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Temperature variation and its driving forces over the Antarctic coastal regions in the past 250 years

作者: ZHANG Mingjun REN Jiawen

By comparing the oxygen isotopic temperatures recorded by many shallow ice cores from the coastal regions of Antarctica, this paper presents the special characteristics of the temperature variations over the Antarctic coastal regions in the past 50 years, 150 years and 250 years. In the past 50 years, the isotopic temperatures recorded in the ice cores over different sites on the Antarctic coastal regions differ greatly. For instance, although increasing isotopic temperatures have been reported for many sites studied, many sites show decreasing trends, the regional regularity in temperature variations is still insignificant. In the past 150 years, the isotopic temperature trends in the coastal regions of Antarctica show an alternate-distributing pattern. In the past 250 years, all the ice cores from the coastal regions of Antarctica have recorded the so-called Little Ice Age (LIA). The above-mentioned spatial characteristics of the temperature variations over the Antarctic coastal regions are likely to reflect the impacts of the unique Southern Hemisphere atmospheric circulation, the Antarctic Circumpolar Wave (ACW) and the special terrain (such as the large drainage basins) on the coastal regions of Antarctica. Furthermore, the impacting intensity of the unique Southern Hemisphere atmospheric circulation, the Antarctic Circumpolar Wave and the special terrain differs in terms of the temporal scale of the temperature change.

ZHANG Mingjun1, 2, REN Jiawen2, CHENG Guodong2, LI Zhongqin2, XIAO Cunde2, QIN Dahe2, KANG Jiancheng3, LI Jun4 (1. College of Geography and Environment, Northwest Normal University, Lanzhou 730070, China; 2. Cold and Arid Regions Environmental and Engineering Research Institute, CAS, Lanzhou 730000, China; 3. Chinese Institute of Polar Research, Shanghai 200129, China; 4. Antarctic Cooperation Research Center and Australian Antarctic Division, Hobart 7001, Australia) 1 Introduction Description and understanding of the physical mechanism of climate change on seasonal, interannual, decadal and centennial scales and extending the range and improving the precision of climate forecast on seasonal and interannual scales by developing global coupling climate model, is one of the keystones to study climate change. Due to lack of meteorological data, it is difficult to study climate change over Antarctica. So far, neither the short temporal history and mechanism of climate change over Antarctica, nor the responses of the climate change over Antarctica to it over low- and mid-latitude regions have not been fully recognized. Therefore, it is important to extract high-resolution climate information from shallow ice cores to study climate change over Antarctica. From its original formulation in 1990, the International Trans-Antarctic Scientific Expedition (ITASE) has had as its primary aim the collection and interpretation of a continental-wide array of environmental parameters assembled through the coordinated efforts of scientists from several nations. The primary planned product of this cooperative endeavor is the description and understanding of environmental change in Antarctica over the last 200 years. As a demonstration of the importance of the original scientific objectives posed by ITASE, they were adopted as a key science initiative by both the International Geosphere-Biosphere Program (IGBP) and the Scientific Committee on Antarctic Research (SCAR) (US ITASE, 1988). In the past ten years, many ice cores have been drilled from Antarctica with the implementation of ITASE, such as America in West Antarctica, European countries in Dronning Maud Land, Japan in Mizuho Plateau and Australia in Lambert Glacier Basin. Based on the data of the ice cores, the features of the climatic changes in the main geographical regions in Antarctica have been concluded. However, scientists are puzzled by the features of the climatic changes in the main geographical regions in Antarctica over a hundred years. For instance, although increasing accumulation rates have been reported for many sites, several sites show decreasing trends. A similar situation is apparent

