ID: 17

# Using car observations in road weather forecasting

V. Karsisto and P. Nurmi

Finnish Meteorological Institute, Helsinki, Finland

Corresponding author's E-mail: virve.karsisto@fmi.fi

**ABSTRACT**

This paper provides some preliminary results of using mobile observations in road weather forecasting. Road surface temperature and road conditions were measured in the city of Oulu with an optical instrument attached to a local commuter bus as part of the national Data to Intelligence program. Some of the observations were used in the initialization of the road weather forecast model run by Finnish Meteorological Institute and the rest in forecast verification. The forecasts were produced for 23 selected points along the bus route. Two different model version using bus observations were tested and they were compared against the control run with no mobile observations. The results show that the versions using car observations produced considerably lower error values than the reference run. Consequently, mobile observations have great potential to improve road weather forecasts in the future, especially as they become more widely available.

**Keywords:** Mobile observations, Road weather forecasting

## 1 INTRODUCTION

Having precise road weather information is important for winter road maintenance. However, the road weather stations cannot alone provide enough details about road conditions along the whole road network. The distance between stations is typically several kilometers and they are mostly located along the main roads. Therefore, there is a lack of road condition information in-between the stations and from smaller roads, meaning that detailed forecasting of road conditions covering the entire road network is highly challenging. Measurements from mobile sources are expected to be at least a partial solution to the issue.

Mobile observations have been utilized previously in a project called SRIS (Slippery Road Information System) [1, 2]. The goal was to estimate winter conditions using information from moving vehicles in addition to information from fixed road weather stations. Observations were collected from 100 cars in Sweden equipped with measurement instruments. The project was reported to be a success and the observations have been used later in a project called MOBI-ROMA [3].The goal of MOBI-ROMA was to develop, test and verify new methods to estimate the road conditions. A program was developed to be used in the planning of road maintenance operations. Another continuation project following SRIS is RSI (Road Status information) [4] with the goal to develop products where data from different sources are merged together to provide information about winter road conditions, bearing strength of the roads, pavement quality and air pollution.

The present paper provides preliminary results on how the use of car observations in road weather modeling can improve road surface temperature forecasts. The required mobile observations were collected during a measurement campaign in the city of Oulu on the western coast of Finland some 540 km north of Helsinki. The campaign was part of the national Data to Intelligence program carried out by the University of Oulu, Oubus Company and Finnish Meteorological Institute (FMI).

## 2 FMI ROAD WEATHER MODEL

The FMI road weather model (RWM) is an energy balance model that calculates the one dimensional road temperature profile [5]. The model predicts the road surface temperature and the amounts of water, ice, snow and deposit on the road. It calculates also the surface friction based on statistical equations [6] and has an additional mode for forecasting the pavement conditions serving pedestrians. The RWM requires as its input air temperature, relative humidity or dew point temperature, wind speed, precipitation and incoming long and short wave radiation. The model run consists of an initialization phase and a forecast phase. In the initialization phase the model is run using observation data. The principal goal is to obtain a good starting state for the forecast phase. In the forecast phase the model uses a forecast from a three dimensional numerical weather prediction model (NWP) as forcing.

## 3 DATA

### 3.1 Mobile observations

The observations were made with a *Teconer RCM411* optical instrument attached to a local commuter bus in the city of Oulu. The *RCM411* device determines the road surface temperature, friction and amount of water on the road based on spectral analysis [7].The instrument was connected to a cell phone providing GPS location information. The measurement period was 1-22 December 2015. The bus route was 15 km in length, and the bus operated it 18 times during an optimum day with measurements being made every second. Figure 1 shows the surface temperature along the route from the run made on 8$^{th}$ December 2015, 16:16-16:57 local time with the black dots representing the locations of the selected forecast points. It is seen that the surface temperature is higher near the city center (purple color) and lower in the less constructed areas. There is a pedestrian crossing with a snow melting system in the city center, which often caused unrealistic peaks in the road surface temperature observations. Consequently, observations near this point were deleted from the dataset.

