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Enviro-RISKS:

Man-induced Environmental Risks: Monitoring, Management and Remediation of Man-made Changes in Siberia

Alexander Baklanov and Evgeny Gordov, Editors

Volume 5: Information Systems, Integration and Synthesis

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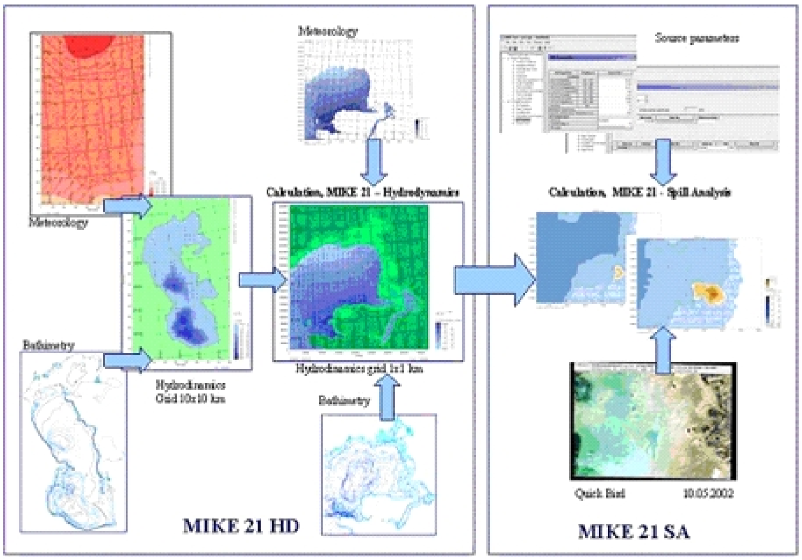

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Enviro-RISKS Report Content:

Executive Summary

Enviro-RISKS Project and its Major Outputs *(in a separate Volume1: www.dmi.dk/dmi/sr08-05-1.pdf)*

Thematic Focus 1: Atmospheric Pollution and Risk *(in a separate Volume 2: www.dmi.dk/dmi/sr08-05-2.pdf)*

Thematic Focus 2: Climate/Global Change and Risks *(in a separate Volume 3: www.dmi.dk/dmi/sr08-05-3.pdf)*

Thematic Focus 3: Terrestrial Ecosystems and Hydrology and Risks *(in a separate Volume 4: www.dmi.dk/dmi/sr08-05-4.pdf)*

Thematic Focus 4: Information Systems, Integration and Synthesis *(in this Volume 5)*

EXECUTIVE SUMMARY

Siberia environment has been subjected to serious man-made transformations during last 50 years. Current regional level environmental risks are: direct damages to environment caused by accidents in process of petroleum/gas production and transporting including their influence on water, soil, vegetation and animals; caused by deforestation (legal and illegal cutting and forest fires) variations in Siberian rivers runoffs and wetland regimes; direct and indirect influence of forest fires, flambeau lights and losses of gas and petroleum during their transportation on regional atmosphere composition; deposition of hazardous species leading to risks to soil, water and consequently to risks in the food chain.

In this Final Report, published in five separate Volumes, the major Enviro-RISKS project (http://project.risks.scert.ru/) outcomes are summarized. They include the state of the art of environmental RTD activity in Siberia, suggested methodology and recommendations on future environmental research in Siberia. These outcomes are based on results obtained by the four Thematic Expert Groups in process of preparation of Thematic Focuses Reports.
Three Thematic Focuses/Groups consider major risks inherent to Siberia environment. These groups (with their leaders) are the following:

1. **Atmospheric Pollution and Risks** (Alexander Baklanov (DMI) and Vladimir Penenko (ICMMG)),
2. **Climate/Global Change and Risks** (Martin Heimann (MPI for Biogeochemistry) and Vasily Lykosov (INM)), and
3. **Terrestrial Ecosystems and Hydrology and Risks** (Michael Kabanov (IMCES) and Anatoly Shvidenko (IIASA)).

The forth Focus has a generic nature and is devoted to:

4. **Information Systems for Environmental Sciences, Integration and Synthesis** (Evgeny Gordov (SCERT) and Edige Zakarin (KGC)).

The groups analyzed relevant RTD projects (lists of those are mentioned in the Introduction and attached to respective Focus Groups Reports) and summarized the state of the art, existing methodology and applications in the considered area. Additional contributions of all Project Partners also have been used in this Report.
On this basis also practical recommendation to international research community and regional environmental decision makers were formulated (see in Volume 1). These recommendations are translated into Russian and disseminated to targeted community via direct mailing and the Project web site.

Content of Volume 5:

Abstract

Siberia environment has been subjected to serious man-made transformations during last 50 years. Current regional level environmental risks are: direct damages to environment caused by accidents in process of petroleum/gas production and transporting including their influence on water, soil, vegetation and animals; caused by deforestation (legal and illegal cutting and forest fires) variations in Siberian rivers runoffs and wetland regimes; direct and indirect influence of forest fires, flambeau lights and losses of gas and petroleum during their transportation on regional atmosphere composition; deposition of hazardous species leading to risks to soil, water and consequently to risks in the food chain.

To understand dynamics of regional environment under such a pressure properly and perform its assessment on the base of monitoring and modeling an information-computational infrastructure is required. Management of multidisciplinary environmental data coming from large regions requires new data management structures and approaches. The fist Part of this Report is devoted to description of two approached used to develop key elements of such infrastructure, which is to usage of Internet based information-computational systems and to usage of more traditional GIS. Also here general properties of distributed information-computational infrastructure required in particular to support planned within Siberia Integrated Regional Study (SIRS) investigations of environmental changes in Siberia are discussed.

Scientific background used for these Part is formed by a number of different levels RTD projects devoted to near all aspects of the theme. The set comprise EC funded thematic international projects performed within FP5, FP6 and liquidating now INTAS, national projects supported by Siberian Branch of RAS, RAS and Russian Foundation for Basic Research and projects performed by research institutions and SME under contracts with regional/local administrations and petroleum/gas producing and transporting enterprises/companies.

Resumé

This Report summarizes results of activities of Enviro-RISKS Project Partners in area of Information Technologies for Environmental Sciences development and usage. It consists of two independent Chapters devoted to the web-based Information Technologies (prepared by E. Gordov) and to the GIS-based Information Technologies (prepared by E. Zakarin) and the third Chapter Integration and Synthesis devoted to basic and specific applications of Information Technologies to environmental problems of the region under analysis. In this Chapter Sections 3.1-3.3 are written by E. Gordov, Sections 3.4-3.6 are written by E. Zakarin and Section 3.7 is written by A. Tridvornov. Usage of results obtained by D. Belikov, A. Fazliev, V. Lykosov, B. Mirkarimova, V. Moskvichev, I. Okladnikov, A. Starchenko and A. Titov is acknowledged. Contributions and expertise of all Project Partners also have been used in this Report.

1. Development of Web Based Information-Computational Infrastructure for Environmental Sciences and its Usage for Siberia Integrated Regional Study

1.1. Introduction

The fact that specifics of basic Earth system science and their regional/local environmental applications (Environmental Sciences) make them multidisciplinary and require to involve into studies a number of nationally and internationally distributed research groups is a common knowledge nowadays. Really, here multidisciplinary (in virtue of problems treated and in nature of the environmental issues tackled), "distributed" teams of specialists should perform cooperative work, exchange of data and knowledge and co-ordinate activities optimizing the usage of information-computational resources, services and applications. Also the community acknowledged that to understand dynamics of regional environment properly and perform its assessment on the base of monitoring and modeling more strong involvement of information-computational technologies (ICT) is required, which should lead to development of information-computational infrastructure as an inherent part of such investigations [1, 2]. In particular, recently it was stressed that management of multidisciplinary environmental data coming from large regions requires new data management structures and approaches [3]. Thus the contemporary challenge is to save efficiency of such efforts via development of a platform/mechanism providing a collaborative working environment for scientists engaged, as well as giving an access to and preservation of scientific information resources, such as environmental data collections, models, results, etc. All these issues are among the priorities within the R&D strategy of major actors in the field now.

It is clear nowadays that a very beneficial synergy effect could be achieved by closely coupling the areas of Environmental Sciences (ES) and Information-Computational Technologies (ICT) that is for an interdisciplinary field concerned with the interaction of processes that shape our natural environment (ecology, geosciences, hydrology, and atmospheric sciences), and the way that these processes are "mapped" into an information system architecture and are dealt with, via relevant software tools. Formally the latter belongs to Informatics, which is applications of formal and computational methods to analysis, management, interchange, and representation of information and knowledge, while its synergetic usage in ES can be defined as Environmental Sciences Informatics (ESI). Being a subdivision of Informatics, ESI mainly aimed at formal representation of the spatial and temporal hierarchical structure of subsystems compounding regional environment or Earth system as a whole and relationship between these compounds. At the same time, being a subdivision of Environmental Sciences, it is aimed at design, development, and application of tools to acquire, store, analyze, visualize, manage, model, and represent information about spatiotemporal dynamics of the environment system to interdisciplinary community. In other words ICT or ESI plays a pivotal role in developing the 'underlying mechanics' of the work, leaving the earth scientists to concentrate on their important research as well as providing the environment to make research results available and understandable to everyone. Major efforts here are undertaken either in attempt to provide GIS platforms with required web accessibility, computing power and data interoperability or to exploit completely huge potential of web bases technologies. In spite of some remarkable achievements (see for details the Open Geospatial Consortium web portal http://www.opengeospatial.org/) we consider attempts to save GIS functionality together with computing power required to support modern models as well as huge data archives sharing not very promising and the approach relying upon web technologies potential was chosen for development of the information-computational infrastructure required.

There are two key projects strongly employing web technologies potential nowadays, which mainly determine direction for software tools design in thematic domain of Earth Science, namely, PRISM (Program for Integrated Earth System Modelling, http://prism.enes.org) and ESMF (Earth System Modeling Framework, http://www.esmf.ucar.edu/). PRISM aims at providing the European Earth System Modeling community with a common software infrastructure. A key goal is to help assemble, run, and analyze the results of Earth System Models based on component models (ocean, atmosphere, land surface, etc.) developed in the different climate research centers in Europe and elsewhere. It is organized as a distributed network of expertise to help share the development, maintenance and support of standards and state-of-the-art software tools. The basic idea behind ESMF is that complicated applications should be broken up into smaller pieces, or components. A component is a unit of software composition that has a coherent function, and a standard calling interface and behavior. Components can be assembled to create multiple applications, and different implementations of a component may be available. In ESMF, a component may be a physical domain, or a function such as a coupler or I/O system. It should be noted that announced in the both projects on-component approach is not yet realized consistently.

A little bit different approach is based on suggestion [4] that each separate computational task (it also might be a data assimilation task as well or combination the both above) can be represented as an information system, employed the three-level model – data/metadata, computation and knowledge levels. Usage of this approach for development of Internet-accessible information-computational systems for chosen thematic domains and organization of data and knowledge exchange between them looks as a quite perspective way to construct distributed collaborative information-computational environment to support investigations, especially, in multidisciplinary area of Earth regional environment studies.

The first step in this direction was done in course of development of the bilingual (Russian and English) scientific web portal ATMOS [5, 6] (http://atmos.iao.ru/). ATMOS is designed as an integrated set of distributed but coordinated topical web sites, combining standard multimedia information with research databases, models and analytical tools for on-line use and visualization. The main topics addressed are from Atmospheric Physics and Chemistry domain. It should be noted that in spite of the fact that the portal middleware employs PHP scripting language (http://www.php.net/), it has quite flexible and generic nature, which allows one to use it for different applications. Currently on this basis are developed and launched web portals, providing distributed collaborative information-computational environment to organizations/researchers participating in execution of EC FP6 projects "Environmental Observations, Modeling and Information Systems " (http://enviromis.scert.ru/) and "Enviro–RISKS - Man-induced Environmental Risks: Monitoring, Management and Remediation of Man-made Changes in Siberia" [7, 8] (http://risks.scert.ru/). The portals are also powerful instruments for dissemination of the projects results and open a free access to collections of regional environmental data and education resources.

While in the ATMOS portal only the data and computation levels were employed, appearance in 2004 RDF and OWL recommendations and supporting software allowing get conclusions on the base of specified according to these recommendations knowledge formed a basis to include metadata and knowledge levels into a typical information system, which is especially important for complex environmental tasks and problems solving. In particular, the three-level model was used to implement on the base of the ATMOS software the distributed information system "Molecular Spectroscopy", employing elaborated task and domain ontology [9]. Additional opportunities appeared as a result of Semantic Web development (http://sweet.jpl.nasa.gov/). The Semantic Web would enable a new breed of applications on the basis of knowledge sharing: smart agents instead of search engines. These agents will be able to establish dialogue with other agents or portals to exchange and request information, determine available resources, settle agreements on operations, cooperate in several tasks and return processed results to their user or forward them to other agents for further processing. In order for this cooperation to work, agents must share information in a common language. Ontologies provide a framework for knowledge expression. The field is still maturing and there is no unified ontology for all knowledge domains (although there are efforts such as Standard Upper Ontology from IEEE and similar activity within GEOD community - codex web portal for creating and managing personal and community ontologies for scientific research). These new opportunities open additional potential for the information-computational infrastructure under development and also should be made available to Earth and Environmental Sciences professional community. Quite recently a significant step in organization of environmentally oriented ICT community was undertaken and the Earth and Space Sciences Informatics (ESSI) was officially approved by EGU Council as its Division. The Earth and Space Science Informatics Community was established in 2007 with a strong liaison with AGU – ESSI. Relevant group of the European Geosciences Union was mainly conceived as a European forum for an Earth System Science multidisciplinary community, in the framework of the Spatial Information Community. More information about undertaken and planned ESSI activity can be found at http://sites.google.com/a/imaa.cnr.it/egu-essi/.

In this Part of the Report described are first elements of the web based environmental informatics system (with accompanying applications) forming distributed collaborative information-computational environment to support multidisciplinary investigation of Siberia as that will form a powerful tool for better understanding of the interactions between the ecosystem, atmosphere, and human dynamics in large Siberia region under the impact of global climate change. Being generic it should provide researchers with a reference, open platform (portal plus tools) that may be used, adapted, enriched or altered on the basis of the specific needs of particular applications in different regions. On this initial stage major attention was paid to crucial for subsequent applications components aimed at handling/processing/ different data sets coming from monitoring and modeling regional meteorology, atmospheric pollution transformation/transport and climate important for regional environment dynamics assessment under climate change.

Below briefly developed information-computational systems be discussed in more details: the ATMOS web portal Climate site current version (http://climate.atmos.iao.ru) providing an access to climatic and mesoscale meteorological models; the Enviro-RISKS web portal Climate site (http://climate.risks.scert.ru/) providing an access to interactive web-system for regional climate assessment on the base of standard meteorological data archives; web system for visualization and analysis of air quality data for city Tomsk (http://air.risks.scert.ru/tomsk-mkg/) ; and web system for presentation of climate modeling results (http://kvs.inm.ras.ru/index.html).

1.2. Web portal on environmental sciences “ATMOS”

The Internet increasingly functions as the backbone of interdisciplinary collaborative research in area of environment, and becomes a tool for the efficient access to, and exchange of research data and tools. Among a set of project aimed at development of environment for cooperative work with Earth system science information resources and mathematical models most promising are described in http://www.enes.org, http://www.esmf.ucar.edu, http://www.earthsystemgrid.org. The central technical problem there is to give researchers opportunity to integrate mathematical models of weather or climate forming from compound for different subsystem behavior and save them from tedious tasks related with harmonization of input and output data of different models developed by different groups. At the same time models for each subsystem comprise a number of physical and chemical processes, which are studied by hundreds research groups. Thus there appears a problem of detailed comparative study of these models and multivariate construction of research integrative models, which is not solved on the current stage of development of cooperative modeling within

Internet. Below an approach to this problem used at development of the web portal on Atmospheric Sciences ATMOS is presented.

The bilingual ATMOS web portal comprises information resources on physics and chemistry of atmosphere (http://atmos.iao.ru) as well as those on air quality issues and two Siberian territorial objects, which are West Siberia and Lake Baikal (http://atmos.scert.ru). Design of an information resource implies development of different level models describing the chosen thematic area. In our case Siberia is an object of investigations and its properties under investigation are weather and climate. Their description is based on atmospheric dynamics, which requires knowledge of atmospheric radiation and subsequently of major chemical cycles in different atmospheric layers. To calculate radiation fluxes in atmosphere, one has to deal with spectral properties of atmospheric gases and aerosols, whose concentrations are determined by photo-chemical transformations. Investigation of those properties is domain on a set of basic sciences including atmospheric spectroscopy, atmospheric chemistry, atmospheric radiation and atmospheric aerosols. The major concern in process of the portal design was to provide a qualified user with opportunity to get relevant information on all levels of relevant physical and chemical processes descriptions. Say, in the portal part dealing with atmospheric processes major part of calculation tasks are decomposed into elemental stages, which can be controlled by user.

To provide the portal with such functionality, a special middleware was designed [10]. Based on it, portal operates as an Internet accessible multi-user system oriented on applied problems solving. In it user can solve typical problems from the thematic domains, save intermediate of final results on the server side, compare results with stored in the system experimental or computational data (this functionality is supported for molecular spectroscopy only), etc. To submit data required in computational tasks or to choose those from the prepared list specially designed on the base of recommendations on HTML interfaces are used. Figure 1 presents structure of the portal and middleware. An apparatus part comprises three components, which are database server, applications server and computational cluster oriented to atmospheric chemistry and climate problems solving. The middleware consists of a set of services and a transaction processing monitor, which performs function of a dispatcher of each user request and of some services. Part of the services is shown in Fig.1.

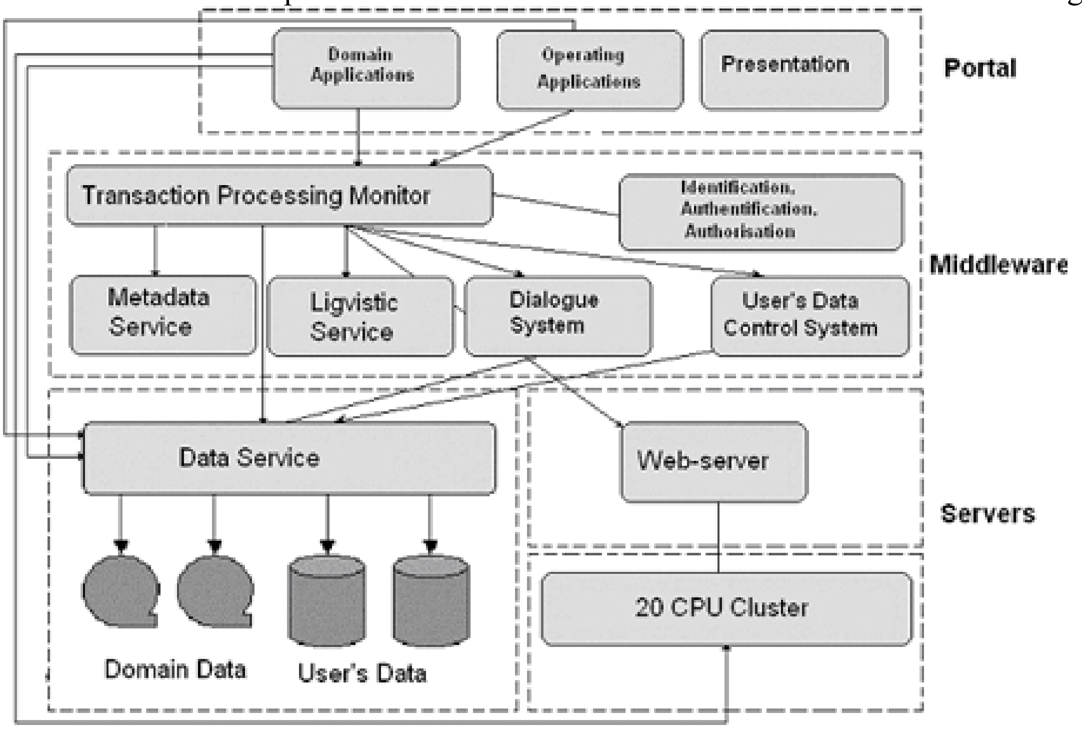

Fig.1. The portal and the middleware structure.

The dialogue system forms menu on the base of applied logic formed for each site. The user's data control system secure integrity of user's data in process of usage of the relevant site calculation part. The linguistic service is providing multi-language information presentation on site and in the dialogue system. Since till now there is no international standards on relevant middleware (see, for example, Network Working Group, Request for Comments: 2768) technological choices were based of W3C recommendations. In particular, Apache web server was used as well as PHP script language and MySQL DBMS. It should be noted that a "make" approach was used since at the start of the project in 2000 there was no software available, which allowed one to develop Internet accessible systems aggregating computational applications with a dynamically formed dialog system and control of integrity of user's data saved at the server side. Typical software adjusted to these tasks is not available yet. It should be also added that to make the information-computational system open via Internet to professional community we used a multilevel client-server architecture. Relevant software significantly differs from those adjusted for LAN. Here the key elements are a web-server, supporting its operation middleware and standards for data and metadata descriptions. While the standards are elaborated by W3C and web-servers are suggested by companies developing software the middleware is still the domain in which neither standards nor companies developing software are presented. This area is actively developed only nowadays, see, for example, works on Internet-2, supported by NSF (USA) (http://middleware.internet2.edu).

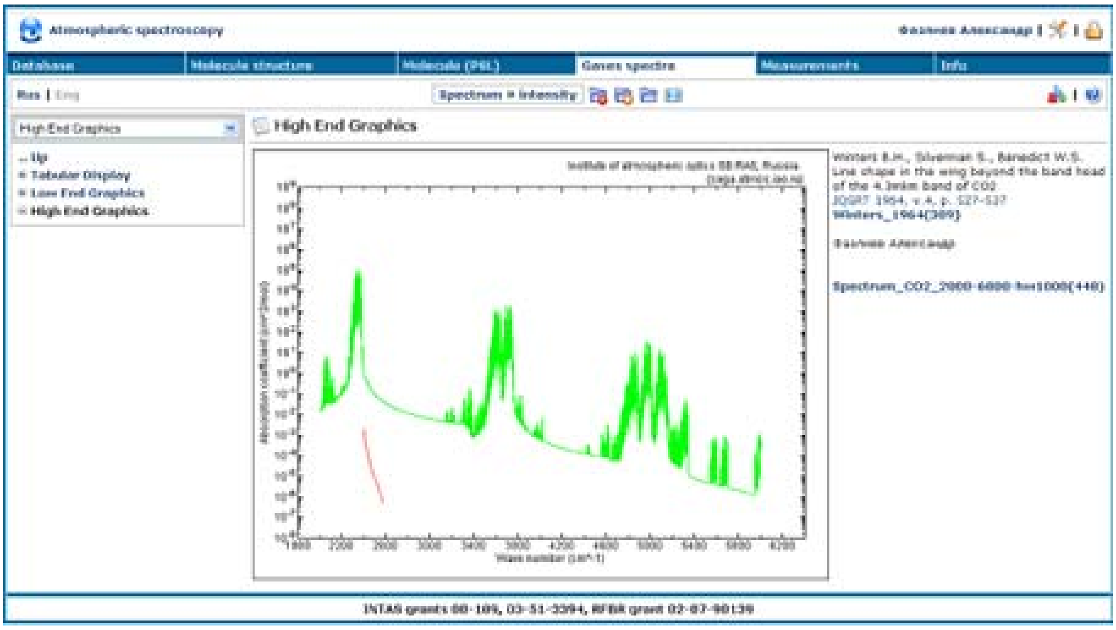

Fig. 2. High resolution end graphics example (absorption coefficient of CO_2 in spectral range 1900-6000 cm^{-1}).

Below the two groups of the portal are described briefly. It should be noted that the thematic domains presented in the system cover the area of basic atmospheric science and it applications, in which either project partners or their collaborators group have professional expertise. The collaborators, mainly belonging to SB RAS research institutions, also formed a user group, whose requirements were taken into account in process of the system design and development. Each thematic site of Atmospheric Physics and Chemistry group is based on databases or data sets inherent to its thematic domain. Computational models accessible in the portal after registration include the 3-D atmospheric circulation (climate) model of INM RAS [11], land cover-atmosphere interaction INM RAS model [12], model of light scattering on spherical particles [13], model describing short and long wave radiation in atmosphere [14], etc. The group comprises six sites, four of which are described below, while the climate site is described in the separate section.

Atmospheric spectroscopy (http://saga.atmos.iao.ru/) information system is based on the HITRAN [15] and GEISA [16] spectral data banks. Within it user can simulate spectral properties of an isolated molecule as well as of homogeneous or inhomogeneous molecular gas. Calculated data can be presented in table or graphical form. Graphical data presentation can be done by low end graphic, when only relevant plot is available to user, or by high resolution end graphic. In this case, user is provided with data massive and relevant web services allowing him different presentations, scales, sets of curves, etc. Figure 2 shows the graphical presentation of CO_2 molecule spectrum.

This information-computational system is provided with other services as well. Its information part contains in particular some text books on molecular spectroscopy. More detail description of the site is given in [17 - 19]. Information part of Atmospheric aerosol (http://aerosol.atmos.iao.ru/) site comprises two editions of three volumes of M.V. Kabanov monograph “Optics of disperse media”, L.S. Ivlev monograph “Physics of atmospheric aerosols systems” and materials of nine annual Workshops "Siberian Aerosols". Computational component of the site includes a version of the aerosol calculator [20], which performs algebraic computations of aerosol physical characteristics, the Andreev-Ivlev model [21] for calculations of near – earth layer aerosols characteristics on horizontal paths and relevant extinction/absorption factors as well as for calculations of scattering matrix elements for radiation scattered on single or two layer particle and ensemble of particles. Atmospheric chemistry (http://atchem.atmos.iao.ru/) information-computational system is aimed at organization of access to atmospheric chemical reactions database, derivation of kinetic equations for a chosen by user reaction set and qualitative analysis of the derived kinetic equations. Within it local chemical processes occurred at atmospheric conditions are analyzed in the following order:
1. Chemical reactions/cycles choice from the database (chemical system forming);
2. Kinetic equations derivation (closed or open systems);
3. Choice of atmospheric conditions for subsequent analysis (altitude, temperature, pressure, statistical model of atmosphere, albedo of surface, etc.);
4. Calculation of reactions coefficients;
5. Determination of the chemical system steady states and relevant time constants;
6. Determination of atmospheric compounds concentrations time behavior;
7. Determination of the chemical system phase portraits and analysis of scenario for its possible dynamical behavior.

The above steps are supported by a specially developed dialog system. This site is described in details in monograph [22]. Atmospheric radiation site (http://atrad.atmos.iao.ru/) supports calculations of radiation fluxes in cloudless cloud atmosphere. Here accessible are the Frolkis model [23], as well as a software support for atmospheric transmittance function calculations [24]. The information part of the site contains data on two statistical models of atmosphere [25, 26] and monograph by A.V. Vasiliev and I.N. Mel’nikova “Shortwave solar radiation in the Earth atmosphere: Calculations, measurements and interpretation”. An example of a screenshot from the site is shown below.

Each site of the second group this group is an information system devoted to relevant environmental issues, including atmospheric pollutions and environmental characteristics of two geographic objects of Siberia, namely Lake Baikal and West Siberia Plain. Air quality assessment and management (http://air.atmos.scert.ru/) site is providing an access to information resources on air quality monitoring and management and general description of Siberia environment state is given as well as to the AIR-EIA system, which was designed by a project partner to provide improved access to state-of-the-art multi media information resources on Air Pollution aspects of Environmental Impact Assessment. Lake Baikal site (http://baikal.atmos.scert.ru/) contains the first results of scientific assessment of the environmental and climatic situation in the Lake Baikal area. It is based on the book “Ecologically oriented land use planning in the Baikal region” by A.N. Antipov, V.M. Plusnin, O.I. Bashenova and others – Irkutsk: Published by the Institute of Geography SB RAS, 2002 – 103 pp. and gives an access to relevant descriptions, maps and photos. The West Siberia site (http://west-sib.atmos.scert.ru/) contains the first results of scientific assessment of the environmental and climatic situation in the region important for climatic variations under natural and anthropogenic pressure. Descriptions of regional climate, hydrology, vegetation and other environmental characteristics are given. It also includes a book summarizing recent findings on Great Vasyugan Bog state and dynamics.

Fig. 3. Results of fluxes calculation in the framework of the zonal model of the atmosphere.

1.3. ATMOS Climate site

In process of the information-computational system "Climate" design integration of three scale models was organized. Those are global model, regional models and models of city level. The global scale model chosen is GCM [27] of the RAS Institute for Numerical Mathematics (INM), regional scale models are presented by Mesoscale Model 5 (MM5) [28] and Weather Research and Forecasting Model (WRF) [29], while final selection of a city level model is not finalized yet. An access to computational resources of the climate system is free, however user should register and be authorized firstly to get an access to resources. To diminish amount of traffic, user gets results of modeling as plots. On-line regime is used only for choice of input parameters and to look through results obtained. Results of calculations are saved at the database server and available for user at any time. Technically, process of task execution is determined by the four-level architecture of the system (client, web server, database server and computational cluster). When input data of the problem are transmitted to server, relevant process is created at the cluster and Torque task manager [30] controls them. User has to reserve the server resources for access to domain applications (tasks). For this aim one may to form catalogues and tasks, where the results of calculation will be stored.

The INM climate model is equipped with a comprehensive physical package that includes advanced parameterizations of the boundary-layer turbulence and air-sea/air-land interaction, solar radiation transfer, land surface and soil hydrology, and other climatic processes. The detailed model documentation is presented at the AMIP (Atmospheric Model Intercomparison Project) site **(**http://www-pcmdi.llnl.gov/projects/modeldoc/amip2/dnm_98a/index.html**).** The space resolution of the model is 5 degrees in longitude, 4 degrees in latitude and 21 levels in vertical from the Earth surface to the height of about 30 km. The implemented web-interfaces for this model can be found at http://climate.atmos.iao.ru.

Interfaces to work with the mesoscale meteorological models MM5 and WRF are accessible via Internet at the ATMOS portal (http://climate.atmos.iao.ru/star/mm5, and http://climate.atmos.iao.ru/star/wrf). These models are aimed at numerical weather forecast mainly, but also can be used to study convective systems, city heat islands, etc. These interfaces allow user to change input data, to initiate calculations on the supporting system calculations cluster and get results in graphical forms. Below those are described on example of MM5 model usage. It should be noted that absence of some types of data forced us to restrict the possibility of weather characteristics calculations presented by MM5 model.

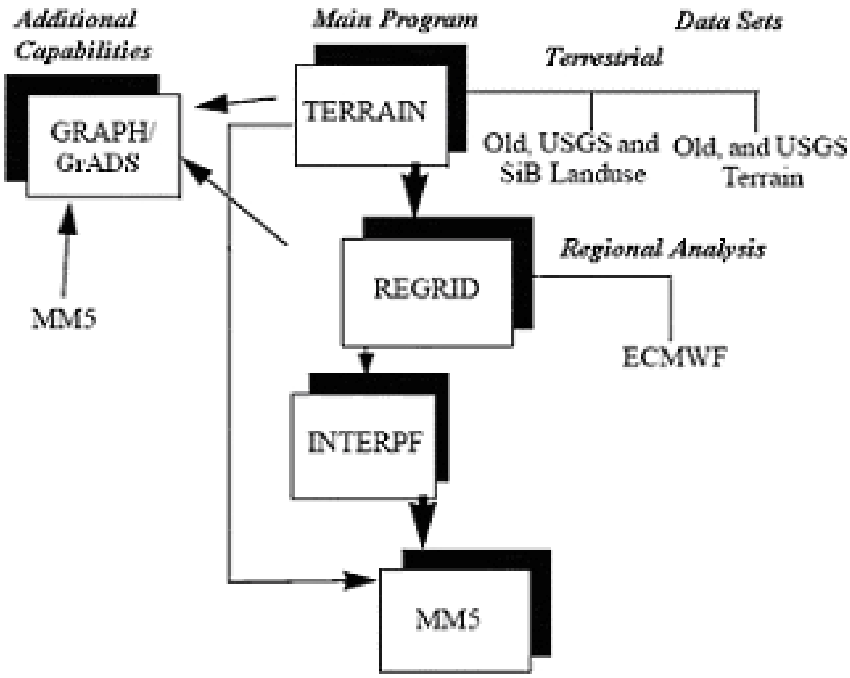

Fig. 4. Implemented part of MM5 system.

Figure 4 shows a scheme of implemented part [31] of MM5, which reflects the sequence of application executions, data flows and briefly characterizes its principal functions. Surface and isobaric meteorological data are interpolated by TERRAIN and REGRID modules on the longitude-latitude grid into the high definition variable region, which is situated on the Lambert straight angle projection, polar stereographic projection or Mercator projection. INTERPF application interpolates values of physical variables (initial and boundary conditions) from isobaric levels MM5 model's sigma system. Sigma levels near the Earth surface coincide with the relief and as the distance to surface becomes greater they come near the isobaric surfaces.

The user of the MM5 model has to present data about the relief, land use and vegetation for the whole territory of interest. The topographical data sets of different resolution are used for geographical location of the MM5 model. The reanalysis data of ECMWF for period 1991-2002 is used as input data. The sequence of data preparation by user includes three stages. On the first stage user defines the coordinates of the region and the number of embedded regions, the type of cartographic projection, the scale of horizontal grid, on which user initializes relief, the distribution of land use categories and types of vegetation. User also defines the resolution of vertical grid. During the second stage user assigns time period of modeling, the value of temporal digitization of the meteorological data (as a rule 6 or 12 hours are stored in DB) and list of altitudes where calculations have to be done. During the final stage for every embedded region defined by user, one makes choice of parameterization scheme for microphysics of humidity, cloudiness, boundary layer and radiation in the atmosphere.

Input data files, formed in conversation mode are delivered from web server to the cluster. Application Torque controls the queering, the task and control the task line. Computational modules of the MM5 application depend on the number of embedded regions, that's why this application is compiled every time before the execution. Obtained output is stored and provided with unique identifications, which allows the system to connect them with the user and solved by him problems. The results are represented in three groups of physical parameters separated on their distribution in space: 3D (24 parameters) and 2D (31 parameters) variables and combined ones (7 parameters). One can find at the site the full list of the parameters including temperature, pressure, humidity, wind direction and so on. User can get plots of results in form of maps with contour lines, colored maps or maps with vector fields. Graphical depiction of the results is done using the GRADS package.

