

The FMI Road Weather Model

Markku Kangas, Marjo Hippi, Johanna Ruotsalainen, Sigbritt Näsman,
Reija Ruuhela, Ari Venäläinen and Martti Heikinheimo
Finnish Meteorological Institute, Meteorological Research
P.O.Box 503, FIN-00101 Helsinki, Finland
Markku.Kangas@fmi.fi

1 Introduction

Simulation of road surface temperature and estimation of road slipperiness is a classical application of physical meteorology treated e.g. in the COST-30 project already in the 1970's (Nysten, 1980). Since these times several European meteorological institutes have developed their own road weather services applying models with varying complexity. The model developments by Nysten and his colleagues at FMI did lead to an operational road weather service in the early 1980's, but it was later discontinued (Heikinheimo et al., 2000).

During 1999-2000, a new road weather model was developed at the Finnish Meteorological Institute (FMI). The model is a useful tool especially for meteorologists when forecasting road conditions and giving road weather and traffic conditions warnings to drivers and information to road maintenance personnel (Kangas et al., 2001). The model has been in daily operative use since spring 2000. The past few years have seen an increased interest in the road weather model development, with several new spin-offs and applications, including pedestrian warning system (Ruotsalainen et al., 2004), a road maintenance application (Hippi, 2004) as well as a mobile phone based warning system (Driver Alert) for heavy traffic (AINO, 2004-2007). The model has also been applied in a study on the effect of climate change on road maintenance needs in Finland (Venäläinen and Kangas, 2003).

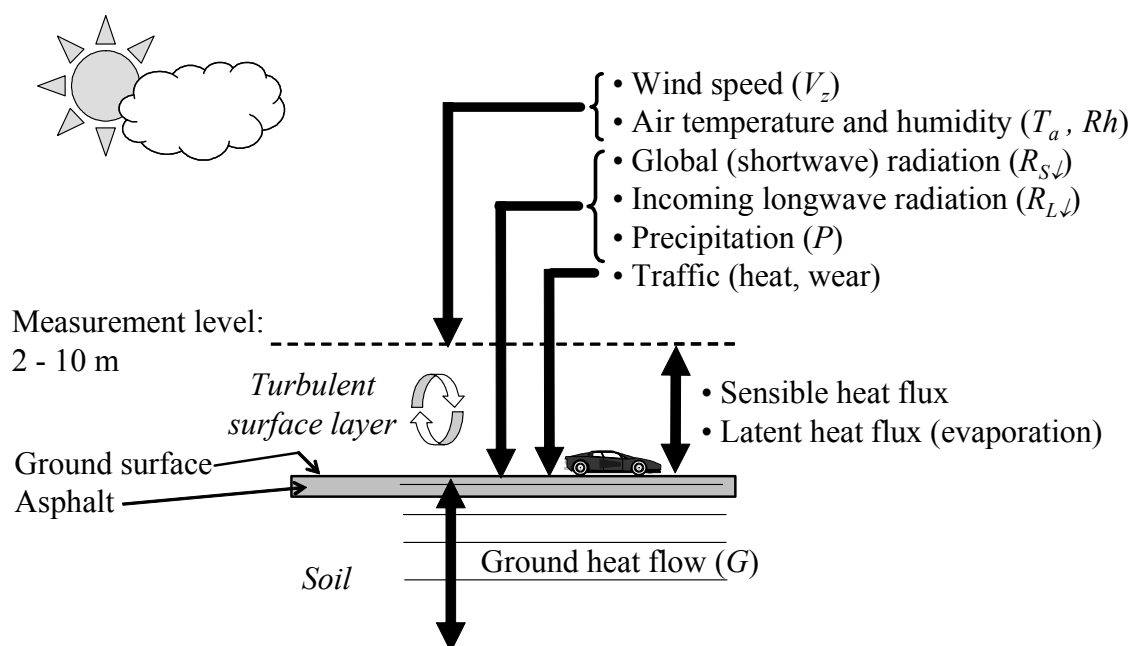


Figure 1 : Road weather model - ground energy balance.

