The EC-Guidelines to estimate the dust contribution to PM_{10}: application in Spain

A. Alastuey, N. Pérez, X. Querol

Environmental Geochemistry & Atmospheric Research Group, Institute of Environmental Assessment & Water Research, Barcelona, Spain

Outline

- What is desert dust?
- Procedure for the detection and quantification of natural dust contributions
- Application of the method in Spain
- Concluding remarks

GOBIERNO DE ESPAÑA
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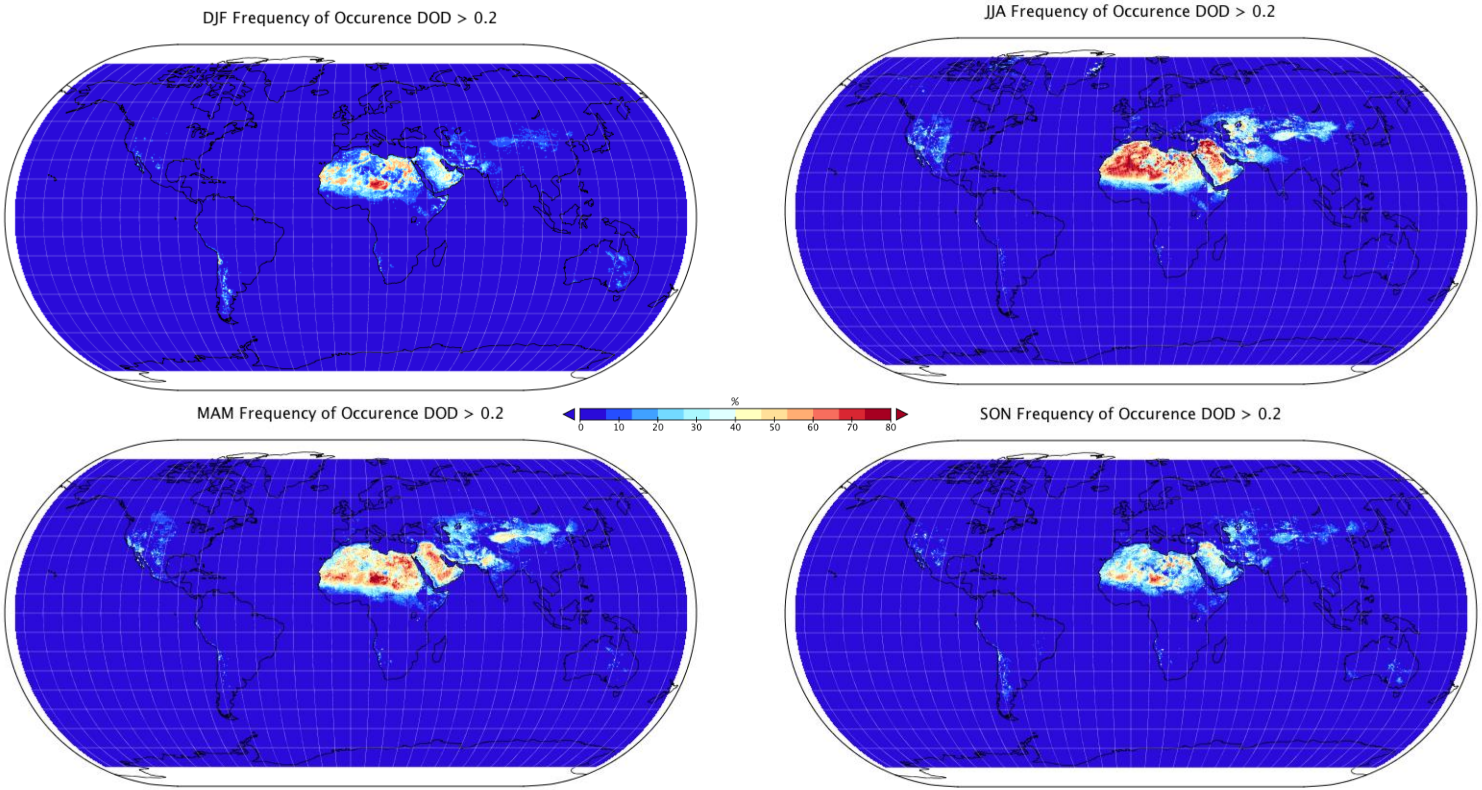
Dust sources, emissions and transport



Ginoux P. et al., 2012. Rev Geophys 50:1–36.

Dust sources, emissions and transport

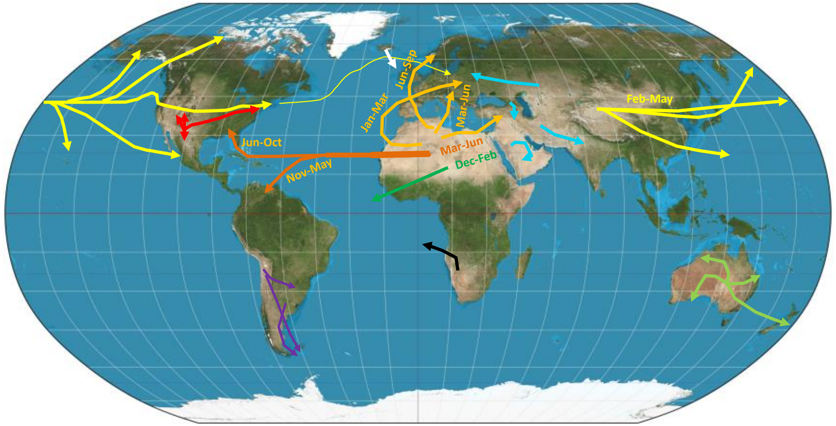
Global MASS of mineral dust aerosols: 16 Mega (10^6)-tons

Emissions

- N-Africa 790-840 Mt/yr
- Gobi 140-220 Mt/yr
- C. Asia, E. Australia, Atacama and South Africa 10- 60 Mt/yr each
- S. US-N. Mexico 2- 60 Mt/yr

Prospero J.M., 2002. Rev. Geophys 40(1):1002
Huneeus N. et al., 2011. Atmos Chem Phys 11(15):7781–816
Ginoux P. et al., 2012. Rev Geophys 50:1–36
Ginoux P. et al., 2010. J Geophys Res Atmos 2010;115(5):1–10
Washington R. et al., 2003. Ann Assoc Am Geogr 93(2):297–313
Varga G., 2012. Hungarian Geogr Bull 61(4):275–98

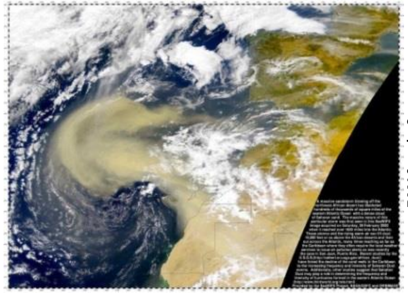
Atmospheric transport



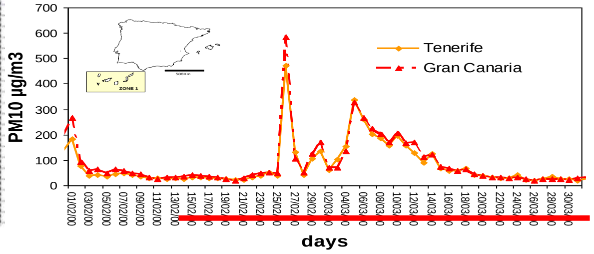
Modified from Griffin DW., 2007. Clin Microbiol Rev;20(3):459–77.

Duration

Atmospheric life time, hours- weeks



25/02 to 17/03/2000
Exceeding the PM10 DLV



PM levels and size

- PM10 and PM2.5 vary widely during desert dust episodes according the regions and episodes in the same region
- PM size might also vary a lot

Mori et al., 2003 (TSP)	up to 6700 µg/m^3	8h	Inner Mongolia (China)
	up to 1500 µg/m^3	6h	Beijing (China) 95% coarse
	up to 230 µg/m^3	24h	Japan remote island 64% coarse
Aryal R, 2012 (PM10)	up to 11800 µg/m^3	1h	Sydney, Australia
Krasnov H, et al., 2014 (PM10)	up to 2000 µg/m^3	24h	Beer-Sheva, Negev, Israel
Viana et al., 2002 (PM10)	up to 675 µg/m^3	24h	Canary Islands, Spain
Sotoudeheian et al., 2016 (PM10)	up to 650 µg/m^3	24h	Central Iran cities
Achilleos et al., 2014 (PM10)	up to 470 µg/m^3	24h	Nicosia, Cyprus
Querol et al., 2009 (PM10)	up to 250 µ/m^3	24h	Mainland Spain remote sites

Querol et al., 2009; Pey et al., 2011: Mediterranean region

17 to 37% of the days are affected by dust transport
9 to 43% of the annual ambient PM10 levels at remote sites
1 to 8 µg/m^3 of the annual PM10 averages
25-30%. of dust days receive daily dust of 25 µg/m^3 in PM10
10% in Northwestern Mediterranean

Krasnov H,et al., 2014: Beer Sheva, Israel

10% of the dust days exceed 71 µg/m^3 PM10
122 µg/m^3 PM10 daily net dust to PM10 during dust days

Prospero et al., 2005: Barbados

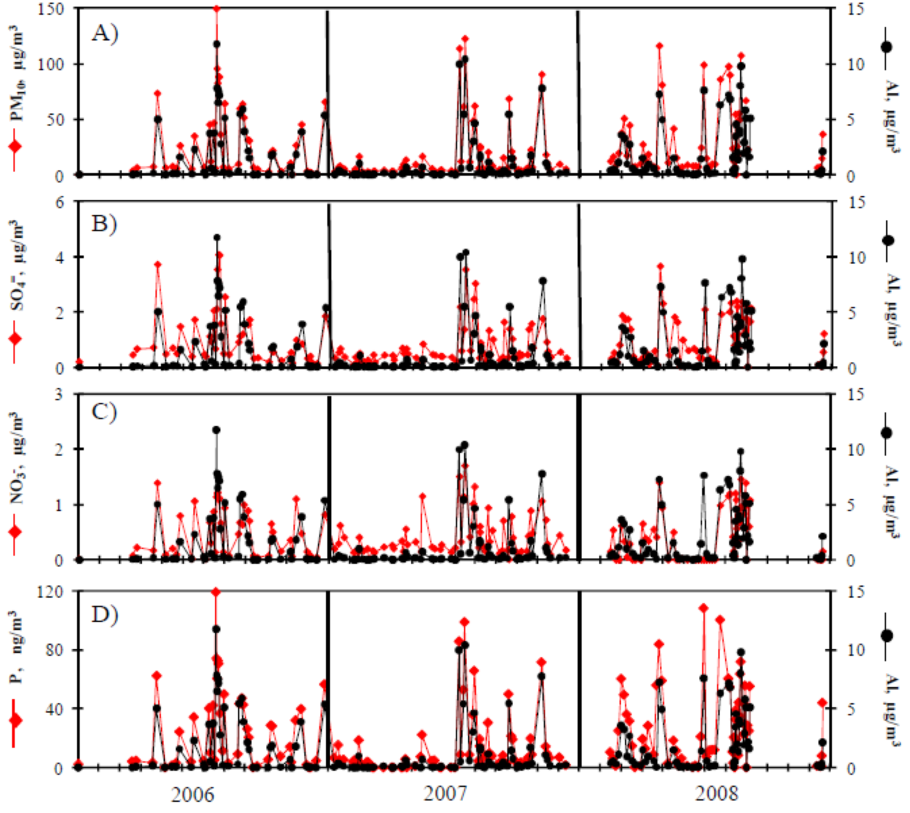
35 days recorded dust contributions >50 µg/m^3, 7 days >100 µg/m^3.

PM composition during dust episodes

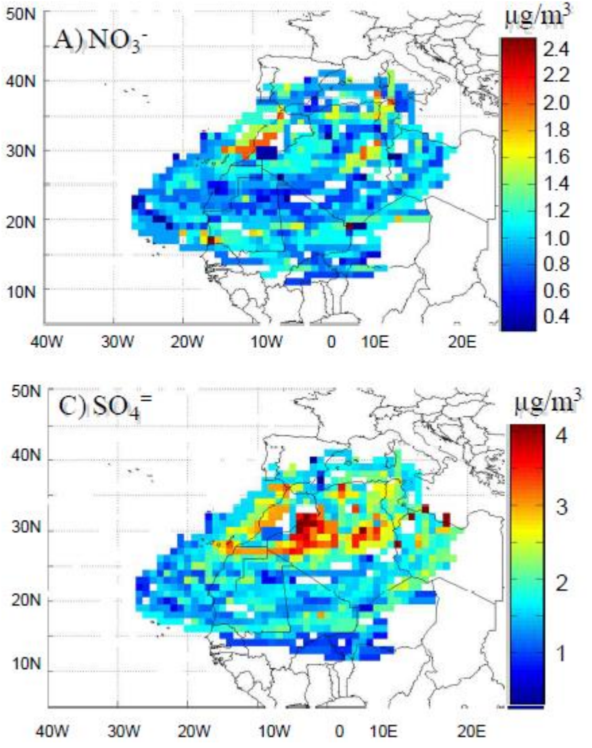
- **Saharan** dust: quartz, illite, calcite, montmorillonite, palygorskite, feldspars(Claquin et al., 1999)
- **Sahel** dust: quartz, kaolinite, hematite, feldspars (Claquin et al., 1999)
- **North-eastern China** desert dust: illite, kaolinite (47-52%), quartz (25-27%), feldspar and plagioclase (6-7%), calcite and dolomite (13-18%), traces of gypsum, hornblende (an Al-silicate), and halite (NaCl) (Shen et al., 2009)
- **Middle East-Central Asia dust**: higher Ca-Mg carbonates; lower SiO_2, Fe- and Mn-oxides (Goudie and Middleton, 2006 and Labban et al., 2004)
- **Australian** desert dust: quartz, anatase (TiO_2), calcite, feldspars, halite, hematite, and clays (kaolinite, illite and montmorillonite) (Aryal, 2012).

