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Relationship of Temperature Variation between in the Stratosphere and the Troposphere

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Abstract

The temperature variation in the stratosphere is very important in the global climate system. It is considered to be the key to study atmospheric temperature vertical profiles, ozone and water vapor. The temperature change in some layers from the mid-troposphere to the upper stratosphere was analyzed by using monthly mean temperature data of ECMWF reanalysis. The research results show that: (1) From 1958 to 2001, there are some differences of the temperature variation in each layer in the troposphere and the stratosphere, the global temperature in the mid-troposphere and mid-stratosphere rises remarkably, but it decreases in the lower and upper stratosphere. (2) In summer and winter, the temperature variation in each layer is almost the same. More over, the change is clearer in summer than that in winter. (3) There is a close relationship of the temperature variation between in stratosphere and in troposphere.

Keywords: Stratosphere, Temperature Variation, Climate Change

1. Introduction

The interaction between the stratosphere and the troposphere plays an important role in the climate change. And the relationship of the temperature variation between in the stratosphere and the troposphere is an important component in the change of the climate system. Researches show that the global warming is caused by the increase of the greenhouse gases which rise the temperature in the near ground and the troposphere. However, the temperature above the stratosphere keeps dropping. The change of air temperature between the upper and lower atmosphere must cause the variation of the temperature stratification conditions. It can further influence the variation of the gravity wave, planetary wave and residual circulation in the atmosphere, which alter the exchange of the quality, energy and momentum between in the stratosphere and the troposphere. The plan of the Stratospheric Processes and their Role in Climate (SPARC) which is created by the World Climate Research Programme (WCRP) specially set up a Stratospheric Temperature Trends Assessment (STTA) group.

Many researchers have done some observations and model researches on the interaction between the

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stratosphere and the troposphere at home and abroad. Leroy[1] used a simple radiative-convectional model to simulate the climate change (CO2 forcing). And then the temperature variation between in the stratosphere and the troposphere is contrasted. Angell[2] also did the similar work. Brasseur[3]and Brush[4] respectively did a experiment with numerical model, the result shows that the temperature in the stratosphere cools down by 16k to 22k at the end of the 21st century. It is found that the anomaly of the stratosphere can have an important effect on the weather systems in the troposphere through the Arctic Oscillation (AO), which means that the negative anomaly of the Arctic Oscillation (AO) in the stratosphere in winter can evoke cold wave at high latitudes and the positive anomaly of the Arctic Oscillation (AO) leads to warm, sunny weather at the same region[5]. Deng Shumei[6] used the NCEP data to analyze the characteristics of the Stratospheric Sudden Warming (SSW), the results show that the variation of the temperature and circulation in the stratosphere have an impact on the troposphere. During the period of the Stratospheric Sudden Warming (SSW), the planetary wave has a remarkable change, which will effect the troposphere through wave-flow interaction[7]. Zhen Bin[8] analyzed the temperature cooling in the lower stratosphere and its effects on zonal wind, they pointed out that the change of the mean zonal wind in the lower stratosphere is the result of the temperature variation's longitudinal nonuniformity in this region. Chen Yuejuan[9] used the HALOE data from 1992 to 2005 to analyze the variation trends of trace gases (CH4 , H2O and O3) in the stratosphere at 20-50 degrees north latitude and over China, which is contrasted with the temperature of the stratosphere. The analyses show that the seasonal variations, the quasi-biennial oscillation (QBO) signals and the long-term trends are clear for all the traces, and the trends of the trace gases in various levels of the stratosphere are different. Chen Quanliang[10,11] studied the spatial distribution of the temperature in different levels in the stratosphere, it turns out that the temperature variation in the stratosphere showed a decreasing trend, except that the temperature which is in the middle stratosphere at high latitudes and in the low stratosphere at high latitudes in the southern hemisphere changed differently.

These research results provide a good reference to our research on the interaction between the stratosphere and the troposphere. There are some defects of understanding the temperature variation in different levels in the global stratosphere, since the length and the height of the data used is limited. The ECMWF data of the global temperature is used to analyze the temperature variation at different levels between the troposphere and the stratosphere, to provide a certain reference to study the interaction between the change of the stratosphere and the change of the troposphere, and also the global climate change.

2. Data and methods

The data used in this study is the monthly ERA-40 reanalysis data from ECMWF, the time scale is from 1958 to 2001, the horizontal resolution is 2.5°×2.5°。

First, the monthly average data is processed as the corresponding annual average temperature data and the trends of the temperature variation in different levels from the troposphere to the stratosphere can be studied. Second, the relationship of the temperature variation between the troposphere and the stratosphere is analyzed through the method of the synthetic analysis.

3. Global temperature trend at different levels

Through the analysis of the global mean temperature trend, it is found that there are obvious five layers of temperature variation from the bottom to the top, such as the middle and the upper stratosphere, the lower, the middle and the upper stratosphere. This paper studies the trend of the temperature variation at different levels by selecting 500hPa (middle troposphere), 200hPa (upper troposphere), 70hPa (lower stratosphere), 20hPa (middle stratosphere) and 2hPa (upper stratosphere) as representative layers.

