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GOGNITIVE GRAFICS, SEMANTIC MODELING AND 3D-GEOVISUALIZATION FOR GEOSPATIAL SOLUTIONS IN RUSSIAN ENERGY SECTOR

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ABOUT OUR INSTITUTE

Energy Systems Institute named L.A. Melentiev SB RAS (Irkutsk) is one of the leaders in the field of energy system researches.

THE MAIN DIRECTIONS OF RESEARCHES:

- The theory of creating energy systems, complexes and plants and controlling them.
- Scientific foundations and mechanisms of realizing energy policy in Russia and its regions.

THE MAIN DIRECTIONS OF RESEARCH

Energy Systems Institute realizes the researches in the fields of the power industry; heat supply; natural gas industry; coal supply; oil and its products provision.

Also the Institute carries out the problems connected with **energy security in Russia**, the regional energetic and interconnection of energetic and economy.

SMART GRID (INTELLIGENT ENERGY SYSTEMS OR INTELLIGENT ELECTRIC NETWORK)

At present, the world to actively promote the conception, called Smart Grid (intelligent energy systems). Smart Grid is electric power systems with the use of new technologies such as in the power equipment, as well as in the field of information support, aimed at improving the quality of technical and economic parameters.

PROPOSED SOLUTION: IT-INFRASTRUCTURE OF IPS

The creation and development of IES is offered on the basis of available experience in the ESI SB RAS (IT-laboratory).

IT-infrastructure separates out on the following major substructure:

- intelligent infrastructure,
- information infrastructure,
- computing infrastructure,
- telecommunications infrastructure

IT-INFRASTRUCTURE

Telecommunications infrastructure is based on the generally accepted principles (for example, similar to the telecommunications infrastructure (SB RAS data network), subject to the requirements of computer and information security.

Information infrastructure includes technologies and tools for data description, storage and processing. The repository is the core of Information infrastructure and stores metadata (descriptions of data streams, databases, data models, etc.).

Computing infrastructure integrates software systems (e.g., for EPS regimes modeling and management). Automated systems of energy plants control can be attributed to the same infrastructure.

Intelligent infrastructure includes intelligent components (such as the above-mentioned components of the intelligent decision support management regimes).

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SOLUTION OF THE SPACE PROBLEMS IN ENERGY SECTOR

- Solution of the space problems has always been important for the management of energy systems of Russia, which are characterized as a large extent of the energy routes (pipelines and power transmission lines (PTL)) and the distribution of energy facilities in the vast areas of the country.
- Currently, this urgency has escalated due to the rapidly changing political and economic environment and the need to promptly inform decisions on energy development.
- To solve spatial problems of the team, led by the author, it is proposed the integration of mathematical and semantic modeling and visual analytics techniques, including the use of geo-information technologies.

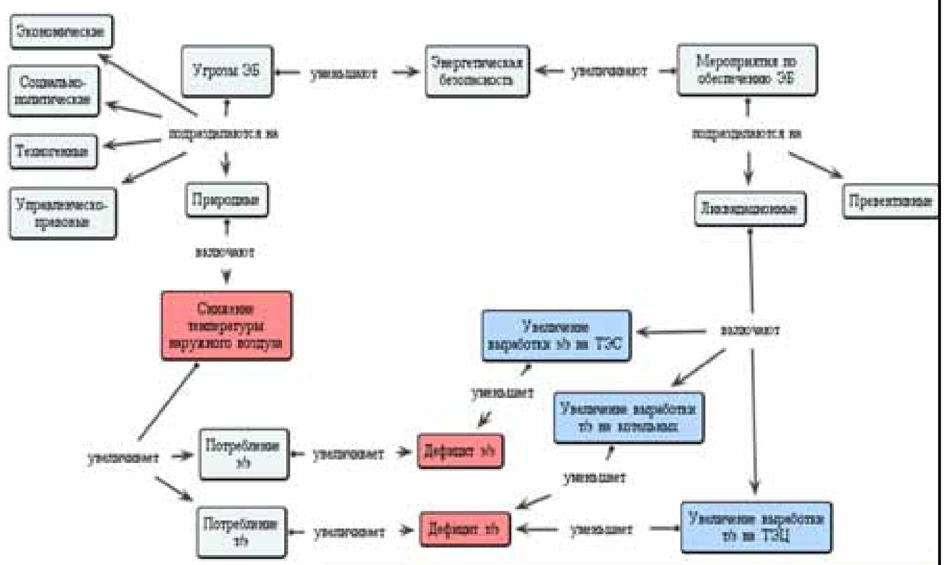
SEMANTIC MODELING

- The semantic modeling is one of the modern trends of artificial intelligence and is associated with the description of the subject area with the help of concepts (basic concepts) and relations between them.
- The group of authors developed these types of semantic modeling as an ontological, cognitive, event and probabilistic modeling .
- The first (the ontological) is used to classify domain concepts, the second (cognitive) allows you to identify causal relationships between concepts (factors) and the contribution of factors, such as the formation of the threats to energy security.
- Probabilistic and event simulation in this case are used to model the development of critical and emergency situations resulting from the implementation of energy security threats.

