

Periodicity Study of Erythemal Ultraviolet-B Radiation Data over Egypt

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Abstract. Periodicity of the daily and mean monthly values of Erythemal UV-B radiation of the stations El-Arish, Aswan, Hurghada and South Valley has been examined. The harmonic analysis has been applied to study the variations of the daily and monthly time series of Erythemal UV-B radiation of these four stations. Results revealed that the dominant waves that appeared with the analysis of the daily time series of the four stations were 13, 13.5, 13.4, 13.4 months respectively. The analysis of the mean monthly values for the four stations showed that the dominant wave in these four time series was the annual wave with high statistically significant results. These annual waves were used in forecasting UV-B radiation for these stations.

1. Introduction

A time series is a list of values of a variant according to time. Normally, the time interval between observations of the variant (called the data interval) is being constant. The interval in case of meteorological time series may extend from small fractions of a second (for studies of turbulence) to thousands of years (for the study of climatic fluctuations). The purposes of the statistical analysis of time series are: 1) To understand the basic properties of the time series, its variability, and characteristics of its periodic and irregular oscillations, this understanding helps the primary purpose of the time series analysis. 2) To predict the behavior of the time series in the future.

The type of analysis most commonly applied to the periodic variations of the meteorological parameter is "harmonic analysis". Such an analysis helps in the physical understanding of the regular fluctuations. According to mathematical

principles, any function that is given at every point in the interval can be represented by a series of sine and cosine functions. This series is called a Fourier series, and the method of finding the functions, Fourier analysis. The objective of this work is to study the periodicity of the daily and mean monthly values of Erythemal UV-B radiation of the stations El-Arish, Aswan, Hurghada and South Valley.

2. Data

The Erythemal exposure data product is an estimate of the daily-integrated ultraviolet irradiance calculated using a model for the susceptibility of Caucasian skin to sun burn. This can be interpreted as an index of the potential for biological damage due to solar irradiation. These data were archived on regular latitude-longitude grid points with resolution of $1^\circ \times 1.25^\circ$. From this archive of data, the daily data for the period 1998-2001 were used (1440 values for each station were found) to study the periodic variation of Erythemal UV-B radiation.

3. Methodology

In this work the harmonic analysis was applied to the time series consisting of the daily Erythemal UV-B radiation at different stations. A known limitation of this analysis is that it usually detects waves with oscillation period equal to the length of the record (N) and sub-multiples of this length (N/2, N/3, and so on). In order to avoid this, the analysis was applied for different lengths of the record to get the true wave which had the largest contribution to the variance of our variable and its length less than or equal the length of our record (Schickedanz and Bowen, 1975). We will deal with record with lengths (N, N-1, N-2, ...). Each time we get the wave with the largest contribution. From these waves we considered the one with minimum root mean square deviation from the actual data as a real wave in the record. After subtracting this wave from the actual data, the analysis is repeated again to obtain the next one. This analysis continues until it reaches waves with negligible contribution to the record.

4. Results and Discussions

A) Periodicity

Periodicity of the daily and mean monthly values of Erythemal UV-B radiation of the stations El-Arish, Aswan, Hurghada and South Valley has been examined. The harmonic analysis has been applied to study the variations of the daily and monthly time series of Erythemal UV-B radiation of these four stations. The spectral analysis of the daily time series of our stations is presented in Fig. 1. Analysis of the daily time series of Aswan for the mentioned period shows that, there is also one dominant wave. Its length is 405 days (13.5 months) and its amplitude is $0.2215E-02$. The spectral analysis of this time

