

## SYSTEMS ANALYSIS

### INTEGRATION OF THE UKRAINIAN SCIENCE INTO THE WORLD DATA SYSTEM

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*Creating the World Data Center for Geoinformatics and Sustainable Development (WDC-Ukraine), its certification and integration into the World Data System are described. The main principles of the WDC and its research priorities are considered. Main projects carried out by the WDC are reviewed. One of them is global modeling of the sustainable development in the context of the safety and quality of life aimed to get a set of indices and indicators for the sustainable development of complex systems at different levels.*

**Keywords:** *World Data System, Ukraine, IASA, World Data Center, geoinformatics, sustainable development.*

#### WORLD DATA SYSTEM

The system of World Data Centers (WDC) and Federation of Astronomical and Geophysical Data Analysis Services (FAGS) were created by the International Council for Science (ICSU) in 1956 during the preparation to the International Geophysical Year (1957–1958), the largest international scientific project of the 20th century, to collect, store, distribute, and analyze data acquired in many scientific fields. The system of WDC and FAGS served successfully to the international scientific community for more than fifty years [1]. Huge data and information files were accumulated during these years, knowledge and wide experience were acquired in organizing international exchange of data, their analysis and processing, in creating data archives and providing their long-term storage, and data control systems were developed. By now, there are about 50 World Data Centers and 13 FAGS offices located in 13 countries in North America, Europe, Asia, and Australia (the number of World Data Centers in each country is shown in Fig. 1). However, these systems are now inadequate to the needs of science and are insufficiently flexible to be used in interdisciplinary studies. Therefore, it was decided at the 29th General Assembly of ICSU in Maputo (Mozambique) at the end of 2008 to integrate WDCs and FAGS into a new interdisciplinary structure, World Data System (WDS) for a new, coordinated global approach to scientific data and information that would guarantee a universal equal access to qualitative data and information for studies, education, and informed decision making. The newly created system is coordinated by the World Data System Scientific Committee (WDS-SC) consisting of 11 scientists who represent WDCs and FAGS. The major problems to be solved by the committee in the nearest future are the unification of data transmission formats and protocols and organization of the quality assurance of scientific data and information [2].

To coordinate the actions under the transformation to the World Data System and to organize a common information space to maintain data acquisition, handling, and exchange and to solve fundamental and applied interdisciplinary problems, the Russian-Ukrainian regional cluster of the World Data System was created based on the World Data Centers of the Russian Federation and Ukraine. The cluster includes the WDC for solid Earth physics and the WDC for solar-terrestrial

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Fig. 1. Russian-Ukrainian segment of the WDS.

physics, which are based of the Geophysical Center of the Russian Academy of Sciences (GC RAS, Moscow, Russia); the WDC for meteorology, the WDC for oceanography, and the WDC for rockets and satellites and rotation of the Earth, which are supported by the All-Russian Scientific and Research Institute of Hydrometeorological Information — World Data Center (RIHMI-WDC, Obninsk, Russia), and the WDC for geoinformatics and sustainable development, which functions based on the Institute for Applied Systems Analysis (IASA) of the Ministry of Education and Science of Ukraine (MESU) and National Academy of Sciences of Ukraine (NASU) affiliated with the National Technical University of Ukraine “Kyiv Polytechnic Institute” (NTUU “KPI,” Kyiv, Ukraine) [3]. Figure 1 presents main research areas for which data are provided by the cluster, as well as the leaders of the centers.

## CREATION AND DEVELOPMENT OF THE WORLD DATA CENTER IN UKRAINE

As one of the largest Soviet republics with many outstanding scientific schools, Ukraine was involved in collecting global data as late as the first two WDCs were created (WDC A in the USA, Boulder; WDC B in the USSR, Moscow). Data were mainly gathered and prepared at specialized academic institutions all over the USSR and then were transmitted to the WDC B. After the break up of the USSR and occurrence of new countries in the 90s, Ukrainian scientists became isolated from the global scientific community since former partnership in scientific data exchange was broken and new relations were not established.

Ukraine is a young state; at its early years, it faced the challenge of mitigating the consequences of the Chernobyl disaster. Solving a wide variety of problems drawn the attention of scientists all over the world and gave rise to new approaches to predicting and modeling natural and industrial accidents and promoted the renewal of networks of scientific observations and scientific data collection.

