12th ITS European Congress, Strasbourg, France, 19-22 June 2017

TP0915#

Towards Intelligent Real-Time Road Weather Services Utilizing Mobile Vehicular Data

Virve Karsisto, Pertti Nurmi, Timo Sukuvaara and Kari Mäenpää
Finnish Meteorological Institute, Finland
Email of corresponding author: virve.karsisto@fmi.fi

Abstract
Today's road weather services are commonly based on weather information generated for either large geographical areas or at specific spots like a city centre. However, more accurate weather forecasts and services tailored for specific road stretches would be more beneficial for road users, thus also increasing traffic fluency and safety. For such purposes one would need to have access to local observations originating for example from mobile vehicles. The Finnish Meteorological Institute has studied the exploitation of vehicular data as input for its road weather forecasts model in a pilot system conducted in the city of Oulu in north-central Finland. The results show that mobile observations have great potential to improve road surface temperature forecasts. Further development work covers a more sophisticated testing and development environment constructed on a special winter driving test track and supported by an operational truck fleet collecting road weather information along its driving route.

Keywords:
Road weather forecasting, mobile vehicle observations, IEEE 802.11p

1. Introduction

The production of accurate road weather forecasts covering the full road network is a big challenge due to the lack of observations. Road weather stations are mainly located along major roads and are typically several kilometers apart. Accurate forecasts are highly important for the timing of road maintenance operations in an optimal way and thus for keeping the roads safe during the cold winter season. Currently, a growing number of available mobile observations are expected to be beneficial in solving the observation data void issue. Using mobile observations in a road weather forecasting experiment was done by utilizing data obtained in a measurement campaign which was realized in the city of Oulu some 540 km north of Helsinki in Finland. The campaign was part of the national Data to Intelligence program and was realized by the Finnish Meteorological Institute (FMI) jointly with the University of Oulu and the Oubus Company. The outcome of the study was first introduced in [1] and Chapter 2 of the present paper summarizes the results.

Road weather services exploiting traffic data allow for a more accurate real-time service generation directly to different traffic and transport actors. The next steps are to generate more extensive piloting of services in more controlled conditions and under real-life traffic conditions. FMI is presently preparing for large-scale test environments for these purposes: the *Sod5G* project in a controlled testing area, and the *Arctic Intelligent Trucks* project for operational vehicle fleet testing within a normal highway traffic environment under challenging weather conditions. These test environments are introduced in Chapter 3.

2. Using mobile observations in road weather forecasting

The measurement instruments (*Teconer RCM411, RTS411*) were affixed to a local commuter bus that operated a 15 km route through the city of Oulu. The *RTS411* observes the road surface temperature optically and *RCM411* determines the road condition based on infrared spectroscopy. It estimates also the surface friction and amount of water on the road [2]. The GPS location information was obtained from a cell phone that was connected to the instruments. The measurements were made during 1-22 December 2015, and the bus operated the route 18 times during an optimal day. The frequency of measurements was once per second. Figure 1 shows an example of the observations made along the route on 8th December 2015, 16:16-16:57 local time. The black dots represent the locations of the selected forecast points. The surface temperature is clearly lower in the less constructed areas (blue color) than in the city center (purple color). A snow melting system under a pedestrian crossing caused unrealistic peaks in the road surface temperature measurements at one point in the city center. Therefore, the observations near this point were removed from the data.

Road weather forecasts were produced for 23 selected points along the route (see Figure 1). Five of the points were located on bridges where road conditions can differ from the main road. Average road surface temperature observations within a 25 m radius from the points were calculated to obtain observation dataset for each point. This was done for each bus run to form time series of observations. The road weather forecasts were made with the state-of-the-art FMI road weather model (RWM) which estimates the road temperature profile according to a heat balance equation [3]. In essence the RWM predicts road surface temperature, the amounts of water, ice, snow and deposit on the road surface as well as the road surface friction [4]. In this study, only the surface temperature forecasts were analyzed. In practice the RWM requires as its input data information about some governing atmospheric weather variables. These were obtained from (i) interpolated weather station observations and (ii) from the 3-dimensional atmospheric HARMONIE (Hirlam Aladin Regional/Meso-scale Operational NWP Europe) forecasting model.

