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Some aspects of Chinese-Australian cooperation in Antarctic Research over the past forty years

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Abstract China and Australia have been collaborating in Antarctic activities since the early 1980s and that collaboration has grown and become more formalized as China's Antarctic program has expanded. This collaboration has involved personnel exchange, logistic support, environmental protection and particularly scientific research. China and Australia have signed a series of memorandums and treaties of friendship and cooperation on Antarctic activities in the past few years. Relevant mechanisms of cooperation between expedition plans and programs have been established, and the exchange and cooperation in people, science and technology, services, and supplies are undertaken across a range of organizations. Here we overview the history of the bilateral collaboration and provide a few examples of the many areas of cooperation. These examples are focused on activities in Hobart, the key centre of the Australian Antarctic program.

Keywords **China, Australia, Antarctic research, bilateral collaboration, memorandum of understanding**

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1 Introduction

Although China did not participate in the International Geophysical Year of 1957-1958, and was not an original signatory to the Antarctic Treaty, it has since developed, over the last more than 30 years, a strong and very active Antarctic research program. Zou[1] argues that China's development of an Antarctic program has involved three stages. Stage 1 (1978 to 1984) was when China learned from the expertise of others in order to set up its Antarctic program; Stage 2 (1985 to 1989) was when China was able to set up its own bases and began to launch independent expeditions; and Stage 3 (1990 and beyond) was when China began to shift its priorities into scientific research. It is our premise that particularly the initial development during Stage 1, was greatly facilitated by cooperation with Australia. Stages 2 and 3, China's first Antarctic independent expeditions, particularly in East Antarctica, and expansion of its scientific research were also undertaken with assistance from the Australian Antarctic program. China's Antarctic program has grown very substantially over the last 30 years, but still bears a legacy from the early collaboration with Australia.

Brady[2] has subsequently suggested a Stage 4 (2005 to present) when China has sought a leadership role in Antarctic affairs. Within this stage also, China and Australia have continued strong cooperation on a range of Antarctic activities. These now include personnel exchange, scientific research, logistic support and environmental protection. They have also helped each other with transport, emergency response and rescue.

Hobart, the capital city of the Australian state of Tasmania, is a logistic gateway to the Antarctic. It is also a concentrated centre of Antarctic science, with eight research institutions on Antarctica and Southern Ocean located there, including the Australian Government's Australian Antarctic Division (AAD), the Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Oceans and Atmosphere, the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) and the Institution

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of Marine and Antarctic Studies (IMAS) of the University of Tasmania (UTAS). Activities centered on Hobart have provided China and Australia with a platform on which both countries could extend their bilateral concrete and tangible cooperation on Antarctica and the Southern Ocean. This paper will hence emphasize the Chinese connection with Hobart in Antarctic research.

2 Early Chinese-Australian Antarctic science links

In January 1980, two Chinese scientists, Dong Zhaoqian and Zhang Qingsong, under the sponsorship of AAD, flew first to the U.S. Antarctic station, McMurdo, and then on to Casey Station in East Antarctica. They thus became the first two Chinese to land on the Antarctic continent. In January 1981, the same two scientists joined an Australian National Antarctic Research Expedition (ANARE) to East Antarctica at the invitation and with the logistic support of the AAD, initiating China's involvement in Antarctic field research[3]. In 1994, the ice breaking research vessel *Xue Long* (Snow Dragon) undertook its first Antarctic expedition and visited the port of Hobart on 15th November 1994 on its way to East Antarctica. Since then Hobart, as well as Fremantle in Western Australia, has become an important supply port for the vessel on its way to the Chinese Antarctic Zhongshan Station in Prydz Bay, East Antarctica. Over the past three decades, scientists and scholars from both countries have visited each other's key polar research institutions many times. They have developed cooperation on Antarctic research, Antarctic expeditions, resource-oriented services, and more.

2.1 Initial links between China and Australia in Antarctic glaciology

Even before these early links between the two countries in Antarctic research, collaboration between China and Australia in glaciological research had been initiated in 1979, and this later developed to focus on Antarctic glaciology. The "glaciological" links was initially established when Prof. Shi Yafeng, the founder of Chinese glaciology and the director of the Lanzhou Institute of Glaciology and Geocryology (LIGG) of the Chinese Academy of Sciences (CAS), attended the General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Canberra in February 1979. He subsequently visited the AAD, then in Melbourne, and the University of Melbourne. Following this, several Chinese students from Lanzhou undertook PhD studies at the University of Melbourne, primarily in laboratory studies of ice mechanics under the guidance of Prof. W. F. Budd and Dr. T. H. (Jo) Jacka.

2.2 Chinese scientists participating in Australian Antarctic expeditions, 1980-89

In January 1980, at the invitation of AAD, Chinese scientists Dong Zhaoqian and Zhang Qingsong, joined the AAD director, Mr. Clarence McCue, and acting deputy director, Dr. Knowles Kerry, on an Australian air force Hercules aircraft flight from Christchurch, New Zealand to the United States Antarctic station McMurdo, becoming the first two Chinese nationals to land on the Antarctic continent. While there they also visited the nearby New Zealand Scott Station before flying on to the Australian Casey Station in a U.S. ski-Hercules (Figure 1). They arrived at Casey on 14 January 1980 and remained there till 17 February, returning to Australia on the *MV Thala Dan*, and visiting the French station, Dumont d'Urville (February 21—27) enroute. During this visit, they collected a wealth of information on building, logistic support, transport, communications, safety, and scientific programs, which would become important reference material for the subsequent establishment of the Chinese national Antarctic program.

