Sergey N. Bobylev[1], Olga Yu.Chereshnya[1], Markku Kulmala[2], Hanna K. Lappalainen[3,4,5], Tuukka Petäjä[3,5], Svetlana V. Solov'eva[1], Vladimir S. Tikunov[1*], Veli-Pekka Tynkkynen[6]

[1] Moscow State University, Russia

[2] Institute for Atmospheric and Earth System Research, University of Helsinki, Helsinki, Finland

[3] University of Helsinki, Finland

[4] Finnish meteorological Institute, Finland

[5] Tuymen State University, Russia

[6] Aleksanteri Institute, Department of Social Research, University of Helsinki, Helsinki, Finland

[*] **Corresponding author:** vstikunov@yandex.ru

INDICATORS FOR DIGITALIZATION OF SUSTAINABLE DEVELOPMENT GOALS IN PEEX PROGRAM

ABSTRACT. This article describes the Pan-Eurasian Experiment (PEEX) program and indicators for monitoring of implementation and digitalization of Sustainable Development Goals (SDG) in Russia, especially environmental goals. The authors considered the possibility of integration and identification of the methodological approaches of the socio-economic research to environmental sciences. Paper gives insights into the international framework of the United nations, addreses several relevant indicators to be monitored in a Russian perspective and summarizes shortly the status of the monitoring activities and provide an overview on the main tasks for the upcoming years to reach the sustainable development goals established by the United Nations. The tasks to which the Goals divided are considered in detail. The indicators of Russian statistics that can be used to monitor the implementation of these tasks are determined. It is shown, that more detailed regional analysis and new data is needed in order to quantify the feedbackloops.

KEY WORDS: sustainable development goals, Pan Eurasian Experiment, digitization

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INTRODUCTION

The Pan-Eurasian Experiment (PEEX) program, initiated in 2012, is motivated by the environmental Grand Challenges for the Arctic – boreal regions. The program is especially designed for practical solutions in the field of climate change and air quality (Kulmala, 2015, Kulmala et al. 2015, 2016, Lappalainen et al. 2014, 2016). The research agenda addresses the complexity of the different types of feedbacks between land atmosphere – ocean and society interfaces and continuum (Lappalainen et al. 2016).

At the moment, the main focus of the research program is on quantifying the so-called COntinental Biosphere-Aerosol-Cloud-Climate (COBACC) feedback hypothesis relevant to the changing climate of the Northern Eurasian boreal (taiga) forest regions. The COBACC has two major overlapping loops (Kulmala et al. 2013) boosted by the increased atmospheric CO_2 levels and air temperature. The increased CO_2 and temperature effects ecosystem gross primary production (GPP), increase the amount of emitted biogenic volatile organic compounds (BVOC) and consequently increases the secondary organic aerosol (SOA) formation. The SOA formation contributes increase the share of diffuse solar radiation and number concentration of cloud condensation nuclei in the atmosphere and increase further the cloud droplet number concentration. The increasing CO_2 and consequent increase in average temperature is influenced by the anthropogenic activities and emissions. The COBACC feedback loop suppresses global warming. It can provide a broad framework to connect the human activities, continental biosphere, and changing climate conditions (Kulmala et al. 2014).

The near-future challenge in implementing the PEEX research agenda is to achieve a successful integration and identification of the methodological approaches of the socio-economic research to environmental sciences (Lappalainen et al. 2015). The first step in this task is to establish a researchers' network in the field of natural sciences and socio-economic sciences and initiate research collaboration between socio-economics and environmental sciences. Here we give insights into the international framework of the United Nations, address several relevant indicators to be monitored in a Russian perspectives and summarize shortly the status of the monitoring activities and provide an overview on the main tasks for the upcoming years to reach the sustainable development goals established by the United Nations.

