Methods for displaying data using web technologies for the Arctic region and the continental shelf

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Abstract. In this article we discuss the principles of geospatial data design, which underlie the methods of displaying information based on the projection methods for the Arctic region and the continental shelf, using various web technologies. Various cartographic services were studied depending on their functionality, the software development geography, and the associated mathematical system basis. We assessed the metric capabilities of the main projections underlying the mapping services and determined the search functionality and demonstration tasks that can be solved by means of similar information systems. It is pointed out that it is necessary to provide the analytical functions for services and geoportals, which is necessary for mapping tools in making decisions. The principle of increasing accuracy, unification, ease of use was supported by the development of the unified approach for choosing a projection, that is the Unified Isometric Cartographic Projection. The use of this projection will make it possible to approach the data design issue in a unified manner, which, on the whole, will increase the cartographic security of the region and will make it possible to solve the cartographic problems in the unified manner. The accurate evaluation of the data obtained on the basis of this projection showed that the results can be within the two meters accuracy. Such metric parameters are sufficient to make the design decisions on the infrastructure facilities' development in the Arctic region and the continental shelf. In order to improve and develop the geoportal "The Arctic Spatial Data Infrastructure" (Arctic SDI), the option of improving its mathematical basis is a promising direction. In addition, the use of the Unified Isometric Cartographic Projection in a GIS user environment will remove the issue of the complex search for the optimal projection. Regardless of the tasks of mapping, when choosing the element needed (GIS user environment, 2D and 3D mapping services, databases) that defines the web mapping technology, data designing according to the single principle will remove a number of technical issues and inconveniences, bringing it closer to the best option.

Introduction
The choice of data design principles is a key aspect in the applied mapping matters. The geodata design on the surface (plane) is determined by the choice of coordinate systems, the projection and the associated cartographic and coordinate grids, as well as scale.

Depending on the cartographic tasks being solved by means of the web technologies, various information systems are used: cartographic services and the servers integrated with databases, user geographic information systems (GIS), in which the principles of data design are different.
The selection of optimal principles for the geospatial data design is an important, urgent scientific and technical task, the solution of which will provide the reliable cartographic support as a means of increasing the stability and efficiency of the infrastructure facilities’ development in the Arctic region and the continental shelf.

**The Information Systems’ Functional capabilities**

At the present stage of the scientific and technical relations’ development, an integral part is the connection between the necessary visualization of spatial data on plane or spherical surfaces in order to facilitate the search and delivery of information about them to the consumers [9].

To solve the user’s everyday tasks related to the spatial data visualization, cartographic services are used, the list of which is large depending on their functionality, development geography and the mathematical basis of the system associated with it. In the Table 1 it is possible to see a list of mapping services used in practical life.

**Table 1. Cartographic Services**

| Description | Developer (country, company, year) | Mathematical framework |
|-------------|-----------------------------------|------------------------|
| **Overseas** |                                   |                        |
| Bing Maps   | USA, Microsoft, 2005              | The Mercator (cylindrical conformal) map projection (WGS-84) |
| Google Maps | USA, Google, 2005                 |                        |
| Yahoo! Maps | USA, Yahoo, 2002                 |                        |
| Map Quest   | USA, AOL, 1996                    |                        |
| OpenStreetMap | United Kingdom, OpenStreetMap Foundation, 2004 | The Marnauz-Tyrsky (equirectangular) geographical projection (WGS-84) |
| Google Earth| USA, Google, 2005                 |                        |
| **Domestic** |                                   |                        |
| Yandex Maps | Russia, Yandex, 2004              | The Mercator (cylindrical conformal) map projection (WGS-84) |
| Maps.me     | Russia, Geocentre-consulting, 2006|                        |

As we can see from the data presented in Table 1, despite an extensive list of the open access mapping services, almost all of them are united by a common design basis based on The Mercator (cylindrical conformal) map projection, developed in 1569 [1], which is quite explainable from the point of view of its properties.

