Episodes of Saharan dust intrusions affecting mainland Spain from 2005 to 2020

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INTRODUCTION

The Sahara desert is a primary source of dust aerosols: about 1400 Tg of mineral dust is uploaded to the atmosphere every year [1].The short distance between the Sahara desert and the Iberian Peninsula enables the arrival of air masses of African origin laden with mineral dust. In recent years, natural episodes of dust intrusion from North Africa have become a relevant topic from a scientific point of view. The suspension of these particles allows them to stay in the atmosphere for a long time and be transported over long distances, resulting in a reduction of air quality in the areas influenced by these episodes. Unfortunately, Saharan dust particles can cause several effects on both human health and the environment.

Climate change has led to an increase in the number and intensity of this type of natural episodes due to the acceleration of erosive processes in arid areas [2]. Furthermore, the atmospheric circulation could be increasing the frequency of the weather types associated to Saharan intrusions.

In Spain, high levels of PM_{10} particles are recorded during Saharan intrusions, often exceeding the daily concentration limit of 50 µg m^{-3} established by the Directive 2008/50/EC.

This study focuses on the temporal trend of natural events of Saharan dust intrusion in mainland Spain from 2005 to 2020. Furthermore, the weather types under which these intrusions take place have been analyzed and a detailed study of a Saharan dust intrusion affecting León city from 15 to 17 February 2008 is also presented.

METHODOLOGY

Study zone

Fig. 1. Sectors defined by the Ministry for the Ecological Transition and the Demographic Challenge and location of León.

Database

Saharan dust outbreaks: Ministry for the Ecological Transition and the Demographic Challenge (MITECO).

PM_{10} concentration in LE01 traffic air quality station (León): Air Quality Network of Junta of Castilla y León.

Pressure for weather types: National Center for Atmospheric Research.

Aditional tools

Models: HYSPLIT, NAAPs and BSC/DREAM

Weather types

LAMB TYPES

ANTICYCLONIC TYPES		PURE DIRECTIONAL		CYCLONIC TYPES	
A	Anticyclonic	NE	Northeast	C	Cyclonic
ANE	Northeast-anticyclonic	E	East	CNE	Northeast-cyclonic
AE	East-anticyclonic	SE	Southeast	CE	East-cyclonic
ASE	Southeast-anticyclonic	S	South	CSE	Southeast-cyclonic
AS	South-anticyclonic	SW	Southwest	CS	South-cyclonic
ASW	Southwest-anticyclonic	W	West	CSW	Southwest-cyclonic
AW	West-anticyclonic	NW	Northwest	CW	West-cyclonic
ANW	Northwest-anticyclonic	N	North	CNW	Northwest-cyclonic
AN	North-anticyclonic			CN	North-cyclonic

RESULTS

Weather types frequency (2005-2020)

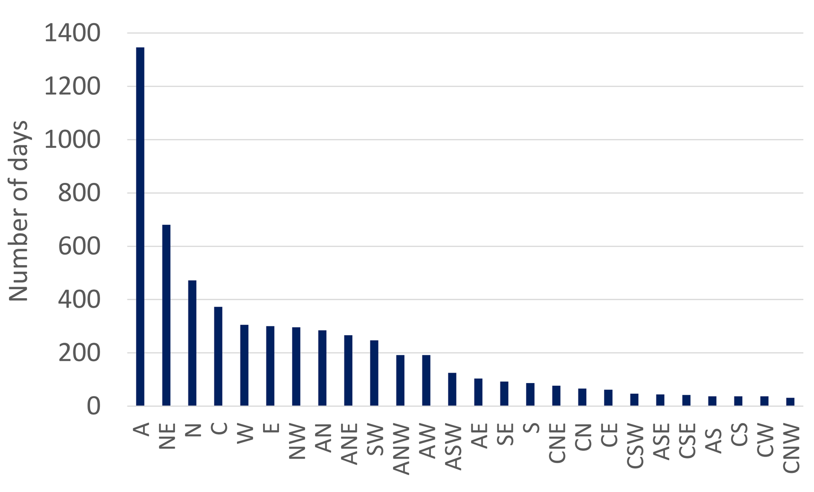


Fig. 2. Frequency of weather types between 2005 and 2020 in the Iberian Peninsula.