2 Model physics

The road weather model is a 1-dimensional energy balance model that calculates vertical heat transfer in the ground and at the ground-atmosphere interface, taking into account the special conditions prevailing at road surface and below it. The effect of traffic is also accounted for. Output from a weather forecast model, either directly or with duty meteorologist's corrections, is used as a forcing at upper boundary. This input also provides the horizontal coupling between the individual points. For climatological research purposes, the model can be run using observed meteorological data. At the lower boundary, the climatological ground temperature is used as boundary condition.

The main body of calculation refers conditions in the ground, where the vertical temperature distribution is solved to a depth of up to about 6 metres. For this purpose, the ground is divided into 15 layers of varying thickness, with the thinnest ones (2-10 cm) next to the ground surface, where the temperature changes are largest and swiftest. The lowest layer that is about 1.5 metres thick and reaches a depth of about 5.8 metres, is assumed to follow a sinusoidally-varying climatological temperature.

The atmosphere is taken in the model as forcing. It has an effect on the ground surface through a number of variables:

- ambient temperature
- relative humidity
- wind speed
- short-wave radiation
- long-wave radiation (mostly from clouds)
- precipitation

The values of these variables can be taken from observations or from a forecast; the model does not make any distinction as to the source of the data. On the basis of these variables, the heat balance at the ground surface is solved, taking into account such factors as sensible and latent heat flux as well as atmospheric stability (Fig.1). The effect of melting or freezing is also included in the energy balance.

An additional forcing at the surface is the traffic, which causes not only increased turbulence but also mechanical wear of e.g. snow, ice or frost that is present on the surface. For the time being, a spatially constant traffic effect is assumed. During night time, a smaller traffic factor is used.

When the road weather model is used for prediction purposes, the input data needed are obtained from weather forecast models like HIRLAM (Hirlam, 2006), but the model can also be run for climatological purposes using observed meteorological data as input.

When using observed data as model input, the radiation components are estimated using synoptic cloud observations data. The formula used operationally at the Finnish Meteorological Institute to calculate global solar radiation is based on a method originally explained by Iqbal (1983) and which was further modified for Finnish conditions (Venäläinen & Heikinheimo, 1997; Venäläinen et al., 1999).

3 Road condition interpretation

In addition to calculating ground and surface temperature, the model also makes a road condition interpretation. At present, eight different road surface classes, or descriptions, are used (cf. Figs 2 and 3):

