PM contribution of wood burning in Paris (France)

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LSCE
LABORATOIRE DES SCIENCES DU CLIMAT & DE L'ENVIRONNEMENT

PRESENTATION

+ Domestic wood burning in France

+ New techniques to characterize wood burning aerosols

+ Intensive Field studies of wood burning aerosols in Paris region

+ Spatial and Temporal distribution of wood burning aerosols in Paris

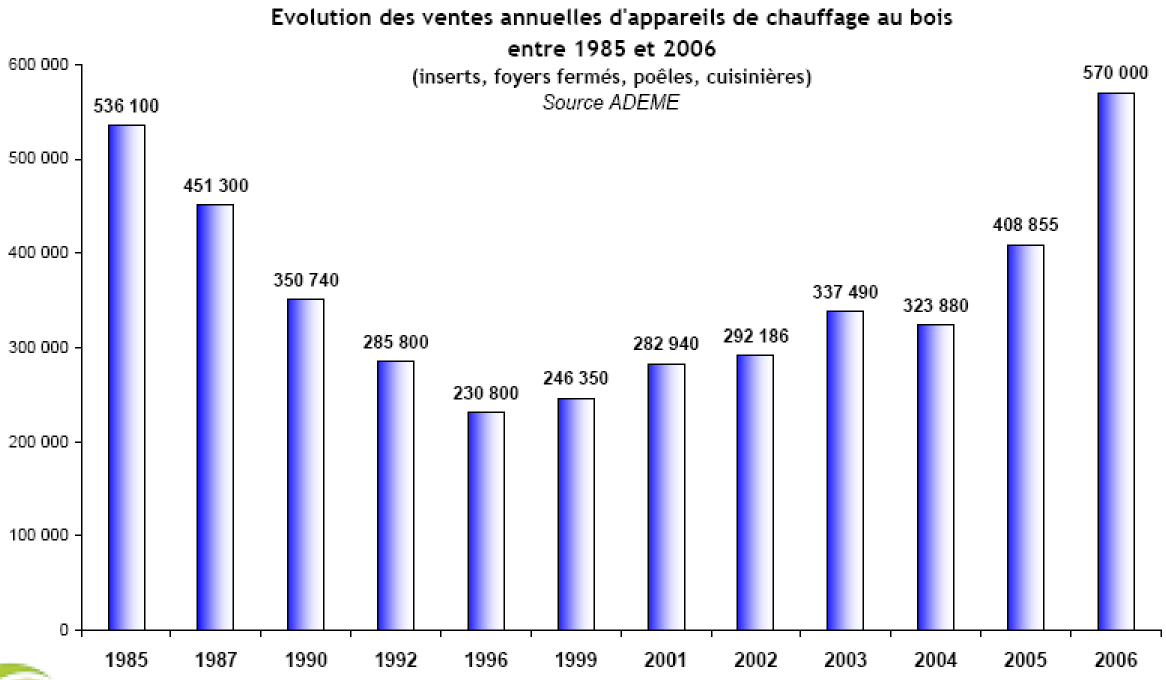
+ Conclusions

CONTRIBUTION OF WOOD BURNING IN DOMESTIC HEATING IN FRANCE

+ France is the **first consumer of wood (energy-use) in Europe** (in front of Sweeden, Finland and Germany); most of it being use for domestic heating

+ **50% of French household owe individual wood burning heating system**

+ 60,000 employments in 2006 !



+ 40% increase sell of domestic heater using woodIncrease due to

1) Economic criteria (regular increase of the price of fossil fuel energy)

2) Life quality (incl. esthetic perspectives)

Atmospheric emissions of wood burning domestic heaters (1/2)

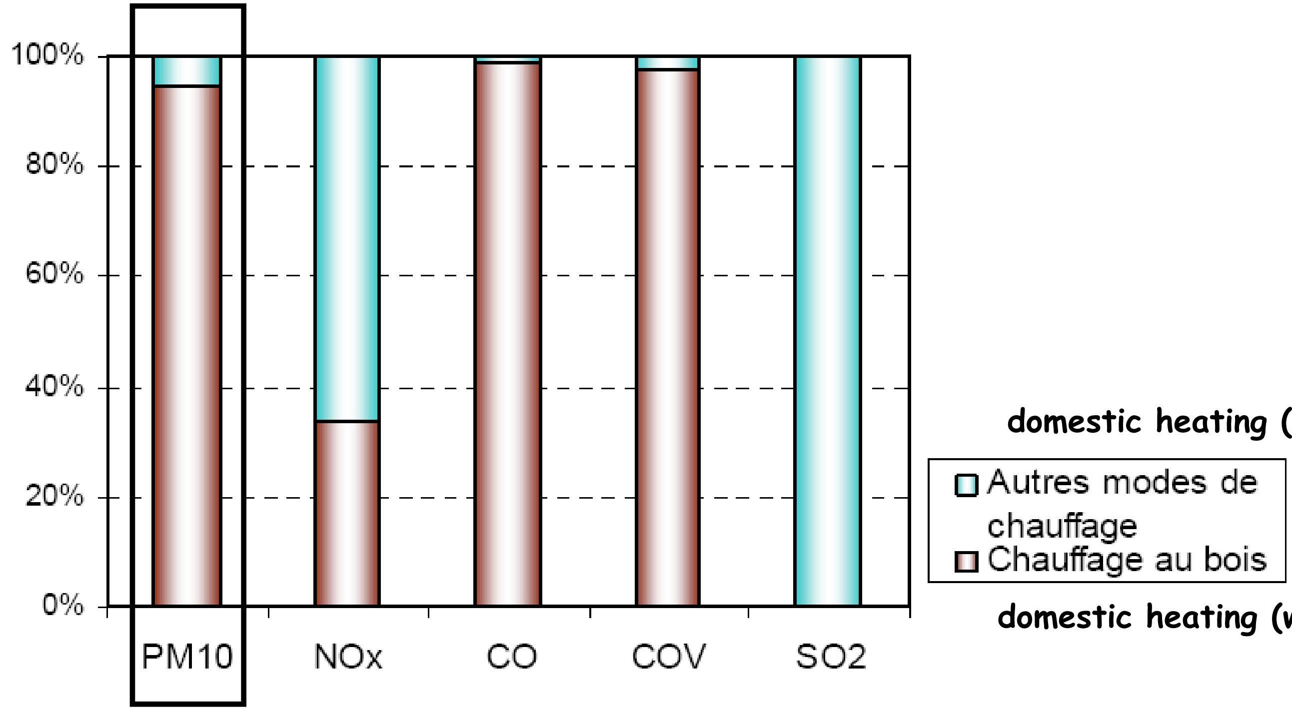
Émissions	Cheminées ouvertes	Poêles	Cuisinières	Foyers fermés	Chaudières anciennes	Chaudières classe 1	Chaudières classe 3
SO_2 (en g/GJ)	20	20	20	20	20	20	20
NOx (en g/GJ)	50	50	50	50	50	50	50
COVNM (en g/GJ)	1700	1600	1600	1600	1600	400	40
CO (en g/GJ)	7000	7000	7000	6000	7000	3200	950
Particules (en g/GJ)	750	310	310	310	250	34	20
Dioxines (ng.ITEQ/GJ)	100	100	100	100	100	100	100
HAP (en mg/GJ)	284	602	602	224	55	34	34

