DIGITAL EARTH BASED ON METADATA ELECTRONIC MAPS STANDARD

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Digital Earth was at the center of attention at 19th International Cartographic Conference (Ottawa) and 1st International Symposium on Digital Earth (Beijing) in 1999 [1, 2]. The discussion raised in the papers on the theory of Metadata Standard Systems that could be used in International and National Spatial Information Infrastructures to establish Digital Earth still continues. We highly appreciate the essential contribution made by Chinese scientists: Zhao Yongping, Huang Fang, Guo Jingjun, Feng Quan, Cui Weihong.

Since 1990s the Information Society is being created in Russia. Each member of this Society will be able to obtain complete and actual information, including geoinformation, in any point of geographical space, by means of Internet. Today it is obvious that this problem could be solved in most effective way by using electronic libraries of various intent, including electronic map libraries. Completeness, methods and form of geoinformation, temporal factors of the information supply can be considered as the main criteria for evaluating quality of the electronic geoinformation resources. In the process of creating the electronic geoinformation resources, standardization in the area of geoinformation technologies plays the main role.

Today, at the boundary of millennia, the Global Geoinformatic Mapping (GGM) appears as the prior direction of scientific and technical progress. Its goal is the cartographic representation of the real world and creation of the global computer model of the Earth, comprised of millions of space images and electronic maps of various subjects and scales, themes and also reference information [3, 4]. Theoretical fundamentals of GGM are being elaborated by Institute of Informatics Problems and Institute of Geography (Russian Academy of Sciences) and 29 Defense Research Institute. Digital Earth is considered as one of the most important problems of GGM. This problem can be solved by cartographers from various countries, who should meet the 21 century as partners, possessing new ideas, courage and intellectual technologies for creation and application of maps.

The matter of GGM is preparation and fulfillment of measures directed to develop and implement conceptual and methodological basis, normative and legislative documents and standards of metadata for geographic, geodetic, gravimetric, space, photogrammetric and cartographic information, electronic photomaps and and spatial (3D) terrain models, formats for spatial data interchange; to develop and implement methods, hard- and software tools and technologies for acquisition, storage, analysis and processing digital cartographic data, creation of usual (paper) and electronic maps; to develop and implement Base of metadata and Bank of spatial data, digital and electronic maps, geoinformation systems of various intent. At the modern stage, GGM is closely connected to the development of geography, geodesy, remote sensing, photogrammetry and cartography.

For the creation of Digital Earth may be applicated the new State Standard of the Russian Federation GOST R 51353-99 Geoinformatic Mapping. Metadata of the Electronic Maps. Composition and Content [5]. This Standard provides cartographic representation of the real world and creation of Digital Earth that is based on strict geodetic base by means of using millions air- and space high-resolution images, electronic maps of various intent and scale, and textual reference information. GOST R 51353-99 allows to synthesize the digital (electronic) image of the Earth as a spatial and temporal representation of our planet. This representation is based on mathematical and semantic modeling of spatial data changing dynamically and is realized as the aggregate of distributed electronic cartographic libraries (Electronic Maps Libraries) united in whole system by means of telecommunication technologies.

But only one or several electronic maps cannot be regarded as a universal tool for all customers who want to see Earth as it is, solving multi-purpose control and navigational tasks in area of industry, agriculture, transportation, communication, meteorology, tourism etc. It is necessary to combine different electronic maps of various scale, projection, coordinate system, content and appearance in the whole system. This means to create the united computer model of the Earth, which includes thousands of electronic maps of various purposes and scales. We speak about the development of the Electronic Maps System that means the aggregate of electronic geographic, topographic and thematic maps integrated under common idea and ordered by geodetic base, content and design. It also includes orthophoto maps, city maps, air- and space photo images, reference information stored on computer media [6, 7, 8].

Electronic maps are one of multiple forms of representing spatial data. So the electronic maps system has been creating as the whole base of spatial data which is described by metadata. In reality, GOST R 51353-99 provides creation of Digital Earth.

