AirMonTech

Black Carbon Measurements for Improved Urban Air Quality Monitoring

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www.airmontech.eu

Barcelona, April 25-26, 2012

Air Pollution Monitoring Technologies for Urban Areas

Outline

CSIC

- Critical Air Quality parameters in EU
- Road traffic, air quality and aerosol measurements
    1. PMx
    2. Carbonaceous aerosols
    3. BC
    4. BC & N
    5. PM & BC
    6. UFP
    7. PM speciation and receptor modelling
    8. Receptor modelling and UFP
- Future trends
- Conclusions

CGL2010-19464/CLI

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

GOBIERNO DE ESPAÑA MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE

Contract S-G D Air Quality and Industrial Environment

SAPUSS

MARIE CURIE ACTIONS

Air Pollution Monitoring Technologies for Urban Areas

Critical (URBAN) Air Quality problems in EU

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

CRITICAL PARAMETRES

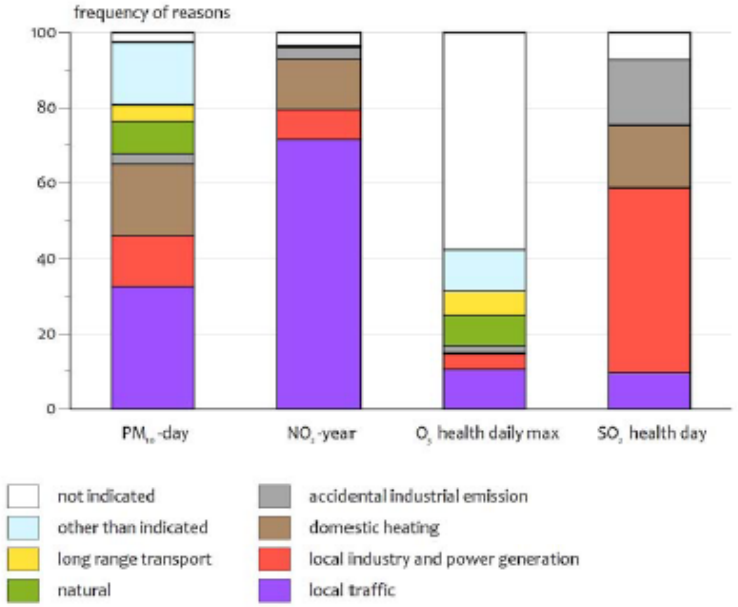
Critical Air Quality problems in EU

Reporting on ambient air quality assessment in the EU Member States, 2008

ETC/ACC Technical Paper 2010/11
December 2010

Benno Jimmink, Frank de Leeuw, Erik Noordijk, Jana Ostatnická, Markéta Coňková

European Topic Centre
on Air and Climate Change



* data extracted from form 11 and 13 of AQ questionnaire

Figure 7: Reported reasons for exceedances of limit and target values of PM_{10}, NO_2, O_3 and SO_2, 2008

Air Pollution Monitoring Technologies for Urban Areas

Road traffic, air quality and aerosol measurements

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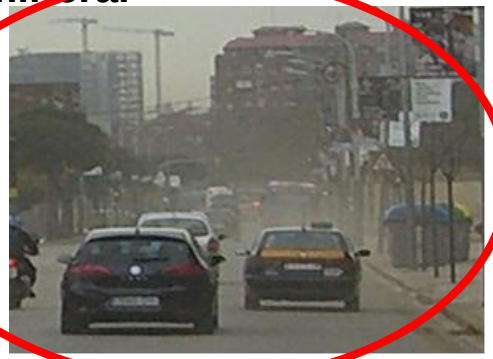
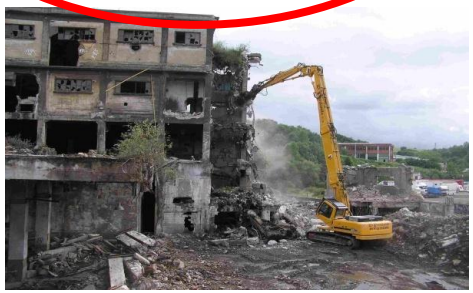
PM components

Crustal-mineral

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





Carbonaceous aerosols OM and EC

Secondary Inorganic aerosols

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

Sea spray

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

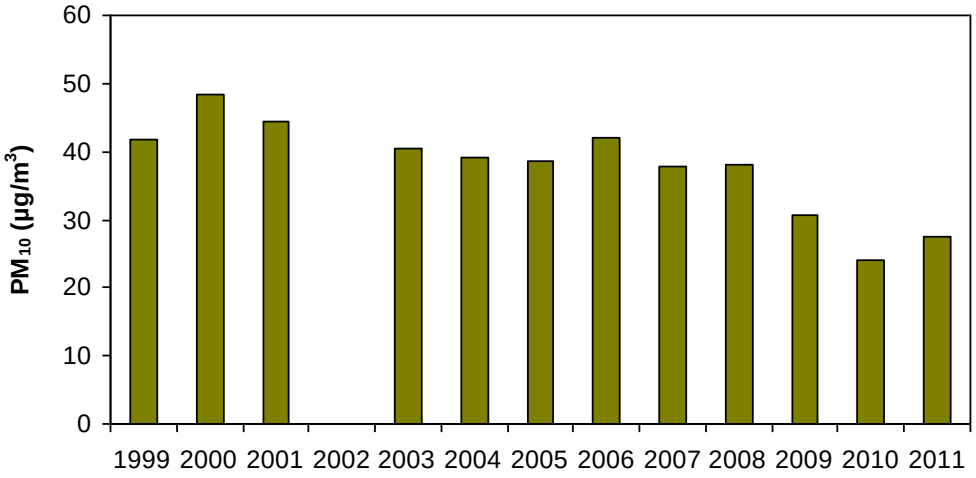
Trace elements

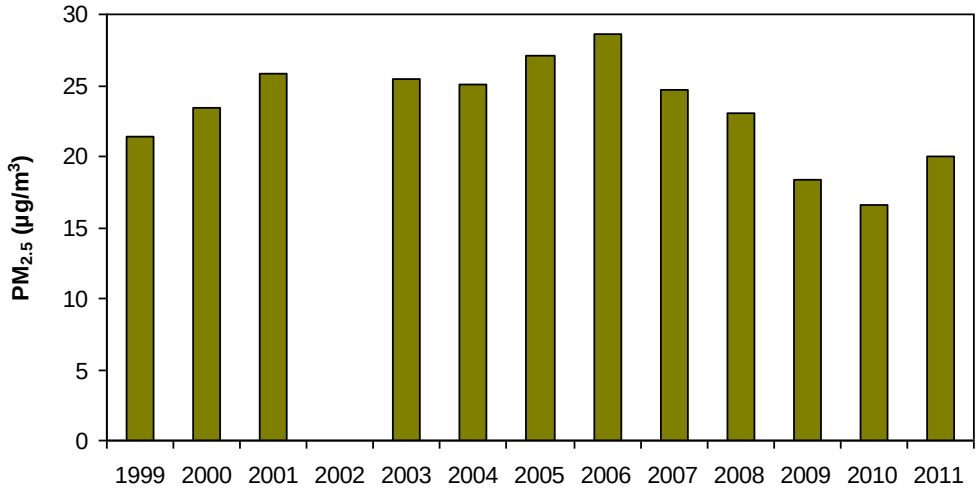
As, Ba, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Ga, Gd, Ge, Hf, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Th, Ti, Tl, U, V, W, Yb, Zn, Zr

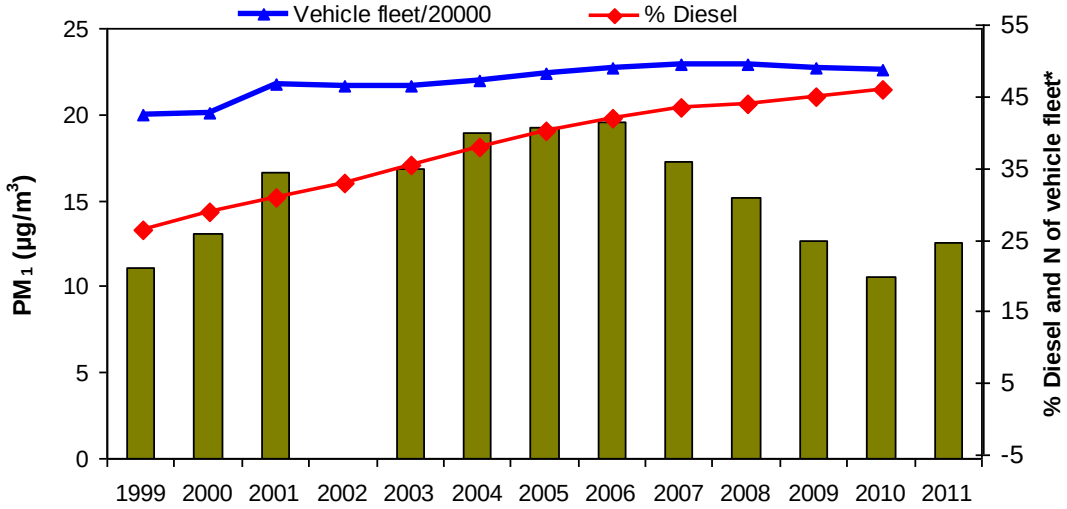
Large proportion of PMx exceedances

Road traffic, air quality and aerosol measurements

1. PMx: BARCELONA 1999-2011 PM10, PM2.5, PM1???



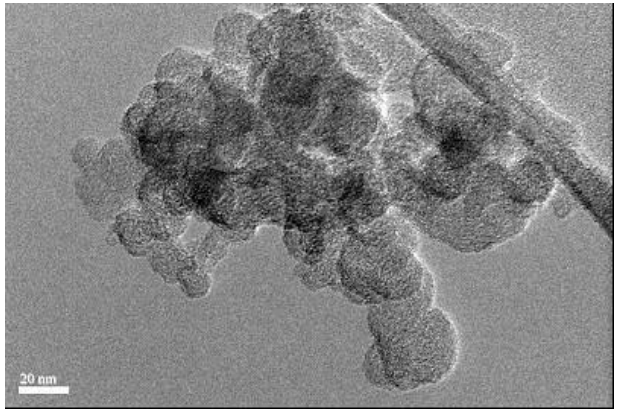




2. Carbonaceous aerosols: Organic and elemental carbon

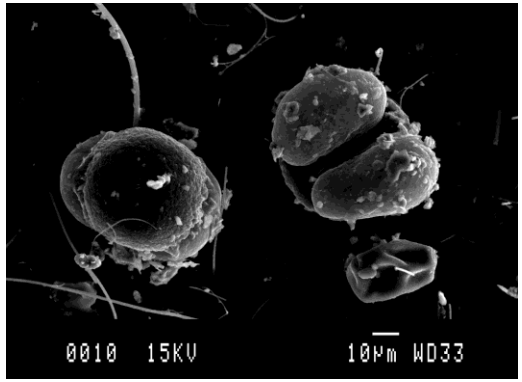
Elemental carbon

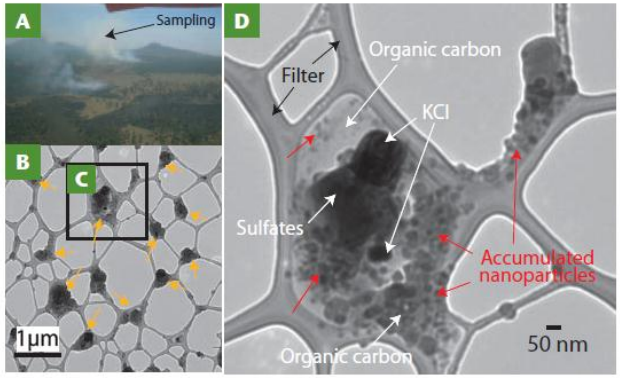
Instrumentally defined parameter for mass concentration of graphitized C (unburned and char)