Tableau 3. Facteurs d'émission de polluants par unité d'énergie entrante pour différents types d'appareils

75% of the French domestic heaters using wood

Only 15% of the French domestic heaters using wood

Atmospheric emissions of wood burning domestic heaters (1/2)



domestic heating (other)

domestic heating (wood)

Atmospheric pollutant emissions in France (2003) / Source Atmo Rhône-Alpes 2007

⇒ PM emissions from residential heating is almost exclusively due to wood burning

+ New techniques to characterize wood burning aerosols

Inter-comparison of source apportionment models for the estimation of wood burning aerosols during wintertime in an Alpine city (Grenoble, France)

Atmospheric Chemistry and Physics

O. Favez[1,*], I. El Haddad[2], C. Piot[3,4], A. Boréave[1], E. Abidi[2], N. Marchand[2], J.-L. Jaffrezo[3], J.-L. Besombes[4], M.-B. Personnaz[5], J. Sciare[6], H. Wortham[2], C. George[1], and B. D'Anna[1]

Three different methods to discriminate between fossil fuel, wood burning, and secondary organics

A chemical mass balance (CMB) model using filter sampling data: specific source tracers (levoglucosan) and *a priori* knowledge of their emission rate for this source (*Schauer et al., 1996*)

An Aethalometer model using aethalometer instrument & filter sampling data: *Sandradewi et al.* (2008) based on the UV-absorbing properties of biomass burning aerosols (brown carbon)

A Positive Matrix Factorization (PMF) model using AMS data (Aerosol Mass spectometer)

Approach #1: The "CMB" model (mono-tracer approach)

This method relies on

1) the use of levoglucosan, an unambiguous tracer of the cellulose combustion,
2) the use of a specific emission ratio between this tracer and organic carbon from wood burning

$$[OC]_{wood\ burning} = 7.35 \times [levoglucosan]$$

↓

Typical ratio provided by *Fine et al. (2002)*

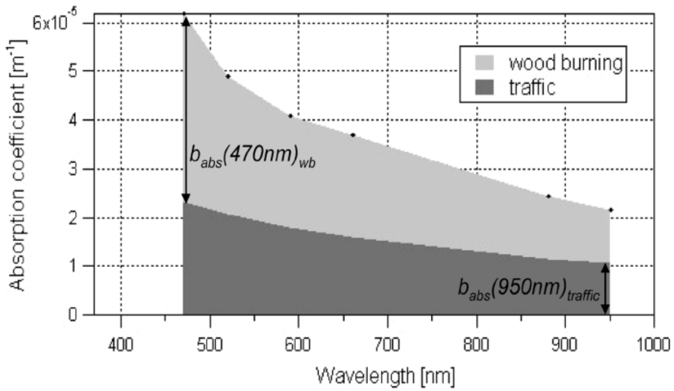
Advantage	Disadvantage
Filter-based technique (easy to deploy in the field)	+ Low time resolution (typically 24h) + Lab analysis + The ratio (7.35) is dependent on wood type and combustion efficiency

Fine, P. M., Cass, G. R., and Simoneit, B. R. T. : Chemical characterization of fine particle emissions from the fireplace combustion of woods grown in the Southern United States, Environ. Sci.Technol., 36, 1442–1451, 2002.

Approach #2: The "AETHALOMETER" model

Methodology published by *Sandradewi et al.* (EST, 2008) and reported in Favez (AE 2009; ACP 2010), Sciare et al. (JGR 2011)

The main concept of this model is that wood burning is strongly absorbing in the UV



Wood burning absorbs 4 times more in the UV compared to near-IR

Magee Scientific Aethalometer AE31

This instrument provides real-time (5-min) measurements of black carbon from near UV to near IR

