IMPACT OF AFRICAN DUST ON AIR QUALITY

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OUTLINE

- ATMOSPHERE & POLLUTION
- ATMOSPHERIC PARTICULATE MATTER (PM)
- AFRICAN DUST
- IMPACT OF AFRICAN DUST ON AIR QUALITY IN (SOUTHERN) EUROPE
- HEALTH IMPLICATIONS
- CONCLUDING REMARKS

HISTORIC DATES ON AIR QUALITY

http://www.co.mendocino.ca.us/aqmd/pages/AQhistory.htm

Ca. 1800 BC. Earliest documented impact of anthropogenic air pollution on human beings. The Beauty of Loulan's lungs were extensively damaged by sand dust and campfire smoke.

Ca. 500 BC. Lao Tzu states impact of man on environment, including air quality.

Ca. 300 AD. Local Roman magistrate passes laws regulating certain sources of air pollution in York, England. (breweries, meat slaughtering)

1180. Moses Maimonides - Describes air pollution in cities and its effects on man.

1272. Edward I - Banned use of "sea coal ". Parliament ordered punishment by torturing and hanging of people who sold and burned the outlawed coal.

1390 (?) Richard II - Regulated and restricted use of coal in London.

1420 (?) Henry V - Ditto.

1661. John Evelyn - Earliest extant treatise on air pollution. "Fumifugium; or the Inconvenience of the Air and Smoke of London Dissipated; Together with Some Remedies Humbly Proposed".

1692. Robert Boyle - " a General History of the Air ", mentions "nitros or salino-sulphureous spirits".

1772. Hales- Analysis of dew and rain, noted that "the air is full of acid and sulphurus particles".

1734. Linne (Sweden) - Studied effects of an iron smelter on local air.

1775. Sir Percival Pott - Intuited that soot has a carcinogenic component causing high incidence of cancer of the scrotum in chimney sweeps.

1852. Robert Angus Smith - Noted three zones of air pollution; fields and open country with carbonate and ammonia, ammonium sulfate in suburbs, and acid sulfate and sulfuric acid in town.

1855. Austria, Germany - Enacted laws against pollution with specific exemptions for air and water!

1872. Robert Angus Smith - "Air and Acid Rain: The Beginnings of a Chemical Climatology" - First use of the term "acid rain".

1895. Earliest known US air pollution law making illegal the "showing of visible vapor" as exhaust from steam automobiles.

1911. Crowther and Ruston - Tie together acid rain and combustion.

1956. British Clean Air Act

1963. US Clean Air Act (CAA)

1965. Title II (US CAA) Motor Vehicle Air Pollution Control Act

1977. Amendments to CAA look for carcinogenic materials (POMS, PNAs).

1980. US/Canada Memorandum of Intent to develop a bilateral approach to the acid rain problem.

1987. Montreal protocol to reduce CFC production (ozone destruction in upper atmosphere)

1987-1997. US NAAQS, 2003 review.

1996 and 2008- EU Air Quality Directives

ATMOSPHERIC POLLUTION

"Comparing the air from cities and deserts and arid terrains is like comparing fetid and dirty waters with pristine waters. In the city, due to the high of the buildings, the narrow streets and all emissions from the inhabitants and their wastes…… the air is stagnant, dense and fogy … If the air is slightly altered, the psychical spirit will be also noticeably altered."

Maimónides (Rabi Mose Ben MAIMON)

Sefardí Doctor from Cordoba, Spain, 1135-1204

ENVIRONMENTAL STRANDARDS FOR AIR QUALITY: EC

		293 °K , 101,3 kPa
Directive 2008/50/CE		except PM and metals, Evrriron. Cond.
Hourly	350 μg/m³ SO_2	24 times per year
Daily	125 μg/m³ SO_2	3 times per year
Annual prot. ecos.	20 μg/m³ SO_2	not exceeding annual and mean 1 Oct-31 Mar
Hourly	200 μg/m³ NO_2	18 times per year
Annual	40 μg/m³ NO_2	not exceeding
Annual prot. vegetation	30 μg/m³ NO_x	(reported as NO_2) not exceeding
Annual	30 (5) μg/m³ Benzene	not exceeding
Mean 8-h max. in a day	10 mg/m³ CO	not exceeding
Annual	500 ng/m³ Pb	not exceeding
Annual	40 μg/m³ PM_{10}	not exceeding
Daily	50 μg/m³ PM_{10}	n<35 per year
Anual	(25 y 20 (18) μg/m³ $PM_{2.5}$)	not exceeding
2010-2020	(reducing 20% $PM_{2.5}$ triennial for mean of urban background)	
2004/107/CE		
Annual	6 ng/m³ As	not exceeding
Annual	20 ng/m³ Ni	not exceeding
Annual	5 ng/m³ Cd	not exceeding
Annual	1 ng/m³ Benzo[α]pirene	not exceeding

Critical parameters (exceedances)

ENVIRONMENTAL STRANDARDS FOR AIR QUALITY: EC

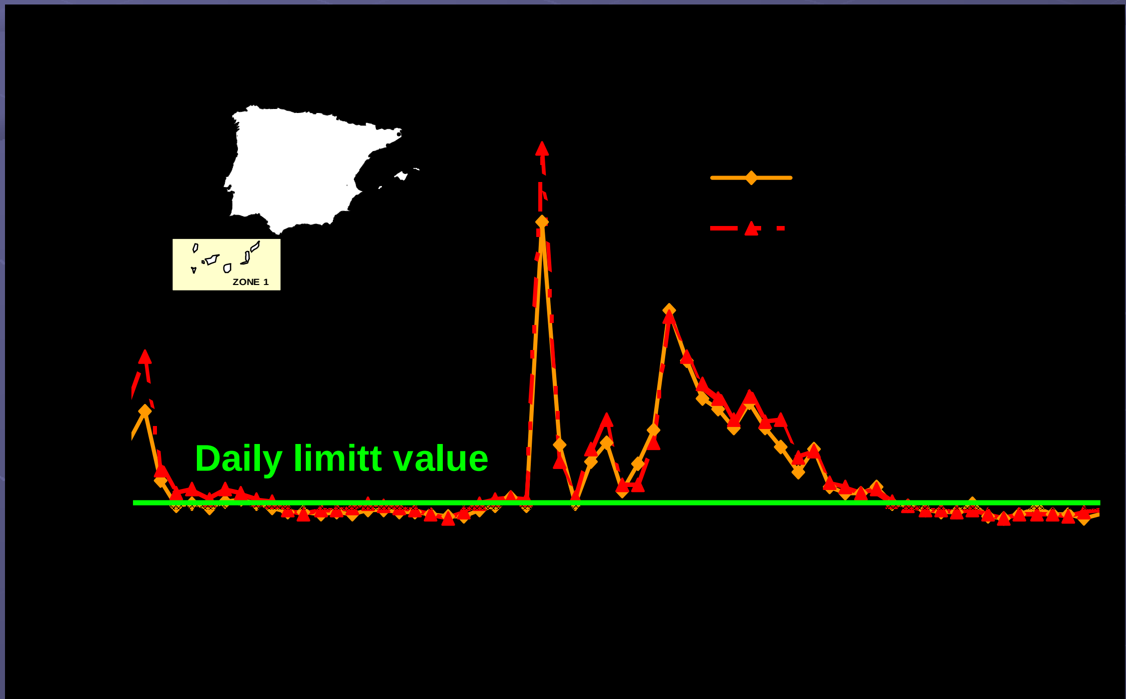
AOT40 [expressed in (µg/m3·h] = as sum of the difference between hourly levels exceeding 80 µg/m^3 and 80 µg/m^3 along a given period using only hourly values measured between 8.00 and 20.00 h, Central Europe Time (CET), for every day.

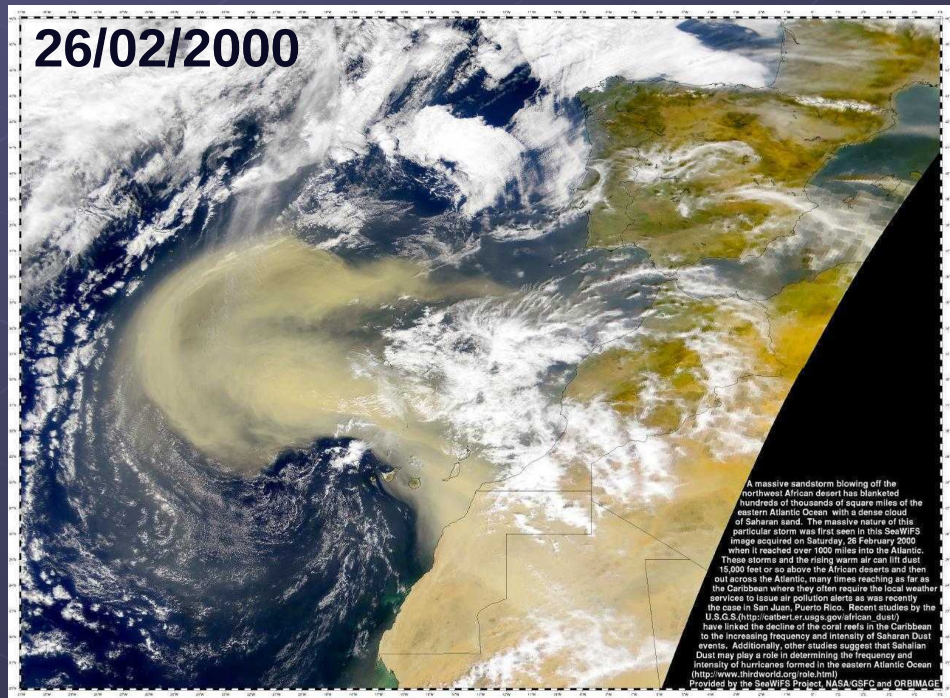
Target value **Protection human health** **Maximum of 8 h means of a day**	**120 µg/m^3 O_3**	**not exceeding 25 day/year mean for 3 years**
Target Value **Protection of vegetation** **AOT40, hourly values from Mayo to July**	**18.000 µg/m^3·h O_3**	**not exceeding as a mean of 5 years (c)**
Information threshold value: hourly		**180 µg/m^3 O_3**
Alert threshold value : hourly		**240 µg/m^3 O_3**

High levels out of urban agglomerations

EC AQ ENVIRONMENTAL STRANDARDS: NATURAL EPISODES

- **2008/50/CE Clean Air for Europe and Air Quality Directive, Article 2: (15) "contributions from natural sources" shall mean emissions of pollutants not caused directly or indirectly by human activities, including natural events such as volcanic eruptions, seismic activities, geothermal activities, wild-land fires, high-wind events, sea sprays or the atmospheric resuspension or transport of natural particles from dry regions;**