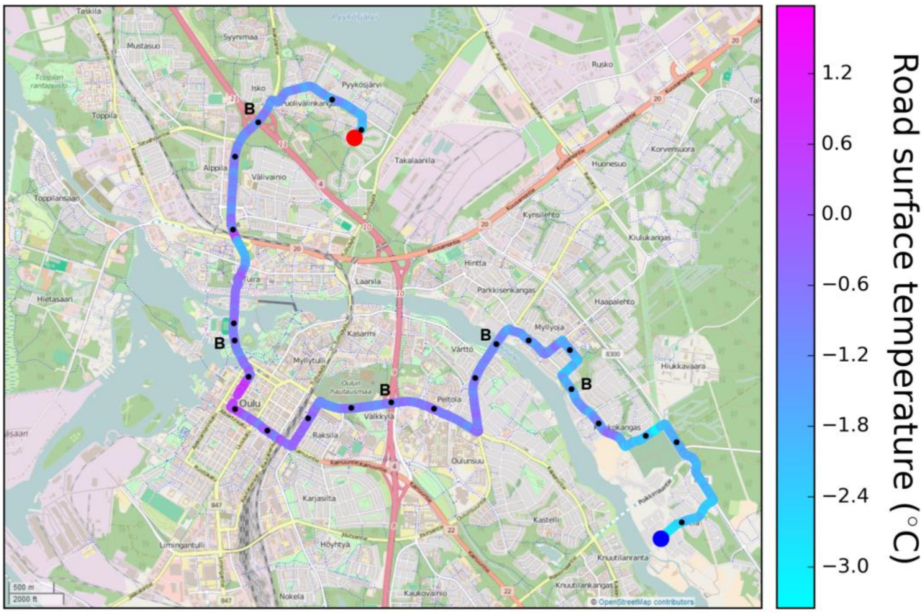

Figure 1 - Road surface temperature along the bus route on 8th December 2015, 16:16-16:57 local time. [1] The red and blue dots show the start and end points of the route, respectively. The black dots indicate the selected forecast points. The locations of bridge points are marked as "B".

Each RWM run consisted of a two-day initialization phase and 24 h forecast phase. The HARMONIE forecasts were used as input forecasts. The model utilized mobile observations using a so-called coupling method [5], which changes the incoming radiation flux in the model so that the obtained road surface temperature corresponds to observation. Two different versions of the model utilizing mobile observations were used. The first version called "coupling" used only one mobile observation within 3 hours from the start of the forecast. The second version called "multi-coupling" adapted the coupling method several times in one RWM run and used multiple observations. Separate "control" RWM runs were also made without mobile observations to assess their effect to the forecasted road surface temperature. A more detailed explanation about these experiments is given in Karsisto and Nurmi [1].

Table 1 shows the root mean square errors (RMSE) of surface temperature forecasts calculated for different forecast lead times. The results include all 23 forecast points. The forecast errors are considerably smaller (i.e. smaller RMSE values) with the model versions using mobile observations and the different coupling methods. For example, the coupling versions produce c. 0.5 °C smaller RMSE values in the + 3-5 h range. It is to note that both the coupling and the multi-coupling version have lower RMSE values with forecast lead times of 7-9 h than the control version with the lead time of 3-5 h. Both coupling versions produce comparable RMSE values.

Table 1 - Root mean square error (RMSE, °C) of surface temperature forecasts based on the different model versions [1] during 1-22 December 2015 with all 23 forecast points being included. The three vertical columns show RMSEs for forecast lead times 3-5, 5-7 and 7-9 hrs, respectively.

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

These results manifest that the use of mobile meteorological vehicle observations have indeed a significant effect on the quality of road surface temperature forecasts. Therefore, their inclusion and utilization in operational road weather forecasting practice would definitely benefit novelty ITS application development.

