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Road Weather Modelling System:
Verification for 2008-2009 Road Weather Season

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Abstract

For the last road weather season (1 October – 1 May) 2008/2009, the scores for the 3 hour forecasts of the road surface temperature with an error of less than ±1ºC is almost 80%, based on more than 519 thousand corresponding forecasts. The overall seasonal averages of the bias and mean absolute error are -0.11ºC and 0.76ºC. This is comparable to season 2007-2008, where the bias and mean absolute error were 0.18ºC and 0.78ºC, respectively.

Resumé

For den sidste vejsæson (1. October – 1. May) 2008/2009 er scoren for forudsagt vejtemperatur 80%, hvor scoren er defineret som det procentvise antal af 3 timers prognoser for vejtemperatur der har en fejl mindre end ±1ºC. Der indgår 519 tusinde prognoser i beregningen af scoren. For hele sæsonen er bias og middelfejlen henholdsvis -0.11ºC og 0.76 ºC. Det er omtient det samme som for sæsonen 2007-2008, hvor bias og middelfejlen var henholdsvis 0.18 ºC og 0.78 ºC.

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 to 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 an interest in gaining access to verification report after each season. Briefly, the RWM system uses the continuous observations from the Danish road stations as well asstandard meteorological and satellite based observations and 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), Petersen et al., (2007, 2008)*. Operational irregularities for the 2008-2009 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 continue from October through April. The reason for this period is based on a potential risk of slippery road in these months. In the last years the warmer winters have reduced the number of slippery road cases (for example, for the last road weather season, a very low number of forecasts has been verified in October 2008 and April 2009).

The verification of the RWM system performance is based on evaluation of the DMI-HIRLAM model used for road forecasts, which is a specialized version of the DMI-HIRLAM where key parameters are calculated in more than 400 observational points – road stations. In these points the verification is done. The verification of the RCM forecasts for key parameters is done for the 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 less than 1%. 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).

This verification includes analysis of all 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. more than 350 in total) of the Danish road network are included. Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations is shown in Appendix 5 (as a month-to-month variability). 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 2008-2009

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 is 0.72ºC in October 2008, and the lowest is –0.02ºC in December 2008. During the road season, on average, it was -0.11ºC. The highest MAE of 0.88ºC is observed in October 2008 and the lowest – 0.52ºC – is observed in April 2009. During the road season, on average, it was 0.76ºC. The summary of monthly variability for MAEs and BIASes of the *Ts, Ta,* and *Td* temperatures at 5 hour forecasts for the road season 2008-2009 with the corresponding number of the RCM forecasts is given in Tab. 1).

Month Year		Oct 2008	Nov 2008	Dec 2008	Jan 2009	Feb 2009	Mar 2009	Apr 2009
BIAS	**Ts**	0.72	-0.06	-0.02	-0.21	-0.12	-0.17	0.06
	Ta	0.90	0.27	0.22	-0.09	-0.12	-0.28	0.14
	Td	1.06	0.34	0.29	0.24	0.13	0.10	0.38
MAE	**Ts**	0.88	0.84	0.78	0.78	0.70	0.62	0.52
	Ta	1.17	0.97	0.78	0.68	0.60	0.68	1.24
	Td	1.25	1.06	0.76	0.74	0.62	0.63	1.19
RCM forecasts		7360	52726	119845	159825	132273	29635	2495
% of Ts_{for} > ±2ºC		1.48	4.44	3.60	3.26	2.95	1.91	0.98

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 2008-2009 with the corresponding number of the RCM forecasts, and percentage of the *Ts* forecasts with MAE higher than ±2ºC.

As seen the percentage of the *Ts* forecasts higher than ±2ºC is low (on average 2.66%) ranging from 0.98% (April 2009) to 4.44% (November 2008). 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.

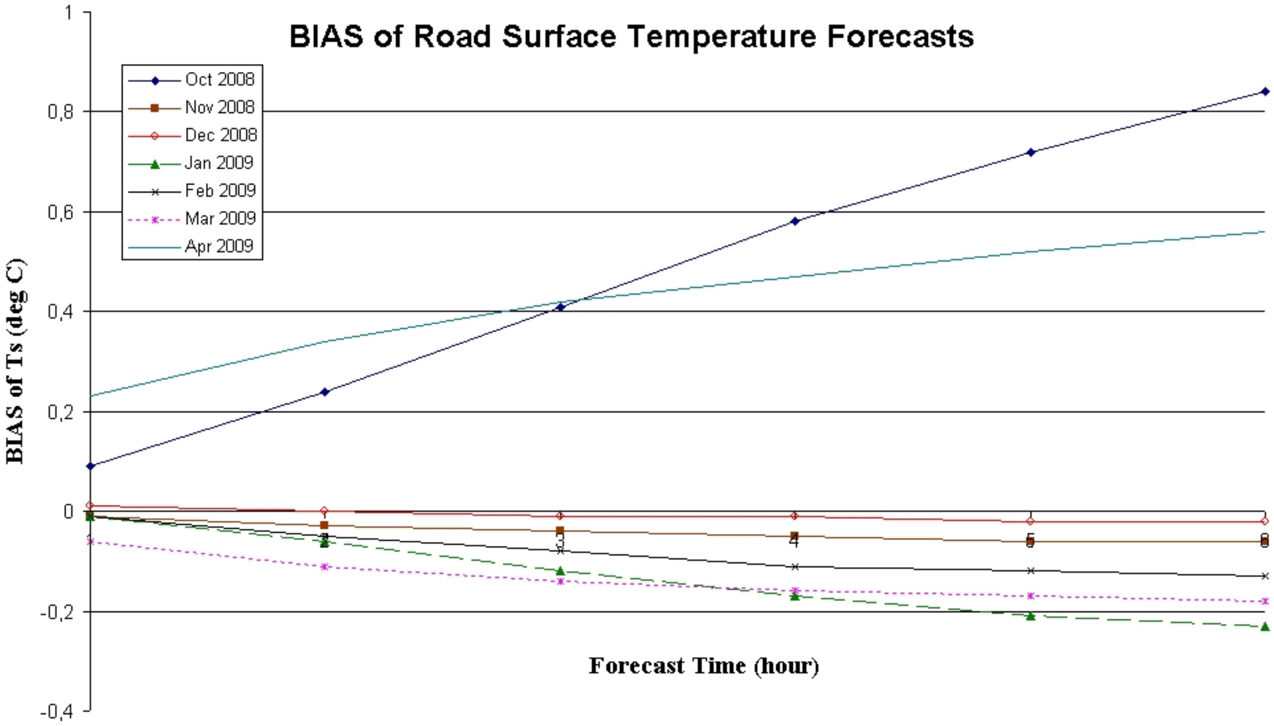

Figure 1. Monthly variability of the mean error (BIAS) of the road surface temperature (*Ts*) vs. forecast time for the road weather season 2008-2009.

