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Climate change: Impact on the Arctic, Antarctic and Tibetan Plateau

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Abstract The Arctic, Antarctic and Tibetan Plateau are very sensitive to global climate change. Hence, it is urgent that we improve our understanding of how they respond to climate change, and how those responses in turn affect both regional and global climate. Against a background of current global warming, the three poles display climate diversities temporarily and spatially, which to different degrees affect the weather and climate over China. Enhanced monitoring of climate change in these three areas, as well as connected work on the responses and feedbacks of the three regions to climate change, will provide necessary support for adaptation and the sustainable development of the Chinese economy.

Keywords **Three poles, Tibetan Plateau, climate change, global change, scientific research, climate change adaptation**

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0 Introduction

The Arctic, Antarctic and Tibetan Plateau are often called the three poles of the Earth, and are key regions for the study of global climate change in several international projects such as WCRP, IGBP[1–3]. Each successive IPCC report[4] has emphasized the importance of these three regions. The Arctic and Antarctic are very sensitive to global climate change. They affect global atmospheric circulation by affecting the temperature difference between the low and high latitudes, and they can affect weather and climate, too. The poles are also key to burying cold water which is transported to lower latitudes by the deep oceans as part of the thermohaline circulation. Sea ice at the poles displays great annual and seasonal variations, which also has important effects on global climate system[5–6] .

The "third pole", the Tibetan Plateau, is often called the "roof of the Earth" with an average elevation of more than 4 000 meters above sea level. It is mainly located in China, covering about one quarter of the Chinese continental area. The Plateau is different from the Arctic and Antarctic in elevation and latitude. It affects not only the weather and climate over China, but also the general atmospheric circulation over the East Asia[7–8]. The Arctic, Antarctic and the middle and lower latitude regions dominated by the Tibetan Plateau are mainly frigid deserts, and environ-changes there have the potential to have knock-on effects on global and regional climates.

Studies based at the poles, and orbiting satellites have recently yielded much atmospheric data, although there is less data from the Tibetan Plateau. Apart from value in their own right, studies of the atmosphere over the three poles also have a wider social value. The global atmosphere as a whole has interaction and interrelationship between at least three of the other parts of the global biogeosphere. The atmosphere also exchanges heat, momentum and moisture between the Northern and Southern Hemispheres. To understand the nature and impacts of global change, a study of climate change as exhibited by the atmosphere over these three regions should be undertaken[5].

1 Climate changes over the three poles of the Earth

The fourth assessment report of IPCC[4], on climate change pointed out that during the last 100 years (1906–2005), the average surface temperature of the Earth had increased by 0.74℃. Thus, global warming should be an indisputable

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fact. Against this backdrop, the climate and atmospheric environment over the Arctic, Antarctic and Tibetan Plateau have also have changed. For example, atmospheric temperatures, ice and snow cover, and stratospheric ozone have all experienced obvious and fast change.

1.1 "Unaami" in the Arctic

The so-called "Unaami" has undergone a rapid change during the last few decades[9]. "Unaami" means "Tomorrow" in the language of the Yup'ik Tribe who live in the Arctic Circle. Their description of the rapidly changing of climate and environment as "Tomorrow" is somehow like "unpredictable" or "uncontrollable". In some ways this is similar to how the term "El Nino" (Christ child) was used to indicate the anomalous warming of ocean waters near the western coast of South America, which attracts people's attention.

A maximum increase of air temperature at the ground surface of about 5℃ has occurred in parts of the Arctic, and the coverage of the sea ice has decreased by 2.9% (area) and about 3%–5%(thickness) per every 10 years during the 20th century. The melting of southern edge of the Greenland ice sheet has become very apparent with the loss of about 50 km^3 of ice per year, although there has been some increase of thickness over the middle of Greenland due to an increase of solid precipitation. The areas of snow cover and permafrost have decreased, with some permafrost melting. Snow cover over Eurasia had decreased about 10% during the last 30 years. The fresh water runoff, precipitation and snow melting have all increased, beginning a process that, if continued, will rebalance the global hydrological cycle. Under that scenario, the salinity of oceans will decrease. Over the last century, the temperature of some ocean waters have increased, for example the temperature of Atlantic intermediate water has increased by about 1℃[4].

