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## Earth Observation Big Data Open Sharing: Challenges and Reflections Postprint

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### Abstract

Earth observation data, as a national fundamental and strategic resource, plays an indispensable role in the national economy, social development, and national security. China is currently confronted with a historic new opportunity to transform from an Earth observation “data giant” to a “data superpower”. This article expounds on the current development trends of big Earth observation data, summarizes the status quo and trends of international Earth observation data open sharing, analyzes the current situation and challenges regarding Earth observation data open sharing in China, and finally proposes three recommendations for the open sharing of China’s big Earth observation data: strengthen the construction of data governance systems to consolidate the foundation for Earth observation data open sharing; place equal emphasis on institutional mechanisms and technological innovation to construct a sound data sharing ecosystem; innovate Earth observation data sharing service models to promote interdisciplinary research, knowledge discovery, and integrated applications. By strengthening efforts in data open sharing, it is anticipated that the potential value of China’s big Earth observation data can be unleashed, its strategic role can be fully leveraged, and the international competitiveness of China’s big Earth observation data can be effectively enhanced.

### Full Text

## Opening and Sharing of Big Earth Observation Data: Challenges and Countermeasures

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## Abstract

Earth observation (EO) data, as a fundamental and strategic national resource, plays an indispensable role in national economy, social development, and national security. China now faces a historic opportunity to transform from a “large country of EO data” to a “strong country of EO data.” This paper expounds on the current development trends of big EO data, summarizes the status quo and trends of international EO data opening and sharing, analyzes the current situation and problems of EO data opening and sharing in China, and finally proposes three recommendations for China’s big EO data opening and sharing: (1) strengthen the construction of data governance systems to consolidate the foundation for EO data opening and sharing; (2) emphasize both institutions and technologies to build a healthy data sharing ecosystem; and (3) innovate EO data sharing service models to promote interdisciplinary integration, knowledge discovery, and comprehensive applications. By strengthening data opening and sharing, we aim to unlock the potential value of China’s big EO data, fully leverage its strategic role, and effectively enhance China’s international competitiveness in big EO data.

**Keywords:** Earth observation big data, opening and sharing, data governance system, data sharing ecosystem, sharing service model

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## 1. Introduction

Big scientific data has become a new engine driving innovation and knowledge discovery in Earth sciences. As an important component of scientific big data, Earth observation data has become a fundamental and strategic national resource, playing an indispensable role in national economy, social development, and national security. Global Earth observation now possesses the capability to acquire atmospheric, oceanic, and terrestrial data with high precision and spatiotemporal resolution, ushering the field into the big data era [2-4]. According to statistics, by August 2017, a total of 4,635 satellites had been launched globally, with 357 launched in just the first half of 2017 [5,6]. Currently, 1,738 satellites are operating in orbit, including 596 Earth observation satellites—approximately one-third of all operational satellites [5,6]. In recent years, microsatellites and satellite constellations such as Planet Labs’ Flock and “Jilin-1” have become new hotspots in the remote sensing market, opening a new era for big EO data acquisition. For instance, on February 15, 2017, 88 Planet Labs-Flock satellites were launched simultaneously via a single rocket [7].

Scientific big data is a new engine for scientific discovery and knowledge innovation, transforming human life and our deep understanding of the world [2]. As a crucial component of scientific big data, big Earth observation data plays a significant role in national strategy, industry applications, and scientific research. The opening and sharing of EO data promotes research and develop-

