5th Training Course on WMO SDS-WAS products

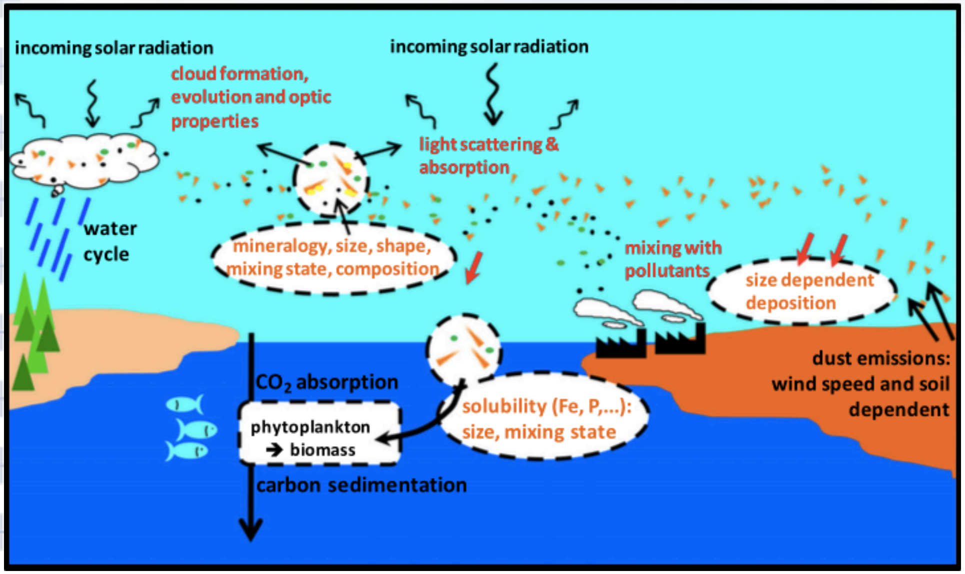
5-9 Nov 2016, Tehran

ground observation of airborne dust

Sergio Rodríguez

srodriguezg@aemet.es

AEMET, Spain



Dust and climate

-light scattering and absorption

-droplets and ice clouds formation

-clouds optical properties

-fertilization (P and Fe) of the ocean

implications on CO_2 budget

dust and health

dust

dust, aerosols and pollutants

in-situ observations:

- PM_{10} and $PM_{2.5}$ levels
- PM_{10} and $PM_{2.5}$ composition
- complementary measurements

remote sensing observations:

- column properties
- altitude resolved properties

let's build our observation network !!!

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dust

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let’s build our observation network !!!

people live in cities and breath a cocktail dust + pollutants

people live in cities and breath a cocktail dust + pollutants

dust - air quality stations

parameters indicative of:

dust
ambient air quality

people live in cities and breath a cocktail dust + pollutants

what is dust?

type of dust sources ?

types of dust sources:

desert dust

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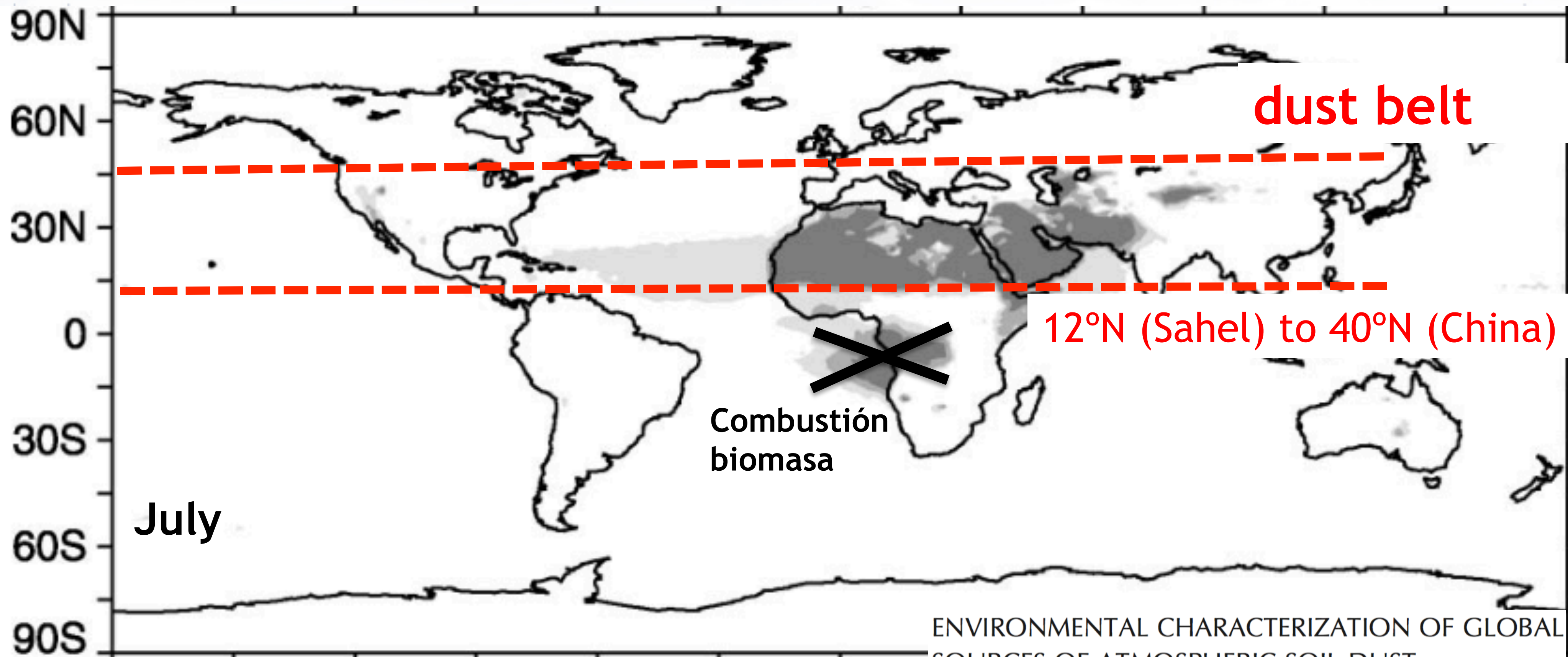
people live in cities and breath a cocktail dust + pollutants

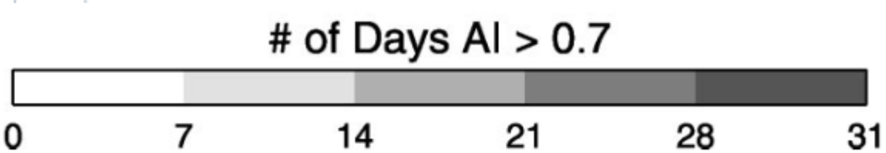
what is this dust?

sources?

UV absorbing aerosols - dust
Satelite

What is dust?





ENVIRONMENTAL CHARACTERIZATION OF GLOBAL SOURCES OF ATMOSPHERIC SOIL DUST IDENTIFIED WITH THE NIMBUS 7 TOTAL OZONE MAPPING SPECTROMETER (TOMS) ABSORBING AEROSOL PRODUCT

Joseph M. Prospero,[1] Paul Ginoux,[2] Omar Torres,[3] Sharon E. Nicholson,[4] and Thomas E. Gill[5]

desert dust

chotts, sabkhas, wadis, salares

1. **what is dust ?**

   There are several types of sources, but the mayor dust sources are associate with <u>dry lakes/rivers beds</u>

2. **chemistry and mineralogy**

   clays, feldspars, oxides, evaporites

   Si, Al, Ca, Fe, Mg, Na, Cl, Mn....

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Table 6. Density and Real Index of Refraction of Minerals Found in Saharan Dust[a]

1. clays

illite	$K_{0.6}(H_3O)_{0.4}Al_{1.3}Mg_{0.3}Fe_{0.1}Si_{3.5}O_{10}(OH)_2 \cdot (H_2O)$
kaolinite	$Al_2Si_2O_5(OH)_4$
montmorillonite	$(Na,Ca)_{0.5}(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH)_4 \cdot n(H_2O)$
smectite	$(Na,Ca)Al_4(Si,Al)_8O_{20}(OH)_4 \cdot 2(H_2O)$
chlorite	$Na_{0.5}(Al,Mg)_6(Si,Al)_8O_{18}(OH)_{12} \cdot 5(H_2O)$

2. evaporites

calcite	$CaCO_3$
dolomite	$CaMg(CO_3)_2$
gypsum	$CaSO_4 \cdot 2(H_2O)$
anhydrite	$CaSO_4$
halite	$NaCl$

4. oxides

hematite	Fe_2O_3
goethite	$FeO(OH)$
rutile	TiO_2

3. feldspars

microcline	$KAlSi_3O_8$	Var oligoclase	$(Na,Ca)(Si,Al)_4O_8$
		Var albite	$NaAlSi_3O_8$
		Var anorthite	$CaAl_2Si_2O_8$

Characterization of African dust transported to Puerto Rico by individual particle and size segregated bulk analysis

Elizabeth A. Reid,[1,2,3] Jeffrey S. Reid,[3] Michael M. Meier,[4] Michael R. Dunlap,[4]
Steven S. Cliff,[4] Aaron Broumas,[4] Kevin Perry,[5] and Hal Maring[6]

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 108, NO. D19, 8591, doi:10.1029/2002JD002935, 2003

desert dust

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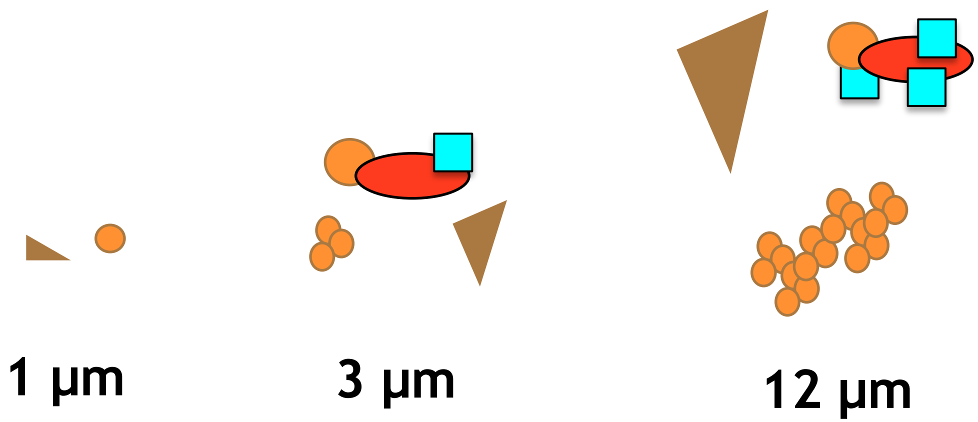
3. Size and morphology

1 and 20 µm
agglomerates



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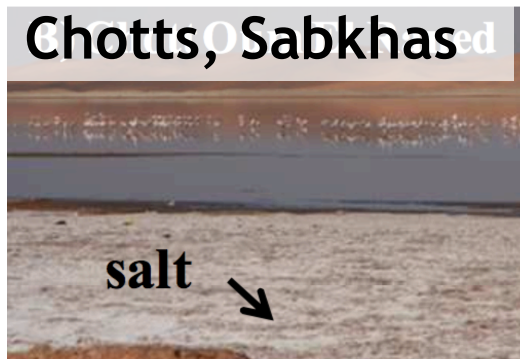
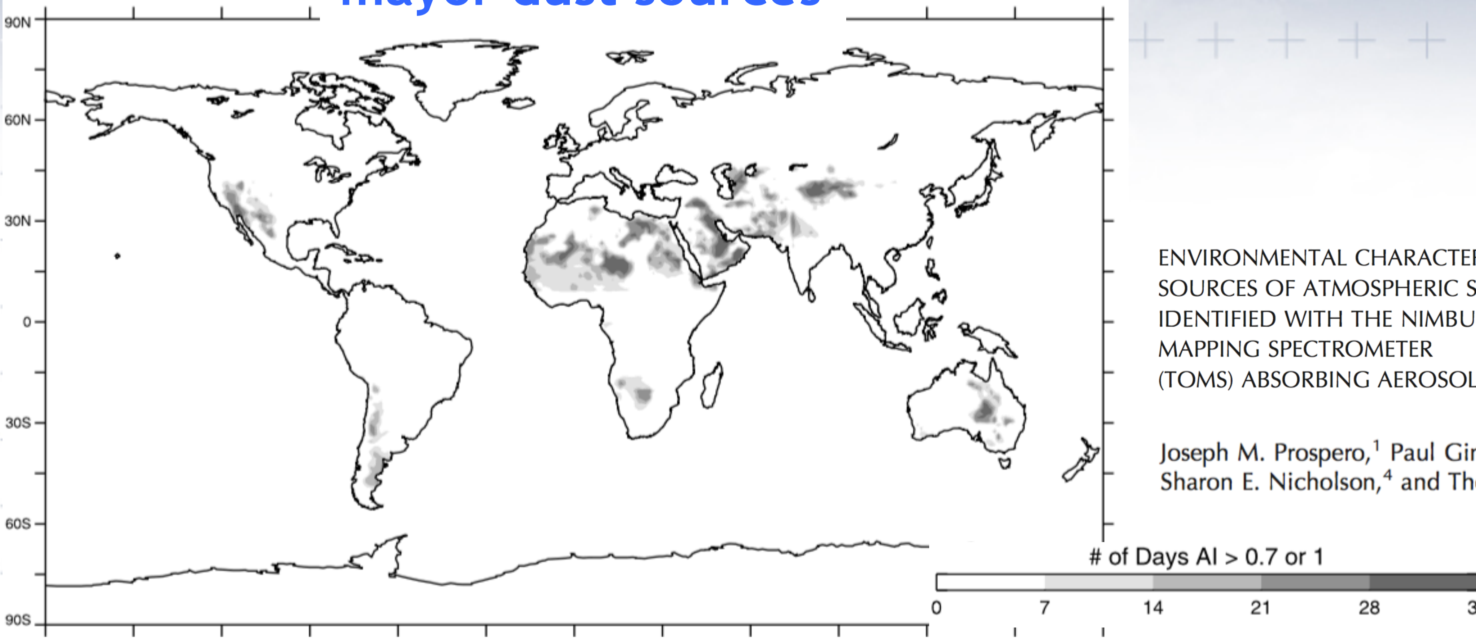


mayor dust sources



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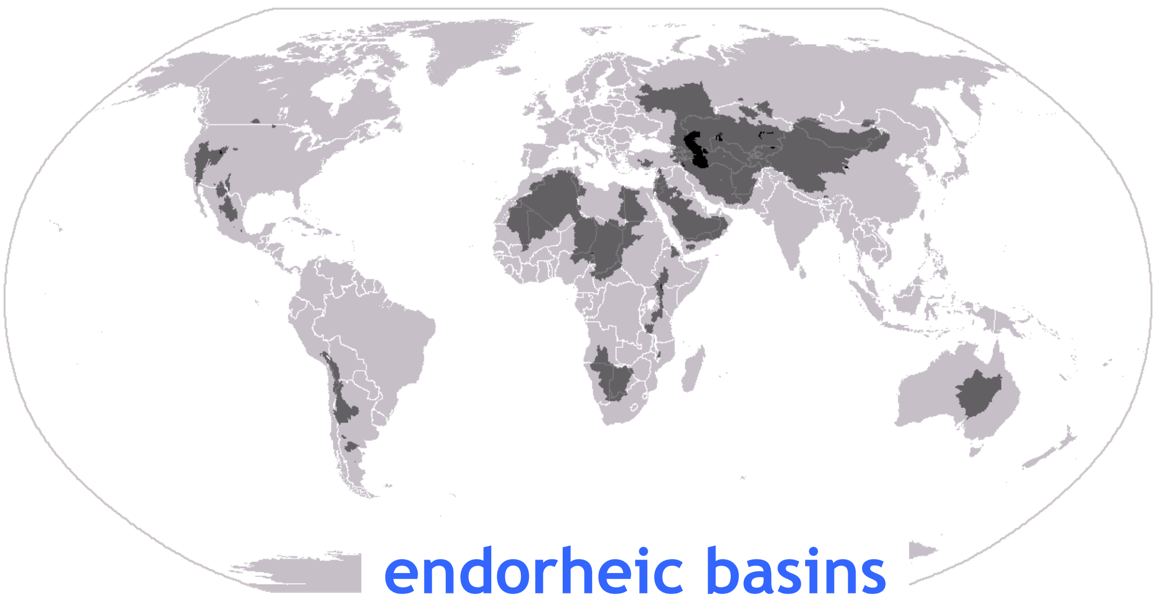
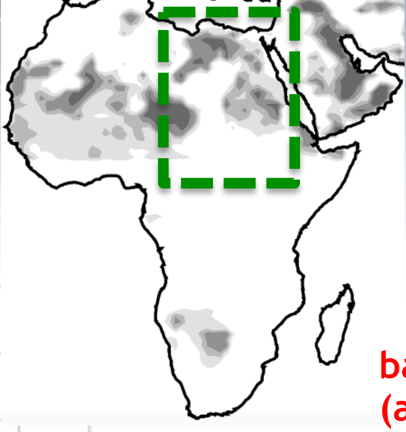
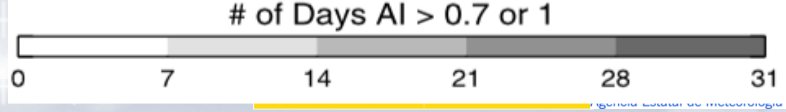


endorheic basins

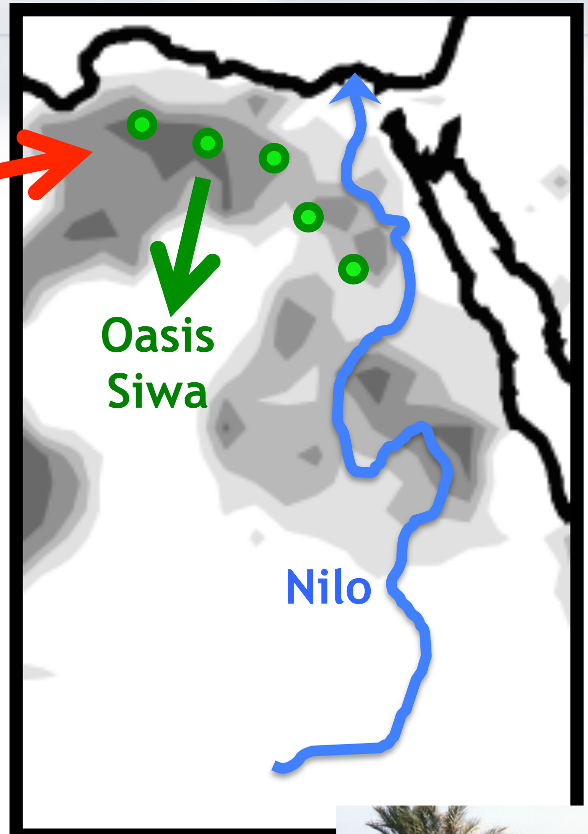
no conection to sea

Detección satélite





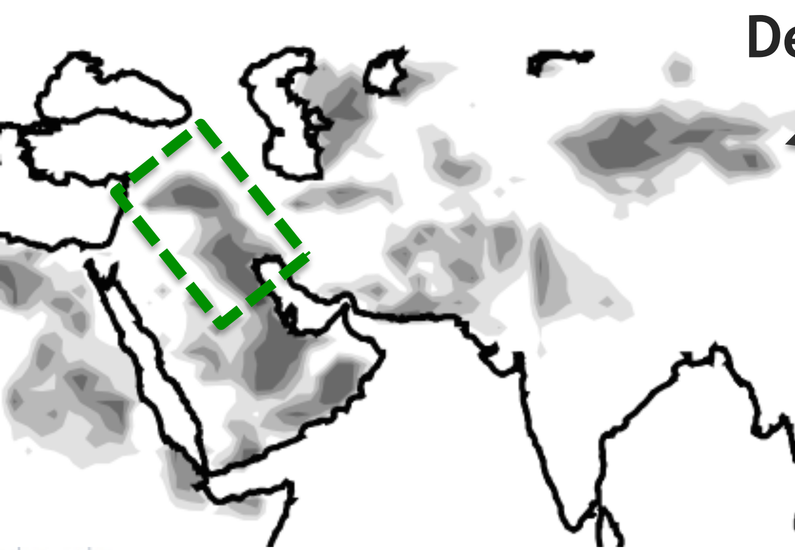
bajas topográficas
(altitudes -)

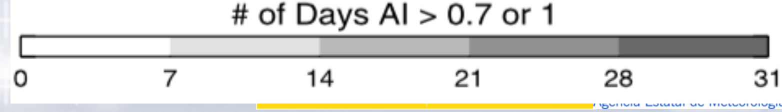


● lakes, oasis,
cultivation,
underground water,
Ancient rivers

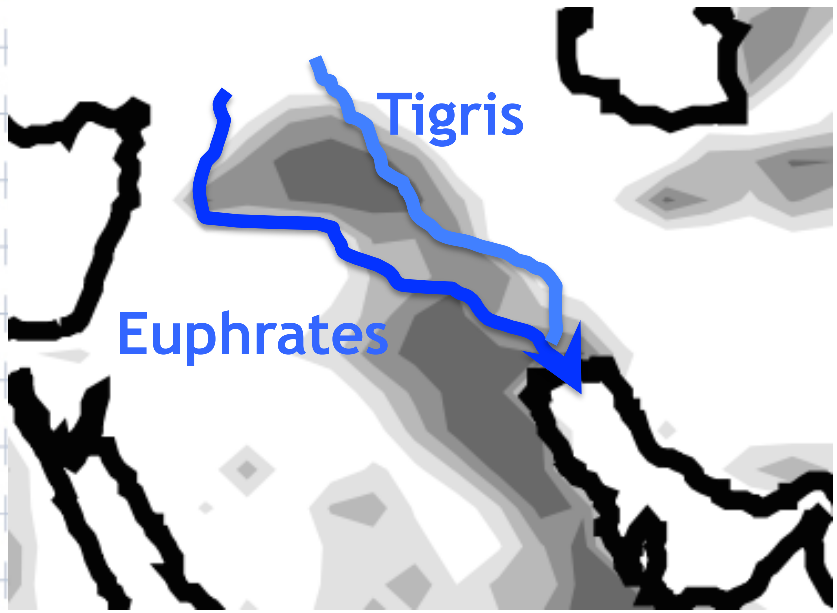
Oasis Siwa
29°13´N, 25°31'E

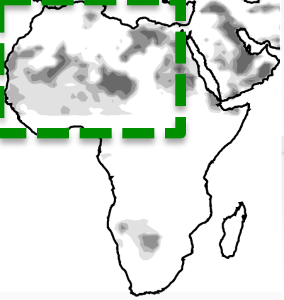
Detección satélite



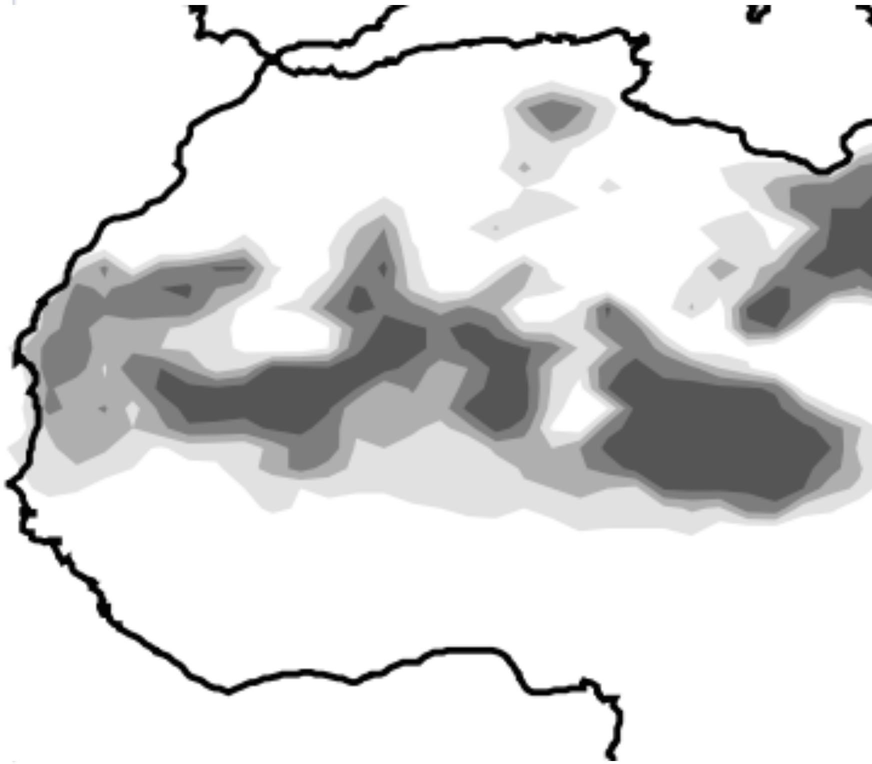


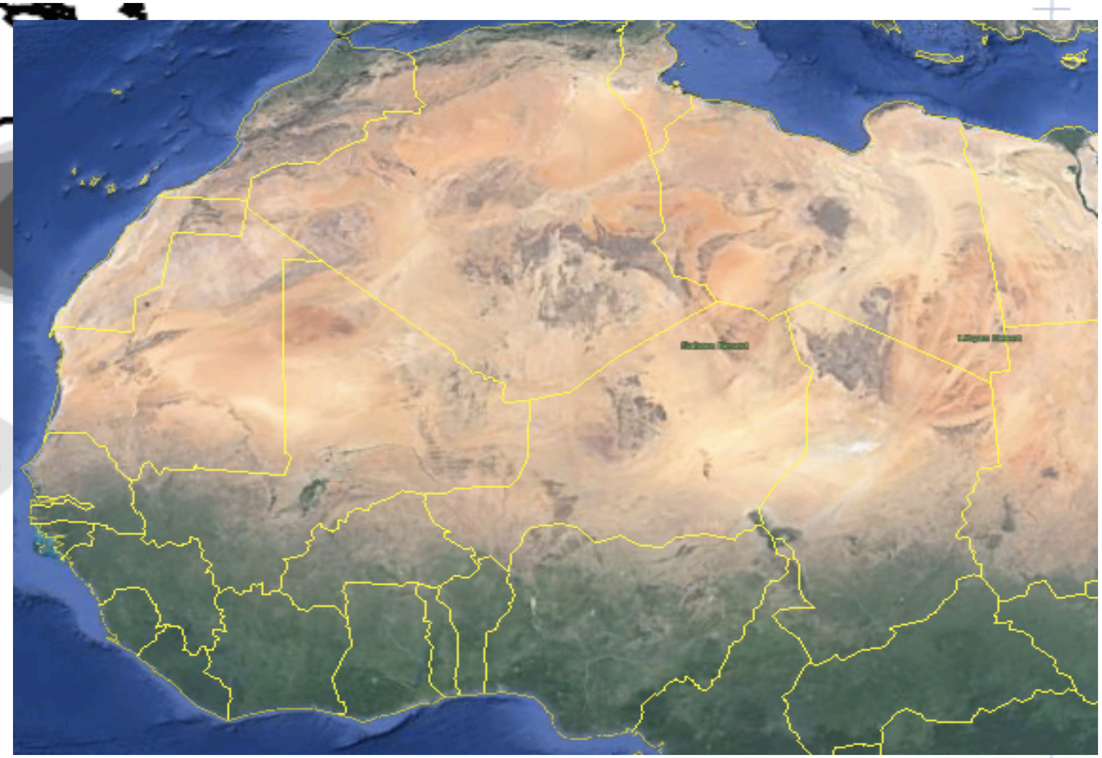
Siria-Irak





Sahara Sahel





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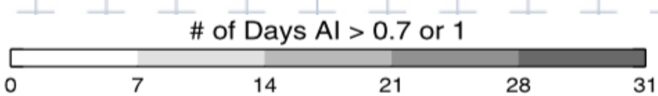

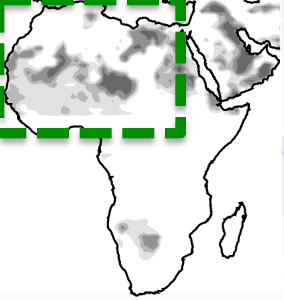

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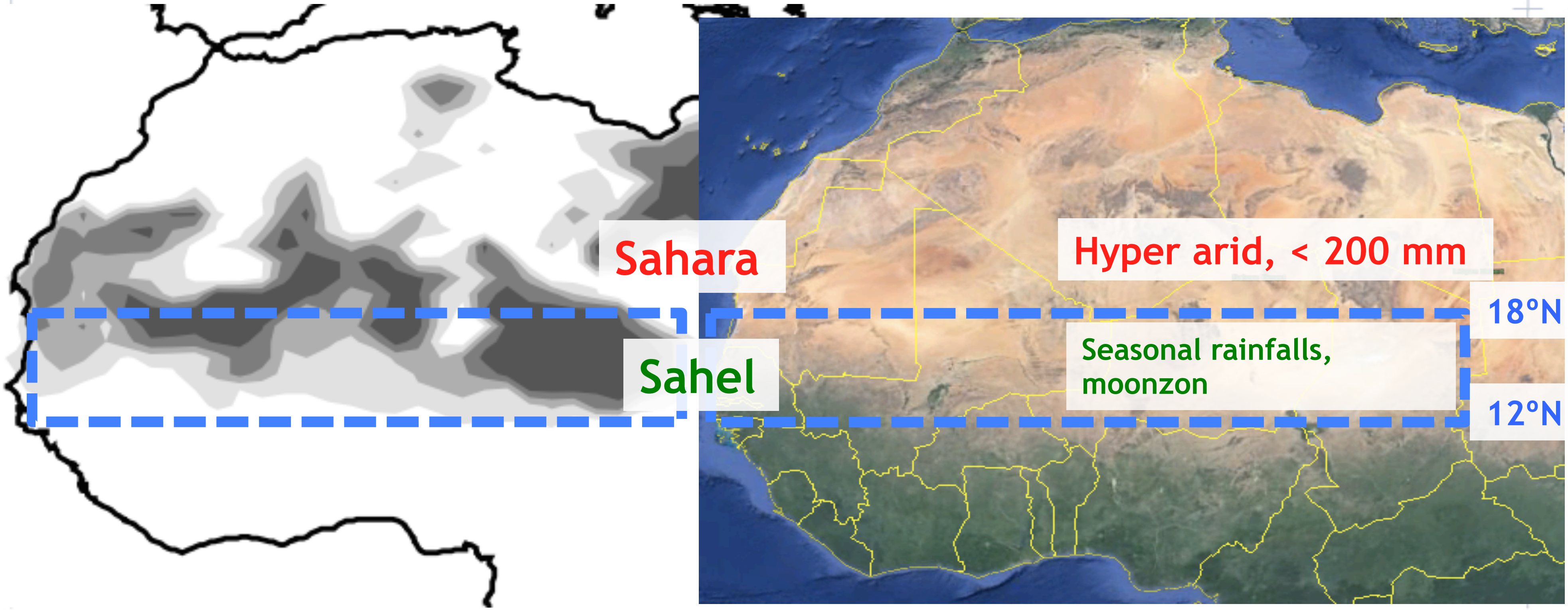
Sahel



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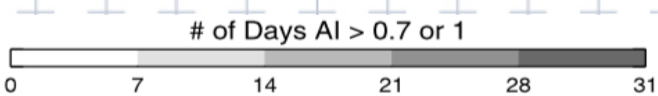

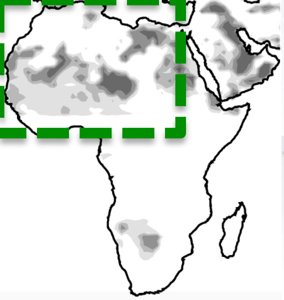

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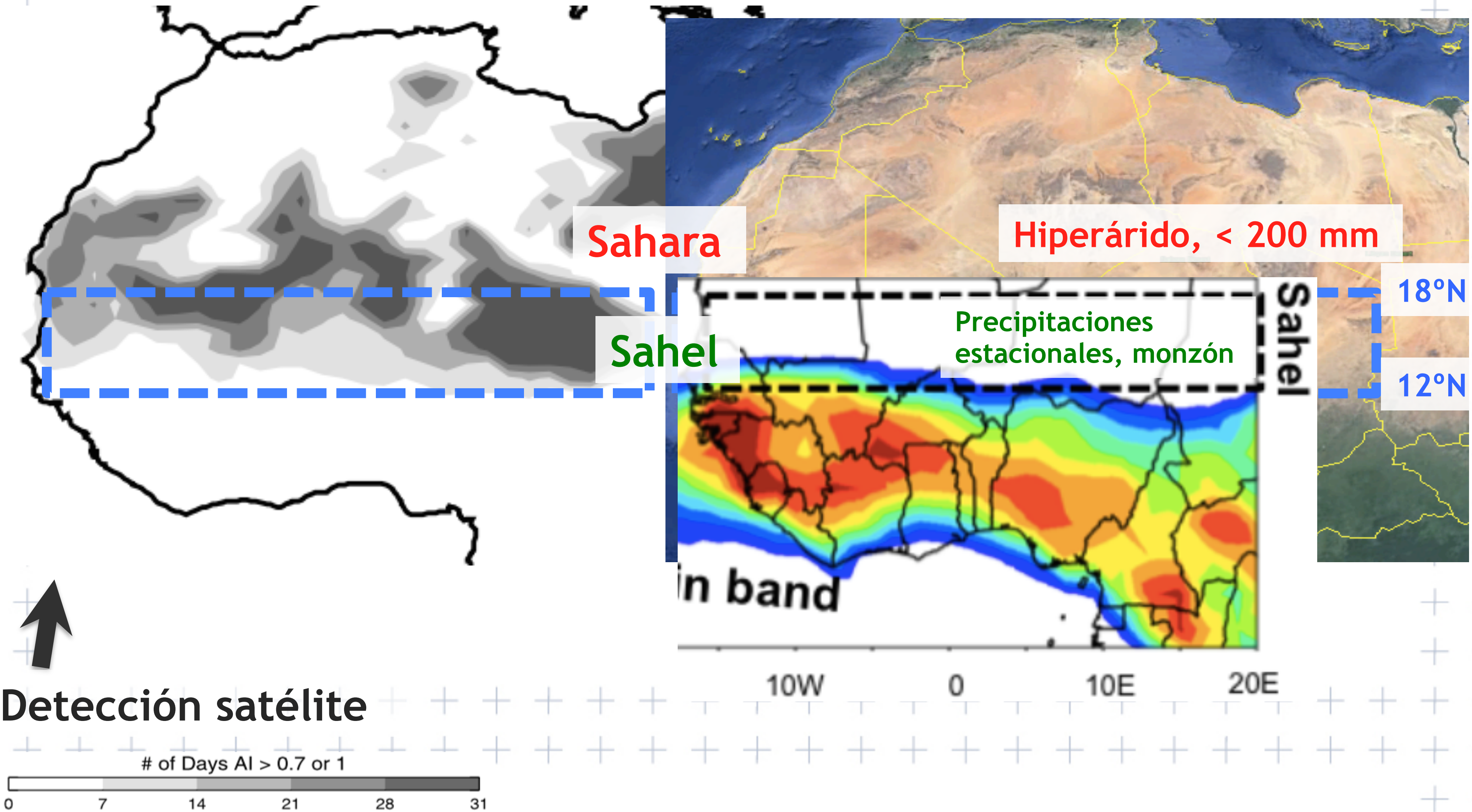

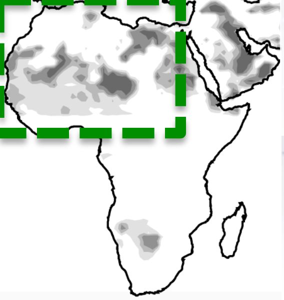

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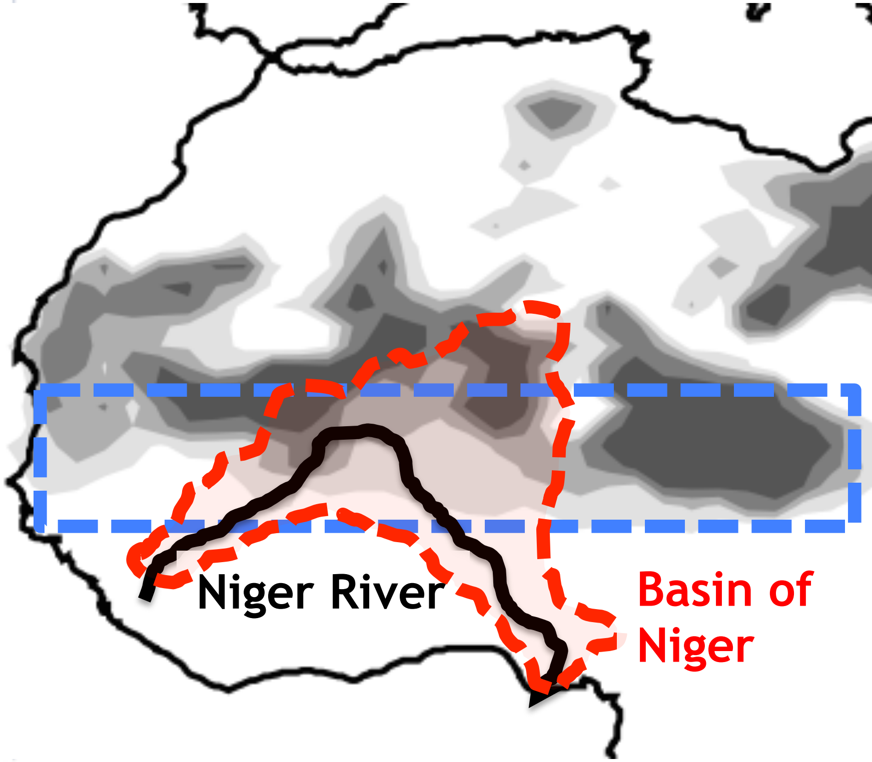
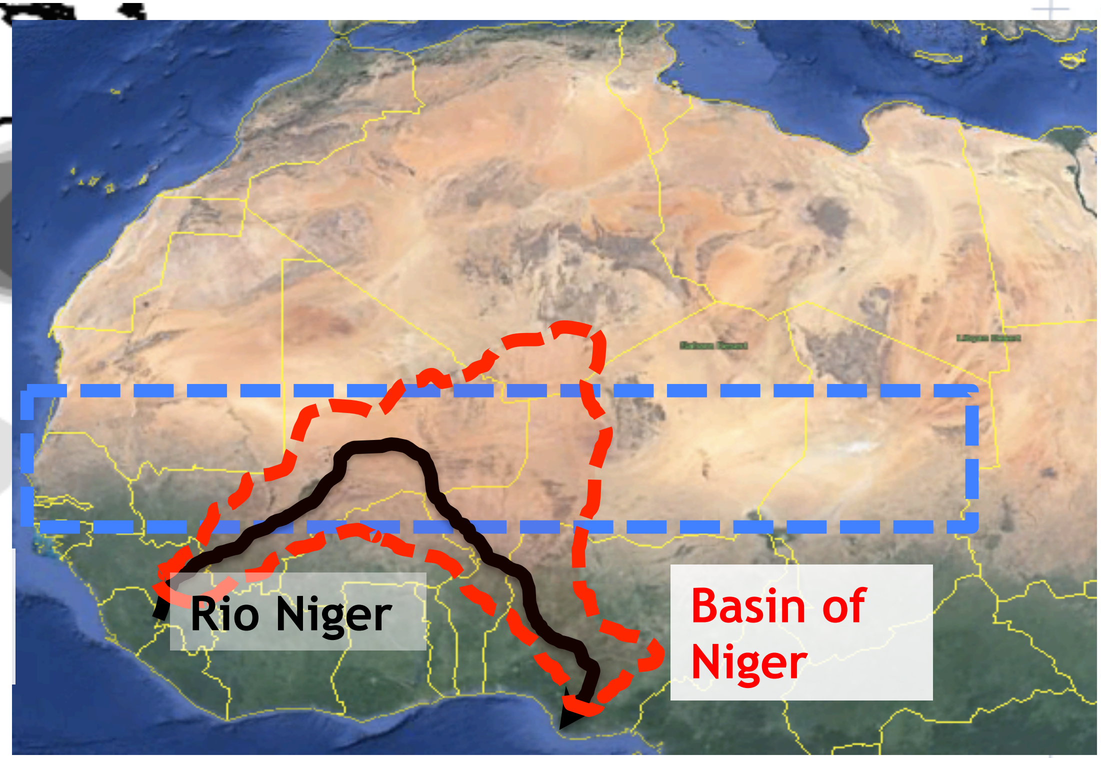
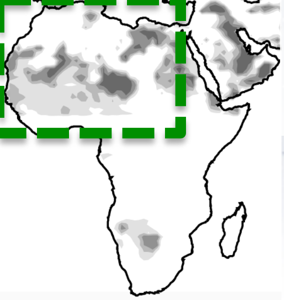




Remote Sensing satelite



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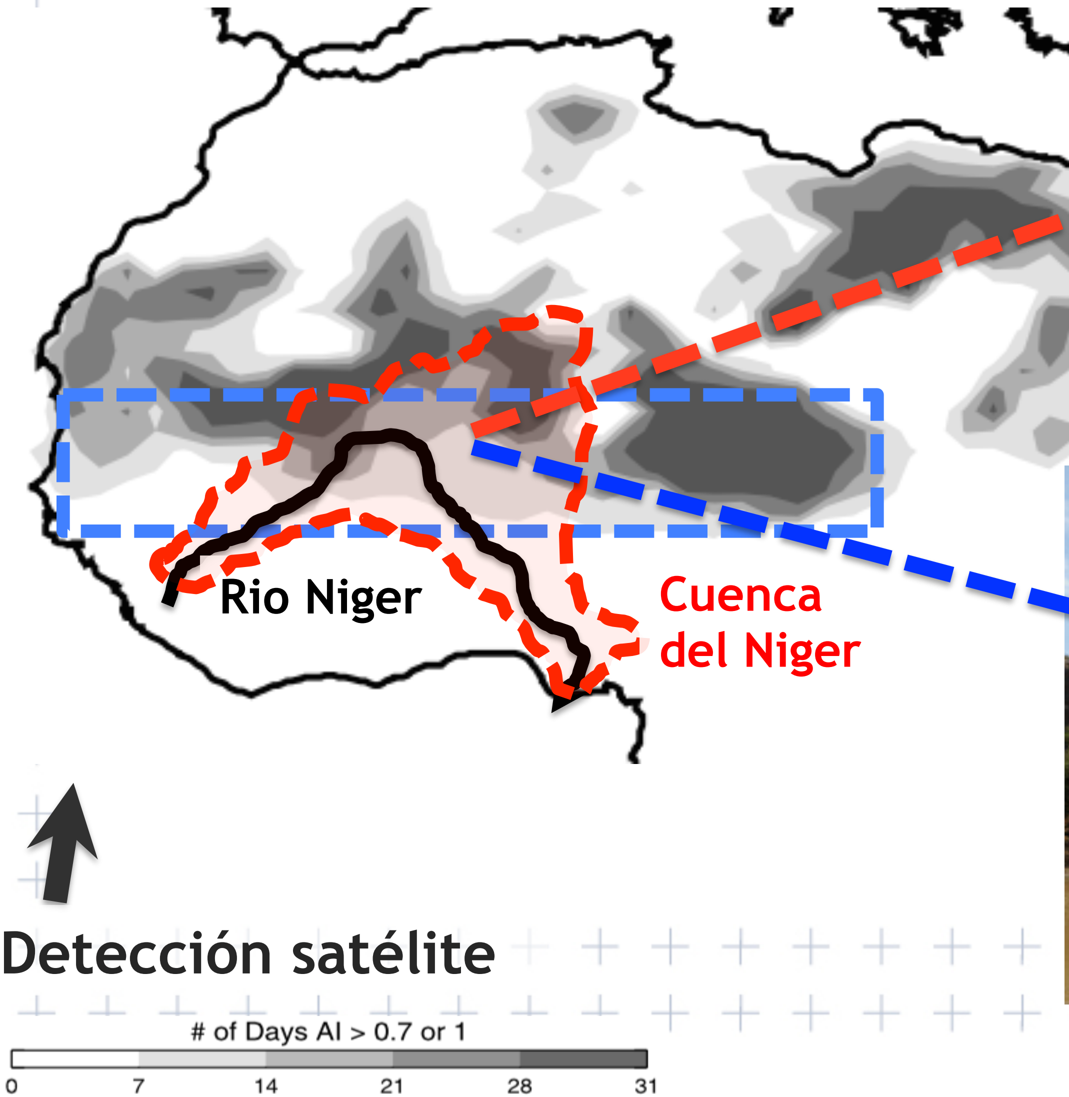

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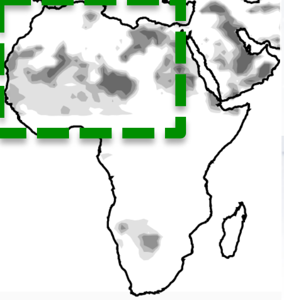
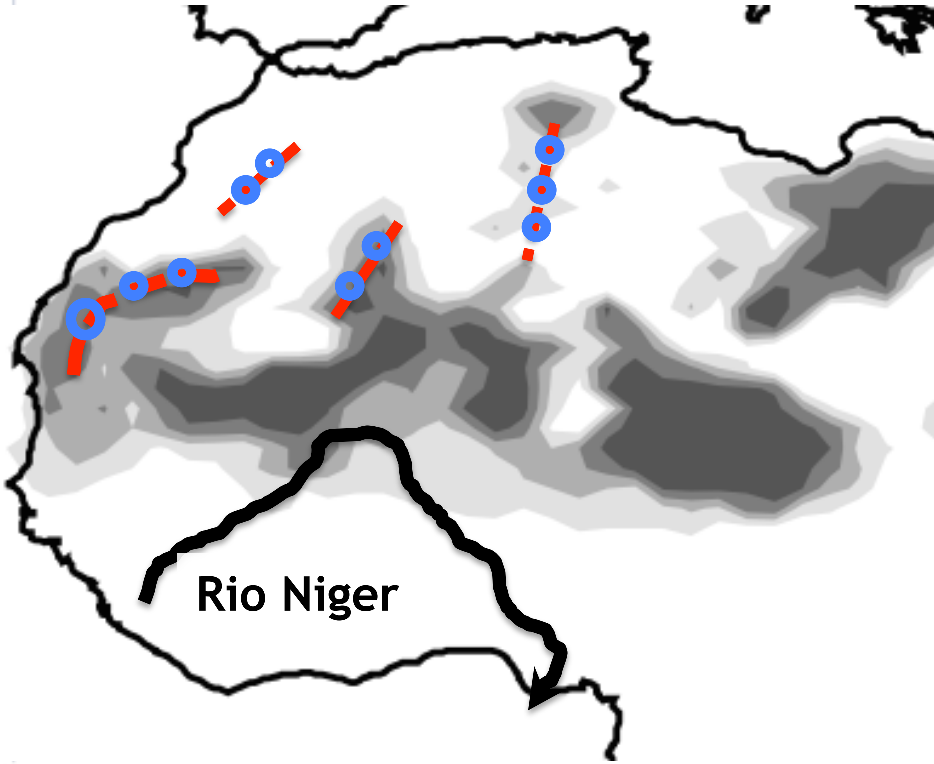
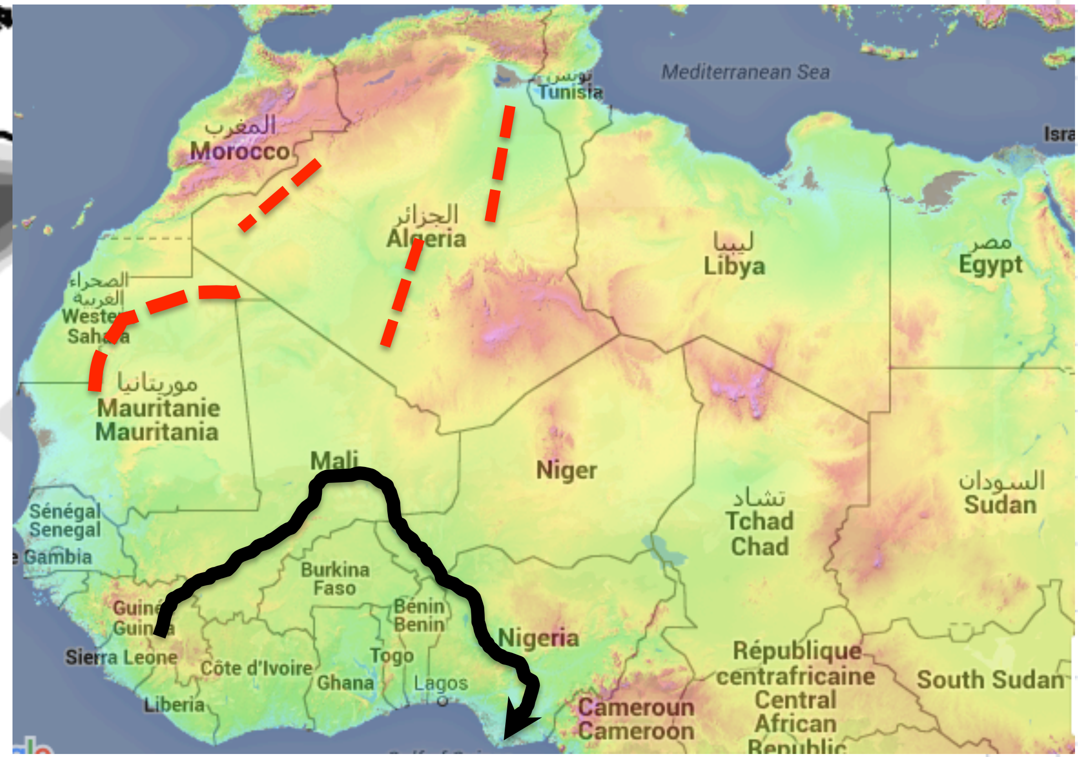


Agencia Estatal de Meteorología

Sahara

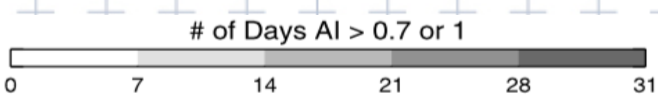


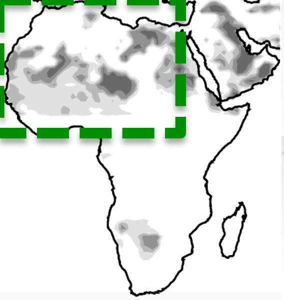


bajas tropográficas
Wakis: barrancos con inundaciones estacionales

chots, sabkas: lechos salados de lagos ecos

Detección satélite

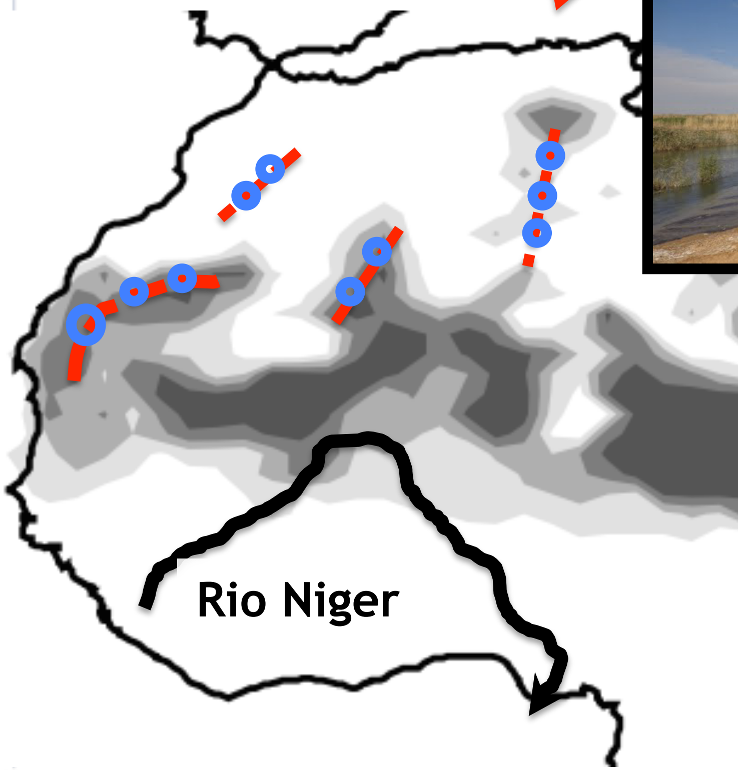


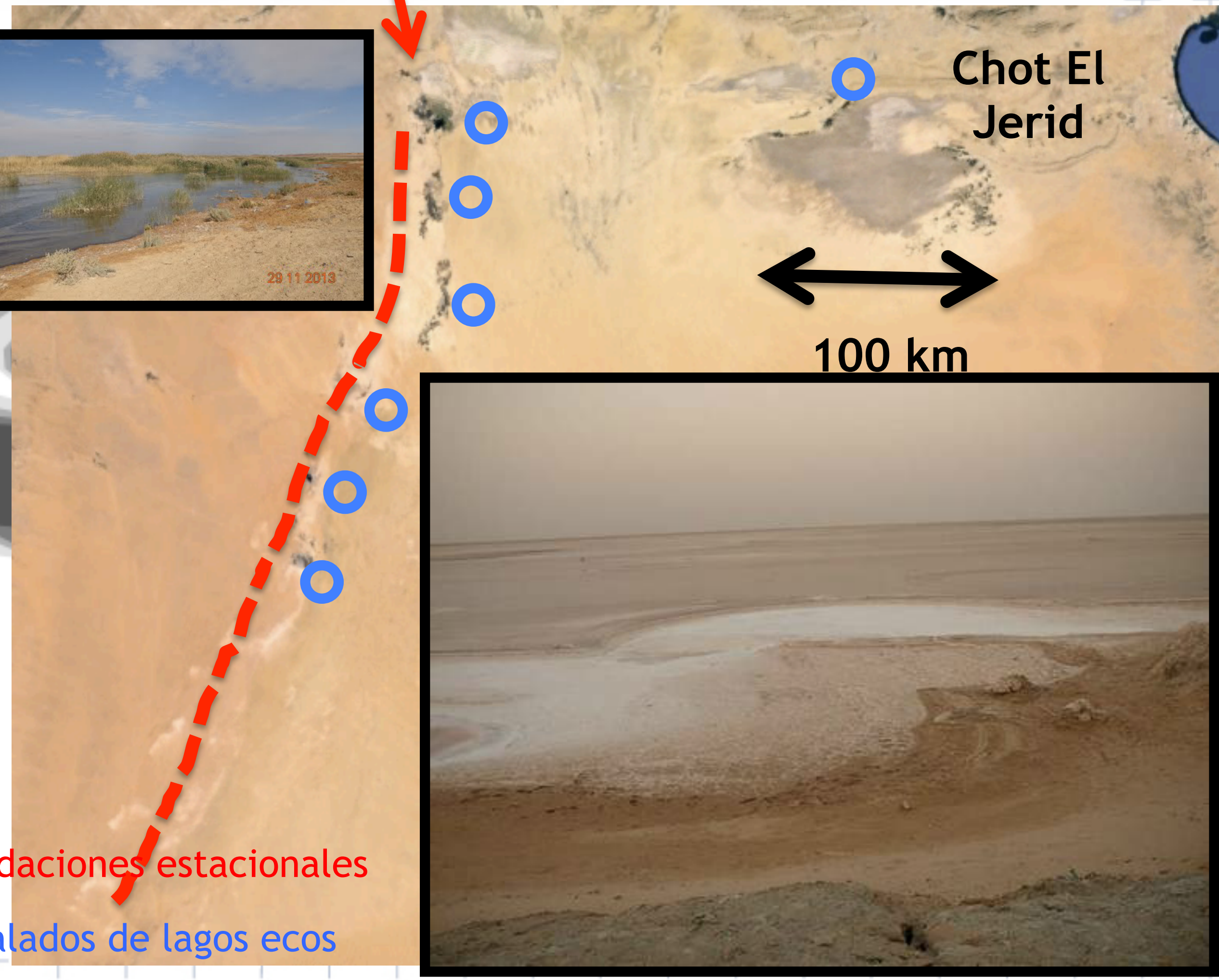


Sahara
Sahel

Cuenca Ouargla

Sahara chots





bajas tropográficas
Wakis: barrancos con inundaciones estacionales

chotts, sabkhas: lechos salados de lagos ecos *chotts, sabkhas, wadis, salares*

1. what is dust ?

There are several types of sources, but the mayor dust sources are associate with <u>dry lakes/rivers beds</u>

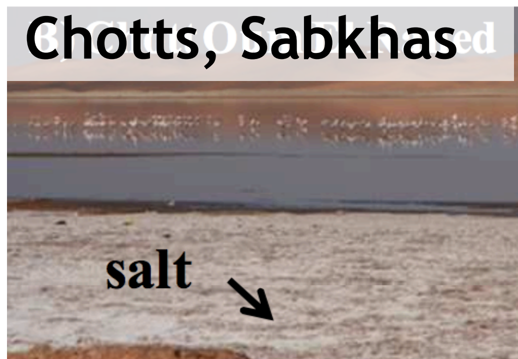
sediments, fluvial & alluvial deposits

2. chemistry and mineralogy

clays, feldspars, oxides, evaporites

3. Size and morphology

1 and 20 µm
agglomerates



strong link between water and dust natural sources

types of dust sources:

desert dust
paraglacial dust

paraglacial dust

paraglacial regions:

> 50°N
> 40°S

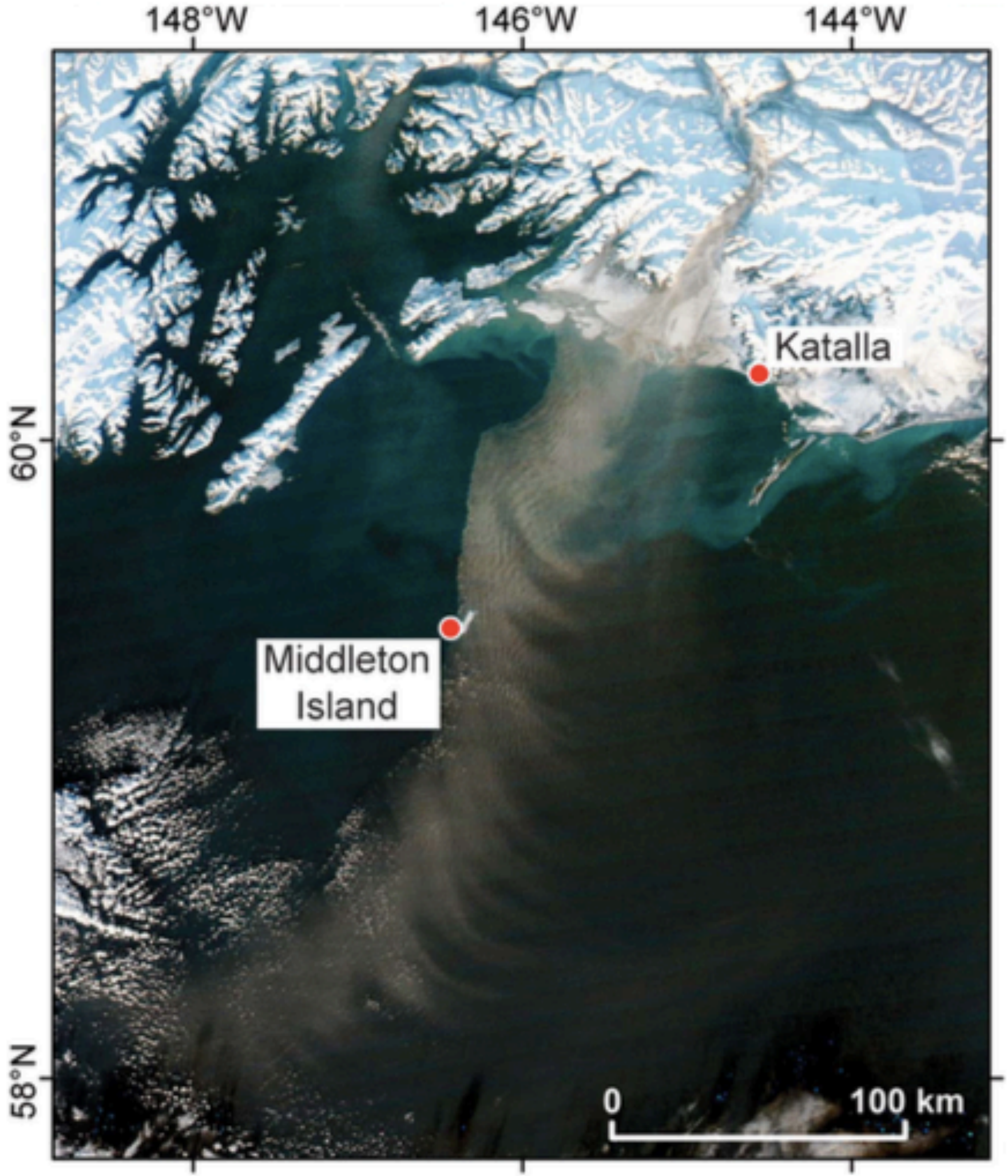
Paraglacial means unstable conditions caused by a significant relaxation time in processes and geomorphic patterns following glacial climates.

