Journal of Global Change Data & Discovery. 2024, 8(4): 366-375
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Progress of the Asia-Oceania Group on Earth Observations (AOGEO) Programme

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Abstract: The Asia-Oceania Group on Earth Observations (AOGEO) Programme, as a key component of the integrated Earth observation system for Asia and Oceania, aims to promote sharing of Earth observation data and enhance technical capacity in the region. The mission is important for deepening international cooperation to meet the challenges of global environmental change. In the context of the surging global demand for Earth observation data and the increasing urgency for regional environmental protection, disaster early warning and resource management, the cutting-edge progress of AOGEO is of great significance to promote regional development. This paper evaluates the China's Decadal Implementation Plan for the Global Earth Observation System of Systems (GEOSS) (2016–2025), and systematically introduces the latest progress of the AOGEO task group in several key areas, such as water cycle, biodiversity, environmental monitoring and protection. These advances have not only significantly fostered the popularization and application of Earth observation technology in the subregion, but also provided indispensable support and supplement for further improvement of the global Earth observation system. In addition, this paper presents an in-depth analysis of the contributions of AOGEO co-leading countries in the field of Earth observation, covering policy formulation, infrastructure construction, investment in scientific research projects and so on. These contributions not only greatly improve the Earth observation capabilities of countries and the region in general, but also lay a solid foundation for global environmental management towards the realization of sustainable development goals. Finally, based on the current status of development and challenges of AOGEO, this paper puts forward the direction of strategic development with certain pragmatic measures, in order to further strengthen regional cooperation, promote continuous innovation and application of Earth observation technology, and improve the overall efficiency of the global Earth observation system.

Keywords: GEO; Earth observation programme; subregion; decadal implementation plan; national contribution; capacity building

DOI: https://doi.org/10.3974/geodp.2024.04.04

CSTR: https://cstr.escience.org.cn/CSTR:20146.14.2024.04.04

Received: 02-10-2024; **Accepted:** 24-11-2024; **Published:** 24-12-2024

Foundations: Ministry of Science and Technology of P. R. China (2021YFE0117400); National Natural Science Foundation of China (42371322); Xuzhou City (KC23079)

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Citation: Wu, J. J., Huang, Z. R., Liu, J. L., *et al*. Progress of the Asia-Oceania Group on Earth Observations (AOGEO) Programme [J]. *Journal of Global Change Data* & *Discovery*, 2024, 8(4): 366–375. https://doi.org/10.3974/geodp.2024.04.04. https://cstr.escience.org.cn/CSTR:20146.14.2024.04.04.

1 Introduction

With the aggravation of global warming, resource shortage and environmental deterioration, Earth observation technology plays an increasingly important role in formulation of global sustainable development strategies. In response to the call of Earth observation organizations, China formulated its Decadal Implementation Plan for GEOSS (2016–2025) in 2016[1], aimed to strengthen the integration of domestic Earth observation resources and systems and form a global integrated Earth observation infrastructure and application technology system, as an effort to contribute to global sustainable development.

In the past decade or so, China has made remarkable progress in the field of Earth observation technology. Satellite remote sensing, unmanned aerial vehicles, ground observation stations and other diverse observation facilities have been developed and continuously improved, data processing and analysis capabilities have also been greatly enhanced, providing strong support for the acquisition and application of Earth observation data. At the same time, China also actively seeks opportunities for international collaborations to promote the development and applications of Earth observation technology, and has established extensive cooperative relations with many countries and international organizations[2,3].

However, Earth observation technology still faces many challenges. On the one hand, with the increasing complexity of global environmental issues, the demand for Earth observation data is becoming more and more diversified. On the other hand, the acquisition, processing and application of Earth observation data are still restricted by many aspects such as technological limitations, funding, and policies. Therefore, China needs to unrelentingly fuel investments and strengthen technological innovations and personnel training to promote the steadfast development of Earth observation technology[1].

The purpose of this paper is to provide a comprehensive evaluation of the progress of AOGEO, especially with regards to the implementation of the Decadal Implementation Plan for GEOSS (2016–2025), as well as the cooperation and development in the field of Earth observation within the subregion. Through in-depth analysis of the development history of AOGEO activities, the progress of various task groups and China's participation and contribution in the construction of global Earth observation systems, the trends and contributions of different countries and international organizations in Asia in promoting the development of Earth observation are elaborated. Finally, the strategic direction and measures for the future development of AOGEO are proposed.

