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Features of temperature changes at Barrow of Arctic in the last 400 a

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Abstract A temperature record from a lake core reveals that it becomes warming at average rate of 0.4 ℃ per century in the past 400 a at Barrow, but it turns cold in the past 200 a. Maximum entropy spectra analysis shows that in the temperature fluctuations there are cycles of 33, 40, 29 a and about 90 a at Barrow. According to statistics and entropy analysis of monthly mean temperature from Barrow Meteorological Observatory in 1921 - 1994, there are cycles of 4, 6, 14, 16 months and 3, 4, 7, 10 a in the recent temperature change.

Key words Arctic, Barrow, temperature change, entropy spectra feature.

1 Introduction

Facing the Arctic Ocean and backed with a flat coastal plain, Barrow (71°20′N, 156°40′W) is in the northernmost part of Alaska. This area is source of polar air mass to North America (Vitevicich 1953). Temperature change at Barrow mirrors the features of activity of polar air mass to a certain extent. Reconstruction and analysis of Barrow 400 a temperature record has important significance in studying on the feature of recent activity and evolving tendency of Arctic air mass, as well as the climate change mechanism of North America. Zhang Qingsong *et al.* got a 60 cm of lake core (AB-67) from Elson Lagoon at Barrow, the mean sedimentary rate of the upper section (0 - 20 cm) of the core is 1.1 mm/a. This paper is to study the features of climate fluctuations and entropy spectra of temperature in 1580 - 1972 through the lake core (Wang *et al.* 1998), and the statistical feature and entropy spectra feature of monthly and annually temperature at Barrow Meteorological Observatory in 1921 - 1994 (Monthly climatic data for the world 1994; Zhang and Zhou 1986; Yang and Gu 1988) by using monthly mean temperature.

2 The feature of temperature change in the last 400 a

2.1 The pattern of change

A comparison made between the 400 a temperature records reconstructed from lake core and the 74 a temperature records of Barrow Meteorological Observatory shows that reconstruction is reasonable (Fig. 1a). The correlation coefficient be-

tween lake core record and the 11 a slide mean curve of temperature from Barrow Meteorological Observatory is 0.878. As shown in Fig. 1b, there are two obvious peaks on the temperature curve in 1580 – 1610, and a weak peak in about 1655; and it was cold in 1610 – 1650 and in 1670 – 1700, the latter is so called Mounder low temperature period, a worldwide event in Maximum Little Age. Later on, temperature rose steadily, peak in about 1770. The temperature was low around 1820, and went up during the next 20 a. It dropped down again after 1870, and reached a valley around 1972. Temperature change in the 400 a at Barrow, except for the 19th century, is very identical to global change.

As a whole, the temperature at Barrow in Arctic was rising during the past 400 a (line 1 in Fig. 1b), its mean rate is 0.4 ℃ per century. Clearly, there are three stages. Since 1771, it is down, with a rate of 0.39 ℃ per century. From 1694 to 1771, it is up sharply, 2.6 ℃ per century. From 1579 to 1694, it is down, with a rate of 0.68 ℃ per century. The regession parameters of line 1, line 2, line 3 and line 4 in Fig. 1b are listed in Table 1.