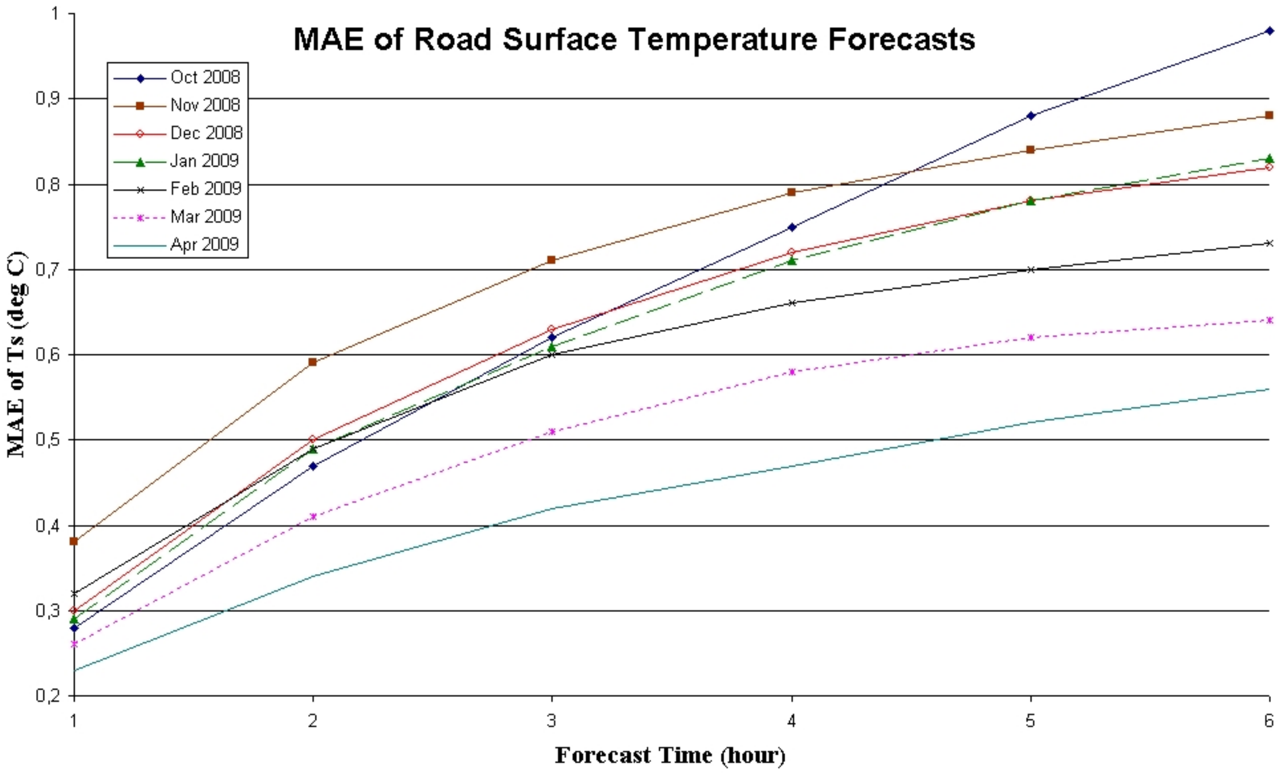

Figure 2. Monthly variability of the mean absolute error (MAE) of the road surface temperature (*Ts*) vs. forecast time for the road weather season 2008-2009.

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 **519070)** is shown in Figure 3 (for the air temperature (Ta) and dew point temperature (Td) - see Appendix 4). 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 lower frequencies. For this road season, approximately 80% of the forecasts are within ±1ºC of the observed values (Table 2).

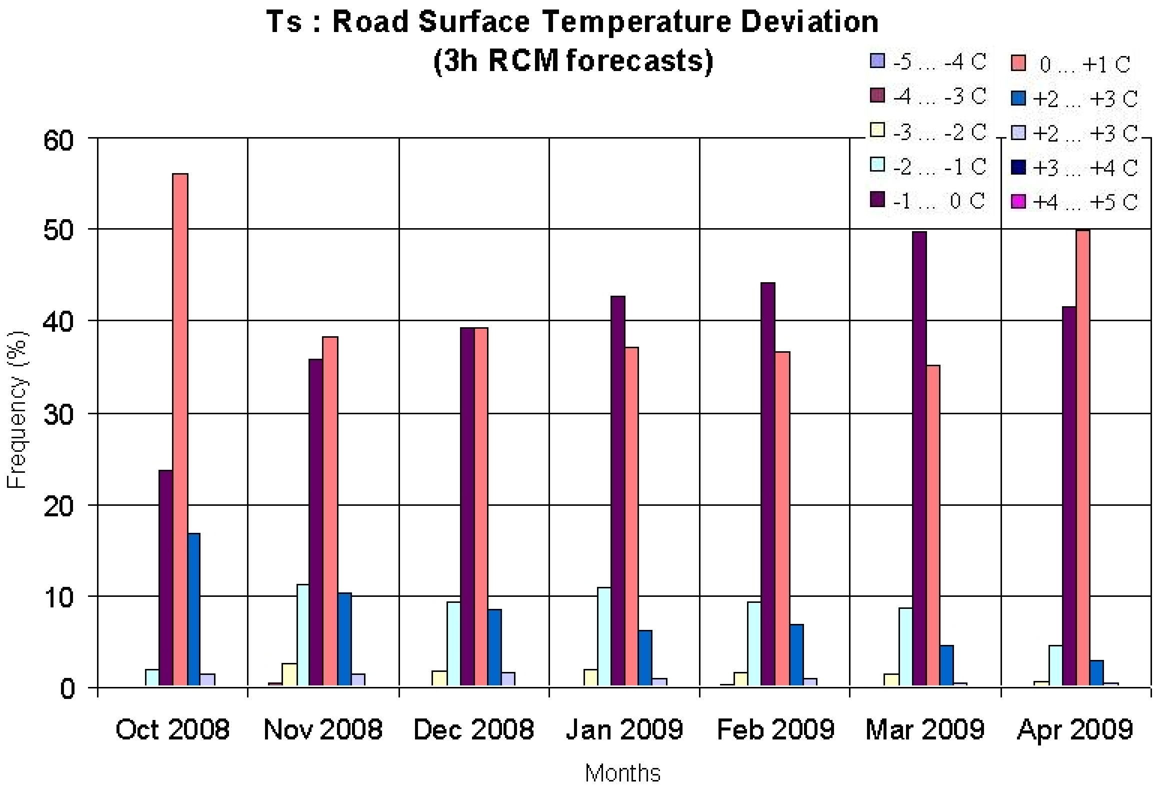

Figure 3. Monthly variability of the road surface temperature (*Ts*) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts for season 2008-2009.

