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VARIATION OF TOTAL OZONE IN LOWER LATITUDE AREA OF CHINA

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ABSTRACT: By using the observational O_3 data of Kunming and Hong Kong during the period of 1997 – 2001, the paper studies the distribution and variation of total ozone in low latitude region of China. The study shows that the characteristics of variation in Kunming and Hong Kong are very similar, and the total ozone in the western areas is larger than in the eastern ones. It is maximum in summer and minimum in winter.

Key words: total ozone; lower latitude; characteristics of variation; latitudinal difference

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1 INTRODUCTION

Ozone is one of the trace components in the atmosphere. It strongly absorbs ultraviolet rays to protect life on Earth. It is just because of the protection of the ozone layer that mankind and other living beings on the surface of the planet can survive. In the meantime, ozone is also one of the greenhouse gases in the atmosphere, which heats the latter by intensely absorbing solar shortwave and part of the longwave radiation in the earth-atmosphere system. Total consumption of ozone mainly takes place in the low levels of the stratosphere. When it loses, these levels decrease the absorption of the solar ultraviolet rays to increase the radiation that passes through the troposphere. It consequently results in the cooling of the lower stratosphere and warming of the troposphere. The changes in the total amount of ozone will affect the thermodynamic nature of the atmosphere and the general circulation. Variations of the total amount and distribution of atmospheric ozone will have important effects on the ecological and climatic environments across the globe. Like other greenhouse gases, ozone has become a hot topic people pay much attention to.

Following the discovery in 1985 by Earman et al. of the presence of an ozone hole over the Antarctic continent[1], Bojkov R D, Stolarski R S and Reinsel G C et al. carried out lots of studies on the trends of decrease, distribution and variation patterns of ozone in and around the ozone hole[2 – 5].

In their 1997 study on the distribution and seasonal changes of total amount of ozone over large-scale mountainous regions (Qinghai-Tibetan Plateau, Rocky Mts. and Andes), Zou et al.[6] report that the landforms reduce the effect of atmospheric ozone. Analyzing the distribution of total ozone amount and its zonal deviation, they note that there is obvious low-value ozone disturbance over the three regions, which is stronger in summer than in winter. It is also shown in

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analyses that the seasonal variation of ozone is the minimum in autumn but maximum in spring over these regions, though the deviation of total amount of ozone over these regions from that over other regions in the same latitude zone reaches the minimum in spring or early summer. They also think that the sensible heating of the atmosphere by the surface of the large-scale mountainous regions is in good anti-correlation with the ozone total.

Receiving much higher ultraviolet radiation as well as solar radiation, living beings on the surface of low latitudes are exposed to more damage than those of higher latitudes. Ozone is the principal substance that absorbs ultraviolet radiation and the low-latitude areas of China are topographically higher in the west than in the east. It is very necessary to understand the distribution and variations of the ozone total in the atmosphere over low-latitude areas of China. Wang et al.[7] once studied the ozone layer zonally averaged over the tropics in terms of dynamic systems without giving the distribution and seasonal variation of the atmospheric ozone in low latitudes. With Kunming (25.02°N, 102.68°E, 1917 m A.S.L.) and Hong Kong (22.38°N, 114.33°E, 0 m A.S.L.) as two cases representing the low-latitude areas in China, the current work studies the zonal distribution, seasonal variation and zonal deviation of the atmospheric ozone in the low latitudes of China, using relevant observations of ozone.

2 DATA AND METHODS

In the work, the dataset of atmospheric ozone total for the Kunming area are from the ozone observation station in Kunming and that for the Hong Kong area and ozone gridpoint data for the Northern Hemisphere are all from the Total Ozone Mapping Spectrometer (TOMS) of NASA. Measured by the satellite Earth Probe, the latter is derived from calculation through the TOMS V.7 program. The total value of ozone refers to its total thickness in unit of atmospheric column that is all converted under standard condition. The unit is expressed as DU (Dobson) where 1 DU = 10^{-3} atmospheric centimeter.

