Overview of environmental measurements: ATMOSPHERIC POLLUTION

Mar Viana, Xavier Querol and IDAEA-CSIC team
Institute for Environmental Assessment and Water Research, IDAEA, CSIC
Spanish Research Council
mar.viana@idaea.csic.es

Institute of Environmental Assessment and Water Research

http://www.idaea.csic.es/

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
SPANISH RESEARCH COUNCIL

Institute of Environmental Assessment and Water Research

IDAEA

Mission:

Study the natural and anthropogenically-induced changes in the ecosystems, mainly those involving toxicity increases in organisms and humans, by means of chemical and geochemical techniques

Leading roles in the application of:

- analytical chemistry
- geochemistry and hydrology
- molecular biology
- methods for the study of environmental problems

Departamental structure:

2 departments:

- Environmental Chemistry
- Geosciences

Outline

1. Atmospheric pollution
2. The problem of NO_2
3. Measurement methods for NO_2
4. The problem of PM
5. Measurement methods for PM
6. Conclusions

Atmospheric pollution

RD, 102/2011, 28th January, for Air Quality & Protection of the Atmosphere:

"Atmospheric Pollution": The occurrence in atmosphere of matter, substances or energy that may imply risk or damage for the safety or health of human beings, the environment……..."

Bearing in mind:

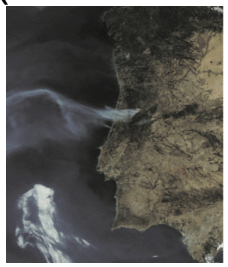
- **Not all harmful substances in atmosphere are already known**
- **For some components there is not a threshold for human protection**
- **Many activities and process (natural and anthropogenic) emit atmospheric pollutants**

Atmospheric pollution: Origin

Wind re-suspension

Al_2O_3
Mg
Ti
Fe
K
SiO_2
CO_3^{2-}
P
Ca

Traffic, fires
(OM and EC), gases



Industry
NH_4^+
SO_4^{2-}
NO_3^-
Gases

Wind emission
Na^+
Cl^-
SO_4^{2-}

Industry, traffic
As, Ba, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Ga, Gd, Ge, Hf, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Th, Ti, Tl, U, V, W, Yb, Zn, Zr

Atmospheric pollution

ATMOSPHERIC DIFUSION OR DISPERSION

Emission characteristics

Pollutant load

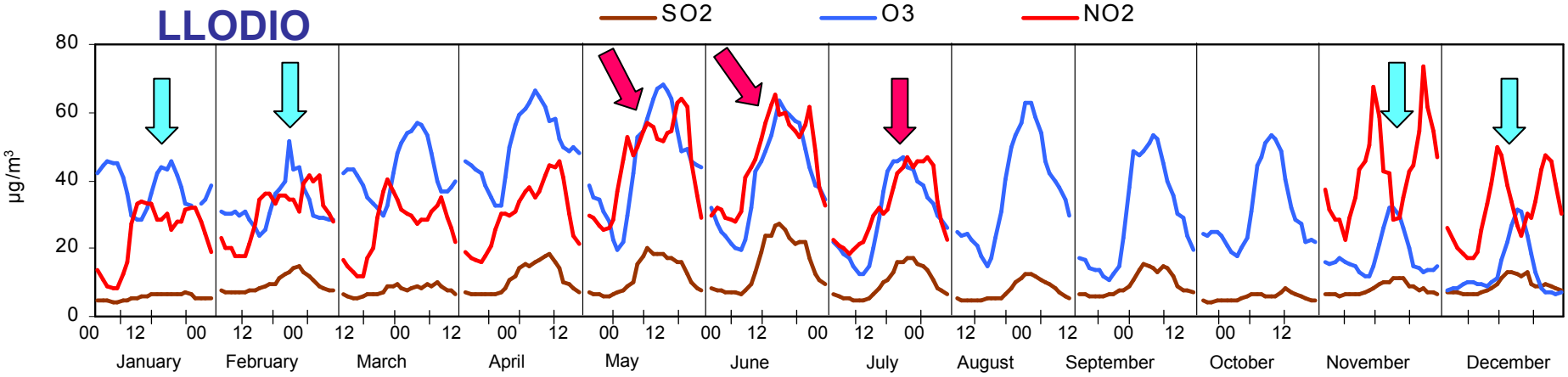
T, V and height of emission

Meteorological features

Atmospheric stratification, W-V, W-D, convection

Topographic and local effects

Marine and slope breeze, topographic obstacles



Atmospheric pollution

ENVIRONMENTAL STRANDARDS FOR AIR QUALITY

Emission

DIRECTIVES

1996/61/EC, 2008/1/EC
2002/51/EC, 2006/120/EC
1998/69/EC, 2002/80/EC, 2007/715/EC

- **IPPC Integrated Prevention and Pollution Control**
- **EURO standards for vehicles**

Ambient air

MOTHER DIRECTIVE
1996/62/CE

- **Evaluation and Managing of air quality**
  Annex I: SO_2, NO_2, NOx, PM10, TSP, Pb, O_3, benzene, CO, PAH, Cd, As, Ni, Hg

Directive 1999/30/EC — **SO_2, NO_2, NOx, PM_{10}, Pb ($PM_{2.5}$??)**
Directive 2000/69/EC — **benzene, CO**
Directive 2002/03/EC — **O_3**
Directive 2004/107/EC — **PAH, Cd, As, Ni, Hg**

(PM2.5) → **Directive Clean Air for Europe and Air Quality, 2008/50/EC & 2004/107/EC**

Deadlines: 2005-2010, 2015, 2020

↓

RD, 102/2011 (Spanish legisltaion)

REVISION IN 2013

Atmospheric pollution

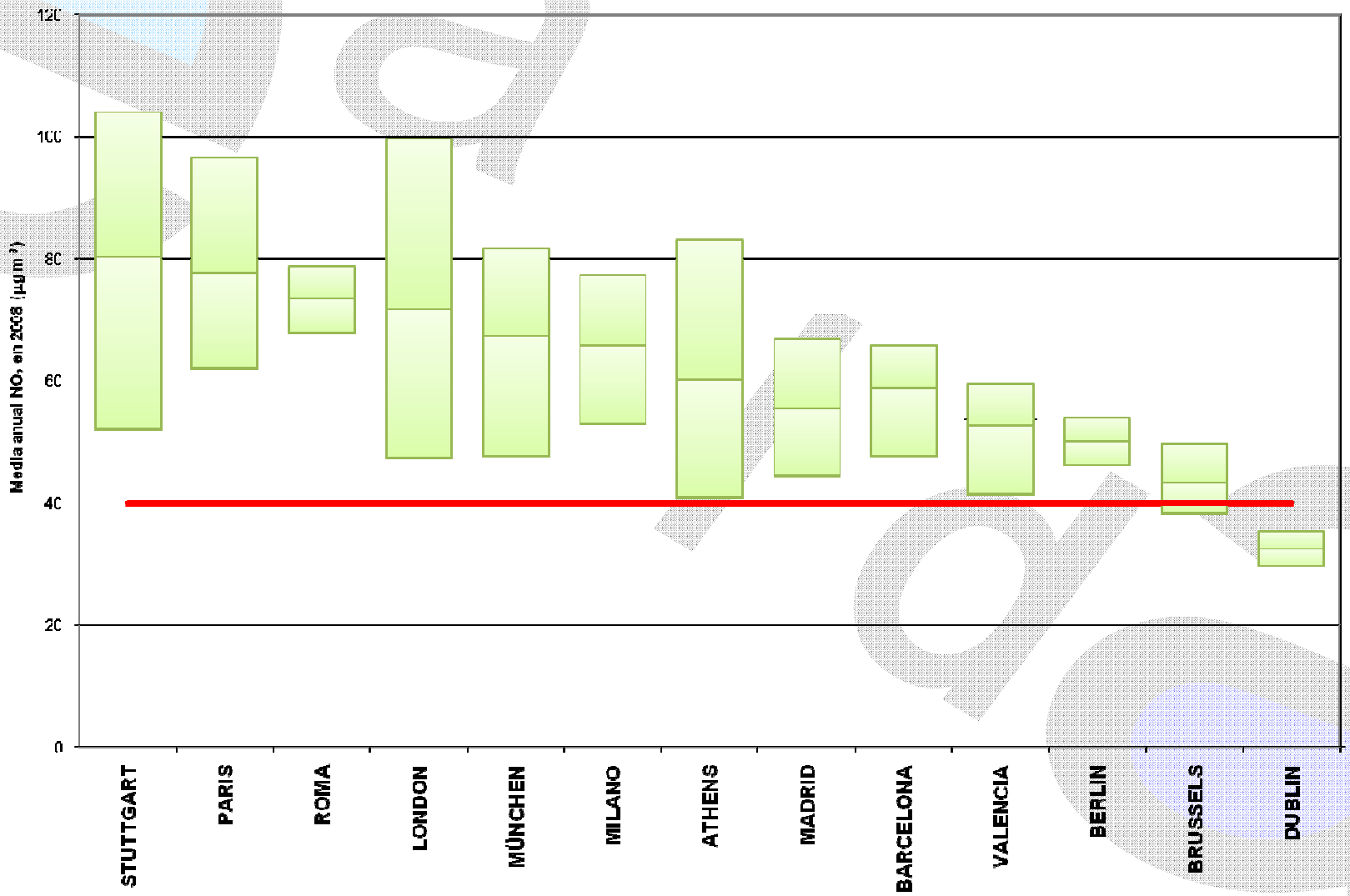
ENVIRONMENTAL STRANDARDS FOR AIR QUALITY

			293 °K , 101,3 kPa,
Directive 2008/50/EC, RD 102/2011			except PM and metals, Evriron. Cond.
Hourly	350 µg/m³	SO_2	24 times per year
Daily	125 µg/m³	SO_2	3 times per year
Annual prot. ecos.	20 µg/m³	SO_2	not exceeding annual and mean 1 Oct-31 Mar
Hourly	200 µg/m³	NO_2	18 times per year
Annual	40 µg/m³	NO_2	not exceeding
Annual prot. vegetation	30 µg/m³	NO_x	(reported as NO_2) not exceeding
Annual	30 (5) µg/m³	Benzene	not exceeding
Mean 8-h max. in a day	10 mg/m³	CO	not exceeding
Annual	500 ng/m³	Pb	not exceeding
Annual	40 µg/m³	PM_{10}	not exceeding
Daily	50 µg/m³	PM_{10}	n<35 per year
Annual	(25 and 20 (18) µg/m³	$PM_{2.5}$)	not exceeding
2010-2020	(reducing 20% $PM_{2.5}$ triennial for mean of urban background)		
2004/107/EC, RD 102/2011			
Annual	6 ng/m³	As	not exceeding
Annual	20 ng/m³	Ni	not exceeding
Annual	5 ng/m³	Cd	not exceeding
Annual	1 ng/m³	Benzo[α]pirene	not exceeding

Critical parameters (exceedances)

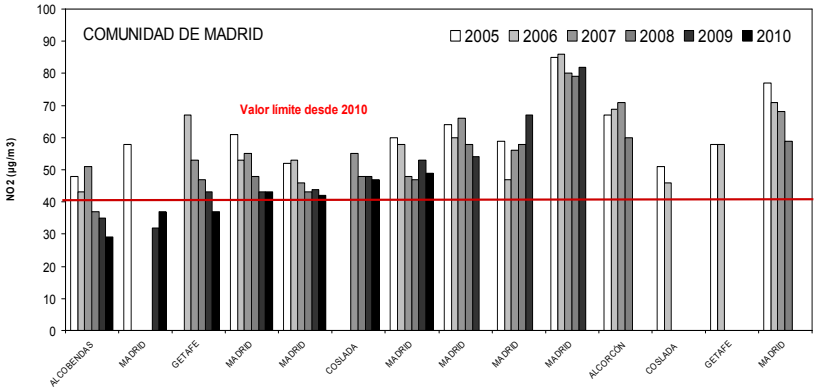
The problem of NO_2

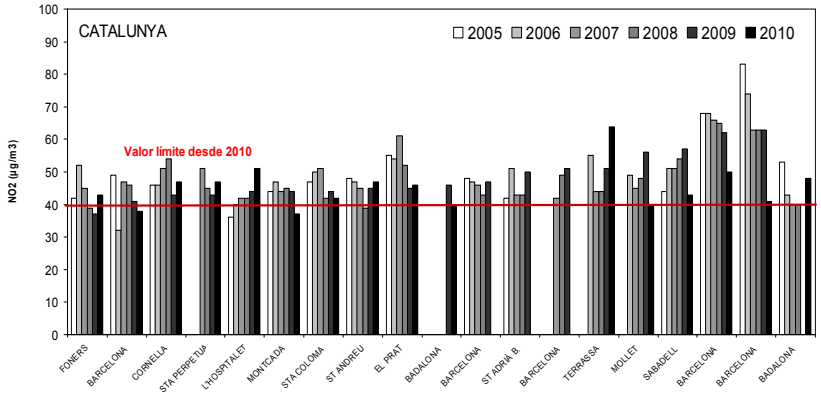
The problem of NO_2

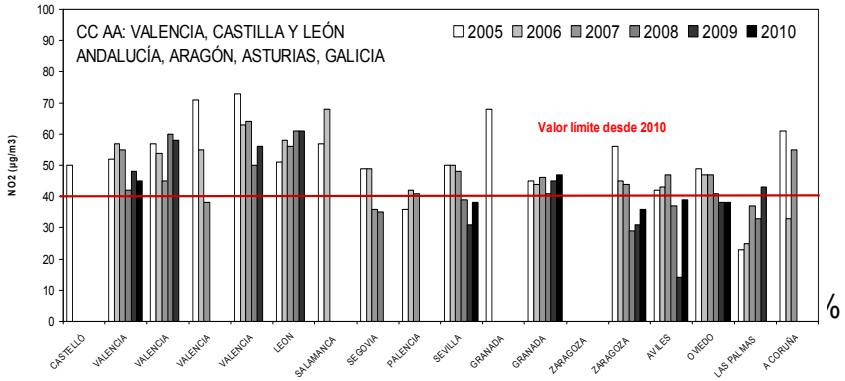


Comparación de los niveles de NO_2 en estaciones de tráfico en ciudades importantes de Europa en el 2008

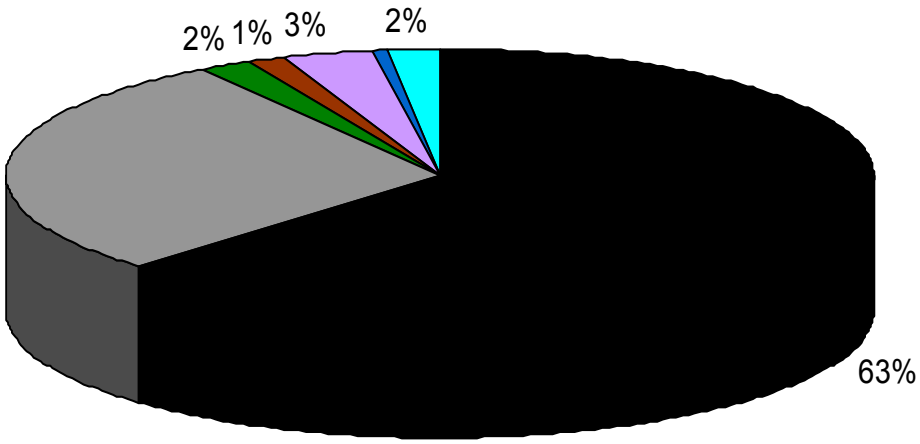
The problem of NO_2







Causas de superación del VLA de NO_2: promedio 2001-2009 (53 estaciones)



