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Interdecadal and decadal variation of temperature over North Pole area and the relation with solar activity

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Abstract

Obvious tendency and periodicity of the air temperature can be detected over the North Pole area. They are reflected as follows: a. the air temperature at the earth surface and in the middle layer of the stratosphere tends to be increased either in winter or in summer. The air temperature has increased 1.3 °C for about 50 years at a speed about 0.025 °C/year in January, and 0.013 °C/year in July. The air temperature in the middle layer of the stratosphere (10 hPa) in January has increased 10 °C. The temperature rising speed in July is 0.14 °C/year. Generally speaking, the temperature rising speed is quicker in winter than in summer and quicker in the upper layer than at the earth surface. b. The air temperature at the top layer of the troposphere (100 hPa) over the North Pole area tends to be increased either in winter or in summer. The air temperature in January has decreased 5.0 °C for about 50 years at a temperature decreasing speed about 0.094 °C/year, and at a temperature decreasing speed about 0.032 °C/year in July. The speed of the temperature decreasing is greater in winter than in summer. c. Periodicity. The air temperature respectively at different altitudes over the North Pole possesses interdecadal variation with a period of 22 years. In July the amplitude of the variation with a period of 22 years decreases rapidly from the high altitude to the low. This means that the 22–year's period is more obvious at the high altitude than at the low altitude. At the earth surface layer in North Pole there also is obvious decadal variation with a period of 11 years. The analysis indicates that the 22-years' period temperature variation is associated with the periodic variation of the solar magnetic field. The 11-year period temperature variation is corresponding to 11 year' period of the variation of the sunspot number.

Key words: decadal variation of air temperature, solar activity, North Pole area

1 Introduction

The latitude of the North Pole area is higher than 62.5°N. The absorption of the sun radiation is much less in the North Pole area than that in the middle and low latitudes. For example, the temperature records of the tundra in Alaska indicate that the average air temperature has increased 2–4 °C for about a century(GRIP,1993). The air temperature in summer at Barrow and Prudhoe Bays in Alaska has increased linearly since the 1970s. At Prudhoe Bay, this rising tendency is even more obvious. The temperature increased from 4.1 °C in 1969 to 6.9 °C in 1990. It increased 2.8 °C in the 21 years. The increasing speed is 0.13 °C/year. The temperature records in the recent 74 years indicate that the annual average temperatures at Balo Cape, the extreme north of Alaska underwent the following variation: high in the 1930s and the 1940s, low in the 1960s and high again in the recent 20 years. Rigor et al(Rigor et al., 2000) found that the surface air temperature in the whole Arctic Ocean in winter and spring gets higher and higher. The temperature in the east layer of the Arctic Ocean in spring has increased 2 °C in the recent 10 years.

The average temperature in Canada increased 1 °C in the past l00 years and 1.5 °C in its northwest and west layers. The data (1895–1996) of the 11 climatic regions indicate that the temperature increased about 1.1 °C(Chen, 2002). In the Bering Sea the temperature gets warmer in a long time. The observational records of Alaska in the recent 30 years indicate that the temperature increased 0.7 °C every 10 years and 0.25 °C in the west layer of the Bering Sea. The ice coverage decreased by 5% in the recent 30 years (Chapman and Walsh, 1993).

The above facts indicate that the air-temperature at the earth surface layer in the North Pole area in re-

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cent 100 yeas has a tendency of temperature increasing. The temperature rising tendency and the amplitudes in different regions can be different from each other(Hansen and Ebedeff, 1998; Suess and Climatic, 1968; Foukal, 1990; Wang and Zhang, 1998; Chen et al., 2000). There are data available of the North Pole area for a synthesis analysis of them, especially for its decadal variation. In the present paper the reanalyzed data are from the Air-temperature Research Center USA NCAR/NCEP, which consist of monthly average temperature data at the grids of 17 vertical layers in the whole globe. The monthly average temperature data in the area (62.5°–90°N) are used for the North Pole area. Deep and overall analysis of the temperatures data at earth surface layer, the middle layer, the top layer layer of the troposphere and the middle layer of the stratosphere has been analyzed. The analysis results indicate that there exists a very large area of the temperature increasing tendency at the earth surface layer and the middle layer of the stratosphere in the North Pole area for more than half a century. However, at the top layer of stratosphere the temperature decreases. It is worthy to notice that in the middle layer of the stratosphere the temperature fluctuates with an obvious 22-years' period without an increasing tendency.

