RELATIONSHIP BETWEEN THE INCREASE TEMPERATURE AND VARIATION OF OZONE LEVEL OVER THE ANTARCTICA AND TIBETAN PLATEAU IN SPRING

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ABSTRACT

Based on the ozone and aerological sounding data at Syowa Station (69° 00′S, 39°35′E), Antarctica during 1966—1979 and Lhasa Station (39°40′N, 91°08′E), Tibetan Plateau during 1979—1983, the processes of temperature increase in spring over the Tibetan Plateau and the Antarctica are compared in this paper, and the relationship between the increase of air temperature and variation of total ozone and ozone partial pressure is analyzed. It is found that: (1) The process of temperature increase over the Tibetan Plateau is quite different from that over the Antarctica in spring. This is a proof that the heating effects of their ground surface on the atmosphere are of great difference; (2) Sudden increase of total ozone is always associated with sudden warming in the stratosphere over the Antarctica, but sudden decrease of total ozone is associated with sudden warming in the troposphere over the Tibetan Plateau in spring; and (3) There is a good positive correlation, with a correlation coefficient of about 0.85, between the temperature increase and variation of ozone partial pressure in the stratosphere over the Antarctica in spring.

I. INTRODUCTION

There are only two ozone observation stations in the Antarctica, namely Japanese Syowa Station (69°00′ S, 39°35′E) and American Amundsen-Scott Station (90°S). Data on both total ozone and ozone partial pressure are available since 1966 for the former, but only total ozone for the latter. Japanese meteorologists have studied the spacial and temporal distributions of ozone and their relation to the variation of air temperature over the Antarctica with these data. Tshida[1] and Sakai[2] have discussed the relationship between the variation of total ozone and sudden warming in the stratosphere with the data at Syowa Station in 1970 and 1978, respectively, and pointed out that the above two phenomena occurred at the same time in spring. Shimizu[3] has analysed the relationship between the variation of ozone and temperature in the stratosphere over the Antarctica in spring with the data of ozone content, ozone partial pressure and aerological temperature at each level, and pointed out that there is a tendency that sudden increase of ozone content is transferred from the upper stratosphere to lower stratosphere over the Antarctica in spring and the increase of ozone partial pressure corresponds to the temperature increase. Chubachi[4] has found that the time of sudden variation of total ozone and sudden warming in the stratosphere at Amundsen-

Scott Station (90°S) is one month later than that at Syowa Station after analyzing the corresponding data at Syowa and Amundsen-Scott Stations in 1982.

Although there is no ozone observation station in the Tibetan Plateau, Reiter and Gao[5] have discussed the relationship between the decrease of total ozone and the enlargement of Tibetan high with satellite data, indicating that the Tibetan high enhances when total ozone decreases.

It is well known that the Tibetan Plateau is a heat source and the Antarctica a cold source in spring[6,7]. Therefore, it should be a new and interesting work to compare the processes of temperature increase and the relationship between these processes and ozone variation in spring over these two different kinds of ground surfaces.

Following the above-mentioned work, this paper analyzes the aerological temperature and ozone data at Syowa Station, Antarctica, during 1966—1979 and Lhasa Station, Tibetan Plateau, during 1979—1983, and indicates that the processes of temperature increase over the Tibetan Plateau are quite different from those over the Antarctica in spring, which also gives the evidence for the difference between the thermal effects on the atmosphere, of the Tibetan Plateau and the Antarctica. It is pointed out that there are two types of sudden variations of total ozone and sudden warmings in the stratosphere over the Antarctica in spring. The correlation coefficient between the variations of ozone partial pressure and temperature in the stratosphere in spring is given.

