2023 Volume 4, Issue 1
Satellite Oceanography and Meteorology
ISSN(Online): 2424-9505
ISSN(Print): 2424-8959

Co-evolutionary Analysis of Marine Ecology and Meteorology in the Mediterranean Region Based on Satellite Data

Raffy R. Argeta*
Departamento de Estudios para el Desarrollo Sustentable de Zonas Costeras, Universidad de Guadalajara, Gómez Farías 82, San Patricio Melaque CP 48980, Jalisco, Mexico

***Corresponding author:** Raffy R. Argeta, rrargeta@costera.melaque.udg.mx

Abstract:

The objective of this study is to deeply explore the co - evolutionary mechanism between marine ecology and meteorological phenomena in the Mediterranean region, as analyzed through satellite data. By meticulously analyzing satellite remote-sensing observation data, this research aims to uncover the interactions between the marine ecosystem and meteorological conditions, as well as their long-term evolution trends, thereby providing solid scientific support for ecological maintenance and sustainable development in the Mediterranean region. The results show that there is a complex co-evolutionary relationship between marine ecology and meteorology. For example, changes in key meteorological variables such as ocean temperature and salinity not only affect the geographical distribution and growth dynamics of plankton but also have a profound impact on the structure and function of the entire marine ecosystem. Conversely, changes in the state of the marine ecosystem can also have a feedback effect on meteorological conditions, forming an interactive cycle.

Keywords:

Mediterranean region
Satellite data
Marine ecology
Meteorology
Co-evolution

Online publication: June 16, 2023

1. Introduction

The Mediterranean Sea, a semi-enclosed sea of great ecological and economic significance, its marine ecological system and meteorological patterns have a profound impact on the human production, living, and ecological environment in the surrounding areas. With the vigorous development of satellite remote-sensing technology, a large amount of marine and meteorological data in the Mediterranean region has been collected. This has laid a solid data foundation and provided a strong impetus for in-depth exploration of the co-evolutionary process of marine ecology and meteorology. Based on this, this study intends to make full use of these high-resolution and multi-dimensional satellite data. Through rigorous data analysis and precise model construction, it deeply analyzes the intricate internal relationships between marine ecological and meteorological elements in the Mediterranean region, and then accurately reveals the potential laws and underlying mechanisms of their co-evolution. This is of great significance and practical application value in many fields, such as scientific theory expansion and practical application.

2. Meteorological characteristics and change trends in the Mediterranean region

2.1. Atmospheric circulation and climate types

The Mediterranean climate is a rare climate type with dry summers and wet winters, so it is also known as the subtropical summer-dry climate. This climate type is mainly distributed on the west coast of the continents between 30° - 40° north and south latitude, including the Mediterranean coast, the Black Sea coast, the coastal areas of California in the United States, the areas around Perth in southwestern Australia and Adelaide in the south, the Southwestern corner of South Africa, and central Chile. Among them, the distribution area along the European Mediterranean coast is the largest and the climate characteristics are the most significant [1]. The Mediterranean region is under a complex atmospheric circulation pattern, affected by the interaction of multiple atmospheric circulation systems such as the subtropical high-pressure belt, the mid-latitude westerlies, and the Mediterranean cyclone. In summer, under the control of the subtropical high-pressure belt, there is a prevailing downward airflow, and the climate is hot and dry. In winter, affected by the mid-latitude westerlies, frontal activities are frequent, presenting a mild and rainy climate characteristic. This unique climate mode has a crucial impact on the marine ecosystem in the Mediterranean waters, deeply shaping the survival and reproduction pattern of marine organisms.

