·Article ·

Advances in Polar Science

doi: 10.3724/SP.J.1085.2011.00042

March 2011 Vol.22 No.1: 42–48

Temperature variations at the Great Wall and Zhongshan stations

BIAN LinGen[1*], MA YongFeng[1,2], LU ChangGui[1] & LU LongHua[1]

[1] Chinese Academy of Meteorological Sciences, Beijing 100081, China;
[2] College of Earth Science, Graduate University of Chinese Academy of Sciences, Beijing 100049, China

Received October 12, 2010; accepted November 27, 2010

Abstract Surface meteorological observations have been carried out at the Great Wall station (GW) and Zhongshan station (ZS) from 1984 to 2008 and from 1989 to 2008 respectively. The variation in mean air temperature and its trends are derived from the meteorological observation data recorded at both stations. The warming rate of the annual mean temperature at GW is similar to that at Bellingshausen station, which is about 3 km distant. Thus, the warming trend is representative of the King George Island region. The warming rate of ZS is less different from that at Davis station,which is about 100 km from ZS. It can be said that the meteorological data recorded at both stations are representative of the regions of the King George Island and east coast of the Antarctic.

Keywords **Chinese Antarctic station, Meteorological observation, air temperature, trend**

Citation: Bian L G, Ma Y F, Lu C G, et al. Temperature variations at the Great Wall and Zhongshan stations. Adv Polar Sci, 2011, 22: 42—48, doi: 10. 3724/SP. J. 1085. 2011. 00042

0 Introduction

There are basically no continual meteorological observation data for Antarctica before the International Geophysical Year of 1957—1958. Observation data recorded since then have showed that the temperature in most regions of Antarctica has been stable; in particular, the long-term records of two stations (Amundsen–Scott and Vostok) on the inland plateau of the Antarctic continent do not have an apparent warming or cooling trend. The IPCC[1] report pointed out that, in the past 50 years, the western coastline of the Antarctic Peninsula has undergone some of the severest warming worldwide. The annual mean temperature is increasing by 0.28℃/10a and the winter mean temperature by nearly 0.3℃/10a. Warming over the eastern coastline of the Antarctic Peninsula is fairly slow, with the faster warming seasons being summer and autumn. At present, a climate model is not yet available to simulate the warming phenomenon observed in Antarctic Peninsula over the past 50 years. The cause for the temperature rise in this region is a matter of debate. The warming resulting from human activity is related with the change of atmospheric circulation in Southern Hemisphere and continual retreat of sea ice in the Bellingshausen Sea, as well temperature rising in the neighboring sea area, and the loss of Antarctic ozone in the spring driving the change in circulation[2–4]. The warming in Antarctic Peninsula greatly affects the environment and ecological environment of the Antarctic Peninsula, and has become one of the key issues in research on global warming. Through the division of climate regions, it has been pointed that climate change in Antarctica and its surrounds has obviously differed from the change in the global mean temperature in space and time[5–6]. The differences of temperature change has been presented using the monthly mean temperature recorded at the Zhongshan Station and Davis Station of Australia in 1989－1999. It is seen that the temperature change in Prydz Bay has an apparent negative trend[7]. Wang et al. pointed out that annual temperature change at Larsman Hill features a coreless winter and pointed summer; the variation in monthly mean temperature is closely related to the high surface pressure of the Antarctic continent and the location and range of low-pressure system center [8].

* Corresponding author (email: blg@cams.cma.gov.cn)

The Great Wall Meteorology Station (62°13' S, 58°58' W, 10 m above sea level) was established on King George Island of the western subantarctic in February 1985 by the first Chinese National Antarctic Expedition. In February 1989, a Chinese Natinal Antarctic Expedition constructed the Zhongshan Meteorology Observatory (69°22' S, 76°22' E, 14.9 m above sea level) on Larsman Hill in Prydz Bay on the eastern Antarctic continent. The observation data have since allowed China to keep pace with international research and clarify the climatology and climate change of the Antarctic Peninsula and Antarctic continent. In this paper, air temperature data for different months recorded at GW (1985－2008) and ZS (1989－2008) are used to analyze the climate characteristics of the Antarctic Peninsula and eastern Antarctic continental coast and their trends, and evaluate the regional representativeness of observation data recorded at GW and ZS for reference in further investigations of climate change affecting the environment and ecological system in Antarctica.