II. THE PROCESS OF TEMPERATURE INCREASE OVER THE ANTARCTICA AND TIBETAN PLATEAU IN SPRING

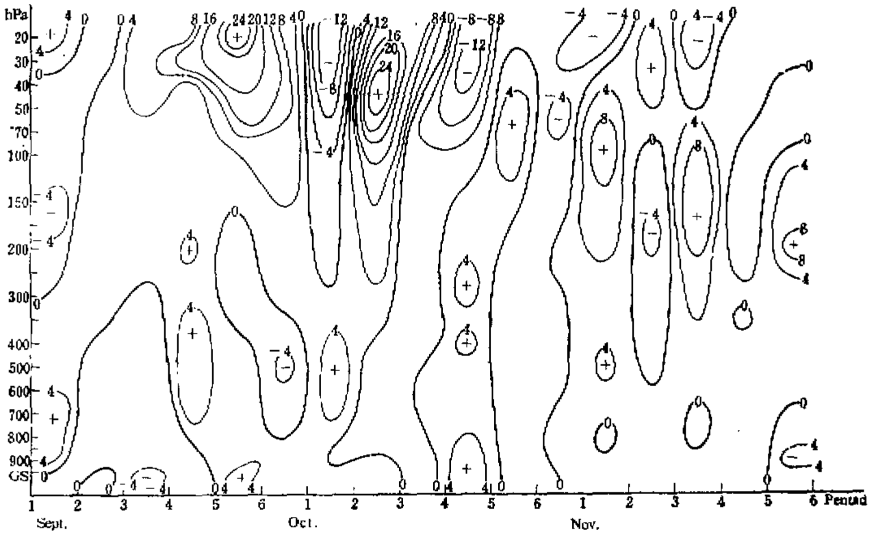

Fig. 1. Time-section of inter-pentad variation of temperature (°C) at Syowa Station, Antarctica, in September and November 1979 (GS represents ground surface).

First of all, a time-section of inter-pentad variation of temperature at Syowa Station, Antarctica (Fig. 1) and Lhasa Station, Tibetan Plateau (Fig. 2) in the same year (1979) in spring is used for comparing the process of temperature increase over the Tibetan Plateau with that over the Antarctica.

From Fig. 1, it can be seen that at Syowa Station, Antarctica the centre of temperature increase was at 20 hPa, in the fifth pentad of September 1979, then it moved downwards gradually. That is, a centre of temperature increase with an increase rate of 27.8°C per pentad was at 20 hPa during the fourth to sixth pentad of September, a centre with an increase rate of 26.6°C per pentad at 40—50 hPa during the second and third pentads of October, a centre with an increase rate of 6.4°C per pentad at 70 hPa during the fifth and sixth pentads of October, a centre with an increase rate of 10.6°C per pentad at 100 hPa during the first and second pentads of November, and finally a centre with an increase rate of 8.1°C per pentad at 200 hPa during the fifth and sixth pentads of November.

It can be seen from Fig. 2 that there were five processes of temperature increase at Lhasa Station, which occurred during the first to the third pentad of March, the sixth pentad of March to the second pentad of April, the third to the fifth pentad of April, the fifth pentad of April to the first pentad of May and from the second to the fifth pentad of May, respectively. These processes of temperature increase always started at the ground surface and then moved upwards gradually. For example, there was a centre of temperature increase with an increase rate of 4°C per day between the ground surface and 500 hPa during the fifth and sixth pentads of April, then the centre moved up to 200 hPa during the sixth pentad of April and the first pentad of May. Another example is that a centre of temperature increase with an increase rate of 7.8°C per day moved from the ground surface up to 70 hPa during the second to fifth pentad of May.