Data: The data set used for EOF analysis in this paper is the 1000-10 hPa air temperature anomaly from the monthly NCEP/NCAR reanalysis data (1948–2000) with 2.5° latitude ×2.5° longitude intervals representing the middle layer of the stratosphere.

2 The interdecadal and decadal variation of the temperature field in the North Pole area

In the North Pole area little sun radiation is absorbed by the air in the winter half a year. Therefore, it becomes very cold to be compared with the lower latitudes (Gong and Wang, 2002). Especially for the decadal variation, as the factors, that affect it, comparatively simple, the features of its decadal variation definitely are relatively clear. In this paper, the temperature data in January is used for analysis of the decadal variation respectively at the earth surface layer, the middle layer of the troposphere, the top layer of the troposphere and the middle layer of the stratosphere in winter. The aim is to reveal the features of the decadal and the interdecadal variation in the North Pole area in winter and their affecting factors.

2.1 *Interdecadal and decadal variation of the temperature fields in the earth surface layer in winter*

In Fig.1 the black line is for the monthly average air temperature anomaly in January at the sea surface (1000 hPa). From Fig.1 it can be seen that the air temperature at the sea surface (1000 hPa) in the Arctic Ocean fluctuates and tends to go up with the air temperature increase 1.3 °C in the 53 years(1948–2000). The annual increasing speed of the temperature is 0.025 °C/year. It is slightly higher than that of the whole north hemisphere. In Fig.1 the blue line is for the upward tendency of the air temperature at the earth surface layer in the North Pole area.

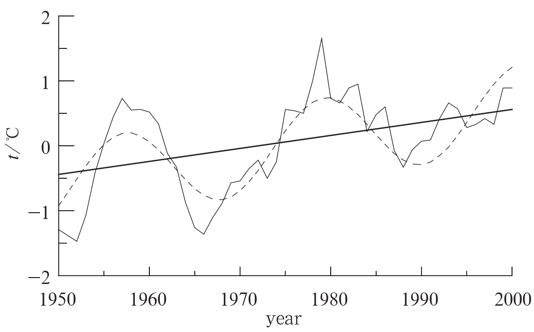

Fig.1. The monthly average air temperature anomaly at the surface layer (1000 hPa) in the North Pole area in January (1950–2000, solid line), the tendency line (oblique line), the tendency plus the component with 22 years period (dashed).

The slope, k=0.024 5, it is the annual increasing speed. The tendency equation is:

$$L(i) = -0.7 + k \times i, \quad (i = 1, 2, \cdots\cdots, 53, \text{ is the sequence numbers from 1948 to 2000}) \qquad (1)$$

From the figure it can be seen that though the air temperature curve periodically fluctuates, its increasing tendency is very clear. Therefore, the temperature increase at the earth surface layer in the North Pole area since the late 1940s is an obvious feature.

To analyze the association of the solar activity with the air temperature, we first remove the tendency (which might be effected by human activity) from the temperature sequence. Subtracting the tendency, $L(i)$, from the original temperature sequence, $t(i)$, the residual temperature sequence without the tendency, $y(i)$ is obtained.The average variance of the original temperature sequence, $t(i)$ is: $s^2 = 1.467$, The average variance of the residual temperature sequence, after the tendency has been removed, S_1=0.376. Therefore, the variation contribution of the tendency, SS is:

$$SS = ((S^2 - S_1^2)/S^2) \times 100\% \\ = ((1.467 - 0.376)/1.467) \times 100\% \\ = 74.4\% \quad (2)$$

This is to say that the temperature increasing tendency, caused by human activities or other factors, is an important feature of the air-temperature at the earth surface layer in the North Pole area and it is over 74.4% of the total abnormal variation.