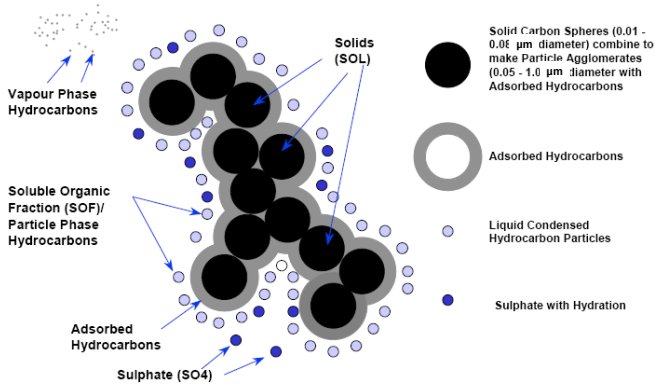
Organic carbon

Instrumentally defined parameter for mass concentration of organic matter carbon

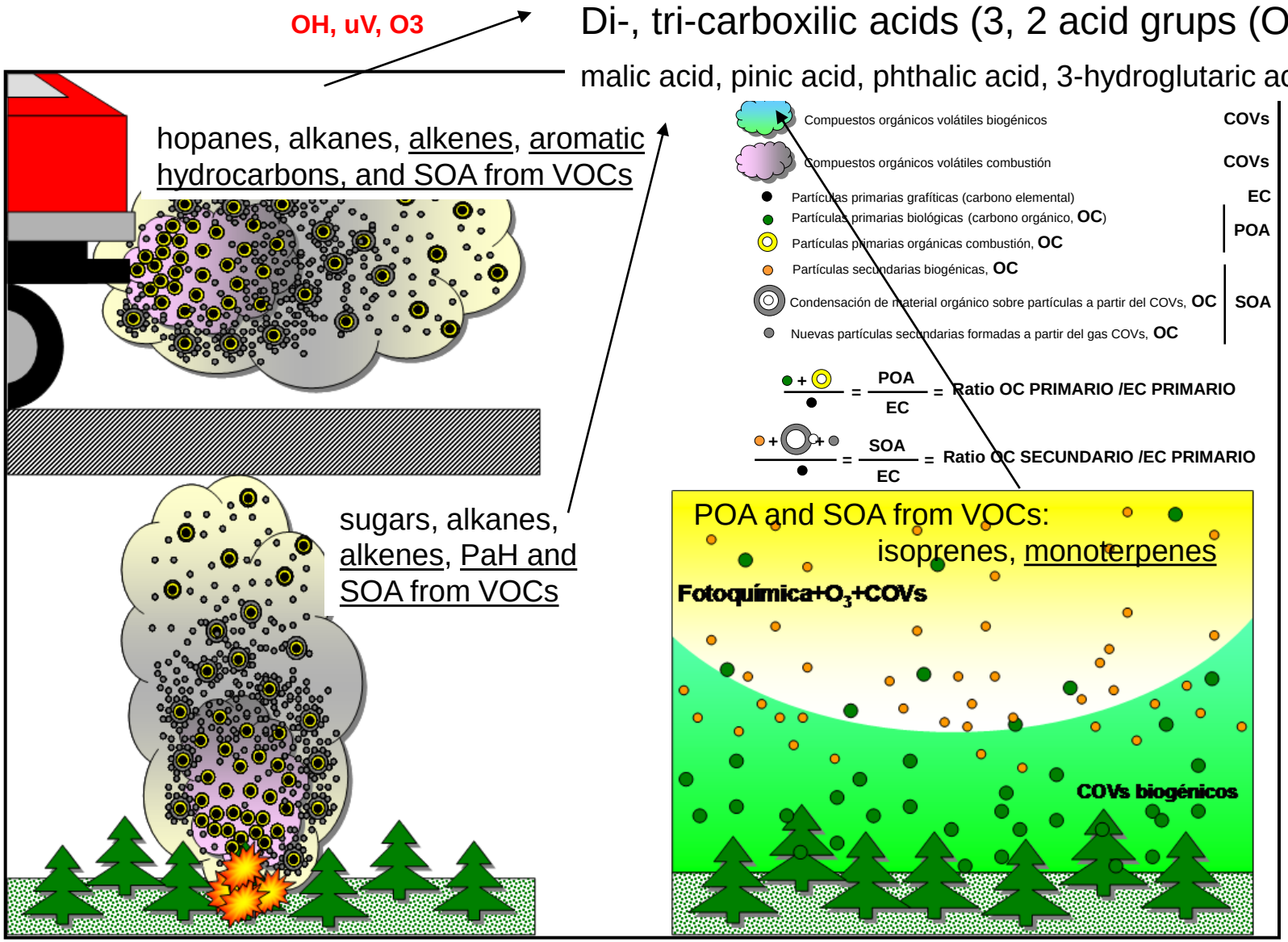




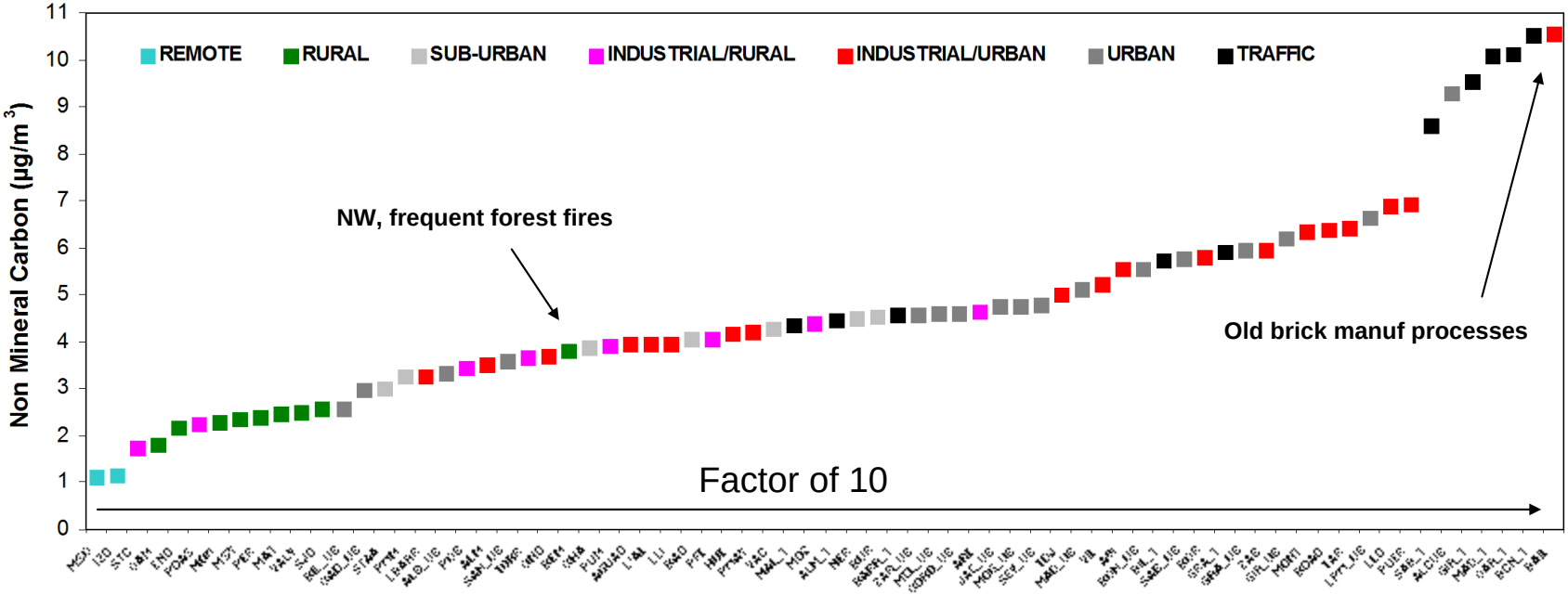
Buseck and Adachi, 2008. Elements, 4.

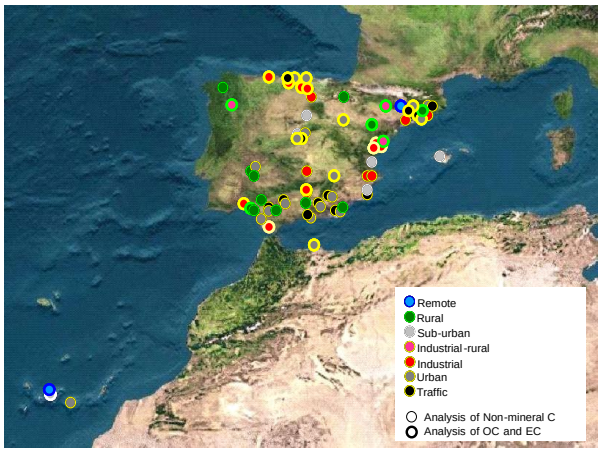


Road traffic, air quality and aerosol measurements



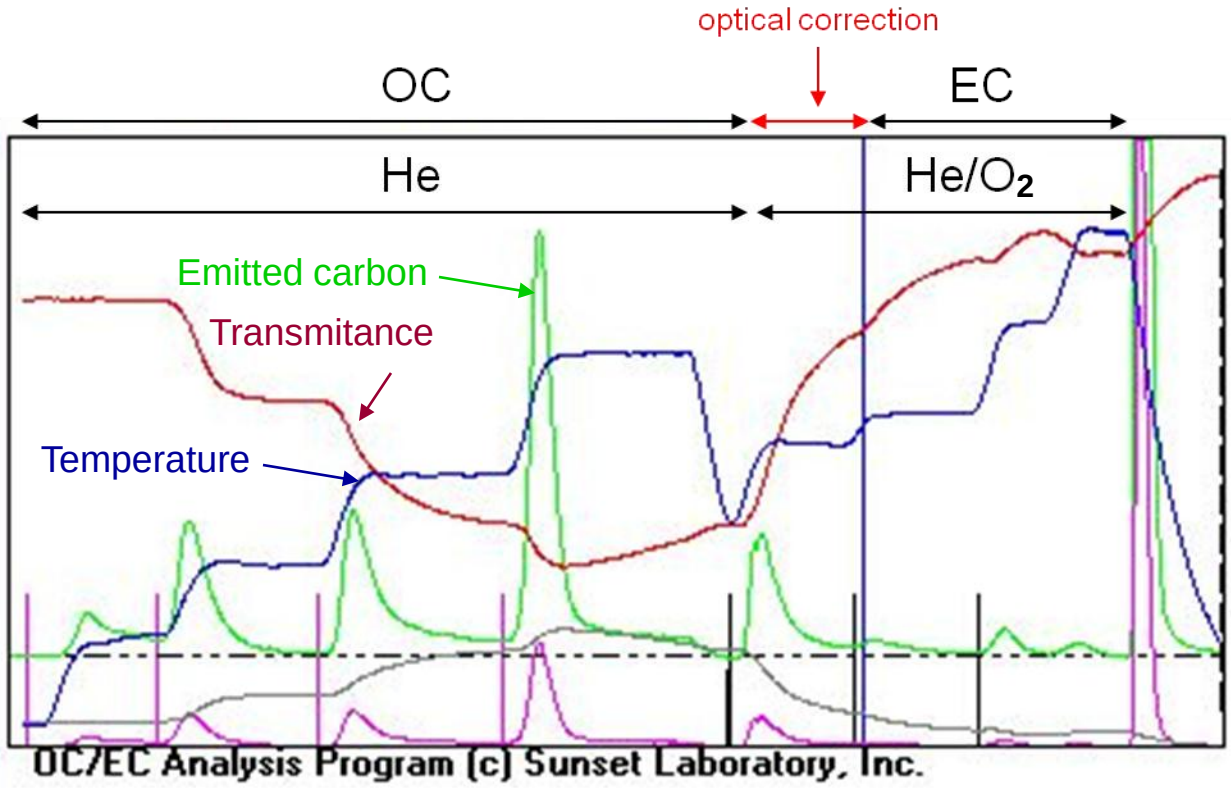
2. Carbonaceous aerosols: Non mineral C 1999-2011 in Spain





2. Carbonaceous aerosols: Organic and elemental carbon

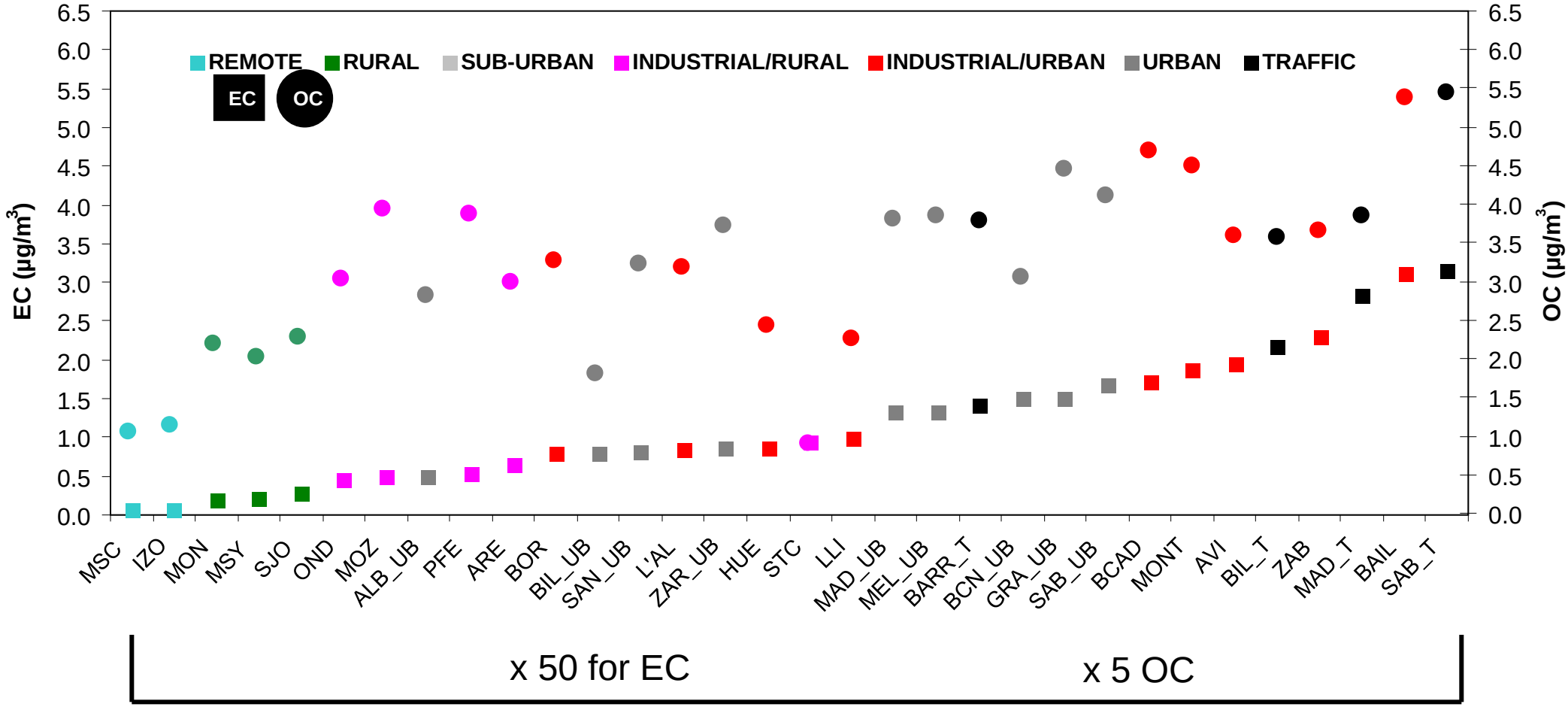
Thermo-optical transmittance analysis (TOT)



