CSIC, Consejo Superior de Investigaciones Científicas
National Research Council of Spain

EEZA, Estación Experimental de Zonas Áridas
Experimental Station of Arid Zones

ground observation of airborne dust

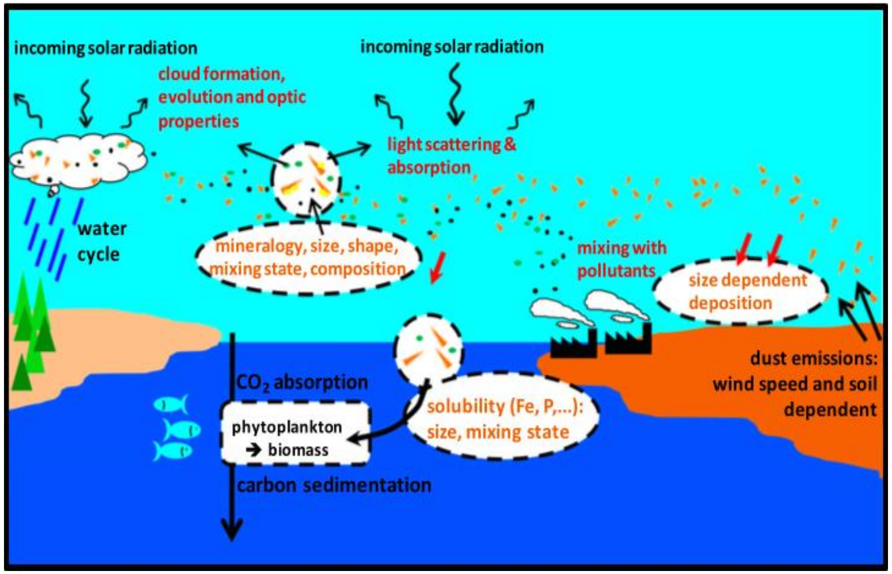
Sergio Rodríguez

sergio.rodriguez@eeza.csic.es

Experimental Station of Arid Zones, CSIC-EEZA

Training Course on WMO SDS-WAS products

10-14 Nov 2018, Ahvaz



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

dust

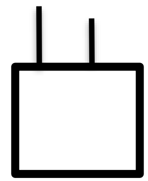
dust, aerosols and pollutants

in-situ observations:

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

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:

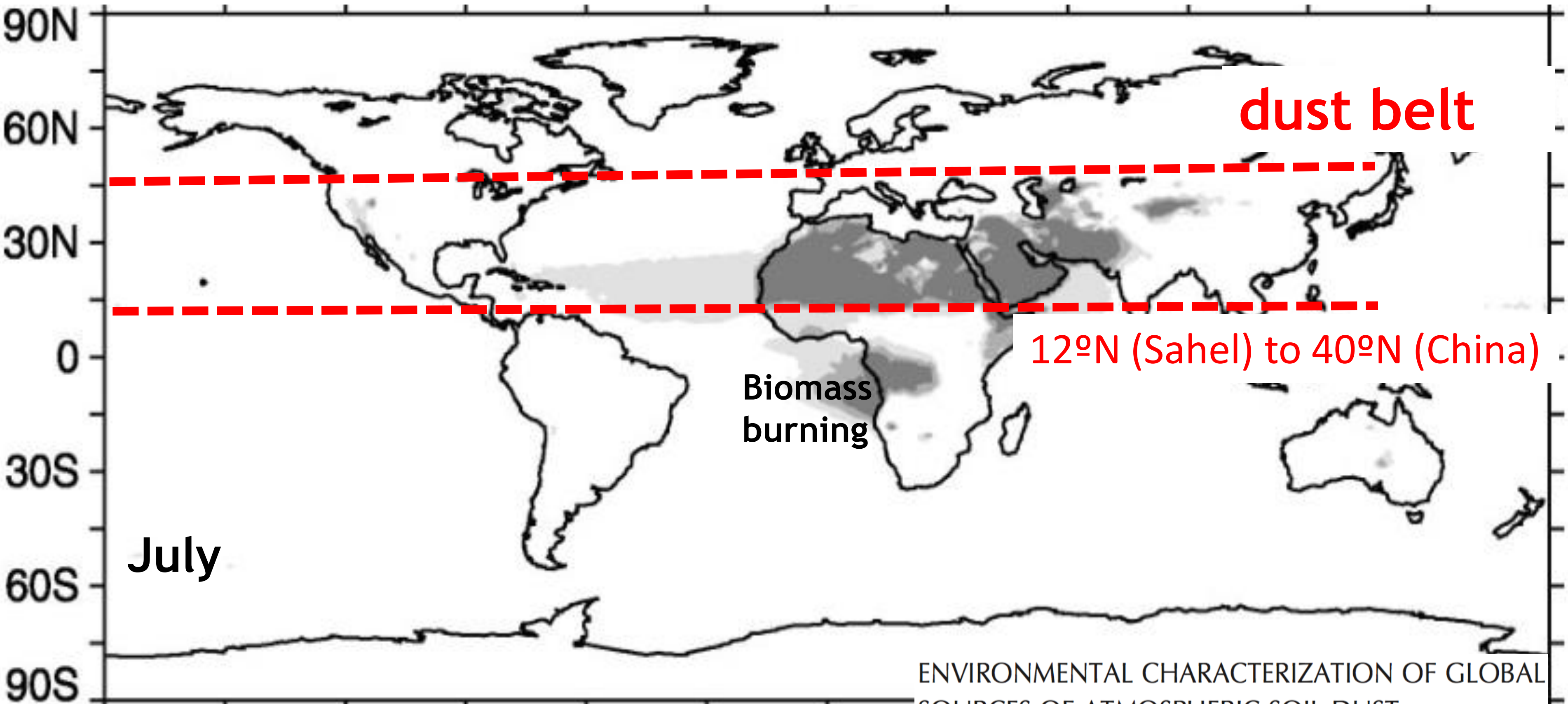
desert dust

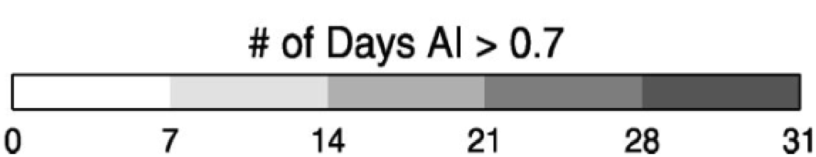
people live in cities and breath
a cocktail dust + pollutants

what is this
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....

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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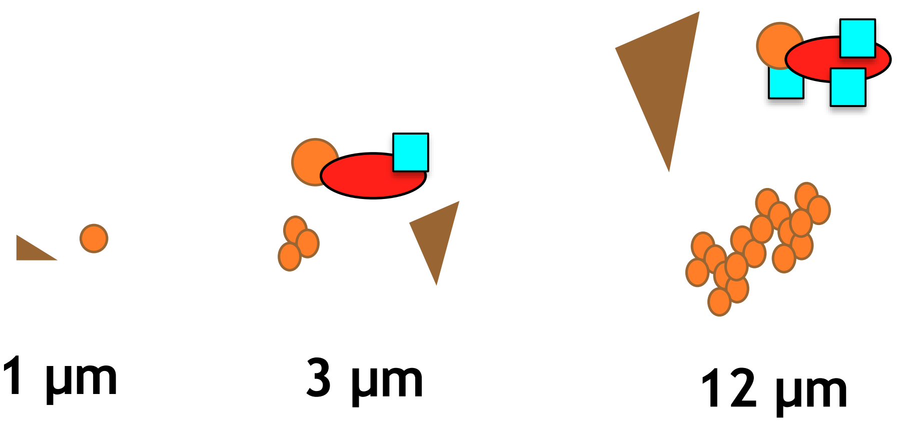
3. Size and morphology

1 and 20 µm
agglomerates



desert dust

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

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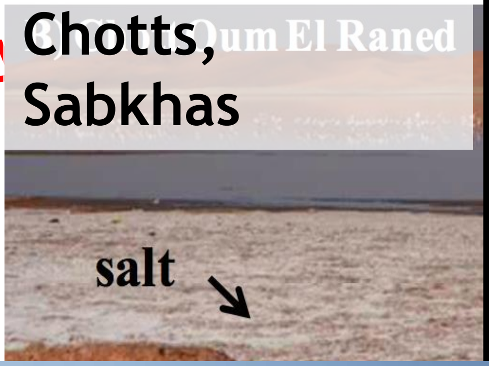
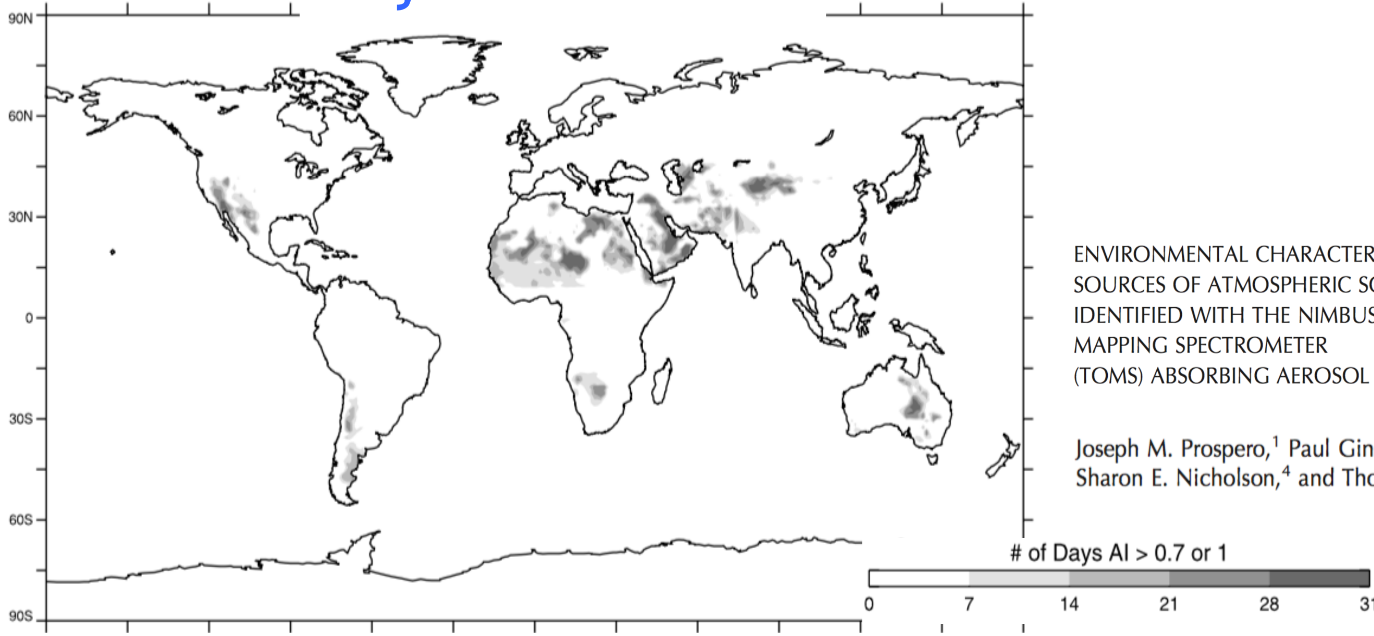


mayor dust sources



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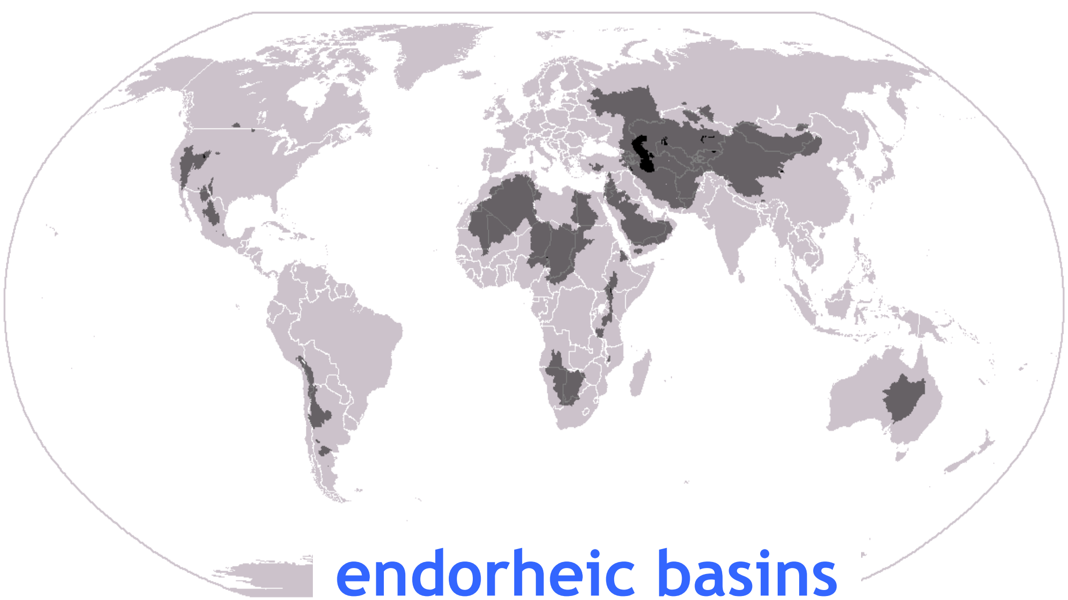
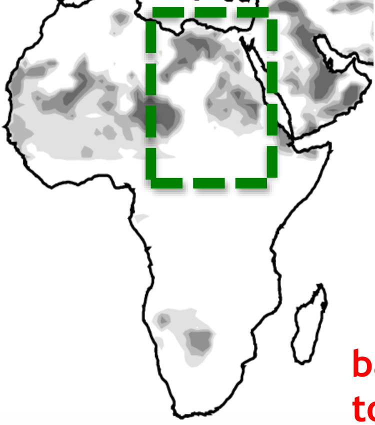
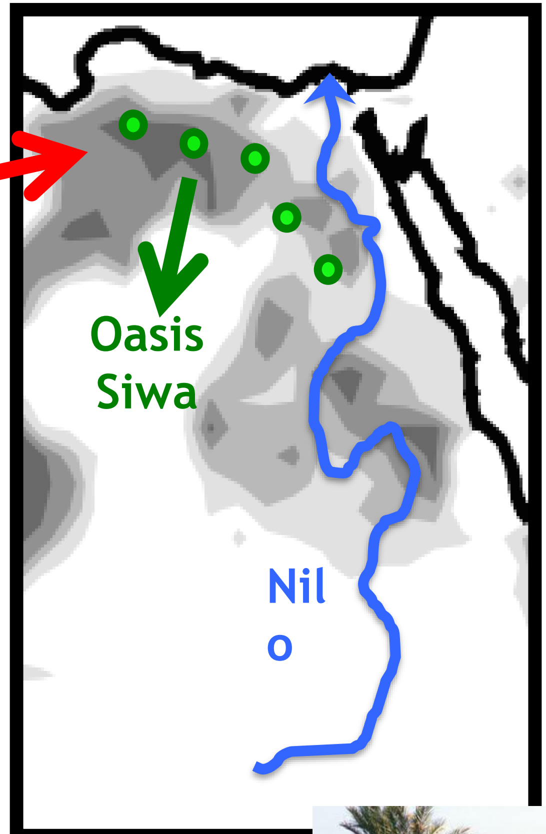


endorheic basins

no conection to sea

Detección satélite



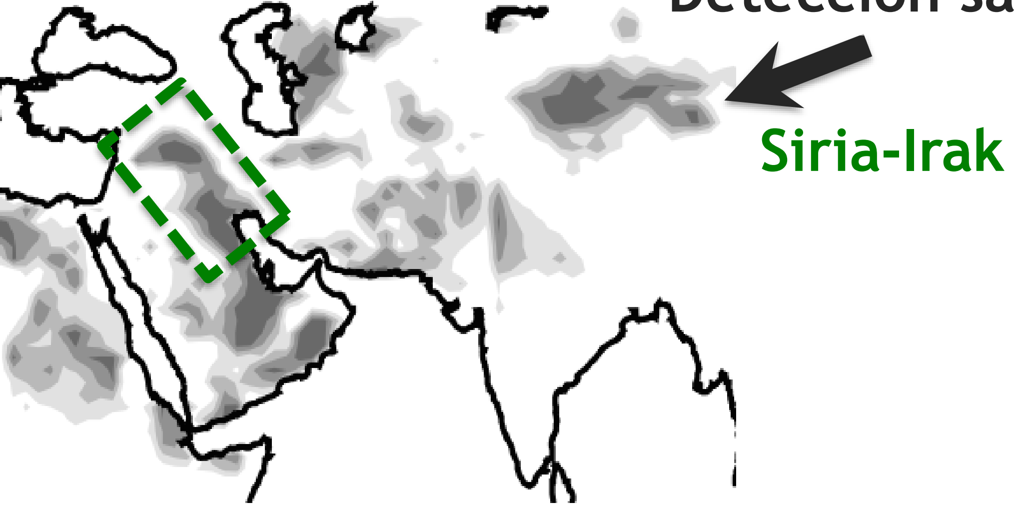


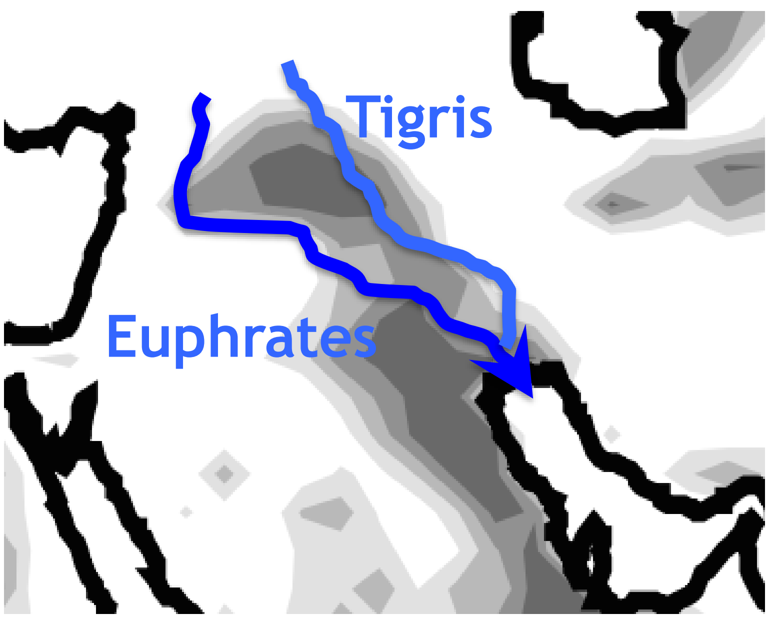
bajas topográficas (altitudes -)

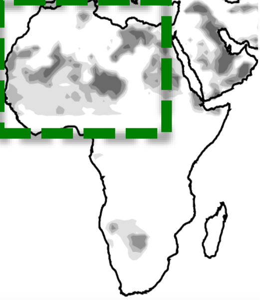
lakes, oasis, cultivation, underground water, Ancient rivers

Oasis Siwa
29°13´N, 25°31’E

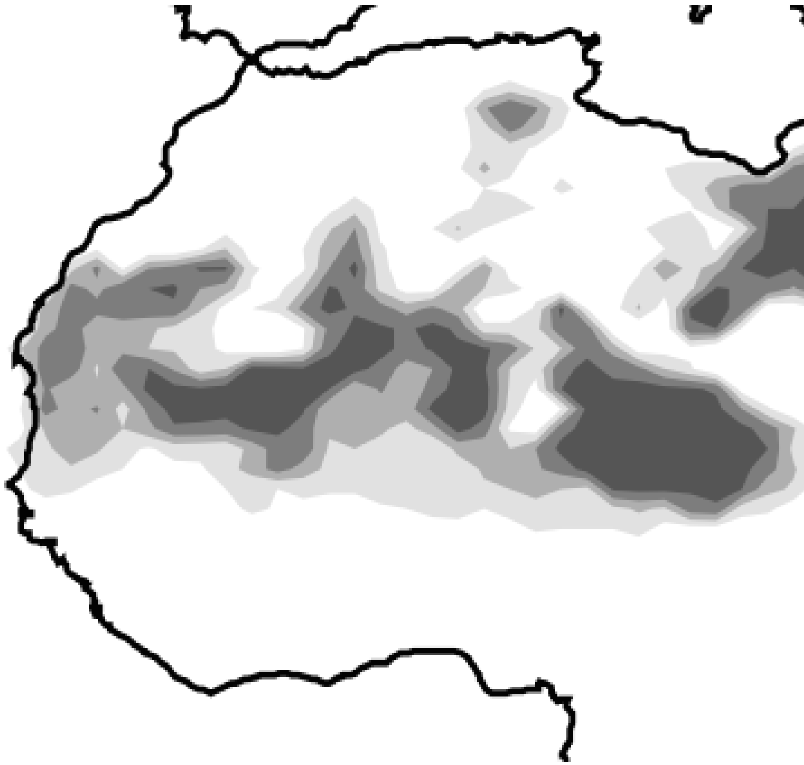
Detección satélite

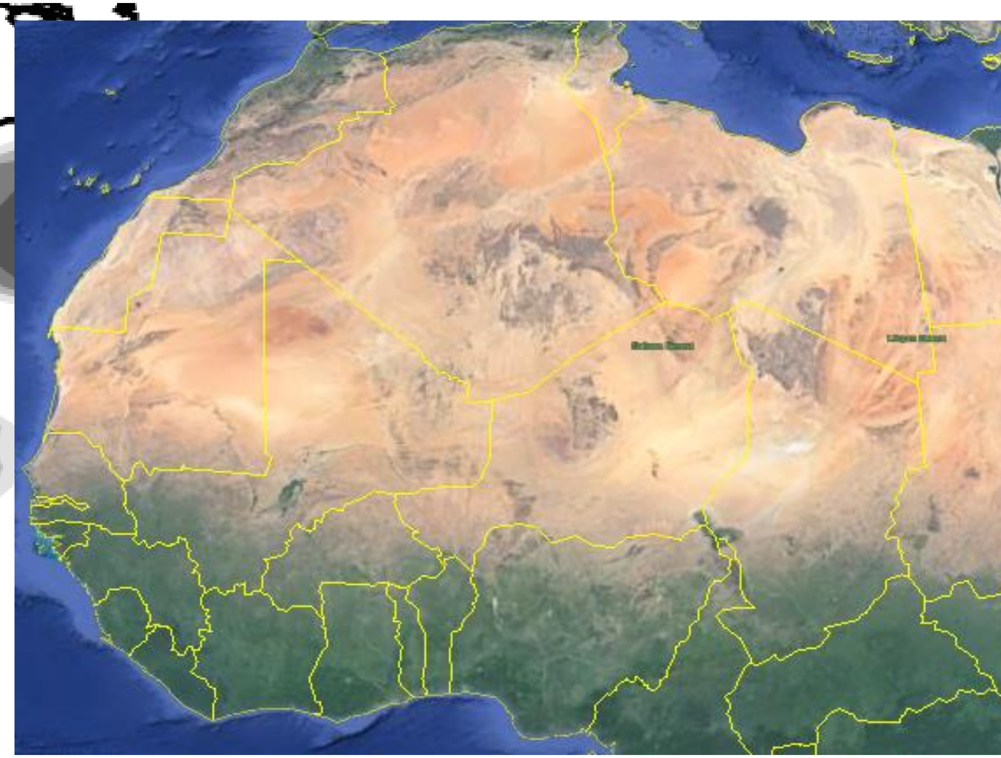






Sahara
Sahel





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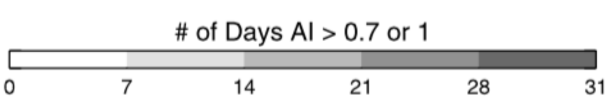

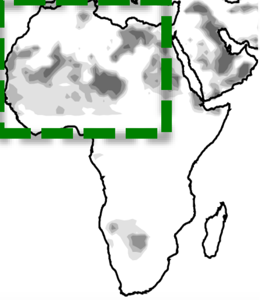

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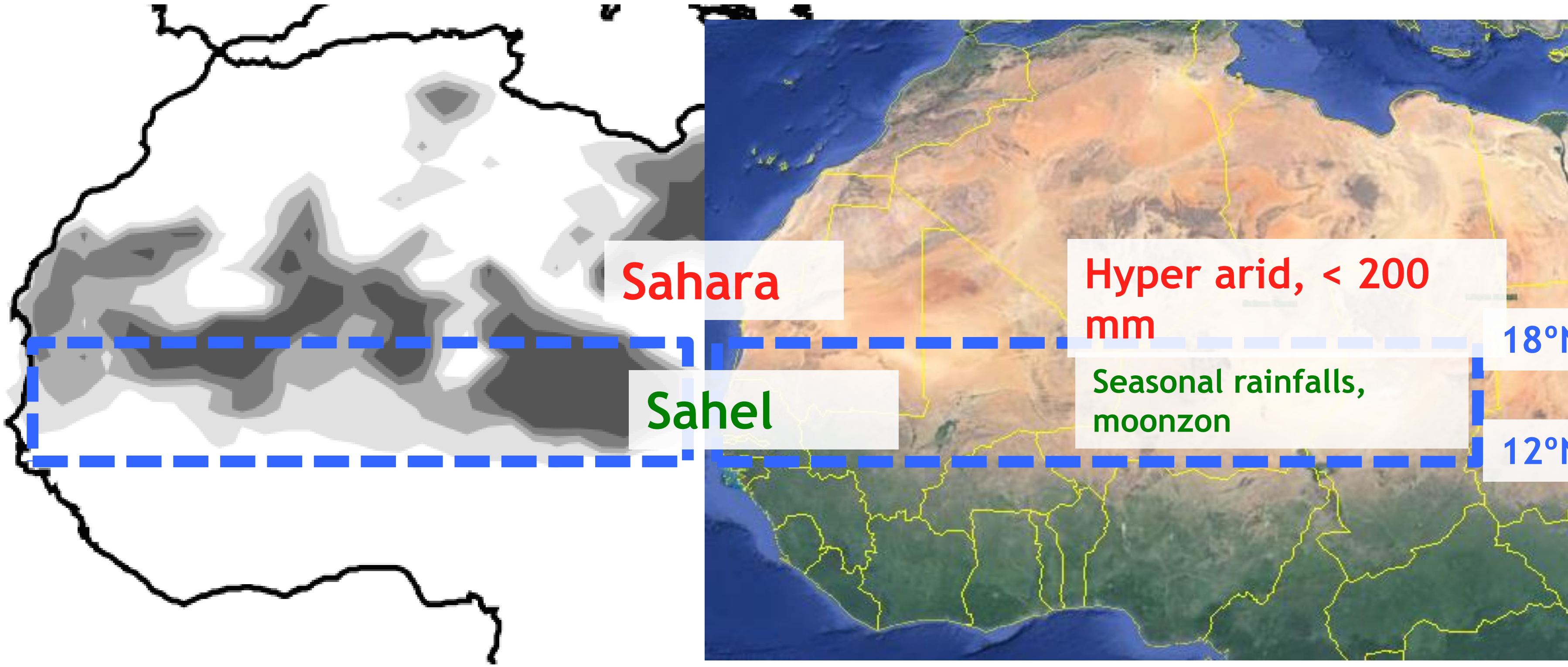
Sahel



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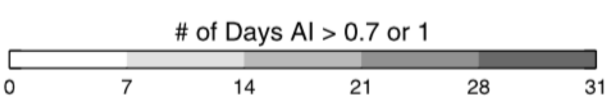
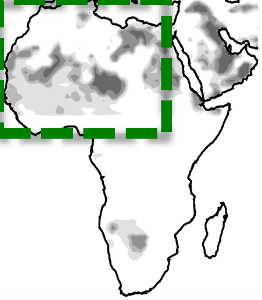
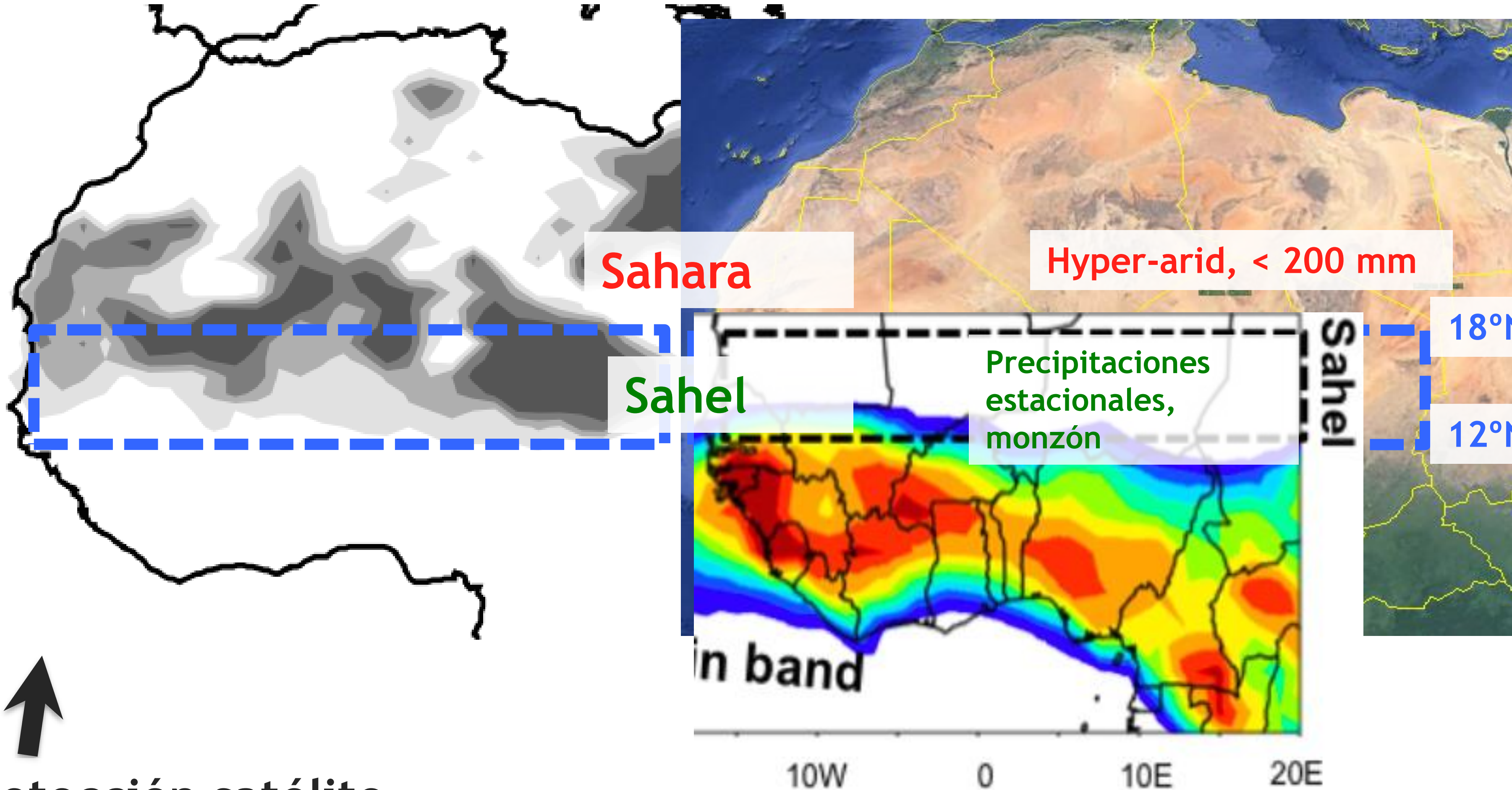




