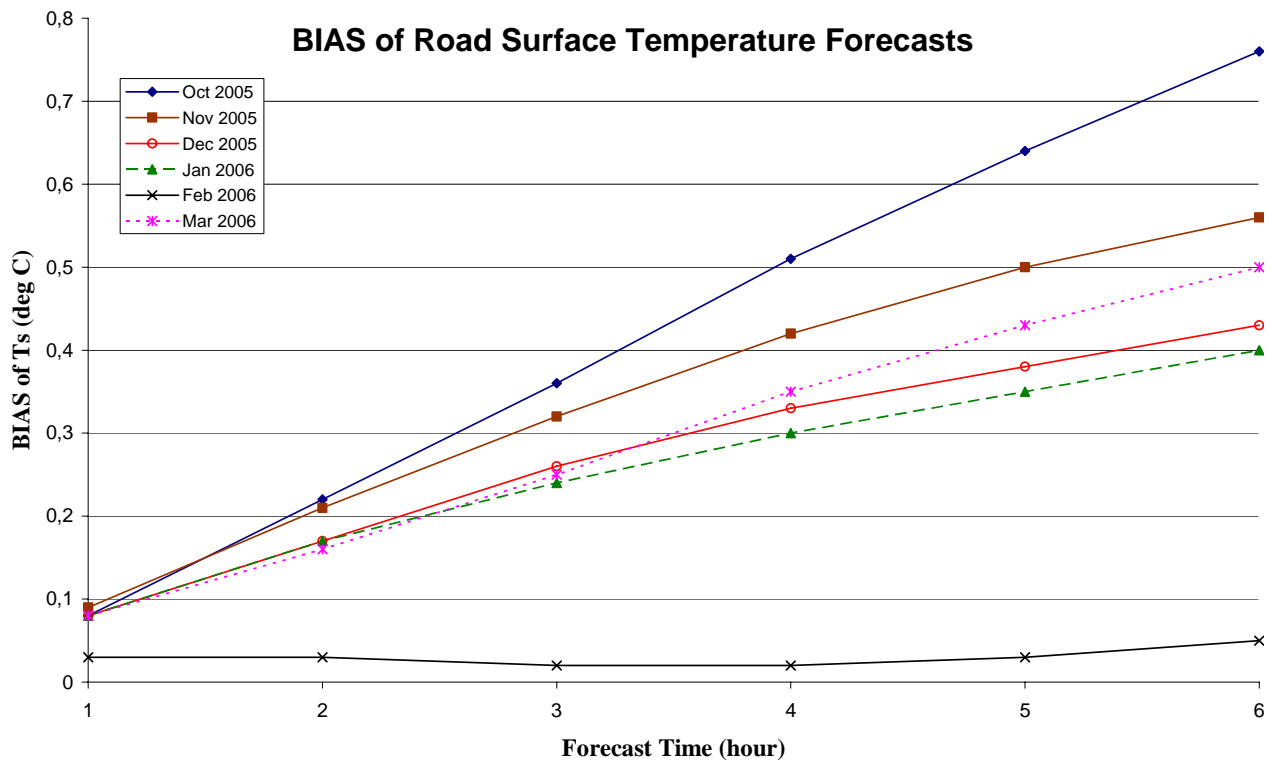

Figure 1. Monthly variability of the mean error (BIAS) of the road surface temperature (*Ts*) vs. forecast time for the road weather season 2005-2006.
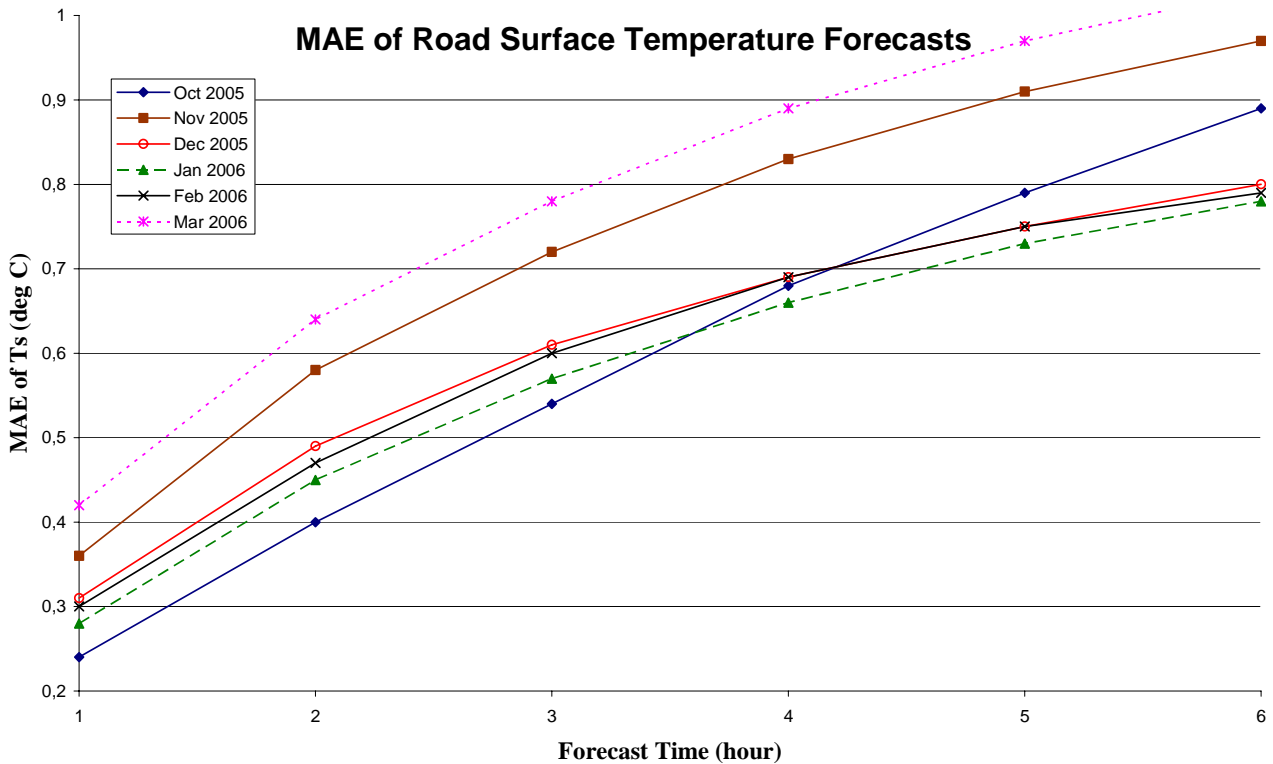
Figure 2. Monthly variability of the mean absolute error (MAE) of the road surface temperature (*Ts*) vs. forecast time for the road weather season 2005-2006.