International frameworks and the sustainable development challenge

The society as a whole need to respond to and cope with the interconnected Grand Challenges. In September 2015, the General Assembly of United Nations adopted the 2030 Agenda for Sustainable Development. This agenda includes 17 Sustainable Development Goals (SDGs) that emphasizes a holistic approach to achieving sustainable development for all. At present, it is clear that comprehensive data in a digital form is the key factor to gauge the socio-economic development in a sustainable manner and taking into account the state of the environment. Digitization of various directions of socio-eco-economic transformations is one of the most important tasks for the transition of the world society towards sustainable development. The concept of sustainable development in recent decades has become widespread as a basic approach to assessing the prospects for the development of society and the state of the environment, as well as the effectiveness of resource management. It is a paradigm of the development of mankind in the 21st century. This approach is clearly constituted in the UN conceptual documents of recent years. Since 2015, there has been a sharp increase in theoretical and practical interest in the measurement of sustainability, which was largely due to the decisions of the United Nations Conference in September 2015, at which the Sustainable Development Goals (SDGs) (Table 1) were adopted for the period 2016-2030. The document is supported by all countries. Along with the formulation of the Goals themselves, relevant tasks and quantitative indicators were proposed. In fact, the process of sustainable development is being digitized, which allows us to monitor and correct them. All UN members intend to develop their own SDGs systems.

Currently, the environmental statistics relevant to SDGs have the largest number of gaps compared to the other social and economic statistics. This situation is observed all over the world. This is explained by quite understandable problems: the colossal complexity of natural interrelations; the difficulty of complete assessing the consequences of the anthropogenic impact on the environment; the challenge of modern science in digitization and adequate quantitative reflection of natural patterns; high costs of obtaining the vast majority of environmental indicators. In this regard, great opportunities are provided by scientific and technological progress, radical technological changes in the field of monitoring the state of the environment, the development of the most complex models reflecting natural transformations. As an example, the European Commission has made significant investment on developing the European

Table 1. Sustainable development goals (SDG) adopted in the United Nations 2030 agenda for sustainable development

Sustainable Development Goals	
Goal 1.	End poverty in all its forms everywhere
Goal 2.	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3.	Ensure healthy lives and promote well-being for all at all ages
Goal 4.	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5.	Achieve gender equality and empower all women and girls
Goal 6.	Ensure availability and sustainable management of water and sanitation for all
Goal 7.	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8.	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9.	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10.	Reduce inequality within and among countries
Goal 11.	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12.	Ensure sustainable consumption and production patterns
Goal 13.	Take urgent action to combat climate change and its impacts
Goal 14.	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15.	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16.	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17.	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

environmental research infrastructures and established "The European Strategy Forum on Research Infrastructures" (ESFRI) in 2002. The ESFRI has a key role in policy-making on research infrastructures in Europe. The European Commission and ESFRI encourage Member States and Associated Countries to develop national roadmaps for research infrastructures (RIs). These roadmaps are vital blueprints which enable countries to set national priorities and to earmark funds for both national and pan-European RIs (ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri). The ICOS (Integrated Carbon Observation System), ACTRIS (European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases) and LTER (Long-Term Ecosystem Research) are the most relevant European infrastructures for the PEEX Program. PEEX has also promoted the environmental monitoring system based on SMEAR (Stations Measuring the Earth Surface – Atmosphere Relations, Kulmala, 2018) which integrates ICOS, ACTIS and LTER measurement concepts and data formats.

Part of the data relevant to the UN sustainable development goals will have to be obtained from alternative in addition to the official statistics system, in particular, based on scientific research and observations. However, it should be borne in mind that the use of alternative sources presents certain problems, since the data may not be of sufficient quality, and the source of information may be unstable. In this regard, it is necessary to use more big data, as well as geospatial, satellite, GIS data. In addition to expanding the array of environmental data, it is necessary to integrate them with the data of the Digital Economy and the Digital Society. Economic and social development data pools needs to connect to the environmental data analysis, in particular, with such fundamental and complex natural processes as climate change, loss and degradation of ecosystems and their services, etc. The Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences (RADI/CAS) has been actively launching the new Digital Belt and Road (DBAR) Program, which could be focusing on the monitoring of environmental change including urbanization in the Belt and Road region. In addition to data analysis based on multidisplinary data pools the facilitating the collaboration between science and government decision-making, DBAR could also enhance scientific practice for environmental change in the Belt and Road region, the transport corridors and their footprint areas across the Eurasian regions.

