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Interactive Comment

Interactive comment on "African dust outbreaks over the western Mediterranean basin: 11 year characterization of atmospheric circulation patterns and dust source areas" *by* P. Salvador et al.

P. Salvador et al.

pedro.salvador@ciemat.es

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Reply to Anonymous Referee #2:

First of all, we would like to thank very much the kind and valuable comments from Referee #2. He/she has detected a number of small mistakes in the paper (mainly those referred as Minor comments 2-10) which will be corrected in the revised manuscript.

In relation with Minor comment 1, we agree that the term "dust load" has not been appropriated used as it may be interpreted as an integrated columnar dust concentration on the site such as those provided, for example, by Cimel sunphotometers.

What we called “dust load” must be interpreted as an estimation of the African dust content deposited during African dust outbreaks, which is contributing to the ambient PM10 daily mean values, recorded at regional background air quality monitoring sites. Hence, only those events exerting any influence on the PM concentration levels at the surface level were taken into account in our study.

The procedure used to obtain these estimations of African dust contribution (Escudero et al., 2007a) is based on the identification of African episodes affecting PM levels in different areas of the Western Mediterranean Basin and the analysis of time series of PM10 levels from regional background air quality monitoring stations.

Firstly, atmospheric back-trajectories were visually analysed together with meteorological charts to determine, on a daily basis, the origin of the air masses at a synoptic scale. Different numerical models (SKIRON, DREAM/BSC-DREAM8b, NAAPs) generate maps every 6 hours showing estimations of the dust concentration over geographical locations. These maps help to identify desert dust plumes moving towards and reaching different areas of the Western Mediterranean Basin. The evolution of the dust plumes can frequently be tracked with satellite imagery. All this information was obtained and analysed on a daily basis to identify the appearance of African dust plumes over the study area. This is a qualitatively way to detect the occurrence of African dust outbreaks. It should be taken into account that different sources of error during the calculation of back-trajectories may also generate occasionally a highly different wind flow regime than the real one. Besides, models results can over or underestimate the dust load transported by the air masses and the geographical position of the dust plumes. For this reason, daily PM concentration values registered at the regional background stations were simultaneously analysed to detect increases during African dust episodic days. No increases in the PM concentration values at these stations prevent the occurrence of the African dust outbreak at this area from happening, from the point of view

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of the air quality at the surface level.

It should be noted that a high number of exceedances of the PM10 Daily Limit Value (50 μg/m3) have been recorded in regional background sites, especially in southern Europe owing to the influence of African dust outbreaks (Viana et al., 2002; Querol et al., 2004; Salvador et al., 2008). Escudero et al. (2007b) have showed that the majority of the exceedances of the PM10 DLV (>70% in most stations, reaching 100% in stations located in the center and southeastern areas of the Iberian Peninsula) in 13 regional background stations of the Iberian Peninsula were caused by African dust outbreaks for the 2001-2003 period.

Escudero et al. (2007a) demonstrated that the 30 days moving percentile 40 determined for each day, excluding the African dust episodic days, reproduces rather suitably the regional background levels at EMEP and other regional background stations in the Western Mediterranean Basin during periods with prevailing atmospheric advective conditions (Atlantic, Mediterranean and European). Thus, at regional background monitoring sites, the origin of the PM10 levels recorded during these days must be local or regional. The methodology used to estimate the net dust load during African dust episodic days, subtracts this regional background levels from the PM10 recorded at the regional background sites. This is the way we have discriminated the impact from local and regional sources from the African dust contribution in African dust episodic days at the regional background sites.

Occasionally, as suggested by the Referee #2, dust layers reach very high altitudes or the dust load transported is very low. Consequently the dust deposition processes over the area of study are inexistent or very weak and the time series of PM concentration values registered at the rural background stations do not show significant increases. These specific events are out of the scope of this study because they do not contribute to ambient aerosol concentration levels in the study area. Otherwise, Escudero et al. (2007a) specifically stated in the page 5519 of their paper that in some cases the African dust transported at relative high altitudes "would reach the ground surface

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in approximately 3 days. Thus, levels of PM could remain high at a given regional background (RB) site 2 days after the episode has ended and, therefore, the African period could also include these dates".

This is a quantitative and simple methodology which was validated by correlating the net African dust load determined by chemical speciation at three regional background sites in Spain (Escudero et al., 2007a), obtaining a high degree of correlation in any case. Published results showed that the method is applicable across the whole Southern Europe (Querol et al., 2009) and when compared to other measurement-based methods to quantify the African dust contribution to PM10 levels, this one was demonstrated to be the most adequate available at the present moment (Viana et al., 2010). Moreover, it has been accepted as one of the methodologies to be included in the EC Guidance for Member States regarding natural events, for evaluating the occurrence of African dust outbreaks and quantifying its contributions (http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/temas/atmosfera-y-calidad-del-aire/Directrices_Comisi%C3%B3n-SEC_208_final-en_tcm7-152574.pdf).