2 Progress in GEO Strategic Plan 2016–2025: Implementing GEOSS

China's Decadal Implementation Plan aims to build an efficient and globally connected integrated Earth observation system, provide high-quality Earth observation data and information products to the world, support sustainable development, foster disaster prevention and reduction, tackle key environmental issues, actively participate in international cooperation, and promote the interconnection and data sharing of global observation infrastructure. To contribute to the achievement of the United Nations 2030 Sustainable Development Goals (SDGs), the key mission framework is shown in Figure 1[1].

The Asia-Oceania Group on Earth observations Program is an important part of the Action Plan of the 2016–2025 10-year plan. Table 1 lists in chronological order of the progress and implementation of AOGEO from 2016 to 2024, and summarizes the main Earth observation activities that China has organized and participated in in recent years, including close cooperation with GEO, participation in international seminars and training courses, all are aimed at strengthening international cooperation for addressing global challenges. These activities cover many aspects, including international cooperation, capacity building, data sharing and policy improvement. By enumerating these activities, we can see that Earth observation organizations have achieved remarkable results in promoting the construction of a global integrated Earth observation system and in improving the capacity of comprehensive monitoring and application services for natural resources and the environment. At the same

time, they also reflect the important role and responsibility of China in the development of GEO.

In retrospect on the development process from 2016 to 2024, AOGEO has launched a series of international seminars, capacity building training courses, and issued the Beijing Declaration, Changzhou Declaration, Macao Declaration, etc., making significant contributions to the international community in multiple dimensions. China has actively participated in the construction of the global integrated Earth observation system, service and capacity building, the development of data processing and information product generation capacity, infrastructure construction plans, the enhancement of comprehensive coordination mechanisms, the strengthening of international cooperation, and the improvement of data sharing policies and operational mechanisms.

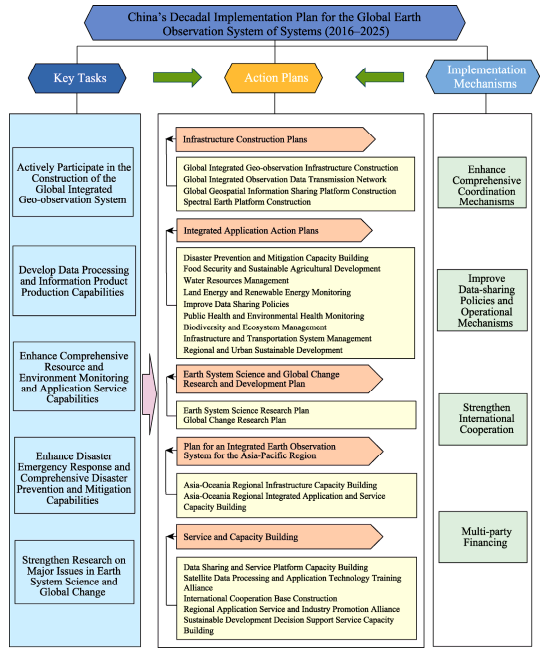

Figure 1 Framework of China's Decadal Implementation Plan for the Global Earth Observation System of Systems (GEOSS) (2016–2025)

By organizing international seminars and training courses, AOGEO has strengthened data sharing, technology exchange and international cooperation, especially in the areas of climate change response, disaster risk reduction and sustainable development. Its global Earth observation technology has provided countries with efficient tools and methods, and promoted technical cooperation and data infrastructure construction[2]. China has made important progress in data processing, information product generation, resource and environmental monitoring systems. Through training courses and other related capacity building activities, China has provided high-quality data and information products to global users, and provided theoretical support for earth system science and global change research. Looking ahead, AOGEO will continue to strengthen international cooperation, improve monitoring and application capabilities, improve data sharing mechanisms, promote technological innovation, and make greater contributions to global environmental change and disaster management[3].