The same approach is applied to design the interface for the WRF model. There are the same four steps, which user has to do for input data assignment. The final list of resulting physical parameters is slightly different from the MM5 list. Below visualization of some results of WRF model runs for Tomsk region are shown.

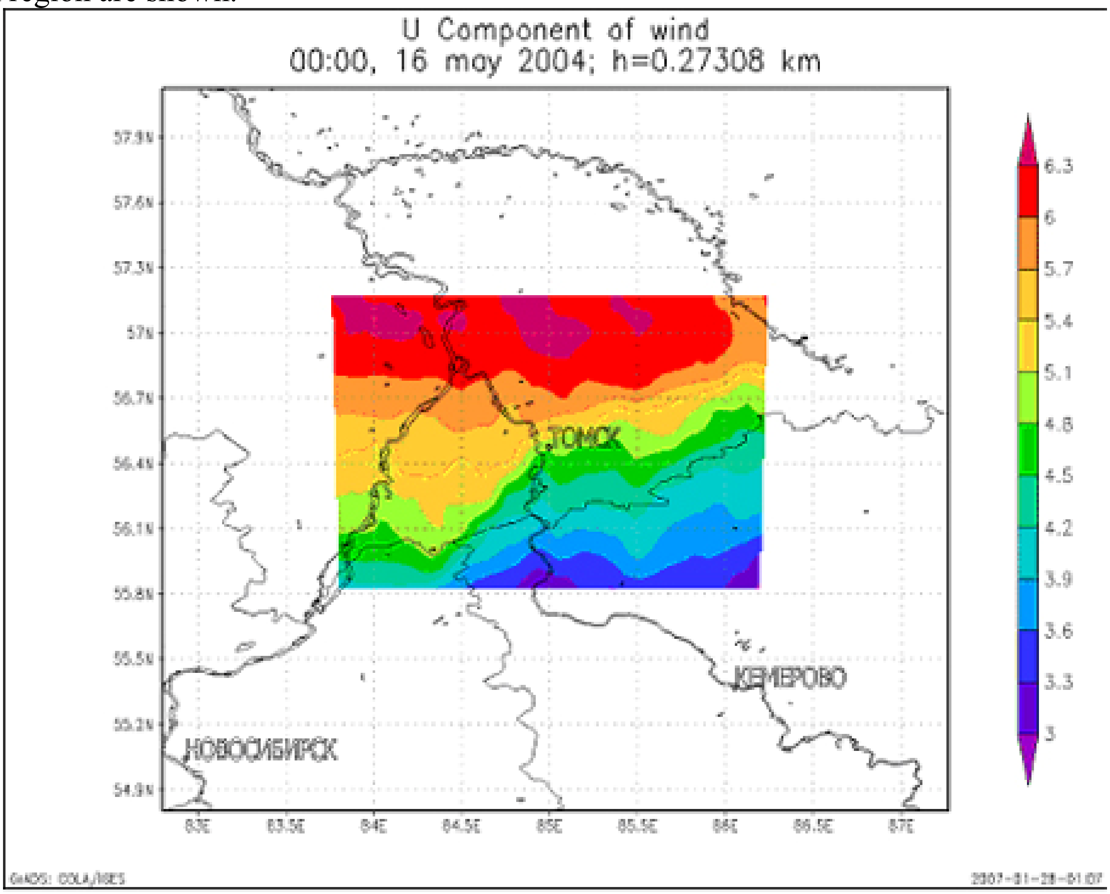

Fig. 5. Representation of the zonal component of the wind velocity calculated in WRF model. The central part of the plot shows the area of West Siberian city Tomsk.

1.4. Enviro-RISKS portal and Climate site

The next element of the infrastructure is formed by the Enviro-RISKS project web-portal (http://risks.scert.ru/). This bilingual (Russian and English) resource [32] is aimed at dissemination of information on general environment issues adjusted also for usage in education process and giving an access to regional environmental data and instruments to process them on-line. The portal is organized as a set of interrelated scientific sites, which are opened for external access. The Portal engine employs ATMOS portal software. The portal opens easy access to structured information resources on Siberia environment and to results of project expert groups studies devoted to regional environment management under anthropogenic environmental risks. A built-in Intranet is used as an instrument for project management as well as for exchange and dissemination of information between the project partners. The portal gives also an access to gathered and analyzed detailed information on all coordinated projects, gathered and systemized results and findings obtained including relevant observation data and information resources, distributed database, which will provide an access to data on characteristics of Siberian environment to the project partners and an access to relevant metadata to all interested professional community. The basic thematic sites currently integrated into the Enviro-RISKS web-portal are the Climate site aimed at an access to specially designed analytical tools allowing to get spatial pattern of selected Siberia climatic characteristics from measured or simulated data sets and the Air Quality Assessment site, which compiles basic and applied aspects of air pollution and environmental impact assessment. Special site is devoted to the project management. It comprises information on the project partners, project management, projects/program coordinated and gives an access to educational recourses gathered by Partners.

The Climate site of the portal (http://climate.risks.scert.ru/) upon a qualified user request gives an

access to interactive web-system for regional climate change assessment on the base of standard meteorological data archives. The system is a specialized web-application aimed at mathematical and statistical processing of huge arrays of meteorological and climatic data as well as on the visualization of results. The data of the first and second NCAR/NCEP Reanalysis editions [33, 34] as well as European and Japanese Reanalyzes are currently used for processing and analysis. Grid Analysis and Display System (GrADS, http://www.iges.org/grads/) and Interactive Data Language (IDL, http://www.ittvis.com/idl/) are employed for visualization of the results obtained.

The system consists of graphic user interface, set of software modules written on script languages of GRADS or IDL and structured meteorological data sets. The graphic user interface is a dynamic web form to choose parameters for calculation and visualization and designed using HTML, PHP and JavaScript languages (Fig. 6).

Set of software modules consists of independent modules implementing analytical algorithms required for meteorological data processing, switched on with assistance of PHP and executed by GRADS/IDL system, which generates a graphical file containing the results of calculations performed. The latter along with corresponding metadata is passed to the system kernel for subsequent visualization at the web site page. The structured meteorological data are stored at the specialized server and available only for processing by the system so that user can not access data files directly while can freely get results of their analysis. The screen shot below (Fig. 7) shows a window of a result graphical output.

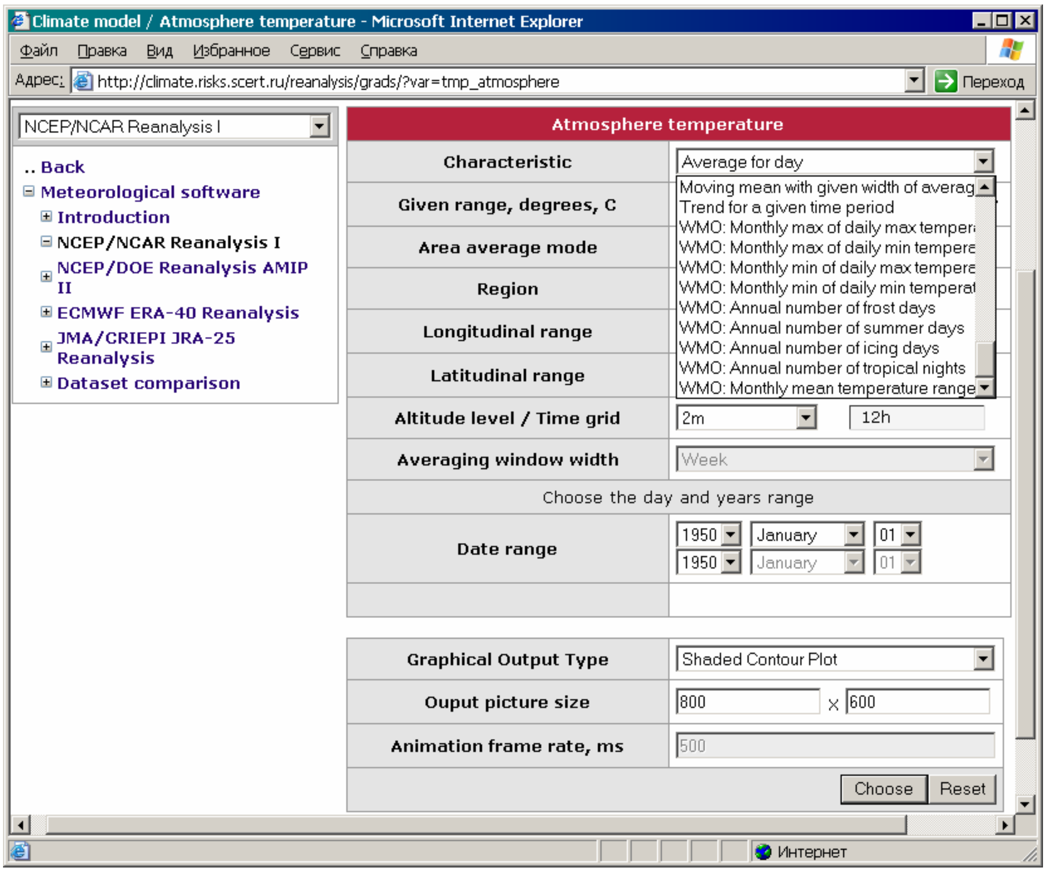

Fig.6. Graphic user interface of the system for selection of required calculations and visualization characteristics.

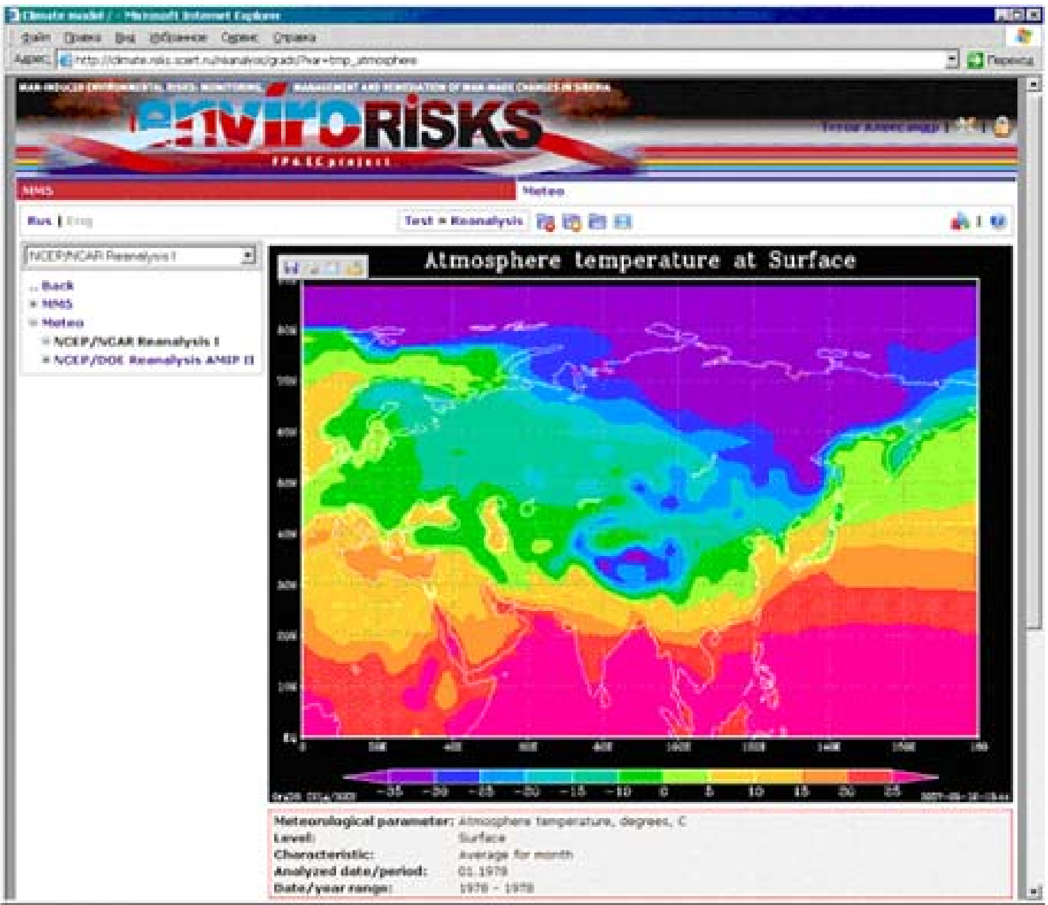

Fig. 7. Surface temperature in January, 1978 for chosen geographical domain (40-90 degrees of the Northern latitude and 0-180 degrees of the Eastern longitude).

At present the following climatic characteristics have been chosen for subsequent analysis: temperature, pressure, air and soil humidity, precipitation level and geopotential height. Due to the middleware used the system structure is rather flexible and this set can be easily expanded by adding new features to the interface as well as to the executable software.

Currently system allows performing for chosen spatial and time ranges the following mathematical and statistical operations, key for the climate assessment: calculation of maximum, minimum, average, variance and standard deviation values, number of days with the value of the chosen meteorological parameter within given range, as well as time smoothing of parameter values using moving averaging window. It is also possible to calculate correlation coefficient for an arbitrary pair of parameters, linear regression coefficients between some pair of characteristics and to determine first (last) cold (warm) period (such as day, week, month) of the year. The user interface allows one to choose geographic domain, time interval, characteristic of interest and visualization parameters. For example, a pulldown menu “Region” includes the following options: Siberia, Europe, Asia, Eurasia, the whole Earth and that is defined by user. The last option choice leads to appearance of "Longitudinal range” and “Latitudinal range” fields in which user should enter coordinates of the geographical domain of interest. User can also choose type of statistical characteristic, interval for averaging, altitude level, and so on. While calculating averages with moving window, which width can be specified as week, month, three months, half of the year and year, one gets the smoothed sequence of spatial distributions for the characteristic of interest. This set is represented as an animation, which can be viewed either in automatic or in controlled regime. Below shots from such sequence are shown including the control bar specifying the viewing mode.

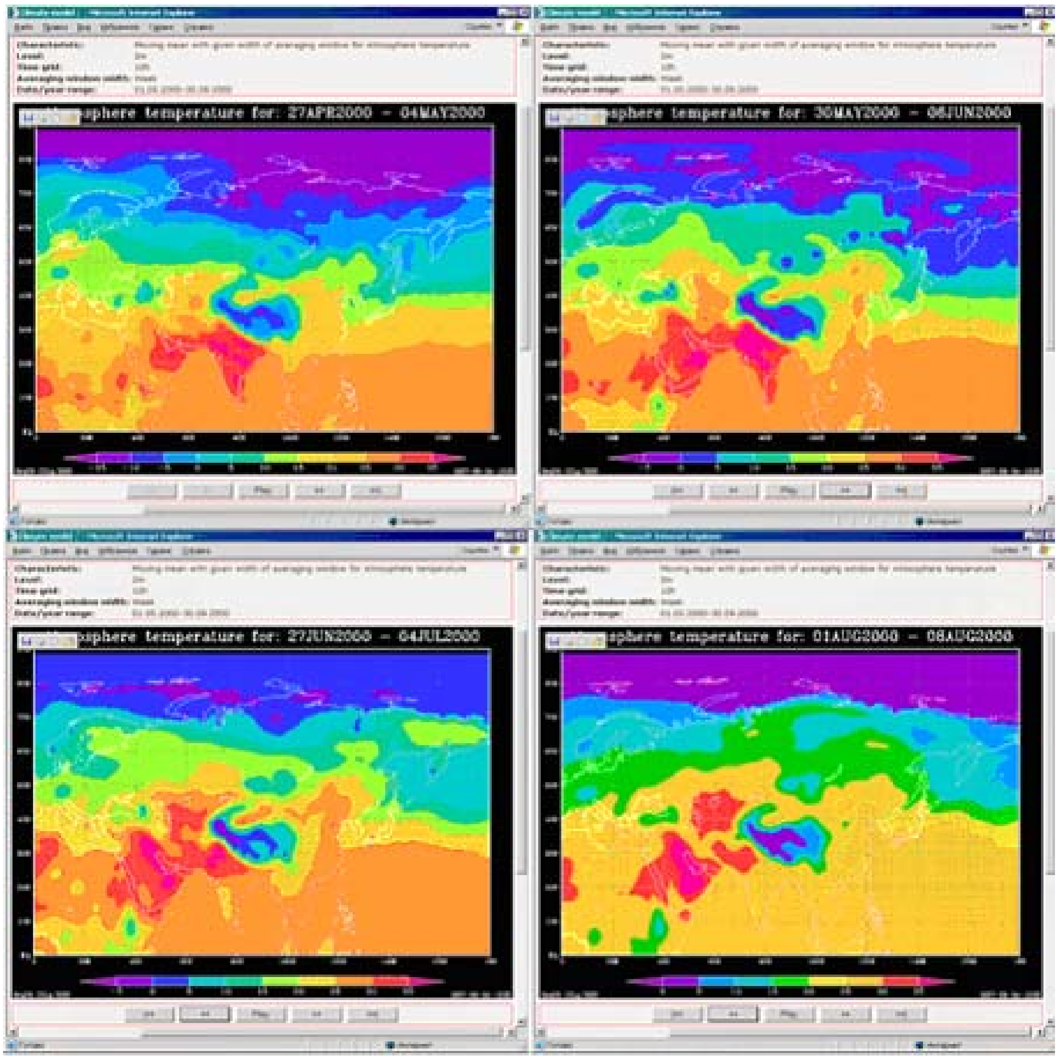

Fig. 8. Results of averaging with moving window.

The system allows to perform different mathematical and statistical operation, including calculations of mean values, standard deviations, determination of the first (last) warm (cold) day (week, month) of the selected year, amount of days with precipitation from the given interval (see Fig. 9 below), etc.

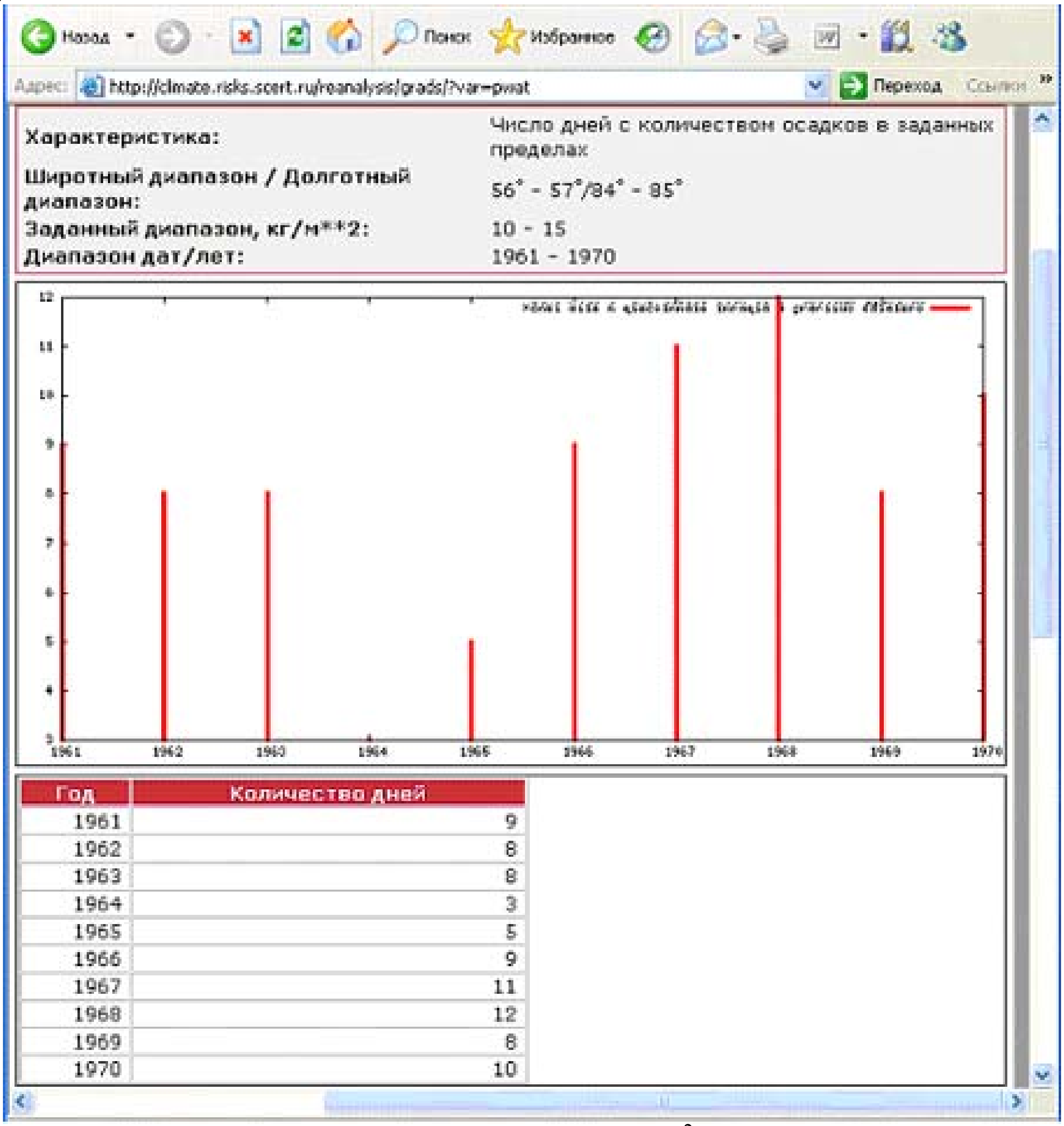

Fig. 9. Amount of days with precipitation within 10 - 15 kg/m^2 on the Tomsk oblast territory during 1961 – 1970.

Comparison of characteristics retrieved from different data sets is also possible. For example, difference between atmospheric pressure in Eurasia during Spring of 2001 looks like following:

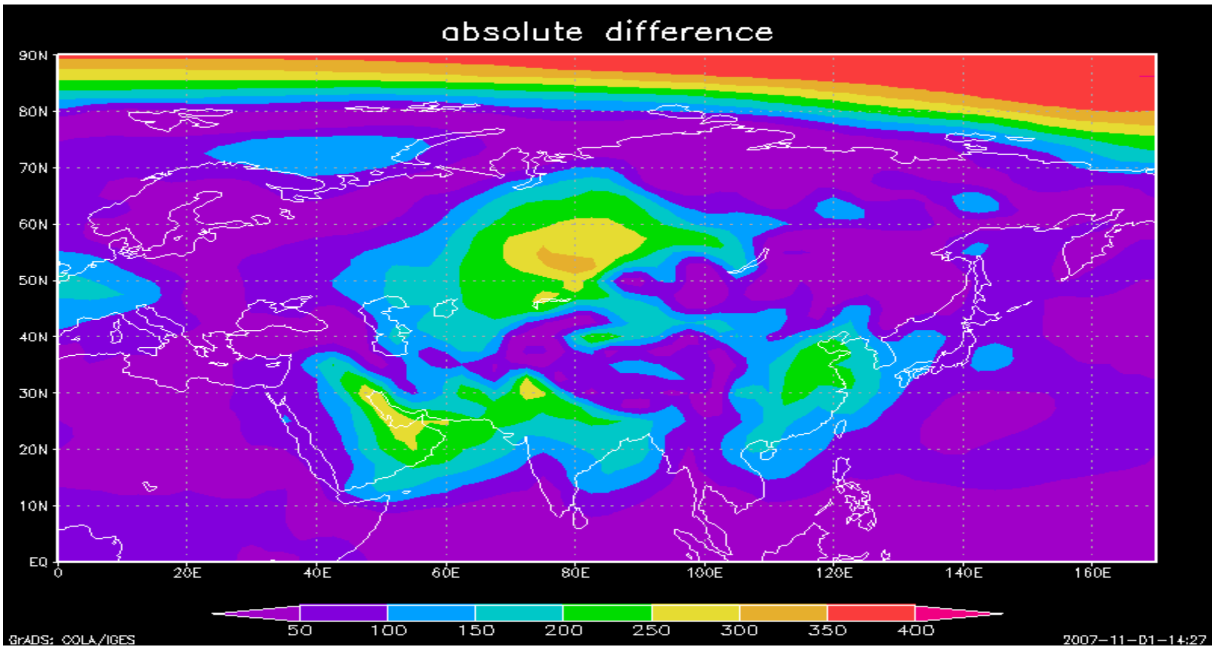

Fig. 10. Absolute difference between pressure $Abs\_dif = |b - a|$, where a and b are relevant mean pressure calculated for Spring 2001.

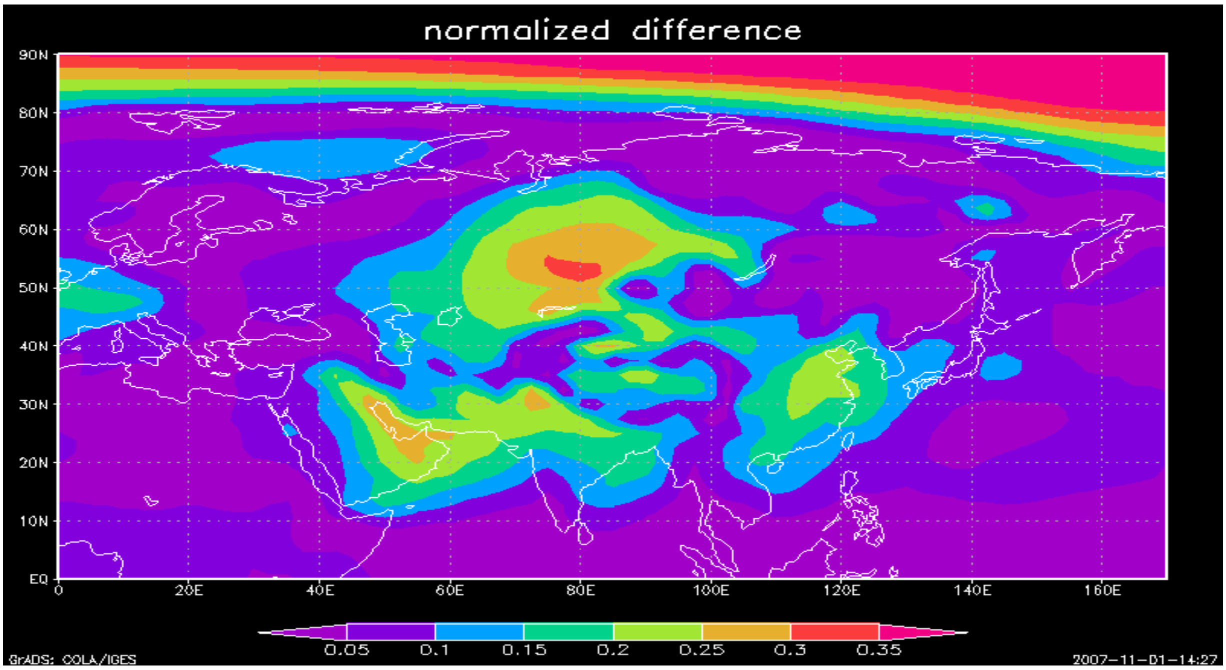

Fig. 11. Relative difference of pressure ($Norm\_dif = \left|\frac{b-a}{a}\right| \cdot 100\%$) for the same period.

Possibility to calculate time trends is also realized in the system. For example, Figs. 12 and 13 shows the calculated annual temperature 8 year trend ($Tr = \frac{\bar{y} - \bar{x}}{n}$, $\bar{x}$ is the mean for the first interval while $\bar{y}$ - for the second interval, n is the chosen interval)

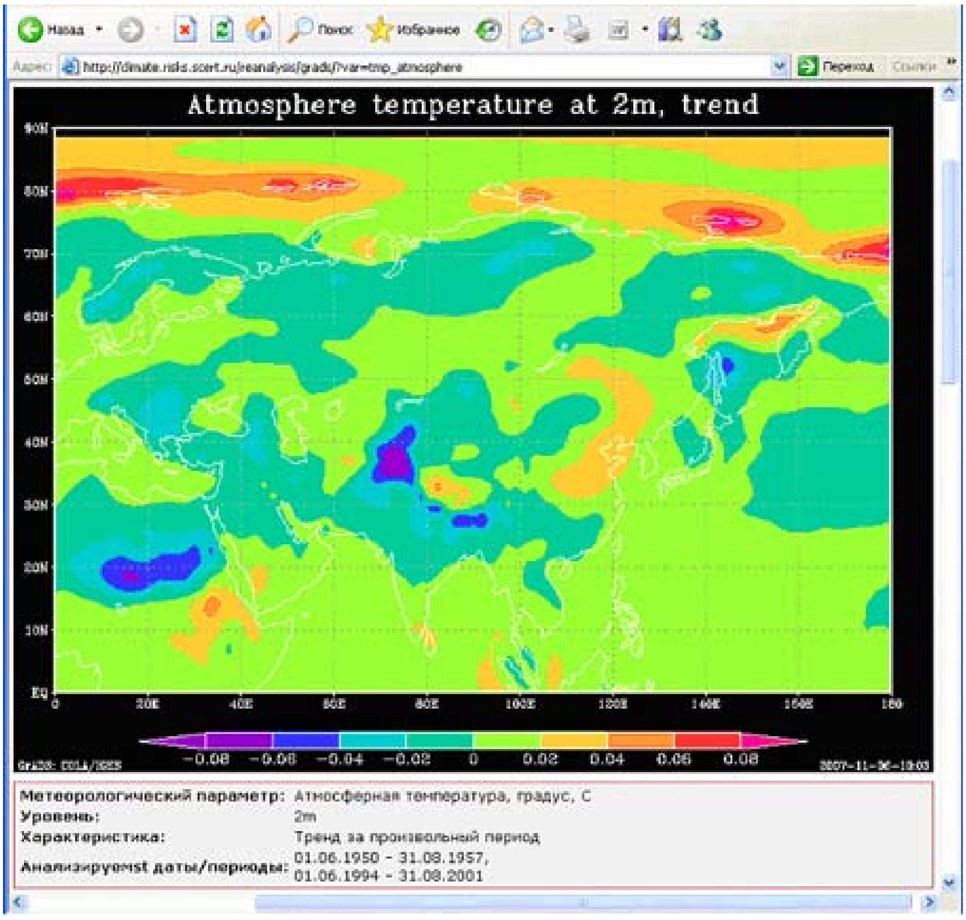

Fig.12. Trend for temperature calculated on the base NCEP/NCAR Reanalysis.

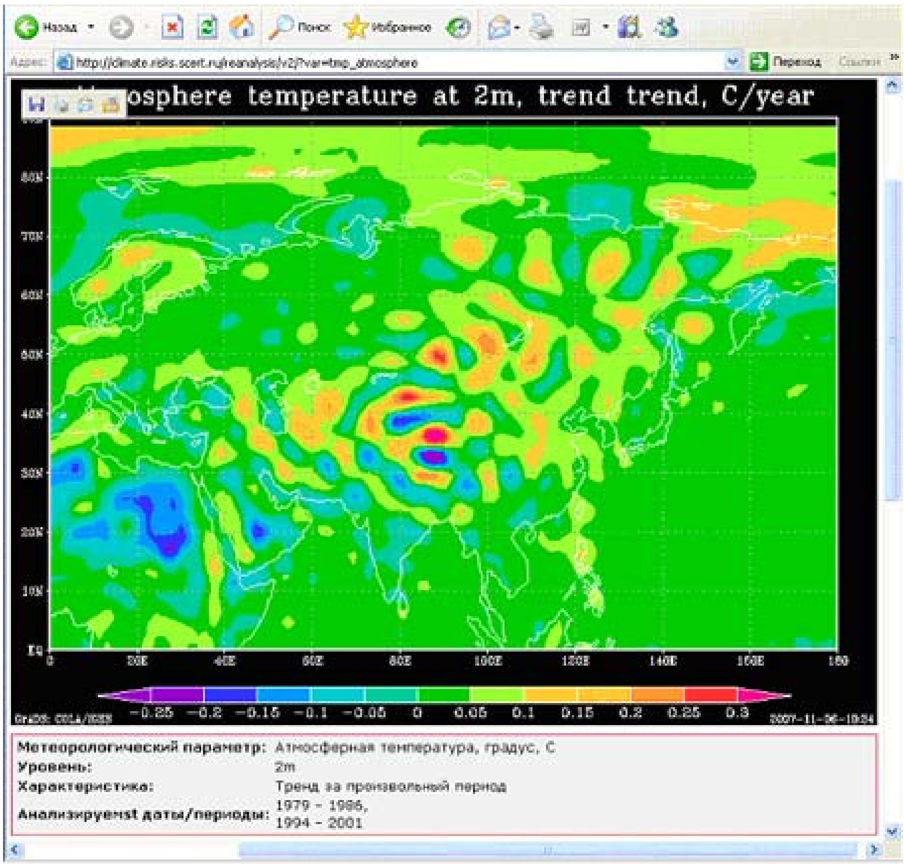

Fig.13. Trend for temperature calculated on the base NCEP/DOE AMIP II.Reanalysis.

The system will be useful for regional meteorological and climatic investigations aimed at determination of trends of the processes being taken place. Also it will simplify the work with huge archives of the spatially distributed data. It should allow scientific researchers to concentrate on the solving of their particular tasks without being overloaded by routine work and to guarantee the reliability and compatibility of the results obtained.

1.5. Air Quality Assessment site

The next element deployed at the portal is a web-system for Tomsk air quality assessment based on mathematical modeling of the pollution transport and transformations. It is aimed at effective air chemical composition assessment and forecast in the conditions of the industrial city area and its suburbs. The technique applied is based on the meteorological observations, taking into account atmospheric emissions of industrial enterprises and traffic, measurements of the concentration of the atmospheric pollutants as well as on the numerical modeling of the gaseous substances transformation and transport processes in the atmosphere. This system is also based on the ATMOS portal middleware. Currently air quality data sets for assessment of Tomsk area air pollution used by the system are obtained with the help of the pollution transport mathematical model employing meteorological characteristics fields calculated with prognostic meteorological models for selected periods within 2000 – 2005 interval. The model takes into account transport, dispersion and dry deposition of the pollutants as well as their photochemical transformations.