The Arctic region has seen some of the most dramatic impacts of climate change with different warming trends in different periods. Between 1880 and 1938, warming was very rapid (especially between 1920 and 1940), reaching a maximum by the end of the 1930s. Temperatures during 1940 to 1970 decreased, and then increased again after the 1970s[10]. There was a similar peak between 1930 and 1950 in China[11]. At the Chinese Arctic Yellow River Station (78.93°N, 11.95°E, Altitude 11 m), located in the Svarbard (78.25°N, 15.47°E, Altitude 29 m) region, the temperature has increased by about 1.13℃ per decade (1980–2007). This is one of the highest rates of temperature increase recorded anywhere in the Arctic, see Figure 1.

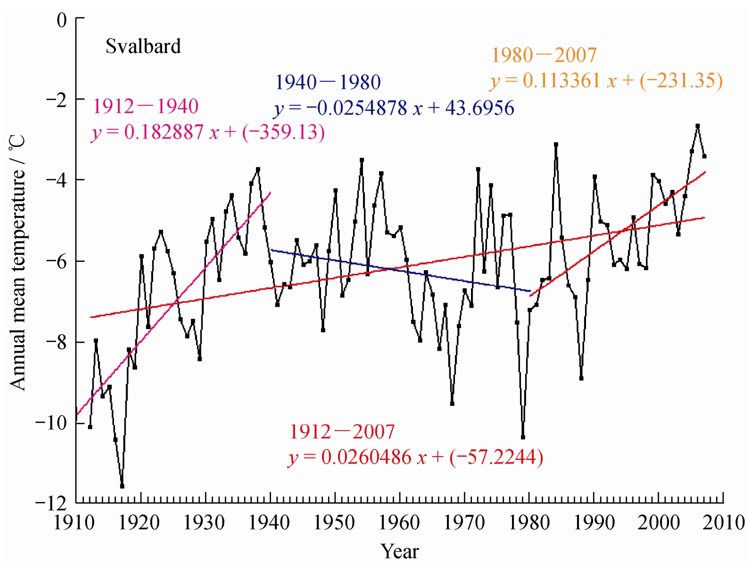

Figure 1 Variations of annual mean temperature (1912–2007) at the Svarbard region, Arctic (data from http://www.unaami.noaa.gov/analyses/sat/sat01008.d and courtesy of Alfred Wegener Institute, German).

1.2 Temporal and spatial diversity of climate change over the Antarctic

Antarctica was one region of the world where until relatively recently, there was little meteorological data, with only the Orcadas Station of Argentina having meteoro-logical data length longer than 100 years. This data shows awarming trend (1.93℃ per century) for the last 100 years. Like many other long term temperature records, the annual average temperatures of the mid 1950s was higher than those of the present, although the appearance of this peak in the Antarctic data is later than that in the

Arctic(Figure 2). After the International Geophysical Year (IGY) in 1957, there was a widespread realization that more data was needed from Antarctica. There is now much more meteorological (and other) data available. Data from other observational stations for the last 50 years has shown that the temperature at the Orcadas station does not represent the change over the whole of Antarctica. Temperature does not change uniformly over Antarctica[12–13].

For the last 50 years there has been an obvious temperature increase on the Antarctic Peninsula, such as at the Great Wall Station[14]. However, this is much greater than the average global warming value of 0.74℃. Furthermore, there has been a temperature decrease for the last 20 years over the East of Antarctica, such as at the Zhongshan Station, see Figure 3[14].