Russian perspectives and the UN Sustainable Development Goals (SDGs)

Specialized hydrometeorological support is one of the most important activities in the effective use of information resources for the digitization of environmental monitoring. Potential and prospects for digitalization can be illustrated by the example of the activity of such a structure as Rosgidromet, which provides a significant part of environmental information for the Russian economy and society based on the environmental monitoring. At present, Russia incurs significant economic losses from hazardous natural phenomena. Only in 2015, 973 such phenomena were recorded on the territory of the country, of which 412 caused significant damage; 140 of them were observed in the waters of the seas in the areas of responsibility of the Russian Federation. (Roshydromet, 2016) There was a clear trend of a rapid increase in the number of dangerous phenomena which lead to various significant socio-economic damage - an average increase of 7-8% per year. In general, the annual damage from hazardous phenomena is estimated by a huge amount of 0.5-1% of the Russian GDP.

In this regard, the timely submission of the hydrometeorological information together with comprehensive data on the status of the environment e.g. via SMEAR observation concept in a timely manner and to the extent it provides significant benefits to society and a wide range of economic sectors and activities. According to the estimates of the Administration of Hydrometeorological Service in 2015, the economic effect of using such information amounted to 32.8 billion rubles. (State report..., 2016.) The bulk of the overall economic effect (70%) accounts for two types of economic activity: «Production and distribution of electricity, gas and water» and «Transport and communications.»

The modern monitoring network allows obtaining large data sets for three natural environments: air, water resources of the land and the shelves of the seas. Observations of atmospheric air pollution are carried out by Roshydromet at 636 posts in 229 cities. Observations of surface waters of the land are carried out at 1725 stations for hydrochemical indicators and at 263 points for hydrobiological indicators. Observations of the marine environment by hydrochemical indicators are carried out at 292 stations in the shelf regions of Russia. At 1,266 stations, radioactive contamination of the environment is monitoring.
Achievements in the relevant fields related to environmental protection are of great importance from the point of view of forming the infrastructure of the digitalization of society and economy, scientific and technological achievements in the relevant fields related to environmental protection are of great importance. Based on these achievements in the Roshydromet system, only 145 patents or certificates of registration of intellectual property objects were received in Rospatent in 2015 (including 10 inventions, 3 utility models, 27 for databases, 105 for software).

Space monitoring and interaction with foreign partners is of particular importance today. Now the state territorially distributed space monitoring system of Roshydromet in the European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk) centres of FGBU «Research Center» Planeta «, acting as a unified information system, regularly received and processed data from 17 foreign and 7 domestic remote-sensing satellites. The satellite remote sensing observation capacity should be matched with a network of ground-based observation sites that provide the ground-truth and calibration services for the remote sensed data.

As an example of important environmental indicators for the digital economy and society, consider possible indicators for some SDGs and their environmental goals, based on available official Russian statistics and research, mainly on Roshydromet data. Table 2 highlights four such goals (SDGs № 11, 13, 14, 15) related to the formation of sustainable cities, combating climate change, preserving ocean and marine resources, and terrestrial ecosystems. We will use the approach of highlighting key indicators (key/core indicators).

At SDG № 11 about the formation of sustainable cities, the important task is to reduce the environmental impact on urban residents. According to medical experts, particulates with a diameter less than 10 and 2.5 microns (PM10 and PM2.5) represent one of the main threats to public health as a result of environmental pollution. Currently, in Russia, correct estimates for this indicator are available only in Moscow - 39 μg/m3, which is an average for the world's cities. For comparison, the maximum PM10 concentrations in the world megacities were recorded in Beijing - 116 $\mu g/m^3$, Istanbul - 51 $\mu g/m^3$, Mexico - 44 $\mu g/m^3$ and Hong Kong - 44.5 $\mu g/m^3$. The minimum indicators for PM10 are fixed in the following European capitals: Stockholm -19 $\mu g/m^3$, Paris - 21 $\mu g/m^3$ and London - 22 $\mu g/m^3$.