It should be noted that with the introduction of new technical means (cartographic services) into practice, the principles of data design in them correspond to the principles developed several centuries ago. This fundamentally does not solve the problem of increasing the accuracy of the data provided by various information systems.

When trying to evaluate the metric properties of the projection, which is the basis of most 2D mapping services (The Mercator (cylindrical conformal) map projection,) we used the conditionally selected extreme points located on the border of the Arctic region and the continental shelf. The scale distortions’ calculation in all directions is presented in Table 2.
Table 2. Disturbance value of Cartographic projection

| The name of the extreme point of the region | Geographical coordinates | Scale parameter | $V_p$ [km$^2$] | Extreme scale of mapping, $V_p$ |
|------------------------------------------|--------------------------|-----------------|----------------|-------------------------------|
|                                           |                          | $m$ | $n$ | $p$ | $\omega$° |                                     |                              |
| Murmansk                                 | N 68°58′45″E 33°05′33″   | 2.786943     | 8   | 2.786943     | 7.7670556 | 0 | 51 623.5 | 1: 258 117 500 000 |
| Vorkuta                                  | N 67°29′55.7″E 64°39″    | 2.612905     | 7   | 2.6129057    | 6.8272763 | 0 | 43 638.4 | 1: 218 192 180 000 |
| Verkhoyansk                              | N 67°33′13″E 133°23′23″  | 2.619043     | 4   | 2.6190434    | 6.8593882 | 0 | 43 774.9 | 1: 218 874 500 000 |
| Srednekolymsk                            | N 67°27′23″E 153°42′08″  | 2.608333     | 6   | 2.6083336    | 6.8034043 | 0 | 43 432.8 | 1: 217 164 370 000 |
| Cape Dezhnev                              | N 66°4′59″E 169°39′0″    | 2.466203     | 2.466203 | 6.8042162 | 0 | 42 554.5 | 1: 212 772 680 000 |
| Point Barrow                             | N 71°23′0″W 156°28′2″    | 3.132488     | 2    | 3.1324882    | 9.8124821 | 0 | 69 792.3 | 1: 348 961 660 000 |
| Fort Good Hope                            | N 66°16′59.8″W 128°38′59.9″ | 2.486225 | 9   | 2.4862259    | 6.1813191 | 0 | 38 102.7 | 1: 190 513 840 000 |
| Forel                                    | N 66°56′00″W 36°47′00″   | 2.552309     | 8   | 2.5523098    | 6.5142851 | 0 | 40 953.1 | 1: 204 765 480 000 |
| Bude                                     | N 67°16′48″E 14°24′18″   | 2.589136     | 7   | 2.5891367    | 6.7036290 | 0 | 42 573.9 | 1: 212 869 510 000 |

Based on the data presented in Table 2, it turns out that, with all the obvious advantages of an equiangular projection, the absence of distortion in the angles ($\omega=0°$), the scales in other directions are significantly distorted, especially in the square measure scale, reaching values from 38,102 km (Fort Good Hope) up to 69,792 km (Point Barrow). This circumstance indicates the impossibility of using the considered cartographic service as the information source, with the help of which it is necessary to solve the applied problems within the Arctic region and the continental shelf. In case of the navigation problems’ partial solution [8], it is not possible to solve the problems associated with taking into account the objects’ area parameters. This is relevant in the formation and development of the region’s infrastructure, in accordance with the promising directions of the state policy of the Russian Federation in the Arctic.

In a number of cartographic services, such as Google Earth, The Marnauz-Tyrs (equiangular) geographical projection is used. It was first proposed in 100 BC (2,117 years ago) [7].