Road Season Month	2008-09 scores	 N
October	79.72	9420
November	74.03	54275
December	78.67	122747
January	79.63	164389
February	80.78	134052
March	82.49	30627
April	91.43	3560
Season	**79.51**	**519070**

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

3. Concluding Remarks

There have only been a few changes in the RCM in the last seasons. This is also indicated in the verification which has a slightly lower score for the last season compared with the previous one (2007-2008). There is a weak tendency to higher verification scores of the road surface and air temperatures in later winter and spring. For the last four seasons (2005-2006, 2006-2007, 2007-2008, and 2008-2009) the score for 3 hour *Ts* forecasts (in the interval ±3ºC) with an error of less than ±1ºC is almost 80, 83, 81, and 80%, respectively. For each month of these seasons the score is listed in the summarized Table given below.

Road Season Month	2005-06		2006-07		2007-08		2008-09	
	scores	**N**	**scores**	**N**	**scores**	**N**	**scores**	**N**
October	88.5	4273	97.1	35	82.7	12369	79.72	9420
November	73.5	71760	79.7	21644	76.3	78434	74.03	54275
December	80.9	137505	75.0	24106	80.9	63487	78.67	122747
January	83.2	173149	76.5	55189	83.1	122915	79.63	164389
February	81.5	152042	84.4	127007	79.8	67884	80.78	134052
March	71.7	96479	84.2	31546	75.9	80306	82.49	30627
April					85.5	16873	91.43	3560
Season	**80**	**635208**	**83**	**259527**	**81**	**442268**	**80**	**519070**

For the season 2008-2009, for the road surface temperature, *Ts,* the bias has changed from +0.18ºC to -0.11ºC, and the mean absolute error has been slightly improved from 0.78ºC to 0.76ºC. For the air temperature, *Ta,* the bias has been changed from -0.04ºC to +0.02ºC, and the mean absolute error has been slightly improved from 0.81ºC to 0.72ºC. For the dew point temperature, *Td,* the bias has changed from 0.31ºC to 0.24ºC, and the mean absolute error has been slightly improved from 0.87ºC to 0.75ºC. Average seasonal values of the mean error, BIAS and mean absolute error, MAE for the Danish road seasons of 2005-2009 are given in the Table below.

Road Season		2005-06	2006-07	2007-08	2008-09
BIAS	**Ts**	0.31	0.22	0.18	-0.11
	Ta	0.15	-0.02	-0.04	0.02
	Td	0.27	0.33	0.31	0.24
MAE	**Ts**	0.78	0.74	0.78	0.76
	Ta	0.80	0.77	0.81	0.72
	Td	0.86	0.86	0.87	0.75
Score		80	83	81	80

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.

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 further downscaling to 2.5 km), and this is one of the tasks of the "Fine-Scale Road Stretches Forecasting" (RSF) project (2008-2011). 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, improved shadow measurements.

Acknowledgments

The computer facilities at the Danish Meteorological Institute (DMI) have been employed extensively. The Danish synoptical meteorological data from the DMI archives have been used in this study. The authors are thankful for collaboration to the DMI Computer Support.

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Appendix 1. Changes in RWM Setup during Road Seasons

During the road weather seasons 2005-2009 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.

- **2007/2008:** 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. The heat capacity for the surface scheme in HIRLAM was slightly modified to a lower value to get higher daily amplitude on temperature. A bug was identified which did not set the temperature for the lowest soil layer correctly to a climatic value. Instead a constant value for the year was used which is too high for the winter months.

- **2008/2009:** The use of satellite data was changed in Jan 2009. High thin cirrus clouds are now interpreted as cloud free to avoid too high temperature. There have been only few irregularities in the forecasting.