2.2.2. Scores for Ts

The monthly variability of the road surface temperature (Ts) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts (in total **635208)** is shown in Figure 3. For this figure all analysis times are included, and the frequencies are divided into one degree intervals, with the highest frequencies corresponding to the temperature intervals: from -1ºC to 0ºC and from 0ºC to +1ºC. Note, all other intervals have substantially low frequencies. For this road season, approximately 80% of the forecasts are within ±1ºC of the observed values (Table 2).

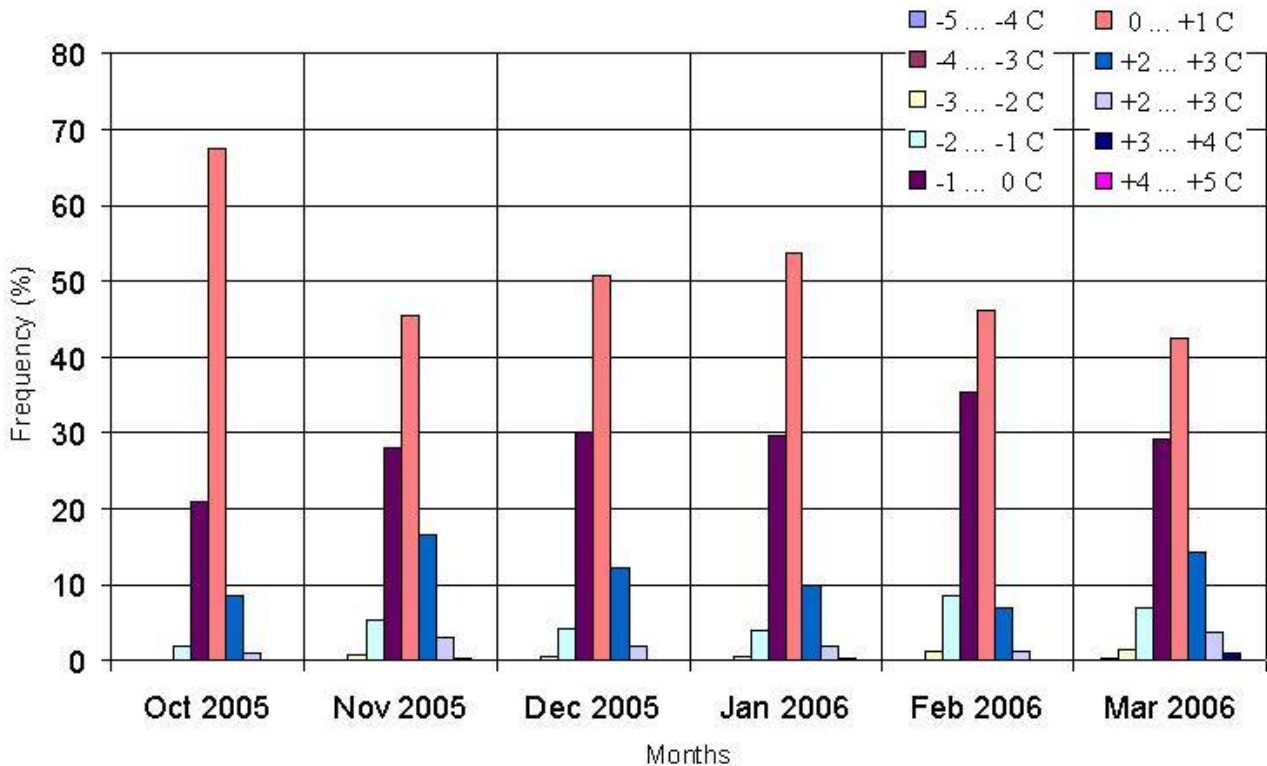## Ts : Road Surface Temperature Deviation
(3h RCM forecasts)

Figure 3. Monthly variability of the road surface temperature (*Ts*) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts for season 2005-2006.

Road Season	2005-06	
Month	**scores**	**N**
October	88,5	4273
November	73,5	71760
December	80,9	137505
January	83,2	173149
February	81,5	152042
March	71,7	96479
Season	**79,9**	**635208**

Table 2. Summary of monthly scores of for the RCM forecasts within a range of ±1ºC with the corresponding number of forecasts & observations.

2.3. Road Weather Season 2006-2007

2.3.1. MAE and BIAS for Ts

The Figures 4-5 show the bias and mean absolute error for road surface temperature (*Ts*) during the first six hour RCM forecasts. As seen at 5 hour RCM forecasts: the highest bias of 0.51ºC is observed in December 2006 and the lowest bias of 0.09ºC is observed in February 2007. During the road season, on average, it was 0.22ºC. The highest mean absolute error of 0.96 ºC is also observed in December 2006 and the lowest – 0.49ºC – is observed in October 2006. During the road season, on average, it was 0.74ºC. The summary of monthly variability for MAEs and BIASes of the *Ts, Ta,* and *Td* temperatures at 5 hour forecasts for the road season 2006-2007 with the corresponding

number of the RCM forecasts is given in Table 3.