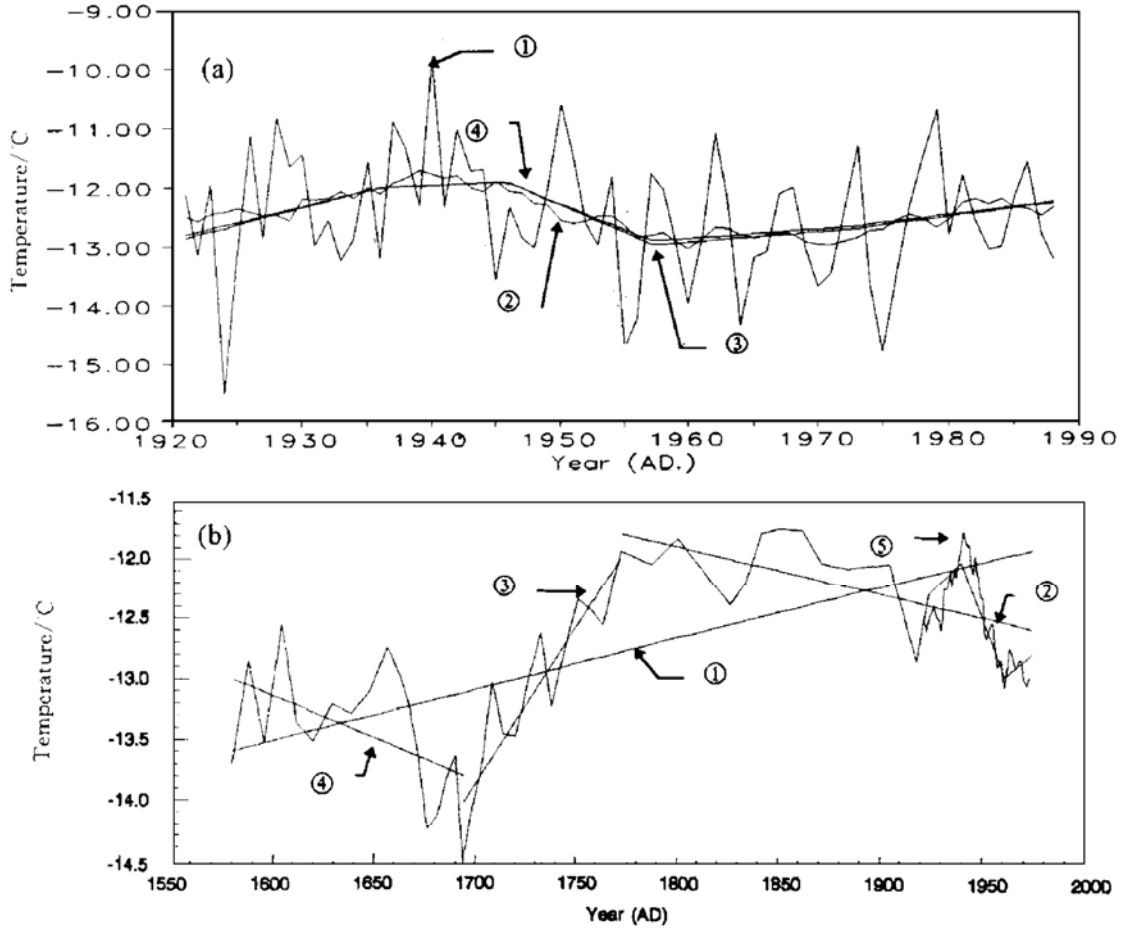

Fig. 1. (a) Comparison between the temperature record from Elson Lagoon and Barrow Meteorological Observatory; (b)Recoverd curve of 400 a temperature record at Barrow, Alaska. Fig. 1a: line 1 is mean annual temperature of Barrow Meteorological Observatory; line 2 is its 11 a slide mean; line 3 is temperature reconstructed from lake core based on mean annual temperature; line 4 is reconstructed temperature based on 11 a slide mean temperature. Fig. 1b: line 1 is a linear regression to the temperature record in the past 400 a; line 2 is a linear regression to the temperature record since 1771; line 3 is a linear regression to the temperature record from 1694 to 1771; line 4 is a linear regression to the temperature record from 1579 to 1694; line 5 is mean annual temperature of Barrow Meteorological Observatory.

Table 1. Correlation statistics of linear regression to the 400 a temperature record from Barrow

Number	Regression equation	Time (AD)	Correlation coefficient	Covariance
1	$y=-20.5348+0.00439269x$	1579 - 1973	0.628292	49.3991
2	$y=-4.83677-0.00390591x$	1771 - 1973	−0.621917	−13.6845
3	$y=-58.8875+0.0264971x$	1694 - 1771	0.908785	15.0631
4	$y=-2.24874-0.00680702x$	1579 - 1694	−0.489201	−9.02611

2.2 The feature of spectra

On entropy spectra of 400 a temperature, there are a strong cycle of 33 a, three weaker cycles of 40 a, 29 a and about 90 a (Fig. 2). These climate cycles were found elsewhere also. Moore first found the 33 a climate cycle in analysis of rainfall in 1839 - 1909. Beijing Meteorological Observatory first found 89 a climate cycle in analysis of dry and waterlog in Beijing area. Analysis of Indian rainfall in 1813 - 1912 by Bluckna, analysis of tree ring in 1050 - 1930 in Japan, analysis of temperature in 1757 - 1886 in Paris, France and rainfall in 1764 - 1900 in Milan, Italy by Brunt gave a 30 a cycle. Yangtse River Basin Planning Office found 41 a cycle in analysis of mean discharge in June to September at Hankou in 1860 - 1974 (Gong *et al.* 1983). The consistency of cycles in temperature change in Borrow with those found in rainfall records in north hemisphere clarifies that the activity of the Arctic air mass is related to the formation of rainfall in north hemisphere.