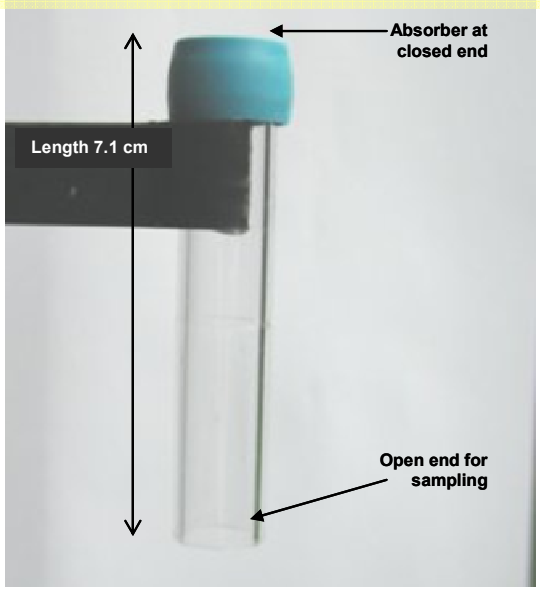
- Heavy traffic
- Proximity to a major road
- Local industry
- Quarrying/mining
- Domestic heating
- Industrial accident
- Non-industrial accident
- Natural source
- Winter sanding
- African dust
- Local petrol station
- Parking facility
- Benzene storage
- Industry

Measurement methods for NO_2

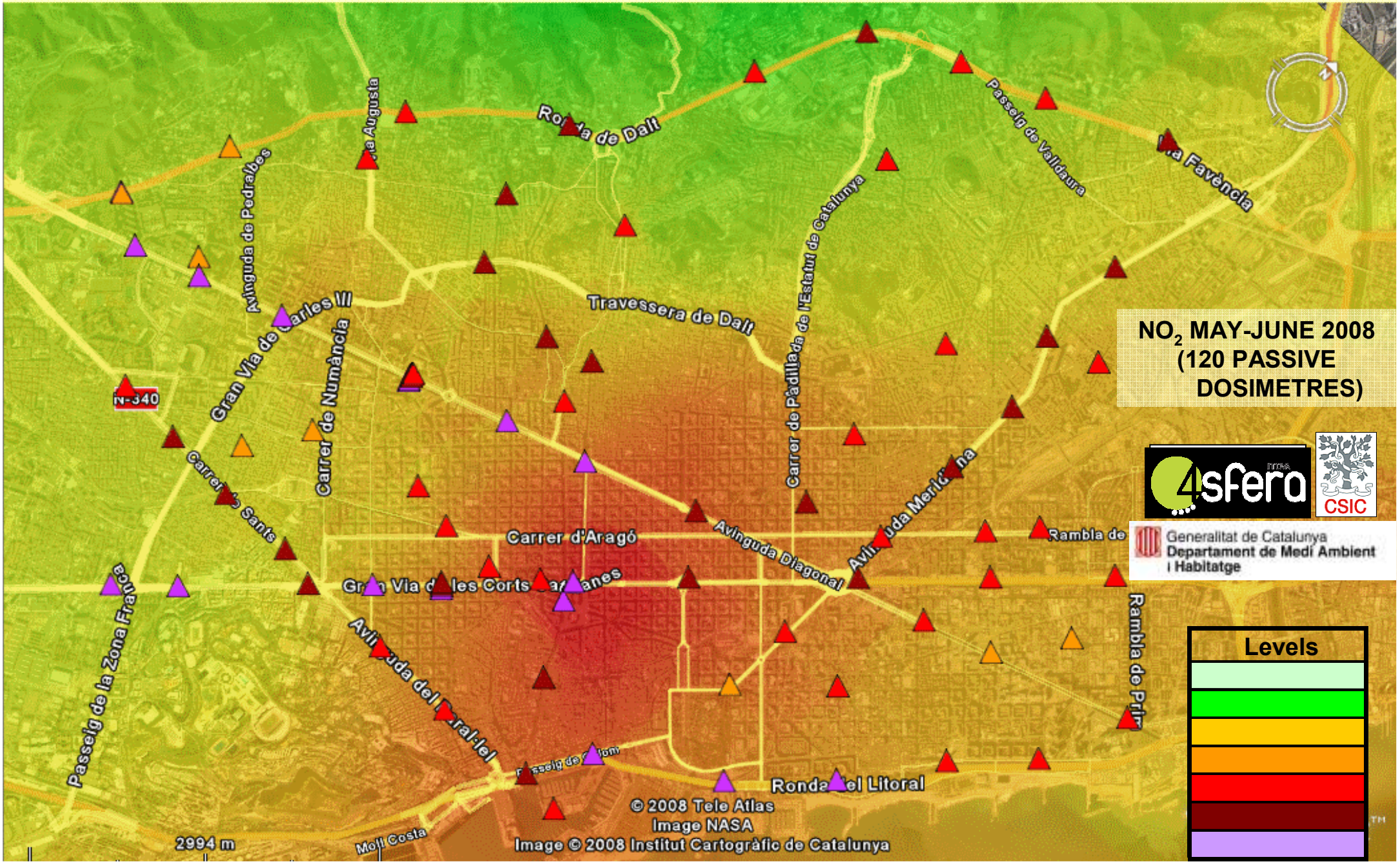
Measurement methods for NO_2

- Conventional NO_2 monitor
- Usually, chemiluminescence

- Dosimeter NO_2
- Molecular diffusion
- Analysis: colorimetry

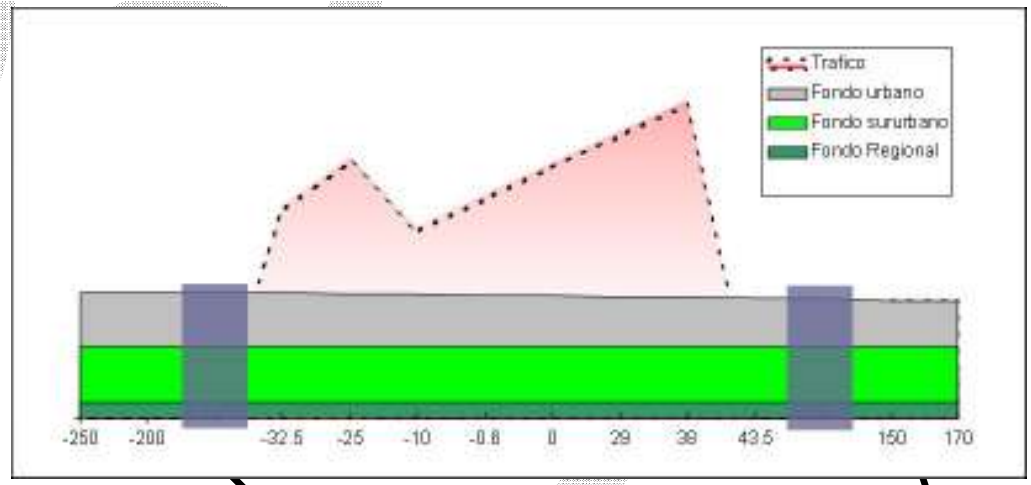


The problem of NO_2



The problem of NO_2

NO_2, high spatial variability

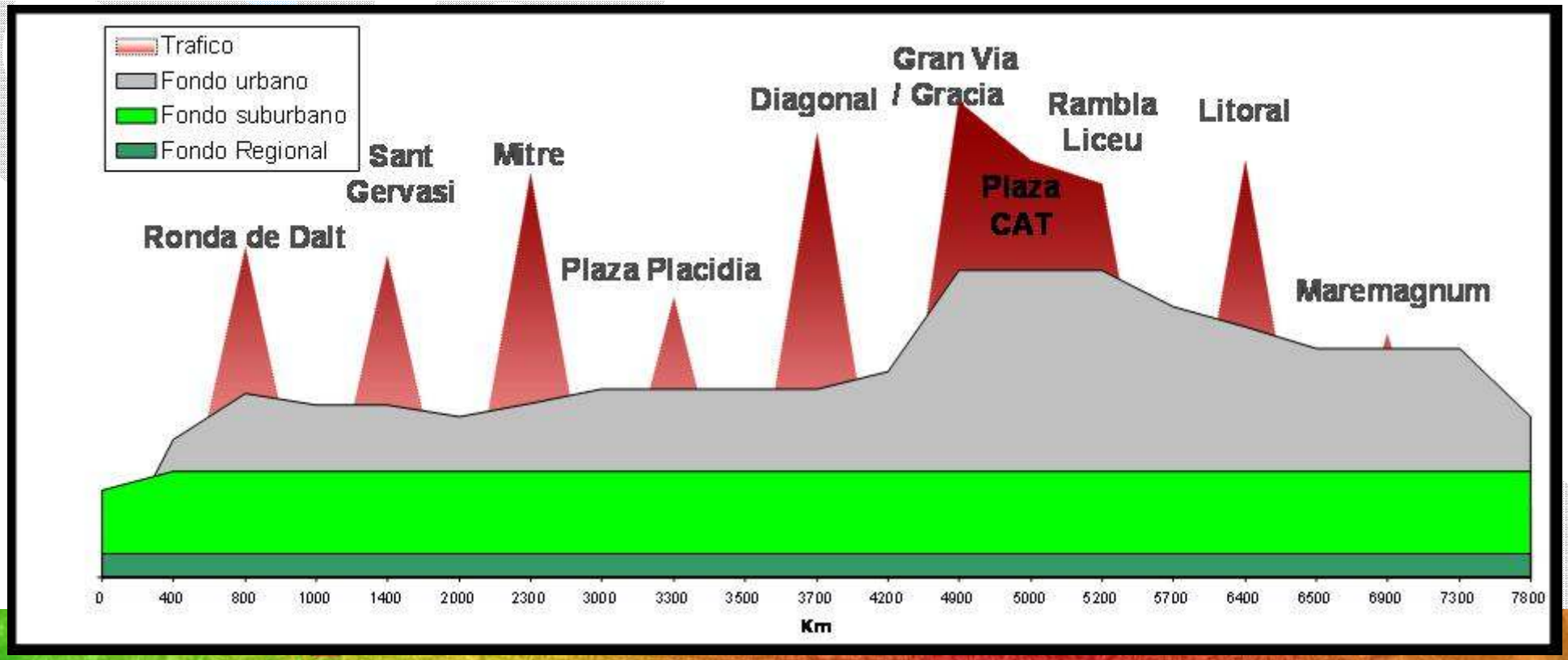


Generalitat de Catalunya
Departament de Medi Ambient i Habitatge

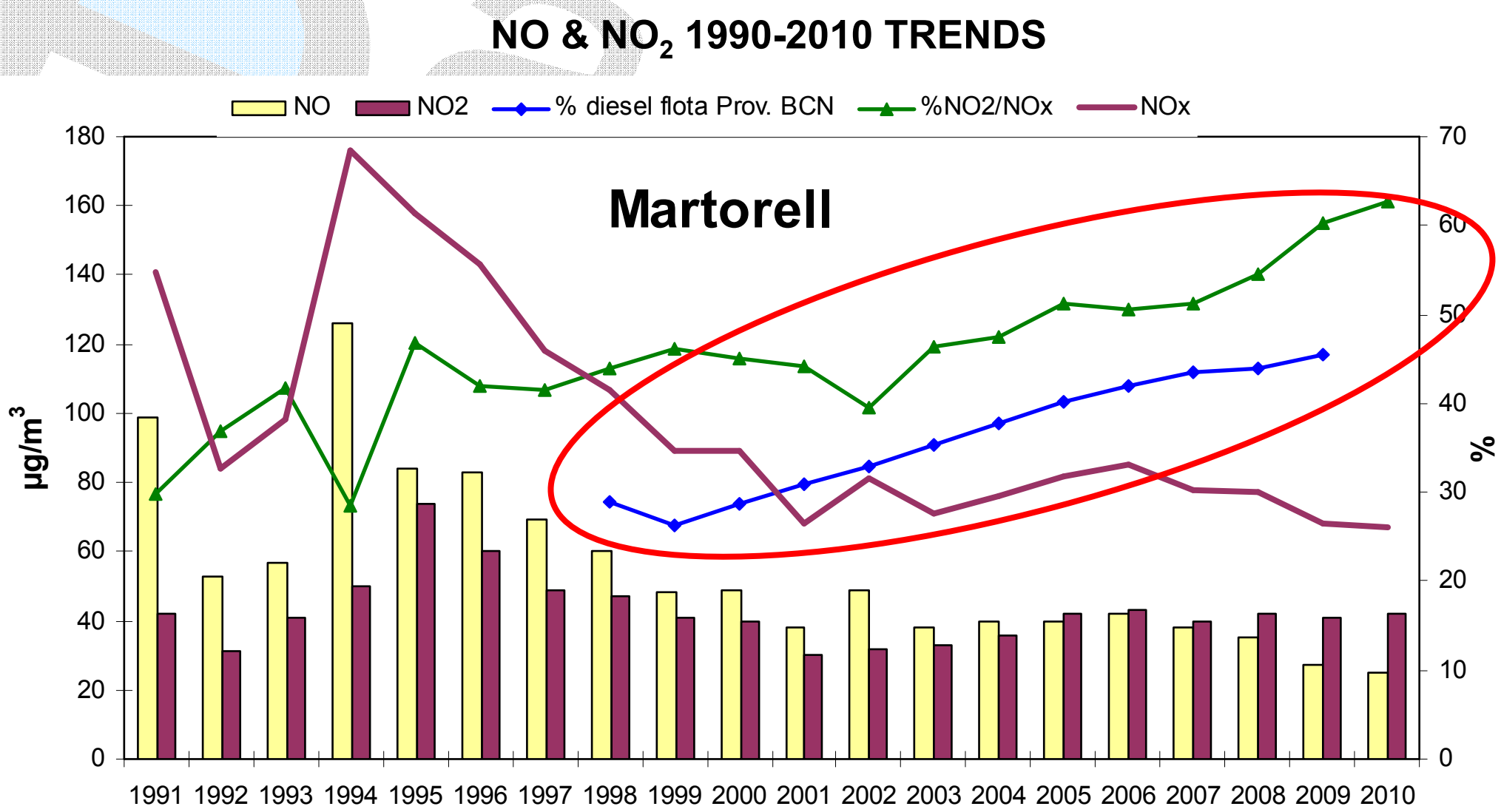
The problem of NO_2

NO_2 MAY-JUNE 2008 (120 PASSIVE DOSIMETRES)