By the decision of the Presidium of NASU, Ministry of Education and Science of Ukraine (MESU), and GC of the Russian Academy of Sciences of April 3, 2006, the Ukrainian branch of World Data Centers (UbWDC) (see Fig. 2) was created on the basis of the IASA NASU and MESU within the structure of the NTUU “KPI” as a branch of the Russian WDC for solar-terrestrial physics and the WDC for solid Earth physics (Moscow).

The interdisciplinary orientation of the IASA, own synthesized data (results of studies on sustainable development carried out by the staff), and plenty of scientific relations with scientific institutions in Ukraine and abroad were important reasons why it was the IASA where the UbWDC was created. Moreover, the NTUU “KPI” and IASA possess necessary resources (both technical and human) to provide long-term activity of the WDC.

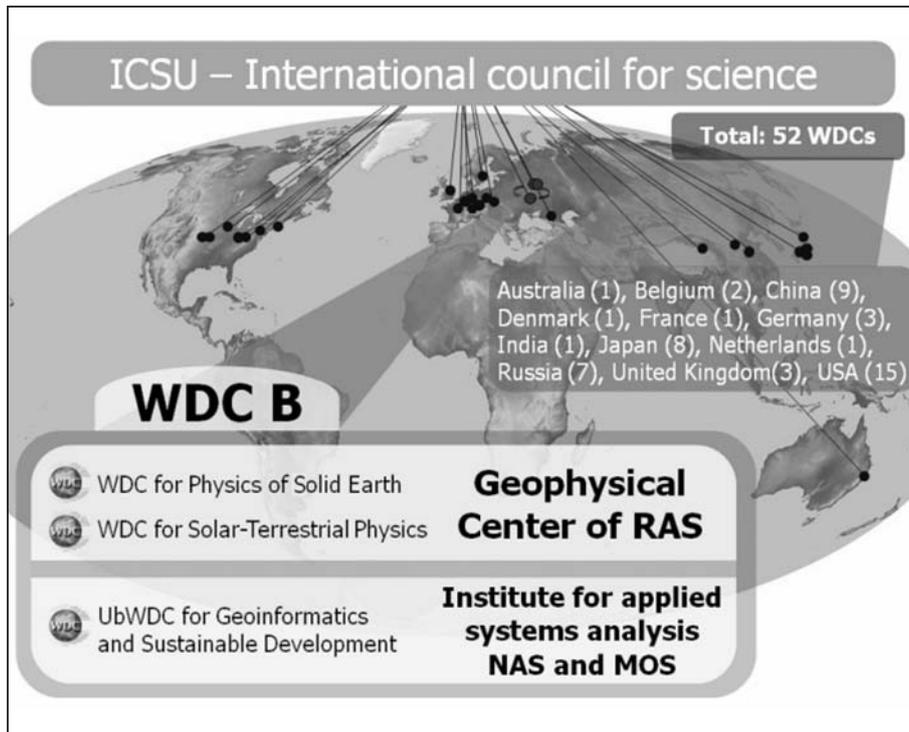


Fig. 2. Formation of the Ukrainian branch of the WDC.