ONTOLOGICAL MODELING

- Ontologies have been proposed for declarative knowledge representation and are defined in general terms as the knowledge base of a special form, or as a "specification of a conceptualization" domain.
- This means that in a domain based on the classification of basic terms are basic concepts (concepts) and establish links between them (conceptualization).
- Then ontology can be represented in graphical form, or is written in a formal language (formal ontology) - a process ontology specifications. The group representing authors, was developed tool OntoMap to support the ontological modeling (can also may be used and other open source tools ontological modeling).

EXAMPLE OF ONTOLOGY FOR COLD THREAT



COGNITIVE MODELING

- Under cognitive modeling refers to the construction of cognitive models, or in other words, cognitive maps (directed graphs), in which the top of the relevant factors (concept), and the arcs - relations between the factors (positive or negative), depending on the nature of the causal relationship.
- Mathematical tool for building cognitive models is the theory of graphs. Cognitive modeling in the energy sector was used by auturthes for situational analysis of the ES problem and threat modeling.
- The group of authors implemented tools to support cognitive modeling - Library CogMap.

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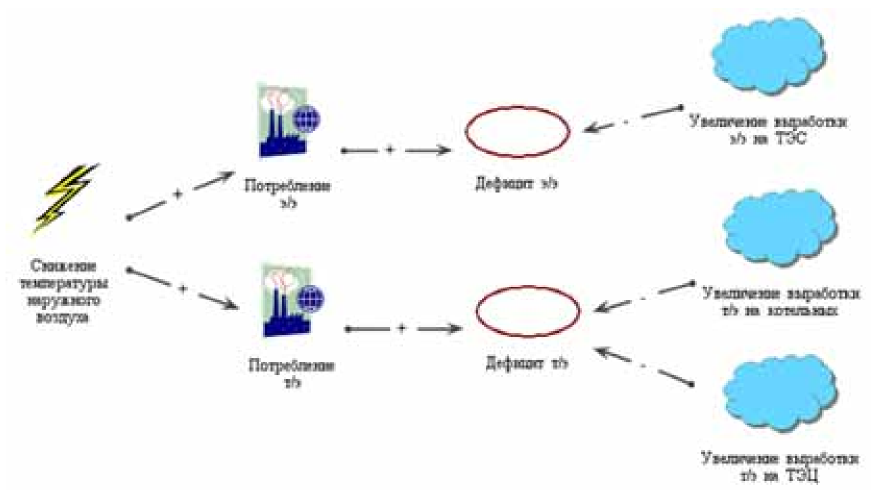
EXAMPLE OF COGNITIVE MAP FOR COLD THREAT



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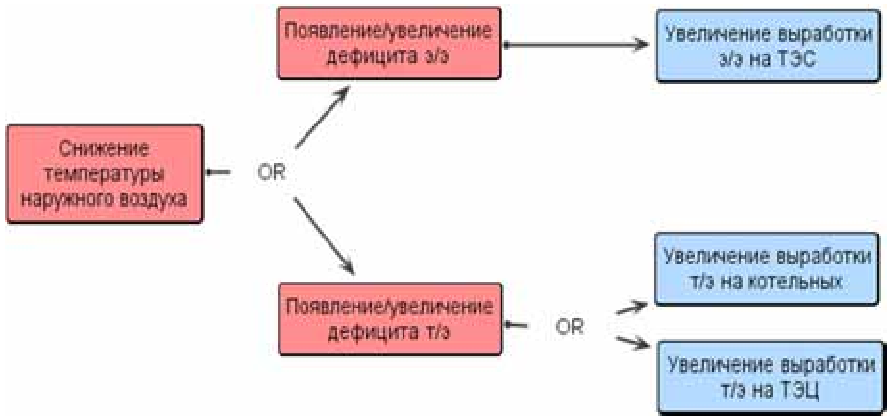
EVENT MODELING

- By event simulation is meant to build behavioral models, and as objects of modeling can be seen as people and technical facilities. The essence of the event simulation method consists in tracing the sequence of events on the model in the same order in which they would occur in a real system.
- Asked model consistent implementation of events - a chain of events - describe the scenario of system response to the occurrence of a triggering event, standing at the beginning of the chain.

EVENT MODELING

- As a tool for event simulation apparatus used Joiner-networks (JN) - a form of algebraic networks, which can be regarded as an extension of Petri nets, focused on the construction of behavioral patterns. The theory JN is the description logic of interaction asynchronous processes as a set of launchers and flag functions, consisting of Boolean functions.
- JN special feature is that they provide both a graphical representation and a description in the form of logical formulas that can automate the process.
- Implemented support tools for cognitive modeling - Library EventMap.