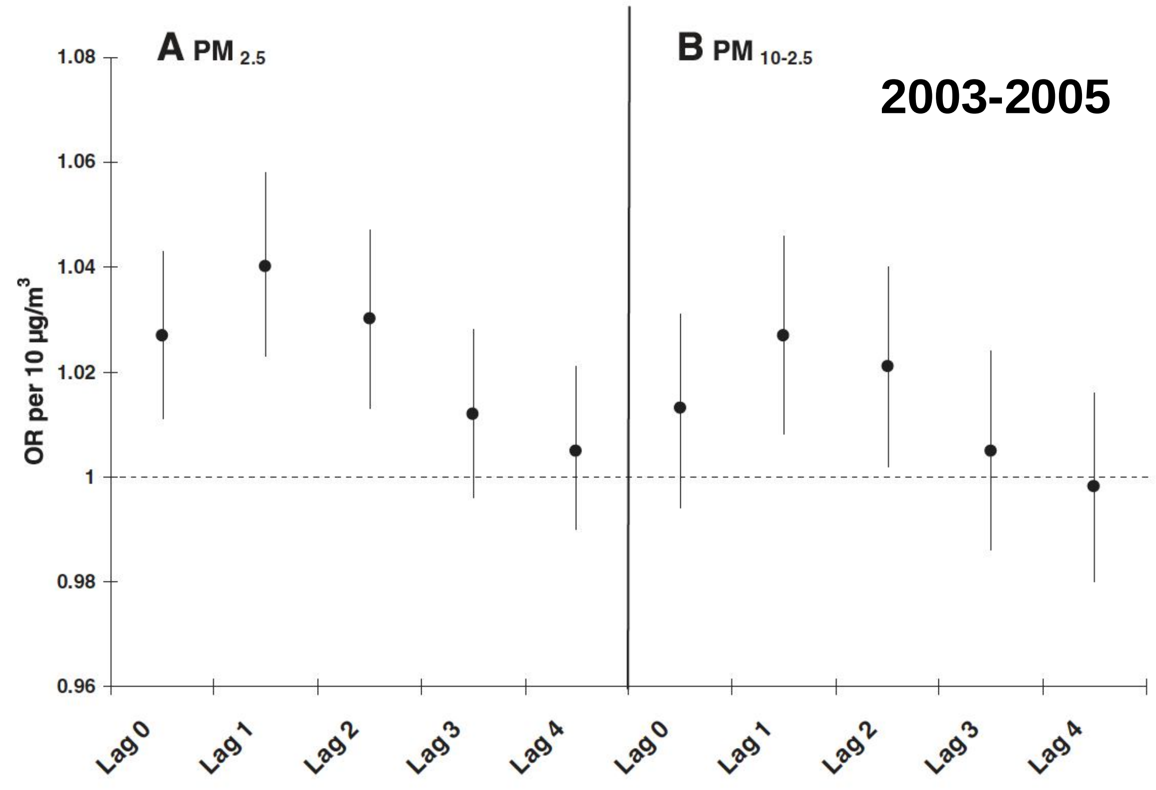




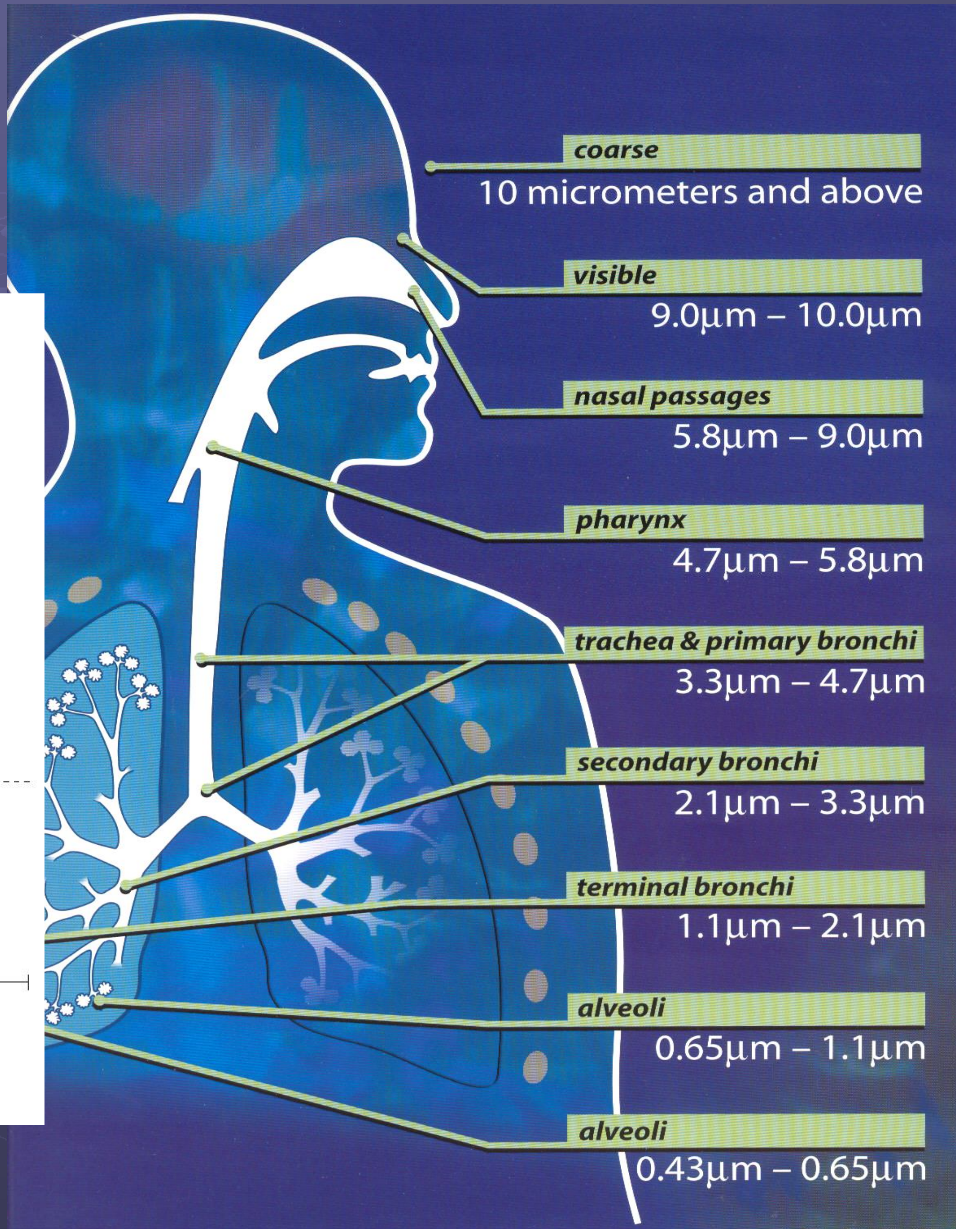
PM EFFECTS

HEALTH EFFECTS

BARCELONA, INCREASE OF MORTALITY

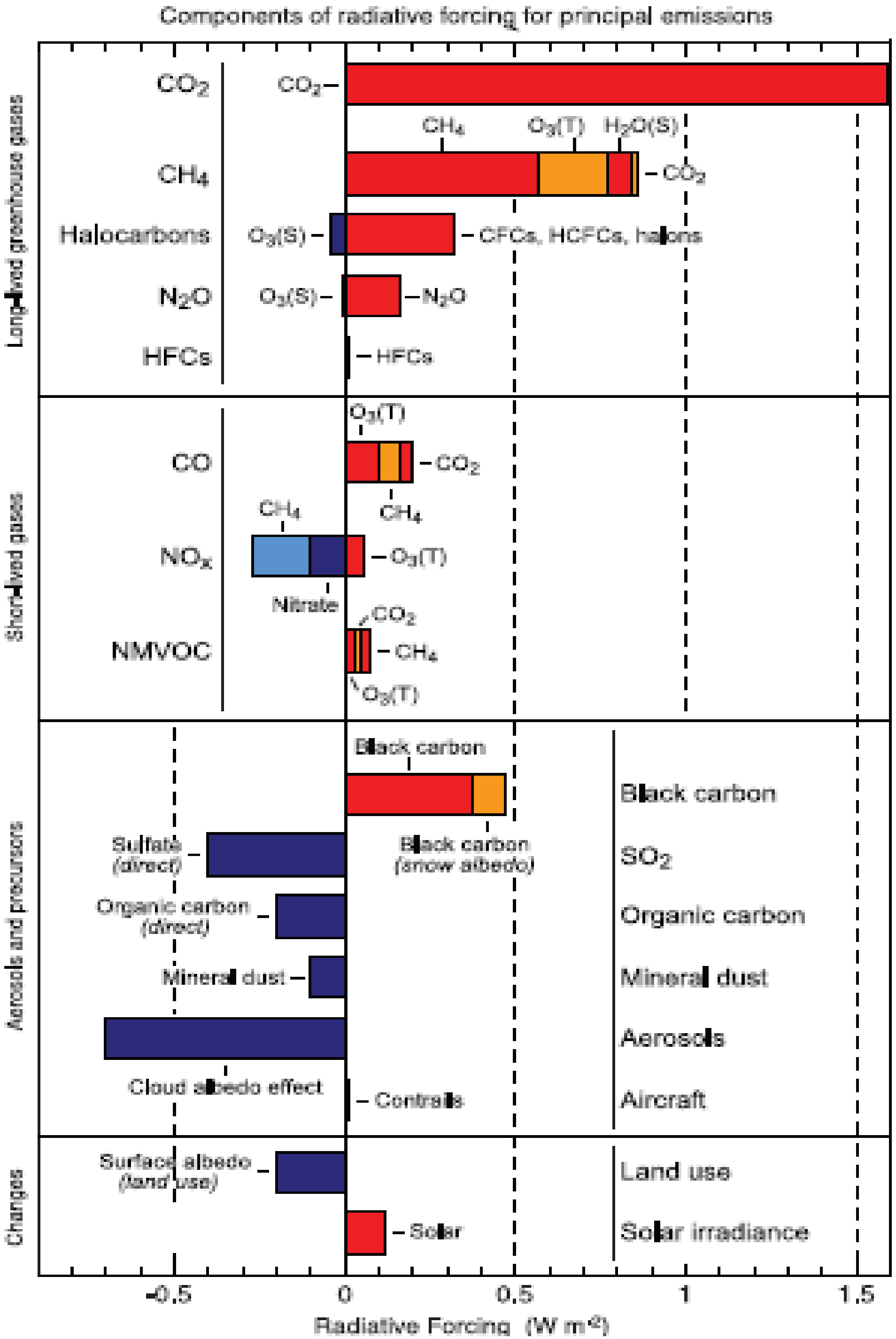


Pérez et al. Epidemiology 2008;19:800-7



PM EFFECTS

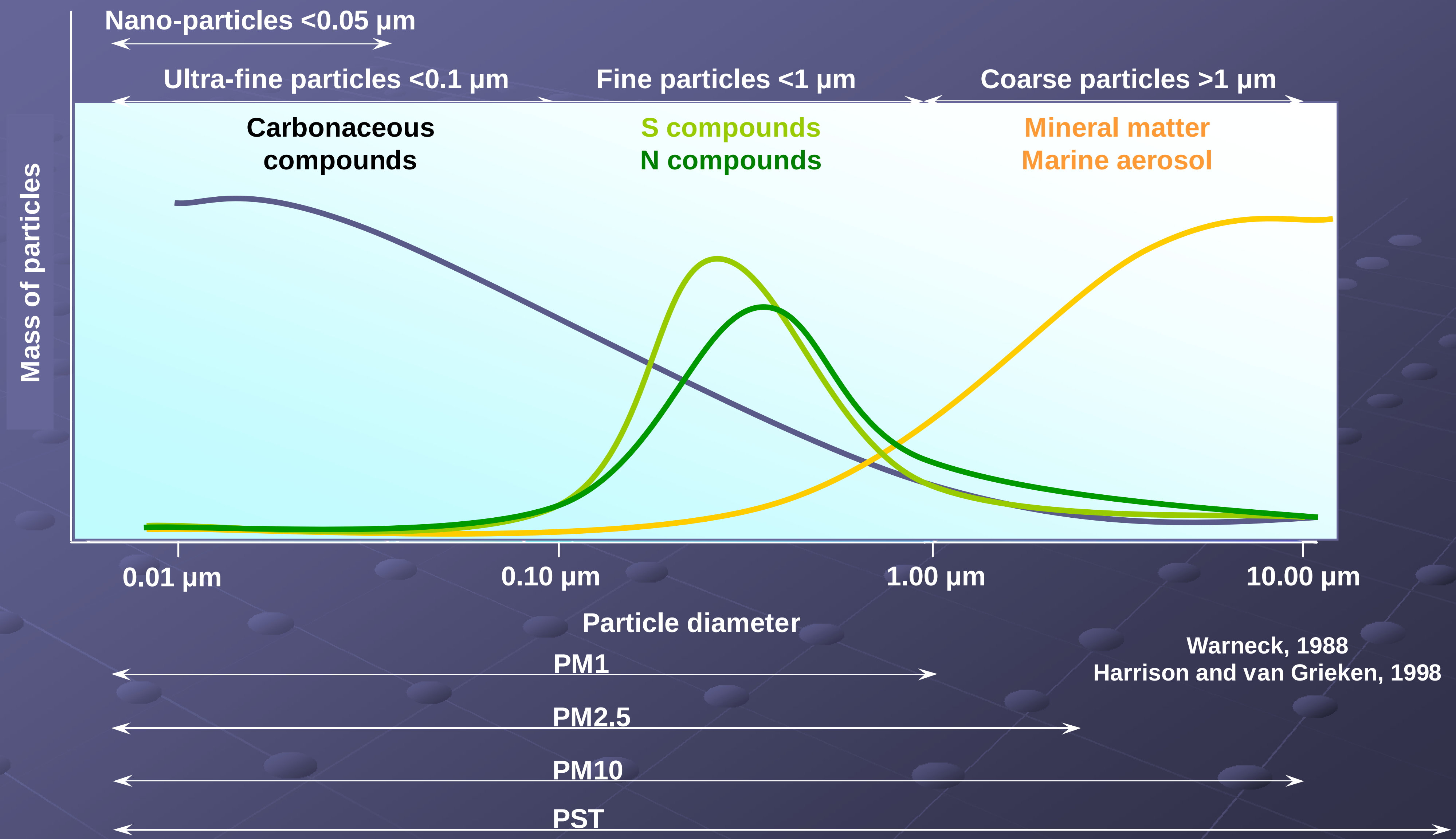
VISIBILITY



Components of radiative forcing for principal emissions
Long-lived greenhouse gases
CO2
CH4
Halocarbons
N2O
HFCs
CO2
CH4
O3(T)
H2O(S)
CO2
O3(S)
CFCs, HCFCs, halons
O3(S)
N2O
HFCs
Short-lived gases
CO
NOx
NMVOC
O3(T)
CO2
CH4
CH4
O3(T)
Nitrate
CO2
CH4
O3(T)
Aerosols and precursors
Black carbon
Sulfate (direct)
Black carbon (snow albedo)
Organic carbon (direct)
Mineral dust
Cloud albedo effect
Contrails
Black carbon
SO2
Organic carbon
Mineral dust
Aerosols
Aircraft
Changes
Surface albedo (land use)
Solar
Land use
Solar irradiance
-0.5
0
0.5
1
1.5
Radiative Forcing (W m-2)

IPCC, 2007

MAIN PM CHARACTERISTICS



Warneck, 1988
Harrison and van Grieken, 1998

CLASSIFICATION OF ATMOSPHERIC PARTICLES

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1. Process of formation:

Primary particles: **directly emitted to the atmosphere as a solid**

Secondary particles: **produced into the atmosphere from gaseous precursors**

example: SO_2 (g) $\rightarrow$ oxidation $\rightarrow$ SO_4^{2-} (s)

2. Origin:

Natural particles

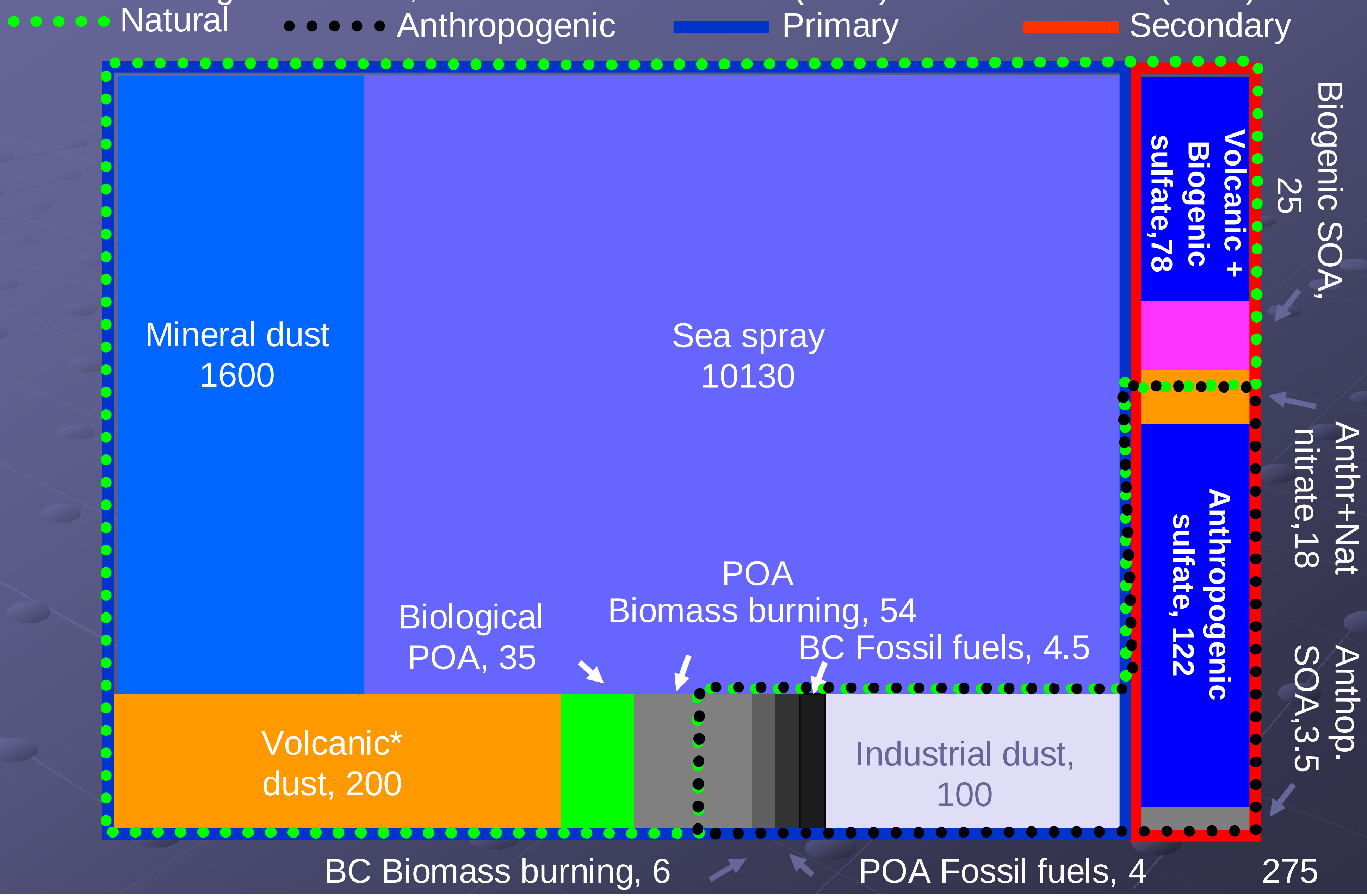
Anthropogenic particles (human activities)

PRIMARY PM

SECONDARY PM

PM ORIGIN

Tera grams / Year, Andreae and Rosenfeld (2008) and Durant et al. (2010)



