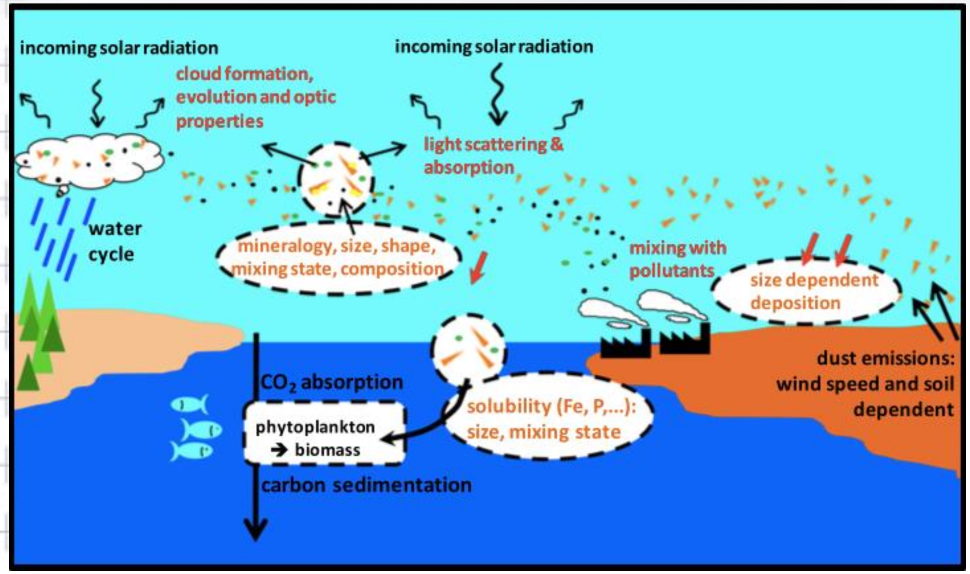
Training workshop on Sand and Dust storms in the Arab region
10-12 Feb 2018, Cairo

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 !!!

dust

dust, aerosols and pollutants

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- PM_{10} and $PM_{2.5}$ levels
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remote sensing observations:

- column properties
- altitude resolved properties

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

people live in cities and breath a cocktail dust + pollutants

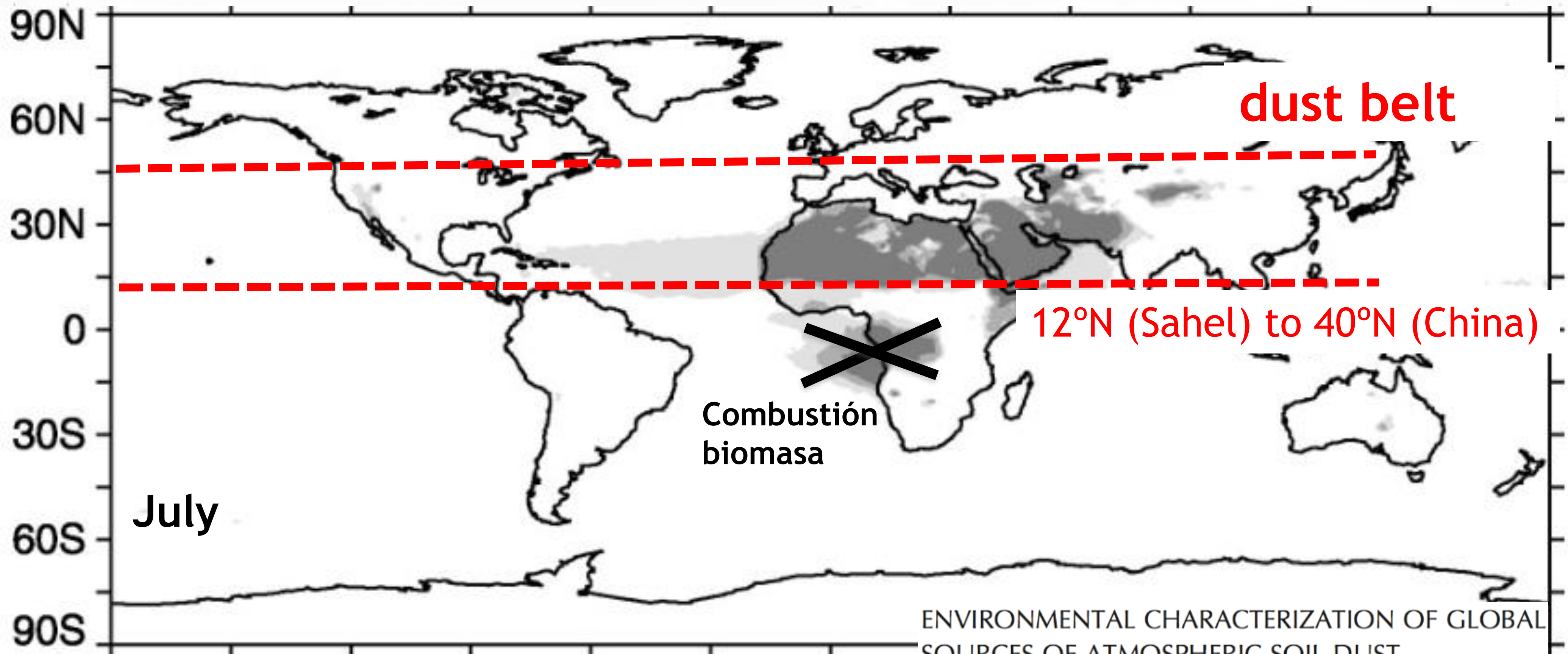
what is this dust?

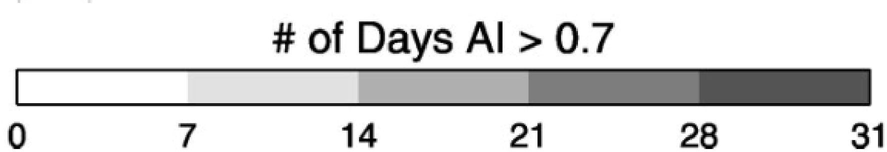
sources?

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

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 dry lakes/rivers beds

2. **chemistry and mineralogy**

   clays, feldspars, oxides, evaporites

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

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

chotts, sabkhas, wadis, salares

1. what is dust ?

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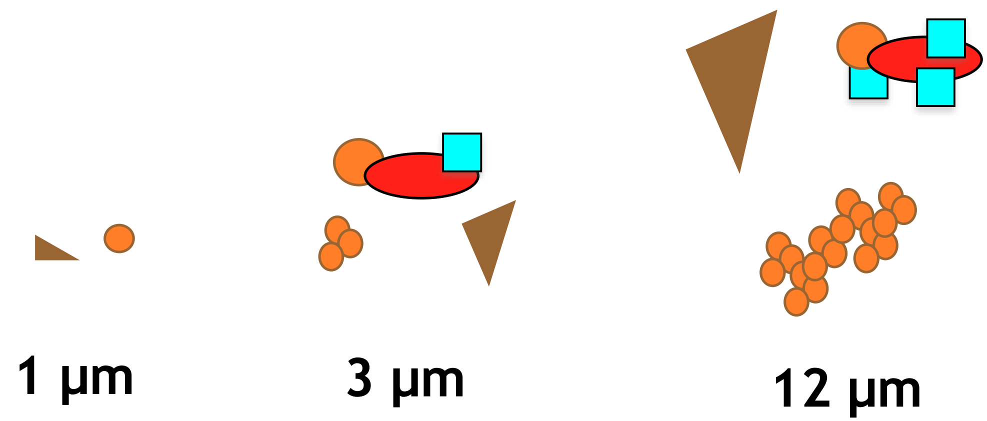
2. chemistry and mineralogy

clays, feldspars, oxides, evaporites

3. Size and morphology

1 and 20 µm
aggregates



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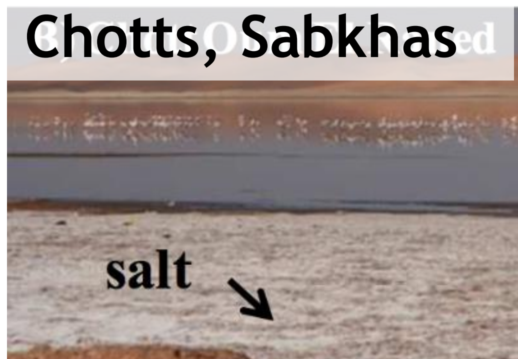
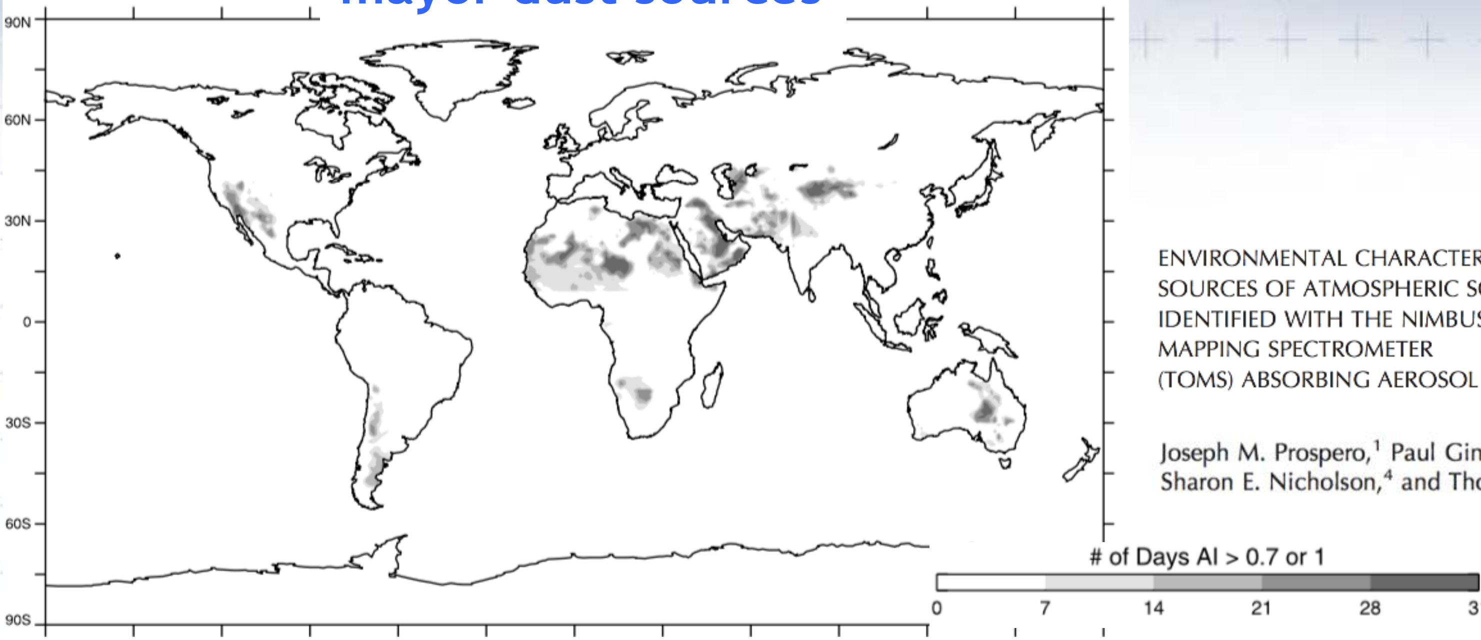


mayor dust sources



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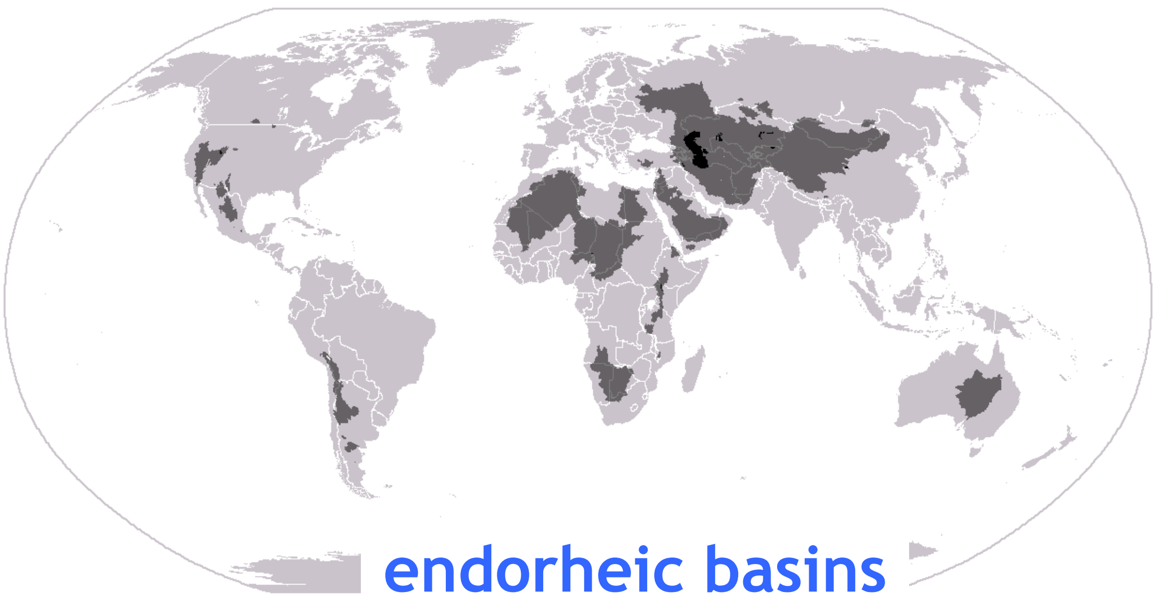
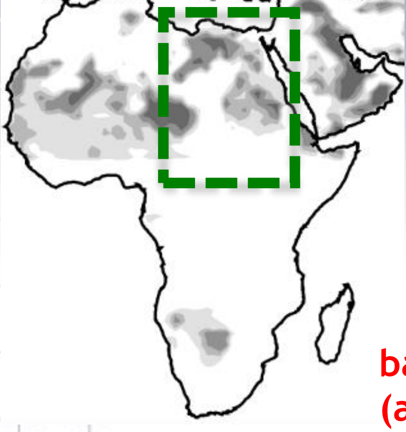


endorheic basins

no conection to sea



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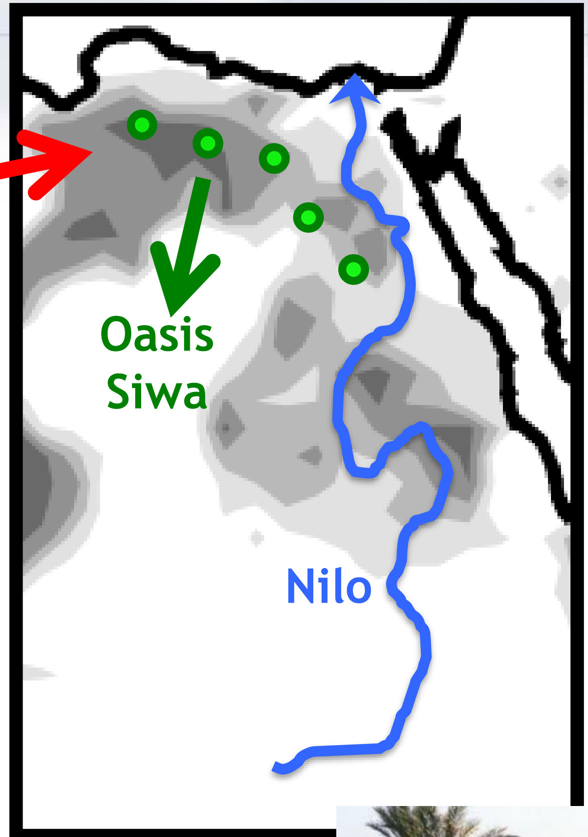
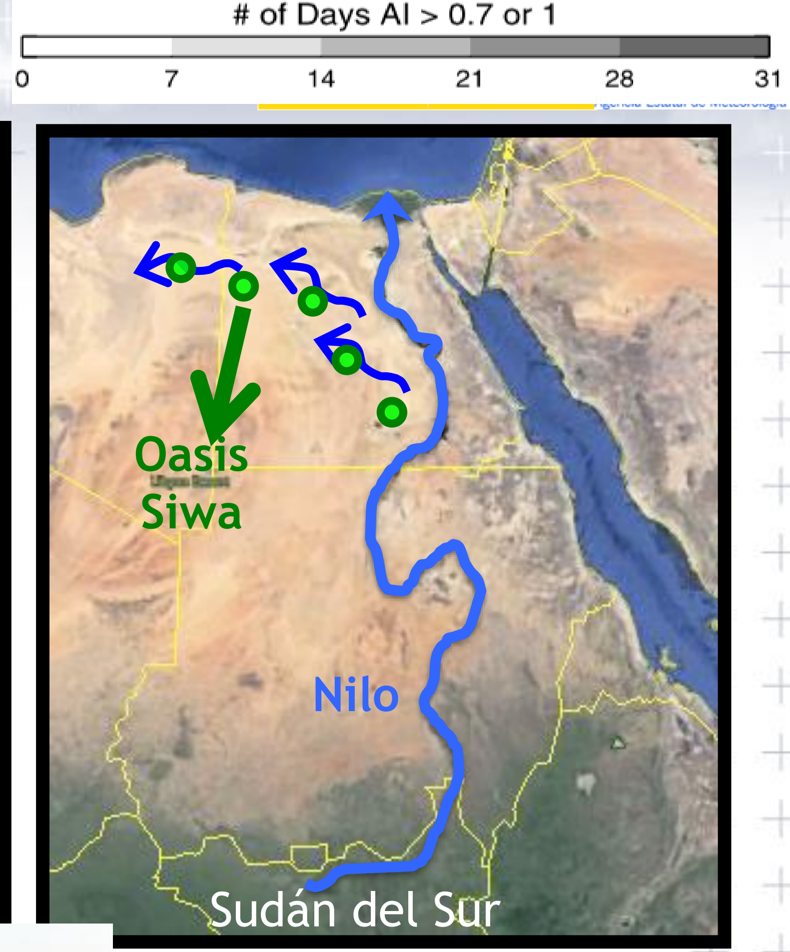


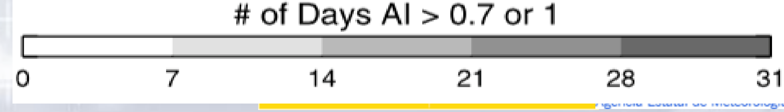


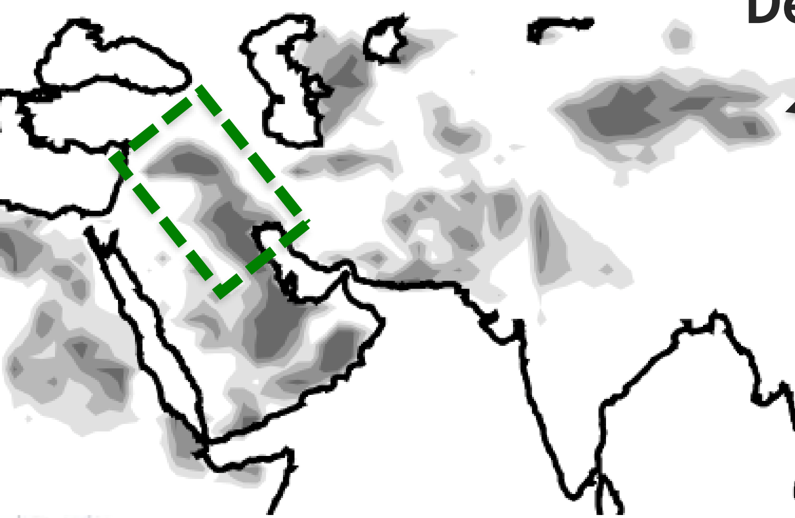
bajas topográficas
(altitudes -)

lakes, oasis,
cultivation,
underground water,
Ancient rivers

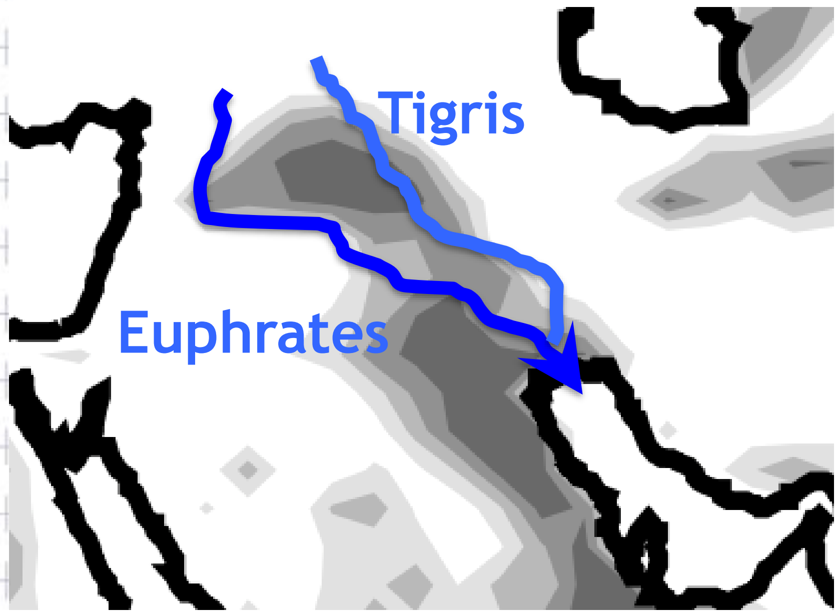
Oasis Siwa
29°13´N, 25°31'E

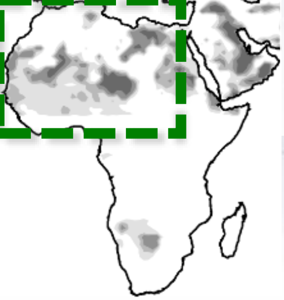
Detección satélite



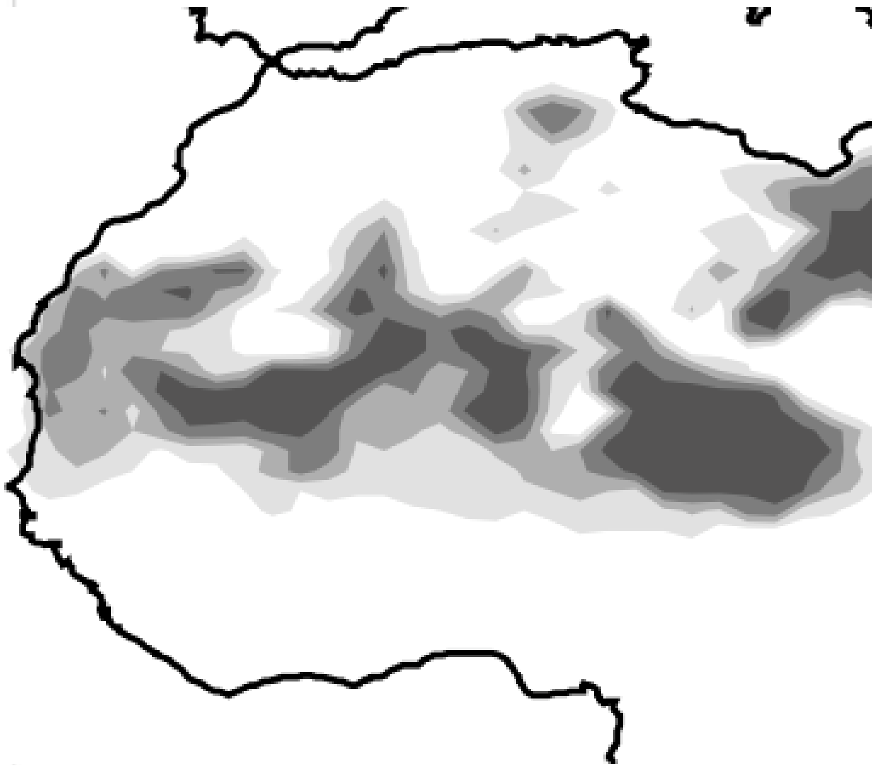


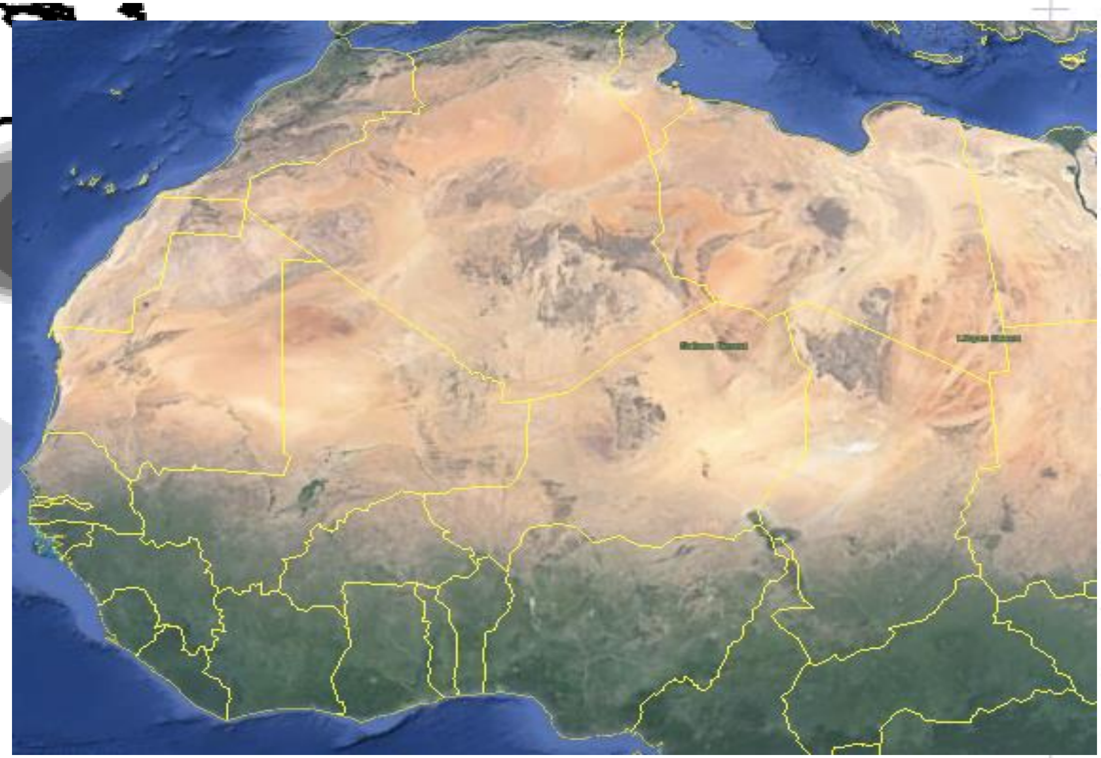
Siria-Irak





Sahara
Sahel





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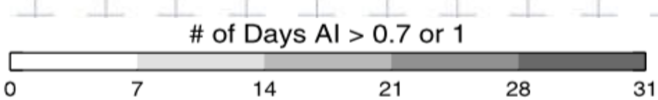
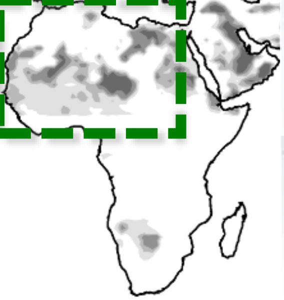
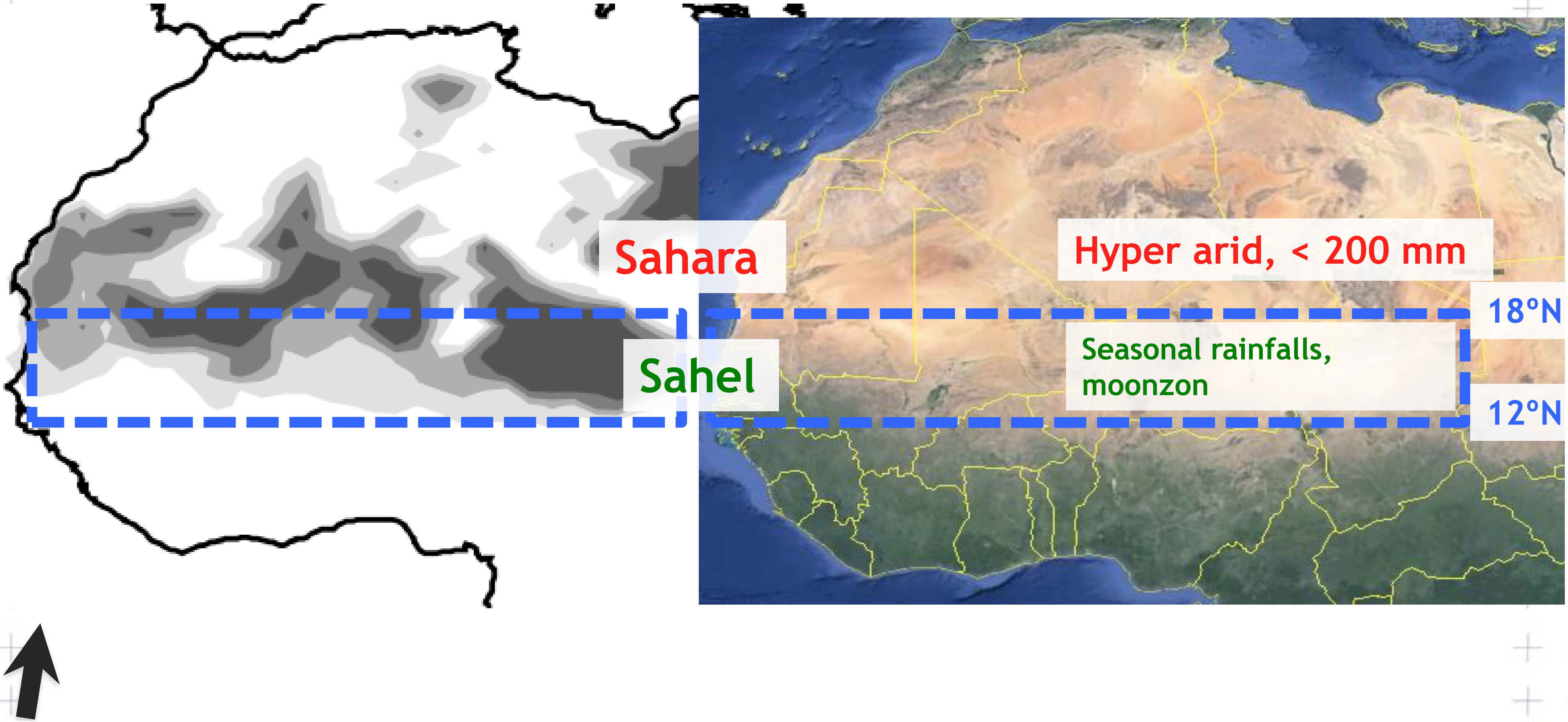




Sahara
Sahel



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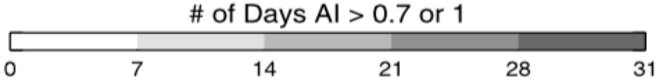
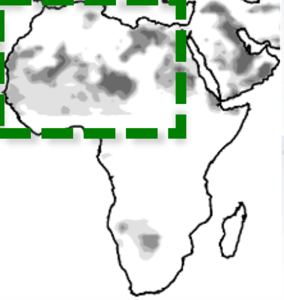
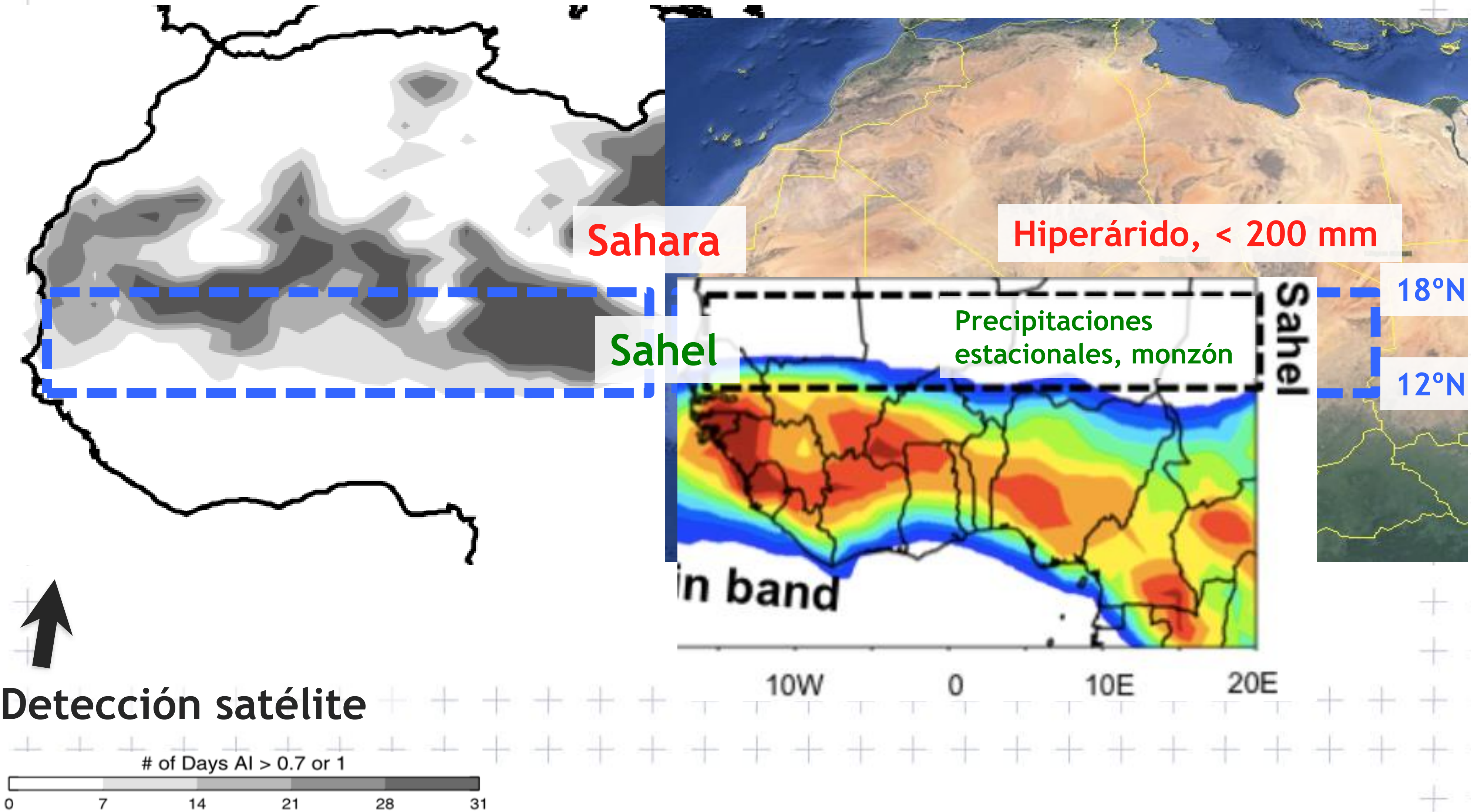
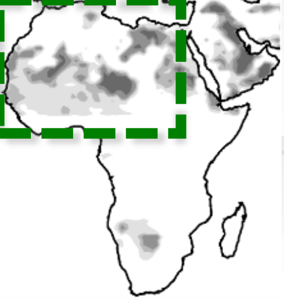


Sahel


Sahara
Sahel


Sahara
Hiperárido, < 200 mm
18°N
12°N
Sahel
Precipitaciones
estacionales, monzón
Sahel
in band
10W
0
10E
20E
Detección satélite
# of Days AI > 0.7 or 1
0
7
14
21
28
31



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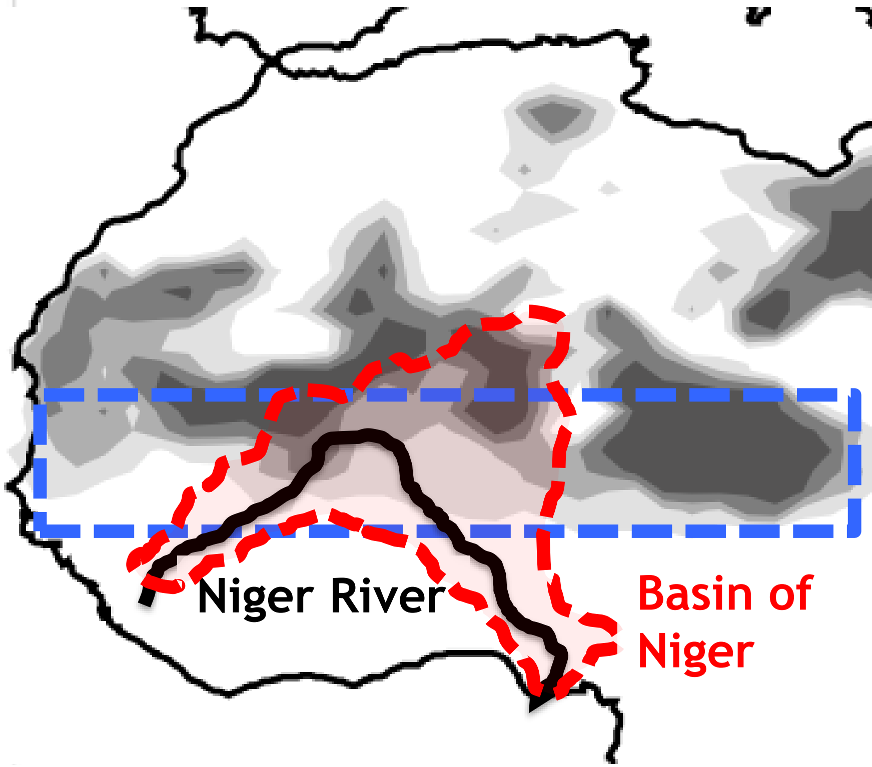
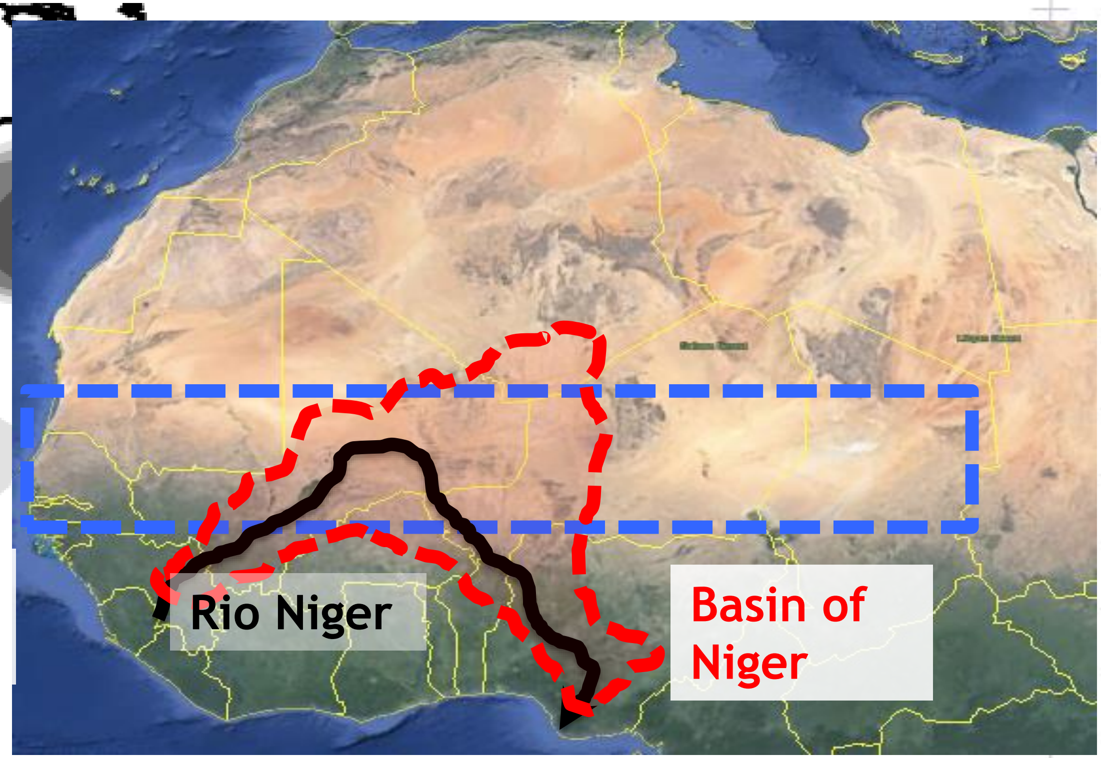
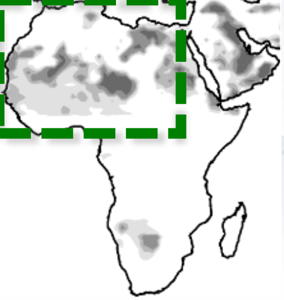
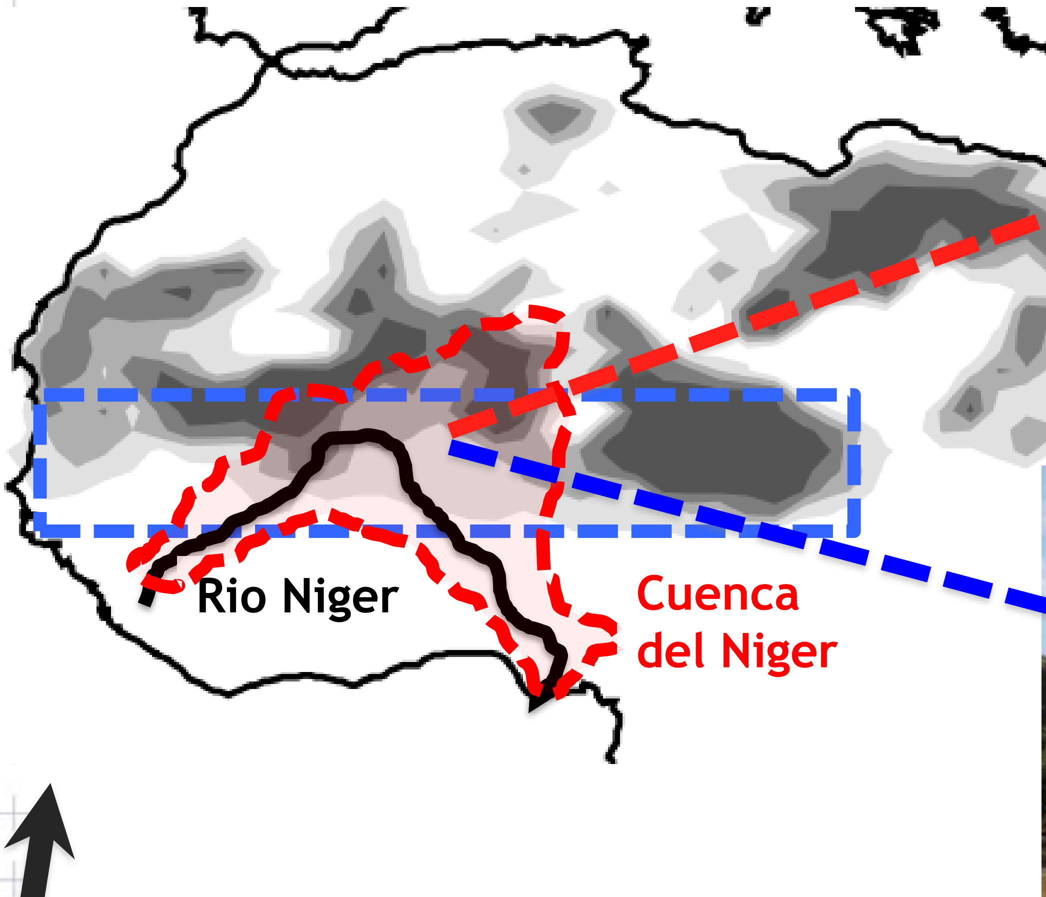