### 3.2 Kriging data

For initialization the RWM used air temperature, humidity, precipitation and wind speed on the observational grid of 1 km x 1 km. The grid point data were derived by the Kriging method using observations from nearby weather stations and radar measurements. The elevation as well as the relative area of sea and lakes within the grid shell were taken into account in the interpolation. More detailed information about the Kriging method and measurements being utilized are given by Aalto et. al [8]. The data were interpolated to the individual forecast points by using bilinear interpolation.

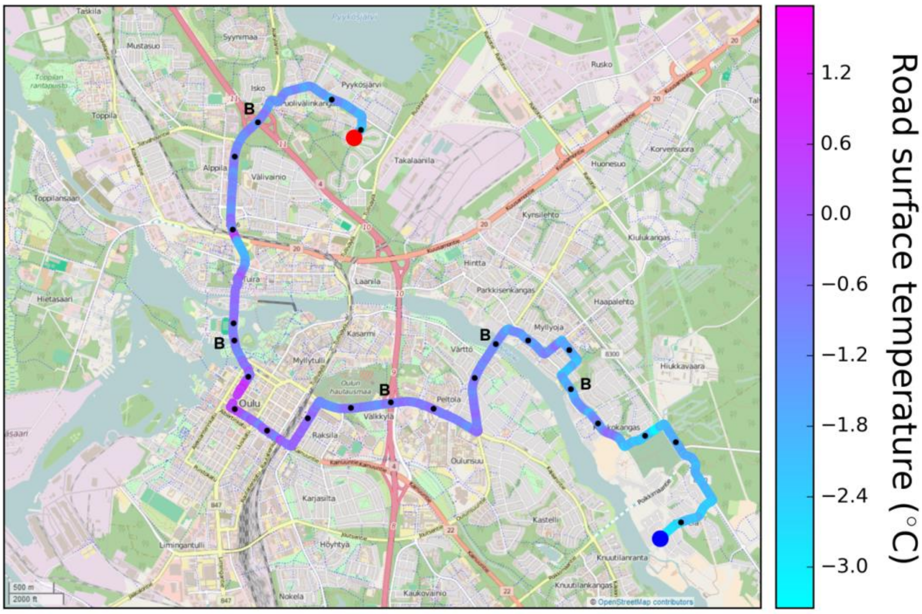


*Figure 1. Road surface temperature along the bus route on 8$^{th}$ December 2015, 16:16-16:57 local time. The red and blue dots show the start and end points of the route, respectively. The black dots indicate the selected forecast points. The locations of bridge points are marked as "B"*

### 3.3 HARMONIE forecasts

The input forecast for the RWM was obtained from the HARMONIE (Hirlam Aladin Regional/Meso-scale Operational NWP in Europe) model, which has a horizontal resolution of 2.5 km and 65 vertical levels. Forecasts are being produced eight times a day, but mainly the 12 UTC (14:00 local time) forecast run was studied because of the timing of the mobile observations. Using the 12 UTC forecast run enabled us to use some of the bus observations in the initialization of the RWM and the rest in the verification.

## 4 METHODS

Forecast points were selected along the bus route with a special focus on bridge locations, where weather and environmental conditions can differ from the main road. There were 23 forecast points in total, five of which were located on bridges (Figure 1). The data were first stratified so that each subset included data from one bus run only. Then, the temperature observations within a 25 m radius from the points were selected, and their average was used as the observation representing those distinct points. The data from different runs for one point were finally combined to get time series of surface temperature.

The RWM was run separately with and without mobile observations to study their effects on the model output. Each run covered a two-day initialization part where observation data were used as forcing and of a one-day forecast part where HARMONIE forecasts were used. The model was run for the period, 1-22 December 2015, using 12 UTC forecast runs for each day. It is somewhat problematic to use car observations in the model, since they will not constitute a dense enough time series to be adapted directly as forcing. By using observation data and applying the kriging method as forcing, the resulting surface temperature is often different from the bus observation. This is due to the observation data set being too sparse to take into account all local features. If the model surface temperature were simply forced to the road surface temperature originating from bus observations, the model would soon drift away from the observed temperature field since it does not fit with the energy balance of the model. Consequently, the energy fluxes in the model need to be modified as well.