PM ORIGIN

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Crustal-mineral

Al_2O_3
Mg
Ti
Fe
K
SiO_2
CO_3^{2-}
P
Ca

Carbonaceous aerosols OM and EC

Secondary Inorganic aerosols

NH_4^+
SO_4^{2-}
NO_3^-

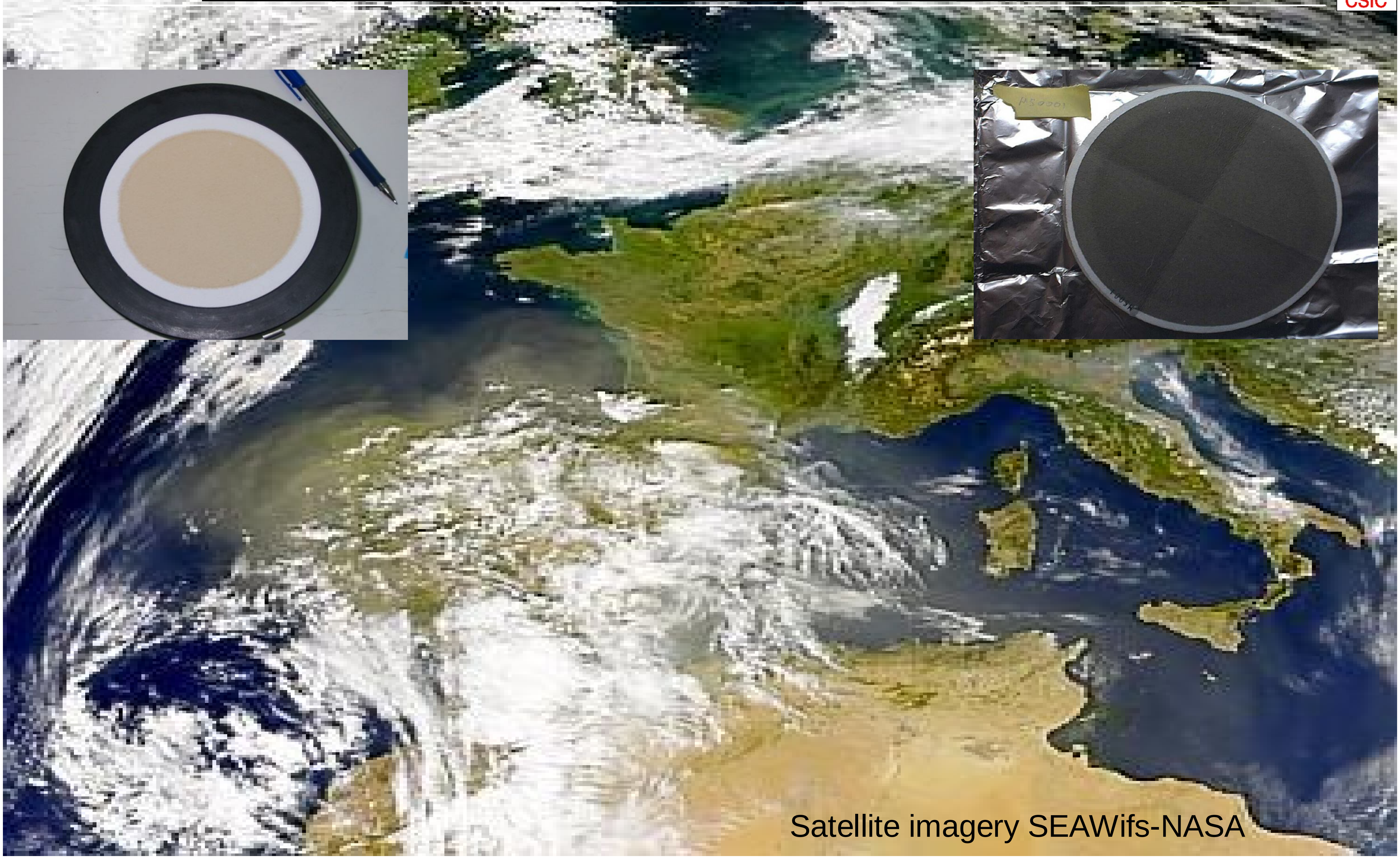
Sea spray

Na^+
Cl^-
SO_4^{2-}

Trace elements

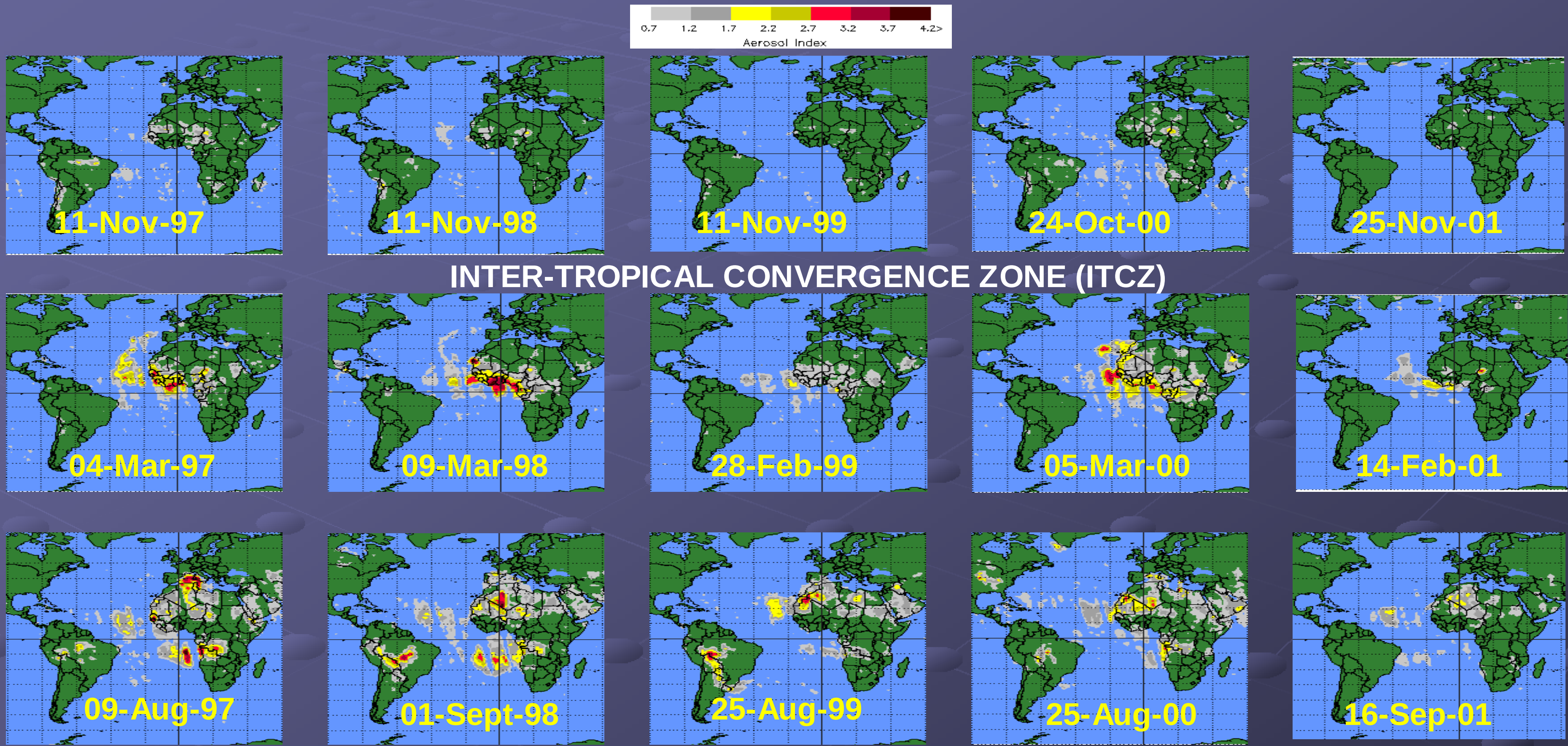
As, Ba, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Ga, Gd, Ge, Hf, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Th, Ti, Tl, U, V, W, Yb, Zn, Zr

IMPACT OF AFRICAN DUST ON AIR QUALITY

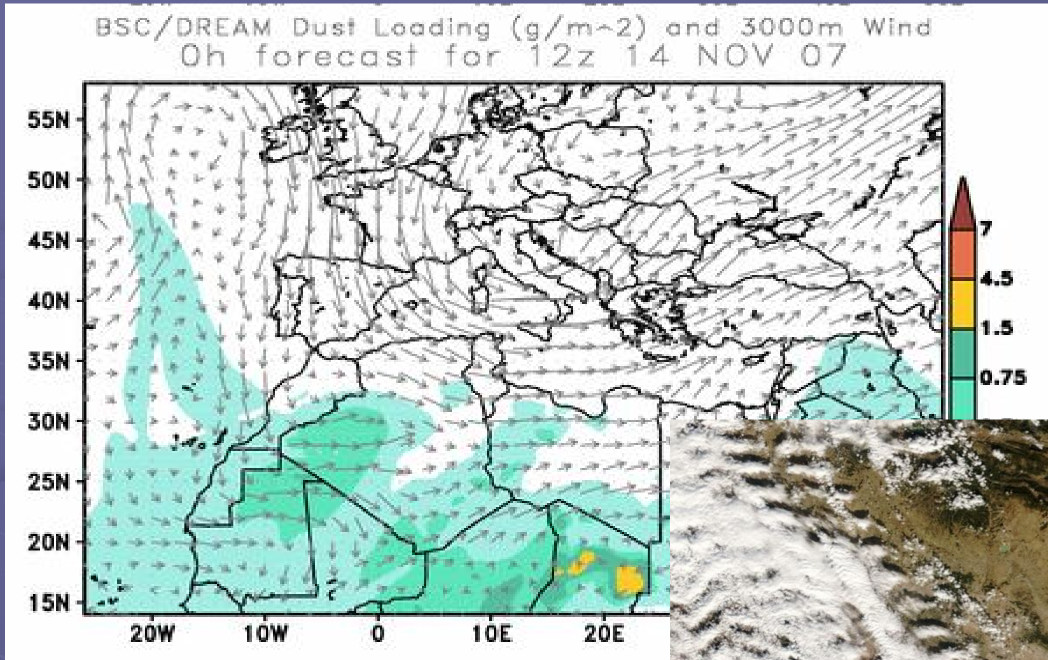


Satellite imagery SEAWifs-NASA

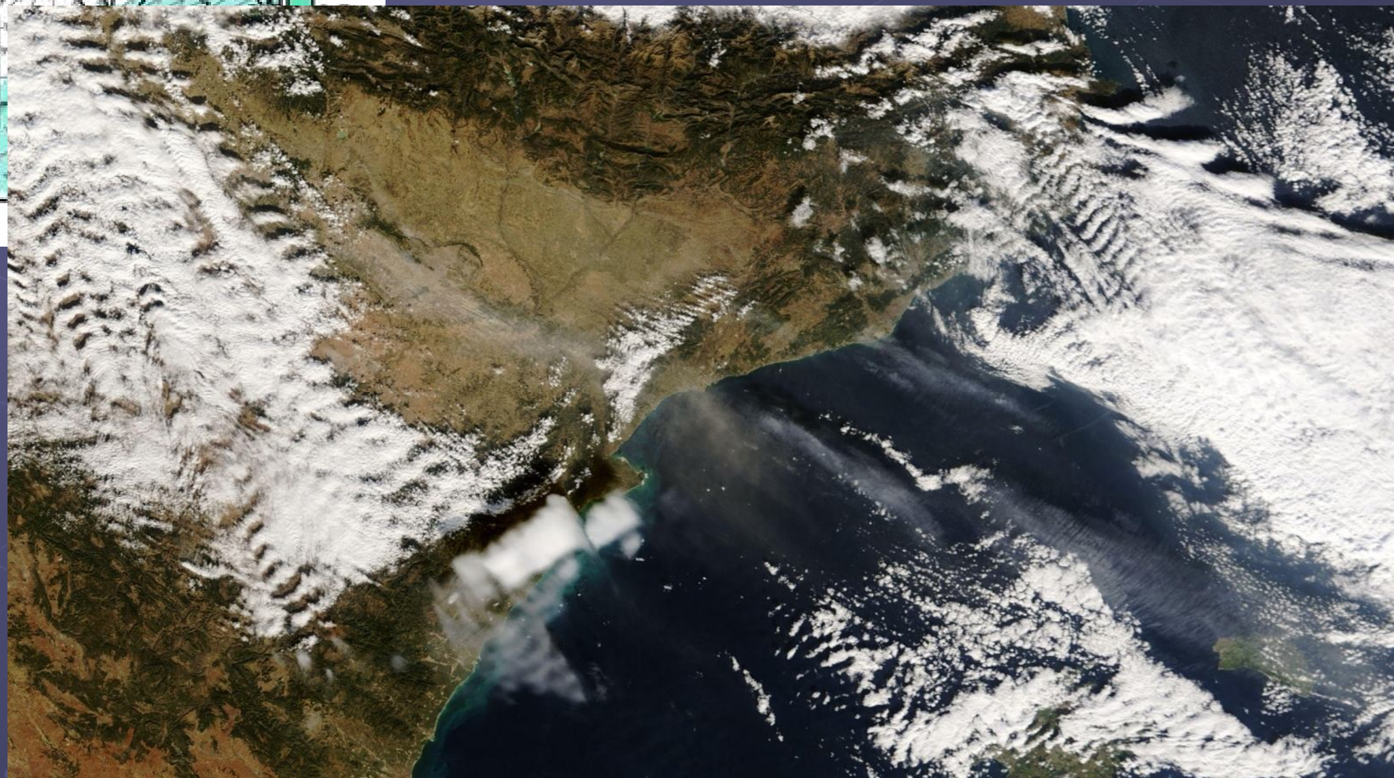
LONG TRANSPORT OF DUST TOWARDS SW EUROPE



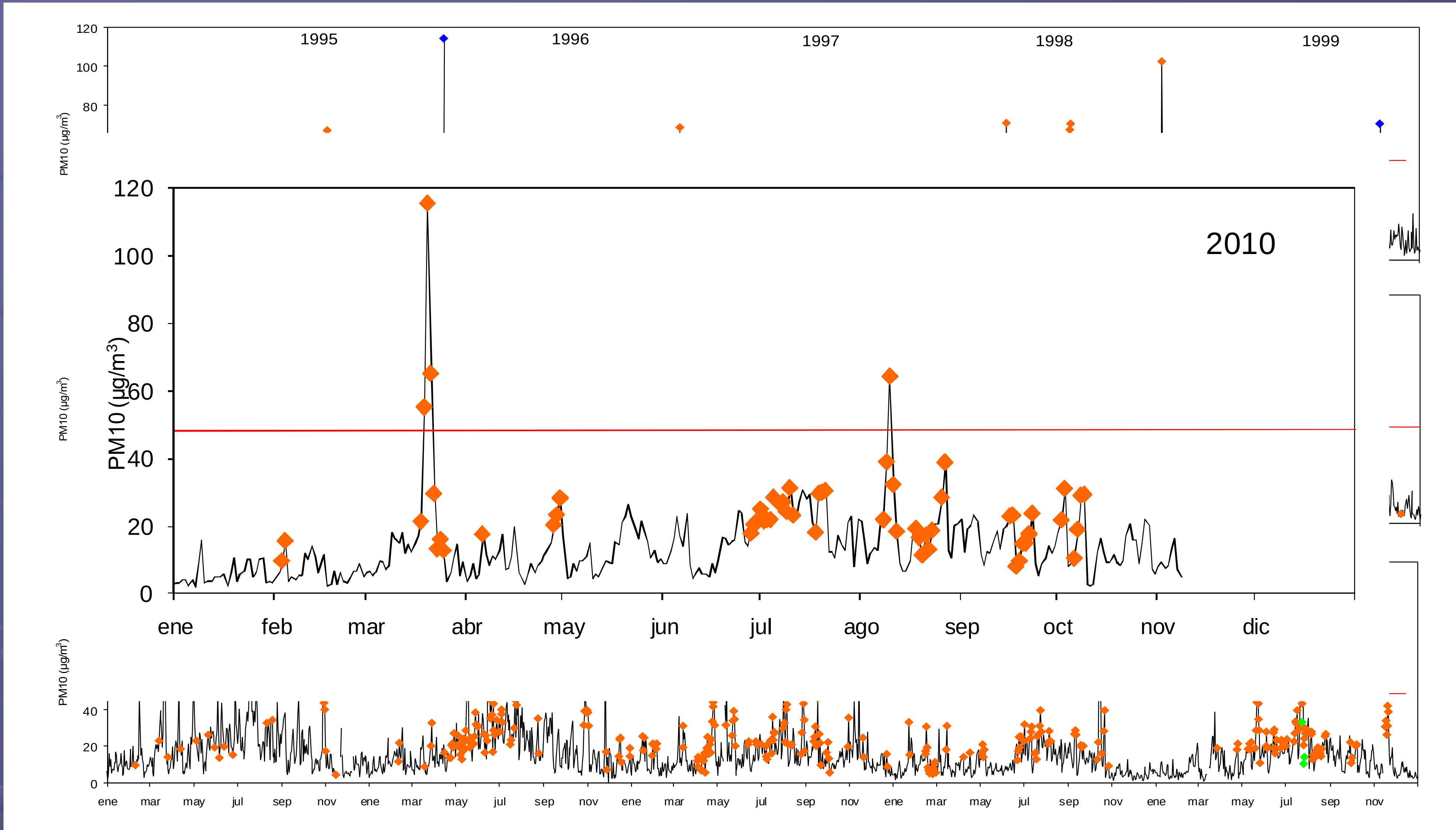
THE EBRO BASIN: A SPORADIC SOURCE OF DUST



Regional dust plume from
Ebro basin 14th November 2007



1995-2009 DAILY PM10 LEVELS: RURAL SITE CALANDA-ALCORISA



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

68 out of 77 exceedances registered in 15.5 years are caused by African dust outbreaks

