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A comparison of climatic change between Svalbard in Arctic and the Qinghai-Tibetan Plateau

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Abstract Discussion is focused on the characteristics of climatic change in Svalbard for the last 80 a, there the climate tend to be slightly warming. But the decreasing of temperature is an abnormal phenomenon in the background of global temperature increasing since the mid-1970s in Svalbard. By analysis of temperature and precipitation at key stations in the last 40 a, it is concluded that in climatic change Svalbard may be compared with the Qinghai-Tibetan Plateau, though there are differences that are caused by other factors.
Key words Svalbard in Arctic, the Qinghai-Tibetan Plateau, climatic change.

1 Introduction

In the global climatic change, Svalbard (Fig. 1) in Arctic and the Qinghai-Tibetan plateau are important owing to their special locations. There is teleconnection between the Qinghai-Tibetan Plateau and other places in the world, especially in the Northern Hemisphere (Ye and Gao 1979). The Qinghai-Tibetan Plateau seems to play a "Trigger Region" role in the global climatic change (Tang and Li 1992). Meanwhile the climatic and environmental change in Arctic, such as the change of sea ice area, has a close relationship to the temperature change in winter in China (Wang *et al*. 1997). So the study on connection and diversity between Svalbard and the Qinghai-Tibetan Plateau is very necessary for better understanding of the climatic change on global scale. In this paper, the characteristics of temperature change in the last 80 a and the precipitation change in the last 40 a are summarized. The relationship between Svalbard and the Qinghai-Tibetan Plateau in climatic change are also discussed after analyzing and comparing the temperature and precipitation change at key stations of the two regions.

2 Data and methods

The earliest record of temperature has traced back to 1912 at Svalbard Airport in

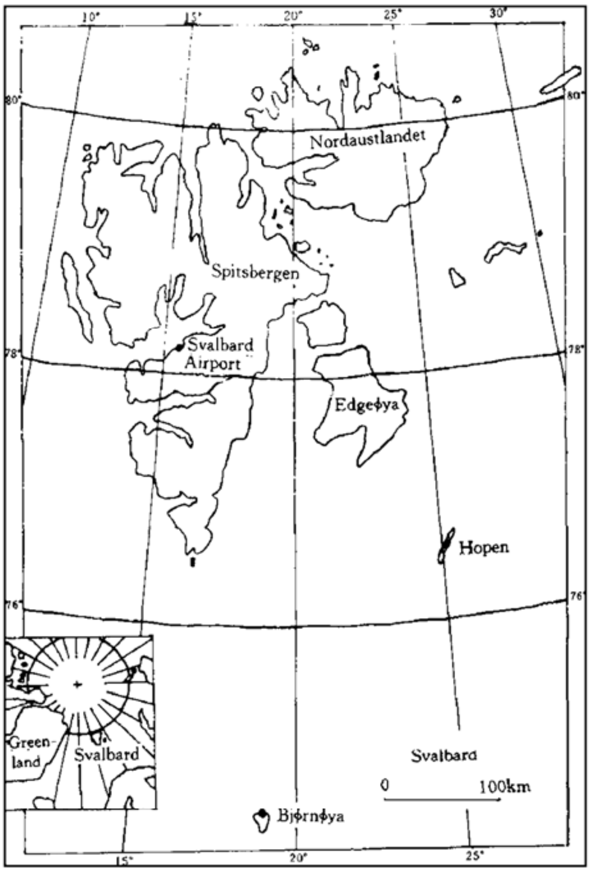

Fig. 1. Map of Svalbard Archipelage.

Svalbard (Hanssen-Bauer *et al.* 1990). At meteorological stations in Svalbard, the changes of temperature are almost unanimous for either long time series (80 a) or short time series (40 a)(Nordli 1990)(Fig. 2). In the present paper, the study has been focused on Svalbard Airport with the longest record of temperature while the others as the supplement. Svalbard Airport is in agreement with Greenland in temperature change (Frydendahl 1989), also the temperature change at Svalbard Airport is similar to Scandinavia, though the change amplitude of temperature in southern Scandinavia is smaller than that at Svalbard Airpotr (Alexanderson and Eriksson 1989). Therefore, Svalbard Airport can be taken as a representative in Svalbard, even in Greenland region in Arctic. Because most stations were moved, long records of precipitation are unbelievable in Svalbard. Only the precipitation record of Hopen, which had not been moved in 1947, is chosen to analyze.

Based on other studies (Lin and Zhao 1996; Kang 1996), 13 meteorological stations which were set up in the 1950s with long period and complete records of temperature and precipitation were intensively studied. Those stations are located in different climatic zones.