3 Actions of the AOGEO Task Groups

3.1 Asian Water Cycle Initiative

The Asian Water Cycle Initiative (AWCI) continues to advocate the development of an Operational Satellite System for Sustainability and Resilience (OSS-SR) in global water management activities, and its initiative has been adopted by the United Nations as a Water Cycle Integrator (WCI). AWCI has deployed its platform in multiple countries, with knock-on effects that reaffirm the importance of local data, scientific methods combined with socio-economic issues, and multi-stakeholder engagement in the water-food-energy relationship. Going forward, AWCI will advance existing activities and accelerate the implementation of WCI and Earth Intelligence, while expanding collaboration into areas

Table 1 Implementation of the AOGEO Programme

Time	Activity name
2016.04	AOGEOSS Initiative Working Group established
2016.11	AOGEOSS Working Group was established in St. Petersburg, Russia
2017.10	GEO Conference Week in Washington, D.C., U.S.A., GEOARC organized Side Events to launch the Belt and Road Report and Exchange AOGEOSS Progress
2018.05	AOGEOSS International Symposium held in Deqing, China
2018.10	GEO Conference Week, AOGEO Symposium, and GEOARC Side Event in Kyoto, Japan
2019.04	Director of GEO Secretariat visited GEO China Secretariat, Aerospace Information Research Institute, Chinese Academy of Sciences, etc.
2019.11	Chinese delegation to Canberra, Australia for GEO Conference Week 2019
2019.11	The 12th International Symposium on Integrated Earth Observation in the Asia-Oceania Region held in Canberra, Australia
2020.01	AOGEO Overseas Capacity Building Training Course held online
2020.06	GEO Virtual Symposium held online
2020.10	2020 International Training Course on Earth Observation in the Service of Sustainable Development in Developing Countries began
2020.10	The Third International Symposium on Integrated Earth Observation Programs in the Asia-Oceania Region held in Changzhou and the "Changzhou Declaration" released
2021.02	Asia-Oceania Regional and Global Remote Sensing Monitoring of Ecosystems Forum cloud shares new achievements
2021.03	The 13th International Symposium on Integrated Earth Observation Programs in the Asia-Oceania Region held online
2021.07	The 4th International Symposium on Integrated Earth Observation Programs in the Asia Oceania Region (IEOP-AOA)
2021.11	The 14th AOGEO Symposium and 2021 GEO Week online, GEOARC Side Event organized
2022.06	The Fifth International Symposium on Integrated Earth Observation Programs in the Asia-Oceania Region held in Beijing, "Beijing Declaration" issued
2022.06	GEO Virtual Symposium held online
2022.08	2022 International Training Course on Earth Observation Services for Sustainable Development in Developing Countries held
2022.09	Main Event of the First GEO China Conference held in Beijing
2022.09	The 15th AOGEO Symposium held online
2023.04	Chinese Delegation Participated in the 60th Executive Committee of the Group on Earth Observations (GEO) in Switzerland
2023.05	Workshop on China's Participation in GEO Work Program Projects held in Beijing
2023.06	The 6th International Symposium on Integrated Earth Observation Programs in the Asia-Oceania Region held in Macao, "Macao Declaration" released
2023.06	Air and Space Academy held Mid-term Review Meeting of GEO Collaboration Projects under National Key R&D Programs
2023.06	2023 International Training Course on Earth Observation Services for Sustainable Development in Developing Countries held
2023.10	2023 AOGEO Academic Symposium and International Training Course on Capacity Building held
2023.11	Chinese delegation attended GEO 2023 Conference Week, Cape Town, South Africa
2024.09	The 16th AOGEO Symposium held in Tokyo, Japan
2024.09	GEO Symposium and ODOK Workshop 2024 held in Hangzhou, China

such as sanitation, poverty, health, and peace to innovate for future prosperity[4].

3.2 Asia-Pacific Biodiversity Observatory Network

The Asia-Pacific Biodiversity Observatory Network (APBON) continues international collaboration on capacity building, data and knowledge sharing for assessing regional biodiversity data and knowledge gaps to meet international requirements such as the Convention on Biological Diversity. At present, APBON is advancing data needs and accessibility assessments and plans to develop Essential Biodiversity Variables (EBVs), but faces challenges in field data accessibility[5]. At the same time, APBON strives to align with

the National Biodiversity Strategy and Action Plan (NBSAP) and strengthen scientific and policy collaboration. In the future, APBON will improve data accessibility, develop scientific and policy collaboration as a regional high priority, act as a platform for collaboration, and work with the Group on Earth observations Biodiversity Observation Network (GEOBON) and GEO communities to take coordinated action.

3.3 Asia-Oceania Greenhouse Gas Initiative

The Asia-Oceania Greenhouse Gas Initiative Group (AO-GHG) has developed a multi-data integration system that coordinates a growing number of platforms, such as remote sensing, field observations and inventories, to reduce uncertainty in greenhouse gas sources and sinks, thereby supporting the ultimate goal of net zero emissions as required by the Paris Agreement. In particular, progress has been made with greenhouse gas observation satellites to meet the requirements of accounting for greenhouse gas budgets. A synthesis of several models and methods is proposed to obtain robust greenhouse gas budget estimates. The system will be improved to provide annual and rapid regional GHG budgets, contributing to the global stocktaking process[6].

