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INVESTIGATION OF SENSITIVITY AND NOISE CHARACTERISTICS OF THE BIO-EFFECTIVE UV RADIATION SENSOR IN FIELD CONDITIONS

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Introduction

The aim of our study concerns absolute measurements of the solar ultraviolet (UV) radiation at the ground level in high latitudes. The reason of such measurements is rather valuable for quantitative assessment of biological systems response to the UV radiation (1). Measurement of the UV radiation was carried out early by ozonometers M-124 with several discrete readings per day, but continuous measurements of the short wave UV radiation have never been carried out before in Russia at high latitudes. It is possible to realize this kind of measurements by the ELDONET dosimeter and UV photometer of the Moscow Physics and Technology Institute (MPTI). The paper describes some comparative characteristics of those devices as well as preliminary results. Signal-noise ratio of the low cost MPTI photometer in different field conditions is under consideration too since it defines precision of absolute measurements.

Equipment and methods

The main scientific ground-based instrument for measuring the UV radiation was ELDONET dosimeter of the Solar biologically active UV radiation and MPTI photometer was under testing device (Fig.1a,b). Both instruments were in operation at the Apatity range (φ - 67.57º,λ – 33.37º) in 2005-2006.

The ELDONET instrument is a calibrated dosimeter which measures solar or artificial radiation in three biological important spectral bands: UV-B (280 nm -315 nm), UV-A (315 nm – 400 nm) and PAR (photosynthetic active radiation, 400 nm – 700 nm) with temporal resolution 1 second in continuous way. The instrument uses a 10 cm Ulbricht integrating sphere to collect both directed and undirected radiation. The opening is protected by a hemispherical quartz dome. Three sensitive UV and PAR diodes pick up the radiation behind a baffle. In addition the external and internal temperature are recorded. The instrument together with special software WinDose were designed and calibrated at the Institute of Biology in Erlangen, Germany .


Fig. 1 a) ELDONET dosimeter b) MPTI detector

MPTI detector is presented by authors (2) as a photometer, which operated in biologically active spectral band 290 nm – 390 nm. A gas-filled photocell with a copper photocathode is used as a receiver of radiation. Registration of radiation is carried out by count of pulses. The authors (2) noticed something extraordinary in the amplitude impulses of the solar radiation, which intensity is about 0.1 % of ordinary solar radiation in the same span of wavelength. The temporal resolution of the MPTI photometer is about several seconds. The instrument was equipped with a quarts window at the opening.

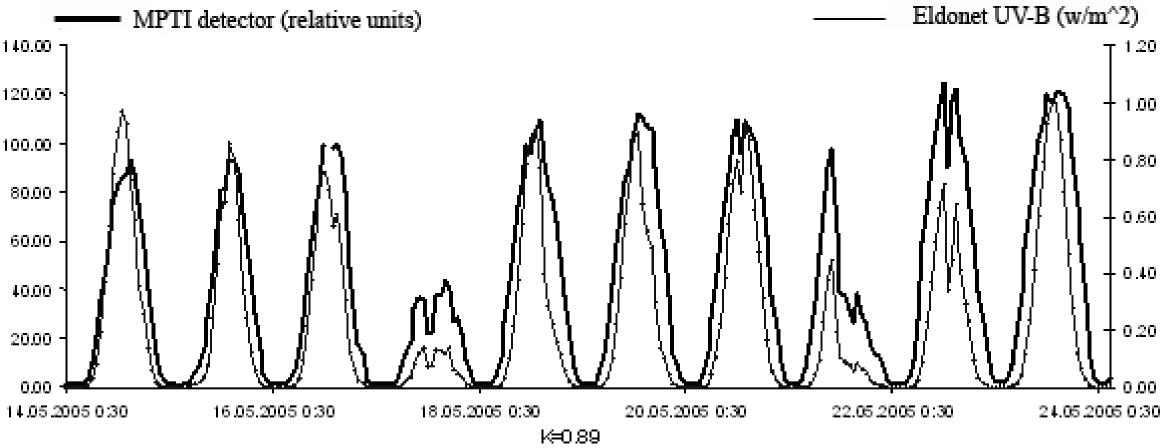

Fig. 2 Temporal variations of the Solar UV radiation by ELDONET and MPTI detectors

