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Road weather forecasts and MDSS in Slovakia

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ABSTRACT

The system of meteorological forecasts, developed for the purpose of winter road maintenance and operated in Slovakia is described in this article. The system consists of several interconnected modules. The basis for preparing weather predictions is the numerical model ALADIN, developed in international cooperation and operated directly at the Slovak Hydrometeorological Institute. Output data from the model, particularly useful for general forecasts are further specified by INCA nowcasting and METRo road forecast modules. The combination of local measurements (professional and road weather stations) and weather forecasts allows now detailed predictions and alerts for each Road Weather Segment (road section with similar microclimatic conditions), that means differentiated danger levels of road conditions are shown on the dynamic map for a given lead time. The collection, combination and visualisation of all the information of this Maintenance Decision Support System give the operator the possibility to make decisions efficiently and to dynamically manage road maintenance and thus he is able to increase the road safety and improve the traffic flow. Therefore the Slovakian Road Authorities decided to implement a Maintenance Decision Support System (MDSS) for the whole Slovakia.

Keywords: Maintenance Decision Support System (MDSS), practical example, Slovakia

1 INTRODUCTION

The main goal of quality winter maintenance is to ensure the safety and free flow of traffic on the roads. It should be performed efficiently, effectively and in accordance with the requirements of environmental protection.

There are many factors that the strategy for winter road maintenance depends on. Along with the traffic density, there are the demographic and climatic factors together with the current weather situation and its prediction that play a key role in the decision-making process. The current air temperature and road conditions, the occurrence of precipitation, the wind speed and direction are analyzed on the basis of data from professional and road weather stations. For the correct decisions in the process of management of winter maintenance of roads and highways, the further development of meteorological elements and weather patterns is very important. Decision-making is almost directly dependent on the weather forecasts.

In cooperation with the National Highway Company, the Transport Research Institute and private sector, we developed and tested the modular system for data collection, specific road weather forecast preparation and complex visualization in Slovakia. The main goal was to provide reliable and well arranged information about the current weather and road conditions, especially for highways, and outlook of meteorological situation with the emphasis on temperature, surface temperature and precipitation.

The system itself is composed of several modules, specialized in data measurement and collection, numerical weather prediction, nowcasting, postprocessing and visualization. Especially for warning purposes, the support from weather forecasters – "manual" preparation and control of issued warnings is necessary. The visualization part is solved by software package for visualization of road data and weather forecasts BORRMA-web, developed by Boschung Mecatronic AG Company and used successfully in Austria, Switzerland, France and Germany [1, 2]. The basic scheme of the mentioned system is displayed in Figure 1.