Appendix 2. Verification of 2 m Air Temperature for Road Season 2008-2009

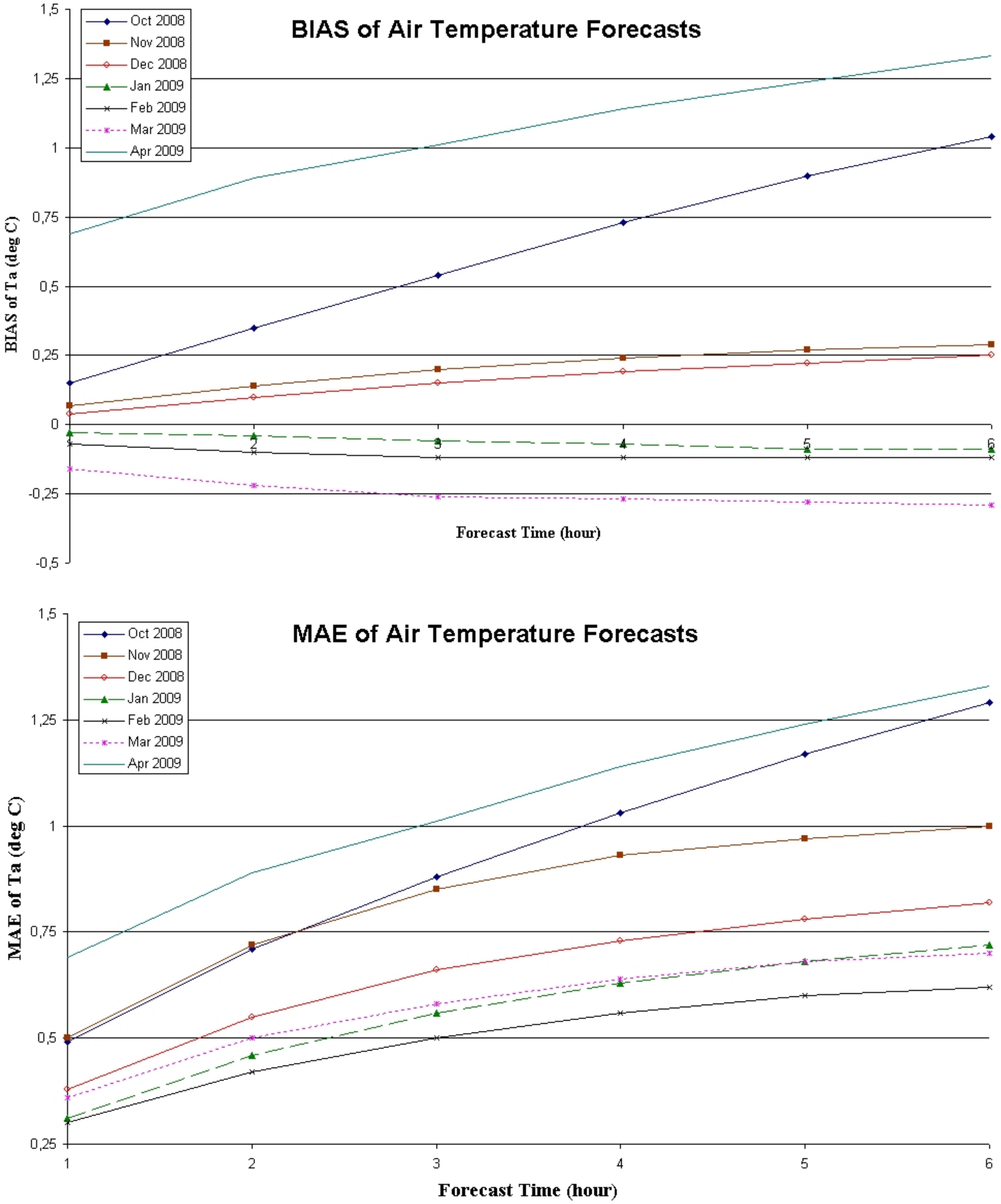
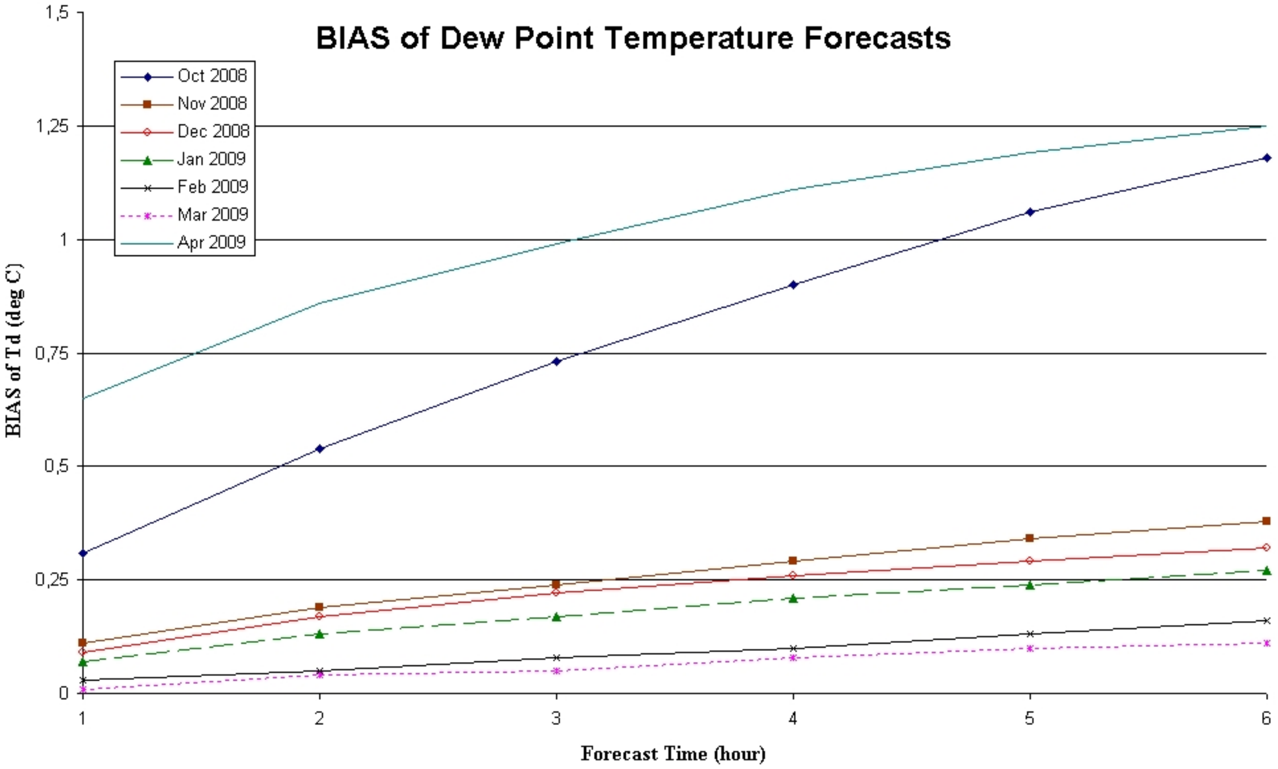


Figure 2A. Monthly variability of the mean error, BIAS (top) and mean absolute error, MAE (bottom) of the air temperature (Ta) vs. forecast time for the road weather season 2008-2009.