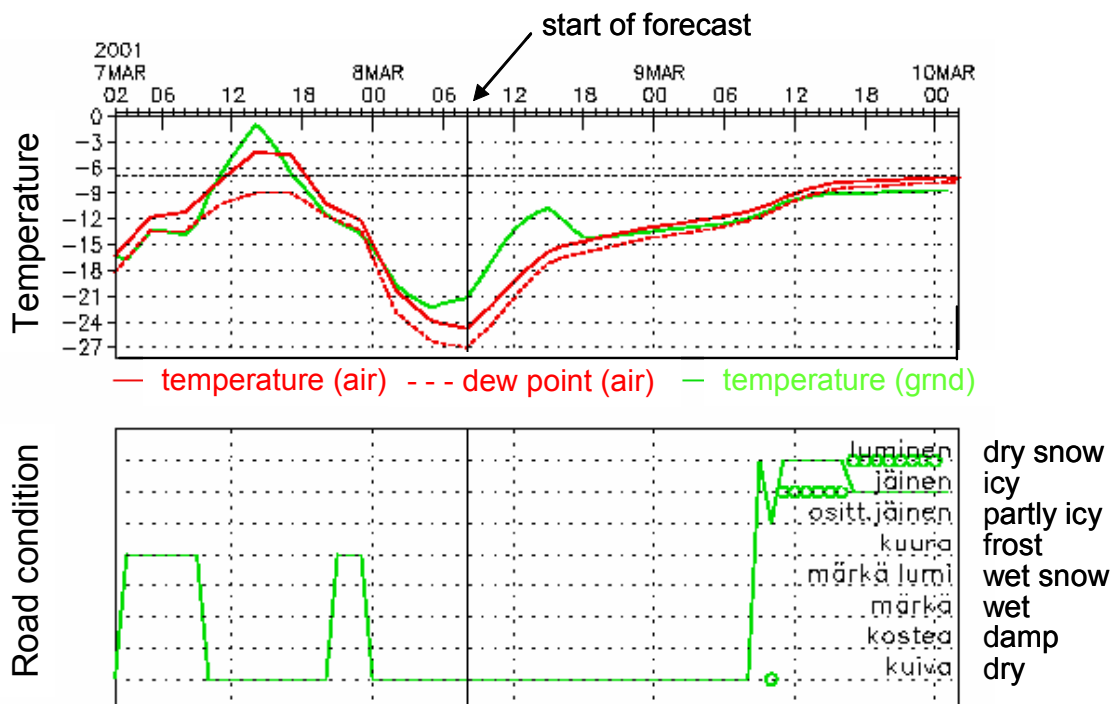


Figure 2 : Road surface temperature and road condition interpretation from the model

- dry
- damp
- wet
- frost (deposit)
- dry snow
- wet snow
- partly icy
- icy

The 'partly icy' case means conditions in which only part of the road surface, e.g. lanes with less traffic, is covered by ice. In this case the model also makes a secondary road condition interpretation, which describes the road surface in places where no ice is present. Similarly, the secondary road condition class is used in cases with snow or water on ice.

The road condition interpretation is based on various storage terms, which describe the amount of water, snow, ice, and frost (deposit) on the surface. The model constantly tracks changes in the storages caused by melting, freezing, evaporation, condensation, and mechanical wear. The storages may also interact with each other, e.g. the size of the water storage is increased by precipitation as well as by melting of snow or ice.

The model further combines information about the road condition, storage sizes and certain weather parameters (notably wind speed, precipitation intensity, lighting conditions) to produce a three-valued

(normal, bad, very bad) traffic condition index describing the traffic conditions in more general terms (Fig.4). This is the same classification as used in traffic condition warnings issued by FMI.

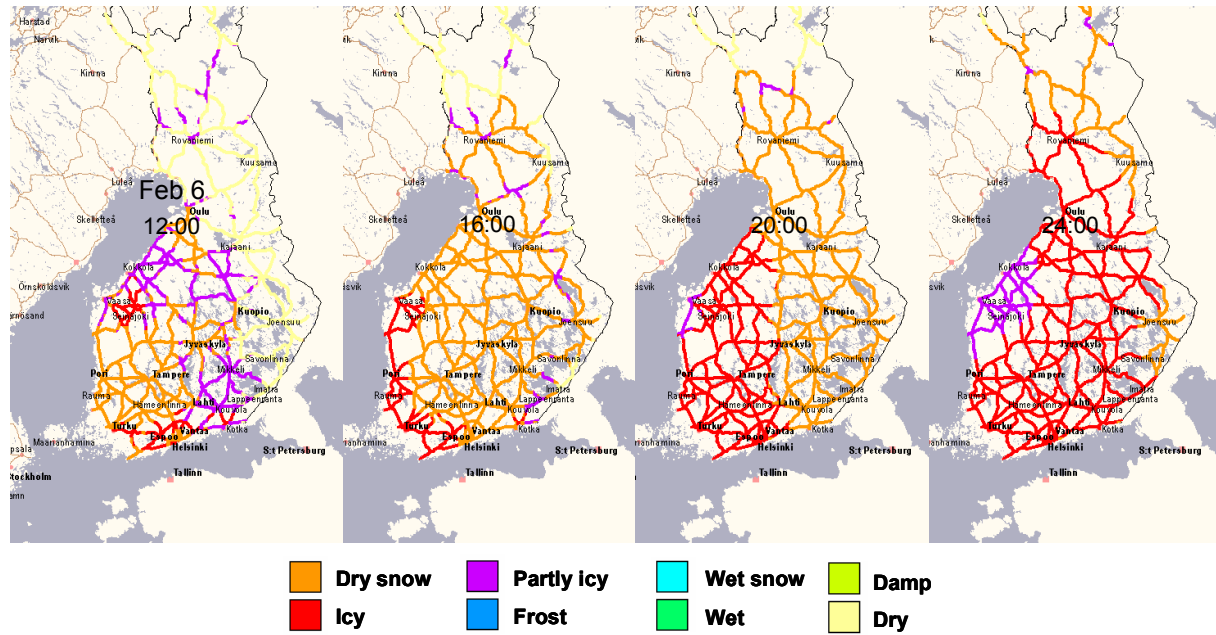


Figure 3 : Road condition index map superimposed on Finnish main road network.