ment of global-scale scientific and environmental monitoring products, drives disciplinary innovation, and facilitates sustainable human development. The implementation of the Earth Observing System (EOS) program, led by NASA and involving multiple countries, has sparked a wave of EO technology development. This system comprises multiple satellites including ACRIMSAT, Aqua, Terra, Landsat-7, and Jason-1, enabling comprehensive applications across atmospheric, oceanic, terrestrial, and biological disciplines [18,19]. NASA's EOS-DIS system provides sharing services for MODIS TERRA and AQUA satellite data and related products, playing an important role in international remote sensing scientific research [20,21]. In 2003, the European Space Agency (ESA) implemented the "Copernicus Program" (GEMS, formerly "Global Monitoring for Environment and Security"), emphasizing the coordination and utilization of EO platform data. In 2008, the U.S. Geological Survey (USGS) began providing global Landsat data sharing and download services, and in recent years has gradually provided high spatiotemporal consistency ARD (Analysis Ready Data) products to facilitate direct user analysis [22,23]. In 2013, ESA began implementing Sentinel series satellite data sharing, providing high-quality data, information, and knowledge for sustainable development, environmental governance, and security policies in Europe and globally [24].

Since the 21st century, EO data has grown rapidly, and data sharing has shown trends of global resource integration, standardized technical specifications, and informatized sharing services. Large-scale sharing systems between countries have begun to form, such as the Global Earth Observation System of Systems (GEOSS) [25]. GEOSS achieves global opening and sharing of EO data through worldwide data integration and provides users with three major categories of products and technical services: data, information, and knowledge [26-28].

## 2. International Status and Trends of EO Data Opening and Sharing

Internationally, many countries increasingly emphasize the formulation of EO data sharing policies. Developed countries such as the United States and some European nations have successively established national or industry EO data opening and sharing policies to enhance international competitiveness and regulate domestic markets. The United States adopts a "completely open" sharing management mechanism for government-owned and funded data, while proposing the marginal cost compensation principle to protect data providers' interests; for commercially invested data, it adopts an "equal competition" market-based management mechanism [13-15]. This hierarchical sharing management mechanism greatly promotes the opening, sharing, and widespread application of EO data. Europe's EO data policy emphasizes sharing as the core. The European Space Agency released a revised ESA Earth Observation Data Policy, dividing remote sensing data use into free use and limited use categories. The 2013 GMES "Sentinel" data policy clarified the principle of "non-discriminatory access," allowing all users to obtain data for free [16,17].

In 1991, NASA led the proposal and implementation of the Earth Observing System (EOS) program, which sparked a wave of EO technology development. The system consists of multiple satellites including ACRIMSAT, Aqua, Terra, Landsat-7, and Jason-1, enabling comprehensive applications in atmospheric, oceanic, terrestrial, and biological disciplines [18,19]. NASA's EOSDIS system provides sharing services for MODIS TERRA and AQUA satellite data and related products, playing an important role in international remote sensing scientific research [20,21].

In 2008, the USGS implementation of Landsat series satellite data opening and sharing made possible the production of thematic products such as global-scale 30-meter resolution forest cover, water bodies, fire scars, and land cover classification [8-11]. Guo Huadong [12] pointed out in a Nature commentary article that to meet the huge and rapidly growing demand for Earth big data applications in the "Belt and Road" initiative, it is necessary to establish an open platform that can share data, codes, and methods to enable scientific analysis of existing EO data and integrated applications of future satellite data, thereby improving data sharing and interoperability capabilities for the "Belt and Road" initiative. It is also necessary to explore new paradigms of big data-driven scientific research, promote Earth big data application services, and serve global sustainable development.

In 2013, ESA began implementing Sentinel series satellite data sharing, providing high-quality data, information, and knowledge for sustainable development, environmental governance, and security policies in Europe and globally [24]. Since the 21st century, EO data has grown rapidly, and data sharing has shown trends of global resource integration, standardized technical specifications, and informatized sharing services. Large-scale sharing systems between countries have begun to form, such as GEOSS [25]. GEOSS achieves global opening and sharing of EO data through worldwide data integration and provides users with three major categories of products and technical services: data, information, and knowledge [26-28].

