NOTES

Accumulation in Dasuopu ice core in Qinghai-Tibet Plateau and solar activity

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Abstract The time series of accumulation in recent 300 years correlated well with solar activity in Dasuopu ice core. Results of spectrum analysis on the accumulation time series of the Dasuopu ice core shows that there are some periods that coincide with the periods of solar activity. By comparing the long-time change trend of the accumulation in the Dasuopu ice core with various kinds of indexes of solar activity intensity, a negative correlation is found between the trend and solar activity.

Keywords: Dasuopu ice core, accumulation, solar activity.

Monsoon assuredly plays a great role in the industrial and agricultural production of South Asia and China. China would be a large desert like the Sahara Desert if the monsoon did not penetrate the Chinese continent[1]. Thus study about the monsoon has not only the significance of science but also is important to national economy and the people's livelihood. However, for historical reasons, we cannot recover the accurate monsoon precipitation backwards faraway. Whereas great development has been obtained in recoviering the accumulation and reflecting the precipitation from ice cores in recent years, and satisfactory results have been acquired from research on shallow and deep ice cores in the Qinghai-Tibet Plateau[2–7]. An important evolution on ice core study is that the accumulation time series of ice cores is a direct credible index for the past precipitation.

Solar activity acts as one of the main forcing factors in the global climate and environment changes, and study of its role in monsoon circulation will help us to deeply understand the monsoon phenomenon. Many kinds of indexes deducing solar activity intensity exist in ice cores; however, researches in this aspect are mainly focused on a few indexes such as ^{10}Be and NO_3^- concentration[8], etc. In this note, the relation between accumulation changes and solar activity is discussed based on the accumulation records in Dasuopu ice core in the Qinghai-Tibet Plateau.

1 Establishment of accumulation data series

Dasuopu glacier (28°21′N, 85°46′E) lies at the northern slope of Himalayas with an altitude of

5 600—8 000 m a.s.l., and about 1 km away from the west part of Mount Xixabangma (fig. 1). Previous results[9—12] indicate that the glacier is an ideal place for ice core study because of its high resolution and fidelity. Dasuopu ice core is the highest altitude ice core (7 000 m) in the world at present, the excellence and accurate of recovering the accumulation from this ice core lies in the following: (i) Low temperature and no ablation. The ice temperature is still −13 ℃ below 140 m. (ii) Recrystallization. Dasuopu glacier is first found formed by recrystallization[9], e.g. the ice is formed by dry snow recrystallization, thus there is no loss of accumulation due to leakage downward of water. (iii) High accumulation. Division of the annual layer indicates that several ten samples were involved each year, and staff observation indicated that the net accumulation in 1997 was more than 2 m (snow). (iv) High altitude meteorological condition. The meteorological observations in 1996 and 1997 show that the mean temperature is −4℃ at 7 000 m a.s.l. on September 14, 1997, and there is no enough energy for vaporization and ablation for snow under such a condition. Therefore, the net accumulation reconstructed from deep ice core is a good substituted index for past precipitation.