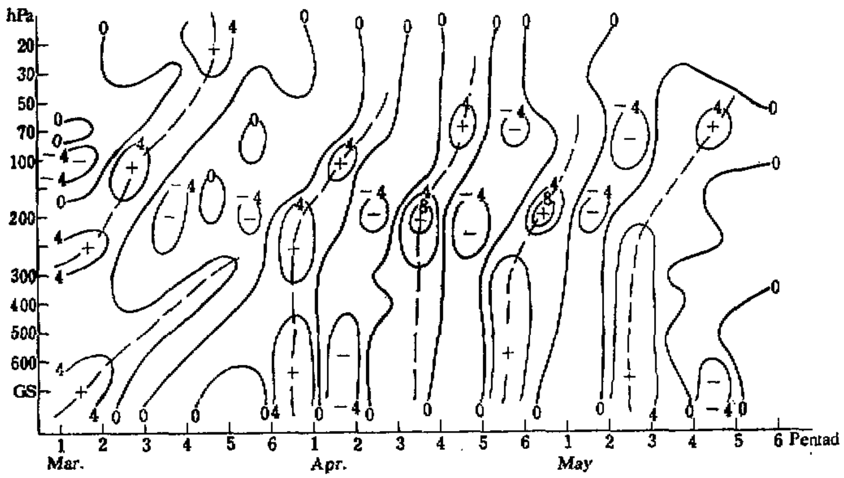

Fig. 2. Time-section of inter-pentad variation of temperature (°C) at Lhasa Station, Tibetan Plateau, during March to May 1979 (GS represents ground surface).

Two centres of temperature increase, sometimes, can be found at the ground surface and the lower troposphere at the same time. For instance, there were two centres of temperature increase separately at the ground surface and 250 hPa during the first and second pentads of March, then the centre at the ground surface moved to 300 hPa and the other one moved upwards gradually through 100 hPa onto 20 hPa.

Comparing Fig. 1 with Fig. 2, we find that the process of temperature increase at Lhasa Station, Tibetan Plateau, is quite different from that at Syowa Station, Antarctica, in spring. Firstly, the centres of temperature increase for the former are always initially found at the ground surface, which then move upwards gradually, but the main centres for the latter are always initially found in the upper stratosphere, moving downwards gradually. Secondly, the obvious area of temperature increase for the former is in between the ground surface and 250 hPa in the troposphere, but for the latter it is at 20—200 hPa in the stratosphere.

The above phenomena are more obvious in the interdiurnal temperature variation (see Figs. 3 and 4).

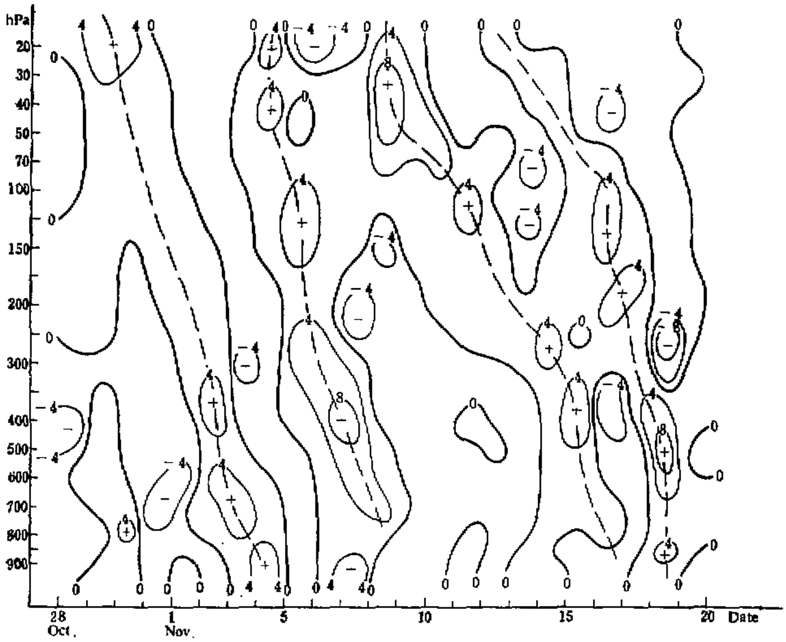

Fig. 3. Time-section of interdiurnal temperature variation (°C) at Syowa Station, Antarctica, during 28 October—20 November 1970.