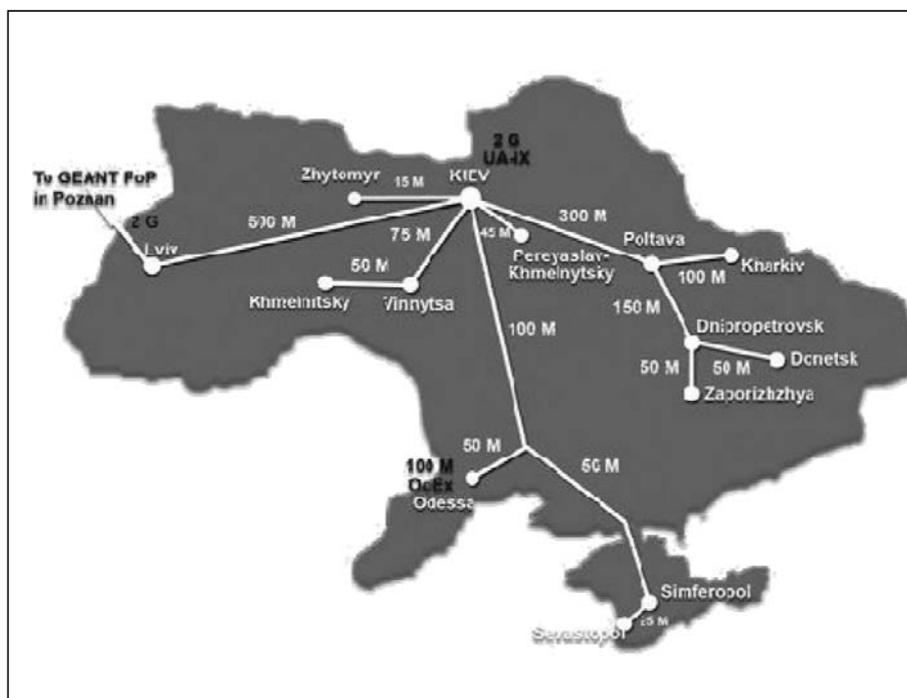


Fig. 3. Ukrainian Research and Academic Network.

The IT-orientation of the NTUU “KPI” became an important aspect of the WDC development. From the very beginning, it allowed organizing all the processes of acquisition, storage, and transmission of data to the WDC based on modern information technologies (IT).

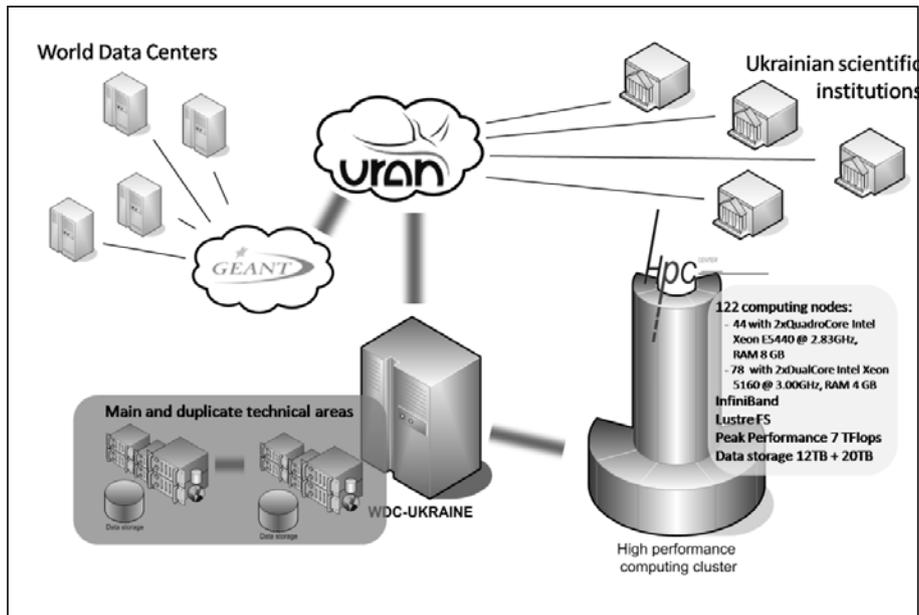


Fig. 4. Organizational structure of the WDC.

Noteworthy is that the NTUU “KPI” is a central node of the Ukrainian Research and Academic Network (URAN), which substantially reduces data transmission costs for the scientific institutions joined the network. Further connection of the URAN to the GEANT2 all-European network in 2007 opened up new possibilities in data exchange with scientific institutions in Europe and all over the world [4]. Figure 3 shows basic nodes of the URAN and throughput of channels.

Significant amount of data and modern mathematical models used to study global systems necessitate a new qualitative level of computing facilities. To this end, a computing center was created in the IASA together with the UbWDC; it provides the operation of a parallel computing cluster based on the Intel Xeon architecture with the performance of 7 TFlops and data storage based on the IPStore technology.

Figure 4 schematizes the general structure of the interaction of WDC links.

## WDC CERTIFICATION

In spring 2008, the UbWDC applied to the WDC system management to join to the system of World Data Centers as a full-fledged member. The certification procedure involved two stages.