The metric properties of the projection used can be estimated from the data given in Table 3.
Table 3. Disturbance value of Cartographic projection

| The name of the region’s extreme point | Scale parameter | \( V_n, \text{Km} / V_p, [	ext{km}^2] \) | \( V \omega, \text{[km]} \) | Extreme scale of mapping, \( V_{np} \) |
|--------------------------------------|-----------------|---------------------------------|-----------------|-----------------|
| Murmansk                             | \( m = 1 \)     | \( n = 2.786943 \)            | 13 631.9        | -3 134.2        | 1: 68 159 980 000 |
|                                     | \( 8 \)         | \( p = 2.789438 \)            |                 |                 |                  |
| Vorkuta                              | \( m = 2 \)     | \( n = 2.612905 \)            | 12 078.5        | -2 951.4        | 1: 60 392 440 000 |
|                                     | \( 7 \)         | \( p = 2.612907 \)            |                 |                 |                  |
| Verkhoyansk                          | \( m = 2 \)     | \( n = 2.619043 \)            | 12 124.4        | -2 958.2        | 1: 60 622 250 000 |
|                                     | \( 4 \)         | \( p = 2.619044 \)            |                 |                 |                  |
| Srednekolymsk                       | \( m = 2 \)     | \( n = 2.608333 \)            | 12 036.8        | -2 946.4        | 1: 60 184 100 000 |
|                                     | \( 6 \)         | \( p = 2.608336 \)            |                 |                 |                  |
| Cape Dezhnev                         | \( m = 2 \)     | \( n = 2.466620 \)            | 10 752.8        | -2 785.9        | 1: 53 763 800 000 |
|                                     | \( 3 \)         | \( p = 2.466620 \)            |                 |                 |                  |
| Point Barrow                         | \( m = 3 \)     | \( n = 3.132488 \)            | 16 887.8        | -3 458.1        | 1: 84 443 480 000 |
|                                     | \( 2 \)         | \( p = 3.132488 \)            |                 |                 |                  |
| Fort Good Hope                       | \( m = 1 \)     | \( n = 2.486225 \)            | 10 929.5        | -2 808.8        | 1: 54 647 590 000 |
|                                     | \( 9 \)         | \( p = 2.486225 \)            |                 |                 |                  |
| Forel                                | \( m = 1 \)     | \( n = 2.552309 \)            | 11 527.4        | -2 884.2        | 1: 57 636 990 000 |
|                                     | \( 8 \)         | \( p = 2.552309 \)            |                 |                 |                  |
| Bude                                 | \( m = 1 \)     | \( n = 2.589136 \)            | 11 861.9        | -2 925.2        | 1: 59 309 390 000 |
|                                     | \( 7 \)         | \( p = 2.589136 \)            |                 |                 |                  |

Table 3 shows that the projection retains the main scale in one direction — the meridians with a significant areas’ distortion: from 10,752.8 km² (Cape Dezhnev) to 16,888.7 km² (Cape Barrow).

After a general assessment of the maximum projection errors’ values, which are the basis of map services, it follows that it is impossible to use them as a cartographic basis for displaying the geospatial information.

The accuracy, visibility and usability of map services for solving the applied problems can only be realized thanks to the development and application of the new approaches to data design, as well as endowment of services with a number of analytical and operational functions.

Often, “convenient data visualization” is solved by applying data when displaying on the model sphere. The spherical surfaces used in 3D services, the virtual globe Google Maps, Google Earth, etc., are described by a radius, the magnitude of which is close to the semi-major axis \((a=b=6370997 \text{ m})\) of the ellipsoid WGS84 [9], which is explained by the American origin of the products.

Thus, the main cartographic task that 3D services solve, virtual globes is a search and demonstration task without strict definition and calculation of mathematical and cartographic parameters of the displayed data about objects, phenomena, processes. The competencies of the search and demonstration tasks include the display of panoramic and satellite images, viewing and downloading GPS tracks, compiling catalogs, etc.

When displaying the data within the framework of cartographic services and servers, it is sufficient to have the data on their initial position (coordinates), usually stored in the attribute table of the objects’ database, for example, PostreSQL, SQL, Server, MySQL, etc. [4]. The use of databases in web mapping is an important, integration part of the information system.

In general, the possibility of using a wide range of mapping services makes it possible to solve the general or thematic search and demonstration tasks that are not unified in nature.