Approach #2: The "AETHALOMETER" model

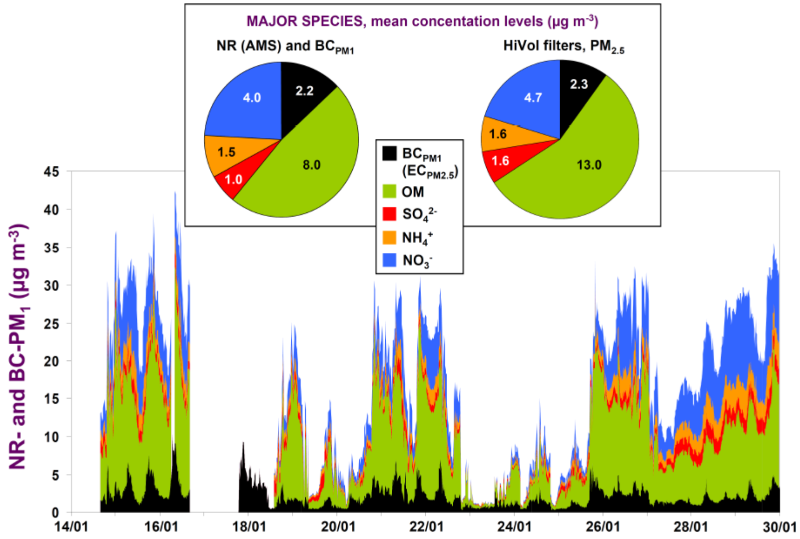
1. Alone (only Aethalometer) provides real-time Black Carbon from wood burning & fossil fuel (BC_{wb} & BC_{ff})

2. With complementary OC (or OM) measurement it provides also real-time organic concentrations of wood burning, fossil fuel, and residual)

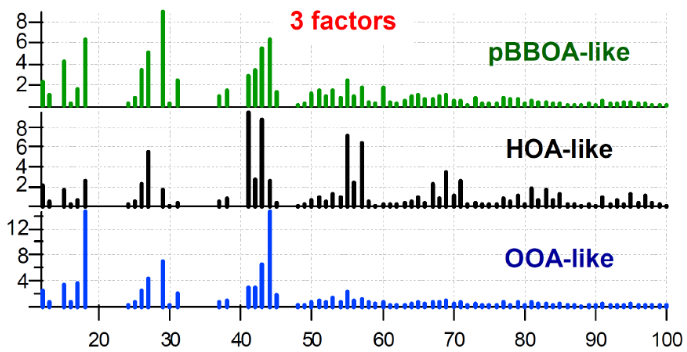
Advantage	Disadvantage
Approach which relies on a field instruments designed for unattended (real-time) long term observations	Recent technique which still requires more studies against other approaches in various environments

Approach #3: The "PMF" model

Real-time Aerosol chemistry provided by AMS (incl. OM)



Statistical data processing (Positive Matrix Factorization, PMF) Of organic fragments detected by AMS



OM wood burning (pBBOA-like)

Inter-comparison of source apportionment models for the estimation of wood burning aerosols during wintertime in an Alpine city (Grenoble, France)

Atmospheric Chemistry and Physics

O. Favez[1,*], I. El Haddad[2], C. Piot[3,4], A. Boréave[1], E. Abidi[2], N. Marchand[2], J.-L. Jaffrezo[3], J.-L. Besombes[4], M.-B. Personnaz[5], J. Sciare[6], H. Wortham[2], C. George[1], and B. D'Anna[1]