Accordingly
Major oxides SiO_2, Al_2O_3, CaO, Fe_2O_3, K_2O, MgO, Na_2O, TiO_2, MnO and P_2O_5.
Relatively high contents of Ti, Mn, Rb, V, Cr, Li, Sc, Be, Rare Earth Elements compared with non-dust days

PM composition during dust episodes

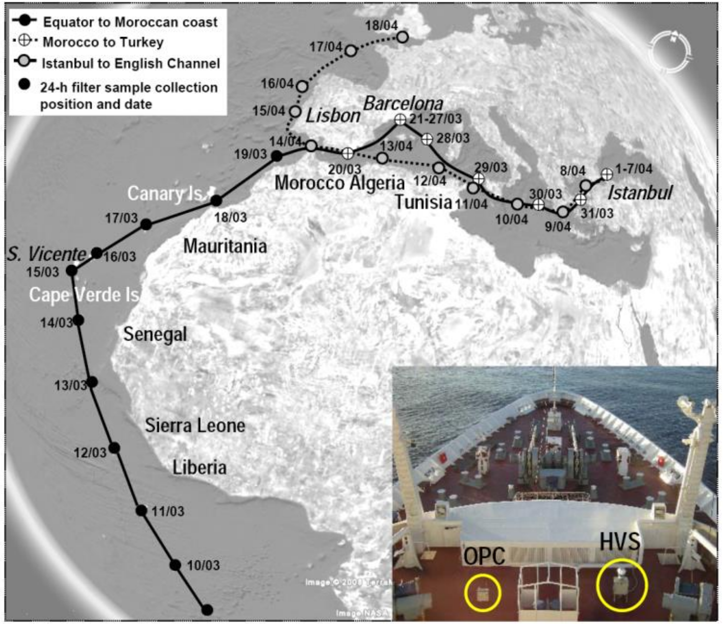


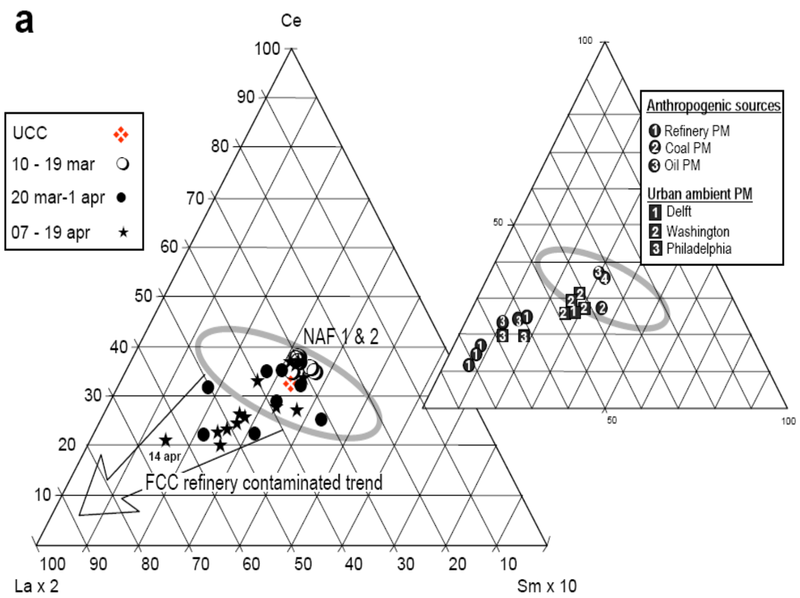
Transport of desert dust mixed with North African industrial pollutants in the subtropical Saharan Air Layer



Rodríguez, S., et al. Atmos. Chem. Phys., 11, 6663–6685, 2011

PM composition during dust episodes

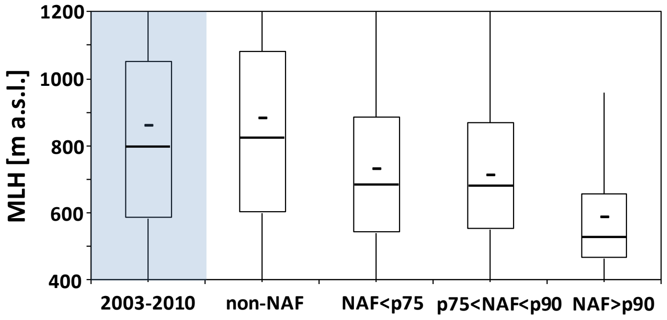


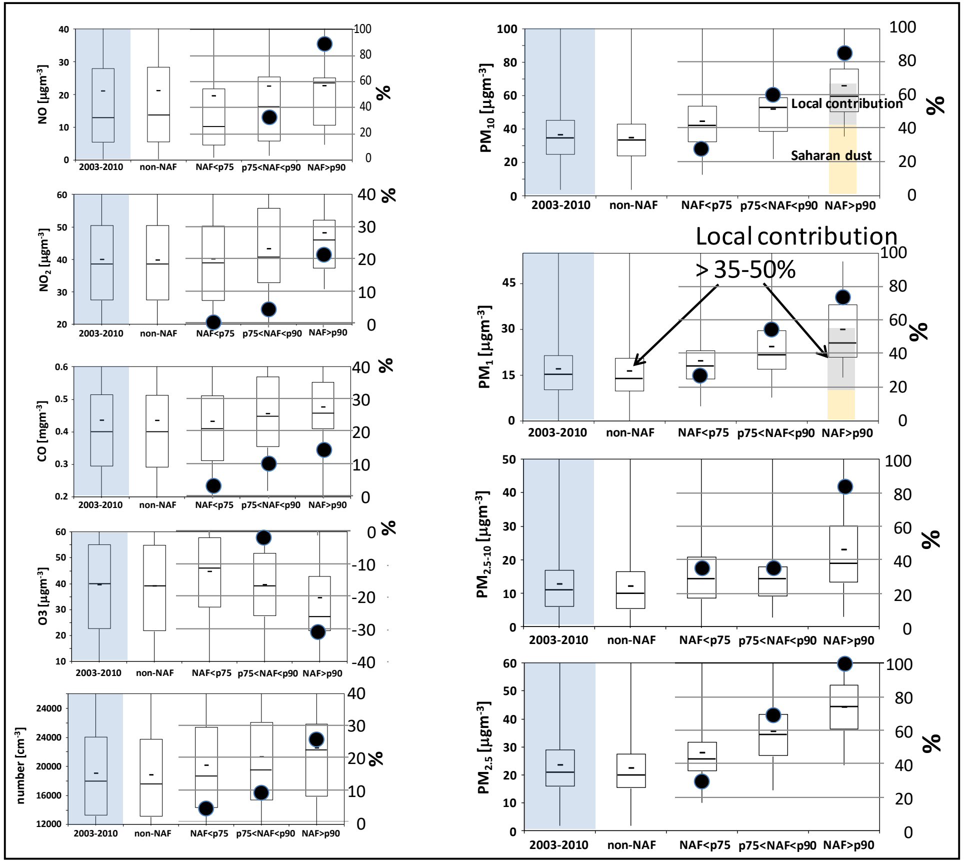


Moreno et al., 2008, Atmos Ennv.

PM composition during dust episodes

BARCELONA 2003 – 2010: 2513 MLH days from radiosounding at 12:00 UTC



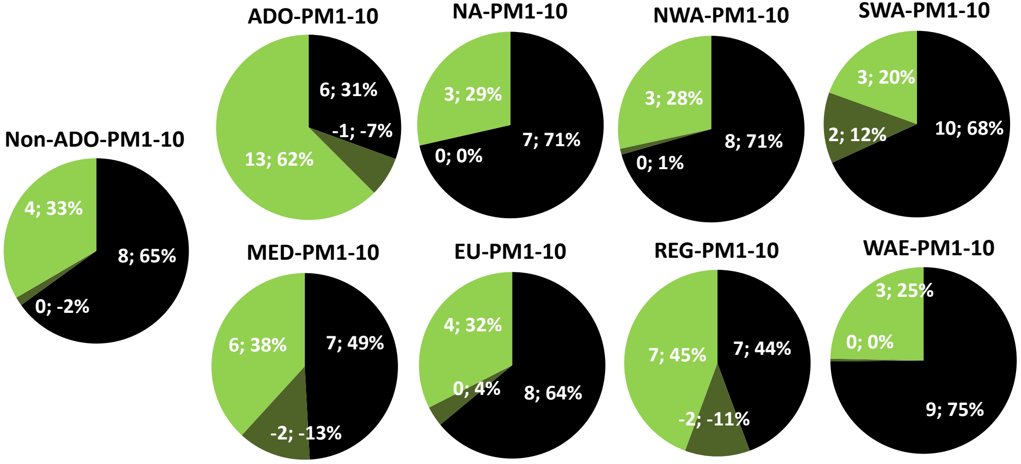


- Effects of Saharan dust outbreaks on MLH
- Effects of MLH oscillation on air quality during Saharan dust outbreaks

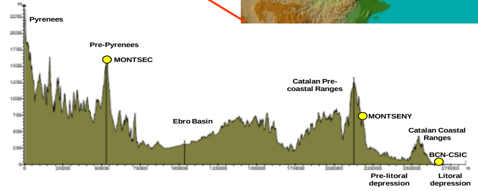
M. Pandolfi et al. STOTEN 494–495 (2014) 283–289

PM composition during dust episodes

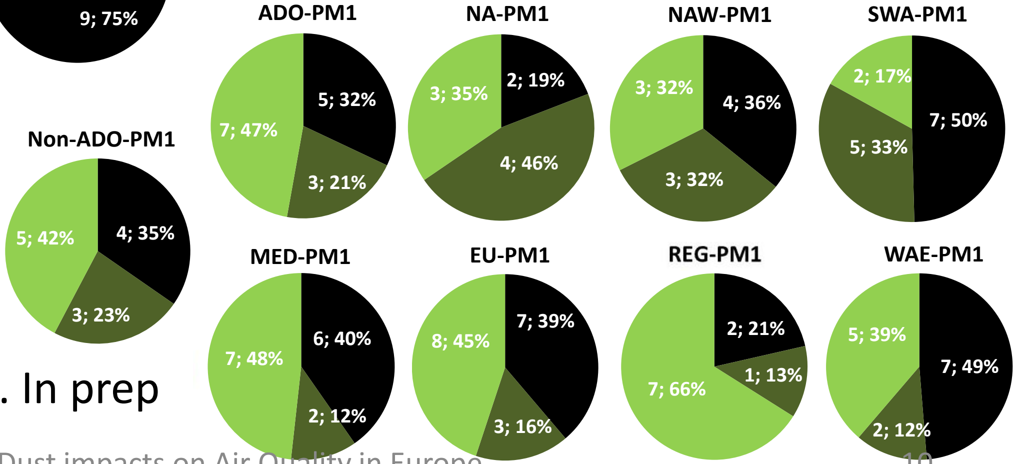
Urban contribution | Regional contribution | Continental contribution

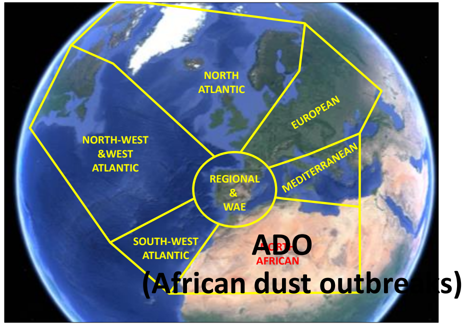


Barcelona, NE Spain 2009-2016



- Hourly UFP, BC, PM10, PM2.5 and PM1 2009-2016 simultaneously
- 1/3 day sampling and speciation PM10, PM2.5 and PM1

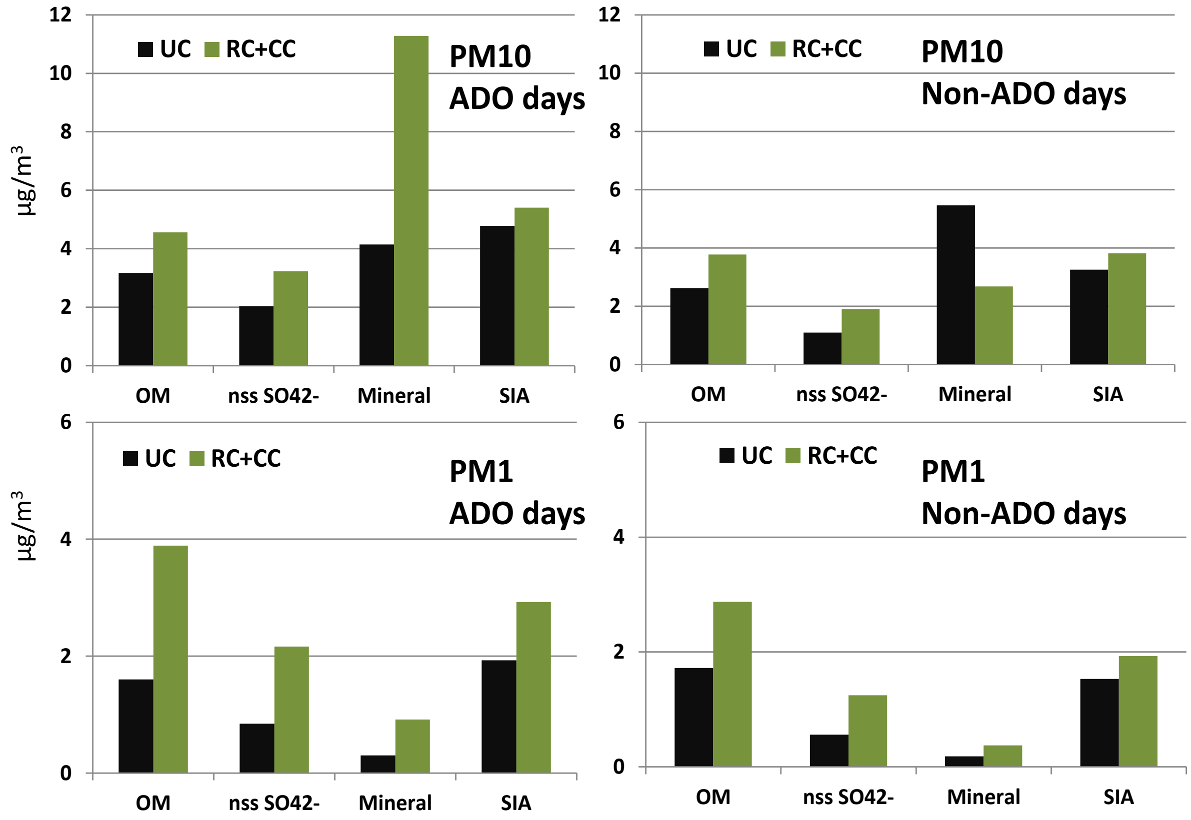




Querol et al., 2019. In prep

PM composition during dust episodes

Barcelona, NE Spain 2009-2016

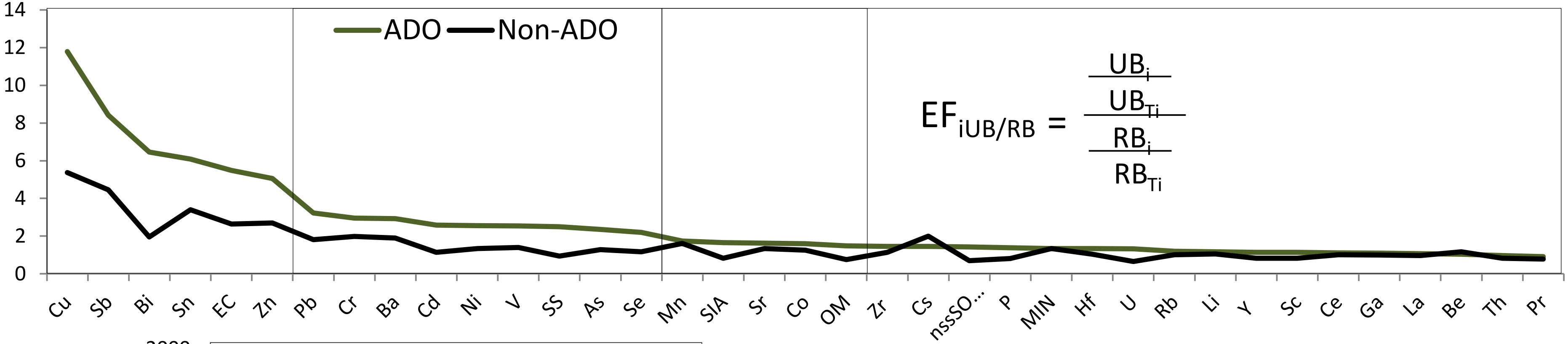


Querol et al., 2019. In prep

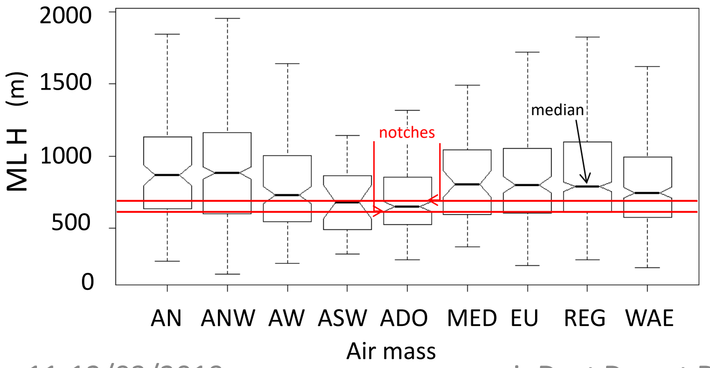
PM composition during dust episodes

Barcelona, NE Spain 2009-2016

Enrichment of PM components in the urban background compared with the regional bacground during ADOs compared with non-ADOs



$$EF_{iUB/RB} = \frac{\frac{UB_i}{UB_{Ti}}}{\frac{RB_i}{RB_{Ti}}}$$



Querol et al., 2019. In prep

PM and atmospheric relevant patterns

Increased PM concentrations during ADOs are caused by:

1. Obviously the transport of mineral matter from desert dust
2. The co-transport of anthropogenic pollutants with dust, both emitted at the source areas or entrained during dust transport
3. The accumulation of locally emitted anthropogenic PM pollutants by:
   3.1. A relatively low mixing layer height accumulate local pollutants
   3.2. Dust favouring the formation of secondary pollutants (such as $nssSO_4^{2-}$)
   3.3. If ADOs frequency is higher in spring/summer: higher secondary PM pollutants

It is not only mineral dust that matters for air quality during dust episodes

Dust-air quality evaluation system (EU)

http://ec.europa.eu/environment/air/quality/legislation/pdf/sec_2011_0208.pdf

EUROPEAN COMMISSION

Brussels, 15.02.2011
SEC(2011) 208 final

COMMISSION STAFF WORKING PAPER

establishing guidelines for demonstration and subtraction of exceedances attributable to natural sources under the Directive 2008/50/EC on ambient air quality and cleaner air for Europe

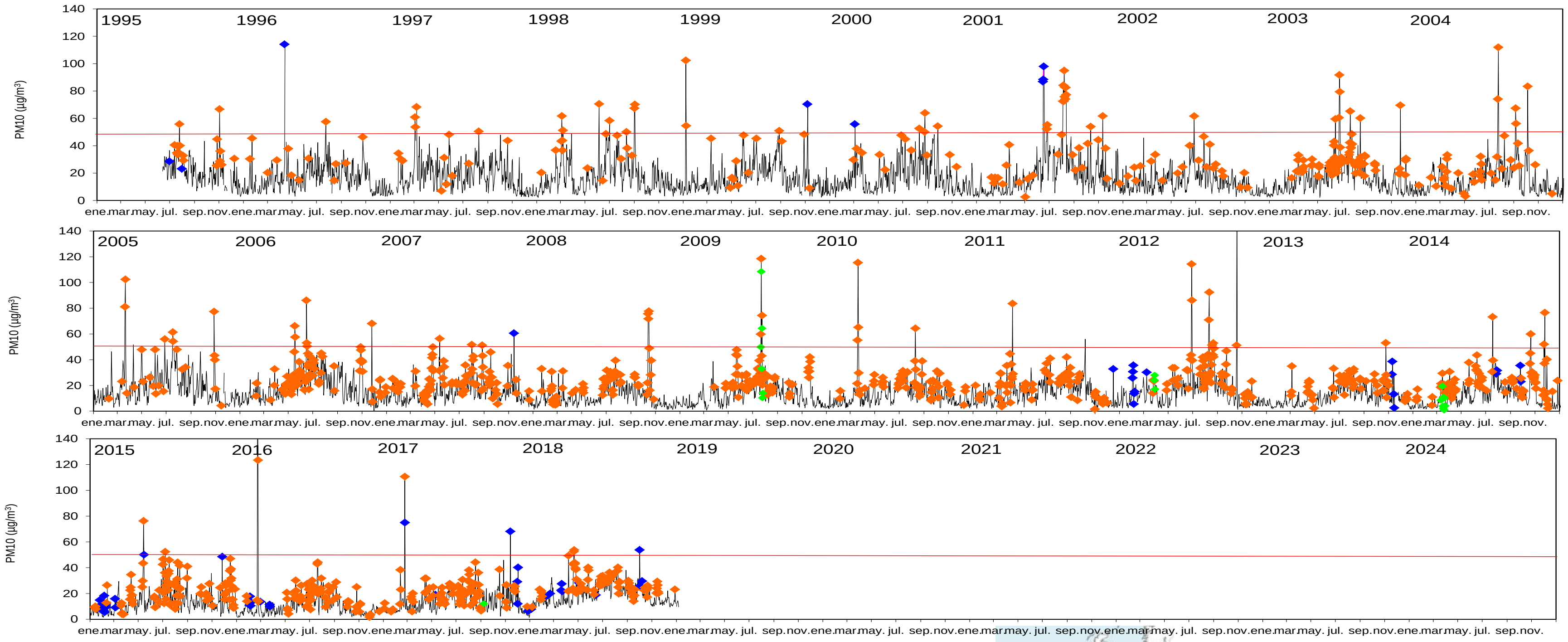
4.1. Methodology for the determination of re-suspended and transported Saharan dust

The following describes a procedure to determine the African origin of the exceedances of the daily mean concentration of 50µg/m^3. The procedure is based on a method developed in Spain and Portugal (Querol et al., 2006) for application in both countries[10]. It focuses on the daily limit value; discounting the contributions by re-suspended and transported natural Saharan dust episodes in the calculation of the annual average of PM_{10} may however also have a

Dust-air quality evaluation system (EU)

African dust, regional background NE Spain

Daily PM10 (µg/m³)



Daily limit value PM_{10} 2008/50/CE (50 µg m^{-3})

87 out of 96 exceedances registered in 21.5 years are caused by African dust outbreaks

- African dust outbreaks
- Local dust from Monegros
- Forest fires

Dust-air quality evaluation system (EU)

The percentile method

AFRICAN DUST, IDENTIFICATION OF EPISODES

Modelling
Aerosol maps

Backtrajectories

Satellite

+

Evaluation of PM concentrations at RB sites

YES

NO

QUANTIFICATION OF DAILY CONTRIBUTIONS TO PMx

Dust-air quality evaluation system (EU)

1. Reporting on the detection of episodes and measurement PM10 levels in EMEP-type sites:

1.1. Model outputs, meteo and satellite imagery tools

1.2. Daily evaluation of PM ambient concentrations recorded in a specific regional background monitoring network made of around 25 remote monitoring sites (Spain and Portugal)

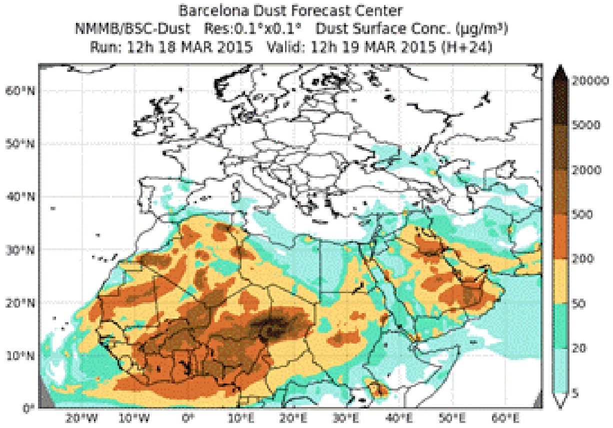
1.3. Reporting on detected episodes and daily levels of PM10 for each station of the regional background network

1.4. Three months after the end of the year, a report to scientifically support the occurrence of each episode included in the list

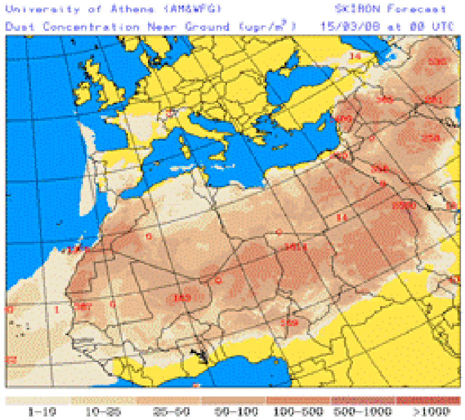
Dust-air quality evaluation system (EU)

Identification of Saharan dust outbreaks

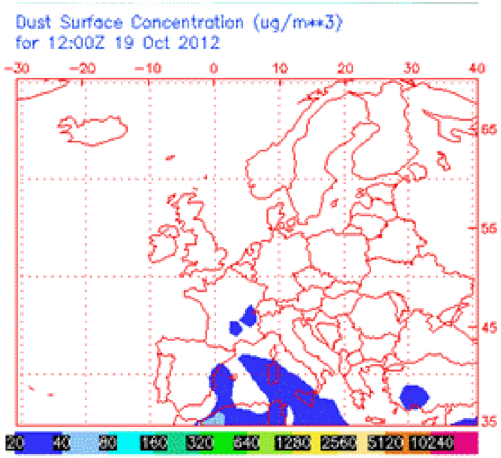
MMMB-BSC-dust



SKIRON simulations



NAAPS - NRL

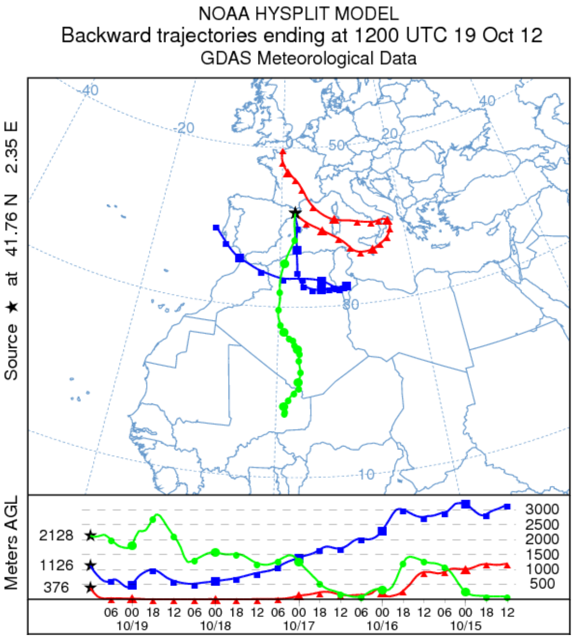


Dust-air quality evaluation system (EU)

Identification of Saharan dust outbreaks

HYSPLIT back-trajectories

Calculated for 120 hours at 3 heights: 750, 1500 and 2500 m a.s.l.

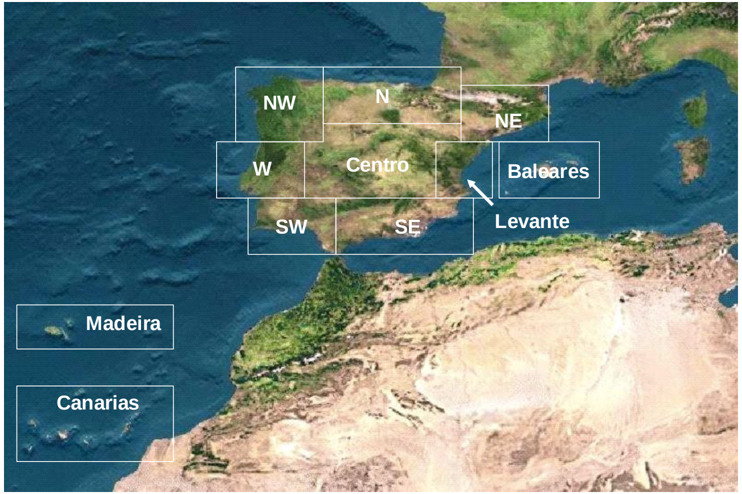


Dust-air quality evaluation system (EU)

Reporting on episodes

Impact on surface PMx concentrations: experimental

- Other than EMEP
- EMEP stations with real time measurements
- EMEP station with gravimetric measurements



Dust-air quality evaluation system (EU)

Dirección General de Calidad y Evaluación Ambiental
MINISTERIO DE MEDIO AMBIENTE

Reporting on episodes

ENERO 2008

ENERO 2008									
	CANARIAS	SUROESTE	SURESTE	LEVANTE	CENTRO	NOROESTE	NORTE	NORESTE	BALEARES
COMBUSTIÓN BIOMASA									
EUROPEO SULFATOS									
AFRICANOS	19-29	23	23	22-23	22-24	22-23	22-24	22-24	22-23

FEBRERO 2008

FEBRERO 2008									
	CANARIAS	SUROESTE	SURESTE	LEVANTE	CENTRO	NOROESTE	NORTE	NORESTE	BALEARES
COMBUSTIÓN BIOMASA									
EUROPEO SULFATOS									
AFRICANOS	6-12 21-23 27-29	12-19 22-28	13-20 22-28	14-20 24-29	14-17 26-27	14-17 23-26	15-17 24-26	15-17 24-29	14-16 19-20 24-29

MAYO 2008

MAYO 2008									
	CANARIAS	SUROESTE	SURESTE	LEVANTE	CENTRO	NOROESTE	NORTE	NORESTE	BALEARES
COMBUSTIÓN BIOMASA									
EUROPEO SULFATOS									
AFRICANOS		2-6	2-6	3-6	2-6	3-6	3-6	2-6	2-6

MARZO 2008

MARZO 2008									
	CANARIAS	SUROESTE	SURESTE	LEVANTE	CENTRO	NOROESTE	NORTE	NORESTE	BALEARES
COMBUSTIÓN BIOMASA									
EUROPEO SULFATOS									
AFRICANOS	5 13-16	2-3 15	1-3 14-16	1-3 14-15	14-15			15	1-3

ABRIL 2008

ABRIL 2008									
	CANARIAS	SUROESTE	SURESTE	LEVANTE	CENTRO	NOROESTE	NORTE	NORESTE	BALEARES
COMBUSTIÓN BIOMASA									
EUROPEO SULFATOS									
AFRICANOS	2-5 14-15 24-29	7 16-17	7 16	7 16	7 16	7 16	16	16-17 27-28	16-17 28