When a large mass of ice melts:

- newly exposed landscape free of vegetation
- water stream discharge, increasing erosion
- sediment deposition

➔ **dust source**

Hubbard Glacier, Alaska



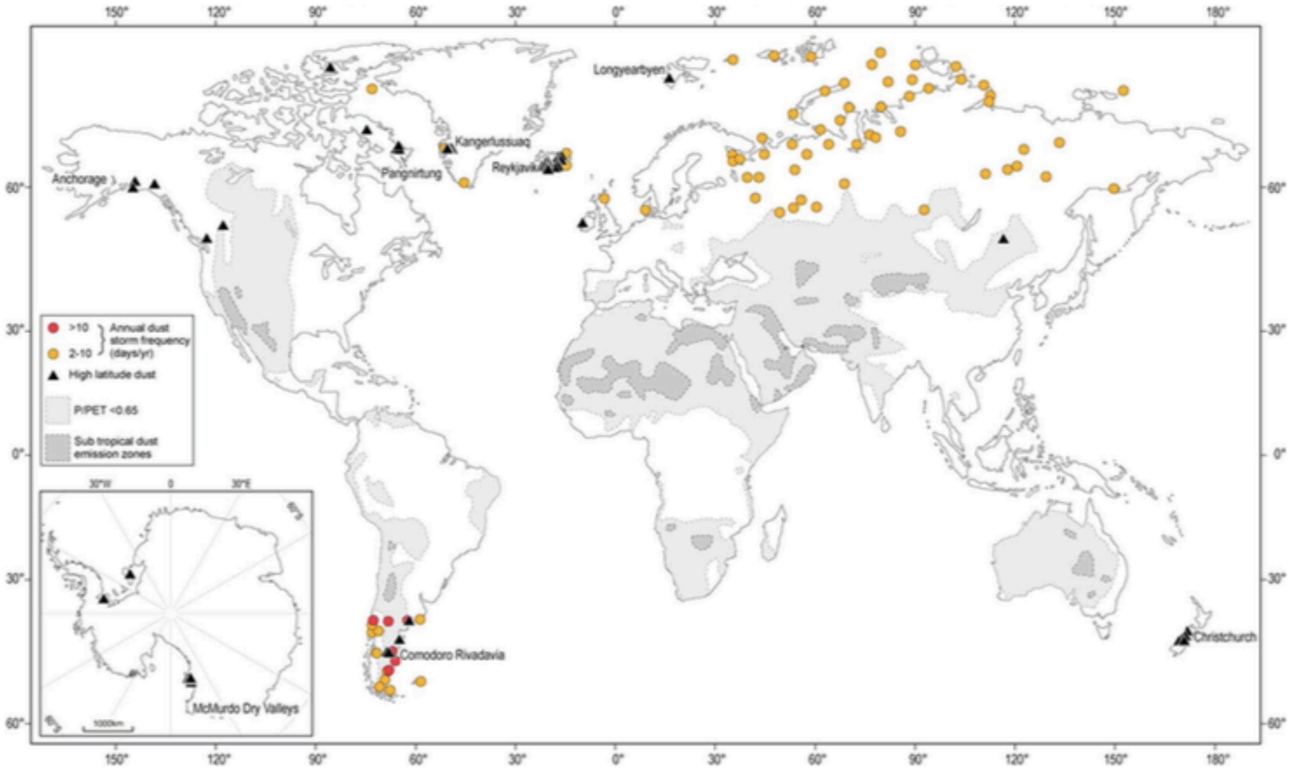
MODIS Aqua
Gulf of Alaska
4-Dec-2015

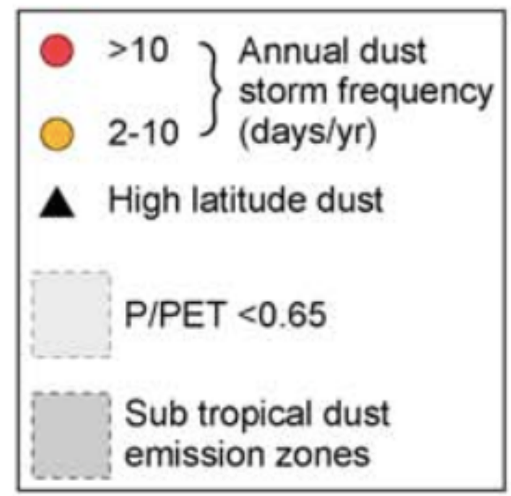
paraglacial dust

paraglacial regions:

- > 50°N
- > 40°S

5% of global dust budget

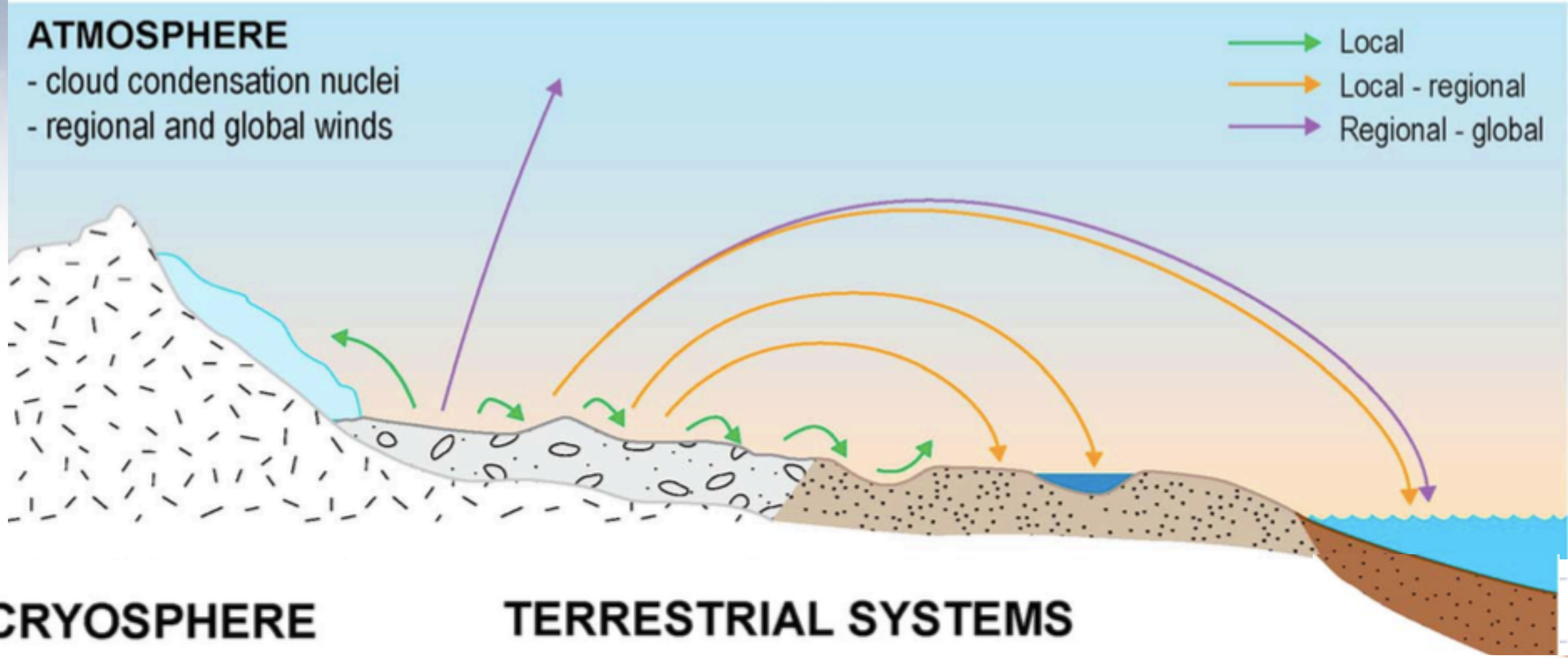




Reviews of Geophysics

High-latitude dust in the Earth system

Joanna E. Bullard[1], Matthew Baddock[1], Tom Bradwell[2], John Crusius[3], Eleanor Darlington[1], Diego Gaiero[4], Santiago Gassó[5], Gudrun Gisladottir[6], Richard Hodgkins[1], Robert McCulloch[2], Cheryl McKenna-Neuman[7], Tom Mockford[1], Helena Stewart[2], and Throstur Thorsteinsson[8]



CRYOSPHERE

-production of fine material

-meltwater transport of fines

-deposition of locally-sourced dust

-strong katabatic winds, weaker up-ice winds

TERRESTRIAL SYSTEMS

Proglacial

- meltwater reworking of sediments

- deflation and aeolian reworking of fine sediments

- multiple phases of local dust entrainment and deposition

- katabatic winds

Distal

- local wind scour and redistribution of fine material

- local-regional scale deposition of dust to form loess

- deposition of dust and nutrients to soils and lakes

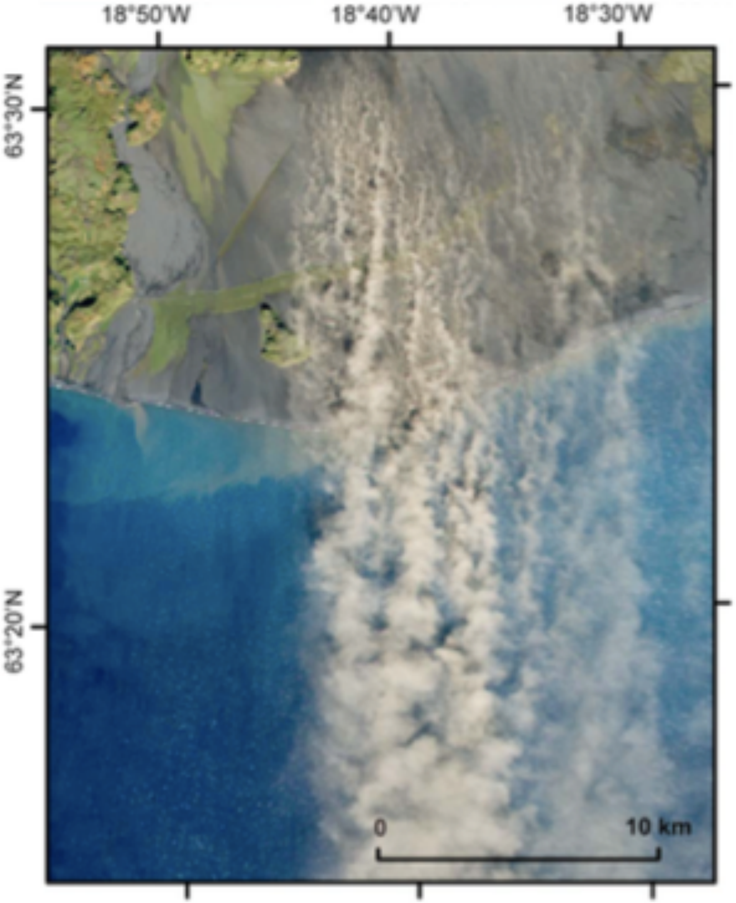
- katabatic and regional winds

MARINE

- deposition of dust and nutrients

- regional winds

Bullard et al., 2016

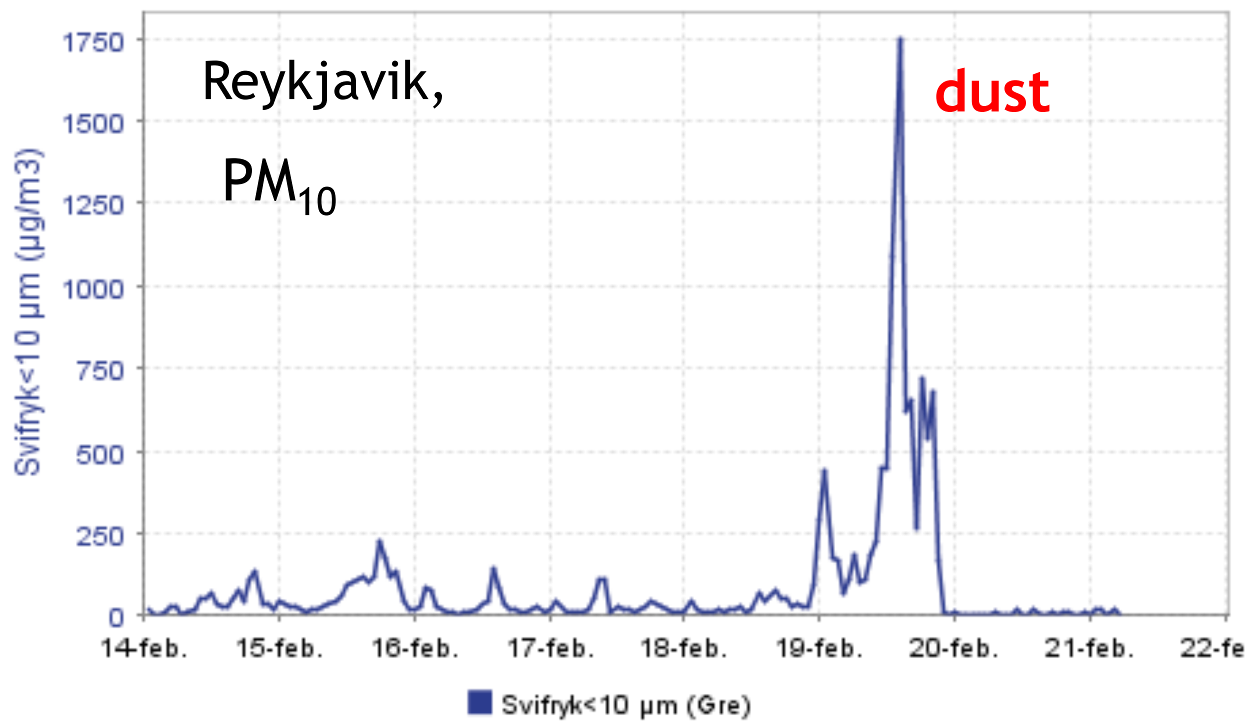


Landsat, 17 Sep 2013, Mýrdalssandur - Iceland

Dangerous air pollution hit Iceland's capital

Posted by Chillymanjaro on February 21, 2014 in categories Dust and haze, Pollution

Follow @TheWatchers_



Bullard et al., 2016

types of dust sources:

desert dust
paraglaciar dust

they exists by natural causes

by man influence:

new climate-change-related

glacier, climate change

Glacier change and glacial lake outburst flood risk in the Bolivian Andes

Simon J. Cook[1,2], Ioannis Kougkoulos[1,2], Laura A. Edwards[2,3], Jason Dortch[2,3], and Dirk Hoffmann[4]

The Cryosphere, 10, 2399–2413, 2016

Bolivia:
surface covered by glacier decreased 43% (1986-2014)

Proglacial lakes

future dust sources

types of dust sources:

desert dust
glacier dust

they exists by natural causes

by man influence:

new climate-change-related
new lakes desiccation

NASA EARTH OBSERVATORY
Where every day is Earth Day

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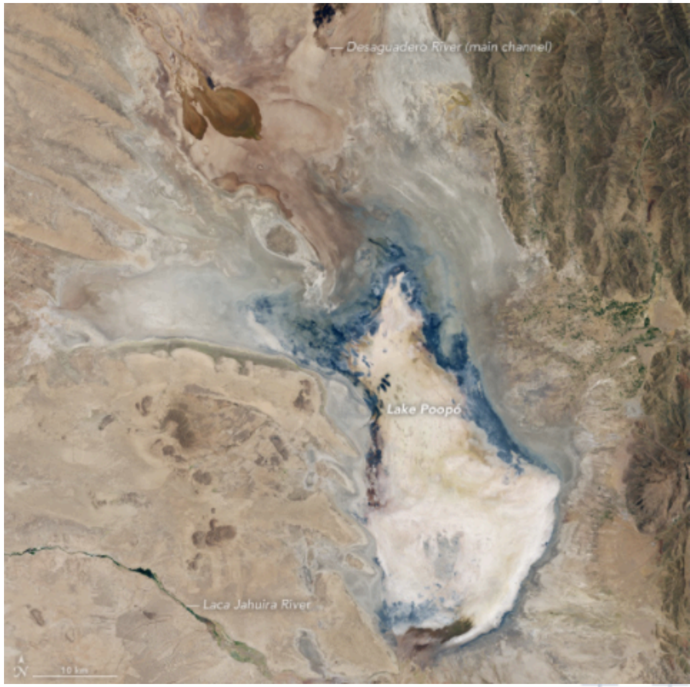
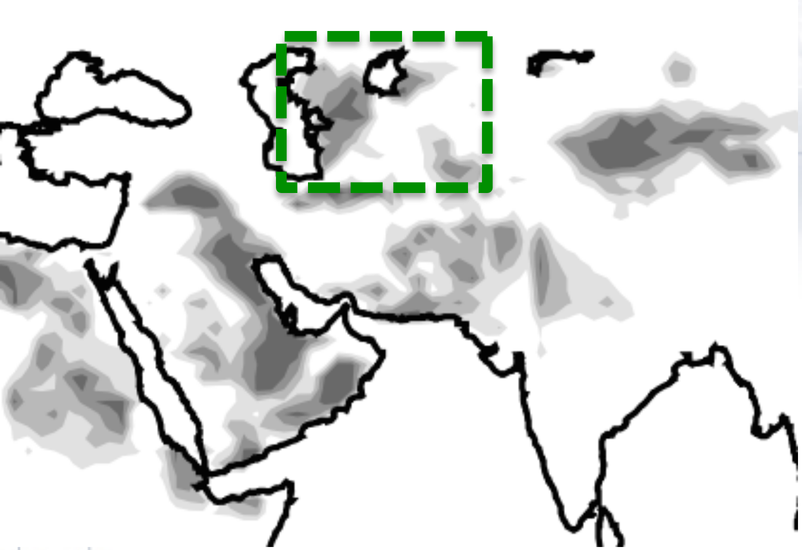
Bolivia's Lake Poopó Disappears

April 2013



Jan 2016

2015-16 drought



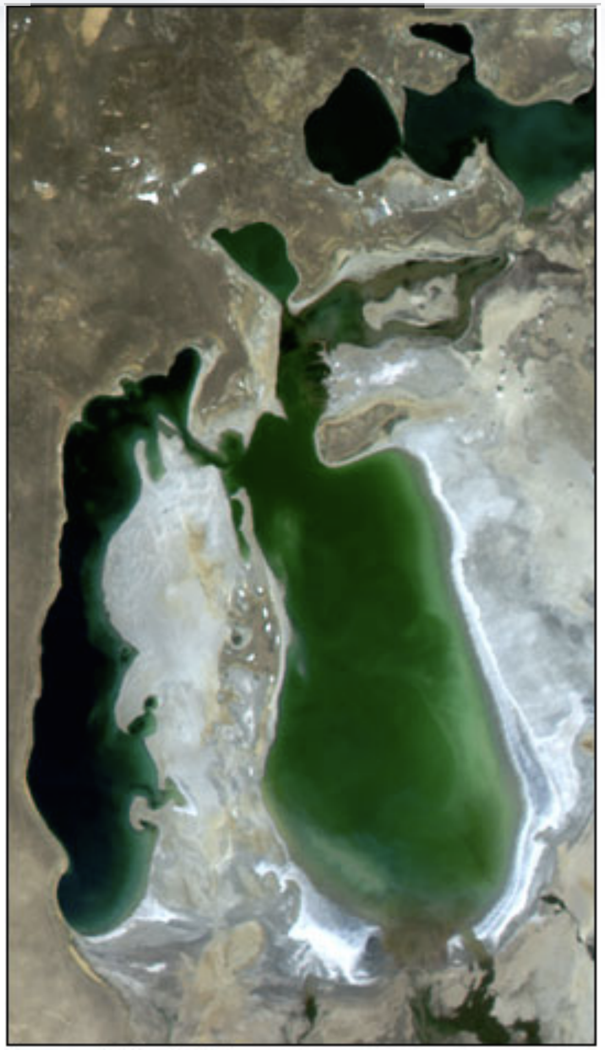
During the 1960s, the Syr y Amu rivers were re- chanelled for crop cultivation and the Aral Sea diminished increasing dust soruces

Aral Sea

1989

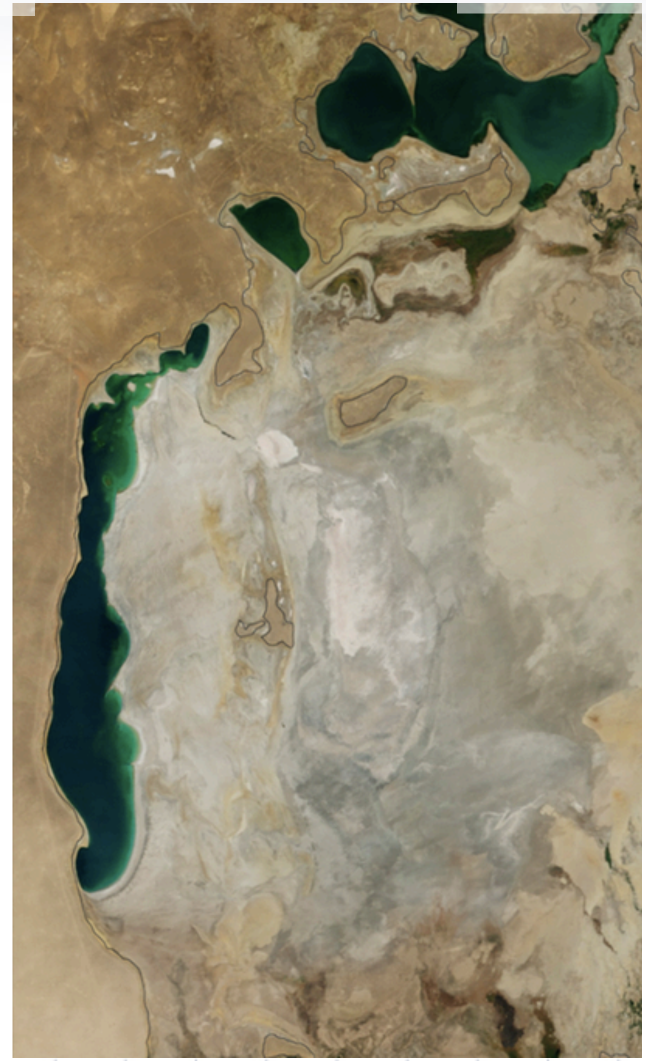
July - September, 1989

2003



August 12, 2003

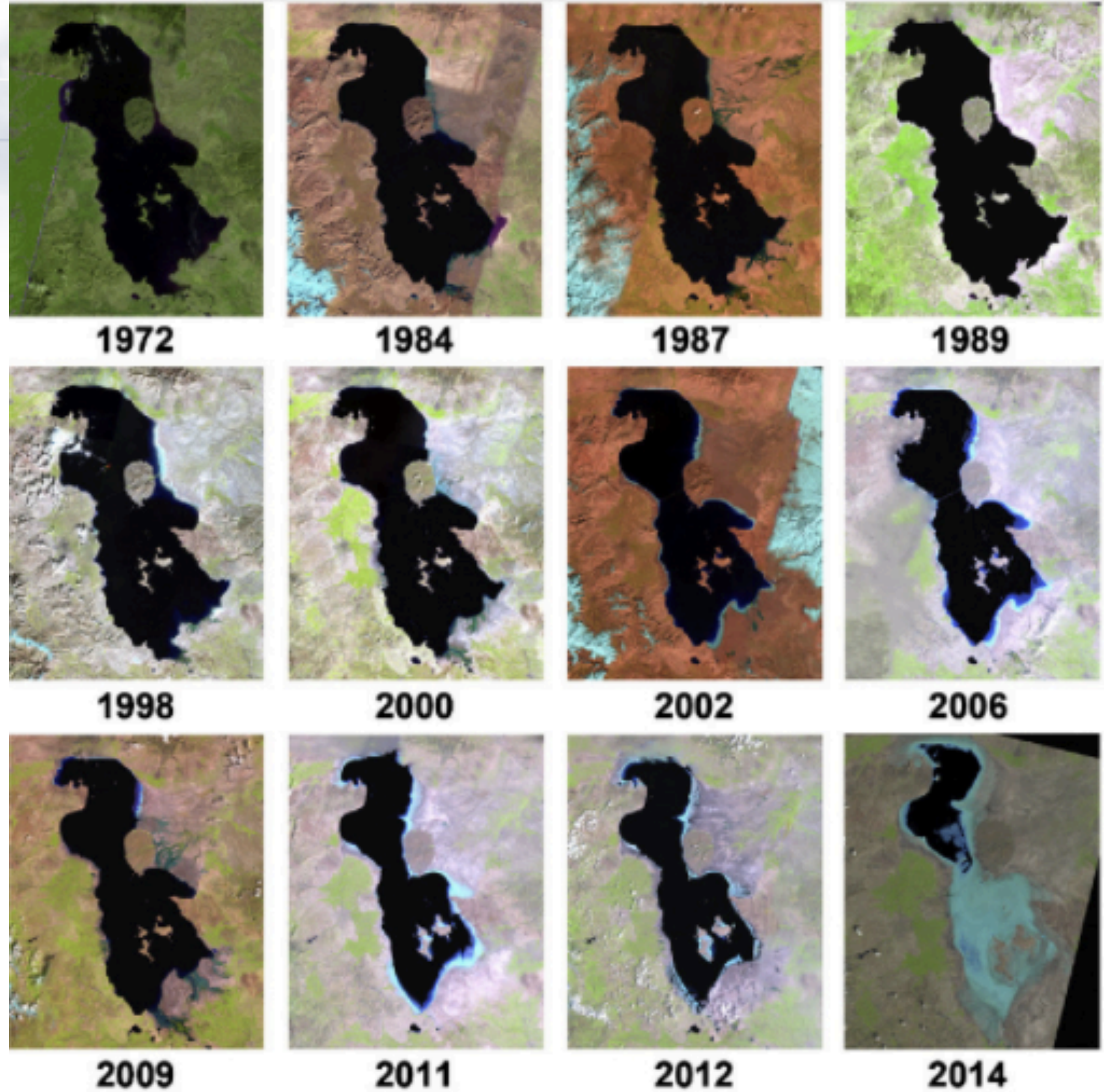
2014



Aral Sea

Urmia lake

an emerging important dust source



https://www.rt.com/viral/353940-urmia-lake-drought-red/

Urmia lake

The Use of HYSPLIT Model to Determine the Affected Areas of Dispersed Sea-Salt Particles of Dried Urmia Lake

Mahshid Nasiri*, Khosro Ashrafi**, Fereydoun Ghazban

ABSTRACT
Urmia Lake is one of the largest permanent hypersaline lakes in the world. In order to study the effects of aridity of Urmia Lake in northwestern Iran on local air quality, the Hybrid Single- Particle Lagrangian Integrated Trajectory (HYSPLIT) model is used to model the dispersion of remained sea-salt particles on the basin. Due to determine the possible affected areas at periphery of Urmia Lake and estimate the aerosol concentration in these areas, 24 hour dispersion has been modeled under various wind directions. Wind directions have been chosen regarded to prevailing wind in the area which is northeast-southwest. The maximum number of affected areas of sea-salt particles dispersion will be under 240 degree wind while the highest concentration of 6400 $\mu g/m^3$ will occur under 90 degree wind.
Keywords - Urmia Lake, Sea-salt aerosols, HYSPLIT

FINANCIAL TRIBUNE
FIRST IRANIAN ENGLISH ECONOMIC DAILY

People Environment
Tuesday, April 19, 2016

Lake Urmia Desiccation Slows

The recent increase in Lake Urmia's water level has had many claiming that the imperiled lake is restored, but an official warns that some people are sort of getting ahead of themselves.

"Lake Urmia is not yet restored, but thanks to high rainfall recently it now holds more water" Mohsen Soleimani, director of Iranian Wetlands Conservation Project, told ISNA. "It's only natural for the lake's water level to rise in rainy months."

types of dust sources:

desert dust
glacier dust

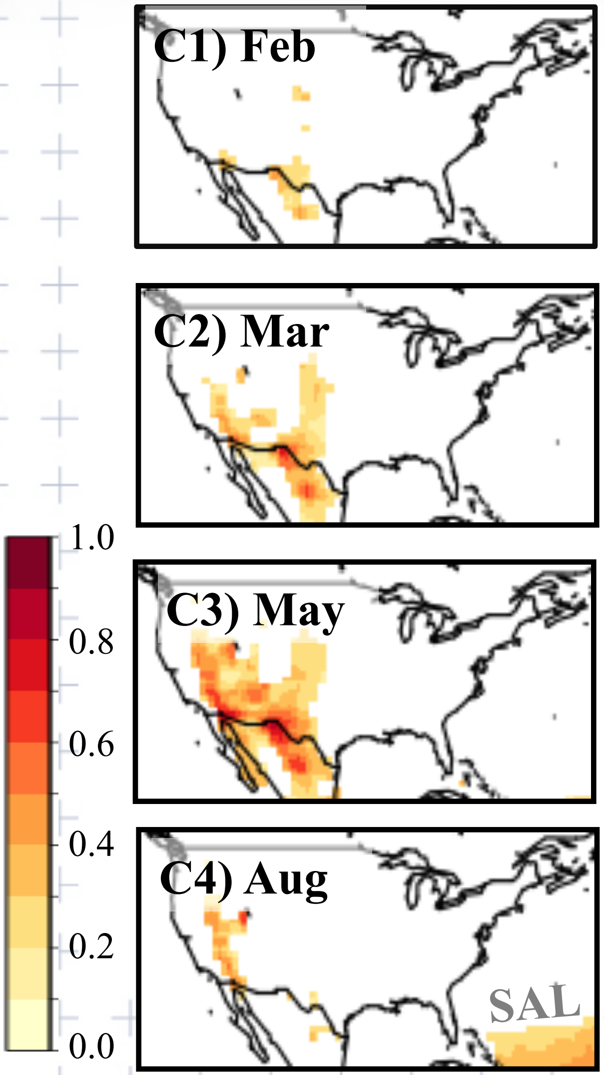
they exists by natural causes

by man influence:

new climate-change-related
new lakes desiccation
agriculture dust

Major Dust Activity Frequency

Aerosol Index > 1



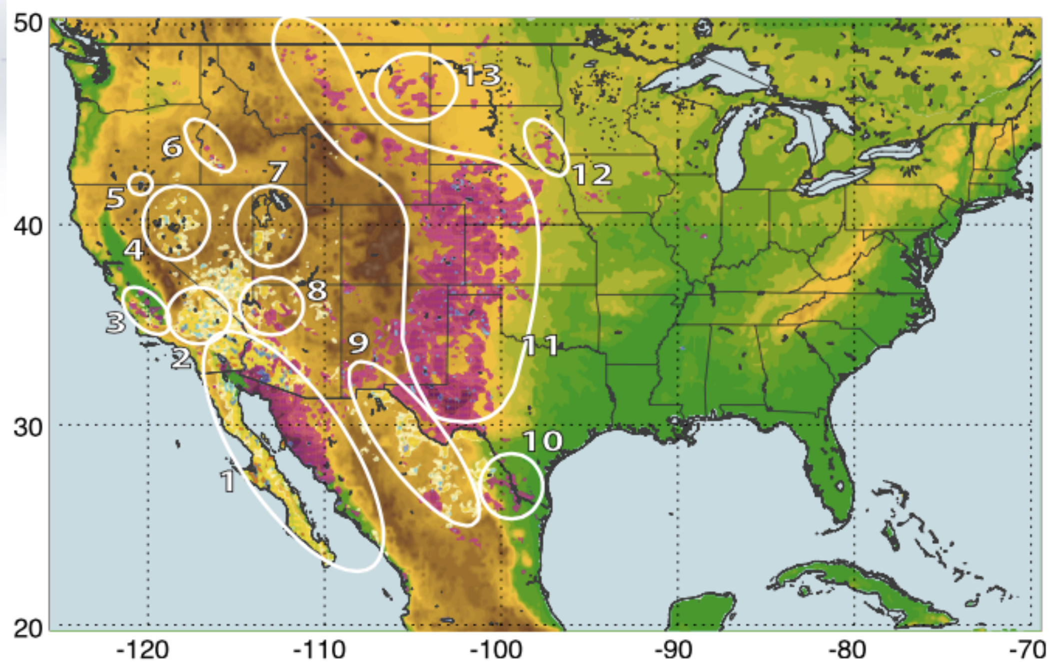
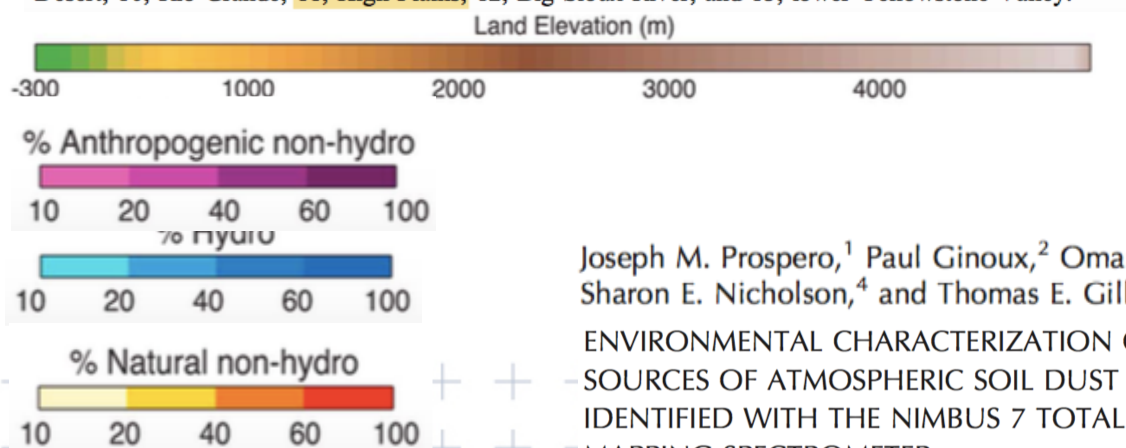


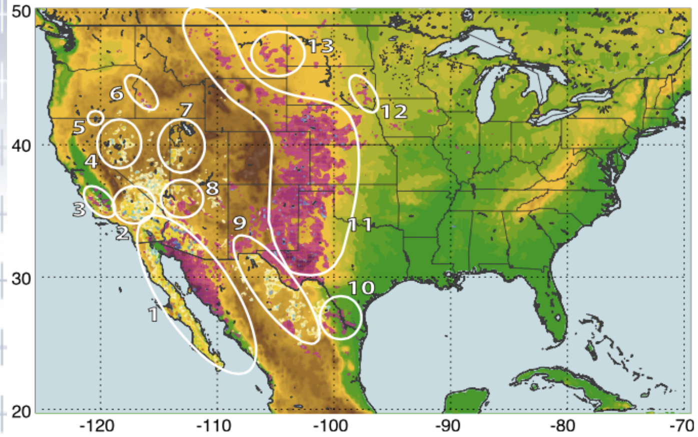
Figure 11. Distribution of the percentage number of days per season (March, April, and May) M-DB2 DOD > 0.2 over North America with color code as in Figure 6. The white circled sources are numbered as follows: 1, Sonoran Desert; 2, Mojave Desert; 3,San Joaquin Valley; 3, Black Rock-Smoke Creek deserts; 4, Goose Lake; 6, Snake River; 7, Great Salt Lake Desert; 8, Colorado River; 9, Chihuahuan Desert; 10, Rio Grande; 11, High Plains; 12, Big Sioux River; and 13, lower Yellowstone Valley.



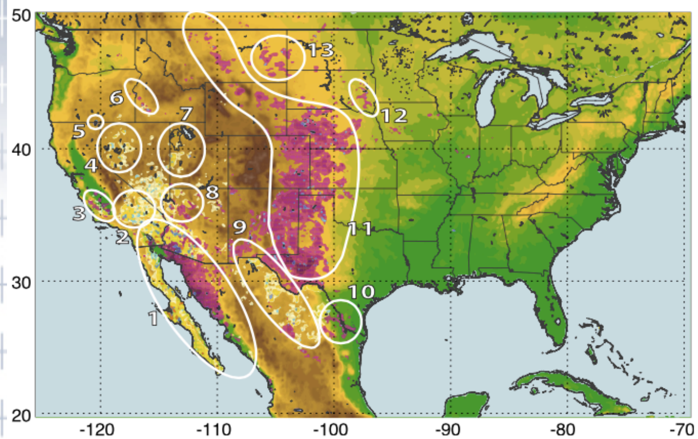
Joseph M. Prospero,[1] Paul Ginoux,[2] Omar Torres,[3] Sharon E. Nicholson,[4] and Thomas E. Gill[5]

ENVIRONMENTAL CHARACTERIZATION OF GLOBAL SOURCES OF ATMOSPHERIC SOIL DUST IDENTIFIED WITH THE NIMBUS 7 TOTAL OZONE MAPPING SPECTROMETER (TOMS) ABSORBING AEROSOL PRODUCT

Great Plains

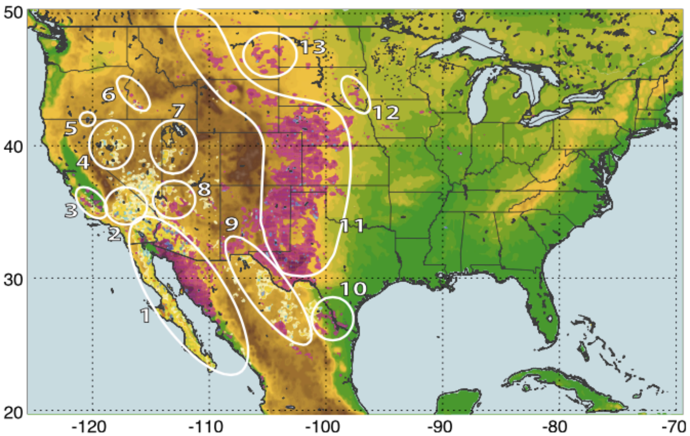


Great Plains

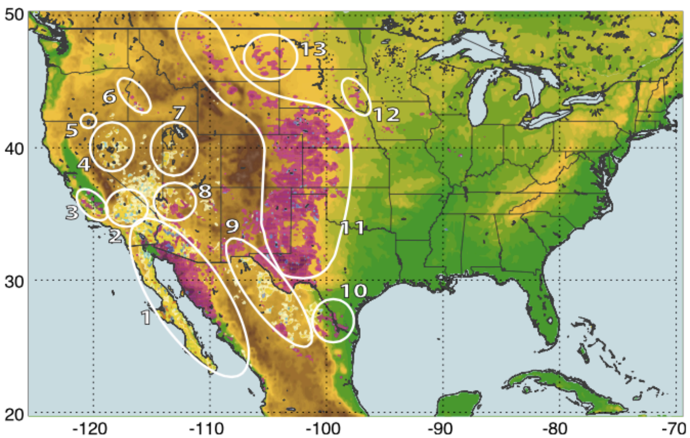


https://www.nrel.colostate.edu/projects/climate_impacts/gptoday.ht1.htm

Great Plains



Great Plains



Managing *wind erosion* on the Plains

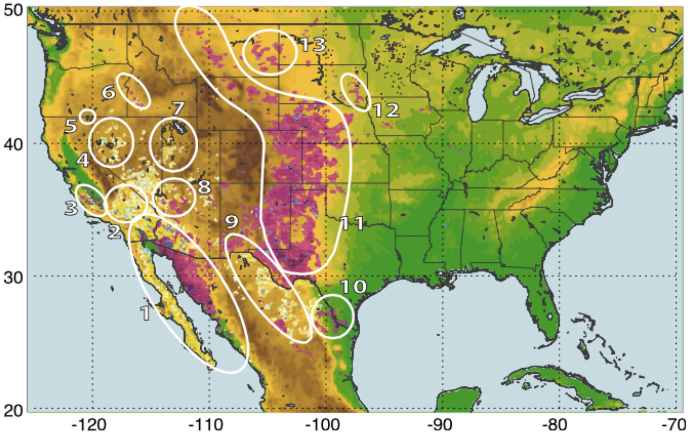
Clay Robinson

Crops & Soils Magazine - Article

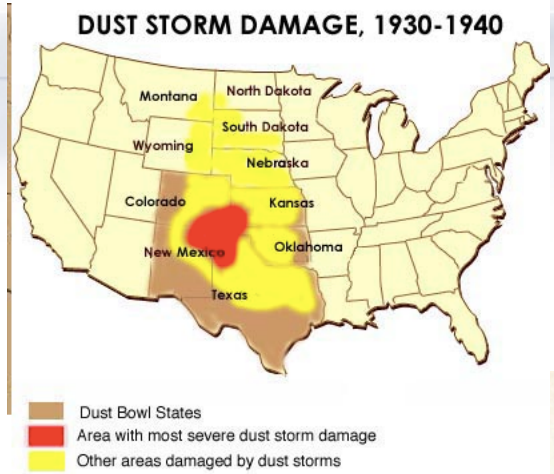
https://dl.sciencesocieties.org/publications/cns/articles/48/1/12

All that was left after the dust settled

Great Plains



Dust Bowl: 1930s



Dust Bowl: 1930s

affected 400,000 km^2 along
Texas and Oklahoma
and adjacent regions of
New Mexico, Colorado and Kansas.

dust –"black blizzards" or "black rollers" – traveled cross country, reaching the East Coast, including New York City and Washington, D.C

https://en.wikipedia.org/wiki/Dust_Bowl#cite_note-5

http://geol105naturalhazards.voices.wooster.edu/eating-sleeping-breathing-dust-health-hazards-of-the-dust-bowl/

types of dust sources:

desert dust
glacier dust

they exists by natural causes

by man influence:

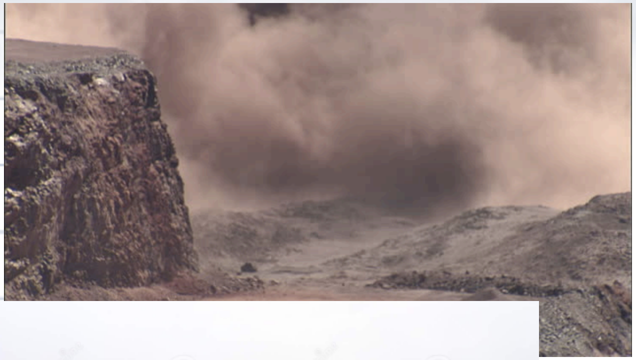
new climate-change-related
new lakes desiccation
agriculture dust

Regional to synoptic scale

industrial dust

Local to regional scale

mines



cement factories

ceramic manufactures

fertilizers plants

phosphate rocks

types of dust sources:

desert dust
glacier dust

new climate-change-related
new lakes desiccation
agriculture dust

industrial dust
construction dust

construction & demolition dust

GOBIERNO DE ESPAÑA
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO
AEMet Agencia Estatal de Meteorología

guidelines for preventing dust emissions

types of dust sources:

desert dust
glacier dust

new climate-change-related
new lakes desiccation
agriculture dust

industrial dust
construction dust
road dust

material accumulated on road and suspended vehicles:

- -construction/demolition dust
- -industrial dust
- -settled desert dust
- -settled air pollutants
- -pavement
- -brakes: barite ($BaSO_4$), hematite (Fe_2O_3), tenorite (CuO), zircon ($ZrSiO_4$), calcite ($CaCO_3$), periclasa (MgO), vermiculite, and sulphide species such as stibnite (Sb_2S_3), pyrite (FeS_2), chalcopyrite ($CuFeS_2$), covellite (CuS), sphalerite (ZnS), hauerite (MnS_2), and molybdenite (MoS_2).
- -tyres: rubber and metals (steel, Zn,...)

http://www.ehu.eus/sem/macla_pdf/macla16/Macla16_154.pdf

types of dust sources:

desert dust
glacier dust

they exists by natural causes

by man influence:

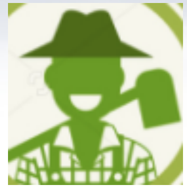
new climate-change-related
new lakes desiccation
agriculture dust

Regional to synoptic scale

industrial dust
construction dust
road dust

Local to regional scale

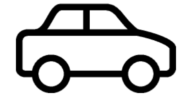
desert dust



agriculture

construction

industry



road dust

people live in cities and breath a cocktail
different of dust
+ pollutants

dust = desert + agriculture + construction + industrial + road-dust + ...

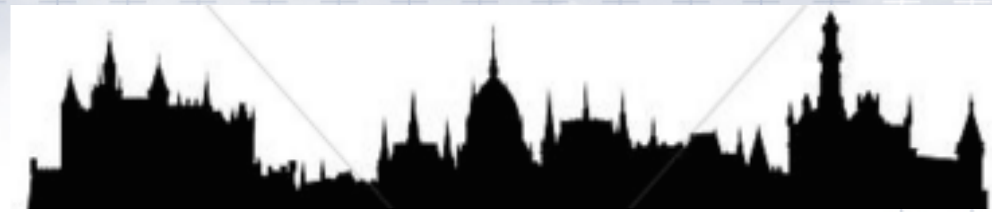
dust, aerosols and pollutants

in-situ observations

- PM_{10} and $PM_{2.5}$ levels
- PM_{10} and $PM_{2.5}$ composition
- complementary observations

remote sensing observations

let's build our observation network !!!



people live in cities and breath a cocktail dust + pollutants

aerosols, a cocktail of chemicals:

- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

size: 1 nm (10^{-9} m) to 20 µm (10^{-6} m)

human hair: 70 µm

aerosols, a cocktail of chemicals:

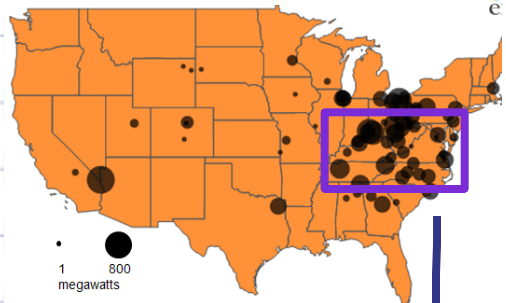
- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

gas precursor			aerosol
$SO_2 \rightarrow$	$SO_3 \rightarrow$	$H_2SO_4 \rightarrow$	$SO_4^{=}$
NO / NO_2	$\rightarrow HNO_3$	$\rightarrow$	NO_3^{-}
NH_3	$\rightarrow$		NH_4^{+}
			NH_4NO_3 $(NH_4)_2SO_4$

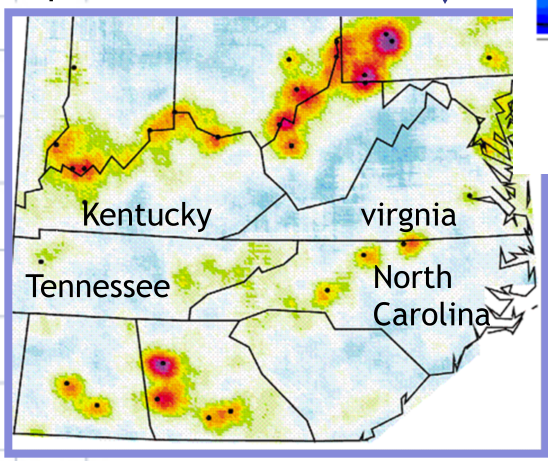
SO_2: oil refineries, coal power plants, ships, industry sulfato

122 Tg/y

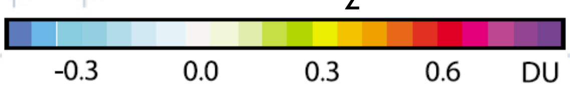
coal power plants



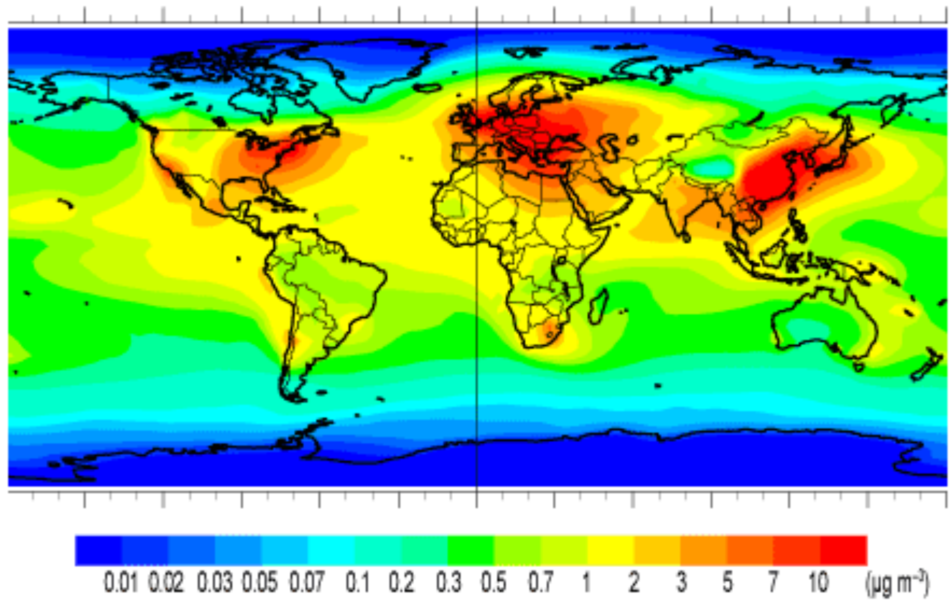
promedio 2005-2007



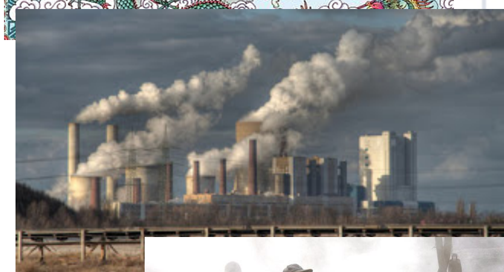
OMI SO_2 DU



sulfate



coal power plants



VOL. 15, NO. 4 JOURNAL OF CLIMATE 15 FEBRUARY 2002

Single-Scattering Albedo and Radiative Forcing of Various Aerosol Species with a Global Three-Dimensional Model

TOSHIHIKO TAKEMURA* AND TERUYUKI NAKAJIMA
OLEG DUBOVIK, BRENT N. HOLBEN, AND STEFAN KINNE

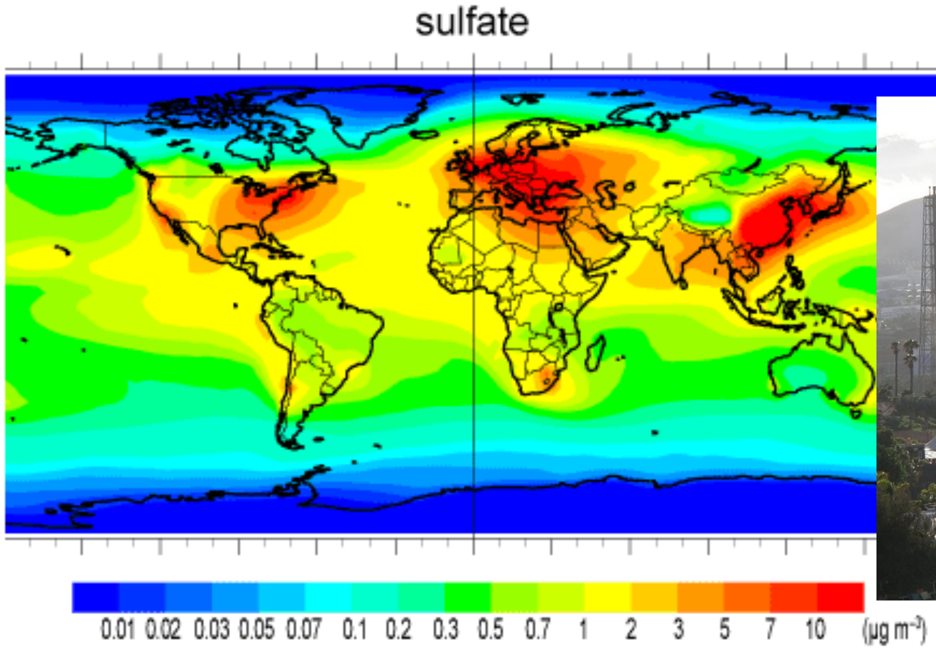
GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L21811, doi:10.1029/2011GL049402, 2011

Estimation of SO_2 emissions using OMI retrievals

V. E. Fioletov, C. A. McLinden, N. Krotkov, M. D. Moran, and K. Yang

sulfato

Oil refinery



Oil refinery

ships

aerosols, a cocktail of chemicals:

- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

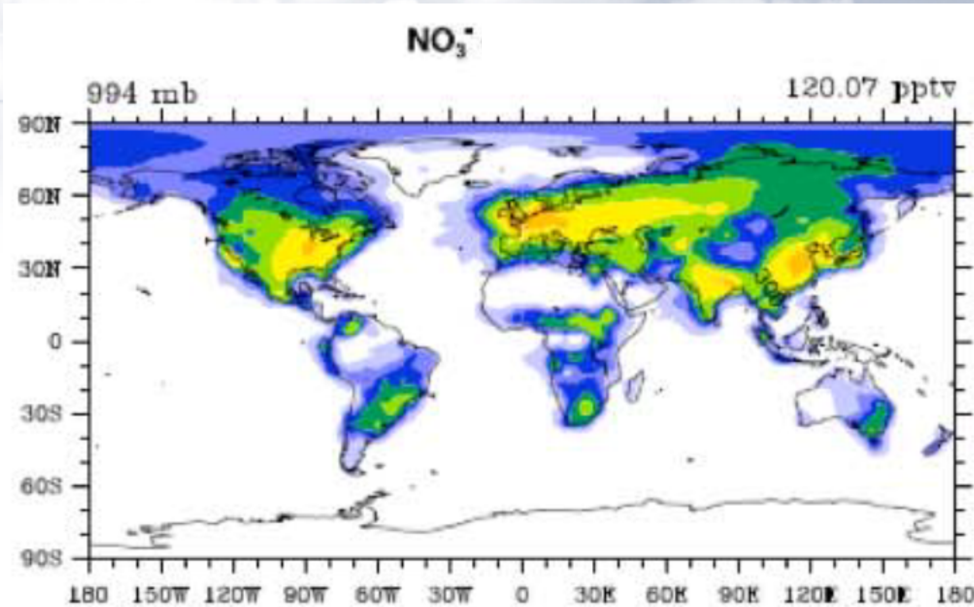
gas precursor			aerosol
SO_2 →	SO_3 →	H_2SO_4 →	$SO_4^{=}$
NO / NO_2 →		HNO_3 →	NO_3^-
NH_3 →			NH_4^+
			NH_4NO_3
			$(NH_4)_2SO_4$

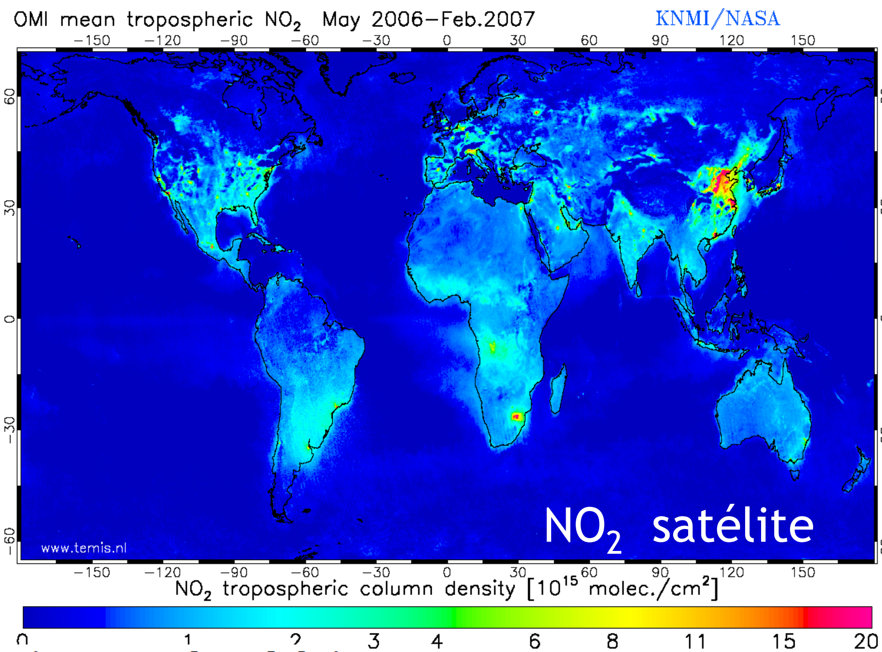
NO_x: vehicle exhaust, power plants, industry

nitrate

18 Tg/y

NH_4NO_3



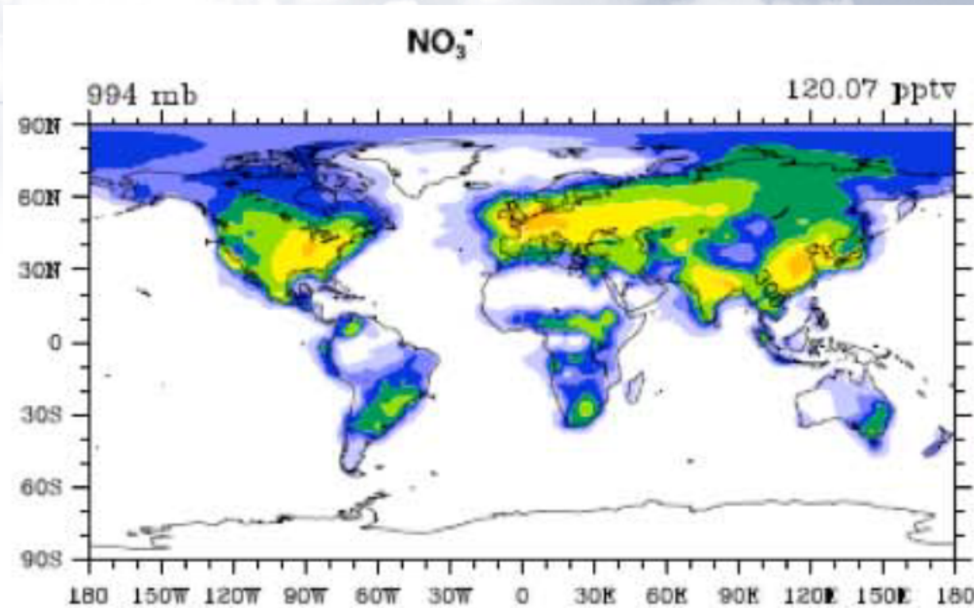


Atmos. Chem. Phys., 12, 9479–9504, 2012
www.atmos-chem-phys.net/12/9479/2012/

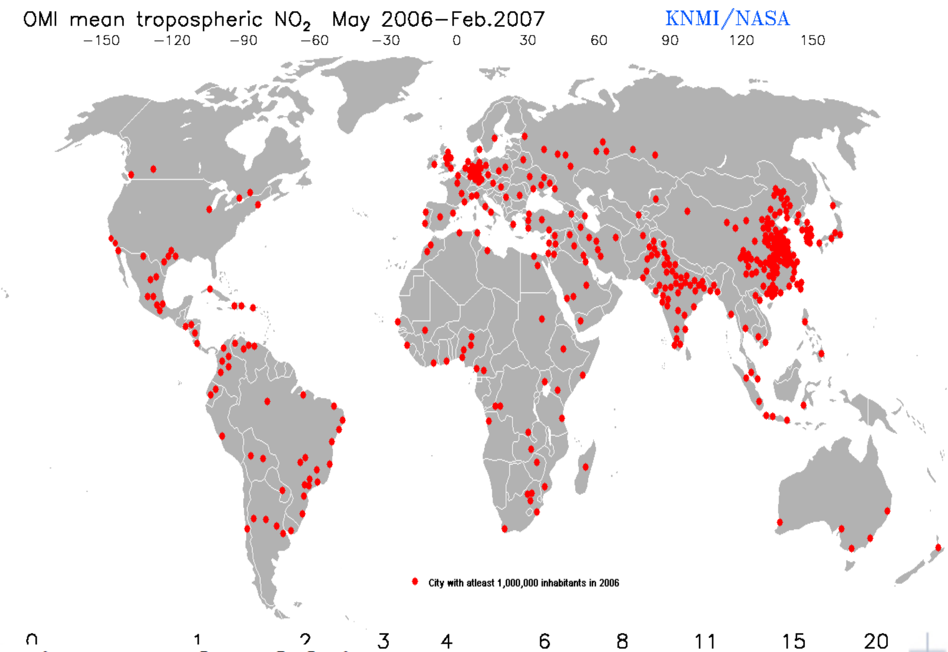
L. Xu and J. E. Penner

Global simulations of nitrate and ammonium aerosols and their radiative effects

nitrate



NH_4NO_3



cities > 1 million inhabitants

Atmos. Chem. Phys., 12, 9479–9504, 2012
www.atmos-chem-phys.net/12/9479/2012/

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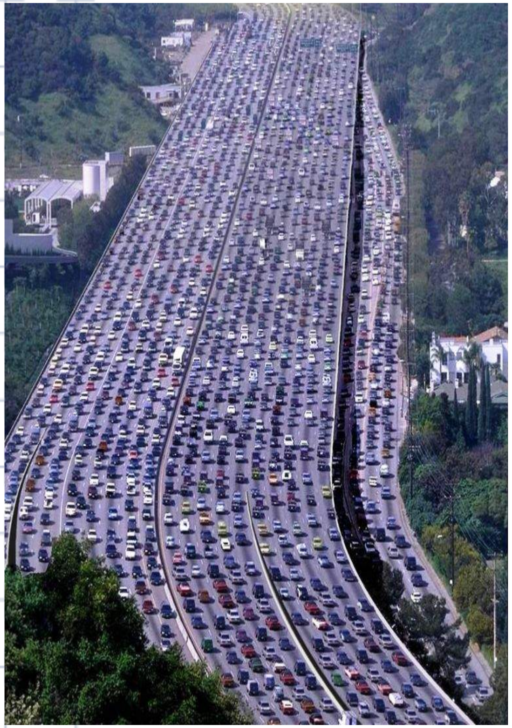
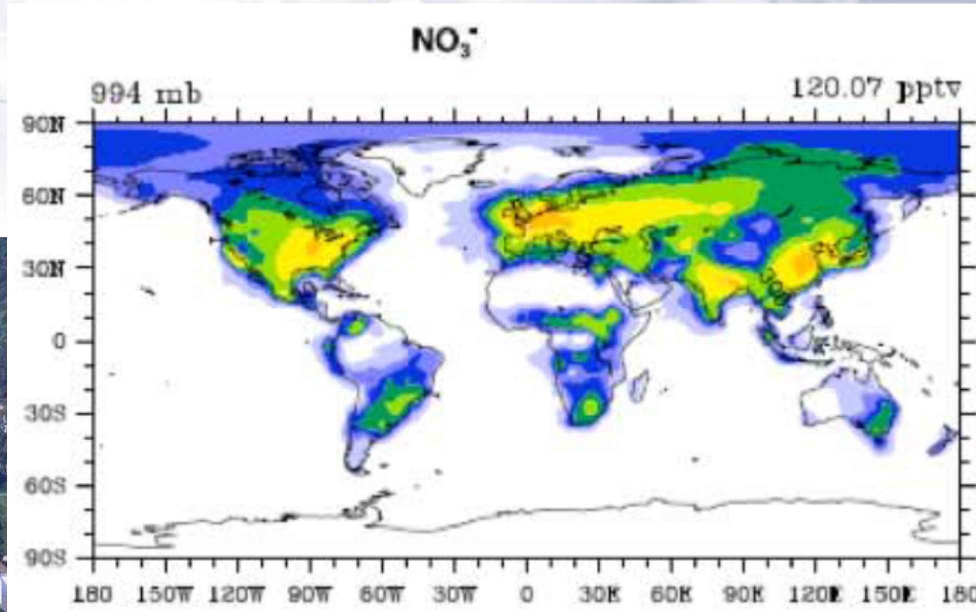
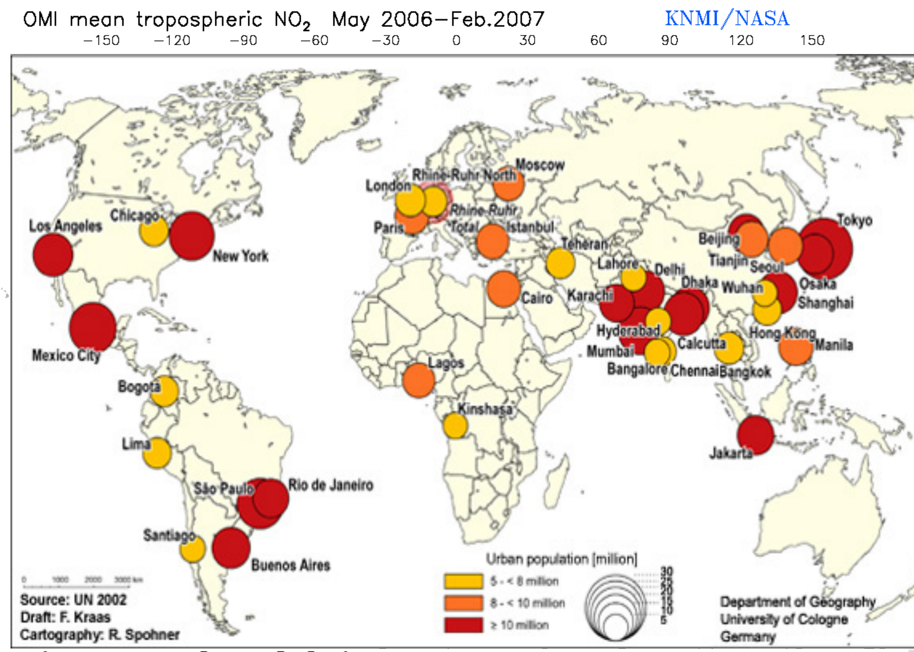




NH_4NO_3



Mega-cities, > 5 Millones habitants

Atmos. Chem. Phys., 12, 9479–9504, 2012
www.atmos-chem-phys.net/12/9479/2012/

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Global simulations of nitrate and ammonium aerosols and their radiative effects

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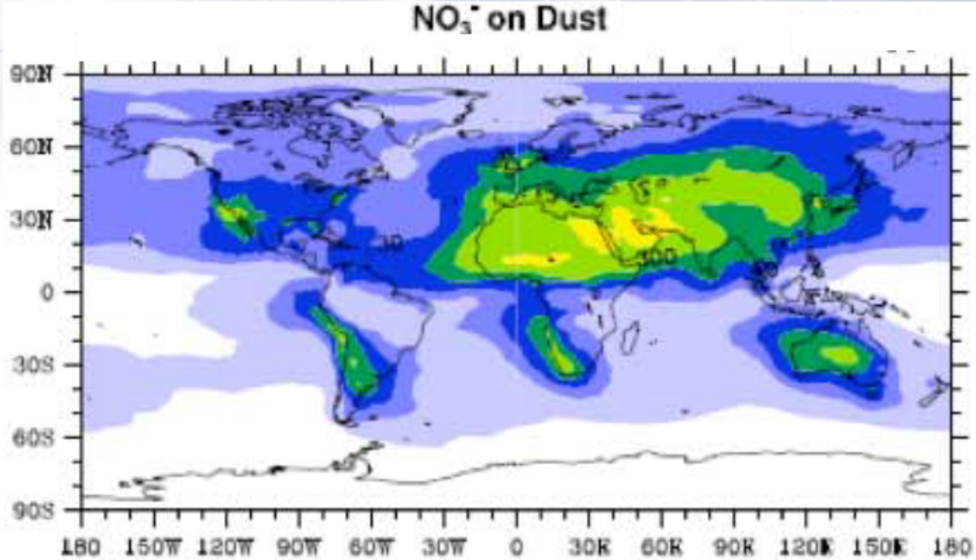
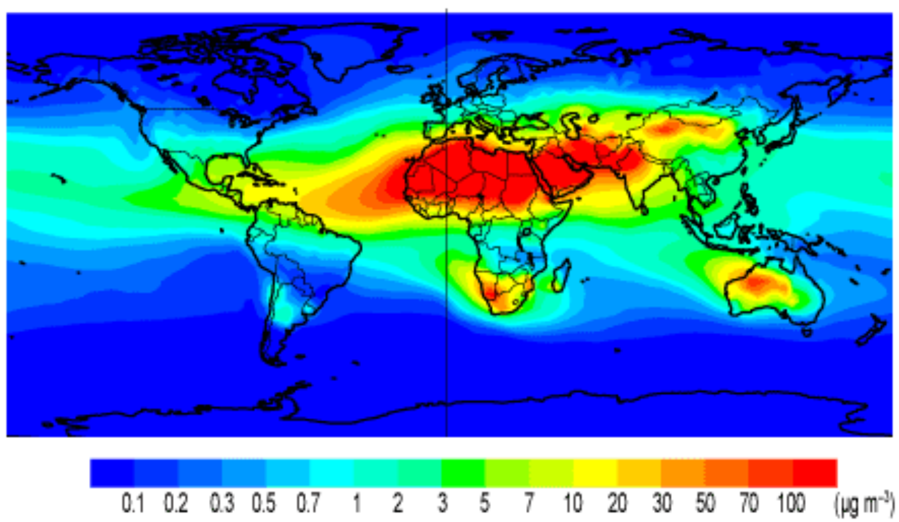


NO_3^- - dust
$Ca(NO_3)_2$

soil dust



Atmos. Chem. Phys., 12, 9479–9504, 2012
www.atmos-chem-phys.net/12/9479/2012/

L. Xu and J. E. Penner

Global simulations of nitrate and ammonium aerosols and their radiative effects

http://www.knmi.nl/omi/research/product/index.php

aerosols, a cocktail of chemicals:

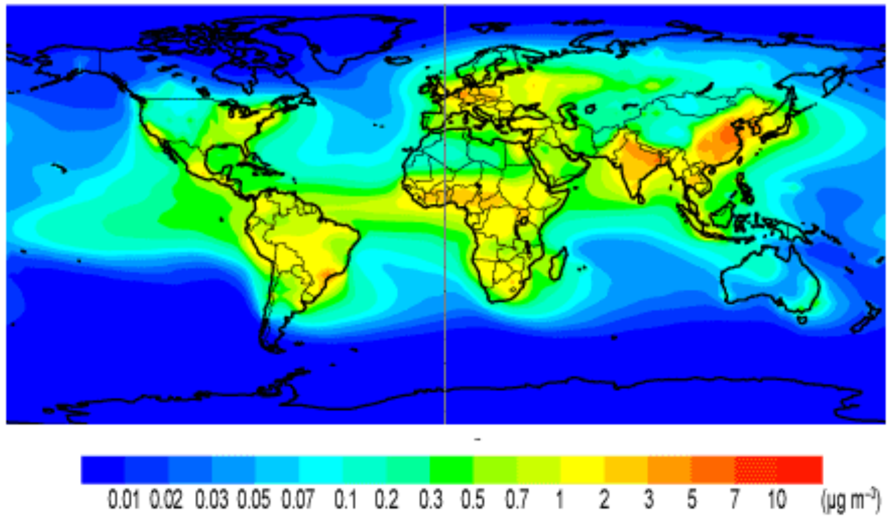
- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

Black carbon: vehicle exhaust (diesel) , combustion sources black carbon

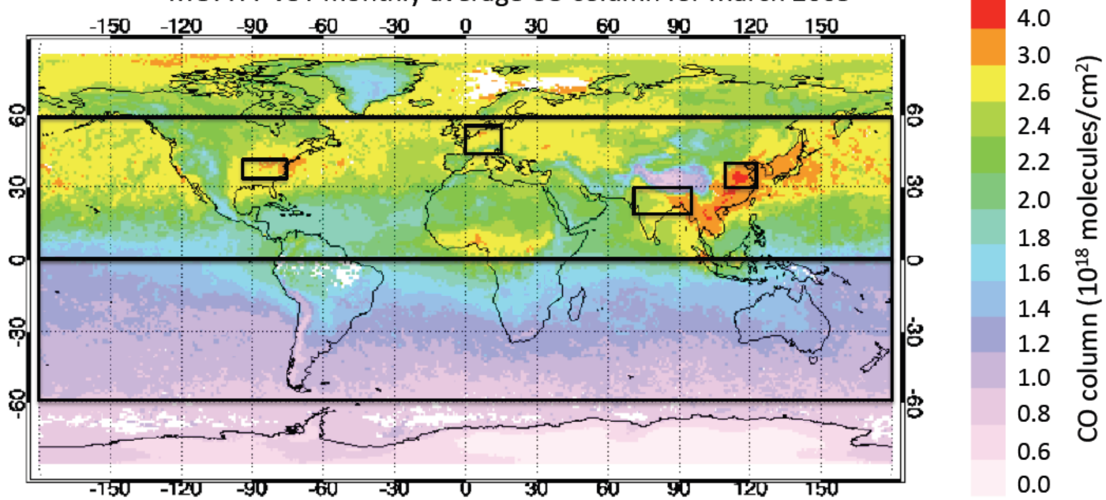
10.5 Tg/y

diesel, 4x4, camiones

black carbon



MOPITT V5T monthly average CO column for March 2005



automóviles

India

Atmos. Chem. Phys., 13, 837–850, 2013
www.atmos-chem-phys.net/13/837/2013/
doi:10.5194/acp-13-837-2013

Atmospheric Chemistry and Physics

Decadal record of satellite carbon monoxide observations

H. M. Worden[1], M. N. Deeter[1], C. Frankenberg[2], M. George[3], F. Nichitiu[4], J. Worden[2], I. Aben[5], K. W. Bowman[2], C. Clerbaux[3,6], P. F. Coheur[6], A. T. J. de Laat[5,7], R. Detweiler[1], J. R. Drummond[8], D. P. Edwards[1], J. C. Gille[1], D. Hurtmans[6], M. Luo[2], S. Martínez-Alonso[3], S. Massie[1], G. Pfister[1], and J. X. Warner[9]

Vol. 15, No. 4 JOURNAL OF CLIMATE 15 February 2002

Single-Scattering Albedo and Radiative Forcing of Various Aerosol Species with a Global Three-Dimensional Model

Toshihiko Takemura* and Teruyuki Nakajima
Oleg Dubovik, Brent N. Holben, and Stefan Kinne

aerosols, a cocktail of chemicals:

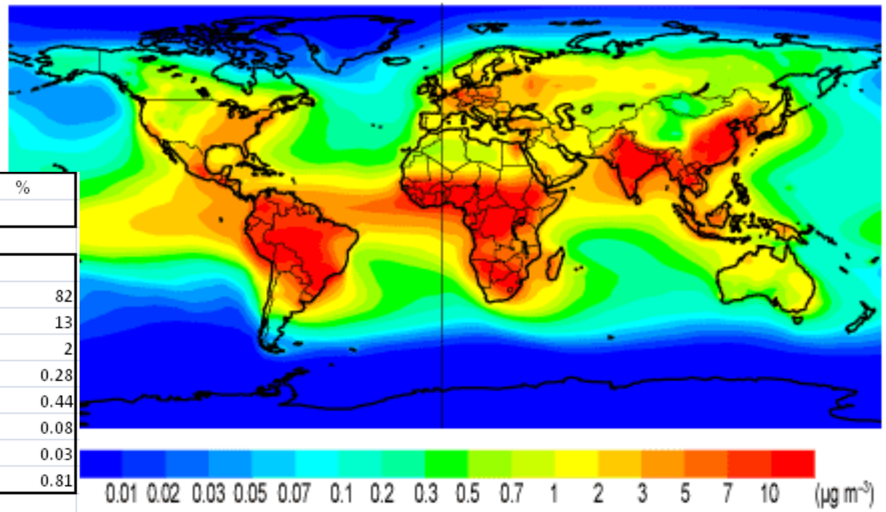
- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

organic matter: combustion sources, vehicle exhaust

organic carbon

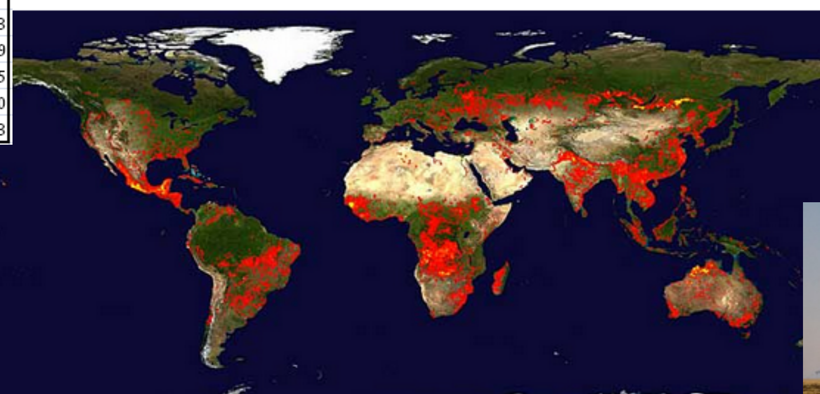
		Tg/y	%
	TOTAL:	12380	
PRIMARY			
Prim Nat	sea salt:	10130	82
Prim Nat	desert dust:	1600	13
Prim Nat	fine volcanic ashes:	200	2
Prim Nat	biogenic: →	35	0.28
Prim Nat + Ant	POA (biomass burning, biofuels): →	54	0.44
Prim Ant	black carbon:	10.5	0.08
Prim Ant	POA (combustion fossil fuels): →	4	0.03
Prim Ant	Industrial dust:	100	0.81
SECONDARY			
Sec Ant	SOA (industrial + fossil fuels): →	3.5	0.03
Sec Ant	Sulphate (fossil fuels):	122	0.99
Sec Ant+Nat	Nitrate:	18	0.15
Sec Nat	SOA (biogenic): →	25	0.20
Sec Nat	Sulphate (volcanic and biogenic):	78	0.63

organic carbon



Vehicle exahust

←Satelite detecion of fires

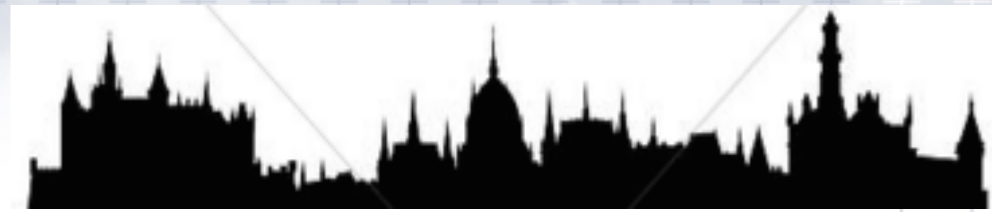


Paraguay: burn forest for cultivation of soja and suggar cane

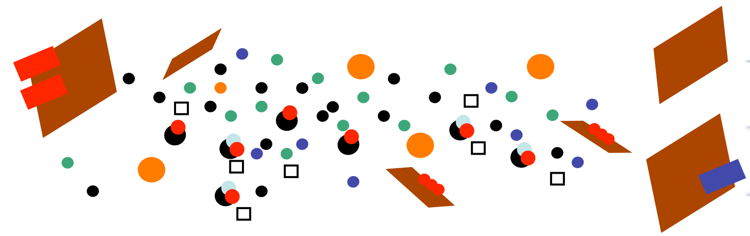
Deforestation of the Amazonia

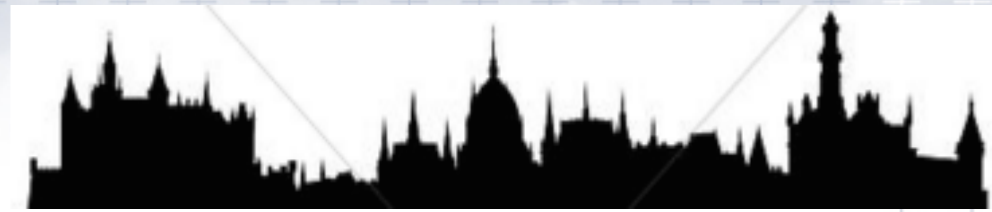
Sabana Africana

GOBIERNO DE ESPAÑA
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO
AEMet Agencia Estatal de Meteorología



people live in cities and breath a cocktail dust + pollutants





people live in cities and breath a cocktail dust + pollutants

In air quality, aerosols:

PM_{10}: mass concentration (µg/m^3) of all aerosols smaller than 10 µm
inhalable particles

$PM_{2.5}$: mass concentration (µg/m^3) of all aerosols smaller than 2.5 µm
alveolar particles

people live in cities and breath a cocktail dust + pollutants

PM$_{10}$: Σ dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals)

PM$_{2.5}$: Σ dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals)

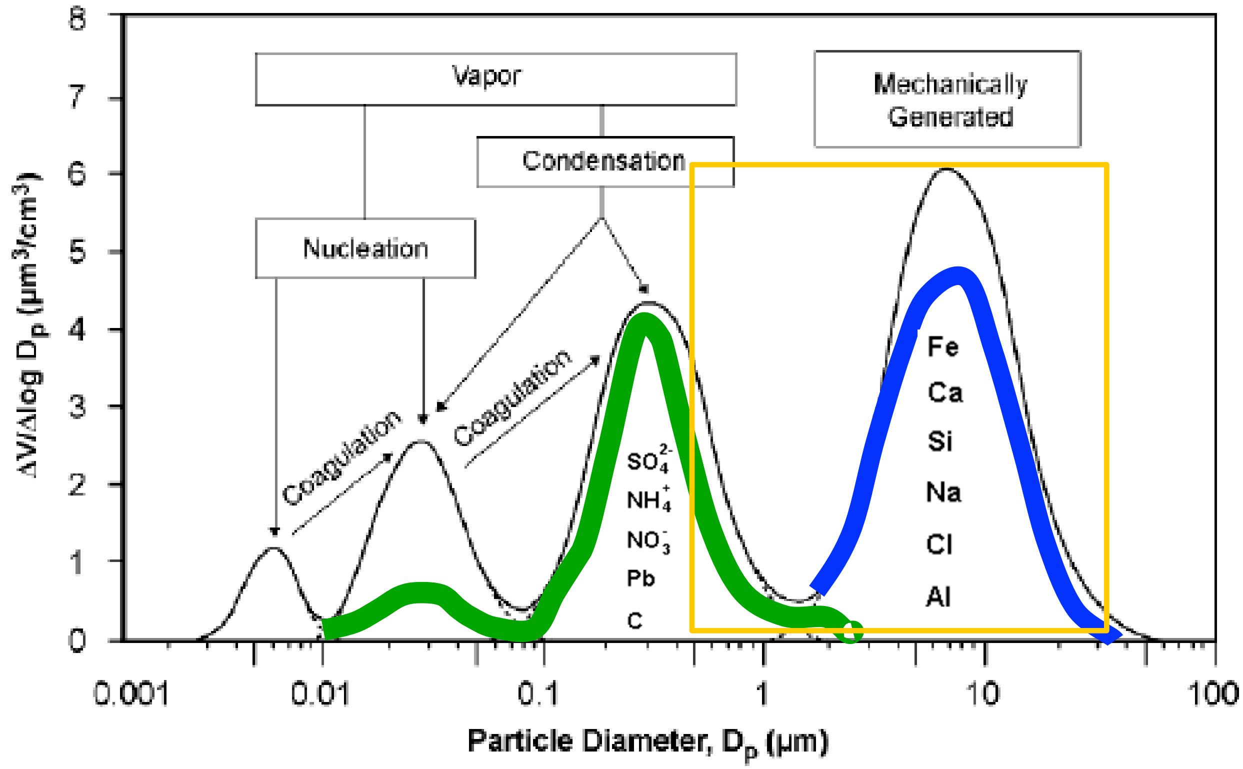
PM$_{10}$: Σ dust + sea salt + vehicle exhaust + oil refining + power plants + ships +...

