World Health Organization

منظمة الصحة العالمية

World Meteorological Organisation

GOBIERNO DE ESPAÑA

MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

AEMet Agencia Estatal de Meteorología

1st Africa/Middle East expert meeting and workshop on the health impact of airborne dust

2-5 Nov 2015, Amman

ground observation of airborne dust

Sergio Rodríguez

srodriguezg@aemet.es

AEMET, Spain

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

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

dust, aerosols and pollutants

in-situ observations

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

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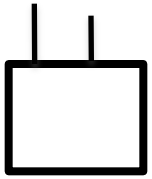
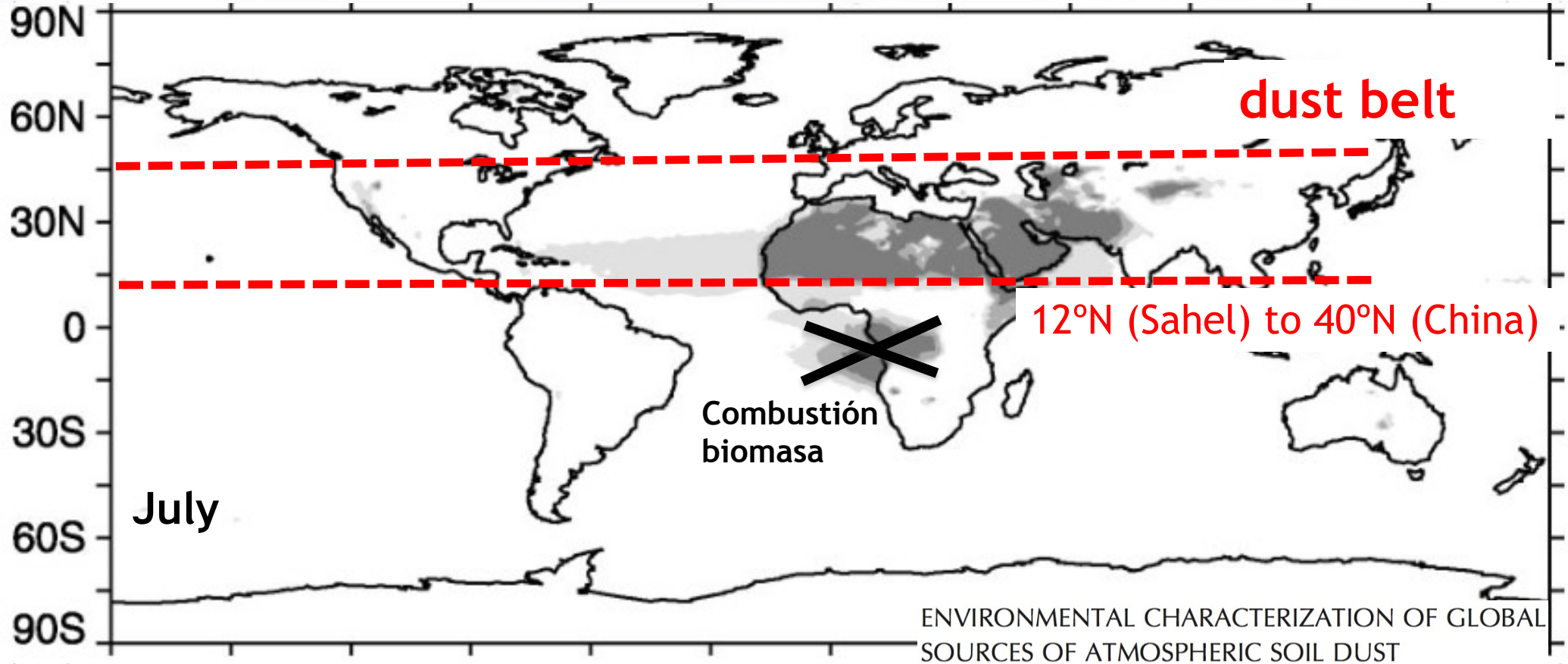


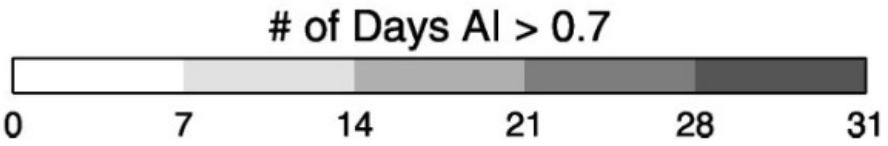
dust - air quality stations

what is dust?

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]

dust, aerosols and pollutants

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

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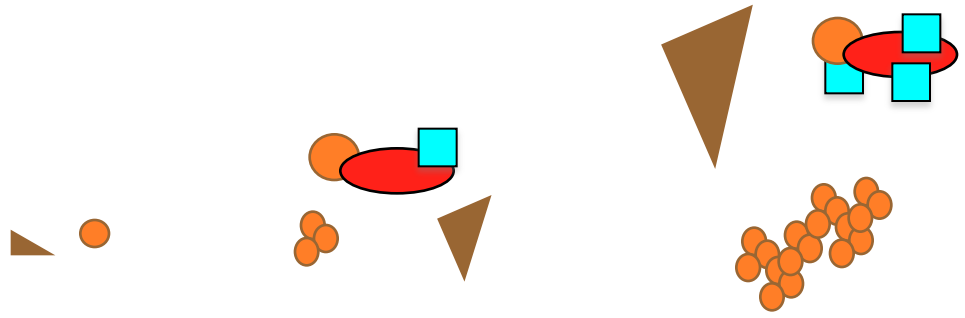
3. Size and morphology

1 and 20 µm

agglomerates



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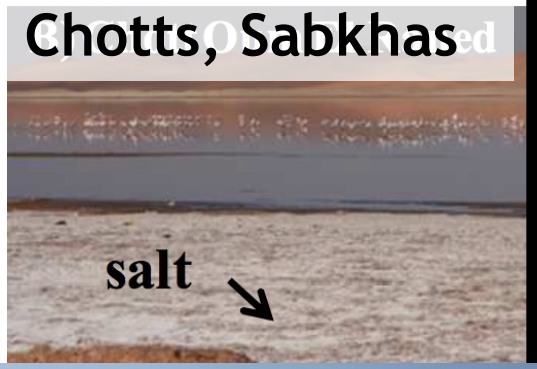
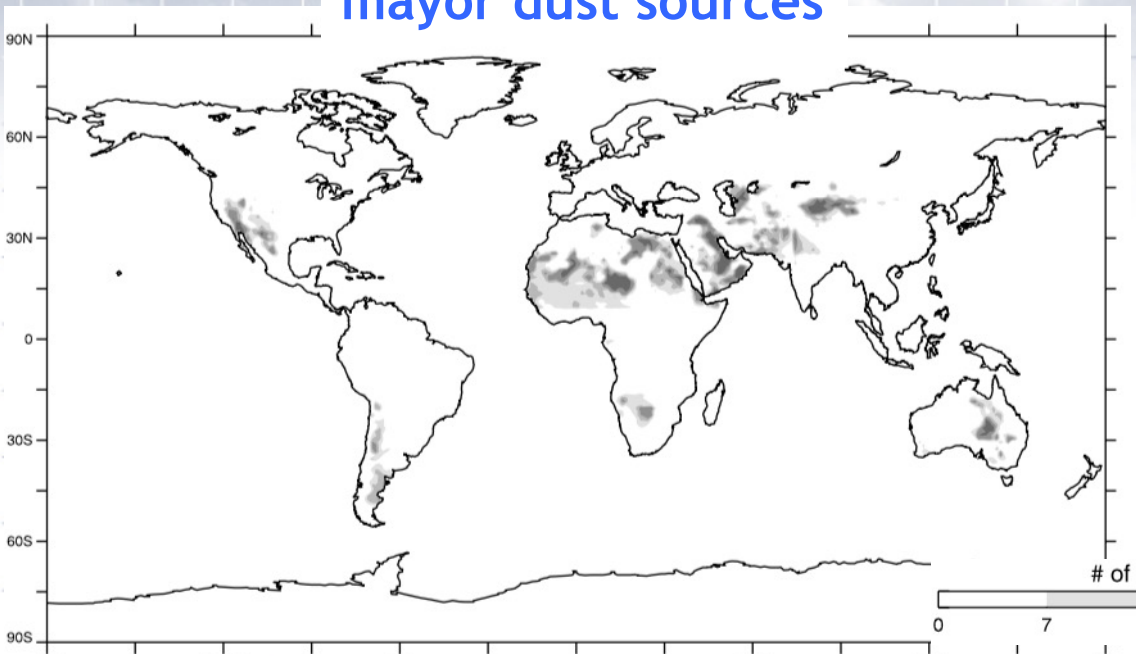


mayor dust sources



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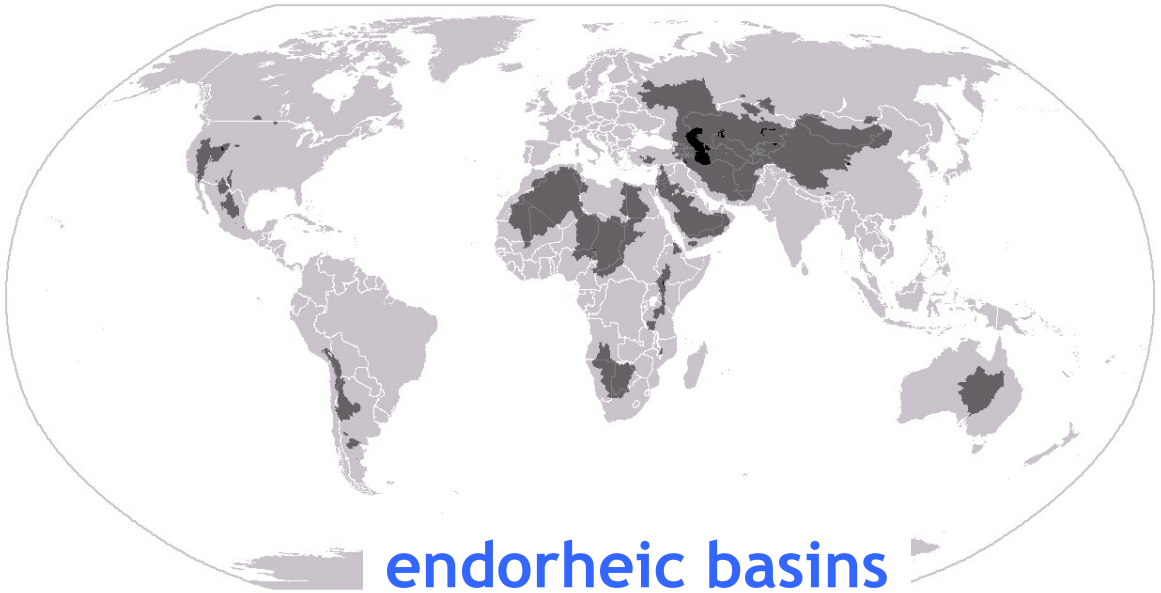
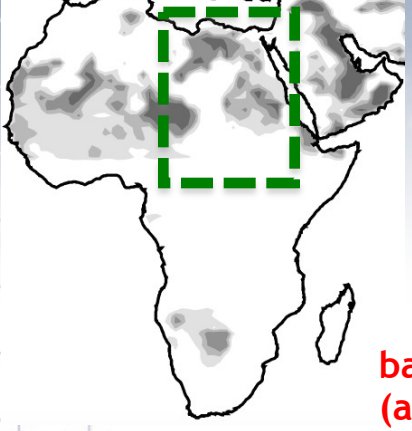


endorheic basins

no conection to sea



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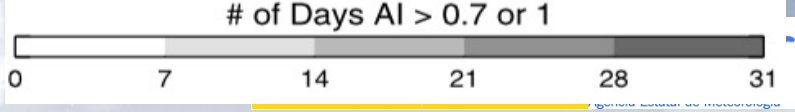
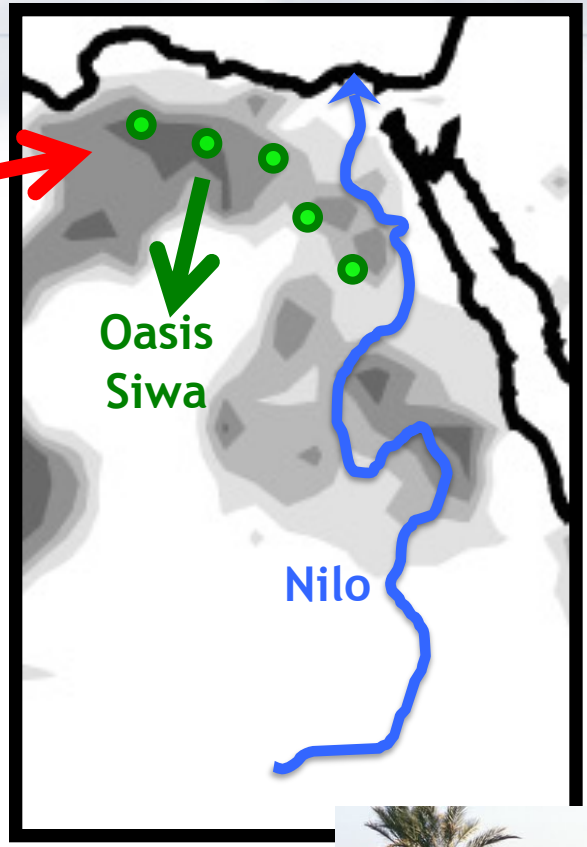


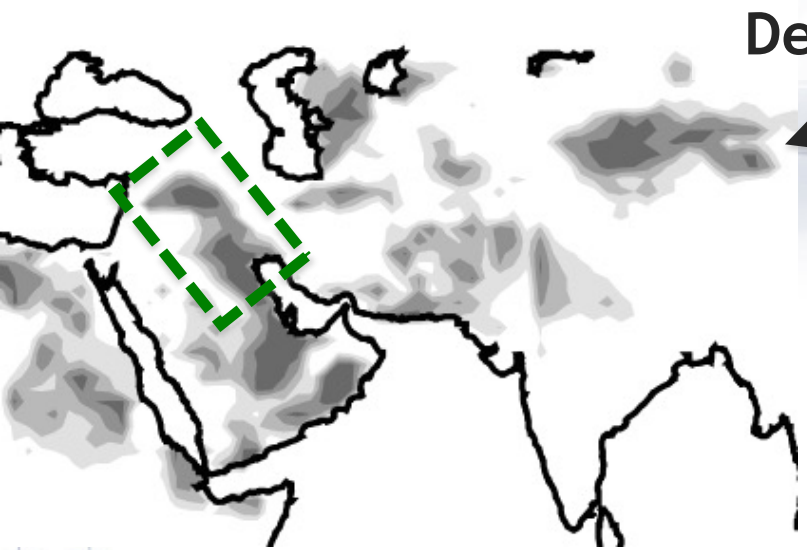
bajas topográficas
(altitudes -)

lagos, oasis, cultivos
aguas subterráneas
antiguos ríos

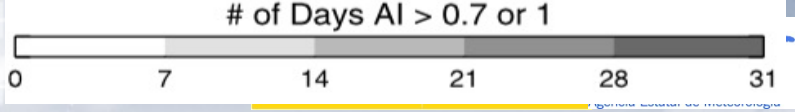


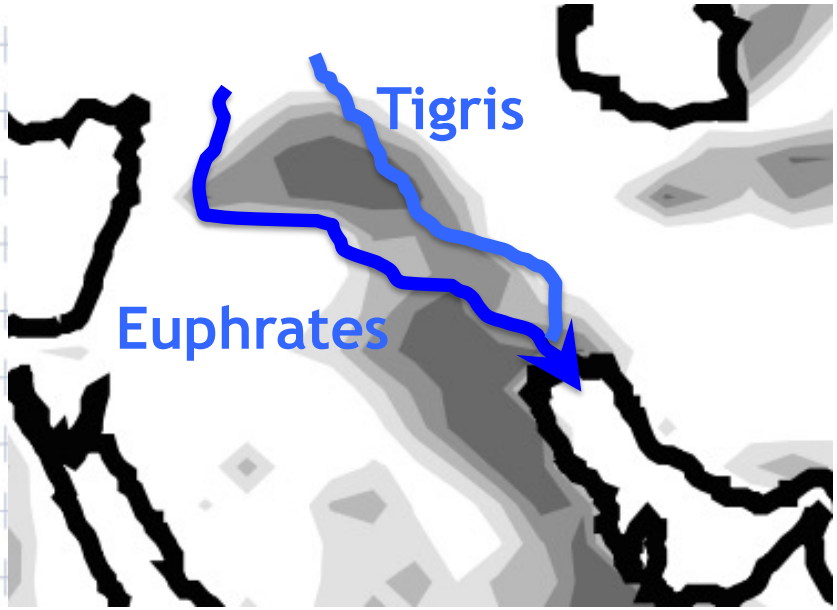
Oasis Siwa
29°13´N, 25°31'E

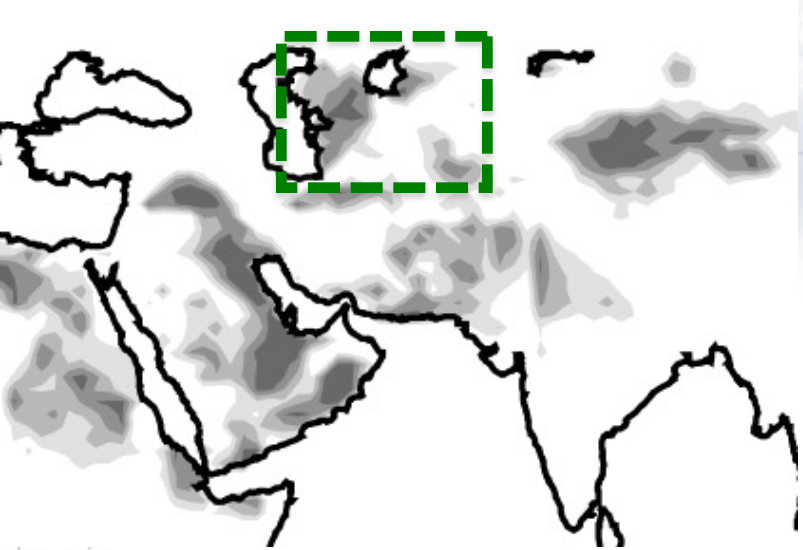
Detección satélite



Siria-Irak







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

Aral Sea

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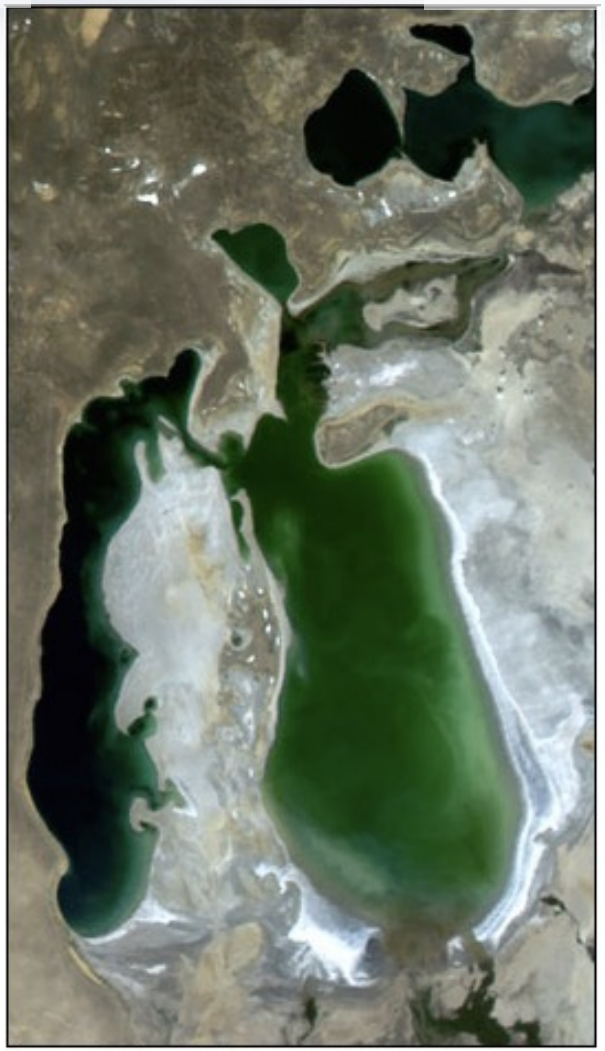
1989