1 Observation data

After GW and ZS were established, their meteorological observations were incorporated into the standard management of Antarctic operational observations of the State Oceanic Administration of China and China Meteorology Administration, and the observations have not been interrupted. The stations were soon included in the basic weather station net of Antarctica (ABSN) and basic climate station net of the World Meteorology Organization, and ZS was also included in the ground station net of the Global Climate Observation System; their international indices are respectively 89058 and 89573. The instrumentation, methods and accuracy of the surface observation systems (including visually observed items) of the two stations are in accordance with the surface observation specifications of the China Meteorology Administration[9]. Before 1990, meteorological observations at the two stations were manually recorded. Since then, the temperature, humidity, wind direction, wind speed and air pressure have been recorded by an automatic electronic measurement system according to the requirements of the China Meteorology Administration. Other observation items including cloud cover, cloud form, and visibility are still observed manually.

After the automatic observation system was employed to ensure the continuous accuracy of observation data, an observer has read and recorded data from a thermometer and humidity self-recording apparatus in a standard shelter four times a day for reference and comparison. In this paper, the monthly mean air temperature data are presented as daily mean values derived from data recorded at 00:00, 00:06, 12:00, and 18:00 UTC each day. The monthly maximum and minimum temperatures are automatically determined from the daily maximum and minimum temperature data. Each year, the surface meteorological observation data for the two stations are compiled as monthly reports and an annual report as per the specifications of the China Meteorological Administration. After the data in the reports are corrected and checked with software, they are submitted to the data center of the China Meteorological Administration and China Polar Research Center for archiving. Note that while GW (January 1985) and ZS (January—February 1989) were being built, there was no observation of the maximum and minimum temperatures, and the daily four-time temperature data were observed using a Assmann ventilated psychrometer; its accuracy is equivalent to that of the temperature observation of the shelter (see specifications of the meteorological observation for the observation method[9]).

2 Monthly mean temperature

Figure 1 shows the time series of the monthly mean temperature for 288 months recorded at GW (January 1985 to December 2008) and for 240 months recorded at ZS (January 1989 to December 2008). It is seen that the monthly mean temperatures at the two stations stably vary with apparent annual cycles. The monthly mean temperature at GW is between – 1.2℃ and – 2.9℃ in summer (DJF) and between – 1.0℃ and – 13.4℃ in winter (JJA).

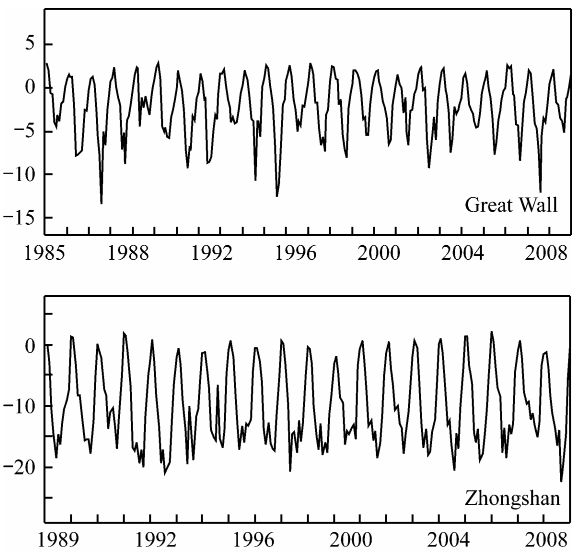

Figure 1 Time series of monthly mean temperature at the Great Wall station (1985–2008) and Zhongshan station (1989–2008); the vertical axis is temperature (t, ℃) and the horizontal axis is years, as for all following figures.