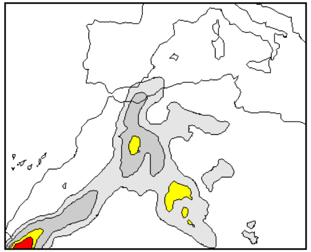
MAYO 2008

MAYO 2008									
	CANARIAS	SUROESTE	SURESTE	LEVANTE	CENTRO	NOROESTE	NORTE	NORESTE	BALEARES
COMBUSTIÓN BIOMASA									
EUROPEO SULFATOS									
AFRICANOS		2-6	2-6	3-6	2-6	3-6	3-6	2-6	2-6

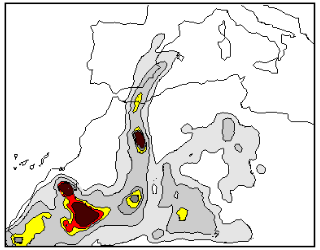
Dust-air quality evaluation system (EU)

Example of detection and support information in reporting

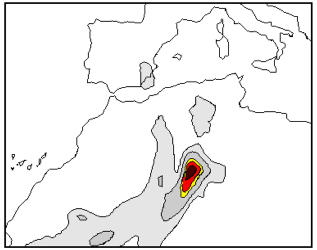
21-Jan'97 22-Jan'97 23-Jan'97



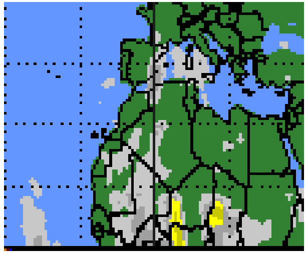
00:00 UTC 21 January 1997

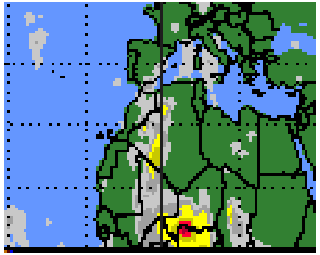


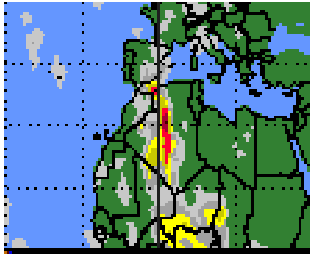
18:00 UTC 22 January 1997

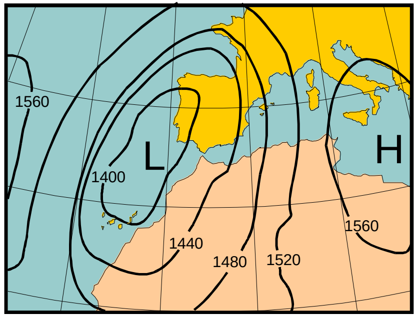


06:00 UTC 23 January 1997

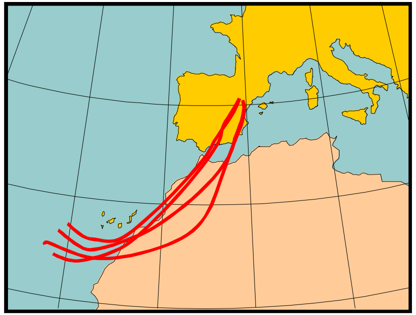






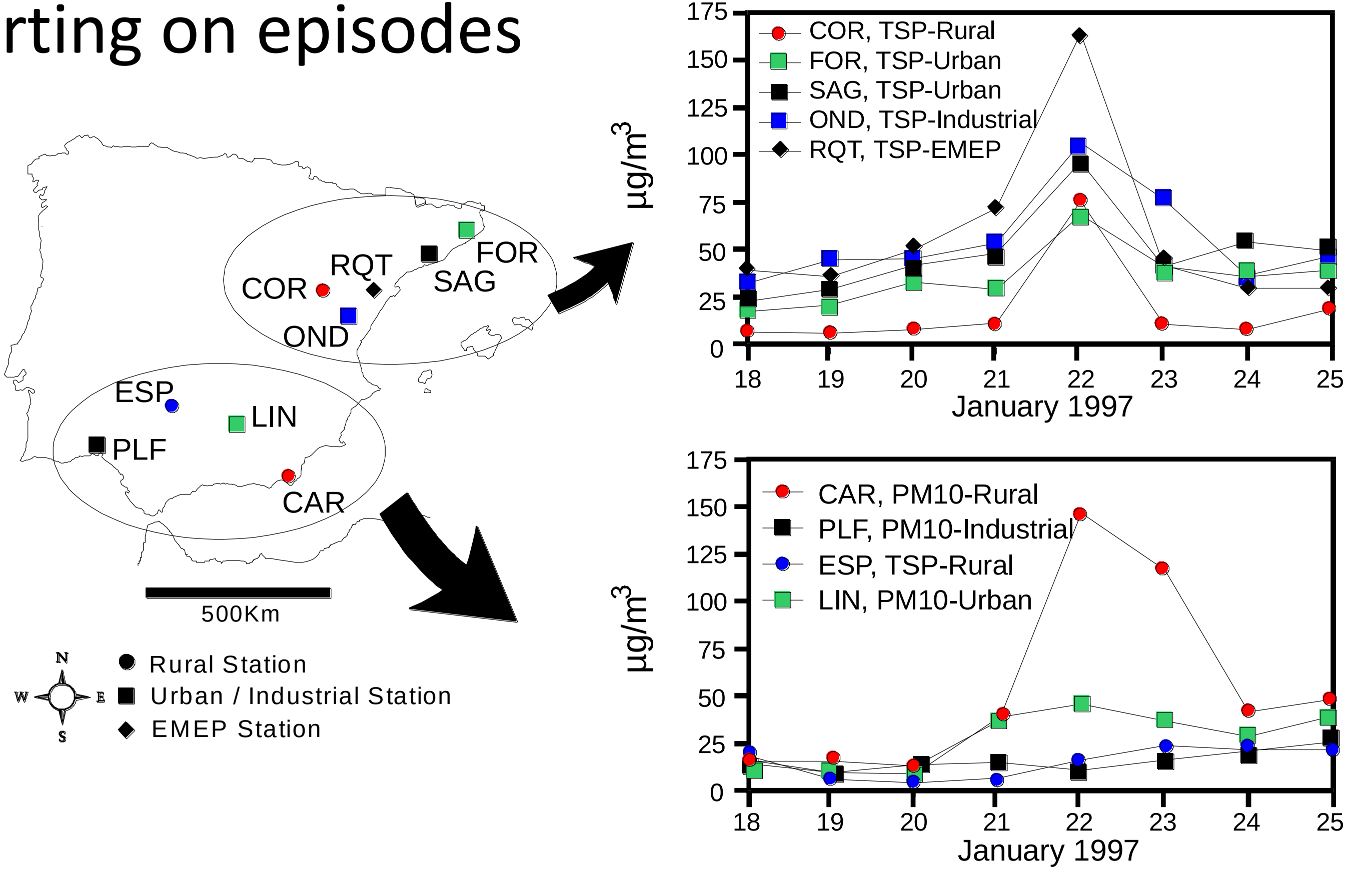


12 UTC 21 January 1997



Dust-air quality evaluation system (EU)

Reporting on episodes



Dust-air quality evaluation system (EU)

The quantitative approach

Procedure for the quantification of natural contribution to ambient levels of PM

2. Determining the natural contribution **'net dust load'** for each day of the list of African episodes

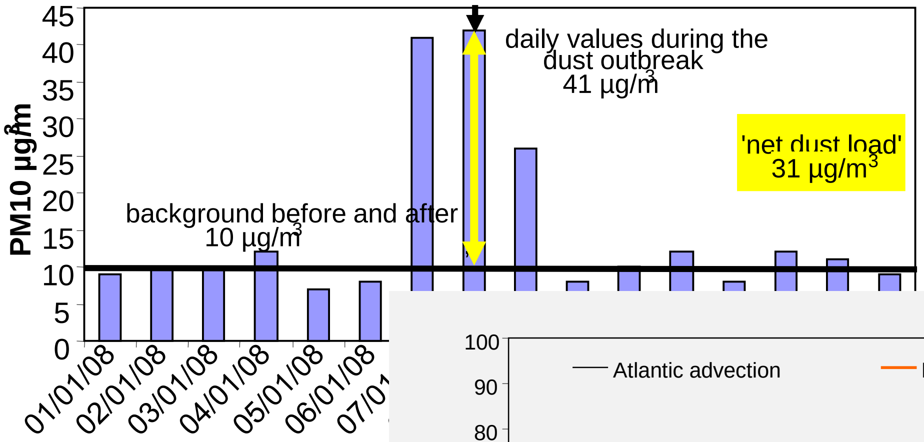
2.1. **Local-regional PM_{10} contribution (LRC, without African origin)** determined to be subtracted to the bulk PM_{10} levels during the episode

2.2. LRC daily calculated from monthly mobile **40 percentile** (centring the considered day in the middle of the month period) of the PM_{10} levels excluding the African days

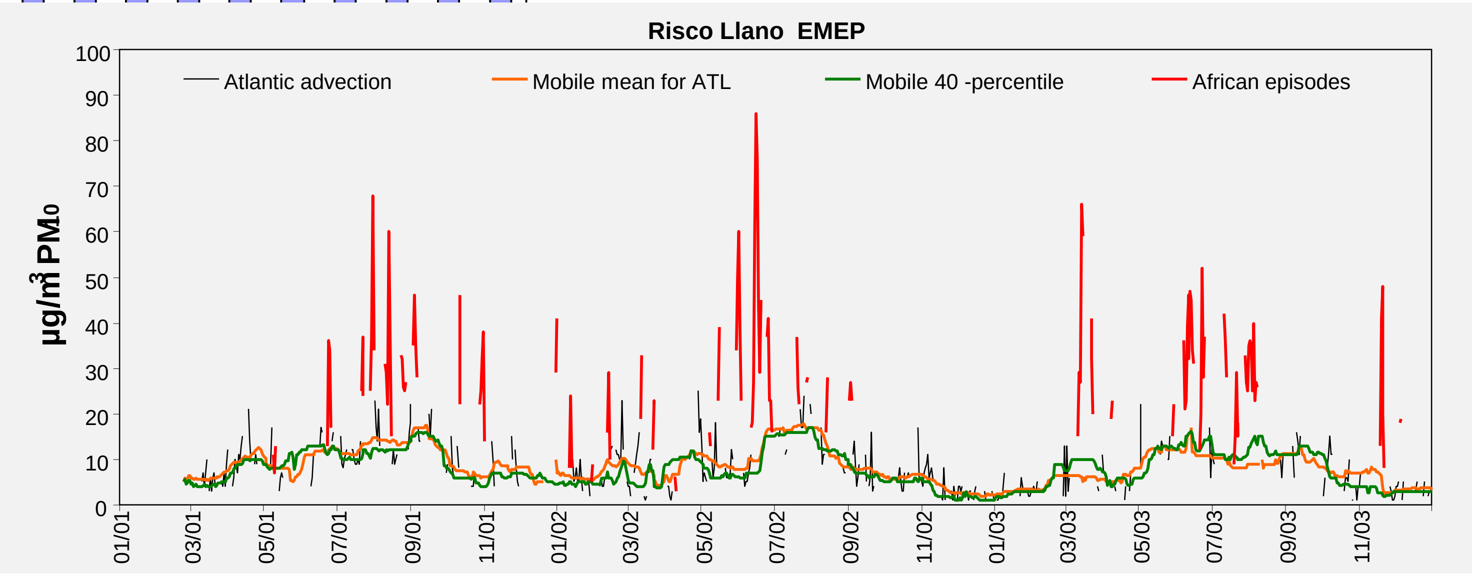
2.3. Then '**net dust load**' for a given day with African dust influence in one regional background station is determined: PM_{10}-LRC

2.4. A list of 'net dust load' values for each day and regional background station is produced to be used to subtract the natural dust contribution to PM_{10} during days with exceedances of the DLV recorded at the AQ monitoring sites close to this specific regional background station. The **list** is **produced by the Ministries of the Environment from Portugal and Spain**

Dust-air quality evaluation system (EU)



The quantitative approach



Dust-air quality evaluation system (EU)

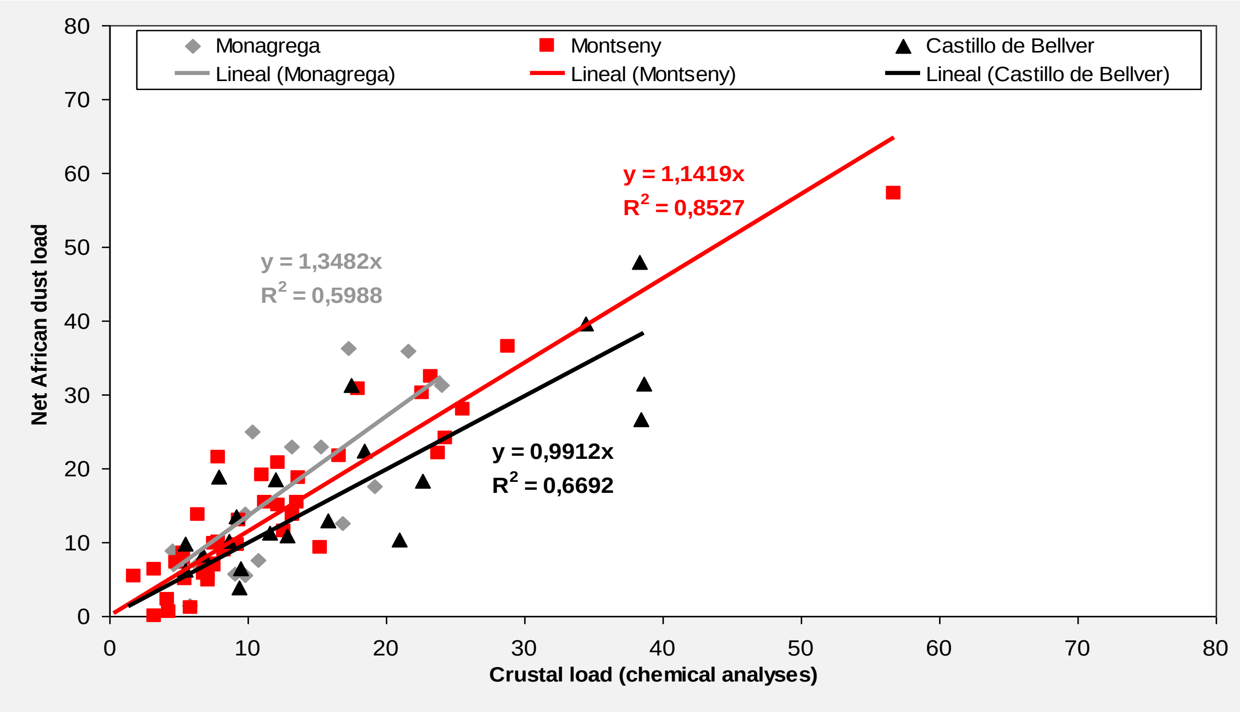
Quantification of Saharan dust

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		España FR	España EMEP		SIN NAF	SIN NAF		PERC 40	PERC 40		Bellver	Mahón		
2		Bellver	Mahón		Bellver	Mahón		Bellver	Mahón		Descuentos	Descuentos		N/
3836	01/07/2011	22	15		22	15		17	14					
3837	02/07/2011	15	11		15	11		17	14					
3838	03/07/2011	20	16					17	14		3	2		
3839	04/07/2011	32	20					17	14		15	6		
3840	05/07/2011	22	15		22	15		17	14					
3841	06/07/2011	26	16		26	16		17	14					
3842	07/07/2011	22	21		22	21		17	14					
3843	08/07/2011	28	19		28	19		16	14					
3844	09/07/2011	26	16		26	16		16	14					
3845	10/07/2011	22	20					15	13		7	7		
3846	11/07/2011	31	25					15	13		16	12		
3847	12/07/2011	45	26					15	13		30	13		
3848	13/07/2011	24	17					14	13		10	4		
3849	14/07/2011	17	17		17	17		13	13					
3850	15/07/2011	17	10		17	10		13	11					
3851	16/07/2011	13	11		13	11		13	11					
3852	17/07/2011	21	14		21	14		13	10					
3853	18/07/2011	17	14		17	14		13	11					
3854	19/07/2011	20	19		20	19		13	11					
3855	20/07/2011	11	13		11	13		13	10					
3856	21/07/2011	13	9		13	9		13	10					
3857	22/07/2011	13	13		13	13		13	10					
3858	23/07/2011	14	14		14	14		13	10					
3859	24/07/2011	13	15		13	15		12	10					
3860	25/07/2011	11	10		11	10		12	10					

LEYENDA | OESTE | CANARIAS | SUROESTE | SURESTE | ESTE | CENTRO | NOROESTE | NORTE | NORESTE | BALEARES | MAD

Dust-air quality evaluation system (EU)

Validation of the procedure by chemical analysis of PM10



Dust-air quality evaluation system (EU)

The quantitative approach

Determining the anthropogenic and natural contributions to PM in an urban site

3. **The AQ monitoring networks** compile a list of dates with exceedances of the DLV coinciding with the African dust outbreaks from the report by the **Ministry of the Environment**.

