REGIONAL DECISION SUPPORT SYSTEM

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ABSTRACT

MeteoTrassa system has been developed to provide the road authorities with a decision support tool for winter maintenance. It provides actual data, warnings, and short range forecasts of the road weather. The system is based on the following data inputs: road weather stations and weather cameras, thermal mapping, weather radars, hydrological sensors, regional forecasts and warnings, mesoscale and local forecasts. The system takes an advantage of existing weather data sources, combines data to present integrated road weather observations and predictions for the road network and generates recommendations on road treatment strategies based on standard practices for effective winter road maintenance.

1. INTRODUCTION

Winter road maintenance is an important application field of meteorology in those areas which experience frequent snow, sleet, ice, and frost. RWIS and maintenance decision support systems (MDSS) are designed to help winter maintenance to take proper action at right time and place to keep up safety on the roads and save costs of winter maintenance /1/. In order to provide timely short-period high-accuracy forecasts an automated system MeteoTrassa has been developed /2/. MeteoTrassa brings together real-time and forecast information and presents it to the road maintenance personnel.

Numerical model of atmospheric boundary layer has been designed to provide detailed forecasts of the road weather and surface condition (ice and frost prediction as a main goal) for a forecast range up to 4 hours which is the time range the road authorities need in order to have enough time for adequate road service actions. Site specific weather forecasts are provided for locations where road sensors exist. The availability of input data with a high resolution in time and space (mesoscale model and weather radar data) has increased the possibility to improve short term forecasting.

Thermal mapping of a road network identifies temperature profiles and particular problem areas and different climatic zones. Thermal maps are used to extrapolate information from road sensors to the whole road network and to perform ice and frost prediction over the road network.

The system will warn users as to where and when ice or frost is likely to form providing sufficient time to apply de-icing agents ahead of a danger. It analyses current and prognostic data and generates recommendations on road treatment strategies.

2. CONFIGURATION

MeteoTrassa system is a sophisticated data collection, management and display system comprised of road weather stations, central computer, workstations, special-purpose software, and communication tools.