Sahel



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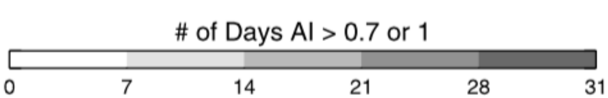

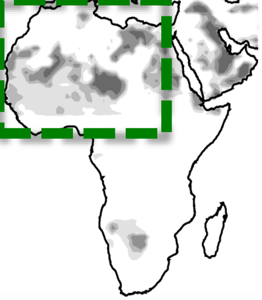

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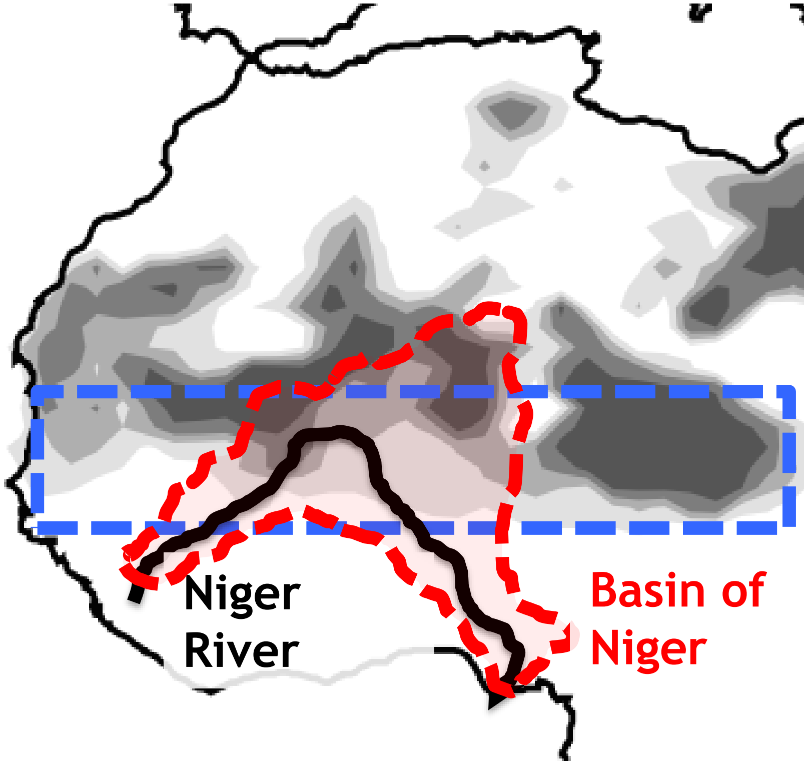
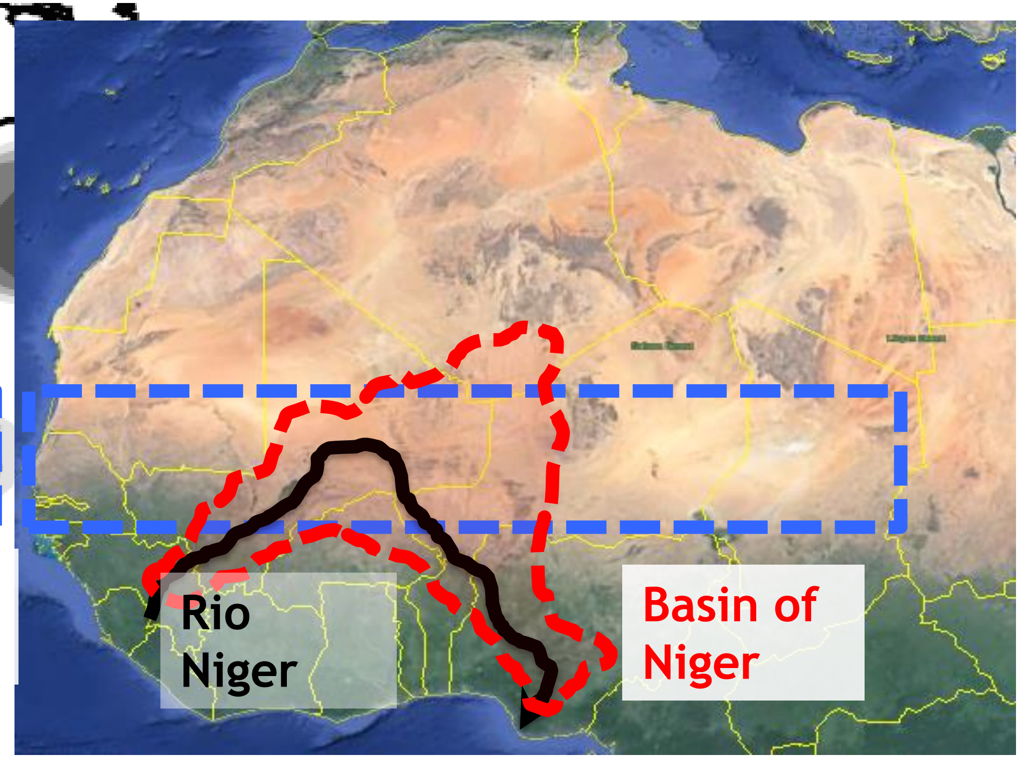
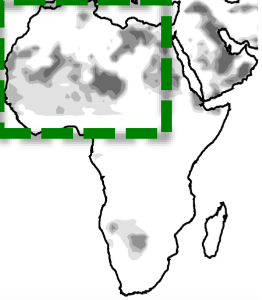
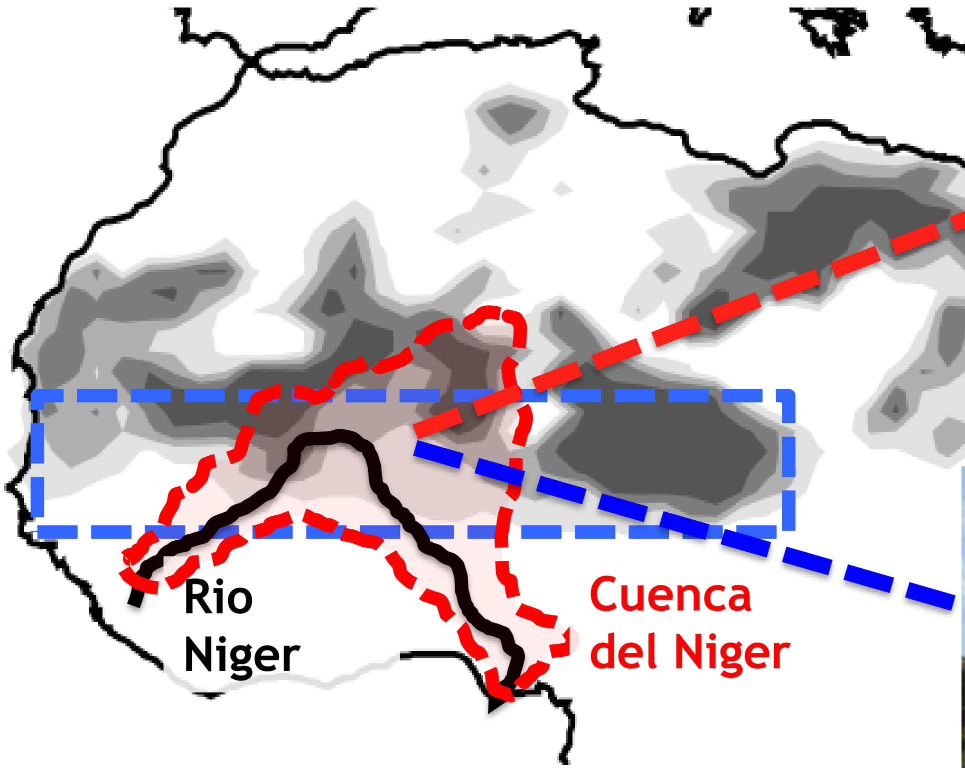




Remote Sensing
satelite



Sahel



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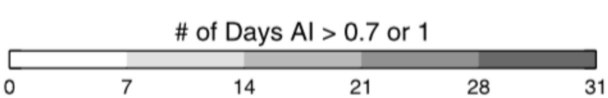
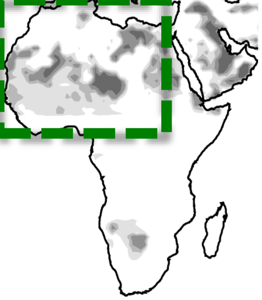
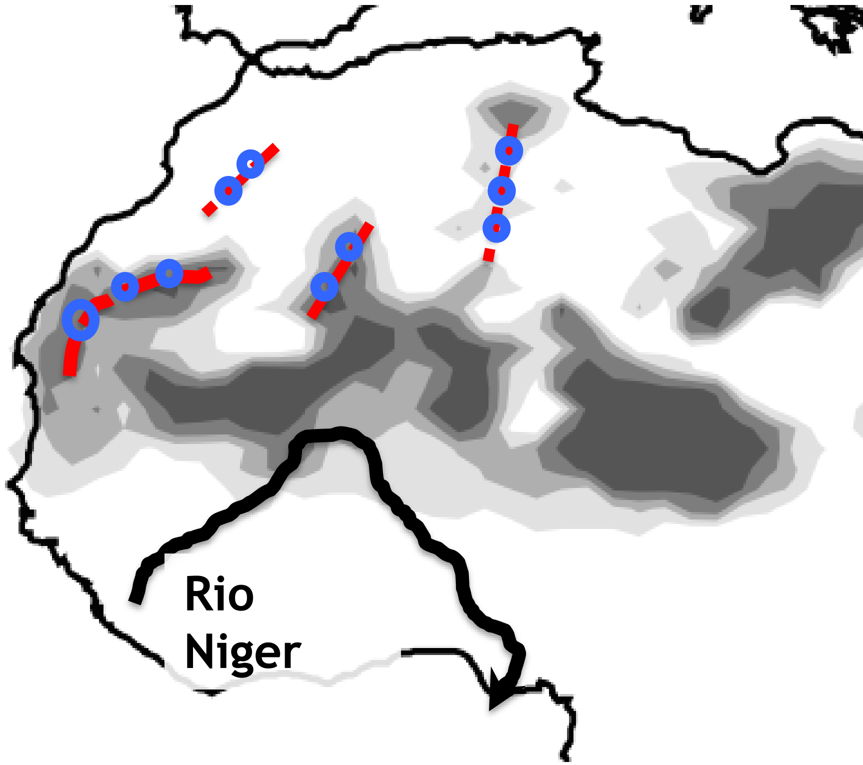
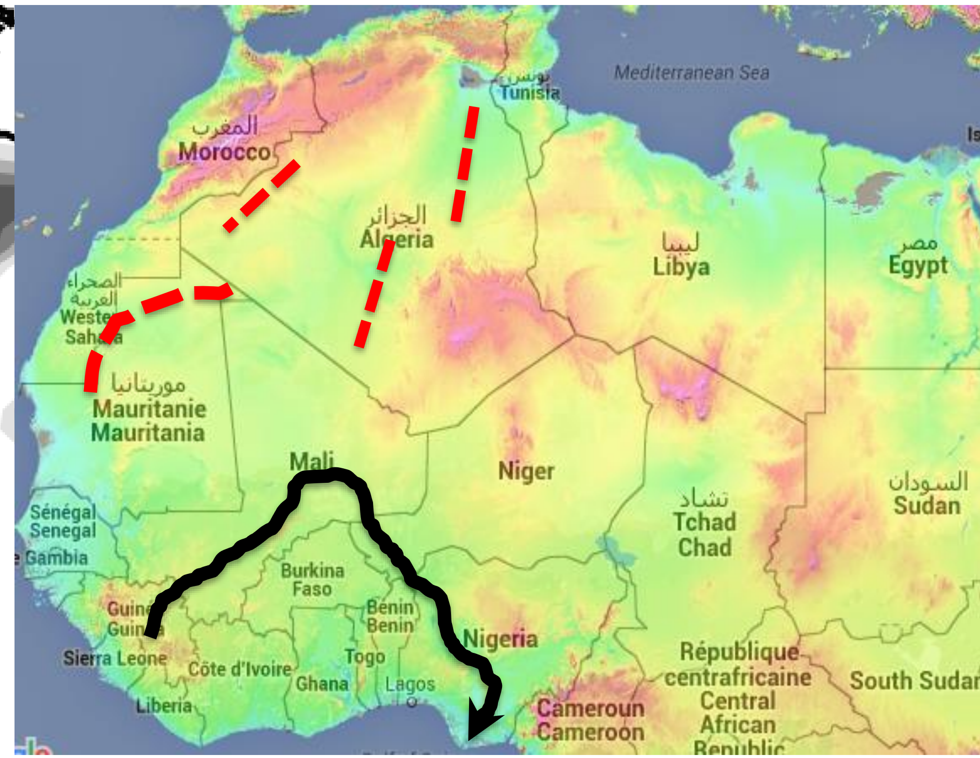




Sahara
Sahel

Sahara

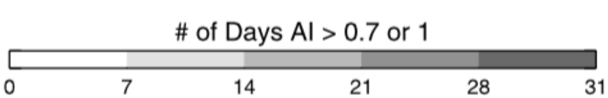


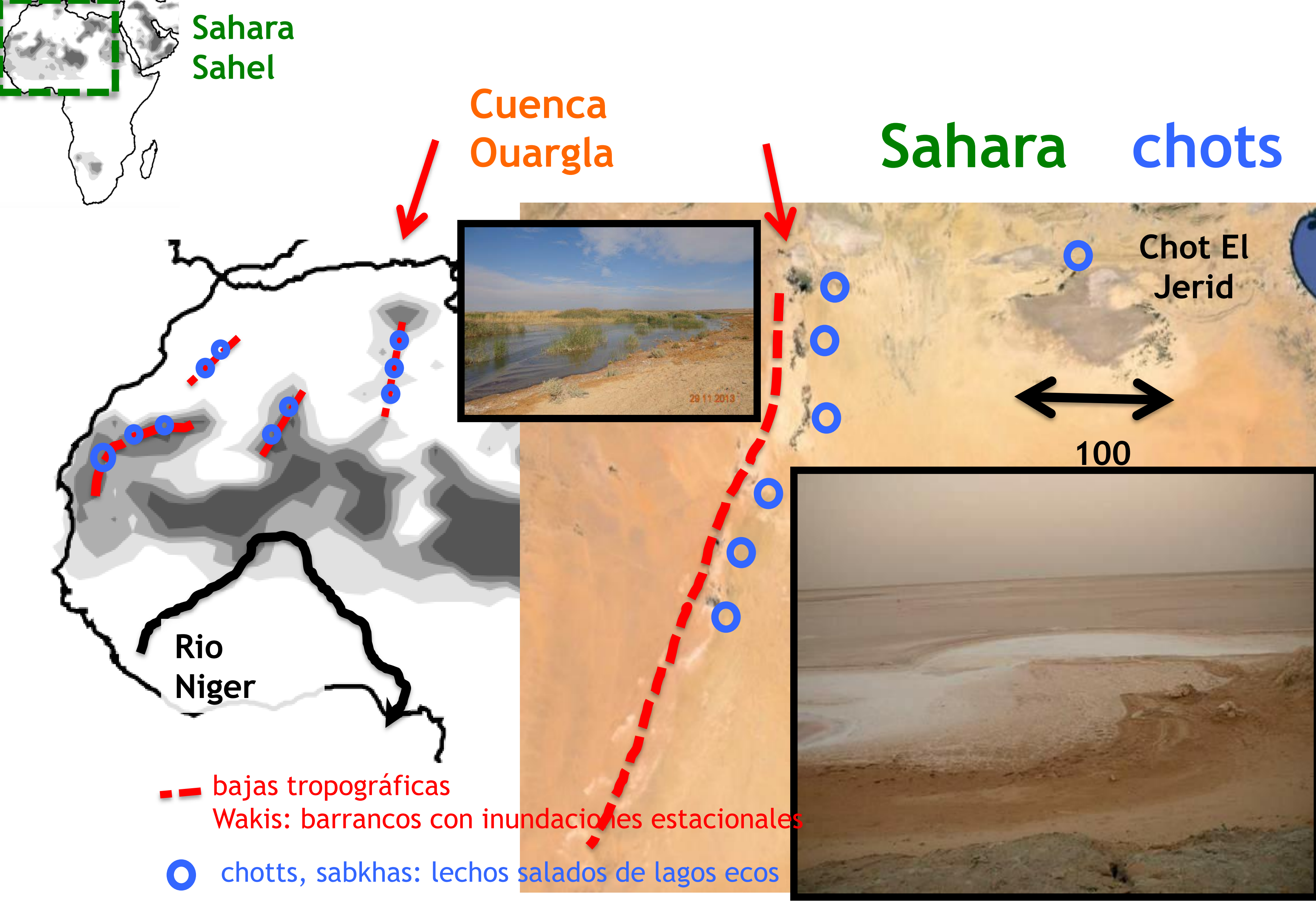


bajas tropográficas
Wakis: barrancos con inundaciones estacionale

chots, sabkas: lechos salados de lagos ecos

Detección satélite

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Rio
Niger
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 vegetatio
- water stream discharge, increasing erosion
- sediment deposition

➔ **dust source**

Hubbard Glacier, Alaska

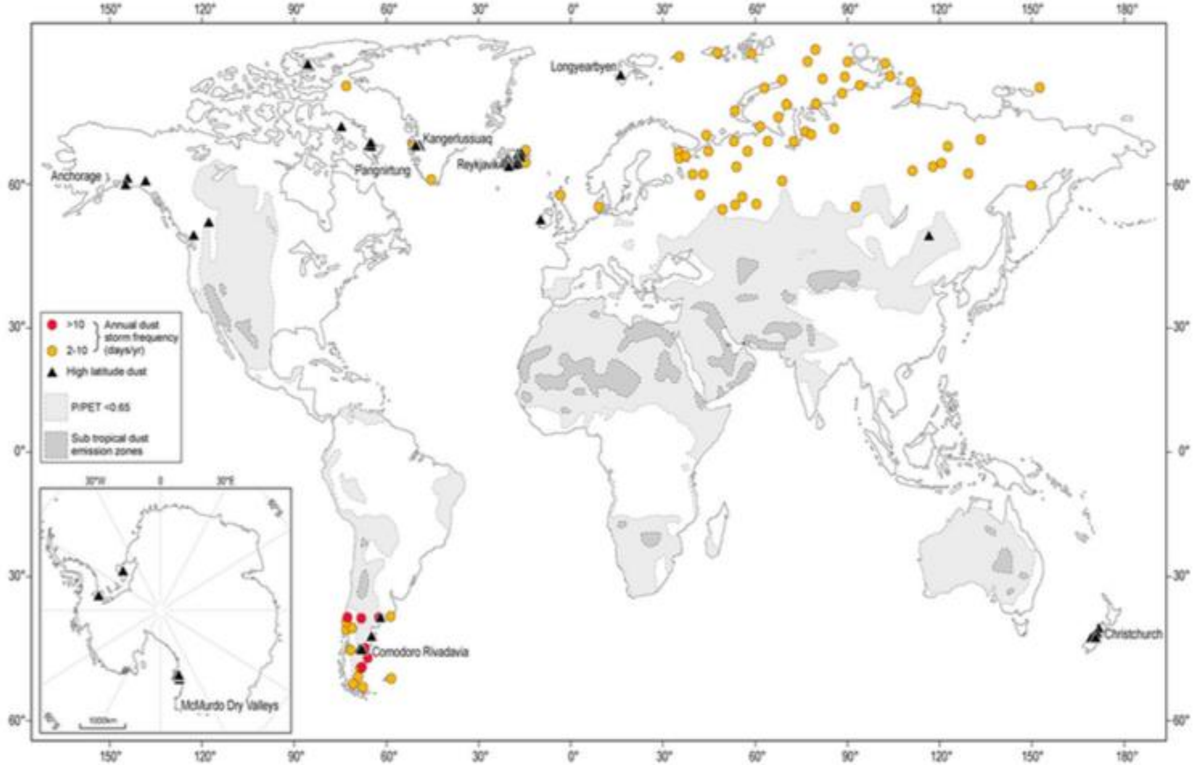
MODIS Aqua
Gulf of Alaska
4-Dec-2015

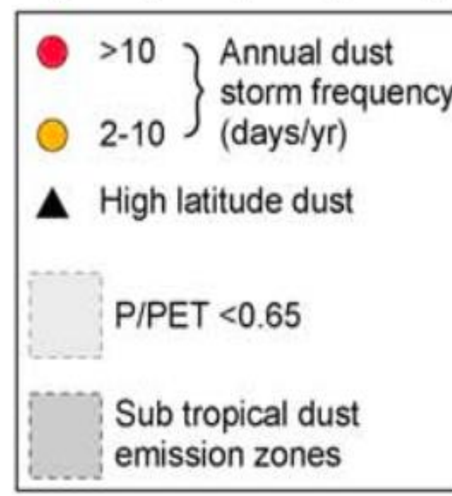
paraglacial dust

paraglacial regions:

- > 50°N
- > 40°S

5% of global dust budge

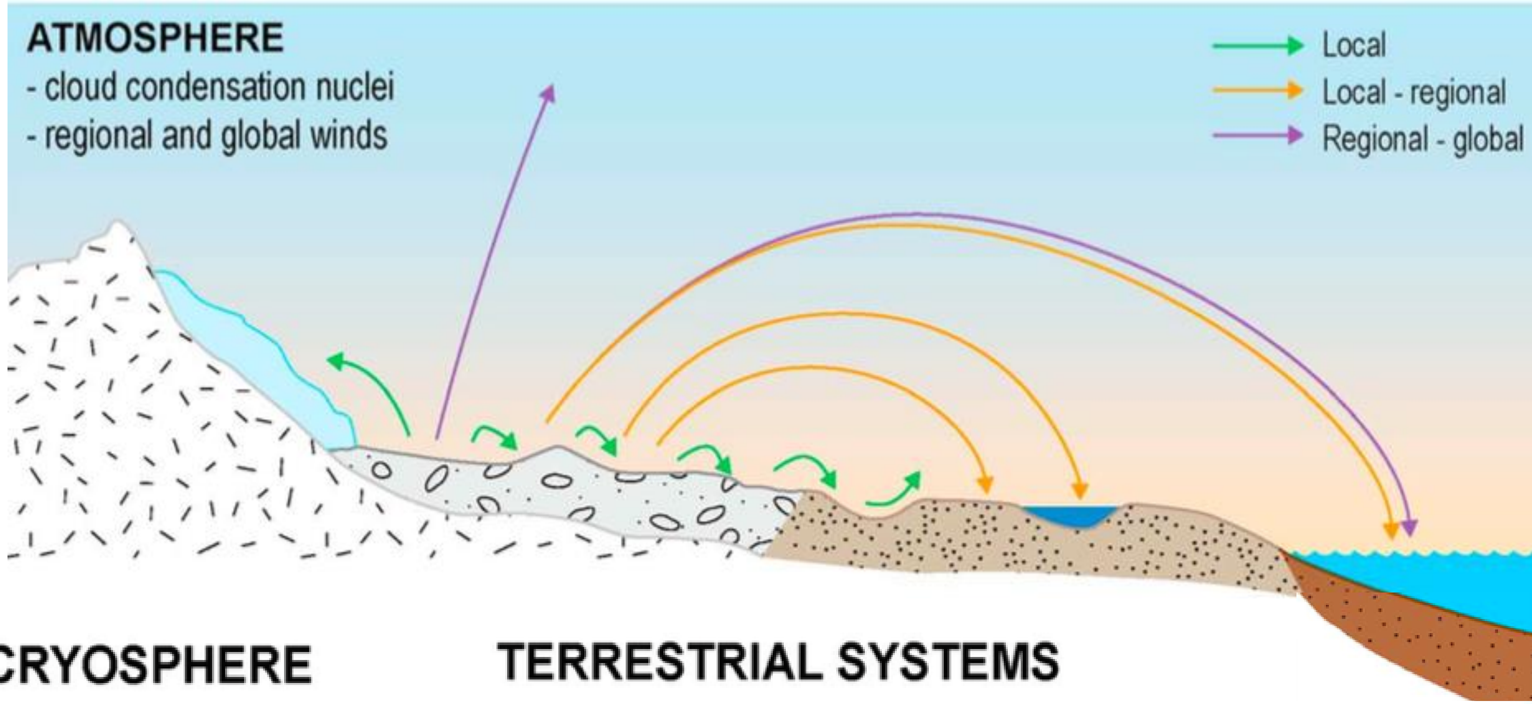




Reviews of Geophysics

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

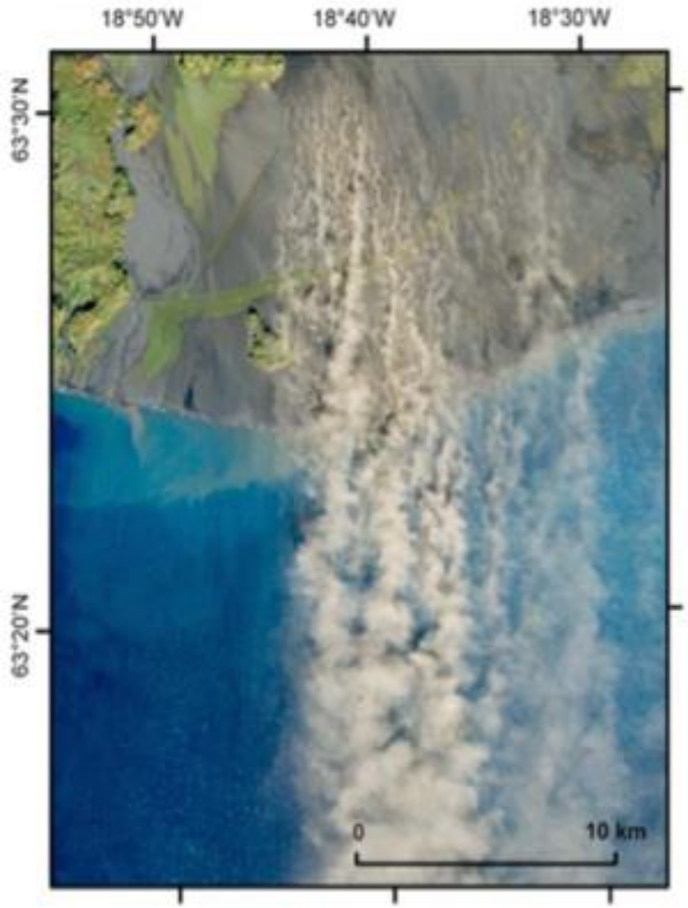
Distal

- 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

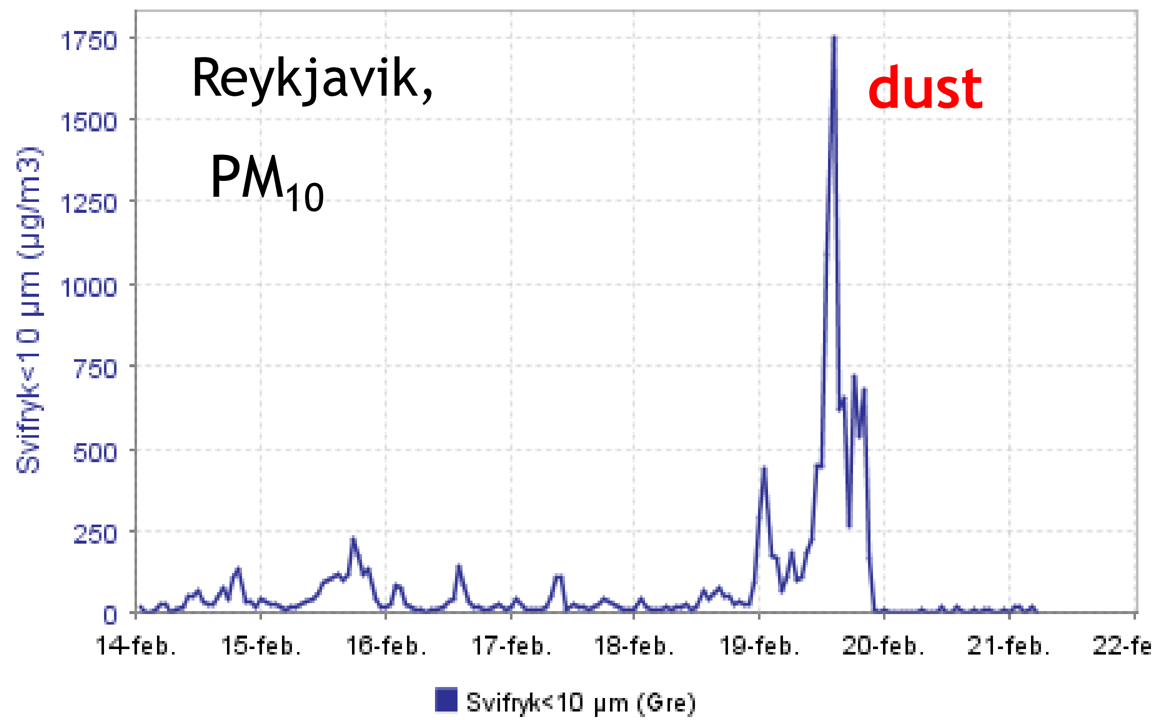


Landsat, 17 Sep 2013, Mýrdalssandur - Iceland

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

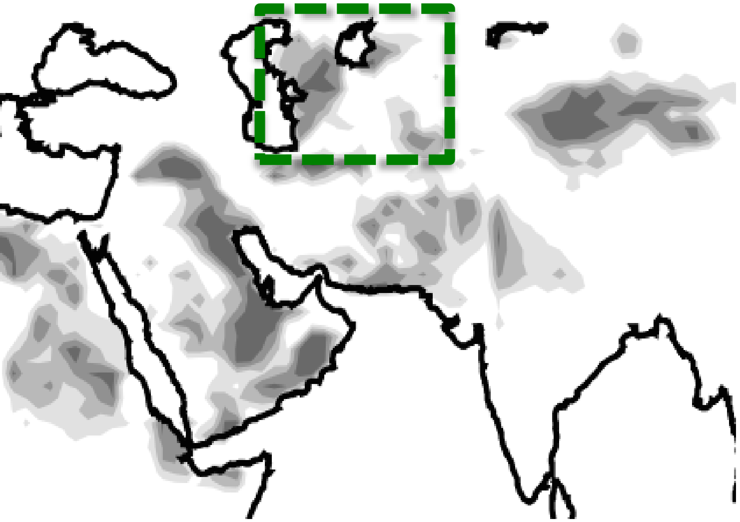
NASA EARTH OBSERVATORY
Where every day is Earth Day