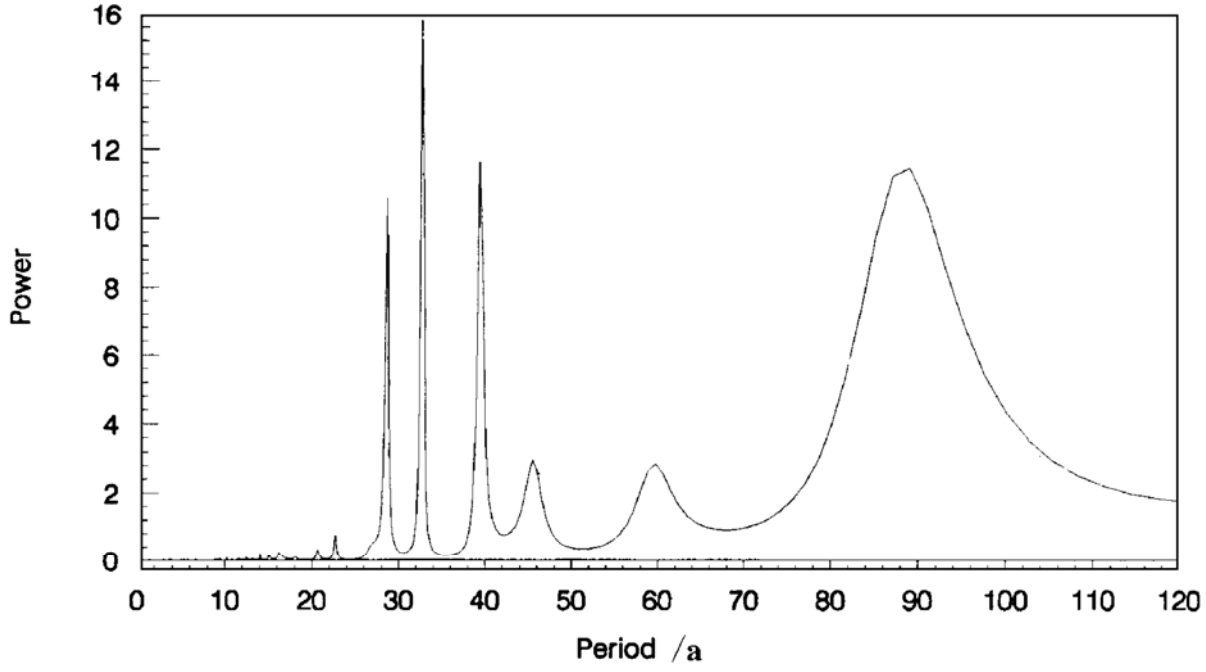

Fig. 2. The feature of spectra of the temperature in the past 400 a at Barrow, Alaska.

3 The feature of modern temperature change at Barrow

3.1 The statistical feature of monthly temperature

According to 1943 - 1994 temperature data from Barrow Meteorological Obser-

vatory, monthly mean temperature in summer is comparatively stable. In the last 52 a, temperature standard difference in June is 0.97 ℃, mean difference 0.72 ℃, and they are 1.14 ℃, 0.89 ℃ respectively in July (Table 2). Temperature in winter fluctuates most violently. The statistical standard difference and mean difference in February are 4.08 ℃, 3.20 ℃, and in November 3.82 ℃, 3.23 ℃ respectively. Sorting by statistics standard difference from small to large, the orders are from June, July, May, September, August, March, April, October, January, December, November to February. As a feature of internal annual temperature change, the temperature almost rises up from March to June. There is a high peak, of temperature curve occurring almost in every year from June to September. The temperature drops unsteadily in September and October. In the trough of temperature curve between November and March there exist irregular undulations because of strong air mass activity and frequent shifting of Arctic Front in winter.

