9.1 THE SOLAR ULTRAVIOLET RADIATION ENVIRONMENT IN THE WASHINGTON-BALTIMORE METROPOLITAN AREA

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1. INTRODUCTION

Ultraviolet radiation from the sun, especially the UVB (280 to 320 nm), has important roles in urban ecosystems, including effects on human health (Heisler and Grant 2000). In urban areas, incoming UVB irradiance may differ significantly from rural areas, where it is more commonly measured (Grant et al. 2000). In part to determine how the UVB environment of Baltimore differs from adjacent more rural locations, the Baltimore Ecosystem Study (BES LTER site) Solar Radiation Monitoring Station began in May 2001. In this paper, the May through August radiation measurements are compared to weather conditions, surface ozone levels, total ozone column thickness (TO3), and aerosol optical thickness (AOT) to evaluate differences in the urban and rural UVB radiation environment.

2. METHODS

Figure 1 – Locations of UVB (filled circles) and some of the surface air quality (open circles) measurements made in the Washington-Baltimore area.

The UVB radiation environment in the Washington-Baltimore metropolitan area was evaluated using measurements made at three locations: Baltimore, Beltsville, and Queenstown. Hourly UVB irradiance, as well as photosynthetically active radiation (PAR), and total solar short wave (SW) radiation were measured at Baltimore, MD as part of the BES LTER program. UVB

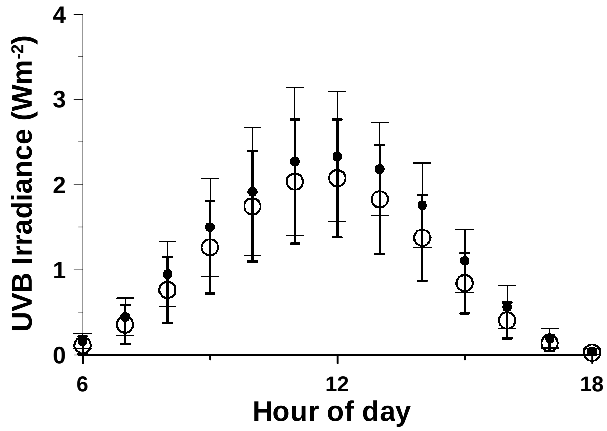

Figure 2 – Daily variation in UVB irradiance. The mean and standard deviations of the UVB irradiance at Queenstown (open circles, heavy bar) and Baltimore (closed circles, light bar) are indicated.

irradiance at 3-min intervals was measured at Beltsville, MD (46 km SSW) and Queenstown MD (67 km SE) (filled circles, Figure 1) as part of the USDA UV-B Radiation Monitoring and Research Program (Bigelow et al., 1998).

The UVB exposure at Baltimore was correlated to measurements of: 1) UVB exposure at Queenstown and Beltsville, 2) AOT and TO3 at Queenstown and Beltsville (provided by the USDA UVB Monitoring Program Office), 3) [NO_2], [SO_2], [O_3] measurements made at a number of locations in the Baltimore area as part of the EPA state air quality monitoring (open circles, Figure 1), and 4) 24-hr backwards trajectory analysis for specific days and locations of interest using the HYSPLIT4 trajectory model with 80 km grid meteorological data (HYSPLIT4, 1997).

3. RESULTS

The UVB irradiance at Baltimore was more similar to that at Beltsville in the Washington-Baltimore metropolitan area than Queenstown across the Chesapeake Bay. The mean difference (0.3 KJm^{-2}) in daily UVB dose between the Baltimore and Beltsville sites was not significant while that between Baltimore and Queenstown (2.1 KJm^{-2}) was significant at an α of 0.05. Daily variability was greater between Baltimore and Queenstown (standard deviation of difference = 7.4 KJm^{-2}) than between Baltimore and Beltsville (standard deviation of difference = 4.8 KJm^{-2}). The difference in UVB irradiance between Baltimore and Queenstown was typically greatest during the afternoon hours (Fig. 1). The greatest differences in daily UVB exposure

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between Baltimore and Beltsville occurred when the winds were from the east or the air was nearly stagnant over the region, indicative of conditions with advection of similar rural air or dominant local urban influence on the radiative environment. The daily UVB dose at Queenstown and Beltsville was largely dependent on the AOT and not TO3. Assuming AOT measured at Beltsville was similar to that at Baltimore, comparisons were made between the AOT of Queenstown and Beltsville on days in which the daily Baltimore UVB exposure was greater than 40 KJm^{-2} and the difference in daily Queenstown to Baltimore UVB exposure was more than two standard deviations from the mean. Results showed that reduced UVB over Beltsville (and presumably Baltimore) relative to Queenstown was associated with increased afternoon AOT at the Beltsville. This may be indicative of afternoon air pollution or, more likely, cloud cover induced from convection over warm urban heat islands.