By correlation matrix analysis (Huang 1990), the characteristics of temperature and precipitation change at different stations, the correlation and diversities among

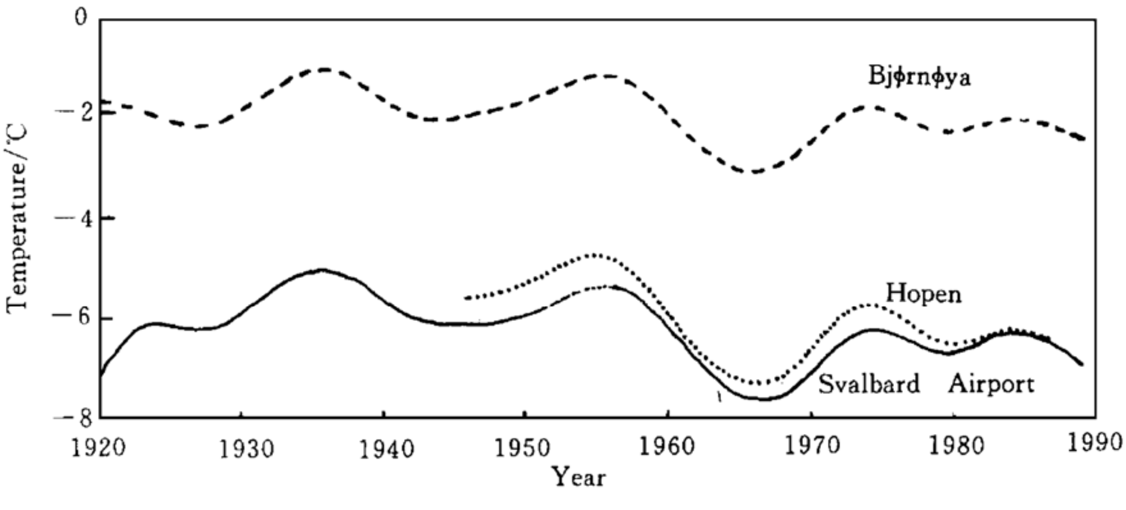

Fig. 2. Time series of temperature in Svalbard.

stations in Svalbard and the Qinghai-Tibetan Plateau were studied. Meanwhile the spectral analysis was also used to study the significant period of temperature change. In order to study the changing tendencies of temperature and precipitation at each station, climatic rate of change was calculated, which is ten-times slope of linear fitting the change processes and represents the changing value of temperature and precipitation every 10 a.

In this paper, March to May, June to August, September to November and December to February represent spring, summer, autumn and winter respectively.

3 Characteristics of temperature change in Svalbard

Fig. 2 shows the characteristics of temperature change in Svalbard. The increasing of temperature is very distinct from the 1910s to the end of the 1930s, for example, the temperature of Svalbard Airport was 4.4 ℃ higher in the 1930s than that in the 1910s. It was decreasing but still higher than mean value in the 1940s. It was increasing again in the 1950s but little lower than that in the 1930s. The dramatic decreasing of temperature appeared in the 1960s, at Svalbard Airport temperature was 2.2 ℃ lower in the 1960s than that in the 1950s. The amplitude of temperature rising in the 1970s was much smaller than that in the 1930s and the 1950s. Temperature was decreasing with fluctuation in the 1980s.

By the spectral analysis, the long significant periods of temperature change in Svalbard, e.g. at Svalbard Airport, are 26 a, 13 a and 15.6 a, short one is 2.4 a in the last 80 a.

Seasonal characteristics of temperature change in Svalbard Airport are showed in Fig. 3 and Fig. 4. Fluctuation of mean annual temperature has good agreement with

