

2D and 3D road climatic models

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ABSTRACT

The method for the creation of special 2D and 3D road climatic models for solving problems of works control on the winter road maintenance is provided in the article. Road and climatic information are used for modeling. 3D models are created on the maps basis. The procedure of constructing 2D and 3D models with the help of software system CREDO is described. The method of processing meteorological data for reception of blizzards settlement parameters is considered. 2D model calculation results are shown on distribution maps of total snow transfer volume and blizzards duration. The method of creation line road climatic graphs is suggested. The task list of management work on roads winter maintenance, where the modeling results can be used, is shown.

Keywords: Road climatic model, blizzard, winter slipperiness, generalized climatic index and line road climatic graphs.

1 INTRODUCTION

Road safety during the winter period is one of the topical problems of ground traffic. Usually slipperiness on road surface is eliminated by the use of snow removal, anti-icer and de-icer salts. However, the more efficient way is to allow no formation of a snow and ice layer and, hence, to keep high ride ability and road grip of a tyre.

The process of snowdrifts and ice formation is very intricate, it is influenced by many weather and road factors and the degree of dependency from these parameters we can't be explained [1]. The problem of road slipperiness prediction is complicated. Using the conventional research methods cannot solve it. To solve this problem it is necessary to use the method of mathematical modeling and computing experiment.

The proposed 2D and 3D road climatic models can be used in solving the tasks of winter road maintenance. The results can be used for the works management on the winter road maintenance:

- Design of snow protection
- Priority of operations against winter slipperiness
- Planning of snow removal
- Calculation of resources for winter road maintenance
- Planning the location of automatic road meteorological stations, etc.

2 CREATION OF 2D AND 3D MODELS USING THE PROGRAM CREDO

Models are created as follows:

- Bitmapped substrate is created in the program TRANSFORM – a map of the roads network and location of observation points for weather information (e.g., State meteorological observation network).
- Bitmapped substrate is exported to the program CREDO DOROGI to digitize and build 2D and 3D models.

The locations of meteorological stations serve as control points for digitizing maps. Numerical values of climatic parameters are given in the control points. The layers are created for the construction of climatic models. The model of one climatic parameter is constructed in each layer. This allows to observe simultaneously the change of the parameters distribution on the territory and apply additional data on the generated model.

The closed contour is created to build the model. Three-dimensional surface and its two-dimensional image in the lines interpolation (isolines) form are constructed inside the contour. Isolines represent the same values parameter in the terrain different points in the first approximation. Isolines step can vary for different layers. Its value depends on the variability of climatic factors in the space, the accuracy of its calculation, and tasks.

The program CREDO DOROGI allows to build 2D models in the form of cuts along road axis and display the any parameter distribution on the road as a line graph.

3 METHOD FOR DETERMINATION OF BLIZZARDS SETTLEMENT PARAMETERS FOR CONSTRUCTION OF ROAD CLIMATIC MODELS

The blizzards settlement parameters allow road organizations to solve the task of snow protection design and organize the snow removal works on the roads.

Initial data for calculation are meteorological station observations [2]:

- Location of meteorological stations
- Date of the blizzard
- Time of beginning of the blizzard
- Time of finishing of the blizzard
- Wind speed
- Wind direction
- Air temperature

The snow transfer volume in winter period to the formula by D.M. Melnik is calculated [3, 4]:

$$W_t = \frac{t}{m} \sum_{i=1, (V>5)}^m C \cdot V_i^3 = I_c \cdot t, \quad (1)$$

where t is the summary duration of blizzards for winter period, hour; m is the number of measurements of the wind speed during blizzards (at speeds over 5 m/sec); C is an empiric factor, equal to 0,00046 for density of snow 0,17 m³/m; V_i is the wind speed during blizzards, m/sec; I_c is the average intensity of blizzards during the winter period, m³/m·h.

The dependency between the average intensity of horizontal snow transfer and the wind speed at the weathercock height is expressed by the following formula:

$$I = C \cdot V^3, \quad (2)$$

where I is the intensity of horizontal snow transfer, m³/m·h; C is the factor to proportionality which depends on density the snow; V is the wind speed at the weathercock height, m/sec.

The total snow transfer volume on 16 directions for one winter period is calculated by the formula:

$$W_{cn} = \sum_{i=1}^{16} W_i \quad (3)$$

The average year snow transfer volume for n years is calculated by the formula:

$$W_{cp} = \frac{\sum_{j=1}^n W_j}{n} \quad (4)$$

The average year duration of blizzards is calculated by the formula:

$$T = \frac{\sum_{j=1}^n t_j}{n} \quad (5)$$

where t_j is the total duration of blizzards for j -th winter period, hours.