Fabra - Barceloneta

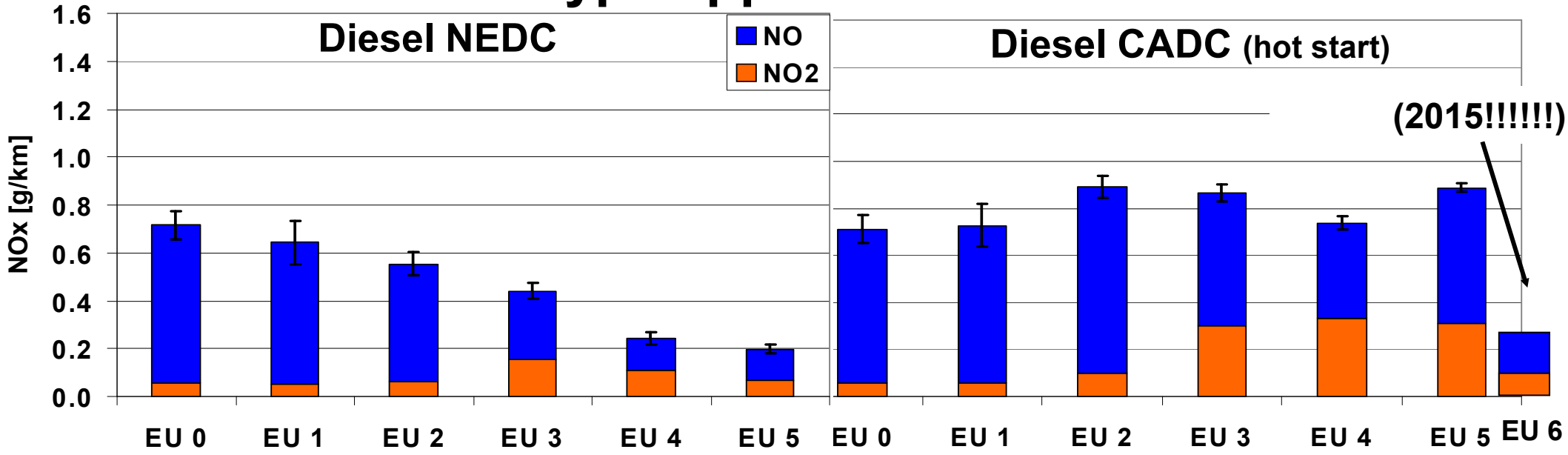


The problem of NO_2



The problem of NO_2

Actual emissions: type approval vs.real world emissions



NEED FOR HIGH-TIME RESOLVED, PORTABLE LOW-COST MONITORS/SENSORS

Courtesy: Prof. Dr. S. Hausberger T.U. Graz

The problem of PM

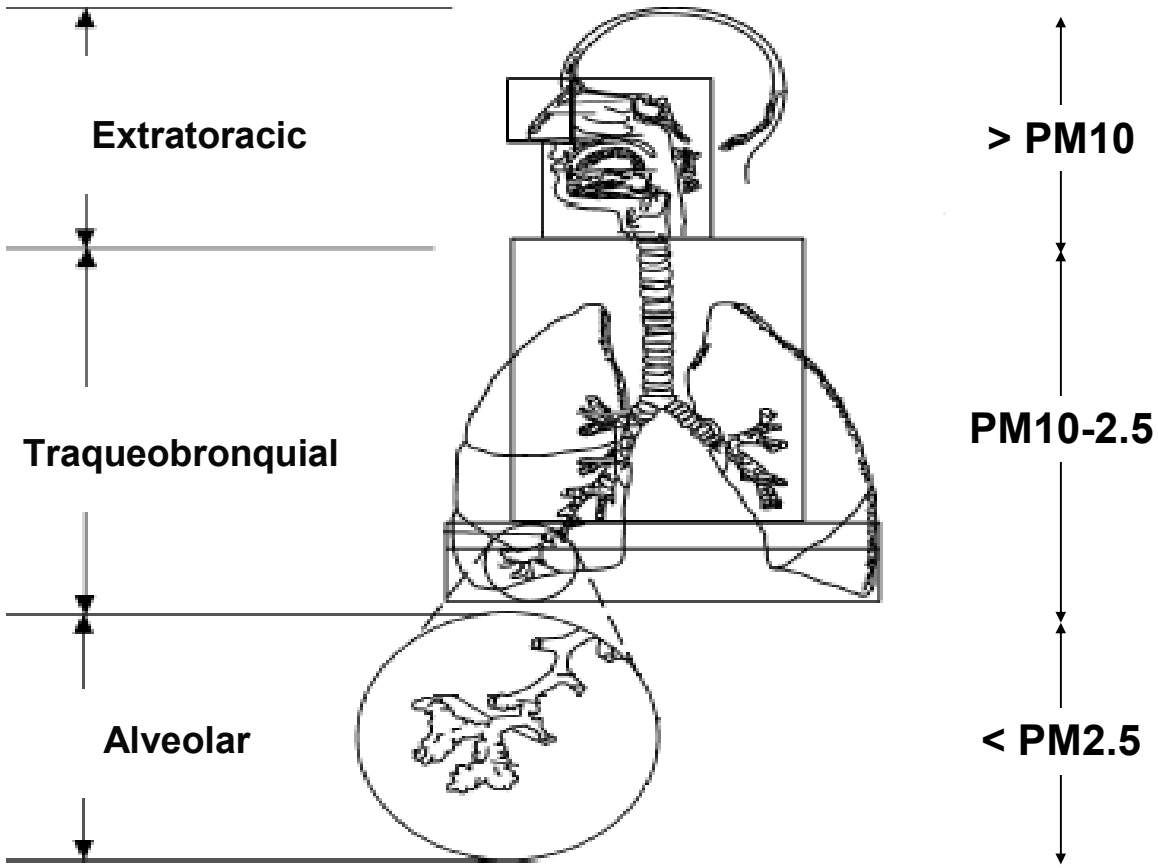
The problem of PM

Atmospheric particulate matter (PM): **heterogeneous solid and/or liquid material present in suspension into the atmosphere**

- **Health impact**
- **Ecosystems**
- **Climate change**
- **Building materials**
- **Visibility**

The problem of PM

PM EFFECTS



PM10-2.5
Allergens,
inflammation, oxidative stress
Happo et al., 2008
Javala et al., 2008
Pérez et al., 2009

PM2.5-0.1
Additional lung physical effect

PM0.1
Cardiovascular, UFPM
Reaching all important organs

The problem of PM

Particulate Matter and health effects in Barcelona

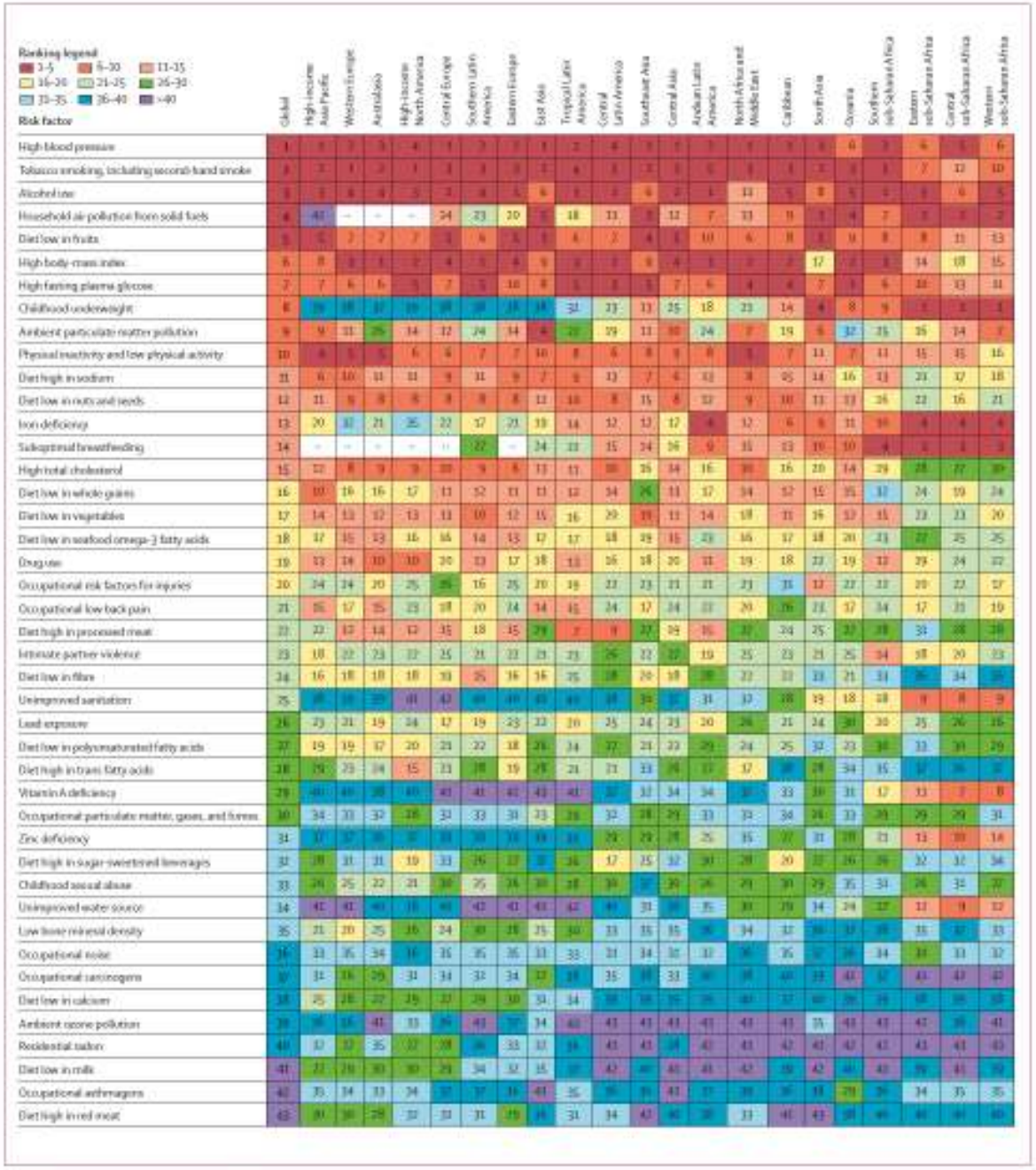
Perez et al., 2009 ES&T

Selected results

Fraction	Respiratory mortality (Lag2)	Cardiovascular mortality (Lag1)	Cerebrovascular mortality (Lag1)
$PM_{10-2.5}$	1.033 (0.980-1.089)	**1.059 (1.026-1.094)**	**1.098 (1.030-1.171)**
$PM_{2.5-1}$	**1.206 (1.028-1.416)**	0.984 (0.892-1.086)	0.905 (0.743-1.102)
PM_1	1.010 (0.963-1.059)	**1.028 (1.000-1.058)**	**1.063 (1.004-1.124)**

Odds ratio per 10 ug/m3

The problem of PM



Risk factors ranked by attributable burden of disease for 2010

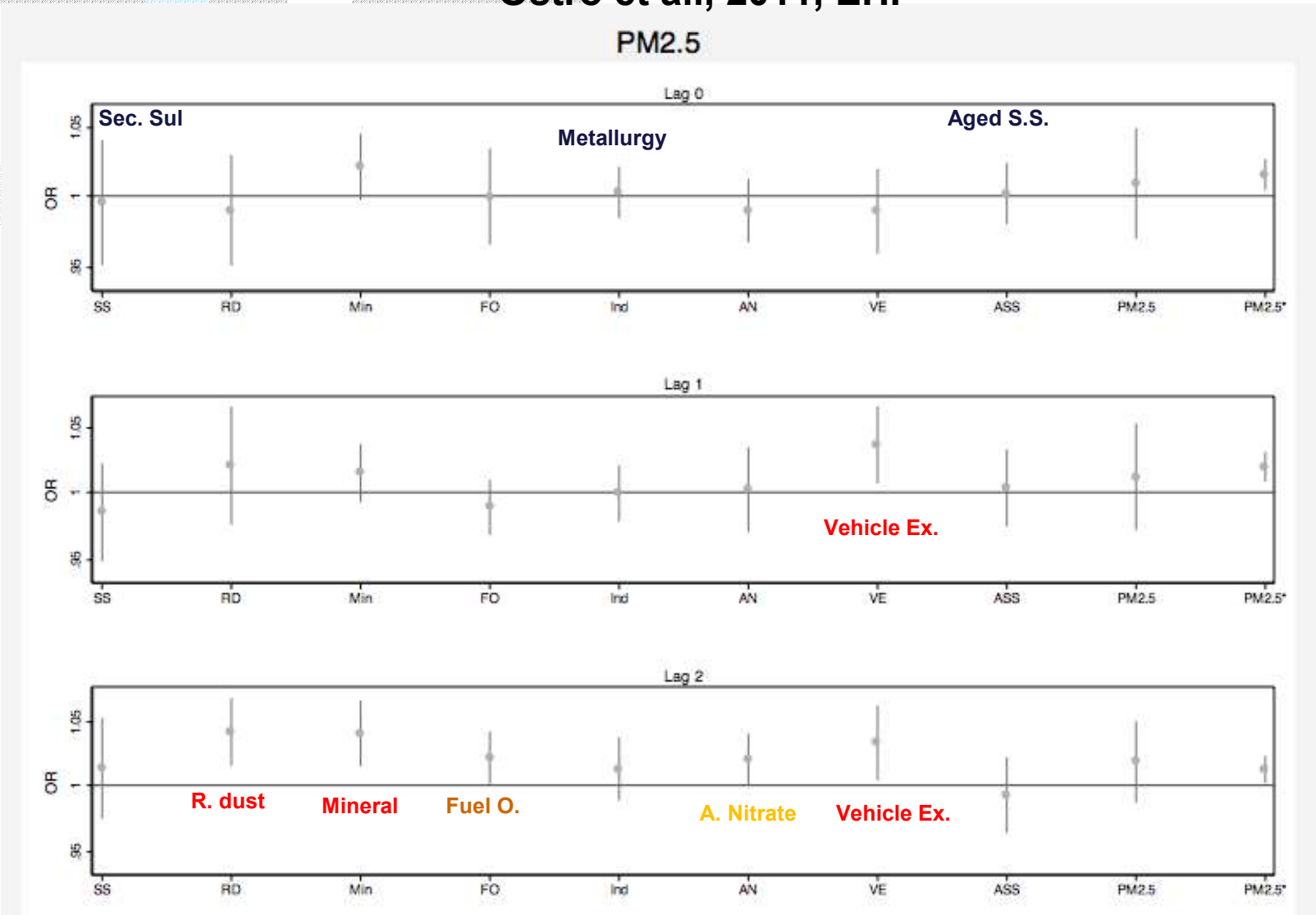
***Lim S.S., Lancet* 2012; 380: 2224–60**