$OM_{wood\ burning}$ (approach#1 – levoglucosan) = 68% of OM

$OM_{wood\ burning}$ (approach#2 – Aethalometer) = 61% of OM

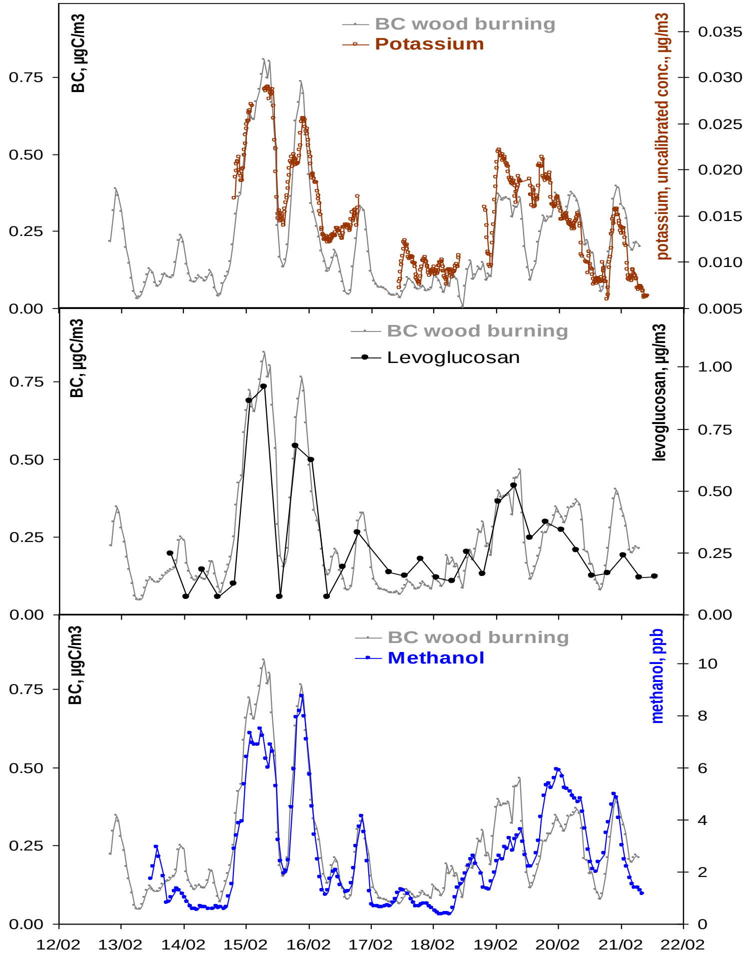
→ **Quite similar results**

$OM_{wood\ burning}$ (approach#3 – AMS & PMF) = 37% of OM

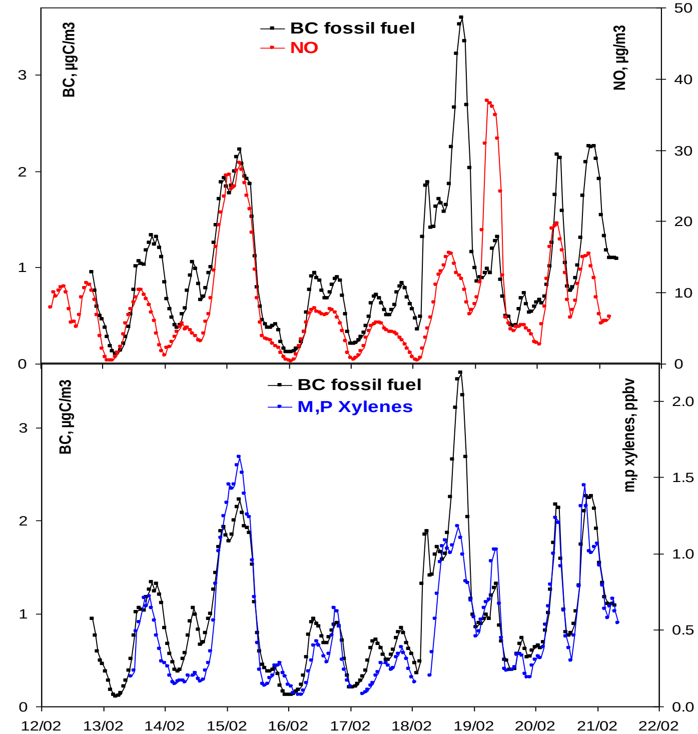
→ Missing fraction of wood burning (mis attribution of wood burning to SOA)
As recently proposed by *Donahue et al. (2009)*

Validation of the "AETHALOMER" model / Field experiments in the region of Paris

Comparison between $BC_{wood\ burning}$ and biomass burning tracers



Comparison between $BC_{fossil\ fuel}$ and fossil fuel tracers



Good ability of the aethalometer to discriminate between wood burning & fossil fuel BC

Sciare et al., (2011), JGR Atmosphere, in revision

Validation of the "AETHALOMER" model / Field experiments in the region of Paris

Comparison with the mono-tracer approach (levoglucosan)

Aethalometer
with AD<2.5µm

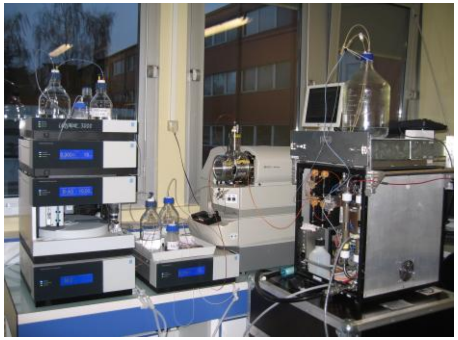
Aethalometer
Model →

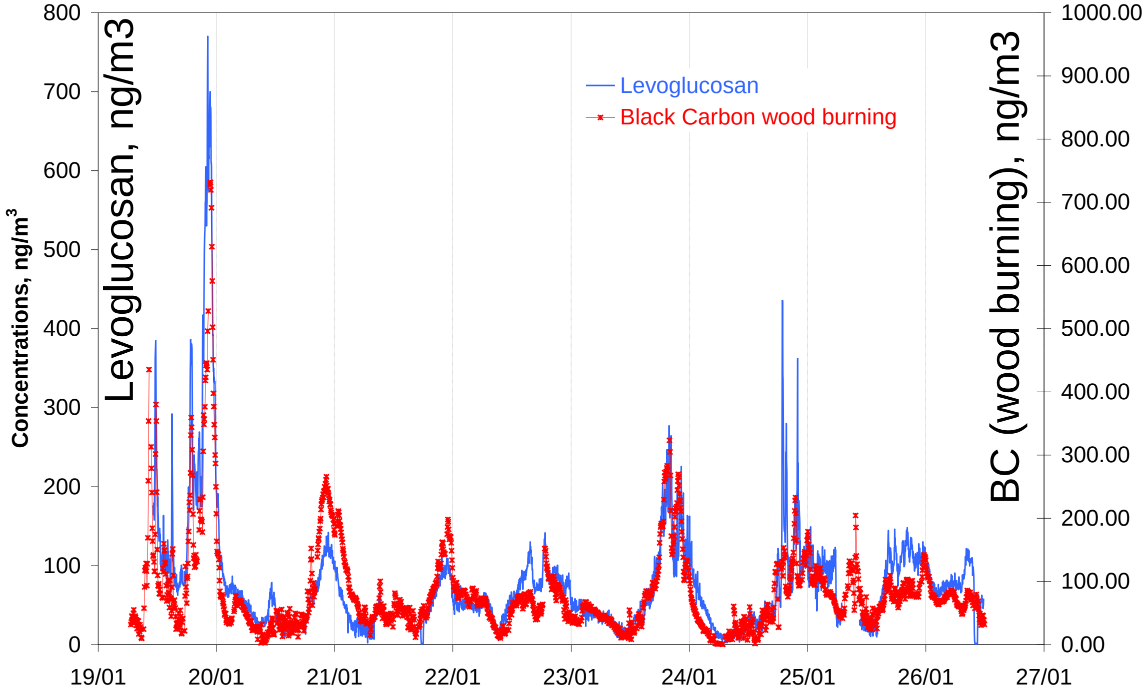
BC wood burning
For AD <2.5µm

BC fossil fuel
For AD <2.5µm

⇔

PILS-MS/MS→levoglucosan





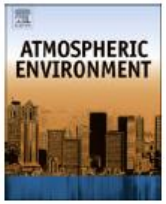
Very Good agreement between the 2 techniques

Sciare et al., (2011), AMT, in preparation

+ Intensive Field studies of wood burning aerosols in Paris region

INTENSIVE FIELD STUDIES ON WOOD BURNING AEROSOLS IN PARIS (FRANCE)

Paris (center) – winter 2005



Evidence for a significant contribution of wood burning aerosols to $PM_{2.5}$ during the winter season in Paris, France