for the isotope temperature records (Bindschadler et al., 1993; Graf et al., 1990; Isaksson and Karlen, 1994; Jones, 1995; Kamada et al., 1990; Morgan et al., 1991; Mosley-Thompson et al., 1995; Peel and Mulvaney, 1988; Pourchet et al., 1983; Ren et al., 1999; Xiao et al., 2001). When studying on the reasons of the climatic variations in Antarctica, researchers found some climatic variations have been related to ENSO events, however, others have not been related to them. Therefore, it is important to address the following questions: How does climate vary over Antarctica on decadal and centennial scales, and what are the controls on this variability? China is one of the members of ITASE countries. Since 1996/97 Chinese First Antarctic Inland Expedition, three Chinese Antarctic Inland Expeditions from Zhongshan Station to Dome A have been carried out, and five ice cores covering depths of 50 m to 100 m have been drilled (Qin et al., 2000). These ice cores extend back to 200 to 1000 years ago; the resolution of the ice cores from coastal regions of Antarctica may be seasons to years, however, the resolution of the ice cores from inland regions of Antarctica may be years to decades. By comparing the oxygen isotopic temperatures recorded by ice cores recovered from the routes of Chinese Antarctic Inland Expeditions with the other oxygen isotope temperature records from coastal regions of Antarctica, this paper presents the special characteristics of the temperature variations over the Antarctic coastal regions in the past 50 years, 150 years and 250 years and tries to interpret the controls on the temperature variations. 2 Data sources Series of cores have been extracted at the sites of DT001, DT085, LGB16, MGA and GC30 by Chinese scientists or by Chinese and Australian scientists jointly, other data of the ice cores come from references. The ice core drilling, sapling, analysis and dating are discussed in detail (Aristarain et al., 1990; Goodwin, 1991; Isaksson and Karlen, 1994; Isaksson et al., 1996; Li et al., 1999; Mosley-Thompson, 1992; Oerter et al., 1999; Qin and Wang, 1990; Ren et al., 1999; Satow and Watanabe, 1990; Stenni et al., 1999; Zhang et al., 2001; 2002a). Figure 1 shows the location of ice core sites discussed in the text. 3 Spatial characteristics of the temperature variations over the Antarctic coastal regions in the past 50 years Dramatic warming of both hemispheres during the past century has been evidenced by both observation and stimulations (Fyfe et al., 1999; Wu et al., 1999). Despite the overall increasing trends of both temperature and accumulation rate for the past century and the forthcoming decades, isotopic temperature and accumulation rate recorded in the ice cores over different sites on Antarctic ice sheet differ greatly (Isaksson and Karlen, 1994; Ren et al., 1999; Xiao et al., 2001). For instance, although increasing accumulation rates have been reported for many sites studied, several sites show decreasing trends. A similar situation is apparent for the isotopic temperature records. The complexity has been evidenced not only by ice cores, but also by the instrumental records at meteorological stations all over the continent (Jones, 1995). Taking the isotopic temperature variations in the past 50 years over the Lambert Glacier Basin (LGB) as an example (Figure 2), temperature trends at the eastern LGB were increasing in the past 50 years, but at the western LGB the situation was much more complex. The most remarkable feature is that, although the increasing rate at western DML was similar to those at the eastern LGB, the decreasing or constant temperature trends were found at Kamp Land and Mizuho Plateau. Instrumental temperature records at coastal stations also confirm this complexity (Xiao et al., 2002). Making a comprehensive view of the isotopic records of the ice core from coastal regions of Antarctica (Jones, 1995; Lu et al., 1997), the temperature trends recorded in the ice cores over different sites on the Antarctic coastal regions are much different and complex. 4 Spatial characteristics of the temperature variations over the Antarctic coastal regions in the past 150 years Both hemispheric and global annual surface air temperatures show increasing trend in the past 150 years based on the studies of global meteorological data (Jones et al., 1999). However, due to lack of meteorological data in Antarctica, the temperature variations in the past 150 years in Antarctica were not included in the study. Therefore, it is significant to recover the past temperature features of Antarctica to study the temperature variations of the Globe, especially the Southern Hemisphere. Making a comprehensive view of the isotopic records of the ice cores from coastal regions of Antarctica (Figure 4), we can see that, most of isotopic temperature records of the ice cores show warming trend in the past 150 years; however, the records from Antarctic Peninsula and Princess Elizabeth Land show a decline trend of temperature. The preliminary results of the oxygen isotopic temperature in the firn core collected from Princess Elizabeth Land of East Antarctica during 1997-1998 Chinese Second Antarctic Inland Expedition show similar decreasing trend during the period 1860-1996 (with Dr. Xiao personal communication). Figures 1 and 4 show that the isotopic temperature trends in the coastal regions of Antarctica in the past 150 years show an alternate-distributing pattern. 5 Spatial characteristics of the temperature variations over the Antarctic coastal regions in the past 250 years In the past 250 years, the most remarkable climatic event was the so-called Little Ice Age (LIA). This "colder" period was reconstructed from Northern Hemisphere temperatures and proxy records (Groveman and Landsberg, 1979). Lamb placed this episode between 1550 and 1850 AD (Lamb, 1977). From a series of proxy data of different origin, Jones and Bradley (1992) argued that the LIA was characterized not by a single long-lasting cold period but by a number of colder intervals. M