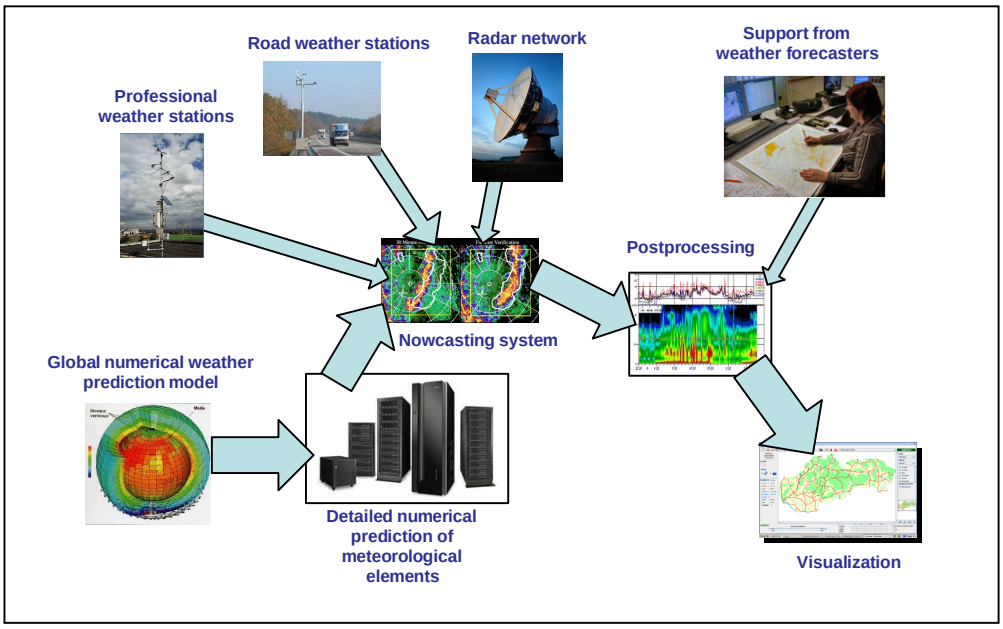

Figure 1. Chart of the modular forecasting system used for road weather forecasts in Slovakia.

2 INPUT DATA

2.1 Data from weather stations

For the purpose of monitoring of the actual state of weather and road conditions, the National Highway Company operates the network of 115 road weather stations, located along more than 600 km of highways and speedways over the whole Slovakia. The network consists of 15 control centres. Due to ensuring the homogeneity and equal relevance of the measured data, each part of highway belonging to one control centre is equipped with a road weather station (RWS) of the same type. Two kinds of RWSs operate at present: Boschung (73 items) and Vaisala (42 items). Both systems allow the integration of a large number of various meteorological and pavement sensors. The Boschung stations are equipped by active pavement sensors providing the accurate freezing point temperature, independently of the type of de-icing agent spread on the road. This process measures the freezing point temperature of the liquid solution by artificially cooling a small area on the surface of the sensor up to 15°C below the current pavement temperature. This measurement takes implicitly into account all parameters that influence the freezing point temperature (type and remaining quantity of chemicals, dust, tire particles etc.), thus delivering the most accurate information [3]. The abovementioned active pavement sensors are used especially in areas with difficult winter conditions, as bridges or deep valleys in hilly part of the country. The fact that only these two kinds of measurement devices are operated ensures easy integration of all measurements into one system. The data from those measurements are used to describe the present weather and road conditions as well as to prepare the specialized forecasts.
Apart from the network of RWSs also data from automatic weather station and rain gauges of SHMI – the national meteorological service are used. These measurement points are not located directly near highway, but the very accurate data obtained in accordance with World Meteorological Organization rules are very useful in the process of forecasts production and nowcasting.

2.2 Numerical weather prediction

The weather forecast is based on the numerical weather prediction model ALADIN. Model ALADIN (Aire Limitée, Adaptation Dynamique, Development International) is a limited area forecasting model intended for short term forecast (72 hours) of atmospheric processes in the horizontal scale of the order of 10 km. The model is developed in a consortium of 16 countries. At present, ALADIN model is running at SHMI 4 times a day, on a 9x9 km horizontal grid, whereas the initial and boundary conditions necessary for the calculation of the model are transmitted from the global model ARPEGE (MeteoFrance). The outputs of the ALADIN model are an essential source of information about the expected development of meteorological elements over the territory of Slovakia for the following 72 h.
Products generated by the numerical prediction are sets of figures that characterize the expected development of meteorological elements for the forecasted period. For every point where a road weather station is located, sets of forecasts are generated. Forecasts are generated 4 times a day with a time step 1h on the following 24 hours. In addition, forecasts with a time step 3h for period of 00 to 72 hours are provided 2 times a day. The files contain forecasts of the following elements: air temperature, dew point temperature, relative humidity, surface

temperature, average wind speed, wind gusts, wind direction, precipitation type, precipitation amount, cloud amount, pressure and intensity of sunlight. In the future, also other elements (such as type of cloud) will be included, as these cannot be provided currently by a numerical model. Output data, particularly useful for general forecasts are further specified by INCA and METRo modules.

INCA (Integrated Nowcasting through Comprehensive Analysis) is a high-resolution, real-time analysis and forecast system developing in international cooperation implemented through the Central Europe Programme that is co-financed by the European Regional Development Fund. One of the pilot implementation areas is road safety. Detailed analysis of the current status of temperature, precipitation and other elements is based on the measurements of automatic weather stations and measurement systems, such as weather radars. After 2-6 h of forecast time the nowcast is merged into an NWP forecast provided by a limited-area model ALADIN [4, 5].