3. Further developments in closed and open test environments

The meteorological R&D and resulting intelligent road weather forecasting applications introduced in the previous chapter have formed the backbone of several ITS applications and projects undertaken by FMI in recent years. One highly successful such undertaking was the EU FP7 project FOTsis (2011-2015), where an intelligent road stretch (or route) weather forecasting application was developed for given European highway corridors. This concept has been extensively reported in the ITS World framework (see e.g. [6])

The new EU ERDF funded Sod5G project will build a test environment for intelligent transport, road weather services and the 5G network in the area of Sodankylä airport in Finnish Lapland. The project was started in December 2016 and is expected to become operational in the autumn of 2017. The main objective of this project is to build a 5G network piloting environment to serve the needs of dedicated special multi-authority, intelligent traffic and vehicle winter testing. As a result of this project an accurate location-based road weather information and forecast service will be implemented throughout the test area road network, to be delivered in real-time through advanced 5G development network to authorities, vehicles, and the rest of the traffic actors.

The Sod5G test site is presented in Figure 2. The background of the figure on the left shows the whole airport area with a variety of test roads (with white lines). The right side extraction of the figure shows the most important test drive track showcasing locations of the two road weather stations.

Accurate road weather services for the test track are generated by combining (i) general meteorological road weather information for the area produced by FMI, (ii) road weather station (RWS) measurements in the area, and (iii) supplemental mobile data provided by test track vehicles. Both 5G cellular networking and IEEE 802.11p vehicular networking are employed in this scenario and the experiment was started with the local scale IEEE 802.11p scenario. In the pilot system, two vehicles are driving on the test track with embedded friction instrumentation. Surface friction data are collected during the pass of RWS with IEEE 802.11p. Along with the vehicle data, also both of the RWSs collect weather data with their fixed friction instrumentation. Thereafter, the entire data are delivered to the test site road weather service computer. This computer combines these different data sources to form a specific test track road weather service and delivers information back to test track vehicles in real-time manner during each RWS pass.

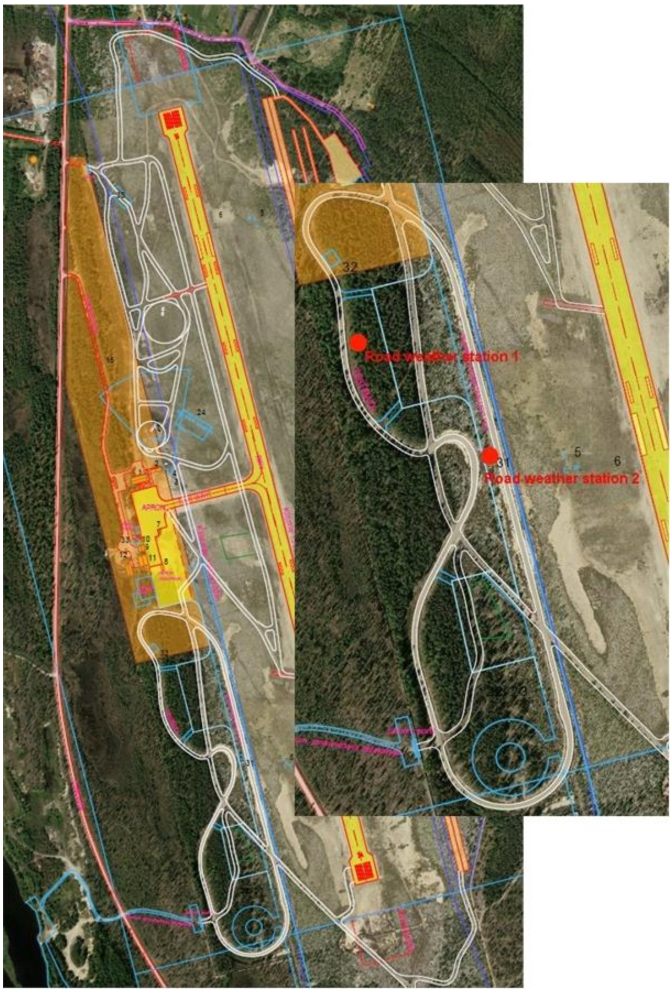

Figure 2 - Sod5G test track.

