Scholar Publishing Group
Frontiers in Ocean Engineering
https://doi.org/10.38007/FOE.2020.010302
ISSN 2790-2706 Vol. 1, Issue 3: 10-19

# *Modern Satellite Altimetry Gravity Anomaly Resolution Technology and its Application in Marine Resources Survey*

**Zabolotny Wojciech***

*Mil Tech Coll, Comp Dept, Cairo, Egypt*

*corresponding author*

***Keywords:*** Satellite Altimetry Gravity Technology, Anomaly Resolution Analysis, Marine Resources Survey, Application Analysis

***Abstract:*** With the development of science and technology, the scope of marine resources(MR) is also changing and developing. MR are an important part of natural resources. The development of science and technology and the improvement of ocean exploration ability provide an important way to solve a series of problems such as population expansion, resource scarcity, environmental pollution and so on. In recent years, with the convenience of science and technology, human beings have been exploiting various land resources, which makes the increasingly scarce land resources appear to be in short supply under the huge demand of human development. The vast and resource rich ocean has gradually become the focus of future interest competition. Therefore, this paper analyzes the resolution ability of modern Satellite Altimetry Gravity(SAG) anomaly, and discusses its application in MR survey. The validity and feasibility of applying modern SAG technology to MR survey are verified by experiments.

## 1. Introduction

With the development of space science and technology, satellite observation has gradually become an important means for people to observe and study the ocean because of its superiority in space-time scale. Among them, compared with the traditional means of ship survey, altimetry satellites and gravity satellites have shown unparalleled advantages in the acquisition and research of ocean gravity field related parameters such as ocean geoid and vertical deviation, which effectively supplement the research data of ocean gravity field. At the same time, the classification of MR and the accurate and clear division of MR are of great significance to the control of the quantity, distribution and development and utilization of various MR, and are also the basis for targeted planning, development and efficient utilization of MR, thus effectively promoting the sustainable utilization of MR. The classification of MR is of great significance to comprehensively measure the level of development and utilization of MR.

Many scholars at home and abroad have studied and analyzed the resolution of modern SAG anomaly and its application in MR survey. The academic circles have been studying the ocean and MR for a long time, but they have not reached an agreement on the definition of its connotation. Geography studies believe that the ocean is a multi-dimensional ecological structure, consisting of marine water, marine organisms, the atmosphere over the sea area and the coastline. This description delineates the scope of MR from the perspective of geography, but neglects the interactive relationship between people and the ocean [1]. From the perspective of economics, the ocean is the treasure house of resources for human survival and development, and it is considered that the ocean is equal to MR. Chinese scholars have conducted a lot of research on the definition and division of MR from the perspective of the spatial scope, formation conditions and human relations of MR [2].

In this paper, modern SAG technology is introduced for MR survey, the resolution ability of modern SAG anomaly is analyzed, the basic theory of satellite altimetry inversion of marine gravity anomaly is discussed, and the gravity reduction, waveform denoising method, empirical mode decomposition method and singular spectrum analysis method are proposed and compared; Finally, through the application of SAG technology in MR survey, the MR of China are investigated and analyzed. The analysis results verify the effectiveness and feasibility of modern SAG anomaly resolution technology applied to MR investigation [3-4].

## 2. Analysis of Resolution of Gravity Anomaly in Modern Satellite Altimetry

The marine gravity anomaly is an important basic data for the research of seabed terrain inversion. At present, the main means of marine gravity measurement include the fixed-point observation of seabed gravimeter and the sea surface measurement of ship borne gravimeter. However, due to the disadvantages of high measurement cost, sparse data points, long measurement period and poor repeatability, this measurement method is difficult to meet the needs of obtaining large-scale spatial marine gravity field information in a short time [5-6]. Usually, according to the relationship between the sea depth and the ocean gravity anomaly, the sea depth can be inversed, making satellite altimetry an effective way to obtain high-resolution ocean depth information. Although the accuracy of the sea depth obtained by altimetry inversion is low at present, the results still play a very important role in the positioning of obstacles in the ocean circulation and shallow seamounts [7].