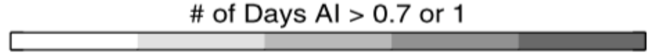
Remote Sensing satelite

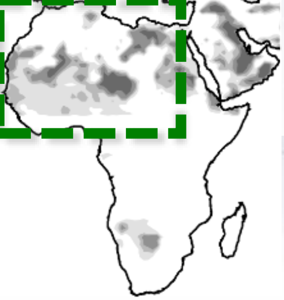


Sahel



Detección satélite





Sahara
Sahel

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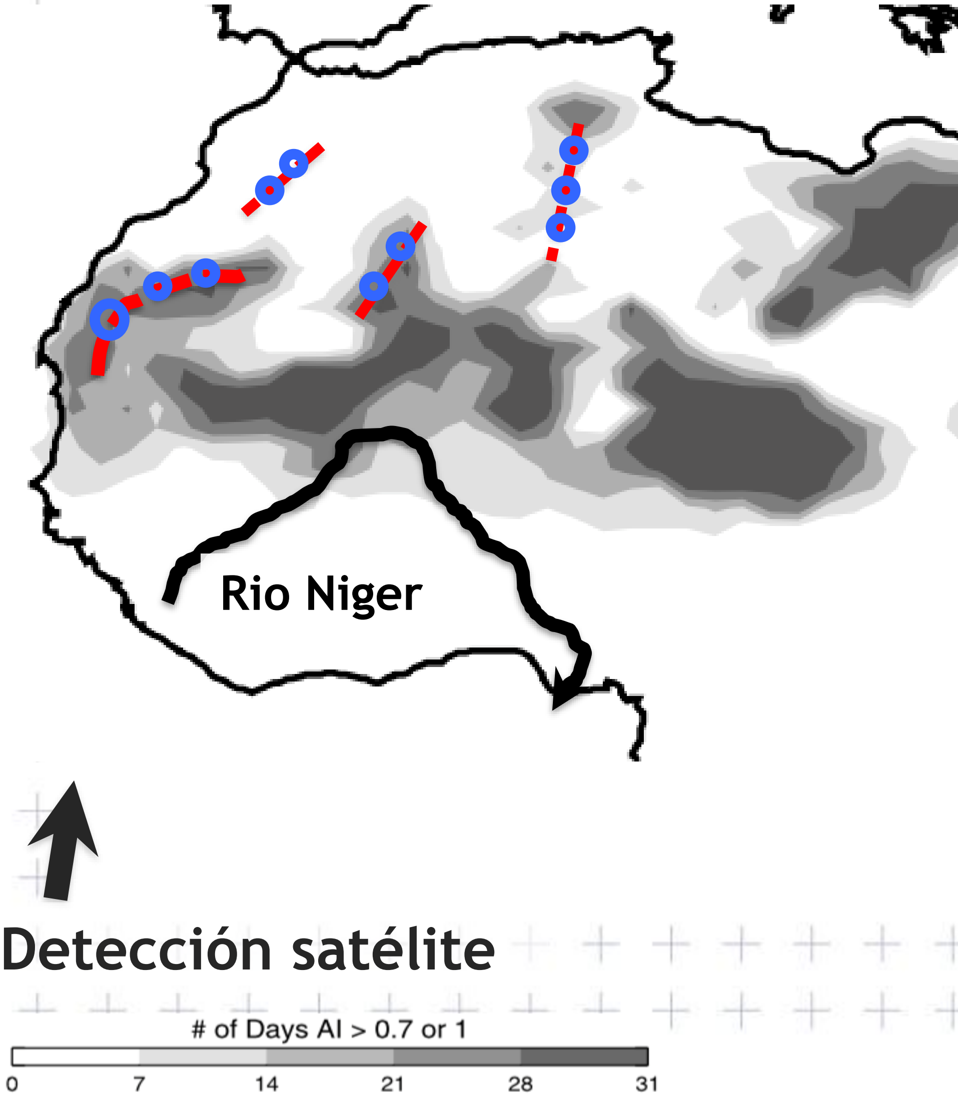
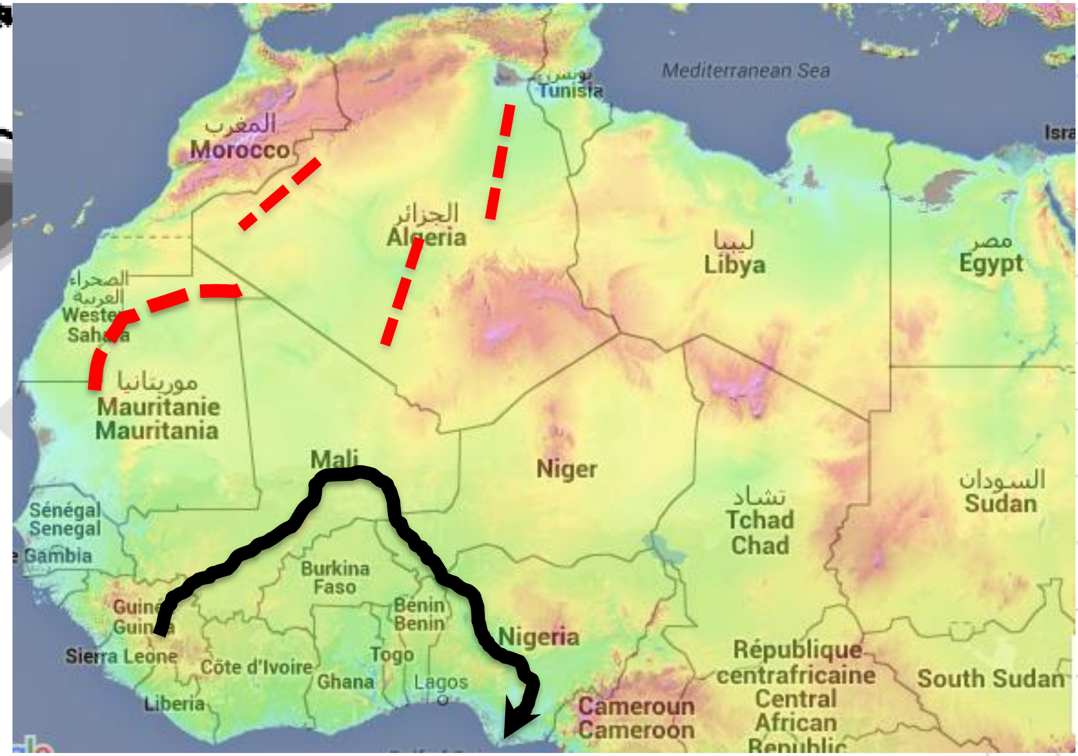
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO
AEMet Agencia Estatal de Meteorología

Sahara



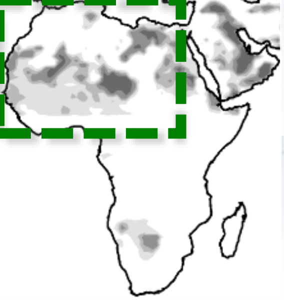


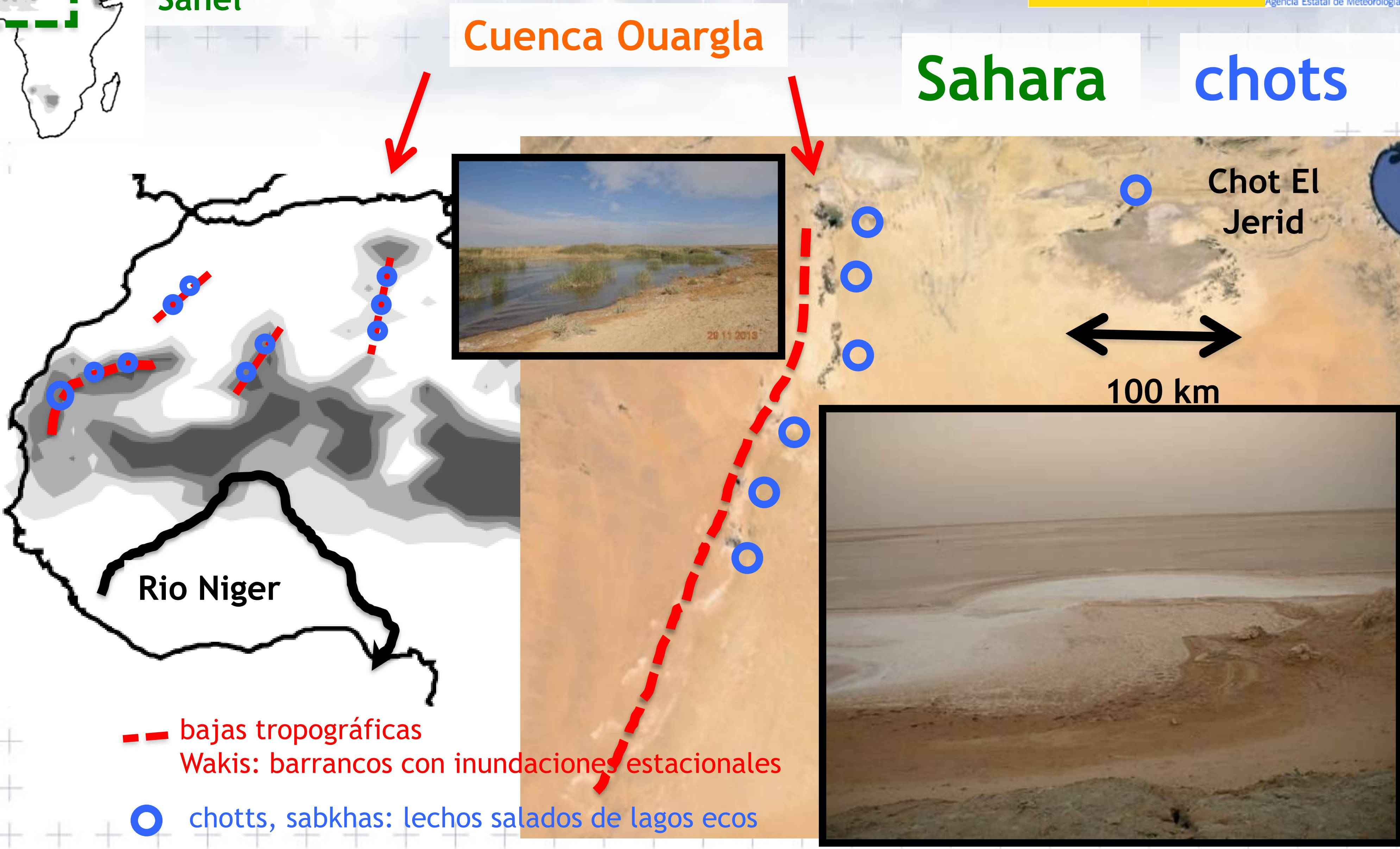
Detección satélite

bajas tropográficas
Wakis: barrancos con inundaciones estacionales

chots, sabkas: lechos salados de lagos ecos

Sahara chots





chotts, sabkhas, wadis, salares

1. what is dust ?

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

sediments, fluvial & alluvial deposits

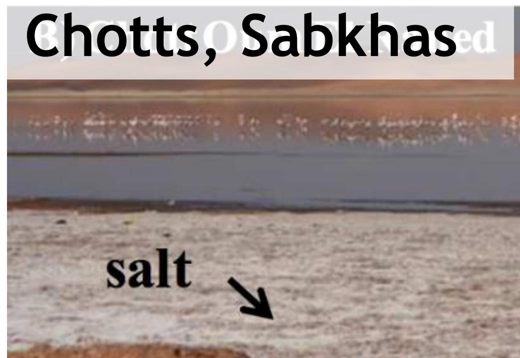
2. chemistry and mineralogy

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

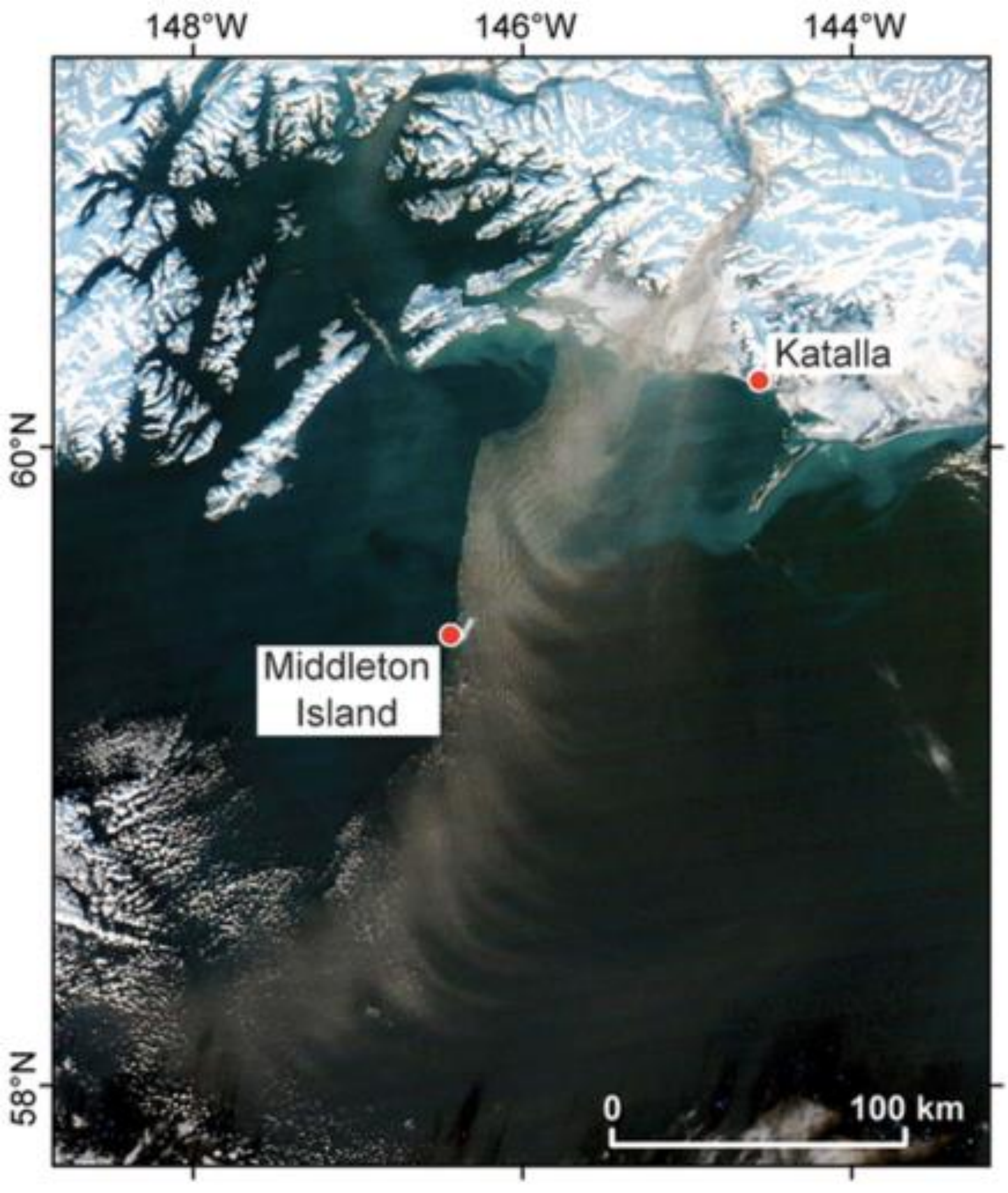
<u>Paraglacial</u> means unstable conditions caused by a significant relaxation time in processes and geomorphic patterns following <u>glacial climates</u>.

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



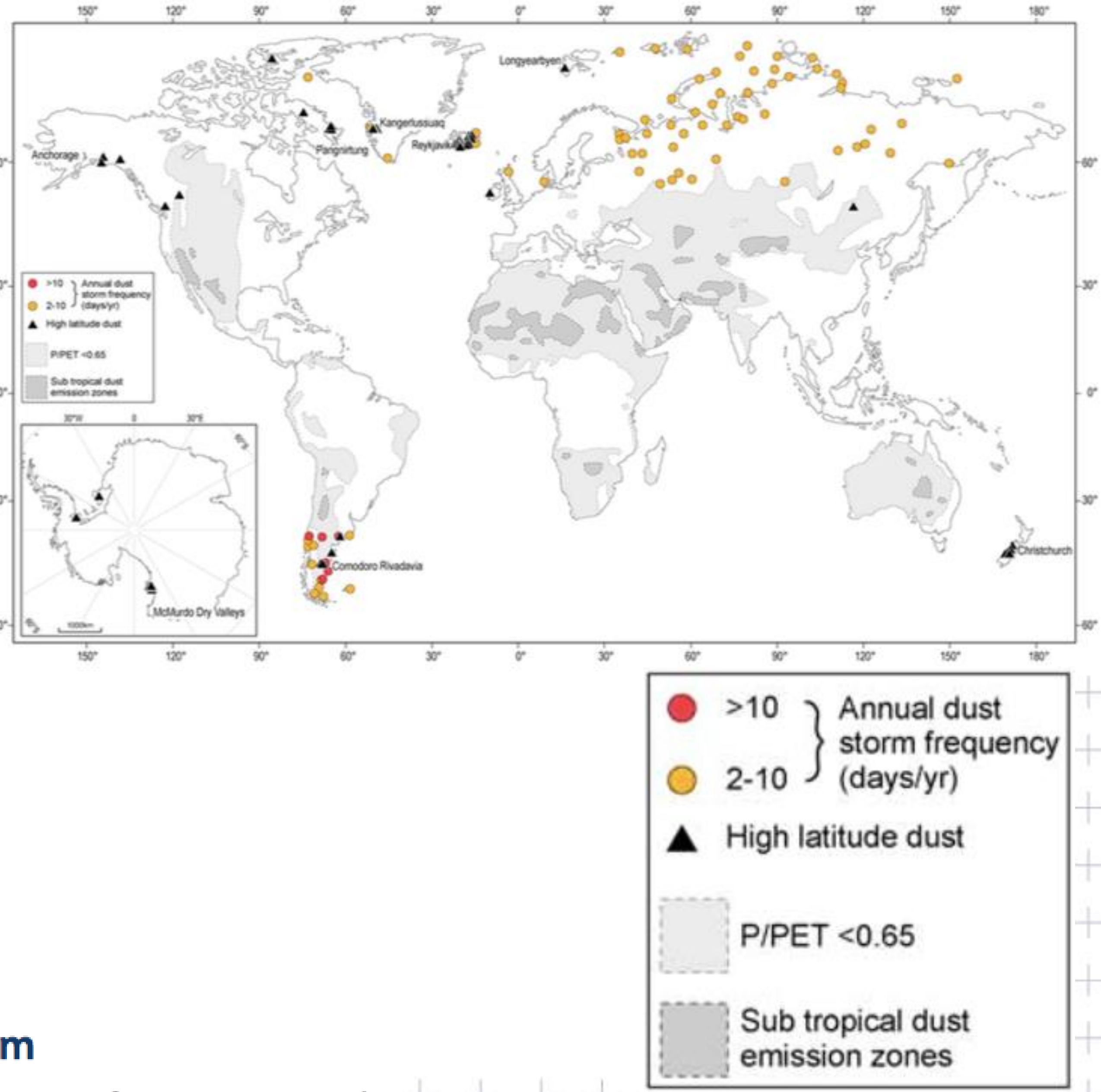
MODIS Aqua
Gulf of Alaska
4-Dec-2015

paraglacial dust

paraglacial regions:

- > 50°N
- > 40°S

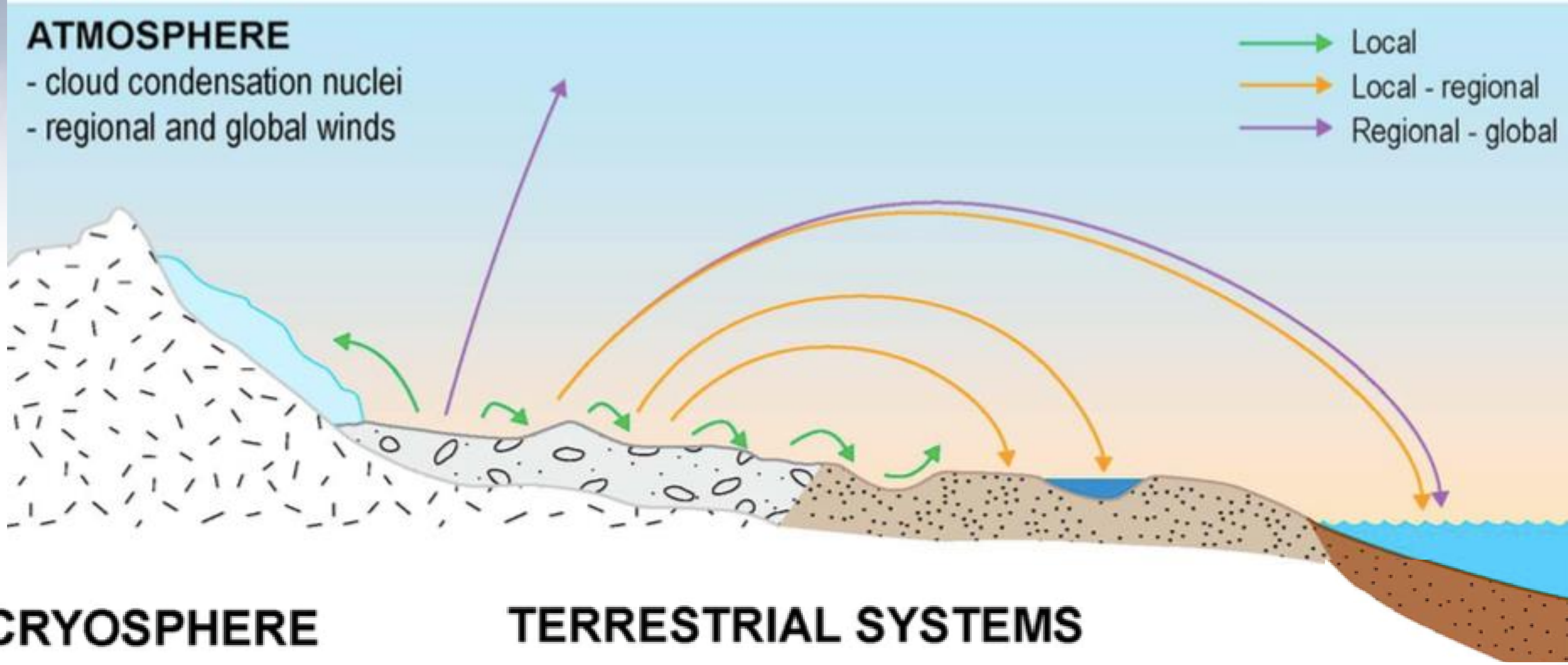
5% of global dust budget



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

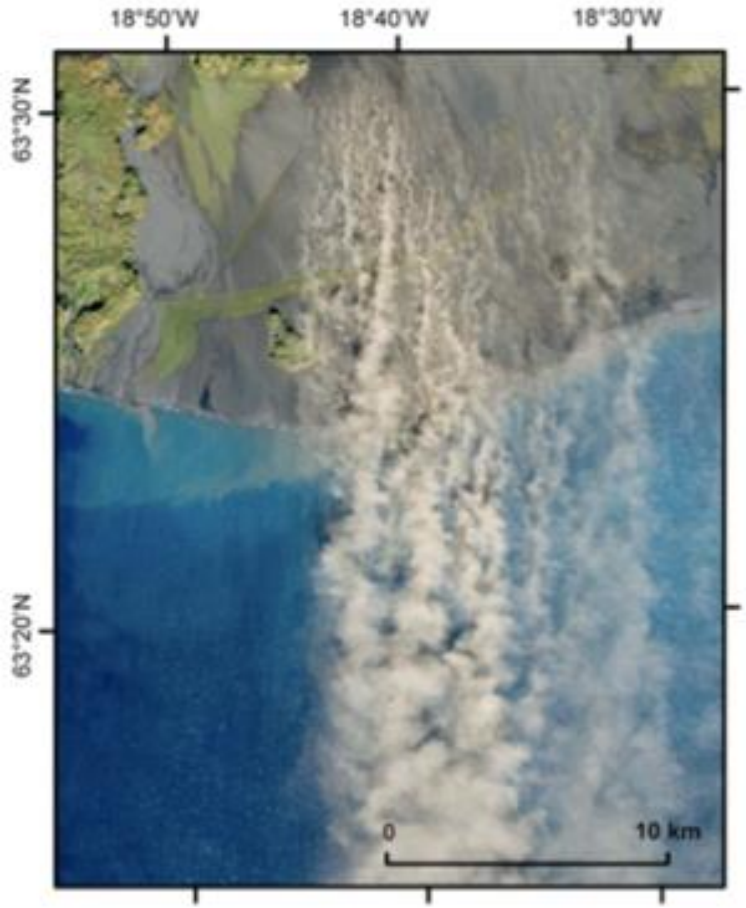
- katabatic and regional winds

MARINE

- deposition of dust and nutrients

- regional winds

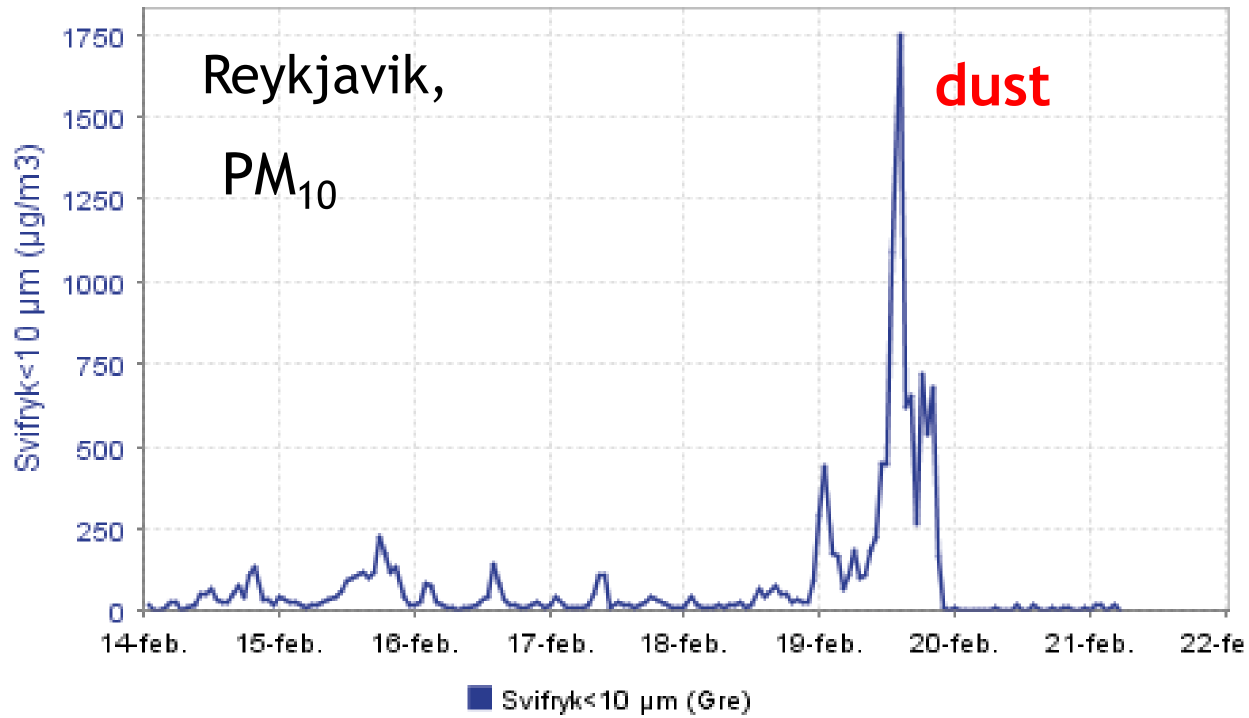
Bullard et al., 2016



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
paraglacier 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

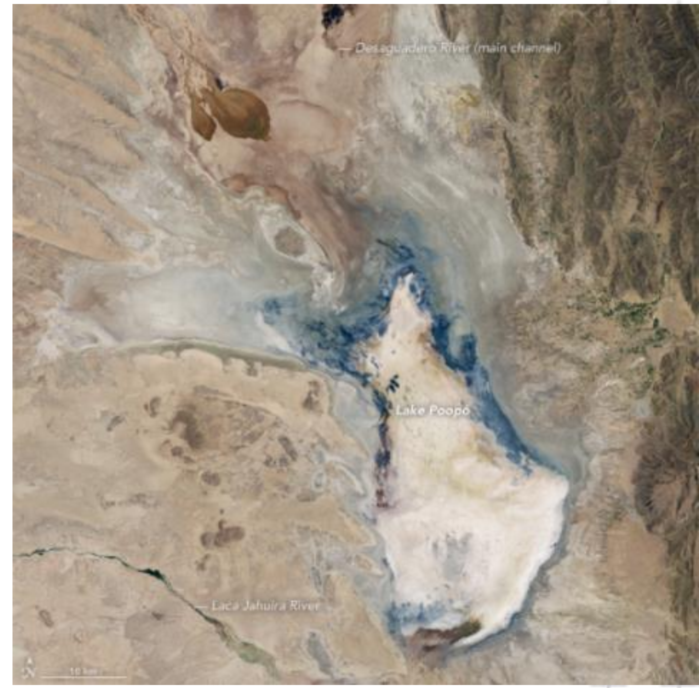
by man influence:

new climate-change-related
new lakes desiccation

EARTH OBSERVATORY
Where every day is Earth Day

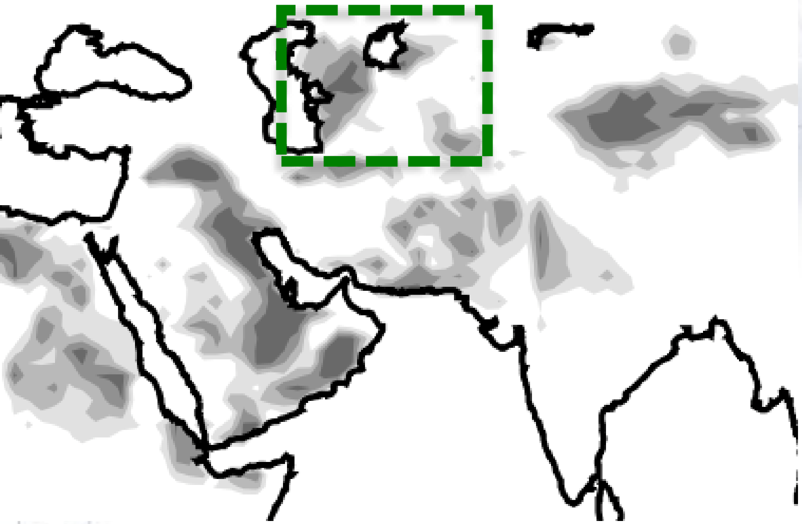
Bolivia's Lake Poopó Disappears

April 2013



Jan 2016

2015-2016 drought ENSO enhanced



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

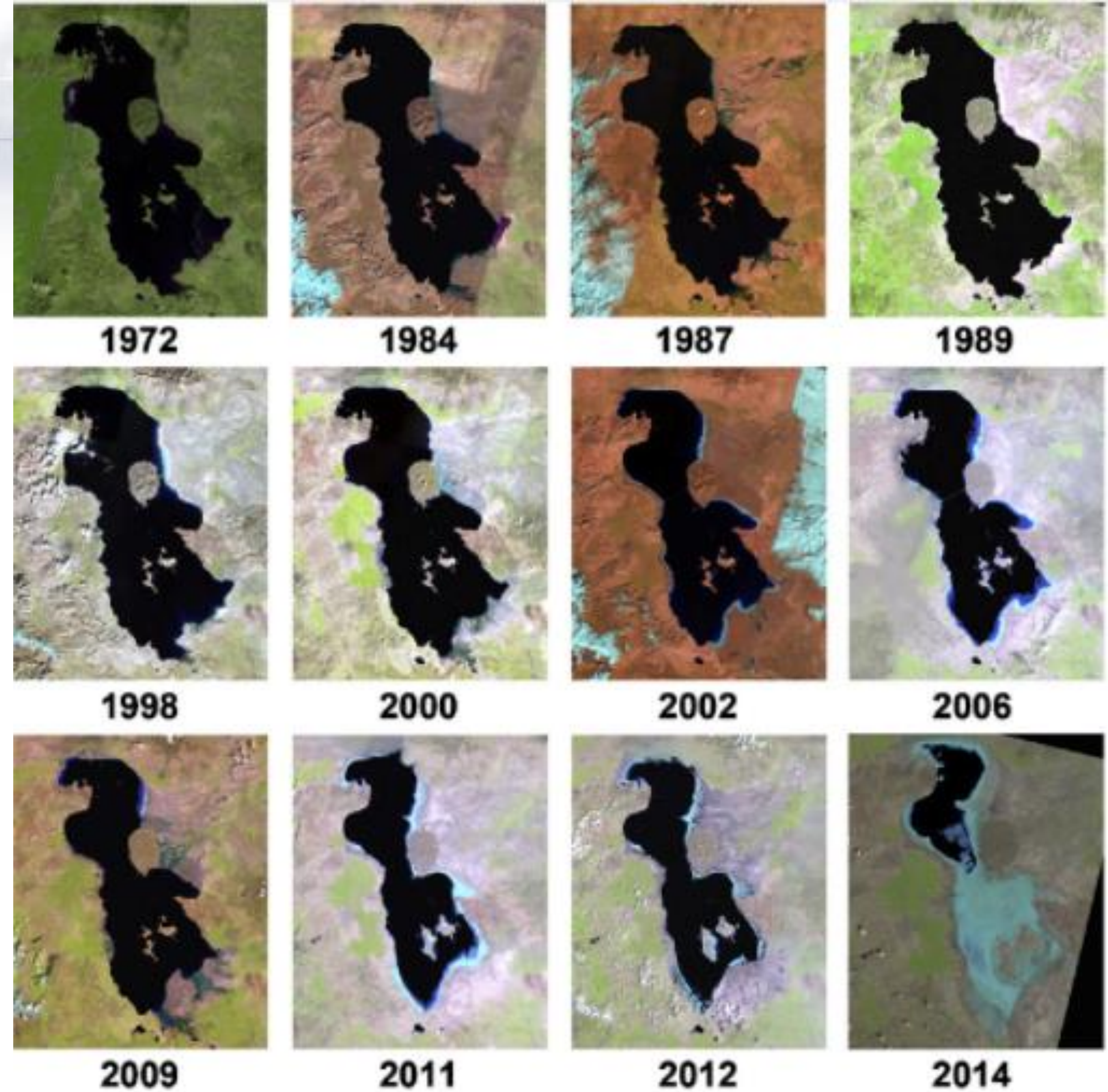
August 12, 2003

2014

Aral Sea

Urmia lake

an emerging important dust source



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

types of dust sources:

desert dust
glacier dust

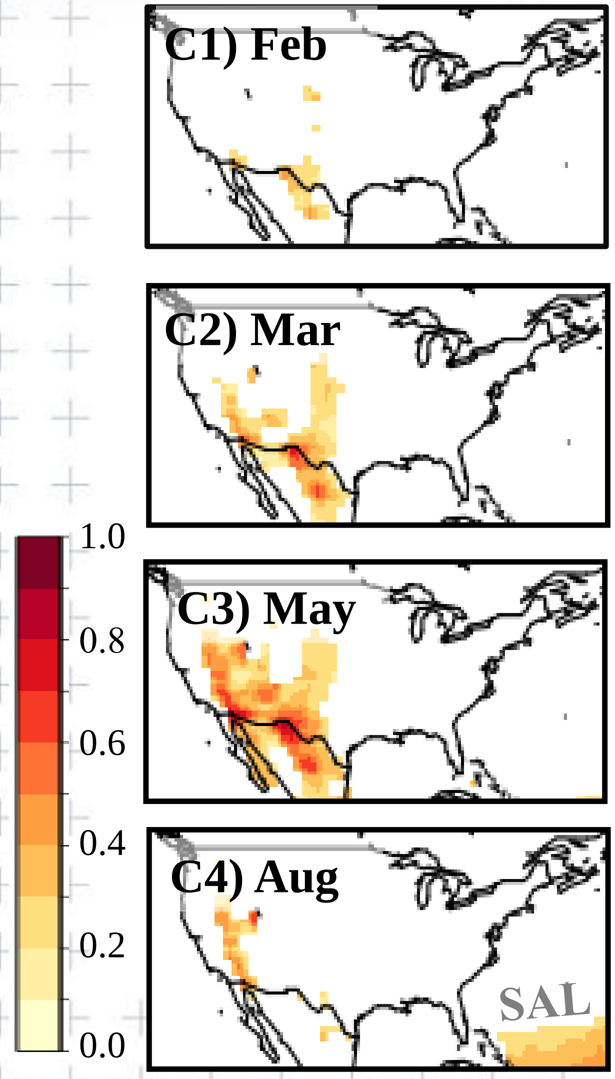
they exists by natural causes

by man influence:

new climate-change-related
new lakes desiccation
agriculture dust

Major Dust Activity Frequency

Aerosol Index > 1



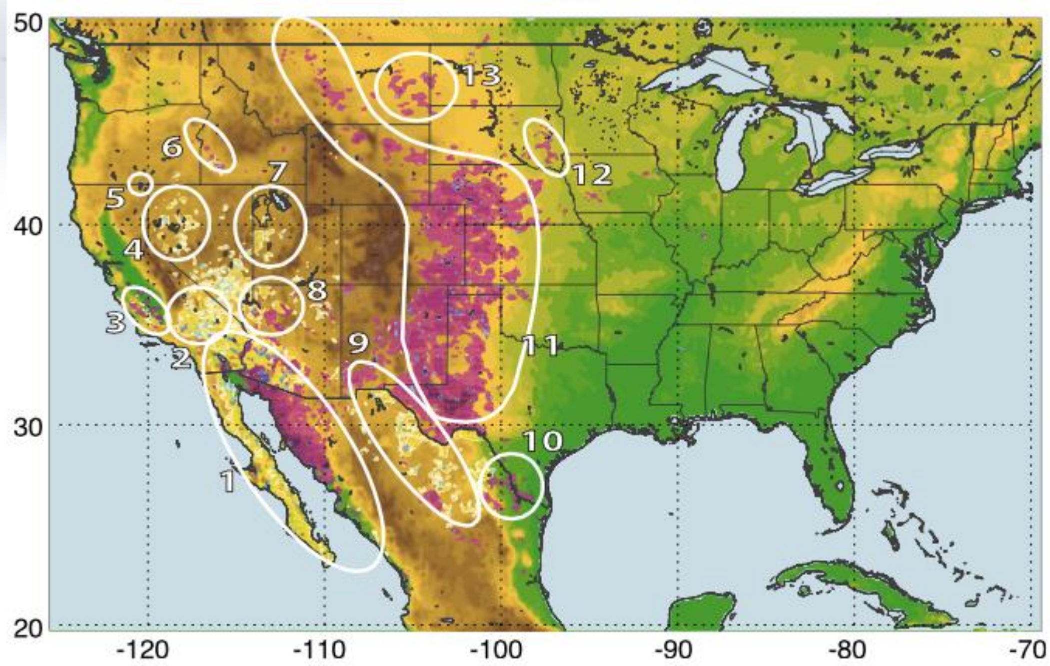
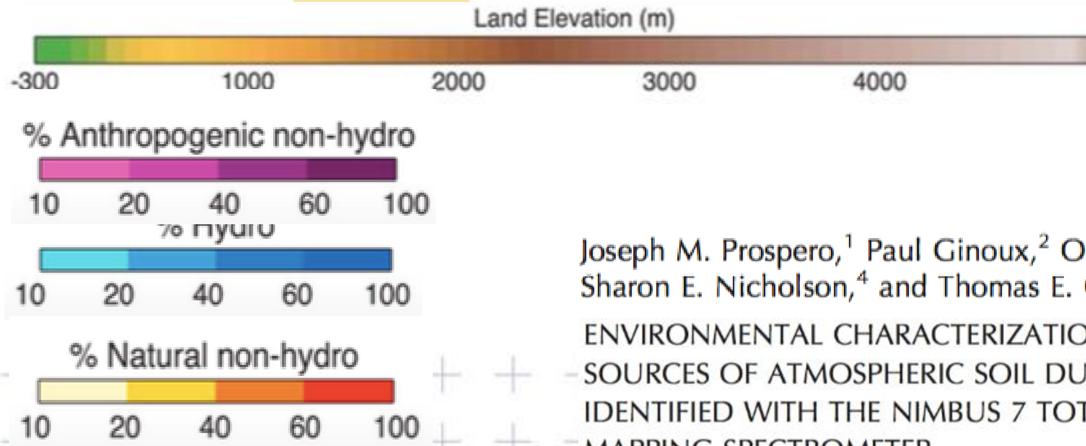


Figure 11. Distribution of the percentage number of days per season (March, April, and May) M-DB2 DOD > 0.2 over North America with color code as in Figure 6. The white circled sources are numbered as follows: 1, Sonoran Desert; 2, Mojave Desert; 3,San Joaquin Valley; 3, Black Rock-Smoke Creek deserts; 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]

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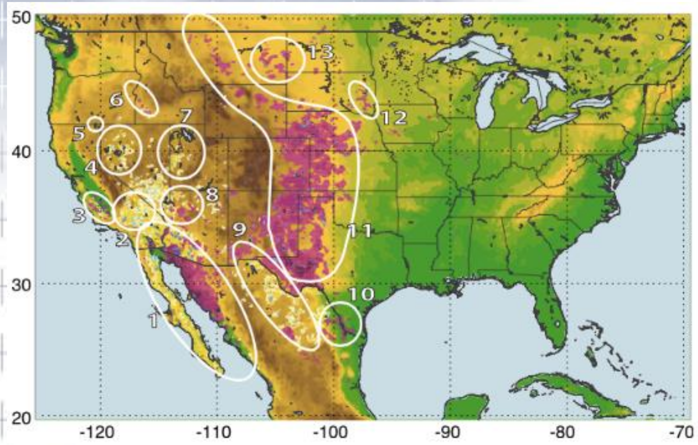
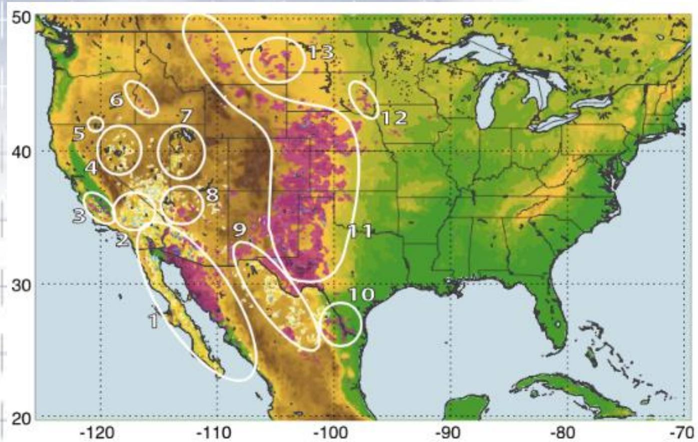
Great Plains

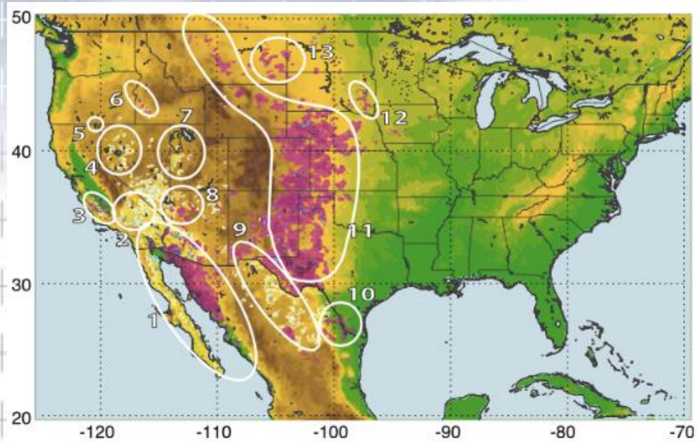


Great Plains

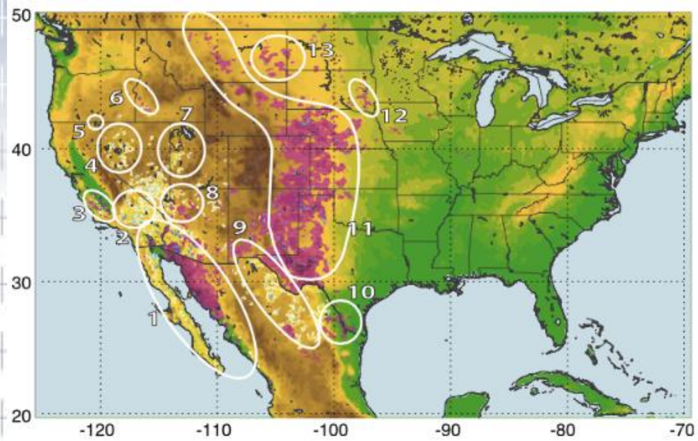


https://www.nrel.colostate.edu/projects/climate_impacts/gptoday.ht1.htm

Great Plains



Great Plains



Managing *wind erosion* on the Plains

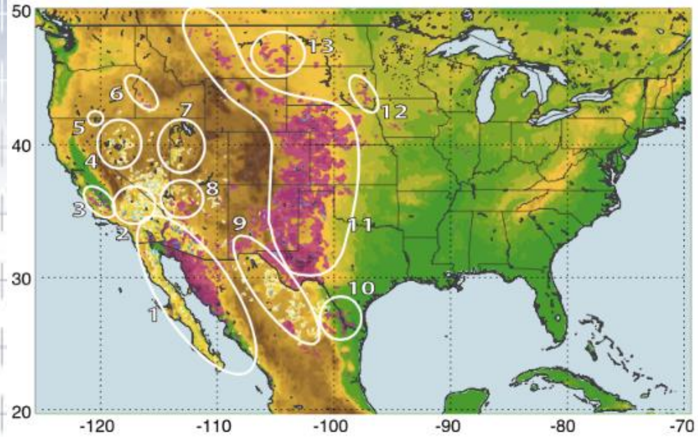
Clay Robinson

Crops & Soils Magazine - Article

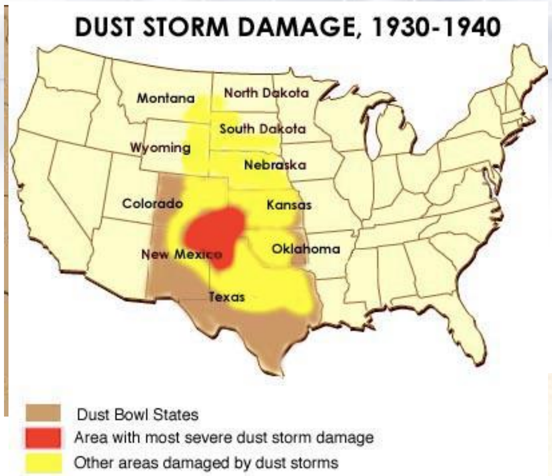
https://dl.sciencesocieties.org/publications/cns/articles/48/1/12