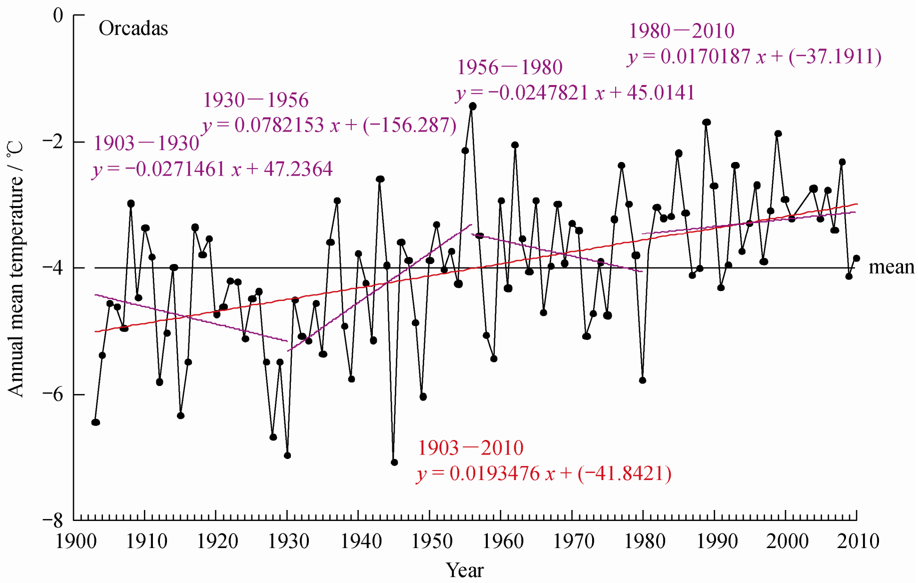

Figure 2 Variations of annual mean air temperature (1903–2009) at the Orcadas Station, Antarctica (data from http://www.antarctica.ac.uk/met/READER/).

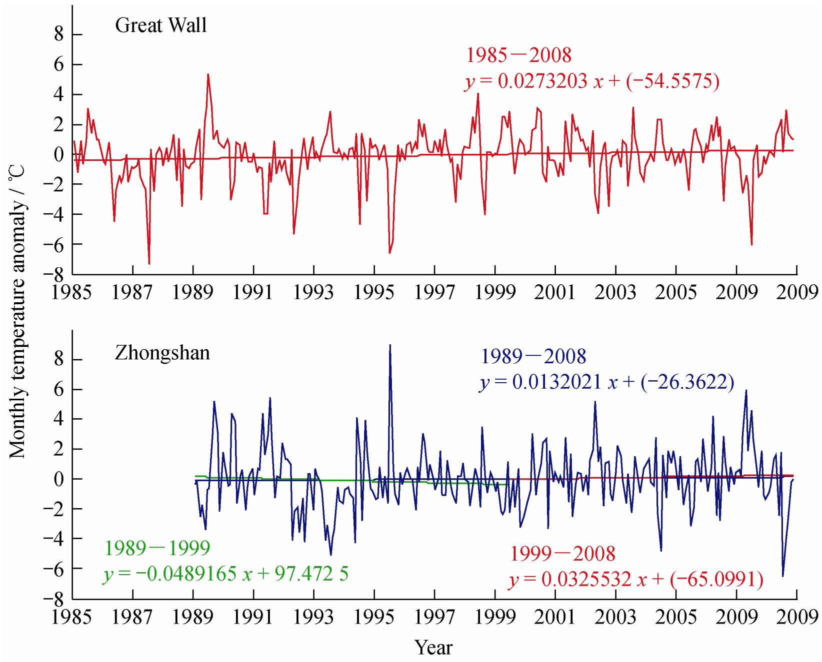

Figure 3 Variations of monthly mean air temperature at the Great Wall and Zhongshan Stations, Antarctica(data from Chinese National Arctic and Antarctic Data Center, http://www.chinare.org.cn/).

The ice shelf melting and collapse have often happened in West Antarctica, but this is not so in East Antarctica during recent years. Glaciological studies also show that the different Antarctic ice sheets are stable to different degrees. The Western Antarctic Ice Sheet is unstable, as recently ice added to it has been less than that lost. Whereas the Eastern Antarctic Ice Sheet remains stable and is now growing[7].

The changing trends of sea ice have also been different for the Arctic and Antarctic during the last 20 years. The sea ice coverage in the Arctic has shrunk at about 2.7% per decade, and summer sea ice at 7.4% per decade. This contrasts with that in the southern hemisphere where the average annual change has been very small: indeed, over the last 20 years, sea-ice has been increasing[4] .

This underlines the point that the dynamics of global climate change, of which global warming is but a part, are complex. Hence interpreting temperature changes in the Arctic and Antarctic is not straightforward. There is an urgent need to understand the different climatological significance of long and short term trends of temperature changes in the Arctic and Antarctica[12–13].