Iberian Peninsula

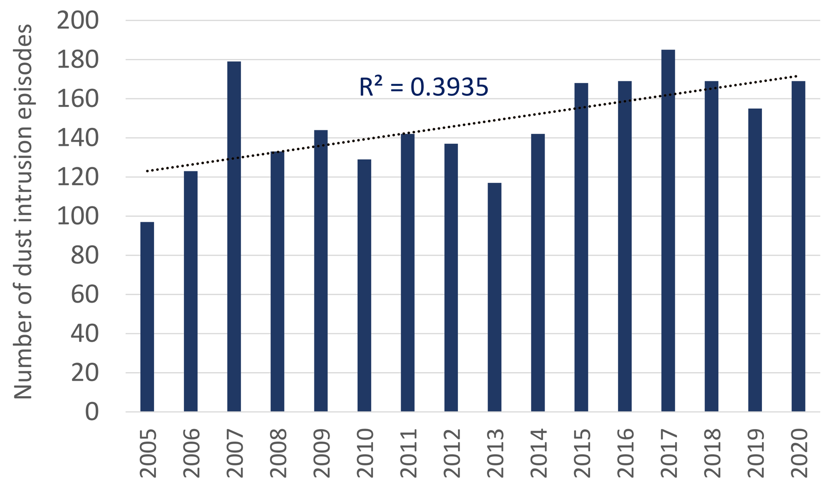


Fig. 3. Evolution of the number of Saharan dust intrusion episodes in the Iberian Peninsula during the studied period (between 2005 and 2020).

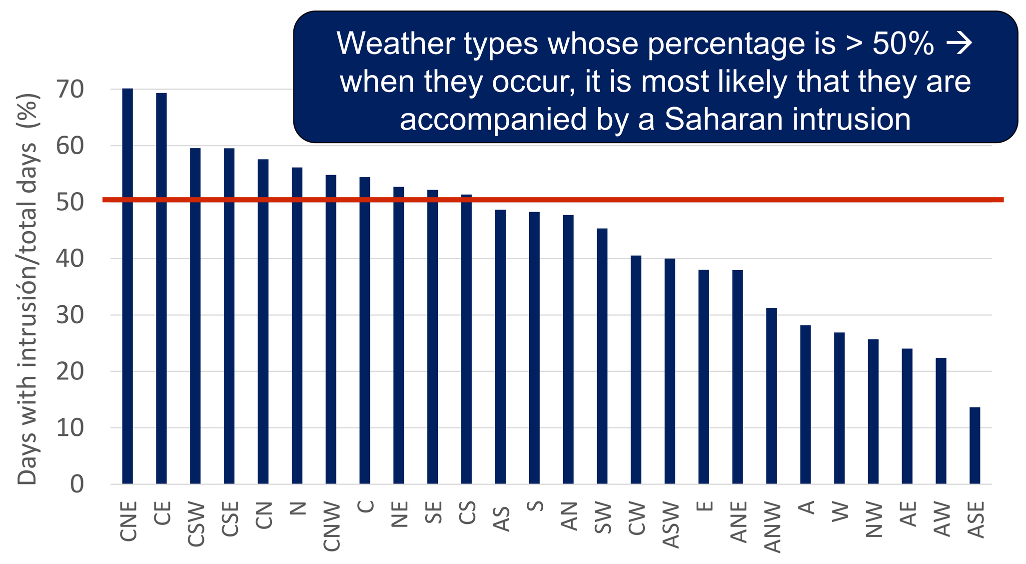


Fig. 4. For each weather type, ratio between days with Saharan dust intrusion and total days during the study period.

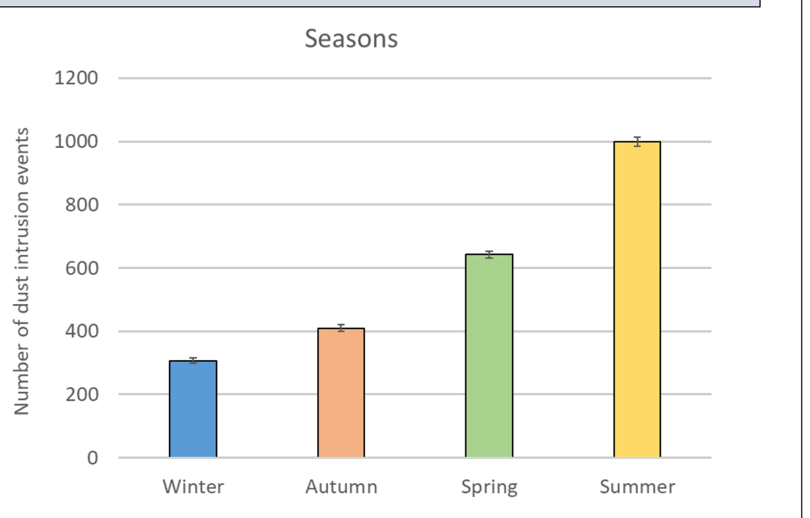


Fig. 5. Number of Saharan dust intrusion events by seasons in the Iberian Peninsula between 2005 and 2020.