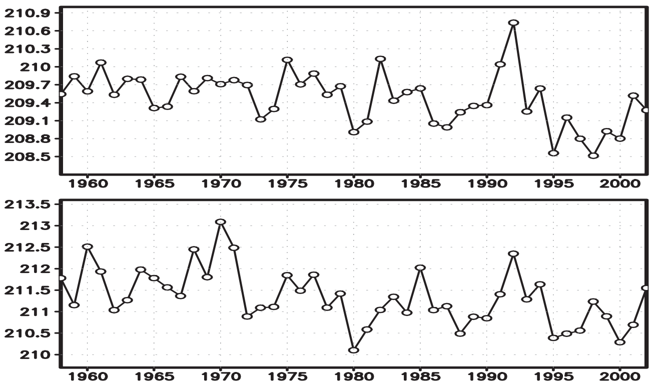

Fig.1 Global temperature variation at 70hPa (the upper is in summer and the lower is in the winter, unit: K)

Fig 1 shows the trend of the global temperature variation in summer and in winter. It can be found that the global temperature in summer changed volatile from 1958 to 1990, it decreased sharply after a sensible rise from 1990 to 1992, reaching its lowest value over the course of 44 years. It can be seen from diagram that the temperature trend takes on a descending trend from 1960 to 1967, the temperature rose slightly from 1967 to 1970, but it decreased rapidly over the next ten years and reached the lowest value over the course of 44 years, it rose slightly again in 2001. Overall, the temperature variation in the upper stratosphere is similar with the global variance of the temperature in winter and summer and both of them didn't show a obvious downward trend.

Fig 2 shows the variation tendency of the temperature in the middle stratosphere (20hPa) in winter and summer. It can be seen from the graph that the global temperature in summer increased obviously over the course of 44 years. There is a massive rise in temperature from 1980 to 1981 and a decrease in 1984. After the temperature increased from 1984 to 1986, it reached the high value in 2001 over the course of 44 years. Fig 2b depicts the interannual change of the global temperature in winter is large, the temperature oscillation is from 225k to 221.5k over the course of 44 years, the temperature in winter doesn't have a obvious relationship with the global temperature trends. In general, the temperature variation and its trends in summer are nearly the same with the global temperature variation and its trends.

Fig 3 shows the variation trends of the global mean temperature at 20hPa in summer and winter. From 1958 to 1972, the temperature has barely changed. It increased obviously in the same way from 1974 to 1975 and then it decreased. It has changed little from 1977 to 2001, but in general, it shows a descending trend. Compared with the change of the global mean temperature, the temperature variations in winter and summer correspond well with the trend of the global mean variation.

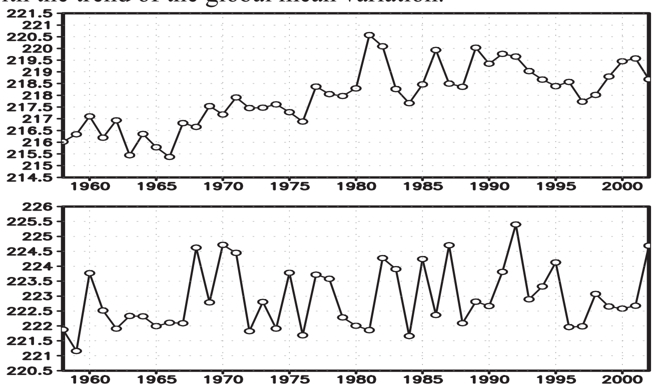

Fig 2 Global temperature variation at 20hPa
(the upper is in summer and the lower is in the winter, unit: K)

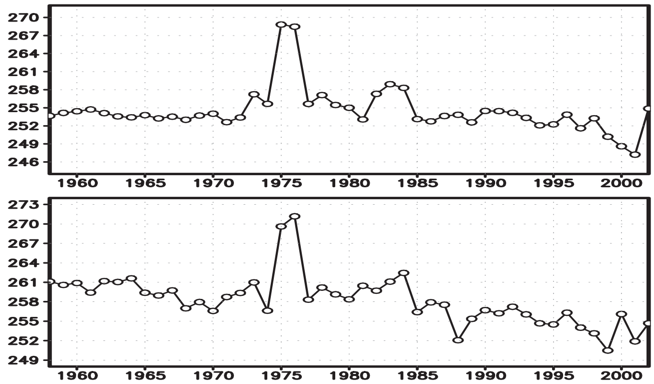

Fig 3 Global temperature variation at 2 hPa
(the upper is in summer and the lower is in the winter, unit: K)

4. Relationship of the temperature variation between in the stratosphere and the troposphere

Fig 4 compares the global mean temperature trends at 500hPa and 20hPa. It can be found that there is a good positive correlation between them over the course of 44 years, the temperature at 500hPa descends from 1958 to 1965. It also descends at 20hPa from 1960 to 1966. After the middle 1960s, both of them are on the rise and the small fluctuations of them correspond well in this changing course. The temperature trend at 20hPa lags behind it at 500hPa for one or two years and the amplitude of variation at 20hPa is larger than it at 500hPa. The correlation coefficient of the temperature trends between at 500hPa and 20hPa is 0.51976 with the correlation analysis, which passed the significance test of α =0.01. Table 1 is the correlation coefficient of the temperature trends between at 500hPa and 70hPa, 20hPa, and 2hPa, respectively. From Table 2, there is a good correlation between them. And, there is a negative correlation between the temperature trends at 500hPa and it at 70hPa and 2hPa, whose correlation coefficients have passed the significance test of α =0.05, and a positive correlation between it at 500hPa and 20hPa, whose correlation coefficients have passed the significance test of α =0.01.