Olivier Favez [a,*], Hélène Cachier [a], Jean Sciare [a], Roland Sarda-Estève [a], Laurent Martinon [b]

Magee Scientific Aethalometer AE31

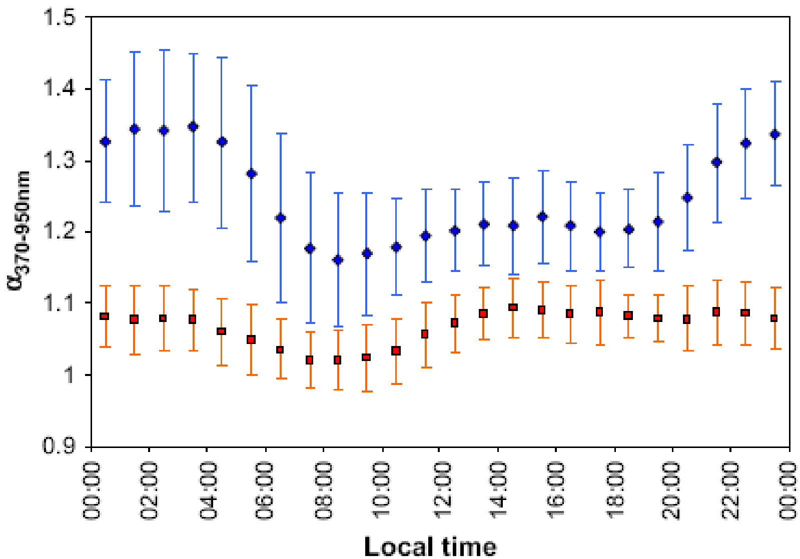


Fig. 3. Mean diurnal pattern of the absorption Ångstrom exponent ($\alpha_{370-950nm}$) during the winter and summer field campaigns (mean value ± standard deviation).

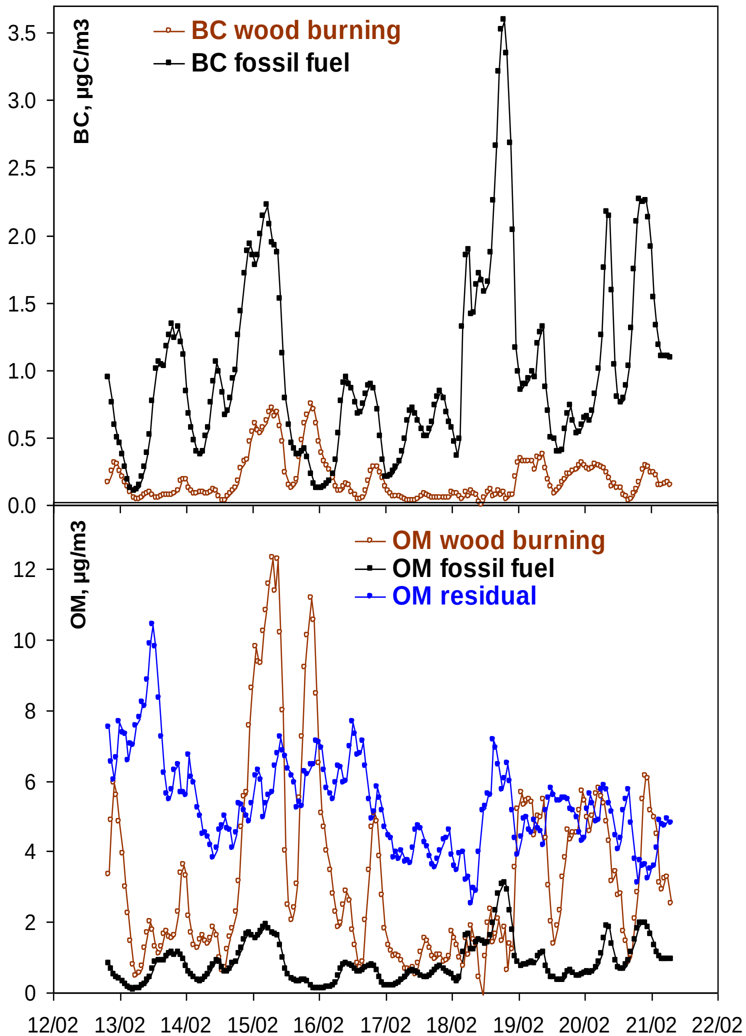
Absorption Agnström exponent > 1.1 ⇒ Influence of wood burning

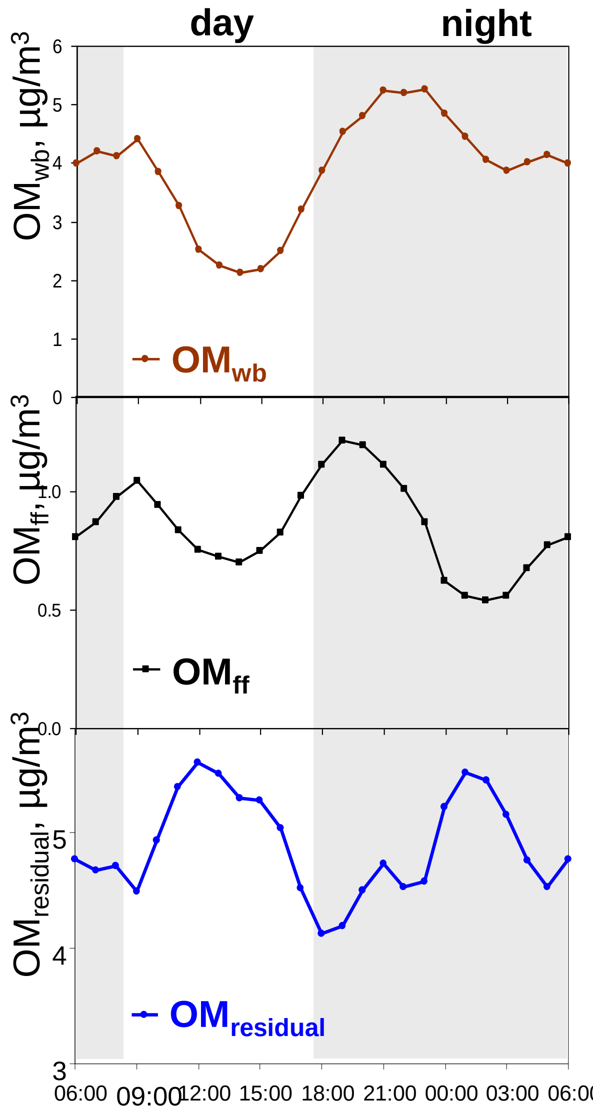
Absorption Agnström exponent of 1-1.1 ⇒ combustion aerosols dominated by fossil fuel (traffic)