According to the recommendations, the International Russian-Ukrainian seminar “Formation of a common geoinformation space to study topical Earth problems” was held on April 23-25, 2008, were technical maintenance of the WDC, prospects for its long-term stability, conformity to the standards and obligations of World Data Centers, etc. were discussed.

Representatives of academic institutions of the National Academy of Sciences of Ukraine (NASU) and Russian Academy of Sciences (RAS) took part in the seminar: A. G. Naumovets, Academician of NASU, Vice-President of NASU; M. Z. Zgurovsky, Academician of NASU, ICSU national scientific member from Ukraine, scientific supervisor of the WDC; V. I. Starostenko, Academician of NASU, Director of S. I. Subbotin Institute of Geophysics; E. E. Sovga, Scientific Secretary of the Marine Hydrophysical Institute of NASU; V. I. Lyal’ko, Corresponding Member of NASU, Director of the Scientific Center for Aerospace Research of the Earth; Ya. S. Yatskiv, Academician of NASU, Director of the Main Astronomical Observatory of NASU; Yu. G. Leonov, Academician of RAS, Academician Secretary of the Geosciences Department of RAS; A. O. Gliko, Academician of RAS, Director of the O. Schmidt Institute of Physics of the Earth of RAS; A. D. Gvishiani, Corresponding Member of RAS, Director of the Geophysical Center of RAS, and others.

Participants of the seminar concluded that the first stage of UbWDC assessment, i.e., the assessment by the national scientific community, was completed successfully. It was recommended to hold the final stage of UbWDC certification as the World Data Center for geoinformatics and sustainable development (WDC-Ukraine) on October 5–8, 2008 at the CODATA-2008 conference.

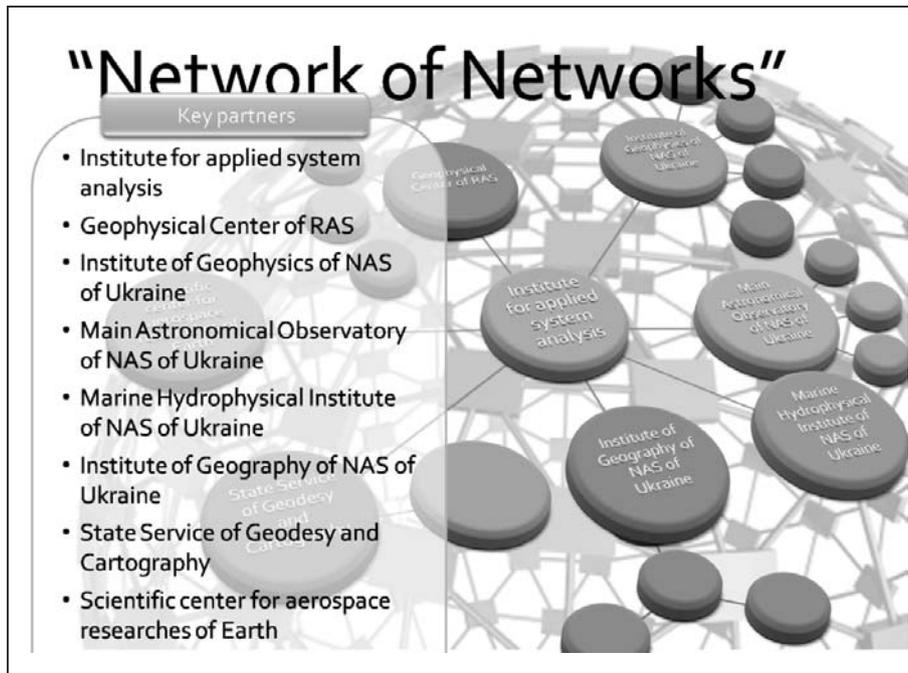


Fig. 5. WDC Network model.

During the CODATA-2008 conference, the Ukrainian branch of the WDC was presented at the special session “Emerging Technologies and Opportunities for Global Data Management and Exchange” under the chairmanship of Prof. Jean-Bernard Minster, a co-chairman of the Transition Committee of the World Data System. Heads of the largest World Data Centers and representatives of the WDS Transition Committee took part in the session. As a result of discussions, it was decided that UbWDC would join the World Data System created at that time as the World Data Center for geoinformatics and sustainable development (<http://wdc.org.ua>) [2].

