SYNCHRONOUS MEASUREMENTS OF OZONE CONTENT IN THE TROPICAL AND MIDLATITUDE ZONES IN MARCH–MAY, 1990

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During the period from March till May of 1990 a series of synchronous measurements of the total ozone content have been conducted at the lake of Issyk–Kul', Kyrgyzstan and Thumba, India located at the same longitude of 77° W *but at the latitudes* 42.62° *and* 8.53° N, *respectively. Measurements have been carried out using a highly precise instrumentation. A Brewer* No. 044 *spectrophotometer of the Scientific–Production Union "Taifun" and the ozonometric instrument SFSU of Kyrgyz State University used in these measurements were mutually verified and compared with the international etalon instrument "Brewer* No. 017". *A statistically proved correlation between the variations of daily mean values of the total ozone content over the lake of Issyk–Kul' and the solar radiation flux at the* 2800–MHz *frequency has been revealed. In the case of measurement data obtained in tropics such a correlation cannot be considered statistically proved.*

During the period between March and May, 1990 within the framework of the international program DYANA[1] a series of synchronous measurements of the total ozone content have been conducted at the lake of Issyk–Kul', Kyrgyzstan, and Thumba, India located at the same longitude of 76.98 and 76.87° E but at different latitudes 42.62° and 8.53° N, respectively. The station in Thumba is located in tropics and that near the lake of Issyk–Kul' is in midlatitudes. The measurements were carried out using a highly precise spectrometric instrumentation. The total ozone content over Thumba was measured using direct solar radiation (DS–measurements) with the help of a Brewer No. 044 spectrophotometer developed by the SCI–TEC Instrument Inc. (Canada) with constant participation of the Canadian Center on Atmospheric Studies (AES) and being in constant operation at the Scientific–Production Union "Taifun", Goskomgidromet SSSR (Obninsk). Following Ref. 2, the precision of the DS measurements of the total ozone content was 1%. On the eve of this synchronous experiment (tropics–midlatitudes) the Brewer spectrophotometer was verified and compared with the etalon instrument Brewer No. 017 in Alma–Ata located appoximately 70 km northwards of the lake of Issyk–Kul'. The disagreement in the ozone data obtained with these two instruments as well as those obtained with the Brewer No. 017 spectrophotometer and the Dobson No. 093 etalon spectrophotometer (Boulder, USA) did not exceed 1%, Ref. 3. The total ozone content over the lake of Issyk–Kul' was measured using an ozonometric setup SFSU of Kyrgyz State University. It was varified with the Brewer No. 044 spectrophotometer in October, 1989. In the absence of a dense haze the disagreements did not exceed 1%, see Ref. 4. All the above said allows one to arrive at a conclusion that although the experimental data on the total ozone content used in this paper were obtained with different instrumentation, they have approximately one and the same accuracy and also they standardized with respect to the international ozonometric scale.

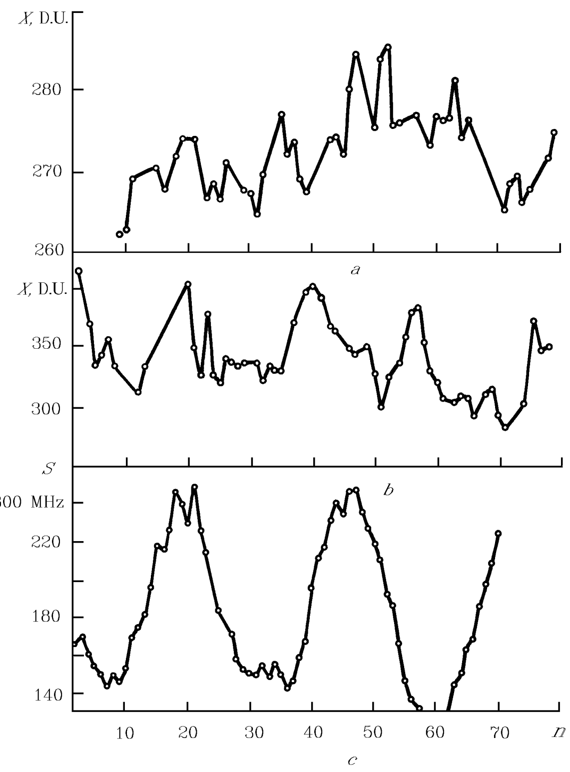

FIG. 1. Daily averaged values of the total ozone content in Dobson's units obtained using measurements in direct solar radiation: a) using the Brewer No.°044 *spectrophotometer in tropics over Thumba (India,* 8.53° N *and* 76.87° E*), b) using the SFSU ozonometric instrument of Kyrgyz State University at midlatitude over the lake of Issyk–Kul' (*42.62° N *and* 76.98° E*), and c) the solar radiation flux at the* 2800 MHz *frequency.*