(EUSAAR2.par temperature protocol; Cavalli et al., 2010)

3. BC: Levels of EC and OC in Spain (Thermo-optical analysis)

BC may be proportional to contribution from traffic (+ biomass b.) and can be calibrated with EC



3. BC: On line BC optical measurements: Optical absorption of particles (collected on filters)

3.1. TRANSMITTANCE METHOD

- **Aethalometer (up to 7 wavelenghts)**
- **Particulate Soot Absorption Photometer (PSAP) (3 wavelenghts)**

- Measure the attenuation of a beam of light transmitted through the sample when collected on a fibrous filter.
- Affected by the wavelength of the light.
- The change in transmission from one measurement to the next is related to the **optical absorption coefficient** (**Abs**, m-1) of the aerosol:

$$\lambda\text{-dependent Abs- } (m^{-1}) = \frac{AREA}{VOLUME} \ln\left(\frac{I_0}{I}\right) f(Tr)$$

f(Tr) filter + aerosol load correction factor
I_o transmited intensity prior sample
I transmited intensity of sample

3.2. MAAP METHOD

- **Multi Angle Absorption Photometer (MAAP)**

The **Abs** at 637nm is determined by radiative transfer considerations (multiple scattering effects and absorption enhancement by reflections). This calculation is based on directly measured values of transmission, direct and diffuse back scattering (130 and 165º)

$$MAAP\text{-}Abs\ (m^{-1}) = \frac{(1-\omega_0)\ln(tr)AREA}{VOLUME}$$

ω_0 is the single scattering albedo, dependent of the particle absorption and filter matrix scattering
Tr, transmitance of the aerosol layer on the filter

$$Abs\ (637nm)\ (m^{-1}) = MAAP\text{-}Abs\ (m^{-1}) * f$$

Road traffic, air quality and aerosol measurements

3. BC: ORIGIN OF BC AND MASS ABSORPTION CROSS SECTION (MAC)

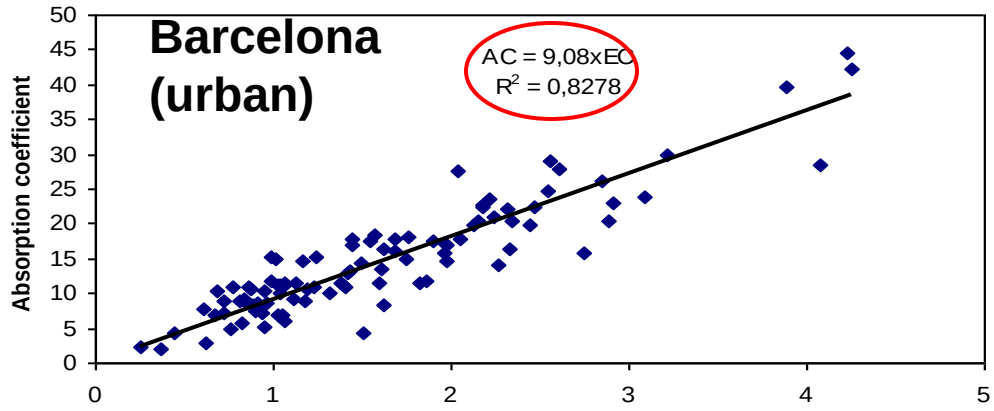
$$Abs_{BC}^{\lambda}(m^{-1}) = \sigma_{BC}^{\lambda}(m^{2}g^{-1}) \times [EBC](gm^{-3})$$

MAC

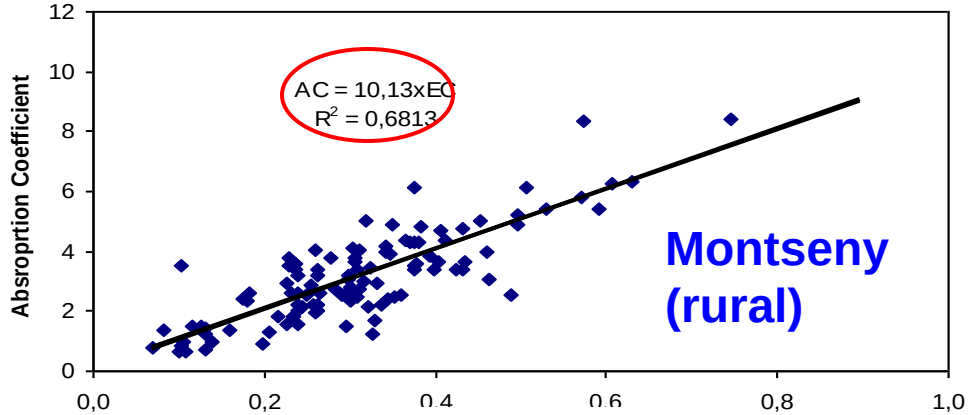
(MAAP)

(EC; SUNSET)