The Intelligent Arctic Trucks project, also funded by the ERDF, comprises a 260 km road stretch along which six heavy trucks will carry out measurements (Figure 3). The project started in September 2016, and the truck fleet will be fully instrumented until the winter of 2017-2018. The trucks will form a mobile real-time test laboratory for studying and developing ITS and road weather applications. The project provides effective and accurate local road weather information in real-time with instrumentation installed on the trucks and produces road weather forecasts for the road stretch between Kevitsa and Kemi. The instrumentation consists of surface friction and temperature instruments (*Teconer RCM411*, *RTS411*) identical to the Oulu pilot (see Chapter 2), and a special vehicle telematics device (Sunit T7 vehicle PCs and EE Innovations devices) for achieving data from the vehicle CAN-bus. The data are collected from trucks using cellular 4G communication with cloud-based data entity for the storage of vehicular data, as well as the completed service data to be regularly delivered back to the trucks. The size of the friction measurement equipment alone means that it is not a feasible solution for all cars, but for example scheduled coaches or selected transport operators could provide data from certain main routes in the foreseeable future. The project also investigates how many vehicles are needed to produce sufficiently accurate data on the prevailing road conditions. Figure 4 shows two example analysis of road surface temperature along the route for 17th March 2017 7:00 a.m. local time. The panel on the left shows the starting temperatures when the road weather model did not use any mobile observations in the analysis and the surface temperatures are interpolated values from measurements made at road weather stations. The panel on the right shows the analysis where the mobile observations are included. As can be seen, these observations can have an effect of several degrees to the starting state of the model.

