-S-I-R-W-E-C-

15th International Road Weather Conference
Quebec City, Canada, 5-7 February 2010

ROADIDEA **Session**

A statistical forecast model for road surface friction

Marjo Hippi
Ilkka Juga
Pertti Nurmi

Finnish Meteorological Institute (www.fmi.fi)
Meteorological Research Applications
e-mail: marjo.hippi@fmi.fi

Abstract

Road surface slipperiness caused by ice and snow increases risk of traffic incidents. Wintry road conditions may exist during several months in countries located at high latitudes or in mountainous areas. Icy and snowy road conditions reduce the friction, which is defined as the grip between the car tire and the underlying road surface. The value of friction reduces markedly in cases of freezing rain or snowfall. Also, wet road surface may become icy if temperature cools down below zero degrees.

The Finnish Road Administration has defined limits for the minimums of friction and the acceptable durations for low friction values. Good friction – with values around 0.8 – is observed when road surface is dry and clear. The most slippery situations are experienced when roads are covered by ice and with a small water layer above the ice - friction is then typically close to 0.1. There is nowadays a network of Vaisala DSC111 instruments along the Finnish road network for monitoring the prevailing friction. Previously there were no direct means to observe or forecast friction.

Finnish Meteorological Institute has developed a statistical friction model to forecast friction several hours ahead. The formulae of the model were developed based on statistical analysis utilizing road weather station data. The friction model has lately become part of FMI's operational road weather forecast model. This paper presents the development process of the model and some first test results. Also, problems and future scenarios will be shown.

This study is associated with the EU/FP7 Project ROADIDEA and the EU/COST Action TU0702. The major goals of these undertakings are to study the adverse effects of weather on traffic and to develop new and innovative methods and tools to increase traffic fluency and safety.

Introduction

Slippery road conditions increase traffic incident risk. Conventional road weather models have been developed to forecast parameters like road surface temperature and road condition. Such forecasts are useful tools in the hands of operational meteorologists in the process of producing road weather warnings, e.g. if the road weather is expected to be normal, bad or very bad. Also, road maintenance authorities use road weather forecasts extensively in the planning of their road maintenance activities.

Friction means the grip between car tires and road surface. In cases of dry and clear road the value of friction is typically around 0.8. Water, snow and especially ice reduce friction, and under very slippery situations the friction can be as low as 0.1. The connection between the description of road surface and friction values are presented in Figure 1. The definitions have been made by the Finnish Road Administration.

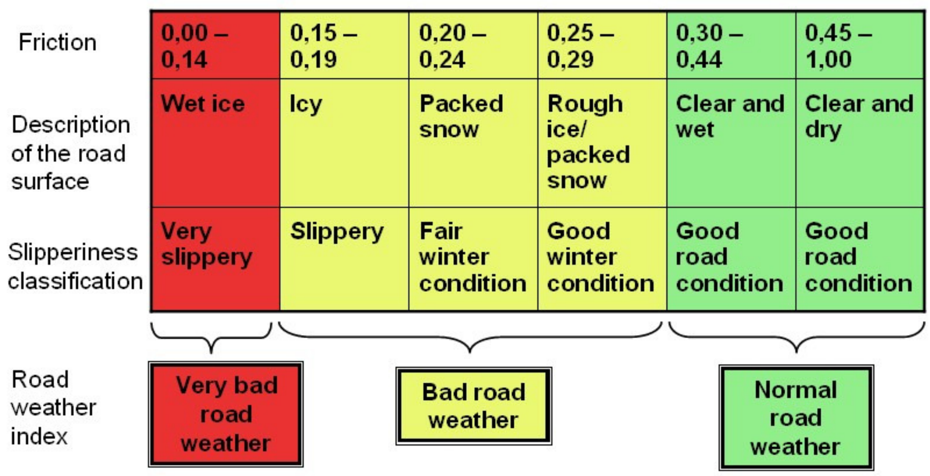


Figure 1: Road weather classification made by Finnish Road Administration.

The friction model presented here was developed by performing a statistical analysis of road weather observations measured with the Vaisala DSC111 sensors (Figure 2a) which measure the thickness of water/snow/ice layer on the surface optically and produce an estimate of prevailing friction [Vaisala, 2005]. There are presently more than 110 road weather stations along the Finnish road network equipped with the DSC111 sensor (Figure 2b).

Road maintenance activities, especially salting and gritting, improve the grip. Unfortunately, the information of road maintenance activities that have been carried out can not be covered by the road weather model because such data are not available at the moment. The condition of car tires and the road pavement may have significant impacts on friction but they are not covered in this application.

a)  b) 

Figure 2: Vaisala DSC111 sensor (a) and locations of road weather stations with DSC111 sensors (b).