Discussion: In order to investigate the physical mingling of the tendency line of the rising temperature the tendency lines of the rising temperature and the density of CO_2 (ppm) in January are given in Fig.1.1 at the same time (see next figure). It can be seen from Fig.1.1 that the tendency line of the rising temperature (inclined lineand the density of CO_2(ppm, broken lineat ground level in the North Pole in January vary with the same characters. This means that the tendency of the temperature rising is coincident very well with the tendency of the rising of the greenhouse air, represented by the density of CO_2 at ground level in the North Pole in January. This indicates that at the ground level in the North Pole, it is just the same as in the Northern Atmosphere the increase of the greenhouse air makes the climate warmer. Therefore, At the ground level in the North Pole in January the tendency line of the rising temperature is the reflection of the increase of the greenhouse air in the variation of the climate. From this viewpoint, the tendency line of the rising temperature and the line the density of CO_2 can be replaced by each other.

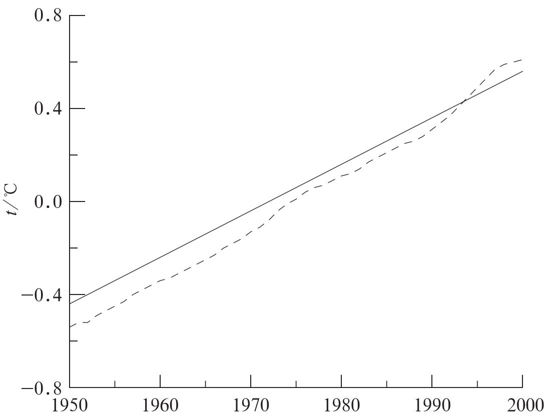

Fig.2. Tendency of air temperature at 1000 hPa (inclined line) and the density of CO_2 (ppm/50) in the North Pole in January

It can be known from the spectral analysis that in the residual anomaly sequences of the air temperature at the earth surface layer (1000 hPa) in the North Pole area in January fluctuates with an obvious 22-year period. Its amplitude is, A=0.644 71°C, its initial phase, φ=–1.329 92 Thus, it can be expressed as:

$$BO_{22}(i) = \sum_{l=1}^{m} A_l \sin(\frac{2\pi}{T_l} i + \varphi_l) = 0.644\ 71 \times \sin(\frac{2\pi}{22} i - 1.329\ 92) \quad (i = 1, 2, \cdots\cdots, 53) \quad (3)$$

where l is the wave number, m is the maximum, i.e. the total number of the wave components. In Fig.1 the red line is the sum of the tendency plusthe component with 22-years' period:

$$L(i) + BO_{22}(i) = (1.3/n) \times i - 0.7 + 0.644\ 71 \times \sin((6.283\ 2 \times i/22) - 1.329\ 92), \quad (4)$$

Comparing the monthly average atmosphere temperature anomaly at 1000 hPa in the North Pole area in January (black line) with the component with 22-years, period (red line), it can be seen that the both are basically consistent. The wave crests and wave troughs of one curve are respectively consistent with those of the other. This indicates that the 22-years period is an obvious feature of the interdecadal variation of the air temperature at the earth surface layer in the North Pole area. Its contribution reaches 24.4%, which is also important in the air-temperature variation of the air-temperature at the earth surface layer in the North Pole area.

Filting out the component with a 22-years period, from the sequence of the residual air-temperature anomaly at the earth surface layer (1 000 hPa) in the North Pole area in January there also exists a variation with an 11–years' period. Its amplitude is A = 0.2003°C, and the initial phase is φ=–1.256 53. It can be expressed as:

$$BO_{11}(i) = \sum_{l=1}^{m} A_l \sin(\frac{2\pi}{T_l} i + \varphi_l) = 0.200\ 3 \times \sin(\frac{2\pi}{11} i - 1.256\ 53) \quad (i = 1, 2, \cdots\cdots, 53) \quad (5)$$

where l is the wave number, m is the maximum, i.e. the total number of the wave components. the red line is the sum of the tendency and the component with 11-years' period.