This means that the interannual change in the monthly mean temperature in summer is distinctly less than that in winter. The characteristics of the average annual cycle are that the maximum monthly mean temperature is in January and the minimum is in July with a range of 8.2℃. The monthly mean temperature at ZS varies between – 4.4℃ and 2.2℃ in summer (DJF) and between –6.7℃ and –20.9℃ in winter (JJA). Again, the variation in temperature in summer is much less than that in winter. The maximum monthly mean temperature (0.1℃) is in January and the minimum (–16.0℃) is in August, with the annual range being 16.1℃. Both stations have a longer cold season. The mean monthly temperature is below zero degrees from March to November at GW and for the entire year at ZS, being lower than –10℃ from March to October at ZS. As shown in the literature[7], the annual cycle variation in temperature at the two stations indicates a coreless winter and pointed summer.

3 Maximum and minimum temperatures

Figures 2 and 3 are time series of the monthly maximum and minimum temperatures at GW (February 1985 to December 2008) and ZS (March 1989 to December 2008). The figures show that the patterns of variation in the maximum and minimum temperatures at the two stations are similar to those of the monthly mean temperature. The difference is only in the amplitude of the annual cycle.

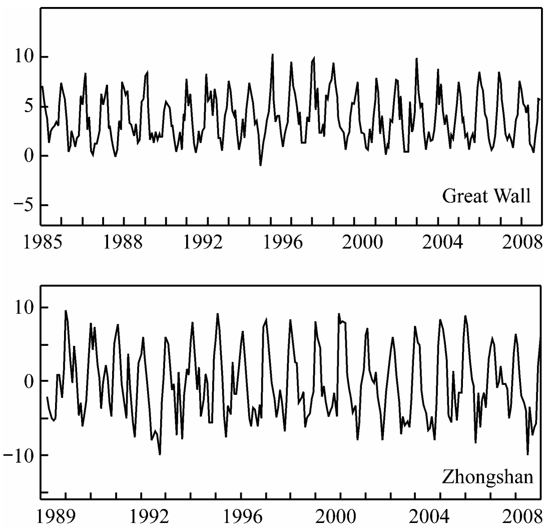

Figure 2 Time series of the monthly maximum temperature (*t*, ℃) at the Great Wall station (1985—2008) and Zhongshan station (1989—2008).

The highest and lowest temperatures at GW were 10.3℃ observed in summer (February 1996) and –27.7 ℃ observed in winter (September 1998). The maximum temperature remains below zero degrees only for a few months of the whole year. The minimum temperatures from May to September were all lower than – 20℃. The lowest temperature in summer (DJF) was recorded as – 8.7℃. The difference between the highest temperature and lowest temperature at GW was about 17℃.

Over the period of 20 years, the maximum temperature at ZS was above zero degrees from November to February, and below zero degrees in all other months, and the highest and lowest temperatures were recorded as 9.6℃ in summer (December 1989) and – 45.7℃ in winter (July 2005). From March to October, the minimum temperatures were all recorded below – 30℃. In summer, the lowest temperature was – 13.5℃. The difference between highest and lowest temperatures at ZS was about 36℃.

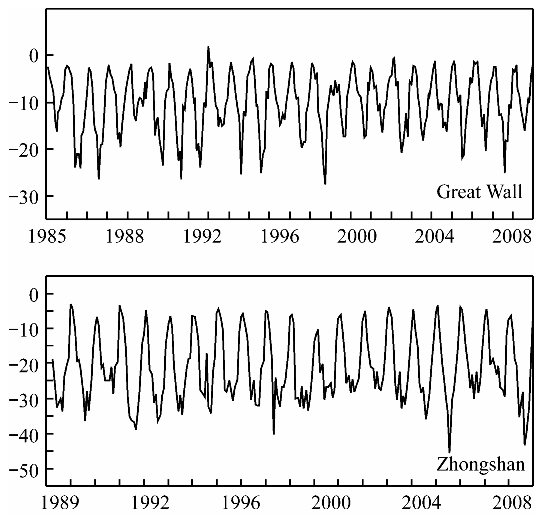

Figure 3 Time series of the monthly minimum temperature (*t*, ℃) at the Great Wall station (1985–2008) and Zhongshan station (1989–2008).