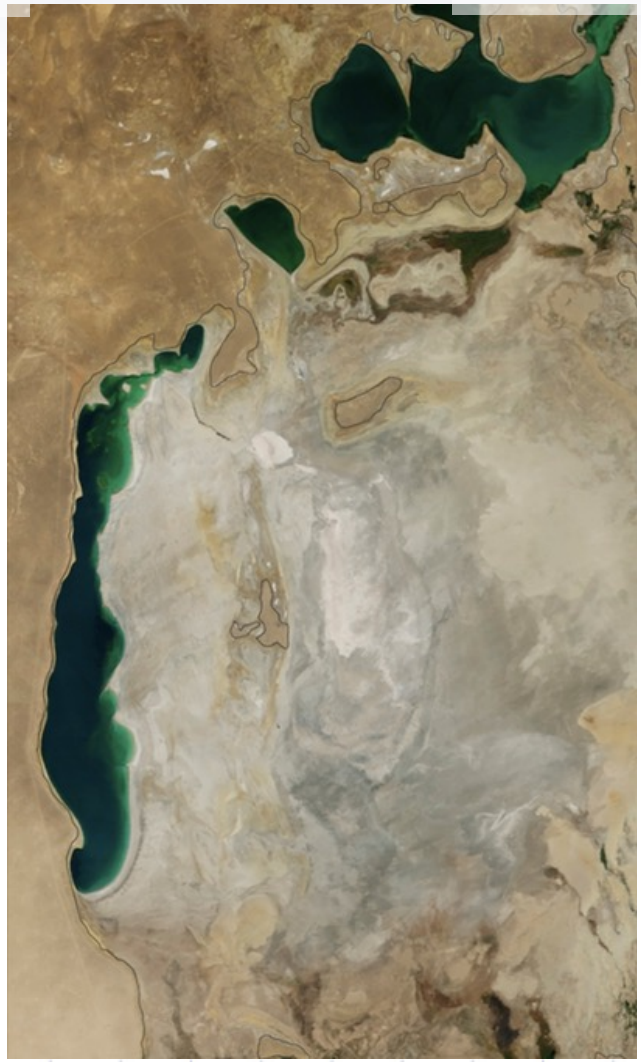
July - September, 1989

2003

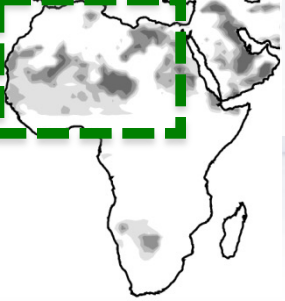


August 12, 2003

2014



Aral Sea



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Sahel

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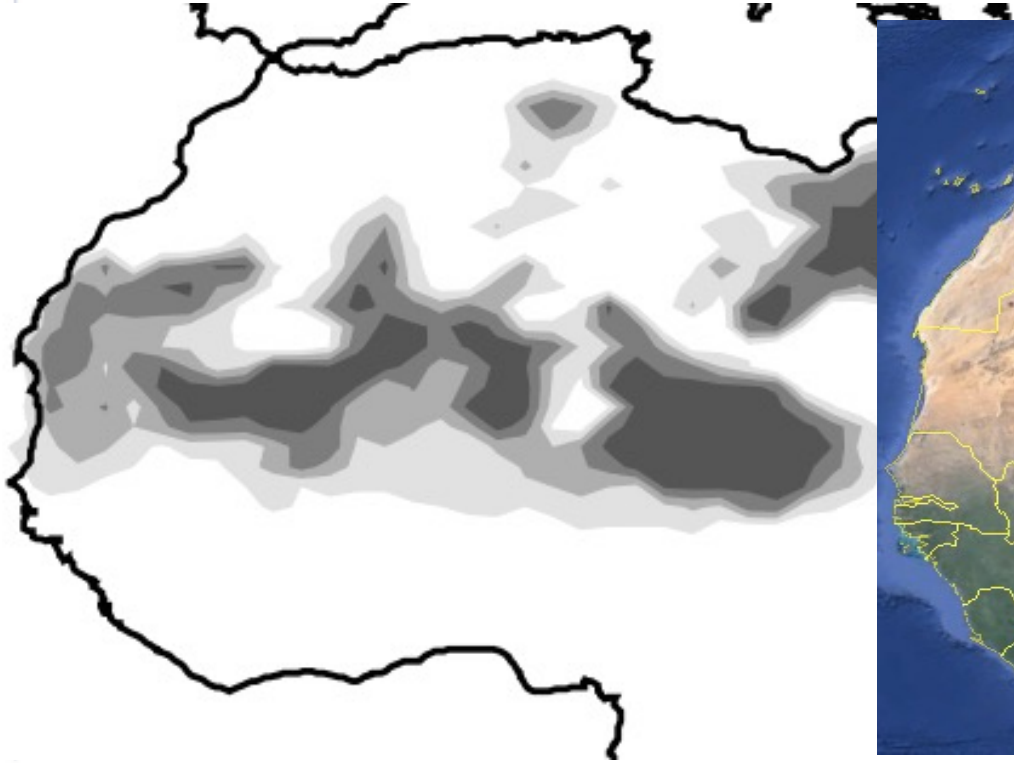

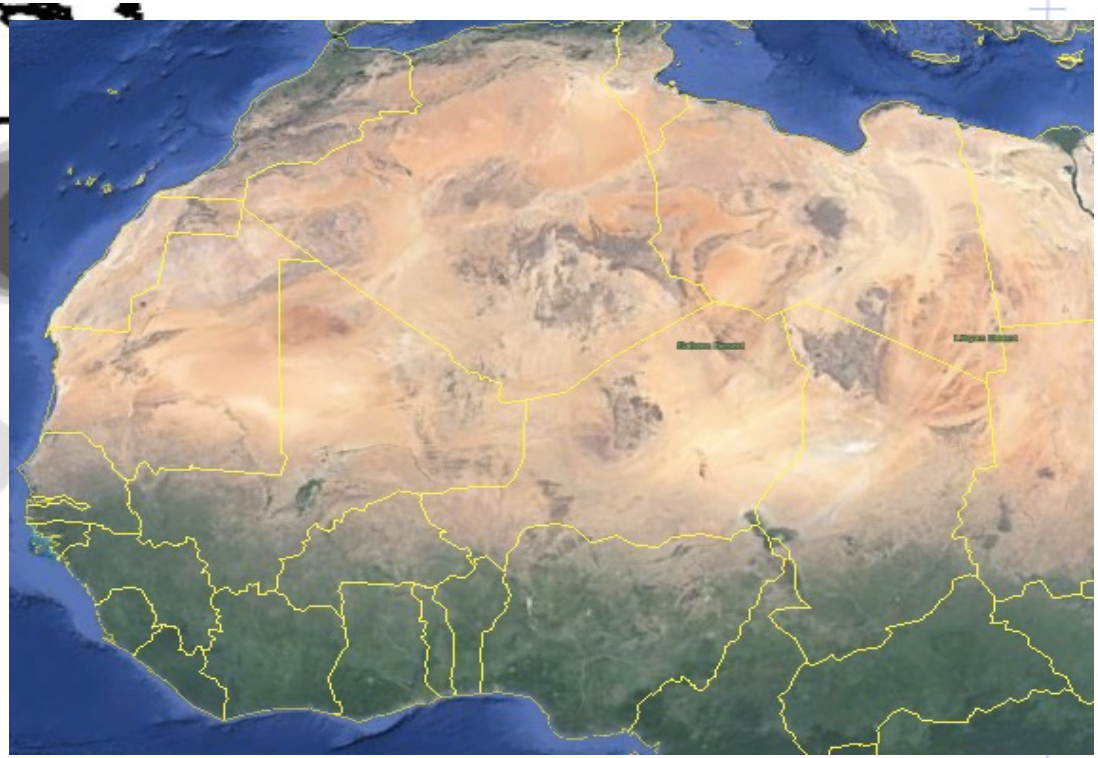

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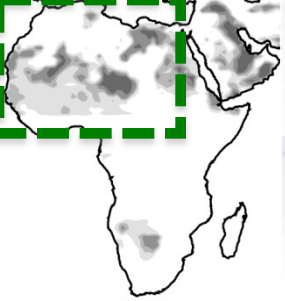

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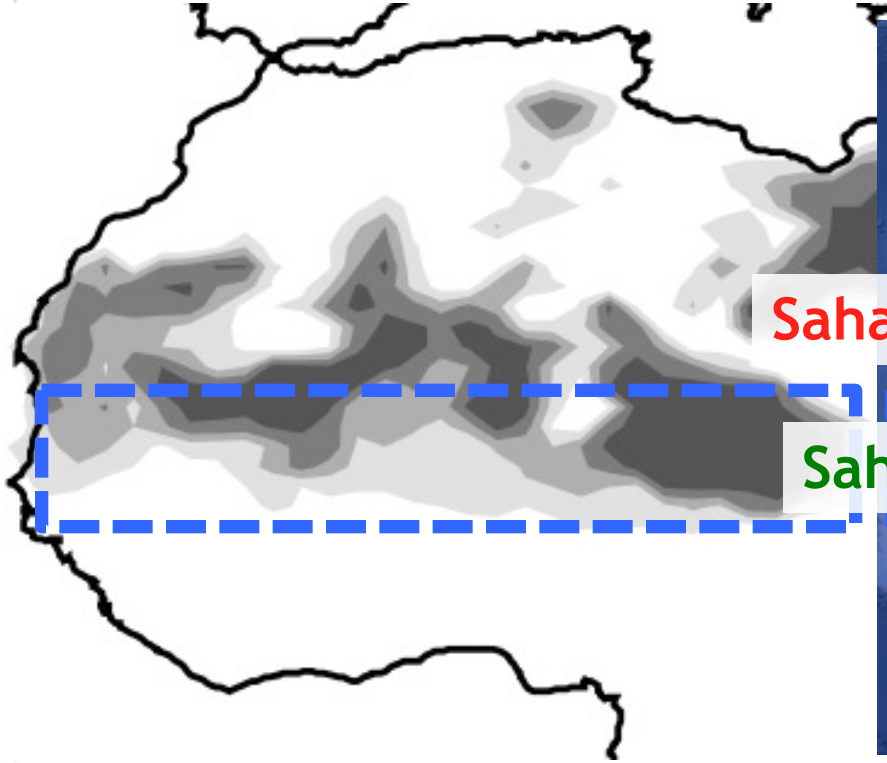

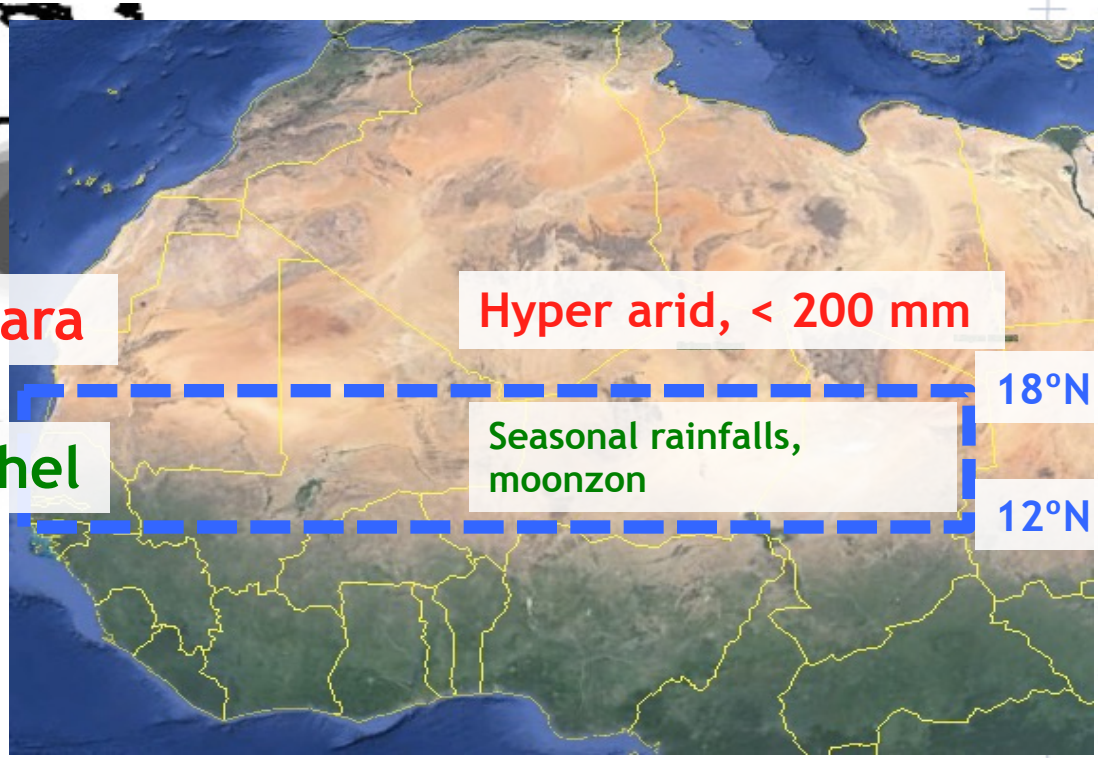

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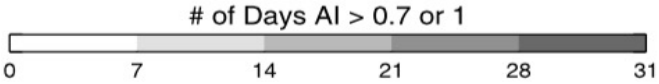

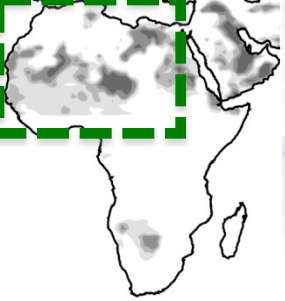

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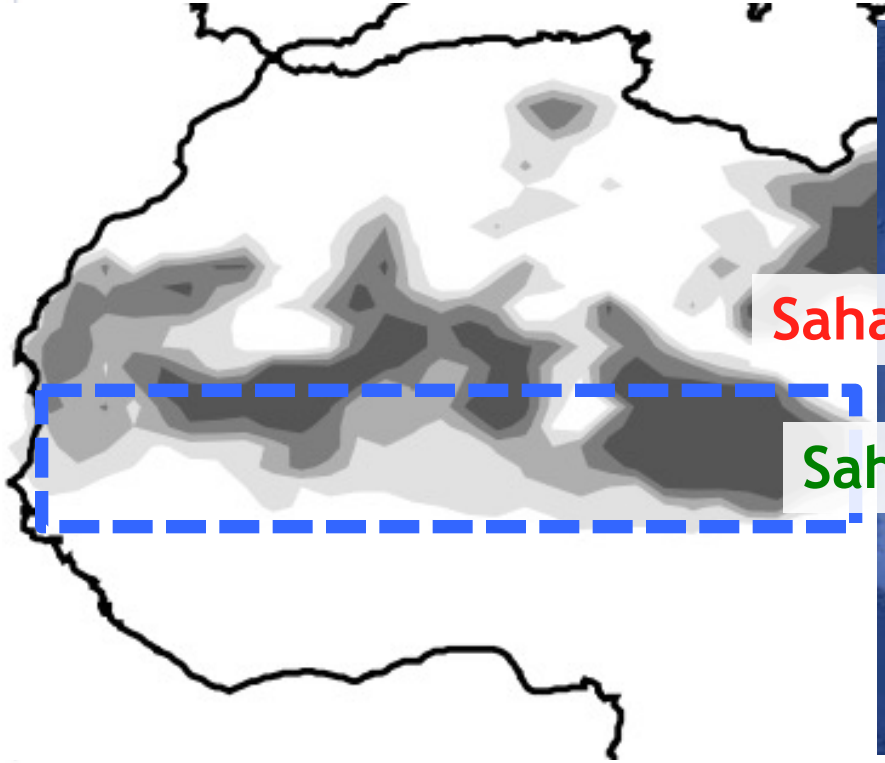

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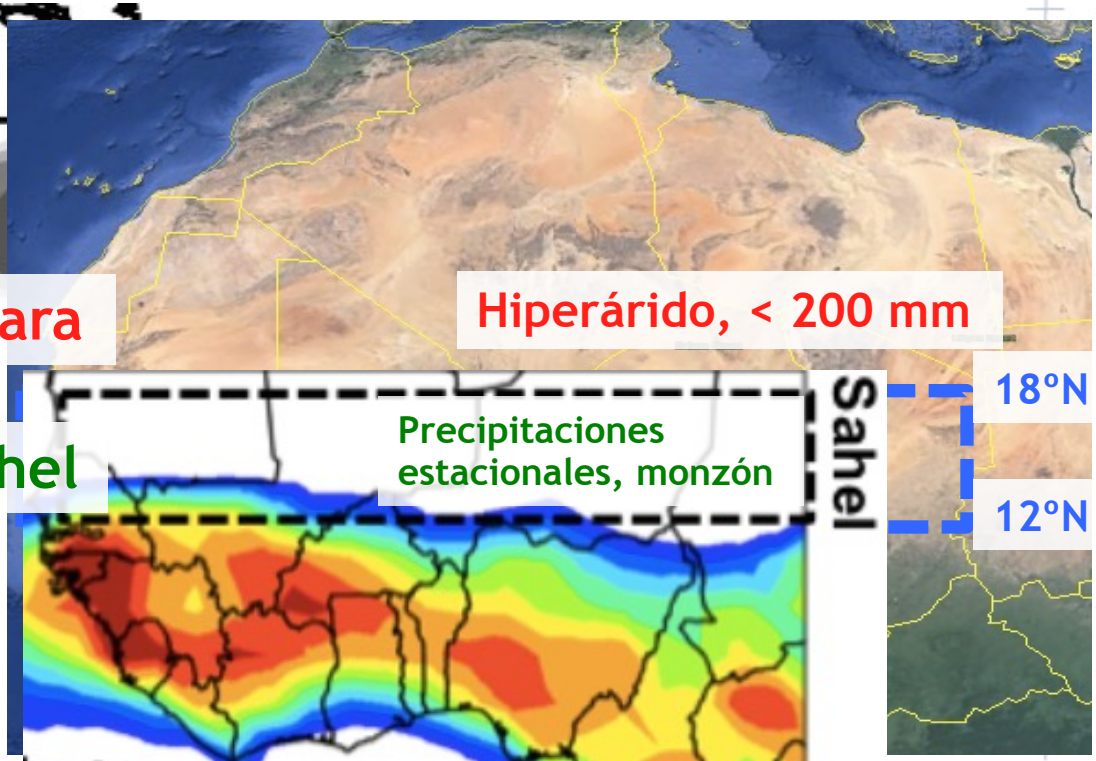

