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Road Weather Modelling System: Verification for 2009-2010 Road Weather Season

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Abstract

For the road weather season (1 October – 1 May) 2009/2010, the scores for the 3 hour forecasts of the road surface temperature with an error of less than ±1ºC is almost 83%, based on more than 473 thousand corresponding forecasts. The overall seasonal averages of the bias and mean absolute error are +0.02ºC and 0.69ºC. This is an improvement compared to season 2008-2009, where the bias and mean absolute error were -0.11ºC and 0.76ºC, respectively.

Resumé

For vejsæsonen (1. October – 1. May) 2009/2010 er scoren for forudsagt vejtemperatur 83%, hvor scoren er defineret som det procentvise antal af 3 timers prognoser for vejtemperatur der har en fejl mindre end ±1ºC. Der indgår ca. 473 tusinde prognoser i beregningen af scoren. For hele sæsonen er bias og middelfejlen henholdsvis +0.02ºC og 0.69ºC. Dette er bedte i forhold til sæsonen 2008-2009, hvor bias og middelfejlen var henholdsvis -0.11ºC og 0.76ºC.

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 as standard 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 h forecasts every hour. For a description of the RWM operational system see the manual *GlatTerm (2004)*. For some previous road seasons the verification reports are given by *Kmit & Sass (1999)*; *Sass & Petersen (2000)*; *Petersen & Nielsen (2000; 2003), Petersen et al., (2007, 2008, 2009)*. Operational irregularities for the 2005-2010 road seasons are listed in Appendix 1 showing 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. Although during the last years the warmer winters have reduced the number of slippery road cases, the recent winter of 2009-2010 was characterized by lower than usual air temperatures and snow conditions starting from the middle of December 2009 and extended further for more than 2 months. Note that a very low number of forecasts had been verified for November 2009.

The verification of the RWM system performance is based on evaluation of the DMI-HIRLAM model used for road forecasts, which is a special version of the DMI-HIRLAM where key parameters are calculated in more than 400 observational points – road stations. In these points the verification is performed. 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 modelled 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, missing observations 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. Note, all road stations (i.e. around 370 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 (i.e. when Ts < 0 and Ts < Td) observed during the 2009-2010 seasons 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 2009-2010

MAE and BIAS for Ts

The Figures 1-2 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 is 0.25ºC (November 2009), and the lowest is –0.01ºC (February 2010). During the road season, on average, it was +0.02ºC. The highest MAE of 0.84ºC is observed in March 2010 and the lowest (0.58ºC) - in January and April 2010. During the season, on average, it was 0.69ºC. The summary of monthly variability for MAEs and BIASes of the *Ts, Ta,* and *Td* temperatures at 5 hour forecasts for the road season 2009-2010 with the corresponding number of the RCM forecasts is given in Table 1).

Month Year		Oct 2009	Nov 2009	Dec 2009	Jan 2010	Feb 2010	Mar 2010	Apr 2010
BIAS	**Ts**	0.23	0.25	0.10	-0.07	-0.01	0.04	0.20
	Ta	1.08	0.43	0.24	-0.08	0.01	0.22	0.58
	Td	0.92	0.50	0.46	0.36	0.46	0.33	0.71
MAE	**Ts**	0.67	0.67	0.73	0.58	0.68	0.84	0.58
	Ta	1.33	0.85	0.73	0.61	0.57	0.79	0.88
	Td	1.21	0.94	0.81	0.75	0.76	0.86	0.94
RCM forecasts		11855	4881	113443	116068	132936	63699	11565
% of Ts_{for} > ±2ºC		1.26	3.25	3.16	1.67	3.75	4.56	1.08

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 2009-2010 with the corresponding number of the RCM forecasts for Ts, 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 2.68%) ranging from 1.08% (April 2010) to 4.56% (March 2010). 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.

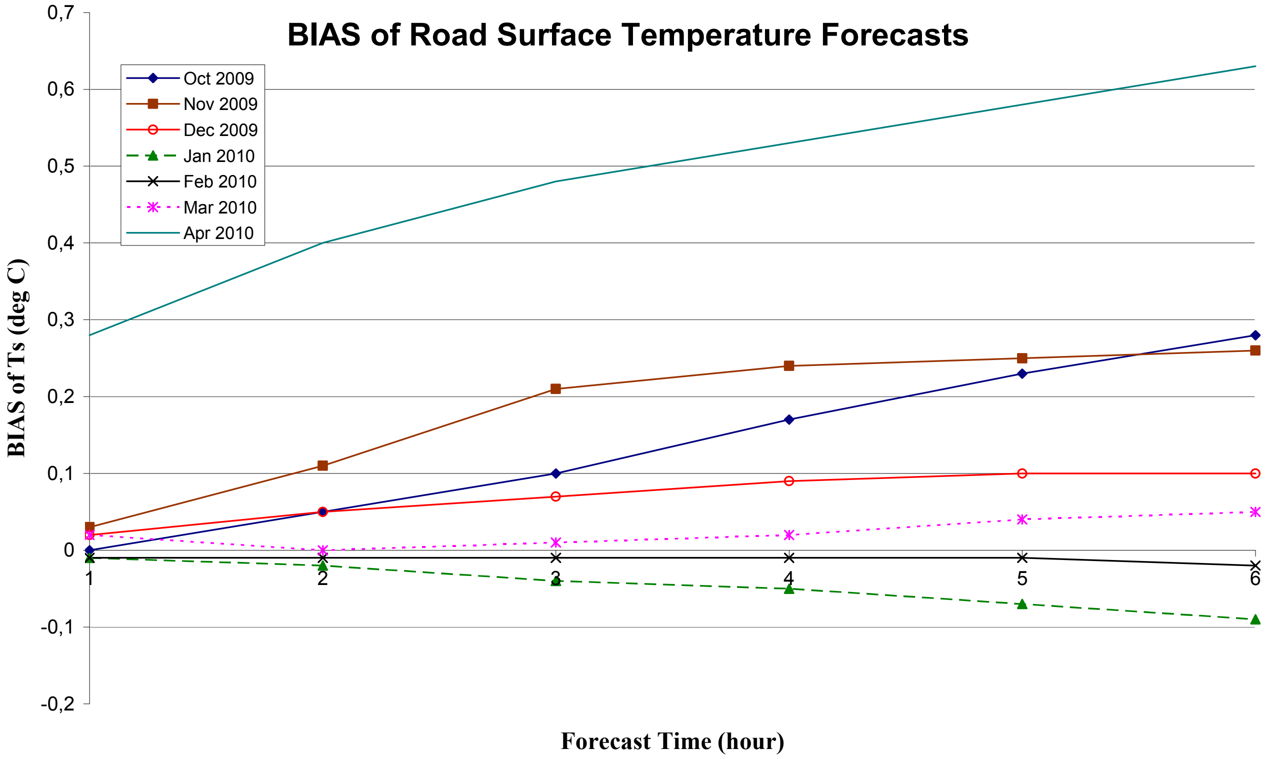

Figure 1. *Monthly variability of the mean error (BIAS) of the road surface temperature (Ts) vs. forecast time for the road weather season 2009-2010.*