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

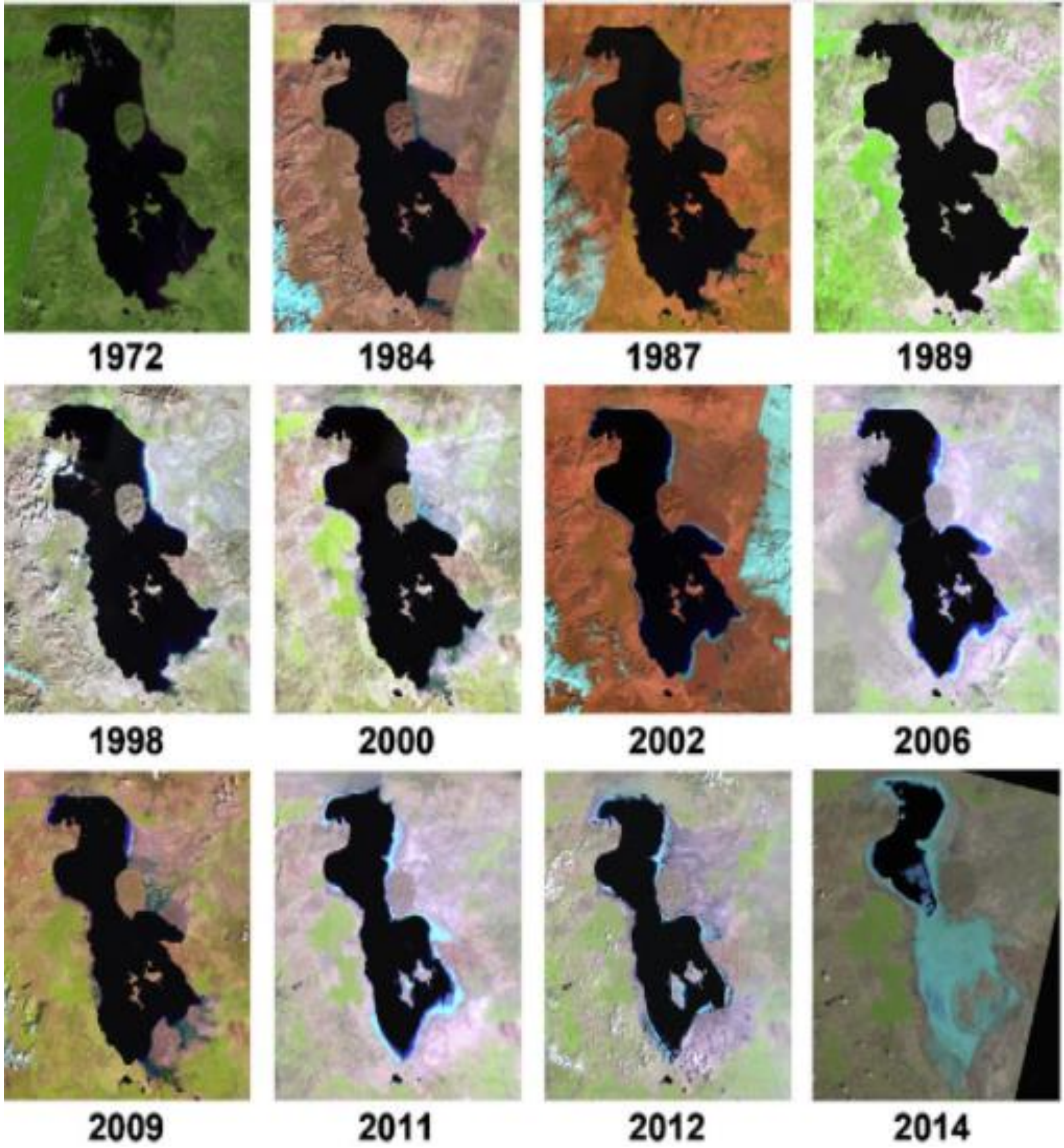
August 12, 2003

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:

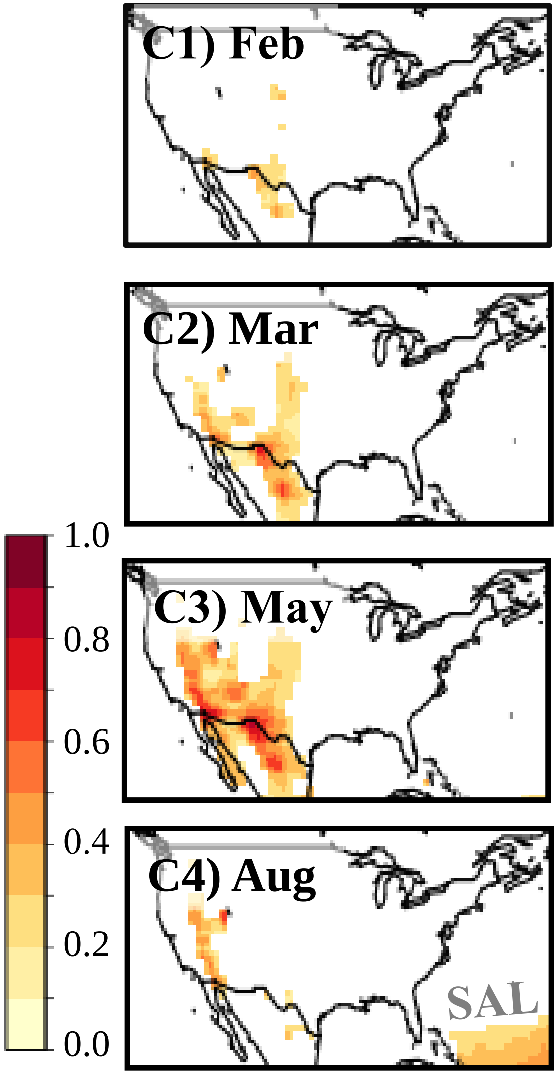
new climate-change-related

new lakes desiccation

agriculture dust

Major Dust Activity Frequency

Aerosol Index > 1



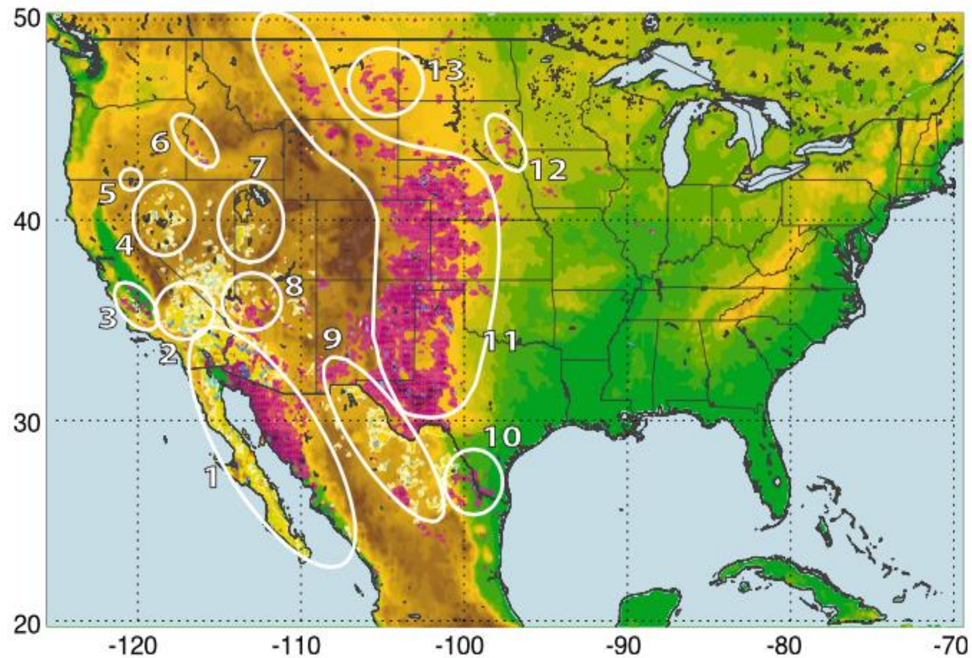
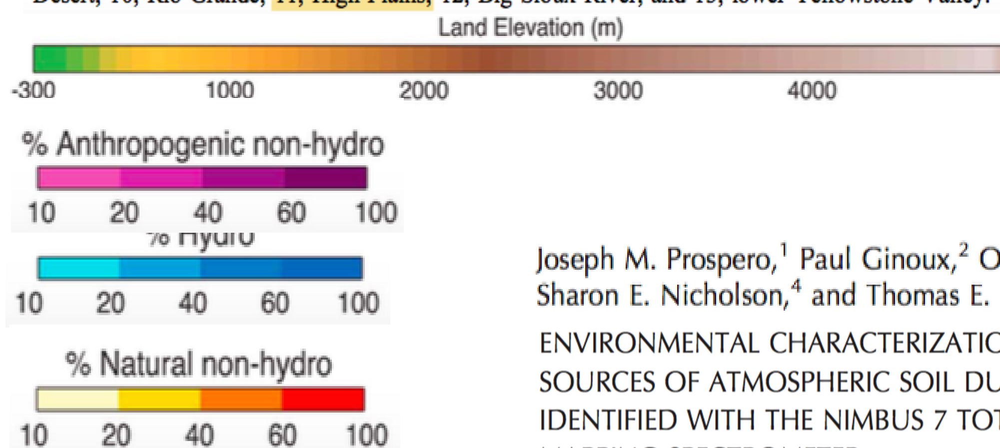


Figure 11. Distribution of the percentage number of days per season (March, April, and May) M-DB2 DOD > 0.2 over North America with color code as in Figure 6. The white circled sources are numbered as follows: 1, Sonoran Desert; 2, Mojave Desert; 3,San Joaquin Valley; 3, Black Rock-Smoke Creek deserts;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

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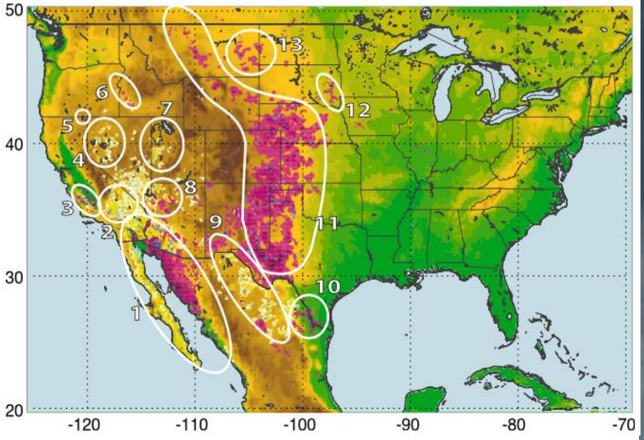
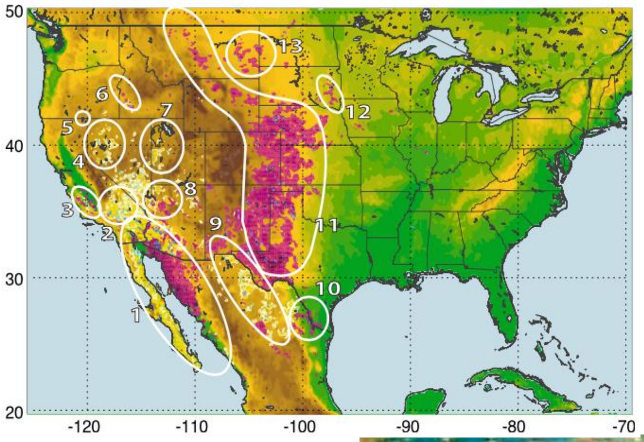
Great Plains

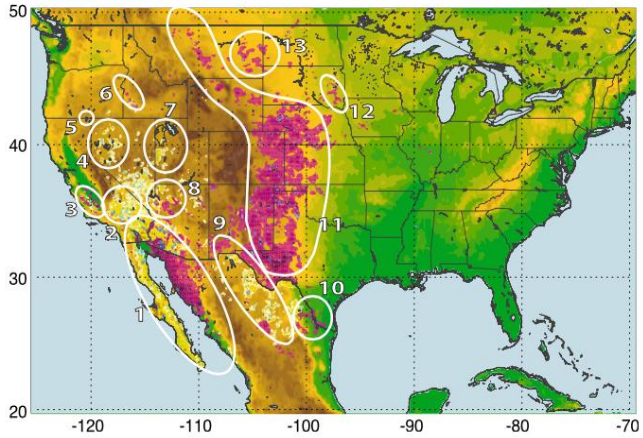


Great Plains

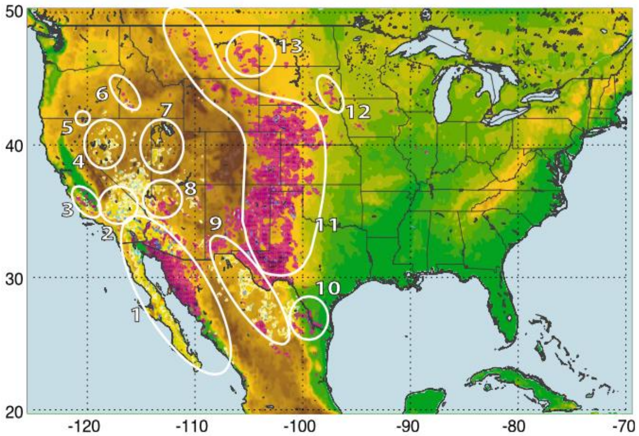


https://www.nrel.colostate.edu/projects/climate_impacts/gptoday.ht1.htm

Great Plains



Great Plains



Managing *wind erosion* on the Plains

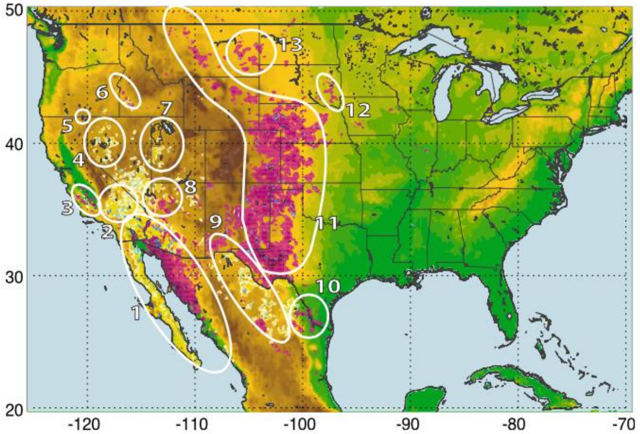
Clay Robinson

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

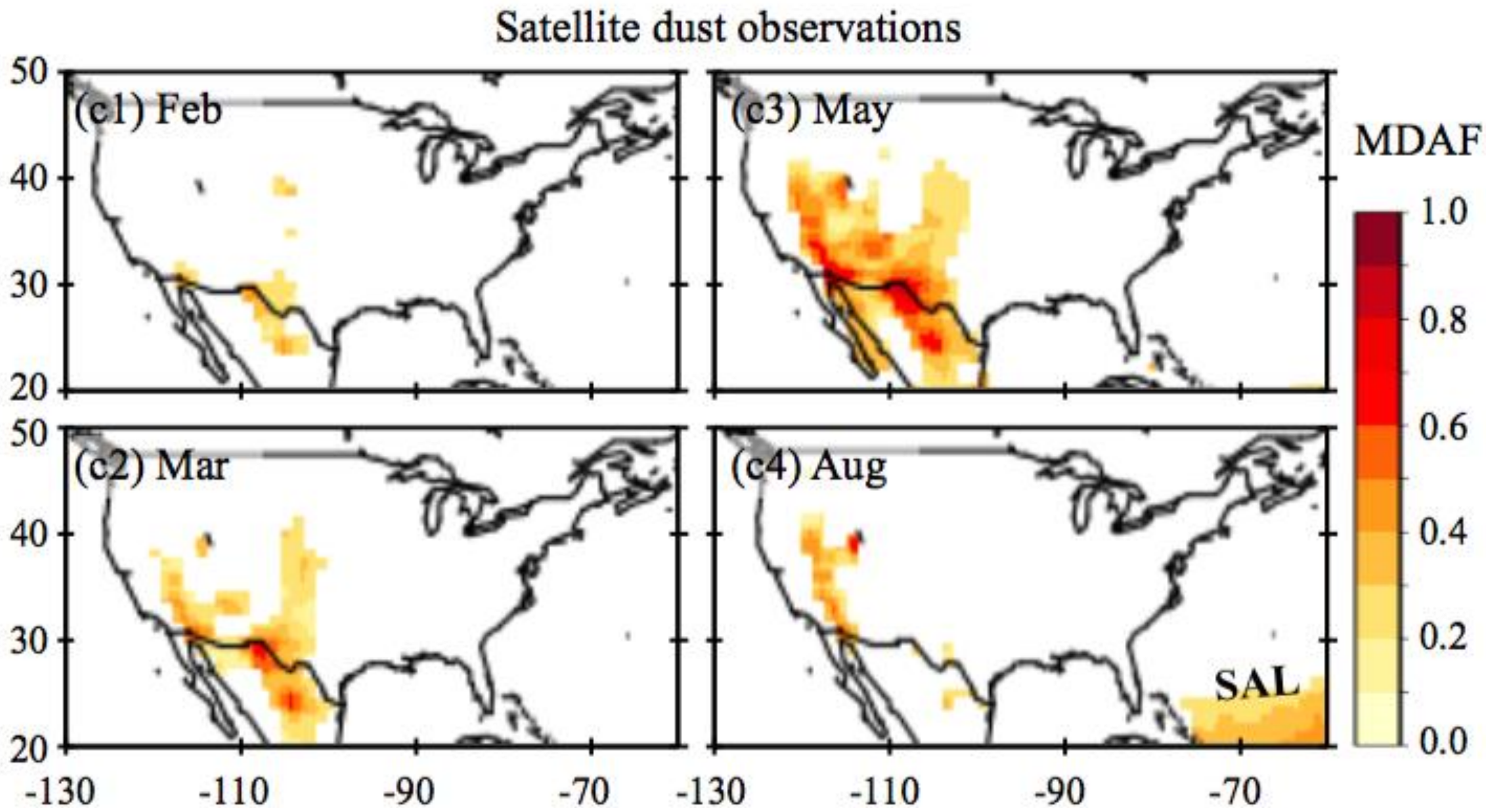
Dust Bowl: 1930s

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/

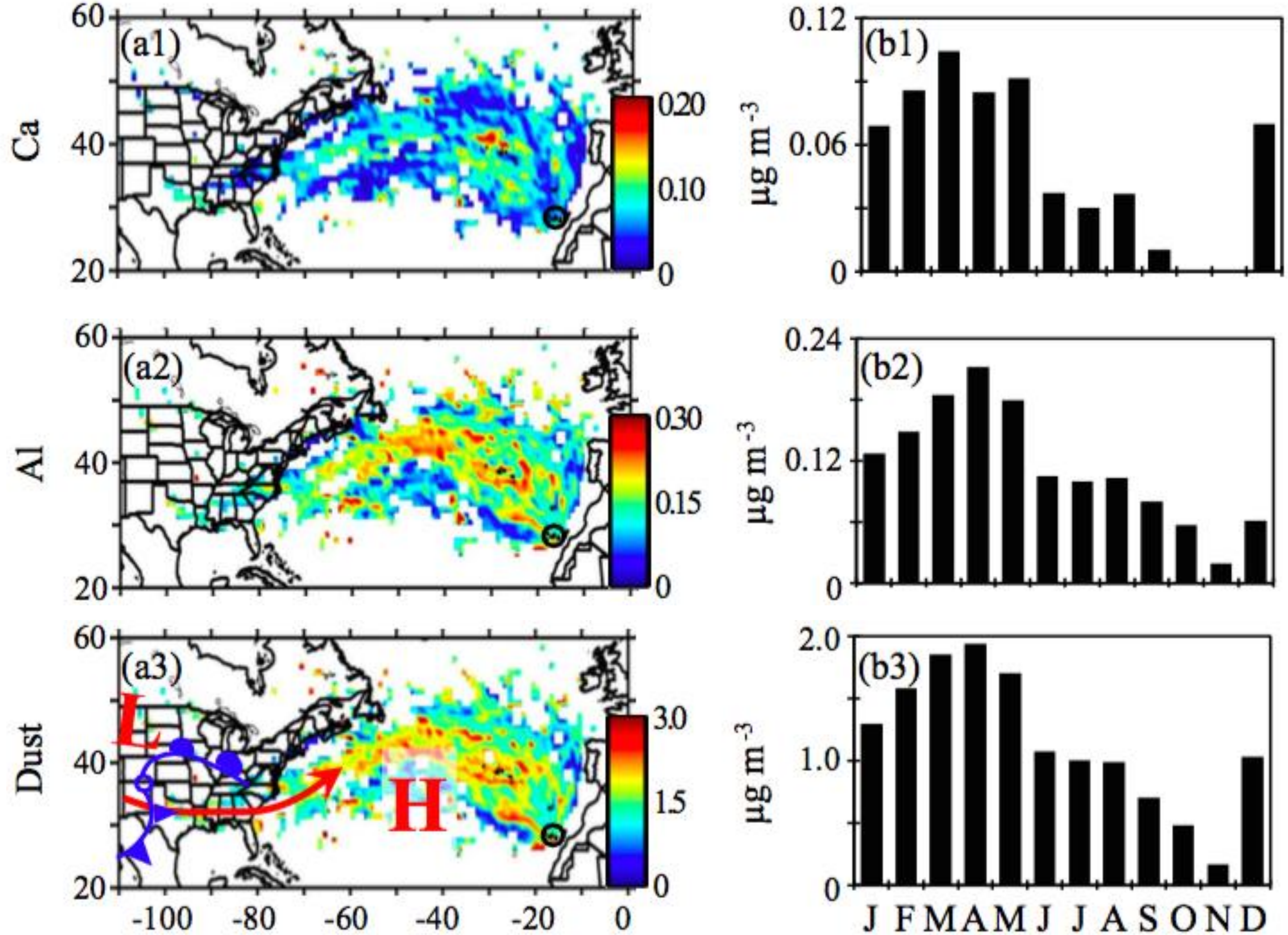


Atmos. Chem. Phys., 17, 7387–7404, 2017

Impact of North America on the aerosol composition in the North Atlantic free troposphere

M. Isabel García[1,2], Sergio Rodríguez[1], and Andrés Alastuey[3]

Izaña Observatory, Tenerife, 2400 masl



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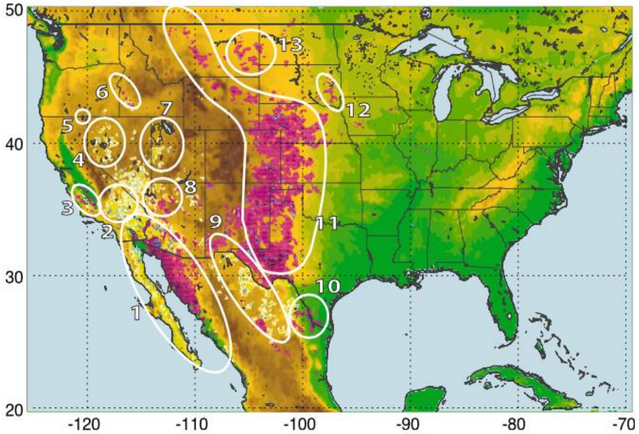
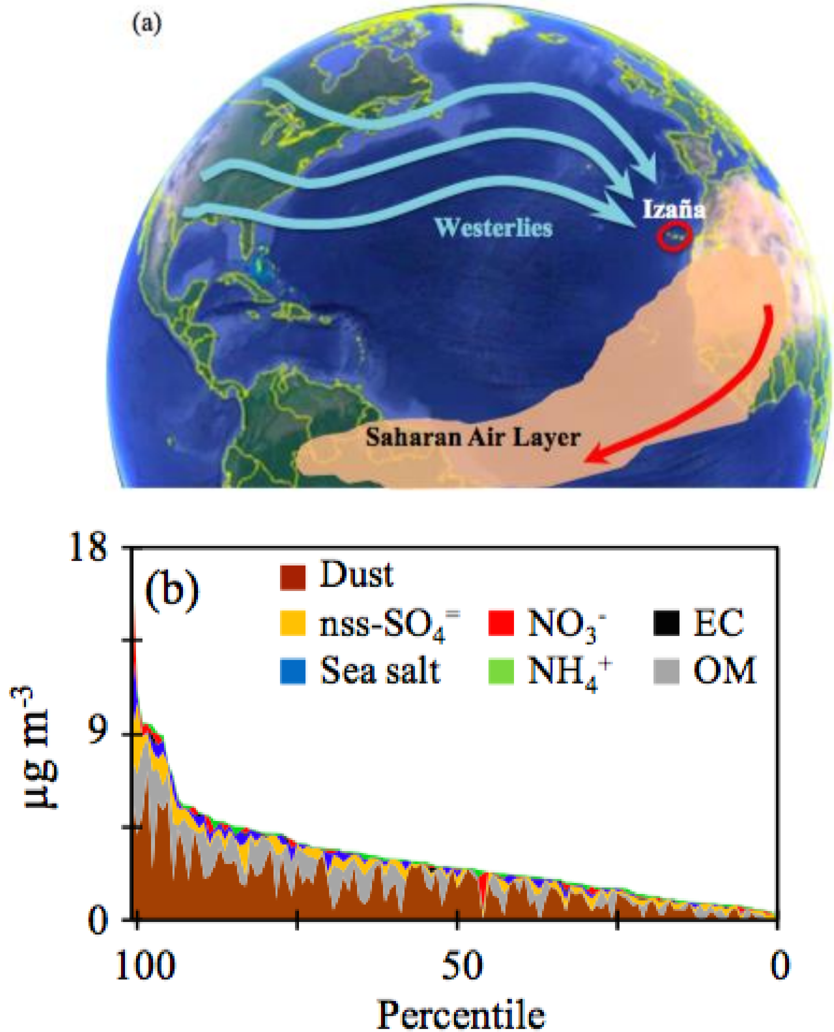
Great Plains





Atmos. Chem. Phys., 17, 7387–7404, 2017

Impact of North America on the aerosol composition in the North Atlantic free troposphere

M. Isabel García[1,2], Sergio Rodríguez[1], and Andrés Alastuey[3]

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

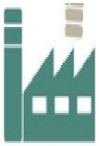
industrial dust
construction dust
road dust

Local to regional scale

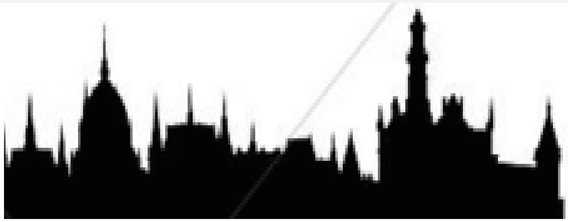
desert
dust

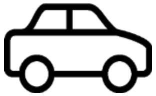
agriculture

constructio
n



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

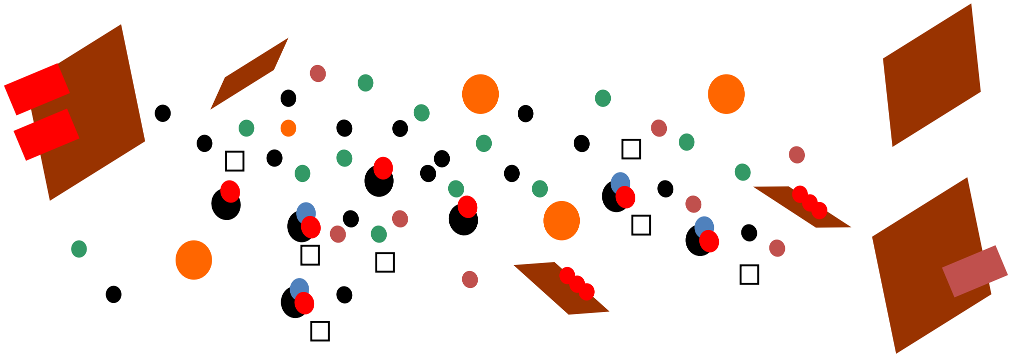
- PM_{10} and $PM_{2.5}$ levels
- PM_{10} and $PM_{2.5}$ composition
- complementary observations

remote sensing observations

let’s build our observation network !!!

aerosols, a cocktail
of chemicals:

people live in cities and breath a cocktail dust + pollutants



- 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

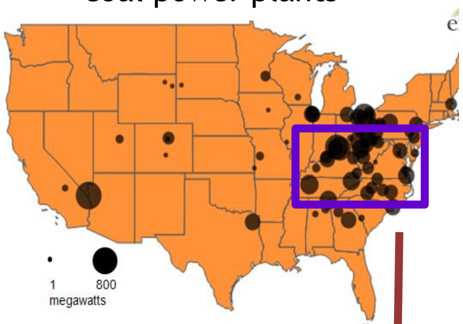
$(NH_4)_2SO_4$

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

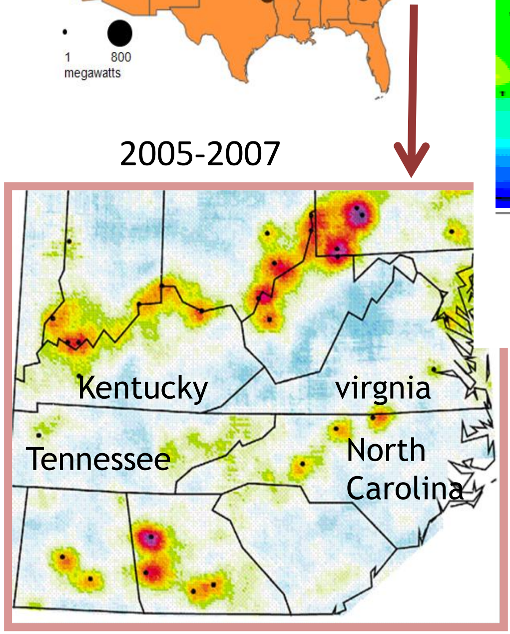
sulfato

122 Tg/y

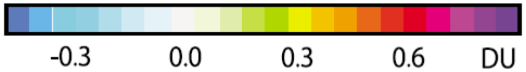
coal power plants



2005-2007



OMI SO_2 DU

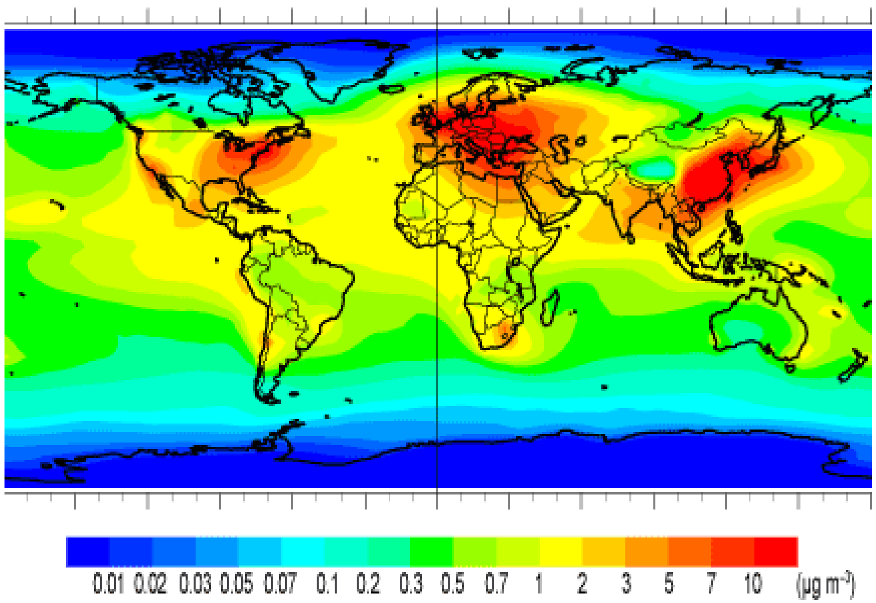


GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L21811, doi:10.1029/2011GL049402, 2011

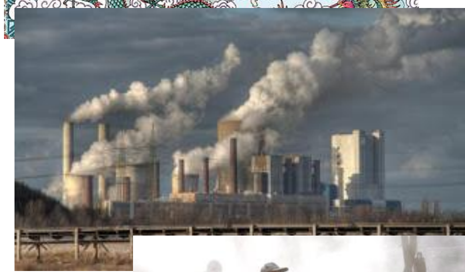
Estimation of SO_2 emissions using OMI retrievals