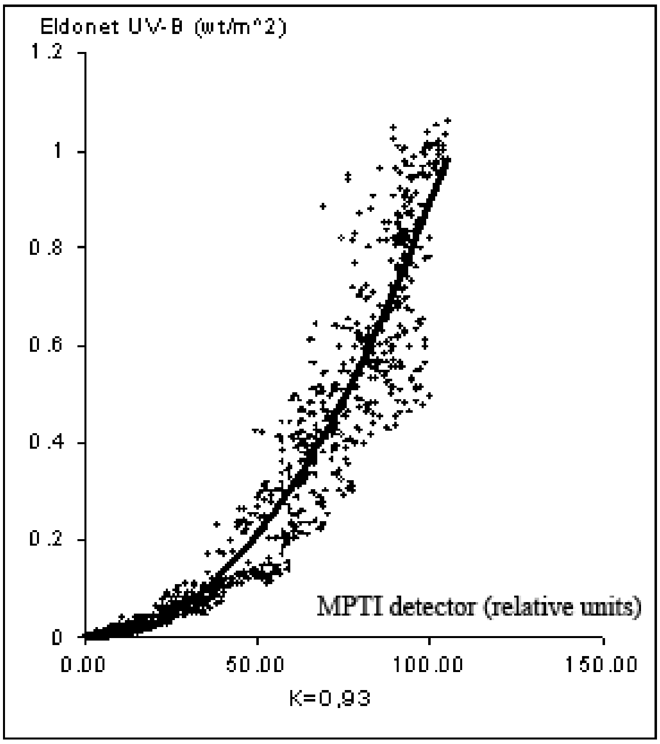

Fig. 3 Correlation dependence of the ELDONET dosimeter and MPTI detector data

Analysis and results

1) Sensitivity of MPTI photometer for recording of the UV radiation in field conditions

MPTI detector is rather a simple, cheap and adjustable construction in comparison with the ELDONET dosimeter and it is of great interest to check if it is possible to use it in regular observations. In order to study this question a comparison of continuous simultaneous recordings of the well calibrated ELDONET dosimeter in the UV- B spectral range of the solar radiation and recordings of the solar radiation by MPTI photometer were done. Time series of the solar radiation intensity measured by the ELDONET during one month in absolute units together with simultaneous time series of the MPTI photometer measurements in arbitrary units are presented in Fig.2. It is obvious, that those curves are similar even in small details. The calculated correlation coefficient is more than 0.9 at the significance level of 0.05. The calibration dependence of measurements of the UV solar radiation by both instruments during one season (5 month) is presented in Fig.3. The correlation coefficient is about 0.93 in this case. An approximating curve is not linear mostly at small values of the intensity of the solar radiation. The reason for that is connected with MPTI photometer characteristics, which are discussed below. Thus, MPTI detector is an acceptable instrument to pick up data on the solar UV radiation even if the correlation coefficient due to general features of the Sun as black body radiation source.

2) Estimation of the MPTI detector noise characteristics

This task permits us to better understand the limitation of accuracy of the UV radiation data obtained by MPTI photometer and to clarify a possibility of registration of the impulse solar UV radiation, which intensity level positioned by authors (2) is about 0.1 % of acting solar radiation intensity in the same spectral range. The methods of investigations of MPTI detector noise characteristics include both measurements by the open optical input of the photometer and closed one. Basic suppositions on noise nature in field conditions were connected with dependence of electronic part of the equipment on meteorological parameters (temperature, humidity and atmospheric pressure) and the cosmic ray intensity. The last one can supposedly show a real effect in order that the gas-filled photocell is rather similar to a gas-filled particle counter. Figures 4a,b,c demonstrate temporal variations of MPTI photometer noise amplitude together with temporal variations of the outer temperature, atmospheric pressure and cosmic rays variation count (Apatity neutron monitor data). The presented measurements were carried out by the closed MPTI detector to obtain its background noise depending on the use outer sensors data. The strongest direct dependence is revealed for variations of the temperature (Fig.4a). Some weak reverse correlation is observed for temporal fragments of the atmospheric pressure (Fig. 4b). It could be explained also by the temperature variation, which takes place during rather stable atmospheric situation in the time interval 01.12.2005 – 11.12.2005. Negligible correlation exists also for the cosmic rays count (Fig. 4c) but it can be explained by the variation of the atmospheric pressure too because we have used neutron monitor data uncorrected for the atmospheric pressure. The corrected cosmic rays data in this temporal span give no correlation. Our conclusion is confirmed by coefficients of correlation, which were calculated and shown in all plots of Fig. 4. Therefore the physical nature of MPTI noise is its temperature dependence. The signal-noise ratio was calculated from recordings during an open input window of the MPTI detector for different levels of the UV radiation. The dependence of the noise amplitude on the amplitude of real signal from UV radiation was constructed on the basis of these data. The physical nature of this noise also shows the outer temperature dependence, which have connected with photo cathode and electronic components noise. The minimal level of the noise amplitude in this case is about 3%. Therefore we can make a conclusion that impulse solar radiation at 0.1 % level of acting UV signal is within the temperature noise band. It must be taken into account in studies of the impulse solar UV radiation at all.