Figure 1 Dong Zhaoqian (left), Dr. Knowles Kerry (middle) and Zhang Qingsong (right) near the Australian Antarctic Casey Station in January 1980 (Photo: Dong Zhaoqian).

In September 1980, Mr. Clarence McCue visited the State Oceanic Administration (SOA) of China and CAS, and discussed Australia-China cooperation on Antarctic expeditions with Mr. Luo Yuru, the deputy administrator of SOA. They reached the agreement that AAD would invite Dong Zhaoqian and Zhang Qingsong again, to take part in the ANARE 1980/81 Antarctic Expedition; and then in subsequent years would invite 2 to 3 Chinese scientists to work year-round at Australian Antarctic stations or on board research vessels. On September 18, 1980, Mr. Fang Yi, the vice premier of China met Mr. McCue and his delegation including Dr. Knowles Kerry, in the Great Hall of the People, Beijing (Figure 2). This initiated a period of nearly ten years when many Chinese scientists participated in ANARE programs, and it was the start of Chinese field research in the Antarctic.

On 9 January 1981, Dong Zhaoqian and Zhang Qingsong joined a voyage of the *MV Nella Dan*, sailing from Melbourne to the Antarctic. Zhang Qingsong, a geomorphologist, disembarked when the ship reached the ANARE Davis station where he spent the whole year, becoming the first Chinese national to spend winter in

Figure 2 In September 1980, Fang Yi (front, centre), then Chinese vice-premier, met Mr. C. McCue, the director of AAD (front, 3rd from left) and Dr. Knowles Kerry, acting deputy director of AAD (front, 3rd from right) in the Great Hall of the People in Beijing. Mr. Luo Yuru, the vice-administrator of SOA (front, 2nd from left) and other SOA officials, as well as Dong Zhaoqian (rear, 2nd from left) and Zhang Qingsong (rear, 2nd from right) also attended the meeting (Photo: Dong Zhaoqian).

Antarctica. Dong Zhaoqian, an oceanographer and later the foundation director of the Polar Research Institute of China (PRIC), participated in a marine ecosystem survey undertaken onboard the newly re-fitted *Nella Dan* (as a contribution to FIBEX, the First BIOMASS Experiment), also visiting Mawson and Casey stations and returning to Hobart on 26 March 1981. He stayed at the AAD for another nine months, analyzing data and working with Australian oceanographers on a paper about the water masses and circulation in Prydz Bay, Antarctica[4].

In November 1982, Mr. Wu Heng, the chairman of the Chinese National Antarctic Committee, led a delegation that visited AAD, and further officially strengthened cooperation between China and Australia.

Over the next eight years they were followed by other collaborating Chinese scientists, many of whom wintered at Australian stations. The 16 Chinese nationals who wintered during this period, as recorded are listed in Table 1[5]. They included Xie Zichu, the first Chinese glaciologist to work in Antarctica, who travelled to Casey Station on *MV Thala Dan* for the winter of 1982. He established a "Chinese glaciological observation site" at the "Rio Grande do Sul" intersection on the Law Dome ice cap, 20 km south of Casey Station. In the same year, Bian Lingen wintered at the ANARE Mawson Station becoming the first Chinese meteorologist to work in Antarctica. Prof. Bian went on to become the leader of Antarctic meteorological research at the Chinese Academy of Meteorological Science (CAMS) of the Chinese Meteorological Administration (CMA) in Beijing.

In 1984, Qin Dahe, now an internationally famous glaciologist and climatologist, spent the year with ANARE at Casey Station. In 1990, Qin was subsequently the Chinese participant in the International Trans-Antarctica Expedition, led by Will Steger (U.S.A.), which also included participants from France, the Soviet Union, U.K and Japan. This six-person team completed the first-ever dogsled crossing of the Antarctic continent, 6000 km from the tip of the Antarctic Peninsula to Mirny Station on the coast of East Antarctica via the South Pole. Prof. Qin published scientific results based on snow samples collected during this expedition and he became

Table 1 Chinese scientists wintering with the Australian National Antarctic Research Expeditions (1981—1989)

Year	Station	Name	Station	Name
1981	Davis	Zhang Qingsong		
1982	Davis	Lu Peiding	Casey	Xie Zichu
	Mason	Bian Lingen		
1983	Davis	Jiang Jialun	Casey	Qian Songlin
1984	Davis	Cao Chong Wang Zipan	Casey	Qin Dahe
1985	Davis	Lin Jianping	Casey	Han Jiankang
1986			Casey	Xi Dilong
1987	Davis	Xu Luqiang	Casey	Li Jun
1988	Davis	He Fuyang		
1989			Casey	Wen Bo

very famous in China, particularly as a role model for youth. He went on to study in France and U.S.A. before becoming the Administrator of the enormous CMA, an academician of CAS, the co-chair of both the Intergovernmental Panel on Climate Change (IPCC) Fourth and Fifth Assessment Reports (Working Group 1) and making many other remarkable achievements in cryospheric and climatological studies, both in China and internationally.

These few examples show how many of the Chinese who first worked with the Australians became the mainstay of Chinese Antarctic research. The help and support from Australia made a big contribution to the early China's Antarctic expedition activities and the development of China's field research in Antarctica.