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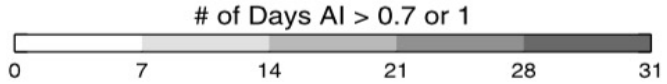

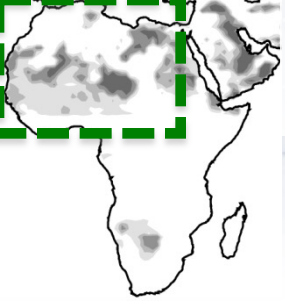

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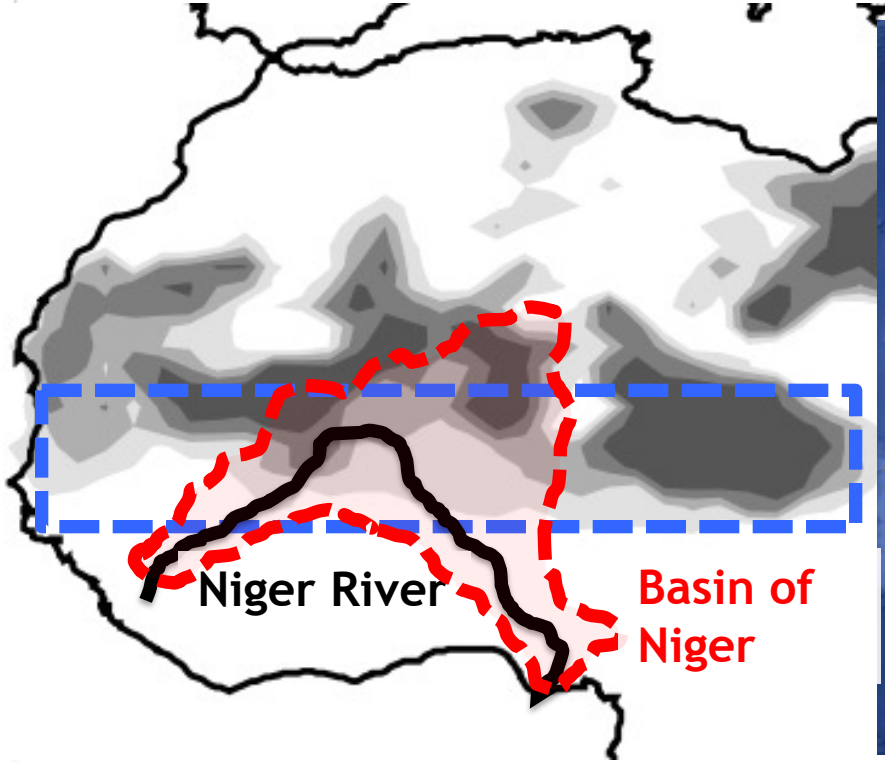
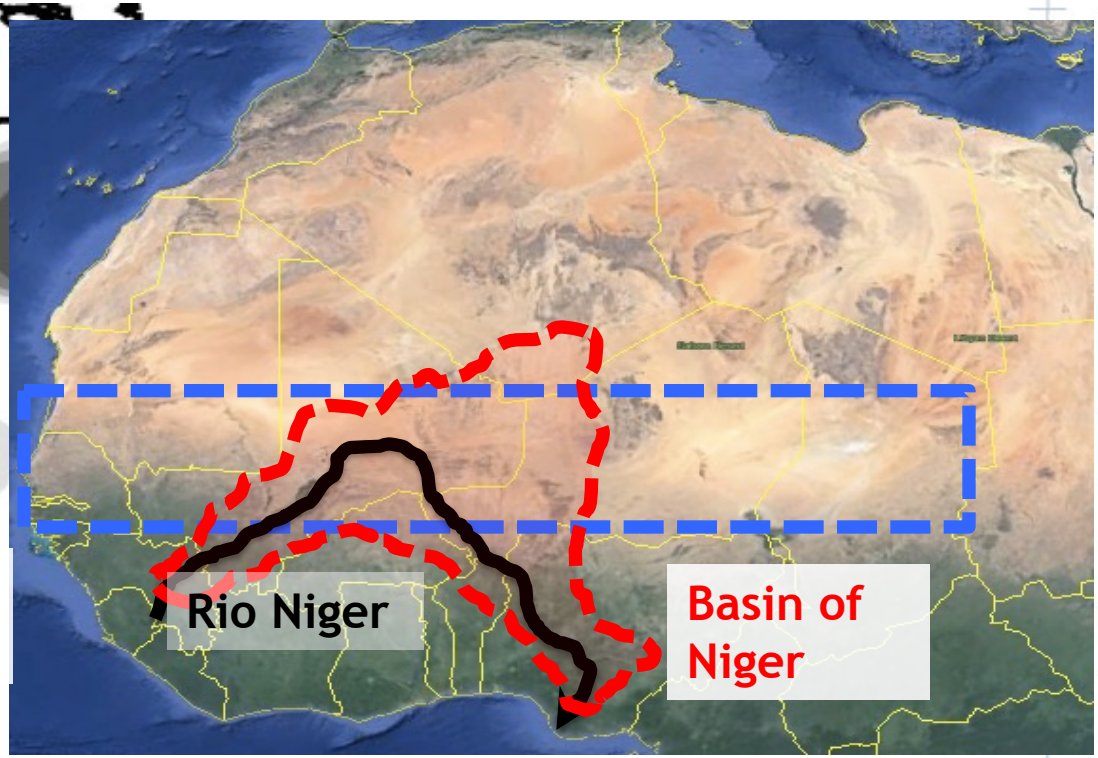
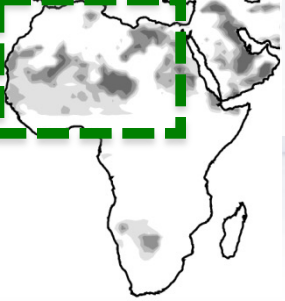




Remote Sensing satelite



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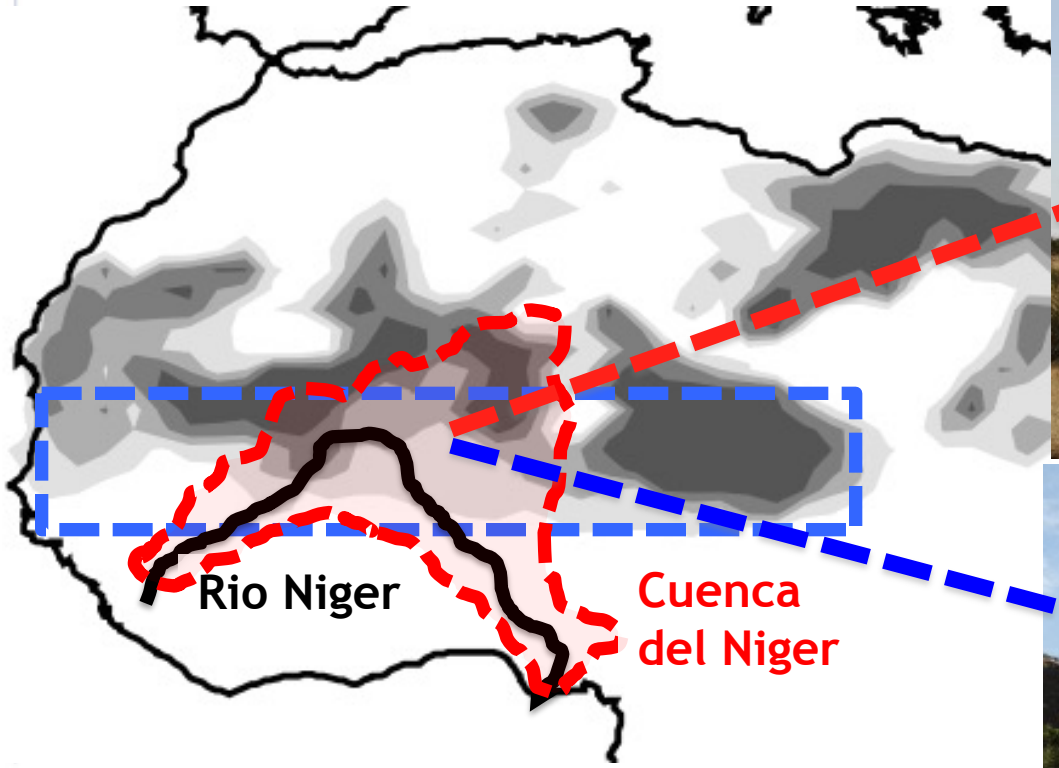
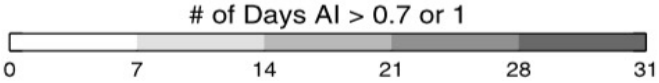
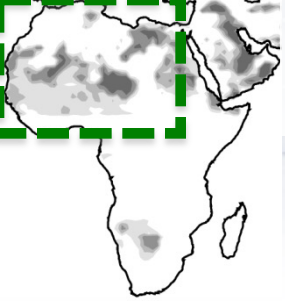


Dry season

Wet Season

Detección satélite





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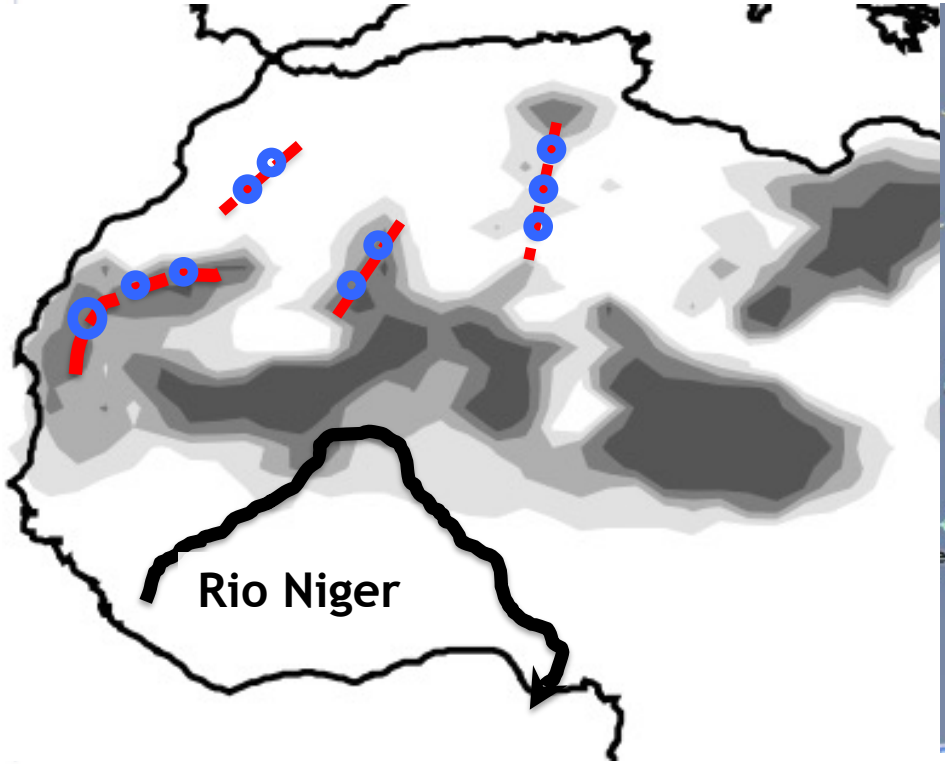
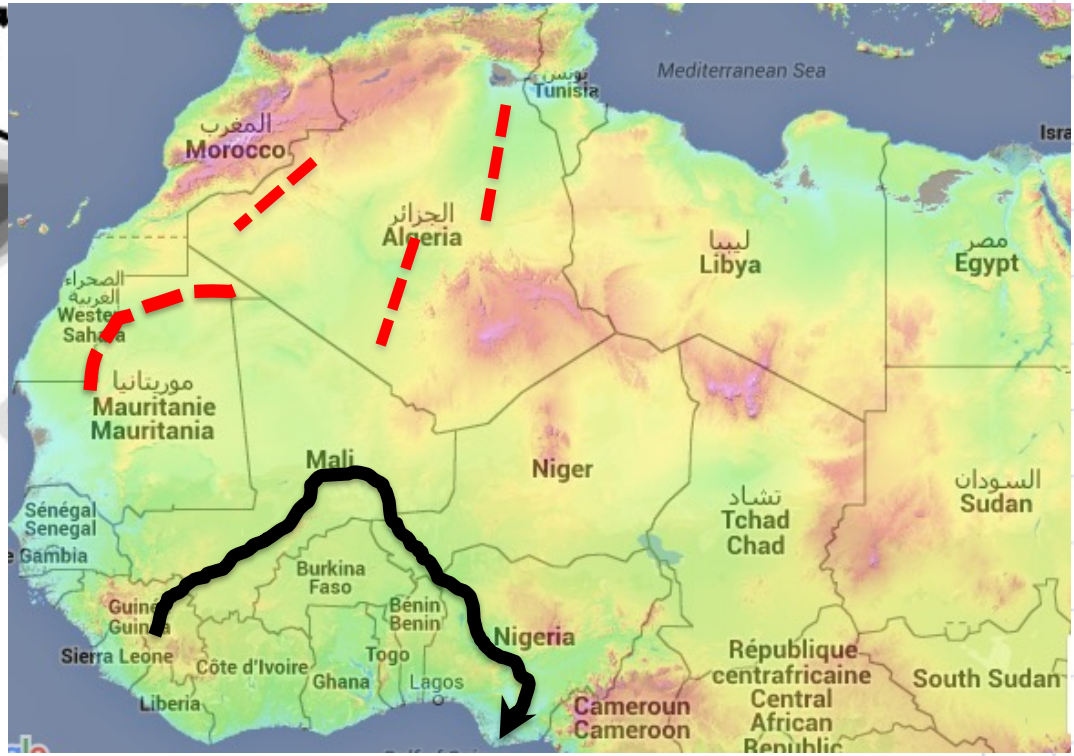
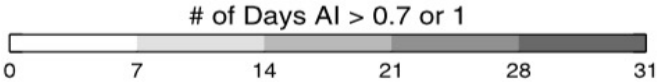


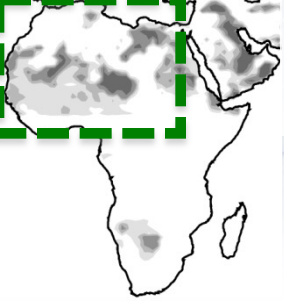


bajas tropográficas
Wakis: barrancos con inundaciones estacionales

chots, sabkas: lechos salados de lagos ecos

Detección satélite





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Cuenca Ouargla

Sahara chots

Chot El Jerid

100 km

Rio Niger

bajas tropográficas
Wakis: barrancos con inundaciones estacionales

chotts, sabkhas: lechos salados de lagos ecos

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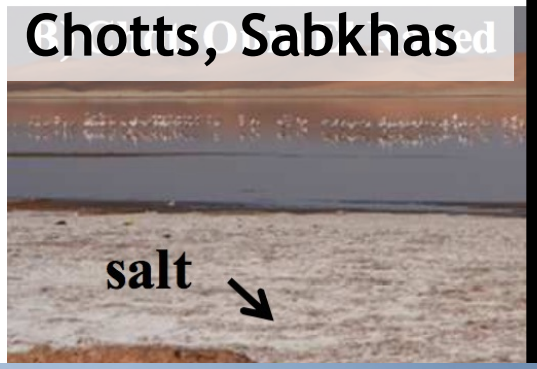

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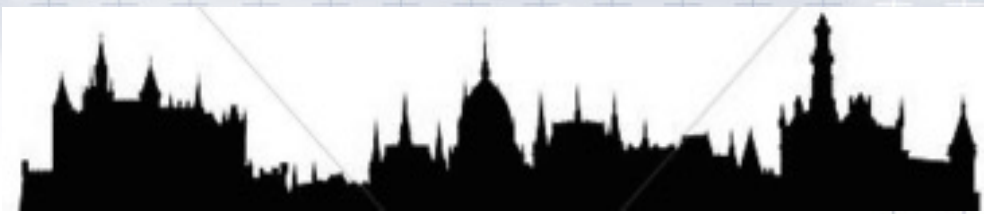

people live in cities and breath a cocktail dust + pollutants

aerosols, a cocktail of chemicals:

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

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

human hair: 70 µm

aerosols, a cocktail of chemicals:

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

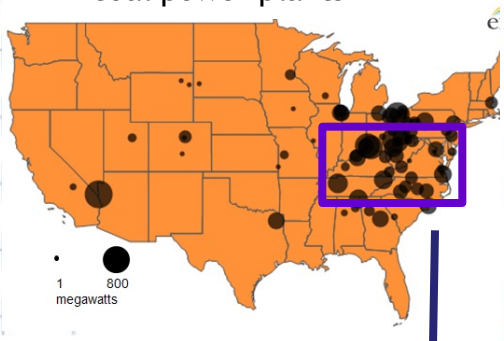
gas precursor				aerosol
SO_2	→ SO_3	→ H_2SO_4	→	$SO_4^=$
NO / NO_2	→ HNO_3		→	NO_3^-
NH_3	→			NH_4^+
				NH_4NO_3
				$(NH_4)_2SO_4$