## WDC NETWORK MODEL

As a rule, World Data Centers have a strongly pronounced disciplinary orientation. The reason is that one of the key functions regulated by the Guide to the WDC System is providing information support for archives and databases; creating and updating inventory catalogues; forming metadata, and providing necessary consultations to end users [5], which is possible only if a WDC has experts in appropriate scientific fields.

The World Data Center in Ukraine should afford access to global information resources of the ICSU on Earth sciences, planetary and space physics, and related subjects for the Ukrainian scientific community and to provide acquisition and storage of national scientific data on the above disciplines and their presentation to the world community. The WDC-Ukraine has also to collect, process, and analyze world data necessary for studies in the field of sustainable development.

Along with the above tasks, the following problems were formulated for the WDC for geoinformatics and sustainable development:

- organizing an efficient information acquisition system;
- searching for data sources;
- establishing contractual relationships with national and world data providers;
- developing direct data acquisition subsystems;
- providing a convenient access for users:
  - creating and supporting a web portal with online access and data search (<http://wdc.org.ua>);
  - providing a multilingual data access interface;
  - design and development of databases;
  - design and development of additional software for convenient data handling.

A deep study of World Data Centers in other countries, the interdisciplinary orientation of the IASA, and system approach have allowed proposing a unique (for the World Data System) network model of functioning of the WDC-Ukraine as a unified interdisciplinary national data center. According to this model, each research area is supervised by one or several scientific organizations of the National Academy of Sciences of Ukraine (Fig. 5). Here are some of them:

- Institute for Applied Systems Analysis NASU and MESU (system coordination of interdisciplinary data, sustainable development);
- S. I. Subbotin Institute of Geophysics NASU (data on seismology, gravimetry, heat flow, archeo- and paleomagnetism, and magnetic measurements);
- Scientific Center for Aerospace Research of the Earth, Institute of Geosciences NASU (aerospace pictures to be used in geology, ecology, agriculture, forestry, and water industry, to predict risks of natural and technogenic processes, global environmental changes, and catastrophic processes);
- Main Astronomical Observatory NASU (space geodesy and geodynamics; cosmic rays);
- Marine Hydrophysical Institute NASU (oceanology and hydrometeorology);
- Institute of Geography NASU (cartography).

The network model was first presented on October 7, 2009 at the special WDC session “Emerging Technologies and Opportunities for Global Data Management and Exchange” within the framework of the CODATA-2008 conference (October 5–8, 2008, Kyiv, Ukraine), where it was approved and conventionally called “Network of networks” [6]. At the session of WDS Scientific Committee on October 13–14, 2009 in Paris, this model was taken as a sample for other WDCs.

In Ukraine, such an approach, on the one hand, allows efficient use of the technological capabilities of the URAN network and the high-performance computing cluster of the NTUU “KPI,” and on the other hand, focusing of the efforts of the WDC staff on solving interdisciplinary system problems important for all the WDC partners.

One of such problems is global modeling of the processes of sustainable development within the context of the quality and safety of life to obtain a set of indices and indicators of sustainable development for complex systems of different levels. Such a modeling enables monitoring the development of the world and individual states and regions, developing scenarios, and formulating recommendations for decision-makers. Studies in this field require a significant amount of diverse data that mostly pertain to geoinformatics [7, 8].

Taking into account wide experience and analysis results obtained by the IASA (the base institution for the WDC-Ukraine) in the field of sustainable development, the WDC Scientific Committee has charged the World Data Center for geoinformatics and sustainable development with preparing annual reports based on the results of global modeling of processes of sustainable development in the context of the quality and safety of life.

## JOINT PROJECTS

The World Data Center for geoinformatics and sustainable development participates in solving a number of problems of the State target program “Information and communication technologies in education and science” for 2006-2010. The WDC-Ukraine also integrates the software and hardware of partners into a unified information infrastructure whose core will be the distributed information system being developed to exchange, process, and store scientific information. This will provide access to any available sources of information irrespective of the type of data, storage medium, or equipment.