2.2. Temperature change trends

The data series constructed by long-term observations using high-resolution satellite remote-sensing clearly shows that in recent decades, the sea surface temperature in the Mediterranean region has shown a very significant upward trend. Specifically, according to the authoritative and detailed observation data provided by the Copernicus Climate Change Service in Europe, during the continuous monitoring period of the past 30 years, the average sea surface temperature in the Mediterranean has increased by 0.9°C, and the warming rhythm shows distinct spatial differences in different sea areas. Take the Levantine Basin in the eastern Mediterranean as an example. As a hotspot area that is extremely sensitive to climate change, the warming rate in the past 30 years has been as high as 0.35°C per decade, which is significantly higher than the overall average warming rate of the Mediterranean [2]. Such temperature dynamics not only directly reshape the thermal environment conditions of marine habitats but also are very likely to trigger deep changes in the structure and function of the marine ecosystem, posing potential challenges to the overall ecological stability of the Mediterranean.

2.3. Precipitation-evaporation balance

In the long-established Mediterranean Sea, the delicate balance between precipitation and evaporation is the main factor regulating the dynamic changes of its water salinity and water-level fluctuations. Recent cutting-edge scientific research has accurately clarified the following phenomena: In the past few years, the precipitation pattern in the Mediterranean region has shown a clear downward trend, while the evaporation rate has generally remained constant, although there has been a slight increase occasionally. The result of this dynamic interaction has led to a gradual increase in the ocean salinity level. This evolutionary trend potentially has an impact on the stability of the ocean circulation system and poses a hidden threat to the balance of the marine ecosystem. This ecological impact amplifies step-by-step along the food chain and ecological network, having a profound and long-term impact on the geographical distribution pattern of marine organisms and the long-term maintenance of species diversity, thus sending a severe warning signal to the overall health of the Mediterranean marine ecosystem.

3. Characteristics and changes of the marine ecosystem in the Mediterranean region

3.1. Plankton community

Plankton, as a fundamental component of the marine ecosystem, can be divided into two key categories: phytoplankton and zooplankton. In the vast Mediterranean Sea, the plankton community shows a high degree of species richness and diversity. Among them, the phytoplankton group, represented by diatoms and dinoflagellates, constructs a significant advantage and firmly occupies a dominant position [3]. Through in-depth analysis of the massive data accumulated by satellite remote-sensing monitoring, it can be observed that phytoplankton shows extremely distinct heterogeneous characteristics in both the spatial-temporal distribution structure and the dynamic changes of biomass, during the alternation of different seasons and in different sea-area ranges. The root cause is that the complex process of its growth and reproduction is regulated by the interactive coupling of multiple environmental factors, such as the periodic fluctuations of light intensity, the gradient changes of water temperature, and the differences in nutrient supply, presenting a complex ecological response.

3.2. Structure and function of the marine ecosystem

The marine ecosystem carried by the Mediterranean Sea has a highly complex structure, widely covering many diverse subsystems such as the shallow-sea ecosystem, the deep-sea ecosystem, and the coral-reef ecosystem. These subsystems are closely interconnected and work together through the tight interaction bonds of material flow, energy flow, and information flow. Thus, they jointly build the core internal support structure that can effectively maintain the overall balance and stable operation of the Mediterranean marine ecosystem [4]. Focusing on the key functional areas of the marine ecosystem, they mainly concentrate on the core dimensions such as the cyclic metabolism of substances, the efficient conversion of energy at each level, and the conservation and maintenance of biodiversity. Particularly importantly, the precise and efficient implementation of these functions is deeply dependent on the integrity and rationality of the internal structure of the ecosystem. The two complement each other and support each other, jointly promoting the orderly evolution of the Mediterranean marine ecology.

3.3. Change trends of the marine ecosystem

In recent years, the marine ecosystem in the Mediterranean region has experienced a series of significant and iconic changes. Driven by factors such as the continuous rise of sea surface temperature and the reshaping and change of the nutrient-salt distribution pattern, the habitat distribution range of some plankton has been forced to adjust, and the dynamics of biomass accumulation have also changed. The resulting ecological chain reaction is transmitted upward, fundamentally restricting the survival and reproduction of marine organisms such as fish that feed on plankton. At the same time, many stress factors such as the intensification of ocean acidification and the accumulation of multiple pollution loads have come one after another, exerting heavy pressure on the Mediterranean marine ecosystem [5]. This directly leads to the frequent occurrence of coral-reef bleaching, a decline in biodiversity, and many thorny problems gradually emerging, casting a thick shadow over the sustainable development process of the regional marine ecology, urgently needing in-depth exploration and effective response.

