

# Networking Observation and Applications of Chinese Ocean Satellites\*

ZOU Bin LIU Yuxin

1(National Satellite Ocean Application Service, Beijing 100081)

2(Key Laboratory of Space Ocean Remote Sensing and Application, Ministry of Natural Resources, Beijing 100081)

**Abstract** This paper presents the networking observation capabilities of Chinese ocean satellites and their diverse applications in ocean disaster prevention, ecological monitoring, and resource development. Since the inaugural launch in 2002, China has achieved substantial advancements in ocean satellite technology, forming an observation system composed of the HY-1, HY-2, and HY-3 series satellites. These satellites are integral to global ocean environmental monitoring due to their high resolution, extensive coverage, and frequent observations. Looking forward, China aims to further enhance and expand its ocean satellite capabilities through ongoing projects to support global environmental protection and sustainable development.

**Key words** Chinese ocean satellites, Networking observation, Ocean forecasting, Ocean disaster prevention and mitigation, Ocean ecological monitoring, Ocean resource development, Polar monitoring, Terrestrial applications

**Classified index** P715.6

## 1 Introduction

China's extensive coastline and vast jurisdictional waters make the ocean crucial for its economy and ecological protection. Ocean satellites play an indispensable role in continuous, real-time, and large-scale monitoring of the ocean environment, contributing to scientific research, resource development, environmental protection, and disaster prevention.

Since the launch of China's first ocean satellite in 2002, there have been notable advancements, evolving from single satellite observations to coordinated networked observations<sup>[1]</sup>. As of now, China has successfully launched 13 ocean satellites, including the HY-1, HY-2, HY-3 series, and the China-France Oceanography Satellite (CFOSAT). Currently, 10 satellites are

operational, forming a comprehensive ocean satellite observation system (see Table 1).

The launch of the new-generation ocean color satellite (HY-1E) in 2023 enhanced global monitoring capabilities for ocean color and Sea Surface Temperature (SST). The networking of HY-1E with HY-1C/D has formed a constellation for ocean color satellites. Similarly, HY-2D, launched in May 2021, forms an ocean dynamic environment satellite constellation with HY-2B/C and CFOSAT. The 1 m C-SAR 02, launched in April 2022, forms an ocean surveillance and monitoring satellite constellation with 1 m C-SAR 01 and GF-3.

Networking observation by ocean satellites enables higher spatial and temporal resolution and coverage, providing precise and timely ocean environmental monitoring data. This improves the accuracy and timeliness of

\* Supported by Remote Sensing Support for Offshore Ocean Environment and Polar Sea Ice Early Warning Services (102121201550000009004)

Received June 20, 2024

©The Author(s) 2024. This is an open access article under the CC-BY 4.0 License (<https://creativecommons.org/licenses/by/4.0/>)

**Table 1 Launch details of Chinese ocean satellites**

| Satellite    | Series                                      | Launch date    | Operational status   |
|--------------|---------------------------------------------|----------------|----------------------|
| HY-1A        | Ocean color satellite                       | May 2002       | Ceased March 2004    |
| HY-1B        |                                             | April 2007     | Ceased February 2016 |
| HY-1C        |                                             | September 2018 | Operational          |
| HY-1D        |                                             | June 2020      | Operational          |
| HY-1E        |                                             | November 2023  | Testing              |
| HY-2A        | Ocean dynamic environment satellite         | August 2011    | Ceased February 2024 |
| HY-2B        |                                             | October 2018   | Operational          |
| HY-2C        |                                             | September 2020 | Operational          |
| HY-2D        |                                             | May 2021       | Operational          |
| CFOSAT       |                                             | October 2018   | Operational          |
| GF-3         | Ocean surveillance and monitoring satellite | August 2016    | Operational          |
| 1 m C-SAR 01 |                                             | November 2021  | Operational          |
| 1 m C-SAR 02 |                                             | April 2022     | Operational          |

ocean disaster warnings, reduces the impact on coastal regions, supports rational ocean resource development, and provides robust support for global ocean environmental protection and sustainable development.

## 2 Networking Observation Capabilities of Chinese Ocean Satellites

### 2.1 HY-1 Series Satellites and Their Networking Observation Capabilities

The HY-1 series are Chinese independently developed ocean color satellites, primarily used for monitoring SST, optical characteristics of seawater, chlorophyll concentration, and suspended sediments. These satellites provide valuable data for ocean resource management and scientific research.

On 15 May 2002, China successfully launched its first ocean satellite, HY-1A, equipped with a Chinese Ocean Color and Temperature Scanner (COCTS) and a Coastal Zone Imager (CZI). On 11 April 2007, the HY-1B was launched, inheriting the main functions of HY-1A while further improving observation capabilities and accuracy. The HY-1C was successfully launched on 7 September 2018. Compared to its predecessors, it added ultraviolet observation bands and an onboard calibration system, expanded the CZI's coverage width, and improved spatial resolution. On 11 June 2020, the HY-1D was launched, achieving networked observations with the HY-1C in the morning and afternoon, significantly enhancing global coverage capability and data acquisition frequency for ocean color monitoring.