EVENT MAP FOR COLD THREAT



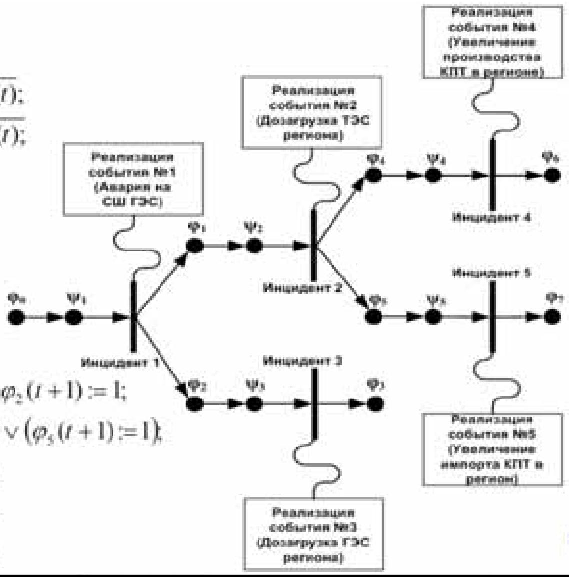
EXAMPLE OF JOINER-NET FOR EVENT MAP

Пусковые функции:

$$\psi_1(t+1)=\varphi_0(t)\cdot\overline{\varphi_1(t)}\cdot\overline{\varphi_2(t)};$$
$$\psi_2(t+1)=\varphi_1(t)\cdot\overline{\varphi_4(t)}\cdot\overline{\varphi_5(t)};$$
$$\psi_3(t+1)=\varphi_2(t)\cdot\overline{\varphi_3(t)};$$
$$\psi_4(t+1)=\varphi_4(t)\cdot\overline{\varphi_6(t)};$$
$$\psi_5(t+1)=\varphi_5(t)\cdot\overline{\varphi_7(t)};$$

Флаговые функции:

$$\varphi_0(t+1):=0;\ \varphi_1(t+1):=1;\ \varphi_2(t+1):=1;$$
$$\varphi_1(t+1):=0;\ (\varphi_4(t+1):=1)\vee(\varphi_5(t+1):=1);$$
$$\varphi_2(t+1):=0;\ \varphi_3(t+1):=1;$$
$$\varphi_4(t+1):=0;\ \varphi_6(t+1):=1;$$
$$\varphi_5(t+1):=0;\ \varphi_7(t+1):=1;$$



PROBABILICTIC MODELING

- In recent years, the area of semantic modeling was extended of using of probabilictic modeling on basis of Bayesian belief networks for assessing the risks of emergency situations, which is implemented to support the library BayNet

EXAMPLE OF BAYESIAN BELIEF NETWORKS FOR COLD THREAT

INTEGRATION OF SEMANTIC MODELING TOOLS

- All semantic models are usually available in graphical form, although each type of semantic model has a mathematical or formal apparatus to describe them: a special formal language for describing ontologies (XML, RDF, OWL, and others.), Graph theory for cognitive models, the theory of Bayesian belief networks for probabilistic and theory of networks Joiner-event models).
- Semantic modeling tools are integrated into the framework of intelligent IT- environment. It will shown at the end of this topic.

COGNITIVE GRAPHICS

- Presentation of semantic models in graphical form allows you to associate them with the cognitive graphics.
- This term was introduced in the Russian science by A.A. Zenkin in the 90s years of last century and originally was associated with new visualization capabilities of research results arising from the emergence of new graphic tools of PCs.
- Subsequently, it was realized that symbols can activate the associative logic of the unconscious thought processes of the human brain that allows you to use cognitive graphics quickly find original and often unexpected solutions.

COGNITIVE GRAPHICS

- In fact, semantic models possess cognitive graphics properties and are particularly useful for professionals with a predominantly figurative thinking.
- It should be noted that the semantic models allow us to perform a qualitative analysis of the problem to be solved.
- For the quantitative study of the proposed solutions should involve the results of mathematical modeling which, moreover, appear to be more convincing to specialists with the prevailing logical thinking.
- Nevertheless, for illustration mathematical solutions can also be used cognitive graphics, which was successfully demonstrated by Zenkin in his works.

