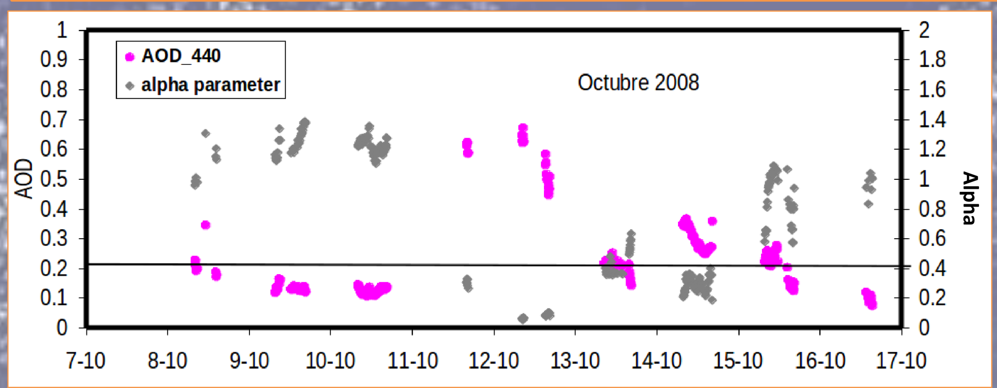
LONG-TERM INVENTORY OF DESERT DUST OUTBREAKS IN PALENCIA SITE (NORTH-CENTRAL SPAIN)

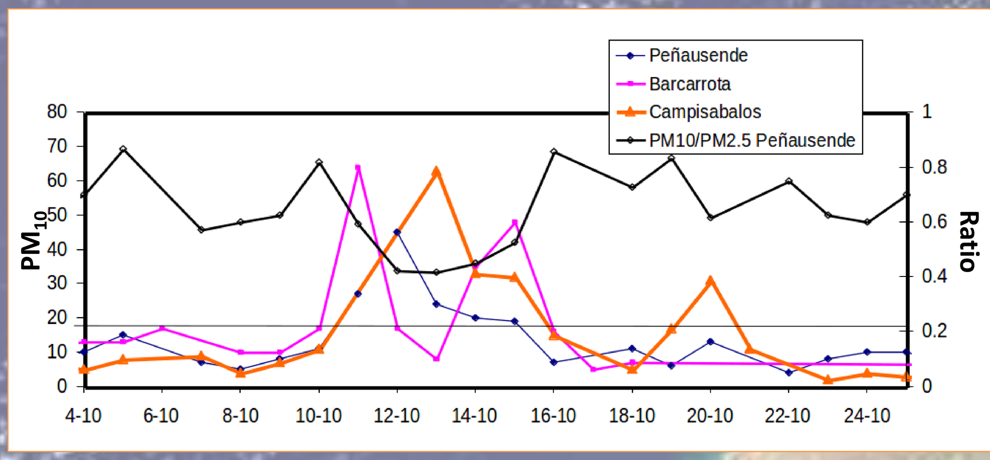
V.E. Cachorro, M.A. Burgos, C. Toledano, D. Mateos, Y. Bennouna, D. Fuertes, R. González, R. Román, C. Velasco-Merino, A. Calle, and A.M. De Frutos
Grupo de Óptica Atmosférica (GOA), Universidad de Valladolid, Valladolid, España.

