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# Saharan dust intrusions in Spain: Health impacts and associated synoptic conditions

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ABSTRACT

*Background:* A lot of papers have been published about the impact on mortality of Sahara dust intrusions in individual cities. However, there is a lack of studies that analyse the impact on a country and scarcer if in addition the analysis takes into account the meteorological conditions that favour these intrusions.
*Objectives:* The main aim is to examine the effect of Saharan dust intrusions on daily mortality in different Spanish regions and to characterize the large-scale atmospheric circulation anomalies associated with such dust intrusions.
*Methods:* For determination of days with Saharan dust intrusions, we used information supplied by the Ministry of Agriculture, Food & Environment, it divides Spain into 9 main areas. In each of these regions, a representative province was selected. A time series analysis has been performed to analyse the relationship between daily mortality and $PM_{10}$ levels in the period from 01.01.04 to 31.12.09, using Poisson regression and stratifying the analysis by the presence or absence of Saharan dust advections.
*Results:* The proportion of days on which there are Saharan dust intrusions rises to 30% of days. The synoptic pattern is characterised by an anticyclonic ridge extending from northern Africa to the Iberian Peninsula. Particulate matter (PM) on days with intrusions are associated with daily mortality, something that does not occur on days without intrusions, indicating that Saharan dust may be a risk factor for daily mortality. In other cases, what Saharan dust intrusions do is to change the PM-related mortality behaviour pattern, going from $PM_{2.5}$.
*Conclusions:* A study such as the one conducted here, in which meteorological analysis of synoptic situations which favour Saharan dust intrusions, is combined with the effect on health at a city level, would seem to be crucial when it comes to analysing the differentiated mortality pattern in situations of Saharan dust intrusions.

## 1. Introduction

### 1.1. Mechanisms of transport of the Sahara dust

The vast arid and semi-arid regions of Northern Africa represent the main sources of dust for the Earth's atmosphere (Prospero et al., 2002; Ginoux et al., 2012). It is now well established that airborne plumes of dust prevenient from the desert (Sahara) and semi-arid (Sahel) regions can be transported over long swathes, particularly the Atlantic Ocean (Prospero et al., 2002), as well as crossing the Mediterranean sea and affect the European continent (e.g. Moulin et al., 1997; Engelstaedter and Washington, 2007).

The transport of dust from North Africa occurs predominately over the Atlantic as a result of the powerful westward trade winds (Prospero et al., 2002), although characterised by an intense seasonal cycle (Engelstaedter et al., 2006). In recent decades several works have addressed the major mechanisms that can drive such transport towards higher latitudes, having found that these are frequently driven by more complex wind fields than in the case of the Atlantic transport and often include cyclonic activity inside and around the Mediterranean basin (Alpert and Ziv, 1989; Moulin et al., 1997). A number of preferential configurations favouring the transport of dust from North Africa towards the Iberian Peninsula are associated with location of low pressure systems close to the Canary Islands or off the coast of Portugal (Rodríguez et al., 2001).

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### 1.2. Why desert dust can affect health?

Not only does long-distance transport bring about a change in the respective atmospheric concentrations of the different sized particles and in the chemical composition of the particles present in the air (Pérez et al., 2008), but there is even evidence to show that desert dust itself transports biological matter harmful to health (Griffin et al., 2007). There are new papers that point that the agents involved in dust toxicity may differ from those of other PMs, raising further questions about mechanisms and implications. It has been hypothesized that the increase risk associated with Saharan dust exposure may be due in part to biological materials contained within the dust; transported Saharan dust may be an adequate medium for survival and proliferation of these microorganisms (Griffin et al., 2001; Griffin, 2007; McCarthy, 2001). The possibility that Saharan dust may contain toxic biological allergens of irritants is now supported by several studies (Garrison et al., 2006; Polymenakou et al., 2008). It is also possible that non-biologic compound in dust may generate adverse health effects or that local conditions change the toxicological properties of the dust. In that direction, recent research in Algeria has shown that desert dust may contain carcinogenic and mutagenic compounds (PAH and oxygenated organics such as phthalates) (Ladji et al., 2009).

Although only there is a little evidence of the different components of PM presents higher risks among them (Atkinson et al., 2015; Stanek et al., 2011). May be these two circumstances of change, i.e., in particulate matter (PM) concentrations and chemical composition, make for clearly differentiated morbidity-mortality patterns, which are observable on days with desert dust intrusions as compared to days without desert dust intrusions (Jiménez et al., 2010; Reyes et al., 2014).

### 1.3. Impact of desert dust on human health

The human health effects of dust storms range from respiratory disorders (including asthma, tracheitis, pneumonia, allergic rhinitis and silicosis), to cardiovascular disorders (including stroke), conjunctivitis, skin irritations, meningococcal meningitis, valley fever, diseases associated with toxic algal blooms, and mortality and injuries related to transport accidents (Goudie, 2014).