We have decided to replace in p. 5501, l.11, "A procedure for the quantification of the net African dust load transported during each ADO was applied to estimate the impact of the African dust contributions on the PM10 daily records" with "A procedure for the quantification of the African dust contribution (ADC) deposited during each ADO was applied to estimate the impact of the African dust contributions on the PM10 daily records". The terms "African Dust Load" (ADL) and "dust load" has been replaced with "African Dust Contribution" (ADC) all across the manuscript.

In relation with Minor comment 6, we agree that this paragraph (pp. 550, l. 13-16) was somewhat obscure (ambiguous). It will be replaced with: "When this pressure gradient between the Icelandic low and the subtropical high is more intense than normal (positive NAO) the westerly winds are stronger across northern Europe, bringing Atlantic air masses over the continent associated with mild temperatures and higher precipitation. On the opposite, dryer conditions than usual are produced at lower latitudes across

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southern Europe". In relation with Minor comment 7, "dust load" refers to the African Dust contribution in PM10. The aim of this figure was to compare the areas with higher values (>22 μg/m3) in the RCF of dust load in PM10 displayed in Figure 6, with a global distribution of dust sources, represented by the dust source function S (Ginoux et al., 2001). We demonstrated by this way that the main potential source areas of African dust obtained in the RCF, correspond to real sources of dust.

In relation with Minor comment 11, we agree with the referee #2 that it would be very interesting finding a link between the source areas of the African dust and its chemical composition. Two main problems arise when we tried to tackle this subject.

On the one hand, we have not available time series of detailed PM10 chemical composition data at regional background sites in the Western Mediterranean Basin. Across the period of study (2001-2011) we obtained a number of short-time data bases (50-100 daily samples obtained during a 12-15 months sampling period) of PM10 and PM2.5 chemical composition at some urban and urban-background sites. At these sites local and regional contributions of typical crustal tracers (Ca, Fe, Mn, Al, Ti, Sr) are relatively high, hampering the discrimination of their contributions due to long-range transport of dust during African dust outbreaks. Aside from natural phenomena such as atmospheric resuspension processes and strong winds, which contribute with crustal components from the local and regional mineral dust sources to the PM10 bulk levels determined at the sampling sites, the resuspension of road dust may be an important carrier of vehicle and construction-demolition related pollutants in urban areas. In fact, it has been demonstrated that road transport has become the main source of mineral dust and metals in large cities without influence of industrial emissions, due to the non-exhaust emissions: road dust resuspension, brake abrasion and tyre wear (Amato et al., 2013 and references therein).

On the other hand, some authors stated that long range transport of dust will inevitably tend to alter the bulk aerosol chemistry by mixing and size fractionation, thus obscuring geological signatures from specific source areas (Schutz and Sebert, 1987; Moreno et

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al., 2006; Gullu et al., 1996; Claquin et al., 1999).

It is well known (Chiapello et al., 1997; Moreno et al., 2006; Avila et al., 2007) that the Tunisia and most of the western Sahara lie upon carbonated lithology. In the occidental Sahara, the Coastal Basin is composed of Mesozoic and Cenozoic carbonatic sediments, dolomites and marls. By contrast, Precambrian and Paleozoic Massifs with low carbonate content cover more southern parts comprising Chad, Sudan, Mali and Mauritania. Consequently higher contents of calcite-dolomite derived elements (Ca, Mg, Sr) should be expected for the African dust contribution produced during many CT-2 and CT-3 episodic days. These circulation types are able to generate the transport of African dust from western Saharan regions and from the Atlantic coastal strip, especially during the spring period. Otherwise, higher contents of clay-silicates derived elements (Al, Fe, K, V, P) should be obtained during episodic days produced during most CT-1 and CT-4 episodic days which may produce the transport of African dust from the Hoggar massif located in central and southern Algeria.

Unfortunately until the present moment our results did not found any statistically significant between PM10 samples obtained at the urban and urban background sites during the different circulation types for their content of crustal tracers. It should be noted that individual particle characteristics of North African dust were determined in 6 Particulate Matter samples obtained in Madrid (Coz et al., 2009) by means of a Computer-Controlled Scanning Electron Microscope coupled to energy-dispersive X-ray spectroscopy (CCSEM/EDX). This is a very expensive and complex procedure that could not be carried out systematically to the samples that composed our data bases.

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