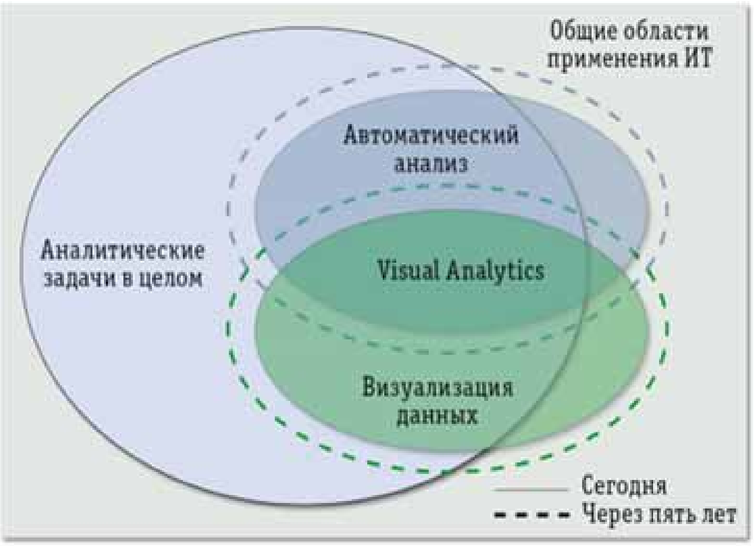
VISUAL ANALYTICS

- The emergence of the term "visual analytics» (Visual Analytics) dates back to 2004, tying him with D. Thomas book "Lighting the way research and development program on Visual Analytics», issued as a policy document of Pacific Northwest National Laboratory, which is among the sixteen US Department of Energy laboratories.
- In this book, visual analytics is defined as **the ability to think analytically, supported GUI**.

VISUAL ANALYTICS

- Visual Analysis has at least two interpretations. According to the first so-called broad range of interdisciplinary research, anyway related to the use of interactive visual tools for data analysis.
- The second value applies to the actual analytical component of Visual Analytics, consisting of automatic and interactive parts. Contact visual analytics with other areas of application of information technology (IT) shown in next slide

COMMUNICATION VISUAL ANALYTICS WITH OTHER AREAS OF IT-APPLICATION



VISUAL ANALYTICS

- Analytic tasks are part of one of the fastest growing areas of IT- application, sometimes unexpected.
- For example, it is now actively developing area of visualization of textual data, which is well correlated with cognitive graphics.
- As shown upper, visual analytics lies at the intersection of two areas: automatic data analysis and visualization.
- In solving spatial problems of visual analytics is certainly closely related to geographic information analytics, supported by geovizualization. Let us on last in detail.

GEOVIZUALIZATION TECHNOLOGIES

- The research areas of energy development was used traditional geographic information system (GIS) integrating databases and integrating electronic cards in vector representation of information.
- Unfortunately, traditional GIS did not enjoy great success with the power industry and have not been widely spread in the strategic objectives of energy development. This was due to the fact, for example, that the laying of new pipelines and power transmission lines, are important features of the relief, which is not clearly illustrated in traditional GIS.

NEOGEOGRAFY

- With the new direction of the visualization of geospatial information, titled neogeography, the opportunity to use in solving geospatial problems in the energy sector realistic maps of the earth's surface (space and aerial photographs) combined with the three-dimensional model of the Earth that takes you to a new level of decision support in the energy sector .
- A new approach certainly does not mean failure of maps or map information, may enter new information medium as one of the elements.

NEOGEOGRAFY

- Neogeography term became widespread after the appearance in 2005 of a fundamentally new geoservice Google Earth, is radically different from previous conventional and digital maps, globes and GIS.
- The novelty of the approach was a completely new approach to working with geospatial information, which was achieved through the merger of several previously known technologies [Eremchenko].

NEOGEOGRAFY

The essential features that distinguish biogeographical products, first isolated in the Russian definition neogeography. Neogeography - a new generation of tools and methods to work with geospatial information, different from the previous (maps and GIS) three basic features:

- using geographic coordinate systems and map projections are not;
- applying bitmap rather than vector representations of geographic information as a primary;
- using open hypertext formats of geodata.

- Neogeography allows the user to arbitrarily select camera angles (and determined their level of detail), view the information at the same time a smooth transition from one view to another as needed.
- This provides a natural and metrically accurate representation of three-dimensional space without a reduction to any surface.
- The user of products and services, which implemented the principle neogeography an opportunity to be "inside" of the data, not just take them "outside", both within the cartographic approach [Erëmchenko].

NEOGEOGRAFY

- The group of authors implemented an approach to using of open geoservices (for example, Google Earth) using
- special copyright geocomponent, converts the data into the required geoservice format KML,
- thus can be used as initial input data and the resulting data of scientific calculations and accumulated data, including GIS database