Sector analysis

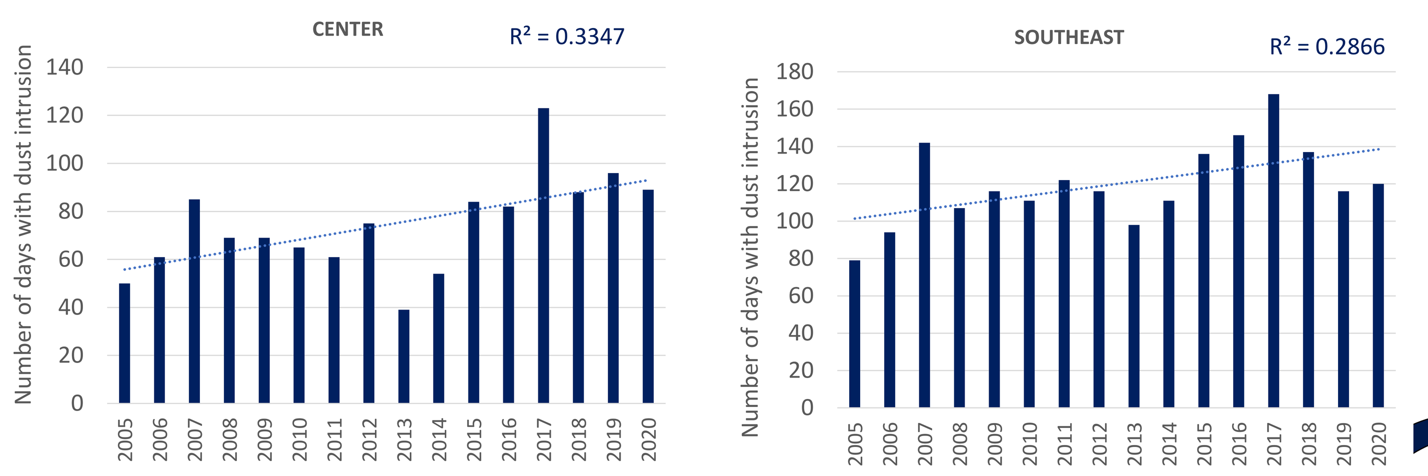


Fig. 6. Evolution of the number of days with Saharan dust intrusion in the Center and Southeast sectors between 2005 and 2020.

A positive trend in all sectors were registered, being significant in the Center and Southeast sectors.

SUMMER

- The number of Saharan dust intrusions increases in all sectors.
- **Southeast sector**: the highest number of intrusions (mean: 54 days/ summer) → More than half of the summer days.
- **Northwest sector**: the lowest number of dust intrusions (mean: 11 days/ summer)

The number of intrusions during summer shows a **significant increasing trend** in all sectors of the Iberian Peninsula with the exception of the Southwest and Northwest sectors.

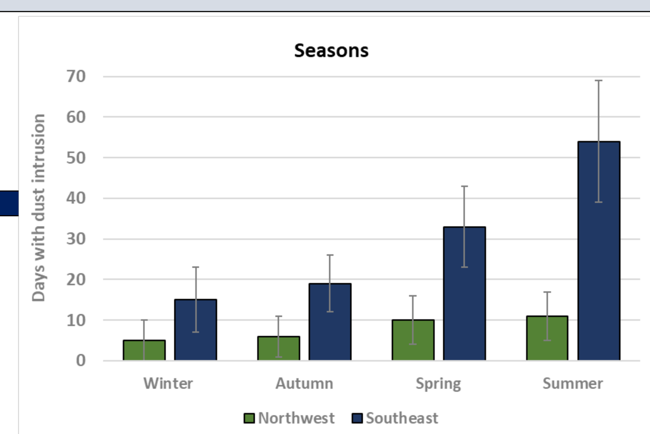


Fig. 7. Number of days with Saharan dust intrusion in NW and SE sectors between 2005 and 2020.

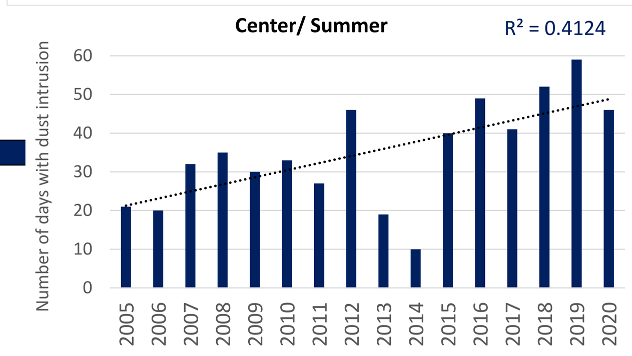


Fig. 8. Number of summer days with intrusion in the central sector, between 2005 and 2020

The number of intrusions for the different weather types under Saharan dust intrusions only shows a **significant trend** under North (increasing), East (decreasing) and Southeast (decreasing) weather types.

