Integrated Satellite Altimetry Data Base: Organization, Data Base Management System and Application

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Abstract

The purpose of the project which was undertaken with support from the Russian Basic Research Foundation (Project N 96-07-89315) was to set up an integrated satellite altimetry data base (ISADB), which would include the results of altimetry measurements carried out by the Russian GEOIK geodetic satellites and by GEOSAT, ERS-1, ERS2 and TOPEX/POSEIDON during the period 1985 – 1998 ISADB also includes supplementary information necessary for the processing and interpretation of experimental data. The functions of data processing and data visualization for the problem-oriented study of the sea level changes of the world ocean, large inland basins and for the determination of the detailed characteristics of the gravity field of the Earth are realized by software, in addition to the standard data base management system (DBMS).

The ISADB shall be loaded on the WWW server of Geophysical Center and thus will be available in the Internet. We believe that the database will be useful for experts in different branch of sciences because the altimetry measurements, carried out by the GEOIK satellites, have not been available before for the scientific community. The altimetry data from other satellites have not been available for many Russian specialists also.

The Russian GEOIK program was started in 1985 to obtain a system of fitted parameters of the Earth (EP-90) including fundamental geodetic constants, geocentric reference system, and the parameters of the figure and the gravitational field of the Earth. Initially, this Program was carried out by the Topography Service of the Ministry of Defense of the Russian Federation and was classified. In 1992 many aspects of this program were declassified. The GEOIK satellites is placed on orbit approximately 1500 km high with inclination of 74 or 83 degrees. Ten satellites were launched till 1996. They were equipped both with radio altimeters (RA) and space-borne geodetic instruments including Doppler system, radio range system, light signaling flash system, and laser corner reflectors. Doppler system gives signals in coherent frequencies of 150 and 400 MHz twelve hours a day to measure radial velocity; light controlling system produces flashes to photograph the satellite against the stars; laser corner reflectors of effective area of 0.024 square meters and relay reflect signals of a ground-based laser ranger and re-emit signals of ground-based radio ranger.

Ground-based stations measure Doppler radial component of satellite velocity with respect to the observation station with an error of 1 – 3 cm/s, determine the satellite position by light flashes with reference to the stars with an error of 1 – 1.5", and measure distances to the satellite by laser and radio rangers with errors of 0.5 – 1 and 1 – 2 m respectively. A great amount of altimeter data which has geodetic applications and is important for oceanographic and for global meteorological researches has been collected during the period from 1985 to 1995.

The bulk of scientific results of GEOIK program includes the model of geopotential of EP-90 up to the 36th degree and EP-

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Table 1.

Russian Satellite Altimetry Program GEOIK

No sat.	Data Launch.	Incl., deg	Period of active work	Stand. dev., cm	Calibr. corr., m
1	14.06.85	73.6	08.07.85 – 31.10.86	60	-17.0
2	11.02.86	83.6	03.03.86 – 28.03.86	140	-25.0
3	02.12.86	73.6	21.12.86 – 15.12.87	166	-36.5
4	19.02.87	73.6	09.03.87 – 12.10.87	105	-26.0
5	30.05.88	73.6	20.06.88 – 27.07.90	88	-22.9
6	28.08.89	73.6	18.09.89 – 26.09.90	-	-
7	30.07.90	73.6	19.08.90 – 05.03.93	-	-
8	10.01.93	73.6	10.01.93 – 23.07.93	-	-29.79
9	1994	73.6	18.12.94 – 28.07.95	-	-25.42

200 up to 200th degree, the improved coordinates of the geodetic network stations, and the catalog of the geoid heights in the World ocean. A list of the satellites, characteristics of their orbits, standart deviation of the altimetry measurements and their operating time are given in Table 1.

So called Geophysical Data Record format (GDR format) of altimetry data is usually used for geophysical applications. The following computation stages have been completed to transform initial GEOIK altimetry data to the GDR format:

- calculations of the orbits of the satellites GEOIK satellite orbits on the basis of tracking data which were obtained by observation with stations located in the area of the former Soviet Union and Antarctic region;
- preliminary processing of radar altimetry data including corrections for reducing measurements to spacecraft center of mass, instrumental delays, and tropospheric effects.

The gravitational field of the Earth, the attraction of the Moon and the Sun, tides in the solid Earth, light pressure, atmospheric resistance, precessions, notations, and poles movements were taken into account for calculation of orbits.

To calculate orbits the model (EP-90) of gravitational field of the Earth up to 36th degree was applied. The following parameters of the ellipsoid EP-90 were obtained: a = 6378136; b = 1/298, 257839303. The GDR format of satellite altimetry data of included in the database are given in Table. 2.