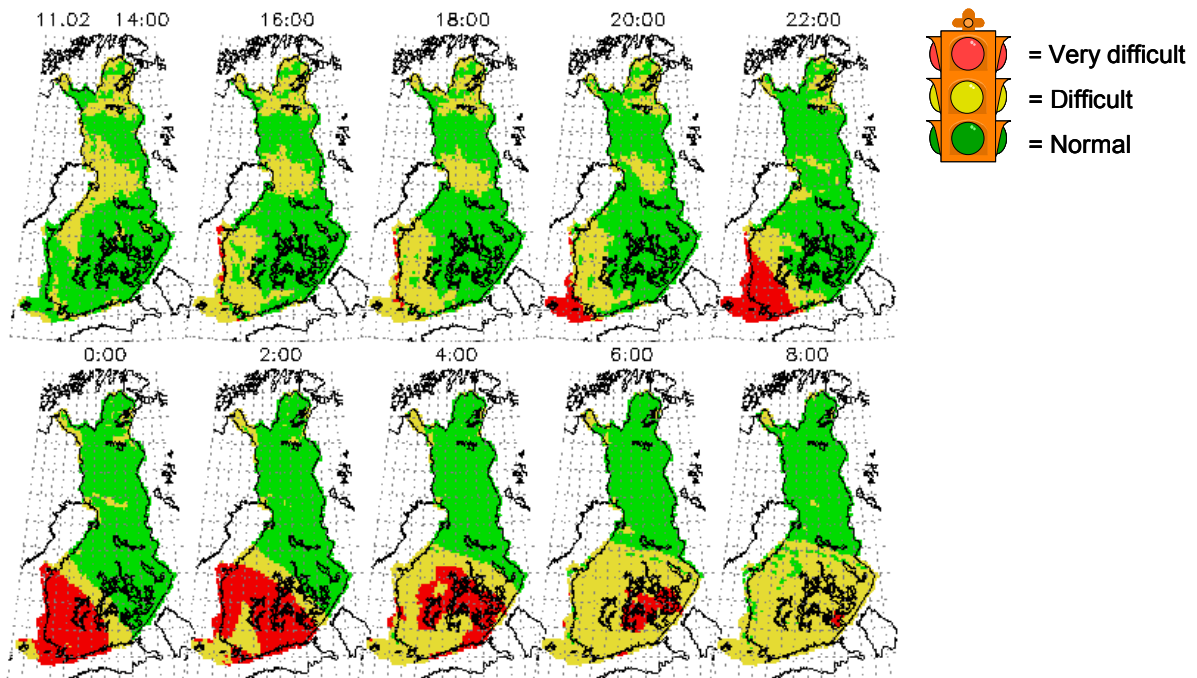


Figure 4 : Traffic condition index as produced by the model.

4 Operational usage

The operational model run consists of two parts, first one being based on observations and second on a forecast. The purpose of the first run ("initialization run" in Fig.5) is to set the initial state of the forecast-based run ("production run") that follows it and starts from the final state of the observation-based run. The length of both runs is 24-48 hours depending on the amount of available input data. The need of initialization run is dictated especially by the lack of measured on-line knowledge of the amount of snow, ice or frost on the road surface.

The model is presently run operationally once an hour. The modelled area covers Finland, and excluding postprocessing to produce graphics, a typical run on an SGI main frame computer takes about 3-4 minutes real wall clock time.

The observation run is based on meteorological SYNOP observations and on weather radar precipitation data, whereas the forecast-based run uses output from a weather forecast model with duty meteorologist's corrections.