Friction model development

The friction model was developed by completing a statistical correlation analysis using road weather observations from some 20 stations equipped with Vaisala DSC111 sensors. Data were collected during winters 2007-2008 and 2008-2009. The main undertaking was to define correlations between observed friction and other road weather parameters.

Observations are typically made every ten minutes at the road weather stations. The available data amounts are hence quite large and different kinds of winter time weather situations were covered. Both of the winters included occasional snow and ice but also warmer periods were encountered with water on the road surfaces and temperatures above zero degrees.

Figure 3a presents a distribution of observed friction and the amount of snow and ice on the road surface at Anjala point (located in south eastern Finland) in winter 2007-2008. The friction values decrease when the snow and ice amount increases although the distribution is quite wide. In cases of high amounts of snow and/or ice the measured friction is always low. Figure 3b shows the measured friction as a function of thickness of water on the surface. The distribution is quite narrow and the measured minimum value for friction is seen at around 0.5 in cases high amounts of water on the surface. Also a small temperature dependency was observed when there was ice or snow on the surface, but in cases of water there was no temperature dependency or it was very small.

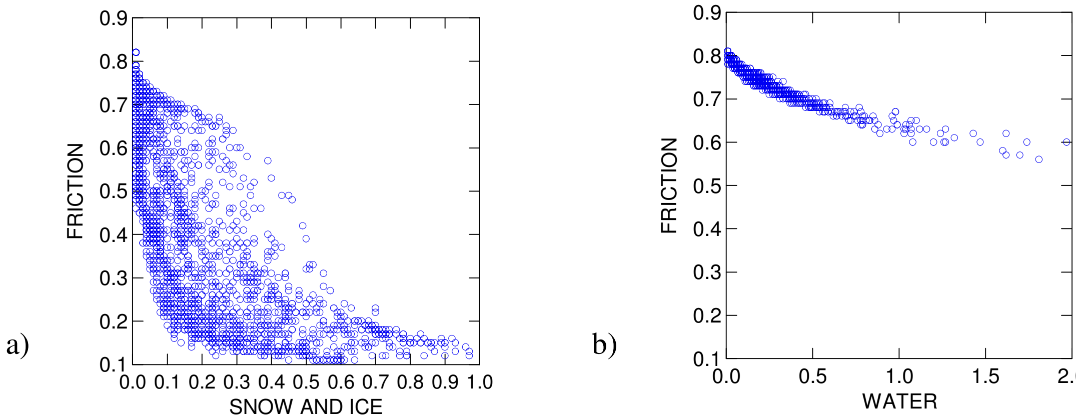


Figure 3: Anjala 2007-2008: Observed friction with ice and/or snow on the surface (a) and same for water (b). Snow and ice amounts are in equivalent mm.

Individual formulae were developed for (a) icy and/or snowy roads, (b) wet roads, and (c) clear roads. For icy and/or snowy roads, friction is a function of the thickness of ice and snow on the road and, including a small temperature dependency. For wet roads, the formula is a function of the thickness of water layer, only, and for dry and clear road surfaces, friction is a constant 0.82. This value represents the default maximum value of friction as measured by the DSC111 instrument. The resulting formulae are given below:

$$\text{Friction} = \begin{cases} A \times f\,(\text{Snow\_mm} + \text{Ice\_mm}) + B \times \text{T\_road} + C & \Leftrightarrow \ \text{Snow\_mm} + \text{Ice\_mm} > 0 \\ D \times f\ \text{Water\_mm} + E & \Leftrightarrow \ \text{Snow\_mm} + \text{Ice\_mm} = 0,\ \text{Water\_mm} > 0 \\ 0.82 & \Leftrightarrow \ \text{Snow\_mm} + \text{Ice\_mm} = 0,\ \text{Water\_mm} = 0 \end{cases}$$

All the required parameters of the friction formulae (Snow_mm, Ice_mm, Water_mm and T_road) are output parameters of FMI's road weather forecast model, so the model can produce friction forecast based on the given relationship.

Figures 4a and 4b present the capability of the derived statistical relationship (based on winter 2007-2008 data) to simulate the logic behind the DSC111 instrument utilizing an independent dataset from winter 2008-2009. Modeled (FC, x-axis) data was calculated using the observed thickness of ice/snow/water and the road surface temperature. Coefficients A-E in the formulae vary slightly for individual stations. The distributions shown here present Anjala results which look quite promising with relatively high correlation values as can be seen from the figures. A more detailed study of the verification of the friction model is provided in the follow-up paper by [Nurmi et al., 2010].

