Road weather modelling at FMI

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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 was discontinued probably due to rapid development of the road station network and changes in computer hardware and software (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 as well as giving warnings to drivers and information to road maintenance personnel (Kangas et al., 2001).

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.

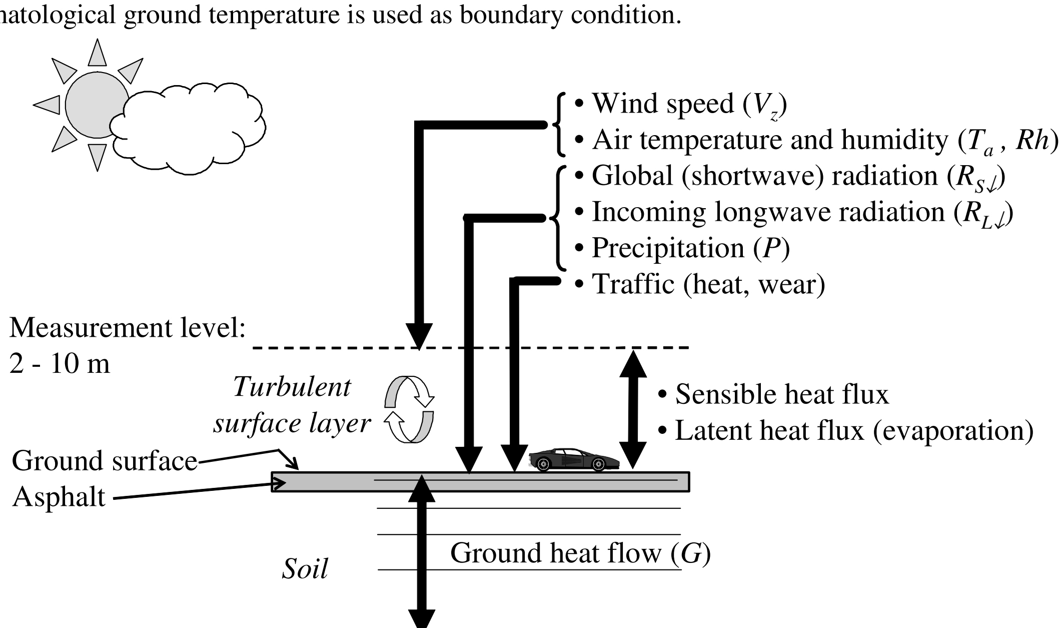

Figure 1 : Ground energy balance.

The main body of calculation refers conditions in the ground, where the vertical temperature distribution is solved for 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, also taking into account such factors as sensible and latent heat flux as well as atmospheric stability (Fig.1). The effect of melting or freezing (snow and ice) is also included in the energy balance.

An additional forcing at the surface is caused by 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, but for climatological purposes the model must be run using observed meteorological data. The radiation components are problematic parameters, as global solar radiation is only measured at about 15 stations and downward long-wave radiation only at two stations in Finland. An estimate of the radiation components can be obtained for stations making synoptic cloud observations. 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). The operational system for the calculation of downward long-wave radiation based on synoptic observations is built using a method introduced by Lind and Katsaros (1982). In this method, the influence of each cloud layer on long-wave radiation is estimated by defining the cloud amount at various heights based on the synoptic cloud code. The temperature of the lowest cloud layer is estimated from the surface temperature assuming a constant lapse rate of 6 °C/km. The temperature of medium and high clouds is assumed to be –18°C and –30°C, respectively (Venäläinen and Kangas, 2003).

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):