However, to address the sustainable development goals in a more detailed level, the monitoring of air quality and health effects should be developed with a comprehensive approach (e.g. Kulmala, 2015) as the negative health effects are not only limited to the aerosol mass concentration. Specifically, aerosol number concentration in the ultra-fine size range (below 100 nm in diameter) has been identified to be even more harmful (e.g. Kim et al. 2015) than the larger PM2.5 particles that typically do not penetrate deep into the lungs or the blood circulation (Hussein et al. 2013). The long-term observations should be incorporated as part of a measurement network (Hari et al. 2016) and operated in connection with detailed emission analysis frameworks (Crippa et al. 2015).

SDG № 11 includes also social and cultural aspects of sustainability, therefore data on particle emissions is able to tell only a limited story how inclusive and resilient society is. Thus, it is better to add indicators on social cohesion and equity issues vis-à-vis the environmental change, for example, differences in socio-economic wellbeing between groups of people; the divide between the very rich and very poor; distribution of health problems caused by the environmental change among the population. A resilient society is such where the effects of environmental problems do not disproportionally burden people in a lesser socio-economic position. These groups protected from the environmental problems caused by economic activities that are benefitting well-off groups.

SDG № 13 is aimed at providing measures to combat global climate change (IPCC, 2013). For Russia, climate issues are becoming more relevant as awareness of significant negative consequences increases (e.g. Schuur et al. 2015). This is largely due to the increase in the number of natural disasters and dangerous natural phenomena. Climatic changes occur much faster than in the Arctic countries of the world: taking into account the data for 2016, the average annual temperature in the territory of the Russian Federation is growing more than 2.5 times faster than the global temperature, at a rate of 0.43 ° C during the last 10 years. Especially rapid growth is observed in the polar region, where the growth rate reaches 0.8C for 10 years. (Revich, 2011). In the future, as a result of warming, the risks associated with economic and social objects located in the permafrost zone (which is spread over two-thirds of the Russian territory) sharply increase. According to World Bank experts (2009), Russia can become the most vulnerable country in Eastern Europe and Central Asia in the process of global climate change. In several decades, the total damage from climate change for the Russian economy could reach $ 10 billion, which will be caused by an increase in the number of natural disasters and disasters on its territory. The country's territory is located in different climatic zones, therefore the list of hydrometeorological phenomena causing natural disasters in its regions is very large. The greater part of the country needs, to one degree or another, protection against dangerous natural phenomena. The melting of permafrost can lead to catastrophes in the energy sector, infrastructure, settlements. In the zone of potential climate, problems are the main objects of the energy sector and productive agricultural regions.

In climatic goal № 13, there are two important tasks (Table 2) for national sustainable development policies. For the first task, the key indicator is the number of people affected by natural disasters. Unfortunately, Russia does not have comprehensive statistics on the number of such victims. Nevertheless, the number of them is undoubtedly great. This is evidenced by medical studies that determined the additional mortality in the country as a result of anomalous heat waves in the summer of 2010. This year, a prolonged wave of heat in 2010 led to 58 thousand additional deaths among 60 million people

Table 2. Selected indicators in the environmental objectives of sustainable development

Sustainable Development Goals	Task	Indicator	Value
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.6. By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	11.6.2. Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)	Data only for Moscow - 39µg/m3

Goal 13. Take urgent action to combat climate change and its impacts	13.1. increase resistance and adaptability to dangerous climate events and natural disasters in all countries;	13.1.2. Number of deaths, missing persons and persons affected by disaster per 100,000 people	**additional deaths caused by climatic disaster 96,7 (prolonged wave of heat in 2010 year)**
	13.2 Integrate climate change measures into national policies, strategies and planning	**13.2.1 Integrated policy/strategy/plan which increases countries' ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production 13.2.(+). Greenhouse gas emissions and its trend**	2651,2 million tons of CO2-equivalent in Russia
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1. By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	14.1.1. basic substances that pollute marine ecosystems (proposed by the authors for Russia in connection with the availability of Roshydromet data on marine pollution)	- petroleum hydrocarbons - pesticides - biogenic substances - heavy metals
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.1. By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.1. Forest area as a proportion of total land area 15.1.(+) Share of protected areas	47% of Russia 12% of Russia (208 mln.ha)

in the European region of Russia. (Revich, 2011) This phenomenon was 'natural', but the estimate is that such occasions will become more frequent as the climate changes. As an indicator for SDG № 13 per 100 thousand of the population, this will amount to 96.7 people. (Table 2). Overall, the indicators for the development of climate relevant parameters (such as greenhouse gas and aerosol concentrations) should be incorporated with the comprehensive observation networks along with the meteorological variables.