At present, there are about 394 ozone observation stations in a network called Global Ozone Observation System (GOOS). Its data center (WOUDC) is in Toronto, Canada. With a serial code of 209, the Kunming observation station is part of the global ozone-monitoring network in which the Dobson measuring instruments are used. It is also one of the earliest stations in China that measures the conventional elements of ozone.

The Dobson ozone spectrometer is a prism-equipped monochromatic instrument that measures the intensity of radiation from two sources with different wavelengths being about 20 mm from each other within the Huggins absorbing zone of the ultraviolet ozone frequency (with the wavelength about 300 nm – 340 nm). An optical wedge installed with the spectrometer is designed to lower the intensity of radiation observed with weak wavelengths. Then a zero location is based to determine relative radiation intensity to arrive at the ozone total in the vertical air column. Up to the present, the Dobson ozone spectrometer is still the standard instrument designated for ozone total observation in the global network, in addition to the fact that it serves as reference for other systems (including those on board satellites) that observe the ozone total.

Ever since the 1980's, the World Meteorological Organization (WMO) authorized Code 83 Dobson ozone spectrometer (installed at the atmospheric resources laboratory of NASA, Boulder, Colorado) as the world-level ozone measurement instrument. The Dobson ozone spectrometer in Kunming is sent to Australia or Japan at fixed intervals of time for simultaneous observation and comparison with regional-level Dobson instruments to ensure high-quality and reliable data.

As the observation of ozone are frequently interrupted due to problems with the equipment, the period from 1997 to 2001, which is with relatively good record of total ozone record, is selected.

In the computation of the zonal deviation of ozone, the TOMS data at the gridpoint

(103.125°E, 25.5°N) is used as the ozone total for the region of Kunming, in view of the possibility for deviations to appear in comparison due to the difference in dataset used in the TOMS data and the Kunming Ozone Observation Station. The zonal deviation *P* is defined as

$$P=Z-W$$

in which *Z* is the ozone total at the gridpoint for Kunming and *W* is the zonal mean of the latitude at which the gridpoint locates.

3 VARIATION CHARACTERISTICS OF ATMOSPHERIC OZONE TOTAL IN KUNMING AND HONG KONG

Fig.1 compares the monthly mean ozone totals in Kunming and Hong Kong and Fig.2 compares the annual mean ozone totals in the two areas, over the period from 1997 to 2001.

Fig.1 gives two curves of monthly mean variation of ozone total for the two areas. Analyzing Fig.1, it is found that:

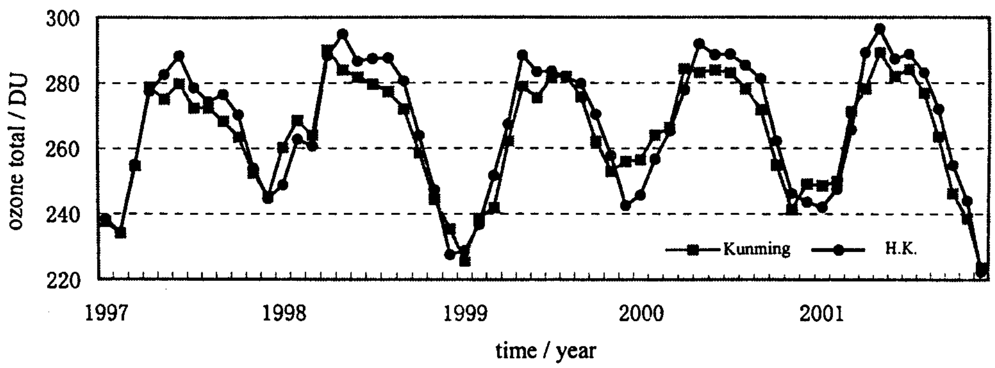

Fig.1 Comparisons of monthly mean ozone totals between Kunming and Hong Kong

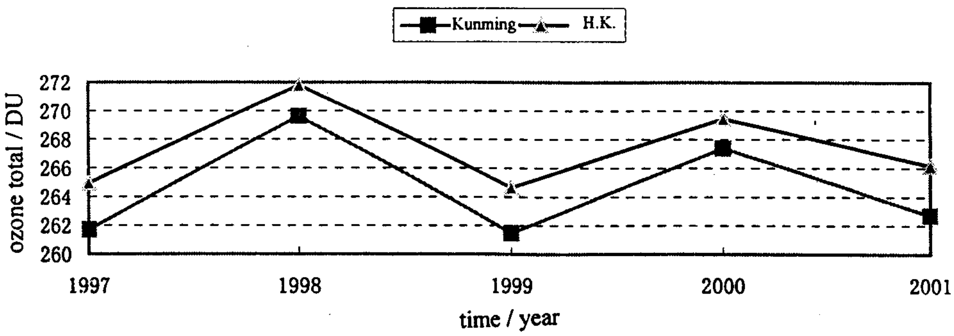

Fig.2 Comparisons of annual mean ozone totals between Kunming and Hong Kong

(1) Similarities are found with the variation curves for both areas, with a correlation coefficient of 0.953 in terms of monthly mean series of the ozone total. Separated by nearly 12 longitudes, Kunming and Hong Kong are in the west and east of China respectively. The fact that ozone varies so consistently leads one to judge that the variation of ozone total as observed in both places can well describe the characteristics of atmospheric ozone total in the low-latitude

areas of China.

(2) The maximum ozone total for Hong Kong is higher than that for Kunming. It is partly explained by the topographic differences between them — it is nearly 2000 m higher in Kunming than in Hong Kong, which is consistent with the conclusion by Zou et al. [6] that large-scale mountainous regions are decreasing the atmospheric ozone content. It may also be attributed by the fact that Hong Kong is on the east coast of Asia so that it is usually under the East Asian trough to have relatively high level of ozone[9, 10].

(3) The maximum occurs at somewhat different time in Hong Kong and Kunming. It indicates that the ozone variation there are affected by factors other than altitude.

Fig.2 compares the annual mean of ozone total in the two areas. From the figure, we first note that it is 2.1 – 3.5 DU lower in Kunming than in Hong Kong, consistent with the second point of conclusions in Fig.1. Low latitudes in China are of higher terrain in the west than in the east. Then, we also note that the ozone total oscillates at quasi-two-year periods in both areas and so does the difference in the total. It must be reflecting some kind of governing mechanism, which requires further study.

With a five-year mean of monthly mean ozone totals for both stations, curves are derived of seasonal changes as shown in Fig.3. The figure shows that:

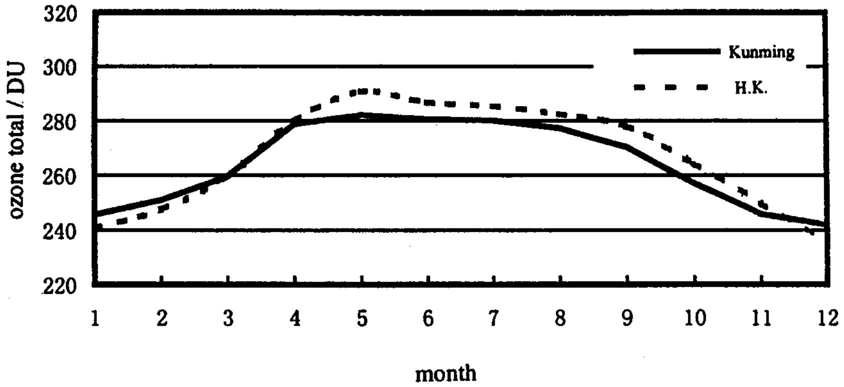

Fig.3 Comparisons of the seasonal variations of ozone totals between Kunming and Hong Kong.

(1) The difference in ozone total is relatively small in March and April between the two areas but the largest in May, 8.7 DU, about 3.29% of the Kunming total. From December to March, ozone has a higher value in Kunming than in Hong Kong while otherwise is true in the remaining months. On the whole, however, the difference is not large.

(2) For the seasonal variation, additionally, similar annual trends of variation can be found between the two stations, i.e. the ozone total reaches the maximum in summer (May) and the minimum in winter (December).