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

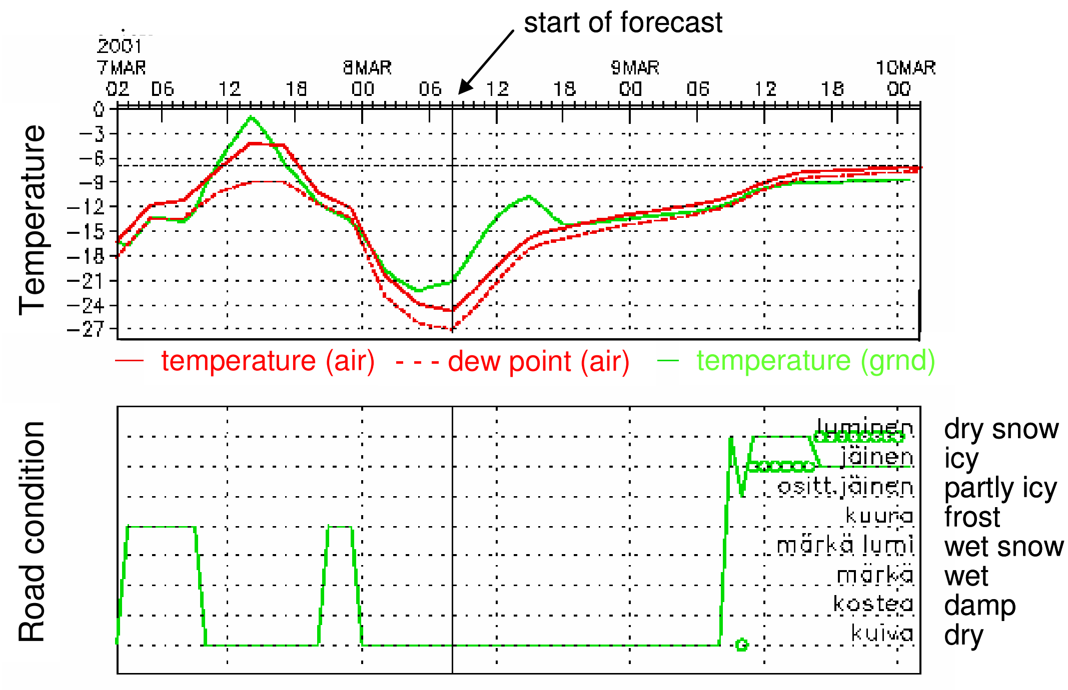

Figure 2 : Road surface temperature and road condition interpretation from the model.

The 'partly icy' case means conditions in which only part of the road surface, e.g. lanes with less traffic, is covered by 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.

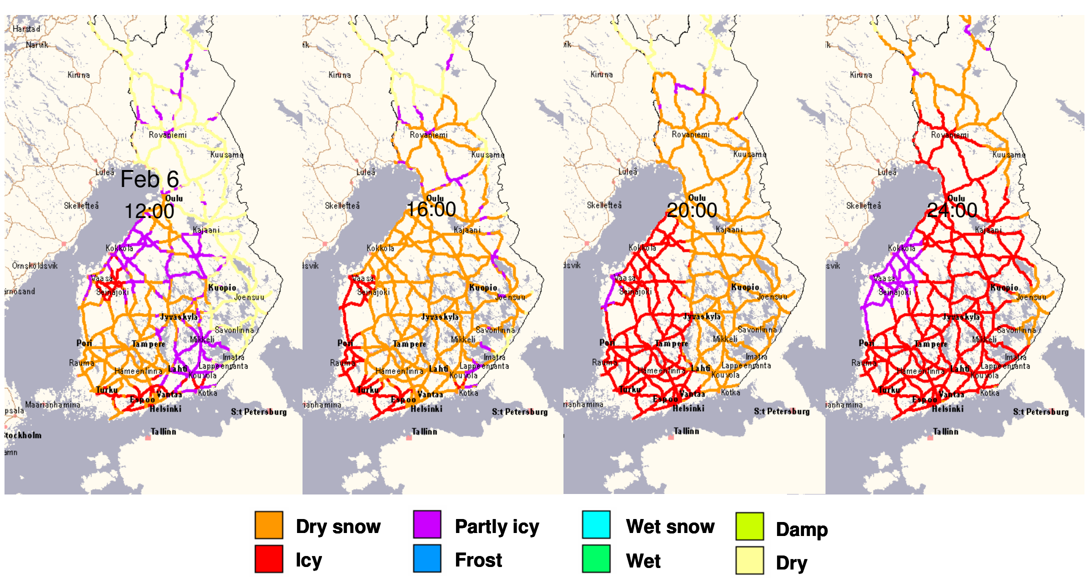

Figure 3 : Road condition index map superimposed on Finnish main road network.

