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Satellite Hydrophysics

Soft- and hardware for the reception and treatment of satellite and reference data and their application to monitoring hydrometeorological fields*

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Abstract — The paper describes the functional scheme of the soft- and hardware complex designed to receive, to treat and to disseminate satellite and reference hydrometeorological data. The complex displays a high degree of integration and unification of soft- and hardware techniques and packages.

The operation of the complex is studied through the monitoring of cloud fields in the Atlantic–European section of the Northern hemisphere during the winter-time synoptic season of 1995–1996. The complex is shown to be capable of identifying large-scale cloud anomalies and of estimating their coherence in the individual regions of the Atlantic–European zone.

Short-term climatic fluctuations observed over the last decade in the Atlantic-European section of the Northern hemisphere gives rise to significant weather anomalies in the Ukraine. On some occasions, as was the case in 1994, such anomalies may lead to droughts over vast areas.

Of course, various branches of the agriculture and water supply system of the country experience an acute need for information about the current tendency of the evolution of atmospheric processes. Presently, the monitoring of hydrometeorological fields appears to be quite feasible, as multiple meteorologic satellites and satellites of the OCEAN series are continuously orbiting the earth. The complexity of monitoring of the atmospheric processes consists in organizing the reception and treatment of a large amount of remotely sensed data. This paper is devoted to describing an automated system for the reception and treatment of satellite data and its utilization to monitor the cloudiness field.

SOFT- AND HARDWARE DESIGNED TO TREAT SATELLITE AND REFERENCE DATA

The progress achieved in the development of remote sensing instrumentation and computer equipment permit hydrometeorological information to be resolved on a new technological basis. Its distinctive mark consists in the combined use of the data provided by the land-mounted weather stations and posts, as well as by the space platforms, in conjunction with the comprehensive employment of computer facilities intended to handle,

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store and circulate the data. The Marine Hydrophysical Institute of Ukraine's Academy of Sciences, being involved with the study of the World's Ocean, has long needed information of this kind to cover the areas where traditional networks of observational techniques fail to provide it. In view of this, over the last two decades, we have been developing the means of reception, treatment, storage and dissemination of satellite and reference data that could be used to monitor the sea and the overlying atmosphere. Alongside this work, we have sought to adopt the data remotely sensed by the satellites launched by other countries to our data-receiving instrumentation. In the framework of the SEREDOVISHCHE project of the Ukraine's National Space Agency we have produced a soft- and hardware complex for the reception, treatment and circulation of satellite and reference hydrometeorologic data. Specific features of the complex in question include the efficient unification of soft- and hardware techniques, their compatibility with the channels and formats of transmission of telemetric imagery of the most widespread satellite platforms and reference data. This enables the complex to act as a universal tool capable of receiving remotely sensed data from such satellites as NOAA, METEOSAT, SeaStar, METEOR, RESOURCE, OCEAN, and SICH. Schematic arrangement of the complex is shown in Fig. 1.

The complex incorporates four units for the reception and preliminary treatment of data:

(1) the unit for the reception, digitization and preliminary treatment of data received via the analog channel of communication with the METEOSAT satellite;

(2) the unit for the reception, digitization and preliminary treatment of data provided via the analog channels from the NOAA (APT regime), METEOR, OCEAN and SICH satellites;

(3) the unit for the reception, digitization and treatment of facsimile weather charts transmitted via radio channels; and

(4) the unit for the reception and treatment of satellite information transmitted through digital channels, frequency 1.7 Hz, by the NOAA (HRPT regime) and SeaStar (SeaWIFS) equipment satellites; it also features a facility for the treatment and dissemination of data.

All the information is treated and stored in the digital form in the IBM PC-486. Besides, it may be possible to receive satellite and reference data from other sources, which are presently not adapted to our technology. In this paper, we describe the three pilot units for the reception and treatment of data and the complex for data treatment and dissemination.