For the second task, incorporate climate change response measures into national policies, strategies, and planning, the authors propose an indicator of greenhouse gas emissions. The emission trend, would be much more informative, showing are Russia's emissions increasing or falling. In comparison with 1990, the aggregate greenhouse gas emissions decreased by 45.8%, taking into account the absorbing capacity of ecosystems, and by 30% - without taking into account the volume of absorption. As of the end of 2015, the emissions amounted to 2132.5 million tons of CO_2-eq, respectively, and 2,651 million tons of CO_2- equivalent. (Table 3).

The SDG№ 14 on the conservation of oceans and seas for sustainable development is difficult for quantitative identification of indicators. Nevertheless, the potential for providing the necessary data is available. Information hydrometeorological support of oceanic and marine activities in Russia is carried out with the help of the Unified System for the World Ocean (ESIMO). In the activity of ESIMO, 31 organizations of twelve ministries and departments of Russia, as well as a number of commercial organizations. Automated workstations for ESIMO users are supported in 24 regional offices of the Ministry of Emergency Situations of Russia, the State Marine Emergency and Rescue Coordination Service of the Russian Federation, the Ministry of Transport of the Russian Federation, the Situation Centers of the Ministry of Emergencies of Russia, the Ministry of Natural Resources of Russia, Roshydromet, the Department of Shipbuilding Industry and Marine Equipment, and Roskosmos. ESIMO is actively using spatial data and services to assess the situation in the seas of Russia and the World Ocean based on the widespread use of GIS technologies. The electronic sea atlas ESIMO contains more than 6000 information layers with data in the field of hydrometeorology, physics of the sea, pollution of the marine environment, marine geology, geophysics and others. The total amount of information resources ESIMO is more than 15 terabytes. About 30% of the resources are updated from a few minutes to a day.

As indicators for SDG № 14, the data on which provides Russian statistics, there are four: oil carbohydrates, pesticides, nutrients, heavy metals (Table 2). In general, in coastal marine areas, the quality of seawater changed from «clean» to «moderately polluted». Almost everywhere reduction of oil hydrocarbons and pesticides was noted. Priority pollutants

Table 3. Greenhouse gas emissions in Russia (Bulletin Main indicators of environmental protection, Rosstat 2017)

	1990	2011	2012	2013	2014	2015
Total Incl.:	**3363,32**	**2284,29**	**2295,05**	**2643,1**	**2648,9**	**2651,2**
carbondioxide (CO_2)	2505.36	1648.13	1656.77	1666.6	1671.6	1670.8
methane (CH_4)	593.40	506.76	502.55	856.6	859.1	864.1
nitrousoxide (N_2O)	223.27	116.95	115.95	89.9	90.2	90.4
hydrofluorocarbons (HFC)	28.41	9.41	11.34	21.5	24.1	21.2
perfluorocarbons (PFC)	11.68	2.54	2.47	3.4	3.1	3.6
sulfurhexafluoride (SF_6)	1.20	0.51	5.97	4.9	0.8	1.1

in the bottom surface layers are biogenic substances and heavy metals, their content is lower or at the level of MPC. The dirtiest sea water in the Russian shelf is the sea in the north of the Caspian Sea. The long-term observational capacity should be extended to uptake of greenhouse gases to the ecosystems via photosynthesis and emission inventories should be obtained for the utilization of gas and oil, including black carbon emissions due to flaring. The problem thus far has been that overall emissions trends in the Russian hydrocarbon industry have not been either known or are not accurate. It is well known than thousands of smaller oil spills take place in production and pipelines. The estimates range from one to five per cent of production, that is a minimum of 5 million tonnes of oil spilled to the environment. Here, satellite data, big data and other data using versatile methods should be applied to unfold real volumes of spilled oil.