The solid line is the final residual anomaly of the air temperature (1948–2000) at 1000hPa in the

North Pole area in January, after filtering out the tendency, the component with a 22–years' period and the components with an 11–years' period. The red line is the component with an 11-years period only. $z(i) = 0.200\,3 \times \sin((6.283\,2 * i/11) + 1.885)$. From the Figure, it can be seen that the variation tendencies of component with an 11–years' period and the measured values are basically the same. The wave crests and wave troughs occur mainly at the same time. Based on the calculation it can be known that the contribution of the component of the 11–years' period to the valiancy can reach 8%. This indicates that in the decadal variation of the atmosphere temperature at the earth surface layer in the North Pole, the 11 years' period is an obvious periodic feature.

In Fig. 1.2 the red line is the component with an 11 years' period of the air temperature at 1000hPa in the North Pole area in January. The blue line is the relative number of the sunspots. It can be seen from the figure the variation of the 2 curves are consistent. The wave crests and wave troughs of one curve are respectively consistent with those of the another. These indicate that the 11-years period in the air temperature in the North Pole area is associated with the solar activity. It is sort response of the air temperature field to the 11-year period of the sunspots. Thus, it could be seen that the solar activities affect the air temperature in 2 ways: one is affected by the variation of the solar magnetic field which is not shown. The other one is effected by the relative number of the sunspot. The former is more important than the latter.

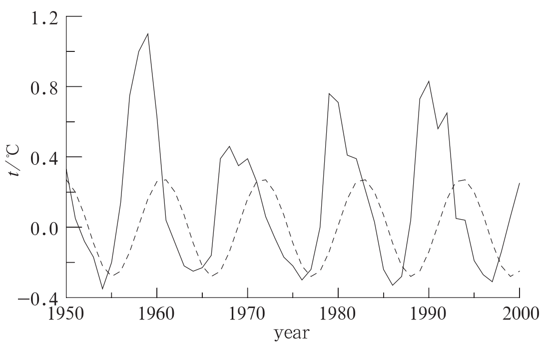

Fig.3. The component with 11 years' period at 1000 hPa in the North Pole in January (dashed line), the relative number of the sunspots (solid line).

2.2 *The interdecadal variation of the temperature field in the middle layer of the troposphere over the North Pole area in winter*

In the North Pole the continuous warming of the air temperature is gradually weakened in the higher layers. In the middle layer of the troposphere (500 hPa, about 4–5 km above the surface) the warming can not be detected. Instead, there appear the variation with a 22-year period. The spectral analysis shows that the variational period of 22 years in the air temperature in the middle layer of the troposphere (500 hPa) have passed the significance test with a confidence level of 0.95. The amplitude, $A = 0.439°\text{C}$, the initial phase, φ=–1.329 92,The component with a 22–years' period can be expressed as:

$$BO_{22}(i) = 0.439 \times \sin((6.283\ 2 \times i/22) - 1.270\ 85) \quad (6)$$

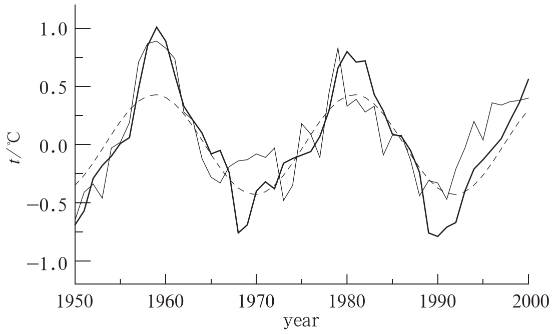

Fig.4. The anomaly of the air temperature at 500 hPa in the North Pole in January of 1948–2000 (solid line) and the component with a 22–year period (dashed line), and the number of the sunspots (divided by 100, black line)

In Fig. 2 the red line is the component with 22–year's period. From the comparison between the anomaly of the air temperature at 500 hPa in the North Pole in January (solid line) and the component with a 22–year's period (dashed line) it can be seen that the two curves are consistent with each other. The wave crests and wave troughs of one curve are consistent with the another. This indicates that the 22–year period is an obvious periodic feature of the interdecadal variation of air temperature in the troposphere in the North Pole area. Its variance contribution reaches 88.1%. This 22–year period is the feature of the interdecadal variation of the air-temperature in the middle layer of troposphere in the North Pole area.

