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GIS applications for the investigation of hydrometeorological and biochemical conditions of coastal areas

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Abstract

The paper discusses the use of Geographical Information Systems (GIS) in the aspects of marine environmental research, as approached by Russian and Greek groups. The scientific teams apply the same GIS platform in both cases, but with a different orientation, according to the particular driving forces of the projects involved.

In general, the Russian team manipulates GIS as a subsystem of problem-oriented applications in order to enlarge the possibilities to run non-standard user programs. The subsystem of problem-oriented applications (POA) is designed for the following: (1) analysis of data and information to implement applied tasks; (2) preparation of output information products of the system in the form of hard and electronic copies in accordance with the required formats; and (3) dissemination of information products according to the users requirements.

The Greek group focuses on the GIS use as a tool for joining different layers of spatial information in the marine area under investigation. Also, incorporated in the GIS is the drainage basin that supplies the marine area with water, sediment load and also human derived substances. Layers of hypsometry, bathymetry, hydrography, river network, roads, cities, satellite images etc., have been introduced into the system, obtaining significant feedback information. Also, there are developed the relations of the former layers with the marine sampling stations network and the database that describes the station's properties.

The two groups benefit particularly by the exchange of ideas and methods, as different consideration is undertaken to resolve marine research issues.

Keywords: GIS, Oceanography, Models, Aegean Sea, DEM.

Introduction

The use of Geographical Information Systems (GIS) has been widely adopted during the past decade in the support of many and diverse scientific issues. Oceanography, as one of the highly multidisciplinary earth sciences, is taking advantage of this relatively new technology in order to investigate various themes related with the marine environment, such as the coastline change and associated hazards (e.g. El-Raey, 1997; Zeidler, 1997; Cooper & McLaughlin, 1998), sedimentation processes (e.g. Kastler & Wiberg, 1996; Rooney & Smith, 1999), estuaries pollution (Nasr *et* *al.*, 1997), or even marine tectonics (GOLDFINGER *et al.,* 1997).

The scope of this paper is to present two GIS applications designed for the analysis of different oceanographic issues. The applications have been developed independently by a Russian and a Greek group of scientists, demonstrating similarities and differences in both the architecture and the tools employed. Both applications will be described and compared in terms of scientific orientation, development tools and types of produced results.

Materials and Methods

The applications were developed under UNIX and Microsoft Windows NT® operating systems, using mainly commercial software. The Arc/Info® GIS software platform was chosen to serve the application development, along with the ArcView™ GIS, which provides a wide set of useful build-in tools like zoom-in, zoom-out, distance measurement, setting layers on-off, etc. Other software packages used were Avenue®, Dialog Designer®, Spatial Analyst® and 3D Analyst®, and several product licences were obtained.

Results and Discussion

Problem Oriented Applications (POA)

The RIHMI-World Data Centre of Russia is working towards the development of Problem Oriented Applications (POA). The POA subsystem provides flexible, user friendly means for scientific and practical aims, using integrated data, procedures as well as tools. The concept, architecture and development procedure of the POA subsystem will be presented together with an example application in the Kara Sea.

Basic concept of the POA

The POA should accomplish the following major tasks:

· provision of data and information by requests as hard copies or in electronic form;

· obtain environmental characteristics (including extreme) and assessment of the background conditions of the environment;

· monitoring the current environmental conditions in the course of construction and maintenance.

Application domain of the subsystem is defined by priority tasks and consists of several classes of objects:

· data and information on marine environmental conditions;

· models and methods of calculation of environmental characteristics for the region of investigation.

On the physical level the POA are constructed using the following basic components:

· methodological component in form of the requirements on the environment monitoring and protection;

· information component, which consists of the information holding in the form of archived datasets of textual, factographical and spatial data;

· linguistic component, representing tools to support the interface to the data and programs which provide the calculation and modelling;

· software-technological component, which consists of GIS ArcView®, calculation and modelling programs, realising information technologies in the subsystem.