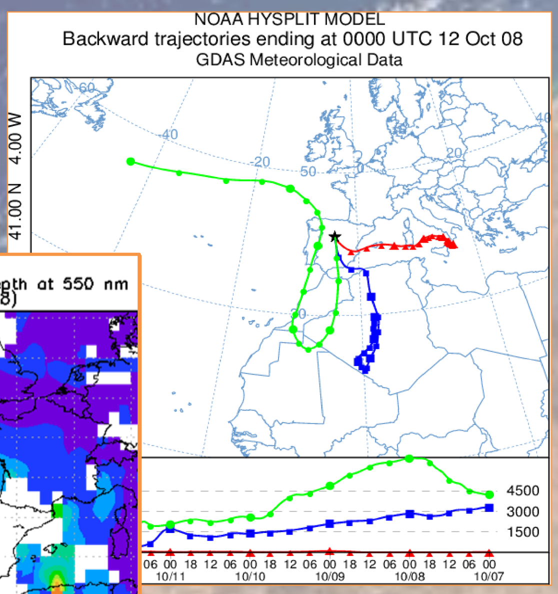
ABSTRACT

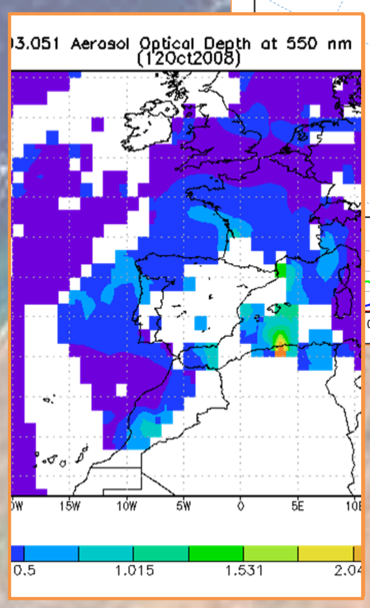
With the aim of knowing the impact of desert dust (DD) aerosols over the well-known climatology in the North-center region of the Iberian Peninsula, an inventory of desert dust outbreaks has been carried out for the period Jan/2003 to Dec/2013, developed by means of columnar sun-photometer (AOD_{440nm} and $Alpha_{440-870nm}$) and surface (PM_{10}) measurements from AERONET and EMEP networks, respectively.

The main AERONET site is Palencia (41.9 N, 4.5 W) a rural area isolated of big urban and industrial nuclei, where desert intrusions are clearly observed. The main EMEP site is Peñausende, using when necessary data from the sites of Barcarrota and Campisábalos.









METHODOLOGY

I. Visual inspection of the databases evolution: once the threshold values of AOD>0.18, Alpha<1.0 and PM_{10} >13 µg·m^{-3} are established (these choices are based on the climatology of the site and our expertise working with them, [1]; [2]), the central or more intense days of an intrusion are easily detected (since the data exceed these values).

II. First and last days of a DD event can show a low or moderate signature of desert dust particles, thus, it is necessary to exactly determine and classify the days composing the event. For this purpose, it will be helpful the analysis of supplementary information as Back-trajectories (evaluated at three high levels, 500,1500 and 3000 m.) and PM_{10} data of the three sites (Peñausende, Campisábalos and Barcarrota) that point out the path followed by the intrusion. We also use satellite images (MODIS) and meteorological maps. The True Color MODIS image of 12 October 2008 shows the cloudiness and the consequent difficulties of sampling of some days.

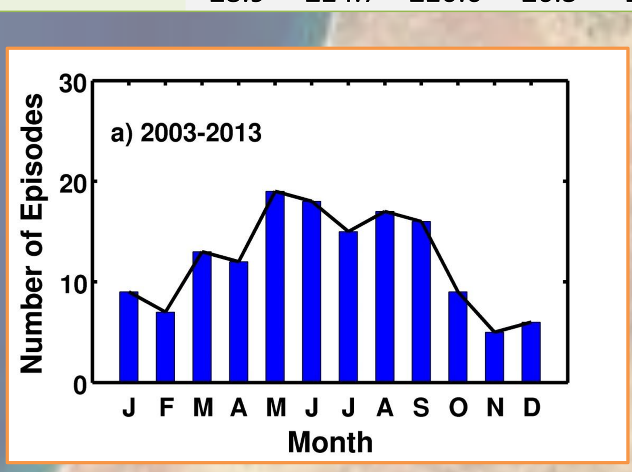
III. Each day composing the event will be classified as Pure Desert (named D, with Alpha≤1) or Mixed Desert (DC, with Alpha>1 that reflects the mixture of desert dust with other aerosol type).

