Use of geo-information technologies in the Project "Aerosols of Siberia"

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Spreading of admixtures in the atmospheric boundary and near-ground layers is studied using the technologies of combined data processing in the environment of information systems. For this purpose, remote sensing data pertaining to different spatial scales are used. Admixture diffusion in the atmosphere is modeled for the case of an aerosol generator with controlled disperse composition taken as a source of aerosol.

The Project "Aerosols of Siberia" is aimed at organizing the monitoring of atmospheric aerosol all over the territory of Siberia.[1] To solve the problems formulated in the Project, detailed spatial information on environmental objects is required. Characteristics of the studied objects vary widely in space and time. The full range of the spatial scales under study can be conventionally divided into several sub-scales:

1. Global linear objects (characteristic size of more than 1000 km);
2. Regional objects (characteristic size of 100–500 km);
3. Local objects (characteristic size of 30–50 km);
4. Microscale objects (size from ≈ 10 m to several kilometers);
5. Elements of the studied objects (size ranging from 1–10 m down to 10 μm or less).

Thus, the full range of the spatial scales spans 12 decades. The studied timescales, in their turn, range from several hours to ten years, thus spanning 5 decades.

In the environmental study, only remotely sensed (from space, aircraft, and other) data can cover a full range of scales from global one down to microscale. Although it is not a new source of information, computer methods of data processing and utilization procedures are now rapidly developing and, used together with widespread geo-information systems, make possible more efficient use of remotely sensed data.

Global-scale studies can be performed using, in particular, remote sensing of the Earth's surface and the atmosphere from space. Such observations provide spatial resolution from hundreds to tens meters, so that one scene may have a side of several tens or even hundreds kilometers. Figure 1 shows a fragment of a 200-m resolution image of Siberia recorded from the Meteor satellite.

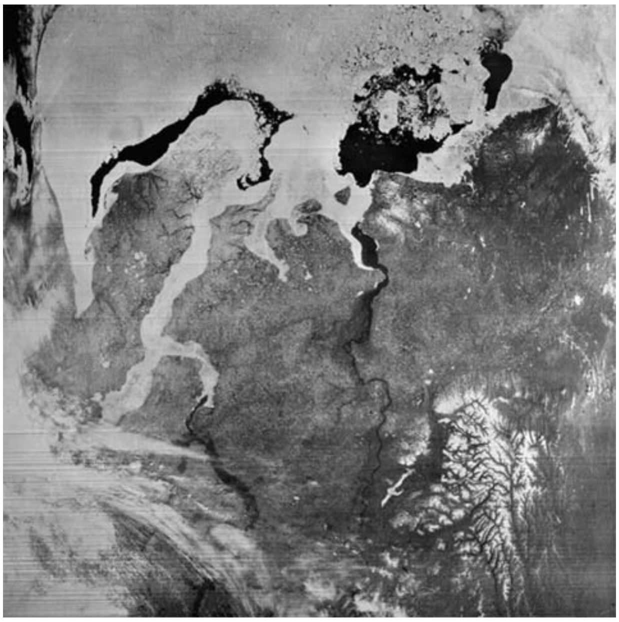

Fig. 1. Fragment of satellite image of Siberia.

Regional studies are preformed on a smaller spatial scale with finer spatial resolution. These scales range from 1 : 500 000 to 1 : 50 000, while the accuracy of geographical and altitude referencing is within hundreds to tens meters and within tens meters, respectively. Such studies can be performed from both spacecraft and aircraft with spectrally different sensors installed on them. For real-time monitoring and displaying fast dynamic processes, such as emission and spread of atmospheric and sea-surface pollutants, information is acquired remotely by scanning sensors and then transmitted to ground-based stations through telemetric channels.

