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Title: **IRWIN a winter road index***

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ABSTRACT

The main objective of IRWIN is to develop an improved winter road index capable of assessing the implications of climate change in various weather parameters and also related costs and benefits. Climate change scenarios have so far been calculated based on ordinary meteorological data, which have large limitations in respect to resolution. The idea of IRWIN is to combine the best traditionally made climate scenarios with the much more accurate spatial data from field stations in the Road Weather Information systems (RWIS) installed in most northern hemisphere countries.

The data collection phase of IRWIN revealed that there is enough archived RWIS data in Sweden and Finland to perform the planned winter index development. Ten years of observations were collected from 50 road weather stations in Sweden and 49 stations in Finland. Observations in each country were divided into three regions with distinctive climatic characters. Extensive processing had to be performed first to create a high-quality database with corrected and uniform observations. Maintenance activities from the regions of interest were collected as well, to be used in the winter index calculations.

Target user groups of IRWIN results are the road owners and administrations in ERA-NET countries and the EU.

*) Short version of: IRWIN Report Nr 2, 1.6.2009 and report Nr 3 10.12.2009.
Project Nr. TR80A 2008:72539.

1.Introduction

This study is a part of ERA-NET ROAD – Coordination and Implementation of Road Research in Europe which was a Coordination Action funded by the 6th Framework Programme of the EC. The partners in ERA-NET ROAD (ENR) were United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.road-era.net). Within the framework of ENR this joint research project was initiated. The funding National Road Administrations (NRA) in this joint research project are Federal Ministry of Transport, Innovation and Technology (BMVIT), Austria, Federal Ministry of Transport, Building and Urban Affairs (BMVBS), Germany, Ministry of Transport, Danish Road Directorate (DRD), Denmark, Centre for Studies and Research in Public Works (CEDEX), Spain, Finnish Road Administration (Finnra), Finland, National Roads Authority (NRA), Ireland, Directorate of Public Works and Water Management (RWS), the Netherlands, Norwegian Public Roads Administration (NPRA), Norway, General Directorate of National Roads and Motorways (GDDKiA), Poland, Swedish Road Administration (SRA), Sweden, and Department for Transport, Highways Agency (HA), the United Kingdom.

IRWIN is one of the research and development projects initiated by ERA-NET ROAD in 2008. The main objective of IRWIN is to develop an improved winter road index capable of assessing the implications of climate change in various weather parameters and also related costs and benefits.

Climate change scenarios have so far been calculated based on ordinary meteorological data, which have large limitations in respect to resolution. The idea of IRWIN is to combine the best traditionally made climate scenarios with the much more accurate spatial data from field stations in the Road Weather Information systems (RWIS) installed in most northern hemisphere countries.

After the initial data collection phase, the raw archived observational data to be processed into regular interval time series. The Finnish and Swedish data werereformatted to similar data format. Once a good quality observational database was completed, the climate downscaling task was started to establish the climate database. Weather classes were developed to select the historical analogue days matching the future days.

The final phase of the project developed a winter index technique to evaluate such phenomena as the spatial variations of winter maintenance needs as well as the cost/benefit of various winter maintenance strategies. Target user groups of IRWIN results are the road owners and administrations in ERA-NET countries and the EU.

2. Methods

Historical observations were analyzed to understand how the actual climates in the study areas were, to see the natural variations in climate both within and between the six different regions (fig. 1) and to be able to compare the observed values to the future modeled changes. Data from the 1st of October to the 31st of March, 1997 to 2008 were analyzed. It was on the historical data that the modeled future scenarios were done.
In this study the change in climate was calculated as the average temperature, precipitation or wind speed during the winter period (1st of November to the 31st of March) from 2025 to 2055 minus the average from the same months from 1980 to 2010. Two models were used, the "ECHAM5" and the "CCSM3".

The spatial resolution of GCMs is too rough to be used for climate change studies on regional and local scales. Instead, *IRWIN* uses statistical downscaling to combine the GCM climate change scenarios and the historical road-weather station data. Statistical downscaling identifies relationships between large-scale atmospheric patterns and road weather from historical time-series, and then applies these relationships to the large-scale patterns from GCM outputs to obtain climate change scenarios at a local scale.

Table 1, mean road and air temperature per region from the 1st of October to the 31st of March, 1997 to 2008.