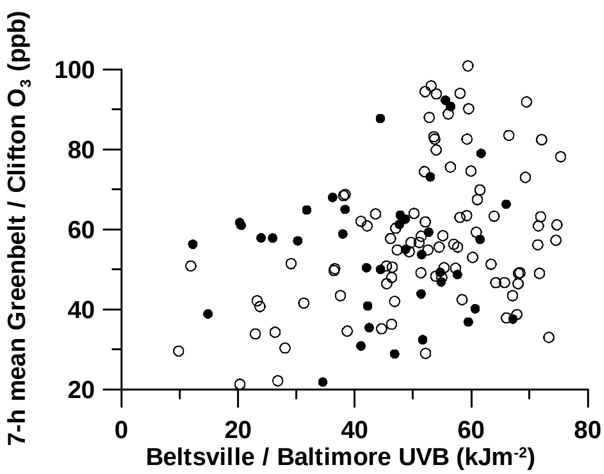

Figure 3 – Correlation of the daily UVB exposure at Beltsville, MD and nearby Greenbelt surface ozone (open circle) and UV exposure at Baltimore and nearby Clifton surface ozone (filled circle).

There is generally greater traffic intensity and consequently higher levels of traffic emissions (including NO) in urban areas compared to rural areas. Prior studies have indicated that surface UVB irradiance should be positively correlated with surface [O_3] when sufficient NO_2 is available as an ozone precursor and negatively correlated with surface ozone if low levels (1-2 ppb) of NO_2 are present (Bronnimann et al. 2001). Surface ozone concentrations in the Metropolitan area (both urban and suburban) were correlated to the UVB irradiance at Beltsville and Baltimore (Fig. 2). The 7-h mean [NO_2] for both Baltimore city air quality monitoring locations (Fig. 1) over the period of study were 12.5 ppb-- indicating sufficient NO_2 in the urban metropolis for UVB irradiance to contribute to surface [O_3]. Surface [O_3] was inversely correlated (weakly) with TO3.

Only one of the five highest ozone events corresponded with high UVB indicating that urban precursors were probably more causal of peak ozone events. The highest surface ozone events occurred in the presence of low to calm winds and with fronts or troughs nearby producing significant fog and cloud cover, limiting the UVB irradiance at the surface.

HYSPLIT4 trajectory analyses for the days of significantly greater UVB irradiance at Queenstown than Baltimore indicated that the air arriving over Queenstown generally did not pass over the Baltimore-Washington or other metropolis as often as air arriving over Baltimore and may therefore have less urban-produced pollutants from the advection of precursors from distant sources.

The daily exposure to UVB at Baltimore was highly correlated with the total daily SW radiation received, with an unexplained residual ranging between –13.9 KJm^{-2} and 10.1 KJm^{-2} of the approximately 10 KJm^{-2} to 80 KJm^{-2} UVB daily exposure. Underestimated UVB exposures (based on SW radiation) appeared to be related to partly cloudy conditions that may be more typical of urban areas during the afternoon.

4. CONCLUSIONS

The urban Baltimore UVB irradiance was very similar to that of a nearby urban measurement location at Beltsville, MD. A positive correlation between UVB and surface 7-h mean [O_3], was observed for both urban and suburban locations; likely due to the influence of clouds on overall UVB irradiance. The urban Baltimore UVB irradiance was significantly different from that of the more rural Queenstown location with daily exposures 4% lower in Baltimore. Differences were greatest during the afternoon—again possibly due to cloud cover.

The ability to relate differences in the rural and urban environments to differences in UVB irradiance was limited by the high frequency of nearby frontal systems during the study period. Supplementary air quality measurements greatly enhance the value of the UVB monitoring in urban areas.

5. REFERENCES

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