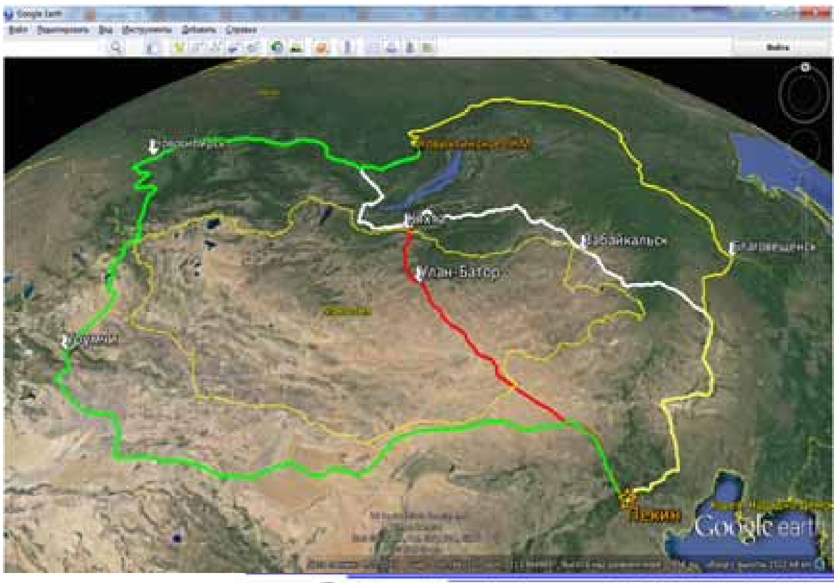
EXAMPLES OF ENERGY PROBLEMS SOLVING USING 3D-GEOVIZUALIZATION

- The authors develop appropriate methods and tools of 3D-geovizualization (named geocomponent) for solutions of spatially distributed energy problems
- Recently geocomponent implemented as a Web-based application. Now a number of problems are solved with the use of geospatial 3D-geovizualization, such as:

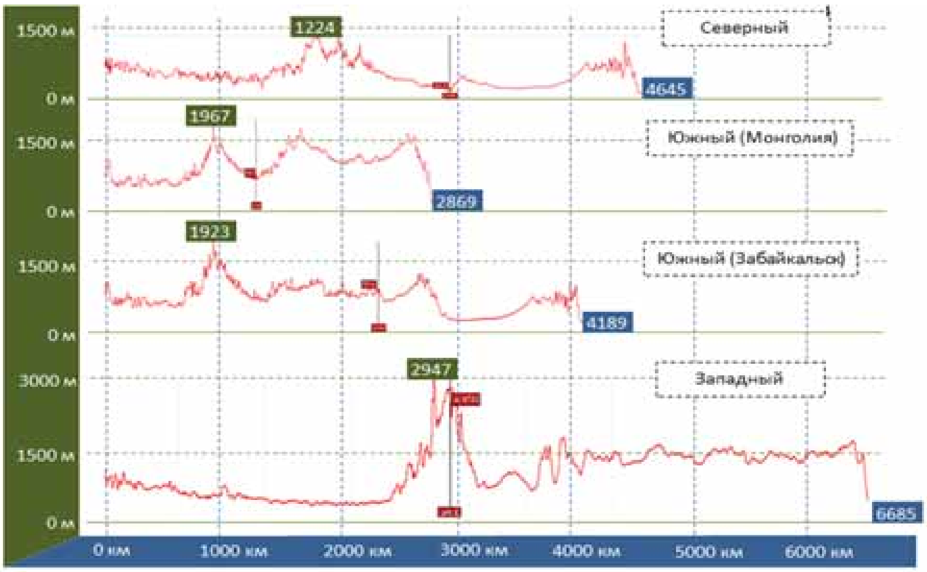
EXAMPLES OF ENERGY PROBLEMS SOLVING USING 3D-GEOVIZUALIZATION

- The task of relief and profile sections with different geological conditions for the construction of the primary economic justification pipeline routes;
- the problem of determining the contribution of various energy facilities in pollution by visualizing the fields of emissions and pollutants distribution functions;
- the illusration of a current status of the energy security problem in Russia as a whole and for individual federal districts by displaying indicators of energy security in relation with the territories

3D-geovizualizaion four comparable gas transportation routes from the Kovykta gas condensate field on the export to China