Area	Road T (˚C)	Air T (˚C)
S1	0.63	0.78
S2	-0.44	-0.24
S3	-4.52	-4.10
F1	-2.38	-2.39
F2	-4.05	-4.29
F3	-5.50	-5.50

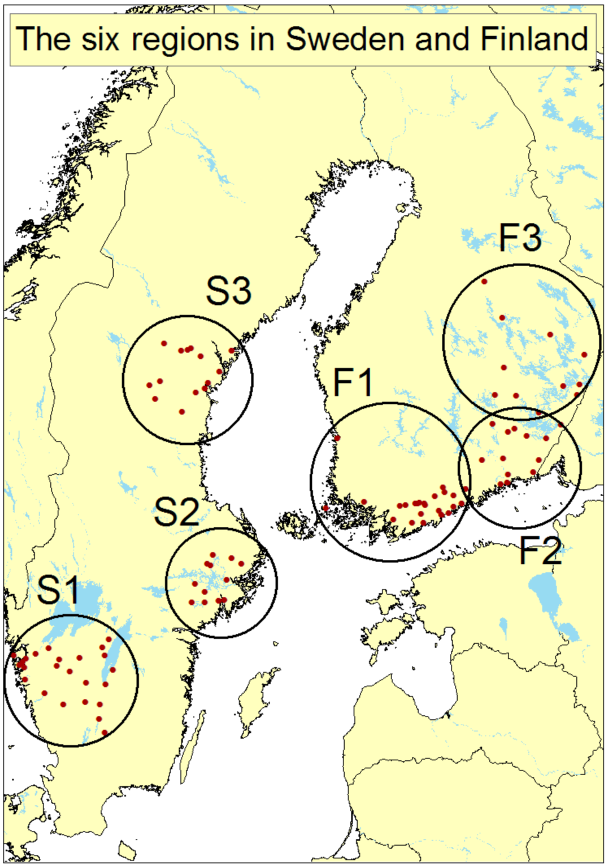

Figure 1: The six regions and the stations in Sweden and Finland.

IRWIN uses the analogue model for statistical downscaling. This method involves iterating over each day in the GCM future scenario, and for each day finding the day in the historical record for which the large-scale atmospheric patterns match most closely. The future roadweather for each future day is taken to be the historical road-weather on the most closely matched historical day. By using measures of both atmospheric circulation and temperature, future time-series were generated where (under global warming) the winter road-climate of the future becomes more similar to the fall/spring climates of today.

3. Results

The resulting half-hourly datasets contain all the original climate parameters. These will allow stakeholders to generate graphs and statistics which give meaningful information about the climate scenarios. Some examples are shown here to demonstrate what is possible.

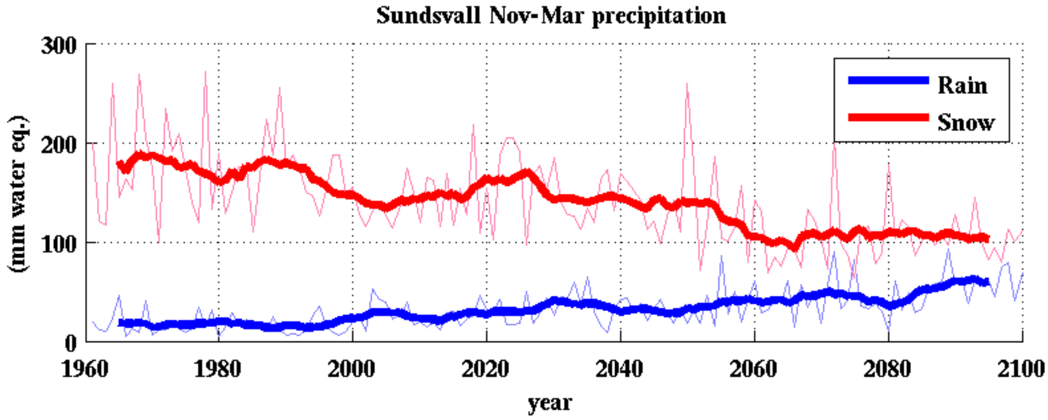

Figure 2: Average November-to-March rain- and snowfalls for all stations in the Sundsvall region for the ECHAM-5 based scenario. Thin lines are annual means, thick lines are 10-year averages. Under this scenario, the amount of snow declines by nearly 50% by year 2100, whereas the rainfall increases by over 100%. This demonstrates the value of the IRWIN statistical downscaling methodology – the publicly available GCM outputs do not differentiate between rain and snow, only total precipitation is provided.