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

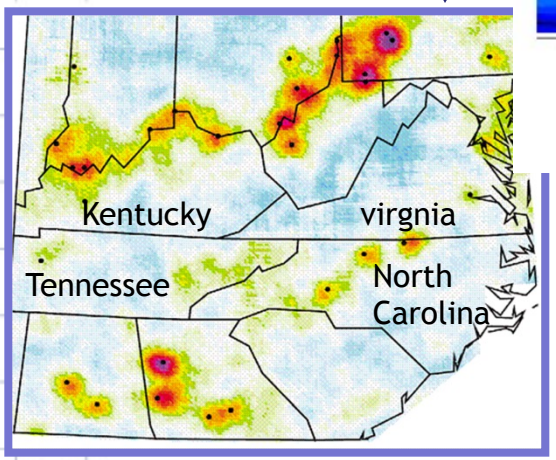
sulfato

122 Tg/y

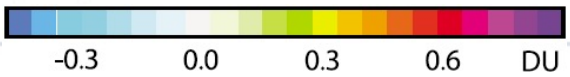
coal power plants



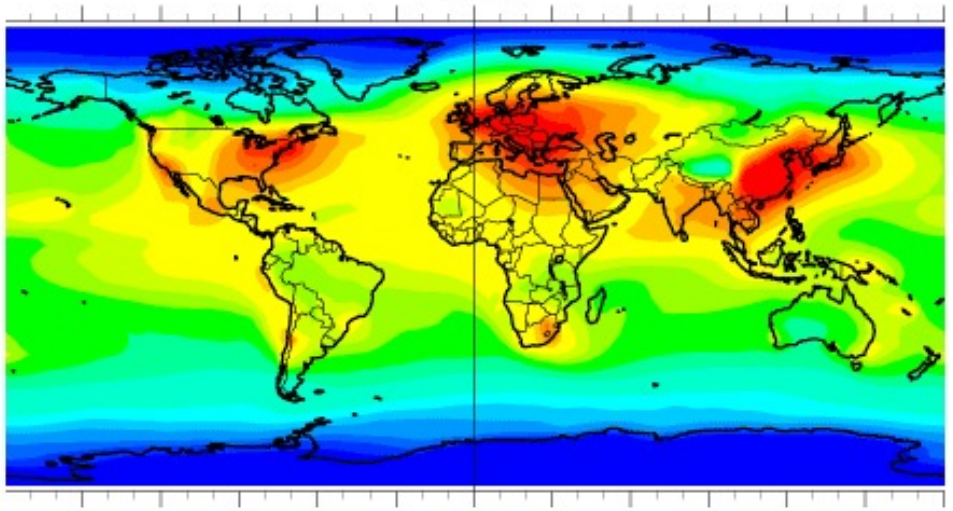
promedio 2005-2007



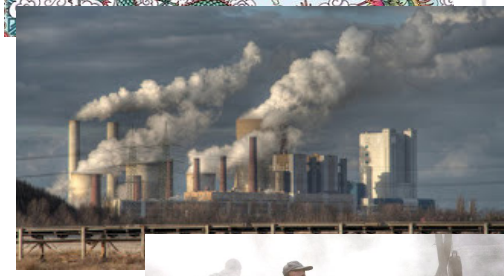
OMI SO_2 DU



sulfate



coal power plants



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

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

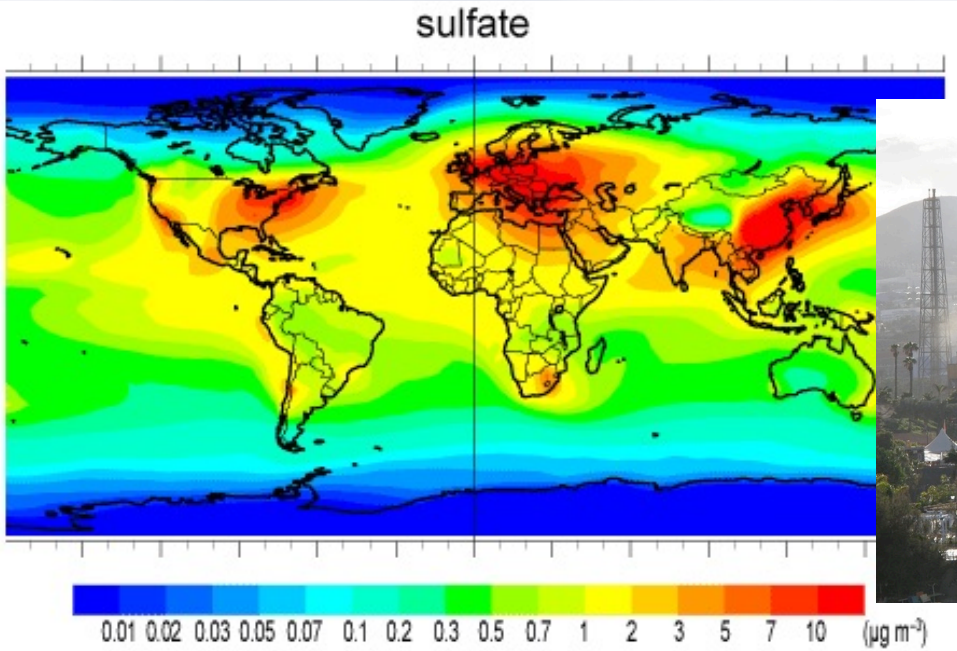
Single-Scattering Albedo and Radiative Forcing of Various Aerosol Species with a Global Three-Dimensional Model

TOSHIHIKO TAKEMURA* AND TERUYUKI NAKAJIMA

OLEG DUBOVIK, BRENT N. HOLBEN, AND STEFAN KINNE

sulfato

Oil refinery



Oil refinery

ships

aerosols, a cocktail of chemicals:

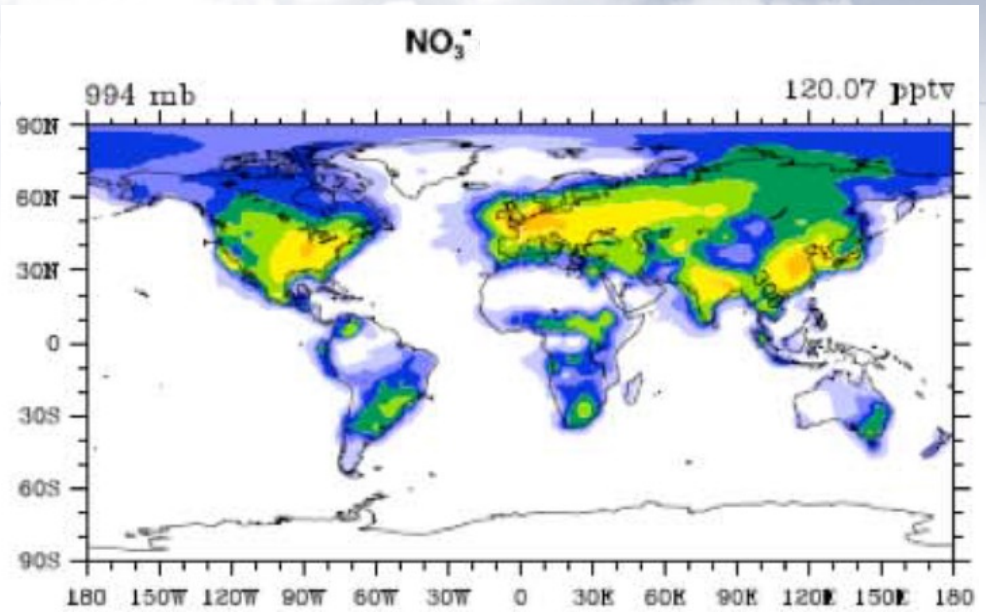
- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

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
			$(NH_4)_2SO_4$

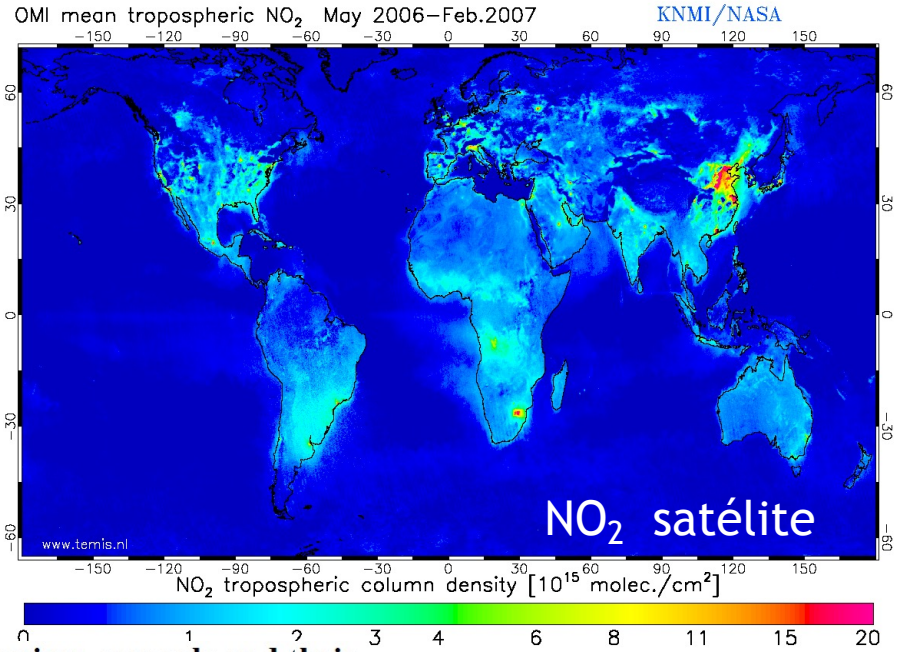
NO_x: vehicle exhaust, power plants, industry

nitrate

18 Tg/y



NH_4NO_3

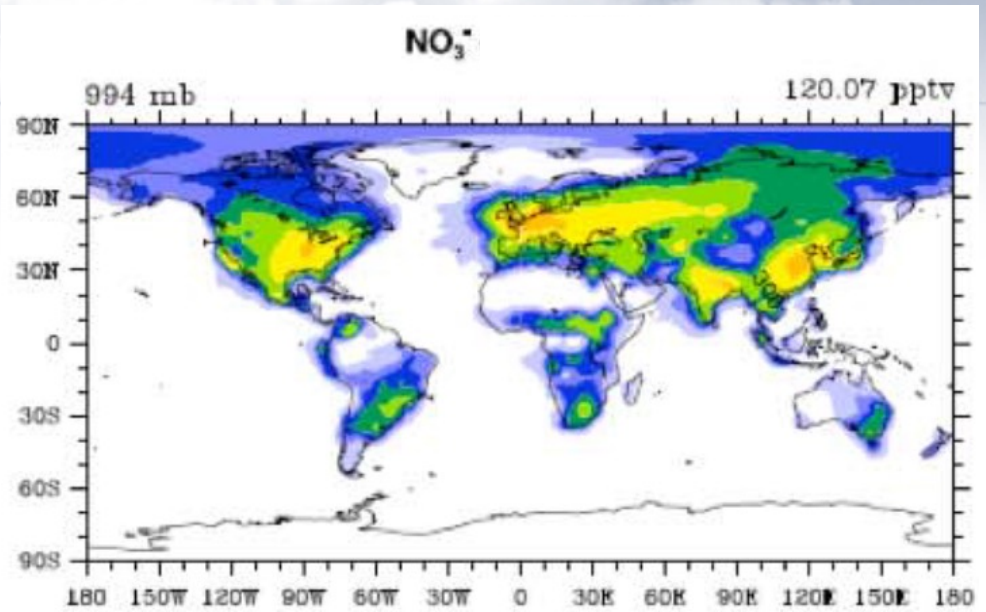


Atmos. Chem. Phys., 12, 9479–9504, 2012
www.atmos-chem-phys.net/12/9479/2012/

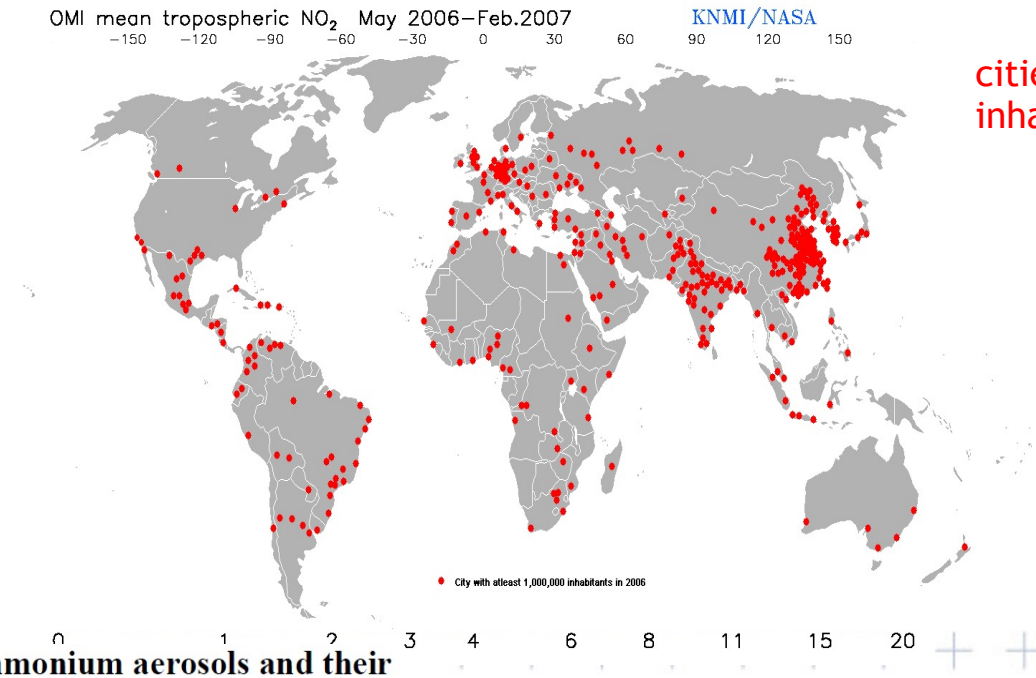
L. Xu and J. E. Penner

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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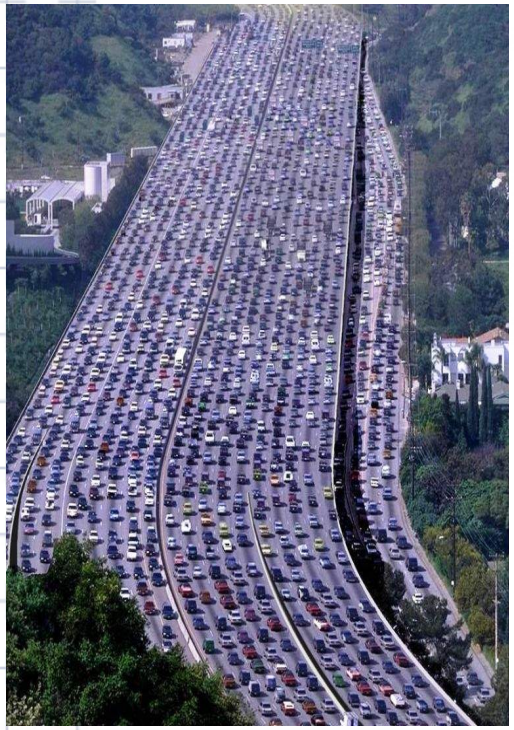
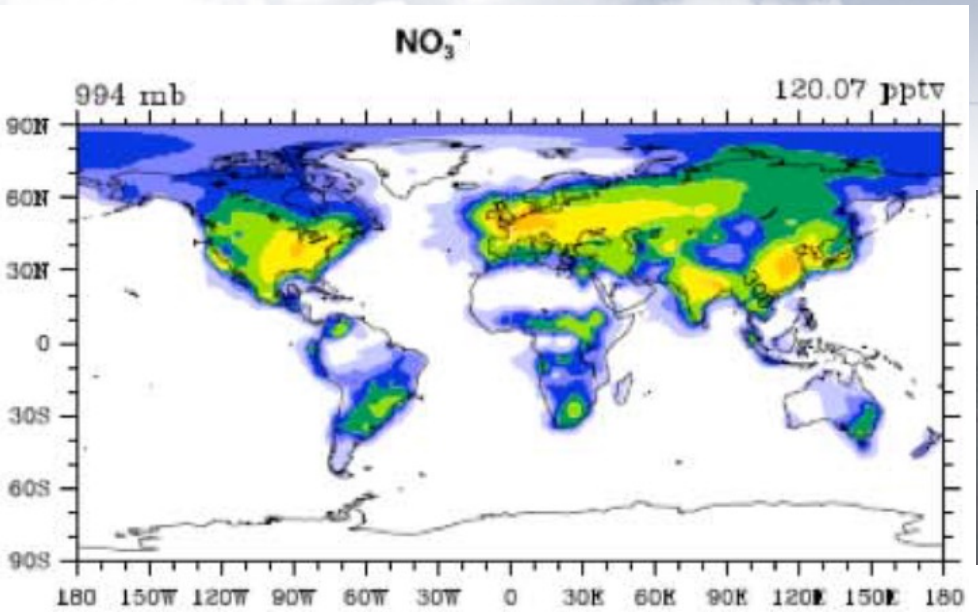
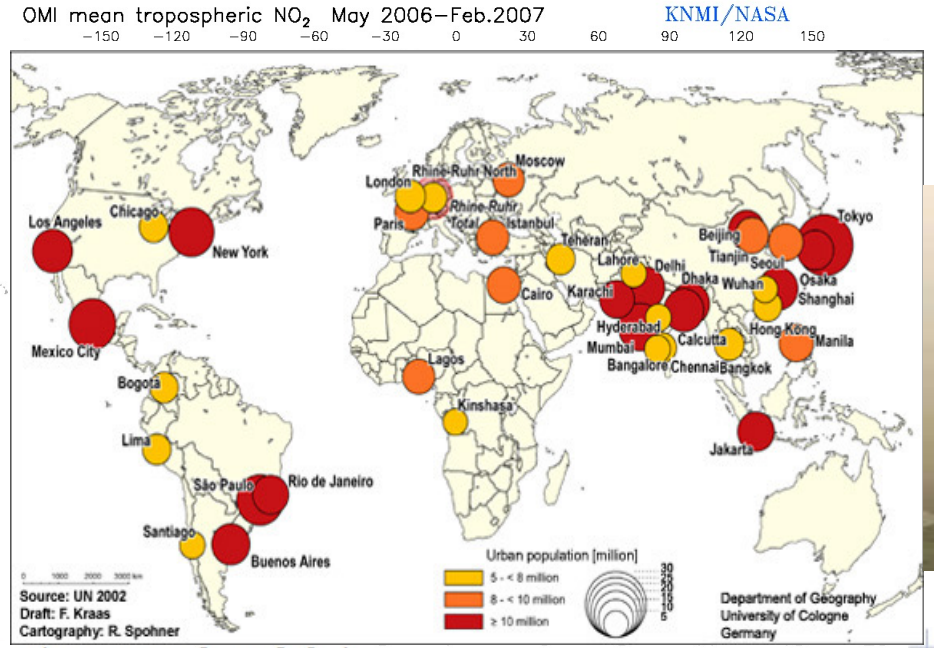
Global simulations of nitrate and ammonium aerosols and their radiative effects

nitrato





NH_4NO_3



Mega-ciudades, > 5 Millones habitantes

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

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Global simulations of nitrate and ammonium aerosols and their radiative effects