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

fertilizers plants

phosphate rocks

ceramic manufactures

types of dust sources:

desert dust
glacier dust

new climate-change-related
new lakes desiccation
agriculture dust

industrial dust
construction dust

construction & demolition dust

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

agriculture

construction

industry

road dust

desert 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 !!!

aerosols, a cocktail of chemicals:

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

people live in cities and breath a cocktail dust + pollutants

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

human hair: 70 µm

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aerosols, a cocktail of chemicals:

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- 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

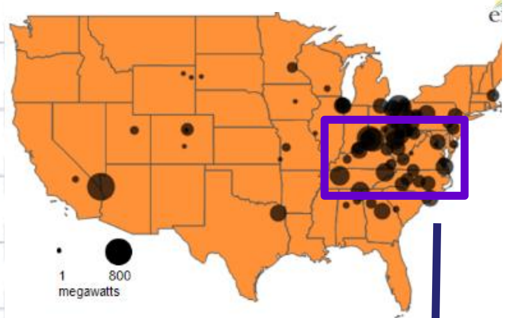
$(NH_4)_2SO_4$

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

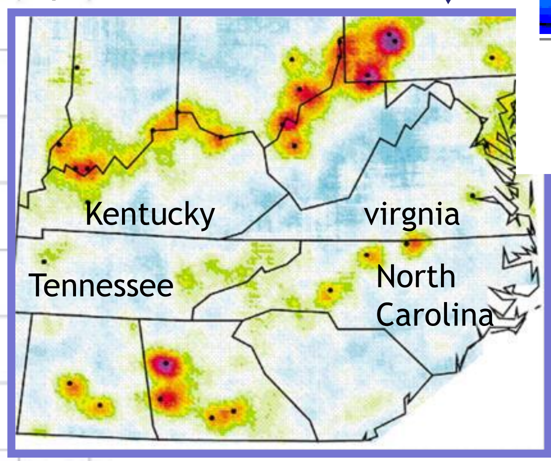
sulfato

122 Tg/y

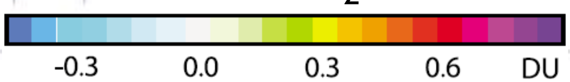
coal power plants



promedio 2005-2007



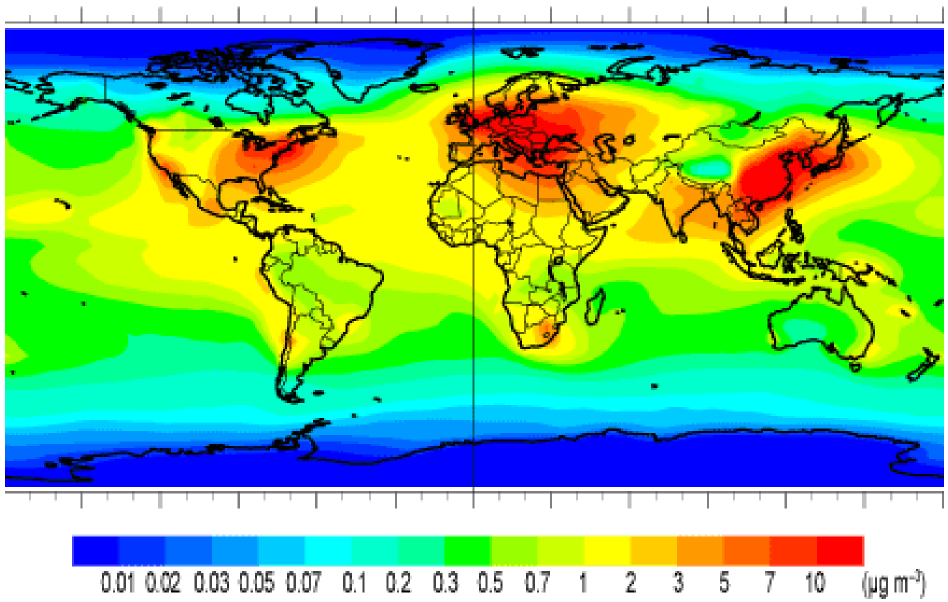
OMI SO_2 DU



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



coal power plants

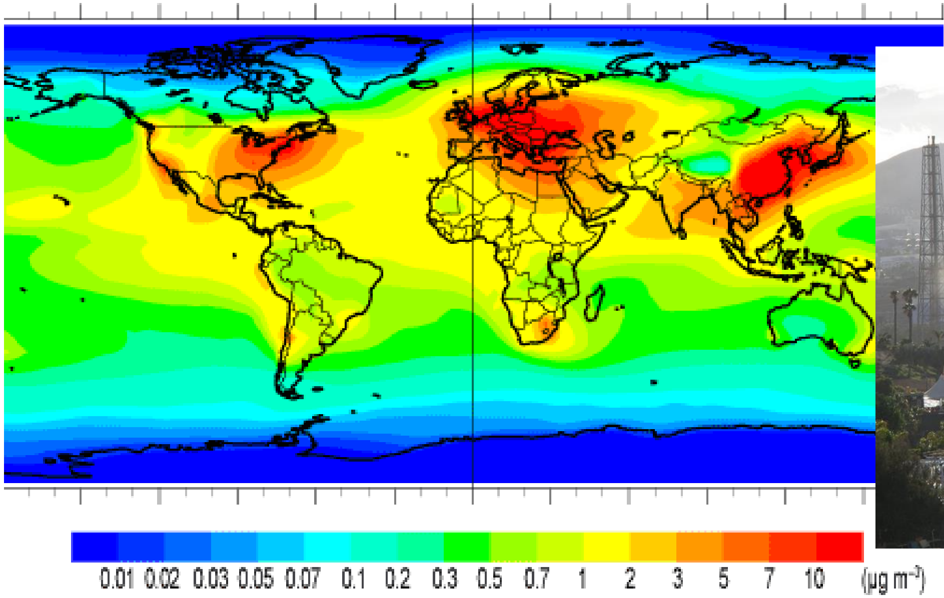
VOL. 15, NO. 4 JOURNAL OF CLIMATE 15 FEBRUARY 2002

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

sulfato

Oil refinery



Oil refinery

ships

aerosols, a cocktail of chemicals:

- dust
- sulphate
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- sea salt

gas precursor → aerosol

$SO_2 \rightarrow SO_3 \rightarrow H_2SO_4 \rightarrow SO_4^{=}$

NO / $NO_2 \rightarrow HNO_3 \rightarrow NO_3^{-}$

$NH_3 \rightarrow NH_4^{+}$

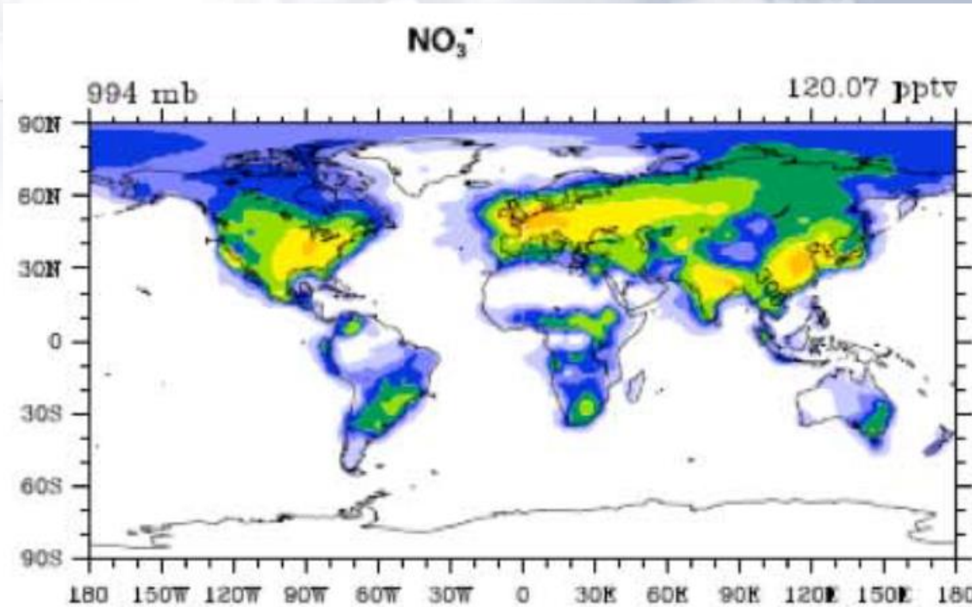
NH_4NO_3

$(NH_4)_2SO_4$

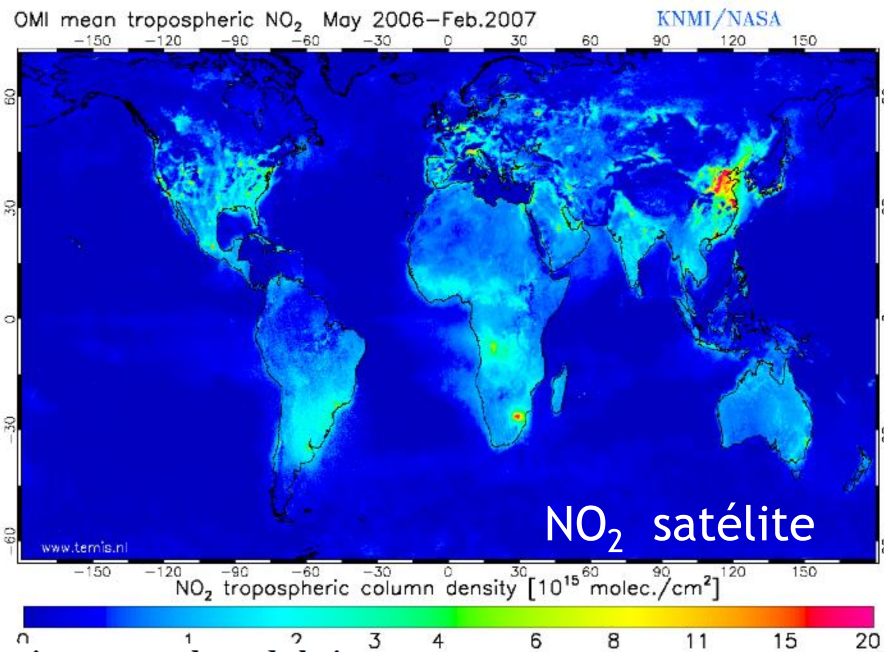
NO_x: vehicle exhaust, power plants, industry

nitrate

18 Tg/y



NH_4NO_3

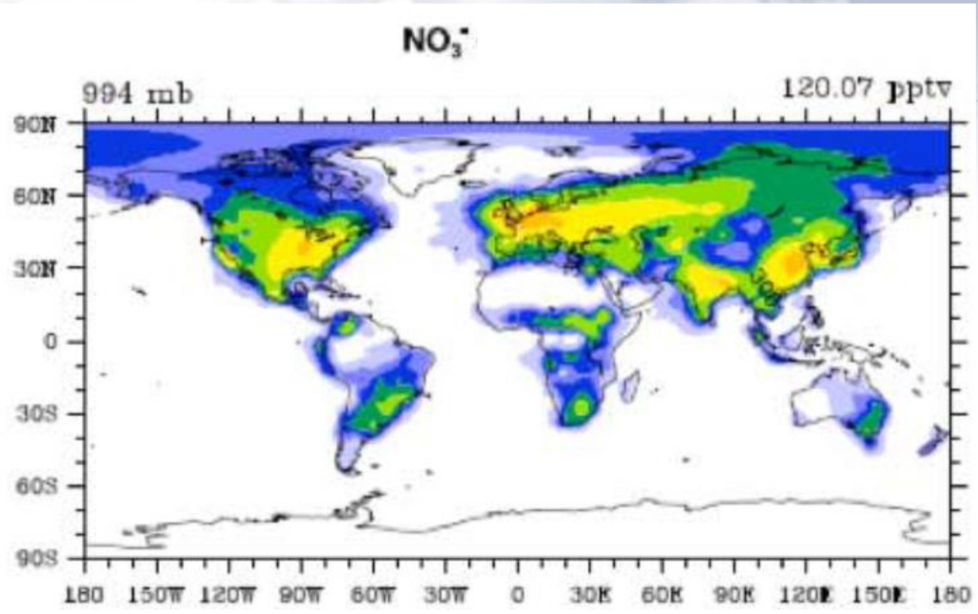


Atmos. Chem. Phys., 12, 9479–9504, 2012
www.atmos-chem-phys.net/12/9479/2012/

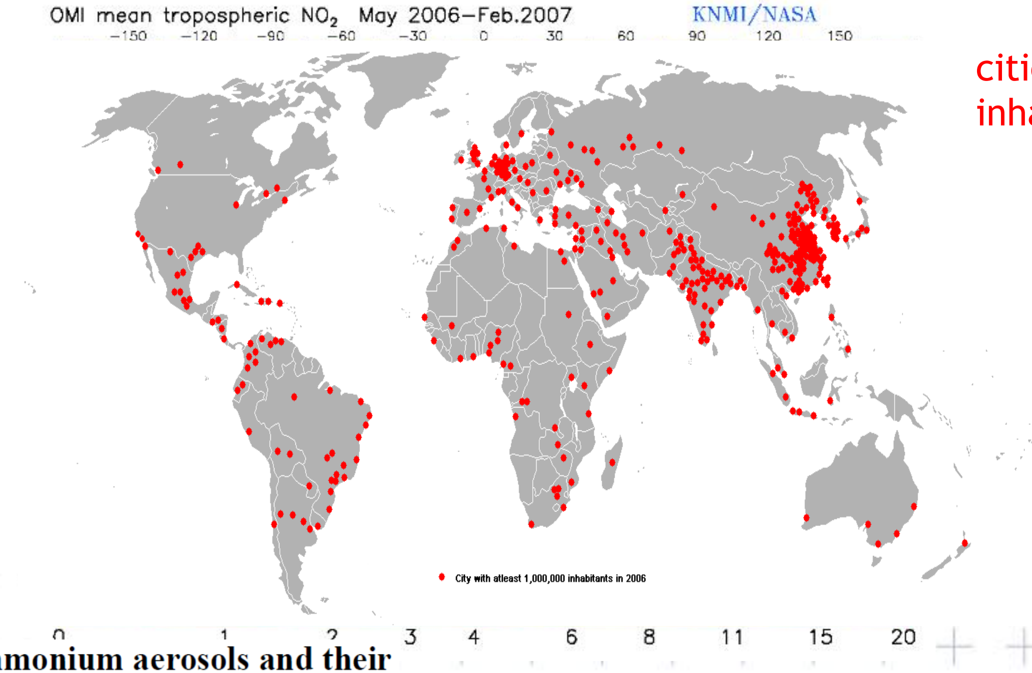
L. Xu and J. E. Penner

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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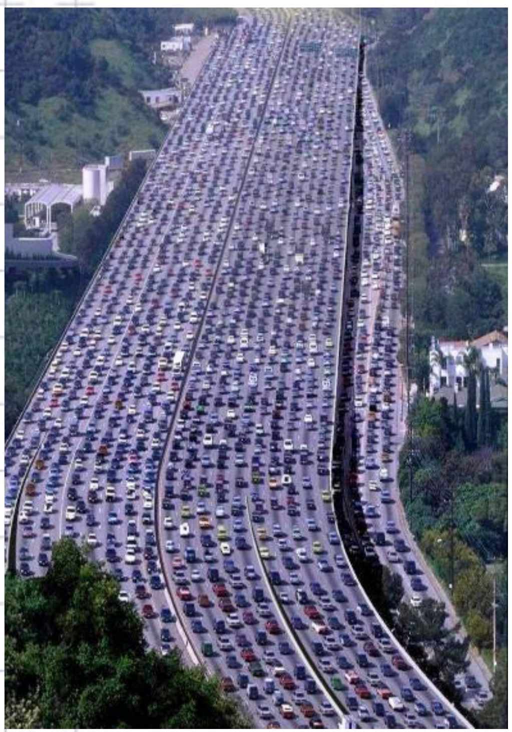
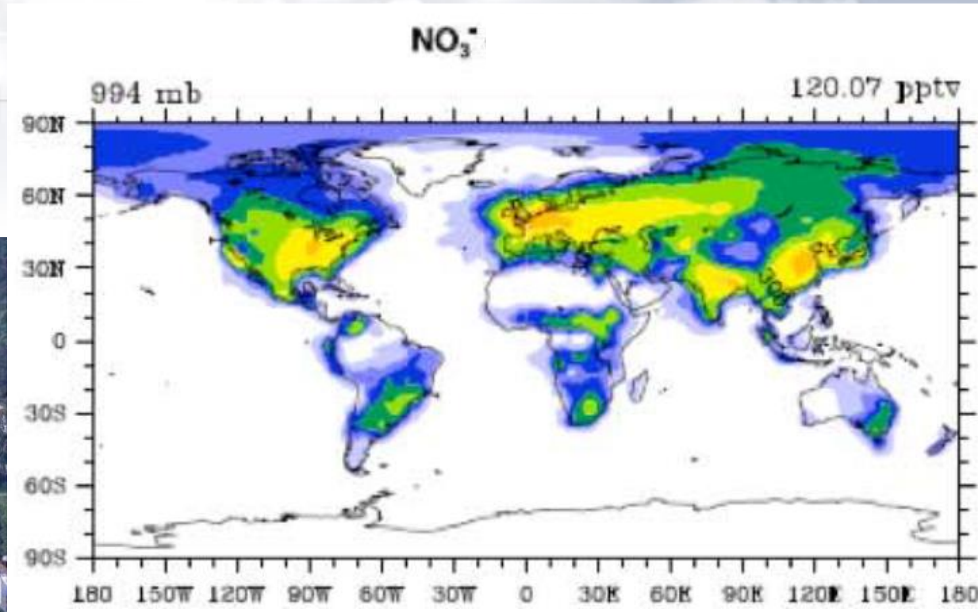
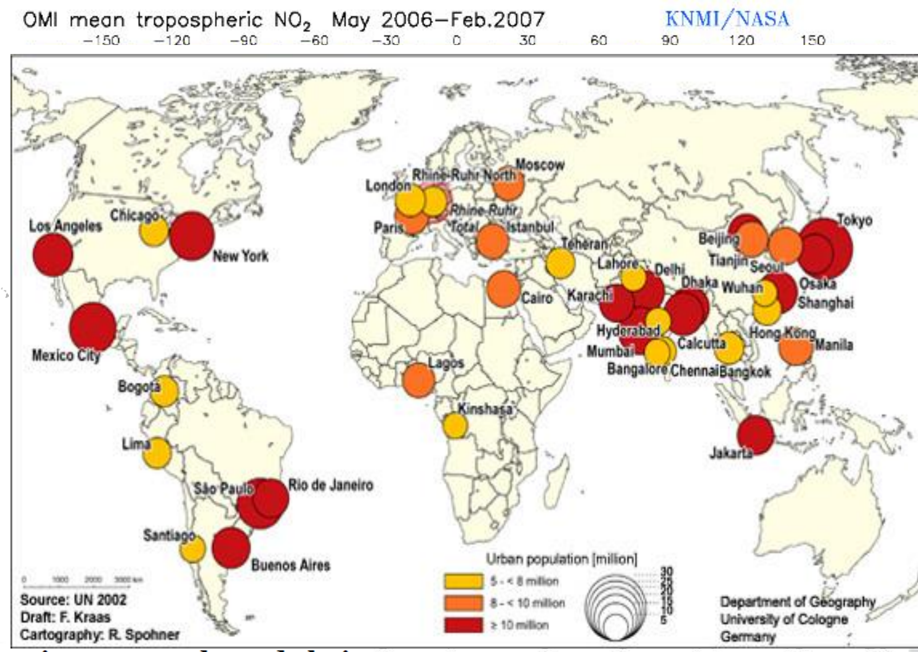




NH_4NO_3



Mega-cities, > 5 Millones habitants

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

L. Xu and J. E. Penner

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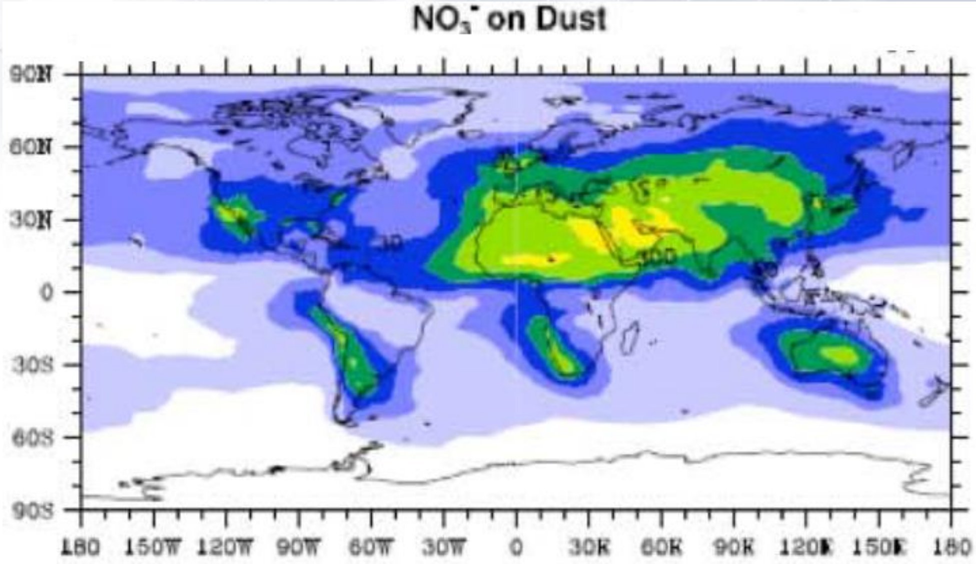
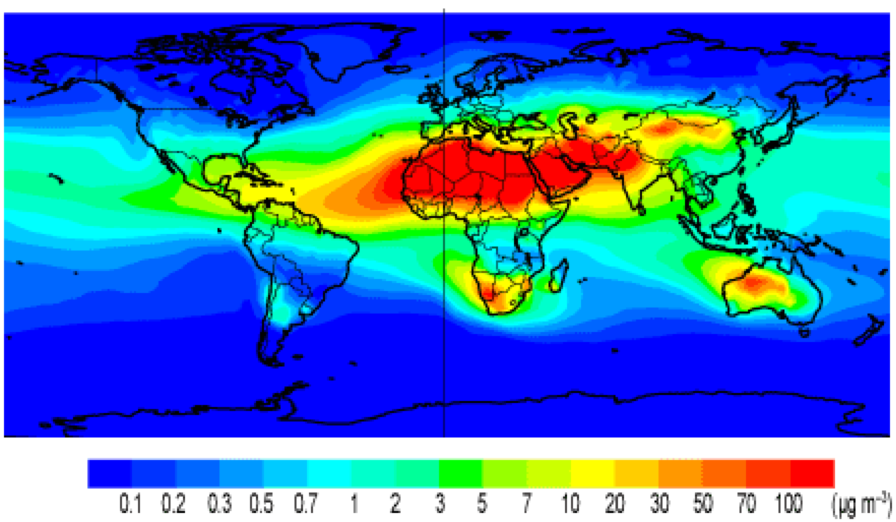


NO_3^- - dust
$Ca(NO_3)_2$

soil dust



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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:

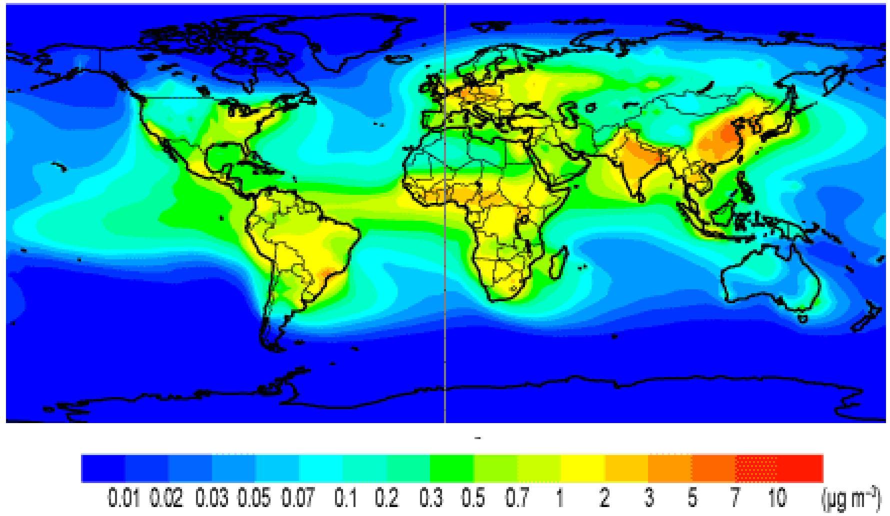
- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

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

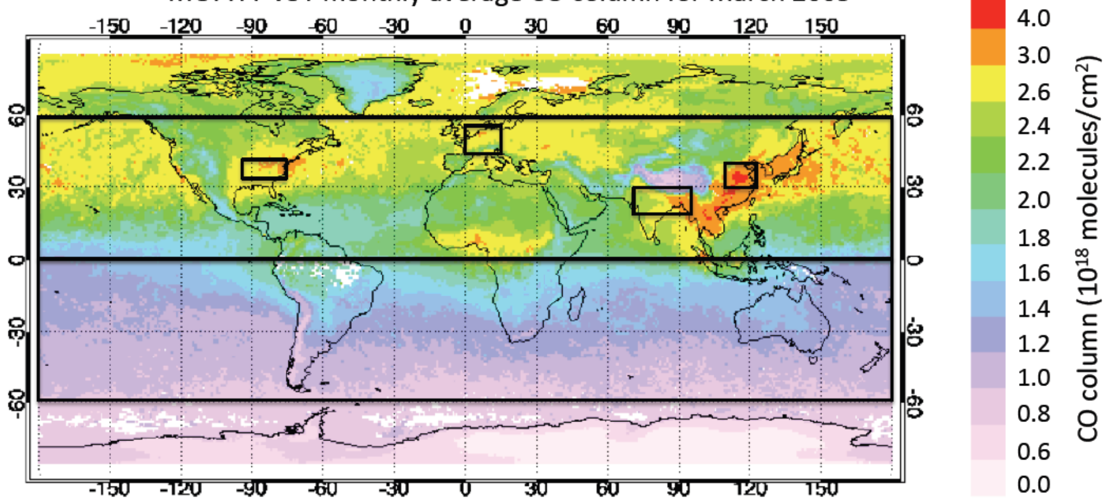
10.5 Tg/y

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

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

aerosols, a cocktail of chemicals:

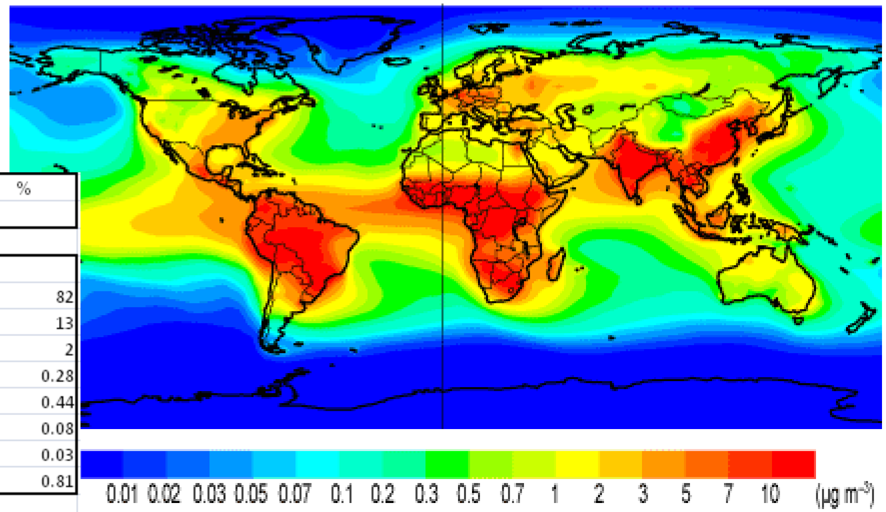
- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co…)
- sea salt

organic matter: combustion sources, vehicle exhaust

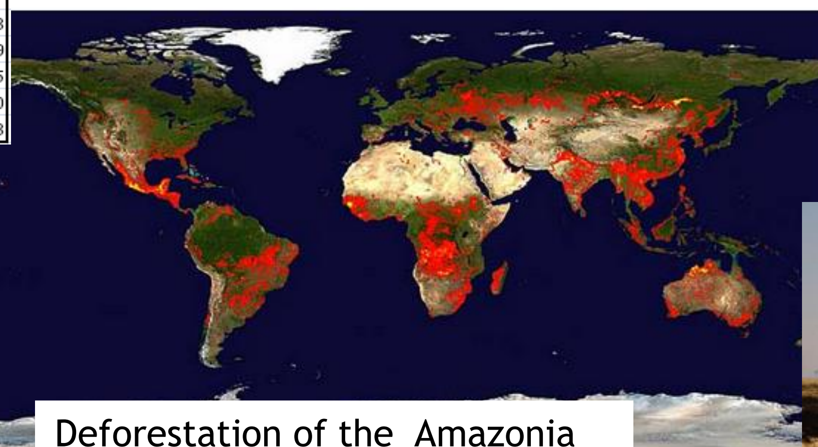
organic carbon

		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



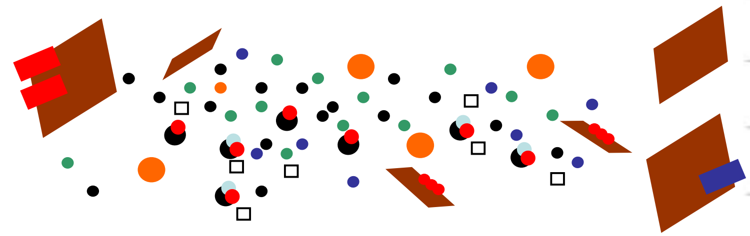
←Satelite detecion of fires

Paraguay: burn forest for cultivation of soja and suggar cane

Deforestation of the Amazonia

Sabana Africana

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)

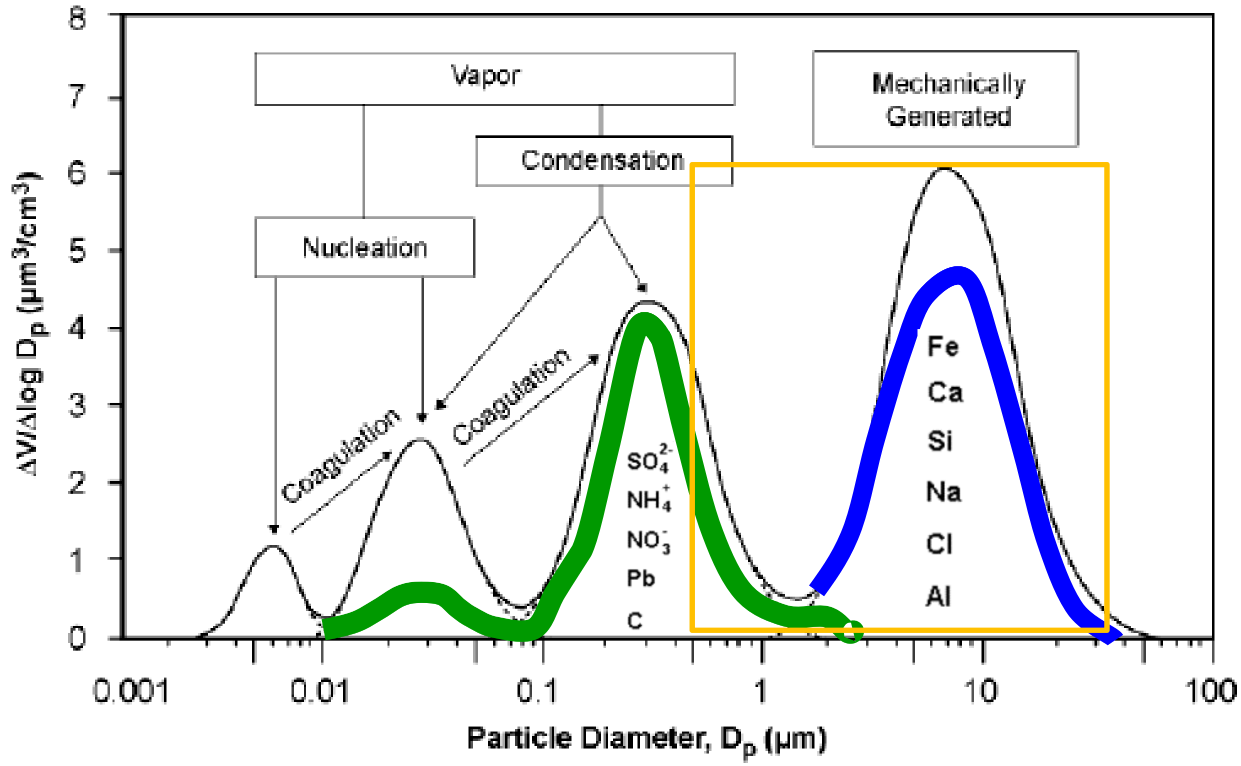
PM_{10}: Σ dust + sea salt + vehicle exhaust + oil refining + power plants + ships +...

$PM_{2.5}$: 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 :

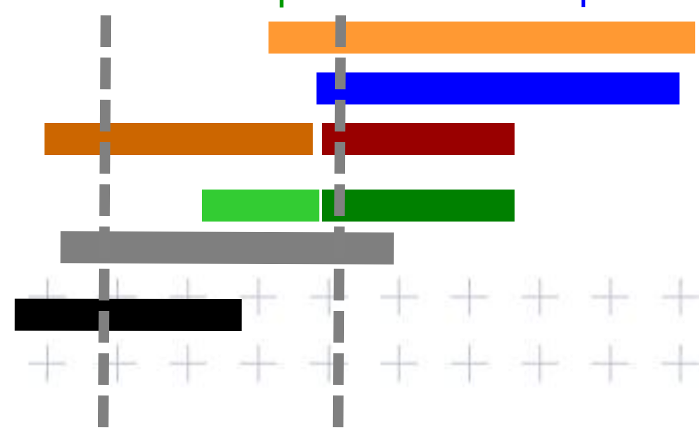
Marine salt:

Sulfate:

Nitrate:

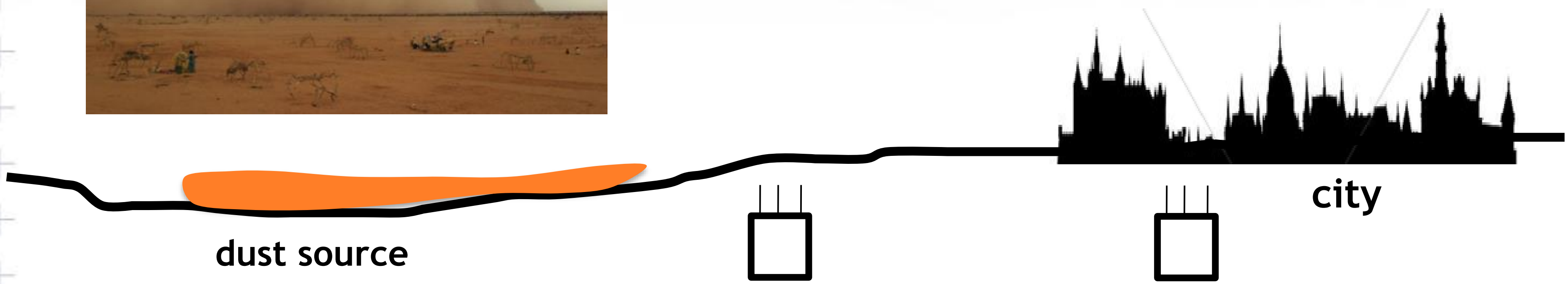
Organic aerosol:

black carbon:



dust, aerosols and pollutants

in-situ observations



how to measure 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

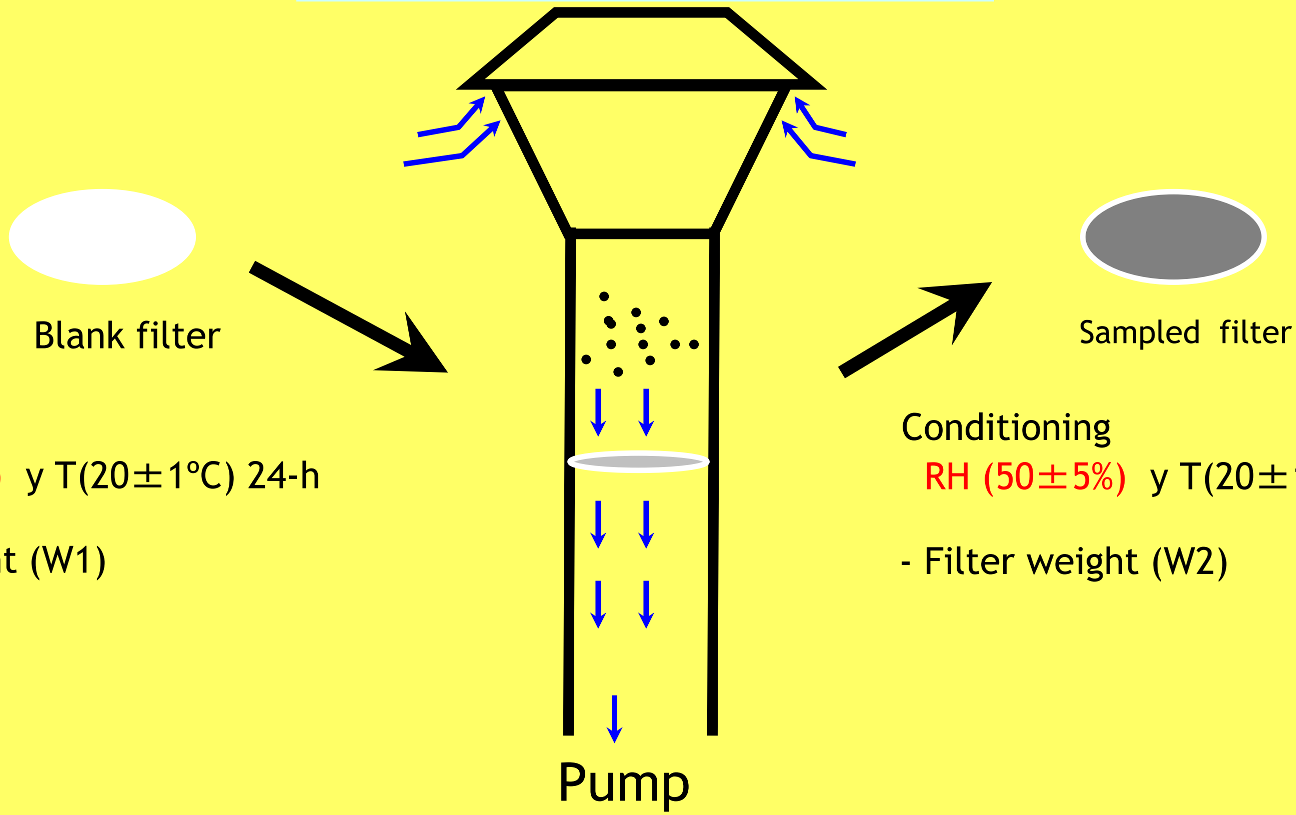
dust air quality

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 20°C

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

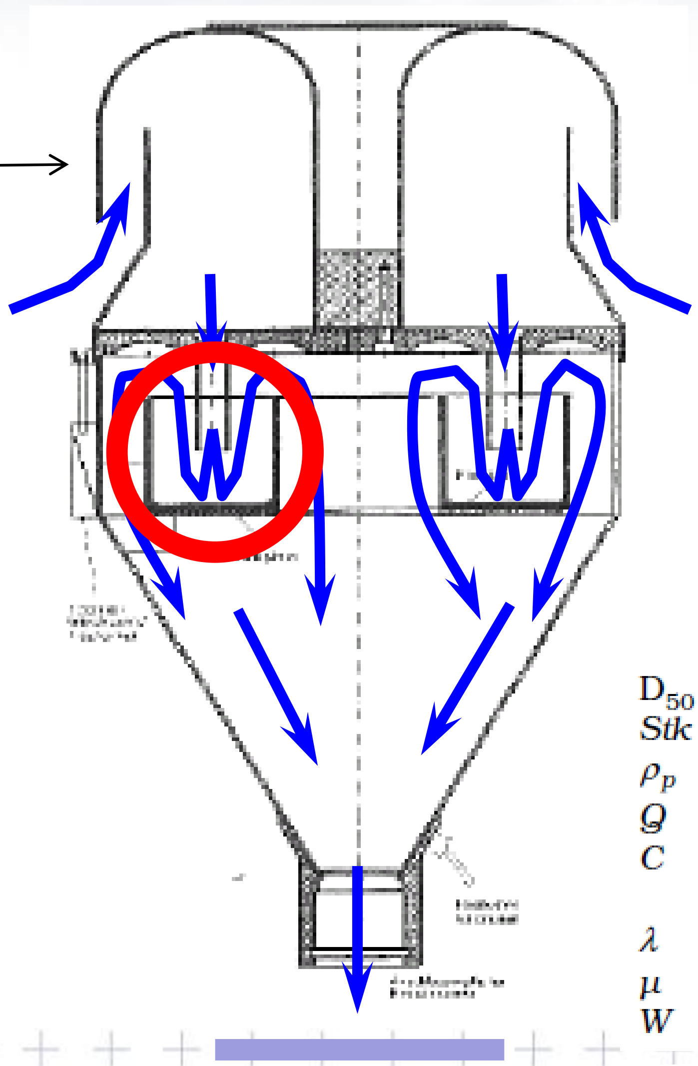
HVS: 68 m^3/h

HVS: 30 m^3/h

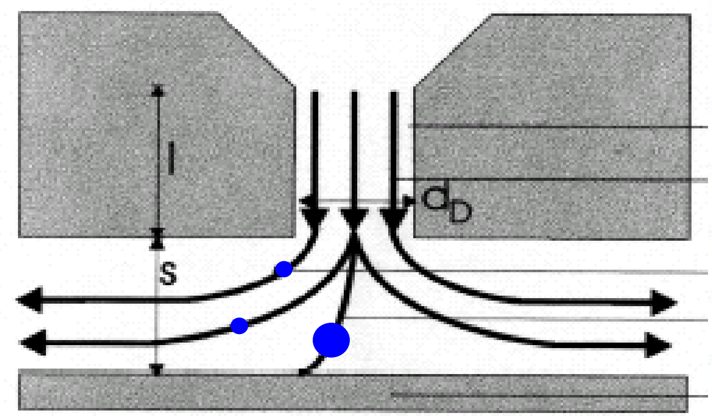
-we recommend you use a specific normalised method (e.g. EN12341:2014). Ask to the distributor if the sampler sis designed to any standards

Inlets, airflows....

PM_{10}, $PM_{2.5}$



Filter



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

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 ($dyne \cdot s/cm^2$)
W = nozzle diameter (cm)

The Stokes number is a dimensionless parameter that characterizes impaction.