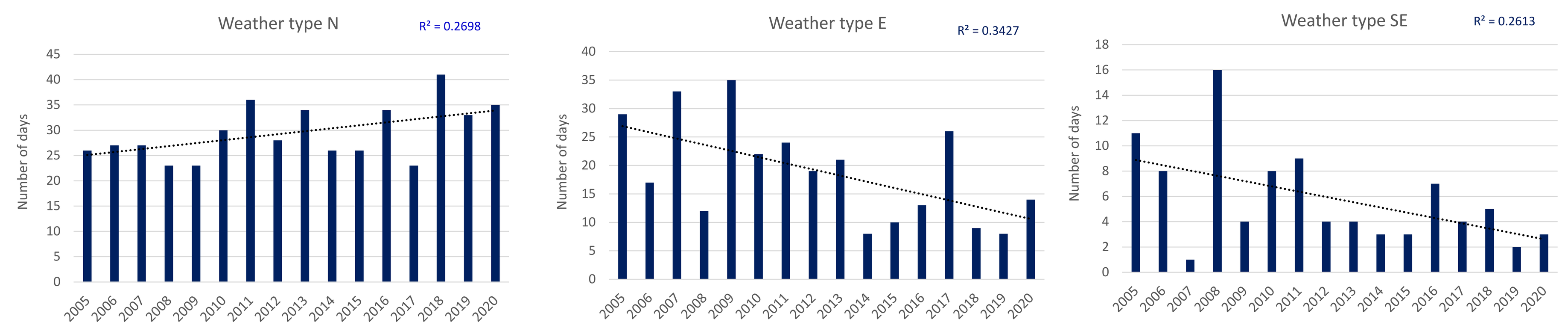


Fig. 9. Evolution of the annual frequency of Saharan dust intrusions in E, N and SE weather types.

Saharan dust intrusions in León (North sector)

A decrease in the number of daily PM_{10} limit value exceedances is observed (probably due to the application of new regulations), with Saharan dust outbreaks becoming the main cause of these exceedances.

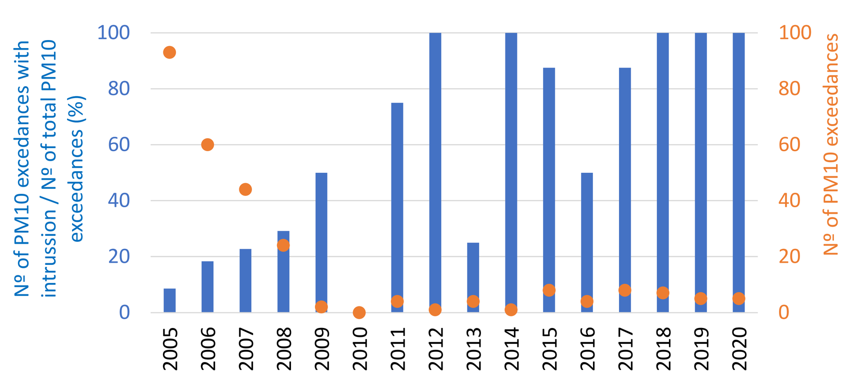


Fig. 10. Ratio between the number of daily PM_{10} exceedances established by the Directive 2008/50 / EC (50 µgm^{-3}) under Saharan dust intrusion and the number of total exceedances. Number of daily PM_{10} limit value exceedances.

