Ozone during Stratospheric Warmings at Uccle

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ABSTRACT

The day–to–day variations in ozone content at Uccle (51°N) during some stratospheric warming events are examined. In particular, the attention is focused on the timing of commencement of ozone enhancement prior to peak day of warming and on the relationship in the ozone content between the upper and lower stratosphere. These two features are compared with the predictions of ozone transport models. There seems to be an agreement between model predictions and observed features in some cases.

I. INTRODUCTION

Some studies on ozone content during stratospheric warming events at high latitudes indicated strong inverse relationship in the ozone content between the upper and lower stratosphere (Ghazi, et al., 1976; Wu et al., 1985 and 1987). According to nonacceleration theorem the ozone transport can be achieved by the nonconservative planetary waves. Hartmann and Garcia (1979) have shown enhanced poleward transport of ozone by time dependent wave forcings. This model does not however take the effect of time varying wave forcing on the zonal mean flow into account. Kawahira (1982) improved the model, taking the wave–mean flow interaction into account. Kawahira's model predicts southward transport of ozone in the upper stratosphere above 30 km by wave number 1 (WN = 1) and above 45 km by WN = 2 leading to inverse relationship in ozone content between the upper and lower stratosphere. Initially, southward transport dominates for both waves in the lower stratosphere below 20 km prior to warming. The model also predicts commencement of increase in the ozone content (i. e., northward and downward transport) prior to peak day of warming (see Figs. 4 and 8 in Kawahira, 1982). This note is intended to examine the variations in the ozone content at Uccle (51°N) during the period of some stratospheric warming events and compare them with the predictions of Kawahira's model.

II. DATA AND ANALYSIS

The total ozone for each layer of 4 km thickness and the entire column, along with the vertical distribution of temperature at Uccle are considered in this study. The data were obtained from "Bulletin Trimestrial, Observations d'Ozone" published by Institute of Royal Meteorology of Belgium, Brussel, Belgium. We have examined the data for the period December to March for about 15 years (1971–1985). It is decided to examine the variations in total ozone, 10 days before and after the peak day of warming. With this end in view we have limited our study for the warming events which satisfy the following criteria;

1. The data for Uccle are available at an irregular interval of days. For our study the data (ozone and temperature) should be available for at least five days either before or after the peak day of warming allowing a maximum gap of two days.

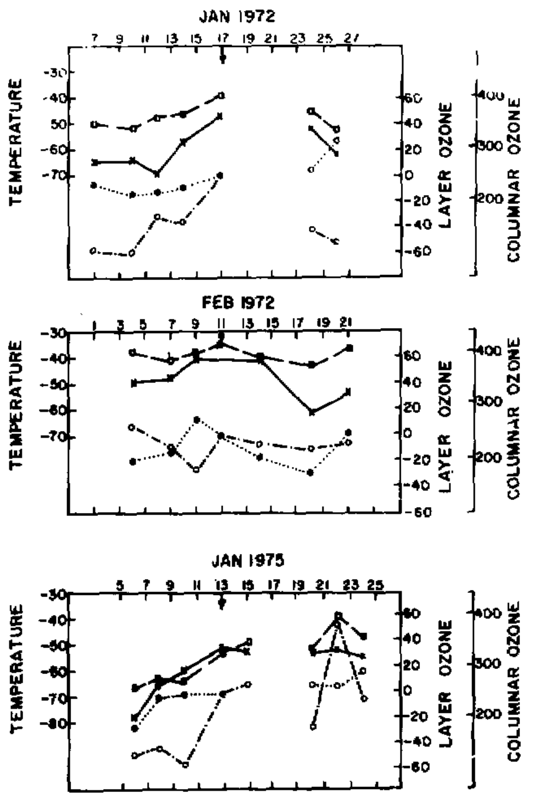

Fig.1. Total ozone in dobson units during some stratospheric warmings (see text) □— —□ ozone in the entire column. ○— · —○ ozone in the layer 8–24 Km. ●⋯⋯● ozone above 24 Km. * —— * temperature in ℃ at 16 hPa.

2. The warming rate at 16 hPa should be more than 2 K per day to avoid ambiguity, if any, that can be introduced by radiative heating during spring. The level 16 hPa is chosen because of scarcity of the temperature data above this level.

On the basis of the above criteria we could identify eight warming events at Uccle.

III. RESULTS AND DISCUSSION

The results are presented for eight events in Figs.1–3. The black arrow in the figures indicates the peak time of warming. The columnar ozone shows increase prior to peak day of warming in all the cases. In Fig.1, two warming events occurring in 1972 are presented. During these two events the columnar ozone shows increase about four days prior to the peak day of warming. This could be attributed to the northward and downward transport of ozone as well as heat by WN = 1 as predicted by Kawahira's model. Labitzke (1982) analysed the geopotential height amplitudes of zonal wave numbers 1 and 2 at 60°N at 30 hPa during the period November –April for 1965–1981. The amplitude of WN = 1 shows increasing tendency whereas the WN = 2 declining four days prior to peak day of above two warming events.