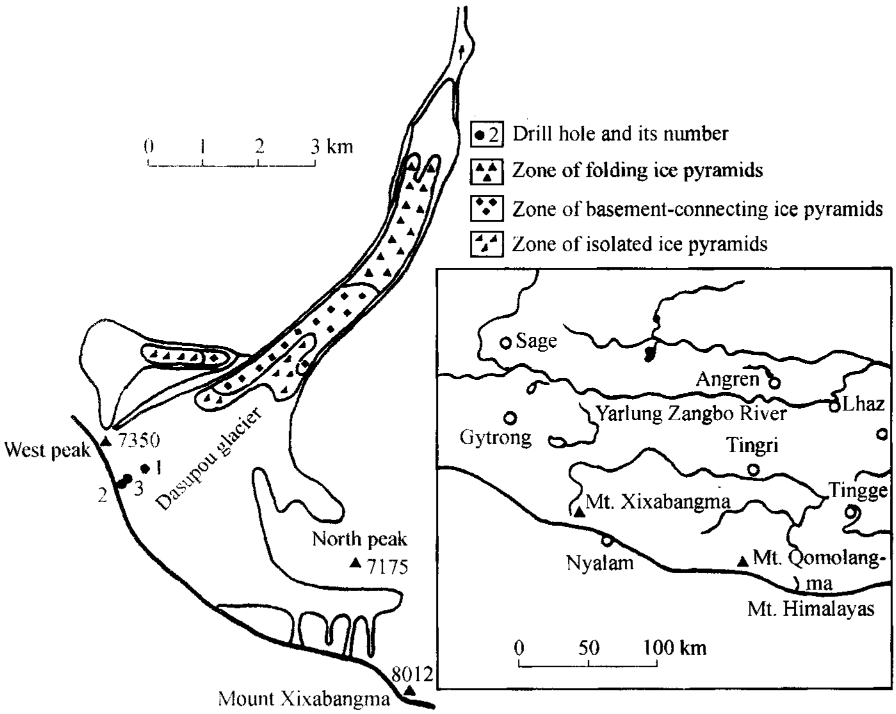

Fig. 1. Location of Dasuopu Glacier.

2 Relation between accumulation and India monsoon precipitation

The main precipitation in Mount Xixabangma comes from summer monsoon circulation on the plateau[13]. In regions affected by the southwest monsoon, the air of the lower to middle part of troposphere is very moisture, and so much as in the high part of troposphere, and the extension of this moist region at the upper part of troposphere can be observed from the water vapor map[14]. The water vapor from the Arabian Sea of the Indian Ocean and Bengal Gulf can rise and reach the plateau over the Indian continent[15]. From meteorological observations in field location (7 000 m a.s.l.) in 1996 and 1997, large cloud masses at the southern part of the glacier swarmed northwards before September 22, 1997. After the cloud masses rise from the southern slop of Himalayas, they generally turn to the east direction immediately together with rain and snow after they reach the top as soon as possible. General analysis on the water vapor map, cloud map and weather map of the middle ten days of June to the first ten days of July in 1995 indicate that the eastern back type circumfluence feature of middle to high part water vapor transported to the plateau is that the deep channel of transporting water vapor formed from the middle to high part of southwest water vapor, transported the middle to high part water vapor on the southern side of the plateau to the plateau and formed precipitation. From the satellite water vapor map we can see that the shallow ashen water vapor tongue turn over the southern side mountain of the plateau in the range of 80°—90°E (the longitude of Dasuopu glacier is 85°46′E) and swarm into the plateau[14].

The left upper chart in fig. 2 is the comparison of accumulation reconstructed from a shallow ice core drilled out in 1996 with monsoon precipitation of northeastern India[6]. Both change trends are very identical. An obvious conclusion drawn from the above analysis is that the water vapor transported by Indian monsoon can reach directly the plateau.

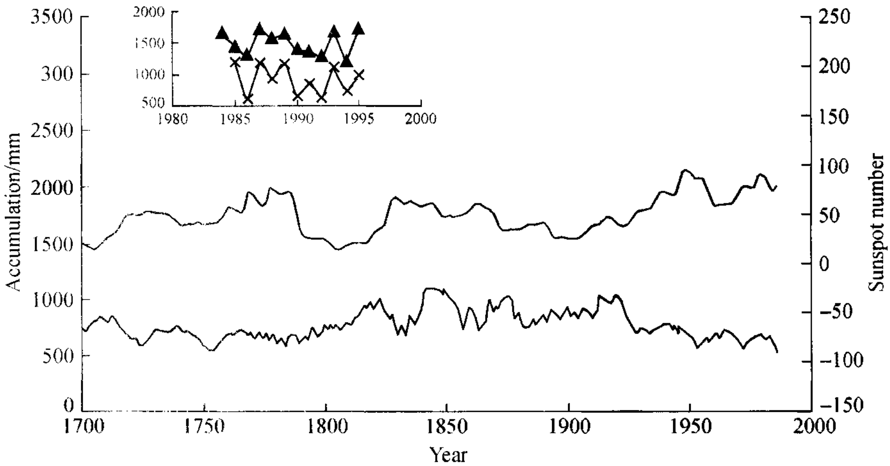

Fig. 2. Accumulation in Dasuopu ice core (lower) and smoothed average curve of sunspot relative number (upper) in 1700—1996. In the inset the upper line (with ▲symbol) stands for the precipitation of India and the lower line (with × symbol) the accumulation of Dasuopu ice core.