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

COMPOSITION OF AFRICAN DUST

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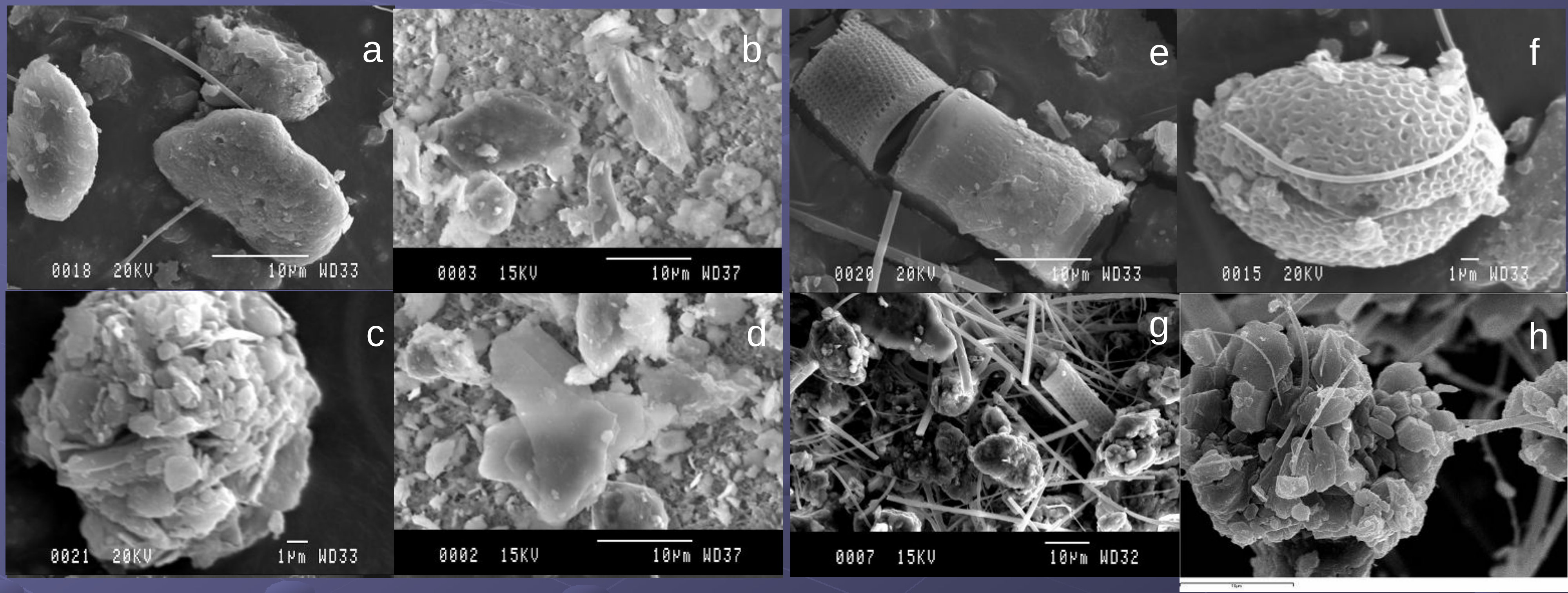
	IZAÑA			STA. CRUZ		
Period	28/07/02 20h to 31/07/02 20h			28/07/02 13h to 31/07/02 13h		
µg/m^3	TSP	PM2.5	PM2.5/TSP	TSP	PM2.5	PM2.5/TSP
PM	396.2	64.5	0.16	344.7	33.2	0.10
SiO_2	182.7	26.5	0.15	89.6	3.2	0.04
Al_2O_3	60.9	8.8	0.15	29.9	1.1	0.04
Ca	12.8	1.7	0.13	15.6	0.3	0.02
K	7.0	0.9	0.13	4.8	0.2	0.05
Mg	5.4	0.9	0.17	5.2	0.2	0.05
Fe_2O_3	24.1	3.5	0.15	14.9	0.3	0.02
TiO_2	2.8	0.4	0.16	2.3	0.0	0.02
Na	4.6	0.4	0.10	19.6	1.6	0.08
Cl^-	2.4	0.2	0.10	33.9	0.3	0.01
SO_4^{2-}	4.3	2.5	0.59	29.4	8.7	0.30
NO_3^-	2.1	0.5	0.25	13.2	0.4	0.03
NH_4^+	0.4	0.4	0.89	6.7	2.5	0.37
Total C	4.0	1.3	0.34	11.1	3.3	¡0.30!
Trace elem.	1.0	0.2	0.17	1.1	0.1	0.13
Determined	>80%	>75%		>80%	>70%	

COMPOSITION OF AFRICAN DUST

MINERALOGY		Izaña	Sta Cruz
		30/07/2002	30/07/2002
		%	%
Quartz	SiO_2	23	23
Clay minerals			
Paligorskite	$Mg_5(Si,Al)_8O_{20}(OH)_2.8H_2O$	10	9
Illite	$(KH_3O)Al_2Si_3AlO_{10}(OH)_2$	15	13
Kaolinite	$Al_2Si_2O_5(OH)_4$	14	10
Cinochlore	$(Mg,Fe)_6(Si,Al)_4O_{10}(OH)_8$	8	9
Feldspars			
Albite	$NaAlSi_3O_8$	5	5
Microcline	$KAlSi_3O_8$	4	5
Hematite	Fe_2O_3	1	1
Calcite	$CaCO_3$	9	6
Gypsum	$CaSO_4.2H_2O$	3.5	10
Halite	NaCl	0	2
Mascagnite	$(NH_4)_2SO_4$	6	5

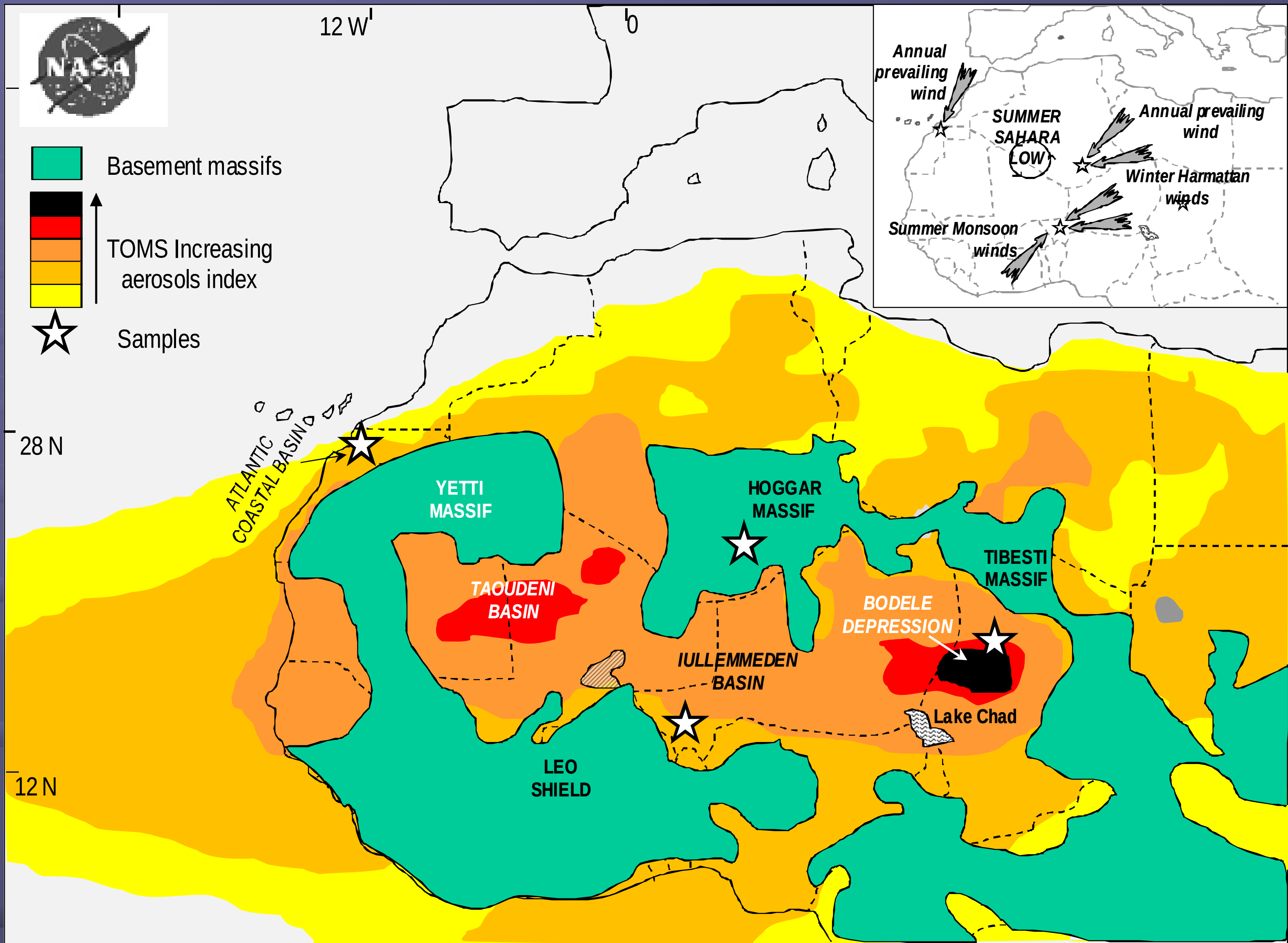
COMPOSITION OF AFRICAN DUST

CSIC

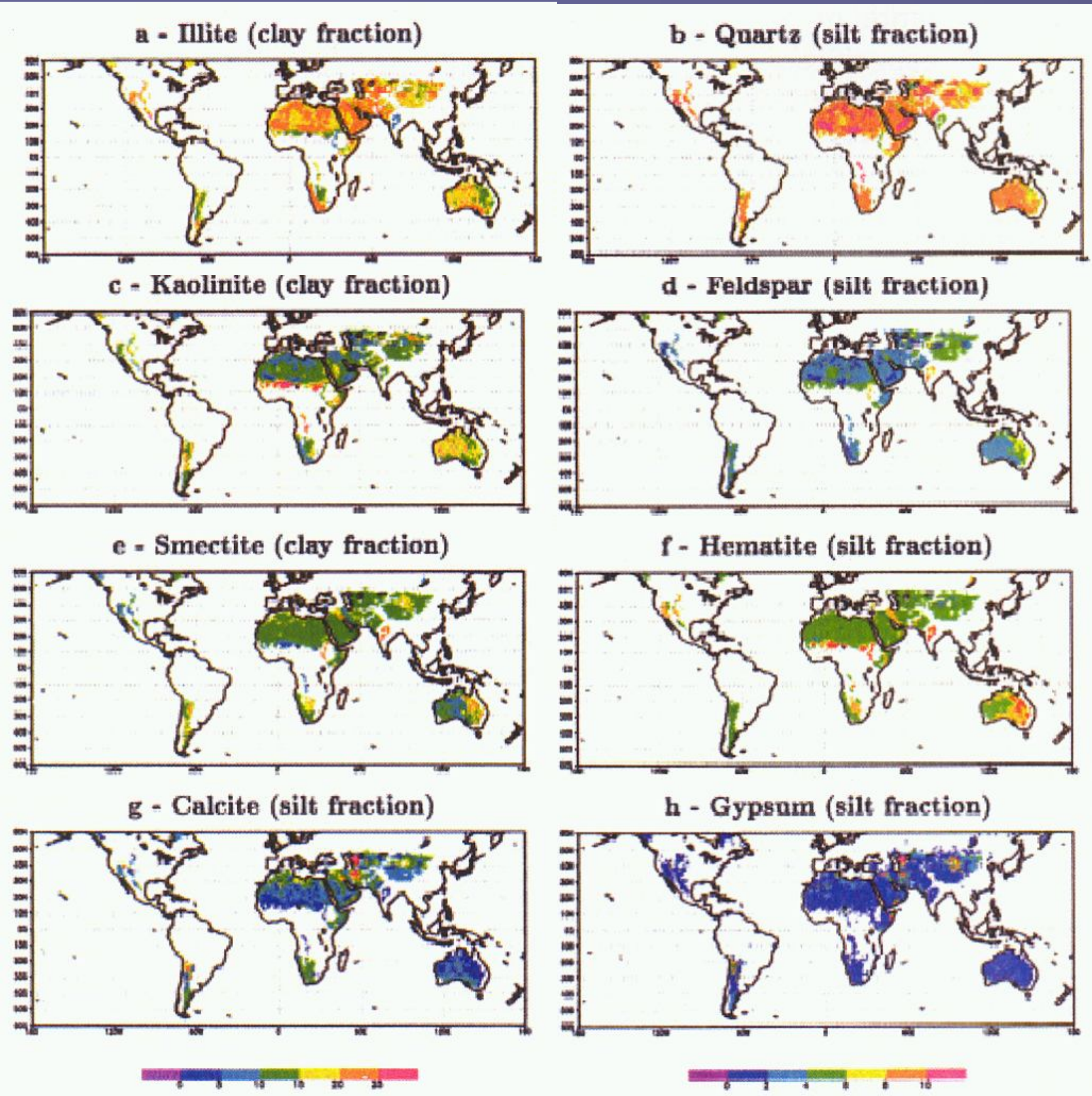


SOURCE AREAS OF DUST

MORENO T. et al., 2006. Chemosphere

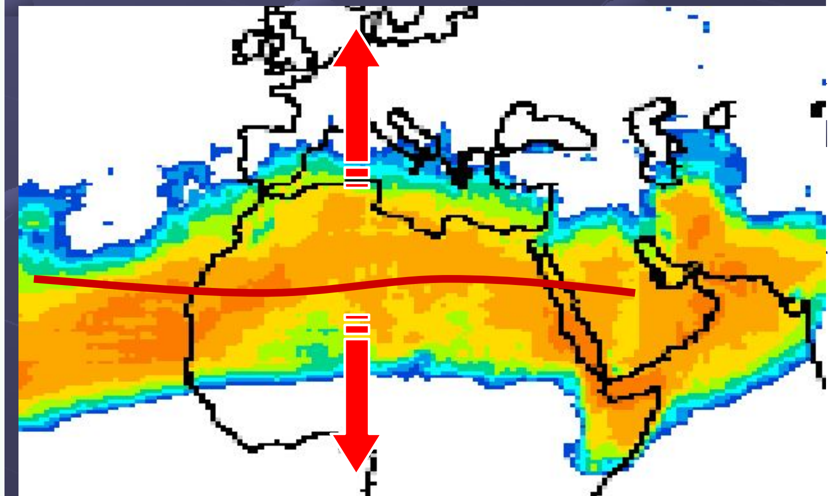


COMPOSITION OF AFRICAN DUST AS A FUNCTION OF SOURCE AREA



Geographical variations in mineral aerosols distribution

Illite, chlorite, paligorskite, montmorillonite, carbonates



Kaolinite, hematite

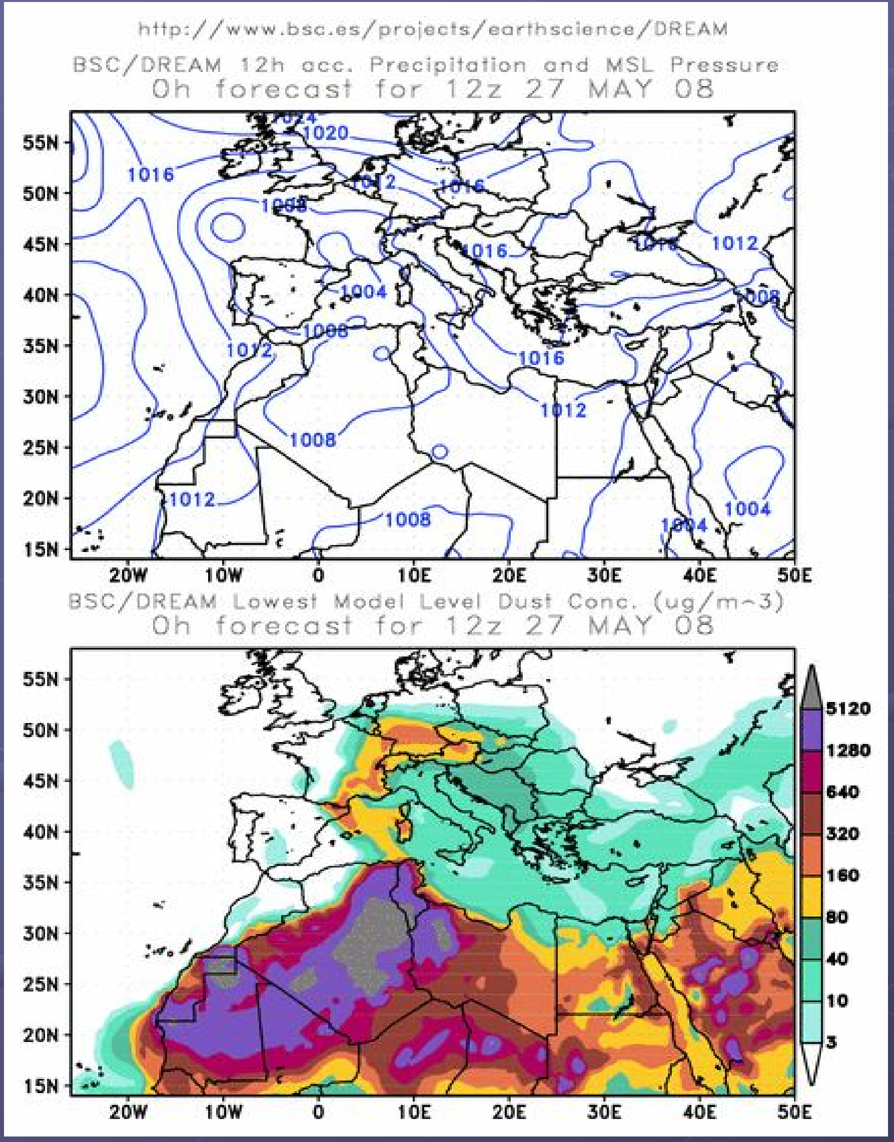
Claquin et al., 1999

DETECTION OF DUST OUTBREAKS

CSIC

1. TOMS
2. SKIRON
3. BSC-DREAM
4. NAAPs-NRL
5. AIR MASS BACK-TRAJECTORIES (HYSPLIT)
6. NASA satellite imagery
7. HYSPLIT Dust storm forecast system
8. SeaWIFS, MODIS-Terra satellite imagery