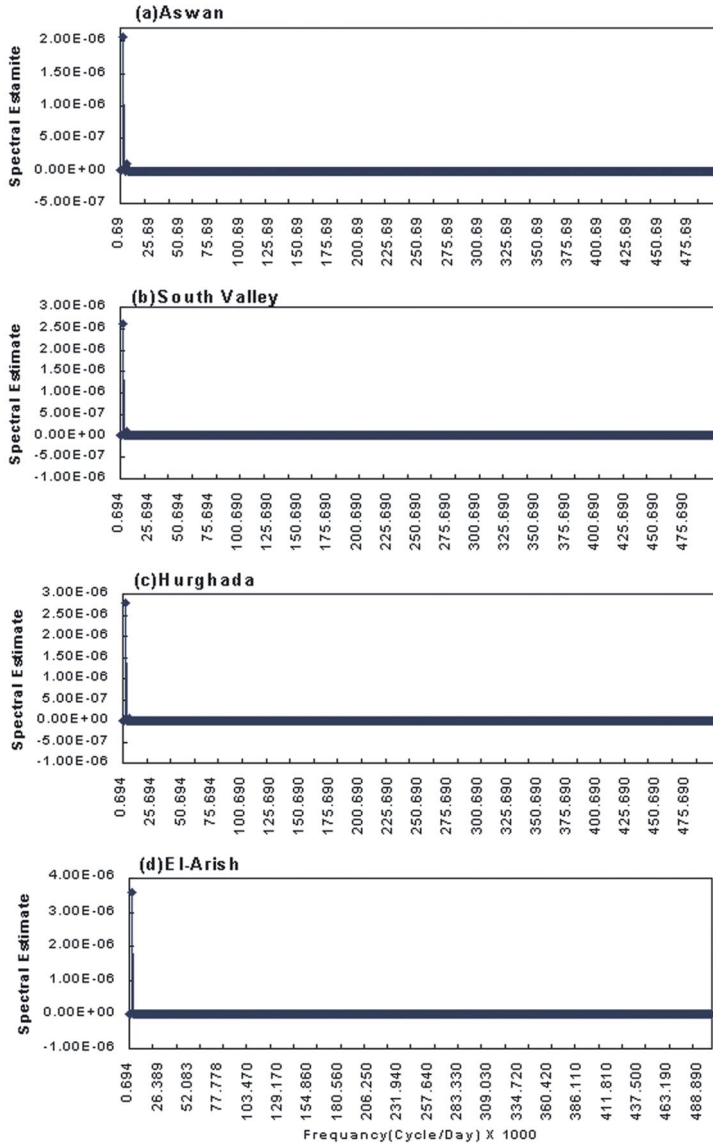


Fig. 1. Spectrum by direct harmonic analysis for the daily values of: a) Aswan, b) South valley, c) Hurghada, and d) El- Arish for the period of study.

series is shown in Fig. 1a. Results of the UV-B radiation time series of South Valley and Hurghada are illustrated in Fig. 1b and 1c. The dominant wave in these two series is 402 days (13.4 months), which accounts for 96% of the total variance in the two series during our study period. The amplitudes of these waves are $0.2441E-02$ and $0.251987E-02$ for the time series of South Valley and Hurghada, respectively. Results of the analysis of the daily values of UV-B radiation of El- Arish for 1440 days (about four years) are given in Fig. 1d. It could be shown that there is only one dominant wave in this time series which is 360 days (13 months), it accounts for 96% of the total variance of UV-B radiation during the study period, and its amplitude is $0.2806E-02$.

Results of the analysis of the mean monthly values (48 values) for the four station show that the dominant wave in those four time series is the annual wave. It accounts for 99% of the total variance of El- Arish time series, 95% for the Aswan time series, 98% of the Hurghada time series and 95% for the time series of South Valley. The amplitudes of these waves are $0.2688E-02$, $0.2053E-02$, $0.2382E-02$ and $0.2319E-02$ for El-Arish, Aswan Hurghada and South Valley respectively.

The dominant waves that appear with the analysis of the daily time series of the four stations (13, 13.5, 13.4 & 13.4 months) seem to be associated with quasi-biennial oscillation (QBO), which has almost double period (26-28 months). This connection has been mentioned by other researchers. Schergag (1967) found that with quasi-biennial oscillation (QBO) appears to affect the overall mean temperature of the entire (northern hemisphere) atmosphere from the surface up to 16 km. The changes in solar UV-B radiation reaching the ground has been documented recently in addition that the QBO also affects clear sky UV solar irradiances at Thessaloniki, Greece (Zerefos, *et al.*, 1998). Recently, Udelhofen, *et al.* (1999) performed a detailed time series analysis for the Australian continent, based on TOMS erythemal exposure dose observations. They associated changes of UV erythemal exposure, to phases of the QBO and the solar activity cycles. Cabrera and Fuenzaliada (1999) reported evidence of the QBO in measurements of UV solar irradiance at Santiago, Chile.

The relative importance of the QBO cycle to the amplitude of the annual variation of the UV erythemal dose was examined by the ratio of the QBO amplitude over the amplitude of the annual variation at the same latitude, and for different latitude zones (Zerefos, *et al.*, 2001). In the tropics, the amplitude of the QBO effect is about 40% that of the annual cycle, while at middle latitudes, where Thessaloniki and San Diego are placed, it is only 5%, decreasing with latitude. Therefore, Zerefos, *et al.* (2001) concluded that the biological important erythemal dose reaching ground level at low latitudes, has a QBO component which cannot be overlooked, even in comparison with the amplitude of the annual cycle.