4. The 'net PM10 dust contribution' for the closest regional background site is subtracted from the PM_{10} levels of list produced in task 3 to discount the natural contribution

5. If after subtraction, the PM_{10} levels are < DLV (50 µg/m^3) then the exceedance will be attributed to the natural contribution, otherwise will be attributed to anthropogenic causes

6. PM10 levels of the days where the exceedances was attributed to natural contributions are not included in the annual average.

7. The AQ monitoring networks reports on:

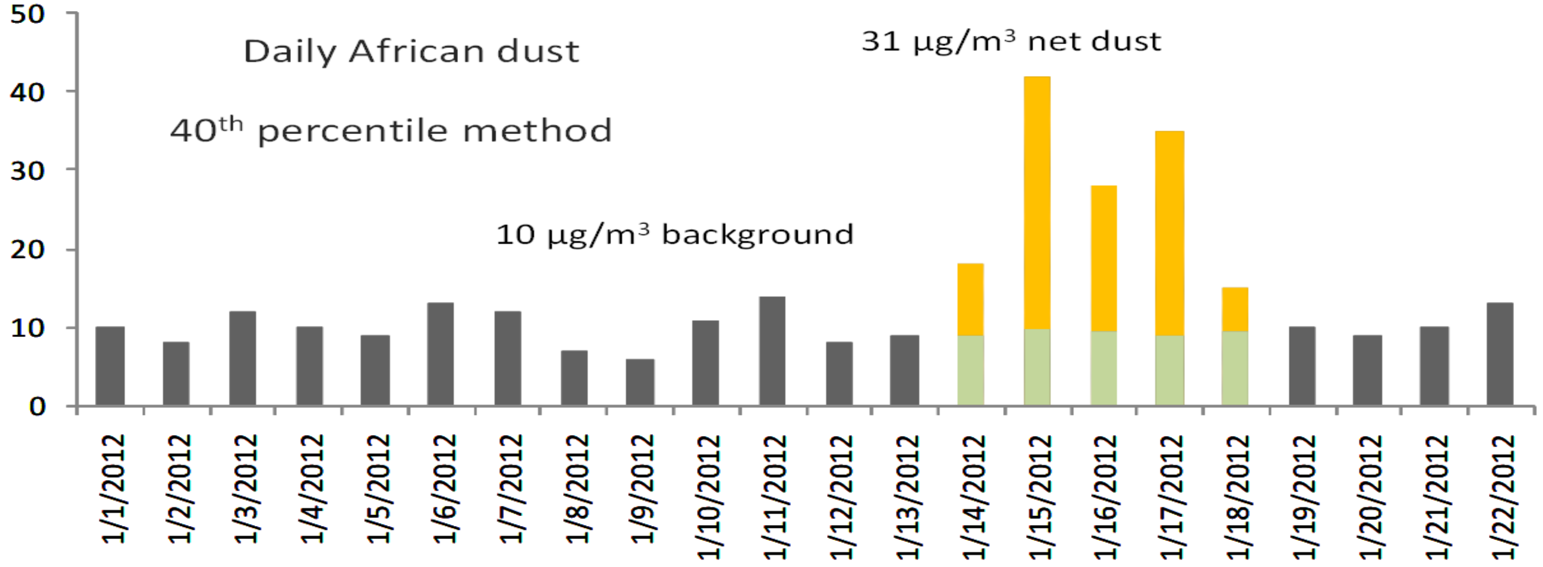
    7.1. Mean average and total number of exceedances

    7.2. List of exceedances attributed to natural contributions (exceedances are not deleted!!!)

    7.3. Calculated dust contribution to the annual mean (from the difference of the annual mean-annual mean with the subtractions of the calculated daily net dust loads).

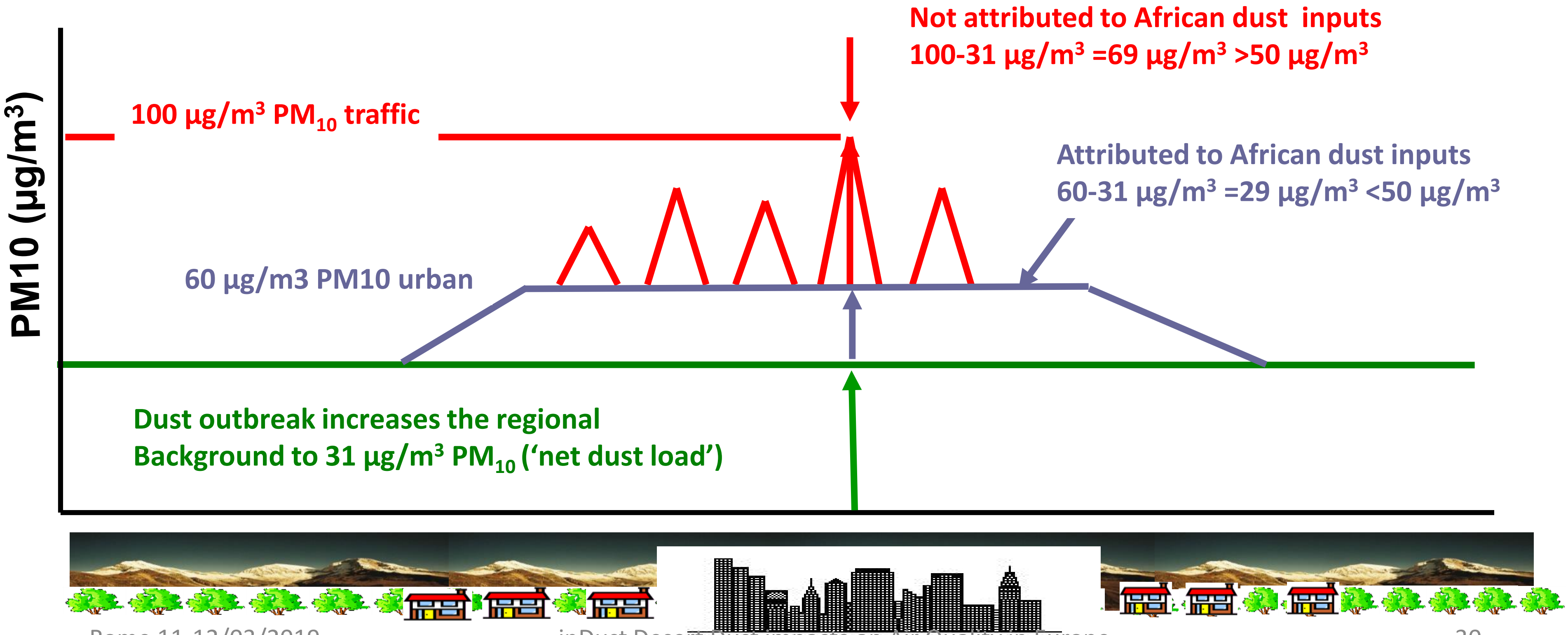
Dust-air quality evaluation system (EU)

Determining the anthropogenic and natural contributions to PM at an urban site



Dust-air quality evaluation system (EU)

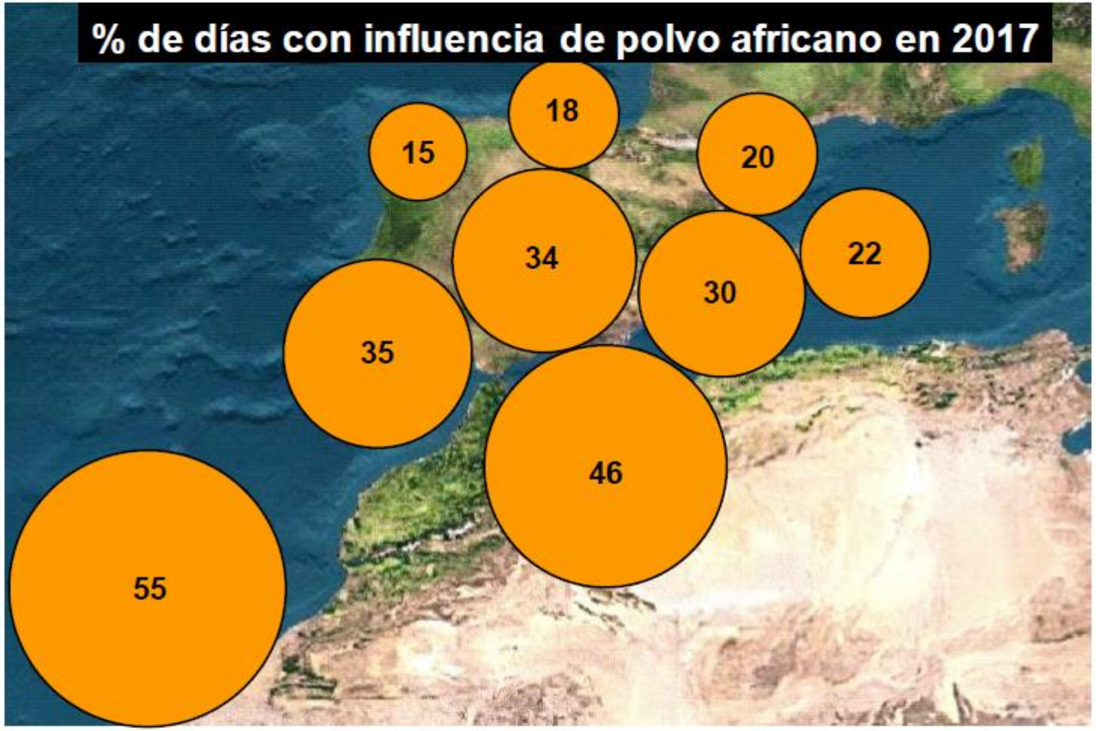
Determining the anthropogenic and natural contributions to PM in an urban site