As output, the operational weather model produces surface and ground temperature as well as the different road condition indexes mentioned above both in plain text format and in special binary format for GrADS (Grid Analysis and Display System, <http://grads.iges.org/grads/head.html>) visualization package. The plain ASCII files can be used for further postprocessing, whereas GrADS is used to produce on-line special graphical web pages (cf. Figs. 2-4) for program monitoring, development and to be used as forecasting aid. These pages include time series of various parameters in both plot (meteogram) and map format as well as the possibility to compare model results with on-line measurements and photos provided by the Finnish Road Administration (<http://www.tiehallinto.fi/eindex.htm>).

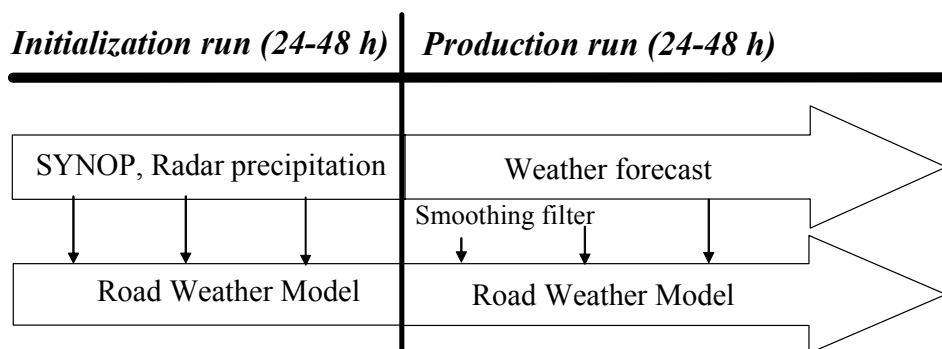


Figure 5 : Operational model run structure.

5 Model applications and spin-offs

5.1 Pedestrian warning system

The pedestrian warning version of the model aims at predicting sidewalk conditions from the viewpoint of the pedestrians (Ruotsalainen et al., 2004). For this purpose, the surface condition interpretation and related warning system has been modified in co-operation with the Finnish Institute of Occupational Health, which performed in-situ foot gear friction measurements using a special stepping robot (Ruuhela et al., 2005).

The motivation of the pedestrian warning system is that quite a lot of suffering and economical loss is produced by people falling down because of slippery sidewalks during wintertime. Since 2004, FMI has been operationally issuing warnings of slippery sidewalks for pedestrians. The model is used in this service as an aid for the meteorologist when considering the need to issue warnings. Additionally, hospitals have shown interest in this model application for the purpose of advance planning of personnel availability in case of approaching bad sidewalk conditions and a possible rush on patients.

5.2 Road maintenance scheduling

The basic road weather model does not include the effects of road maintenance, providing thus a kind of what-if-nothing-is-done scenario. One traffic related application of the model is a modification of the it to produce advance information about approaching need for road maintenance.

For this purpose, the model was provided with enhanced snow storage handling including ploughing of the roads. Three road classes with different road maintenance needs are simulated by the model. The maintenance needs include maximum allowed amount of snow on the surface as well as time limits during which certain road maintenance have to be performed. A special output with forecasted maintenance needs is provided to ease the planning of the maintenance scheduling.

This work was performed in co-operation and with the funding of Finnish Road Enterprise (<http://www.tieliikelaitos.fi/english/>), who has been using the system operationally since autumn 2005.

5.3 Driver Alert for heavy traffic

As a part of national AINO (R&dD Programme on Real-Time Transport Information) a special mobile phone based warning system for transport traffic called Driver Alert has been developed (AINO, 2004-2007). As to weather warning part, the system is based on early warnings given by road weather model.

The system works so that when developing dangerous traffic conditions are observed by the the road weather model, it alerts the operational personnel in the form of a special warning index (e.g. "rapidly changing weather conditions"). The operator then checks the situation by using other available data, and if there is reason for warning, the system is launched. First, traffic entering the danger area within the next half an hour or so is determined using mobile phone based localisation techniques. A voice message giving the warning and detailing the situation is then sent to the mobile phones of the appropriate vehicles.