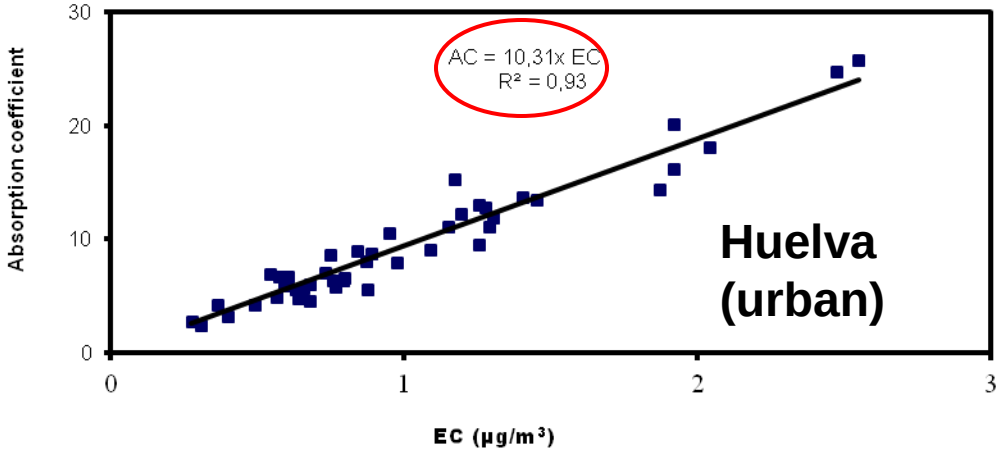
EC=AC/9



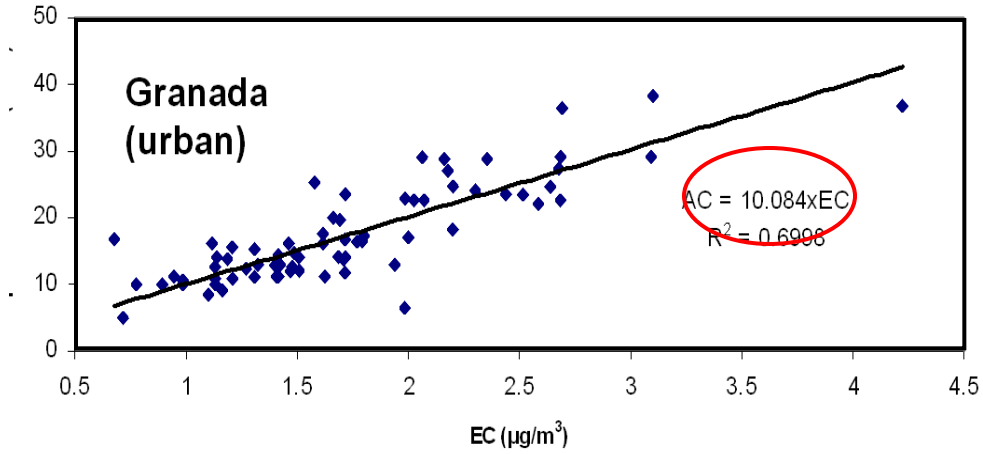
EC=AC/10



EC=AC/10

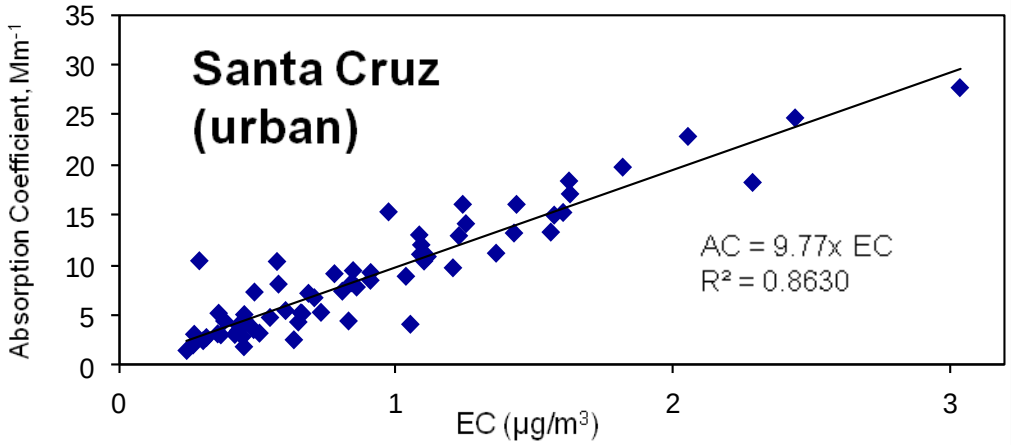


EC=AC/10

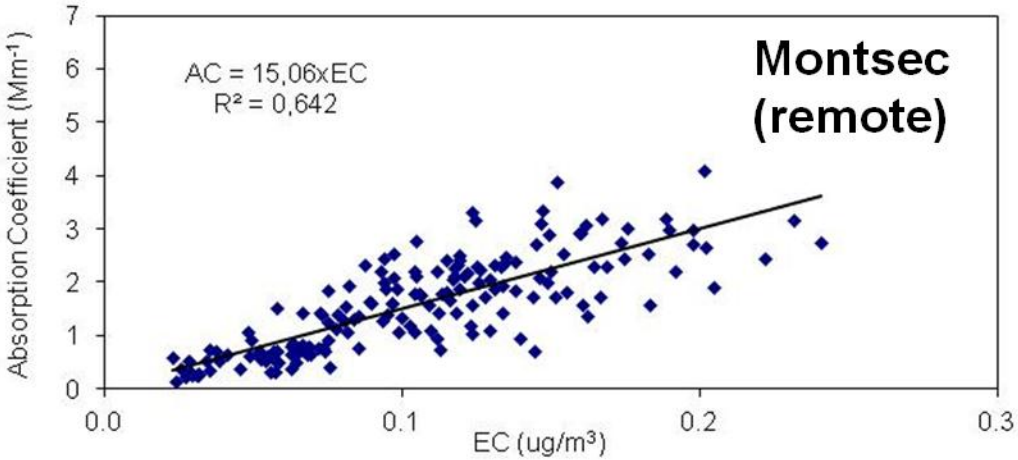


3. BC: ORIGIN OF BC AND MASS ABSORPTION CROSS SECTION (MAC)

EC=AC/9.8



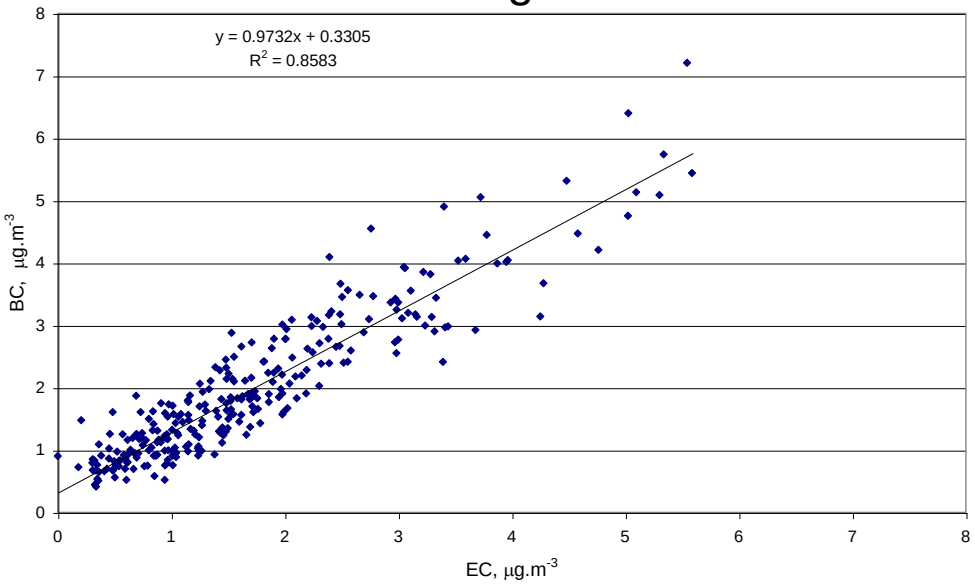
EC=AC/15



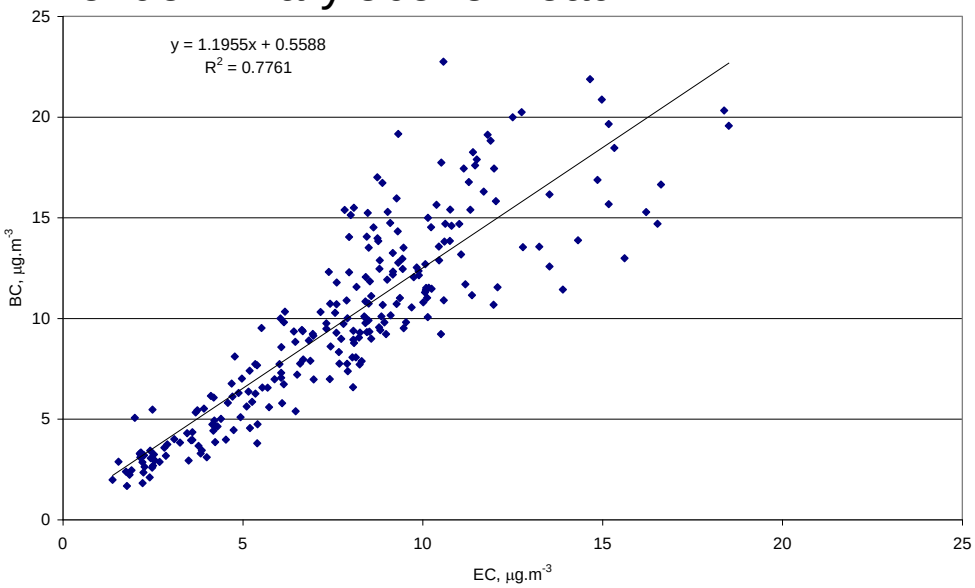
Road traffic, air quality and aerosol measurements

3. BC: Levels of BC compared with EC (EBC): Aethalometre and Sunset (NIOSH)

London: North Kensington



London: Marylebone Road



Courtesy: P. Quency & DEFRA

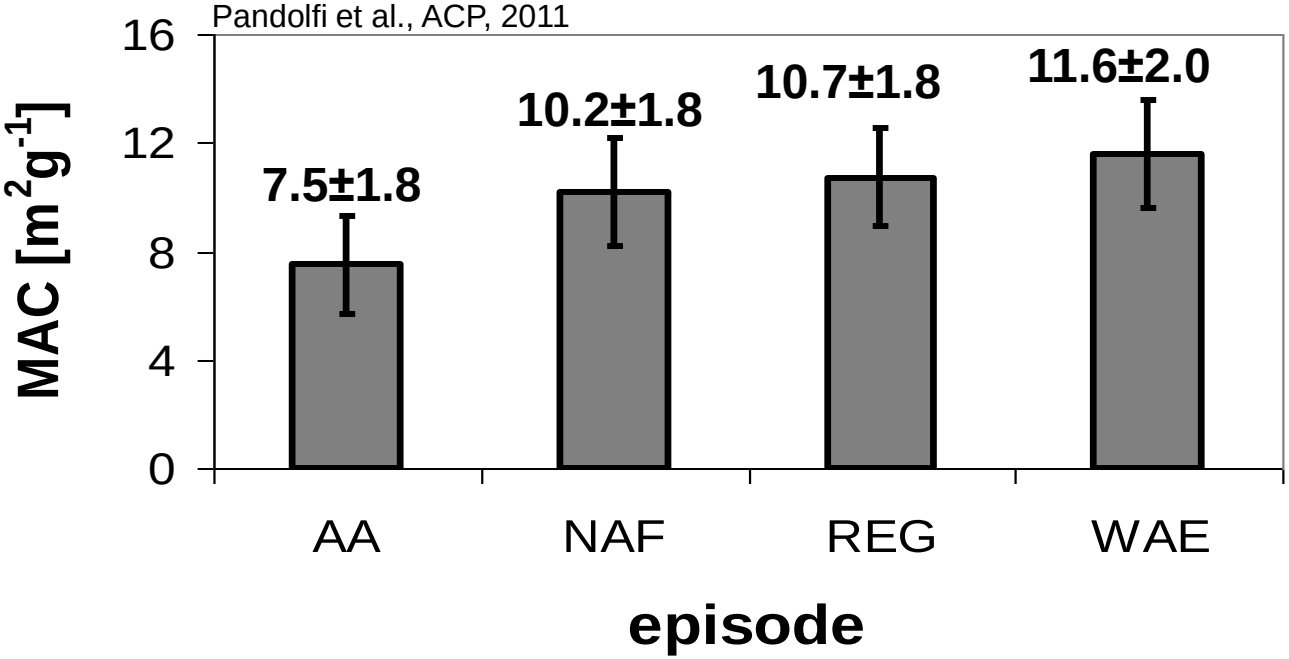
3. BC: ORIGIN OF BC AND MASS ABSORPTION CROSS SECTION (MAC)

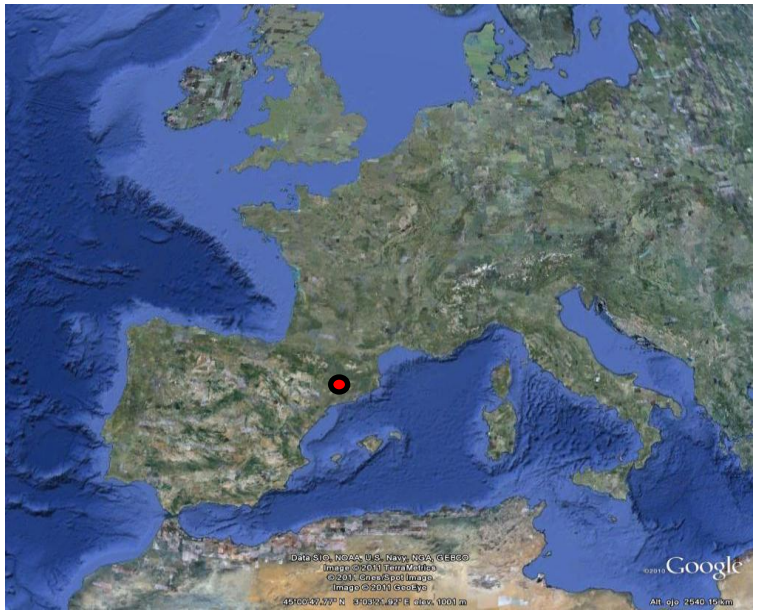
$$Abs_{BC}^{\lambda}(m^{-1}) = \sigma_{BC}^{\lambda}(m^{2}g^{-1}) \times [EBC](gm^{-3})$$

7 – 15 m^2g^{-1}

MSY (04/2008 – 02/2010)

Pandolfi et al., ACP, 2011





Pandolfi et al., Atmospheric Chemistry and Physics, 2011

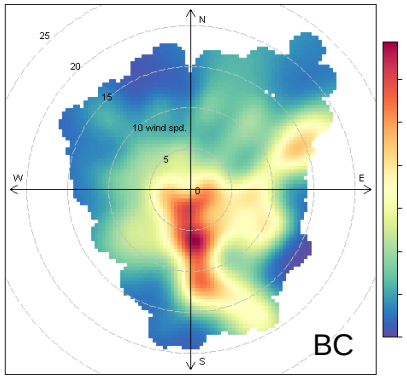
Air Pollution Monitoring Technologies for Urban Areas

Road traffic, air quality and aerosol measurements

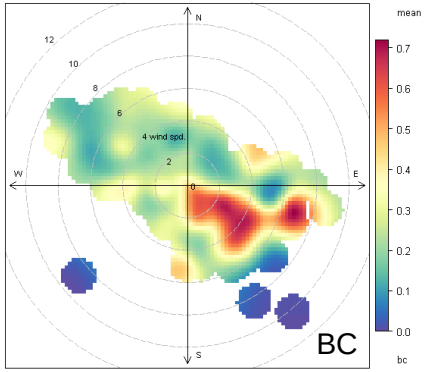
CSIC

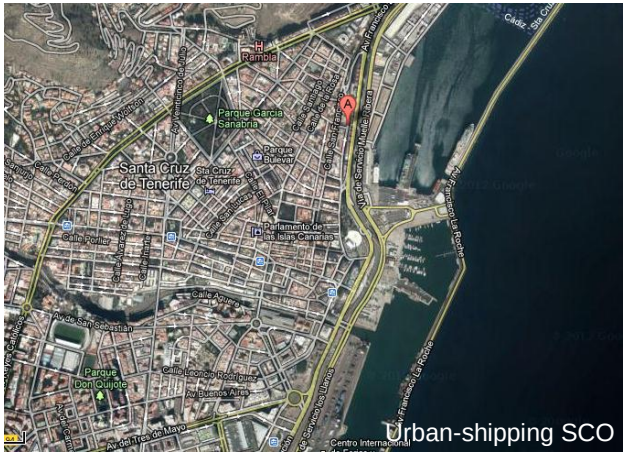
3. BC: Local vs external EBC

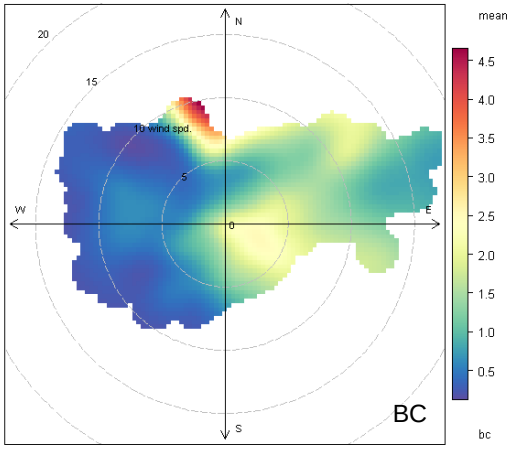
Montsec

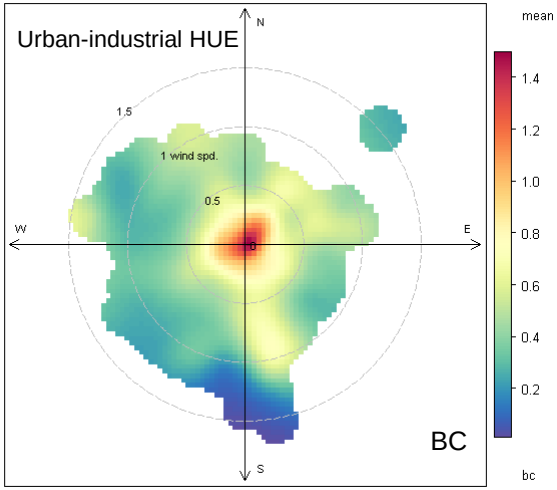


Montseny









Air Pollution Monitoring Technologies for Urban Areas

Road traffic, air quality and aerosol measurements

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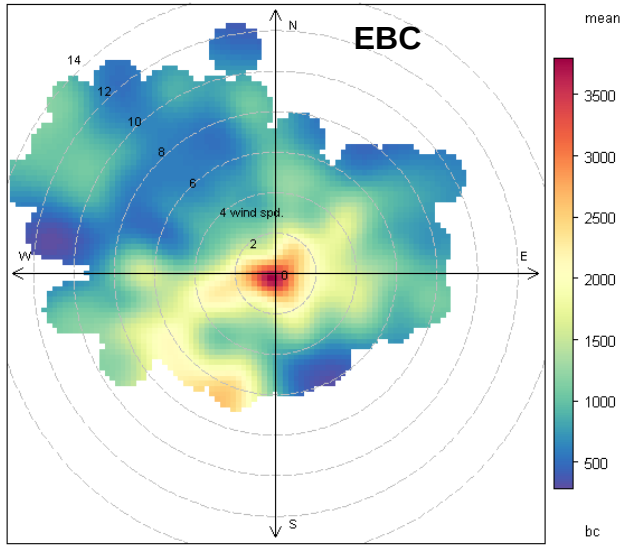
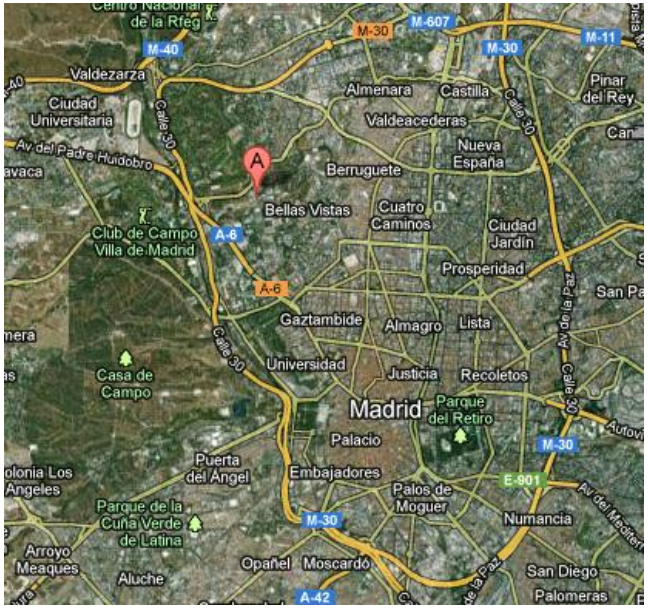
3. BC:

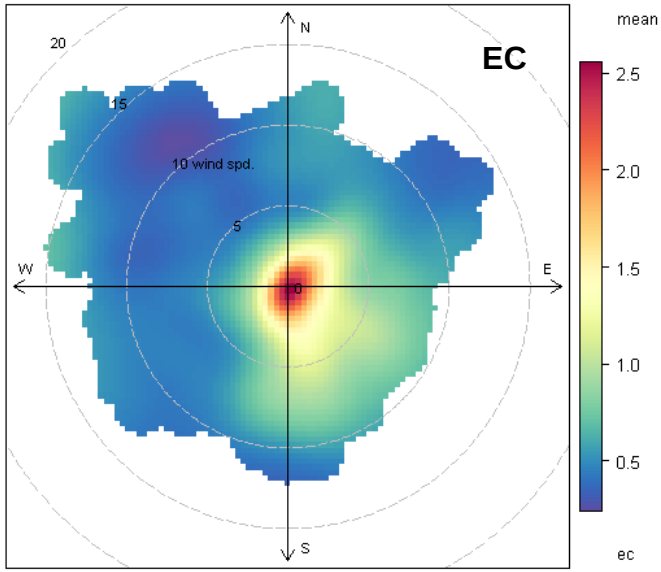
Local vs external EBC & EC-OC

Barcelona IDAEA





Madrid CIEMAT



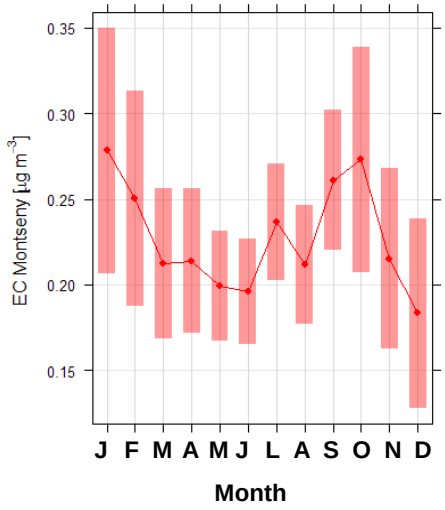
Air Pollution Monitoring Technologies for Urban Areas

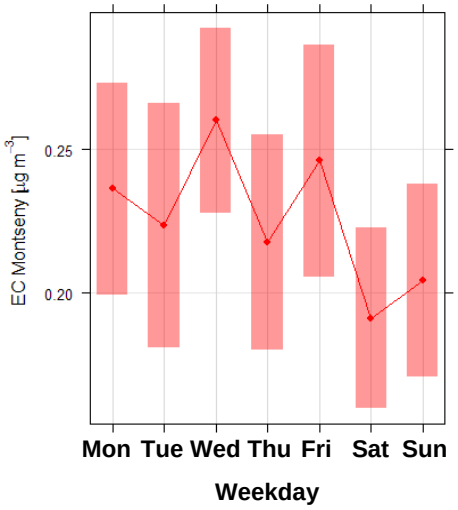
Road traffic, air quality and aerosol measurements

3. BC: Seasonal and weekly patterns: EC

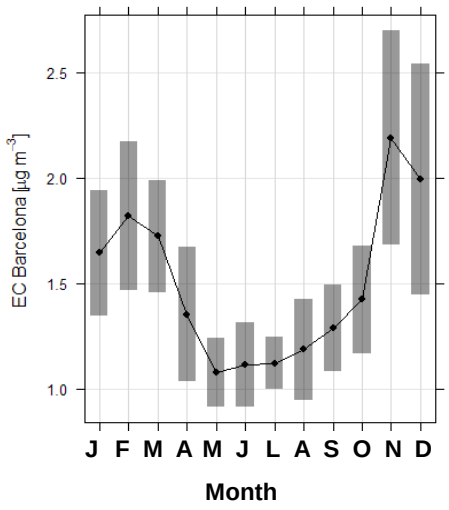
CSIC

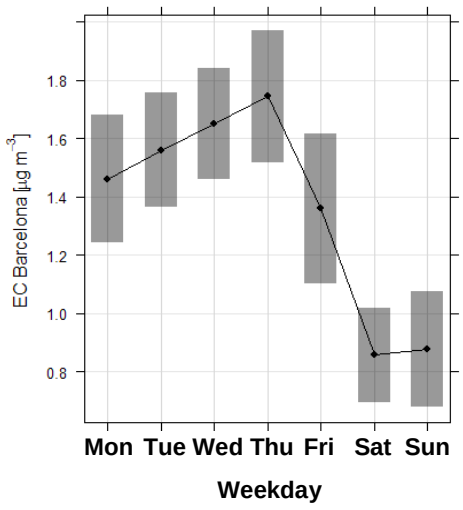
Montseny





Barcelona





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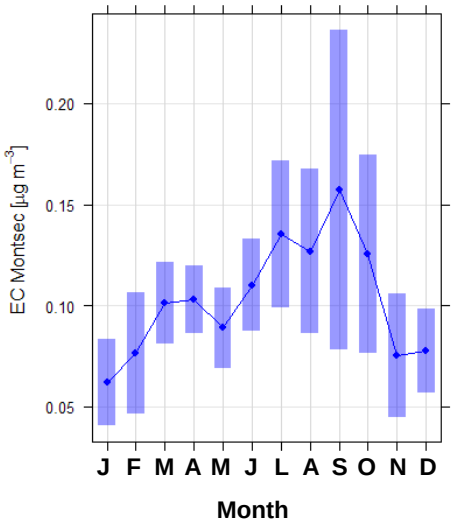
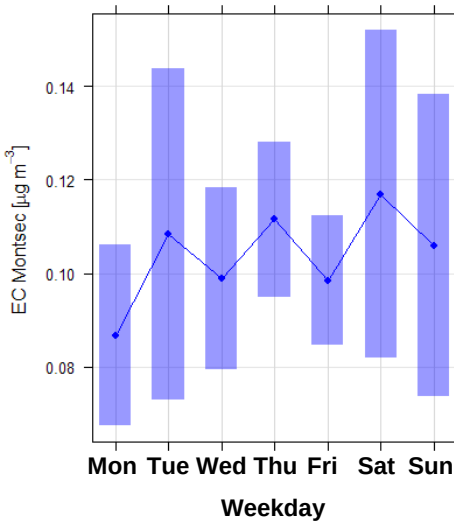
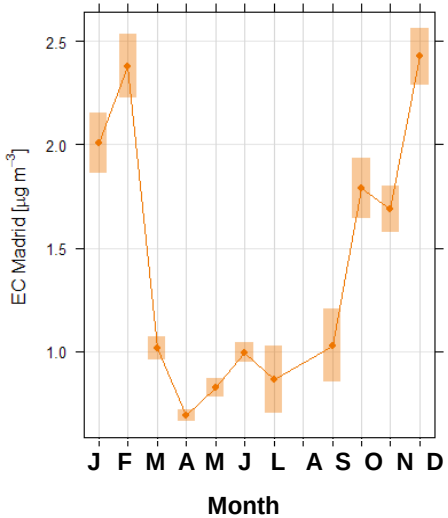
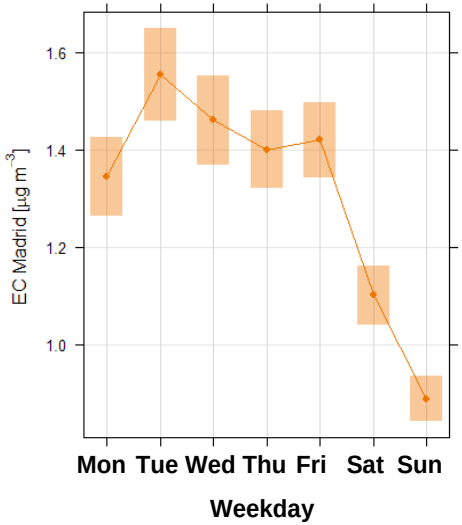




Madrid



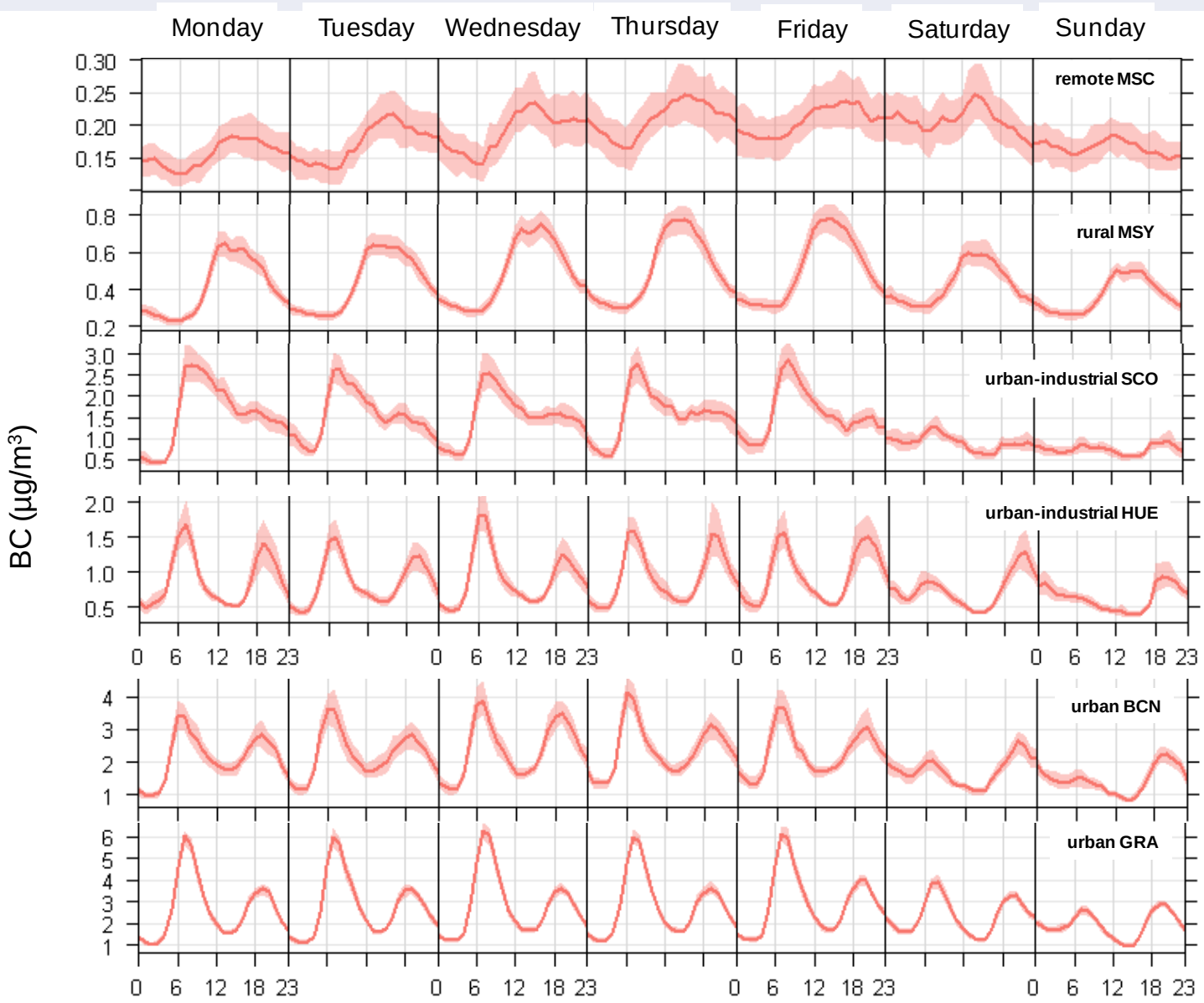


Air Pollution Monitoring Technologies for Urban Areas

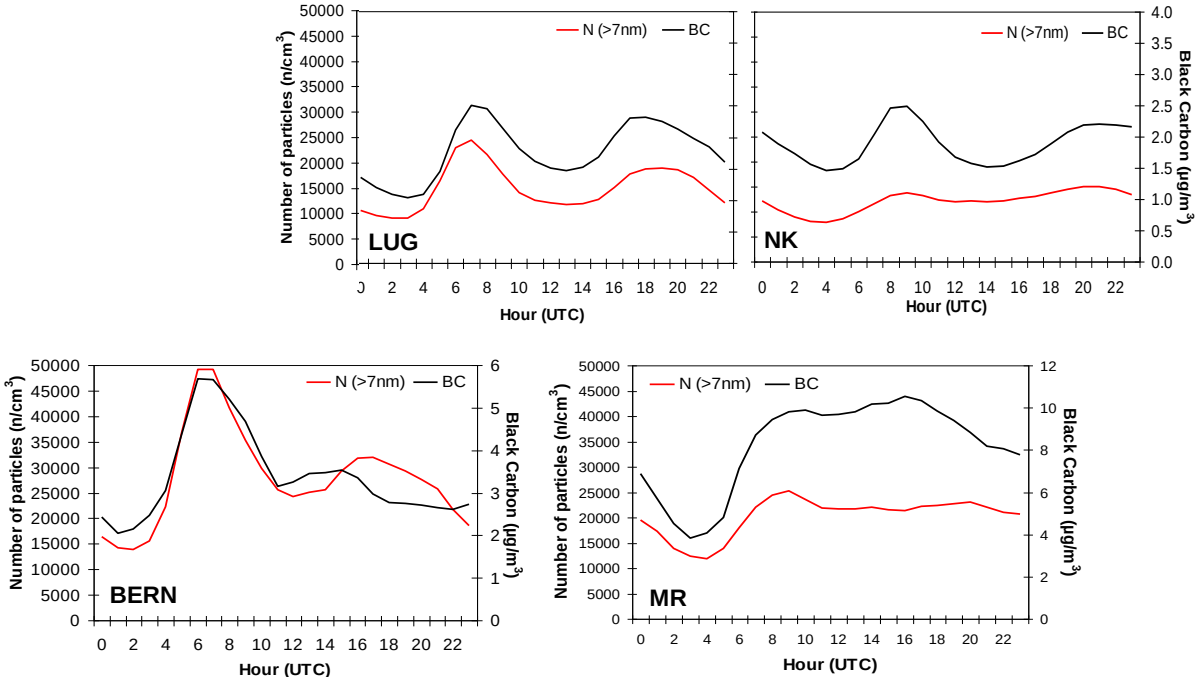
Road traffic, air quality and aerosol measurements