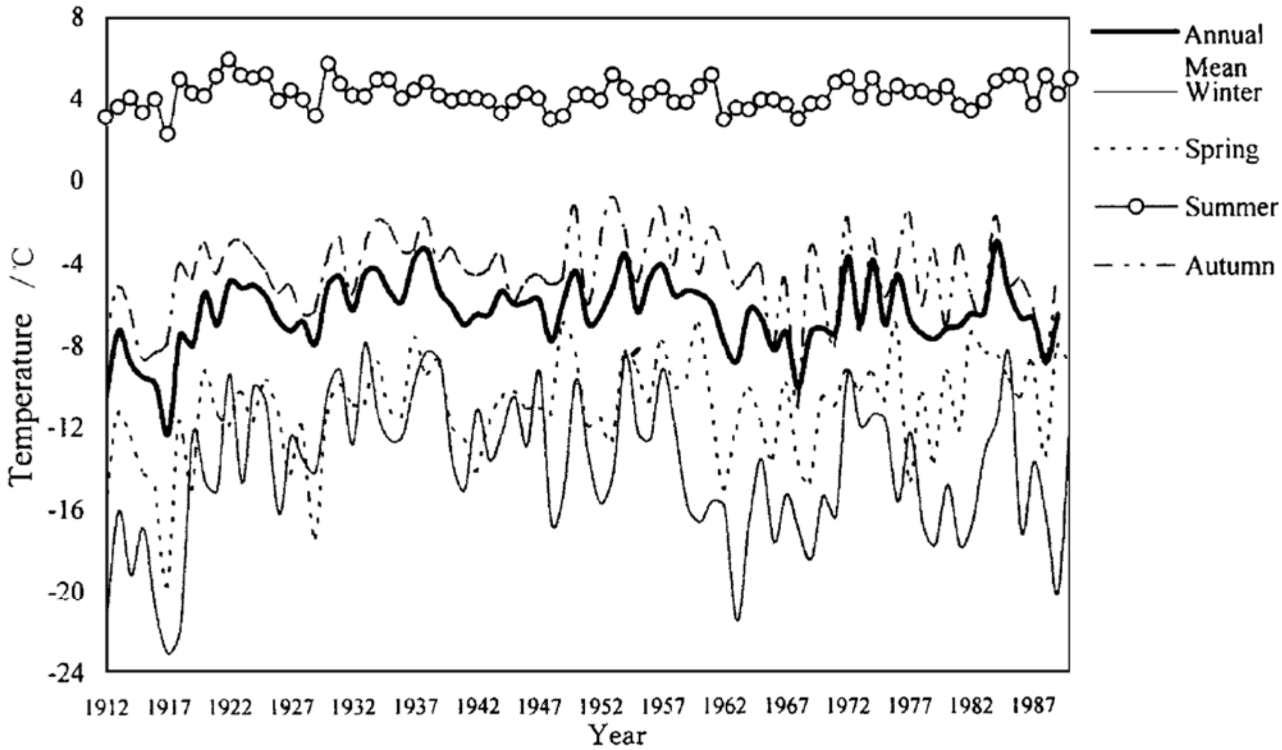

Fig. 3. Temperature change and tendency at Svalbard Airport.

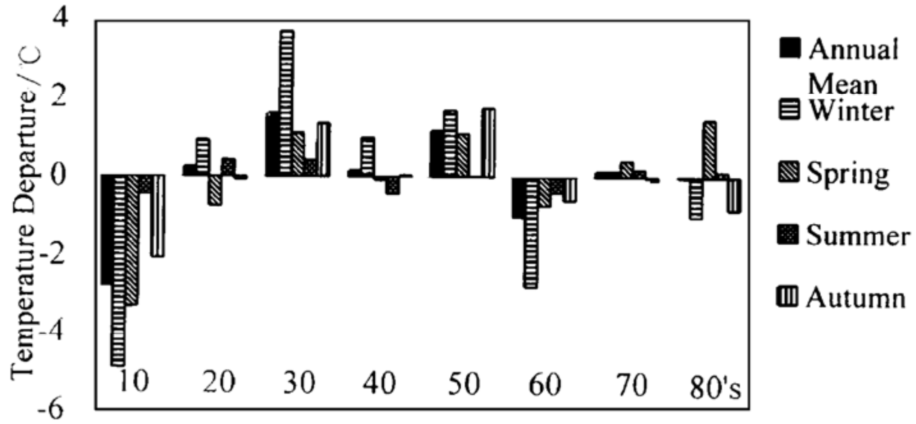

Fig. 4. Departure of every 10 a temperature at Svalbard Airport.

that of winter and autumn, and the amplitude of winter fluctuation is the largest. Winter temperature was 8.6 ℃ higher in the 1930s than that in the 1910s, still higher in the 1940s and the 1950s. It was dramatically decreasing in the 1960s and 6.5 ℃ lower than that in the 1930s, the slightly increasing appeared in the 1970s. However there was a slight decrease (1.0 ℃ lower than the average) in the 1980s. Autumn temperature had an increasing tendency from the 1910s to the 1950s, the increment was 3.8 ℃. It has been below the average level since the 1960s and was about 0.2 ℃ lower in the 1980s than that in the 1960s. Since the 1910s the general tendency of spring temperature change has been ascent and warmer phase appeared in the 1930s, 1950s, 1970s and 1980s. It was in the 1980s that the temperature reached the highest value and was 4.7 ℃ higher than that in the 1910s. There has been no obvious trend in fluctuation of summer temperature since the 1910s. In the last 80 a, the temperature inclinations of mean annual, spring, summer, autumn and winter are 0.088, 0.369, 0.002, −0.005 and −0.013 ℃/(10 a) respectively. Therefore the obvious trend of temperature increasing appeared only in spring, while the slowly increasing trend appeared in mean annual temperature. The characteristics of seasonal temperature change at Svalbard Airport is consistent with that of other stations in Svalbard(Nordli 1990).

4 Comparison of temperature change between Svalbard and the Qinghai-Tibetan Plateau

According to the correlation matrix analysis of 13 stations in the Qinghai-Tibetan Plateau, Wudaoliang, Xigaze and Yushu are taken as key stations, they are representatives of the northern, southern and eastern Qinghai-Tibetan Plateau respectively.

