5.2 THE INTERPOLATION OF DAILY SOLAR ULTRAVIOLET RADIATION DURING THE GROWING SEASON

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1. INTRODUCTION

Often predicting the irradiance or exposure of solar ultraviolet-B (UVB) radiation on humans, terrestrial plants and aquatic organisms requires the ability to estimate the irradiance for locations where no measurements are or have been made. One approach to estimating the UVB irradiance is to interpolate the measured values of UVB irradiance between measurement locations. This paper evaluates the potential for interpolating the daily UVB exposure in the continental USA from measurements made by both broadband and narrowband instrument in climatologically similar regimes. Of particular interest is the accuracy for interpolating exposure during the agricultural growing season between measurement locations in the continental USA.

2. METHODS

The study evaluated the spatial correlation of broadband global UVB using a UVB-1 radiometer (Yankee Environmental Systems, Turners Falls, MA) and narrow band direct beam and diffuse sky irradiance measurements at 305 and 368 nm using a multi-filter rotating shadow band radiometer (UV-MFRSR, Yankee Environmental Systems, Turners Falls, MA). Correlations were based on measurements made over the May through August growing seasons of 2000 and 2001 at sixteen locations in the USDA-UVB Climatological Monitoring Network (MD, IN, IL, OH, MN, WI, TX, NM, SK, CO, GA, MS, OK, MT, NE). Statistics were based on 12 paired differences in daily horizontal exposure (integrated from 3-min measurements) H of UVB, 300 nm and 368 nm radiation. Stations were paired based on similar climatological conditions. Station pairs varied from 76 km to 1046 km spacing. The daily mean aerosol optical thickness (AOT) and total column ozone at all nine locations were provided by the USDA UVB Monitoring Program Office using methodologies reported elsewhere.

The spatial correlation for wavelength n ($\rho_n(d_{i,j})$) of the m records of daily horizontal exposure H between two locations i and j spaced by distance $d_{i,j}$ is:

$$r(d_{ij}) = \frac{(1/n)\sum_{1}^{n}(H_i - \overline{H_i})(H_j - \overline{H_j})}{s_H^2} \qquad [1]$$

were σ is the standard deviation of the sample of H. The semi-variogram $\gamma_n\,(d_{i,j})$ for the daily horizontal exposure H, describing the expected squared difference between the pairs of measurements is defined by (Cressie, 1993) as:

$$g(d_{ij}) = (1/2n)\sum_{1}^{n}[H_i - H_j]^2 \qquad [2]$$

The spatial structure of the 300 nm and 368 nm radiation was described using a linear model of:

$$X = Ad_{ij} + B \qquad [3]$$

with X either $\gamma_n(d_{i,j})$ or $\rho_n\,(d_{i,j})$ (Ashraf et al., 1997). The model fit was described by the correlation coefficient (r^2) for a given range in distance $d_{i,j}$.

3. RESULTS

For most locations, the diffuse component of both H_{300} and H_{368} was greater than the direct component. In cloudy, high AOT and low H climates, the frequency distributions of the direct beam component of both H_{300} and H_{368} were typically positively skewed with the majority of daily values at low levels and only infrequently at high levels. Dry climate locations with high UV radiation and AOT less than 0.85 (TX, NM, OK) had direct components greater than diffuse components and negative skew in the direct component. In these climates, unusually high UV radiation was infrequent. In general the diffuse component of H_{368} was positively skewed while the diffuse component of H_{300} was negatively or slightly positively skewed.

For paired locations with small spacing distances (eg. $d_{i,j}$ = 131 km), the correlation of the diffuse components of both H_{300} and H_{368} were greater than the direct beam components (Figs. 1 and 2).

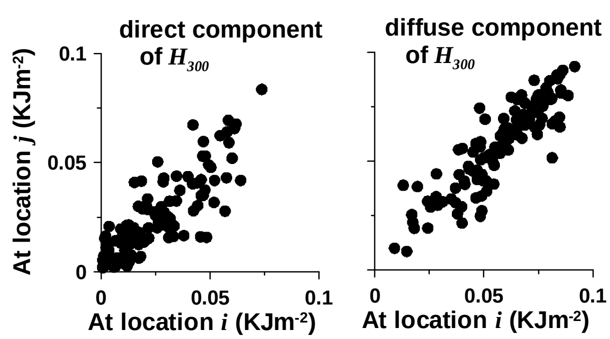

Figure 1 – Correlation in the components to H_{300} between a site in Bondville, Illinois (i) and Lafayette, Indiana (j) separated by 131 km.