3.4 Oceans, Coasts and Islands

The Oceans, Coasts and Islands Group is working to build a new Earth observation-based platform to provide timely, sustainable, accessible and usable Earth observation data and information to serve researchers, society and stakeholders, address emerging issues in the region and support sustainable development. Among them, the development of the Asia Coastal Ocean Gateway (A-COP) based on satellite remote sensing is one of the core activities aimed at observing and monitoring persistent environmental problems in the Asian coastal oceans, such as eutrophication, hypoxia, red tides, etc. In the future, this task group will reposition its research activities to focus on building models and algorithms to evaluate these biogeophysical variables, and introducing these models and algorithms into A-COP for socio-economic benefits. A prototype of the A-COP is expected to be launched in 2024.

3.5 Agriculture and Food Security

Asian Rice Crop Estimation & Monitoring (Asia-RiCE) is committed to promoting the Sustainable Development Goals, particularly in the areas of agriculture and food security. During the COVID-19 pandemic, the organization has advanced rice surveillance in the Asia-Pacific region, developed advanced rice mapping algorithms, and established an open data sharing platform. At the same time, through the multilateral network of agro-meteorological information and rice monitoring, data integration and regional cooperation have been strengthened to improve the accuracy of rice yield estimation. Asia-RiCE also works in partnership with multi-stakeholders to use Earth observation data for rice yield forecasting and statistical inventory, and to promote research and development cooperation. In 2023, Asia-RiCE continued to deepen the agrometeorological information and rice monitoring, strengthen capacity building, use machine learning for data fusion, achieve cloud-based sharing, combine remote sensing and crop models for rice yield estimation and prediction, and promote research in rice field water management.

3.6 Environmental Monitoring and Protection

Environmental Monitoring and Protection (EMP) has progressed on many fronts, including the development of algorithms and products, the launch of environmental monitoring platforms, compilation of annual reports, and fostering international collaborations. Remote sensing basic products at national and global scales have been produced using China’s domestic satellite data. The Asia-Oceania Environmental Monitoring Platform (AOEM) has been developed to facilitate information sharing. EMP has also organized a number of

international conferences and training events to strengthen Earth observation capacity building. In addition, the use of Chinese satellite data has provided global remote sensing data and products for international services and collaborative applications. Ecosystem research has also been conducted in countries and regions such as Cambodia, with relevant reports being published.

The task forces have made remarkable achievements in their respective fields. These accomplishments not only promote innovations in scientific research, but also provide strong scientific support for solving global challenges through international cooperation. They reflect the important role of scientific and technological innovation in solving global problems, demonstrating the huge potential of international cooperation in promoting global sustainable development. In the future, with the persisting progress of science and technology and the deepening of international cooperation, we firmly believe that these task forces will continue to make more breakthroughs in their respective fields and make greater contributions to the sustainable development of mankind.

4 Contribution of AOGEO Co-lead Countries

AOGEO is one of the four regional GEOs in the world, and is jointly led by China, Japan, Australia, and South Korea. This section focuses on evaluating the key contributions from AOGEO co-lead countries.

4.1 China

From 2016 to 2024, China actively participated in and hosted a series of international activities related to Earth observation, covering many fields such as data sharing, environmental monitoring, climate change, disaster management and agricultural remote sensing. These activities have been described in Section 2 and outlined in Table1. Through cooperation with GEO Secretariat, BRICS and other international organizations, China has made remarkable progress in promoting the application of Earth observation technology, promoting regional coordinated development, and enhancing the international influence. At the same time, China has also played an important role in organizing AOGEO international seminars and capacity building training courses, which not only promoted the innovation and application of Earth observation technology, but also made important contributions to training both senior scientists and young talents in promoting the realization of sustainable development goals[1].

Promoting regional cooperation and platform building: As a co-lead country of AOGEO, China has successfully held a series of AOGEO workshops, attracting a wide range of international participants and promoting in-depth exchanges and cooperation in the fields of data fusion, global eco-environmental monitoring, and capacity building. In addition, China has actively advocated the construction of regional cooperation mechanisms and provided strong support for the capacity building and collaboration network construction of the comprehensive priority research area in the Asia-Oceania region[7].