1.3 Climate change on the Tibetan Plateau

Against the background of global warming, great environment change is taking place on the Tibetan Plateau. In the 20th century, the warmest period for the Tibetan Plateau was during the 1940s. Since that time, the air temperature decreased until the mid-1960s, and then increased again. This pattern is consistent with that from other regions of China[11], and not dissimilar to that in the Arctic. On the Tibetan Plateau, the climate is clearly warming, at an average rate of about 0.52℃ per decade (at Lhasa from 1963 to 2009). This is greater than both the global average as well as that of the Arctic, see Figure 4.

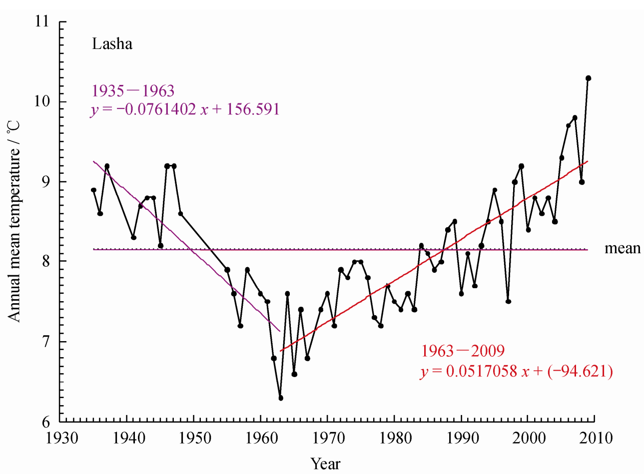

Figure 4 Annual air temperature variations (1935–2009) at the Lhasa Station, Tibetan Plateau, China(data from China Meteorological Data Sharing service System, http://cdc.cma.gov.cn/).

While most of the glaciers on the plateau are shrinking, some are expanding by between 5% and 20%. The behavior of glaciers in western China is quite different from that in other regions. Glacial melting has increased since 1980s resulting in a 10% to 13% increase of runoff over Northwest China. The frozen soils and permafrosts of the Tibetan Plateau and Northeast and Northern China are shrinking[7].

Since the 1960s, climate change on the Tibetan Plateau has not been uniform having different spatial and temporal characteristics. The Plateau has areas where the temperature is increasing, others where it is decreasing, and in some places both trends are apparent at different times. Temperature changes are not always consistent with altitude, and the relationship between temperature and precipitation change is also not the same across the Plateau. To exemplify this complexity, there is a belt of decreasing precipitation across the Plateau from the southwest to northeast. In the southeast region below 3 000 m, the air temperature is increasing and the precipitation is falling. However above 3 000 m the trend reverses toward the center and the west of the region. On the other hand, in the North and South, it is warming with increasing precipitation, except in the Southeast where below 3 000 m it is becoming cooler and drier[11].

1.4 Changes in stratospheric ozone in spring in the Antarctic

In 1984 and 1985, Japanese and British scientists discovered that the total amount of ozone over the Antarctic fell dramatically with the onset of spring. The change was so dramatic that compared to that over surrounding areas, it appeared that there was a hole in the amount of ozone over Antarctica, and it was thus called the Antarctic Ozone Hole. This phenomenon is caused by the onset of photochemistry (after the long Antarctic winter) on the surfaces of aerosol droplets that make up Polar Stratospheric Clouds. In the Antarctic winter, when stratospheric temperatures are at their lowest, CFC molecules adsorb onto the droplet surfaces. The advent of sunrise provides energy and the CFCs are broken apart, destroying ozone in the process. The “hole” does not appear all year around, but only occurs in the Austral Spring. Generally, Antarctic ozone starts to fall from about 20 July, and the ozone “hole” becomes obvious by the middle of August. The area of the hole reaches a maximum from about 20 September to about 10 October. By the end of October, with the increase of ozone, the hole is gradually closed and by the middle of December it disappears[15].

