Experience on education in Geoinformatics

V.I.Klenov
Education Center 654, Moscow, Russia
e-mail: c.klenov@mtu-net.ru

Abstract

Geoinformatics in a Moscow college (Education Center 654) is in teaching since 1993 as the 2 years course for 10-11 classes of geographical specialty (about 250 hours). The purpose of the course is to connect the Geoinformatics with problems of the Environment. Several computers in provide the course auditory. The own long time practice and experience in geography, mathematics, programming, modeling, was applied for GI education. The author worked up all computer models used in the course. Main topics of the course are as follows:

- Problems of the Environment due to governing processes in scales from local to continental.
- General tasks and properties of GIS,
- Models of Environmental processes and models of nature systems in Geoinformatics.

Problems of the Environment are connected with four geography scales (from local to continental), which determine governing processes for each scale. The processes may be disastrous (storms, earthquakes, floods) and may be induced by general flows (water, air, human activity), which are both acting pressure/impact loaders of sediments and pollution. The conclusion of the part is emphasizing on environmental processes in interaction.

Introduction

The school education on Geoinformatics differs on the similar in Moscow State University, where Geoinformatics is looked in relation with cartography, with the main attention on Geography Information Systems (GIS). However, it seems that Geoinformatics should be seemed to be widely. The Geoinformatics should be directly connected with the growing problems in the Environment (climate warming, disastrous floods, snow avalanches, storms, and others). The problems of the Environment are to identify and analyze trends in environmental processes under both natural and technical pressure. The attention to trends in environment is be supported and searched by computer models. So the education in Geoinformatics makes attention on computer modeling of Environmental systems, in view to teach children to understand processes and to know, how modern computing helps to understand processes and to see ways to protect or to mitigate environmental and ecology catastrophes, by simulating of them, by execution various scenarios of disasters for the purpose of disasters management and mitigation.

Discussed are the next:

- Nature and technical accidents and disasters on the Earth in direct or indirect connection with water flows in nature systems.
- The primary aim for Geoinformatics in connection with problems of the Environment is to deal with governing processes of water/mass/ energy flows (exchange) in nature systems, and especially of disastrous processes (Klenov, 2003a, 2003c).
- The objects are widespread nature systems over the Earth: river basin(s), river net and coastal zone of a sea in scales from local to global.
- The corresponding computer tools are author's simulation models on: the River Basin Simulation Model (RBSM) (Klenov, 1998), the River Net Contamination Model (RNSM) (Klenov, 1999a), the Coastal zone Simulation Model (CZSM) (Klenov, 1999b), the Debris Flows Simulation Model (DFSM) (Klenov, 2003, 2003a), the coupled model of River Basin, Delta (Estuary), Coastal Zone (RIDEC) (Klenov, 2001b), models of 'Oil on Earth - TerOil', and 'Oil in Sea - Spill '.
- The other source for teaching is last direction in the science: the Hydroinformatics (dealing with modeling) and the Digital Earth (dealing with remote sensing and vast flows of information to reform for usage.

- The discussed problems of environment are also natural and technical accidents/disasters as follows: floods, debris-flows, soil erosion, storms, bottom/coastal abrasion, oil spread in rivers, sea, and earth surface, contamination in river net from various sources.
- GIS: components and functions (data storage, data search, multi-layer mapping, applications, and others) are seen in connection with other direction – with modeling of systems.

Models in Geoinformatics

Historically the Geoinformatics was appeared as the science, belonging to Cartography. The task of the Cartography is mapping, i.e. fixing distribution and properties of objects in geographical space. The resulted were Geoinformation Systems (GIS), which deal mainly with storage and exposition of information by mapping. It is right and it is necessary but insufficient because of Geoscience deals as well with Environmental Processes**,** which are real core of Geoinformatics. Dealing with Environmental processes leads to study responses of nature systems on external and human impacts. To dealing with a system in action demands for elaboration for models of a nature system to calculate governing processes inside a system under external drivers. Of course, the Cartography as Geographical science should fix chosen/current state of a system. But advanced Process Models has additionally functions of 'standard' GIS. Therefore, process models should be central computer tools for Geoinformatics.

The Earth is covered by various nature systems. Each of them is a unit of Environment, extracted from the Environment for some objectives. The most of Earth surface is covered by a system – River Basin (of any scale and structure). The Basins has clear boundaries as water divides what make it's to be easily extracted for search. The other widespread system is Coastal Zone of seas. It is a global scale system. For the practice it may be divided on more ore less durable fragments. On of boundaries is a coastline, the offshore boundary is the depth of penetration limit for wind wave energy (by determine), both sides of a coastal system may be artificial, or 'natural' (gulf shore). Other systems, being determined for to cover the World are as follows: Oceans, Glaciers, and Deserts. These models demand for other governing processes and were not elaborated for the course.

