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Original paper

Spatial and temporal variations of atmospheric aerosol optical thickness in northwestern Mexico

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Resumen

El propósito de este trabajo fue el estudio de los aerosoles atmosféricos en el Noroeste de México mediante el parámetro conocido como Espesor Óptico del Aerosol (AOT). Este parámetro representa uno de los coeficientes de extinción de la radiación solar y un indicador de partículas suspendidas en la atmósfera. Para la determinación del AOT recurrimos al uso de sensores remotos localizados fuera de la atmósfera. En particular, el Espectroradiómetro de Imágenes de Media Resolución (MODIS), el cual es capaz de obtener mediciones del AOT atmosférico. La información proporcionada por MODIS debe ser validada antes de considerarse fiable; para esta tarea, se obtuvieron mediciones desde la superficie para establecer una correlación con los datos derivados del sensor remoto. El artículo describe el proceso de validación que fue aplicado a los datos del sensor MODIS en contraste con mediciones obtenidas por uno de los fotómetros de la Red Robótica para medición de Aerosoles (AERONET) ubicado en la ciudad de Hermosillo, Sonora. Adicionalmente, se presenta un análisis temporal basado en el comportamiento de las gráficas del AOT, así como un análisis espacial derivado de la información contenida en los mapas de distribución del AOT.

Palabras clave: AOT, aerosoles, MODIS, AERONET, noroeste de México, análisis temporal, análisis espacial

Abstract

The purpose of this paper was to study aerosol particles in the Northwestern region of Mexico (NWM) through Aerosol Optical Thickness (AOT) parameter in the atmosphere. This parameter represents one of the extinction coefficients of solar radiation and the rate of suspended particles in the atmosphere. For determination of AOT, we considered the use of remote sensors outside of the atmosphere. In particular, Moderate Resolution Imaging Spectroradiometer (MODIS) which can measure the atmospheric AOT thickness. Data from the MODIS sensor must be validated before they are considered reliable. For this task, we required surface measurements to obtain a correlation with the data acquired with the remote radiometer. The paper describes the validation process performed for data obtained with MODIS through measurements provided by an AErosol RObotic NETwork (AERONET) photometer located in the city of Hermosillo, Sonora, NWM. Additionally, we carried out a temporal analysis based on the behavior of the AOT graphics and spatial analysis supported in maps with sufficient information.

Key words: AOT, Aerosols, MODIS, AERONET, Northwestern Mexico, Temporal analysis, Spatial analysis.

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Introduction

One of the main factors that interact actively with the energy from the Sun is identified as aerosol particles, which influence the processes of absorption, refraction, and scattering of solar radiation that is present in the atmosphere and that create a dynamic climate on Earth as a result of these interactions (Iqbal, 1983). This information from aerosol monitoring is useful not only for others as part of the study of the atmosphere, but it can also find many applications in research on climate change and air pollution caused by human activities and natural phenomena. Many of these applications lie on identifying optimal areas in the use of alternative and renewable energy, such as that from the Sun (Deepak, 1982) (Gueymard and Wilcox, 2011; Broesamle *et al*., 2001).

Recent models for estimating solar resource use require parameters such as topography, vegetation, albedo, and optical thickness of aerosols in the atmosphere among other elements (Bosch *et al*., 2010). The use of ground stations is economically unfeasible for estimating AOT over large territories; thus, the use of satellite images represents a viable option for estimation of several atmospheric and geographic parameters that affect the solar radiation that reaches the Earth's surface (Perez *et al*., 1997).

AOT is used generally to determine the concentration of atmospheric solid particles; their knowledge is useful in conducting studies and in the analysis of smoke from forest fires (Chia *et al*., 2007), air quality in urban areas (Grosso *et al*., 2007), the relationship between AOT and wind speed over the ocean surface (Glantz *et al*., 2006), the influence of anthropogenic aerosols on climate change (Charlson *et al*., 1992), as well in numerous validation studies using instruments located on surface (Bai *et al*., 2008), (Correia and Pires, 2006; Ichoku *et al*., 2002a; Liang *et al*., 2006), among others. One of the most interesting applications of the estimation of AOT in the atmosphere comprises estimation of solar radiation on the surface because of the importance that this implies in the planning and design of solar applications for power generation (Gueymard and Wilcox, 2011; Broesamle *et al*., 2001; Bosch *et al*., 2010; Perez *et al*., 1997).

There are several sensors that orbit the Earth for the acquisition of data from numerous natural variables that are utilized for studies of the Earth's surface and for analyzing the dynamics of the atmosphere. In particular, the MODIS radiometer, is set on-board the platforms Terra (launched on 1999) and Aqua (launched on 2002) and offers the possibility of obtaining values related with a large amount of data among 36 spectral bands spanning from visible to infrared spectrum, 0.425–14.235 μm, respectively, providing images with spatial resolution at nadir of 1 km, and at 500 and 250 m (Wolfe *et al*., 1998). The advantages of MODIS sensor in the study of atmospheric phenomena are very broad and it has specific advantages in the analysis of AOT.

Aerosol data provided by MODIS sensor must be validated by surface-based measurements (Liang *et al*., 2006). For this task, the photometers from AErosol RObotic NETwork (AERONET) can be used. Using this data is possible to obtain optical thickness values at a particular point while the platform in which MODIS is attached performs its coverage over the same area. In the present study, the validation process is developed for Northwestern Mexico (NWM), where to our knowledge no study of this type has been conducted before. The method used for data acquisition and refinement covers the period from 2001–2003, which was selected according to available information for first years of MODIS sensor on Terra satellite and AERONET data availability in the city of Hermosillo, Sonora. In addition, we present the criteria to determine the extent of the area in which AOT values were processed from satellite images, the parameters for granting the same mapping characteristics, and the extraction of spectral bands for the optical thickness spray on the land surface.

Data acquisition and pre-processing

Information source – MODIS

MODIS aerosol products were downloaded from Atmosphere Archive and Distribution System (LAADS Web) of the National Aeronautical and Space Agency (NASA) Goddard Space Flight Center. The products selected were derived from Terra platform level 2 (MOD04 L2) with spatial resolution of 10 × 10 km at nadir in hierarchical data format (HDF) files, which contain values at three different wavelengths for corrected optical depth land (0.47, 0.55, and 0.66 μm) among 62 science data-set options. Data acquisition was performed in terms of NWM as main covered area in all images through h07v06 and h08v06 tiles. Period between 2001 and 2003 was selected as temporal span. Terra products were selected over Aqua due to data availability, regarding the launching date of each platform. All files were reprojected into Lambert conical conformal projection employing the same cartographic parameters that are commonly established by Mexico's National Institute for Statistics and Geography (INEGI, 2011).

The wavelength selected for validation process with AERONET data was 0.66 μm, broadly to 0.675 μm available from sun photometer measurements and regarded in previous studies