METRo - Model of the Environment and Temperature of Roads is a system of algorithms developed in the Environment Canada. The module combines information from road weather stations with forecast of atmospheric conditions and improves the prediction of road conditions, focused on surface temperature, freezing rain, accumulation of snow, frost and thaw [6, 7]. We decided to use the METRo model because of the open, quite well documented source code and implementation in real service. However, it requires subsurface measurements that are not available in Slovakia, or that are performed at different depth below surface from which is necessary for these purposes. In many cases we have also no information about pavement structure, so we are trying to calculate the physical characteristics based on the direct measurements, where they are available.

ALADIN model calculations are intended mainly for the production of short-term forecasts of synoptic scale phenomena up to 72 hours. However, the crucial period for the management of road maintenance is often only a few hours ahead. Significant changes in weather conditions can occur in this very short period of time, mainly due to the nonlinear development of cloudiness, thunderstorms, or precipitation type. Especially by a combination of modules INCA and METRo we can try to provide the accurate predictions for the next minutes and hours.

A set of numerical predictions mentioned in the preceding paragraph could be accompanied by manually added part, including warnings of meteorological phenomena, whose occurrence can significantly affect traffic on roads. These elements are heavy rain, thunderstorm, hails, heavy snowfall, snow drift, fog / reduced visibility, freezing rain / icing, windstorm. The specific warning editor allows quick adding of expected phenomena by meteorologist. We plan to partly automate this process by specific outputs from INCA nowcasting system. However, automation of hail, fog, snow drifts and reduced visibility forecast is not possible, due to the complexity of microphysical processes that cause these phenomena.

2.3 Data from the weather radar

Data are provided in the form of image information on the intensity of precipitation calculated from measurements of two meteorological radars operated by SHMI. The picture of the current state is updated every 5 minutes. The recipient of the product will be able to view the time evolution of precipitation intensity and movement of rain areas over the territory of Slovakia (Figure 2).

After starting the INCA precipitation nowcasting into operational service, we will be able to combine these radar measurements with data from rain gauges to give a comprehensive analysis of precipitation over the territory of Slovakia. The complex quality control will be followed by precipitation nowcasting for the next few hours with time step 10 minutes. In addition to the graphical overview of the evolution of precipitation for the previous period, the estimate of further development of precipitation areas in the next minutes and hours will be calculated. This is particularly crucial for prediction of convective rainfall associated with storm clouds during summer.