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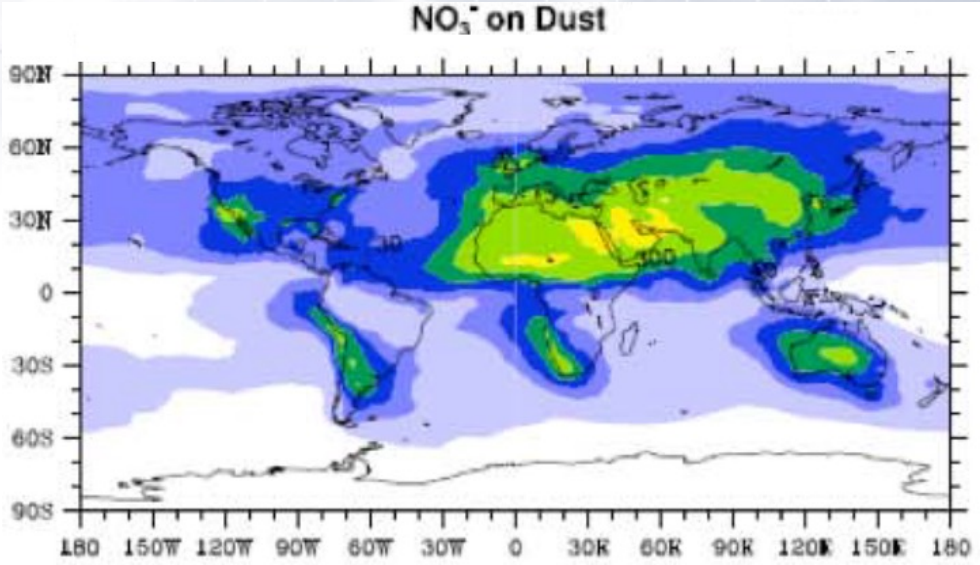
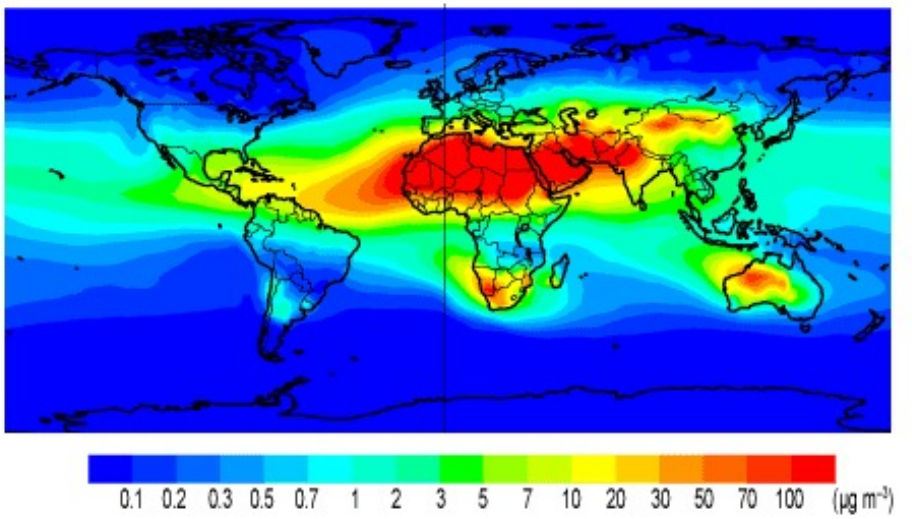


NO_3^- - dust

$Ca(NO_3)_2$

soil dust



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www.atmos-chem-phys.net/12/9479/2012/

L. Xu and J. E. Penner

Global simulations of nitrate and ami... aerosols and their radiative effects

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

aerosols, a cocktail of chemicals:

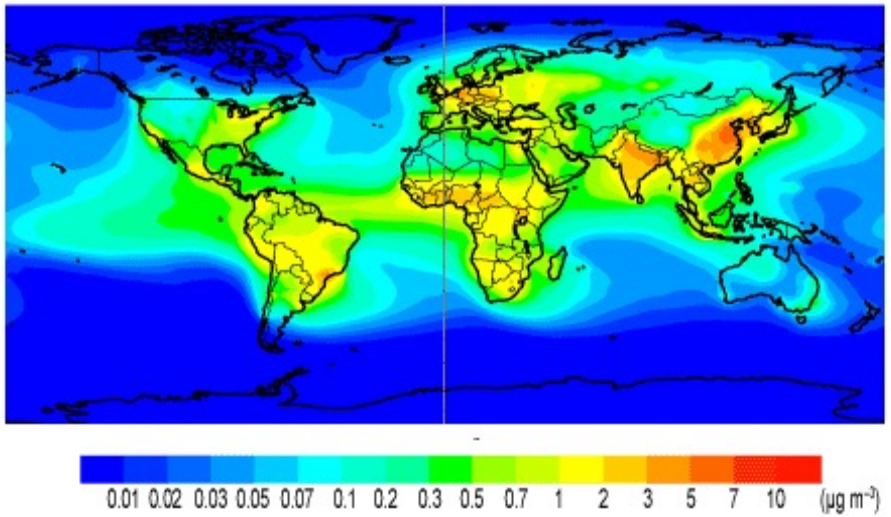
- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

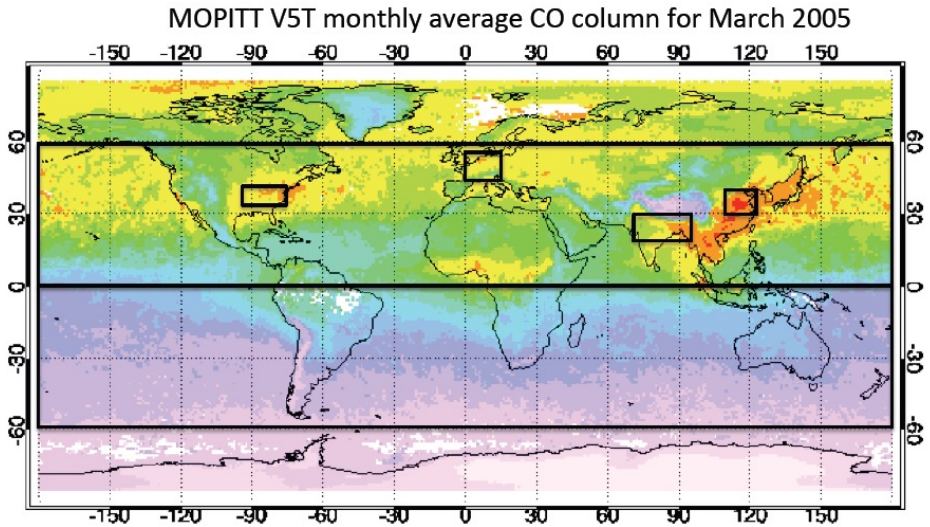
Black carbon: vehicle exhaust (diesel) , combustion sources

black carbon

10.5 Tg/y

diesel, 4x4, camiones





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

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TOSHIHIKO TAKEMURA* AND TERUYUKI NAKAJIMA
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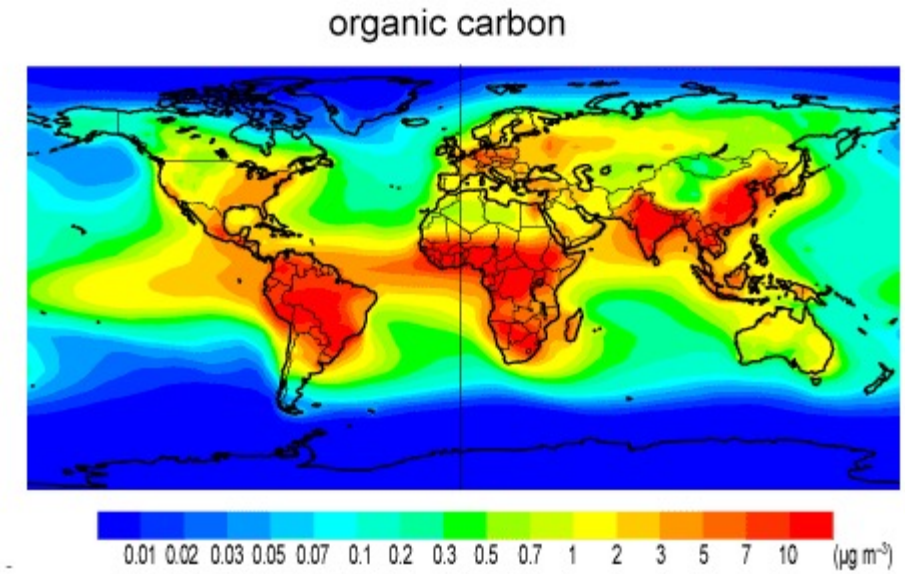
aerosols, a cocktail of chemicals:

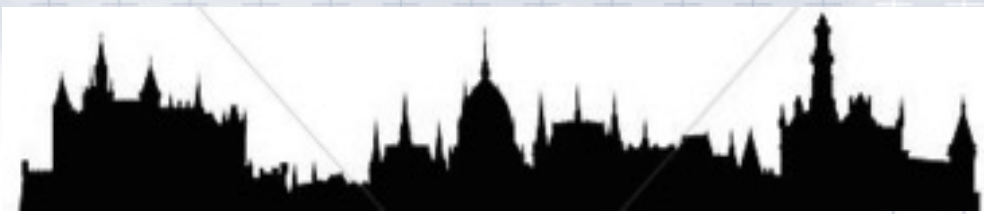
- dust
- sulphate
- nitrate
- organic mater
- black carbon (soot)
- metals (Ni, As, Cd, V, Co...)
- sea salt

organic matter: combustion sources, vehicle exhaust

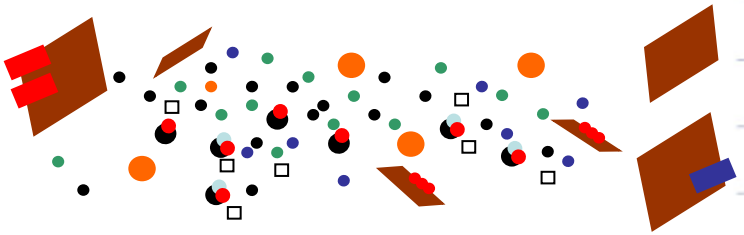
carbono orgánico

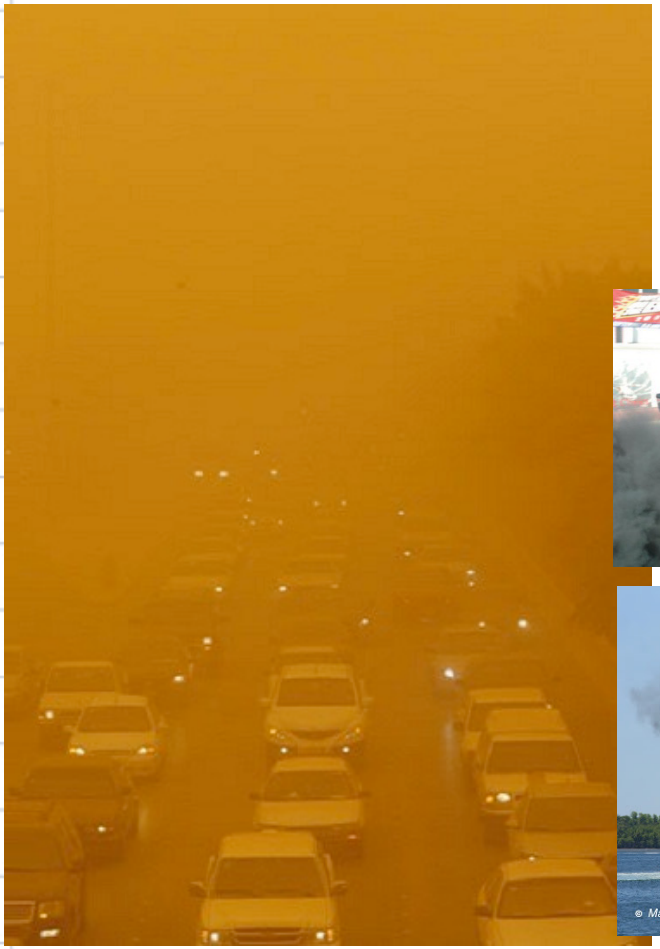


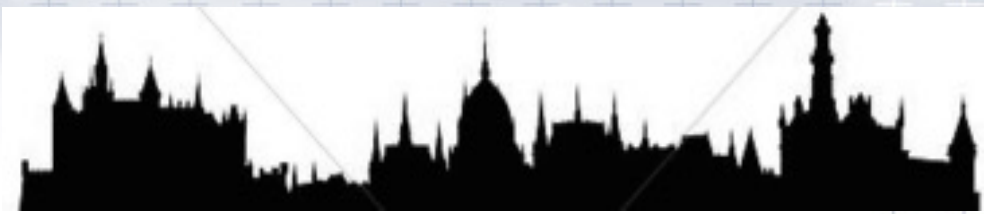
automóviles



people live in cities and breath a cocktail dust + pollutants







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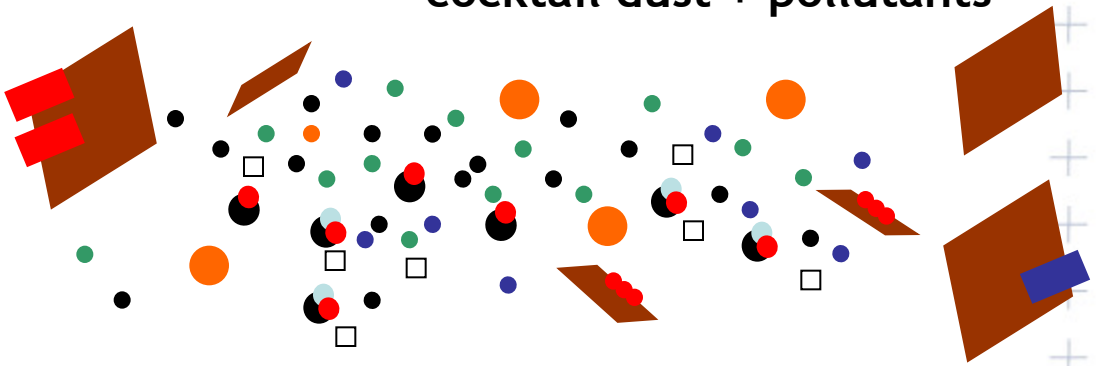
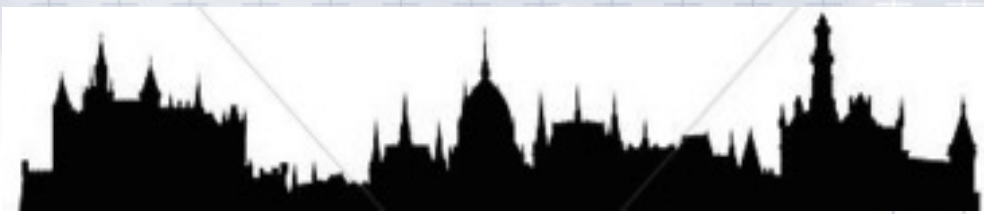


In air quality, aerosols:

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

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



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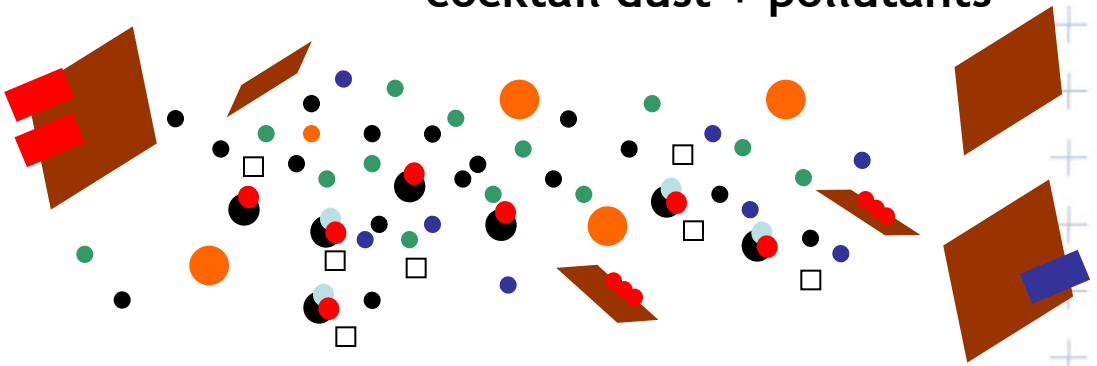


PM_{10}: dust + sea salt + (sulphate + nitrate + organic matter + black carbon +metals) ..

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

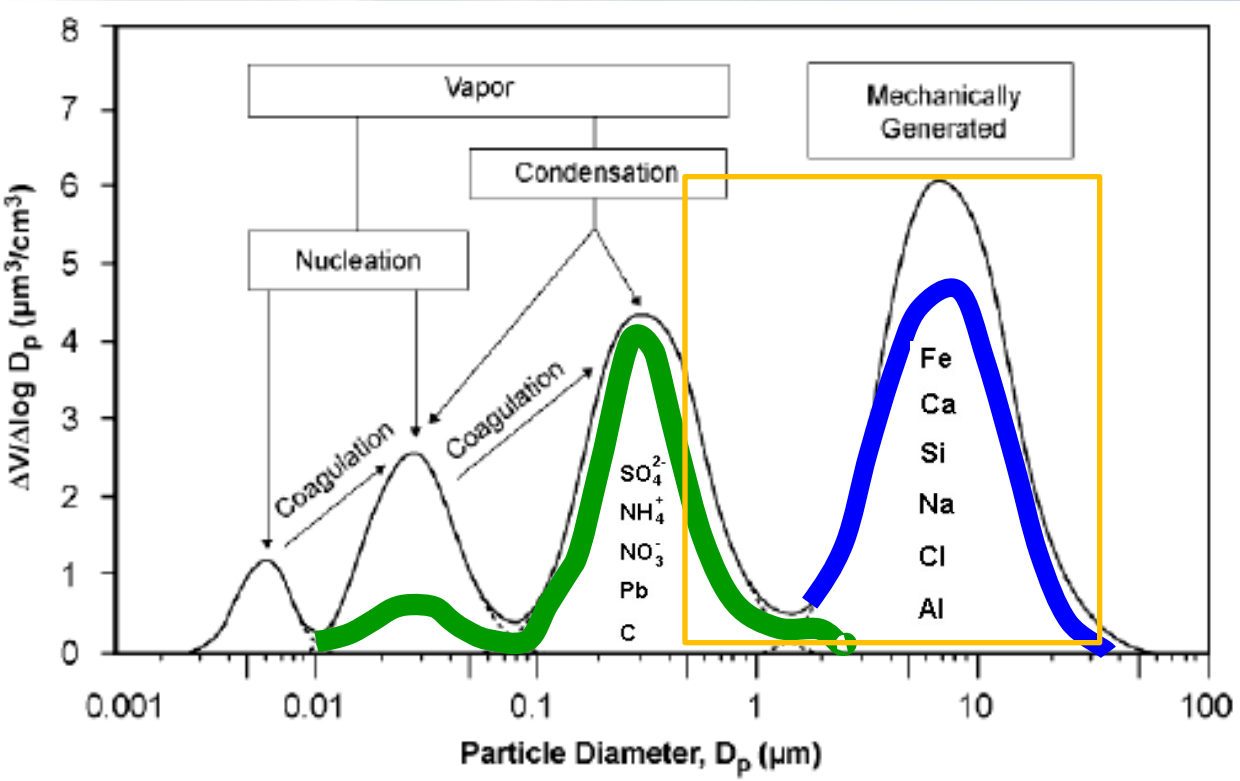
PM_{10}: dust + sea salt + vehicle exhaust + oil refining + power plants + ships +...