SDG № 15 is related to the conservation of terrestrial ecosystems. Within the framework of this Goal, for task 15.1, the specific weight of the area covered by forests in the total area (indicator 15.1.1 in Table 2) is the main indicator. The terrestrial ecosystems can provide adaptation processes by greenhouse gas uptake and secondary biogenic aerosol production (Kulmala et al. 2014). The observational facility should be able to determine these feedback mechanisms and provide insights into their optimization. A fairly simple indicator is related, nevertheless, with the need to implement high-quality monitoring, satellite observations, a large-scale monitoring network. In particular, this is due to significant fluctuations in some areas of forest area as a result of fires, pest damage, mass felling, including illegal, etc. Sometimes, for example, large areas of forest fires can differ several times according to ground and satellite observations. Now the proportion of forests in the country is 47% (these data differ from some international databases, in particular, FAO and the World Bank). (State report ..., 2016.) More forests only in Brazil - 58%. In general, ten countries with the largest forest potential account for about 67% of the world's forests. Russia's share is leading on the planet - 20% of the total forest area; Brazil's share is 12%, Canada - 9, the United States - 8, China - 5%. Much more interesting figures would be the ones depicting how the quality of Russia's ecosystems is changing, for the better or for worse and what is the share of original, untouched ecosystems in Russia. For this purpose, can be used indicator of the share of protected areas. The share of protected areas of federal, regional and local significance without marine areas amounted in 2015 to 12% of the country's territory, 208.6 million hectares. This indicator has some deficiencies. For example, regional proportions of adequate protected territories size are different due to a large spectrum of ecosystem patterns in Russia; many protected areas in industrial regions are situated within impact zones and their ecosystems experience anthropogenic transformation. But now it is the most approximate indicators from the available statistics.

CONCLUSION

In order to meet the UN Sustainable Development Goals (SDGs) in, which are also integral aspects, especially the SDGs No 11, 13, 15, 17, of the PEEX program we a roadmap for strengthening the Russian contribution to international frameworks. The resent analysis and statics of the SDG relevant indicator in Russia demonstrates the economic losses from hazardous natural phenomena and the state of the greenhouse gas emission in general. More detailed reagional analysis and new data is needed in order to quantify the feedbackloops such as COBACC.

The PEEX program provides a platform for coordinating the socio-economic research with the natural sceinces in Russia and to analyze and quantify the feedbacks between anthropogenic and other society (human) activites and alnd – atmospheric – ocean systems. Roshydromet is significant player in providing the atmospheric and hydrologiocal observations in Russia, Furthermore, the Roshydemet coordinates and facilitates a significant research infrastructure (in situ observation network). This is addressing great synergy between

Roshyderomet and PEEX Program.

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Vladimir S. Tikunov is Professor, D.Sc. in Geography, Head of the Integrated Mapping Laboratory, MSU Faculty of Geography, and Director of the Center of the World Data System for Geography. He is Professor Emeritus of the Lomonosov Moscow State University. He lectured at a number of national and international universities. He has led a number of Russian and international projects. His work has been used in many thematic maps and atlases: National Atlas of Russia (Editor-in-Chief of Vol. 3), National Atlas of the Arctic, Environmental Atlas of Russia, Atlas of Socio-Economic Development of Russia, Atlas of the Khanty-Mansi Autonomous District – Yugra, etc. He is a recipient of the D.N. Anuchin Award for his work in mathematical cartographic modeling. He is also a recipient of the Award in Science and Technology of the Russian Federation Government for the development of environmental and natural-resources atlases of Russia. He was Vice-President and, currently, is Chairman of the Commission on GI for Sustainability of the International Cartographic Association. He has been a member of the editorial boards of 14 Russian and international journals. Since 1994 he has been organizing annual international conferences InterCarto-InterGIS that take place both in Russia and abroad. He published over 500 scientific works, including 21 monographs, textbooks, and manuals in 28 countries of the world and in 14 languages.