The equipment for reception and preliminary treatment of data incorporates antennas, data receivers, and interfaces linking the receiver with the data-treating PC and PC-486, which builds up to the data being received over one contact and performs its preliminary treatment. The specific feature of the soft- and hardware complexes is that the whole of the initial information being received is transmitted through analog radio channels on 1700, 137 and 3–30 MHz frequencies, respectively. It is this fact that accounts for the generality and differences in the soft- and hardware complexes under consideration.

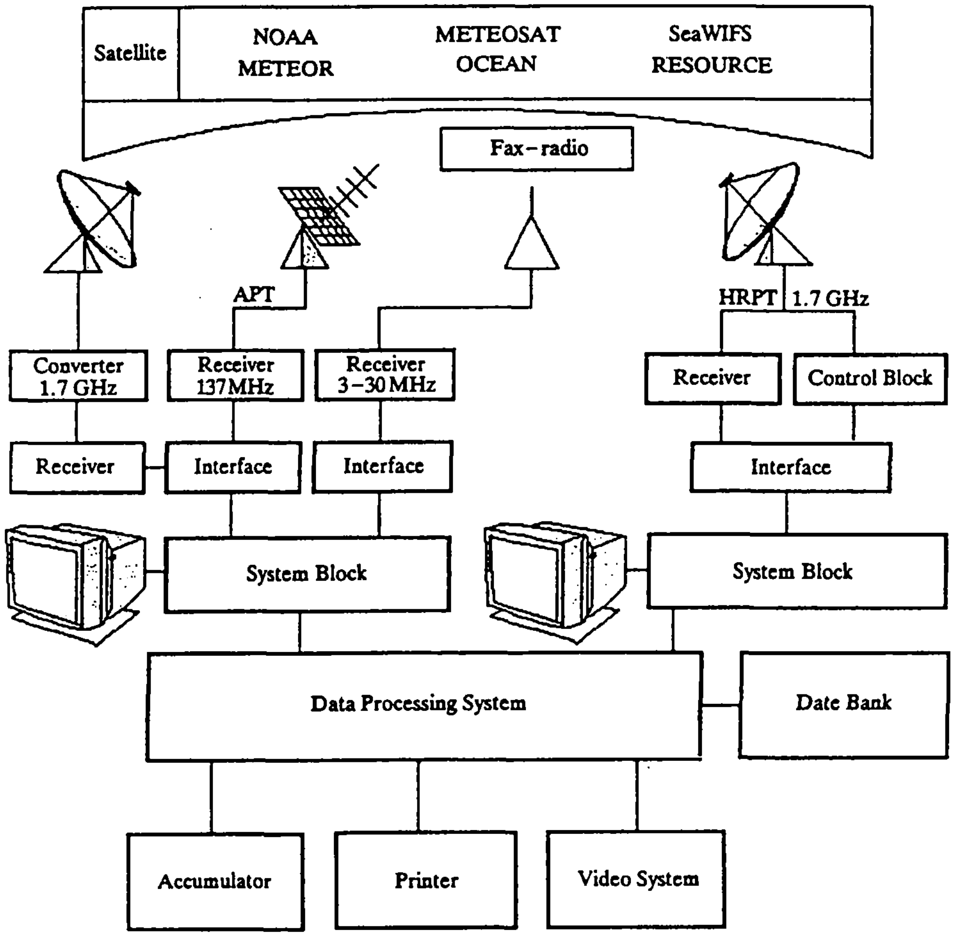


Figure 1. Functional arrangement of the complex for the reception and treatment of satellite and reference data.