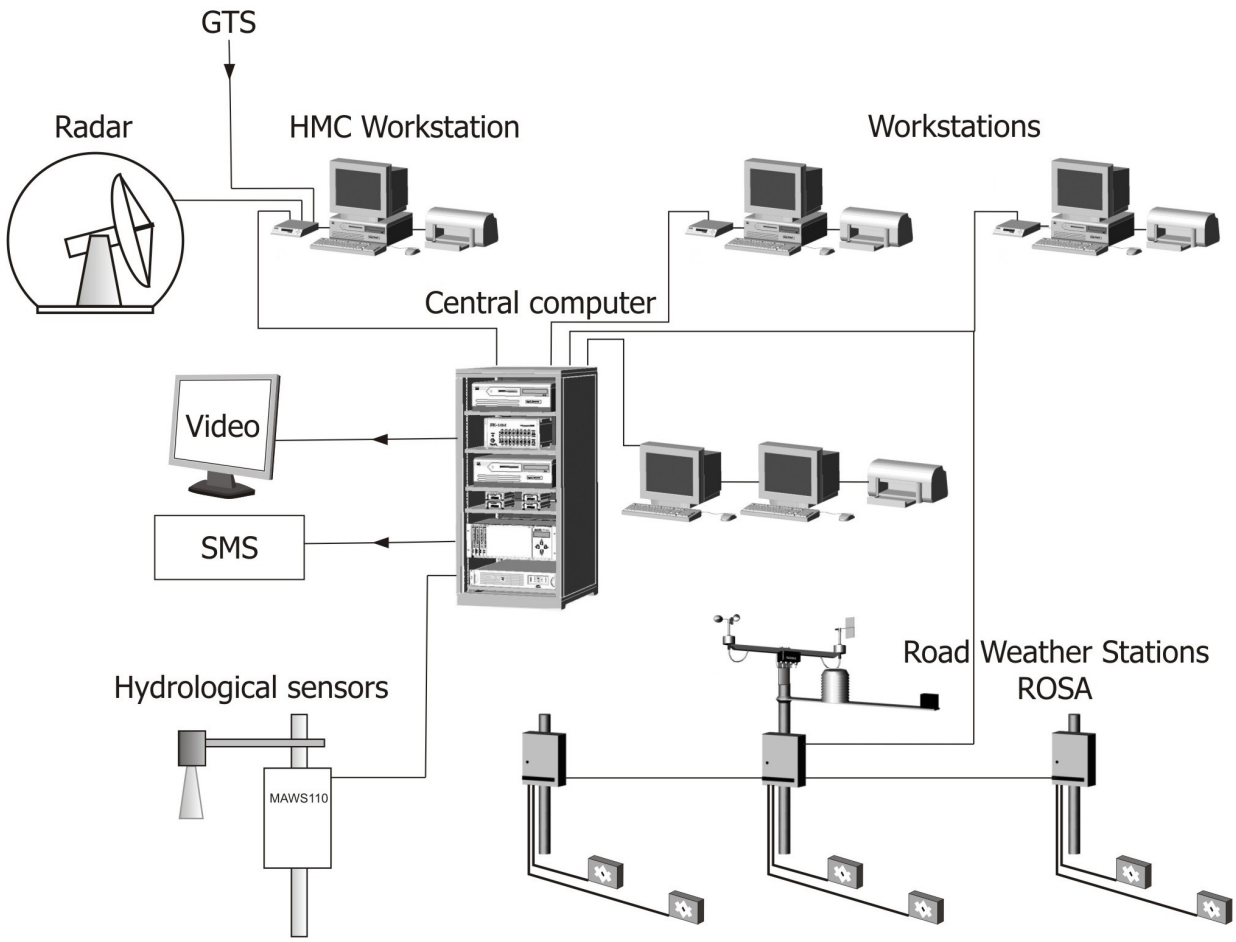

Fig.1. Configuration of the MeteoTrassa system.

Road weather station ROSA (produced by Vaisala Oyj) consists of the following sensors (e.g.): surface sensor (pavement or remote sensor), air temperature and relative humidity probe, pressure sensor, precipitation detector, present weather sensor, depth temperature sensor, wind speed sensor and wind direction sensor.

Surface sensor accurately reproduces the thermal behaviour of the road. The Vaisala surface sensors are capable of accurately detecting surface temperature, surface condition (dry, moist, wet, moist and treated, wet and treated, frost, ice, and snow) and presence and concentration of deicing chemicals.

Each ROSA weather station provides information about the following states, warnings and alarms:

- Clear – no warnings or alarms
- Rain warning – precipitation (rain or snow) detected recently and there may be subsequent freezing, as the road temperature is close to, or below freezing
- Frost warning – surface temperature is negative and within a given limit of the dew point. Hence hoar frost, or ice, is either present or expected very soon.
- Ice warning – close to freezing point; either there is ice already or there will be very soon.

With the data received from its sensors the ROSA weather station is capable of making the following analysis: air temperature, dew point, relative humidity, rain intensity (none, light, moderate, heavy), wind speed and direction, gust speed and direction and depression of freezing point temperature of solution. The ROSA weather station responds to requests for data from the Central station (MeteoTrassa PC) at pre-defined polling times.

MeteoTrassa software is responsible for collection of the data from the road weather stations, data processing, analysis, storing and distribution, presentation of the data, forecasting and generation of recommendation on road treatment.

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

MeteoTrassa manages and presents information about weather conditions on roads in real-time. Chart, graphs and tables are available. The data is updated at certain intervals (15-30 min, usually) as determined automatically or by a user. All the data is stored. The observational data is checked for critical alarm states as it arrives.

The system is capable of generating recommendations on road treatment strategies based on standards for effective winter road maintenance which are tailored to the procedures of the local road service agency. To make the right decision on an action to take and its timing, one needs to have a weather forecast and road-specific forecast.

3. FORECAST OF THE ROAD WEATHER AND SURFACE CONDITION.

The most essential information for making the right decision is road surface temperature, depression of freezing point and precipitation. 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-e turbulence closure scheme and an energy balance equation.