Dust contribution in Spain from EC Guidelines application

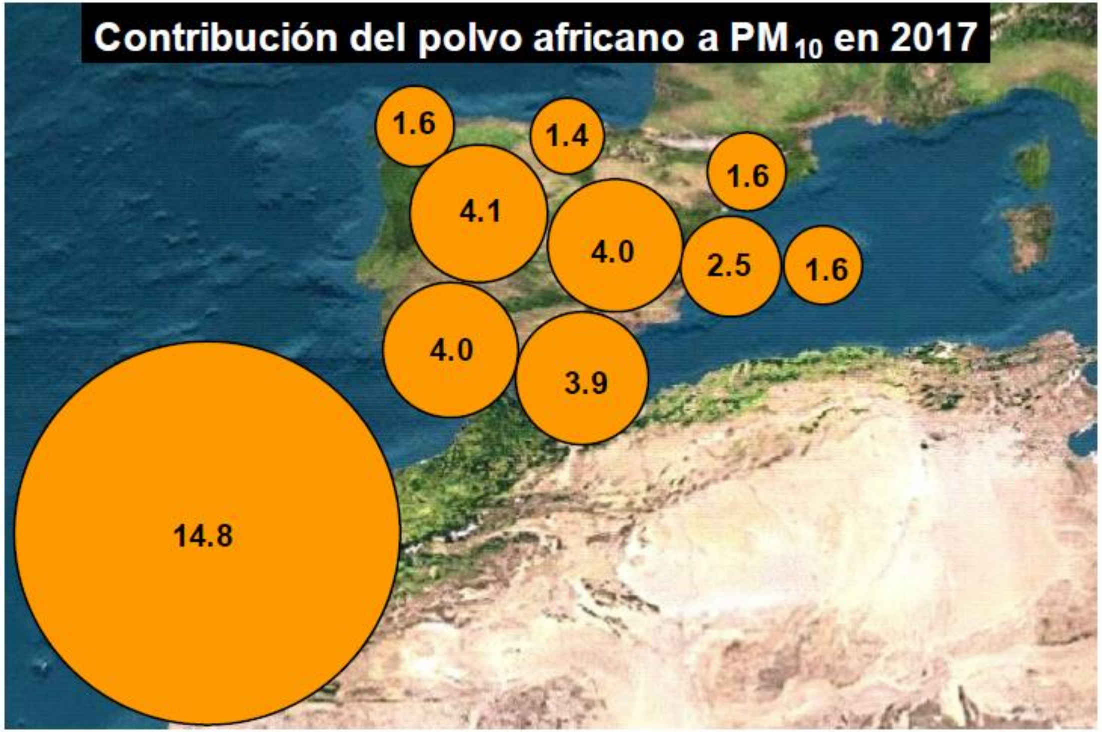
Dust contribution in Spain

% of African dust days in PM10



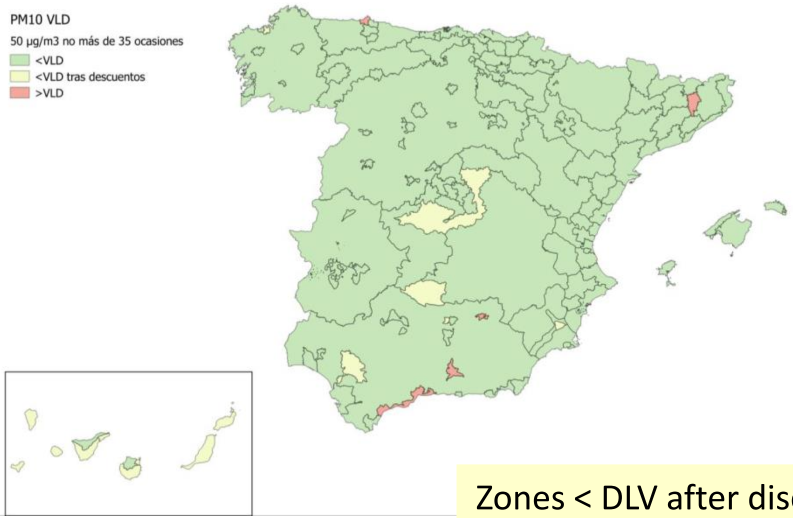
Dust contribution in Spain

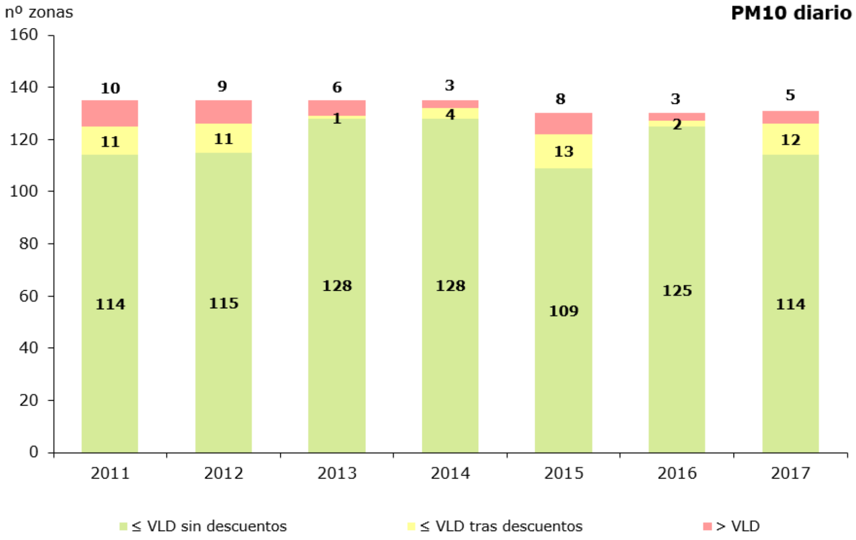
Average African dust in PM10 in 2017



Dust contribution in Spain

2017: zones exceeding the daily limit value - DLV





Zones < DLV after discounting of net dust

- Islas Canarias (5 zonas)
- Zona industrial Bailén
- Nueva zona Sevilla y Área Metropolitana
- Comarca de Puertollano
- Zona industrial del Norte
- A Coruña + Área Metropolitana
- Ciudad de Murcia

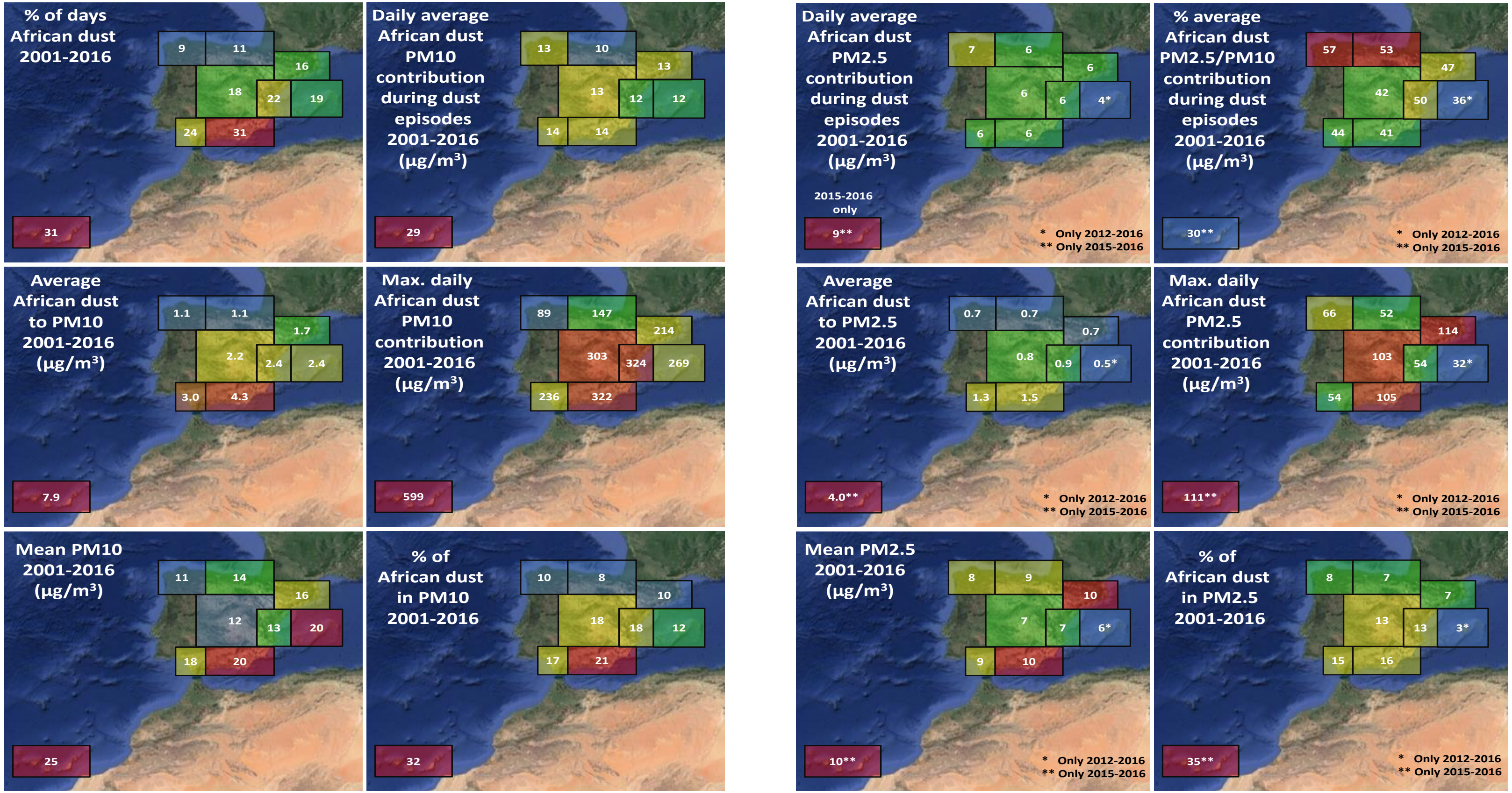
Evaluación de la calidad del aire en España 2017

MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA

Zones >DLV 2017

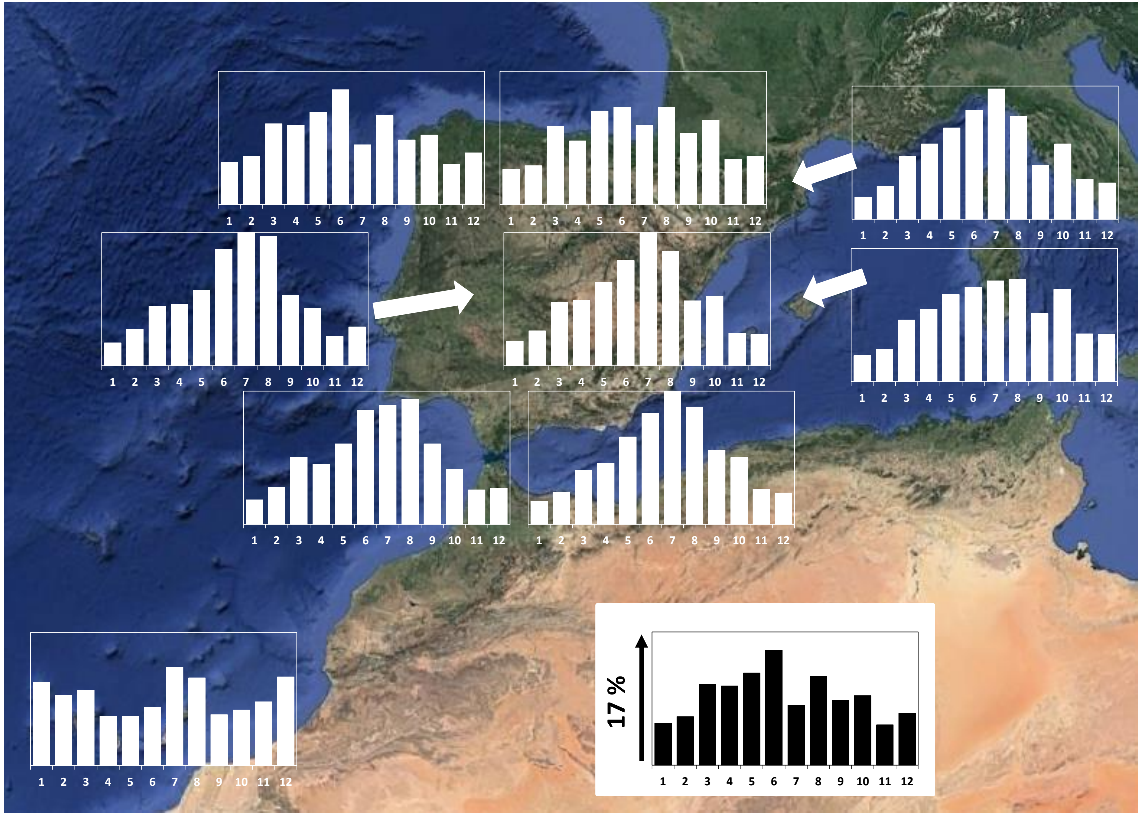
- Granada y Área Metropolitana
- Málaga y Costa del Sol
- Zona Villanueva del Arzobispo
- Avilés
- Plana de Vic

Dust contribution in Spain: 2001-2016



Querol et al., 2019. In prep

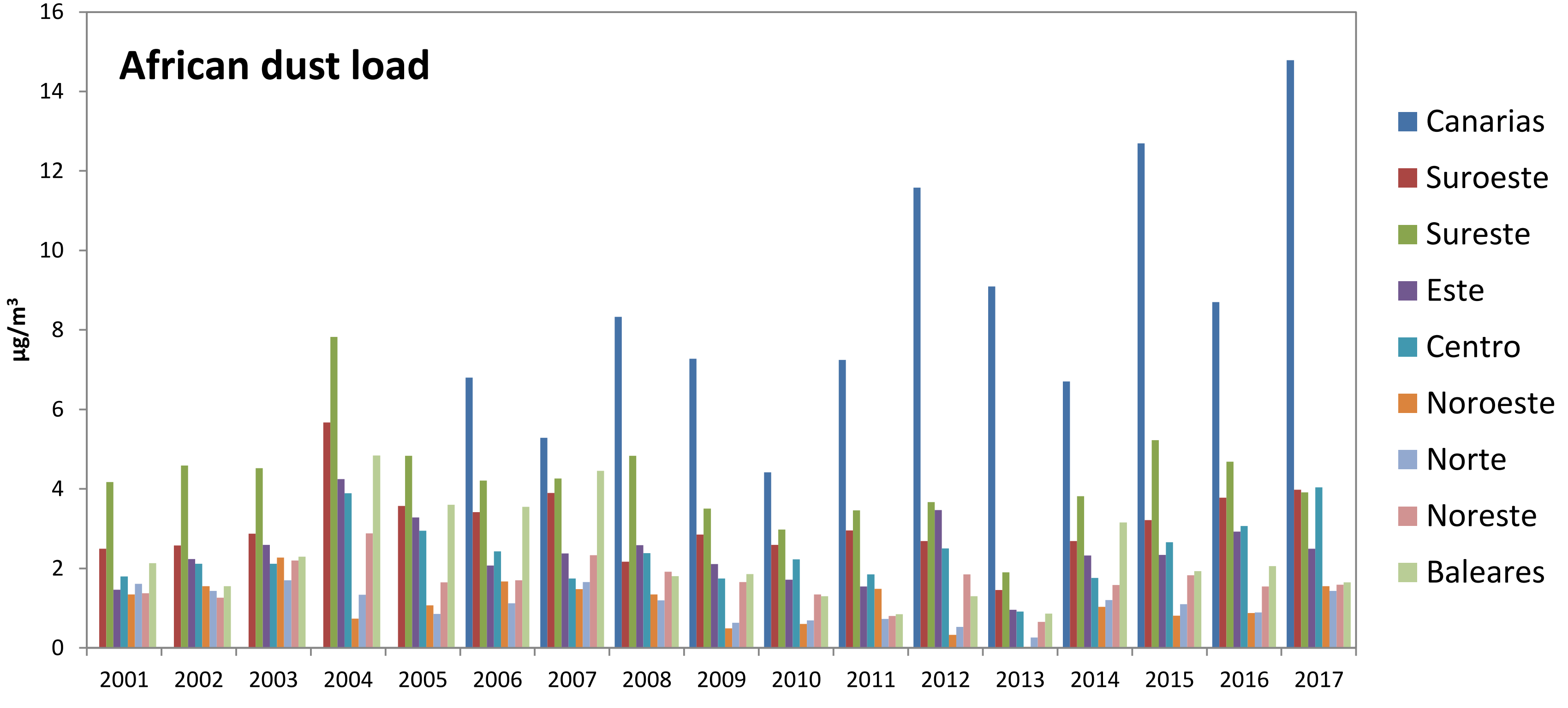
Dust contribution in Spain: 2001-2016



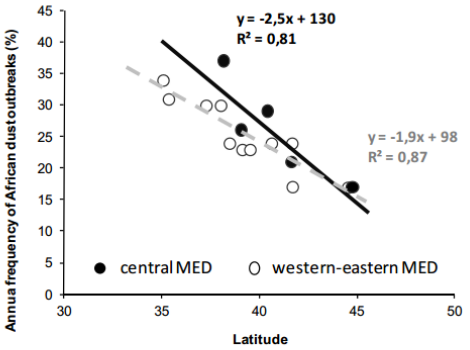
Querol et al., 2019. In prep

Figure 4. Percent seasonal average occurrence of ADOs over Spain for the period 2001-2016.