DETECTION OF DUST OUTBREAKS



DREAM-BSC

Surface dust concentration maps, free download from BSC:

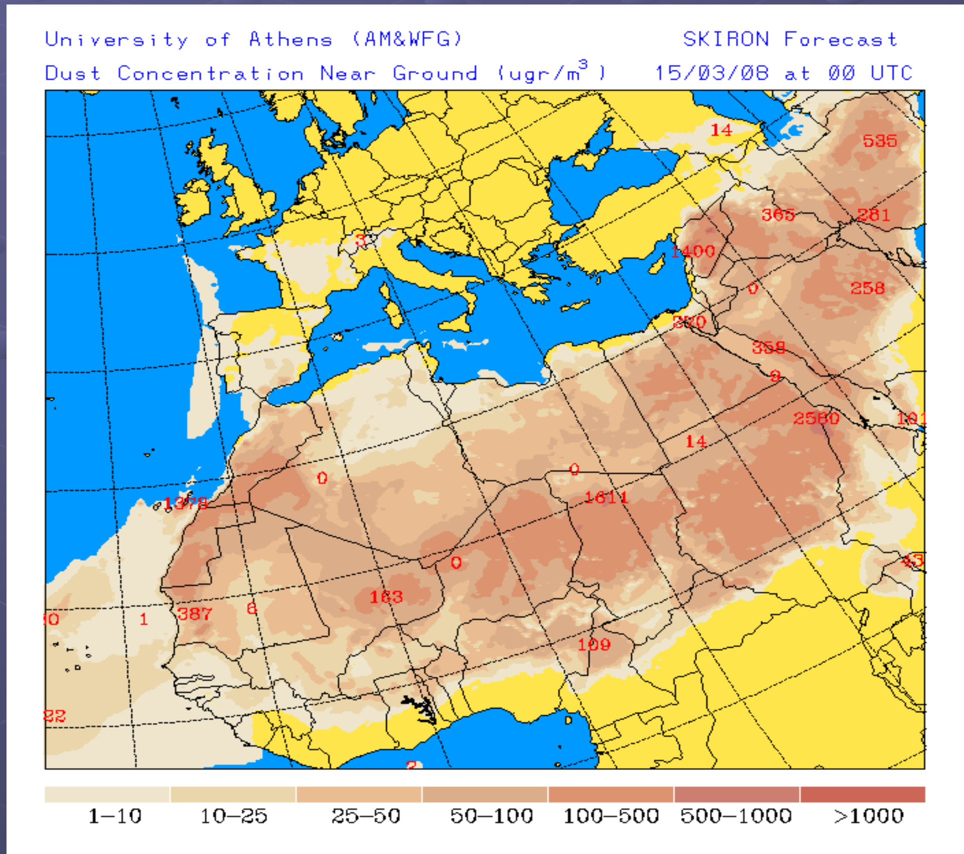
http://lma.upc.es/DREAM/

DETECTION OF DUST OUTBREAKS

SKIRON simulations

Integrated dust load maps, free download from Athens University:

http://forecast.uoa.gr



DETECTION OF DUST OUTBREAKS

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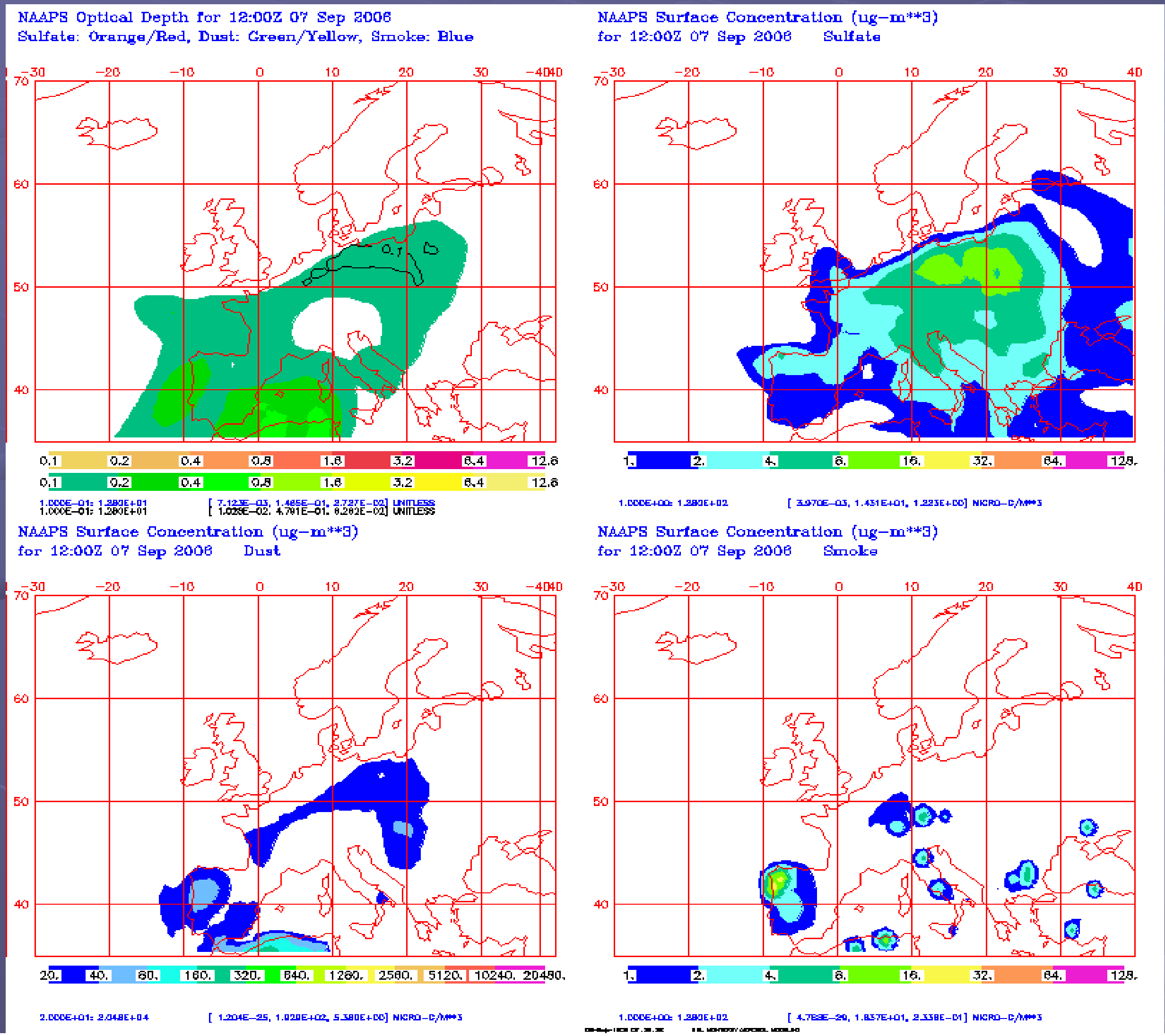
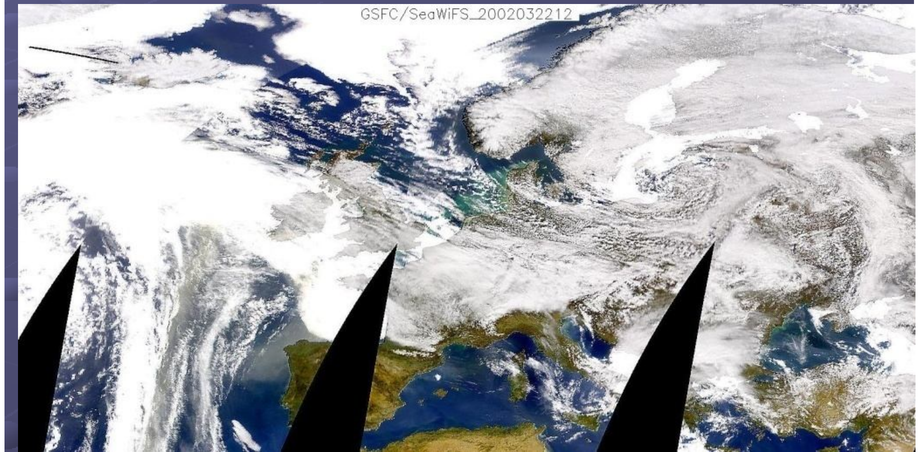
NAAPS - NRL

Surface dust, sulfate and smoke concentration maps, free download from NRL:

http://www.nrlmry.navy.mil/aerosol/

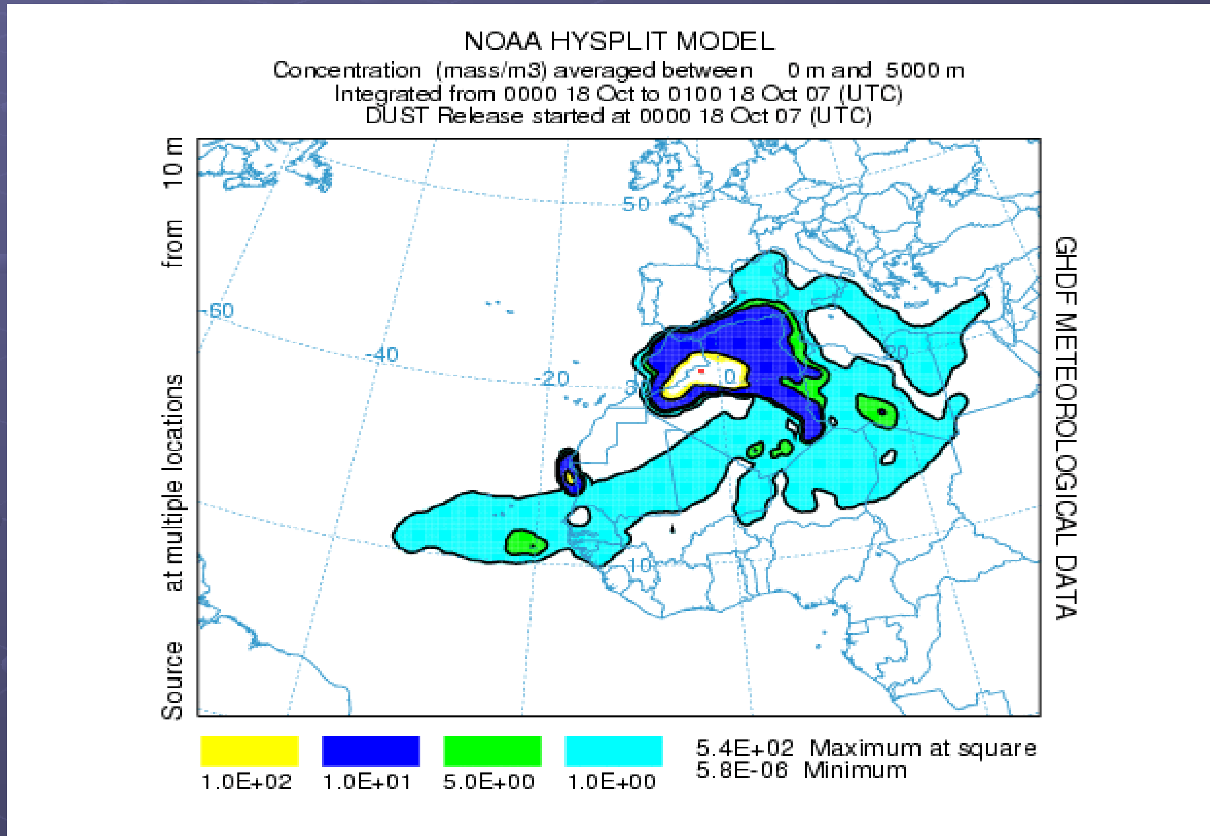




DETECTION OF DUST OUTBREAKS

HYSPLIT DUST storm forecast system

Results posted:
http://www.ciecem.uhu.es



National Oceanic and Atmospheric Administration
ARL
Air Resources Laboratory

Universidad de Huelva

Consejería de Medio Ambiente

CSIC

QUANTIFICATION OF DUST CONTRIBUTIONS

CSIC

ZONES AND MONITORING NETWORK

Other than EMEP

EMEP stations with real time measurements

EMEP station with gravimetric measurements

GOBIERNO DE ESPAÑA

MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

QUANTIFICATION OF DUST CONTRIBUTIONS

CSIC

List of episodes

Dirección General de Calidad y Evaluación Ambiental

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			

FEBRERO 2008

FEBRERO 2008						
	CANARIAS	SUROESTE	SURESTE	LEVANTE	CENTRO	NOROESTE
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

MAYO 2008

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

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

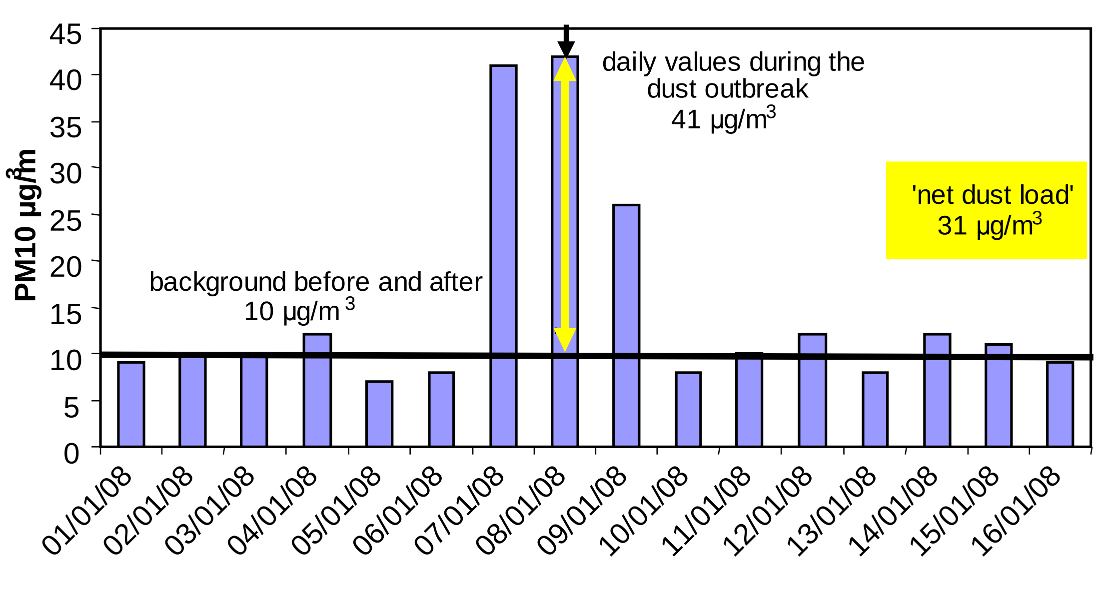
MAYO 2008

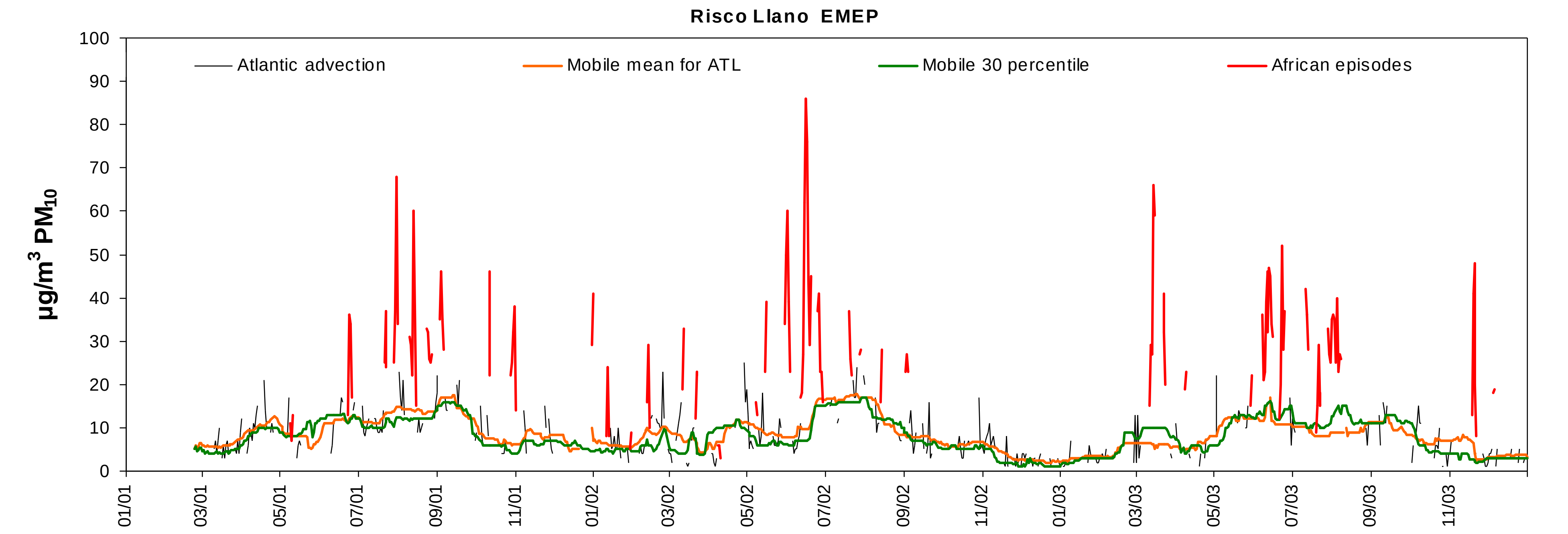
MAYO 2008									
	CANARIAS	SUROESTE	SURESTE	LEVANTE	CENTRO	NOROESTE	NORTE	NORESTE	BALEARES
COMBUSTIÓN BIOMASA									
EUROPEO SULFATOS									
AFRICANOS		2-6	2-6	3-6	2-6	3-6	3-6	2-6	2-6