GOST R 51353-99 establishes the requirements to the composition and content of common, geodetic, gravimetric, photogrammetric and cartographic metadata used for creation (updating) and application of electronic maps. Geodetic and gravimetric metadata characterize systems of geodetic parameters of Earth, ellipsoids, coordinate and elevation systems, catalogues of geodetic stations and leveling points, formula for normal gravity acceleration, gravimetric systems, catalogues of gravimetric stations, models of gravity field, catalogues of average gravity anomalies. Photogrammetric and cartographic metadata describe materials of survey (including digital images), digital terrain elevation matrices, digital terrain models, digital orthophotos, electronic topographic and thematic maps and orthophoto maps.

The development of standards is carried out by the Technical Committee 22 “Information Technologies” that includes the Subcommittee on Standards for Geoinformation Technologies. This Subcommittee deals with standardization in the field of creation and application of geoinformation technologies based on methods and tools of acquisition, collection, analyzing, displaying, processing and retrieving of spatial data for the needs of electronic mapping. TC 22 also includes committees on terminology, telecommunication and information interchange, programming languages and system program interfaces, computer graphics and image processing, encoding audio, image, multimedia and hypermedia information, automatic identification, methods and tools for data acquisition.

Within the Subcommittee on Standards for Geoinformation Technologies there was GOST R 51353-99. In November 1999 this standard was adopted by the Russian Federation State Committee on Standardization and Metrology. In the process of GOST R 51353-99 development, we used the experience of long and fruitful co-operation with the ICA Commission on Standards of Spatial Data.

The need in development of GOST R 51353-99 grew from the necessity of:

- acquisition of metadata of electronic maps and information used for creation and storage of electronic maps;
- effective application of metadata by customers for the acquisition, storage, analyzing, processing and transfer of geoinformation;
- increasing quality of electronic maps;
- information compatibility of control, navigation systems and GIS;
- electronic maps and metadata interchange both inside Russia and worldwide.

GOST R 51353-99 establishes requirements for the composition and content of common metadata as well as metadata of geodetic, gravimetric, photogrammetric and cartographic information used for creation, updating and application of electronic maps.

The statements of this Standard are liable to application by all authorities and organizations located in Russian Federation, independently of their form of government and subjection, which are engaged in acquisition, systematization, analysis, processing and transfer of spatial data, creation and application of electronic maps, organization of bases of metadata and digital cartographic databanks.

This Standard refers to the following State Standards: GOST 34.003-90 Automated Systems. Terms and Definitions, GOST 22268-76 Geodesy. Terms and Definitions, GOST 24284-80 Gravitational and Magnetic Exploring. Terms and Definitions, GOST 23935-79 Air Photo Cameras and Photo Survey. Terms and Definitions, GOST 21002-75 Phototopography. Terms and Definitions, GOST 21667-76 Cartography. Terms and Definitions, GOST 28441-90 Digital Mapping. Terms and Definitions, GOST R 50828-95 Geoinformatic Mapping. Spatial Data, Digital and Electronic Maps. Common Requirements.

Metadata of electronic maps is data that allows to describe contents, spatial extents, quality (accuracy, complexity, consistency and actuality) and other characteristics of electronic maps. It must contain the following sections:

- Common metadata;
- Metadata of geodetic and gravimetric information;
- Metadata of photogrammetric information;
- Metadata of cartographic information;

Common metadata corresponds to the top level in metadata hierarchy and must reflect the most common characteristics of spatial geodetic, gravimetric, photogrammetric and cartographic information. Common metadata must include:

- name of metadata;
- information about organization - metadata provider who is responsible for the maintenance of data dictionary (name and address);
- information about organization - developer of electronic map, license, registration number of the electronic map, name of fund where it is being registered;
- encoded description of cartographic product, including two sections: identification section (code of production type) and information section (codes of attributes and their semantic values);
- identification information (data description, temporal period, status, keywords, limitations of data acquisition and usage);
- date (year) of electronic map production and/or update, state of terrain (year);
- information about country (territory); publication language; author(s) and editor;
- quality information (attributive and positional accuracy, data completeness, criteria of data generalization, lineage);
- spatial query information (coordinate systems, projections, grids, parameters of figure of Earth);
- date of metadata preparation (month, year);
- security limitations;
- characteristics of data storage and movement: address of storage organization; address of sender; mailing date and number; address of the recipient; receiving date and number;
- price list;
- contact information.

