



The Chinese Antarctic science programme: origins and development

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Abstract: In 1980, at the invitation of Australia, the first Chinese scientists went to Antarctica. China was therefore a relative 'latecomer' to engage in Antarctic science. In the period since its first Antarctic expedition in 1984, China's presence in Antarctica has expanded both in terms of its logistics and infrastructure and its scientific research. This paper outlines the development of China's national Antarctic programmes under the influence of corresponding national policies from the late 1970s to the present, noting the application of various scientific disciplines to Antarctic fields. The paper outlines and analyses the broadening and deepening of China's Antarctic science research, infrastructure and engagement.

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Introduction

China's Antarctic science endeavours began in 1980 when, following collaboration with the Australian Antarctic Division, two Chinese scientists travelled to the Antarctic continent in 1980 as part of the Australian Antarctic programme and initiated scientific observations (Zhang & Wang 2008). China acceded to the Antarctic Treaty in 1983 and became a Consultative Party after its first research station, Great Wall Station, was built in 1985. Although China is a latecomer in Antarctica, it has made rapid progress. In < 40 years, China has established four Antarctic research stations in Antarctica, including two permanent stations (Great Wall Station and Zhongshan Station) and two summer stations (Taishan Station and Kunlun Station). At present, a fifth station located on Inexpressible Island in the Ross Sea is under construction and is expected to be completed in 2022, which will meet the needs of a permanent station. There are two icebreakers, *Xuelong* and *Xuelong 2* (*Snow Dragon* and *Snow Dragon 2*), serving China's Antarctic expeditions. Now, a third vessel, a polar heavy icebreaker, is under construction and is a key project in the just-released 14th Five-Year Plan (FYP) (PRIC 2021). While China is quickly developing its Antarctic infrastructure and logistics capabilities, its Antarctic science is also developing.

Following the adoption of the eighth FYP in 1980, China implemented its national Antarctic expedition plan, developed its Antarctic administration (Zhang & Wang

2008) and established several major Antarctic science programmes. For example, programmes such as *Nanbeiji Huanjing Zonghe Kaocha Yu Pinggu* [Comprehensive Arctic and Antarctic Environment Research and Assessment] and the China International Polar Year Program have been successfully implemented (SOA 2017), and the *Nanji Kaocha Huodong Xingzheng Xuke Guanli Guiding* [Provisions on Administrative Licensing Management of Antarctic Expedition] were issued in 2014. Work on developing China's domestic law in relation to Antarctica is also currently in progress (Xinhua 2018).

The development of China's Antarctic science programme and its associated logistics and infrastructure has attracted attention from the international community. Although a relative 'latecomer' to Antarctica, China has become a major polar actor, being considered by some commentators as a 'polar great power' (Brady 2017). As a result, China's rapidly growing logistical strength and investment in base construction and advanced equipment have become focuses of international discussion. Attention has been given to China's goals and strategic aims in relation to global ecopolitics and Antarctic governance (Harrington 2017). China's Antarctic research has also been assessed in terms of scientific output (e.g. using metrics to assess publications). This has led to some arguments that China's scientific output does not match its growing logistical and construction capabilities (Brady 2017), with Gray & Hughes (2016) showing that China ranks low among Consultative Parties in terms of scientific

research output and citation counts. There is also Chinese literature that uses bibliometrics to analyse the achievements of Chinese Antarctic scientific research from 1982 to 2011, which has found that while the numbers of Chinese publications and citations are increasing, they still lag behind those of the leading Antarctic states, such as the USA and Australia (Zhang & Hua 2014). However, there is no literature giving a detailed assessment of China's Antarctic science programmes. This paper seeks to fill this gap by providing an overview of the Chinese Antarctic science programme from the 1980s to the present.

This paper begins with an introduction to the establishment and development of the Chinese Antarctic science programme in terms of its administration, infrastructure and logistics. It aims to show the origins and progress of the development of China's Antarctic science by describing the evolution of the Chinese Antarctic activities and affairs over the past 40 years and noting the development of Antarctic science disciplines.

China's presence in Antarctica

Origins

China's focus on the Antarctic emerged in the late 1970s. While China had shown some interest in the 1957–1958 International Geophysical Year (also known as the third International Polar Year (IPY)), ultimately it did not participate (He 2016). On 5 March 1978, the National Science Conference was held in Beijing, a milestone event in the history of the development of China's science and technology programmes and capabilities. At this conference, Deng Xiaoping, China's paramount leader, put forward the viewpoint that '*kexue jishu shi diyi shengchanli*' [science and technology are the primary productive forces], and he called on all parts of the country to vigorously promote and popularize scientific knowledge. The conference led to a sharp increase in the circulation of science and technology newspapers and popular science books (Yuan 2008). In December 1978, China held the Third Plenary Session of the Eleventh Central Committee. The important national policy of 'reform and opening up' was put forward at this meeting. This policy encouraged scientists to use their strengths and to cooperate actively with the outside world. As few Chinese scientists had ever been abroad at that time, let alone to Antarctica, the curiosity and interest of scientists in opportunities to work in the most southerly continent can be imagined. It is against this background that China began a new chapter in Antarctic scientific exploration.

1980–1990

The late 1970s to the early 1980s was the initial period of China's scientific and technological reform. The Science

Foundation of the Chinese Academy of Sciences and the National Key Technologies Research and Development Programs of China were established in this period (Fan 2018). In terms of the Antarctic and Southern Ocean research, this was also a period when China began research on and fieldwork in Antarctica.

In January 1980, two Chinese scientists, Zhang Qingsong and Dong Zhaoqian, were invited to join an Australian National Antarctic Research Expedition (ANARE) team to Casey Station under the sponsorship of the Australian Antarctic Division. Then they visited the USA's McMurdo Station, New Zealand's Scott Station and France's Dumont d'Urville Station with the then director of the Australian Antarctic Division. In 1981, Qingsong spent the winter at the Australia's Davis Station to gain additional experience in station construction and management, becoming the first Chinese national to overwinter in Antarctica (Chen & Allison 2016).

In 1981, China applied for accession to the Antarctic Treaty and the Scientific Committee on Antarctic Research (SCAR) but was told that it did not meet the requirements for Consultative Party status as set out in the Antarctic Treaty (not having independently conducted an Antarctic expedition or established a research station in Antarctica). At that point, China could only seek to join as a Contracting Party and could not participate in decision-making in the Antarctic Treaty Consultative Meeting (ATCM). As a result, in 1982, China sent a large number of scientists to visit and study other countries' Antarctic stations (Hao 2013). In 1983, China signed the Antarctic Treaty and officially became a Contracting Party to the Antarctic Treaty.

