Road Weather Forecasting

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1. INTRODUCTION

Heavy precipitation and ice formation can result in dangerous conditions and accidents on roadways. Road weather forecasts are extremely helpful for those responsible for managing roadway to optimize their winter maintenance activities to keep road safety. The MeteoTrassa system provides maintenance personnel with current weather information, road weather forecasts (up to 4 hours ahead) and warnings and recommendations on road treatment [1 - 4]. It operates as a maintenance decision support system (MDSS) in different climatic regions of Russia (see Fig.1-2). The system has been operational at a new Management Center of Ring Highway in Saint-Petersburg since year 2011 [3]. Results of nowcast verification for the Ring Highway are presented.

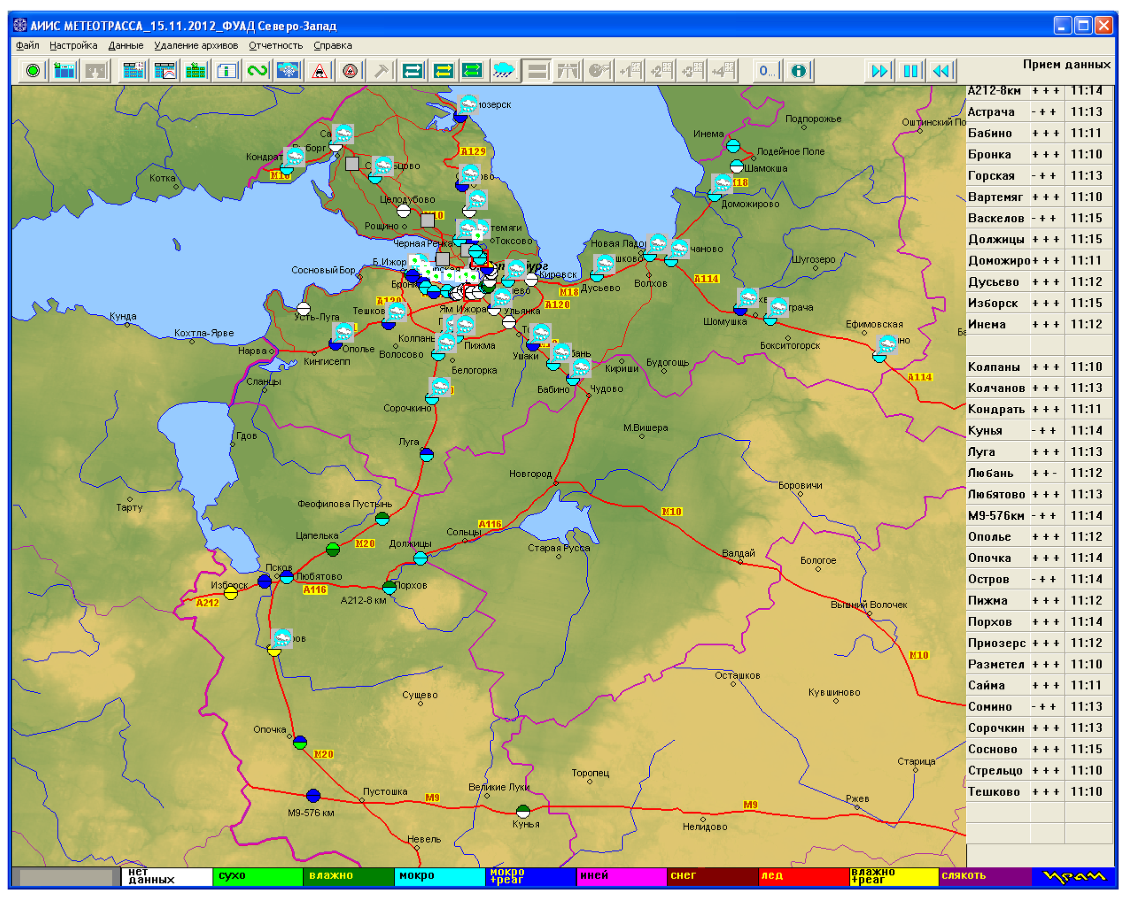

Figure. 1. The MeteoTrassa 4-hour nowcast for the road network of north - west region of Russia

Figure. 2. The MeteoTrassa 4-hour nowcast for the road network of south region of Russia (Krasnodar region)

2. CONFIGURATION

The system at the Ring Highway is comprised of 25 road weather stations ROSA (each of them being installed with 8 road sensors), central computer, workstations, special - purpose software and communication tools. 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. Current weather data and nowcasts are transmitted to workstations and to the Traffic Management system.