We tested two different scenarios to use the bus observations. The coupling method was applied in the first test to modify the forecasted radiation flux so that the model surface temperature matched one bus observation. The running of a large scale NWP model often takes several hours, so new observations are being made before the forecast becomes available. The idea of coupling is to iterate the first few hours of the forecast and modify the radiation during each cycle until the most fitting correction coefficient is found. The model then uses this coefficient to modify the radiation in the forecast so that the effect of the correction decreases over time. The coefficient is set either for long or short wave radiation depending on which of them has the higher intensity at the start of the coupling period. The coupling period started at the HARMONIE forecast initial time and ended at the last observation time within the 3-hour period from the beginning of the forecast. The eventual "real" forecast to be verified starts at the time of the last used observation. A more detailed description of the coupling is given by Karsisto et. al [9].

Only one mobile observation at a certain location was used in the previous method. The coupling method was developed further to take into account additional measurements in the initialization. We call this "multi-coupling" as it applies the coupling method multiple times already in the initialization phase. The mobile observation data were modified before starting the simulations so that if there were multiple observations available within a 30-minute interval, the average of them was taken. There were multiple coupling phases during the model runs, each ending at the averaged observation. Each coupling period started two hours before the observation time if there were no other observations available during the two-hour period and, otherwise, directly from the previous observation. The obtained radiation coefficient from each period was then used to correct the radiation flux until the next coupling period started. The radiation values used in the initialization were taken from previous HARMONIE runs as no radiation observations were available. The coefficient from the last coupling period, which ended within a 3-hour period from the HARMONIE start time, was used like in the previous test in the real forecast phase. The advantage of this method is that the model surface temperature matches the observations also in the initialization phase, so the temperature profile is more realistic at the start of the actual forecast.

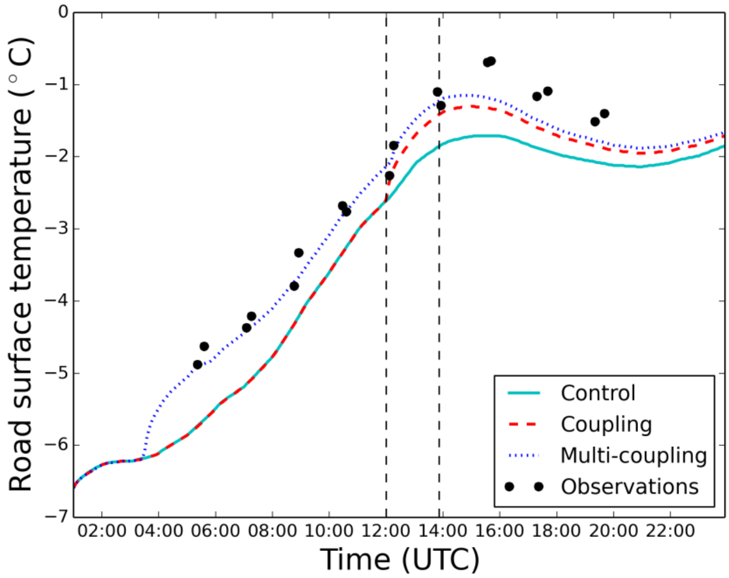


*Figure 2. Road surface temperatures for 18th December 2015 forecast runs for the point nearest to the red start point of Figure 1. The control run is shown with cyan continuous line, the run with simple coupling with red dashed line, and the multi-coupling run with blue dotted line. Black dots are mobile observations. The left vertical line at 12:00 noon shows the start of HARMONIE forecast, and the right one the end of the last coupling period of the multi-coupling model run.*

## 5 RESULTS

The bus observations made after 15 UTC each day were utilized in forecast verification. Figure 2 shows the road surface temperature for 18th December 2015 based on the 12 UTC HARMONIE forecast run. The multi-coupling model version starts to follow the observations neatly as they become available, but both the control run and the coupling version using only one coupling cycle have a marked cold bias during the initialization phase. After the start of the actual forecast (~14:00 UTC), i.e. after the last coupling period, the multi-coupling version displays also a modest cold bias but still remains warmer than the control run. The version with only one coupling cycle shows quite similar results as the multi-coupling version but produces slightly lower temperatures.