There were four processes of temperature increase at Syowa Station during 28 October to 20 November 1970 (see Fig. 3). The centres of temperature increase first occurred in the upper stratosphere and then moved to the lower troposphere gradually. For example, there were two centres of temperature increase with an increase rate over 4°C per day separately at 20 hPa and 40 hPa during 4—5 November, then they went down day by day, i. e., at 100 and 150 hPa during 5—6 November, at about 400 hPa during 7—8 November, and finally at 700 hPa during 8—9 November. Other examples were: a centre at 20 hPa gradually moved down to 900 hPa during 29 October to 5 November; a centre with an increase rate of 10.8°C per day moved from 30 hPa to 400 hPa during 8—16 November; and a centre moved down from 100 hPa to 850 hPa during 16—19 November.

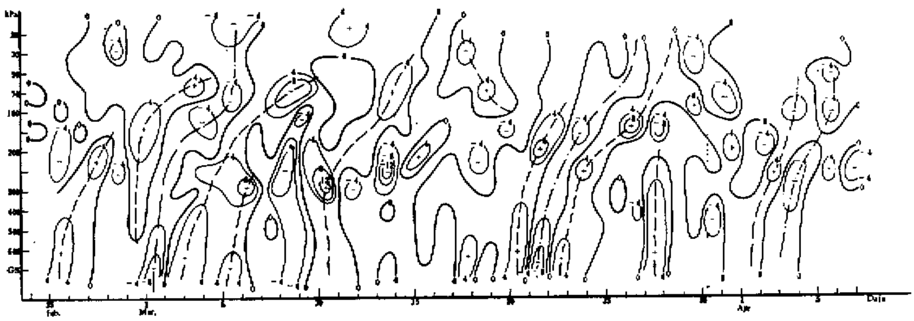

Fig. 4. As in Fig. 3, except for Lhasa Station, Tibetan Plateau, during 24 February—7 April 1980.

There were ten processes of temperature increase (see Fig. 4) at Lhasa Station, Tibetan Plateau during 24 February — 7 April 1980. Nine of them first showed their centres at the ground surface or in the lower troposphere, then moved up gradually. For instance, a centre of temperature increase with an increase rate of 4.8°C per day first occurred at the ground surface during 25—26 February, then moved up to 200 hPa during 27—28 February, with an increase rate of 5.0°C per day. The centres of temperature increase of other processes, such as those appearing during 2—7 March, 20—23 April and 22—27 April etc., also first occurred at the ground surface, and then moved up to the upper troposphere or stratosphere.

Summing up Figs. 1, 2, 3 and 4, in both inter-pentad and interdiurnal temperature variations, we can see that the processes of temperature increase over the Tibetan Plateau are quite different from those over the Antarctica. For the former, the centres of temperature increase first occurred at the ground surface, and then moved upwards gradually, which explained the heating effect of ground surface on the atmosphere and were associated with the heat source of Tibetan Plateau. For the latter, on the contrary, the centres of temperature increase first occurred in the upper stratosphere, then moved downwards gradually, which showed that the processes of temperature increase over the Antarctica from winter to summer were mainly associated with the heating effect of the sun on the upper atmosphere, while the ground surface had no heating effect on the atmosphere. It may be associated, in a certain degree, with the cold source of the Antarctica.

III. SUDDEN WARMING IN THE STRATOSPHERE AND SUDDEN VARIATION OF TOTAL OZONE

It is found from the data on total ozone and aerological sounding during 1966 to 1979 at Syowa Station, Antarctica that there are two types of relationship between the sudden warming in the stratosphere and the variation of total ozone.

1. *Type of One Sudden Variation*

This type was first discussed by Tshida[1] and Sakai[2]. Fig. 5 is an example of this type. While the total ozone had a sudden variation from 318 to 475 (m atm-cm), with an increase rate of 20 (m atm-cm) per day, during 22—30 October 1968 at Syowa Station, Antarctica, the temperature at 50 hPa had a sudden increase from −62.5°C to −27.5°C, with an increase rate of 7°C per day. Afterwards the total ozone remained at about 470 (m atm-cm) while the temperature at 50 hPa kept up at −30 °C for a long time. It means that the transition of temperature from winter to summer in the stratosphere finished after this sudden variation.