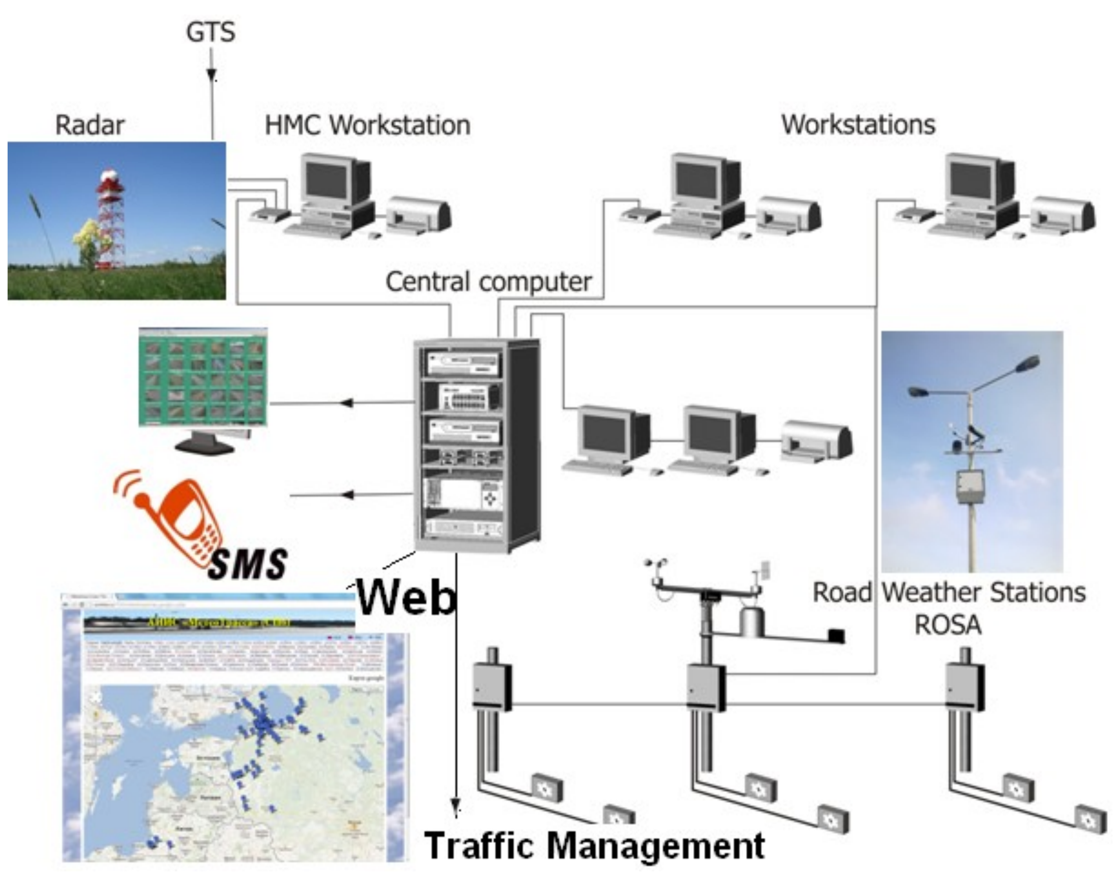

Figure 3. The system configuration scheme

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. Doppler weather radar data enhance the system performance providing good basis for precipitation nowcasts. The system simulates road surface temperature and condition on a route by route basis by using the thermal mapping database.

In order for a MDSS 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.

3.1 Model

Numerical model of atmospheric boundary layer provides forecasts of road surface temperatures and road condition. 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. Mesoscale NWP model data at level 850 hPa is used to prescribe a top boundary condition.