3. BC: Hourly patterns: EBC

CSIC



4. EBC & N: N vs EBC???

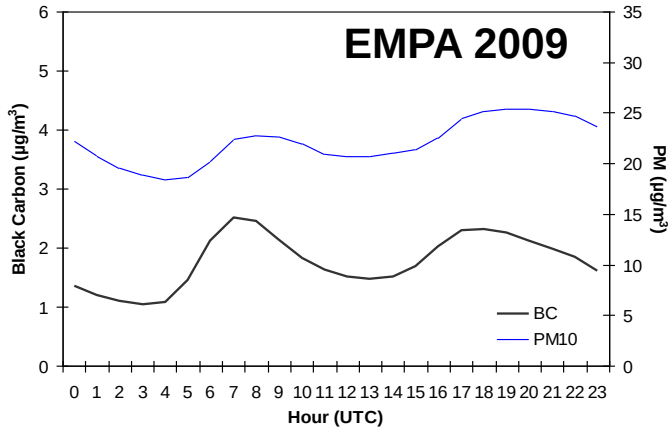


Reche et al., 2011. Atmospheric Chemistry and Physics

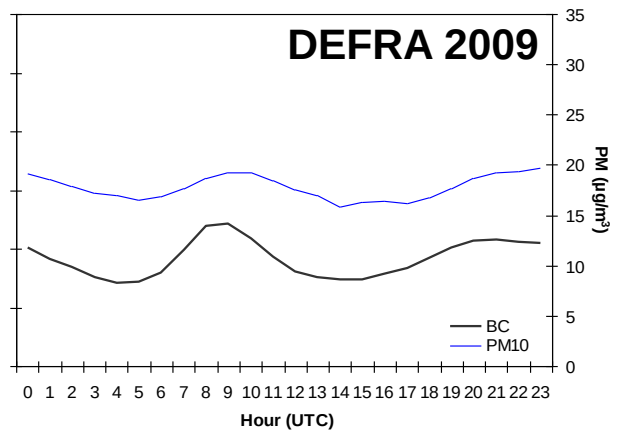
Road traffic, air quality and aerosol measurements

5. PMx, BC: PM10 does not always co-vary with traffic

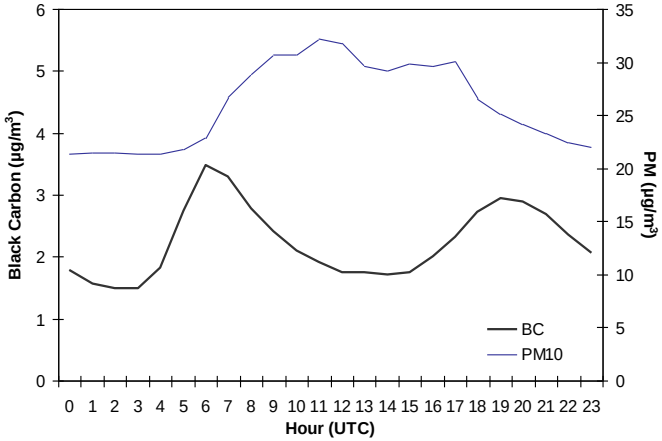
LUGANO URBAN SITE



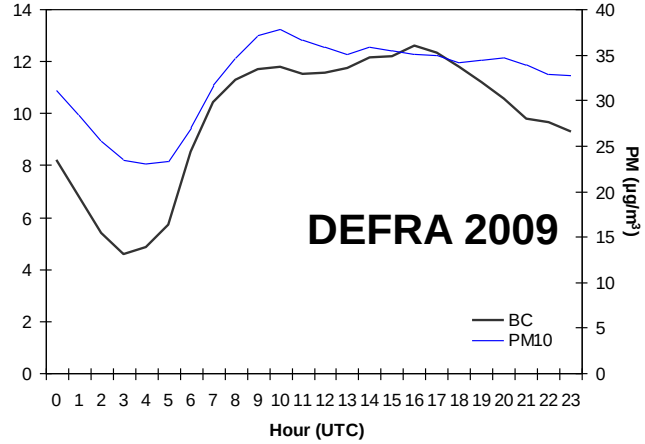
N. KENSINGTON URBAN SITE



BARCELONA URBAN SITE



MARYLEBONE KERBSIDE SITE (TRAFFIC)



Reche et al., 2011. Atmospheric Chemistry and Physics

Air Pollution Monitoring Technologies for Urban Areas

Road traffic, air quality and aerosol measurements

Barcelona 2010

CSIC

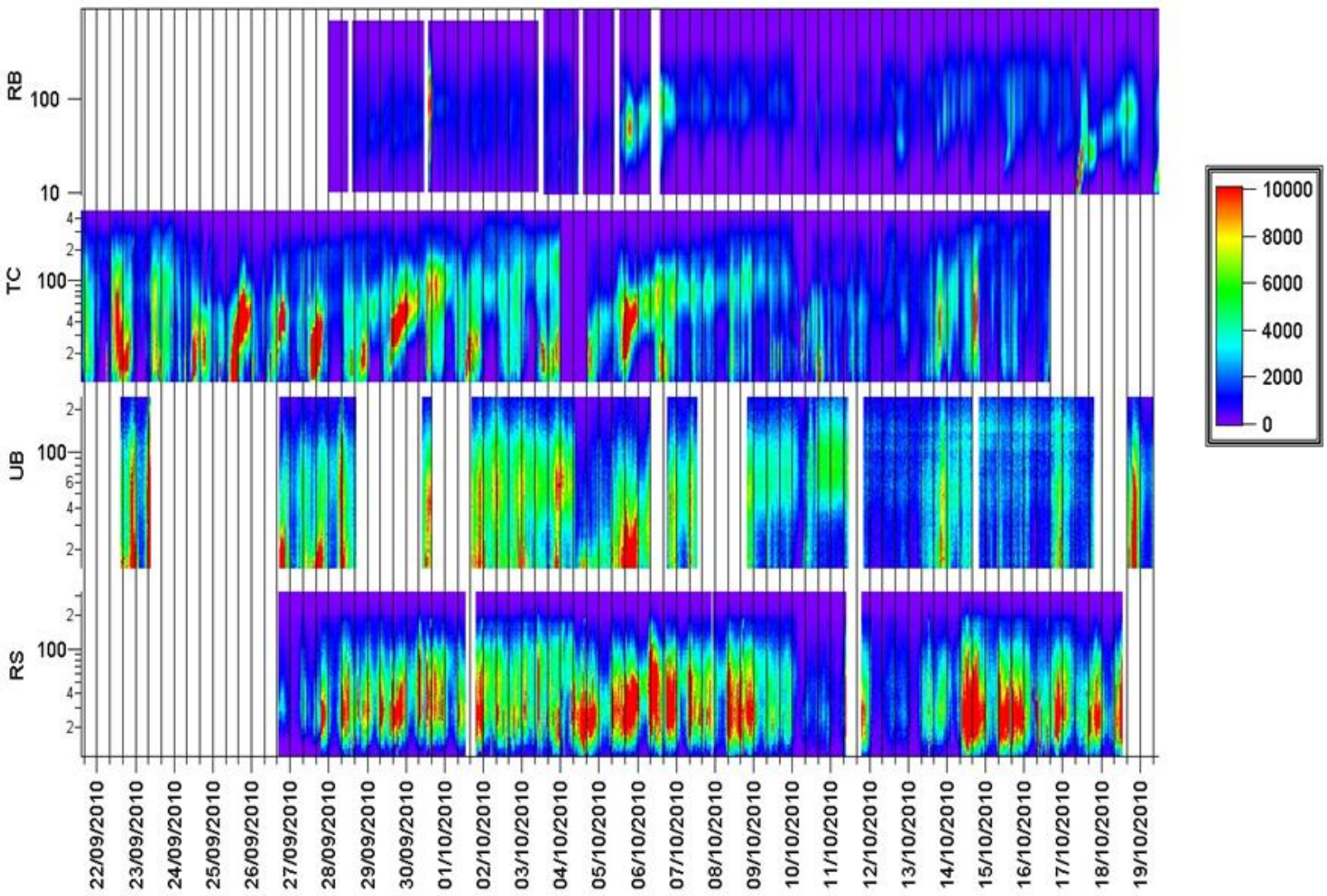
6. UFP:

RURAL

SUBURBAN

URBAN B.

TRAFFIC



Dall'Osto et al., 2012a Atmospheric Chemistry and Physics (submitted)

Air Pollution Monitoring Technologies for Urban Areas

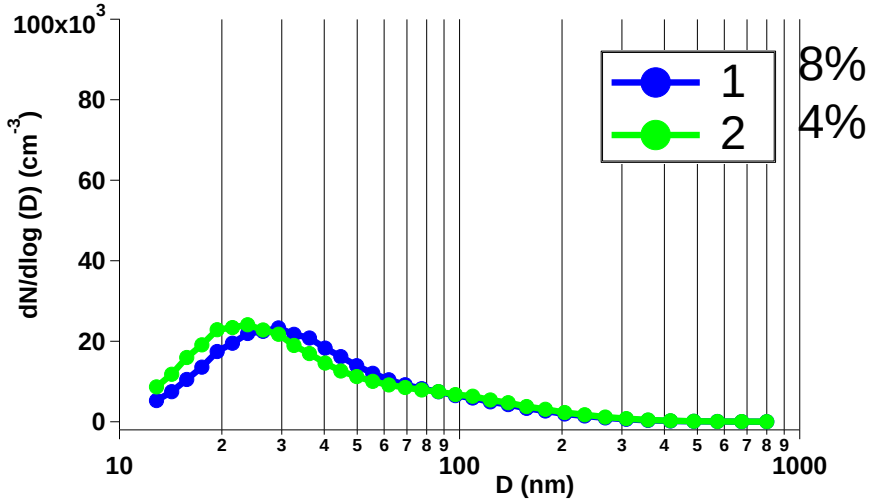
Road traffic, air quality and aerosol measurements

CSIC

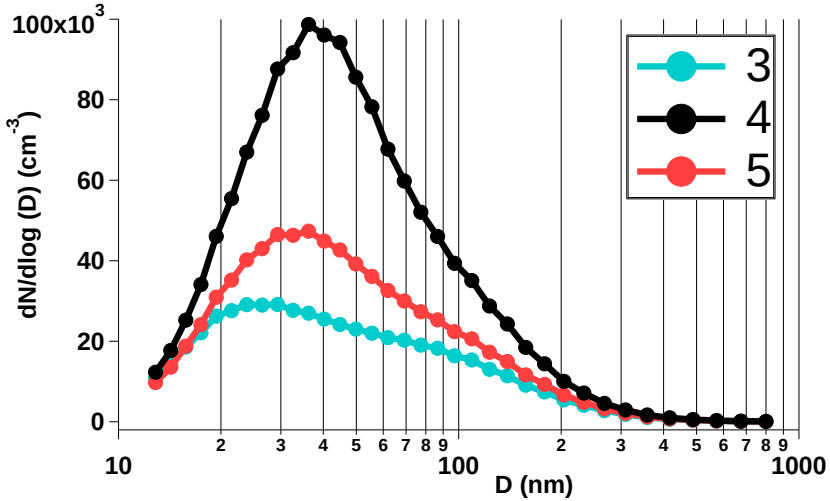
Dall'Osto et al., 2012b Atmospheric Chemistry and Physics (submitted)

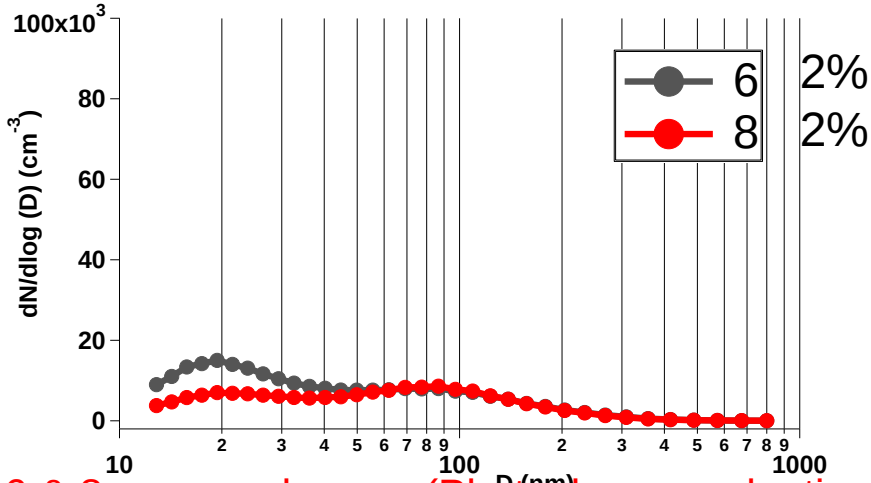
Barcelona 2004, Cluster analysis using k-means >6000 hourly size distributions $N_{10\text{-}800}$