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

PM_{10} (diameter <10 microm)

$PM_{2.5}$

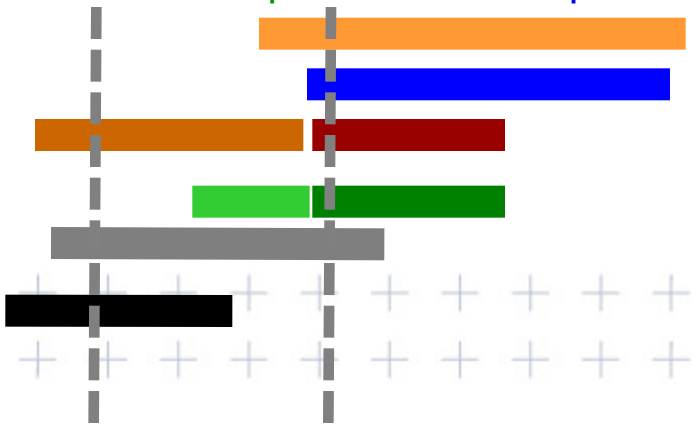
$PM_{2.5-10}$



ultrafine <0.1 µm

accumulation 0.1 – 1 µm

Coarse 1 - 10 µm



Mineral dust :

Marine salt:

Sulfate:

Nitrate:

Organic aerosol:

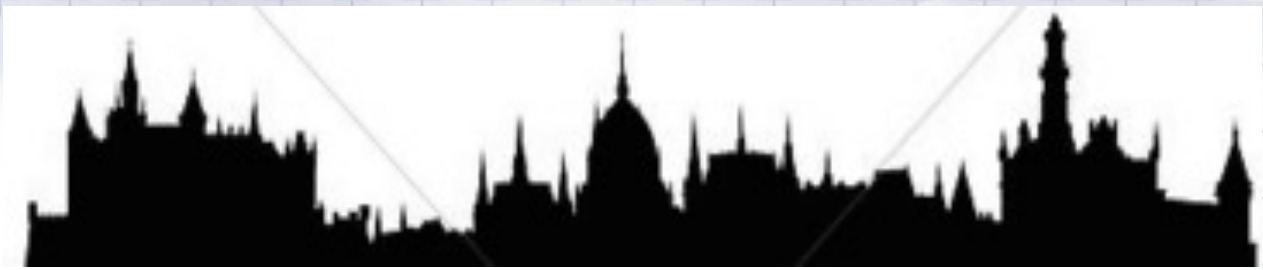
black carbon:

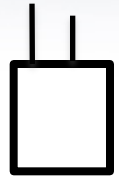
dust, aerosols and pollutants

in-situ observations

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

observation network





dust - air quality

What to measure to protect human health ?

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

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AEMet Agencia Estatal de Meteorología

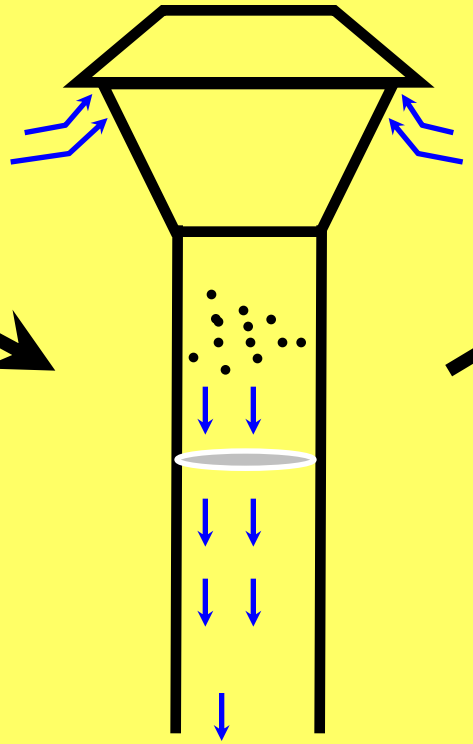
dust air quality

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

-method-01 manual gravimetry method

-method-01: reference - manual gravimetry

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



Blank filter

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

- Filter weight (W1)

Sampled filter

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

- Filter weight (W2)

Pump

It is recommended to use standardised protocols

national standard method

or already existing international standard methods

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

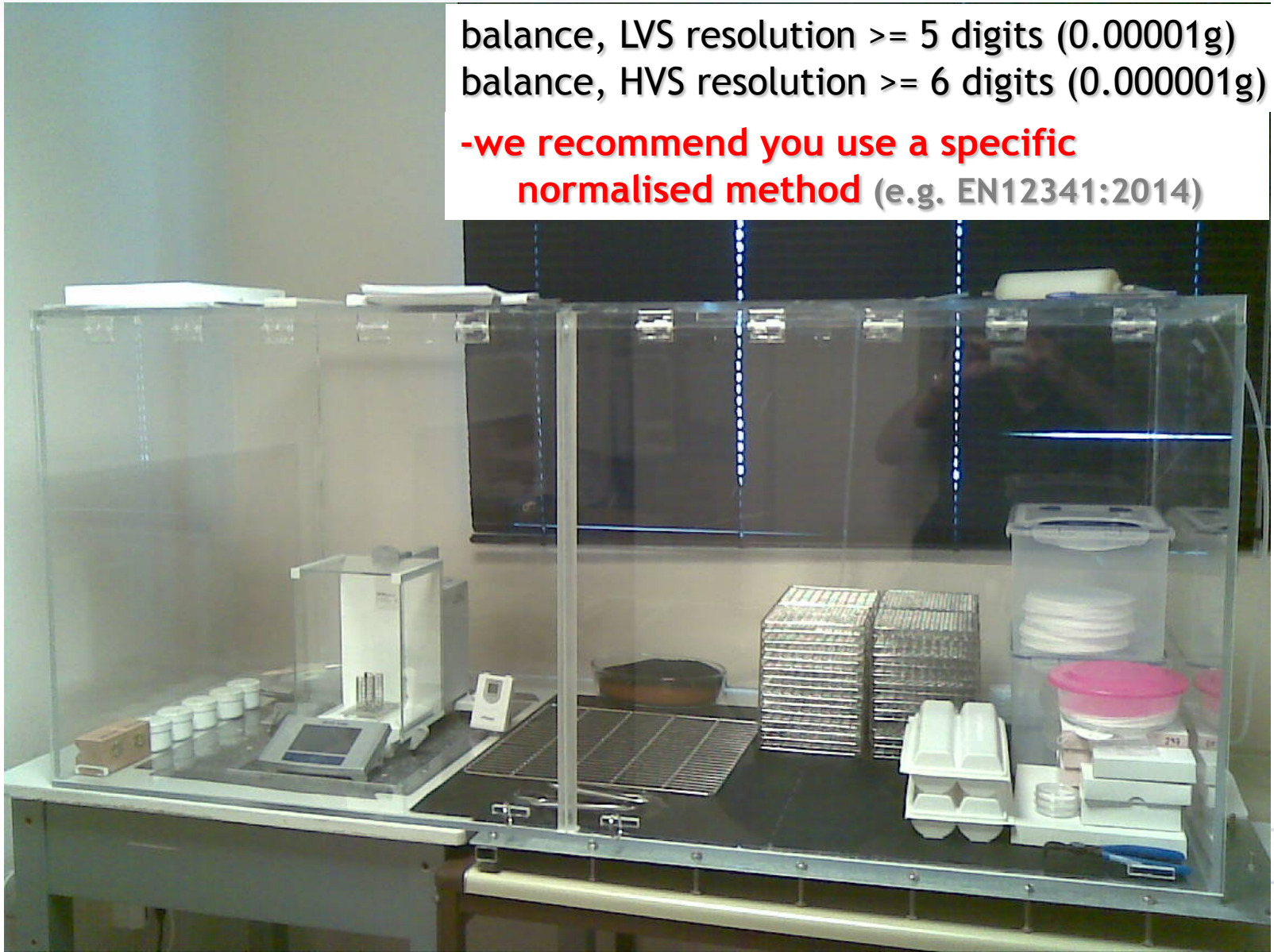
example:

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

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

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

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



PM_{10}
Blank filter

PM_{10}
sample urban air

PM_{10}
sample in dust days

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

Filters: Quartz, Teflon, Cellulose

Low Volume Sampler

High Volume Sampler

LVS:2.3 m^3/h

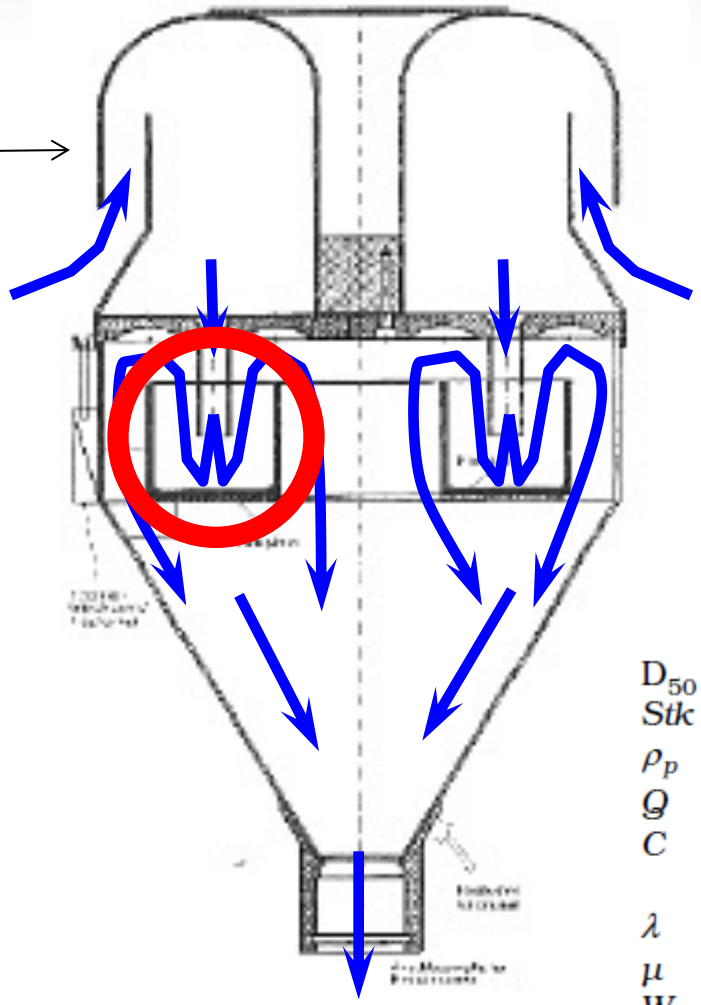
HVS: 68 m^3/h

HVS: 30 m^3/h

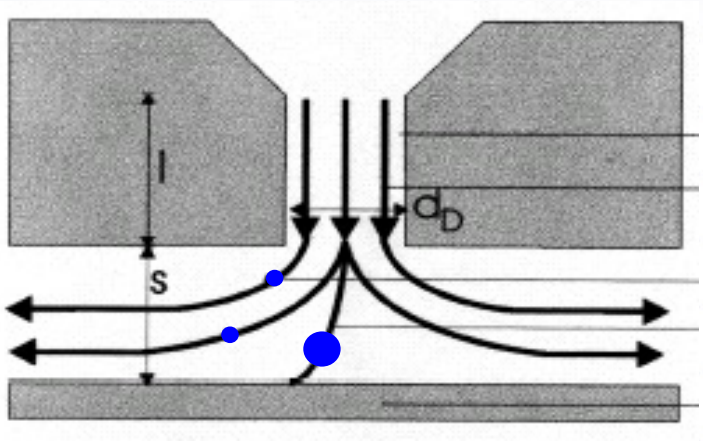
-we recommend you use a specific normalised method (e.g. EN12341:2014). Ask to the distributor if the sampler sis designed to any standards

Inlets, airflows....

PM_{10}, $PM_{2.5}$



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

Manual gravimetry

advantage: reference method

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

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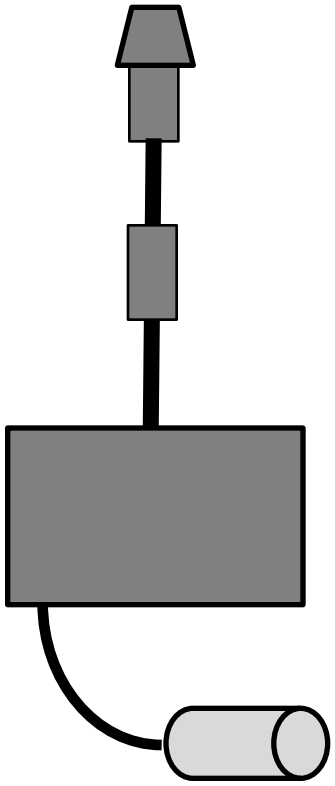
dust air quality

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

   -method-01: reference - manual gravimetry

   -method-02: automatic

-method-02: automatic



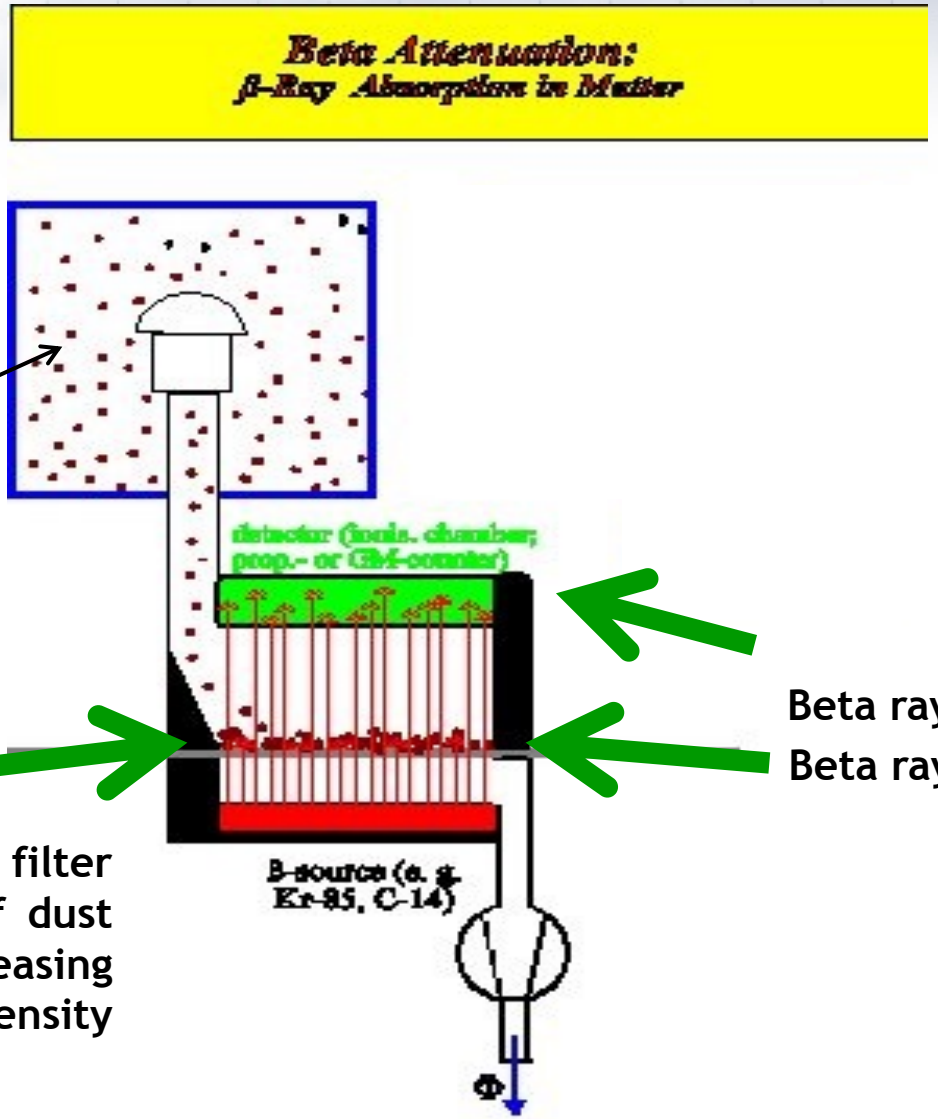
1. Impactor PM_{10} / $PM_{2.5}$
2. RH reductor / heater
3. Sensor

   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

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

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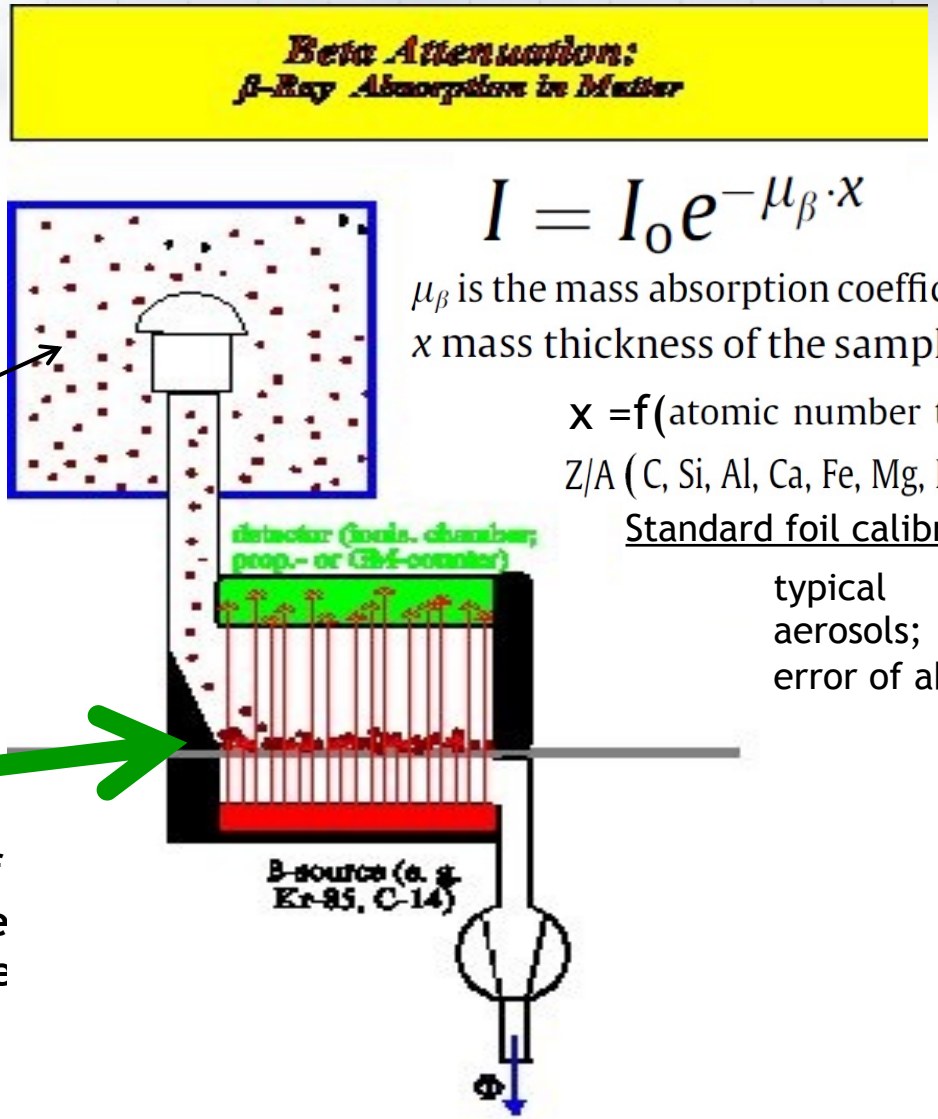

$$I = I_0 e^{-\mu_\beta \cdot x}$$

μ_β is the mass absorption coefficient for beta radiation

x mass thickness of the sample

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

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

Standard foil calibration

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

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} & $PM_{2.5}$ ≈ $$c = \frac{m}{Ft}$$