One of the basic principles of generation of the equipment for the reception and treatment of data involves the adaptation of relatively inexpensive antennas and receiving devices manufactured by the Ukrainian companies and abroad. With that being borne in mind, to receive data transmitted within a 1-m band on the 137 MHz frequency, we employed a commercial specialized receiving station ELSA made in Finland. To receive data transmitted by the METEOSAT and GOES satellites via the 10-cm communication channel, we utilized a receiving station operating on the 10-cm radio waveband. The station included a commercially produced 1.8-m paraboloidal reflector, a special DM-M converter designed to transform the frequency of the signal from the decimeter band (1700 MHz) to the 1-m one (140 MHz), and a receiver R-313M2, operating within the range from 100 to 400 MHz. For the reception of facsimile weather charts transmitted via short-wave radio channels, we use an antenna of the 'inclined beam'-type. The signal is amplified by means of a short-wave receiver. As the data are transmitted via analog radio channels, we cannot enter the information being received directly into

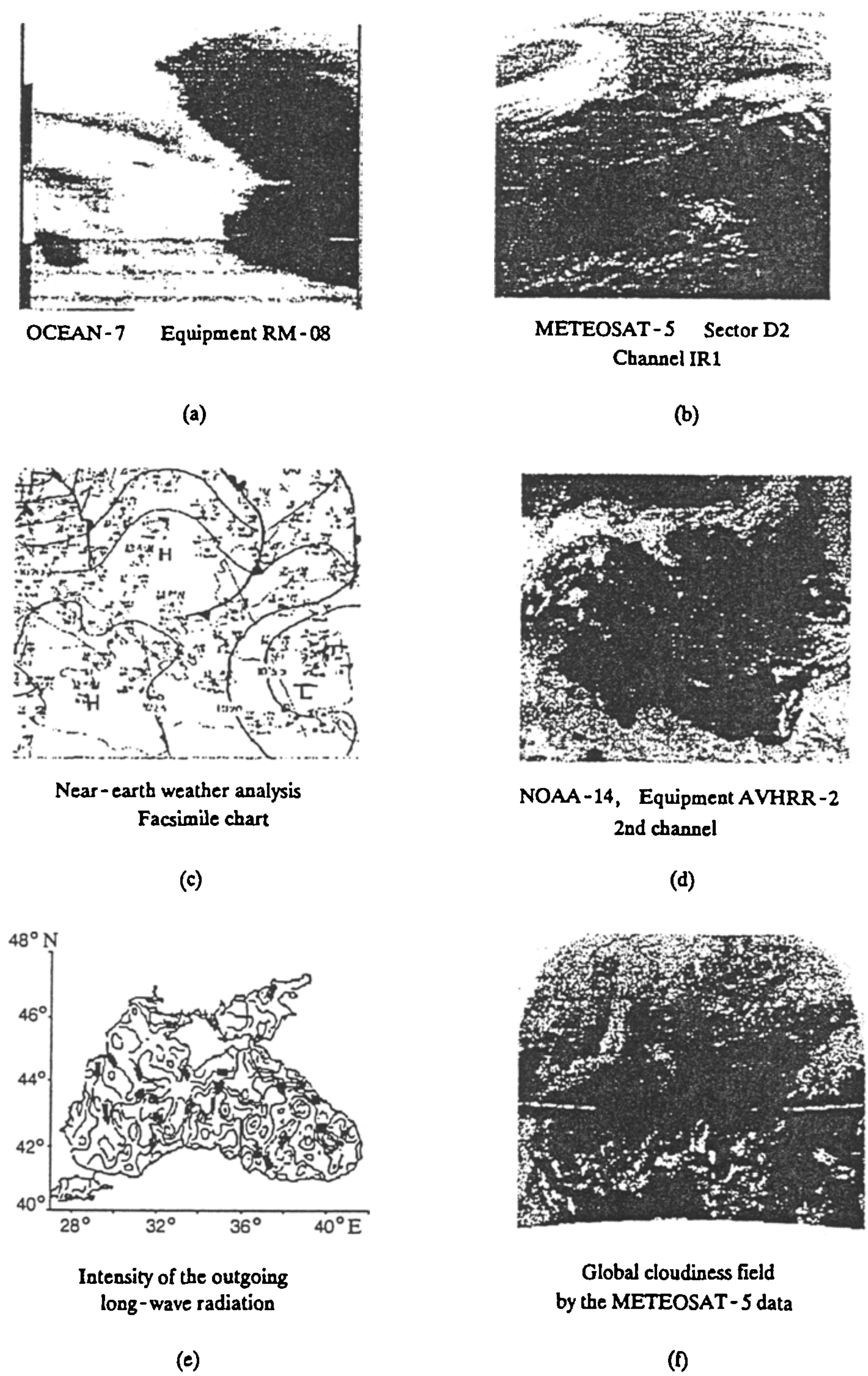


Figure 2. (a)–(d) crude images and (e)–(f) processes images.