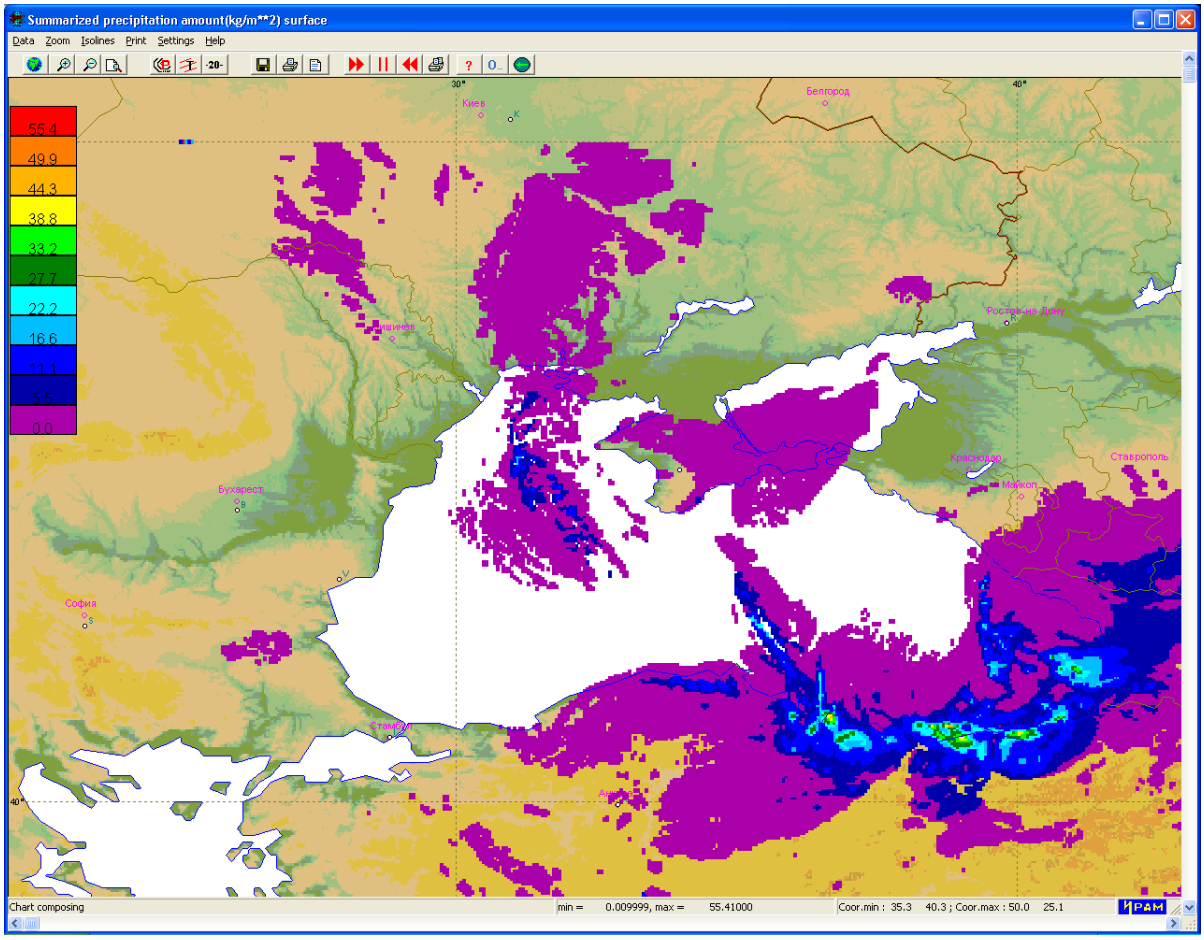

Fig.2. Mesoscale model output: forecast of precipitation amount

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. Information about precipitation and clouds derived from the radar data is used in the model. Albedo and emissivities of road and atmosphere, heat capacity and conductivity and other parameters are predefined.

