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Seasonal Variations in Total, Direct and Diffuse UVB in a Higher Mountainous Region in Japan

By

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Summary

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The authors investigated how the intensity of total B Range Ultraviolet Radiation (UVB) and its components such as direct and diffuse UVB varied during 1998 and 1999 in Nagano, a higher mountainous region. The intensity of solar radiation at out of the Earth's atmosphere (Su) and at ground surface (SR) reached a peak at the Summer solstice. However, the peak for UVB did not agree with that of Su, reaching its peak a little bit later than did the peak of Su. Normally, the seasonal variation of total intensity of UVB is affected by solar altitude and ozone concentration in the atmosphere. The ratio of intensity of diffuse UVB to that of direct UVB at noon under fine weather conditions varied by over 0.71 in summer and 2.35 in winter. The slope of the rate decrease of UV-B from autumn to winter was steeper than that of the increase of UVB from spring to summer. The seasonal variation of the component of diffuse UVB was lower than that of the component of direct UVB. However, in autumn and winter when the solar altitude at noon is lower, the component of diffuse UVB was higher than that of the direct one. A daily total UVB of 41.9 kJ/m^2d was measured on July 30, 1999, the maximum value within the 1998-1999 measuring period. This intensity is approximately 3% higher than the maximum daily total UVB of 40.6 kJ/m^2d, was measured on July 31, 1999, in the lower place, *Matsudo,* where close to *Tokyo*, has been reported by KON & al. 2004.

Introduction

It is recognized that the intensity of Ultraviolet Radiation (UV) at the ground surface is enhancing due to the reduction of the stratospheric ozone con-

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centration. The impact that this has had on species living on the ground surface has been estimated; GRANT & HEISLER 1999, WEBB & al. 1999 and WEIHS & al. 2000 have reported on the nature of UV radiation. In addition, farmers and other outdoor workers have been affected by this increase as they are exposed to high levels of sunshine, including ultraviolet radiation. Ultraviolet radiation can be divided into three categories; UVA, UVB and UVC. At present, the intensity of UV radiation is believed to be increasing worldwide, especially in the UVB range. This has led to considerable concern regarding its possible impact, especially due to its ability to inflict damage on DNA in tissue.

Nagano, a central area of Japan, is a mountainous prefecture. The main industries are agriculture and electronics, due in part to its clear atmosphere. However, the higher region means a shorter path-length for solar radiation through the atmosphere, leading to higher intensities of UV than for lower-lying regions. Farmers in this area are exposed to significant amounts of radiation during their work in sunlit fields; caps, hats or other kinds of sunshade devices are often used to limit exposure, and sun-blocking lotion is also used. However, our lack of understanding of the nature of UV and how it interacts with biological tissue has limited our ability to find adequate ways of protecting ourselves from its effects. This study was carried out to ascertain the nature of the seasonal variations of UVB.

Material and Methods

Since 1998, UVB radiation has been measured at the top of a building at the College of Shinshu University, 36.8N, E137.2, EL788.35m. The height of the building is approximately 12m. UVB has been measured using a UVB radiometer (EKO MS-201W, EKO Co LTD, Japan), and solar radiation using a radiometer (PCR-03, Kipp & Zonenn, Netherlands).The spectral components of UV have also been measured using a UV spectral meter(MS-701 EKO Co LTD, Japan). During the 1998 and 1999 seasons, the direct and diffuse UVB intensities at noon (JST) were measured using a blackened ball with a bar of approximately 1m in length. These data, except for the measurement of the direct and diffuse intensity of UVB, were logged every 1 minute using a data logger. The instruments measuring UV-B were calibrated once a year and were compared with new instruments. A period of about a month was used to calibrate the sensors used. Data were calibrated using a regression equation for both data sets.

Results and Discussion

Seasonal variations in daily UVB

Seasonal variations in the UVB intensity with solar radiation (short wave radiation) at out of the earth's atmosphere (Su) are shown in Fig. 1(a). Also Fig. 1(b) shows variations of the measured global solar radiation (SR). Su are calculated use common model. Comparing these figures indicates that the variations in global solar radiation seem almost to follow the same trend in the sense that the mean peaks and troughs are mostly in agreement. On the other hand, for UVB and solar radiation at out of the earth's atmosphere the peaks and troughs do not seem to agree. This result can be explained by the fact that the ozone layer in the atmosphere is thinner during the summer and recovers during the early autumn for UVB's peak season. The results suggesting that in Nagano the strongest UVB intensity is in late July.