Table 2. The list of monthly temperature statistics in 1921 - 1994

	Mean	Maximum	Minimum	Square deviation	Standard deviation	Divided difference
Year	−12.4	−9.8	−15.5	1.1	1.1	0.9
Jan.	−26.0	−14.7	−34.0	14.5	3.8	3.0
Feb.	−27.8	−13.0	−36.1	15.2	3.9	3.1
Mar.	−26.1	−20.9	−32.6	5.9	2.4	2.0
Apr.	−18.2	−11.7	−26.7	7.5	2.7	2.2
May.	−7.2	−3.1	−11.3	2.6	1.6	1.2
Jun.	1.0	3.5	−1.3	1.2	1.1	0.9
Jul.	4.1	7.4	1.4	1.7	1.3	1.0
Aug.	3.3	8.1	−0.3	3.7	1.9	1.6
Sep.	−0.9	2.7	−4.6	3.6	1.9	1.5
Oct.	−9.2	−3.8	−17.5	9.9	3.1	2.6
Nov.	−18.2	−9.3	−24.9	13.5	3.7	3.1
Dec.	−24.0	−17.4	−32.6	9.1	3.0	2.4

3.2 The spectra feature of monthly temperature fluctuation

Entropy analysis revealed that there are obvious cycles of half a year and 4 months of temperature change in the 888 months in 1921 - 1994 (Fig 3a).

3.3 The spectra feature of inter-annual temperature

Entropy analysis of temperature in 1921 - 1994 shows that there are primary cycles of 1.2 a and 1.4 a (Fig. 3a), a secondary cycle of 4 a, and a weak cycle of 10 a (Fig. 3b). It seems the 10 a cycle is the longest one of temperature change in the last 74 a. This reflects clearly the controlling role of solar spot activity on the Arctic air mass.

3.4 11 a slide mean tendency

It is shown by 11 a slide mean temperature that the climate in Barrow was warm in the period from the late 3rd decade to the early fourth decade of the century, 1 ℃

