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CARTOGRAPHY AND GIS

ASSESSMENT OF THE NORMATIVE DEPTH OF SEASONALLY FROZEN SOIL LAYER IN WESTERN SIBERIA USING GIS

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ABSTRACT

This work was carried out for purposes of geological engineering survey, to create of a database for quick calculation of the depth of seasonally frozen soil layers in Western Siberia. The research consisted three stages: 1) the climatic zoning - composing maps of the sum of the absolute values average monthly negative temperatures; 2) development of a database for the calculation of normative depth soil freezing; 3) mapping of the observed maximum depth soil freezing.

The input data have served regulations acting in the Russian Federation [8, 9], the data on average monthly air temperature and daily mean temperature of the soil at the hydrometeorological stations in Western Siberia [10]. At all stages of the research data is stored and processed in the ArcGIS (geodatabase).The main tools of spatial analysis have served interpolation (weighted by the inverse distance IDW), the creation of buffers and the construction of Thiessen polygons.

As a result, have been constructed maps of normative depth freezing of clayey soils, the actual maximum depth soil freezing and map their relation.

Keywords: seasonally frozen soil layer, normative depth of seasonally frozen soil layer, climatic zoning

INTRODUCTION

When building in the areas with the development of seasonally frozen soil layer to determine the depth of the foundations of constructions and structures must take into account the depth of seasonally frozen soil layer. This is depth to which the soil freezes in the cold season. In this paper the authors attempted to map the depth of seasonally frozen soils in Western Siberia. Determination of the depth soil freezing conducted in two ways – compliance with regulatory documents [6, 7] and according to long-term observations of soil temperature at the hydrometeorological stations [10]. The study used data from 35 observation stations of Roshydromet (Federal Service for Hydrometeorology and Environmental Monitoring in Russia).

The initial data to determining normative depth of seasonally frozen soil layer are the engineering-geological sections and climatic characteristics (the sum of the absolute values average monthly negative temperatures). If the engineering and geological sections are built on the results of surveys, then climatic characteristics must be taken [7] compliance with regulatory documents [6]. At absence in these data of particular area of construction, the necessary characteristics are taken from observations of hydrometeorological station in similar conditions to the area of construction.

The main purpose of the study is to develop a data base of structure to automated calculation of normative depth soil freezing in Western Siberia.

To achieve this goal it is necessary to solve the following tasks:

– To create a database of climate data and to conduct zoning of Western Siberia;

– To develop an algorithm of automatic calculation of normative depth soil freezing (dfn) based on maps of climatic parameters distribution.

In order to do of these tasks were used software packages ArcGIS 10 (ESRI).

CLIMATIC ZONING

Preliminary analysis of the data revealed the insufficient density of the network of meteorological stations in Western Siberia, mostly it is typical for the northern part of the territory.

The SP 131.13330 "Building Climatology" [8] indicated that in areas distant from the nearest weather station more than 100 km, the climatic parameters must be determined by inquiries in NIISF RAASN, in the Voeikov main geophysical observatory or Territorial Department of Hydrometeorology and Monitoring of environment Roshydromet.

The existing network of meteorological stations is uneven and insufficient to cover large parts of Western Siberia. As an alternative to determining the temperature conditions in areas distant from the nearest weather station more than 100 km, it is proposed to use the results of climatic zoning.

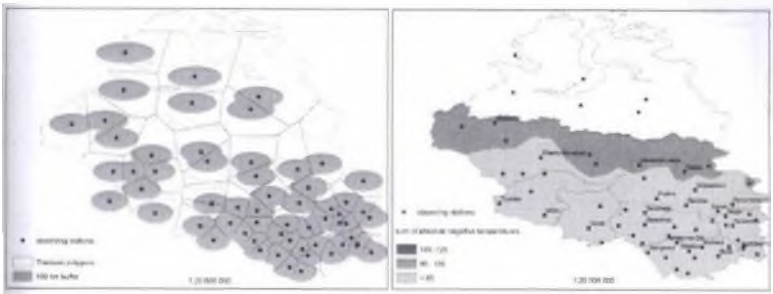
The zoning of meteorological objects is an effective way to generalization of information on meteorological quantities fields. The aim of zoning meteorological fields is areas allocating on the statistical properties of these fields, and similar in terms of features of the spatio-temporal structure of the studied fields. The zoning of meteorological objects is necessary solutions for a variety of practical problems. including in the construction climatology [1, 3, 4, 11].

It is known that meteorological network is considered to be optimal for the majority of the observed meteorological quantities. If the distance between the meteorological stations is on average 50–70 km, that is, the density index (thous. km2 for 1 point) of observation points corresponds to a value of 2.5–4.5. At the same time, at present the Roshydromet meteorological network, unlike most developed countries in Europe and Asia (where the density of the index ranges from 1.0 to 4.5), had on January 1, 2015 the average density index is 8, 9 (based on established AMC) [5].

Authors of paper were done work to identify areas within the 100-kilometer zone of influence of the of meteorological stations, by constructing the buffer zones using the software ArcGIS 10 (Fig. 1a).

