Influence of the aerosol load on the Erythemal variation

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Abstract

In this work we have studied the impact of the mineral dust over the daily UV erythemal exposure (EUV). To characterize the load of mineral dust the TOMS AI product has been used, and the UV erythemal exposure has been calculated by TOMS instrument (TOMS EUV), on board Earth Probes, and by Brewer instruments located in ground based stations (BEUV). EUV variations have been evaluated under different aerosol load conditions in stations frequently affected by the two main mineral dust sources (Gobi and Sahara-Sahel regions). The ground stations are located in Japan (3 stations) and in the Canary Islands (1 station), and the studied period encompass from 1997 to 2000. There is not a similar pattern of variations of the TOMS EUV levels with the TOMS AI between the all stations. In addition, the behaviour observed for the Atlantics station is different to the measured for the Japanese observatories.

1. Introduction

The UV-VIS spectral region has special significance due to its direct effects on the biosphere, being very important to study the factors that can affect these irradiance levels. The action spectrum that gives the wavelength-dependent sensitivity of Caucasian skin was proposed by McKinlay and Diffey (1987), and adopted as a standard by the *Commission Internationale de l'Eclariage (CIE).*

The main factors that affect these irradiance levels are: ozone, clouds and aerosols. The ozone effect is well-known: in general, the CIE weighted irradiance increases by approximately 1.2% with a decrease of 1.0% in the ozone value (Tarasick et al., 2003). The clouds factor can be study by means of the Cloud Modification Factors (CMFs) [COST 713] and its effect depends strongly on type and height of the clouds. Regarding the aerosols its effect is more complex due to its great geographical and temporal variation, among its variety material composition. For instance, the scattering of volcanic aerosol reduces the Erythemal UV irradiance by about 5% (Tsitas and Yung, 1996). And, the largest reductions in UV are associated with dust and smoke plumes in Africa and South America, with observed reductions that frequently exceed 50% (Herman et al., 1999). Thus, the present day global mean radiative forcing due to the direct and first indirect (Twomey effect) effects of tropospheric anthropogenic aerosol particles is estimated to be between –1.1 and –2.7 Wm^{-2} (IPCC, 2001).

Due to the geographical and temporal scale of the problem, satellite remote sensing plays an indispensable role in providing information on the spatial and temporal variations of surface UV radiation and aerosols distribution. In particular the TOMS Earth Probe sensor gives daily Erythemal UV exposure (TOMS EUV), joint with the Aerosol Index (TOMS AI), which gives information about absorbing aerosols in the UV range, and Reflectivity which is related with the cloud cover. Due to the complexity of the algorithm based on data obtained by satellite platforms it is necessary a continue work of intercomparison with data obtained in ground based stations. The most important network to measure UV irradiances and total ozone is based on the performance of Brewer instruments. The Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO) creates in 1960 the World Ozone and Ultraviolet Radiation Data Centre (WOUDC). This is one of five World Data Centres which provides, in a planetary scale, a variety of UV data sets to the international scientific community.

2. Data and methodology

The data used in this work are version 7 from Earth Probe platform and they are mapped onto a grid of 1.25º in longitude by 1º in latitude. The Erythemal Exposure data product is an estimate of the daily integrated ultraviolet irradiance calculated by the next expression:

$$EUV=\frac{1}{d_{es}^2}\int_{280}^{400} d\lambda S(\lambda)W(\lambda)\int_{t_{sr}}^{t_{ss}} dtC(\lambda,\vartheta,\tau_{cl})F(\lambda,\vartheta,\Omega) \tag{1}$$

where d_{es} is the Earth-Sun distance in A.U; S is the solar irradiance incident on the top of the atmosphere; W is the Biological action spectrum for Erythemal damage proposed by McKinlay and Diffey (1987); t_{ss} and t_{sr} time of sunrise and time of sunset; C is the cloud attenuation factor, τ_{cl} is the cloud optical thickness, ϑ is the solar zenith angle, F is the spectral irradiance at the surface under clear skies and Ω is the total column ozone.