Several governing processes operate in each nature system. A system model describes and calculates leading processes in systems: flows of water, sediment, energy, and pollution. Several external pressure/impacts are meteorological processes on the Earth, wind/wave energy in a Sea, and additionally tectonics and sea level changes in large complex systems. Intensity and spatial variability of internal processes lies under control of elevation and bathymetry (depth), and under surface properties (soil/rock strength, streams velocity, infiltration, among others).

Models are preliminary written in the form of multi-layer grids of variables and parameters. Examples of interacting grids are: soil/rock strength, elevation, water thickness, snow thickness, distribution of precipitation and temperature, topography of aquifer, soil porosity, among others. Dynamics of a system is estimated as water/mass/energy exchange between all neighbor cells of the whole grid and in incessant temporal steps. Incessant computer mapping corresponds modeling by reforming of continuously estimated grids to contour maps. User's choice and overlapping of layers are foreseen. Movie mapping makes visible processes in a system. Estimation of flows and influence of parameters are calculated by range of empirical equations. The simplified models of complex system nevertheless are suitable for any real structure of system and are mainly invariant to scale. Change of a scale (from local to continental), however may require to include or to exclude layers from a calculation. The family of models, being builds with single algorithms and interface, goes not cover earth surface.

Disastrous processes

Governing problems of Environment are nature disasters as follows: floods, debris-flows, storms, earthquakes, and others. The others are technical/ecology catastrophes (toxic pollution, oil, dam failure). Most of them are in the competency of above mentioned models, because those ore closely connected with water flows. Earthquakes must be taken into account. Meteorological and tectonic processes are not included in the systems, and are external drivers, given by 1D and 2D records. Models describing the events are variable in scale because of disasters are varied in scale from local to regional, for example, local and regional floods.

The external information is space distributed and variable. The modeling of disasters is intended for disasters monitoring for management, engineering, hazards mitigation, forecasting. Rapid expansion of space observation and enlarge of information 2D flows leads to problem for rapid and effective reform of enormous data to new information.

The task of monitoring of nature system seems to be simple by help of system models. For the purpose to evaluate flood intensity as response of external pressure/impact (rainfall, snowmelt) it is enough 'only' to calculate all water flows in the system. This 'simple' task was unreliable until (1) fast and powerful computers were elaborated, (2) the enormous external data (driving factors) became accessible due space observation. (3) Necessary component element for disaster monitoring is only mathematic system model for reforming of data to water, mass, and energy flows through nature systems. Nature systems are seen as operational unit of environment. Mathematical model is a model of processes. Demands to the model properties depends on variety of nature system of each class of its. There are a lot of models. But models must be simple as possible and universal as possible to be applicable for variety of nature system. It seems, that the convenient is so named simulation model, which is preferable to call forever as Models of Systems, or models of processes, or at last Process Models. The models can be combined in complex systems with property of self - organization of flows and self – determining of processes. All models enable to generate thresholds and to estimate disasters.

Common 'law of data deficiency'(under national peculiarities, under scientific or other reasons) it is necessary to elaborate models with abilities to enhance parameters and to mine data in a process of modeling. In a whole the process model of concrete system for a concrete area is 'a factory', which reforms natural source (space data) to new product as new vital information about a water and water related flows in earth systems, and estimation of hazardous processes. The use of this 'estimated' information for disasters monitoring is discussed.

Education models

The first requires to Education model of nature systems is that those should be operable and must be easy visible for scholars. By other words, all models must be and are provided by corresponding computer mapping, in combine with possibility to change situation by commands through display, or/and by functional keys of keyboard. The second is that they must include criteria (in 5 balls system) of successful decision of a practical task. It means that tasks is in enhancing of initial bad ecological state of the area by each scholar in view to receive the highest balls by cleaning of an object (area), or by mitigation of hazards. The third is that they provide large variety of tasks for each model and variety of environmental models. It means that it is initial standard task, which can be done more difficult by added conditions (by teacher), or can be studied on other object (area). The forth is that models must be installed on several powerful computers (for individual work) for education groups in view to provide independent work for one/two scholars at one computer. Not all of these conditions are provided by the Education Center. Commonly, the backgrounds for any model are processes and problems in the Environment. The tentative list of practice consists on the followings:

- River net contamination and cleaning.
- River net accidents (oil/toxic accidents – ecological catastrophes).
- Oil spills – tankers or pipeline failure.
- Earth surface oil accidents – oil spread with additional conditions and processes.
- Coast/beach abrasion and protection.
- Seasonal monitoring for floods.
- The most advanced is the RIDEC as the unit of river basin – delta – coastal zone models.
- The additional tasks: modeling of information losses in nature systems.
- Thresholds in Opened Nature Systems (debris flows).
- Advanced tasks – scenarios for decision support.