In 2023, HY-1E was successfully launched, further enhancing its observation performance<sup>[2]</sup>. The spatial resolution of the COCTS has been improved from 1.1 km to 500 m. The CZI's spatial resolution has been increased from 50 m to 20 m, and it has acquired the ability to detect panchromatic information of land cover with a spatial resolution of 5 m. Additionally, HY-1E includes a Programmable Medium-Resolution Imaging Spectrometer (PMRIS) with 100 m resolution.

The three-satellite network of the HY-1 series has established a more comprehensive ocean color satellite constellation, providing higher resolution and more frequent data (as detailed in Table 2<sup>[3]</sup>). It can obtain medium-resolution images of 50 m or 100 m once per day, playing an important role in monitoring disasters such as sea ice, green tides, red tides, oil spills, and floods.

### 2.2 HY-2 Series Satellites and Their Networking Observation Capabilities

The HY-2 series satellites integrate active and passive microwave sensors to monitor ocean dynamic environment parameters in all weather conditions and at all times. These satellites primarily monitor elements such as Sea Surface Height (SSH), Sea Surface Wind (SSW), and SST, providing high-precision data support for ocean scientific research, resource management, and disaster warning.

On 16 August 2011, China successfully launched its first ocean dynamic environment monitoring satellite, HY-2A. This satellite was equipped with various remote sensors, including Radar Altimeter (RA), Scatterometer (SCAT), Scanning Microwave Radiometer (SMR), and

**Table 2** Observation capabilities of HY-1C/D/E

| Payload | Spatial resolution                       | Band number                        | Swath width                                | Monitoring capability                                                                                                                                                                      | Networking coverage capability           |
|---------|------------------------------------------|------------------------------------|--------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| CZI     | 50 m (20 m+5 m)                          | 4 (8+1)                            | 950 km (60 km, up to 1000 km side imaging) | Coastal zones, sea ice, red tide, ulva prolifera, suspended sediments, coral reefs, coastal wetlands, invasive species, mangroves, pollutants, large water bodies, vegetation, <i>etc.</i> | Once daily                               |
| PMRIS   | Multi-spectral 100 m/Hyperspectral 200 m | Multi-spectral 19/Hyperspectral 94 | 950 km                                     |                                                                                                                                                                                            |                                          |
| COCTS   | 1 km (500 m)                             | 10 (18)                            | 2900 km (3000 km)                          | Chlorophyll concentration, suspended sediments, dissolved organic matter, SST, polar sea ice, large water bodies, vegetation, soil moisture, <i>etc.</i>                                   | Ocean color 3 times/day, SST 6 times/day |

**Note** Information in parentheses represents the HY-1E remote sensors.

Calibration Microwave Radiometer (CMR). On 25 October 2018, HY-2B was launched, inheriting the main functions of HY-2A while improving data quality and adding Data Collection System (DCS) and Automatic Identification System (AIS) payloads. In September 2020, HY-2C was launched, followed by HY-2D in May 2021. These satellites carried RA, SCAT, CMR, DCS, and AIS. Currently, the HY-2B/C/D satellites are conducting networked observations, forming a satellite constellation for monitoring the dynamic ocean environment. As detailed in Table 3<sup>[4]</sup>, these three satellites equipped with SCATs can achieve 85% global ocean coverage every six hours.

Additionally, CFOSAT, launched in October 2018, carries SCAT and the Surface Waves Investigation and Monitoring instrument (SWIM). It achieved the first global continuous, large-scale, synchronous observation of wave direction spectra and SSW<sup>[5]</sup>. Working in conjunction with the HY-2 series satellites, CFOSAT enhances the capability to obtain data on the dynamic ocean environment.

Currently, the SSW and SSH products of the HY-2 series satellites have reached internationally advanced levels. According to evaluations by the China Meteorological Administration (CMA), this data significantly contributes to its global medium-range numerical weather prediction system.

In 2023, the National Satellite Ocean Application Service (NSOAS) released three types of fusion products based on the HY-2 series satellites: a global (1/4)° resolution and regional (1/8)° resolution SSH fusion product, a global 25 km resolution six-hourly SSW fusion product, and a 5 km resolution daily SST fusion product. These products will better serve climate change monitor-

ing, ocean dynamics research, disaster warning, and ocean engineering support.

### 2.3 HY-3 Series Satellites and Their Networking Observation Capabilities

The HY-3 series satellites are independently developed ocean surveillance satellites, currently including GF-3 and the 1 m C-SAR 01/02. These satellites are equipped with C-band multi-polarization Synthetic Aperture Radars (SAR), offering high-resolution, wide-coverage, multi-polarization, and multi-mode ocean and land observations (as detailed in Table 4). They provide high-resolution information on ocean dynamic environment parameters, natural disasters, maritime emergency events, land use, surface water monitoring, *etc.*

On 10 August 2016, the GF-3 was successfully launched, becoming China's first C-band multi-polarization SAR with a resolution of 1 m. It features 12 imaging modes, including two ocean observation modes (ocean mode and global observation mode), and is capable of acquiring single polarization, dual-polarization, and full polarization data.

