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Frolov G.[1], Azimov O.[2]

(1) Institute of Geological Sciences of the National Academy of Sciences of Ukraine, Kyiv, Ukraine. E-mail: saintmer4ant@gmail.com
(2) State Institution «Scientific Centre for Aerospace Research of the Earth of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine», Kyiv, Ukraine. E-mail: azimov@casre.kiev.ua

APPLICATION OF DIGITAL METHODS OF PROCESSING SATELLITE ALTIMETER DATA FOR RESEARCHING THE DYNAMICS OF SEA SURFACE CHANGE

The method of satellite altimetry as a relatively new approach of high-precision satellite imaging provides various fields of Earth sciences with the most complete information about the state of the ocean and its changes over time, which is used, in particular, in scientific research in geology, geodesy, oceanography and climatology [1, 11-15].

Satellite altimetry is one of the active methods of remote sensing of the surface from a spacecraft. It is basically a technique for measuring height. Satellite radar altimetry measures the time taken by a radar pulse to travel from the satellite antenna to the surface and back to the satellite receiver. Moreover, this measurement yields a wealth of other information that can be used for a wide range of applications [5, 12-14].

According to [3], sea surface heights, measured by satellite altimeters, can be converted to gravity anomalies. Gravity anomaly differences and characteristics between basins reflect variations in crustal thickness, basement properties, depth, stratigraphic framework, and overlying cover strata structures. Therefore, usage of altimetry data provides us with an opportunity to develop a much higher resolution gravity map for all offshore areas of the world. Such a detailed map might allow us to explore and map hydrocarbon locations for profitable oil and gas extraction.

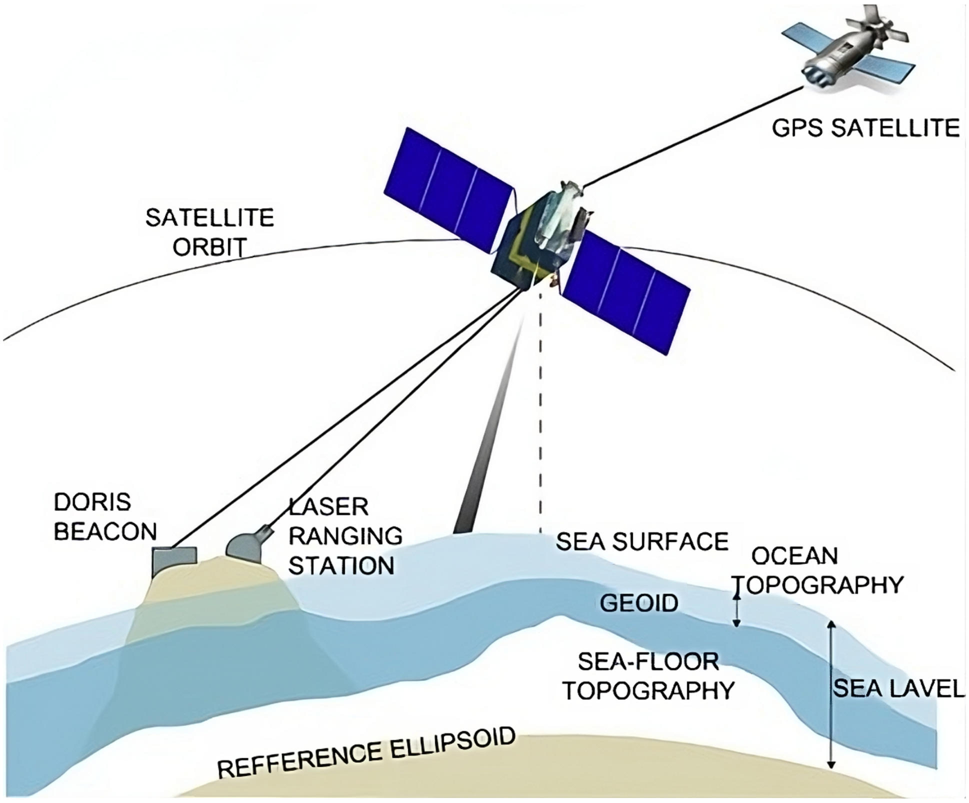

Figure 1. The essential principles of a satellite altimeter measuring system (according to [9])

A satellite altimetry system includes a radar to measure the height of a satellite above the earth's surface and a tracking system to determine the height of a satellite in a geocentric coordinate system. The system measures the sea level rise relative to the center of mass of the Earth. Thus sea surface form can be obtained.

The distance from the satellite to the underlying surface is calculated by the return time of the probing radio pulse, which makes it possible to determine the height of the sea surface.

