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Advance and key research outputs in China's Antarctic and Arctic science program—commemorating three decades of Chinese National Polar Research Expeditions

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Abstract The Chinese National Antarctic Research Expedition (CHINARE) was established and first reached the Antarctic in 1984. Up until 2017, China has undertaken 33 cruises to Antarctica, and seven cruises to the Arctic Ocean. The 30th anniversary of CHINARE was recently celebrated. This thematic issue of *Advances in Polar Science* contains seven papers reviewing outcomes of polar research during the last 30 years. The results from the CHINARE research program published in this and subsequent issues reflect the achievements and contributions of Chinese scientists to polar science.

Keywords China, Antarctic, Arctic Ocean, station, observation, cruise

It is now more than three decades since the first Chinese National Antarctic Research Expedition (CHINARE) reached Antarctica in 1984, and commenced China's direct involvement in polar scientific research. The rapid development and progress of the CHINARE program in the Antarctic and the Arctic is reflected by ongoing evolution and a greater research focus. In this and subsequent issues of *Advances in Polar Science*, the three decades of scientific achievement will be recognized in a number of papers reviewing outcomes from a wide range of research disciplines.

The Chinese polar stations Great Wall, Zhongshan Kunlun and Taishan in Antarctica, and Yellow River in the Arctic, were established in 1985, 1989, 1999, 2014, and 2004, respectively. The research vessels "*Xiangyanghong 10*", "*Jidi*" and "*Xuelong*" have successively carried out 33 cruises to the Antarctic and 7 cruises to the Arctic Ocean, undertaking multi-disciplinary observations which are ongoing.

Scientific research in many polar disciplines has been undertaken by surveys in the Arctic and Antarctic regions. These have included glaciology, oceanography, atmospheric science, geology, geophysics, geochemistry, biology and ecology, medicine, Antarctic astronomy, environment and engineering.

This special milestone review issue will be not only a valuable archive for Chinese scientists to overview Arctic and Antarctic research achievements and a guide to developing future science programs, but also of interest to the broader international polar community.

The review articles in this thematic issue include the following contributions.

Yang et al. (2017) review the Holocene climate change record, responses of the ecosystems to climate change, and the anthropogenic impacts on the environment based mainly on Chinese research from Ny-Ålesund. To better understand climate change and its driving mechanisms, long-term reconstructions throughout the Holocene and high-resolution records of the past few hundred years are required. Intense anthropogenic activities in the Arctic have also had a great impact on the local environment. Over recent decades, anthropogenic activities have caused serious pollution and deterioration to the local environment in areas of Svalbard frequented by people. The authors suggest that greater environmental protection is therefore needed to reduce the anthropogenic impacts on the local environment.

As is well documented, the Arctic Ocean and Arctic sea ice have undergone a series of rapid changes. Since 1999, oceanographic surveys have become one of the key missions of the Chinese National Arctic Research Expeditions. Cao et al. (2017) present the main results of research on Arctic water masses, currents, the structure of the upper ocean and other major hydrological phenomena over the past two decades, from physical oceanographic surveys.

Lei et al. (2017) summarize the results of research on Arctic sea ice physics from the Chinese National Arctic

Research Expedition (CHINARE-Arctic), mainly focusing on the Pacific sector of the Arctic Ocean. They utilize sea ice observations made from icebreaker, helicopter, small boat, ice floes and buoy platforms. Some new technologies have been developed, in particular, the underway auto-observing system for sea ice thickness using an electromagnetic instrument. Long-term measurement systems, such as sea ice mass balance buoys, allow observations to extend over the full year. Arctic sea ice observations have been used to verify remote sensing products, identify changes in Arctic sea ice, optimize the parameterizations of sea ice physical processes in models, and assess ship access in ice-covered waters, especially through the Northeast Passage.

In 2012 and 2014, the 5th and 6th CHINAREs-Arctic worked in the Bering Sea, the Arctic Ocean (including the Chukchi Sea), and the Norwegian Sea. Li et al. (2017) describe studies during these voyages aiming for a better understanding of the marine biology and ecology in the Arctic and sub-Arctic regions, particularly in the Pacific Arctic sector. Their results showed that rapid changes observed in the Arctic environment include the shrinking of cold-water masses in the Bering Sea in the summer, and elevated water temperatures promoting phytoplankton blooms, leading to an increase in phytoplankton transferred to higher trophic levels. As a result, the efficiency of transport of organic matter toward the ocean bottom weakened, leading to a reduction in benthic biomass. Influenced by Pacific water inflow, fluvial runoff and melting sea ice, the Chukchi Sea had different responses to various environmental changes. Interactions between water masses led to other interannual ecological shifts.

Li and Yang (2017) present the main results from zooplankton ecology studies conducted in Prydz Bay by Chinese researchers since 1989. These include: (1) a description of the biology and ecology of Antarctic krill (*Euphausia superba*), the key zooplankton species of the Southern Ocean ecosystem; (2) zooplankton community structure, including the horizontal distribution in the epipelagic region and vertical distribution between the surface and 1500 m; (3) the feeding ecology of dominant species such as Antarctic krill, salps and copepods; and (4) a short introduction to mitochondrial genome and DNA barcoding studies in Antarctica.

In the ice-free areas of Antarctica, lake and terrestrial sediments that contain penguin guano, seal excrement and other biological remains provide natural archives of ecological, geological and climatic information that range from hundreds to thousands of years old. The review by Yang et al. (2017) focuses on the paleoecology of typical Antarctic marine organisms (penguins, seals and Antarctic krill) and their responses to climate change over centennial and millennial timescales and, more recently, to human activities. They found that land-based seabirds and marine mammals played an important role in linking the marine and terrestrial ecosystems and act as bio-vectors, transporting large amounts of nutrients and contaminants from the ocean to the land.

Research into chemical oceanography of the Southern Ocean has been one of the key missions of CHINARE from 1984 to 2016. Chen et al. (2017) review the major progress in chemical oceanographic research, focusing on the sea-surface distribution and air–sea flux of CO_2 and N_2O, and investigations of the transport, flux and budget of organic matter using isotopes in the Southern Ocean, especially in Prydz Bay. They also outline the nutrient distribution and deep-water particle export in Prydz Bay, and aerosol heavy metal characteristics.

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