In November 2021, the 1 m C-SAR 01 was successfully launched, followed by the 1 m C-SAR 02 in April 2022. These satellites are successors to GF-3, inheriting its mature technology with several improvements<sup>[6]</sup>. These enhancements include the addition of AIS to improve maritime vessel monitoring and the conversion of three traditional scanning imaging modes to TOPSAR mode. Additionally, they are equipped with onboard real-time processors, enabling real-time imaging processing, water body extraction, and oil spill detection functionalities.

The network of three satellites significantly enhances the spatio-temporal resolution and coverage of ocean monitoring, reducing the average revisit period to less than one day.

**Table 3** Observation capabilities of HY-2B/C/D

| Payload          | Spatial resolution | Working frequency                 | Swath width | Monitoring capability                                                               | Networking coverage capability           |
|------------------|--------------------|-----------------------------------|-------------|-------------------------------------------------------------------------------------|------------------------------------------|
| RA               | 7 km               | 13.585, 5.25 GHz                  | 7 km        | SSH, significant wave height, and gravity field, <i>etc.</i>                        | About 14-day mesoscale coverage          |
| SMR (HY-2B only) | 25–90 km           | 6.925, 10.7, 18.7, 23.8, 37.0 GHz | 1600 km     | SST, sea surface water vapor content, liquid water, and rain intensity, <i>etc.</i> | Daily coverage of over 80% of open ocean |
| SCAT             | 25 km              | 13.256 GHz                        | 1700 km     | SSW, <i>etc.</i>                                                                    | Global 85% coverage every six hours      |

**Table 4** Observation capabilities of GF-3, 1 m C-SAR 01/02

| Payload | Spatial resolution | Band number                                 | Swath width | Monitoring capability                                                                                                                                     | Networking coverage capability |
|---------|--------------------|---------------------------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| SAR     | 1–500 m            | C-band, full polarization, 12 imaging modes | 10–500 km   | Global maritime targets, ocean structures, detailed ocean dynamic environment parameters, maritime emergency events, land use, surface water, <i>etc.</i> | Daily                          |

### 3 Applications of Chinese Ocean Satellites

#### 3.1 Ocean Forecasting and Disaster Prevention

##### 3.1.1 Typhoon Monitoring

SCAT and SAR are effective tools for SSW monitoring, providing data on typhoon wind speed, direction, radius, center position, and intensity. These tools assist in tracking typhoon movement using multi-satellite observations. Figure 1 shows the observation of Typhoon Ewiniar by the HY-2B on May 30, 2024.

##### 3.1.2 Sea Ice Monitoring

From late November to the end of March, sea ice in the Bohai Sea and northern Yellow Sea can severely impact maritime transport and offshore operations. By utilizing HY-1C/D/E for daily coverage and SAR during cloudy periods, the spatial distribution, area, boundary, and thickness of sea ice can be extracted. This provides critical information for sea ice forecasting and maritime disaster prevention. Figure 2 shows the HY-1D CZI image of the Bohai Sea area on 22 January 2024.

##### 3.1.3 Sea Surface Height Monitoring

Currently, there are 10 satellites in orbit worldwide equipped with Radar Altimeters (RA), including China's HY-2B/C/D. These satellites can measure Sea Surface Height (SSH), significant wave height, and other related information. Additionally, by combining SSH with geoid data and using gravity inversion techniques, the ocean

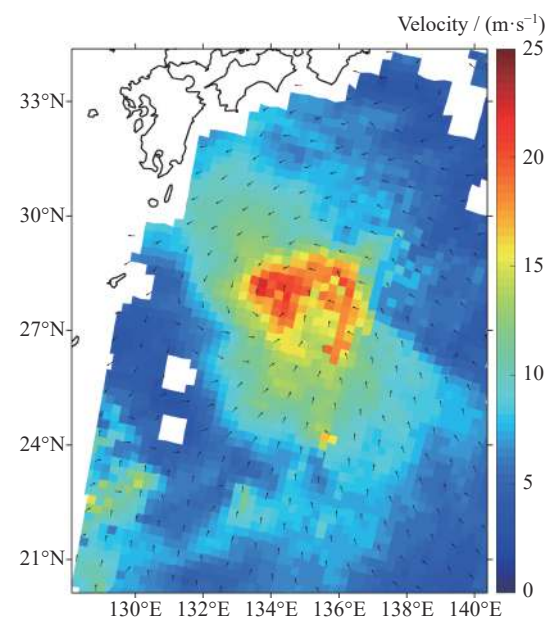


Fig. 1 Observation of typhoon Ewiniar by HY-2B

gravity field can be obtained. Through the modeling of gravity and topography, this allows further inference of seafloor topography. Figure 3 shows the regional 1/8° resolution sea level anomalies fusion product, primarily based on data from the HY-2 series satellites, released by NSOAS.

