AEROSOL OPTICAL DEPTH RETRIEVAL AT THE IZAÑA ATMOSPHERIC OBSERVATORY FROM 1941 TO 2013 BY USING ARTIFICIAL NEURAL NETWORKS

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A 73-year time series of the daily aerosol optical depth (AOD) at 500 nm has been reconstructed from 1941 to 2013 at the subtropical high-mountain Izaña Global Atmospheric Watch (GAW) Observatory (IZO) located in Tenerife Island (The Canary Islands, Spain; 28º18' N, 16º29' W, 2.367 m a.s.l) (see Figure 1). For this purpose, we have combined AOD estimates from Artificial Neuronal Networks (ANNs) from 1941 to 2001, and AOD measurements directly performed with Precision Filter Radiometer (PFR) between 2003 and 2013. The analysis is limited to cloud-free conditions (Oktas = 0) and to the summer season (JAS), where the largest aerosol load is observed at IZO (Saharan mineral dust particles). In order to account for the observed AOD inter-annual/decadal variations, we have done a preliminary study about the relationship between AOD time series and the large-scale climatic indexes, such as the Atlantic Multidecadal Oscillation (AMO), obtaining a significant anti-correlation.

SITE DESCRIPTION

Figure 1.- Location of the study area. Saharan mineral dust event over the Canary Islands (image from MODIS/TERRA on 25 June 2012).

IZO is above a quasi-permanent inversion layer with excellent conditions for *in situ* and column measurements of trace gases and aerosols under "free troposphere" conditions. These conditions are only significantly modified by episodes of Saharan desert mineral dust during summer months, the period of greatest activity in the North Sahara-Sahel region (Rodríguez et al., 2011), as shown in Figure 2. This figure depicts the annual cycle of the AOD measurements available at IZO (2003-2013). We clearly observe that the maximum AOD values are reached in summer (from July to September, with a median AOD of 0.13±0.01), when the mineral dust is an important aerosol source. For this reason, in this work, we will consider only the summer season (JAS) to estimate the AOD values.

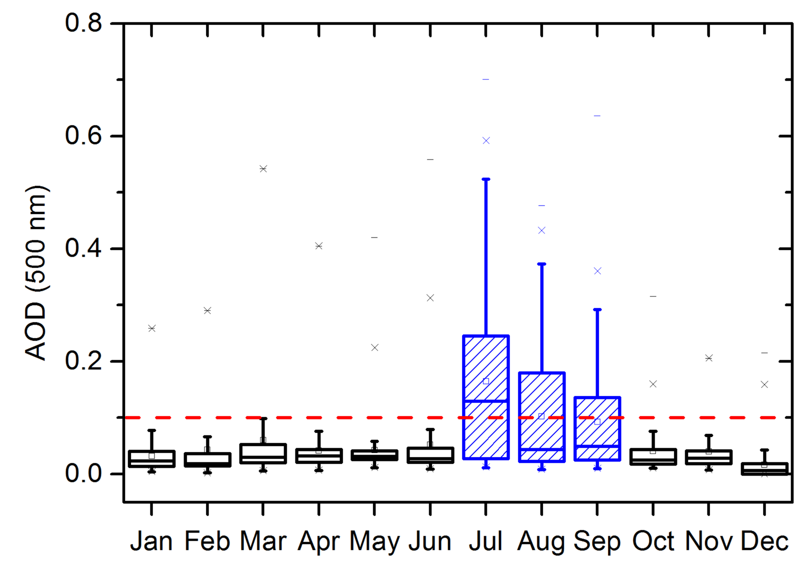

Figure 2.- Annual cycle of monthly AOD at 500 nm for the period 2003-2013 at IZO. Lower and upper boundaries for each box are the 25 and 75 percentiles, respectively, the solid line is the median value, the crosses indicate values out of the 1.5 fold box area (outliers), and hyphens are the maximum and minimum values. The red dashed line represents the AOD= 0.10.

ESTIMATION OF AOD USING ARTIFICIAL NEURAL NETWORKS (ANNs)

Methodology:
ANNs algortihm: Matlab Neural Network Toolbox
Period: 1941-2001
Conditions: Cloud free (oktas = 0)

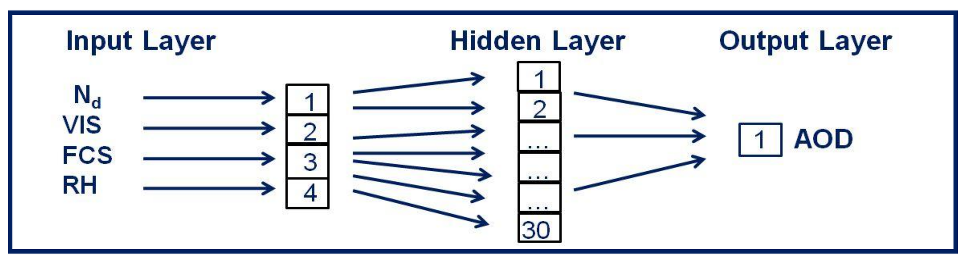

Figure 3.- Schematic representation of the ANNs used in this work.

