What is “desert dust”?

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Pre-conference workshop: Desert Dust & Sand Storms, 29th October 2018
First Global Conference on Air Pollution and Health:
Improving Air Quality, Combatting Climate Change – Saving Lives
Geneva, 30th October to 1st November 2018

World Health Organization

EGAR idæa CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

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BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación

2. Department of Earth Sciences. Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS), Barcelona , Spain

GFDL Geophysical Fluid Dynamics Laboratory NOAA

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Rationale

Desert dust and sand storms: Patterns relevant for air quality monitoring with a health impact assessment focus

Key reviews & papers

- *Dubief et al., 1977*
- *Prospero et al., 2002, 2012*
- *Reid et al., 2003*
- *Griffin, 2007*
- *Hashizume et al., 2010*
- *Ginoux et al., 2012*
- *Karanasiou et al., 2012*
- *de Longueville et al., 2013*
- *Goudie 2014*
- *Knippertz and Stuut, 2014*
- *Tobias et al., 2018 (WHO systematic review)*

- Among others: 233 articles in the WHO systematic review

Objective

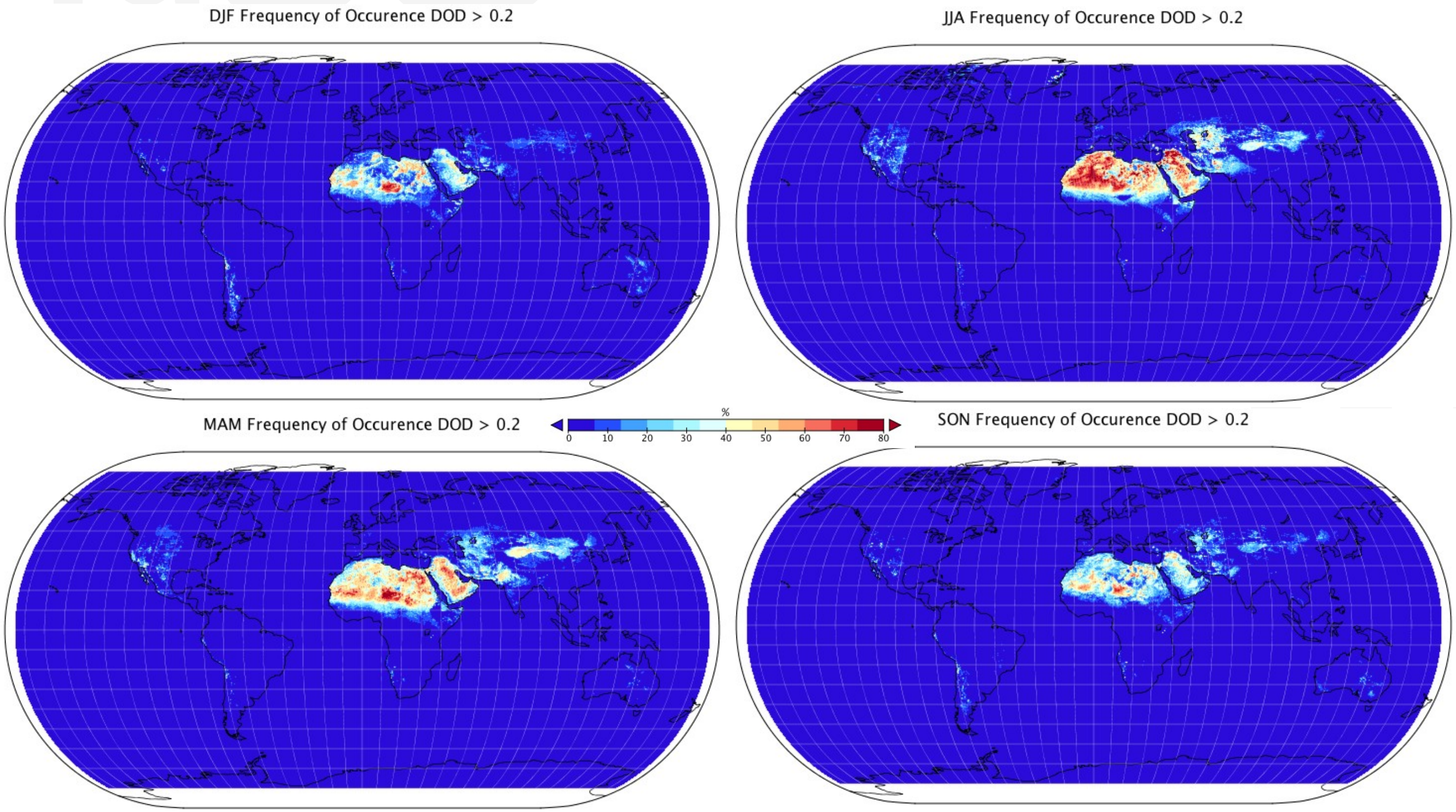
WHO global air quality guidelines: Systematic Review of Health Effects of Dust and Sand Storms

To supply a systematic review of the scientific evidence on the health effects of desert dust and sand storms, in the framework of the update of the WHO Global Air Quality Guidelines (AQGs); a global project coordinated by the WHO Regional Office's European Centre for Environment and Health (ECEH) in Bonn (Germany), including participation from all WHO Regions and WHO headquarters