In order to analyze the relation between the temperature variation with a 22–year'speriod in the air-temperature of the North Pole and that of the sunspots, the sunspots periodicity is drawn in Fig. 2 (black line) (Qu and Deng, 2004). From this figure it can be seen that the sunspots number variation with a 22–year period (black line) and the anomaly of the air temperature at 500 hPa in the North Pole area in January (dashed line) are consistent with each other.

The wave crests and wave troughs of one curve are consistent with the another. This indicates that the obvious 22–year period in the air temperature in the North Pole area is associated with the solar activities. It is a sort of response of the air temperature field to the solar magnetic field with a 22-year period. In Fig. 2 the temperature variation is not so regular as that of the sunspots number, and inconsistency between the two might be associated with the fact that the air-temperature variation are affected not only by solar activities, but also by other factors. Based on the above analysis it can be known that the variation with a 22-year period in the temperature of the North Pole area are associated with the solar activities. The variance contribution of the solar activities to the variance of the abnormal variation of the temperature in the North Pole is over 88.1% and it is the most important factor, affecting the decadal variation of the air temperature in the middle layer of the troposphere in the North Pole area.

2.3 *The interdecadal variation of the temperature field at the top layer of the troposphere (100 hPa) over the North Pole area in winter*

The interdecadal variation of the air temperature at the top layer of the troposphere or at the bottom of the stratosphere (at 100 hPa, about 8–9 km high) in the North Pole area have the opposite tendency to that at the earth surface layer. In the recent 50 years the temperature at 100 hPa in the North Pole area decreases continuously. In Fig. 5, the black line is for the anomaly of the air temperature at 100 hPa in the North Pole area and the blue line is for the tendency: $L(i) = 2.5 - (5.0/n) \times i$. In the 53 years the air temperature at 100 hPa decreased 5.0 °C. The annual decreasing speed is 0.094 °C/year. It is higher than the temperature-increasing speed at the earth surface. Its variance contribution is over 92.4%. It is next to the variance contribution of the component with a 22–year period at 100 hPa in the North Pole area.

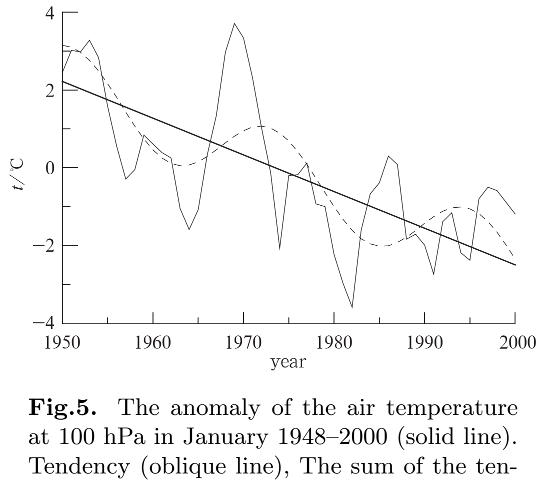

Fig.5. The anomaly of the air temperature at 100 hPa in January 1948–2000 (solid line). Tendency (oblique line), The sum of the tendency and the component with a 22–year period (dashed line).