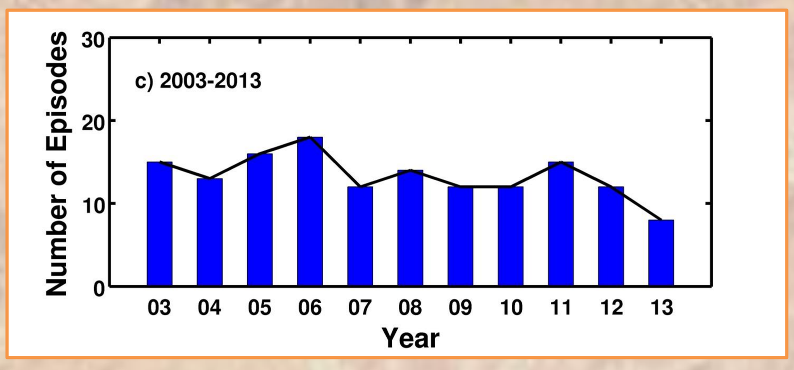
RESULTS

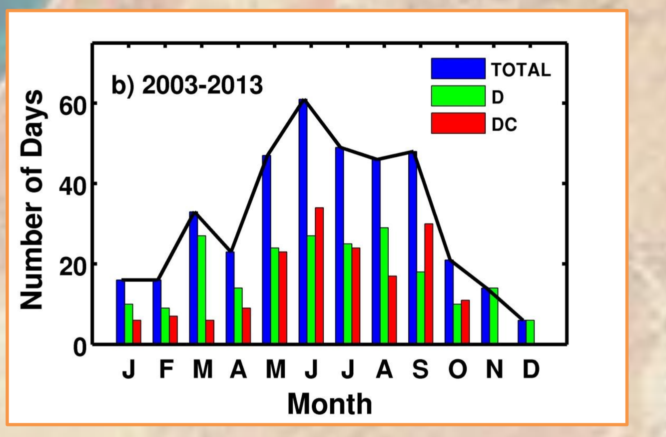
OCCURENCES

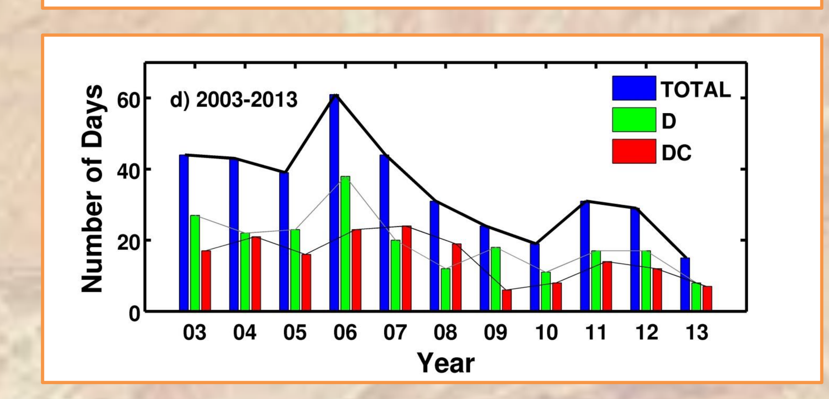
The inventory of desert dust intrusions includes, mainly: information of each episode and its associated days; the daily values of AOD, Alpha, PM_{10}, and $PM_{2.5}$, among others; cloudiness, synoptic scenarios, and origin of air masses back-trajectories at the three altitude levels mentioned before.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total	By Year
Number of Episodes	15	13	16	18	12	14	12	12	15	12	07	146	13.27
Number of Days	44	43	39	61	44	31	24	19	31	29	15	380	34.55
Percentage of Days	12.05	11.78	10.68	16.71	12.05	8.49	6.58	5.21	8.49	7.95	4.11	9.46	9.47
Mean Duration	2.93	3.31	2.44	3.39	3.67	2.21	2.00	1.58	2.07	2.42	2.14	2.60	2.60
Mean AOD_{440nm}	0.31 ±0.11	0.34 ±0.15	0.29 ±0.18	0.25 ±0.10	0.31 ±0.11	0.28 ±0.10	0.20 ±0.05	0.31 ±0.11	0.27 ±0.09	0.30 ±0.10	0.19 ±0.10	-- --	0.28 ±0.11
Mean Alpha	0.96 ±0.36	0.96 ±0.42	0.96 ±0.44	0.80 ±0.32	1.04 ±0.36	1.01 ±0.47	0.81 ±0.36	0.80 ±0.51	0.91 ±0.37	0.78 ±0.47	0.99 ±0.45	-- --	0.92 ±0.41
Mean PM_{10}	28.6 ±12.8	30.3 ±32.6	31.3 ±29.2	21.6 ±8.1	19.3 ±11.7	22.1 ±7.9	15.8 ±6.4	25.0 ±25.8	20.9 ±10.4	23.2 ±20.4	16.4 ±4.8	-- --	23.1 ±15.5
Mean $PM_{2.5}$	15.0 ±6.2	14.4 ±8.8	16.1 ±11.6	11.9 ±3.5	10.0 ±4.1	14.8 ±4.7	8.4 ±5.0	10.6 ±9.4	8.8 ±3.1	8.0 ±3.3	8.5 ±3.7	-- --	11.1 ±5.8
Mean $PM_{2.5-10}$	13.7 ±8.9	15.9 ±24.7	15.2 ±20.6	9.7 ±6.5	9.3 ±8.2	7.3 ±5.5	7.5 ±2.9	14.4 ±16.5	12.1 ±7.9	15.5 ±17.7	7.6 ±4.7	-- --	11.6 ±11.3