1 & 2 clean atlantic advection

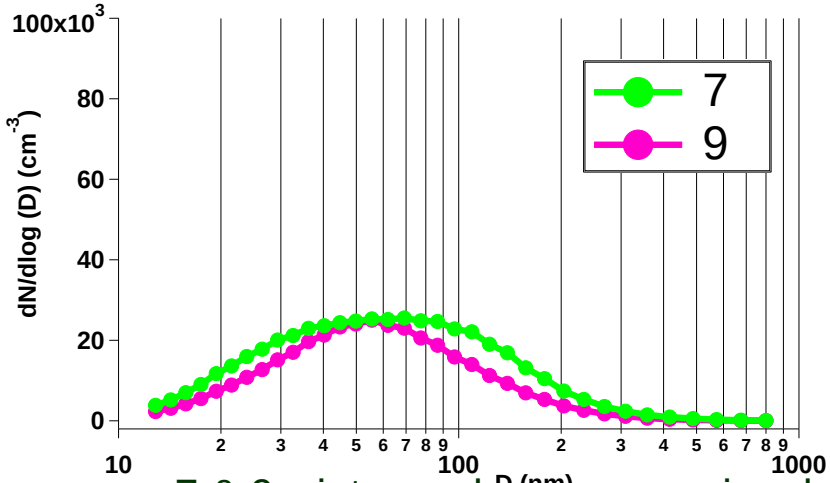


3 to 5 traffic pollution





6 & 8 summer breeze (Photochem. nucleation)



7 & 9 winter and summer regional

Road traffic, air quality and aerosol measurements

Air Pollution Monitoring Technologies for Urban Areas

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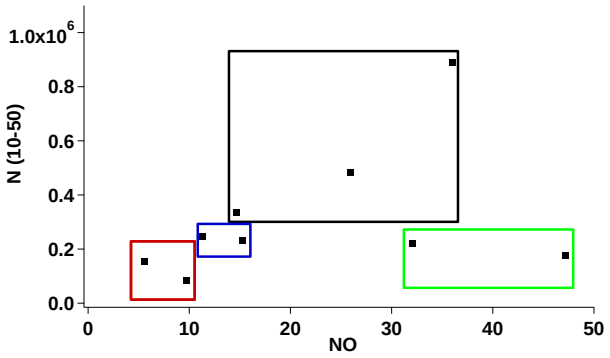
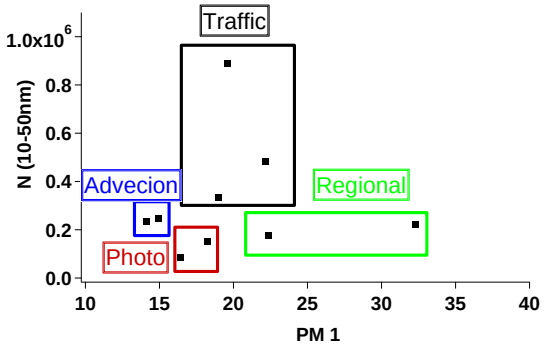
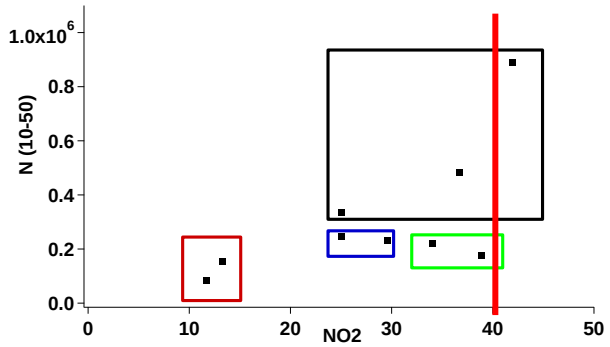
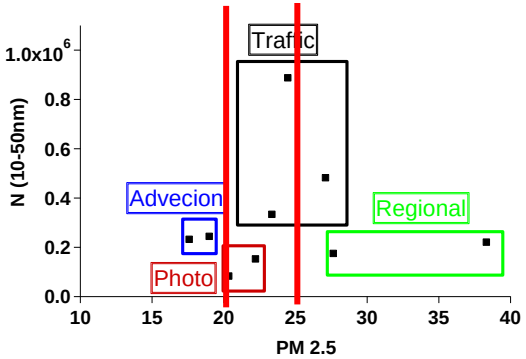
Dall'Osto et al., 2012b Atmospheric Chemistry and Physics (submitted)

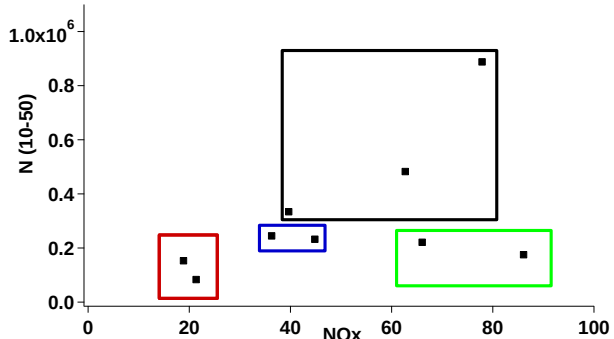
Barcelona 2004, Cluster analysis using k-means >6000 hourly size distributions $N_{10\text{-}800}$

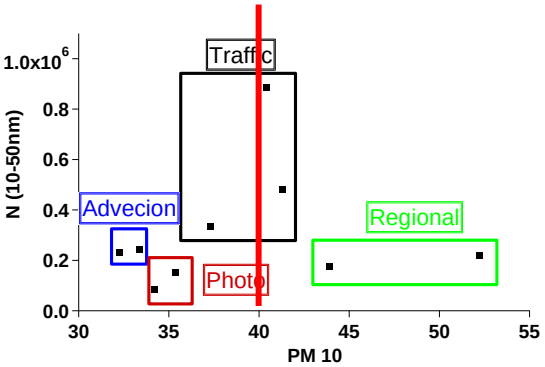












Not only N
is relevant but
also toxicity of the type of
UFP from the 7 clusters!!!

In our study characterisation
of photochemical nucleation
limited by N>13nm DLI!!!

7. PM speciation and receptor modelling

Large data set on PM speciation needed (t & $)
(at least 100 days/year for annual representativity, all days for daily control)
Ex. Off-line inorganics, IDAEA-CSIC

Crustal-mineral

Al_2O_3	ICP-AES
Ca	ICP-AES
K	ICP-AES
Mg	ICP-AES
Fe	ICP-AES
Ti	ICP-AES
P	ICP-AES
CO_3^{2-}	ind. Ca
SiO_2	ind. $3*Al_2O_3$

Marine aerosol

Na^+	ICP-AES
Cl^-	Ion Cromat.
SO_4^{2-}	ind. Na

Anthropogenic

OC & EC Thermo-optical

Inorganic Secondary Species

NH_4^+	C.FIA
SO_4^{2-}	Ion Cromat.
NO_3^-	Ion Cromat.

40 Metals (ICP-MS)

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

Accounted
75-85 % mass PM

Air Pollution Monitoring Technologies for Urban Areas

Road traffic, air quality and aerosol measurements

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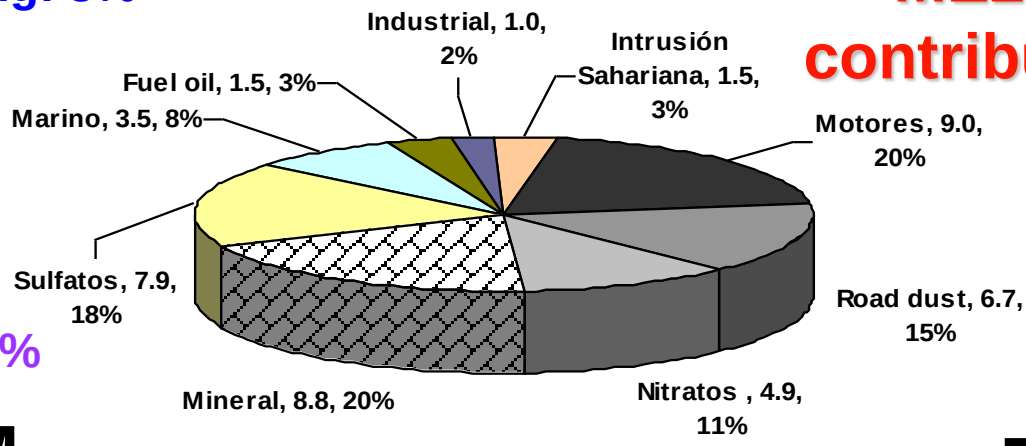
PM_{10}

