

Validation of MODIS aerosol optical depth over a Mediterranean and coastal urban environment (Valencia, Spain)

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Introduction

Aerosols are considered to have one of the largest uncertainties in climate modeling. They play an important role in the energy balance of the Earth by scattering and absorbing solar radiation, and they also have an impact in modifying clouds, or affecting air quality and thus, human health. In order to get a better knowledge of them, a great number of measurements all over the world have been done with different ground-based instruments and, in the last years, also with satellites.

MODIS (Moderate Resolution Imaging Spectroradiometer) is a sensor employed for satellite remote sensing, which offers atmospheric aerosol products. The data obtained by the different sensors onboard satellites (such as MODIS) need to be validated with ground-based measurements.

The most important effort to characterize the atmospheric aerosols worldwide comes from AERONET (Aerosol Robotic Network). AERONET is an international operative network of Cimel CE318 sunphotometers that provides the most extensive aerosol data base globally available of ground-based measurements.

Another research network is ESR (European Skynet Radiometers). ESR is a federated network of SKYNET and therefore, it uses Prede POM sunphotometers. However, Cimel CE318 data can be also processed with the ESR software, so it can be used with independent instruments.

In this work we present a validation of MODIS aerosol optical depth (AOD) over Valencia (Spain) employing CIMEL CE318 measurements since 2002 to 2007 (ESR data, as the AERONET data was not available prior to 2007) and from 2007 to 2011 (AERONET data).

What is MODIS?

MODIS is a spectroradiometer onboard both NASA Earth Observing Systems (EOS) Terra and Aqua satellites, which provides almost complete global coverage every day. Table 1 shows the specifications of both satellite platforms, while in Table 2 the characteristics of the MODIS sensor have been indicated.

Characteristics	TERRA	AQUA
Launch date	18 December 1999	4 May 2002
Hour crossing equator	10.30 UTC (North to South)	13.30 UTC (South to North)
Altitude	705 km	705 km
Orbit	Polar	Polar
MODIS product	MOD	MYD

Table 1. Terra and Aqua characteristics.

MODIS		
Spectral bands	36 channels	250 m (2 bands)
Range	0.415 - 14.235 μm	Spatial resolution 500 m (5 bands)
Swath width	2330 km	1 km (29 bands)

Table 2. MODIS characteristics.

AOD is part of the MODIS atmosphere products and represent the extinction of the solar radiation as it goes through the atmosphere. It is retrieved employing different algorithms depending on the underlying surface, which introduce different errors in the final value (Remer et al., 2005):

- **Land algorithm:** $\Delta\tau = \pm(0.05 + 0.15\tau)$
- **Ocean algorithm:** $\Delta\tau = \pm(0.03 + 0.05\tau)$

Methodology

Validation of MODIS AOD has been done by employing the method proposed by Ichoku et al (2002) which consists on a *spatio-temporal comparison* of the data. The characteristics of MODIS and AERONET data has been specified in Table 3.

MODIS (spatial average)		AERONET (temporal average)	
Product	MYD/MOD04 C 5.1	Frequency	15 min
Data level	2	Data level	1.5
Pixel size	10 x 10 km ²	Time averaged	± 30 min
Pixels needed	At least 5	Measurements	At least 3
Subset area	50 x 50 km ² (5 x 5 pixels)		

Table 3. MODIS and AERONET data employed for the spatio-temporal validation.

Validation is done with the ground based AOD at 550 nm. This value is obtained from our measurements by employing a *second order polynomial fit* over the data (Eck et al., 1999):

$$\ln AOD_{CIMEI}(\lambda) = a_0 + a_1 \ln \lambda + a_2 (\ln \lambda)^2$$

How are MODIS data presented?

Valencia is a medium size Spanish city (~1,800,000 inhabitants in the metropolitan area) located in the Western coast of the Mediterranean Sea (Figure 3a). As shown in Figure 3b, the subset area of 5 by 5 pixels covers both land and ocean, therefore, a different validation is done depending on the surface.