The first China Antarctic Research Expedition (CHINARE) team (591 people) went to the Antarctic in November 1984 to build a research station on King George Island and to conduct scientific investigations. The total cost of the expedition was ~20 million Chinese yuan (CNY; ~3.04 million US dollars at current rates; Wen 2008). Before they set off, Deng Xiaoping wrote an inscription for the CHINARE: '*Wei renlei heping liyong nanji zuochu gongxian*' [Contribute to mankind's peaceful use of Antarctica]. Since then, this slogan has become the guideline for China's Antarctic activities and policies. Chinese Antarctic expeditions to the South Pole became an annual practice after 1984.

In 1985, Great Wall Station was built on King George Island on the Antarctic Peninsula. Eight Chinese scientists completed their first wintering at Great Wall Station. Therefore, with the establishment of Great Wall Station and the independent completion of an Antarctic expedition, China met the requirements for Consultative Party status and was formally accepted by the ATCM as an Antarctic Treaty Consultative Party on 7 October 1985. As a result, China had at that time the right to participate in decision-making on Antarctic affairs. In

1986, China officially became a member of SCAR. In 1988, the fifth CHINARE went to East Antarctica for the first time, and the second annual station, Zhongshan Station, was established in the Larsemann Hills by Prydz Bay.

China submitted reports to SCAR in 1988 and 1989 reporting its key scientific activities in Antarctica (Chinese Committee on Antarctic Research 1989). The reports said that the projects carried out at Great Wall Station included research on spatioigraphy, meteorology, atmospheric whistling, the ionosphere, glaciology, geomagnetism, geology and geography, seismology, biology and human physiology. Among them, Great Wall Station also cooperated with scientists from Japan's National Polar Research Centre for biological investigations. The key projects in Zhongshan Station included research on meteorology, the ionosphere, spatioigraphy, geomagnetism, geology and geography, surveying and mapping, biology and human physiology. In addition, during the ocean component of the expedition, scientists also carried out surveys on krill, marine hydrology and marine chemistry (Chinese Committee on Antarctic Research 1989).

In the first 10 years of China's entry into Antarctica, its main activities were focused on the establishment of the two research stations and the preliminary investigations and understanding of various scientific disciplines in Antarctica, focusing on conventional observations on a small scale.

1990–2000

The period from 1990 to 2000 saw China implement the eighth and ninth FYPs. Beginning in 1990, China's focus on Antarctica gradually shifted from station building to scientific research and resource investigation. In 1990, China carried out the first Antarctic inspection of some research stations in the King George Island area and submitted a report to the ATCM. In the same year, Qin Dahe, a Chinese glaciologist and climatologist, and five other scientists from different countries completed the 'International Trans-Antarctica Expedition' and obtained ice and snow samples that filled a gap in Chinese glaciology (Qin *et al.* 1998).

In 1992, the United Nations Conference on Environment and Development adopted 'Agenda 21', a global action plan to address the Conference's sustainability commitments. In 1994, China passed 'China's Agenda 21'. To better implement the spirit of 'China's Agenda 21' in the marine field, the State Oceanic Administration (SOA) formulated 'China's Marine Agenda 21' in 1996. 'China's Marine Agenda 21' clearly put forward the objectives of improving the comprehensive management mechanism of national marine resources, protecting the marine environment, strengthening marine scientific research and

technological development (Sun 1997). Chapter 10 of the 'China's Marine Agenda 21' gives instructions for polar exploration and, reflecting a key principle of the Antarctic treaty, which is committed to the peaceful use of the region, sets the goals of actively participating in the ATCM, maintaining the purposes and principles of the Antarctic Treaty, strengthening cooperation with SCAR and expanding collaborations and exchanges with countries engaged in polar science (SOA 1996).

During the period of the eighth FYP, China initially formed a logistical and support system of 'one ship, two stations' for scientific expeditions to the Antarctic. This also enabled the key research project 'China's Antarctic Expedition and Scientific Research' to proceed smoothly (Pan 2014). There were seven special studies in this project, which included research programmes on 1) the development and utilization of krill resources in the Southern Ocean, 2) ecosystems in key areas of Antarctica, 3) the lithospheric structure, formation, evolution and geodynamics of the Antarctic continent and continental shelf basin, 4) the climate and environmental changes and the modern environmental background since the late Pleistocene, 5) the interaction between Antarctica and the global climate and environment, 6) the global behaviour of the solar-terrestrial system in Antarctica and 7) the influence of the Antarctic environment on human physiology, psychology, health and labour capacity and medical support. Among these programmes, high-level research results have been obtained in three major research fields, including the study of the Antarctic krill ecosystem, Antarctic geological structure research and the study of upper atmospheric physics, which have been recognized and appreciated by the international scientific and technological community (Pan 2014).

On the basis of the scientific research achievements of the eighth FYP, China's polar scientists continued to carry out key Antarctic projects during the ninth FYP period and expanded China's Antarctic activities. The National Science and Technology Commission of China finally agreed to include the project 'Research on the Antarctic Region's Response and Feedback to Global Changes' in the 1998 National Key Technologies Research and Development Programs. This project focused on the basic processes of ocean, atmosphere and terrestrial interactions in East Antarctica and their impacts on global environmental changes (Chen 2010). In 2001, the above project was completed, including a national evaluation of its achievements.

One of the achievements of this project was that, in 2000, Sun Liguang, a Chinese ecologist, published a paper on Antarctic research in *Nature*, which was the first paper by a Chinese ecologist to be published in this prestigious journal. This study, entitled 'A 3,000-year record of penguin populations', proposed a typomorphic

element combination method for identifying penguin dung in sediments and reconstructed the changes in the population of penguins in Adelaide Island in Antarctica over the past 3000 years (Sun *et al.* 2000). This important scientific achievement was also rated as an 'Excellent Achievement in Scientific and Technological Research in the 9th FYP' by the Ministry of Science and Technology, Ministry of Finance, State Development Planning Commission and State Economic and Trade Commission. During the 10 years of the eighth and ninth FYs, China's Antarctic expedition and research system took shape and produced internationally influential results. In 1999, the Chinese Antarctic and Arctic Administration (CAA) also began legislative work on the 'Regulations on the Management of Antarctic Activities' (CAA & PRIC 2014).