There is a large number of altimetric satellites in outer space. All of them have sufficient accuracy to investigate the marine geoid and the influence of underwater relief elements on it.

The following key reference surfaces are used for the analysis of altimetric observations:

1. Geoid - model of global mean sea level that is used to measure precise surface elevations.

2. Mean sea surface (MSS) - the long-term average of the sea surface height (at least over one year). It is determined by averaging sea surface heights over a certain period of time, minus tidal forces.

MSS is generally derived by direct interpolation of the averaged sea surface height (SSH) observations or the along track SSH gradients using various sophisticated interpolation techniques [4]. The accuracy of the MSS determination has improved significantly over time due to the increase in the number of observations, improvements made in satellite orbit determination, etc. Throughout the history of the development of altimetry, an increase in the averaging period can be observed, which leads to a decrease in the influence of interannual fluctuations of the sea surface level on the results of observations.

Early altimetry products had a 7-year MSS calculation period, while modern altimetry datasets have a 20-year MSS calculation period [1].

Satellite altimetry provides us with data about sea surface heights (SSH). Sea level anomalies (SLA) represent the height of the water surface above the MSS at some point in time in the specified region. They are analyzed to study the dynamics of changes in sea surface level [2, 12-14].

$$SLAN = SSH – MSSN$$

Operational oceanography systems are heavily dependent on near-real-time sea surface height data from multiple satellite missions. In recent years, significant progress has been made in the development of high-quality altimetry products and many improvements have been made, primarily related to data processing algorithms and the timeliness of their acquisition.

Certain errors cannot be removed by calibration. These are classed as either random or bias errors. Let us dwell on a number of the main causes of errors in measurements, which to one degree or another affect the accuracy of the initial data, as well as methods for reducing their influence on research results:

1. Global ocean tidal atlases are used in order to provide altimetry missions with tidal de-aliasing correction at the best possible accuracy. The satellite data for the global tide model are based on data from four altimetry satellites. These satellites observe the distance between the satellite and the sea surface averaged over a region of 5 km along pre-selected ground tracks, and have done so for years at regular intervals [6].

2. Atmospheric delays are caused by the water vapor present in the atmosphere. To some extent, this effect is corrected using the measurements of the radiometer instrument on board the altimetry satellites. It's called a wet tropospheric correction (WTC). However, a large uncertainty is associated with these measurements. For further reduction of its impact on altimetry data, highly stable water vapor climate data records can be used. These can be obtained from independent microwave radiometer (MWR) measurements on board meteorological satellites [7].

3. Orbit errors in processing of satellite altimeter data are caused largely by inaccuracy of the gravity model which is required for the computation of the trajectory of the spacecraft. To reduce impact of such errors minimization of the crossover differences of profiles measured by the altimeter radar is required.

4. Instrument noise is mixed with oceanic SSH signals in altimetry measurements. According to [8], using nearly simultaneous observations from two altimeters, the white noise level of altimeter instrument noise was best estimated from the SSH spectral values at wavelengths of 25–35 km. The white noise spectrum can simply be subtracted from the SSH wavenumber spectrum to minimize the effects of instrument noise in the spectral estimates.

Nowadays, SSH are provided along-track for all available satellite altimetry missions. All measurements are already corrected by the most actual geophysical corrections. Moreover, as the data of all missions have been carefully harmonized and cross-calibrated in advance, it should be possible to merge and combine SSH of any mission in order to improve the spatial and temporal resolution.

Satellite altimetry has become an indispensable instrument in the observing climatological changes of the World Ocean's surface heights and the largest ice shields of Greenland and Antarctica. Altimetry observations of sea level are the only source of information that allows us to remotely display the subsurface state of the ocean. The use of results of such observation proves useful when it is necessary to quantitatively assess the consequences of climate change or when conducting geological, geophysical surveys, etc.

Tides, atmospheric delays, orbit determination and instrumental noise are the most notable sources of negative impact on the accuracy of altimetry data. Each of them require a special approach to be dealt with (i.e. to reduce its influence on research results).

Numerous studies have proved the connection between low-amplitude local anomalies of gravity and magnetic field with oil and gas deposits in both platform and geosynclinal areas [10]. Altimetry data can be converted to gravity anomalies, which allow us to better localize and track trap structures within potential hydrocarbon basins.

Recently, within the framework of scientific research, methods have been developed to reduce the influence of the main sources of errors on the accuracy of source data in general, and research results in particular. Combining different methods for processing altimetry data can allow us not only to better directly measure sea surface heights, but also to improve the accuracy of gravity model maps, etc.

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