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

sulfate



coal power plants



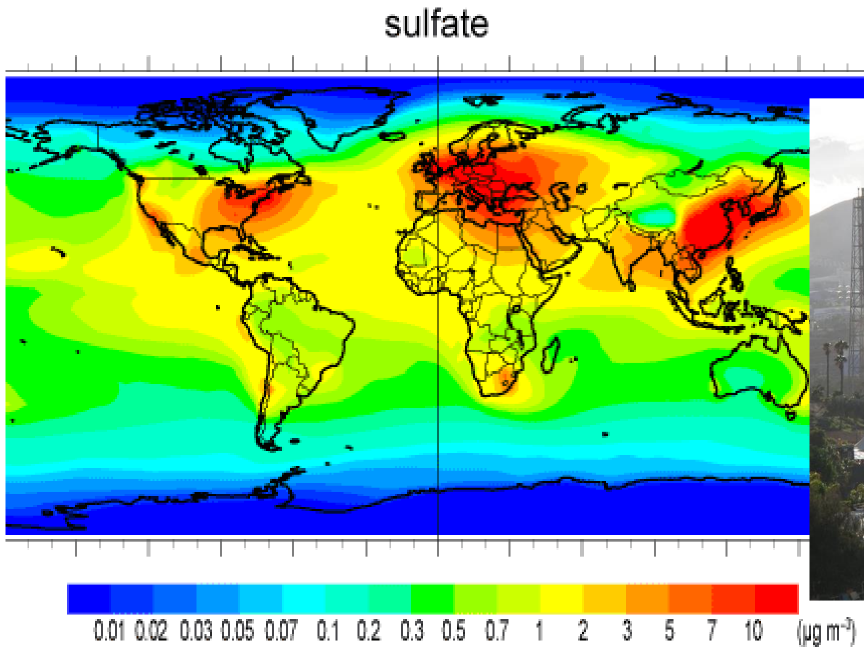
VOL. 15, NO. 4 JOURNAL OF CLIMATE 15 FEBRUARY 2002

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

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^+

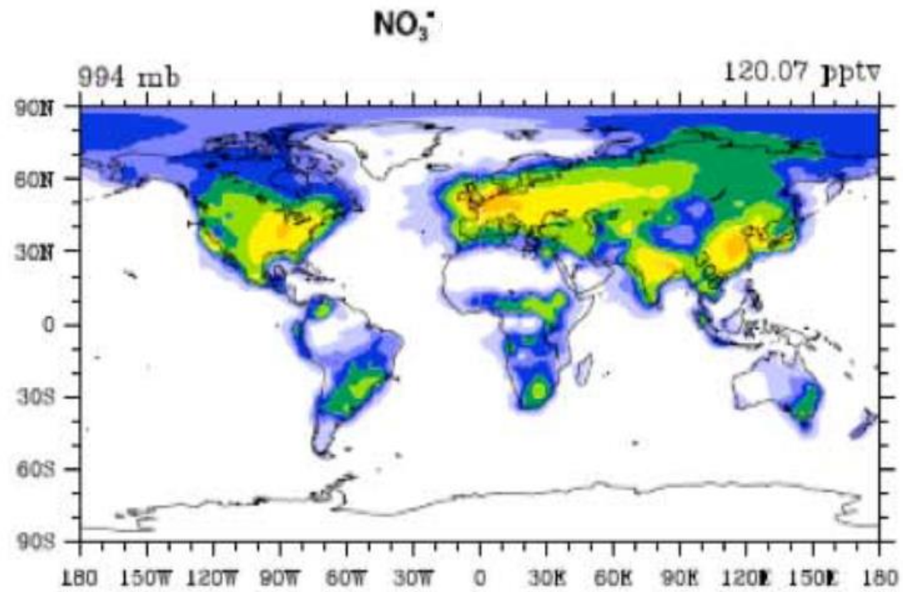
NH_4NO_3

$(NH_4)_2SO_4$

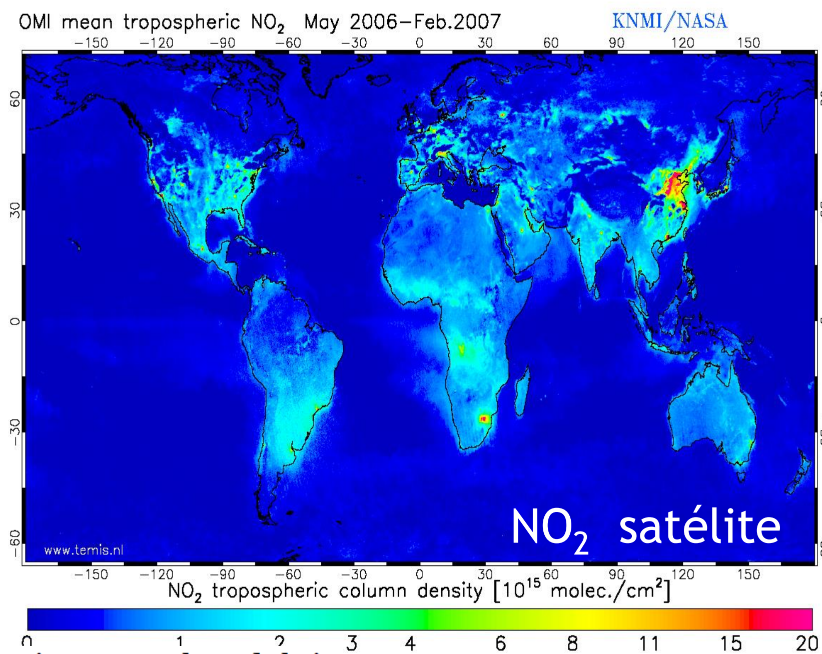
NO_x: vehicle exhaust, power plants, industry

nitrate

18 Tg/y



NH_4NO_3

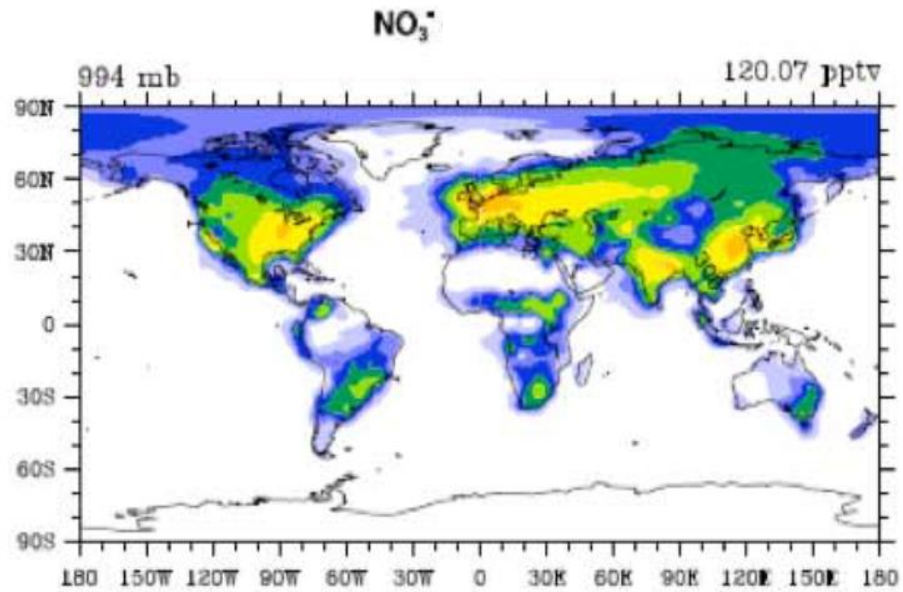


Atmos. Chem. Phys., 12, 9479–9504, 2012
www.atmos-chem-phys.net/12/9479/2012/

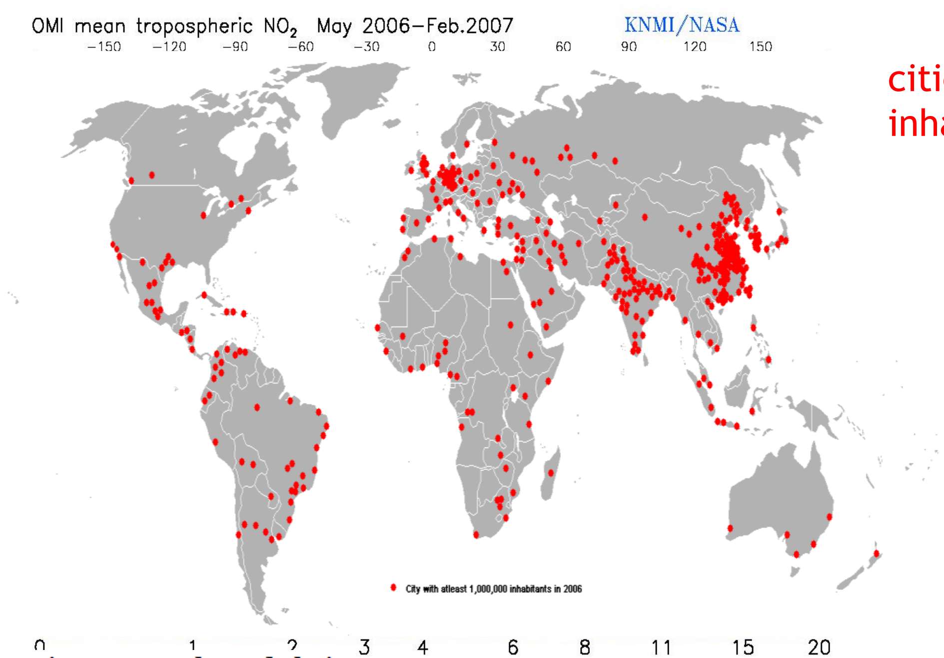
L. Xu and J. E. Penner

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
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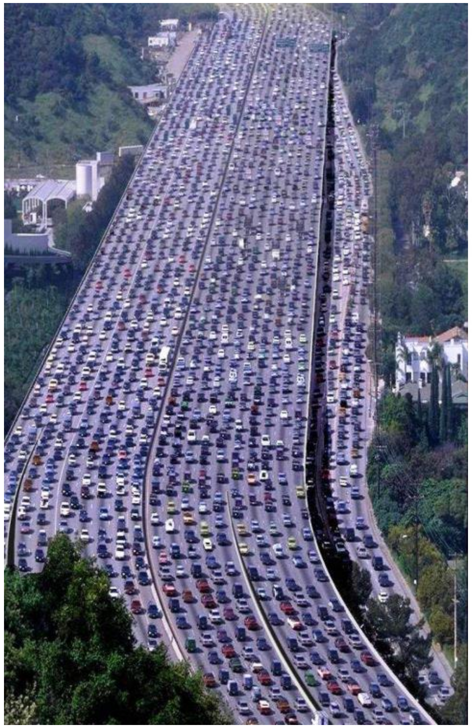
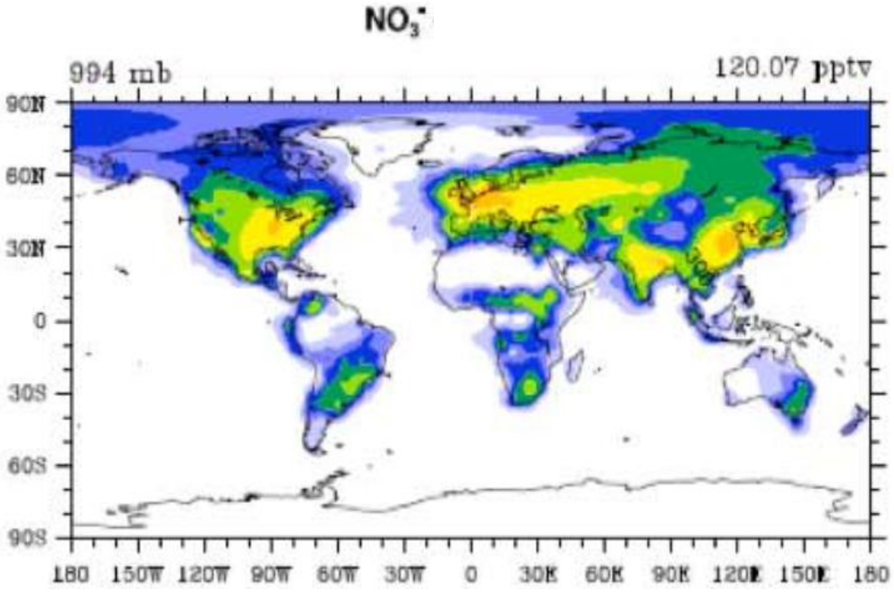
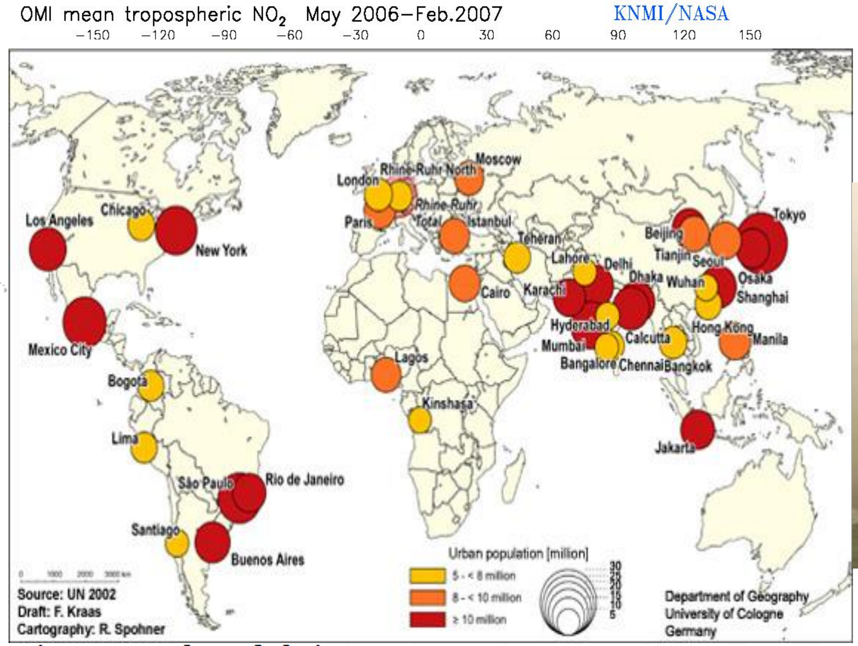




NH_4NO_3



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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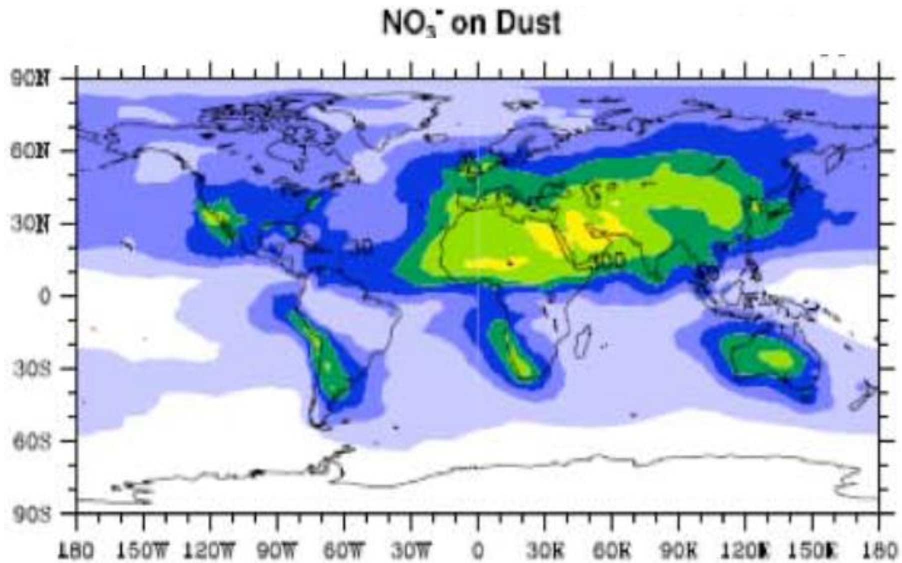
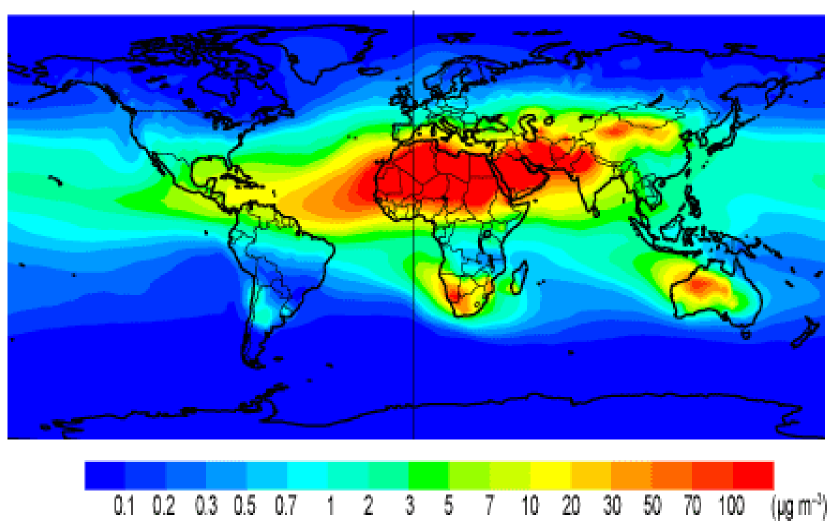


NO_3^- - dust

$Ca(NO_3)_2$



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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**

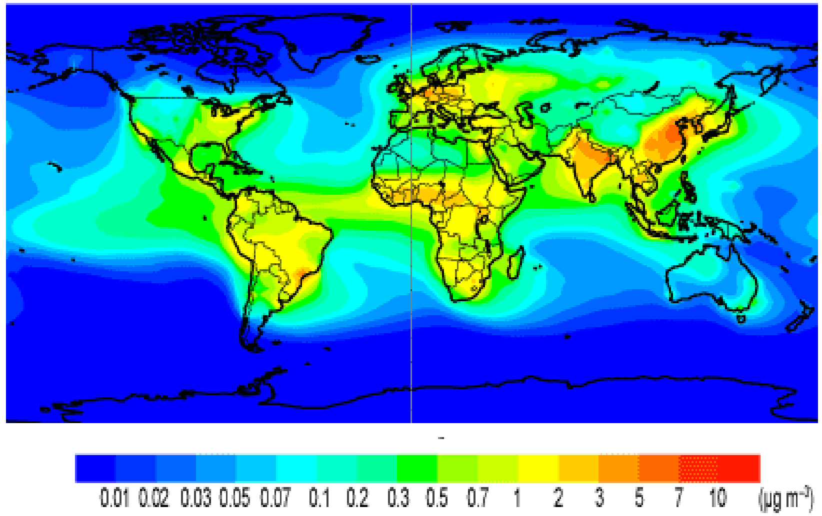
Black carbon: vehicle exhaust (diesel) , combustion sources

black carbon

10.5 Tg/y

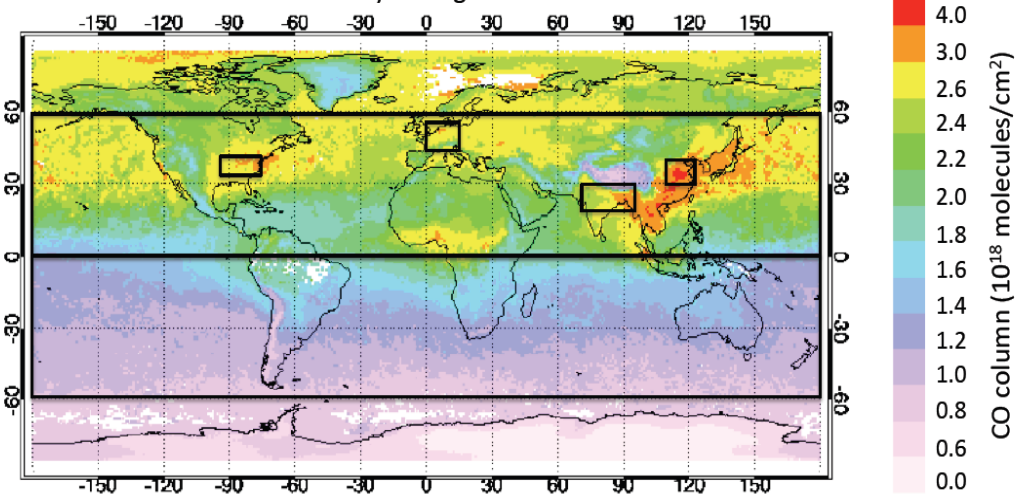
diesel, 4x4, camiones

black carbon



automóviles

MOPITT V5T monthly average CO column for March 2005



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

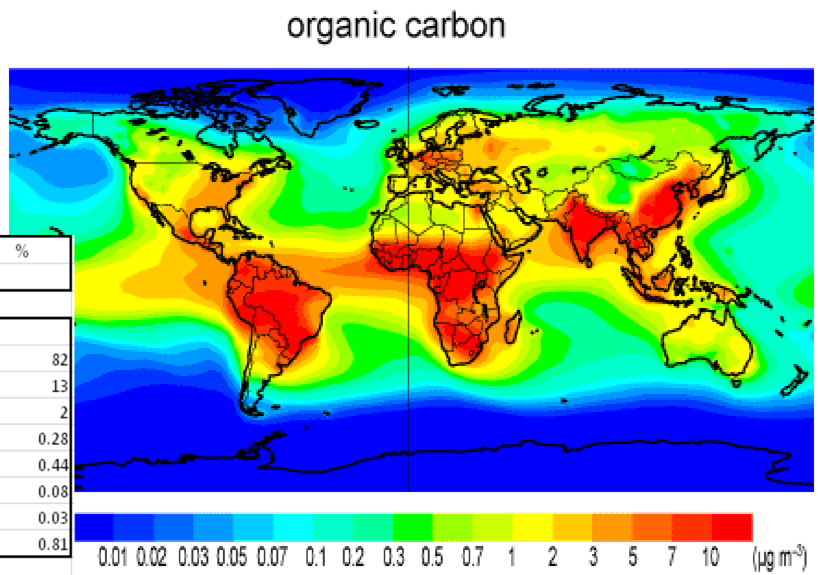
Toshihiko Takemura* and Teruyuki Nakajima
Oleg Dubovik, Brent N. Holben, and Stefan Kinne

aerosols, a cocktail of chemicals:

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

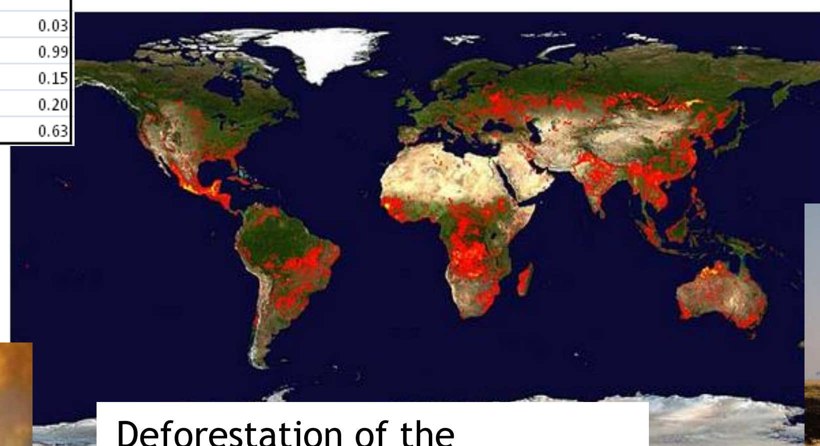
organic matter: combustion sources, vehicle exhaust

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

Vehicle exahust

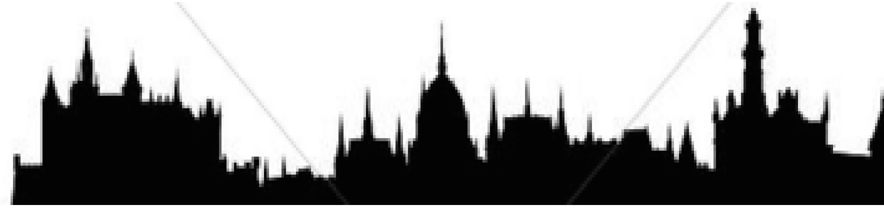


←Satelite detecion of fires

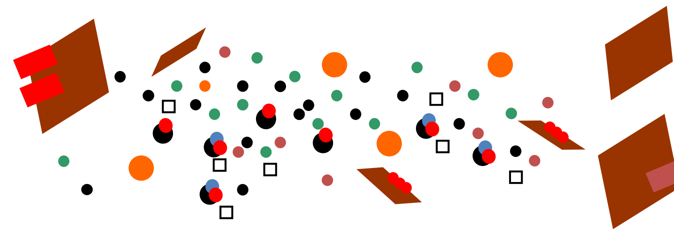
Sabana Africana

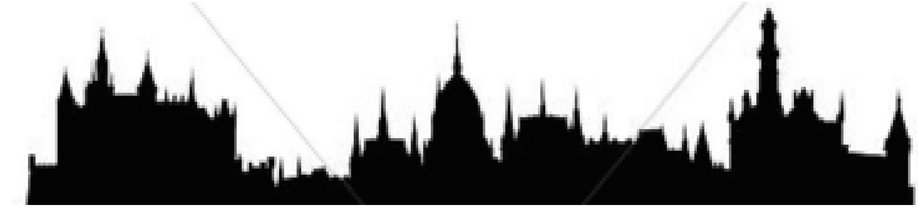
Paraguay: burn forest for cultivation of soja and suggar cane

Deforestation of the Amazonia



people live in cities and breath
a cocktail dust + pollutants





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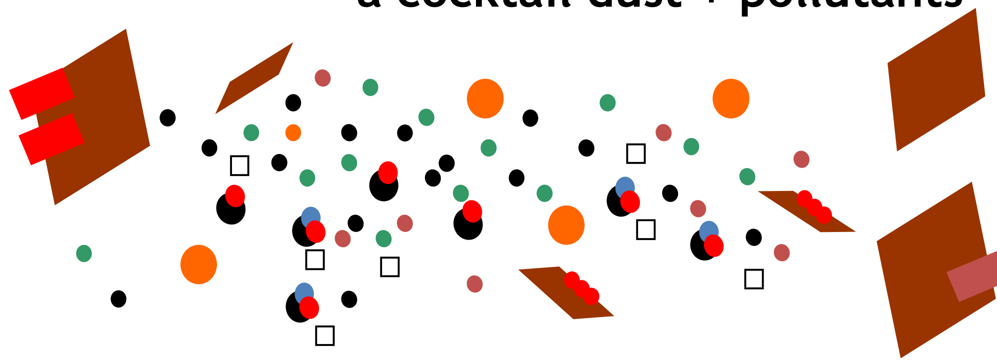


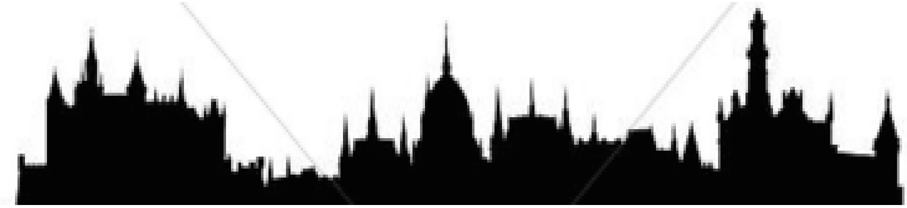
In air quality, aerosols:

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

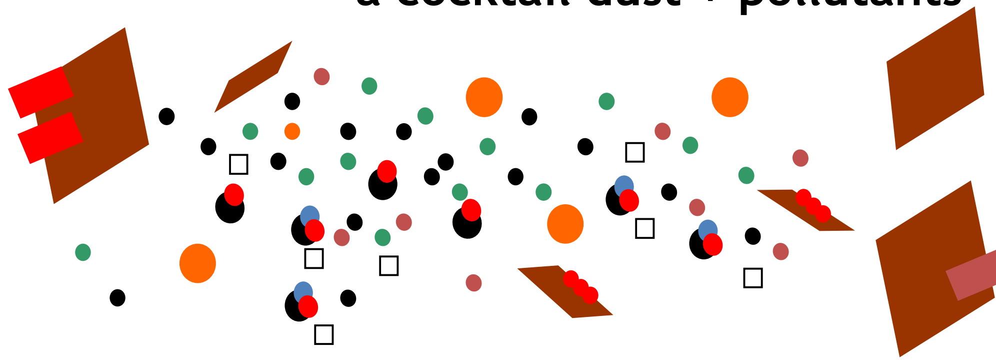
inhalable particles

$PM_{2.5}$: 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

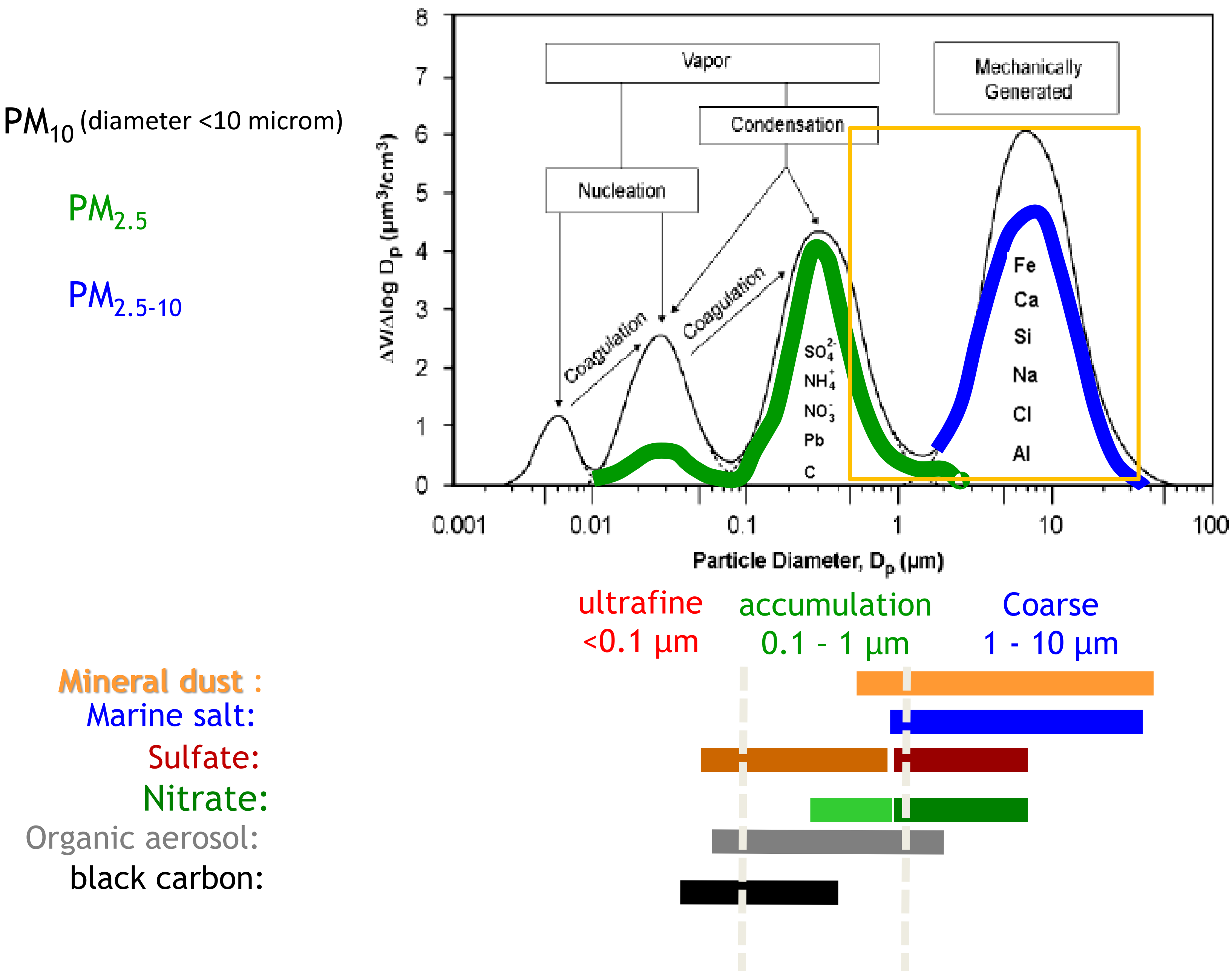


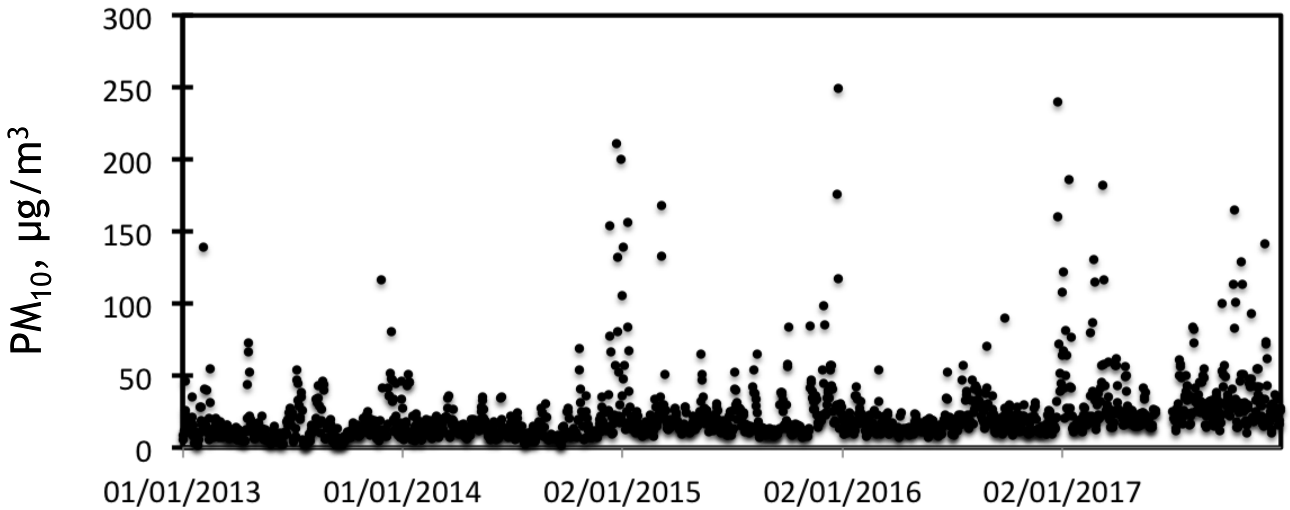
PM_{10}: Σ dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals)

$PM_{2.5}$: 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 +...