It can be seen from Fig. 3 that after adding the decreasing tendency to the component with a 22–year period the periodic feature still appears in the air temperature at 100 hPa in the North Pole area. The spectral analysis indicates that after filting out the tendency, in the air temperature series at 100 hPa in the North Pole area in January there still exists an obvious 22-yeat's period. The amplitude is A=0.973 14°C. The initial phase is φ =0.411 38. The component with a 22–year period can be expressed as:

$$BO_{22}(i) = \sum_{i=1}^{m} A_l \sin(\frac{2\pi}{T_l} i + \varphi_i) = 0.973\ 14 \times \sin(\frac{2\pi}{22} i + 0.411\ 38) \quad (i = 1, 2, \cdots\cdots, 53) \qquad (7)$$

where l is the wave number, m is the maximum delay, is the total number of the wave components, T is the length of the period. In Fig. 3 the red line is the sum of the tendency and the component with a 22–year period:

$$L(i) + BO_{22}(i) = 2.5 - (5.0/n) \times i + 0.973\ 14 \times \sin((6.283\ 2 \times i/22) + 0.411\ 38). \quad (8)$$

From the comparison between the curve of the air temperature anomaly at 100 hPa in the North Pole area (black line) and the component with a 22–year period (red line), it can be seen that the two curves are consistent with each other.The wave crests and wave troughs of one curve are consistent with those of the another . This indicates that the 22-year period is an obvious periodic feature of the interdecadal variation of the air temperature at the bottom of the stratosphere (100 hPa) in the North Pole area. Its variance contribution reaches 4.6%. In the recent 50 years it has become most significant in the temperature at 100 hPa in the North Pole area.

2.4 *The interdecadal variation of the temperature field at 10 hPa the middle layer of the Stratosphere over the North Pole area*

From the bottom of the stratosphere (100 hpa) to the middle layer of the stratosphere (10 hPa, about 25 km high), the air temperature increases in the similar manner to that of the temperature increase at the sea surface. Therefore, its figure is omitted. Since 1948 the air temperature has a tendency to go up.The air temperature increased 10°C in 53 years. The annual increasing speed of the temperature is 0.19 °C/year. It is 7.8 times of that at the sea surface. The tendency slope of the temperature increasing in the middle layer of the stratosphere (10 hPa) in the North Pole area, k=0.19. It is the annual increasing speed. The tendency equation is as follows:

$$L(i) = -5.0 + (10.0/n) \times i,$$
$$(i = 1, 2, \cdots\cdots, 53, \text{start from 1948}) \qquad (9)$$

The temperature also fluctuates, but it clearly tends to go up. Therefore, since the late of 1940s, the warming tendency has become the most significant feature in the temperature in the middle layer of the stratosphere (10 hPa) in the North Pole area. Based on the computation it can be known that its variance contribution can reach 70%.

It can be known from the spectral analysis that after the tendency is removed, in the anomaly sequence in the middle layer of the stratosphere (10 hPa) in the North Pole area for January, there is obvious component with a 22–year period. Its amplitude, A=0.808 °C, initial phase, φ =0.140 3. The equation of the component with a 22–year period is as follows:

$$BO_{22}(i) = \sum_{i=1}^{m} A_l \sin(\frac{2\pi}{T_l} i + \varphi_i) = 0.808 \times$$
$$\sin(\frac{2\pi}{22} i + 0.140\ 3) \quad (i = 1, 2, \cdots\cdots, 53) \qquad (10)$$

where l is the wave number, m is the maximum (total number of wave components). From the comparison between the curves of the air temperature anomaly in the middle layer of the stratosphere (10 hPa) in the North Pole in January and the component with a 22-year period, it can be seen that both curves are consistent with each other. The wave crests and wave troughs are consistent to each other. This indicates that the 22–tears' period is an obvious periodic feature of the air temperature in the middle layer of the stratosphere (10 hPa) in the North Pole area. Its variance contribution reaches 14.5%. It is the secondary feature next to the tendency in the middle layer of the stratosphere (10 hPa) in the North Pole area.

3 The interdecadal variation of the temperature fields in the North Pole area in summer

Day time becomes the longest in summer in the North Pole area, the solar radiation can be absorbed the most in a year. Therefore, it is interesting to learn the interdecadal variation of the air-temperature in the North Pole area in summer. The authors have made an analysis of the interdecadal variation of the temperature respectively in the earth surface layer, the middle layer of the troposphere, the top layer layer of the troposphere and the middle layer of the stratosphere in the North Pole area in summer. The results indicate that the main features are basically similar to those in winter. We will discuss in details the interdecadal variation at 10 hPa level.