The characteristics of temperature change in Svalbard and the Qinghai-Tibetan are showed in Table 1, Figs. 5 and 6 in the last 40 a. Both Svalbard and the Qinghai-Tibetan Plateau were in warmer period in the 1950s, coldest period in the 1960s. The temperature was a little higher than the 40 a average level at Wudaoliang and Yushu, while it was at the average level at Svalbard Airport and Xigaze in the 1970s. The distinct difference appeared in the 1980s. It was warmer in the Qinghai-Tibetan Plateau, but colder in Svalbard. In fact, the detail can be seen in Fig. 5. Ascent tendency of temperature in the Qinghai-Tibetan Plateau was very distinct, but descent tendency appeared in Svalbard after the mid-1970s.

Table 1. Characteristics of temperature change at key stations in Svalbard and the Qinghai-Tibetan Plateau in the last 40 a

Station	Temperature inclination /℃·(10 a)$^{-1}$	Significant period/a	Change characteristics	Seasonal change characteristics (seasonal inclination)
Xigaze 29°13′N 88°55′E	0.028	12.7 2.9 4.8	Warmer in the 1950s, coldest in the 1960s, warmer in the early 1970s, warming with fluctuation in the 1980s, little dropping in the early 1990s.	No obvious trend of change in summer (−0.0003 ℃·(10 a)$^{-1}$), increasing trend in winter (0.187 ℃·(10 a)$^{-1}$).
Wudaoliang 35°13′N 93°05′E	0.156	9 3	Warmer in the 1950s, coldest in the 1960s, obviously increasing in the 1970s, relatively cold in the early 1980s, warmer from the end of the 1980s to the early 1990s.	Slowly increasing in summer (0.029 ℃·(10 a)$^{-1}$), obviously increasing in winter (0.496 ℃·(10 a)$^{-1}$).
Yushu 33°01′N 97°01′E	0.093	2 4.8 2.5	Warmer in the 1950s, coldest in the 1960s, increasing with fluctuation from the 1970s to the early 1990s and exceeding that of the 1950s at the end of the 1980.	Increasing both in summer and winter, more distinct in winter (0.205 ℃·(10 a)$^{-1}$) than that in summer (0.042 ℃·(10 a)$^{-1}$).
Svalbard Airport 78°13′N 15°35′E	−0.281	13.3 2.5 10	Warmest in the 1950s, coldest in the 1960s, warmer in the early 1970s, decreasing from the mid-1970s to the end of the 1980s.	Slowly increasing in summer (0.099 ℃·(10 a)$^{-1}$), distinctively decreasing in winter (−0.401 ℃·(10 a)$^{-1}$).