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

-method-01: reference - manual gravimetry

Manual gravimetry

advantage: reference method

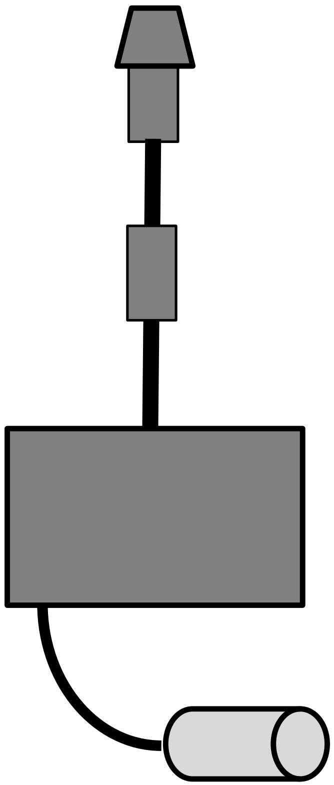
disadvantage: poor time resolution, 24-h average
manual work
takes 3 days to know PM_{10} concentration

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

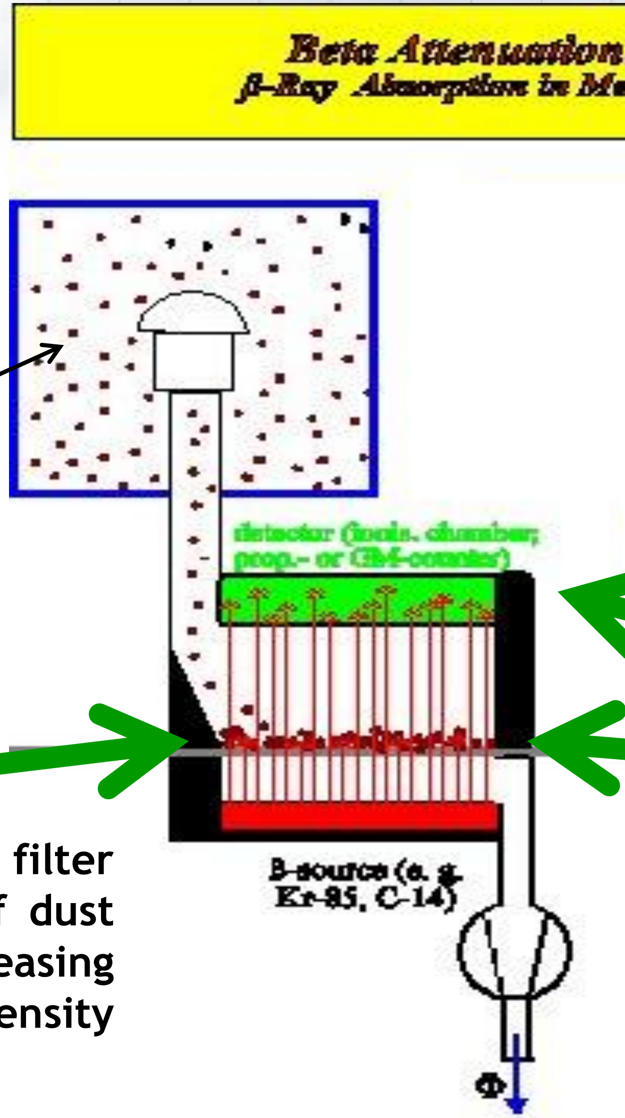
   Beta radiation attenuation

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

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.

Beta rays detector

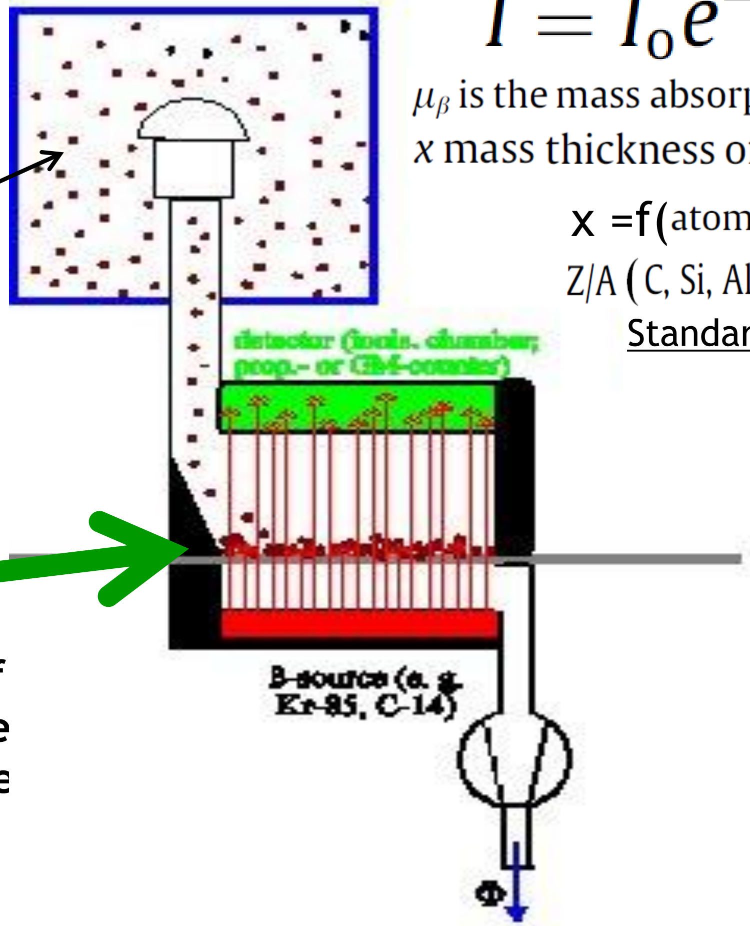
Beta rays source (Kr-85)

Pump and flowmeter

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).

Beta Attenuation:
β-Ray Absorption in Matter



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

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

<u>Standard foil calibration</u>

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

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

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

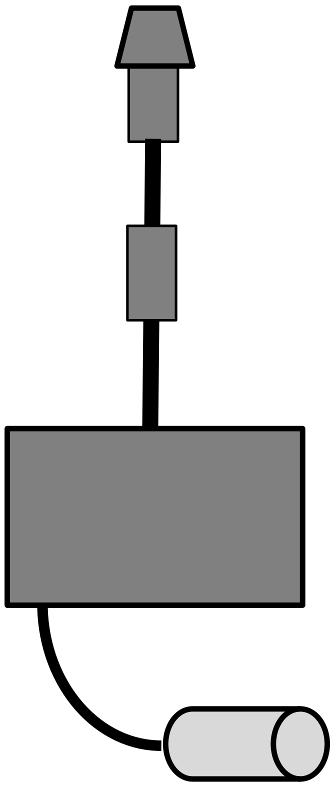
The intensities I_0 and I are measured with the detector system. F_{cal} has to be measured directly during the calibration procedure. This is accomphished by replacing the filter with the element having a known mass (mass calibration kit)

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

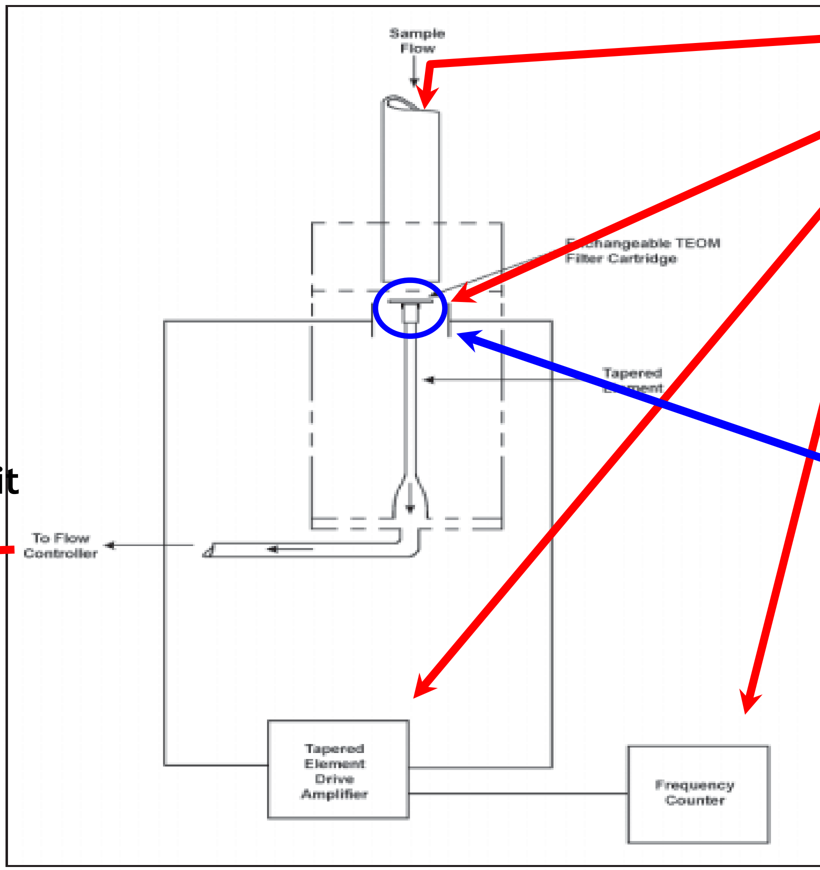
Automatic continuous measurements

TEOM :Tappered Element Oscillating Microbalance

1. TEOM mod.1400a

sensor

mass=function (frequency)



Flow exit

Sampling flow rate (16.67 l/m)

Sample accumalated in the filter

Micro-oscilation of constante amplitue GENERATOR

Frequency sensor

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

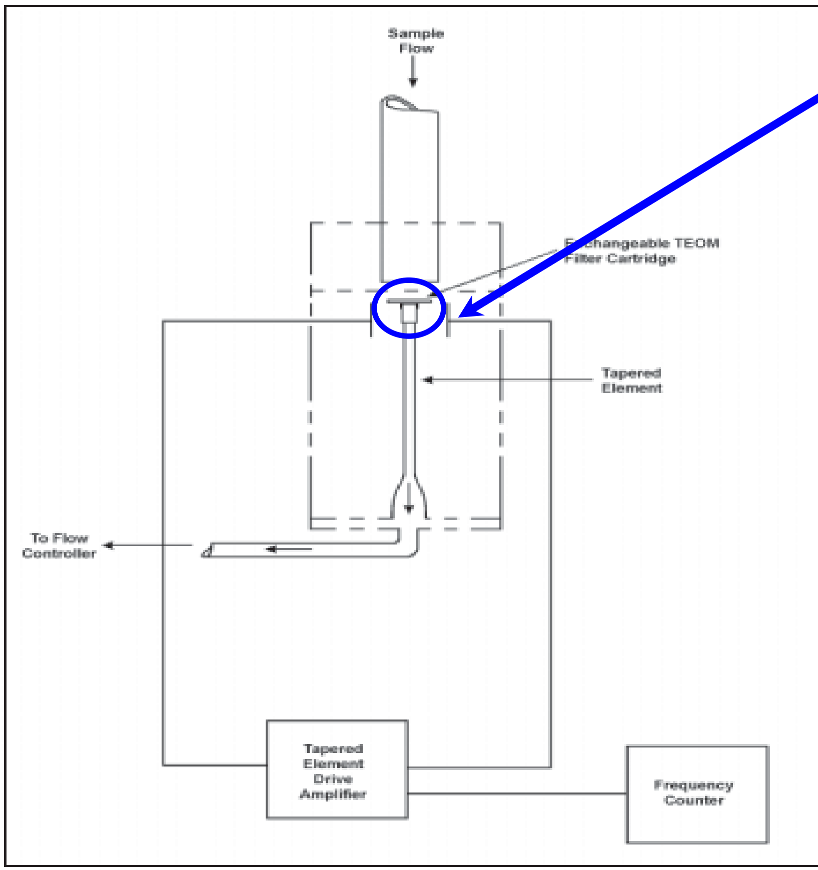
Mass concentration

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

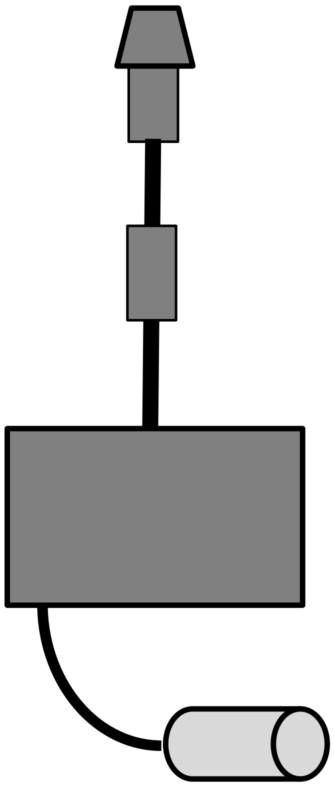
K and M are in consistent units. The relationship between mass and change in frequency can be expressed as:

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

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

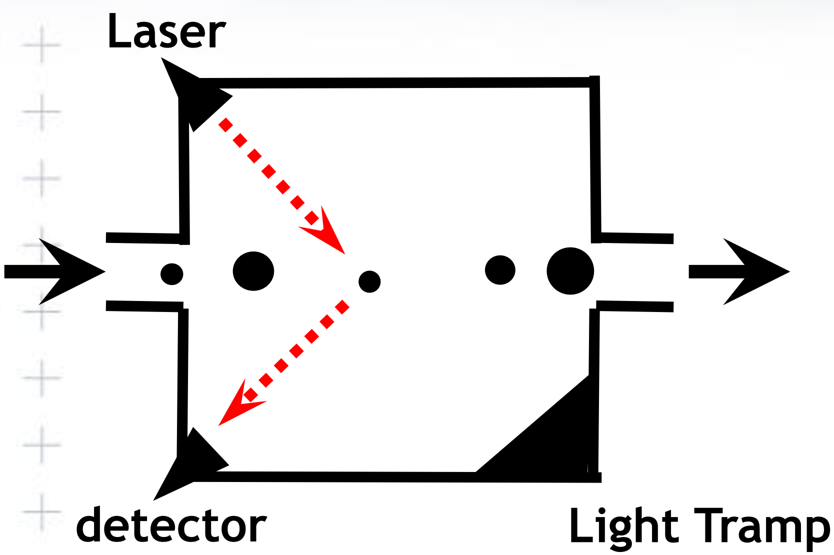
   Beta radiation attenuation
   TEOM
   Optical Particle Sizers

4. Pump / Flow meter

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

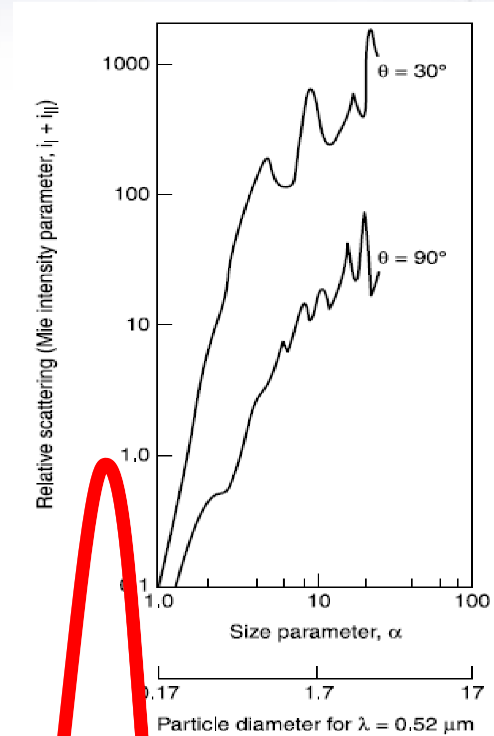
Optical Particle Sizer

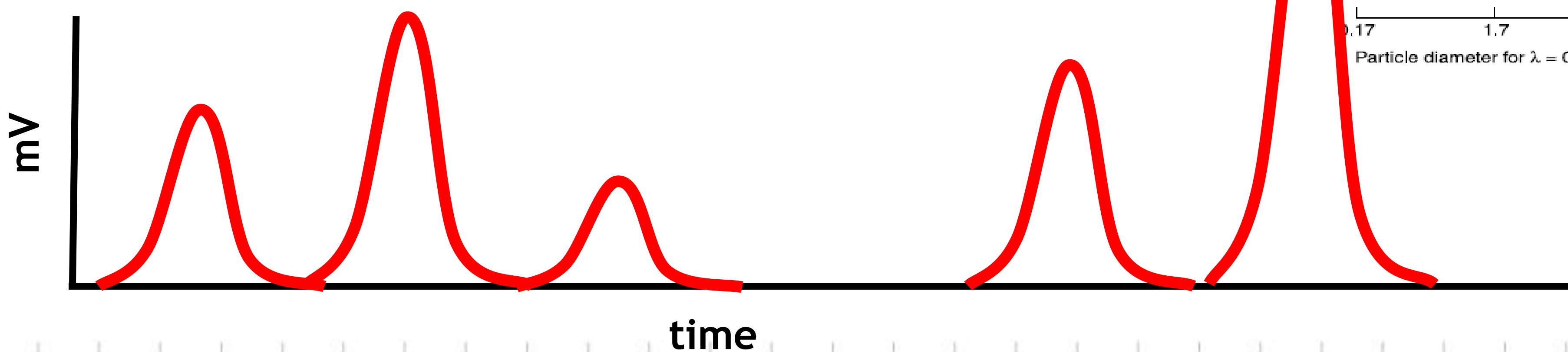
number size distribution 0.3 - 20 µm

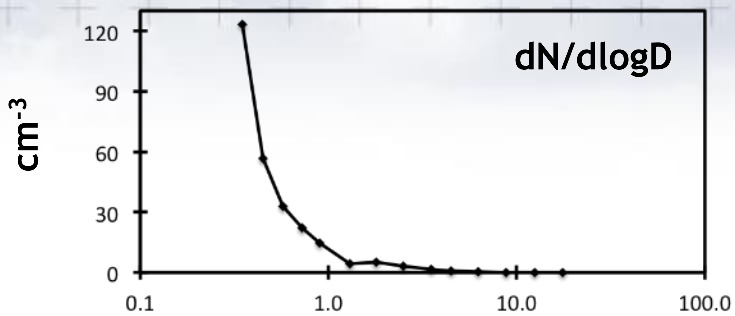


Intensity of scattering

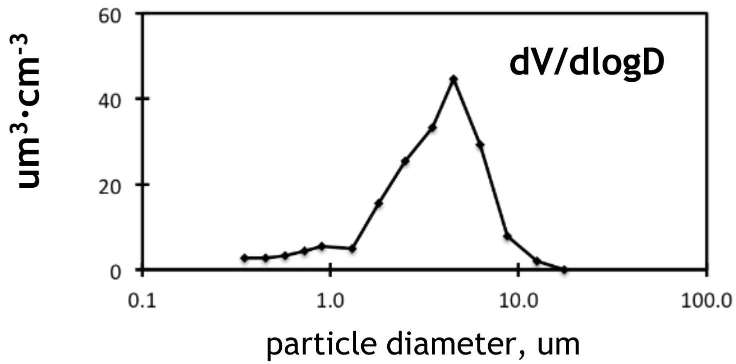
I(dp,θ, λ, **m**)

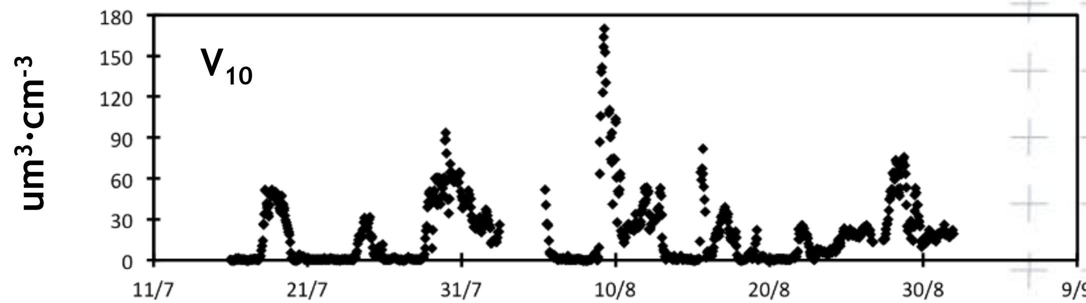






$\frac{3}{4} \cdot \pi \cdot r^3$





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

Density: 1.6 to 2.65 g/cm^3

-method-02: automatic

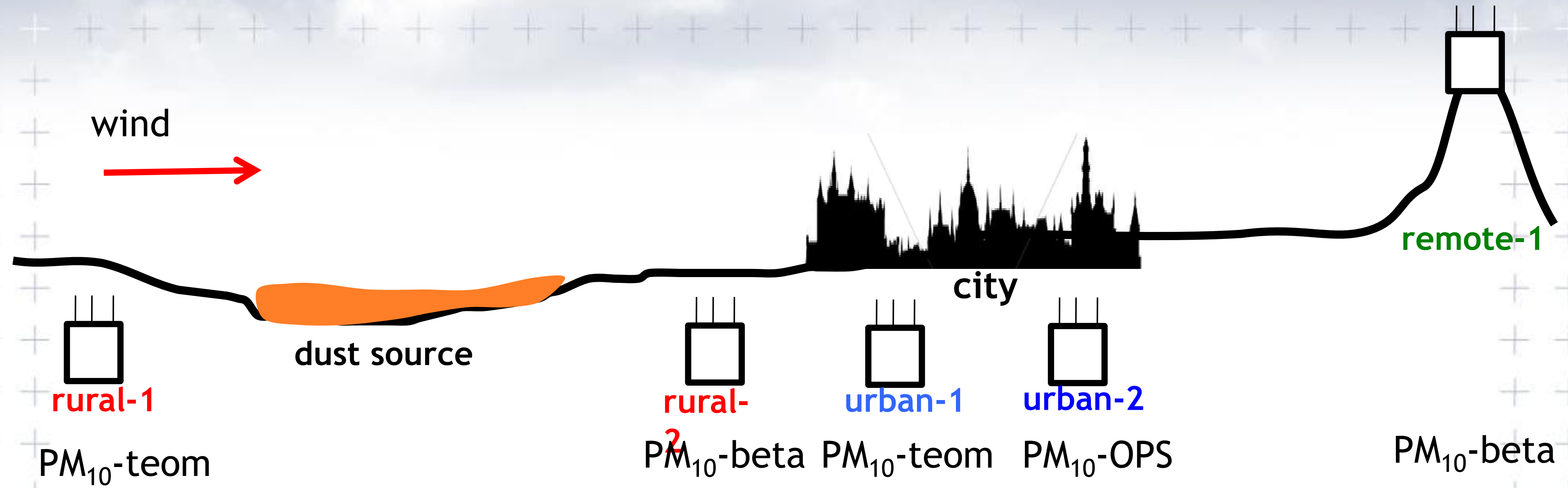
The most extended method and the most robust for dusty regions

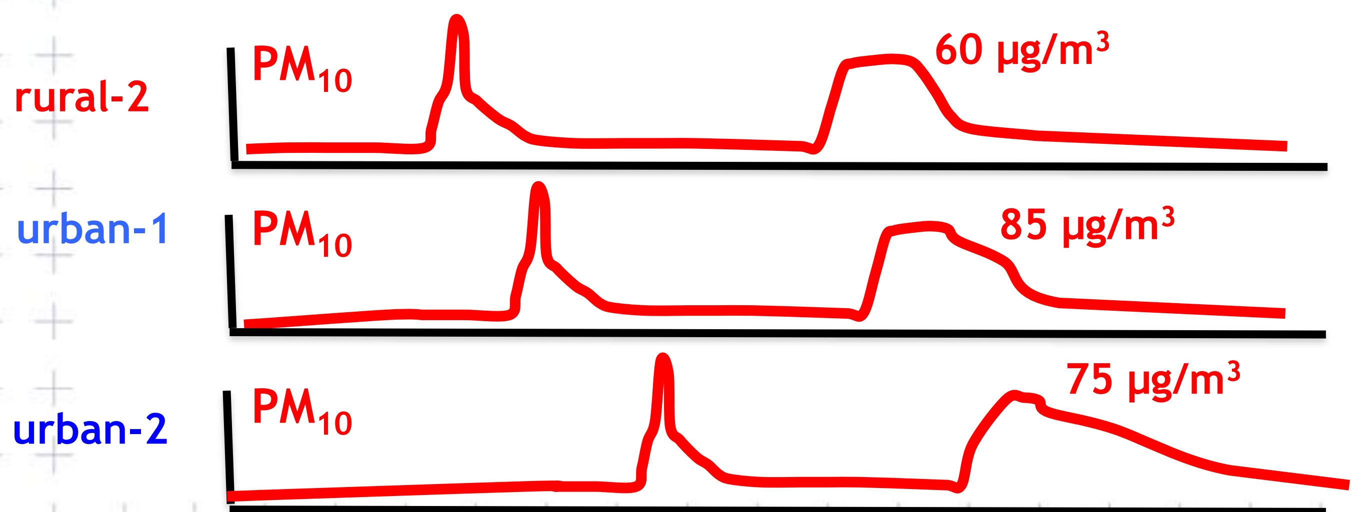
beta

Tapered Oscillating Microbalance
TEOM
Manual change of the filter

Optical Particle Counters

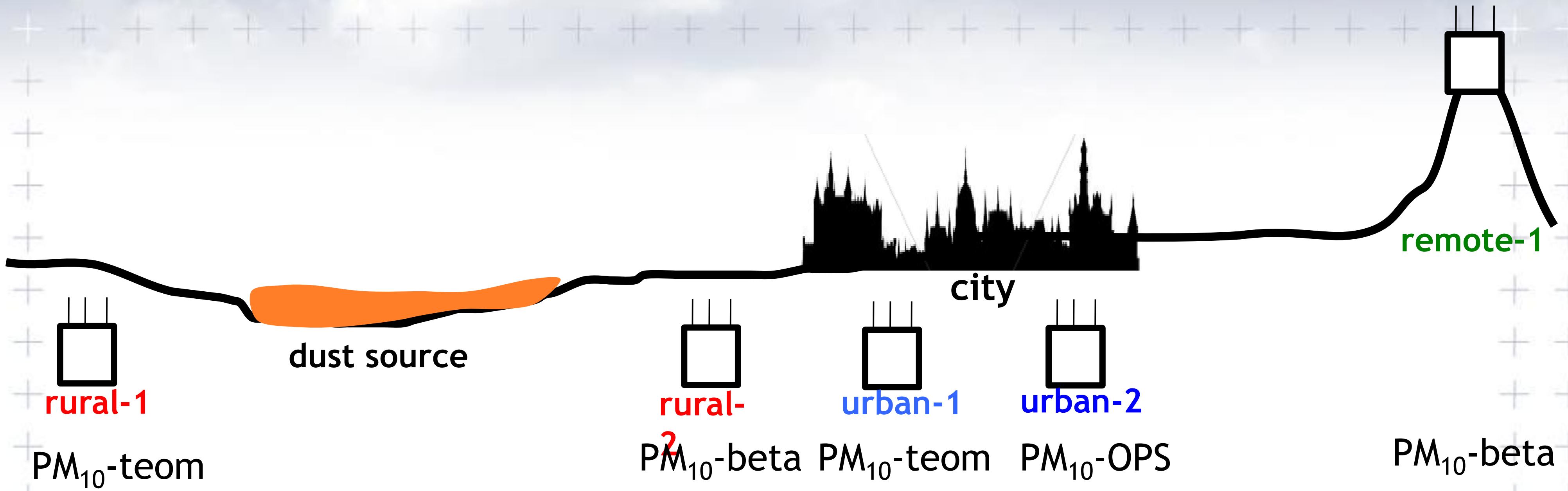
cleaning of optics
laser maintenance





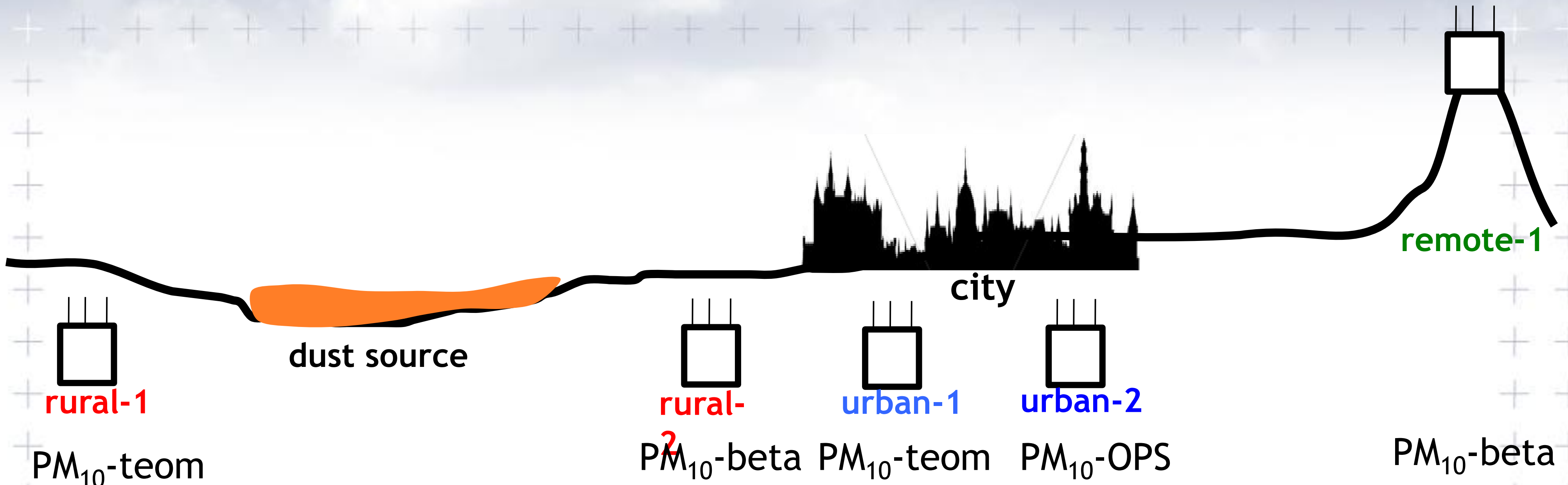
are PM_{10} data collected with different methods comparable?

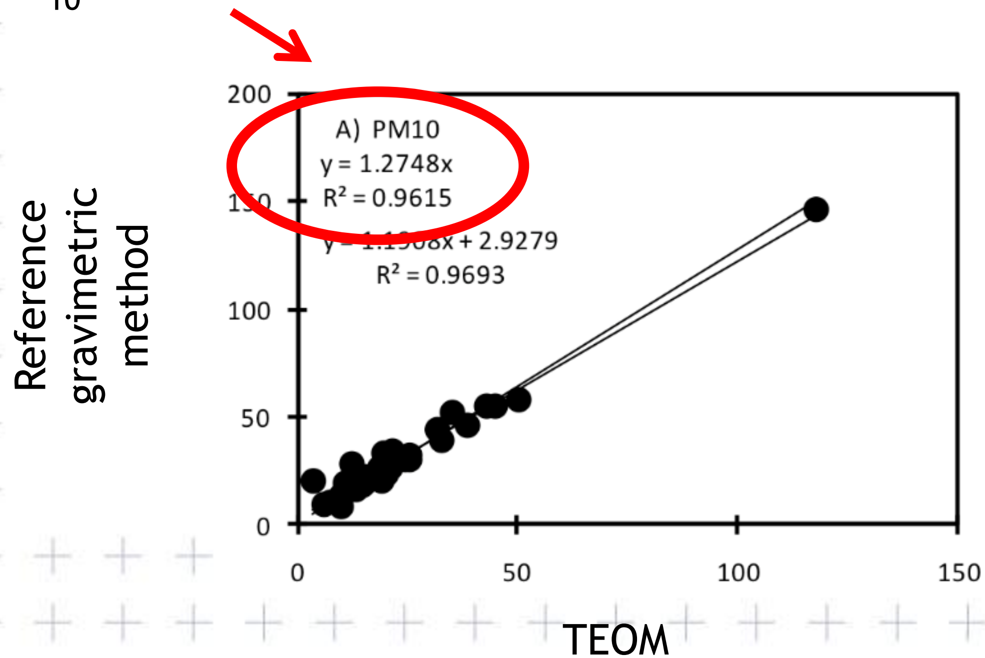
we need a standard for the network



the standard in the network:

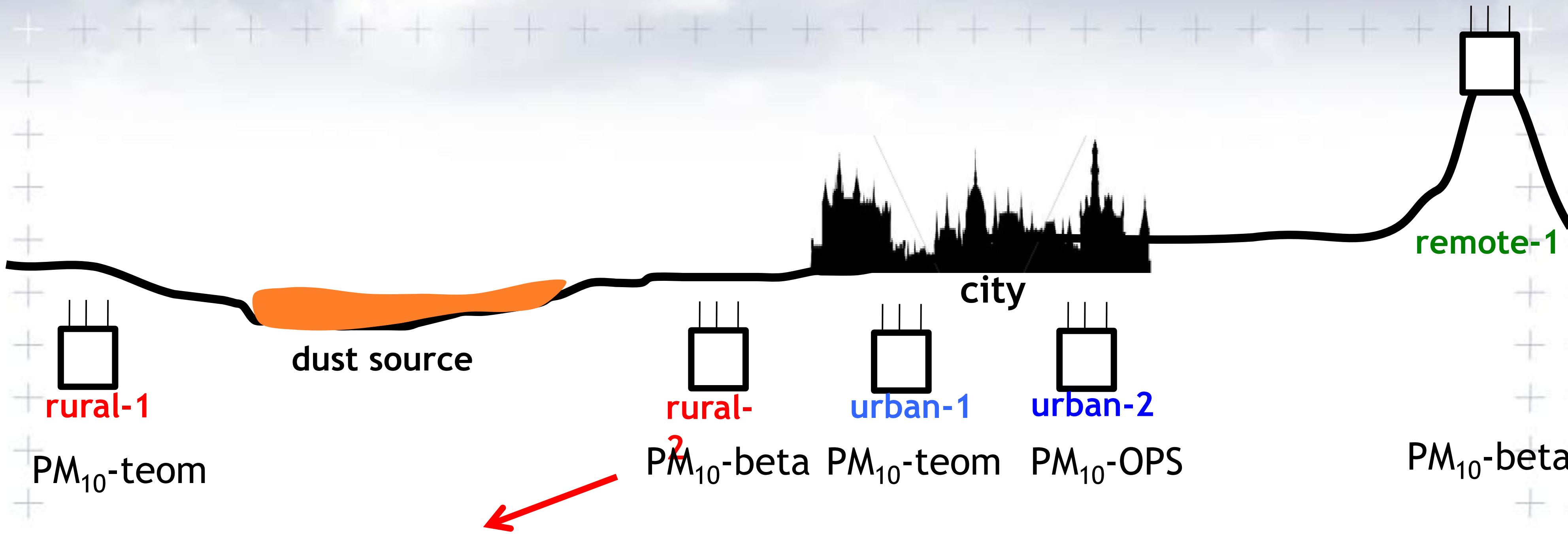
intercomparison of each automatic instrument with the manual reference method

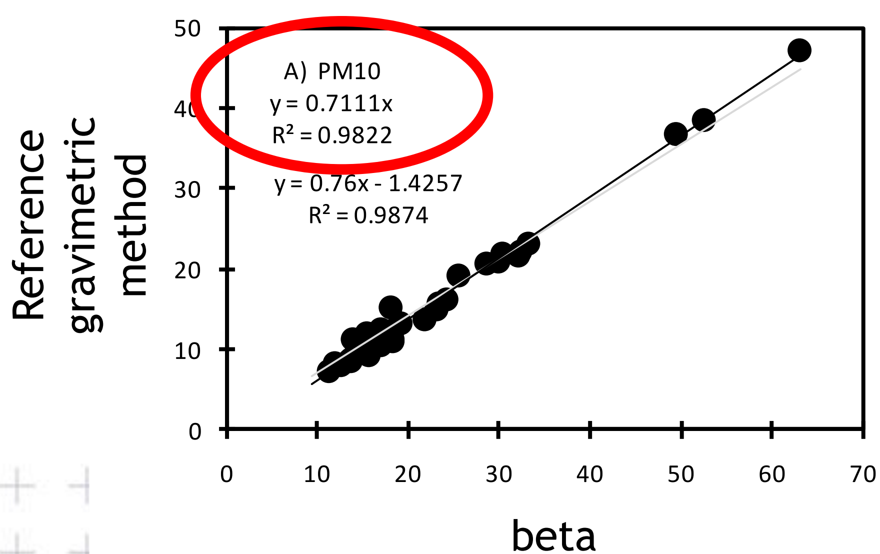




PM_{10} (grav equiv) = 1.27 PM_{10} (TEOM)

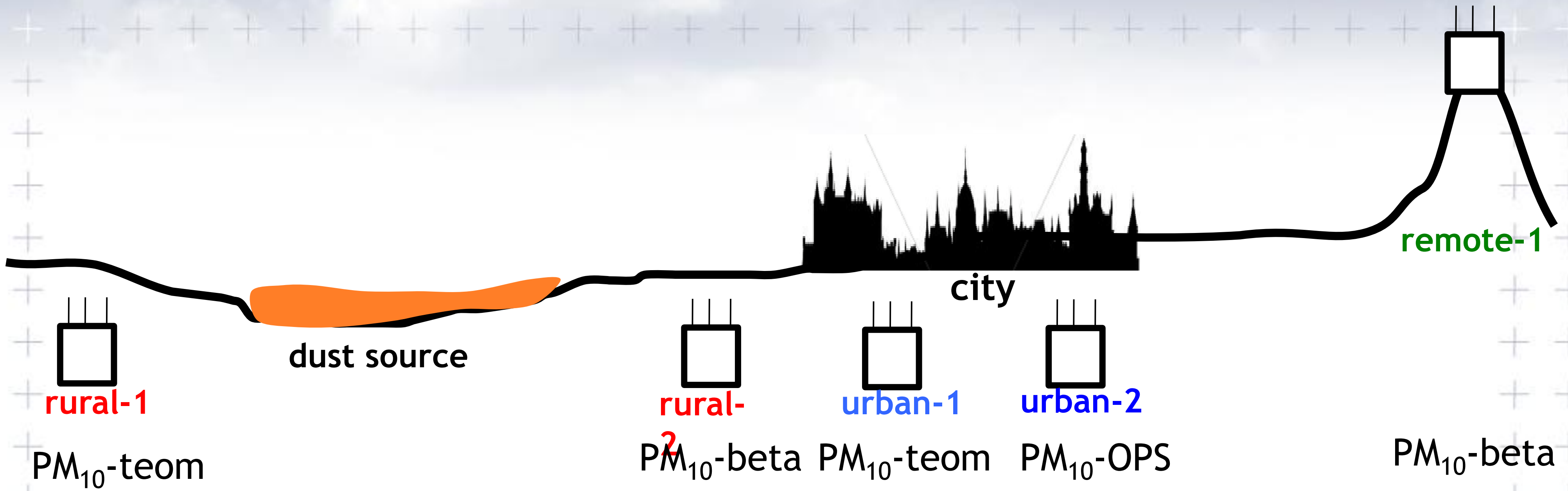
Valid for rural-1 TEOM

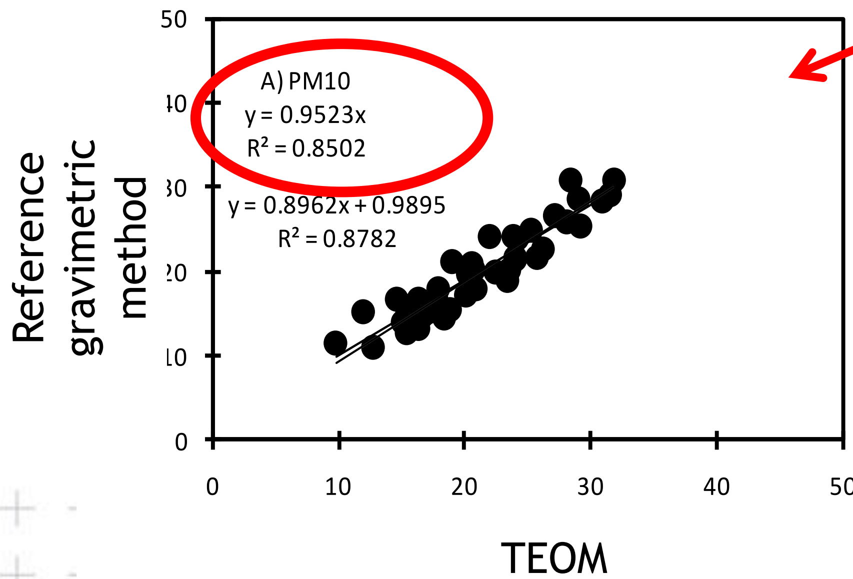




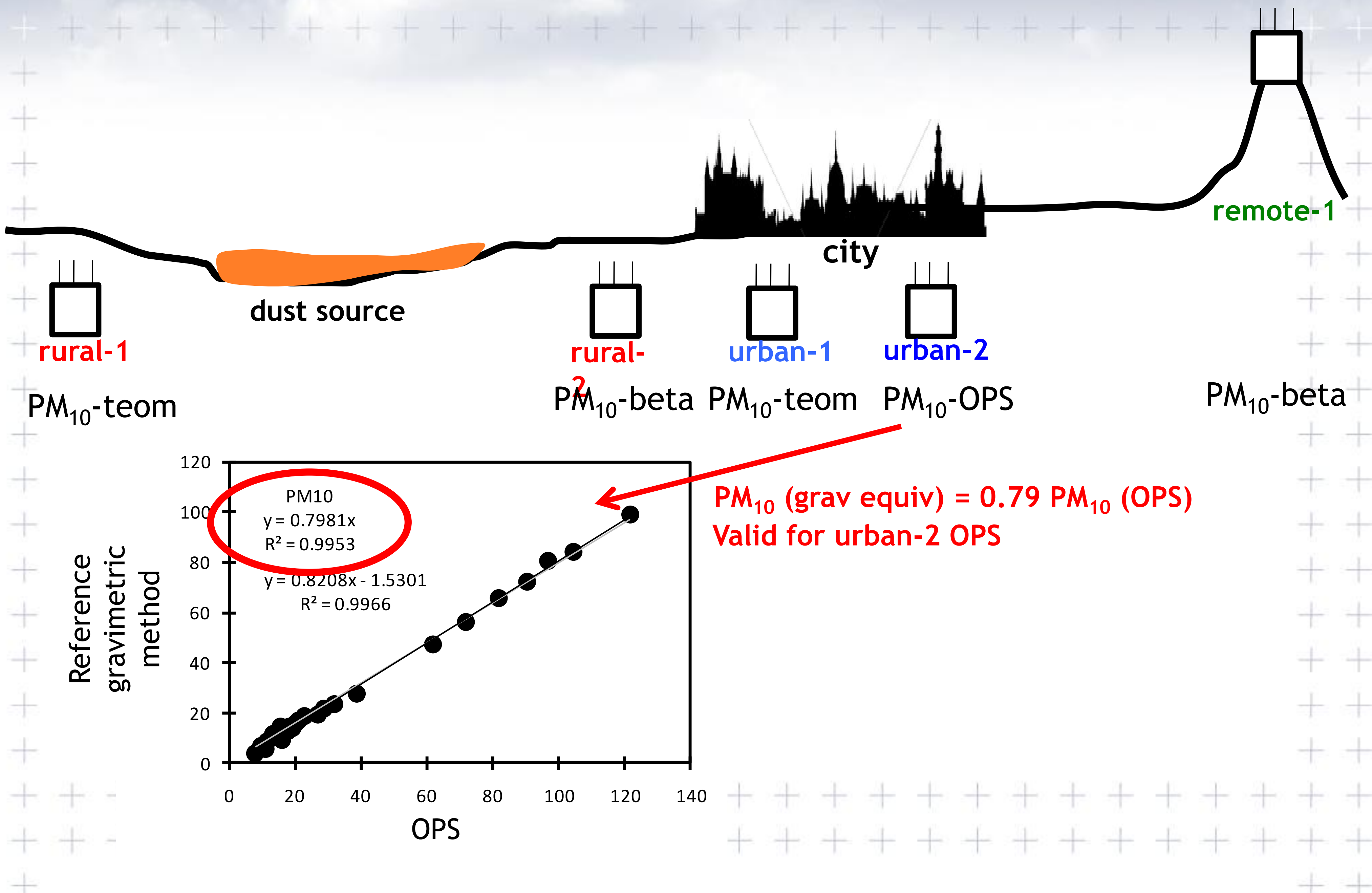
PM_{10} (grav equiv) = 0.71 PM_{10} (BETA)

