Road Weather Forecasting for a Ring Highway

T. A. Bazlova, N. V. Bocharnikov , M.S.Vinogradov and A. S. Solonin

Institute of Radar Meteorology,
Saint-Petersburg, Russia

iram@iram.ru

ABSTRACT

Road weather forecasting tool has been developed in the framework of MeteoTrassa system to provide information for winter maintenance of a ring highway in Saint-Petersburg. The ring highway is a complicated engineer object which stretches over 112 km under the influence of different local climate conditions and consists of flyovers, bridges, low and high sections. Road surface temperature and condition are influenced by a wide range of meteorological, geographical and road construction parameters. From thermal mapping, we determined large local differences in road surface temperature up to 5 deg Celsius over a distance of several hundred meters. The system forecasts road surface temperatures and conditions for an entire route for 4-6 hours ahead based on a local atmospheric boundary layer numerical model, thermal mapping and road construction data. Doppler weather radar data enables us to nowcast and to forecast precipitation in terms of onset and cessation of snowfall, its intensity, amount of snowfall for separate sections of the highway. The system takes an advantage of existing weather data sources (25 road weather stations, Doppler weather radar, regional and mesoscale forecasts), combines data to present integrated road weather observations and forecasts for the entire highway. Road weather station network of high density gives basis for forecast verification.

Keywords: road weather station, Doppler weather radar, thermal mapping, road weather model, NWP mesoscale model.

1 INTRODUCTION

Ring highway in Saint-Petersburg was constructed in 2011. Heavy rain, snow and ice can result in dangerous conditions and accidents on the highway. The MeteoTrassa system has been installed as a part of its infrastructure to provide maintenance personnel with current weather information and road weather forecasts and warnings and recommendations on road treatment. The MeteoTrassa system is a dedicated data collection, management and display system for road authorities. It operates as a maintenance decision support system (DSS) in different climatic regions of Russia [1,2]. The system facilitates cost effective maintenance, road safety and high road capacity with minimal damage to the environment.

Road weather forecasts are extremely important and helpful for those responsible for managing the ring highway to optimize their winter maintenance activities to keep road users safe. To limit the impact on the travelling public, it is vital for road maintenance decision-makers to have warnings of hazards like ice beforehand so they can apply precautionary treatment. The MeteoTrassa system contributes to keeping the highway moving by providing forecasts and warnings. Winter road maintenance operatives can determine much more accurately which sections and which traffic lanes of the road need treating. This means they can selectively treat routes, or segments of routs, in order to manage salt supplies more effectively, operate more effectively, and reduce costs without comprising safety. The aim is to provide the highway engineer with an online map where the salting routes are colour-coded depending on the treatment required.

The ring highway stretches over 112 km under the influence of different local climate conditions and consists of flyovers, bridges, low and high sections. Parameterization of some variables influencing road surface temperature in road weather forecast model is needed because of the lack of the data concerning road construction (albedo, thermal conductivity, thermal diffusivity, emissivity, depth of construction, etc.). Forecast techniques rely on the model simulation for road weather stations and thermal mapping to make spatial temperature interpolations between road weather stations. Doppler weather radar data enhance the system performance providing good basis for precipitation forecasts. The system simulates road surface temperature and condition on a route by route basis by using the thermal mapping database.

2 CONFIGURATION

The system has been operated since year 2011 at a new Management Center of Ring Highway in Saint-Petersburg. It is comprised of 25 road weather stations ROSA (each of them being installed with 8 road sensors in accordance with the number of traffic lanes), central computer, workstations, special-purpose software and communication tools. The MeteoTrassa software is responsible for collection of the data, processing, analysis, storing and distribution, presentation of the data, forecasting and generation of recommendation on road treatment.

The system receives data from different sources:

- Road weather stations network
- Doppler weather radar
- Regional hydrometeorological center
- Mesoscale NWP model (GRIB-coded output of WRF-ARW model).

The ROSA weather station responds to requests for data from the central station at pre-defined polling times with 5- min intervals.