Antarctic atmospheric ozone first began to fall in about 1970, after which there was a loss trend of about －2.9% per decade[15]. Although the change trend of the total amount of atmospheric ozone over the Antarctic is the same as that for the global trend (it only occurs over the Antarctic), it has had its own characteristics[13]. The maximum area of the Antarctic ozone hole has exceeded 28 million km^2 (in 2000), equivalent to three times the area of China, and covering the whole of Antarctica. The depletion of the total amount of ozone in the center has been about 70% less than normal, whereas the minimum area has been 3 million km^2 less (in 2002); this was 1/7 of the average for the last 10 years[16]. Both the observational data of the atmospheric ozone at the Chinese Antarctic Zhongshan Station in and the satellite-retrieved data are consistent with the above changes (see Figure 5)[14].

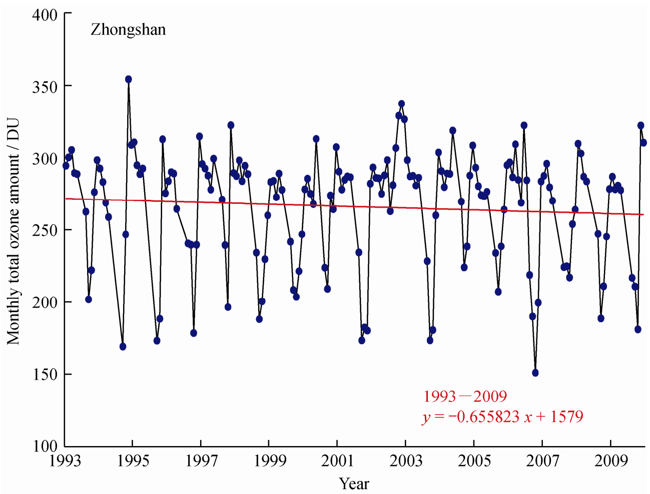

Figure 5 Variations of monthly total ozone amount at Zhongshan Station between 1993 and 2009 (data from Chinese National Arctic and Antarctic Data Center, http://www.chinare.org.cn/).

The CFCs and Halons, etc. (including chlorine and Bromine) emitted into the atmosphere by human activities damage the substance in ozone layer. When the photochemical reaction takes place between the emitted gases with the PSCs and liquid sulfate aerosols, a great amount of ozone will be consumed. The PSCs and liquid sulfate aerosols can be formed under the temperature below −78℃. Therefore, the CFCs and Halons, etc. (human factors) emitted by human activities is a sufficient condition for the formation of Antarctic ozone hole, whereas the low temperature (nature factors) in Antarctic vertex in spring is a necessary condition.

The ozone hole appears over the Antarctic in spring, but not over the Arctic or Tibetan Plateau. The air temperatures in the stratosphere over Antarctica are colder than those above any other place, hence it is the only place where there are sufficient polar stratospheric clouds to form an ozone hole. For both the Tibetan Plateau and Arctic, there can be some reduction of ozone in summer, but these are due to different mechanisms and are incomparable to the ozone hole over the Antarctic[17].

1.5 Climate change information provided by ice cores at the three poles

Ice sheets in Polar Regions, mountain glaciers and lake, ocean and terrestrial sediments can contain detailed records of past climates. These records are often the major source of information on how climate has changed in remote and extreme regions.

By studying the chemical and isotopic composition of the ice and air bubbles within it, scientists from many countries have obtained much data on past climates. In the Antarctic, palaeo-data of temperature, ice volume, atmospheric state, marine biological state, and the atmospheric concentration of carbon dioxide, methane, etc. have been extracted using deep-hole ice cores from the Antarctic Orient Station, Dome C and Dome F, with a data length about 420 000, 740 000 and 330 000 years, respectively[4, 7]. From the Arctic, a record of climate and environment change for the past 250 000 year has been obtained[7] from the Greenland ice cores. From the glaciers on the northern, southern and central parts of the Tibetan Plateau and the Pamirs, ice core data is available that shows palaeoclimatic data since the last interglacial. The ice-cores from all three poles are recording global as well as local events, so their records are individual in detail, but consistent and congruent with each other. However the Tibetan Plateau records lower latitude data, and hence gives greater detail and sensitivity[7].

Consistent with the Milankovitc Theory of orbital variation, these records show climate variation on the 10 000, 45 000, and 23 000 year timescales. Changes in the Earth’s orbital eccentricity, obliquity and precession mean that the amount of heat received from the sun by different areas varies. This variation gives rise to glacial and interglacial periods both regionally and globally. There are differences between the different ice core records which are the result of the local setting of the ice core[4].