Finally, a rough estimate of the contribution of wood burning carbonaceous aerosols to $PM_{2.5}$ could be achieved. This contribution was found to be as high as 20 ± 10% on average at the Paris background site investigated here. (ndlr : winter 2005)

INTENSIVE FIELD STUDIES ON WOOD BURNING AEROSOLS IN PARIS (FRANCE)

Gif/Yvette (surburban area) / 20km South of Paris – winter 2009





OM$_{wood\ burning}$
1 Max
at night21:00-23:00 LT
(domestic heating)

OM$_{fossil\ fuel}$
2 Maxima

(~09:00 & 19:00 LT)
(traffic = rush hours)

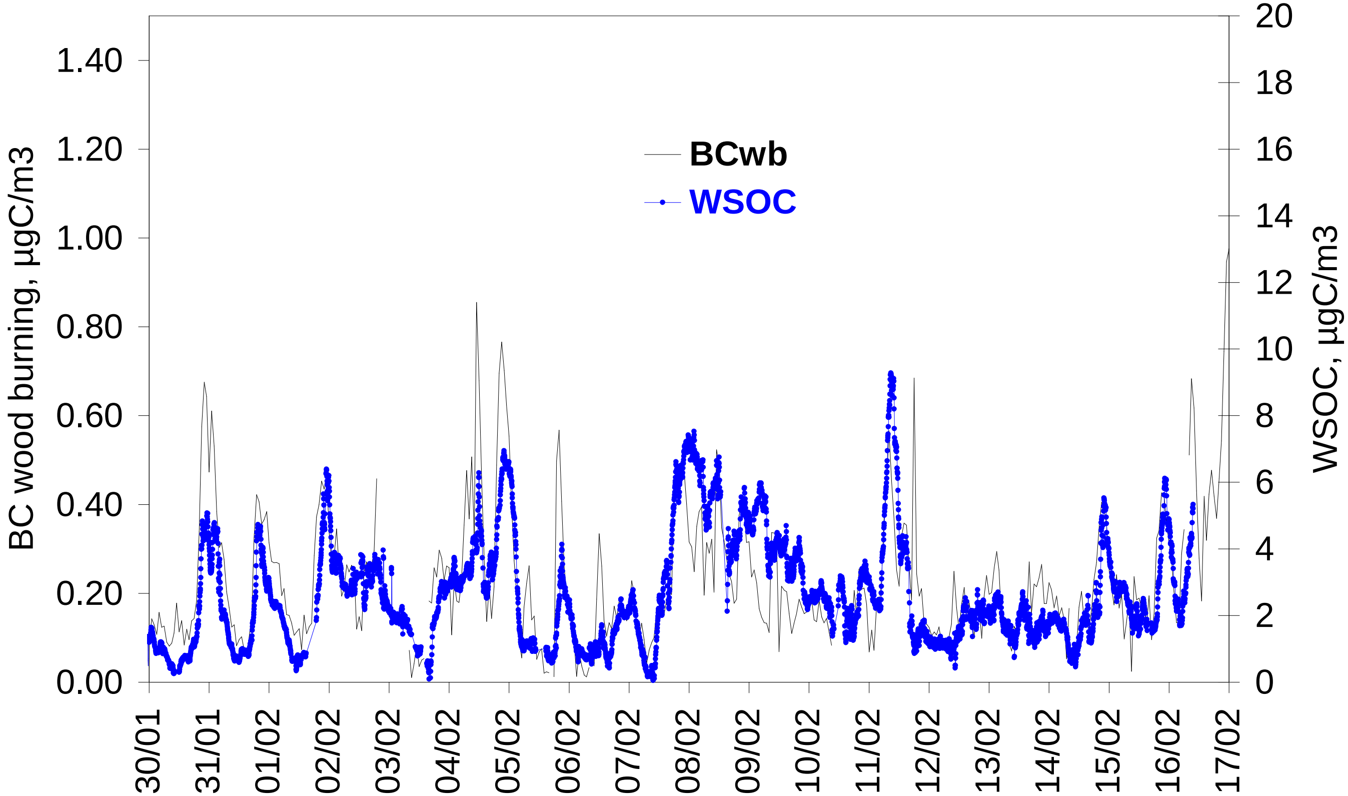
OM$_{residual}$ (=SOA)
2 Maxima

- 1 during daytime (photoχ?)
- 1 during nighttime (?)