Valid for rural-2 BETA

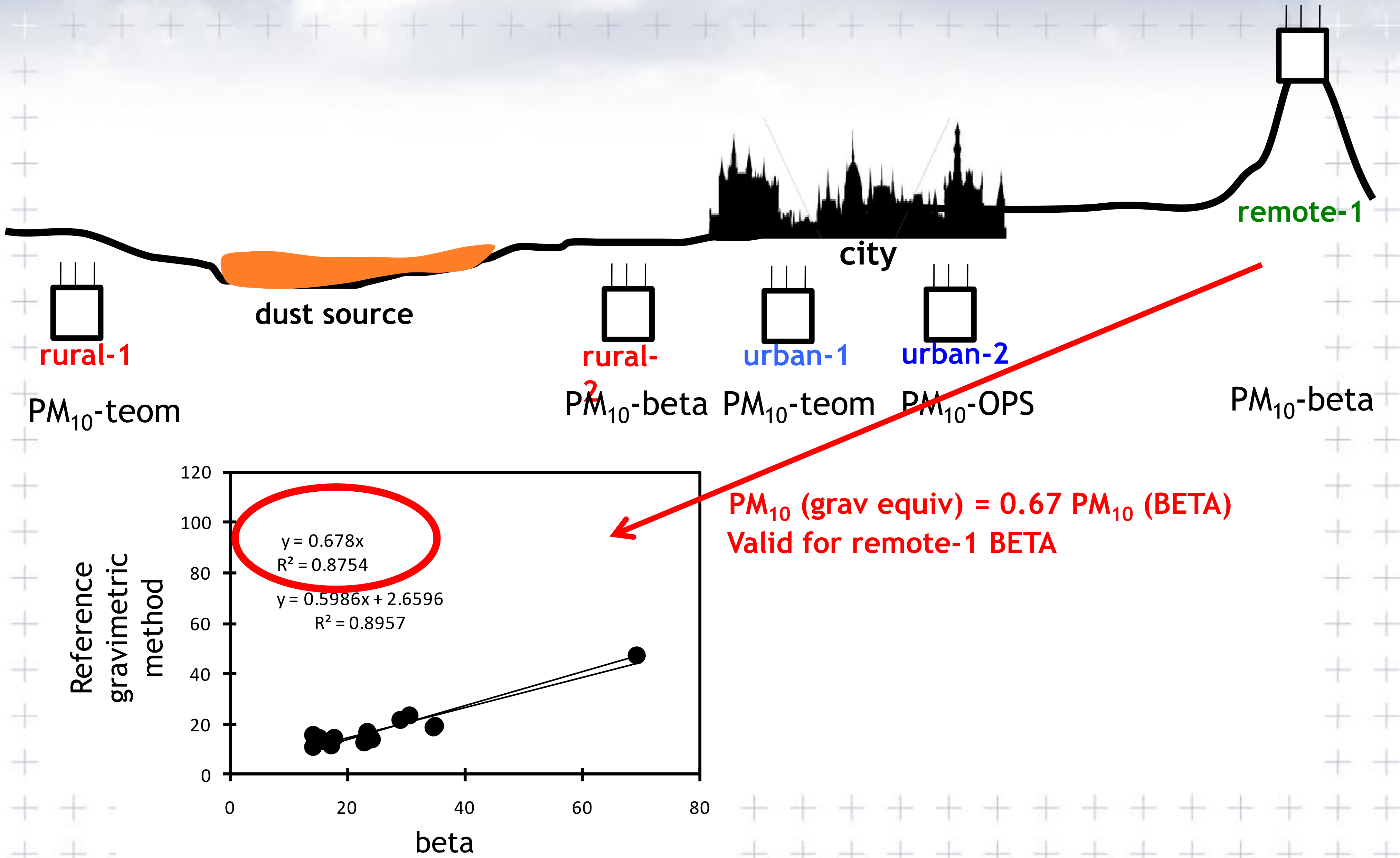




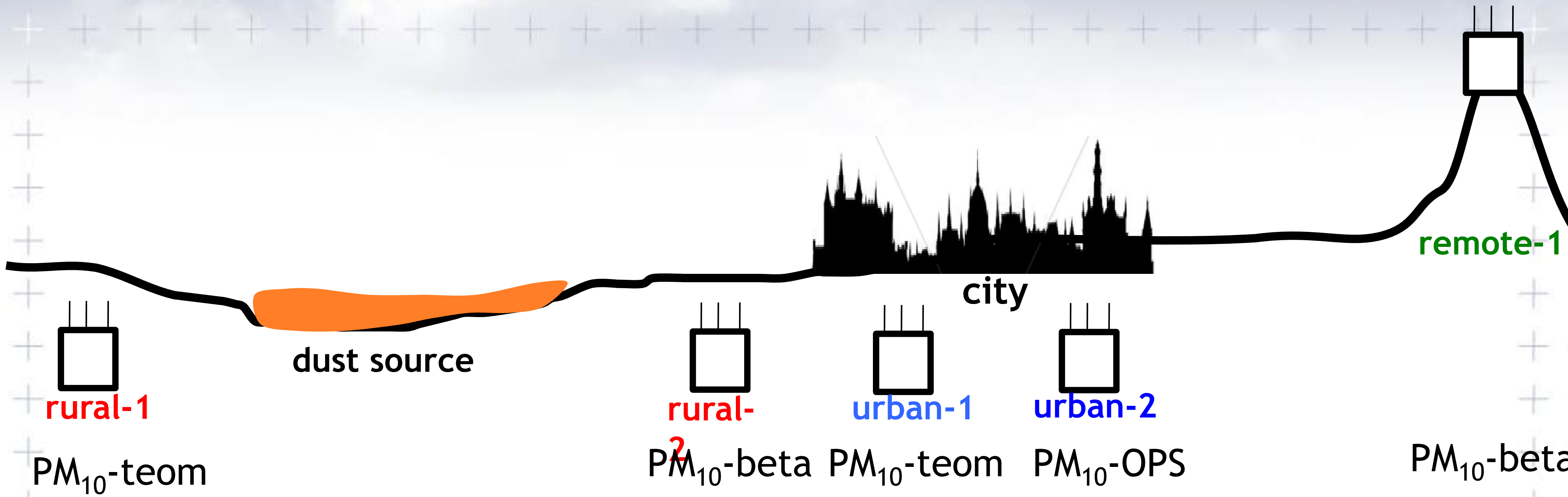
PM_{10} (grav equiv) = 0.95 PM_{10} (TEOM)
Valid for urban-1 TEOM



city
dust source
rural-1
PM$_{10}$-teom
rural-2
PM$_{10}$-beta
urban-1
PM$_{10}$-teom
urban-2
PM$_{10}$-OPS
remote-1
PM$_{10}$-beta
PM10
y = 0.7981x
R² = 0.9953
y = 0.8208x - 1.5301
R² = 0.9966
Reference gravimetric method
OPS
0
20
40
60
80
100
120
140
PM$_{10}$ (grav equiv) = 0.79 PM$_{10}$ (OPS)
Valid for urban-2 OPS

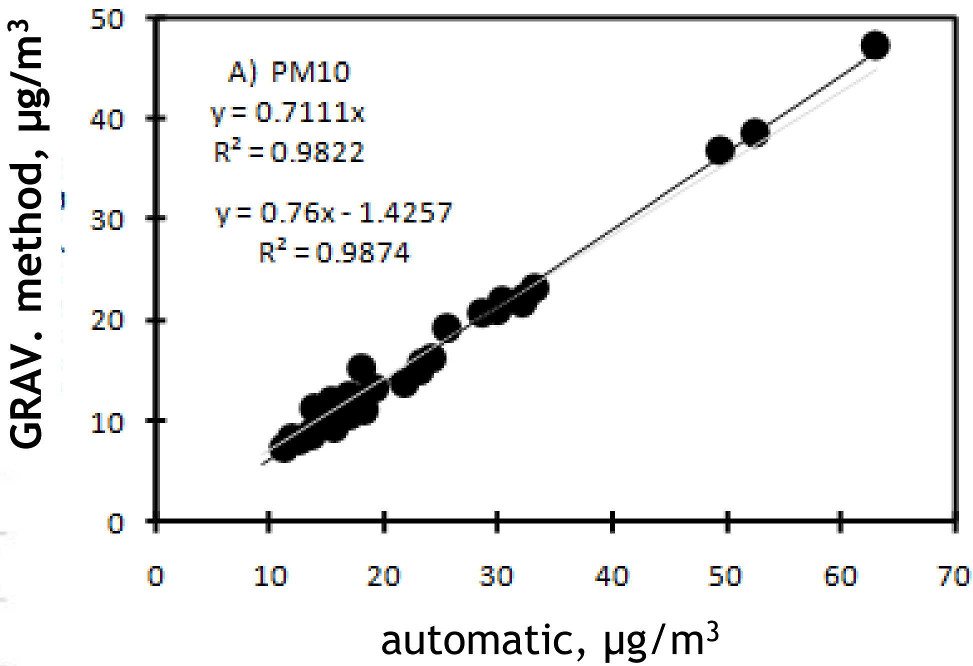


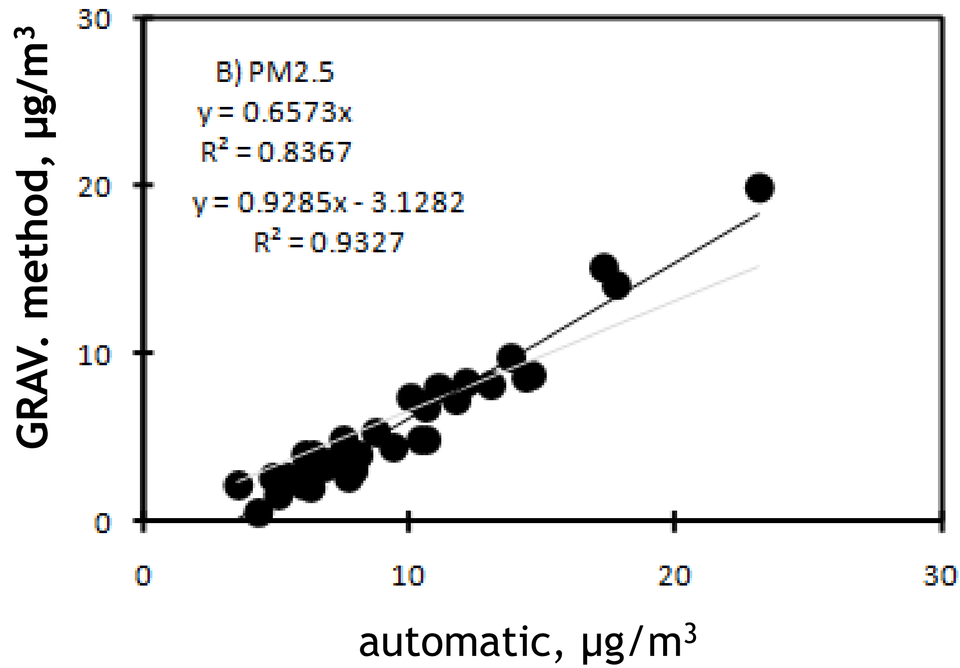
remote-1
city
dust source
rural-1
rural-2
urban-1
urban-2
PM10-teom
PM10-beta
PM10-teom
PM10-OPS
PM10-beta
y = 0.678x
R² = 0.8754
y = 0.5986x + 2.6596
R² = 0.8957
Reference gravimetric method
beta
0
20
40
60
80
100
120
0
20
40
60
80
PM10 (grav equiv) = 0.67 PM10 (BETA)
Valid for remote-1 BETA



	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

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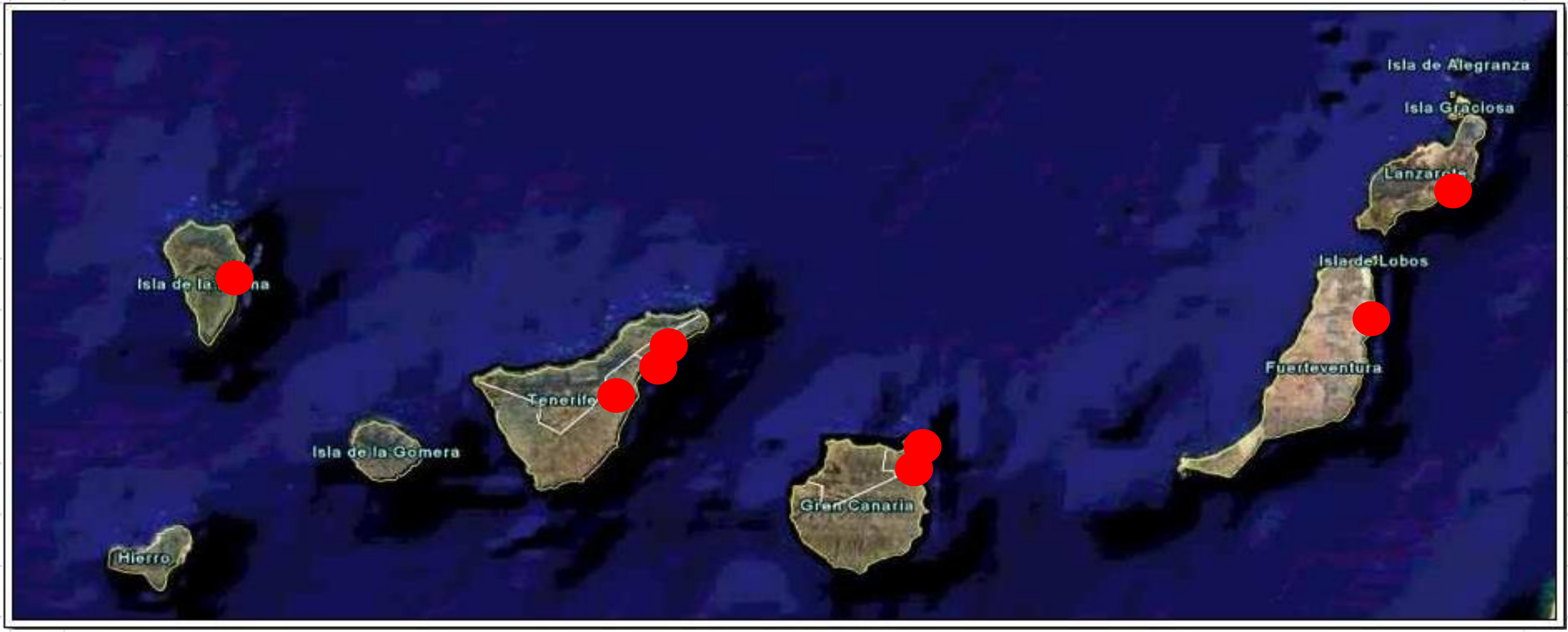
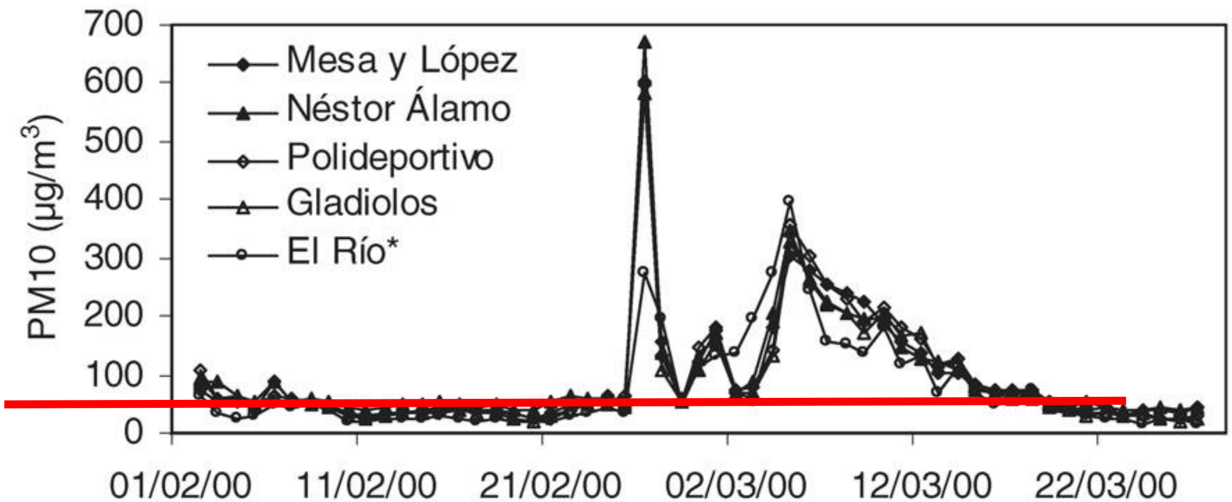
MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO
AEMet
Agencia Estatal de Meteorología

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

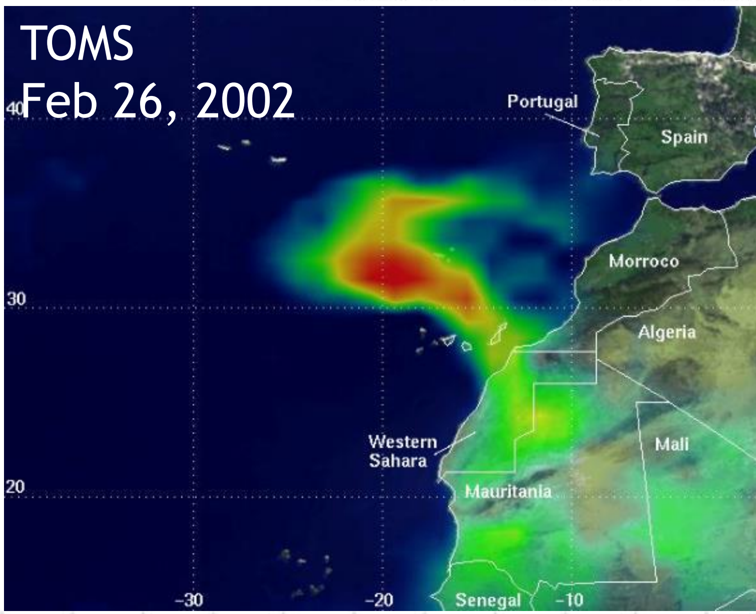


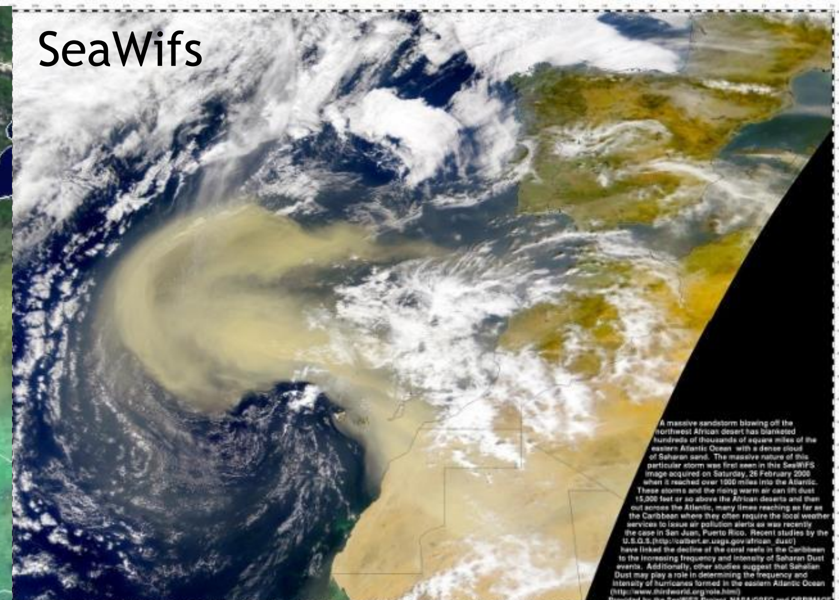
In-situ dust characterization

Air quality stations at Tenerife Island



The WHO recommend PM_{10} (24-h) do not exceed 50 μg/m³





Viana et al., Atmospheric Environment , 2002

EXAMPLE, Canary Islands

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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 $PM_{2.5}$

ARAFO

GLADIOLOS

CIUDAD DEPORTIVA

MERCADO CENTRAL

TOME CANO

TELDE

REHOYAS

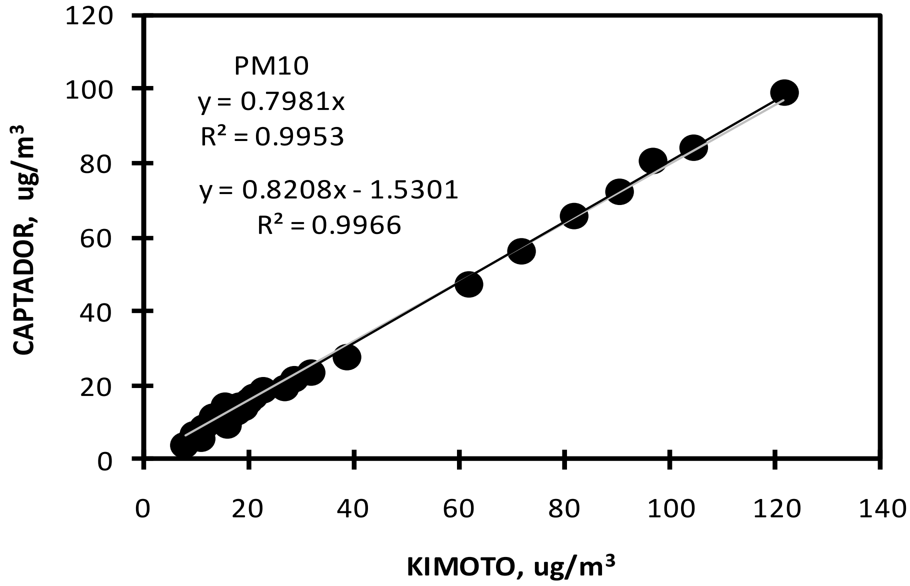
QUALITY CONTROL

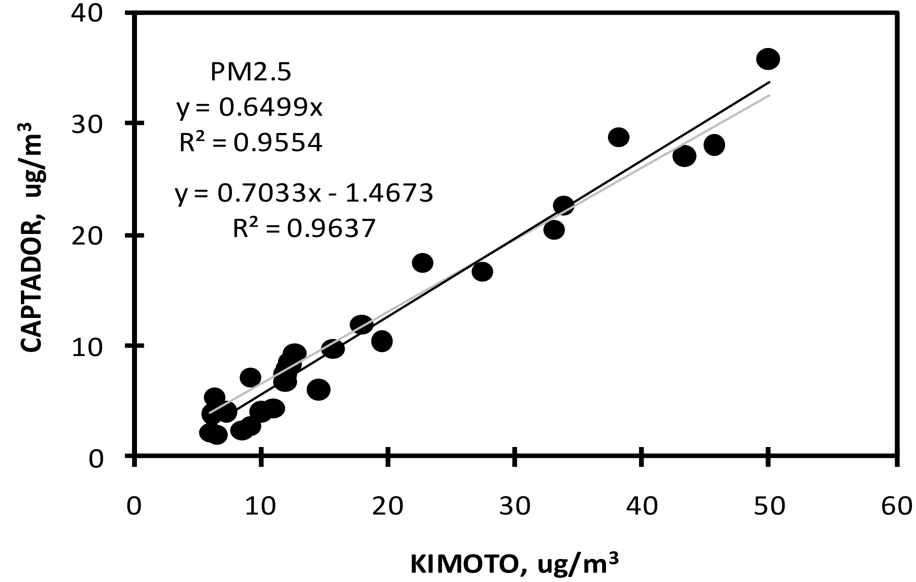
SAMPLER

PM monitor

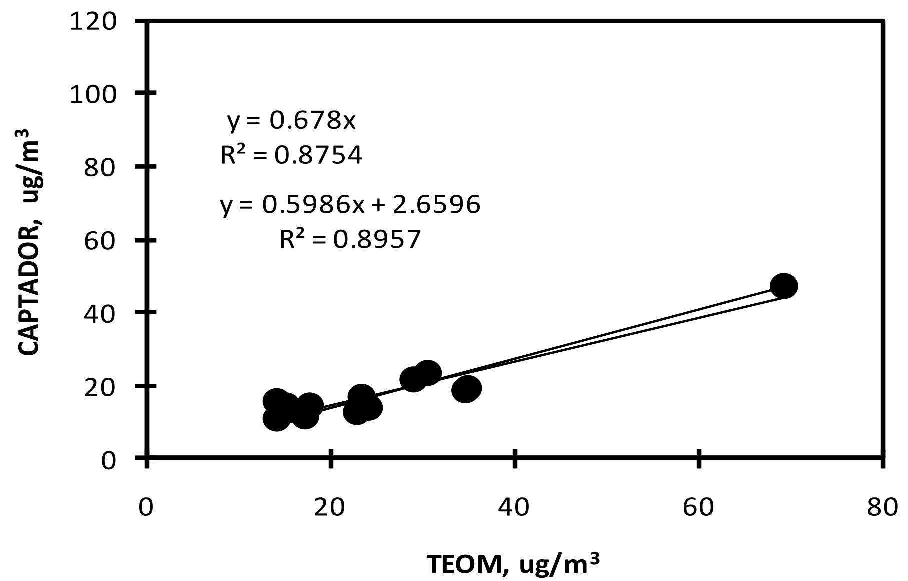
airflow accuracy
calibration of the sensor
leaks
cleaning

ARAFO

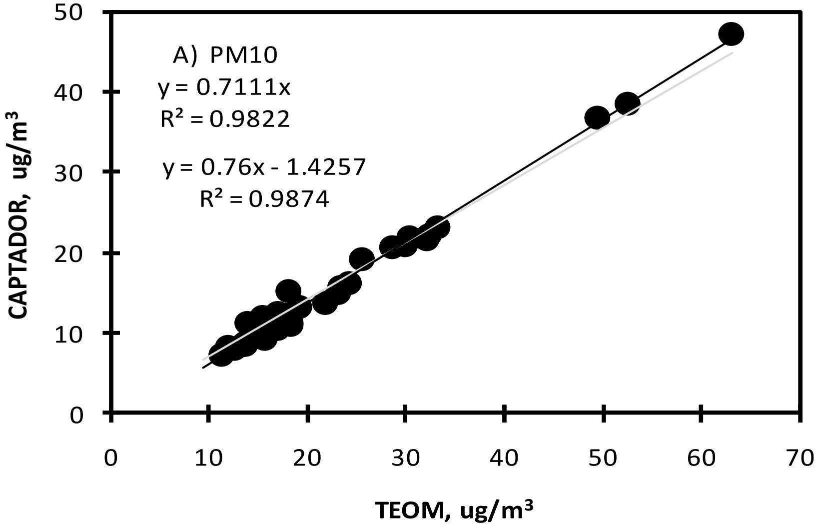


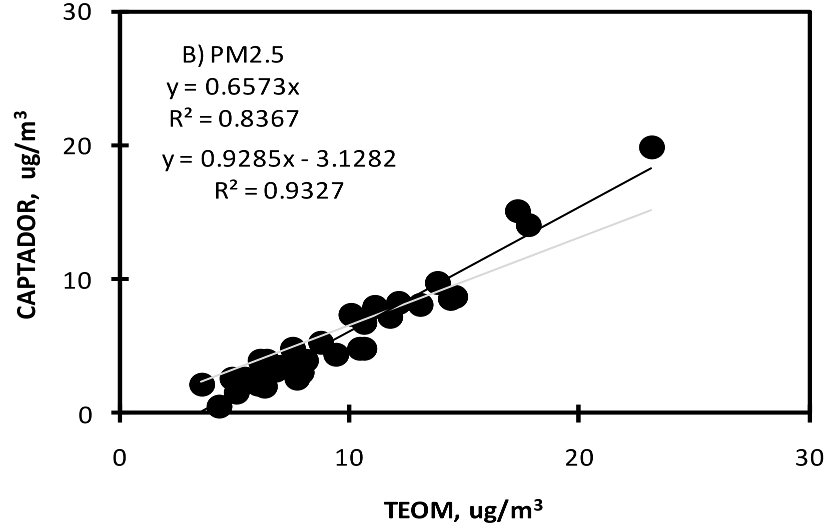


UNIDAD MOVIL



GLADIOLOS





TOME CANO

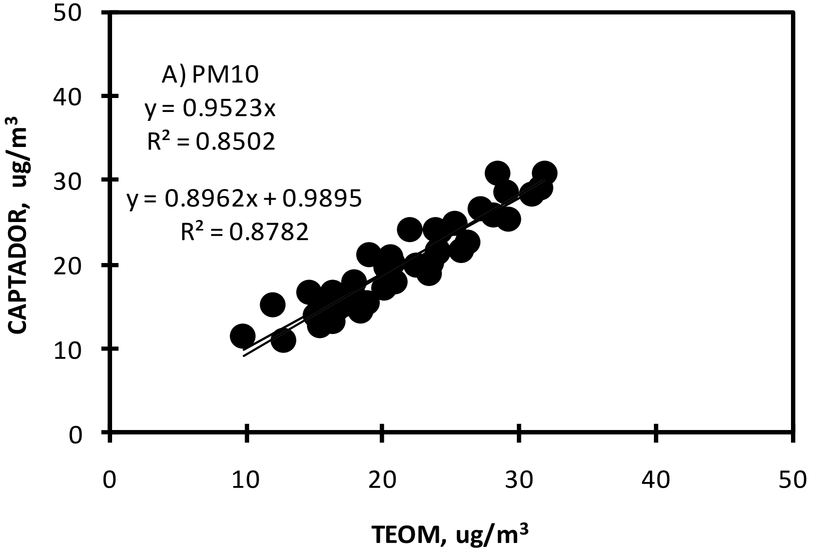


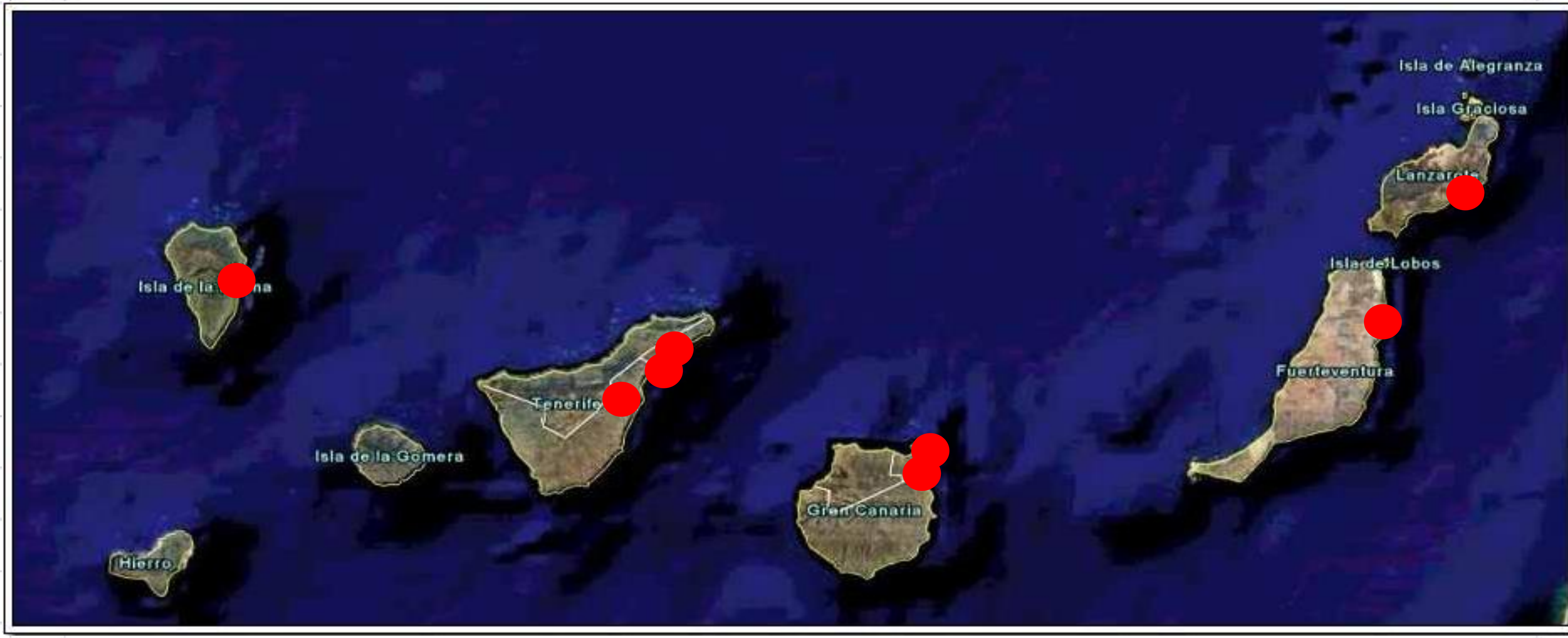
Tabla 1. Recopilación de ecuaciones obtenidas en intercomparaciones de analizadores de PM10.

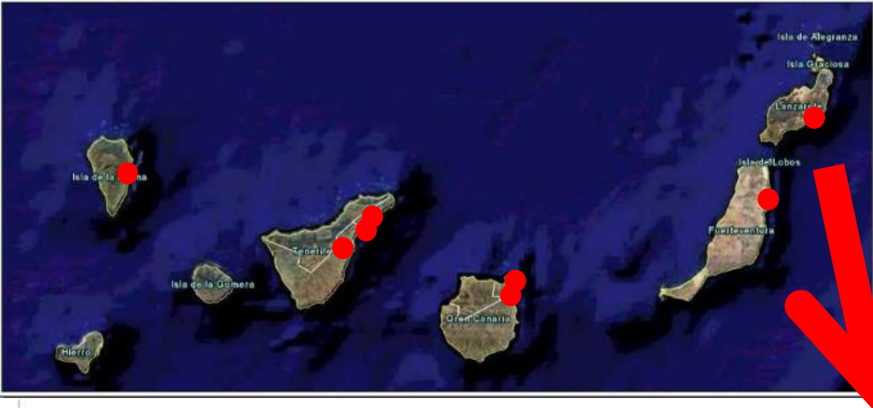
Estación	Fecha	Periodo	T, ºC	P hPa	Y=a·x	R^2	¿VALIDA?	Y=a·x+b	R^2	¿VALIDA?	N
LA HIDALGA	21/02/2009 – 24/03/2009	INVIERNO	20.2	972	y=0.798x	0.995	SI	y=0.820x + (-1.530)	0.997	SI	28
LOS GLADIOLOS	27/04/2009 – 09/06/2009	PRIMAVERA	24.4	993	y=0.711x	0.982	SI	y=0.760x +(-1.425)	0.987	SI	34
TOME CANO	04/08/2009-17/09/2009	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.

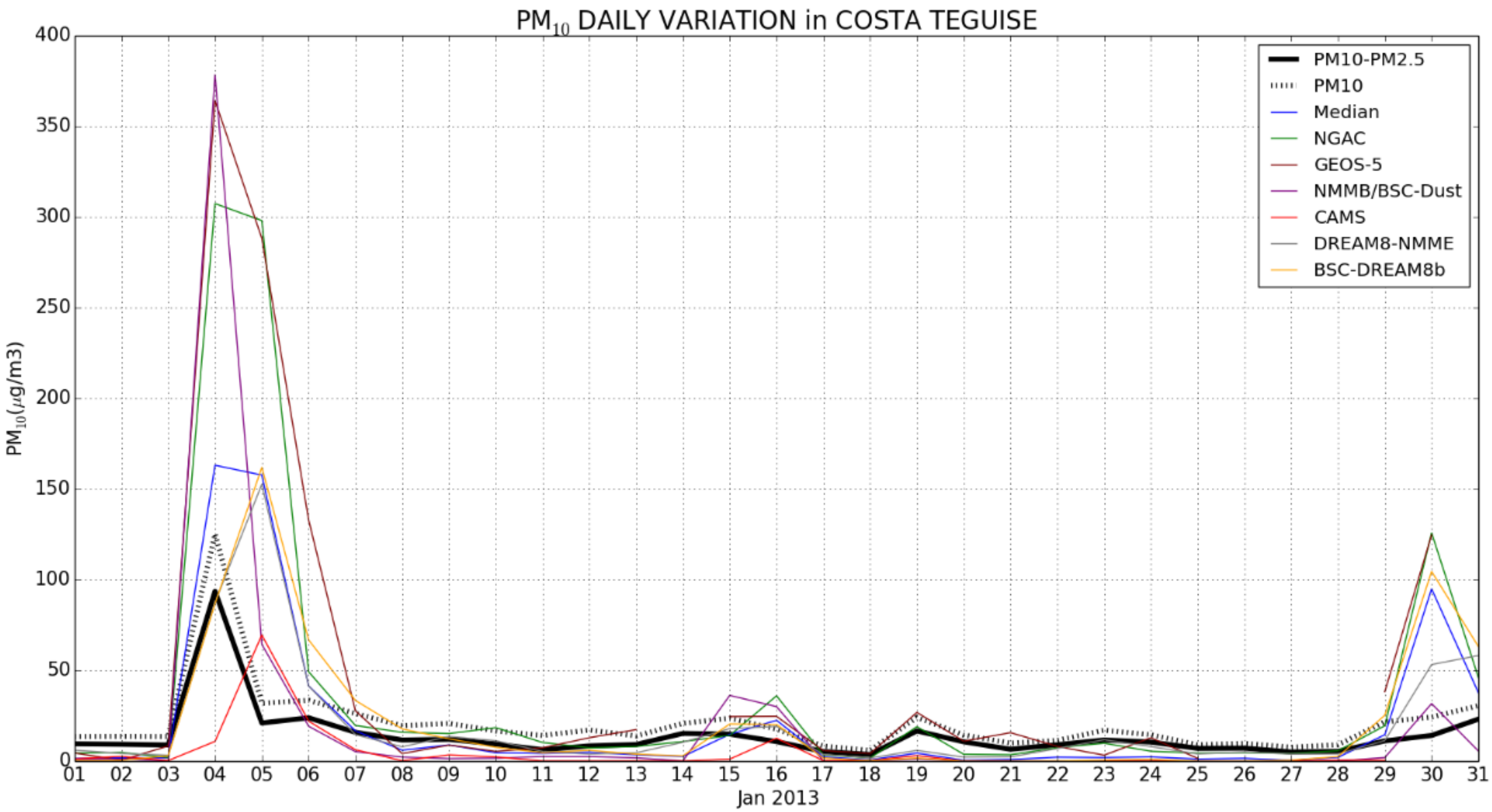
Estación	Fecha	Periodo	T, °C	P hPa	Y=a·x	R^2	¿VALIDO?	Y=a·x+(b)	R^2	¿VALIDO?	N
LA HIDALGA	21/02/2009 – 24/03/2009	INVIERNO	20.2	972	y=0.650x	0.9554	SI	y=0.7033x + (–1.4673)	0.9637	SI	28
LOS GLADIOLOS	27/04/2009 – 09/06/2009	PRIMAVERA	24.4	993	y=0.657x	0.8367	SI	y=0.9285x +(-3.1282)	0.9285	SI	33
MERCADO 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



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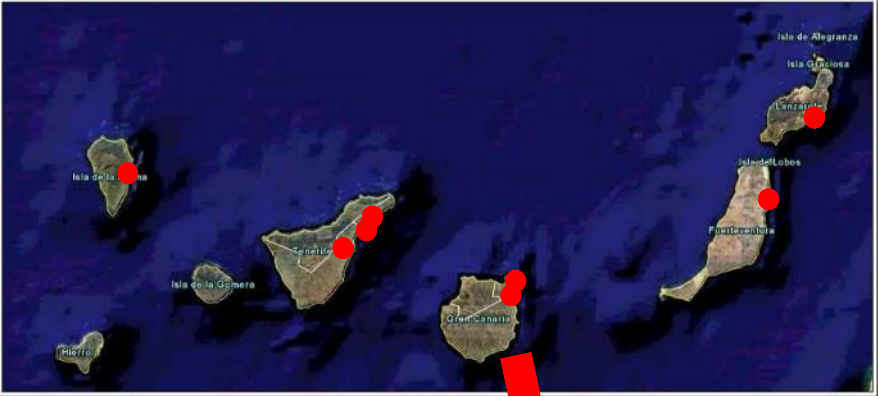
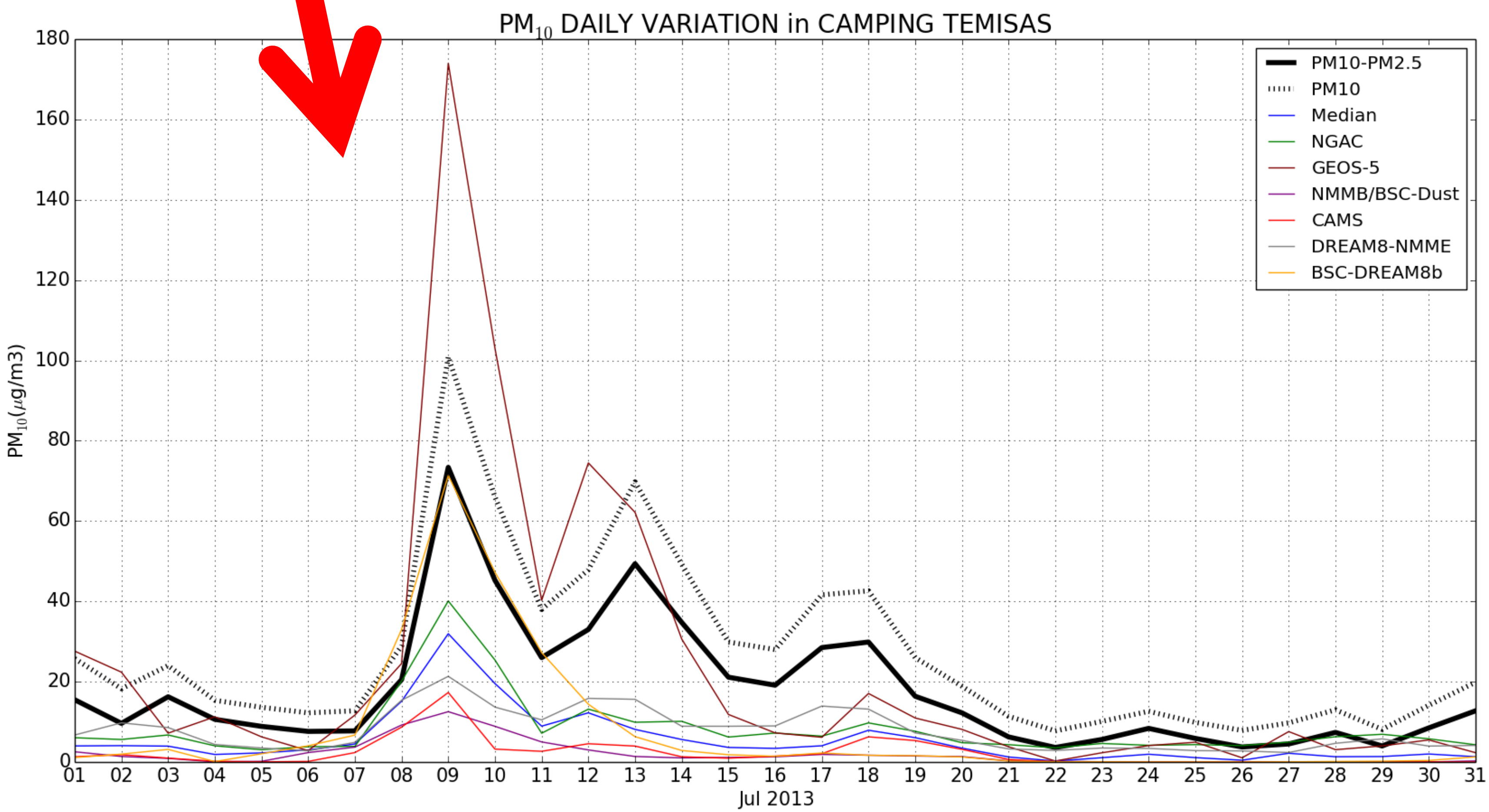


