Accumulation and temperature changes in Princess Elizabeth Land, Antarctica in the past 250 years*

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Abstract A 50 m firn core drilled in Princess Elizabeth Land, Antarctica, during the 1996/1997 Chinese First Antarctic Inland Expedition, has been measured for $\delta^{18}O$ and major ions. Based on these data, the features of the climate change in the investigated region in the past 250 years have first been studied. In the past 250 years, the change trend of climate in this region can be divided into two periods by the year 1860. Both the temperature and accumulation rate display increasing trend before 1860, while after 1860, the decreasing trend of the temperature is obvious but the change of the accumulation rate is not clear. Although both the temperature and the accumulation rate are increasing in the past 50 years, they are not the highest values in the past 250 years. So it is clear that the climate change in this region during this period does not reflect recent global warming.

Keywords: **Antarctic ice sheet, firn core, accumulation rate, temperature.**

Because of their high resolution, long time span and precise dating, the ice cores become one of the major sources in studying the past climate and environmental changes. Due to its unique geographical setting, the Antarctic ice sheet becomes an exceptional region in reflecting and contributing to global climate change. Therefore, it is significant to recover the past climate features of Antarctica by means of ice core study.

There has not been any systematic investigation on glaciology and climatology in Princess Elizabeth Land, Antarctica, which is a virgin region for ice core study. So to recover the climate features of this region using the ice core records is very important. A 50m firn core drilled during 1996/1997 Chinese First Antarctic Inland Expedition provided us with valuable data, and based on it we will discuss the accumulation rate and temperature change in the studied region for the past 250 years.

1 Sampling, analysis and dating

During 1996/1997 Chinese First Antarctic Inland Expedition, one 50 m firn core was drilled at

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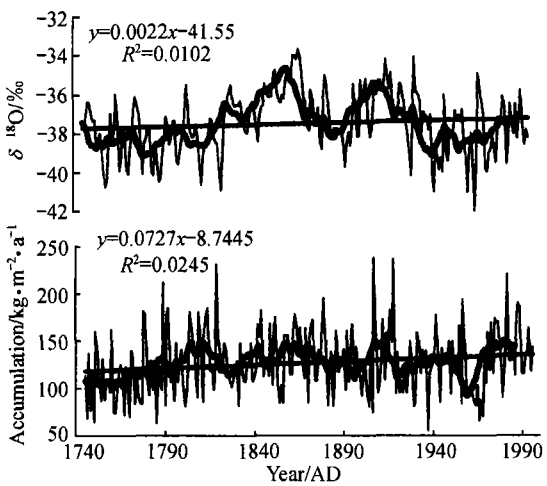

Fig. 1 Annual average (thin lines) and 11-year running mean (thick lines) of $\delta^{18}O$ and accumulation rate in Princess Elizabeth Land, Antarctica from 1745 to 1996. The straight line represents the trend after linear regression described by the formula at the upper-left corner.

LGB65 (position shown in Fig. 1 in Ref. [1]). The ice core drilling, sampling and analysis are discussed elsewhere in detail[1,2].

Ice core dating is the basis for ice core research. For this, we paid special attention to the seasonal variations of the major ions in the snow and firn recovered from Princess Elizabeth Land, Antarctica[1,2]. The results show that the variations of sea-salt ions (Cl^- and Na^+) and NO_3^- can well represent the seasonal variations. Therefore, the firn core is dated on the basis of the well-preserved $\delta^{18}O$ (smoothed below 3 meters), NO_3^-, Cl^- and Na^+ seasonal cycles which are counted to establish the depth-age relationship with excellent accuracy (e.g. the 1815 Tambora eruption was dated in the firn core at 1817, as expected[3]). The accumulated errors, attributable to a few ambiguous seasonal cycles, are estimated to be only ± 3 years at the end of the record. The 50 m firn core is dated for 251 years (1745 ~ 1996 A. D.).

2 Results and discussion

The accumulation rate in the study region is calculated according to the following formula:

$$b(t) = h(t) \cdot d(t),$$

where $b(t)$ is the accumulation rate ($kg \cdot m^{-2} \cdot a^{-1}$), $h(t)$ the depth of a specific annual layer of firn core ($m \cdot a^{-1}$) and $d(t)$ the average firn density of the annual layer ($kg \cdot m^{-3}$). As the firn core is shallow, we do not consider the impact of ice flow on recovering the accumulation rate. Because of the low firn temperature (about −33.1℃) at the sampling site (10 m below), the accumulation rate in this region can represent the precipitation. At the same time, $\delta^{18}O$ can represent temperature according to the previous work and our study[4~6].

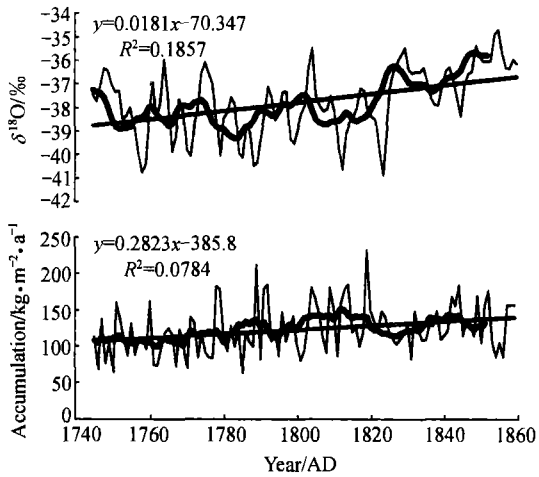

Fig. 2 Annual average (thin lines) and 11-year running mean (thick lines) of $\delta^{18}O$ and accumulation rate in Princess Elizabeth Land, Antarctica from 1745 to 1860. The straight line represents the trend after linear regression described by the formula at the upper-left corner.