In areas where the overlap zone of influence of several of meteorological stations, is offered the construction of polygons Thiessen [14]. These polygons are used to show the area of influence of point objects. Applied to climatic zoning can be concluded that if the site of geotechnical surveys is within any polygon Thiessen, the climatic characteristics of the station are made for him, in which this polygon is constructed.

Figure 1 shows as the buffer zones around the of meteorological stations (100 km) can be divided into zones of influence of each of them, using Thiessen polygons.



a) b)

Figure 1 – a) The zones of influence of of meteorological stations marked with buffering and construction of polygons Thiessen; b) GRID-distribution model the sum of absolute negative temperatures in Western Siberia.

In order to solve the task of zoning in areas not included in the zone of influence of meteorological stations was held interpolation of existing data by the inverse distance weighted (IDW) and GRID-derived model of the distribution of the absolute amount of negative temperatures (Fig. 1b) [3, 15].

The conducted climatic zoning was used in the calculation the normative depth freezing soil on the various types of engineering and geological sections.

NORMATIVE DEPTH FREEZING SOIL

In areas where depth soil freezing does not exceed 2.5 m, normative depth freezing soils is based on the formula [3]:

$$d_{fn} = d_0\sqrt{M_t},$$

where M_t - the sum of the absolute negative average monthly temperatures, d_0 - coefficient that for each type of soil has a various value. d_0 is defined as the weighted average within the depth freezing for an inhomogeneous soil.

To automate the calculation were created a database whose structure implies a formalized description of the cuts in the form of a table. This database allows to automatically calculate the normative depth freezing Interbedding with different soil types. Table 1 shows an example of a formalized description of engineering-geological sections and the calculation of the normative depth freezing. In the table of engineering-geological section is described as an alternation of layers of different types of soil, also in the table sum of the absolute negative average monthly temperature (M_t) is given for each section. The number of layers is limited to five layers, each layer in this example described by two characteristics – the size of d_0 and capacity of the layer .

Table 1 – Example of automated calculation of the normative depth soil freezing in the database

M_t, C°	layer 1		layer 2		layer 3		layer 4		layer 5		dfnl	Medium- weighted coefficient of the type of soils	Normative depth freezing soil
	d_0	H	d_0	H	d_0	H	d_0	H	d_0	H			
64	0,28	0,50	0,23	1	0,34						2,24	0,28	2,22
92	0,23	0,30	0,3								2,21	0,29	2,50*
89	0,28	1,00	0,23	1	0,34						2,64	0,28	2,50*

* in excess of 2.5 m depth freezing is automatically copied value "2.50". *When designing a building is used the estimated depth freezing.*

In different types of soils value of d_0 is accepted in the following ratios:

Type soil	d_0
Clays and loams	0,23
Sandy loam, fine sand and silty	0,28
Sand medium, large, gravelly	0,3
Coarse soils	0,34

Sum of absolute negative average monthly temperature (Mt) in the implementation of the data structure in ArcGIS 10 is extracted as an attribute of the polygon layer table with the results of climatic regions. The other quantities, including normative depth soil freezing are calculated automatically and can be easily displayed on the map.

The developed database structure allows to create maps of capacity seasonally frozen layer of various types of engineering and geological sections. In particular, was created the map of normative depth freezing of clayey soils (Figure 2).

MAXIMUM ACTUAL DEPTH SOIL FREEZING

Since 1960 observations have been held monitoring the temperature of soil at different depths (from 2 to 320 cm) in most of the meteorological stations .When compiling and generalizing the data from 25 stations were identified the maximum depth soil freezing during the whole observation period (30–50 years).

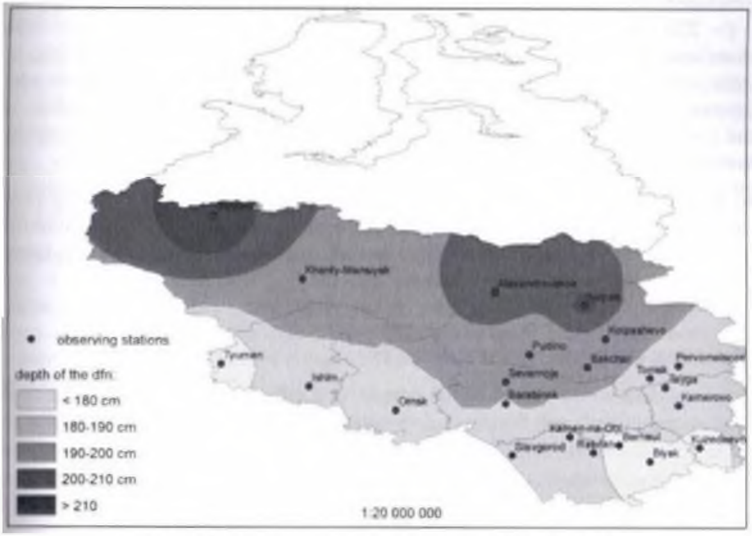


Figure 2 – Normative depth freezing of clayey soils

According to the data of soil temperature at different depths was drawn up the map of actual maximum depth soil freezing (Figure 3).