Information about precipitation and clouds is retrieved from the radar data.

The prediction of road surface state is based on consideration of temperature, dew point temperature, and precipitation status.

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

3.2 Weather radar information

Weather radar is useful in determining and nowcasting of precipitation and other weather phenomena such as thunderstorm, hail, severe winds, and cloudiness [4]. Information about onset and cessation of snowfall, its intensity, amount of snowfall for separate sections of roads is of most interest for the purpose of winter road maintenance.

The radar images are updated every 10 minutes at the radar workstation MeteoCell covering 400 km x 400 km area providing actual weather information and nowcasts for 2 hours ahead at spatial resolution of 1 km. Fig.4-5 show cases of dangerous weather in the Ring Highway area. Black line identifies the Ring Highway.

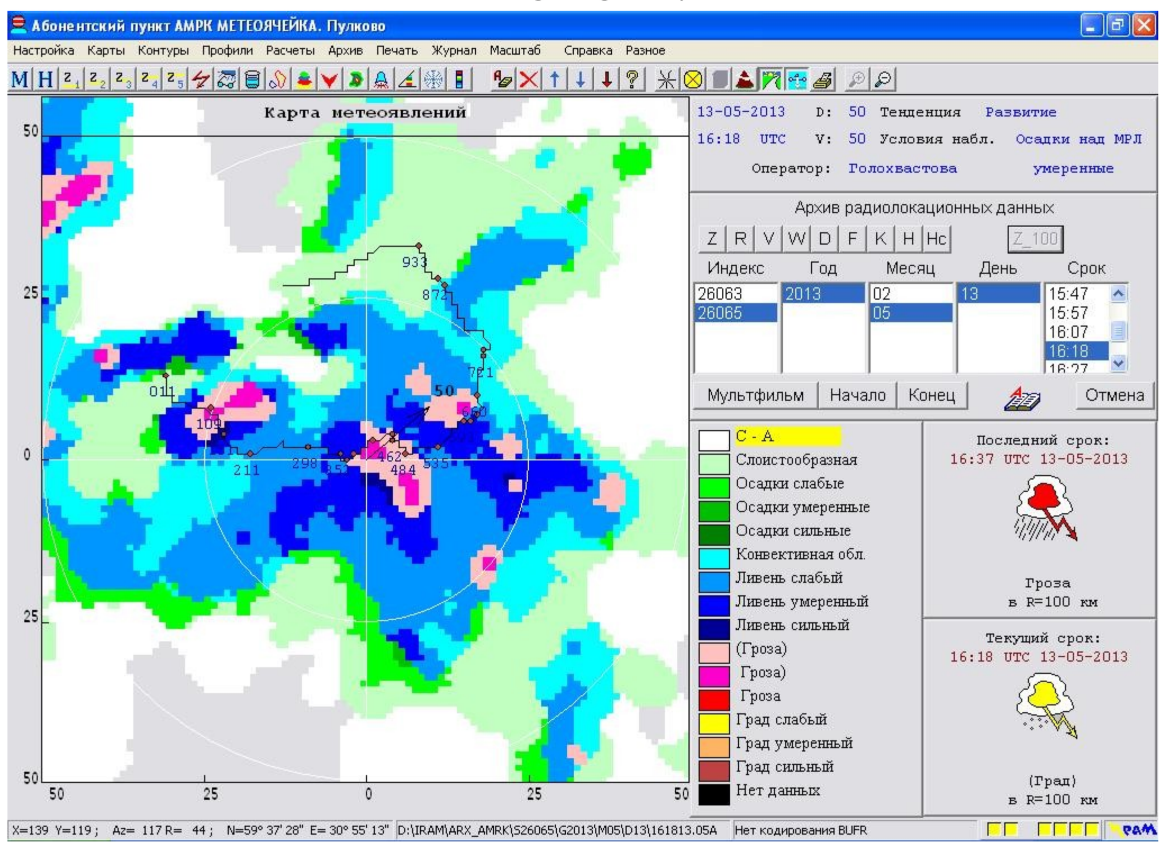

Figure 4. Dangerous weather (thunderstorm and heavy rain) in the Ring Highway area