PM$_{2.5}$: Σ dust + sea salt + vehicle exhaust + oil refining + power plants + ships +...

PM_{10} (diameter <10 microm)

$PM_{2.5}$

$PM_{2.5-10}$

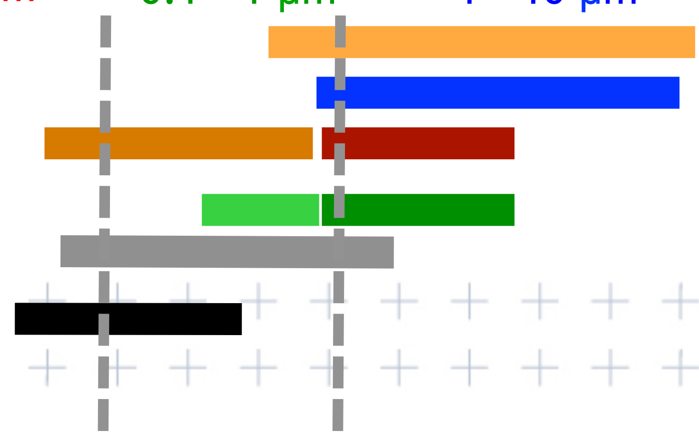


ultrafine
<0.1 μm

accumulation
0.1 – 1 μm

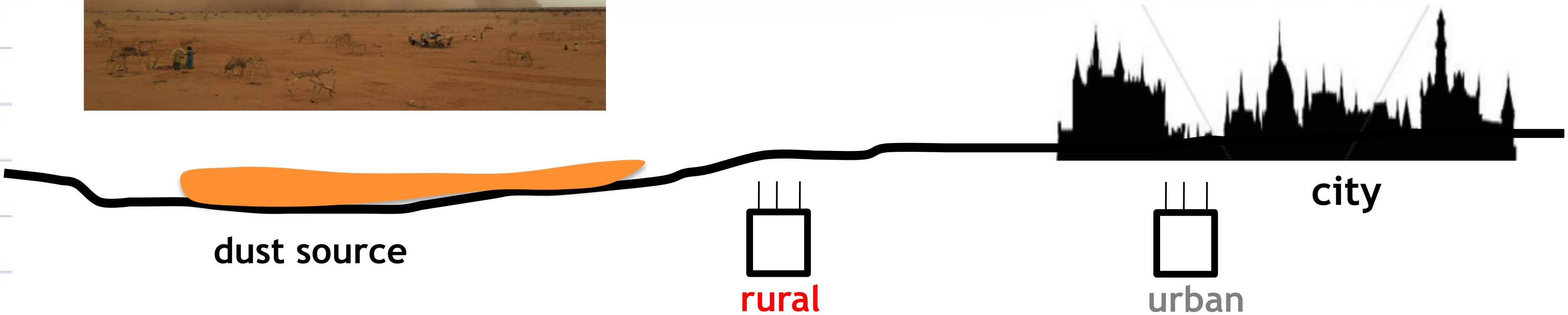
Coarse
1 - 10 μm

Mineral dust :
Marine salt:
Sulfate:
Nitrate:
Organic aerosol:
black carbon:



dust, aerosols and pollutants

in-situ observations



how to measure of dust aerosol

there are no standardized automatic method for measuring dust

alternatively we measure bulk aerosol PM...

PM_{10}: Σ dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals)

$PM_{2.5}$: Σ dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals)

dust, aerosols and pollutants

in-situ observations

PM_{10} and $PM_{2.5}$ levels
PM_{10} and $PM_{2.5}$ composition
complementary observations

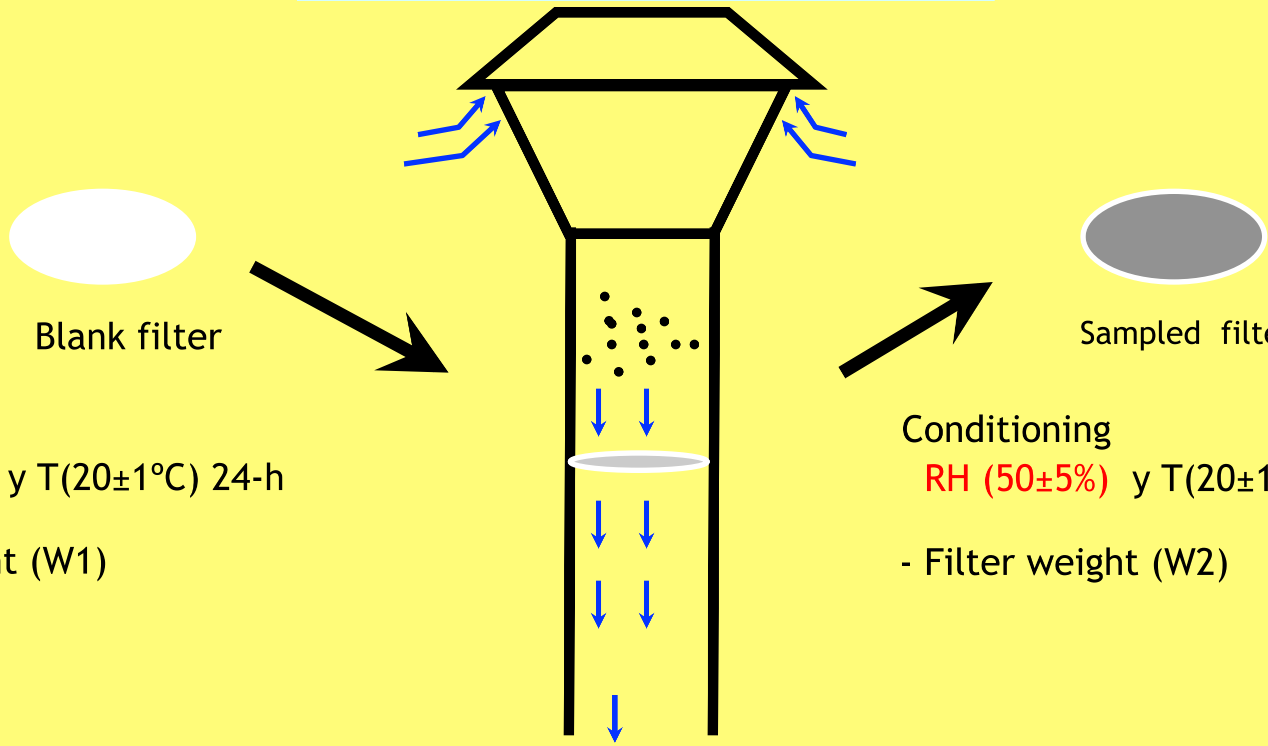
observation network

1. PM_{10} and $PM_{2.5}$ levels

-method-01 manual gravimetry method

-method-01: reference - manual gravimetry

$$PM = \frac{(W2-W1)}{Volume} \ \mu g/m^3$$



Conditioning
RH (50±5%) y T(20±1°C) 24-h

- Filter weight (W1)

Conditioning
RH (50±5%) y T(20±1°C) 24-h

- Filter weight (W2)

It is recommended to use standardised protocols

national standard method

or already existing international standard methods

-PM_{10} and $PM_{2.5}$ sampler
-sampling procedure
-weighing procedure

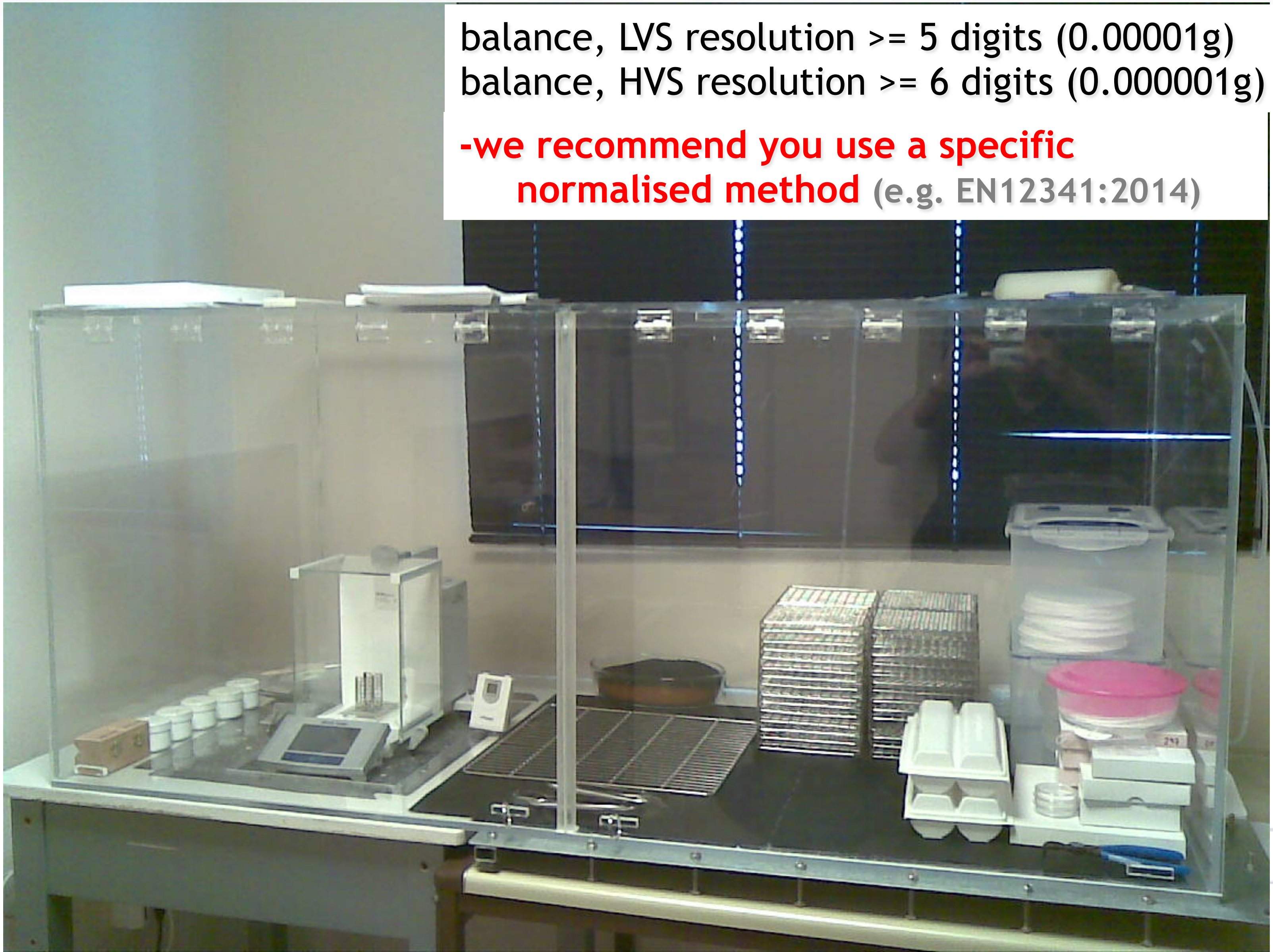
example:

EN 12341:2014
Ambient air. Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2,5}$ mass concentration of suspended particulate matter

Room for weighting the filters: RH =50% (30 %) and 20ºC

balance, LVS resolution >= 5 digits (0.00001g)
balance, HVS resolution >= 6 digits (0.000001g)

-we recommend you use a specific normalised method (e.g. EN12341:2014)



PM_{10}
Blank filter

PM_{10}
sample urban air

PM_{10}
sample in dust days

-we recommend you use a specific normalised method (e.g. EN12341:2014)

Filters: Quartz, Teflon, Cellulose

Low Volume Sampler

High Volume Sampler

LVS: 2.3 m^3/h

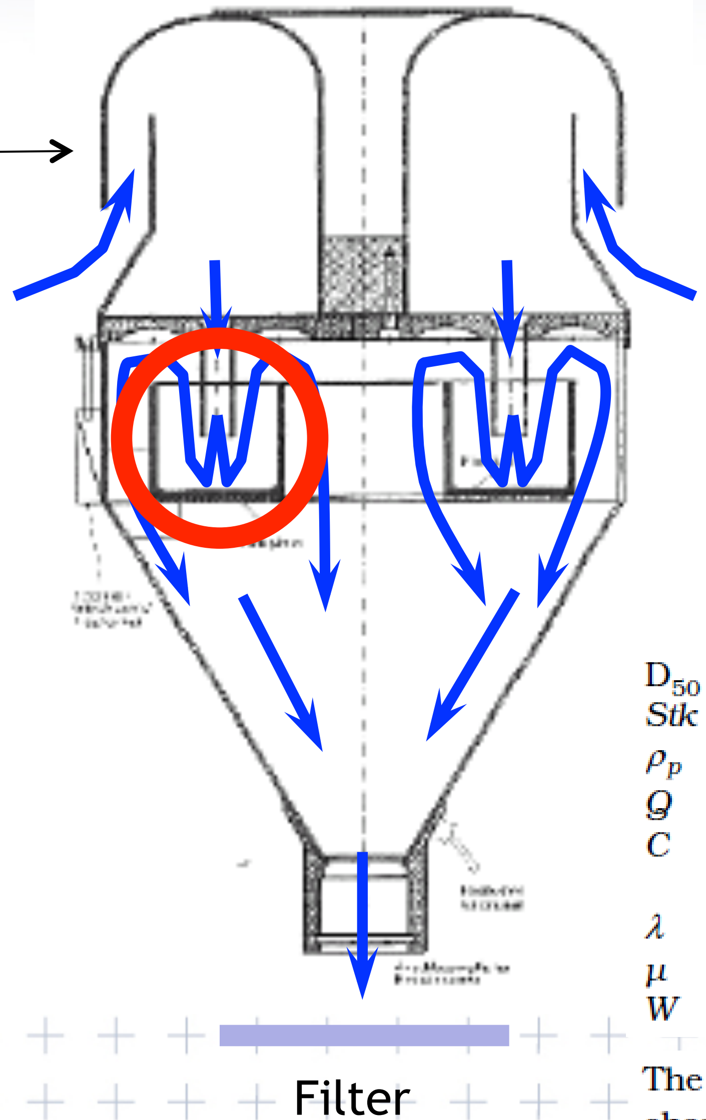
HVS: 68 m^3/h

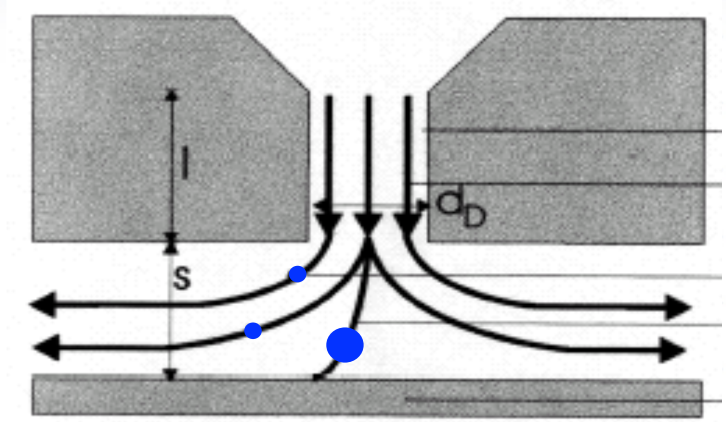
HVS: 30 m^3/h

-we recommend you use a specific normalised method (e.g. EN12341:2014). Ask to the distributor if the sampler sis designed to any standards

Inlets, airflows....

PM_{10}, $PM_{2.5}$

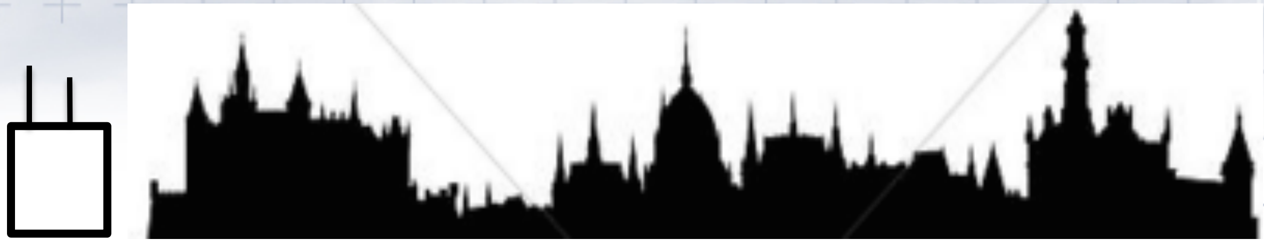




$$D_{50} = \sqrt{\frac{9\pi Stk \, \mu W^{3}}{4\rho_p C Q}}$$

D_{50} = particle cut-point diameter centimeter
Stk = Stokes number = 0.23
ρ_p = particle density (g/cm^3)
Q = volumetric flow rate (cm^3/s)
C = Cunningham slip correction
= $1 + 2.492\,\lambda/D_{50} + 0.84\,\lambda/D_{50}\exp(-0.435\,D_{50}/\lambda)$
λ = gas mean free path
μ = gas viscosity (dyne•s/cm^2)
W = nozzle diameter (cm)

The Stokes number is a dimensionless parameter that characterizes impaction.



dust air quality

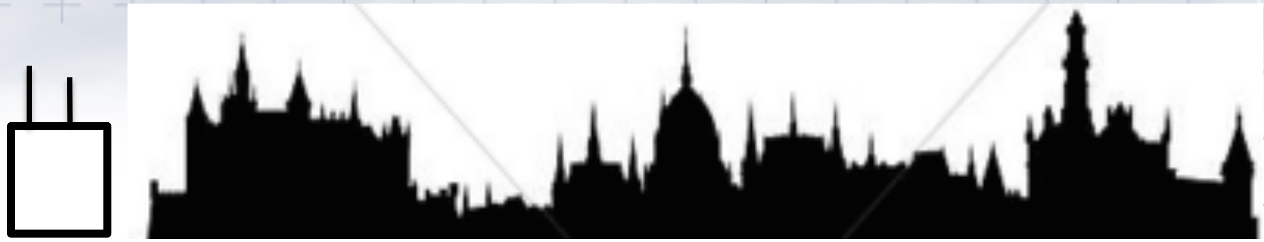
1. PM_{10} and $PM_{2.5}$ levels

-method-01: reference - manual gravimetry

<u>Manual gravimetry</u>

advantage: reference method

disadvantage:
poor time resolution, 24-h average
manual work
takes 3 days to know PM_{10} concentration



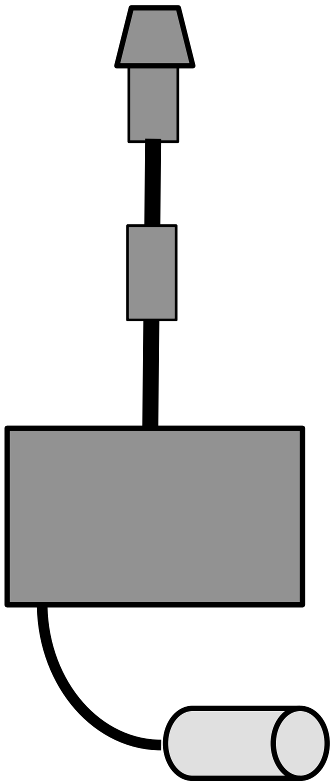
dust air quality

1. PM_{10} and $PM_{2.5}$ levels

   -method-01: reference - manual gravimetry

   -method-02: automatic beta, teom, OPS

-method-02: automatic



1. Impactor PM_{10} / $PM_{2.5}$
2. RH reductor / heater
3. Sensor

   Beta radiation attenuation

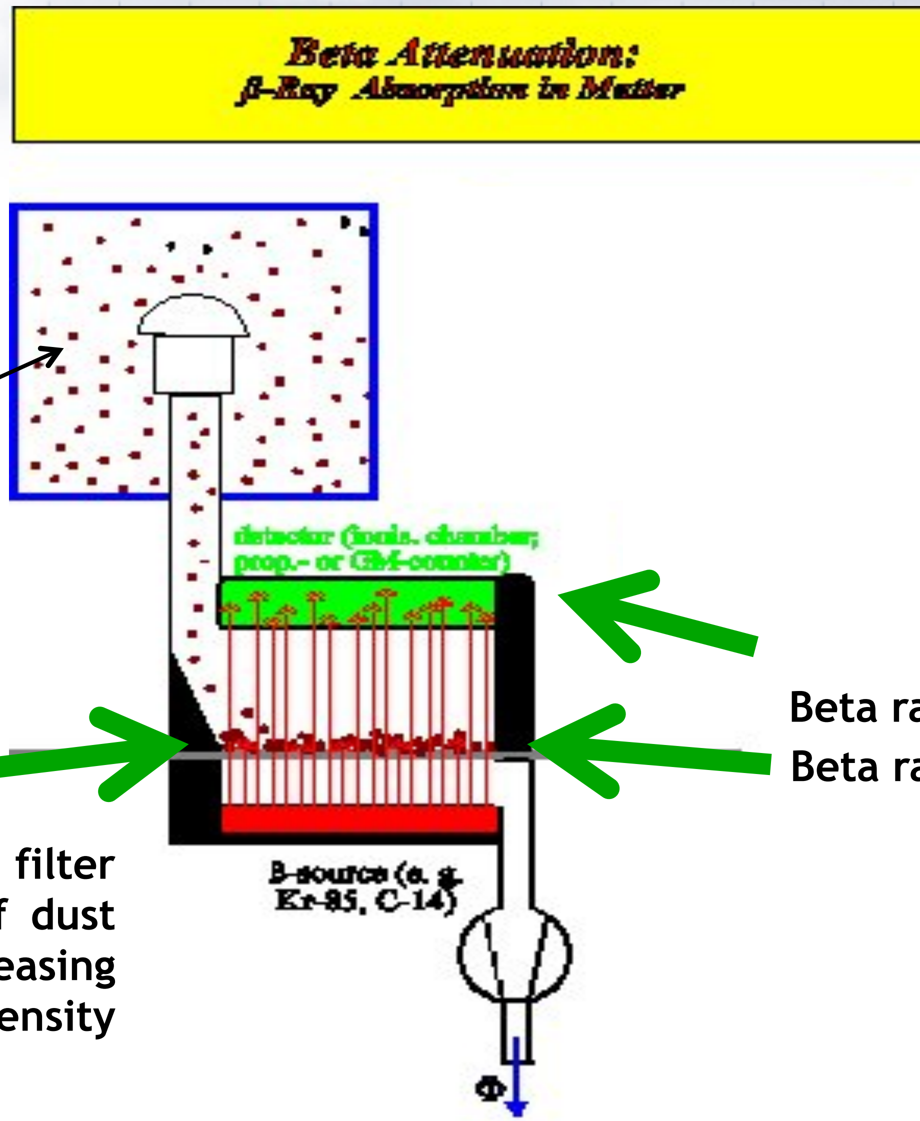
4. Pump / Flow meter

Continuous measurements of PM (PM_{10}, $PM_{2.5}$, PM_1 or TSP)

PM with Beta atenuation

Krypton-85 or Carbon-14 is used as source of beta radiation (emitted by electrons during the nuclear decay of radioactive elements).

Ambient air is drawn through the sample system



Beta rays detector

Beta rays source (Kr-85)

Dust is deposited on a filter continuously. The layer of dust is building up and this increasing dust mass weakens the intensity of the beta beam.

Pump and flowmeter

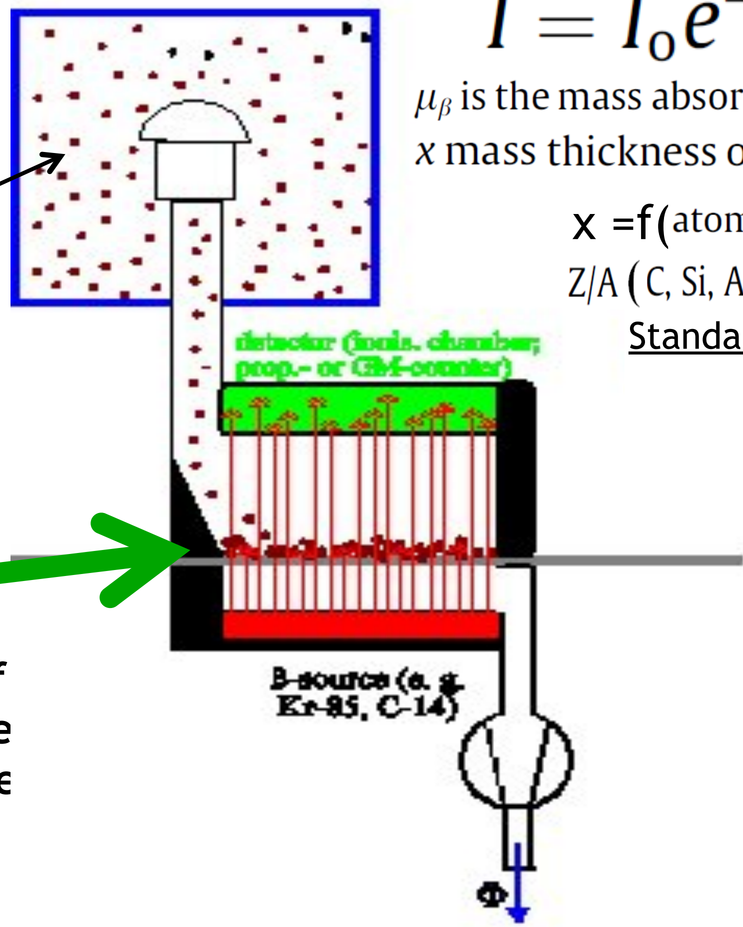
PM with Beta atenuation

Beta Attenuation:
β-Ray Absorption in Matter

Krypton-85 or Carbon-14 is used as source of beta radiation (emitted by electrons during the nuclear decay of radioactive elements).

Ambient air is drawn through the sample system

Dust is deposited on a continuously. The layer of is building up and this incre dust mass weakens the inte of the beta beam.



Pump and flowmeter

$$I = I_0 e^{-\mu_\beta \cdot x}$$

μ_β is the mass absorption coefficient for beta radiation

x mass thickness of the sample

x =f(atomic number to atomic mass ratio (Z/A))

Z/A (C, Si, Al, Ca, Fe, Mg, K, Cl, Na, N, O and S) 0.47–0.50

Standard foil calibration

typical elements of aerosols; fixed Z/A ratio: error of about 10%

PM with Beta atenuation (2)

$$m = F_{cal} ln\left(\frac{I_0}{I}\right)$$

- **m:** increasing particle mass [µg]
- F_{cal}: calibration factor
- I_0 beta ray intensity at empty filter
- I beta ray intensity at loaded filter

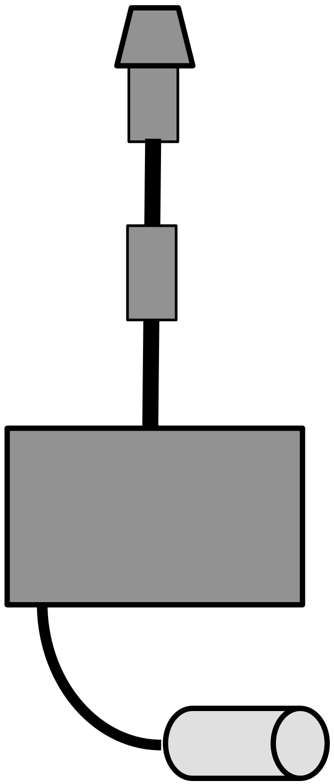
The intensities I_0 and I are measured with the detector system. F_{cal} has to be measured directly during the calibration procedure. This is accomphished by replacing the filter with the element having a known mass (mass calibration kit)

The mass concentration is calculated from:

$$PM_{10} \,\&\, PM_{2.5} \approx c = \frac{m}{Ft}$$

Where:
c: concentration [µg/m³]
F: measured air flow [m³/h]
t: time [h]

-method-02: automatic



1. Impactor PM_{10} / $PM_{2.5}$

2. RH reductor / heater

3. Sensor

   Beta radiation attenuation
   TEOM

4. Pump / Flow meter

Continuous measurements of PM (PM_{10}, $PM_{2.5}$, PM_1 or TSP)

Mass concentration

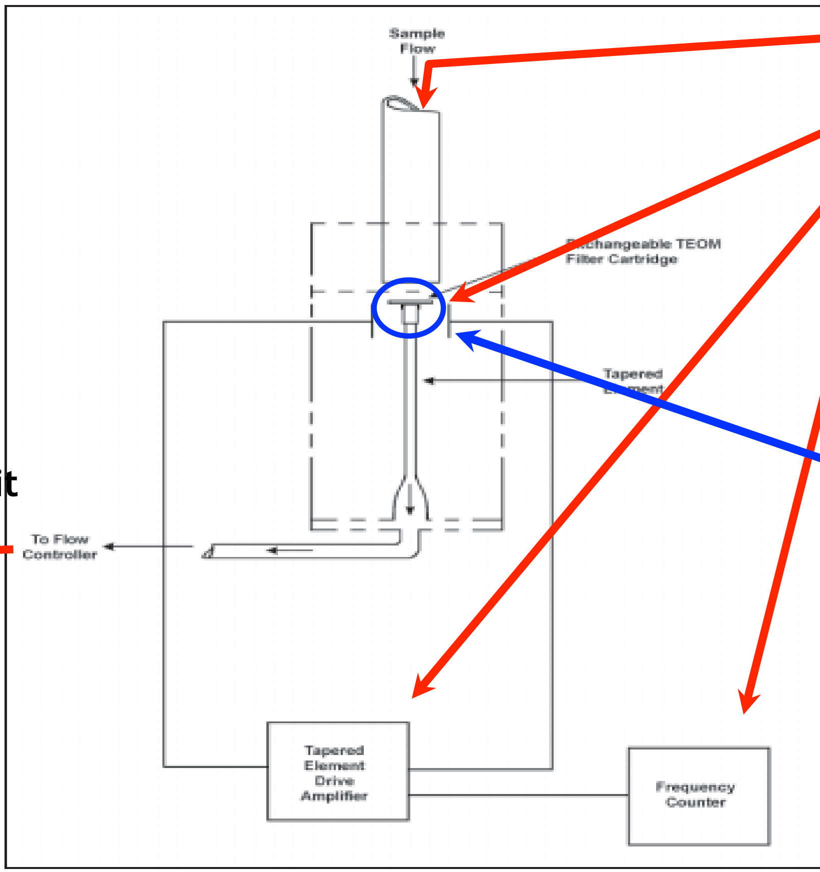
Automatic continuous measurements

TEOM :Tappered Element Oscillating Microbalance

1. TEOM mod.1400a

mass=function (frequency)

sensor



Sampling flow rate (16.67 l/m)

Sample accumalated in the filter

Micro-oscilation of constante amplitue GENERATOR

Frequency sensor

Flow exit

An increase in the amount of sample (dust) accumulated in the filter ➔ decrease in the oscillation frequency

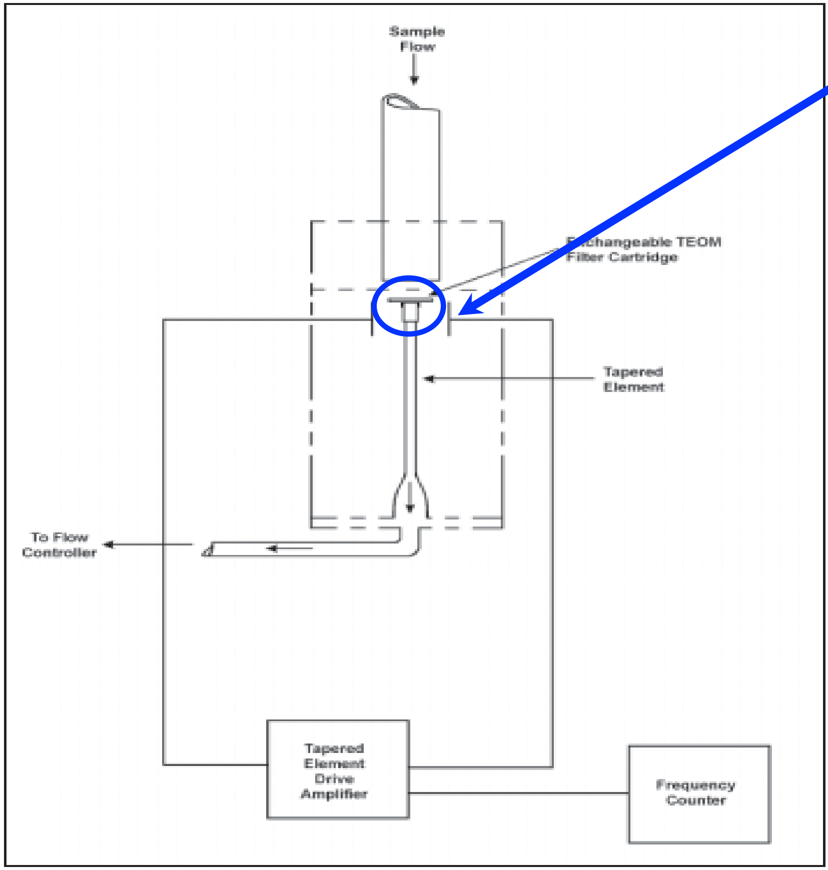
Mass concentration

Automatic continuous measurements

TEOM :Tappered Element Oscillating Microbalance

1. TEOM mod.1400a

sensor



mass=function (frequency)

more dust ➔ lower oscillation frequency

In a spring-mass system the frequency follows the equation:

$$f = (K / M)^{0.5}$$

where:

- f = frequency (radians/sec)
- K = spring rate
- M = mass

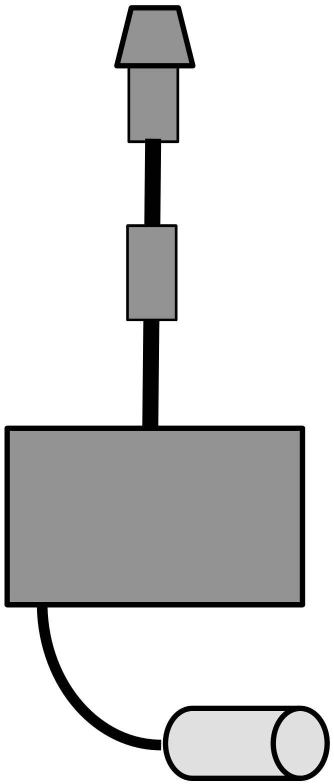
K and M are in consistent units. The relationship between mass and change in frequency can be expressed as:

$$dm = K_0 \left(\frac{1}{f_1^2} - \frac{1}{f_0^2} \right) \qquad (2)$$

where:

- dm = change in mass
- K_0 = spring constant (including mass conversions)
- f_0 = initial frequency (Hz)
- f_1 = final frequency (Hz)

-method-02: automatic



1. Impactor PM_{10} / $PM_{2.5}$
2. RH reductor / heater
3. Sensor
   - Beta radiation attenuation
   - TEOM
   - Optical Particle Sizers
4. Pump / Flow meter

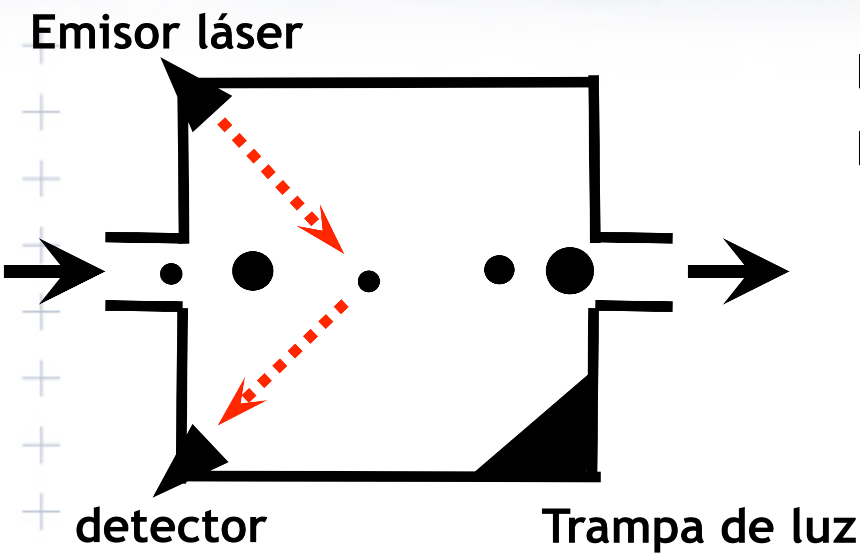
Continuous measurements of PM (PM_{10}, $PM_{2.5}$, PM_1 or TSP)

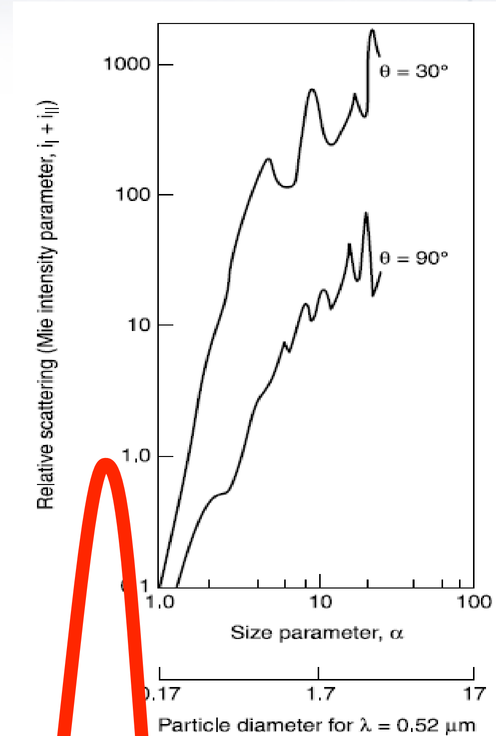
Optical Particle Sizer

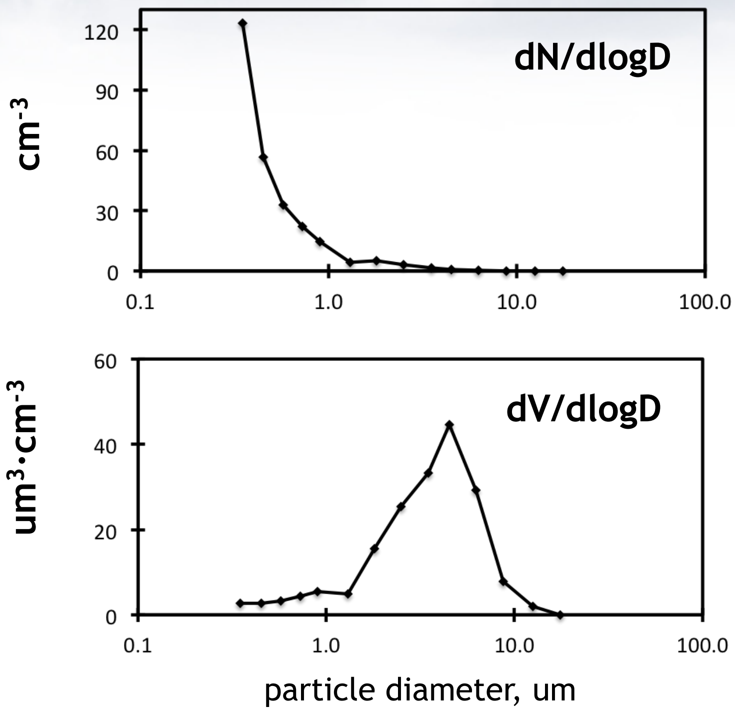
number size distribution 0.3 - 20 µm

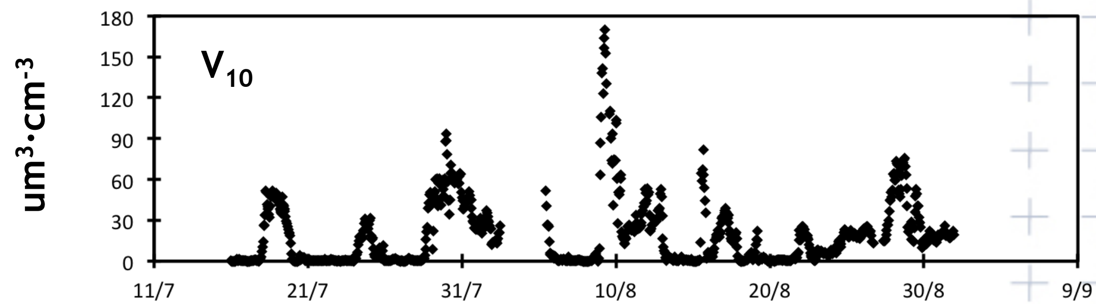
Intensidad del scattering

$I(dp, \theta, \lambda, m)$









$PM_{10} = V_{10} \cdot density$

Density: 1.6 to 2.65 g/cm³

-method-02: automatic

The most extended method and the most robust for dusty regions

beta

Tapered Oscillating Microbalance

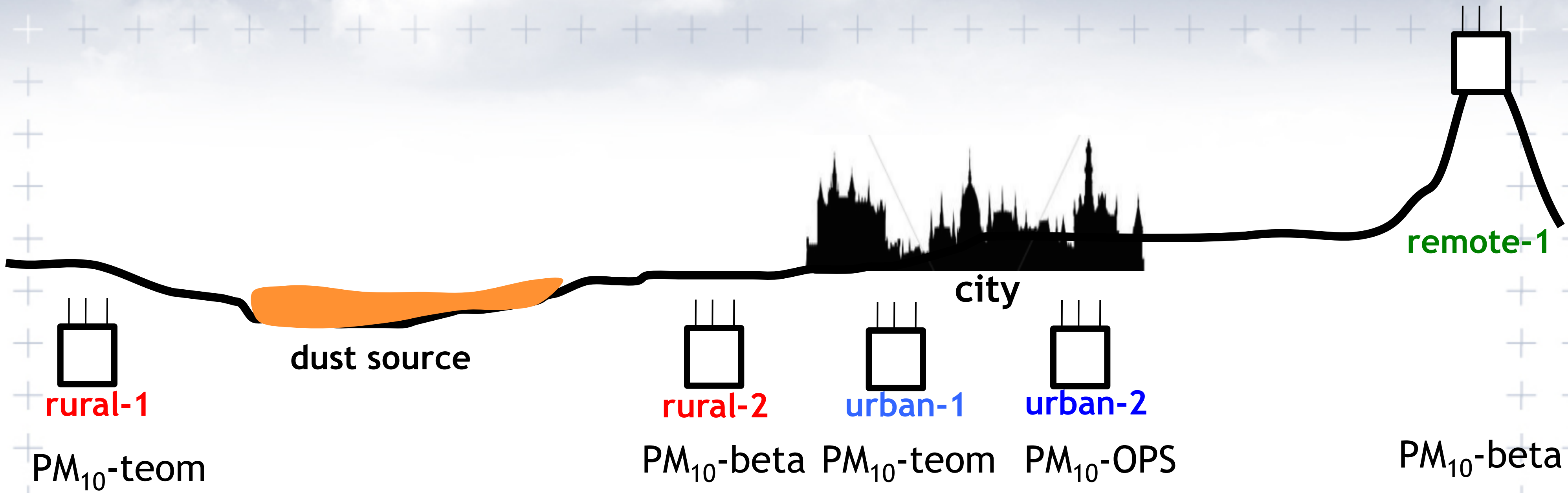
TEOM

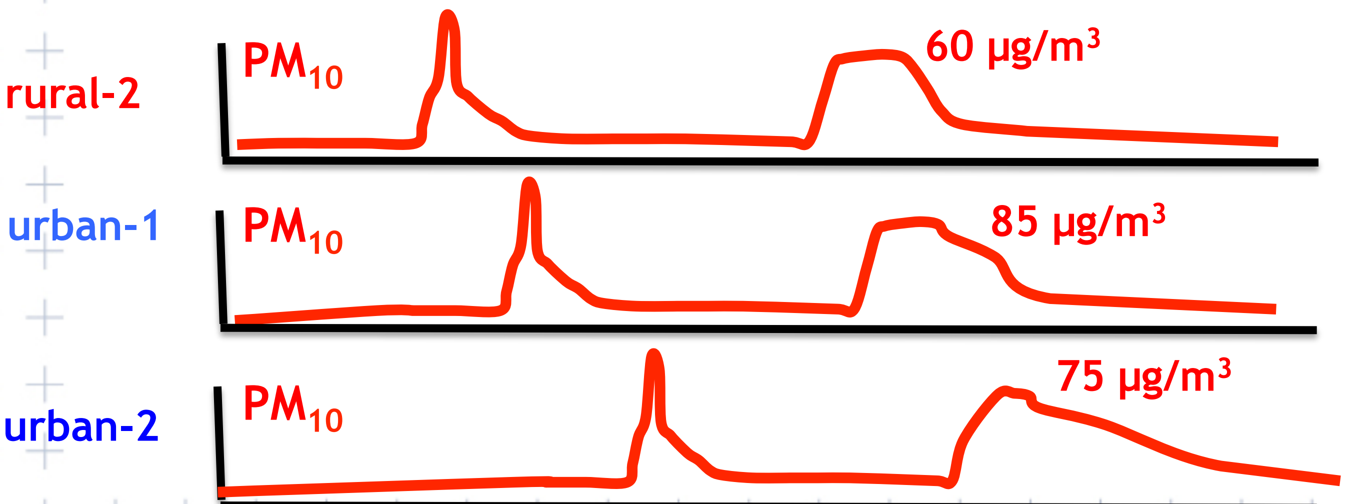
Manual change of the filter

Optical Particle Counters

cleaning of optics

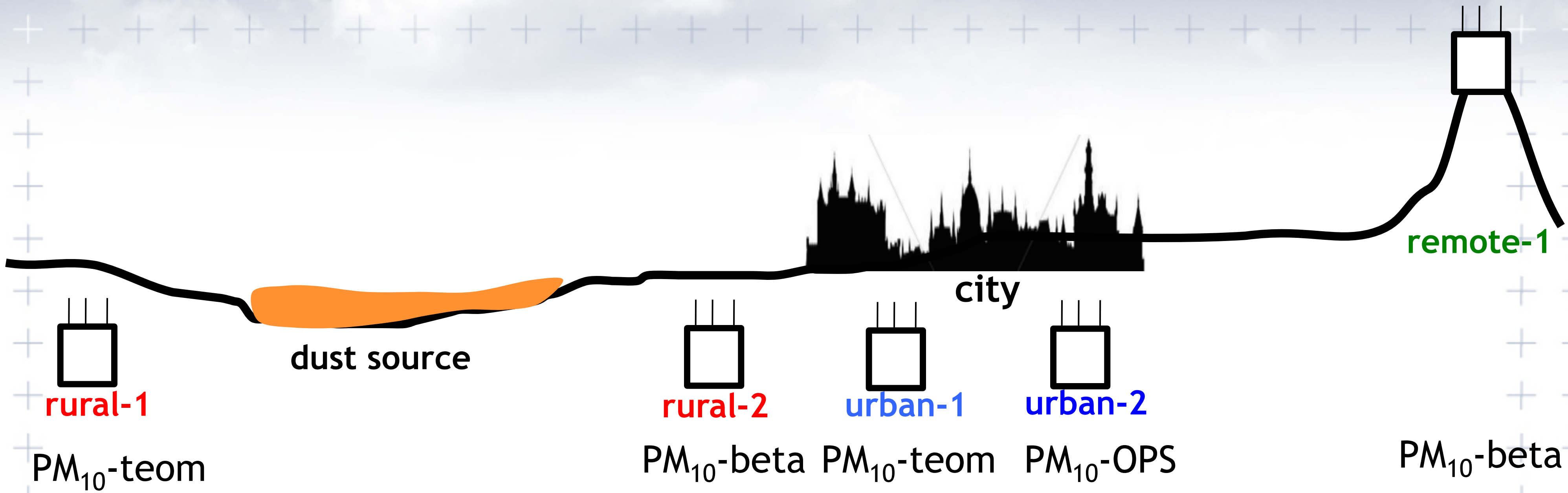
laser maintenance





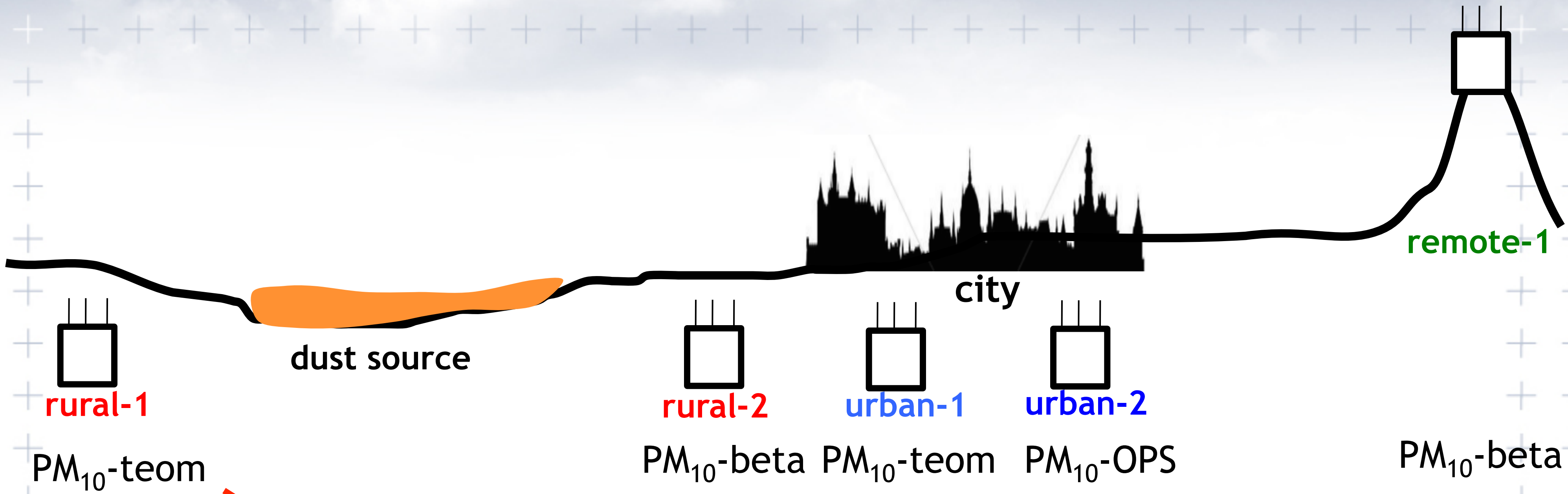
are PM_{10} data collected with different methods comparable?

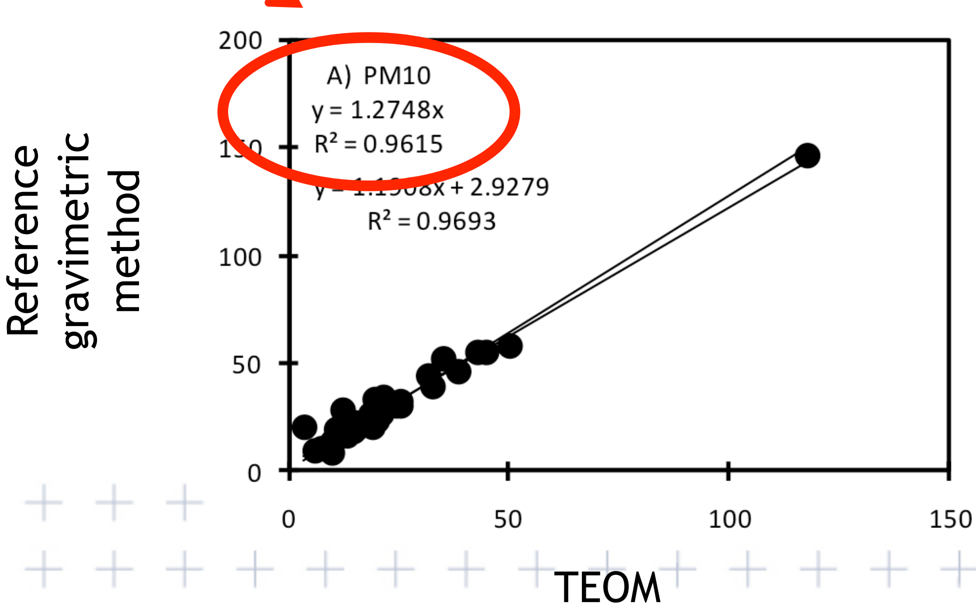
we need a standard for the network



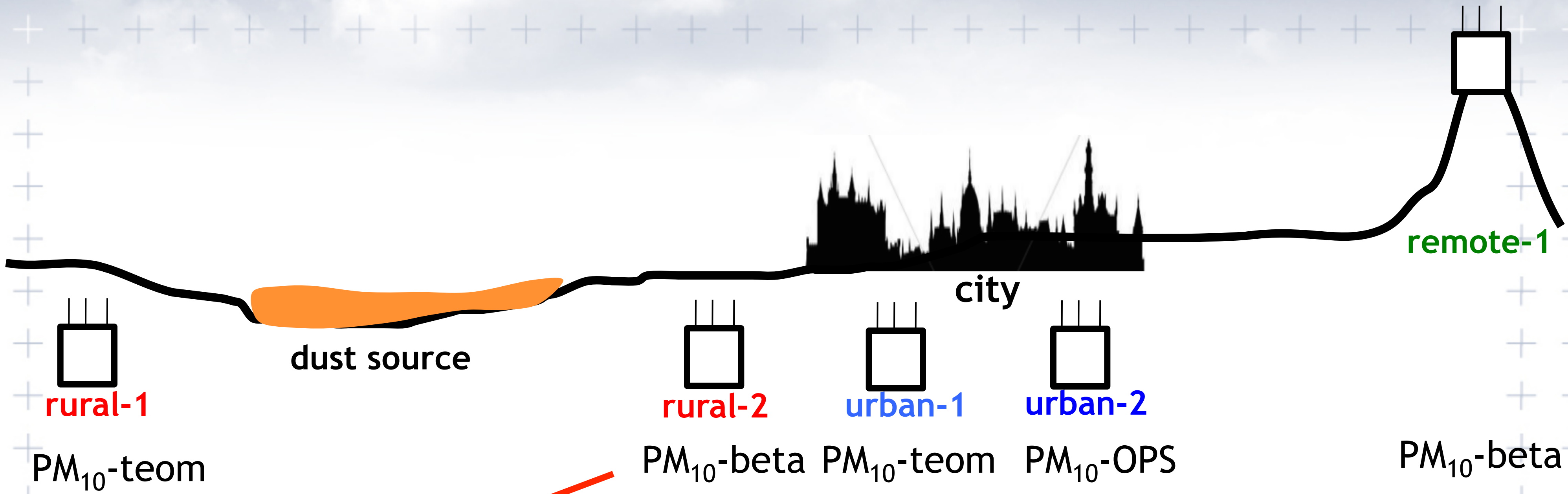
the standard in the network:

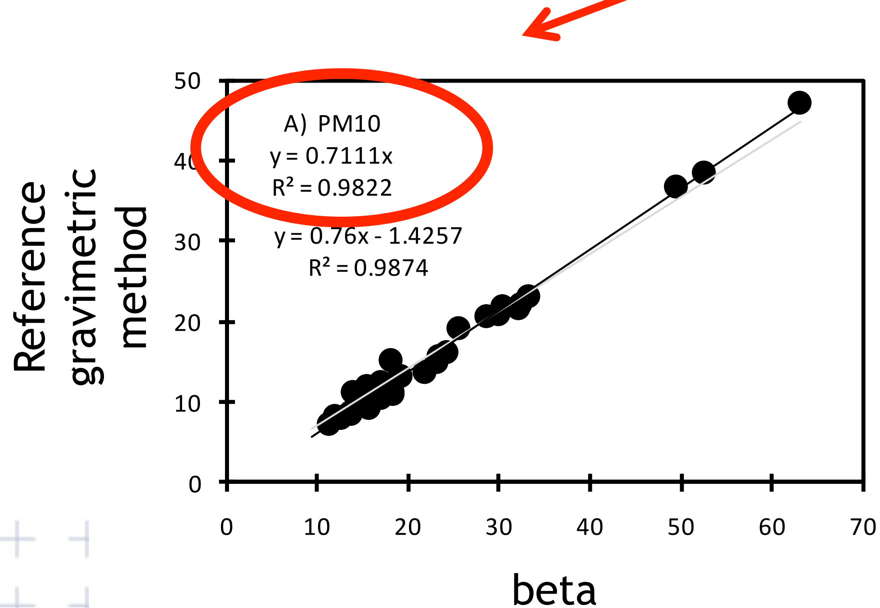
intercomparison of each automatic instrument with the manual reference method



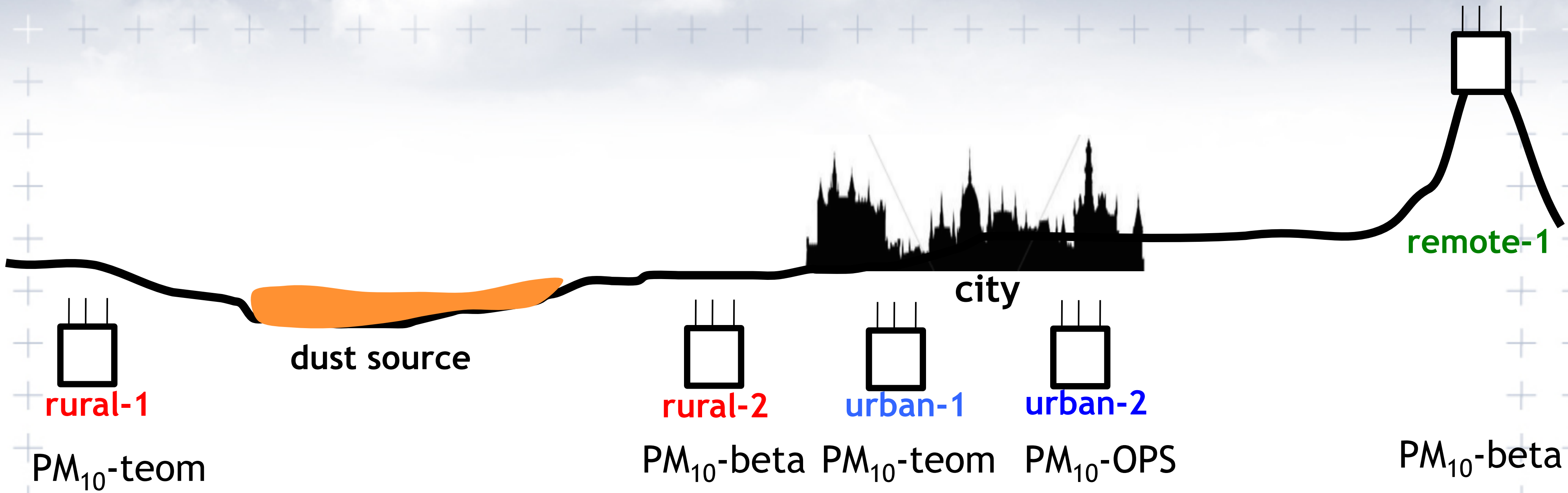


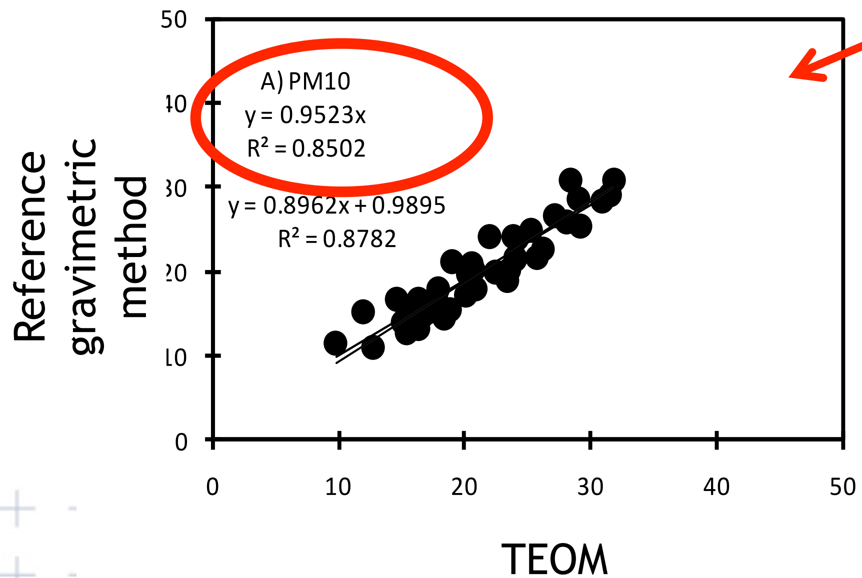
PM_{10} (grav equiv) = 1.27 PM_{10} (TEOM)
Valid for rural-1 TEOM