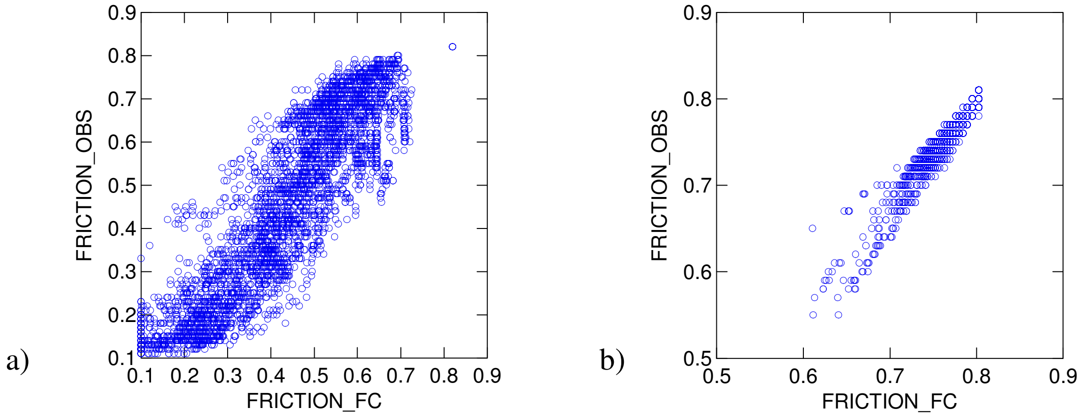


Figure 4: Anjala 2008-2009: Observed (OBS) and modeled friction (FC) in case of icy and/or snowy roads, correlation 0.89 (a). Same for water (b), correlation 0.97.

Operational friction model

The derived friction model is linked to FMI's present operational road weather forecast model [Kangas et al., 2006]. The model is tailored to run for point locations having DSC111 sensors installed (see Figure 2b). As of winter 2009-2010 the number of stations is about 110. The model is being run operationally once an hour, and the model results are visualized in a format shown in Figure 5. All of the locations have presently the same formula and same coefficients.

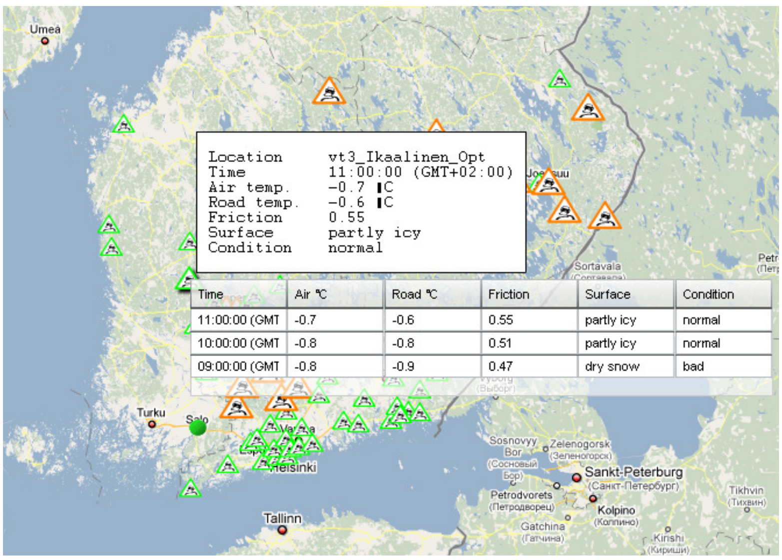
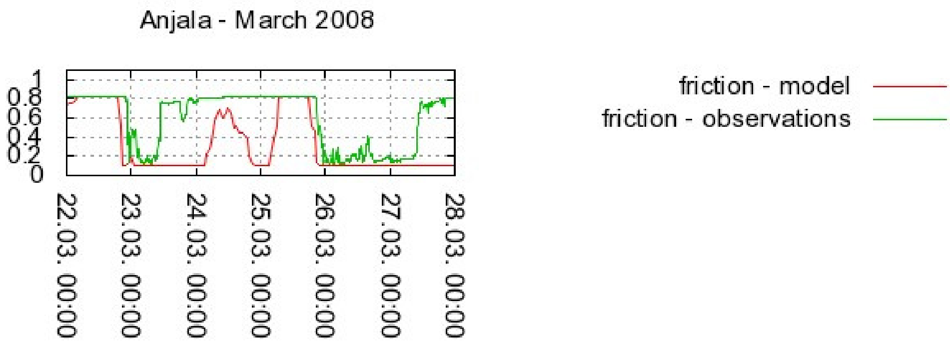