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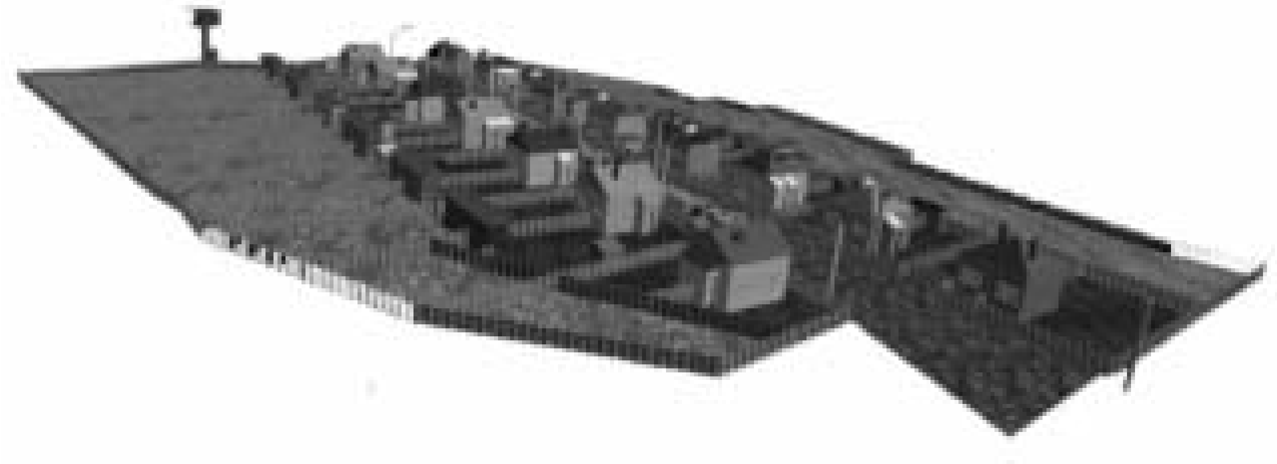

Fig. 2. Three-dimensional map of one street of a settlement.

The next scale of data acquisition is local. The range of local scales is quite wide (1 : 50 000, 1 : 25 000 – 1 : 1 000) and is determined by the accuracy required in specific measurement campaigns. The associated spatial resolution is from several meters to several centimeters. Local-scale information is inferred from multispectral air photographs, as well as from the data of ground-based sensing. The local-scale observations provide a detailed information on the relief of the Earth's surface. With a computer, it is possible to visualize measurement results in the form of three-dimensional maps. The three-dimensional map of one of the streets of Yarkovo village (Novosibirsk Region) is shown in Fig. 2. The coordinates of land management facilities in this map are determined using air photographs of 1 : 6 000 scale.

Photogrammetric technologies based on digital image processing are an efficient tool for data retrieval from images. "esides, modern computer technologies provide, in addition to traditional map, such qualitatively new information as three-dimensional models of relief, allowing most detailed study of environmental objects and, what is most important, permitting practically adequate model representation of the studied objects preserving their actual metric characteristics.

Digital data processing by the photogrammetric method produces a maximally full set of spatial data. This set, being easily incorporated in a geo-information system (GIS) and integrated with geographic map (or some other) data, can then be comprehensively interpreted.

In developing this technique, we used Siberian Digital Stereoplotter (SDS) station created at the Department of Photogrammetry and Remote Sensing of the Siberian State Geodesic Academy (Ref. 15). The SDS can be used to solve many applied problems dealing with retrieving information from air and other local-scale images. The list of these problems includes

– plotting digital topographic and thematic maps,
– keeping land cadastre and inventory,
– updating various digital maps,
– replenishing and updating GIS data,
– developing digital orographic models, and
– converting images.

The SDS is oriented toward end product and accuracy of initial data (in particular, pixel size and image scale are chosen so as to achieve the desired accuracy of the final data). Strategically, the SDS relies on data as accurate as required, rather than most accurate ones. This gives a significant gain in efficiency.

The digital photogrammetric system of the SDS includes several software packages and, correspondingly, several image processing techniques. Its main module performs processing of a stereo-pair through simultaneous stereoscopic analysis of initial images and acquired graphic information to produce a model of a studied region together with its electronic map. Also included are extra modules for processing of single images used for creation and update of digital maps of flat regions (for which errors in relief mapping can be neglected), for construction of digital orographic models, and for orthogonal-photographic image conversion in processing of images of hilly and mountainous regions.

As a part of digital photogrammetric processing, spatial coordinates of mapped objects are determined with prescribed quantization and accuracy, and the graphical information (contours) is acquired. As a next step, new constructed images and digital graphic data files obtained at a digital photogrammetric station are transmitted to GIS for storage in the form of separate information layers (Fig. 3).

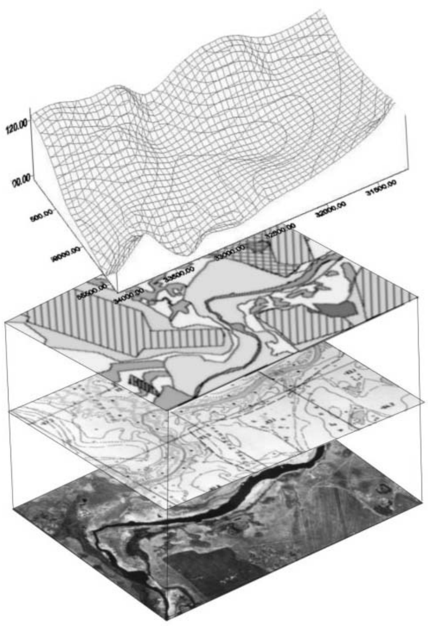

Fig. 3. GIS information layers (air photograph, topographic map, thematic map, orographic surface).