Seasonal variations in the maximum and minimum temperatures(Figure 4) show that, although both stations have a longer winter, the climate at GW is warmer than that at ZS and is a typical subantarctic ocean climate. The climate at ZS is severely cold, the difference between the highest and lowest temperatures is more than 20℃ greater than that at GW, the winter is longer, the annual mean temperature is about 8℃ lower than that at GW, and it is a typical Antarctic continent climate(Figure 4). Thus, the observation data of the two stations are useful for the detailed analysis of climate and environmental change in Antarctic in different climate zones.

4 Trend of change in air temperature

The trend of the change in air temperature can be represented by a trending coefficient, change rate, and difference in mean values of the former and latter periods. The calculation of the trend coefficient for air temperature is

$$r_{xt} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(i - \bar{t})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(i - t)^2}} \qquad (1)$$

This is in fact the coefficient of correlation between temperature at each time and the natural sequence 1,2,3⋯*n*, where *n* is the year. X_i is the mean temperature of the year, and $\bar{x}$ is the climate mean value. $\bar{t} = (n + 1)/2$. When the trending coefficient (r) is positive (negative), the air temperature has the trend of a linear increase (decrease) within the statistical time; employing this method, the temperature trending coefficient for the year, season or month is calculated. The rate of temperature change can then be computed employing the least-squares method to derive the climate factor value and linear regression coefficient of time. In the formula

$$a = \frac{\sum_{i=1}^{n}(t_i y_i) - \frac{1}{n}\sum_{i=1}^{n} y_i \sum_{i=1}^{n} t_i}{\sum_{i=1}^{n} t_i^2 - \frac{1}{n}(\sum_{i=1}^{n} t_i)^2} \qquad (2)$$

y_i is the time sequence of factor, t_i is time (t_i = 1,2,3⋯), *n* is the data length (number of years), and a is the temperature change rate.

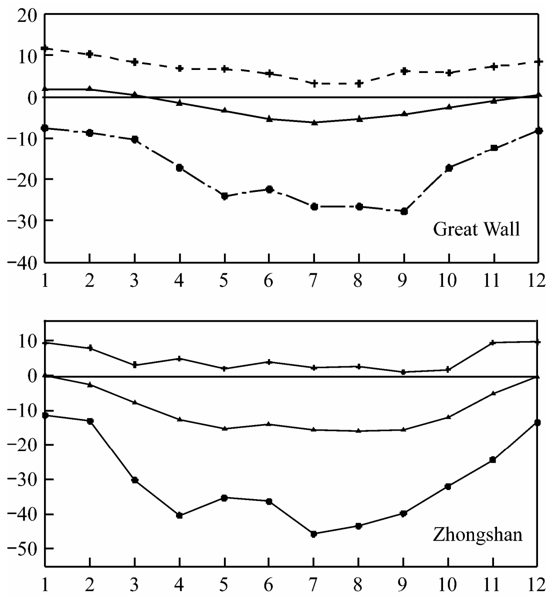

Figure 4 Annual variations in the monthly mean temperature at the Great Wall station (1985—2008) and Zhongshan station (1989—2008). Up curve is monthly maximum temperature and middle curve monthly mean temperature and down curve the monthly minimum temperature. The vertical axis is temperature (*t*, ℃) and the horizontal axis is the month.