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

The model uses the following information as input data:

- Data from the road weather stations
- GRIB-encoded global prognostic data
- GRIB-encoded mesoscale prognostic data
- Weather radar data.

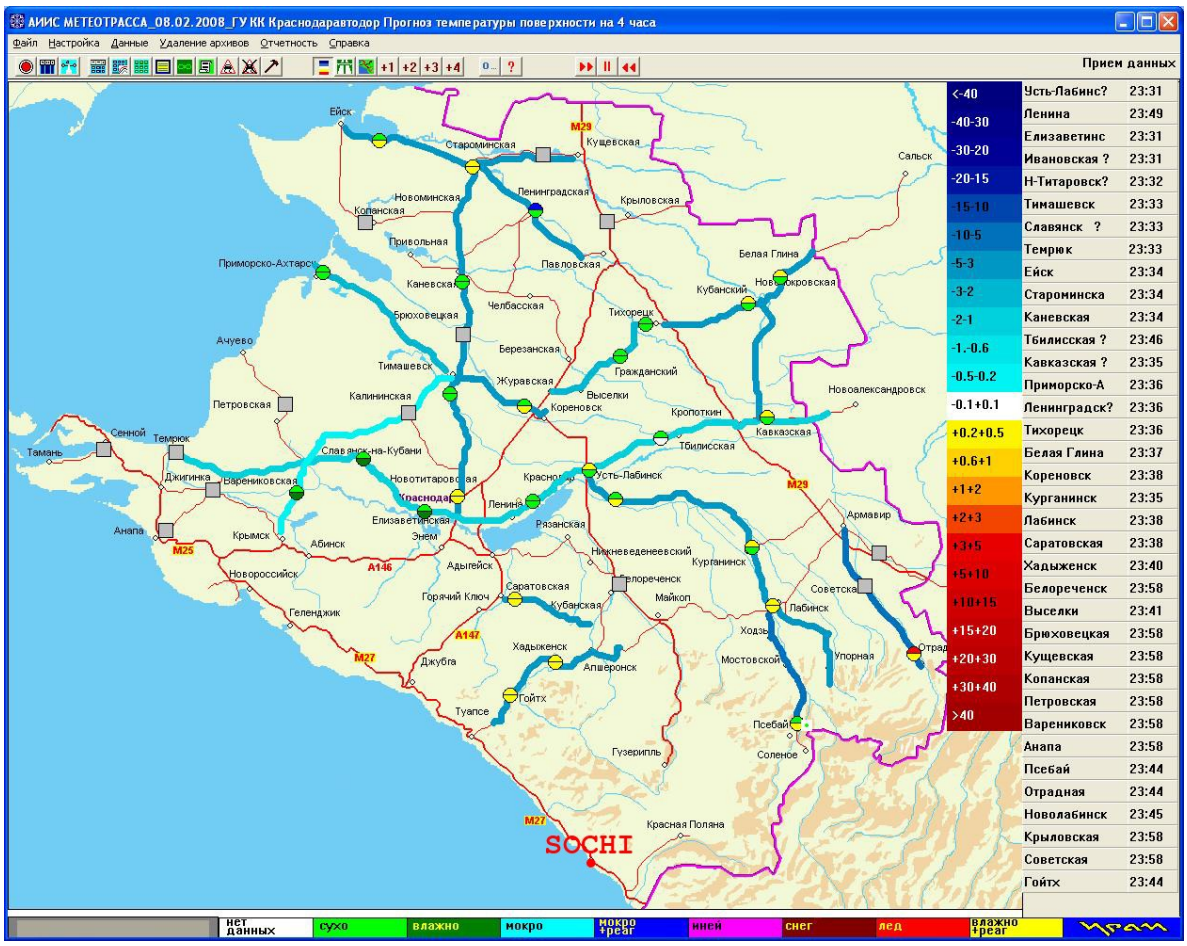

Fig.3. Road surface temperature forecast for 1, 2, 3 or 4 hours.