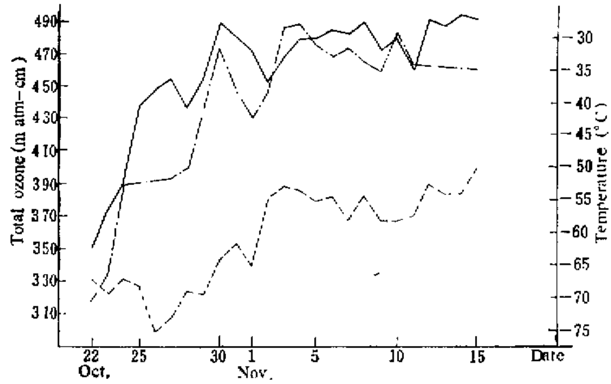

Fig. 5. Interdiurnal variations of total ozone (dot dash) and the temperature at 50 hPa (solid) and 200 hPa (dashed) at Syowa Station, Antarctica during 22 October—15 November 1968.

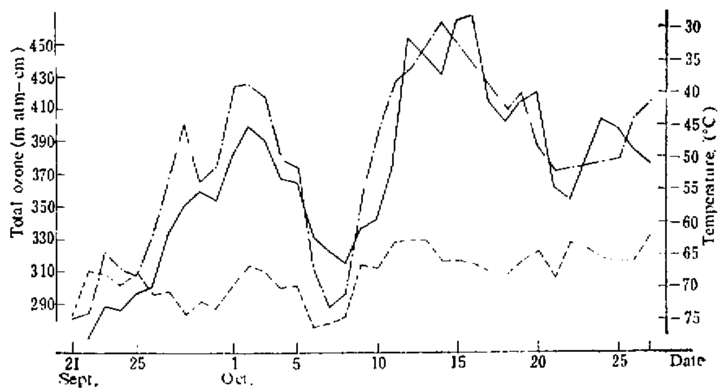

Fig. 6. As in Fig. 5, except for 21 september—27 October 1979.

2. *Type of Two Sudden Variations*

This type occurs infrequently. Fig. 6 is an example of this type. In this figure there were two sudden variations of total ozone and temperature at 50 hPa, one during 25 September — 2 October, and the other during 8—12 October. The total ozone, for the first one, varied from 299 to 424 (m atm-cm) during 25 September—1 October, increasing about 21 (m atm-cm) per day on the average. Correspondingly, during 26 September—2 October, one day later, the temperature at 50 hPa changed from −69°C to −45°C with an increase rate of 4°C per day. During 8—12 October, for the other one, the total ozone varied from 296 to 434 (m atm-cm) with an increase rate of 34.5 (m atm-cm) per day, and the temperature from −66.0°C to −31.5°C with an increase rate of 8.6°C per day.

From Figs. 5 and 6, it can be seen that the sudden warming in the stratosphere has an influence, in a certain degree, on the temperature variation in the upper troposphere. At the time (see Fig. 5) of the sudden warming in the stratosphere, three or four days later (see Fig. 6) the temperature at 200 hPa also increases with an increase rate of 3—4°C per day. This is consistent with the characteristics, as mentioned above, of the transfer of temperature increase over the Antarctica in spring.

IV. TEMPERATURE INCREASE IN THE TROPOSPHERE AND VARIATION OF TOTAL OZONE

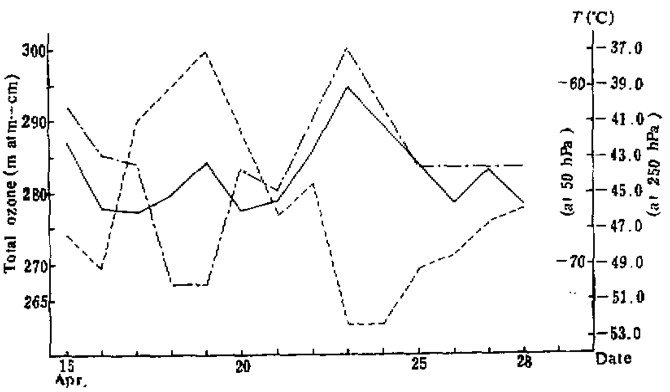

Fig. 7. As in Fig. 5, except for Lhasa Station, Tibetan Plateau, during 15—28 April 1979 (total ozone data from Reiter and Gao[11]).