Figure 5 shows the time series of the annual mean temperature for the two stations. Since 1985, the annual mean temperature for GW has had an obvious rising trend with the change rate of 0.27℃/10a. The annual mean temperature increased approximately 0.67℃ over 24 years. It is seen that after 1995, there were only two years with an annual mean temperature lower than the average. Before 1995, there were only three years warmer than average. Therefore, the warming at GW has been mainly observed since 1995. To describe the representativeness of the temperature observation at GW, observation data of the temperature at Bellingshausen Station of Russia (Bellingshausen, http://www.antarctica.ac.uk/), which is about 3 km from GW, were compared for the same period. The annual mean temperature is 2.1℃ at both stations. The temperature change rate for Bellingshausen Station was about 0.33℃/10a, which is higher than that for GW. The difference may, to some extent, be due to the observational environments of the two stations. The temperatures at the two stations have apparently increased, as reported in the literature, the annual mean temperature of the Antarctic Peninsula has increased by about 0.28℃/10a and this warming rate is maximum during past 50 years in the Southern Hemisphere[3].

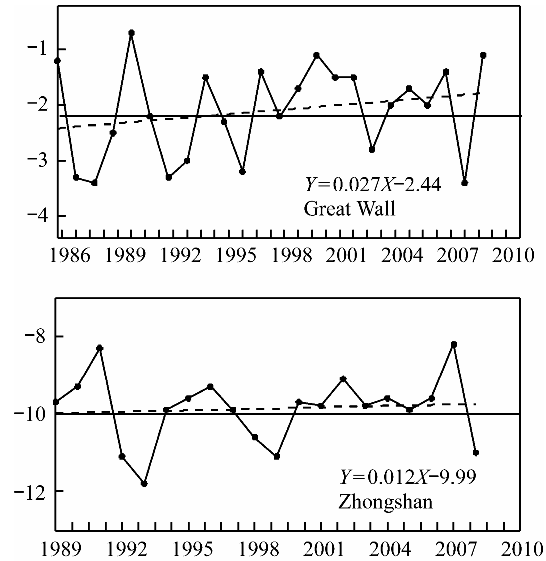

Figure 5 Time series of annual mean temperature (*t*, ℃) at the Great Wall station (1985–2008) and Zhongshan station (1989–2008); dashed lines indicate trends and straight lines indicate mean values.

Figure 5 shows the time series of the annual mean temperature for ZS. Since 1989, the annual mean temperature has had a small rising trend. There are much warmer years with positive departure than colder years with negative departure. The temperature change rate is 0.12℃/10a. The temperature rise is about 0.24℃ over 20 years. To describe the representativeness of the temperature observed at ZS, a comparison was made with temperature observation data recorded at Davis Station (Davis, http://www.antarctica.ac.uk/), which is located on the east coast of the Antarctic continent, for the same period. The temperature change rate for Davis Station was 0.07℃/10a, and the mean temperature rise over 20 years was about 0.14℃. This result is similar to that for ZS. The two stations are about 100 km apart and both located on the coast, east of Prydz Bay. Thus, the trend of the change in surface observation data at ZS is regionally representative of the east coast of the Antarctic continent.

The annual mean maximum and minimum temperatures are derived from monthly maximum and minimum temperatures. Figures 6 and 7 are time series of the annual mean maximum and minimum temperatures for both stations. It is seen that the inter-annual trend of the change in the annual mean maximum temperature (0.12℃/10a) differs from that of the annual mean minimum temperature (0.75℃/10a) at GW; i.e., the rise in the annual minimum temperature is more apparent than the rise in the maximum temperature at GW.

