VARIATIONS OF THE GROUND-LEVEL ULTRAVIOLET RADIATION IN EAST SIBERIA

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ABSTRACT

Daily measurements of the ground-level ultraviolet radiation (UVR) for the years 1998-2000 were used to investigate the seasonal UVR variation in the East Siberian region. The study revealed the asymmetry of the seasonal UVR variation with respect to the angular altitudes of the Sun, caused by the seasonal variation of the total ozone content (TOC), and possibly by the presence of the snow cover. Characteristics of the occurrence of short-lasting increases in UVR are considered, which are associated with TOC anomalies and with high atmospheric transparency. Fluctuations of the ground-level UVR with periods of 2.8, 6-13 and 26 days are identified. A study is made of the dependence of the ground-level UVR on solar activity. Statistically significant correlation coefficients with solar activity indices are obtained.

INTRODUCTION

The flux of solar ultraviolet radiation (UVR) plays an important role in phenomena occurring in the atmosphere and on the Earth's surface, and participates in many photochemical and chemical-biological processes. The UVR level and variations are strongly affected, in addition to heliophysical factors associated with the angular altitude of the Sun and its activity, by the variability of the total ozone content (TOC), variations in composition and concentration of aerosols and other atmospheric species, atmospheric pollution, and by the cloudiness.

Results derived from investigating the TOC indicate, in addition to a general tendency toward its decrease (Stolarski et al., 1991), the occurrence of regions with decreased values of the TOC in some periods in some regions of the planet (Kruchenitsky et al., 1998). The most considerable ozone depletion is observed in the Antarctic (Farman et al., 1985). Some authors have emphasized the changes of Earth's cloud regime (Nezval, 1996; Justus and Murphey, 1994). Owing to this, there is still enhanced interest in research on the ground-level solar UVR in different regions of the Earth characterized by different climatic conditions (Bernhard et al., 1997; Blumthaler and Ambach, 1990; Kruchenitsky et al., 1998; Pu Bu Ci Ren et al., 1999; McKenzie et al., 1993). Such regions on the globe involve also the Asian region, including East Siberia where TOC anomalies have been observed in recent years (Kruchenitsky et al., 1998). This region is characterized by a strong influence of the extensive Asian anticyclone which in many respects determines the state of the atmosphere and its dynamic regime during the spring-summer period. This paper presents the results of spectral measurements of ground-level UVR in Irkutsk (52°N, 104°E) during the time interval from September 25, 1998 to April 30, 2000. Characteristics of the seasonal

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variation of UVR for that period, the variations during periods of short-lasting TOC anomalies, and the dependencies of UVR on solar activity are considered.

**OBSERVATION RESULTS**

Measurements were made of the near-noon values of UVR in the spectral range 295-345 nm using the spectrophotometer with a spectral resolution of about 0.24 nm and the scanning rate of ~0.33 nm/s. Records were made of the intensity of radiation incident on a vertical mat quartz area with the angular half-width of the view field of the entire optical channel of ~18°, i.e., the direct UVR and some of the scattered UVR were recorded. The stability of the measuring channel was monitored every day with a reference light source. The scatter of signals from the reference light signal did not exceed 1%. For absolute calibration of the system, a banded tungsten lamp and Buger's method of straight lines were used. Finite values of the UVR intensity were reduced to the intensities arriving at the surface perpendicular to the solar rays. The TOC values were taken from satellite measurements (NIMBUS-7, TOMS version 6.0 and 7.0 (NASA Goddard Space Flight Centre, the TOMS Science Team).

Figure 1a presents the UVR intensity variations at the wavelength $\lambda = 310$ nm for all days of observation, including clear and cloudy days, and the TOC values over Irkutsk for the period from September 25, 1998 to April 30, 2000. The mean UVR level in June 1999 exceeded the level of December 1998 for 310 and 323 nm wavelengths, respectively, by a factor of ~34 and ~10. A characteristic feature of the seasonal variation of the UVR, shown in Figure 1a, is the asymmetry expressed in the difference of the increasing (winter 1998 - summer 1989) and decreasing (summer 1999 - autumn 1999) branches of the seasonal variation. With the identical solar angular altitude of ~25-35°, the values of the UVR corresponding to February-March 1999 exceed the values of the UVR corresponding to September-October 1999, while for the solar angular altitude of ~40-55° there is an excess of the value of the UVR in August compared to the period of April-May 1999 (with a maximum excess of ~1.45) (see Figure 1b). This difference may be caused by the different values of the TOC in the spring and autumn of 1999 which is typical of the seasonal variation of the TOC in the region of Irkutsk (Kazimirovsky et al., 1999). In 1999 for these time intervals the ratio of the TOC values was as high as ~1.6. The difference in the UVR levels in the range of angular altitudes of the Sun 25-35° is likely to be associated with the presence of a stable snow cover in February-March which is absent in September-October.