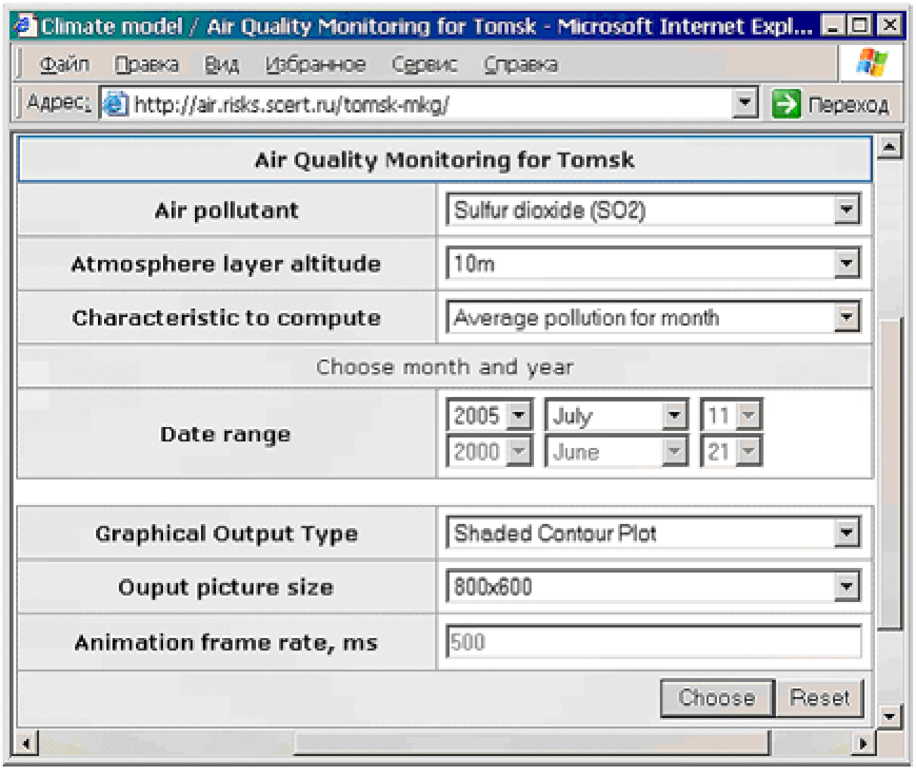

Fig. 14. Graphic user interface for air quality assessment system.

The system comprises three following parts: generated by the model and converted into binary files by a specially developed Java utility, stored at the server data archives containing calculated fields of the pollutant concentrations; graphic user interface; and a set of PHP-scenarios to perform calculations with subsequent visualization. Currently it allows a registered user to get visualized results of such characteristics as average monthly and seasonal pollutions along with their annual dynamics as well as daily dynamics for various pollutants. GrADS open source software has been used for the visualization of results for it has strong capabilities for the table graphic data representation. Graphic user interface is implemented using HTML, PHP and JavaScript languages and represents dynamic HTML form [41] for choice of input parameters and visualization characteristics (Fig. 14).

The form allows user to set the following parameters:

1. “Air pollutant” with such options as airborne particulate matter, sulfur dioxide, nitrogen dioxide, carbon oxide and ozone
2. “Atmospheric layer altitude” ranging from 10 to180 meters
3. “Characteristic to compute”. At present it is possible to calculate such characteristics as average pollution for month, season and their dynamics within the time interval, and hourly dynamics during the selected day
4. Date range, graphical output type and picture size. There is also a possibility to choose animation frame rate to see dynamics of the concentrations. Screen shots below demonstrate instances of hourly dynamics of sulfur dioxide during July 11, 2005

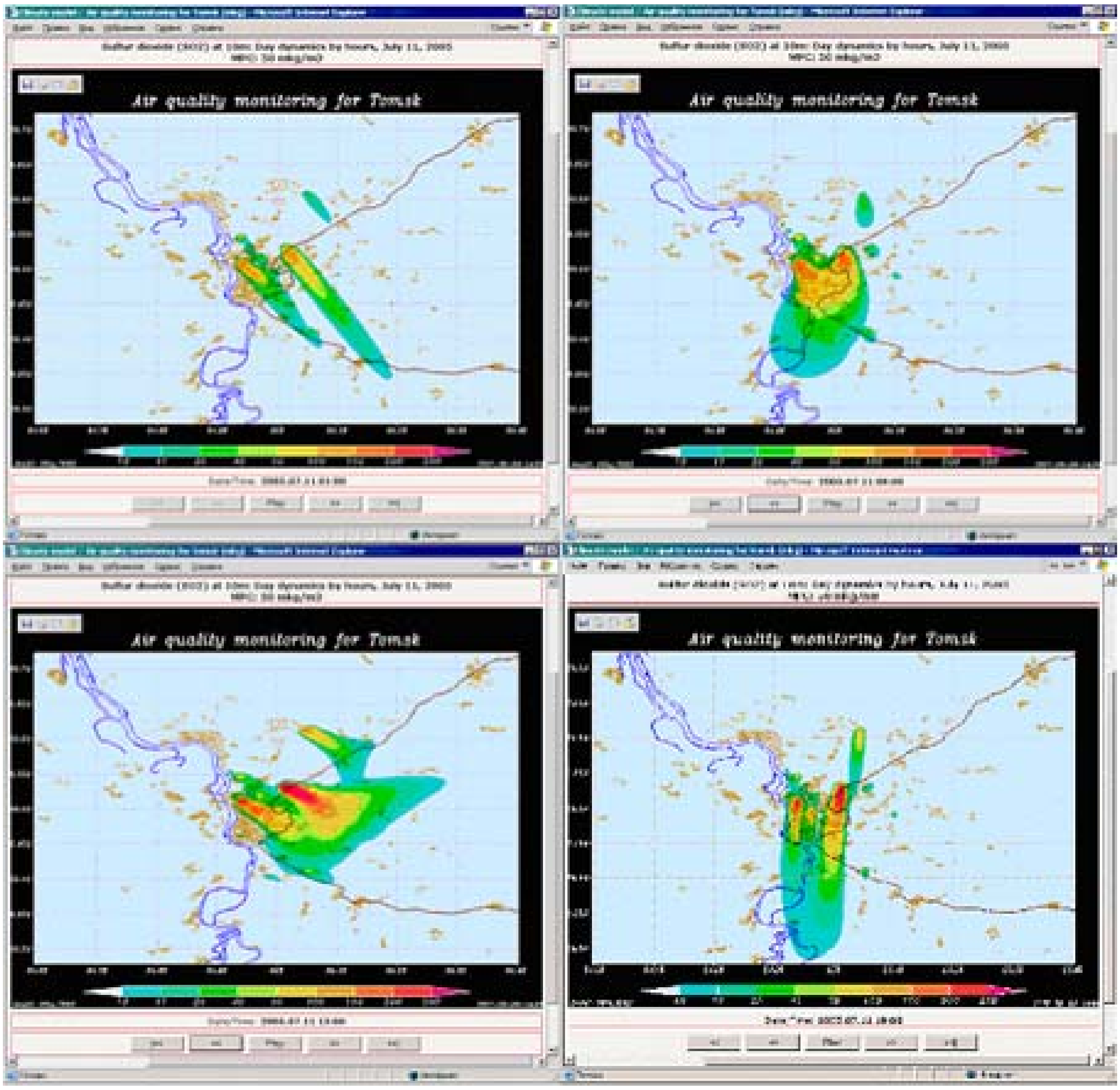

Fig. 15. Sulfur dioxide concentration dynamics during July 11, 2005.

Also monthly and seasonal dynamics of chosen pollutants can be visualized as well.

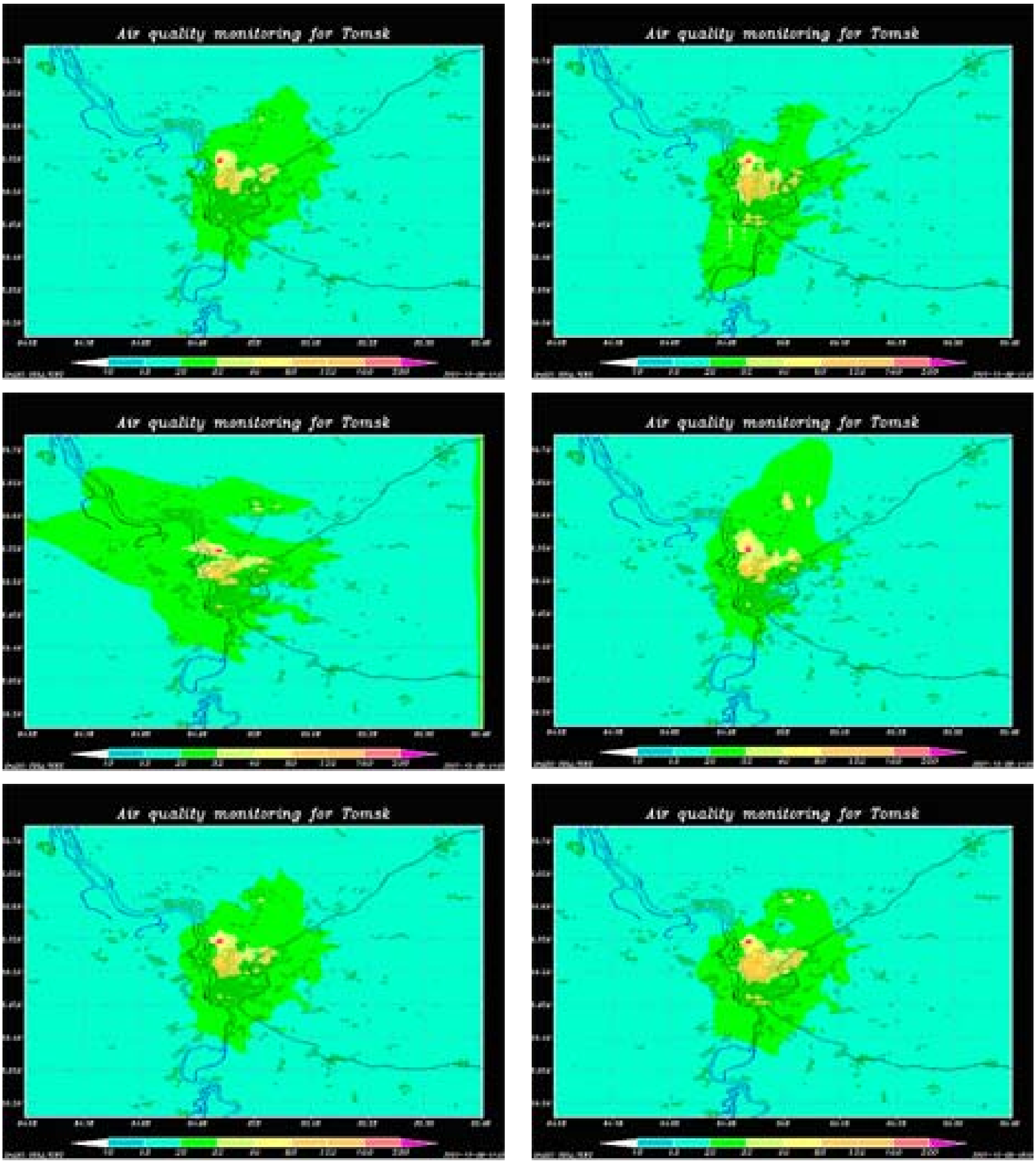

Fig.16. Monthly (July) NO_2 behavior in period 2001-2006.

The system might be used by regional ecologists and decision makers to determine characteristics of pollution distribution above the territory and their dynamics under different weather conditions, to estimate input of selected pollution sources (industry enterprises, transport, etc.) into the pollution fields, as well as to estimate consequences of possible accidents leading to additional pollutants blowouts. Also it might be used to understand degree of anthropogenic influence on regional environment and climate. It should be added that the system has generic character and being provided with characteristics of industrial and transport pollution sources, local meteorology data, surface properties and generated by the photochemical transport and transformations model pollution data sets it can be easily adjusted for conditions of an arbitrary city.

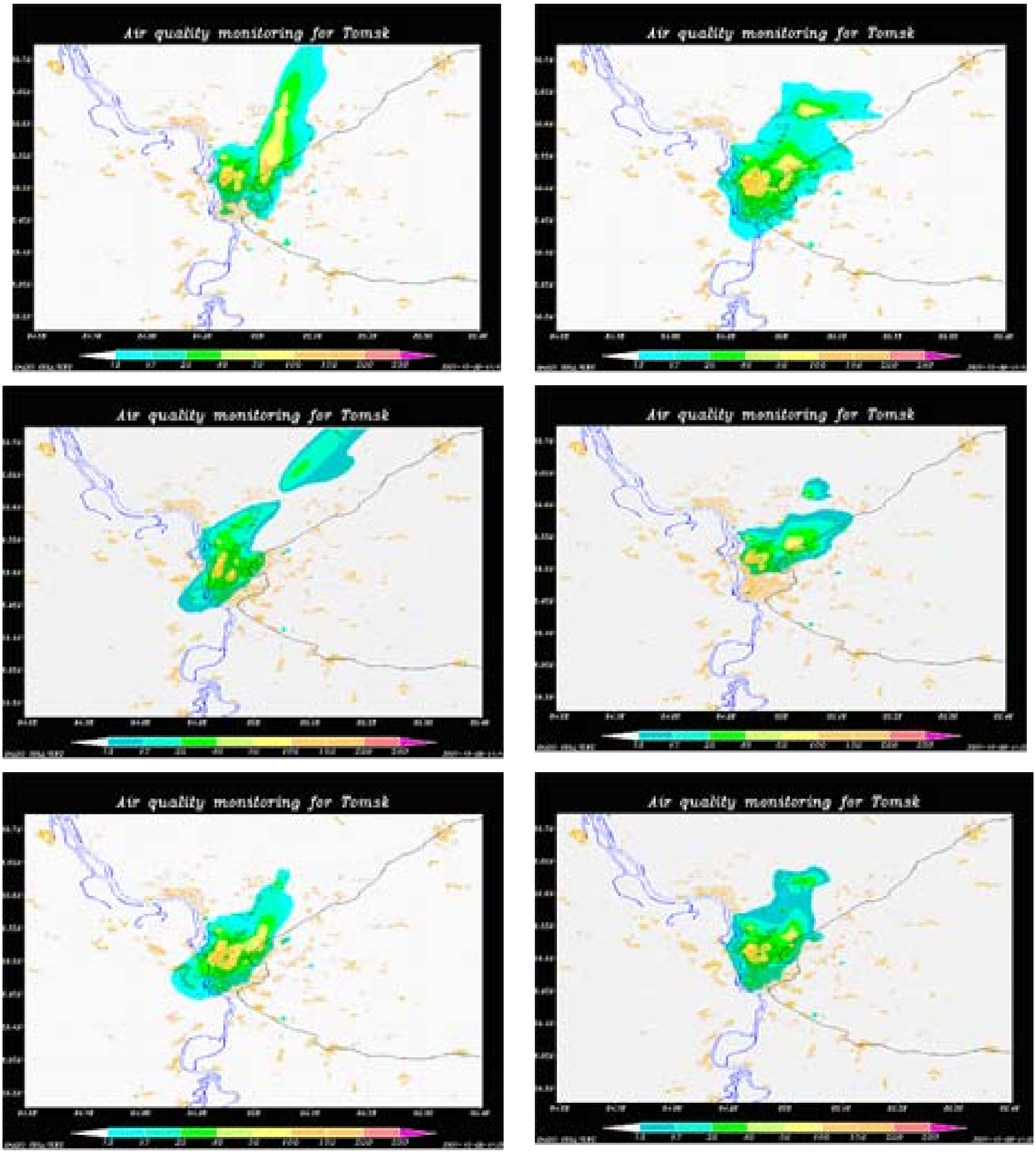

Fig. 17. Seasonal (Spring) SO_2 dynamics in 2001-2006.

1.6. Web-presentation of climate modeling results

The system developed at the Institute for Numerical mathematics is not integrated into the SIRS information-computational infrastructure yet. It contains description of the INM climate model and results of numerical experiments with this model and launched it at the INM site (http://kvs.inm.ras.ru/index.html). These numerical experiments were devoted to reproduction of climate change in the 20th century and estimation of possible climate change in the 21st and 22nd centuries. At the moment, there are 3 sections in menu of this database: 1) the description of the model and experiments, and some selected publications, 2) tools to calculate and plot one-dimensional data, and 3) tools for two-dimensional data post-processing and plotting. An example of the menu page is given in Fig. 18.

Fig. 18. Screenshot of the menu main page.

An user of this database has a possibility to learn on the present-day state of climate and climate change mathematical modeling, to extract the digital information related to modeled climate, to calculate and plot geographical distributions of climate characteristics for selected regions. The menu page with options for plotting geographical distributions of selected climate characteristics is given in Fig. 19. An example of 2-d plot obtained with the help of site tools is presented in Fig. 20.

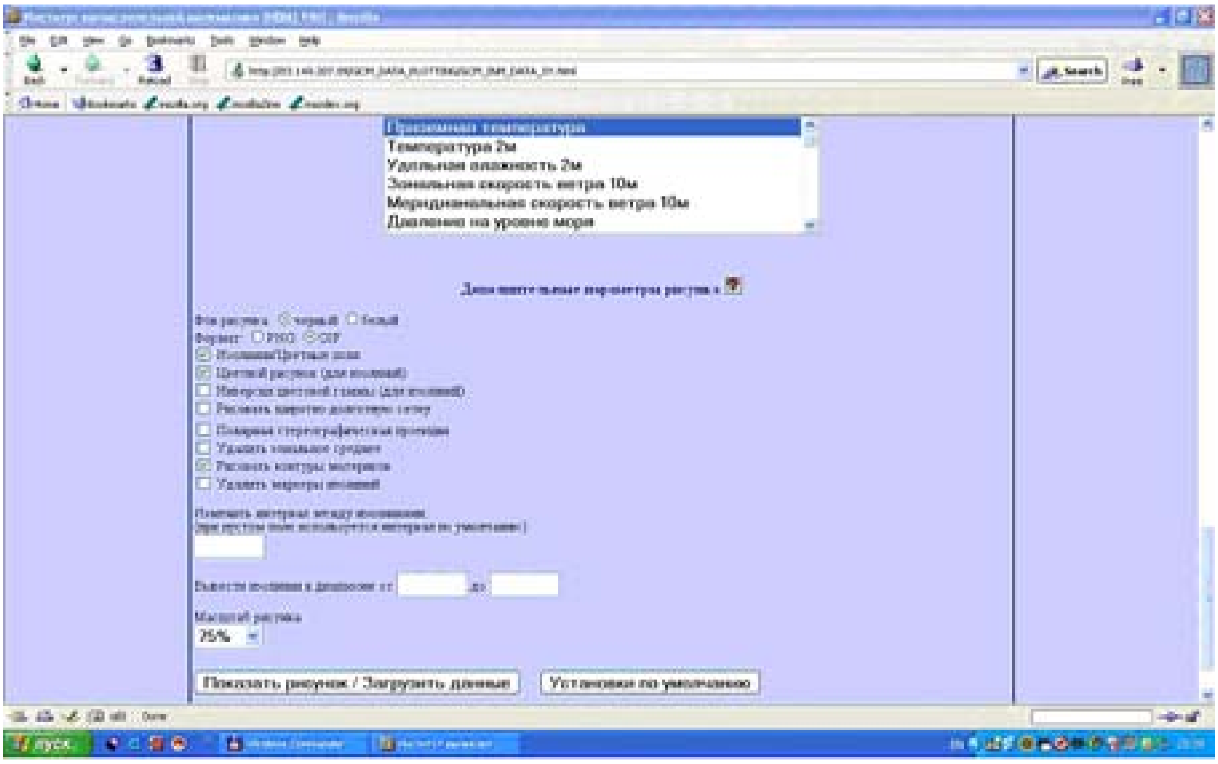

Fig. 19. Screenshot of menu page with plot options.

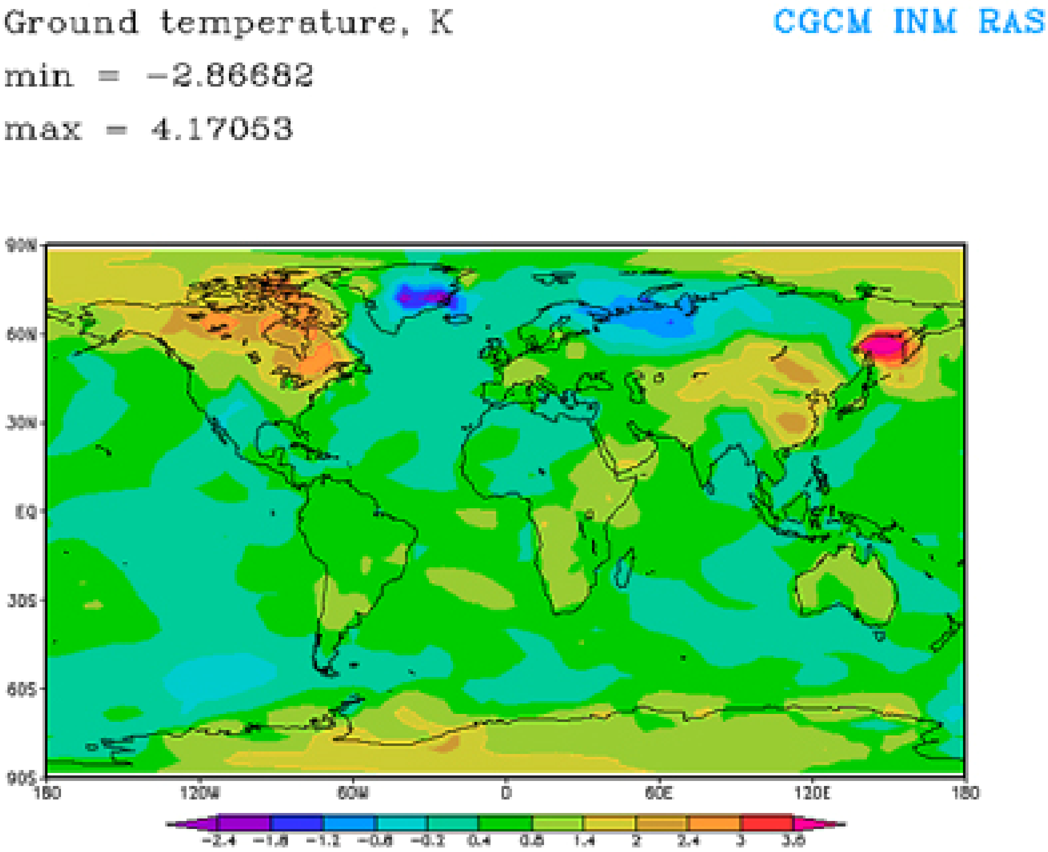

Fig. 20. Ground winter temperature difference between pre-industrial climate and the present-day climate.

Recently the bilingual (Russian and English) version of this site is implemented and additional datasets were made available and new numerical experiments were added to this database. These numerical experiments were devoted to reproduction of climate change in the 20th century and estimation of possible climate change in the 21st and 22nd centuries. There are 3 sections in menu of this database: 1) the description of the model and experiments, and some selected publications, 2) tools to calculate and plot one-dimensional data, and 3) tools for two-dimensional data post-processing and plotting.

Additionally to the coupled atmosphere–ocean general circulation model, an atmosphere model coupled with a simple balance model of the heat content of a homogeneous 50-m ocean layer is used. This model also involves the calculation of sea ice and uses the correction of heat fluxes at the ocean surface. Such a simplified coupled model allows prompt obtainment of an equilibrium response to a prescribed external forcing, for example, to an increase in the CO_2 concentration. Results from the following numerical experiments with this model are launched at the site:
1. Control “upper ocean” experiment (labelled as CNT 50M). This experiment is aimed on simulation of the climate of the late 20th century via a model with a 50-m ocean. The duration of the experiment was 60 years, excluding 20 years during which an equilibrium climate was reached.
2. Doubled CO_2 “upper ocean” experiment (labelled as 2CO2 50M). This experiment is different from the previous one by doubled CO_2 concentration. The duration of the experiment was also 60 years, excluding 20 years during which an equilibrium state of climate was reached.

The sensitivity of a climate model to an increase in the concentrations of greenhouse gases is characterized primarily by an increase in globally averaged surface air temperature under CO_2

increased by 1% per year up to its doubling and by an equilibrium increase in surface air temperature under doubled CO_2 in the model with a homogeneous 50-m ocean layer. In the INM model, according to the data obtained from the experiment with CO_2 increased by 1% per year, warming is 1.57 K under doubled CO_2 (years 41–60) as compared to the same years of the control experiment. This value is close to the mean (1.61 K) over all models participating in similar experiments in the CMIP (**C**oupled **M**odel **I**ntercomparison **P**roject) framework. The scatter in the data obtained with the models is sufficiently wide. For example, the minimum warming is 0.75 K, and the maximum warming is 3.77 K. The spatial distribution of the surface air temperature difference between two experiments is presented in Fig. 21, which was constructed with the help of cite tools for two-dimensional data post-processing and plotting.

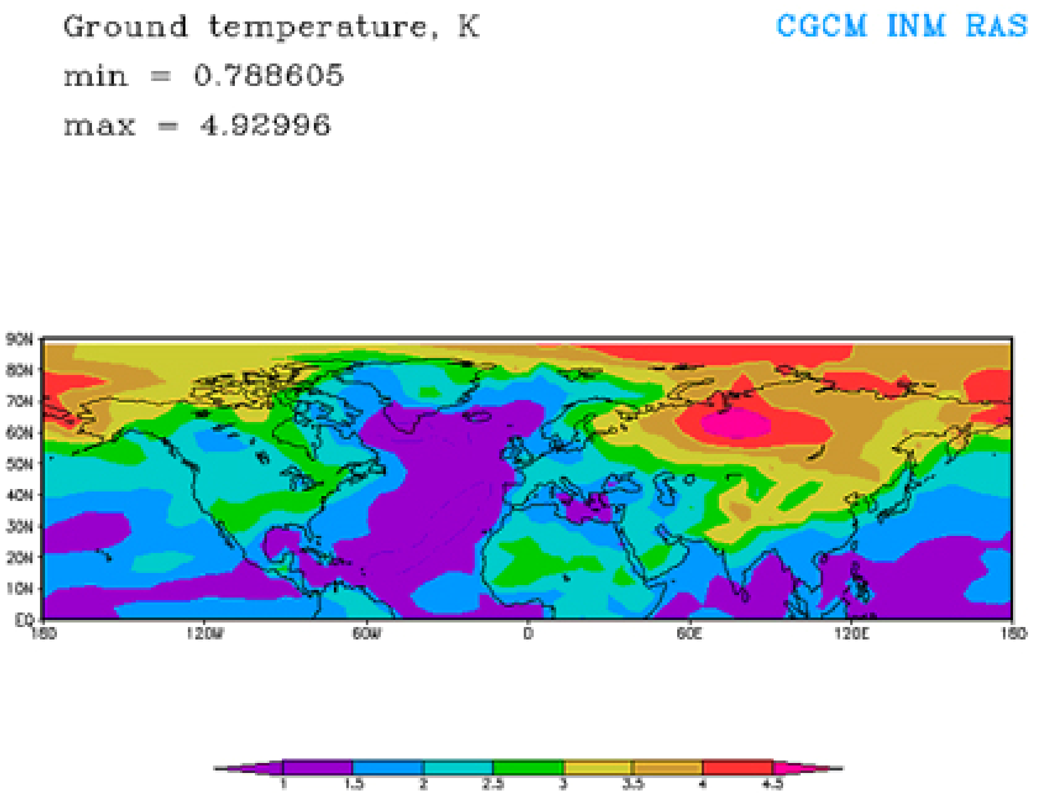

Fig. 21. Spatial distribution of the surface air temperature difference in the Northern Hemisphere due to CO_2 doubling.

At present, the above mentioned site should be considered as a demonstration of prototype for future bilingual site, which will be used for information exchange, scientific studies, e.g. devoted to possible catastrophic climate changes in Siberia, especially, in permafrost regions, and training, including educational process in universities.

Conclusions

As seen from above several useful for applications information-computational systems have been elaborated by this time. However they have proved their efficiency yet. This development should be continued. Next challenges in these directions are development of a web system for analysis of satellite images and a system combining GIS and web functionalities.

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2. Development of GIS-Technology Based Simulation of Atmospheric Pollution Caused by Oil-Field Operations in Caspian Region

2.1. Introduction

Regional problems of Kazakhstan and Siberia, in spite of all climate and landscape differences, are very similar due to high sensitivity of environment to climate changes and anthropogenic impact. In Kazakhstan it is risk of transformation of semiarid territories into desert, in Siberia it is degradation of forest-tundra especially in permafrost area. Besides, both regions have similar problems caused by development of oil-gas fields on large thinly populated territories. Under these conditions remote survey provides the possibility to monitor the Earth surface, to use natural resources and to undertake environment protection measures. However the best solution of regional problems can only be found after thorough analysis of process development with the use of mathematical and cartographic modeling methods. In this process information obtained with the use of satellite and aerial survey is the most important part of data simulation procedure. In the given report general approach and specific experience of space monitoring and geoinformation modeling of oil pollution of the sea and pollution of the atmosphere near oil extracting fields on the shelf of Caspian Sea is stated, which might be useful for investigations of similar regional problems.

As known, there are plenty of oil wells in the coastal zone of the North Caspian, where works on laying up and liquidation works have been carried out without taking into account possible flooding by sea waters, without taking into account shearing of ice, just by the simple blind closing. Thus, life of all creatures, living in Caspian Sea appears to be under dramatic effect of polluting substances which results in various negative consequences. Such objects are potentially dangerous and in the near future they can lead towards large ecocatastrophes with unpredictable consequences for the sea‘s biota and with significant difficulties for its liquidation. That is why the main task here is development of GIS technology for monitoring and modeling of the flooded oil wells. To solve this problem space survey data are used to detect oil pollution as well as forecast modeling to predict pollution spreading.

The flares used for burning of oil gas also have negative influence on the ecological situation of the region. But unfortunately they are the integral part of the technological cycle of oil production. During the process of oil field exploitation the particulate matter, sulfurous anhydride, carbonic acid, nitric oxide and carbohydrates are emitted into the atmosphere. Ecological situation is deeply aggravating because of the air basin pollution by the mercaptans that belong to the second class of the danger.

The solution of the defined tasks could be implemented by the use of mathematical models that enable one to simulate and to consider the suggested variants of the development of the situations caused by the influence of various factors and to make the decisions on mitigation of their ill effects in advance. Integrated ecological analysis of such complex object is a very important issue. Many serious interdisciplinary problems (mathematical, ecological, informational, etc.) related to the development of respective simulation model have to be surmounted to solve it [1, 2]. Atmospheric air protection presents a very serious problem, particularly recovery of associated and natural gas during the production of hydrocarbons. At present these gases are normally burnt in well head flares polluting vast territories with the combustion materials. Hydrocarbons evaporated from oil sumps, spilled oil, production equipment also contribute to the air pollution. GIS-technology presented below covers all stages of computation of air pollution by multiple oil/gas industry sources, from the location of well head flares to prognostic calculation of combustion materials distribution.

That is why the use of GIS technologies is the most effective approach in this matter. Following this approach the mathematical model is plunged into GIS and all the modeling and analysis phases are accomplished in the informational sphere, based on the real data. Such method is known as geoinformation modeling [3] and it shortens period during which research work is implemented into practice.

2.2. Mathematic simulation of industrial pollution of atmosphere

Mathematic model of industrial pollution of atmosphere IAP is based on the calculation of pollutant diffusion at specified time. This means that based upon input data the level of atmospheric pollution can be calculated for the current time or for the period of weather forecast. Furthemore, IAP has been developed as a GIS model i.e. it can be easily built in GIS developed in ArcGIS environment customized to the conditions of Kazakhstan sector of Caspian Sea. Mathematic foundation of IAP model is based on the concepts presented in [4]. During the model implementation as a part of GIS project, solutions developed in [4] were used.
The calculations are based on the formula of pollutants' mass conservation that describes advection, turbulent diffusion, chemical reactions, sewage and sources of contaminants:

$$\frac{\partial C}{\partial t} + div\left(C\mathbf{u}\right) + \sigma C = \mathbf{K} \bullet \mathbf{\Delta} C + f$$

$$\mathbf{u} = \{u, v, w\}, \quad \mathbf{K} = \{K_x, K_y, K_z\}, \quad \mathbf{\Delta} = \left\{\frac{\partial^2}{\partial x^2}, \frac{\partial^2}{\partial y^2}, \frac{\partial^2}{\partial z^2}\right\} \qquad (1)$$

In this formula C is pollutant's mass concentration, $\mathbf{u}$ is velocity vector of the medium (atmosphere or sea); $\mathbf{K}$ is vector of turbulent diffusion coefficients; f is for sources; σ is rate of precipitation.
Boundary conditions:

$$\frac{\partial C}{\partial z} = 0, \quad \text{где} \quad z = H(t)$$

$$-K_z \frac{\partial C}{\partial z} + \sigma C = \alpha, \quad \text{при} \quad z = z_0 \qquad (2)$$

$$C\big|_{\Gamma} = 0, \quad \text{при} \quad V_n < 0 \qquad \left.\frac{\partial C}{\partial n}\right|_{\Gamma} = 0, \quad \text{при}\, V_n \geq 0,$$

Input data:

$$C(t, x, y, z)\big|_{t=0} = 0 \qquad (3)$$

In these equations α is the surface source, z_0 is roughness, Γ is lateral face, n is outer perpendicular to the face Γ, V_n is perpendicular component of wind speed vector.
The equations (1) - (3) after the averaging of computation area over height can be converted to the following 2D equations:

$$\frac{\partial C}{\partial t} + div(C\mathbf{u}) + \sigma C = \mathbf{K} \bullet \mathbf{\Delta} C + f$$

где $\mathbf{u} = \{u, v\}$, $\mathbf{K} = \{K_x, K_y\}$, $\mathbf{\Delta} = \left\{\frac{\partial^2}{\partial x^2}, \frac{\partial^2}{\partial y^2}\right\}$

$$\sigma = \frac{1}{H - z_0}\left[\frac{\partial H}{\partial t} - \frac{V_d K_{z_0} \mu_0'}{K_{z_0} \mu_0' + V_d(\mu - \mu_0)}\right] \tag{4}$$

$$f = \frac{\alpha}{H - z_0} \cdot \left[1 - \frac{V_d(\mu - \mu_0)}{K_{z_0} \mu_0' + V_d(\mu - \mu_0)}\right] + Q$$

$$C\big|_{\Gamma} = 0, \text{ при } V_n < 0 \quad \left.\frac{\partial C}{\partial n}\right|_{\Gamma} = 0, \text{ при } V_n \geq 0 \tag{5}$$

$$C(0, x, y) = C^0(x, y), \quad \text{при } t = 0$$

All designations used here have been derived from the referenced work [4].
The numerical solution of Eqs. (4) – (5) was done with the help of a method proposed by Smolarkiewicz P.K., see references [5, 6, 7, 8], that allowed to reduce the influence of elasticity approximation.