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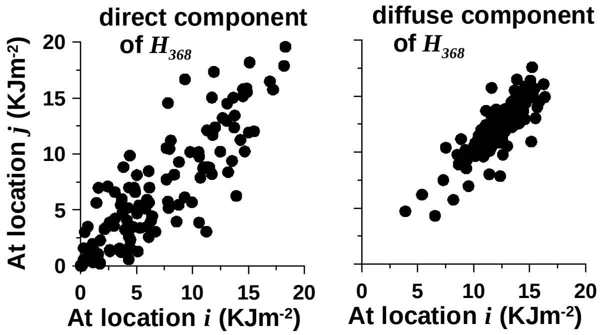

Figure 2 – Correlation in the components to H_{368} between a site in Bondville, Illinois (i) and Lafayette, Indiana (j) separated by 131 km.

The spatial correlation of daily exposure between stations was similar for both wavelengths for distances up to 300 km (Fig. 3A). Beyond 300 km, the correlation of H_{300} was greater than that for H_{368} (Fig. 3A).

In general, the spatial correlation of the diffuse component to H_{300} varied less with distance than the direct beam component (Fig. 3B). At 368 nm, the spatial correlation of the direct beam component was much greater than the diffuse component.

Table 1 – Linear model of spatial statistics structure

X	A	B	r^2
	Structure (X = A *d* + B), d [km]		
ρ(H_{300})	-0.000543	0.750	0.57
ρ(H_{368})	-0.000786	0.789	0.81
ρ(H_{SW})[1]	-0.00132	0.975	0.89
γ(H_{300})	2.31E-6	6.55E-5	0.49
γ(H_{368})	0.0396	4.883	0.75
γ(H_{SW})[1]	0.0552	0.769	0.87

1: Ashraf et al., 1997

The semi-variogram of the diffuse and direct beam components of H_{300} were similar and suggest a linear model is appropriate for spatial interpolation. Semi-variograms of the diffuse and direct beam components of H_{368} differed substantially, with the diffuse component reaching a constant value plateau at small distances (<400 km) while that of the direct beam component did not plateau.

The linear model describing the spatial structure of the H_{300} and H_{368} estimated the spatial correlation at 100 km as 0.74 and 0.78 for the H_{300} and H_{368} respectively. The relatively high spatial correlation of H_{300} at distances of approximately 1000 km was largely due to the high correlation of the diffuse component of H_{300}. In general, the magnitude of the diffuse component to H_{300} was similar to that of the direct component to H_{300} while the magnitude of the diffuse component to H_{368} was less than that of the direction component. This was probably due to the greater clear sky diffuse fraction at 300 nm than 368 nm and the smaller difference between the diffuse fraction under clear and cloudy skies for the 300 nm than 368 nm waveband (Grant and Gao, 2001).

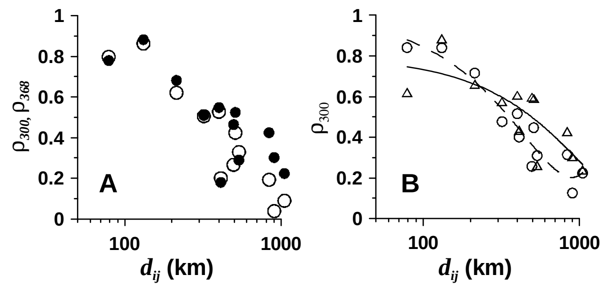

Figure 3 – Spatial correlation of H_{300} (•) and H_{368} (o) in panel A and the diffuse (Δ) and direct beam (o) components to H_{300} in panel B.

4. CONCLUSIONS

The spatial correlation of the 300 nm and 368 nm daily exposure between locations was approximately 0.8 for distances of 100 km. The 300 nm daily exposure was typically more highly correlated between locations than the 368 nm daily exposure. The direct beam component to the daily exposure was typically more highly correlated between locations than the diffuse sky component. A linear isotropic semi-variogram model was the best fit for the daily exposure in all wavebands.

5. REFERENCES

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