THE PROFILES OF RELIEF FOR 4-TH VARIANTS OF LINE PIPE WITH COMMON LENGTH AND MAXIMAL ALTITUDE FOR EACH OF VARIANTS



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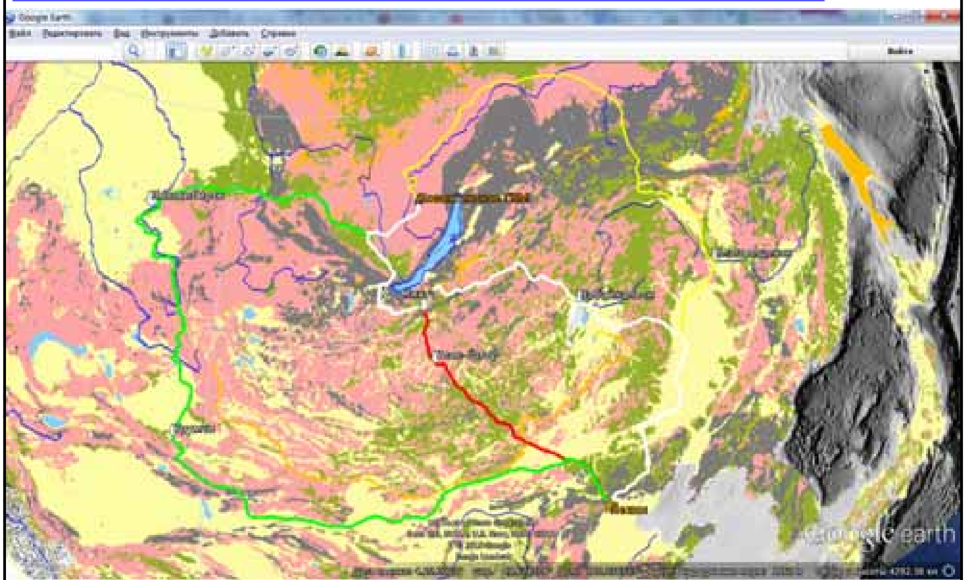
СЛОЙ ПОЧВЕННЫХ КАРТ РЕГИОНА (SOIL MAP)



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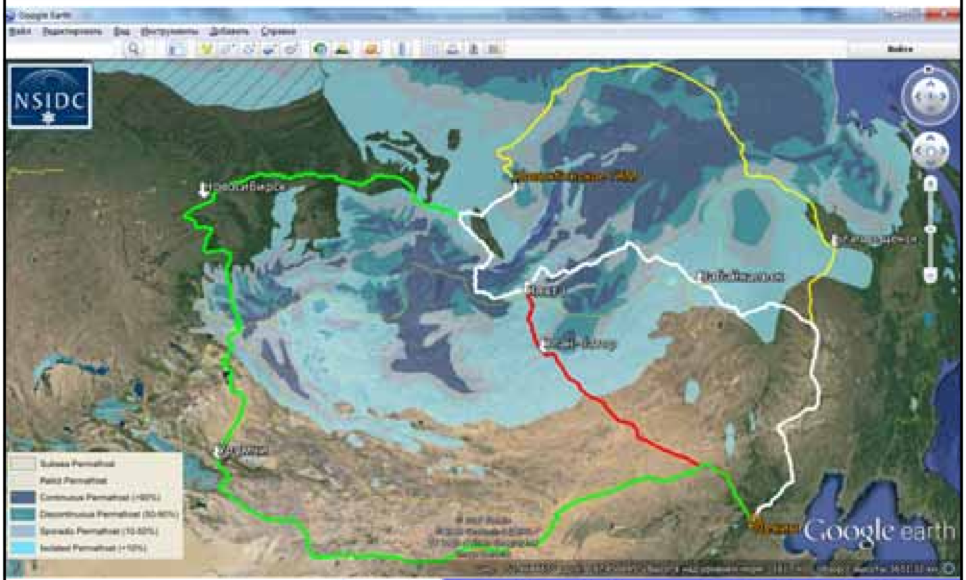
СЛОЙ МЕРЗЛЫХ ПОЧВ (FROST SOIL MAP)



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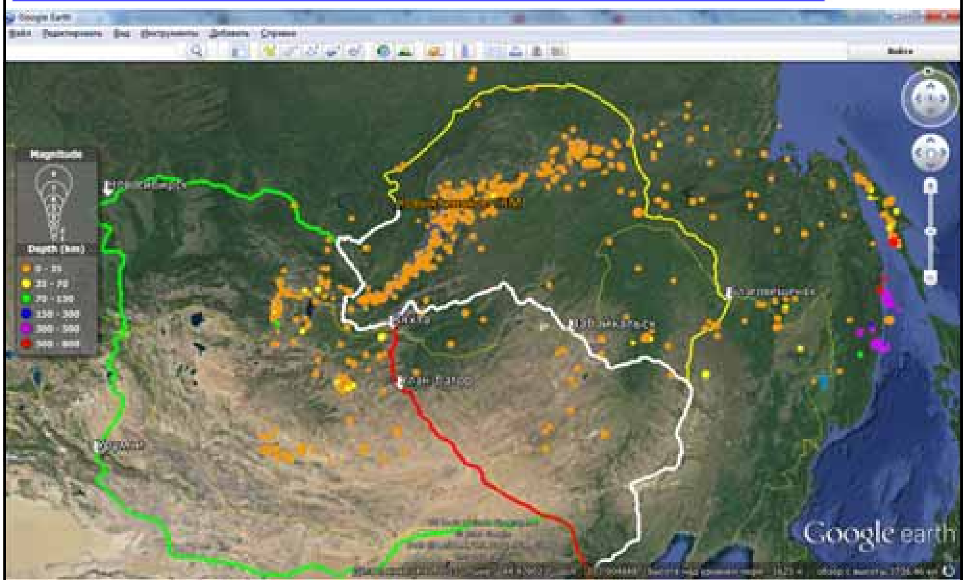
СЛОЙ ЭПИЦЕНТРОВ КРУПНЫХ ЗЕМЛЕТРЯСЕНИЙ (1900-2011 гг.) (EARTHQUAKES)