2.3. GIS IAP modeling complex structure

The GIS IAP structure is shown on a drawing (Fig. 1). Actually the system consists of two parts. First is a creation of data modeling as a combination of input data and alternative computation algorithms. Second is a control program resulting in a computation of a chosen algorithm. Control program is highlighted by grey background on a drawing. Let's briefly describe the first part of a system – data modeling.

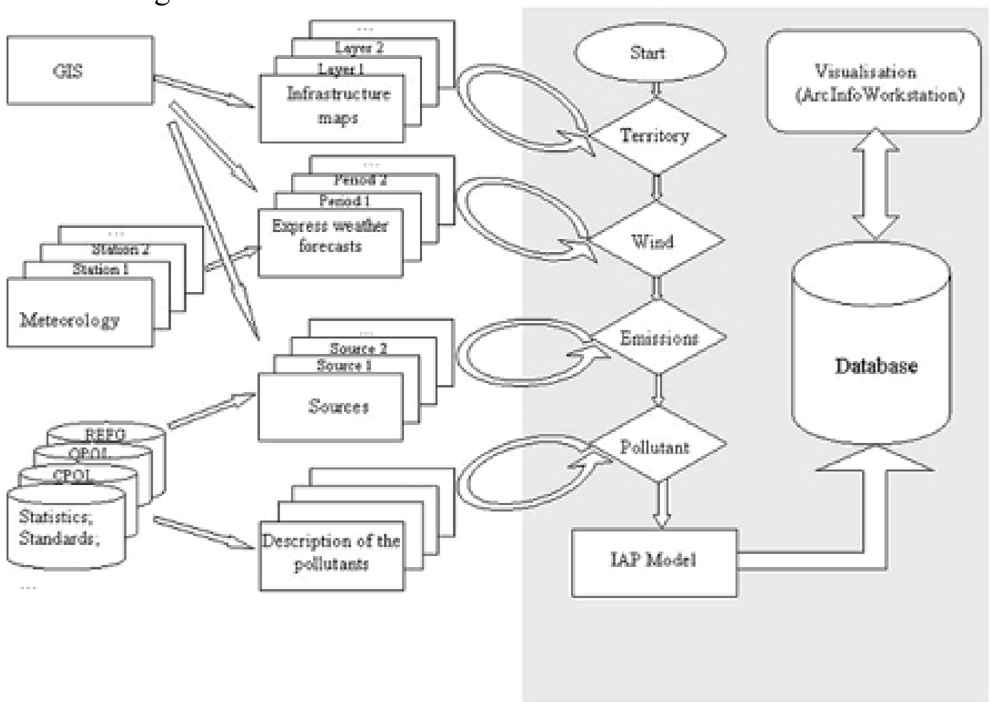

Fig. 1. Structure of GIS «IAP».

As one can see the data modeling part consists of 4 blocks: Territory, Wind, Emissions and Pollutant.

Window interface of the control program, consisting of main window, several ancillary windows, graphic display window and system console, is shown below (Fig. 2).

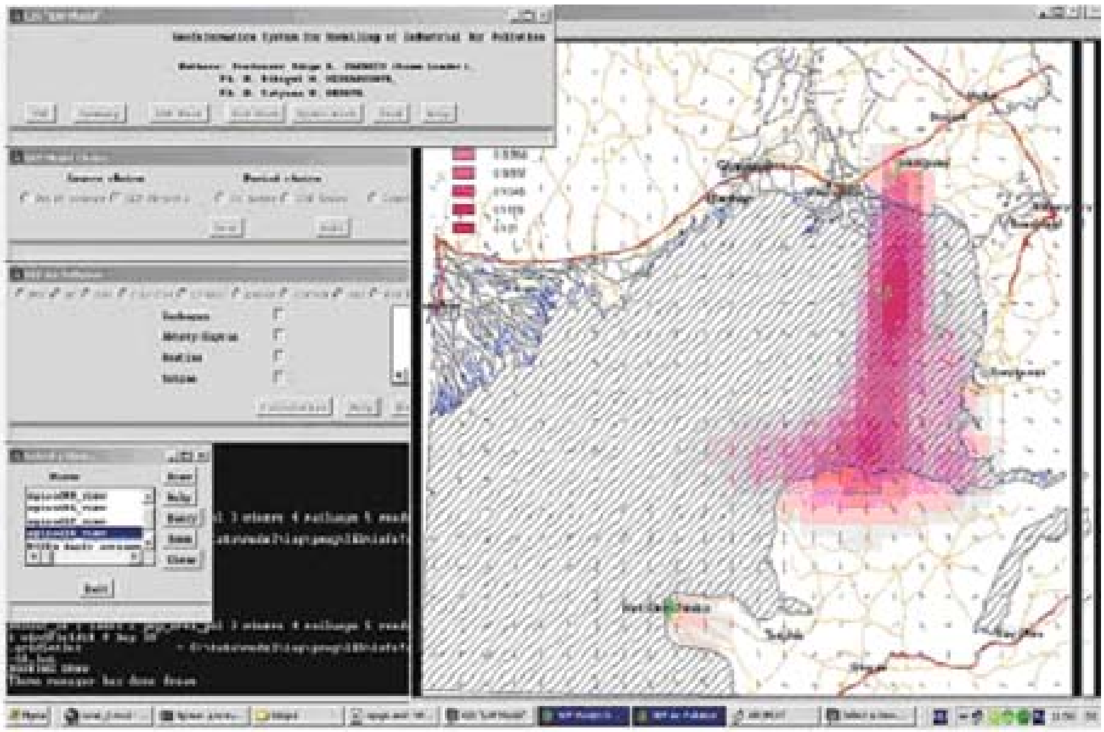

Fig. 2. Window interface of the control program.

2.4. Design of geoinformation modeling system (SysGISM)

For the purpose of unification of the methods of information systems development intended for the in-depth analysis of satellite survey data, a project was developed for the system of geoinformation modeling of territorial processes SysGISM (System of GIS - Modeling). Project decisions implemented in SysGISM are quite universal and can be used for the region of Siberia as well. UML (Unified Modeling Language) was chosen as a project tool. Preliminary analysis showed that UML suited the modeling of any system [9, 10, 11]: from enterprise level information systems to distributed Web-applications to even built-in real time systems. According to this method SysGISM project was done with UML stage by stage: (1) target setting, (2) analysis, (3) designing, (4) system programming.

Target setting defines the following requirements to SysGISM:

- Support operation of different GIS-technology applications;
- Make provision for SysGISM annexation to the National System of Space Monitoring NSSM as an analyzing subsystem;
- Provide the possibility of complex analysis of remote survey data, surface survey data and results of scientific researches of certain territorial processes;
- Make provision for the vacancies within the system for model designers and for the users of the results of modeling with common access to information thus speeding up the realization of scientific researches.

Object Field Analysis is the most important part and it is based on the development of certain models, describing the system from three different points of view. Those are: class model, state model and interaction model. The following classes have been defined (Fig. 3a)

- Class NSSM, identifying National System of Space Monitoring;
- Class CentreRS, identifying alternative (stand by) source of remote survey data;
- Class SysGISM, identifying the system of geoinformation modeling;
- Class Server, providing relations with the clients, uploading, storage and use of databases;
- Class ClientC, providing communication interface with the user, order creation, access to databases and report analysis;
- Class ClientE, providing communication interface with the designer, creation of reports, uploading and use of databases;
- Class GISTech, identifying GIS technology used by the performer.

Class model describes the structure of system objects, their personality, relationship with other objects (inheritance, aggregation, etc.), attributes and operations. Respective UML diagram is shown in a picture below (Fig. 3b), the attributes and operations are not specified since abstract SysGISM project will get the details during the design of real projects.

State model consists of several state diagrams, one for each of the classes, which development affects an application. State diagram is a standard information theory concept that links events and states. The events represent external actions and the states represent the value of the objects. State diagrams for classes ClientC and ClientE are shown in Fig. 3c below.

The last stage of object field analysis is an interaction modeling. Interaction diagram reflects all classes of the system and relationships among them. In an interaction diagram (Fig. 3d) ClientC and ClientE classes are specified as major classes and the rest of the classes are presented as personages.

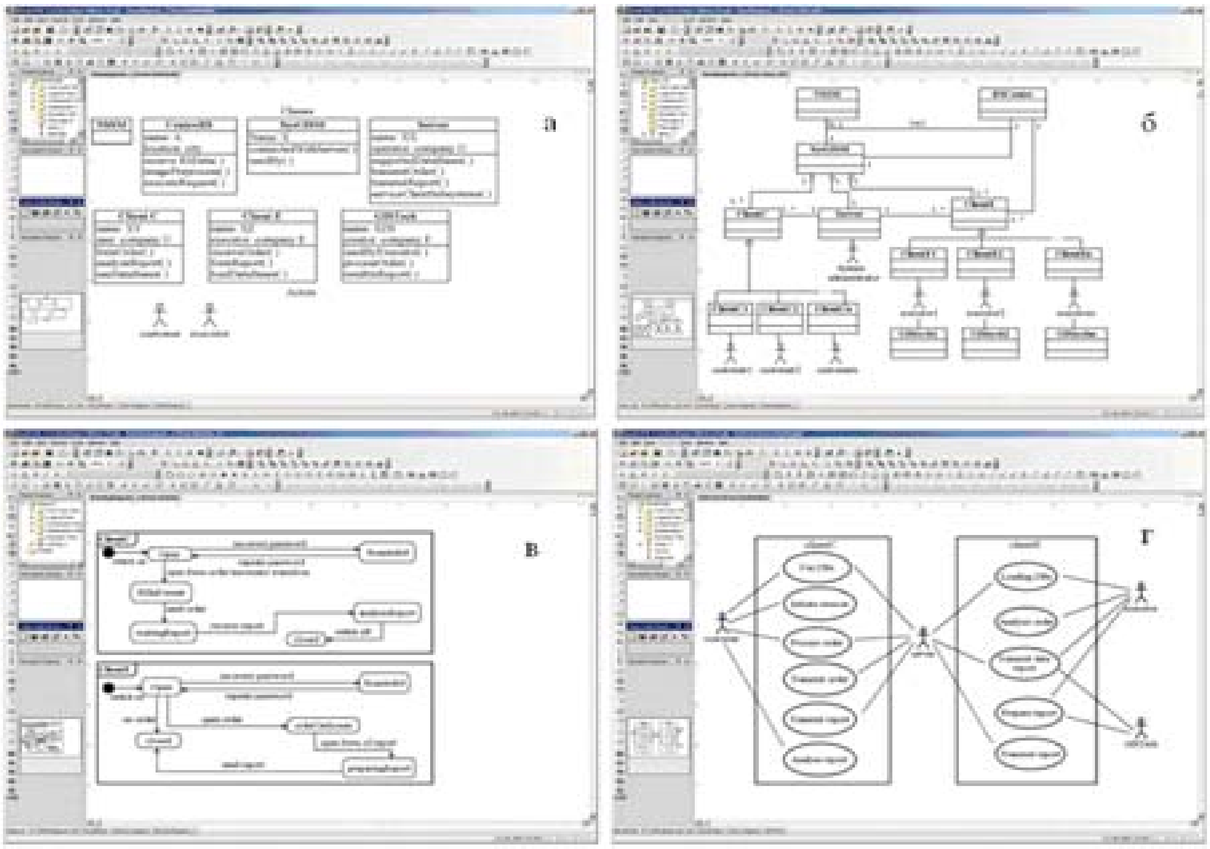

Fig. 3. UML diagrams used for the analysis of object field.

On the basis of presented diagrams the architecture of SysGISM system meeting all conditions of target setting was built. According to the architecture SysGISM system supports the communication between the users and designers of different territorial tasks, stores all related data on the territory and processes and provides advanced GIS service for storing and data processing via respective interfaces. During the design stage all details of object field models were thoroughly elaborated, UML diagram package was created to give the project specifics it needs for object oriented programming.

2.5. Remote survey data analysis with the purpose of detection of well head flares

Operative survey and interpretation of remote survey data is a mandatory part of monitoring of atmospheric pollution due to the well head burning of associated oil gas (AOG). For this monitoring MODIS remote survey data received from Terra satellite were used. Well heads burning of associated oil gas can be detected as high temperature zones, so fire detection algorithm available with ScanEx Image Processor software was applied. The procedure of monitoring of well head flares is as following:
a) Preliminary processing of MODIS data (decompression, calibration, geospatial analysis);
б) Classification according to fire detection algorithm.
Below (Fig. 4) a high temperature zone detected at Tengiz oilfield is shown.

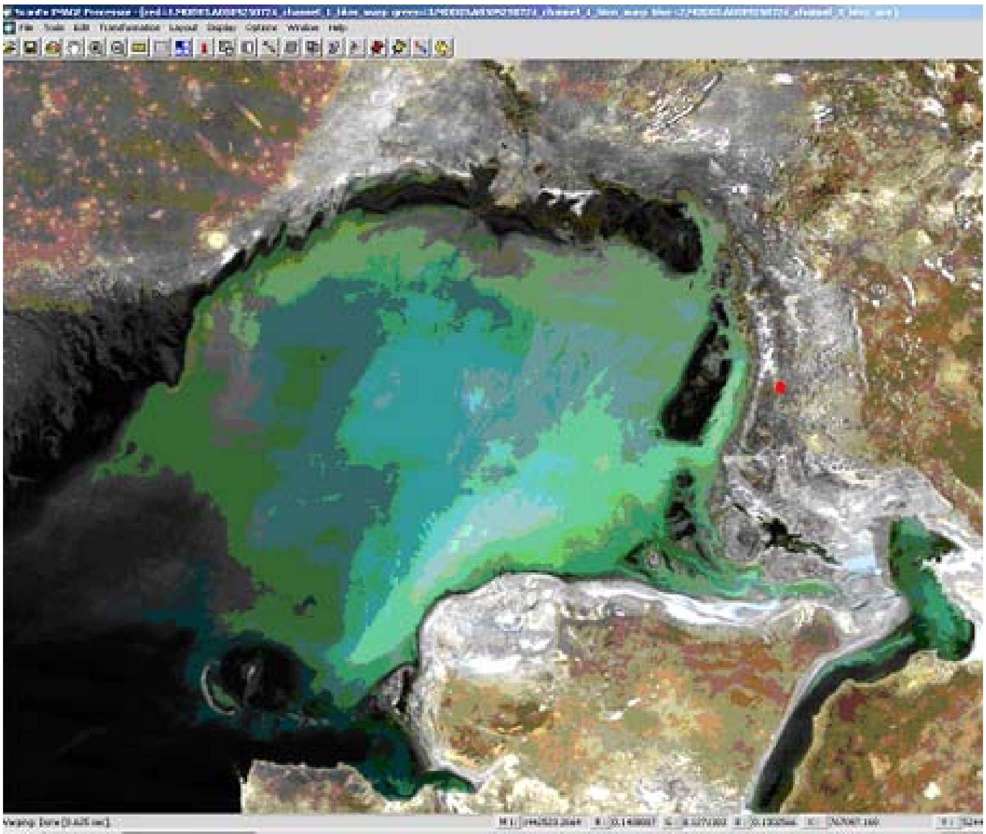

Fig. 4. Fire mask, Terra/MODIS data, September 25, 2005, red spot points to a gas flare at Tengiz oilfield.

Conclusions

The GIS systems developed form a bridge from basic science to its environmental applications. As it will be shown in the third Chapter their usage allowed us to consider a number of applied environmental problems and to suggest regional decision makers realistic ways to solve them.

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3. Integration and Synthesis: Applications of Information Technologies to Environmental Problems of the Region

3.1. Introduction

To understand dynamics of regional environment properly and perform its assessment on the base of monitoring and modeling, an information-computational infrastructure is required. Management of multidisciplinary environmental data coming from large regions requires new data management structures and approaches. In this chapter on the base of an analysis of interrelations between complex (integrated) environment study in large region and modern information-computational technologies major general properties of distributed information-computational infrastructure required in particular to support planned within Siberia Integrated Regional Study (SIRS) investigations of environmental changes in Siberia are discussed. SIRS is a Northern Eurasia Earth Science Partnership Initiative (NEESPI) mega project co-ordinating national and international activity in the region in line with Earth System Science Program (ESSP) approach. The infrastructure developed in cooperation of Russian Academy of Science (Siberian Branch) specialists with their European and American partners/counterparts is aimed at support of multidisciplinary and "distributed" teams of specialists performing cooperative work with tools for exchange and sharing of data, models and knowledge optimizing the usage of information-computational resources, services and applications. Recently developed key elements of the SIRS infrastructure are described in details. Among those are the Climate site of the environmental web portal ATMOS (http://climate.atmos.iao.ru) providing an access to climatic and mesoscale meteorological models and the Climate site of the Enviro-RISKS web portal (http://climate.risks.scert.ru/), providing an access to interactive web-system for regional climate assessment on the base of standard meteorological data archives. As an example of the system usage recent dynamics of some regional climatic characteristics are analyzed.

Below firstly the Siberia Integrated Regional Study (SIRS) will be described, which forms a testbed and major users community for the system under development. Then its information computational infrastructure based on yet developed elements will be discussed in more details.
To illustrate the system potential, dynamics of some regional climatic characteristics will be analyzed and discussed with its usage. Also usage of GIS approach to environmental modeling/monitoring will be illustrated on several Kazakhstan's examples as well recent results on territorial natural and man-made risks estimation for Krasnoyarsk region will be presented.

3.2. Siberia Integrated Regional Study

The regional (region here is a large geographical area, which functions as a biophysical, biogeochemical and socio-economical entity) aspect of science for sustainability and of international global change research is becoming even more important nowadays. It is clear now that regional components of the Earth System may manifest significantly different Earth System dynamics and changes in regional biophysical, biogeochemical and anthropogenic components may produce considerably different consequences for the Earth System at the global scale. Regions are "open systems" and the interconnection between regional and global processes plays a key role. Some regions may function as choke or switch points (in both biophysical and socio-economic senses) and small changes in regional systems may lead to profound changes in the ways in which the Earth System operates. Few years ago IGBP suggested [1] to develop integrated regional studies of environment in selected regions, which would represent a complex approach to reconstruct the Earth System dynamics from its components behavior. It considered as a complementary effort to the thematic project approach employed so far in the international global change programs. Nowadays Integrated Regional Study (IRS) approach is developed by the Earth System Science Partnership (http://www.essp.org/), joining four major Programs on global change research. IGBP initiative aimed at development of IRS in the most important regions of the planet puts a set of prerequisites for such studies:

- The concept should be developed in the context of the Earth System as a whole;
- Scientific findings should support sustainable development of the region;
- Qualitative and quantitative understanding of global–regional interconnections and the consequences of changes in these interconnections should be achieved.

The word 'integrated' in IRS refers specifically to two types of integration: (i) 'horizontal integration', involving the integration of elements and processes within and across a region; and (ii) vertical integration', involving the two-way linkages between the region and the global system. There are two examples of existing IRS - a matured large biosphere-atmosphere experiment in Amazonia (LBA, http://lba.cptec.inpe.br/lba/indexi.html) and a recently started ESSP Monsoon Asia Integrated Regional Study (MAIRS, http://www.mairs-essp.org/).

Siberia is one of the promising regions for the development of such basic and applied regional study of environmental dynamics [2]. Regional consequences of global warming (e.g. anomalous increase of winter temperatures [3]) are strongly pronounced in Siberia. This tendency is supported by the results of climate modeling for XX-XXII centuries [4]. The climate warming not only threatens Siberia with destruction of the most part of extractive and traffic infrastructure caused by the shift of permafrost borders northwards but also can change the dynamics of the natural-climatic system as a whole. Although many projects supported by national (SB RAS, RAS) and international (EC, ISTC, NASA, NIES, IIASA, etc.) organizations are devoted to study modern dynamics of Siberian environment, scientists know little about the behavior of main components of the regional climatic system as well as about responses and feedbacks of terrestrial and aquatic ecosystems. Regional budget of the most important greenhouse gases CO_2 and CH_4 still makes first steps with respect to individual land classes. Measurements *in situ* are limited and still lacking any systematic basis. Responses of boreal forests and Siberian wetlands to the climate change and the emerging feedback influencing the climate dynamics through exchange of momentum, energy, water, moment, greenhouse gases and aerosol are poorly understood and almost not identified yet. Change of climatic characteristics creates the prerequisites for large and significant biological, climatic and socio-economically coupled land use variations throughout this region. Science issues for region are growing in global importance not only in relation to climate change and carbon, but also for condition and stability of aquatic, arid, and agricultural systems, snow and ice dynamics. IGBP reported recently that the circumboreal region including Northern Eurasia is one of the critical "Switch and Choke" points in the Earth system, which may generate small changes in regional systems potentially leading to profound changes in the ways in which the Earth System operates.

The rather short-term SIRS history has been started in 2002, when Will Steffen (IGBP) at the conference on boreal forests in Krasnoyarsk had suggested launching, with assistance of SB RAS and on the base of its research infrastructure, SIRS project as a part of implementation of IGBP and ESSP regional strategy to develop one of Integrated Regional Studies namely here. This idea was supported by a group of Russian scientists and their abroad partners and specific activity had been begun under the overall coordination of the Siberian Center for Environmental Research and Training (SCERT) in 2003. The approach adopted was examined and endorsed by the Siberian Branch of the Russian National Committee for IGBP in 2005, which has decided that during the first stage of SIRS development it is necessary to focus on four lines of investigation:

- Quantification of the terrestrial biota full greenhouse gas budget, in particular exchange of major biophilic elements between biota and atmosphere;
- Monitoring and modeling of regional climate change impact;
- Development of SIRS information-computational infrastructure; and

- Development of an anticipatory regional strategy of adaptation to and mitigation of the negative consequences of global change.

The SIRS (http://sirs.scert.ru) development [5, 6] leads to appearance of number large-scale projects on Siberia environment investigations in line with SIRS objectives and very beginning of their clusterization. Among those are thematically relevant SB RAS Integrated projects (2006-2008), RAS Programs projects (2006-2008), as well as EC, ISTC and NASA funded projects and clusterization is giving them substantial added value. A key role in these projects is played by the institutes of SB RAS. At the same time, new and larger national and international initiatives are emerging to develop a study of that kind on the territory of the whole Northern Eurasia. Appeared few years ago as a joint program of RAS and NASA “Northern Eurasia Earth Science Partnership Initiative” (NEESPI) now has transformed into the international Program and quite recently it was adopted as one of external projects of IGBP. The list of projects that are currently under umbrella of NEESPI (http://www.neespi.org/) is quite impressive. After series of discussions it was agreed that SIRS will be a NEESPI mega project co-ordinating national and international activity in the region in line with ESSP approach. Among planned jointly steps to consolidate cooperation are organization of Distributed Centers to support NEESPI activity in the region based in Krasnoyarsk (Forestry and Remote Sensing) and Tomsk (Data and Modeling) as well as co-ordination of training and educational activity aimed at young scientists involvement into this scientific theme. The SIRS state of the art was examined recently at the Open Meeting of Russian Committee for IGBP at the ENVIROMIS-2008 Conference: Development of Siberia Integrated Regional Study (http://www.scert.ru/en/conferences/enviromis2008/).

It was stated that currently SIRS has four basic components:

- Scientific: Clustering national (SB RAS, RAS, RFBR) and international projects on Siberia environment in line with SIRS objectives;
- Infrastructural: Development of informational-computational infrastructure of integrated regional study of Siberia environment;
- Organizational: Siberian Branch of Russian National Committee for IGBP is responsible for SIRS development;
- Educational (capacity building): ENVIROMIS Multidisciplinary Conference with elements of YSS (invited lectures embedded as well as thematic workshops) & CITES (Computational and Information Technologies for Environmental Sciences) YSS and Conference (lecture courses, training sessions as well as invited lectures).

According to the Siberian Branch of RNC the initial stage of SIRS is and will be centered along the four following activities through a projects clustering approach:

- Study of greenhouse gases and aerosol exchange between biota and atmosphere ;
- Regional climate change impact monitoring and modeling;
- Development of information-computational infrastructure;
- Regional social-economical consequences of Global Change.

The most recent results in the first direction are related to boreal forests and wetlands, the two major Siberian ecosystems dynamics, with a special emphasis on their role in the carbon cycle as well as results of climatic modeling for the region under study and first elements of the SIRS information-computational infrastructure forming glue for relevant multidisciplinary research.
One of the key SIRS scientific activities is the study of the carbon cycle. A key experimental station is the ZOTTO tower. ZOTTO is legally owned and operated by the V.N. Sukachev Institute of Forest (Krasnoyarsk) and administered through the International Science and Technology Center (ISTC). It is scientifically lead by a consortium of core institutions:

- Max-Planck-Institute for Biogeochemistry, Jena (performing continuous biogeochemical trace gas measurements, eddy covariance flux measurements, meteorology observations and local ecosystem process studies),

- Max-Planck-Institute for Chemistry, Mainz (performing measurements of aerosols and CO_2 concentration and isotopes)
- V.N. Sukachev Institute of Forest (performing local ecosystem process studies).

This leadership is supervised by a scientific steering committee. A data management facility supports the exchange of measurements and auxiliary data among the different partners performing measurements at the tower.

As far as regional climate studies are concerned, statistical analysis and data reanalysis confirm a significant increase of weekly and monthly mean near surface temperatures in Northern Eurasia during winter, spring and summer seasons, and reveal temperatures time series inhomogeneities in some regions of Siberia. In the central part of Eurasia, the number of frost days increases annually by up to 1 day, while vegetation period duration increases by 1 day a year. It might manifest transient phenomena appearing at nonlinear climate system regime changes.

The educational/capacity building programme includes [7]
- ENVIROMIS biannual Multidisciplinary Conference with elements of YSS (embedded Invited lectures and thematic Workshops)
- CITES (Computational and Information Technologies for Environmental Sciences) biannual YSS and Conference (Lecture courses, Training sessions and Invited lectures).

The IC infrastructure is developed in cooperation with European and American partners. It aims at supporting multidisciplinary distributed teams performing cooperative work with tools for exchange and sharing data, models and knowledge. The use of information-computational resources, services and applications has been optimized. The key elements are Web portals in with thematic web sites are providing an interactive access to data, models and tools: ATMOS, RISKS & ENVIROMIS**.** A Web based online system for analysis of climatic changes allows processing and performing reanalysis of meteorological stations data archives in Siberia, leading to such results as those presented above.

The SIRS perspectives and associated hypotheses are as follows.
The main ecosystems under study are forests (Krasnoyarsk), wetlands (Tomsk), and permafrost (Tyumen). The structure is distributed between
- an Instrumental center (Krasnoyarsk - Tomsk participating for services),
- a data and services Center (Tomsk offering internet access to data and services for all participants)
- data and modeling Centers (Jena, Krasnoyarsk, Tomsk, Novosibirsk, Moscow).

The analysis is decentralized and involves all partners.

The creation of NEESPI/SIRS data bases and mirroring relevant NEESPI data bases in Siberia will provide regional researchers with easy and inexpensive access. SB RAS would be able to cover hardware, operational and internal traffic costs, if other funding agencies cover relevant software and external traffic cost.

The Organization of distributed NEESPI Siberia Focus Research Center (SFRC) is as follows
- Krasnoyarsk (SB RAS Institute of Forest and Siberian Federal University) is in charge of boreal forests study and GHG measurements and associated capacity building/education,
- Tomsk (SB RAS Institute of Monitoring of Climatic and Ecological Systems and Siberian Center for Environmental Research and Training) is in charge databases and modeling and capacity building/education

  SB RAS and SFU together with abroad partners would be able to co-fund SFRC, thus providing stability for its operations.

As underlined above, a distributed information-computational infrastructure is a prerequisite to successful SIRS development. Key features are as follows.

- In the adopted approach**,** each separate computational task can be represented as an information system, using a three-level model: data/metadata, computation and knowledge levels.
- It is implemented by developing Internet-accessible information-computational systems (Web sites and portals) for chosen thematic domains and organization of data and knowledge exchange between them to form a distributed collaborative information-computational environment supporting investigations in multidisciplinary area of Earth regional environment studies.

3.3. Information-computational infrastructure for Siberia Integrated Regional Study

The information-computational infrastructure takes advantage of the SB RAS IT structure [8] and includes the key elements listed above (ATMOS, RISKS, ENVIROMIS, web system for analysis of climatic modeling) [9] . All the above show that developed information-computational infrastructure supporting SIRS activity is an inherent part of this large scale multidisciplinary investigation of huge region environment dynamics. Moreover, currently SIRS is the testbed for Earth System Sciences Informatics approaches including environmental information-computational systems under development.

Among others, Enviro-RISKS Climate site, which is the online system for visualization and statistical analysis of meteorological and climatic data allows performing basic mathematical and statistical computations on various data delivered by observations (*in-situ*, satellites) and models (global and regional models, reanalysis) with consequent graphical representation of results. The system helps researchers to save time while performing the same repetitive analytical tasks via implemented access to datasets stored on the dedicated server. Additional datasets and additional functionalities have been developed recently, such as the computation of some standardized Climate Change Detection Indices (ETCCDI). The system is useful for regional meteorological and climatic investigations aimed at determination of trends of the processes being taken place. Also it simplifies the work with huge archives of the spatially distributed data. It should allow scientific researchers to concentrate on the solving of their particular tasks without being overloaded by routine work and to guarantee the reliability and compatibility of the results obtained. For example, using the Climate system one can easily see dynamics of winters in Eurasia (Fig. 1 below)

One can see that in results of global warming in the region occurred significant winter warming. zero temperature can occur in any place of Northern Eurasia (compare two upper panels), while well known" severe Siberian January frosts" became significantly less severe (see lower panel).

One more example of this system usage for analysis of recent dynamics of some regional climatic characteristics was recently reported [10]. Due to multifactor forming of atmospheric processes statistical methods are the most reliable approach to quantitative assessment of characteristics of climatic dynamics and the reported study deals namely with those. In particular, statistical properties of recent variability of precipitations and near-the-surface (2 meters) temperature in West Siberia were analyzed. To support this analysis a set of functions built into the web system was employed. Among those are determination of the first warm/cold day, week and month in a year (variability of the warm season duration); determination of number of days with daily mean precipitation amount from the chosen interval (variability of precipitation amount); determination of number of days with daily mean temperature from the chosen interval (variability of warming); calculation of correlation coefficients for different pairs of meteorological parameters (degree of their linear dependence,). Both, parametric and non –parametric statistical criteria were used for analysis. The analysis performed shows that precipitation amount is slightly decreasing during warm seasons and slightly increasing during cold seasons. However homogeneity of precipitation data sets allows one to consider these differences during last 50 years as insignificant. Analysis of daily temperatures dynamics for each season reveals their insignificant difference within obtained series. However mean temperatures for larger intervals (weeks, two weeks and month) for each season form inhomogeneous series. Thus one can state that according NCEP/NCAR Reanalysis and NCEP/DOE Reanalysis-2 data in West Siberia significant increase of mean temperatures takes place during spring and summer. For winter season results obtained reveals more complicate dynamics. Namely, weekly mean temperatures are decreasing, while for two weeks and monthly mean temperatures are increasing. It should be noted, that since the system is processing currently only fields of meteorological characteristics obtained from NCEP/NCAR Reanalysis and NCEP/DOE Reanalysis AMIP II projects, conclusions derived will characterize these data sets mainly. The latter are not fairy well correlated with reality in this region due to poor observational network taken into account.

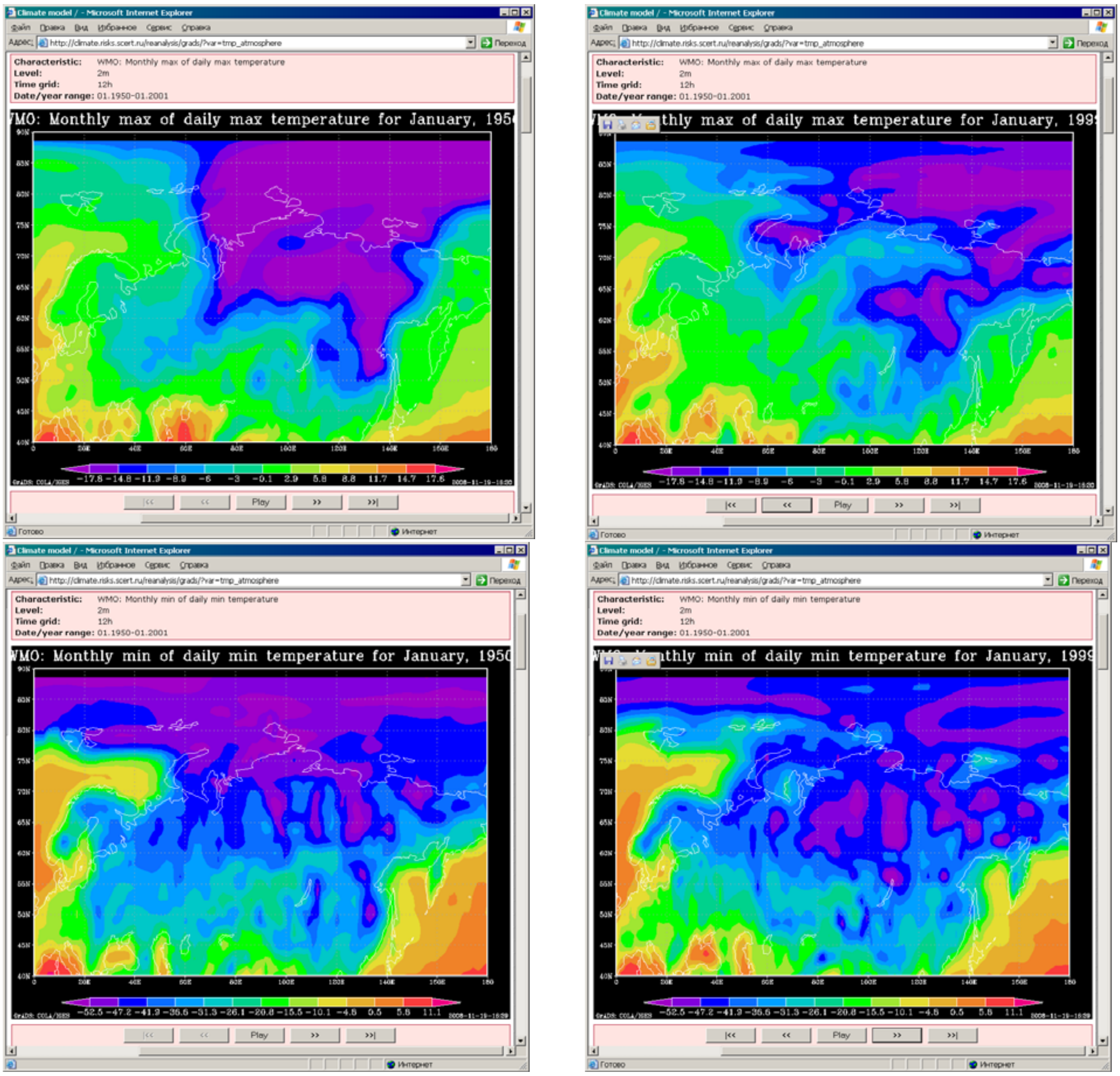

Fig. 1. Comparison of monthly maxima of maximal daily air temperature (above) and minima of minimal daily air temperature (below) for January 1950 (left panel) and January 1999 (right panel).