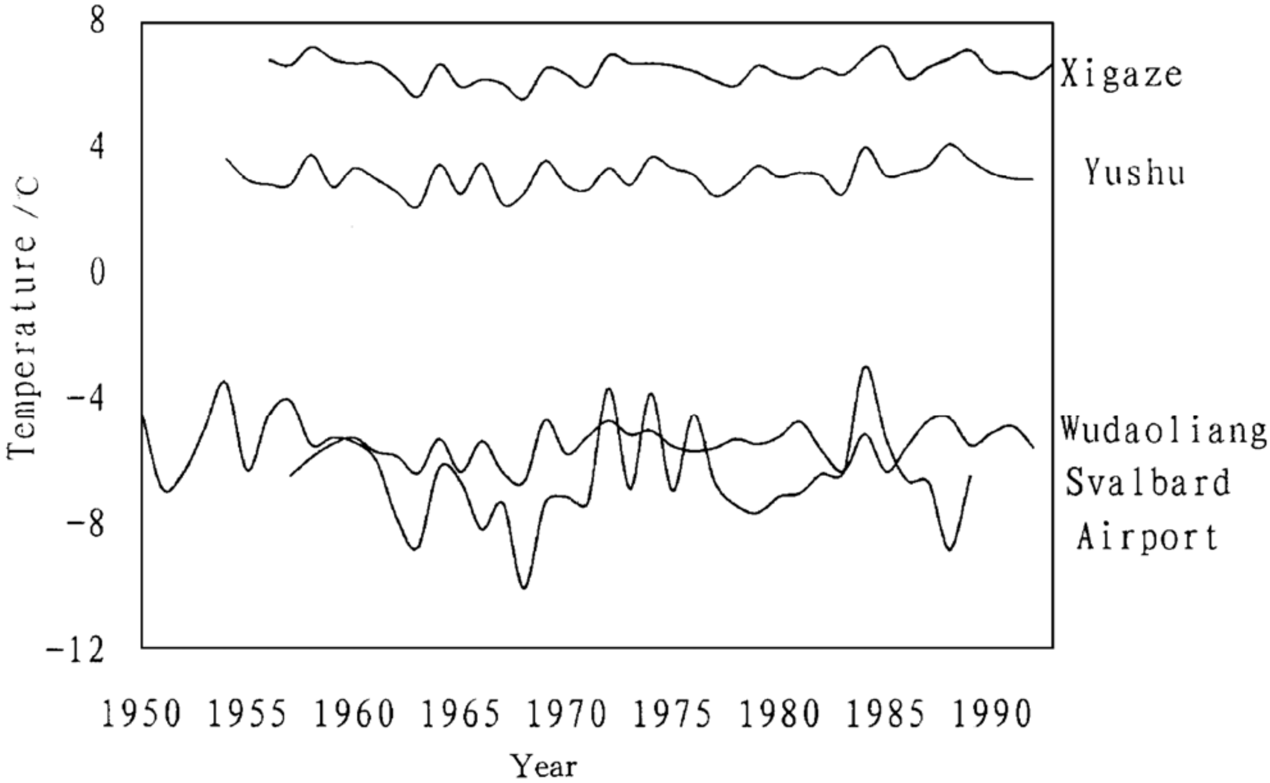

Fig. 5. Temperature change and linear fitted tendency in Svalbard and the Qinghai-Tibetan Plateau.

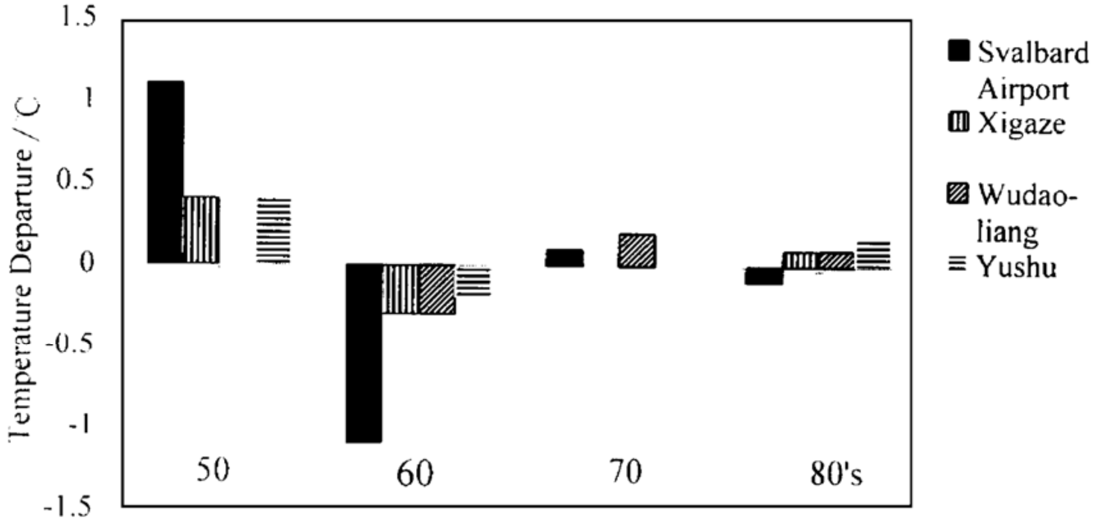

Fig. 6. Departure of every 10 a temperature in Svalbard and the Qinghai-Tibetan Plateau.

Significant period of 4 stations shows that Svalbard Airport has the same period with the Qinghai-Tibetan Plateau, the long period is about 13 a and the short period is 2 – 3 a. The temperature fluctuation of Svalbard Airport with 2 – 3 a is in agreement with the others, especially with Xigaze and the correlation coefficient is 0.63. The difference is that the amplitude of temperature fluctuation is much larger at Svalbard Airport than that at Xigaze.

The general tendency, which is showed by temperature inclination in the last 40 a, is distinct descent at Svalbard Airport. The temperature dropped about 0.3℃ every 10 a, but it has increased at 3 stations in the Qinghai-Tibetan Plateau, especially at Wudaoliang. As previously mentioned, slowly ascent tendency of temperature appeared in the last 80 a at Svalbard Airport. The distinct increasing of temperature which happened in the Northern Hemisphere in the 1970s did not appear at Svalbard Airport. This shows that the exception appeared only in the short phase change of temperature at Svalbard Airport. Maybe it was caused by the local factors of climatic change.

The slowly ascent tendency of summer temperature at Svalbard Airport is consistent with that at Wudaoliang and Yushu (Table 1, Fig. 7), while no obvious trend at Xigaze in the last 40 a. The increasing of mean annual temperature are mainly caused by winter temperature rising at 3 stations in the Qinghai-Tibetan Plateau, in contrast, decreasing of mean annual temperature are mainly caused by dramatic winter temperature decrease at Svalbard Airport. The amplitude of temperature fluctuation in winter is larger than that in summer at 4 stations and the largest appeared in winter at Svalbard Airport (Fig. 8). Either in summer or in winter, the temperature fluctuation was in agreement year by year among 4 stations, especially the winter temperature between Svalbard Airport and Xigaze. The consistency of the fluctuation of mean annual temperature with that of winter temperature, is much better than that with summer at all 4 stations. So the winter temperature change is main factor to contribute to the change of mean annual temperature.