Examples are as: river net, oil accidents (sea, river, earth). First order tasks are contemporary easy and rapidly computed. Second order tasks – modeling of floods, flood protection – needs or for powerful computers, or for more time for process estimation (what is not optimal for scholars during a lesson), and chosen tasks for advanced children.

Models of nature systems were reformed to education versions by restriction to input-output operations, and by reducing of functions, and by adding of valuation criteria for successful decisions. Below are some of them. Models are divided for 'active' decisions and for 'passive' processes observation.

Cleaning up for contaminated river-net is the initial version is the RNPM (River Net Pollution Monitoring). It is the moving model for contamination transport along river net from local and distributed sources. Pollution with similar various characteristics (PLC, stability, dispersion, and others are distributed on several simultaneously evaluated layers. The sum of pollution at each short part of a river (0.5-5 km) is in dependence on scale. Number of elementary parts of cell is in principle not restricted. The river net is colored in dependence on concentration of pollution (in dependence of estimated or giver river discharge at every cell). Estimated is quantity of population, being under polluted water. The task is to establish of artificial cleaning points to clean most of pollution from local sources (factory, other.). The task may be more difficult by existence of moving pollution in a river and hazardous wastes. The advanced versions use interaction between layers, seasonal variations of discharge. The peculiarity of the model is possibility to input all necessary data (and river net) directly on the screen. Figure 1 shows initial and final steps. Advanced scholars make all modeling tasks independently for real situation, for example, for disastrous toxic wastes in river nets (Danube, Ob). Several such reports were successfully presented on school conferences.

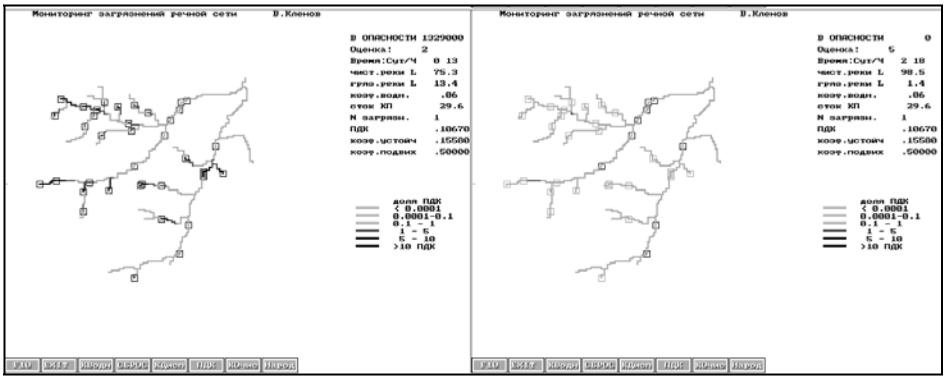

Figure 1. Modeling of river net contamination (RNCM): initial and final steps to clean up.

Tracking and cleaning for oil spills in a sea are results of tentative or real accidents with tankers). Contours of coastline and islands are driven on the screen, surface and sea surface is automatically written in the memory as a grid with high spatial resolution. The driving factors of oil spills are wind power and direction (being under control from keyboard) and current of any configuration, also being driven from keyboard. Any tentative waste(s) of oil must be input also on the screen from keyboard. By influence of winds, currents, and self-spreading oil spills move, reach a coast and disturb environment. The square of disturbed sea is calculated. The thickness/value of oil at any cell is seen in contours or by cursor location (fig. 2, left). The task is following up of oil during nearest coast by varied scenarios, and to cleaning of sea surface by oil withdrawing simulated. The tasks may be varied by any plane configurations of coastline, by any quantity of sources, and under varying of parameters (oil mobility, stability, and others), and under changing of wind power and direction by scenario or/and by keyboard. Quantity of conditions and scenarios is non-restricted. The several real catastrophes with tankers were modeled (Japan Sea, Japan Sea, Biscayan Gulf). The model “Oil Spill’ is more variable, then RNCM.