(3) Studying large-scale mountainous region[6], Zou et al. conclude that the maximum seasonal changes in ozone levels occur in spring (March) and the minimum in autumn (October) for the Qinghai-Tibetan Plateau. It is then seen that the Kunming's maximum appears about 2 months later than over the plateau for it is on its southeastern edge[6].

4 ZONAL DEVIATION OF OZONE IN KUNMING

In view of the similarity of ozone characteristics between Kunming and Hong Kong, only the case of the former (103.125°E, 25.5°N) will be used in our study.

Fig.4 gives the monthly distribution of zonal deviation of ozone in Kunming (the curve) and its tendency (the slanted line). The deviations are all negative, showing that the ozone total in Kunming is lower than its mean over the circle of the latitude at which it locates, mainly due to the effect of large-scale landform such as the Yunnan-Guizhou Plateau and Qinghai-Tibetan Plateau[6]. Fig.4 shows that in the five-year from 1997 to 2001, the largest zonal deviation in Kunming occurred in March 1999, –22.84 DU, about 8.6% of the mean ozone total there; the smallest one in February 1998, –0.15 DU. It is known from the line of tendency that the zonal deviation of ozone over the period tends to increase each year with the deviation reducing about 1 DU. At the same time, however, the zonal mean ozone for the same latitude as Kunming tends to rise, showing that the low-value ozone zones tend to enlarge to the east over the Qinghai-Tibetan Plateau, at a rate that deserves our attention. Of course, more verification needs to be done on basis of more observations.

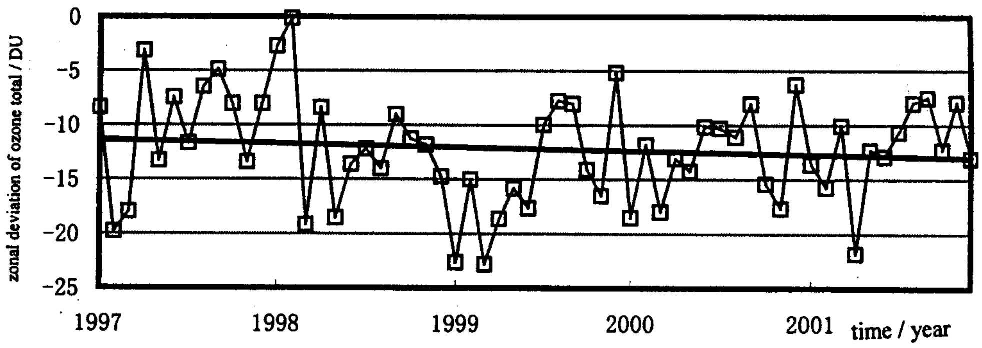

Fig.4 The monthly distribution of zonal deviation of ozone in Kunming and its tendency calculated for the period 1997 – 2001.

Fig.5 gives the comparisons of seasonal changes between the ozone level in Kunming and mean ozone level at the same latitude as the city. The solid line stands for the seasonal variation of the ozone mean at its latitude and the dashed line for the seasonal variation of the ozone in Kunming. The figure shows that the curves of seasonal changes are much alike between the Kunming ozone and the zonal mean, with a correlation coefficient of 0.984. The maximum for Kunming is in May (281 DU) and the minimum in January (245 DU). In contrast, the zonal mean has its maximum in May (296 DU) and minimum in December (255 DU).

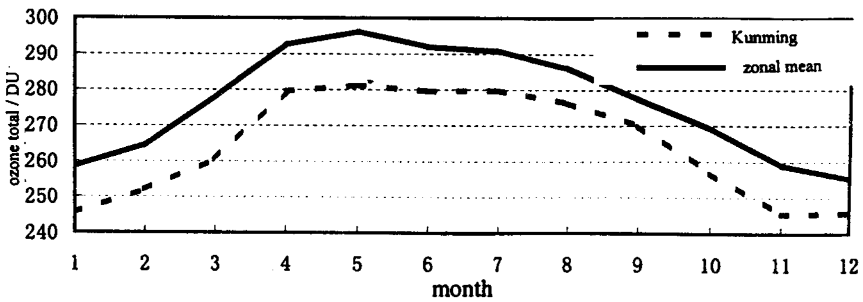

Fig.5 The comparisons of seasonal changes between the ozone level in Kunming and mean ozone level at the same latitude as the city.