3.1 *The interdecadal variation of the temperature fields in the middle layer of the stratosphere (10 hPa) in the North Pole area*

In Fig. 4 the black line is the monthly average anomaly of the air temperature in the middle layer of the stratosphere (10 hPa) in July. The air-temperature anomaly not only fluctuates but also tends to go up.The basic features are similar to those in January in winter. In the figure the blue line is for the tendency: $L(i) = 7.2 \times i/53 - 3.7$. The slope is 0.136, i.e. the annual increasing speed of the temperature reaches 0.136 °C/year, and it is a little less than that at the same height in January (0.19 °C/year). The variance contribution of the tendency is 87.7%, and these are the basic features of the air temperature in the middle layer of the stratosphere (10 hPa) in the North Pole in July. In the figure the red line is for the sum of the tendency and the component with a 22-years' period: $7.2\times i/53-3.7+0.861\ 3\times \sin((6.283\ 2\times i/22) + 3.208\ 7)$. From the comparison between red line and black line in Fig. 4, it can be seen that their variation are consistent to each other. The wave crests

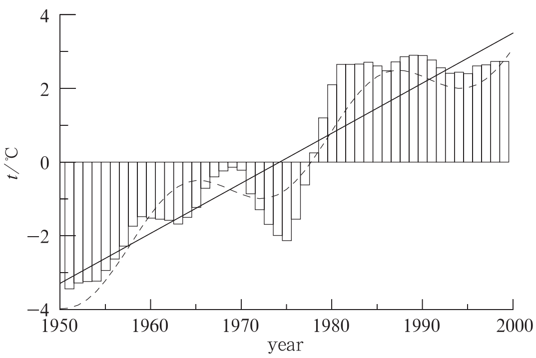

Fig.6. The anomaly of the air temperature at 10hPa in the North Pole area in July (1948–2000) (solid line), tendency (oblique line), the sum of the tendency and the component with a period of 22 years (dashed line).

and wave troughs of the black curve are consistent to those of the red curve. This indicates that the 22-year period is an obvious periodic feature of the interdecadal variation of the air temperature in the middle layer of the stratosphere (10 hPa) in the North Pole area in summer. Its variance contribution reaches 9%. It is the secondary feature in the middle layer of the stratosphere (10 hPa) in the North Pole area after the tendency.

3.2 *A comparison between the features of the interdecadal variation of the air-temperature in the North Pole area in winter and summer*

The analysis results show that in the North Pole area in July the basic feature of the interdecadal variation is still the sum of the tendency and the variation with a period of 22–years. (As it is shown in Fig. 4) The difference between summer and winter is that the variance contribution of the tendency is greater in summer than in winter, but the variance contribution of the 22–years period is greater in winter than in summer. Furthermore, there is an abrupt change in the tendency variation of the temperature at the ocean surface (1000hPa) in the North Pole area in July, but there is not in January (winter). In this paper July is representative for summer, and January is for winter. The parameters for the variation respectively in the surface layer, the middle layer of the troposphere, the top layer of the troposphere and the middle layer of the stratosphere in the North Pole area in summer are shown in the following Table 1.

Table 1. A comparison among the variance contributions made by the tendency of the temperature and the periodic variation at the isobars in the North Pole area in winter and summer

Layer		The variance contributions S and the annual speed of the temperature increase			The variance contributions S of the component with a period of 22-year period and the amplitude A			
Month		1 000 hPa	100 hPa	10 hPa	1 000 hPa	500 hPa	100 hPa	10 hPa
January	S	74.4	92.4	70.0	18.7	88.1	4.6	14.6
	KorA	0.03	–0.09	0.19	0.65	0.44	0.97	0.81
July	S	77.1	77.7	87.7	9.3	74.7	11.6	9.0
	KorA	0.01	–0.03	0.14	0.05	0.16	0.37	0.86