The graph of total snow transfer volumes for three meteorological stations in Nizhny Novgorod region for 14 years of observations is shown in Figure 1.

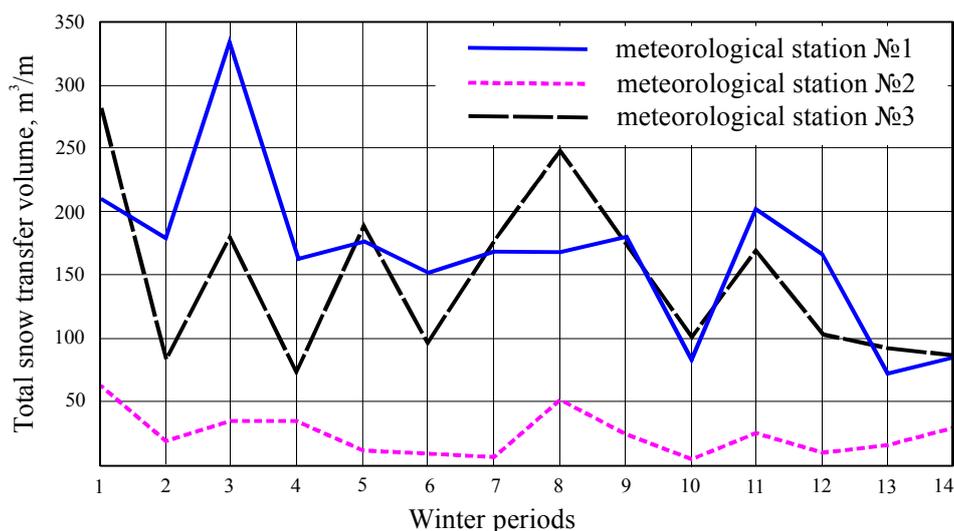


Fig.1. Total snow transfer volume.

The calculation results show considerable variation of parameter for three points of an area.

The probability distribution curves were constructed using the three-parameter gamma-distribution on the obtained experimental data.

The calculation results were placed in the descending series. Each member of series is associated with the empirical probability of exceedance [5].

$$P_m = \frac{m}{n+1} \cdot 100\% \quad (6)$$

where m is serial number of series member; n is members of series (number of observation years).

Example of constructing the probability distribution curves total snow transfer volumes for three meteorological stations is shown in Figure 2.

The calculation results of the snow transfer volume on 16 directions for the Nizhny Novgorod region are shown in Figure 3.

They allow to identify the predominant directions of snow transfer and to evaluate the possibility of snow drifts on the road separate sites with the known their direction. Mapping the blizzards parameters of the region are made to show their distribution (created digital 2D and 3D models of variation parameters). An example of a 2D model creation for the total snow transfer volume and duration of blizzards in the form of three-dimensional model projections to plane shown in Figures 4 and 5.

Similar 2D models in the maps form were obtained for climatic parameters:

- Number of transitions through the air temperature -2°C

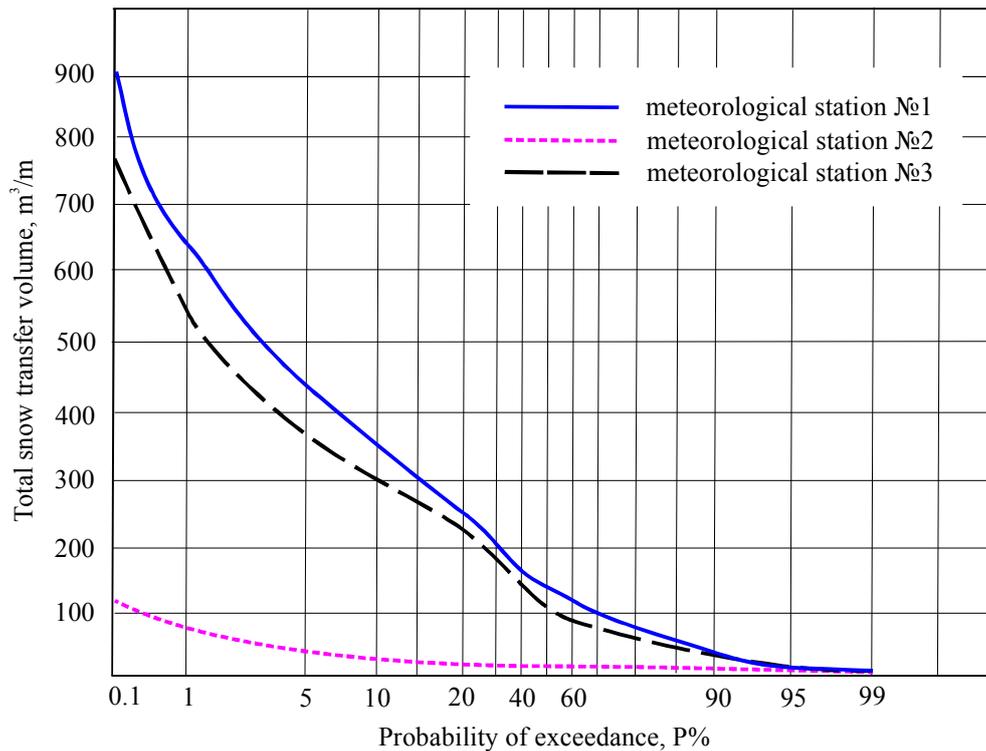


Fig.2. Distribution curves of total snow transfer volume.