2.3 Early development of the Chinese national Antarctic program

While these first Chinese scientists were gaining experience in the Antarctic with Australian expeditions, China was establishing infrastructure to support its own Antarctic research program. In 1981, the Beijing-based Chinese Antarctic Administration (CAA) was established as an agency of the SOA. It planned and implemented the first Chinese National Antarctic Expedition (CHINARE 1) to King George Island (Shetland Islands, West Antarctica). CHINARE 1 landed on King George Island in December 1984 and built Great Wall Station (62.22S, 58.96W), which was opened in February 1985.

China first acceded to the Antarctic Treaty, as a non-Consultative party on 8 June 1983 and became a full Consultative party on 7 October 1985 after initiating its own Antarctic research program. In 1986 China became the 18th nation to join the Scientific Committee on Antarctic Research (SCAR), an Interdisciplinary Body of the International Council of Science and the peak non-governmental organization initiating, developing and coordinating high quality international scientific research in the Antarctic and Southern Ocean region. Later, in 1992, Dong Zhaoqian, the earliest Chinese scientist to collaborate with AAD, was elected as a vice-president of SCAR.

In April 1986, Mr. J. E. Bleasel, the director of AAD, visited China at the invitation of SOA, as China was preparing to establish its second Antarctic station in East Antarctica. He raised some issues that might need attention during a voyage in the ice-covered Southern Ocean, and agreed that China would send a ship officer to gain experience on board the Australian Antarctic vessel. In October 1986, Mr. Teng Zhengguang, the first officer of Chinese *Jidi* vessel, joined a voyage of the Australian-chartered MV *Ice Bird* for familiarization in Southern Ocean navigation.

In February 1989, during CHINARE 5, China's first station on the Antarctic continent was established in the Larsemann Hills, Princess Elizabeth Land, East Antarctica. This station was named Zhongshan (69.37S, 76.38E). Also in 1989, the Polar Research Institute of China (PRIC) was founded in Shanghai to coordinate Chinese polar research. PRIC, an agency of SOA, undertakes comprehensive studies of the polar region including glaciology, oceanography, upper atmospheric physics, biological science, and data management and archiving.

2.4 Visits of Chinese Antarctic vessels to Hobart 1994—2013

Several of the vessels used by China for Antarctic expeditions and transport since 1984, have visited Hobart and other Australian ports. Overall China has used five vessels: *Xiangyanghong 10*, *J121*, *Haiyang 4*, *Jidi* and *Xuelong*. But the first three ships conducted only one expedition each. The *Jidi*, a supply transport vessel and China's first ice-capable vessel started its first Antarctic voyage for CHINARE 3 in October 1986. *Jidi* undertook six CHINARE expeditions before being decommissioned in 1994. During this period, *Jidi* first visited Hobart during CHINARE 5, and again during CHINARE 8.

R/V *Jidi* was replaced by the ice-breaking (Class B1) *Xuelong*, which first saw service in the 1994 CHINARE 11. *Xuelong* (literally Snow Dragon) has since undertaken 19 Antarctic expeditions and six Arctic expeditions. During its first expedition, *Xuelong* berthed at Hobart, and then visited again in 1998 (CHINARE 15), 2013 (CHINARE 29), 2014 (CHINARE 31) and in 2015 (CHINARE 32). In most other seasons *Xuelong* has called at the port of Fremantle, enroute to or returning from Zhongshan Station.

In January 2013 (CHINARE 29), *Xuelong* made its third visit to Hobart at the invitation of Lara Giddings, the then premier of Tasmania. The AAD hosted a workshop with colleagues from the *Xuelong*, to exchange ideas, particularly on opportunities for collaboration. After the workshop, the AAD and Tasmanian government hosted a dinner with representatives of CHINARE 29. Chen Yuming, the ambassador of China in Australia, Qu Tanzhou, the voyage leader of CHINARE 29 and also the director of the Chinese Arctic and Antarctic Administration (CAA), Wang Jianzhong, the captain of *Xuelong*, and other representatives attended the dinner. Also attending were the Tasmanian premier, the former Tasmanian governor, the Lord Mayor of Hobart, representatives of Hobart's key scientific institutions and private sector interests with connections to Antarctica, and senior representatives of the Tasmanian government (Figure 3).

The visit of *Xuelong* brought new opportunities for Tasmania and Hobart, as China will increasingly use Hobart as an Antarctic gateway. This will also enhance the collaboration between the Chinese and Australian Antarctic programs.

3 Some examples of Chinese-Australian Antarctic research collaboration over the last three decades

Academic exchange between Chinese and Australian Antarctic researchers is one demonstration of the Chinese-

Figure 3 The crew members of CHINARE 29 at Hobart port (19th January 2013) (left). Qu Tanzhou, the voyage leader of CHINARE 29, presents a model of *Xuelong* to Damon Thomas, Lord Mayor of Hobart on 20th January 2013 (right). (Photo: PRIC).

Australian collaboration in Antarctica. Over the past three decades, the two countries have promoted exchange and cooperation in Antarctica in various ways such as short-term visit, post-graduate training, seminars, and workshops. They have also collaborated on a number of large Antarctic research programs, some examples of which are detailed in the following.

