ATTENUATION OF SOLAR UV RADIATION BY AEROSOLS DURING AIR POLLUTION EPISODES

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1. INTRODUCTION

Increase in the amount of solar UV radiation reaching the surface due to decrease in stratospheric ozone continues to be a major concern (WMO, 1998). However, recent studies show that absorption and scattering by aerosols during air pollution episode decreases the amount of radiation reaching the surface (Dickerson et al., 1997; Jacobson, 1998; Papayannis et al., 1998; Repapis et al., 1998; Kondragunta et al., 1999). To examine the role played by column ozone and aerosols in perturbing the solar radiation reaching the surface, we analyzed four years of spectrally resolved UV radiation measured by Brewer spectrophotometer at Gaithersubrg, MD (39.1° N and 77.2° W). Transport from upwind regions and local pollution result in severe air pollution episodes at Gaithersburg when meteorological conditions are favorable. We present observations of aerosol optical depth and column ozone (from ground based sun photometers and satellites) and ground measurements of spectrally resolved UV flux. We will compare the observed and computed effects of aerosols on surface UV flux and discuss the implications.

2. OBSERVATIONS AND RADIATIVE TRANSFER CALCULATIONS

Continuous measurements of aerosol optical depth are made at Greenbelt, MD, 25 miles east of Gaithersburg, using an automated sun photometer/sky radiometer at six different wavelengths (Holben et al., 1998). Aerosol optical depths at Gaithersburg (where UV flux measurements are made) were deduced by using a linear correlation between aerosol optical depths measured at Greenbelt and Gaithersburg for three months in 1996 (Figure 1). Observations of aerosol optical depth for non-absorbing aerosols from TOMS instrument on Earth Probe satellite were provided by NASA/GSFC (Torres et al., 1998). Continuous measurements of spectrally resolved UV flux in the wavelength range 305 to 365 nm, column ozone, column sulfur dioxide, and column nitrogen dioxide contents are made at Gaithersubrg by the EPA network of Brewer spectrophotometers. For this study, we used only UV flux and ozone measurements which have been corrected for instrument drifts but not for changes in cosine response of the instruments. The overall uncertainty in UV flux measurements is about 10%. For ozone measurements, comparisons with TOMS measurements indicate a bias of 4.8 D.U (1.5%) over a period of 4 years.

Radiative transfer model calculations were performed using the Discrete Ordinate Radiative Transfer Model (DISORT) developed by Stamnes et al., 1988. Inputs to this model include surface albedo, molecular and aerosol optical depth, aerosol single scattering albedo, asymmetry factor, phase function, and extra-terrestrial solar irradiance. Optical properties of aerosols were obtained by providing retrieved aerosol size distributions from sky radiometer and a refractive index of 1.45-0.005i for scattering aerosols as inputs to Mie code (Wiscombe, 1980; d'Almeida et al., 1991).

3. RESULTS AND DISCUSSIONS

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Aerosols and column ozone have opposite effects on the UV flux reaching the surface. For example, radiative transfer model calculations show that a decrease in 40 D.U. of column ozone increases the erythemal (Diffey weighted) UV flux (DUV) by 14% at 50° solar zenith angle; the effects are larger at larger solar zenith angles. Similarly, for a fixed column ozone, increase in aerosol optical depth of 1.0 in the UV decreases the DUV by 21%. To isolate the effect of aerosols on measured UV flux from the combined effect of aerosols and ozone, we analyzed the UV flux at 340 nm where ozone absorption cross section is negligible. Radiative transfer calculations and observations show that aerosols reduce the surface flux at a rate of 80 $mW/m^2/nm$ per unit aerosol optical depth in the UV (Figure 2).

Observations show that summer time aerosol optical depth in the UV (340 nm) in the eastern US can range between 0.1and 2.0, with a mean value of 0.74 for all smoggy days during 1994 to 1998. To learn about potential implications of aerosol effects on UV flux during pollution events we now focus on one specific episode in 1997. Conditions conducive for a pollution event resulted in a severe multi-day episode during July 08-18 1997; high concentrations of ozone and aerosols were observed at the surface across the entire eastern US. Table 1 shows daily average aerosol optical depth at 380 nm as measured by TOMS satellite and ground based sun photometer. The sun photometer measurements are from Greenbelt, MD (39.01° N and 76.87° W). The satellite measurements are averages around a 1° arc from the Greenbelt site.

Julian Day	AOD @ 380 nm (TOMS)	AOD @ 380 nm (Sun photometer)
193	0.315	0.341
194	0.719	0.750
195	0.921	1.447
196	NA	1.203
197	NA	0.996
198	NA	0.696
199	NA	0.469

Table 1: Comparison of aerosol optical depth measurements at 380 nm measured by satellite (TOMS instrument) and ground instrument (sun photometer) during the air pollution episode in 1997.

Based on the data shown in Table 1, we found the JD193 and JD195 ideal for analyzing the effects of aerosols on UV fluxes because low and high aerosol optical depths were observed on those two days respectively. Both days were clear (cloud-free) and had similar column ozone measurements (318 and 320 DU respectively).
Figure 3 shows observed and DISORT model calculated UV flux ($watts/m^2/nm$) as a function of wavelength for JD193 and JD 195 at 50° solar zenith angle. Observations and model calculations agree well; observations have a fine structure compared to model calculations because of higher spectral resolution (0.5 nm). Both calculations and observations show a decrease in UV flux up to 19%. The effect of aerosols on integrated UV flux (295 to 365 nm) as a function of solar zenith angles for the same two days (JD193 and JD195) are shown in Figure 4. Model calculations are slightly higher than observations; possibly due to exclusion of SO_2 absorption in the model calculations. Aerosol scattering decreased integrated UV flux by up to 14 to 17% depending on zenith angle.

4. CONCLUSIONS

Observations and radiative transfer model calculations show that aerosols attenuate solar UV radiation at 340 nm reaching the surface at a rate of 80 $mW/m^2/nm$ per unit aerosol optical depth; this effect is about 17 to 19% depending on wavelength. Depending on solar zenith angle, aerosols attenuate the integrated UV flux (295 to 365 nm) by up to 17%.

Reduced UV flux near the surface due to aerosol scattering may decrease the amount of photochemical processing of pollutants (smog production) at the surface but increase it aloft. Life time of photodegradable carcinogens in air-borne and aquatic particulate matter may increase. In future studies we will focus on quantifying these effects in relation to health-effects.

5. REFERENCES

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Acknowledgment: We like to thank Omar Torres at NASA/GSFC for providing satellite retrieved aerosol optical depth. This work was funded by the Environmental Protection Agency (EPA)/National Exposure Research Laboratory (NERL) and administered by the University Corporation for Atmospheric Research (UCAR).