### 1.4. Researches in human health effects

Many studies have been conducted in different places around the world on the impact of desert dust on health (Crooks et al., 2016; Kanatani et al., 2016; Coulibaly et al., 2015; Diokhane et al., 2016; Abuduwailil et al., 2015; Merrifield et al., 2013; Taylor et al., 2013).

#### 1.4.1. Impact on morbid-mortality in Europe

In the European setting, mention should be made of the study undertaken in 13 southern European cities (Stafoggia et al., 2016), including Madrid and Barcelona, which analysed the relationship between $PM_{10}$ and hospital admissions and mortality on days with and without Saharan dust advections. The results obtained show that excess $PM_{10}$-related morbidity-mortality is similar for days with and without these advections.

In this line of inconclusive results regarding the effect of Sahara dust intrusion on mortality in Europe, is found the work Samoli et al. (2011a); conducted in Athens (Greece). In this study the PM effects were significantly higher during non-desert dust days cause of "that PM from traffic sources prevail on non-desert dust days, have more toxic effects than the ones originating from long-range transport, such as Sahara dust". Another paper conducted in Italy (Zauli Sajani et al., 2011) concludes that the days with Saharan dust intrusions increase mortality in person aged 75 years or more by respiratory causes but not by circulatory causes. This fact occurs for the whole year and the warm season. Moreover, in this paper there is no evidence of an effect modification of dust events on the concentration-response relationship between $PM_{10}$ and daily deaths. At last, a study located in Nicosia (Neophytou et al., 2013) found a relation with the increment of mortality due to circulatory causes in days with desert dust, but not relation with respiratory causes was found. About the relation studied with Sahara dust intrusions on hospital admissions, one study located in Rome in which analysed specific causes, (Alessandrini et al., 2013) concludes that a clear enhanced effect of $PM_{2.5–10}$ on respiratory diseases and of $PM_{10}$ on cerebrovascular diseases emerged during Saharan dust outbreaks. Another study located in Nicosia (Middleton et al., 2008), that is not so specific as the Rome study´s, established that there was an increased risk of hospitalization on dust storm days, particularly for circulatory causes.

#### 1.4.2. Impact on morbid-mortality in Spain

In Spain, relatively few studies have analysed the health impact of Saharan dust intrusions, and, at a city level, have focused on Barcelona and Madrid. In the case of Barcelona, a recent study linked Saharan dust intrusions to an increase in cases of meningococcal disease in the 4 weeks after the intrusion (Tobías et al., 2011a). Studies have also examined whether Saharan dust intrusions might be related to complications in pregnancy, though no conclusive associations have been established in this respect (Dadvand et al., 2011). With regard to daily mortality, another study conducted in Barcelona (Pérez et al., 2008) reported an increase in mortality on days with versus those without Saharan dust intrusions, with this being linked to the coarse $PM_{10\text{-}2.5}$ fraction, and no statistical association being detected between mortality and $PM_{2.5.}$ Along these same lines, though in relation to daily mortality due to different specific causes and various sizes of PM, attention should be drawn to Pérez et al. (2012) study, which detected a differentiated effect on mortality due to different diseases, according to the size of the particles and the presence or absence of Saharan dust intrusions. In the case of the city of Madrid, a number of studies have addressed this subject in the last few years. Hence, a study conducted into daily all-cause mortality on days with and without intrusions reported a differentiated mortality behaviour pattern, with $PM_{10}$-related mortality being higher on days with than on days without Saharan dust intrusions (Pérez et al., 2008). Other studies undertaken in Madrid, for both the general population and the segment aged over 65 years (Jiménez et al., 2010), indicate that on days without Saharan dust intrusions it is $PM_{2.5}$, a pollutant having its main source in road traffic, which displays a stronger association with daily mortality: in contrast, on days with Saharan dust intrusions, this association assumes greater statistical significance for $PM_{10}$. This pattern detected for mortality has likewise been seen for emergency hospital admissions (Reyes et al., 2014). Lastly, as regards studies conducted into the influence of Saharan dust on health in the Canary Islands, there was one such study which targeted emergencies in Santa Cruz de Tenerife (García et al., 2001). The results indicated that the presence of Saharan dust in suspension in the air brought about an increase in the demand for emergency health care for respiratory diseases, anxiety disorders and atypical chest pains. Similarly noteworthy is a recent study (López-Villanueva et al., 2012) conducted in two Canary capital cities, which analysed the impact of $PM_{2.5}$ and $PM_{10\text{-}2.5}$ on daily mortality and linked increases in this particulate matter to increases in mortality due to both circulatory and respiratory causes.

### 1.5. Synoptic patterns in relation with Sahara dust intrusion

Several studies have been conducted on the influence of meteorological patterns on PM dispersion in southwestern Europe (e.g. Russo et al. (2014) for $O_3$, PM10 and $NO_2$ in Portugal; Pey et al. (2013), Gaetiani and Pasqui (2014) and Salvador et al. (2014) for PM in the Mediterranean). These applications associate a certain type of circulation pattern to the long-range transport, linking a particular air mass to dispersion conditions and also to the mesoscale meteorological behaviour that controls the regional transport of air pollution (Russo et al.,