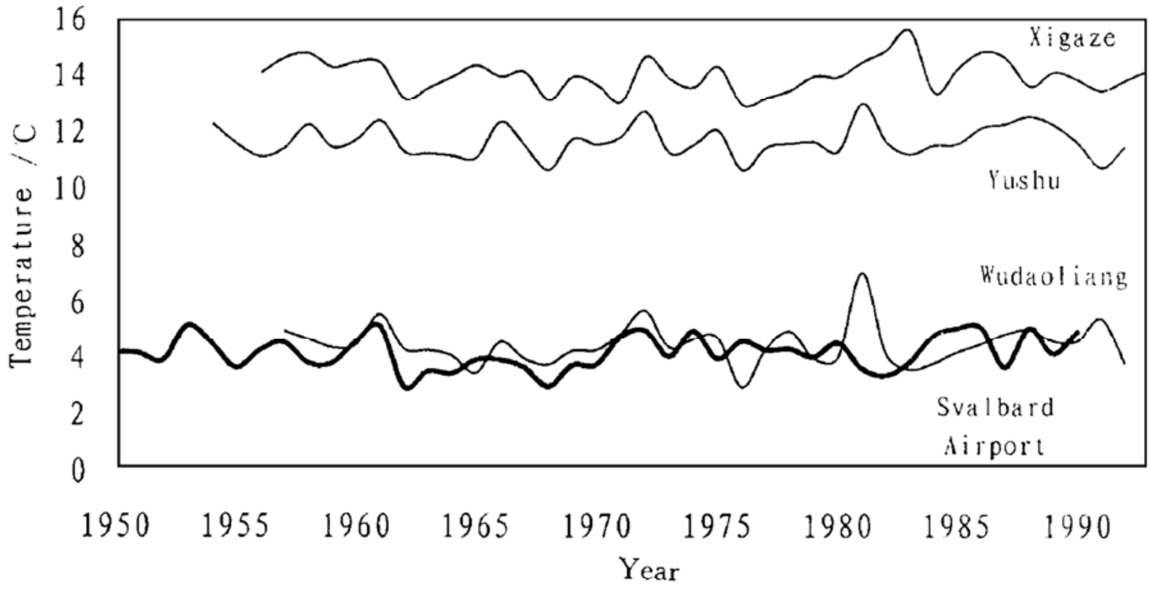

Fig. 7. Temperature change in Svalbard and the Qinghai-Tibetan Plateau in summer.

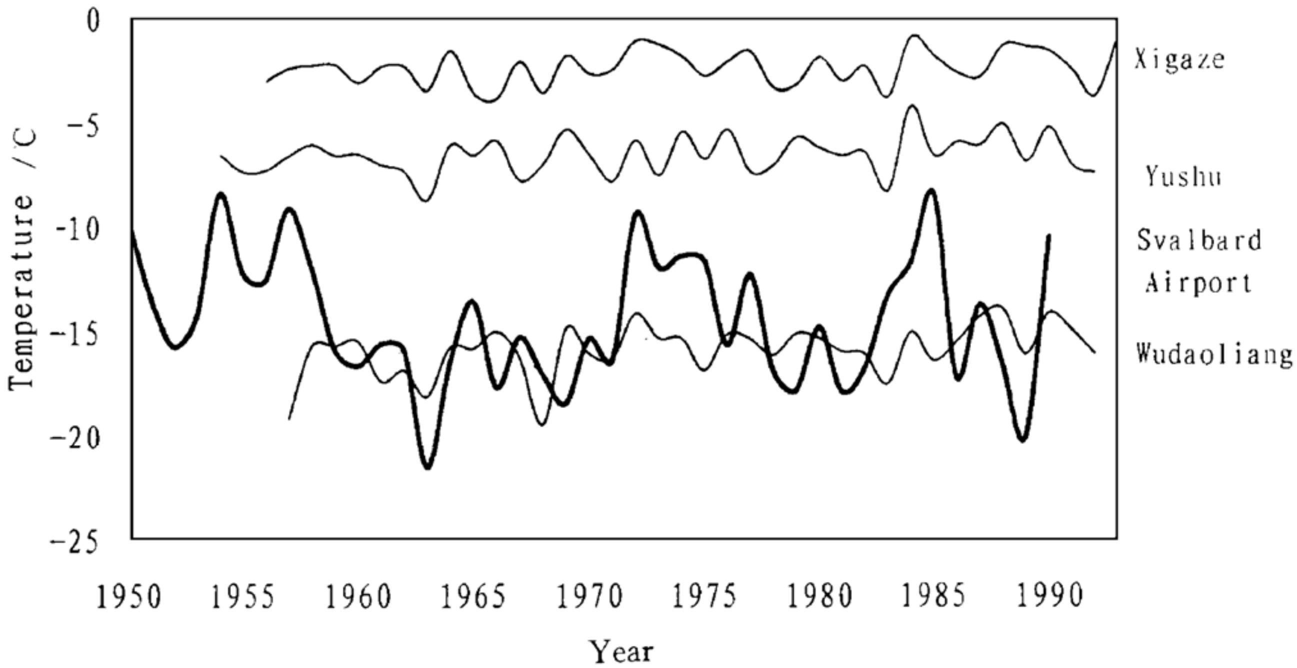

Fig. 8. Temperature change in Svalbard and the Qinghai-Tibetan Plateau in winter.