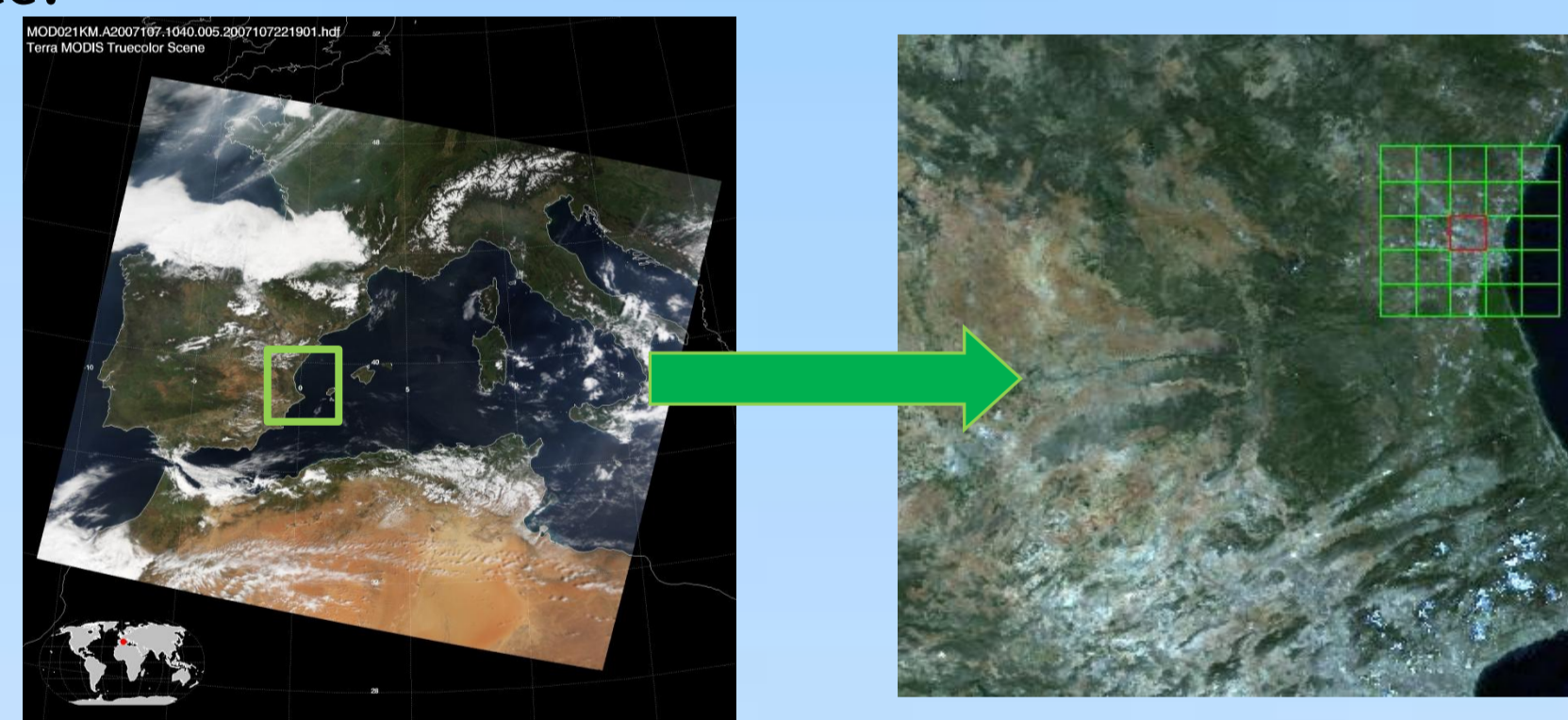


Figure 3. True color image of 17th April 2007 10.40 UTC provided by the MODIS sensor aboard the NASA EOS Terra spacecraft. (a) Granule of level 1b. (b) MODIS image with the subset area for the spatial validation centered in the AERONET station (red pixel).

AOD values are selected with a **QA = 3**, for **clear skies** (0% - 30% clouds), and for pixels with no spatial distortion (**bow tie effect**) by setting 30 km as the maximum distance.

Results

Validation of MODIS AOD has been made for both satellites Terra and Aqua over ocean and over land (Figure 4). The results of the linear fit are shown in Table 4.

	N	% within expected error	slope	intercept	R
TERRA LAND	650	82 %	0.89	0.02	0.85
AQUA LAND	719	84 %	0.97	0.02	0.87
TERRA OCEAN	461	64 %	0.97	0.01	0.90
AQUA OCEAN	361	67 %	0.84	0.01	0.90

Table 4. Results obtained with the linear fit: total number of data (N), % expected error, slope (m), origin (n), and correlation coefficient (r). (Best values for m and r are highlighted in bold)

Black shadowed lines of Figures 4a - 4d represent the MODIS 'expected errors' that contain the mean and first standard deviation (~66 %) of all points. Results shown in Table 4 agree with the accuracy assumptions: 84 and 82% over land (as the error is higher) and 64 and 67% over ocean.