Section 1: Relevant desert dust patterns for health studies

Section 2: Health impact systematic review

Dust sources, emissions and transport



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

Dust sources, emissions and transport

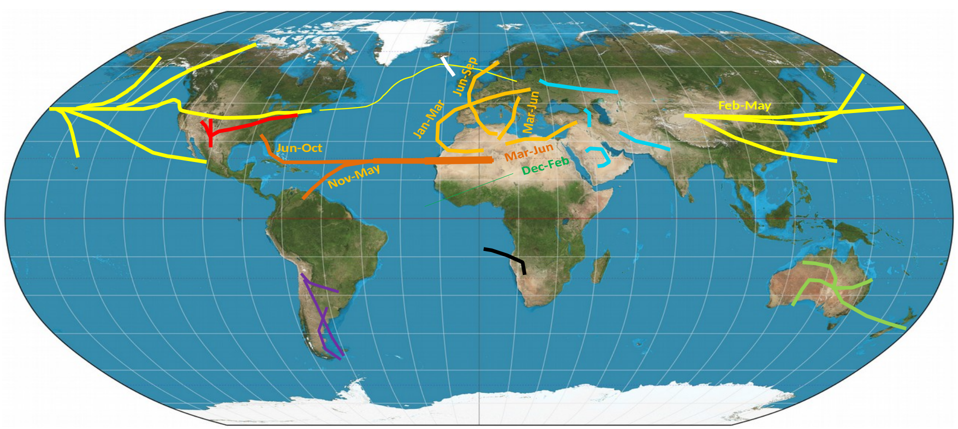
- **Global MASS of mineral dust aerosols: 16 Mega (10^6)-tons**

Emissions 1200-1600 Mt/yr

- **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**

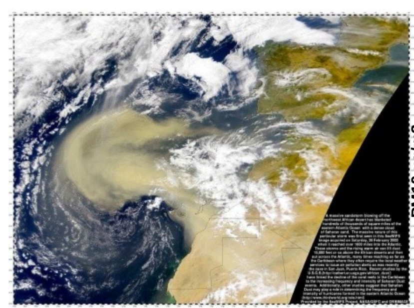
Prospero J.M., 2002. Rev. Geophys 40(1):1002
Ginoux P. et al., 2012. Rev Geophys 50:1–36
Washington R. et al., 2003. Ann Assoc Am Geogr 93(2):297–313
Huneeus N. et al., 2011. Atmos Chem Phys 11(15):7781–816
Ginoux P. et al., 2010. J Geophys Res Atmos 2010;115(5):1–10
Varga G., 2012. Hungarian Geogr Bull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

Atmospheric transport

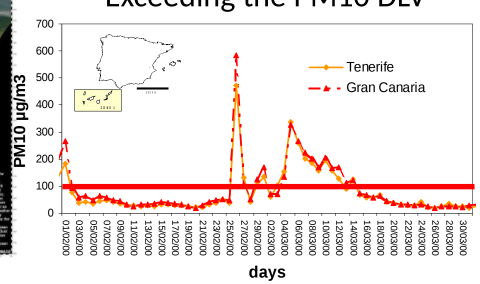


Duration

Atmospheric life time, hours- weeks
Duration, hours to several weeks



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



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

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

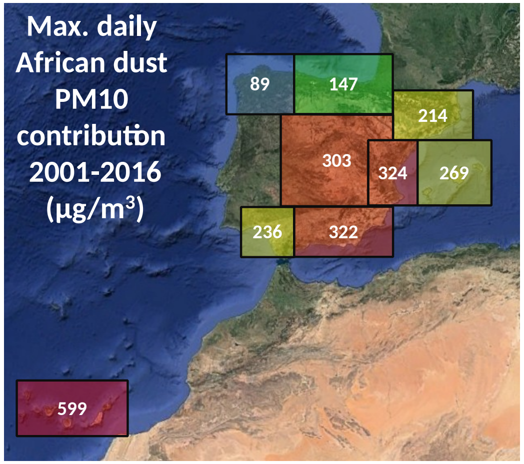
Krasnov H,et al., 2014: Beer Sheva, Israel
10% of the dust days exceed 71 µg/m^3 PM10
122 µg/m^3 PM10 daily net dust to PM10 during dust days