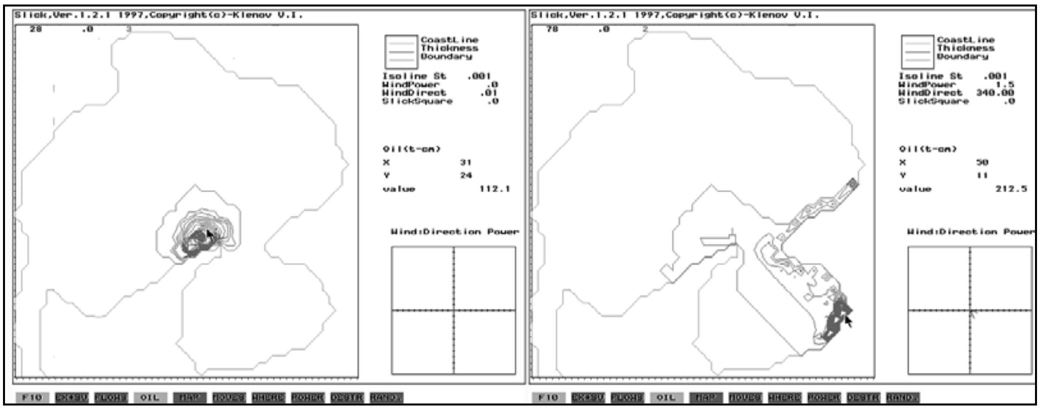

Figure 2. Modeling of Oil Spill moves in a sea under influence of changeable wind power and direction.

A model of Oil pipelines accidents on the earth is in active use. Scholars/students must prevent oil spread independently by artificial channels, carriers, dams, and withdrawing. The model titled “TerOil” needs more initial information: Elevation grid, grids for soil properties for oil delay, and observed or tentative records of precipitation and air temperature.

The proposed is to prevent spread of oil to protect population sites, rivers, etc. The provided are several methods for it: building of dams (Fig. 3), excavation of channels, and withdrawing of oil by ‘pumps’. The restriction of the TerOil for real cases is demand to more initial information, necessity in high-resolution grids. All other information may be artificial.

Several following models: RBSM, DFSM, CZSM, and RIDEC are portrait installation and may be used for any scenarios for response of a real system (River Basin, Coastal Zone of a Sea, Common system of large River, Delta, and nearby sea. These models provide observation of systems during seasons and years (in model time), and impacts on systems by relief engineering, waste damping, flood mitigation through being observed processes in systems (precipitation, snow coverage and melting) and by any scenario of natural/human impact. These advanced education models may be applied at next levels of education, in use of them in real nature systems for study of Environmental problems. More powerful computers are necessary.

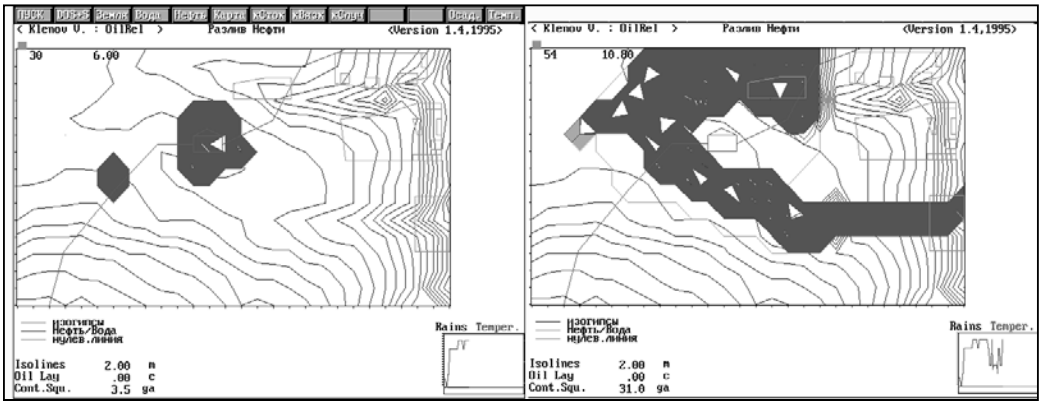

Figure 3. Modeling of Oil accident in a river basin and it mitigation by dams.

Modeling of floods and debris flows in river includes continual ‘observe’ of several processes in a river basin, including snowmelt and rainfall floods, and also catastrophic floods and debris flows (Figures 4, 5).

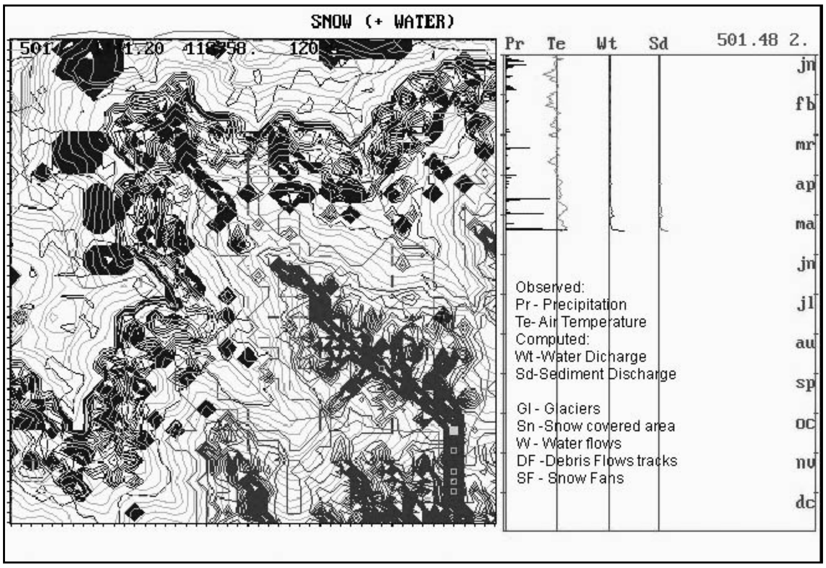

Figure 4. Modeling of seasonal processes & debris flows in the Caucasian basin.