December 2012

The problem of PM

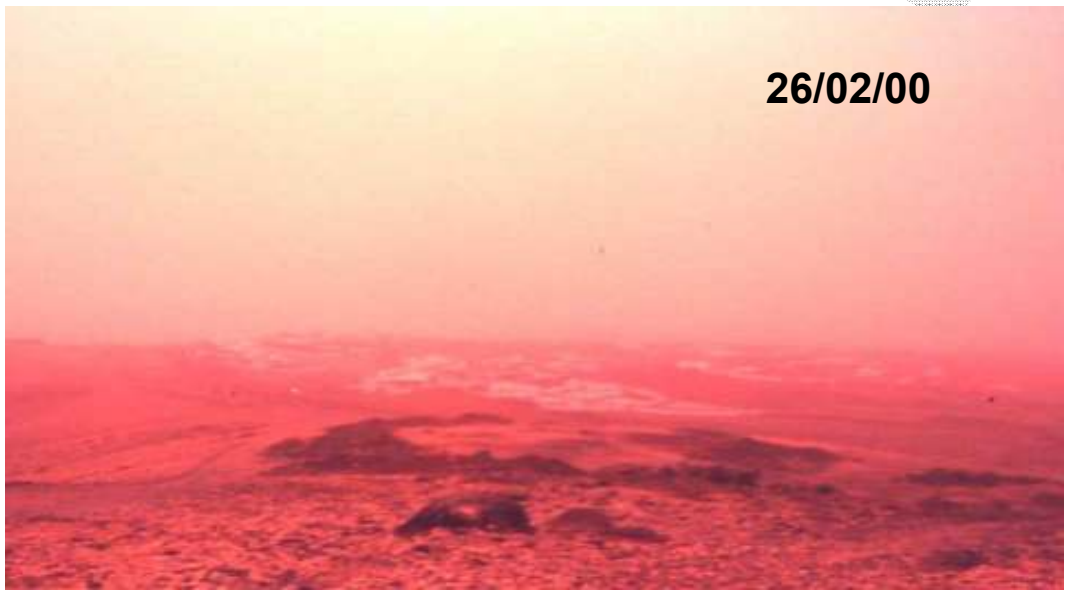
Source apportionment and mortality (Barcelona 2002-2007)

Ostro et al., 2011, EHP



The problem of PM

PM EFFECTS

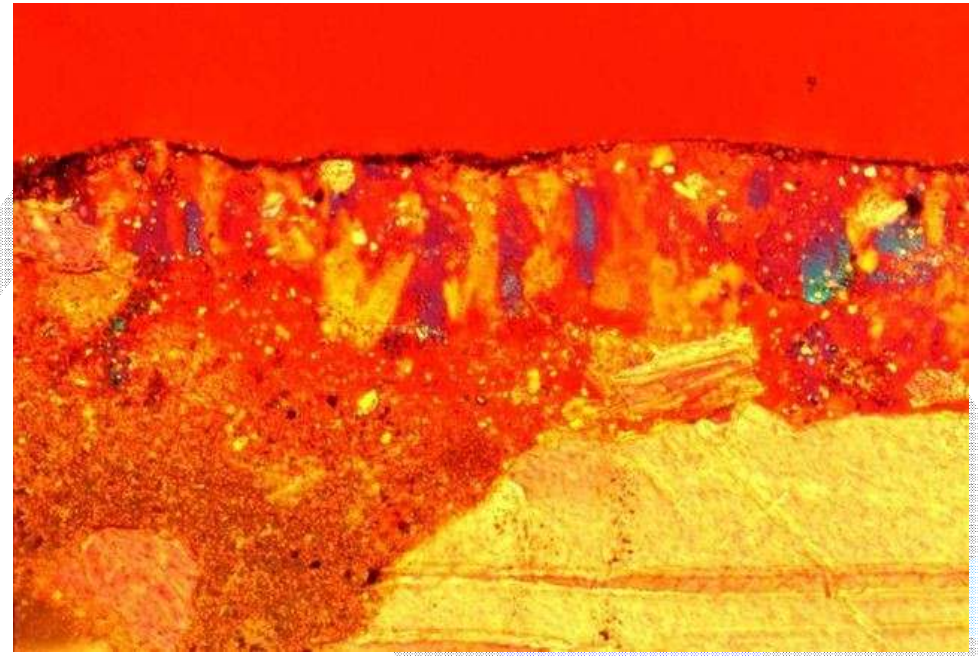


VISIBILITY

The problem of PM

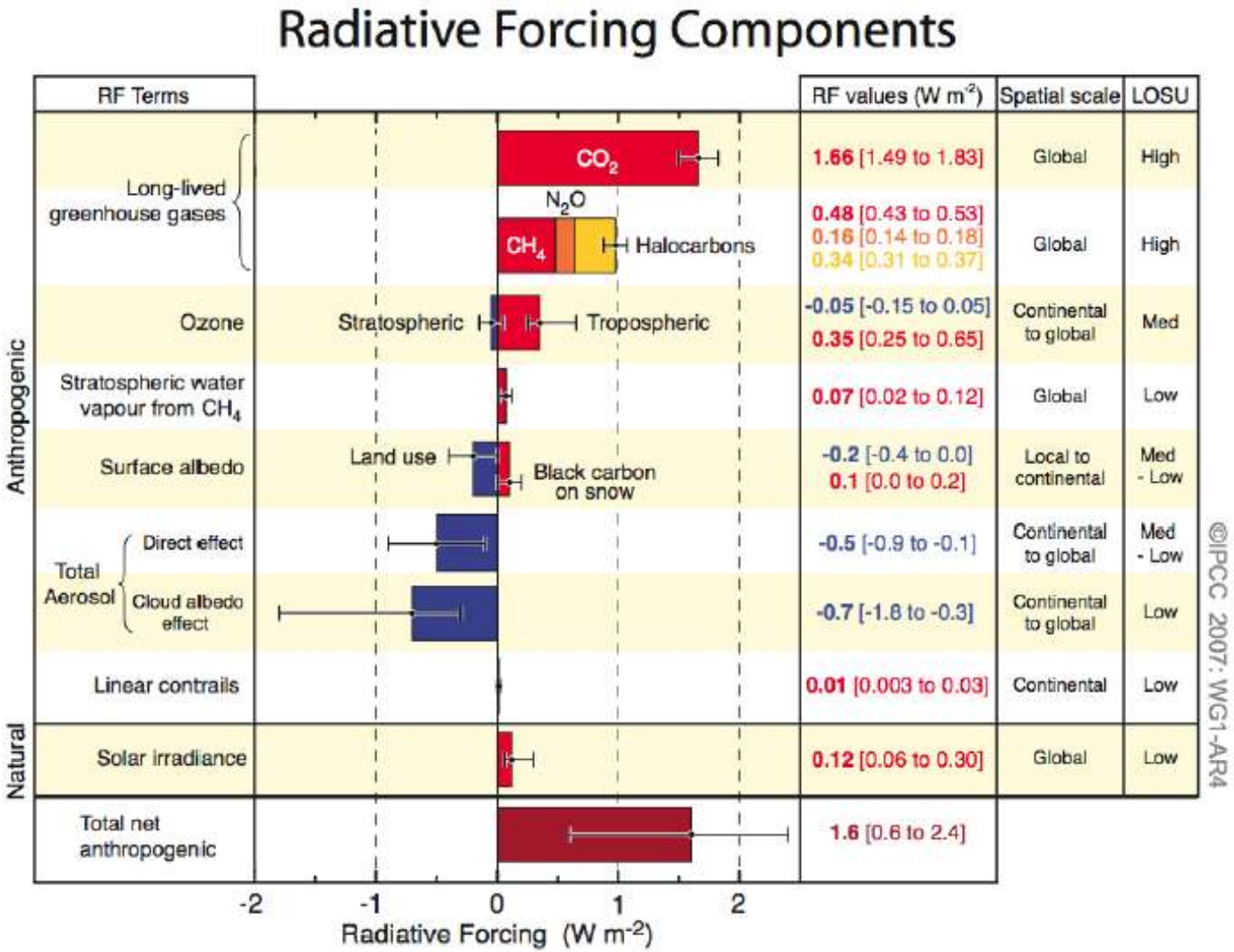
PM EFFECTS

Weathering of building materials



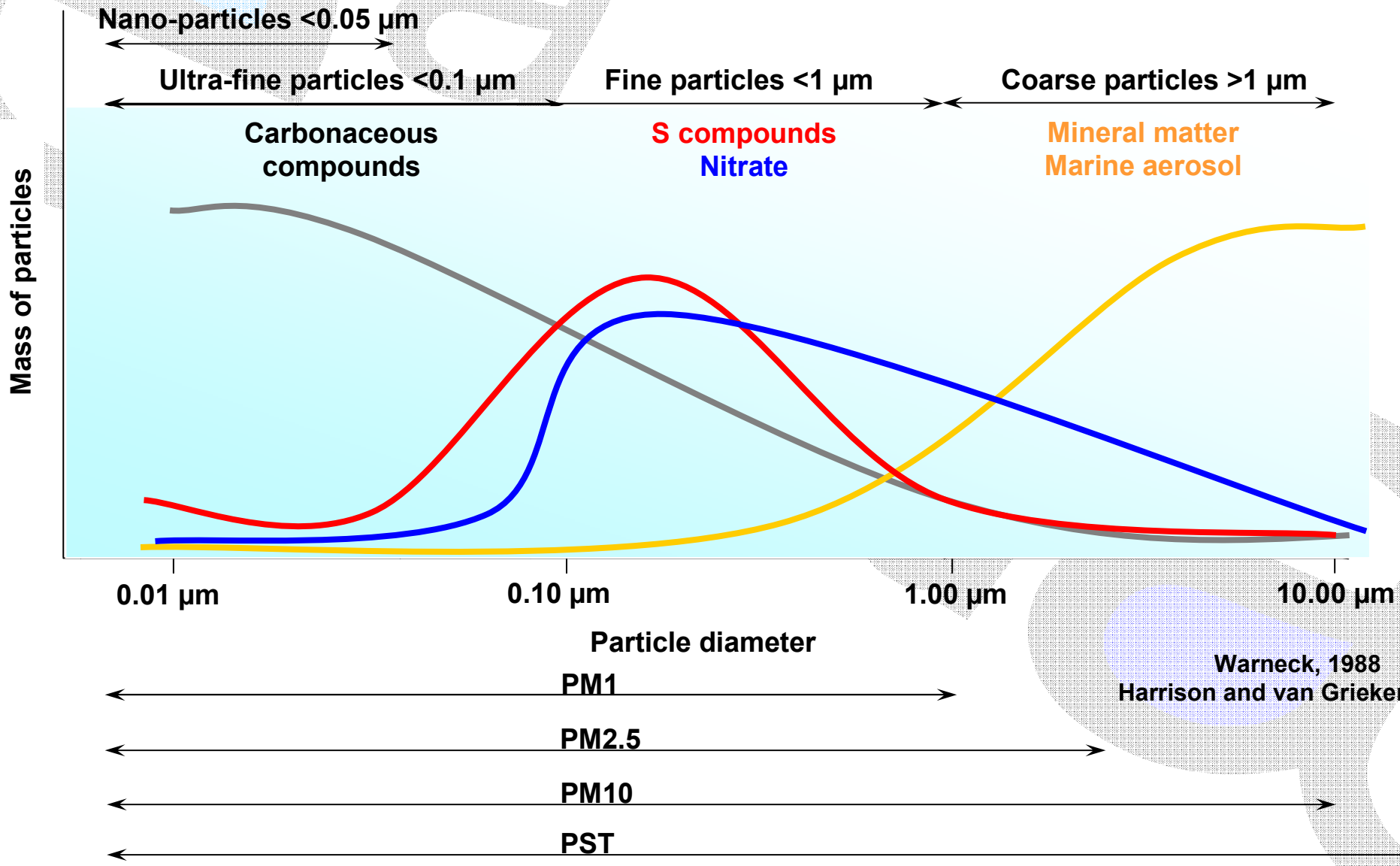
The problem of PM

EFFECT ON CLIMATE, IPCC (2007)



The problem of PM

PM CHARACTERISTICS



Warneck, 1988
Harrison and van Grieken, 1998

The problem of PM

CLASSIFICATION OF ATMOSPHERIC PARTICLES

1. Process of formation:

Primary particles: directly emitted to the atmosphere as a solid

Secondary particles: produced into the atmosphere from gaseous precursors

example: $SO_2\ (g) \xrightarrow[\text{oxidation}]{} SO_4^{2-}\ (s)$

2. Origin:

Natural particles

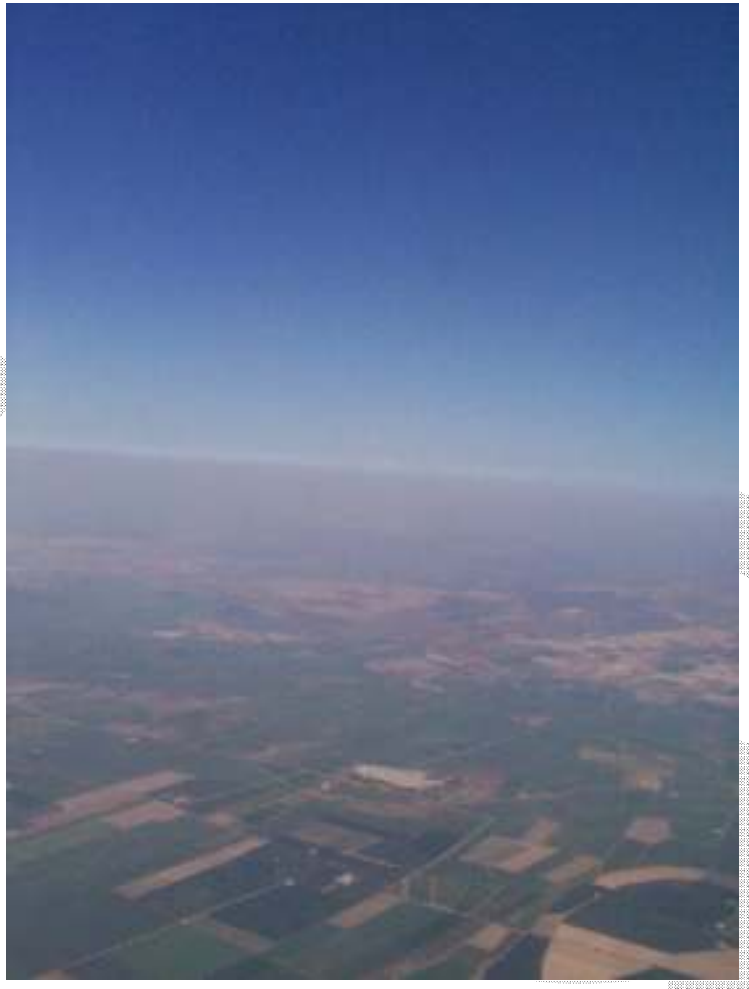
Anthropogenic particles (human activities)