2000–2010

China's plans for Antarctica during 2000–2010 mainly focused on extending the capacity of Antarctic scientific research and on its involvement in the 2007–2008 IPY programmes. The expansions of both Great Wall Station on King George Island and Zhongshan Station in the Larsemann Hills were key capacity-building projects. These were the first large-scale investments and station expansions using modern construction technologies since Great Wall Station was established in the early 1980s (CAA 2003). During the 10th FYP period, China invested 870 million CNY (~134 million US dollars at current rates) in polar research, twice the amount of the previous three FYs (University of Science and Technology of China 2001).

In 2007, China participated the fourth IPY. The IPY is an important event in the polar science community. Polar scientists from all over the world exchange results, discuss the key areas of polar research in the future and introduce to the public how the changes in polar regions affect human life. The first two IPYs were held 50 years apart, in 1882 and 1932. At the end of the Second World War, it was recognized that significant scientific advances supported international collaboration over a shorter period, leading to the establishment of the IGY 1957–1958 (Summerhayes 2008).

As early as 1955, China expressed its intention to participate in the third IGY, but only if Taiwan was not accepted as a participant, reflecting the historical issue of 'two Chinas' (i.e. the People's Republic of China and the Republic of China; Zou 1993). However, China actively participated in organizing and planning the fourth IPY and was an active participant in this significant international event. China proposed 16 research programmes addressing four major topics (Zhang & Wang 2008, Liu 2018). The first was the implementation of the cross-sectional survey of the

Prydz Bay-Amery Ice Shelf-Dome A (the PANDA programme), which was also the core research plan of this IPY. The second was to conduct a comprehensive survey of the Arctic. The third was to strengthen cooperation with various countries in the research of the Antarctic and the Arctic. The fourth was to raise citizens' awareness of the polar regions (Zhang & Wang 2008). With the expansion of Great Wall Station and Zhongshan Station being completed, China highlighted in a new goal, which was to accelerate the construction of an inland summer station. In 2008, China established its first inland Antarctic summer research station, Kunlun Station, in the Dome A area, the highest part of the inland ice sheet.

Wu Jun, deputy director of the CAA, said in an interview in 2008 that, from the perspective of Antarctic scientific research, four areas in the region were of the highest priority: the Terrestrial South Pole, the South Magnetic Pole, Dome C and the highest site at Dome A. Wu continued to note that while the USA, Russia, France and Italy had established scientific research stations at the first three sites, Dome A remained 'blank' (Cui 2008). Therefore, the establishment of Kunlun Station was not only of great scientific importance but also held strategic significance for China.

2010–2020

Between 2010 and 2020, China vigorously promoted research into the polar Earth sciences, the life sciences, the physical sciences and the social sciences, and it actively cooperated in international 'big science' projects (i.e. large-scale scientific research projects with a high budgets funded by one or more governments; Merriam-Webster *n.d.*). At the 18th National Congress of the Communist Party of China in 2012, General Secretary Hu Jintao proposed building China into a maritime power. The *Haiyang Qiangguo Zhanlue* [Marine Power Strategy] included improving China's ability to open up new resources groups, developing the marine economy, protecting the marine environment and safeguarding the country's maritime rights and interests (Wang 2020).

The polar regions are of great significance to the global climate as they drive the global atmosphere, ocean circulation and carbon cycle and are rich in resources such as freshwater resources and living resources. Therefore, improving China's polar capacities is an important part of it becoming a maritime power (Pang *et al.* 2017). Since 2012, various key tasks of the polar expedition have been carried out. The key national programme titled the Comprehensive Arctic and Antarctic Environment Research and Assessment (CAAERA) was officially launched and implemented in 2012 (Luo 2012). One of the CAAERA projects entitled

'Strategic Evaluation of Polar National Interests', which included social science research components, addressed five sub-topics: polar geopolitics research, polar resource utilization strategy research, polar science and technology development strategy research, polar legal systems and polar powers' policy research (CAA & PRIC 2012).

In 2014, seven research institutes and universities were commissioned to carry out special research on issues deemed to be 'hot', including Antarctic protected areas, China's soft power in Antarctica, Antarctic tourism and Antarctic management (CAA & PRIC 2016). In 2015, the 'Proposals of the Central Committee of the Communist Party of China on Formulating the Thirteenth Five-Year Plan for National Economic and Social Development' also made important arrangements for polar work for the first time, proposing active participation in the formulation of international rules in new areas, such as the polar regions (Central Committee of the Communist Party of China 2015).

In 2017, the 40th ATCM was held in Beijing, the first time China had hosted this meeting. A member of the Standing Committee of the Political Bureau of the Central Committee of the Communist Party of China and Vice Premier, Mr Zhang Gaoli, attended the opening ceremony and delivered a major speech. In his speech, Zhang emphasized that China attaches great importance to the governance and development of Antarctica. This speech reiterated the comments made by Chinese President Xi Jinping during a visit to Hobart, Australia, in 2014, which also highlighted the significance of scientific research in Antarctica. President Xi said China was willing to work with the international community to better understand, protect and use Antarctica (Wu 2014). Li Keqiang, Premier of the State Council of China, also proposed the further development of polar expeditions (Ministry of Foreign Affairs of the People's Republic of China 2017).

Before the 2017 ATCM, China released a white paper entitled 'China's Antarctic Activities' that described the achievements of China's Antarctic science over the past 35 years, its interest in Antarctica and its future goals in Antarctica. In 2019, Qin Weijia, director of the CAA, speaking at the China Symposium on Polar Science, noted that the CAA had taken the lead in organizing the preparation of the plan of 'Priority Fields of Basic Research in Polar Science', with > 100 experts from the Ministry of Natural Resources (MNR), the Ministry of Education (MOE), the Chinese Academy of Sciences and the China Meteorological Administration participating in the preparation (Xinhua 2019). Six priorities of basic polar science in the next 5–10 years were identified. These areas included 1) polar ice-sheet instability and sea-level change, 2) Arctic sea ice-air interactions and their effects on the climate, 3) changes in the circulation of the Southern Ocean and their global effects, 4) geological

resources and environment assessments of the North Pole and South Pole, 5) the sensitivities and vulnerabilities of polar ecosystems and 6) solar-terrestrial coupling and polar atmospheric interactions (Xinhua 2019).

China's presence in Antarctica is shaped by broad policy directions, as described above. Key areas are the administration of the Antarctic programme, the management of logistical support and conducting science. The following section outlines the administration of China's Antarctic science programme.