Max. Shipping: 3%

Traffic: 43%

ME2: Annual source contributions in Barcelona

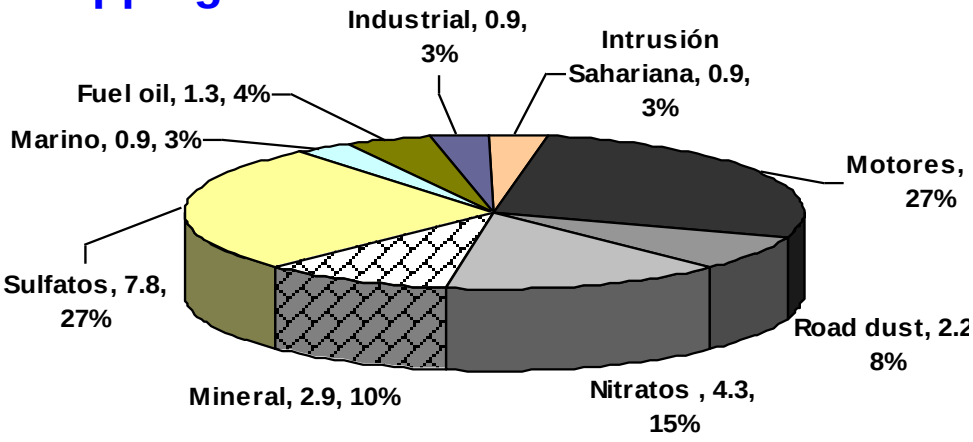


Dem.-res. (reg.): 20%

$PM_{2.5}$

Max. Shipping: 4%

Traffic: 46%

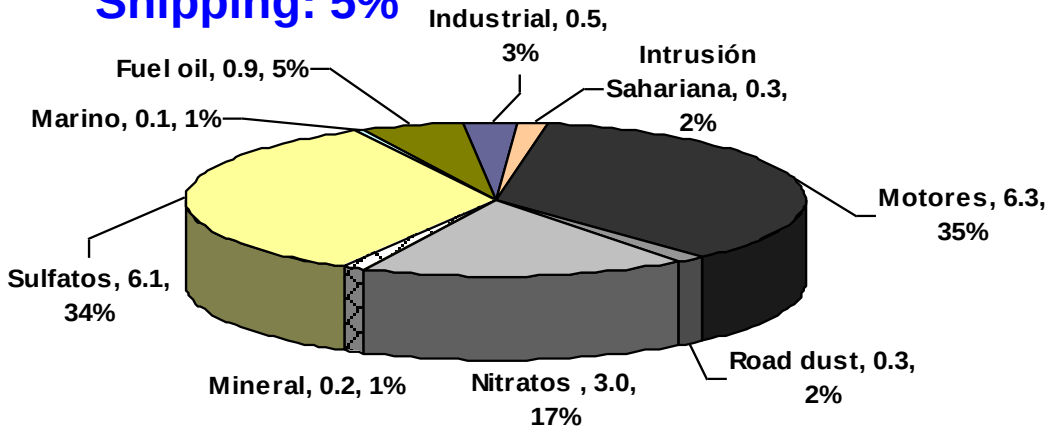


Demolition-resuspension (reg.): 10%

PM_{1}

Max. Shipping: 5%

Traffic: 50%

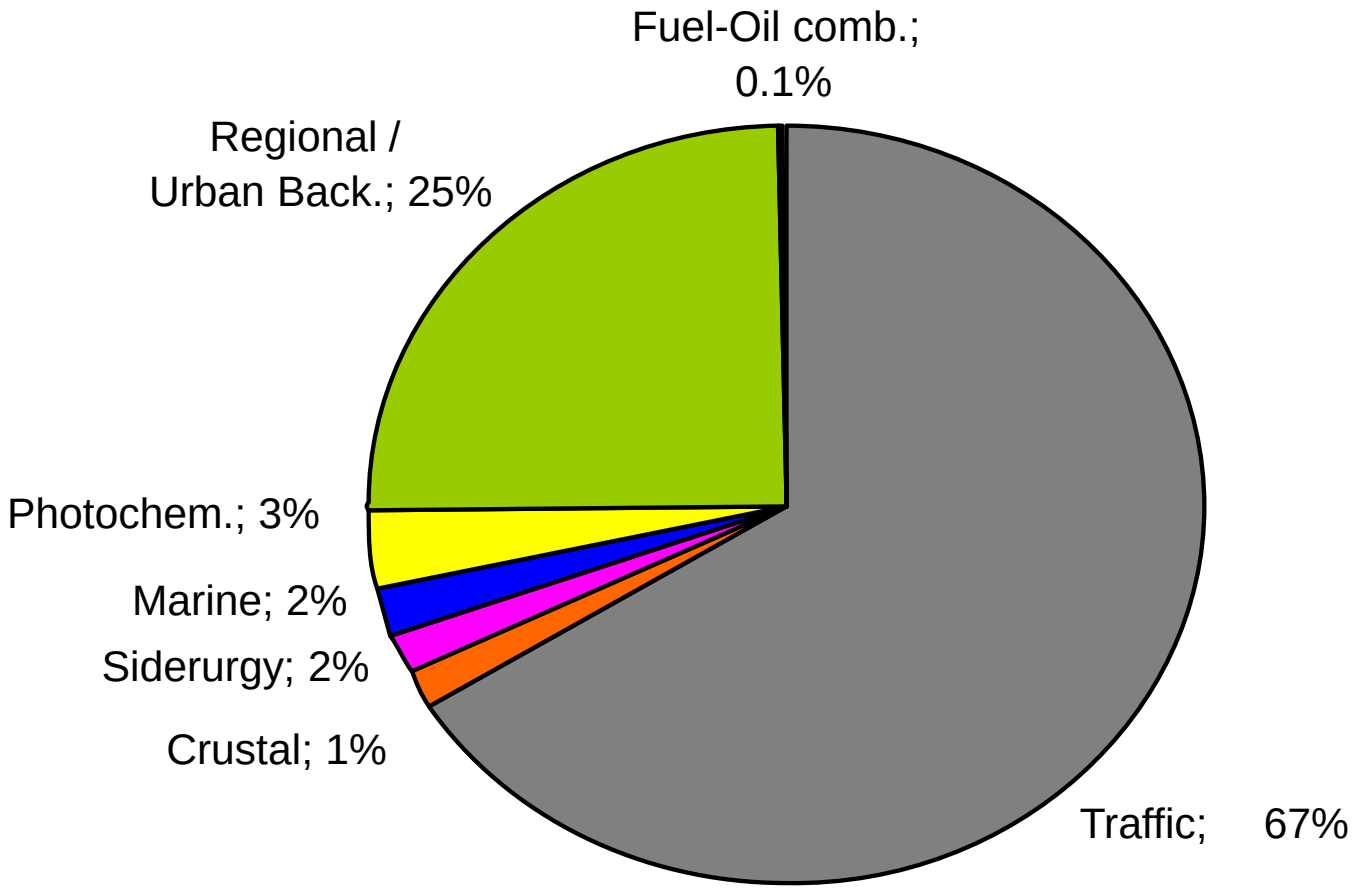


Demolition-resuspension (reg.): 1%

Amato, et al., 2009. Atmospheric Environment

8. Receptor modelling for UFP Barcelona, 2004

Source contribution to the mean annual $N_{10\text{-}800}$



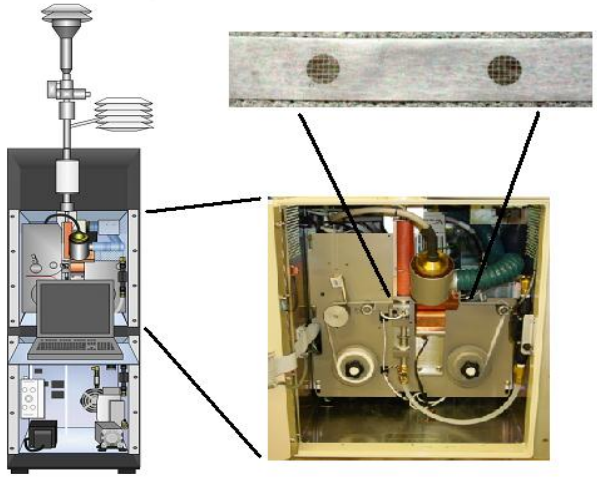
Pey J., et al. 2009. Atmospheric Environment

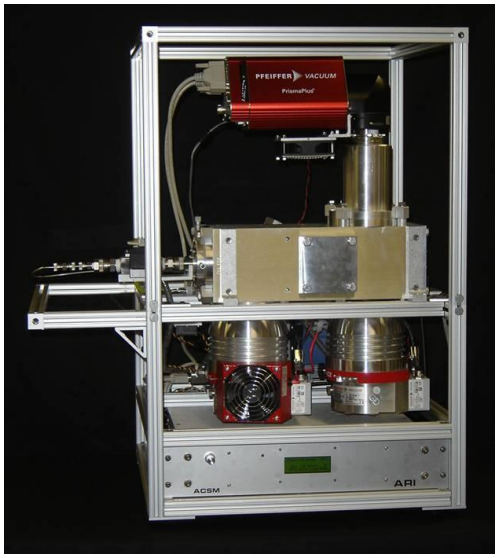
Future trends

OM, sulphate, nitrate, chloride, ammonium

insitu callibreted with EC EUSAAR-2

Metals





source apportionment

But N_{50} not analyzed currently by AMS
Then, UFP measurements will still be
necessary, specially if demonstrated that N_{50} is highly toxic or has cerebrovascular and cardiovascular effects

Conclusions

- **PM10 (mixture of source contributions) and BC (as a source tracer for traffic and biomass burning) offer a good combination for air quality monitoring, specially because exceedances are registered in traffic hotspots**
- **Quantitative receptor modeling applied to data sets of PM speciation may offer the possibility of setting limit values for PM contributions from road traffic (relatively homogeneous emission chemical profiles across Europe). However, BC measurements yield similar information, with real time data, low operational cost and easily to standardize method.**
- **Source apportionment analysis on size-number concentration and speciation measurements yield quantitative information on sources and processes contributions.**
- **Not all current PMx and NO_2 limit values protect exposure for high UFP episodes**
- **In future combination of Mini-AMS + BC + XRF will allow continuous monitoring of most components, but for the finest aerosols, UFP measurements will still be necessary for <50nm), specially if toxicity is high**

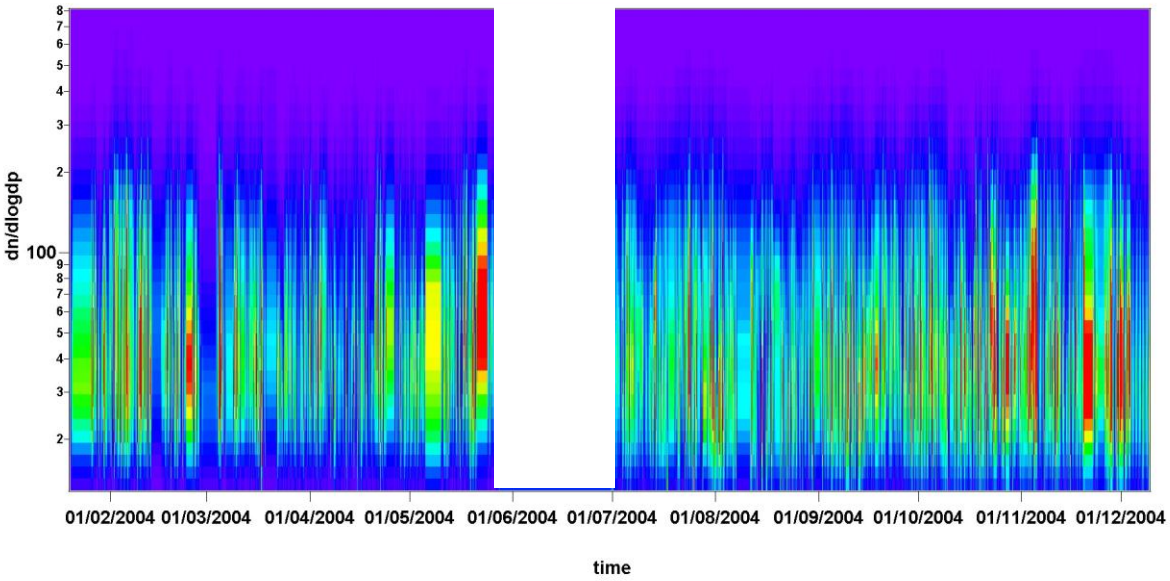
Acknowledgements: AIRMONTECH (VII F.P. EC)
Ministry of the Environment of Spain, Ministry of Sciences and Innovation of Spain
Regional AQ monitoring networks: Generalitat de Catalunya, Andalucía, Aragón, Asturias, Baleares, Canarias, Cantabria, Castilla la Mancha, Castilla León, Euskadi, Extremadura, Galicia, Generalitat Valenciana, Madrid, Melilla, Murcia. Also to DEFRA (UK) and EMPA (CH) for providing data on BC and N, OpenAir (Carslaw & Ropkins, 2011. Environmental Modeling & Software)

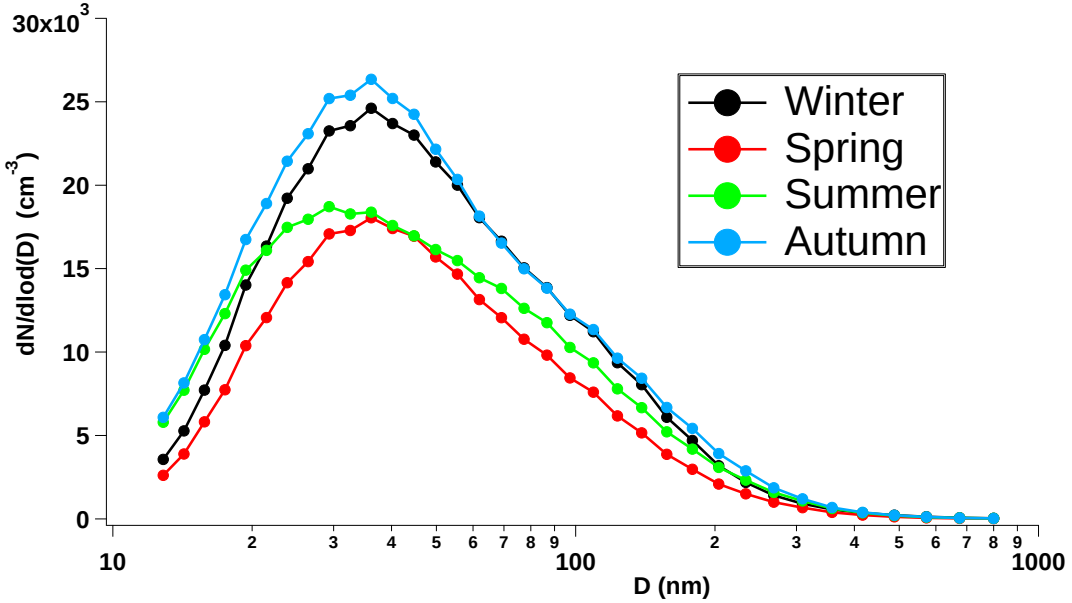
Thank you for your attention !

xavier.querol@idaea.csic.es

Road traffic, air quality and aerosol measurements

6. UFP: $N_{10\text{-}800}$ continuously measured 2004, Barcelona urban background





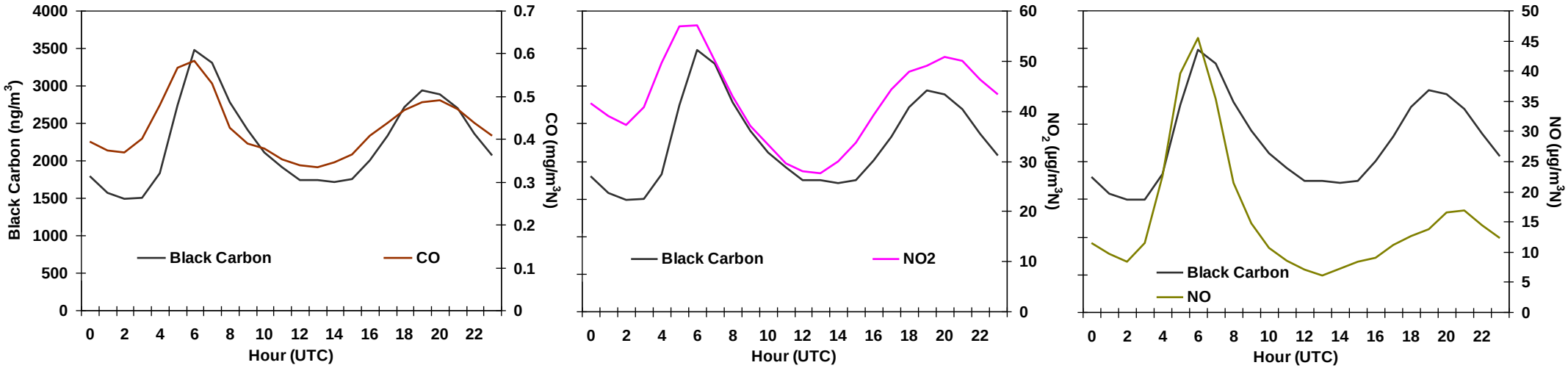
Dall'Osto et al., 2011 ACP (in preparation)

Road traffic, air quality and aerosol measurements

3. EBC: A number of pollutants co-vary along the day with traffic

A large proportion of PM exceedances occur in urban-traffic sites

BARCELONA, urban background, mean values for 2009



Reche et al., 2011. Atmospheric Chemistry and Physics