Month Year		Oct 2006	Nov 2006	Dec 2006	Jan 2007	Feb 2007	Mar 2007
BIAS	Ts	0.34	0.37	0.51	0.37	0.09	0.19
	Ta	0.34	0.78	0.12	0.03	−0.17	−0.10
	Td	0.09	0.69	0.75	0.32	0.17	0.46
MAE	Ts	0.49	0.82	0.96	0.82	0.67	0.66
	Ta	0.55	1.29	0.94	0.78	0.65	0.79
	Td	0.61	1.21	1.10	0.92	0.73	0.91
RCM forecasts		35	21644	24106	55189	127007	31546
% of $Ts_{for} > \pm 2°C$		2.86	2.55	3.53	3.40	2.10	1.72

Table 3. Summary of monthly MAEs and BIASes of the road surface temperature (*Ts*), air temperature (*Ta*), and dew point temperature (*Td*) at 5 hour forecasts for the road season 2006-2007 with the corresponding number of the RCM forecasts, and percentage of the *Ts* forecasts higher than ±2ºC.

As seen the percentage of the *Ts* forecasts higher than ±2ºC is low ranging from 1.72% in March 2007 to 3.53% in December 2006. The bias and mean absolute error for the *Ta* and *Td* temperatures at the height of 2 meters above the ground are given in Appendixes 4-5.
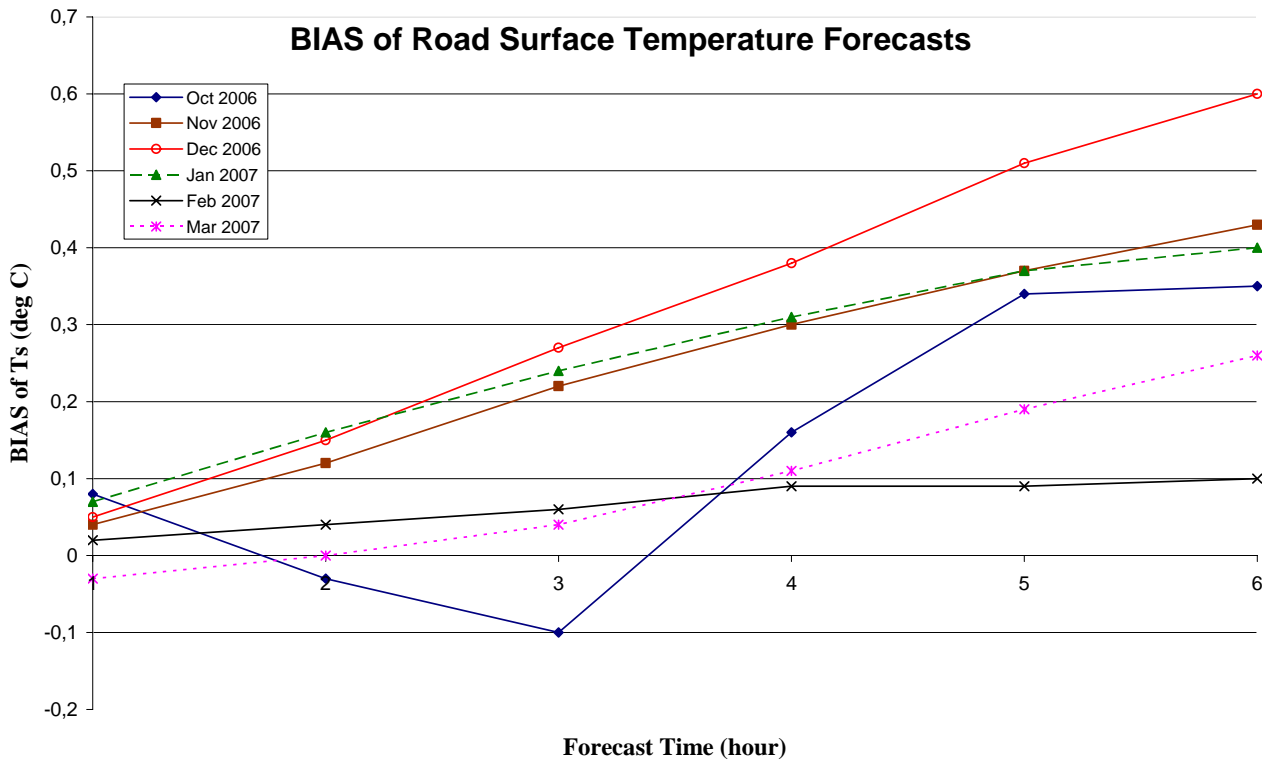