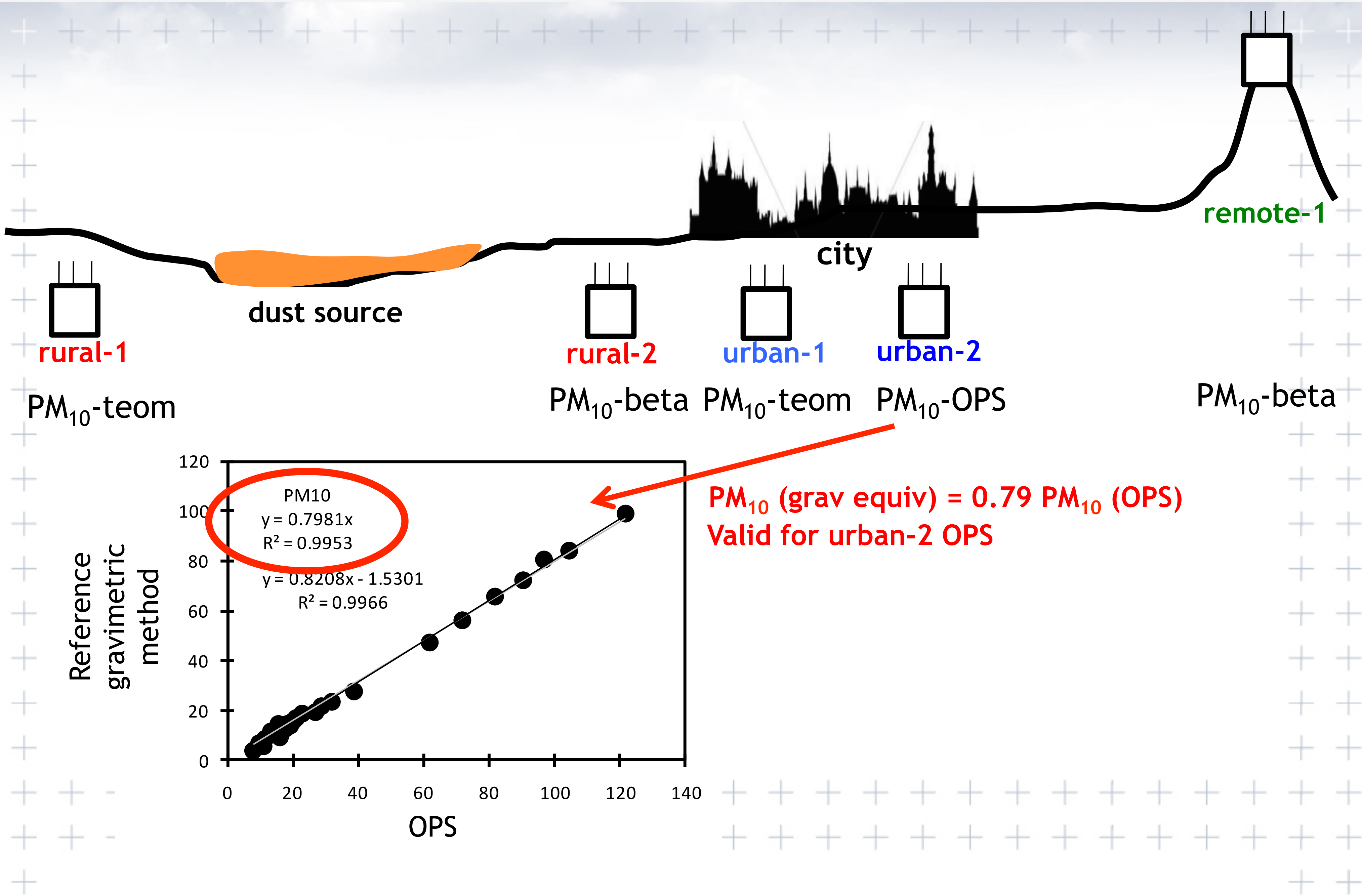


PM_{10} (grav equiv) = 0.71 PM_{10} (BETA)
Valid for rural-2 BETA

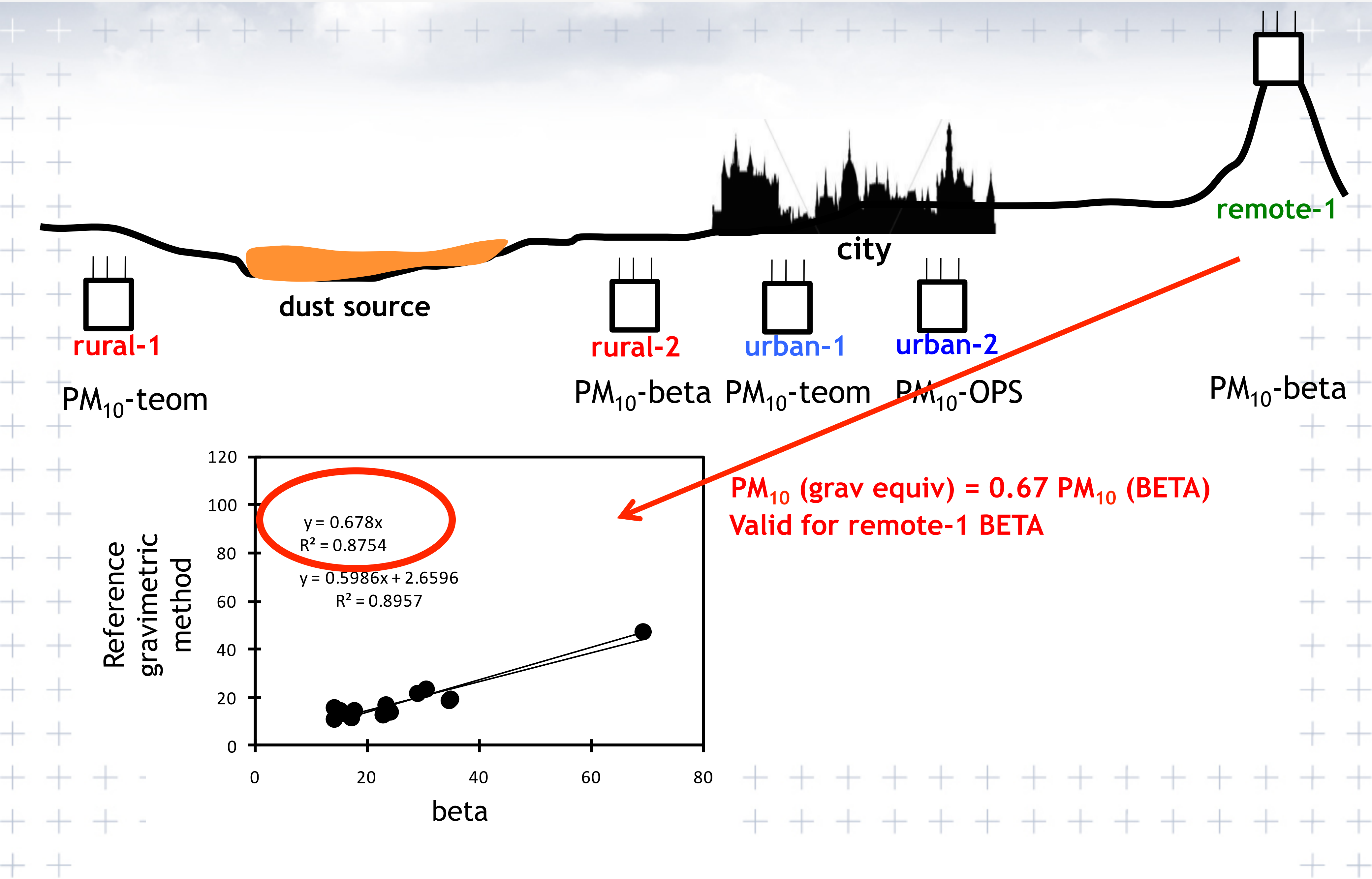




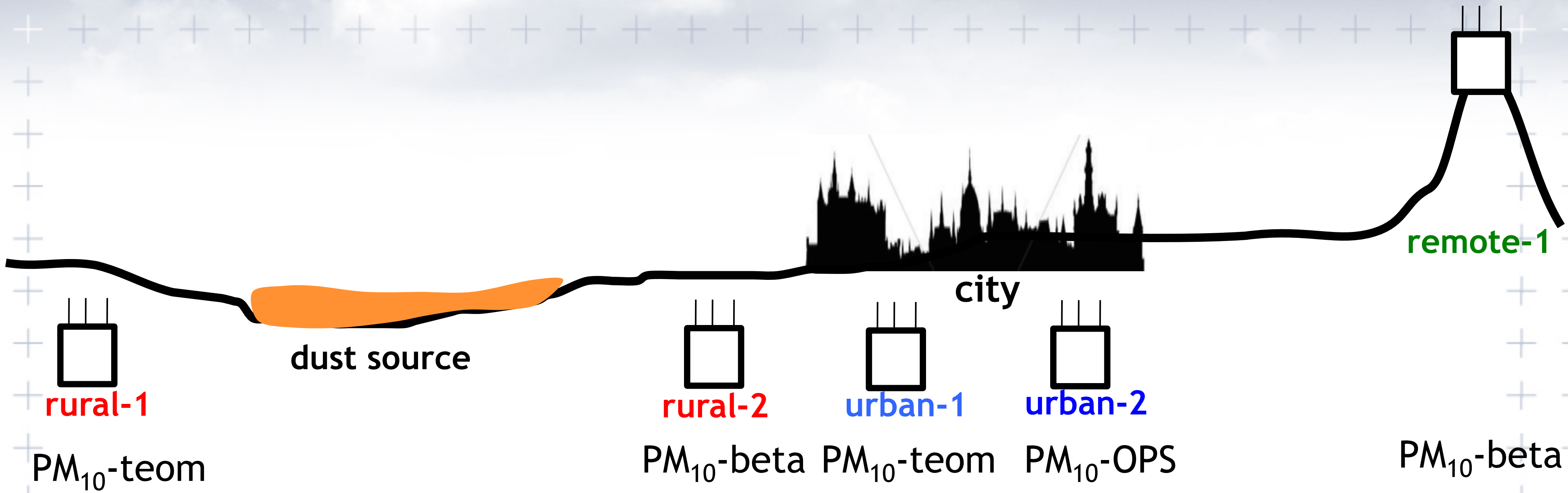
PM_{10} (grav equiv) = 0.95 PM_{10} (TEOM)
Valid for urban-1 TEOM



city
dust source
rural-1
rural-2
urban-1
urban-2
remote-1
PM10-teom
PM10-beta
PM10-teom
PM10-OPS
PM10-beta
PM10
y = 0.7981x
R² = 0.9953
y = 0.8208x - 1.5301
R² = 0.9966
Reference gravimetric method
OPS
PM10 (grav equiv) = 0.79 PM10 (OPS)
Valid for urban-2 OPS

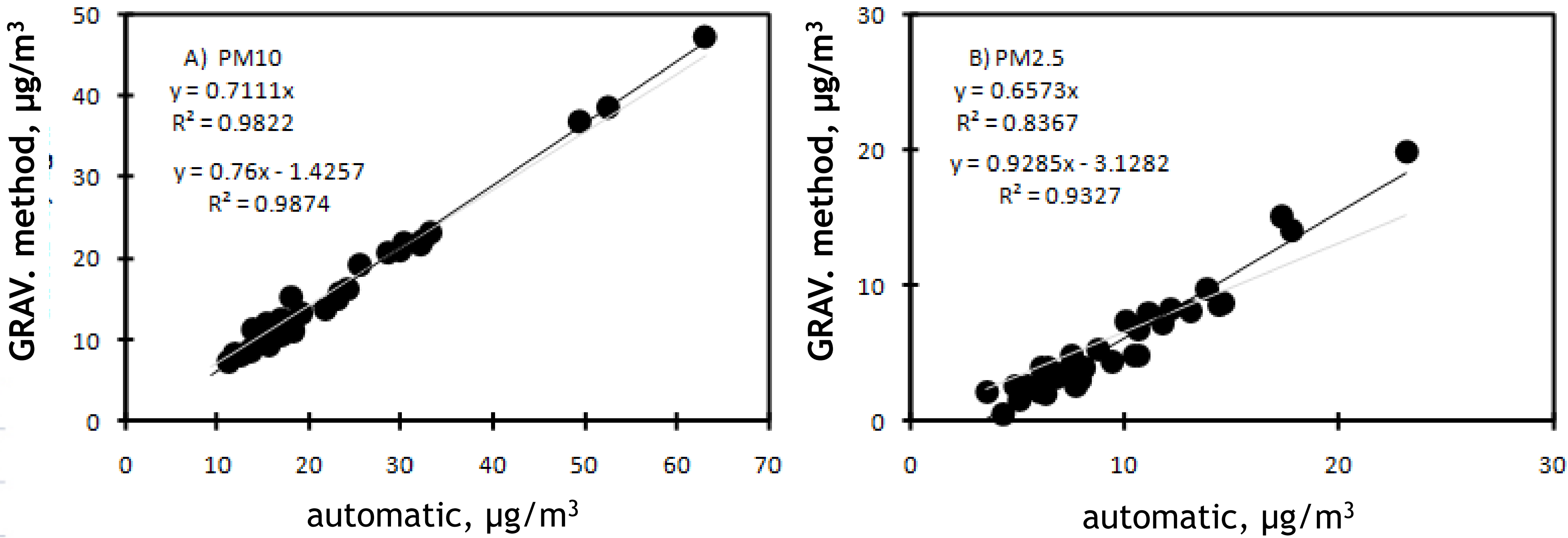


city
remote-1
dust source
rural-1
rural-2
urban-1
urban-2
PM10-teom
PM10-beta
PM10-teom
PM10-OPS
PM10-beta
PM10 (grav equiv) = 0.67 PM10 (BETA)
Valid for remote-1 BETA
y = 0.678x
R² = 0.8754
y = 0.5986x + 2.6596
R² = 0.8957
Reference gravimetric method
beta
0
20
40
60
80
100
120
0
20
40
60
80



	Standarized data	raw data
rural-1	PM_{10} (grav equiv) = 1.27	PM_{10} (TEOM)
rural-2	PM_{10} (grav equiv) = 0.71	PM_{10} (BETA)
urban-1	PM_{10} (grav equiv) = 0.95	PM_{10} (TEOM)
urban-2	PM_{10} (grav equiv) = 0.79	PM_{10} (OPS)
remote-1	PM_{10} (grav equiv) = 0.67	PM_{10} (BETA)

Validation of the automatic measurements
Intercomparisons for calibrations



<u>Data evaluation:</u>

automatic data are valid if they fit A or B:

A) $Y=a \cdot X$; $r^2 \geq 0.8$

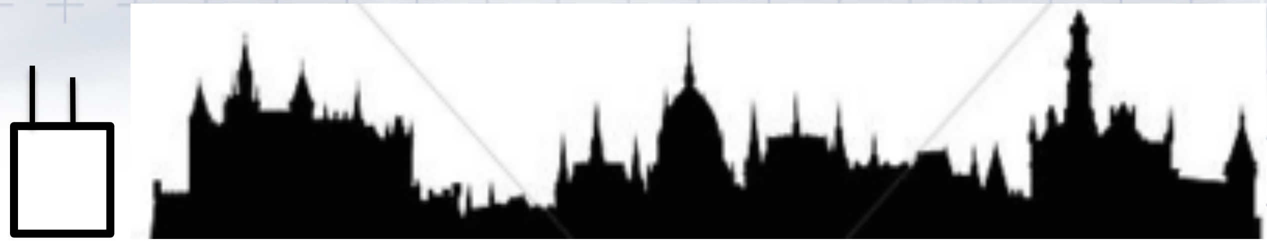
B) $Y=a \cdot X + b$; $r^2 \geq 0.8$; $abs(b)<5$

Y= gravimetric method,

X= Automatic analyzer

PM_{10} (grav) = 0.71*PM_{10} (automatic)

$PM_{2.5}$ (grav) = 0.65*$PM_{2.5}$ (automatic)



dust air quality

1. PM_{10} and $PM_{2.5}$ levels

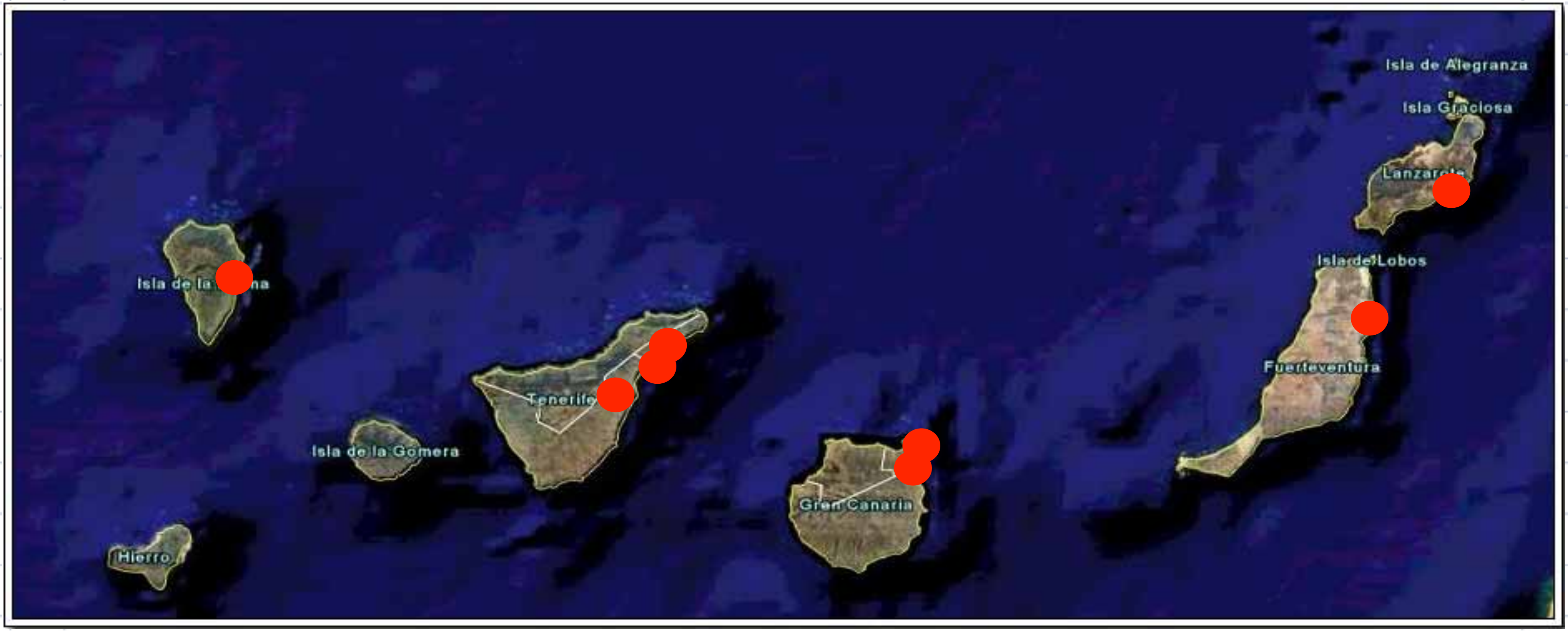
   -method-01: reference - manual gravimetry

   -method-02: automatic

We recommend to convert PM_{10} and $PM_{2.5}$ data obtained with automatic instruments to gravimetric equivalent data.
For this a standard obtained with intercomparisons is necessary

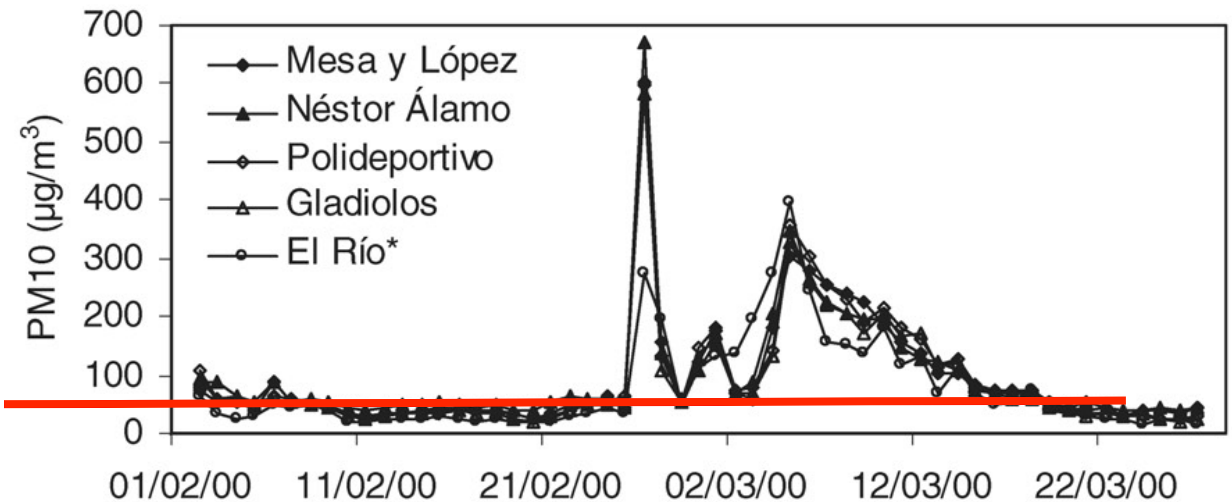
EXAMPLE, Canary Islands

Standarization of PM_{10} y $PM_{2.5}$ in a regional network

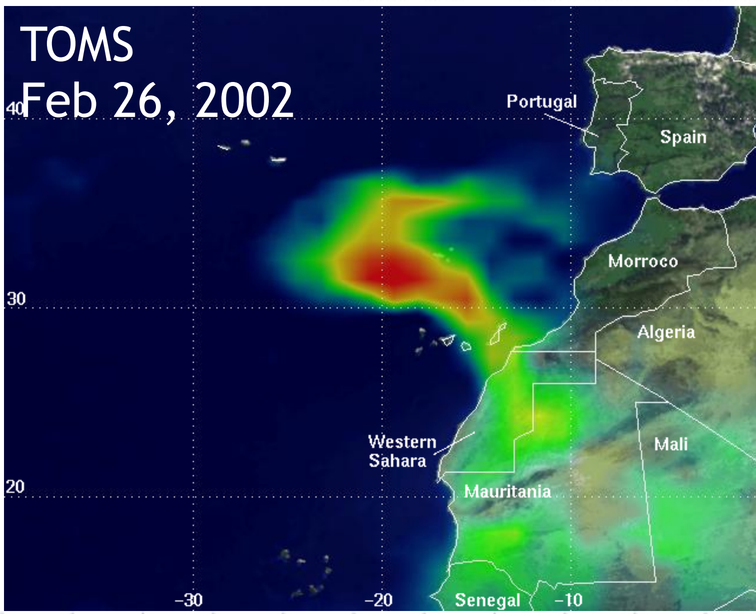


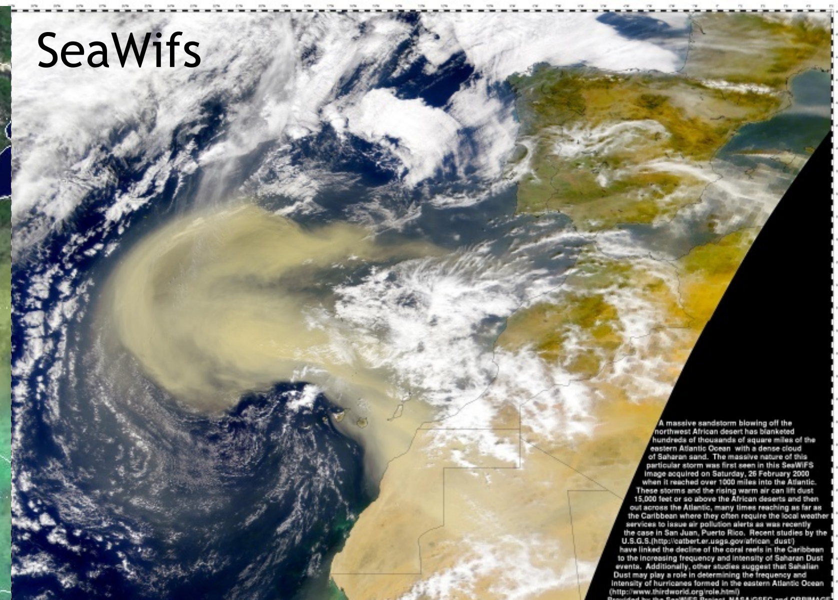
In-situ dust characterization

Air quality stations at Tenerife Island



The WHO recommend PM_{10} (24-h) do not exceed 50 $\mu g/m^3$





Viana et al., Atmospheric Environment , 2002

EXAMPLE, Canary Islands

Ministerio de Medio Ambiente y Medio Rural y Marino · Gobierno de España · AEMet Agencia Estatal de Meteorología

Standarization of PM_{10} y $PM_{2.5}$ in a regional network

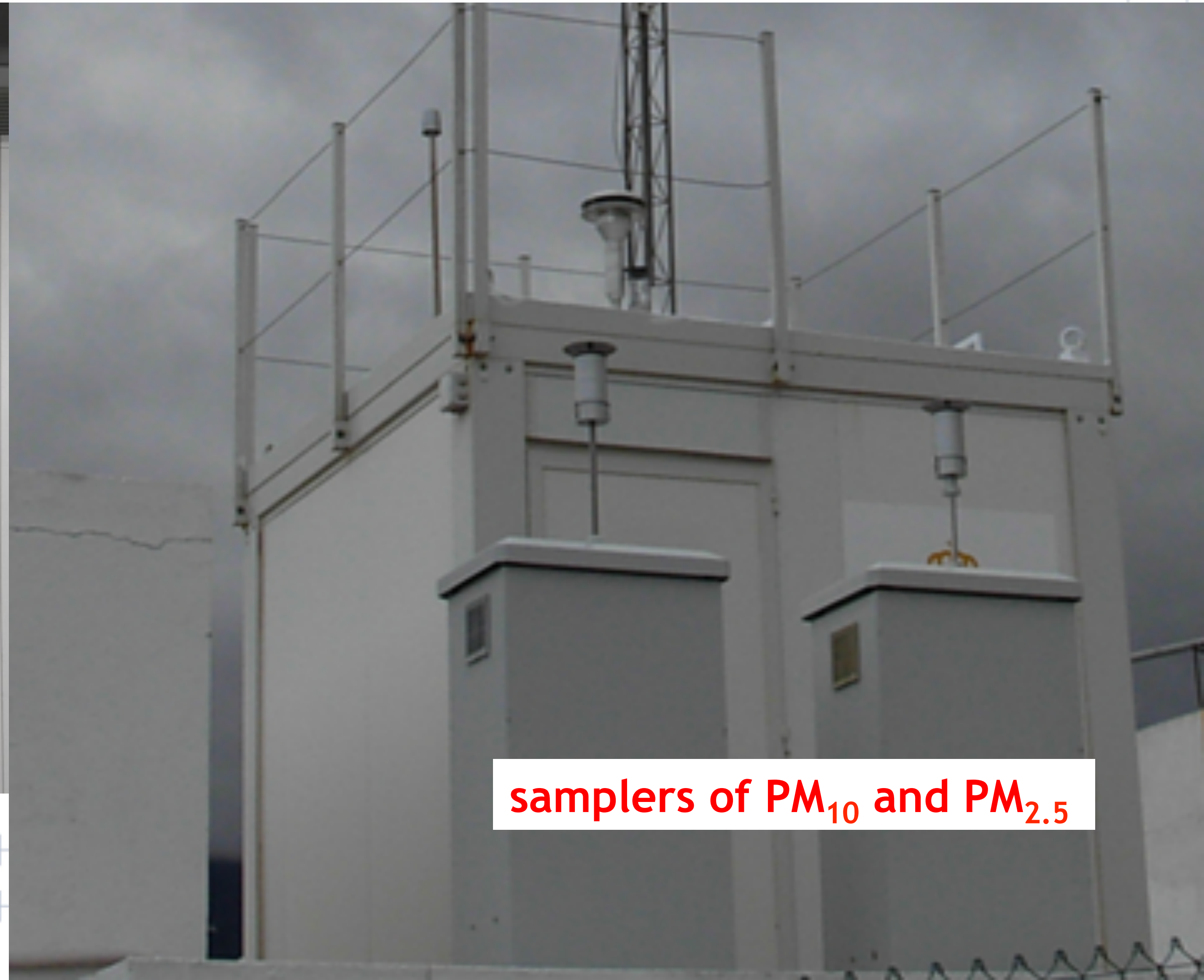
samplers of PM_{10} and $PM_{2.5}$

room of conditioning and weighting filters

1 month in summer (30 days) sampling

1 month in winter (30 days) sampling

at each station



samplers of PM_{10} and $PM_{2.5}$

AEMet
Agencia Estatal de Meteorología

ARAFO

GLADIOLOS

CIUDAD DEPORTIVA

MERCADO CENTRAL

TOME CANO

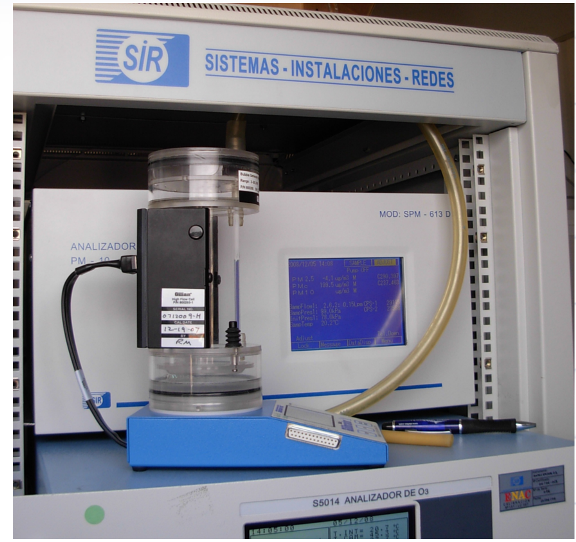
REHOYAS

TELDE

QUALITY CONTROL

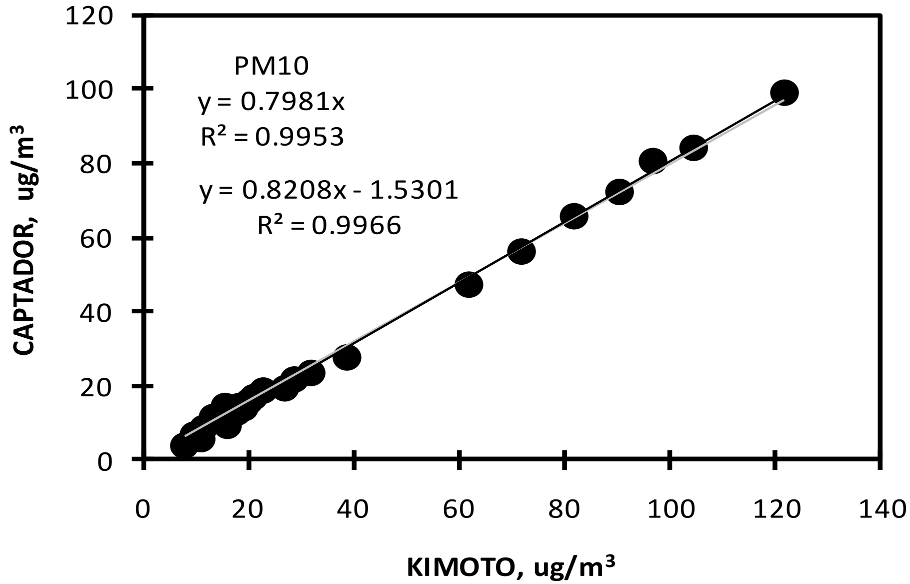
SAMPLER

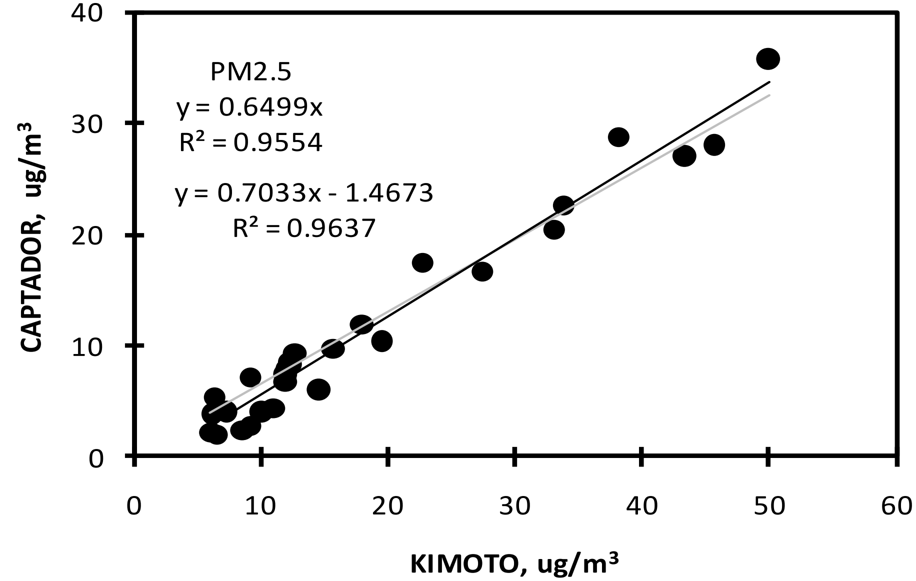
PM monitor



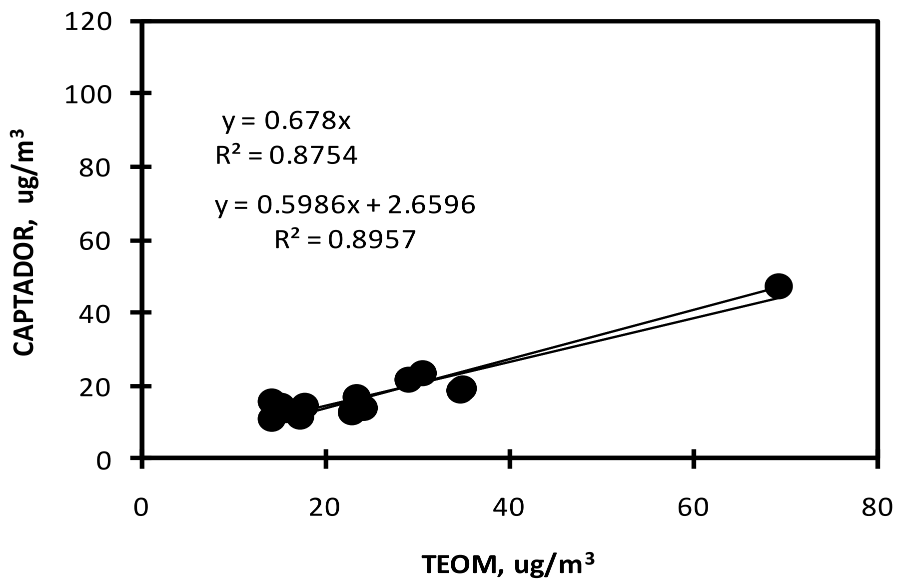
- airflow accuracy
- calibration of the sensor
- leaks
- cleaning

ARAFO

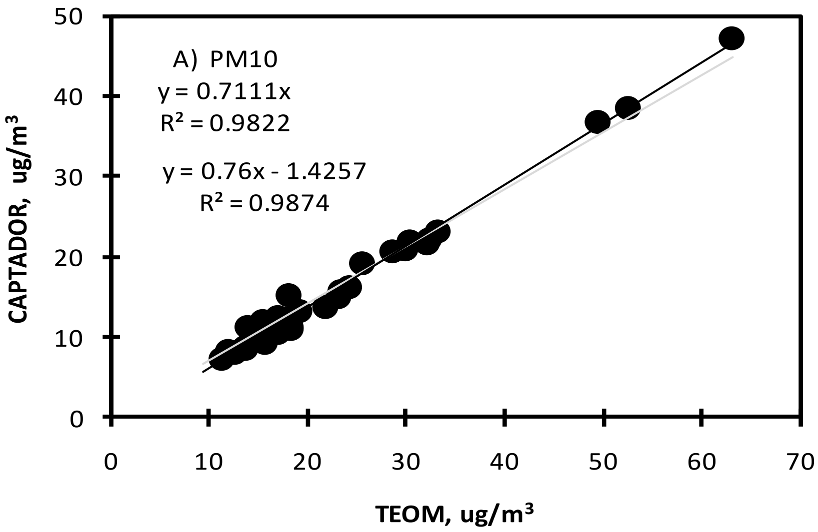


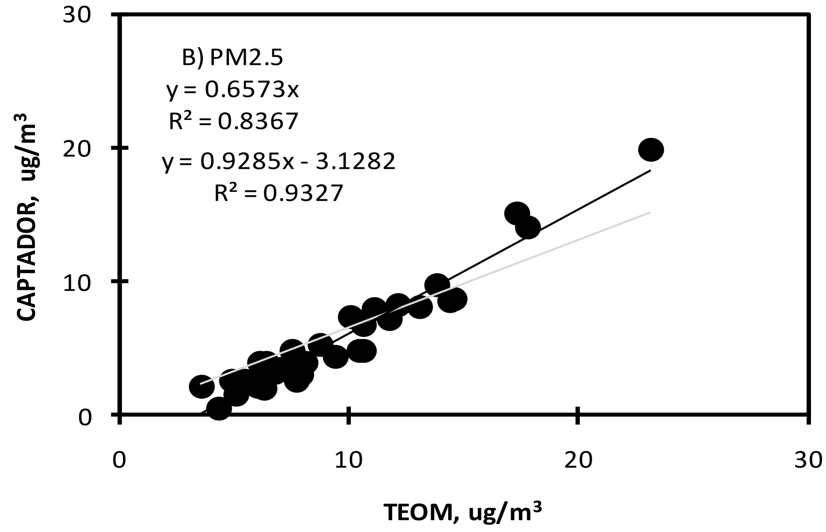


UNIDAD MOVIL



GLADIOLOS





TOME CANO

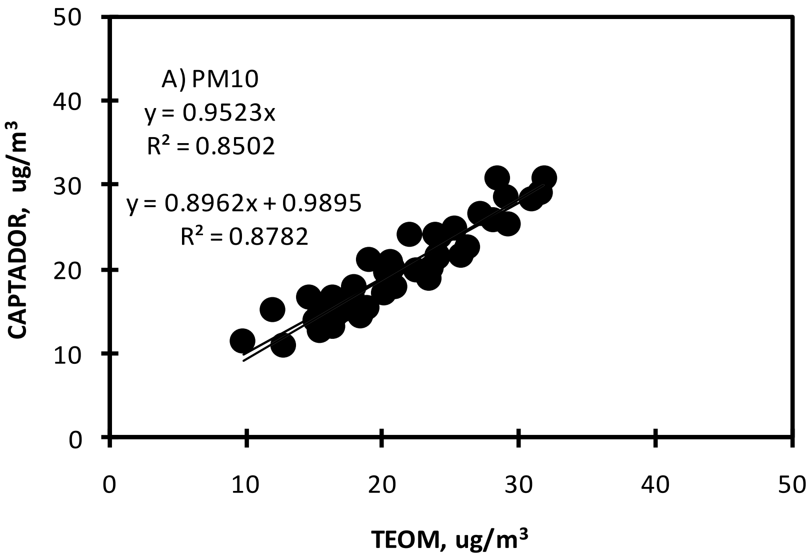


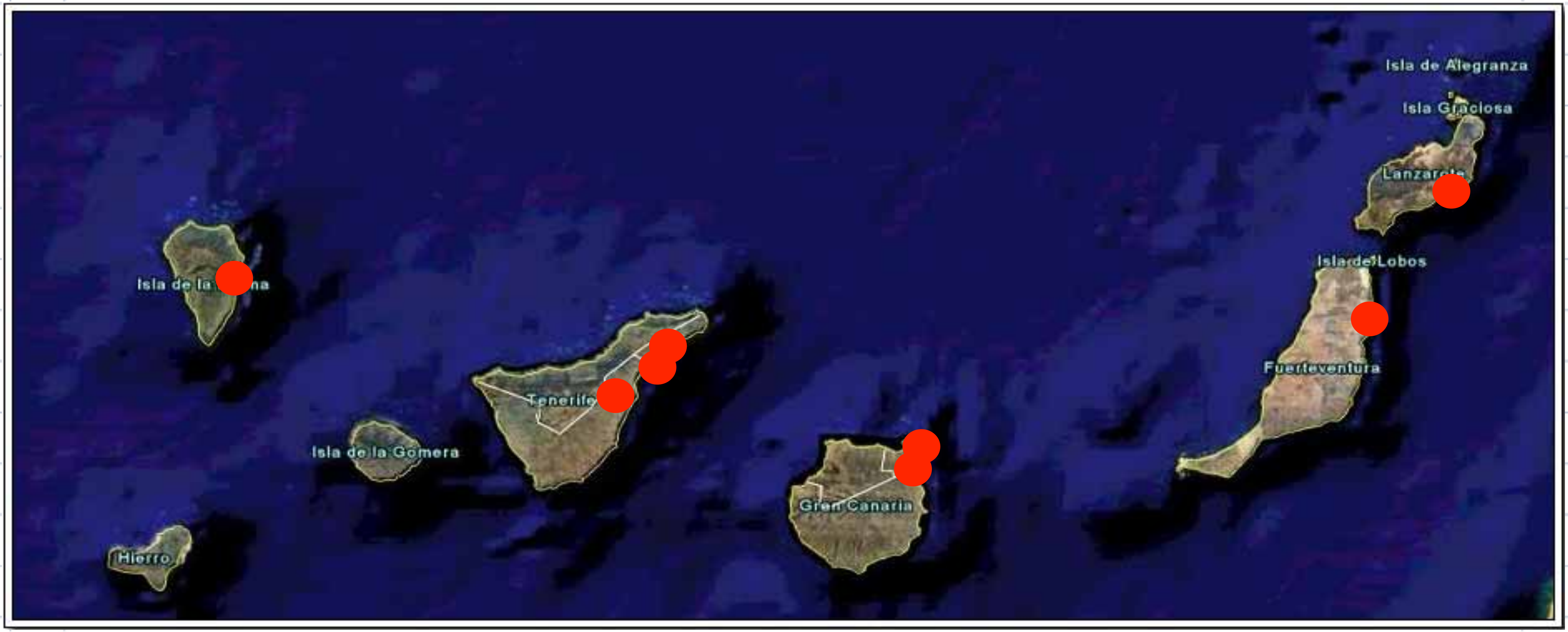
Tabla 1. Recopilación de ecuaciones obtenidas en intercomparaciones de analizadores de PM10.

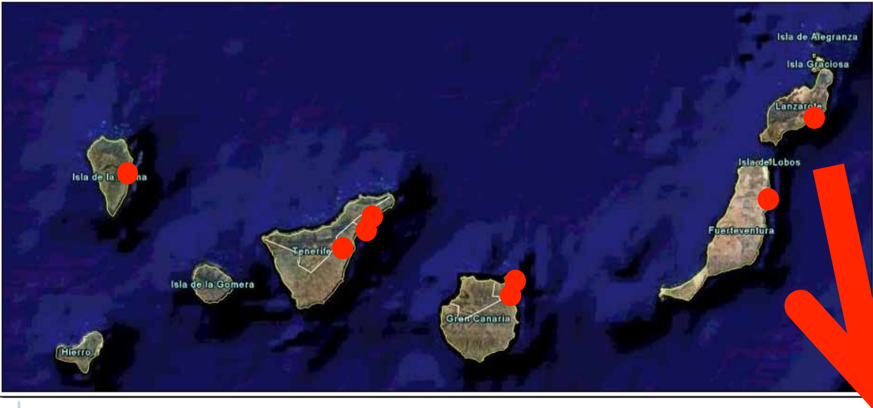
Estación	Fecha	Periodo	T, ºC	P hPa	Y=a·x	R^2	¿VALIDA?	Y=a·x+b	R^2	¿VALIDA?	N
LA HIDALGA	21/02/2009 – 24/03/2009	INVIERNO	20.2	972	y=0.798x	0.995	SI	y=0.820x + (-1.530)	0.997	SI	28
LOS GLADIOLOS	27/04/2009 – 09/06/2009	PRIMAVERA	24.4	993	y=0.711x	0.982	SI	y=0.760x +(-1.425)	0.987	SI	34
TOME CANO	04/08/2009-17/09/2009	VERANO	28.7	995	y=0.952x	0.850	SI	y=0.896x +(0.989)	0.878	SI	44
MERCADO CENTRAL	17/11/2009-23/01/2010	INVIERNO	25.1	1015	y=1.275x	0.961	SI	y=1.191x +(2.928)	0.969	SI	49
MERCADO CENTRAL	09/01/2001-28/12/2001	ANUAL	24.8		y=1.285x	0.872	SI	y=1.142x +(7.151)	0.893	SI	88
PARQUE REHOYAS	05/03/2010-21/04/2010	INVIERNO	22.5	1003.8	y=1.032x	0.875	SI	y=1.062x +(-0.561)	0.876	SI	37
LOS GLADIOLOS	24/05/2010-07/06/2010	PRIMAVERA	25.8	1004.3	y=0.778x	0.931	SI	y=0.896x +(-3.8461)	0.951	SI	39
TOME CANO	14/04/2010-29/05/2010	PRIMAVERA	22.2	1007.6	y=0.773x	0.871	SI	y=0.747x +(0.615)	0.872	SI	47
LA HIDALGA	11/06/2010-29/07/2010	VERANO	23.8	985.1	y=0.702x	0.757	NO problemas mantenimiento	y=0.612x +(2.893)	0.776	NO problemas mantenimiento	39
MERCADO CENTRAL	23/06/2010-01/08/2010	VERANO	26.7	1014.7	y=1.172x	0.901	SI	y=1.240x +(-1.694)	0.911	SI	35
PARQUE REHOYAS	20/09/2010-17/10/2010	VERANO	27.0	1000.7	y= 1.017x	0.839	SI	y=1.125X +(-3.067)	0.849	SI	61
CIUDAD DEP. ARRECIFE	26/08/2010-08/10/2010	VERANO	25.2	1010.9	y=1.085x	0.922	SI	y=1.042X +(0.832)	0.923	SI	34

Tabla 2. Recopilación de ecuaciones obtenidas en intercomparaciones de analizadores de PM2.5. N: número de muestras válidas usadas.

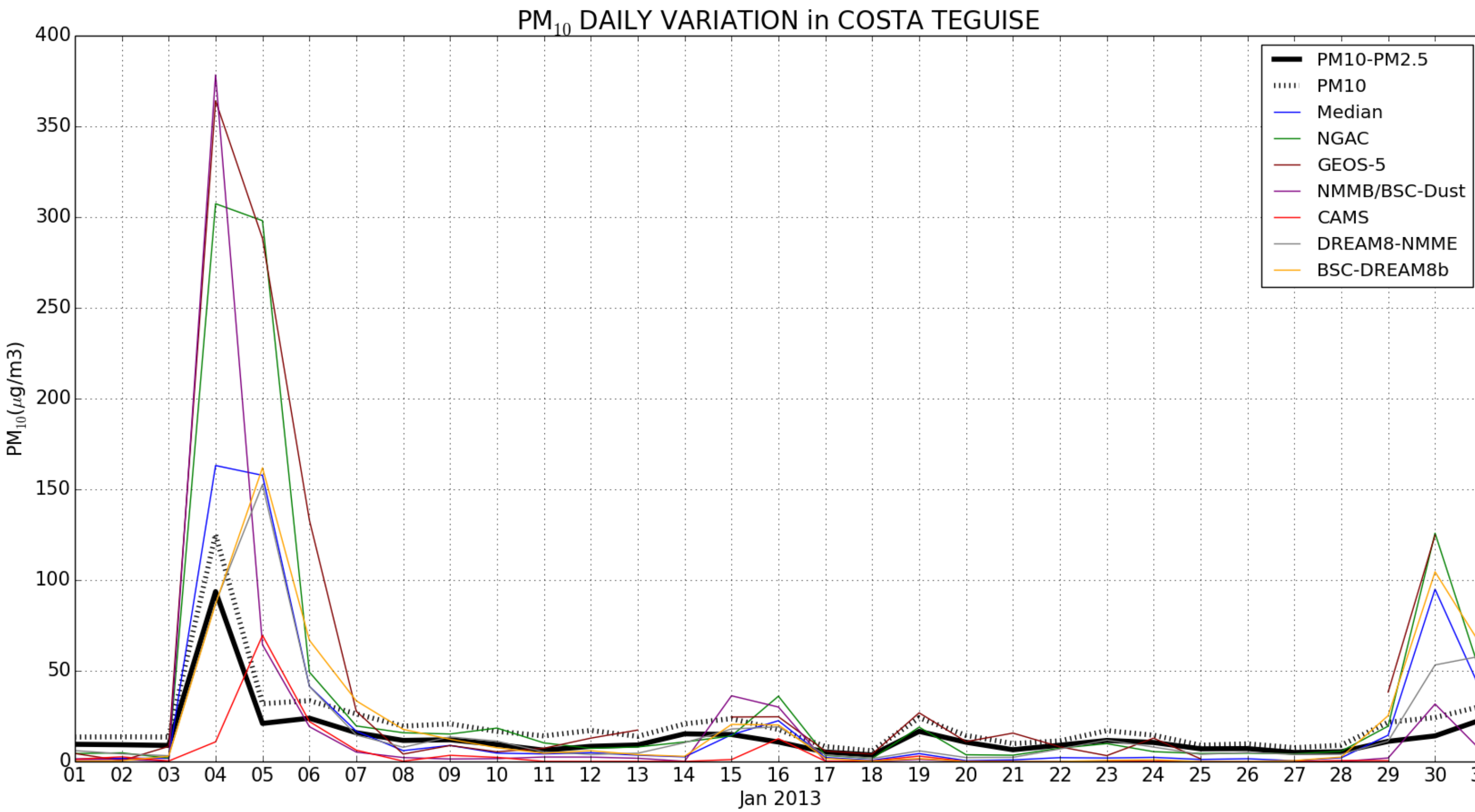
Estación	Fecha	Periodo	T, ºC	P hPa	Y=a·x	R^2	¿VALIDO?	Y=a·x+(b)	R^2	¿VALIDO?	N
LA HIDALGA	21/02/2009 – 24/03/2009	INVIERNO	20.2	972	y=0.650x	0.9554	SI	y=0.7033x + (–1.4673)	0.9637	SI	28
LOS GLADIOLOS	27/04/2009 – 09/06/2009	PRIMAVERA	24.4	993	y=0.657x	0.8367	SI	y=0.9285x +(-3.1282)	0.9285	SI	33
MERCADO CENTRAL	17/11/2009-23/01/2010	INVIERNO	25.1	1015	y=0.865x	0.8707	SI	y= 0.7552 +(1.519)	0.8939	SI	45
PARQUE REHOYAS	05/03/2010-21/04/2010	INVIERNO	22.5	1003.8	y=0.768x	0.582	NO, Conc < 10μg/m³	y=0.908x +(-1.0521)	0.597	NO Conc < 10μg/m³	37
LOS GLADIOLOS	24/05/2010-07/06/2010	VERANO	25.8	1004.3	y=0.684x	0.686	NO, Conc < 10μg/m³	y=0.941x +(-2.462)	0.745	NO, Conc < 10μg/m³	39
LA HIDALGA	11/06/2010-29/07/2010	VERANO	23.8	985.1	y=0.474x	0.680	NO evalua, Conc < 10μg/m³	y=0.559x +(-1.254)	0.699	NO evalua, Conc < 10μg/m³	39
MERCADO CENTRAL	23/06/2010-01/08/2010	VERANO	26.7	1014.7	y= 0.825	0.858	SI	y=0.7494 x + 0.912	0.868	SI	35
PARQUE REHOYAS	20/09/2010-17/10/2010	VERANO	27.0	1000.7	y= 0.797x	0.489	NO evalua, Conc < 10μg/m³	y=1.192X +(-3.243)	0.553	NO evalua, Conc < 10μg/m³	61
CIUDAD DEP. ARRECIFE	26/08/2010-08/10/2010	VERANO	25.2	1010.9	y=0.650x	0.627	NO evalua, Conc < 10μg/m³	y=0.558X +(0.564)	0.635	NO evalua, Conc < 10μg/m³	34

Standardized PM_{10} y $PM_{2.5}$ levels in the network

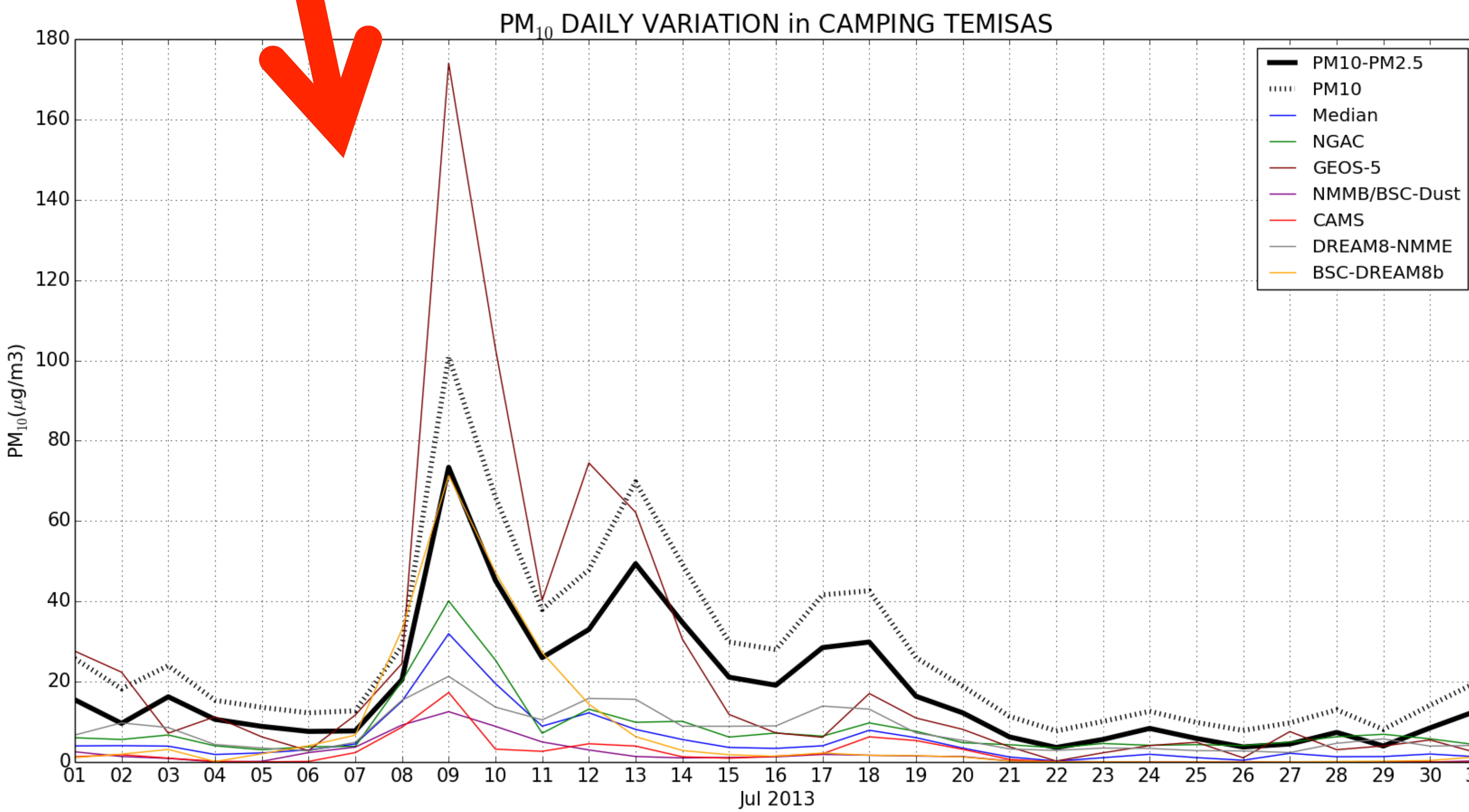




Model validation with standardized PM_{10} y $PM_{2.5}$ data in the network



Model validation with standardized PM_{10} y $PM_{2.5}$ data in the network



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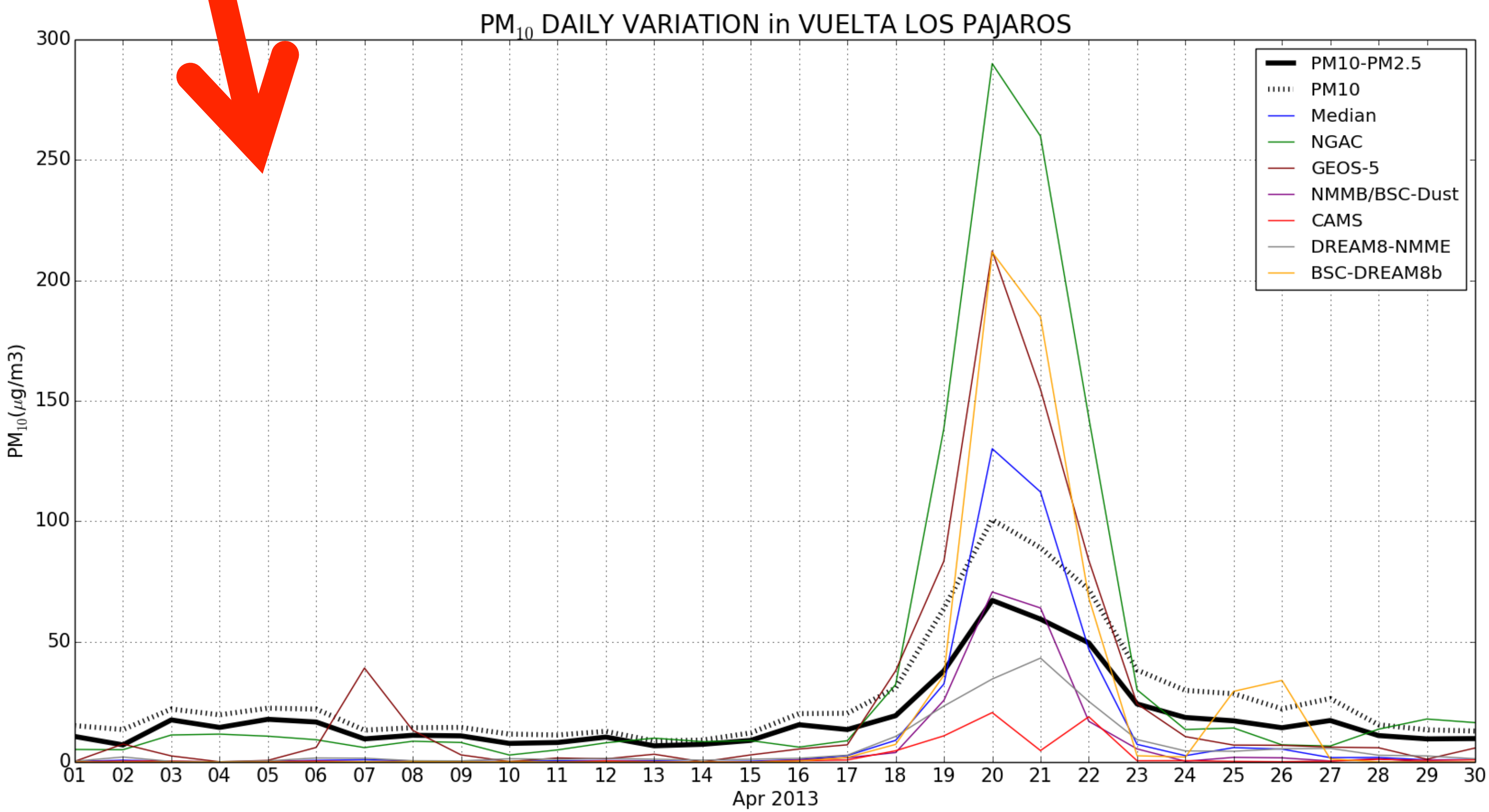
Model validation with standardized PM_{10} y $PM_{2.5}$ data in the network



dust air quality

1. PM_{10} and $PM_{2.5}$ levels

-method-01: reference - manual gravimetry

-method-02: automatic

	<u>Manual gravimetry</u>	<u>automatic</u>
advantage:	reference method	high time resolution, 1h
disadvantage:	poor time resolution, 24-h average manual work takes 3 days to know PM_{10}	Needs validation

we recommend to use the two methods:

-automatic, continuously

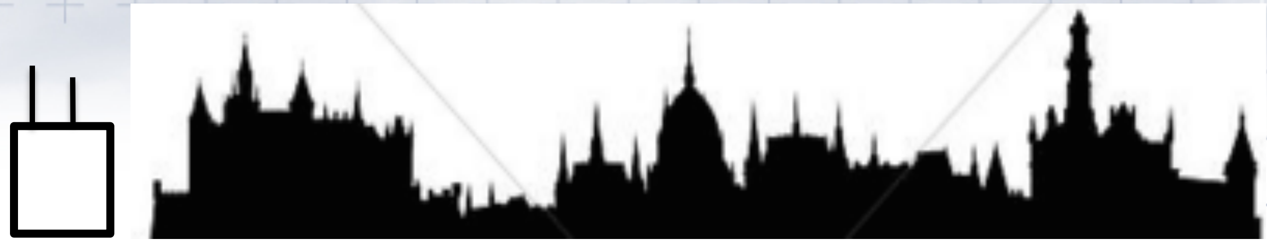
-gravimetric: intercomparisons - 1 month summer, 1 month winter

dust, aerosols and pollutants

in-situ observations

PM_{10} and $PM_{2.5}$ levels
PM_{10} and $PM_{2.5}$ composition
complementary observations

observation network



dust air quality

1. PM_{10} and $PM_{2.5}$ levels

-method-01: reference - manual gravimetry

-method-02: automatic

	Manual gravimetry	automatic
advantage:	reference method CHEMICAL ANALYSIS	high time resolution, 1h
disadvantage:	poor time resolution, 24-h average manual work takes 3 days to know PM_{10}	Needs validation

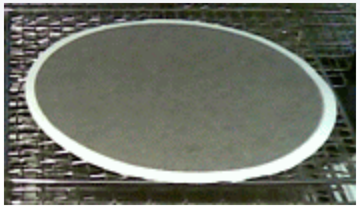
we recommend to use the two methods:
-automatic, constinously
-gravimetric: intercomprisons, 1 month summer, 1 month winter

bulk chemical composition

PM samples:
- fine + coarse (TSP, PM_{10})
- fine ($PM_{2.5}$, PM_1)

Saharan dust

Urban particles



PM ($\mu g/m^3$)= dust + trace elements + **ions ($SO_4^{=}$, NO_3^-, NH_4^+, Na^+, Cl-)** + OC + EC

Elemental Composition:

Major elements (Al, Si, Ca, K, Na, Mg) + trace elements (P, Li , Be , Sc , Ti , V , Cr , Mn , Co , Ni , Cu , Zn , Ga , Ge , As , Se , Rb , Sr , Y , Zr , Nb , Mo, Cd , Sn , Sb, Cs , Ba , La , Ce , Pr , Nd , Sm , Eu , Gd , Tb , Dy , Ho , Er , Tm , Yb , Lu , Hf , Ta, W, Tl , Pb , Bi , Th , U)

Inductively coupled plasma Atomic Emission Spectroscopy ICP-AES

Inductively coupled plasma Mass spectroscopy IPC-MS

Destructive techniques

Ions: $SO_4^{=}$, NO_3^-, NH_4^+, Na^+, Cl^-

Ion Chromatography, ICP-AES, ICP-MS, selective electrodes and colorimetry

Destructive techniques

Thermal/optical reflectance (TOR) and/or thermal/optical transmission (TOT)

destructive techniques

XRF, PIXE, INAA : none destructive techniques

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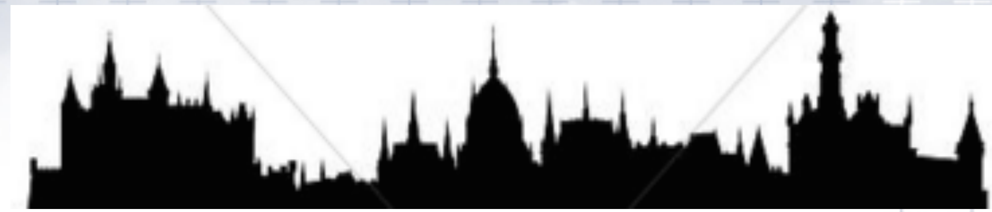


people live in cities and breath a cocktail dust + pollutants

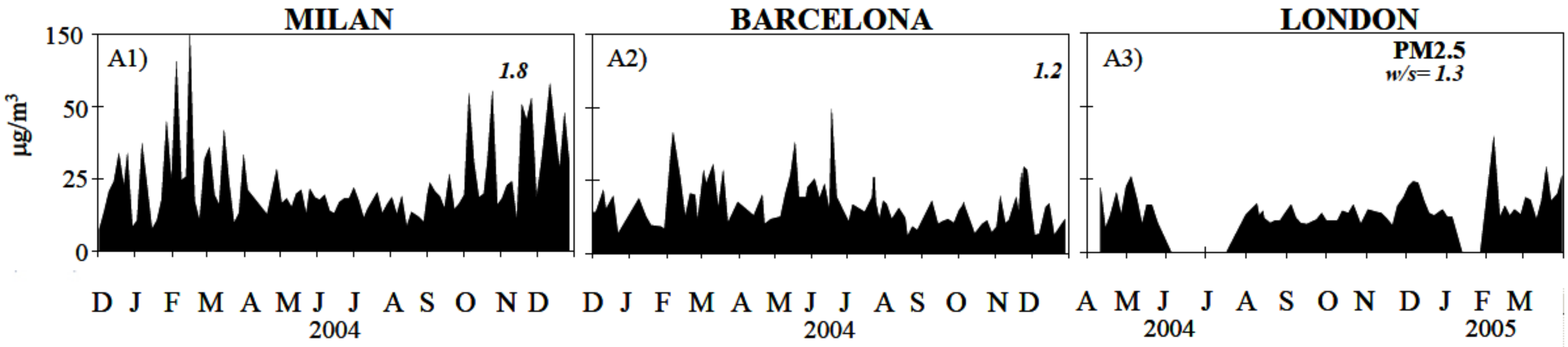
PM_{10}: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ..

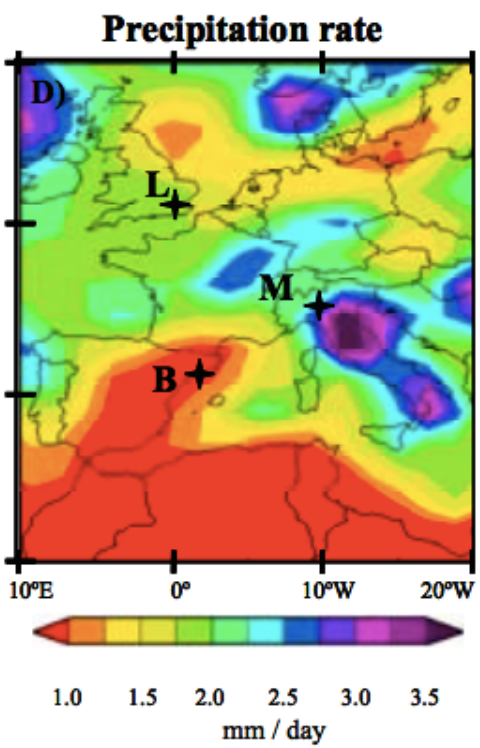
$PM_{2.5}$: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ..

PM_{10}: dust + sea salt + vehicle exhaust + oil refining + power plants + ships +...

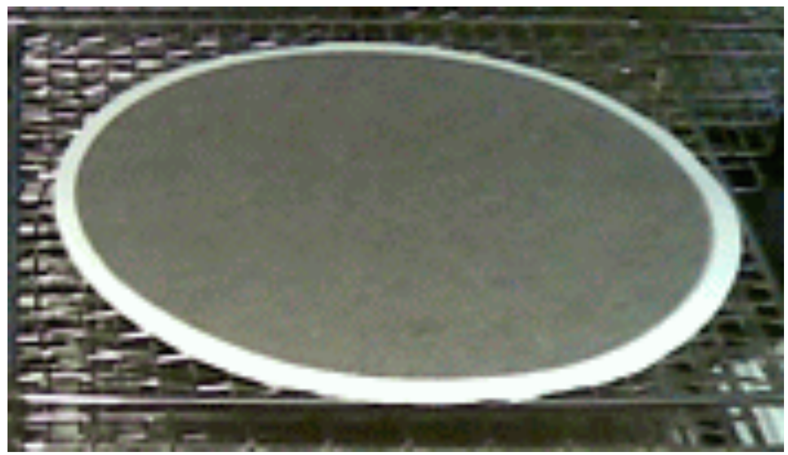
$PM_{2.5}$: dust + sea salt + vehicle exhaust + oil refining + power plants + ships +...