Appendix 3. Verification of 2 m Dew Point Temperature for Road Season 2008-2009



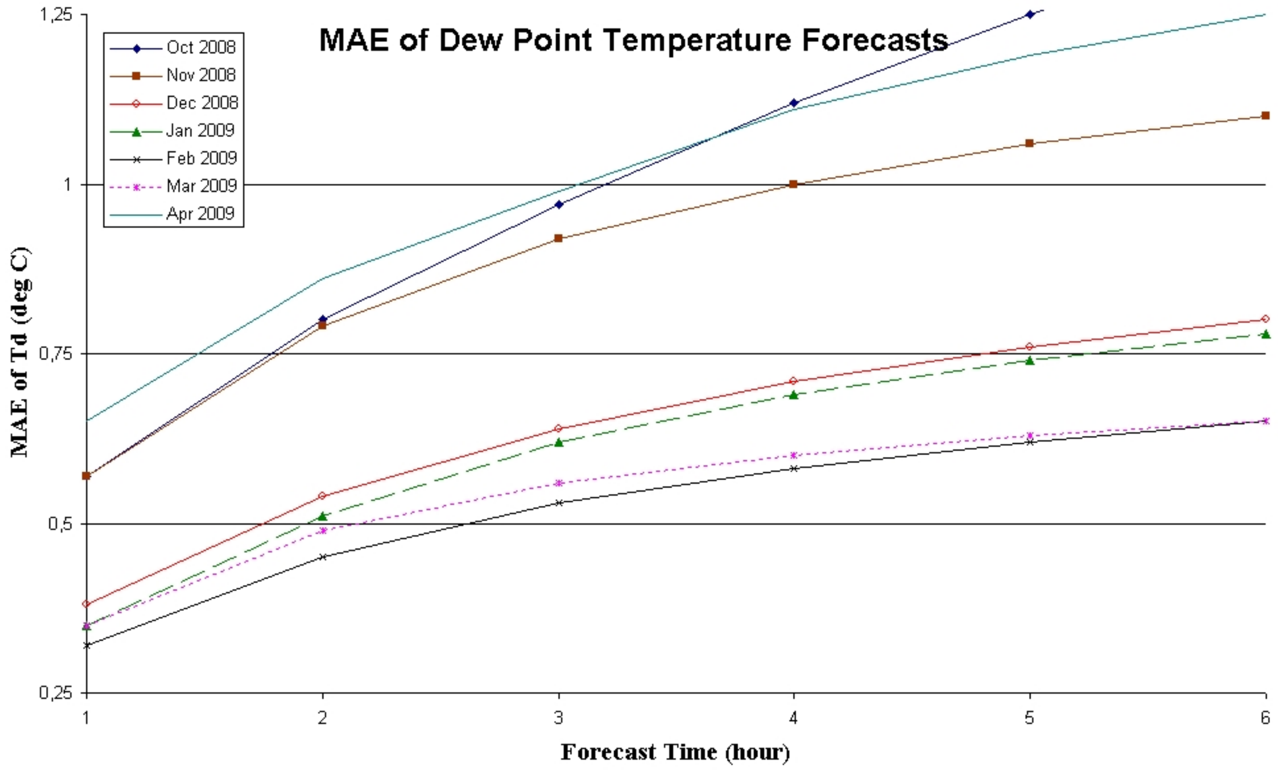


Figure 3A. Monthly variability of the mean error, BIAS (top) and mean absolute error, MAE (bottom) of the dew point temperature (Td) vs. forecast time for the road weather season 2008-2009.

Appendix 4. Monthly Variability of Air and Dew Point Temperatures Deviations as Error Frequencies for Road Season 2008-2009

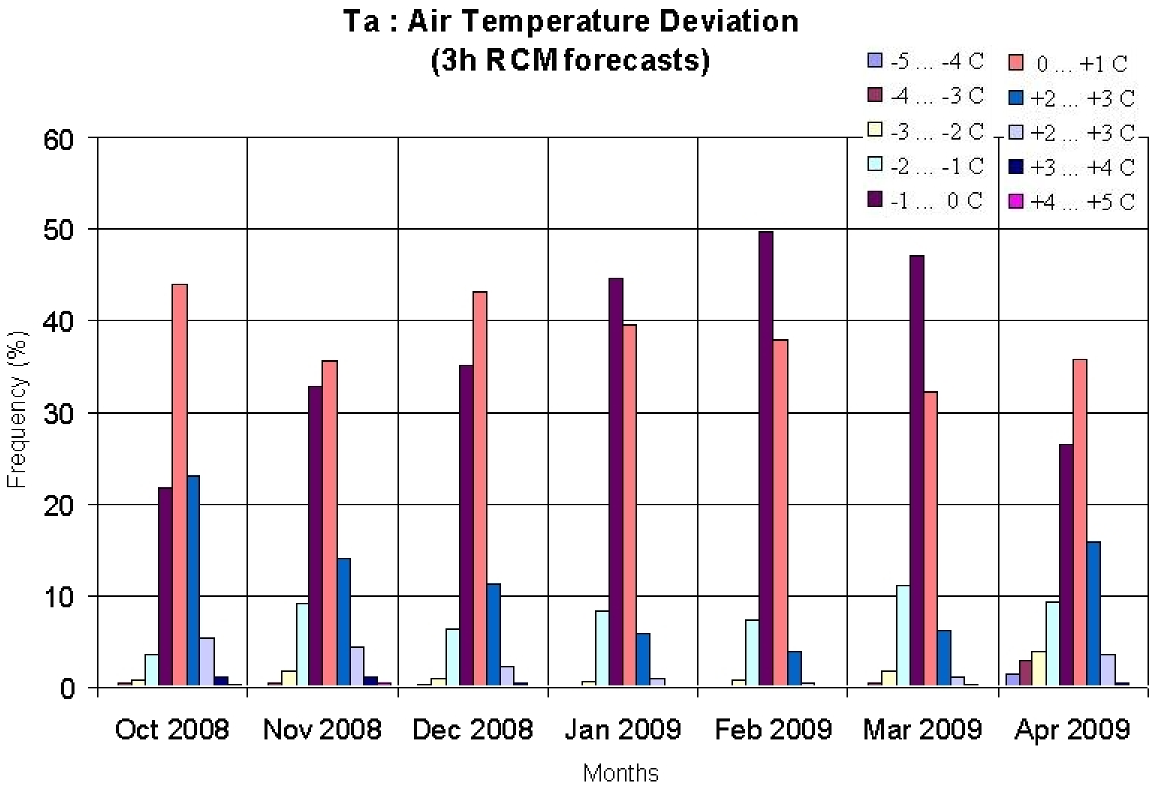


Figure 4A. Monthly variability of the air temperature (*Ta*) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts for season 2008-2009.