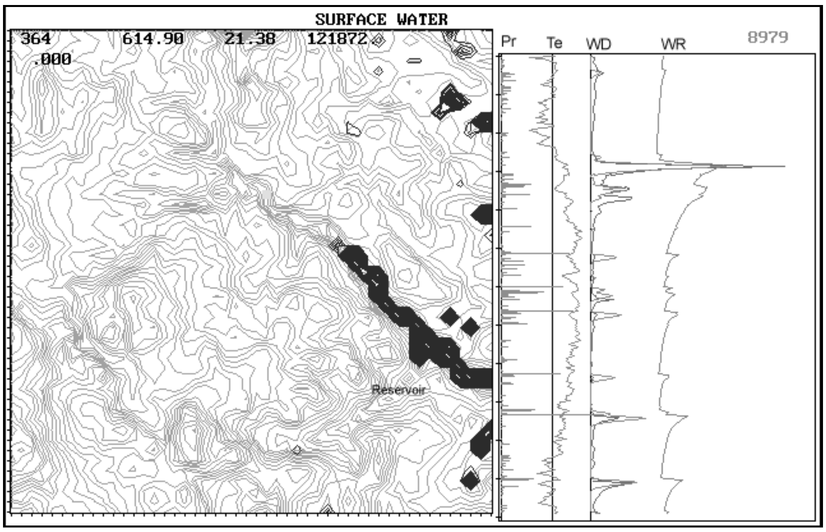

Figure 5. Modeling of floods in a plain river basin (Moscow River upstream).

The study includes 'remote observation' of processes in a river basin by incessant computer mapping under varied scenarios of flood mitigation by land use policy, by dam building, and of others. Assessment of soil and rivers pollution is foreseen in range of provided aims. These models are applied for multiple and multipurpose GI education as computer 'double' of a real basin. Being provided by necessary minimum of data, there are no problems to simulate hazardous/disastrous processes such as debris flows and dam breaks. It is obvious for the purpose of computer support to be effective the model must be provided by necessary data (elevation grids, meteorology and hydrology records, geology, geomorphology distributed data in grid presentation, and data about former disasters).

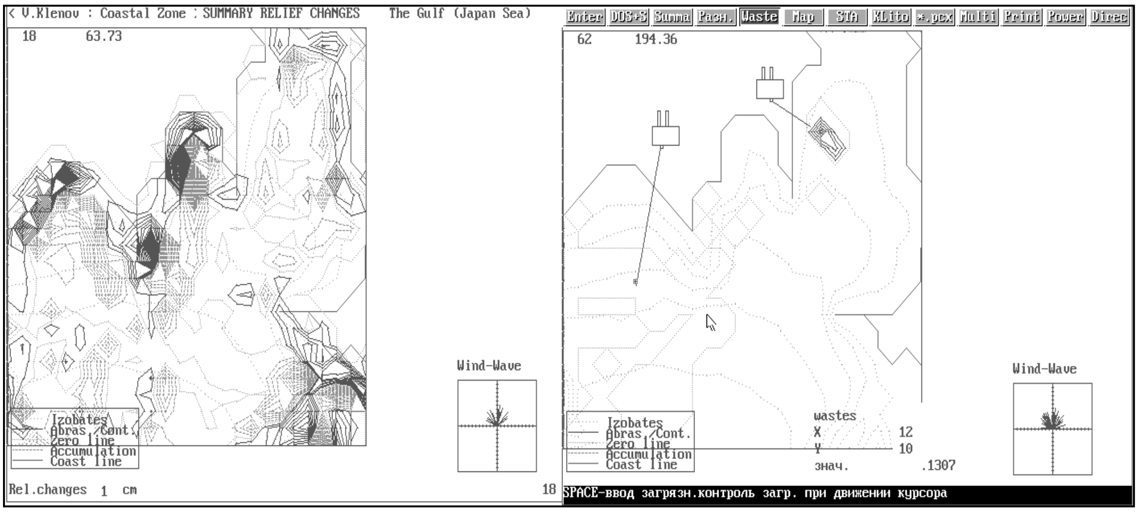

Figure 6. Modeling of processes in a Gulf of the Japan Sea: Abrasion/Sedimentation pattern and valuation (left); Bottom pollution spreads after dumping (right).