Looking at the global development trends of big EO data, driven by demand, policy, and technology, the liquidity of EO data is gradually improving, and the depth and breadth of EO data opening and sharing are continuously strengthening. However, due to policy, institutional, and technical reasons, there remains considerable room for improvement in the degree of data sharing and depth of data application, and the potential value of big EO data has not been fully tapped. As the EO field enters the big data era, data opening and sharing has transformed from a simple data sharing model to new modes represented by Google Earth Engine and Australia's Geoscience "Data Cube." Google Earth Engine integrates global historical archives of long time-series multi-source remote sensing data, allowing users to not only download data for free but also conduct online analysis of large-scale images (such as change detection and trend analysis) [29]. Data Cube achieves seamless integration of Australia's multi-source EO data, rapid time-series analysis, and application of quantita-

tive information products [30].

### 3. Current Status of EO Data Opening and Sharing in China

Since launching its first artificial Earth satellite “Dongfanghong-1” on April 24, 1970, China has had more than 200 satellites in orbit, forming multiple systems in the EO field alone, including “Fengyun,” “Haiyang,” “Ziyuan,” “Gaofen,” “Yaogan,” and “Tianhui” [31,32]. In recent years, China’s investment in the EO field has continuously increased, its scientific and technological innovation capabilities and levels have continuously improved, and EO data has shown “blowout” growth with substantially improved quality.

China has launched more than 10 civilian high-resolution remote sensing satellites, gradually forming a high-spatial-resolution, high-temporal-resolution, and high-spectral-resolution EO system. As the first satellite of the high-resolution EO system, Gaofen-1 had acquired and archived more than 2.3 million scenes of data by June 2018, with approximately 1 TB of new data added daily [33]. On March 31, 2018, Gaofen-1 02, 03, and 04 satellites were launched via a “one rocket, three satellites” approach, marking the formal commissioning of China’s first civilian high-resolution optical operational constellation, which can achieve global coverage in 15 days with 3 satellites, 2-day revisit, and long-term, continuous, stable, and rapid acquisition of global 2-meter panchromatic and 8-meter multispectral imagery [34]. On May 9, June 2, and July 31, 2018, Gaofen-5, Gaofen-6, and Gaofen-11 were successively launched. In addition to domestic satellites, the China Remote Sensing Satellite Ground Station, established in 1986, has continuously received and processed data from nearly 20 foreign EO satellites including Landsat series, SPOT series, THEOS, ERS, and ENVISAT, forming China’s longest archive of multi-source EO satellite data [4].

In terms of policy, China adopts measures of free distribution for medium-resolution remote sensing data and authorized distribution for high-resolution remote sensing data to promote EO data resource sharing and effective utilization and to improve satellite remote sensing application and service levels. However, overall, China’s data sharing ecosystem remains to be further improved, and some sharing programs often lack long-term sustainability and continuity. Through years of practice and exploration, the country has recognized the importance of balancing the data sharing ecosystem.

Compared with EO data acquisition, data opening and sharing work lags behind. Currently, remote sensing data acquired by various satellite systems such as meteorological, land, and ocean satellites are scattered across different departments or data centers. While meteorological satellites have formed a relatively complete data sharing system, some domestic EO satellite data is only open to certain users, or only partial data is publicly available. In 2011, the China Remote Sensing Satellite Ground Station launched the “EO Data Sharing Program” for national users, providing free sharing services of medium-resolution

satellite data for the first time. In 2013, the Computer Network Information Center of the Chinese Academy of Sciences leveraged its technical advantages in high-speed networks, massive storage, and distributed computing to build the Geospatial Data Cloud (GSCloud) to provide data sharing services. To reduce users' data processing burden, the China Remote Sensing Satellite Ground Station of the Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, established an RTU (Ready To Use) product library to provide users with standardized, serialized, and diversified advanced data products for direct application [4,36]. Additionally, China actively participates in GEOSS construction. The National Remote Sensing Center of the Ministry of Science and Technology has organized the establishment of the National Comprehensive Earth Observation Data Sharing Platform, becoming an important window for domestic and international Earth observation data sharing.