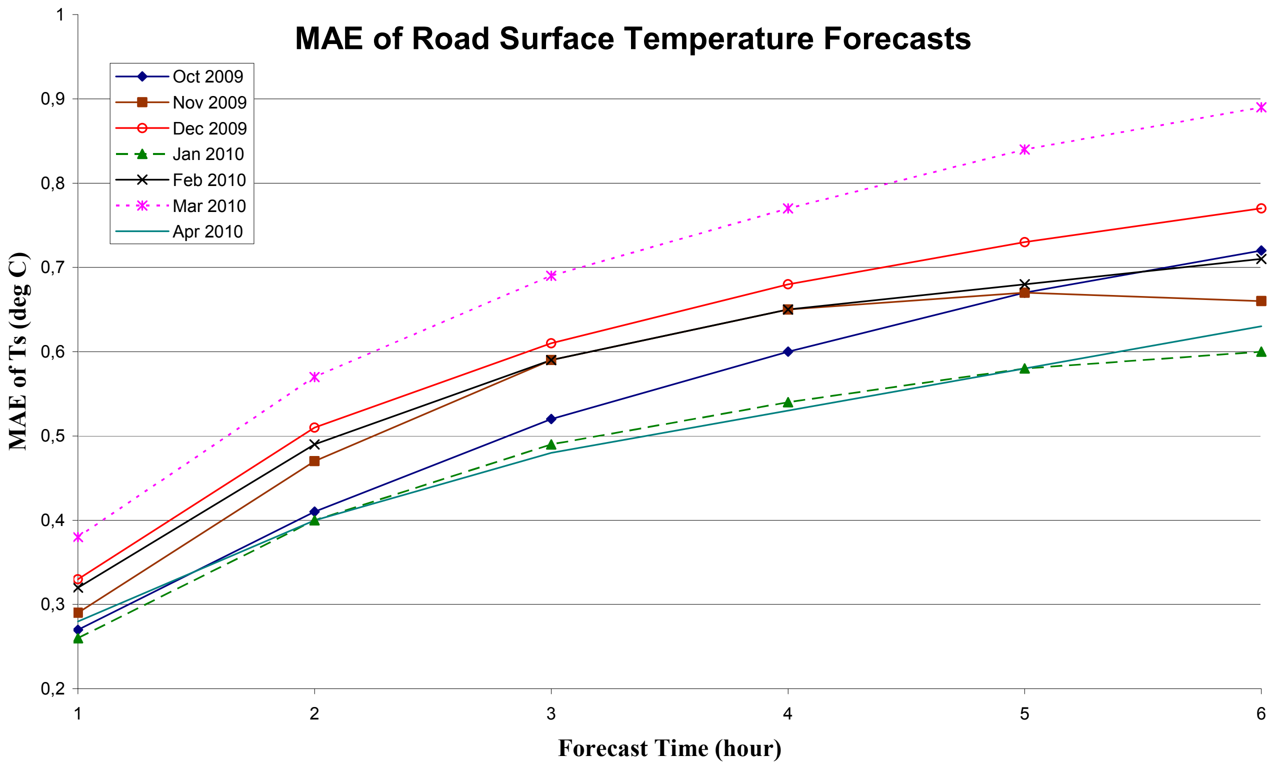

Figure 2. *Monthly variability of the mean absolute error (MAE) of the road surface temperature (Ts) vs. forecast time for the road weather season 2009-2010.*

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 **473628)** 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, 82.5% of the forecasts are within ±1ºC of the observed values (Table 2).

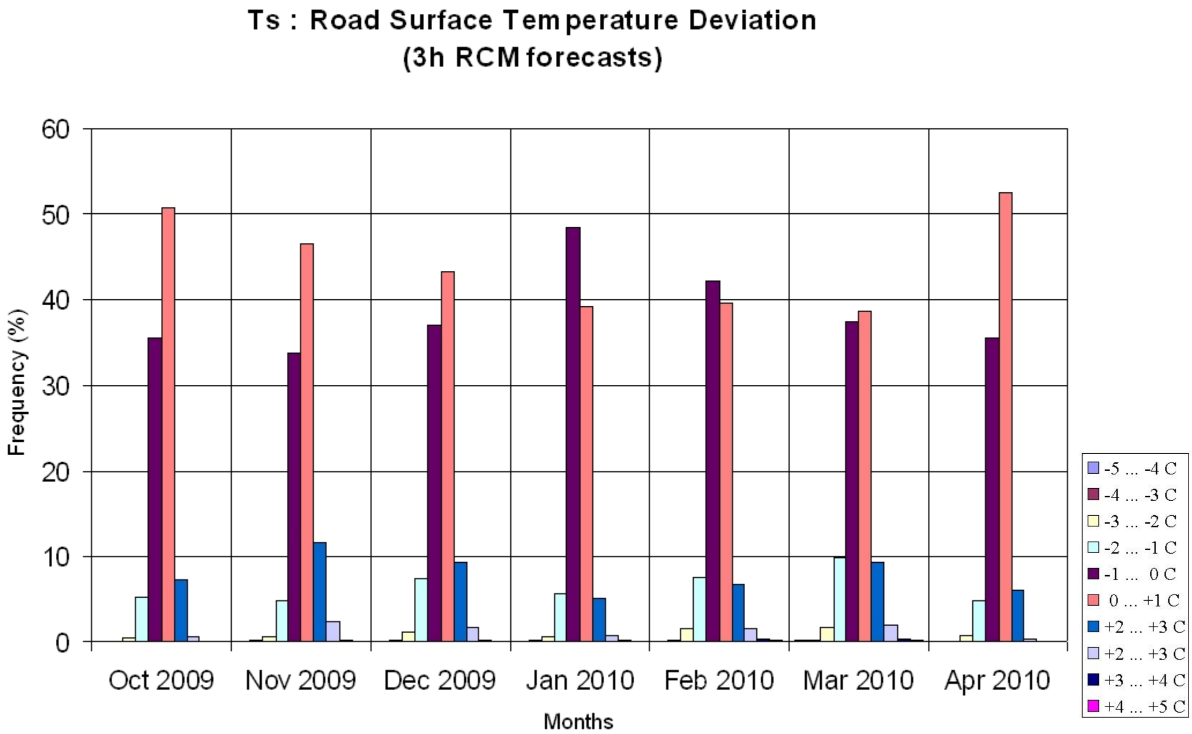

Figure 3. *Monthly variability of the road surface temperature (Ts) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts for season 2009-2010.*

Road Season	**2009-2010**	
Month	**scores**	**N**
October	86.28	13169
November	80.40	5843
December	80.24	116307
January	87.63	120423
February	81.98	138204
March	76.12	66203
April	88.09	13479
Season	**82.44**	**473628**

Table 2. *Summary of monthly scores for the RCM forecasts within a range of ±1ºC with the corresponding number of forecasts and observations during road weather season 2009-2010.*

3. Concluding Remarks

For this season the verification has a better score (by almost 3%) compared with the previous one (2008-2009). There is a weak tendency to higher verification scores of the road surface and air temperatures in middle winter and spring. For the last five seasons (2005-2006, 2006-2007, 2007-2008, 2008-2009, and 2009-2010) the score for 3 hour *Ts* forecasts (in the interval ±3°C) with an error of less than ±1°C is almost 80, 83, 81, 80, and 82.5%, respectively. For each month of these seasons the scores (with corresponding number of forecasts) are summarized in Table 3.