Model validation with standardized PM_{10} y $PM_{2.5}$ data in the network



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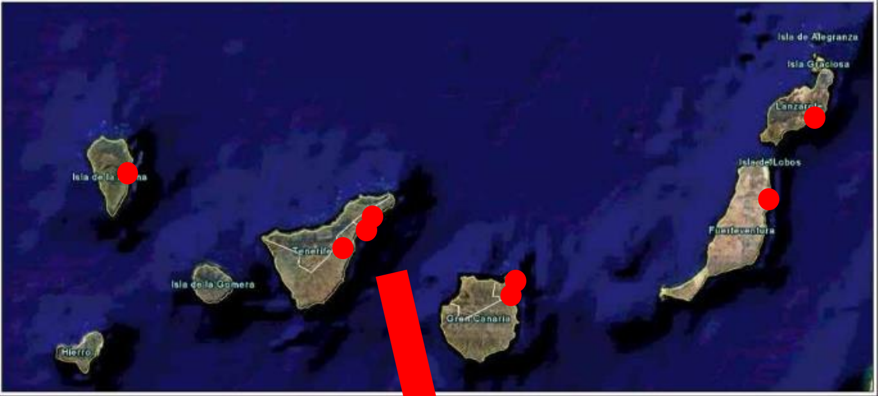
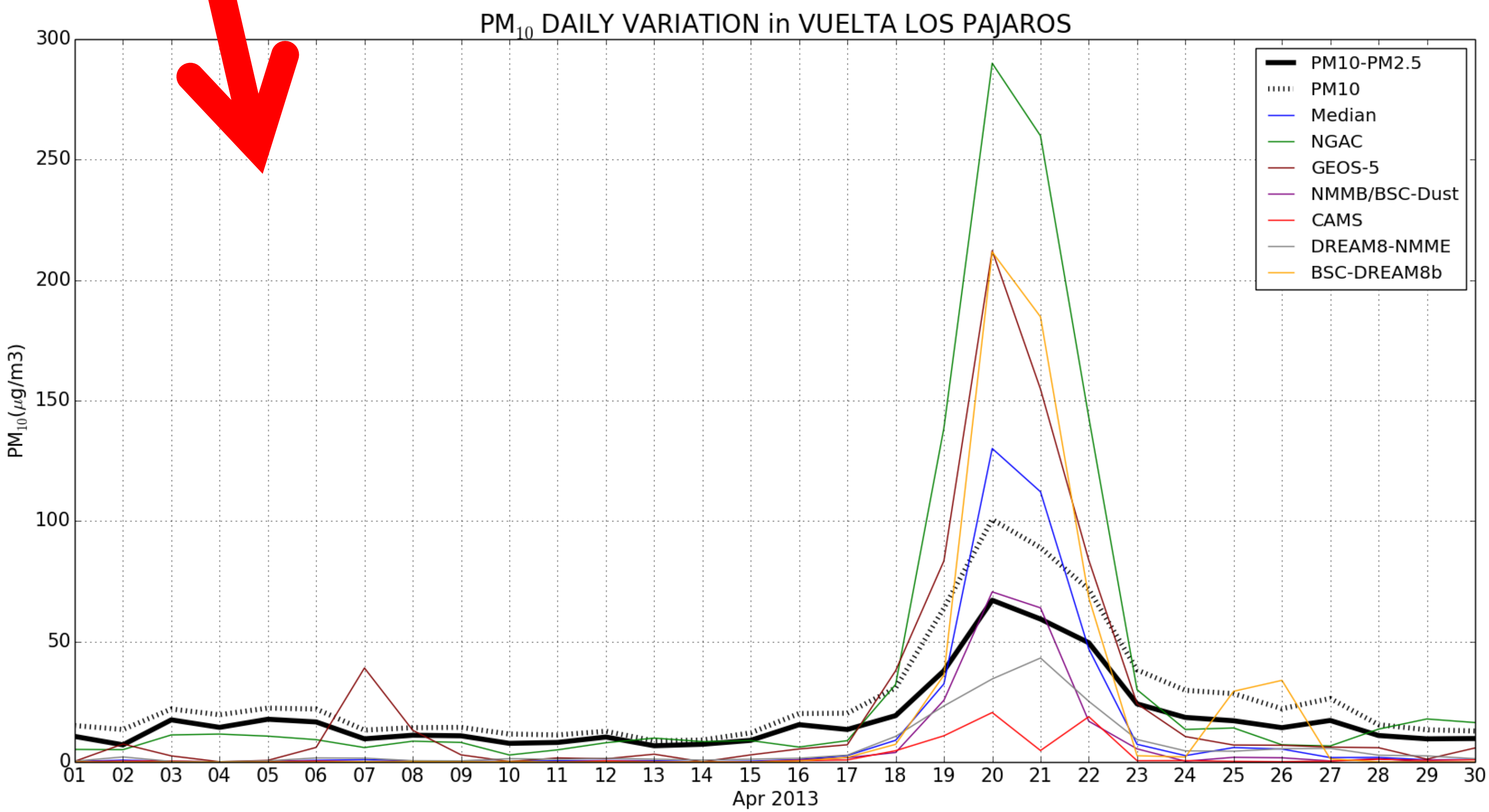


Model validation with standardized PM_{10} y $PM_{2.5}$ data in the network



dust air quality

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

-method-01: reference - manual gravimetry

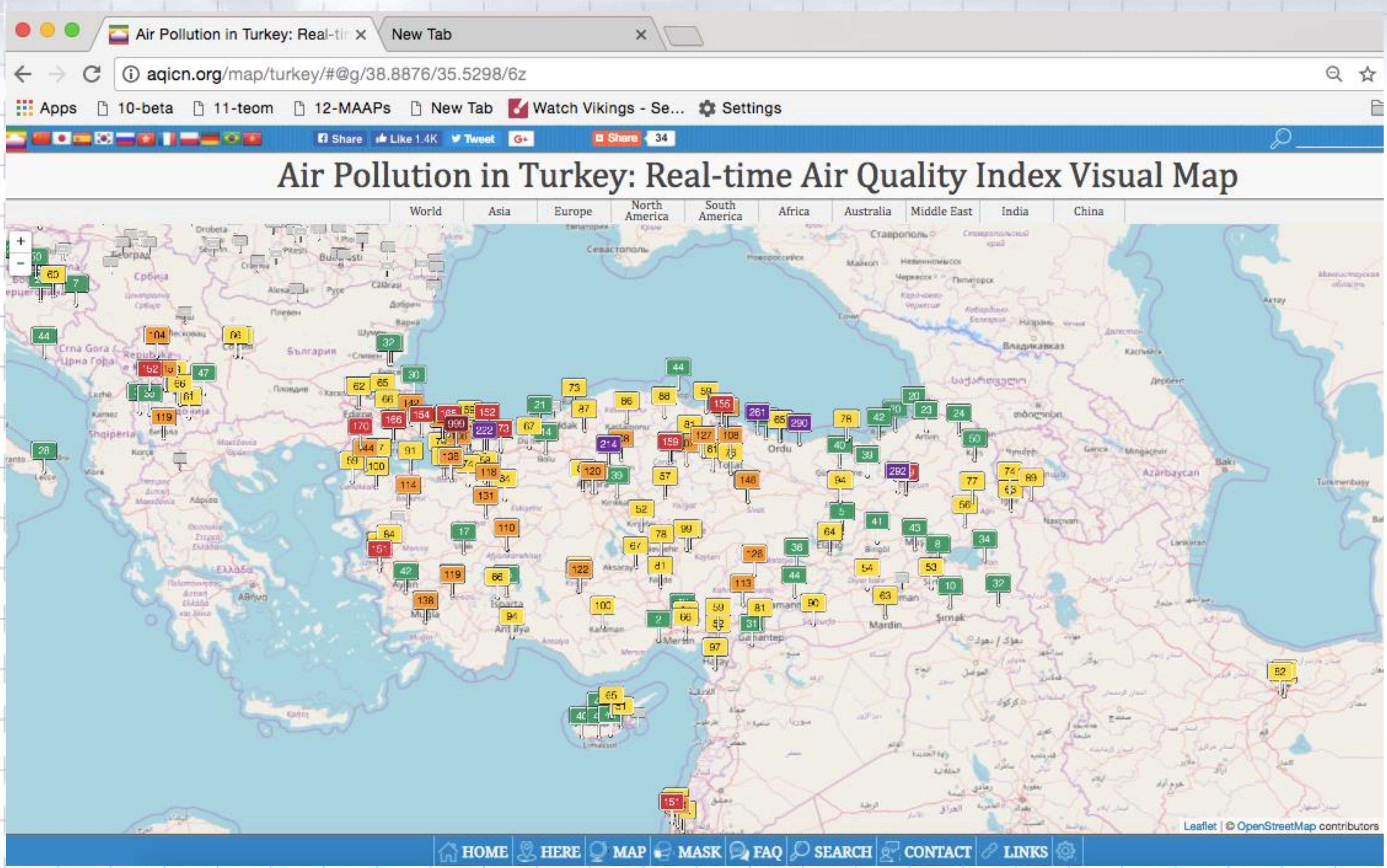
-method-02: automatic

	Manual gravimetry	automatic
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



Air Pollution in Turkey: Real-ti
New Tab
aqicn.org/map/turkey/#@g/38.8876/35.5298/6z
Apps
10-beta
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12-MAAPs
New Tab
Watch Vikings - Se...
Settings
Share
Like 1.4K
Tweet
Share
34
Air Pollution in Turkey: Real-time Air Quality Index Visual Map
World
Asia
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North America
South America
Africa
Australia
Middle East
India
China
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LINKS

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

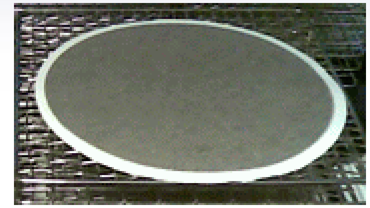
we recommend to use the two methods:
-automatic, constinously
-gravimetric: intercomprisons, 1 month summer, 1 month winter

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

XRF, PIXE, INAA : none 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

bulk chemical composition

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

dust

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)

Bulk dust estimations

33% Si
8% Al
4% Fe
.....

$Al_2O_3 + SiO_2 + CaCO_3 + \ldots$

people live in cities and breath a cocktail dust + pollutants

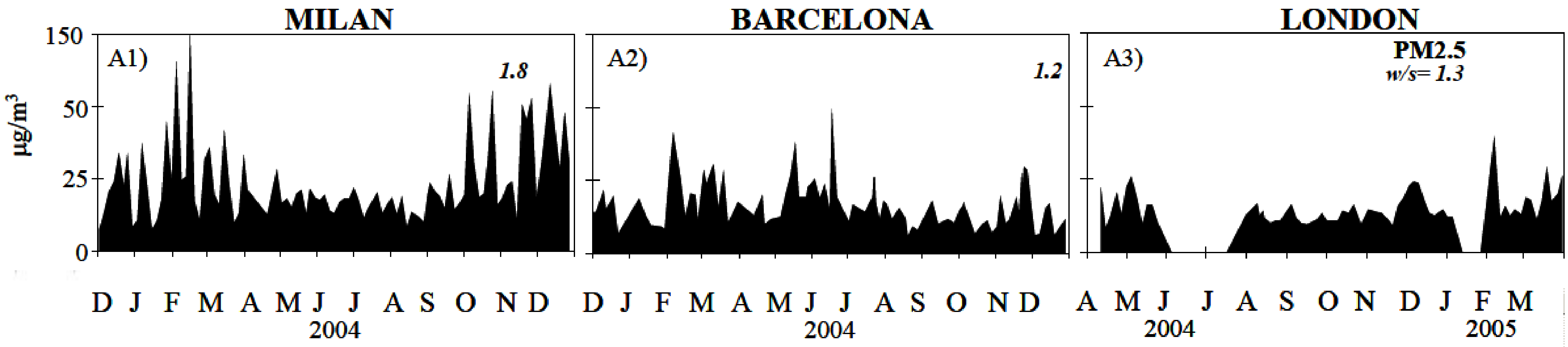
PM_{10}: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ..

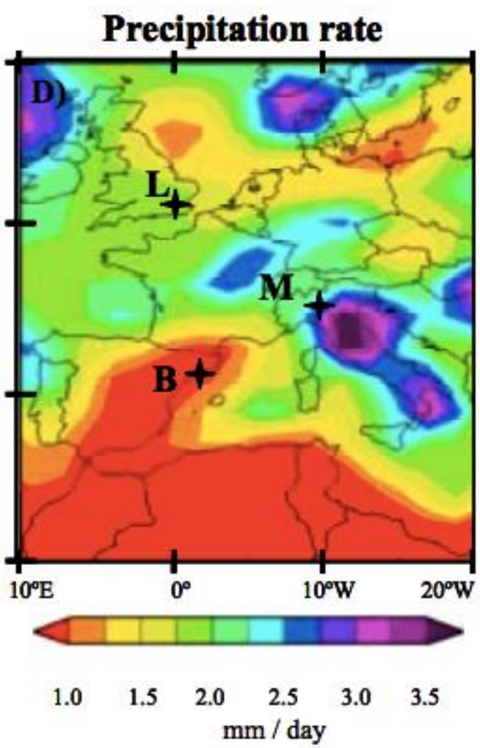
$PM_{2.5}$: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ..

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

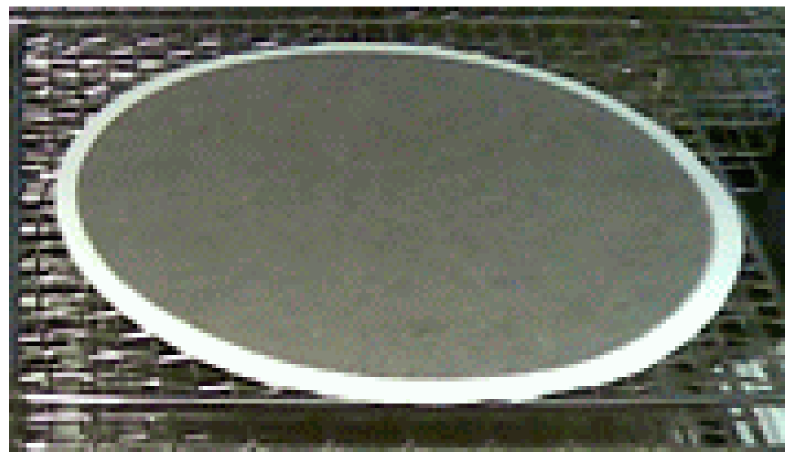
$PM_{2.5}$: dust + sea salt + vehicle exhaust + oil refining + power plants + ships +...

PM in urban areas

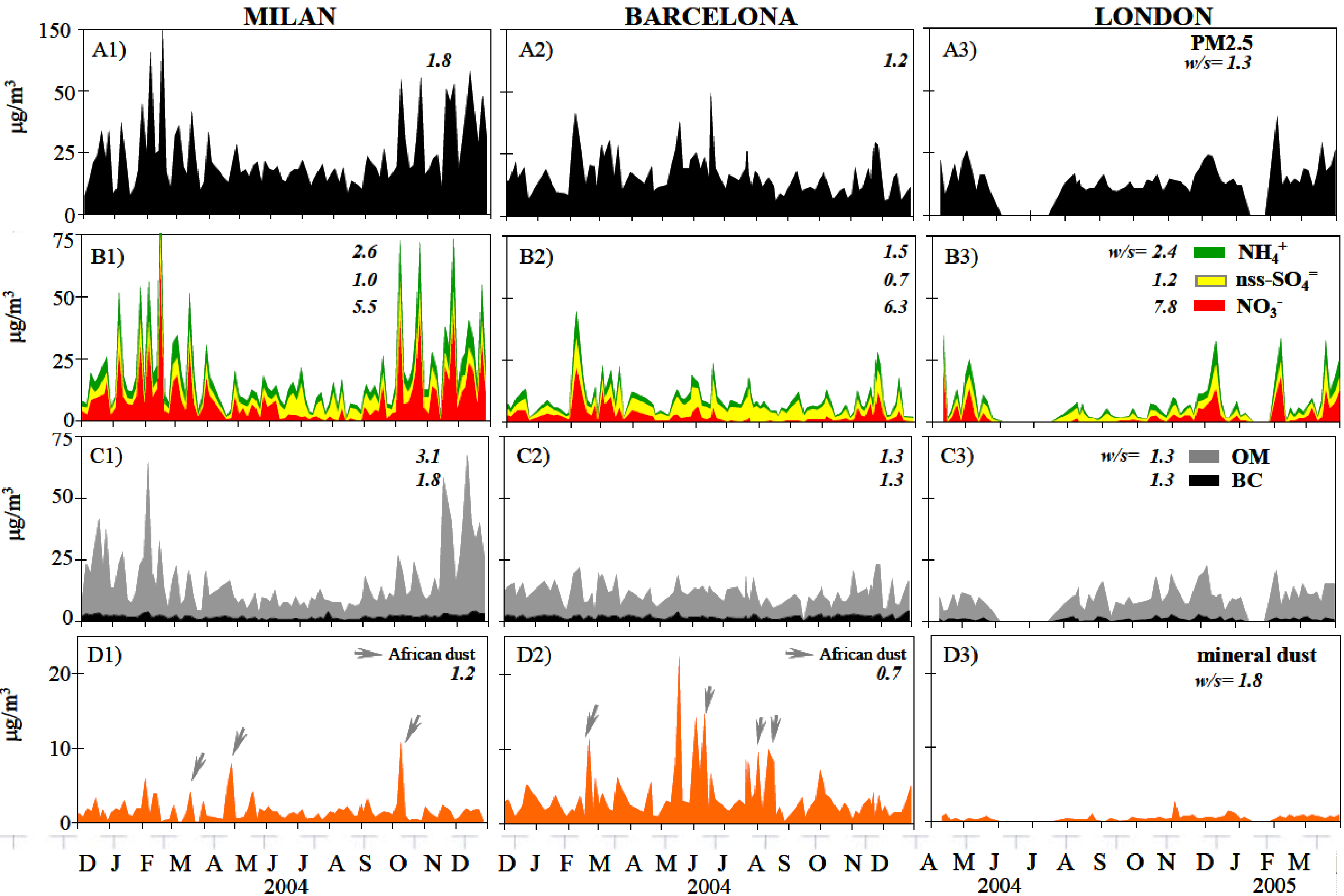




Urban particles

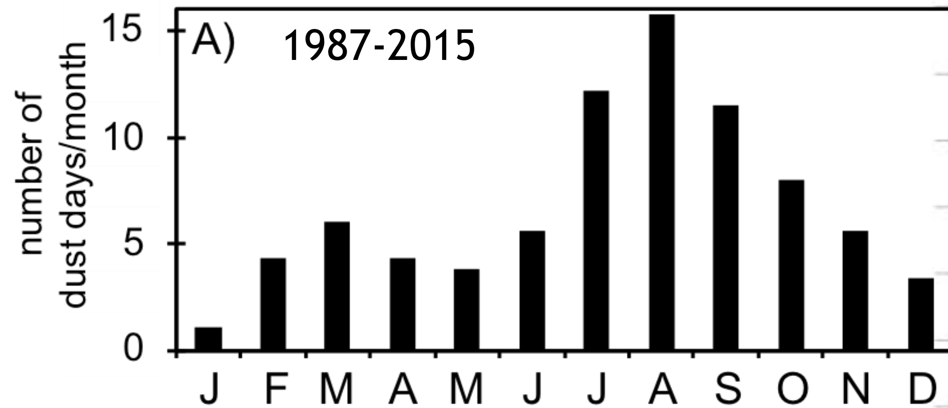


PM in urban areas

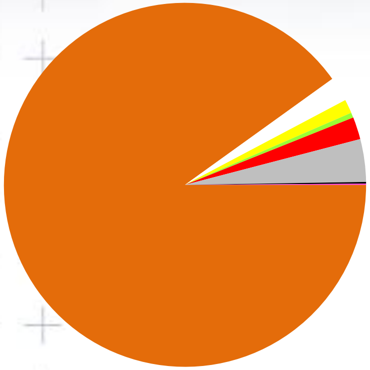


PM in remotes sites

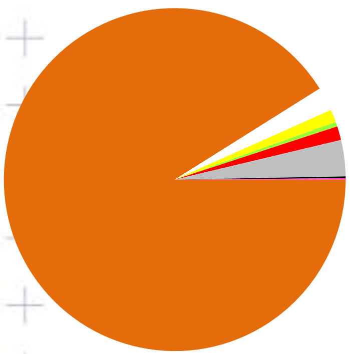
Summer Izaña is within the SAL



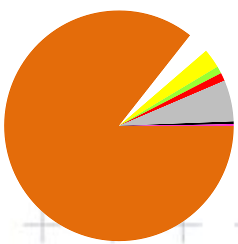
PM_x composition in the SAL



PM_T	47.3 µg/m³	
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

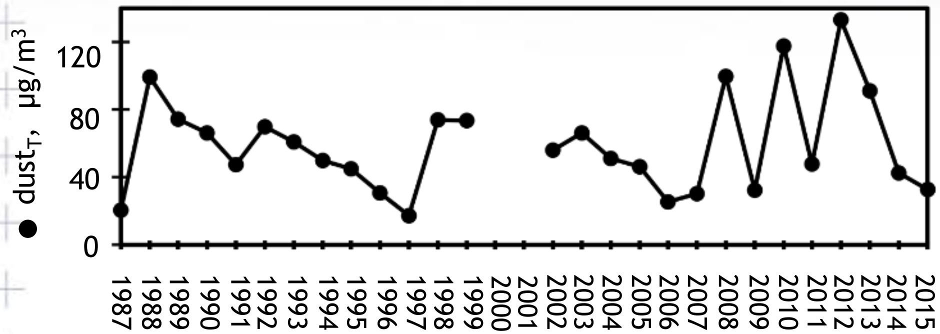


PM_{10}	42.0 µg/m³	
91%	38.3	dust
2.2%	0.9	none ammonium-sulfate
1.2%	0.5	ammonium-sulfate
0.4%	0.2	ammonium
1.3%	0.6	nitrate
3.4%	1.4	organic matter
0.2%	0.07	elemental carbon



$PM_{2.5}$	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

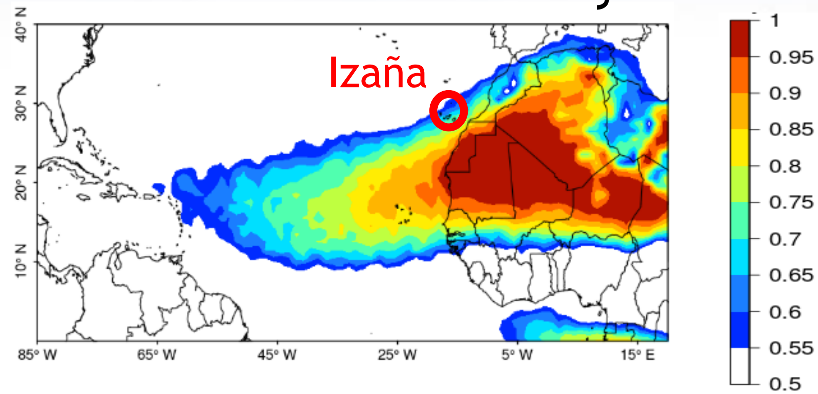
summer dust at Izaña: 1987 - 2015



Max: 133 µg/m³ 2012

Min: 17 µg/m³ 1997

Saharan Air Layer



MDFA: Major Dust Frequency Activity

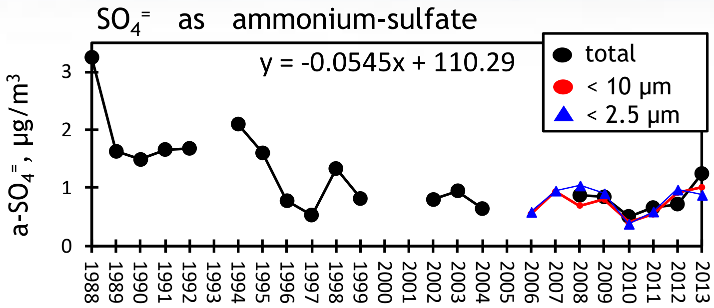
UV Absorbing Aerosol Index = sensitive to iron oxides in dust

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

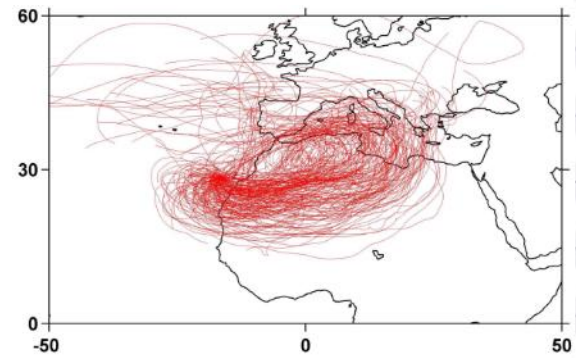
= fraction of summertime AI>1

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

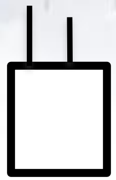
dust, aerosols and pollutants

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

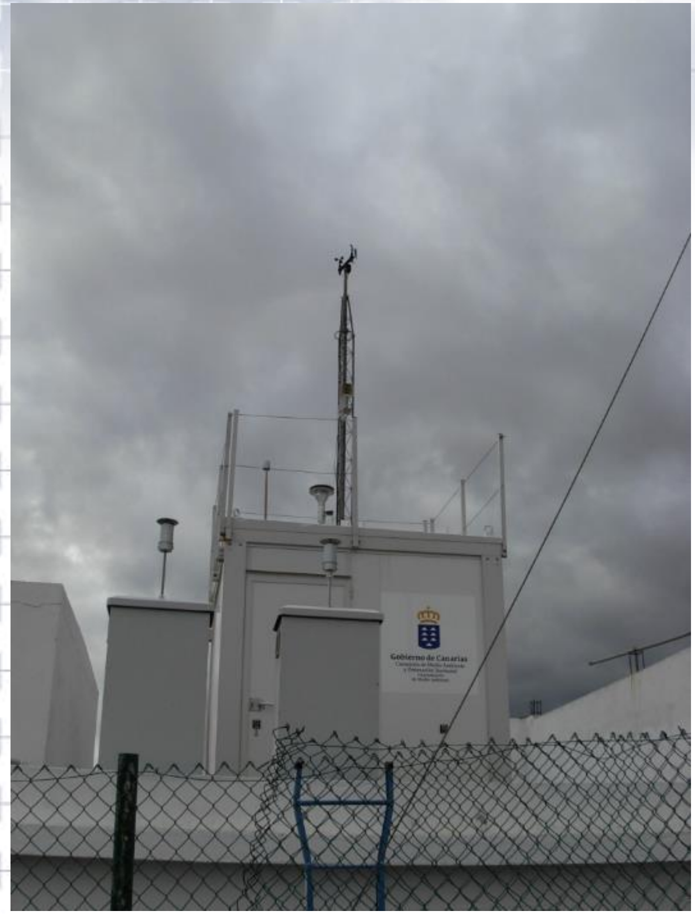
in-situ observations

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:

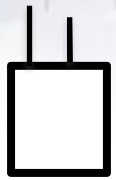
NOx: chemiluminiscense. EN 14211: 2006

SO2: fluorescense. EN 14212: 2006

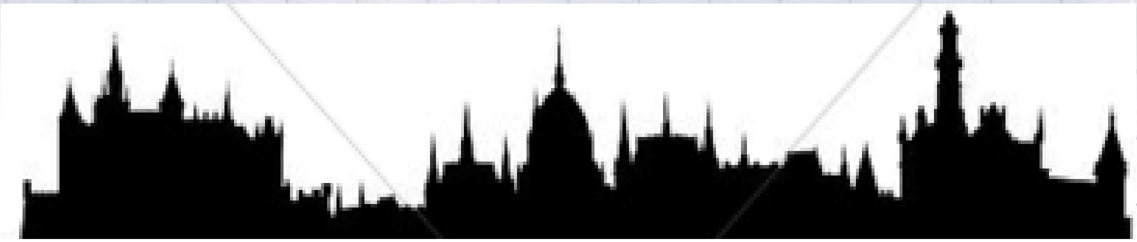
CO: NDIR absorption. EN 14626: 2006

O_3: NDIR absorption. EN 14625: 2006

in-situ observations



dust air quality

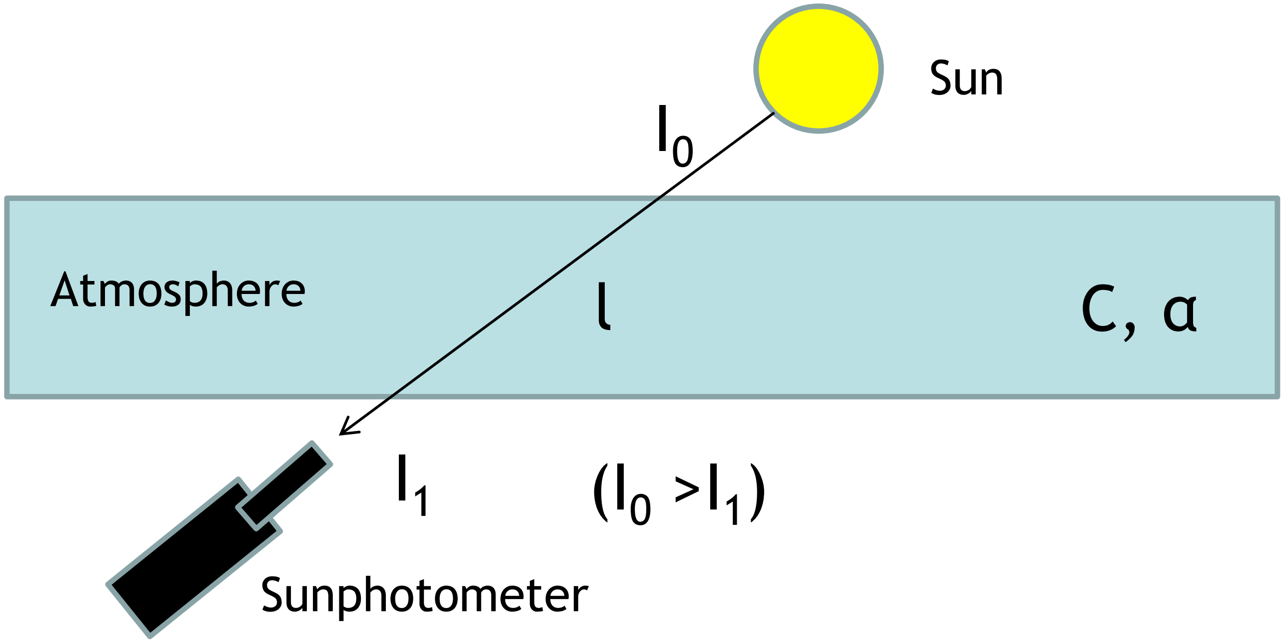


in-situ observations

- 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:

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 (µg/cm^2) is the total aerosol mass in a vertical column of atmosphere.

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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)

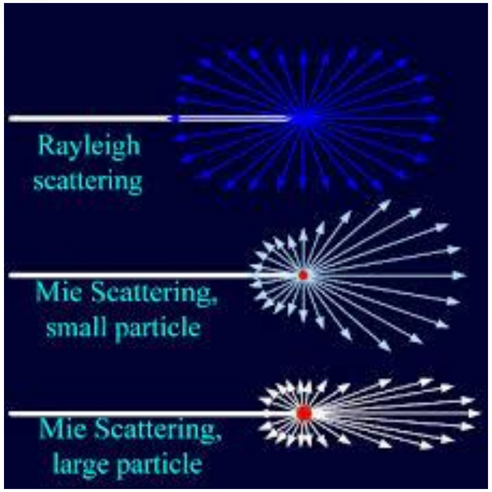
i.e. If AOD >~ 0.2 and α<0.7 then we are observing dust (aprox.)

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):

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

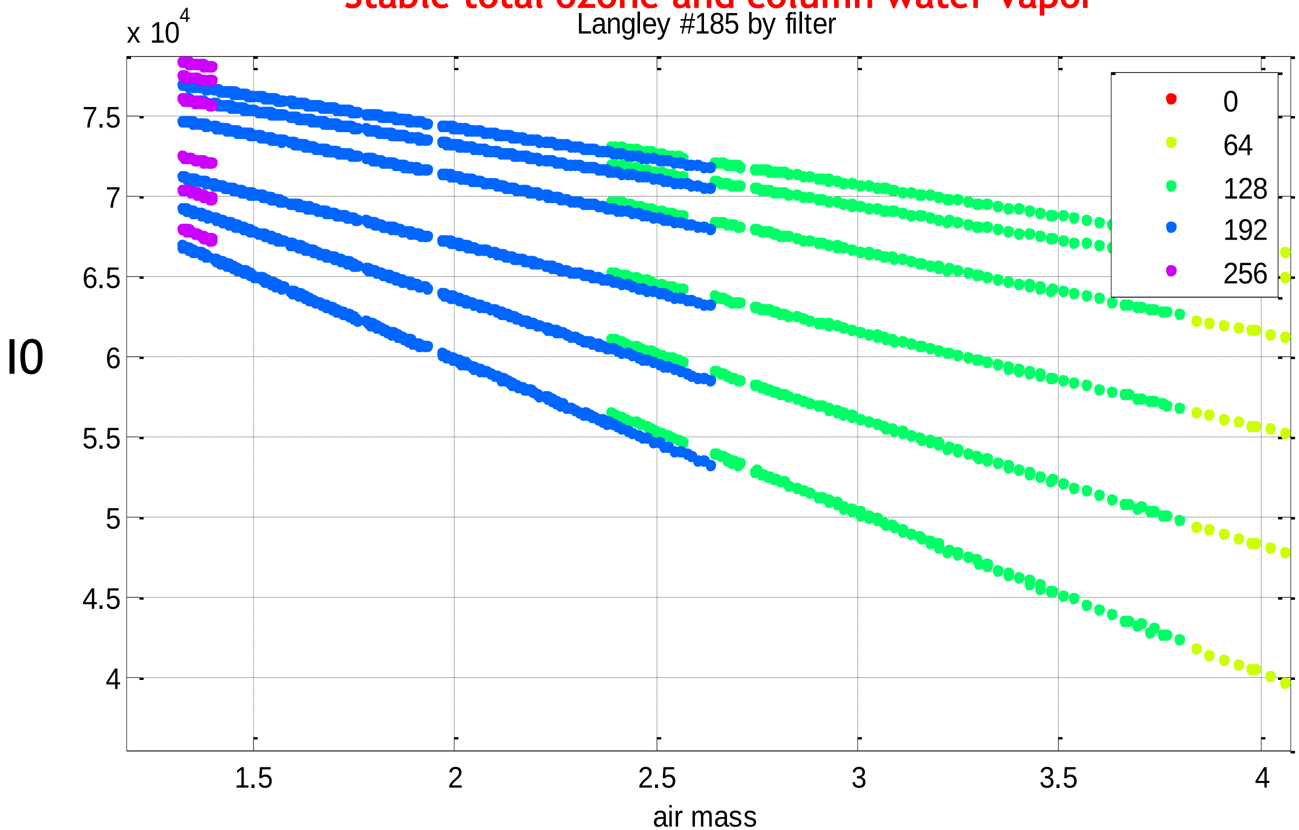
$$\ln I = \ln I_o - \sigma_{ext} L$$

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

Pristine conditions (very low and constant aerosol load

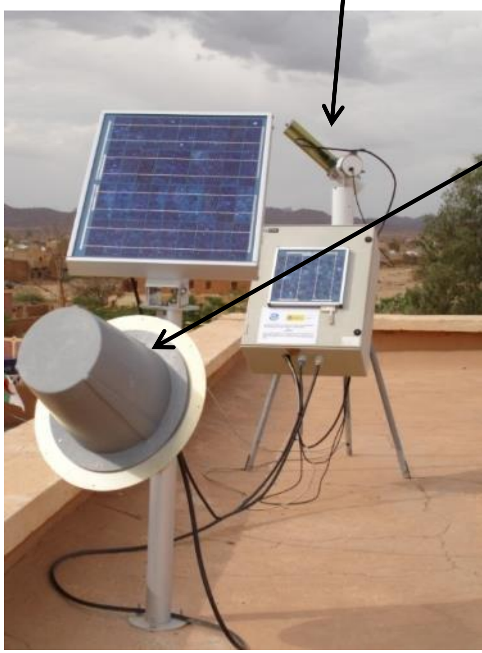
No clouds

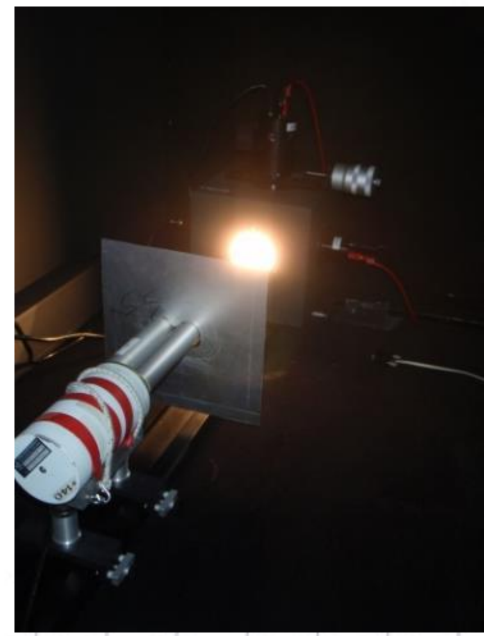
Stable total ozone and column water vapor



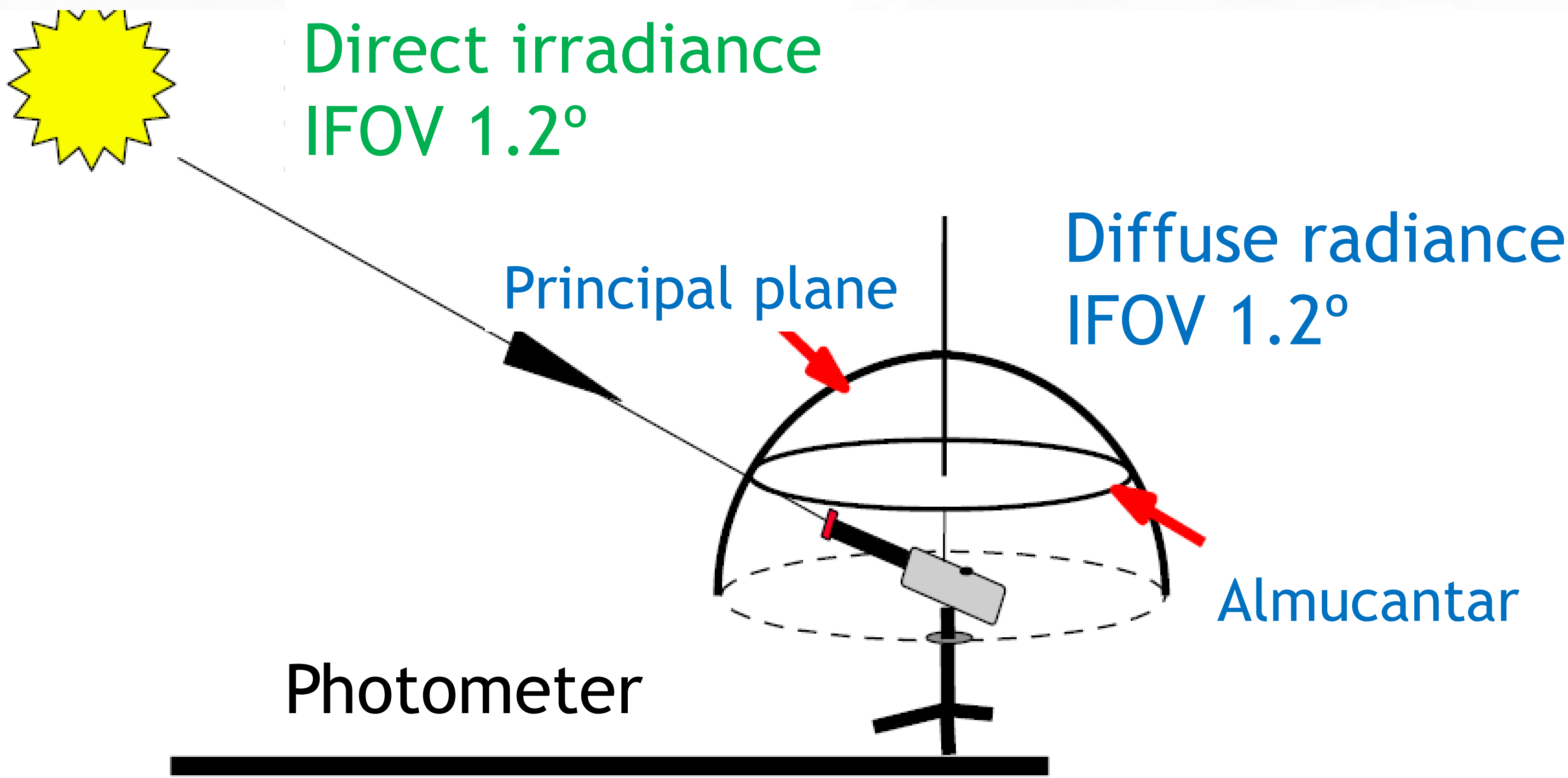
MEASUREMENTS:

- 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.