In 2015, the State Council issued the “Action Outline for Promoting Big Data Development,” which explicitly proposed the important goal of “actively promoting the gradual opening and sharing of scientific data obtained and generated by public welfare scientific research activities supported by national public finance” [37]. In 2018, the Chinese Academy of Sciences launched the Strategic Priority Program (Category A) “Earth Big Data Science Engineering,” dedicated to enhancing the integration and sharing level of massive data in Earth sciences at the CAS and national levels, and actively promoting the opening and sharing of Earth science data. China's EO data sharing is facing new opportunities, but also challenges such as data policy barriers, data standards and quality, and the transformation of data sharing models in the big data era.

## 4. Reflections on China's EO Data Opening and Sharing

In summary, China still faces some problems in its transformation from a “large country of data” to a “strong country of data” in the EO field. On the one hand, as an important strategic resource, the opening and sharing of big EO data has particularities and difficulties. When people realize that EO data possesses asset attributes, data sharing often becomes a pseudo-proposition. On the other hand, constrained by insufficient policies, infrastructure, and technical support and service capabilities, EO data has not yet achieved true circulation. Data that cannot circulate well has difficulty maximizing its potential value. Therefore, it is necessary to establish enforceable EO data management policies, reshape data values, and particularly innovate data sharing models and technical methods to break the bottleneck of EO data sharing and achieve data circulation and application.

### 4.1 Strengthen Data Governance System Construction to Consolidate the Foundation for EO Data Opening and Sharing

First, policy barriers to EO data sharing should be broken. The “Measures for the Management of Scientific Data” issued by the General Office of the State Council in April 2018 clearly stipulates that “scientific data management

follows the principles of hierarchical management, safety and controllability, and full utilization, clarifies responsible entities, strengthens capacity building, and promotes opening and sharing” [38]. Macroscopically, China’s EO data distribution still has problems such as incomplete decoupling of opening and sharing from economic interests and vague classification. On the one hand, the application and approval process for government-invested EO data is often cumbersome, making it difficult for users to conveniently obtain EO data. On the other hand, the “Regulations on the Public Use of Remote Sensing Imagery” impose relatively strict circulation restrictions on satellite imagery with resolution better than 10 meters (especially better than 0.5 meters) [39], creating significant obstacles for opening and sharing high-resolution EO data. Therefore, it is necessary to further clarify the boundaries between government-invested and enterprise-invested EO data, break down barriers between data centers and sub-centers, expand the sharing scope of EO data formed by government budget funding, and enable EO big data to truly circulate. Additionally, policies should keep pace with the times to further study EO data security level classifications conducive to data circulation.

Second, the data sharing evaluation system should be improved, and enforceable intellectual property protection mechanisms and incentive measures such as data sharing indicators should be established. Intellectual property protection and sound incentive mechanisms are important factors determining data producers’ willingness to share data [40]. While mandatory project result data submission policies can ensure the submission and sharing of data generated with national funding, they still cannot fully mobilize researchers’ enthusiasm for data sharing. Data publication is an effective means to protect data intellectual property rights. However, EO data is often used as intermediate data, making it difficult to determine the source of EO data used in final data results, and thus difficult to identify data infringement. Additionally, as a type of image, EO data plagiarism detection is more difficult than traditional text-based literature checking. These are challenges facing intellectual property protection. Therefore, innovative work on EO data publication should be strengthened, considering the introduction of crowdsourcing models and data citation indices to solve quality and intellectual property issues before data publication.

Furthermore, EO data quality and standards should be improved to ensure the authenticity, accuracy, and timeliness of shared data, and to guarantee that data is discoverable, accessible, interoperable, reusable, and citable [41]. Meanwhile, EO data sharing service capabilities should be enhanced, interdisciplinary and cross-domain EO data sharing talent teams should be strengthened, and the cross-integration and comprehensive application of EO big data with other scientific data should be promoted.