Global prognostic data is available due to the World Area Forecast System (from World Area Forecast Centers – WAFC London or WAFC Washington) via GTS. They are supplemented by a high-resolution model WRF-ARW. The model runs at the Russian HMC. 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. The availability of input data with a high resolution in time and space has increased the possibility to improve short term forecasting. GRIB-encoded prognostic data sourced from World

Area Forecast Centers via GTS is another alternative, however with worse space and time resolution.

Forecast output from the models, observations from road weather stations and weather radar data are forwarded to the road weather and surface condition forecast module (RWSCF).

Site specific weather forecasts are provided for locations where road sensors exist and extrapolated to the road network if thermal mapping data is available.

4. 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 /3/.

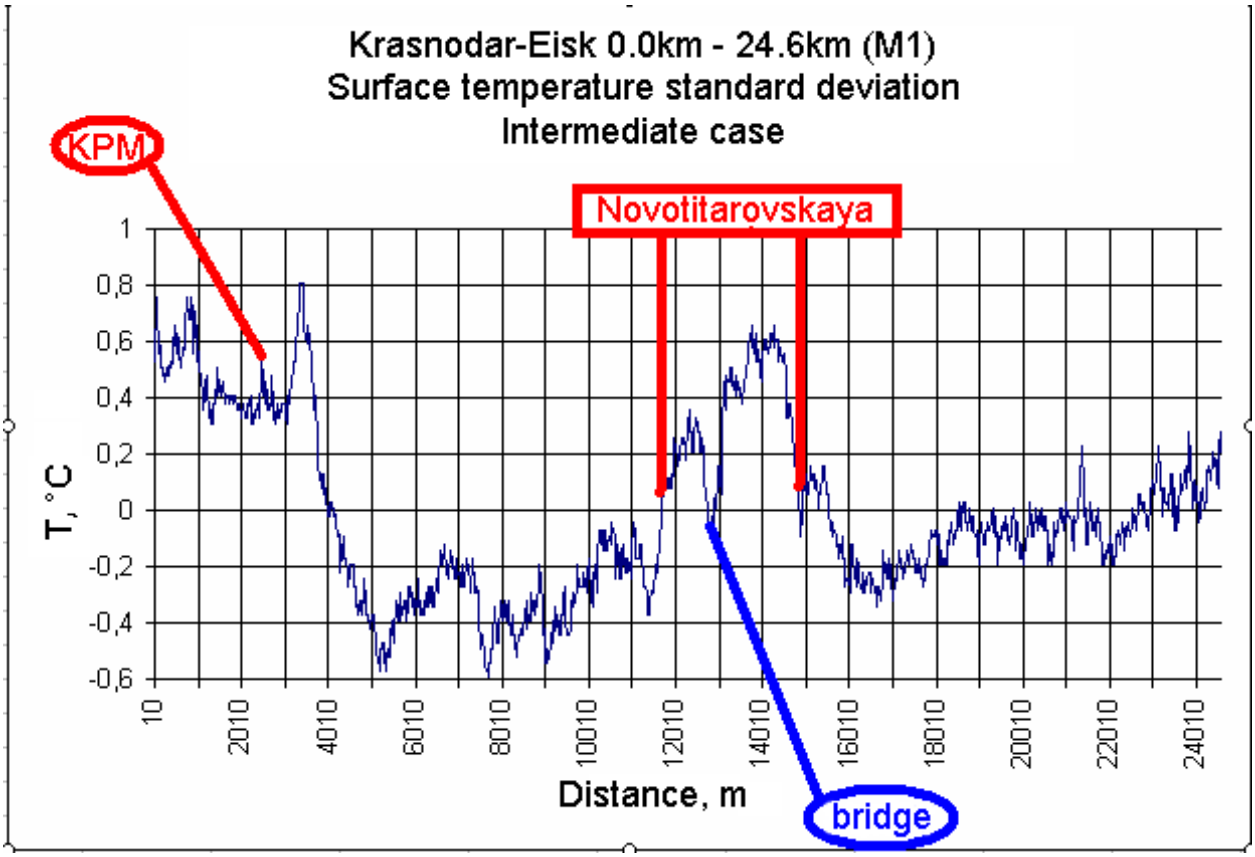

Fig.4. Road surface temperature profile. (Standard deviation of road surface temperature, Thermal Mapping fingerprint category: intermediate)

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.