Architecture (Figure 3):
Input Layer: Julian day (Nd), horizontal visibility (VIS), fracction of clear sky (FCS) (García et al, 2014) and relative humidity (RH)
Hidden Layer: Activation function: hyperbolic tangent function; Neurons 30
Output Layer : daily AOD at 500 nm

ANNs training:
Levenberg-Marquard algoritm for training
Target: AOD performed with PFR (Precision Filter Radiometer) at 500 nm between 2003 and 2013.

VALIDATIONS OF AOD ESTIMATIONS

The AOD ANNs estimates have been validated by comparing with coincident AOD measurements performed with two instruments (Figure 4): CIMEL photometer (AERONET) at 500 nm between 2004 and 2009 (154 days) and solar spectrometer MARK-I at 769.9 nm between 1984 and 2009 (1076 days). The comparison have been performed on a daily and seasonal basis (Figure 4a-4b and Figure 4c, respectively), showing very consistent results and a good agreement between AOD estimations and measurements. Table 1 summarizes the intercomparison statistics.

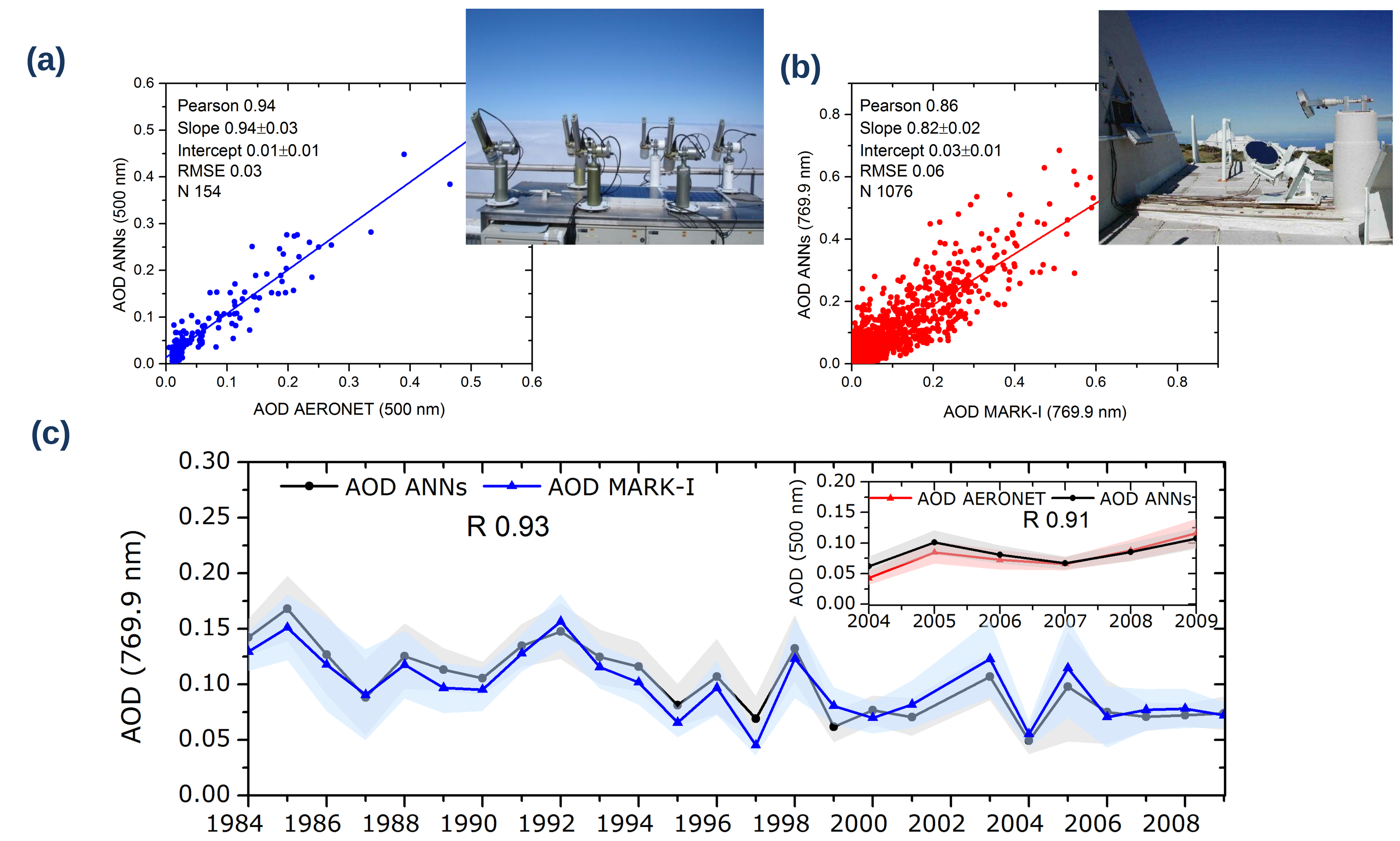

Figure 4.- Scatterplot of the AOD ANNs estimates and measurements (a) daily AOD AERONET at 500 nm and (b) daily AOD Mark-I at 769.9 nm. The least square fits are shown in the legends. (c) Time series of the seasonal median (JAS) of the AOD Mark-I (blue line) and AOD ANNs (black line) at 769.9 nm between 1984 and 2009. The small figure represents the time series of the seasonal median of AOD AERONET (red line) and AOD ANNs (black line) at 500 nm between 2004 and 2009 at IZO. The shading shows the range of ±1SEM (standard error of the seasonal median).

AOD intervals	Data	Days	R	Median	±1SEM
≤0.10	*AERONET*	113	0.73	-0.01	$1.9x10^{-3}$
	MARK-I	691	0.41	-0.02	$1.5x10^{-3}$