Today, not only large enterprises, government agencies and universities, but also the consumers are interested in spatial data analysis. Modern software solutions allow not only to publish the spatial data,
but also to perform the analytical operations. Therefore, it is important both to have an access to spatial information and to process it correctly and present the data to the end user.

Thus, for the purposes of international cooperation on the geospatial data exchange, the geoportal “Spatial data infrastructure of the Arctic region” (Arctic SDI - Geoportal) was developed with the use of the map services’ geospatial data: Russia, Canada, Finland, Iceland, Norway, Sweden, the USA and Denmark (including the Faroe Islands and Greenland self-government administrations), which provide an access to geospatial data of the region, electronic maps and tools in order to improve the quality of monitoring and decisions making [10].

According to the Federal State Registration, Cadastre and Cartography Service (Rosreestr), the publication of cartographic materials on the geoportal is carried out in the WGS84 coordinate system and Lambert azimuthal equal-area projection (WGS84 North Pole LAEA Russia).

Using the mathematical apparatus of this design method [2], the distortions scale was calculated in all directions at the extreme points of the region. The calculation results are presented in Table 4.

| The name of the region | Scale parameter | \( V_m, \text{ km} \) | \( V_n, \text{ km} \) | \( V_{\theta}, \text{ km} \) | Extreme scale of mapping, \( V_{\theta} \) |
|------------------------|----------------|---------------------|-----------------|---------------------|-------------------------------|
| Murmansk               | 0.9832549      | 1.0170303           | 0.967501        | -38.199             | 1: 538 447 000                |
| Vorkuta                | 0.9807853      | 1.0195911           | 1.111567        | -44.617             | 123.731 1: 618 653 500        |
| Verkhoyansk            | 0.9809552      | 1.0194145           | 1.101646        | -44.222             | 122.626 1: 613 132 000        |
| Sredneolymsk          | 0.9807853      | 1.0195911           | 1.111567        | -44.617             | 123.731 1: 618 653 500        |
| Cape Dezhevne          | 0.9783287      | 1.0221513           | 1.255227        | -50.321             | 139.721 1: 698 609 438        |
| Point Barrow          | 0.9868557      | 1.0133193           | 1.515901        | -30.521             | 168.738 1: 843 689 901        |
| Fort Good Hope        | 0.978689       | 1.0217755           | 1.234159        | -49.486             | 137.377 1: 686 883 672        |
| Forel                  | 0.9797503      | 1.0206681           | 1.172045        | -47.021             | 130.462 1: 652 313 783        |
| Bude                   | 0.9804432      | 1.0199468           | 1.131545        | -45.411             | 125.954 1: 629 772 752        |

Table 4 shows that the projection retains the main scale in one direction — the meridians with a significant distortion of areas: from 107.694 km (Murmansk) to 168.738 km (Point Barrow).

Based on the data presented in Tables 2-4, it follows that the selected principles of data design are not optimal for solving the unified applied problems, and the question of finding the best way to design data is relevant.

A single approach to data design for the Arctic region and the continental shelf
The answer to the scientific and technical task is the development of a single unified isometric cartographic projection [6]. Its application will allow to maintain the metric objects’ accuracy in all the scales’ directions within the territory with a large spatial coverage, which is the Arctic region with a total latitudinal extent of about 23°27’. The projection can become the basis for the map services’ design and be included in the GIS projection collection.

Obviously, for the convenience of using maps, a single approach to choosing a cartographic projection while creating them is optimal. However, in classical cartography, a single approach when choosing a projection is to identify the grounds for classifying the projections according to the nature of distortions, the type of auxiliary surface, and the position of the coordinate grid. Initially, this implies the presence of a large number of projections (often approximately several thousands), and to understand them is sophisticated problem for a developer or a GIS user [5].

So, in QGIS Software, using the PROJ4 collection, about 2,700 known projections and coordinate systems are supported. In the GIS Software “Map 2011” about 3,400 known projections and coordinate systems are supported, in the ArcGis, ArcMap software - about 100 known projections are supported, etc.