5 Comparison of precipitation change between Svalbard and the Qinghai-Tibetan Plateau

By correlation analysis of precipitation at Hopen in southern Svalbard and other stations in the Qinghai-Tibetan Plateau, it is discovered that Hopen has positive correlation in precipitation change with the northern Qinghai-Tibetan Plateau but negative correlation with the southern Qinghai-Tibetan Plateau, for example, the correlation coefficients of Hopen with Lhasa, Xigaze, Tuotuohe and Yushu are −0.42, −0.37, 0.42 and 0.38 respectively, these are significant at 95% degree of confidence. Fig. 9 shows the tendency of precipitation change at Hopen and other 3 stations in the Qinghai-Tibetan Plateau. In the last 40 a, a distinct increasing trend of precipitation appears at Hopen, while there is a slowly ascent trend at Yushu and Tuotuohe in the northern Qinghai-Tibetan Plateau, in contrast, obvious descent trend at Lhasa in the southern Qinghai-Tibetan Plateau. In the 1950s less precipitation appeared at Hopen, Yushu and Tuotuohe, while much at Lhasa. In the 1960s less and much precipitation appeared at Hopen and Lhasa respectively, average level appeared at both Yushu and Tuotuohe. In the 1970s much precipitation appeared at Tuotuohe but it was just below average level at others. In the 1980s obvious less precipitation appeared at Lhasa and much at others. The precipitation was higher up to 123.8 mm in the 1980s than that in the 1950s at Hopen, 52.7 mm at Yushu and only 20.8 mm at Tuotuohe, in contrast, 63.7 mm lower at Lhasa (Fig. 10).

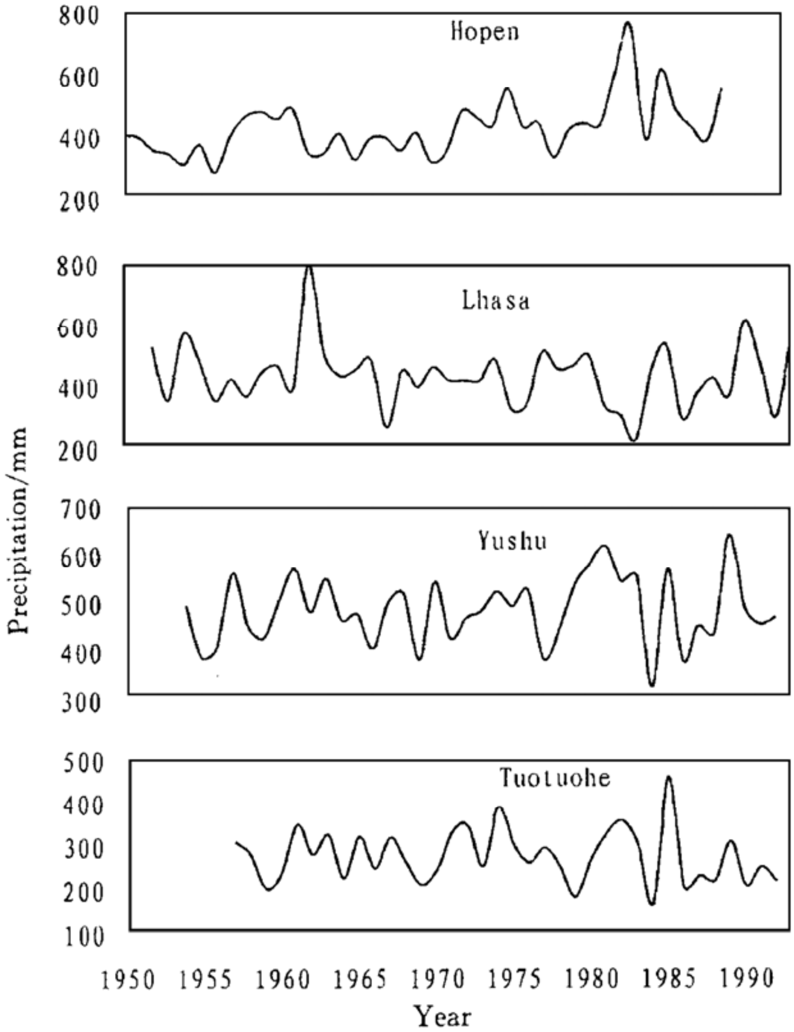

Fig. 9. Precipitation change and tendency in Svalbard and the Qinghai-Tibetan Plateau.