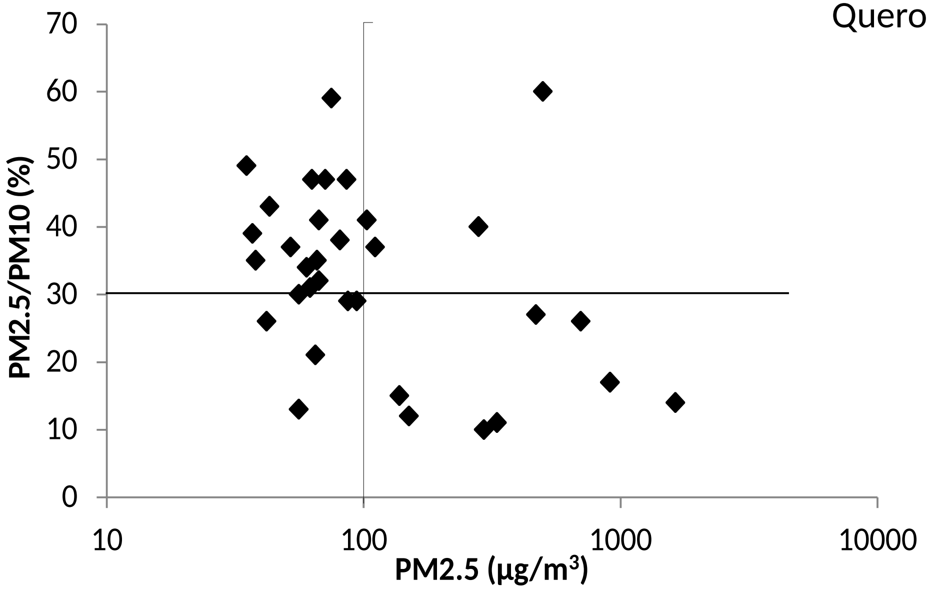
Prospero et al., 2005: Barbados
35 days recorded dust contributions >50 µg/m^3, 7 days >100 µg/m^3.

PM levels and size

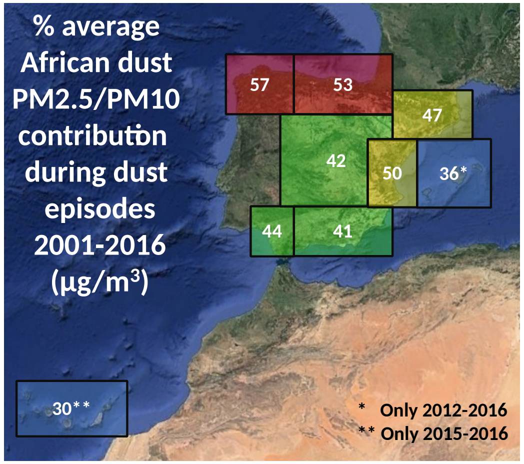
Goudie A.S. , 2014. Env Int 63:101–13

Region	PM10 µg/m³	PM2.5 µg/m³
Southern Europe	150-2,500	43-86
Eastern Asia	134-3,006	63-700
Australia	266-15,366	
Western Africa	312-5,000	42-1,368
North America	123-65,112	
Midde the East	700-5,619	





Querol et al., 2018, in prep



Data obtained from:

- *Goudie A.S., 2014; max. conc. over the world,*
- *Jayaratne et al. (79) dust storm in Brisbane,*
- *Engelbrecht et al. (73) annual mean conc. Middle East*

PM composition during dust episodes

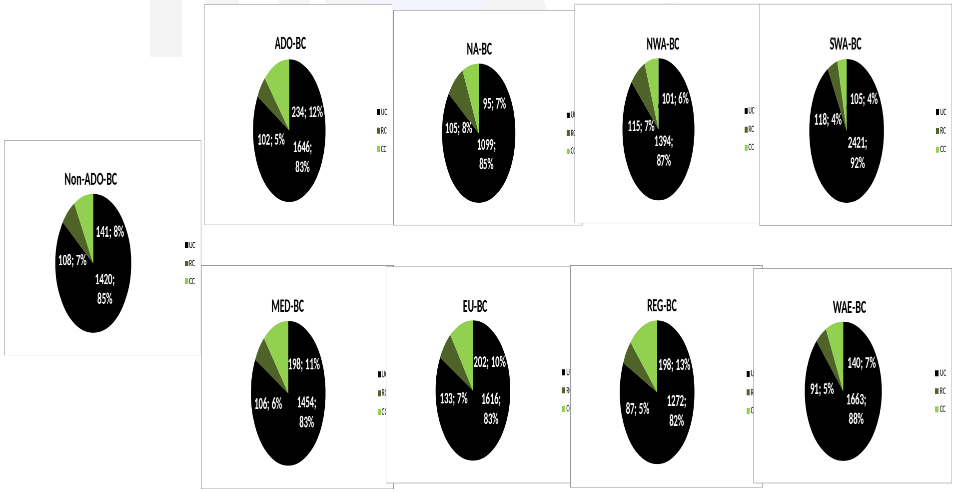
*Minerals typically present in desert dust. Asterisks indicate abundance: ***** very high to * low.*

Silicates & aluminium-silicates	Silicates	Quartz	SiO_2 (mineral grains or diatomea fragments)	*****
	Clay minerals	Kaolinite	$Al_2Si_2O_5(OH)_4$	****
		Illite	$(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$	****
		Chlorite	$((MgFe)_5Al)(AlSi_3)O_{10}(OH)_8$	***
		Palygorskite	$(Mg,Al)_2Si_4O_{10}(OH)\cdot 4(H_2O)$	***
		Montmorillonite	$(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2\cdot nH_2O$	***
	Feldspars	Albite	$NaAlSi_3O_8$	**
		Anorthite	$CaAl_2Si_2O_8$	**
		Microcline/orthocl.	$KAlSi_3O_8$	**
	Other silicate	Zircon	$ZrSiO_4$	*
		Hornblende	$Ca_2(Mg,Fe,Al)_5(Al, Si)_8O_{22}(OH)_2$	*
Carbonates	Ca &Mg Carb.	Calcite	$CaCO_3$	****
		Dolomite	$(CaMg)_2CO_3$	**
Oxides	Iron oxides	Hematite	Fe_2O_3	**
		Magnetite	Fe_3O_4	*
		Goethite	α-FeO(OH)	**
	Other oxides	Anatase & rutile	TiO_2	*
Salts	Chlorides	Halite	NaCl	*
	Sulphates	Gypsum	$CaSO_4.2H_2O$	**
		Thenardite	Na_2SO_4	*
		Epsomite	$MgSO_4$	*
Phosphates		Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$	*