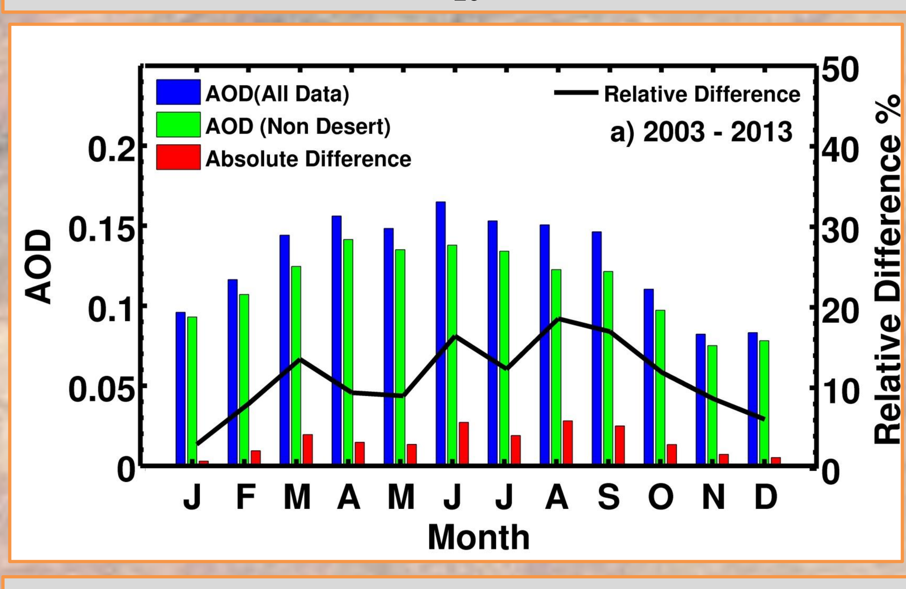


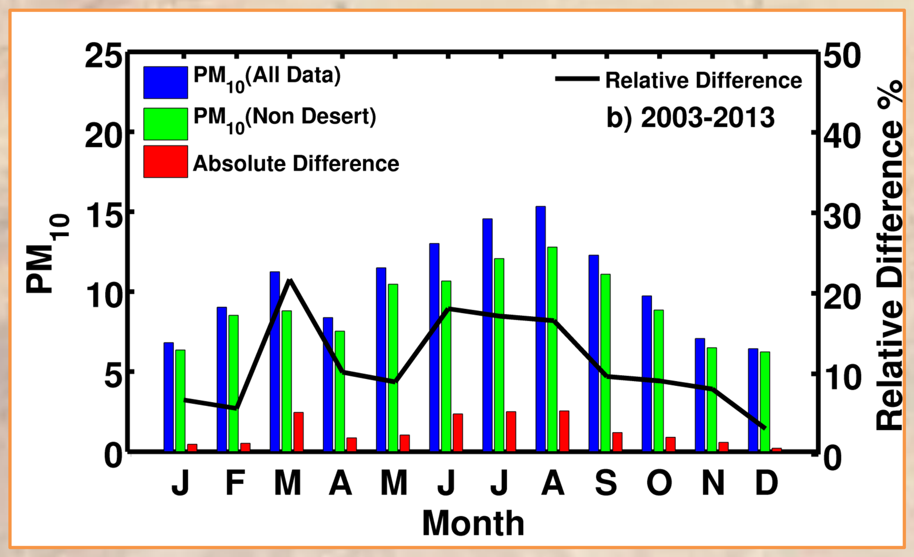


During the analysed period of 2003-2013, a total number of 146 episodes have been registered composed by 380 days (218 classified as D and 162 as DC).
The annual cycles of the number of episodes and days with DD conditions are presented. The pattern followed by the number of episodes and days is very similar with an increase of the DD occurrence in March, a fall in April, and again a notable increment between May and September. An interesting feature is the local minimum of episodes in July which is shift to August in the number of days. The year with most DD days was 2006 (with 61) in opposition to 2013 with15 days.

DESERT DUST CONTRIBUTION TO TOTAL AOD AND PM_{10}

The evaluation of the DD contribution (absolute and relative values) to total AOD/PM_{10} is the most important result showed in this section. It can be obtained as the difference of the annual cycle considering all days of the database and the corresponding value without including the desert cases. Using the yearly AOD/PM_{10} values the inter-annual change of DD contribution is calculated.