Month	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**Season**
Road Season - 2005-2006								
Scores	88.5	73.5	80.9	83.2	81.5	71.7	-	**80**
N	4273	71760	137505	173149	152042	96479	-	**635208**
Road Season - 2006-2007								
Scores	97.1	79.7	75.0	76.5	84.4	84.2	-	**83**
N	35	21644	24106	55189	127007	31546	-	**259527**
Road Season - 2007-2008								
Scores	82.7	76.3	80.9	83.1	79.8	75.9	85.5	**81**
N	12369	78434	63487	122915	67884	80306	16873	**442268**
Road Season - 2008-2009								
Scores	79.72	74.03	78.67	79.63	80.78	82.49	91.43	**80**
N	9420	54275	122747	164389	134052	30627	3560	**519070**
Road Season - 2009-2010								
Scores	86.28	80.40	80.24	87.63	81.98	76.12	88.09	**82.44**
N	13169	5843	116307	120423	138204	66203	13479	**473628**

Table 3. *Summary of monthly and overall season scores for the RCM forecasts within a range of ±1°C (with corresponding number of forecasts, N) during recent road weather seasons 2005-2010.*

The summary for averaged seasonal values of the mean error, BIAS and mean absolute error, MAE for the Danish road seasons of 2005-2010 is given in the Table 4.

As seen, for the season of 2009-2010, for the road surface temperature, *Ts,* the bias has changed from -0.11°C to +0.02°C, and note that for the last five seasons the bias is gradually improving. The mean absolute error has been improved for the last three seasons from 0.78°C to 0.76°C, and then during this season reaching a value of 0.69°C.

For the air temperature, *Ta,* the bias has been changed from 0.02°C to 0.12°C; and the mean absolute error has been improved for last three seasons from 0.81°C to 0.72°C, and then during this season reaching a value of 0.68°C.

For the dew point temperature, *Td,* the bias has changed from 0.24°C to 0.44°C; and the mean absolute error has been changed from 0.75°C to 0.80°C.

Road Season		2005-06	2006-07	2007-08	2008-09	2009-10
BIAS	**Ts**	0.31	0.22	0.18	-0.11	0.02
	Ta	0.15	-0.02	-0.04	0.02	0.12
	Td	0.27	0.33	0.31	0.24	0.44
MAE	**Ts**	0.78	0.74	0.78	0.76	0.69
	Ta	0.80	0.77	0.81	0.72	0.68
	Td	0.86	0.86	0.87	0.75	0.80
Score		80	83	81	80	82.5

Table 4. *Summary of overall BIAS and MAE of the road surface temperature (Ts), air temperature (Ta), and dew point temperature (Td) for the road seasons of 2005-2010.*

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 has been the coldest for the last 14 years in the Danish observations 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

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Appendix 1. Changes in RWM Setup during Road Seasons

During the road weather seasons 2005-2010 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.

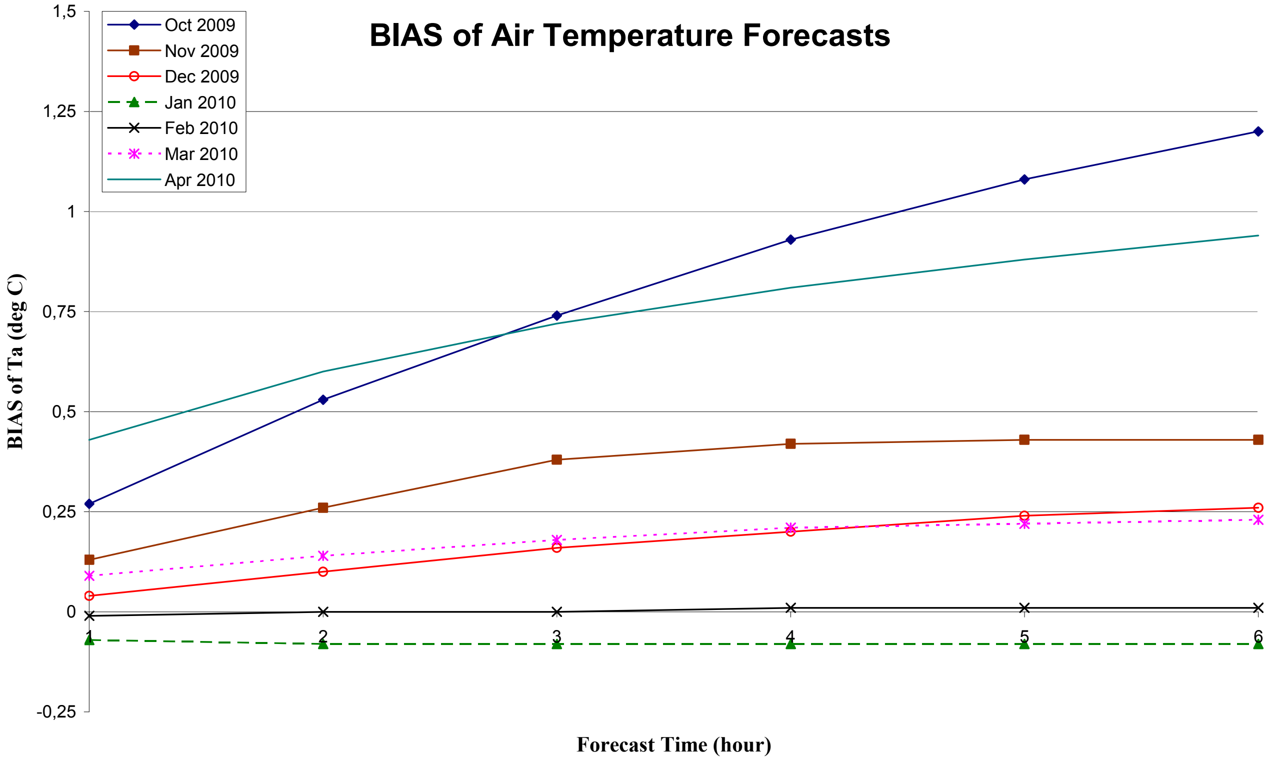
- **2006/2007:** On average about 99.7 % of the forecasts are performed without problems. Most errors have been caused by network or computer hardware errors. On average about 1 model run each month crashes due to numerical instabilities. On January 29 2007, the heat conductivity constant for road was 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.

- **2009/2010:** There have been changes in the snow melting in HIRLAM. Precipitation in the road model is now using HIRLAM snow and rain intensity rather than post-processing of total precipitation. 100% of all forecasts have been performed. However, some might be delayed due to error in the distribution. Few forecasts in October 2009 were delayed for this reason.