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Depicted in Figs. 1*a*, *b*, and *c* are the plots of daily average values of the total ozone content over Thumba, the lake of Issyk–Kul' and a plot of solar radiation flux at the 2800 MHz frequency, respectively. On the abscissa the value $n = 10$ relates to March 14, 1990, $n = 20$ to March 24, 1990, $n = 30$ April 3, 1990, etc. The values of the solar radiation flux have two maxima at $n_1 = 18$ and $n_2 = 47$ and three minima at $n_3 = 7$, $n_4 = 36$, and $n_5 = 61$ at 2800 MHz during the period from March till May, 1990. Since $n_2 - n_1 = 29$, $n_4 - n_3 = 29$, $n_5 - n_4 = 25$, and $n_5 - n_3 = 54$, we can assume that the presence of the aforementioned extrema is due to the known 27–day variations in solar activity.

Qualitative analysis of the data presented in Fig. 1 allows one to believe that the total ozone concentration in the atmospheric column can change synchronously with solar activity. When the first maximum appears in the values of the solar radiation flux there are maxima in the total ozone contents both in tropics and midlatitudes. Synchronous appearance of the maxima in the second case is violated somewhat, but the fact of their existence is undoubtful. At the same time it should be kept in mind that variations in the total ozone content resulted from the solar activity change can be masked to a large degree by the dynamic processes in the lower layers of the atmosphere. Note, for instance, that the weather conditions near $n = 45$ were less stable than those at the beginning of the experiment under consideration. We now pass to quantitative analysis of the experimental data. The values of sampling correlation $r = \rho_{xy}(0)$ between the data sets on the total ozone content and solar activity are given in the table. Three cases are considered for each pair of these data sets: first, in which the sets start with $n_s = 9$ and terminate with $n_t = 71$ (the entire period of the experiment), second, in which $n_s = 9$ and $n_t = 30$ (the first period of the experiment was performed under stable weather conditions), and third, in which $n_s = 31$ and $n_t = 71$ (the second period of the experiment was under less stable weather conditions). The calculations were made using the formulas

$$\rho_{xy}(i) = \frac{S_{xy}(i)}{\sqrt{S_{xx}(0)S_{yy}(0)}},$$

$$S_{xy}(i) = \frac{1}{N-i}\sum_{k-1}^{N-1}\left[x(k) - \overline{x}\right]\left[y(k+i) - \overline{y}\right], \quad (1)$$

where $\overline{x}$ and $\overline{y}$ are the sample means and N is the length of the data set. We shall seek for answer the question on the existence of a significant correlation between the data series under consideration (or between segments of series) following an approximate scheme, which is based on Fisher's z – transform.[5] The hypothesis $r = 0$ (there is no significant correlation) is accepted at the 5% level of significance, if the value

$$z = \frac{\sqrt{N-3}}{2}\ln\left(\frac{1+r}{1-r}\right) \quad (2)$$

falls into the interval $[-1.96; +1.96]$ otherwise it is rejected. The values of the parameter z are also given in Table I.

TABLE I. Values of the sampling correlation $r(1)$ and the Fisher parameter $z(2)$ for temporal data sets starting and terminating with n_s and n_t, respectively.

Station	n_s	n_t	r	z
	9	71	0.08	0.62
Thumba	9	30	0.13	0.66
	9	71	0.28	2.21
Issyk–	9	30	0.56	3.32
Kul'	31	71	0.07	0.43

As can be seen from the table, there is a correlation between the total ozone content variations over the lake of Issyk–Kul' and those of solar activity (at the 5% level). According to the proposed scheme similar correlation for the measurements over Thumba in tropics cannot be considered statistically significant. It should be noted, however, that the observed variations of the total ozone content in tropics are normally much weaker than those in the midlatitude zone. For example (see Fig. 1), the ozone content over the Issyk–Kul' varies from 275 to 397 D.U. with the mean value 340 D.U., while over Thumba it changes from 262 to 286 D.U. with the mean value 273 D.U., that is, in the first case the variation of the total ozone content was 37% with respect to the mean value and in the second case this value was 9%.