A single approach to the choice of cartographic projection solves the question of finding a design method depending on the goals and objectives of mapping, which qualitatively distinguishes it from the approaches of classical mathematical cartography towards unification and optimization.

The metric properties of the proposed projection can be estimated using the scale calculations in all directions of the extreme points located in the Arctic region and on the continental shelf (Table 5).

| The name of the region’s extreme point | Scale parameter | Vm, [m] | Vn, [m] | Vp, [m²] | Vω, [m] | Extreme scale of mapping, V ω |
|--------------------------------------|-----------------|---------|---------|---------|---------|-----------------------------|
| Murmansk                             | 1.000 000 383   | 1.000 000 126 | 1.000 000 509 | 0.0000146 | 0.89 0.29 1.19 1.63 | 1: 8 150                  |
| Vorkuta                              | 1.000 000 458   | 1.000 000 163 | 1.000 000 621 | 0.0000168 | 1.07 0.38 1.49 1.87 | 1: 9 350                  |
| Verkhoyansk                          | 1.000 000 455   | 1.000 000 162 | 1.000 000 617 | 0.0000167 | 1.06 0.38 1.44 1.86 | 1: 9 300                  |
| Srednekolymsk                       | 1.000 000 460   | 1.000 000 165 | 1.000 000 624 | 0.0000168 | 1.07 0.38 1.46 1.87 | 1: 9 350                  |
| Cape Dezhnev                         | 1.000 000 532   | 1.000 000 202 | 1.000 000 734 | 0.0000190 | 1.24 0.47 1.71 2.12 | 1: 10 600                 |
| Point Barrow                        | 1.000 000 272   | 1.000 000 071 | 1.000 000 343 | 0.0000115 | 0.63 0.17 0.8 1.28   | 1: 6 400                  |
| Fort Good Hope                       | 1.000 000 523   | 1.000 000 196 | 1.000 000 719 | 0.0000187 | 1.22 0.46 1.68 2.08 | 1: 10 400                 |
| Forel                                | 1.000 000 508   | 1.000 000 188 | 1.000 000 696 | 0.0000173 | 1.19 0.44 1.62 1.98 | 1: 9 900                  |
| Bude                                 | 1.000 000 469   | 1.000 000 169 | 1.000 000 638 | 0.0000171 | 1.09 0.39 1.49 1.9  | 1: 9 500                  |

As it can be seen from the data presented in Table 5 in a single territory with a large spatial coverage (Zmax = 23.9°), it is possible to maintain high accuracy of the data in all the scales’ directions - at least 2.12 meters, which makes it possible to unify any applied task using the map.
The application of a single approach to data design will optimize this process using any information system, which, in general, will increase the cartographic security of the region.

Main conclusions and Results
A number of main conclusions on the work should be noted:

1. The Arctic is a modern and promising area in terms of exploration, study, research, not only for Russia, but also for the world as a whole, which allowed to formulate the actions in the field of public policy, including the issues of cartographic support. Thus, the creation of “The Arctic Spatial Data Infrastructure” (Arctic SDI) geportal is a direct confirmation of this.

2. The functionality of services and geportals makes it possible to map any kind of information in the projection that is used solely as the projection basis. This frees the user from the choice and deprives the search option of the best (optimal) cartographic projection.

3. Cartographic services are only a “base” for displaying and working with spatial information, without solving analytical problems, which defines a promising task for the web technologies’ development in cartography.

4. The search for a unified isometric cartographic projection is an important scientific and technical task when working in a GIS user environment, since it simplifies the researcher’s task in choosing the best projection depending on the tasks and mapping goals. The domestic cartographic projection development is a good addition to the mathematical module of the modern software systems that ground their work on the digital maps basis.

5. Using a unified approach to data design in all elements of web technologies will increase, in general, the Map Coverage in the region’s infrastructure development.

Summary
Thus, regardless of the mapping tasks, when choosing the element needed (GIS user environment, 2D and 3D mapping services, databases) that defines the web mapping technology, data designing according to a single principle will remove a number of technical issues and inconveniences, bringing it closer to the best option.

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