the computer. This can be done only after converting it from the analog form to the digital one. The conversion of data is accomplished by the PC-controlled special buffer interfaces. These devices are mainly intended to digitize the analog signal received and to coordinate the rates of data reception and recording. The principal advantage of the interfaces in question, as compared with their counterparts, is that a number of original solutions protected by the inventor's certificates [1] have been used there. This allows as to essentially improve the quality of digitized information.

Prior to being applied, the acquired data is expected to go through a series of preliminary and special treatments.

Software of the units for preliminary data treatment is intended to perform the following procedures:

— to transform formats and scales of satellite imagery records;
— to convert data to diverse formats of data storage and displaying;
— to reference satellite-provided images to geographic sites;
— to produce and apply masks and bounds of areas;
— to transform geographic projections;
— to filter out the images;
— to manufacture and apply a variety of colours; and
— to calculate sighting angles for the image pixel given.

Data treatment/circulation software are designed to carry out the following operations:

— to archive and store satellite imagery and facsimile charts;
— to select and copy information about specific regions and time intervals;
— to choose satellite data for comparison with on-land measurements;
— to superimpose satellite images and charts of the earth's surface, derived for different objectives;
— to treat jointly satellite and on-land observations;
— to monitor the atmosphere and underlying surface (monitoring of the dynamics of cloud formations, atmospheric fronts, vortical and frontal formations on the sea surface, calculations of the sea surface temperature, wind speed, cloudiness parameters, atmosphere's radiation, etc.).

The unit for reception and treatment of satellite and reference data allows one to conduct continuous monitoring of the region under study. The unit has proven to be very efficient in resolving the problems related to meteorology, agriculture, fisheries, and other applications. Figure 2 demonstrates examples of the processed information. Below, we will show how the soft- and hardware generated in Marine Hydrophysical Institute is being employed to monitor cloudiness fields with the purpose of improving weather forecasts in the Black Sea region.

MONITORING OF CLOUDINESS IN THE ATLANTIC-EUROPEAN SECTOR OF THE NORTHERN HEMISPHERE, USING THE SOFT- AND HARDWARE COMPLEX

The processes taking place in the atmosphere of the Atlantic–European sector directly impact the climate and weather in the Black Sea region. Hence, weather monitoring there, including the Sea of Azov, as well as the Ukraine's central and eastern areas, must encompass the entire Atlantic–European sector.

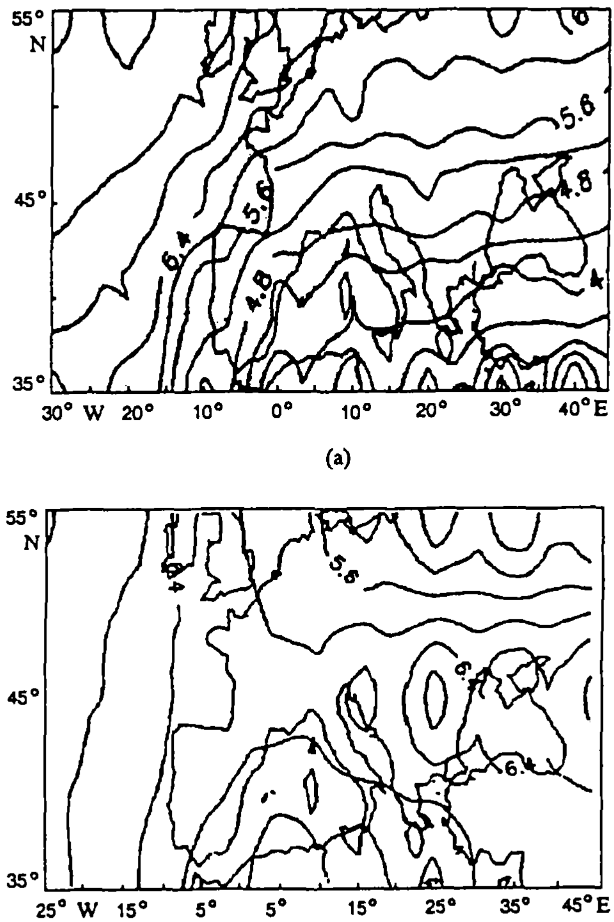
Weather variations in this paper, first and foremost, imply the spatio–temporal variability of the cloudiness field, as the latter represents not only the most important synoptic aspect, but the climatic aspect, too, responsible for the atmosphere's general circulation [2].