### 2.1. Basic Theory of Inversion of Marine Gravity Anomaly by Satellite Altimetry

The open sea area is an ideal observation object for satellite altimetry. The following takes the open sea area as an example to give the basic measurement principle of satellite altimetry. The satellite altimeter transmits pulse signals to the sea surface at a certain frequency along the vertical direction by the antenna. The pulse signals arrive at the sea surface and are reflected. The reflected signals are received by the altimeter and processed to obtain the satellite altimeter echo waveform [8-9]. The on-board processor on the altimeter satellite analyzes and processes the echo waveform, and accurately measures the time interval △ t taken during the whole propagation process from signal transmission to reception. The propagation speed of the signal in the vacuum is known to be c. the average distance L from the altimeter satellite to the instantaneous sea surface of the ground sub satellite point can be calculated by the following formula:

$$L = c \cdot \frac{\Delta t}{2} \tag{1}$$

To obtain the height of the sea surface relative to a certain reference ellipsoid, it is necessary to determine the orbit position of the altimetry satellite, which is usually accurately obtained by several tracking means. The common means include Doris, prape, GPS and SLR. Among them, Doris and prape determine the satellite speed by the measured Doppler frequency shift, and SLR is mainly used for correction.

The height h of the altimeter satellite relative to the reference ellipsoid is obtained by the tracking means, the distance r between the satellite and the sea surface is known, and the correction term △ lcor such as atmospheric refraction and instrument deviation suffered by the signal in the propagation process is taken into account. The sea surface height of the satellite altimeter halt (referred to as altimeter sea surface height) can be calculated by the following formula:

$$h_{alt} = H - L - \Delta L_{cor} \tag{2}$$

In oceanography, sea level height h sea Can be expressed as:

$$h_{sea} = N + h_{dyn} + h_{tide} + h_{inv} \tag{3}$$

Where n represents the fluctuation of geoid; Hdyn represents the sea surface topography, which includes static and dynamic parts; Htide represents tidal influence, which is divided into sea tide and solid tide; Hinv indicates the influence of reverse pressure. The correction term △ Rcor caused by atmospheric refraction is called the distance correction term, and the three terms hdyn, htide and hinv are called geophysical correction terms. The hsea can be obtained directly by selecting the calculation model. The difference between altimeter sea level height and ocean sea level height is generally called altimeter sea level height difference, while the halt obtains the commonly known sea level height through tide correction and inverse pressure correction [10-11].

### 2.2. Gravity Reduction

Gravity measurement is usually carried out on the ground or sea surface. In order to directly compare with the normal gravity on the ellipsoid, it is also necessary to calculate these gravity observation values on the geoid. This calculation process is called gravity calculation. Gravity reduction includes three parts: spatial correction, Bouguer correction and local terrain correction [12]. Assuming that the geoid is a non rotating homogeneous spherical surface, the calculation formula of spatial correction is:

$$K = 0.3086H - 0.72 \times 10^{-7} H^2 \tag{4}$$

Where, the unit of H is m and the unit of K is MgAl. Since the spatial correction value is very small, the influence of this assumption on the calculation results can be almost ignored.

#### 2.2.1. Waveform Denoising Method

The return waveform received by the microwave radar altimeter can be regarded as composed of two parts: one is the main waveform information including thermal noise, waveform leading edge and waveform trailing edge; The other part is noise information. Noise is generated by different reflection surfaces such as land and sea. The presence of noise affects the accuracy of height measurement waveform resetting, and further affects the height measurement distance correction [13-14]. In this paper, the altimeter waveform is constructed as a one-dimensional long-scale time series, and the main waveform information and noise information in the time series are stripped away to achieve the purpose of denoising. Next, the denoising methods used in this paper are introduced in detail: empirical mode decomposition method, singular spectrum analysis method and combination method.