3. WEATHER RADAR INFORMATION

Weather radar is useful in determining precipitation and other weather phenomena such as thunderstorm, hail, severe winds, and cloudiness /4/. The software MARS has been designed to process, to archive radar data, and to make a weather radar composition.

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.

Telecommunication workstation MeteoTelex delivers radar data 24 hours a day to the HMC workstation and to the Central computer. The radar images are updated every 10 minutes at the radar workstation MARS covering 1000 km x1000 km area with resolution 4 km x 4 km. The BUFR-encoded radar data transmission is performed via GTS.

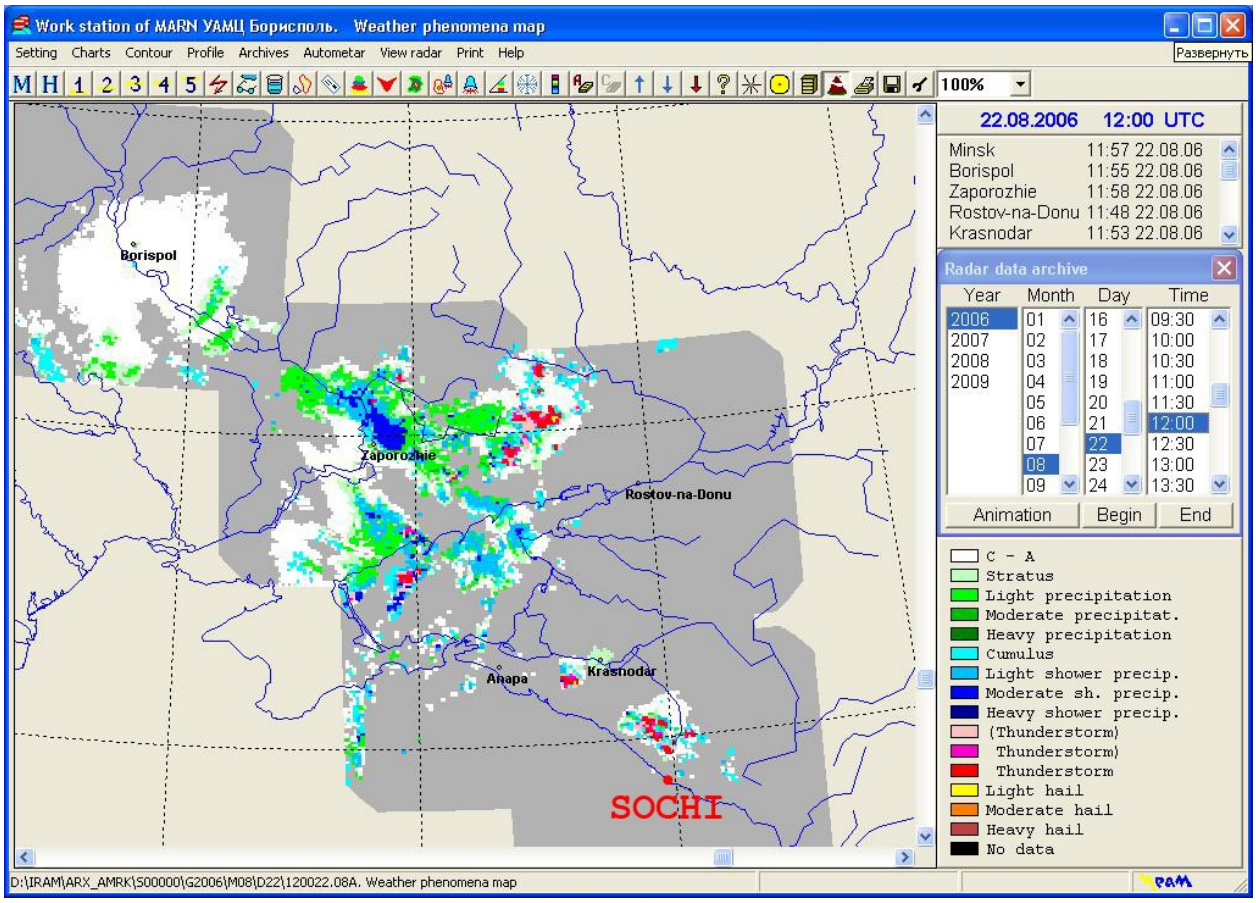

Fig.5. Weather radar composite map with indication of meteorological phenomena

Assessment of weather system movement for up to 2 hours based on radar data and wind forecast is performed. Composite radar images are generated based on the radar network consisting of five radars in the North Caucasus region and two radars in Ukraine.

4. HYDROLOGICAL INFORMATION

A set of hydrological sensors gives information useful for monitoring of floods.
Software installed on the Central computer is responsible for

- Collection of the data from the hydrological sensors
- Data processing, analysis, and storing
- Presentation of the data.

Hydrological information in chart, graphic and tabular forms is available. It includes indication of excess over the critical water level.

5. RECOMMENDATIONS ON ROAD TREATMENT STRATEGIES

Specialized component of the system such as treatment recommendation (TR) module uses the current data, RWSCF outputs and weather radar data to generate guidance for treatment procedure. The most essential information for making the right decision is highly specific precipitation data, road surface temperature and depression of freezing point.

The TR module analyses the data and generates recommendations on road treatment strategies in accordance with accepted technology and with prognostic information taken into account.
Treatment recommendations include the following information:

- Recommended treatment procedure (chemical use, abrasives, combination chemical plus abrasives, plough),
- Recommended chemical amounts, chemical concentration and dilution rates
- Timing of initial treatment and necessity of subsequent treatment
- Recommended pretreatment.

Four different procedures on road treatment are loaded into the system. The user chose the most suitable among them depending on available de-icing agent.

6. VERIFICATION