Figure 4. Monthly variability of the mean error (BIAS) of the road surface temperature (*Ts*) vs. forecast time for the road weather season 2006-2007.
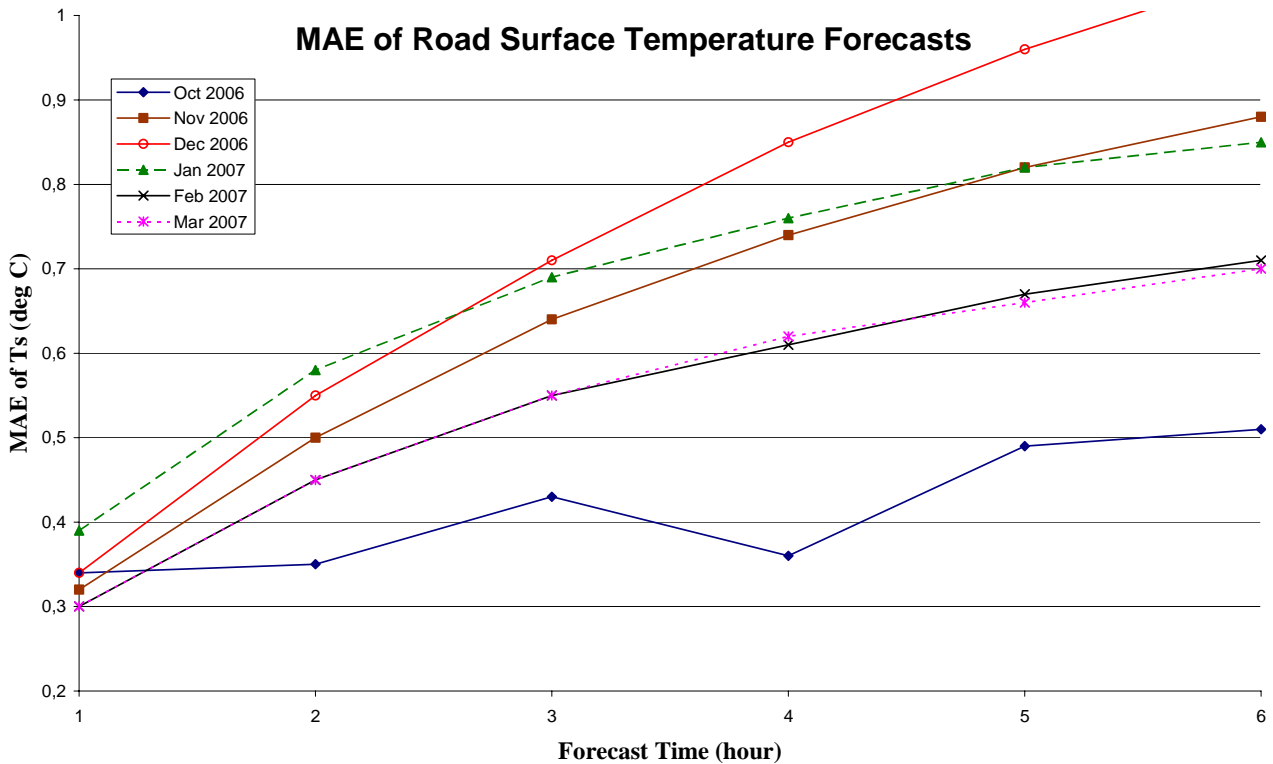
Figure 5. Monthly variability of the mean absolute error (MAE) of the road surface temperature (*Ts*) vs. forecast time for the road weather season 2006-2007.

2.3.2. Monthly Scores for Ts

The monthly variability of the road surface temperature (Ts) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts (in total **259527)** is shown in Figure 6. For this figure all analysis times are included, and the frequencies are divided into one degree intervals, with the highest frequencies corresponding to the temperature intervals: from –1ºC to 0ºC and from 0ºC to +1ºC. Note, all other intervals have substantially low frequencies. For this road season, approximately 83% of the forecasts are within ±1ºC of the observed values (Table 4).
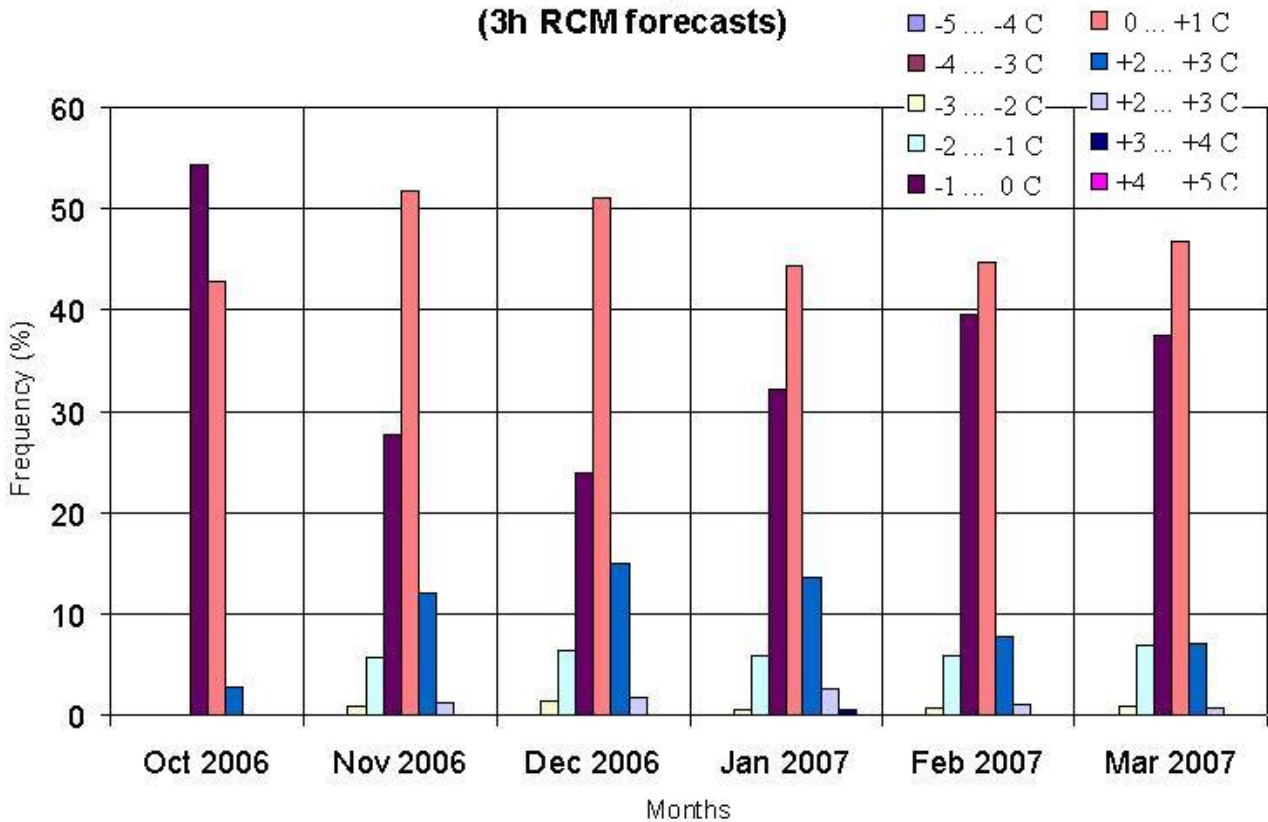
Figure 6. Monthly variability of the road surface temperature (*Ts*) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts for seasons 2006-2007.