The problem of PM

PRIMARY PM

The problem of PM

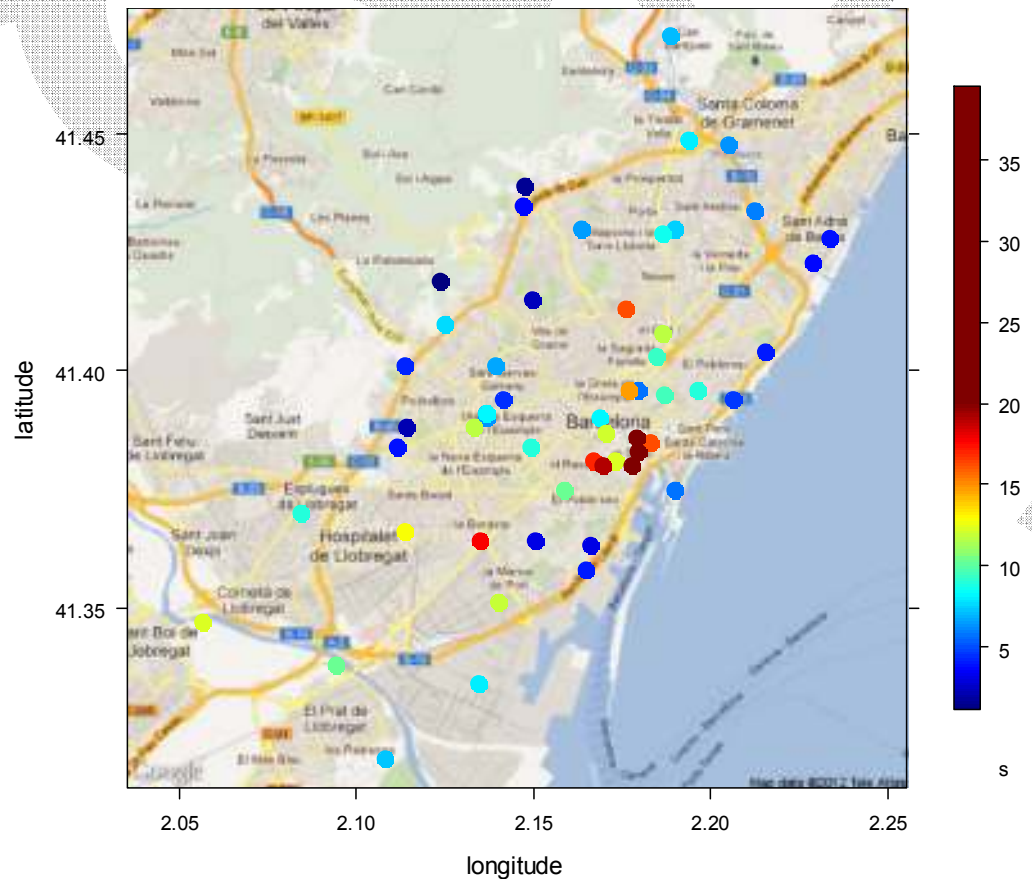
SECONDARY PM



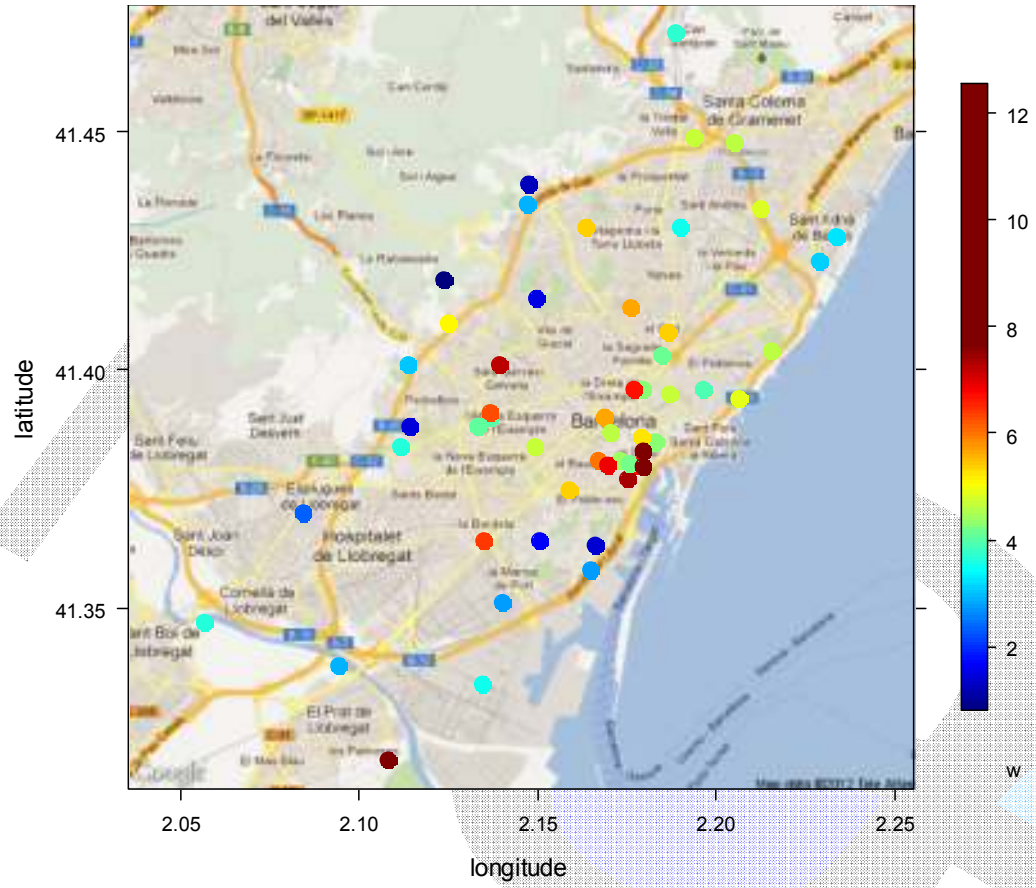
The problem of PM

URBAN AMMONIA

NH_3 (μgm^{-3})
Summer 2010



NH_3 (μgm^{-3})
Winter 2010



Atmospheric pollution

EMISSION SOURCES AND TRACERS

Stationary sources combustion

Power plants, heating, industry

Industrial processes, incineration

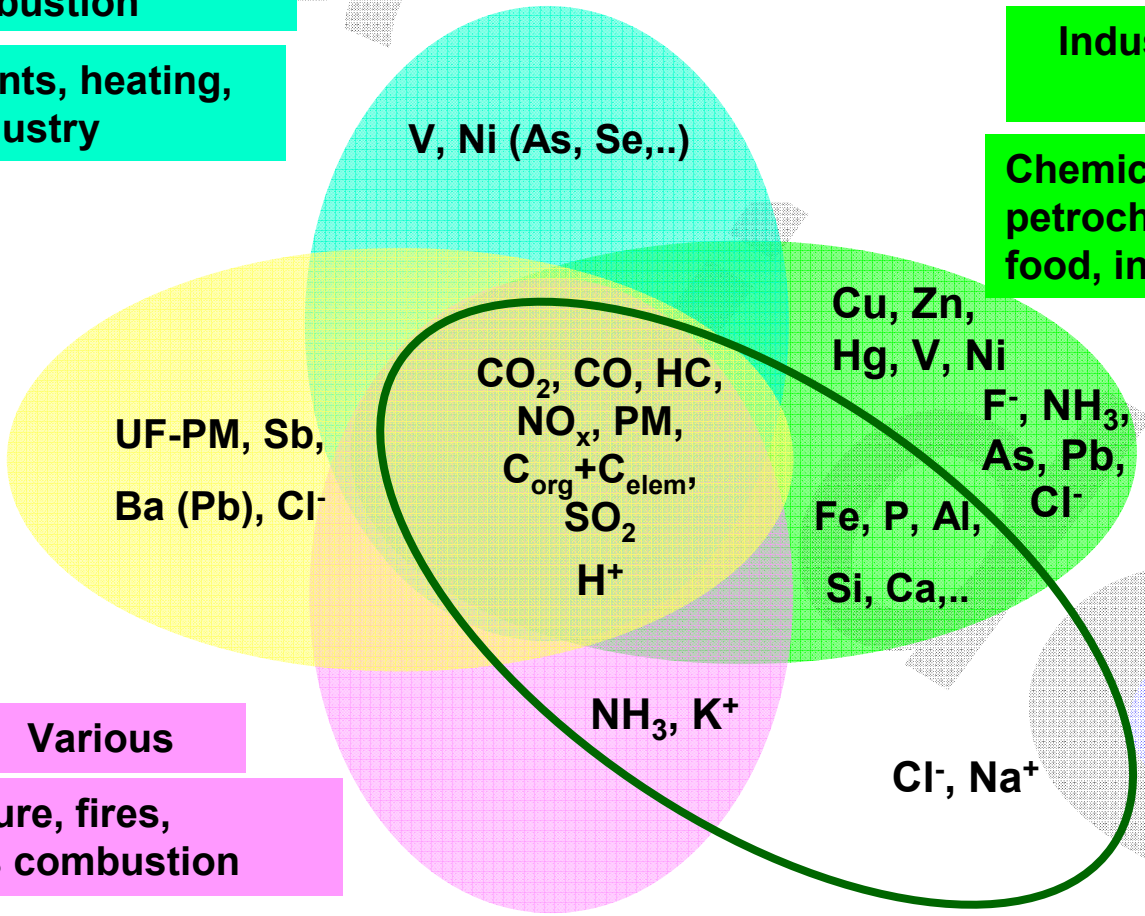
Chemical, metallurgical, petrochemical, mineral food, incineration

Transport

Road, air, rail, fuel storage,……..

Various

Agriculture, fires, biomass combustion

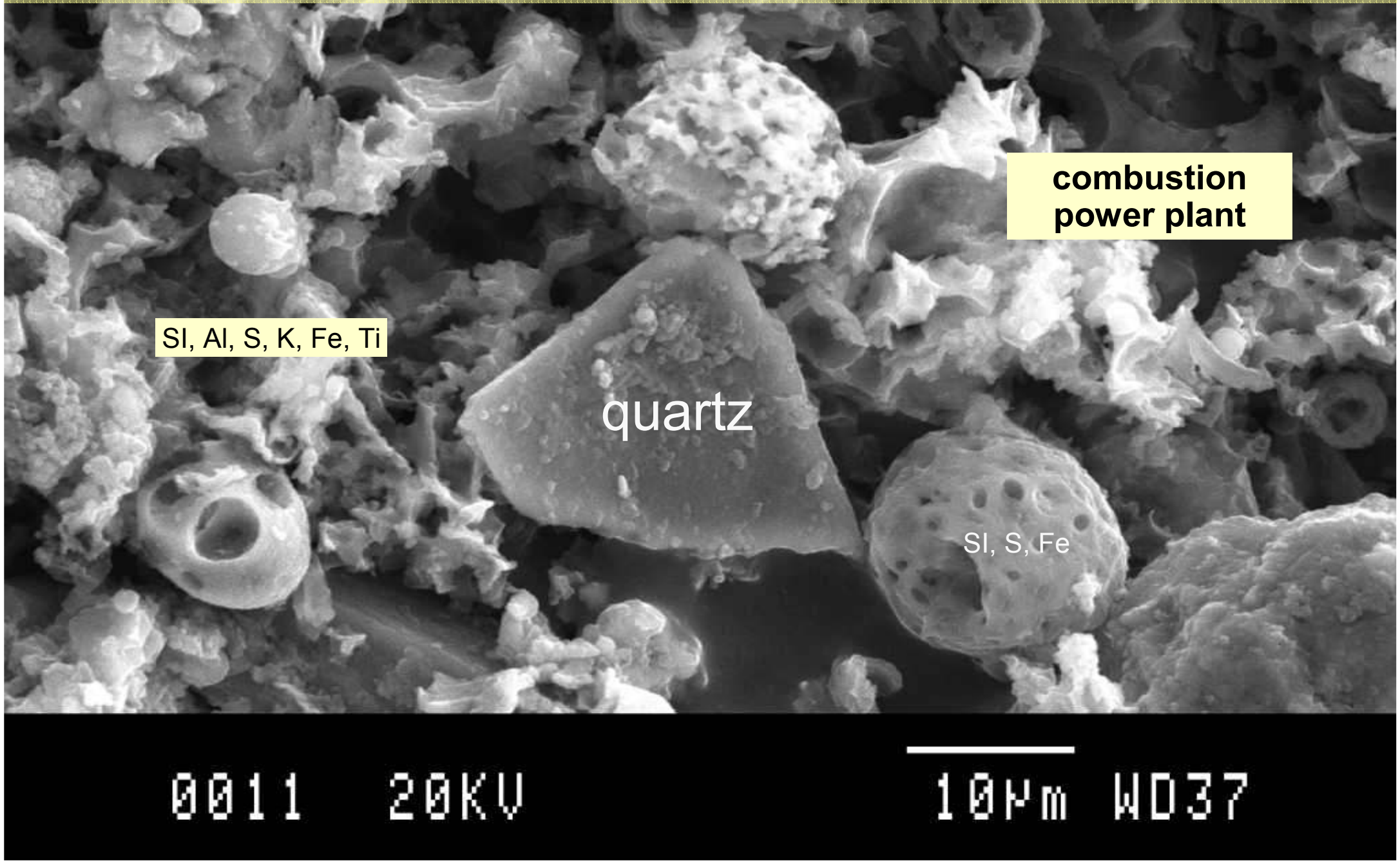


Other:
Harbor (shipping) emissions
Air transport
Construction-demolition
Domestic and residential