6 Discussion and conclusions

During the last decade global temperature has increased, perhaps due to an increasing greenhouse effect. In the last 80 a, temperature series of Svalbard Airport is compared with the mean temperature of the Northern Hemisphere (Jones 1988). Before about 1975 the two curves show the same fluctuations, and the amplitude of fluctuation at Svalbard Airport is larger than that in the Northern Hemisphere. Also there is a phase delay in the fluctuation of the Northern Hemisphere comparing with that of Svalbard Airport. After 1975, in contrast to the distinctly ascent trend in the hemisphere, there is a little descent in Svalbard. The temperature fluctuations be-

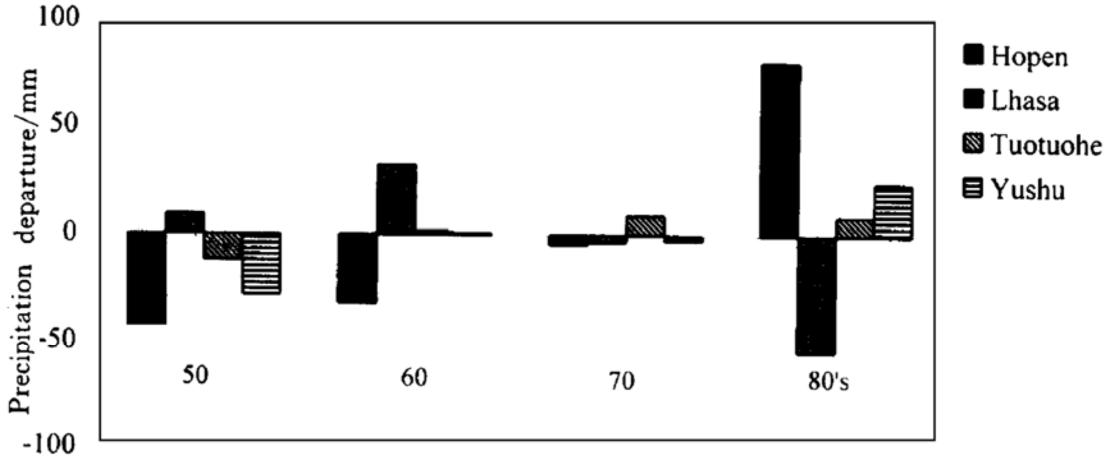

Fig. 10. Departure of every 10 a precipitation in Svalbard and the Qinghai-Tibetan Plateau.

tween the Northern Hemisphere and the Qinghai-Tibetan Plateau are also consistent, especially for the temperature increasing during the last decade.

Since the 1970s, the climate has become cold in Svalbard. The reason may be due to local climatic conditions. Owing to the dramatic decreasing of winter temperature, there is lower temperature in Svalbard. The winter temperature is mainly influenced by cyclonic activity moving from the North Atlantic Ocean and the Warm North Atlantic Current. The abnormal decreasing of winter temperature shows that those two factors have been changing, but the mechanism needs to be further studied. The secondary feasible reasons causing the climatic warming in the Qinghai-Tibetan Plateau is strengthening of Longitudinal Circulation, it is mainly displayed in the enlarging on frequency and strengthening of storms on the Bay of Bengal and Arabian Sea because this kind of storm with tropical cyclone enhances the transportation of hot and humid vapor form tropic ocean on low latitude to the Qinghai-Tibetan Plateau along vaporous passage constantly. Storms in the Bay of Bengal occurring more frequently in the period between September and December may be the one reason causing winter warming (Lin and Wang 1995). The reason of positive correlation in precipitation between Svalbard and the northern Qinghai-Tibetan Plateau, negative correlation between Svalbard and the southern Qinghai-Tibetan Plateau should be studied further. But it is inferred that the change of precipitation both in Svalbard and the northern Qinghai-Tibetan Plateau may be controlled by strengthening or weakening of Eurasian Circulation. When there is much precipitation in both regions, the vapor source becomes weak in the southern Qinghai-Tibetan Plateau and there is less precipitation.

Based on the above analysis, the conclusions are as follows:

(1) In the last 80 a, the climate in Svalbard becomes slightly warming, especially in the first 30 a climatic warming was distinct. Taking 1975 as a boundary, before that, the climatic change in Svalbard was consistent with the Qinghai-Tibetan Plateau, namely, warmer in the 1950s, colder in the 1960s, after that, Svalbard was in cold period, while the Qinghai-Tibetan Plateau was in the warmest period. The cold period after the 1970s in Svalbard was an abnormal phenomenon in the back-

ground of global warming.

(2) In the last 40 a, the period of temperature fluctuations in Svalbard and the Qinghai-Tibetan Plateau are almost consistent, the long period is 13 a, the short is 2 – 3 a. For the seasonal change, mean annual temperature has a good consistency with winter temperature and the trend of summer temperature is not distinct both in Svalbard and the Qinghai-Tibetan Plateau.

(3) In the last 40 a, both Svalbard and the northern Qinghai-Tibetan Plateau were getting wet, in contrast, the southern plateau was drying. The precipitation change in Svalbard has positive correlation with the northern Qinghai-Tibetan Plateau, negative correlation with the southern Qinghai-Tibetan Plateau.

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