

## THE DAYTIME COURSE OF TOTAL OZONE CONTENT CAUSED BY CLOUD CONVECTION

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## ABSTRACT

Presented are the experimental data on the daytime course of the total  $O_3$  and  $SO_2$  content obtained by Brewer 044 spectrophotometer in the tropics (Thumba, India, 8.53N, 76.87W, March-May 1990) and at middle latitudes (Obninsk, Russia, 55.12N, 36.6W, May-October 1991) of the Northern Hemisphere. The analysis showed that under fine warm weather conditions without precipitation (air mass change and frontal passage were not observed during several days) in days with well-developed convective clouds (cloudless morning, convective clouds in the daytime, no clouds in the evening) there is a typical nearly symmetric (with respect to local noon) course of the total  $O_3$  (with the minimum at about local noon) and  $SO_2$  (with the maximum at about local noon) content. The minimum depth is about 2-5% of the average daytime values of the total ozone content. The synchronous measurements of pressure pulsations with microbarograph (they are the indicator of convective and turbulent motion development in the lower subcloud atmospheric layer) showed that during these days there is a nearly symmetric course of pressure pulsations with the maximum at about local noon (Netreba, 1991).

## 1. INTRODUCTION

It is known that with frontal passage, air mass change and their adaptation observed are significant (sometimes to 150%, Ozone Data for the World) variations in daytime values of the total ozone content. Clearly, that if continuous measurements with the interval of several minutes are carried out during the whole day, one can register the daytime course of the total ozone content. Examples are available from literature (Semenov et al., 1985).

So, the presence of daytime course of the total ozone content is a well known fact established experimentally. It turned out that under fine warm weather conditions a typical daytime course of the total ozone content occurs. There - for presented experimental data on the daytime course of the total ozone content ask for series analysis.

## 2. QUALITY OF OZONE DATA

The daytime course of the total  $O_3$  and  $SO_2$  content was measured with Brewer 044 spectrophotometer (SCI-TEC Instruments Inc., K.Lamb). The period of a single simultaneous measurement of the total  $O_3$  and  $SO_2$  content from direct Sun was 30 sec. The results of 5 adjacent single measurements are combined in to one DS-measurement. According to Operators Manual of the firm - manufacturer (Brewer Ozone Spectrophotometer Operator Manual, Canada, 1987) the DS-measurement error of the total ozone content is less than 1%. It is confirmed also by the results of a long comparison of the reference Brewer 017 spectrophotometer with the reference Dobson 083 spectrophotometer (Geophysical Monitoring for Climatic Change, Summary Report 1987. No. 16. Boulder, 1988). The DS-measurement accuracy of the total  $SO_2$  content remains to be seen, it is clear however that these measurements properly reflect the relative variations in the total  $SO_2$  content during the day. The comparison of Brewer 044 spectrophotometer with the reference Brewer 017 spectrophotometer was carried out in July 1989 and September 1991. The discrepancy between two devices for the first comparison was less than 1%, for the second - 1.5%. On the basis of second comparison varied were the temperature coefficients for Brewer 044, after that the discrepancy between two devices were again below 1%. It is noted that utilization of new temperature