The based on mathematical modeling of the pollution transport and transformations web-system for Tomsk air quality assessment might be used by regional ecologists and decision makers to determine characteristics of pollution distribution above the territory and their dynamics under different weather conditions, to estimate input of selected pollution sources (industry enterprises, transport, etc.) into the pollution fields, as well as to estimate consequences of possible accidents leading to additional pollutants blowouts. Also it might be used to understand degree of anthropogenic influence on regional environment and climate. It should be added that the system has generic character and being provided with characteristics of industrial and transport pollution sources, local meteorology data, surface properties and generated by the photochemical transport and transformations model pollution data sets it can be easily adjusted for conditions of an arbitrary city.

As shown above developed key elements of SIRS information-computational infrastructure proved yet its efficiency. However, in order to serve educational and capacity building objectives, Information Computational technologies (ICT) tools should be newcomer friendly and provided with extensive thematic help. Earth & Space Sciences Informatics is dealing now with the following facing challenges. In particular, a holistic approach to mediate and harmonize the different models and interfaces characterizing the two communities (i.e. Information Society and Earth & Space Sciences) is required for a real interoperability. For instance:

- When addressed by the GIS (solid earth and societal impacts) community, the world is a collection of static *features* with geographic footprints on the Earth (surface). These *features* are discrete geometric objects with attributes which can be stored and manipulated conveniently in a database**.**
- When addressed by the Fluid Earth Sciences communities, the world is a set of *parameters* which vary as continuous functions in 3-dimensional space and time. The behavior of theses *parameters* in space and time is governed by a set of equations, while data are simply discrete points in the mathematical function space.

A possible answer is GIS web server based upon open codes. It could be developed by the SB RAS Institutes of Krasnoyarsk (Institute of Mathematical Modeling), Novosibirsk (Institute of Computational Technologies) and Tomsk (Institute of Monitoring of Climatic and Ecological Systems).

3.4. Calculation of the emission to atmospheric air due to associated gas flaring at well heads

For the regular oil production activity the emission rates can be obtained from 2TP-air forms but in case of venting or contingency emissions like during well tests or accidents, specified technique should be used. For the calculation of pollutants' emission in oil producing areas certified "PNG-ECOLOG" version 1.0 software developed by Integral company, Saint-Petersburg, is used. The software was approved by Voyeikov's MGO (see, for example, "PNG-ECOLOG" software implementation" in "Calculation of the emissions of pollutants to atmosphere during the flaring of associated oil gas", Atmosphere Research Institute, 1997). Example of calculation of the pollutants' emission to atmosphere during the flaring of associated oil gas is shown below (Fig. 2).

Calculations made with IAP model were based on taking into account of multiple industrial sources located in Kazakhstan sector of Caspian region. Total number of sources was 10. Calculation results of atmosphere pollution from different pollutants for November 16, 2004 are shown in the figures below. The results are shown for the different periods of time during the day of acquisition (Fig. 3, Fig. 4).

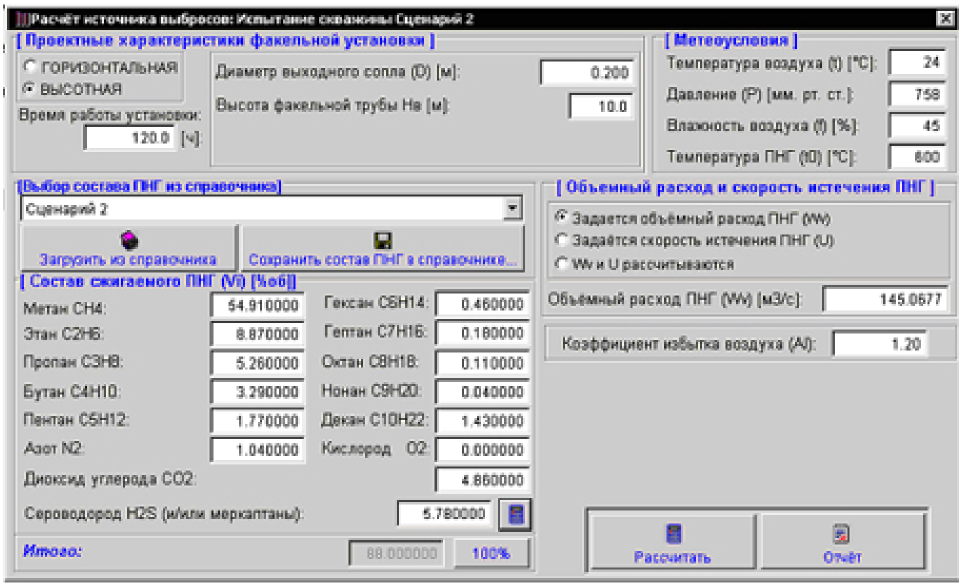

Fig. 2. Input data for the calculation of emissions with “PNG-ECOLOG”.

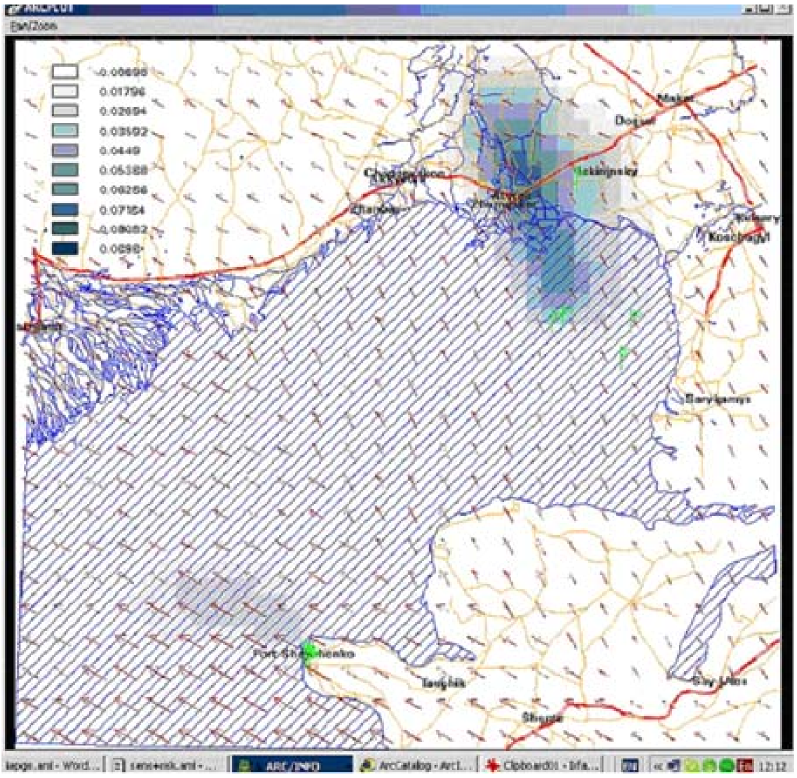

Fig. 3. Maximum rated territory. Pollution sources – oil/gas producing facilities. Emissions – according to the report 2TP-air for the first half of 2004. Meteofields – recovered from the weather stations data for November 16, 2004. Pollutant – 0330 sulphur dioxide. Time 06.00.

The mathematical models of air basin pollution are very helpful for the environment protection measures, forecasting the air quality, the projects of area development, and the regulation of emission of harmful substances. They enable calculating and considering all probable variants of situation development that are caused by the influence of various factors. They also allow making the decisions on decreasing their negative consequences in advance. For the solution of the atmosphere pollution control task during the flare burning of associated gas mathematical hemispheric model DERMA could be used (DERMA is Danish Emergency Responsible Model for Atmosphere, developed by Danish Meteorological Institute for modeling of pollution transfer, which is numerical 3-D atmospheric model of the Lagrangian type). DERMA was used to simulate a long-term atmospheric transport, dispersion, and deposition of pollutants [11]. The calculations of DERMA model for 1985 have been analyzed. This year has in average statistically typical meteorology. Two scripts of atmosphere pollution have been developed:

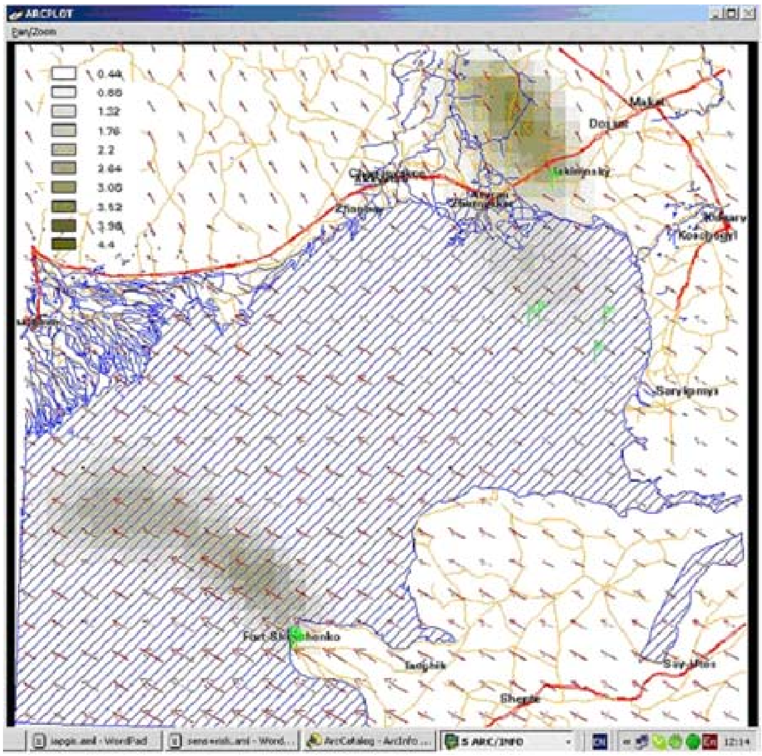

Fig. 4. Maximum rated territory. Pollution sources – oil/gas producing facilities. Emissions – according to the report 2TP-air for the first half of 2004. Meteofields – recovered from the weather stations data for November 16, 2004. Pollutant – 0006 VOC. Time 12.00.

1. Large failure on oilfield Kashaghan on a shelf of Caspian Sea, accompanied by emission of large amount of sulphuric anhydride. It was supposed, that failure happened on January, 1, the source functioned for 24 hours, pollutant was distributed for 15 days. Power of a source during modeling was equal to 105 kg/s.
2. All-the-year-round burning of associated oil gas on a flare of Kashaghan oilfield. The flare was lit on January, 1 and burned the year round. Distribution of sulphuric anhydride has been calculated. Source power during modeling was equal to 0.05 kg/s.

For every calculation day there are 4 types of the output data:

- Air concentration;
- Dry deposition;
- Wed deposition;

Processing of the received DERMA model results have been made in the following way:

1. The executable file was run that assigned for the text results extraction from the archives and the fragmentation of every text file onto 28 separate files. Each extracted file corresponds to a certain calculation day, a certain calculation point and a certain type of the output data. It also represents a set of spatially distributed data in ASCII format for 14 calculation days after every 12 hours – altogether 48 sets divided between themselves by the information line about a present step and the first calculation day. After that, we had 1 text file corresponded to each calculation day. This file contained both spatially distributed information on one type of the output information and data on coordinate reference of this file that was ready to be converted in grid format in ArcInfo Workstation.

2. The aml-file from the ArcInfo Workstation Software product was run that accomplished the following actions:

- Converting of ASII files in grids;
- The geographical coordinate system definition for each grid;
- Grid reprojection into Lambert azimuth projection for more obvious presentation of the received results;

Map formation in ArcMap.

In the figures presented below, results of model DERMA work for the script 1 on all three parameters - pollutant concentration (Fig. 5), dry sedimentation (Fig. 6) and sedimentation due to deposits (Fig. 7) are illustrated. As it is seen from the pictures, under meteorological conditions similar to those of 1985, the polluting substance will be distributed basically towards Russia partly capturing western and northern areas of Kazakhstan. On the same territories there will be a dry and wet sedimentation.

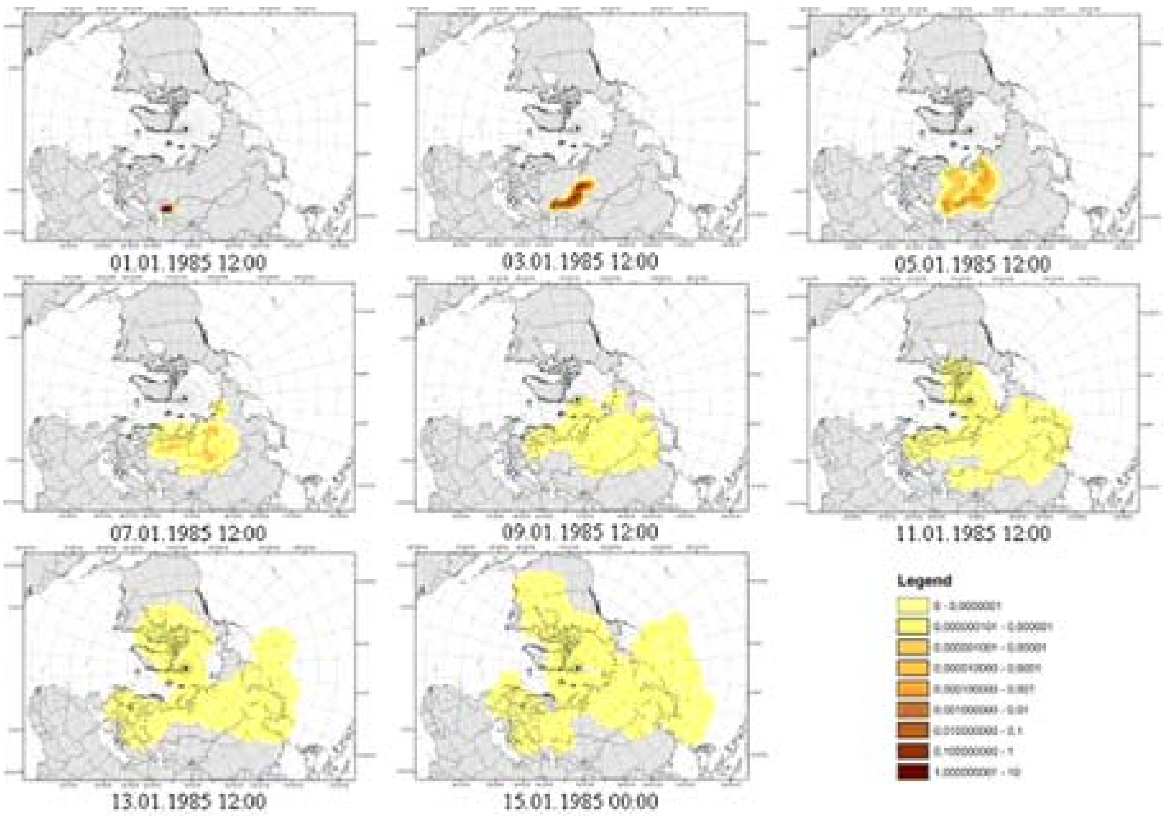

Fig. 5. Pollutant concentration.

As it is seen from the figures, under meteorological conditions similar to those of 1985, the polluting substance will be distributed basically towards Russia partly capturing western and northern areas of Kazakhstan. On the same territories there will be a dry and wet sedimentation.

Results of calculations under the script 2 are represented below as monthly average ground concentration.

Since DERMA model is a trajectory model, the continuous source was modeled as a transfer of a series of discrete emissions, each of which was distributed and dispersed during 15 days. Calculations under this script show that in this case atmosphere pollution occurs basically on the Caspian Sea near the areas of emissions. Distant admixture transfer is carried out in various directions depending on a month, but, basically, eastwards (see Fig. 10), and the concentration is very small.

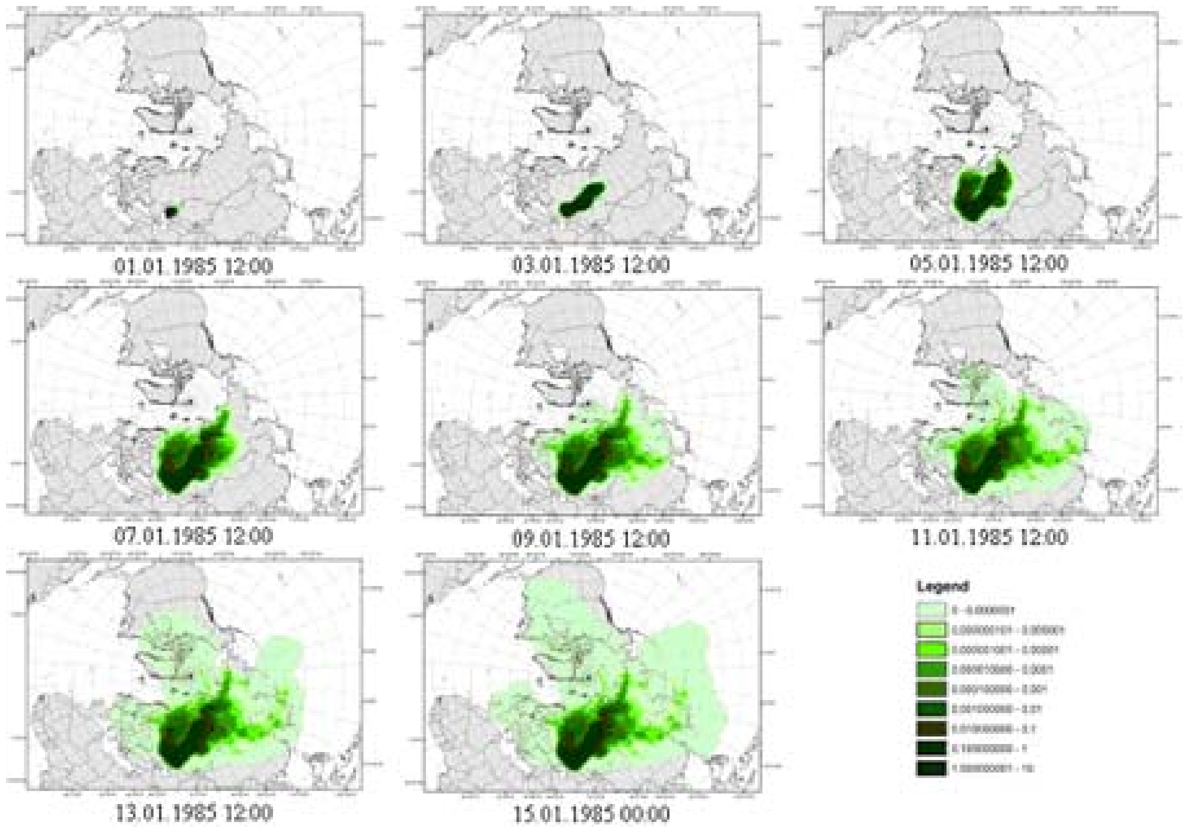

Fig. 6. Dry sedimentation.

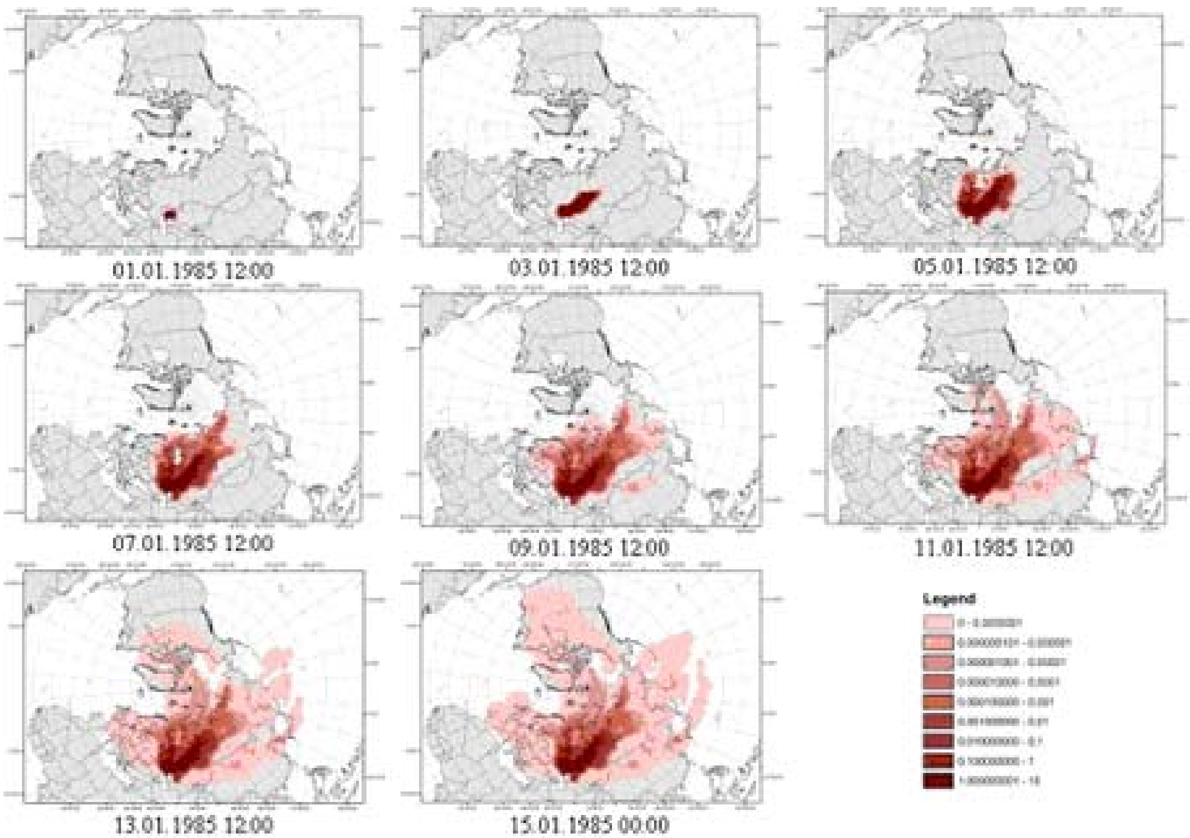

Fig. 7. Sedimentation due to deposits.

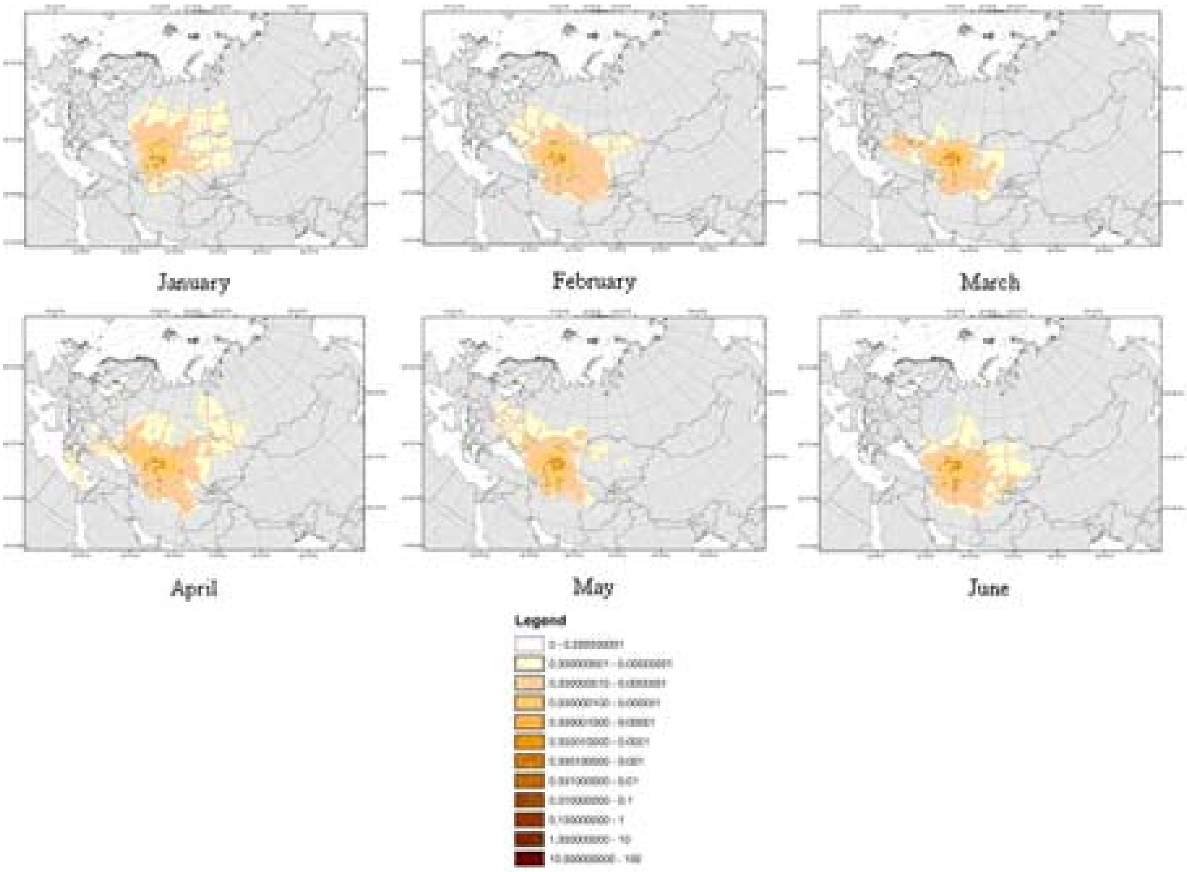
January
February
March
April
May
June
Legend

Fig. 8.

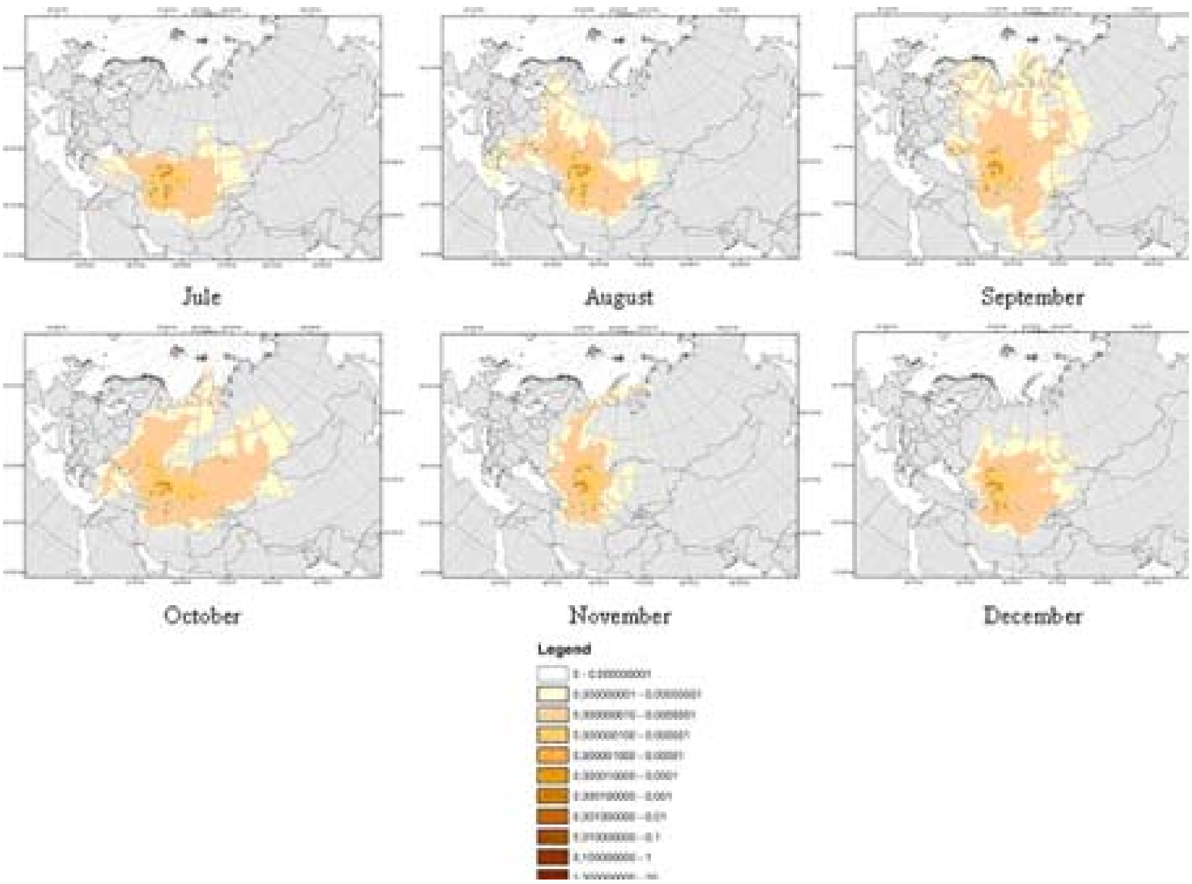
Jule
August
September
October
November
December
Legend

Fig. 9.

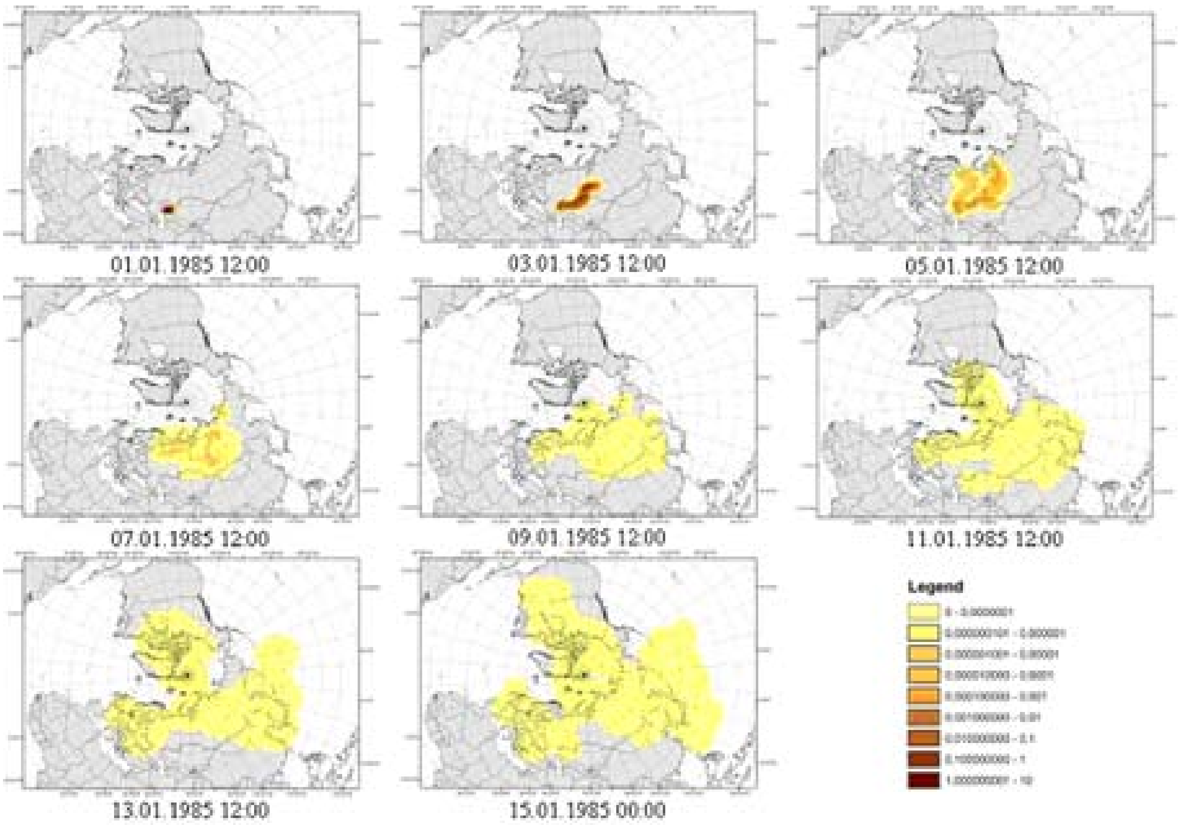

Fig. 10. Near surface concentration (μg/m^3).