The above (Fig. 6) model of the Coastal Zone (CZSM) of a gulf in Japan Sea demonstrates response of bottom and coastal abrasion/sedimentation processes in dependence of sea depth and of coastline configuration, and estimates spread or concentration of bottom wastes from land sources in various locations of damping under compound conditions of sea depth, wind power/direction, coastline configuration. Scenarios of dam/bon building, sea level oscillations and trends are provided directly from keyboard. Models of natural systems are suitable for any real object and needs for grids of depth/bathymetry. The variety of properties and scenarios makes models suitable for enhanced level of education, for training, and for applications.

Modeling of complex nature systems

Models of complex systems are including several basins, or river basin and coastal zone of a nearby sea; included delta or estuary is intended for enhanced goals at the final part of education course. Example case study is the sub continental river basin (the Rhine Basin), the delta (the Netherlands) and the nearby part of Coastal Zone of the North Sea (Fig. 7). In this single executable module are united several nature systems, with varied external drivers. The model is called RIDEC (River basin - Delta – Coastal Zone). The land part of the vast area is described by algorithm of the RBSM, the sea part – by the CZSM.

In the first external factor are: precipitation, tectonics, and maybe sea level changes (sea level changes are foreseen in the CZSM). The main peculiarity of the RIDEC is that it include additional factor (what is foreseen in 'partial' systems but were de facto not activated). These factors are as follows:

- Meteorology disasters are modeled as input driver of systems**.** Unfortunately, the author has not own models on meteorology processes (cyclones, storms, and other synonymous). Nevertheless meteorology/hydrology 1D and 2D records are factors of earth systems activity and are widely used as external factors for modeling.
- Tectonics activity is foreseen**.** Existing or proposed data on various recent tectonic deformations of the earth core, and resulted changes of earth processes are included in the models. The external 'tectonics' influence essentially change spatially distributed flows and changes a pattern of erosion/sedimentation in earth systems. It was simulated also for other practical goals.
- Sea level trends and oscillations (tides) are modeled in CZSM and in the RIDEC especially in scenarios for explanation of last opinion on sea level rise. Sea level change is governing reason for coastal

abrasion, beach destruction, and bottom abrasion/sedimentation (in relation with marine agriculture). It is meaningful factor for stability of shore proof engineering (dams, bones). The insertion of any factor or process in a model depends on tasks of modeling, on scale, and on temporal step (daily, centennial, etc.).

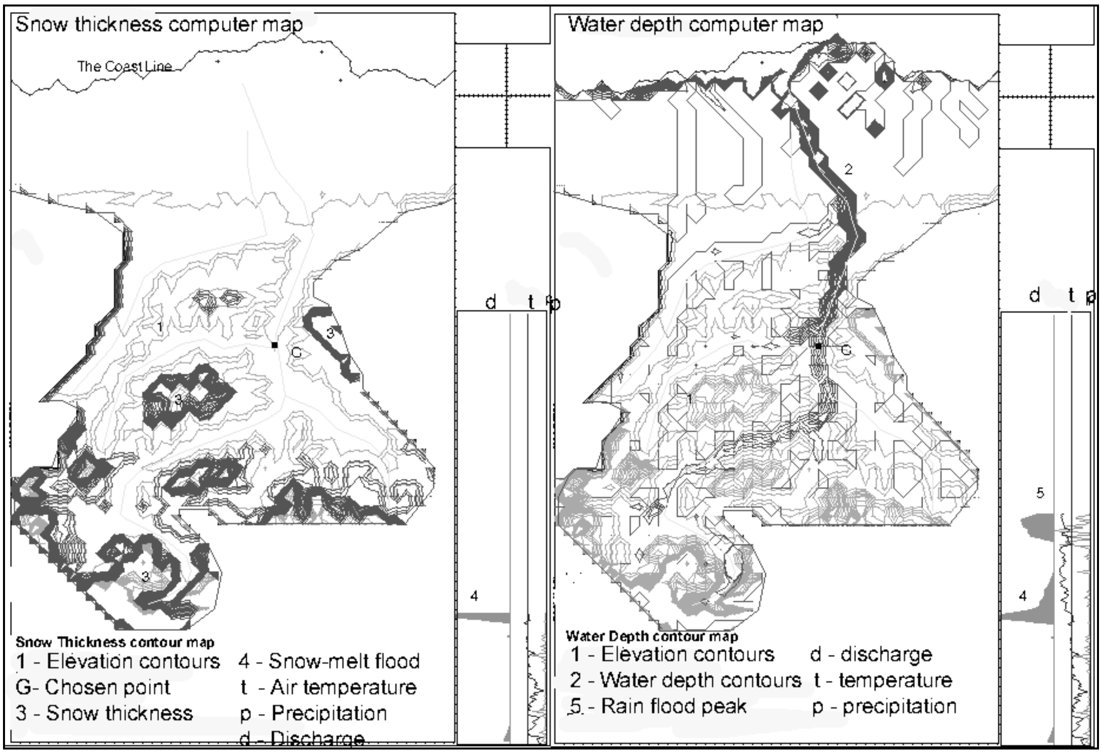

Figure 7. Multi-objective model for study of Land - Ocean Interaction in Coastal Zone (LOICZ): for the system of Rhine Basin – Delta (the Netherlands) – Coastal zone of the North Sea.