#### 3.2 Ocean Ecological Monitoring

##### 3.2.1 Ocean Ecological Disasters Monitoring

Ulva prolifera green tides, Sargassum, and red tides pose significant threats to the ecological environment, eco-

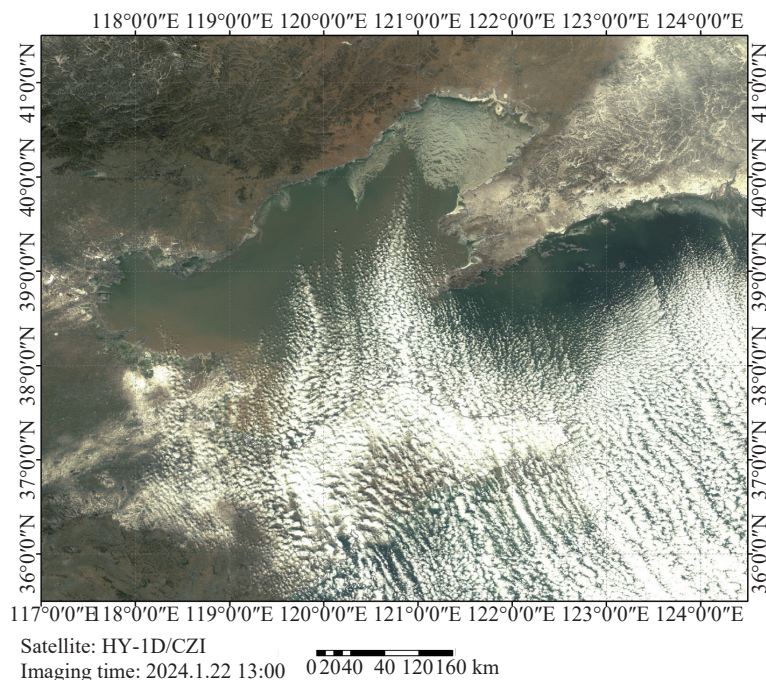


Fig. 2 HY-1D CZI image of the sea ice in the Bohai Sea

nomic development, and public health of coastal countries, necessitating effective monitoring and management measures.

The HY-1 series satellites are primarily used for ocean environmental monitoring and ocean resource investigation. Equipped with CZI and PMRIS with resolutions of 50 m and 100 m, these satellites can effectively identify and monitor large algae and abnormal ocean color distributions. By utilizing the coordinated monitoring capabilities of HY-1 and SAR, the dynamic changes of *Ulva prolifera* green tide and Sargassum can be promptly detected and tracked, providing robust technical support for ocean environmental protection and the management of ocean ecological disasters. Figure 4 and Figure 5 show the HY-1E CZI image of the *Ulva prolifera* green tide in the Yellow Sea on 24 June 2024, and the HY-1C CZI image of the red tide in the East China Sea on 16 August 2023, respectively.

Oil spill incidents not only pose serious threats to the ocean's ecological environment but also significantly impact fisheries, tourism, and the livelihoods of coastal residents. By comprehensively utilizing GF-3 and HY-1C/D, enhanced monitoring of affected areas can be conducted to obtain information on oil spills from offshore oil platforms and ships<sup>[7]</sup>. This provides crucial information support for safe production, ocean environ-

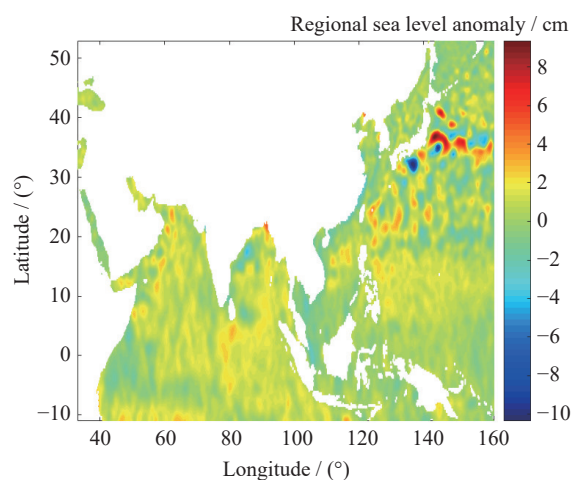


Fig. 3 Regional 1/8° resolution sea level anomalies fusion product

mental assessment, and disaster response. Figure 6 shows the monitoring image of the oil spill incident in the Yellow Sea in China in 2023.