Geodetic metadata must contain the following information. System of geodetic parameters of the Earth: name; year; country; authority. Type of geodetic coordinates: 3-D systems; space rectangular (values of X, Y, Z, integrated square error); spherical (latitude/longitude, integrated square error); plain rectangular of various projections (values of X, Y, integrated square error). Types of elevations: geodetic, normal. Elevations measurement systems: name, year, country, initial point, elevation of the initial point; integrated square error. Fundamental geodetic constants: system of the Earth parameters; geodetic gravity constant, considering atmosphere. Parameters of ellipsoid: name, year, country, semi-major axis, flattening, mean square error. National coordinate systems: country, name, spheroid of reference, semi-major axis, mean square error, flattening, mean square error, geodetic coordinates of the initial point: name, latitude, longitude, name of main direction; geodetic azimuth of main direction; elevation of quazi-geoid over spheroid of reference in the initial point. Coordinate systems orientation elements: names of systems between which elements are established, linear elements, scale, correlation system of orientation elements (number of rows and columns in triangular matrix, cell of matrix). Catalogue of geodetic points coordinates: map sheet designation, year of publication, country; number of points in the catalogue, name of the National coordinate system, name of elevations

measurement system, name of type of geodetic coordinates. Geodetic point: section in the catalogue; index of the point in the catalogue, point type, point class, point name, type of coordinates, coordinates of the point, normal elevation, type of geodetic sign, central mark number, name of direction from the point, direction angle, base line.

Gravimetric metadata must contain the following information. Normal gravity: formula for normal gravity acceleration, name, year, gravity acceleration at the equator, correlation to gravity acceleration at zero level considering atmosphere interference, coefficients of normal formula. Gravity anomalies: gravimetric system (year, name, country, formula for normal gravity acceleration). Models of gravity: name, type (planetary, regional, local), country, year, spatial resolution, mean square error of gravity anomaly description and quazi-geoid elevations, presentation form (coefficients, point masses etc.) Models of gravity as rows of spherical functions: name, country, year, degree, numbered harmonical coefficients, mean square error.Models of gravity as a potential of point-mass systems: name, type, country, extents of model; coordinates of North-West point (latitude, longitude); number of point-mass subsystems; number of point masses in each subsystem; type of geodetic coordinates of points. Catalogue of average gravity anomaly values: coordinates of North-West point (latitude, longitude); type of gravity anomaly reduction; gravimetric system (country, year, author, name); lineage (gravimetric data, altimetry, quazi-geoid etc.), anomaly of gravity acceleration, normal elevation; number of rows and columns in matrix, step by latitude, step by longitude. Catalogue of gravimetric points: region, number of map sheets, points classes, number of classes, gravimetric system, normal formula for values of gravity acceleration; year of publication, author, number of survey points. Gravimetric point: number in catalogue; name, coordinates (type, latitude, longitude), normal elevation, point class, method for calculating gravity acceleration, gravimetric system, year of survey, normal formula for calculating gravity acceleration, availability of points-satellites, type of center, gravity acceleration, mean square error, anomalies of gravity acceleration (number of anomalies, values, mean square error).

Photogrammetric metadata must contain the following information. Information about survey materials: object number, rout number, object code, scale, camera type, focus length, range of survey, percentage of longitudinal overlap, date of survey, frame number, exposure time, frame format, height of survey, height of the Sun, coordinates of main point, name of the territory, maximum angle , coordinates of frame corners, availability of external orientation data, information about any defects (percentage: cloudness, snow coverage, physical damages, electrostatic discharge, blur, haze, Newton circles), integral evaluation of the frame, optical density of a veil, minimal optical density, maximal optical density, average optical density, average resolution, resolution at terrain. Information about digital matrices of relief: map sheet designation, security limitations, vertical unit, size of discrete cell, coordinates of matrix South-West corner, maximal elevation, minimal elevation, average level of elevations mean square errors, parameter of relief homogeneity, date of creation. Information about digital terrain models: code, available feature classes, plane unit, vertical unit, maximal elevation, minimal elevation, mean square errors of relative heights, contour interval, radius of correlative elevation function. Information about digital orthophoto plans (maps): coordinates of the corners, projection and coordinate system, mean square error of calculating the absolute and relative coordinates of points.