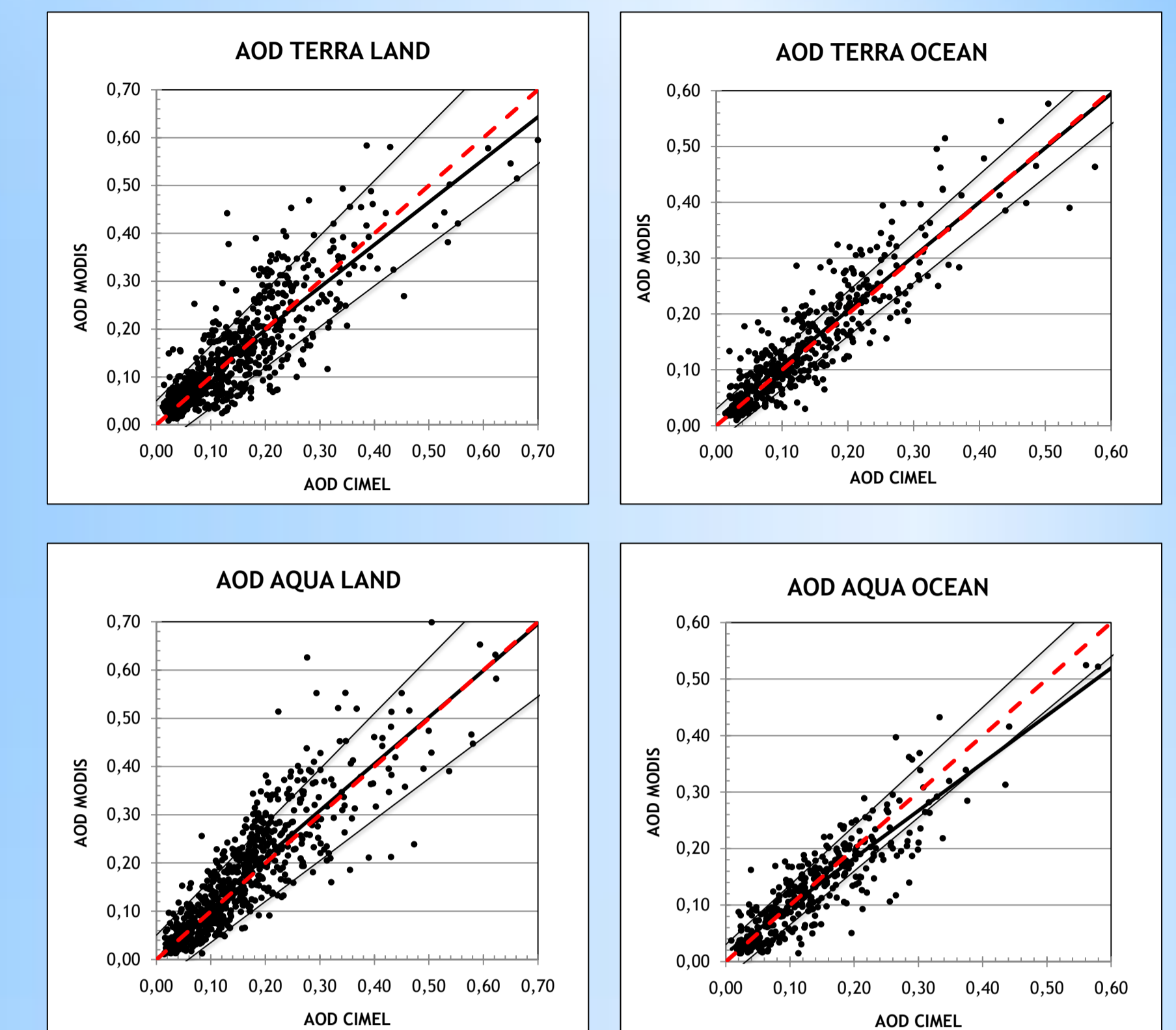


Figure 4. Validation of MODIS AOD for both satellites and both algorithms with the lines for 'expected errors': (a) Terra's AOD over land, (b) Terra's AOD over ocean, (c) Aqua's AOD over land, and (d) Aqua's AOD over ocean.

Conclusions

Validation of MODIS AOD has been made for many places in the world, globally and regionally. One of the advantages of our site is that, as it is located in the Mediterranean coast, it can be used for the validation of the two MODIS algorithms (land and ocean). Also, this study introduces an improvement respect other studies by using only those pixels with no spatial distortion over land.

Although validation of MODIS AOD using ground based measurements over Valencia shows good results, some notes have to be done. For Terra, both algorithms agree with ground based data; However, values obtained over **ocean** are slightly better than those obtained over **land**, especially for higher AOD. For Aqua, results over **land** are better than over **ocean**, especially for higher AOD. The difference between both satellites could be related to the overpass time. However, both datasets have been validated and can be used for further studies.

References

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