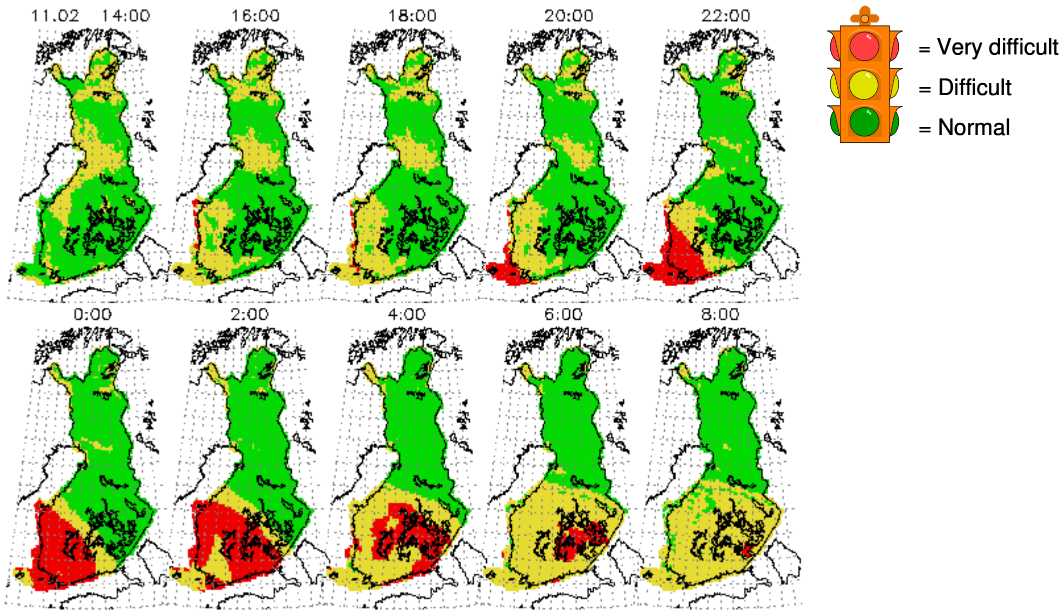

Figure 4 : Traffic condition index as produced by the model.

The model further combines information about the road condition, storage sizes and certain weather parameters (notably wind speed, precipitation intensity) to produce a three-valued traffic condition index describing the traffic conditions in more general terms that are used in traffic condition forecasts and warnings issued by road officials (Fig.4).

4 Operational usage

The operational model run consists of two parts, first one 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.

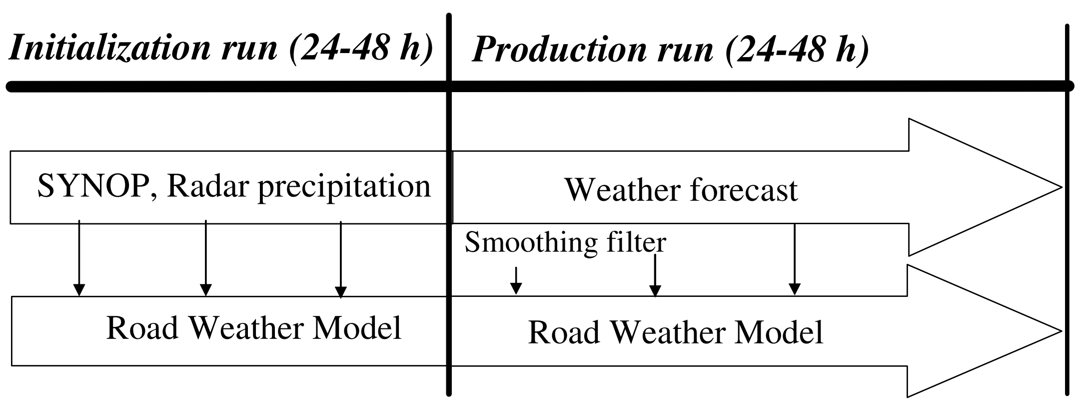

Figure 5 : Operational model run structure.

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 5-7 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 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 to on-line measurements and photos provided by the Finnish Road Administration (http://www.tiehallinto.fi/eindex.htm).

5 Model development

The present 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 generalize the results. There is, however, on-going work to transfer the model to pedestrian environment (Ruotsalainen et al., 2004) as well as road maintenance planning (Hippi, 2004).

Further planned future enhancements of the model include to better account for varying traffic and environmental conditions.

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