3.1 The Australian Lambert Glacier traverses and the Chinese Zhongshan Station to Dome A traverses

Between 1989 and 1995, ANARE ran a series of over-snow traverses into the interior of the Lambert Glacier Basin between Mawson Station and the Larsemann Hills, the location of Zhongshan. This glaciological research program aimed to clarify the state of balance of the large inland basin draining ice via the Lambert, Mellor and Fisher Glaciers, through the Prince Charles Mountains and into the Amery Ice Shelf. The traverses operated over five summer seasons along an inland route approximately following the 2500 m ice sheet elevation contour. The comprehensive range of measurements made along the route included ice sheet surface elevation, ice thickness[6], surface ice velocity at 73 locations (using the then newly introduced GPS technology), snow accumulation at canes spaced every kilometre[7], observations of surface snow features and surface snow sampling (for determining physical and chemical properties) and recovering firn cores to 60 m depth at several locations. In addition, six automatic weather stations, which transmitted hourly data via satellite link, were established along the route.

The first three years of this project concentrated on establishing fuel depots and making measurements on the western (Mawson) end of the route. During 1992-1993, the third season, Ren Jiawen from the Lanzhou Institute of Glaciology, CAS joined the traverse team. After returning from Antarctica he worked with the Australian glaciology group in Hobart, analysing ice cores collected at several locations along the route and deriving a record of variations is snow accumulation and temperature over the previous 50 years[8-11].

In the austral summer of 1996/97, CHINARE 13 commenced a traverse program along a route between Zhongshan Station and Dome A, the highest point on the Antarctic Ice Sheet. The initial part of this route, between Zhongshan and LGB69 (70°50'S, 77°04'E, 1854m) followed the route of the ANARE Lambert Glacier traverses, and was able to repeat some of the measurements made on this line. Li Jun, a Chinese born and educated glaciologist who subsequently emigrated to Australia and joined he Australian Antarctic program, was the Australian representative on this CHINARE traverse.

Over the next few years the CHINARE traverses pushed further south, eventually reaching Dome A on 18 January 2005 (CHINARE 21), and establishing Kunlun Station near there in the summer of 2008-09 (CHINARE 25). Many of the measurements made along this 1228 km route were similar to those made on the ANARE Lambert traverses including more than 20 sites, established at approximately 50 km intervals during 2004-05, to monitor the surface ice velocity. Automatic weather stations were also deployed along the route in a joint Chinese-Australian cooperation, discussed further in section 3.3.

3.2 Collaborative work on the Amery Ice Shelf

Commencing in the 1999-2000 Antarctic summer season, Australian glaciologists undertook a multi-year and multi-disciplinary investigation of the interaction between the Amery Ice Shelf and the underlying ocean known as the Amery Ice Shelf Ocean Research (AMISOR) project. This had overall aims of quantifying the interaction between the ocean and the Amery Ice shelf; determining the implications of this interaction for the discharge of grounded ice and to water mass modification; and deriving a long term record (from sediment and ice cores) of the time variability of the interaction. It included using a hot water drilling system to penetrate the ocean cavity beneath the ice shelf at AM02 (69°42.8' S, 72°38.4' E, 373 m ice thickness) in 2000-2001 and at AM01 (69°26.57' S, 71°25.03' E, 479 m ice thickness) in 2002-03[12]. This latter site was known from much earlier studies to be in a region where marine ice was accreted beneath the ice shelf[13]. Marine ice is mainly formed by the accumulation and consolidation of ice platelets formed in the ocean cavity onto the underside of the ice shelf and provides

evidence of a vigorous and widespread sub-ice shelf ocean circulation[14].

The 300-350 mm diameter AMISOR boreholes were used to sample the ocean and sea floor beneath the ice shelf and to install long-term monitoring instruments suspended near the ice-water interface and in the seawater below. The hot water drilling system was able to collect discrete ice samples at a number of depths, but could not collect a continuous ice core. Measurements on and through the ice shelf were supplemented by ship and mooring measurements made by the Australian program in Prydz Bay, off the front of the Amery Ice Shelf[15].

The Chinese Antarctic program conducted oceanographic research in Prydz Bay for many years, also with a focus on interaction between Prydz Bay circulation and the Amery Ice Shelf[16-18]. In January 2003, 13 hydrographic profiles were measured across the front of the shelf from Xuelong, complementing the AMISOR work of the two previous seasons. Also in the 2002-03 austral summer season, a CHINARE-19 party used a mechanical ice drill to recover a 296 m long continuous ice core at a site only 1 km from the AM01 borehole[19]. This penetrated into the top 20 m of marine ice.

The 6-person AMISOR group returned to AM01 in the 2003-04 season and, as part of a growing collaboration between the programs, were accompanied by three CHINARE expeditioners. The CHINARE team carried out an ice radar survey of the local area around AM01, on a 10 km×10 km grid, with a line spacing of 2.5 km. These data provided a regional map of the depth of the marine ice layer. They also conducted a GPS re-measurement of an ice movement pole at the Chinese drill site, established a 500 m×500 m strain grid square for future observations, and revisited a set of 10 bamboo canes for snow accumulation assessment in the area (Figure 4). Although the Chinese and Australian scientists largely operated as independent teams, they shared logistics, camp facilities and duties, and exchanged data and scientific ideas.

In 2003 Cai Minghong of PRIC was awarded a Prince of Asturias Fellowship by the Scientific Committee on Antarctic Research (SCAR), enabling him to travel to Hobart and work with biologists and glaciologists at the AAD and at ACE CRC between October 2004 and June 2005, and again between June and July 2006. His work involved physical, chemical and biological analyses (including stable isotope mass spectrometry, scanning electron microscopy, flow cytometery and ion chromatography) of the marine sections of the Amery Ice Shelf cores collected by both the Chinese and Australian programs[20-21].

