Atmospheric Research 157 (2015) 66–73

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Assessment and application of MODIS ocean and land algorithms for the characterization of aerosol properties over a Mediterranean coastal site

S. Segura [a,*], V. Estellés [a], A.R. Esteve [b], F. Tena [a], M.P. Utrillas [a], J.A. Martínez-Lozano [a]

[a] *Departament de Física de la Terra i Termodinàmica, Universitat de València, Dr. Moliner 50, 46100 Burjassot (Valencia), Spain*
[b] *Departament de Didàctica de les Ciències Experimentals i Socials, Universitat de València, Tarongers 4, 46022 València, Spain*

ARTICLE INFO

Article history:
Received 12 November 2014
Received in revised form 20 January 2015
Accepted 20 January 2015
Available online 30 January 2015

Keywords:
Atmospheric aerosols
Aerosol optical depth
Ångström exponent
MODIS
AERONET
ESR

ABSTRACT

The aerosol optical depth (AOD) and Ångström exponent (α) obtained from MODIS Terra and Aqua over the coastal urban site of Burjassot (Spain) during the period 2002–2011 have been compared with retrievals from AERONET (AErosol RObotic NETwork) and ESR (European Skynet Radiometers) in order to investigate the performance of MODIS algorithms over land and ocean, respectively. The comparison of the MODIS aerosol products C051 over both land and ocean has been performed for a window size of 50 km × 50 km centred on the monitoring site. The correlation coefficients obtained from the comparison of the AOD from MODIS with that from ground-based measurements are 0.85 and 0.87 over land for Terra and Aqua, respectively, and 0.90 over ocean for both satellites. For the comparison of α, the correlation coefficients are 0.25 and 0.30 over land and 0.73 and 0.66 over ocean for Terra and Aqua, respectively. Since our analysis shows that the MODIS algorithm over ocean characterizes better the aerosol parameters over the coastal urban site of Burjassot (Spain), this dataset has been used to perform a multi-year analysis of the aerosol properties in order to derive a local climatology over this site. The mean AOD at 550 nm is 0.16, with percentiles 25 and 75 of 0.07 and 0.21. These results indicate a relatively clear atmosphere in the area in spite of local anthropogenic and remote dust sources.

1. Introduction

Atmospheric aerosols, due to their high spatial and temporal variability, are one of the major sources of uncertainty in different processes affecting climate (IPCC, 2013), and they also have effects on visibility (Samet et al., 2000), air quality (Torres et al., 2002), and human health (Samet et al., 2000). Among their effects on climate, their role in radiative forcing is highly important (Charlson et al., 1992). On the one hand, they have a direct effect by scattering and/or absorbing earthbound solar radiation, which contributes to cooling and warming of the atmosphere. On the other hand, they have an indirect effect acting as cloud condensation nuclei (CCN) (Ramanathan et al., 2001), modifying the microphysical and radiative characteristics of clouds (Kaufman et al., 2005). Besides, they have a semi-direct effect influencing precipitation and albedo (Rotstayn and Penner, 2001).

Aerosol characterization can be performed by means of in situ measurements, ground-based remote sensing techniques, and remote sensing from satellites. In situ measurements and ground-based remote sensing techniques have good temporal resolution, although their spatial coverage is low. However, satellite products provide a global coverage of the Earth although they have a lower temporal resolution. The accuracy of satellite measurements is also lower since the radiance measured by the sensor is affected by that reflected by the Earth's surface. This affects the quality of the data and makes it necessary to validate satellite data against ground-based measurements (Kaufman et al., 1997a; King et al., 1999; He et al., 2010; El-Metwally et al.,

* Corresponding author.
E-mail address: Sara.Segura@uv.es (S. Segura).

http://dx.doi.org/10.1016/j.atmosres.2015.01.019

2010; Xie et al., 2011). Nevertheless, all these methods are important and provide complementary aerosol information such as composition, size, optical properties and spatial and temporal distributions.

The use of remote sensing techniques to retrieve aerosol parameters has advanced significantly over the last years. In this work we have used products from the Moderate Resolution Imaging Spectroradiometer (MODIS) (http://modis.gsfc.nasa.gov) on board both Terra (http://www.ioccg.org/sensors/Terra.html) and Aqua (http://www.ioccg.org/sensors/Aqua.html) satellites, launched as part of the NASA Earth Observing System (EOS). MODIS has the ability to retrieve different aerosol properties such as the optical thickness or the Ångström exponent both over land and ocean by employing different algorithms. MODIS aerosol products have been previously compared with ground-based data from sun photometers of the Aerosol Robotic Network (AERONET) (Chu et al., 2002; Ichoku et al., 2004; Pan et al., 2009; de Meij and Lelieveld, 2011; de Meij et al., 2012; Benas et al., 2013).

The main objective of our study is to compare MODIS aerosol products over land and ocean with retrievals from a ground-based sun photometer located in Burjassot, Spain (39.5°N, −0.418°E, 60 m a.s.l.), in order to assess which one provides a better characterization of the aerosol properties over this site. Since Burjassot is located near the coast, this has allowed us to compare both MODIS algorithms with the same ground-based dataset.