The POA architecture and development

The problem oriented application subsystem consists of a base module, from which user programs are called, and application software, solving individual tasks of modelling and processing directly. The base module is developed as GIS-application, using the wide GIS possibilities to run non-standard user programs. No restrictions are set in the application program development,

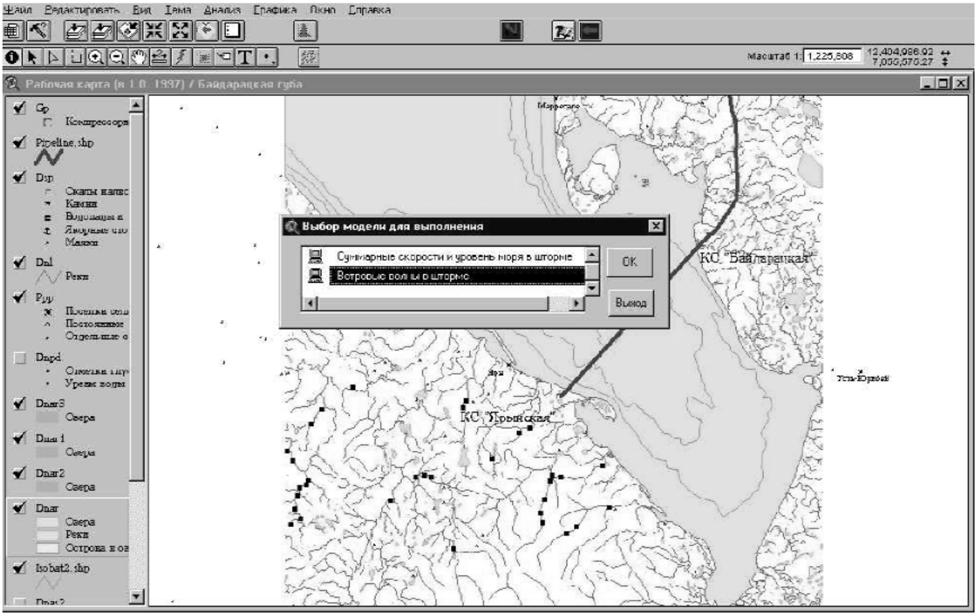

Fig. 1: The choice of the wind waves model in the POA panel (ArcView GIS-application).

except for the requirement that they can be produced in the form of DLL-libraries. The POA architecture provides a flexible basis for the integration of non-standard user projects such as external models and other computational procedures.

The key feature of the POA is to combine a variety of user-defined programs. For this scope, a special unified input and output parameter definition language was developed. The language includes a number of modules allowing practically the specification of any parameter required for user programs to be set up and run. It should be mentioned that the language enables the specification of fixed parameter sets, or of parameters that can be changed during the program operation. At the same time, the language allows the construction of a Graphic User Interface (GUI), such as buttons, menu bars, sliders, etc., in order to help the user to perform parameter input in a friendly manner.

During the operation, the application programs can make use of both the internal (GIS) and external databases (DBMS). The internal database is used with the link-tables defined in the input and output parameter specification language. The external database is involved in a conventional manner by using ODBC and SQL-requests.

Pipeline route in Baydaratskay bay

An example of a POA development is the investigation of hydrometeorological conditions and their impact on a pipeline construction in the bay of Baydaratskay (Kara Sea). The application provides several background information for the area, such us hypsography, bathymetry, river network and other information layers. In this example, the potential user selects the Wind-Wave model to be executed (Fig. 1). The Wind-Wave model is an external module that has been developed independently. However, input-output procedure calls have been adopted in order to fit the GIS prerequisites. The procedure comprises the following steps:

1. Selection of the required (Wind-Wave) model.

2. User input of desired wind speed and direction, employing graphic menus and bars, setting of minimum and maximum val-

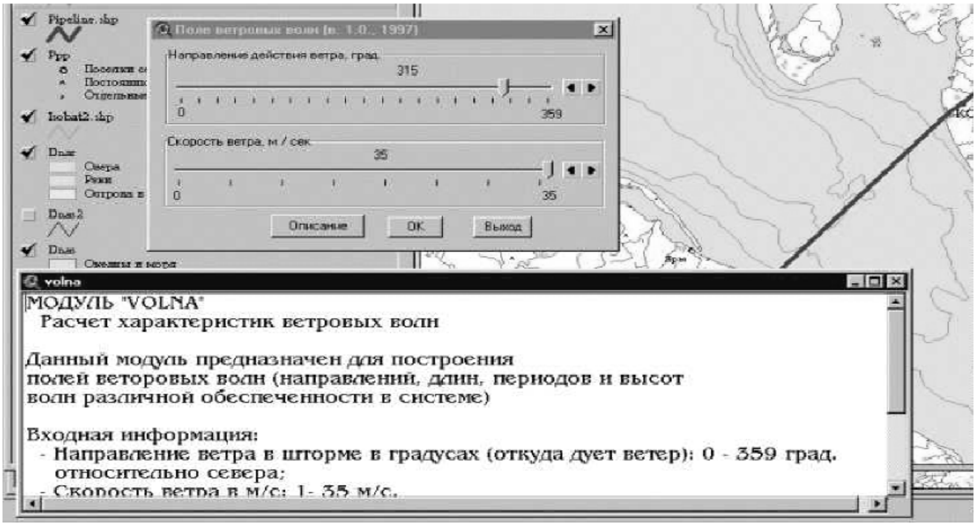

Fig. 2: The view of the input parameters panel of the wind waves model.

ues (Fig. 2). Alternatively, a file with these parameters may be used.

3. Transformation of the information read into standardised file with a description of input and output data flow (automated task).

4. Link to the electronic map and specification of the boundaries of the region for which the task is to be performed (automated task).

5. Model execution.

6. Visualisation of the results on the electronic map as well as additional diagrams and tables in individual windows of the screen (Fig. 3).

In this POA example the produced results concern the computation of the mean and extreme values of the wave height, period and direction. The results may be displayed

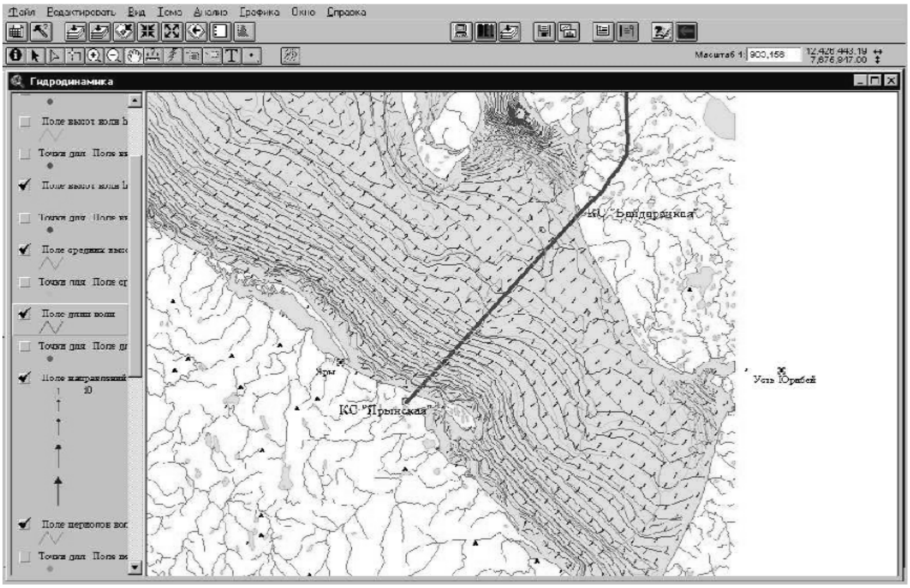

Fig. 3: The results of wind waves model: the fields of 1-% probability and mean wave heights mean periods and directions.