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

-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

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dust air quality

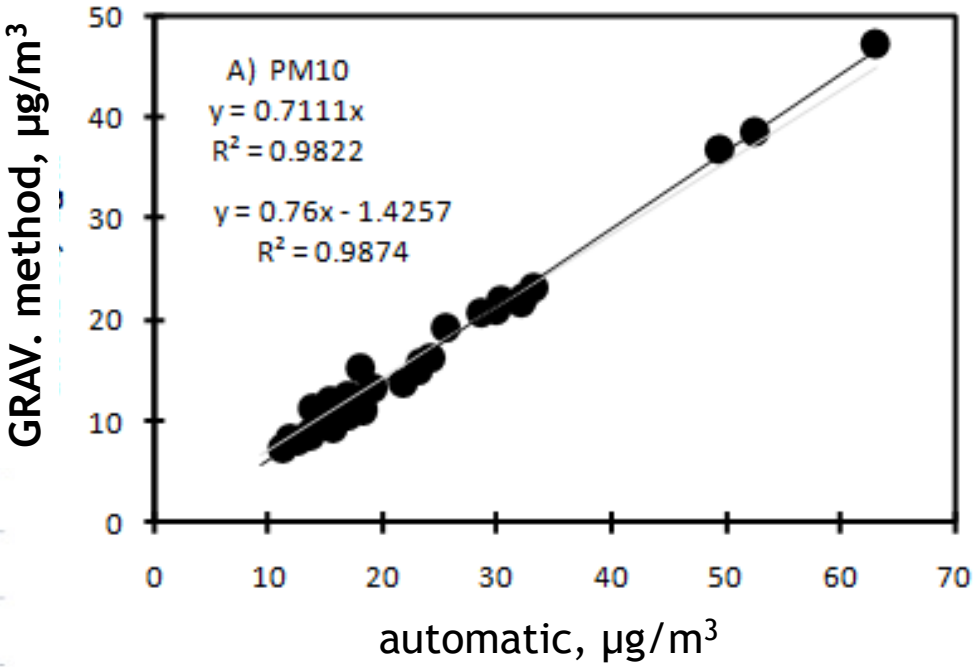
1. PM_{10} and $PM_{2.5}$ levels

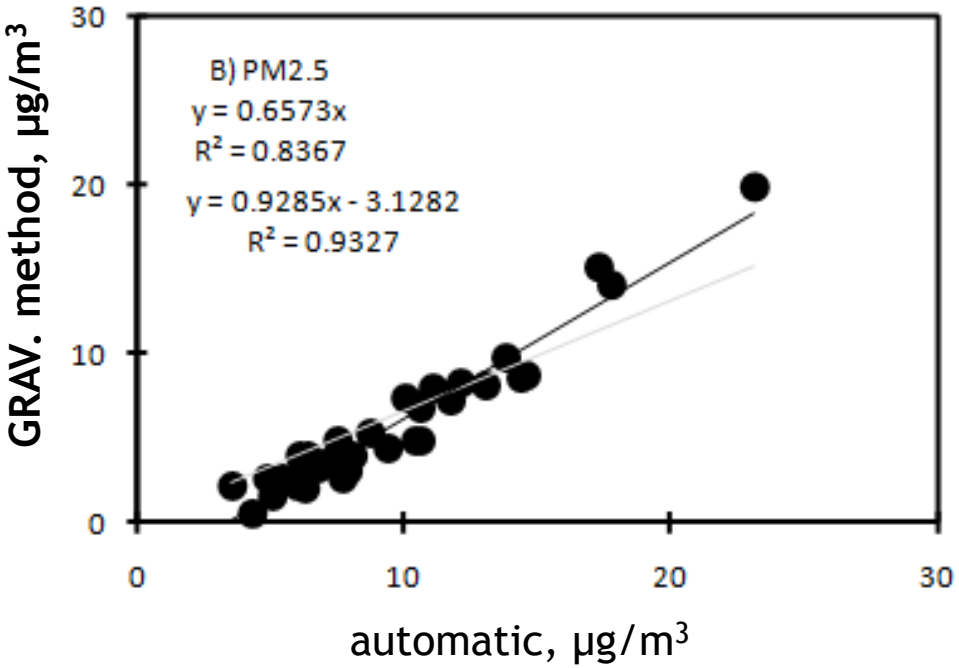
   -method-01: reference - manual gravimetry

   -method-02: automatic

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

Validation of the automatic measurments
Intercomparisons





Data evaluation:

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

	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

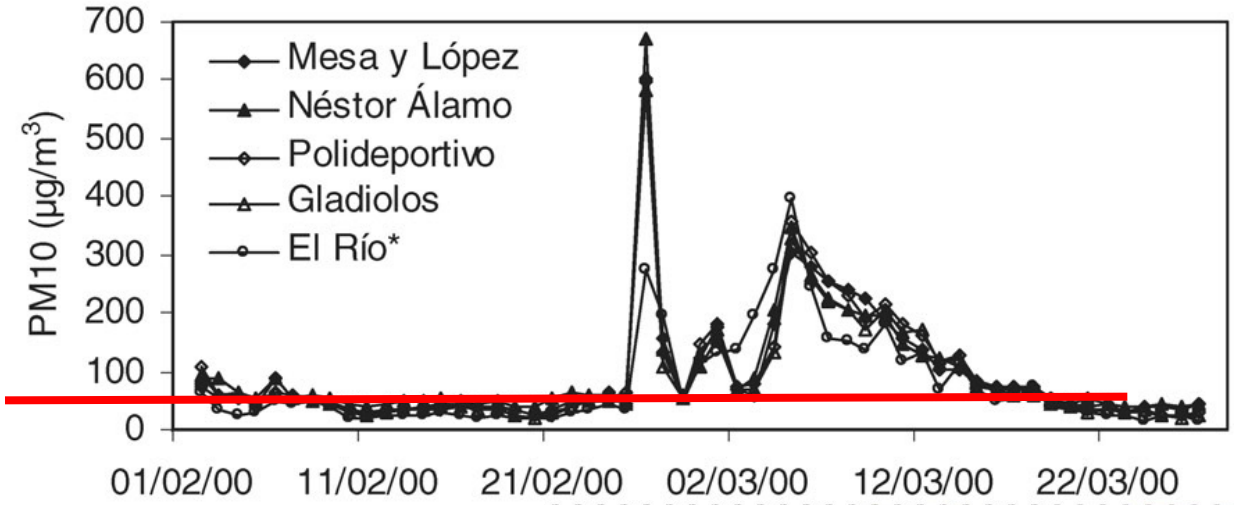
we recommend to use the two methods:

-automatic, continuously

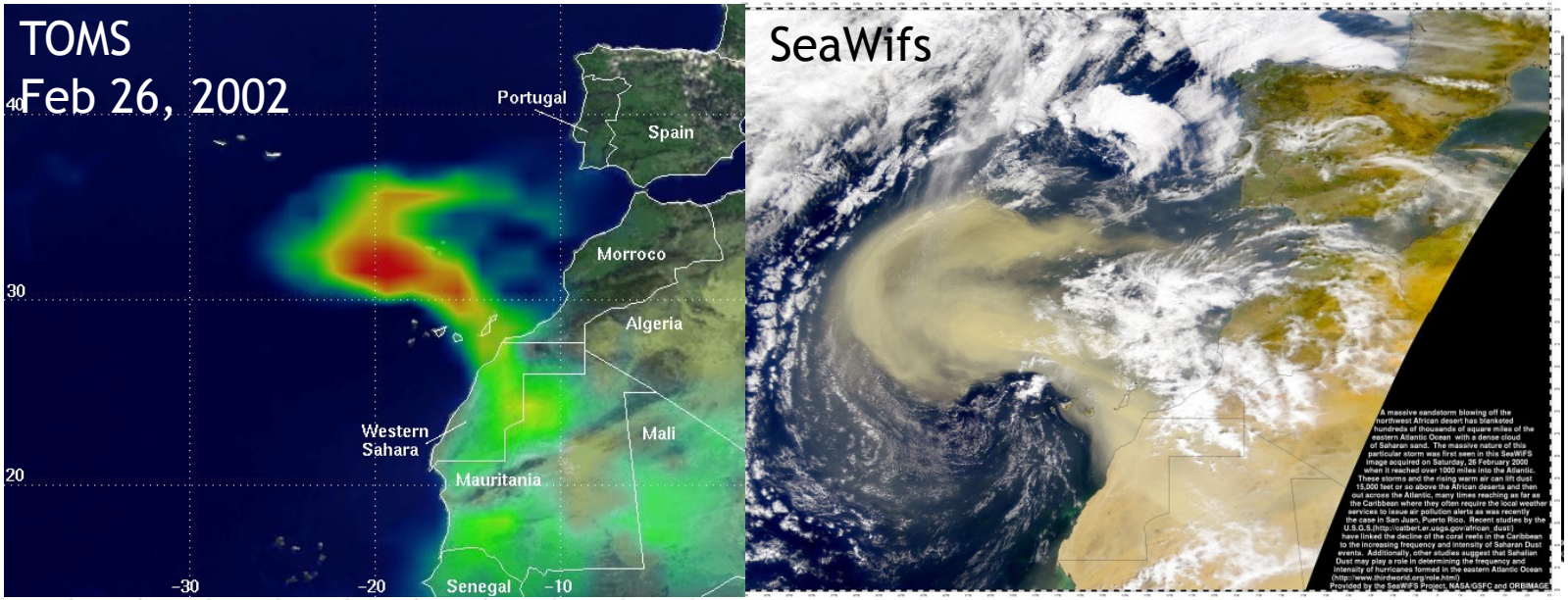
-gravimetric: intercomparisons - 1 month summer, 1 month winter

In-situ dust characterization

Air quality stations at Tenerife Island



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



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

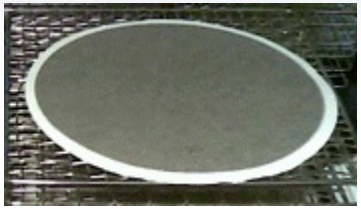
-gravimetric: intercomprisons, 1 month summer, 1 month winter

bulk chemical composition

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

Saharan dust

Urban particles



PM ($\mu g/m^3$)= 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

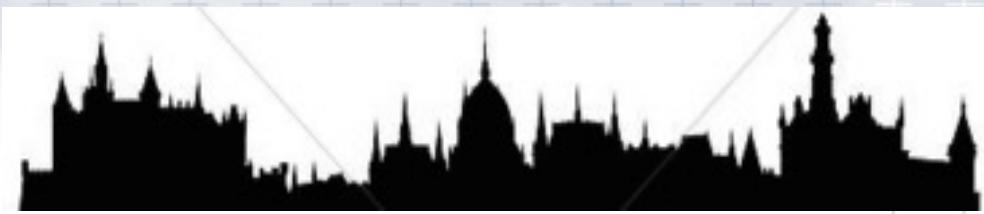
Ions: $SO_4^=$, NO_3^-, NH_4^+, Na^+, Cl^-

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

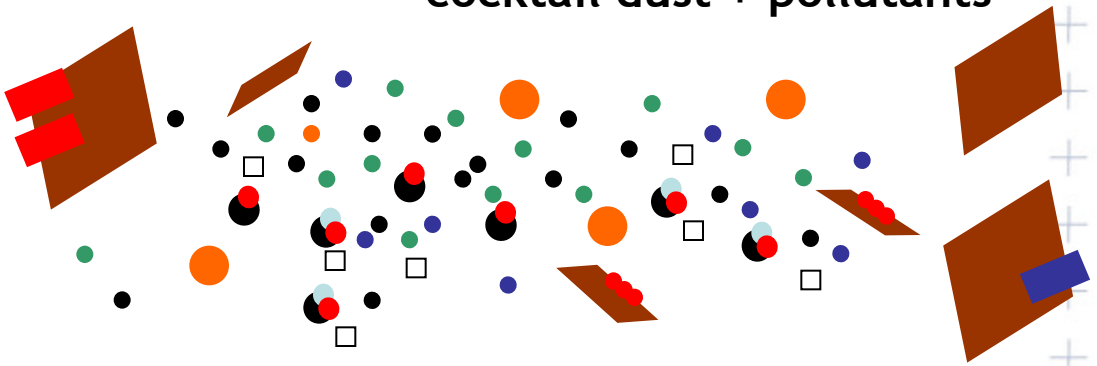
Destructive techniques

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

destructive techniques



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 +...

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

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

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

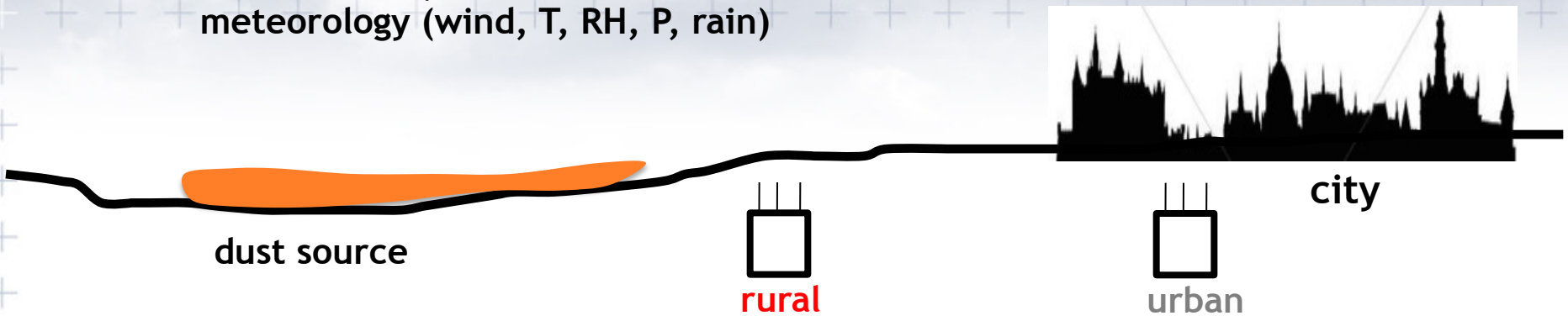
dust air quality

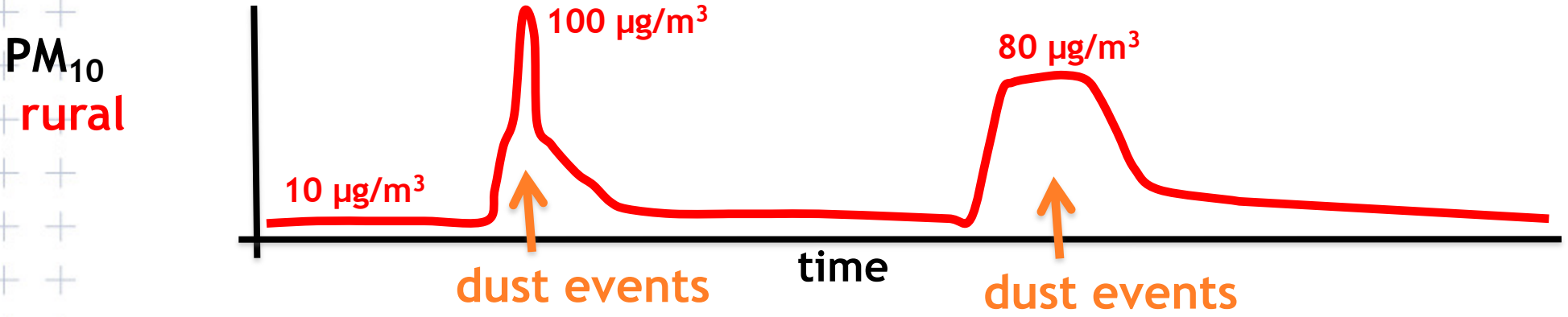
Recommended priorities

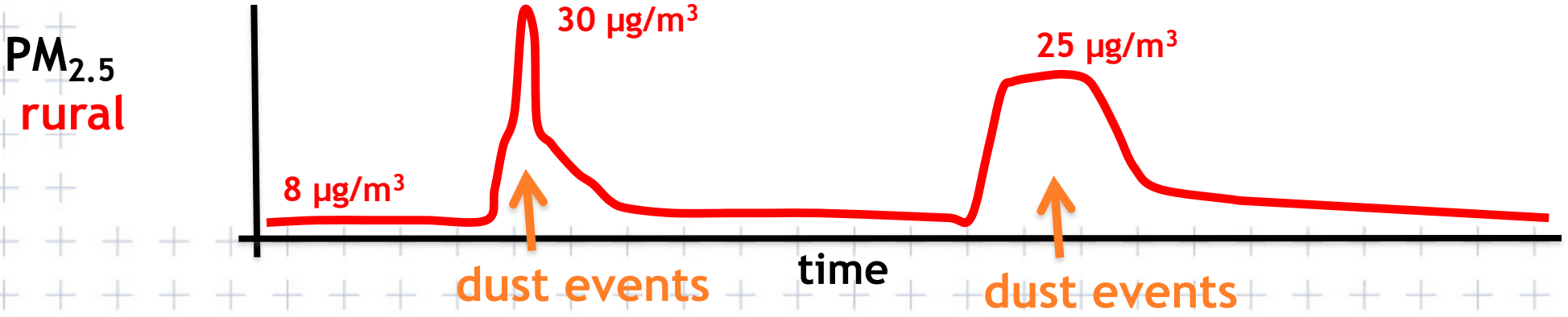
Level 1	-	PM_{10} and $PM_{2.5}$ levels - automatic methods
Level 1	-	meteorology (wind, T, RH, P, rain)
Level 2	-	PM_{10} and $PM_{2.5}$ levels – complementary gravimetric method
Level 3	-	gaseous pollutants: NO_x, SO_2 , CO,...
Level 4	-	PM_{10} and $PM_{2.5}$ chemical composition