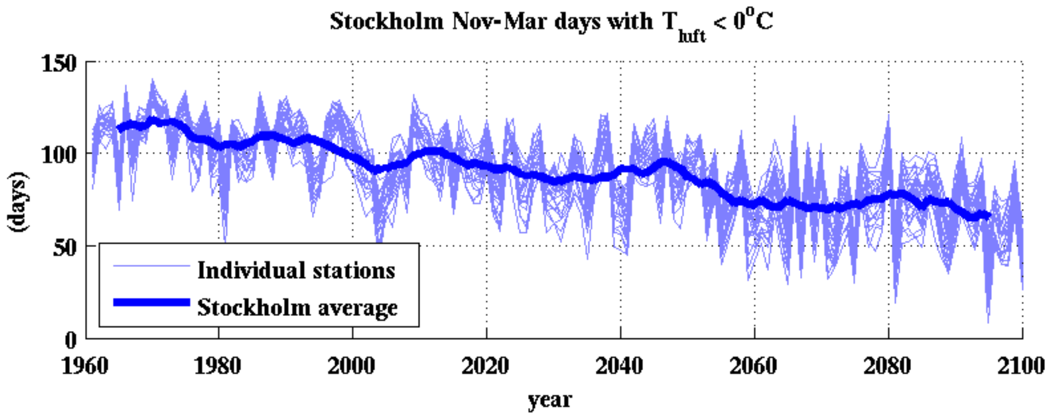

Figure 3: Number of days in the winter season (November-to-March) in the Stockholm region where the air temperature falls below 0ºC. The thin lines are the time-series for individual stations; the thick line is the 10-year regional average. Under this ECHAM-5 based scenario the number of days where temperature falls below freezing will decrease by ~30% by 2100.

This study used the outputs from two General Circulation Models (GCMs), the Community Climate System Model, version 3.0 (CCSM3), and the ECHAM5/MPI-OM model (ECHAM5). Data were downloaded from the WCRP CMIP3 multi-model database. We used SRES A1B emission-scenario runs, which we consider mid-range emissions-scenarios in-terms-of 21st Century global warming.

Road weather

Both air and road temperature will increase in the future according to the Echam and NCAR scenarios. The highest temperature rise will be in the north in the F3 region, and the smallest in south in the S1 area. The NCAR model and the Echam model show more or less the same result, although the NCAR shows higher temperature increases in general. The NCAR model also shows a more easterly gradient in temperature increase. Finland, according to the NCAR model, will have a higher temperature increase calculated as percentage when compared to Sweden than Finland according to the Echam model. In Echam it seems as if the northerly gradient is stronger than the easterly.

According to the Echam model the precipitation as snow will decrease in all areas in the future, most in S2. Rain will increase in all regions but most on the west coasts (S1 and F1).

The overall precipitation change maps show that the S3 and S2 areas will have the least precipitation increase (almost none at all) in the future when both snow and rain is taken into consideration. In S1 the precipitation will increase the most of all six areas.

The NCAR model shows in line with the Echam model that snowfall will decrease in all areas in the future, most in S1, S3 and F1, although the decrease is larger than for the Echam model. Rain will increase most in F2 and S1 and as in line with the Echam model not so much in S3. The futures total precipitation pattern is quite similar to the Echam model. In S2 and S3 however, the seasonal total averaged precipitation will decrease when compared to the present climate. Instead of S1 as in the Echam model, S2 will experience the largest precipitation increase.

The wind change patterns from present climate to future climate do not vary much from region to region. According to the Echam model the maximum wind speeds will increase most in S3 and F3. The NCAR model shows different results with higher maximum wind speeds in F3, S1 and S2. The S3 region which in the Echam model shows quite high a wind speed change for the future shows opposite results in the NCAR model.

IRWIN index

The indices were calculated to see the potential change in need of maintenance activities such as ploughing and salting in the future. They were calculated using the ECHAM5 model. Periods of 4 hours were selected to present an "event". These events were then calculated to see the change in numbers of events from the historical period (1980 - 2010), to the future period (2025 - 2055).
The indices were calculated as into seven categories (Index 1-7).

Index 1, 2 and 3 shows the number of occasions when snow has accumulated for 4 hours with a temperature between -3˚C to +1˚C. The wind varies in the different indices and we have seen before that the low wind occasions dominate. These events with low wind values (index1) are quite frequent in all regions although most frequent in the S2 region and least frequent in S3 and F1. Index2, with stronger winds are most frequent in the S1 region, but also in S2. Index3 with wind values over 14m/s shows very high values at one station in S1 area. This station is however positioned on a bridge in the archipelago. Index 1 shows a positive change (in the more northerly regions) for the future which means more events when these conditions will occur. As for index 2 and 3 these events will not be as frequent in the future as they were historically (table 2).