The Aerosol Index, TOMS AI, which characterizes the aerosol load, is defined as the difference between the observations and the model calculations from a pure molecular atmosphere with the same surface reflectivity and measurement conditions. Thus the TOMS AI is obtained from the spectral contrast of the backscattered radiances at the wavelengths of 331 and 360nm.

$$AI=-100\left[\log\left(\frac{I_{331}}{I_{360}}\right)_{meas}-\log\left(\frac{I_{331}}{I_{360}}\right)_{calc}\right] \tag{2}$$

The database encompass the period from 1997 to 2000. In order to compare the results for the two main mineral sources of mineral dust, the selected pixels are located over stations close to the Sahara-Sahel and the Gobi desert regions. Fig. 1 shows dust outbreaks over the ground based selected stations (WOUDC stations) located in the two study zones. These observatories are very useful to intercompare the obtained results from satellite data with those achieved from the ground stations with Brewer instruments. The dust outbreaks over the stations selected (Table 1) have a strong seasonal behaviour. In the Japanese stations, this period ranges from March to May. Whereas in the Canary Islands station (IZO station), there are two periods: February-March and from June to August. To analyze those periods with the presence of mineral dust it has been selected days with an aerosol index (TOMS AI) higher than 0.7. A screened to remove clouds has been applied considering cloudless scene those with a TOMS reflectivity lower than 25%. In addition, it has been checked these days with the SeaWifs images. So, the final number of analyzed data in each station is showed in Table 1.

3. Results

Fig. 2 shows the TOMS AI frequency of occurrence over these stations for the whole period: 1997-00. There is a distinct season pattern in the dust transport between the selected stations in the Atlantic Ocean and those in the Pacific Ocean. The main period for dust presence in the Asian region is in winter-spring, whereas in the northeast subtropical Atlantic region the presence of dust along the year is continues except in autumn. Nevertheless, the higher probability is in summer. In this region, the air mass typologies are strongly linked to the position and extension of the Azores High as well as the development of pressure systems over North Africa and the Iberian Peninsula. So the dust transport in the cold season are mainly at low altitudes, within the marine boundary layer, whereas in the warm one the dust is transported above 2 km asl, in the Atlantic free troposphere (i.e. over the thermal inversion layer).

For the dusty period at each station, the change on the EUV has been evaluated with the aerosol load. In each one of the two regions (Canaries –Fig. 3– and Japan –Fig. 4–) the TOMS EUV is represented versus the TOMS AI obtained for the same day. Once it has been applied the cloud screening methodology the number of cloudless days is 3050 of a total of 5269 days with reflectivity less than 25% . Using these days it is observed that for the Kagoshima Japanese station there is a reduction in the TOMS EUV when the TOMS AI increases. In the case of Tateno station is not observed a clear variation of the TOMS EUV ratio with the presence of UV-absorbing aerosols, so whereas for TOMS AI values less than 1.00 an increase of about 30% in the ratio is measured, for TOMS AI values bigger than 1.00 this ratio is close to 1.00. For Naha station the median ratio values for all AI TOMS range is near 1.00. The same behaviour is observed for the ground data obtained using Brewer instruments (BEUV) versus the AI TOMS in all Japanese stations. At IZO station, two different patterns are observed depending on the dusty season. For summer period, the TOMS EUV ratios are above 1.00, for any AI value. Whereas in winter time, up to TOMS AI values of 1.3, TOMS EUV ratios are below 1.00, and above this AI value are bigger than 1.00

4. Conclusions

From the obtained results it is observed that the effects of the UV-absorbing aerosols, as detected by TOMS AI product, on the EUV depend on the particulate conditions of the ground measurement stations. Even for two stations, Tateno and Naha, with high concentrations of particles the EUV records are not modified regarding to those obtained during events of low AI values. Nevertheless for Kagoshima station the mineral dust effect is important, decreasing the Erythemal UV ratio up to 0.5 in the TOMS AI interval 1.0 – 1.3. Brewer instruments measured the same behaviour observed by TOMS sensor. On the other hand, this EUV reduction is not clear in the Canary Islands station, showing different behaviour depending on the dusty season. The different transport mechanism of the dust in this subtropical Atlantic region, depending on the season of the year (i.e., on the synoptical meteorological pattern), produces that the altitude of the dust is below 2 km in wintertime, whereas in summer the trajectories of the dust are mainly in altitudes above 2 km. These different transport patterns, beside the problems of the TOMS to detect UV-absorbing aerosols below 2 km must be taking into account to explain the results obtained for the IZO station.

5. Acknowledgements

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6. References

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Table1. Stations selected

Station	**Name**	**Country**	**Latitude**	**Longitude**	**Altitude (m asl)**	**# of data**
STN 007	Kagoshima	Japan	31.63	130.6	283	649
STN 014	Tateno	Japan	36.05	140.13	31	285
STN 190	Naha	Japan	26.2	127.67	42	463
STN IZO	Izaña	Spain	28.3	–16.5	2367	466

FIGURE CAPTIONS

Figure 1. Aerosol Index TOMS image showing the location of the stations used in this study.