Chinese scientists have successfully collected the samples of marine deposits and lake sediments in the Southern Ross Sea in East Antarctica, Chinese Great Wall Station and Zhongshan Station. They have conducted the geochemical analysis, and reconstructed the relative temperature changes and the annual average precipitation record back until 4 000 years ago. Using cluster analysis on the elements from lake sediments and penguin dung, as well as radiochemical dating, historic penguin populations have been estimated, and correlated with the past climates (temperatures) in which they lived[18].

2 The impacts of the atmospheric environmental change on the atmospheric circulation over East Asia and the weather and climate over China

As parts of the global biogeosphere, the three poles respond to climate drivers (e.g. solar insolation, greenhouse gas concentrations, etc.), and those responses can themselves further affect or modify climate in other parts of the globe. The degrees of interconnected feed-back loops that comprise the global climate system are currently a matter of keen interest to climate scientists. So the atmospheric environmental changes over Polar Regions, especially changes in temperature, ice/snow amounts and cover, and the polar atmospheric circulation and oscillations, have important effects on the atmospheric circulation over the East Asia, and hence the weather and climate experienced in China. In the same way, the amount of accumulated snow cover on Antarctica seems linked with the Meiyu over the Yangtze River and cooler summer temperatures in Northeast China. The amount of Antarctic sea ice is related to the polar vortex index, which is linked to other parts of the biogeosphere, e.g. ocean temperatures at the equator, the subtropical high over the Western Pacific, and typhoon and monsoon cycles[5–6].

This inter-connectedness means that changes in one part of the system can affect climates in other places apparently remote from the initial cause. The North Atlantic and Arctic Oscillations, ENSO events and winter sea-ice changes in the Barents and Kaka Seas seem to have a close relation with the inter-annual and inter-decadal changes of climate over China and changes in the winter monsoon over East Asia. Hence, changes in polar regions can affect the regional weather and climate over China. The polar sea ice and oscillation can be used to predict changes of the atmosphere circulation over East Asia and hence the weather and climate over China[19].

Like the Arctic and Antarctic, the Tibetan Plateau is also a key region responding to global changes and thus in turn affecting the weather and climate over China. The temporal and spatial changes of snow cover on the Plateau correlate with changes the general atmospheric circulation because of their effects on thermal differences. Hence, anomalous snow cover on the Plateau affects precipitation over China. The thickness of snow cover in winter is closely related with the North Atlantic Oscillation and the ENSO, variations of winter and summer monsoons, the drought and flood in the middle and lower reaches of the Yangtze River. If the Plateau has heavy snow in winter, the northward shift of the subtropical high in summer over the West Pacific will be delayed, causing the main rainfall belt to stay south, leading to more precipitation in the region near the Yangtze River[8].

3 Conclusions

Both inside and outside of China, the study and investigation of the three poles started within the time-frame of the recent global change. The Arctic, Antarctic and Tibetan Plateau are regions sensitive to global climate and climate change. Against the backdrop of global warming, changes in the climate and environment of the three poles implies that the weather and climate over China will also change. Hence an understanding of those changes will support the sustainable development of the Chinese economy.

Although global warming has become largely indisputable, the reasons underlying those changes are complex. Over the last century or so the evidence for increasing temperatures is abundant; however, over the last 10 years that change has slowed[20]. The IPCC is unequivocal[4] that the increase of average temperatures observed during the last 50 years over most of the globe is related with the rapid increase of the green-house gases in the atmosphere, and hence human activities. Some small climate skeptic organizations disagree with the global consensus of scientists and insist that either climate change is not happening, or that the observed changes are caused by natural (non anthropogenic) causes[21]. The complexity of the results of climate change over individual areas, for example the three extreme regions in this study, make it difficult for any one person to have a complete picture. Therefore, the community should judge the reasons and effects of the global warming based on scientific results and observed facts.

The environments of the three extreme regions in this study are less polluted and affected by human activities than many others. The atmospheric chemical properties at these background sites are very important as a benchmark against which to judge anthropogenic impacts. The study of the environment, and the way it is changing is crucial to provide benchmarks for governments to make polices, as well as protect their own economic development. Climate change is not only a scientific issue, but also an environmental issue, an energy issue, an economic issue, and of course a political issue. There will always be a tension between economic growth and environment.