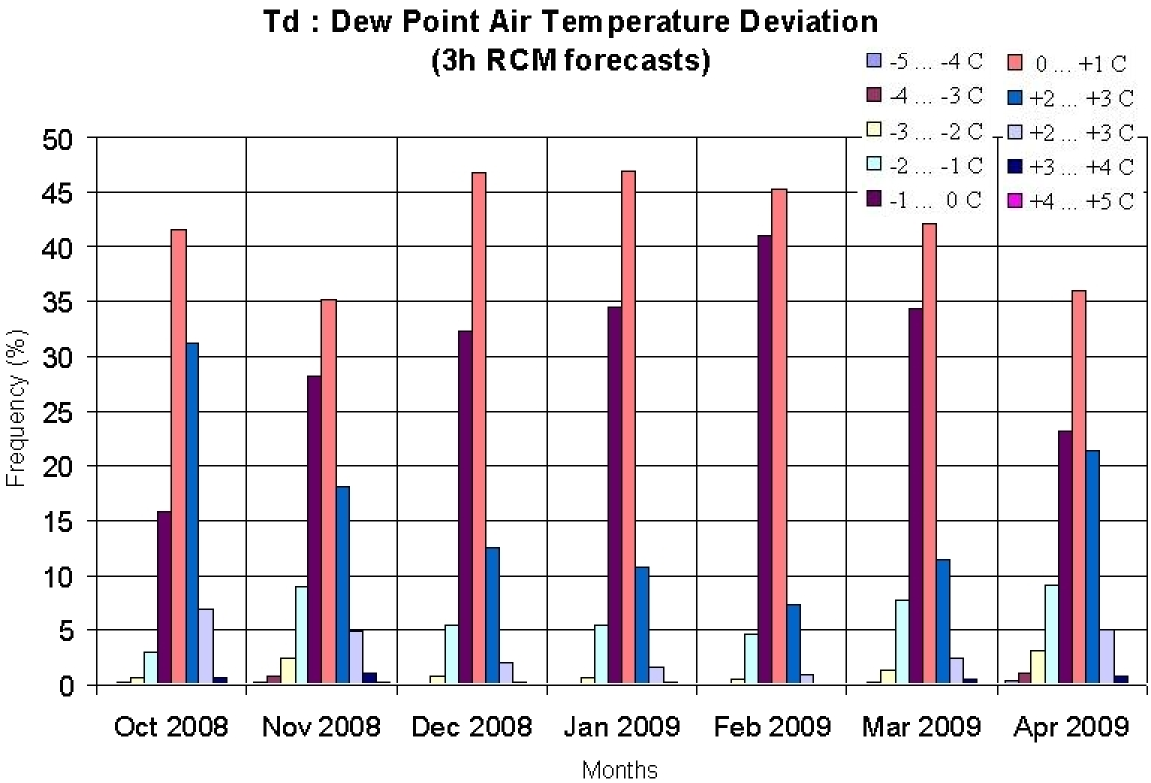


Figure 4B. Monthly variability of the dew point temperature (*Ta*) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts for season 2008-2009.

Appendix 5. Monthly Variability of Road Icing Conditions in Denmark for Road Season 2008-2009

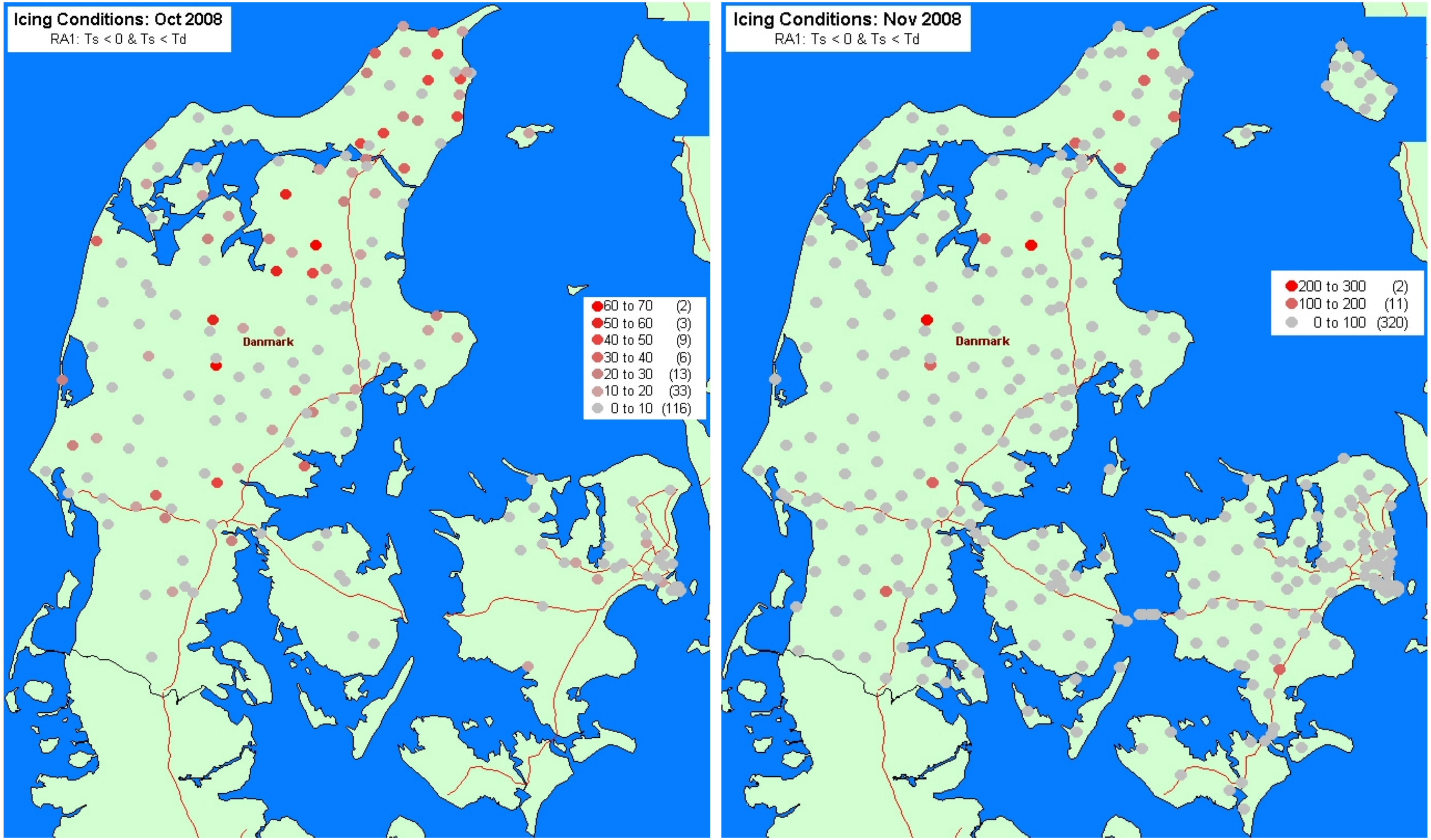


Figure 5A : Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during (left) October 2008 and (right) November 2008 /number in brackets corresponds to number of the road stations with similar conditions, and intensity of the colored symbol corresponds to higher likelihood of icing/.