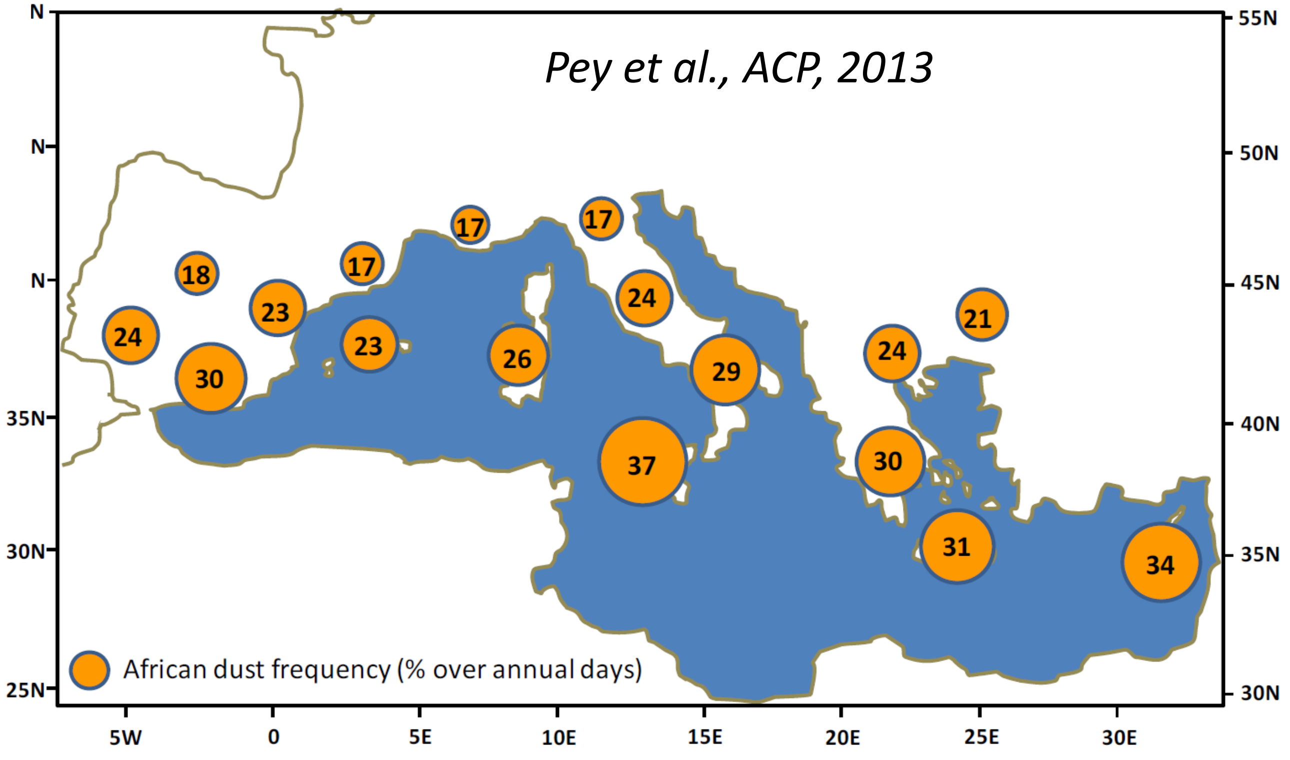
Dust contribution in Spain: 2001-2016



Dust contribution in the Mediterranean

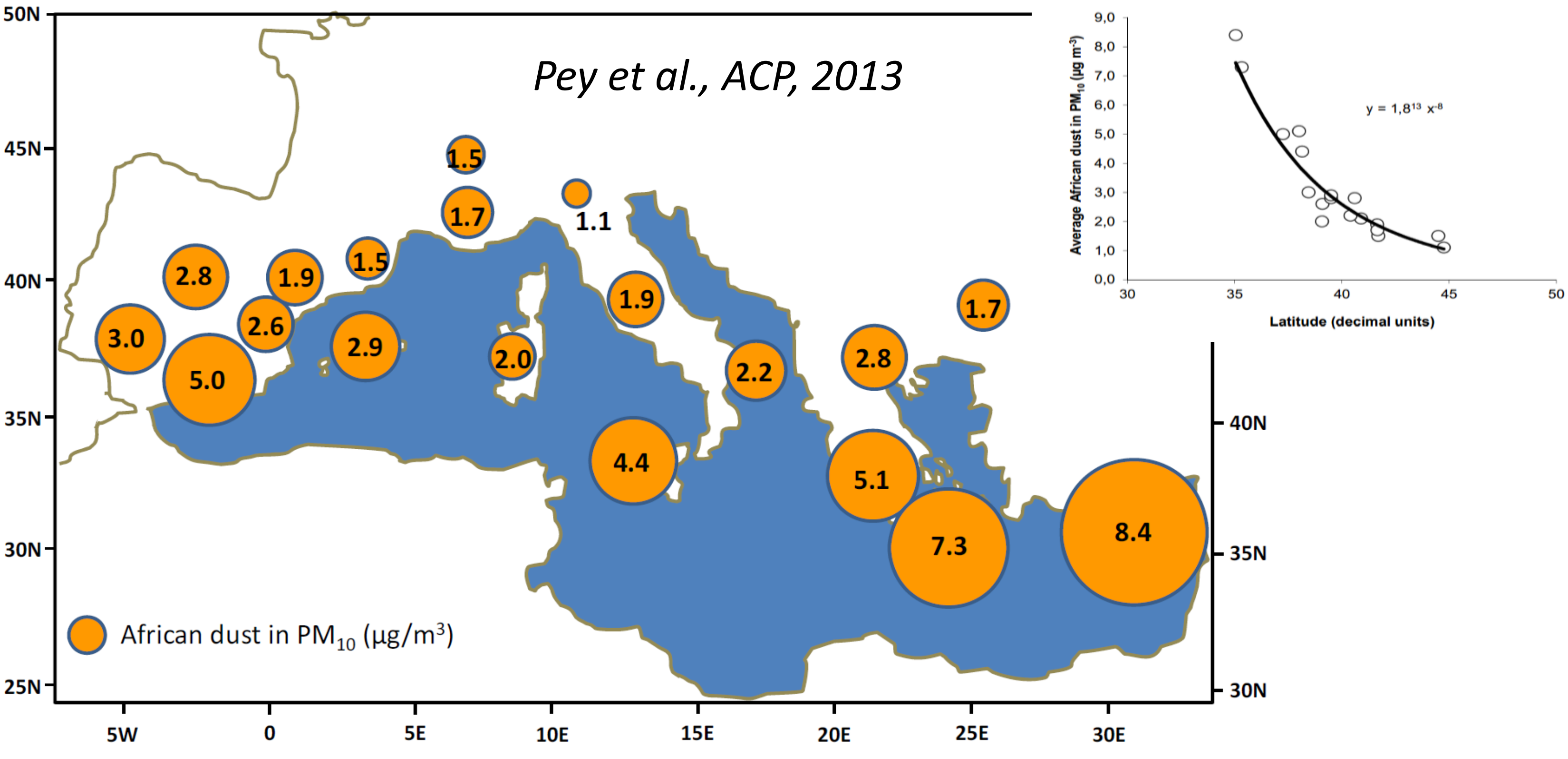


African dust outbreak frequency



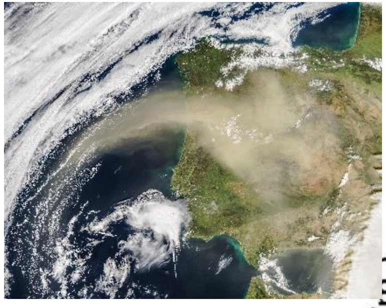
Dust contribution in the Mediterranean

African dust contribution to PM10 in REGIONAL BACKGROUND sites



Spatial variability

Titos et al. J. Geophys. Res. Atmos., 122, 4052–4069, doi:10.1002/2016JD026252.



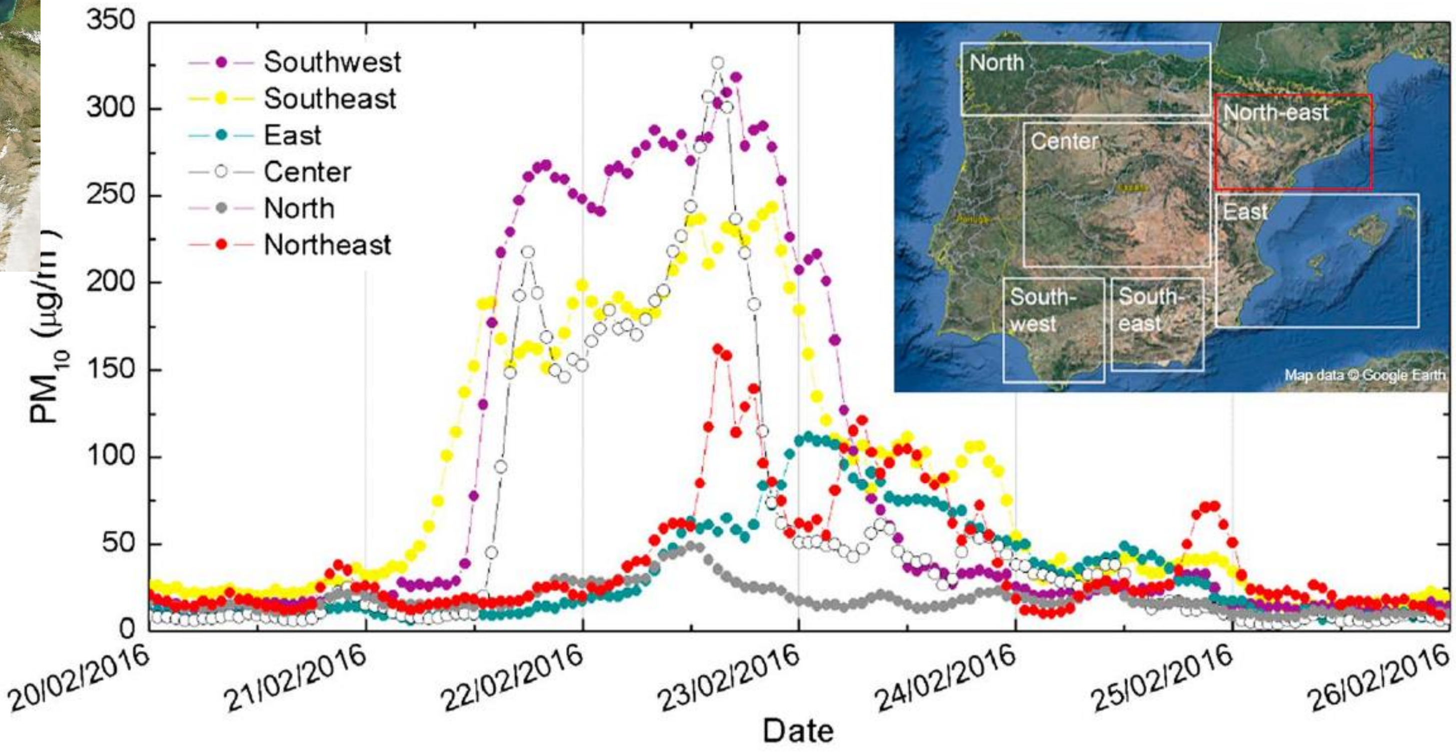


Figure 2. Hourly PM_{10} concentrations (median values) corresponding with the different regions (inset map).

Spatial variability

Titos et al. J. Geophys. Res. Atmos., 122, 4052–4069, doi:10.1002/2016JD026252.

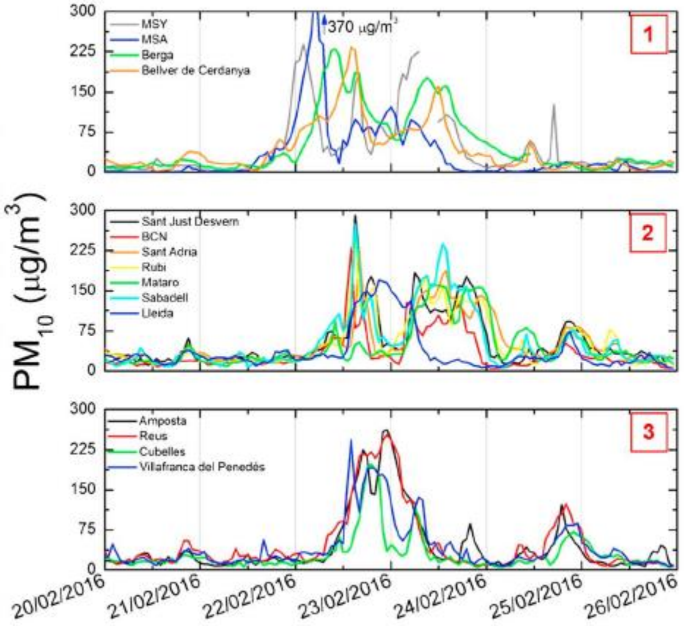


Figure 3. North-easternmost part of the Iberian Peninsula (Catalonia region) with the air quality stations marked and split into three sectors (1 = north, 2 = center, and 3 = south) and hourly PM_{10} mass concentrations at each station.

Vertical variability

Titos et al. J. Geophys. Res. Atmos., 122, 4052–4069, doi:10.1002/2016JD026252.

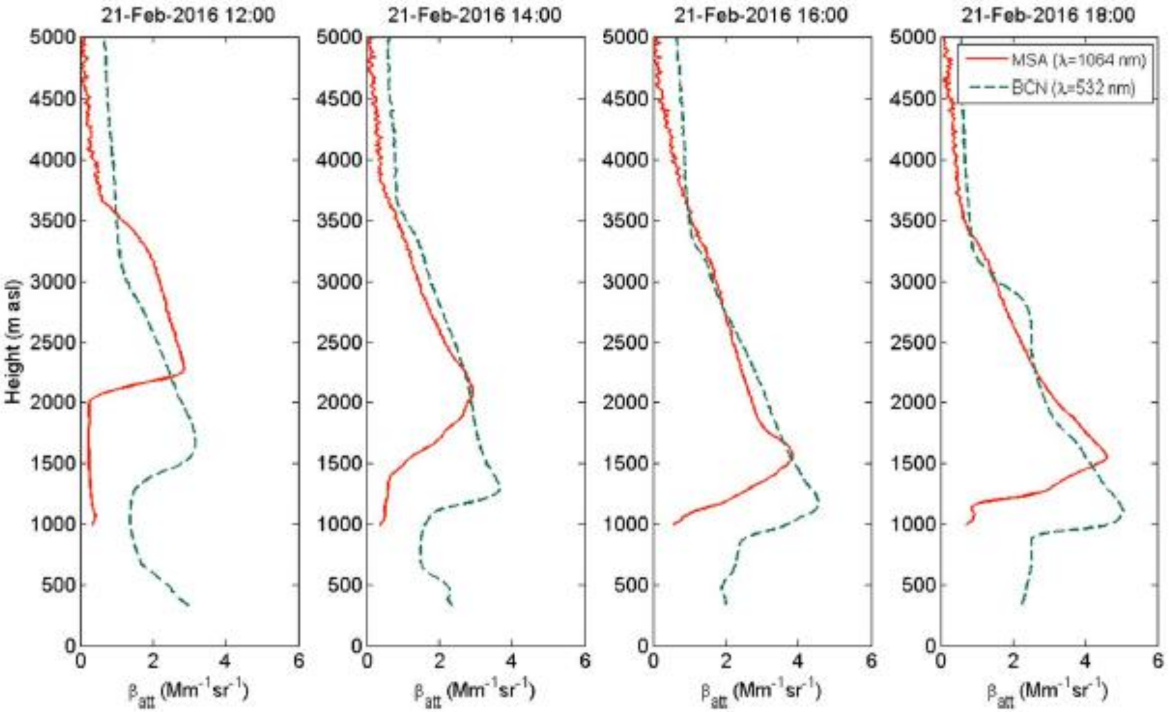


Figure 4. Vertical and temporal evolution of the attenuated backscatter coefficient, $\beta_{att}(\lambda)$, measured with ceilometer at MSA and micropulsed lidar at BCN (1 h average). Time refers to UTC.