Conclusion

The investigation of sensitivity and noise characteristics of the bio-effective UV radiation sensor in field conditions was done. The comparison of time series of the solar UV radiation intensity obtained by the ELDONET dosimeter and MPTI photometer permits to construct a calibration curve for the last instrument. Physical nature of the MPTI detector noise in field conditions is its outer temperature dependence. The results show a possibility of using the MPTI photometer for rough measurements of the bio-effective solar UV radiation. The signal –noise ratio of the MPTI detector should be taken into account in studies of the impulse UV radiation of the Sun.

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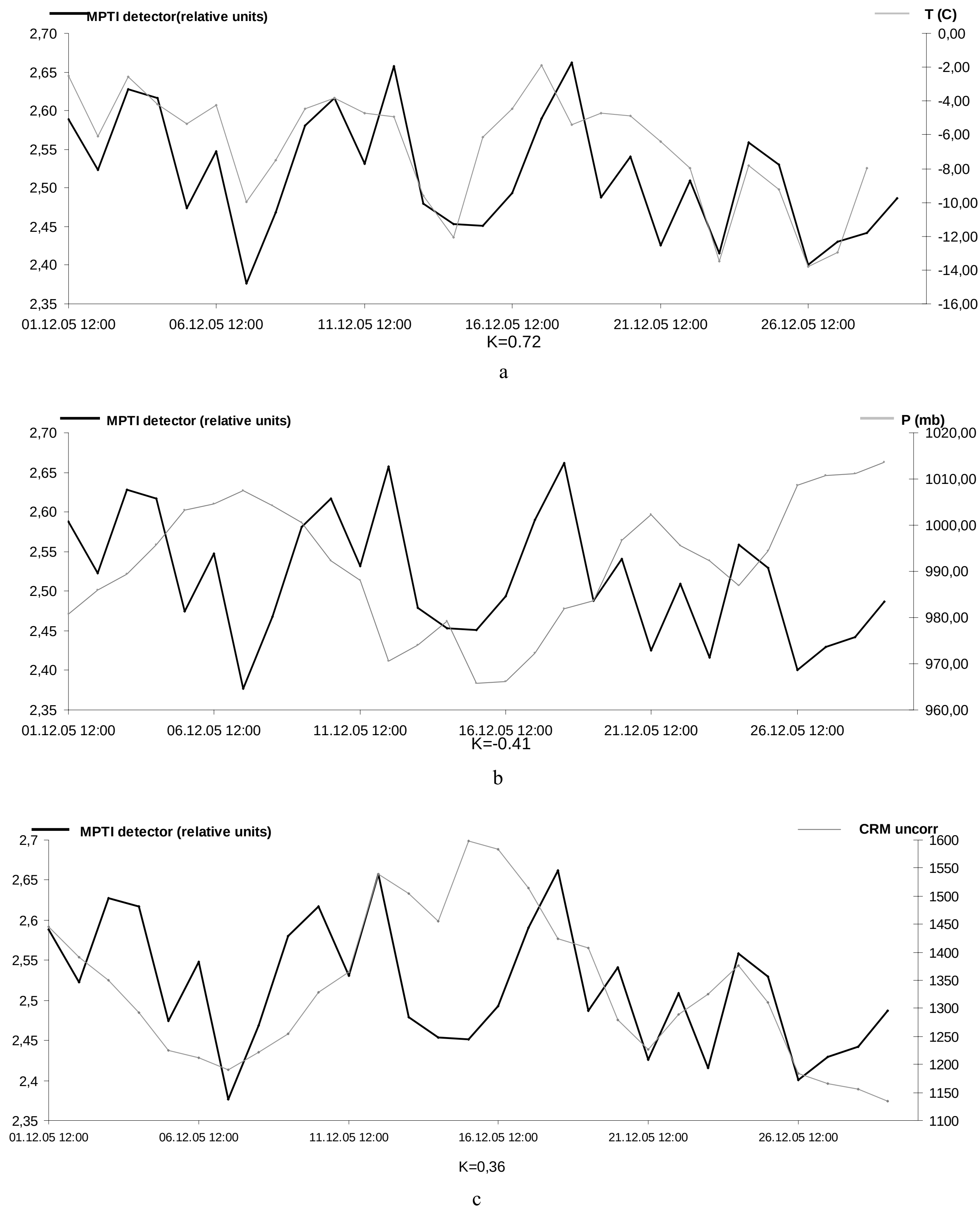

Fig. 4 (a,b,c) Noise amplitude temporal variations of the closed MPTI photometer and simultaneous recordings of variations of meteorological parameters and cosmic rays intensity