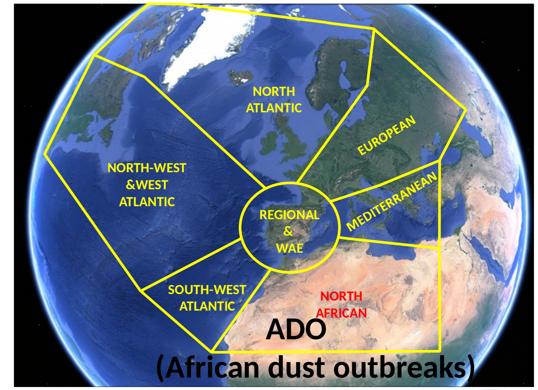
PM composition during dust episodes

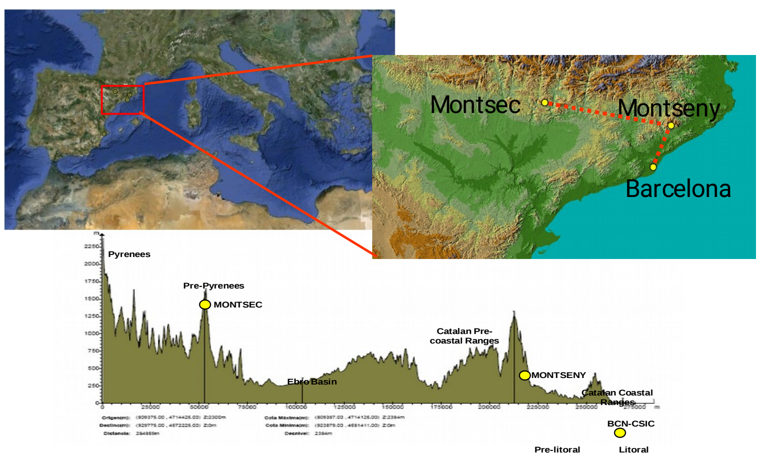
- **Saharan** dust: quartz, illite, calcite, montmorillonite, palygorskite, feldspars(Claquin et al., 1999)
- **Sahel** dust: quartz, kaolinite, hematite, feldspars (Claquin et al., 1999)
- **North-eastern China** desert dust: illite, kaolinite (47-52%), quartz (25-27%), feldspar and plagioclase (6-7%), 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).