The Australian program went on to complete boreholes through the Amery Ice Shelf at a total of 6 sites. Further collaboration with Chinese scientists included joint deployment of an Acoustic Doppler Current Profiler at site AM06 to measure ocean currents and ice shelf basal melt rates. The Australian field data from the Amery Ice Shelf has also been used to validate Chinese-led remote-sensing estimates of the distribution of melting and refreezing beneath the ice shelf [22].

3.3 The Zhongshan-Dome A automatic weather station network

Three AAD designed and built automatic weather station (AWS) were deployed as part of Australian-Chinese collaboration along the 1228 km CHINARE traverses from Zhongshan Station to Dome A between 2002 and 2005. These were at the sites LGB69 (1854 m elevation), Eagle

Figure 4 Scientists working on the Amery Ice Shelf, in January 2004. Inspecting the Australian hot-water drill (left); Chinese ice thickness sounding radar (top right); communal dumplings at the shared camp (bottom right). (All photos: Mike Craven).

(2852 m) and at Dome A itself (4091 m) (Figure 5). In 2008 an additional AAD station was installed at Panda-N (2584 m) and an AWS was also deployed at Panda-S (4027 m) in collaboration with the University of Wisconsin, USA. Two further Chinese-constructed AWS were deployed in the region at Panda-1 (2737 m) in 2011 and at Taishan summer station (2626 m) in 2013 (Figure 5).

All these stations send their data in near-real time via the ARGOS satellite data relay system. The data are available for operational meteorology and for research into the surface climate and processes over the ice sheet. The stations are maintained during the CHINARE traverses to Dome A and the data processing and analyses are shared collaboratively between the partners. The data are also freely available on the internet.

The AWS network has contributed to understanding of the surface climate over the ice sheet [23-24]; the surface energy balance[25-27]; snow accumulation rates and the suitability of Dome A as a site to recover an ice core more than one million years old[28-31]; and to validate meteorological reanalyses[32-33].

Meteorological observations for some stations between ZhongShan and Dome-A are now available for more than a decade, and will provide a reference for future study of climate change. An overview of meteorology of the region is provided by Bian L G, et al. (in press)[34].

3.4 Astronomy from the high Antarctic plateau

Over a decade of site testing in Antarctica, at both South Pole and Dome C by the astronomy group at the University of New South Wales (UNSW), has shown that the Antarctic plateau contains exceptional sites for astronomy, with certain atmospheric conditions (e.g., turbulence, water vapour content, and infrared emission) that are greatly superior to those at existing mid-latitude observatory sites[35]. The highest point on the Antarctic plateau, Dome A, experiences even colder atmospheric temperatures, lower wind speeds, and a turbulent boundary layer that is confined even closer to the ground[36]. Collaborative astronomical facilities have hence been developed near Dome A, where the best conditions on the Earth's surface for a wide range of astronomical observations from optical through infrared to millimetre-wave measurements.

As part of the International Polar Year 2007-2008 (IPY) projects, PANDA and Astropoles, an agreement was signed among the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC), PRIC, and UNSW Australia, to develop and deploy an autonomous observatory called PLATO (PLATeau Observatory) to Dome A. PLATO is a self-contained automated platform for conducting year-round, experiments completely robotically from the Antarctic plateau and it was delivered to Dome A in January 2008[37]. A large international team has contributed to the observatory and its instruments, with Iridium satellite communication being provided by the U.S. Antarctic Program (USAP).

PLATO ran continuously for 204 d in 2008. Following servicing missions in early 2009, 2010, and 2011 (by CHINARE 25, 26 and 27), it then ran continuously throughout the next three years. PLATO-A, an evolution of the original PLATO experiment, was taken to Kunlun Station at Dome A by CHINARE 28, and began collecting scientific data in early January 2012

Instruments currently running on PLATO-A include two Antarctic Survey Telescopes (AST3-1 and 3.2), 50/68 cm Schmidt-like equatorial-mount telescopes and the biggest telescopes located in Antarctic inland; a high resolution all-sky camera; the Chinese Small Telescope Array (CSTAR) consisting of four identical f/1.2 Schmidt telescopes on tracking mount; and a Near-Infrared Spectrograph (NIRSpec). During part of 2011 a meteorological tower also operated as part of the PLATO observatory, measuring temperatures and

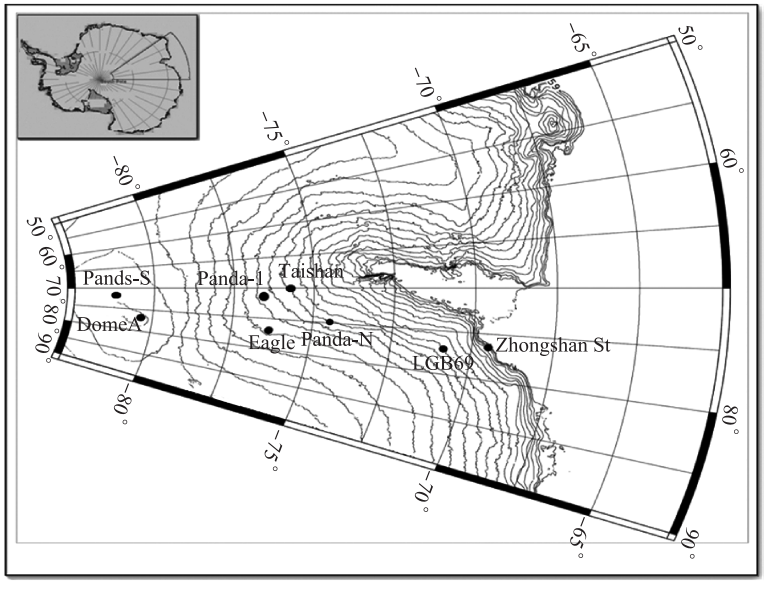

Figure 5 Location of AWS between Zhongshan Station and Dome-A.

wind speeds at eight elevations between the snow surface and 14.5 height.