## 4.2 Emphasize Both Institutions and Technologies to Build a Healthy Data Sharing Ecosystem

In 2014, big data was first written into the government work report, and since then, big data has gradually become a focus of attention for governments at all levels. In 2015, the State Council officially issued the “Action Outline for Promoting Big Data Development.” In 2017, the state successively issued multiple policy documents including the “Implementation Plan for Integrating and Sharing Government Information Systems” and the “Guidelines for Compiling Government Information Resource Catalogs (Trial)” to promote the aggregation, sharing, and opening of government data, achieving considerable progress [37,42,43]. In December 2017, the 19th Central Political Bureau of the Communist Party of China conducted a collective study on implementing the national big data strategy, where General Secretary Xi Jinping profoundly analyzed the current situation and trends of China’s big data development and proposed five requirements. In 2018, the General Office of the State Council issued the “Measures for the Management of Scientific Data” [38].

Although the state has deployed policies at both strategic and tactical levels for data sharing, achieving the requirements of complete openness, consistent rights and responsibilities, availability, sustainability, and innovation-driven principles, and realizing a data ecology of “whoever owns is responsible, whoever uses is responsible, whoever transfers is responsible, and whoever opens benefits,” still faces obstacles and challenges in practice. Relevant technical system support and guarantees are needed, and in some cases, technology determines the degree and possibility of data sharing realization [35,38,44].

Data circulation is a key link in achieving EO data sharing to release data value. However, EO data circulation is accompanied by many issues such as ownership, quality, compliance, and security, which have become bottlenecks restricting EO data circulation, such as the impact of intellectual property rights on data sharing enthusiasm mentioned earlier. Technologies or technical frameworks applied to data circulation such as blockchain and secure multi-party computation provide inspiring solutions to problems in the data circulation process [45]. Through the application of these new technologies, it is expected to promote the whole process of data sharing and circulation to be monitorable, controllable, and traceable, reduce the risk of intellectual property infringement, and solve the problem that EO data resource owners are unwilling or afraid to share.

## 4.3 Innovate EO Data Sharing Service Models to Promote Interdisciplinary Integration, Knowledge Discovery, and Comprehensive Application

The entry of the EO field into the big data era has profoundly transformed its data sharing models, mainly manifested in the shift from simple data sharing to service sharing, information sharing, and proactive sharing, entering an intelligent stage characterized by deep data mining and integrated applications.

Under this new service model, data sharing service providers will proactively push customizable, diversified, and high-level data or even information products to users on demand at the first moment of new data generation, thereby opening up the complete chain from EO data reception and processing to information extraction and sharing distribution [4], and improving the efficiency of data circulation and mining. The development of cloud computing and artificial intelligence provides technical support for innovating EO data sharing models in the big data era.

New EO data sharing service models represented by Google Earth Engine in the United States, Data Cube in Australia, and Copernicus by ESA have emerged internationally. This model shares not only data but also information and services. In the future, users will not only be able to utilize the data resources, algorithm resources, and computing resources of the CAS Earth Data Bank system but also upload their own data, models, and algorithms to conduct specific application services. Meanwhile, this platform-as-a-sharing service model is conducive to breaking down EO data and information barriers, further strengthening the traceability of data circulation processes, protecting intellectual property rights from infringement, improving data producers' sharing enthusiasm, achieving integration of multi-source EO data, effectively promoting cross-integration of EO data with other disciplinary data and geoscience knowledge discovery, and deepening the comprehensive application of EO data.

The report of the 19th National Congress of the Communist Party of China strategically mentioned “promoting the deep integration of the Internet, big data, artificial intelligence, and the real economy.” The CAS Earth Data Bank system being built by the Chinese Academy of Sciences' Strategic Priority Program “Earth Big Data Science Engineering” is precisely the deep integration of the Internet, artificial intelligence, and EO big data, creating a new data sharing model that integrates data, computing, and services.

## 5. Conclusion

The opening and sharing of big EO data is an inevitable trend in the big data era. China's big EO data sharing still faces many challenges, including data sharing policy barriers, data standards and quality issues, and the transformation of data sharing models. To transform from a “large country of data” to a “strong country of data” in the EO field and achieve true opening, sharing, and circulation of big EO data, research work needs to be carried out in three aspects: data governance system construction, healthy sharing ecosystem building, and data sharing service model innovation, to form a sustainable new environment for EO data sharing.

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