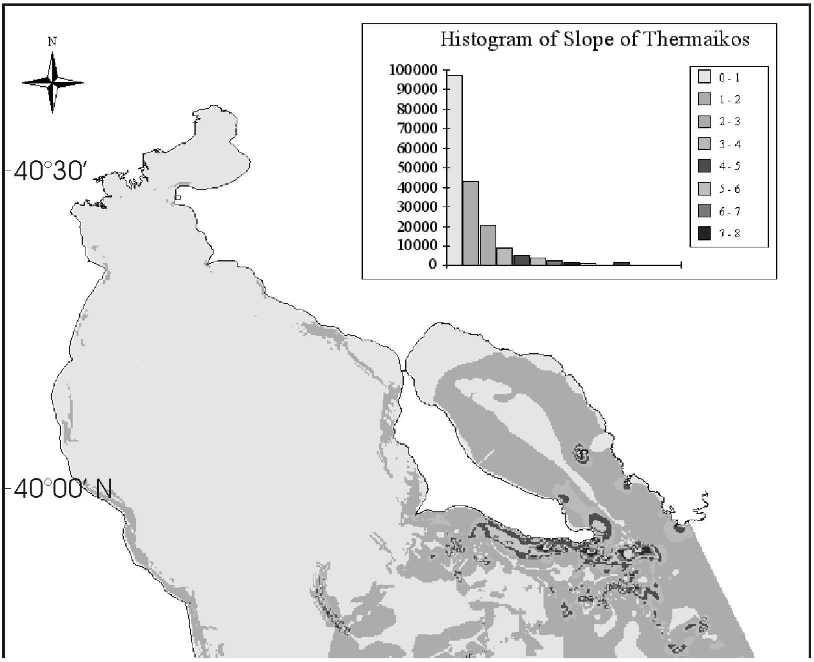

Fig. 4: Digital Elevation Model (DEM) of the NW Aegean Sea and the corresponding catchment area. Hillshade applied. Illumination source azimuth 315° and altitude 45°. The political boundaries and the major rivers are also illustrated.

as contour lines (Fig. 3), diagrams and text. This output data can be used for the estimation of wind-generated waves and their possible impact on the pipeline construction in the area. The model may also compute the sea level and its surge component oscillations.

Metro-Med GIS

The application "Metro-Med GIS", was developed at the National Centre for Marine Research of Greece, in order to support the EU MAST-III project Metro-Med (Dynamics of Matter Transfer and Biogeochemical Cycles: Their Modelling in Coastal Systems of the Mediterranean Sea; MAS3-CT96-0049). The project commenced in 1996.

Basic concept of the Metro-Med GIS

Metro-Med is a multi disciplinary oceanographic project collecting physical, chemical, geological and biological information in the marine area of the NW Aegean Sea. Metro-Med studies the marine area as an integrated system with the surrounding land, since terrestrial input in fresh water, sediments, nutrients, pollutants (heavy metals, pesticides, sewerage, etc.) is of major importance.

In this multi-thematic concept, the NCMR team developed an application able to provide GIS based information for the catchment area of Thermaikos gulf and Sporades basin as well as oceanographic data (KARAGEORGIS *et al*., 1997; 1998; 1999).

The Metro-Med GIS architecture and development

The Metro-Med GIS combines vector and raster data. Various thematic layers were introduced in the system over a period of 2.5 years. These coverages concern the hypsometry, hydrography, political borders, road network, urban area and the bathymetry. Digital data and maps from various scales

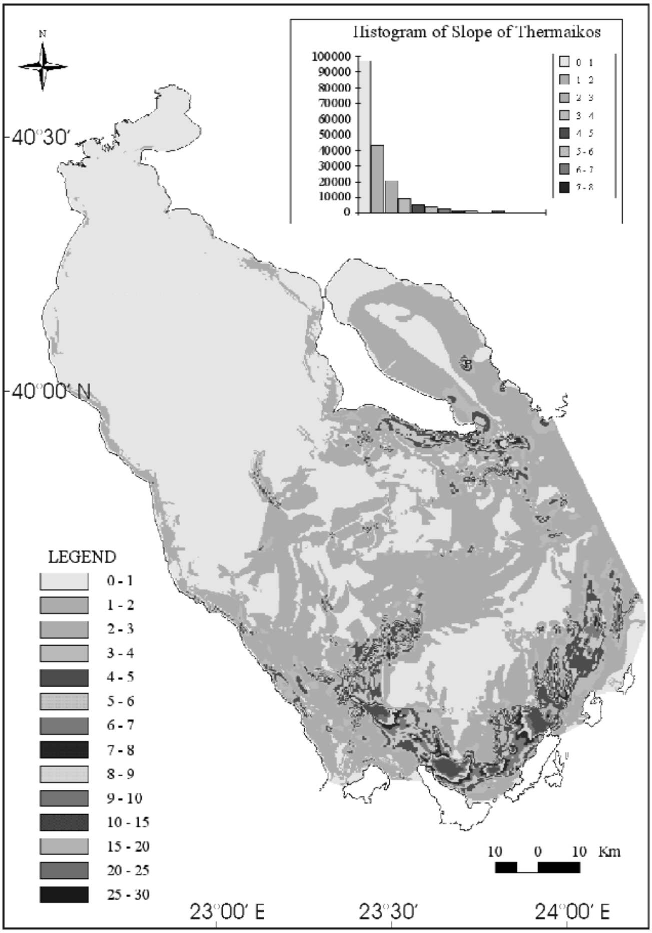

Fig. 5: Slope classification (in degrees) over the NW Aegean marine area, generated by the embedded tools of ArcView. Frequency distribution of slope is presented in the histogram (vertical axis represents a number of grid cells).

were used in order to cover the Hellenic territory and the surrounding countries. CZCS images and LANDSAT TM images were also georeferenced and embedded in the application.