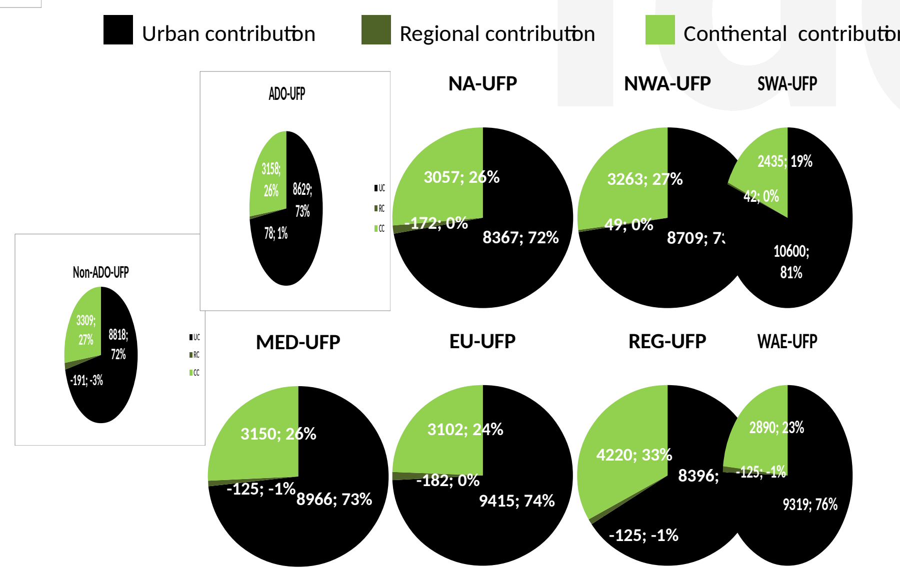
PM composition during dust episodes



Barcelona, NE Spain 2009-2016





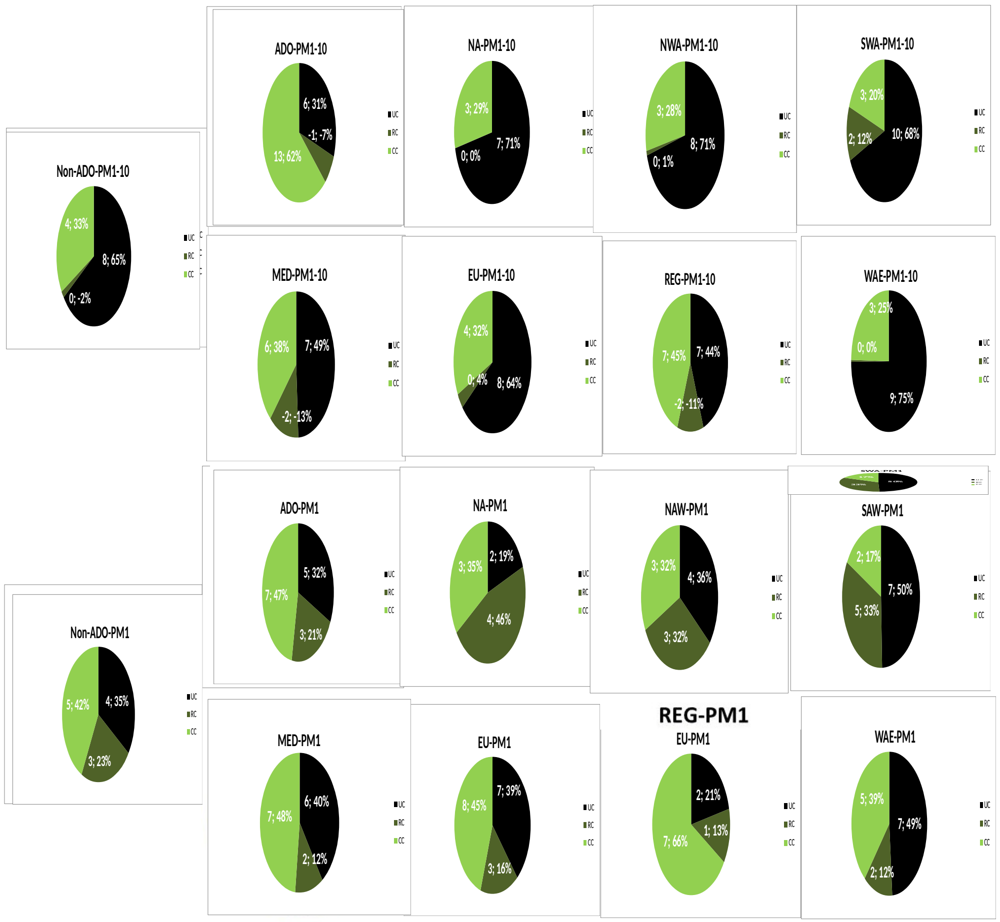


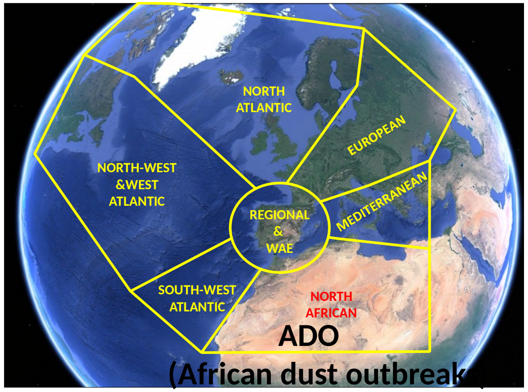
- Hourly UFP, BC, PM10, PM2.5 and PM1 2009-2016 simultaneously
- 1/3 day sampling and speciation PM10, PM2.5 and PM1