China's Antarctic science programme

Administration

China's Antarctic expedition and research project management are undertaken through cooperation between many national organizations and universities. Figure 1 gives a simple outline of China's Antarctic administration. The SOA was established in 1964 and was managed by the Chinese Navy at that time. By 1993, the management of the SOA was transferred to the State Scientific and Technological Commission of the People's Republic of China (now the Ministry of Science and Technology of People's Republic of China). In 1998, the SOA was under the management of the Ministry of Land and Resources. China established the MNR in 2018, which integrated the responsibilities of the Ministry of Land and Resources (which will be described later). After the reform and opening up in 1978, China vigorously implemented the policy of 'develop the country through science and education', striving to narrow the gap between it and other major countries. As a consequence, in August 1978, the SOA submitted a document on the 'Request for Conducting Antarctic Expedition', suggesting the establishment of a national Antarctic scientific committee and for China to conduct its first Antarctic expedition (Guo 2009).

In 1981, the National Antarctic Investigation Commission (NAIC) was formally established. The members of the NAIC came from the National Science and Technology Commission, the Ministry of Foreign Affairs, the SOA and 16 other organizations. The NAIC was also China's first official institution for polar affairs, which clearly shows China's interest in Antarctica at that time and its determination to develop Antarctic research. In 1989, the Polar Research Institute of China (PRIC) was established in Shanghai. The PRIC is China's only scientific research and support centre that specializes in polar expeditions, and it is affiliated with the SOA. It was mainly responsible for polar scientific research and survey work as well as the management and servicing of polar information and archives.

In 1994, the NAIC was renamed as the Chinese Arctic and Antarctic Administration (CAA) with responsibility

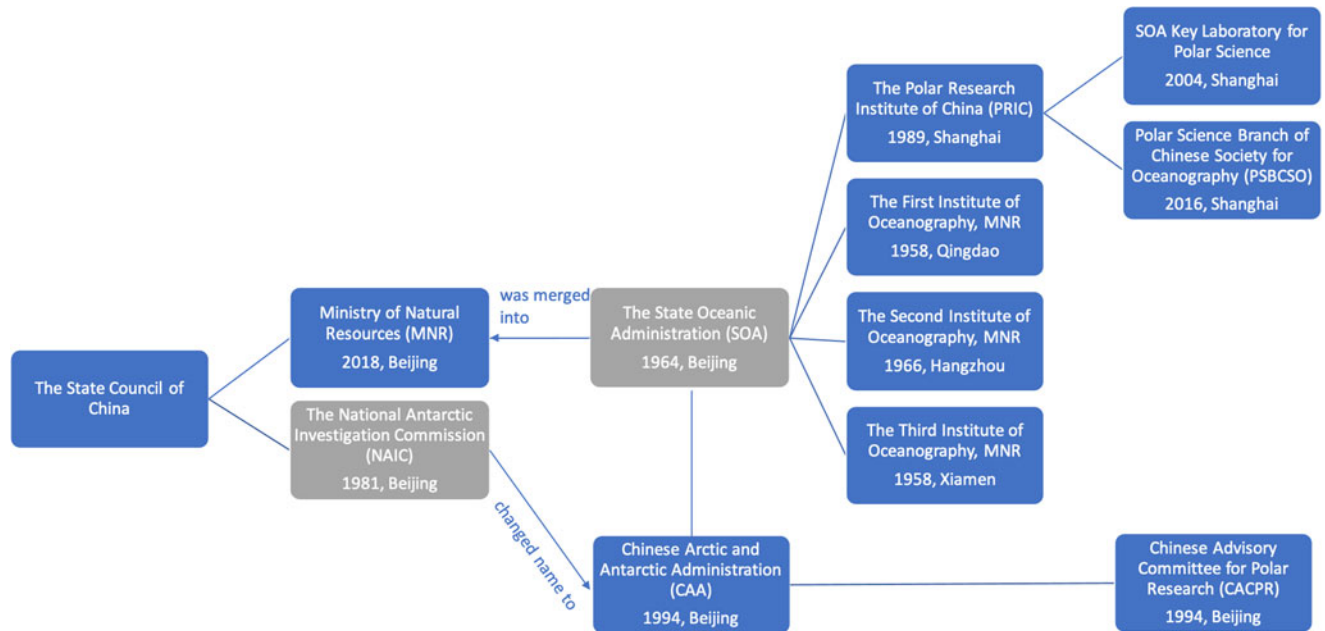


Fig. 1. The structure of China's key Antarctic administrative departments, as well as their founding dates and present locations. The grey boxes indicate that the organization has changed its name or been merged with another (sources from Chinese official websites and Zhang *et al.* 2019).

for formulating policies and strategic plans for the development of China's polar work. In 2018, the 13th National People's Congress approved the plan to establish the MNR, which is under the jurisdiction of the State Council of China. The MNR took over the responsibilities of the Ministry of Land and Resources, which oversaw the SOA, and six other ministries. The MNR has taken over many of the responsibilities of the former SOA (Zhang *et al.* 2019). One of the responsibilities of the SOA was to organize and carry out international exchanges and cooperation in the marine field, to participate in negotiations and consultations on foreign-related marine affairs, to organize the implementation of international marine conventions, treaties and agreements such as the United Nations Convention on the Law of the Sea and the Antarctic Treaty and to undertake affairs related to the polar regions, high seas and international sea beds (SOA 2014).

In addition to these administrative organizations, many universities in China are also involved in Antarctic activities. In 2010, to promote the development of China's higher education in oceanography and marine industries, the SOA and the MOE identified 17 universities directly under the MOE, such as Peking University, Tsinghua University and the Ocean University of China (MOE 2010). These 17 universities have established marine science and marine technology colleges, and the vast majority of Chinese marine workers graduate from these universities. This cooperation with the MOE enables universities to receive

increased financial support for marine disciplines, which increases the strength of key disciplines and the standing of these marine science-orientated universities (MOE 2010).

At the same time, these universities have also been actively developing cooperative education projects and scientific investigation projects together with overseas universities. China aims to cooperate with overseas ocean and Antarctic universities to extend China's ocean and Antarctic research and enhance its international standing. For example, the Ocean University of China (the most prestigious university regarding China's marine disciplines) started the '2+2' cooperation programme of undergraduate education with the University of Tasmania in 2014, which is also a key university regarding marine and Antarctic disciplines in Australia (Institute for Marine and Antarctic Studies 2014). At present, this programme has been undertaken for 7 years.

Logistics and infrastructure

Logistical support is central to the development of Antarctic research, supporting the development and maintenance of the infrastructure to carry out scientific expeditions in Antarctica and ensuring the personal safety of expedition members. The logistics of China's Antarctic expedition are mainly handled by the PRIC. The PRIC's logistics departments mainly include communication, medical, energy, transportation and

environmental protection sections. In the 1980s, a large number of experts from Japan, New Zealand, Australia and other countries visited China many times to impart their experience in Antarctic exploration, organization and management, base construction and logistics, as well as to provide training for China's Antarctic expedition. Before China's first icebreaker, the *Snow Dragon*, was put into operation, most Chinese Antarctic explorers set out from China by plane and then went on to Antarctica aboard other countries' vessels (Chen *et al.* 1988).

