SHORT-TERM OSCILLATIONS OF THE OZONE LAYER IN THE TROPICS AND SOLAR ACTIVITY

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Data on the total ozone content (TOC) obtained with the Brewer device, which operated at Thumba in Southern India (8°N, 76°E) *from March to May 1990, are analyzed. Studies of the TOC power spectrum revealed the presence of some periods from 5 min to 8 h long and fulfilment of the "−5/3" law. This law usually manifests itself in wind fluctuations. This fact confirms the dynamic character of TOC oscillations revealed and their possible connection with the oscillations of vertical motions caused by the gravitational waves. Amplitudes and periods of TOC oscillations demonstrate the* 29-*day periodicity.*

Using special statistical analysis, the coefficients of cross-correlation with the corresponding periods, amplitudes, and indices of solar activity (10.7 cm) *were estimated. Maximum value of this coefficient is about* 0.8 *for the period of* 6–8 h.

In January-May 1990 synchronous measurements, using different techniques, of some dynamic characteristics and chemical composition of the middle atmosphere, including ozone, were conducted under the DYANA International Program.[1] The TOC measurements with the Brewer automated spectrophotometer No. 44 were conducted above Thumba Equatorial Rocket Launching Station (TERLS).

First results of the analysis of TOC behavior in the tropics and mid-latitudes were published in Ref. 2. In that case, under consideration were daily average TOC values. Below we present the results of the analysis of TOC behavior within every diurnal (daytime) interval of 47 days of successfull observation. As far as we know, this is the first case of successfull use of the Brewer device under severe tropical conditions. To decrease the influence of moisture and create favorable temperature conditions, dry argon and nitrogen were blown through the device.

According to Ref. 3, the accuracy of TOC measurements against direct sun is 1%. Before transportation into India, the device was checked against the reference Brewer spectrophotometer No. 17; the same was done in September 1991 once the observation have been finished. In the first case the difference was below 1% while in the second case it was below 1.5% (Ref. 4). Here we are dealing with the absolute accuracy of measurements referred to the world scale. The relative accuracy, important for recording of short-term TOC oscillations with the amplitude below 1 Dobson unit (1 D.u. = =0.001 atm·cm), is far greater what is readily seen from Fig. 1 which demonstrates the TOC diurnal behavior on one day of observations. In addition to 8-hour harmonic, one can readily see here 80-minute and shorter harmonics. Every of 120 experimental points on the plot is the average of five successive measurements with a step less than 1 min.

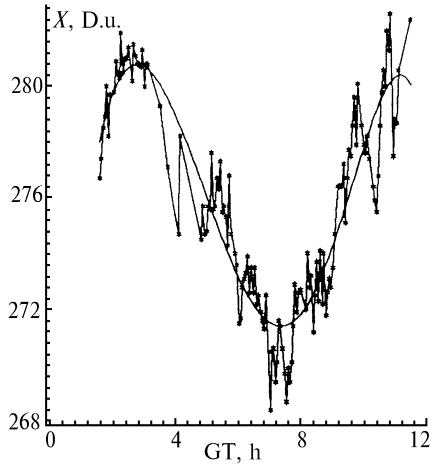

FIG. 1. TOC daily behavior on April 26, 1990. Greenwich time shown on the scale lags behind the average Indian time by 5.5 h.

Unfortunately, sometimes bad weather or other reasons broke the uniformity of the data series, that did not allow us to reliably estimate the amplitude and period of TOC oscillations. That is why we used in our analysis only selected, most reliable data. Below we present the periods, T and amplitudes, dX, of TOC oscillations for three sets of experimental data, having size N.

N	T, min	dX, D. u.
16	7–30	0.7–1.4
21	70–140	1.2–3.0
33	200–650	2.0–6.0

It should be noted, that there is practically no information in the intervals of 20–70 and 140–250 min.

The Brewer device can also be used for TOC estimation by observing the moon in the periods of full moon, usually 5–6 days long. In this case, it is very important that the moon elevation above the horizon be high because of the attenuation of weak UV radiation flux from the moon. This is illustrated by the lower curve in Fig. 2, where this attenuation is readily seen as the moon sinks to the horizont after midnight.