The most convenient, in their context, are the data provided by the METEOSAT satellite, which are being received and handled by the METEOSAT complex for the reception and preliminary treatment of data. Dynamics of the cloud cover is being monitored by a series of digitized images of six sectors of the Earth's surface within the vapour absorption band 0.7–7.1 μm, covering the region bounded between 20° S–70° N and 72° W–72° E. The spatial resolution of satellite-provided images of cloudiness for the nadir at zero latitude and longitude is 2.5×2.5 km. The images are being received daily over half an hour. The preliminary volume of the data being received is equivalent to about 7 Mbytes. Then the images are subjected to preliminary treatment. First, we transform the data format. Then, using the markers available on each of the six images, geographic referencing is performed. At the third stage, we transform the images into a proportional angular projection, with a spatial resolution of 0.1°×0.1°. As a result of this transformation, each pixel of the new image situated in the line n and column m has geographic coordinates linearly connected with m and n. At the final stage of the procedure, the six transformed images of the sectors are synthesized into one composite picture covering the studied region. The duration of the full cycle of preliminary treatment is about 30 min. The acquired digital composite image, having a volume of 1.3 Mbytes, is used as original material for performing quantitative analysis of cloudiness fields. To derive a rough estimate of the cloudiness fields, we used a 10° × 10° grid. In each square of the grid, we determined the percentage of the entire area covered by clouds (general cloudiness), which was then converted into points. The thus treated IR-image of the METEOSAT represented a set of 10° × 10° squares with the points of general cloudiness indicated. In the course of the subsequent analysis of the acquired cloudiness estimate, we took account of the fact that mean monthly values for the adjacent 10° × 10° squares are independent [2].

A tentative monitoring of cloud systems was conducted in the winter of 1995–1996. Therefore, following ref. 2, it was reasonable to study cloud systems for the natural synoptic winter season, which begins on 25 December and ends on 10 march. During that period, synoptic processes in the Atlantic–European sector typically intensify. At the same time, it is known that the inter-annual variability of the atmospheric circulation may essentially change weather conditions in a specific region, thereby facilitating predominantly cyclonic or anticyclonic circulation [3, 4]. These anomalous weather conditions are manifested in the cloudiness field [2].

Cloudiness fields demonstrated in Fig. 3 allow us to see differences between the situation observed in some specific year and the mean historical cloudiness field [5]. It is readily visualized (Fig. 3a) that the mean multi-annual cloudiness field over the European continent is zonal, where clouds tend to build up from south to north. Over the Central and Eastern Atlantic, general cloudiness tends to decline from north-west to south-east, which is typical of the winter season.

The cloudiness field of the 1995–1996 winter exhibits a suite of fundamental differences from the mean multi-annual field. The basic differences are well seen in Fig. 3b. Firstly, the field's zonality at the mid-latitude of Europe was violated. Three local maximuma of cloudiness occurred there: above the northern part of the Adriatic Sea, the Balkan Mountains and the Black Sea. From these areas, cloudiness tends to become less compact in both the south- and northward direction. Secondly, above the east Atlantic, cloudiness declines from west to east.



(b)

Figure 3. General cloudiness in the Atlantic–European sector during the winter-time natural synoptic season: (a) mean cloudiness in January–March from 1971 to 1980; (b) mean cloudiness over the period from 23 December 1995 to 12 March 1996.