Appendix 2. Verification of 2 m Air Temperature for Road Season 2009-2010



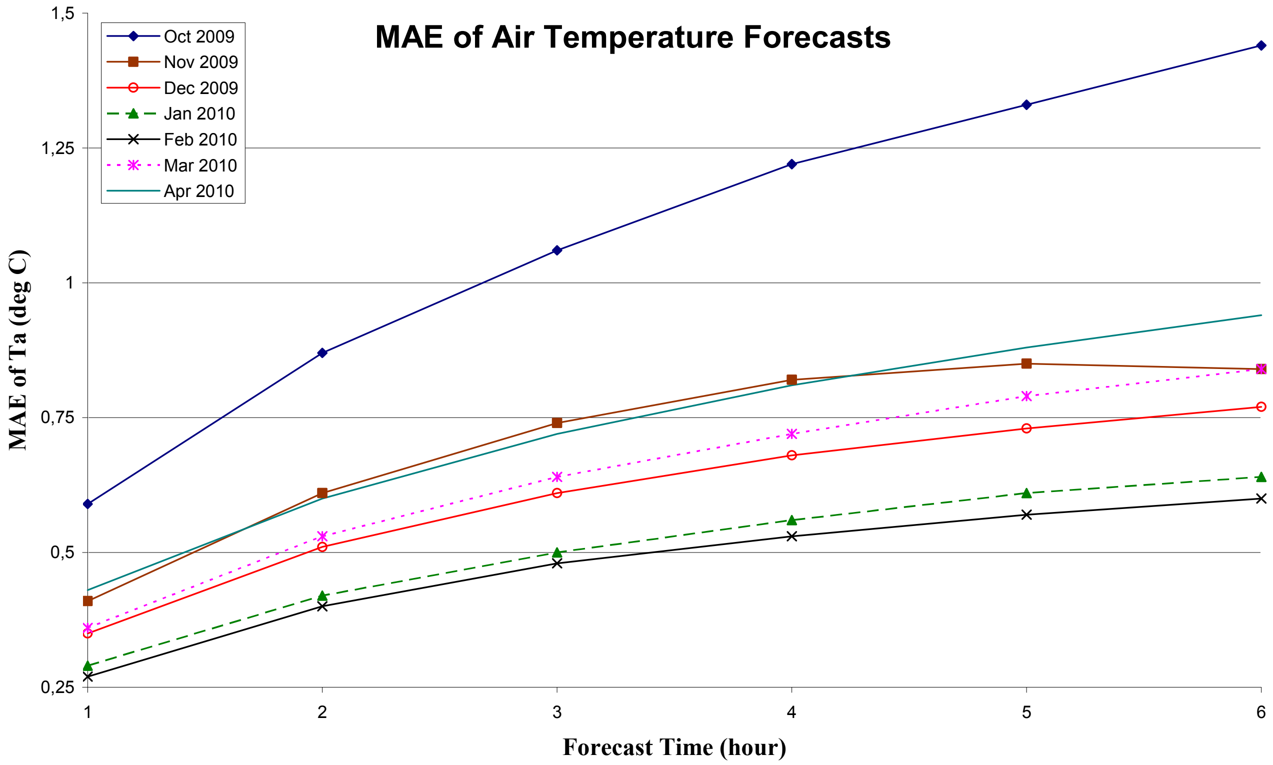
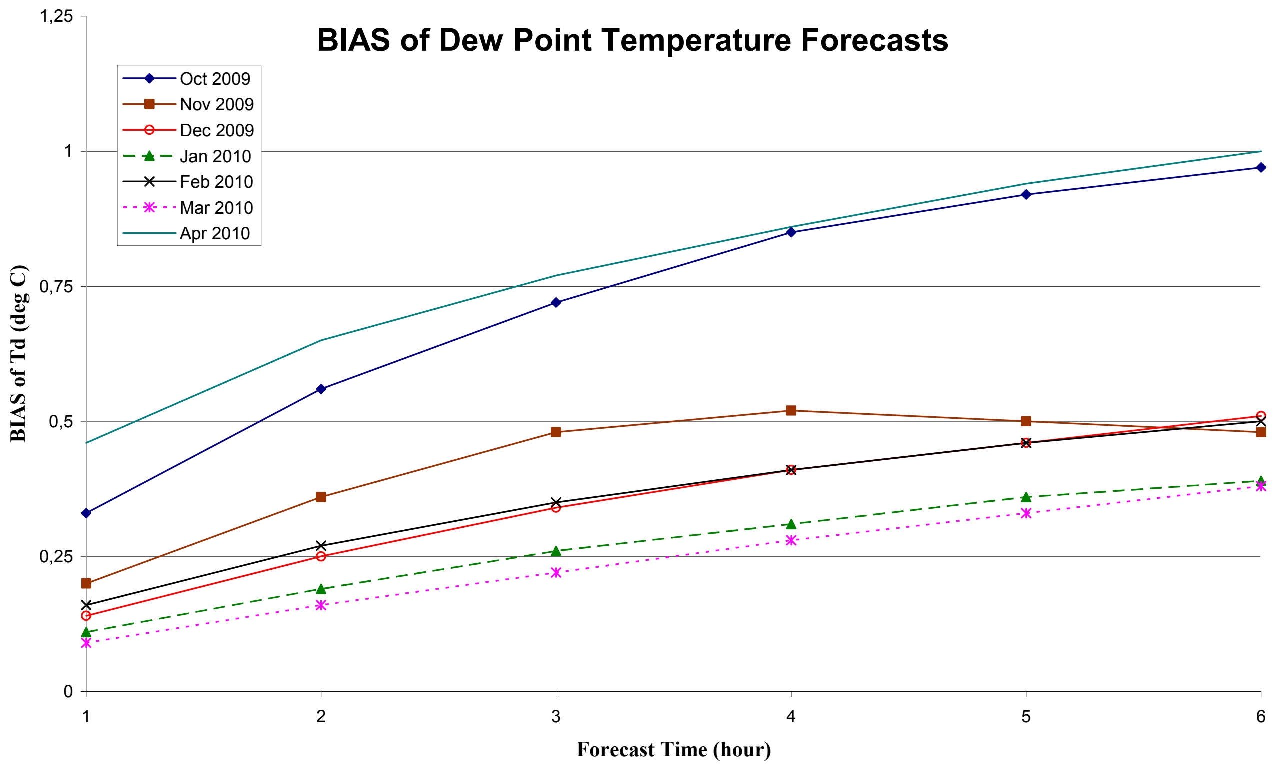


Figure 2A. *Monthly variability of the mean error, BIAS (top) and mean absolute error, MAE (bottom) of the air temperature (Ta) vs. forecast time for the road weather season 2009-2010.*