Forecasts of air temperature, dew point temperature, road surface temperature and road surface state has been verified during winter periods of 2007 – 2008 and 2008 – 2009. Total number of cases taken into account is 135624. The model was verified against observations from 56 road weather sensors.
The results averaged over all sites show that root-mean-square error of 4-hour forecasts for temperatures is 2.1 °C. The model has a near-zero bias for temperature forecasts.

The surface condition predicted by the model is compared with the actual state recorded by the surface sensor. The performance of forecasting varies from site to site due to different geographical and topographical environments at different sites. Accuracy of ice and frost predictions for 4 hour forecast period compared against sensor measurements varies from 83 to 93%. Salt on the road will cause or keep the road surface wet or moist for longer than the road of no salting being taken. This effect is considered to be a contributory factor to the worse forecast performance at sites where heavy salting in winter is commonplace. Average accuracy amounts to 87%.

7. OPERATIONAL USE

Fifteen automated MeteoTrassa systems have been installed till now. One of the biggest systems is operated in Krasnodar region. Road authorities in Krasnodar region make use of the system in operation mode since 2001. In this case road network consists of 28 road weather stations gathering data every 30 minutes. Thermal mapping of roads (more than 1900 km length) has been performed till now. Database of thermal maps is used in forecasting. Five hydrological sensors give information for monitoring of floods. Central computer MeteoTrassa delivers data to the workstation at the Hydrometeorological Centre in Krasnodar and to 45 user workstations all over the region to supply road service providers with data and forecasts and recommendations on the treatment procedures and the timing.

The system takes an advantage of existing weather data sources integration, and presents predictions for the whole road network. Regional forecasts and warnings are transmitted to the Central computer from HMC MeteoTrassa workstation. Forecasts for the road network are available for 1 – 4 hours ahead with updating every 30th minutes.
Future development of the nowcasting system is connected to the 2014 Winter Olympic Games in Sochi. New weather road stations in that region are planned to be installed. Both mesoscale and local models are to be improved for most adequate forecasting in such complicated area.

8. REFERENCES

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