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**Fig. 1.** UVR intensity variations at $\lambda = 310$ nm for all days of observation, and in total ozone content as deduced from the TOMS data over Irkutsk for the period September 25, 1998 to April 30, 2000 (a), and smoothed UVR curves for the same period depending on the angular altitudes of the Sun (b).
On some occasions the seasonal variation of the ground-level UVR reveals days with anomalously high values of the recorded radiation which exceed near-lying points obtained during a relatively clear weather. Thus, Figure 2 presents relative deviations of the UVR (in percentage) from the mean for the period under consideration after the removal of the seasonal trend at 310, 323 and 344 nm wavelengths for clear days (a), the relative deviations of $I_{310}/I_{344}$ (b), as well as the relative deviations of the TOC (c) for summer 1999. On August 3, 1999 the largest relative increase (by 27%) was recorded in the UVR at 310 nm wavelength. At 323 and 344 nm wavelengths these changes were, respectively, 17% and -1.4% (on Figure 2 this event is presented by dash line). The value of $I_{310}/I_{344}$ showed an excess of the mean by 25%, and the TOC value on that day was decreased by 10%. A similar substantial abrupt increase in the UVR at all wavelengths (by up to 35% at 344 nm wavelength) was observed on August 21-24. However, neither a decrease of the TOC nor an increase of $I_{310}/I_{344}$ was observed during that event, unlike the preceding case.

The occurrence of such events can be caused by two factors. In the first place, it is a decrease of the TOC level, and secondly, it is an increase in atmospheric transparency. The behavior of the radiation with 344 nm wavelength can serve as a qualitative characteristic of the state of atmospheric transparency (Mikhalev et al., 2000). The radiation at 310 nm wavelength is in the ozone-dependent part of the ground-level ultraviolet spectrum. Therefore, the ratio $I_{310}/I_{344}$ reflects mainly the dependence of the UVR on the TOC. It is likely that the former case is associated with the decrease of the TOC. The latter case can be associated with an increase in atmospheric transparency. The statistics of the occurrence of such events shows that their durations are usually limited to 1-3 days, which seems to be caused by the typical synoptic time scales of the existence of high atmospheric transparency in the area of observation. The values of the UVR that were recorded on August 3, 1999 during a TOC anomaly and on August 21-24, 1999 at a normal TOC level were found to be extremely high for the period under examination, and in the former case for the entire period of observation.

A presence of correlation with solar activity is pointed out for many meteo- and geophysical parameters of the atmosphere, specifically in some publications for the erythemal UVR. Thus, a substantial increase of the UVR by as much as 5-10% in the tropical and subtropical regions of the Australian continent is associated by the authors of (Udelhofen et al., 1999) with an increase in the solar radio emission flux $F_{10.7}$.

We have carried out a spectral and correlation analysis of the measurement data of the ground-level UVR intensity at 310 and 323 nm wavelengths, of the solar activity indices and of the TOC values for the period under consideration. Sunspot numbers $W$ and the solar radio flux $F_{10.7}$ were taken as the solar activity indices (World Data Centre for STP). Two durations of observational samples were analyzed, one
of which covered a more than one-year long interval (from September 25, 1998 to October 31, 1999), and the other covered the summer-autumn period of 1999. A spectral analysis of the UVR measurements for all days of observation showed a clear maximum over a period of 26 days and less pronounced maxima for the periods of 2.8 and 6-13 days. For the comparison, a spectral analysis of the UVR measurements only for days with clear weather was carried out for the same time intervals. In the spectrum of the latter time series the high-frequency harmonics with periods of 2.8 and 6-13 day were disappeared, which were identified when analyzing all measurements without separating into clear and cloudy days. This suggests that the appearance in the UVR spectrum of short-period oscillations with periods from several days to ten days (i.e. of a synoptic scale) introduces a meteorological factor associated with the cloud regime of the atmosphere.