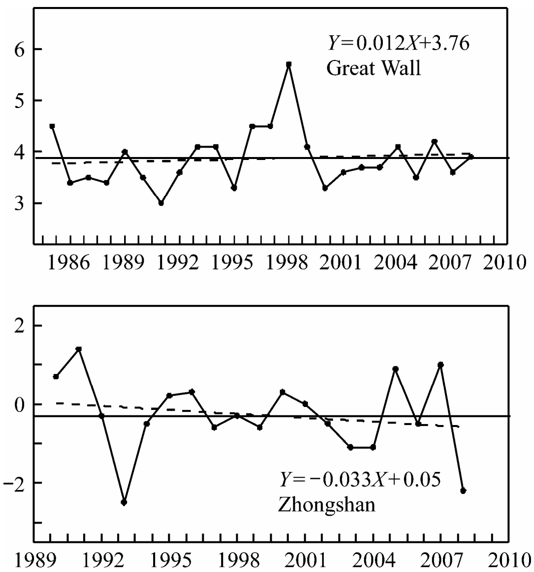

Figure 6 Time series of the annual mean maximum temperature (*t*, ℃) at the Great Wall station (1985—2008) and Zhongshan station (1989—2008); dashed lines indicate trends and straight lines indicate mean values.

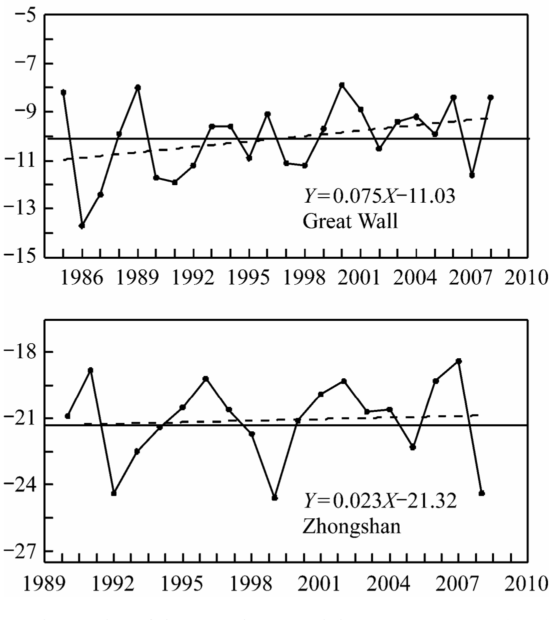

Figure 7 Time series of the annual mean minimum temperature (*t*, ℃) at the Great Wall station (1985—2008) and Zhongshan station (1989—2008); dashed lines indicate trends and straight lines indicate mean values.

The trends of change in the annual mean maximum and annual mean minimum temperature are respectively –0.33 ℃/10a and 0.23 ℃/10a at ZS; the former is a decreasing trend and the latter is a rising trend. The contrary trends reflect the climate change characteristics on a large scale without an apparent warming trend on the east Antarctic continent.

To consider the change characteristics of seasonal mean temperatures at both stations, the mean temperatures in spring (SON), summer (DJF), autumn (MAM) and winter (JJA) are obtained for separate time sequences. Figure 8 presents the inter-annual change and trend of the seasonal mean temperature for the two stations.

The inter-annual fluctuations of the seasonal mean temperature of the two stations are both large; nevertheless, there are apparent differences in the trends. The mean temperatures of the four seasons at GW appears to have a warming trend with a change rate of 0.16℃/10a for spring, 0.05℃/10a for summer, 0.55℃/10a for autumn and 0.32℃/10a for winter; i.e., the rate is highest in autumn and then winter. The change rates for the mean temperatures of the four seasons at ZS are – 0.06℃/10a in spring, 0.02℃/10a in summer, 1.1℃/10a in autumn and – 0.46℃/10a in winter; i.e., the trends in spring and summer are very weak, and autumn and winter have opposite trends (a warming trend in autumn and cooling trend in winter). Thus, there is an apparent difference in the warming characteristics of the four seasons at GW and ZS. The rates of change in autumn and winter at GW are higher than those for the other two seasons.

The rates in autumn and winter for ZS are also high but with opposing trends. The results further indicate that the warming trend on the Antarctic continent is rather small but the Antarctic Peninsula is a region with a strong warming trend.