The root means square error (RMSE) was calculated for forecasts with different lead times, including all available bus observations and all 23 forecast points. The results for three lead times, 3-5 h, 5-7 h and 7-9 h from the start of the HARMONIE forecast runs are shown in Table 1. It should be kept in mind that observations were used by two model coupling versions, so that the actual forecast started within 3 hours from the start of the HARMONIE runs depending on the time of available observations. We can clearly see improved road surface temperature forecasts when using car

| Model version | 3-5 h | 5-7 h | 7-9 h |
|---|---|---|---|
| Control | 1.10 | 1.18 | 1.22 |
| Coupling | 0.61 | 0.77 | 0.92 |
| Multi-coupling | 0.59 | 0.76 | 0.91 |

*Table 1. Root mean square error (RMSE, °C) of surface temperature forecasts based on the different model versions. Forecasts were based on daily HARMONIE 12 UTC runs during 1-22 December 2015 with all 23 forecast points being included. The three vertical columns show forecast errors with lead times 3-5 hrs, 5-7 hrs and 7-9 hrs from the HARMONIE run start time, respectively.*

observations as input data. The RMSE in the + 3-5 h range is 1.10 °C for the control forecast, whereas it is 0.5 °C smaller for the coupling versions, and with slightly smaller errors for the multi-coupling version. The model versions utilizing bus observations (i.e. coupling) produce smaller RMSE values even at lead times 7-9 h when compared with the control run at lead time 3-5 h.

## 6 CONCLUSIONS

The use of mobile observations appears to have great potential to improve road weather forecasts. In this study the forecast error decreased considerably when mobile observations were utilized. However, there is still need to study different methods to find the most optimal way to use such observations. The observations from the *Teconer RCM411* instrument were considered reliable, but if data from vehicles' own instrumentation are used the data quality needs to be assessed. It is also a challenge to locate information from a certain road point from a moving source, since the measurements are usually not made exactly at the same points. Using the average of measurements within the 25 m radius may have caused some error to our results, because for example screening effects can have a considerable impact on temperature observations. The data in this research were also restricted to a small area meaning that more mobile observations are needed to study their effects on road surface temperature forecasts more comprehensively.

**Acknowledgements**. Financial support from the Finnish Cultural Foundation is gratefully acknowledged.

## REFERENCES

[1] Bogren J and Gustavsson T, 2012*:* Intelligent Transportation Systems and Support System for Winter Road Maintenance, *TRB's Transportation Research Circular*, **E-C162,** 65-71
[2] IVSS (2008). SRIS – Final report, 15 p.
[3] Saarikivi P, Andersson MC, Ekström P, Zachrisson E, Gustavsson T and Müller S, 2014: MOBI-ROMA tool for mobile road monitoring, *Transport Research Arena 2014*, Paris, available at http://tra2014.traconference.eu/papers/pdfs/TRA2014_Fpaper_17793.pdf (accessed 17 March 2016), 10 p.
[4] Bogren J and Gustavsson T, 2014: RSI – Road Status Information, A new method for detection of road conditions. *In proceedings of 17th International Road Weather Conference (SIRWEC),* La Massana, Andorra, 30 Jan- 1 Feb 2014, available at http://www.sirwec.org/Papers/andorra/27.pdf (accessed 17 March 2016), 6 p.
[5] Kangas M, Heikinheimo M, Hippi M. 2015: RoadSurf – a modelling system for predicting road weather and road surface conditions. *Meteorol. Appl.* **22**: 544-533
[6] Juga I, Nurmi P, Hippi M. 2013: Statistical modelling of wintertime road surface friction. *Meteorol. Appl.* **20**: 318-329.
[7] Haavasoja T, Nylander J and Nylander P, 2012: Experiences of Mobile Road Condition Monitoring. *In proceedings of 16th International Road Weather Conference (SIRWEC),* Helsinki, Finland, 23-25 May 2012, available at http://www.teconer.fi/downloads/SIRWEC_2012_Experiences%20of%20Mobile%20RCM_ID14.pdf (accessed 17 March 2016), 7p.
[8] Aalto J, Pirinen P and Heikkinen J, 2013: Spatial interpolation of monthly climate data for Finland: Comparing the performance of kriging and generalized additive models. *Theor. Appl. Climatol.* **112**:99-111
[9] Karsisto V, Nurmi P, Kangas M, Hippi M, Fortelius C, Niemelä S and Järvinen H. 2016. Improving road weather model forecasts by adjusting the radiation input. *Meteorol. Appl.* In Press