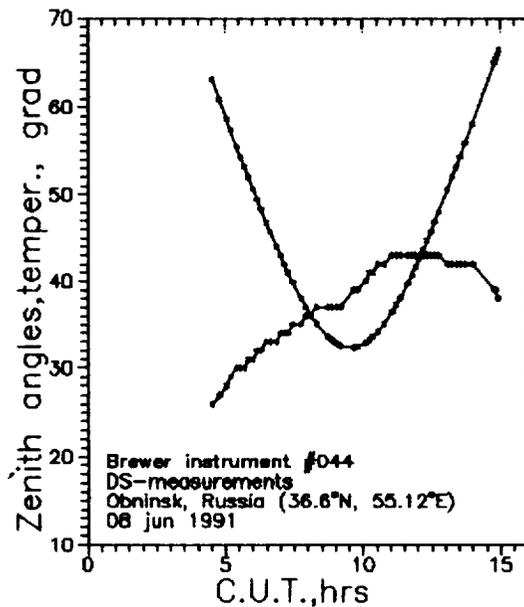
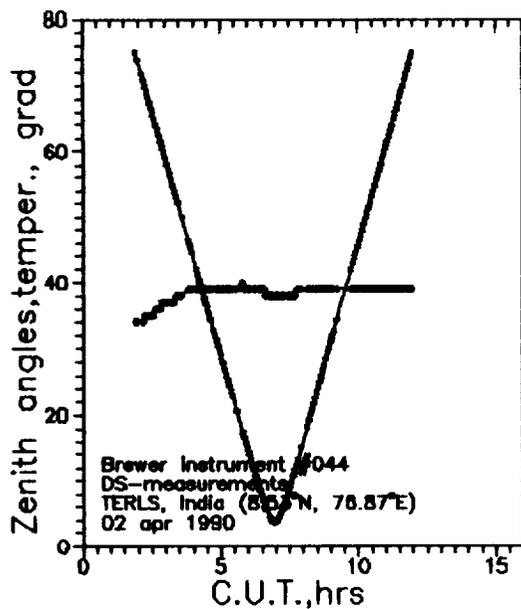
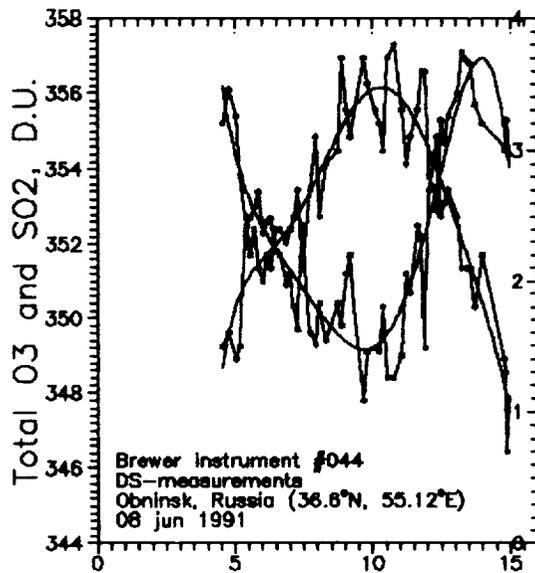
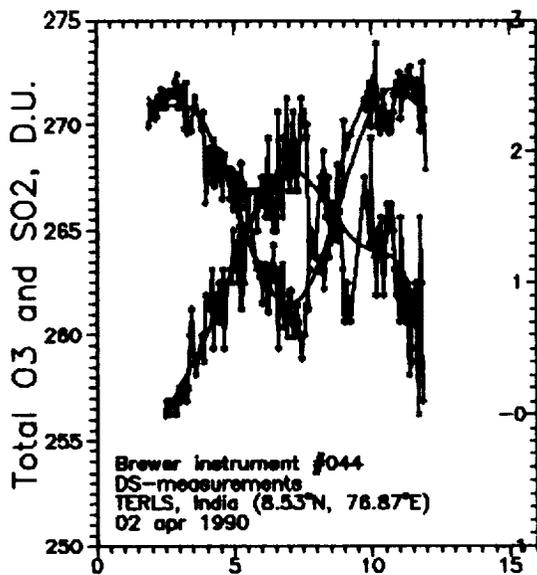


Fig. The diurnal course of the total ozone and sulphur dioxide content, solar zenith angle and device temperature under fine warm weather conditions without precipitation on days with convective clouds. Pressure pulsations on these days are symmetric relative to local noon with the maximum at local noon.

coefficients results in increase of the total  $O_3$  content values obtained in September 1991 by 5 D.U., however the relative daytime course of the total  $O_3$  and  $SO_2$  content does not vary. Therefore

the found daytime course of the total  $O_3$  content can not be caused by the incorrect working state of Brewer (44) spectrophotometer.

### 3. DISCUSSION

The daytime course of the total ozone content was measured in the tropics and at middle latitudes in various days with different aerosol atmospheric turbidity, different range of variations in the solar zenith angle, in UV solar radiation, in temperature of the device (sometimes the device was compulsory heated according to a special program). The connection between these parameters with the position and depth of the total ozone content minimum is not discovered. The displacement in position of the total  $O_3$  content minimum seems to be correlated only with the displacement in position of the pressure pulsation maximum.

A statistically important anti-correlation between the series of the total  $O_3$  and  $SO_2$  content is observed in the days with the considered daytime course of the total ozone content. (It is not the case, for example, in days with monotonous increase of the total  $O_3$  content caused by approaching cold air masses and accomplished by development of cumulonimbus clouds). Therefore it is hardly caused by the fact that values of the total  $O_3$  and  $SO_2$  content are calculated from intercorrelated formulas.