Road Season	2006-07	
Month	**scores**	**N**
October	97,1	35
November	79,7	21644
December	75,0	24106
January	76,5	55189
February	84,4	127007
March	84,2	31546
Season	**82,8**	**259527**

Table 4. Summary of monthly scores of for the RCM forecasts within a range of ±1°C with the corresponding number of forecasts & observations.

3. Concluding Remarks

There have only been a few changes in the RCM in the last two seasons. This is also indicated in the verification which became a slightly better for the last season compared with the previous one. There is a weak tendency to higher verification scores of the road surface and air temperatures. For the last two seasons 2005-2006 and 2006-2007, the score for 3 hour Ts forecasts (in the interval ±3ºC) with an error of less than ±1ºC is almost 80% (83%). For each month of these seasons the score is listed in the summarized Table given below.

Road Season	2005-06		2006-07	
Month	**scores**	**N**	**scores**	**N**
October	88,5	4273	97,1	35
November	73,5	71760	79,7	21644
December	80,9	137505	75,0	24106
January	83,2	173149	76,5	55189
February	81,5	152042	84,4	127007
March	71,7	96479	84,2	31546
Season	**79,9**	**635208**	**82,8**	**259527**

During the last two seasons, for the road surface temperature, $Ts,$ the bias has changed from 0.31ºC to 0.22ºC, and the mean absolute error has been slightly decreased from 0.78ºC to 0.74ºC. For the air temperature, $Ta,$ the bias has been improved from 0.15ºC to –0.02ºC, and the mean absolute error changed from 0.80ºC to 0.77ºC. For the dew point temperature, $Td,$ the bias has changed from 0.27ºC to 0.33ºC, and the mean absolute error remained the same of 0.86ºC. Average seasonal values of the mean error, BIAS and mean absolute error, MAE for the Danish road seasons of 2005-2007 are given in the Table below.

Road Season		2005-06	2006-07
BIAS	**Ts**	0.31	0.22
	Ta	0.15	-0.02
	Td	0.27	0.33
MAE	**Ts**	0.78	0.74
	Ta	0.80	0.77
	Td	0.86	0.86
Score		79.9	82.8

There may be several factors influencing the verification scores for the road surface temperature prediction in the current season compared with the previous seasons and first of all, the natural variability of the weather conditions is considerable from year to year. The last season is considered to be one of the warmest in the Danish records, and it is reflected also in the quarterly DMI-HIRLAM model verification reports.

There are a number of factors which may have influenced the performance of the RCM during the recent seasons. This has been described in Appendix 1. Note, for individual road stations there can be a large difference in verification score even though they are situated close to each other, and this difference can also be large from one county to another. Also the climatology in DMI-HIRLAM data, and especially from the road stations located close to the coast, can affect the result. However, the most needed improvement is a better representation of spatial variability of simulated meteorological parameters used in the RCM as input. This can be done by changing of the horizontal

resolution of the DMI-HIRLAM NWP model (i.e. from 15 km to 5 km), and it is a one of the tasks of the VIKING-6 "Road Segment Forecasting" (RSF) project for the year 2007-2008. In the future it seems useful to consider "problematic" cases showing poor forecasting of Ts, e.g. with difficult atmospheric conditions. This needs to be done in order to estimate more clear impact of modifications in the RWM system. Several such cases should be considered when testing new methods for predicting the critical weather parameters such as cloud cover and precipitation.

Acknowledgments

References

GlatTerm, **2004**: Brugervejledning til GlatTerm version 2.73. *Technical Documentation for the DMI Road Weather Modelling system*, 31p, September 2004.

Kmit M., B. Sass **1999**: Verification Report for the 1997-1998 Slippery Road Season. *DMI Technical Report* N 99-1, 32 p.

Petersen N.K., Nielsen N.W., **2000**: Isbilmålinger i perioden januar - marts 1999. *DMI Teknisk Rapport* 00-06, 12 p.

Petersen N.K., Nielsen N.W., **2003**: Analyse af isbilkørsler I vinteren 2002. *DMI Teknisk Rapport* 03-29, 25 p.

Sass B., **1992**: A Numerical Model for Prediction of Road Temperature and Ice. *Journal of Applied Meteorology,* 31, pp. 1499-1506.

Sass B., **1997**: A Numerical Forecasting System for the Prediction of Slippery Roads. *Journal of Applied Meteorology,* 36, pp. 801-817.

Sass B., C. Petersen, **2000**: Verification Report for the 1998-1999 Slippery Road Season. *DMI Technical Report* N 00-02, 26 p.

Sass B., Woetmann, N.W., Jorgensen, J.U., Amstrup, B., Kmit,M., K.S. Mogensen, **2002**: The operational DMI-HIRLAM system 2002 - version. *DMI Technical Report* N 02-05, 60 p.

Appendix 1. Changes in RWM Setup during Road Seasons

During the road weather seasons 2005-2007 several modifications and up-grades of both the DMI-HIRLAM and RWM systems, and RCM model have been done:

- **2005/2006:** On average about 99.7 % of the forecasts are performed without problems. Most errors have been caused by network or computer hardware errors. However, in October 2005 some model runs crashed as a result of numerical instabilities in the model. On average about 1 model run each month crashes due to numerical instabilities. The model setup was changed to perform 24 forecasts for road stations. Still the model deliver 5 hours forecast in a separate file and the 24 hour forecast in a separate file. The latter with a delay of about 20 minutes.