Appendix 3. Verification of 2 m Dew Point Temperature for Road Season 2009-2010



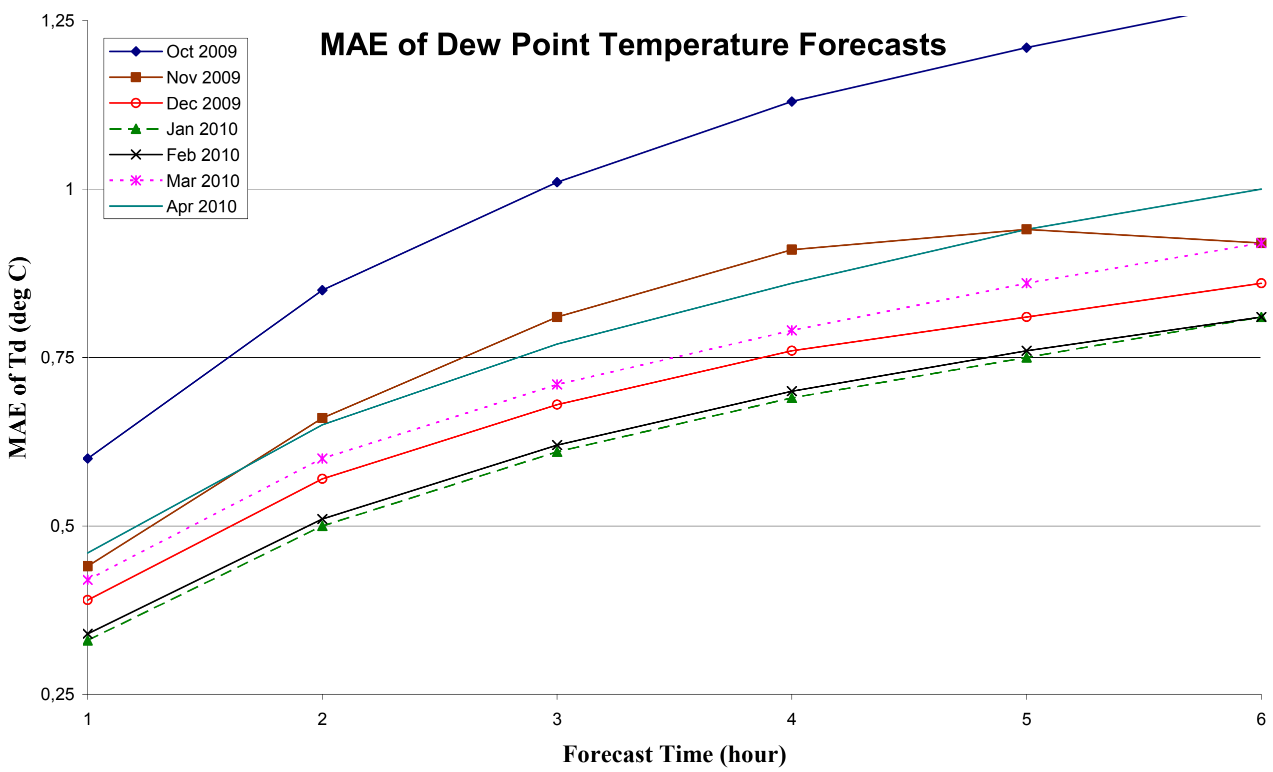


Figure 3A. *Monthly variability of the mean error, BIAS (top) and mean absolute error, MAE (bottom) of the dew point temperature (Td) vs. forecast time for the road weather season 2009-2010.*

Appendix 4. Monthly Variability of Air and Dew Point Temperatures Deviations as Error Frequencies for Road Season 2009-2010

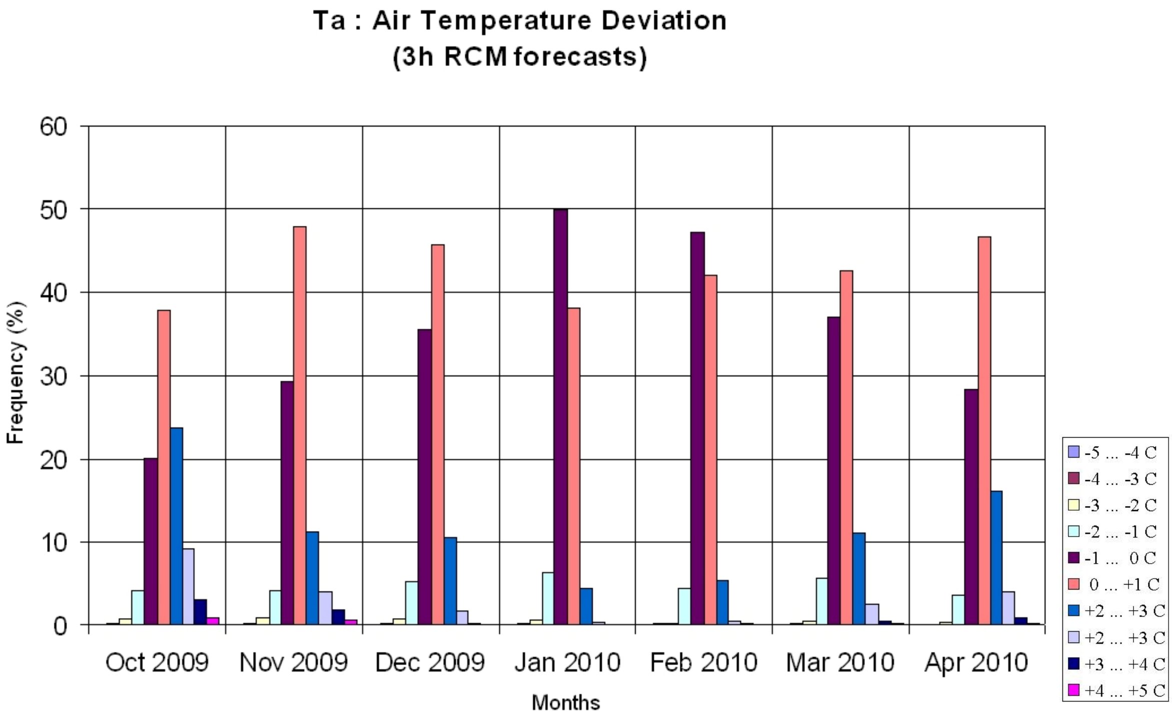


Figure 4A. *Monthly variability of the air temperature (Ta) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts for season 2009-2010.*