Hypsometric and bathymetric data was used for the DEM preparation (Fig. 4). DEMs were generated employing the techniques of Hutchinson (1988; 1989) and Wahba (1990) in order to obtain the best possible fits for streams and ridges. DEMs may be easily analysed through Arcview build-in tools, such as slope and aspect derivation, hillshade calculation and others. For the marine area of Metro-Med the slope map was generated, accompanied with the histogram of slope distribution (Fig. 5).

Metro-Med GIS and DBMS

During the field measurements of the project, a network of 150 hydrographic stations was visited four times (seasonal sampling). The next step of Metro-Med GIS involved the relation of the former layers with the sampling station network and the database that describes the station's properties (Fig. 6). The database was developed in MS Access® and the tables were converted for use in Arcview in ".dbf" format. Station

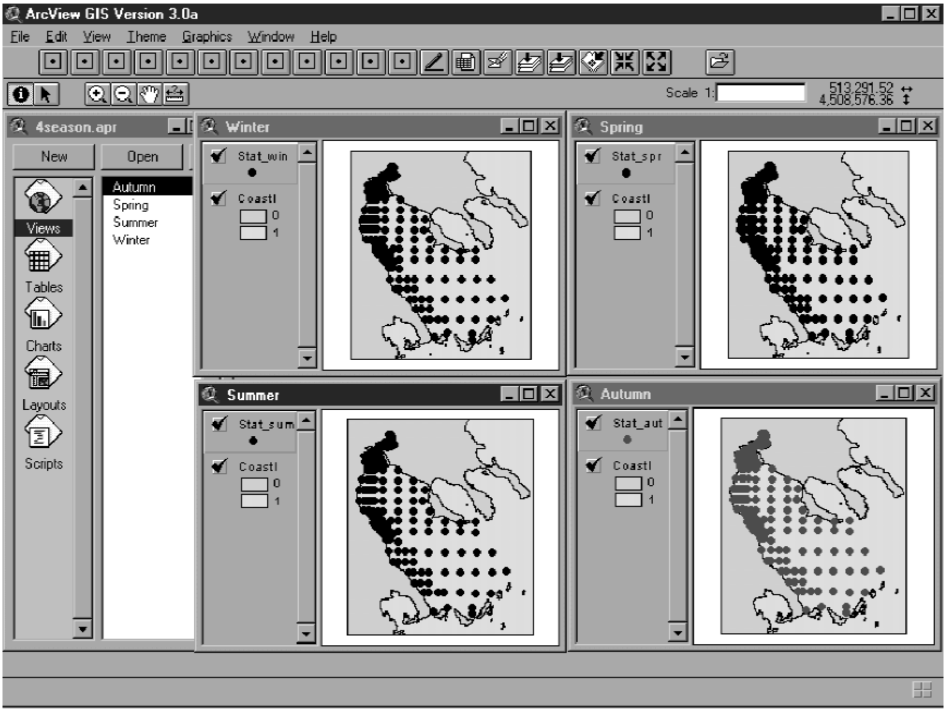

Fig. 6: Oceanographic sampling stations in Metro-Med project. Each station is related to a database that describes all performed measurements in a four-season cycle.

properties can be displayed in a table after a selection with the mouse. Subsequently, the user may construct contour plots of the desired parameter.

Conclusions

The Russian and the Greek groups are both working on the development of GIS applications with similarities and differences in the architecture, design and working tools. Common aspects are the use of similar software and hardware platforms, the development of GIS for coastal areas with user-friendly interface and the definition of similar data sets and parameters

The Russian group concentrates on the use of GIS for the incorporation of models and the subsequent presentation of the model output; emphasis is placed upon Problem Oriented Applications (POA). The Greek group makes use primarily of embodied GIS tools and addresses the marine survey area as a whole with the drainage basin; emphasis is placed upon research project's support.

The exchange of expertise between the Russian and the Greek groups was fruitful and further collaboration is underway, for the design and development of common applications regardless of geographic region, establishing proposals for the use of standard application attributes, generation of common data bases and integration of DBMS and GIS.

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