Such a modular system based on open standards has ample opportunities to integrate with information resources of the WDS. An example may be the software developed within the framework of the joint Russian-Ukrainian project “Development of a network of World Data Centers to study the fundamentals of global modeling of complex natural and anthropogenous systems” [9].

The WDC for geoinformatics and sustainable development together with its partners have launched a number of projects and obtained certain results. The Center cooperated with the following institutions:

- International Council for Science: CODATA-2008 conference (<http://codata08.org.ua>).
- IASA NASU and MESU: analyzing processes of sustainable development in the global and regional contexts; developing methods of artificial intelligence to analyze interdisciplinary data.
- Geophysical Center RAS: joint grant of the Russian Foundation for Basic Research and NASU “Development of a complex of databases and processing algorithms for a system prediction of the behavior of complex anthropogenous and natural systems;” joint grant of the Russian Foundation for Basic Research and the State Fund of Basic Research of Ukraine “Development of a network of World Data Centers to study the fundamentals of the global modeling of complex natural and

anthropogenous systems;” creation of the GIS “Russia–Ukraine;” participation in the EGY (Electronic Geophysical Year) project; additional training of experts from the WDC in the GC RAS.

— S. I. Subbotin Institute of Geophysics NASU: completing the first stage of introducing a computer-aided system of storing geophysical data with partial publication of seismological data; developing recommendations to upgrade seismological data transmission and storage systems; developing the Intermagnet network in Ukraine; developing a computerized national seismological network for information transmission and processing.

— Scientific Center for Aerospace Reserches of the Earth, Institute of Geosciences NASU: creating a set of models to solve thematic problems of remote sounding of the Earth to be implemented based on the computing facilities of the WDC.

— Institute of Geography NASU: developing (with the use of WDC technical facilities) and supporting the electronic version of the National atlas of Ukraine (2008, chief developers: Institute of Geography NASU and LLC “Intellectual’nye Sistemy (Intelligent systems)–GEO”), creating a joint scientific and training laboratory of spatial (geographical) databases and using geoinformation systems.

## SERVICES PROVIDED

The information and data are prepared and published on the specialized web portal <http://wdc.org.ua>, which provides users from any country with real-time full and open (free and unlimited) access to the services.

Let us dwell on some services provided at the WDC-Ukraine portal.

**SPIDR.** The Space Physics Interactive Data Resource is designed to allow a solar terrestrial physics customer to intelligently access and manage historical space physics data for integration with environment models and space weather forecasts (<http://wdc.org.ua/spidr/>). SPIDR is a distributed network of synchronous databases and 100% Java middle-ware servers accessed via the World Wide Web. By enabling easy data mirroring and eliminating the network bottlenecks associated with transcontinental links, the distributed system architecture is a key factor for low latency in multimedia data visualization and fast data delivery.

**National Atlas of Ukraine.** The full electronic version of the National Atlas of Ukraine was issued on DVD in Ukrainian with a run of 5000 copies. It contains 875 maps in the following sections:

- general characteristics (38 maps);
- history (79 maps);
- natural environment and natural resources (320 maps);
- population (181 maps);
- economy (181 maps);
- ecological state of the environment (76 maps).

The maps in the “Population” and “Economy” sections are prepared in isgeoMap vector format, the other sections in Adobe Flash format.

**World Data System Activity.** The World Data System Activity is an information system that contains a classifier of electronic resources of the World Data System, provides monitoring, statistics gathering, and visualization of the current state of electronic resources of the WDC, and provides interactive access to the information about each World Data Center (<http://activity.wdc.org.ua>). An important feature of the system is its modularity and possible integration with resources of other WDCs irrespective of the technologies they use.

**Expanded System of Publishing the Results of Modeling Processes of Sustainable Development.** The system provides a convenient and open interface for public access to the data on sustainable development. The user not only can obtain data on individual countries or regions but also can compare them in a tabular and visual form, which is rather convenient for the analysis.

All the functions are implemented as a web page and are available at any time (<http://wdc.org.ua/node/389>, <http://wdc.org.ua/node/396>). As an example, Fig. 6 shows the sustainable development profile of Ukraine plotted based on the results of modeling the sustainable development of world’s countries in 2009.