Figure 2*a* depicts the plots of autocorrelation and covariation functions for the measurements over the lake of Issyk–Kul'. The calculations were also made using formula (1), where the index of delay i took the values of from 30 to +30. The autocovariation function for a data set of the solar radiation flux has its maximum at $i = 0$, two secondary maxima at $i = -26$ and $i = +26$, and two minima at $i = -13$ and $i = +13$. The form of this function makes it possible to unequivocally conclude that the observed changes in the solar radiation flux are actually caused by the known 27–day cycle of variations in solar activity. The autocovariation function for the data set of the total ozone content has its principal maximum at $i = 0$ and two secondary maxima at $i = -19$ and $i = +19$. The covariation function for these two sets has two well pronounced maxima at $i = +2$ and $i = +28$.

Thus the plots indicate the relationship between the variations in the total ozone content over the lake of Issyk–Kul' and those in the solar radiation flux at 2800 MHz caused by a 27–day cycle of variations in solar activity. In this case, as was already noted, such a correlation is statistically significant.

Similar plots for the measurements over Thumba are shown in Fig. 2*b*. The autocorrelation function for the ozone data set has its principal maximum at $i = 0$ and two secondary maxima at $i = -14$ and $i = +14$. The covariation function has its maxima at $i = -4$ and $i = +24$ and minima at $i = -23$ and $i = +9$. A quantitative behavior of the last curve also is indicative of the relationship between the total ozone content increase and the increase of the solar radiation flux, though it cannot be quantitatively treated to be statistically significant. This is probably due to weaker variations in the total ozone content over tropics compared to ozone variations over midlatitudes what is quite a typical situation. It is worth noting that the total ozone content increase in tropics lags behind the solar radiation flux increase by four days.

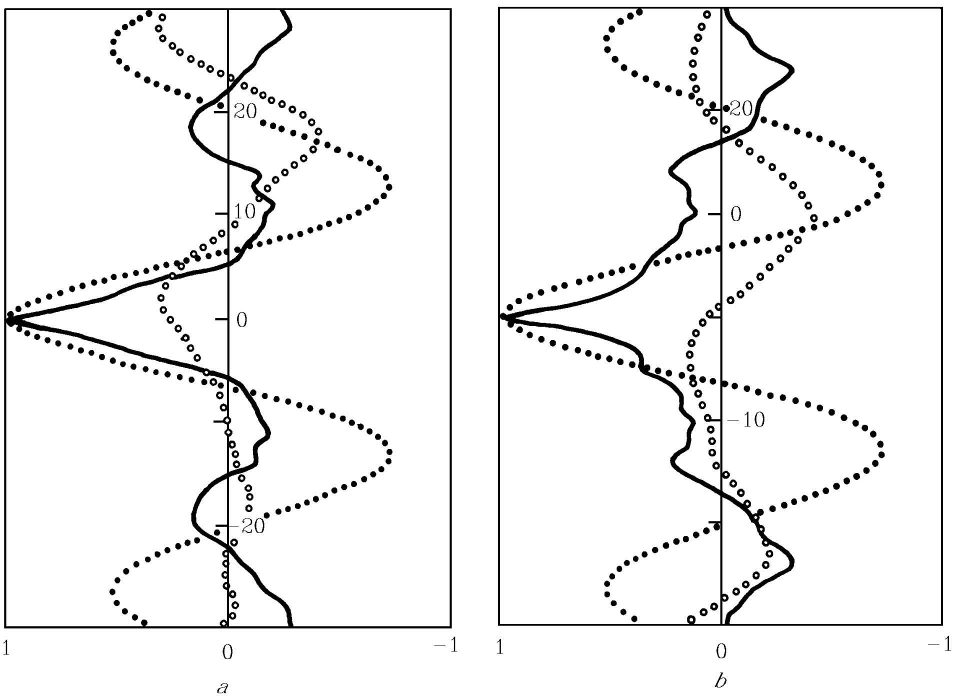

FIG. 2. Autocovariation function for a data set of the solar radiation flux at 2800 MHz *(dotted curve), autocovariation function for a data set of the total ozone content (solid curve), and covariation function for these two data sets (circles): a) over the lake of Issyk–Kul' and b) over Thumba (tropics).*

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