In October 1994, the *Snow Dragon's* first voyage transported Antarctic scientific researchers and supplies to Zhongshan Station. In December 1995, as part of the 12th CHINARE, the *Snow Dragon* voyaged to Great Wall Station for the first time. Due to a fire caused by the failure of a generator, the *Snow Dragon* was forced to cancel several other scientific activities and planned logistical and transport activities (Qin 1997). In 1997, the *Snow Dragon* voyage to Great Wall Station supported the clean-up and removal of 250 tons of waste that had accumulated at the station. The support team also built a new wharf and completed large-scale repair and improvement work. At Zhongshan Station, the installation of the hydropower project and sewage treatment system was completed and a comprehensive clean-up of equipment and waste in the station area took place (Chen 1999). In 2001, the SOA reformed the main responsibilities, internal institutions and staffing of the CAA. The CAA transferred the management and logistical support functions of Great Wall Station and Zhongshan Station to the PRIC (CAA 2003).

From 2001 to 2010, China completed a series of capacity-building projects at its Antarctic stations. The expedition teams demolished the old buildings and installed new sites at Great Wall Station and Zhongshan Station. This process included building a new power plant, accommodation and activity centre and the construction of a satellite communication system and e-mail system at Zhongshan Station (Xinhua 2009). Through the renovation of the original equipment and facilities and the construction of several new buildings, the business support and logistical capacities of the two stations were greatly improved, as were the living conditions of the station staff. During the fourth IPY from 2007 to 2008, China established *Xiongmao Matou* (PANDA Terminal) in the Larsemann Hills at Zhongshan Station, which is regarded as a high-quality wharf (Australian Antarctic Data Centre 2008). The PANDA Terminal is the only wharf built on the Antarctic landmass by China. It is used for cargo loading and unloading during annual Antarctic expeditions. The PANDA Terminal was also important in the construction of China's first inland station: Kunlun Station. In 2009, Kunlun Station, situated at

Table I. Number of scientific and logistical projects for the 12 China Antarctic Research Expeditions (CHINARE) from 2004 to 2016 (data from the *China Ocean Yearbook* series of articles).

CHINARE	Scientific projects	Logistical projects
21st (2004–2005)	> 30	8
22nd (2005–2006)	35	12
23rd (2006–2007)	12	7
24th (2007–2008)	36	11
25th (2008–2009)	48	8
26th (2009–2010)	59	11
27th (2010–2011)	31	20
28th (2011–2012)	41	12
29th (2012–2013)	37	15
30th (2013–2014)	30	15
31st (2014–2015)	46	8
32nd (2015–2016)	45	30

Dome A, the highest point of the Antarctic inland ice sheet, was constructed with an area of 402 m², which can be used by up to 15–20 people for summer scientific research.

In terms of logistics personnel selection, the SOA started in 2007 to organize the pre-selection of overwintering support personnel for Great Wall Station and Zhongshan Station. After physical examinations, psychological tests, indoor education, outdoor training and base-related knowledge assessment, the personnel who have obtained a pre-selection qualification are then selected (CAA 2008).

China's development of its logistical support system as part of the development and expansion of its Antarctic science programme has had other outcomes. It has been involved in a large number of cooperative international logistical exercises to Antarctic and has supported search-and-rescue activities where required (Chen & Allison 2016, Bergin & Press 2020, Hong 2021).

Table I shows the number of scientific and logistical projects for the 12 Antarctic expeditions from 2004 to 2016. The available data on the number of scientific and logistical projects have been used to compare China's scientific programmes and its logistical programmes. On the whole, the numbers of scientific and logistical projects carried out by CHINARE are relatively stable each year, with 30–50 scientific projects and ~10 logistical projects. It is worth noting that in the 23rd CHINARE, the scientific and logistical tasks were lower in number than those of other years, especially the scientific tasks. At that time, the *Snow Dragon* was being upgraded and did not take part in the 23rd CHINARE. Therefore, with the support of the Australian Antarctic Division, the personnel and supplies for Zhongshan Station were transported by Australian ships. The personnel and supplies for Great Wall Station were flown in by the Chilean Air Force as in previous years. The scientific missions of the

24th, 25th and 26th CHINAREs have increased in number due to the implementation of China's plan for the fourth IPY for 2007–2008.

Science as the 'currency of credibility'¹

As early as 1957, Zhu Kezhen, vice president of the Chinese Academy of Sciences, proposed the necessity of polar research (Lu & Bian 2011). After the initial phase of Chinese Antarctic research, the completion of Great Wall Station and Zhongshan Station led to the establishment of work in glaciology, meteorology, biology, geology, geodesy, oceanography, environmental science and human science, reflecting the broadening of the programme and the deepening of scientific research analysis.

Early scientific work included routine observations, including land observations, such as meteorological observations and field investigations, issuing weather forecasts, recording earthquake frequencies, drawing maps, collecting various animal, plant and rock samples, drilling palaeomagnetic samples and ice and snow samples, etc. As for the marine observations, the main tasks were biological and chemical sampling and catching krill (Yang 1992).

In the late 1980s, China recognized the need to improve its status within the Antarctic Treaty System (ATS) and to have its scientific research and Antarctic programmes recognized by the other Antarctic Treaty Consultative Parties. In formulating China's eighth FYP and 10 year plan for Antarctica, China proposed that its Antarctic work in the next 10 years would focus on scientific investigation and research, strive to make breakthrough progress in the investigation of and research into relevant disciplines, achieve international best practice in science, improve China's scientific and technological development, continuously enhance China's influence and decision-making power in Antarctic affairs, and safeguard China's rights and interests. After nearly 40 years of development, China's Antarctic investigation and research have moved from a single discipline to a comprehensive, multidisciplinary approach, from the local region to the large scale, closely combining Antarctic scientific research with global climate change research (Shen 2017). As China's Antarctic science has developed, it has broadened in scope. The following sections describe the development of various disciplines from the early 1980s.