Figure 2. Aerosol Index frequency of occurrence for the stations selected from 1997 to 1998.

Figure 3. Box plot of Brewer and TOMS Erythemal doses (EUV) ratio between the median in the AI range 0.0 – 0.7 and the EUV value at different AI intervals at the Canary station. The line in the centre of the box indicates the median. Lower and upper boundaries for each box are the 25th and 75th percentiles. The whiskies encompass 1.5 times the range of the box.

Figure 4. Box plot of Brewer and TOMS Erythemal doses (EUV) ratio between the median in the AI range 0.0 – 0.7 and the EUV value at different AI intervals at the Japanese station. The line in the centre of the box indicates the median. Lower and upper boundaries for each box are the 25th and 75th percentiles. The whiskies encompass 1.5 times the range of the box.

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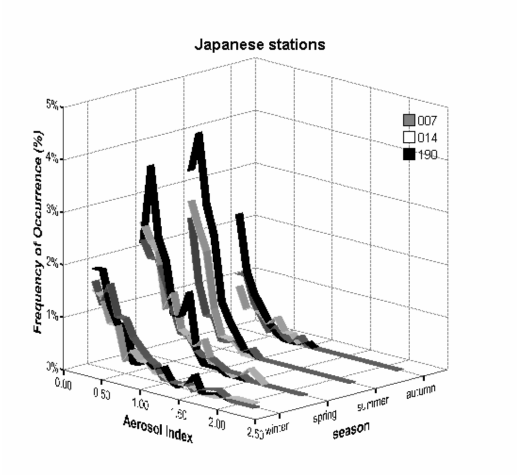
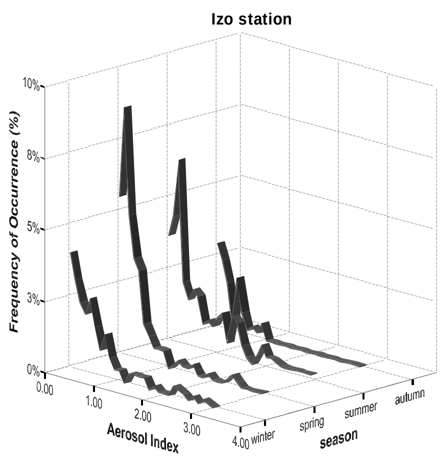
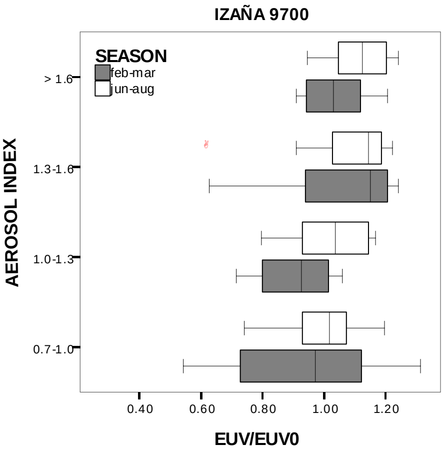
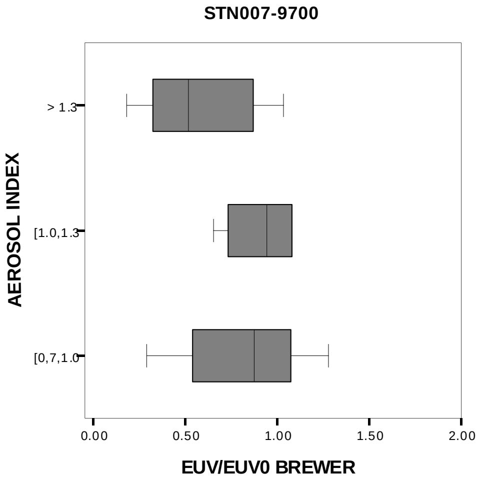

Japanese stations
Frequency of Occurrence (%)
007
014
190
Aerosol Index
season
winter
spring
summer
autumn


Izo station
Frequency of Occurrence (%)
10%
8%
5%
3%
0%
0.00
1.00
2.00
3.00
4.00
Aerosol Index
winter
spring
summer
autumn
season