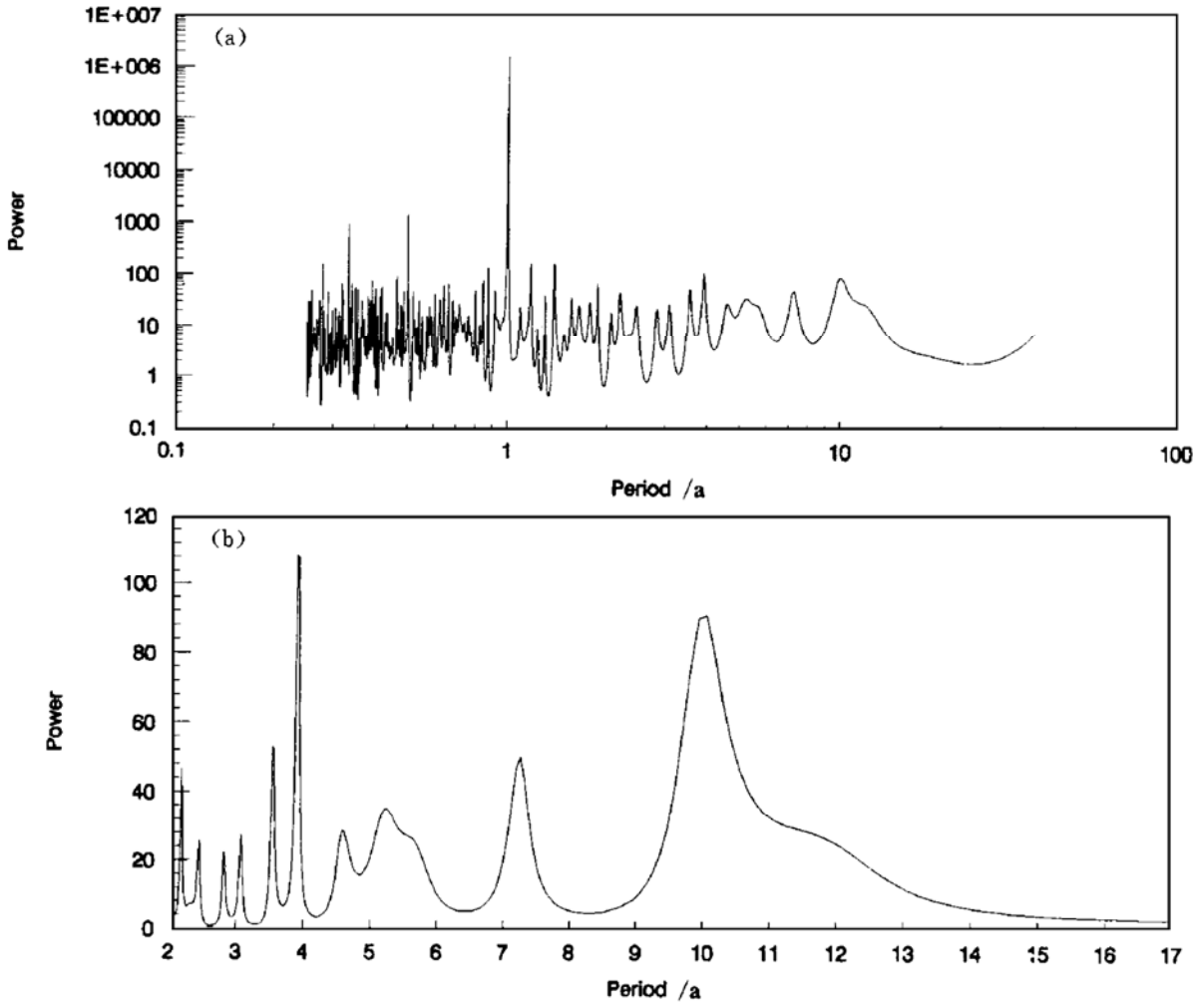

Fig. 3. The spectra feature of monthly temperature fluctuation from 1921 to 1994 at Barrow.

higher than the mean temperature in 74 a. It was cold in the whole sixth decade, its difference is 1 ℃ lower than the mean temperature. Spring temperature began to fall sharply from 1935, it lowered 1.4 ℃ up to 1975; but it rose up 1.5 ℃ in the following 19 a. Change of temperature in summer is similar to that in spring in pattern, but there are a 11 a in time lead. The change of autumn temperature is special, it was warm in 1938 - 1953, and it kept cold since then. Winter temperature was lower (Fig. 4).

4 Conclusions

(1) As a whole, it is warmming in the past 400 a at Barrow. There are three stages: cooling in 17 century, warming sharply in 18 century and cooling slowly in the recent 200 a.

(2) In the long term of temperature change at Barrow there exist cycles of about 90 a and 33 a.

(3) In Mounder Minimum, temperature at Barrow was the lowest in the past 400 a. Recent temperature fluctuation at Barrow obviously had 11 a cycle. This shows that solar spot event and activity has a control role on polar air mass.

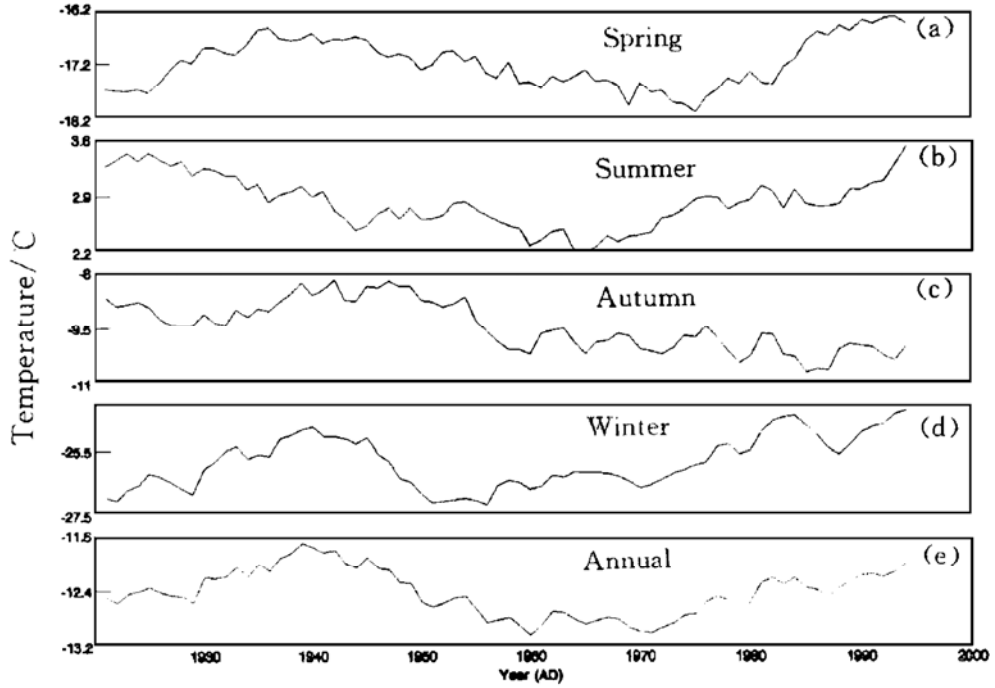

Fig. 4. Tendency of temperature change at Barrow from 1921 to 1994.

(4) Temperature records in the past 74 a show that mean annual temperature at Barrow was high in 1930s - 1940s, low in 1960s, and warming up in the recent 20 a.

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