The Doppler weather radar Meteor-MeteoCell at Pulkovo airport operates at 10-min intervals. The radar data is accessible from the regional hydrometeorological center (HMC) FTP-server.

Workstations are installed at road service contracting organizations and the regional HMC. Workstations receive observation data and textual messages from the central computer automatically. HMC workstation sends area specific weather forecasts and warnings of the regional HMC to the central computer, which then distributes them to other user workstations automatically.

3 FORECAST TECHNIQUES

Forecast techniques rests on the model simulation for road weather stations and thermal mapping to make spatial temperature interpolations between road weather stations. The most essential information for making the right decision on road treatment is road surface temperature, depression of freezing point and precipitation. The system simulates road surface temperature and condition and precipitation. It employs different data sourced from the road weather stations, Doppler weather radar, regional HMC forecasts and mesoscale NWP model.

The forecasts have sufficient lead times (up to 4 hours ahead) to support tactical aspects of winter maintenance operations. The regional HMC provides forecasts for strategic time periods (up to 72 hours ahead). In order for a DSS to support round-the-clock operations, the forecasts update every 30 minutes or on a user request. Forecast accuracy can benefit from frequent updates based on observations with high resolution (both temporal and space) and new model runs.

3.1 Model

Numerical model of atmospheric boundary layer provides forecasts of road surface temperatures and road condition for a forecasting period up to 4 hours. The model is based upon the boundary layer hydrodynamics equations with k-ε turbulence closure scheme and an energy balance equation. The Monin – Obukhov similarity theory is employed to retrieve first-guess profiles of temperature, wind and humidity at a surface layer depending on atmospheric stability.

In order to calculate fluxes of heat and moisture and to derive surface temperature in the energy balance equation a parameterization procedure is used. Energy transfers from radiative and turbulent processes are calculated from measurable or predictable variables such as air temperature, dew point temperature, wind speed, cloud amount and cloud type. These values are supplied for the forecast period along with the time and type of precipitation. The incoming solar radiation flux on the surface is given by parameterization with surface slope taken into account. The effect of clouds on the incoming both solar and long-wave radiation is parameterized in terms of the effective cloud cover.

Information about precipitation and clouds derived from the weather radar data is used in the model. Albedo and roughness of road, emissivities of road and atmosphere, heat capacity and conductivity and other parameters are predefined. At the lower boundary, the climatological ground temperature is used as boundary condition.

The model employs information from road weather network and Doppler weather radar and GRIB-encoded mesoscale prognostic data as input data.

Mesoscale NWP model data is used to prescribe a top boundary condition (level 850 hPa is regarded as a top boundary of atmospheric boundary layer). High-resolution model WRF-ARW runs at the HMC of Russian Federation. The fine scale model has a grid spacing of 3 km and time resolution of 1 hour. Its outputs are available at the HMC server via FTP-connection. An example of temperature and wind forecast is represented in Fig. 1.