**WDSearch System.** The WDSearch system (<http://search.wdc.org.ua>) is designed for efficient information and data search in the network of World Data Centers and electronic resources of the institutions of NASU and RAS. The key advantages of the system are the quality (only scientific data and information are indexed); purposefulness (search on individual research areas); relevance of the information and data (high updating rate of search index); search in files (all popular file formats are indexed: pdf, ppt, doc, xls, xml, rtf, txt, etc.).

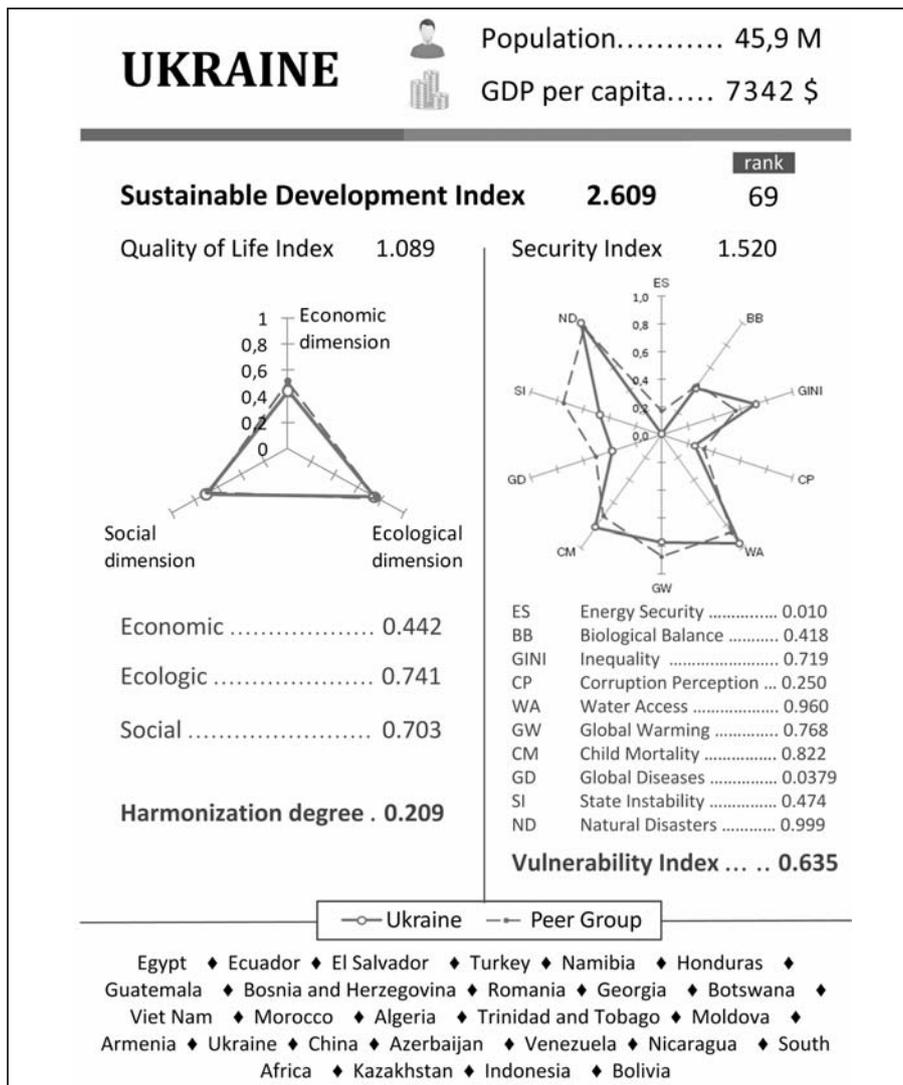


Fig. 6. Sustainable development profile of Ukraine (modeling of 2009).

## CONCLUSIONS

Creation of the World Data Center in Ukraine not only makes global data available for Ukrainian researchers but also substantially stimulates the integration of the Ukrainian science into global science.

It is still of priority to unify data transmission protocols and formats, organize the quality assurance of scientific data and information, to create data processing and granting services, and to organize a common information space for the Russian-Ukrainian segment of the World Data System and a network of partners of the World Data Center for geoinformatics and sustainable development.

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