Observing the variability of road and weather conditions with hybrid mobile and fixed sensors

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ABSTRACT

Project ColdSpots was studying problematic road stretches in Finland having more than average accidents due to road conditions. In January-February 2007, the project conducted an intensive observing campaign. Few main roads in Southern Finland were measured with a mobile unit to find out the local variability of weather parameters and in particular friction. Fixed and mobile observations were combined, and their ability to reveal the local variability analysed. Further development of hybrid road weather observing systems is encouraged.

Keywords: road condition, friction, road weather observation

1. INTRODUCTION

Project ColdSpots was a three year project (2005-2007), performed by the three main parties of winter road weather services in Finland: Private weather service company Foreca Ltd as coordinator, Finnish Meteorological Institute as main weather service model developer, and Destia Ltd, who is in charge of the most winter maintenance works in Finland. Intention was to find and concentrate on the most problematic spots on main roads, which cause more than average accidents due to bad road conditions. Typically those are spots that freeze easily, thus having unexpectedly low friction, which may come as a surprise to drivers. In a second paper in SIRWEC 2008 on ColdSpots [1], the analysis of these spots is presented in more detail. This study describes the measuring techniques, and in particular, analysing the variability of friction on the highways as revealed by mobile measurements. Project ColdSpots results are published in two final reports [2], [3]. A summary of the project's first phase was also presented in SIRWEC 2006 [4].

2. MEASURING ROUTES AND INSTRUMENTS

The main observing route was from Helsinki to Salo and back, along Main road 1, which is known for its difficult and rapidly changing road conditions. It is also equipped with exceptionally dense network of road weather stations. Another route was to the east of Helsinki along Main roads 6 and 7 and some local countryside roads. Routes are shown in Fig.1 as blue (1) and green (2), respectively.

Fig. 1 Main ColdSpots measuring routes in Southern Finland

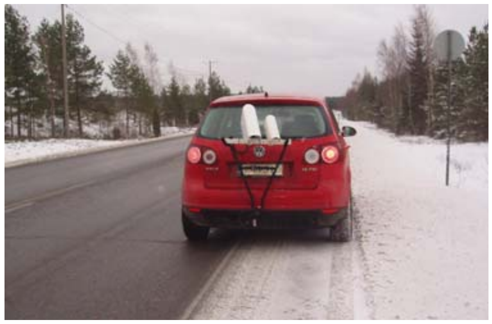

Fig. 2 DSC111 and DST111 installed for mobile measurements

The mobile measuring unit was installed at the back of VW Golf. The optical sensors DSC111 and DST111 by Vaisala Inc [5], [6] where tilted somewhat to measure the area behind the right wheel path. The measuring area was thus approximately a palm-sized oval few meters behind the car. DSC111 is measuring the amount of ice, snow and water on the road surface and calculating friction from the observed values. DCT111 measures road and air temperature and moisture. Continuously measured values are averaged every six seconds, corresponding to about 130 meters distance with normal 80 km/h speed. Data from sensors was transmitted to a measurement PC via Bluetooth connection. The PC had a separate GPS receiver to collect the exact position of the car.

It was observed that the exhaust fumes and the car itself made a consistent warming effect of 2-4 degrees to the DST111 air temperature measurements, and thus those were not used in the analysis. Observations of road weather stations along the routes were collected, as well as the temperature sensor measurements of the VW car.

The early winter in 2007 was the warmest ever observed in Finland, and spring started very early. Nevertheless, 11 interesting cases were measured in January-February. The last measurement included also a comparison study using the Norwegian TWO friction wheel. Fig.3 shows one example of a route, which started on snow-covered small road and ended up to a well-maintained main road. One can see that the observations are by and large quite similar, but the measured values vary between 0.2-1.1 and 0.1-0.8 for TWO and DSC111, respectively.

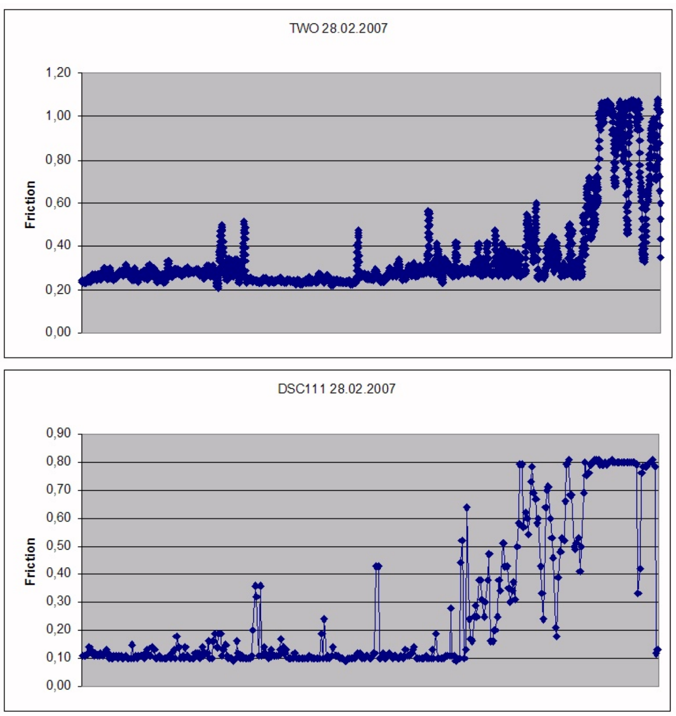

Fig. 3 Comparison of friction measurements with optical DSC111 and TWO friction wheel