PM composition during dust episodes

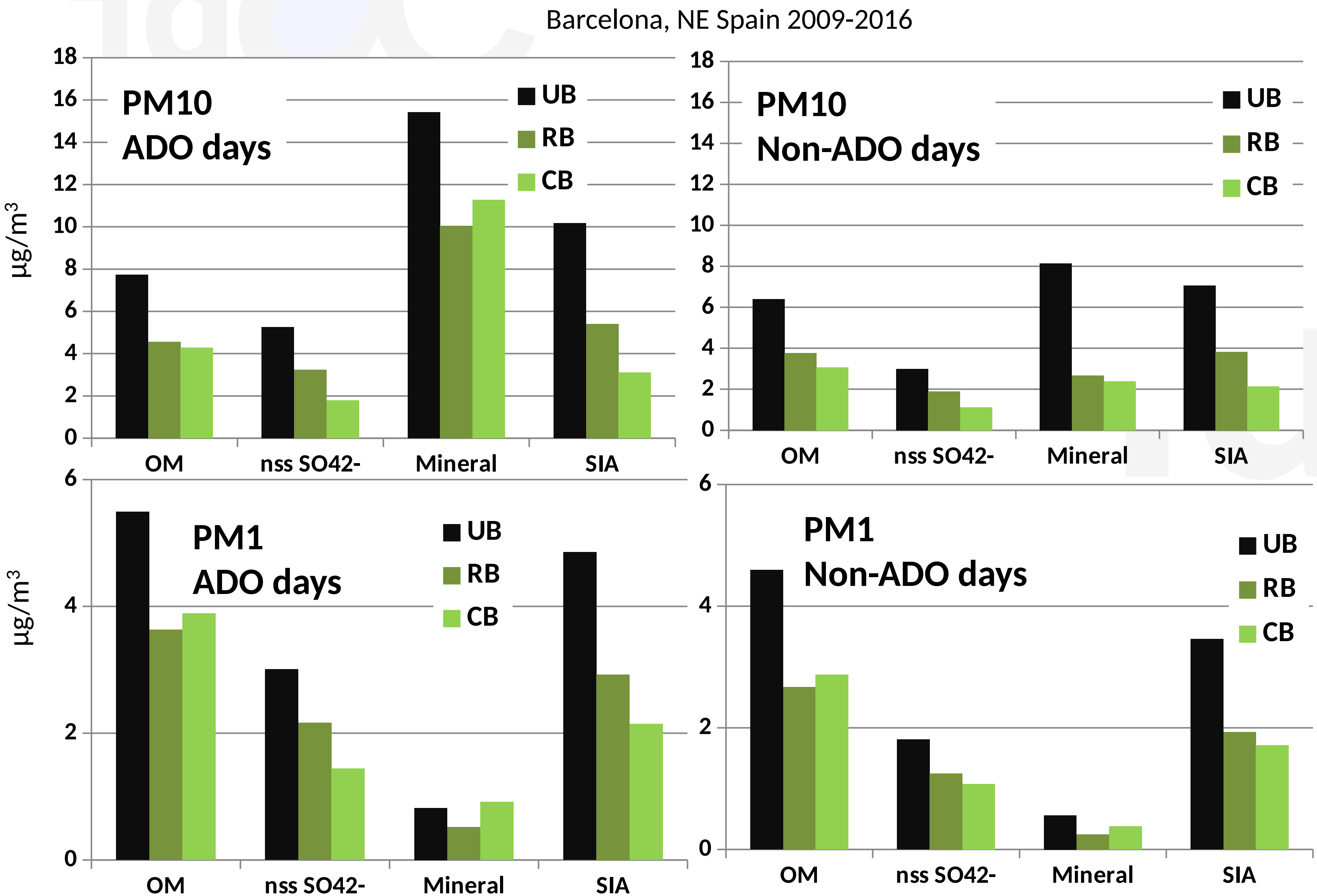
Barcelona, NE Spain 2009-2016

Urban contribution Regional contribution Continental contribution





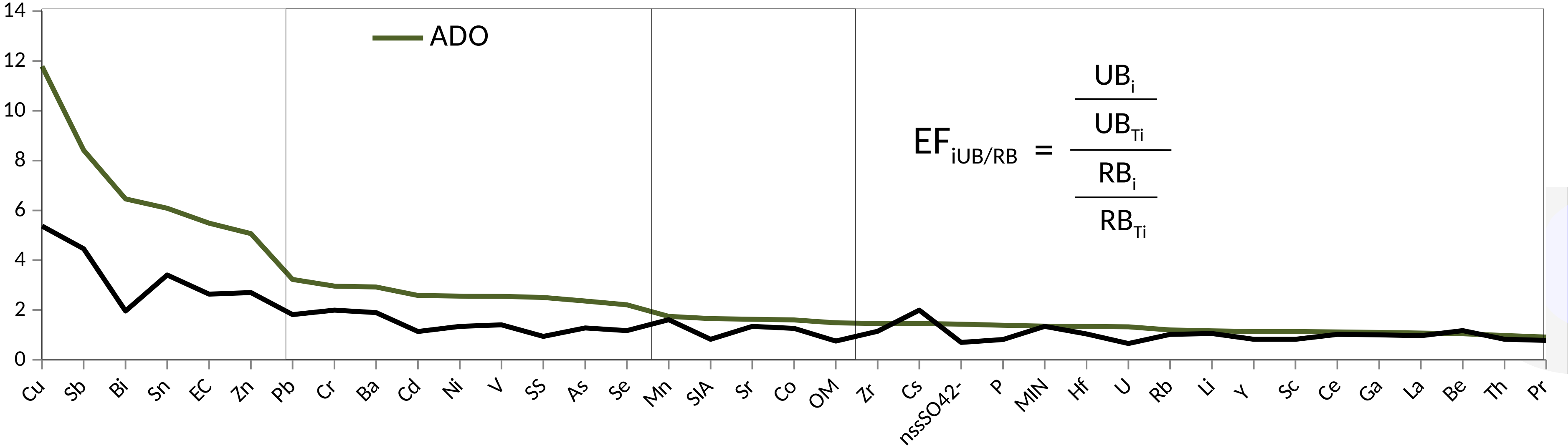
PM composition during dust episodes



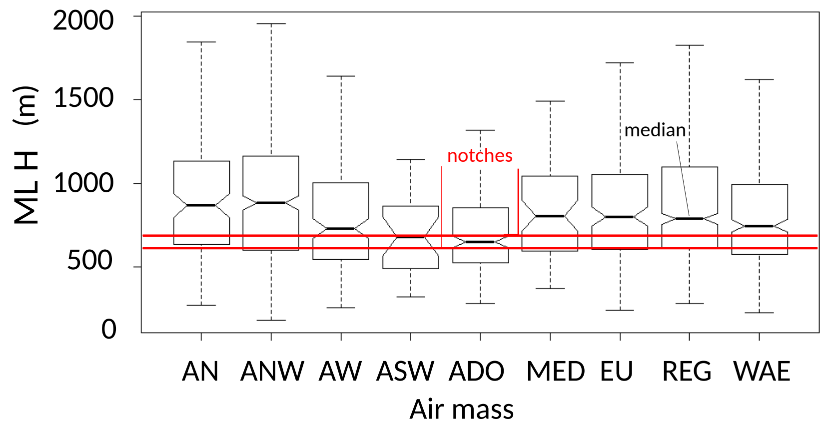
PM composition during dust episodes

Barcelona, NE Spain 2009-2016