It can be seen from the table that the variance contributions of the tendencys at all the different isobars in the North Pole area in winter and summer are very large within a range from 70.0% to 92.4%, and is not the case in other regions of the earth. This tells us that the temperature increasing tendency in the earth surface layer, the decreasing tendency of the temperature at the top layer of the troposphere and the increasing tendency in the middle layer of the stratosphere are the main features of the interdecadal variation of the temperature in the North Pole area. This also means that the features of air-temperature in the North Pole area are stable. Originally, it was thought that the North Pole area was far away from industry and the human population is sparse, the temperature increasing tendency associated with the human activities should be less obvious, but the date analysis shows that this assumption is incorrect. In fact, the temperature increasing tendency in the North Pole area is much clearer and more stable. This can be attributed to the effects of the atmospheric circulations in the north-south direction and the mass transportation. Moreover, in the North Pole area area CO_2 can also be released into the air. It is learnt from the observations of the CO_2 flux in Alaska tundra in recent 20 years made by Whiting et al. (1992), Oechel and Vourlitis (1995) that the transition from a CO_2 source to a CO_2 sink in the atmosphere of the area. Fang et al. (1998) have also observed the release of CO_2 from the tundra covered by snow in the North Pole area area. Billings (1982) did the simulation and indicate that the warming of the globe temperature is an important factor for the CO_2 release from the tundra soil.

After filtering out the tendency, the interdecadal variation of air-temperature in the North Pole area has a period of 22 years. Its variance contribution has a range from 4.6% to 88.1% depending on the altitude. This tells us that the variation with its period of 22 years is an important component of temperature in the North Pole area. It can be seen from the table that the variance contribution of the component with a period of 22 years at each isobar level in the North Pole area area is larger in winter than in summer.

In the table it can be also seen that the variance contribution of the component with a 22–year period becomes the largest at the 500 hPa level, 74.7% in July and 88.1% in January. The variation period of 22-years becomes the main component of the interdecadal variation in the middle layer of the troposphere in the North Pole area area. The tendency is not clear. The 500 hPa level is situated in the middle layer of the troposphere, which is at the height of the transition from the temperature increasing tendency in the earth surface layer to the temperature deceasing tendency at the top layer of the troposphere. Therefore, the temperature there does not have any tendency.

4 Summary

The features of the interdecadal variation of the air-temperature in the North Pole area are very clear. They are:

a. In the earth surface layer and the middle layer of the stratosphere in the North Pole area, either in winter or in summer, the air temperature fluctuates. In January the air temperature increased 1.3 °C in the 53 years. The annual increasing speed of air-temperature is 0.024 5 °C/year. In the middle layer of the stratosphere (10 hPa) the air temperature increased 10 °C in the 53 years. The annual increasing speed of the temperature is 0.19 °C/year. It is 7.8 times of that at the sea surface. The increasing speed of air-temperature is faster in winter than in summer.

b. Either at the top layer of the convection layer or at the bottom of the stratosphere (100 hPa) in the North Pole area both in winter and in summer, air temperature fluctuates with a continuous decreasing tendency. The air temperature decreased 5.0 °C in the passed 53 years. The annual speed of the temperature decreasing is 0.094 °C/year; it is faster in winter than in summer.

c. Periodicity: There are the interdecadal variation features with a period of 22 years in the air temperature fields at the heights in the North Pole area area. The amplitude of the component with a period of 22 years rapidly decreases from the high altitude to the low in July. This indicates that the 22-year period is clearer at the high altitude than at the low. At the earth surface layer there is still the decadal variation with an obvious 11-year period. Based on the above analysis it can be concluded that the 22-year period is associated with the variation of the sunspot number. This 11-year period is consistent with the 11-year period of the relative number of the sunspots. Both are associated with the solar activities.

d. The interdecadal variation with the 22-yearsperiod in the middle layer(at 500 hPa) of the troposphere is the first feature of the multi-year variations. The 11-yearperiod is its secondary feature. There is no tendency variation.

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