Index 4, 5 and 6 shows the number of occasions when snow has accumulated for 4 hours, the temperature is less than -3˚C and the wind varies as in the first three indices. Also here the low wind occasions are dominating. As a matter of fact there are close to no events at all with the criteria in index 6, when temperature is below -3˚C and the wind is more than 14m/s. The only case is station 1002 in F1 which has strong wind values. This station is positioned in the southern archipelago. The high negative change (-50%) from historical to future values are due to the one event in the past and then no events at all in the future. Happenings like this are likely to make the changes look larger than they are in reality. Index 4 shows more occasions in S3 in northern Sweden and in F3 in northern Finland, which might be due to the lower temperatures up there. Index 5 however does not show the same trend. There the highest values were obtained in S1 and S2, which might me due to the more seaside station positions which has stronger winds (table 2).

Index 7, 8 and 9 are salting indices. Index 7 shows the number of events when it is raining on a cold surface, and the results shows that this occurs most often in the F2 and F3, while

S1 has the least number of events of this kind. Index 8 shows when salting is needed due to frost, and here there is a clear trend with more cases the further north we come.
Index 9 shows the number of events when temperature shifts from plus to minus degrees and therefore causing slipperiness. There is a clear trend that southern areas experience this shift more often. This is due to the colder weather in the north. Temperature doesn´t reach plus degrees in the winter as often as it does further south.

Only the S1 area shows a decrease in frost events caused by this temperature shift and the other areas show an increase. The same trend has been observed before when Erik Källström (2009) used the ECHAM4 model to make the same predictions. The number of events increased in north and decreased further south as a response to the warming in the future (table 3).

Table 2: Percent change in ploughing indices from historical to future period. Based on the Echam model.

Seasonal mean events change per area

Area	% change Index 1	% change Index 2	% change Index 3	% change Index 4	% change Index 5	% change Index 6
S1	-3.0%	1.2%	-48.0%	-27.1%	-9.5%	0%
S2	-5.8%	-12.2%	-20.0%	-34.2%	-25.5%	0%
S3	20.3%	1.8%	0%	-16.6%	11.1%	0%
F1	-2.7%	-0.3%	-50.0%	-18.0%	31.9%	-50.0%
F2	5.9%	-16.7%	0%	-15.6%	-11.6%	0%
F3	13.2%	-26.7%	0%	-13.1%	-9.1%	0%

Table 3: Percent change in salting indices from historical to future period. Based on the Echam model.

Seasonal mean events change per area

Area	% change Index 7	% change Index 8	% change Index 9
S1	-2%	-2%	-2%
S2	-7%	2%	5%
S3	15%	16%	23%
F1	-5%	3%	6%
F2	12%	10%	16%
F3	13%	11%	18%

Below are the calculated changes in events when there was a certain amount of snow falling within a 4 hour period. Almost all areas will have a decrease of snow events in the future, and region S2 will experience a large decrease. And the F2 and F3 regions will however have an increase in snow events 3 to 5mm and more than 5 mm (table 4). These results seem to be fairly consistent with the scenario changes calculated before.

Table 4: Percent change in snow events from historical to future period. Based on the Echam model.

Seasonal mean events change per area

	Change snow 1-3mm	Change snow 3-5mm	Change snow >5mm
S1	-8.90%	-8.28%	-7.53%
S2	-15.38%	-17.42%	-15.03%
S3	-3.06%	-4.20%	-8.46%
F1	-4.85%	-2.76%	-0.60%
F2	-4.35%	-1.71%	2.48%
F3	-0.62%	0.45%	1.90%

Maintenance needs

An example of how to use the index calculations above are to multiply the length of the roads with the number of times ploughing was needed each winter season to get the total road length which has to be ploughed each season (table 5).

Changes in the index calculations from past to the present climate showed that for index 1, in the past in the S1 region according to Echam model, 51970 km of road was ploughed per season. In the future the same area would only need to plough 50209 km of road. This indicates a decrease of 1761 km. See table 4 for more values on the other indices. Only region S1 was analyzed here as an example of how the index calculations can be used to follow the development in the future and the needs to come.

Table 4: Kilometers of road in the S1 region which according to the 9 different indices had to be "maintained" in the past, for the future and the change from past to the future according to the Echam model scenario.

Kilometers of main roads in S1 region which need maintenance

	km 1980-2010	km 2025-2055	km change
Index1	51970	50209	-1761
Index2	4775	4569	-207
Index3	0	0	0
Index4	20603	14875	-5728
Index5	2062	1814	-248
Index6	0	0	0
Index7	14002	13693	-309
Index8	144543	141814	-2730
Index9	96934	94765	-2169

4. References

IRWIN 1st Inception Report: Final Work Plan and State-of-Art. ENR SRO3 report 2009, 27 p.

IRWIN 2nd Inception Report: Data Collection and Database. ENR SRO3 report 2009, 27 p