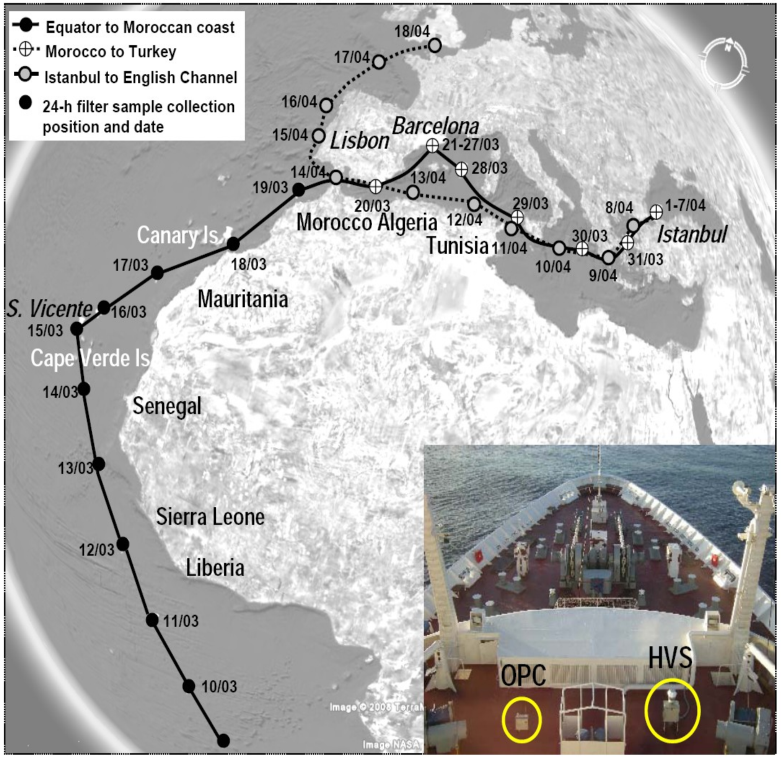
Enrichment of PM components in the urban background compared with the regional bacground during ADOs compared with non-ADOs

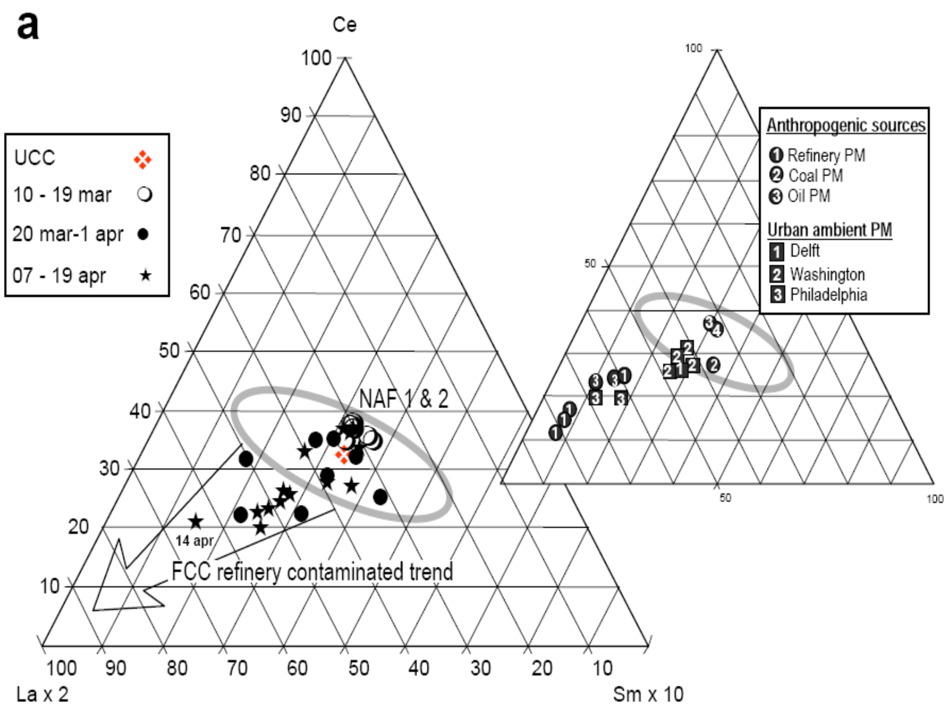


$$EF_{iUB/RB} = \frac{\frac{UB_i}{UB_{Ti}}}{\frac{RB_i}{RB_{Ti}}}$$



PM composition during dust episodes





Moreno et al., 2008, Atmos Ennv.