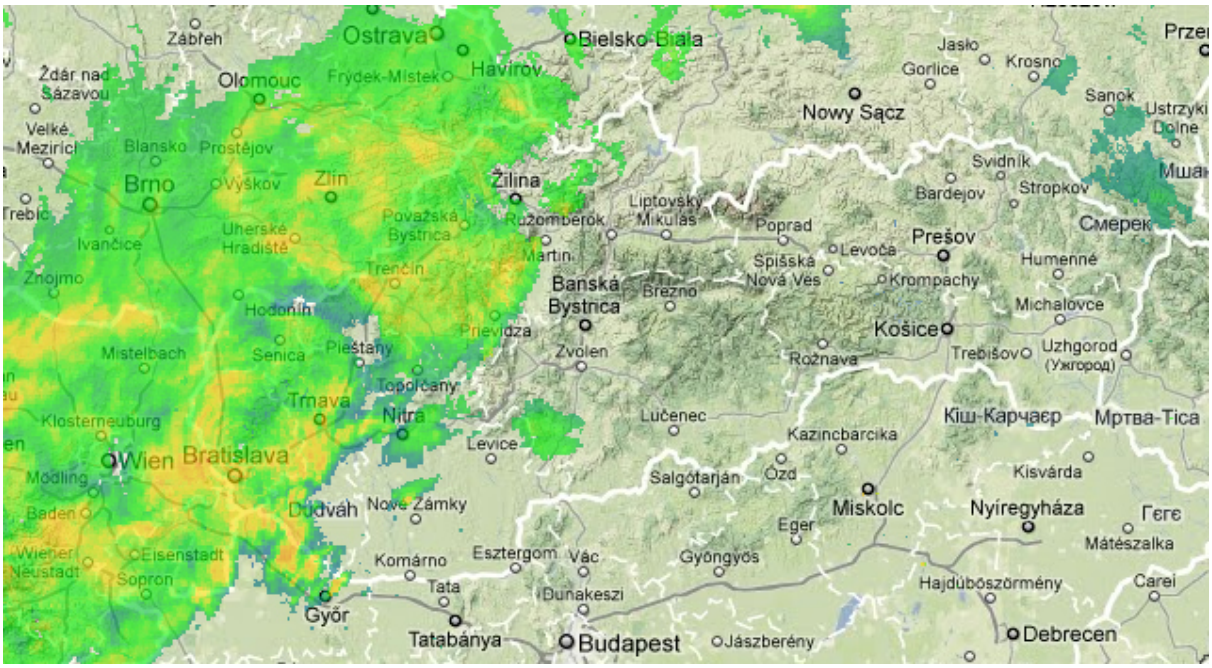

Figure 2. Map of precipitation intensity calculated from radar measurements (SHMI, 24 Aug 2010, 8:40 UTC).

2.4 Text forecasts

Text forecasts serving as supplementary information for users of forecasting products provide a broader overview of the expected development of weather during next 3 days. Text is arranged by the administrative districts and formulated for the larger region – not only for the road itself, and besides, the forecasts are focused on phenomena that can cause problems in road traffic.

3 OUTPUTS AND VISUALIZATION

During the process of planning and management of winter maintenance activities, the road operator have to monitor many common conditions and influencing parameters, such as legal rules requirements, meteorological parameters and weather conditions, the current and forecasted road surface conditions and other factors of traffic that must be immediately included in the decision-making process. Especially in the case of very difficult winter conditions such as heavy snow or freezing rain, it is essential that winter maintenance operator is supported by detailed visualization of information on the immediate situation, forecast and possible critical states or different levels of risk. The dynamic map of BORRMA-web system meets all these requirements.

All relevant data and information obtained from static and mobile devices are displayed on the live dynamic map. The map is designed in order that also the workers without any meteorological knowledge and experience have an immediate and accurate summary of the overall condition of the highway. The map consists of different layers (vector maps, satellite images, etc.) and dynamic information such as weather stations, vehicles, warnings, etc. The weather stations are shown as small flags - informative windows, which displays the current measured data (Figure 3). Displayed parameters and informative content is individually configurable to the needs of each user. All dynamically changing data, such as levels of risk, alarm messages about the dangers of icing on each road segment, meteorological data, etc. are continuously and automatically updated. Alarm reports from weather stations are shown clearly, neatly and precisely, the relevant part of the road or highway is graphically highlighted as a color section on which the alarm condition is declared. The dynamic map displays real-time data. Former data can be visualized by means of a time cursor. The time cursor can also be shifted forwards in order to display forecasted values. In cases where it is not necessary to display data from all weather stations, operator can disable flags and weather stations appear only as a coloured point on the map (Figure 4). The alert levels or expected risk at road sections are clearly displayed on a live map with appropriate graphics and colour changes (Figure 5). The road section is coloured based on weather forecasts from meteorological institute and on measured data. The lead time of forecasts and warnings is up to 72 hours. The appropriate risk level from 1 to 4 is then graphically displayed on the live map, in the area of road section.