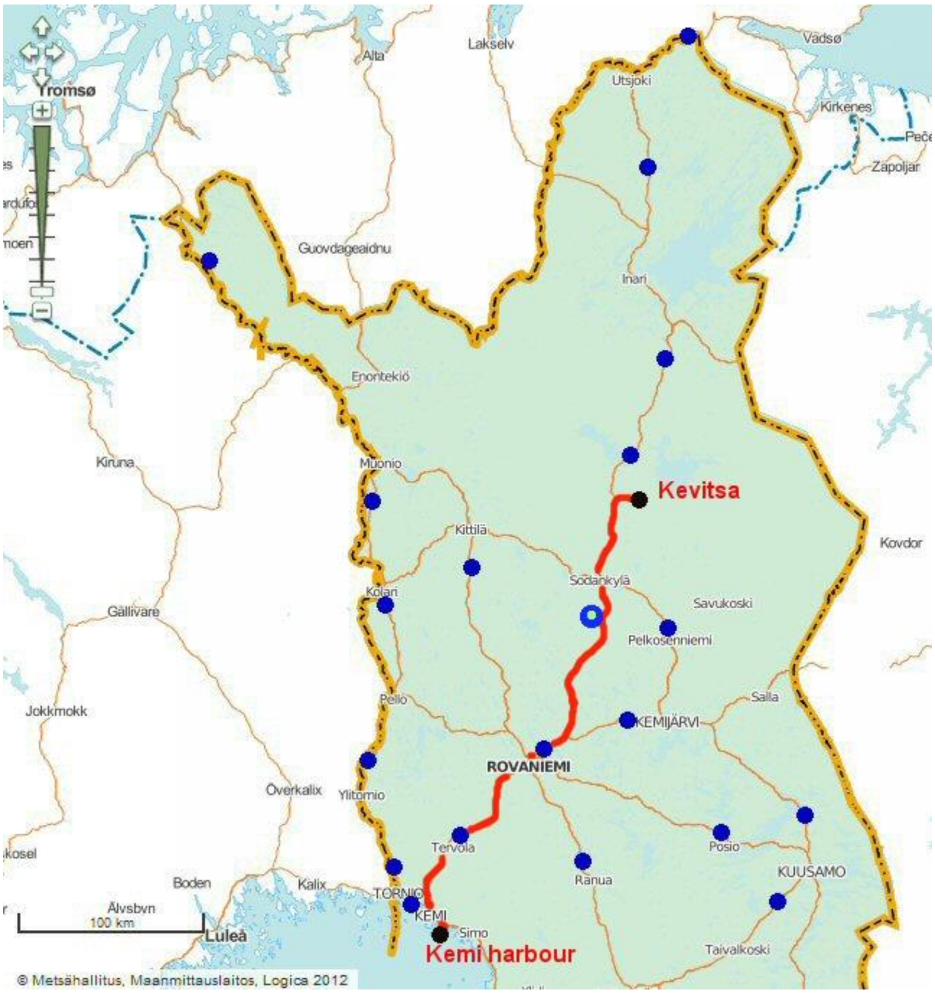

Figure 3 - Intelligent Arctic Trucks route and the existing RWS network. The RWSs shown with blue dots are operated by the Finnish Transport Agency, and the interactive research RWS of FMI with extensive instrumentation is shown with an open blue dot.

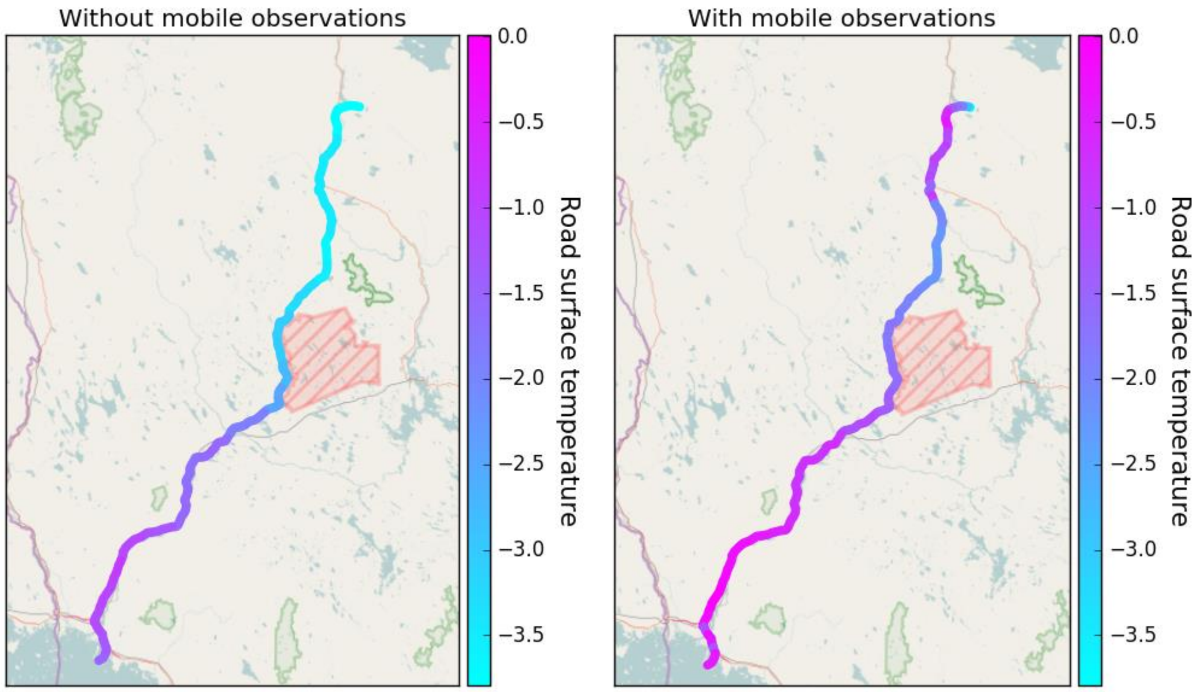

Figure 4 – Road surface temperature along the truck route in the road weather model before the start of the forecast. Panel on the left shows analysis made without mobile observations and panel on the right has them included.