5 Discussion and Summary

Since GW was established in 1985 and ZS in 1989, surface meteorological observation data have been recorded continually for 24 and 20 years respectively. To study the climate change pattern in the long term, although time series of data are not sufficiently long, the above analysis demonstrates that the characteristics of short-term temperature change at two stations can be used as important references in determining the Antarctic role in global climate change. The main results of this paper are as follows.

(1) The rates of change in temperature at GW and Bellingshausen Station in the same period are 0.27℃/10a and 0.33℃/10a respectively. Irrespective of whether investigations are short term or long term, the trends of the two stations are comparable. Thus, the trend of the temperature change observed at GW is representative of the change for King George Island in Antarctic.

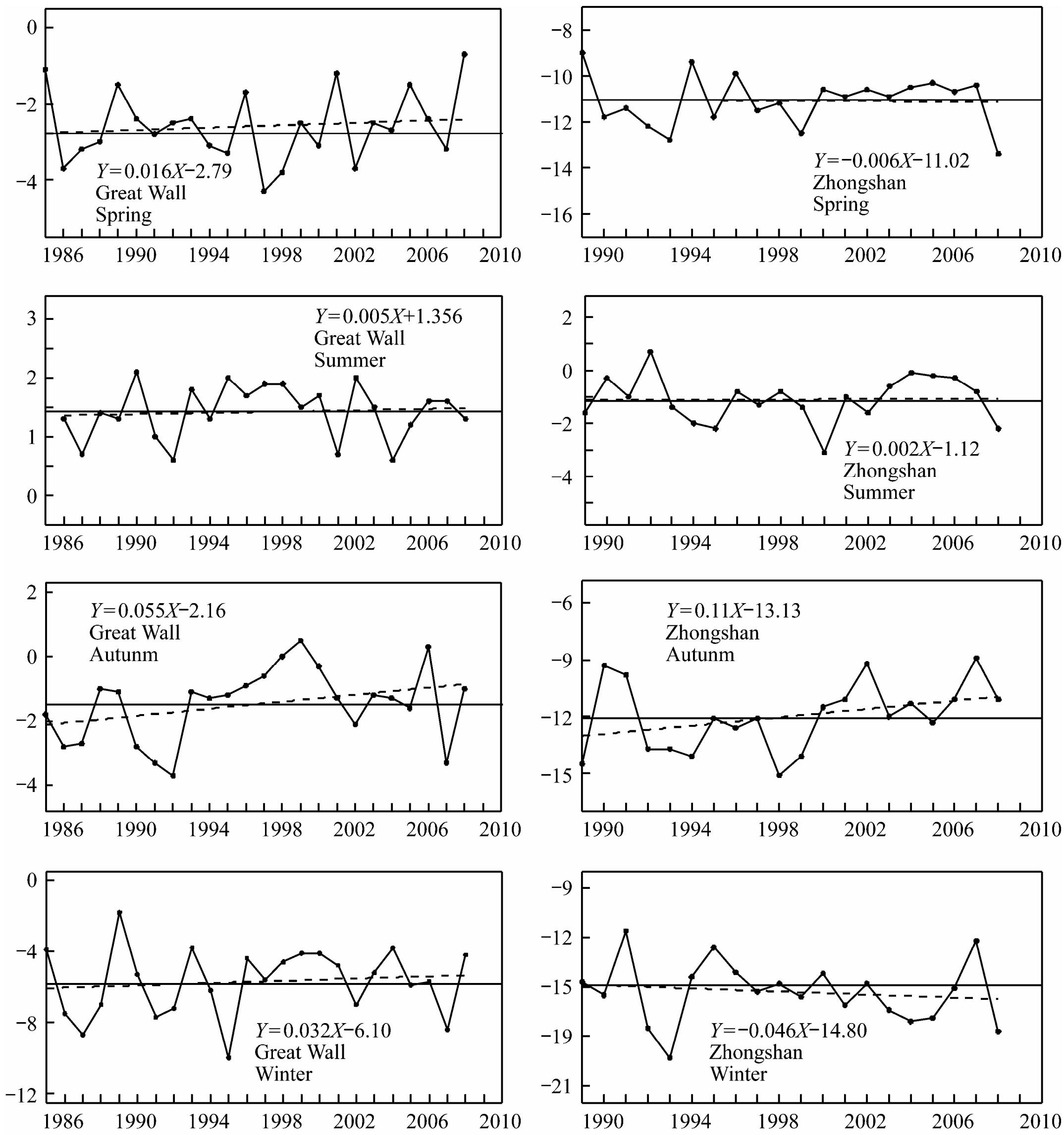

Figure 8 Time series of seasonal mean temperature (curves, *t*, ℃) at the Great Wall station (1985—2008) and Zhongshan station (1989—2008); dashed lines indicate trends and straight lines indicate mean values.

(2) The mean temperatures for four seasons at GW appear to have warming trends with the change rates of 0.16℃/10a for spring, 0.05℃/10a for summer, 0.55℃/10 a for autumn and 0.32℃/10a for winter; i.e., the rate is highest for autumn and then winter.

(3) The rates of change in temperature at ZS and Davis Station in the same period are 0.27℃/10a and 0.33℃/10a respectively. Both stations are located east of Prydz Bay on the east coast of Antarctica. Their long-term and short-term temperature trends are basically similar. Thus, the temperature data recorded at ZS are representative of the temperature of the east coast of the Antarctic continent.

(4) The mean rates of the change in temperature for the four seasons at ZS are – 0.06℃/10a in spring, 0.02℃/10a in summer, 1.1℃/10a in autumn, and – 0.46℃/10a in winter; i.e., there are cooling trends in spring and winter and warming trends in autumn and summer.