The specific feature of the satellite altimetry data bases is that the information is recorded in the binary Hewlett-Packard or VAX format, as the direct-access files inverted by time (the geodetic and exact repeatable GEOSAT program), by time and satellite series (the GEOIK experiment), by space (the intersection point bases), by exact repeatable cycles (the TOPEX/POSEIDON satellite), or by the numbers of orbital arcs (the ERS-1 experiment).

Software. The search and selection of data, stipulated by the developed software, are oriented on the specific features of the structure of satellite information. The search criterion is a logical construction based on a single search attribute (the simple search criterion) and on the combination of simple search criteria by the logical operations OR, AND, NOT in order to organize the search by several attributes. Moreover, a few additional virtual attributes of search are suggested: region, data and time, season, cycle, the serial number of the satellite, and the orbit's number. The attribute «region» allows to select the region of research on a real geographical map with precision up to 0.1 sec. Since the time in the data bases is given in seconds or in the number of days and seconds from the start of the count, the virtual «data and time» parameter, for the user's convenience, permits to give the time of measurement in the usual terms: data, month, year, hour, minute and second. The attribute «season» is designated for selection of a certain seasonal period of time for the whole base. The presence of virtual attributes of search, such as the cycle, the satellite series, and the number of the orbit, provides accomplishment of automatic selection without involving the supplementary data.

Table 2.

ISADB Geophysical Data Records Format

Item	Parameter	Units	Bytes
1	Universal Time Coordinated at the begining 1985	sec	4
2	Complementary time	10^{-3} sec	2
3	Latitude	10^{-6} deg	4
4	Longitude	10^{-6} deg	4
5	Sea surface height (SSH) corrected on Instrumental, Wet and «Dry» Tropospheric, Ionospheric and Electromagnetic Bias correction	10^{-2} m	2
6	Number of valid points for 1 second SSH		1
7	Root Mean Square (RMS) range SSH	10^{-2} m	2
8	Height offset to be added to all SSH	m	2
9	Inverse barometer correction	10^{-3} m	2
10	Mean sea surface height	10^{-2} m	2
11	Geoid height	10^{-2} m	2
12	Gravity anomaly	10^{-4} Gal	2
13	Elastic ocean tide	10^{-3} m	2
14	Loading tide effect	10^{-3} m	2
15	Solid earth tide	10^{-3} m	2
16	Geocentric pole tide	10^{-3} m	1
17	Mean dynamic topography by hydrological measurements	10^{-2} m	2
18	Ocean depth	m	2
19	Significant Wave Height	10^{-3} m	2
20	Wind speed	10^{-2} m/s	1
21	Flag		

The so-called map of search is compiled before the search by using the selected criterion of a search on the basis of inverting the files procedure. The map is a succession of the disk number for the multi-volume data base, and the names of the files, which information satisfies, in the first approximation, the given logic conditions of the search. This procedure greatly increases the rate of search and selection. Moreover, the system automatically requests the disk necessary for reading. We should note that in the process of search and selection, the system operates only with the disk numbers, the name of the files and the number of records; consequently; the volume of the service file with the results of selection is small.

The important peculiarity of the DBMS is the availability of multistage selection of information. After completion of the first stage of selection into the subbase1 and the analysis of the selected information, we can undertake the search with previously selected data by using any new or already existing criterion and store the data into the subbase-2. After selection of information, the system allows copying of selected information either in the symbolic format into the file, or in the binary format with merging of the entire bulk of information within one data base. On this step one can specify the parameters necessary for the next steps of processing. One can also to conserve the binary format of distributive or to decode the data if the data is output in the binary format.

The system allows to conduct simultaneous selection and copying of information into the user's data base. This data base retains the inverted structure of the initial CD-ROM. The system allows to display values of parameters of selected records and to draw plots of selected temporal data series without termination of the search mode.

The block of Express-analysis and preliminary data processing allows to identify selected data with tracks of satellite, to determine the type of these tracks (ascending or descending), and to check their position in space. It allows also to display variations of any parameter along the track, or on some part of it. The function of improvement of the values of sea surface heights by introducing various corrections and the function of visualization of these values as deviations from the reference surface (for example, from the geoid in the dynamic topography of the ocean) are realized in this block.

The space structure of the studied parameter is analyzed by averaging the data on a selected grid at the knots or centers of its cells with subsequent visualization of the obtained field in the form of isolines; an opportunity is provided, by analogy with the previous statement, to correct the values of heights of sea surface by introducing different corrections, or by the display of deviations from the standard surface.

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