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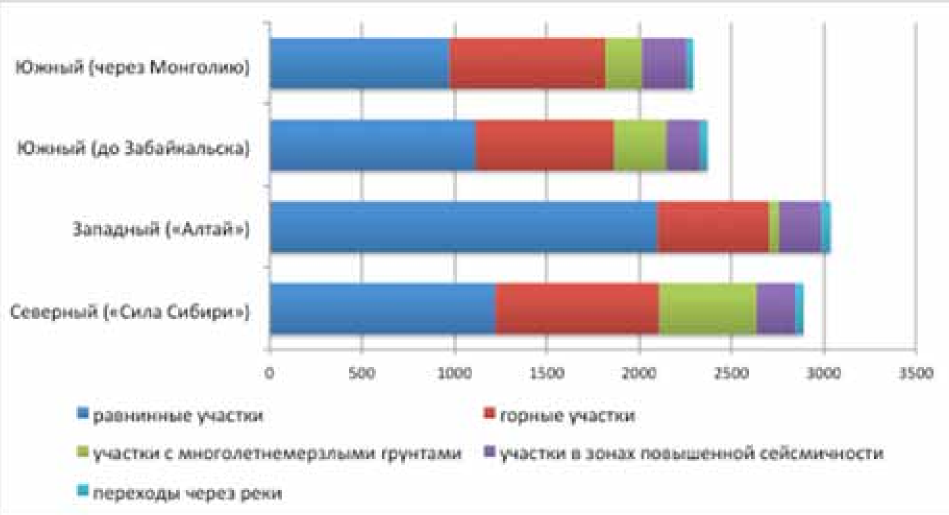
COMMON DIAGRAMS



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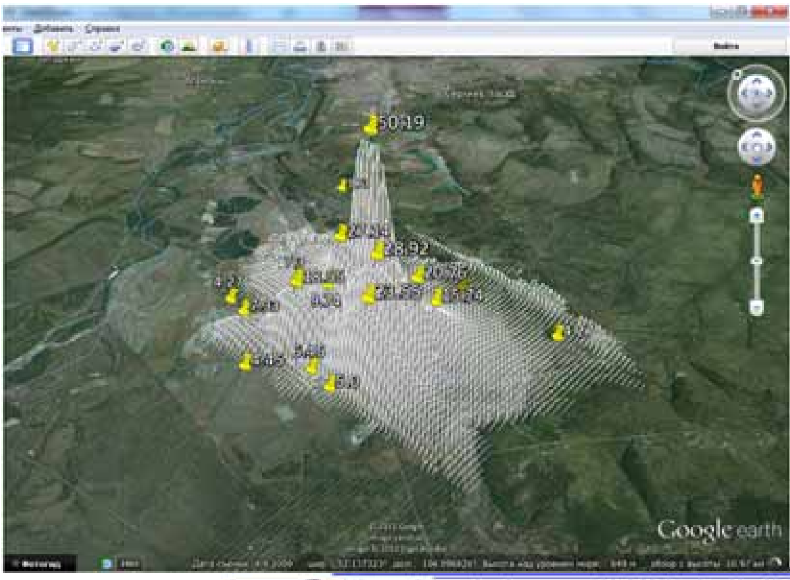
3D-geovizualization for measurements of pollution near power facilities and field emission with using of bicubic interpolation