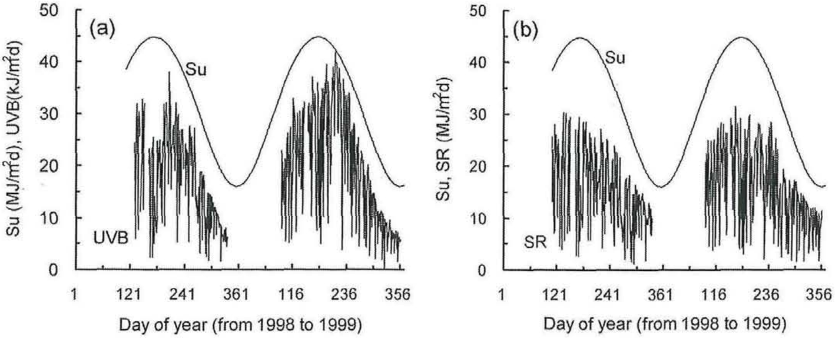

Fig. 1. Seasonal variations in UVB (a) and global solar radiation (b) with solar radiation at out of the earth's atmosphere in the Mountainous region of Nagano. Gaps for SR and UVB in figures show the periods when the sensors were being calibrated.

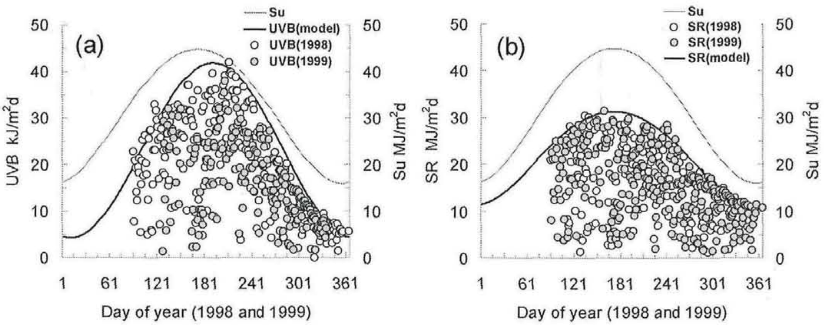

Fig. 2. Trend of seasonal variations for UVB and Su (a), and SR and Su (b). Figs. indicate measured value for UVB and Su in 1998 and 1999, and enveloped trends for these measured values (UVB(model) and SR(model)).

A UVB intensity of 41.9 kJ/m^{2}d was measured on July 30, 1999, the maximum value within the 1998-1999 measuring period. This intensity is approximately 3% higher than the maximum daily total UVB of 40.6 kJ/m^{2}d, was measured on July 31, 1999, in the lower region, *Matsudo,* close to *Tokyo*, which has been reported by KON & al. 2004. Data in Fig.1 have been analysed in respect to the potential intensity. Fig. 2(a) and (b) show 2 years daily intensity in UVB and SR at each season. The black solid lines in (a) and (b) indicate fitted maximum.

Compared with UVB and Su, SR and Su show more clearly the characteristic that the peak of UVB appears 20 days later than the peak of Su, and that the peaks of SR and Su are in agree. As well, in Fig. 2(a), some measured data show stronger than ***UVB***(model) value in spring. The other hand in autumn, no data show above the ***UVB***(model). The slope of the rate decrease of UVB from autumn to winter was steeper than that of the increase of UVB from spring to summer.

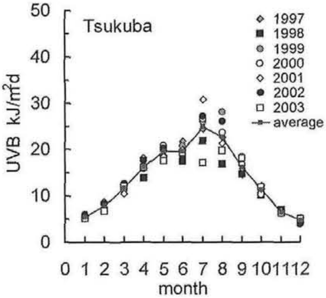

Fig. 3. Annual variations of UVB in Tsukuba. Solid line indicates 7years average.

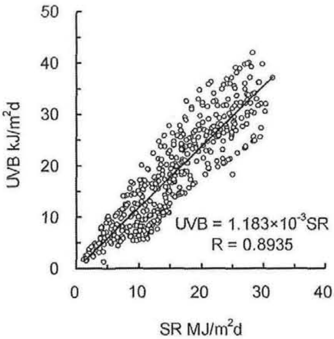

Fig. 4. Correlation between SR and UVB at Nagano.

Figure 3 shows the averaged UVB intensity for the 1997-2003 period at *Tsukuba, Ibaraki*. This figure shows the maximum value measured in July, and this trend agrees with the results at Nagano, as shown in Figs. 1 and 2. Fig. 4 shows the result of regression analysis carried out between global solar radiation and UVB intensity for daily averages of data obtained in 1998 and 1999. The regression equation is $\boldsymbol{UVB}=1.183\times10^{-3}\boldsymbol{SR}$ ($\boldsymbol{r}=0.89$).

It indicates that the daily energy of UVB is about 0.1183% of the daily global solar radiation in Nagano.