Glaciology

In November 1981, a Chinese glaciologist, Xie Zichu, was selected by the former NAIC (now CAA) to overwinter at

Australia's Casey Station to learn glacier survey techniques. This was the beginning of China's Antarctic Glaciology research. By June 1988, five glaciologists had carried out glacial research at Casey Station, mainly studying the surface profile and understanding the physical processes in the near-surfaces of glaciers and the chemical and physical characteristics of ice cores. From the summer of 1985, Chinese glaciologists began to analyse the geochemistry of Nelson Ice Cap near Great Wall Station, measure the speed and thickness of the ice surface, observe the seasonal variation in sea ice and snow cover and drill shallow ice cores (< 30 m deep; Yang 1992). The study of ice cores is an important discipline of Antarctic research because it provides a lot of valuable information relating to long-term climate change. In 2004, China's 21st Antarctic expedition went to Dome A for the first time to conduct a scientific investigation on the inland ice sheet and obtained a 108 m ice core at the top of Dome A (CAA 2006). In 2009, Kunlun Station was built in the Dome A area. So far, China has drilled 800 m of ice core at Dome A. Regarding studying the origins and evolution of the Antarctic ice sheet, China has carried out a detailed survey of the topography of the Gambutchev Mountains and has revealed the original topography of the alpine longitudinal valley in the core area of the mountains for the first time in the world (SOA 2017).

Meteorology

In 1981, Bian Lingen, a meteorologist of the Chinese Academy of Meteorological Sciences, took part in the overwintering expedition at Australia's Mawson Station, becoming the first Chinese meteorologist to visit the Antarctic (Lu & Bian 2011). In 1985 and 1989, China's meteorological stations at Great Wall Station and Zhongshan Station were recognized by the World Meteorological Organization (WMO) and included in the World Weather Watch. The two stations regularly carried out ground meteorological observations every day, compiled meteorological telegrams and sent them to the world meteorological centre through Chile's Base Presidente Eduardo Frei Montalva and Australia's Davis Station. From September 1983 to November 1987, China sent three upper atmospheric physicists to Australia's Davis Station and Casey Station and Japan's Showa Station to observe the aurora, whistles and the ionosphere. In 1986, Great Wall Station installed an ionospheric detector, and Chinese atmospheric physicists began to observe and analyse ionospheric phenomena independently (Yang 1992). Since 2002, China has set up several automatic weather stations on the route from Zhongshan Station to Dome A. Therefore, in addition to routine observations, Chinese scientists started to study the dynamic physical and chemical science of the

¹Concept used by Quilty (1990).

upper atmosphere and developed an Antarctic climate model from data gained at Zhongshan Station. Some important achievements have been made in the study of the polar atmospheric boundary-layer structure and energy balance, extreme weather, sea-ice modelling, interactions between the sea, ice and atmosphere and the teleconnection mechanisms of climate impacts on China (Lu & Bian 2011).

Biology and life sciences

China's research on Antarctic biology was initially carried out at foreign Antarctic stations. From November 1981 to March 1986, China sent 10 biologists to Australia's Davis Station, New Zealand's Scott Station and Chile's Marsh base for biological investigation and research. After the completion of Great Wall Station, Chinese biologists mainly studied intertidal organisms, plankton, microorganisms, terrestrial organisms and birds at Great Wall Station and the South Shetland Islands (Yang 1992). Therefore, China's early research on Antarctic biology mainly focused on the classification of animals and plants and some ecosystem research. After the establishment of the CAAERA programme, comprehensive biological and ecological studies began. Since 2012, Chinese scientists have carried out background ecological environment investigations at the base of Great Wall Station and undertaken an observation programme at a site at Great Wall Station (SOA 2016c). In addition, human science in Antarctica was also in the scope of early Chinese research. However, it was not until 2007 that China systematically carried out physiological and psychological research on the inland ice sheet expedition members for the first time. China carried out a study of the adaptive physiological and psychological changes and mechanisms of humans at Dome A, an extremely cold and low-oxygen environment. This study was one of the nine international cooperative research projects of the fourth IPY led by the expert group of human science of the SCAR (Zhang 2007).

Geology and geophysics

China's systematic study of Antarctic geology began in 1984 with the establishment of Great Wall Station and the comprehensive launch of scientific investigation. Previously, some expatriate scientists visited the Vestfold Hills at Davis Station and the dry valley across the Antarctic mountains at Scott Station (Zhao *et al.* 2018). From 1985 to 1989, Chinese geologists conducted a series of geological surveys on the Fildes Peninsula on King George Island, carried out petrological, mineralogical, trace element and isotopic studies and established the stratigraphic sequence of the Fildes Peninsula (Yang 1992). Later, the scope of the geological

investigation was gradually expanded. Geological investigation of the Grove Mountain area was carried out near Zhongshan Station, describing in detail the evolutionary process of the East Antarctic ice sheet since the early Pliocene (SOA 2017).

During the 2004–2005 CHINARE, the expedition team carried out a comprehensive and systematic geological survey of the eastern edge of the Amery Ice Shelf and the coastal area of Prydz Bay and established a geological event sequence for the region. During the 2007–2008 IPY, the Chinese expedition team set up six seismic stations in the Antarctic inland and acquired valuable data. In 2019, China's self-developed polar ice sheet and subglacial bedrock drilling equipment was first utilized in Antarctica, and the nearly 200 m-thick Antarctic ice sheet was drilled through to obtain continuous ice-core samples and subglacial core samples. In recent years, scientists have also conducted local investigations and analyses of some mineral areas, such as the North Prince Charles mountain area and the South Shetland Islands area (Zhao *et al.* 2018). In the field of marine geology, Chinese geologists have been engaged in the investigation and study of submarine topography, marine sediments, gravity anomaly fields, geomagnetics, tectonic divisions and geological evolution (Yang 1992).

Surveying, mapping and remote sensing

In 1984 and 1988, a surveying and mapping team established geodetic origin and temporary elevation data at Great Wall Station and Zhongshan Station, respectively, and established a geodetic control network. They carried out satellite positioning observations, astronomical surveys, gyrostatic orientations, laser ranging, levelling, aerial photography, gravity surveys and close-range photogrammetry at the two stations. In 1995 and 1997, Great Wall Station and Zhongshan Station participated in the SCAR Epoch Global Positioning System (GPS) Campaigns (Dongchen & Zhang 2012). So far, > 400 maps covering nearly 300 000 km² of Antarctica have been mapped and compiled and > 300 Antarctic regions have been named. In 1999, the Chinese Antarctic Centre of Surveying and Mapping initially established China's Antarctic Geographic Information System (GIS).

In 2007, CHINARE scientists deployed several ice and snow environmental sensors from Zhongshan Station to Dome A, started the field collection of remote sensing parameters (including albedo, temperature and aerosols) and carried out remote sensing mapping, ice velocity and ice and snow change research. As one of the projects of the CAAERA programme, the Antarctic Environmental Remote Sensing Investigation project has made some achievements, and there are plans to expand the investigation area in the future in order to carry out

research on changes in polar environmental characteristics and improve the utilization rate of Chinese satellite data (SOA 2016a).