UVR variations with periods approaching the 27-day periodicity of solar activity suggest their possible interrelationship. On the other hand, UVR variations with periods close to the period of a small solar cycle may also be caused by other factors, among which we may point out the variations in atmospheric circulation, cloud regime, atmospheric transparency, and atmospheric species which determine the UVR absorption and scattering, and others.

Tinsley et al. (1989) and Pudovkin and Babushkina (1992) point out variations in atmospheric circulation and in the state of the lower atmosphere associated with solar and magnetic disturbances. Changes in the cloud regime in connection with cosmic-ray variations have been discussed by Veretenenko and Pudovkin (1996). Some publications are devoted to the different temporal scales variations in atmospheric transparency due to solar activity changes (Roldugin and Starkov, 2000) and changes in the cloud regime in connection with cosmic-ray variations (Veretenenko and Pudovkin, 1996).

The parameters governing the photochemical (aerosol composition, the degree of atmospheric pollution with admixtures), thermal and meteorological (cloud cover, moisture content) state of the lower and middle atmosphere are in close connection with dynamic processes occurring at these heights. As regards the interpretation of the oscillations with periods close to 27-day periods, it is also necessary to take into account planetary waves generated in the lower atmosphere as a consequence of the inhomogeneities of the thermal field (orography, ocean-land temperature differences) and having typical periods of 5-30 days. These internal waves penetrate from the troposphere into the stratosphere during the winter-spring period and, while propagating upward, affect the character of regular transport and the chemical composition of the middle atmosphere (they cause longitudinal variations in the distribution of ozone, nitrogen oxide, and atomic oxygen) (Hood and Zaff, 1995).

The largest values of the cross-correlation coefficients were obtained for the UVR and the sunspot number $W$. For the summer-autumn period of 1999 at cross-correlation functions maxima these values were 0.54 and 0.46 with a time shift of 9 days, and for the annual period September 1998 - October 1999 they were 0.37 and 0.47, respectively at 323 and 310 nm wavelengths. The correlation coefficient for the UVR and for the index $F_{10.7}$ was 0.39 for 323 and 310 nm wavelengths for the summer-autumn period of 1999, and for the annual period the value of the cross-correlation coefficient was lower. The value of the correlation coefficient between the UVR and the TOC for the time intervals under consideration did not exceed 0.26-0.29, which is likely indicate a secondary role of the TOC values in variations of the ground-level UVR intensity compared to other factors.

Despite the relatively small cross-correlation coefficients, these values are statistically significant, which suggests the presence of connections between the UVR variations and solar activity within limits 5-25% (determination coefficients) for the recording conditions under consideration. The results presented in this paper don't permit – at this preliminary stage of study – to identify any particular reasons for the UVR variations with periods close to 27 days. Nevertheless, considering the literature on this subject, it is impossible to exclude that solar activity has an indirect influence on variations of the ground UVR level through changes in optical characteristics and in the dynamic regime of the atmosphere. Currently intense research is done into the mechanism of solar activity effects on the Earth's lower atmosphere (troposphere, stratosphere) through a variability of the intensity of cosmic rays flux. There is evidence
that through this channel solar activity can influence the conditions of the lower atmosphere by changing the concentration of radiation-active minor gas species, temperature and pressure, and hence the character of the atmospheric gas circulation in high and then middle latitudes, the character of the cloudiness (Veretenenko and Pudovkin, 1996), and atmospheric transparency, which, in turn, has a direct influence on the ground-level UVR intensity.

CONCLUSIONS

Daily measurements of the ground-level ultraviolet radiation for the period 1998-2000 have been used to investigate the seasonal variation of the UVR level in the East Siberian region. The study revealed an asymmetry of the seasonal UVR variation with respect to the angular altitudes of the Sun which is caused by the seasonal variation of the TOC and perhaps by the presence of the snow cover.

Peculiarities of the occurrence of short-lasting increases in UVR which are associated with TOC anomalies and with high atmospheric transparency have been considered.

Fluctuations of the ground-level UVR with periods of 2.8, 6-13 and 26 days have been identified.

The dependence of the ground-level UVR on solar activity has been investigated. Statistically significant correlation coefficients with solar activity indices have been obtained.

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