Strengthening international cooperation and exchange: China has organized a series of “International Training Courses on Earth observation for Sustainable Development in Developing Countries” among other related activities, providing a platform for learning and exchange for young scholars from all over the world, and promoting the international dissemination and application of Earth observation technology[8]. At the same time, China has actively participated in international seminars and training programs to discuss with other countries on the latest progress and future development direction in the field of Earth observation.

Promoting data sharing and emergency response: Through its National Integrated Earth observation Data Sharing Platform, China has been working closely with international

organizations such as GEOSS and the United Nations Environment Programme (UNEP) to share a large number of selected datasets and enrich global Earth observation data resources[9]. In response to natural disasters overseas, the platform responded promptly, providing timely data support for relief on the Turkey-Syria earthquake, hurricane in New Zealand, flood in Peru, and other disasters, demonstrating China's strong ability and sense of responsibility in Earth observation data emergency response[10].

Leading technological innovation and application: China not only focuses on the research, development and application of Earth observation technology, but also actively promotes technological innovation in knowledge transfer. By developing remote sensing platforms for monitoring global crop conditions, water resources and drought, China has provided precision agriculture and water resources monitoring services for many countries, providing strong support for global food security and alleviation of water shortages among other issues[11,12]. China has also developed environmental observation technology in key regions such as the Himalayas and island regions, and emphasized its key applications in disaster reduction, urban and ecological monitoring, all are positive contributions to global sustainable development[13].

4.2 Japan

As a co-lead country of AOGEO, Japan has made important contributions in many ways. A series of AOGEO Symposia were organized from 2016 to 2024 to promote the sharing and cooperation of Earth observation data and support sustainable development in the Asian region. In terms of data integration and cloud computing, Japan has played a key role in integrating and processing environmental monitoring data using cloud computing and big data technologies. For example, at the 16th AOGEO Symposium, Japan demonstrated progress in processing and analyzing large-scale remote sensing data through data cube technology. These technologies contribute to better monitoring and management of environmental change, especially in the Himalayas and other high mountain regions[12].

Environmental protection and ecosystem restoration: Japan is involved in several environmental protection and ecosystem restoration projects, including coral reef protection and coastal zone restoration. Through these projects, Japan is working to improve the health of coastal and marine ecosystems and strengthen their resilience to climate change.

International cooperation and capacity-building: Japan nurtures international cooperation initiatives in the APEC region, and these efforts contribute to the creation and provision of geointelligence.

Biodiversity information sharing mechanism for Asia and the Pacific: Through the BISMaL system, Japan integrates and shares marine biodiversity information, which not only enriches the Ocean Biodiversity Information System (OBIS), but also facilitates the establishment and management of marine protected areas in Japan and other Asian countries.

Continuously Operating Reference Station (CORS) network: The Japan International Cooperation Agency (JICA) is working with countries such as Thailand to enhance the capacity of CORS data centers, using high-precision positioning technology to support the development of infrastructure, smart agriculture and automated driving.

OSS-SR training program: Through the OSS-SR program, Japan has trained experts in Earth observation utilization and policy development, especially in flood warning system construction and water disaster response, provided e-learning courses and hands-on training, and strengthened the capacity of local stakeholders to respond to natural disasters.

Addressing global challenges: Japan supports global efforts on climate change, health and disaster prevention through Official Development Assistance (ODA) programs. These projects not only help developing countries address environmental and social challenges, but also contribute to the achievement of the global Sustainable Development Goals (SDGs).

4.3 Australia

Data integration and sharing: Australia promotes data integration and sharing through its geospatial and remote sensing technologies. Australia's Earth observation data is widely used in areas such as environmental monitoring, disaster management and agricultural management. For example, Australia has provided key data support in land use and cover change monitoring to better understand and respond to regional environmental change[3]. Through Australian National Data Cube (ANDS) and Digital Earth Australia (DEA) programs, Australia provides extensive datasets and support for Earth observation in the Asia-Pacific region. DEA provides an efficient platform for processing and analyzing spatiotemporal data from satellites such as Landsat and Sentinel. These data cover a long-time span, making environmental monitoring and change analysis more accurate. DEA's datasets and tools are open and freely accessible to users, supporting scientific research, policy development, and public service. Open Data Cube (ODC) is an international collaborative project that aims to advance the adoption of data cube technology worldwide. Australia is involved in the project through Geoscience Australia, providing technical support and data resources. The ODC platform is capable of efficiently processing large volumes of high-resolution satellite imagery, providing a powerful tool for scientists and policymakers.