B) Prediction

The analysis of the monthly values of Erythemat UV-B radiation for the four stations indicated that the dominant wave in these four time series is the annual wave where it has the greatest amplitude. So, the monthly values of Erythemat UV-B radiation can be represented successfully by the annual wave of each station without any additional harmonics need to be added. Figure 2a-d shows the monthly values of UV-B radiation at our stations during the period of study (solid curves). Dashed curves represent the calculated annual waves, it extended (as a forecasted) 3 years after the actual data. The error between the actual and calculated values is presented below each figure.

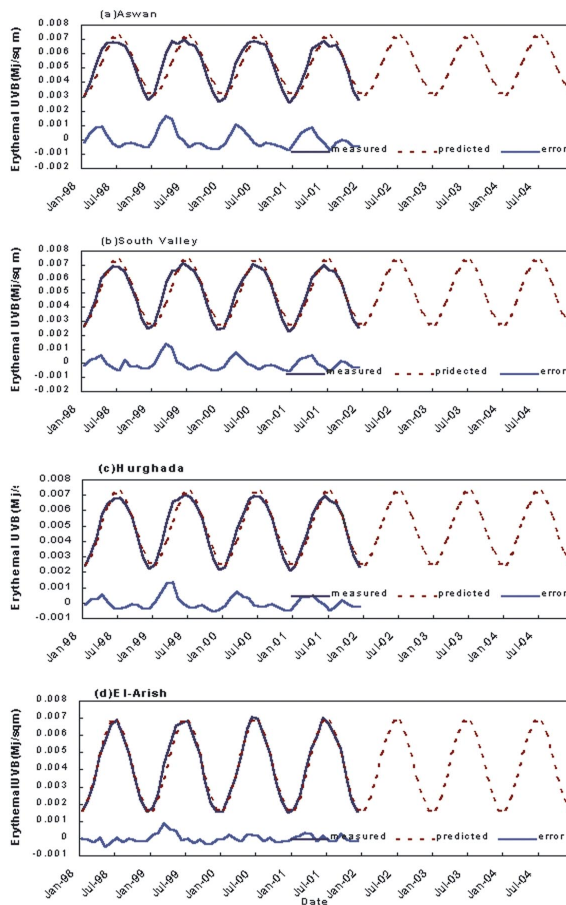


Fig. 2. The monthly mean values of Erythemat UV-B radiation (solid curves), the predicted values of Erythemat UV-B radiation (dashed curves) and the error between the actual and the predicted values of Erythemat UV-B radiation at: (a) Aswan, (b) South Valley, (c) Hurghada, and (d) El-Arish.

5. Conclusions

This work aimed to study the periodicity of the daily and mean monthly values of Erythral UV-B radiation of the stations El-Arish, Aswan, Hurghada and South Valley. The main results of this study can be summarized as follows:

– The dominant wave that appears with the analysis of the daily time series of the four stations are 13, 13.5, 13.4, 13.4 months respectively. These waves seem to be associated with quasi-biennial oscillation.

– The analysis of the mean monthly values for the four stations shows that the dominant wave in those four time series is the annual wave. These annual waves were used in forecasting UV-B radiation for those stations.

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دراسة دورية لبيانات الأشعة فوق البنفسجية - ب فوق مصر

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المستخلص. يهدف البحث إلى عمل دراسة دورية لبيانات الأشعة فوق البنفسجية - ب لمحطات العريش وأسوان والغردقة وجنوب الوادي في مصر. تم تطبيق التحليل التوافقي لدراسة متسلسلات قيم الأشعة فوق البنفسجية - ب اليومية والشهرية للمحطات الأربعة. وقد وجد أن الموجات المسيطرة والتي ظهرت من تحليل البيانات اليومية للمحطات هي الموجات ذات الطول الموجي ١٣، ٥، ١٣، ٤، و١٣، ٤، و١٣ شهر على الترتيب. وتحليل قيم المتوسطات الشهرية للمحطات الأربع اتضح أن الموجة المسيطرة هي الموجة السنوية. وتمت الاستفادة من هذه النتائج بالنسبة للموجة السنوية واستخدامها في التنبؤ بالأشعة فوق البنفسجية - ب للمحطات الأربع.