### 3.2.2 Ocean Ecological Elements Monitoring

The COCTS on the HY-1 series satellites has a swath width greater than 2900 km and a spatial resolution of up to 500 m. It can cover the globe three times daily, enabling the acquisition of global ocean chlorophyll concentration and total suspended matter concentration. This capability helps in assessing the health of the glo-

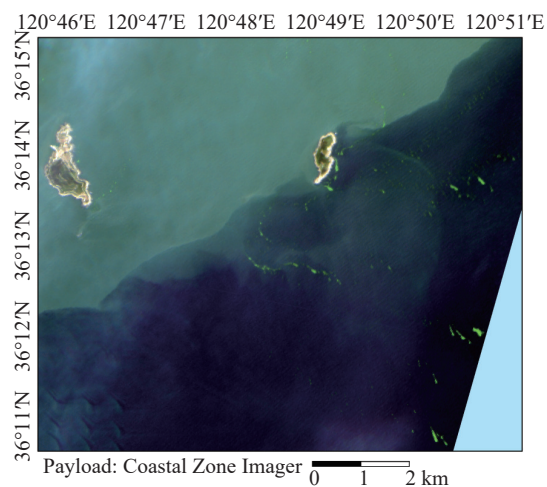


Fig. 4 HY-1E CZI image of ulva prolifera green tide in the Yellow Sea

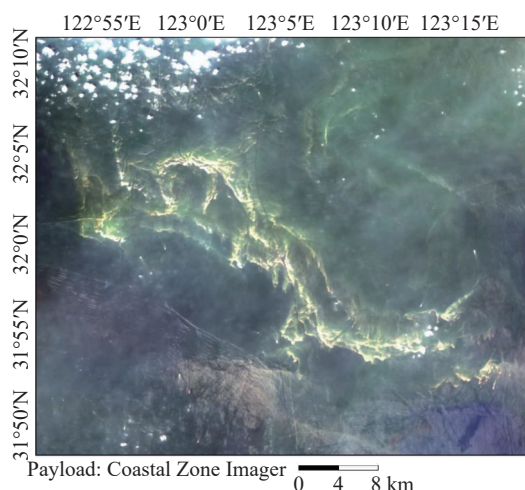


Fig. 5 HY-1C CZI image of red tide in the East China Sea

bal ocean ecological environment. Figure 7 shows the monitoring product of chlorophyll-a concentration from HY-1C COCTS in the South China Sea.

### 3.3 Ocean Resource Development and Management

#### 3.3.1 Offshore Wind Energy Monitoring

Offshore wind energy is an important source of clean energy. However, traditional monitoring methods struggle to achieve wide-area monitoring of the sea surface. The HY-2 series satellites can conduct wide-area SSW observations, but offshore wind farms are mainly distributed in nearshore areas within 50 m of water depth, where SCAT cannot effectively acquire data. SAR has the capability to observe high-resolution SSW. Using high-resolution data from GF-3 and 1 m C-SAR 01/02, it is possible to perform wind vector inversion for offshore wind farms and evaluate wind resources. This provides opera-

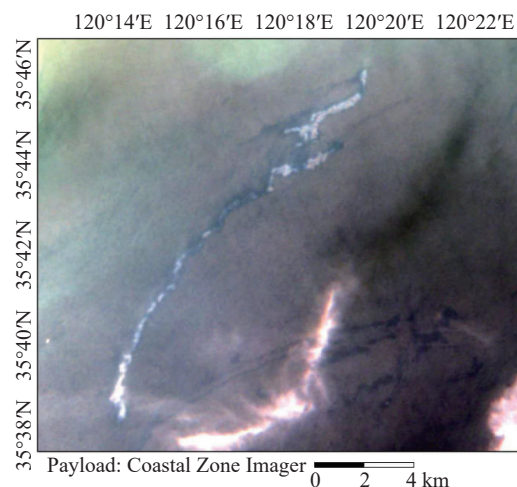


Fig. 6 HY-1C CZI image of oil spill in the Yellow Sea

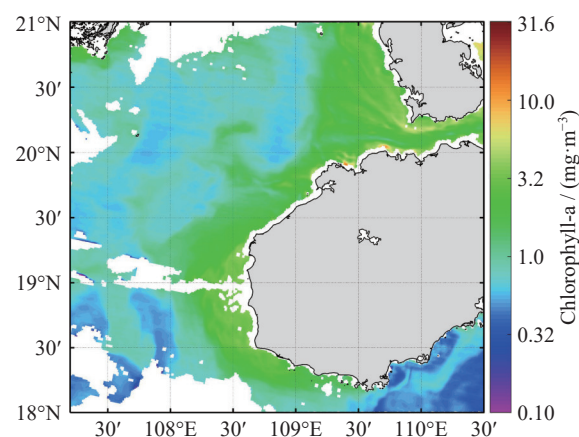


Fig. 7 Chlorophyll-a concentration from HY-1C COCTS

tional services for wind power companies in the construction and operation of offshore wind farms. Figure 8 shows the wind energy assessment results of the Bohai Sea area in China using data from multiple SAR satellites.

#### 3.3.2 Coastal Wetland Land Classification

Based on full-polarization SAR incoherent polarization decomposition technology, different types of land cover can be finely distinguished by analyzing the polarization information of radar echoes. By analyzing the remote sensing characteristics of coastal wetlands, a remote sensing information sample database and an information extraction index for coastal wetlands are established. Additionally, an information extraction model for coastal wetlands is constructed, enabling the extraction of coastal wetland information. Figure 9 illustrates the classification of wetlands in the Yellow River Delta, derived from SAR polarization decomposition data.