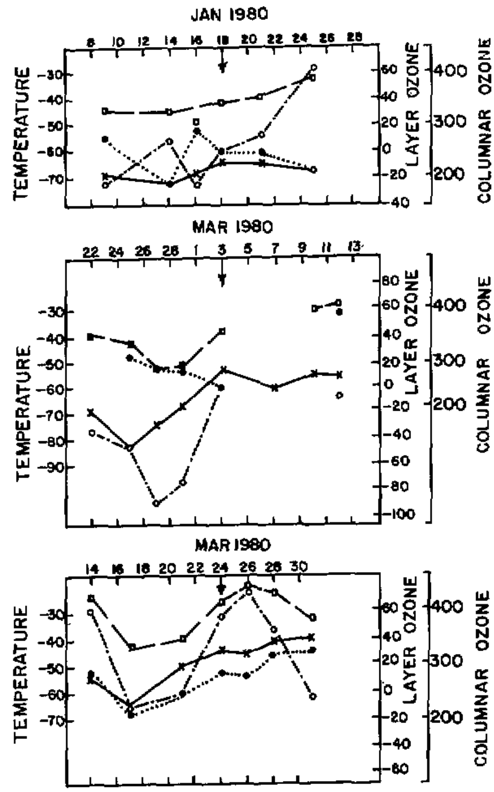

Fig.2. Same as Fig.1.

In the second week of January 1975 the WN = 1 amplitudes show declining tendency with WN = 2 increasing. In this case the increase in columnar ozone commenced about ten days prior to peak day of warming which is also predicted by the model by Kawahira (1982) for WN = 2 increasing. In this case the increase in columnar ozone commenced about ten days prior to peak day of warming which is also predicted by the model by Kawahira (1982) for WN = 2. Fig.2 shows increasing trend in columnar ozone about four days prior to peak day of warming for third week of January 1980 event. During this week WN = 1 is in the recovery phase from the earlier declining phase. During the fourth week of February and first week of March 1980 event the WN = 1 tendency is in agreement with that of ozone tendency. During fourth week of March 1980, the increasing trend in ozone is observed about seven days prior to peak day of warming. In this case the wave activity (WN = 1 and 2) is suppressed remarkably. The increase in ozone in this case may be due to the final warming. The variations in ozone content during two warming events presented in Fig.3 for 1985 appear to be related with WN = 2 activity.

In order to look for relationship between the upper and lower stratosphere, we divided the stratosphere into two layers 8–24 km and 24–∞. The ozone transport models actually predict the "Zero Transport" contour around 30 km. Unfortunately the ozone data above 24 km is scarce. Therefore we decided to see the relationship between below and above 24 km.

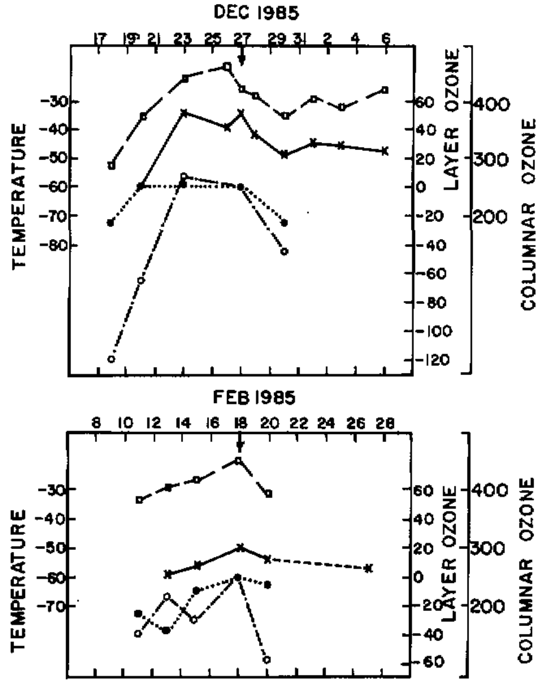

Fig.3. Same as Fig.1.

The total ozone above 24 km is obtained by subtracting the total ozone in the layer 0–24 km from columnar ozone. The layer ozone presented in all the figures is the difference between the ozone content on peak day and that on each day.

The total ozone in the layer 8–24 km (lower stratosphere) shows increasing tendency prior to peak day of warming in most cases. This is consistent with the present day ozone transport models and longer photochemical life time of the layer at higher latitudes. The opposite relationship between the upper and lower stratosphere is also evident in some cases.

IV. CONCLUSIONS

The predictions of ozone transport model (Kawahira, 1982) seem to be in agreement with the observed ozone content in the following examined features.

1. The timing of commencement of ozone enhancement in the lower stratosphere.
2. The inverse relationship in the ozone content between the lower stratosphere and upper stratosphere.

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