There were two sudden variations of total ozone and temperature at 250 hPa during 15—28 April 1979 at Lhasa Station, Tibetan Plateau, one during 15—19, and the other during 23-26 April (See Fig. 7). During 15—18 April, total ozone decreased from 292 to 265 (m atm-cm) with a decrease rate of 90 (m atm-cm) per day. Correspondingly, during 16—19 April, the temperature at 250 hPa varied from −49.3°C to −39.1°C with an increase rate of 3.4°C per day. During 23—25 April, the average decrease rate of total ozone was 8.5 (m atm-cm) per day. Correspondingly, during 24—26 April, temperature increase rate at 250 hPa was 2°C per day.

During 19—23 April 1979, when the total ozone at Lhasa Station increased from 268 to 300 (m atm-cm), the temperature at 50 hPa also had an increase, with an increase rate of only 1°C per day.

It can be seen from the above discussion that the relationship between sudden warming and sudden variation of total ozone over the Tibetan Plateau is not as significant as that over the Antarctica in spring.

V. RELATIONSHIP BETWEEN THE PROCESS OF TEMPERATURE INCREASE AND VARIATION OF OZONE PARTIAL PRESSURE

During the sixth pentad of September and the fourth pentad of November (see Fig. 8), there were three processes of temperature increase and ozone partial pressure increase. In the first, the region of ozone partial pressure increase was in between 30 and 150 hPa, the region of temperature increase was in between 30 and 300 hPa during the first and second

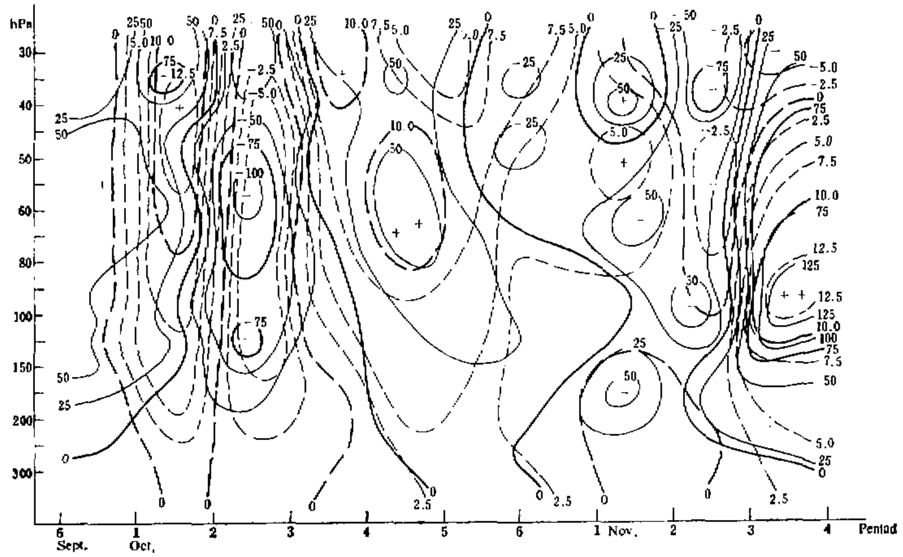

Fig. 8. Time-section of inter-pentad variations of temperature (°C, dashed) and ozone partial pressure (hPa, solid) at Syowa Station, Antarctica, during the sixth pentad of September and the fourth pentad of November, 1974.

pentads of October, and the centre of ozone partial pressure increase was at 35 hPa, with an increase rate of 70 μhPa per pentad, the centre of temperature increase was at 40 hPa, with an increase rate of 14°C per pentad. In the second, the regions of ozone partial pressure increase and temperature increase were in the same layer, between 25 and 250 hPa, during the same period, the fourth and fifth pentads of October, and the centres of them were at the same level, 60 hPa, and with increase rates of 71.0 μhPa and 11.1 °C per pentad. In the thrid, the maxima of ozone partial pressure increase and temperature increase, 129.0 μhPa and 12.5 °C per pentad, were at the same level, 90 hPa during the third and fourth pentads of November.