Furthermore, this technology has vast potential in the management of ocean and coastal natural resources. By enabling precise classification and monitoring of changes in land cover, it offers crucial information for overseeing

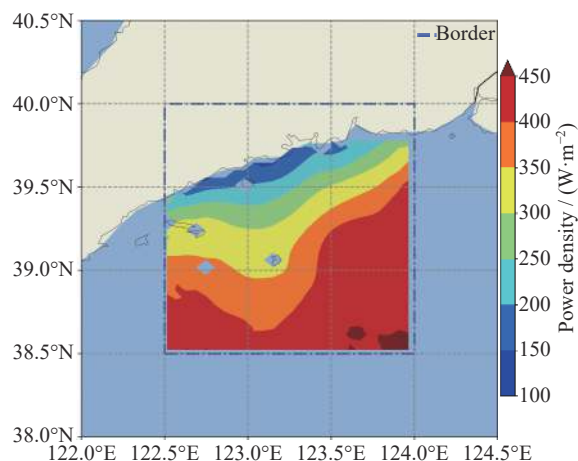


Fig. 8 Wind energy average power density distribution assessment at 100 m height in the Zhuanghe sea area of the Bohai Sea, China

offshore aquaculture areas, planning coastal land use, protecting ecosystems, and issuing disaster warnings.

### 3.4 Polar Monitoring

Using passive microwave brightness temperature data from the HY-2B, it is possible to generate daily sea ice concentration products, providing large-scale sea ice distribution information for the Arctic and Antarctic regions. These products are crucial for climate change monitoring and numerical model forecasting, and they also offer valuable reference information for navigation routes through ice zones, ensuring the safety of scientific expeditions and other vessels. Figure 10 displays the Antarctic sea ice concentration product derived from the HY-2B SMR.

In addition to large-scale sea ice concentration products, integrating multi-source remote sensing imagery from HY-1 series satellites, SAR, and other sources can provide detailed information on sea ice changes, land snow cover, glaciers, and ice shelf distribution, thereby enhancing polar monitoring.

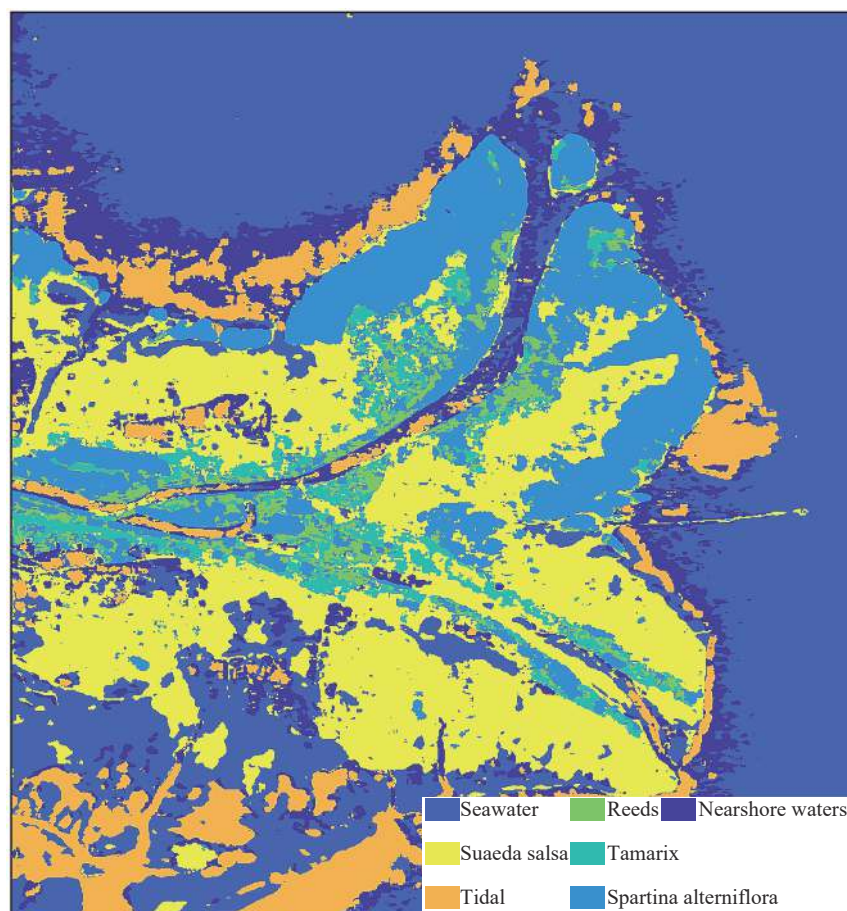


Fig. 9 Wetland classification in the Yellow River Delta based on SAR polarization decomposition data