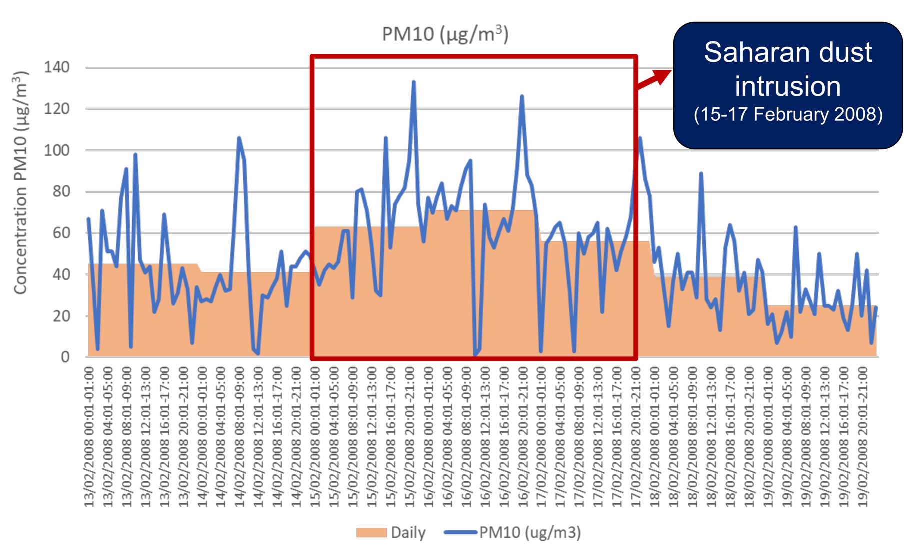


Fig. 11. Hourly evolution of PM_{10} between February 13, 2008 and February 19, 2008, at LE01 air quality station in León.

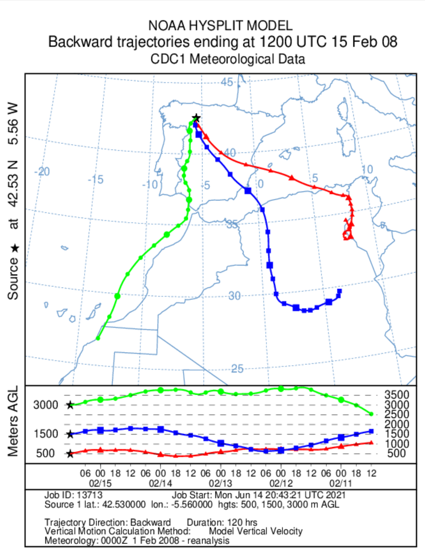
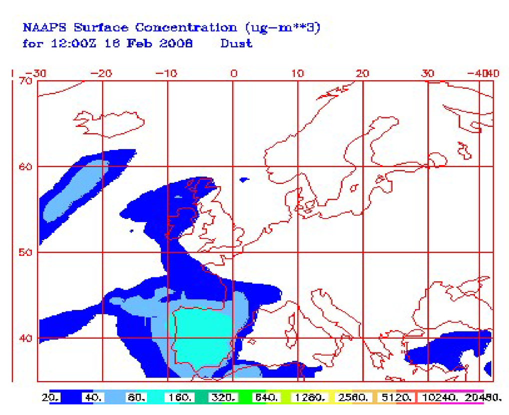


Fig. 12. Back trajectories calculated with the HYSPLIT model.

Fig. 13. Dust concentration (µg / m^3) for February 16, 2008, obtained from the NAAPs model.



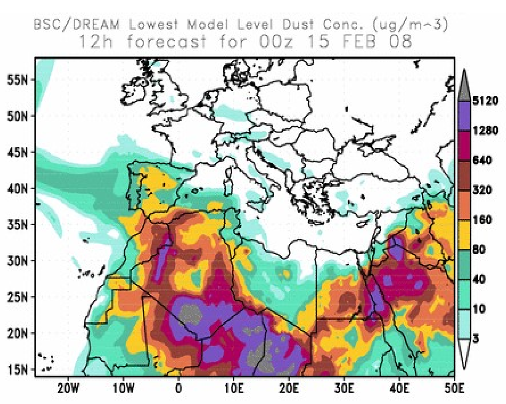


Fig. 14. Dust concentration (µg / m^3) for February 15, 2008 obtained from the BSC / DREAM model.

CONCLUSIONS

- The annual number of intrusions in the Iberian Peninsula shows a significant increasing trend from 2005 to 2020. In addition, a positive trend is observed in all the sectors (only significant in the SE and Central sectors). Summer was the only season in which significant sectorial trends were recorded.
- In summer, the number of Saharan dust intrusions increases in all sectors, and it shows a significant increasing trend in all sectors (except in SW and NW sectors).
- The weather types most likely to be accompanied by a Saharan intrusion are: pure cyclonic, cyclonic from all directions except W and, within the pure directional, only flows from the N, NE and SE. The ASE type is the least common during Saharan dust intrusion events.
- 270 exceedances of the daily PM_{10} limit value established by the Directive 2008/50 / EC were identified in the city of León, of which 76 could have been due to Saharan dust intrusions.
- A Saharan dust intrusion affected León city during three days in February 2008 and caused the exceedance of the PM_{10} daily limit value.

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[2] Fernandez, et al. (2019). Atmos. Res., 228, 223–241.