### 2.2.2. Empirical Mode Decomposition Method

The main working principle of empirical mode decomposition is to decompose the signal into a series of intrinsic mode functions (IMF) and a residual trend term that meet specific requirements one by one according to the interpolation method. Each IMF component represents the detailed information of the original signal on different time scales and generates different IMF components in order from high frequency to low frequency. The application of empirical mode decomposition method to waveform denoising is shown in Figure 1:

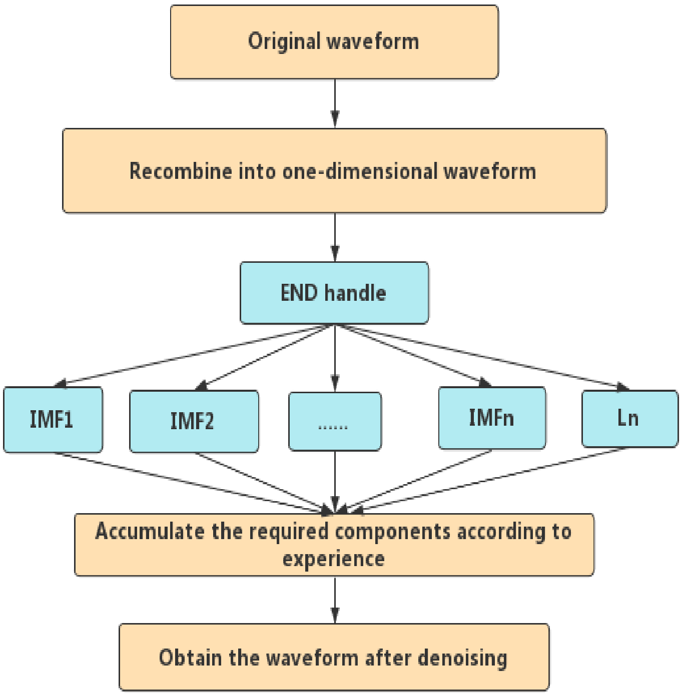


*Figure 1. EMD calculation flow chart*

The waveform denoising based on EMD method mainly takes the high-frequency IMF component as the noise information and directly deducts it without considering the possible noise in the low-frequency IMF. Its disadvantage is that it ignores the possible effective signal in the high-frequency IMF and the possible noise information in the low-frequency IMF [15-16].

### 2.2.3. Singular Spectrum Analysis Method

The main working principle of singular spectrum analysis (SSA) is to transform the observed one-dimensional time series data into a trajectory matrix, which is applied to the time series of altimeter waveforms. SSA constructs a multidimensional trajectory matrix for the waveform sequence, decomposes and reconstructs the trajectory matrix, and extracts signals representing the main waveform information and noise information. The calculation flow chart is shown in Figure 2:

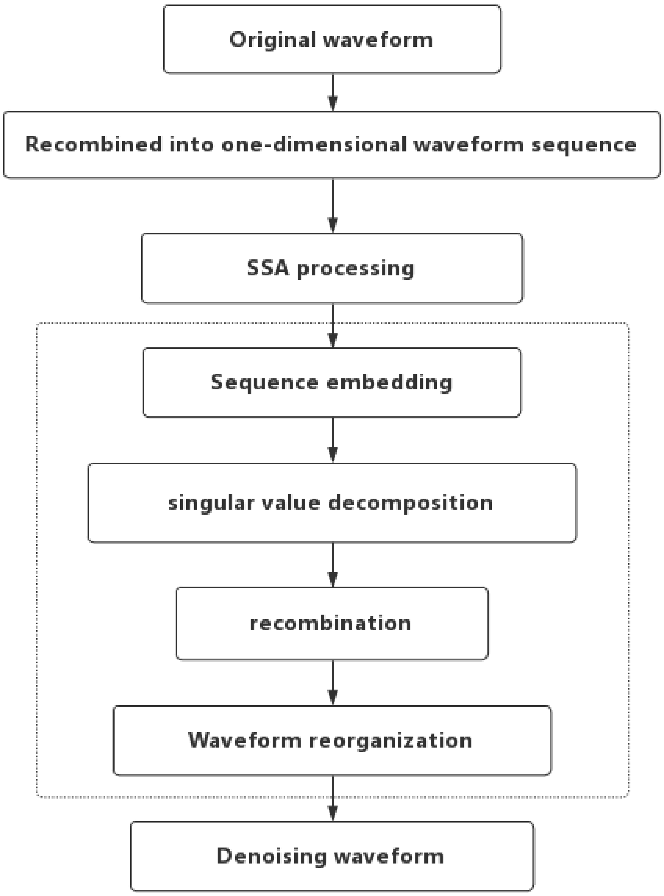


*Figure 2. SSA calculation flow chart*

The main problem of SSA method denoising is that there is still no clear standard for the acquisition of parameters in the grouping step, and the new waveform sequence reconstructed according to the parameters acquired by experience will have excessive denoising and insufficient denoising [17-18].