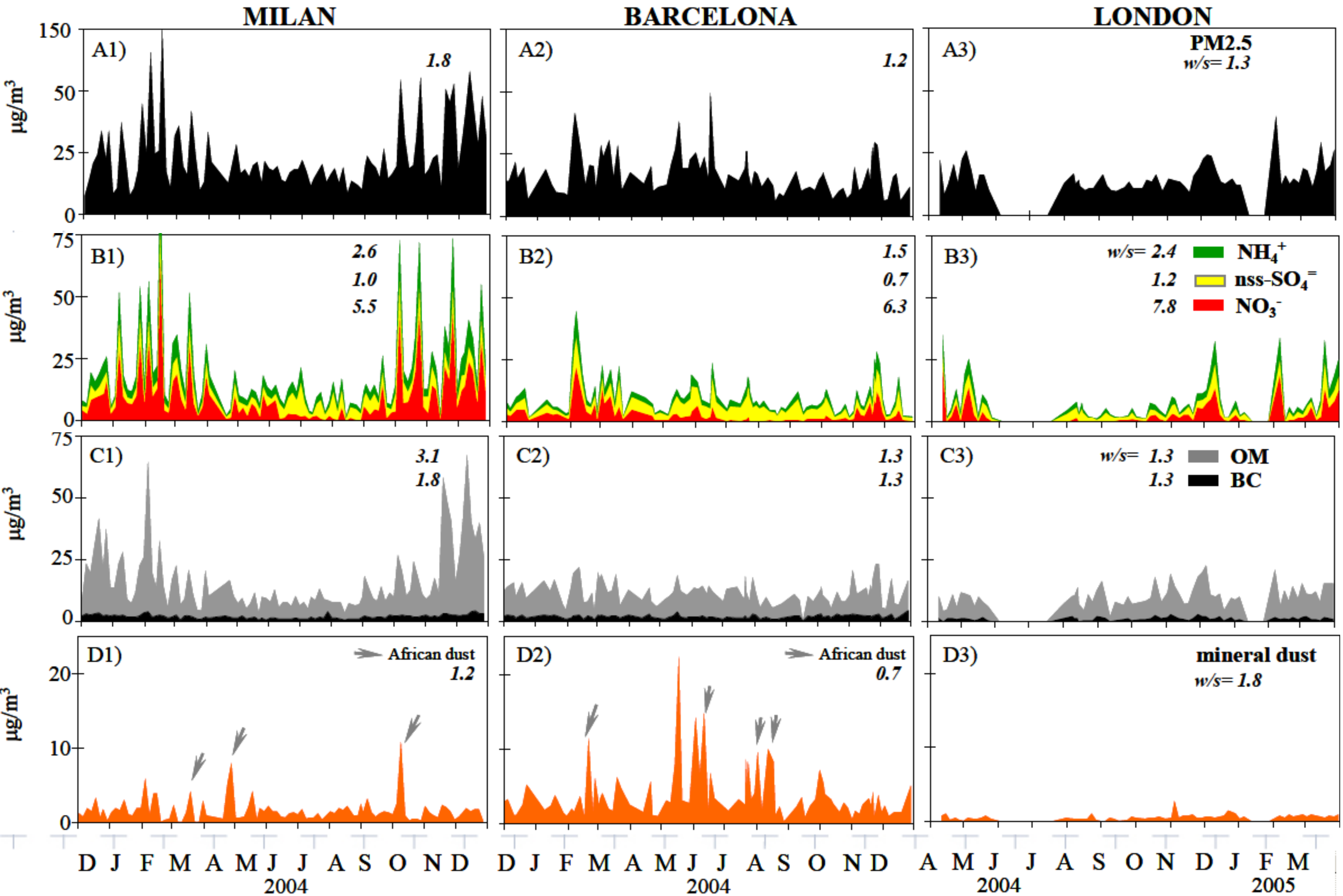
PM in urban areas





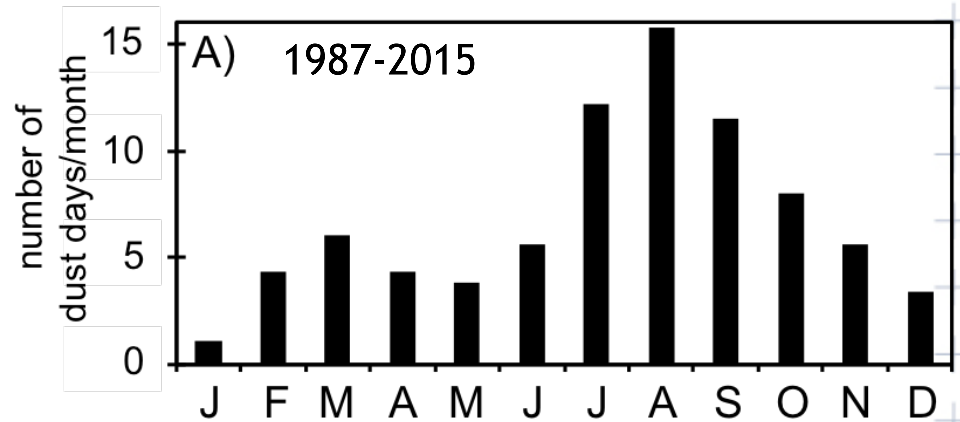
Urban particles




MILAN
BARCELONA
LONDON
A1)
1.8
A2)
1.2
A3)
PM2.5
w/s= 1.3
B1)
2.6
1.0
5.5
B2)
1.5
0.7
6.3
B3)
w/s= 2.4
1.2
7.8
NH4+
nss-SO4=
NO3-
C1)
3.1
1.8
C2)
1.3
1.3
C3)
w/s= 1.3
1.3
OM
BC
D1)
African dust
1.2
D2)
African dust
0.7
D3)
mineral dust
w/s= 1.8
µg/m3
D J F M A M J J A S O N D
2004
A M J J A S O N D J F M
2004
2005

PM in remotes sites

Summer Izaña is within the SAL



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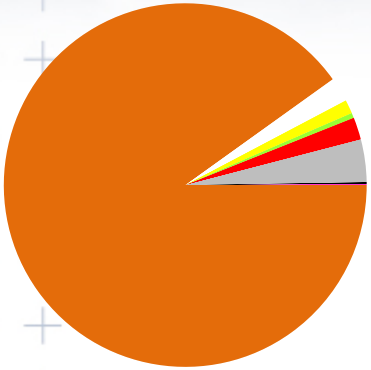
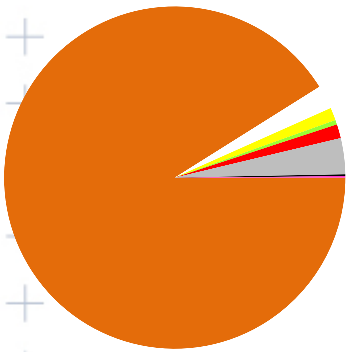
PM_x composition in the SAL



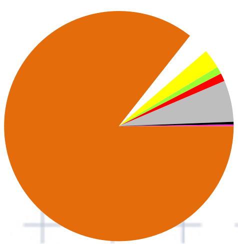
PM_T 47.3 µg/m^3

%	µg/m^3	Component
91%	42.6	dust (Al, Fe, Ca, Ti..)
2.2%	1.0	none ammonium-sulfate
1.2%	0.5	ammonium-sulfate
0.4%	0.2	ammonium
1.9%	0.9	nitrate
3.8%	1.8	organic matter
0.2%	0.07	elemental carbon



PM_{10} 42.0 µg/m^3

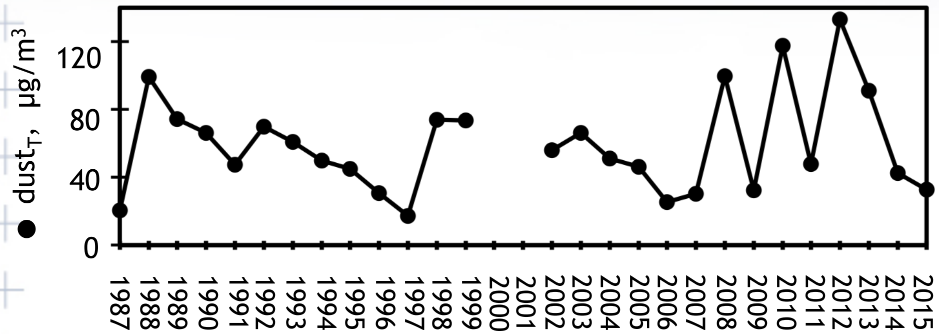
%	µg/m^3	Component
91%	38.3	dust
2.2%	0.9	none ammonium-sulfate
1.2%	0.5	ammonium-sulfate
0.4%	0.2	ammonium
1.3%	0.6	nitrate
3.4%	1.4	organic matter
0.2%	0.07	elemental carbon



$PM_{2.5}$ 18.5 µg/m^3

%	µg/m^3	Component
85%	15.8	dust
3.0%	0.6	none ammonium-sulfate
2.7%	0.5	ammonium-sulfate
1.0%	0.2	ammonium
1.1%	0.2	nitrate
5.8%	1.1	organic matter
0.4%	0.07	elemental carbon

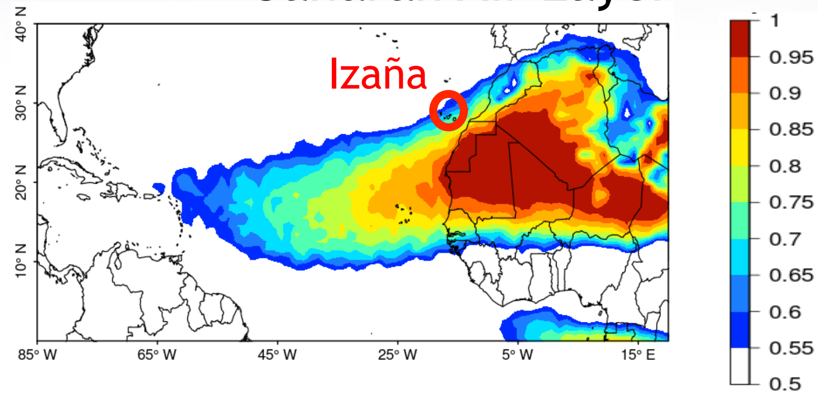
summer dust at Izaña: 1987 - 2015



Max: 133 µg/m^3 2012

Min: 17 µg/m^3 1997

Saharan Air Layer



MDFA: Major Dust Frequency Activity

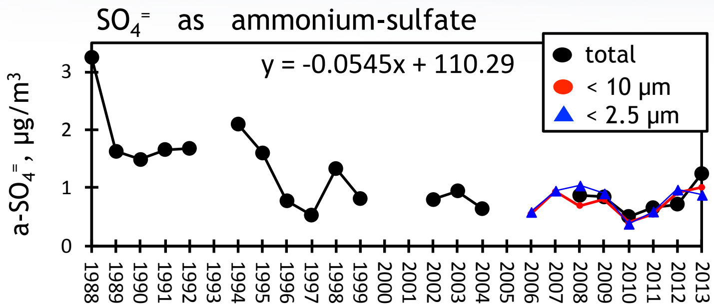
UV Absorbing Aerosol Index = sensitive to iron oxides in dust

$$\text{MDFA} = \frac{\text{number days UV Absorbing Aerosol Index } > 1}{\text{total number of days in the month}}$$

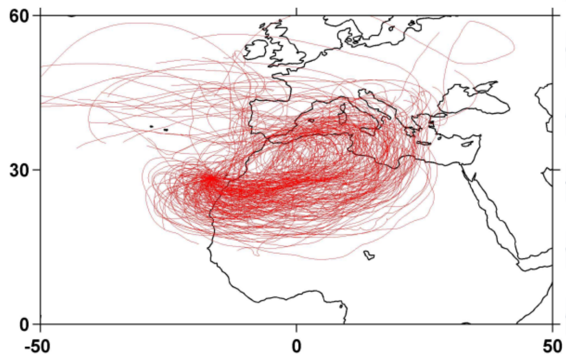
= fraction of summertime AI>1

Satellite (Earth Probe, Nimbus 7, Aura):
Total Ozone Monitor Spectrometer (1987-2001)
Ozone Monitor Instrument (2005-2012)

ammonium-sulfate in the Saharan Air Layer



(1) air laden in Saharan dust has previously passed over the Mediterranean and Europe



August 1987-2012, dust days

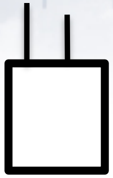
dust, aerosols and pollutants

in-situ observations

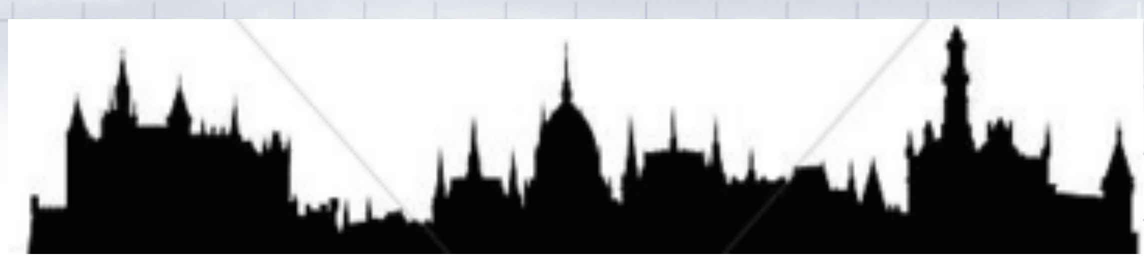
PM_{10} and $PM_{2.5}$ levels
PM_{10} and $PM_{2.5}$ composition
complementary observations

let's build our observation network !!!

in-situ observations



dust air quality



in-situ observations

PM$_{10}$ and PM$_{2.5}$ levels
PM$_{10}$ and PM$_{2.5}$ composition
complementary observations *in-situ*

meteorology:
wind, temperature, relative humidity, pressure

gaseous pollutants (reference methods):

NO_x: vehicle exhausts, ships, oil refining, power plants..
SO_2:, ships, oil refining, power plants
CO: vehicle exhausts

Examples of reference methods:

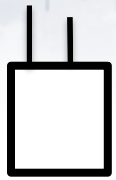
NOx: chemiluminiscense. EN 14211: 2006

SO2: fluorescense. EN 14212: 2006

CO: NDIR absorption. EN 14626: 2006

O_3: NDIR absorption. EN 14625: 2006

in-situ observations



dust air quality

in-situ observations

PM_{10} and $PM_{2.5}$ levels

PM_{10} and $PM_{2.5}$ composition

complementary observations

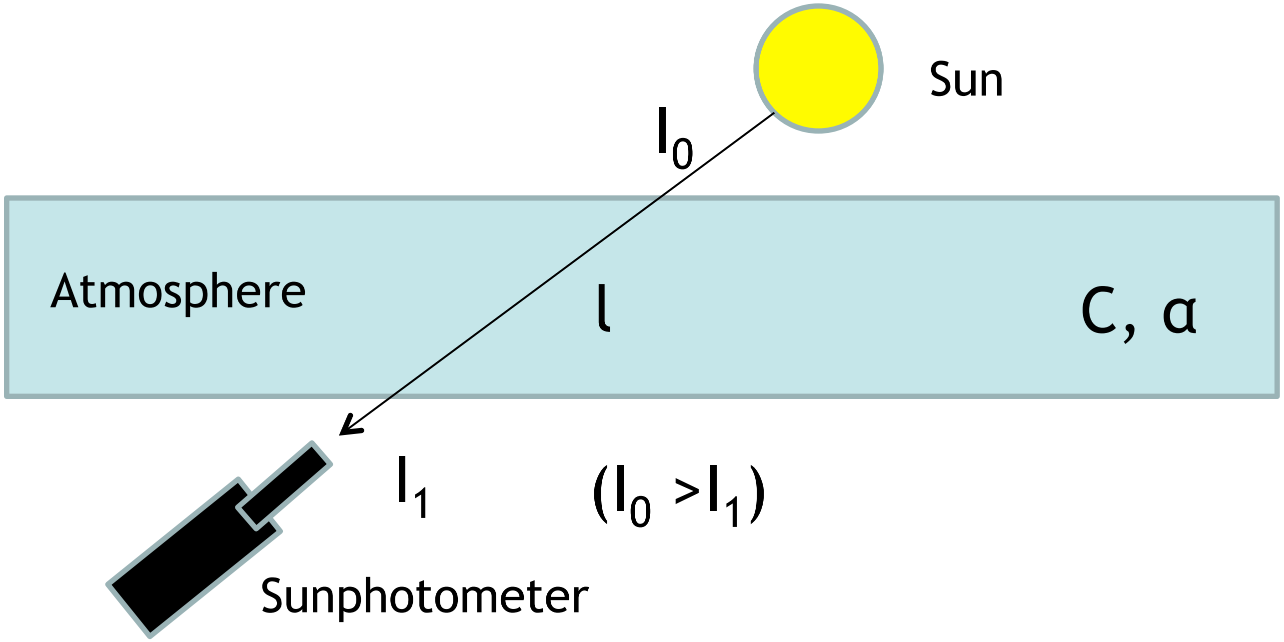
ground based remote sensing

column

vertical distribution

CONCEPTS:

Knowing the sunlight's energy at the top of the atmosphere, the thickness of the atmosphere, and the amount of sunlight transmitted to the earth's surface may allows us to determine **the amount of extinction**, and thus, the amount of **aerosols (dust).**



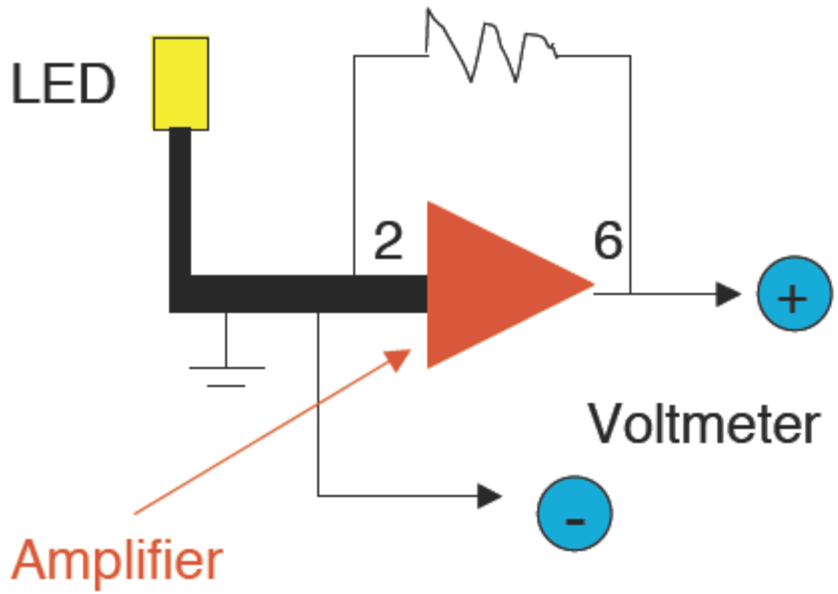
Beer's Law

$$I = I_o \cdot e^{-\sigma_{ext} \cdot L}$$

Transmissivity (T)
Extinction coefficient (σ_{ext}): εC
path length (L)
molar absorptivity of the absorber (ε)
concentration of absorbing species in the material (C)

CONCEPTS:

Sun Photometers absorb *direct* sunlight energy with a LED light and convert the intensity into a quantified voltage to measure aerosols in the atmosphere.



The intensity of sunlight at the top of the earth's atmosphere is constant. While the sunlight travels through the atmosphere, aerosols can dissipate the energy by scattering (Rayleigh and Mie) and absorbing the light. More aerosols in the atmosphere cause more scattering and less energy transmitted to the surface.

CONCEPTS:

Aerosol Extinction: A measure of attenuation of the light passing through the atmosphere due to scattering and absorption by aerosol particles.

Extinction coefficient (σ_{ext}) is the fractional depletion of radiance per unit path length (also called attenuation). It has units of km $^{-1}$.

Aerosol Mass Load: The columnar aerosol mass concentration ($\mu g/cm^2$) is the total aerosol mass in a vertical column of atmosphere.

CONCEPTS:

Aerosol Optical Depth (or Thickness)

"Aerosol Optical Depth“ (AOD) is the degree to which aerosols prevent the transmission of light. The aerosol optical depth or optical thickness (τ) is defined as the integrated extinction coefficient over a vertical column of unit cross section.

$$AOD = \int_{z=0}^{z=toa} \sigma_{ext}(z)\,dz$$

Angstrom Exponent (α)

An exponent that expresses the spectral dependence of Aerosol Optical Depth (τ) with the wavelength of incident light (λ). The spectral dependence of aerosol optical thickness can be approximated (depending on size distribution) by:

$$AOD = \beta\,\lambda^{\alpha}$$

α >> 0.9 FINE particles

α << 0.7 COARSE particles

where α is the Angstrom exponent (β = aerosol optical depth at 1 μm)

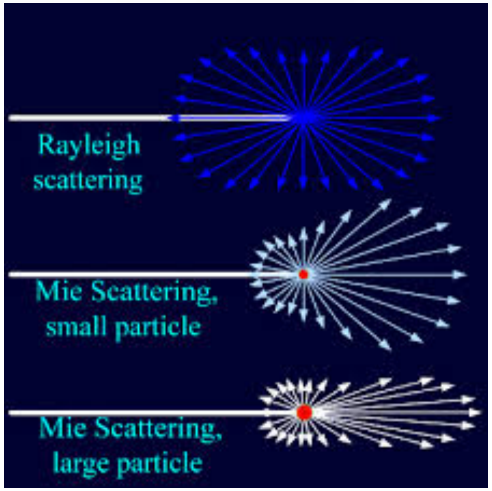
i.e. If AOD >~ 0.2 and α<0.7 then we are observing dust (aprox.)

CONCEPTS:

Aerosol Asymmetry Factor A measure of the preferred scattering direction (forward or backward) for light encountering aerosol particles.

$$g = \frac{1}{2} \int_{-1}^{+1} \cos\Theta \, P(\cos\Theta) \; d\cos\Theta$$

$$P(\cos\Theta) = \frac{1 - g^2}{\left(1 + g^2 - 2g\,\cos\Theta\right)^{3/2}}$$



In general, **g=0 indicates scattering directions evenly distributed** between forward and backward directions, i.e. isotropic scattering (e.g. scattering from small particles)

g<0 scattering in the backward direction (i.e scattering angle > 90 deg.), often referred to as backscattering, is scattering at 180 deg.

g>0 scattering in the forward direction (i.e scattering angle < 90 deg.), often referred to as forward-scattering, is scattering at 0 deg. **For larger size or Mie particles, g is close to +1. Including DUST**

ASSESSMENT OF OBSERVATIONS CONSISTENCY

Langely plot calibration (I00 determination for each wavelenght):

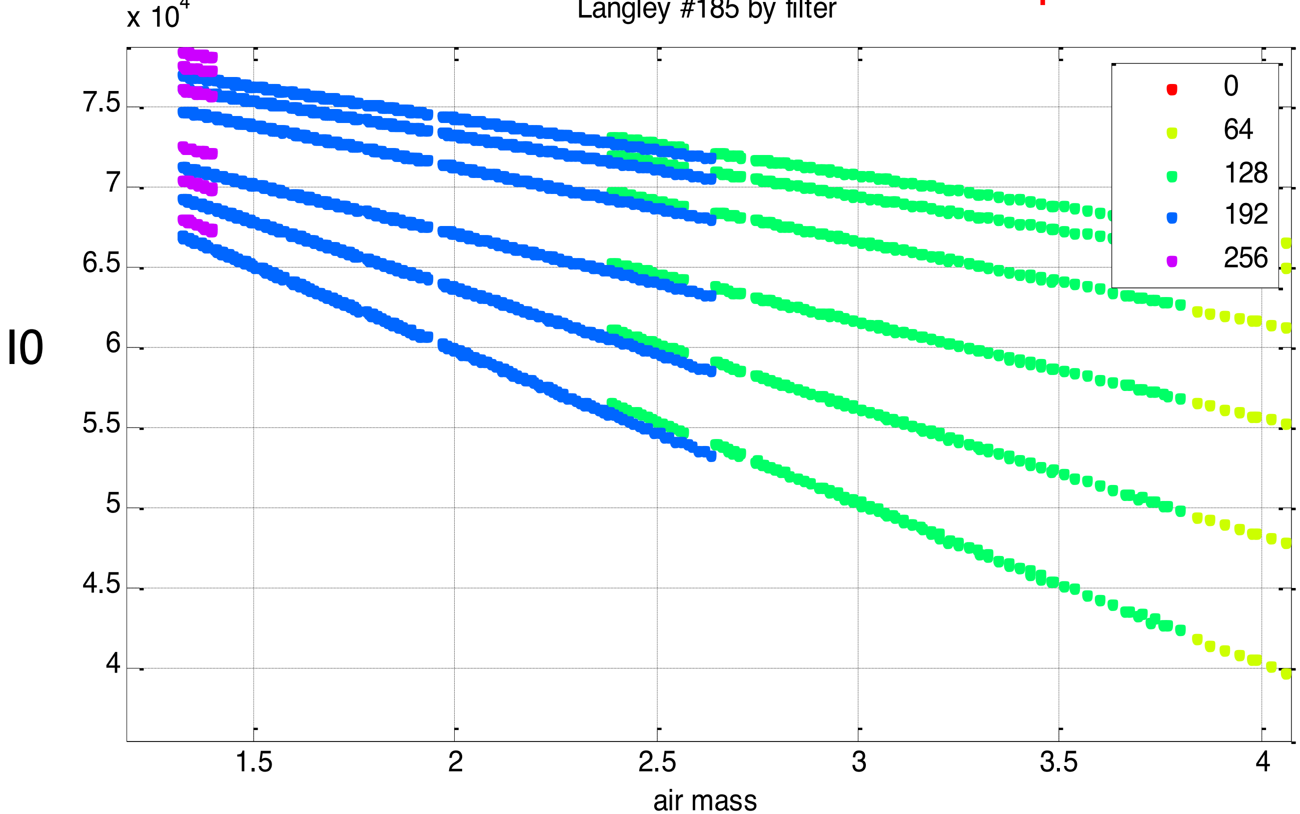
$$I = I_o \cdot e^{-\sigma_{ext} \cdot L} \qquad LnI = LnI_o - \sigma_{ext} L$$

If σ_{ext} is constant during the observation → We can determine I_o

Pristine conditions (very low and constant aerosol load

No clouds

Stable total ozone and column water vapor

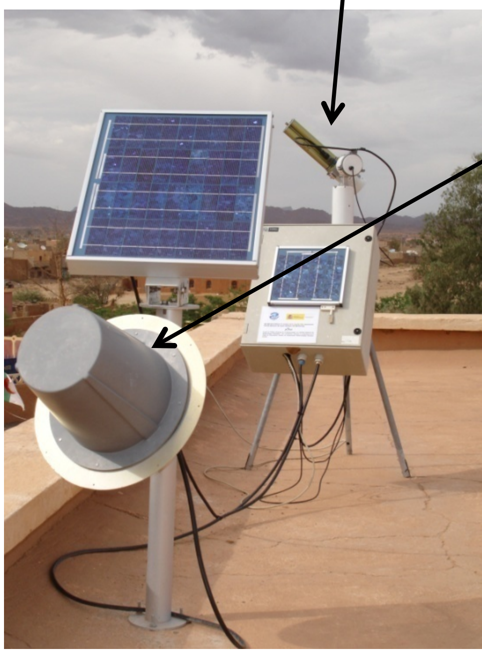


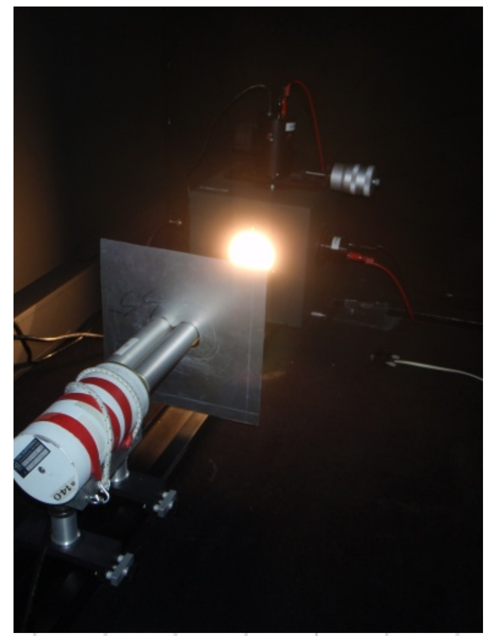
MEASUREMENTS:

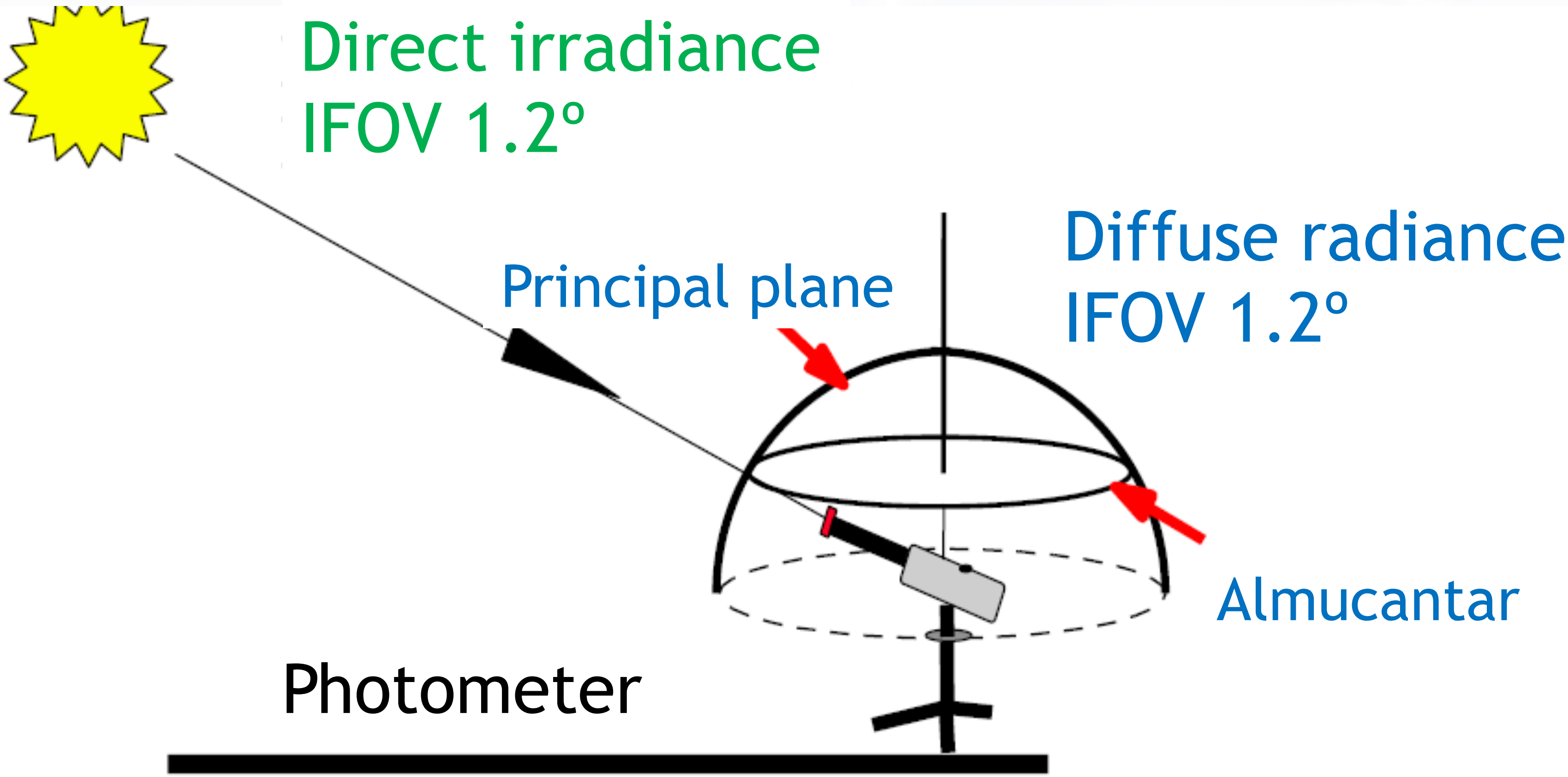
- The **Cimel Electronique 318** spectral radiometer is a solar-powered, weather-hardy, robotically-pointed sun and sky spectral sun photometer.

- A sensor head points the sensor head at the sun according to a preprogrammed routine.

- The Cimel controller, batteries, and the optional Vitel **satellite transmission** equipment are usually deployed in a weatherproof plastic case.

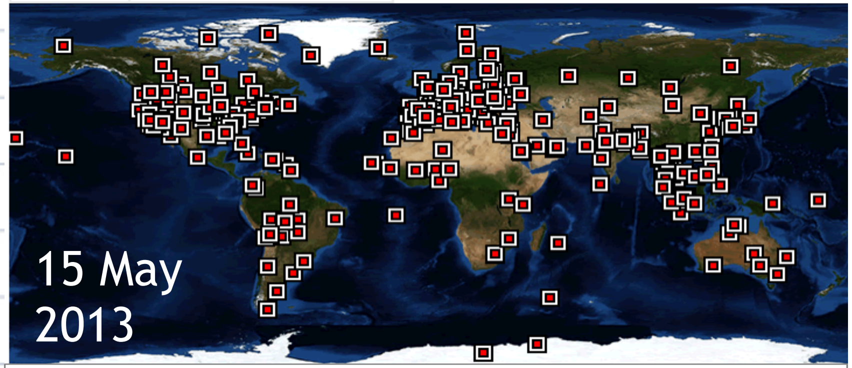


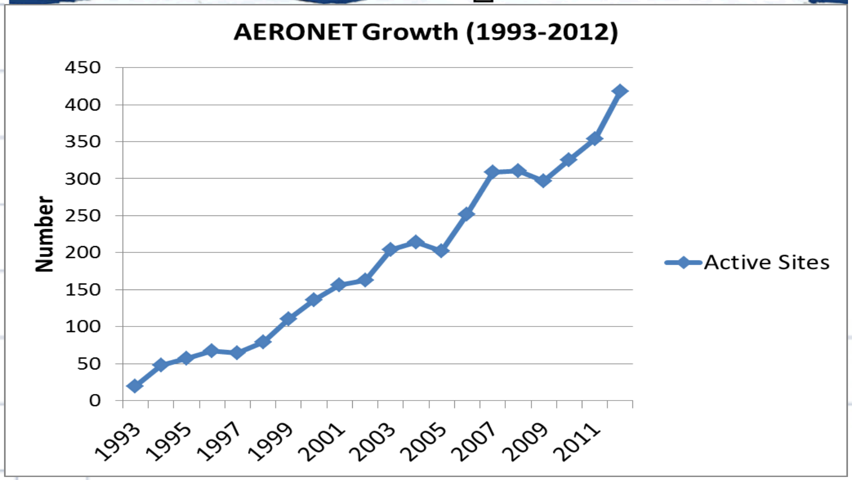




Sun measurements
Sky measurements

AERONET Aerosol Robotic Network-Twenty Years of Observations and Research





The AERONET program is a federation of ground-based remote sensing aerosol networks established by NASA and LOA-PHOTONS (CNRS) and has been expanded by collaborators from international agencies, institutes, universities, individual scientists and partners.

- >7000 citations
- >400 sites
- Over 80 countries
- http://aeronet.gsfc.nasa.gov

AERONET provides a long-term, continuous public database of aerosol optical, microphysical, and radiative properties for aerosol research and characterization, validation of satellite measurements, and synergism with other databases.

AERONET Data Flows

http://aeronet.gsfc.nasa.gov

Holben et al.
RSE, 1998
Holben et al.
JGR, 2001

Eck et al.
JGR, 1999

Smirnov et al.
RSE, 2000

Dubovik and King
JGR, 2000
Dubovik et al.
JGR, 2000
GRL, 2002

Flux measurements

Direct - l=340, 380, 440, 500, 670, 870, 940, 1020 nm
Diffuse - l=440, 670, 870, 1020 nm (alm, pp, pol)

Calibration and processing information

Mauna-Loa and Izaña
CNRS-University of Lille and University of Valladolid

Aerosol optical depth and precipitable water computations

Cloud screening and quality control

Inversion products

Volume size distribution (0.05 < size <15 μm), refractive index, single scattering albedo (l=440, 670, 870, 1020 nm)

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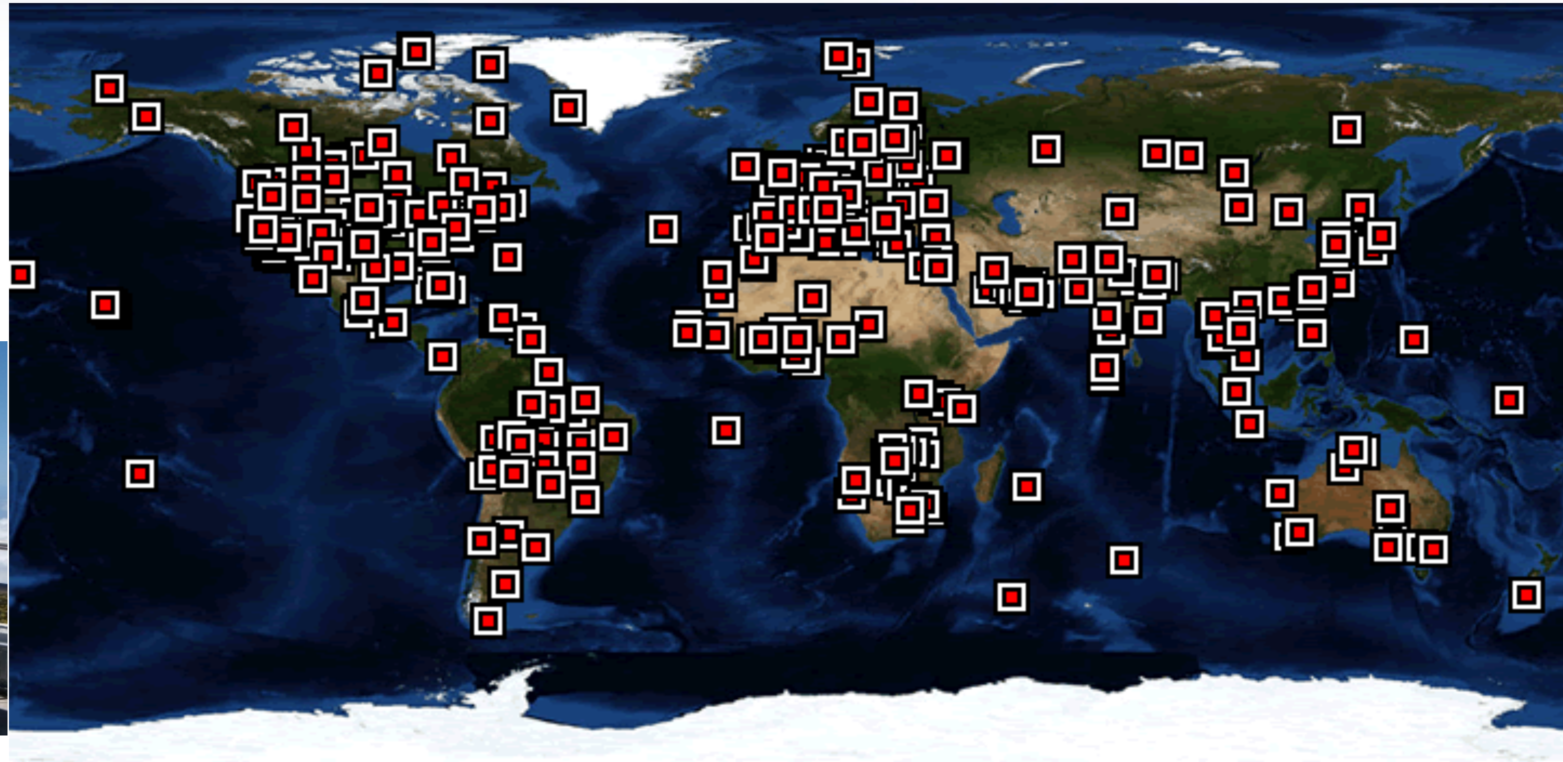
AERONET (AErosol RObotic NETwork)- http://aeronet.gsfc.nasa.gov

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE



An internationally Federated Network

- Characterization of aerosol optical properties
- Validation of satellite aerosol retrieval
- Near real-time acquisition; long term measurements

AERONET provides:

- global Aerosol Optical Depth of Dust in near real-time
- robust optical properties of Dust: size distribution, ref. Index, etc. (e.g. Asian Dust has stronger and less spectral dependent absorption than Saharan Dust)
- climatological models that reproduce observed optical properties of aerosol (useful for satellite retrievals)

Ground-based remote sensing

MEASUREMENTS:

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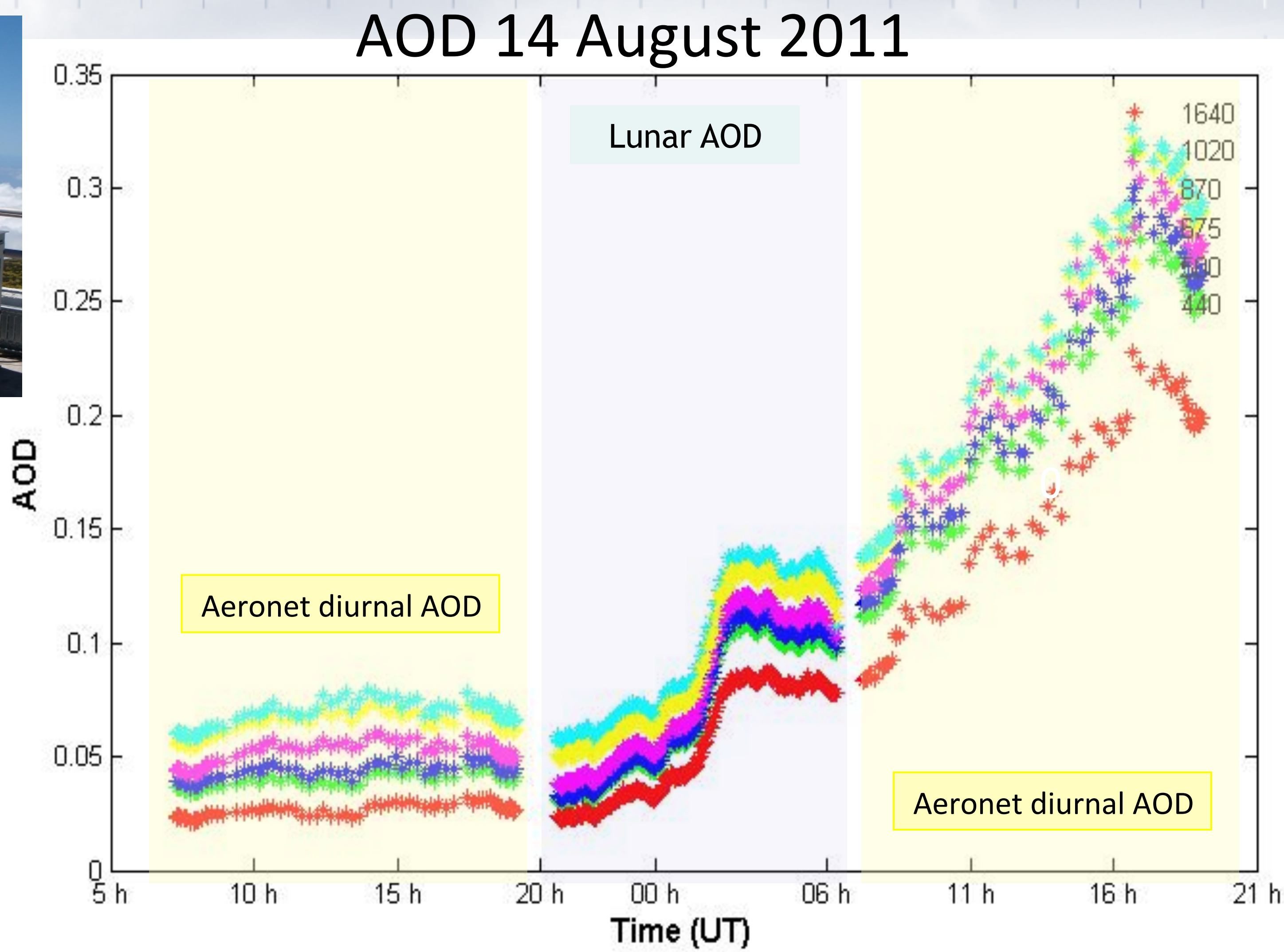
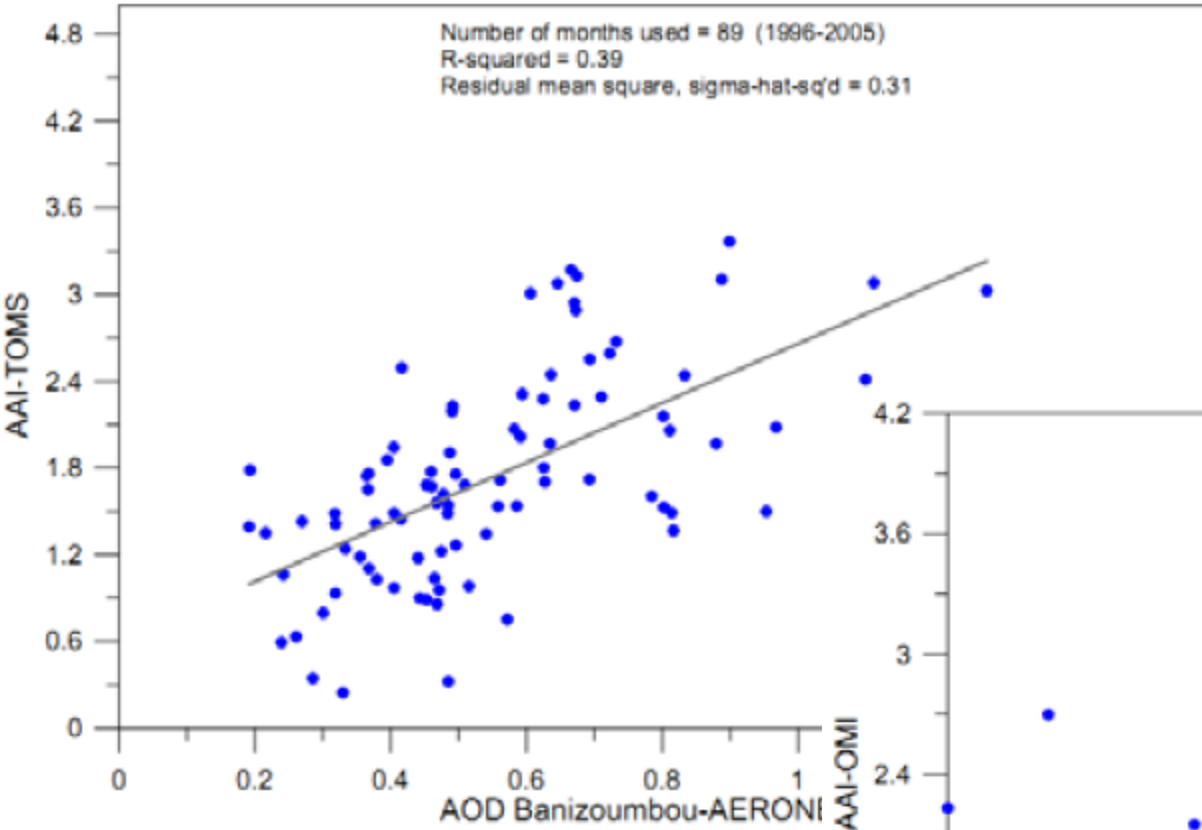
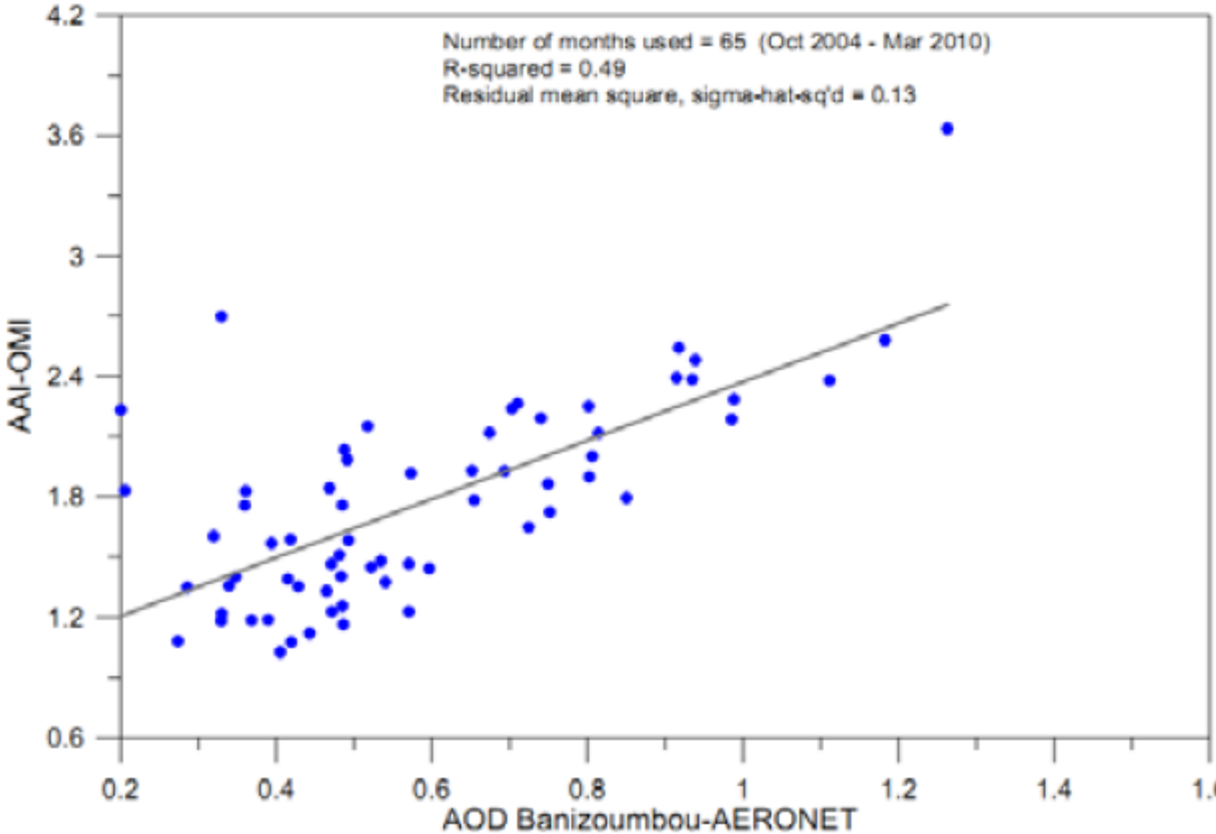
Agencia Estatal de Meteorología

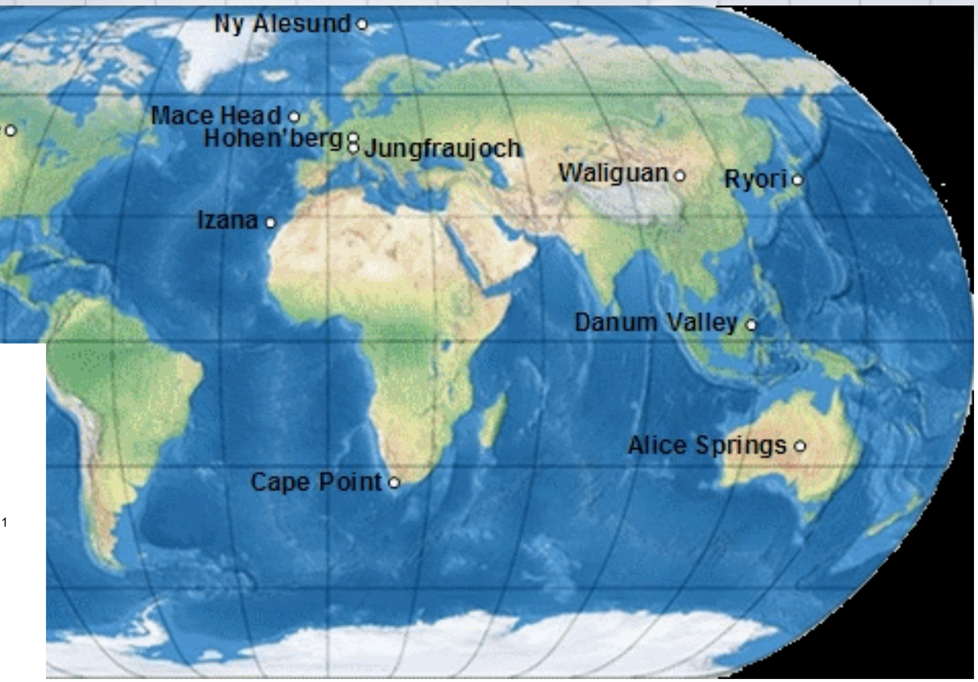


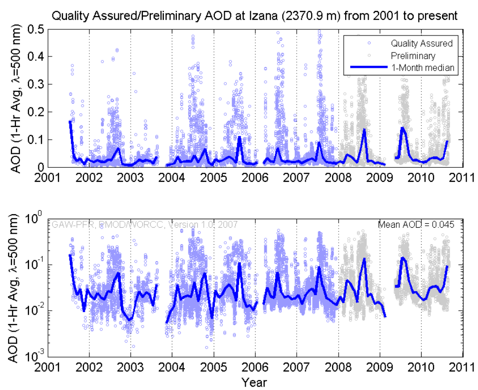
August 13 | August 14


Number of months used = 89 (1996-2005)
R-squared = 0.39
Residual mean square, sigma-hat-sq'd = 0.31
AAI-TOMS
AOD Banizoumbou-AERONET
0
0.6
1.2
1.8
2.4
3
3.6
4.2
4.8
0.2
0.4
0.6
0.8
1


Number of months used = 65 (Oct 2004 - Mar 2010)
R-squared = 0.49
Residual mean square, sigma-hat-sq'd = 0.13
AAI-OMI
AOD Banizoumbou-AERONET
0.6
1.2
1.8
2.4
3
3.6
4.2
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

MEASUREMENTS:
GAW-PFR AOD Network





- Classic extinction measurements at the recommended 4 WMO wavelengths 368, 415, 500 and 862 nm using Precision Filter Radiometers (PFRs).
- Continuous sampling at a 1- minute frequency by automated systems.
- Data products: AOD and the Angström coefficients alpha and beta (no inversions).
- Hourly mean AOD archived at the World Data Center for Aerosols (WDCA). Data with a 1-minute resolution are available from WORCC upon request.

GAW-PFR provides:

- long-term high-accuracy AOD and Angström Coefficients
- GAW-PFR provides AOD Dust in near real-time

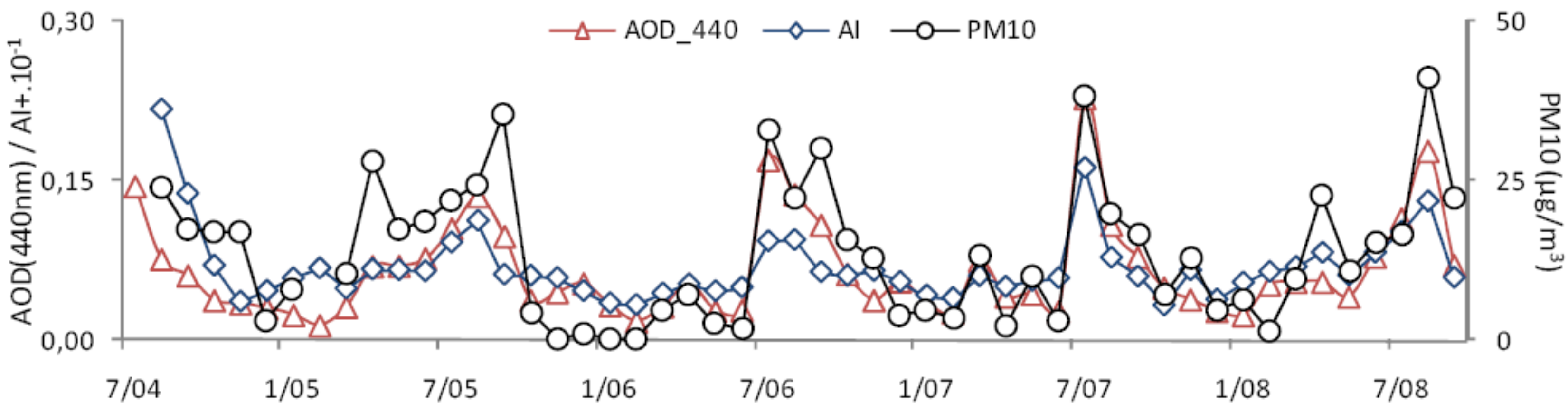


Figure 2. Monthly means of PM_{10} ($\mu g/m^3$), AOD and AI positive values.

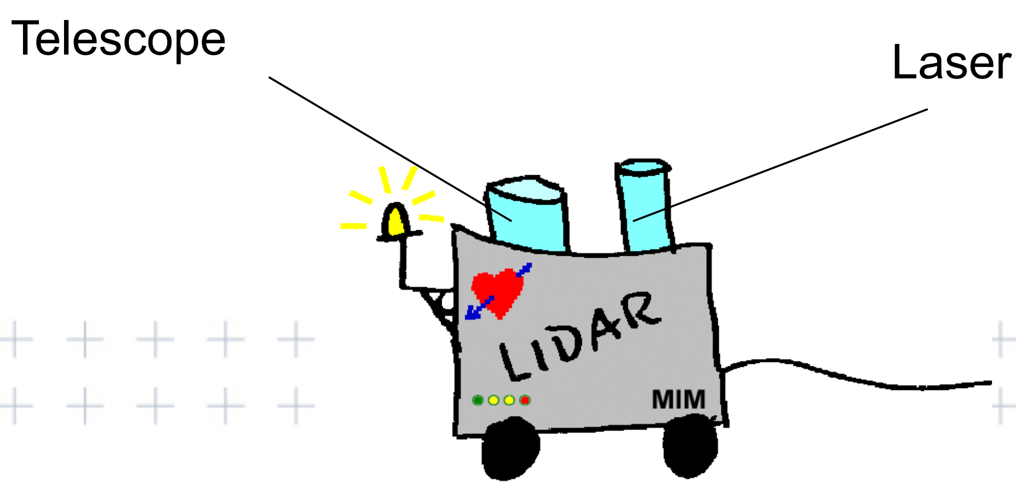
Adam et al., 2010 (ACP-Interlaken): Detection of the Saharan dust air layer in the North Atlantic free troposphere with AERONET, OMI and in-situ data at Izaña Atmospheric Observatory

From total column observations…

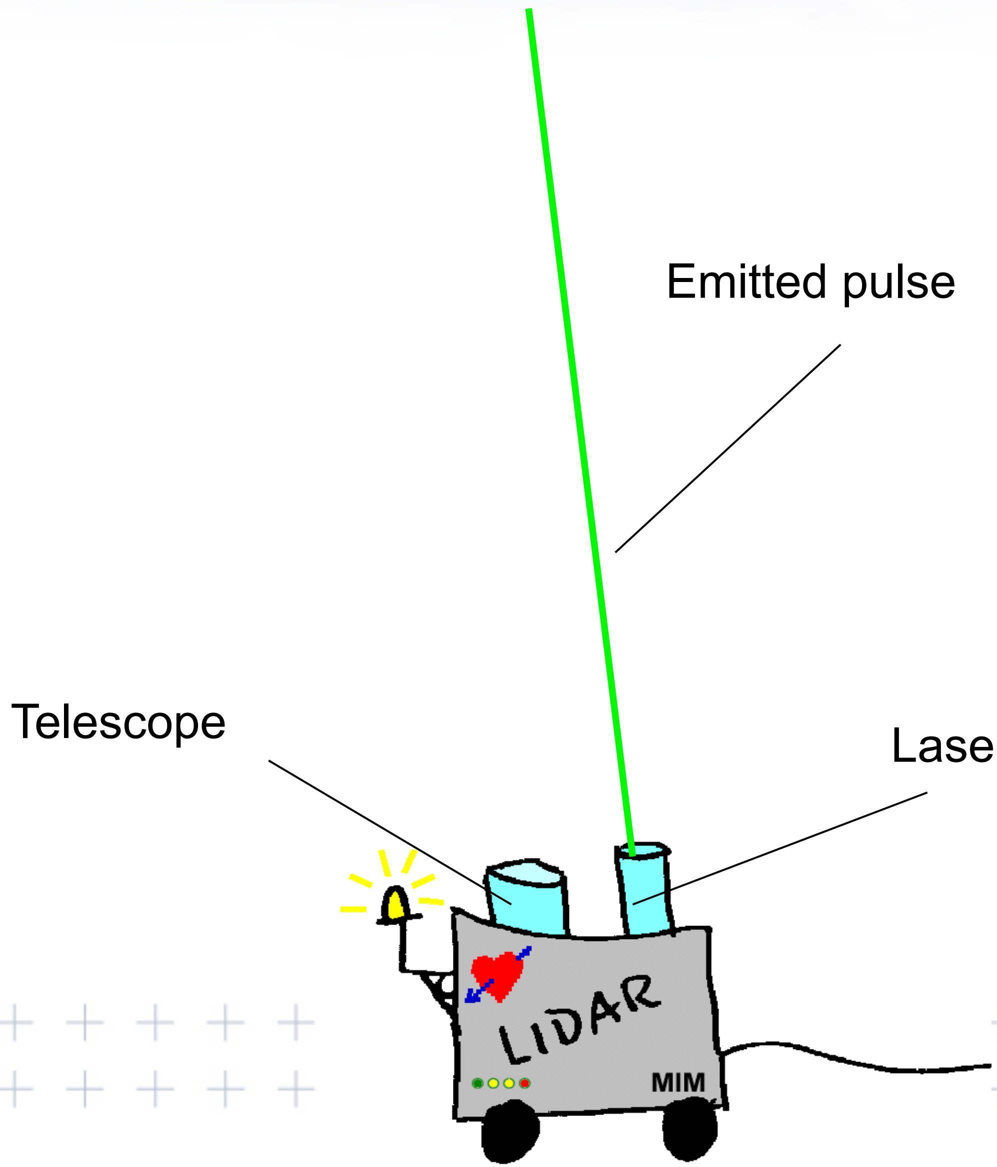
to vertical resolved observations

Lidars

Ground-based remote sensing

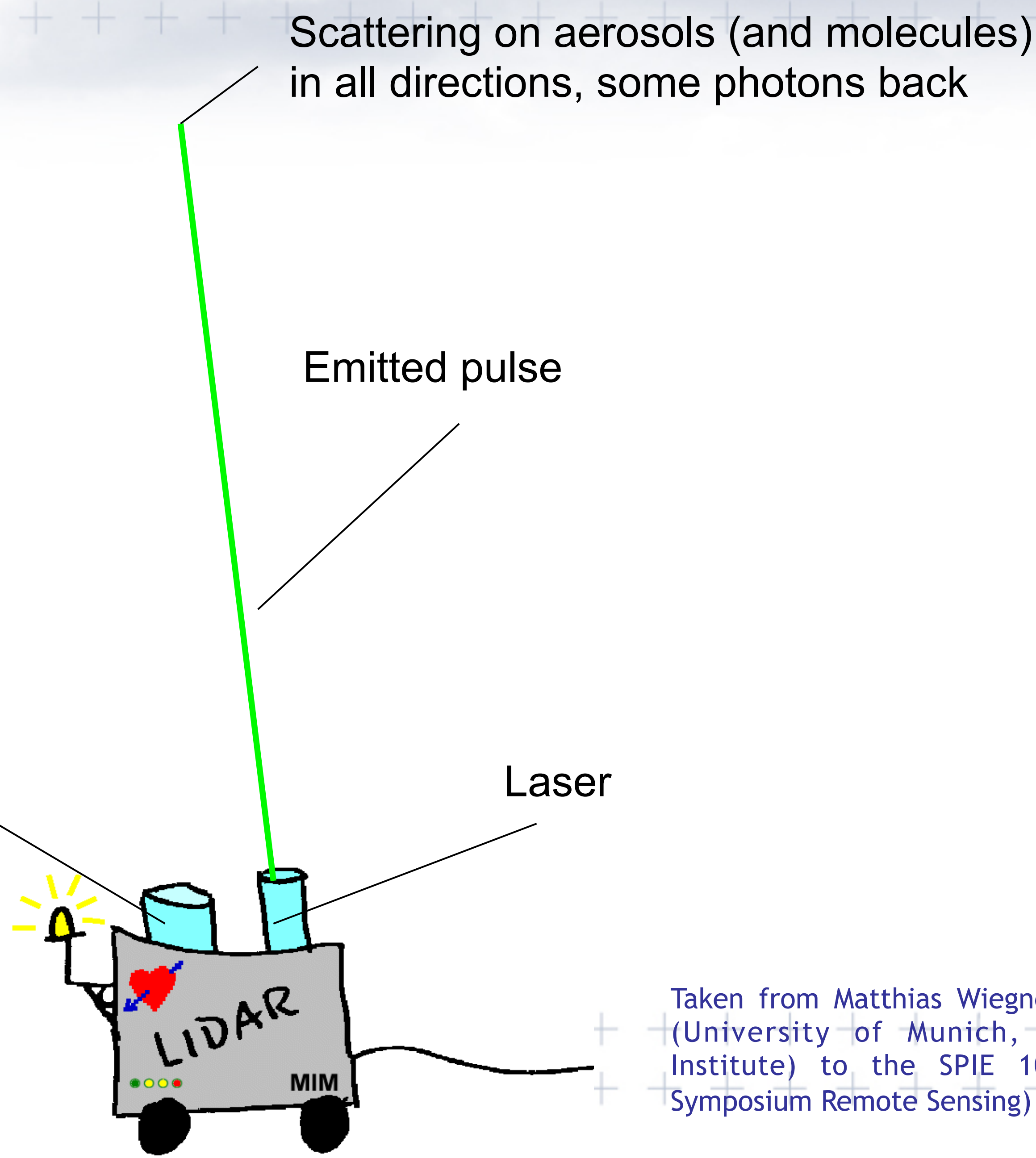


Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)



Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)

Ground-based remote sensing



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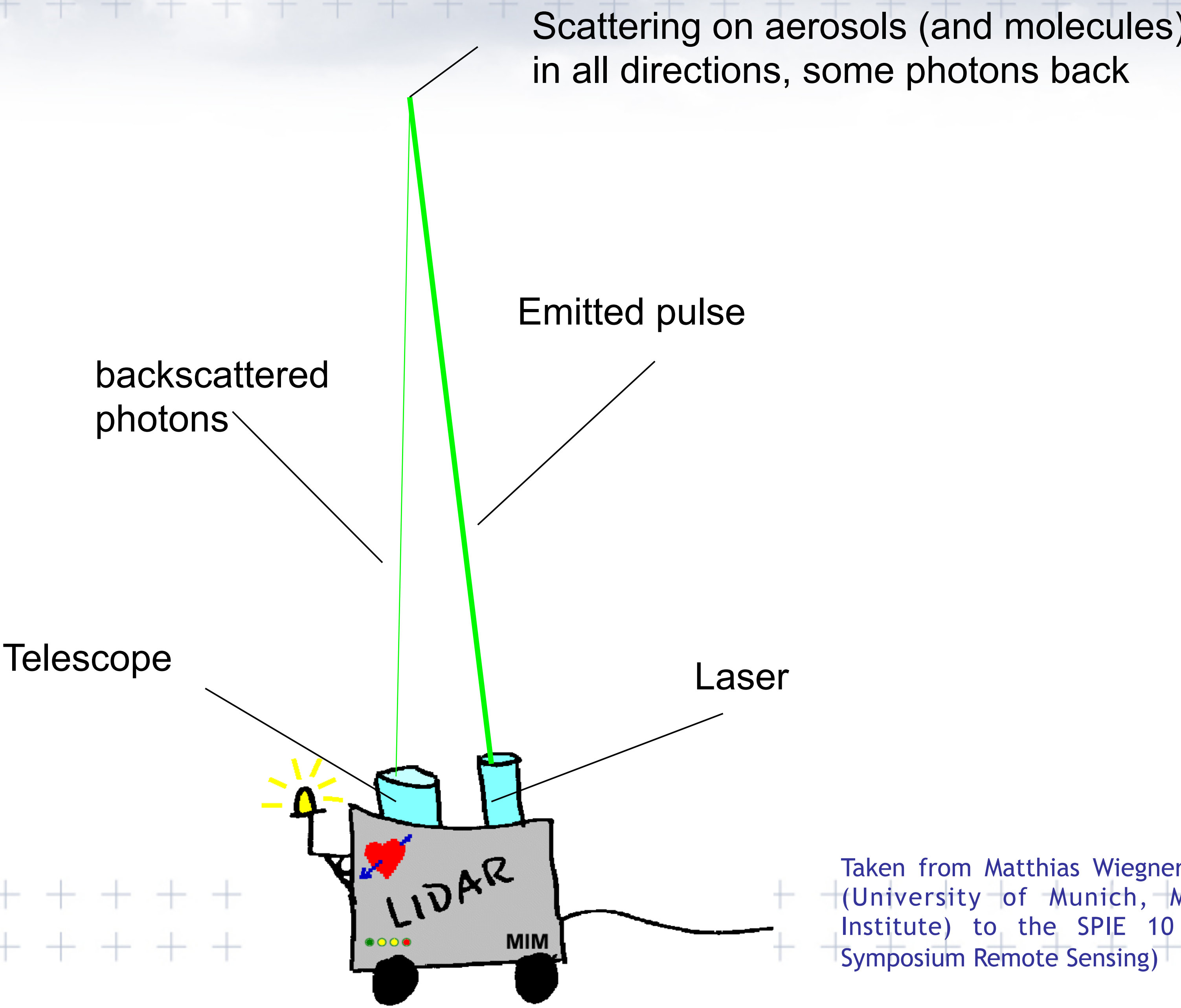
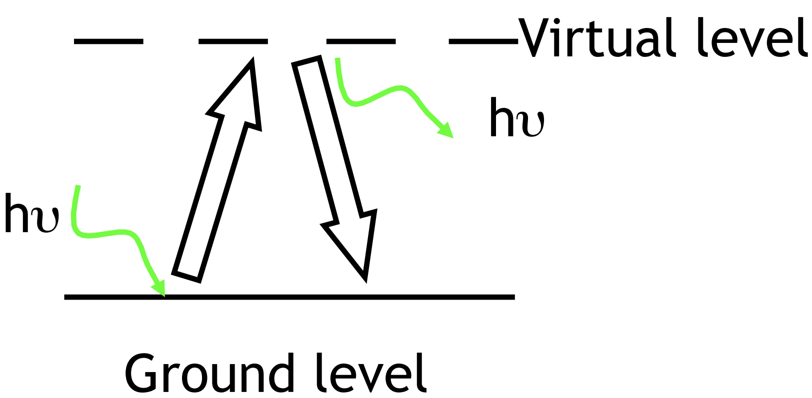
Ground-based remote sensing



Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)

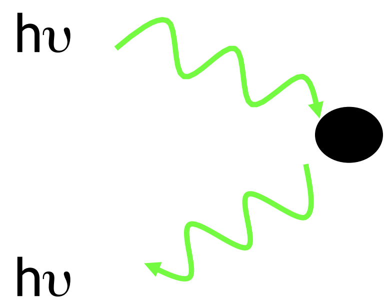
- Rayleigh Scattering

  "Laser radiation elastically scattered from atoms or molecules is observed with no change of frequency"



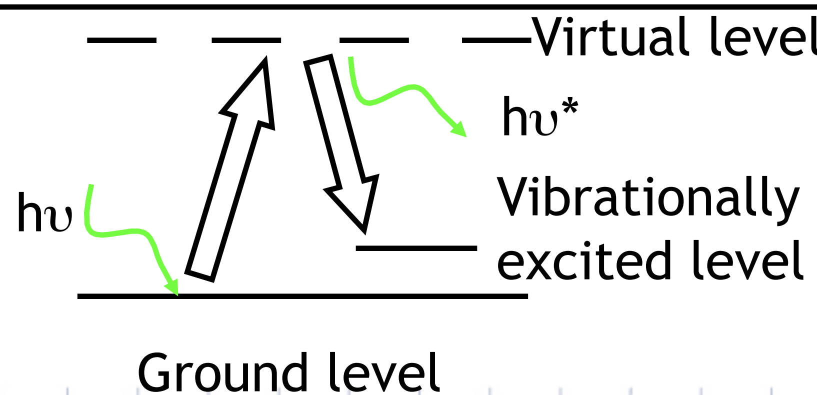
- Mie Scattering

  "Laser radiation elastically scattered from small particulates or aerosols (of size comparable to wavelength of radiation) is observed with no change in frequency"



- Raman Scattering

  "Laser radiation inelastically scattered from molecules is observed with a frequency shift characteristic of the molecule (hν - hν* = E)"



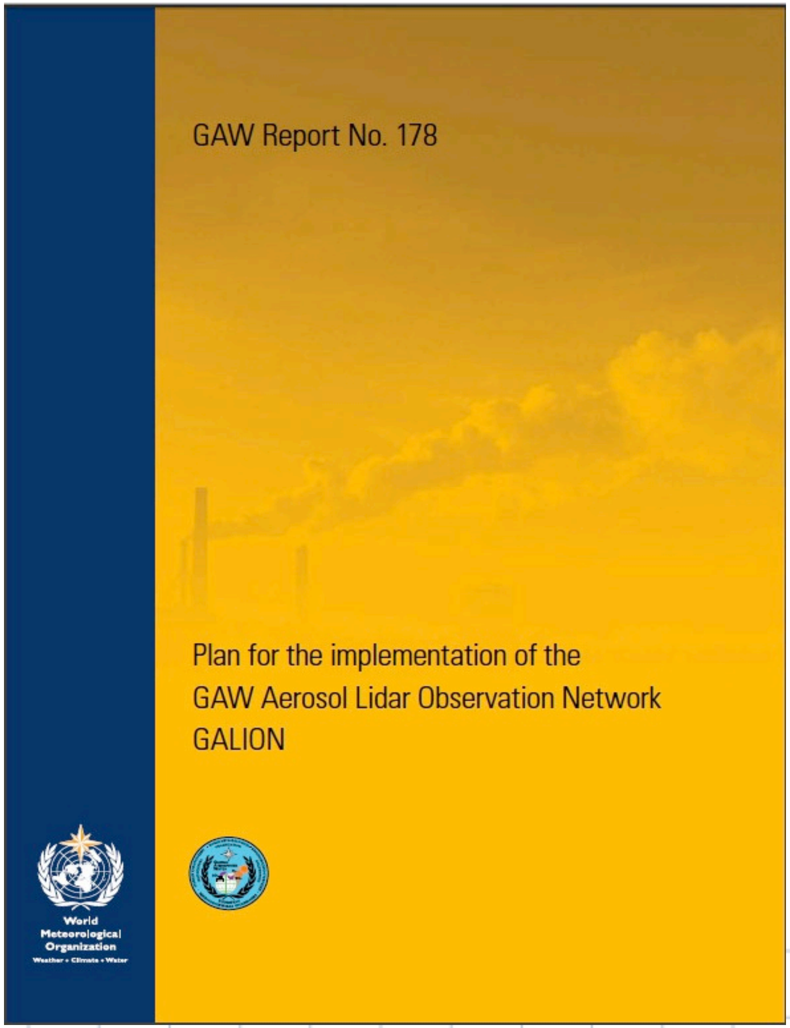
Taken from Laser Remote Sensing Fundamentals and Applications by Raymond M. Measures (pgs 206-207)

Ground-based remote sensing

Lidar-Barcelona (UPC)
Raman Lidar
EARLINET-SPALINET

Lidar-Tenerife (INTA-AEMET); Elastic lidar
MPLNET

GAW Atmospheric Lidar Network (GALION)


GAW Report No. 178

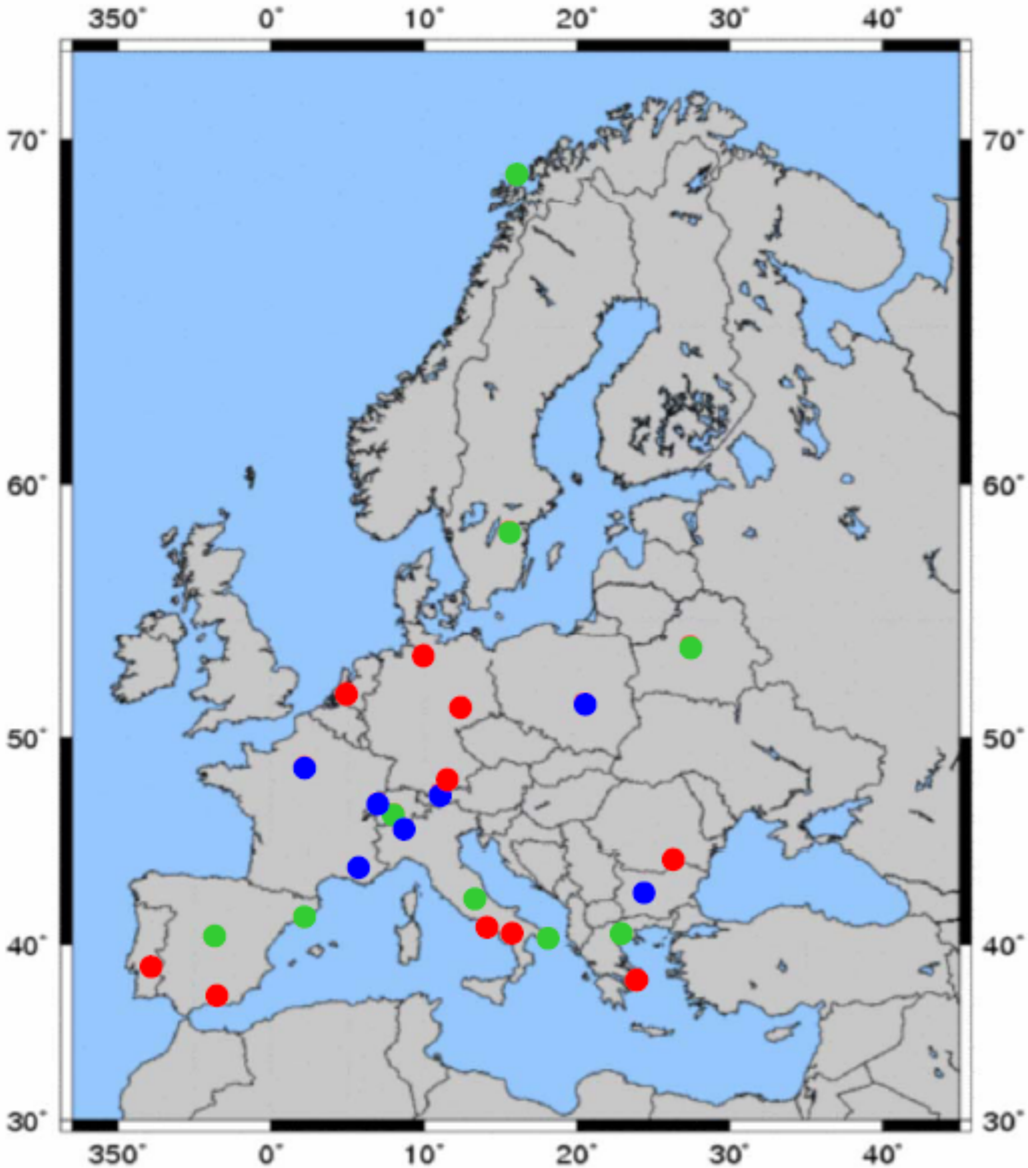
Plan for the implementation of the
GAW Aerosol Lidar Observation Network
GALION

World Meteorological Organization
Weather • Climate • Water

ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw178-galion-27-Oct.pdf

Agencia Estatal de Meteorología

EARLINET



EARLINET (**European Aerosol Research LIdar NETwork**) is a network of advanced lidar stations distributed over Europe with the main goal to provide a comprehensive, quantitative, and statistically significant data base for the aerosol distribution on a continental scale. EARLINET provides independent measurements of <u>aerosol extinction and backscatter</u>, and retrieval of aerosol microphysical properties.