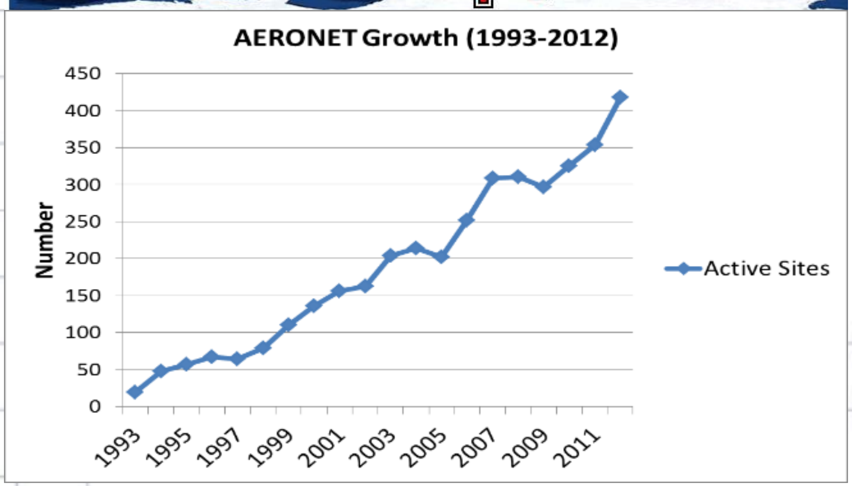


MEASUREMENTS:



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

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

Eck et al. JGR, 1999

Aerosol optical depth and precipitable water computations

Smirnov et al. *RSE*, 2000

Cloud screening and quality control

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

Inversion products

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

Ground-based remote sensing **MEASUREMENTS:**

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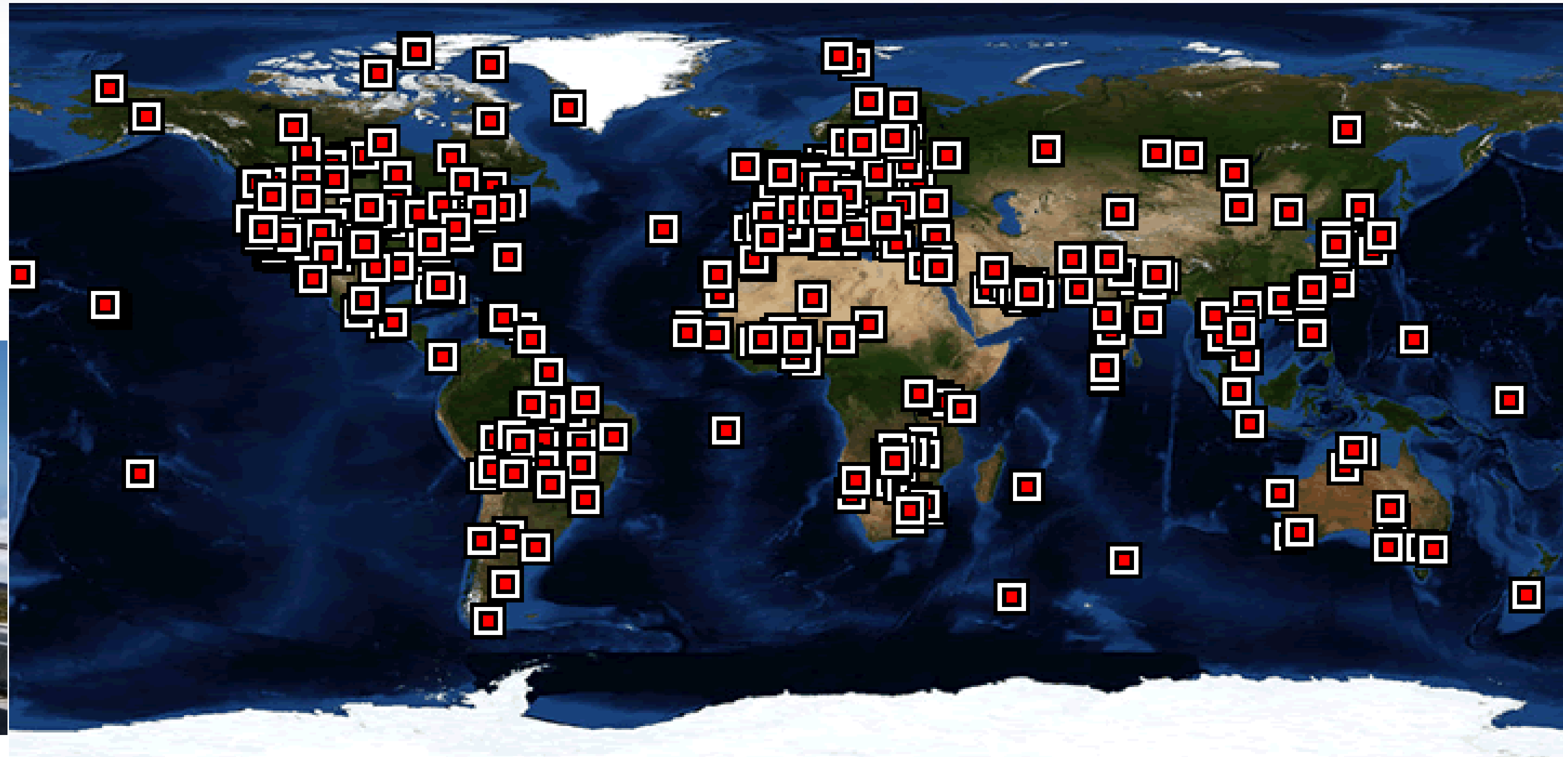
AERONET (AErosol RObotic NETwork)- http://aeronet.gsfc.nasa.gov

NASA cnes CNRS 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

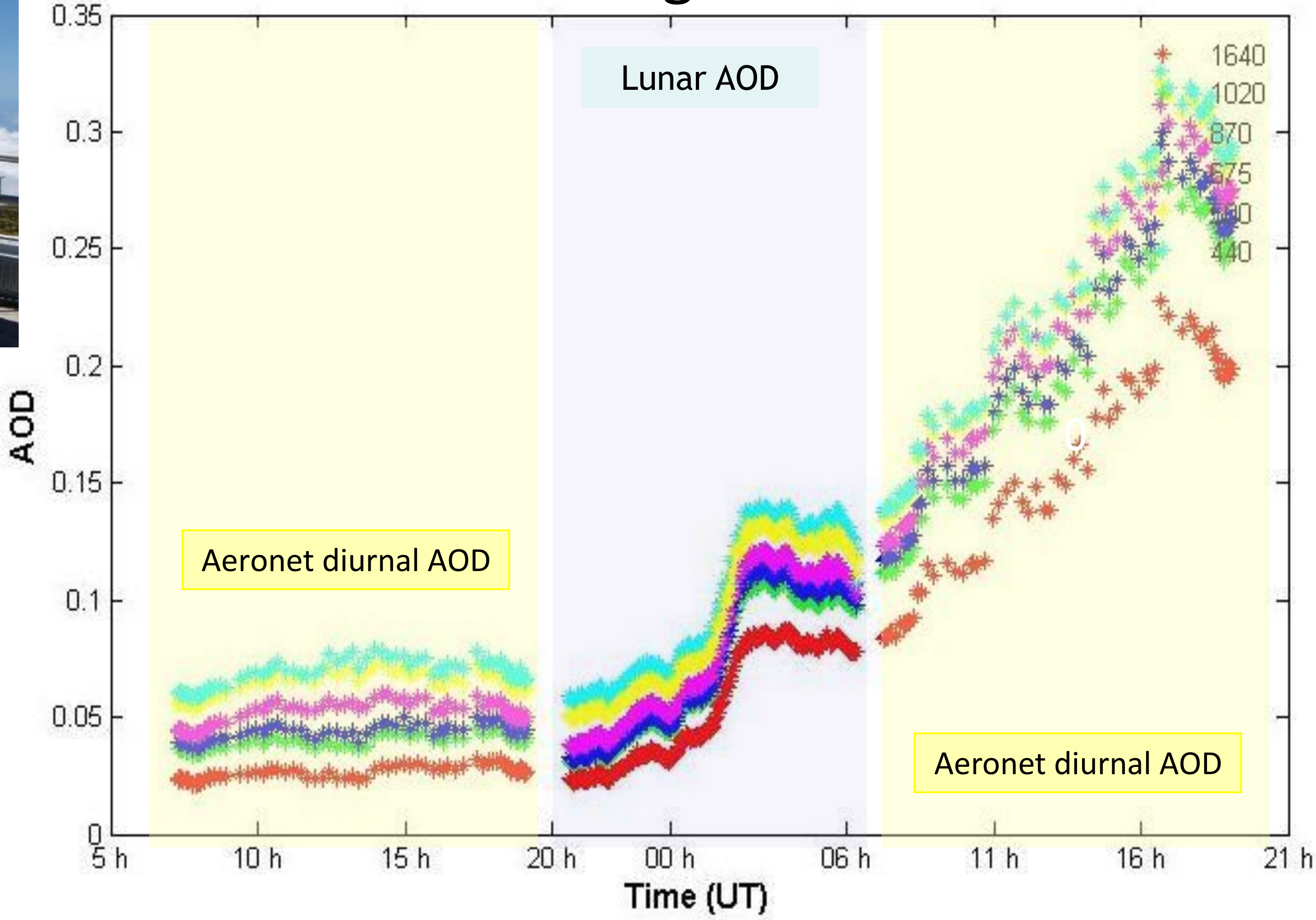
AERONET provides:

- 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:

AOD 14 August 2011



August 13

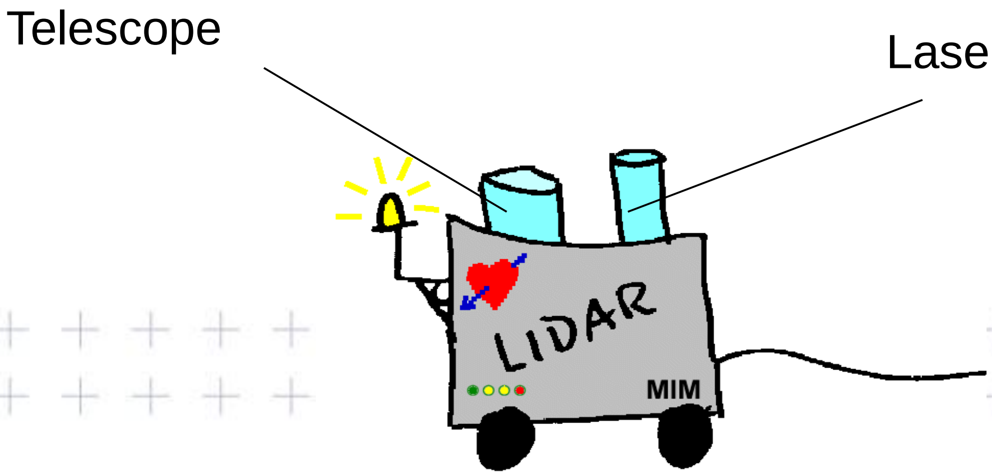
August 14

From total column observations…

to vertical resolved observations

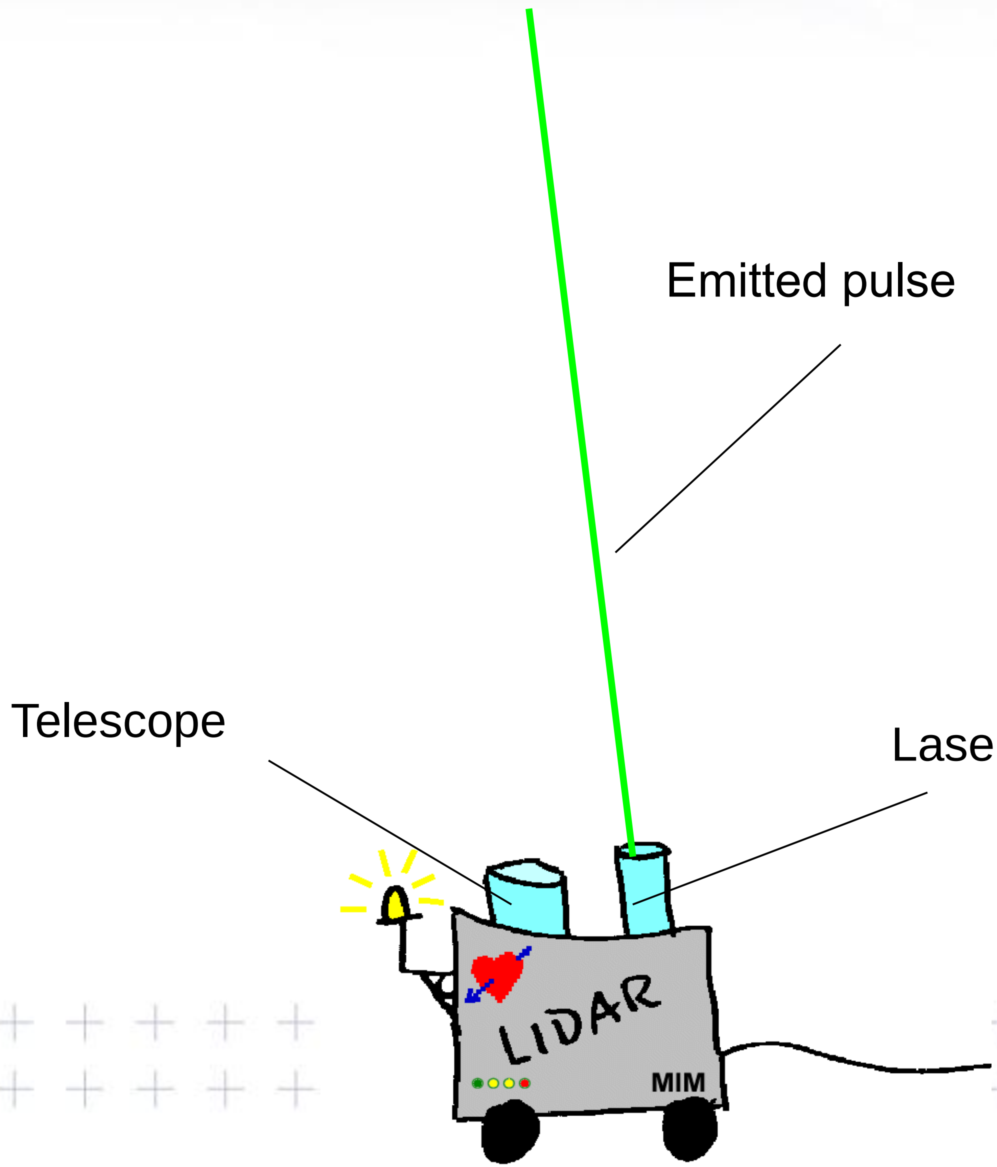
Lidars

Ground-based remote sensing



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

Ground-based remote sensing



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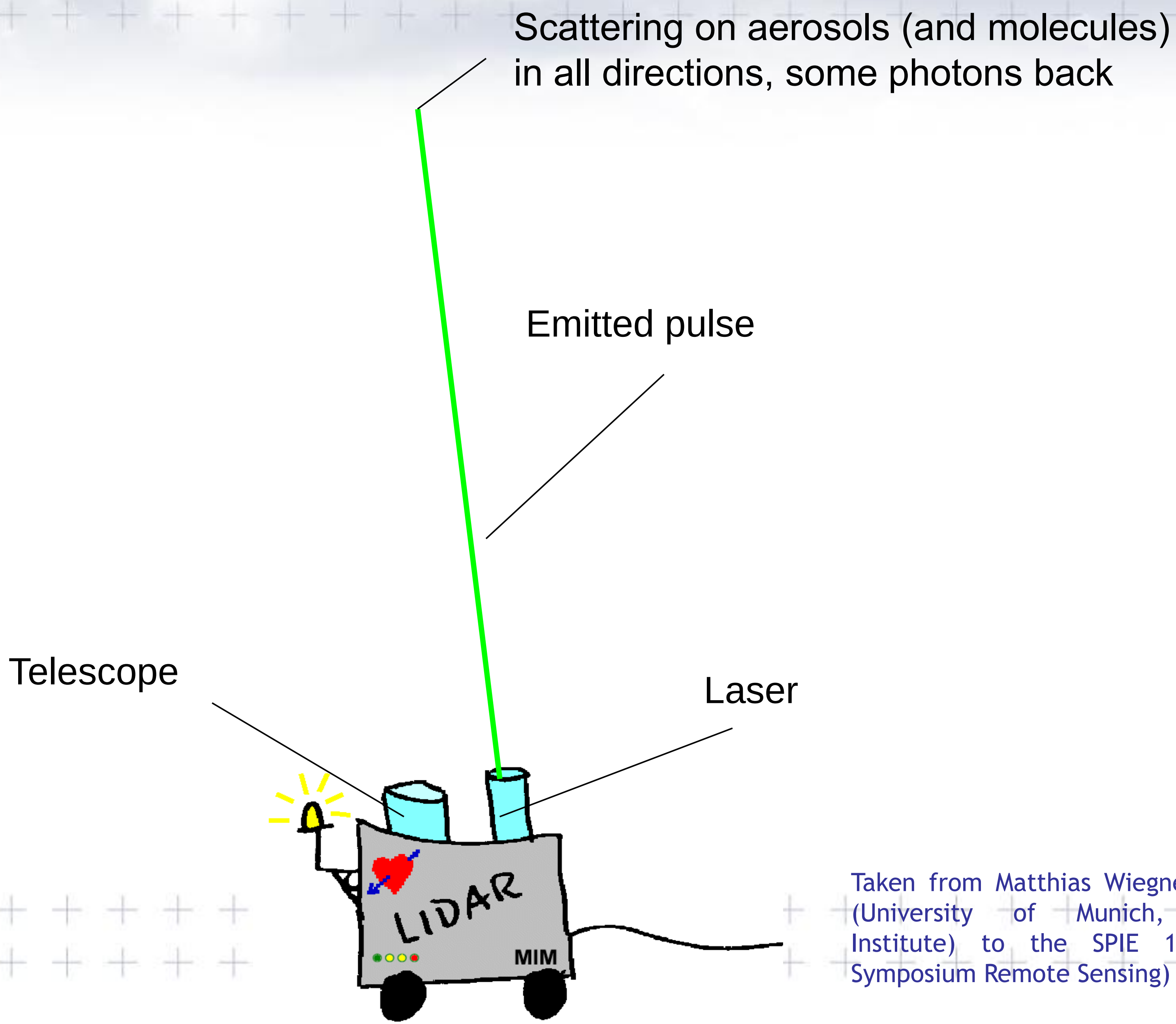
Ground-based remote sensing



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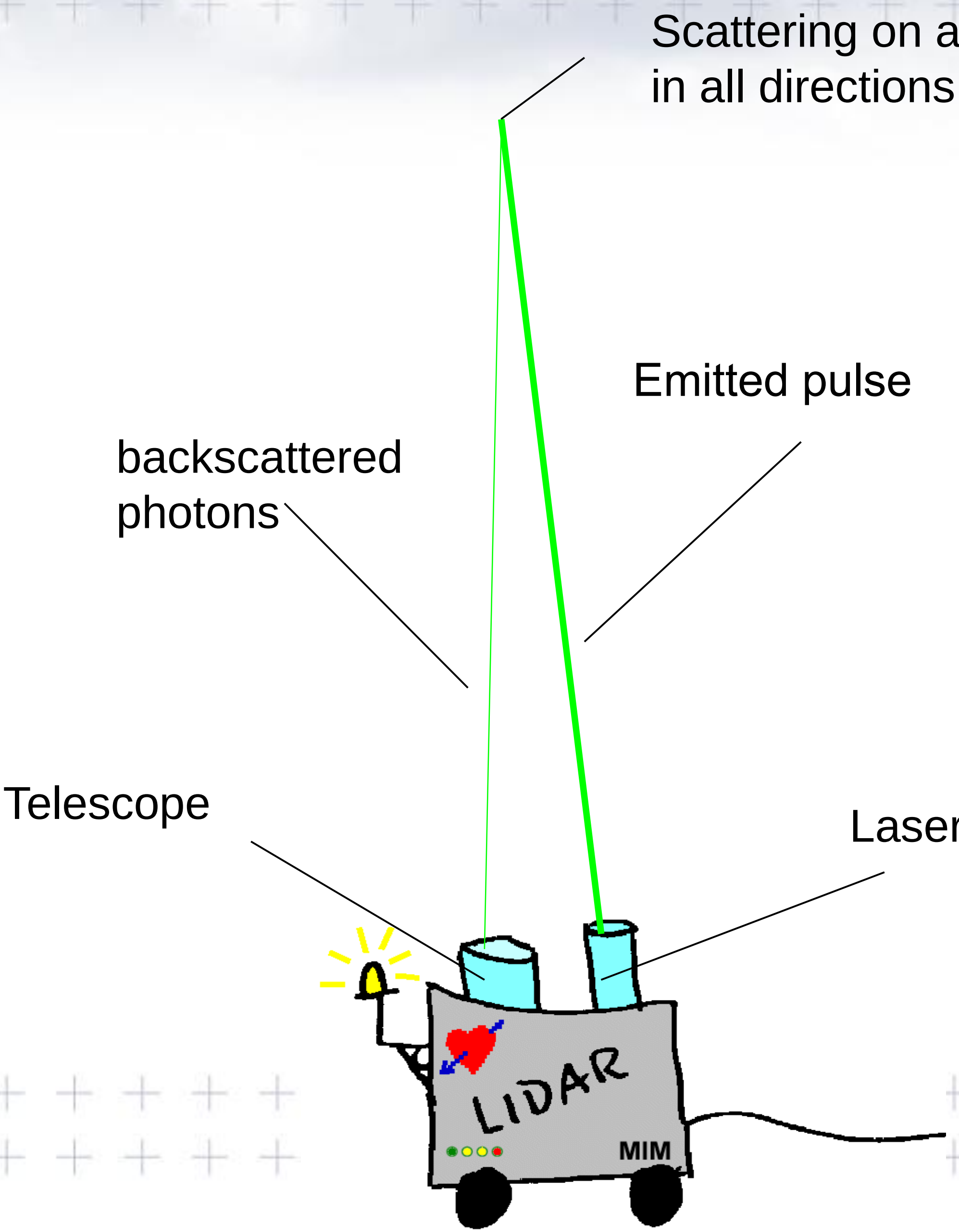
Ground-based remote sensing

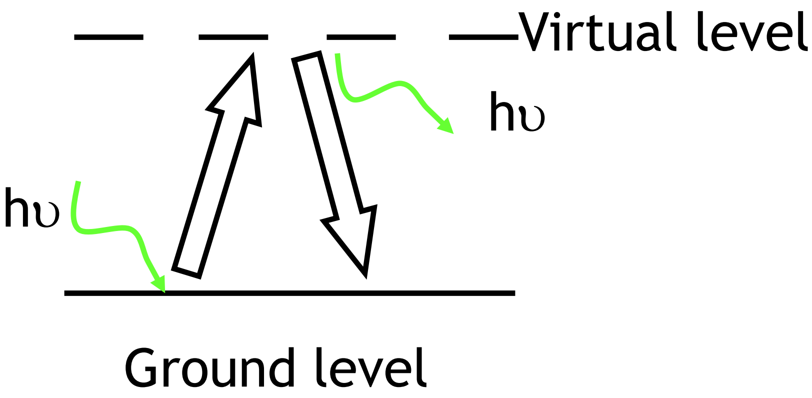


Taken from Matthias Wiegner's presentation (University of Munich, Meteorological Institute) to the SPIE 10 (International Symposium Remote Sensing)

Ground-based remote sensing

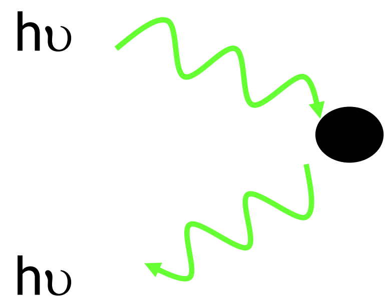
- **Rayleigh Scattering**

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



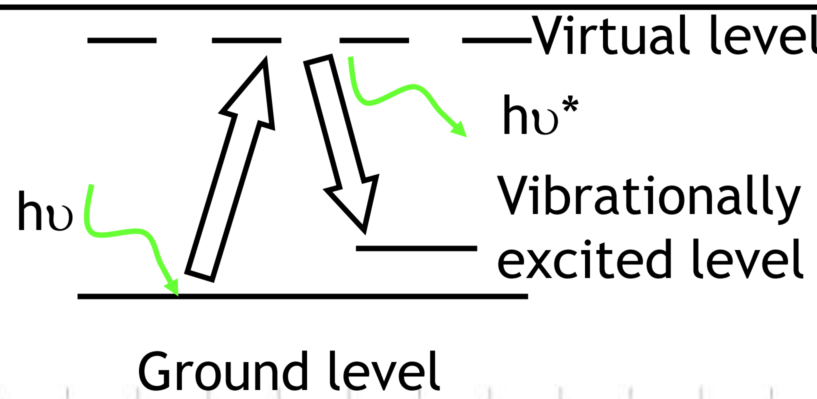
- **Mie Scattering**

  "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 ($h\nu - h\nu^* = E$)"



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

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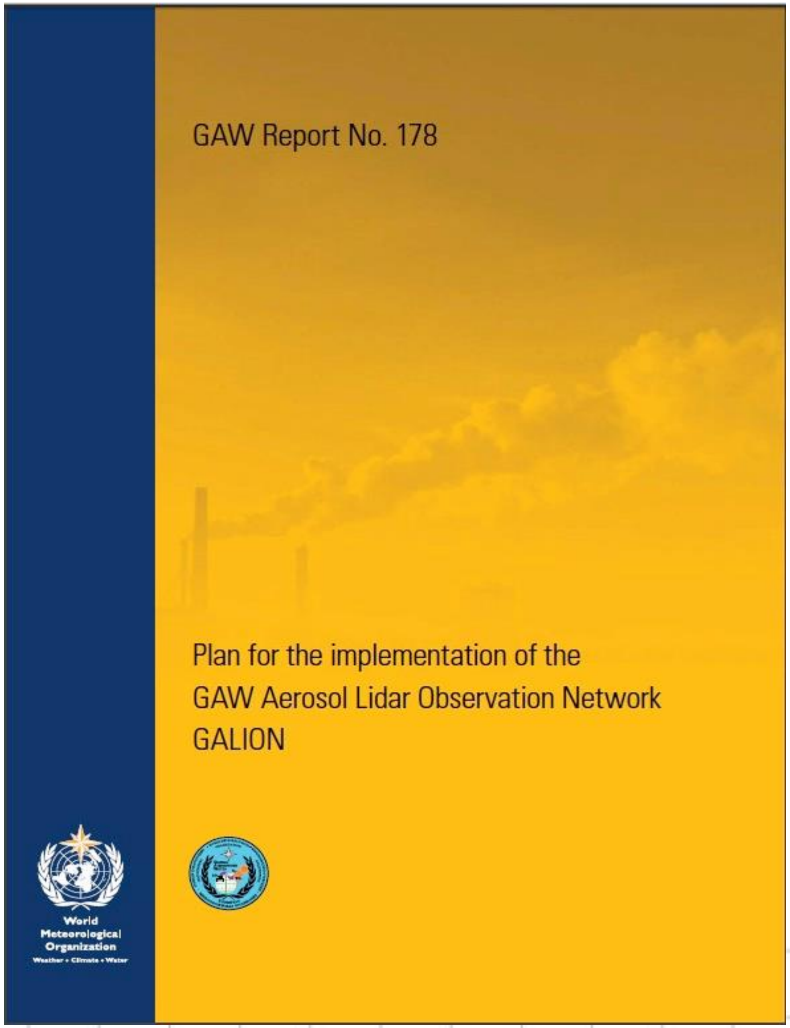
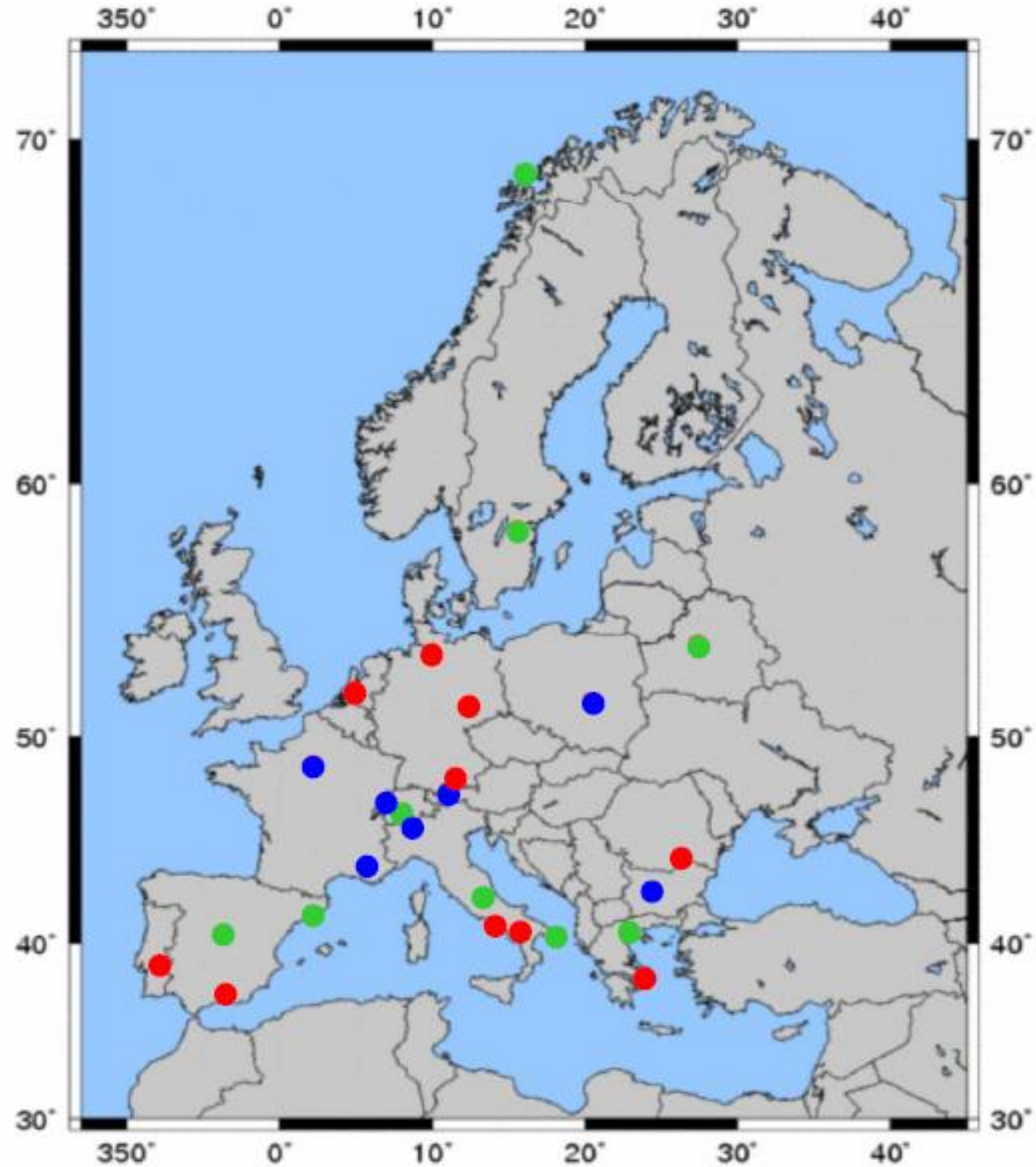
AEMet Agencia Estatal de Meteorología

GAW Atmospheric Lidar Network (GALION)



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



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 aerosol extinction and backscatter, 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**

Ground-based remote sensing

Aerosol lidar (MPLNet)

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

523 nm MPLNET
Automatized since July 2005

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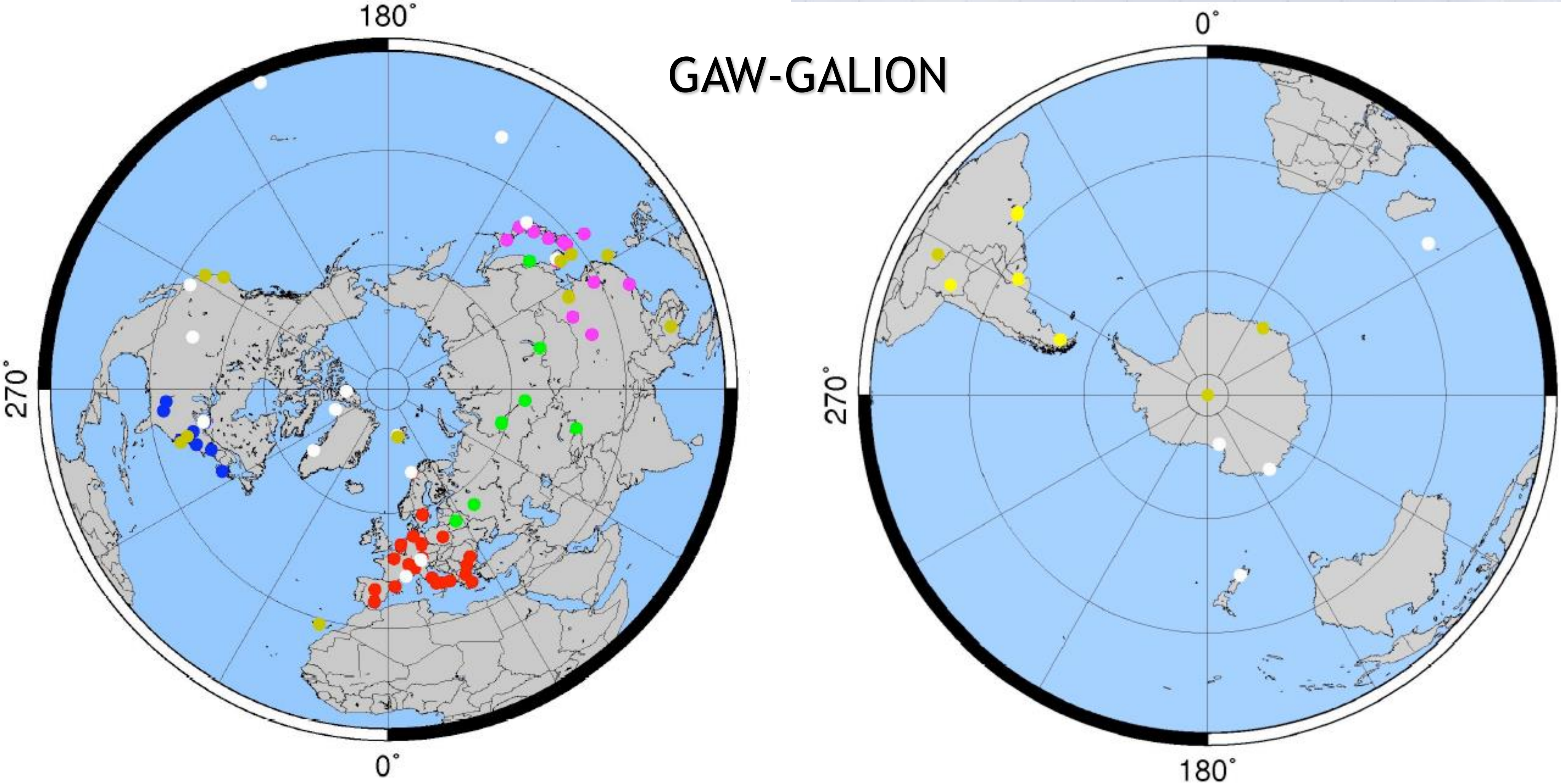
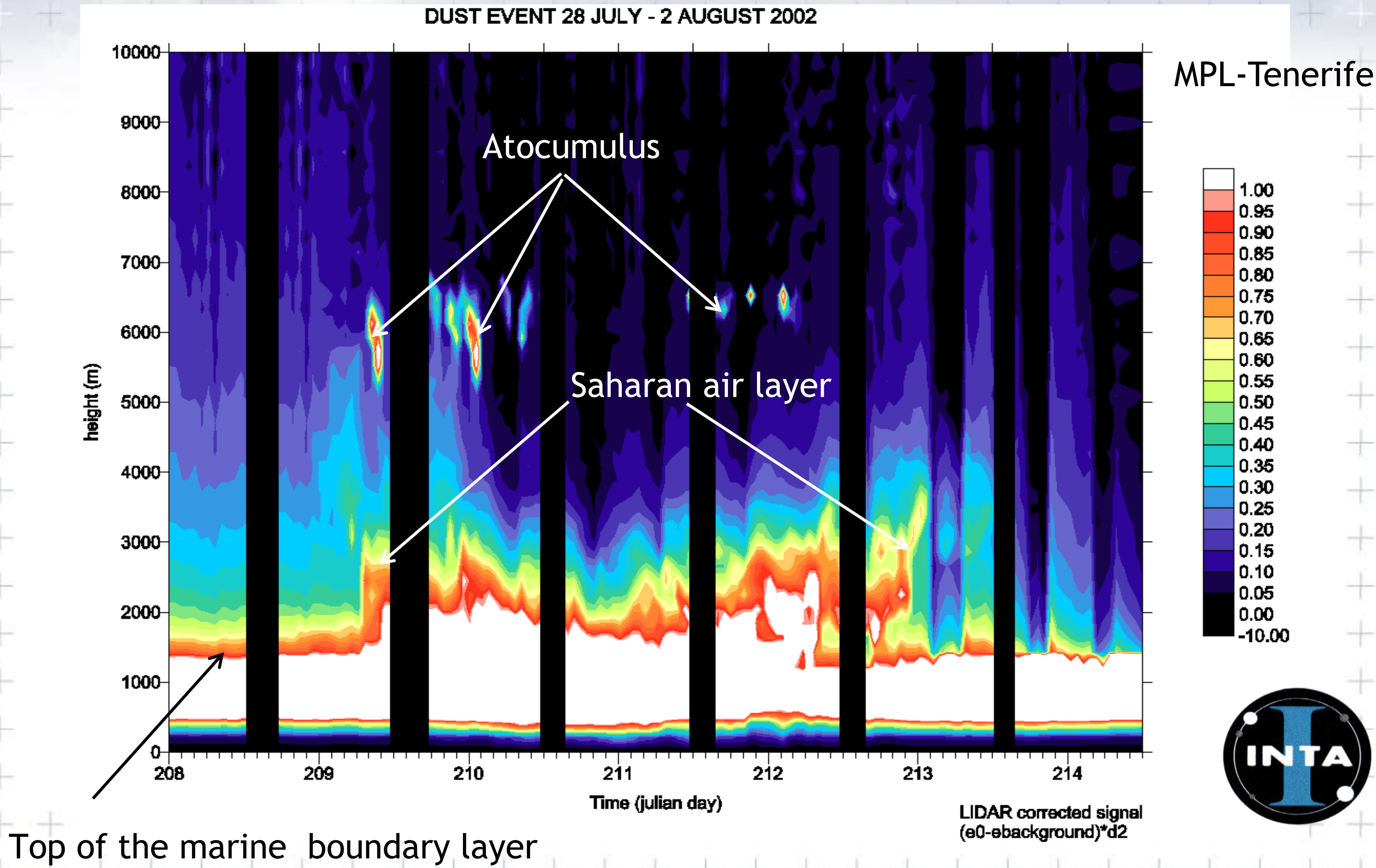
GAW-GALION



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


DUST EVENT 28 JULY - 2 AUGUST 2002
MPL-Tenerife
Atocumulus
Saharan air layer
Top of the marine boundary layer
height (m)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
208
209
210
211
212
213
214
Time (julian day)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-10.00
LIDAR corrected signal
(e0-ebackground)*d2
INTA

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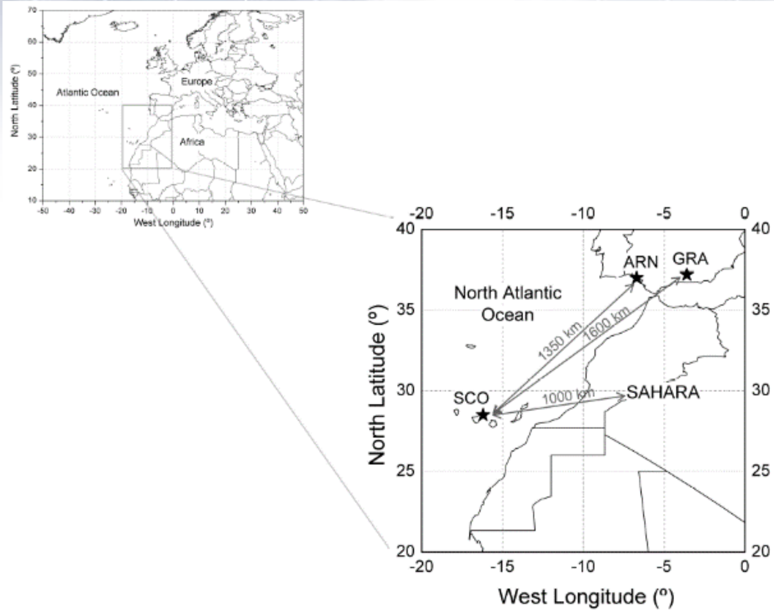
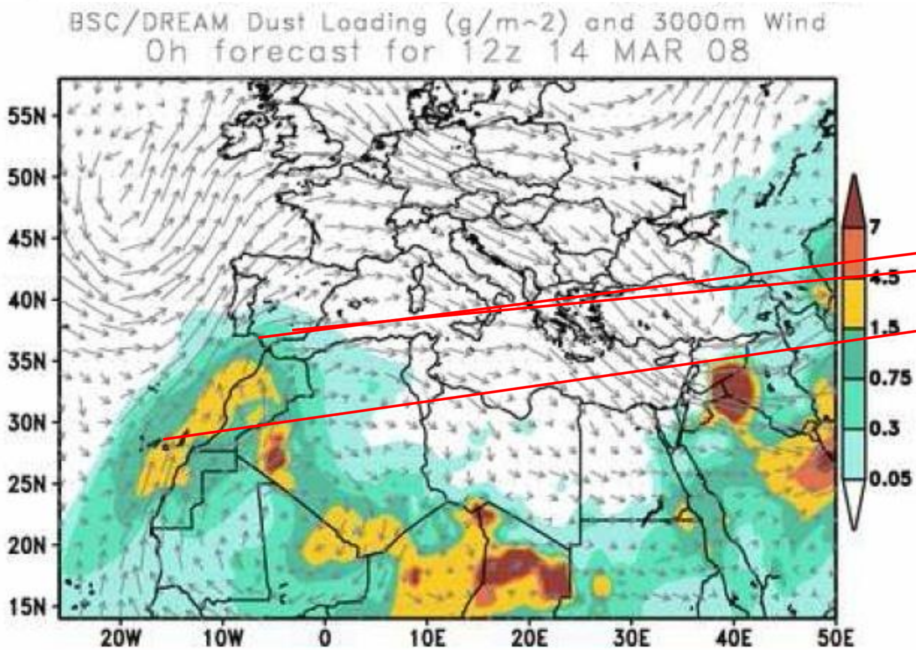
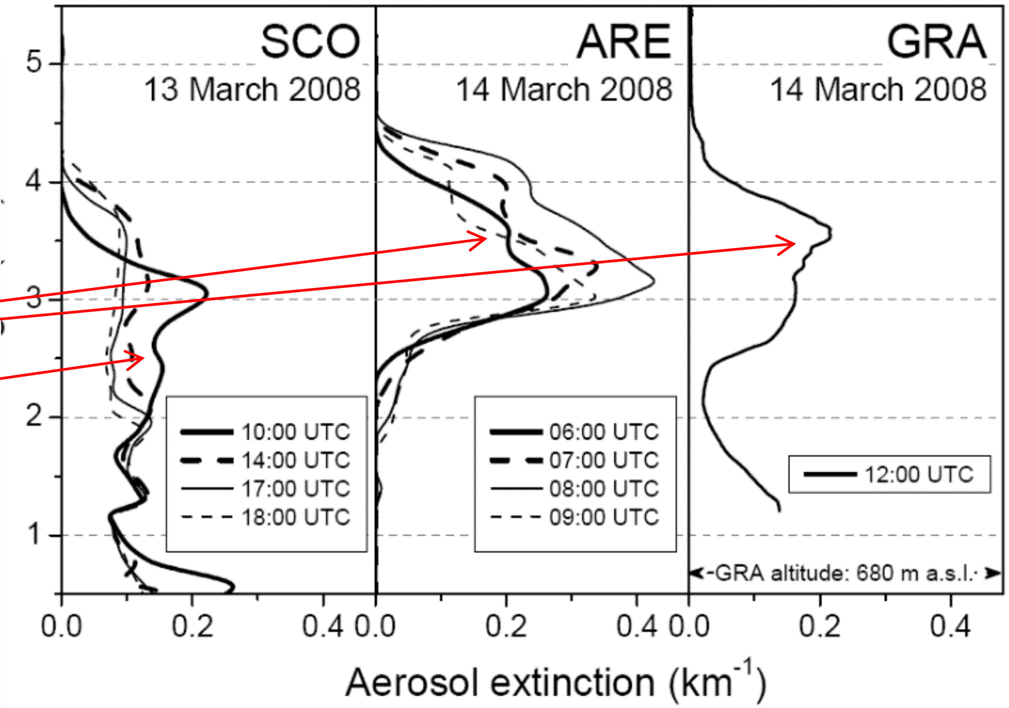


A case study of dust transport from Canary Islands to Iberian Peninsula

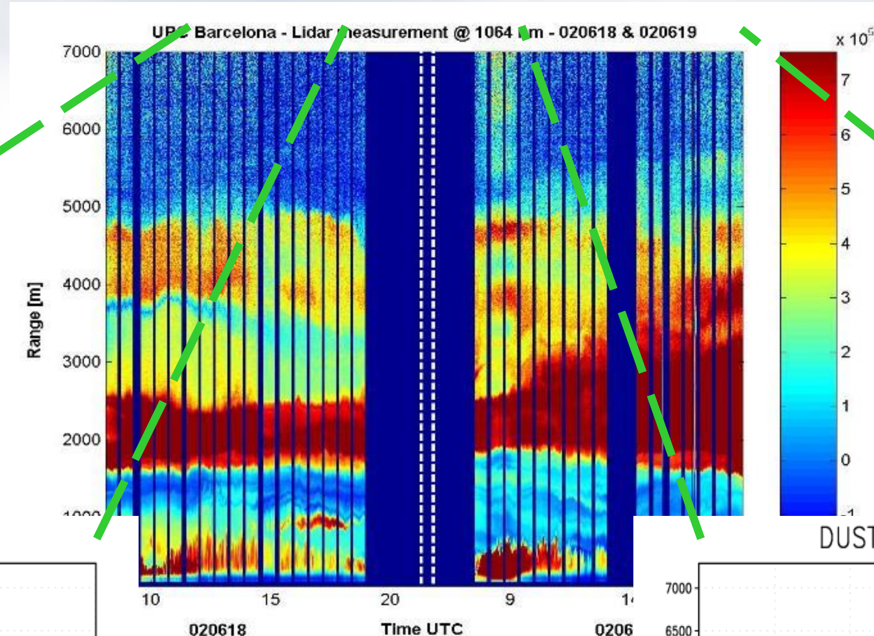
Córdoba-Jabonero et al., ACP Discuss., 2010