Modeling of the large system in the sub continental scale was done with simultaneous changing and oscillations of meteorology regime, varied trends of sea level and small regional tectonics (Figure 7) as external drivers of the system. Because of even simplified version of the RIDEC is not convenient for fast study, because of it needs for a long time to simulate seasonal processes in interaction, it may be used under conditions of powerful computers and by varied scenarios of nature and technical influences (reservoirs, floods, sea level changes, tectonics and a lot of others). It was applied in by advanced scholars for modeling of floods in a Chinese large river). In a whole the group education was applied for comparatively easy tasks for better understanding of processes. Individual tasks were proposed for advanced children and for chosen interested models. One of main objectives of the GI is the Decision Support. The below is an example of it (Fig.8), which is demonstrated as application of modeling.

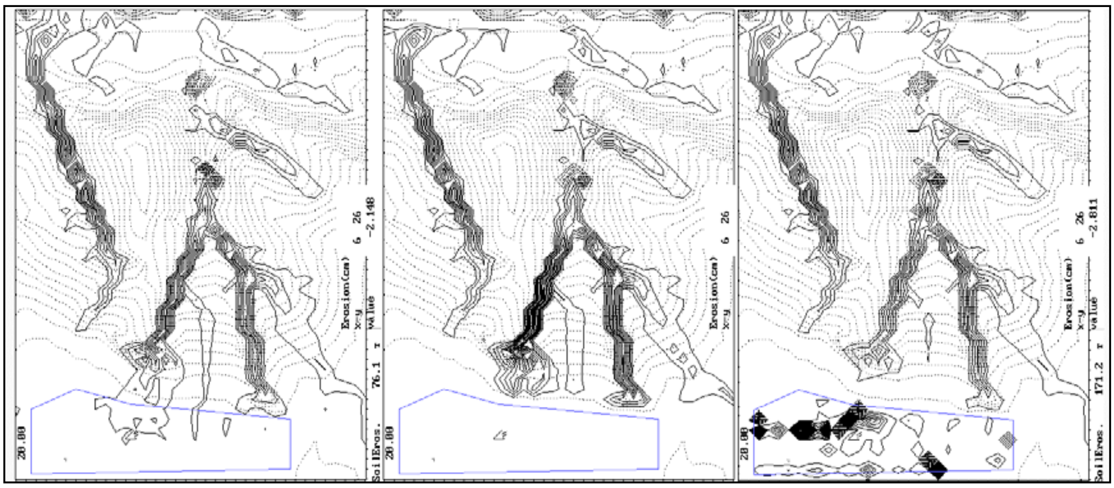

Figure 8. Scenarios for Erosion mitigation in Building site (in tributary of the Moscow River).

Real case study consists on several scenarios for the purpose to prevent soil erosion upstream the small tributary of the Moscow River in view to protect site of building from erosion. The three resulted scenarios are case of non-disturbed soil (left), protected soil (centre), and destroyed soil (right). The comparison of synchronizes computer maps shows that impact on the Environment for 'protection' resulted in increasing of soil erosion in the tributary upstream nearby site of building, what needs to search other compromises decisions by other scenarios of the system protection. Moreover, the necessity of validation both models and decisions demands for long time records and other relevant information to assist long time forecasting of decision consequences.

Models of other complex system (system of inter-mountain depression between mountains) enable to operate in geological time with centennial time steps. It makes possible to model evolution of river-net, filling up of lakes, and relations between sedimentation and external climatic, tectonic pressure, for search of information save/loss laws. The purpose is to find relations between real (simulated) history and it restore in sediments – for important objective to find criteria for long time trends.

Due to necessity to teach in location of geographical names for the purpose of examination in the MSU it was worked out and widely applied the training tool 'Geographical Names' (GNOM) for a large list of geographical names over the World (rivers, seas, mountains, gulfs, and so on) for different regions of the World. Children deal with maps should locate all names on blank maps, being asked by the GNOM and with automatic valuation of results. Most of above discussed models are made in form games, with criterions of winning after successful decisions of ecology problems. Recently children were asked about an interest to most used tasks/models to determine a 'rating'. The results were calculated and graphically prepared by children (Figure 9).