>0.10	*AERONET*	41	0.86	$-1x10^{-3}$	$6.7x10^{-3}$
	MARK-I	385	0.80	0.02	$4x10^{-3}$

Table 1.- Statistics for the bias between daily AOD measurements and estimates for different AOD intervals (median of the bias and ±1SEM). R is the Pearson coefficient of the straightforward comparison.

1941-2013 TIME SERIES OF ESTIMATED AOD

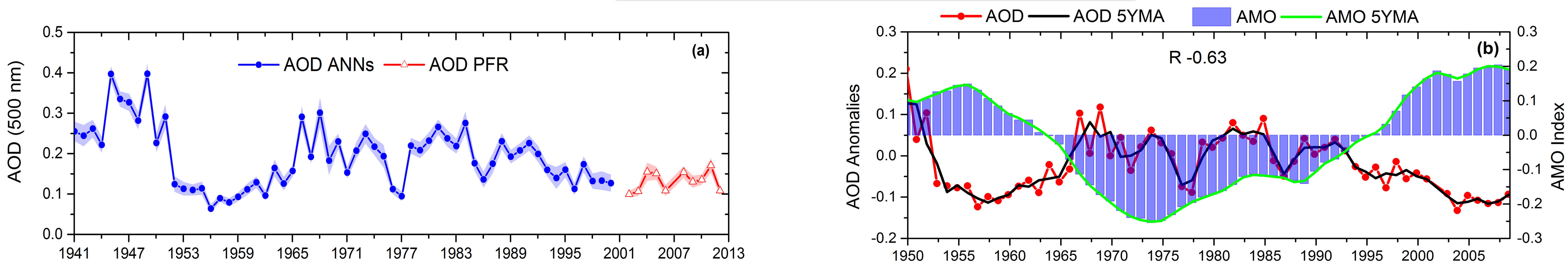

Figure 5.- Time series of AOD (a) seasonal medians (JAS) at 500 nm. The blue dots represent the AOD obtained from ANNs between 1941 and 2001 and the red triangles represent the AOD measured by PFR between 2003 and 2013 (the shading shows the range of ±1SEM (standard error of the seasonal median)) and (b) seasonal medians (JAS) of AOD anomalies at 500 nm (red line) and the Atlantic Multidecadal Oscillation (AMO; http://www.esrl.noaa.gov/psd/data/timeseries/AMO/) seasonal medians (JAS) (blue bar) between 1950 and 2009 (five-year moving average, 5YMA, is shown in black for AOD, and in green for AMO).

CONCLUSIONS

ANNs has proved to be a very useful tool to reconstruct the time series of AOD from *in-situ* meteorological measurements (Nd, VIS, FCS and RH). The agreement between AOD ANNs estimates and measurements is rather good, with Pearson correlation coefficients (R)>0.90. This agreement is consistent over time, therefore the AOD ANNs can be valid for reconstructing the AOD time series and for trends studies.

Also, we have found an significant anticorrelation between AMO and AOD (R=0.63), pointing out that the Saharan mineral dust transported to the Atlantic Ocean at subtropical latitudes might be governed by cyclic atmospheric circulation anomalies at a global scale.

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