GOBIERNO DE ESPAÑA

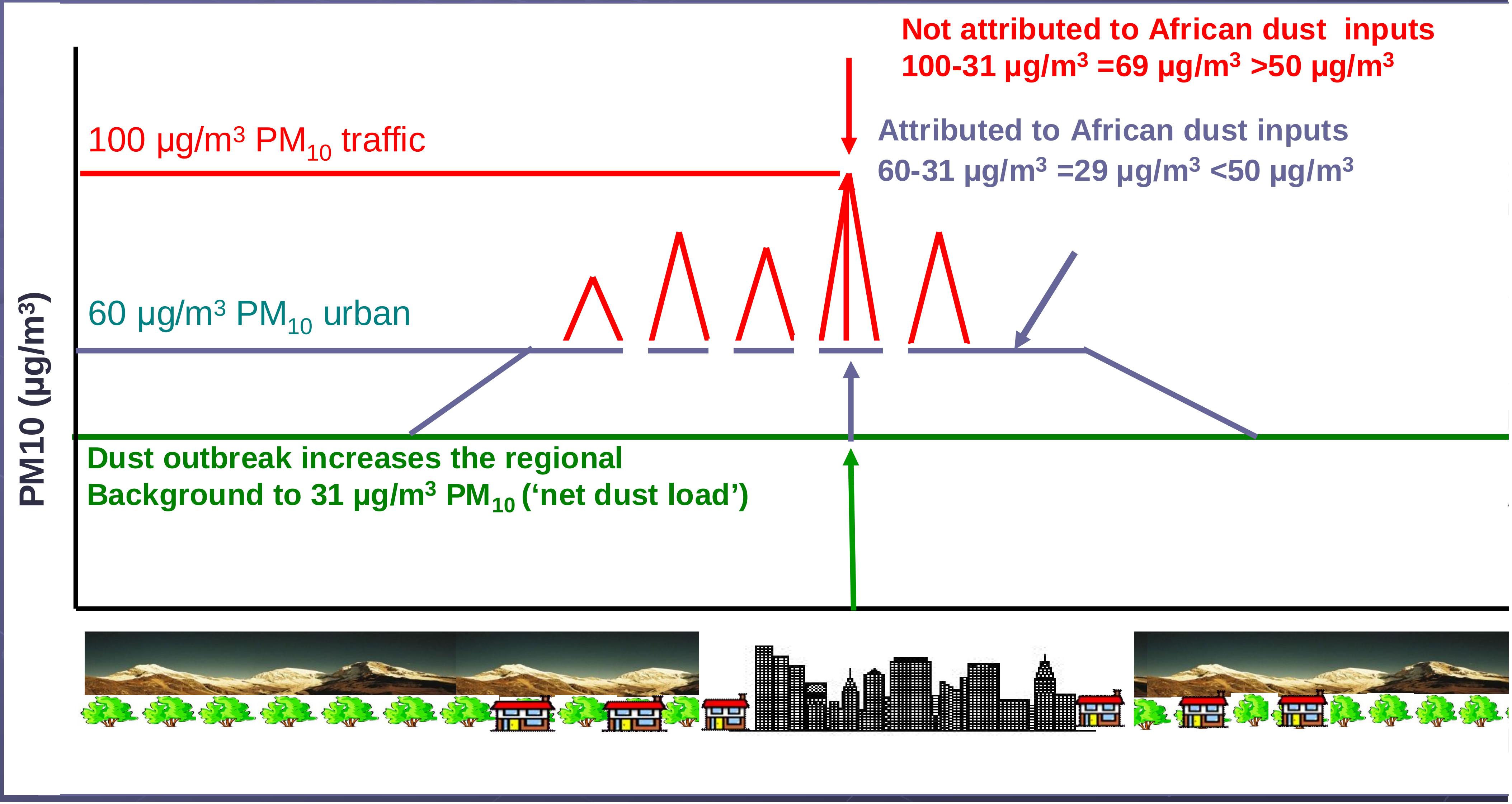
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

QUANTIFICATION OF DUST CONTRIBUTIONS



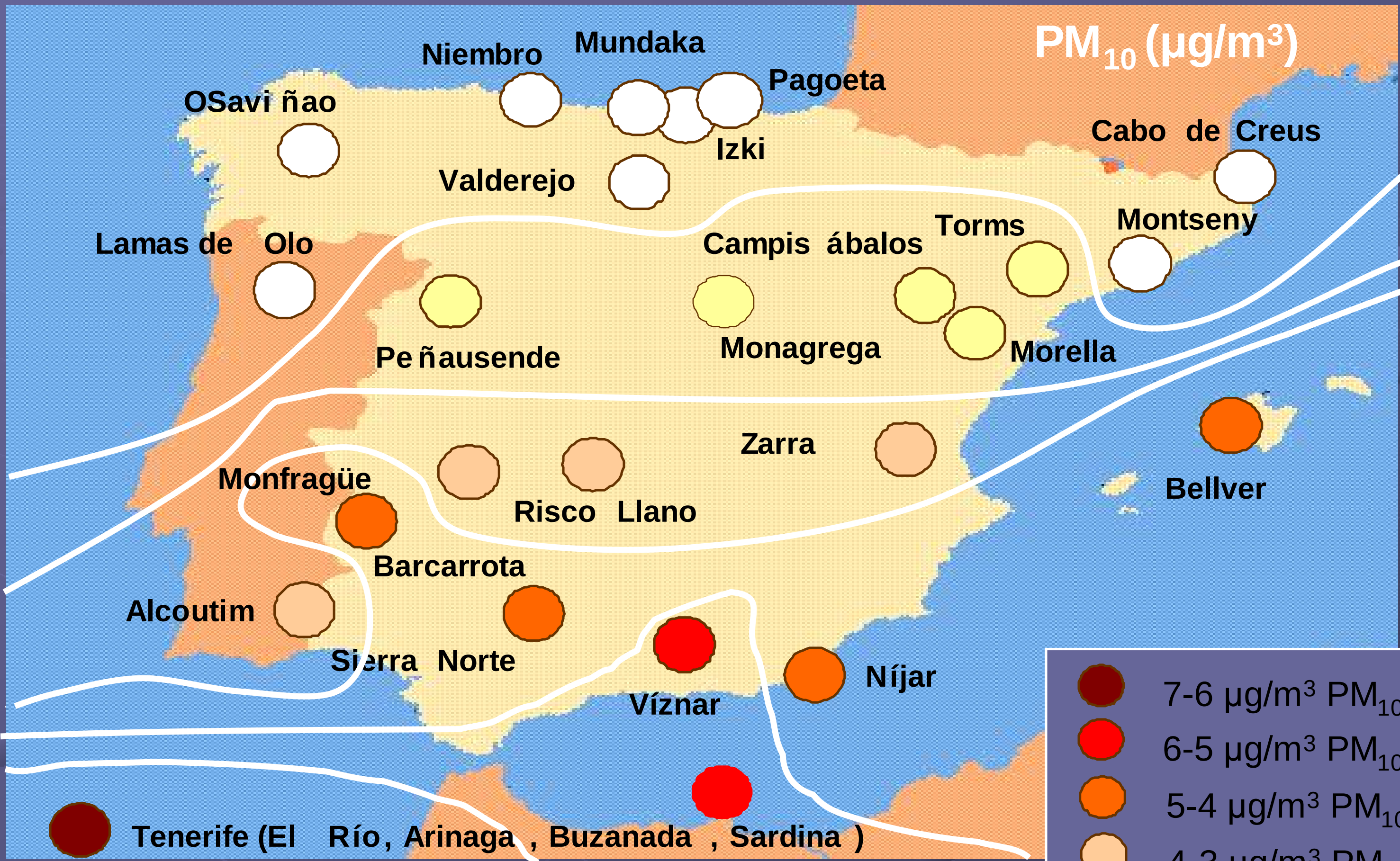


QUANTIFICATION OF DUST CONTRIBUTIONS



QUANTIFICATION OF DUST CONTRIBUTIONS

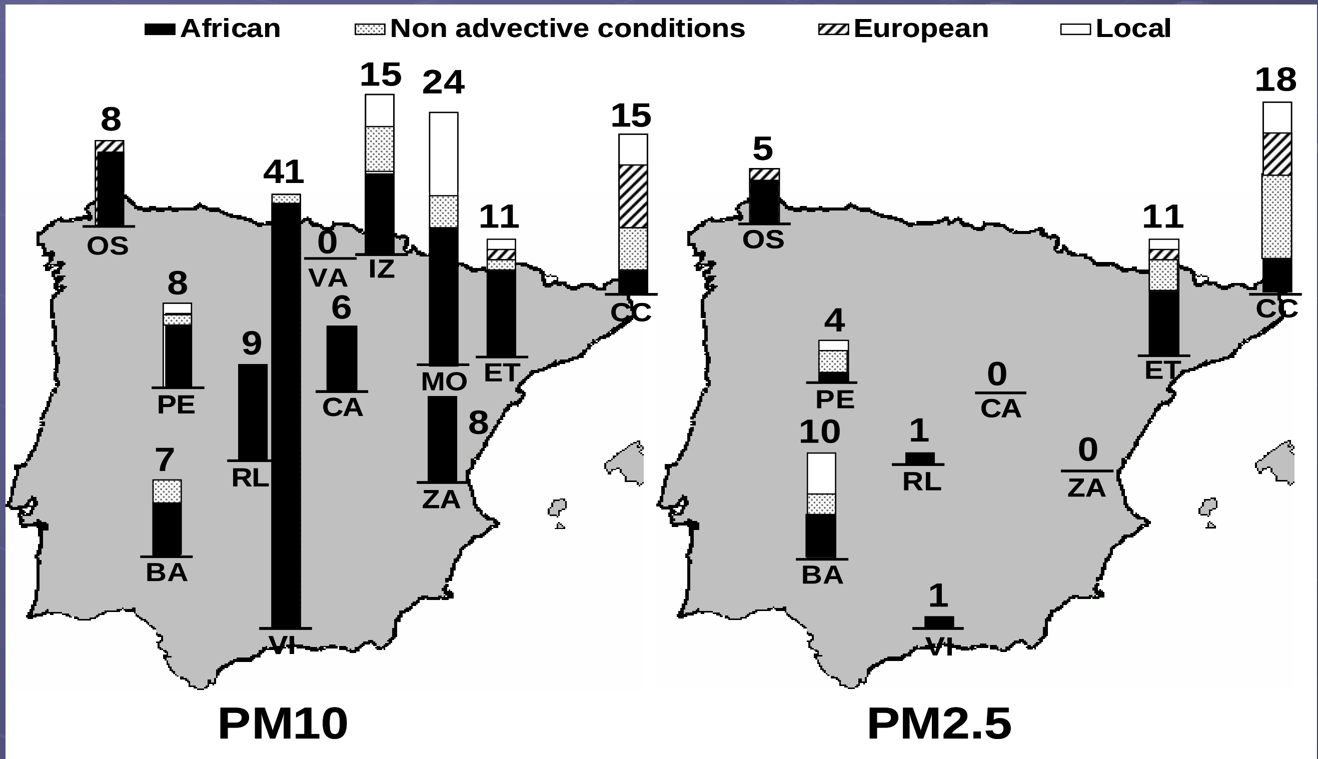
African dust contributions to the annual PM_{10} mean levels



- 7-6 µg/m³ PM_{10} on an annual basis
- 6-5 µg/m³ PM_{10} on an annual basis
- 5-4 µg/m³ PM_{10} on an annual basis
- 4-3 µg/m³ PM_{10} on an annual basis
- 3-2 µg/m³ PM_{10} on an annual basis
- 2-1 µg/m³ PM_{10} on an annual basis

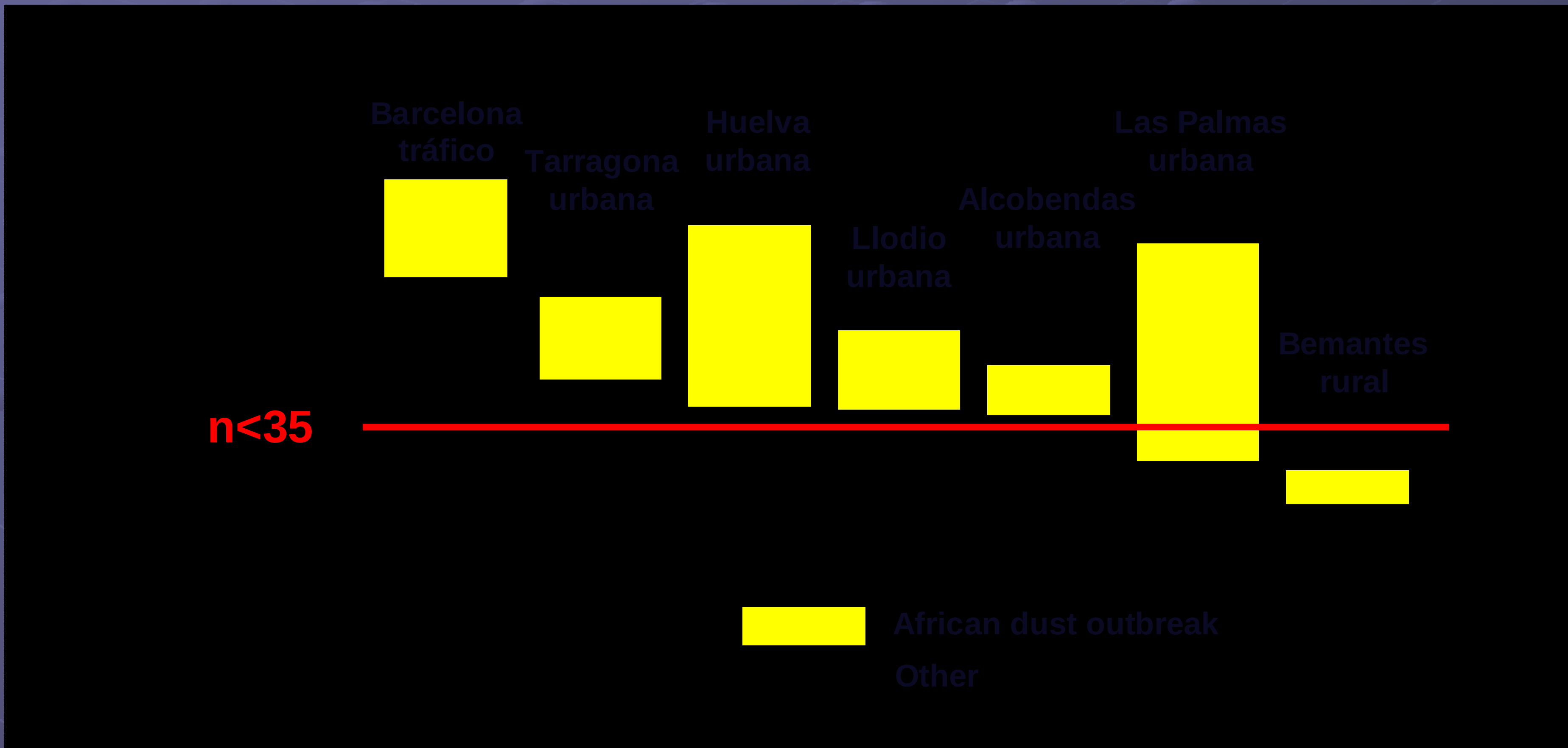
QUANTIFICATION OF DUST CONTRIBUTIONS

EMEP stations :Exceedances of the daily limit values (2001-2003)