Figures 1 ~ 3 show that in the past 250 years the accumulation rate and $\delta^{18}O$ in Princess Elizabeth Land can be divided into two stages by the year 1860. Both the accumulation rate and $\delta^{18}O$

increased during 1745 ~ 1860 by contrast, during 1860 ~ 1996 $\delta^{18}O$ decreased obviously, while the trend of the accumulation rate was not clear. It is also found that the trend of the accumulation rate in Dronning Maud Land is not clear since 1860[7], but the trend of $\delta^{18}O$ in this region is increasing, which conflicts with our results. On the background of global and southern hemispheric warming in the past hundred years[8], the temperature in Princess Elizabeth Land decreased obviously after 1860, showing that the climate trend in this region in centennial scale is rather unusual. So further research is needed to find out the features of the climate in this region.

It has been accepted that the temperature of the whole globe was rising in the past decades. The ice core study either in polar region or in Qinghai-Tibet reflects the warming trend in the past 50 years[9~11]. More recent increase of accumulation during the last 30 ~ 40 years has been reported for Antarctica[12]. The result of our study in Princess Elizabeth Land shows that both the temperature and the accumulation rate were increasing in the past 50 years[13]. However, if we consider the temperature and accumulation changes in centennial scale, we can see that the temperature decreases but the trend of accumulation rate is not clear (Fig. 2). In fact, Fig. 1 shows that although the temperature was increasing in the past 50 years, the temperature at present is not the highest during the past 250 years (the temperature around 1860 is the highest).

Looking at Figs. 1 ~ 3, we can see that the variations of $\delta^{18}O$ are partly in phase with those of the accumulation rate. That is, the increasing temperature is accompanied by increasing precipitation, and *vice versa*. Table 1 shows the average values of $\delta^{18}O$ and accumulation rate per 50 years. Fig. 1 and Table 1 show that this period may represent the stages of $\delta^{18}O$ and accumulation rate. The values of $\delta^{18}O$ and accumulation rate during 1745 ~ 1790 are both the lowest in the past 250 years. During 1791 ~ 1840, the average values of $\delta^{18}O$ and accumulation rate revealed warming temperature and increasing precipitation. The following two 50 years showed high temperature, especially during 1841 ~ 1890, both the temperature and the accumulation rate are the highest in the past 250 years while the accumulation rate during 1891 ~ 1940 is lower with respect to the temperature. It is unusual that the average value of $\delta^{18}O$ in the past 50 years is lower than the average of the past 250 years, but the accumulation rate is higher than the mean value of the past 250 years. Therefore, the temperature and precipitation show different variations.

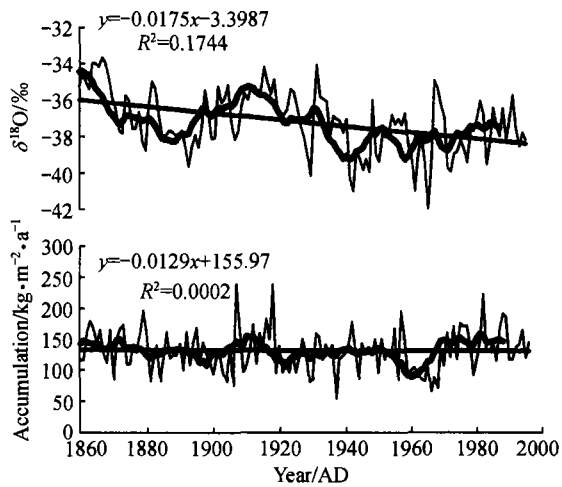

Fig. 3 Annual average (thin lines) and 11-year running mean (thick lines) of $\delta^{18}O$ and accumulation rate in Princess Elizabeth Land, Antarctica from 1860 to 1996. The straight line represents the trend after linear regression described by the formula at the upper-left corner.

In order to analyze further the variations of $\delta^{18}O$ and accumulation rate in Princess Elizabeth Land, we calculated the standard deviation of $\delta^{18}O$ and the accumulation rate in this region (Table 2).

Table 1 Average values of $\delta^{18}O$ and accumulation rate for each 50 years during the past 250 years

Period	$\delta^{18}O$/‰	Accumulation rate/$kg \cdot m^{-2} \cdot a^{-1}$
1941 ~ 1996	-38.14	132
1891 ~ 1940	-36.69	127
1841 ~ 1890	-36.25	136
1791 ~ 1840	-37.77	130
1745 ~ 1790	-39.16	112
1745 ~ 1996	-37.44	127

Table 2 Standard deviation of $\delta^{18}O$ and the accumulation rate in Princess Elizabeth Land in centennial scale

Period	Relative standard deviation of $\delta^{18}O$/%	Relative standard deviation of accumulation rate/%
1860 ~ 1996	4.49	26.63
1745 ~ 1860	3.79	26.55
1745 ~ 1996	4.19	26.60

Table 2 shows that the variation of accumulation rate is slight either during 1745 ~ 1860 or 1860 ~ 1996, but the variation of $\delta^{18}O$ during 1860 ~ 1996 is bigger than that during 1745 ~ 1860, which shows that the amplitude of cooling is bigger than that of warming.

3 Conclusion

As has been noted, the accumulation rate and temperature in Princess Elizabeth Land, Antarctica in the past 250 years can be divided into two stages by the year 1860. It is special that the temperature in the studied region decreased obviously after 1860 against the background of the whole southern hemispheric warming, which may be caused by local atmospheric circulation, wind field, etc. Princess Elizabeth Land is located in the east of Lambert Glacier Basin, the biggest basin in east Antarctica, where the local atmospheric circulation and wind field are complicated. Therefore, we need to further study many shallow firn cores to reveal the overall features of the climate change in this region in the past hundred years.

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