PLATO-A runs without any human intervention on site. In fact, the closest person is over 950 km away and there is no possibility of any maintenance apart from during a 3-4 week window in January each year. PLATO-A has to generate its own electricity and heat, and is responsible for its own internet connectivity. Iridium satellite communication is used for monitoring and control, with the majority of the data being returned by the traverses each summer.

3.5 Cooperation in sea ice research

An important focus of the Australian research program, particularly after the establishment of the Antarctic Cooperative Research Centre in 1991 (later becoming the ACE CRC) and acquisition of the ice-capable research vessel *RSV Aurora Australis* in 1990, was on the role of Antarctic sea ice in the climate system and ecosystems. But the first Australian-Chinese collaboration on sea ice research took place in 1983. When Qian Songlin spent that year at the Australian Casey Station he investigated the growth and characteristics of the land-fast annual sea ice cover there[38-39].

China also commenced sea ice research programs when *Xuelong* became available, first in the Antarctic but then also, in 1999, in the Arctic. In 2000, Prof Kang Jiancheng, then with PRIC, joined a November-December ANARE voyage that involved a considerable sea ice research component. His mission was to exchange ideas that would help develop the CHINARE sea ice program. This voyage was onboard the ice-strengthened *MV Polar Bird*, not the ice-breaking *RSV Aurora Australis*. Following a period of strong winds on November 28, the vessel became beset in thick and heavily ridged first year cake ice and drifted slowly WNW for three weeks with the pack. Some, but not all of the science programs were successfully completed before the pack relaxed and the vessel was freed on December 19. Kang returned to collaborate on another ANARE sea ice research program in September-October 2003 onboard *RSV Aurora Australis*. This involved a "ground-truthing" survey of sea ice and snow cover conditions in the region bounded by 64°S-65°S and 112°E -119°E in order to validate new satellite sea ice sensing systems. Kang's participation on these voyages helped to develop China's Antarctic sea ice research[40], while the Arctic sea ice program was guided mostly by collaboration with Finnish institutions.

In September—October 2007, Li Zhijun and Wang Yongxue from the State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology, joined another major ANARE sea ice research cruise on *Aurora Australis*—the Sea Ice Physics and Ecosystem Experiment (SIPEX). This was a major Australian-led contribution to the International Polar Year 2007-2008. It investigated relationships between the physical sea ice environment and the structure of Southern Ocean ecosystems. The Chinese component of the program involved measurements investigating how the surface topographical roughness of the sea ice affected the wind drag coefficient, and hence the sea ice dynamics. The researchers were well experienced in this work, having made similar measurements in other parts of the Antarctic sera ice zone[41].

More recently, the National Marine Environment Forecasting Centre (NMEFC) of China, and the ACE CRC have agreed on a collaborative program of sea ice observation and forecasting in Antarctica to aid navigation (see Section 4).

3.6 Some additional examples of academic exchanges.

Many other academic exchanges between China and Australia have occurred in various fields of Antarctic research. Recent visits made by Chinese scientists to Hobart include that of Prof. Wen Jiahong, the director of the Department of Geography, Shanghai Normal University, who spent 3 months (May to August 2011) at ACE CRC undertaking cooperative research on the Amery Ice Shelf. Mr. Ling Xiaoliang, researcher from PRIC, visited the Australian Antarctic Data Centre (AADC), ADD in 2001. He learnt how the AADC operated and worked on data management initiatives there, helped with the development of an Antarctic Biodiversity Database for the SCAR project, Regional Sensitivity to Climate Change, and introduced Antarctic data management activities to China on his return. Dr. Xiao Cunde from the Chinese Academy of Meteorological Sciences, visited ACE CRC and AAD in January—February 2009 working on the analysis and interpretation of data obtained from automatic weather stations between Zhongshan Station and Dome A that are jointly operated by China and Australia.

In May 2015, Prof. Cheng Xiao attended the Council of Managers of National Antarctic Programs (COMNAP) Workshop on Sea Ice Changes jointly hosted by the AAD and the ACE CRC in Hobart. Prof. Cheng reported on navigational sea ice analysis for the Xuelong in Prydz Bay. He also showed videos of the work of one of his master students, Luo Sihan, on building a 3D model of the Larsemann Hills using data gathered from a fixed-wind UAV 'Polar Hawk -1', during CHINARE 31. Yuan Shaohong, (vice director of PRIC), Zhang Lin (Director of the Polar Environmental Research and Forecasting Division, NMEFC, SOA), Wang Jianzhong (Captain of *Xuelong*) and Wu Yilin (Consul of China in Sydney) also attended this workshop. After the workshop, Cheng Xiao discussed future cooperation in Antarctica with Richard Coleman, Director of the Australian Antarctic Gateway program, and with Matt King, the professor of Polar Geodesy and an Australian Research Council Future fellow.