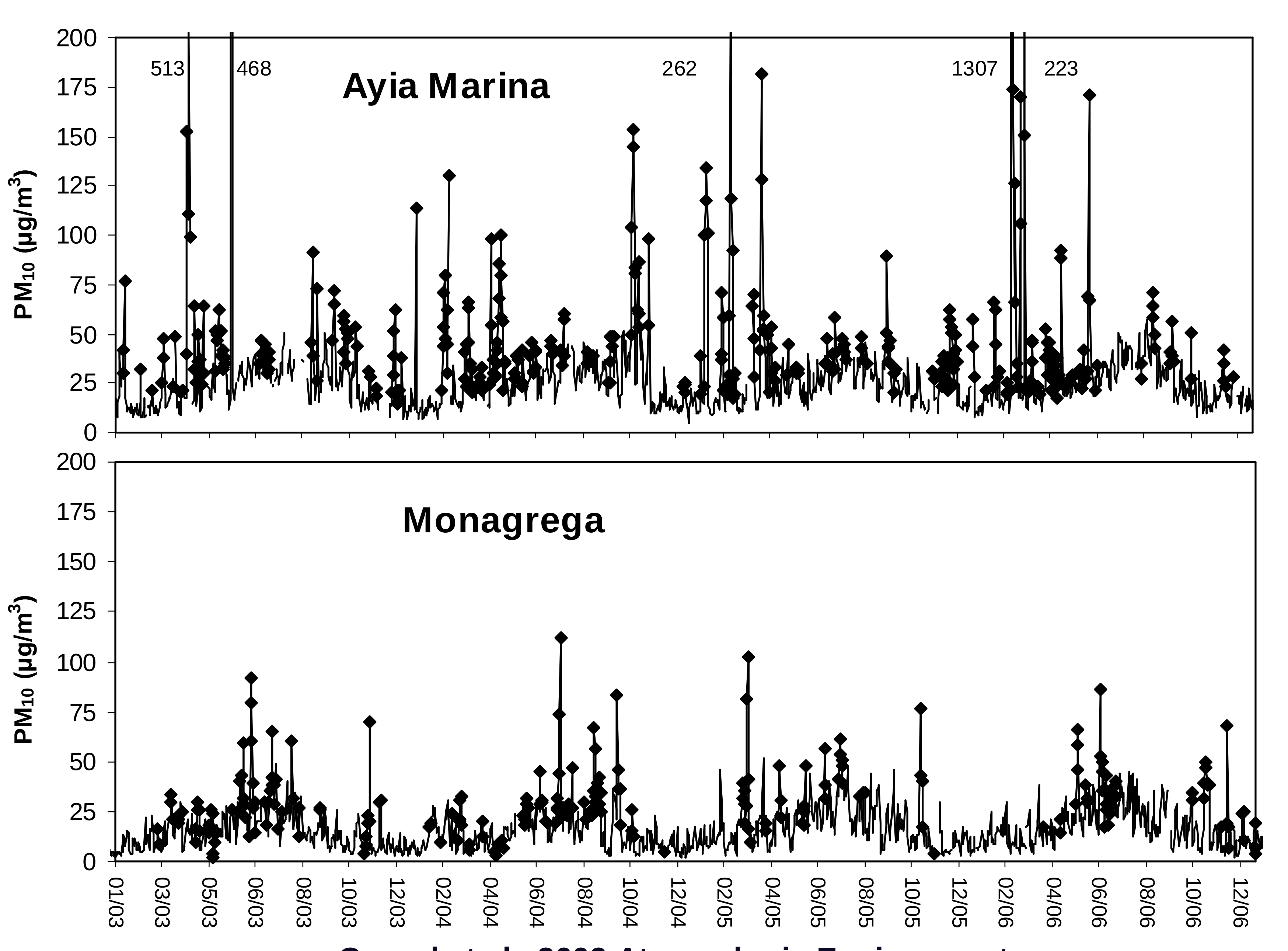


QUANTIFICATION OF DUST CONTRIBUTIONS

‘n’ of exceedances of the DLV 50 µgPM10/m3 in urban areas



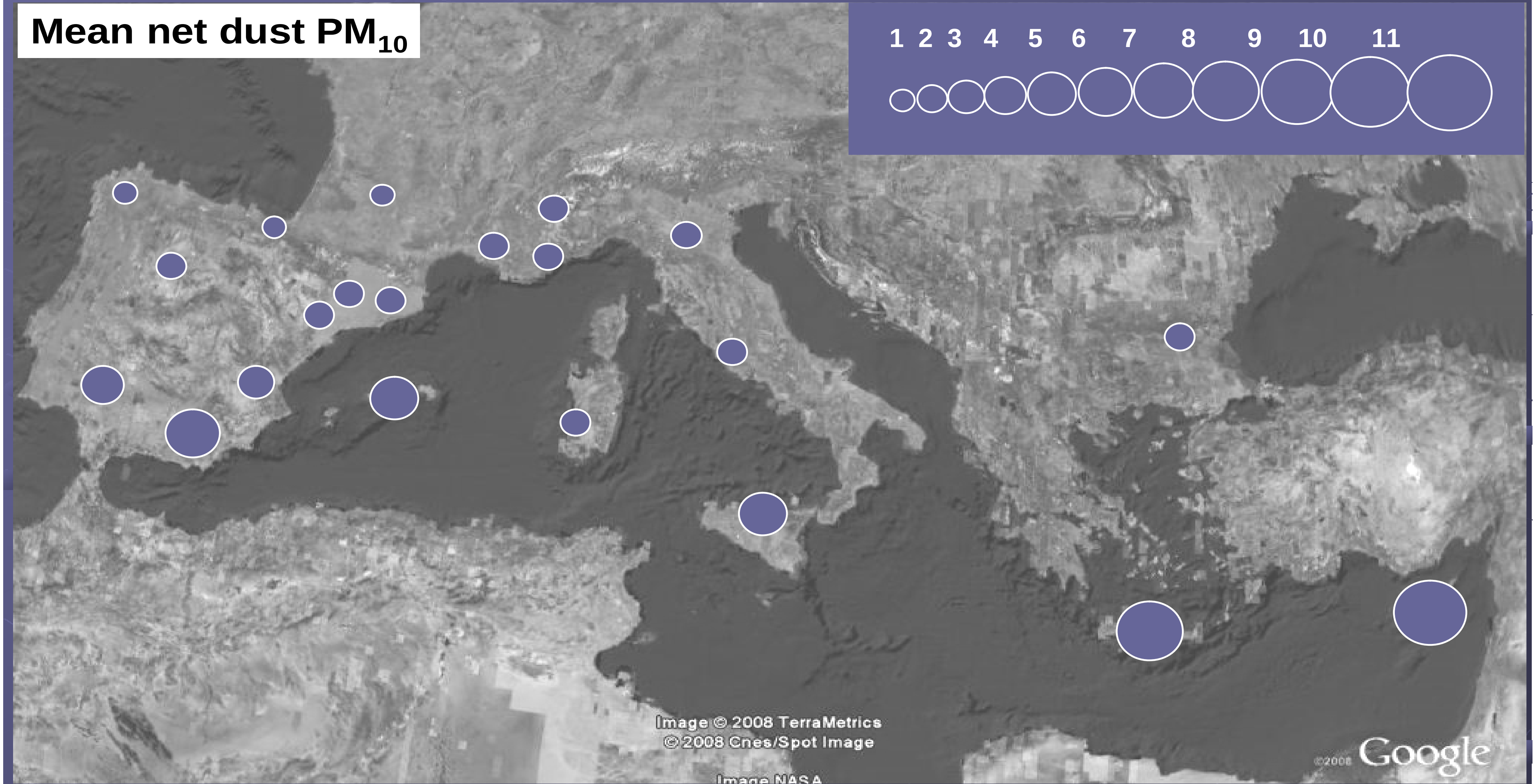
QUANTIFICATION OF DUST CONTRIBUTIONS



Querol et al., 2009 Atmospheric Environment

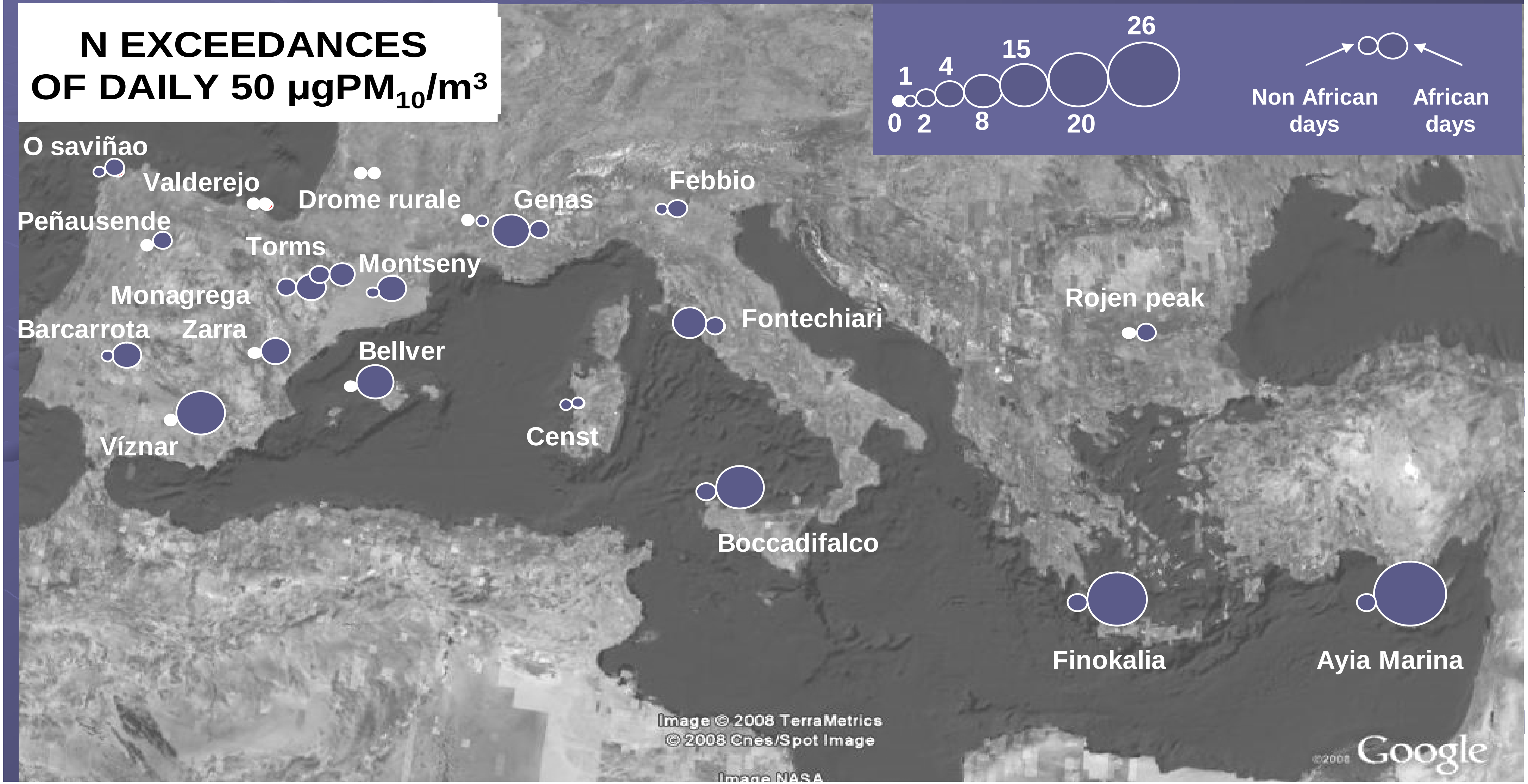
QUANTIFICATION OF DUST CONTRIBUTIONS

Querol et al., 2009 Atmospheric Environment



QUANTIFICATION OF DUST CONTRIBUTIONS

Querol et al., 2009 Atmospheric Environment

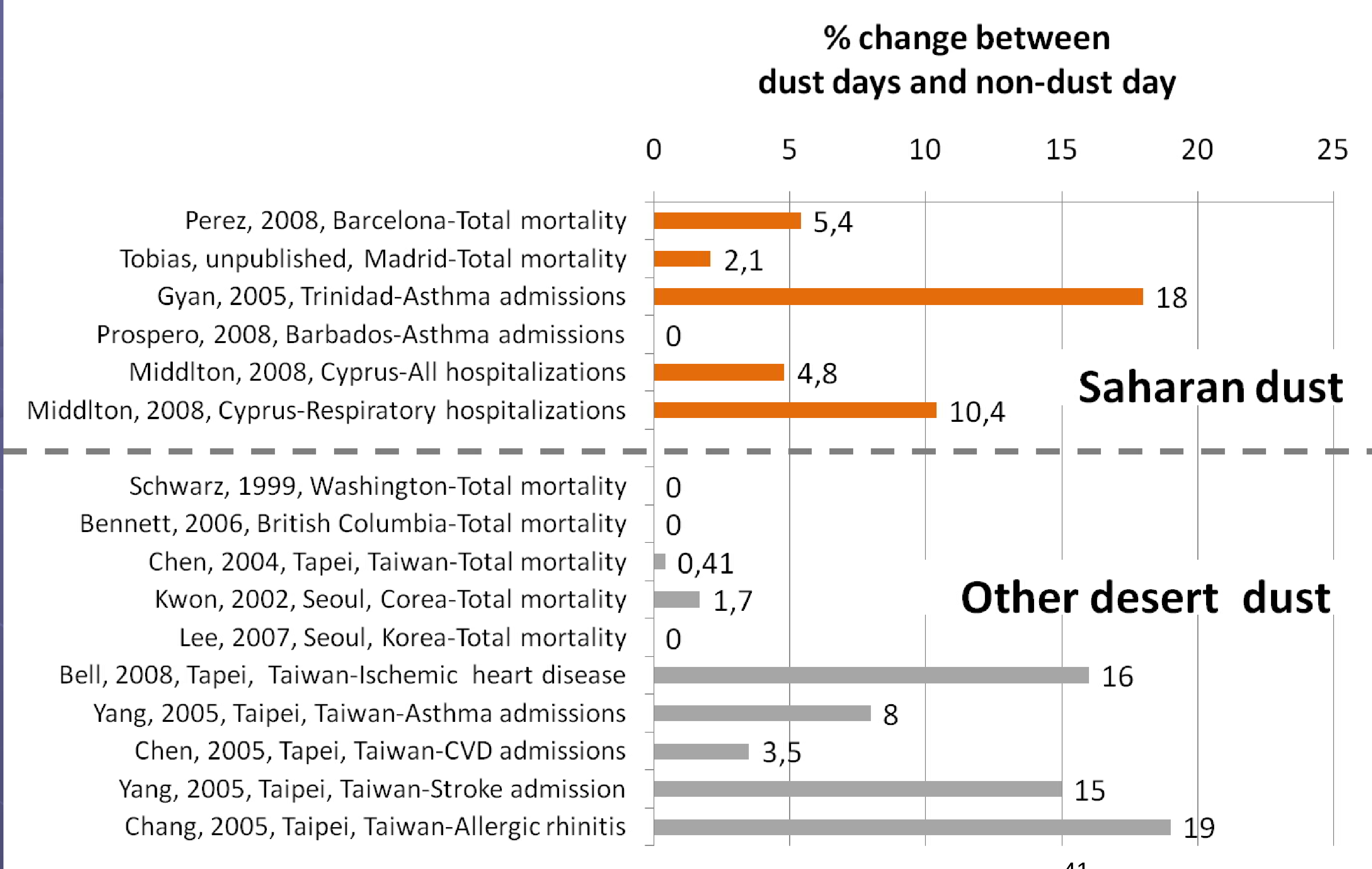


LONG TRANSPORT OF SAHARAN DUST AND HEALTH EFFECTS

CSIC

Tobias et al., 2010

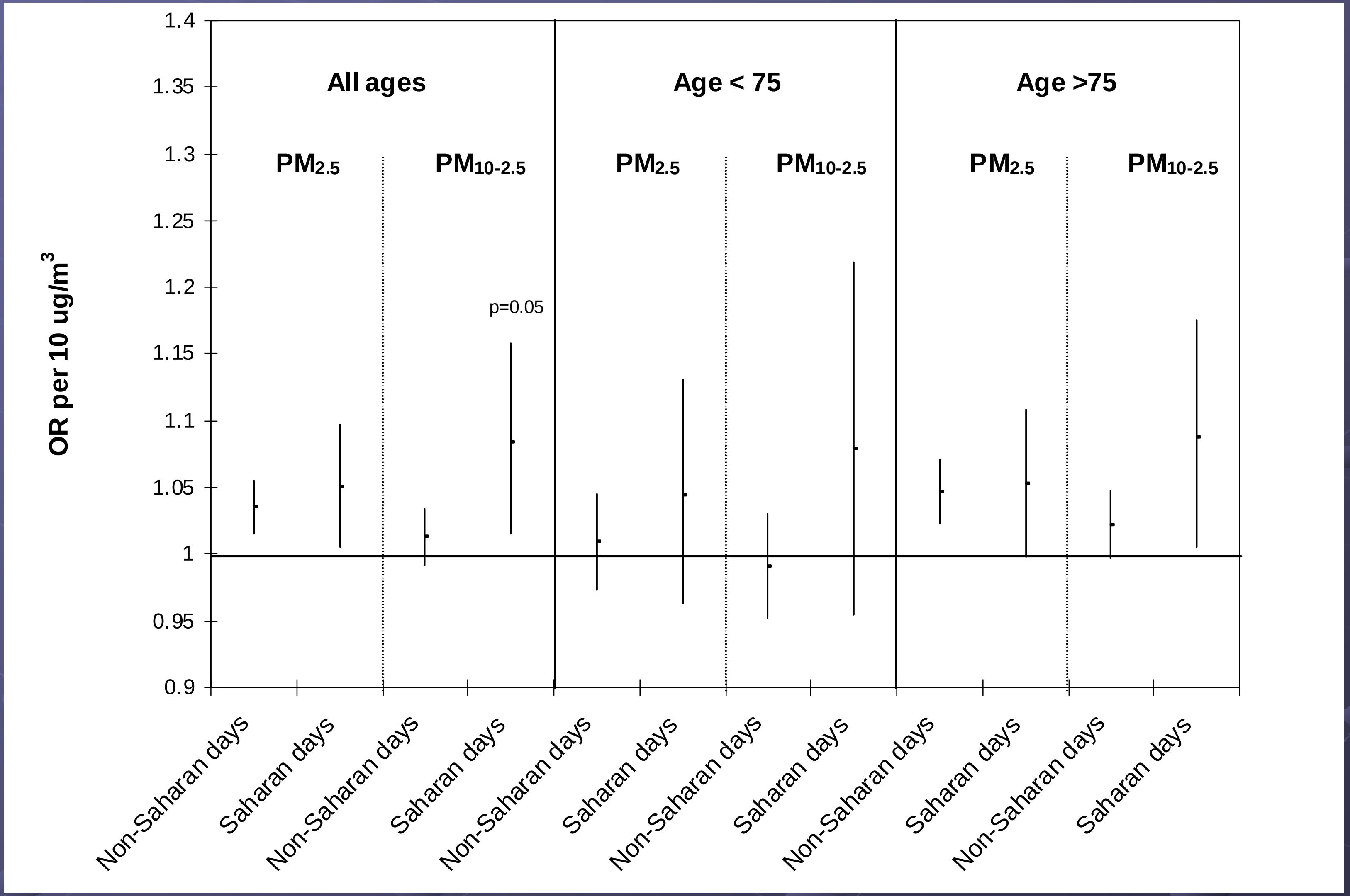
European Respiratory Society Annual Meeting , Barcelona, 18-22 September 2010



LONG TRANSPORT OF SAHARAN DUST AND HEALTH EFFECTS

Pérez L. et al., 2008. Epidemiology

2003-2005, mortality, Barcelona, 1 day after the episode



LONG TRANSPORT OF SAHARAN DUST AND HEALTH EFFECTS

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Tobias. et al., 2010. European Respiratory Society Annual Meeting

2003-2007, RESPIRATORY mortality, Barcelona, 2 days after episode

Models (lag 2)	**Non-saharan dust days**	**Saharan dust-days**
	OR (95% CI)	OR (95% CI)
Single pollutant		
PM_1	1.028 (0.995, 1.062)+	1.015 (0.904, 1.139)
$PM_{2.5-1}$	1.128 (1.019, 1.248)*	1.170 (0.982, 1.393)+
$PM_{10-2.5}$	1.043 (1.008, 1.080)*	1.021 (0.906, 1.150)
Multiple pollutants		
PM_1	1.017 (0.981, 1.054)	0.985 (0.875, 1.110)
$PM_{2.5-1}$	1.061 (0.939, 1.199)	1.172 (0.980, 1.403)+
$PM_{10-2.5}$	1.035 (0.996, 1.076)+	0.999 (0.886, 1.127)

OR for an increase of 10 $\mu g/m^3$

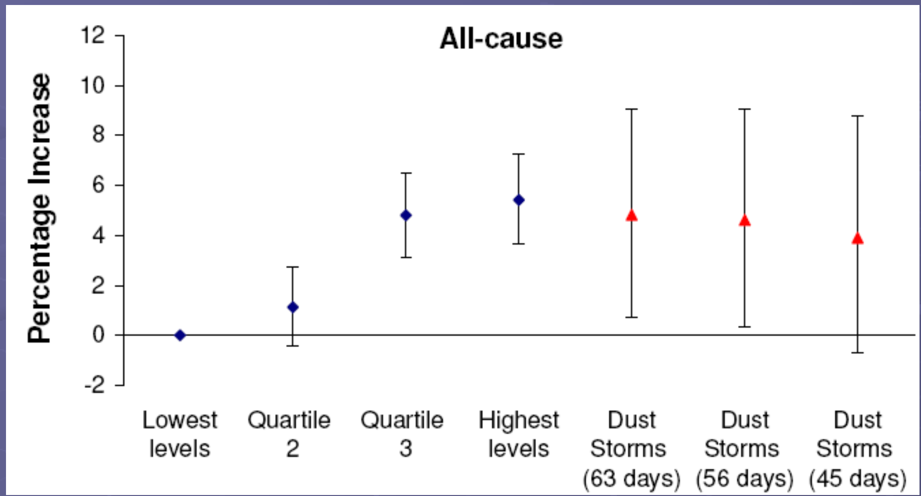
Models also adjusted for temperature, humidity and influenza

$^{*}p<0.05$, $^{+}p<0.1$

LONG TRANSPORT OF SAHARAN DUST AND HEALTH EFFECTS

Middleton et al., 2008, Environmental Health

1995-2004, Hospital admissions, Nicosia, Cyprus



% increas hospital admissions dust days vs non dust days

Jiménez et al., 2010, The Sci. Total Environ. In press

2003-2005, Mortality elderly, Madrid

Table 4
Relative risk of mortality by specific cause for each increase of the concentration of the ambient variables, during the days with and without Saharan dust intrusions in Madrid.[a]

		Variable	RR (IC 95%)
Days without Saharan dust	Total organi	NO_2 (lag 0)	1.014 (1.008–1.020)
		Thot (lag 0)	1.023 (1.010–1.036)
		Tcold (lag 3)	1.006 (1.003–1.010)
		$PM_{2.5}$ (lag 2)	1.023 (1.010–1.036)
		SO_2 (lag 4)	1.059 (1.029–1.089)
	Circulatory	Thot (lag 0 and 4)	1.059 (1.057–1.062)
		Tcold (lag 5)	1.008 (1.007–1.009)
		$PM_{2.5}$ (lag 2)	1.033 (1.031–1.035)
	Respiratory	LEQday (lag 0)	1.043 (1.003–1.083)
		$PM_{2.5}$ (lag 4)	1.032 (1.004–1.059)
		SO_2 (lag 2)	1.180 (1.120–1.239)