PM10 (diameter <10 microm)
PM2.5
PM2.5-10
Vapor
Mechanically Generated
Condensation
Nucleation
Coagulation
Coagulation
SO4 2-
NH4 +
NO3 -
Pb
C
Fe
Ca
Si
Na
Cl
Al
ΔV/Δlog Dp (µm3/cm3)
0
1
2
3
4
5
6
7
8
0.001
0.01
0.1
1
10
100
Particle Diameter, Dp (µm)
ultrafine
<0.1 µm
accumulation
0.1 – 1 µm
Coarse
1 - 10 µm
Mineral dust :
Marine salt:
Sulfate:
Nitrate:
Organic aerosol:
black carbon:

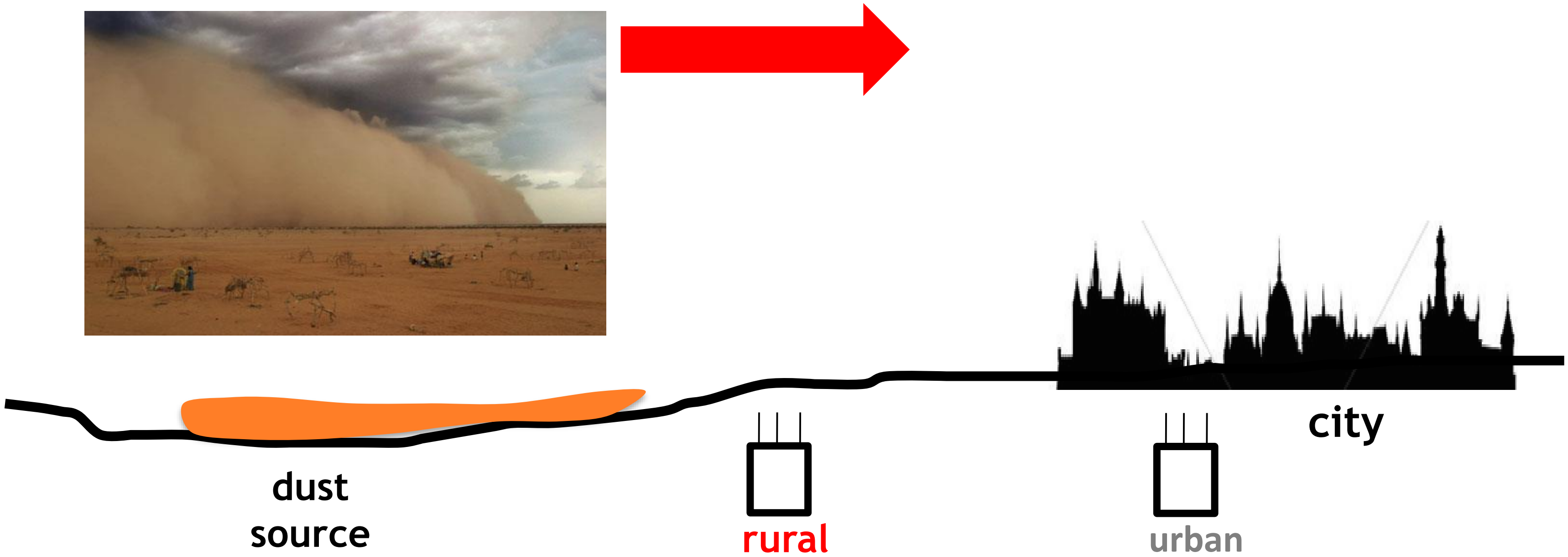


PM_{10}: Σ dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals)

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

dust, aerosols and pollutants

in-situ observations



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

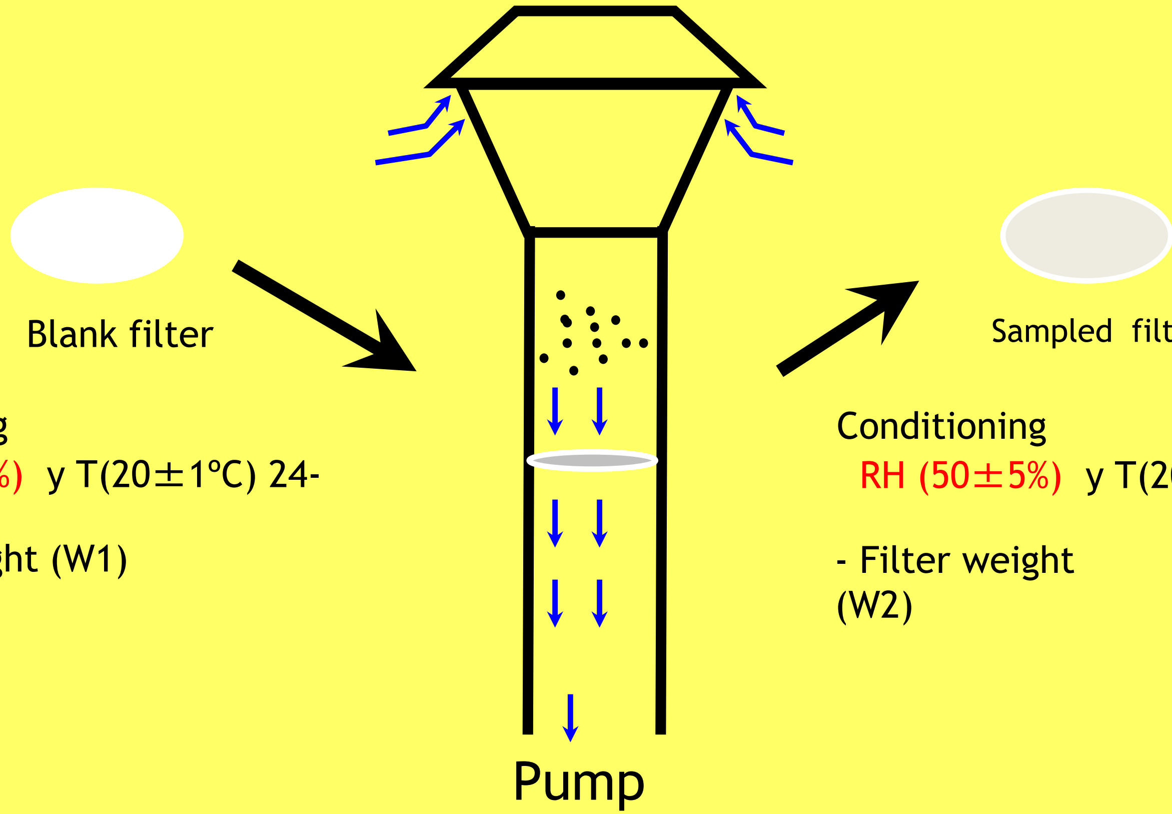
dust air quality

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 14970: 2015
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)

- -we recommend you use a specific normalised method (e.g. EN14907:2015)

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. EN14907:2015)

Filters: Quartz, Teflon, Cellulose

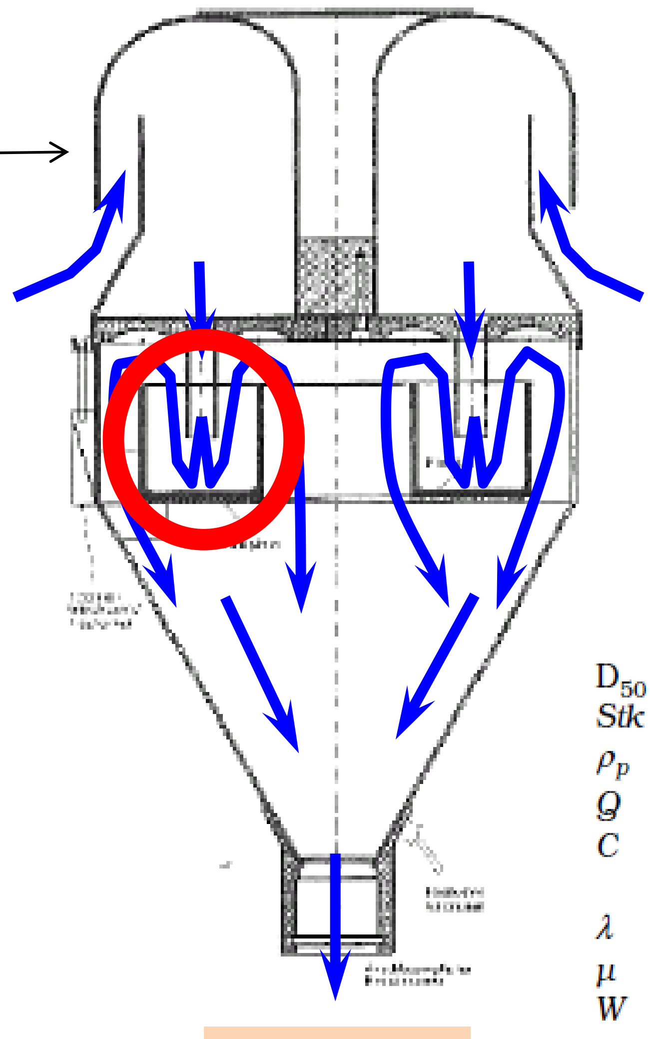
Low Volume Sampler High Volume Sampler

LVS: 2.3 m^3/h HVS: 68 m^3/h HVS: 30 m^3/h

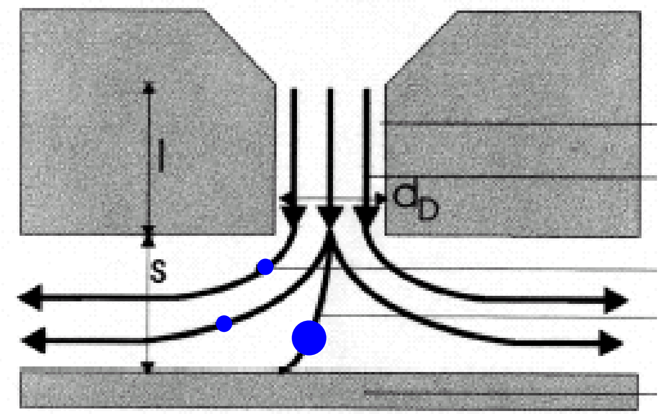
-we recommend you use a specific normalised method (e.g. EN14907:2015). Ask to the distributor if the sampler sis designed to any standards

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•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>

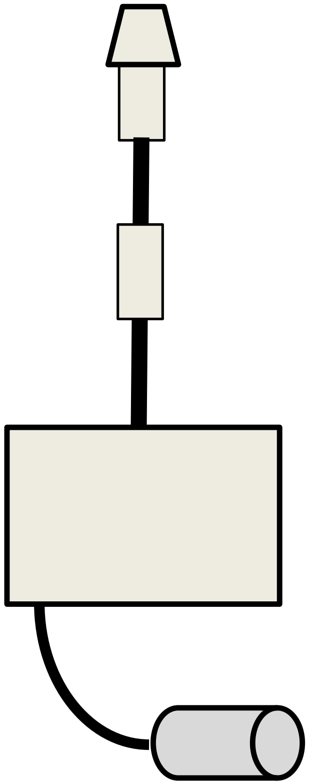
advantage: reference method

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

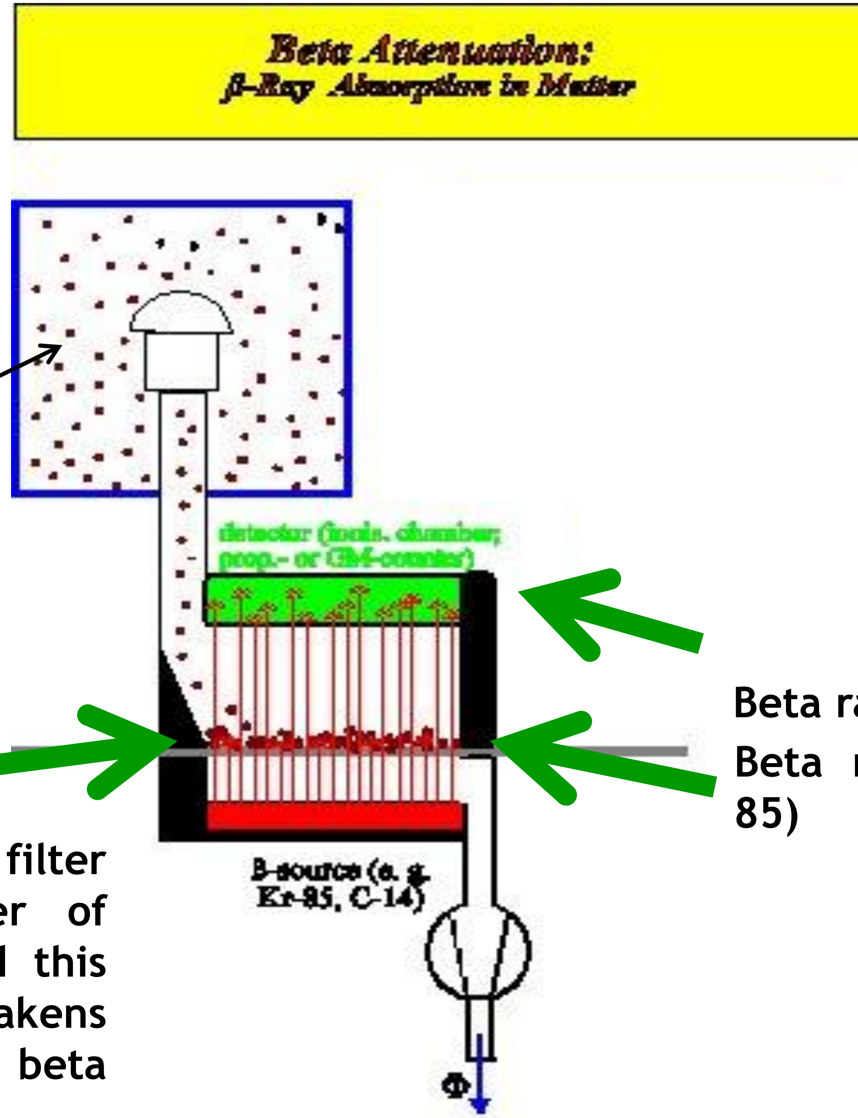
4. Pump / Flow meter

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.

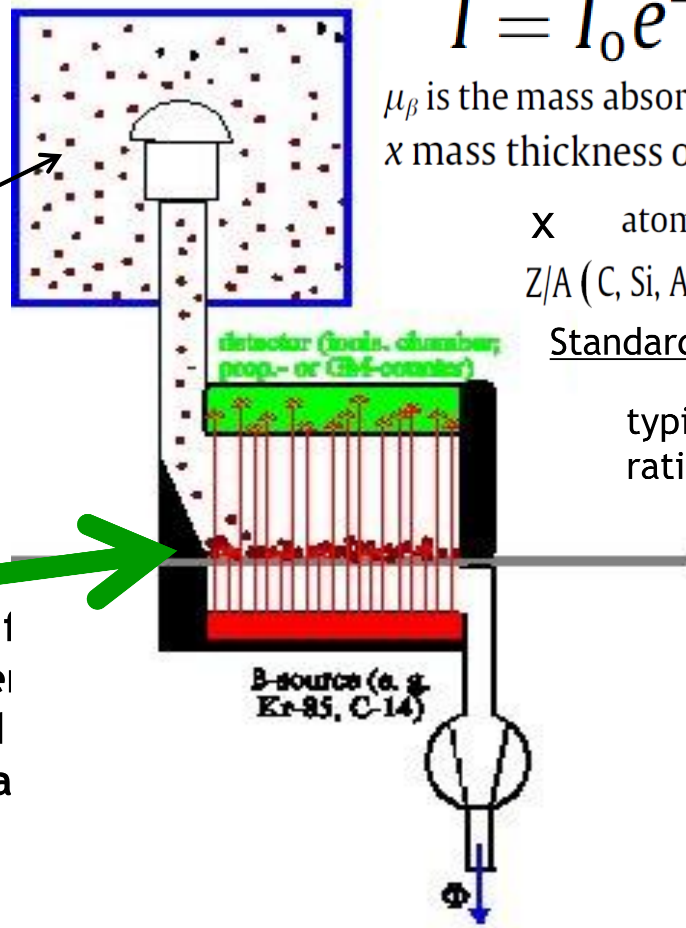
Pump and flowmeter

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



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

μ_β is the mass absorption coefficient for beta radiation

x mass thickness of the sample

x 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%

Dust is deposited on a f continuously. The laye dust is building up and increasing dust mass wea the intensity of the 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

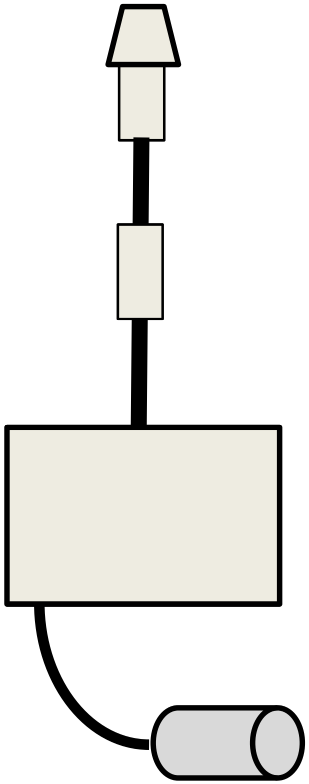
The intensities I_0 and I are measured with the detector system. F_{cal} has to be measured directly during the calibration procedure. This is accomphished by replacing the filter with the element having a known mass (mass calibration kit)

The mass concentration is calculated from:

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

Where:
c: concentration [µg/m^3]
F: measured air flow [m^3/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

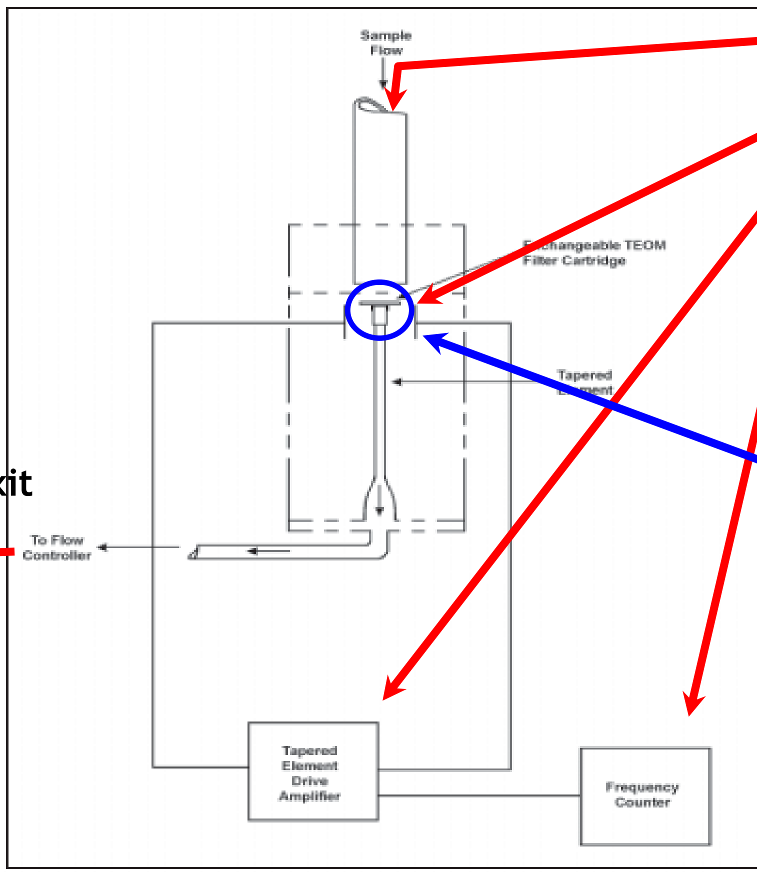
Automatic continuous measurements

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

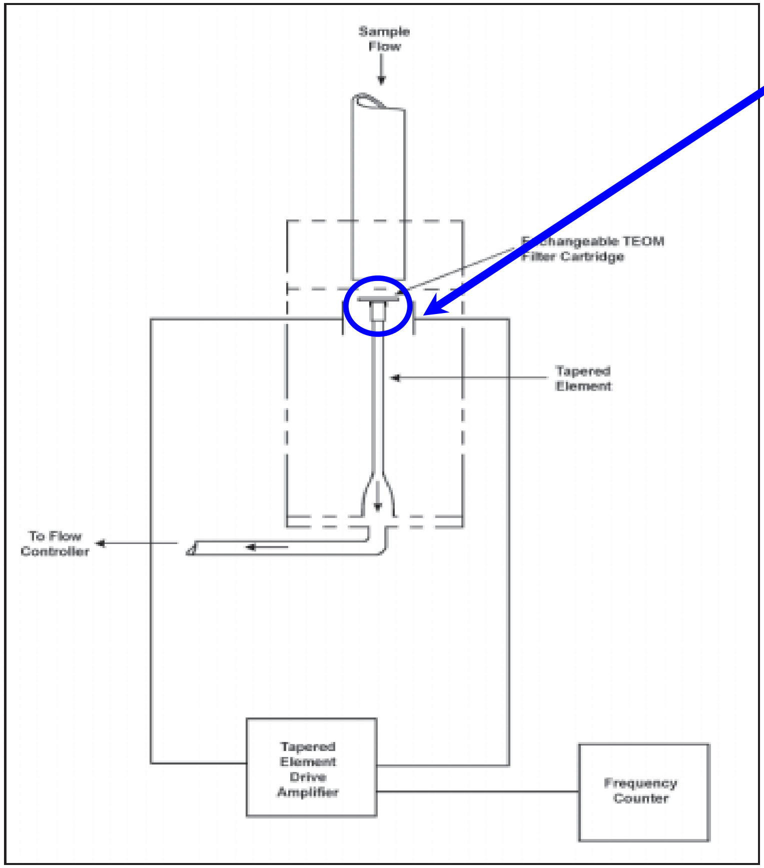
Mass concentration

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

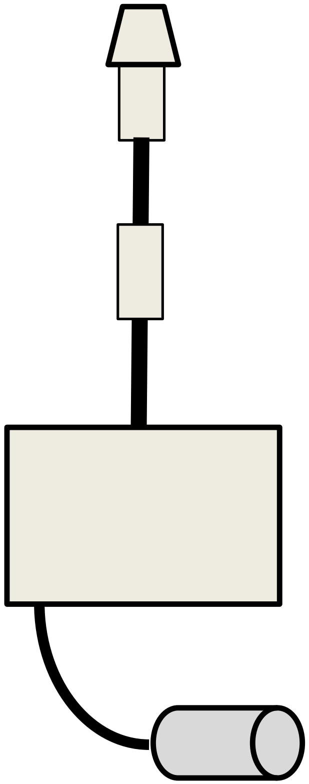
K and M are in consistent units. The relationship between mass and change in frequency can be expressed as:

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

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

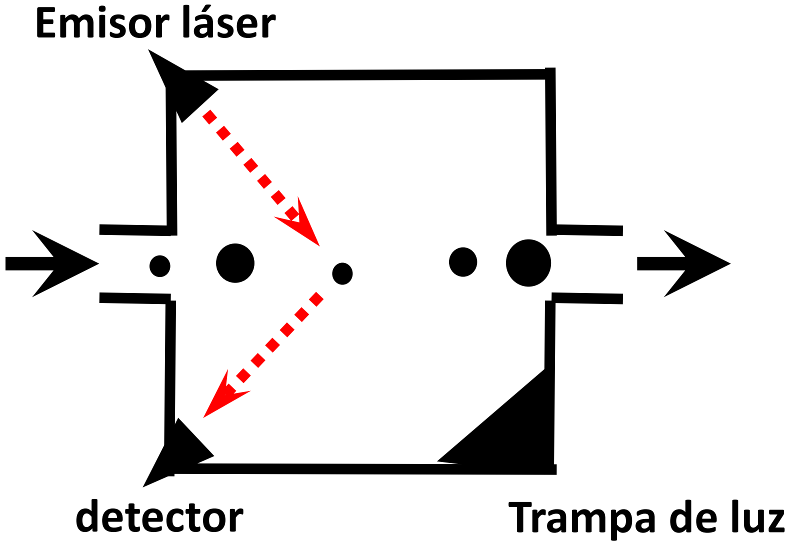
   Beta radiation attenuation
   TEOM
   Optical Particle Sizers