Cartographic metadata must contain the following information. Identification data: map sheet designation, type of the electronic map, map name (name of the main settlement or, if none, of a prominent geographic object). The most essential features of the main types of topographic, geographic and thematic (special) maps: intent, contents, form of presentation (vector/raster). Information about geodetic and mathematic base: scale, projection, availability and step of a rectangular coordinate grid, geodetic and rectangular coordinates of map sheet corners, semi-sphere, values of the main parallel(s), size of map sheet sides in angular and linear units, magnetic declination at the time of publication, magnetic variation per year, rectangular coordinates of South-West corner of an extended map sheet, availability of elevations matrix and its characteristics (number of rows and columns, size of a cell), initial point of triangulation, coordinate system, elevation system, initial meridian, ellipsoid parameters, resolution of coordinate presentation, mean plane error of objects location, mean elevation error, integral evaluation of map precision, main parallel(s) and meridian of the map projection, addition to the longitude for reference to Greenwich meridian; addition to the

latitude to refer to the equator. Statistical characteristics: predominant terrain inclination angle, average level of mean square declinations of elevations, radius of elevations correlation, minimal and maximal elevation, maximal height of high-rise objects. Information about availability and characteristics of feature classes, single features and methods of their presentation: contents of the cartographic data, availability of feature classes, availability of state borders data, description of the terrain, contour interval, variable-scaled contour intervals, methods for presentation of the terrain relief and settlements. Information about electronic photo maps (orthophoto maps): code, coordinates of the corners, projection and coordinate system, mean square error of calculating absolute and relative coordinates of points, availability and characteristics of feature classes, map symbols and annotations, plane and vertical units; method for presentation of the terrain relief, contour interval, method for presentation of settlements.

The area of GOST R 51353-99 application are as following: information and analytical supply of state authorities, GIS, systems and tools for communication, business, transportation, navigation, ecological monitoring, state and private cartographic enterprises, defense. The particular importance is attached to the cooperation and collaboration between governments, governmental and non-governmental organizations, international organizations and institutions in creation of Digital Earth and its application for social, economic, scientific, educational and technological development.

In Russia synonym of Digital Earth is Electronic Earth. But it is unique multi-dimensional computer model of the structure and development of our planet designed on the base of integrated analysis of geographic, surveying, cartographic, geologic, geophysical and other researches of Earth. There is not only a subject of modeling of Earth surface as well as the objects and phenomena on it. The very important topic in this concern is collection and visualization of spatial information in the dynamic of its changes in the lithosphere, hydrosphere, atmosphere and biosphere as well as in their patterns.

References

1 Proceedings of the International Cartographic Conference.- Ottawa, 1999. - Vol. 1, 2. - 1908 p.

2 Proceedings of the International Symposium on Digital Earth.- Beijing, 1999. - Vol. 1, 2. -1086 p.

3 Martynenko A.I. Global Geoinformatic Mapping as the Methodology and Technology of the Future // Proceedings, 19th ICA International Cartographic Conference, Ottawa, 1999, vol. 1, pp. 39-42.

4 Martynenko A.I. The development of Concept and Methods for Creating an International System of Geographic Maps as an Universal Basis of the Earth Knowledge // Proceedings, 17th ICA International Cartographic Conference, Barcelona, 1995, vol. 2, pp. 33-40.

5 Государственный стандарт Российской Федерации ГОСТ Р 51353-99 "Геоинформационное картографирование. Метаданные электронных карт. Состав и содержание".

6 Martynenko A.I. The Concept of the Electronic Maps System // Proceedings, 16th ICA International Cartographic Conference, Cologne, 1993, vol. 2, pp. 1160-1163.

7 Martynenko A.I. Advances in electronic mapping systems // World Aerospace Technology, London, Sterling Publications Ltd., UK, 1996, pp. 81-82.

8 Martynenko A.I. GIS and Geospatial Metadata // Proceedings, 18th ICA International Cartographic Conference, Stockholm, 1997, vol. 1, pp. 79-82.