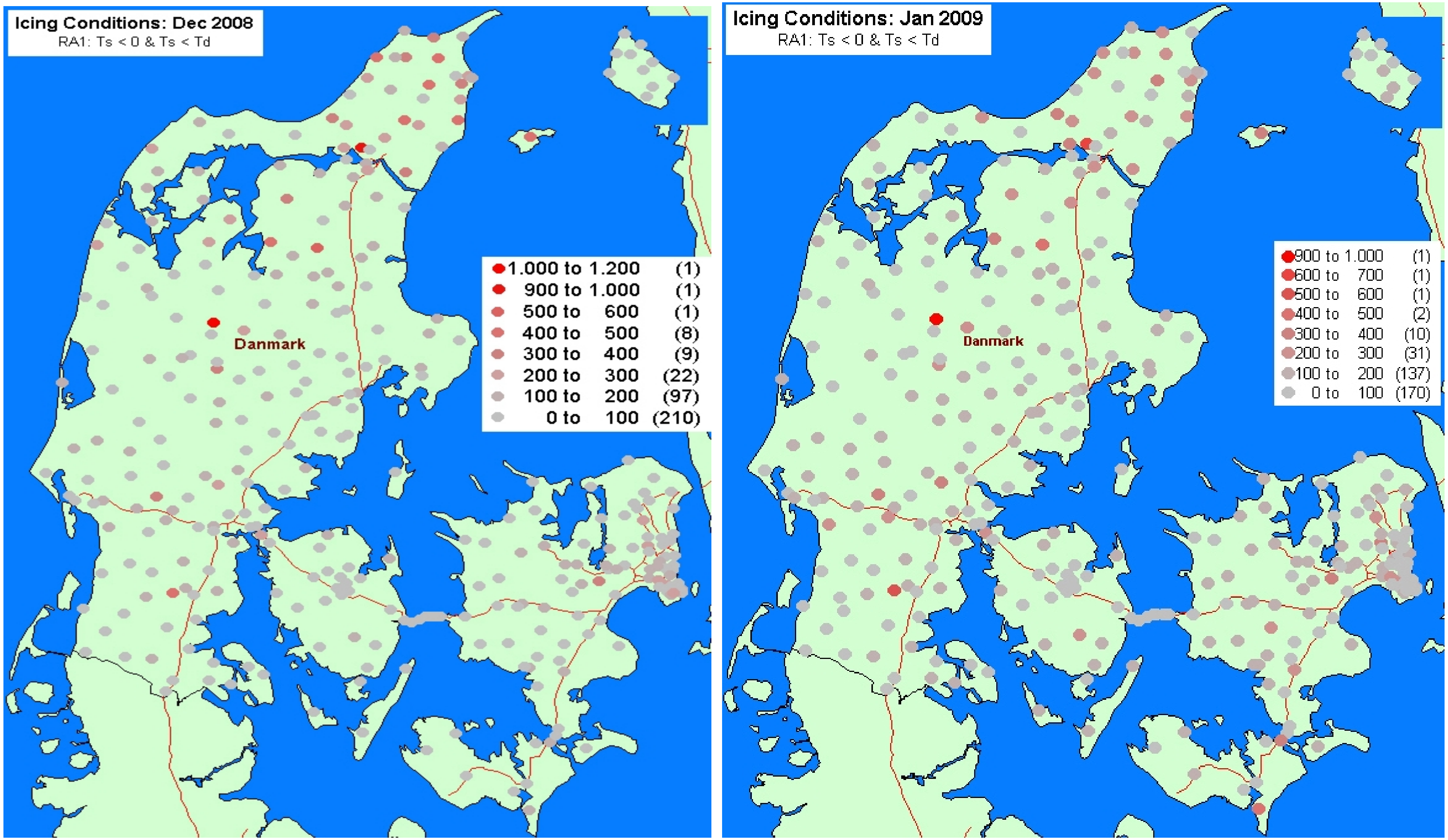
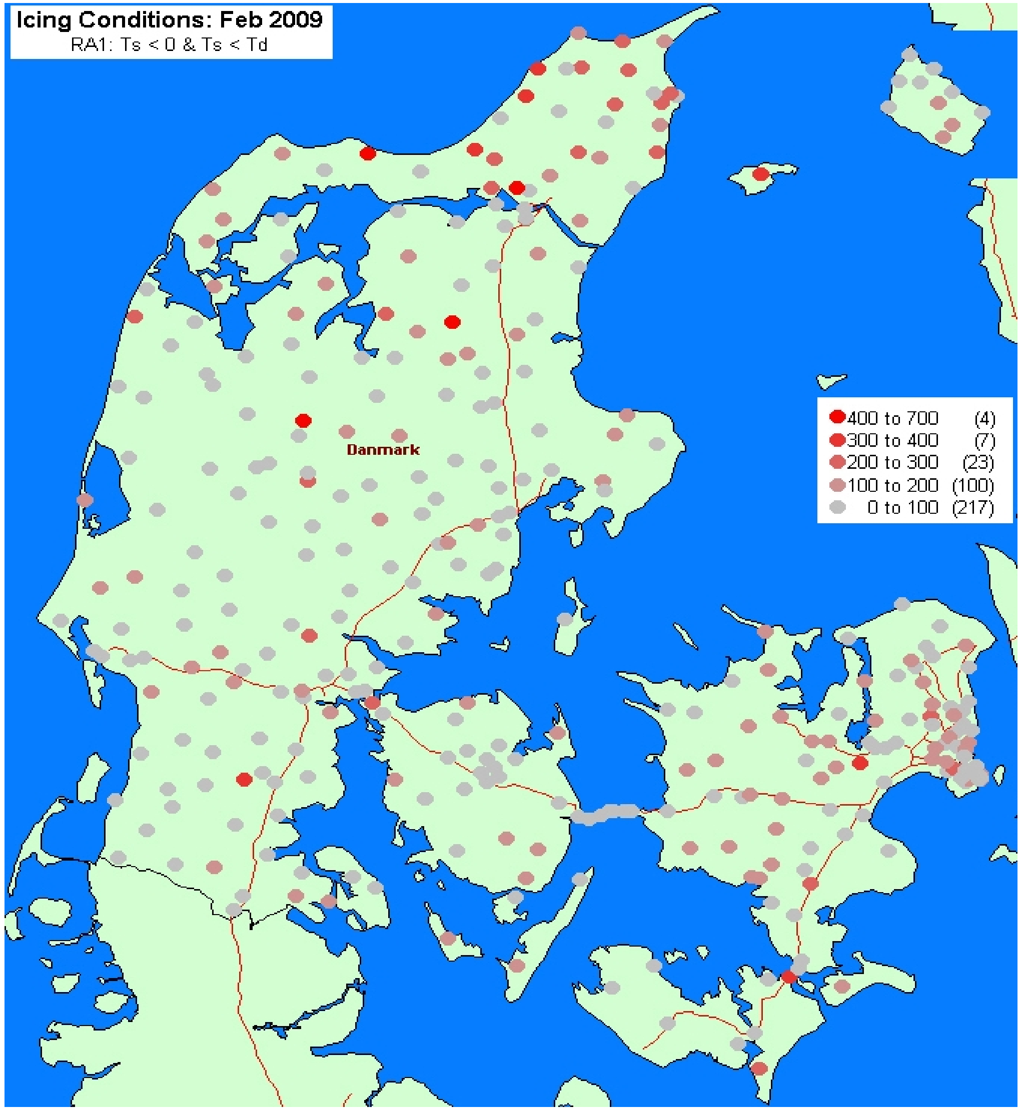


Figure 5B : Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during (left) December 2008 and (right) January 2009 /number in brackets corresponds to number of the road stations with similar conditions, and intensity of the colored symbol corresponds to higher likelihood of icing/.