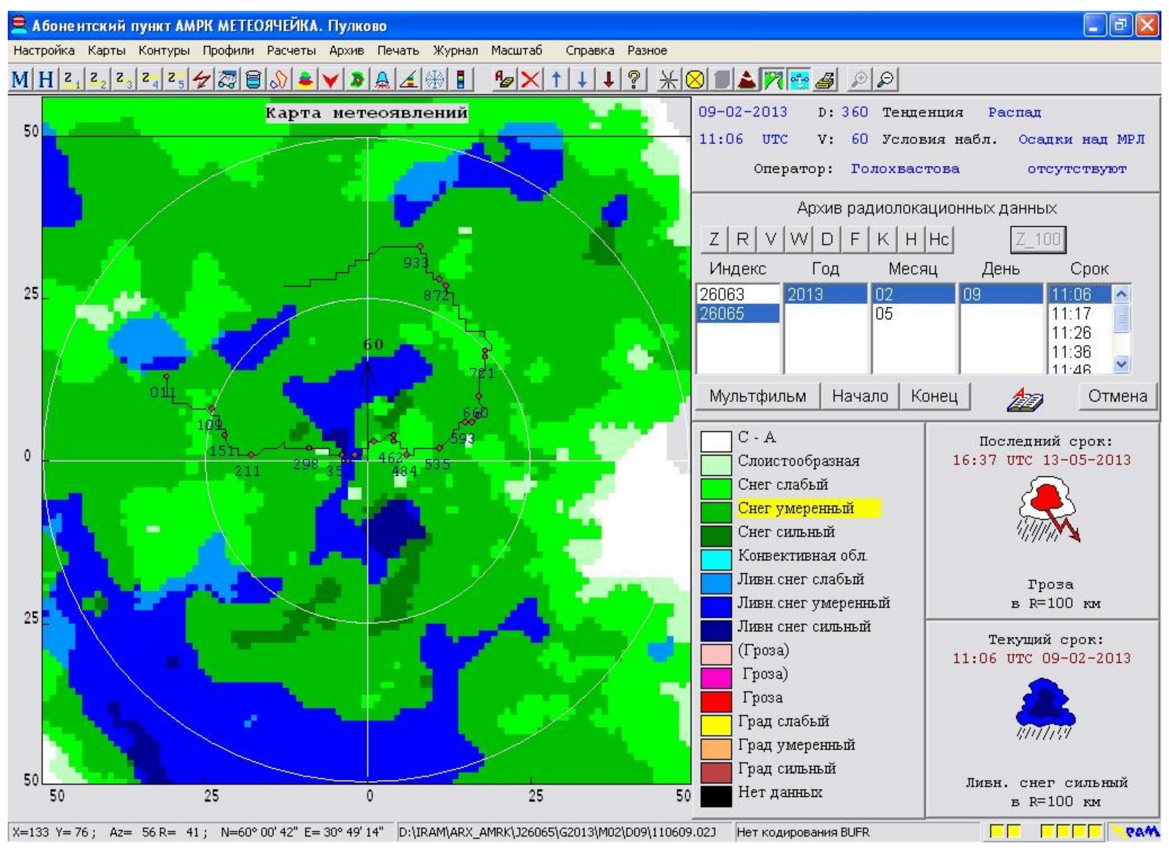

Figure 5. Moderate to heavy snow in the Ring Highway area

A combination of three methods is employed to estimate precipitation movement (a cross-correlation tracking method, averaged Doppler velocity, and prognostic wind at fixed levels - 700 hPa, 500 hPa and 300 hPa).