Sciare et al., (2011), JGR Atmosphere, in revision

INTENSIVE FIELD STUDIES ON WOOD BURNING AEROSOLS IN PARIS (FRANCE)

Paris (center) – winter 2010

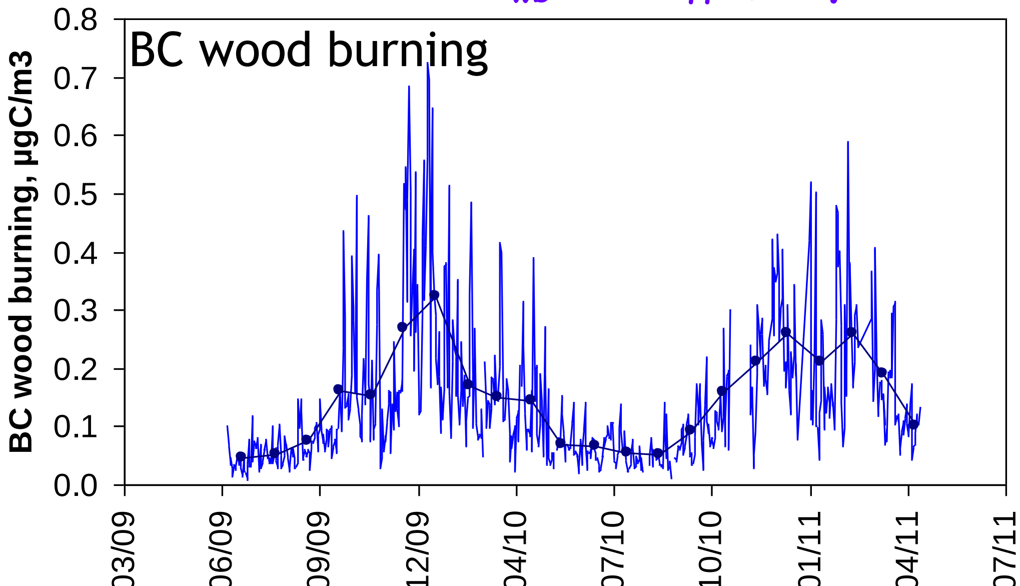


Strong correlation between BC wood burning and the water-soluble fraction of OC (i.e. WSOC).

(about 65% of OC is water-soluble during this study)

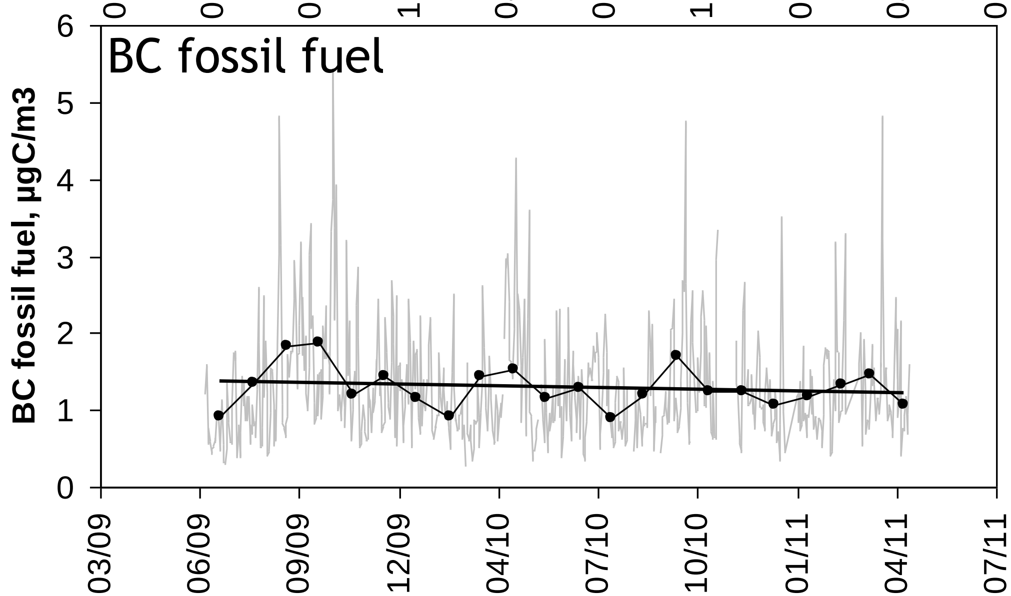
+ Spatial and Temporal distribution of wood burning aerosols in Paris

AETHALOMETER model:
Daily concentrations of BC_{wb} & BC_{ff} (July 2009 – April 2011)



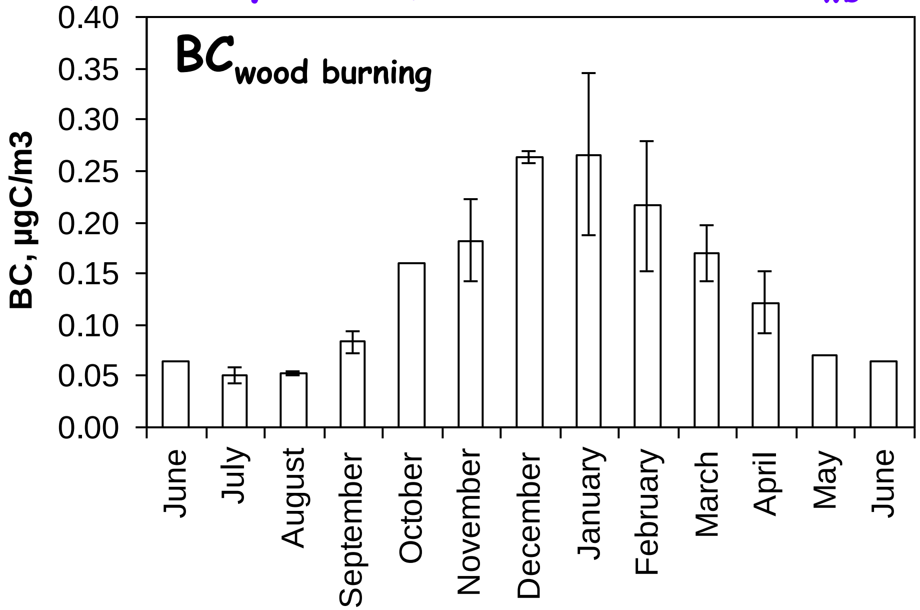
Winter 2009-2010 : (Oct. – Apr.)
$[BC_{wb}]$ = 0.20 µgC/m^3