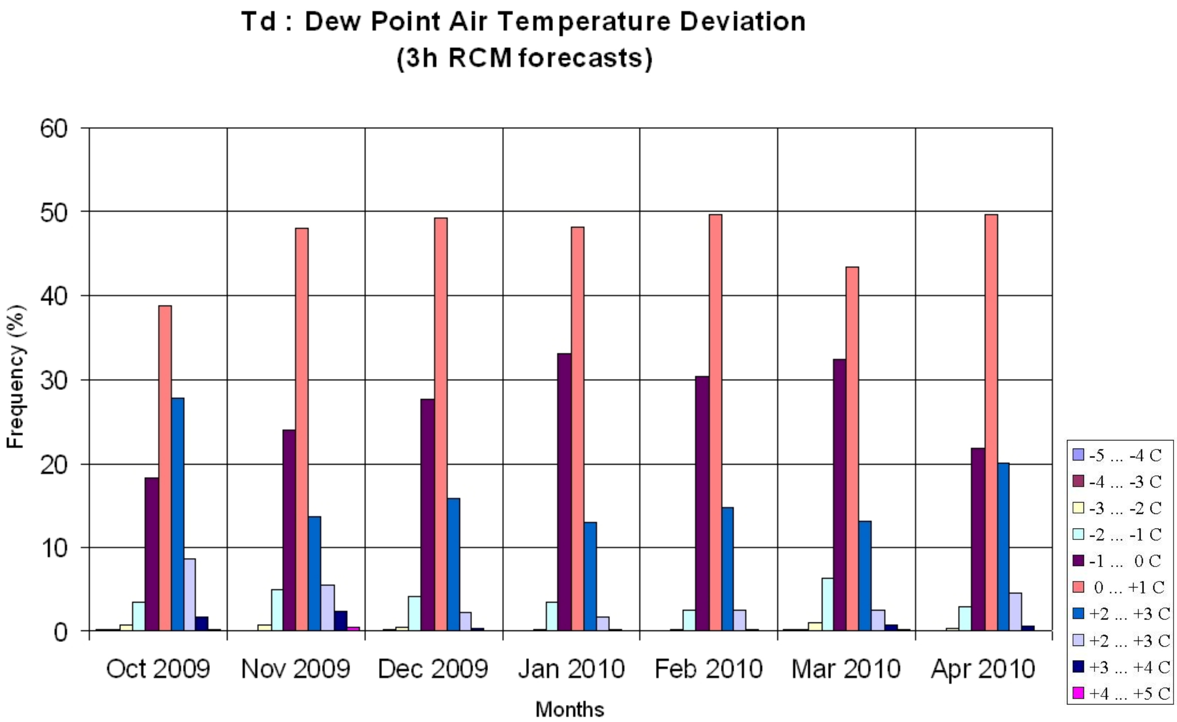


Figure 4B. *Monthly variability of the dew point temperature (Ta) deviations as error frequencies (%) for the Danish road stations based on 3 hour RCM forecasts for season 2009-2010.*

Appendix 5. Monthly Variability of Road Icing Conditions in Denmark for Road Season 2009-2010

Table 5A. *Top 10 road stations with largest number of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1: Ts < 0 and Ts < Td) observed at the Danish road stations during road weather season 2009-2010 (total number of cases at all road stations is equal to 166226, with smallest number – 145 – in November 2009, and largest number – 55329 – in January 2010).*

Road Station	***Oct 2009***	***Nov 2009***	***Dec 2009***	***Jan 2010***	***Feb 2010***	***Mar 2010***	***Apr 2010***	***Season 2009-2010***
6800	12	8	1254	1207	695	309	4	3489
5800	1	9	485	1156	736	324	17	2728
6123	3		624	622	438	271	4	1962
6181	38	6	705	544	403	249	2	1947
3800	5	6	339	734	508	262	2	1856
6015	17	2	636	707	290	115	5	1772
2019	10		325	539	381	216	21	1492
6160	2		336	535	368	207		1448
1015			258	606	326	195		1385
6125	1		476	424	255	197		1353

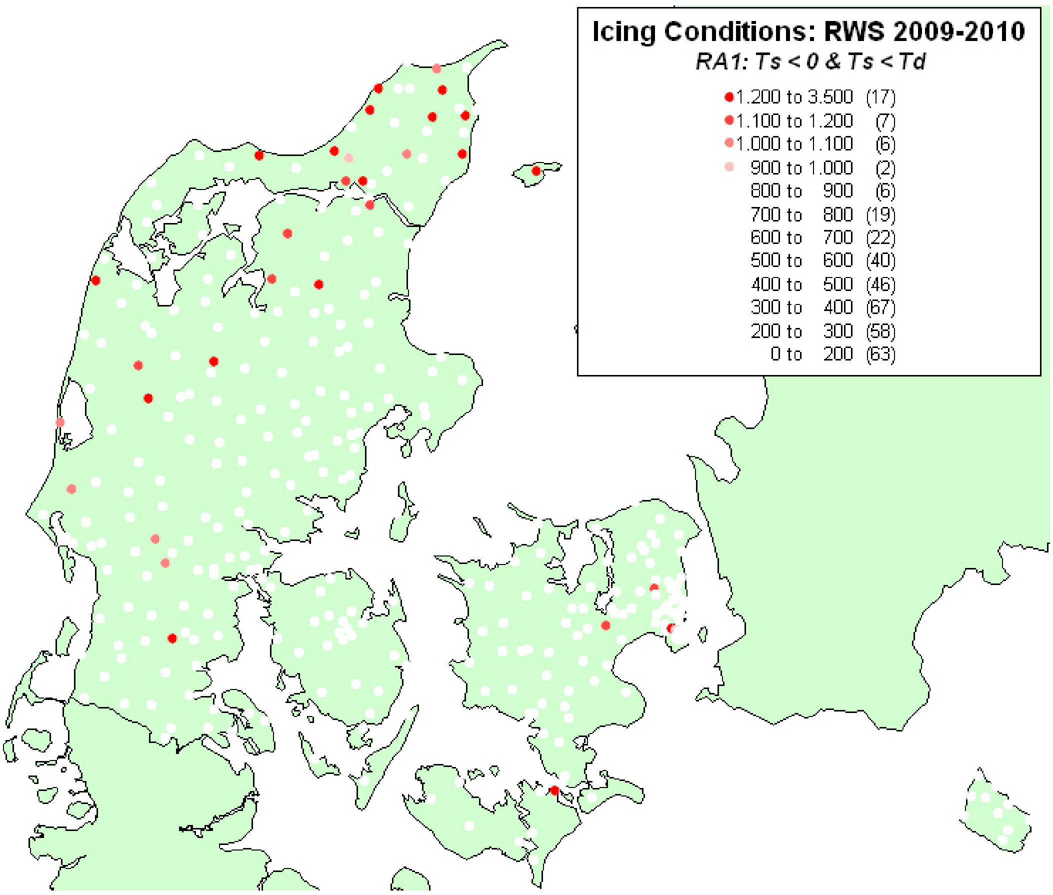


Figure 5A. *Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during October 2009 – April 2010 /number in brackets corresponds to number of the road stations with similar conditions, and intensity of the colored symbol corresponds to higher likelihood of icing/.*