oreover, the coldest periods do not coincide between different geographical regions, and the temporal distribution va ries from one area to another (Stenni et al., 1999). From Figure 4, we can see that all the ice cores from the coasta l regions of Antarctica record the Little Ice Age (Mosley-Thompson, 1992; Mosley-Thompson et al., 1990; Stenni et a l., 1999). 6 Analysis and conclusions The possible reasons for the complexity of the temperature variations over the Antarctic ice sheet are obtained as follows. There is a lack of high/low latitude link particularly due to the natur e of the Southern Hemisphere atmospheric circulation. It does not favor strong north-south energy exchange, due to th e relatively small meridional amplitude of the long waves and to the strong circum-polar circulation around Antarcti c continent. Studies show that the climate change over the coastal regions of the east Antarctic ice sheet may have a close connection with the climatic variation over the Southern Ocean (Xiao et al., 2001; 2002). In the past severa l years, a phenomenon called Antarctic Circumpolar Wave (ACW) was found by oceanographers (White and Peterson, 199 6). ACW is a phenomenon that transmits climate anomalies around the Globe induced by the circum-polar circulation. Th e climate anomalies include sea surface temperature (SSTs), sea level pressure (SLP), meridional wind stress (MWS), s ea ice extent (SST), etc. Studies show the anomalies of sea and air of the Southern Hemisphere such as ENSO can be ca rried to the circum-polar circulation, which caused the anomalies of the temperature and pressure in alternate distri bution around the Southern Ocean (Figure 5). This distributing pattern may affect the coastal regions of Antarctica a nd cause the climate in the coastal regions showing obviously regional differences. The temperature variations record ed by ice cores over the Antarctic coastal regions in the past 50 years, 150 years and 250 years are likely to reflec t the impacts of the unique South Hemisphere atmospheric circulation, the Antarctic Circumpolar Wave (ACW) and the sp ecial terrain (such as the large drainage basins) on the coastal regions of Antarctica. From the spatial characterist ics of the temperature trends over the Antarctic coastal regions in the past 50 years, 150 years and 250 years, we ca n see that, on the time scale of 50 years, the special terrain (such as the large drainage basins) may be the most im portant factor affecting the temperature trends, therefore, the temperature trends recorded in the ice cores over dif ferent sites on the Antarctic coastal regions are much more different and complex. On the time scale of 150 years, th e Antarctic Circumpolar Wave (ACW) may be the main factor which determines the temperature variations over the Antarc tic coastal regions and causes the isotopic temperature trends showing an alternate-distributing pattern (Zhang et a l., 2002b). However, in the Little Ice Age, all the ice cores from the coastal regions of Antarctica recorded it. The refore, the unique Southern Hemisphere atmospheric circulation, even the global atmospheric circulation, may mainly a ffect the Little Ice Age event recorded by ice cores from Antarctica. All in all, the impacting intensity of the uniq ue Southern Hemisphere atmospheric circulation, the Antarctic Circumpolar Wave and the special terrain differs in ter ms of the temporal scale of the temperature change. As have been noted, the above-mentioned discussion is only the pr eliminary study on the spatial characteristics of the temperature variations and their driving forces over the Antarc tic coastal regions on the time scale of a hundred years. With the implementation of the International Trans-Antarcti c Scientific Expedition (ITASE), especially for further studies on the series of ice cores recovered from the route o f Chinese ITASE, the reasons for the temperature variations over Antarctica may be fully understood.

关键词： Antarctica; ice core; temperature; terrain; Antarctic Circumpolar Wave (ACW); circumpolar circulation