It is shown from the above discussion that the processes of temperature increase are always associated with those of ozone partial pressure increase.

Table 1 shows the correlation coefficient between the variations of temperature and ozone partial pressure at 30—850 hPa at Syowa Station in the Antarctica in the spring of 1974, which is calculated from 207 pairs of data on variations of temperature and ozone partial pressure at 23 isobaric surfaces between 30 and 850 hPa.

From Table 1, it can be seen that the correlation coefficient (r_e) at each isobaric sruface between 30 and 850 hPa is always positive, with a maximum of 0.9135. In the stratosphere, most of the correlation coefficients are about 0.80, and it is 0.8519 between 30—250 hPa. In the troposphere, the correlation coefficients vary in the range of 0.0063 to 0.7500, and are 0.4071 between 300 and 850 hPa. It shows that there is a good positive correlation between variations of temperature and ozone partial pressure, i. e., the temperature increases or decreases are well related to the increases or decreases of ozone partial pressure, in the stratosphere at Syowa Station, Antarctica. However, the situation in the troposphere is somewhat different from that in the stratosphere over the Antarctica, and there is no close correlation between the variations of temperature and ozone partial pressure.

Table 1. Correlation Coefficient between Variations of Temperature and Ozone Partial Pressure between 30 and 850 hPa at Syowa Station, Antarctica in the 1974 Spring

hPa	30	35	40	45	50	55	60	70	30—250 hPa
r_0	0.5547	0.7391	0.8318	0.8099	0.8444	0.8826	0.8650	0.9069	
hPa	80	90	100	125	150	175	200	250	r_t=0.8519
r_0	0.7972	0.8947	0.8250	0.9135	0.8584	0.8607	0.7910	0.8772	
hPa	300	350	400	500	600	700	850		300—850 hPa
r_0	0.0063	0.6001	0.7356	0.7500	0.6305	0.4628	0.2390		r_t=0.4071

Note: r_0 is the correlation coefficient at each isobaric surface, r_1 the correlation coefficient between 30 and 250 hPa and between 300 and 850 hPa.

VI. CONCLUSION

(1) The process of temperature increase at Lhasa Station, Tibetan Plateau is quite different from that at Syowa Station in the Antarctica in spring, which is a proof that the heating effects of them on the atmosphere in spring are different. Firstly, the obvious phenomenon of temperature increase is almost only found in the stratosphere over Syowa Station in the Antarctica, but it is mainly in the troposphere over Lhasa Station in the Tibetan Plateau. Secondly, the centres of temperature increase are almost first found at the ground surface or at the lower troposphere at Lhasa Station in the Tibetan Plateau, but most of them are in the stratosphere at Syowa Station in the Antarctica. Thirdly, the centres of temperature increase will move upwards at Lhasa Station in the Tibetan Plateau, but will move downwards at Syowa Station in the Antarctica.

(2) The sudden increase of total ozone is always associated with the sudden warming in the stratosphere at Syowa Station, Antarctica, which includes two types, namely one time and two times of sudden variation. The sudden increase of total ozone, however, can only bring about a light temperature increase in the stratosphere and its sudden decrease is associated with sudden warming in the troposphere at Lhasa Station, Tibetan Plateau in spring.

(3) There is a good positive correlation, with a correlation coefficient of about 0.85, between variations of temperature and ozone partial pressure in the stratosphere at Syowa Station in the Antarctica in spring. It means that the temperature increases or decreases are related to the increases or decreases of ozone partial pressure at each level in the stratosphere at Syowa Station in the Antarctica in spring.

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