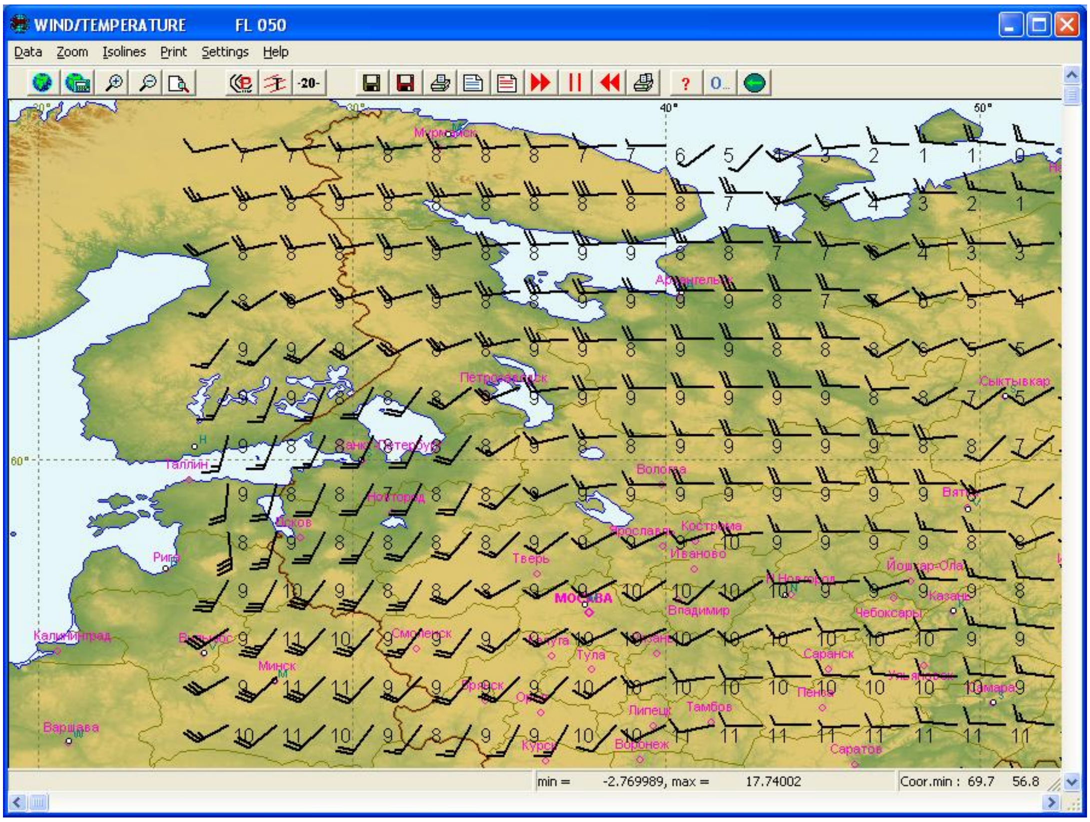

Figure 1. WRF-ARW output: forecast of temperature and wind at 850 hPa.

The availability of input data with high resolution in time and space has increased the possibility to improve short term forecasting of road weather. An example of presentation of road weather station data at 5-min intervals is shown in Fig.2. Air temperature, dew point temperature, road surface temperature, ground temperature and freezing temperature are represented in graph form.

The prediction of road surface conditions is based on consideration of temperature, dew point temperature, and precipitation status. The single – point forecast is available at any time on a user's request (see Fig.3). The user gets prognostic information like surface condition, precipitation (onset and cessation), air temperature, dew point temperature and surface temperature up to 6 hours at 1-hour intervals together with current weather data.