In March 2015, the CEO of ACE CRC, Prof. Tony Worby visited Prof. Cheng Xiao's group at the Polar Research Centre of Beijing Normal University (PRC BNU), to further the implementation of the MoU between China and Australia on Cooperation in the field of Antarctic and Southern Ocean Affairs (Figure 6). Their discussions focused on developing bilateral cooperation in polar remote sensing, including personnel exchange, cooperative field work in Antarctic, and the use of communication satellites.

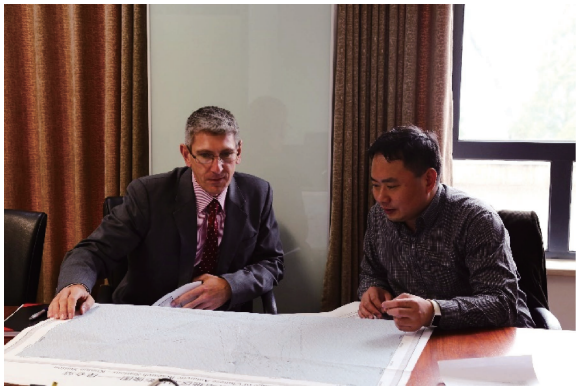

Figure 6 In Beijing, Tony Worby and Cheng Xiao discuss cooperation (Photo: PRC BNU).

These recent examples are just a few of the very many academic exchanges between Australian and Chinese Antarctic researchers to each other's home institutions. There are many others, particularly in the fields of biology and oceanography that are not discussed here.

4 Close ties strengthened by agreements

China and Australia are both Consultative Parties to the Antarctic Treaty, and they are also parties to the Protocol on Environmental Protection to the Antarctic Treaty and the Convention for the Conservation of Antarctic Marine Living Resource (CCAMLR). Within their bilateral cooperation on Antarctica and the Southern Ocean, China and Australia have signed a series of cooperation agreements for strengthening their relationship. For example, in June 2012, the CAA signed a Memorandum of Understanding (MoU) with the AAD during the 35th Antarctic Treaty Consultative Meeting held in Hobart (Figure 7).

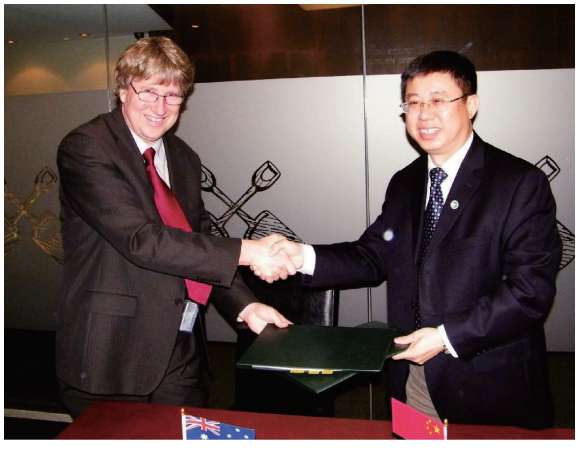

Figure 7 Tony Fleming, Director of the AAD, and Qu Tanzhou, Director of the CAA, sign a MoU at the Antarctic Treaty Consultative Meeting in June 2012 (Photo: AAD).

On the 25th August 2012, a MoU regarding Antarctic Astronomy was signed between Astronomy Australia Limited (AAL) and the Division for Basic Research of the Chinese Academy of Sciences in Beijing, during the International Astronomical Union's XXVIII General Assembly (Figure 8). This addresses current collaboration between astronomers in key areas of mutual scientific interest, as well as exploring future possibilities. It includes the use of data from the Chinese-led telescopes at Kunlun Station and supporting observations from Australian astronomical infrastructure.

Figure 8 Brian Schmidt (Nobel Laureate and Director, AAL) and Liu Minghua (Director for Basic Research, Chinese Academy of Sciences) sign the MoU, Beijing, 25 August 2012 (Photo: Michael Burton).

In September 2013, the administrator of China's State Oceanic Administration (SOA), Liu Cigui met with Lara Giddings, Premier of Tasmania, in Beijing, where they signed a MoU on Antarctic Gateway Cooperation between the Government of Tasmania and the SOA (Figure 9). This has the objective of developing closer future cooperation in research, supply services and international affairs. According to the MoU, Australia will provide logistic services for Chinese Antarctic Research Expeditions, and the opportunities for the Chinese Antarctic Research Expedition to use Hobart as a gateway would be maximized, thus also encouraging the exchange of personnel, procedures, goods and services in activities of common interest.

Figure 9 Lara Giddings, Premier of Tasmania, and Liu Cigui, Administrator of SOA, sign the MoU in Beijing in September 2013 (Photo: PRIC).

On November 18th 2014, during a visit to Hobart, President Xi Jinping of China and Prime Minister Tony

Abbott of Australia witnessed the signing ceremony of a MoU between the Government of the People's Republic of China and the Government of the Commonwealth of Australia on cooperation in the field of Antarctic and Southern Ocean affairs, as well as a schedule on Antarctic Gateway cooperation between the SOA and the Government of Tasmania. These broadened and deepened the bilateral Antarctic and Southern Ocean ties.