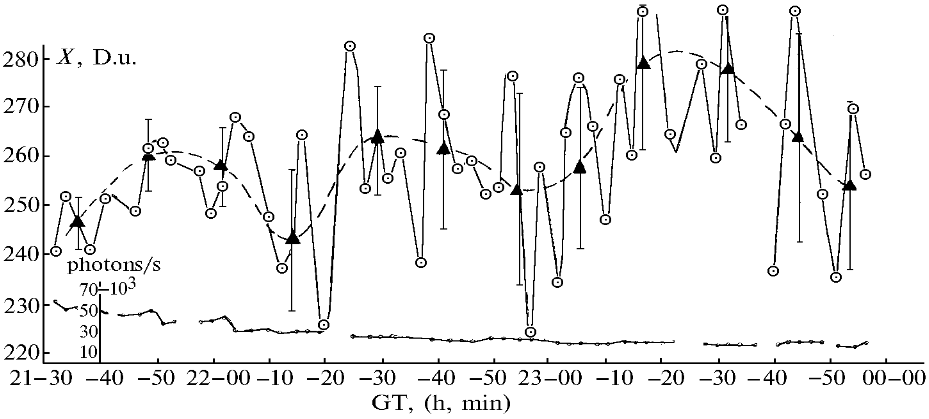

FIG. 2. TOC night behavior when measured with the Brewer device during full moon. Shown in the lower part is the behavior of UV radiation intensity in one spectral channel.

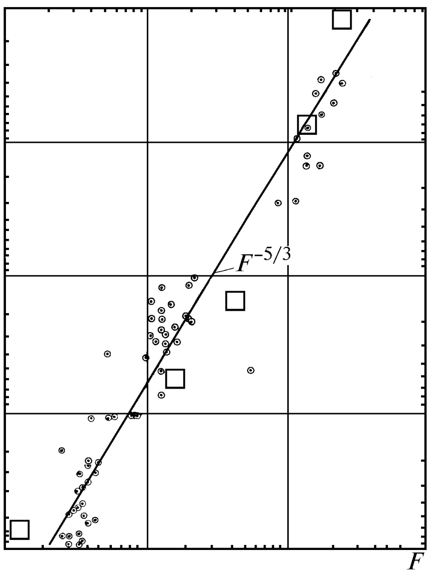

FIG. 3. Spectral power of TOC oscillations versys the oscillation frequency. The data for mid–latitudes. Squares are borrowed from Ref. 5.

Let us note two features in the night behavior of TOC, typical for this expedition. First, one can notice the period of 45–50 min, absent in daytime observations and having rather high amplitude; about 10 D.u. Second, the general positive trend (about 20 D.u. for 2.5 h) of TOC is evident, which can be interpreted as a "tailB of a more low-frequency, for example, 8-hour harmonic (in other periods of full moon the negative TOC trend was observed before midnight). Let us also note that the variance of separate TOC measurements (by five points with interval of 2.5 min), as is seen from Fig. 2, increases from 5 D.u. at the intensity of $50 \cdot 10^3$ photons/s in one of the spectral channels selected for this device, to 15 D.u. once this intensity is 2.5 times decreased. Thus, the identification of most short-term oscillations becomes unreliable.

Figure 3 shows the spectral power of TOC oscillations in $(dX)^2/F$ only for daytime conditions as a function of frequency $F = 1/T$, together with the results from Ref. 5. All data can be well approximated by the known "$-5/3$B power law, which usually describes the variability of characteristics of three wind components in the atmosphere when analyzing observations of the internal gravitational waves (IGW). At the same time, some discrepancy between our data and those from Ref. 5 in the frequency interval 10^{-4}–$3 \cdot 10^{-4}$ s^{-1} should be noted: amplitudes of TOC oscillations in the tropics are less than in mid-latitudes, that can be explained by difference in the temperature profiles, ozone and IGW characteristics. The IGW spectrum, for example, is more rich in mid-latitudes (see Fig. 3).

The most interesting result our data analysis is shown in Fig 4, which demonstrates the cross-correlation functions describing the behavior of periods and amplitudes of TOC oscillations (presented above) in relation to the so-called 27-day solar activity period, whose three full periods were related to the whole period of our observations. High anticorrelation of the index of solar activity at the frequency of 2800 MHz is most pronounced for the oscillation periods in the region 200–650 min, and the correlation coefficient is higher, for longer period or amplitude of TOC oscillations analyzed. It is clearly seen that for highest frequencies – 7–30 min – the correlation of the period with the solar index is yet seen, whereas for the amplitudes of these oscillations it is practically absent.