Level 1

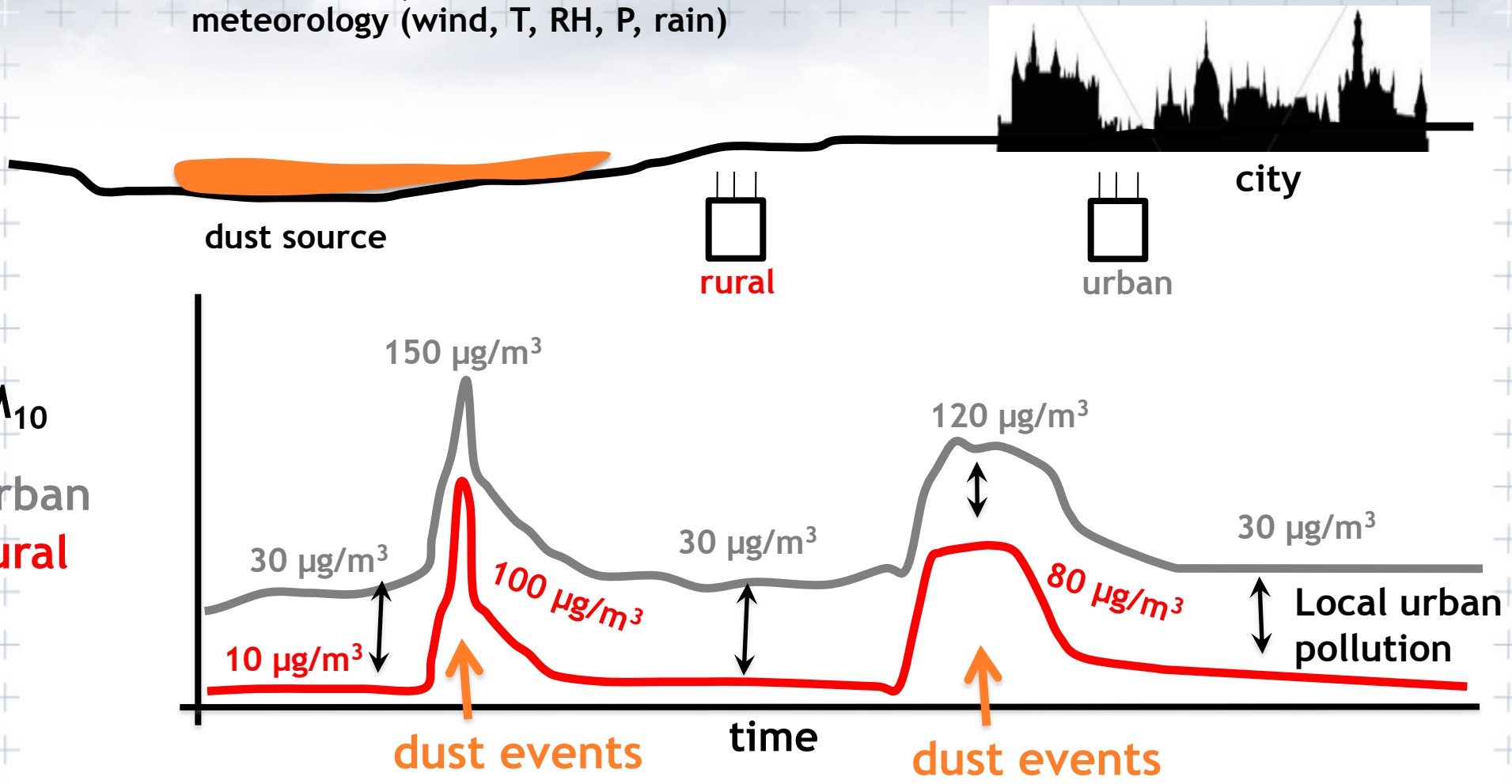
PM_{10} and $PM_{2.5}$ - automatic methods
meteorology (wind, T, RH, P, rain)



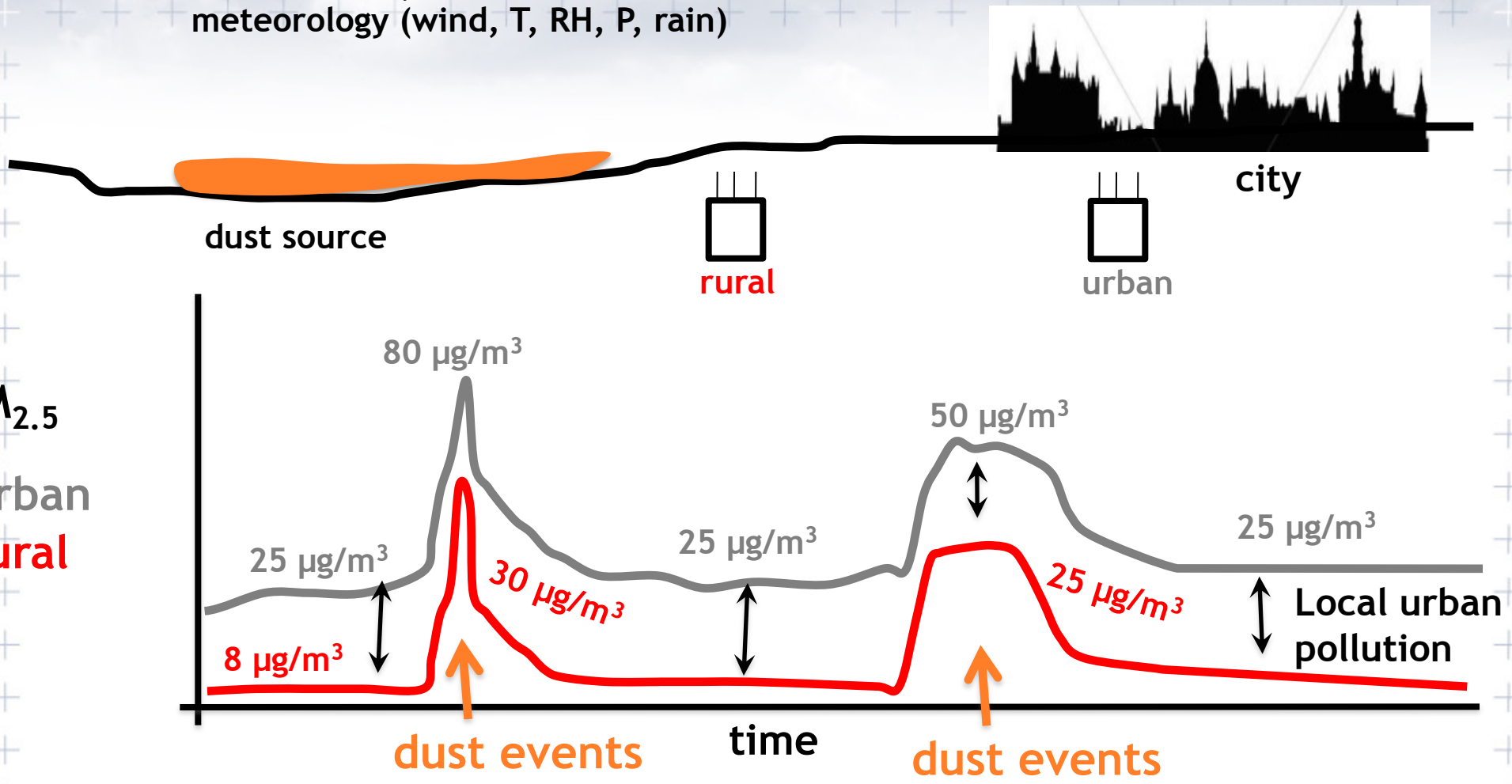




Level 1 PM_{10} and $PM_{2.5}$ - automatic methods meteorology (wind, T, RH, P, rain)



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



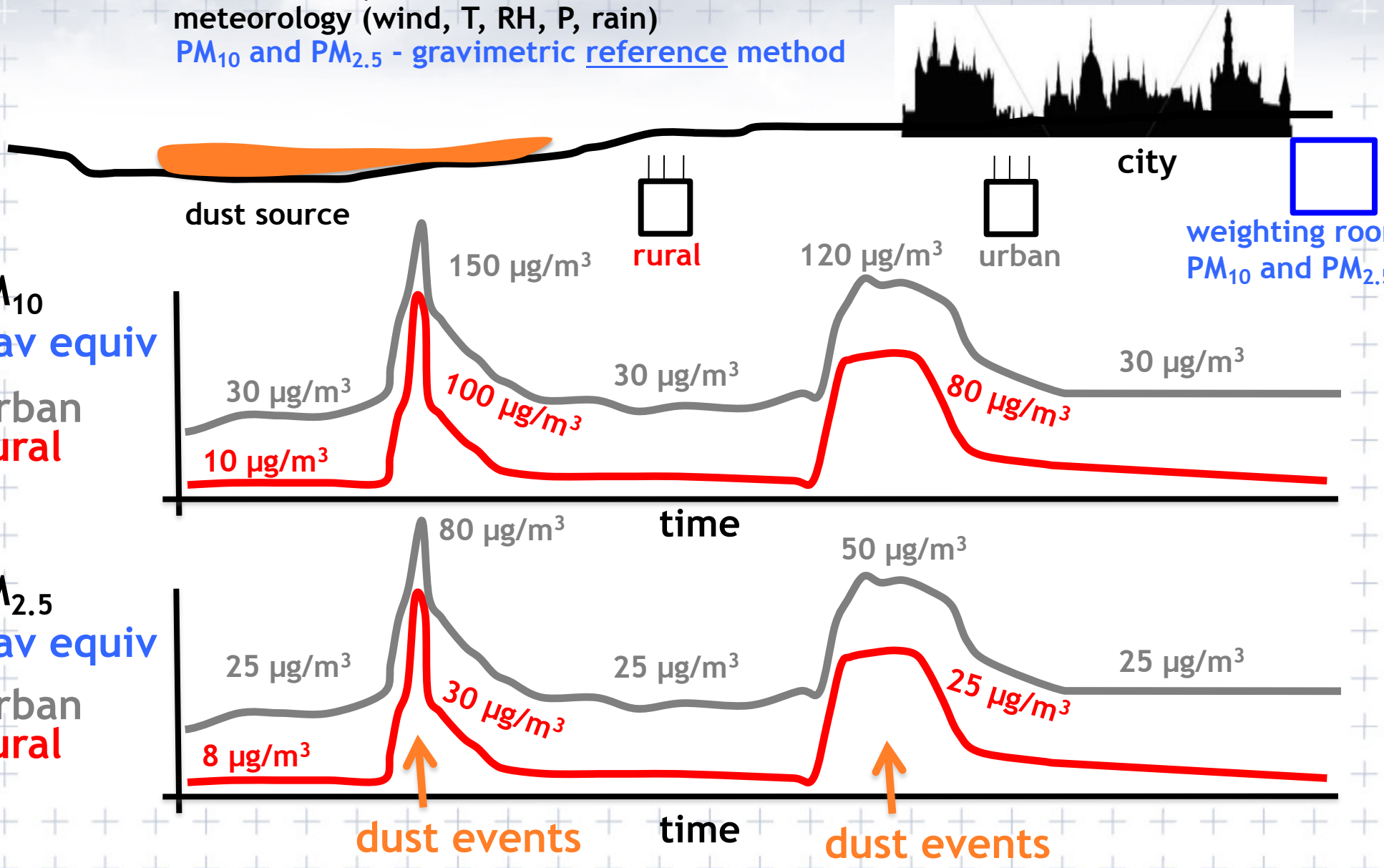
dust air quality

Recommended priorities

Level 1	-	PM_{10} and $PM_{2.5}$ levels - automatic methods
Level 1	-	meteorology (wind, T, RH, P, rain)
Level 2	-	PM_{10} and $PM_{2.5}$ levels – complementary gravimetric method
Level 3	-	gaseous pollutants: NO_x, SO_2 , CO,...
Level 4	-	PM_{10} and $PM_{2.5}$ chemical composition

Level 2

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



dust air quality

Recommended priorities

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

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

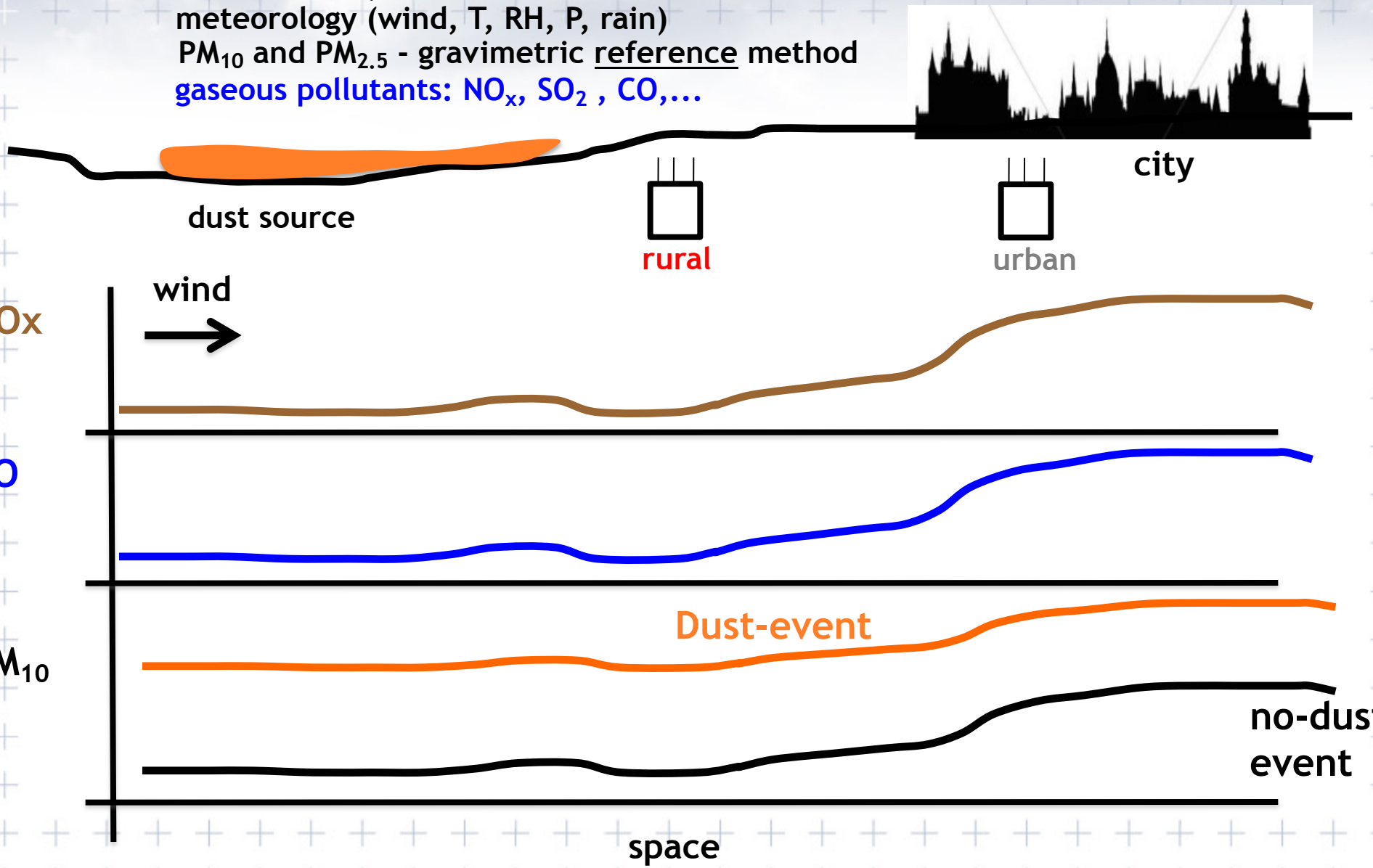
Level 2 - PM_{10} and $PM_{2.5}$ levels - complementary gravimetric method

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

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

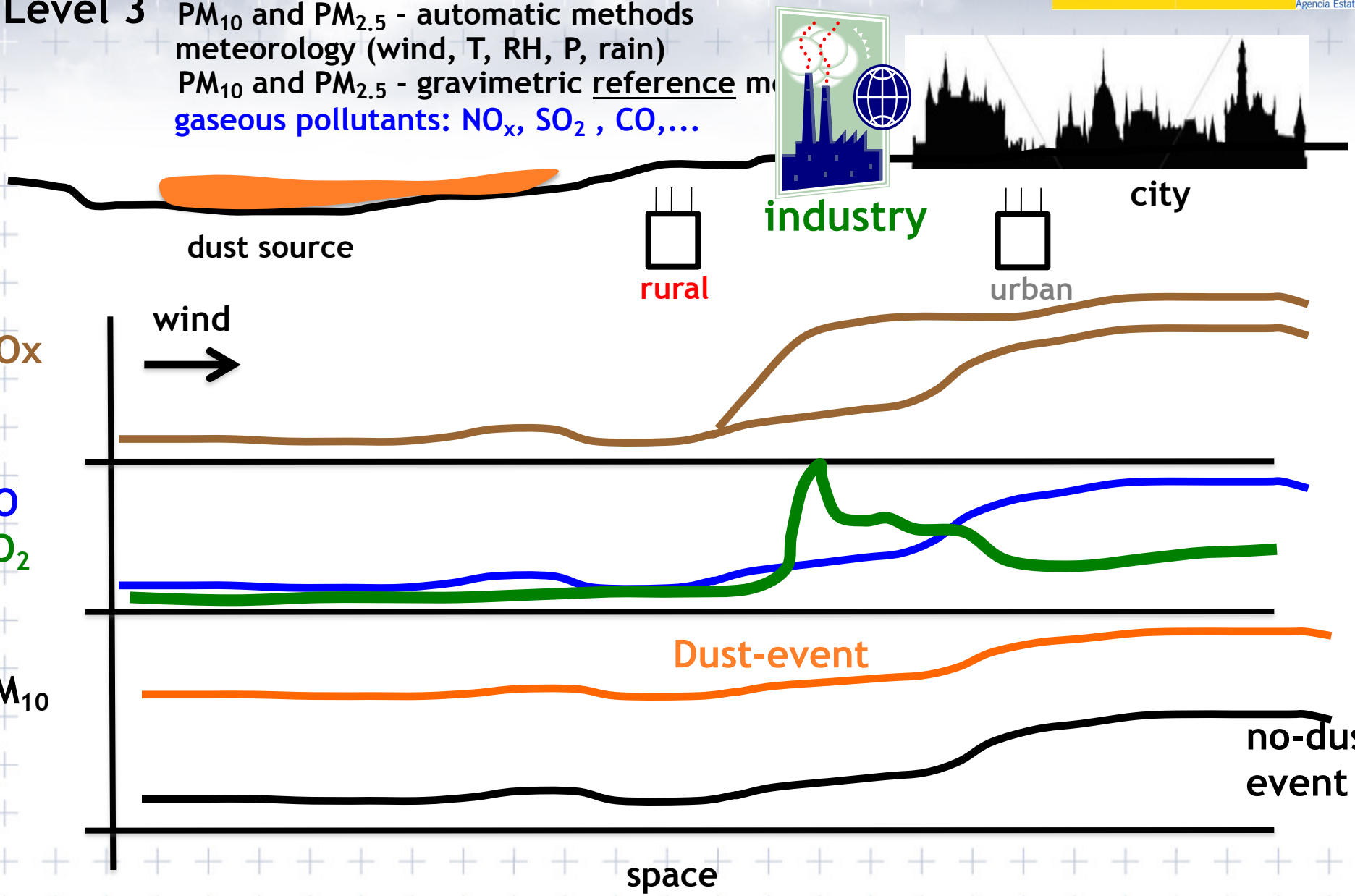
Level 3

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



Level 3

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



dust air quality

Recommended priorities

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

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

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

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

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

Level 4

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