Local cloudiness maxima observed during the 1995–1996 winter may imply an intensification of cyclonic activity in those areas, compared with the mean multi-annual regime of cloudiness. Also, it will be appropriately noted that the well-pronounced cloudiness maximum in the mid-latitudes of Europe represents a sort of channel, through which cyclones migrating from the Atlantic travelled over the European continent. This means that the winter season of 1995–1996 was very humid for Central Europe.

The monitoring of cloudiness in 1995–1996 makes it possible to assess the interrelation of cloud fields observed in widely separated areas. For us, of primary interest is cloudiness evolving over the Black Sea and the Balkan Mountains, because, in large measure, it dictates weather conditions over practically the entire Ukraine. The search for a 'key' $10° \times 10°$ square for those areas in the Atlantic has enabled us to establish that the cloudiness field in the chosen areas is most intimately correlated with the cloudiness in the area having the following coordinates: $\varphi = 30$–$40°$ N and $\lambda = 10$–$20°$ W.

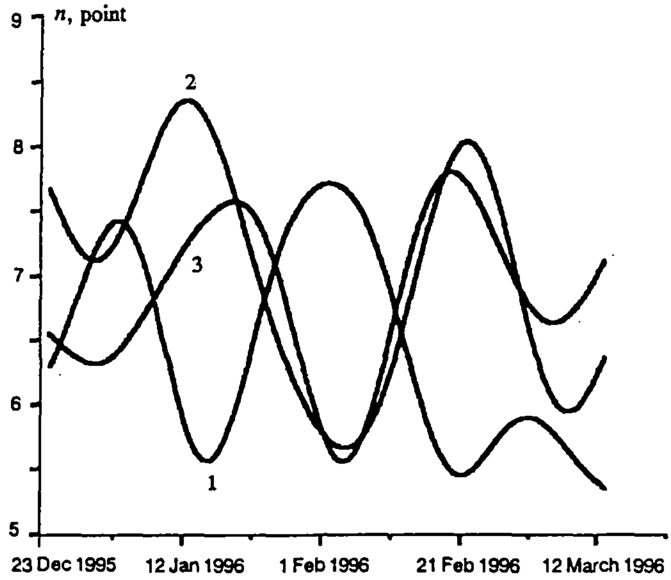


Figure 4. The variability of cloudiness in the east Atlantic and south-eastern Europe.

We will demonstrate graphically the variability of cloudiness in the areas indicated above. For convenience, the Atlantic square will be denoted by 1, the Balkan square (φ = 40–50°N; λ = 20–30°W) by 2, and the Black Sea square (φ = 40–50°N; λ = 30–40°W) by 3. The plots of cloudiness variability in the three squares are shown in Fig. 4. Cloud values given here have been smoothed out using a low-pass filter, which allowed us to suppress synoptic variability. It is seen that cloudiness in the adjacent 10°×10° squares, i.e. above the Balkan Mountains and the Black Sea, tends to change in simphase. At the same time, the tendency for the east Atlantic cloudiness to modify in counterphase with cloudiness in south-western Europe is clearly evident. An estimate of cloudiness correlation between those areas indicates that the Atlantic 'key' square's correlation coefficient with the Balkan square and Black Sea square equals 0.29 and 0.39, respectively. Both coefficients are significant at a 95% level of significance. Moreover, the mean cloudiness in the east Atlantic, Balkan and Black Sea squares over the winter-time natural synoptic season was 6.4 points (σ = ±1.5), 7.0 points (σ = ±1.3) and 6.8 points (σ = ±1.1), respectively. Such distribution of cloudiness in the chosen squares is not typical of the winter season. The mean multi-annual cloudiness distribution in those squares is opposite to the situation observed during the current winter.

Thus the complex for satellite data reception and treatment enables us to monitor cloudiness fields in the Atlantic–European sector, as well as to gain a deeper insight into the mechanism for the transport of clouds over European continent.

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