Meteorites and astronomy

During China's 15th Antarctic expedition in 1998–1999, four meteorites were harvested for the first time during the first comprehensive expedition to the Grove Mountain area. By 2019, China has carried out seven comprehensive investigations in the Grove Mountain area and collected 12 665 meteorite samples. In December 2000, a seminar on Chinese Antarctic Meteorite research was held in Shanghai and the first Chinese Antarctic meteorite research expert committee was elected. The committee is responsible for the collection, preservation, use and scientific research of Antarctic meteorites. During the 19th CHINARE in 2002–2003, meteorite collection was listed as an important scientific research activity for the first time. Since 2006, China has gradually established and improved its Antarctic meteorite sample network-sharing platform and launched in-depth research studies. China ranks third in the world in terms of the number of Antarctic meteorites collected, although it lags behind the USA and Japan in terms of quantity of meteorites and level of research conducted. The study of Antarctic meteorites is important because the concentration of Antarctic meteorites is considered to be closely related to changes of climate and ice-sheet behaviour over the past few million years (Harvey 2003). At the suggestion of scientists, China has drawn up plans to set up a special Antarctic meteorite project or a special Antarctic meteorite investigation team to continue work in new meteorite-rich areas and to further the study of the evolutionary history of the Antarctic ice sheet (Wang *et al.* 2018).

In 2007, with a series of national key research projects underway, China began to construct the Dome A astronomical observation base at Kunlun Station. The comprehensive survey of the Dome A observatory site was also one of the PANDA programmes during the fourth IPY, and it is also a project of international cooperation with the participation of China, Australia and the USA. Work at the Dome A observatory site in Antarctica shows that the astronomical observation conditions in the inland area of Antarctica are better than those of any other conventional astronomical observation site on Earth. In addition, the unique geographical location and physical environment also help to make Dome A one of the best astronomical observation sites. China's Antarctic astronomical observation has gone through the stage of astronomical site selection and observation using small-scale equipment. At present, trial observation using medium-sized equipment has begun, and the construction of large astronomical scientific facilities will soon begin (Qiu 2012). Since 2007, China's Antarctic astronomy has

developed from a stationary small optical telescope array (Chinese Small Telescope Array; CSTAR) to a trio of medium-sized Antarctic survey telescopes (AST3), and China plans to build two advanced large-scale facilities (i.e. a 2.5 m survey telescope - Kunlun Dark Universe Telescope (KDUST) - and a 5 m telescope - Dome A Terahertz Explorer-5 (DATE5); Qiu 2012). The project involving the construction of the Antarctic observatory has been listed in the 'Medium and Long-Term Plan for the Key National Technology Infrastructure Construction (2012–2030)' issued and implemented in 2013. Its main scientific objectives are to study dark matter and dark energy, the highly red-shifted universe, the formation and evolution of stars and galaxies and exoplanets and the origin of life (Wang *et al.* 2018).

Marine physics

In 1980, two Chinese physical oceanographers made the first observation of the Southern Ocean at Casey Station. During China's first Antarctic expedition in 1984, the Southern Ocean expedition team completed a comprehensive oceanographic survey focusing on the waters around the South Shetland Islands and the north-east of the Bellingshausen Sea. This was the first time that China had carried out *in situ* observation of the Southern Ocean on one of its own ships (Shi *et al.* 2013). During its third Antarctic expedition, China conducted its first global oceanic scientific expedition. After the completion of Zhongshan Station in 1989, the focus of China's Southern Ocean investigation shifted to the water mass and circulation in Prydz Bay in the Indian Ocean sector. Its key research areas and contents also include the south-east Indian Ocean and the Drake Passage, the Antarctic Polar Front, the Antarctic Circumpolar Current, sea-ice process, etc., and using satellite remote sensing in order to carry out large-scale long-term continuous observation of the Southern Ocean (Yang 1992, Shi *et al.* 2013).

Scientific investigation of the Southern Ocean has always been one of the key tasks carried out by Chinese Antarctic research vessels. After nearly 40 years of investigation and research, China's physical oceanography research has made great progress, although it still lags behind the world's best science in terms of both depth and breadth of research (Shi *et al.* 2013). According to Shi *et al.* (2013), an important research direction for Chinese physical oceanographers in the future is work on the inter-annual and inter-decadal variation of the Southern Ocean and its role in the global climate system.

Marine chemistry

The Chinese study of marine chemistry in the Southern Ocean began in 1984 with its first Southern Ocean

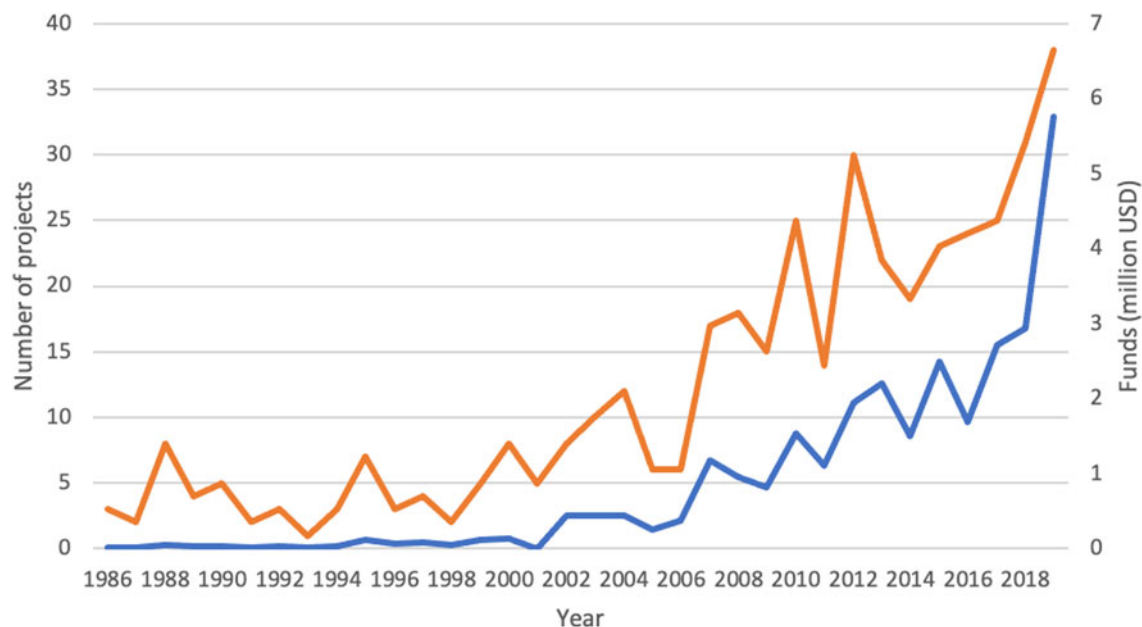


Fig. 2. The general trend of changes in China's Antarctic scientific projects from 1986 to 2019. The orange line shows the number of projects and the blue line shows the level of funding (data from the National Natural Science Foundation website: <https://fund.sciencenet.cn>).