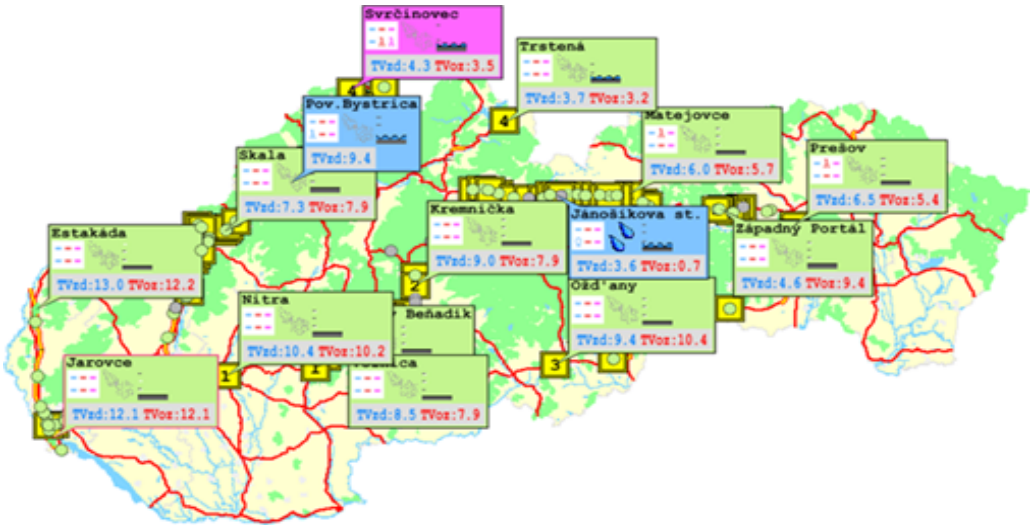

Figure 3. The dynamic map displaying a selection of information from road weather stations.