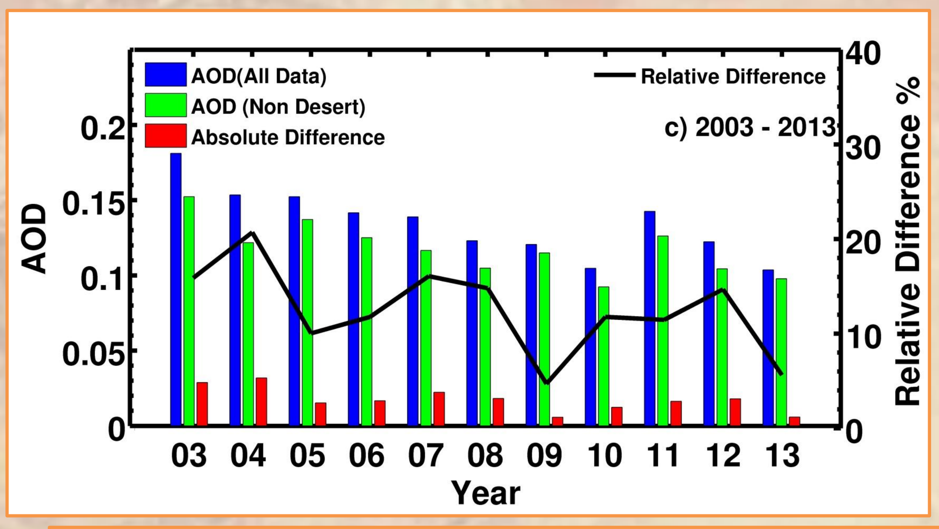


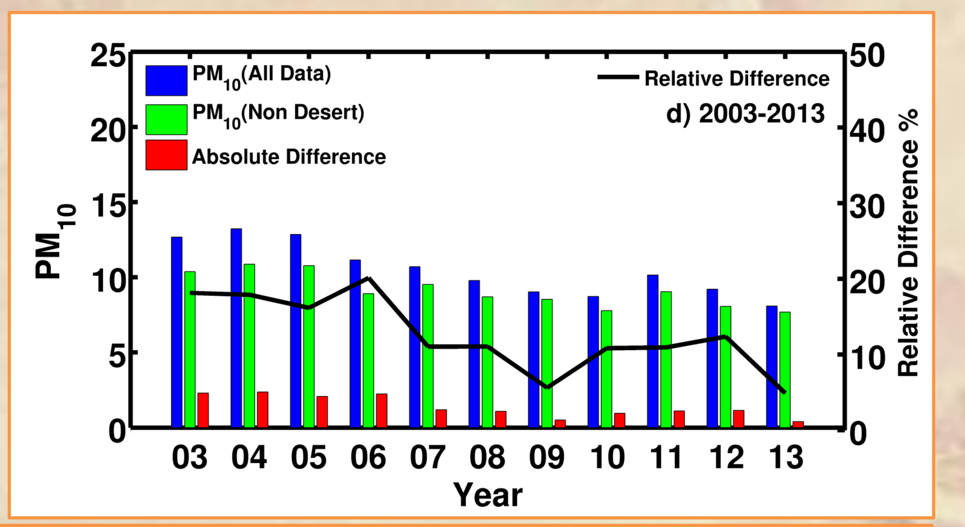


The annual pattern of DD contribution to AOD presents two maxima: the first one in March and the strongest one in August (absolute and relative contribution of 0.028 and 18.6%, respectively), with June presenting a large contribution too. The first reduction occurs in April and May and a local minimum is evidenced in July. Beyond August, a progressive decline of the DD contribution is observed. The absolute minimum is obtained in January (0.0029 or 3.0%).

The annual cycle of DD contribution presents a similar shape of that obtained in the southwestern area by, e.g., [2], and [3]. Due to the closeness to the African continent the total AOD signal is clearly impacted by DD events in the Southern Iberian coast (with relative contributions overcoming the 30%), while in the North-center region the DD modulation is masked, leading to a South-North decreasing gradient.

Annual cycle of DD contribution to PM_{10} presents the absolute maximum in March (with 2.44 µg m^{-3} or 21.7%), and the three summer months (June to August) also present large values. The April minimum is observed, but the relative contribution is slightly smaller in May. As expected, winter months (DJF) exhibit the weakest effect of the African intrusions.





The mean DD contribution to AOD for 2003-2013 is 0.017 or 12.5%. With respect to its inter-annual change in the analyzed period, in a quick-look analysis it can be noted that it has declined. The DD contribution to AOD archive its maximum value in 2004 with 0.032 or 20.7%, it falls in 2005 