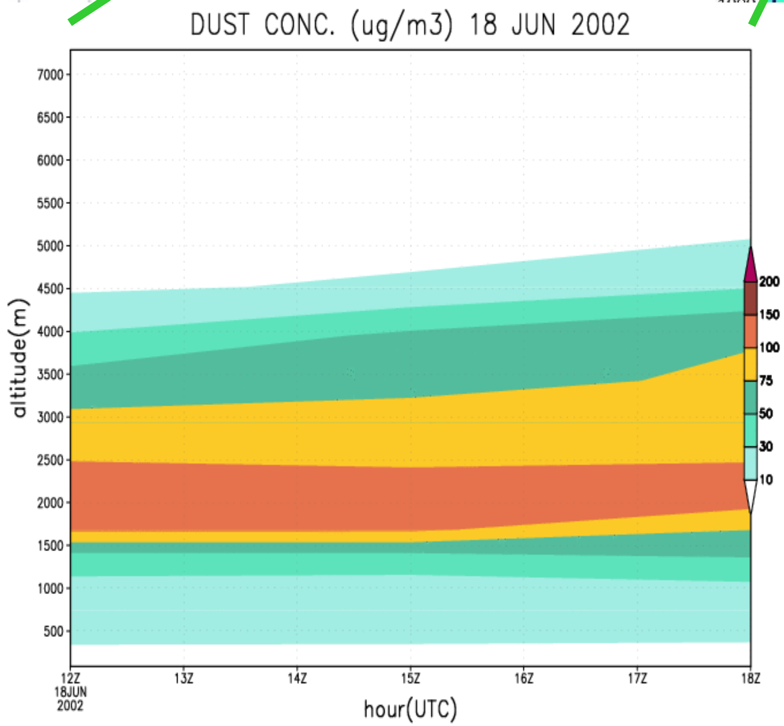
Ground-based remote sensing

Barcelona lidar vs DREAM BSC

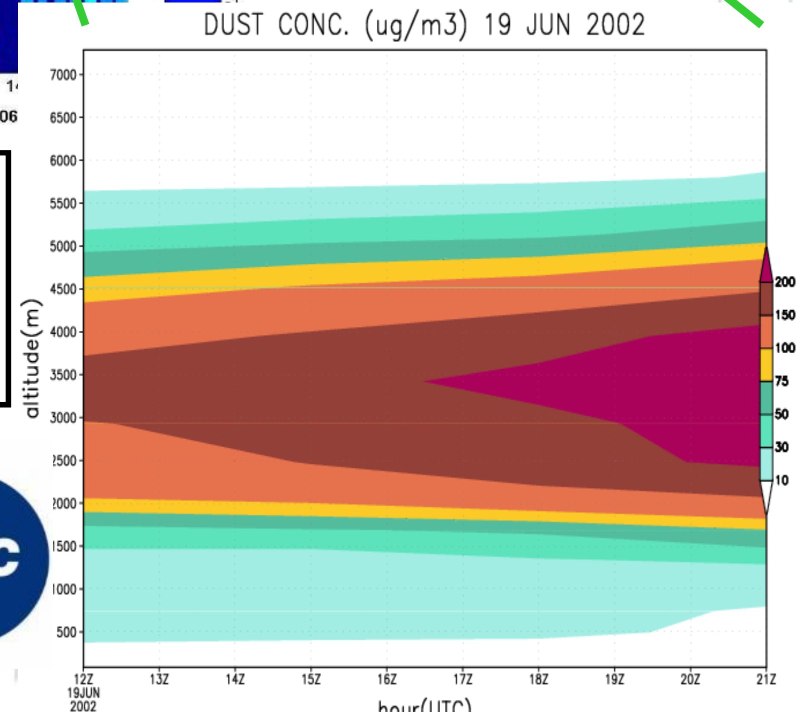


EARLINET: Lidar-UPC, Barcelona

18-19 June 2002

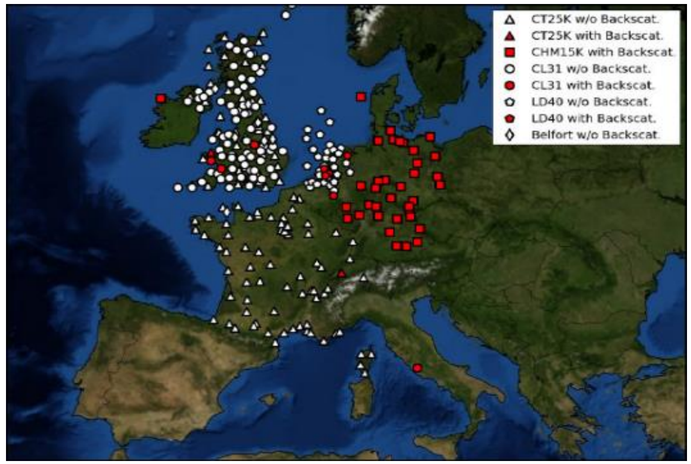


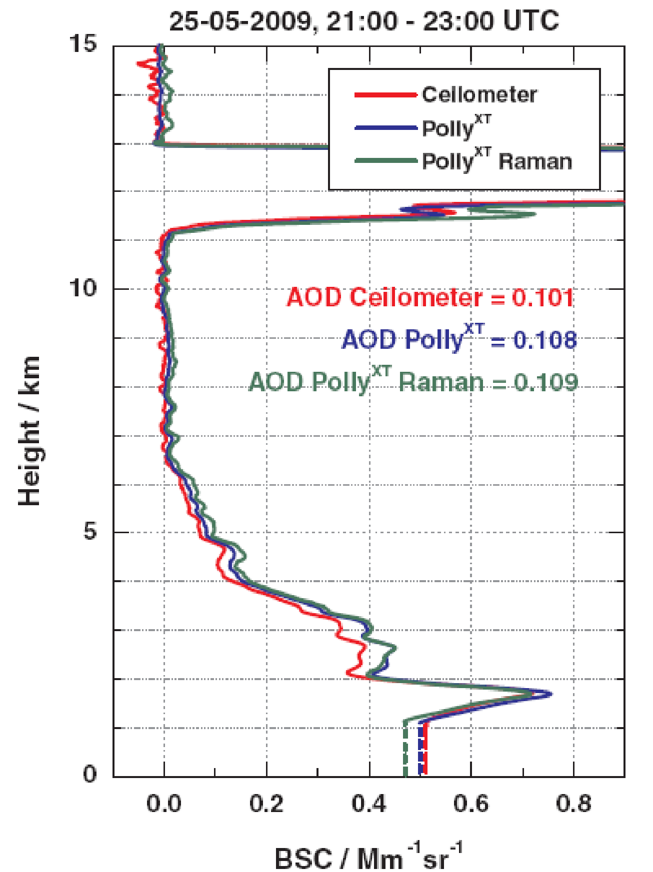
Vertical dust distribution validation: AIRLINET-DREAM



Ceilometer network

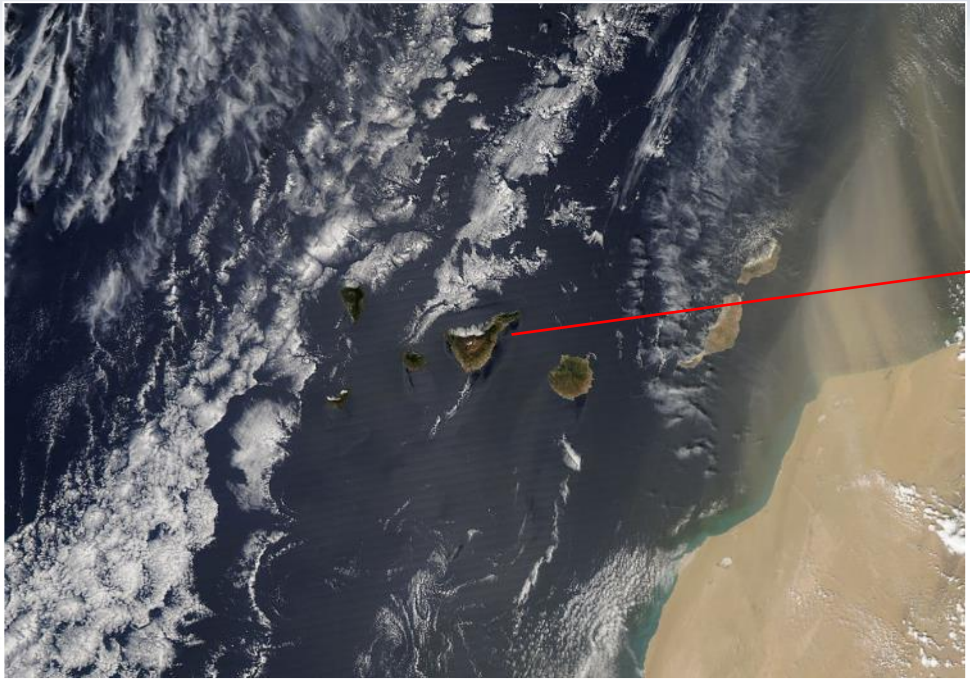
Met Services are replacing **cloud-base** ceilometer networks by **aerosol backscatter profiling ceilometers** (**IR wavelenght**).
Objective: To monitor MLD (Mixing Layer Depth) based on **several hundred profiling ceilometers (100km sampling)**





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

Optimal for desertic areas !!



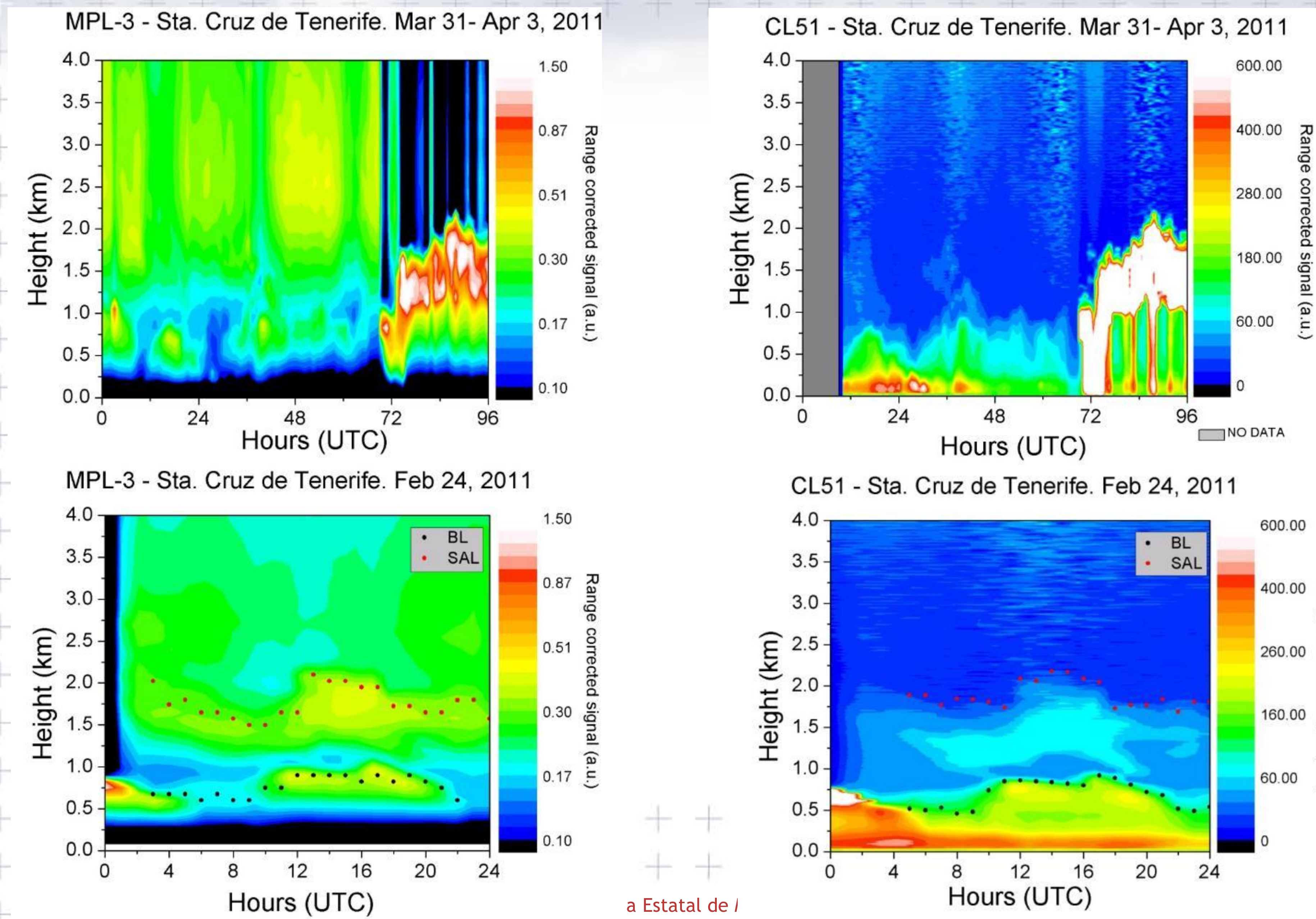
Viasala Ceilometer CL-51

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



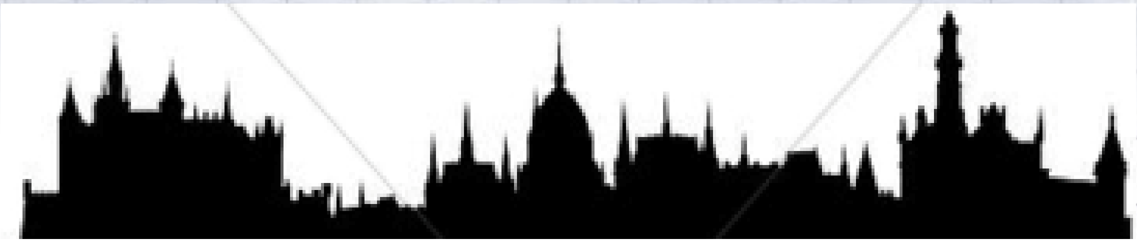
dust, aerosols and pollutants

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

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

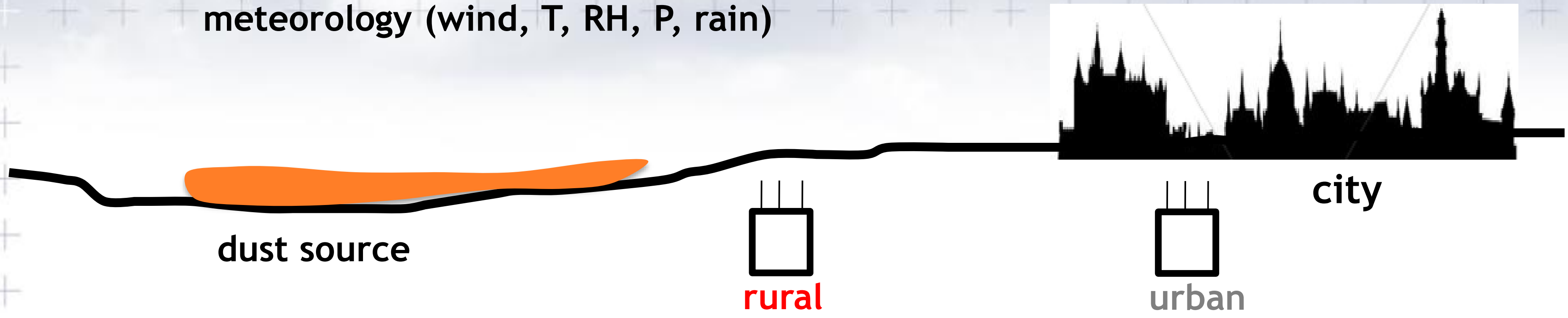
Level 1 - meteorology (wind, T, RH, P, rain)

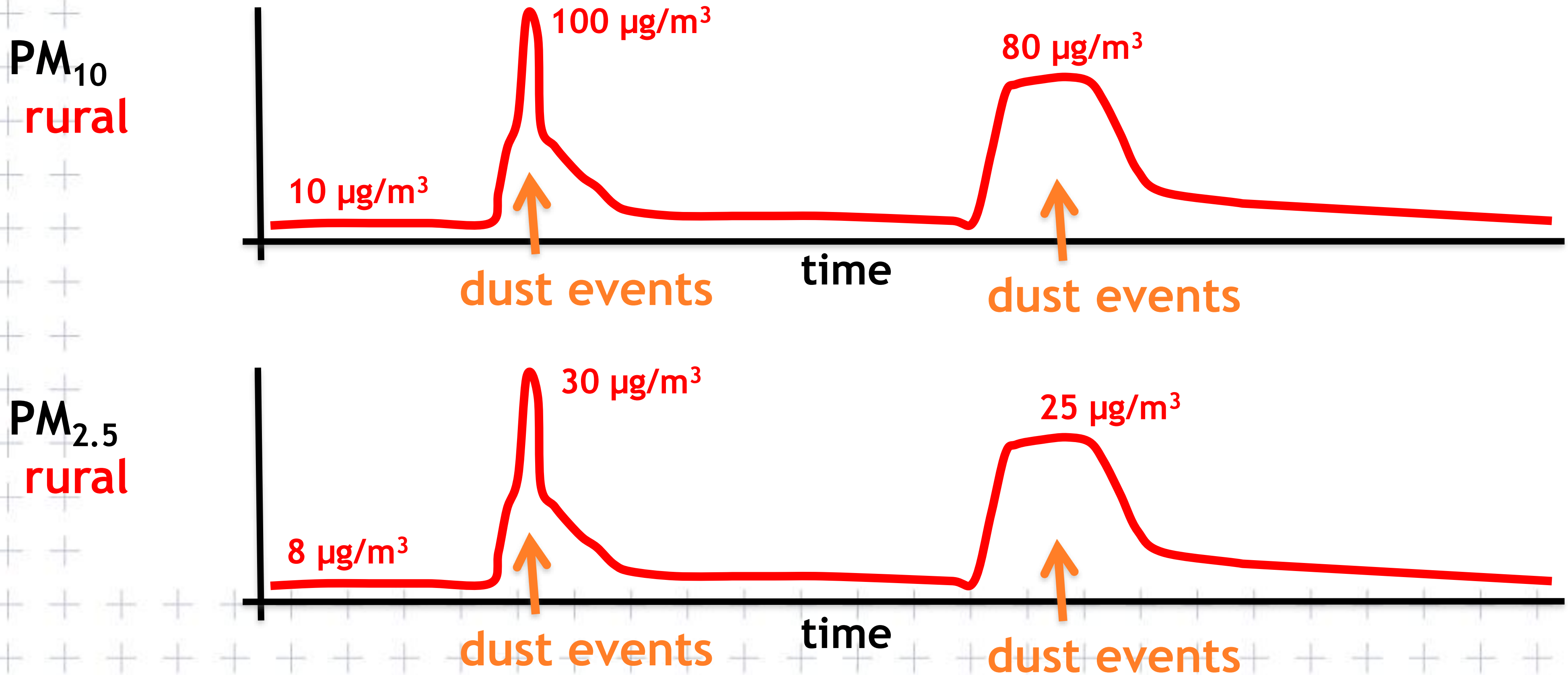
Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

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

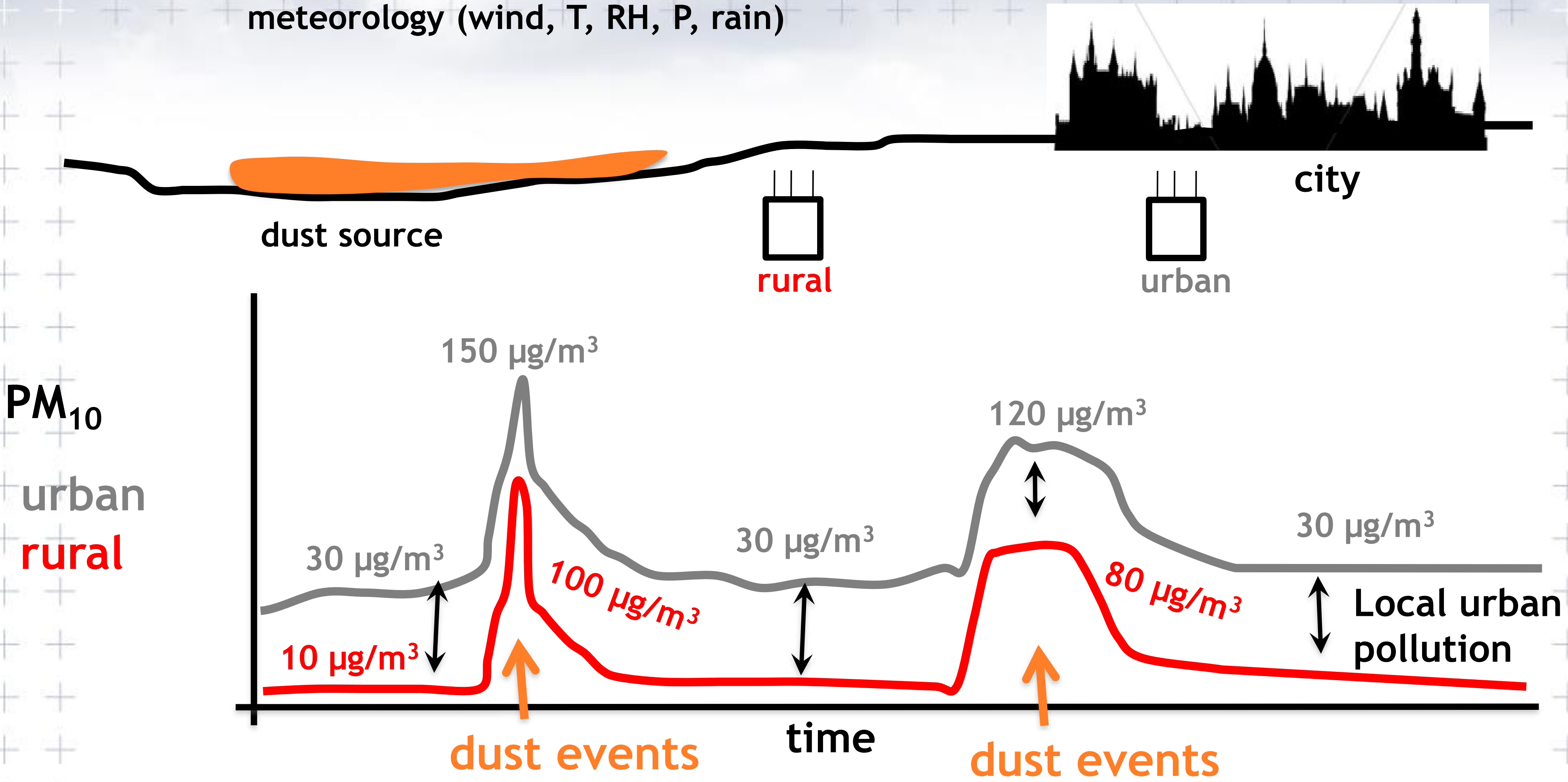
Level 4 - PM_{10} and $PM_{2.5}$ chemical composition

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

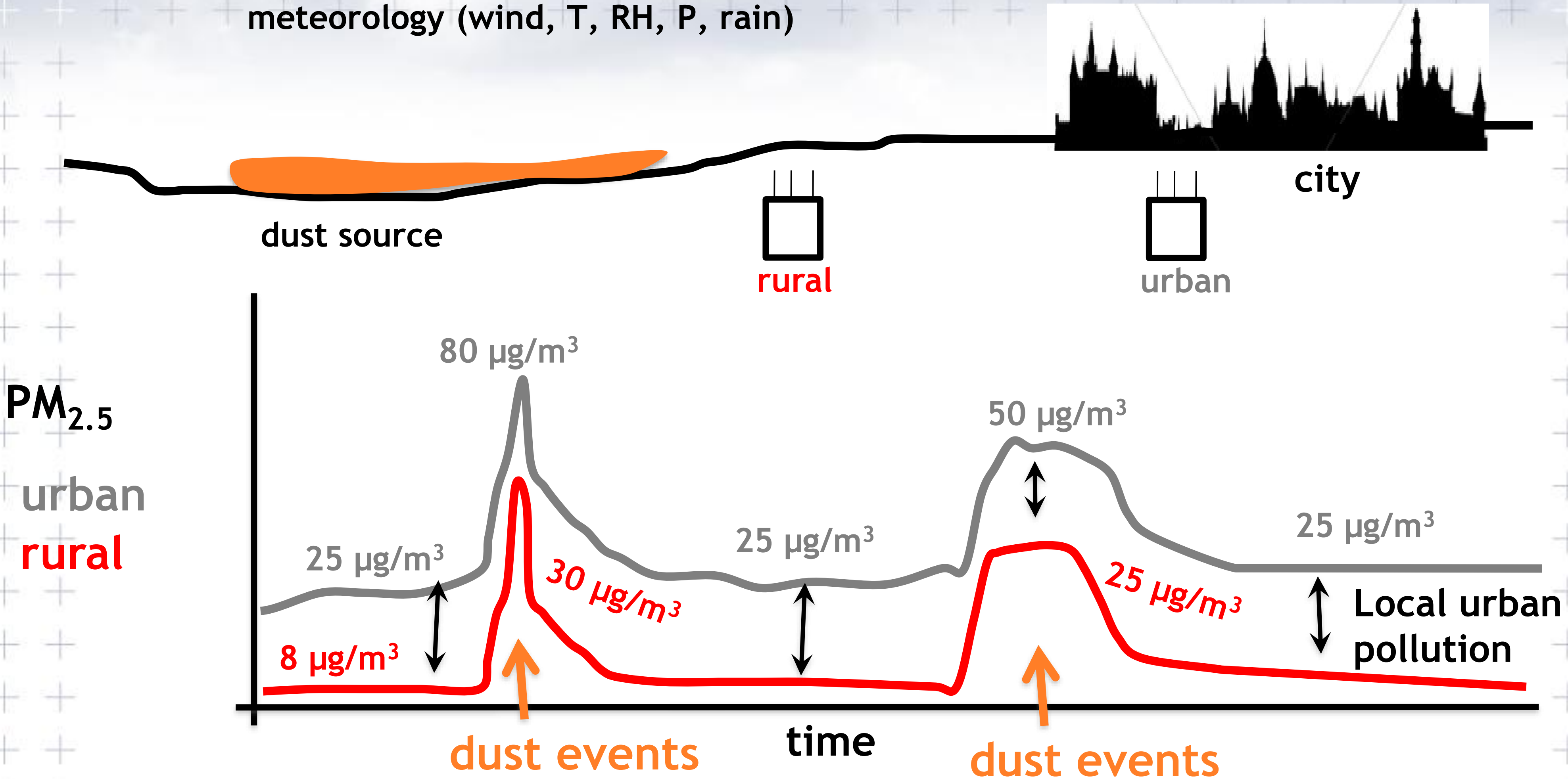




Level 1 PM$_{10}$ and PM$_{2.5}$ - automatic methods
meteorology (wind, T, RH, P, rain)



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)

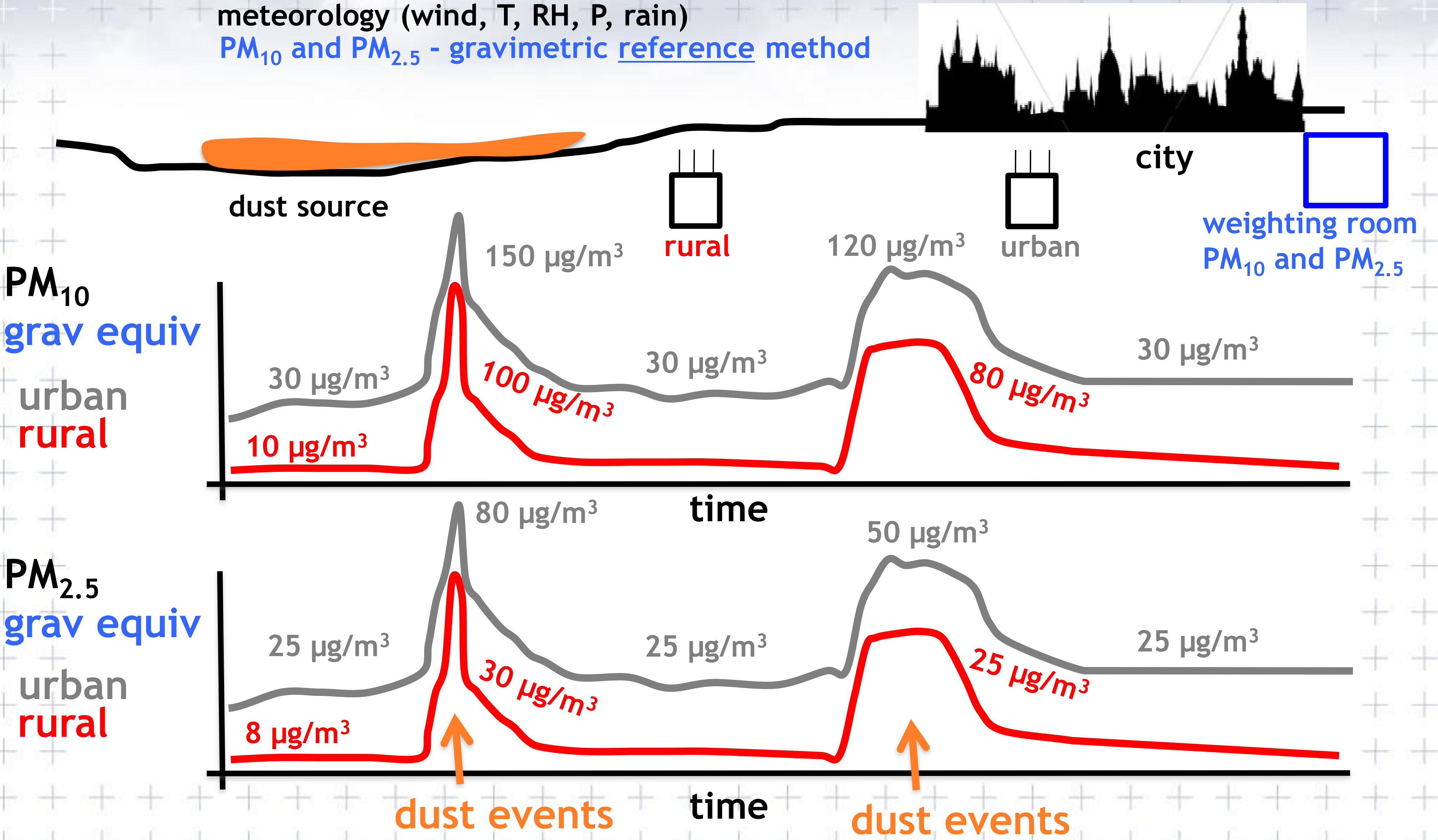
Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

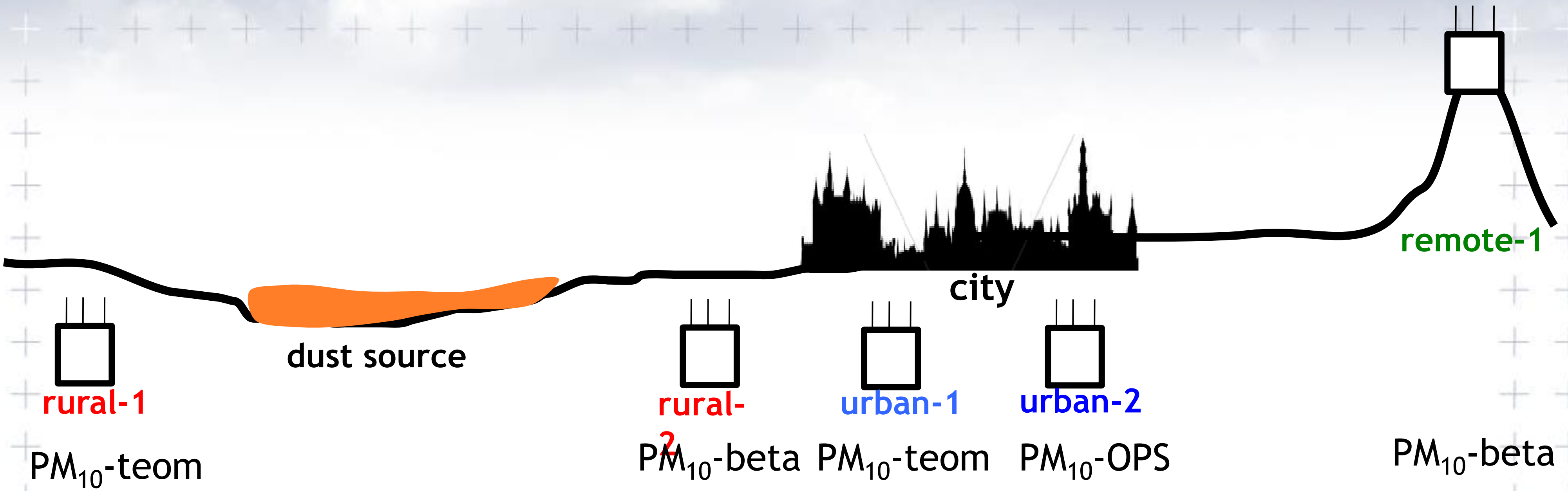
Level 3 - gaseous pollutants: NO_x, SO_2 , CO,...

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





	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)

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

dust air quality

Recommended priorities

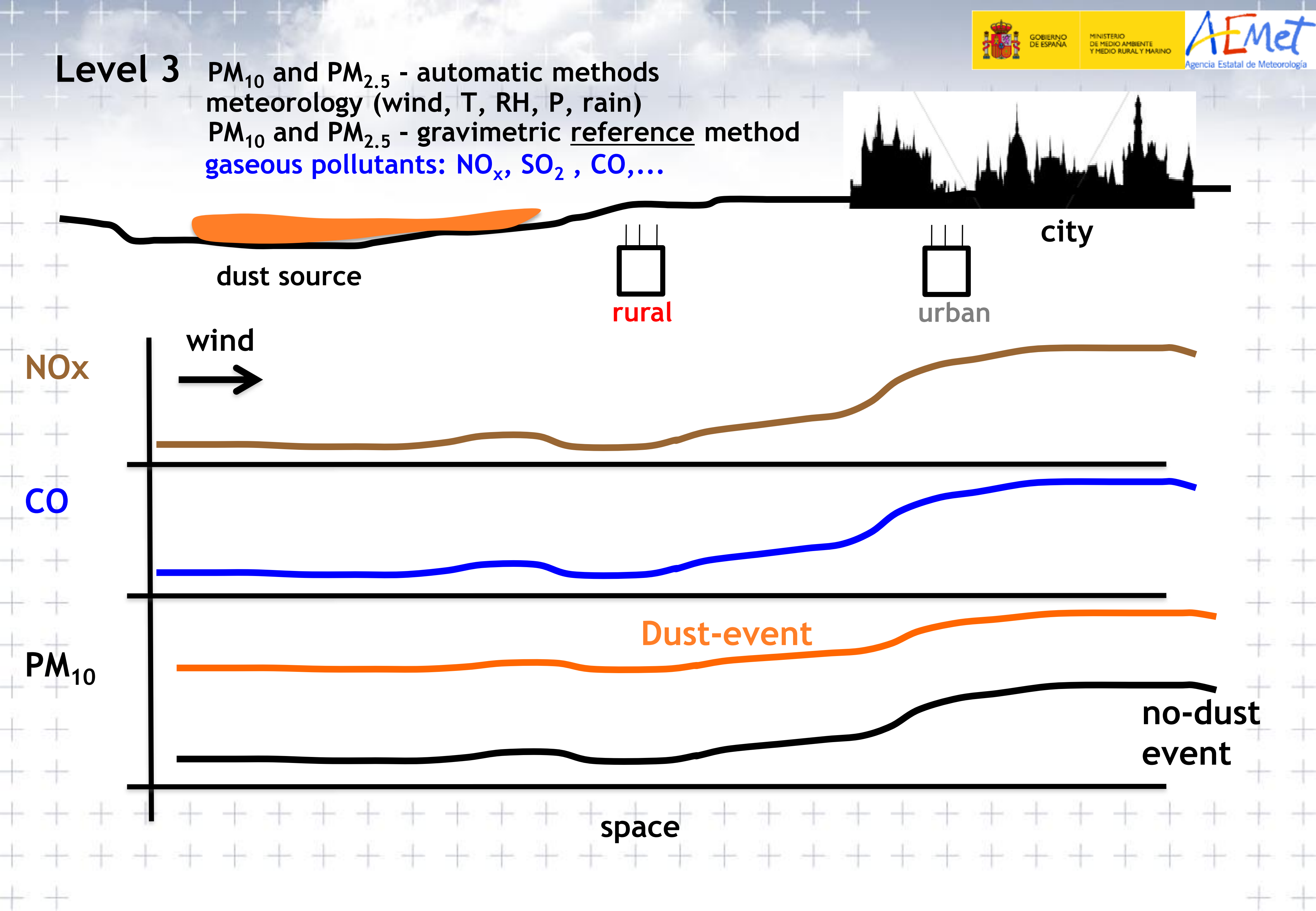
Level 1 (max) - PM_{10} and $PM_{2.5}$ levels - automatic methods

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 3
PM10 and PM2.5 - automatic methods
meteorology (wind, T, RH, P, rain)
PM10 and PM2.5 - gravimetric reference method
gaseous pollutants: NOx, SO2 , CO,...
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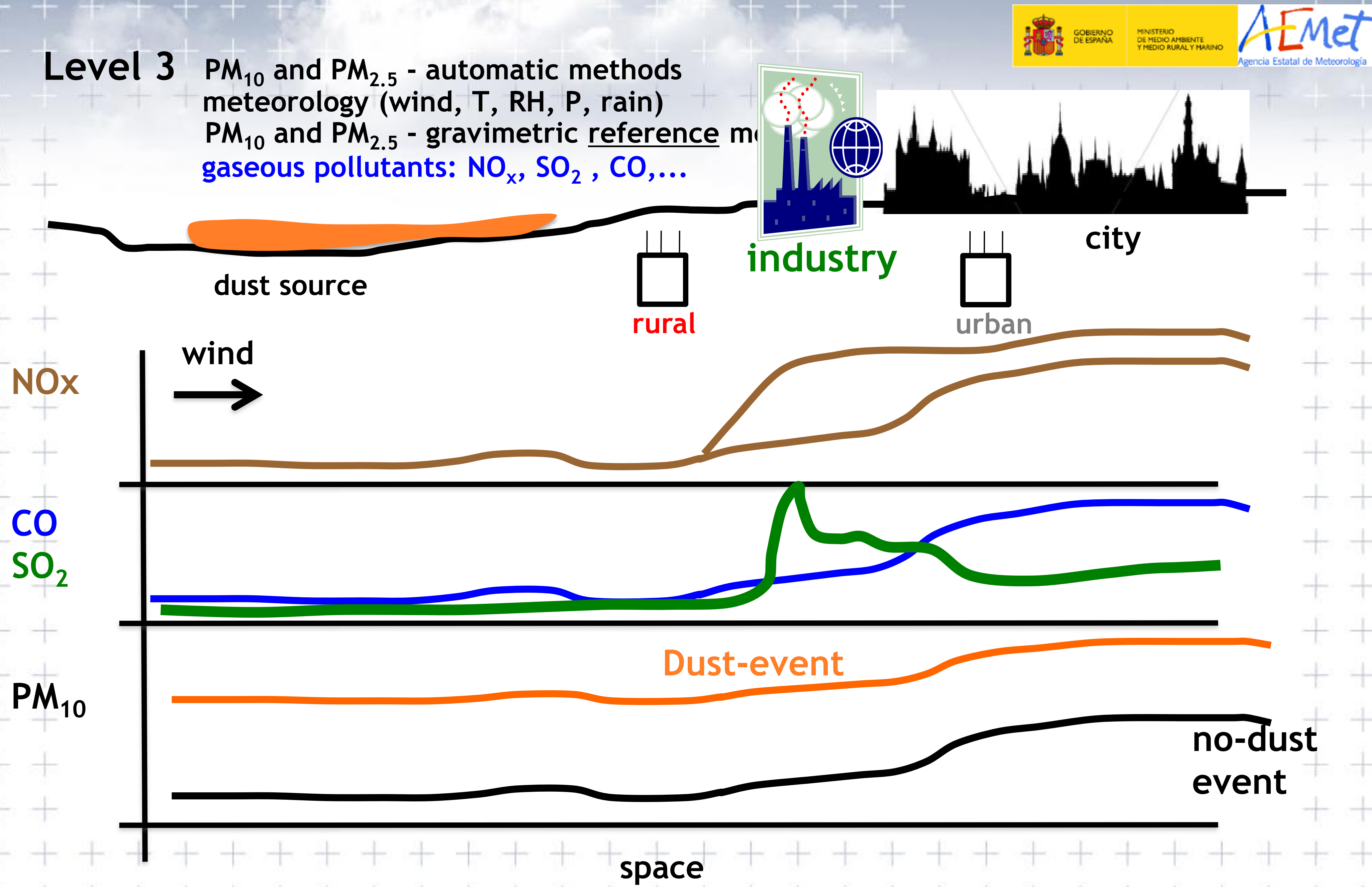
dust source
rural
urban
city
wind
NOx
CO
PM10
Dust-event
no-dust event
space



Level 3
PM10 and PM2.5 - automatic methods
meteorology (wind, T, RH, P, rain)
PM10 and PM2.5 - gravimetric reference m
gaseous pollutants: NOx, SO2 , CO,...
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AEMet
Agencia Estatal de Meteorología
dust source
rural
industry
urban
city
wind
NOx
CO
SO2
PM10
Dust-event
no-dust event
space

dust air quality

Recommended priorities

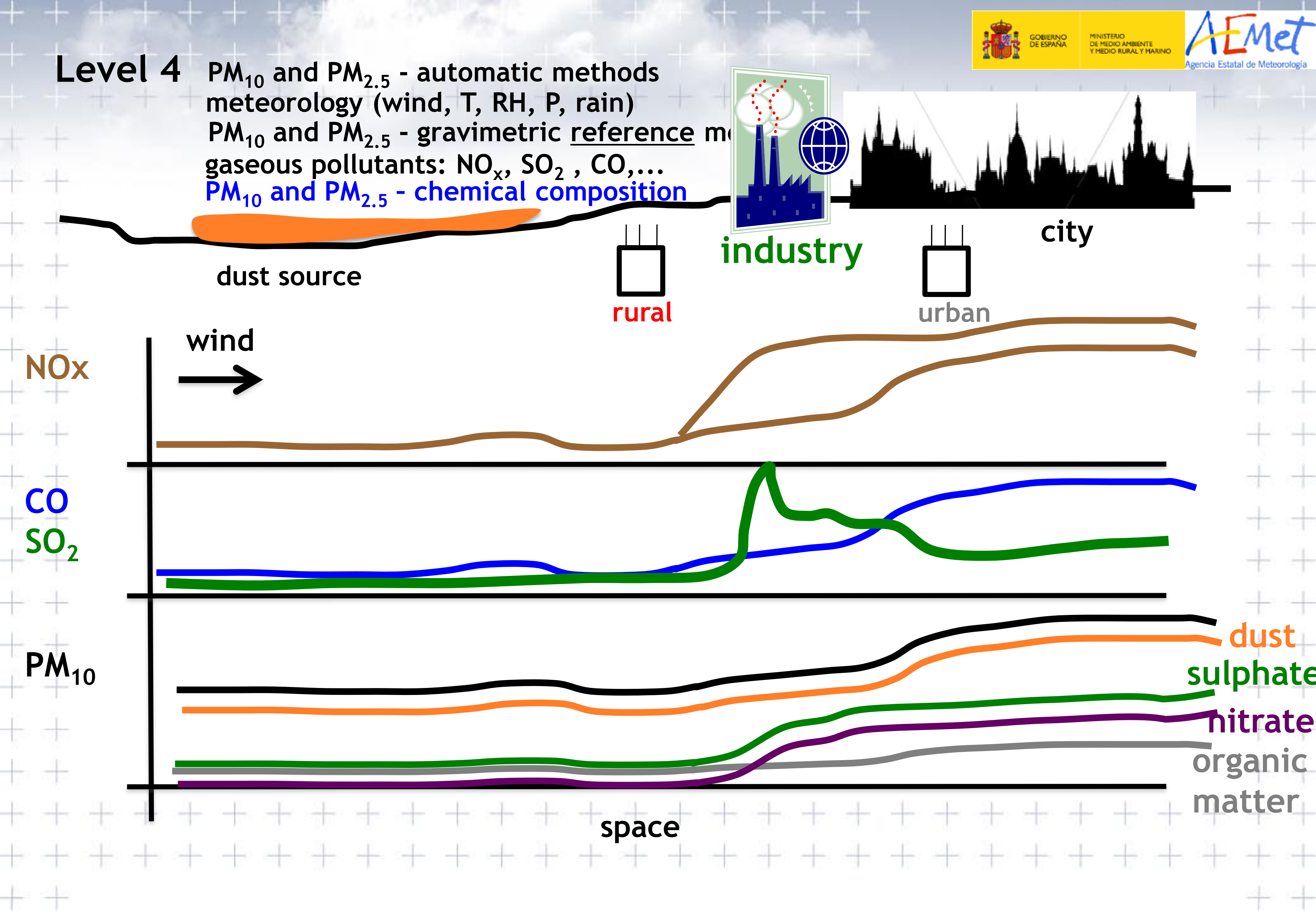
Level 1 (max) - PM$_{10}$ and PM$_{2.5}$ levels - automatic methods

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
PM10 and PM2.5 - automatic methods
meteorology (wind, T, RH, P, rain)
PM10 and PM2.5 - gravimetric reference m
gaseous pollutants: NOx, SO2 , CO,...
PM10 and PM2.5 - chemical composition
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AEMet
Agencia Estatal de Meteorología
dust source
rural
industry
urban
city
wind
NOx
CO
SO2
PM10
dust
sulphate
nitrate
organic matter
space