## 3. Application of SAG Technology in MR Survey

### 3.1. Comprehensive Index Evaluation Index System of MR Development

The resources in the ocean, in essence, are the marine land resources, and are also the MR frequently mentioned by people at present. Its scope includes all marine natural resources within the territorial sea, as well as all marine natural resources within its jurisdiction, such as the 200 nautical mile exclusive economic zone and the continental shelf. The MR endowment is different, so there are obvious differences in the comprehensive level of MR development.

In order to more objectively and comprehensively reflect the comprehensive level of MR development, the following principles shall be observed in the process of selecting indicators:

Scientific principle: each indicator in the indicator system of MR development comprehensive index should have its own scientific meaning in the process of selection.

Systematic principle: the marine resource system is a multi-level and open giant system. Therefore, in the design process of the relevant indicator system, each level should be composed of several indicators with the same level of function, similar position and mutually complementary contents, so as to avoid the occurrence of unclear indicator levels, chaotic matching and overlapping contents. Therefore, the indicator system constructed under the principle of systematization should reflect all the sub dimensional elements of MR development as orderly and coordinately as possible.

Objective oriented principle: the specific design of the evaluation index system should not only be satisfied with the ranking of the development results of the current situation, but also reflect the guiding characteristics of serving the future development goals. The purpose of the evaluation of the comprehensive level of MR development in China is not simply to determine the advantages and disadvantages of the results. More importantly, on the basis of comprehensive measurement, it is to deeply explore the relationship and interaction between the comprehensive level of MR development and the development of marine economy, We will comprehensively improve the "quality" and "quantity" of marine economic development under the new normal.

Principle of comparability and operability: compared with other natural resources, MR have their own characteristics in the process of development and utilization. Therefore, in the process of measuring their comprehensive development level, the construction of indicator system should highlight their comparability. For some indicators with poor comparability, they should be converted into indicators with greater comparability through relevant formulas and calculations to achieve objective consistency of evaluation results; At the same time, there are some relatively important indicators, but the actual operability of their statistics is poor. Therefore, the complexity and fuzziness of such indicators should be removed through corresponding tools, and they should be converted into numerical or qualitative indicators that can be measured as much as possible, so as to avoid the difficulty of handling them with traditional methods.

Principle of comprehensiveness: MR involve different types, and different types of resources have different characteristics. Therefore, the comprehensiveness of indicators must be ensured in the process of constructing the indicator system. Therefore, in the process of indicator design, it is necessary to reflect different types of MR according to the connotation and classification of MR, and at the same time, the specific indicator selection of each type of MR should also be significantly representative.

### 3.2. Quantitative Analysis of the Results of Modern SAG Technology Applied to MR Survey

The signal-to-noise ratio, correlation coefficient and root mean square error of the denoised waveform sequence processed by EMD method, SSA method and EMD + SSA method are calculated. The results are shown in Table 1 and figure 3. The signal-to-noise ratio and correlation coefficient of EMD method, SSA method and combination method are gradually improving. The root mean square error of EMD method, SSA method and combination method is gradually decreasing. According to these three criteria, it can be judged that the combined method has better filtering and denoising effect.

*Table 1. Table of different calculated denoising signal-to-noise ratio, correlation coefficient and root mean square error*

| Method | EMD | SSA | EMD+SSA |
|---|---|---|---|
| Signal to noise ratio | 16.85 | 20.17 | 40.19 |
| Correlation coefficient | 0.97 | 0.98 | 0.99 |
| Root mean square error | 16.39 | 11.19 | 0.70 |