- Number of snowfall with precipitation more than 2 mm in 12 hours
- Number of days with rain at air temperatures below 0
- Amount of solid precipitation at air temperatures below 0
- Number of days with ice and hoar frost
- Total amount of precipitation
- Number of days with blizzards
- Snow depth
- Average annual snow transfer
- Average annual blizzards duration.

4 CREATION LINE ROAD CLIMATIC GRAPHS

The cuts on the road axis allow to analyze the change in various climatic parameters along the route. Road and climatic information was used for calculation of road climatic graphs.

Road information

- Road area, the border areas
- Roads sections length
- Technical category of the road
- Level of road service (standard requirements to the maintenance level)
- Traffic volume
- Road axis geometry (plan and longitudinal profile)
- Placement of infrastructure (storage of anti-icing agents, road machines bases).

The introduction of specialized climate information, combined with road data, allows to solve the problem of management winter road maintenance.

Data of blizzards activity can be used for:

- The establishment of areas with possible snow drifts.
- The design of the various options for snow protection.
- Planning the snow drifts removal.

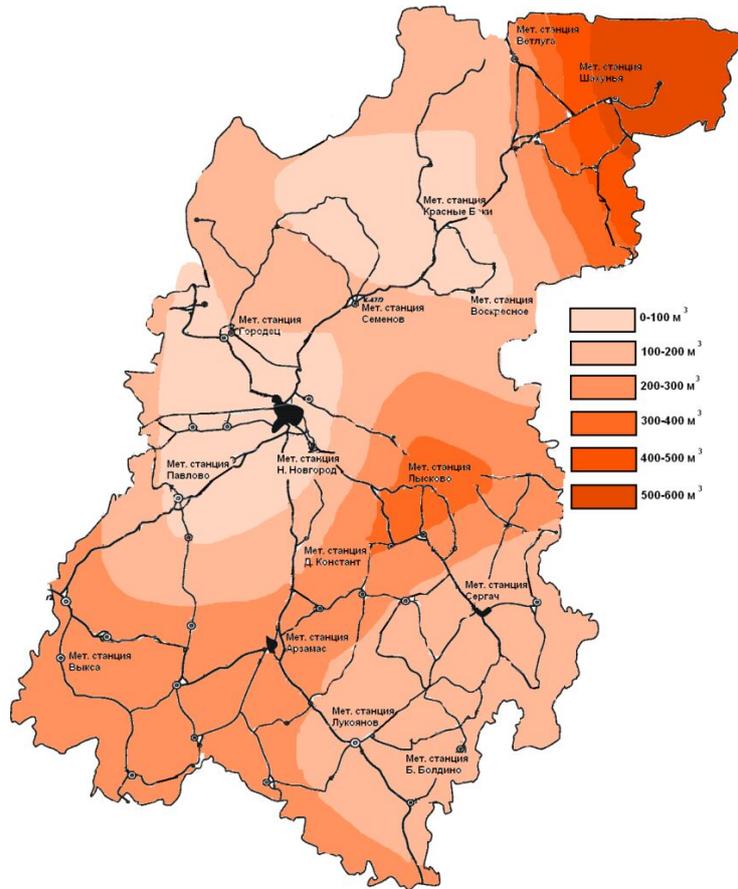


Fig.4. Map of total snow transfer volumes for Nizhny Novgorod region.

