Based on the EOF analysis of seasonal changes in ozone concentrations at different altitudes in the Northern Hemisphere.

Huan Zheng,

University of Chinese Academy of Sciences, China

Introduction

The mechanisms that affect the concentration changes of ozone in the troposphere and stratosphere are different. For the Northern Hemisphere, the spatial and temporal distribution of ozone concentration follows a certain pattern, after quality control of the ozone sounding data from 22 stations in the Northern Hemisphere, empirical orthogonal function (EOF) was performed based on altitude stratification. The results show that the seasonal cycle of ozone concentration presents a yearly periodicity, with the first mode being particularly significant. The seasonal characteristics of the low-latitude and mid-to-high-latitude stations differ spatially, and the concentration changes of ozone at different altitudes also exhibit their respective characteristics due to different mechanisms. Ozone is produced in the stratosphere based on Chapman mechanism, the concentration is low in mid-to-high latitudes with low radiation, and high in low latitudes with strong radiation. Ozone in the stratosphere has a longer lifespan. Mid-to-high-latitude ozone can be transported from low-latitude circulation horizontally, with strong transport in winter, which is the period of high ozone concentration in mid-to-high latitudes and low ozone concentration in low latitudes. When the transport decreases in summer, the ozone concentration in low-latitude areas increases, and the ozone concentration in high-latitude areas decreases accordingly. Ozone in the upper troposphere and lower stratosphere is mainly affected by stratospheric input and photochemical consumption, with the maximum occurring in late spring and early summer each year. The seasonal characteristics of ozone concentration near the ground differ from those at other altitudes. Considering the climate of different stations, this study suggests that wet removal plays an important role in the concentration of ozone near the ground.

Data and method

Global ozone sonde data were used for quality control and then stations in the northern Hemisphere were selected for analysis. In order to study the seasonal variation of ozone concentration at different heights, the data were highly stratified in space, divided by ten days in time, and the data characteristics were reflected by the median. After the data of the stations were standardized, EOF analysis was conducted to study the seasonal changes of 22 stations in the northern hemisphere at different heights of the troposphere and stratosphere.

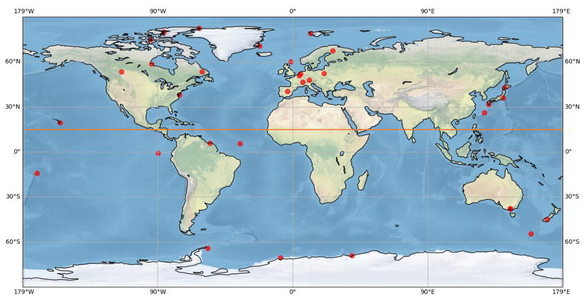

Figure 1

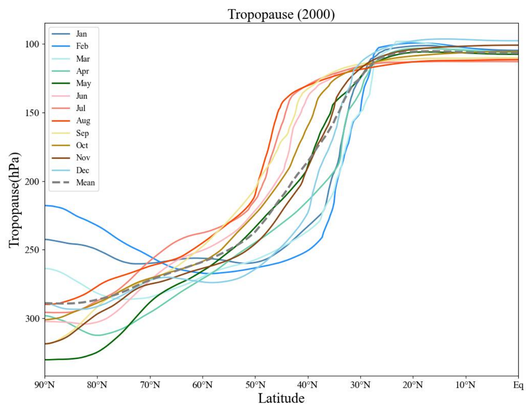

Figure 2

Using reanalysis of barometric and temperature data, tropopause heights at different latitudes were calculated. Combined with the seasonal variation of tropopause height in the northern hemisphere, the characteristics of ozone input from stratosphere to troposphere at different latitudes were further analyzed.

Results

850-700hPa

The ground to 850hPa

Figure 3

Seasonal characteristics of 22 stations:

850-700hpa:

- The mid-high latitude station is dominated by the first mode (65.71%): the high ozone concentration occurs in spring and summer of each year, and the maximum O3 occurs in late spring and early summer of each year.
- Some middle latitude stations are controlled by two modes.

The ground to 850hPa:

- The high latitude station is controlled by the second mode (47.82%): high ozone concentrations occur in the spring and summer of each year.
- The middle latitude station is controlled by the first mode (38.36%): high ozone in summer and low ozone in winter and spring.