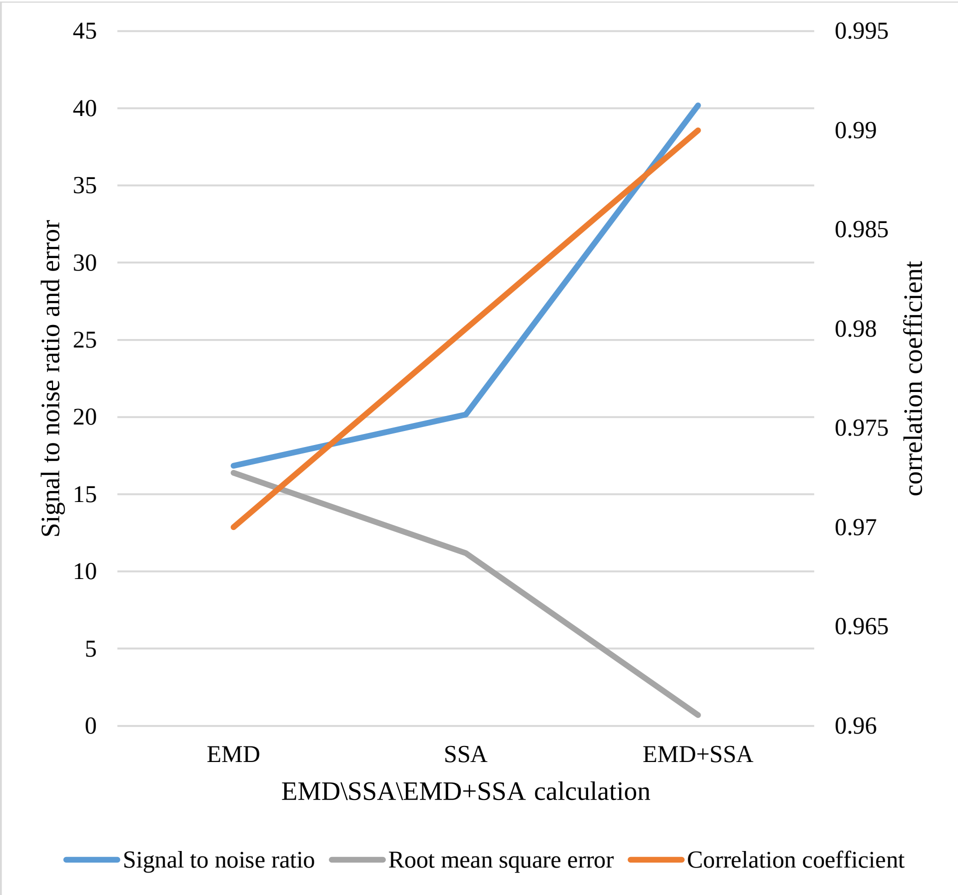


*Figure 3. Comparison of results of different calculation methods*

The value evaluation of MR is necessary to achieve sustainable development, which further proves that it is very necessary to evaluate the value of MR. At the same time, on the other hand, it is feasible to evaluate the value of MR, and the analysis of the value of MR must be measured from both qualitative and quantitative perspectives. Some things are of great value from a qualitative perspective, but not necessarily from a quantitative perspective. The qualitative analysis of MR in this paper is mainly from the perspective of contribution. Whether MR contribute to national economic development, including structural optimization, whether MR contribute to national economic security, and what impact MR have on national opening and development strategy. These contributions are also an aspect of the value of MR. However, these values are difficult to express in terms of quantity, so only qualitative analysis can be made.

## 4. Investigation and Analysis of MR in China

From the regional point of view, the distribution of MR in China shows a large imbalance. There are great differences in the types and quantities of MR distributed in various regions and sea areas. The pace of comprehensive utilization of various MR has gradually accelerated. In recent years, the pace of comprehensive utilization of MR in China has obviously accelerated, and the level of comprehensive utilization of various MR has been greatly improved. For example, the crude oil output of China's offshore oil is constantly increasing. At the same time, China's total output value of offshore oil and gas is also increasing year by year, more than doubling in three years. Moreover, the growth rate of its output value is obviously faster than that of its output, as shown in the following figure:

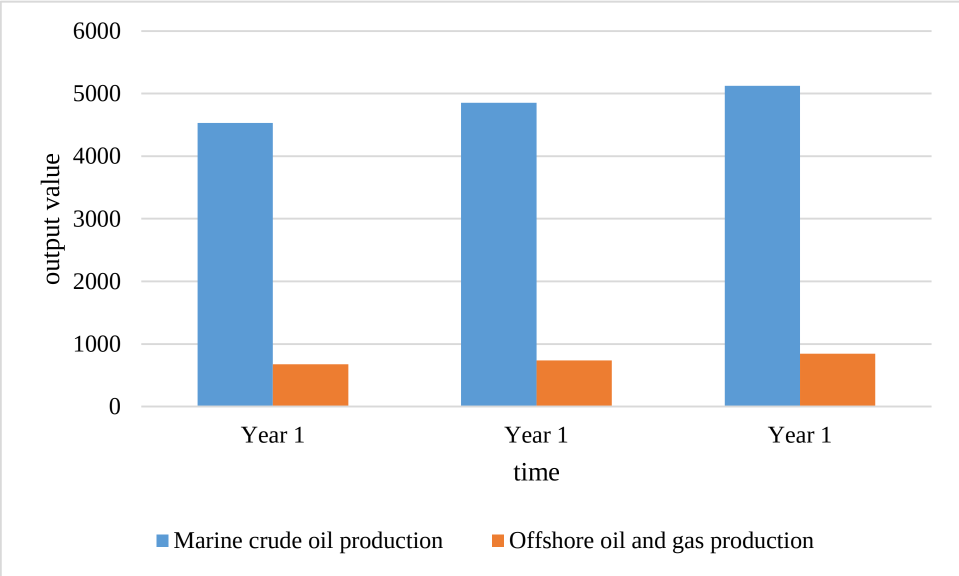


*Figure 4. Offshore oil and gas production and oil and gas output value*

The above figure shows that the crude oil output of China's offshore oil is gradually increasing, which reflects that China's ability to develop MR is constantly improving, and the offshore oil and gas is also growing year by year, which also reflects that China's ability to comprehensively process and utilize MR is constantly improving. In the past three years, the output of offshore oil and crude oil has increased by 23.2%, while the output value of offshore oil and gas has increased by 57.6%. The latter is obviously faster than the former. This further reflects that China has made remarkable achievements in the utilization of the sea and other MR. For example, in the development of modern marine economy, deep-water ports, a unique resource, are playing an increasingly important role, and China's ability to develop marine shoreline resources is also gradually improving, which is reflected in the rapid development of China's marine transportation industry and the continuous and steady increase of the throughput of Coastal Ports.

In this paper, MR are estimated separately. In the process of estimation, a typical resource is selected from each type of MR for simplification. The estimated results are: the balanced value of China's marine fishery resources is about 1.8-2 trillion yuan, the value of marine oil resources is about 205 trillion yuan, the direct economic value generated by seawater desalination is more than 300 billion yuan, and the potential profit space can reach about 80 billion yuan. In terms of offshore wind power, the offshore exploitable wind energy resources in the east coast are about 750 million kilowatts, The direct losses caused by the reduction of environmental pollution are more than 6 billion yuan.

## 5. Conclusion

In this paper, the resolution ability of modern SAG anomaly is analyzed, and its application in MR survey is discussed and studied, and good results are achieved. But there are also shortcomings. Certain policies and measures should also be taken to ensure the full realization of the resource value of the four categories of MR, including marine life, marine chemistry, marine power and marine minerals, which are subject to value assessment: further clarify the ownership and intensive management of marine living resources; Improve the compensation mechanism of marine mineral resources; Actively guide and encourage the development of marine power resources; Pay attention to improving the technological innovation of marine chemical resources development. The MR investigation of modern SAG technology needs further study.

## Funding

This article is not supported by any foundation.

## Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Conflict of Interest

The author states that this article has no conflict of interest.

## References

*[1] Fokin P A ,Zakrevskaya E Y , Sahakyan L G , et al. Composition and Formation Conditions of Lower Eocene Shallow-Marine Carbonates in Southern Armenia. Lithology and Mineral Resources, 2020, 56(5):438-459. https://doi.org/10.1134/S0024490221040039*

*[2] Vieira E ,Lazar C , Fernandes M J . Spatio-temporal variability of the wet component of the troposphere- Application to satellite altimetry. Advances in space research, 2019, 63(5):1737-1753. https://doi.org/10.1016/j.asr.2018.11.015*

*[3] Said A ,Macmillan D . 'Re-grabbing' marine resources: a blue degrowth agenda for the resurgence of small-scale fisheries in Malta. Sustainability science, 2020, 15(1):91-102. https://doi.org/10.1007/s11625-019-00769-7*