In November 2015, the director of NMEFC, Wang Hui, headed a delegation to visit the Australian Bureau of Meteorology (BoM), the AAD, IMAS, CSIRO and ACE CRC in Hobart. Under the witness of Tasmanian premier Will Hodgman, Wang Hui and Mark Kelleher, the deputy CEO of ACE CRC, signed a MoU between the NMEFC and ACE CRC (Figure 10). This established a cooperation mechanism associated with sea ice observation and forecasting in Antarctica to aid navigation. On signing this agreement, the two countries will share data used for forecasting sea ice conditions, strengthen personnel exchange and visits between the two countries, and together develop sea ice field observations and scientific methods to support the safe navigation of vessels in the Antarctic sea ice zone. The MoU will also help integrate the resources of both countries, and provide reliable sea ice analyses and forecasting to aid Antarctic shipping. Both the First Institute of Oceanography, SOA and the CAMS of CMA are formal participants in the ACE CRC in Hobart.

Figure 10 Wang Hui, Director of NMEFC, and Mark Kelleher, the Acting CEO of ACE CRC, sign a MoU on 15th November 2015 (Photo: ACE CRC).

5 The Christmas Day 2013 rescue of the Russian ship *MV Akademik Shokalskiy*

At 5:00 am on Christmas Day 2013, the Russian ship *MV Akademik Shokalskiy* with 52 scientists and tourists, and 22 crew members on board, issued a 'mayday' distress call to the Falmouth Maritime Rescue Coordination Centre (MRCC) in the United Kingdom. The vessel was on a (non-national) research expedition to Antarctica, when it became trapped in unusually heavy sea ice near Commonwealth Bay. Although only initially trapped for one day the ship, which was ice-strengthened but had no icebreaking capability, became endangered after a blizzard pushed sea ice around the ship, freezing it in place, and pushing the vessel towards the coast. The vessel's engine was not working and a seam had opened in the hull.

The Australian Maritime Safety Authority's (AMSA) Rescue Coordination Centre (RCC) assumed coordination of the incident and, at about 5:50 am, issued a call for assistance to vessels in the area. Three nearby ships (the AAD icebreaker *Aurora Australis*, the Chinese icebreaker *Xuelong*, and the French *Astrolabe*) responded and came to the aid of the trapped vessel in the remote location approximately 1500 nautical miles south of Hobart. *Xuelong* was the first to arrive and rammed through much of the sea ice until it came within six nautical miles of the stranded vessel. On January 2nd 2014, a Chinese helicopter from the *Xuelong* picked up the 52 scientists and tourists from the *Akademik Shokalskiy* in groups of 12 and flew them to the Aurora Australis (Figure 11). However, after the rescue on January 3rd, *Xuelong* itself became stuck in dense and extensive pack ice. China's National Commission for Disaster Reduction and National Marine Hazard Mitigation Service initiated an emergency response mechanism, and developed a rescue plan with help from other institutions. The SOA organized and attached great importance to the rescue of *Xuelong*, and its NMEFC provided accurate forecasting of sea ice conditions to assist the successful breakout of the vessel. On January 7th, a polar remote sensing group guided by Prof. Cheng Xiao from the PRC BNU and using analyses of sea ice conditions from various high-resolution satellite data, suggested that *Xuelong* should breakout in a southeast direction as the wind changed direction from an easterly to a north-westerly, also changing the direction of ice drift. Following this suggestion, *Xuelong* moved out of entrapment in only one hour; meanwhile the *Akademik Shokalskiy* also reached clear water on the same day. During this rescue, *Xuelong exchanged* information with the AMSA RCC every 6 hours, which helped guarantee the safety of all the vessels and coordinate the cooperation that achieved a successful rescue of *Akademik Shokalskiy*.

Figure 11 The CHINARE helicopter transporting rescued passengers from the *Akademik Shokalskiy* on 2nd January 2014 (Photo: Jessica Fitzpatrick, Commonwealth of Australia).

6 The 2014 visit of Chinese president Xi Jinping to Hobart coinciding with the visit of the Chinese polar vessel *Xuelong*

In November 2014, the *Xuelong*, undertaking CHINARE 31, berthed at Hobart port for its fourth time to replenish stores (Figure 12). This coincided with the historic visit of the Chinese president Xi Jinping to Hobart, providing further significance to the connection between *Xuelong* and Hobart. On November 18, President Xi Jinping, accompanied by Australian Prime Minister Tony Abbot, visited the Hobart waterfront and inspected displays of Australian Antarctic research equipment. Both leaders spoke via live video-link with scientists working in the Antarctic, at both China's Zhongshan Station and Australia's Davis Station. A MoU on Antarctic cooperation was signed in the presence of the President and Prime Minister, with an objective of comprehensive and in-depth collaboration between the two countries for continuing work in Antarctica. After the signing ceremony, President Xi and his wife Madame Peng Liyuan boarded the *Xuelong*, viewed an on-board exhibition celebrating the 30th anniversary of China's polar expeditions, and sent greetings to the crew members.

Figure 12 *Xuelong* berthed at Hobart on 18 November, 2014 (Photo: Tasmanian Government).

7 Concluding remarks

The vastness, isolation and extreme environment of the Antarctic region means that comprehensive research activities are best undertaken by multi-national collaboration, and such collaboration has long been a feature of Antarctic exploration and research. The collaboration between Australia and China in Antarctica, only a small fraction of which has been discussed here, has been ongoing for over 40 years. New initiatives and agreements will ensure this collaboration continues to be strong and to develop further into the future.

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