The above analysis provides the basic characteristics of temperature change for further application of meteoro–logical data recorded at the two Chinese Antarctic stations and research into the process of Antarctic climate change and its role in global change.

Acknowledgments This research was funded by the National Science and Technology Infrastructure Program of the Ministry of Science and Technology of China (Grant No. 2006BAB18B05). Special recognition is given to the logistic support provided by the Chinese Arctic and Antarctic Administration, SOA and Polar Research Institute of China and meteorological observers on the 1st to 26th Chinese National Antarctic Expeditions for their invaluable contributions.

References

1 IPCC, Climate Change, The Physical Science Basis. Contribution of mental Panel on Climate Change. [Solomon S, Qin D, Manning M,Working Group I to the Fourth Assessment Report of the Inter-governet al.(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007

2 Turner J, Colwell S R, Marshall G J, et al. Antarctic climate change during the last 50 years. Int J Climatol, 2005, 25: 279–294

3 Turner J, Lachlan-Cope T A, Colwell G J, et al. Significant warming of the Antarctic winter troposphere. Science, 2006, 311: 1914–1917

4 Chapman W L, Walsh J E. A synthesis of Antarctic temperatures. J Climate, 2007, 20: 4096–4117

5 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. Sci China Ser D, 1997, 40(4): 432–438

6 Zhou X J, Zheng X D, Lu L H, et al. Ground- based measurements of column abundance of ozone and UV- B radiation over Zhongshan Station, Antarctica for 1993 ozone Hole. Ann Rep, AMS,1994–1995, Beijing, China Meteorological Press, 1995:7-16

7 Bian L G, Xu Z F, Lu C G. Short term climate characteristic over Larsman hill. Ant Res, 1998:10(1)

8 Wang X, Bian L G, Lu L H. The characteristics of temperature change over Prydz Bay in recent 10 years. Polar Res, 2002:14(3): 195–202

9 Chinese Meteorological Administration. Guide of surface meteorological Observation. Beijing: Meteorological Press, 1980:1–95