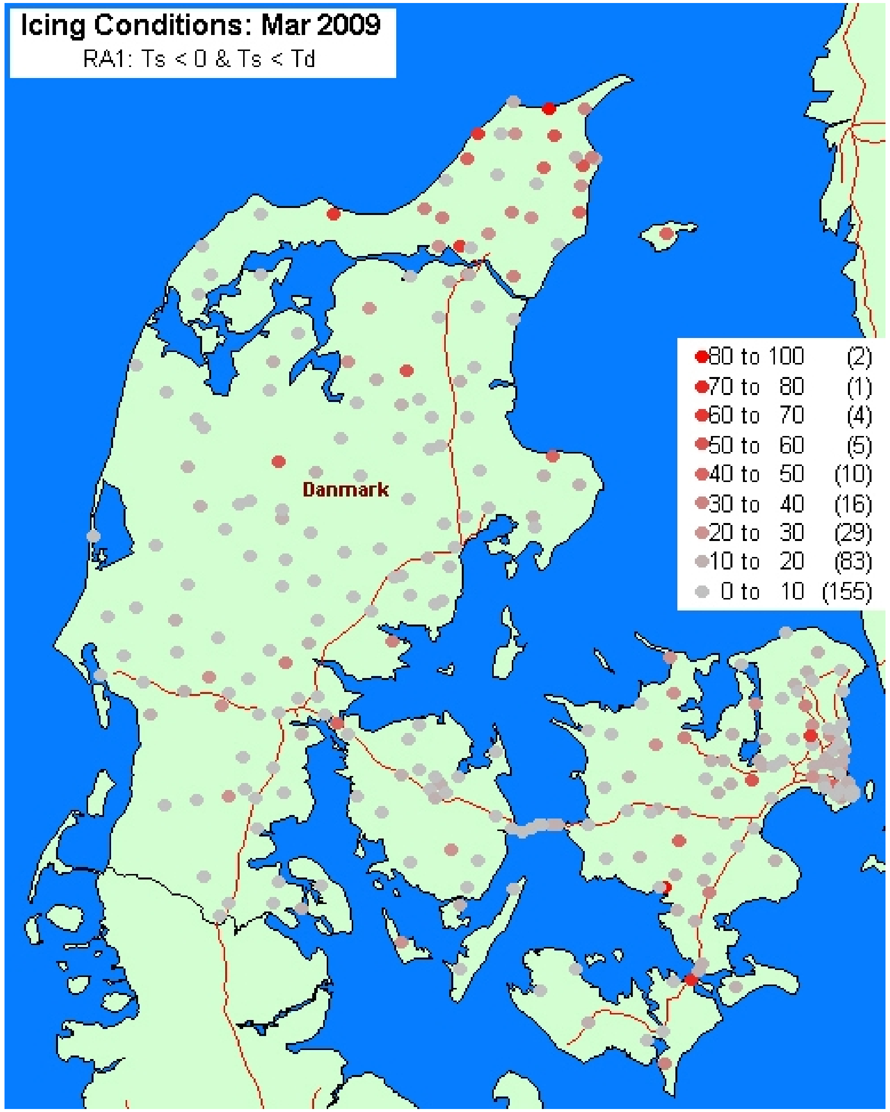


Figure 5C : Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during (left) February 2009 and (right) March 2009 /number in brackets corresponds to number of the road stations with similar conditions, and intensity of the colored symbol corresponds to higher likelihood of icing/.

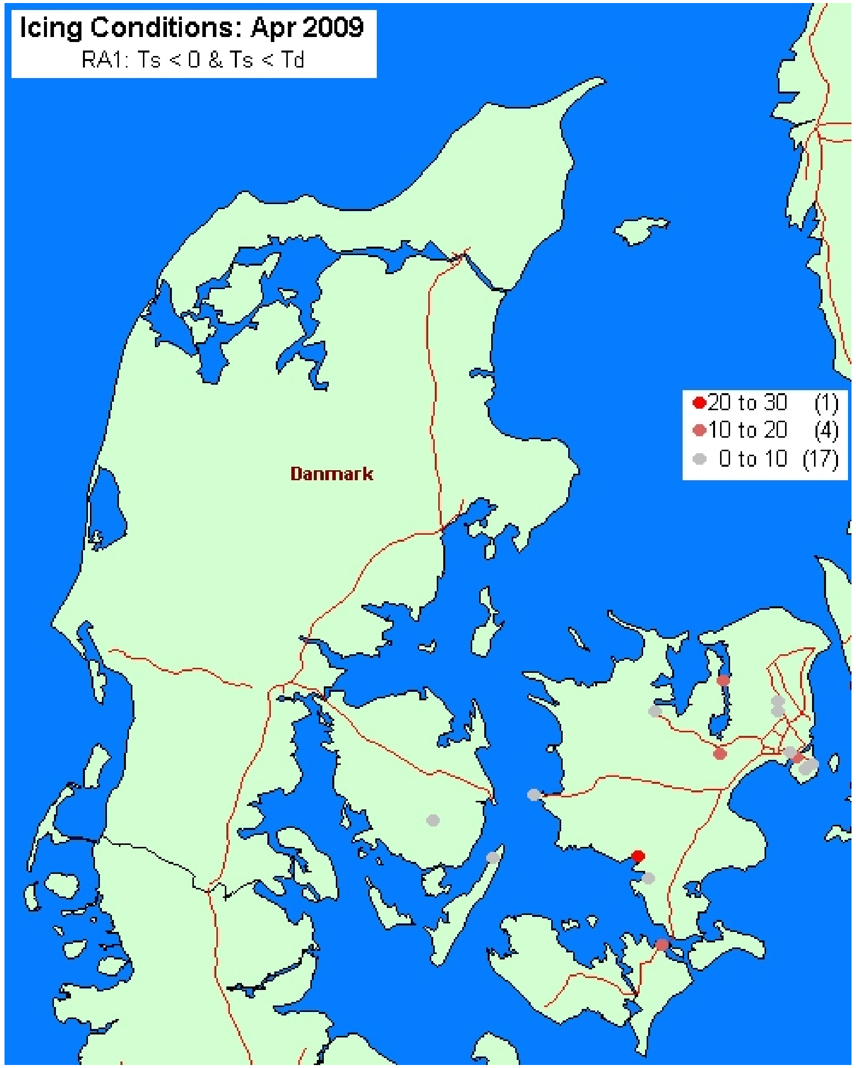


Figure 5D : Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during April 2009 /number in brackets corresponds to number of the road stations with similar conditions, and intensity of the colored symbol corresponds to higher likelihood of icing/.