Further international collaboration to study the three extreme regions discussed in this work should be facilitated. Field investigations, as well as modeling, need to take place to increase our understanding of the responses and feedbacks of the three poles to global change. These will provide scientific information to guide policymakers in their response to climate change and assist sustainable economic development.

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References

1 GARP. The physical basis of climate and climate modeling. GARP

Publication Series, 1975, No: 16.WMO/ICSU
2 IGBP. Towards global sustainability. IGBP Science Series, 2001, 4: 27–29
3 SCAR. Antarctic Climate Change and Environment. Published by the Scientific Committee on Antarctic Research, Scott Polar Research Institute, Lend field Road, Cambridge, UK, 2009
4 IPCC. Climate Change 2007, the Physical Scientific Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, UK: Cambridge University Press, 2007: 1009
5 Lu L H, Bian L G. Polar regions play on the earth system. Sun Jiulin and Lin hai, Chief Editors. Research on the earth system and scientific data. Beijing: Science Press, 2009: 414–433 (In Chinese)
6 Gao D Y, Zou H, Zhou L B, et al. Expedition research and prospect on atmospheric sciences in the Polar Regions. Chinese Journal of Atmospheric Sciences, 2008, 32(4): 882–892 (In Chinese with English abstract)
7 Qin D H, Xiao C D, Ding Y J, et al. Progress on cryospheric studies by international and Chinese communities and perspectives. Journal of Applied Meteorological Science, 2006, 17(6): 649–656 (In Chinese with English abstract)
8 Lu L H, Bian L G, Xiao C D. Progress on Chinese cryospheric and polar meteorological studies in the passed 30 Years. Chinese Meteorological Society Edition. Review and prospect of atmospheric scientific study. Beijing: China Meteorological Press, 2008: 1–22 (In Chinese)
9 SEARCH SSC. SEARCH：Study of environmental arctic change, science plan. Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, 2001: 89
10 Polyakov I V, Roman V B, Genrikh V A, et al. Variability and trends of air temperature and pressure in the maritime Arctic, 1875–2000. Journal of Climate, 2003, 16: 2067–2077
11 Zhu W Q, Chen L X, Zhou Z J. Several characteristics of contemporary climate change in the Tibetan Plateau. Science in China (series D), 2001, 44(Supp): 410–420
12 Lu L H, Bian L G, Jia P Q. The temporal and spatial characteristics of the surface air temperature variations over the Antarctic and its surrounding area. Science in China (series D), 1997, 40(4): 432–438
13 Zhou X J, Lu L H, Bian L G, et al. Recent variations of Antarctic temperature, sea ice and ozone. Chinese Journal of Polar Science, 1999, 10(1): 1–9
14 Lu L H, Bian L G, Cheng Y J. Chinese Antarctic meteorological expedition and research on global change. Earth Science Frontiers, 2002, 9(2): 255–262 (In Chinese with English abstract)
15 Zhou X J, Lu L H(Chief Editors). Research of the interactions and impact between Antarctica and global climate and environment. Beijing: China Meteorological Press, 1996: 1–402 (In Chinese)
16 Lu L H. The new discovery of Antarctic ozone hole. Meteorological Knowledge, 2002(6): 4–7(In Chinese)
17 Lu L H. The Antarctic ozone hole and environmental protection. Science(KEXUE).2008, 60(2): 15–18 (In Chinese with English abstract)
18 Sun L G, Xie Z Q, Liu X D, et al. Eco-geology in the ice-free area, Antarctica. Beijing: Science Press, 2006: 1–306 (In Chinese)
19 Lu L H, Bian L G, Xiao C D, et al. Recent two decades progresses in study on atmospheric sciences of the polar regions. Acta Meteorologica Sinica, 2004, 62(5): 672–691 (In Chinese with English abstract)
20 Kerr R A. What happened to global warming? Scientists say just wait a bit. Science, 2009, 326: 28–29
21 Singer S F. Nature, not human activity, rules the climate: summary for policymakers of the report of the Nongovernmental International Panel on Climate Change. Chicago: The Heartland Institute, 2008