As for the structure of this article, a brief overview of MODIS retrieval algorithms and aerosol products is given in Section 2.1. The AERONET and European Skynet Radiometer (ESR) networks are described in Section 2.2, as well as the Burjassot monitoring site. Section 3 describes the methodology used for the comparison. The results are analysed in Section 4. The characterization of the aerosol properties over Burjassot (Spain) is described in Section 5. Finally, the conclusions of this work are reported in Section 6.

2. Instrumentation

2.1. Moderate resolution imaging spectroradiometer

The first MODIS instrument was launched at the end of 1999 on board the EOS Terra and the second one on board the EOS Aqua in May 2002. Terra's orbit around the Earth is programmed so that it passes across the equator from north to south in the morning (10:30, local time), while Aqua crosses over it from south to north in the afternoon (13:30, local time). Both instruments provide global coverage of the Earth's surface every one or two days, depending on the latitude of the ground-based observation point.

MODIS obtains data from the reflected solar radiance and emitted terrestrial radiance using 36 different spectral bands, ranging from 0.415 to 14.235 μm, at three different spatial resolutions: 250 m (two channels), 500 m (five channels), and 1 km (19 channels). The aerosol retrieval uses seven spectral bands (0.47–2.13 μm) and two independent algorithms to retrieve aerosol parameters over land (Kaufman et al., 1997a; Remer et al., 2005; Levy et al., 2009) and over ocean (Tanré et al., 1997; Levy et al., 2003). These two algorithms rely on calibrated and geolocated reflectances provided by the MODIS Characterization Support Team (MCST), identified as products MYD/MOD02 and MYD/MOD03 for Aqua (MYD) and Terra (MOD), respectively. Pixels from these data are grouped in boxes of 10 km × 10 km and corrected for trace gases and column water vapour. Using geolocation and cloud mask products (MYD/MOD35) makes individual pixels to be classified as land/ocean surfaces. If any pixel is classified as land in the box, the land algorithm is used; otherwise, it uses the ocean algorithm.

There are important differences between the algorithms used for the aerosol retrieval over land and over ocean. First, the algorithm proposed for ocean pixels assumes the surface reflectivity to be ~0, while the algorithm proposed for land pixels derives the surface reflectivity from the radiance measured at 2.13 μm (Kaufman et al., 1997b). Second, the aerosol algorithm over land uses radiances at two wavelengths (0.47 and 0.66 μm), while the algorithm over ocean uses seven wavelengths (0.47, 0.55, 0.66, 0.86, 1.24, 1.63 and 2.13 μm). Third, the algorithm over land distinguishes between dust and non-dust aerosols, but uses prescribed combinations for coarse and fine mode aerosol for each region; while the algorithm over ocean solves for both the type and relative amount of coarse and fine mode aerosol (Anderson et al., 2005; Santese et al., 2007). Finally, validations of the MODIS AOD product show that the algorithm over land has an accuracy of $\Delta AOD = \pm(0.05 + 0.15 \cdot AOD)$ (King et al., 1999; Chu et al., 2002; Remer et al., 2005), while the accuracy of the algorithm over ocean is of $\Delta AOD = \pm(0.03 + 0.05 \cdot AOD)$ (Tanré et al., 1997).

2.2. AERONET and ESR networks

Ground-based measurements used in this paper have been obtained with a CIMEL CE318 sun photometer, operated at Burjassot (Spain) for a period of 10 years (2002–2011) (Estellés et al., 2007). This instrument measures the direct Sun radiance in eight spectral channels ranging from 340 to 1020 nm, and also the diffuse sky radiance in the solar almucantar at four wavelengths (441, 673, 873, and 1022 nm) (Xie et al., 2011). Burjassot is a city of 38,400 inhabitants located in the metropolitan area of Valencia, in the eastern coast of Spain (Fig. 1). Valencia is a city with a total population of 1,832,000 inhabitants, including the metropolitan area. As a

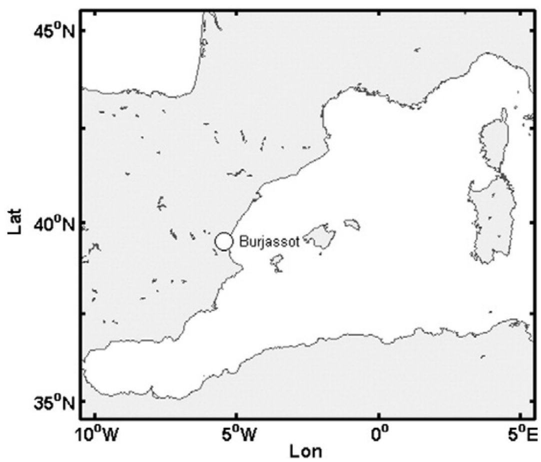

Fig. 1. Geographic location of the AERONET/ESR monitoring site at Burjassot.