IZAÑA 9700
SEASON
feb-mar
jun-aug
> 1.6
1.3-1.6
1.0-1.3
0.7-1.0
AEROSOL INDEX
0.40
0.60
0.80
1.00
1.20
EUV/EUV0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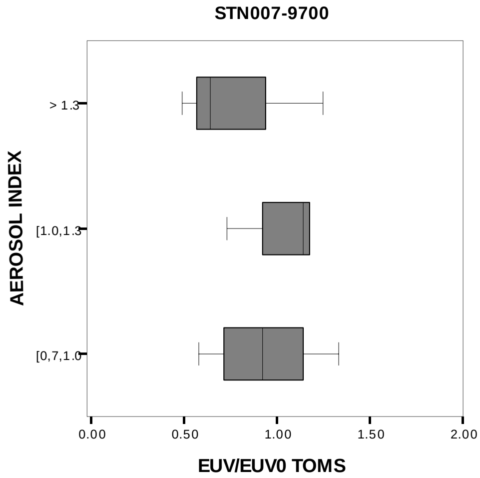
0.50
1.00
1.50
2.00
EUV/EUV0 BREWER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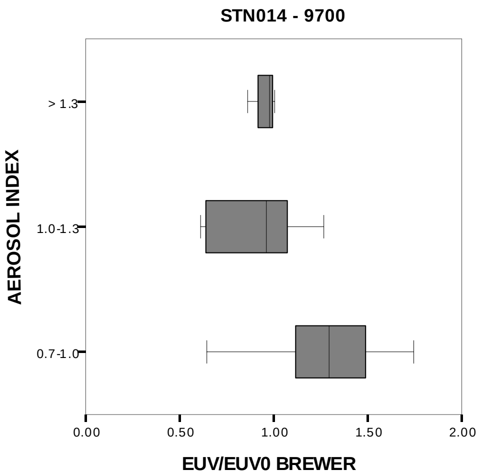
2.00
EUV/EUV0 TOMS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AEROSOL INDEX
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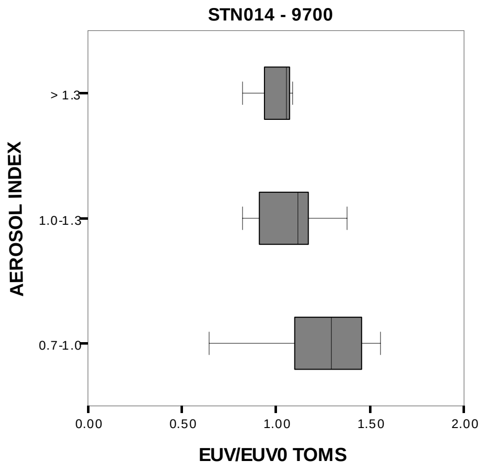
1.0-1.3
0.7-1.0
0.00
0.50
1.00
1.50
2.00
EUV/EUV0 BREWER


STN014 - 9700
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0.7-1.0
0.00
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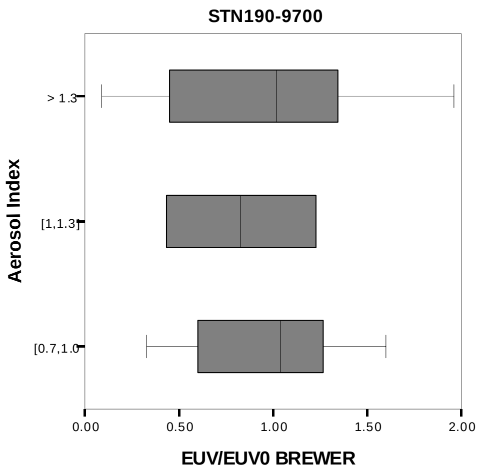
2.00
EUV/EUV0 TOMS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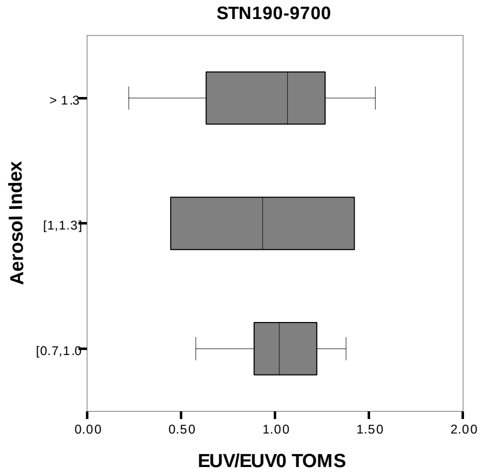
2.00
EUV/EUV0 BREWER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> 1.3
[1,1.3]
[0.7,1.0
0.00
0.50
1.00
1.50
2.00
EUV/EUV0 TOMS