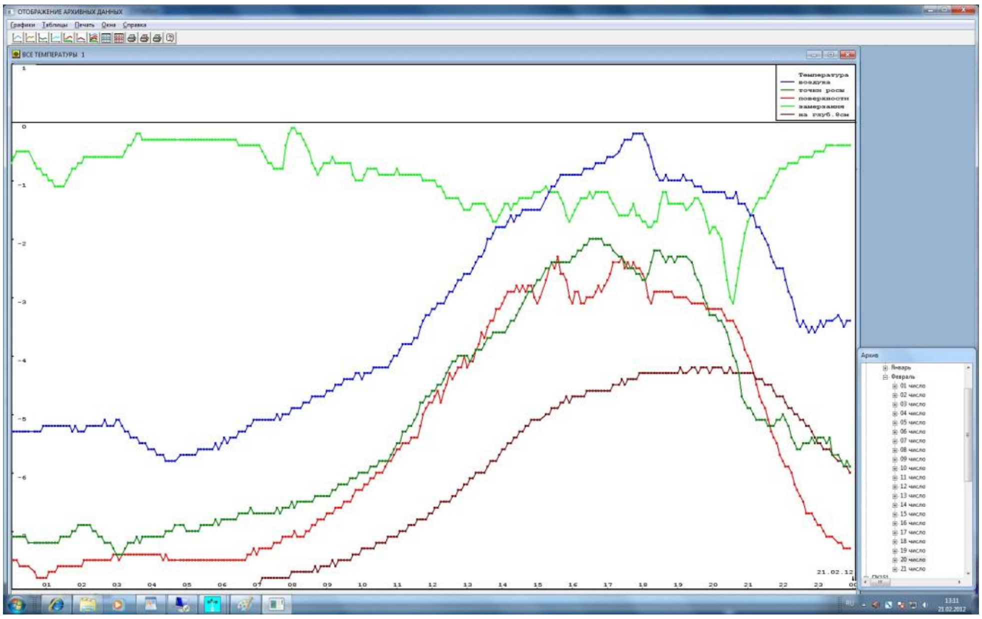

Figure 2. High resolution data (at 5-min intervals) from road weather station.

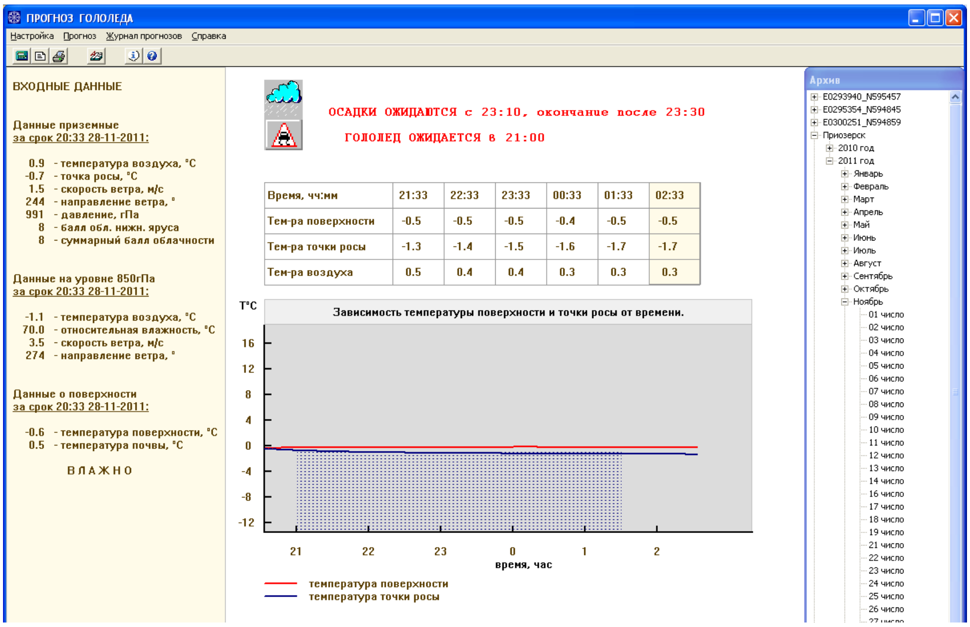

Figure 3. Single – point forecast.

Site specific weather forecasts are provided for locations where road sensors exist and extrapolated to the highway ring so far as thermal maps are available.

3.2 Weather radar information

Weather radar is useful in determining and short-term forecasting of precipitation and other weather phenomena such as thunderstorm, hail, severe winds, and cloudiness.

The following weather radar products are of most interest for the purpose of winter road maintenance: onset and cessation of snowfall, its intensity, amount of snowfall for separate sections of highways and trunk roads. Information about precipitation and clouds retrieved from the radar data is used in the model.

The radar images are updated every 10 minutes at the radar workstation MeteoCell covering 400 km x400 km area with resolution 2 km x 2 km.

Nowcasting for up to 2 hours based on radar data is performed. A combination of three methods is employed to obtain the speed and direction of precipitation zones. These methods are as follows: a cross-correlation tracking method, averaged Doppler velocity at the layer where radioecho area amounts to its maximum value, and prognostic wind at a fixed level (700 hPa or 500 hPa, depending on the season).