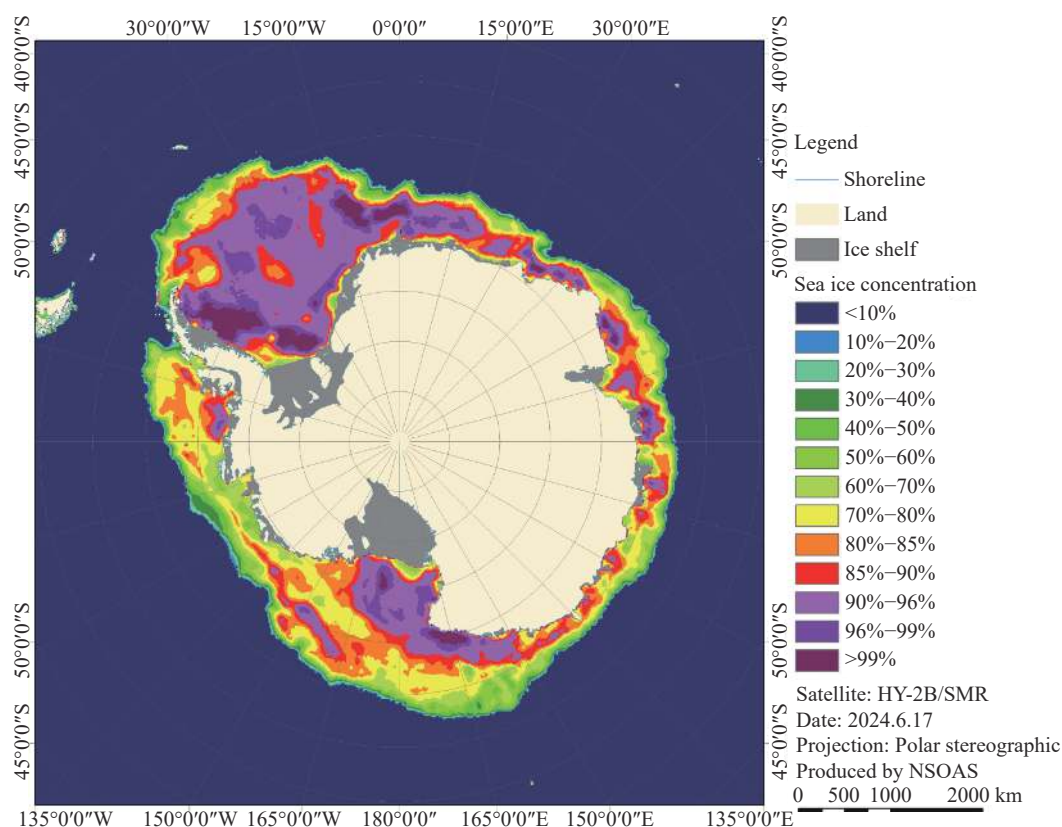


Fig. 10 Antarctic sea ice concentration product of HY-2B

### 3.5 Terrestrial Applications

#### 3.5.1 Flood Monitoring

From July to August 2023, under the influence of Typhoon Doksuri, the Beijing-Tianjin-Hebei region and several areas in northeastern China experienced continuous heavy rainfall, resulting in widespread flooding. Utilizing the advantages of GF-3 and 1 m C-SAR, which are unaffected by clouds and rain, emergency observations of the flood-affected areas were conducted. By comparing pre- and post-disaster images, accurate information was provided for assessing the extent and severity of the damage. Figure 11 shows the GF-3 SAR image of the Songhua River basin on 11 August 2023.

Additionally, the high-frequency observations from HY-1C/D/E can monitor the occurrence and development of urban flooding, providing data support for urban flood prevention and drainage efforts.

#### 3.5.2 Large Water Body Monitoring

Since July 2022, the middle and lower reaches of the Yangtze River have experienced prolonged high temperatures and low rainfall. This has led to increased evaporation and a continuous decline in the water surface area

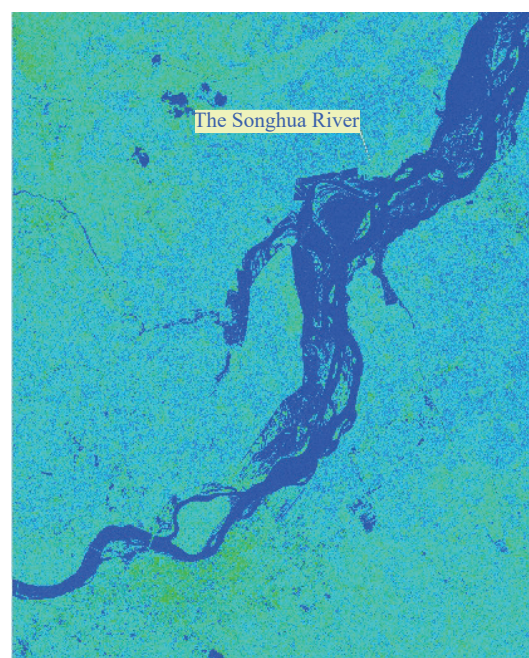


Fig. 11 SAR image of the Songhua River basin

such as Poyang Lake and Dongting Lake due to multiple factors. Utilizing the advantages of HY-1C/D with their wide scanning swath, short revisit periods, and