- **2006/2007:** On average about 99.7 % of the forecasts are performed without problems. Most errors have been caused by network or computer hardware errors. On average about 1 model run each month crashes due to numerical instabilities. On January 29 2007, the heat conductivity constant for road was changed from 2.0 to 1.5. From experimental data this coefficient should be about 1.5 for concrete and 0.8 for asphalt.

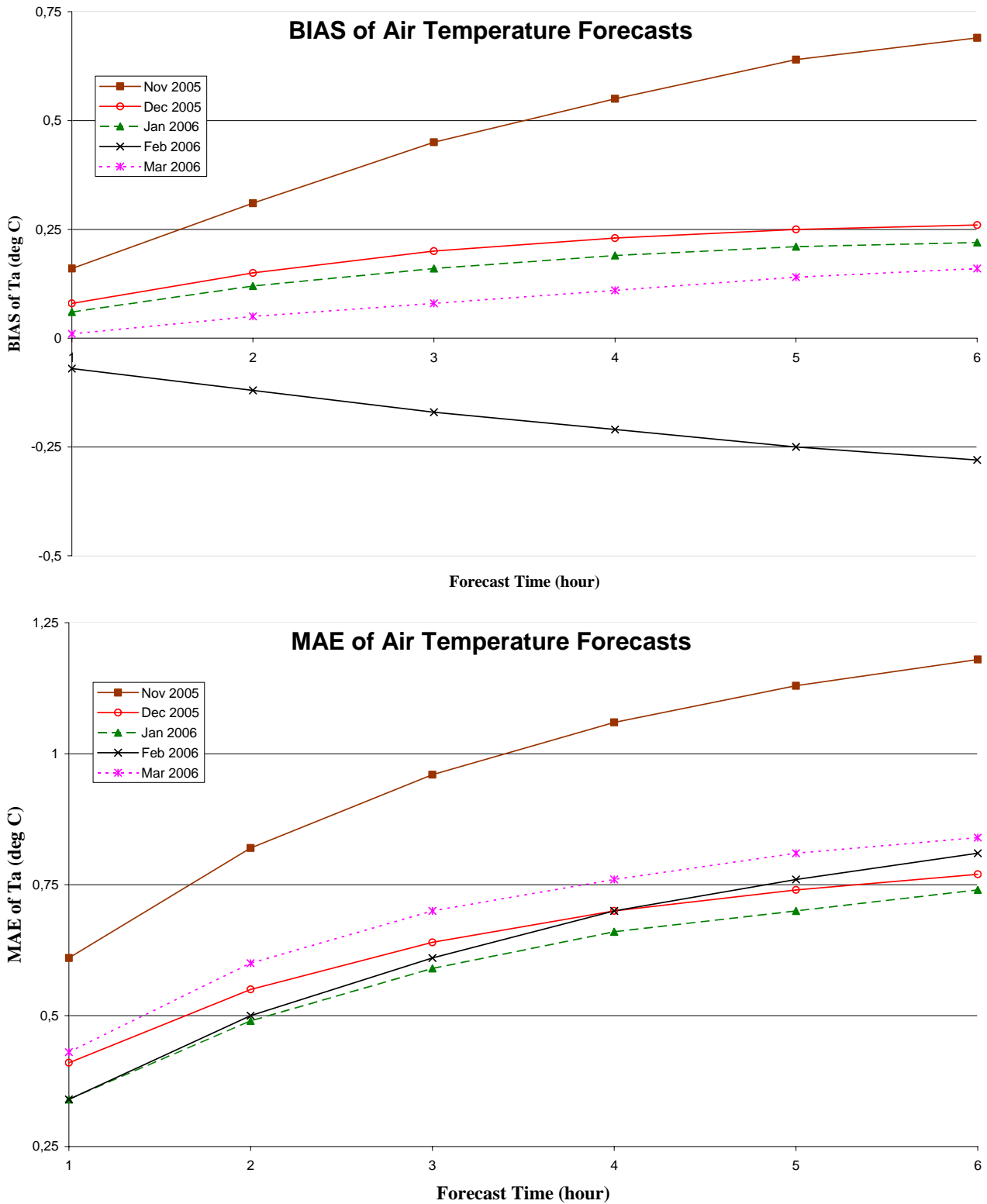## Appendix 2. Verification of 2 m Air Temperature for Road Season 2005-2006

Figure 2A. Monthly variability of the mean error, BIAS (top) and mean absolute error, MAE (bottom) of the air temperature (Ta) vs. forecast time for the road weather season 2005-2006.

Appendix 3. Verification of 2 m Dew Point Temperature for Road Season 2005-2006

BIAS of Dew Point Temperature Forecasts

Legend:
- Nov 2005
- Dec 2005
- Jan 2006
- Feb 2006
- Mar 2006

Y-axis: BIAS of Td (deg C)
X-axis: Forecast Time (hour)