3. LOCAL VARIABILITY OF FRICTION

Generally speaking, it is well known that friction varies considerably across the road as is depicted in Fig. 4.
A typical wintertime main road is shown on the left, and it can have friction variance easily from 0.2 to 0.8, if friction is measured on roadside, wheel path or between lanes. To complicate the scene even further, during snow fall or accumulating hoar frost the effects caused by traffic can be opposite, i.e. friction may be better or worse along the wheel paths. On a local road covered with compacted snow or ice situation is more simple, as friction is usually quite low all along the road. However, with DSC111 friction may be sometimes underestimated with packed snow, or overestimated if packed snow has been covered by a thin layer of water.

a) b)

Fig. 4 Friction varies differently across the roads depending on the road type.
a) Main road with 1 snow walls, 2 road sides, 3 wheel paths, 4 between wheel paths, 5 between lanes.
b) Local road with lower level of service, covered with compacted snow or ice. Friction is generally low all over across the road.

During the measurements it was noticed that the optical sensor is very sensitive and the driver could often verify the reasons for varying friction with bare eyes. In the following, some interesting cases are shown and analysed.

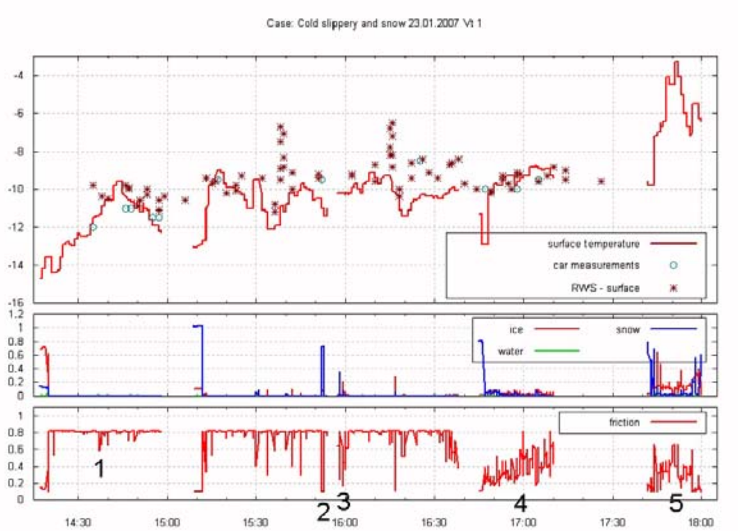

Fig. 5 Case 23012007 starts with cold but fair weather turning into snowfall.

The first case of Fig. 5 was a cold, fair day, which turned into snowfall. Temperature measurements from DST111 (red curve), road weather stations (crosses) and the car (circles) are shown in the upper box. Middle box shows values of ice, snow and water (in mm) observed by DSC111, and the lower box the calculated friction value. Point 1 shows one ColdSpot, when a small bridge was crossed with immediate observation of lower friction. In point 2 the car has been stopped by the roadside, which was snow-covered. There was already weak snowfall, and the passing lanes were covered with a thin snow layer. This is shown well in point 3, where the car was driving along a passing lane. Friction dropped to 0.2-0.3, indicating very slippery road surface.
In point 4, snowfall was getting heavier, causing lower friction. Section 5 on the right shows how the streets of Helsinki look like in these measurements, as they are regularly covered with plenty of snow and ice. City maintenance is very low quality compared to main roads.

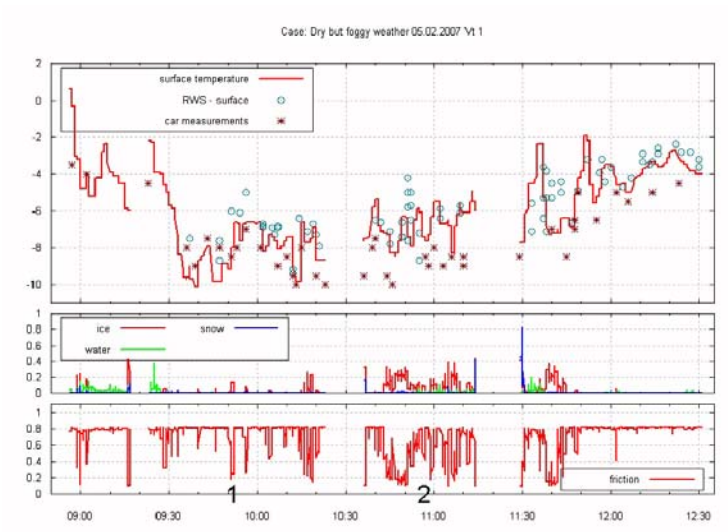

Fig. 6 Case 05022007, fair but foggy, hoar frost

Second case in Fig. 6 was driven with a winter maintenance expert in the car. All temperature sensors recorded similar values between –6…-10 degrees. Point 1 is a ColdSpot, a hillside that is known to get slippery very easily. Also in this case it was noticed that hillside was thinly covered with ice and friction was low. Salting unit was called to maintain the spot. Section two shows the period when air was very foggy at times along the road. Water due to salting and ice due to frost formation was observed on the surface, causing strongly varying values of friction. Good friction values on the right are from well-maintained highway.