10 EARLINET stations are equipped also with sunphotometers (they are part of AERONET).

26 lidar stations

- 10 multiwavelength Raman lidar stations

backscatter (355, 532 and 1064 nm) + extinction (355 and 532 nm) + depol ratio (532 nm)

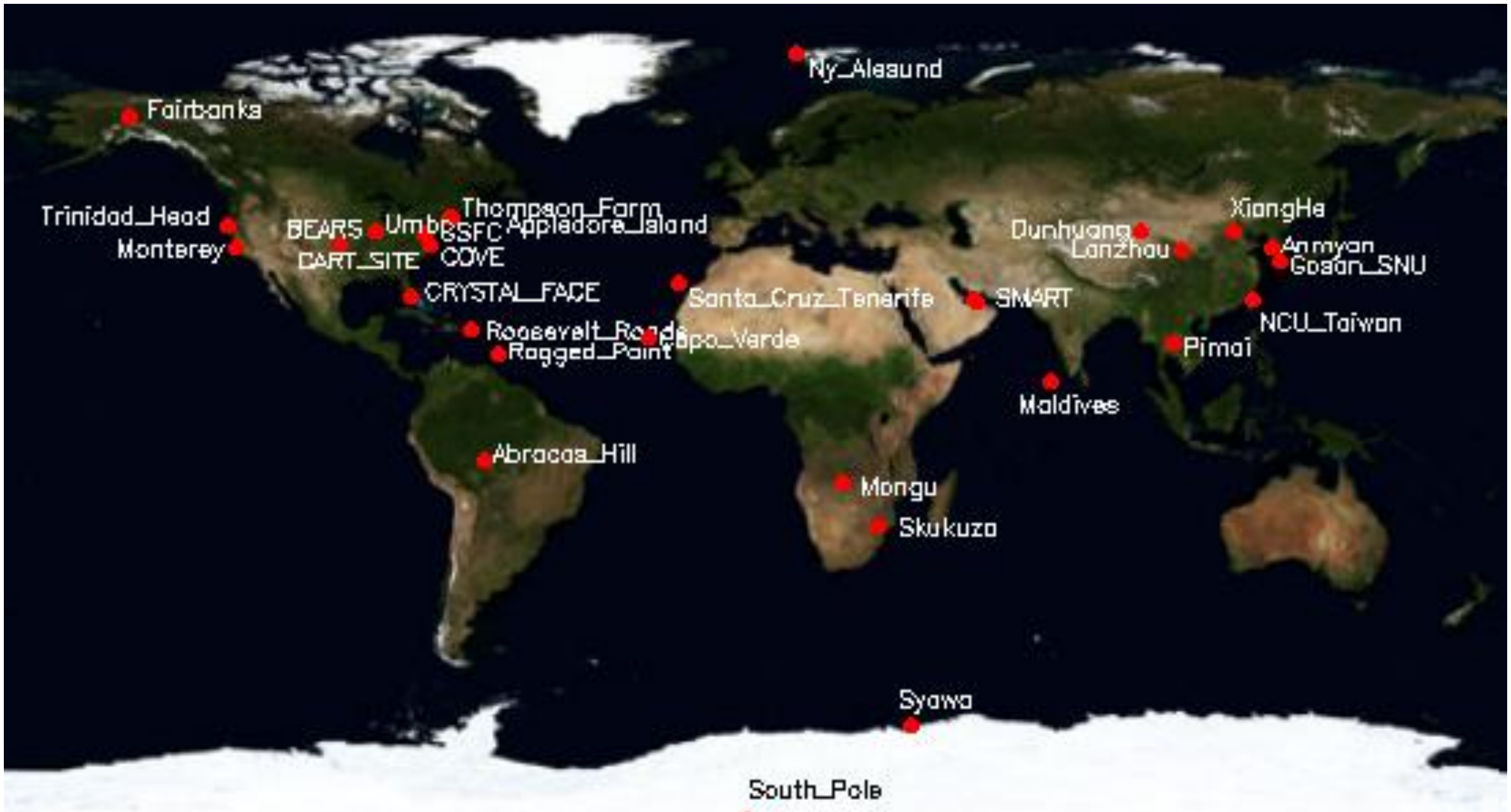
- 9 Raman lidar stations

- 7 single backscatter lidar stations

Aerosol lidar (MPLNet)

http://mplnet.gsfc.nasa.gov/

523 nm MPLNET
Automatized since July 2005



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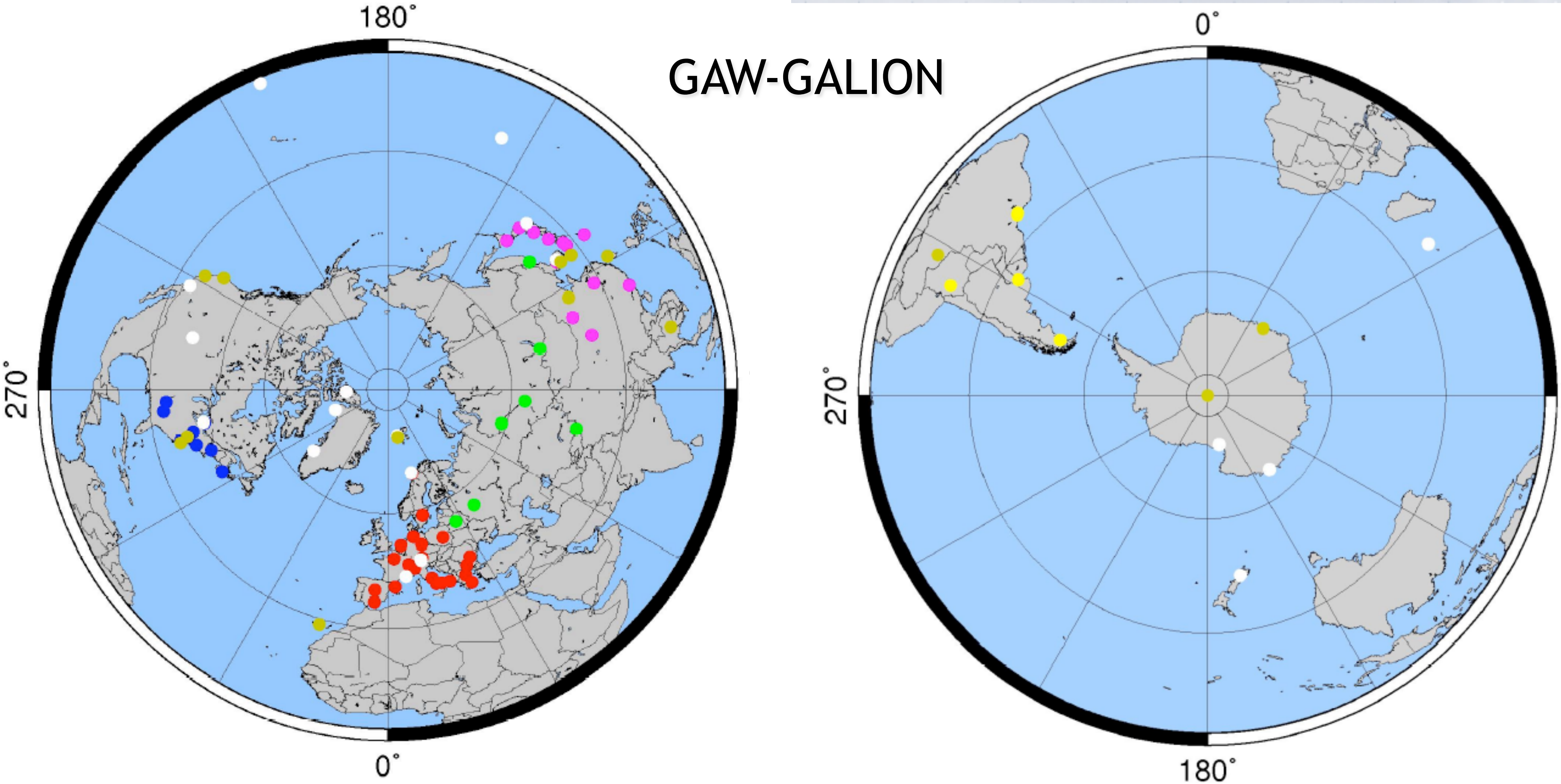
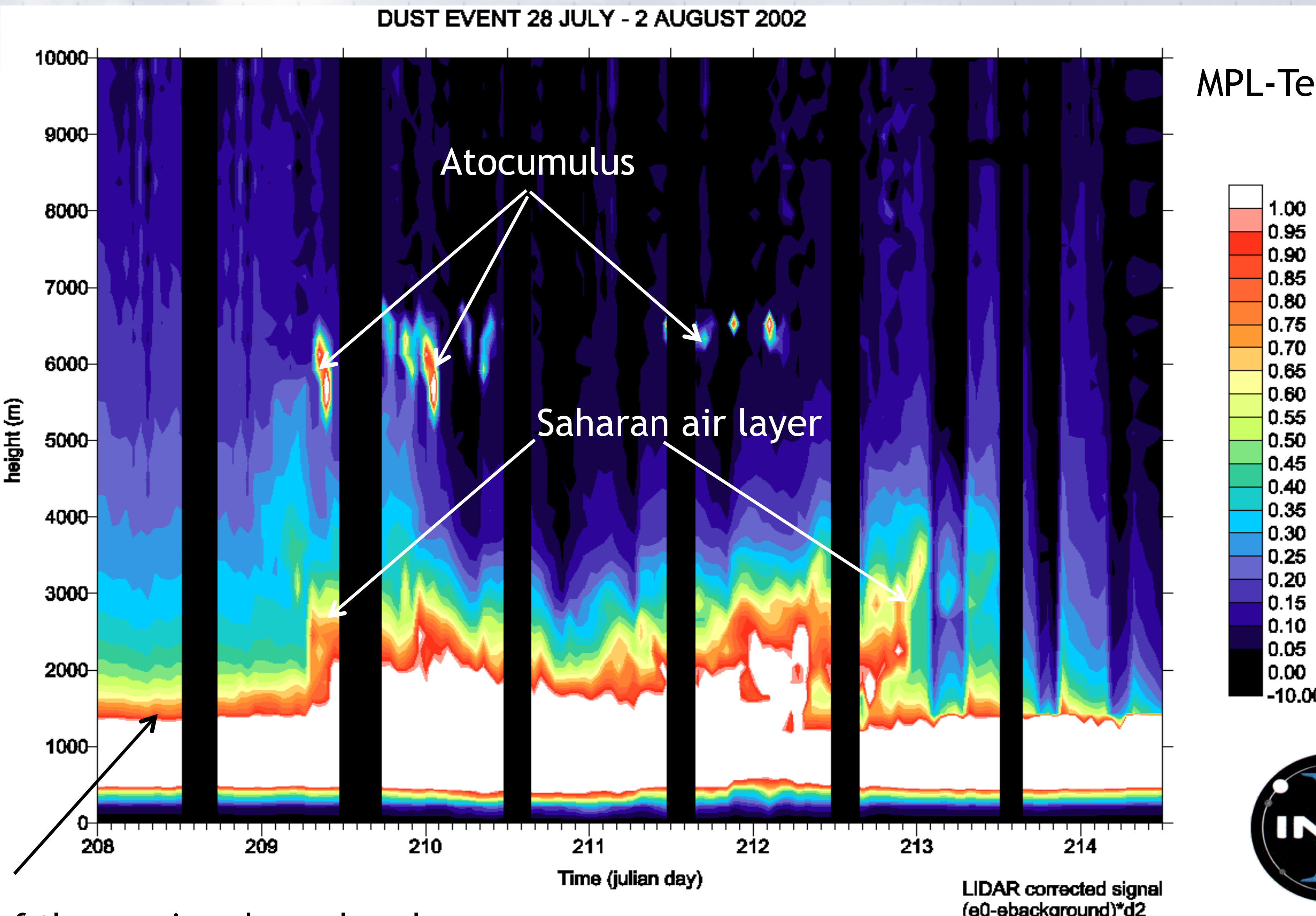
GAW-GALION

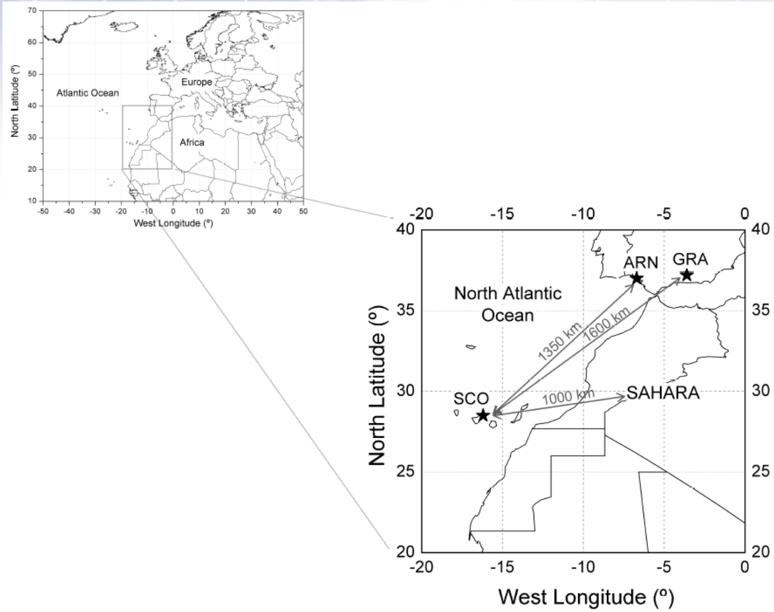


Distribution of stations as available through the cooperation between existing networks: AD-NET , ALINE , CISLiNet , EARLINET , MPLNET , NDACC , REALM .



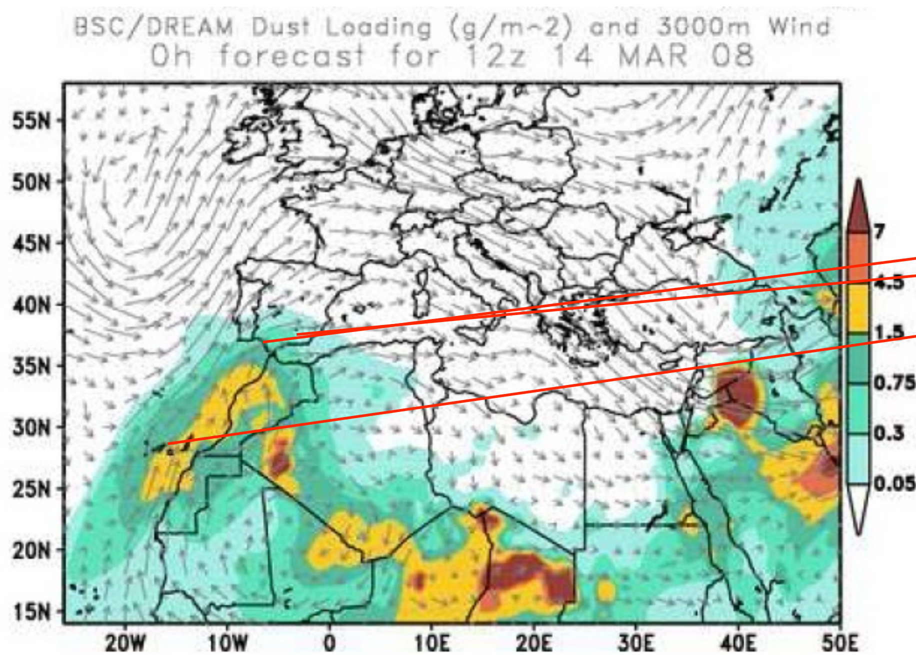
MPL-Tenerife

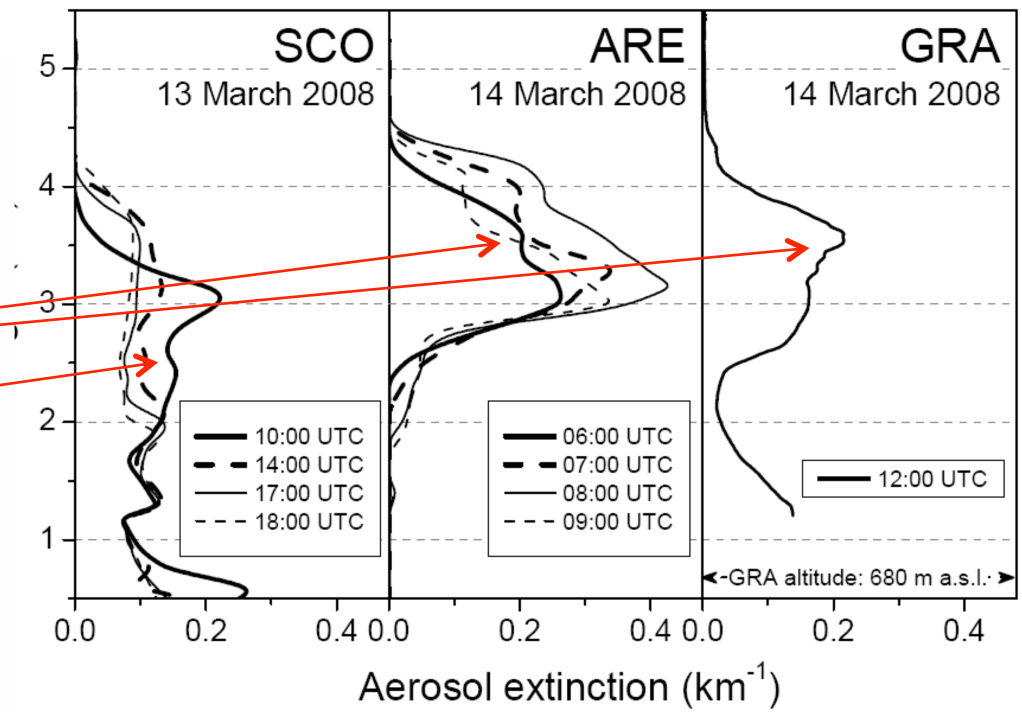
Top of the marine boundary layer



A case study of dust transport from Canary Islands to Iberian Peninsula

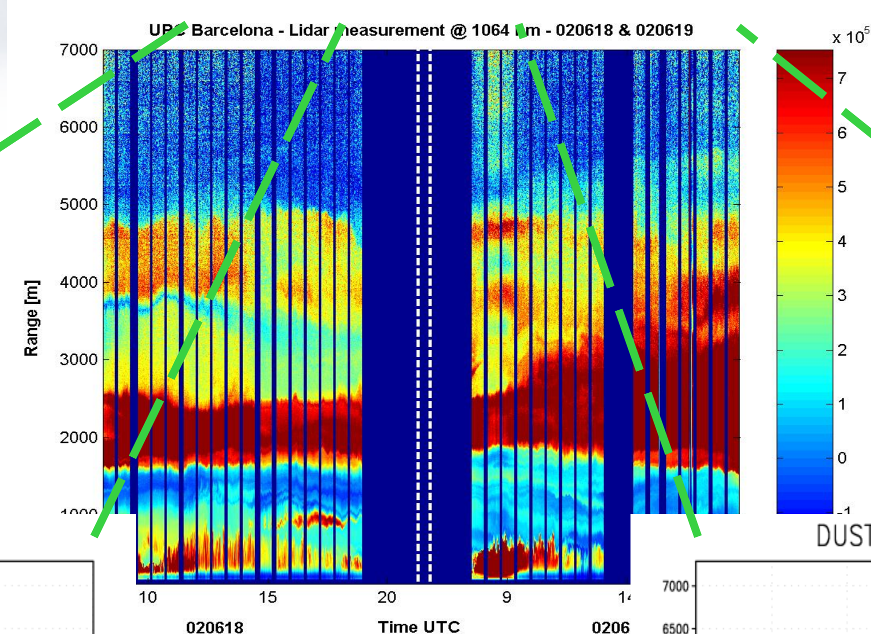
Córdoba-Jabonero et al., ACP Discuss., 2010





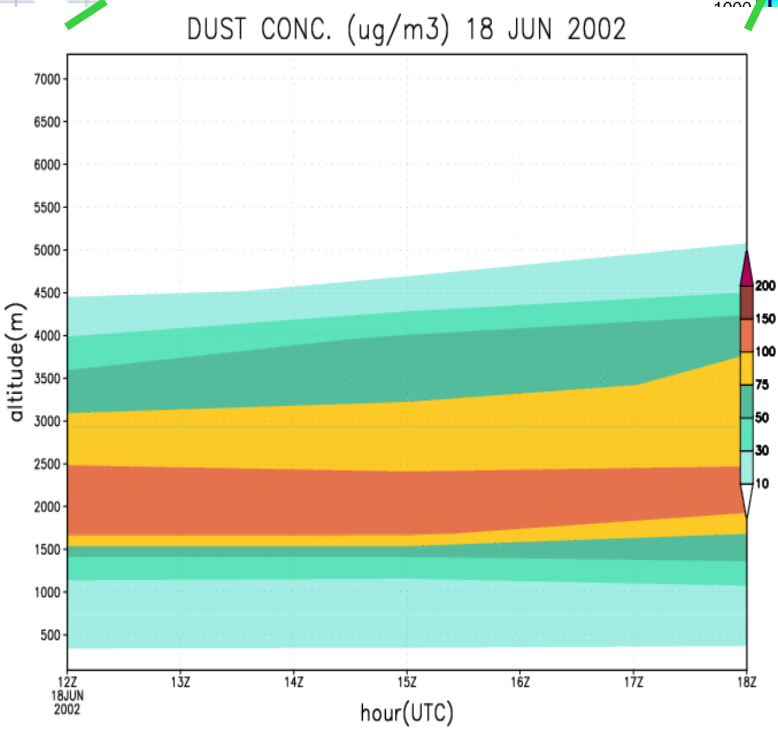
Ground-based remote sensing

Barcelona lidar vs DREAM BSC

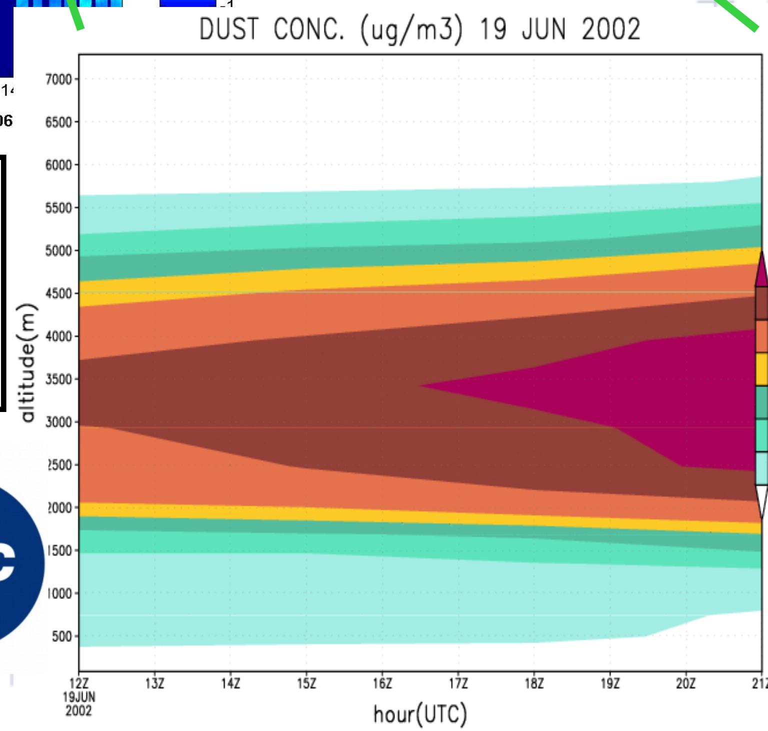


EARLINET: Lidar-UPC, Barcelona

18-19 June 2002

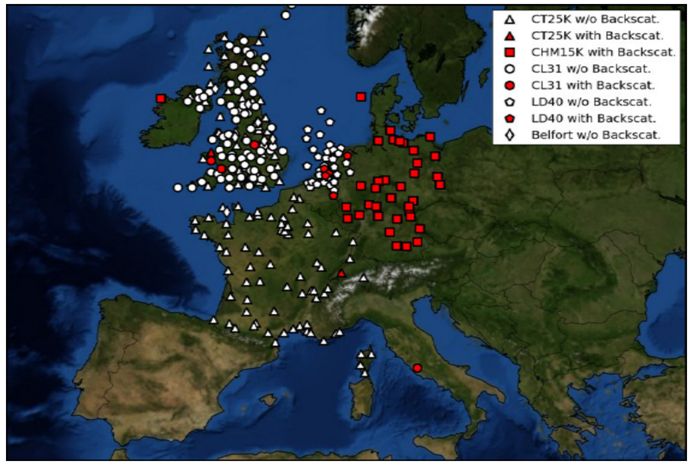


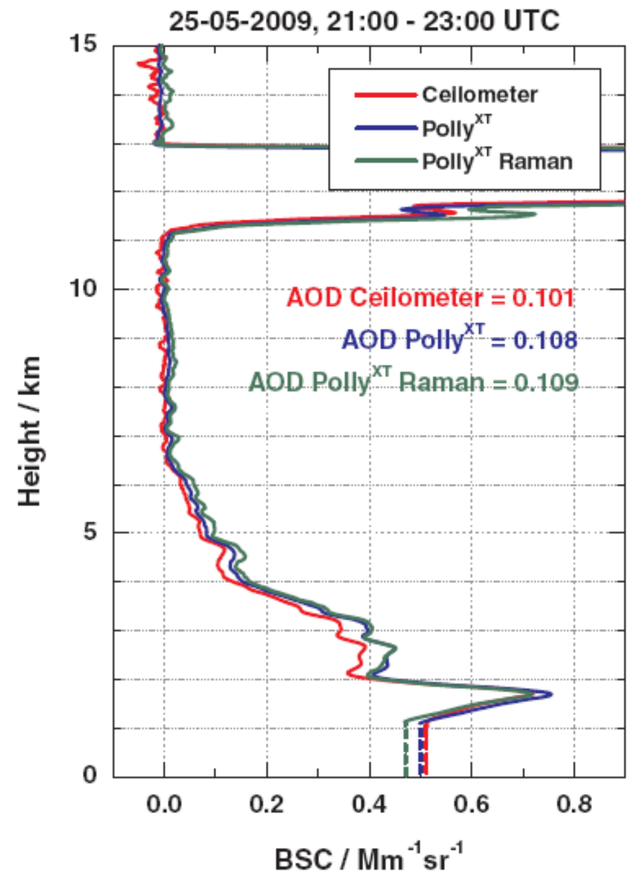
Vertical dust distribution validation: AIRLINET-DREAM



Ceilometer network

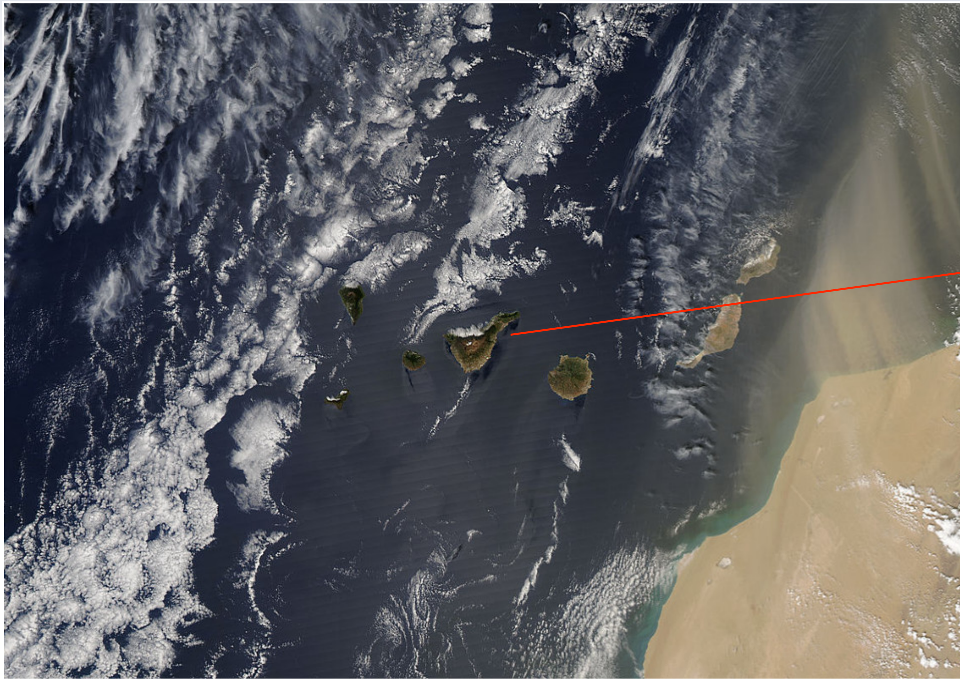
Met Services are replacing **cloud-base** ceilometer networks by **aerosol backscatter profiling ceilometers** (**IR wavelenght**).
Objective: **To monitor MLD (Mixing Layer Depth)** based on **several hundred profiling ceilometers (100km sampling)**





Heese et al., Atmos. Mes. Tech. 2010, Ceilometer-lidar inter-comparison: backscatter coefficient retrieval and signal-to-noise ratio determination

Optimal for desertic areas !!



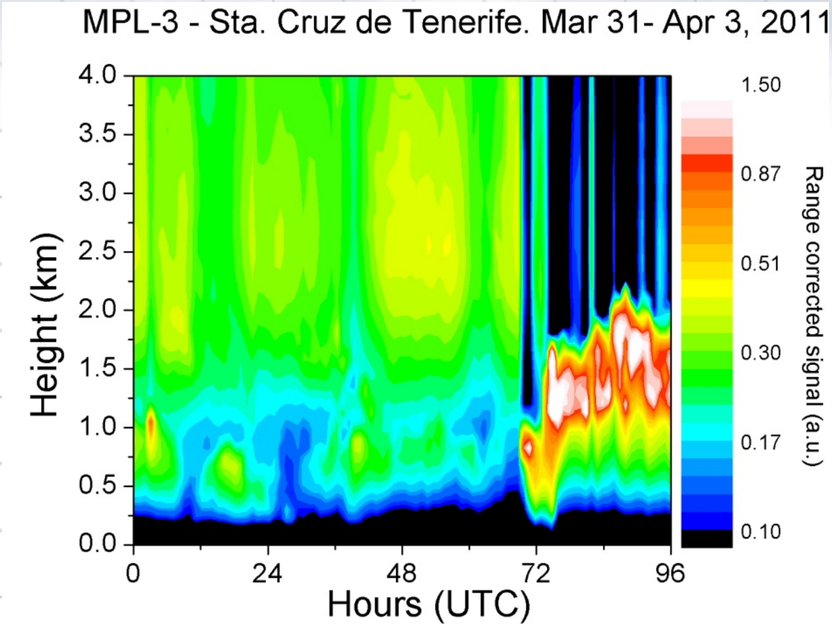
Viasala Ceilometer
CL-51

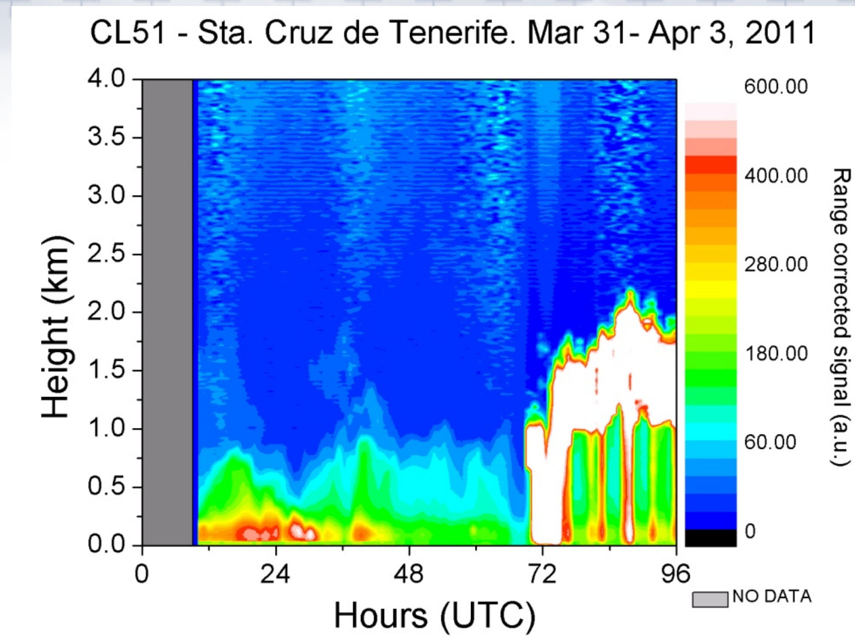
MicroPulse Lidar and Ceilometer inter-comparison during Saharan dust intrusions over the Canary Islands

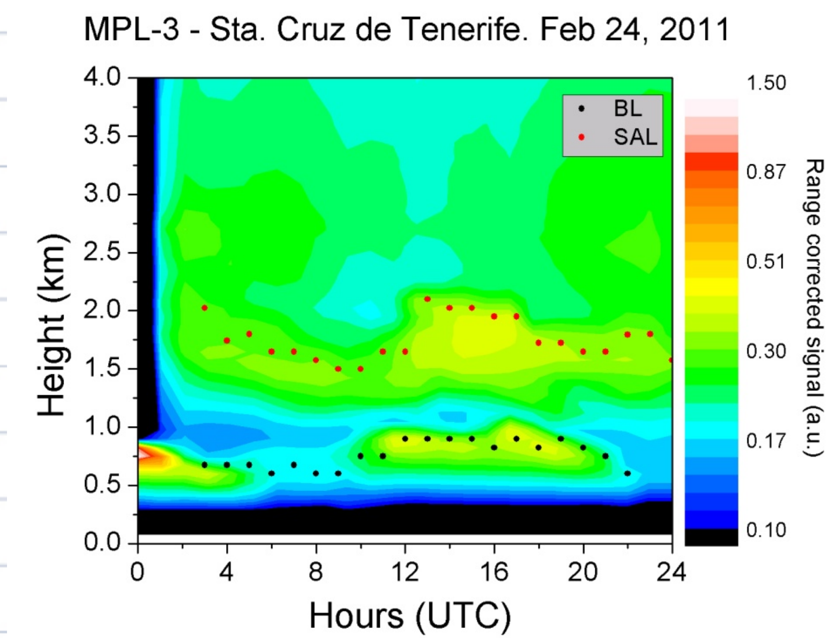
Y. Hernández, S. Alonso-Pérez, E. Cuevas, C. Camino, R. Ramos, J. de Bustos, C. Marrero, C. Córdoba-Jabonero and M. Gil (2011)

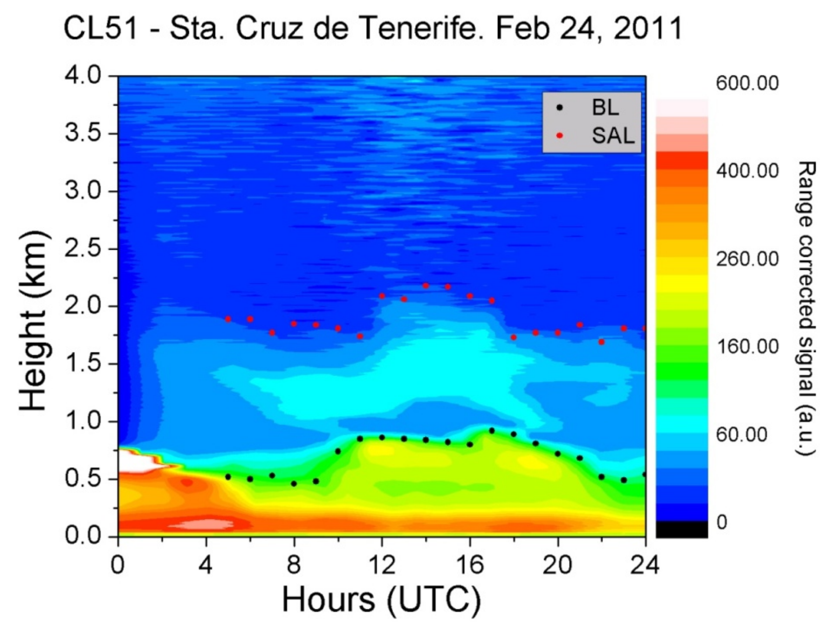
Campaign performed from January to March 2011 in Tenerife island

Ground-based remote sensing









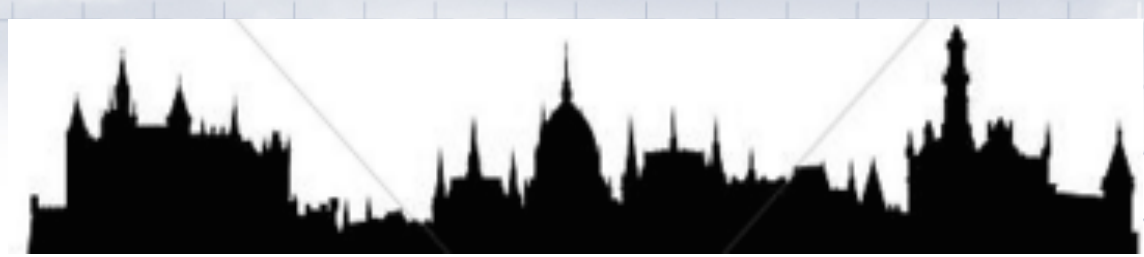
dust, aerosols and pollutants

in-situ observations

PM_{10} and $PM_{2.5}$ levels
PM_{10} and $PM_{2.5}$ composition
complementary observations

observation network

dust air quality



Recommended priorities

Level 1 (max priority) - PM_{10} and $PM_{2.5}$ levels - automatic methods

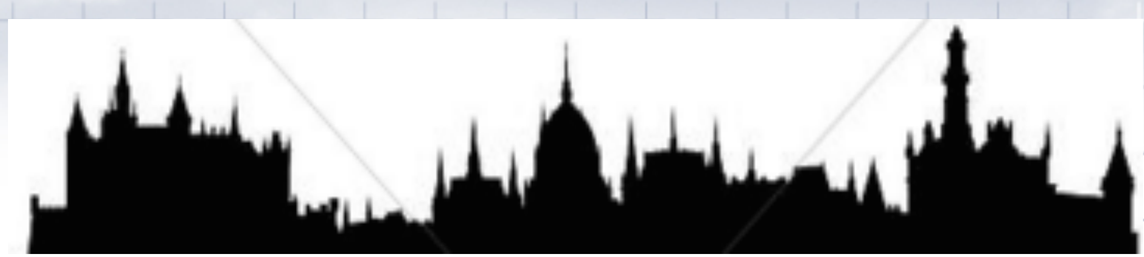
Level 1 (max priority) - meteorology (wind, T, RH, P, rain)

Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

Level 3 - gaseous pollutants: NO_x, SO_2 , CO,...

Level 4 - PM_{10} and $PM_{2.5}$ chemical composition

dust air quality



Recommended priorities

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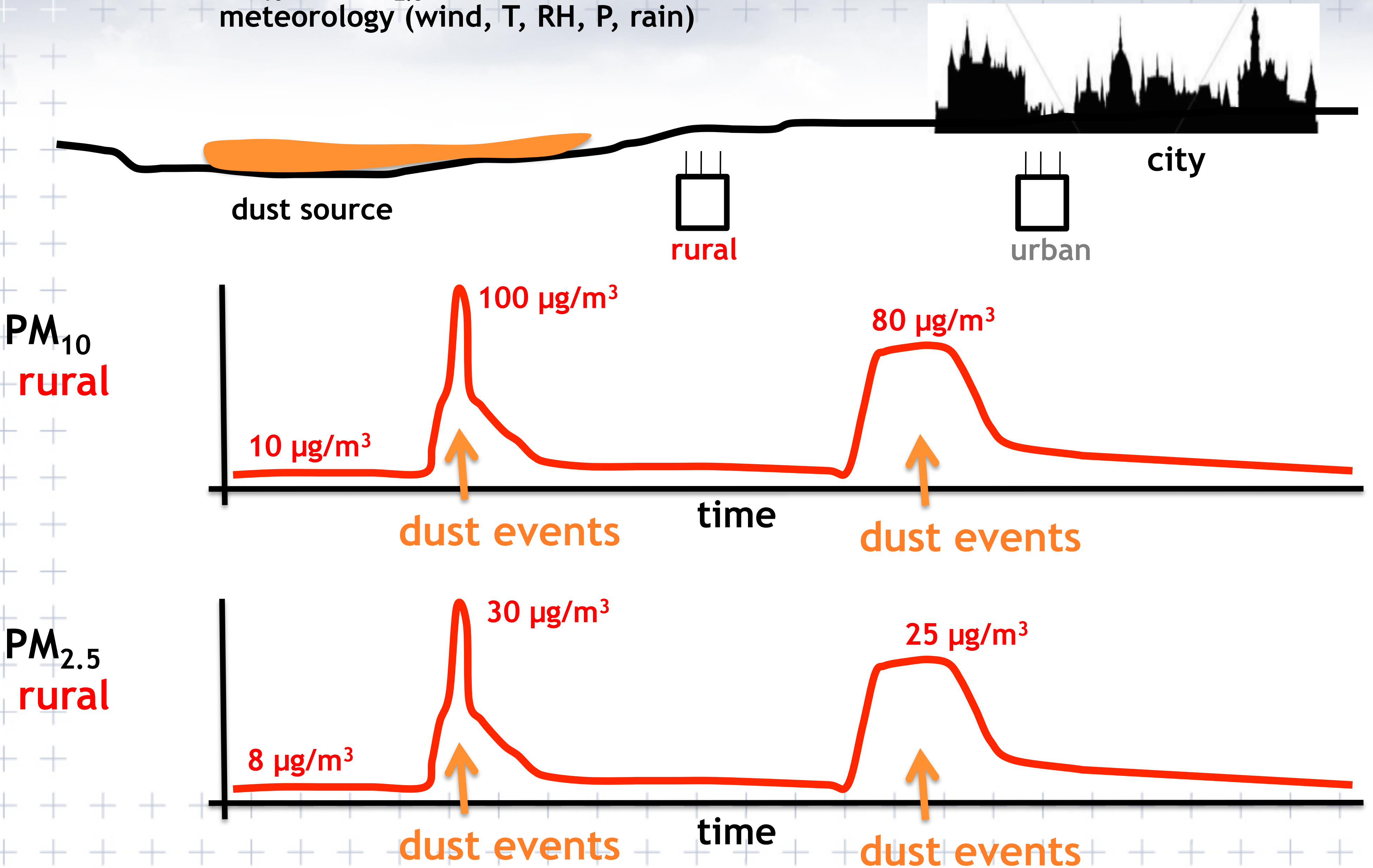
Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

Level 3 - gaseous pollutants: NO_x, SO_2 , CO,...

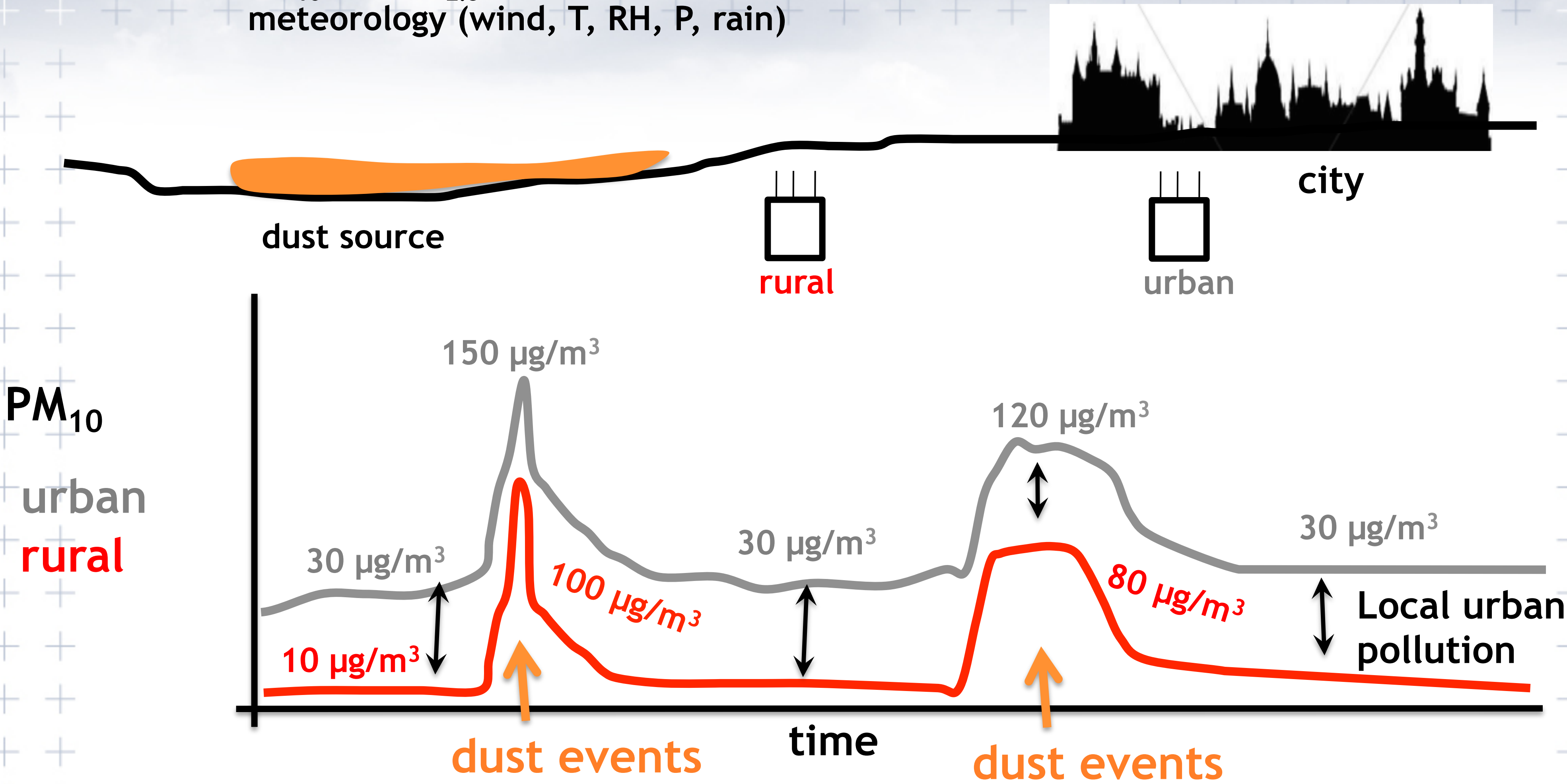
Level 4 - PM_{10} and $PM_{2.5}$ chemical composition

Level 1

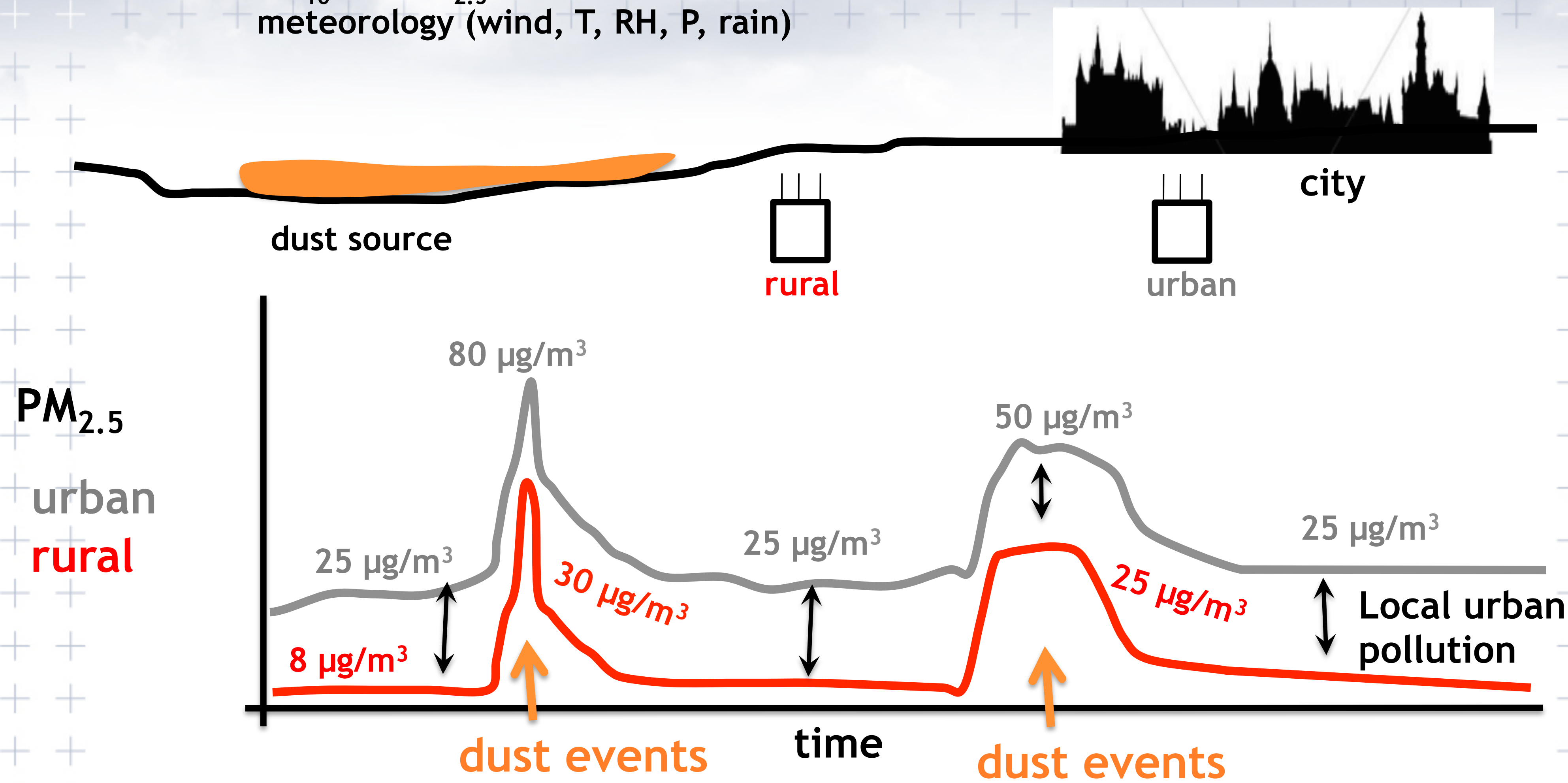
PM_{10} and $PM_{2.5}$ - automatic methods
meteorology (wind, T, RH, P, rain)



Level 1 PM$_{10}$ and PM$_{2.5}$ - automatic methods meteorology (wind, T, RH, P, rain)



Level 1 PM$_{10}$ and PM$_{2.5}$ - automatic methods meteorology (wind, T, RH, P, rain)



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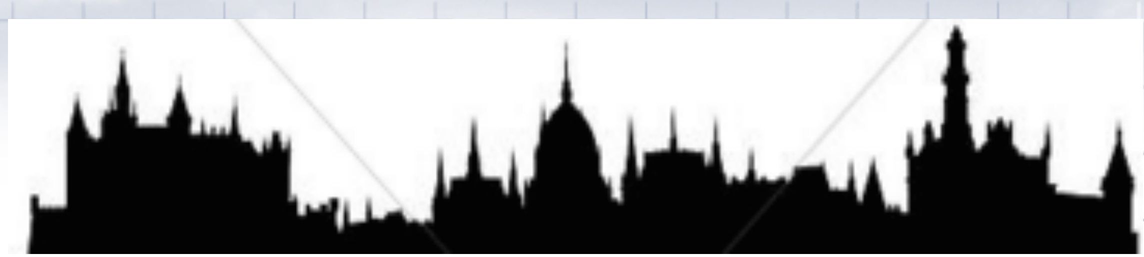


dust air quality

Recommended priorities

Level 1 - PM_{10} and $PM_{2.5}$ levels - automatic methods

Level 1 - meteorology (wind, T, RH, P, rain)

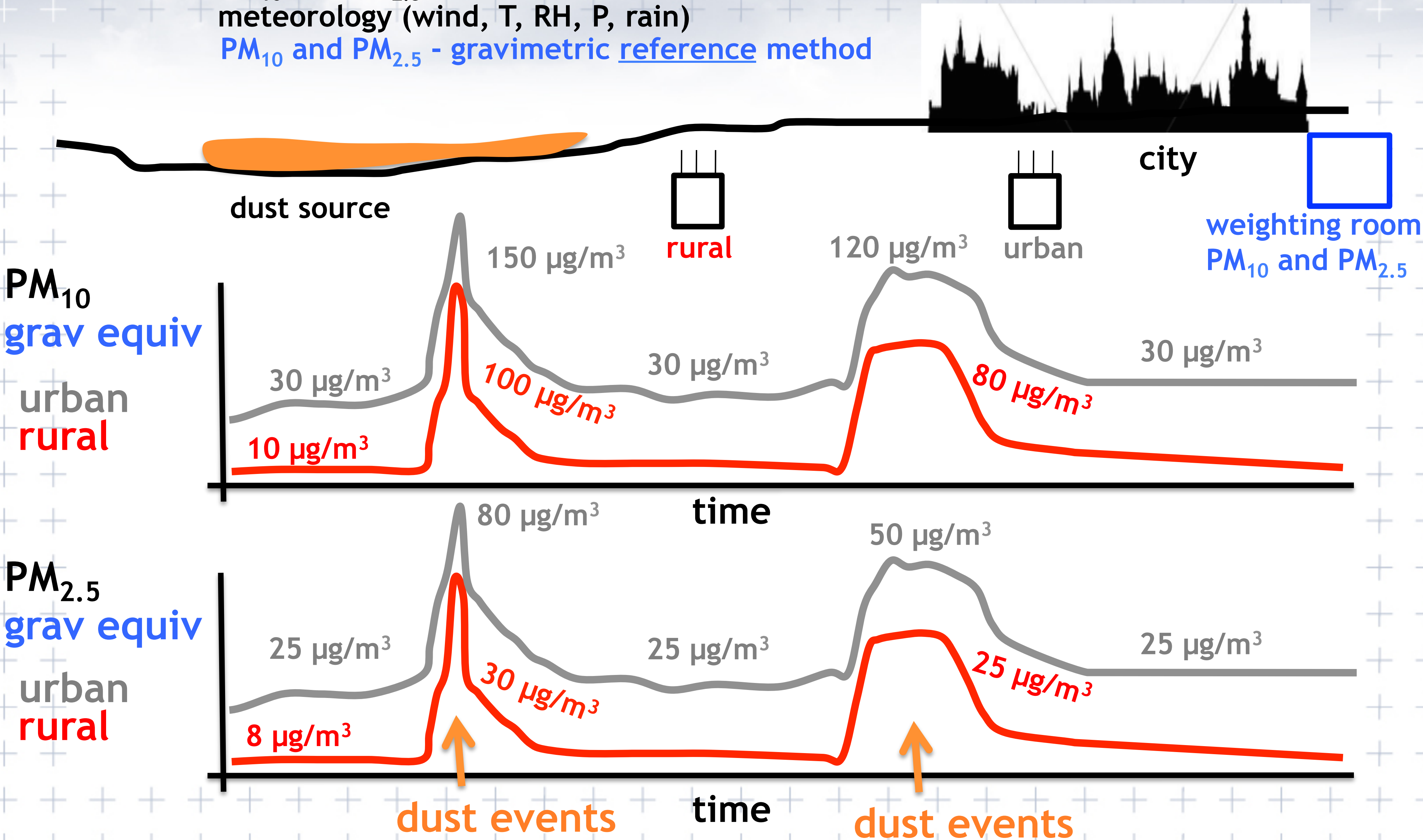
Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

Level 3 - gaseous pollutants: NO_x, SO_2 , CO,...

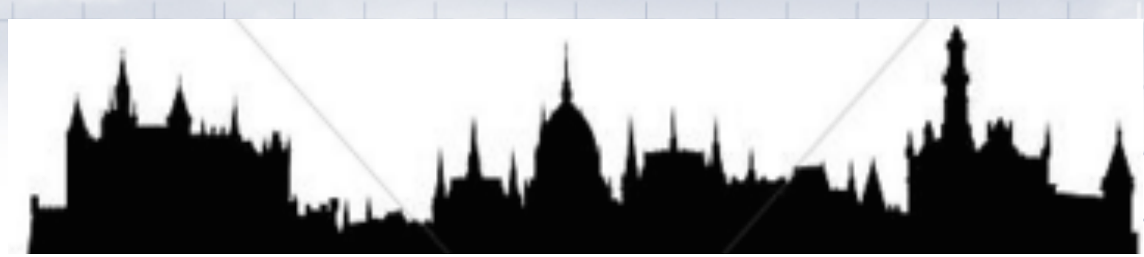
Level 4 - PM_{10} and $PM_{2.5}$ chemical composition

Level 2

PM_{10} and $PM_{2.5}$ - automatic methods
meteorology (wind, T, RH, P, rain)
PM_{10} and $PM_{2.5}$ - gravimetric reference method



dust air quality



Recommended priorities

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Level 1 (max) - meteorology (wind, T, RH, P, rain)

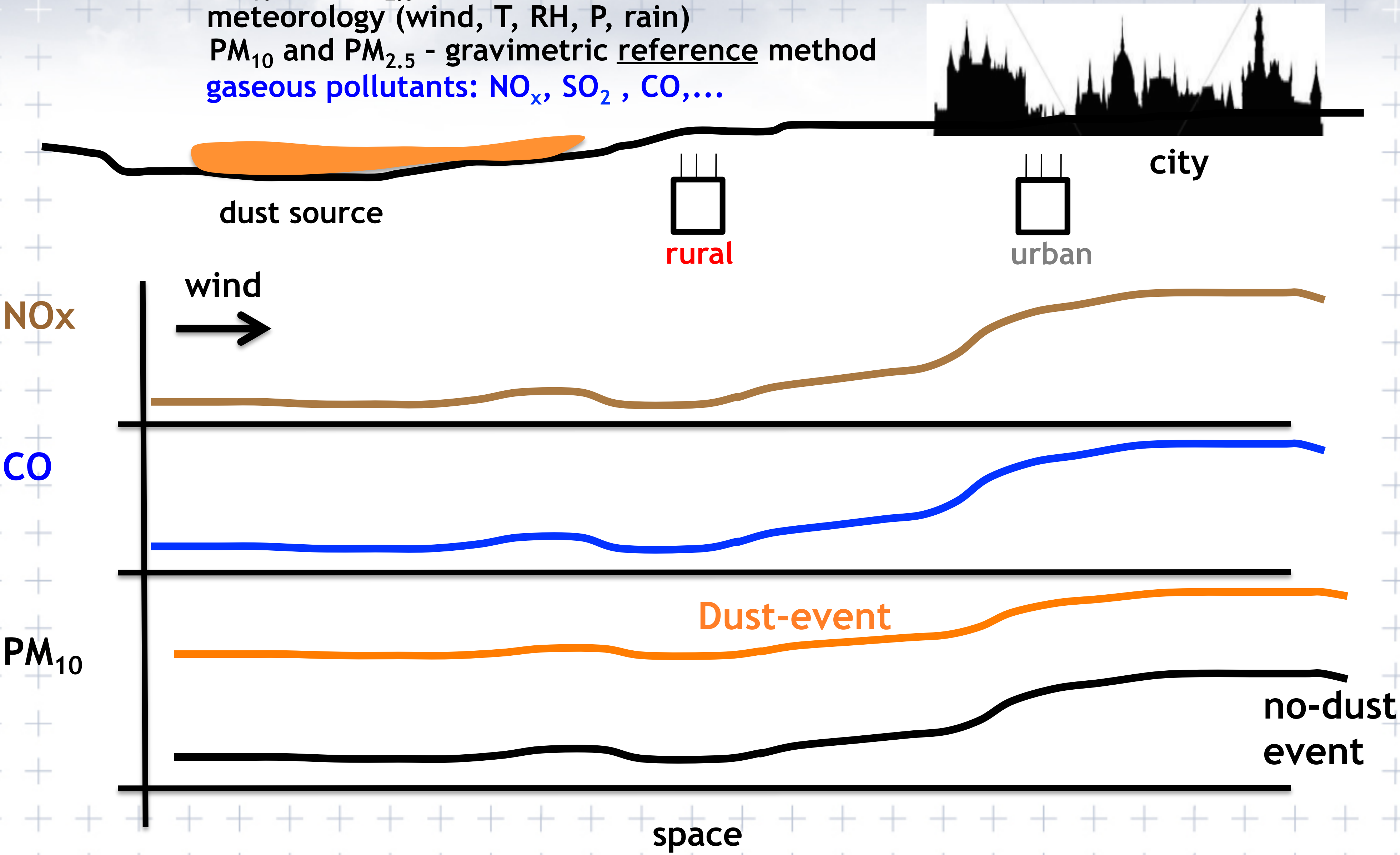
Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

Level 3 - gaseous pollutants: NO_x, SO_2 , CO,...

Level 4 - PM_{10} and $PM_{2.5}$ chemical composition

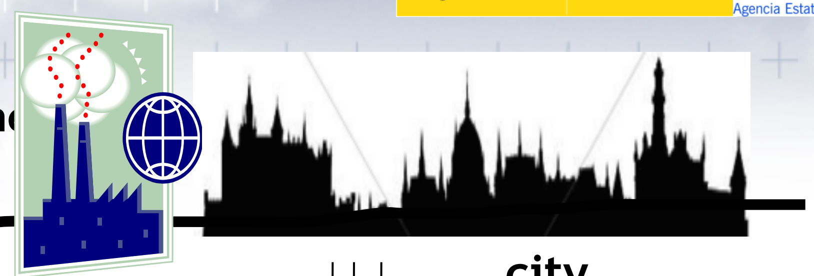
Level 3

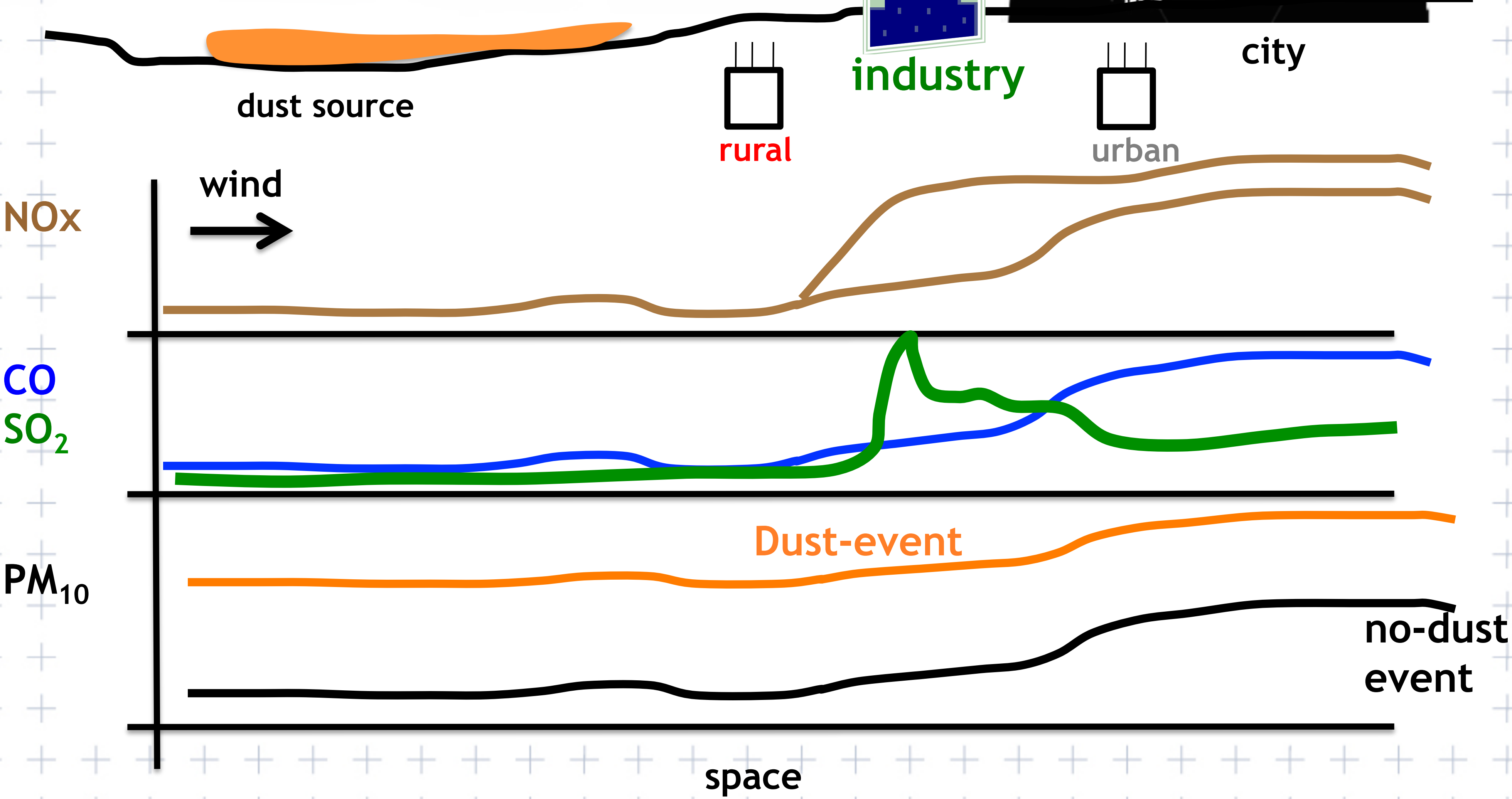
PM_{10} and $PM_{2.5}$ - automatic methods
meteorology (wind, T, RH, P, rain)
PM_{10} and $PM_{2.5}$ - gravimetric <u>reference</u> method
gaseous pollutants: NO_x, SO_2 , CO,...