Upon combined analysis of different GIS layers and their complex interpretation, additional information can be obtained in the form of the secondary layers and their maps (isoline maps, three-dimensional models, hybrid maps, etc.).

The method proposed here is based on the synthesis of the results of air image processing at the digital photogrammetric station and GIS cartographic data. It provides diverse digital information and can be used to maintain the accuracy and representativeness of acquired data within practically meaningful limits.

Complex processes of admixture diffusion in the atmospheric boundary layer and lower troposphere can be studied by many methods, one of which involves the use of artificial aerosol clouds created either using aerosol generators or smoke pots.[2–7] Some researchers employ emissions from smoke stacks and vehicle engine exhausts to visualize smoke plumes. However, unfortunately, industrial and exhaust aerosols usually have poorly known size spectrum and chemical composition, as well as source generation rate. This complicates substantially the quantitative interpretation of measurement results made either visually from the shape of an aerosol cloud or using remote scanning systems. Many of these difficulties are avoided once an aerosol generator of controlled disperse composition[8] is used as an aerosol source. Its main advantages are that it can be used

– in different configurations such as point-like or linear source operating continuously or with variable-rate;

– as a source of aerosol particles with required and controllable size in the range from tenths to tens micron;

– as a generator of aerosol with desired chemical composition;

– as up to three aerosol sources operating simultaneously each with required particle size spectrum, generation rate, and height of injected cloud;

– in different landscapes because of its very high autonomy and mobility.

The source of a smoke plume with variable characteristics has been successfully used in the MADONA international project to study the spread of admixtures under conditions of inhomogeneous surface.[9]

Using the results of mathematical simulation, it is possible to study different sources of environmental pollution with much higher efficiency. ” esides, the method of optimal planning can be very effective in the case of limited experimental data for reconstructing the pollutant fields from known sources and for determining the characteristics (location and strength) of unknown sources.[10–12] Figure 4 exemplifies retrieval of the density field of benz(a)pirene deposit (ng/l) in snow at the territory of ” elovo.[13] The calculations were made using experimental data on the content of the ecological toxicant in snow cover at three locations marked by asterisks in the figure. The location of the pollution source is shown by a circle, and solid lines represent concentration isolines.

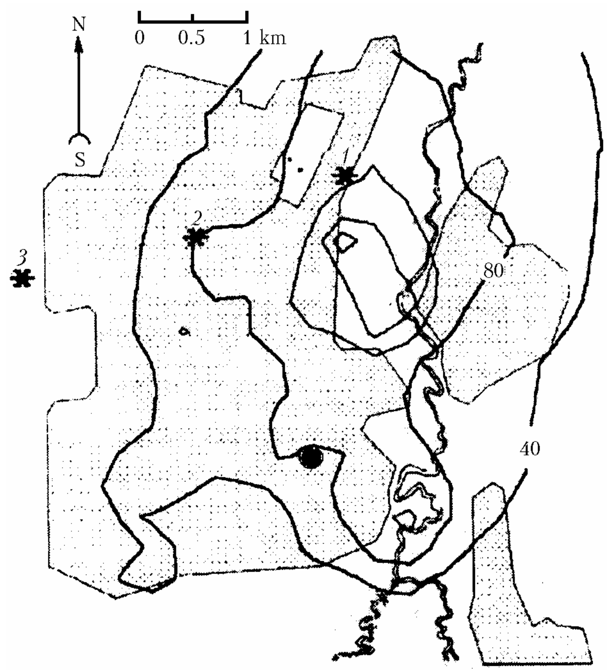

Fig. 4. Reconstructed field of benz(a)pirene deposit density (ng/l) in snow at the territory of Belovo.

Owing to the capability of processing three-dimensional color images in order to obtain actual characteristics of the surface and three-dimensional images of aerosol clouds, GIS-based technologies can increase substantially the information content of studied regularities in propagation and spread of admixtures in the atmospheric near-ground and boundary layers. The use of the SDS digital photogrammetric station for processing of three-dimensional images of pollen grains is described in detail in Ref. 14.

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