4. Pump / Flow meter

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

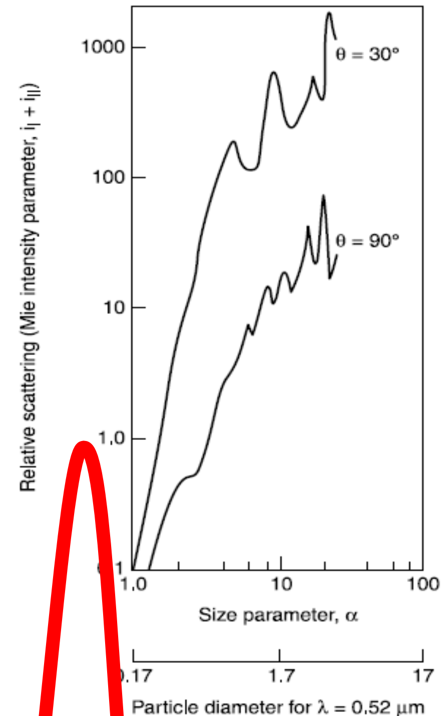
Optical Particle Sizer

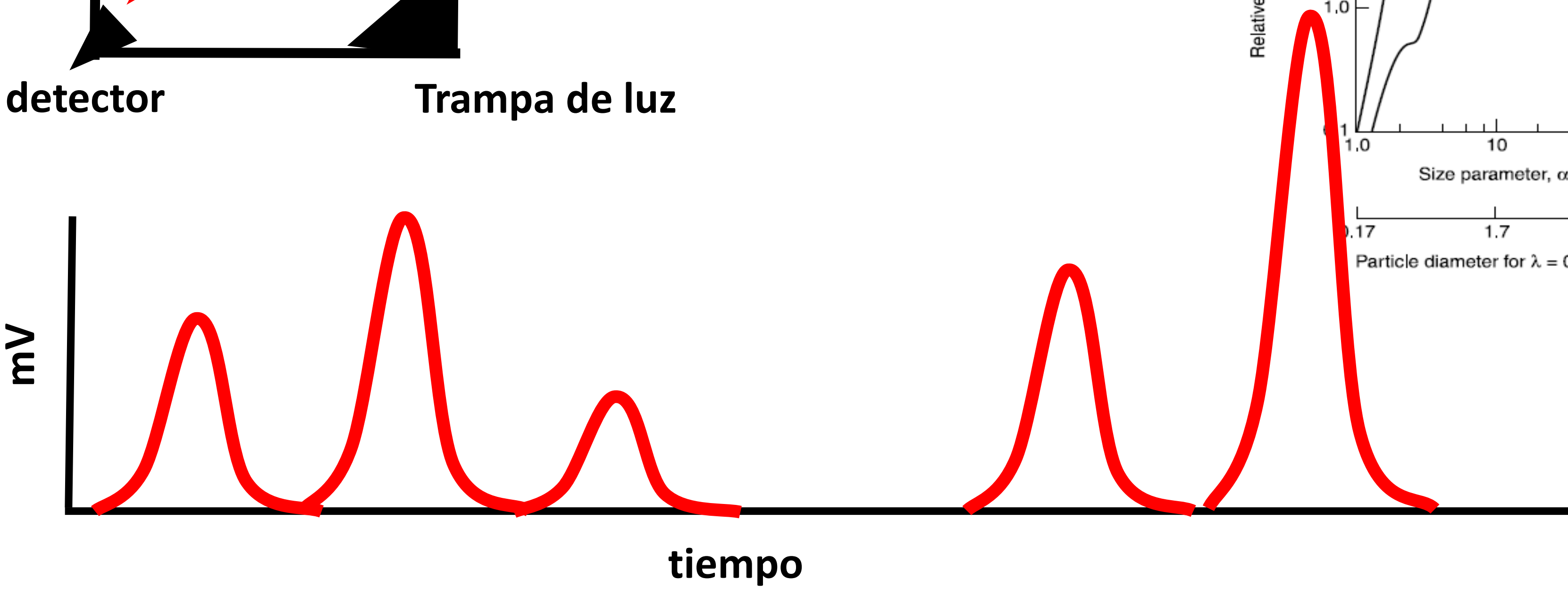
number size distribution 0.3 – 20 µm

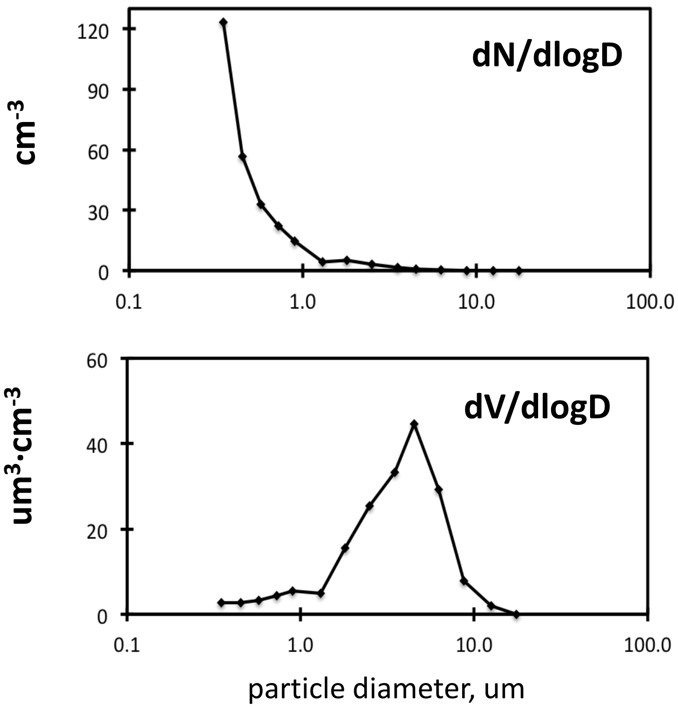


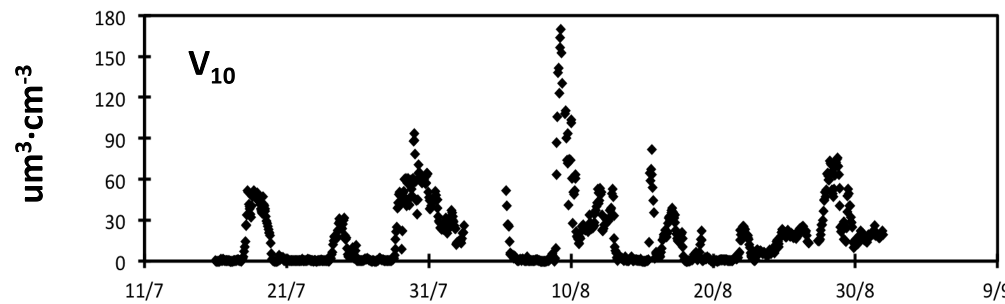
Intensidad del scattering

$I(dp, \theta, \lambda, \mathbf{m})$









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

there are other methods, but are less robust for dusty regions

Tapered Oscillating Microbalance

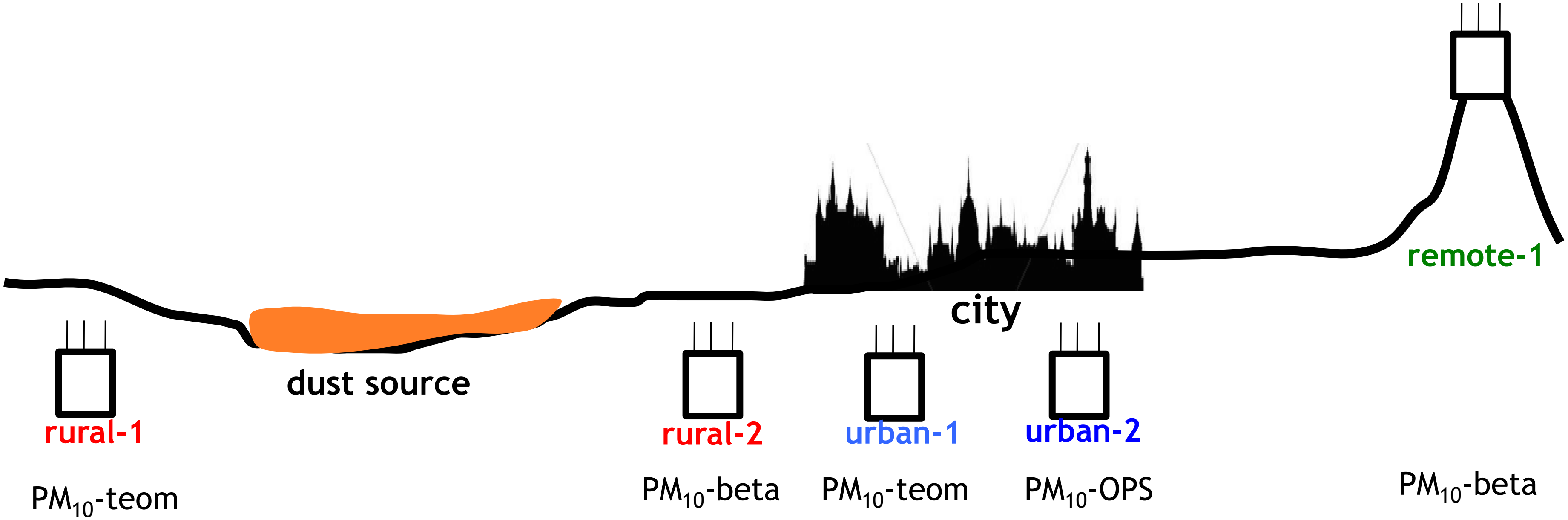
TEOM

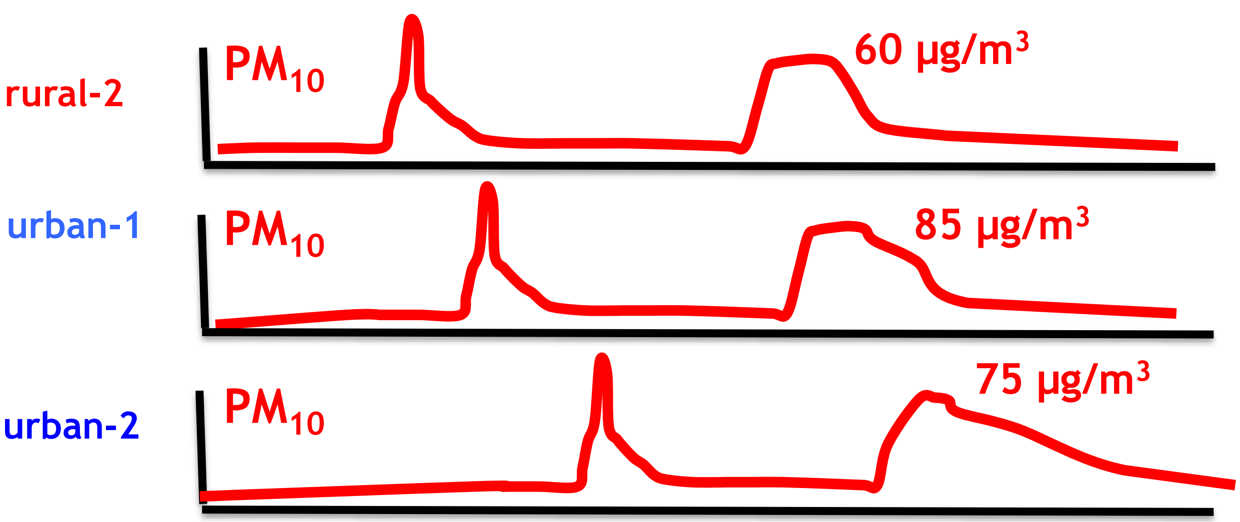
Manual change of the filter

Optical Particle Counters

cleaning of optics

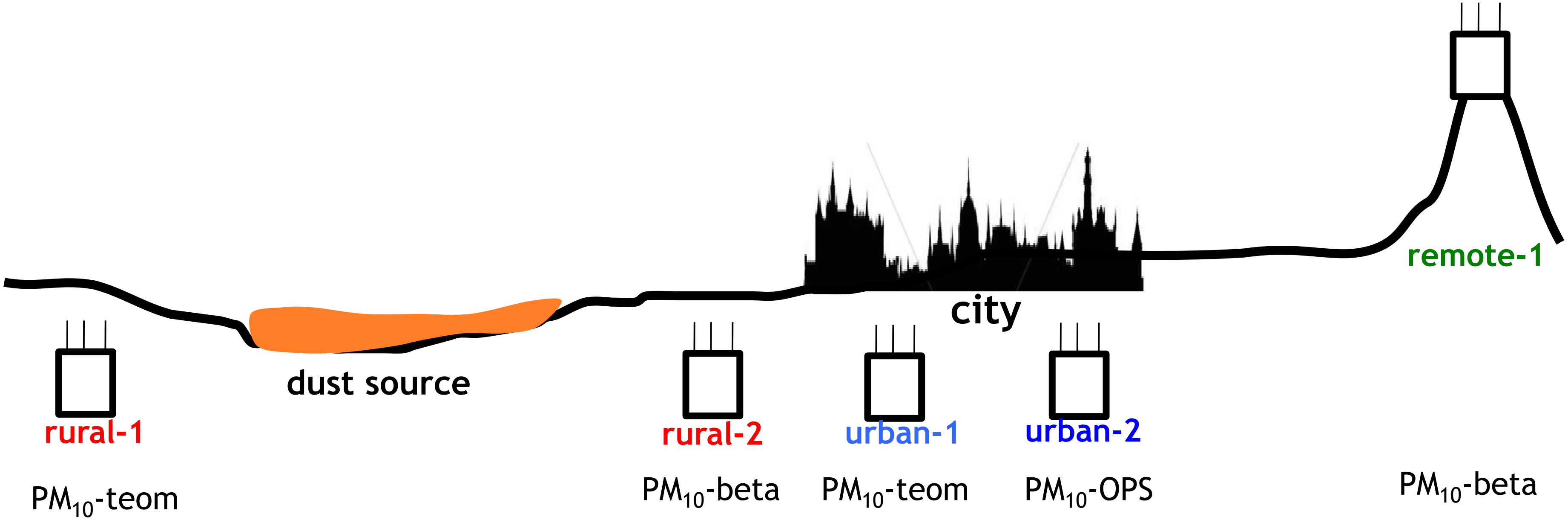
laser maintenance





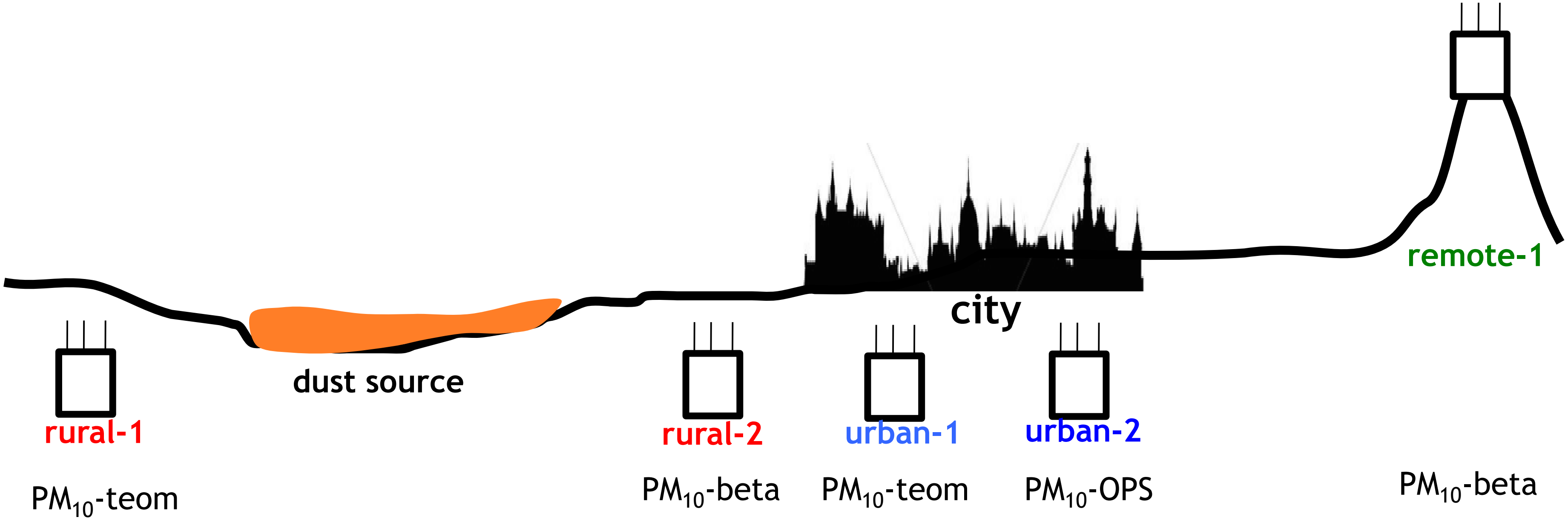
are PM_{10} data collected with different methods comparable?

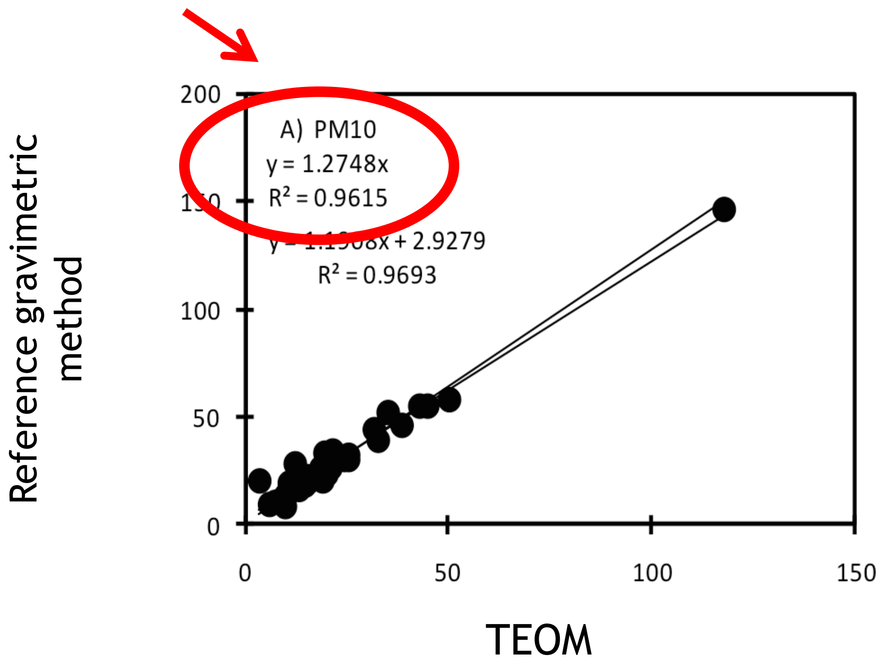
we need a standard for the network



the standard in the network:

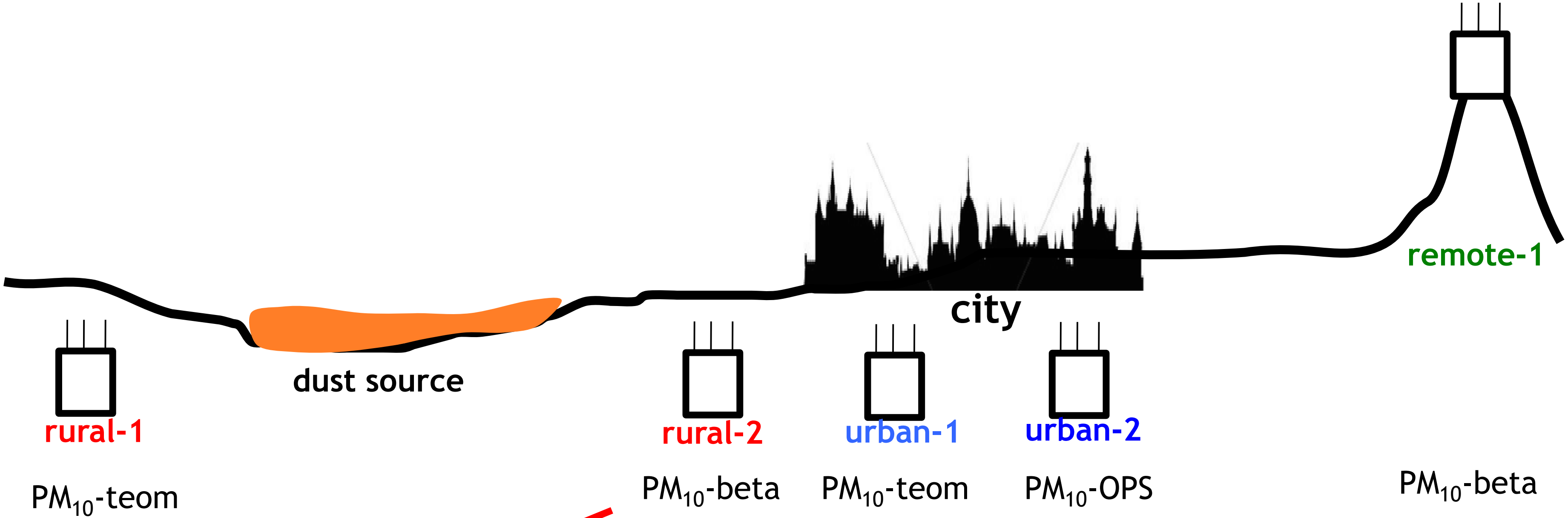
intercomparison of each automatic instrument with the manual reference method

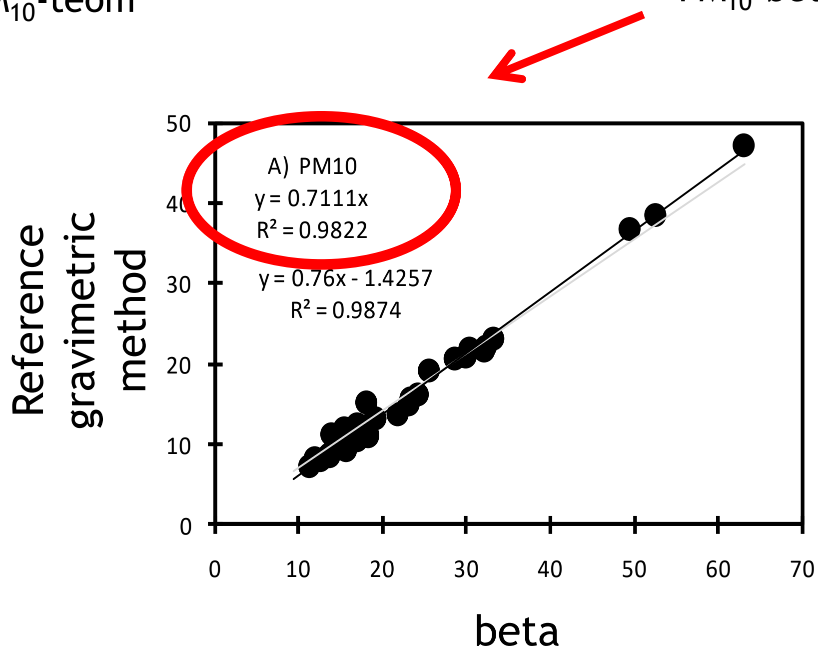




PM_{10} (grav equiv) = 1.27 PM_{10} (TEOM)

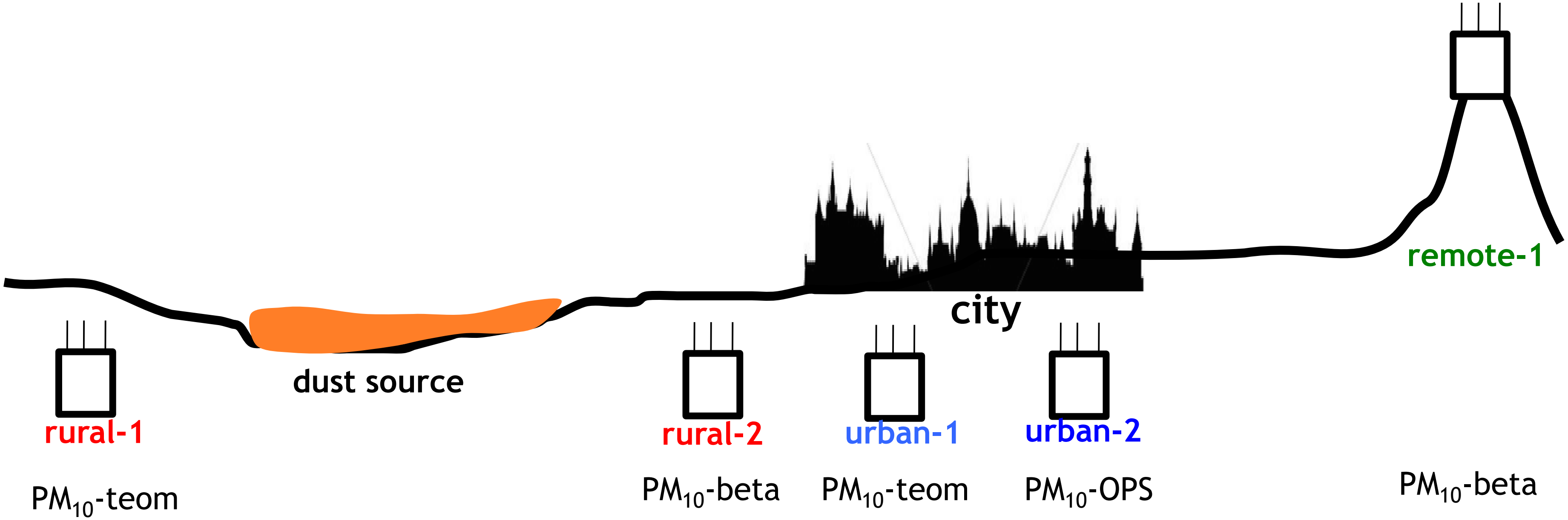
Valid for rural-1 TEOM

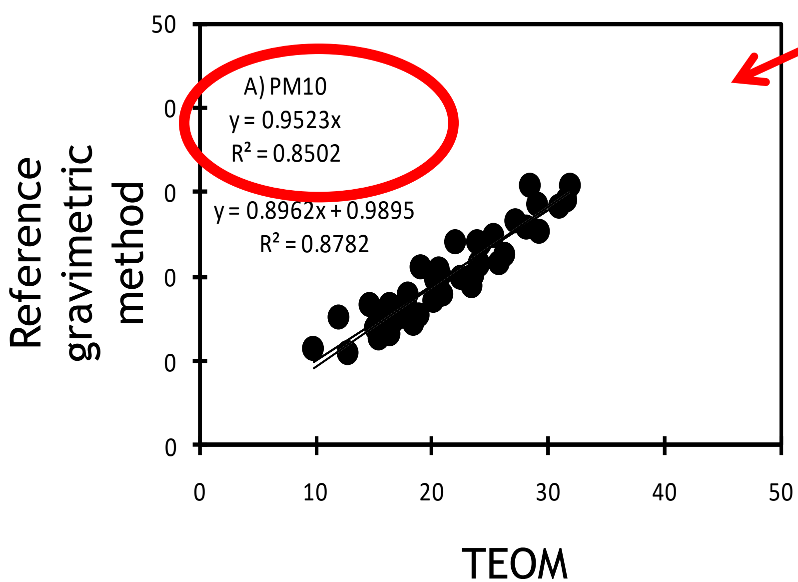




PM_{10} (grav equiv) = 0.71 PM_{10} (BETA)

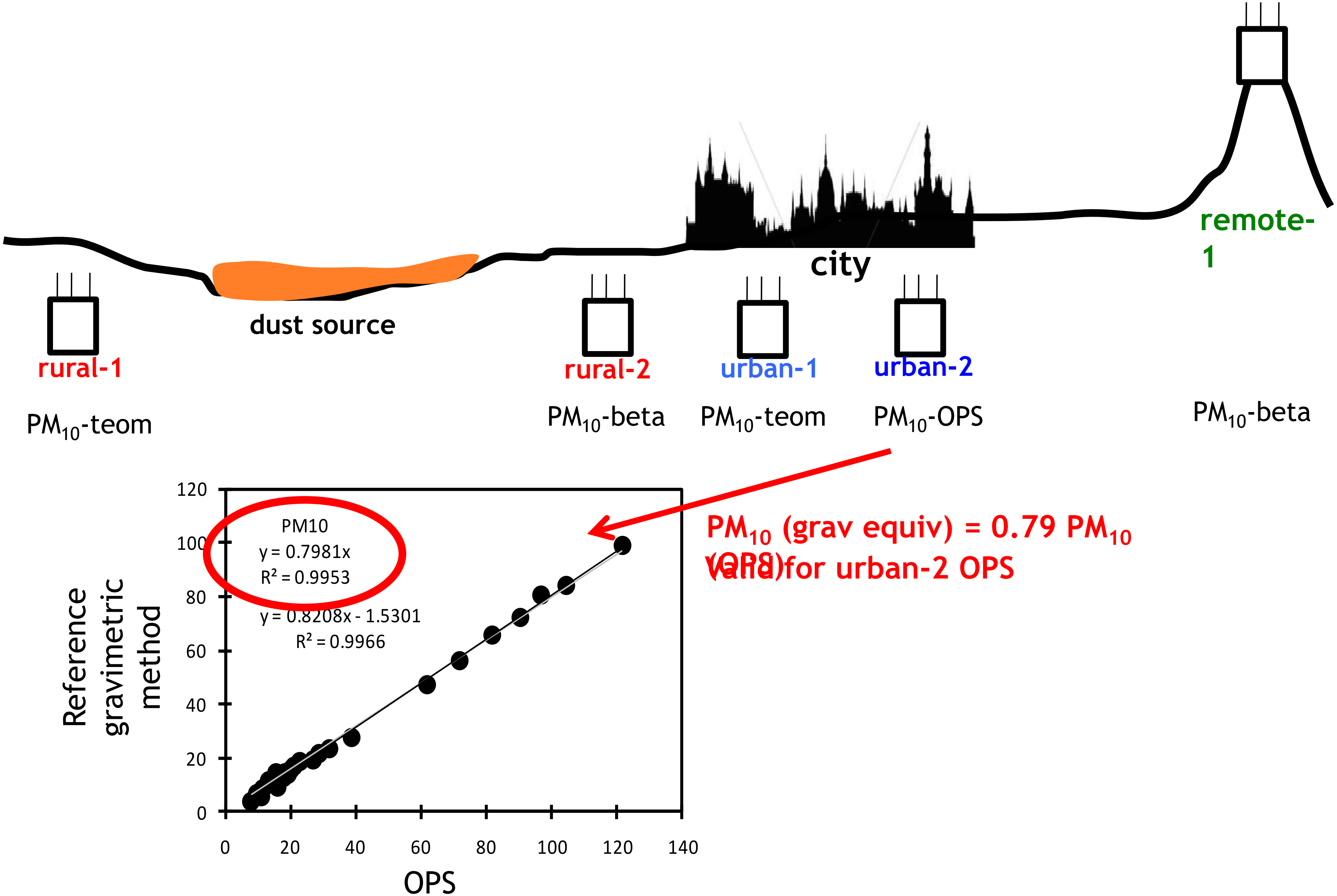
Valid for rural-2 BETA



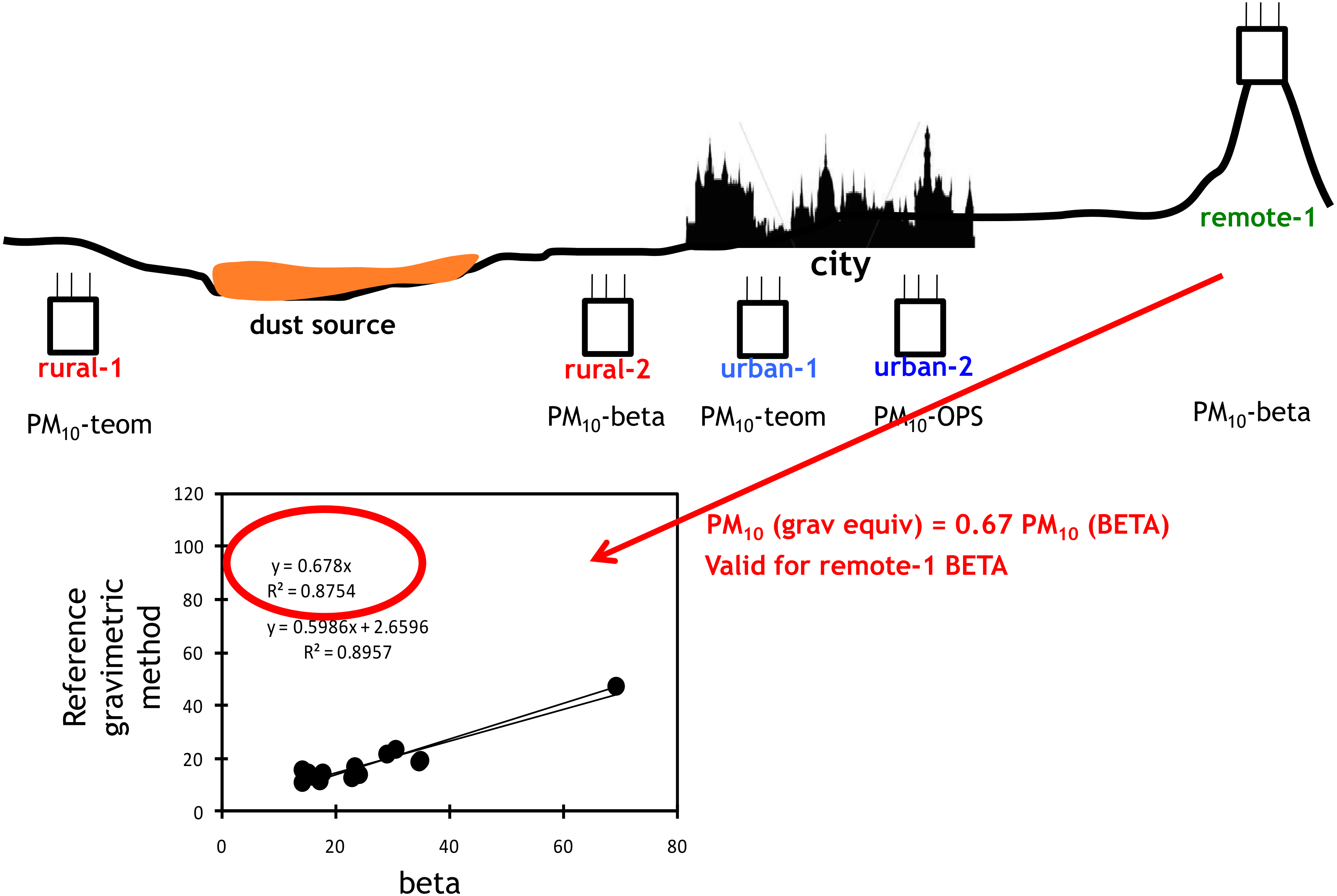


PM_{10} (grav equiv) = 0.95 PM_{10} (TEOM)

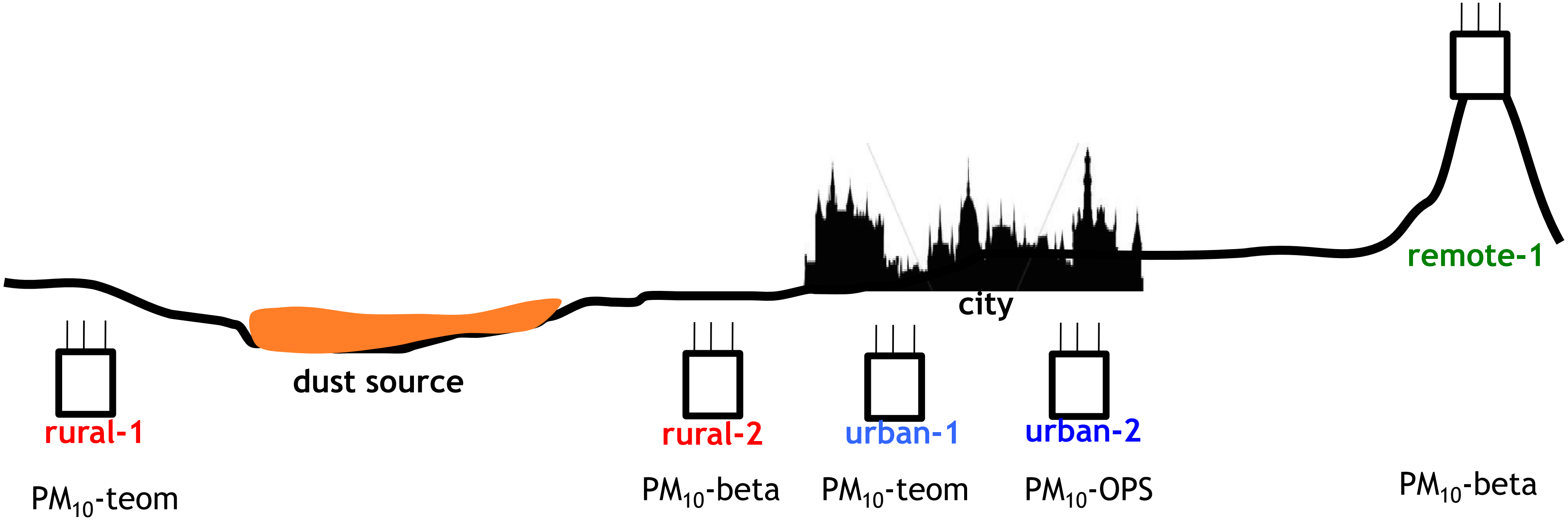
Valid for urban-1 TEOM



dust source
city
rural-1
PM10-teom
rural-2
PM10-beta
urban-1
PM10-teom
urban-2
PM10-OPS
remote-1
PM10-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
PM10 (grav equiv) = 0.79 PM10 (OPS)
valid for urban-2 OPS