Level 3

PM_{10} and $PM_{2.5}$ - automatic methods
meteorology (wind, T, RH, P, rain)
PM_{10} and $PM_{2.5}$ - gravimetric reference me
gaseous pollutants: NO_x, SO_2 , CO,...





dust air quality

Recommended priorities

Level 1 (max) - PM_{10} and $PM_{2.5}$ levels - automatic methods

Level 1 (max) - meteorology (wind, T, RH, P, rain)

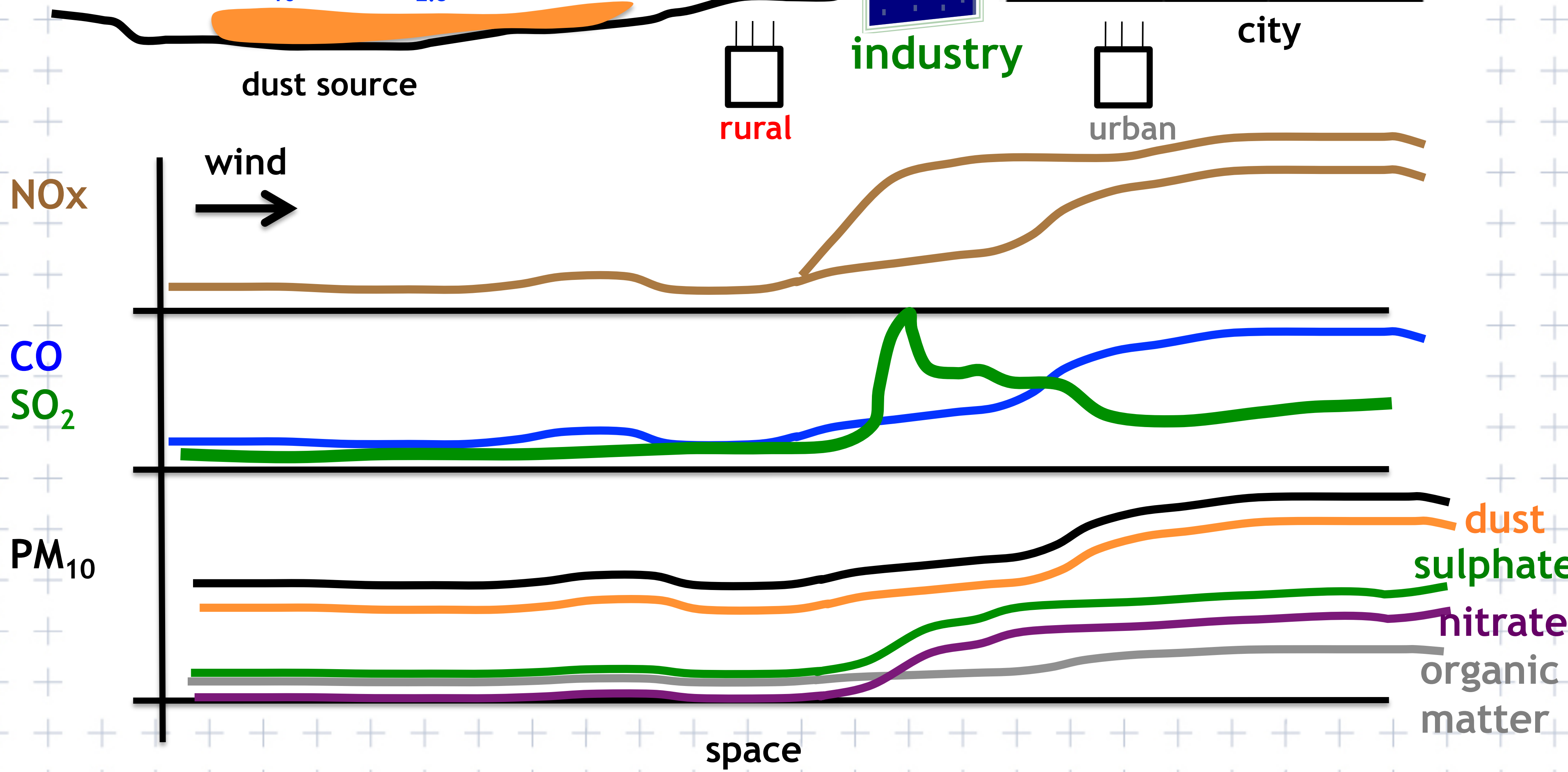
Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

Level 3 - gaseous pollutants: NO_x, SO_2 , CO,...

Level 4 - PM_{10} and $PM_{2.5}$ chemical composition

Level 4

- PM_{10} and $PM_{2.5}$ - automatic methods
- meteorology (wind, T, RH, P, rain)
- PM_{10} and $PM_{2.5}$ - gravimetric reference me
- gaseous pollutants: NO_x, SO_2 , CO,...
- PM_{10} and $PM_{2.5}$ - chemical composition



Izaña: 1916-2016

Agencia Estatal de Meteorología

Trends in the Saharan Air Layer Composition Observed at Izaña - Tenerife

Sergio Rodríguez
srodriguezg@aemet.es
Izaña Atmospheric Research Centre, Tenerife

-North Africa: 50-70% of global dust emissions

-dust exported to the Atlantic
in the Saharan Air Layer

-winter:

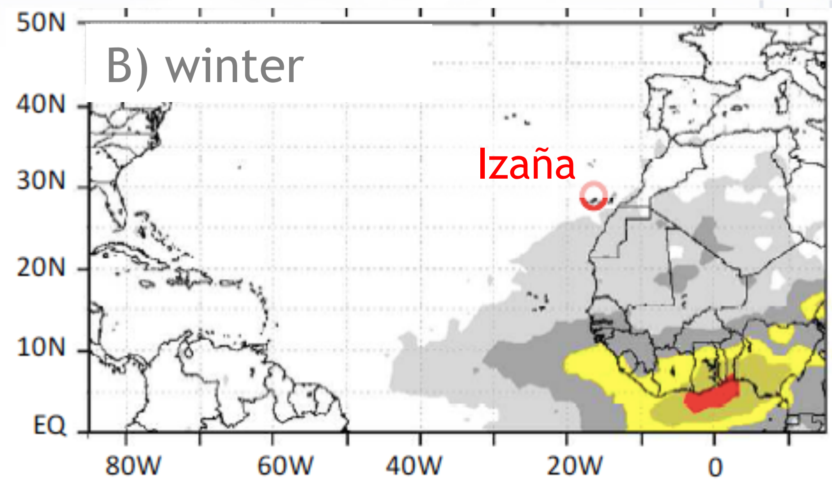
-Sahelian and southern Saharan sources

-SAL is exported to < 2 km.a.s.l. to the tropics

-North Atlantic Oscillation modulates interannual variability in dust export

(Ginoux et al., Environ. Modell. Softw., 19, 113–128, 2004)

Aerosol Index



dust + biomass burning

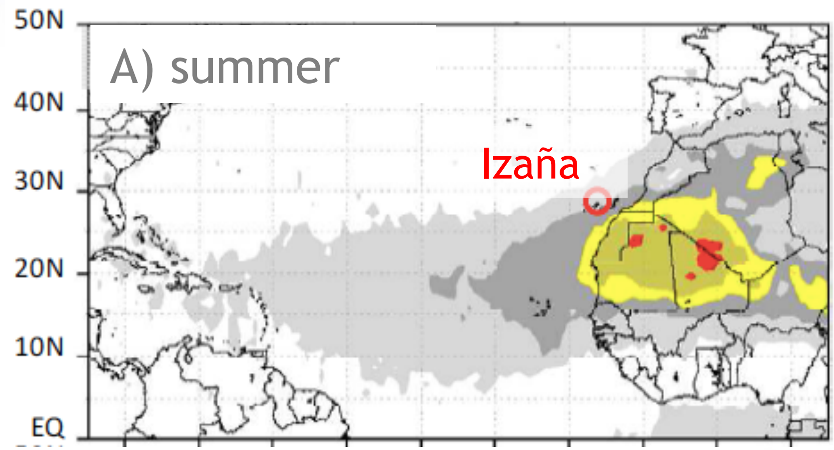
-North Africa: 50-70% of global dust emissions

-dust exported to the Atlantic
in the Saharan Air Layer

-summer:

-activation of subtropical Saharan sources
-max dust emissions
-SAL is exported 1- 5 km.a.s.l. to subtropic
-max dust impacts through the North Atlantic
-Izaña is within the Saharan Air Layer

Aerosol Index



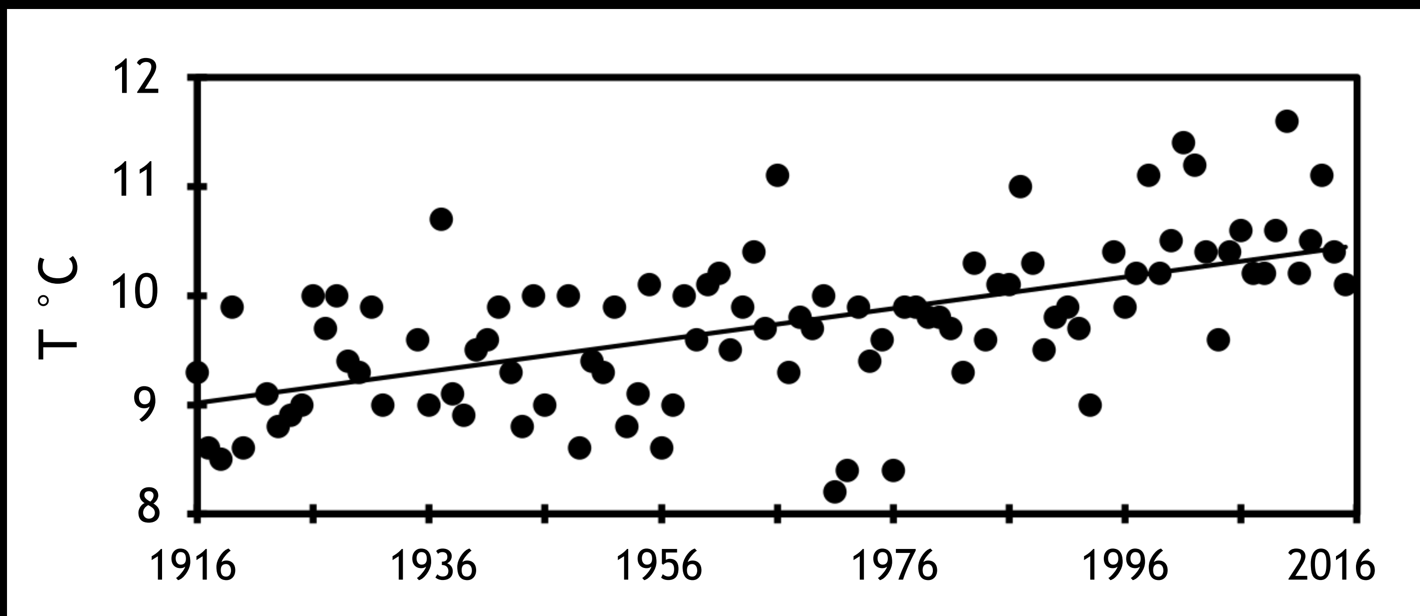
Aerosol Index

dust


Izaña, 2400 masl
Tenerife Island

Izaña: 100-years of atmospheric observations

1916 - 2016



Izaña: 30 years aerosol observations
1987 - 2016

aerosol chemistry	1987

aerosol physic

number concentration	2006
size distribution 10nm – 20 µm	2008
scattering total- and back- 3 λ	2008
absorption 1 λ	2007
aethalometer 7 λ	2012

view from Izaña:

-above the marine stratocumulus
-night-time free troposphere

aerosol chemical composition at Izaña (since 1987): dust (Al, Fe, ...), $SO_4^{=}$, NO_3^{-}, NH_4^{+}, Na, and Cl^{-}

sample collection on filter

1987-1999 J.M. Prospero, University of Miami
30 m3/h

Dust: ash method (normalized Al/dust – 8%)
$SO_4^{=}$, NO_3^{-}, NH_4^{+}, Cl^{-}: ion chromatography
Al, Na, Fe: INAA

cellulose

PM_T: total particulate matter

2002- up to the date AEMET + CSIC + INFN (Italy)
30 m3/h

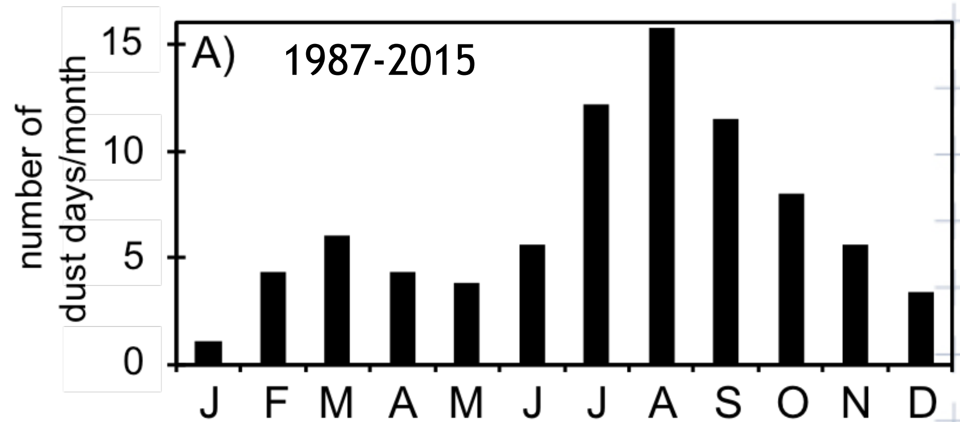
Dust: elemental composition IPC- AES, ICP-MS (normalized Al/dust – 8%)
$SO_4^{=}$, NO_3^{-}, Cl^{-} : ion chromatography
NH_4^{+}: capillary electrophoresis, specific electrode
OC, EC: TOR

quartz microfibber filter

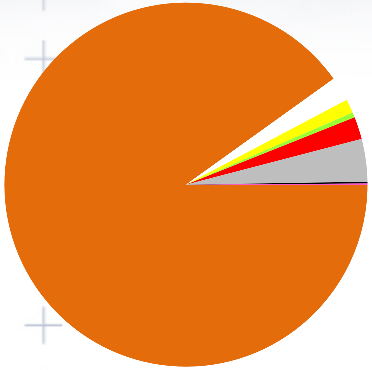
samples collected at night
free troposphere

PM_T: total particulate matter
PM_{10}: particulate matter diameter ≤ 10 μm
$PM_{2.5}$: particulate matter diameter ≤ 2.5 μm

Summer Izaña is within the SAL

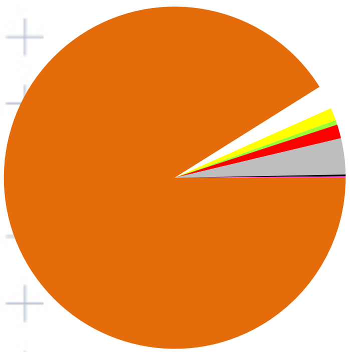


PM_x composition in the SAL



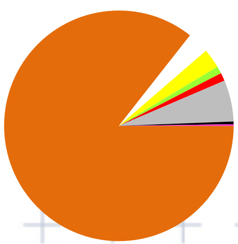
PM_T 47.3 µg/m³

91%	orange	42.6	dust (Al, Fe, Ca, Ti..)
2.2%	white	1.0	none ammonium-sulfate
1.2%	yellow	0.5	ammonium-sulfate
0.4%	green	0.2	ammonium
1.9%	red	0.9	nitrate
3.8%	grey	1.8	organic matter
0.2%	black	0.07	elemental carbon



PM_{10} 42.0 µg/m³

91%	orange	38.3	dust
2.2%	white	0.9	none ammonium-sulfate
1.2%	yellow	0.5	ammonium-sulfate
0.4%	green	0.2	ammonium
1.3%	red	0.6	nitrate
3.4%	grey	1.4	organic matter
0.2%	black	0.07	elemental carbon



$PM_{2.5}$ 18.5 µg/m³

85%	orange	15.8	dust
3.0%	white	0.6	none ammonium-sulfate
2.7%	yellow	0.5	ammonium-sulfate
1.0%	green	0.2	ammonium
1.1%	red	0.2	nitrate
5.8%	grey	1.1	organic matter
0.4%	black	0.07	elemental carbon

Outline

long term variability in the Saharan Air Layer.....

-dust
-dust mixing with pollutants
-dust composition

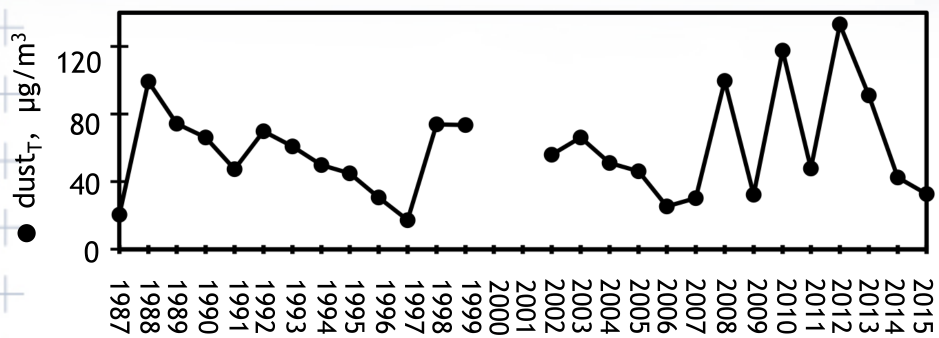
Outline

long term variability in the Saharan Air Layer.....

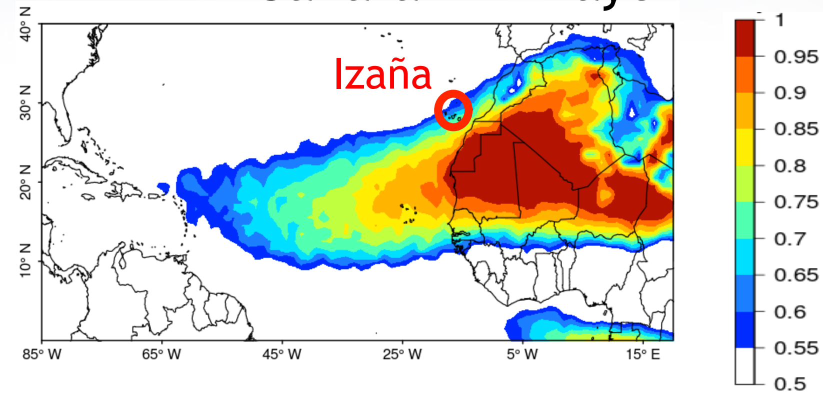
- -dust
- -dust mixing with pollutants
- -dust composition

GOBIERNO DE ESPAÑA
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO
AEMet Agencia Estatal de Meteorología

summer dust at Izaña: 1987 - 2015



Saharan Air Layer



Max: 133 µg/m³ 2012

Min: 17 µg/m³ 1997

MDFA: Major Dust Frequency Activity

UV Absorbing Aerosol Index = sensitive to iron oxides in dust

$$\text{MDFA} = \frac{\text{number days UV Absorbing Aerosol Index} > 1}{\text{total number of days in the month}}$$

= fraction of summertime AI>1

Satellite (Earth Probe, Nimbus 7, Aura):
Total Ozone Monitor Spectrometer (1987-2001)
Ozone Monitor Instrument (2005-2012)

Summer North African meteorological scenario

Complex puzzle from the tropic to the Mediterranean:

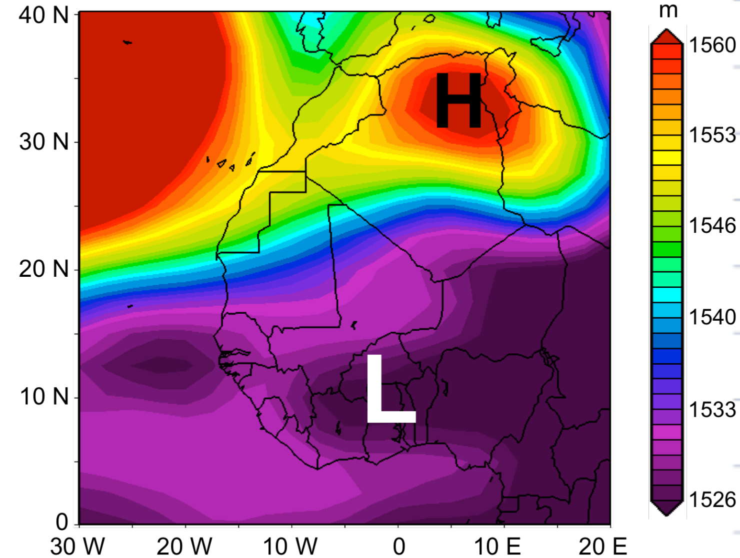
- -Subtropical high pressures, ≈35ºN
- -Harmattan (≈trade) winds 25-30 ºN
- -ITCZ, 20ºN
- -Saharan heat low, 19ºN
- -Tropical low monsoon, 7-12ºN
  - rain band, 5-12ºN
  - Inflow, 5-20ºN

H

L

North African Dipole

850hPa geop
1987-2014



Atmos. Chem. Phys., 15, 7471–7486, 2015

Modulation of Saharan dust export by the North African dipole

S. Rodríguez[1], E. Cuevas[1], J. M. Prospero[2], A. Alastuey[3], X. Querol[3], J. López-Solano[1], M. I. García[1,4], and S. Alonso-Pérez[1,3,5]

Atmospheric Chemistry and Physics

Saharan dust export, connection to…
large scale meteorology in North Africa

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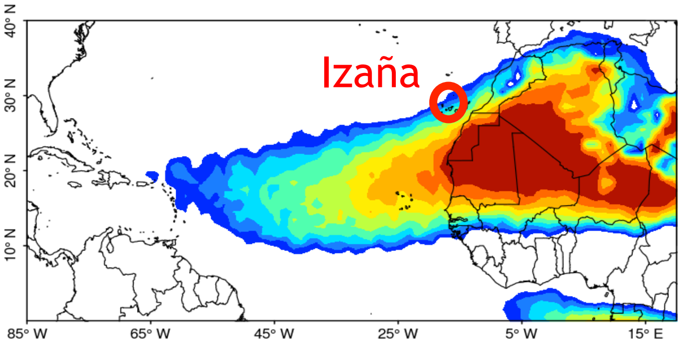
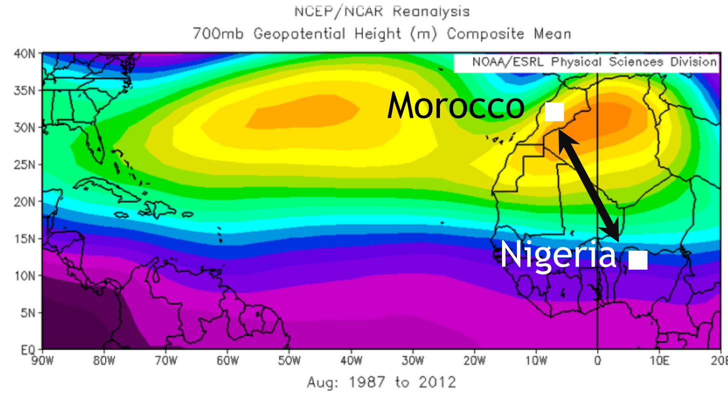


700hPa geop. height



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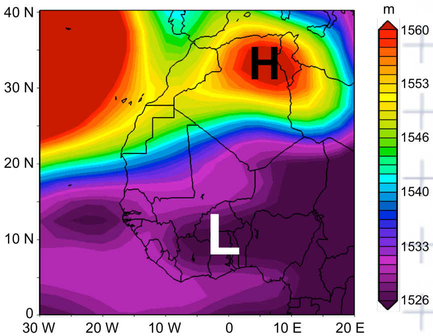
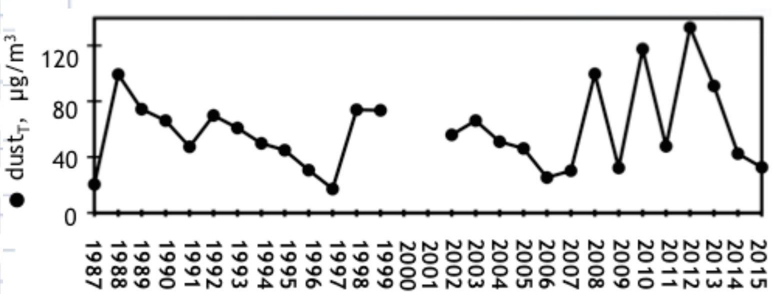


Izaña



North AFrican Dipole Intensity (NAFDI)

$$NAFDI = \frac{1}{10}\left(\left(\Phi_{Mo}^{y} - <\Phi>_{Mo}\right) - \left(\Phi_{Ba}^{y} - <\Phi>_{Ba}\right)\right)$$

700 hPa: relevant level for dust export

In principle, NAFDI is just a measure of the geostrophic component of the North African outflow

but, we will see it is provides additional useful information on climate variability

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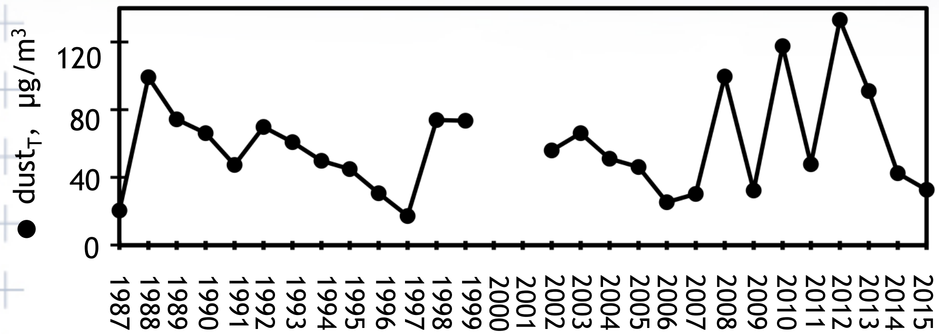
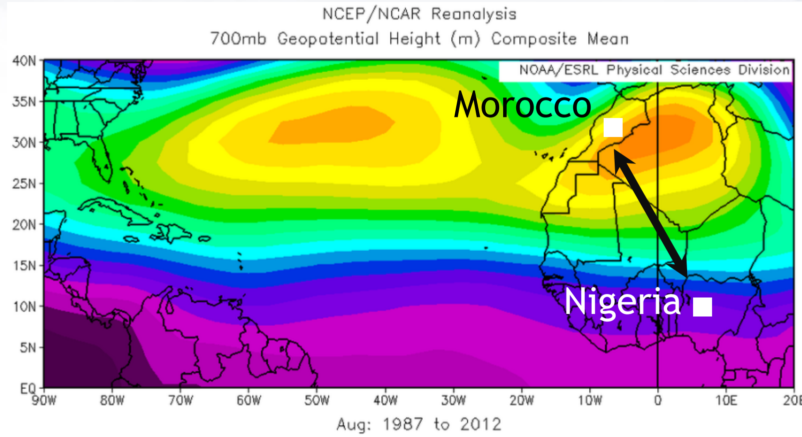
Saharan dust export, connection to… large scale meteorology in North Africa





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Atmospheric Chemistry and Physics

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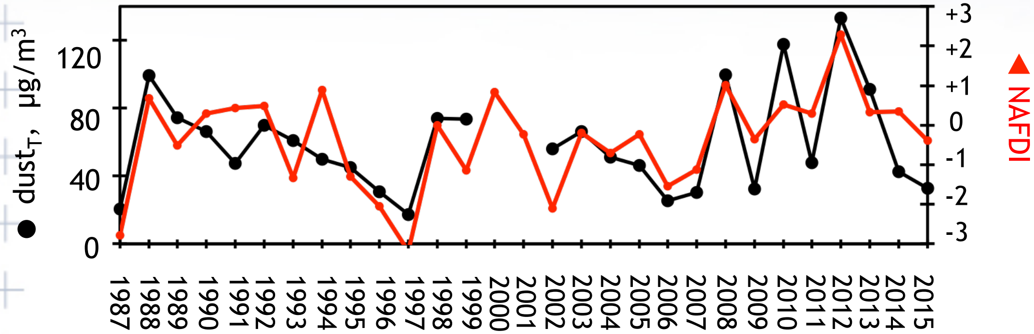

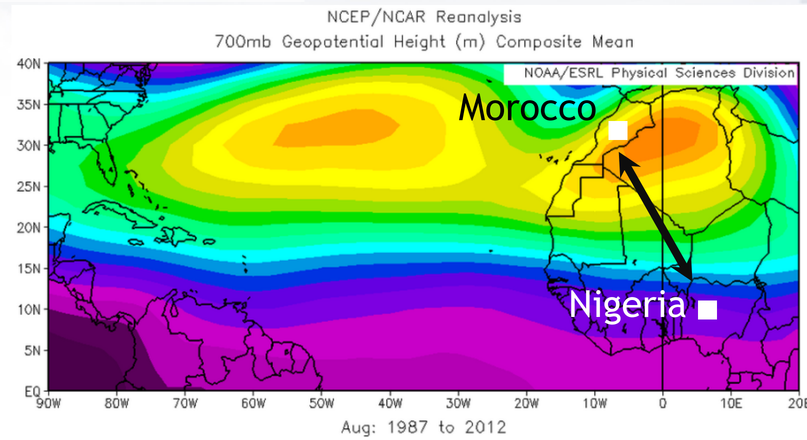

Pearson correlation between NAFDI and the dust at Izaña = +0.71

Variability in dust export is associated with variability in NAFDI

North AFrican Dipole Intensity

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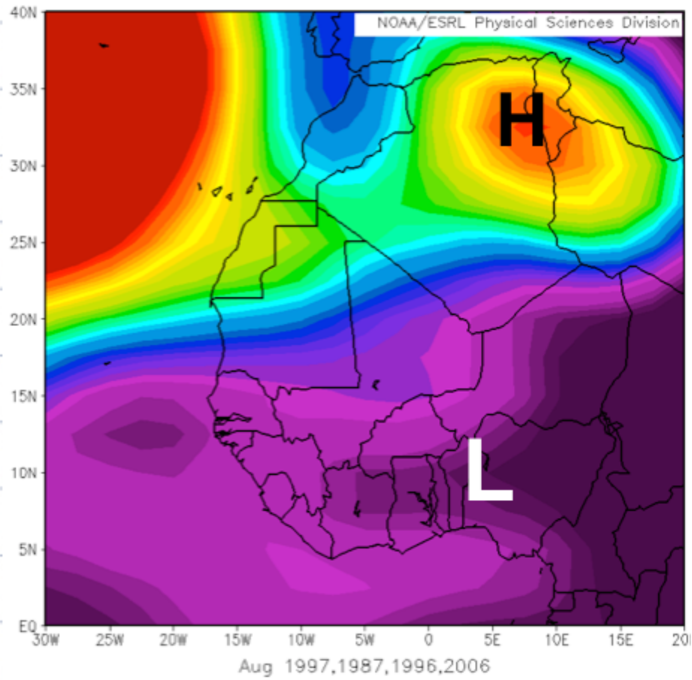
Atmospheric Chemistry and Physics

Saharan dust export, connection to...
large scale meteorology in North Africa

Low NAFDI summers

1987, 1996, 1997 and 2006
-2.79, -2.04, -3.19 and -1.54



850 hPa geop. height

High NAFDI summers

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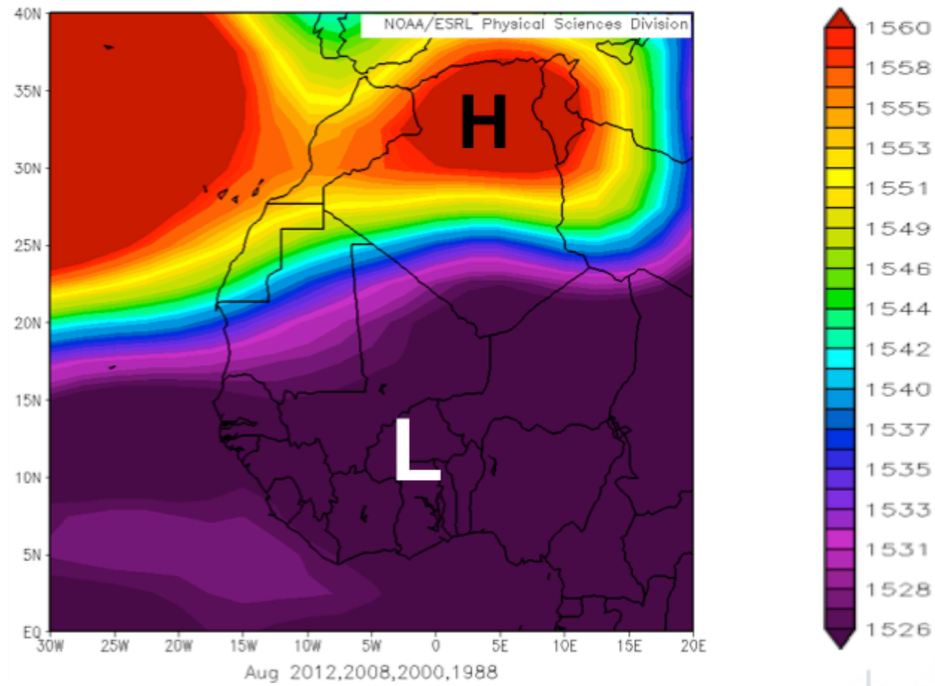
+0.68, +0.83, +1.01 and +2.29



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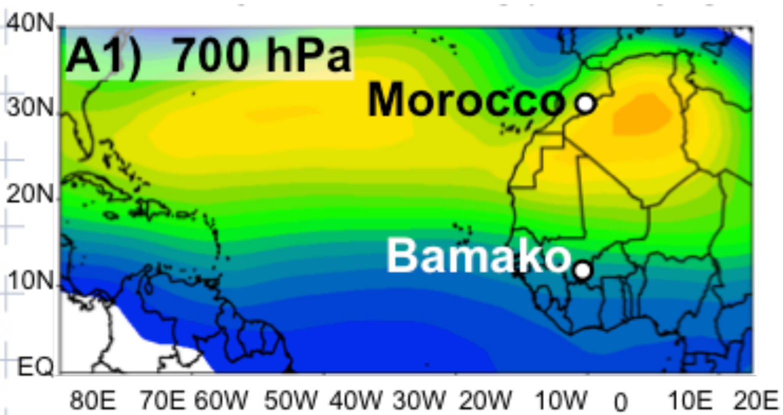

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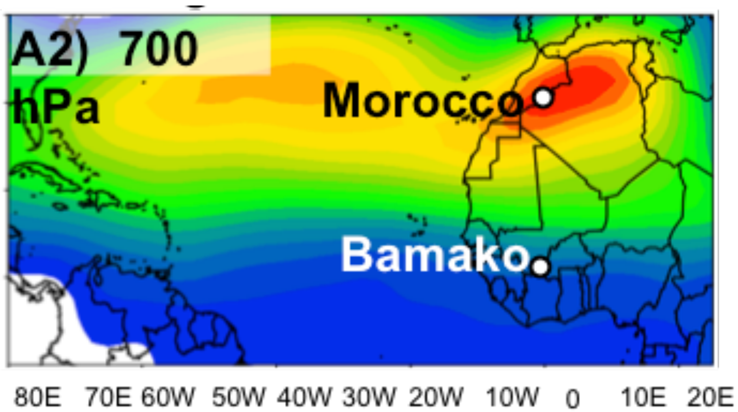

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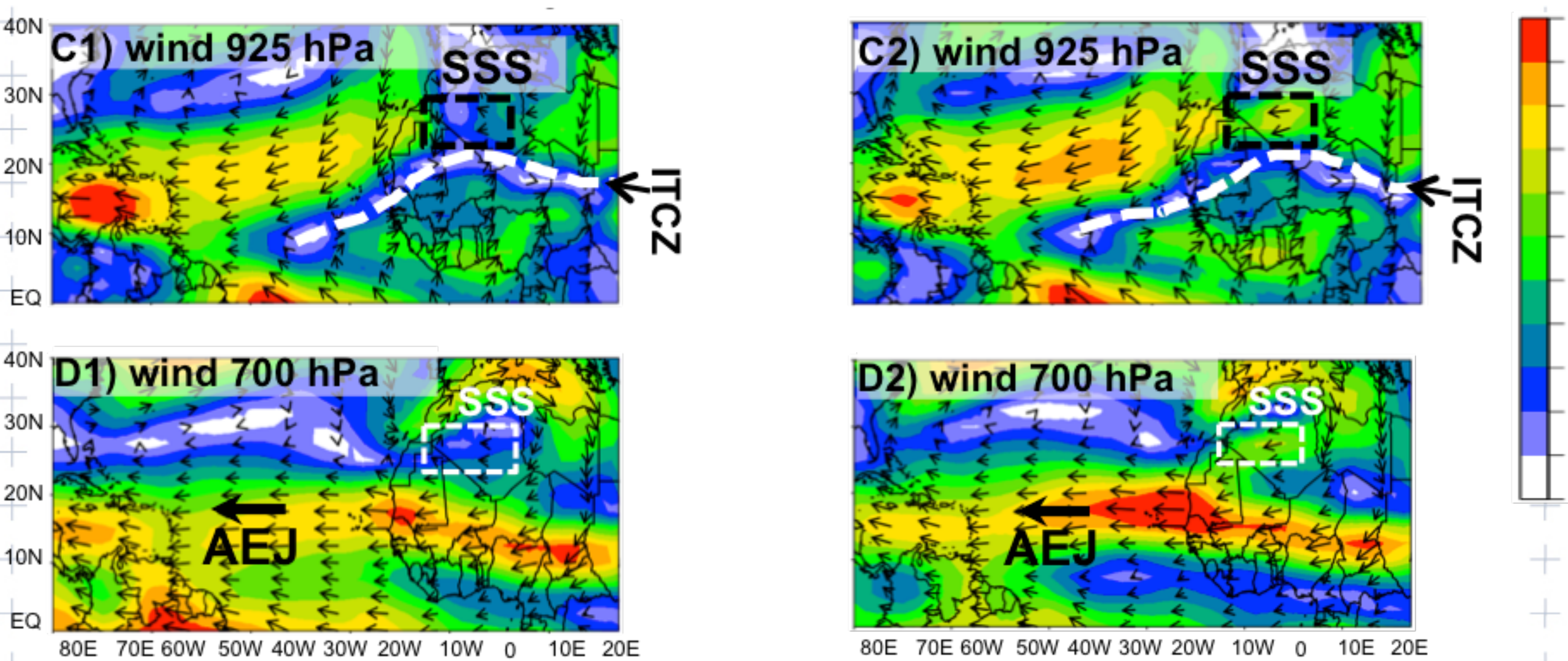
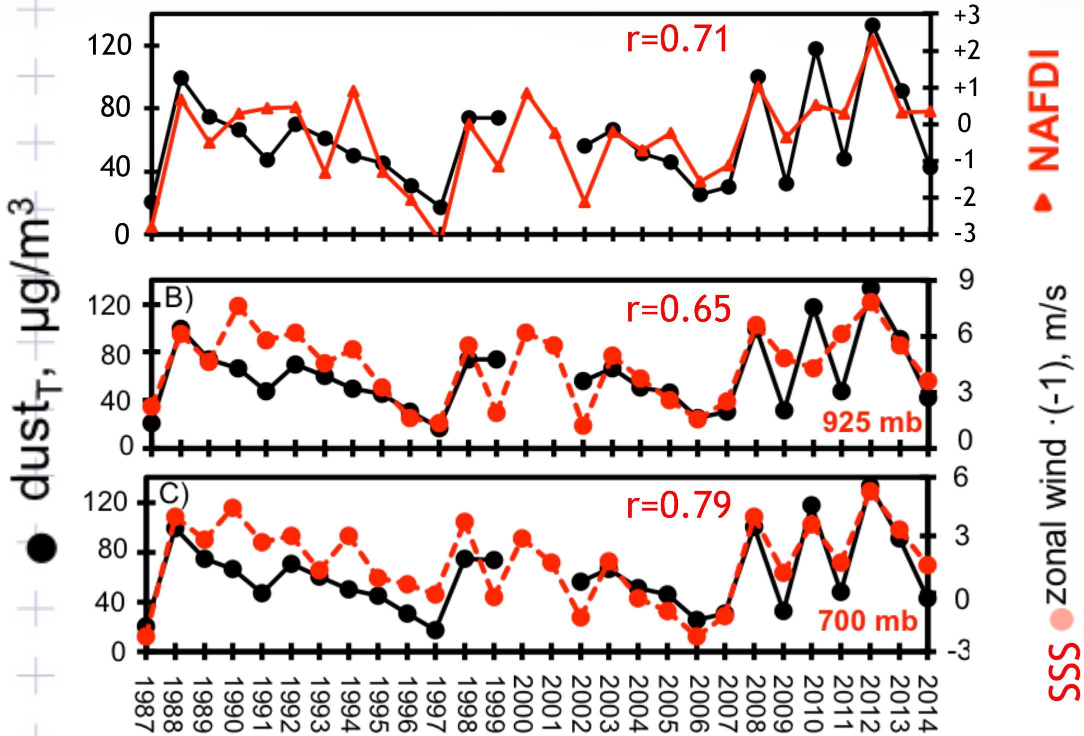


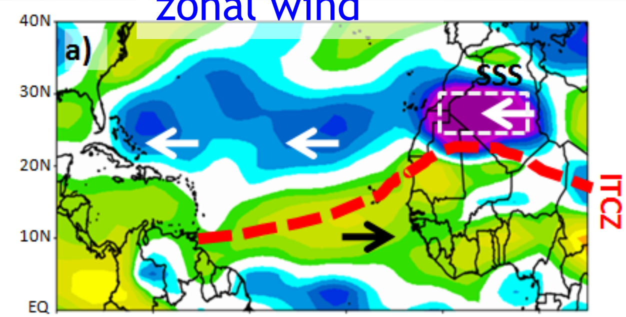
Subtropical Saharan Stripe-SSS: Central Algeria to Western Saharan, 24 - 30 °N

Saharan dust export, connection to...

large scale meteorology in North Africa



correlation of NAFDI with...
zonal wind



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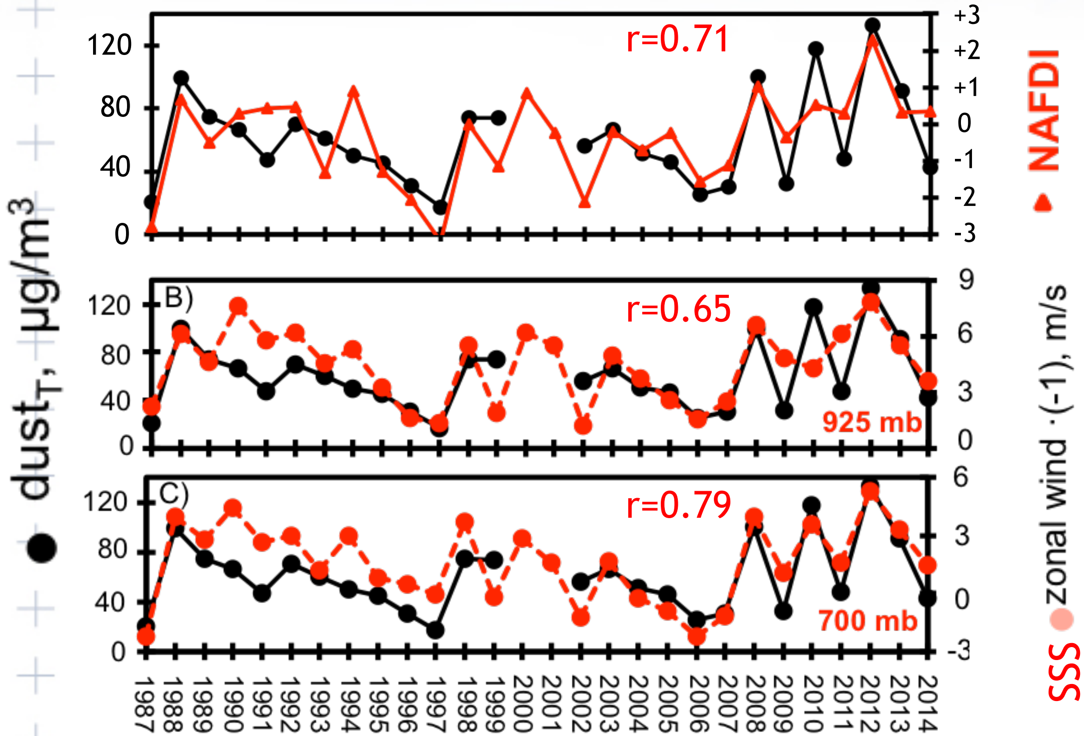
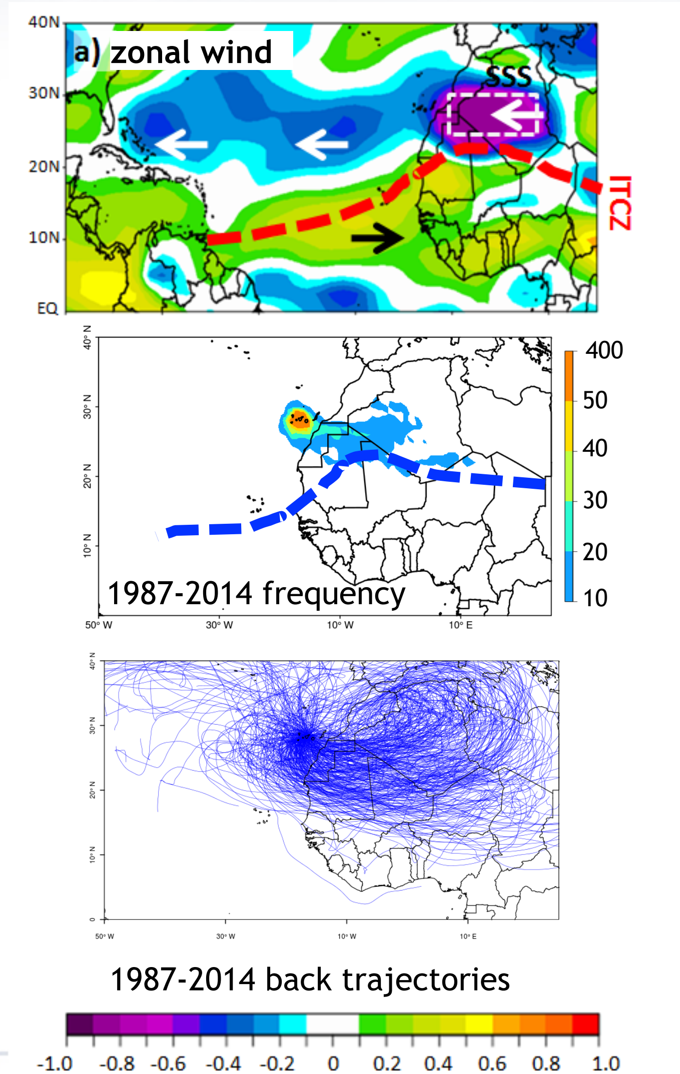


Correlation coefficient between NAFDI and



Saharan dust export, connection to…

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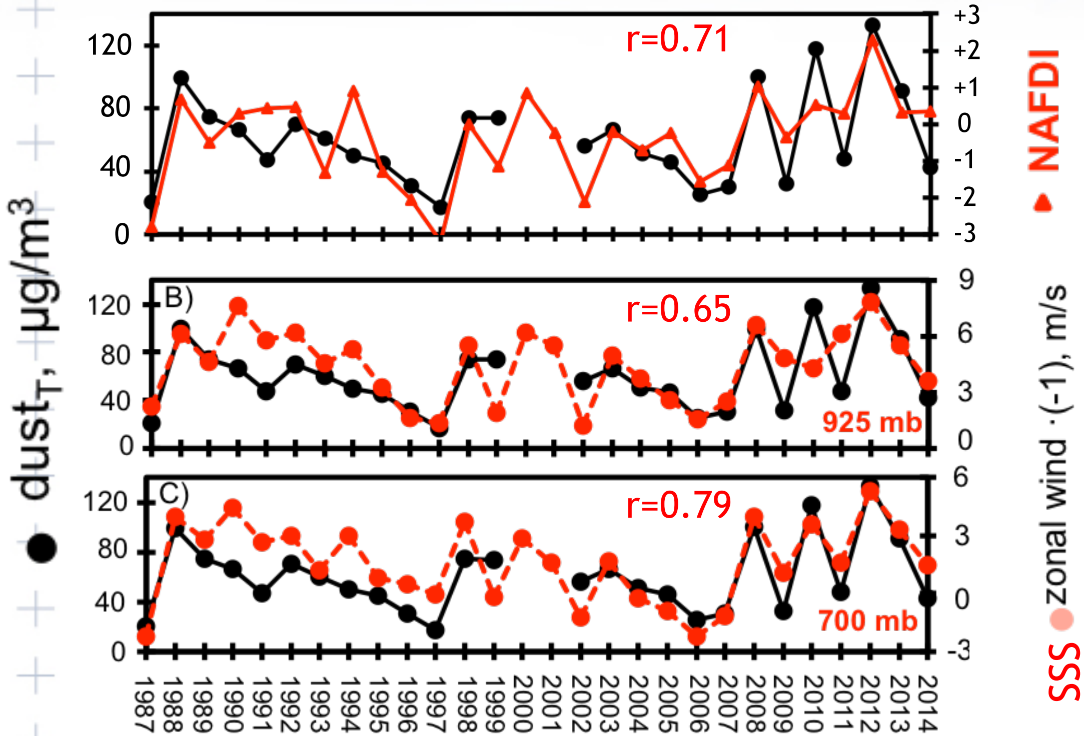

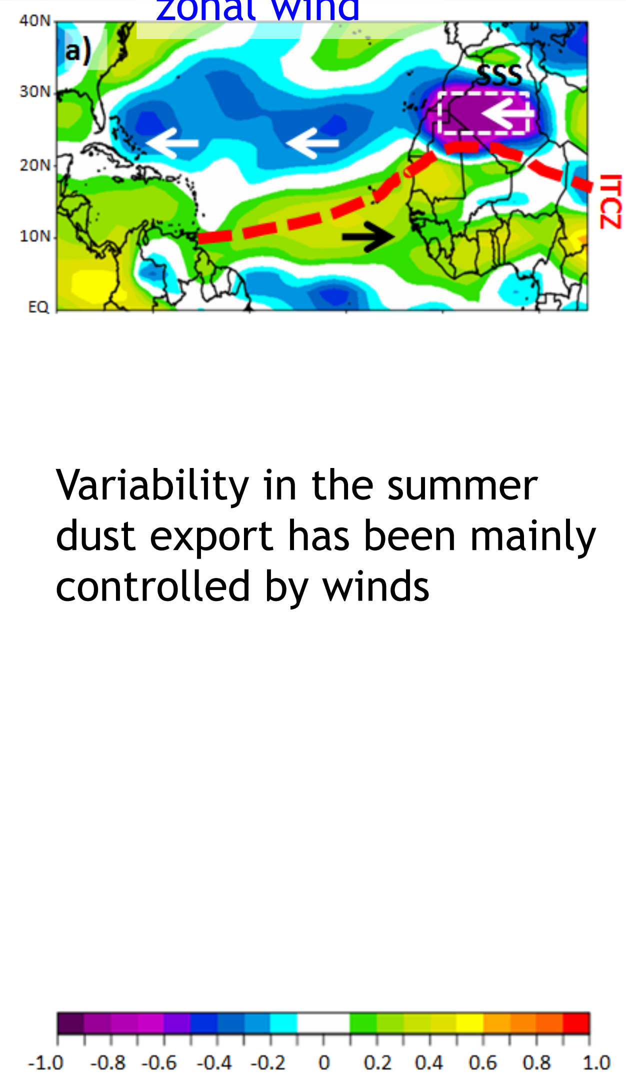

Variability in the summer dust export has been mainly controlled by winds

Saharan dust export, connection to…
large scale meteorology in North Africa

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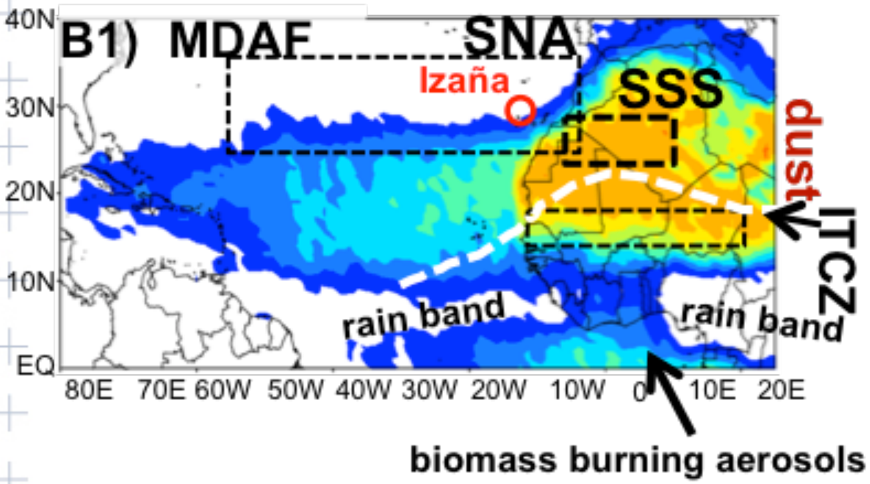

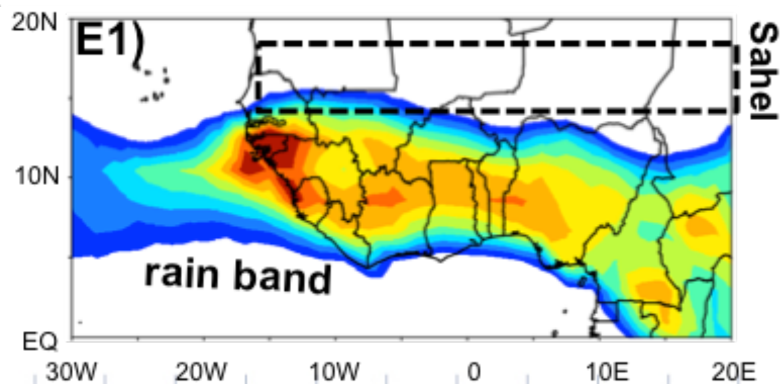

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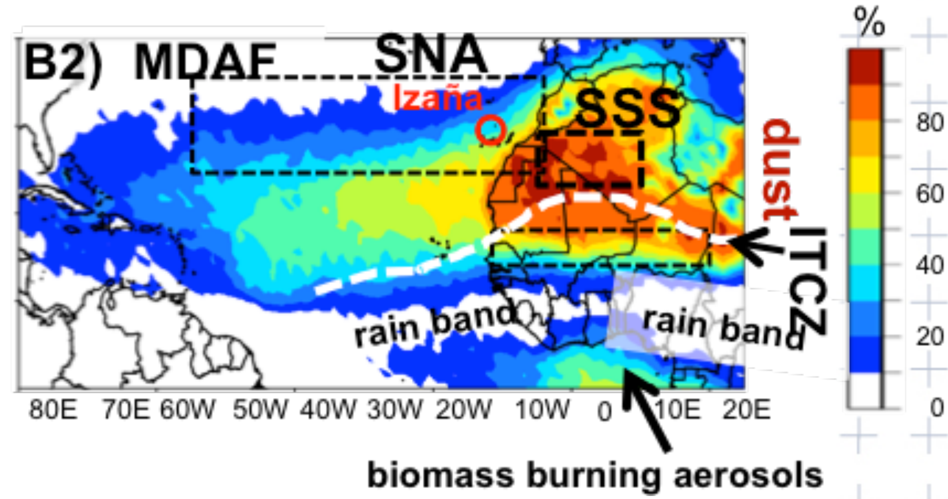
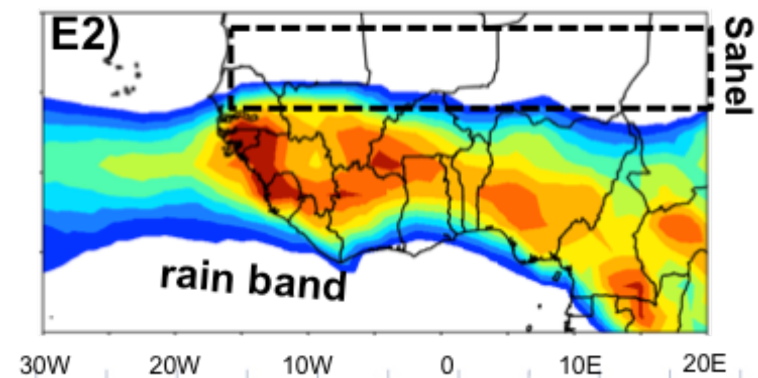
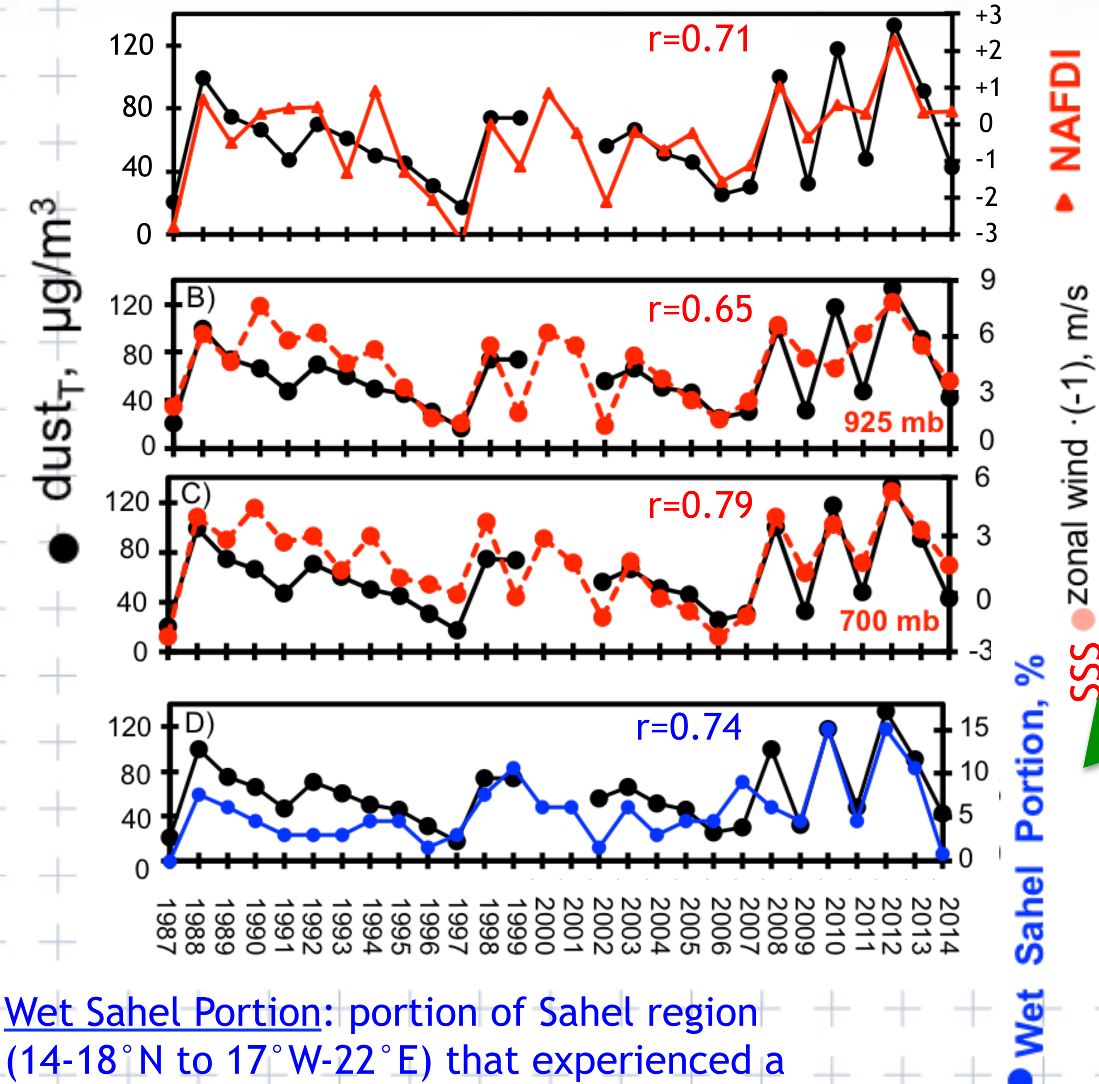


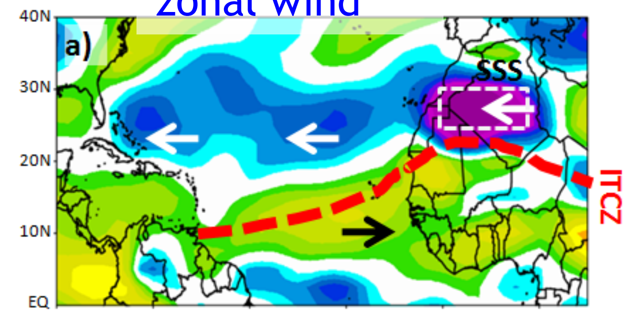


the monsoon rain band shift northward in high NAFDI summers

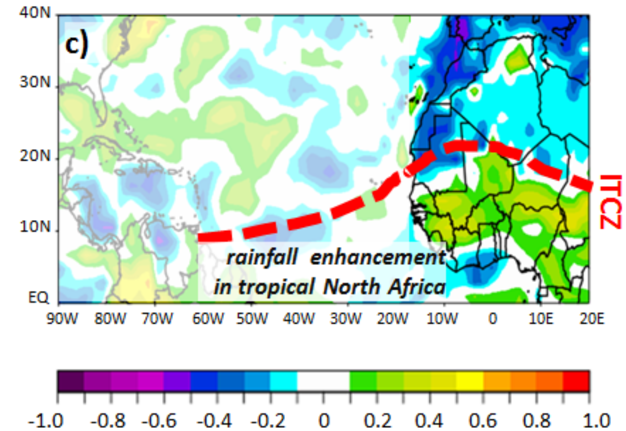
Saharan dust export, connection to…
large scale meteorology in North Africa



correlation of NAFDI with…
zonal wind

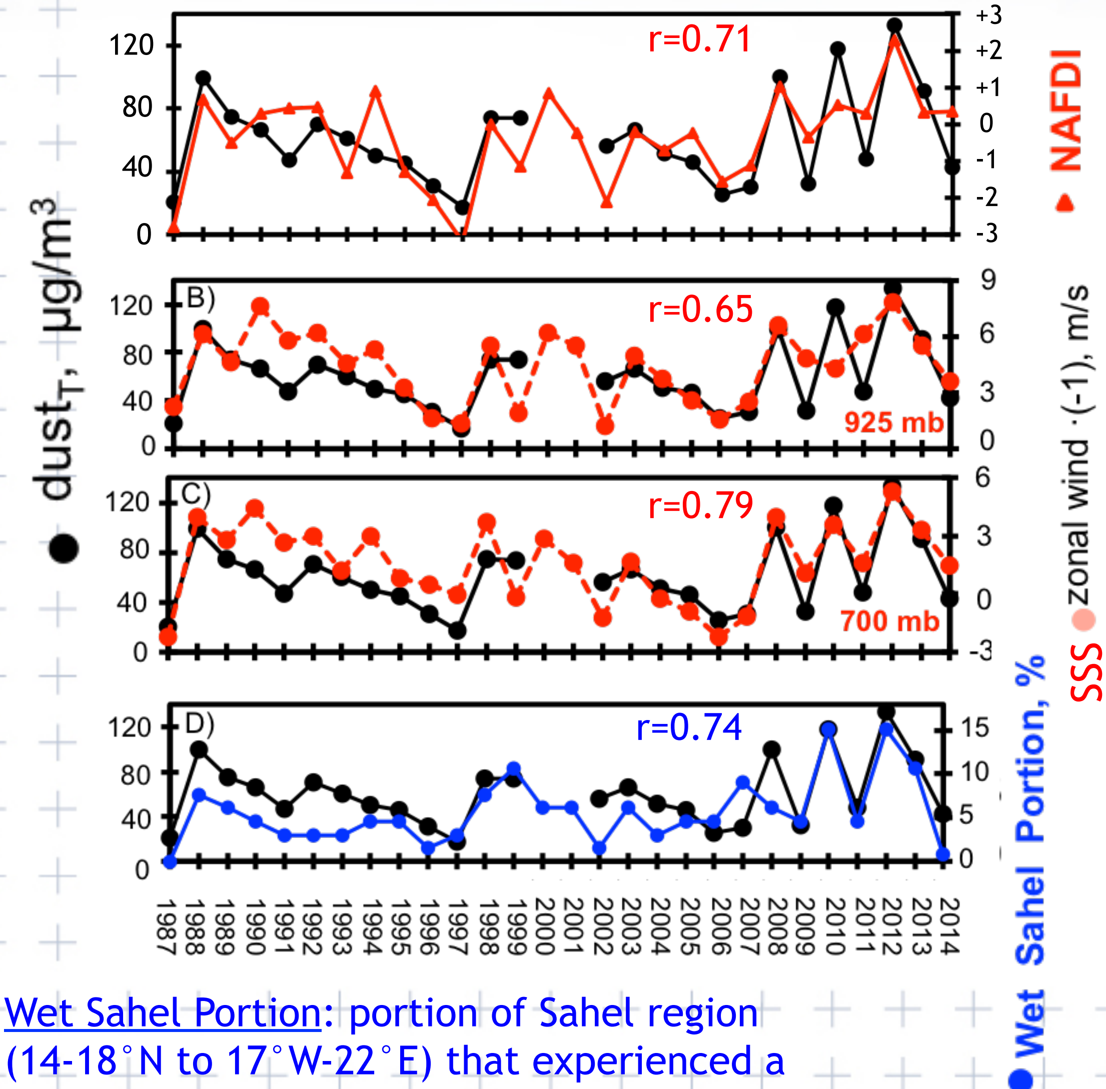


correlation of NAFDI with…
precipitation rates

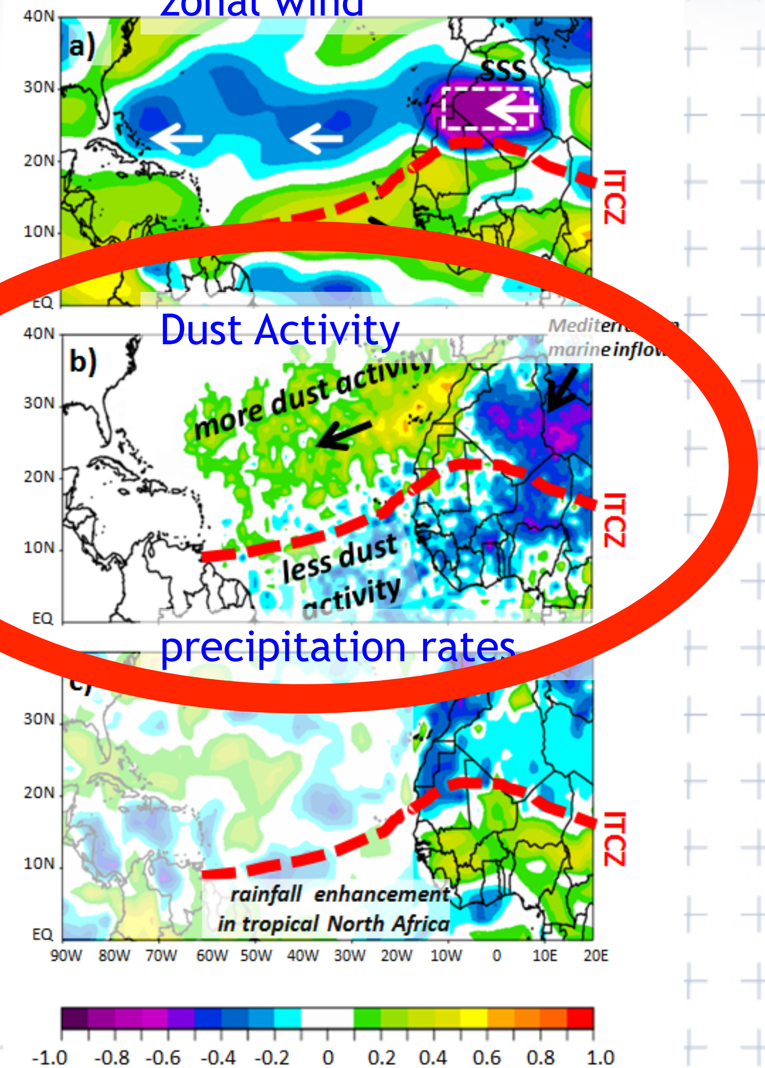


Wet Sahel Portion: portion of Sahel region (14-18°N to 17°W-22°E) that experienced a precipitation rate ≥ 3 mm/day