PM composition during dust episodes

1996-1997, Fungi and bacteria from Africa to the Caribbean with soil dust

Prospero et al., 2005, Aerobiologia

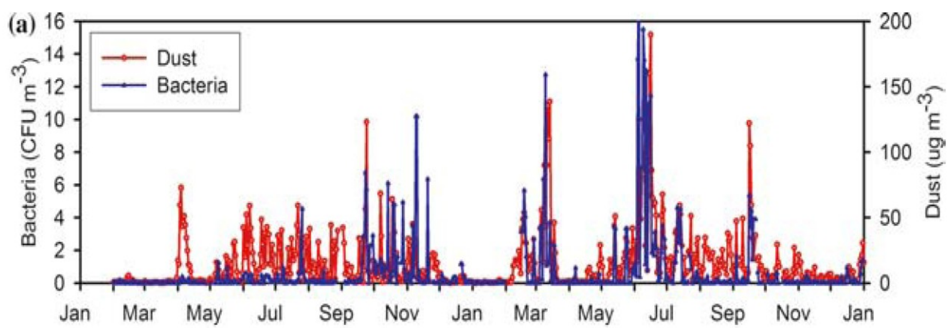
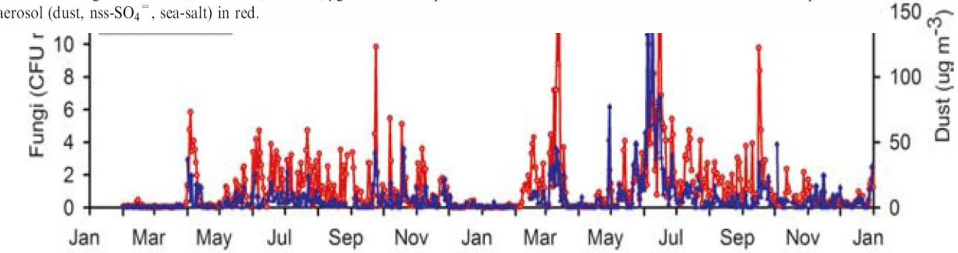
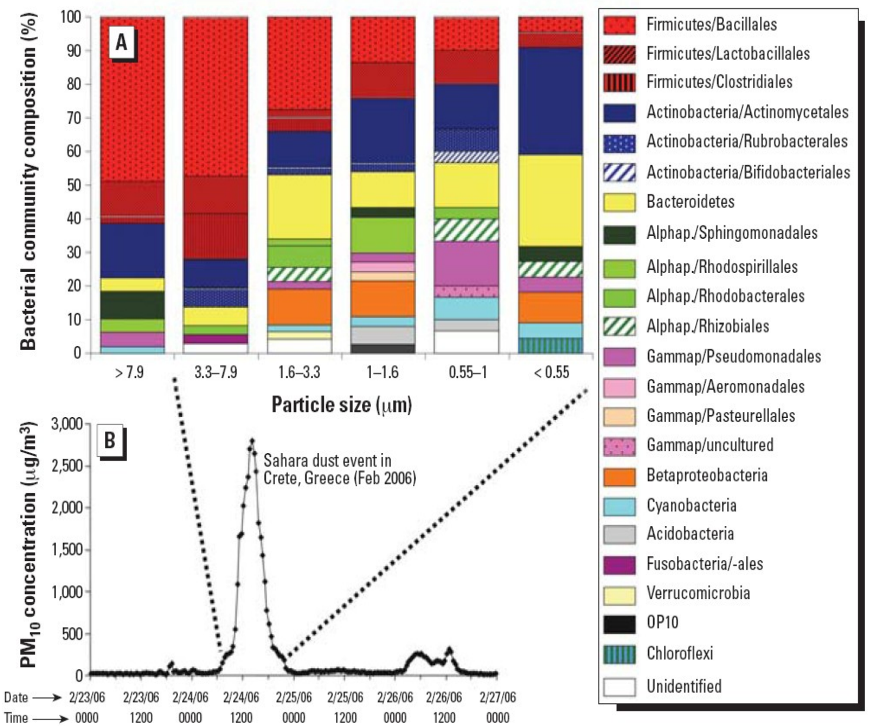


Figure 3. The daily concentration of cultivable fungi and bacteria in Barbados trade winds during 1996 and 1997 in comparison to various aerosol constituents: (a) bacteria and mineral dust; (b) fungi and nss-sulfate (nss-$SO_4^=$); (d) fungi and sea salt. Units: fungi and bacteria, CFU m^{-3}; aerosols,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



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

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



igure 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.

Final considerations

Increased PM concentrations during AODs 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

Considering also bioaerosols

- Patterns of PM during ADOs that might influence human health are very complex
- These might strongly vary from one region to other
- Not only PMx levels have to be quantitatively contrasted with potential health effects
- ADOs also favour the occurrence of individual or synergistic effects that might involve:
  Meteorology
  Anthropogenic co-pollutants
- The impact of this complex mix of PM compounds on human health should be assessed in health assessment analysis of ADOs, if possible independently for anthropogenic and mineral dust loads
- It is not only mineral dust that matters for air quality during dust episodes