MAE of Dew Point Temperature Forecasts

Legend:
- Nov 2005
- Dec 2005
- Jan 2006
- Feb 2006
- Mar 2006

Y-axis: MAE of Td (deg C)
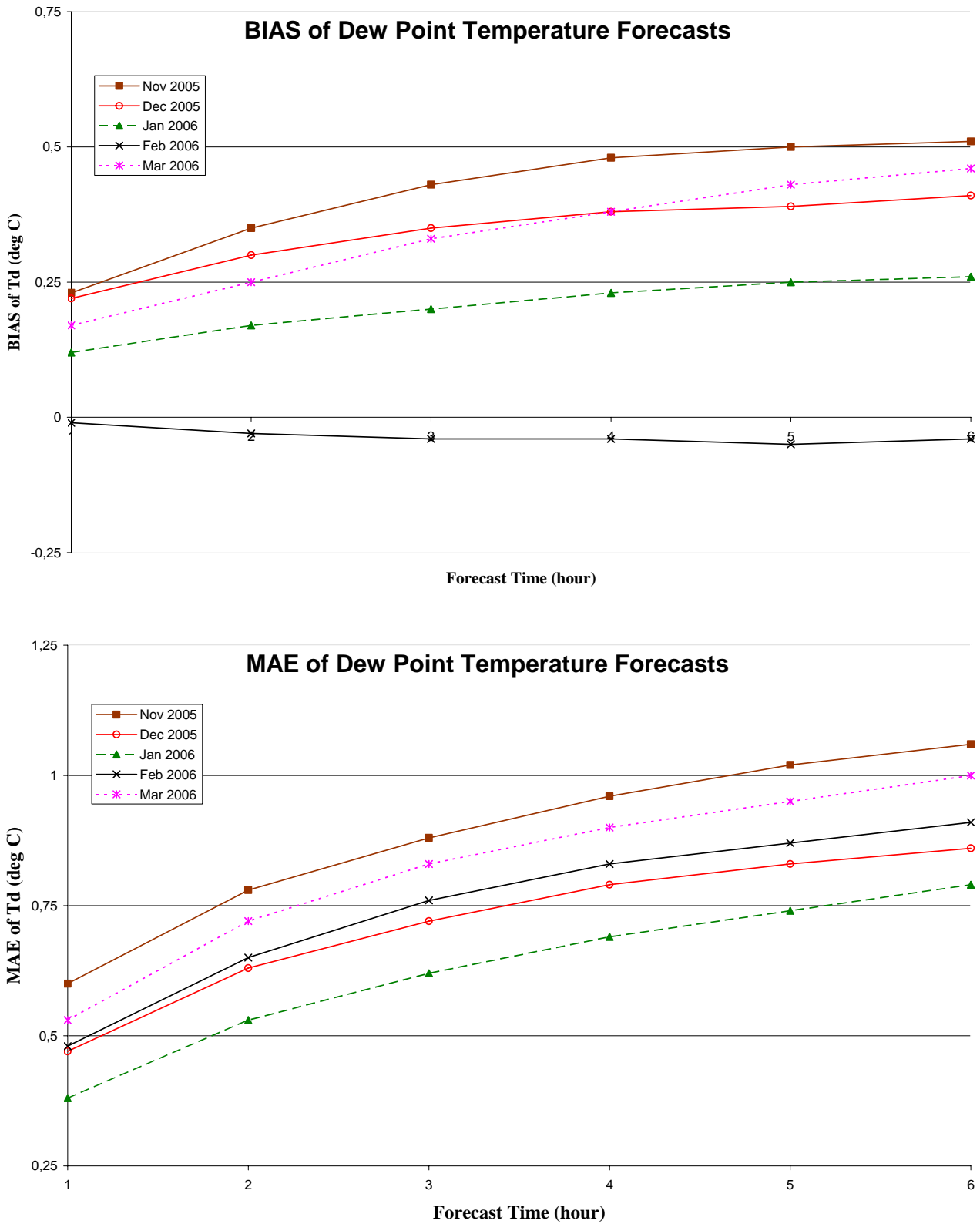X-axis: Forecast Time (hour)

Figure 3A. Monthly variability of the mean error, BIAS (top) and mean absolute error, MAE (bottom) of the dew point temperature (Td) vs. forecast time for the road weather season 2005-2006.

Appendix 4. Verification of 2 m Air Temperature for Road Season 2006-2007
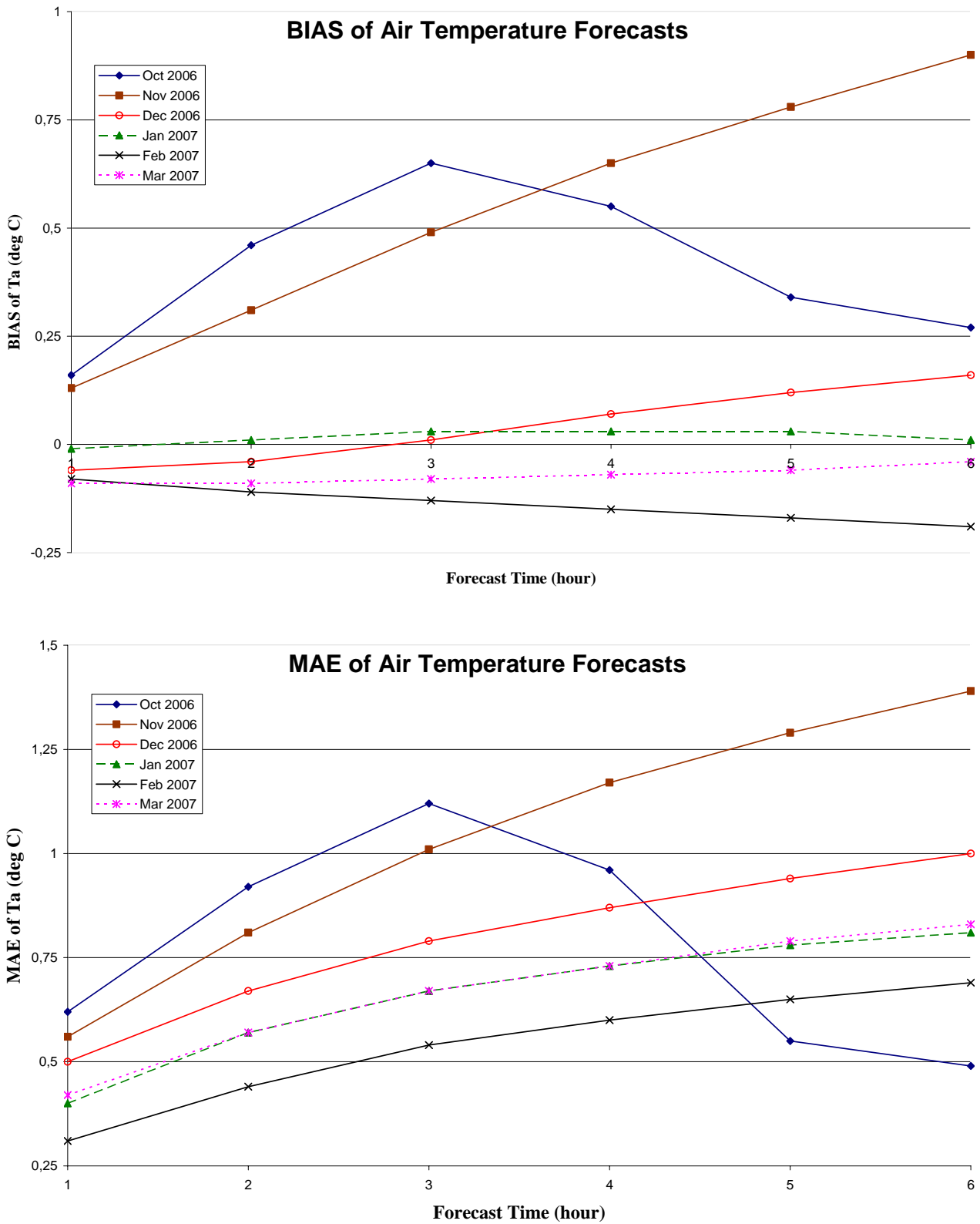