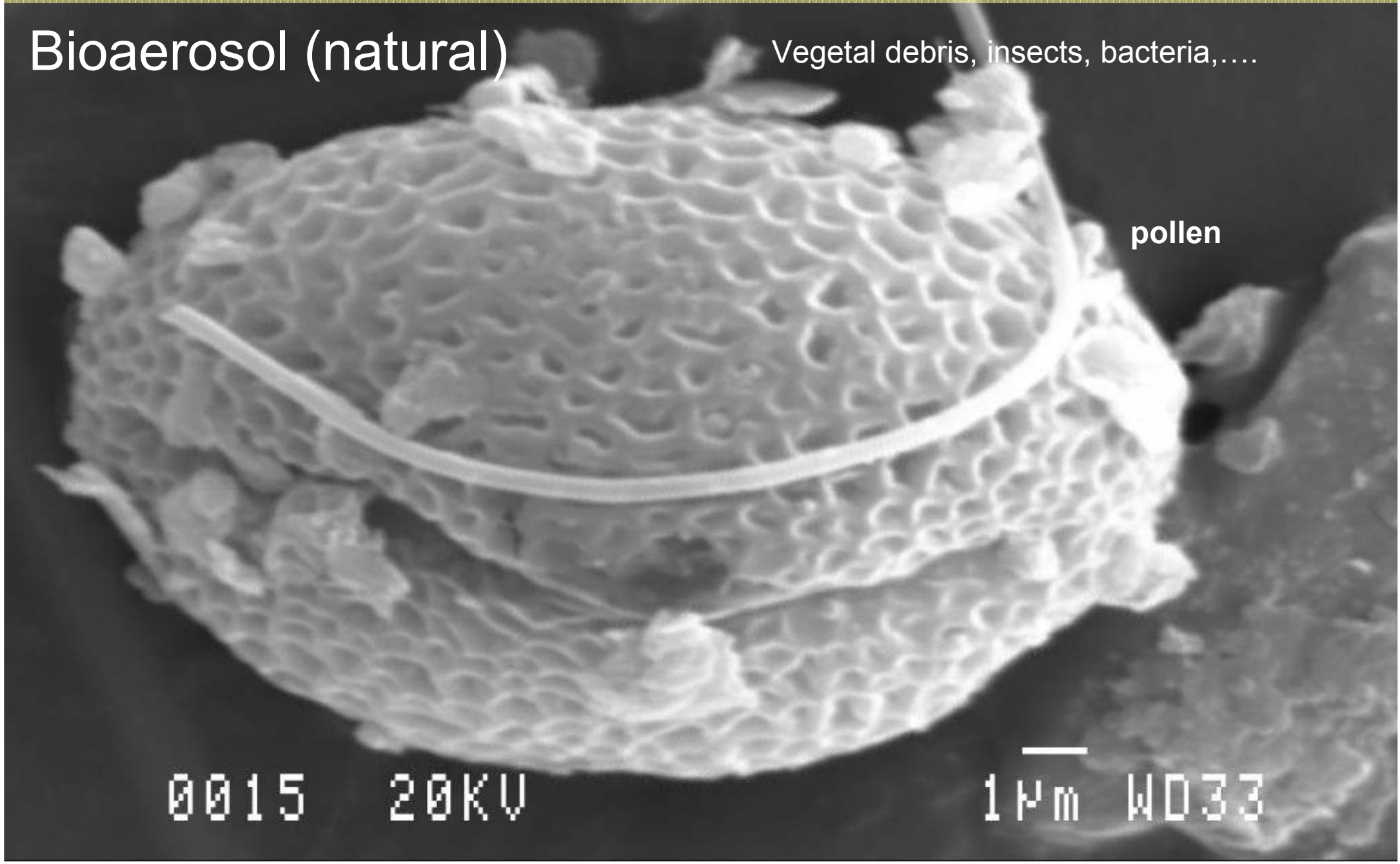
Natural emissions

Biogenic, re-suspension, marine, lightening, volcanoes, fires

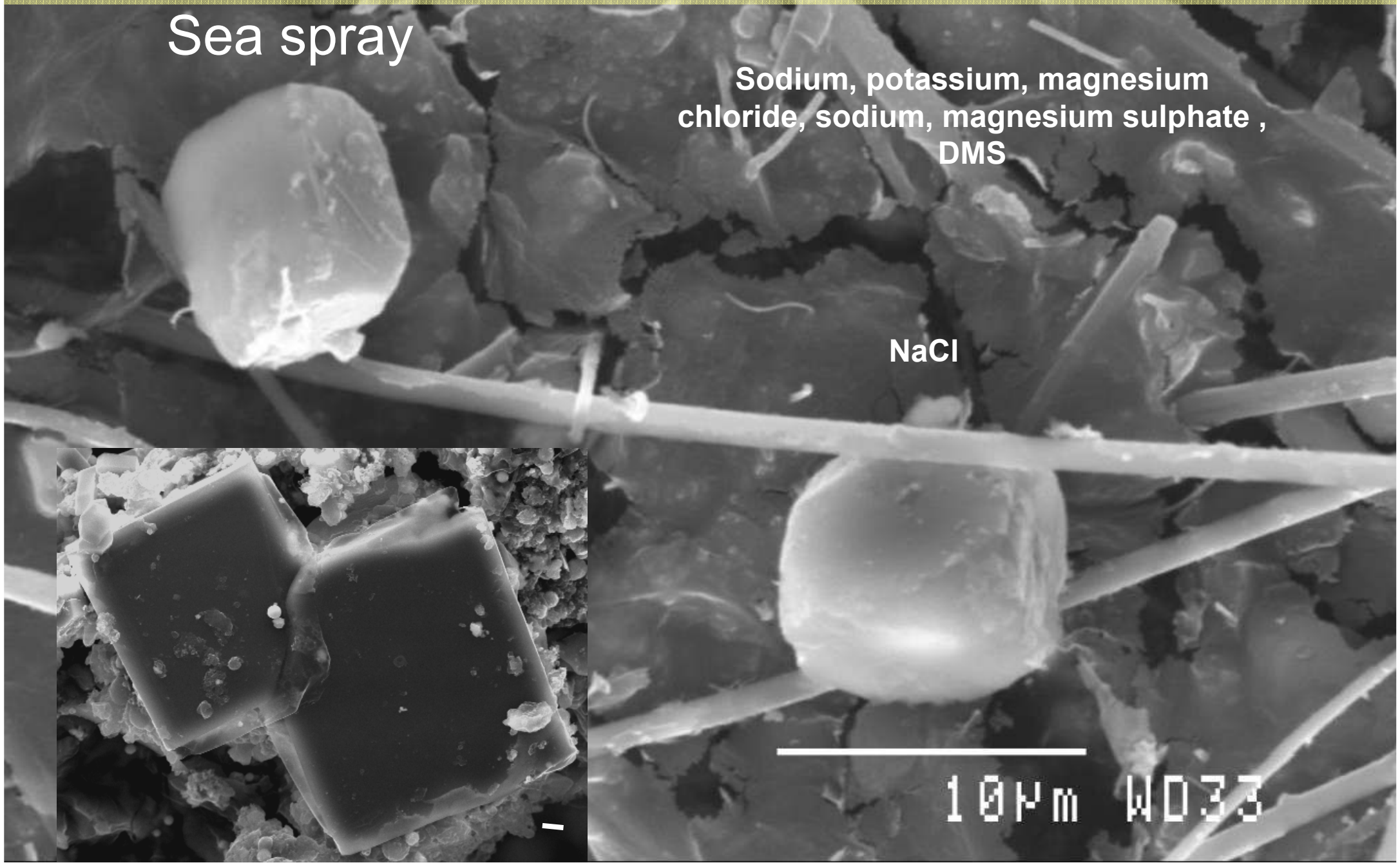
The problem of PM



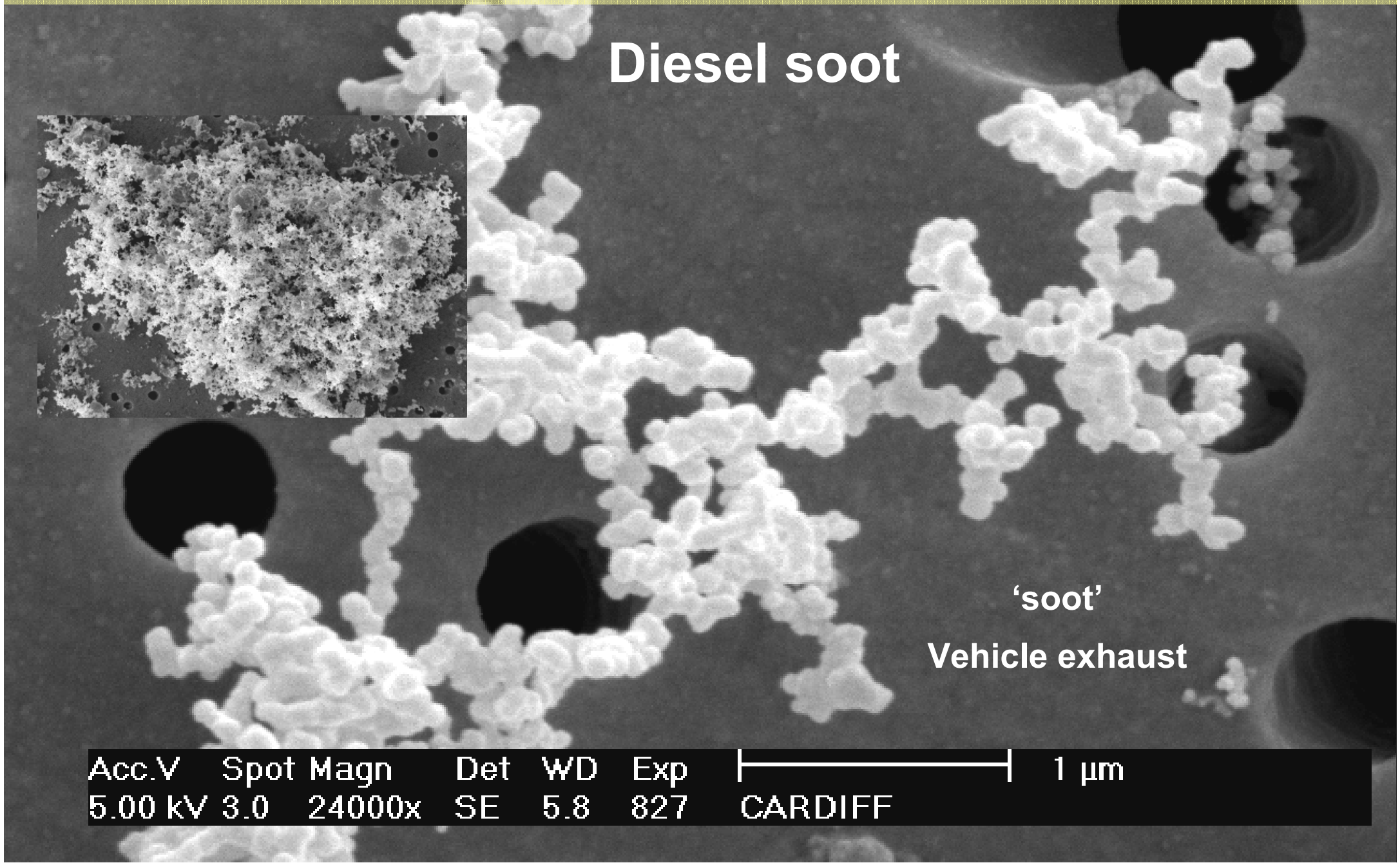
The problem of PM



The problem of PM

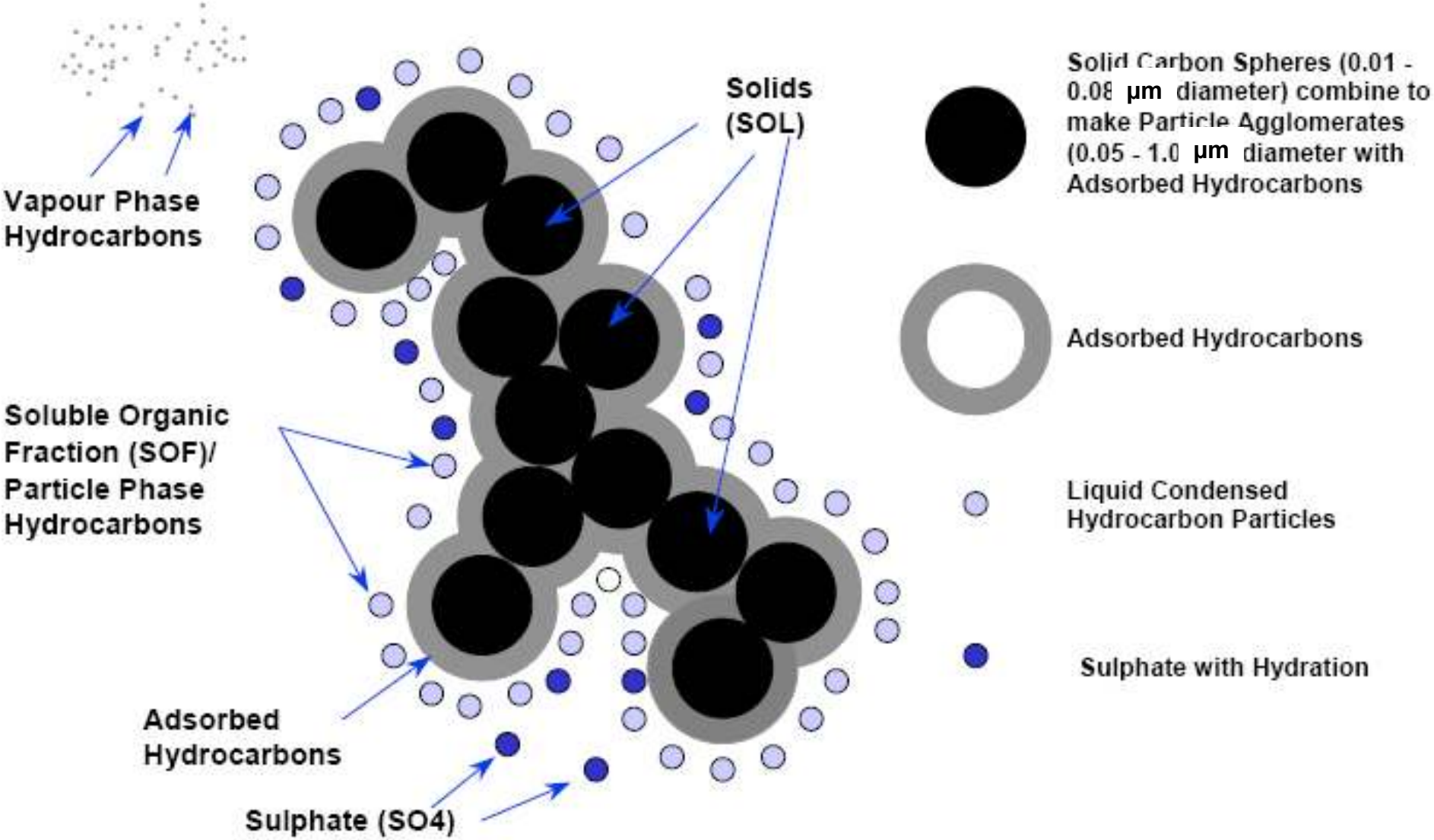


The problem of PM

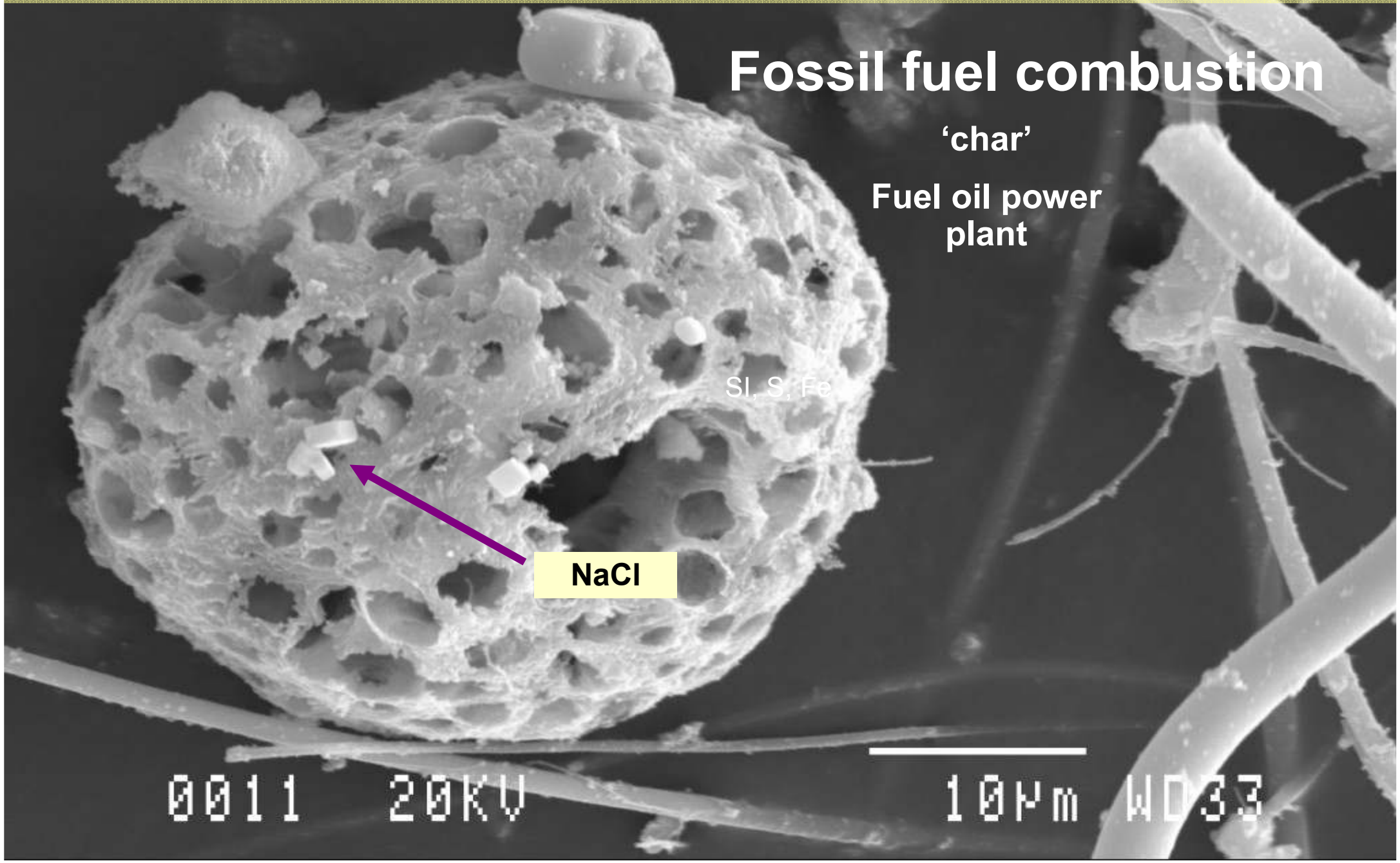


The problem of PM

PM ORIGIN

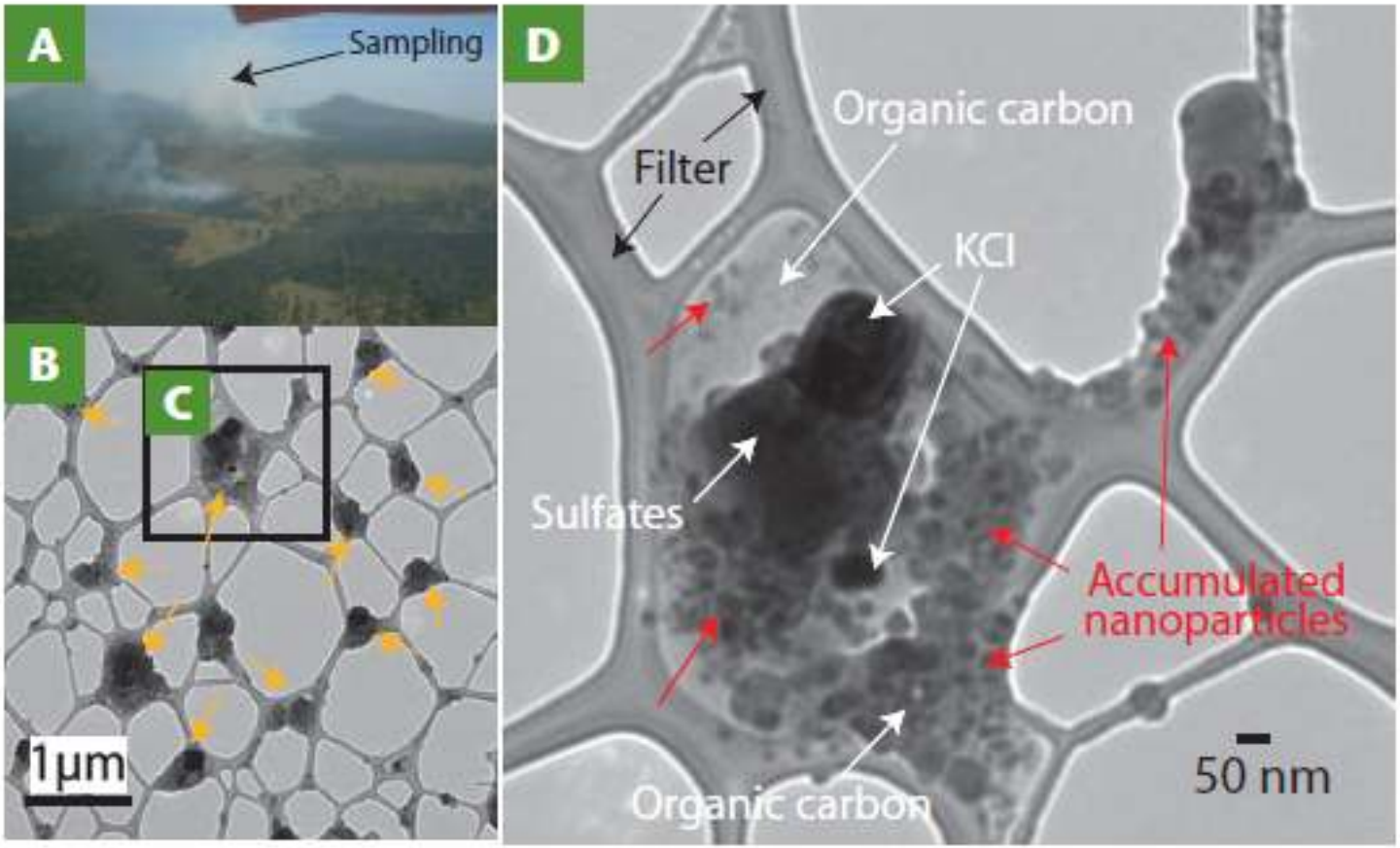


The problem of PM



Biomass Combustion

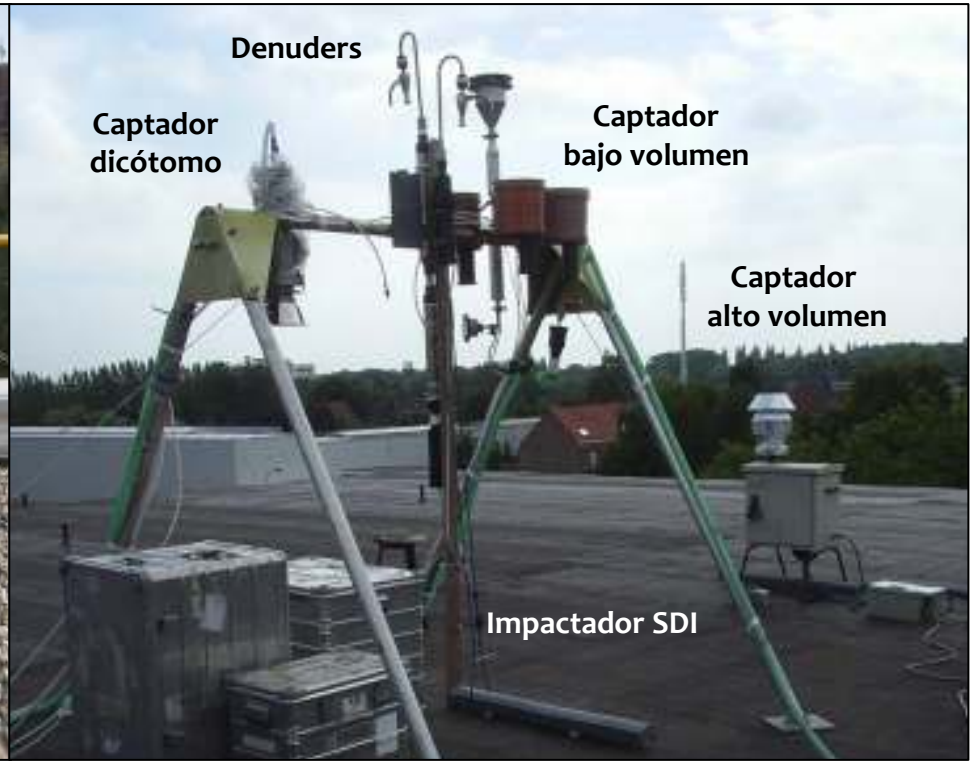
Buseck and Adachi. 2008. Elements. 4.

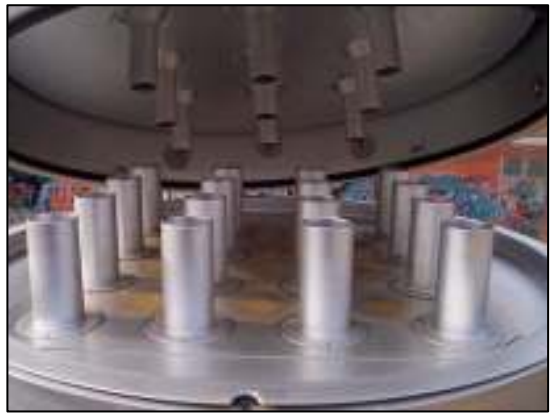


Measurement methods for PM

Characterisation of PM: Methods for measurements