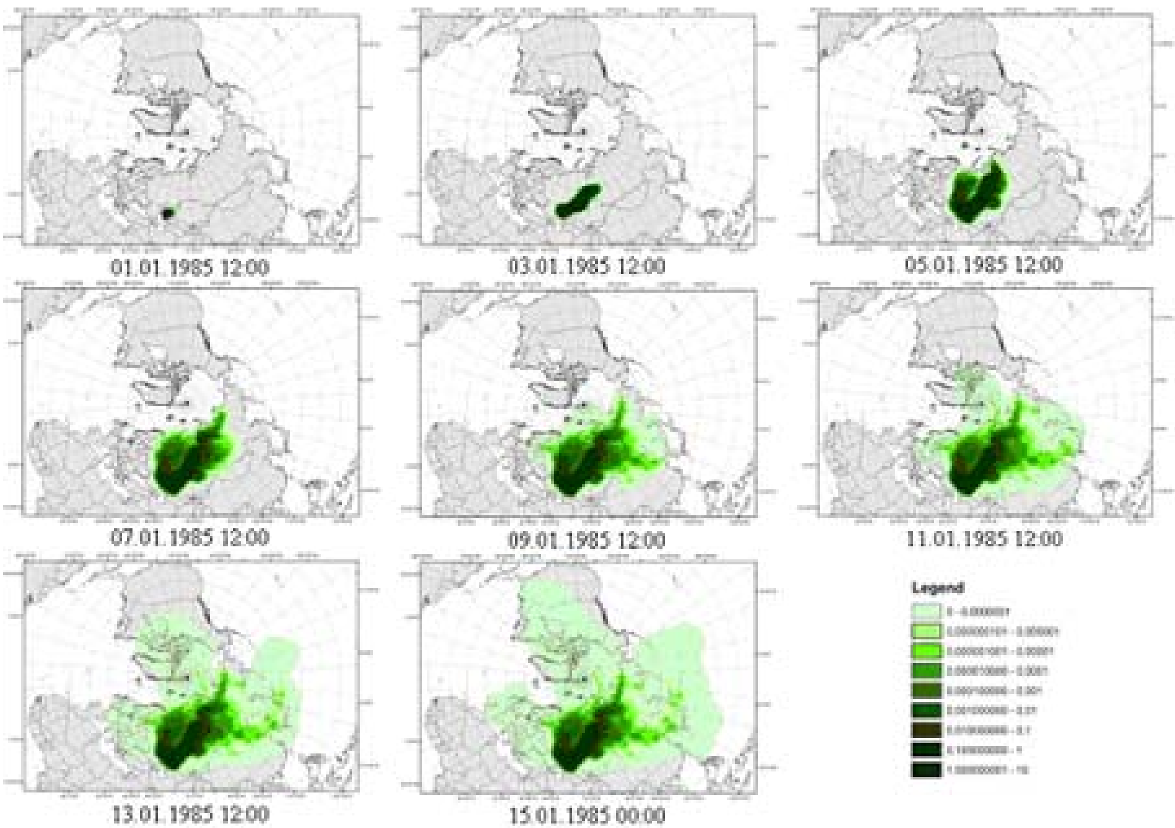

Fig. 11. Dry deposition ($\mu g/m^2$).

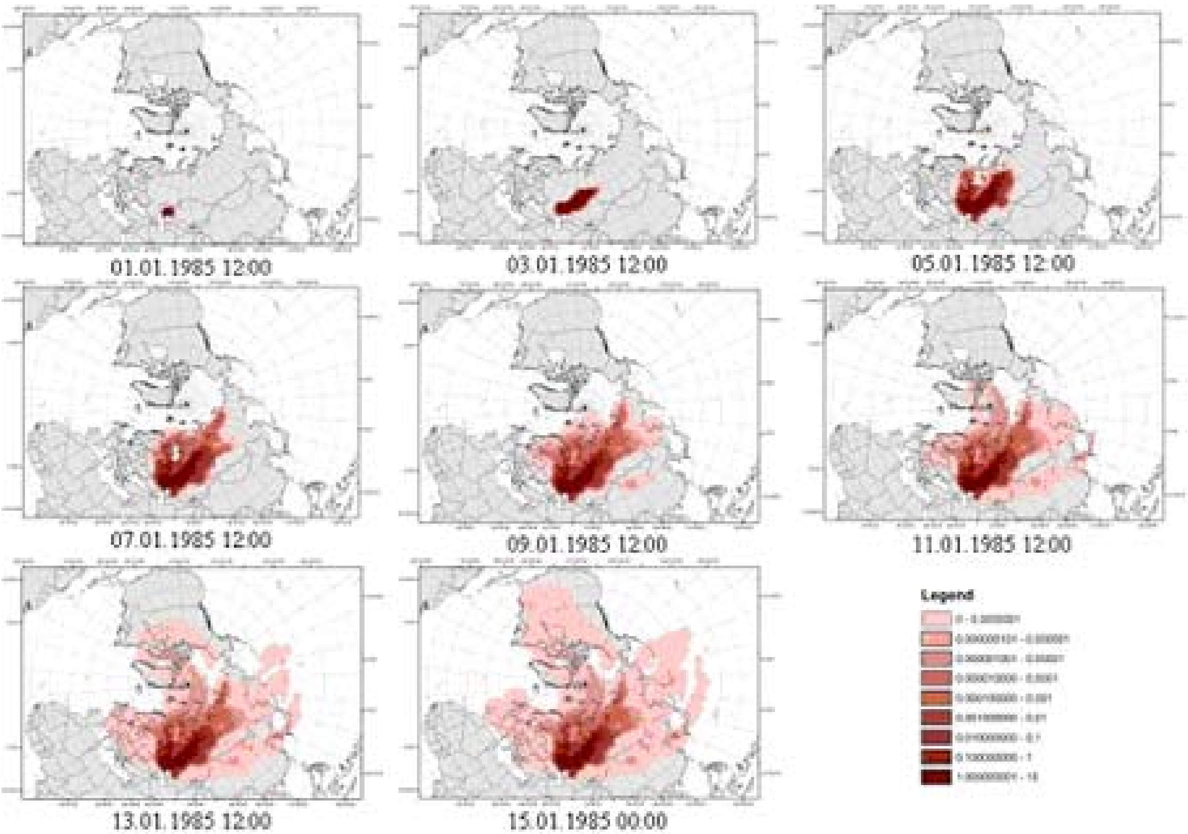

Fig. 12. Wet deposition ($\mu g/m^2$).

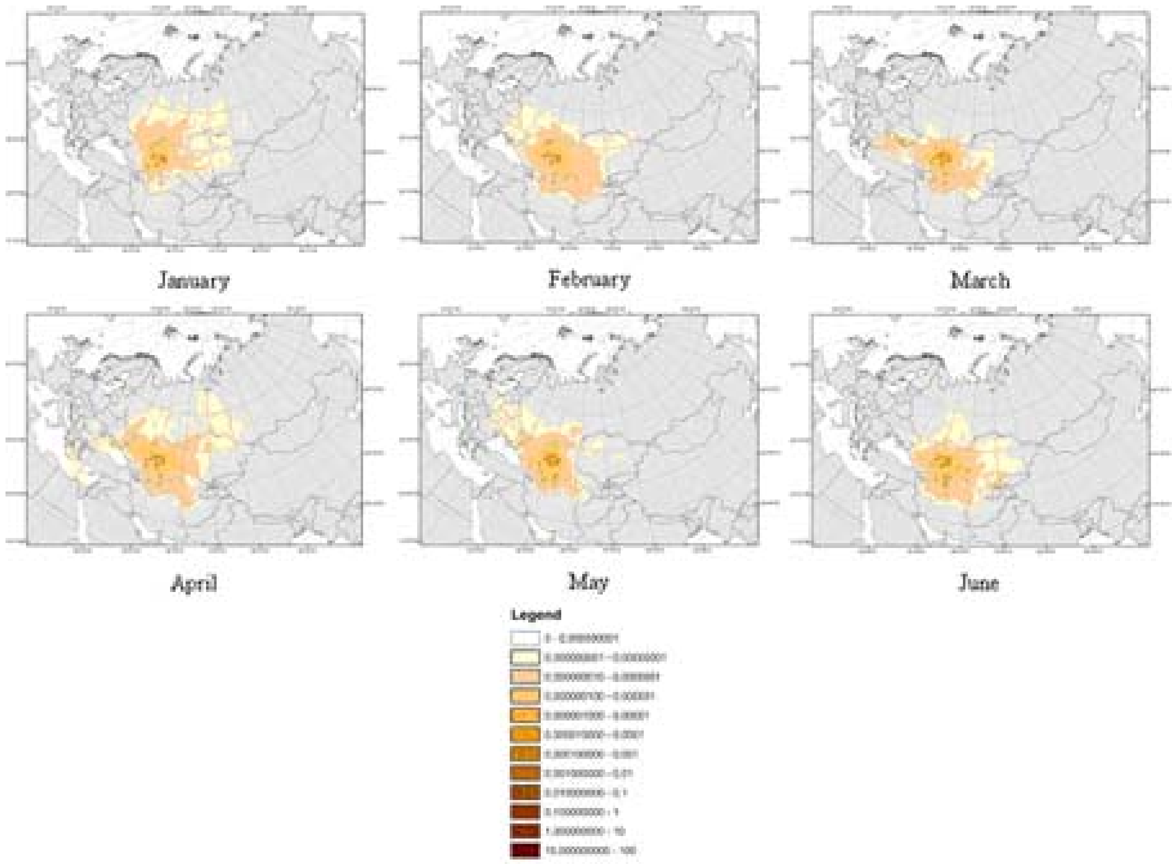

Fig. 13. Average near surface concentration ($\mu g/m^3$).

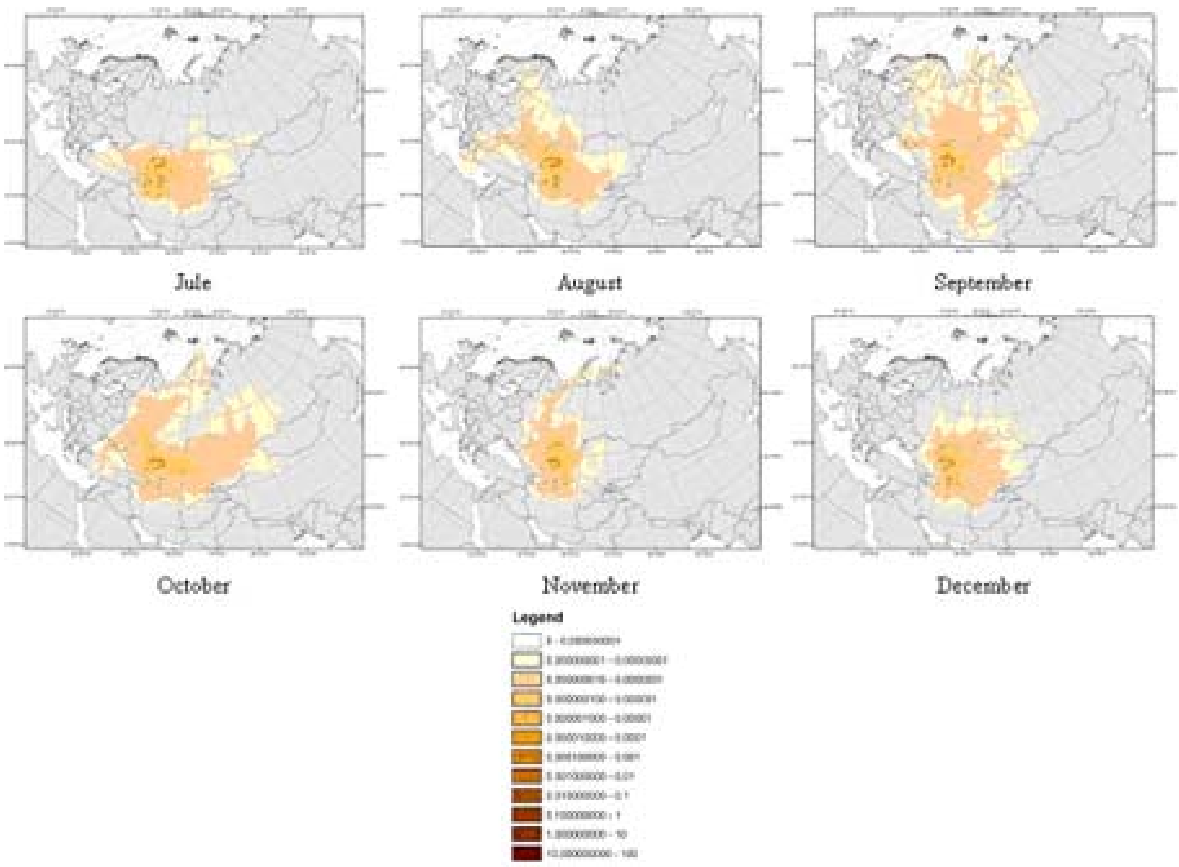

Fig. 14. Average near surface concentration (µg/m^3).

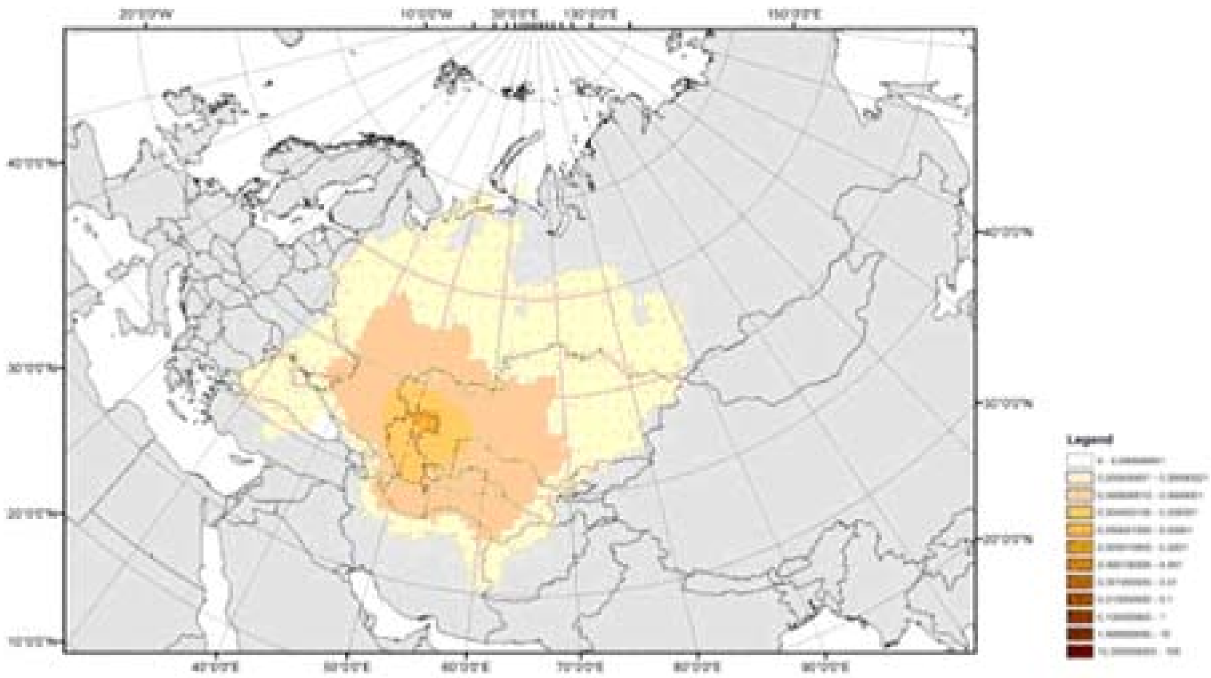

Fig. 15. Semi-annual near surface concentration (µg/m^3).

3.5. GIS- technology for monitoring and modeling of oil pollution spreading at sea

The problem of oil spill and systematic oil leakages, especially from the flooded and underflooded wells, is, no doubt, among the most serious ones that occur during developing of oil and gas areas of the Caspian Sea shelf. During the development of oil and gas areas on the shelf the necessity of forecast of oil spill spreading and the development of adequate tools and methods for the liquidation of pollution influence on seawater areas and coastline is sharply arising. That is why when developing GIS technology for monitoring and modeling, 2 main tasks are pointed out:

1. The realization of continuous space monitoring of the north part of Caspian Sea with the purpose of oil spill detection and definition of the polluter and oil slick area;
2. The realization of modeling of oil pollution spreading at the North Caspian Sea.

The problems connected with the environment pollution as a result of oil spills led to the necessity of development of mathematical models that describe the process of oil spill transfer. The Spill Analysis module of MIKE 21 software of the DHI Water & Environment Company is the most effective here. It is oriented on the solution of the following tasks:

- The forecast of oil spill spreading on-line;
- Risk analysis
- The calculation of possible spills that can help in working up of the plan on immediate reaction and evaluation of possible ecological damage.

For the flooding forecast caused by the flood and dry processes, the test site is chosen, its coordinates are: 44° of the north latitude, 49°30’ of the east longitude, 48° of the north latitude, 54° of the east longitude. Its area is about 151.5 thousand km². It includes territories of Atyrau and Mangystau regions. The research works cover the northern part of the Caspian Sea with its coast almost from the Kazakhstan border with the Russian Federation in the west (area of a settlement Kockarna) up to settlement Kulsary in the east and to the south of Fort-Shevchenko town (Fig. 16). In the following Fig. 17 a space image is of a test site from the scanner MODIS of satellite Terra for October 25, 2006 07:08 GTM is represented.

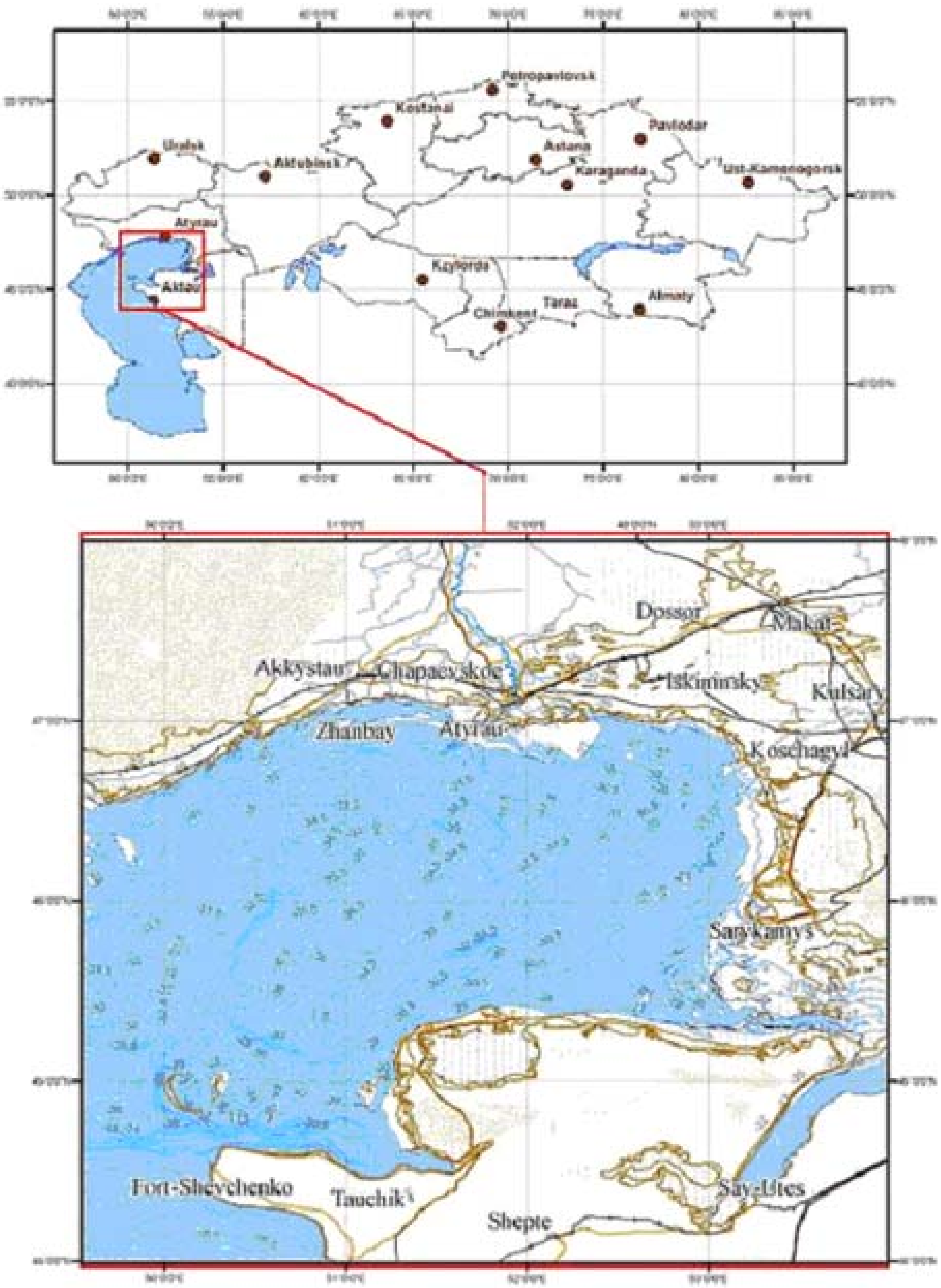

Fig. 16 Map of test site.

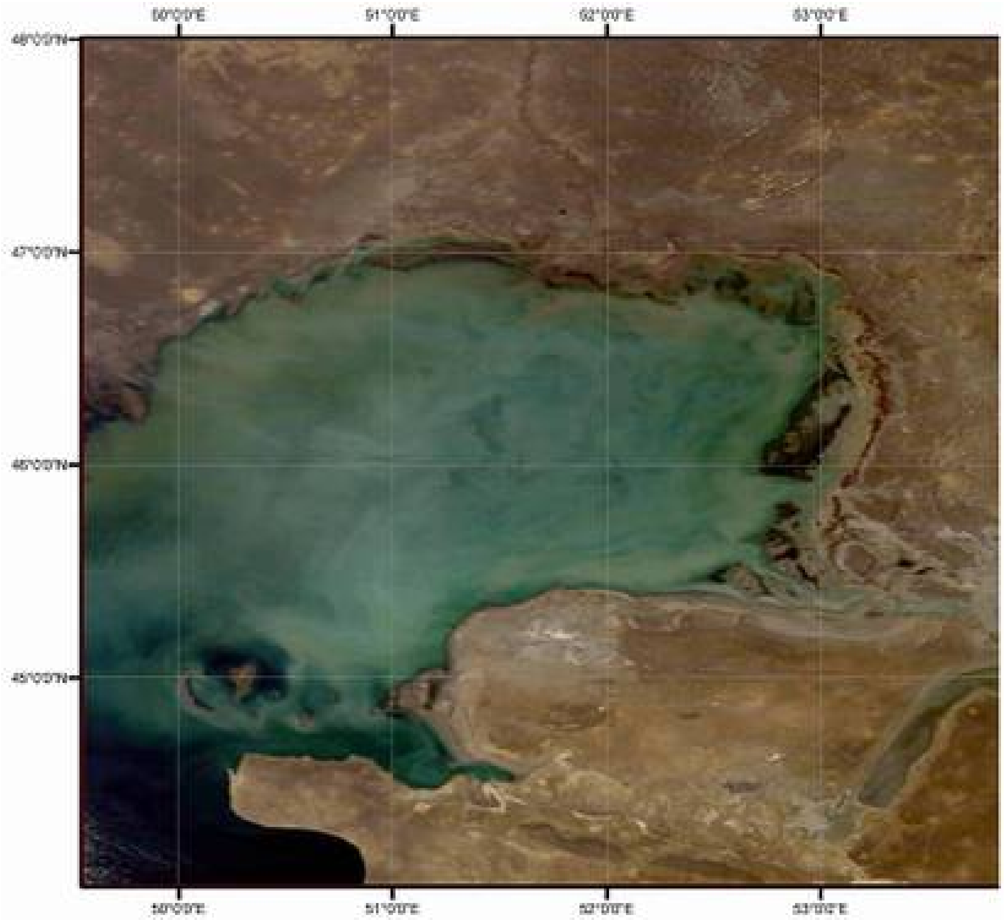

Fig. 17. Space image from Terra/MODIS. 25.10.2006.

The modeling technologies of oil pollution on the North Caspian Sea aimed at forecast of its spreading, consists of the following stages (Fig. 18):

- Carrying out the calculations of hydrodynamics in HD MIKE 21 module and the receiving of the essential set of output results;
- The preparation of the data on the oil pollution source engaging the remote sensing results and other sources of information;
- The data organization necessary for the calculation of the physical and chemical properties of oil;
- Collection and preparation of the meteorological data;
- Collection and preparation of the meteorological characteristics;
- Collection and preparation of the input and additional specifications for the calculation of oil pollution spreading in SA MIKE 21 module;
- Calculation of oil pollution spreading in SA MIKE 21 module;
- Organization of output data in the form of maps, diagrams, tabular data;
- Model verification using remote sensing data.

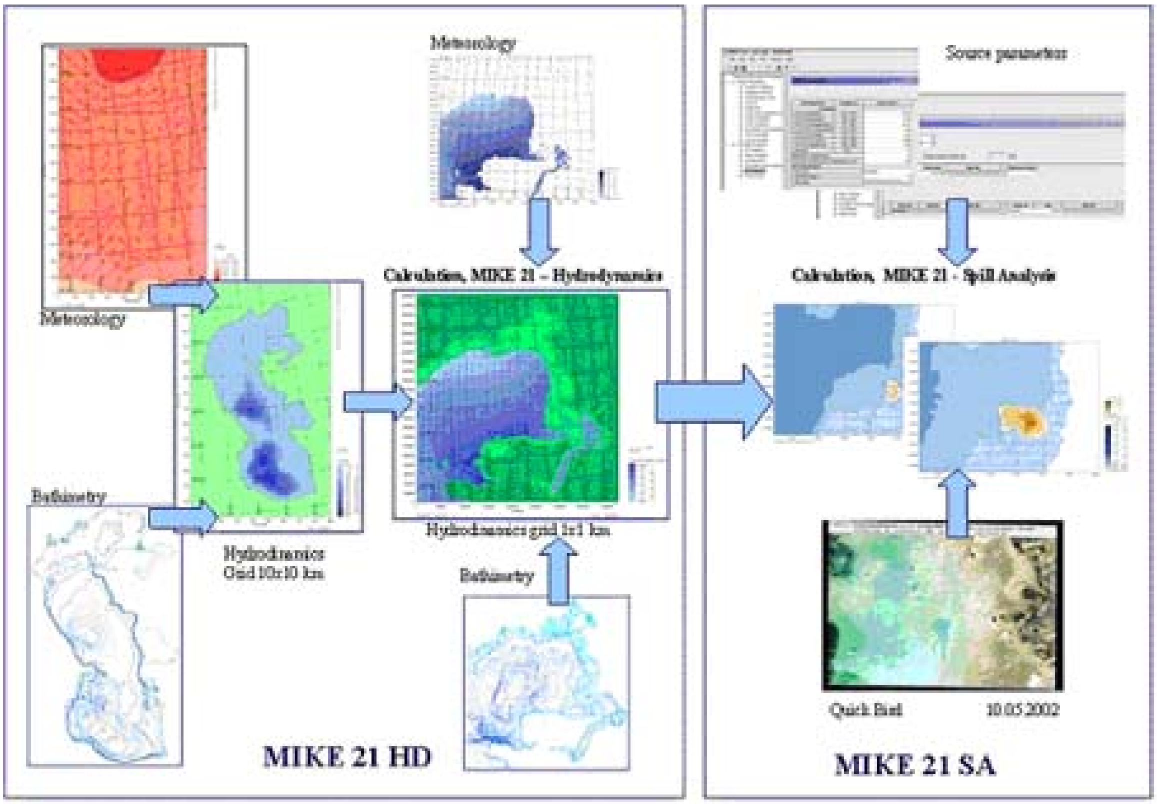

Fig. 18. The technology of oil spill's calculation.

Input data for the Spill Analysis MIKE 21 model can be subdivided into several subgroups:

1. Basic model characteristics:
   - Time step
   - The duration of modeling;
2. Hydrodynamic data;
3. Meteorological data:
   - Water temperature;
   - Water salinity;
   - Air temperature;
   - Cloudiness;
   - Data on wind;
   - Atmosphere pressure;
4. Meteorological parameters:
   - Data on heat transport;
   - Dispersion coefficient;
   - Stratification data;
   - Emulsification data;
   - Dissolution;
5. Initial specifications:
   - Coordinates of oil pollution source;
   - The source power;
   - Chemical and physical properties of oil;
   - Oil temperature;
6. Other specifications:
   - Logarithmic or homogeneous vertical profile;
   - Light absorption;
   - Dominating frequency;

- Current line.

When starting the SA model, it is necessary to define hydrodynamic condition of the water object, for which the calculation of oil slick spreading is being carried out. The complete plan of the necessary works on calculation of the North Caspian Sea hydrodynamics on the 1 x 1 km grid consists of the following:

1. Preparation of the data on the Caspian Sea bathymetry and hypsometry of its coastal zone (the size of the modeling 10 x 10 km grid;
2. Collection and preparation of the initial conditions data;
3. Collection and preparation the forecast meteorological information that includes the data of atmospheric pressure and wind velocities;
4. Preparation of the main and calibrating model characteristics;
5. Calculation of the water depth and its fluxes for the whole Caspian Sea in the HD MIKE 21 module (the modeling grid size is 10 x 10 km);
6. The data preparation on the bathymetry and hypsometry of the North Caspian Sea and its coastal zone (grid size is 1 x 1 km);
7. Formulation of the boundary conditions for the part of the sea based on the received results of the hydrodynamics modeling of the whole Caspian Sea;
8. Calculation of the water depth and its fluxes for the North Caspian Sea in the HD MIKE 21 module (grid size is 1 x 1 km).

Initial specifications

Coordinates of oil source

Several methods can be used for the coordinate definition of the oil pollution source. Among them are: space and airborne monitoring and ground observations. Active and passive space monitoring is the most effective method.

The general technology of the oil spill detection using remote sensing data consists of:

1. Preprocessing of space images (extraction, calibration, georeference);
2. Detection of possible sources of oil pollution. Localization of spills spots.
3. Classification aimed at the oil spill detection.

The methods of radar sensing play an important part in the oil spill researches. They let making the remote control under any type of cloudiness. At present, the radar sensing satellites of RADARSAT type, such as 1 (Canada), ERS 1,2 (Europe), EOS-PM (Japan) are widely used for ecological control of marine oil production activity. The radar survey's sensors are sensible to the changes of surface structure, i.e. the return signal has different values for underlying surfaces of different smoothness. For the seawater territories covered by the oil slick the surface is smoother than it is for the surrounding waters. As a result, the oil slicks appear as dark spots on the image. Artificial structures such as watercrafts and platforms return, as a rule, high SAR signal and appear as bright (clear) spots on the image. During the elaboration of method of oil slick interpretation at sea the RADARSAT – MDA's Geospatial Services International company-operator [12] has worked out the following classification of oil slicks (Fig. 19):

- 1A – Oil present with target attached;
- 1B – Oil present with target in area;
- 2 – Oil present without source'
- 3 – Possible Oil (lowest confidence).

"Oil" means interpreter believes that image characteristics may be associated with oil on water. Also, the methods of statistic analysis are used during the semiautomatic and automatic interpretation of images for detection of oil slicks. According to the data of Joint Research Center (Italy) [13] most of detected oil slicks are from 5 up to 10 km in length and up to 1 km in width (Fig. 20). Besides, the information on spill quantity characteristics, the information about its shape is also used. In case of oil spill from movable source (such as a tanker, etc.) the oil slick shape will first of all depend on tanker's velocity and motion path. In case of oil spill from immovable source (such as a platform, a well, etc.) the oil slick shape will depend on water current velocity and wind velocity. The worked out technological chain of radar images processing looks like the following:

1. Preprocessing of radar images (extraction, calibration, georeference);
2. Check-up of correspondence of the situation to the meteorological conditions (wind velocity is from 3 to 10 m/s);
3. Joint analysis of a space image with the location of possible sources of oil pollutions (on the basis of GIS data on the location of geological oil and gas structures, the object of oil industry (oil wells, platforms, etc.), and reports about incidents leading to oil slicks);
4. Classification aimed at the detection of potentially possible oil spills.

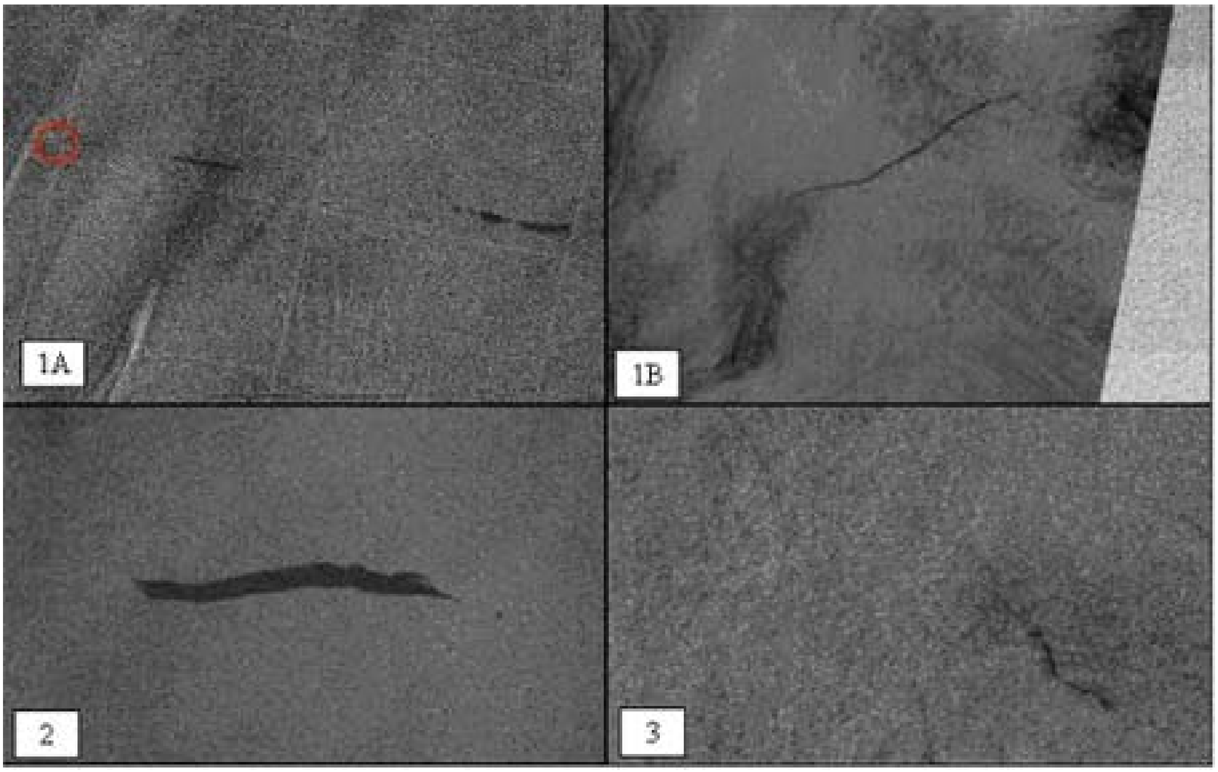

Fig. 19. The example of detected oil spills of various categories.

