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Using MODIS surface albedo and TOMS data for improving the description of air quality model

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Abstract

Accurate representations of photochemistry rates are crucial in photochemical modeling. These reaction rates determine the formation of radicals that drive tropospheric O₃ and secondary aerosol production. For this, correct calculation of spatially and temporally resolved actinic flux is needed. Actinic flux is calculated by the delta-Edington two-stream radiative transfer model (Joseph et al., 1976). Current surface albedo is parameterized as eight discrete values that depend only on wavelengths (Demenjanz et al., 1985), with no temporal or spatial variability. The vertical ozone profiles are set by interpolating seasonal profiles from a default input file, without considering inter-annual, seasonal, or monthly variability.

Remotely sensed satellite data can provide synoptic and geospatial information with high spatial and temporal resolution to ground-based air quality data and modeling (Engel-Cox et al., 2004). In this study, we characterize spatial and temporal variability in surface albedo for our modeling domain in the Central California region, using the MODerate Resolution Imaging Spectroradiometer (MODIS) Bidirectional Reflectance Distribution Function (BRDF)/Albedo product. Temporal trends in the amount and variability of total column ozone are also computed using the Total Ozone Mapping Spectrometer (TOMS) data. We report the results of photochemical simulations and sensitivity studies using the CMAQ modeling system for the Central California region to further quantify the impact of albedo and total column ozone on photochemistry rates and ozone production.

Photolysis Rates in CMAQ

Photolysis Rate Preprocessor (JPROC) is one of the major processors in CMAQ. It is used to calculate chemical mechanism-specific clear sky photolysis rates (J) at fixed altitudes, hour angles, and latitude bands (EPA, 1999). Photolysis reactions in CMAQ

\[ J(\lambda) = \int F(\lambda) \sigma(\lambda) d\lambda \]

where, F(λ) is the actinic flux (photons cm⁻² min⁻¹ nm⁻¹), \( \sigma(\lambda) \) is the absorption cross section for the molecule undergoing photolysis (cm² molecule⁻¹), q(λ) is the quantum yield of the photolysis reaction (molecules photon⁻¹), and A the wavelength (nm). J(λ) and \( \lambda(\sigma) \) are functions of wavelength and unique to species and reactions, measured through laboratory experiments. F(λ) is a radiometric quantity that measures the spectral radiant energy integrated over all solid angles per unit area. It changes with time of day, longitude, latitude, altitude, and season, and is governed by the astronomical and geometrical relationships between the sun and the earth.

The current approach taken for computing the actinic flux in the CMAQ framework follows the delta-Edington two-stream radiative transfer model (Joseph et al., 1976). Teo et al., (1989). A description of the extraterrestrial radiation, aerosol, ozone, and oxygen absorption in the Schumann-Runge Bands, Rayleigh scattering and surface albedo are provided to the radiation model (EPA, 1999).

The problems in current CMAQ include: 1) The albedo data given by Denerjat et al. (1986), as a function of wavelength, are used in the current version of JPROC. They are the discrete values in eight spectral bands, with no temporal or spatial variability (Table 1). 2) The vertical ozone profiles in CMAQ are set by interpolating seasonal profiles from a default input file, without considering inter-annual, seasonal, monthly, or spatial variability. The initial phase of our current study is directed toward improving the description of albedo and ozone parameters in CMAQ.

Surface Albedo from MODIS

The MODIS Albedo 16-Day L3 Global 1km SIN Grid product, MOD43B3, provides black-sky albedo (at the mean solar zenith angle at local solar noon) and white-sky albedo (Figure 1). Each pixel (30°x30°) has one albedo value according to BRDF parameters in seven spectral bands and three broadband bands (Table 2). For the MODIS BRDF/Albedo products, the black-sky albedo (directional hemispherical reflectance) is defined as albedo in the absence of a diffuse component and is a function of solar zenith angle. The white-sky albedo (bihemispherical reflectance) is defined as albedo in the absence of a direct component when the diffuse component is isotropic. Black-sky albedo and white-sky albedo mark the extreme cases of completely direct and completely diffuse illumination. Actual albedo is a value which is interpolated between these two to a function of the fraction of diffuse skylight which is itself a function of the aerosol optical depth (Lucht et al., 2000).

Assessment of MODIS surface albedo and TOMS data for improving the description of air quality model