Saharan dust export, connection to…
large scale meteorology in North Africa



correlation of NAFDI with…



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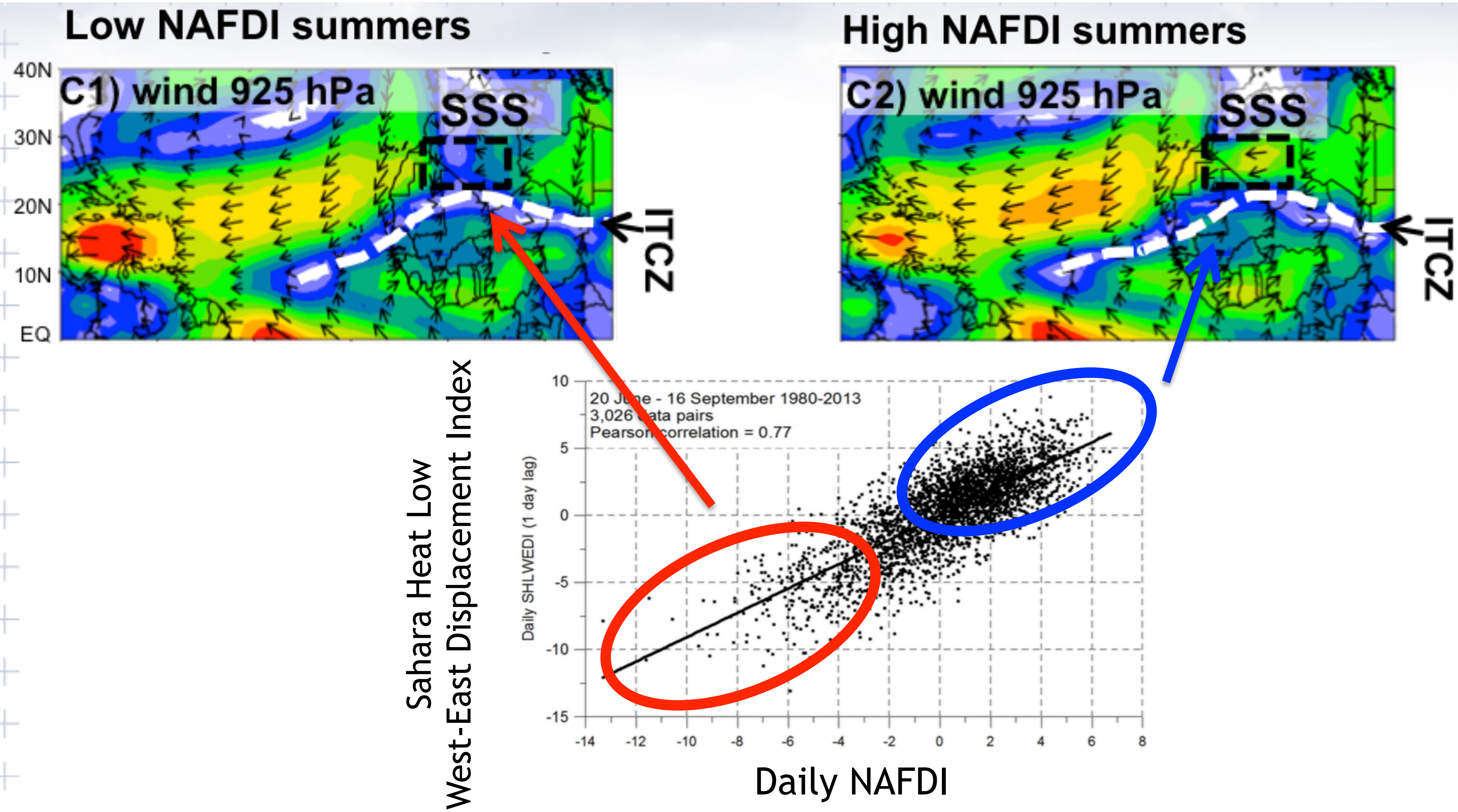
Sahara Heat Low
West-East Displacements are modulated by NAFDI



Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-287, 2016

E. Cuevas[1], A. J. Gómez-Peláez[1], S. Rodríguez[1], E. Terradellas[2], S. Basart[3], R. D. García[1,4], O. E. García[1], and S. Alonso-Pérez[5]

Atmospheric Chemistry and Physics Discussions

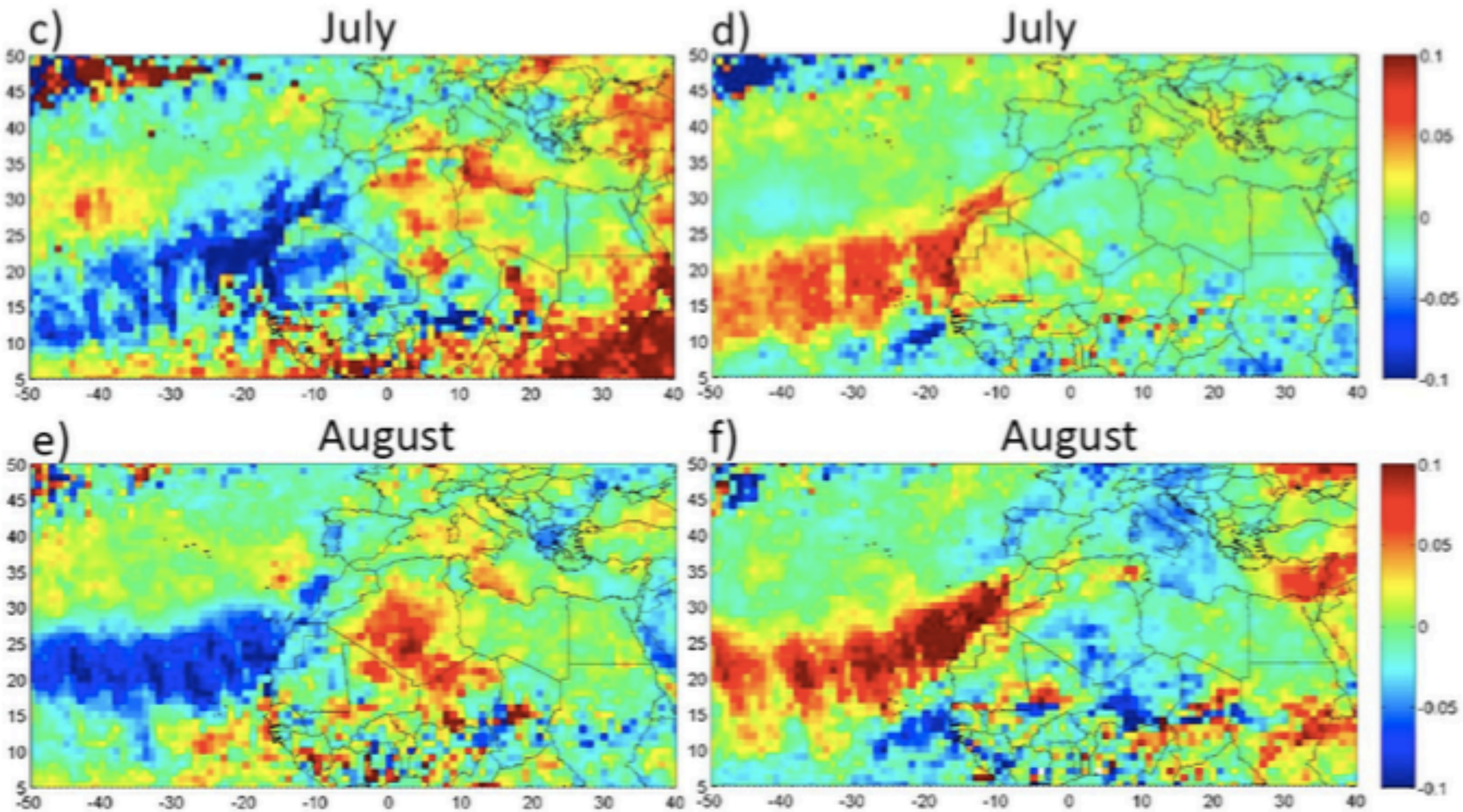
Pivotal role of the North African Dipole Intensity (NAFDI) on alternate Saharan dust export over the North Atlantic and the Mediterranean, and relationship with the Saharan Heat Low and mid-latitude Rossby waves

spatial variability in source activation and dust export modulated by NAFDI

MODIS- satellite AOD

Low (-) NAFDI , < -0.4 — Enhanced impacts on Mediterranean

High (+) NAFDI , > +0.4 — Enhanced impacts on Atlantic - SAL

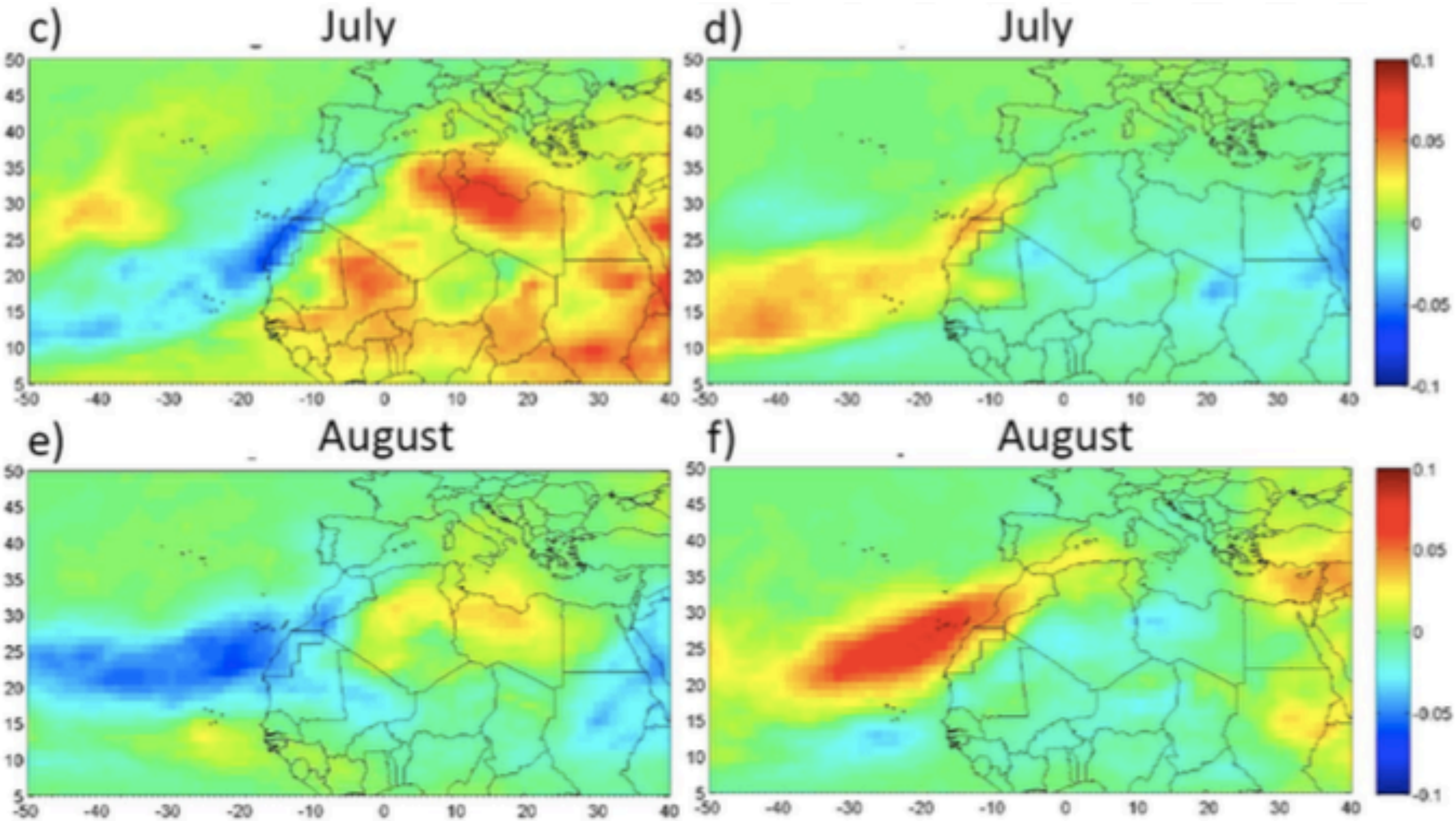


spatial variability in source activation and dust export modulated by NAFDI

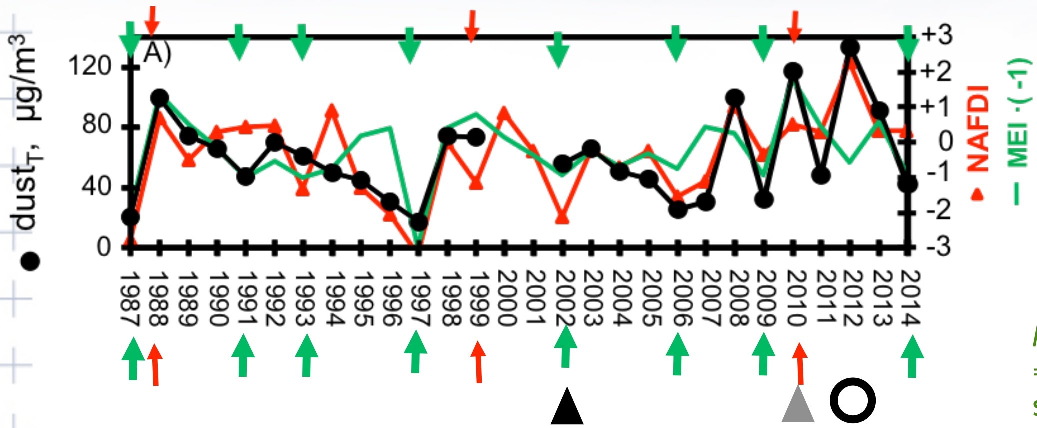
MACC- modelling AOD

Low (-) NAFDI , < -0.4 — Enhanced impacts on Mediterranean

High (+) NAFDI , > +0.4 — Enhanced impacts on Atlantic - SAL



Saharan, dust, NAFDI and teleconections



La Niña: strong trade winds (well defined 'regular' meteorology in the subtropics and tropics)

El Niño: weak trade winds (non 'regular' meteorology in the subtropics and tropics)

MEI (NOAA): Multivariate ENSO (El Niño Southern Oscillation) Index =f(sea level pressure, zonal and meridional surface winds, sea surface T, surface air T and total cloudiness fraction of the sky over the tropical Pacific Ocean)

r(dust-Izaña, NAFDI) = 0.72

r(dust-Izaña, -MEI) = 0.59

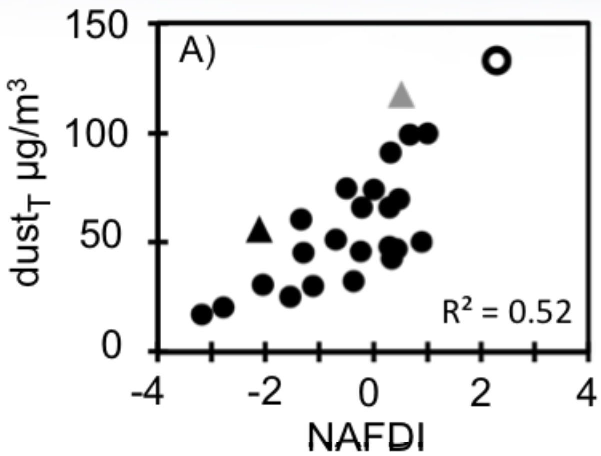
El Niño periods tend to be associated with low NAFDI summers

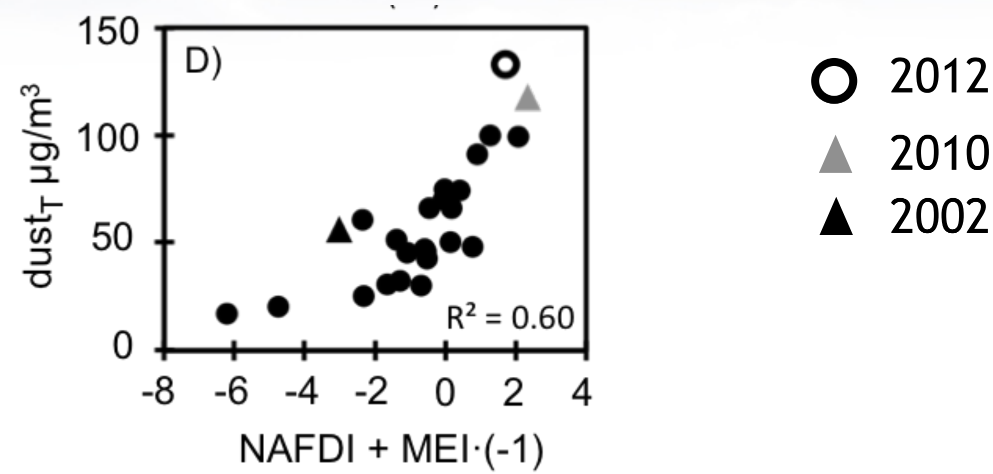
however, peak dust summers associated with MEI peaks but rather low NAFDI values (e.g. 2002 ▲ and 2010 ▲) ...

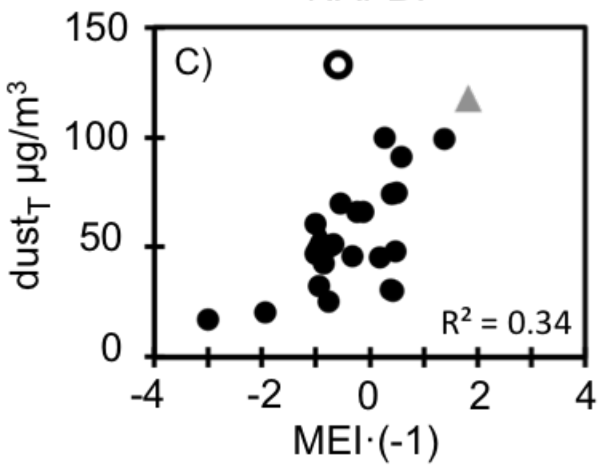
La Niña periods tend to be associated with high NAFDI summers

...and vice versa, peak dust summers associated with NAFDI peaks but rather low MEI values (e.g. 2012 ○).

Saharan, dust, NAFID and teleconections







Multivariate ENSO Index

r(dust-Izaña, NAFDI) = 0.72

r(dust-Izaña, -MEI) = 0.59

r(dust-Izaña, NAFDI+(-1)·MEI) = 0.77

Further investigations on
Tele-connection of MEI with winds in
North Africa

Outline

long term variability in the Saharan Air Layer.....

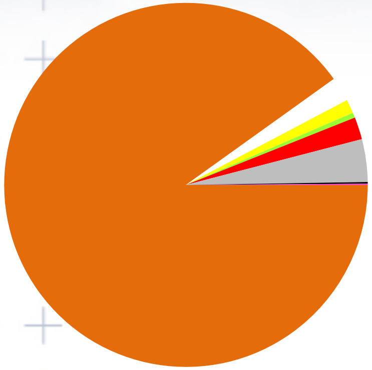
- -dust,highlights:
  - -North African Dipole Intensity NAFDI captures changes in summer meteorology
  - -winds, SHL, monsoon rains
  - -spatial variability in source activation
  - -dust export to Atlantic-SAL
  - -dust impacts on the Mediterranean

Outline

long term variability in the Saharan Air Layer.....

- -dust
- -dust mixing with pollutants
- -dust composition

PM_x composition in the SAL



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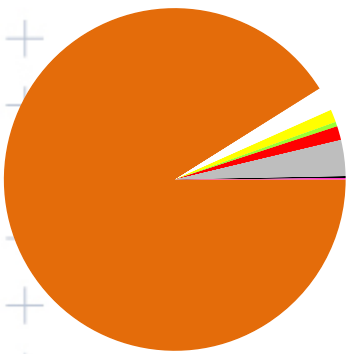
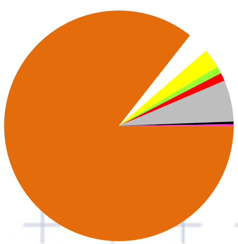
1.2%	0.5	ammonium-sulfate
0.4%	0.2	ammonium
1.9%	0.9	nitrate
3.8%	1.8	organic matter
0.2%	0.07	elemental carbon



PM_{10} 42.0 µg/m³

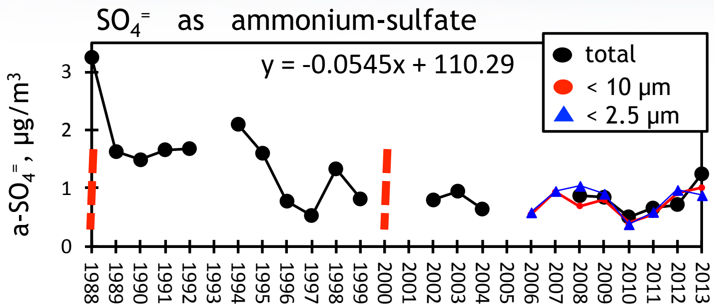
91%	38.3	dust
2.2%	0.9	none ammonium-sulfate
1.2%	0.5	ammonium-sulfate
0.4%	0.2	ammonium
1.3%	0.6	nitrate
3.4%	1.4	organic matter
0.2%	0.07	elemental carbon



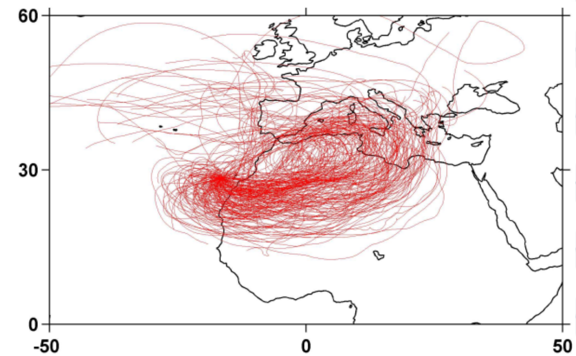
$PM_{2.5}$ 18.5 µg/m³

85%	15.8	dust
3.0%	0.6	none ammonium-sulfate
2.7%	0.5	ammonium-sulfate
1.0%	0.2	ammonium
1.1%	0.2	nitrate
5.8%	1.1	organic matter
0.4%	0.07	elemental carbon

ammonium-sulfate in the Saharan Air Layer

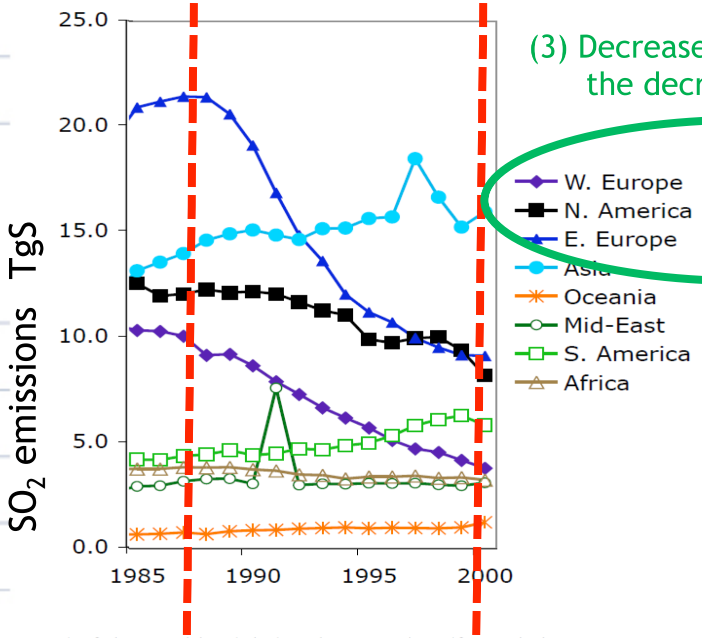


(1) air laden in Saharan dust has previously passed over the Mediterranean and Europe



August 1987-2012, dust days

(3) Decrease in a-sulfate in the SAL is correlated with the decrease in European SO2 emissions



55% decrease

55% decrease

no significant change

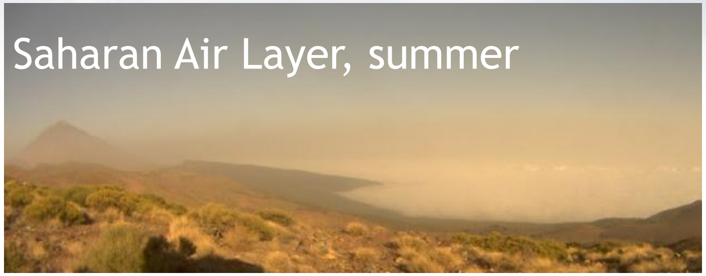
(2) North African emissions of SO_2 did not changed significantly during the 1990s

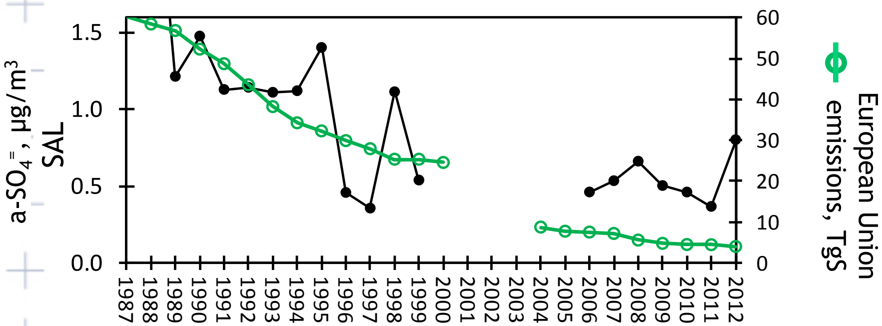
Reversal of the trend in global anthropogenic sulfur emissions

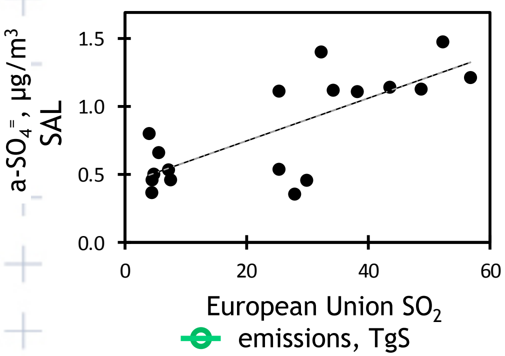
David I. Stern*

Global Environmental Change 16 (2006) 207–220

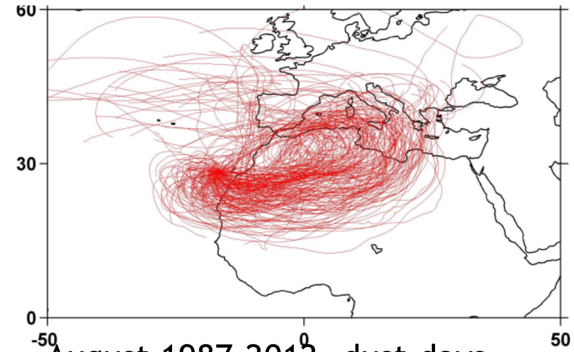
ammonium-sulfate in the Saharan Air Layer







air laden in Saharan dust has previously passed over the Mediterranean and Europe



August 1987-2012, dust days

decrease in a-sulfate in the Saharan Air Layer is correlated with the decrease in European SO_2 emissions

EEA Technical report | No 12/2014

European Union emission inventory report 1990–2012 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP)

European Environment Agency

Reversal of the trend in global anthropogenic sulfur emissions

David I. Stern*

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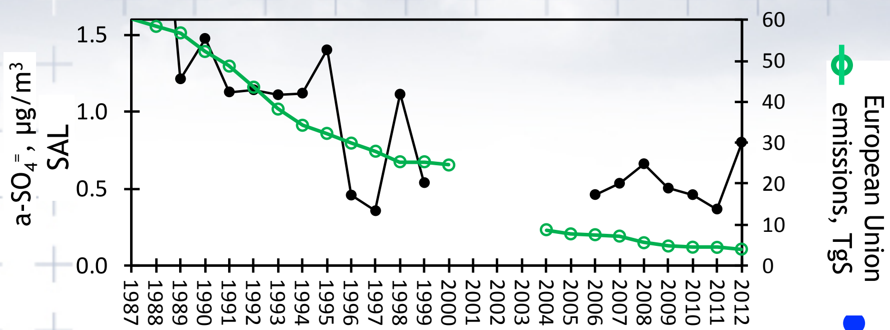
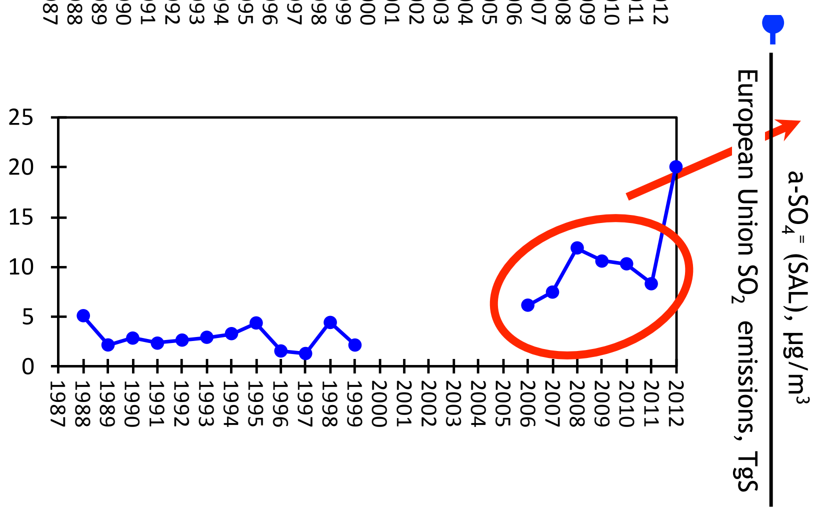
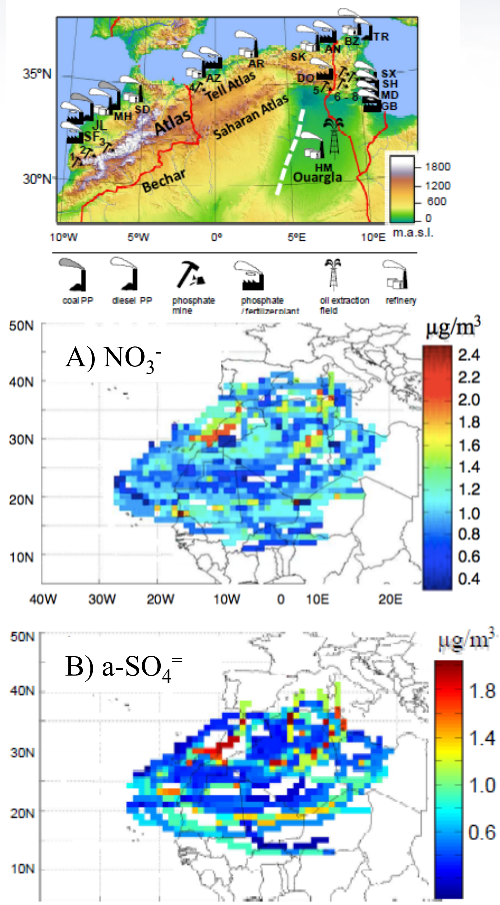
ammonium-sulfate in the Saharan Air Layer





other sources contributing

industrial emissions North Africa

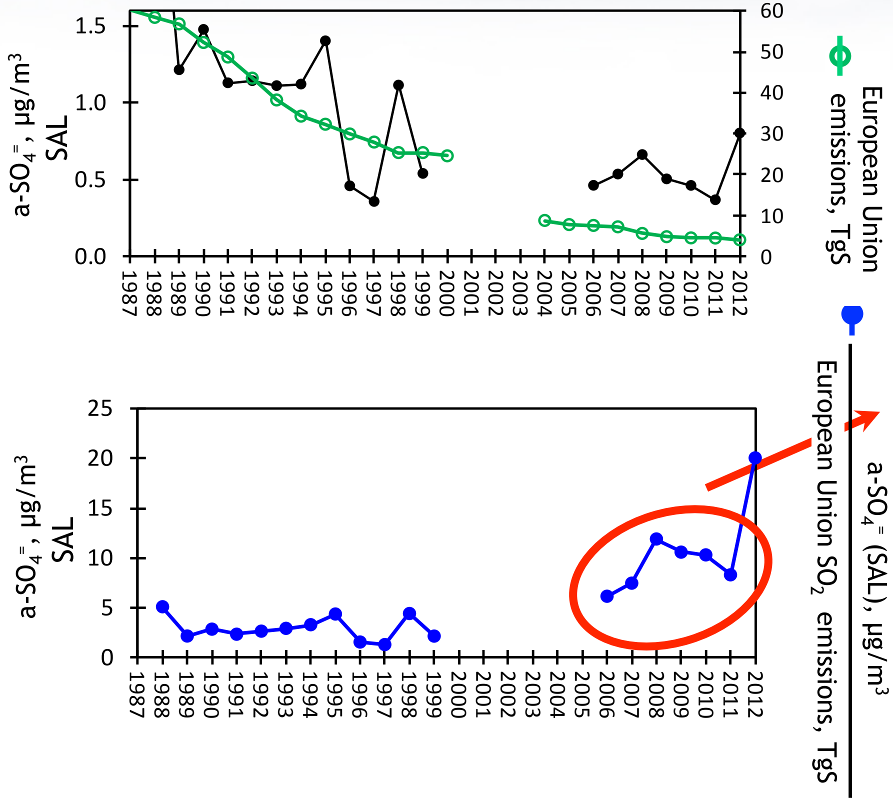


Transport of desert dust mixed with North African industrial pollutants in the subtropical Saharan Air Layer

Rodríguez et al., 2011

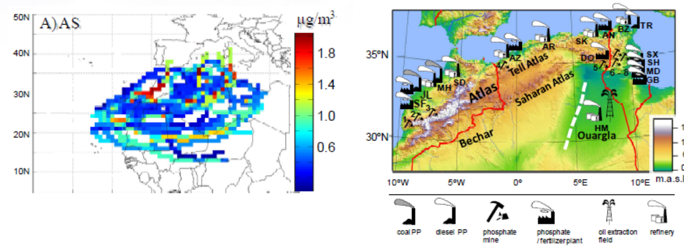
Atmos. Chem. Phys., 11, 6663–6685, 2011

ammonium-sulfate in the Saharan Air Layer



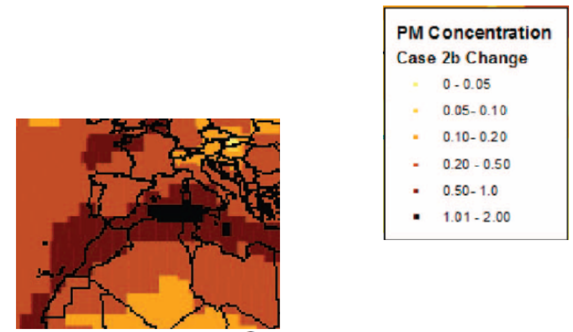
other sources contributing

north African emissions (?)



Transport of desert dust mixed with North African industrial pollutants in the subtropical Saharan Air Layer
Rodríguez et al., 2011
Atmos. Chem. Phys., 11, 6663–6685, 2011

ship emissions in the Mediterranean (?)

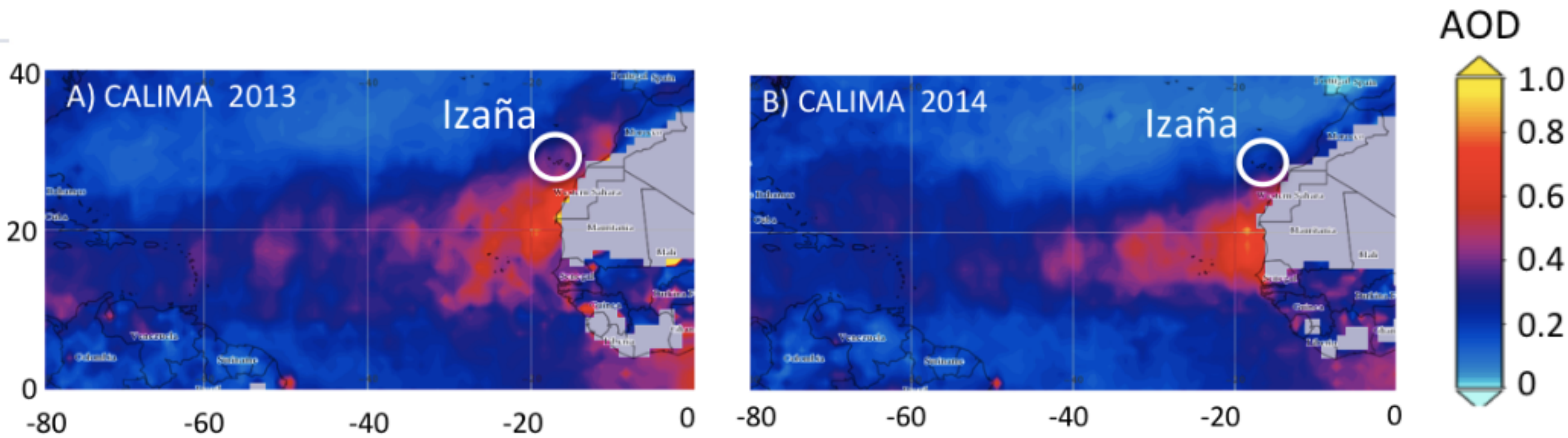


Mortality from Ship Emissions: A Global Assessment
Environ. Sci. Technol. **2007**, *41*, 8512–8518
Cobett et al., 2007

dust mixing with pollutants & implications

dust and ice nucleation

CALIMA campaigns in August 2013 and 2014



Ice nucleating particles in the Saharan Air Layer

Yvonne Boose[1], Berko Sierau[1], M. Isabel García[2,3], Sergio Rodríguez[2], Andrés Alastuey[4], Claudia Linke[5], Martin Schnaiter[5], Piotr Kupiszewski[6], Zamin A. Kanji[1], and Ulrike Lohmann[1]

Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-192, 2016

Atmospheric Chemistry and Physics Discussions

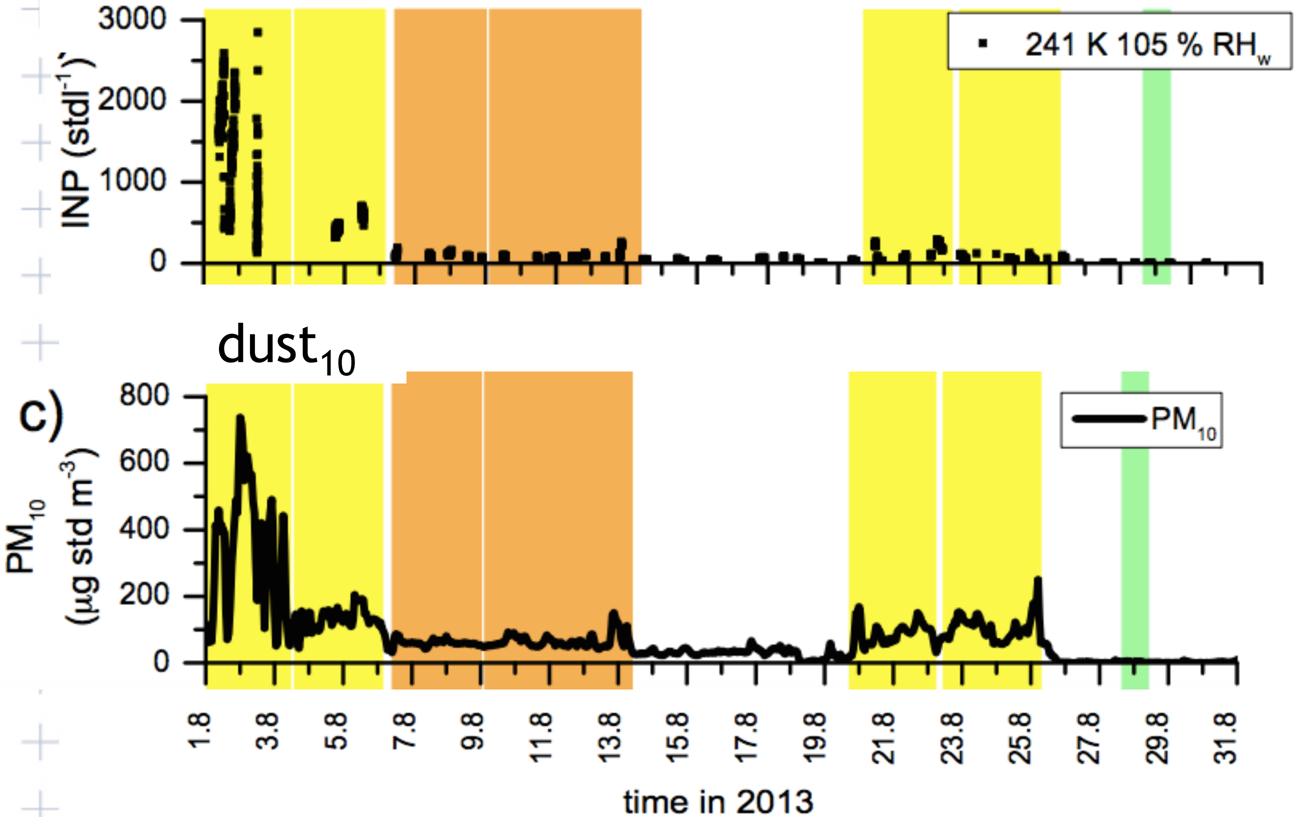
Institute for Atmospheric and Climate Science, ETH Zürich

Izaña Atmospheric Research Centre, Tenerife

dust mixing with pollutants & implications

dust and ice nucleation

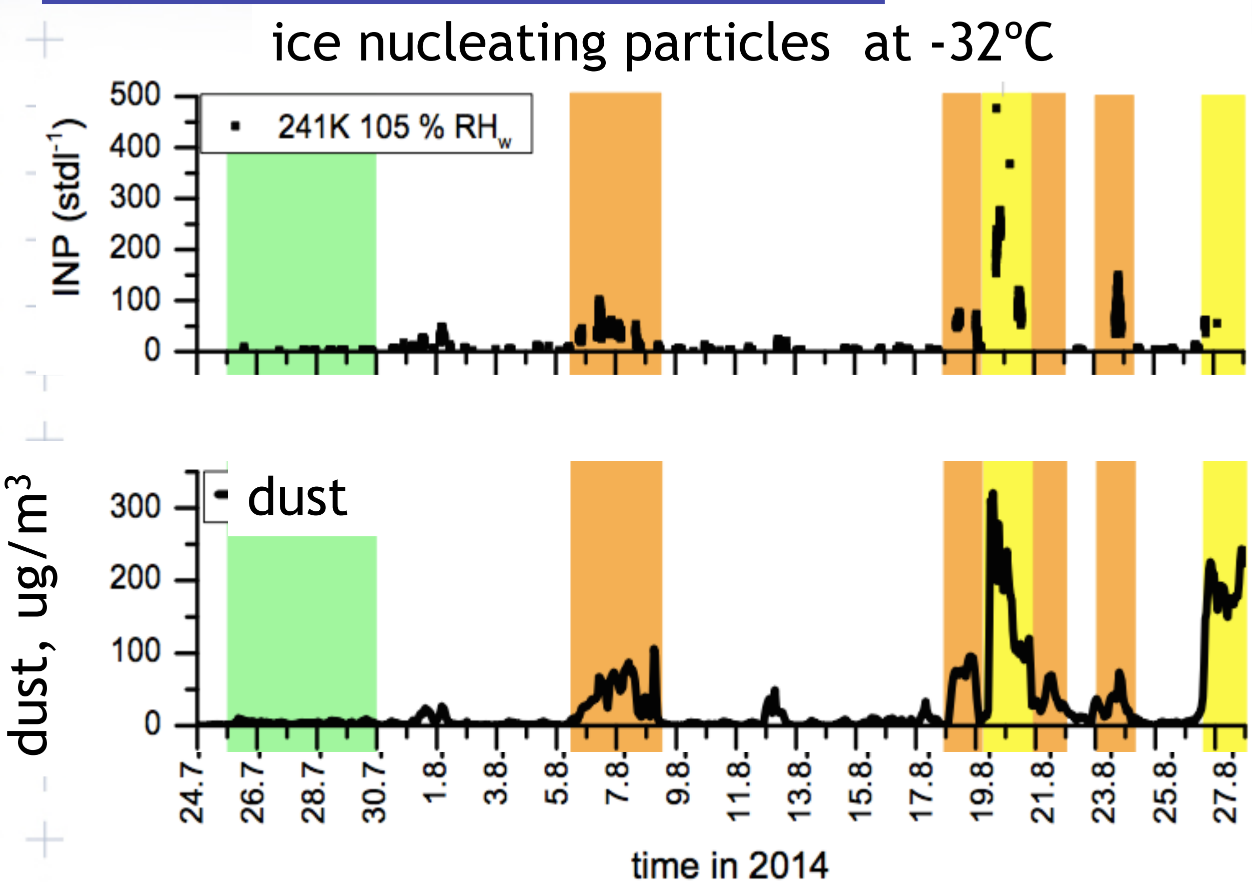
ice nuclei activated at -32°C



PINC measurements
Portable Ice Nucleation Chamber

dust mixing with pollutants & implications

dust and ice nucleation

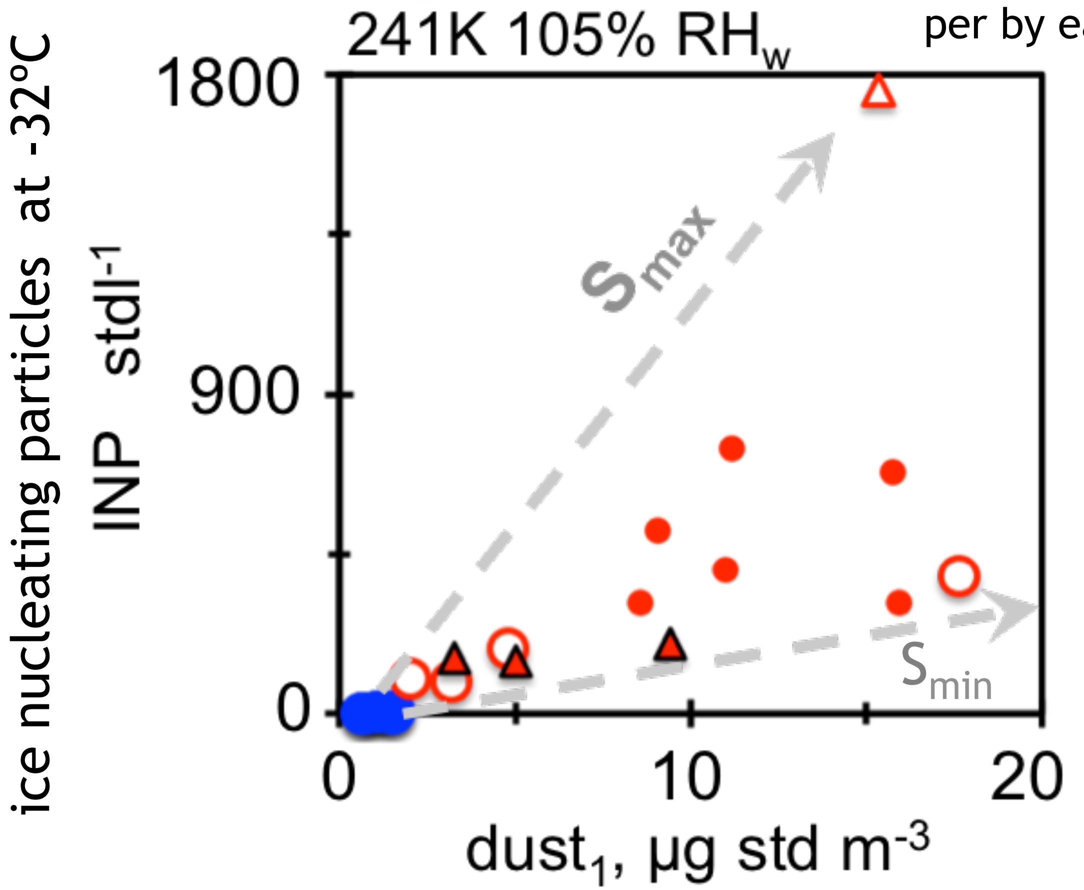


PINC measurements
Portable Ice Nucleation Chamber

dust mixing with pollutants & implications

dust and ice nucleation

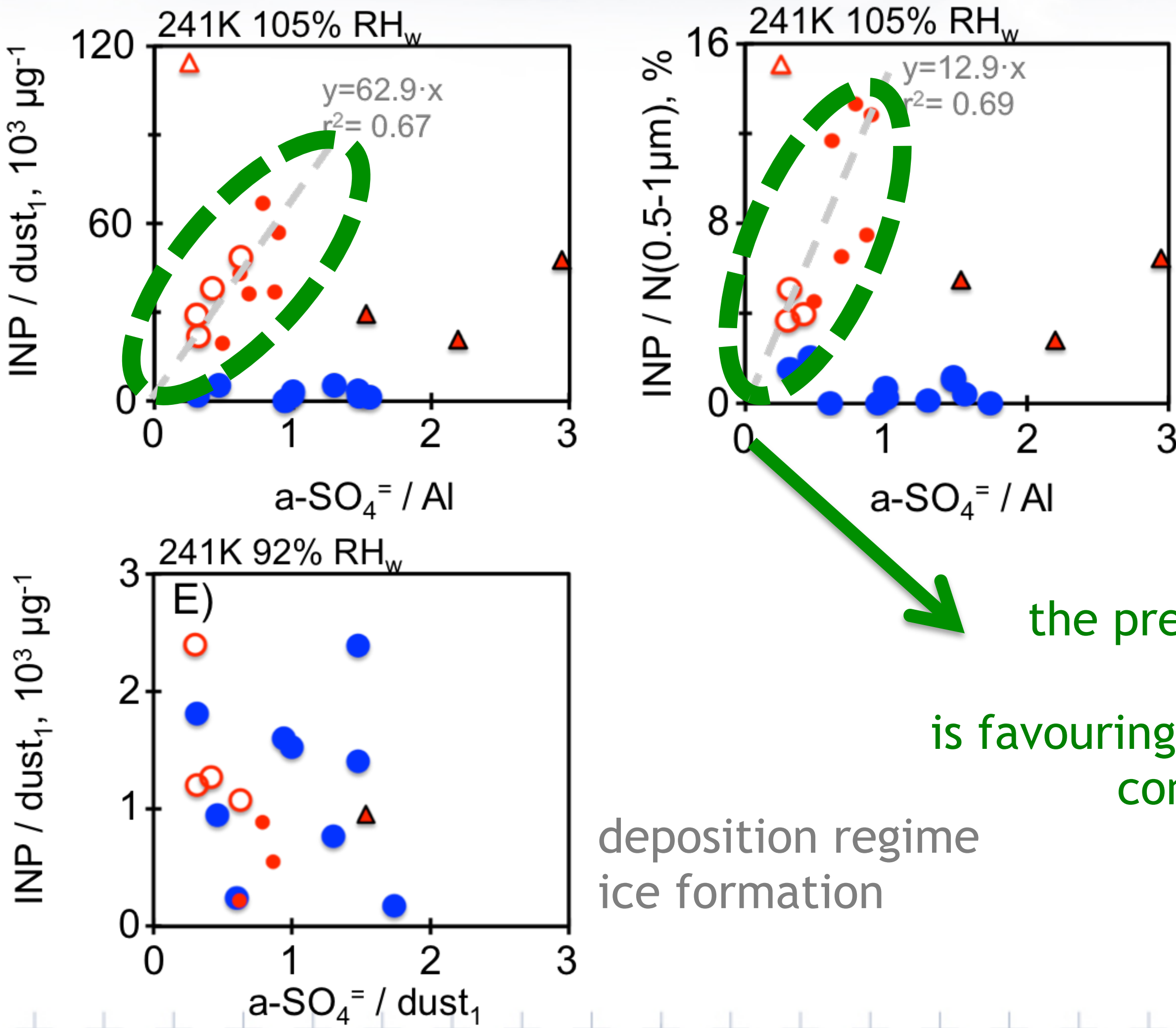
maximum number of ice crystals
per by each µg of dust



minimum number of ice crystals
per by each µg of dust

dust mixing with pollutants & implications

dust and ice nucleation



SAL 2014

SAL 2013

Atlantic airflows

condensation freezing
Regime ice formation

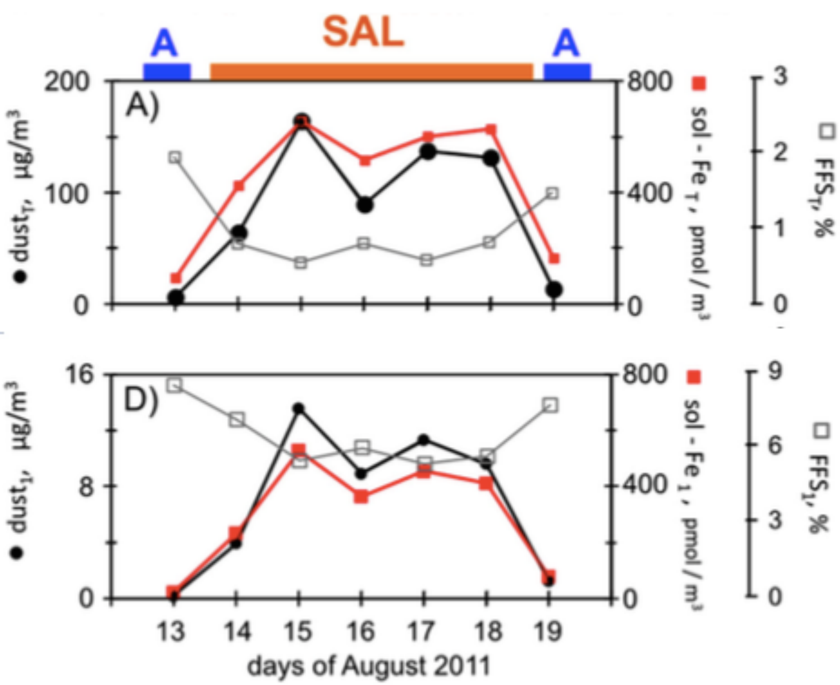
the presence of ammonium – sulphate
mixed with dust
is favouring the formation of ice crystals in the
condensation freezing regime

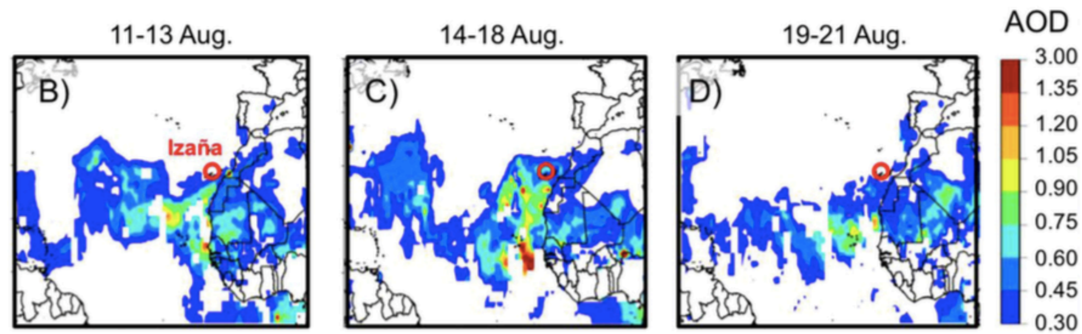
deposition regime
ice formation

dust mixing with pollutants & implications

dust, iron and ocean fertilization

We studied iron solubility in the Saharan Air Layer





Atmospheric Environment 133 (2016) 49–59

Soluble iron dust export in the high altitude Saharan Air Layer

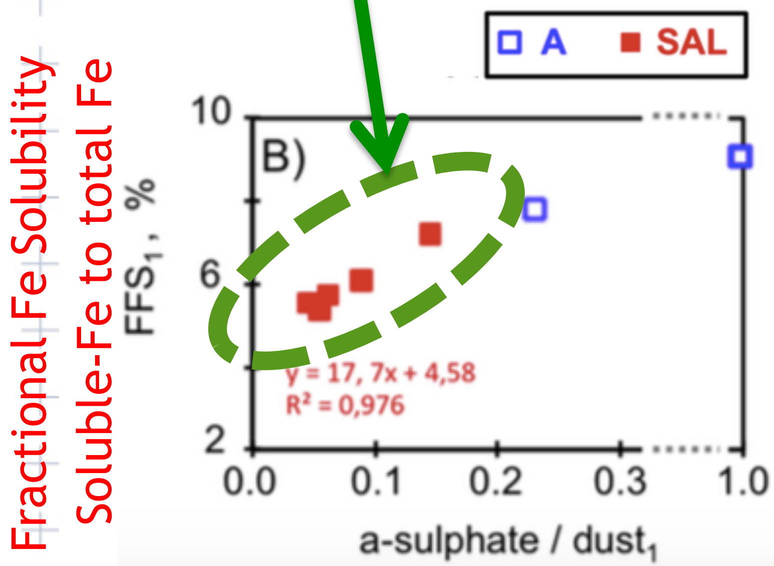
L.M. Ravelo-Pérez [a], S. Rodríguez [b,*], L. Galindo [c], M.I. García [b,c], A. Alastuey [d], J. López-Solano [b]

dust mixing with pollutants & implications

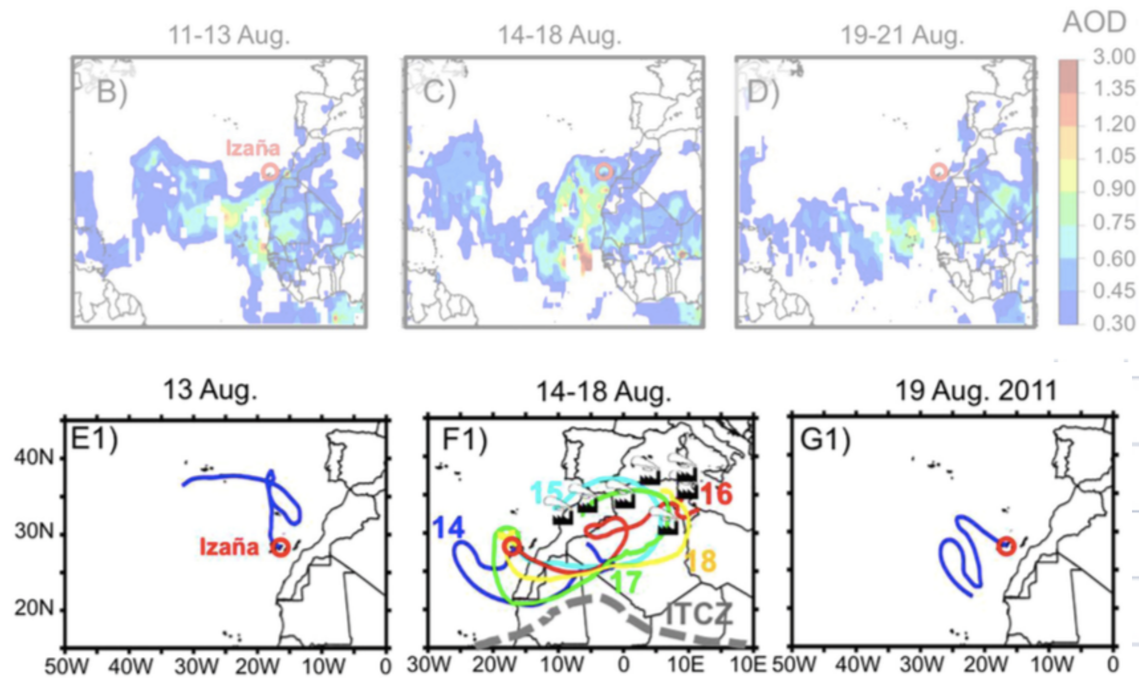
dust, iron and ocean fertilization

We studied iron solubility in the Saharan Air Layer.

We found that the presence of ammonium sulphate in the SAL is associated with a higher fractional iron solubility



ammonium-sulphate to dust



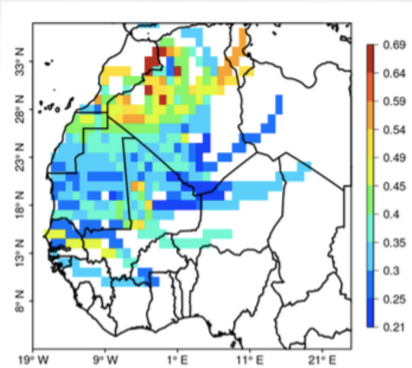
Outline

long term variability in the Saharan Air Layer.....

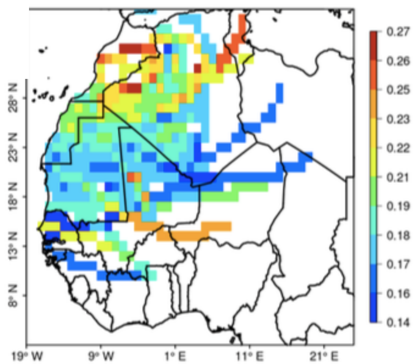
- -dust
- -dust mixing with pollutants
- -dust composition

Izaña samples and back-trajectories

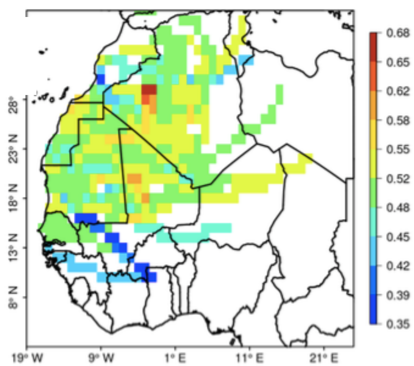
Ca / Al

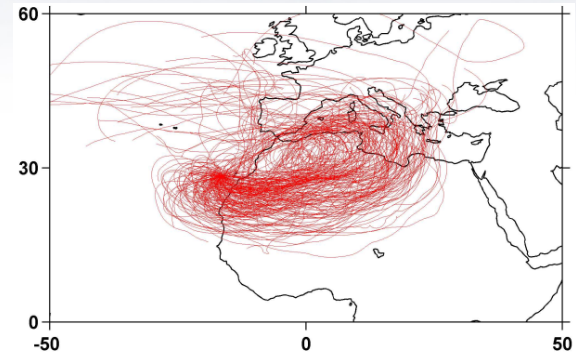


Mg / Al



Fe / Al



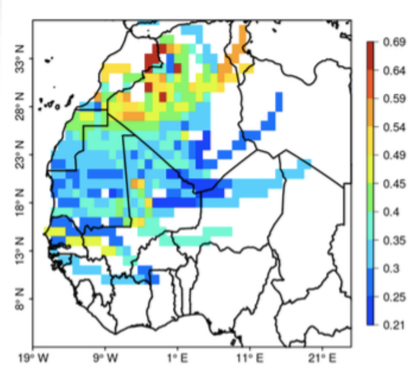


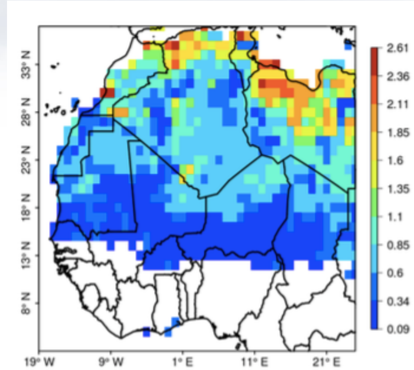
Izaña samples and back-trajectories

GISS emission map NASA

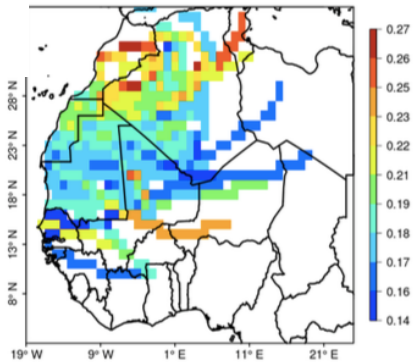
Perez et al., 2016. GLR, submitted

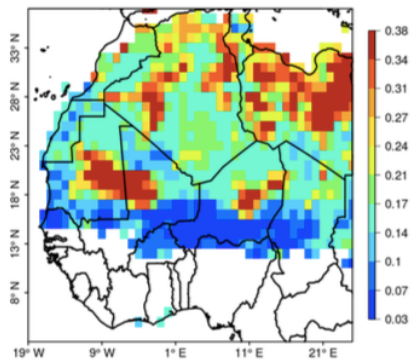
Ca / Al



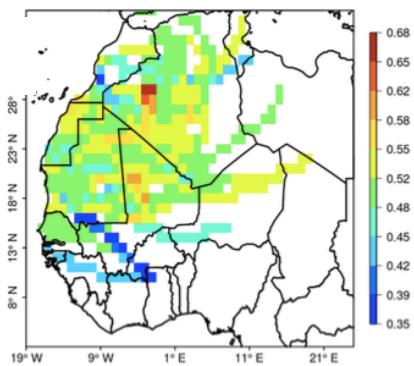


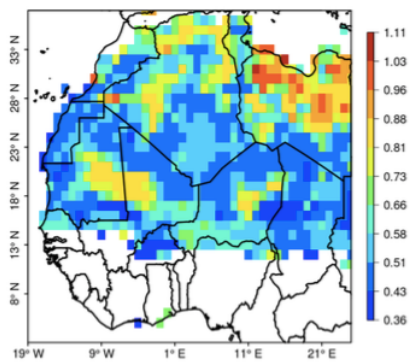
Mg / Al





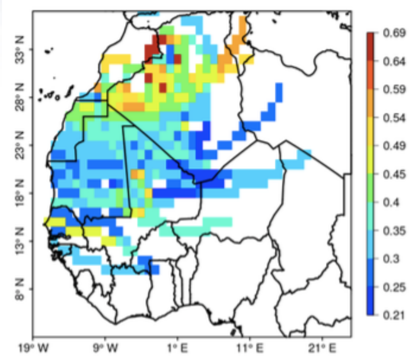
Fe / Al



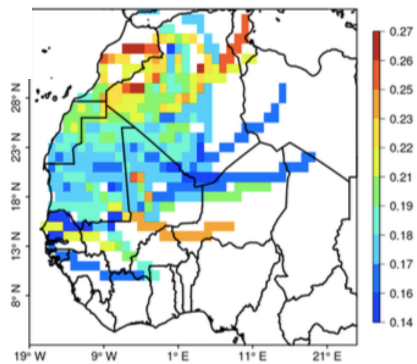


Izaña samples and back-trajectories

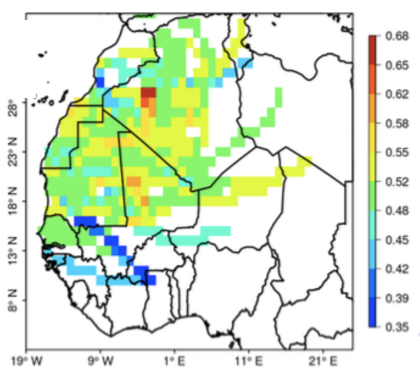
Ca / Al

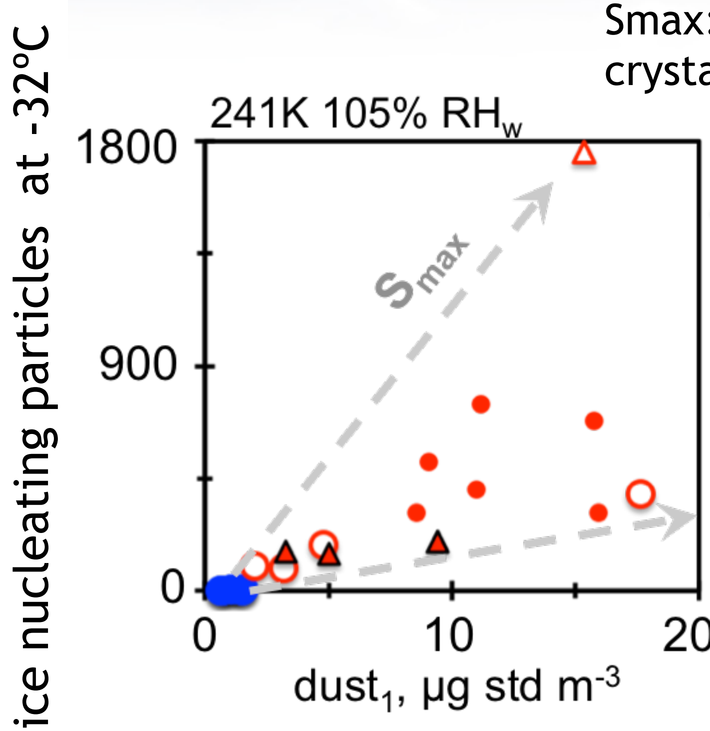


Mg / Al



Fe / Al





Smax: maximum number of ice crystals per by each µg of dust

variability in dust mineralogy

S_{min}

minimum number of ice crystals per by each µg of dust

Highlights

long term variability in the Saharan Air Layer.....

- -dust
  - -modulation of the North African Dipole Intensity - NAFDI
  - -amount of dust in the SAL
  - -north-south-ward shifts of the SAL
- -dust mixing with pollutants
  - -some pollutants modifying climate relevant dust properties
  - -impact of long term pollutants emissions near Sahara
- -dust composition
  - -improve long term observations of dust composition & mineralogy

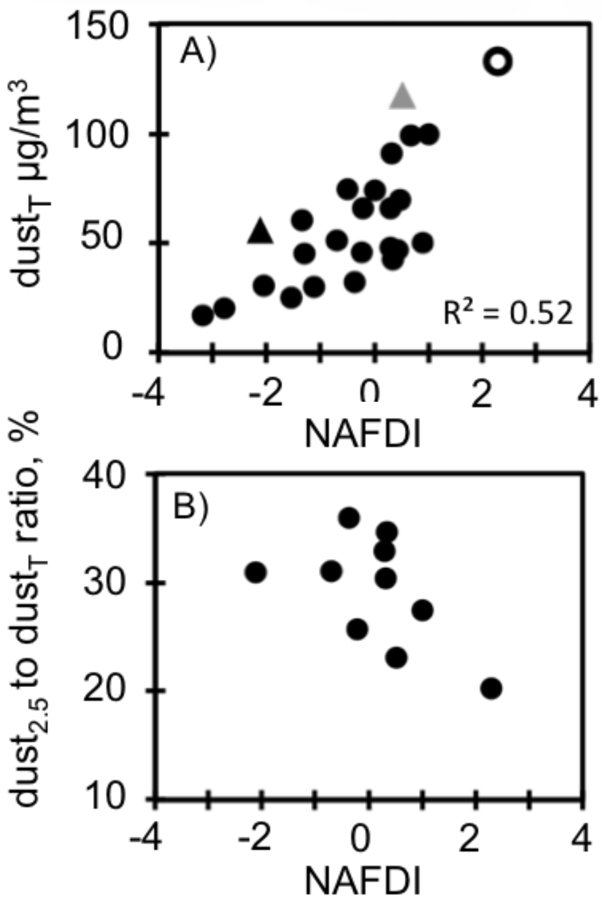
Trans-Atlantic African Dust Transport Under El Niño 2015 Scenario

M.I. GARCIA[1,2], J.M. PROSPERO[3], S. RODRIGUEZ[2], P. ZUIDEMA[3],
E. SOSA[2], A. ALASTUEY[4], F. LUCARELLI[5], G. CALZOLAI[5], J. LOPEZ-SOLANO[2]

AEROATLAN (2015-6622)

Sergio Rodríguez
srodriguezg@aemet.es
Izaña Atmospheric Research Centre, Tenerife

Size distribution: interannual variability



1987-2014 summer average

2002-2014 summer average


PM_{10}
700 µg/m³ (24-h)
Lanzarote, 2012-06-24.

Izaña: 1916-2016

Agencia Estatal de Meteorología

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