Gravimetry: Mass levels; EU standard; Speciation possible; Sampling artifacts



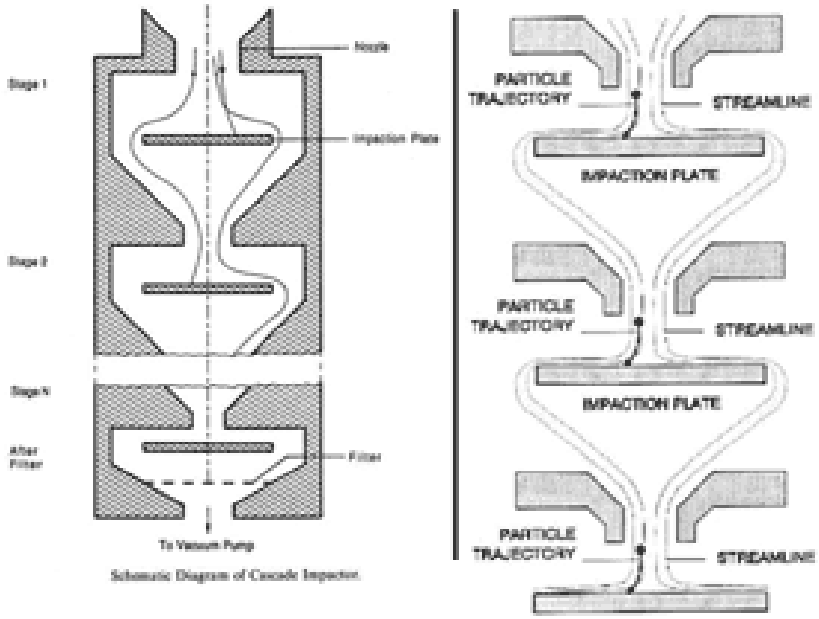


Characterisation of PM: Methods for measurements

Cascade impactor

- Micro-orifice, Uniform-deposit Impactor (MOUDI)
- 30 L/min
- 0.056 – 18 µm
- Substrate requested

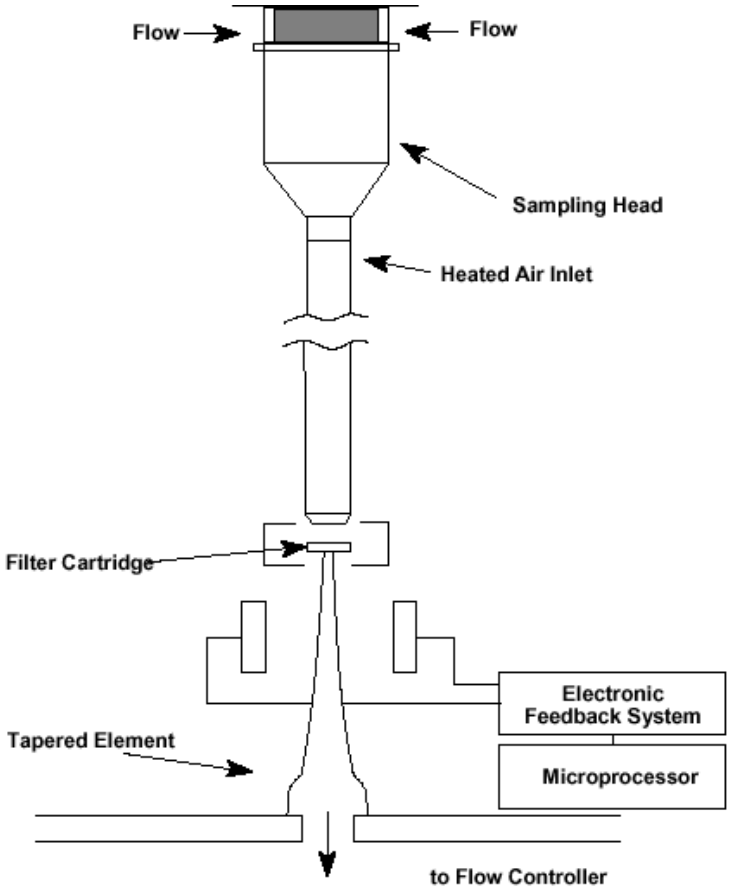
Model 100-1, Non-Rotating 8 Stage, 30 lpm | Model 110 Rotating 10 Stage, 30 lpm | Model 115 Non-Rotating 3 stage, 10 lpm | Model 125B Rotating 13 stage, 10 lpm



Characterisation of PM: Methods for measurements

REAL TIME: MASS

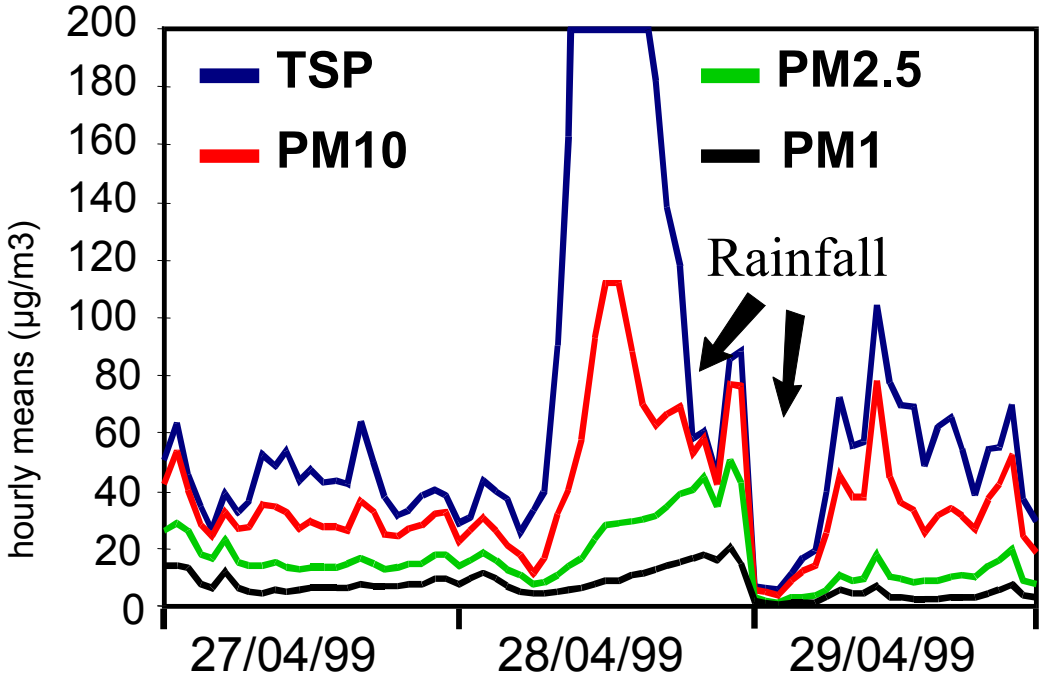
- **TEOM** (thermo oscillating micro-balance)