4. Co-evolutionary mechanism of marine ecology and meteorology

4.1. Impact of meteorological conditions on marine ecology

Changes in sea surface temperature directly affect the growth and reproduction rates of plankton. When the temperature rises, the metabolism of plankton accelerates, which is conducive to their growth and reproduction. However, if the temperature exceeds a certain threshold, it may have an adverse impact on plankton. At the same time, the wind field plays a key role in the marine ecosystem. By affecting ocean circulation and mixing processes, it drives the surface water flow of the ocean, promotes the vertical mixing of seawater, and brings deep-layer nutrients to the surface, providing a material basis for the growth of plankton [6]. The wind field also affects the distribution and migration of plankton, thus influencing the structure and function of the entire marine ecosystem. In addition, precipitation and runoff bring nutrients and pollutants from the land into the ocean, which has a dual impact on the marine ecosystem. An appropriate amount of nutrient input is conducive to the growth of plankton, but excessive nutrient input may lead to eutrophication, triggering ecological disasters such as red tides, and causing serious damage to the marine ecosystem. Therefore, temperature, wind field, precipitation, and runoff jointly act on the marine ecosystem, influence each other, and jointly maintain the balance of the marine ecology.

4.2. Feedback of Marine Ecology on Meteorology

The marine ecosystem significantly affects the concentration of greenhouse gases in the atmosphere through biogeochemical cycling processes, especially the photosynthesis of phytoplankton. This phytoplankton absorbs a large amount of carbon dioxide, convert it into organic carbon, and through the biological pump effect, transport a part of the organic carbon to the deep sea, thus effectively reducing the carbon dioxide concentration in the atmosphere and playing a role in regulating the global climate [7]. At the same time, changes in the marine ecosystem, such as the large-scale reproduction of phytoplankton, not only affect the biogeochemical cycle but also directly affect the sea surface temperature and the air-sea flux. This change increases the albedo of the sea surface, leading to a decrease in the sea surface temperature, and then affects the heat and water-vapor exchange between the ocean and the atmosphere. These feedback effects further change the atmospheric circulation and climate patterns, revealing the complex and close interaction between the marine ecosystem and the atmosphere.

5. Co-evolutionary analysis methods based on satellite data

5.1. Data pre-processing and quality control

In the research workflow based on satellite data, implementing a fine and rigorous pre-processing process and a strict quality-control strategy for the collected satellite data is undoubtedly the key pivot to ensure the high accuracy of research conclusions. Specifically, the pre-processing link includes the conversion of data formats to a standardized paradigm, the precise adjustment of radiometric calibration through professional calibration methods, and the accurate implementation of geometric correction using precise algorithms. The core purpose is to minimize the systematic biases and random disturbances introduced by factors such as the inherent characteristics of the sensor and the observation geometry and to deeply restore the original true appearance of the data [8]. At the same time, with the carefully constructed quality-control algorithm system, the original satellite data is carefully screened and precisely filtered, removing outliers and low-quality data segments, and comprehensively ensuring the reliability, stability, and temporal coherence of the data, laying a solid foundation for subsequent in-depth exploration.

5.2. Statistical analysis methods

To deeply decrypt the intricate co-evolutionary internal logic between marine ecology and meteorology, it is necessary to use a variety of fine statistical analysis strategies to conduct in-depth analysis of satellite data. For example, calculate the correlation coefficient through a rigorous mathematical - deduction process, thereby quantitatively presenting the hidden linear dependence degree between marine ecological variables and meteorological variables, making their relationship clear at a glance. Skillfully apply cutting-edge technical means such as principal-component analysis to efficiently perform dimensionality reduction operations on vast multivariable data sets and accurately extract key features, so as to precisely anchor the core model structure that dominates the coevolutionary process. At the same time, make full use of the powerful tool of time-series analysis to deeply explore the hidden dynamic change trajectories and periodic rhythms of marine ecological and meteorological variables over a long-time span, comprehensively capturing the subtle rhythms of their co-evolution from both spatial and temporal dimensions [9].