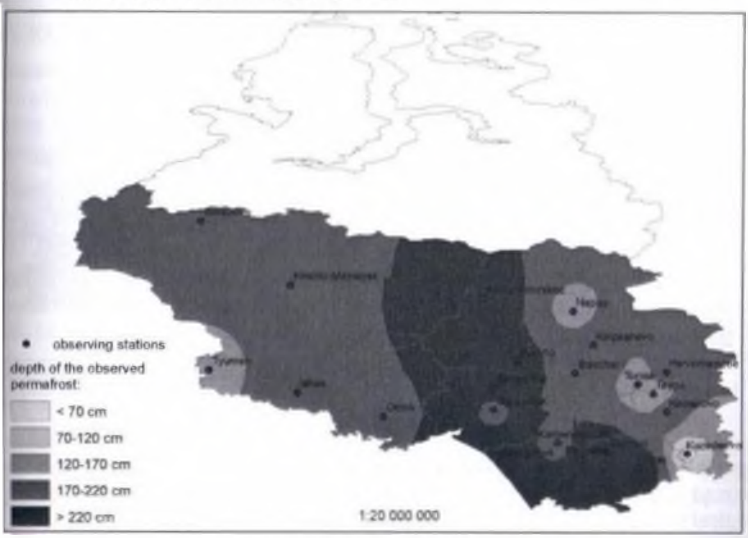


Figure 3 – Maximum actual depth soil freezing

The produced map clearly stands out meridional elongated area of relatively deep frozen soils (> 220 cm). This distribution is due to complex geological and climatic characteristics of the central and southern parts of Western Siberia. For example, in the southern part of Western Siberia (the station Slavgorod, Rebriha, Barnaul, Biysk) are widespread sandy loam and sandy soils, which are characterized, ceteris paribus, more intense freezing. In addition, in this area the snow depth is less than in other regions of Western Siberia, which reduces soil freezing.

Great depth soil freezing in areas of stations Pudino and Aleksandrovskoe possible caused by features of engineering and geological structure. To an unambiguous interpretation of the results is require further geomorphological and engineering-geological exploration in the areas of these stations.

COLLATION OF ACQUIRED RESULTS

The acquired data on the values of the normative depth freezing of clayey soils and the actual maximum depth soil freezing allow to compare them with each other. The result of this comparison was the map of difference of these depth (Figure 4).

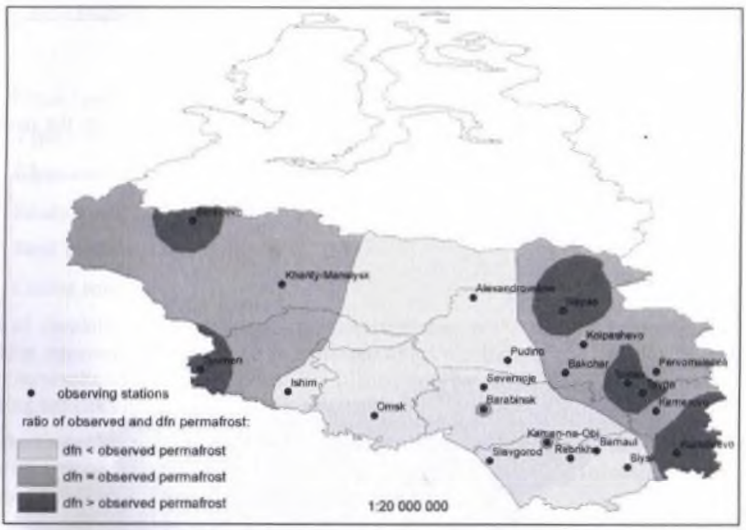


Figure 4 – Ratio of the normative and the actual maximum depth soil freezing

Considerable excess the actual depth soil freezing than normative can be explained by the spread of sandy and sandy loam soils and must be refined through engineering and geological structure of these areas.

CONCLUSION

This paper presents the results of studies features of the seasonally frozen soils of Western Siberia. During this study the authors encountered several methodological issues. The study of methods for calculating the seasonally frozen soils into effect insufficiency of network of hydrometeorological stations became necessary climatic zoning, which in turn has led to the issue of choosing the optimal method of interpolation of meteorological data [3, 15] and also to highlight areas of influence closely located stations.

It should be noted that the northern regions of Western Siberia (mainly the Yamalo-Nenets Autonomous District) [2, 12, 13] is characterized by permafrost and the calculation of the depth of seasonally frozen soil of these areas is not conducted. Because of these features the data of hydrometeorological stations northern regions were used in solving problems of climate zoning, but did not participate in mapping the depth soil freezing .

The main task of this study was creation of a database that would enable quickly calculate the normative depth freezing at any site geotechnical investigations in the territory of Western Siberia. This problem was solved with the use of software package ArcGIS 10.2.

As a result, complex study of the depth soil freezing in Western Siberia in some areas have been identified inconsistencies between the calculated and actual values. Further it is planned a detailed study of these inconsistencies to identify the reasons of this discrepancy.

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