In the two first cases all three temperature measurements were more or less identical or very close to each other. In the next two cases they differ considerably.

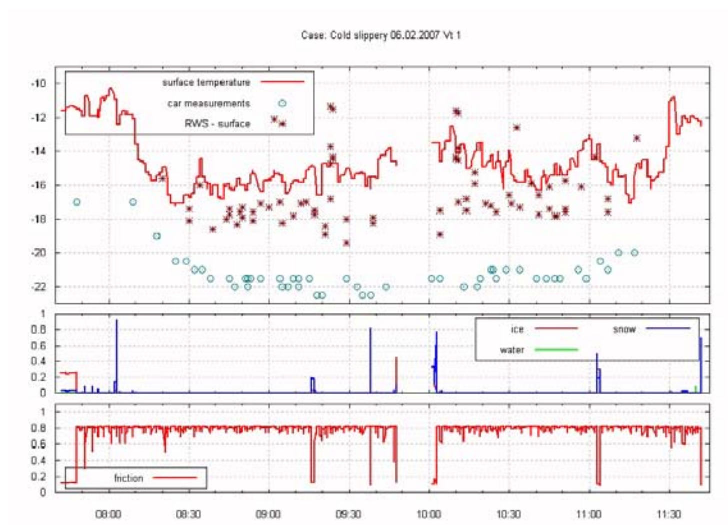

Fig. 7 Very cold case with good friction

The first case is very cold and dry, and the measured friction was very good along most of the route. Only stops at the roadside or driving along the passing lane showed smaller values. Temperature measured by the car sensor was lowest, around –22 degrees, which corresponds to true air temperature rather than road surface temperature. The RWS road surface was some 4-6 degrees warmer. Values measured with DST111 were the warmest, indicating the effect of road body temperature. The previous day had been very warm with the road temperatures around –2 degrees, and thus the road body was still considerably warm.

The final case in Fig. 8 is the one with heavy snowfall and temperature steadily rising. Again there is systematic difference between the three temperature measurements, but now DST111 shows the coldest values. This is logical as the road body temperature was low due to the previous night with temperatures around –10 degrees.

Very low friction values on the left are measured along a local snow packed road. Effects of accumulated snow and water to friction can be seen on the right. Driving conditions were very poor also due to bad visibility.

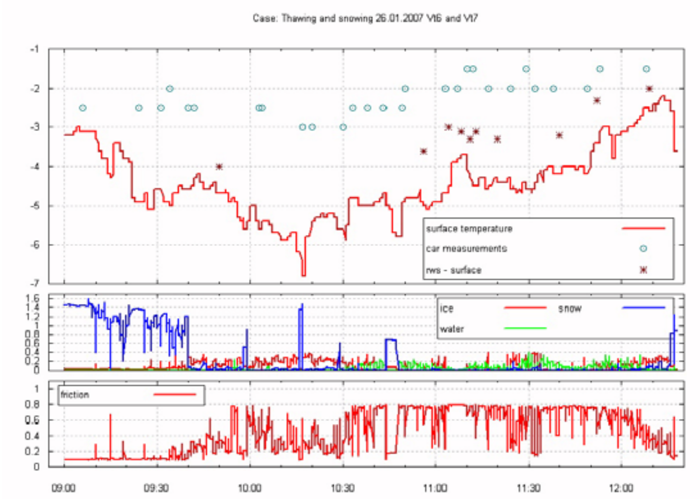

Fig. 8 Case with thawing and heavy snowfall

4. CONCLUSIONS AND RECOMMENDATIONS

This paper presents only a small subset of ColdSpots observations, which showed many interesting details on temperature and friction variability along main roads. A case with strongest spatial variability is shown in [1], indicating some 10 degree changes in few kilometres. A fixed station network can never resolve variance in such small distances. These extreme cases happen typically during cold and calm winter nights, when radiation cooling and pooling of cold air is efficient.

Friction measurements revealed the large variability of friction along main roads and even across the road itself. There is thus a need to study also this variability in more detail. Friction mapping in several typical weather situations should be performed to reveal the most dangerous and slippery spots on the road network.

It can be concluded that hybrid observing methods using both fixed and mobile measurements are the best way to improve spatial density of observations and accuracy of analyses. This is the way to achieve observational analyses comparable with the present grid density of weather and road condition models. On the other hand, ColdSpots cases showed that combining observations is not always straightforward, as different sensors may react to e.g. temperature history and resulting road body temperature in different ways. Thus more observational studies are needed to develop optimal hybrid measuring systems.

5. REFERENCES

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