*[4] Lim D D ,Osman N H . Marine Protected Areas In Malaysia: Towards The Implementation Of Sustainable Development Concept. Journal of Tourism Hospitality and Environment Management, 2020, 5(19):50-66. https://doi.org/10.35631/JTHEM.519005*

*[5] Kong D D , Li X Y , Meng Y , et al. Current situation of heavy metal pollution,detection and removal techniques in medicinal marine organisms in China. Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica, 2019, 44(23):5022-5030.*

*[6] Alam A . Marine spatial planning for Bangladesh: a critical analysis of the legal and institutional regimes. Asia Pacific Journal of Environmental Law, 2019, 22(2):277-288. https://doi.org/10.4337/apjel.2019.02.05*

*[7] Barrios-Garrido H , Shimada T , Diedrich A , et al. Conservation and Enforcement Capacity index (CECi): Integrating human development, economy, and marine turtle status. Journal of Environmental Management, 2020, 262(May15):110311.1-110311.7. https://doi.org/10.1016/j.jenvman.2020.110311*

*[8] V, B, Ushivtsev, et al. Methodology of Directional Development of Local Biocenoses for Optimization of Monitoring and Improvement of the Marine Environment on the Shelves of Russia. Doklady Earth Sciences, 2019, 488(1):1084–1088. https://doi.org/10.1134/S1028334X19090071*

*[9] M Pacé, Gadet B , Beguin J , et al. Drivers of Boreal Tree Growth and Stand Opening: The Case of Jack Pine on Sandy Soils. Ecosystems, 2020, 23(3):586-601. https://doi.org/10.1007/s10021-019-00425-2*

*[10] Lucifora L O ,Barbini S A , Scarabotti P A , et al. Socio-economic development, scientific research, and exploitation explain differences in conservation status of marine and freshwater*

*chondrichthyans among countries. Reviews in Fish Biology and Fisheries, 2019, 29(4):951-964. https://doi.org/10.1007/s11160-019-09584-w*

*[11] Hoof L V , Fabi G , Johansen V , et al. Food from the ocean; towards a research agenda for sustainable use of our oceans' natural resources. Marine Policy, 2019, 105(JUL.):44-51. https://doi.org/10.1016/j.marpol.2019.02.046*

*[12] Lyons C , Carothers C , Coleman J . Alaska's community development quota program: A complex institution affecting rural communities in disparate ways. Marine policy, 2019, 108(Oct.):103560.1-103560.12. https://doi.org/10.1016/j.marpol.2019.103560*

*[13] Vsn A , Vtp A , Lvna B , et al. Marine gravity anomaly mapping for the Gulf of Tonkin area (Vietnam) using Cryosat-2 and Saral/AltiKa satellite altimetry data - ScienceDirect. Advances in Space Research, 2020, 66( 3):505-519. https://doi.org/10.1016/j.asr.2020.04.051*

*[14] Sorja, Koesuma, Ariyanti, et al. Analysis of sea level rise and tidal components based on satellite altimetry Jason-2 and tide gauge data in 2008-2016 in Sunda Kelapa. Journal of Physics: Conference Series, 2019, 1153(1):12016-12016. https://doi.org/10.1088/1742-6596/1153/1/012016*

*[15] Jin T , Zhou M , Zhang H , et al. Analysis of vertical deflections determined from one cycle of simulated SWOT wide-swath altimeter data. Journal of Geodesy, 2020, 96(4):1-13.*

*[16] Abrehdary M , Sjoeberg L E , Sampietro D . Contribution of satellite altimetry in modelling Moho density contrast in oceanic areas. Journal of applied geodesy, 2019, 13(1):33-40. https://doi.org/10.1515/jag-2018-0034*

*[17] Pa'Suya M F , Din A , Yusoff M , et al. Refinement of gravimetric geoid model by incorporating terrestrial, marine, and airborne gravity using KTH method. Arabian Journal of Geosciences, 2020, 14(19):1-19.*

*[18] Sm A , He A , Mb A , et al. Synergy between surface drifters and altimetry to increase the accuracy of sea level anomaly and geostrophic current maps in the Gulf of Mexico. Advances in Space Research, 2019, 68( 2):420-431. https://doi.org/10.1016/j.asr.2019.12.024*