investigation, focusing mainly on marine atmospheric chemistry. At that time, a group of returning Chinese scholars from the USA, the UK and Canada set up the first marine atmospheric chemistry research group in China, installed their own aerosol sampling system on the *Xiangyanghong 10* research vessel and started the first field observation and research on marine aerosol chemistry (Chen *et al.* 2018). Later, China carried out studies on the metallic elements in the atmosphere over the Southern Ocean, the sea-air exchange process and biogeochemical cycle process, the characteristics of the distribution of air pollution and the impacts of human activities in station areas (Yang 1992, Chen *et al.* 2018). At the same time, China also strengthened its research and development of key technologies for real-time observation. According to Chen *et al.* (2018), China's marine atmospheric chemistry research in the Southern Ocean will continue to focus on the impacts of the atmospheric transport of global terrestrial chemicals on the Southern Ocean ecosystem and Antarctic continental environment and strengthen its research into major topics of international concern, such as the carbon cycle of the Southern Ocean and ocean acidification.

Marine biology

In 1981, Dong Zhaoqian joined the Australian Antarctic expedition team for the second time to investigate the Southern Ocean and participated in the Biological

Investigation of Marine Antarctic Systems and Stocks (BIOMASS), an international programme focused on assessing marine living resources such as krill (Pu & Dong 2003). Since 1984, China's biological research in the Southern Ocean has focused on the study of Antarctic krill, as well as other marine organisms, mainly including oceanic phytoplankton, zooplankton, microorganisms, the benthos and seabirds (Yang 1992). A project surveying the Southern Ocean microplankton community structure and biodiversity was one of the key activities carried out by China during the fourth IPY.

China acceded to the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) on 19 September 2006 and became a CCAMLR member on 2 October 2007. It officially launched research into the development and rational utilization of Antarctic krill and other biological resources in 2009 (SOA 2016b). As noted above, in 2010, the SOA launched the CAAERA programme, with the investigation and assessment of Antarctic krill and other biological resources in the waters around Antarctica as one of the key research topics of this programme. Since the first Chinese Antarctic expedition, the investigation of krill biological resources and environmental conditions has been the focus of China's Southern Ocean biological investigation. According to the SOA (2016b), China will continue to study the impacts of global climate change and human activities on the polar ecological environment by analysing the trends in annual variations of krill, and it will assess the regional distribution and

development potential of krill resources to provide a basis for the rational development, utilization and protection of krill. They noted the importance of resource conservation in terms of Antarctic marine microorganisms in order to provide preliminary information for the research and utilization of microbial genetic resources.

Initial view of China's Antarctic science programme

During the four decades from 1980 to 2020, China's Antarctic science programme has developed from a single discipline to multidisciplinary comprehensive research. The development of China's Antarctic science programme can also be studied through an analysis of projects funded by the National Natural Science Foundation (NSFC) between 1986 and 2019.

Figure 2 shows the trends in the numbers of Chinese Antarctic projects and the amounts of funding over time from 1986 to 2019 (in millions of dollars; 1 US dollar = 6.5 renminbi). The orange line in Fig. 2 shows the numbers of projects and the blue line in Fig. 2 shows the amounts of funds. The data are derived from the NSFC website (<https://fund.sciencenet.cn>). The website includes data on the projects approved by the NSFC and the amounts of funding since 1986. In order to gain a general understanding of China's Antarctica-related projects, the names of projects with '*Nanji*' [Antarctica] in their titles were searched for. As the projects in 2020 and 2021 have not been fully counted, 2019 was chosen as the final year for analysis.

It is obvious that both the numbers of projects and the amounts of funding are growing rapidly. The numbers of projects have grown from ~10 in 1988 to ~40 in 2020, and the project funds have grown from tens of thousands of dollars to millions of dollars. It can also be seen that the numbers of projects and the amounts of funding behave consistently; that is, when the numbers of projects increase, the amounts of funding also increase. The IPY in 2007–2008 and CAAERA in 2012 (mentioned above) can explain the high points in 2008 and 2012, with pronounced increases in the numbers of projects and investments. On the whole, the numbers of projects and funding level for China's Antarctic projects have been on the rise and are apparently still increasing.

In an earlier study, Anne-Marie Brady analysed funding for the PRIC's polar (i.e. both Antarctica and Arctic) programmes from 1991 to 2009. She found that the PRIC had received US\$44 million (at the 2017 exchange rate) from several different funders over these two decades. The major sponsors were the NSFC, the SOA and the Ministry of Science and Technology of China, which funded 63, 58 and 45 projects, respectively (Brady 2017). However, our paper analyses the funding of

Antarctic programmes across the country (not just those of the PRIC), but we have so far only looked at the NSFC's investment in them. According to our results, from 1991 to 2009, the NSFC funded 149 Antarctic projects with ~US\$5.5 million in funds (at the current exchange rate).

Conclusion

The White Paper on China's Antarctic activities published in 2017 notes that China would increase its investment in Antarctic work and enhance its logistical support, scientific research and environmental protection capabilities. The White Paper also stated that China would raise public awareness of Antarctica in the hope that China could play a more active and constructive role in the future global governance of Antarctica. After years of learning from other countries, such as Australia and New Zealand, and conducting independent scientific investigations, China's Antarctic science is now growing. It has made achievements in geology and geomorphology, glaciology, atmospheric physics, astronomy, marine science, etc., and has received international attention.

This paper has provided a short historical treatment of the development of China's Antarctic science programme over the past 40 years, focusing on administration, logistics and science. This research highlights the opportunities and challenges that arose from the initial, individual efforts through to the management of CHINARE by an assessment of China's comprehensive Antarctic research and logistics programme. The paper shows the widening and deepening of China's Antarctic infrastructure, scientific research and international participation. At the same time, it is clear that China's scientific research in some fields will continue to strengthen. This analysis shows that, through its growing logistical capacity and deepening scientific research, China's aspiration to become a major polar power is being realized in Antarctica.

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Author contributions

MZ - conceptualization, investigation, methodology, writing original draft. MH - writing, reviewing and editing.

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