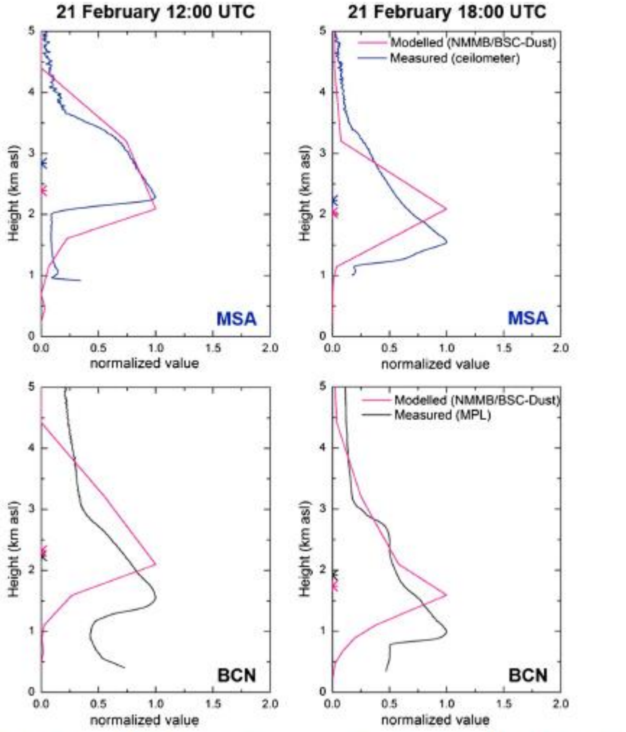


Figure 5. Vertical profiles of normalized dust concentrations forecasted by NMMB/BSC-dust model (Barcelona dust forecast center) and normalized attenuated backscattering coefficients measured over (top row) MSA and (bottom row) BCN on 21 February 2016. The asterisks correspond with the center of mass of the profile.

Concluding remarks

- EC Guidelines in natural dust: is a conservative method (tends to underestimate the natural contribution), relatively easy to apply, and based on real PM time series recorded at AQ networks
- Permits to obtain information on spatial and temporal variation of ADOs impact on PM by using and harmonized and comparable method
- High spatial and vertical variability of dust outbreaks: selection of regional background site is crucial
- Quantification based on regional background sites: minimizes the interference of secondary / local pollutants formed in UB during ADOs

Thank you!

andres.alastuey@idaea.csic.es

noemi.perez@idaea.csic.es

xavier.querol@idaea.csic.es

Acknowledgements

Ministry of the Environment of Spain

Fotografía: Alfons Puertas, Observatori Fabra

Vertical variability

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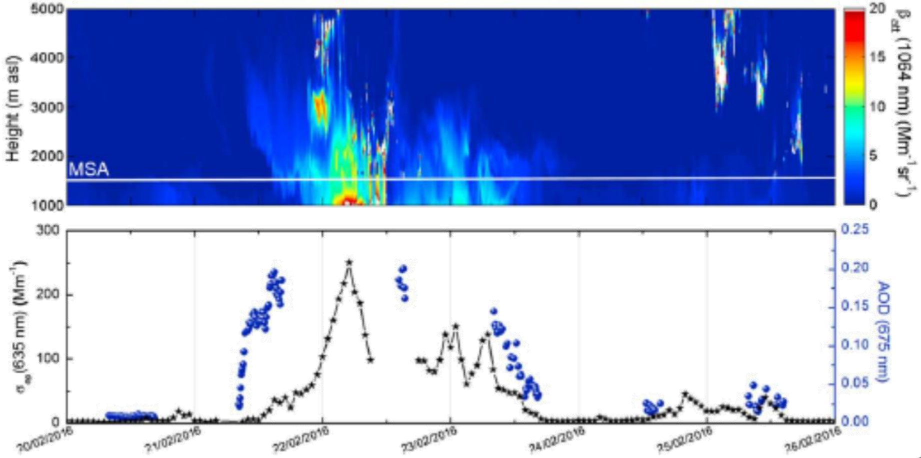


Figure 6. (top) Color map of the temporal evolution of β_{att} at 1064 nm measured with the ceilometer and the altitude of the Montsec station, MSA, marked in white and (bottom) σ_{ep} and AOD measured at MSA.

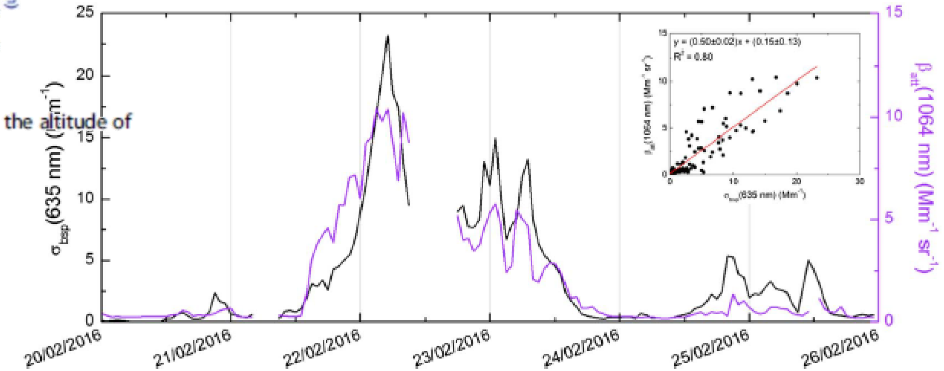
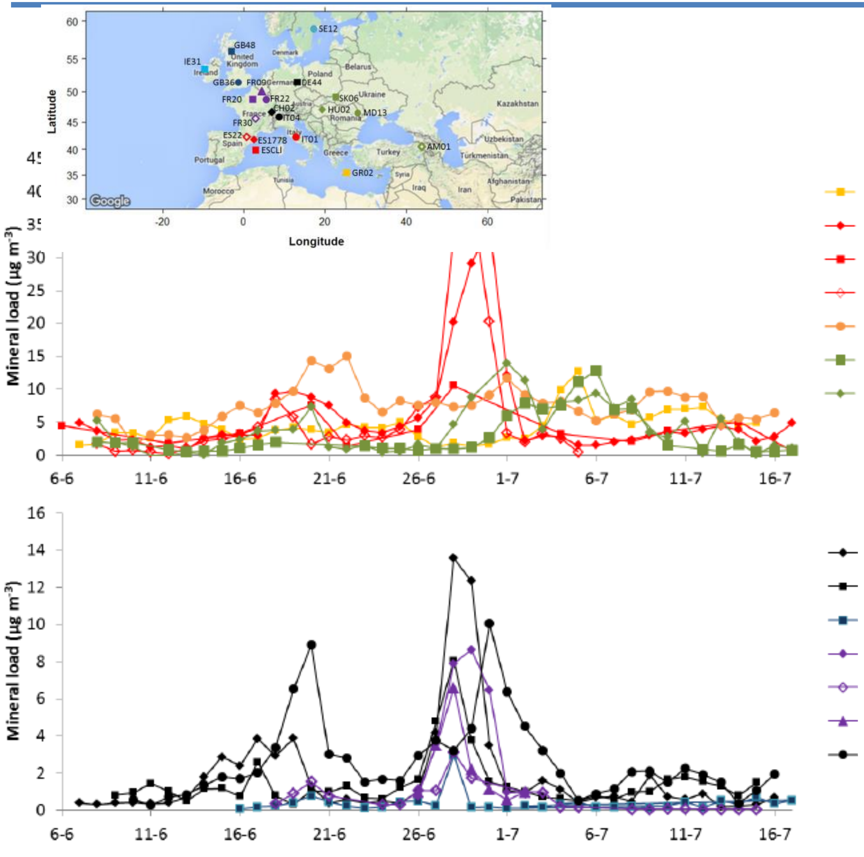
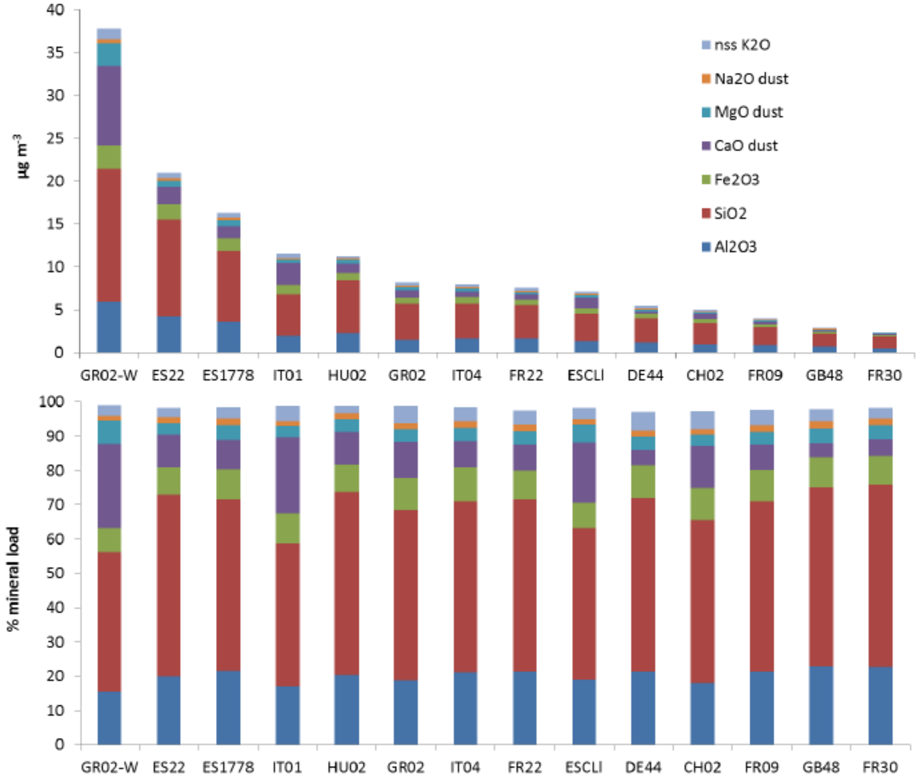


Figure 7. Time series of hourly β_{att} at 1064 nm (measured with the ceilometer) and averaged for the height level 1570 ± 15 m asl corresponding with the MSA station and σ_{bsp} at 635 nm (measured in situ with the nephelometer) at MSA station. A scatterplot of β_{att} (1064 nm) versus σ_{bsp} (635 nm) and the corresponding fitting equation is included.

FFFFF

A. Alastuey et al.: Geochemistry of PM10 over Europe Atmos. Chem. Phys., 16, 6107–6129, 2016

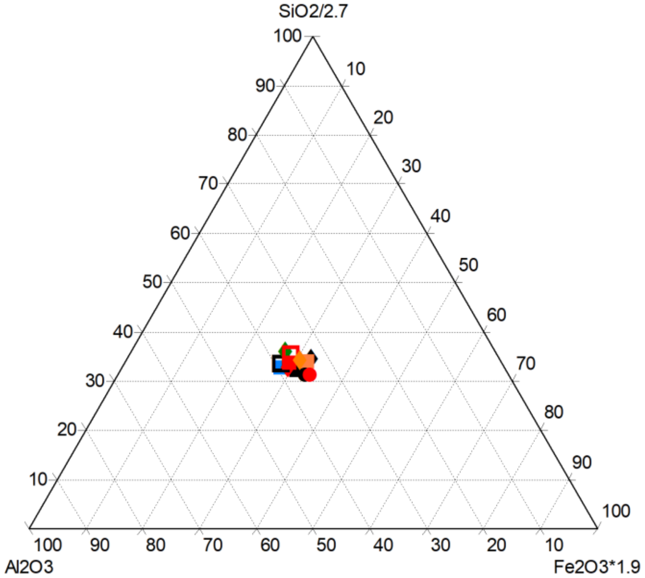




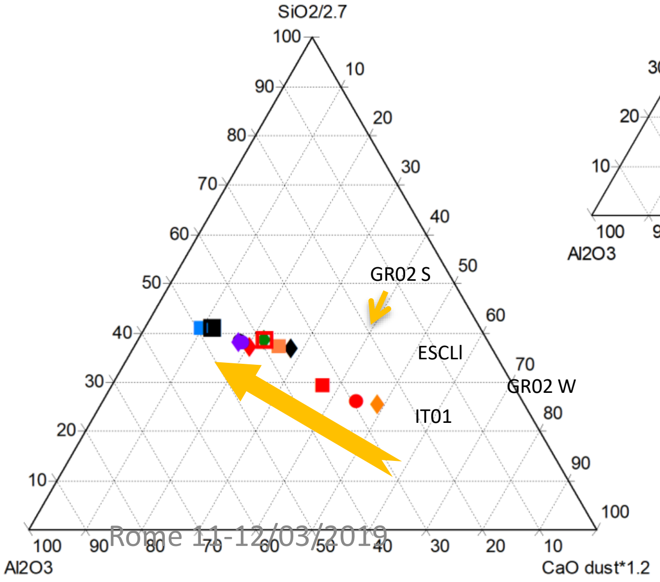
Alastuey et al. ACP 2016

African Mineral dust: average composition

CH02	♦ (black)	FR30	□ (black)
DE44	■ (black)	GB48	■ (blue)
ES1778	♦ (red)	GR02	■ (orange)
ES22	□ (red)	GR02-W	♦ (orange)
ESCLI	■ (red)	HU02	♦ (green)
FR09	♦ (purple)	IT01	● (red)
FR22	● (purple)	IT04	● (black)



Uniform composition



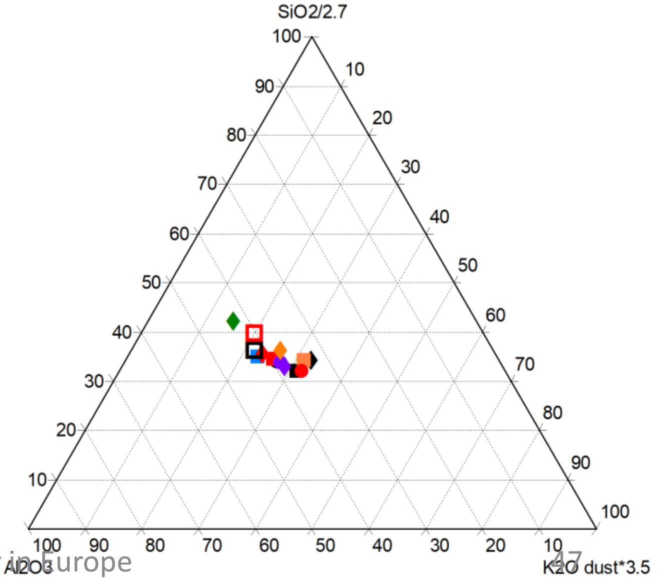
CaO

Source area

Local influence

Transport

sorting



Non-African dust

Heterogeneous composition
High spatial variation