In Fig.6, the dashed line stands for the seasonal changes of the zonal deviation of the ozone in Kunming and the solid line for the tendency line of 6th order polynomial of the zonal deviation in Kunming. It shows that the maximum ozone loss in the Kunming area occurs in spring (–17.6 DU, March), taking up about 6.65% of the mean ozone total there; the minimum loss in autumn (–7.49 DU, September), about 2.83% of the total. From the solid line, it is noted that the absolute values of the zonal deviation starts a process of dual waves, decreasing, increasing, decreasing again before increasing gradually, over the course of a year beginning from winter.

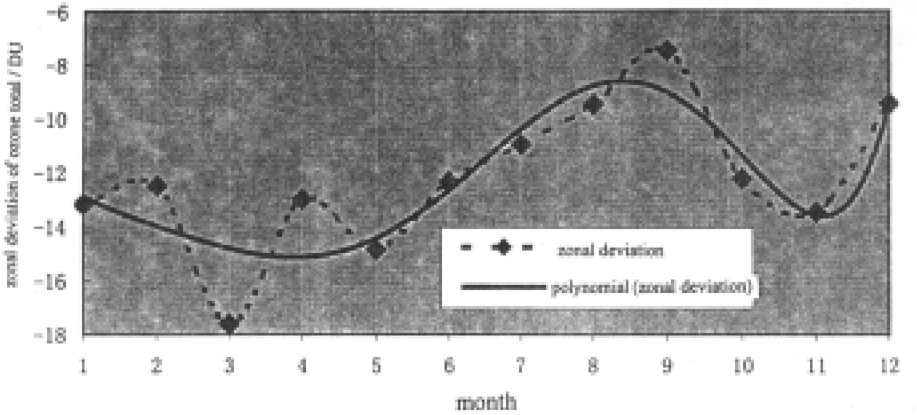

Fig.6 The seasonal changes of the zonal deviation of the ozone in Kunming

6 CONCLUDING REMARKS

a. The variation of ozone is much similar between Hong Kong and Kunming, being 0.953 in terms of correlation coefficient obtained with the monthly mean series of ozone. It then shows that the ozone observations for the two areas can be used to represent the basic overall distribution and evolution over the low latitudes in southern China.

b. The annual mean ozone total in Kunming is 2.1 – 3.5 DU smaller than in Hong Kong, mainly because of the difference in topography and geological locations. The atmospheric ozone total distributes less in the west than in the east in the southern China’s low latitudes. The ozone total reaches the maximum in summer (May) and the minimum in winter (December). Locating on the southeastern edge of the Qinghai-Tibetan Plateau, Kunming has its maximum about 2 months later than the plateau itself.

c. From the zonal deviation of ozone calculated, it is known that there are twin waves in a year in Kunming. Compared with the zonal mean, the Kunming ozone level has its largest loss in spring (March) and smallest loss in autumn (September).

There is another point that should be noted. As the atmosphere transports ozone, it will inevitably result in the variation of ozone across different regions. Since sea surface temperature is necessarily related with the general circulation, it is then inferred that SST has a set relationship with the atmospheric ozone. It has been proved in a large number of studies. For instance, Zhou et al.[11] study the ozone loss and its seasonal variation over the Scandinavian region and conclude that the seasonal changes in SST can be used to estimate the variation of ozone loss in the layer of atmospheric ozone over the Northern Hemisphere. Wang et al.[7] also work on the structure of teleconnection between the SST in tropical eastern Pacific and the boreal atmospheric ozone layer. The current paper also calculates the coefficients of correlation between the ozone total in Chinese low latitudes and the SST in the adjacent regions (maritime regions in the southeast Asia) and find some degree of correlation. At present, it is still difficult to make definitive and reasonable explanations of mechanisms responsible for the interactions between the ozone layer and SST, as the former is in the middle level of the stratosphere about which little is known and of which much is to be known, in addition to complicated processes involved. It is our view that discussions and study on this aspect can be strengthened by increasing observation and making use of diagnostic and numerical simulation.

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