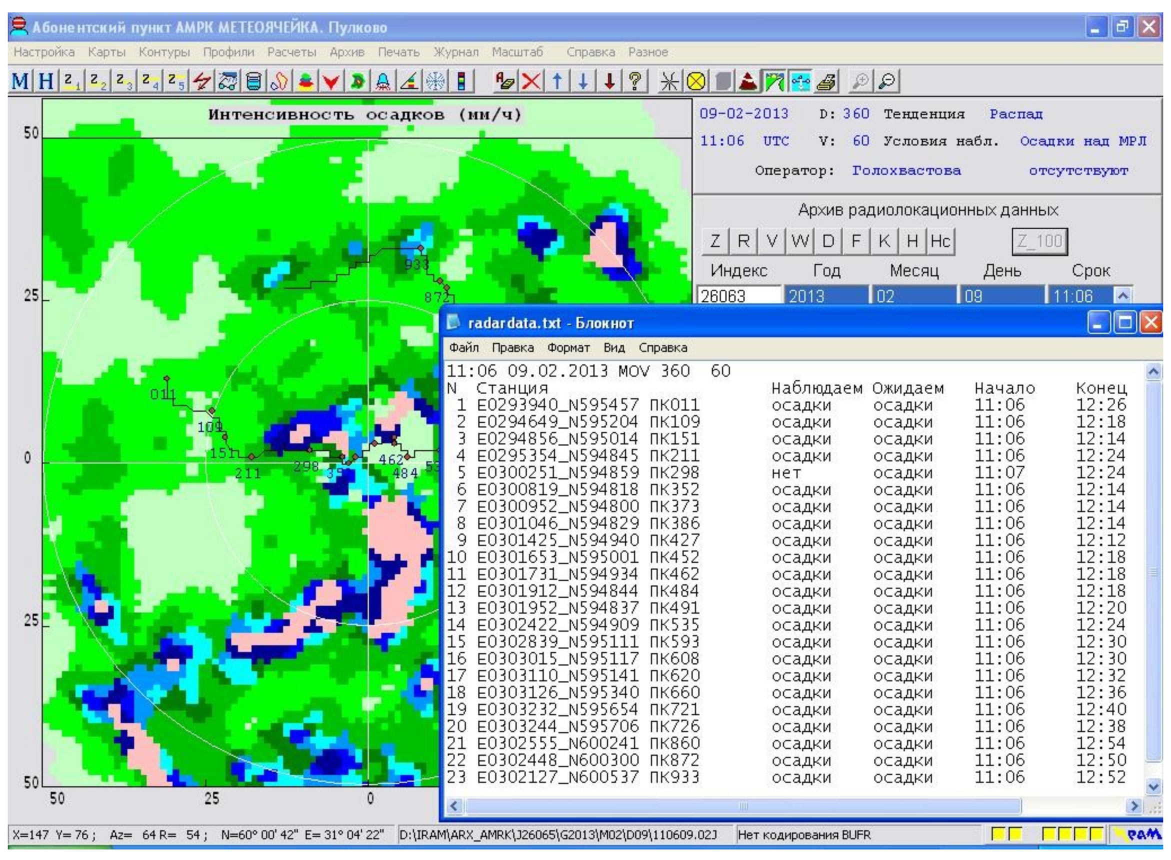

Figure 6. Precipitation intensity and 2-hour nowcast of precipitation

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 decay if precipitation area decreased.

An example of weather radar – based information about precipitation intensity and precipitation nowcast is represented in Fig. 6.

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.

Thermal maps for the Ring Highway were created during winter 2011-2012. Retrieved surface temperatures were compared against measured temperatures at 25 locations. Mean absolute error is equal to 0.4° C.

An example of 4-hour nowcast for the Ring Highway is represented in Fig.7.