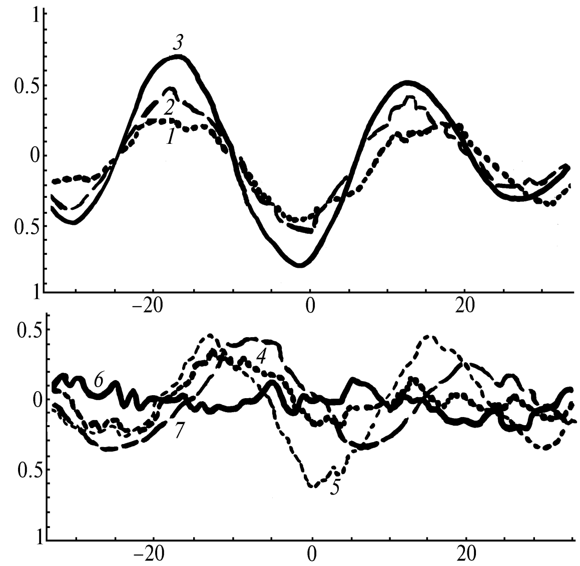

FIG. 4. Crosscorrelation functions, characterizing the correlation of the index of solar activity with the period and the amplitude of TOC oscillations for three frequency ranges of these oscillations. Curves 1 to 3, 4 to 5, and 6 to 7 characterize three ranges of periods: 200 – 650, 70 – 140, and 7 – 30 min, respectively. Curves 1, 4 and 6 correspond to the amplitudes of TOC oscillations, while curves 2, 3, 5 and 7 correspond to the periods; when plotting curve 3 the filtered data were used. Time lags in days are shown on horizontal axes.

The reasons for such a great diurnal change of TOC could be in the diurnal behavior of the dynamic characteristics of wind and, especially, its vertical component. During the DYANA campaign in the equatorial part of Indian Ocean three diurnal series of M–100B meteorological rockets launching were performed along with more frequent launchings of radiosondes. The rockets carried instrumentation for measuring temperature, air density and wind velocity in the stratomesosphere. Analysis of the data obtained showed the values of diurnal and half-diurnal oscillations of the wind velocity to be far greater (by one or two orders of magnitude) than those theoretically estimated.[6] In addition 8-hour harmonic was revealed.[7]

Diurnal behavior of the ozone concentration above 25–30 km is also confirmed by the data of rocket experiments at TERLS test site, conducted during three Soviet-Indian ozone compaigns in 1983, 1987 and 1990, as well as by independent data of Japanese investigators on observation of the diurnal behavior of ozone concentration at different levels in the stratosphere and mesosphere, using radio method from the ground.[8] In the latter case, due to significantly higher statistical coverage of observations, the 8-hour harmonics of ozone change in the upper stratosphere was reliably recorded.

It is far more difficult to explain the influence of solar activity. Satellity observations show a good correlation of ozone and temperature with the 27-day variability of UV radiation in the photochemical region of the tropical ozonosphere. However, the values of these changes are several degrees in temperature and up to 10% in ozone.[9] Such changes can hardly be interpreted by possible influence of changes in the thermodynamic characteristics of the atmosphere on the changes in the spectrum of its oscillation. The mechanism of influence of solar activity on the variability of galaxy space rays (GSRs) ionizing the lower stratosphere and creating some modulation of condensation nuclei physically seems to be more justified. There are evidences of a connection between changes in GSRs and precipitation formation in the tropics.[10] In this case the high-power modulated source of tropospheric oscillation appears that is capable to influence the spectrum of oscillations also in the stratosphere, where the IGWs penetrate.

In conclusion, it should be noted that the advent of Brewer device (now more than 100 devices can be counted) at stations of the world ozonometric network opens new possibilities to study the spectrum of atmospheric oscillations not only on the local scale, but on the wider spatial scale when analyzing, for example, such important for atmospheric physics, global and regional phenomenon, as atmospheric thermal tide, whose characteristics turned out to significantly differ from those predicted previously.[6,7,11]

ACKNOWLEDGMENT

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