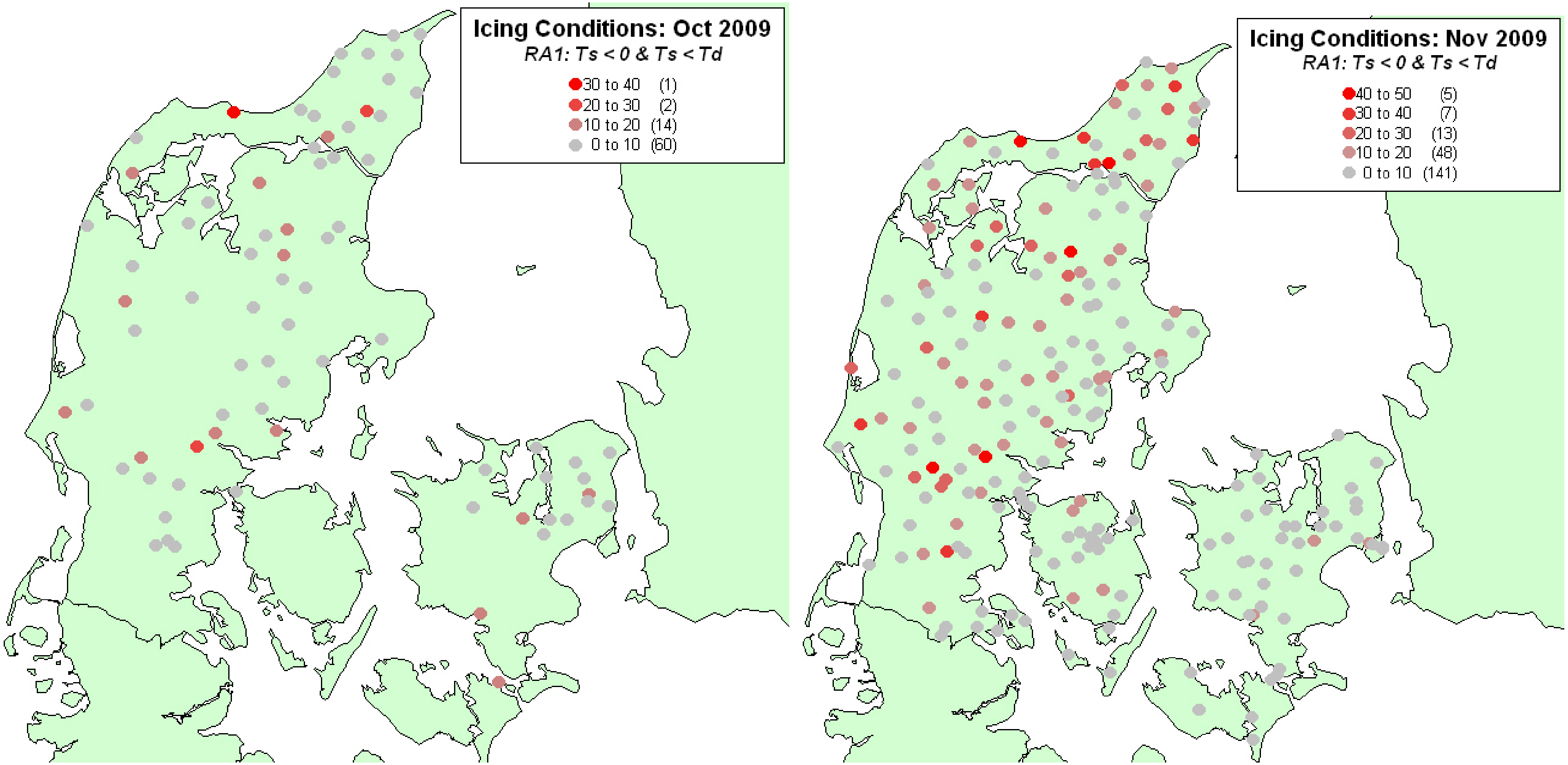


Figure 5B. *Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during (left) October 2009 and (right) November 2009 /number in brackets corresponds to number of the road stations with similar conditions,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

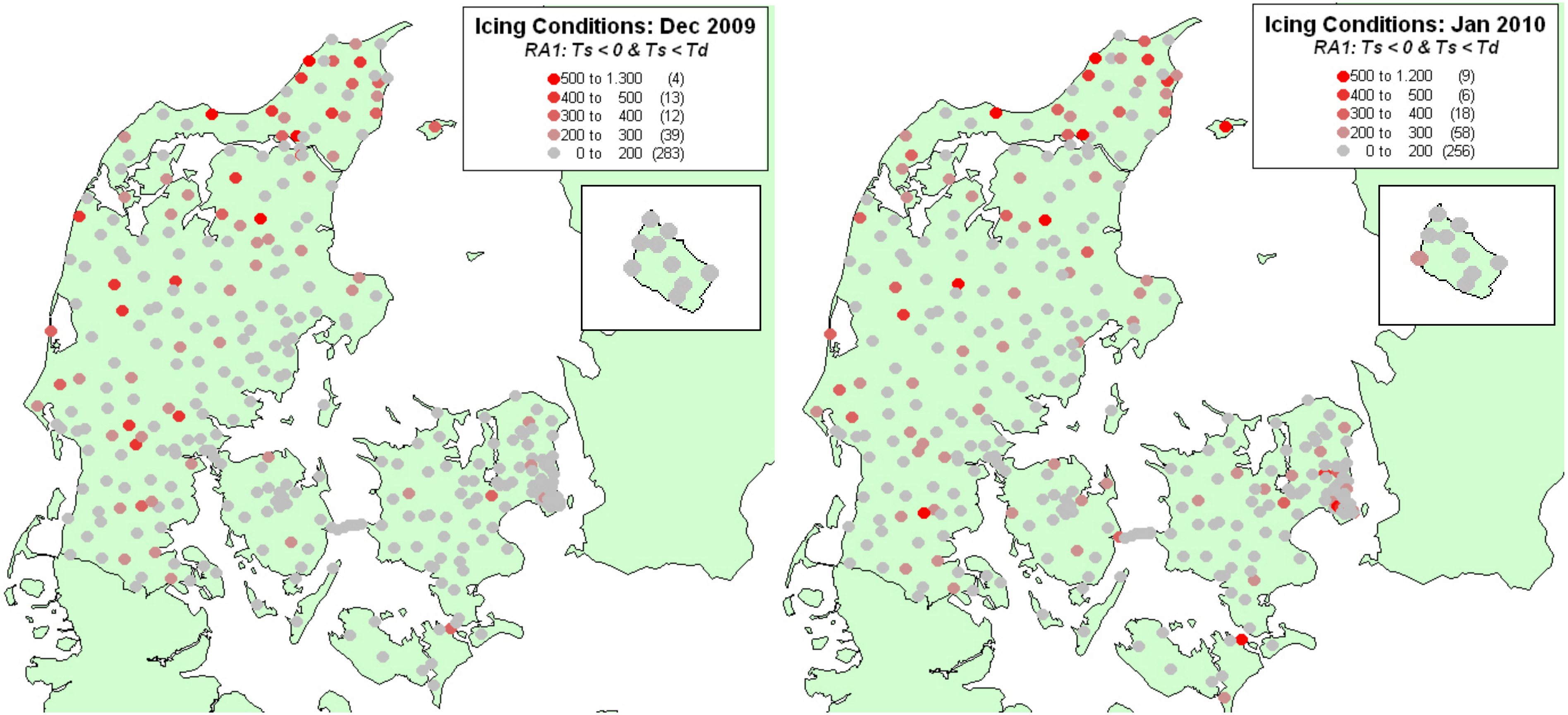


Figure 5C. *Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during (left) December 2009 and (right) January 2010 /number in brackets corresponds to number of the road stations with similar conditions, and intensity of the colored symbol corresponds to higher likelihood of icing/.*