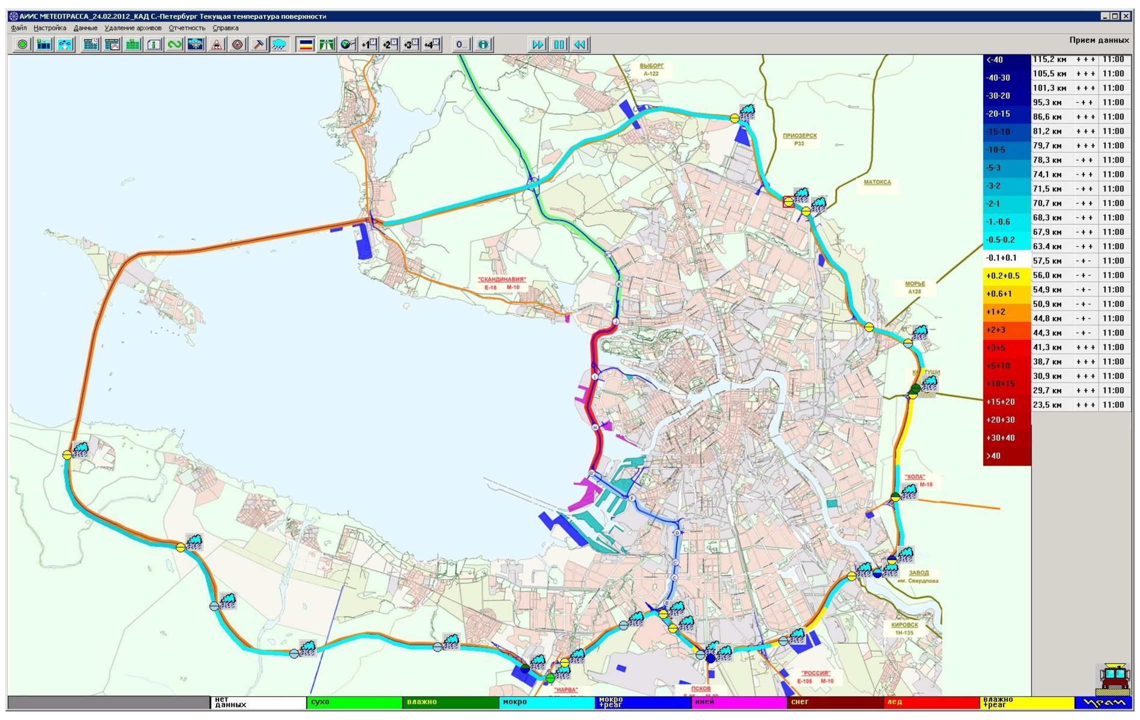

Figure 7. The MeteoTrassa 4-hour nowcast for the Ring Highway in Saint-Petersburg

4. VERIFICATION RESULTS

The 4-hour forecasts surface temperature (Ts), air temperature (Ta), dew point temperature (Td) and road surface state were compared against actual observations at the sites were road weather stations exist.

Forecasts have been verified based on the data for Krasnodar region for winter period 2007 through 2012. Total number of cases is 646717 (observations from 56 road weather sensors). Proportion correct of ice predictions for 4 hours forecast range is amount to 0.94.

Forecasts for the Ring Highway for November 2012 through March 2013 have been verified. Total number of the forecast occasions is equal to 36687. The results of the verification in terms of several scalar accuracy measures are shown in Table 1. The mean absolute error (MAE), bias and root - mean squared error (RMSE) of temperatures and proportion correct (PC) and hit rate (H) of surface state nowcasts are presented.

Table 1. Verification results

	MAE	Bias	RMSE	PC	H
T surface	0.54	0.42	1.48	0.90	
T air	0.53	0.52	1.49	0.91	
T dew point	1.27	1.27	1.52	0.78	
Ice surface state (a)				0.97	0.89
Ice surface state (b)				0.98	0.96
Ice surface state (c)				0.98	0.98

Uncertainty in verification exists when chemicals have been used to prevent ice formation on the highway. These cases (all or part of them) of the road surface precautionary treatment can be regarded as right action due to right forecast. If all cases with observed chemicals on the highway are excluded from the verification sample, then PC =0.97 and H = 0.89 (a). If 50% cases with chemicals are regarded as ice state cases then PC = 0.98 and H = 0.96 (b). If we proceed from the assumption that all 100% cases with chemicals means possible ice state then PC = 0.98 and H = 0.98 (c). These results for the Ring Highway show better forecast performance in comparison with forecasts for other regions, for example, for the road network in Krasnodar region. Doppler radar data usage may lead to this forecast improvement.

5. CONCLUSION

The system provides nowcasts up to 4 hours ahead with updating every 30 minutes based on road weather station data, Doppler weather radar data and model simulation. Results of verification show quite adequate nowcast accuracy for temperatures and road surface state.

6. REFERENCES

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