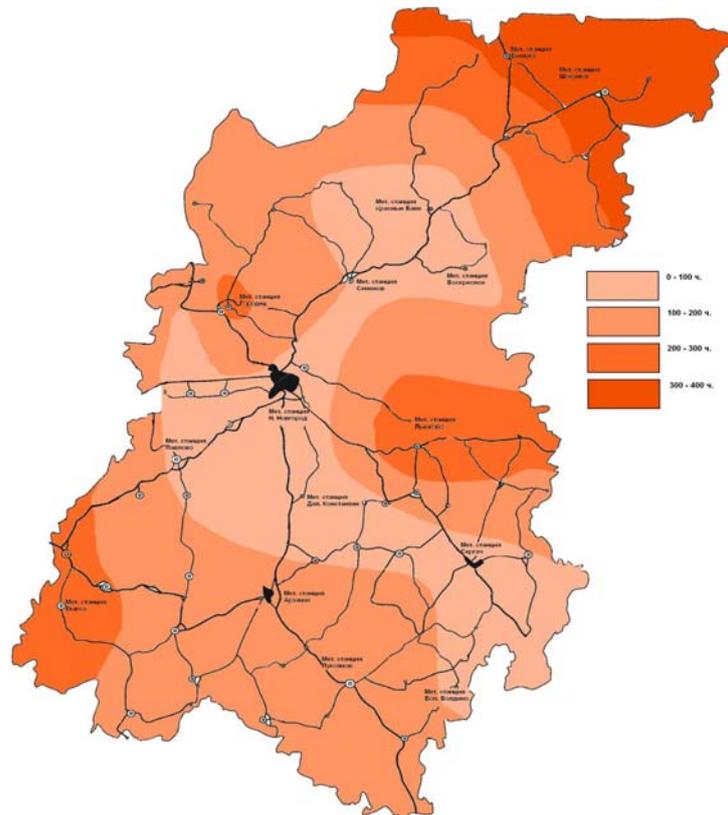


Fig.5. Map of duration blizzards for Nizhny Novgorod region.

"Generalized climatic index" can be calculated and presented on a linear road graph to assess the changing weather conditions along the roads.

$$k = k_1 + k_2 + k_3 + k_4 + k_5, \quad (7)$$

where k_1 is the number of cases, the transitions through the air temperature -2°C (the risk of slipperiness during the freezing of moisture on the pavement); k_2 is the number of snowfall with precipitation greater than 2 mm in 12 hours (the conditional cycle of snow cleaning from the road); k_3 is the number of days with rain at air temperatures below 0 (the risk of glazed frost ice on the road surface); k_4 is the number of days with ice and hoar frost (the risk of glazed frost ice on the road surface); k_5 is the number of days with blizzards (the conditional cycle of snow drifts removal).

"Generalized climatic index" conditionally characterizes by the number of days when work can be conducted against the winter slipperiness (probable cycle of works). This is not the actual cycle of work because these meteorological stations do not fix the road surface condition. The weather conditions may contribute to road surface icing or the formation of compacted snow and snowdrifts, but this does not mean that the real slipperiness is formed on the pavement.

The line climatic graphs are created on 3D models basis, maps that show the distribution of all climatic parameters. Example of road climatic graph, obtained on the basis of maps, is shown in Figure 6.

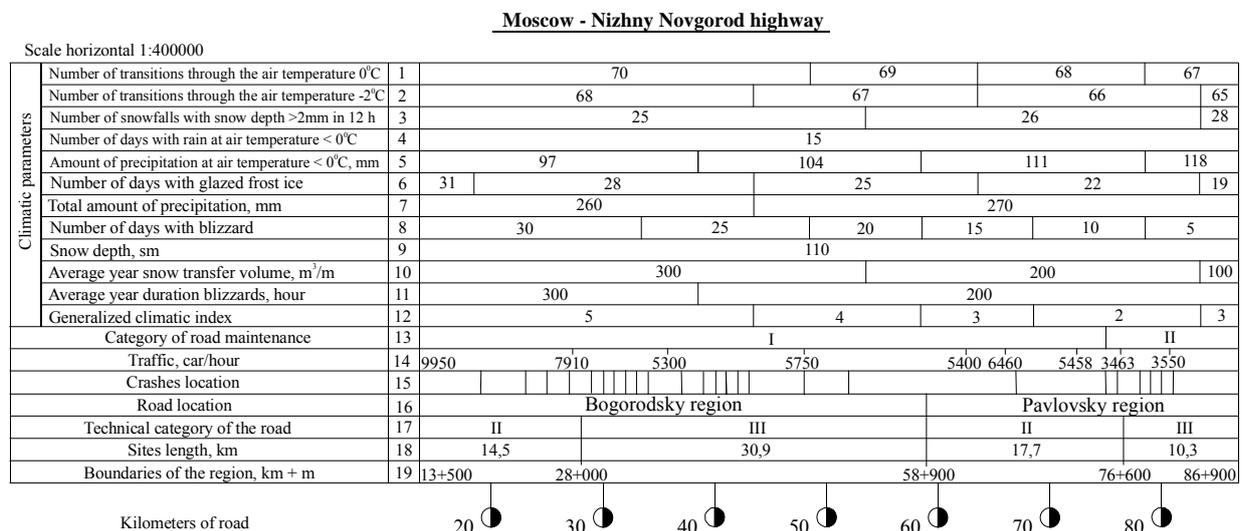


Fig.6. Line road climatic graph.

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