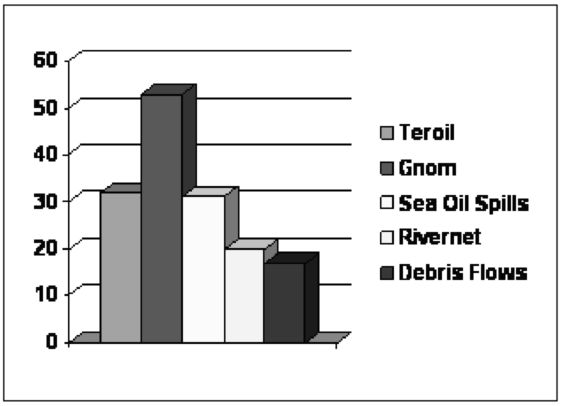

Figure 9. Rating of models, prepared by schoolboys (Kolokolnikov, Philipp &. Shchepansky, Ivan)

Criterions of the rating are variability of active scenarios (TerOil, Sea Oil Spills), benefit for study of World Geography (GNOM). The River net is not multivariable. The Debris Flows (DFSM) is too slow for a lesson time due weakness of used computers. The most interested was GNOM due it necessity in common geography for other teachers (on geography), and the next models: Oil spread over earth (TerOil), and oil spread over sea (Spills), because of possibility to rapid active game of any scenario of ecological disaster with necessity to mitigate and to clean an area. All operation of preparation of computer image, location and input of disasters are made from a keyboard to screen to see processes in move and to try change external nature (wind, currents, rains, etc.) impacts and to respond (by dams, channels, bones, by withdrawing of oil, etc.

Conclusions

The experience on education on Geoinformatics is based on own author's experience on elaboration of a number of 'moving' models of nature systems. Simplified and reduced versions are used in education. The 2D models cover most widespread systems on the Earth and in Coastal Zone of nearby seas: River basin(s), River net, Coastal Zone, and integrated systems of land and coastal zone. All applied models differ on complexity, on quantity of modeled scenarios and applies, by flexibility of input – output operations, by applicability in Environmental tasks. The most of them propose active participation of children/students in all process of modeling form input of initial data to decision. Computer practice is alternated by lectures about problems of Environment, about structure of 'traditional' function of GIS. Operating with systems helps to see complex interactions and consequences of nature trends and human impacts on Environment.

The main direction is in operating with models of dangerous and disastrous processes (floods, debris flows, abrasion in coastal zone) and anthropogenic accidents (oil spill in sea, river, and on earth, spreading of toxic pollution through river net and river basin). The computing of earth systems helps to understand and to manage governing processes in the Earth in their interaction. Properties of the 'Modeling Geoinformatics' are enhanced for computer monitoring of disastrous processes by combination of space data with system modeling, by reforming of source data to new information about earth processes. GI model is a factory of Information. Models of nature systems in action show relation of processes in a system, dependence of ecology problems in a system owing human abnormal land use policy, show vulnerability of systems, and dive a chance to find methods of systems protection and restoration.

The Geoinformatics and GI education in advance consists on two key components: the Digital Earth and models of nature systems activity. Following provides this: space information flows, numerical models of systems, and powerful computers. Being called as the Moving Digital Earth (MDE), those expected to be reliable tools for at last regional monitoring of the Earth Environment. The former System analysis should be expanded to Nature System Numerical Modeling and fast estimation of system processes. System modeling is provided by ability for estimation of processes by 'a Factory of Information'.

The main scientific, education and application objective is prediction and recognition of disasters. Fast reforming of source information to expected information enables, as a first aim, evaluation of catastrophic processes before input of new information at the next temporal step. It is an Outstripping Monitoring. The peculiarity and advantages of the Outstripping Monitoring is in that processes are estimated over all system (basin, area, etc.) and for all system's processes taken into account. There are several strategic steps/parts of the Monitoring Technology by the MDE. The 'fundamental' part is calibration/validation of the MDE tools by former outside records. Only time-span records restrict the period. The first part is Outstripping Monitoring of system's processes (including disastrous ones) being physically based on properties of Open Natural Systems, on system's inertia due accumulated energy of water resources, and by delay of flows in the Past. 'Past water' provides future disasters. The second is the Foresight Monitoring of a system for several following steps. Inertia of a system is combined with inertia of external processes. The third is Forecasting of processes (and disasters) being provided by continual extrapolation or evaluation by independent climate models.

The 'other main' objective is the Decision Support. The Decision Support Systems (DSS) are founded on GIS, Digital Earth, and MDE. The DSS should be provided by validated models, and the models must be based on observed records of data.

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Appendix Structure "Questionnaire"

General information

Moscow Education Center 654 is Moscow school (college) for children with 11 years of education. Two groups (10, 11 classes/levels) have a specialty in Geography. Author is a lecturer/teacher on 'GI and problems of the Environment' since 1993.