5.3. Numerical model simulation

Integrating numerical model-simulation technology into the research system enables us to deeply understand the internal mechanism of the co-evolution of marine ecology and meteorology. In specific practice, give full play to the functions of the marine ecological model and the atmospheric - circulation model. Using the satellite observation data that has undergone strict pre-processing and quality control as the core input parameters, realistically simulate the dynamic development trajectory of the marine ecosystem and the changing trends of meteorological conditions in the spatial-temporal dimension. Subsequently, carefully compare and verify the simulation results with the first-hand real data obtained from field observations [10]. In this process, precisely adjust the key parameters of the model according to the differences, continuously optimize the model-architecture design, and effectively enhance the simulation fidelity and prediction accuracy of the co-evolutionary dynamic process, thereby laying a solid theoretical foundation for forward-looking scientific decision-making and providing a strong basis for marine ecological protection and meteorological disaster prevention and control.

6. Conclusion

This study uses satellite data to deeply analyze the co-evolutionary relationship between marine ecology and meteorology in the Mediterranean region, revealing the laws and mechanisms of their co-evolution. The research results show that there is a complex interaction and feedback relationship between marine ecology and meteorology. Changes in meteorological conditions have an important impact on the marine ecosystem, and changes in the marine ecosystem also have a feedback effect on meteorological conditions. Through the analysis of satellite data and numerical model simulation, some key driving factors have been identified, and the future change trends have been predicted, providing a scientific basis for ecological protection and sustainable development in the Mediterranean region.

Disclosure statement

The author declares no conflict of interest.

References

[1] Chen W, Qu J, Cheng X, 2023, Analysis of the Distribution and Characteristics of the Mediterranean-Type Climate in Central Asia and Adjacent Areas. Journal of China West Normal University (Natural Sciences Edition), 44(5): 505–513.

[2] Wu L, Duan J, 2022, Inter-Annual Variation of the Winter Middle East Jet Center Position and Its Relationship with the Atmospheric Circulation. Transactions of Atmospheric Sciences, 45(1): 65–75.

[3] Yun R, 2022, Second-Generation Mediterranean Basin Observation Small Satellite Constellation-2. Satellite Application, 2022(4): 66.

[4] Mao Y, Zeng J, Hong L, et al., 2021, Key Areas and Promotion Strategies for Marine Resource and Environment Cooperation between China and Arab Countries in the Joint Construction of the "Belt and Road." Journal of Jiangsu Ocean University (Humanities and Social Sciences Edition), 19(1): 28–37.

[5] Zhang Y, Chu Y, 2020, The Governance Model of the Marine Ecological Environment in the Mediterranean Region and Its Enlightenment to China. Journal of Zhejiang Ocean University (Humanities Science Edition), 37(6): 30–35.

[6] Quan Y, Shi C, Yu X, 2020, The Cross-Border Governance Cooperation Mechanism of the Marine Ecological Environment: Inspiration for the East Asian Sea. Journal of Zhejiang Ocean University (Humanities Science Edition), 37(6): 24–29.

[7] Pan Q, Liu L, Ma J, et al., 2022, Research Progress on Satellite Remote-Sensing Monitoring of Marine Environmental Pollution Caused by Human Activities. Marine Science Bulletin, 41(6): 722–736.

[8] Xu Z, Tao G, 2022, Smart Monitoring Helps Improve the Modernization Level of Marine Ecological Environment Governance. China Environment, 2022(8): 34–37.

[9] Huang H, Liu L, 2022, Remote Sensing—The "Eagle Eye" for the Construction of Marine Ecological Civilization. China Environment, 2022(6): 43–44.

[10] Liu J, Ye X, Lan Y, 2022, China's Marine Satellite Remote-Sensing Big Data and Its Application Services. Big Data, 8(2): 75–88.