below 0.015 or 10.0%, and the year 2009 presents the absolute minimum with 0.006 or 4.7%. At the end of the period, DD contribution increases for years 2010-2012 and falls again in 2013. The temporal trends are also evaluated (not shown here) and a negative rate of -0.0016 AOD-unit per year (p-value = 0.087) is quantified.

Regarding the inter-annual variability of the DD contribution to PM_{10}, the first three years (2003-2005) are characterized by similar large values. Starting with the absolute maximum in 2006, the 2006-2009 period shows a continuous fall, which partially recover their levels until 2012. The absolute minimum is observed in 2013. The mean DD contribution to PM_{10} is, for the entire analyzed period,1.4 µg m-3 or 12.6%.

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REFERENCES

[1] Bennouna, Y. S et al.: *Relationships between columnar aerosol optical properties and surface particulate matter observations in north-central Spain from long-term records (2003–2011),* Atmos. Meas. Tech. Discuss., 7, 5829-5882, doi:10.5194/amtd-7-5829-2014, 2014.
[2] Mateos, D. et al., 2015. *Columnar and surface aerosol load over the Iberian Peninsula establishing annual cycles, trends, and relationships in five geographical sectors.* Science of TheTotal Environment, 518-519, 378-392. http://www.sciencedirect.com/science/article/pii/S0048969715002673
[3] Toledano, C. et al., 2007. *Inventory of African desert dust events over the southwestern Iberian Peninsula in 2000-2005 with an AERONET Cimel Sun Photometer*, Journal of Geophysical Research, Vol.112, D21201, DOI: 10.1029/2006JD008307.