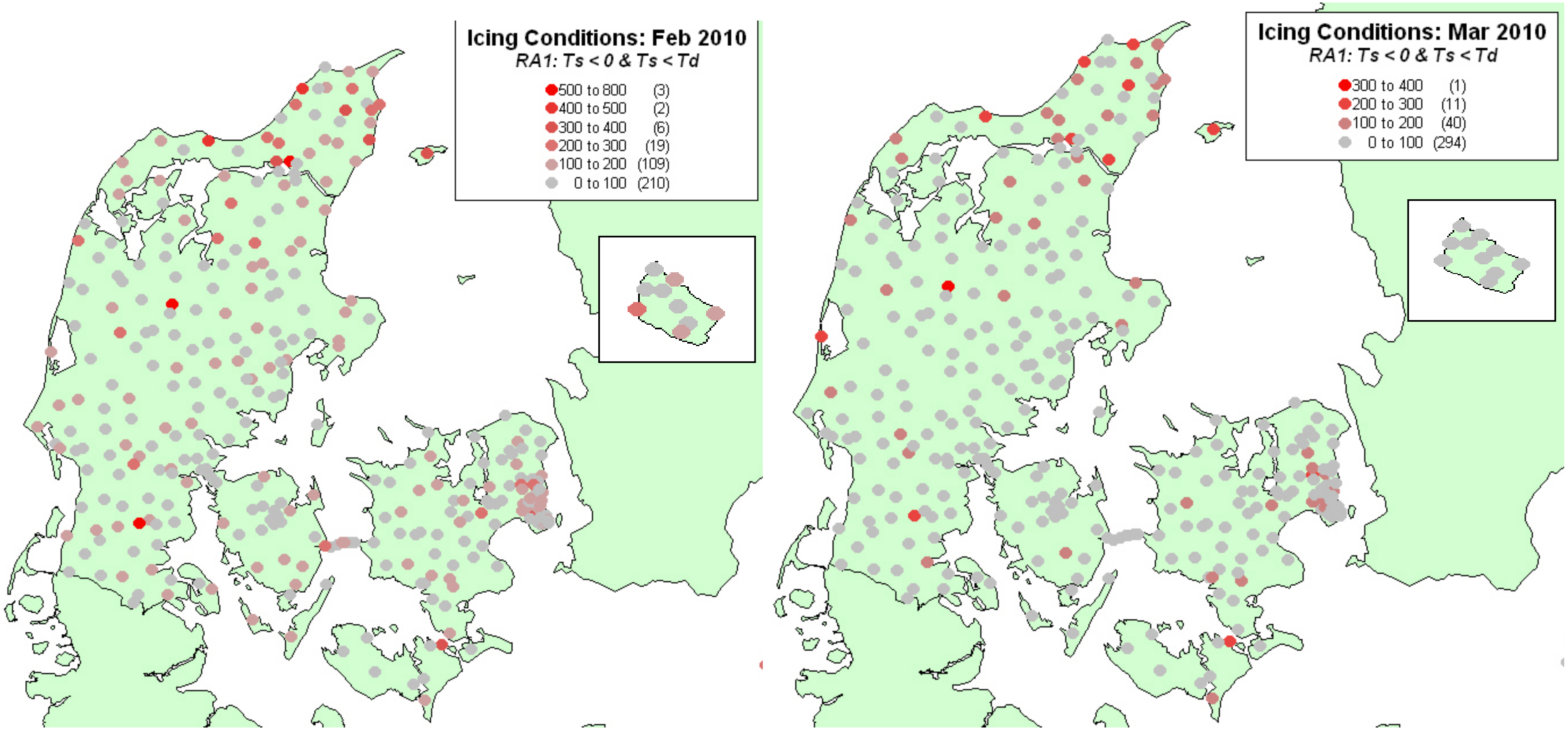


Figure 5D. *Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during (left) February 2010 and (right) March 2010 /number in brackets corresponds to number of the road stations with similar conditions, and intensity of the colored symbol corresponds to higher likelihood of icing/.*

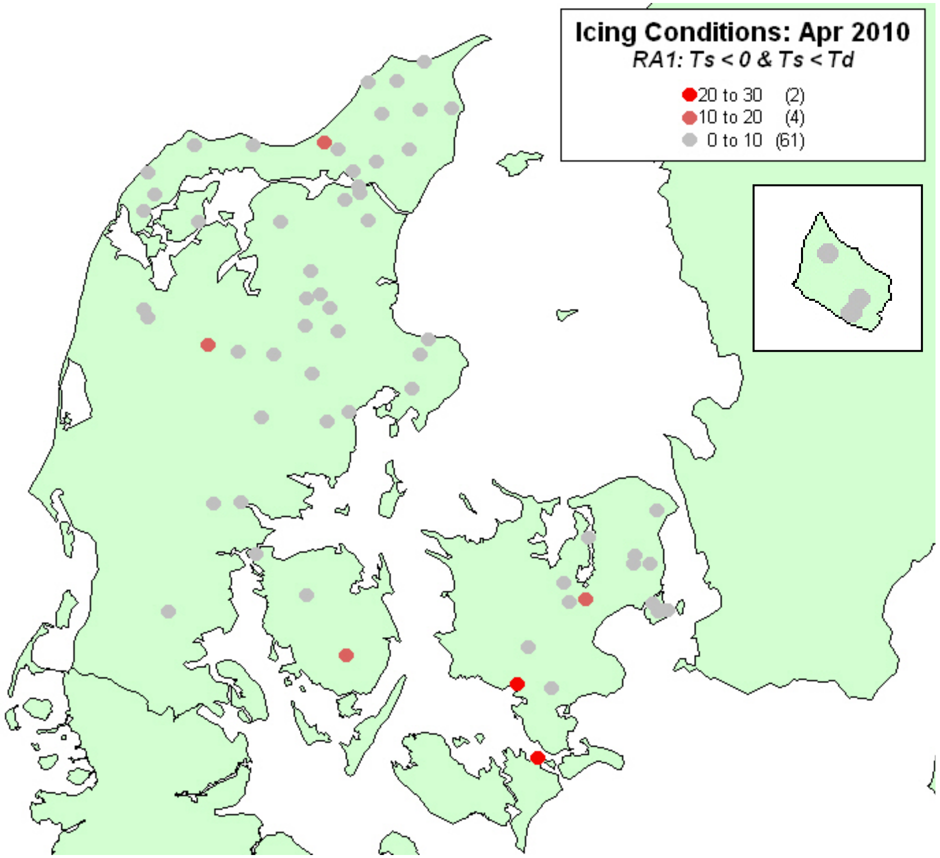


Figure 5E. *Spatial distribution of occurrences of the conditions leading to icing on the roads for the red alert situations (RA1) observed at the Danish road stations during April 2010 /number in brackets corresponds to number of the road stations with similar conditions, and intensity of the colored symbol corresponds to higher likelihood of icing/.*