Seasonal variations in direct and diffuse UVB at noon (JST)

It is well known that UV scatters easier than solar radiation, and also that the fraction of direct and diffuse components changes with the solar zenith angle (*SZA*). Fig. 5(a) shows the seasonal variations in direct and diffuse UVB intensity at 12:00JST at Nagano during the 1998-1999 period. These measurements were carried out for total and diffuse UVB. Direct UVB can then be calculated using

$$UVB_{dir} = UVB_{total} - UVB_{diff,}$$

where UVB_{dir}, UVB_{total}, and UVB_{diff} are the direct, total and diffuse UVB intensities, respectively. Fig. 5(a) also shows the revised direct intensity for UVB given by

$$UVB_{dir,MOD} = UVB_{dir} \cos SZA_{DOY,noon.}$$

where $UVB_{dir,MOD}$ is the revised direct UVB intensity is SZA at noon on a day of year. Fig. 5(b) shows seasonal variations of the fractions of UVB_{diff}/UVB_{total}, UVB_{dir}/UVB_{total} and UVB_{diff}/UVB_{dir}. This figure shows the seasonal variations of the fraction of direct and diffuse components for UVB. In summer, both values are almost equal or sometimes the direct components are a little stronger than the diffuse ones. However, in the winter periods, the direct components became weaker than the diffuse components. As shown in Fig. 5(b), UVB_{dir}/UVB_{total} varies between 0.58 in summer to 0.30 in winter. Then, UVB_{diff}/UVB_{dir} varies 0.71 in summer and 2.35 in winter. As shown in Fig. 5(a), $UVB_{dir,MOD}$ are averaged at about 0.255w/m^2 during the measurement period. This value is similar to the value in winter. The revised direct component of UVB as a function of cos*SZA* shows almost the same trend as in the pre-revised data. These analyses do not consider the

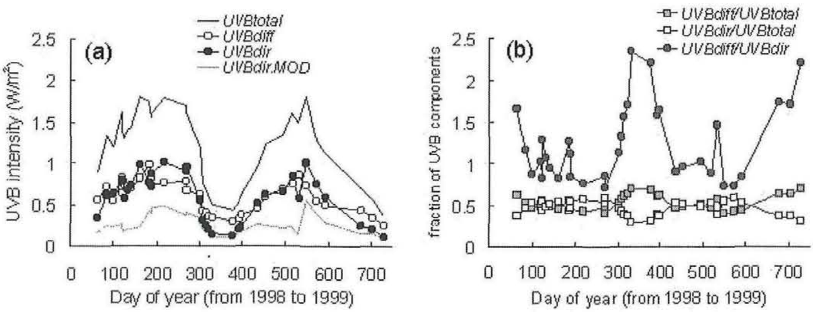

Fig. 5. Seasonal variations in the direct and diffuse UVB, and revised direct UVB as a function of *SZA*(a), and UVB_{diff}/UVB_{total}, UVB_{dir}/UVB_{total} and UVB_{diff}/UVB_{dir}(b).

atmospheric path lengths for UVB. Therefore, these results partly reflect the fact that the ultraviolet radiation is scattered and absorbed by the earth's atmosphere. The most important result indicated in Fig. 5 is the fractions of UVB_{diff} / UVB_{dir} range from 71 to 235%. Fig.6 shows the measured and modelled UVB components at Nagano. The models provide envelopes for the measured data. The total UVB values are described as the direct plus diffuse UVB values, which is of concern in terms of the enhanced the UVB intensity at the Earth's ground surface. This research result highlights the importance of monitoring UVB. Measuring UV intensity with a high degree of accuracy over long periods is difficult because the sensitivity of sensors change under the influenced of UV.

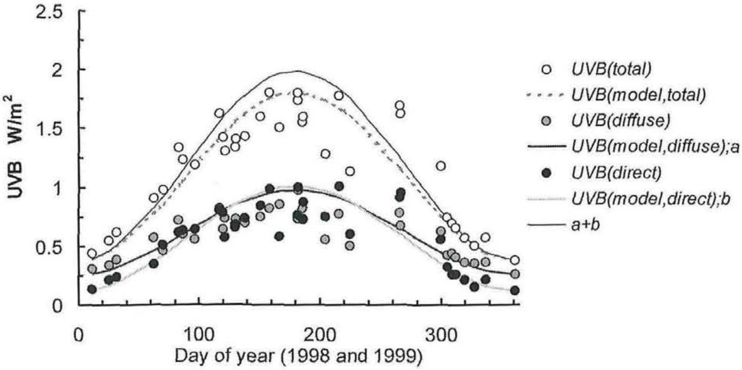

Fig. 6. Comparison of the measured and modelled values of direct, diffuse and total UVB measured at noon (JST) in 1998 and 1999.

Acknowledgements

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