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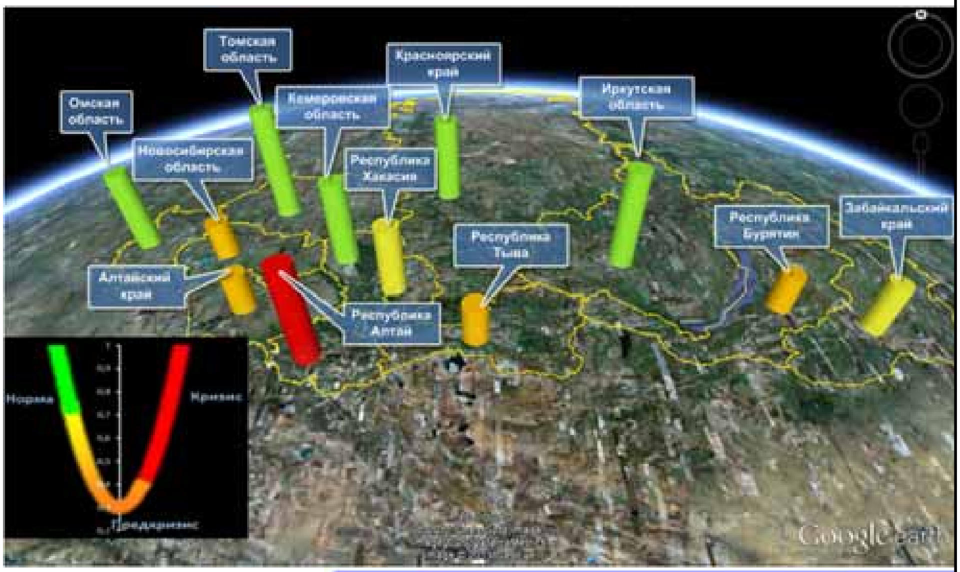
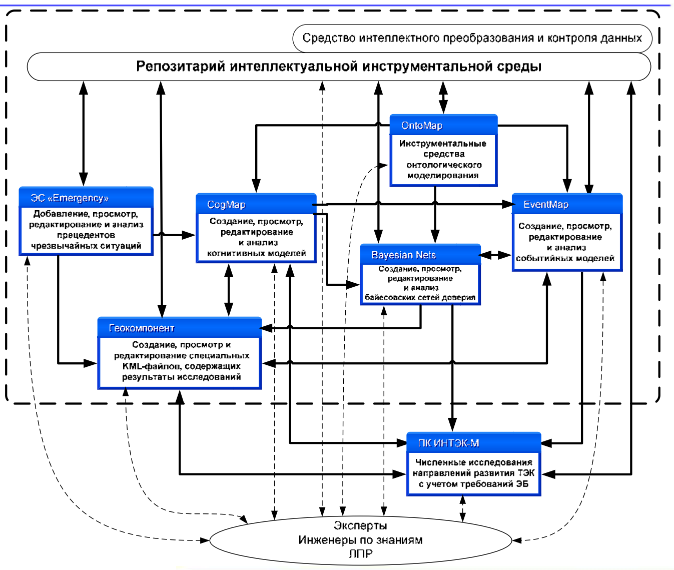
3D-GEOVISUALIZATION OF ENERGY SECURITY INDICATORS IN THE SIBERIAN FEDERAL DISTRICT



INTEGRATION OF SEMANTIC MODELING AND 3D-GEOVISUALIZATION



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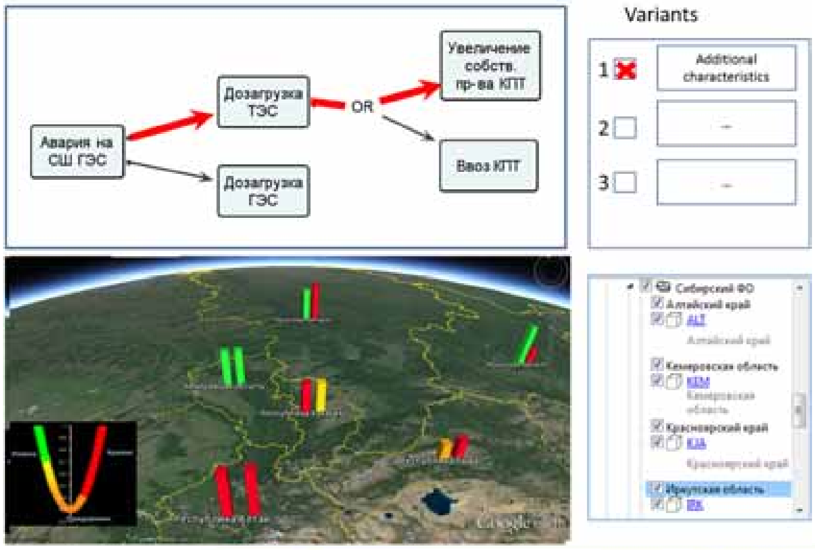
INTEGRATION OF SEMANTIC MODELING AND 3D-GEOVISUALIZATION

- IT- environment provides the ability to transfer the results of the qualitative analysis carried out with the help of semantic modeling in traditional multiagent software packages Intec-M, used to study the problems of energy security.
- Integration of geocomponent and tools for semantic modeling allows to provide 3D-geovizualization of cognitive and event simulation results, which increases "cognitive effects" of these types of modeling.
- In other words, the use of 3D-visualization significantly enhances the effect of cognitive graphics that have a graphics semantic model

THE COMPARISON OF SCENARIOS FOR SITUATION DEVELOPMENT WITH USING ES INDICATORS



CONCLUSION

- "Immersion" of researcher in visual environment for solving of spatial problems provides situational awareness, which is certainly due to the activation of the subconscious mind and improves the quality of tasks, involving intuition and experience.
- Thus, the integration of cognitive graphics and situational awareness based on 3D-visualization, greatly expands the possibilities of visual analytics, giving it a new quality and translates research to the next level,
- allowing you to link the symbolic (semiotic) and unsigned (figuratively) perception of information and use of new opportunities for geospatial solutions of management problems, particularly in the energy sector.

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