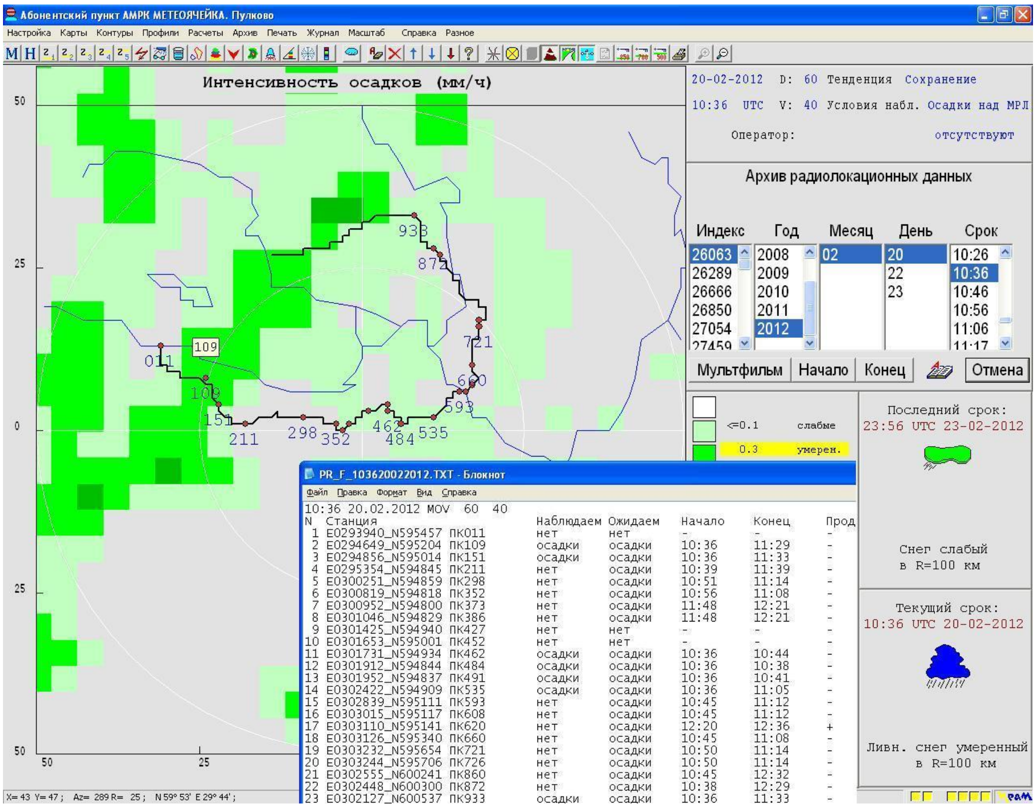

Figure 4. Weather radar – based forecast of precipitation.

The growth and decay trends algorithm consists of the following steps:

- detection of phenomena class (precipitation, heavy rain, thunderstorm and hail)
- estimation of phenomena class changes on the basis of two time steps (previous and current)
- determination of the trend depending on the changes estimated: the growth if more dangerous phenomena class appeared; the decay if less dangerous phenomena class appeared
- in case of no phenomena class changes, the trend is regarded as growth if precipitation area increased, and as decay if precipitation area decreased.

An example of weather radar – based information about precipitation is represented in Fig. 4. Precipitation intensity is shown in the form of colour – coded field. Black line identifies the highway ring. The precipitation forecast is given in a texual form for each point of interest with indication of onset and cessation.

3.3 Thermal mapping

Information on spatial variation of road surface temperature in a road network is needed to make a forecast for a whole network rather than for a set of sites where road weather stations are installed. It is known that topography, local heat sources, basins are important systematic factors controlling the variation of road surface temperature. The process to record and quantify these patterns of road surface temperature is called thermal mapping. It is a reliable and effective method to explore spatial variation of road surface temperature based on the proved fact that the pattern of road surface temperature is reproduced from one night to the next one under the similar weather conditions.