Lat: 67.37°N
Lon: 26.63°E

Lat: 47.8°N
Lon: 11.0°E

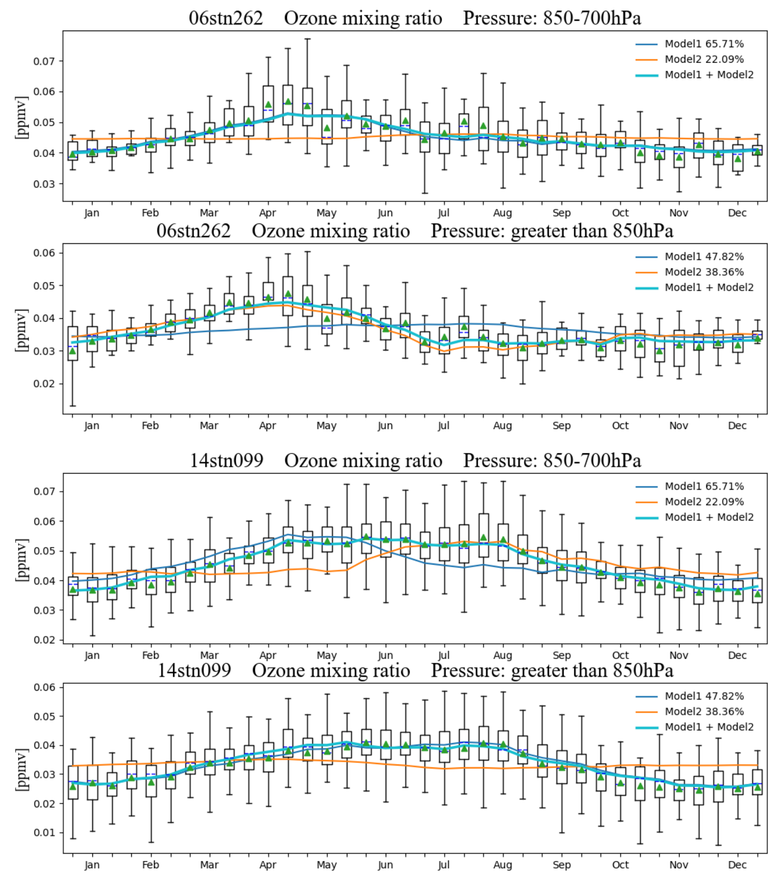

Figure 4

In order to verify the decomposition effect of EOF, the first two modes and the sum of the first two modes are returned to the original data respectively. The results show that the first two modes can reproduce the structural features of seasonal changes more accurately no matter at different altitudes or latitudes:

- In the high latitude region, it basically shows a unimodal structure. The first mode is dominant in 850 to 700hPa and from the ground to 850hPa, which is high in spring and summer and low in autumn and winter.
- In the middle latitudes, it basically presents a bimodal structure. 850 to 700hPa is jointly controlled by two modes, and from the ground to 850hPa, the first mode is dominant, which is basically high in summer and low in winter and spring.

Conclusions

The first mode is very significant (65%-80%) at the mid-high latitude stations in the troposphere. First of all, considering that the station is basically near the sea area or industrial development is not fast, so there is no serious industrial pollution. Secondly, according to the tropospheric formation mechanism, the stratospheric input is the main source, and spring is more effective than summer. Meanwhile, at the height of 300-850hPa in the troposphere, ozone depletion is mainly caused by photochemical destruction, so the ozone concentration gradually decreases at the end of summer when solar radiation is strong.

The analysis results near the ground showed that the interpretation variance of the first mode (47.82%) and the second mode (38.86%) was not much different, and the stations at different latitudes no longer had the similar consistency like the high level, indicating that the two modes may be jointly affected, so as to show inconsistent seasonal variation characteristics compared with the high level. Stations 19-21 basically belong to continental climate or monsoon climate, the precipitation is concentrated in summer, and the ozone concentration basically follows the seasonal variation characteristics of the second mode. The ozone concentration reaches the maximum value of the year in spring, and then rapidly decreases to the lowest value of the year through the wet clearance process of precipitation in summer. Therefore, the high concentration of ozone appears in spring and summer, and the maximum value appears in late spring and early summer.