Figure 4A. Monthly variability of the mean error, BIAS (top) and mean absolute error, MAE (bottom) of the air temperature (Ta) vs. forecast time for the road weather season 2006-2007.

Appendix 5. Verification of 2 m Dew Point Temperature for Road Season 2006-2007
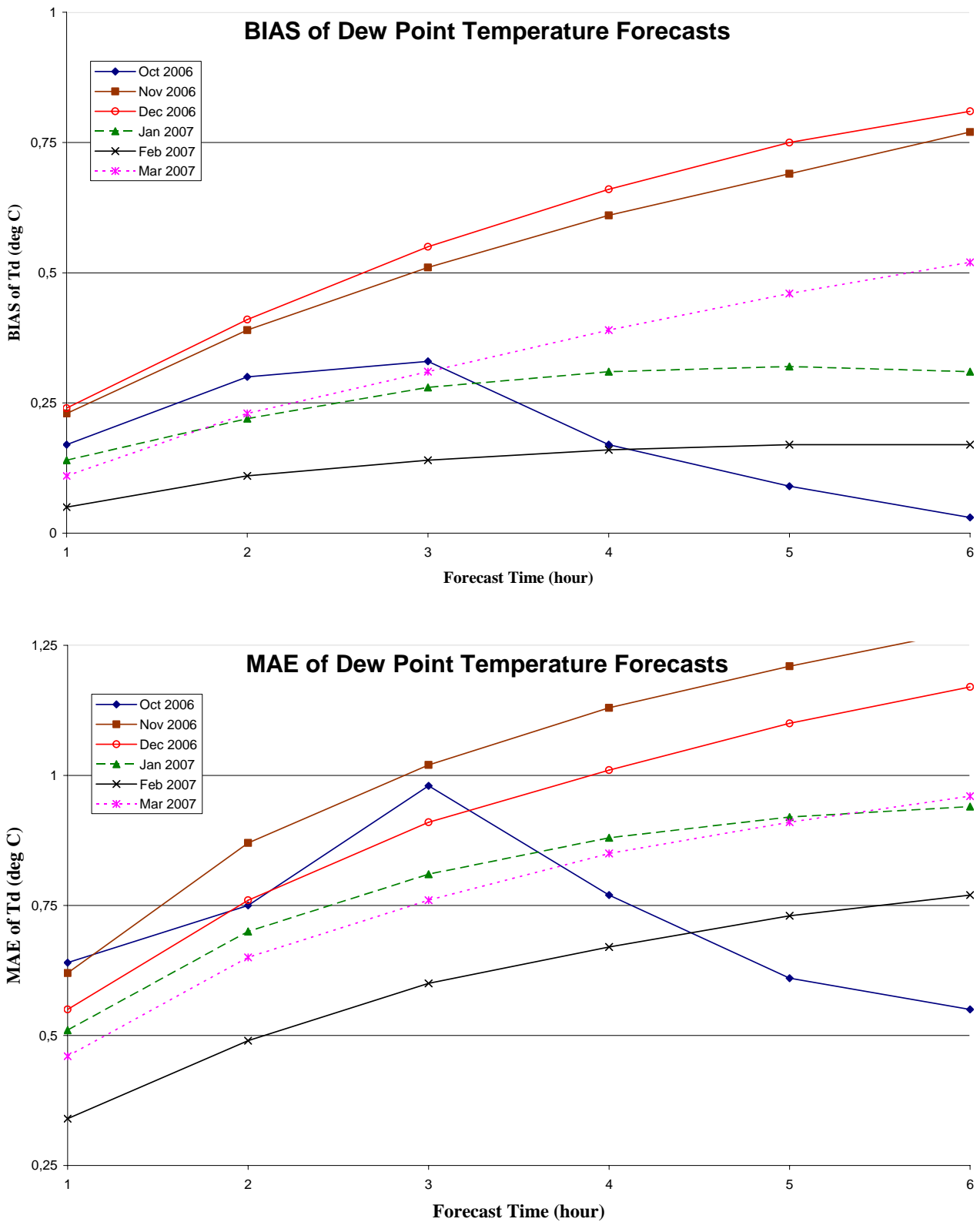

Figure 5A. Monthly variability of the mean error, BIAS (top) and mean absolute error, MAE (bottom) of the dew point temperature (Td) vs. forecast time for the road weather season 2006-2007.

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