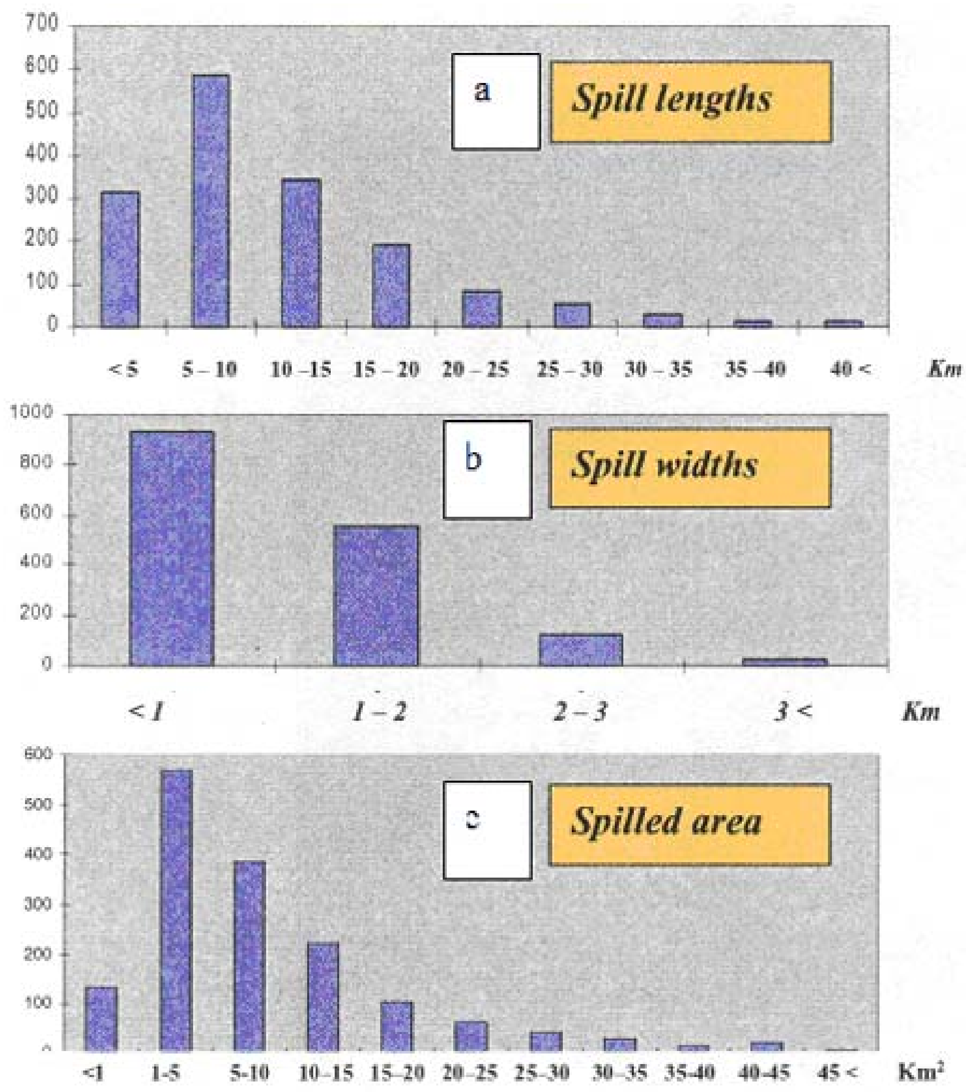

Fig. 20. Statistical data according to spill length, spill width and spilled area.

The source power

The power source of the oil pollution can be defined using remote sensing data. According to [14] the oil slick thickness that is defined with radar sensors is from 0.1 up to 20 mm. Therefore, if we know the area of the oil spill we can receive the possible volume of the oil pollution.

Table 1 illustrates the classification of the pollution by the slick thickness [15].

Table 1. Classification of sea oil pollution

Class number	Layer thickness interval (mm)	Description
1	0.00004 – 0.0003	Sheen (silvery/gray)
2	0.0003 – 0.005	Rainbow
3	0.005 – 0.05	Metallic
4	0.05 – 0.2	Discontinuous true oil color
5	0.2 and more	Continuous true oil color

The spreading model of oil pollution realized in SA module considers the following important processes of oil transportation in the seawater area:

- Spreading;
- Evaporation;
- Dispersion;
- Emulsification;
- Dissolution and entrainment;
- The process of heat transport that subdivides into:
    - Heat transfer between oil and air;
    - Heat transfer between oil and water;
    - Solar radiation;
    - Receiving and emission of earth-emitted radiation by the oil slick;
    - Heat loss because of evaporation.

Chemical and physical properties are considered in SA. The calculation of suspended matter spreading (8 fractions) is being carried out, taking into account meteorological conditions that are under influence of hydrodynamic fields calculated for the North Caspian in the HD MIKE 21 module. SA module in online regime informs about the location of oil spill, the oil amount on the sea surface, the slick spreading and chemical and physical oil properties. At the same time the pollutant transfer is considered as the shift of discrete particles with random path, i.e. the displacement of every particle is calculated as the sum of advective deterministic component and an independent random Marcovian process.

Output data

The calculation results of the oil slick spreading model could be formed for the several areas, the maximum amount of which should not exceed 8. The angular coordinates, the simulation period, the time step and the name of the output file name (that can contain either instant or averaged calculation data) should be defined for every area.

The file of results can consist of the following data:

- The general oil concentration (mm);
- Oil concentration by fractions (mm);
- Emulsification rate (%);
- Oil dissolution (mm);
- Vertical oil dispersion (mm);
- Time of exposition, the application of which is necessary for the case of oil spills near the coast (sec.);
- Current velocity U (m/sec);
- Current velocity V (m/sec);
- Moreover, the fields of oil concentration can be built, that exceed the given threshold.

The calculation example

On July 22, 2002, the oil spill was detected on the oilfield Pribrezhnoye according to the Landsat satellite data. The space image and its processing results are presented bellow (Fig. 21). The joint analysis of the remote sensing data and the vectorial layer of oil wells (Fig. 22) show that oil spill has happened on the oilfield Pribrezhnoye from the wells with numbers: G-99, G-66, G-2 and with coordinates: 53°11’11’’ of the east longitude, 46°16’02’’ of the north latitude, 53°11’34’’ of the east longitude, 46°15’55’’ of the north latitude, 53°11’19’’ of the east longitude, 46°14’56’’ of the north latitude, respectively. The area of oil slick was about 5.8 km², the length of spills from every well was about 6-7 km and the width was about 100-300 m.

The hydrodynamics calculation have been made in HD MIKE 21 module in the modeling grid of 1x1 km with time step of 3 min for the period from 22 till 27 of July, 2002. Figure 23 illustrates the hydrodynamics modeling results of the North Caspian Sea, from which it is clearly seen that there is

dry situation on the east coast and flood situation on the northwest coast.
The calculation of the oil spill spreading has been made on the 1 x1 km grid in SA module of the MIKE 21 Software product. Two wells have been selected for the modeling of the oil slick spreading, because the coordinates of 2 wells were in one cell on 1 x1 km grid. During the calculation it was used: the 120 hour-long forecast for the wind fields and for the pressure made by the European Center for Medium-ranged Weather Forecasts (ECMWF), as well as the calculated for this period hydrodynamics in HD module for the North Caspian Sea. It was presumed that the oil flux for the wells G-99 and G-66, that were in one cell of the calculated area, was 0.00089 m^3/s and for the well G-2 it was 0.000447 m^3/s. Oil has been flowing out during the whole calculation period.
Figure 23 illustrates the received modeling results. As it is seen from the image, the oil slick under the influence of dry situation will move 63 km to the west and 40 km to the northwest from the emission source. The area covered by the oil slick will be 53.8 km^2. Comparative analysis of the calculation results obtained with the SA MIKE 21 model and remote sensing data shows rather good coincidence. To receive more accurate modeling results, it is necessary to decrease the calculation grid that in its turn will increase the calculation data and the memory space.

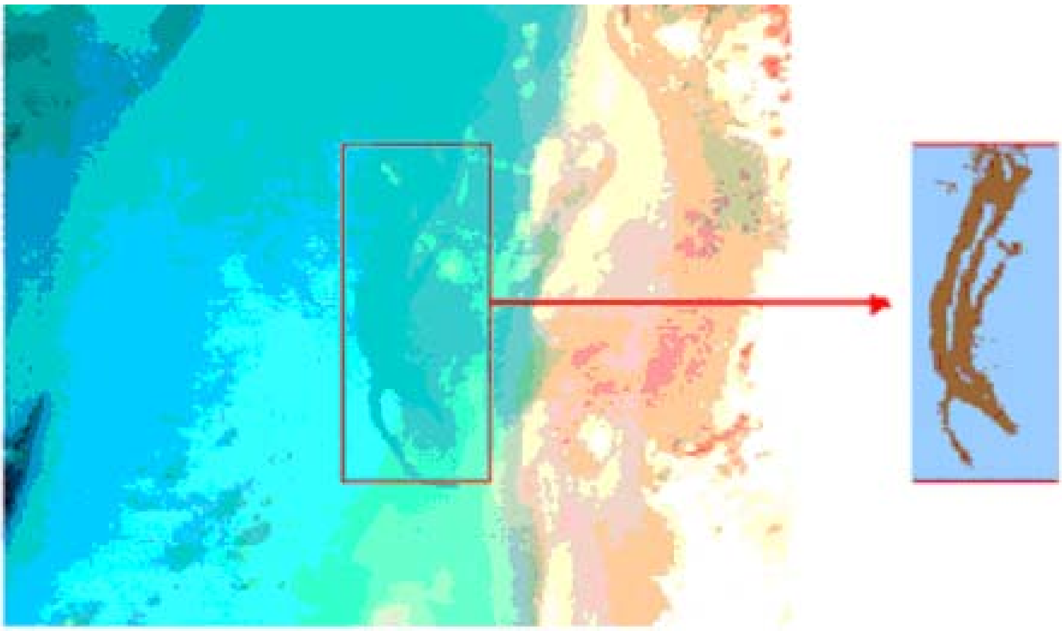

Fig. 21. Space image from Landsat (22.07.2002) and result of its classification.

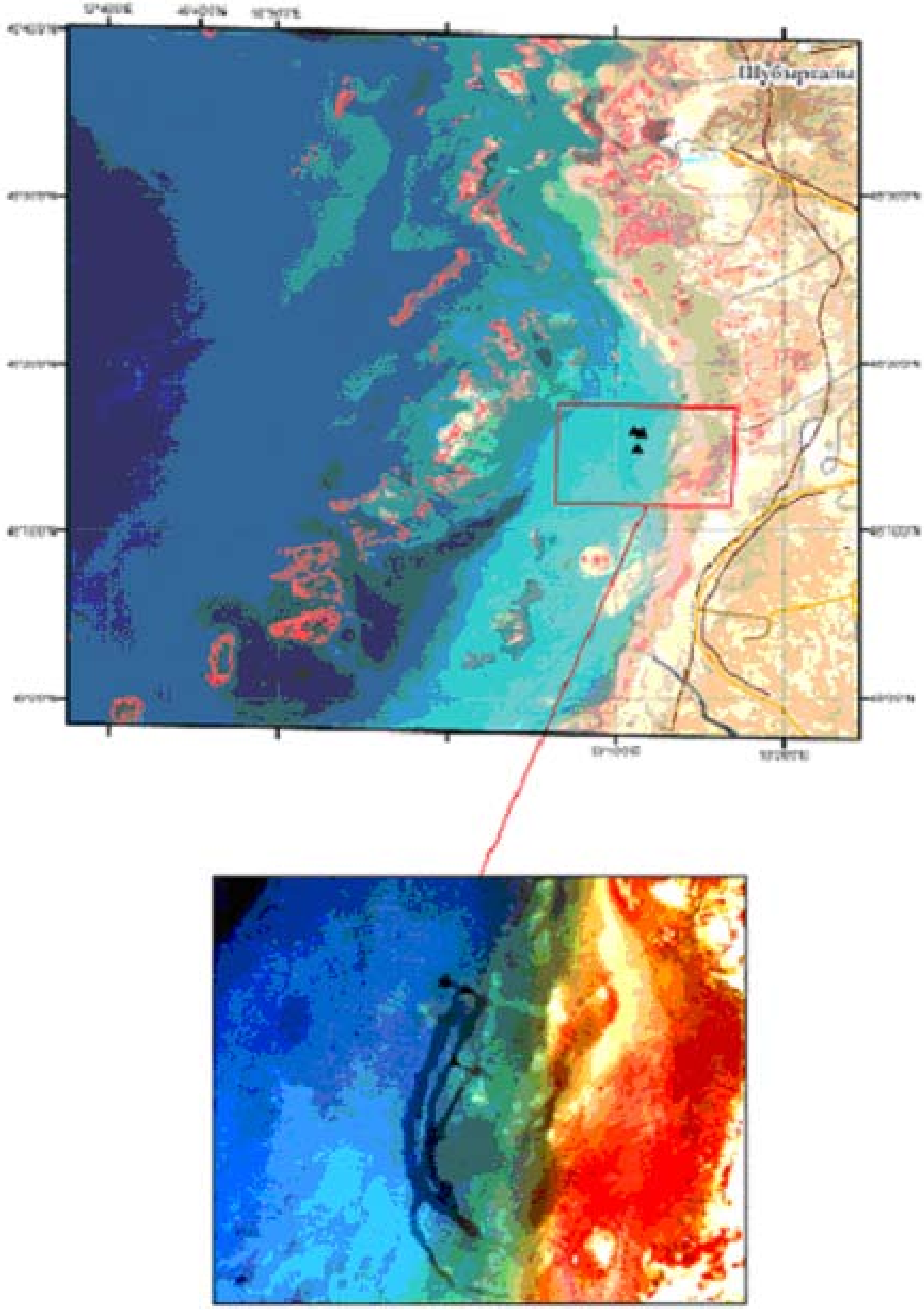

Fig. 22. Oil spill from Pribrezhnoye oilfield well.

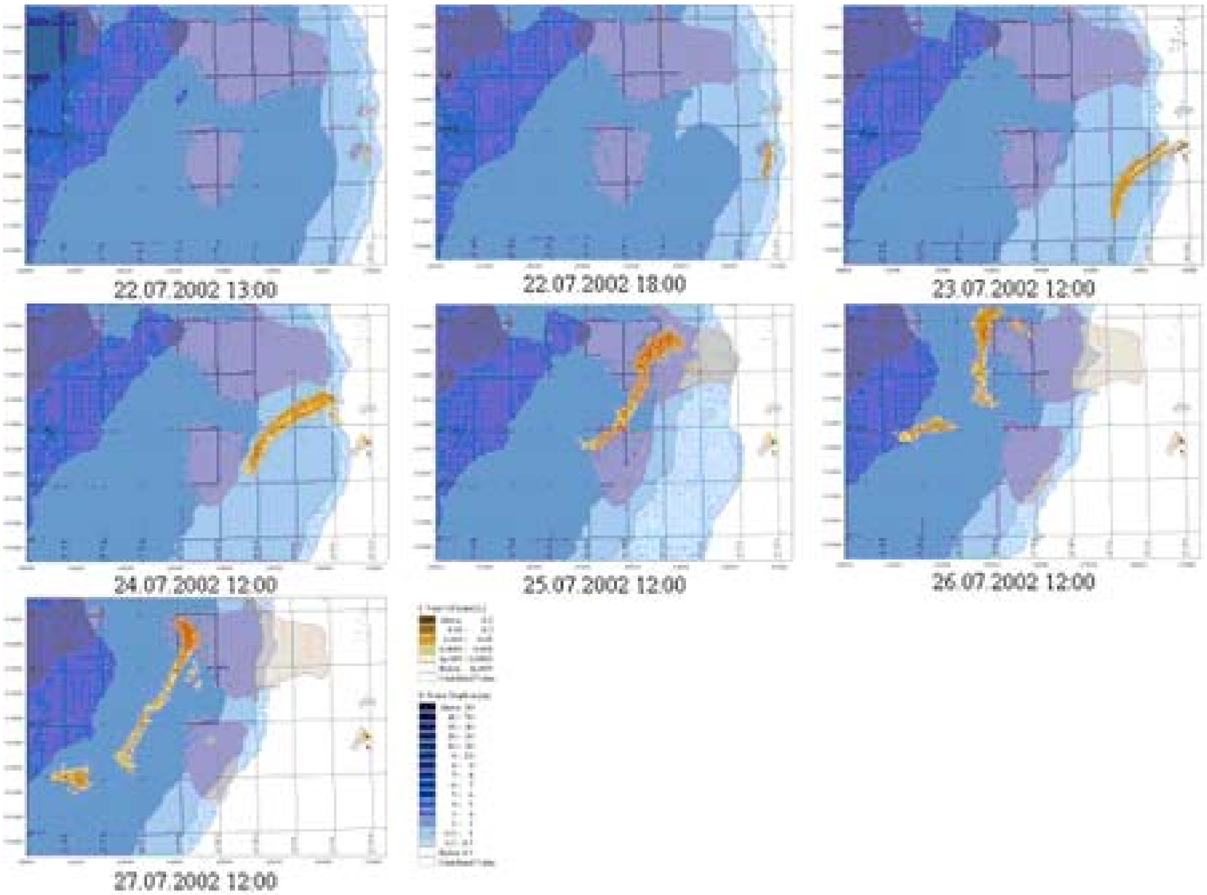

Fig. 23. Transport of oil spill.

Comparative analysis of space data and modeling result showed quite good agreement.

3.7. Use of geoinformation system of territorial processes modeling for Semipalatinsk test site

Numerous tests of the nuclear weapon at the Semipalatinsk test site have a dramatic influence on the environment. Consequences of these tests have different character: from pollution by radionuclides up to the temperature anomalies, which have arisen owing to underground nuclear explosions [16]. It is quite probable, that some consequences of these tests are not explored till nowadays. Among them, for example, is the transboundary radionuclide transfer due to thermal and wind uptaking of radioactive particles from the surface. In the given work the results of GIS development intended to support models of territorial processes on the test site and the analysis of results of modeling are stated. This system was used within the framework of EviroRISKS project for calculation of a transboundary radionuclide transfer aimed at the analysis of possible pollution of territory of Siberia. Plenty of research works are devoted to the studying of the territory of Semipalatinsk nuclear test site [17, 18, 19, 20, 21]. However, in our opinion, it is necessary to put these works on a uniform information basis which will allow proceeding from scientific researches to the solution of practical tasks. The most effective approach in this case is creation of geoinformation system (GIS) [22] of examined areas which will allow keeping the available data and providing an easy access to them, as well as fast and evident receiving of modeling results which can be in their turn combined with the various available data or the space monitoring data. Thus, such GIS must include:

- geographical and information database;
- remote sensing subsystem;
- modeling subsystem.

In Fig. 24 the scheme describing the interaction of all constituent parts of GIS is shown. According to this scheme it is clear that these subsystems are interrelated. The cartographical data "are poured in" a subsystem of remote sensing, in other words they are participating in the process of georeference of space images, which in their turn, are the sources of information for geographical and information database. The geographical and remote sensing data are the input data in the Modeling subsystem. Thus, three independently existing subsystems are united in a single whole - GIS. It illustrates the examples of cartographical information, the processing results of remote sensing data, including the survey of thermal anomaly and calculation field of radionuclides that are being formed due to the transfer by the ground waters (RUNOFF and RESRAD models).

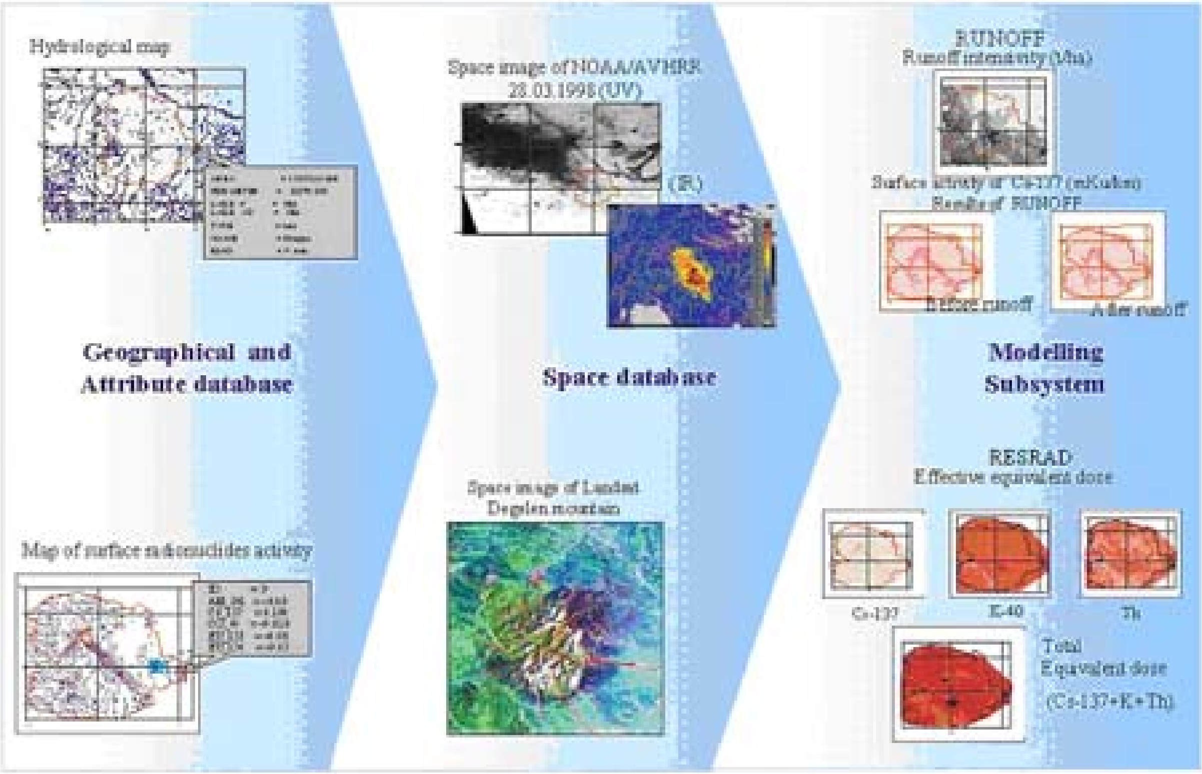

Fig. 24. GIS SNTS.

ArcGIS software is the basic instrument that unites the subsystems into GIS. It is one of the most powerful instruments for the creation of GIS. The opportunity of using plenty of various data formats and availability of using numerous methods for manipulation with the data that allow carrying out complex analysis and process modeling in an environment.

GIS SNTS Semipalatinsk Nuclear Test Site (SNTS) is divided into the following logical blocks:

- initial data
- model data
- space data
- demo, constantly updating catalog, aimed for the viewing, overlapping and analyzing different data types.

The directory initial_data contains the initial vector data about SNTS and its nearest territories which includes:

- A topographical map of SNTS;
- A soil map of SNTS;
- Information on nuclear explosions, includes a map where the places of explosions are pointed and xls-table with the information on all explosions carried out on the territory of USSR [23];

- Geological map of the nuclear test site with indication of stratigrafic divisions, magmatic complexes, tectonic infringements, minerals;
- Hydrogeology data;
- Map of chemical composition and general mineralization of fractured waters of test site Balapan;
- Data of the warm period of the year on 13 meteorological stations: Barshatas, Bayan-aul, Chalobai, Charsk, Ekibastuz, Zharma, Karaganda, Karkaralinsk, Kokpekty, Pavlodar, Semipalatinsk, Semiyarka. In Info tables data on amount of precipitations (cm) and on duration of rain (hour) are given;
- Data on results of autjgammaspectrometric survey on five radiating traces (Co, Cs, Ka, OK);
- Complex pollution by radionuclides (α, β, γ - radiation);
- Map of results of aerogammaspectrometric survey of cesium-137;
- Map of results of aerogammaspectrometric survey of a site Jubilejnoye;
- Map of results of aerogammaspectrometric on thorium, uranium, potassium;
- Map of pollution of SNTS territory plutonium-239;
- Data of power of exposure dose;
- Map of radioactive traces formed after carrying out ground explosions contained in nuclear-trace layer.

Block **model_data** contains programs and the modelling results represented by the cartographical layers and grid data. It consists of two directories:

- dose directory consists of AML programmes which transform RESRAD (DOS) results [24, 25] on calculation of population's radiation dose into grid format.
- Runoff directory consists of AML programmes that realize RUNOFF model [26].
- result_data is the directory of RUNOFF model results;

Block **space_data** is a constantly updating directory which contains space monitoring data from the AVHRR/NOAA, MODIS/Terra satellites.

Block **demo** is a constantly updating directory aimed for the visualization, overlapping and analysis of different data types: initial data and modeling results of. Such layer of geographical data could be overlapped on other layers, such as:

- grid data
- relief, created with helo of tin (triangulation irregular network) (Fig. 25)
- space image (Fig. 26, Fig. 27).

At the same time the layer and grid data colour is being defined and access to their attribute database is being saved.

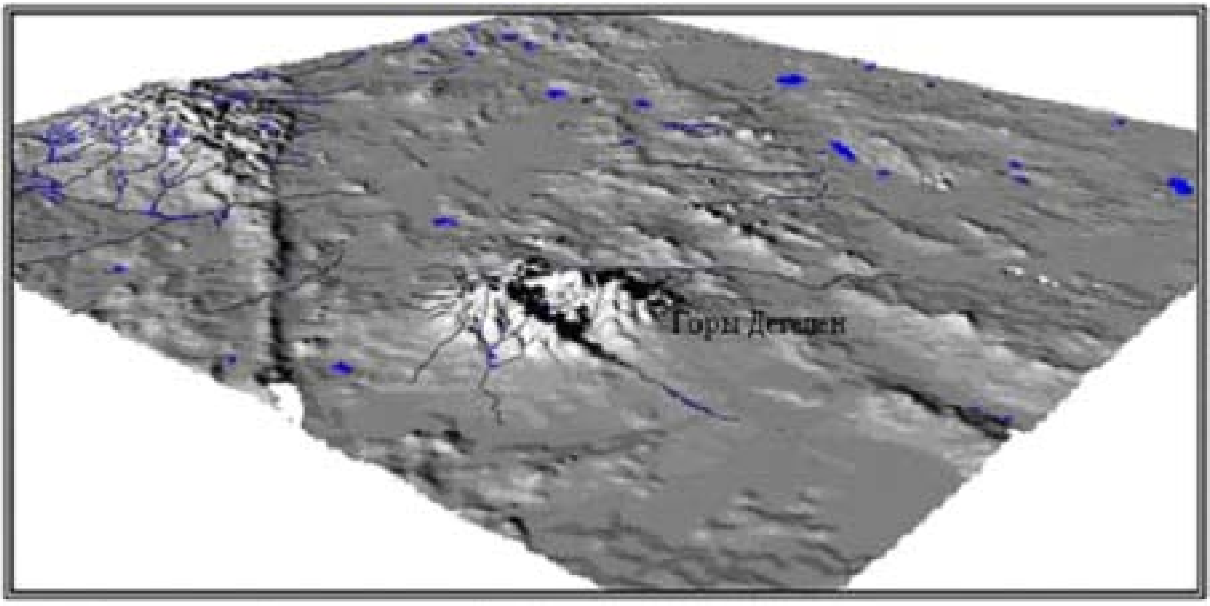

Fig. 25. 3D relief model of the test site's territory with superimposed water objects.

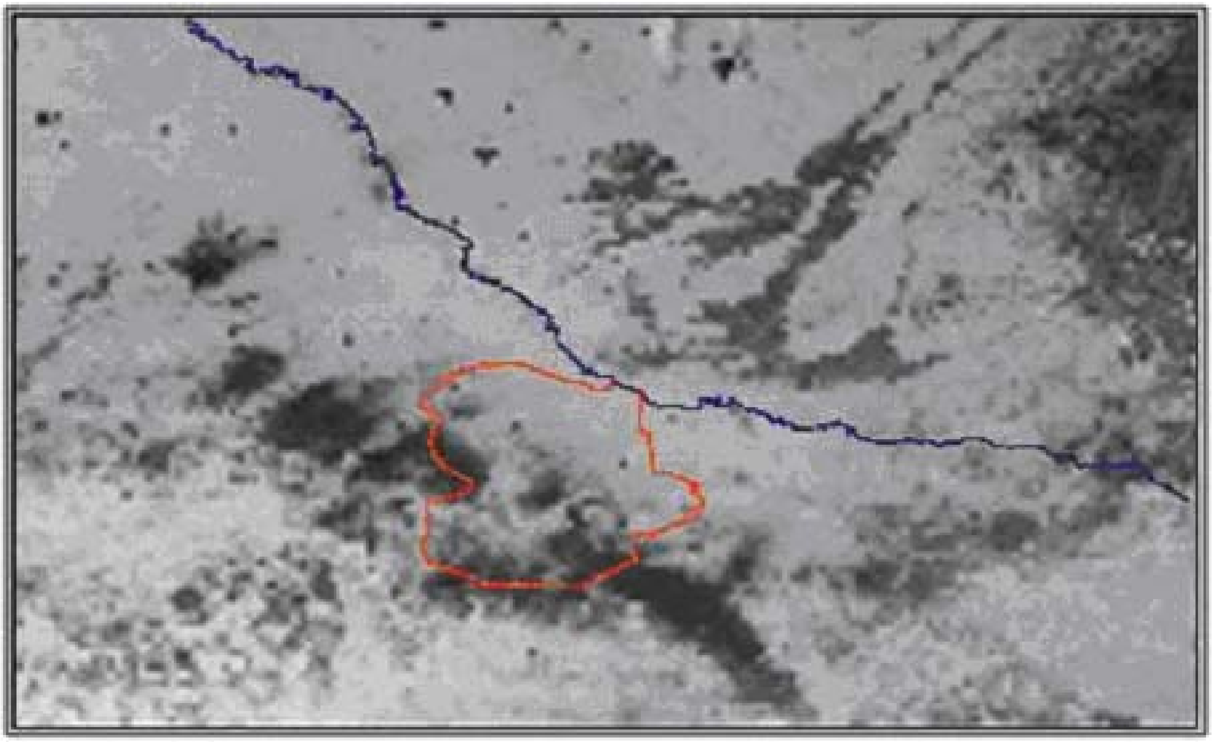

Fig. 26. Space image of AVHRR/NOAA (11.03.2000).

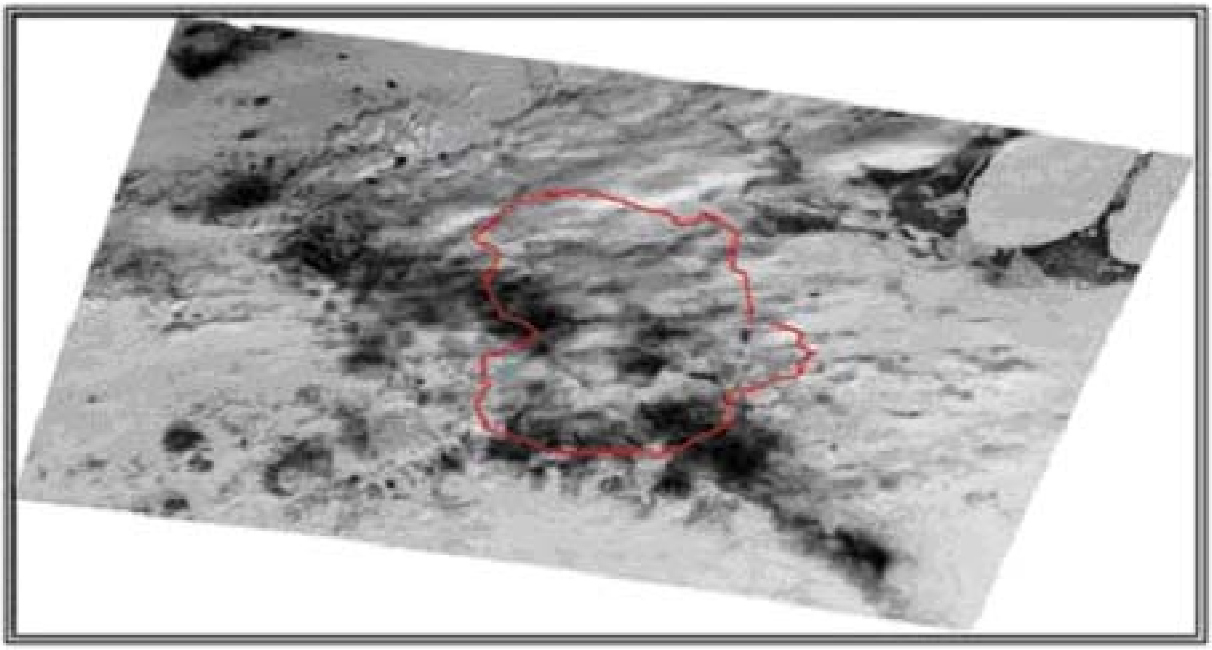

Fig. 27. MODIS data (13.03.2001).

Developed GIS SNTS has been used to simulate a long-term atmospheric transport, dispersion, and deposition of radionuclide (for the calculations of transboundary radionuclide transfer) during carrying out of nuclear weapon tests in 1985. Calculations were based on DERMA model. For a daily hypothetical release of ^{137}Cs at rate of 10^{11} Bq/s can be calculated:

1) air concentration (Bq/m^3) in the surface layer;
2) time-integrated air concentration (Bq·h/m^3);
3) dry deposition (Bq/m^2) field;
4) wet deposition (Bq/m^2) field.