4. Security of wireless road weather services

Road weather service delivery directly to vehicles as well as collecting observation data directly from vehicles require a high level of security and trust. We must be able to ensure that the data transmissions and data handling procedures in the vehicles, service clouds and within the road weather service generation process are not disturbed or contaminated in any way. For this purpose, FMI is participating two projects providing security methodologies for our vehicular networking use cases. The EU ECSEL JU project SafeCOP [7] introduces additional safety and trust for wireless communication with a specific runtime engine controlling the security and validity of each communication entity's operation, with supporting authentication and validation in the connection establishment. These methodologies are employed especially in the road weather service cloud used in the Intelligent Arctic Trucks project introduced in the previous chapter and, more generally, in our vehicular communication entity. The Celtic Plus project CyberWI (http://www.cyberwi.eu) generates tailored safety features for pre-defined operational environments and FMI's RWS structures both in the Sod5G test truck scenario as well as in the interactive RWS along the route of the Intelligent Arctic Truck fleet.

5. Conclusions

We have presented some preliminary results of using mobile vehicular observation data in the context of road weather forecasting which is an important component in the ITS framework. It has been proved that the mobile observations can considerably improve road surface temperature forecasts. Furthermore, services utilizing mobile observations will be embedded in entirely new operational environments of vehicle winter testing tracks as well as operational vehicle fleets running along rural road stretches under harsh winter conditions during the long northerly cold season.

Utilizing mobile observations as part of road weather services serves as a foundation for more advanced, accurate and up-to-date road weather information and forecasts. Our future research will continue to focus on the development of services both under controlled conditions in the vehicle winter testing tracks as well as within open rural roads as part of operational transport. With vehicular user interface receiving the road weather services in real-time, supported by appropriate security features, the road weather services exploiting vehicular data can provide serious improvements in the traffic safety, operational efficiency and travel convenience, especially under harsh winter conditions.

Acknowledgements

This work has been supported in part by the Finnish Cultural Foundation, the European Regional Development Fund (ERDF), European Union ECSEL JU funding, Technology Advancement Agency of Finland (TEKES) and the European Union EUREKA cluster program Celtic. The authors wish to thank all our partners of the Sod5G, Intelligent Arctic Trucks, SafeCOP and CyberWI projects.

References

1. Karsisto, V., P. Nurmi (2016). Using car observations in road weather forecasting, In Proceedings *18th International Road Weather Conference (SIRWEC),* Fort Collins.
2. Haavasoja T., J. Nylander and P. Nylander (2012). Experiences of Mobile Road Condition Monitoring. In Proceedings *16th International Road Weather Conference (SIRWEC),* Helsinki.
3. Kangas M., M. Heikinheimo, M. Hippi (2015). RoadSurf – a modelling system for predicting road weather and road surface conditions. *Meteorol. Appl.* vol. 22, pp. 544-533.
4. Juga I, P. Nurmi, M. Hippi (2013). Statistical modelling of wintertime road surface friction. *Meteorol. Appl.* vol. 20, pp. 318-329.
5. Karsisto V., P. Nurmi, M. Kangas, M. Hippi, C. Fortelius, S. Niemelä, and H. Järvinen (2016). Improving road weather model forecasts by adjusting the radiation input. *Meteor. Appl.,* vol. 23, pp. 503-513.
6. Atlaskin, E., P. Nurmi, D. Dimov (2015). Final Outcome of the FOTsis Project: Intelligent Road Weather & GIS Services for End-users. In Proceedings *22nd ITS World Congress*, Bordeaux
7. Pop P., D. Scholle, H. Hansson, G. Widforss and M. Rosqvist (2016). The SafeCOP ECSEL Project - Safe Cooperating Cyber-Physical Systems using Wireless Communication. In Proceedings *Euromicro DSD, EPDSD special session,* Limassol.