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Retrieval of cloud optical depth from the cloud modification factor (CMF) for overcast skies

David Serrano (1), María José Marín (2), Anna R. Esteve (1), Victor Estellés (1), Manuel Núñez (3), M. Pilar Utrillas (1), and José A. Martínez-Lozano (1)

(1) Departament de Física de la Terra i Termodinàmica, Universitat de València, Spain (david.serrano@uv.es), (2) Departament de Matemàtiques per a l'Economia i l'Empresa, Universitat de València, Spain., (3) School of Land and Food, University of Tasmania, Hobart, Australia.

Clouds generally produce an attenuating effect over solar radiation (up to 80%) that depends, among other characteristics, on the type of the cloud, its optical depth and its distribution in the sky. To analyse the dependence of the atmospheric transmissivity of solar radiation with the cloud optical depth for overcast skies (τ), both in the range of ultraviolet erythemal radiation (UVER) and in the broadband, we have used the cloud optical depths obtained by a minimization process from the irradiation surface measurements. Measurements in the UVER range were obtained by means of a UVB-1 broadband radiometer by Yankee Environmental Systems, with a spectral range of 280 – 400 nm, and in the broadband with a CM-6 pyranometer by Kipp & Zonen, with a spectral range of 310 – 2800 nm. The cloud cover was obtained from cloud sky images, which were acquired at 5 minute intervals using a sky camera by SONA Sieltec Canarias S.L. A CE318 sunphotometer by CIMEL was used in this study for monitoring aerosol optical properties in a vertical column of the atmosphere. Modelled cloud optical depths obtained by the minimization process are iterated until modelled irradiances are equal to or less than 2 percent of the measured value.

This study presents the relationship between the cloud optical depths, obtained by the previous minimization method, and an important atmospheric transmissivity factor, the cloud modification factor (CMF). CMF, defined as the ratio between the measured radiation in overcast sky conditions and the calculated radiation for a cloudless sky, provides a first distinction of cloud radiative effects. CMF can be evaluated for different spectral intervals, ultraviolet as well as broadband.

For the estimation of CMF, we have calculated cloudless sky irradiance in two different ways: first in a simple way using the empirical expression given by Madronich's equation for UVER range and secondly using the SBDART model for both the UVER and the broadband. Data from 2011 were used to obtain this relationship, and data from 2012 were used in order to validate the results.

The analysis shows a decrease of CMF when the cloud optical depth increases, showing that the solar radiation in both the UVER and broadband ranges is very sensitive to this cloud parameter, and thus the cloud optical depth can be adjusted using the equation ($\tau = a + b \cdot CMF^c$). The cloud optical depths, obtained with this equation, have a deviation for both 2011 and 2012 of less than 3%, being the correlation coefficient close to 0.99.