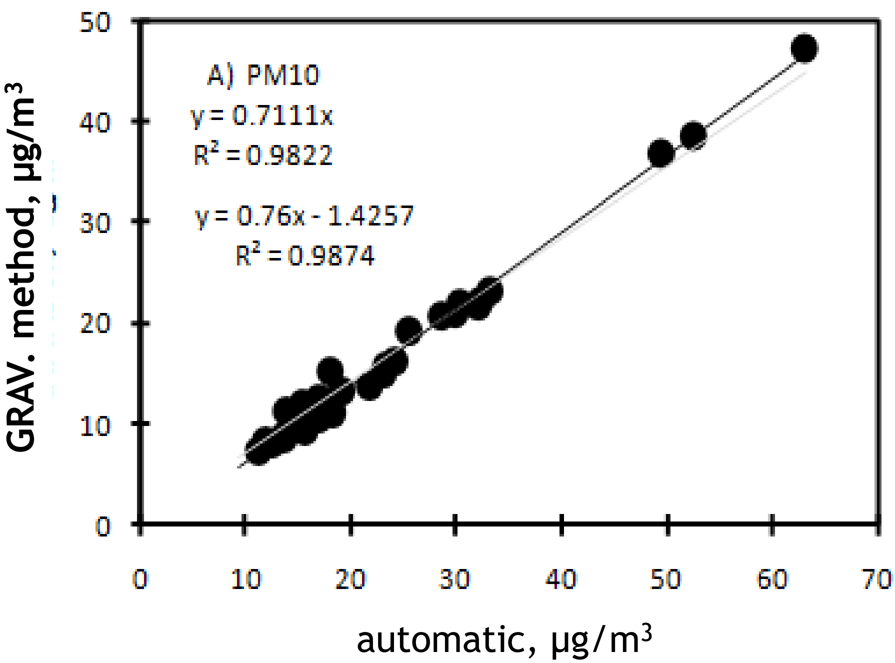


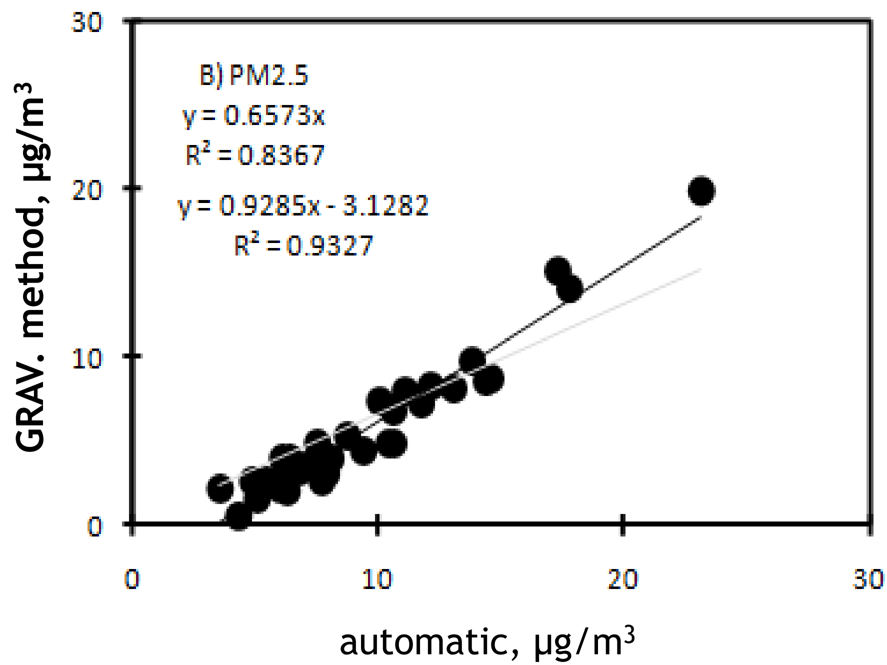
rural-1
PM10-teom
dust source
rural-2
PM10-beta
urban-1
PM10-teom
city
urban-2
PM10-OPS
remote-1
PM10-beta
PM10 (grav equiv) = 0.67 PM10 (BETA)
Valid for remote-1 BETA
y = 0.678x
R² = 0.8754
y = 0.5986x + 2.6596
R² = 0.8957
Reference gravimetric method
beta
0
20
40
60
80
100
120



	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)

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

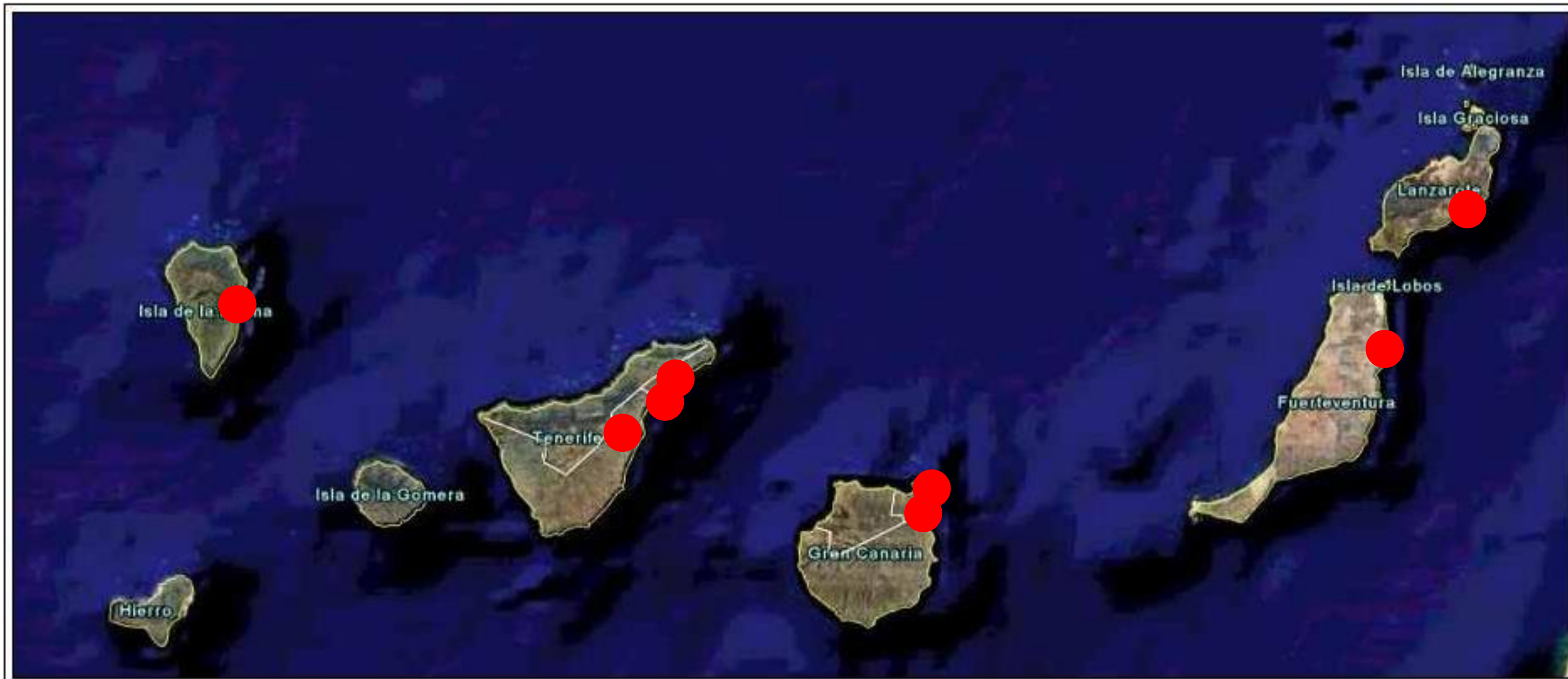
-method-01: reference - manual gravimetry

-method-02: automatic

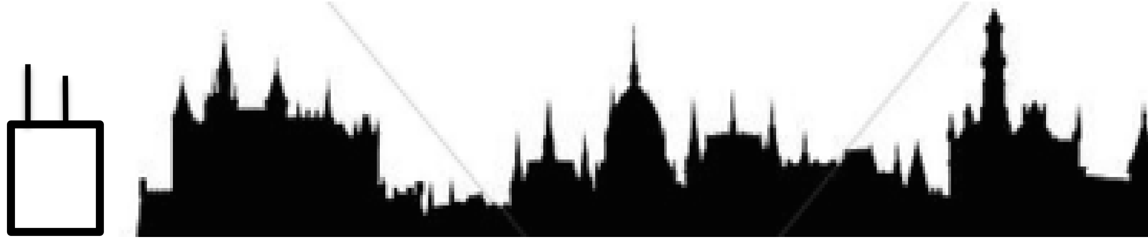
We recommend to convert PM_{10} and $PM_{2.5}$ data obtained with automatic instruments to gravimetric equivalent data.
For this intercomparisons are necessary

INTERCOMPARISONS – calibrations

allows harmonizing the measurement in all the network data become comparable




GLADIOLOS
ARAFO
CIUDAD DEPORTIVA
TOME CANO
MERCADO CENTRAL
REHOYAS
TELDE
Isla de Alegranza
Isla Graciosa
Lanzarote
Isla de Lobos
Fuerteventura
Tenerife
Isla de la Gomera
Gran Canaria
Hierro
Gobierno de Canarias



dust air quality

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

-method-01: reference - manual gravimetry

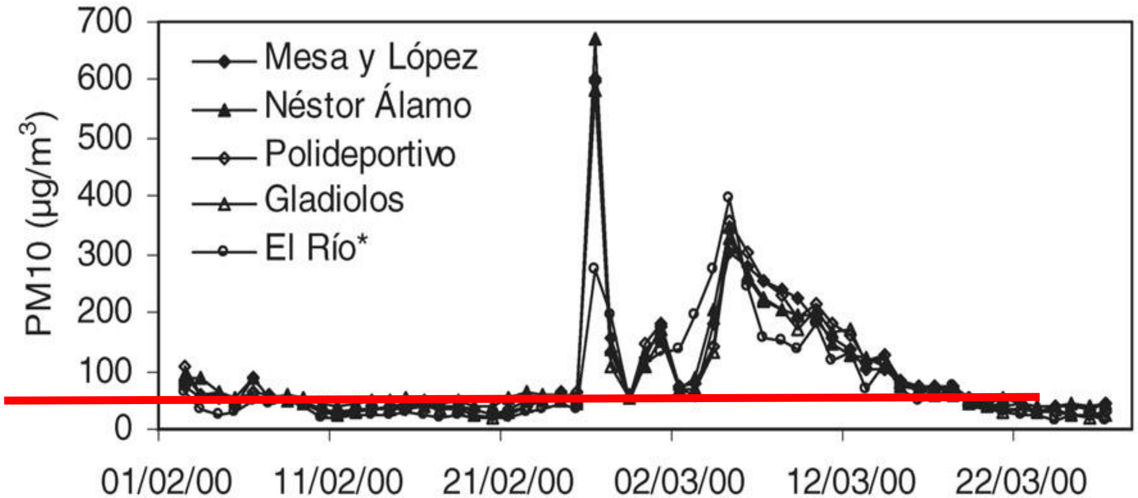
-method-02: automatic

	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

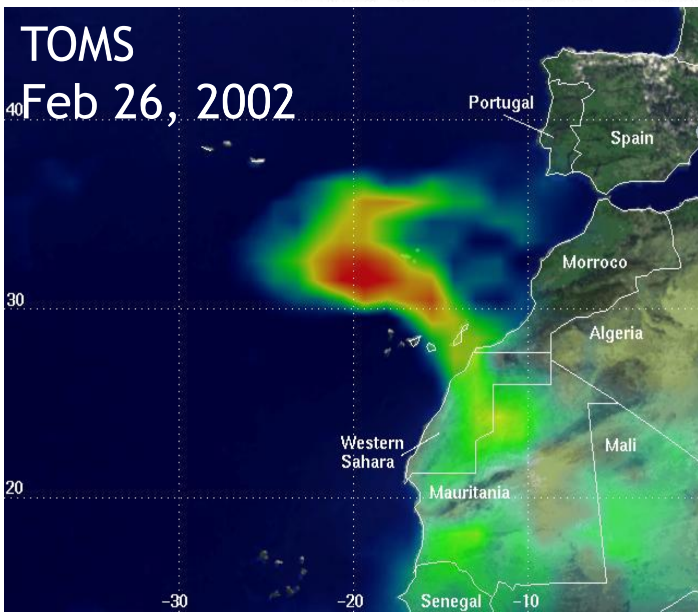
we recommend to use the two methods:
-automatic, continuously
-gravimetric: intercomparisons - 1 month summer, 1 month winter

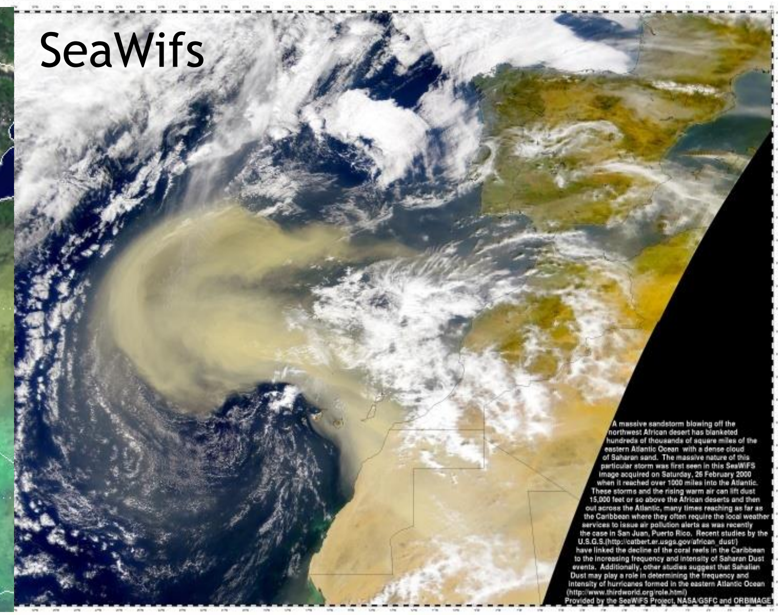
In-situ dust characterization

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

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

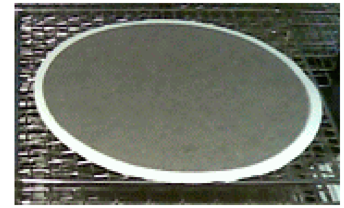
we recommend to use the two methods:
-automatic, constinously
-gravimetric: intercomprisons, 1 month summer, 1 month winter

bulk chemical composition

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

Saharan dust

Urban particles



PM (μg/m³)= <u>**dust**</u> + trace elements + **ions ($SO_4^{=}$, NO_3^-, NH_4^+, Na^+, Cl-)** + OC + EC

Elemental Composition:

<u>Major elements</u> (Al, Si, Ca, K, Na, Mg) + <u>trace elements</u> (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^-

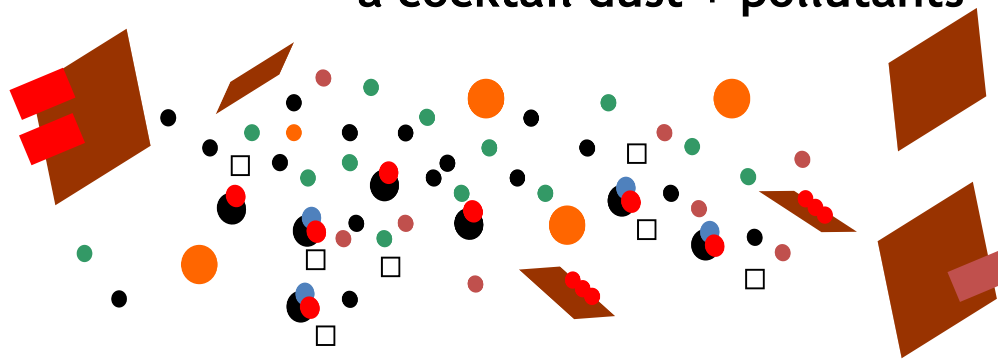
Ion Chromatography, ICP-AES, ICP-MS,
selective electrodes and colorimetry

Destructive techniques

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

destructive techniques

people live in cities and breath
a cocktail dust + pollutants



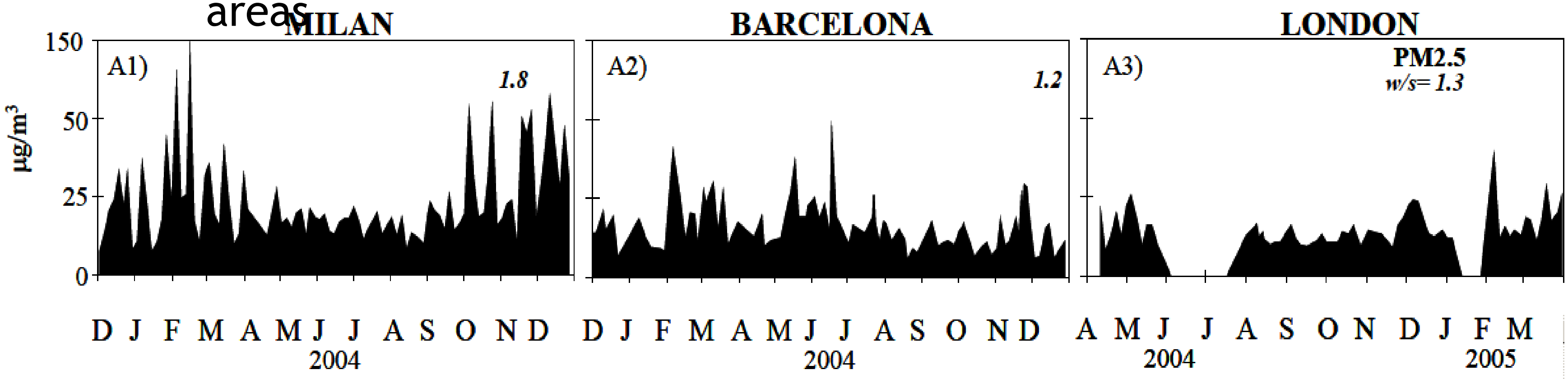
PM_{10}: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ...

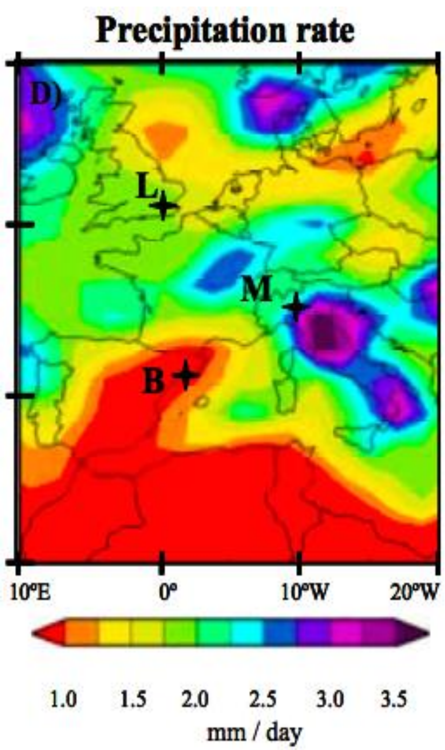
$PM_{2.5}$: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ...

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

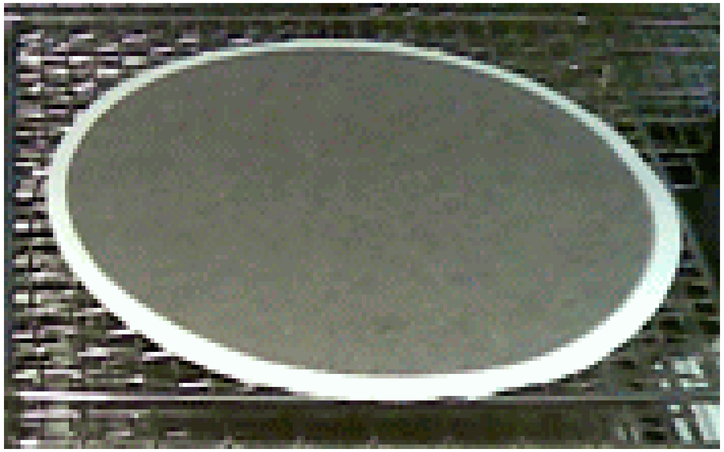
$PM_{2.5}$: dust + sea salt + vehicle exhaust + oil refining + power plants + ships +...

PM in urban areas

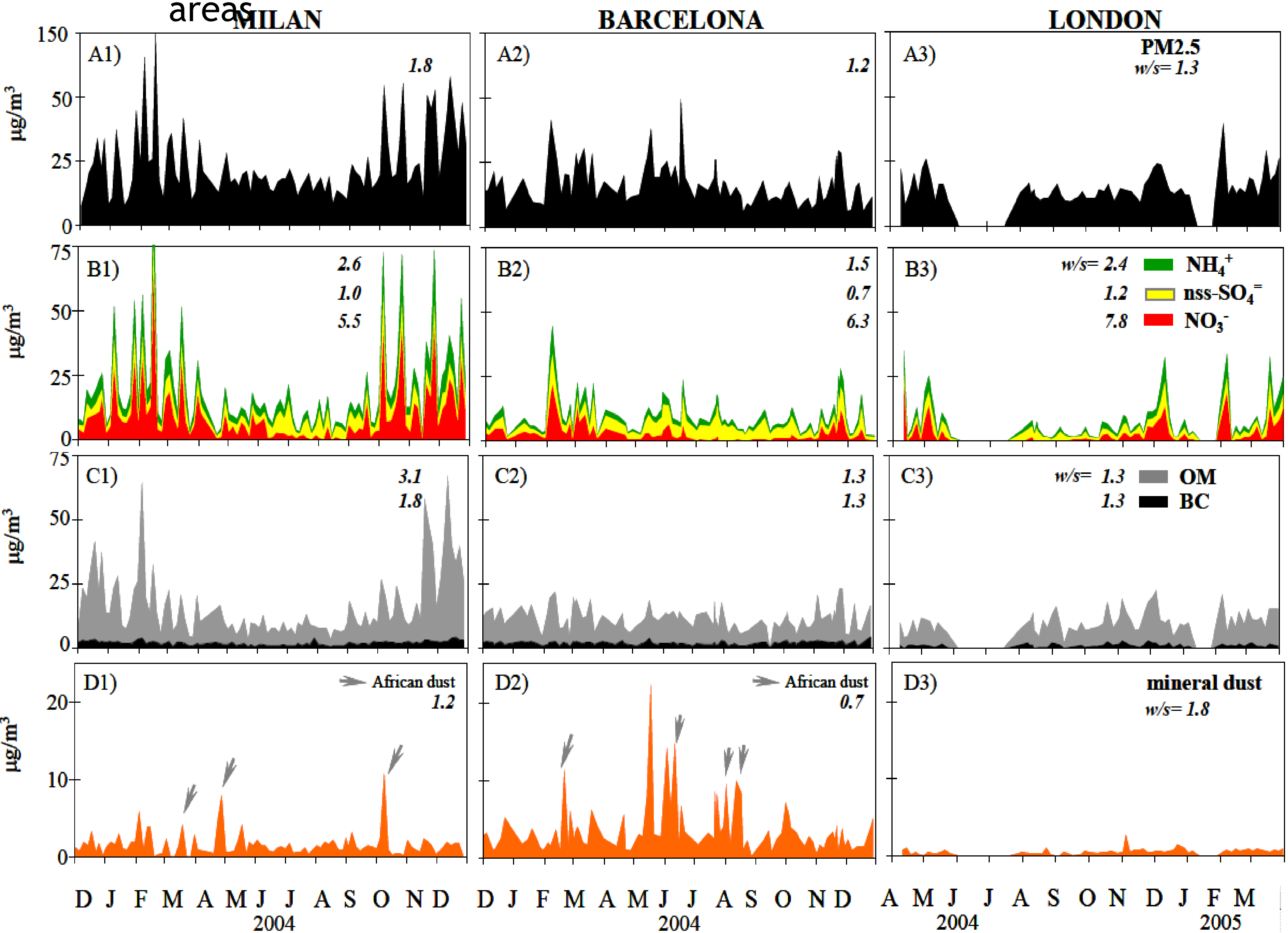




Urban particles

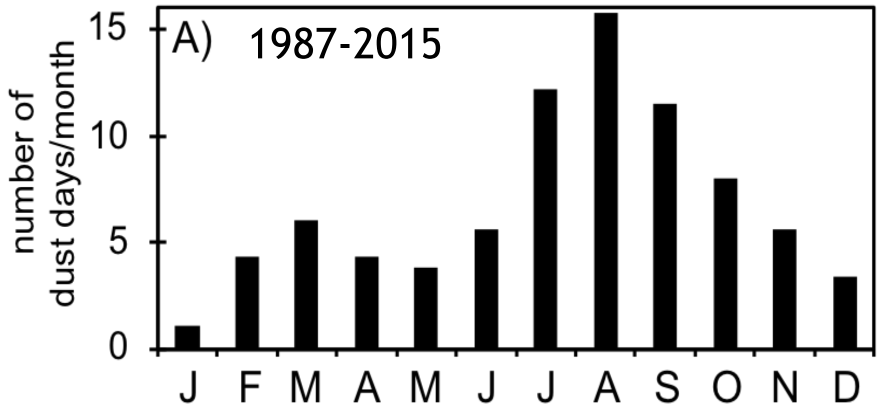


PM in urban areas

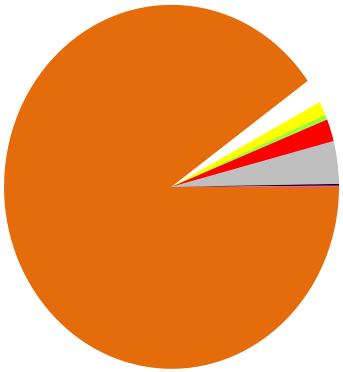


PM in remotes sites

Summer Izaña is within the SAL

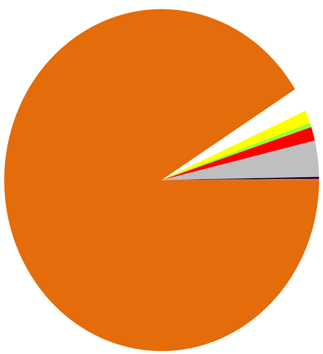


PM_x composition in the SAL



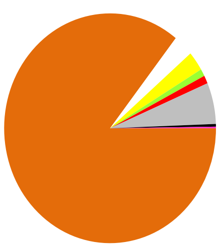
PM_T 47.3 µg/m³

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%	0.0 7	elemental carbon



PM_{10} 42.0 µg/m³

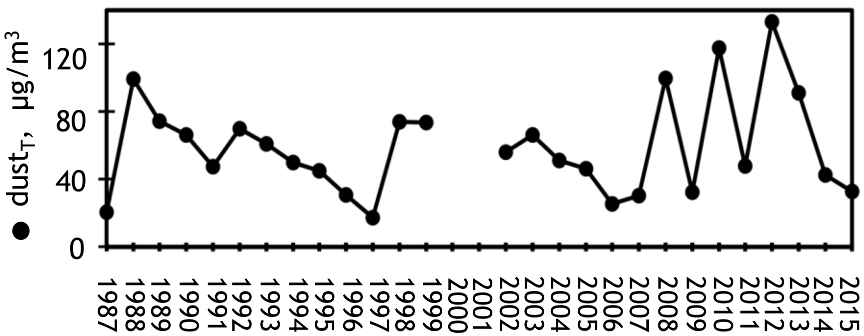
91%	38.3	dust
2.2%	0.9	none ammonium-sulfate
1.2%	0.5	ammonium-sulfate
0.4%	0.2	ammonium
1.3%	0.6	nitrate
3.4%	1.4	organic matter
0.2%	0.0 7	elemental carbon



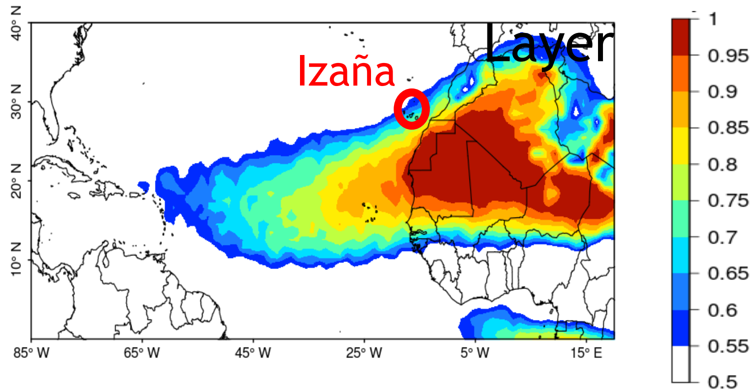
$PM_{2.5}$ 18.5 µg/m³

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%	0.0	elemental carbon

summer dust at Izaña: 1987 - 2015



Saharan Air Layer



Max: 133 µg/m^3 2012

Min: 17 µg/m^3 1997

MDFA: Major Dust Frequency Activity

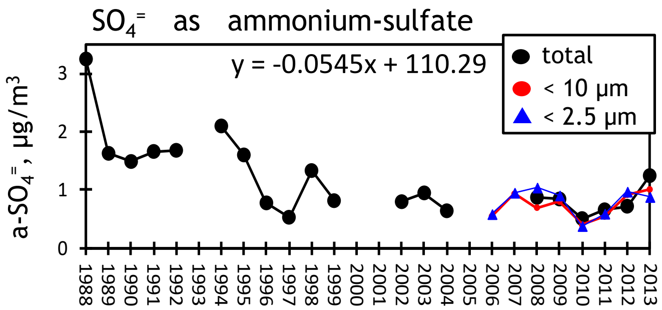
UV Absorbing Aerosol Index = sensitive to iron oxides in dust

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

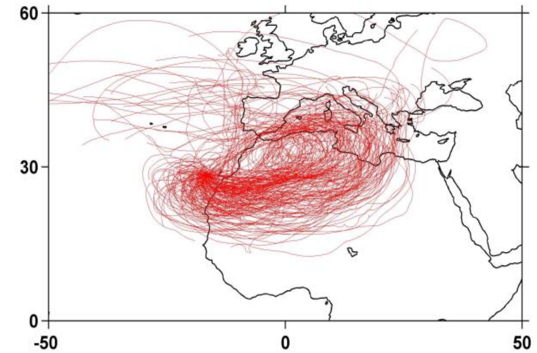
= fraction of summertime AI>1

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

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

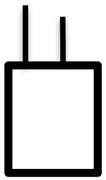
dust, aerosols and pollutants

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:

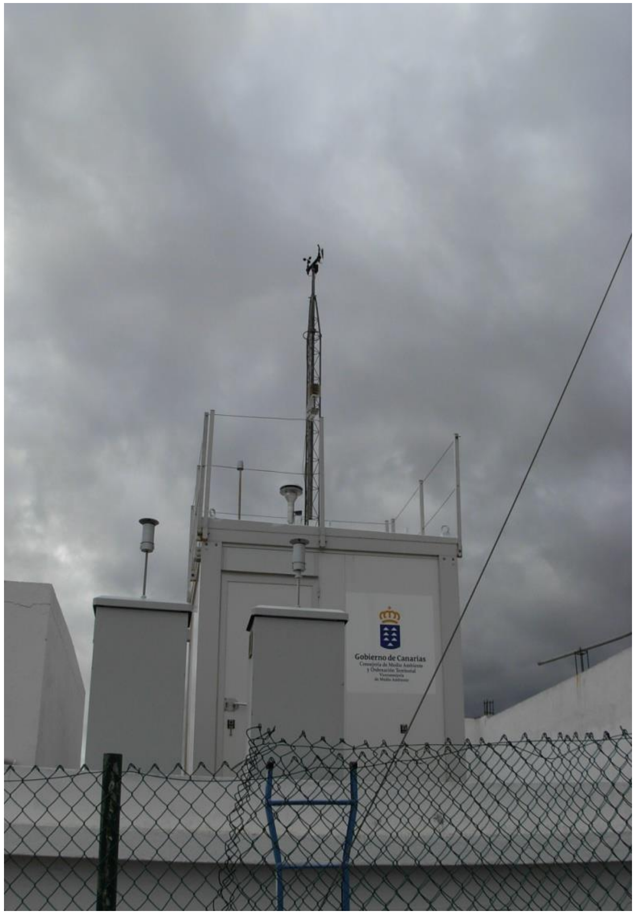
wind, temperature, relative humidity, pressure

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:

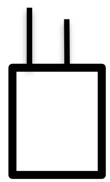
NOx: chemiluminiscense. EN 14211: 2006

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

remote sensing

column

vertical distribution

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, 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 - PM_{10} and $PM_{2.5}$ levels - automatic methods

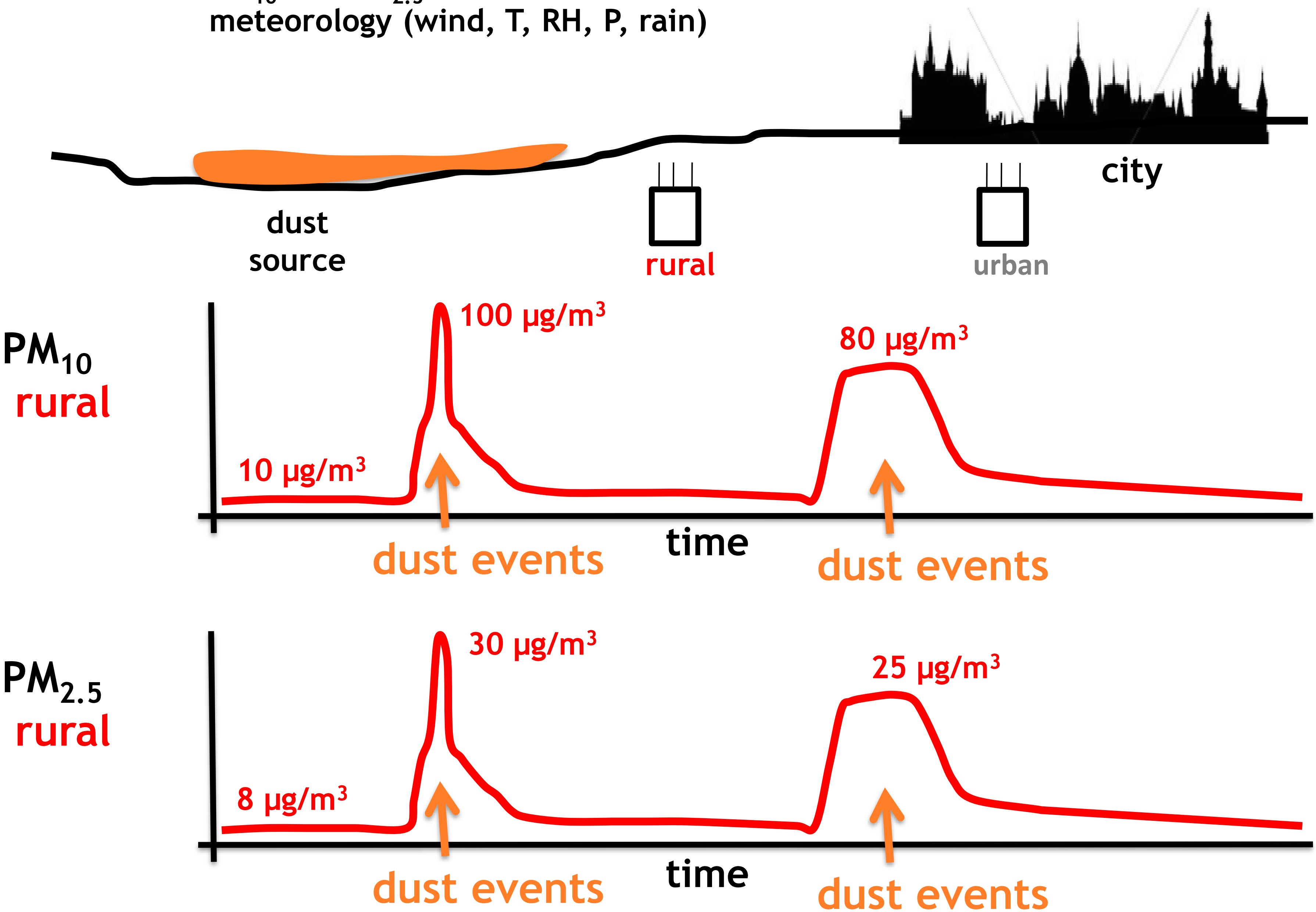
Level 1 - meteorology (wind, T, RH, P, rain)

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

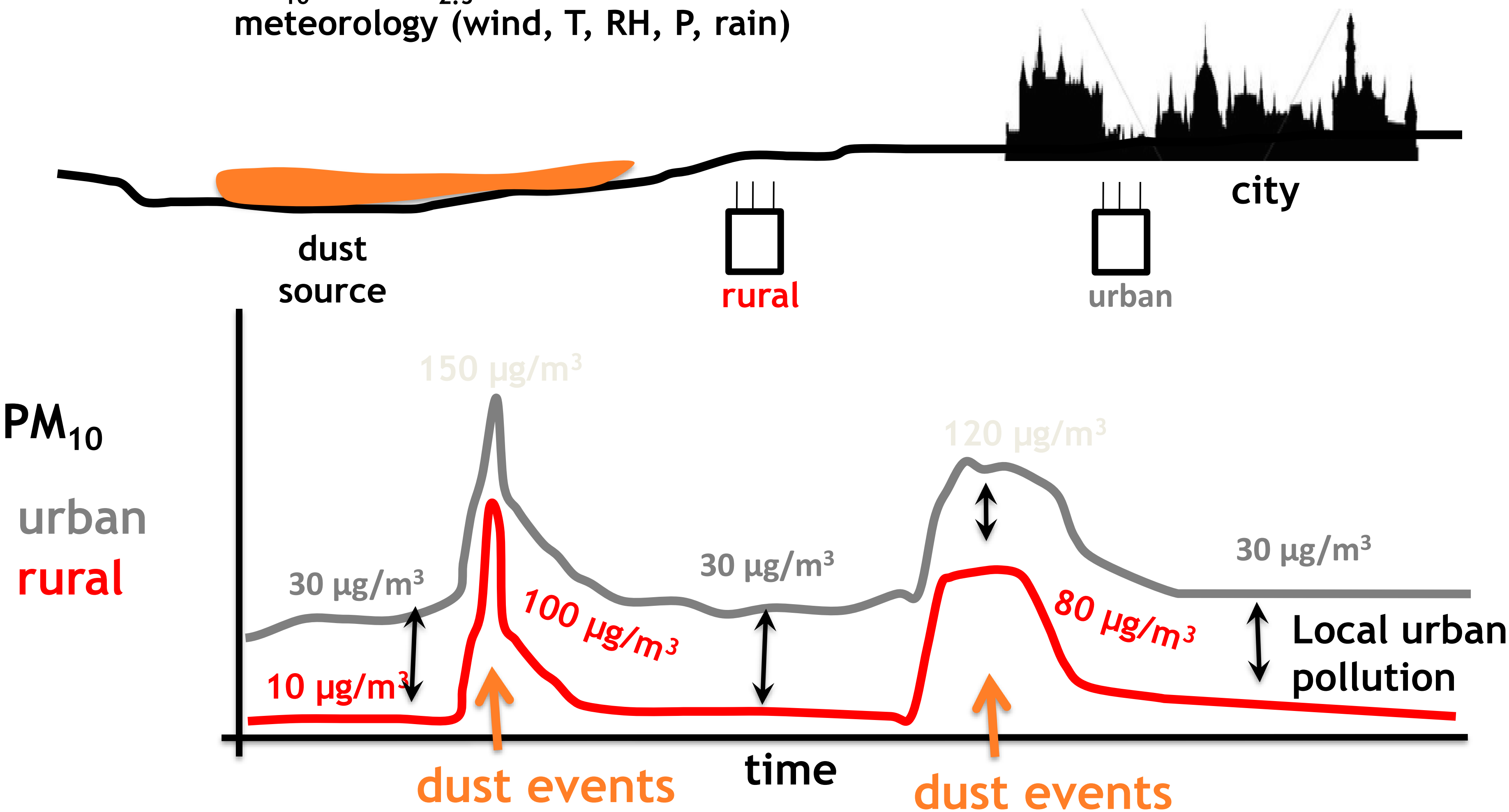
Level 3 - gaseous pollutants: NO_x, SO_2 , CO,...

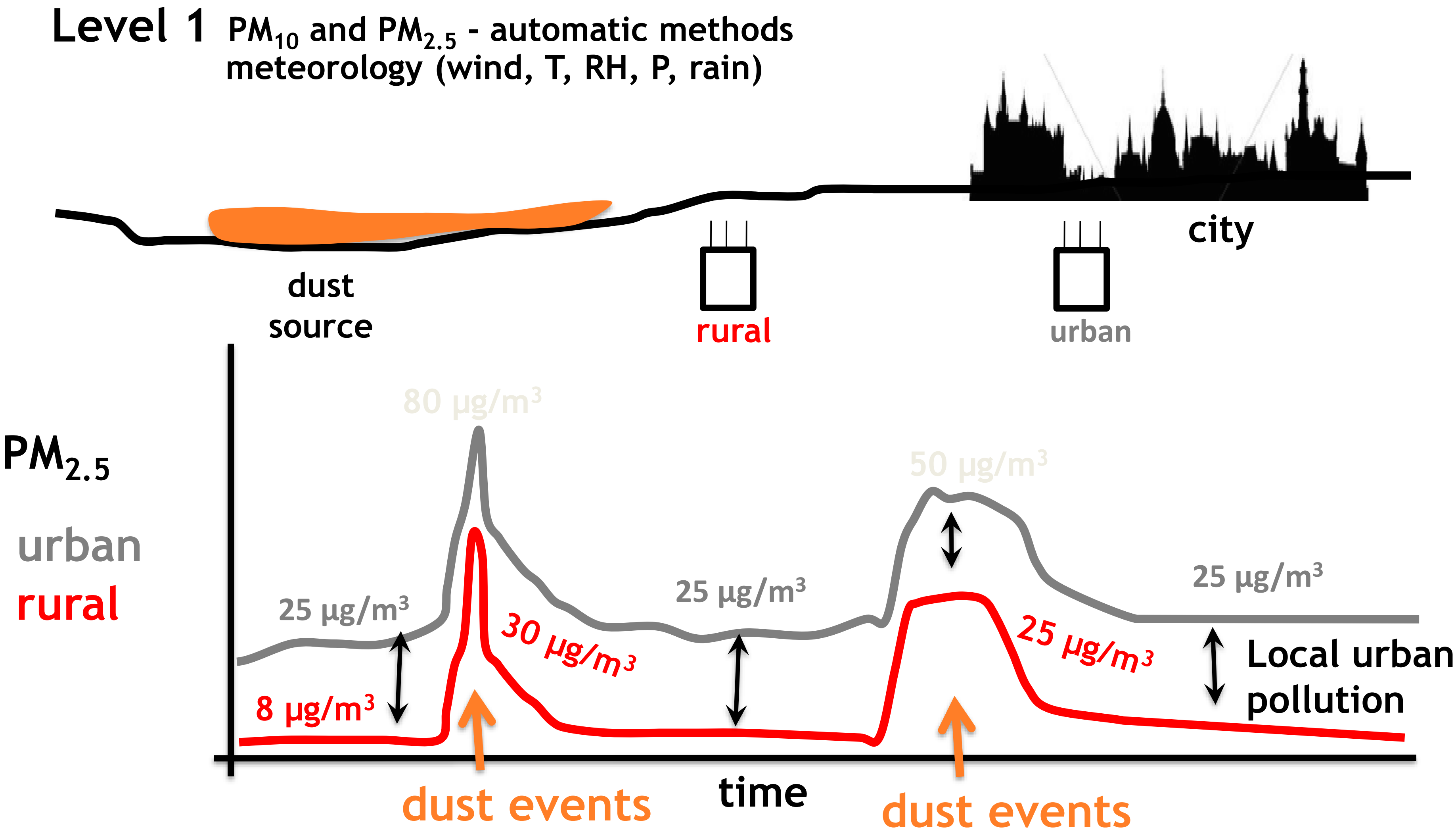
Level 4 - PM_{10} and $PM_{2.5}$ chemical composition

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

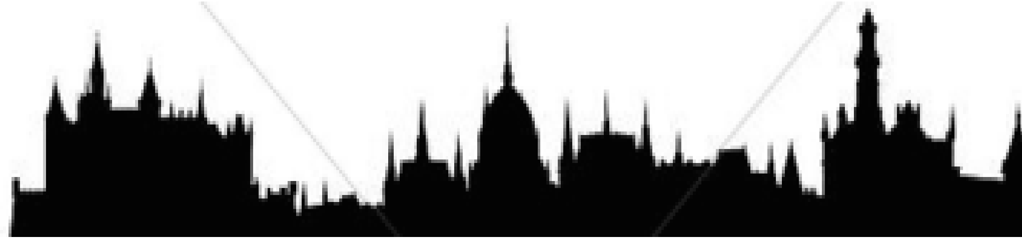


Level 1 PM_{10} and $PM_{2.5}$ - automatic methods
meteorology (wind, T, RH, P, rain)




Level 1 PM10 and PM2.5 - automatic methods
meteorology (wind, T, RH, P, rain)
city
dust
source
rural
urban
PM2.5
urban
rural
80 µg/m3
50 µg/m3
25 µg/m3
25 µg/m3
25 µg/m3
8 µg/m3
30 µg/m3
25 µg/m3
Local urban
pollution
dust events
time
dust events

dust air quality



Recommended priorities

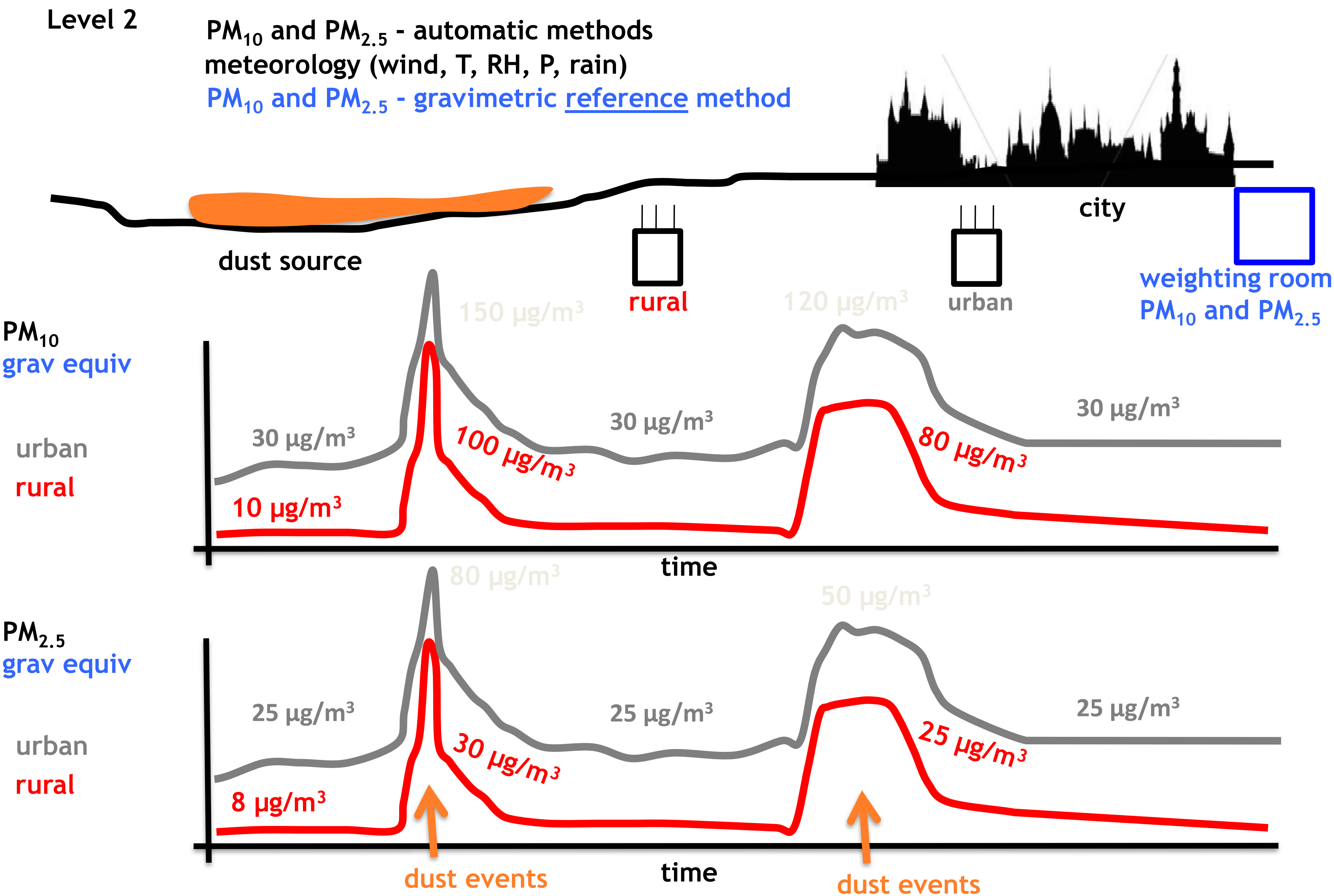
Level 1 - PM_{10} and $PM_{2.5}$ levels - automatic methods

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

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

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

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



Level 2
PM10 and PM2.5 - automatic methods
meteorology (wind, T, RH, P, rain)
PM10 and PM2.5 - gravimetric reference method
city
dust source
rural
urban
weighting room
PM10 and PM2.5
PM10
grav equiv
urban
rural
150 µg/m3
120 µg/m3
30 µg/m3
10 µg/m3
100 µg/m3
30 µg/m3
80 µg/m3
30 µg/m3
time
PM2.5
grav equiv
urban
rural
80 µg/m3
50 µg/m3
25 µg/m3
8 µg/m3
30 µg/m3
25 µg/m3
25 µg/m3
25 µg/m3
time
dust events
dust events

dust air quality

Recommended priorities

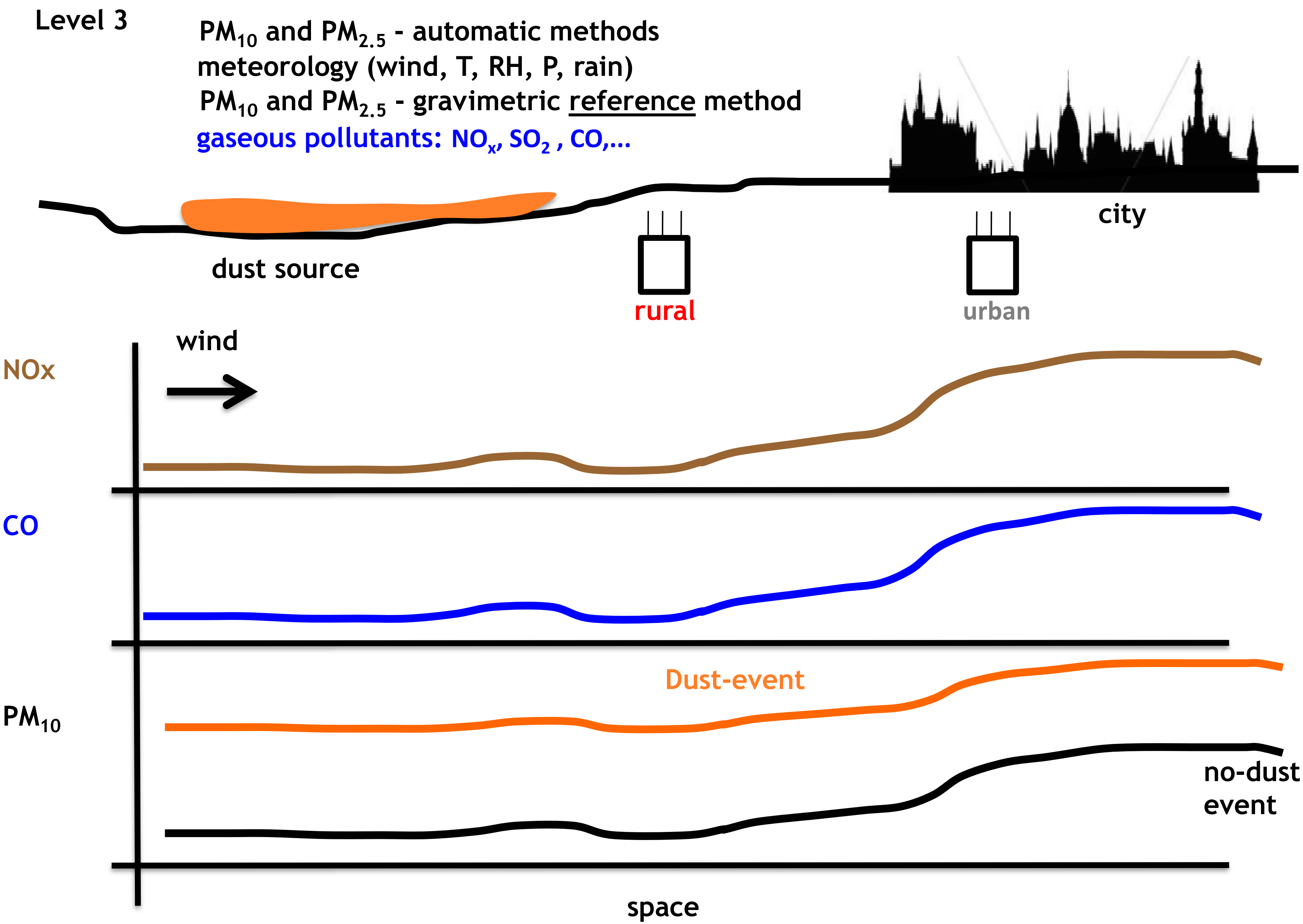
Level 1 (max) - PM_{10} and $PM_{2.5}$ levels - automatic methods

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

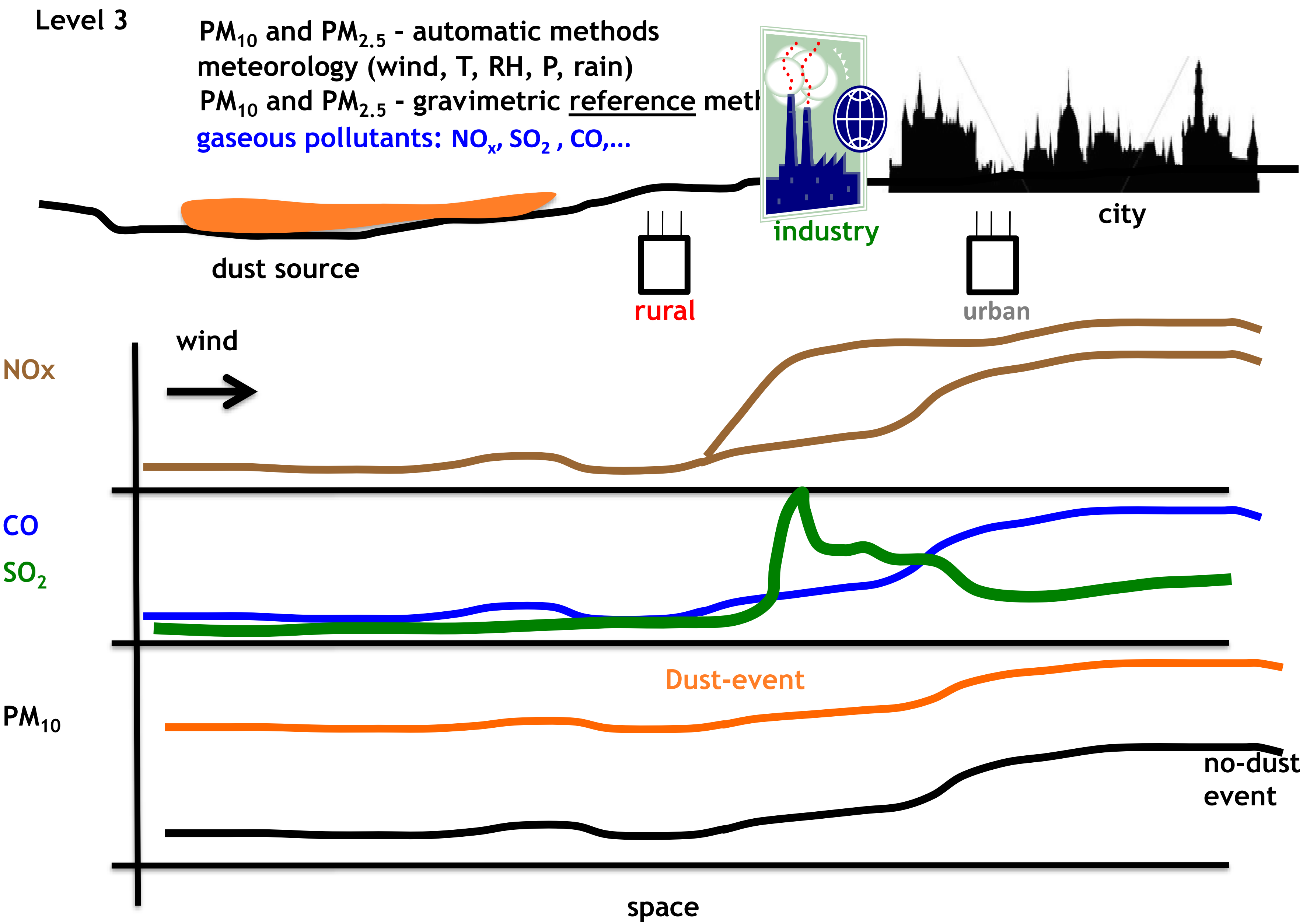
Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

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,...
city
dust source
rural
urban
wind
NOx
CO
Dust-event
PM10
no-dust event
space



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

dust air quality

Recommended priorities

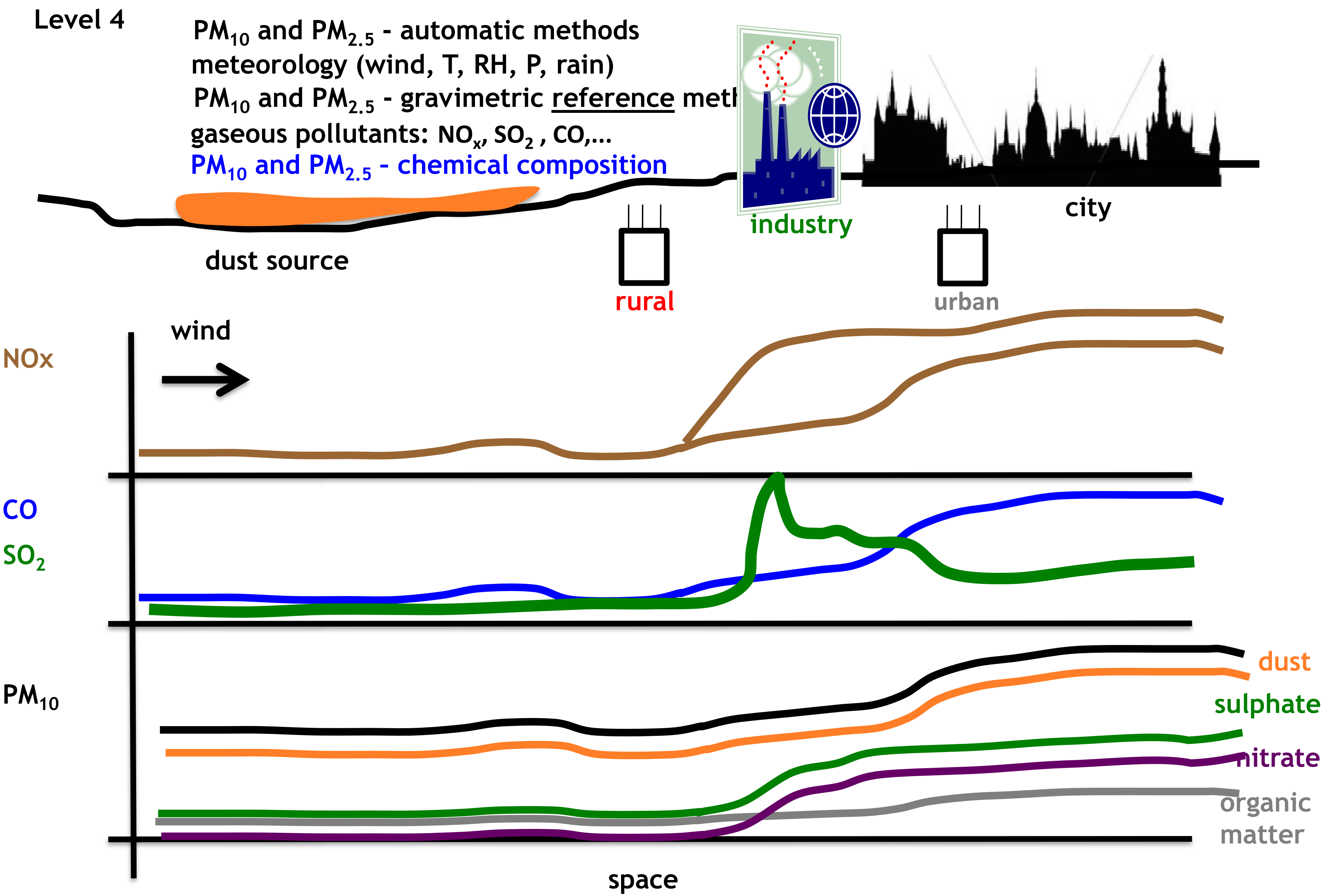
Level 1 (max) - PM_{10} and $PM_{2.5}$ levels - automatic methods

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 meth
gaseous pollutants: NOx, SO2 , CO,...
PM10 and PM2.5 - chemical composition
dust source
rural
industry
urban
city
wind
NOx
CO
SO2
PM10
dust
sulphate
nitrate
organic matter
space

thanks