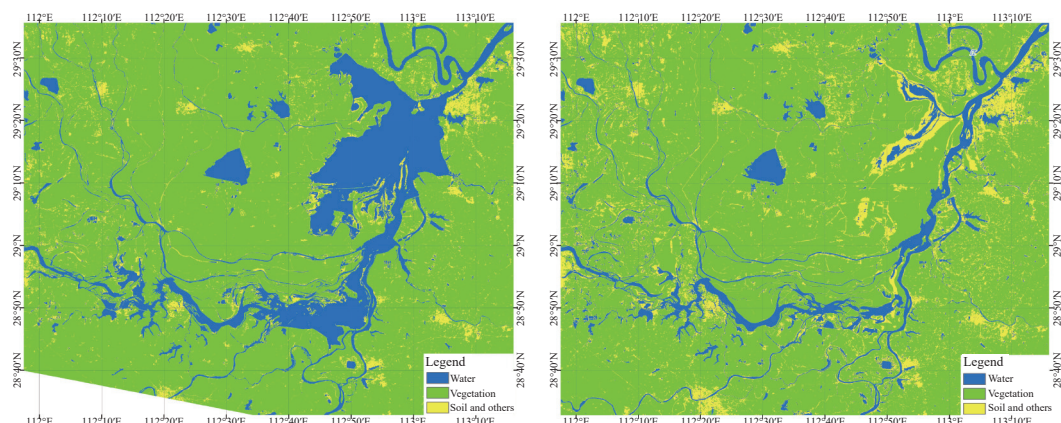


Fig. 12 Comparison of the water surface area of Poyang Lake between 22 August 2022 and 31 August 2021

high-frequency observations, dynamic monitoring of the water bodies in these regions has been conducted. Figure 12 shows a comparison of the water surface area of Poyang Lake between 22 August 2022 and 31 August 2021, captured by the HY-1C CZI.

## 4 Summary

Currently, China has established an initial networked observation capability with the HY-1, HY-2, and HY-3 series satellites. These satellites play a significant role in ocean disaster prevention, ecological monitoring, and resource monitoring. Additionally, due to their wide coverage, high revisit frequency, and high quantitative accuracy, these ocean satellites also make valuable contributions to terrestrial and emergency monitoring.

The new satellites currently under development include the Chinese Ocean Salinity Satellite, HY-2E/F, and the Sea Wind and Wave Detection Satellite, with the Ocean Salinity Satellite scheduled for launch in 2024. Building on the long-term, continuous, and stable observation capabilities of the ocean color, ocean dynamic environment, and ocean surveillance and monitoring satellites, China will further expand observation elements, improve observation quality, develop high-orbit ocean satellites, and strive to achieve comprehensive detection of both surface and subsurface ocean information.

## References

- [1] JIANG X, SONG Q. Ocean satellite programs in China[J]. *Comprehensive Remote Sensing*, 2018, **8**: 278-283
- [2] NSOAS. Successful launch of the new generation ocean color observation satellite[EB/OL]. (2023-11-17) <http://www.nsoas.org.cn/eng/item/266.html>
- [3] NSOAS. HY-1 series[EB/OL]. (2024-4-12) <http://www.nsoas.org.cn/eng/column/145.html>
- [4] NSOAS. HY-2 series[EB/OL]. (2024-4-12) <http://www.nsoas.org.cn/eng/column/146.html>
- [5] WANG L L, DING Z Y, ZHANG L, *et al.* CFOSAT-1 realizes first joint observation of sea wind and waves[J]. *Aerospace China*, 2019, **20**(1): 20-27
- [6] NSOAS. On-orbit tests of 1-meter C-SAR 01 and 02 satellites were successfully completed[EB/OL]. (2023-2-22) <http://www.nsoas.org.cn/eng/item/264.html>
- [7] LIU Jianqiang, LU Yingcheng, DING Jing, *et al.* Oil spills in China Seas revealed by the national ocean color satellites[J]. *Chinese Science Bulletin*, 2022, **67**(33): 3997-4008 (刘建强, 陆应诚, 丁静, 等. 中国海洋水色业务卫星揭示我国近海溢油污染状况[J]. *科学通报*, 2022, **67**(33): 3997-4008)

## Author Biography



**ZOU Bin** Male, born in 1969 in Guangshan County, Henan Province, currently a Senior Engineer at the National Satellite Ocean Application Service and a master's supervisor. His main research direction is ocean remote sensing and its applications.  
E-mail: [zoubin@mail.nsoas.org.cn](mailto:zoubin@mail.nsoas.org.cn)



**LIU Yuxin** Male, born in 1987 in Shangqiu City, Henan Province, currently an Associate Researcher at the National Satellite Ocean Application Service. His main research direction is ocean remote sensing and its applications.  
E-mail: [liuyuxin@mail.nsoas.org.cn](mailto:liuyuxin@mail.nsoas.org.cn)