In order to get relationship between road surface temperature and topography (and other local factors) thermal mapping data obtained by a vehicle-mounted laboratory equipped with IR radiometer, GPS unit, temperature and humidity sensors, and notebook is used. From thermal mapping, we determined large local differences in road surface temperature up to 5 deg Celsius over a distance of several hundred meters. Thermal maps for the ring highway were created during winter 2011-2012. This work is to be continued to obtain better statistics.

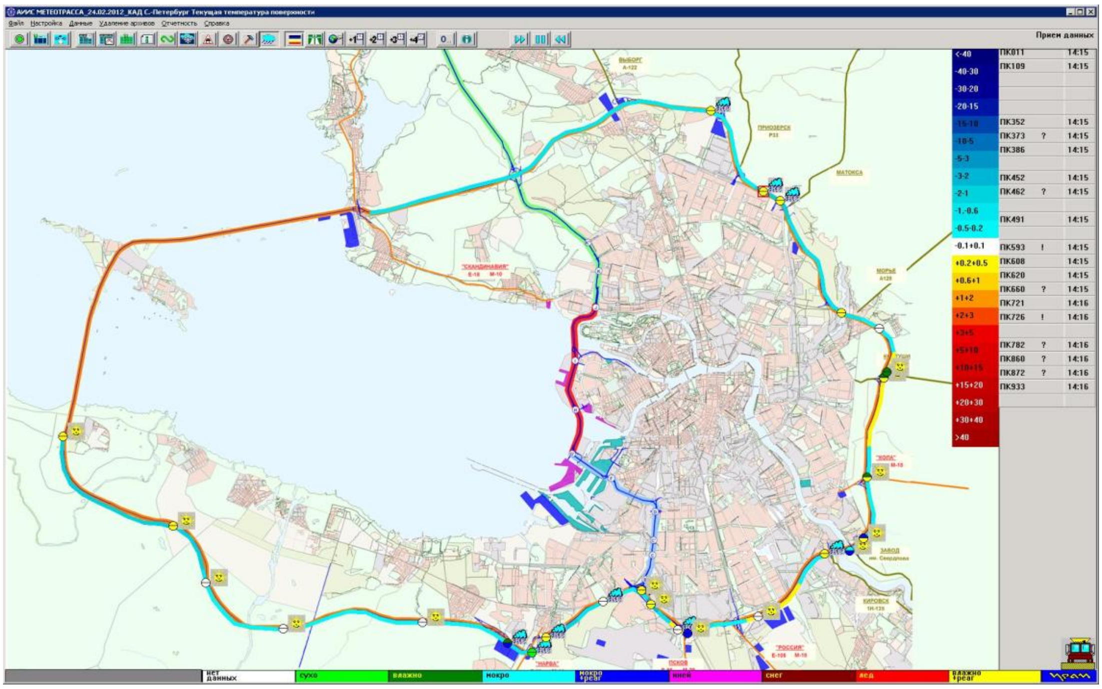

Figure 5. Road surface temperature, condition and precipitation forecast for the highway ring.

An example of road surface temperature, condition and precipitation forecast for the highway ring is represented in Fig.5.

4 CONCLUSIONS

The system takes an advantage of different weather data sources, and presents forecasts and warnings for the highway ring both for tactical and strategic time periods. Forecasts are available up to 4-6 hours ahead with updating every 30 minutes and up to 72 hours ahead with updating every 3 hours. The model is to be verified against observations from road weather sensors.

Future development of the system is connected to the improvement of the model based on the verification results and more thermal mapping data. Detailed information of road construction is also regarded as quite useful when it is available in electronic format.

5 REFERENCES

[1] T. Bazlova, N. Bocharnikov, V. Olenev, and A. Solonin. Road weather nowcasting system. WMO symposium on Nowcasting. 2009, Whistler, Canada.

[2] Bazlova T, Bocharnikov N, Olenev V, Solonin A. 2010. Regional decision support system. *In: Proceedings of SIRWEC 15th International Road Weather Conference, Quebec City, Canada, 5-7 February 2010*. Available from http://www.sirwec.org/conferences/Quebec/full_paper/ 36_sirwec_2010_paper_bazlova.pdf