Disaster management and recovery: Australia is actively involved in disaster management tasks, particularly in improving early warning and response capacity to natural disasters such as floods and droughts. Through advanced remote sensing technology and data analysis, Australia has provided scientific basis and technical support for disaster response in the region.

Climate change and environmental protection: The co-lead country has also made important contributions to combat climate change and to protect the environment. By monitoring greenhouse gas emissions and land cover change, Australia provides important data support for environmental protection and climate change adaptation strategies within the region.

International cooperation and capacity building: Through cooperation with AOGEO member countries, several international training and seminars have been conducted to enhance national capacities in Earth observation and environmental management. Particularly in the areas of agriculture, forest and water resources management, Australia has shared its experience and technologies in remote sensing and GIS applications.

4.4 South Korea

South Korea has made significant progress in the space sector and established the Korea Aeronautics and Space Administration (KASA) in 2024. It has strengthened policy formulation and international cooperation, laying the foundation for space development. The five-year plan focuses on the use of satellite information and improves the data collection and utilization system. South Korea's space technology has made remarkable progress, and the KPLO lunar exploration and the launch of the Nuri-ho rocket demonstrate its independent research and development strength. Research institutes such as KARI lead technological innovation and promote continuous breakthroughs in space research. South Korea actively participates in Earth observation and supports environmental monitoring, disaster management and sustainable development through satellite data. The country is poised to strengthen international cooperation, share satellite data, and jointly address global challenges. KASA supports the participation of the private sector in the utilization of satellite data and encourages innovative solutions. The new five-year plan focuses on promoting civilian-led use of data and strengthening domestic and foreign cooperation to

address global issues.

5 Proposals for AOGEO Development Initiatives

AOGEO's future strategic development focuses on three core directions. First, strengthen regional cooperation strategies to enhance regional Earth observation capabilities by deepening cooperation mechanisms, promoting resource sharing, strengthening technical exchanges and jointly addressing global challenges[14,15]. Second, promote technological innovation and integration, and use emerging technologies such as artificial intelligence and big data to improve the processing capacity and application of Earth observation data, while encouraging research and development innovation and technological application expansion. The third is to serve the needs of regional development, provide Earth observation services accurately and efficiently, support regional economic and social development, monitor the ecological environment, and pay special attention to the needs of developing countries in Earth observation technology.

To galvanize the above-mentioned development strategies, the following measures are proposed. First, establish a long-term cooperation mechanism, including organizing regular international seminars, encouraging international cooperation projects, formulating cooperation framework agreements and project cooperation guidelines to promote knowledge exchange, technical cooperation and policy coordination. Second, strengthen personnel training and data sharing, through the establishment of personnel training funds, hold international training courses, strengthen cooperation with international organizations, establish regional data centers, encourage data sharing and strengthen data analysis and application, promote the efficient use of data. Additionally, pay attention to regional hotspot issues, conduct targeted research, and provide advice and decision-support to policy makers to promote sustainable development in Asia and Oceania.

6 Conclusion

This paper focuses on the implementation of the China's Decadal Implementation Plan for the Global Earth Observation System of Systems (GEOSS) (2016–2025), and summarizes the progress and contributions of China and other countries within the Asian region under the framework of GEOSS. Firstly, an assessment was conducted on the progress of AOGEO task forces in water resources management, biodiversity conservation, greenhouse gas emissions monitoring, marine and island environmental protection, agriculture and food security, environmental monitoring and protection. Secondly, the paper elaborates on the contributions of China, Japan, Australia and South Korea in platform construction, data contribution and international cooperation. These countries have actively promoted the development and application of Earth observation technology by formulating policies, building infrastructure and conducting scientific research projects, making important contributions to the improvement of the global Earth observation system. Finally, suggestions and prospects of future development strategies of AOGEO and measures of implementation are proposed to further strengthen regional cooperation, promote the innovation and application of Earth observation technology, improve the overall efficiency of the global Earth observation system.

Author Contributions

Wu, J. J., Liu, J. L. and Liu, Q. H. designed the overall framework of the article review; Huang, Z. R., Wu, J. J., Liu, J. L. and Liang, L. collected and researched the progress of AOGEO; Wu, J. J. and Huang, Z. R. drafted the initial manuscript; Zhong, B. and Yang, A.

X. revised the draft of the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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