		O_3high (lag 3)	1.124 (1.052–1.195)
Days with Saharan dust	Total organic	PM_{10} (lag 3)	1.027 (1.014–1.041)
		O_3high (lag 1 and 5)	1.158 (1.116–1.200)
		LEQ24 (lag2)	2.253 (1.922–2.584)
	Circulatory	Tcold (lag 10)	1.020 (1.012–1.029)
		O_3high (lag 2)	1.104 (1.029–1.179)
		LEQday (lag 2)	1.080 (1.027–1.133)
		PM_{10} (lag 3)	1.040 (1.017–1.063)
	Respiratory	O_3high (lag 0 and 5)	1.417 (1.330–1.504)
		Tcold (lag 13)	1.025 (1.018–1.032)
		PM_{10} (lag 1)	1.035 (1.009–1.061)

[a] Increases in pollutants refer to increases of 10 μg/m^3. In the case of the temperature, Thot refers to each ºC above 30 ºC and Tcold to each ºC below 30 ºC. In the case of Ozone, O_3high refers to increases of 10 μg/m^3 above 55 μg/m^3. In the case of noise the increase is 1 dBA. In the case of pollinic species the increase is 10 grains/m^3.

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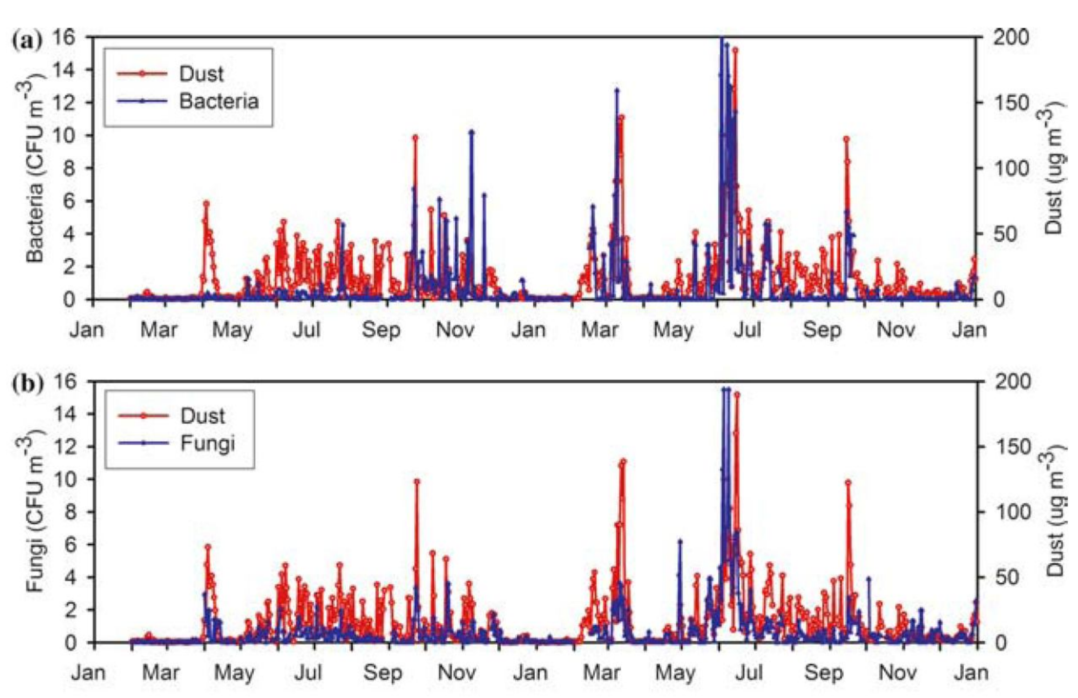

Figure 3. The daily concentration of cultivable fungi and bacteria in Barbados trade winds during 1996 and 1997 in comparison to various aerosol constituents: (a) bacteria and mineral dust; (b) fungi and dust; (c) fungi and nss-sulfate (nss-$SO_4^{=}$); (d) fungi and sea salt. Units: fungi and bacteria, CFU m^{-3}; aerosols, $\mu g\ m^{-3}$. In each panel the MO concentration is shown in blue and the comparison aerosol (dust, nss-$SO_4^{=}$, sea-salt) in red.

Prospero et al., 2005,
Aerobiologia

1996-1997, fungi and bacteria from Africa to the Caribbean with soild dust

Microorganisms and pathogens from Africa to the Eastern Mediterranean, 24-26/02/2006

Polymenakou P.N. et al., 2008,
Environmental Health Prespectives

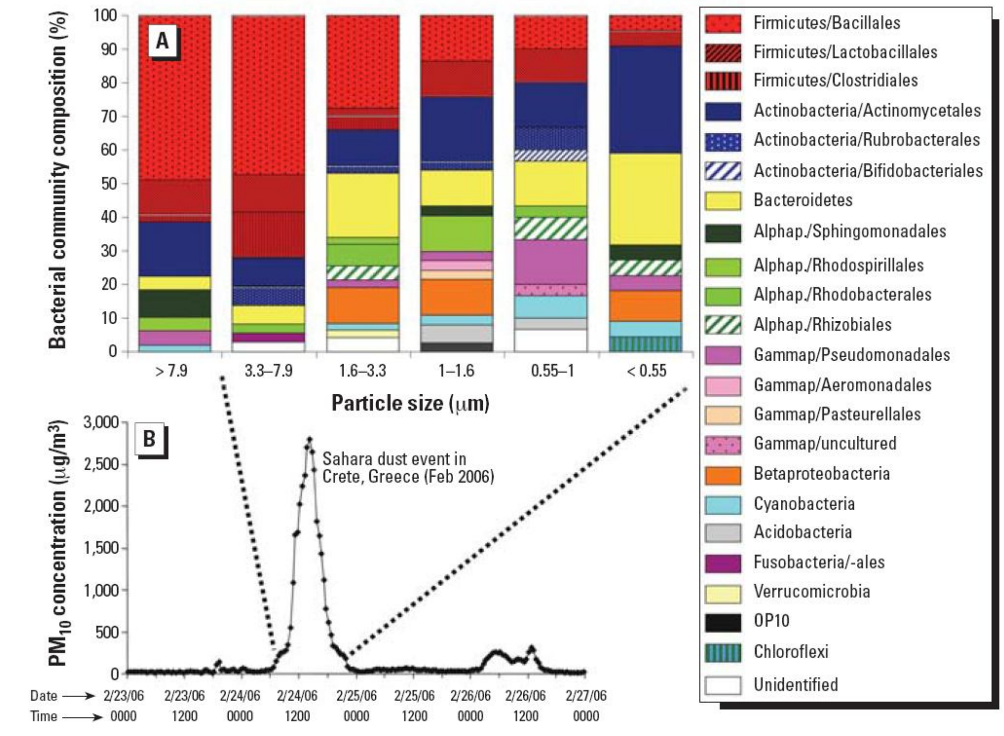

Figure 2. Analysis of dust particles from the Sahara dust event by bacterial community composition and by PM_{10} concentration at different time points. (*A*) Bacterial community composition in particles of different sizes. (*B*) PM_{10} concentrations during the Sahara dust event. Abbreviations: Alphap., Alphaproteobacteria; Gammap, Gammaproteobacteria.

CONCLUSIONS

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- North African (mainly Saharan) dust influences ambient levels of PM in Southern Europe in 10 days/year (East) to 50 (West)
- Daily PM10 levels during these events may exceed AQ limit values due to dust from Africa (25 days/year West, 4 East)
- There is a growing evidence of possible impact of dust on human health, specially when high PM levels are recorded
- Special measures should be taken to reduce exposure and anthropogenic emissions during dust outbreaks

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Thanks for your attention !

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