- **Beta attenuation**

Characterisation of PM: Methods for measurements

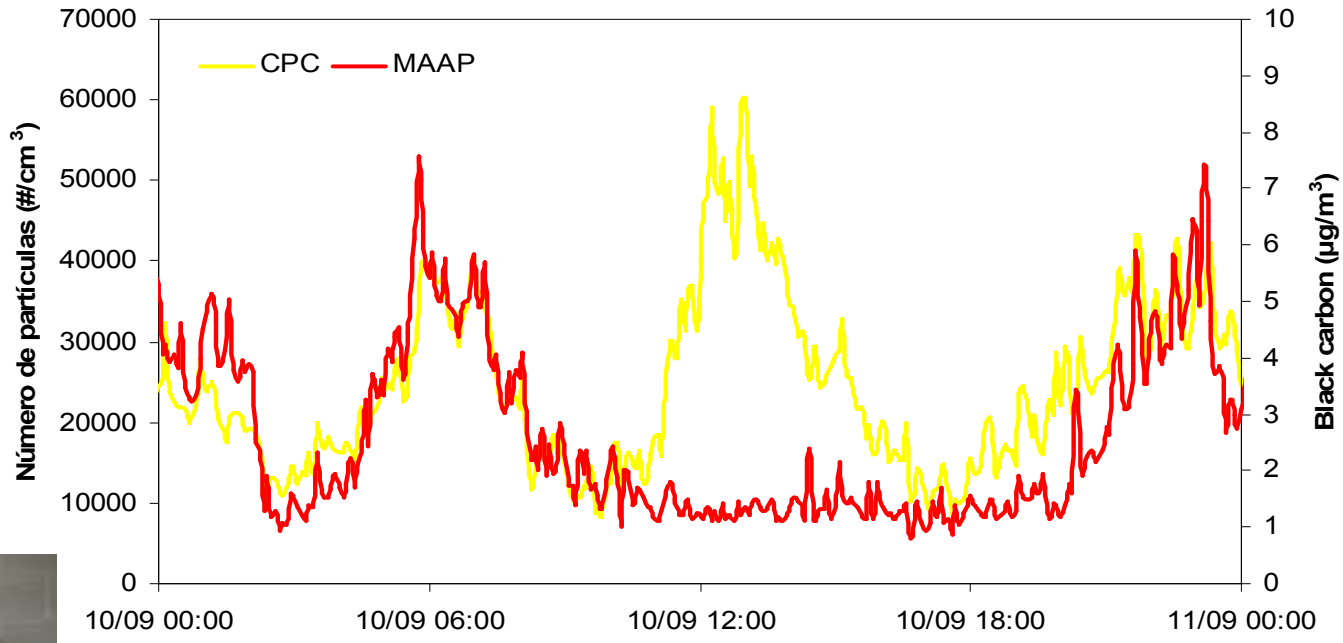
OPTICAL COUNTERS



Characterisation of PM: Methods for measurements

Black carbon: MAAP: Multi Angle Absorption Photometer

Thermo Electron Corporation. Carusso/Model 5012 MAAP



Comparación medidas en tiempo real de Número de partículas y Black Carbon. Medidas experimentales realizadas en el IDAEA de Barcelona, CSIC. Noemí Pérez, tesis doctoral.

Characterisation of PM: Methods for measurements

Real time speciation

Soluble inorganics: Aerosol ions & precursors

URG 9000 IC

Taken from URG web site

MARGA

Taken from Applikon web site

PILS-IC

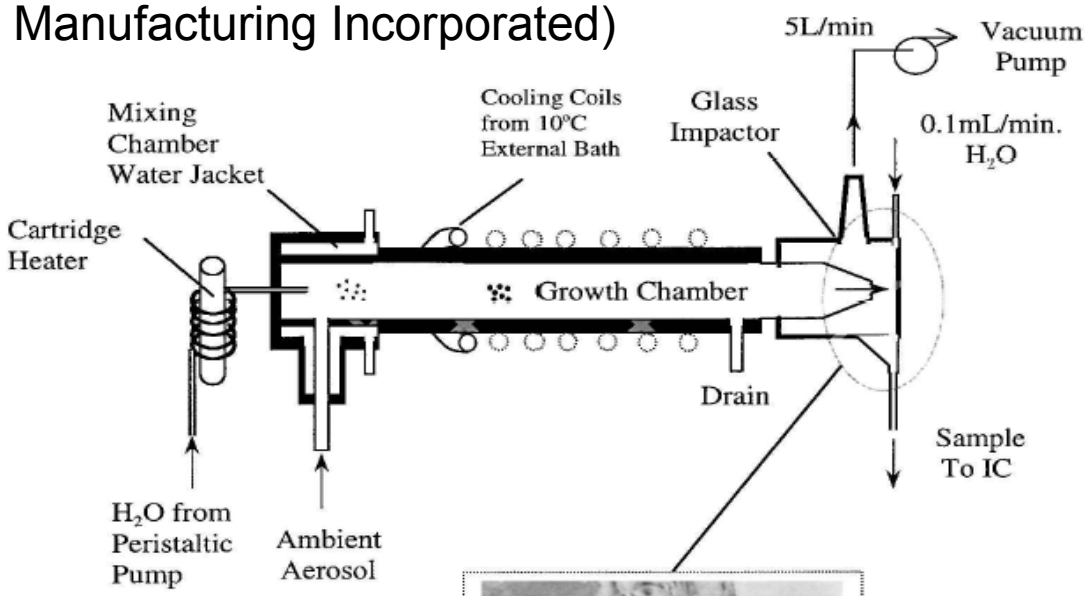
Taken from Metrohm web site

Characterisation of PM: Methods for measurements

Real time speciation

PILS: Particle-into-liquid sampler

(Brechtel Manufacturing Incorporated)



Weber, R.J., D. Orsini, Y. Daun, Y.-N. Lee, P. Klotz, and F. Brechtel, A particle-into-liquid collector for rapid measurements of aerosol chemical composition, *Aerosol Sci. Tech.*, *35*, 718-727, 2001

Characterisation of PM: Methods for measurements

Real time speciation

Thermal decomposition: Nitrate, sulphate, OC, EC

Nitrate, R&P 8400 N
by NO_x analysis (chemiluminiscence)

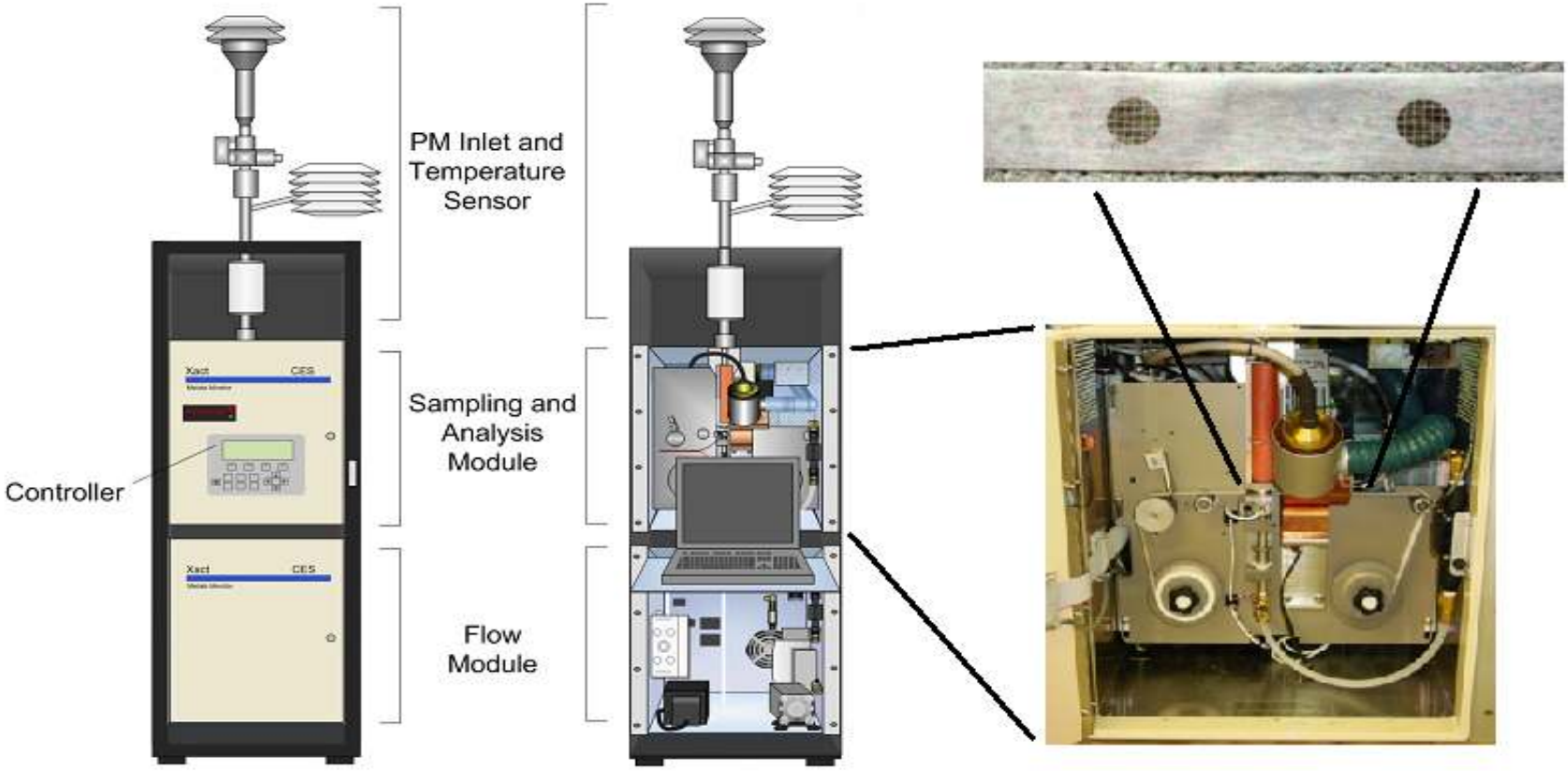
Sulfate,
Thermo 5020-SPA

- **OC and EC,**
- **R&P 5400 C, Sunset on-line analyzer**

Characterisation of PM: Methods for measurements

Real time speciation

On-line XRF analyser: Mostly metals

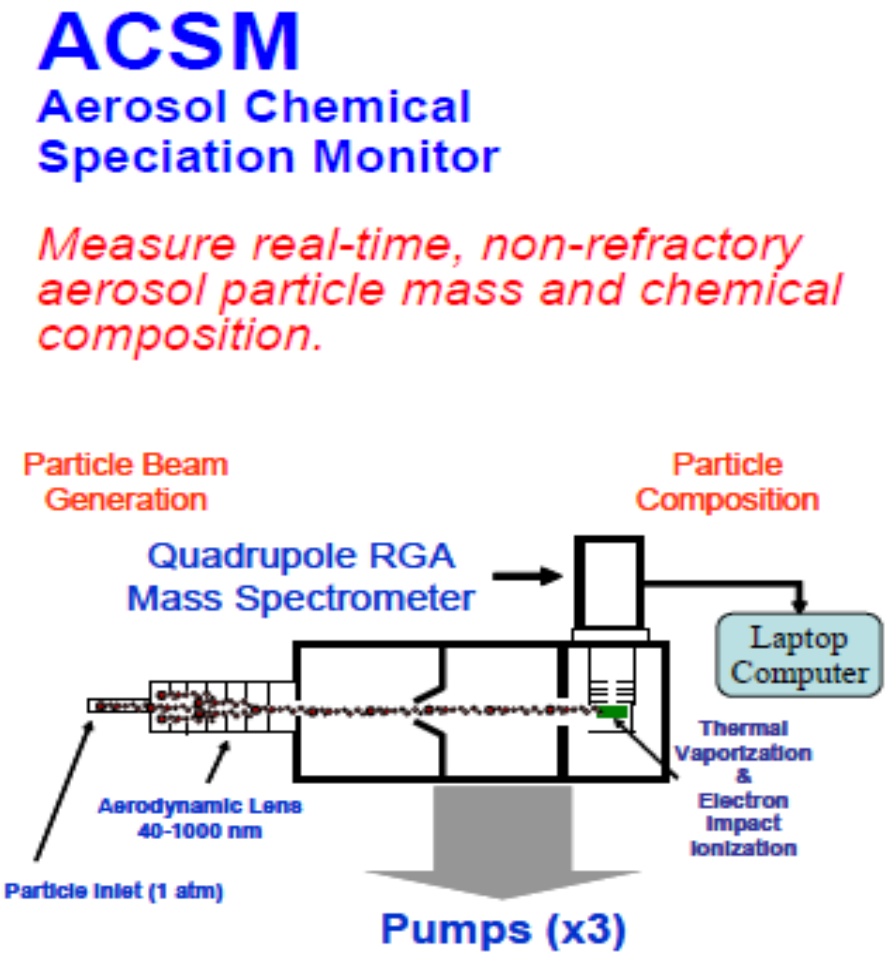


Manufacturer: Cooper Environmental Systems, Australia ;Figure taken from Yadav et al., AAAR 2010

Characterisation of PM: Methods for measurements

Real time speciation

Mini-AMS: Non refractory fraction of PM1

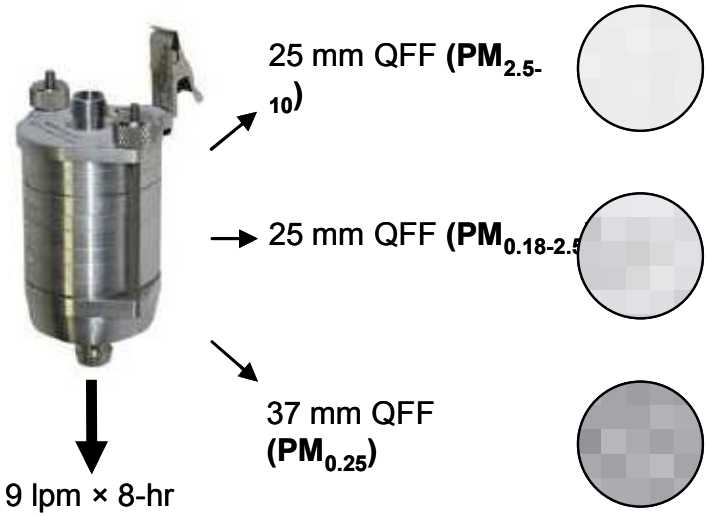


Taken from Aerodyne Research website

Characterisation of PM: Methods for measurements

Geochemistry of ultrafine particles

37 schools in Barcelona: exposure of schoolchildren to metals in UFPs



UFP geochemistry

Particle number

Black carbon

Conclusions

Conclusions

- Main air quality problem in urban environments: NO_2 and PM
- Current monitors are costly, large (size) and static
- Future monitoring networks will probably be based on the combination of fixed monitoring sites with sensor networks:

Thank you for your attention
mar.viana@idaea.csic.es

representativeness (exposure)

- To this end, sensors need to be:
  - Low-cost
  - Portable
  - Small
  - Comparable to conventional instrumentation

This is now YOUR job!