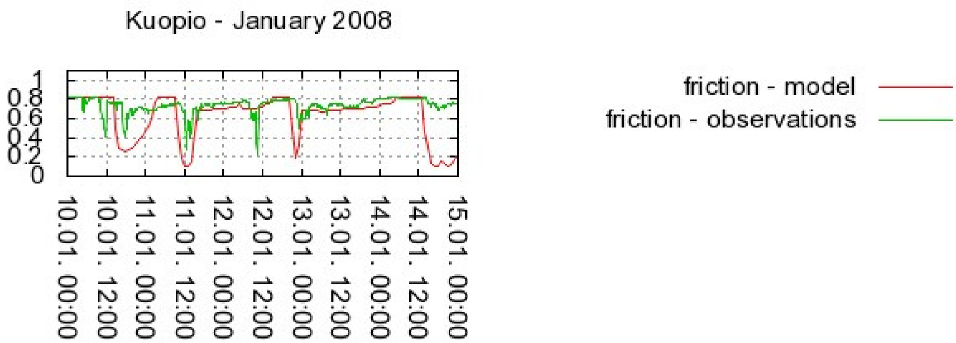
Figure 5: Forecasted friction and other road weather parameters presented in the Google maps ROADIDEA application. It based on close collaboration between ROADIDEA partners FMI, Destia and Demis.

The friction model produces quite good results when the road surface becomes icy. The observed friction decreases rapidly like does the modeled one. However, the modeled friction remains in many cases for too long at low values, whereas the observed friction starts to increase. This is most probably due to the road maintenance activities. Salting and snow plowing operations are carried out to get rid of existing snow and/or ice on the surface to have a better grip.

One of the major bottlenecks in the friction modeling is how to tackle the road maintenance activities – or the lack of information of road maintenance activities that are being carried out. Information of salting and snow plowing operations cannot be covered by FMI's road weather model because the data are not available. Salting and snow plowing improve the road conditions. Friction becomes better and snow amounts on the roads reduce and, moreover, the freezing temperature changes because of usage of salt. For such reasons the road weather model forecasts quite often too bad road conditions and too low friction values.



a)



b)

Figure 6: Examples of modeled vs. observed friction.

A further problem with the friction model is that the road weather model has usually too big storages for water/snow/ice/frost. When these storage terms of the model are too high the eventual friction values become too low. Therefore, the friction formulas must be further developed and/or the wearing of the storages must be adjusted.

Figure 6 presents two examples of the friction forecast model. In Figure 6a the modeled friction is too low because the model produces too much ice and/or snow and also because the road maintenance activities are not included. The calculated friction remains for a long time at a low level, whereas the observed friction reaches a better grip much more rapidly. Figure 6b shows a situation where the modeled friction follows the observations quite nicely excluding the end of the period.

Conclusions and future scenarios

The friction model is a new tool for road weather forecasting. The results and output of the friction model can be used by meteorologists and road maintenance authorities. Also, with eventual further product development there may become useful new products for drivers. However, the presented bottlenecks must be solved in order to have useful forecasts. The worst of the bottlenecks is the lack of information about road maintenance activities. FMI's road weather model quite generally includes too high amounts of ice/snow/water, but this problem can probably be solved by developing the wearing effects of the amount of ice/snow/water within the model.

An idea to further develop the friction model is to generate own formulae for all individual calculation points, because there are large areal differences in road conditions in the country. Roads of the southern parts of Finland are usually kept free of snow, if possible, whereas in the northern parts of the country roads are quite generally covered by ice and snow. Individual formulae could take into account localized microclimatic features.

References

[Vaisala, 2005] Remote Road Surface State Sensor DSC111. Technical report. Vaisala Ltd.

[Kangas et al., 2006] Kangas Markku, Hippi Marjo, Ruotsalainen Johanna, Näsman Sigbritt, Ruuhela Reija, Venäläinen Ari and Heikinheimo Martti: The FMI Road Weather Model. HIRLAM Newsletter no. 51, October 2006, pages 117-123.

[Nurmi et al., 2010] Nurmi Pertti, Hippi Marjo, Juga Ilkka: Evaluation of FMI's new forecast model of road surface friction. Proc. SIRWEC 15th International Road Weather Conference, Quebec City, Canada, 5-7 February 2010.