Driver alert also includes a route planning system which can be used to plan the route to drive in advance. It takes into account the future road weather on different possible routes to the destination. For example, if it starts snowing heavily just when one would be arriving to some location, a different route with more favourable weather can be chosen.

Additionally, Driver Alert includes a possibility for two-way communication with the trucks informing the system about the situation on the road.

The system was officially launched in February 2006. In the first phase it is limited to about 150-200 registered users form the main Finnish transport companies, but future plans include opening it to larger number of users. It has been received very favourably - indeed, in May 2006, it was awarded a traffic safety award by the Finnish Transport and Logistics SKAL.

6 Conclusions and future

The road weather model has been operative since 2000, and with all its spin-offs and application, a total of about 60 model runs are now preformed each day. The model has worked well and proved to be very robust and reliable.

The present main operational model is limited to one road type (Finnish main road network) with no maintenance. It thus gives a generic forecast, from which the forecaster or other model user must use her or his expertise to apply the results.

At present, the model is being enhanced to include observation data also from road weather stations. In this way, the localisation of the model forecasts can be improved. Further planned future enhancements of the model include to better account for locally and temporally varying traffic and environmental conditions.

References

- AINO - R&dD Programme on Real-Time Transport Information (2004-2007) : *DriverAlert. Forecast and warning system for road conditions*. At <http://www.aino.info/indexe.html> .
- Heikinheimo Martti, Kangas Markku, Venäläinen Ari (2000) : *Tests with a new road temperature model for selected winter weather conditions in Finland*. 22nd Nordic Meteorologists' Meeting, Mariehamn 27.6 - 1.7.2000.
- Hippi Marjo : *Teiden talvihoito ja Ilmatieteen laitoksen säämallin jatkokehittäminen (Winter road maintenance and further development of the FMI road weather model)*. Graduate thesis, Helsinki University, Dept. of Physical Sciences, Div. of Atmospheric Sciences, Helsinki, 2004 (in Finnish).
- HIRLAM - High Resolution Limited Area Model (2006). At <http://www.hirlam.org/> .
- Iqbal, M. (1983) : *An Introduction to solar radiation*. Ontario: Academic press Canada.
- Kangas Markku, Heikinheimo Martti, Venäläinen Ari (2001) : *Tiesäämalli - tienpinnan lämpötilan, kelin ja liikenneolosuhteiden ennustamiseen (Road weather model - forecasting road temperature, road conditions and traffic index)*. Kunnosta on kysymys - seminaari teiden ja katujen ylläpidosta (Seminar on road maintenance), Tampere, Finland, 30-31.5.2001 (in Finnish).
- Nysten E. (1980) : *Determination and forecasting of road surface temperature in the COST 30 automatic road station*. Finnish Meteorological Institute, Technical Report No. 23, 32 pp.
- Ruotsalainen Johanna, Ruuhela Reija, and Kangas Markku (2004): *Preventing Pedestrian Slipping Accidents with Help of a Weather and Pavement Condition Model*. Walk 21, The Fifth International Conference on Walking in the 21st Century, Copenhagen, Denmark, 9-11 June, 2004, 12 pp.
- Ruuhela Reija, Ruotsalainen Johanna, Aschan Carita, Torkki Markus and Kangas Markku (2005): *Preventing Pedestrian Slipping Accidents with Help of Weather Service*. 17th International Congress of Biometeorology ICB2005, Garmisch-Partenkirchen, Germany ,5-9 September 2005, 3 pp.
- Venäläinen Ari and Heikinheimo Martti (1997). *The spatial variation of long-term mean global radiation in Finland*. Int. J. Climatol., **17**:415-426.
- Venäläinen Ari and Kangas Markku (2003) : *Estimation of winter road maintenance costs using climate data*. Meteorol. Appl. **10**, 69–73 (2003).
- Venäläinen Ari, Rontu Laura, and Solantie Reijo (1999). *On the influence of peatland draining on local climate*. Boreal Env. Res., **4**, 89-100.