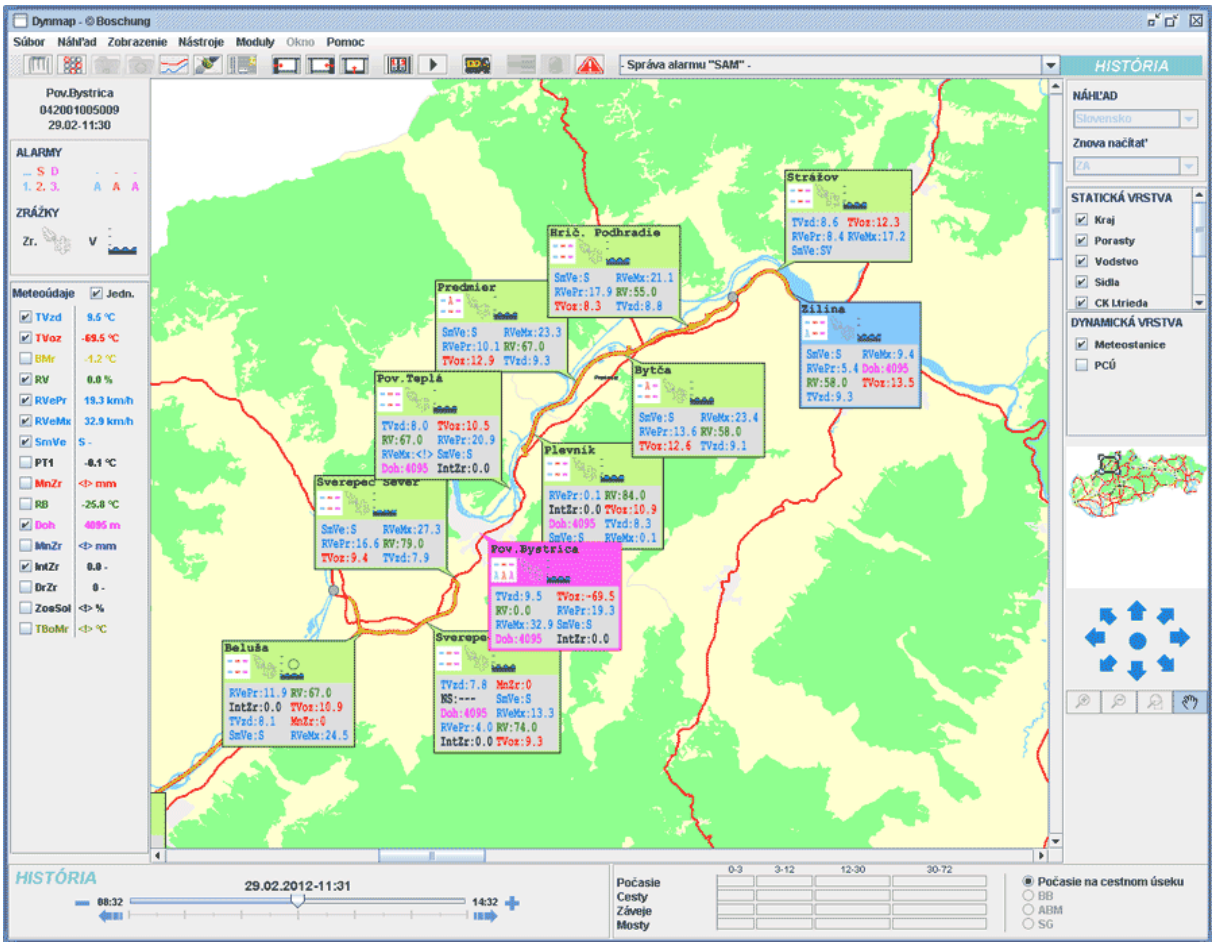

Figure 4. The dynamic map with visualization of selected area of highway. Little “flags” with measured information are coloured in accordance with level of risk.

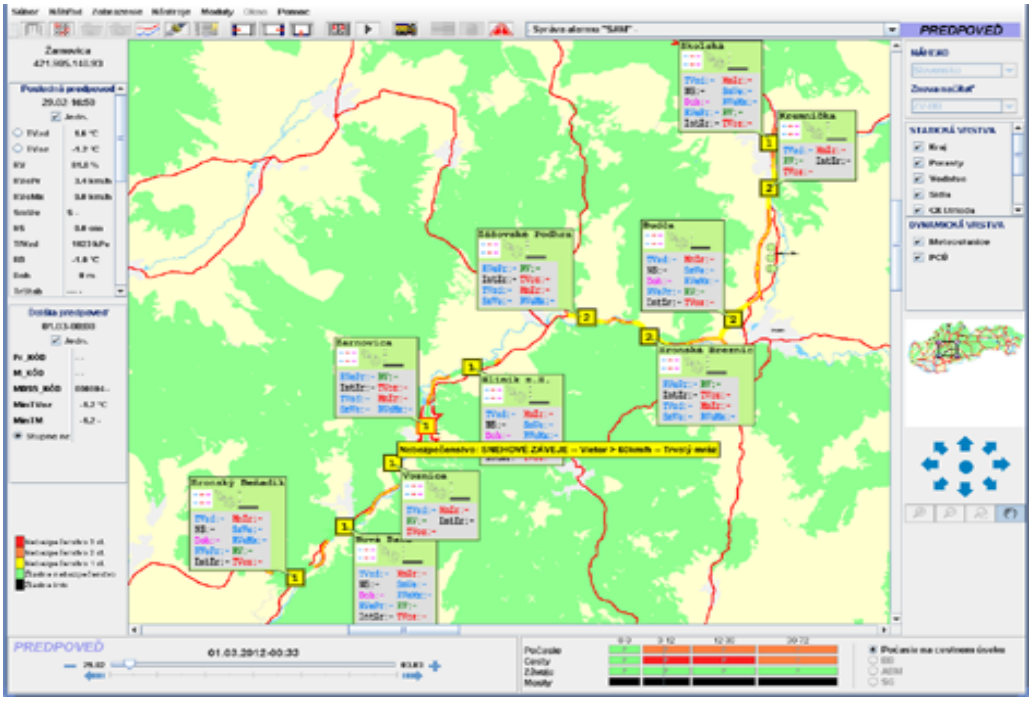

Figure 5. Road segments with displayed forecast and warnings.

The road operator can choose a measuring point he is interested in and visualize the history of measured data also in the summary chart in the form of curves. The possibility to display forecasted values allows us to see the expected changes of meteorological conditions for the next hours, or even for the period of following 3 days. The operator can choose the elements he wants to have displayed. The internal algorithms ensure the smooth combination of real measured data with the data from numerical models. In addition, the displayed charts allow also the comparison of the forecasted values for next minutes with real data and the operator can identify the differences between nowcasted and real values immediately (Figure 6.)