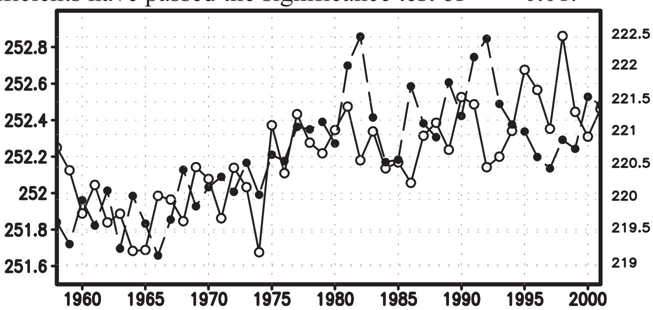

Fig.4 Global mean temperature variations at 500hPa and 20hPa
(the solid line: 500hPa, the dotted line: 20hPa)

Table.1Correlation coefficient of the temperature trends between the middle troposphere and the stratosphere

levels（hPa）	70	20	2
500	-0.26415	0.51976*	-0.34167

（* represents the significance test passed α =0.01 ）

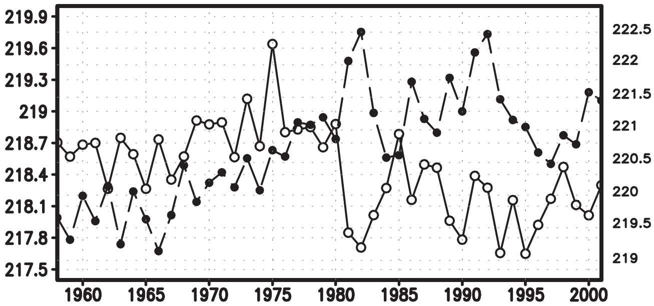

Fig. 5 Global mean temperature variations at 200hPa and 20hPa
(the solid line: 200hPa, the dotted line: 20hPa)

Fig5 compares the global mean temperature trends at 200hPa and 20hPa. It can be found that there is a good negative correlation between them over the course of 44 years, the temperature at 200hPa rises from 1958 to 1965. Although the temperature at 20hPa is in familiar tendency with it at 200hPa at the same time, the fluctuations of them show the opposite change. For example, the temperature at 200hPa shows a rising trend from 1962 to 1963, but it at 20hPa descends. In the late 1970, the general trends of them not only show the opposite trend, but also the fluctuations, the temperature at 200hPa showed a obviously descending trend, while it at 20hPa showed an opposite change. The correlation coefficient of the temperature trends between at 200hPa and 20hPa is -0.48945 with the correlation analysis, which passed the significance test of α =0.01. Table 2 is the correlation coefficient of the temperature trends between at 200hPa and 70hPa, 20hPa, and 2hPa, respectively. From Table 3, there is a good correlation between them. And, there is a positive correlation between the temperature trends at 200hPa and it at 70hPa and 2hPa, and a negative correlation between it at 200hPa and 20hPa. The correlation coefficients of them have passed the significance test of α =0.01.

Table. 2 Correlation coefficient of the temperature trends between the middle troposphere and the stratosphere

levels（hPa）	70	20	2
200	0.35710*	-0.48945*	0.56845*

（* represents the significance test passed α =0.01）

4.Conclusions

By using the ECMWF data of the global temperature, the temperature variation in different levels between the troposphere and the stratosphere is analyzed. The conclusions are as followings:

(1) From 1958 to 2001, there are some differences of the temperature variation in each layer in the troposphere and the stratosphere. There is a obviously rising trend in the middle troposphere at 500hPa, while a descending trend in the upper troposphere. Before the 1980s, the temperature is on the high side. It is low after that period. The temperature in the lower stratosphere is on the decline at 70hPa, especially in 1992, the descending trend is obvious. The temperature in the middle stratosphere at 20hPa is clearly on the rise, though it descends remarkably in the 1990s, it is still the high temperature period since 1958. The temperature shows a significant decrease in the upper stratosphere at 2hPa.

(2) In summer and winter, the temperature variation in each layer is almost the same. Moreover, the change is clearer in summer than that in winter.

(3) There is a close relationship of the temperature variation between in the stratosphere and the troposphere. The temperature trends between the middle troposphere and the lower and the upper stratosphere shows a negative correlation, also the correlation coefficient of the temperature trends between the upper troposphere and the middle stratosphere is same. There is a positive correlation of the

temperature trends between the middle troposphere and the middle stratosphere, and the correlation coefficient of the temperature trends between the upper troposphere and the lower and upper stratosphere is the same, too.

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