3 Results and discussion

The accumulation time series in Dasuopu ice core records many kinds of periods of solar activity. Power spectrum analysis results on accumulation time series in Dasuopu ice core in recent 300 years show that accumulation changes are obviously periodic, and the most distinct period is 22 a period. This coincides with that of the magnet period of solar activity. Other more distinct periods are 2—4a, 9—12a, 6a, 32a, respectively, and the 9—12a period coincides with the 11a period of solar activity, the 6a period is identical with the double oscillation period (5—6 a). Such a period consistency indicates that the accumulation in Dasuopu ice core, e.g. southwest monsoon precipitation related significantly to solar activity. Sunspot number is considered as a substitute index of solar activity intensity. Sunspot can be resumed to 1645AD, but Eddy pointed out that the relative number of sunspot since 1818 is more reliable[17]. Fig. 2 shows the comparison of the accumulation in Dasuopu ice core with the smoothed average value variation of sunspot relative number from 1700 to 1996. A negative correlation between the long-time change trends of the two parameters is shown in fig. 2. A study pointed out that the period of global temperature changes and that of sunspot activity are synchronous. When sunspot period is long, solar active is weak and the earth temperature decreases[18]. The relation between the length of solar cycle and global temperature changes is so good that the former is the main factor of temperature changes. By comparing the accumulation of Dasuopu ice core with the length of sunspot period (fig. 3), it can be seen that a negative correlation exists between the long-time change trends of the two factors.

Monsoon circulation is caused by different thermal capacities of the continent and the ocean, e.g. sensible heat makes the continent heated faster than the ocean mixture layer. In winter, South Asian continent is cooler than the Indian Ocean, and a high air pressure developed in the Qinghai-Tibet Plateau, as a result anticyclone and Hadley cell affect each other and form a dry and changeable northeast trade wind in South Asia. In summer, because of being heated by sensible heat, a strong low air pressure forms in the Qinghai-Tibet Plateau, and as a result a cyclone controls South Asia from May to September, the southwest wind transport abundant water vapor and monsoon precipitation form in South Asia[19]. This shows that the monsoon circulation variation is the certain result of sensible heat change caused by solar radiation.

Although solar radiation is one of the main factors driving the climate change, as for monsoon circulation is concerned, the boundary condition of earth surface (including ice volume, ocean surface temperature, reflectivity and trace gas concentration in atmosphere) is also one of the main factors affecting monsoon circulation[20]. The thermal capability of the whole atmosphere is only equal to that of less than 3-m-depth seawater. This implies that the warming of ocean is slower than that of the atmosphere in the warming world. Therefore, in a short time scale, when solar activity strengthens, the temperature increases fast in the South Asian continent, especially that in the Qinghai-Tibet Plateau is faster than in the ocean, which causes ice and snow to melt quickly and monsoon to process fast in the Qinghai-Tibet Plateau, as a result monsoon circulation strengthens. In the long-time scale, as solar activity keeps stronger than normal, the ocean enables sensible heat to change into latent heat depending on its large thermal capability, and the ocean mixture layer becomes deeper, ocean temperature increases, and a relative infrabar occurs on the ocean in summer. This will weaken the air pressure difference between the ocean and the continent, and make monsoon circulation weakened, leading to the decrease of the accumulation in Dasuopu ice core.

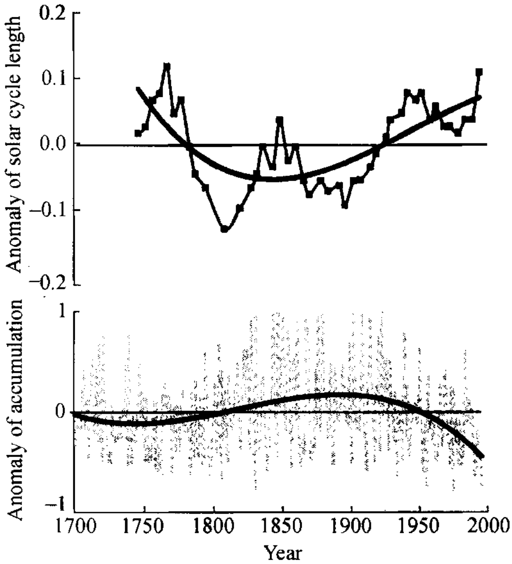

Fig. 3. Accumulation in Dasuopu ice core (lower) and smoothed average curve of length of solar cycle (upper) in 1740—1996[8].

Another obvious feature in fig. 3 is that the change of accumulation lags behind that of solar activity for about 20—40 years. This may be caused by the lag feature of ocean water warming. Therefore, in the monsoon precipitation forecast, the change trend of future precipitation can be forecast ideally by means of the change trend of solar activity.

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