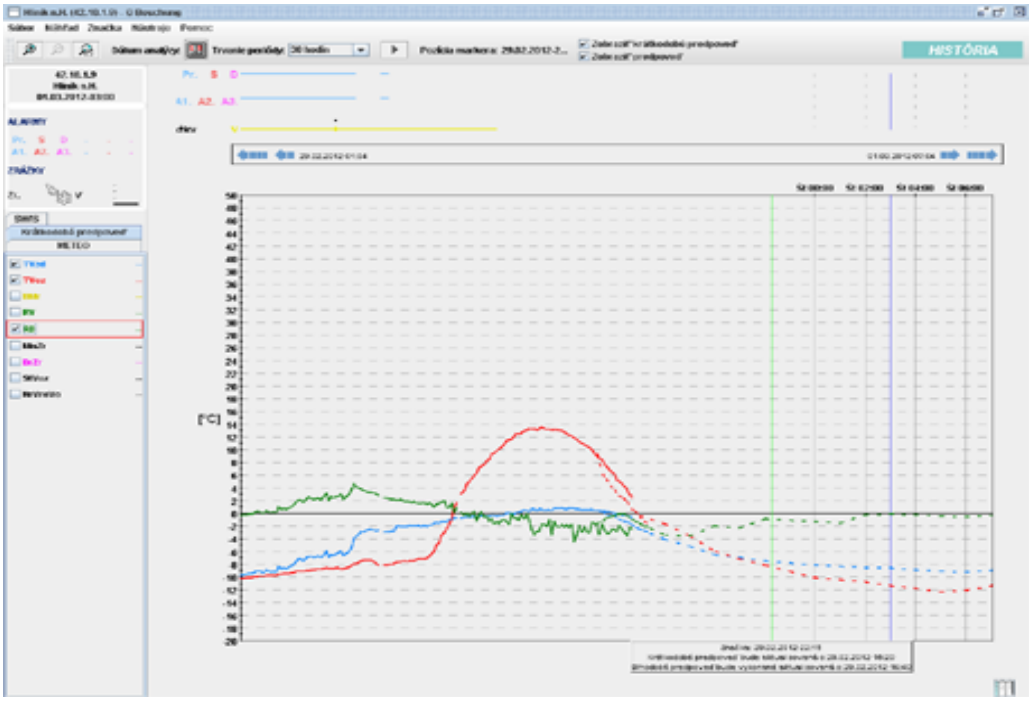

Figure 6. The charts with measured and forecasted data for selected RWS.

4 CONCLUSIONS

The whole set of specialized products based on specifically created algorithms has been designed to supply input of forecasting information into road maintenance decision support system. The forecast of weather and road conditions allows the implementation of precautionary measures and it is a fundamental advantage of this integrated system. It should be noted that it is not possible to directly forecast the biggest weather risks affecting traffic on roads during winter, such as freezing rain, frost, ice, freezing fog, or snow drifts, using the numerical models. Moreover, the road meteorology is a new area that has not been dealt with in Slovakia until now. It is necessary to ensure the close monitoring and subsequent improvement of the whole meteorological process. The algorithms for product generation shall be modified in the future, so that outputs are as close to reality as possible.

During the activities undertaken so far, we developed and started to operate a system that integrates data from several types of the measurement stations into one visualization tool and ensures supply of data into the nowcasting module. The system integrates the predicted values with the measurements and gives an outlook of the expected changes in weather affecting traffic on the road. The cooperation with the national meteorological service guarantees the delivery of predicted data in the highest quality, at current scientific knowledge with potential for much more improvement. The road operator gets the tool which enables a more objective way to improve decision-making process in managing winter road maintenance. The application will be further tested in realistic conditions, and then we will evaluate the accuracy of forecasts and the effectiveness of using at the road control centres. We assume that the outcome will be lower costs for winter maintenance and improvement of roads passability, resulting in the improvement of road safety.

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