In ozonometry the idea of introducing effective coefficients of ozone absorption (Basher, 1982) is traditionally applied to avoid a labour-consuming numerical integration in frequency and height in exact expressions for radiation fluxes registered in one or another spectral channel and to reduce them to calculating effective monochromatic radiation. These coefficient values are found from a requirement for coincidence of the first two terms in the Taylor's series expansion of the exact and approximated equations for fluxes near the exponent  $z_1=0$ . As  $z_1 \sim 1/\cos \theta$ ,  $\theta$  is the solar zenith angle, the error introduced by this approximation into obtained values of the total ozone content will be symmetrical relative to local noon, minimum at noon and will exceed 3% at the solar zenith angles more than  $80^\circ$ . As showed by my accurate calculations with utilization of real apparatus functions for all spectral channels of the Brewer 044 spectrophotometer (Kerr, 1991), it can be responsible for a false daytime course of the total ozone content, but only with the maximum at local noon.

A nearly symmetrical (with the minimum at local noon) daytime course of the total ozone content registered with the help of the Brewer 044 spectrophotometer can not be explained by traditionally considered mechanisms of  $O_3$  transformation in the Earth's

atmosphere: a photochemistry in the upper ozone layer where the period of photochemical process relaxation with participation of  $O_3$  does not exceed 1-2 hours can be responsible for the daytime course of the total ozone content but only with the maximum near local noon, the advective processes in troposphere and air mass adaptation can not initiate the symmetry relative to local noon.

Proposed may be the following scenario for two-layered atmosphere, the lower layer of which is characterized by convective and turbulent motions accompanying the development of cumulus clouds. The daytime course of the integral  $O_3$  and  $SO_2$  content in the upper layer according to photochemical models of the diurnal course of minor gas components is insignificant (Karoł et al., 1987). The concentration of  $SO_2$  in the lower layer decreases exponentially, the height of homogeneous atmosphere is  $H = 2$  km, the course of  $SO_2$  are on the underlying surface level. As the convective and turbulent motions, accompanying cumulus cloud formation, developed, the lower layer become uniformly mixed. The total  $SO_2$  content in the atmospheric column may increase by  $h/H = 2-3$  times if to assume that the upper boundary of cumulus clouds is  $h=5-8$  km. Ozone is considered to be the gas nonactive relative to sulphur dioxide (Skubnevskaya et al., 1982). However the situation can vary after  $SO_2$  irradiation at the upper boundary of the lower layer solar UV radiation at 365 nm. Sulphur dioxide becomes electron excited and according to Fig.2 from (Kopjeva et al., 1982) can decrease  $O_3$  concentration by about 30% during 2-3 hours after irradiation and disappears itself. Considering that in the lower layer the integral content of  $O_3$  is about 10% of the total ozone content we obtain that the total ozone content can decrease by ~3%. In the second half of the day as convective motions attenuated the inflow of  $SO_2$  stopped its total content in the evening was close to that observed in the morning. The recovery of total ozone content up to the previous level can take place in the second half of a day due to turbulent transfer from the upper level. Actually, the turbulent flux of  $O_3$  at the layer boundary is  $F = k_z \cdot dn(O_3)/dz = 10$  D.U. for half a day if to assume that  $k_z = 200$  m<sup>2</sup>/s. As a whole a symmetry relative to local noon is initiated by a symmetry to local noon of convective and turbulent motions in the lower layer accompanying the development of fine weather convective clouds. It is confirmed by pressure pulsations measured by microbarograph.

The suggested scenario, of course,

is only one of possible scenarios of the daytime course of the total ozone content on warm days with fine weather cumulus clouds which is not rejected at once by considered estimates. To explain the presented experimental data in detail required is the correct mathematical modelling of photochemical and dynamical processes of ozone transformation in the lower subcloud layer that is beyond the scope of this paper.

#### 4. CONCLUDING REMARKS

The measurement results obtained by high precision quickrecording spectral equipment indicate that variations in the total ozone content during a day may be of a chaotic (shortperiod variations of the total ozone content) and a regular (the daytime course of the total ozone content) character. Clearly, the daytime course of the total ozone content is the indicator of formation, destruction and transfer of ozone in the Earth's atmosphere which are hidden and about which one can only suspect, bringing hypotheses of a photochemical and/or dynamical character and comparing conclusions obtained on their basis with the tendencies in the total ozone content variation registered experimentally. Experimental studies of the daytime course of the total ozone content are the actual problem because its reproduction in model experiments may be a convincing reason for acceptance, rejection or search of

various new hypothetical (at the first stage) mechanisms of ozonesphere dynamics. It is of particular importance at present, in the period of studying ozone holes and seeking important state economic solutions on protection of the Earth's ozonesphere (Kochler et al., 1990).

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