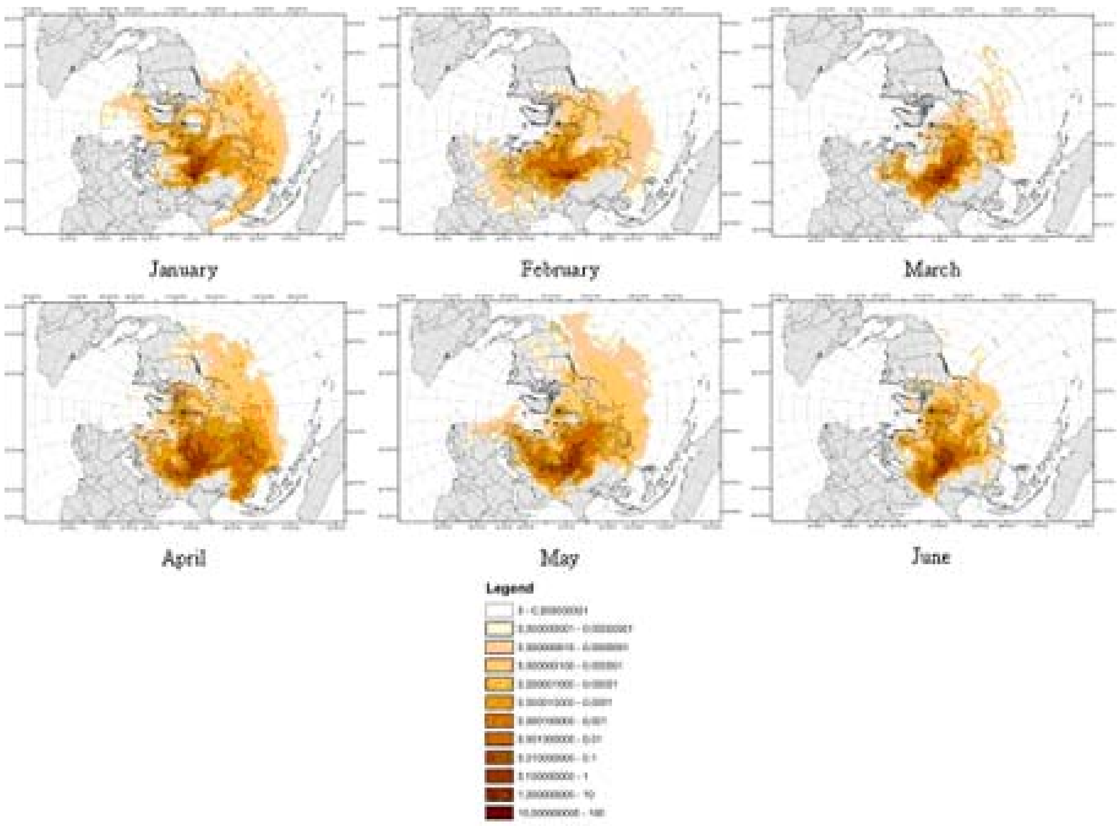

Fig. 28.

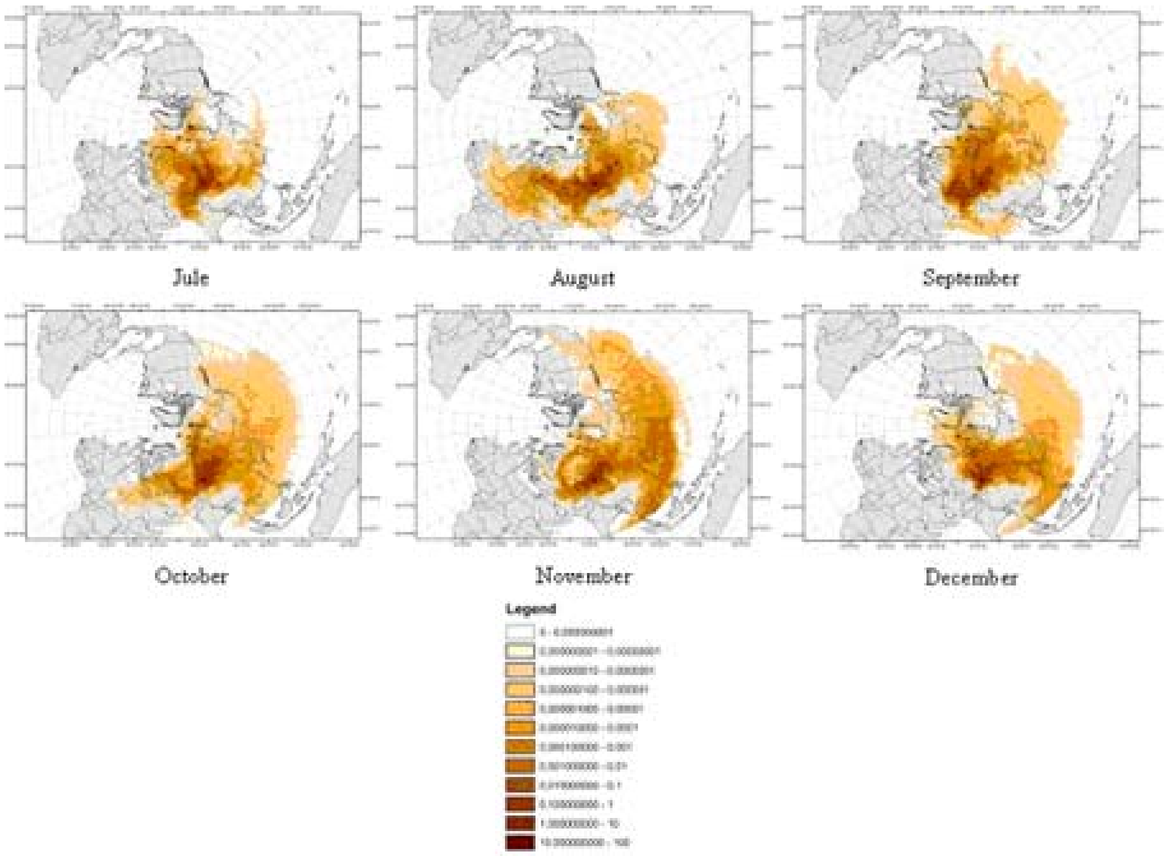

Fig. 29.

Figures 28 and 29 above illustrate the calculations results for the whole year with monthly-averaged radionuclide fields. As it is seen from the figures radioactive substances during nuclear tests are transferred to the great distances. Transfer occurs in east and northeast directions. The map of average annual radionuclide distribution is presented below.

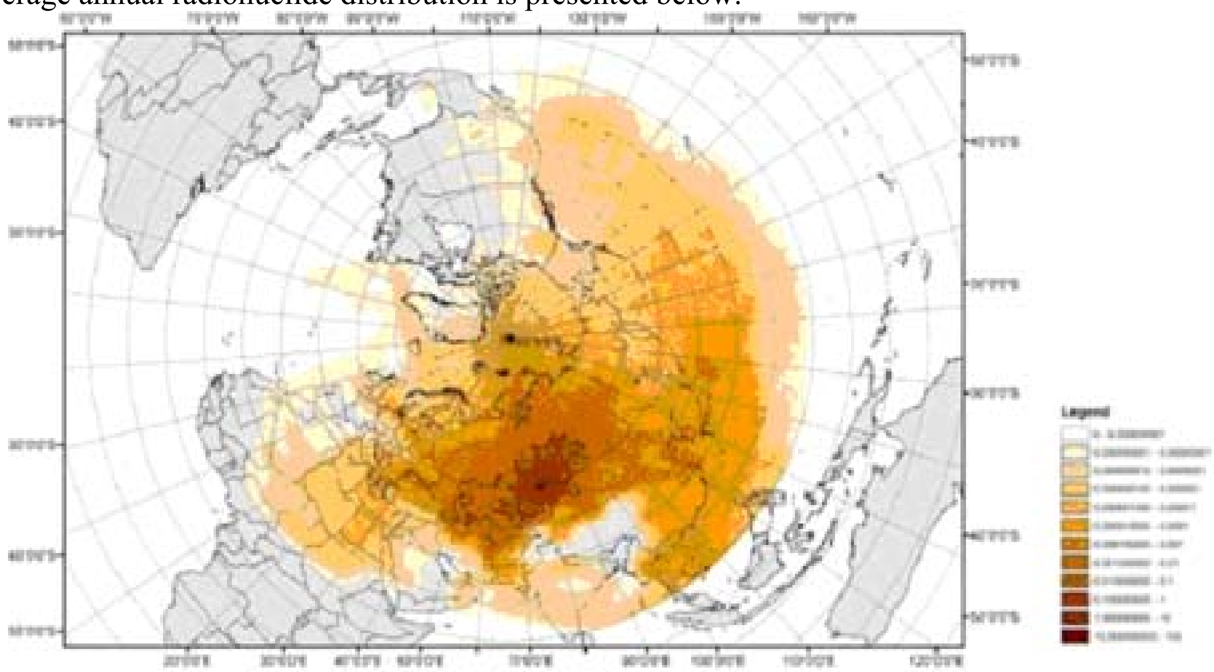

Fig. 30.

The above Fig. 30 is especially characteristic. It is clear, that northeast areas of Kazakhstan and the territory of Siberia are most subject to the risk of radioactive pollution.

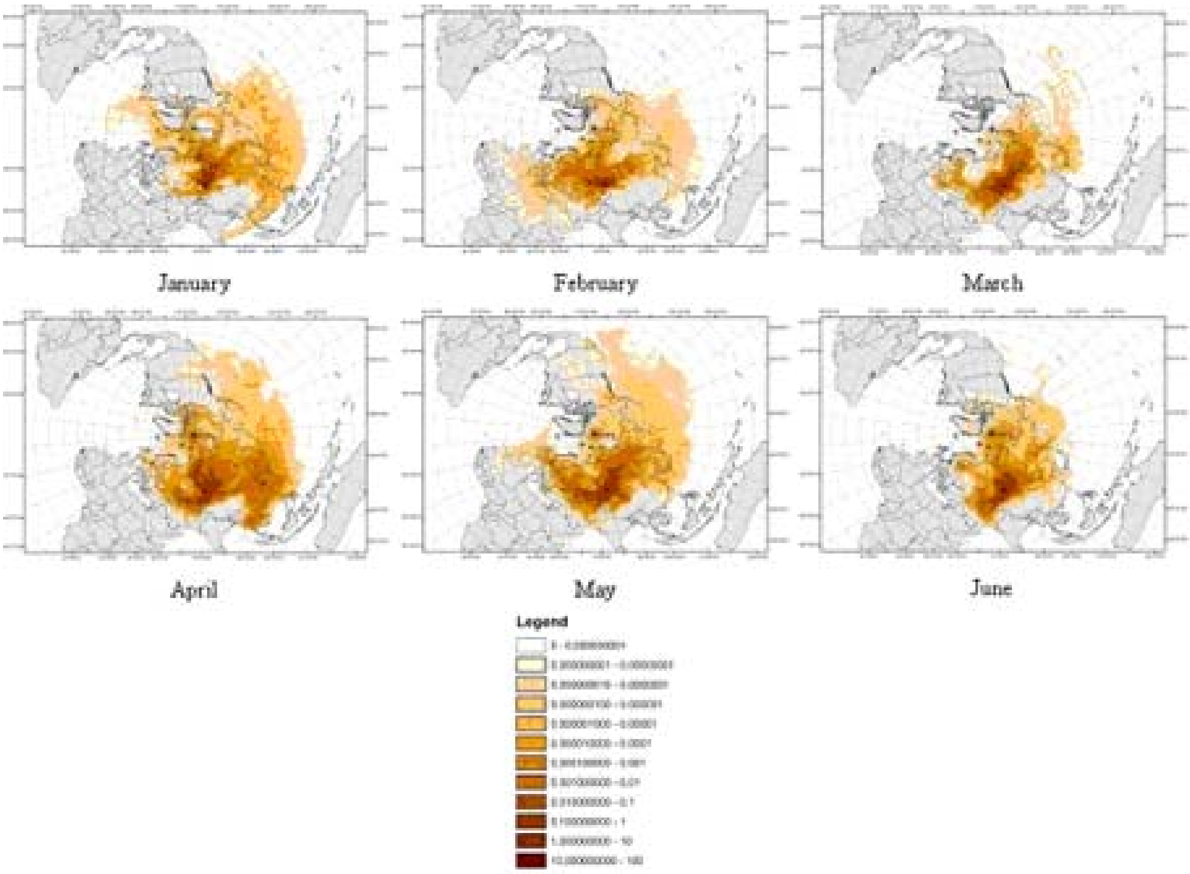

Fig. 31. Average near surface concentration (Bq/m^3).

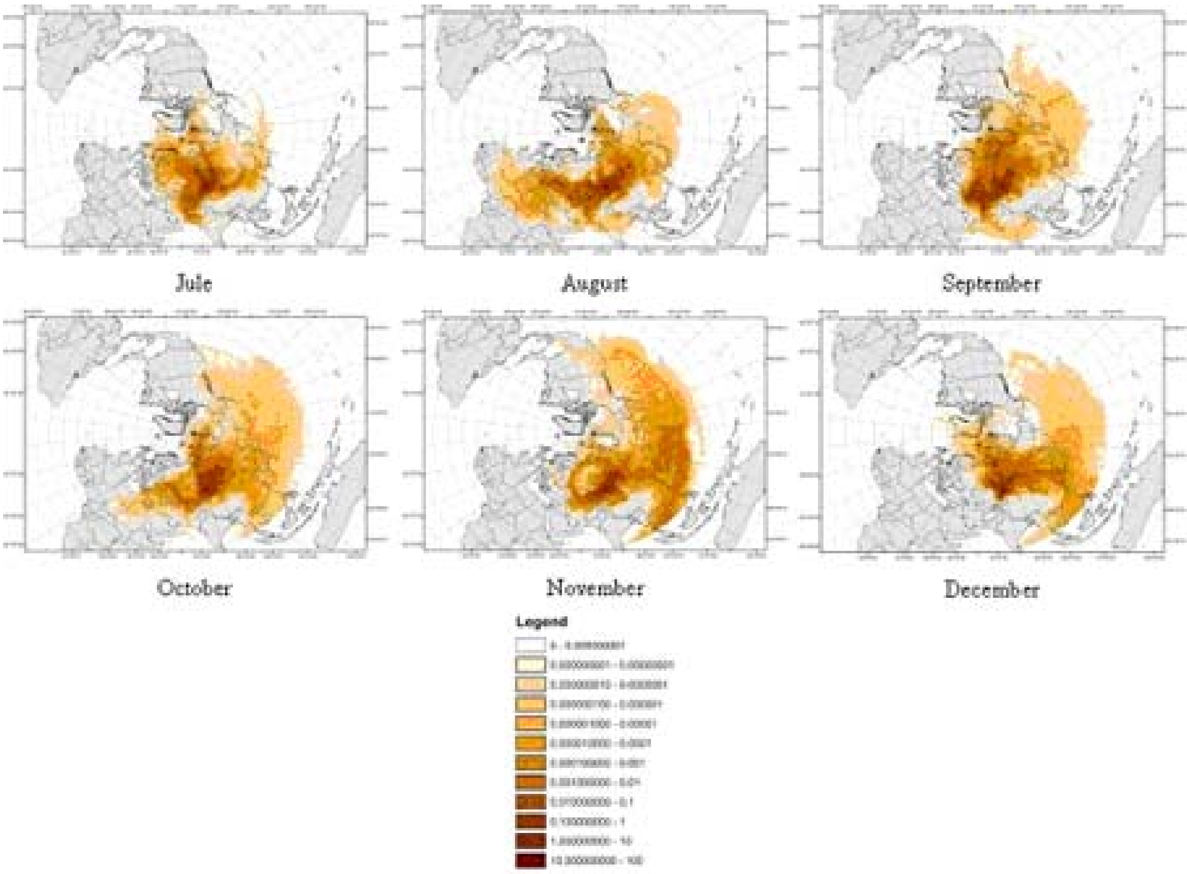

Fig. 32. Average near surface concentration (Bq/m^3).

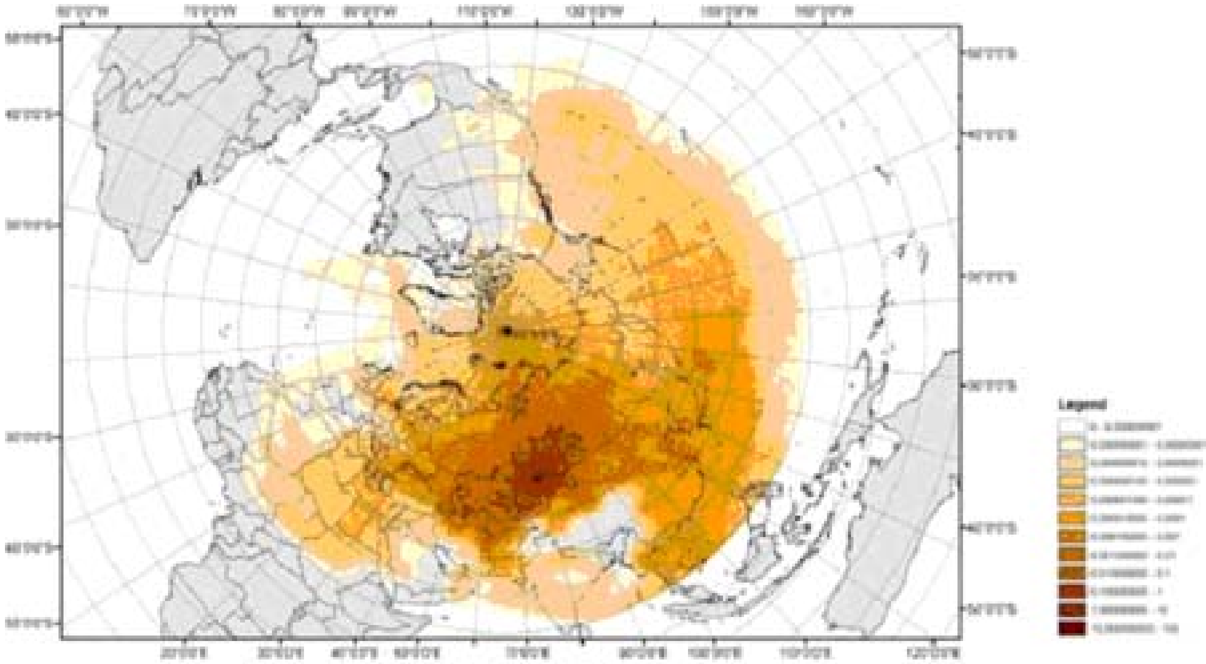

Fig. 33. Annual average near surface concentration (Bq/m^3).

3.8. The evaluation of natural and man-induced risk of the areas of the Krasnoyarsk region

The analysis of the sources of danger and risk shows that within the Krasnoyarsk region a number of natural, man-induced and natural-man-induced emergencies may occur, which requires developing a consistent calculation model allowing quantifying area risks. In a general case, the dynamics of emergency situations in the areas under consideration can be presented as the Poisson stream of events with given frequencies depending on the type of emergency situation. Then, the risk for the territory of an area *S* can be written in the following form

$$R(S) = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{l} \int_{S} P_{ijk}(S) \cdot V_{ijk}(S) \cdot U_{ijk}(S) dS,$$

where n, m, l are the numbers of possible emergency situations of natural, man-induced and natural-man-induced character; $P_{ijk}(S)$ – the probability of emergency; $V_{ijk}(S)$ – the probability of damage of environment, population and infrastructure at emergency situations; $U_{ijk}(S)$ – losses and damages from emergency situations.

Taking into account the above given problem the emergency statistics has been considered [27] and certain risk components have been evaluated within the Krasnoyarsk region during 2001-2006, with the maps of risk-prone areas being created. The analysis of statistics of emergency recorded on the territory of the Krasnoyarsk region [28] shows the following. During the period from 2001 to 2006 there occurred 278 man-induced and 43 natural emergency situations, including 4 hurricanes, 16 floods and 19 big forest fires. According to the statistical data of RF Emergency Ministry the frequency of local and regional natural emergency situations in the region doesn't exceed 3-5 events a year, which is the average level for the Russian Federation. At the same time the frequency of interregional and federal emergency situations appears to be higher than in Russia in general and amounts to 0,8 event a year. The frequency of man-induced emergency situations is within 5-10 events a year. Here, the main part of emergencies is local and municipal ones. Regional emergency situations are observed with a frequency of 0,4 event a year, and interregional and federal ones are less than 0,2 event a year. Damages from flooding the areas of the region during spring snowmelt amount to one third of total damages from all types of emergencies. The map of flood risk showing flood coverage and places of actual high waters is given in Fig. 34. Forest fires recorded in 1996-2004 are presented in Fig. 35.

Based on the population data for localities with critically important objects and areas of occurrence of natural emergencies [29] the total value of individual death risk from emergency situation for the areas of the region is not less than $8{,}27\times10^{-8}$ for an emergency situation a year. Here, for man-induced emergencies this index is $9{,}65\times10^{-8}$ for an emergency situation a year, and for natural ones it is $1{,}72\times10^{-9}$ for an emergency situation a year. The value of complex risk amounts to approximately $1{,}8\times10^{-9}$ for an emergency situation a year. A detailed analysis of statistics and calculation of the values of individual risks for different types of danger and different areas of the region has revealed the following. The risk of death from household fires amounts to $4{,}8\times10^{-6}$ – $1{,}42\times10^{-4}$ for an emergency situation a year. Moreover, for most areas it is the range of $1{,}3\times10^{-5}$ – $9{,}15\times10^{-5}$ for an emergency situation a year. Fires and explosions on industrial facilities in the emergency statistics are represented by few events. Therefore, the obtained values of individual risk $2{,}29\times10^{-6}$ – $1{,}08\times10^{-4}$ for an emergency situation a year may be considered preliminary. Analogous situation is observed for the danger of building and construction destruction. Here, the risk amounts to $3{,}08\times10^{-6}$ – $1{,}09\times10^{-5}$ for an emergency situation a year. The risk of death in transport accidents is in a wide range of $9{,}14\times10^{-7}$ – $1{,}53\times10^{-4}$ for an accident a year. (Fig. 36). It is impossible to evaluate the risk of death due to the other sources of danger because of the non-availability of statistical data.

Individual risks from natural and man-induced emergencies are given in Table 1.

Table 1. Individual risks for the whole Krasnoyarsk region

Emergency type	Individual risk, year^{-1}
Man-induced emergency situations	
Accidents with the emissions of dangerous chemical substances	-
Building destructions	$3{,}86\times10^{-6}$
Accidents in energy-producing systems	-
Accidents of utility systems	-
Industrial fires and explosions	$3{,}16\times10^{-6}$
Armament explosion	$3{,}51\times10^{-7}$
Transport accidents	$4{,}57\times10^{-5}$
Household fires	$1{,}07\times10^{-4}$
Natural Emergencies	
Earthquakes	-
Dangerous meteorological phenomena	$7{,}03\times10^{-7}$
Floods	-
Big forest fires	-
Generalized risk indices for the whole Krasnoyarsk region	
Individual risk (man-induced emergencies)	$1{,}6\times10^{-4}$
Individual risk (natural emergencies)	$7{,}03\times10^{-7}$

Complex risk	$1{,}61\times10^{-4}$

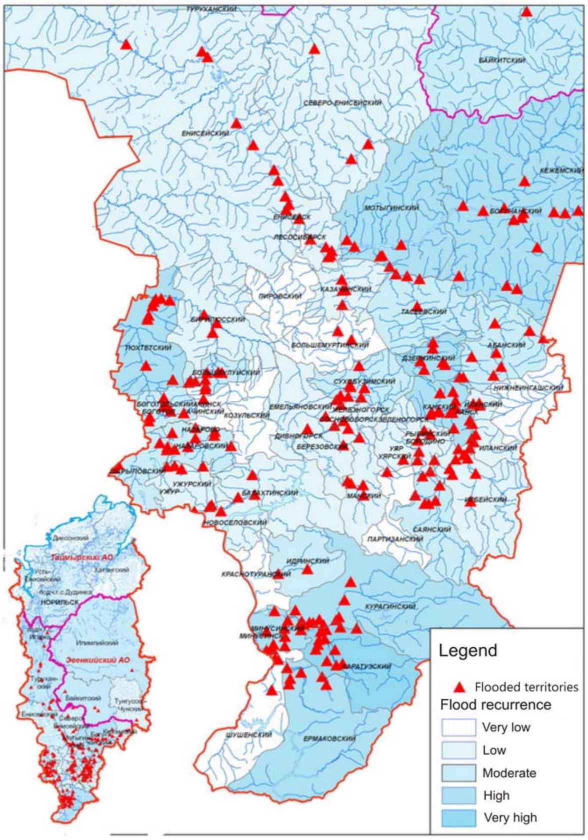

Fig. 34. Flood risks of the areas of the region

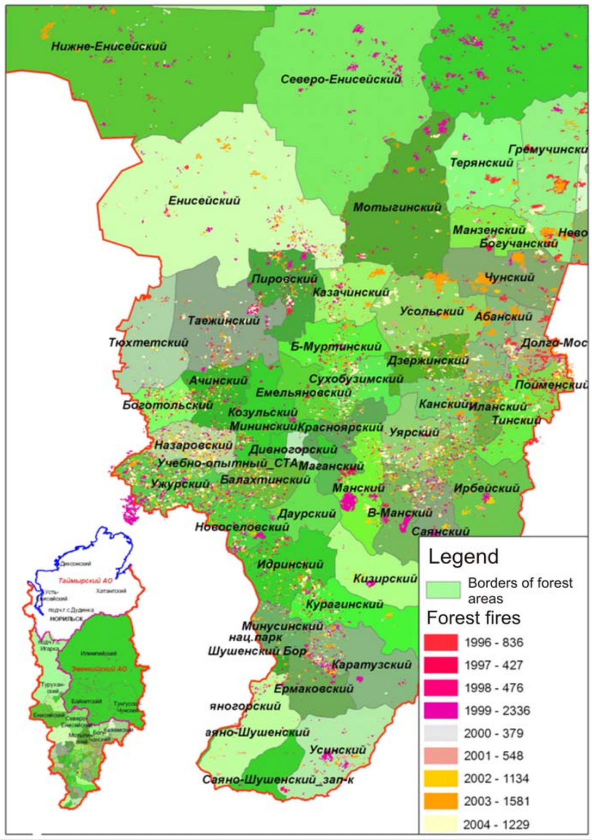

Fig. 35. Forest fires, recorded in 1996-2004

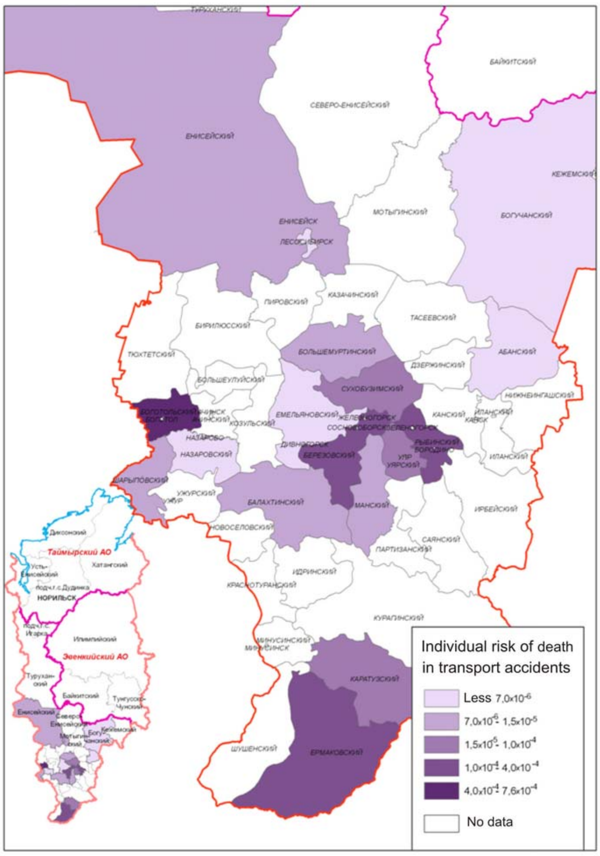

Fig. 36. Individual risk of death in transport

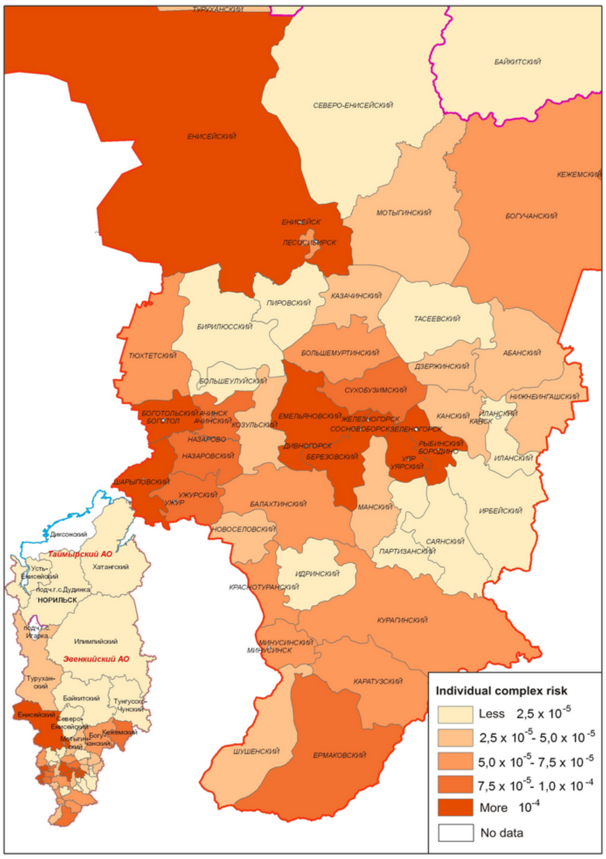

Fig. 37. Complex risk (population-normalized)

accidents

Collective death risk on the chemical enterprises is estimated to be $3{,}8\times10^{-4} – 8{,}6\times10^{-5}$ man/year; on the enterprises of petrochemical complex $4{,}3\times10^{-4} – 2{,}3\times10^{-5}$ man/year; explosive and fire dangerous facilities – $6{,}4\times10^{-5} – 7{,}3\times10^{-6}$ man/year. Social risk in the event of an accident on the explosive and fire dangerous facilities is within $1{,}98\times10^{-9}$ – $1{,}13\times10^{-5}$ man/year. On the accidents on chemically dangerous facilities this index is in the range of $1{,}9\times10^{-10} – 1{,}16\times10^{-7}$ man/year. During the period of intensive industrial development of the region no great man-induced accidents resulting in death and damages of groups of people have been recorded. Complex risks arise due to possible overlapping of danger sources in the areas under consideration. Complex risks were evaluated assuming independence of arising danger sources and absence of multiplicative effects. The map of complex risks is presented in Fig. 37.

One can see that complex risk values obtained vary from permissible ones in Krasnoyarsk ($8{,}0\times10^{-6}$) and in Kansk ($8{,}63\times10^{-6}$) to quite high in Tykhtet ($1{,}34\times10^{-4}$) and Beresovsky ($1{,}03\times10^{-4}$) and Achinsk ($1{,}24\times10^{-4}$), Sharypovo ($1{,}75\times10^{-4}$) regions. It is necessary for these areas to primarily pay attention to developing regional goal-oriented programs of monitoring danger and decreasing risks of natural and man-induced emergency situations. Risk danger in these regions has to be taken into account when developing goal-oriented programs of long-term economical and social development of the areas of the region. The results obtained reveal the possibility to solve the problem of evaluating and subdividing regions according to the risks of natural and man-induced emergencies with creating maps and atlases of risks both for certain regions and for the whole Siberian federal district.

Conclusions

The above consideration shows that the both information technology tools, web based and GIS based, proved their efficiency in support of regional investigations of basic and applied environmental problems of Siberia. Due it inherent distributed character Internet based ICS currently are more suited to be elements of information-computational infrastructure of the Siberia integrated regional study. However we expect that after development of new systems combining properties of GIS and Internet based ICS one can expect that namely thematic portals based on such systems will be mainly used in SIRS information-computational infrastructure.

It should be added that. based on the analysis of emergency statistics during 2001-2006 individual, collective, social and complex risks of man-induced, natural and natural-man-induced emergency situations have been evaluated in the Krasnoyarsk region. GIS technology of mapping risk-prone areas has been developed and the areas of the region have been subdivided according to the risks. The results obtained reveal the possibility to solve the problem of evaluating and subdividing regions according to the risks of natural and man-induced emergencies with creating maps and atlases of risks both for certain regions and for the whole Siberian federal district.

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Appendix 1: List of Projects

List of projects whose results were used in this Report

SB RAS Basic Research Program 4.5.2 (Project 2) **Development of foundations for information-computational system based on web- and GIS technologies intended for studying regional climatic processes.**

SB RAS Integrated Project 34 **Development of distributed information and modeling environment to ecological systems investigations.**

SB RAS Integrated Project 86 **Development of tools for satellite ecological monitoring of Siberia and Far East on the base of modern information and telecommunication methods and technologies**

RFBR grants 05-05-98010 “**Experimental and model studies of air environment in a city with the monitoring and forecasting integrated system of air quality**”

INCO FP6 Project **ENVIROMIS-2 (Environmental Observations, Modelling and Information Systems Special Support Action, INCO-CT-2006- 031303)**

FP5 INCO Project **ISIREMM: Integrated System for Intelligent Regional Environmental Monitoring & Management**

INCO FP6 Project **ENVIROMIS-SSA (Environmental Observations, Modelling and Information Systems Special Support Action**

INTAS project **ATMOS: Web Portal on Atmospheric Environment**

INTAS Project **Modelling and parameterisation of the ’air-vegetation-snow-soil**

Atmospheric Model Intercomparison Project **(AMIP)**

Coupled Model Intercomparison Project (**CMIP).**

SB RAS Interdisciplinary Integrated Project **Siberian Geosphere – Biosphere Program: integrated regional study of contemporary natural and climatic changes (SGBP**)
Ministry of Science and Education RF Program Integration Project **Research of natural and socioeconomic processes dynamics in the interests of education for sustainable development**

The Kazakhstan Ministry of Industry and Trade Project **Remote sensing of land-use and land-cover processes on the ecological stressed territories of Kazakhstan**

The Kazakhstan Ministry of Industry and Trade Project **Monitoring and geoinformation modeling of territorial ecological processes for North part of Caspian sea**

The Kazakhstan Ministry of Industry and Trade Project **Studying ecological consequences (temperature anomaly, radioactivity etc.) of nuclear explosions at the Former Semipalatinsk Test Site.**