Winter 2010-2011 : (Oct. – Apr.)
$[BC_{wb}]$ = 0.20 µgC/m^3

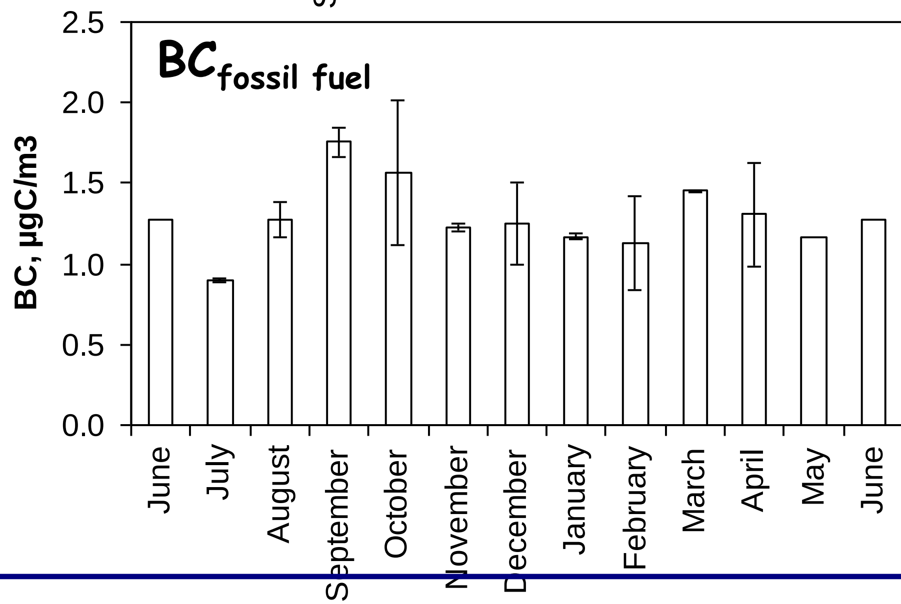


No significant temporality in fossil fuel emissions (traffic) with rather stable concentrations over the 2-year period

AETHALOMER model:
Seasonal (monthly mean) variations of BC_{wb} & BC_{ff}



Strong seasonal variations with significant amount of wood burning from October to April (**7 months**)

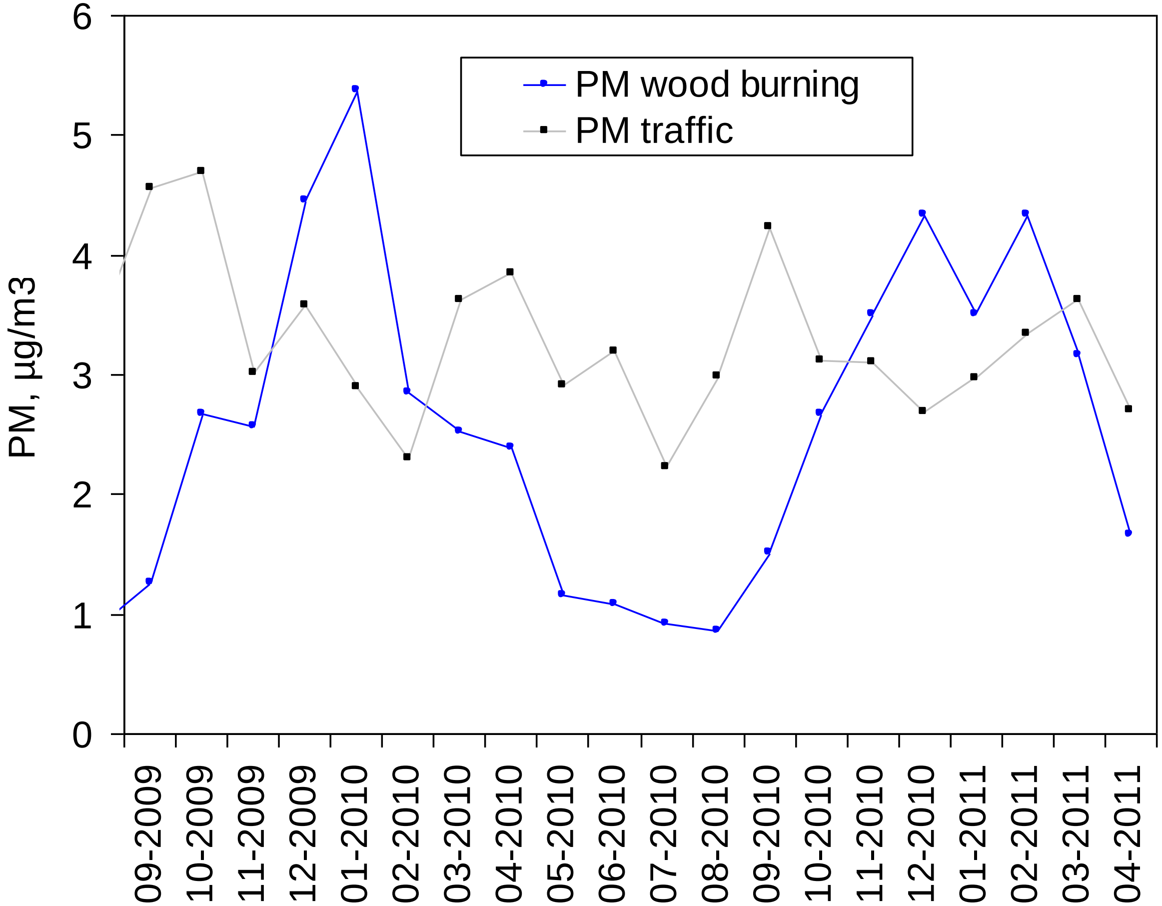


No clear seasonal variations.

High concentrations during the fall period (traffic & met. Conditions)

Low concentrations during the summer period (traffic & met conditions)

AETHALOMER model
Seasonal (monthly mean) variations of PM_{wb} & PM_{ff}



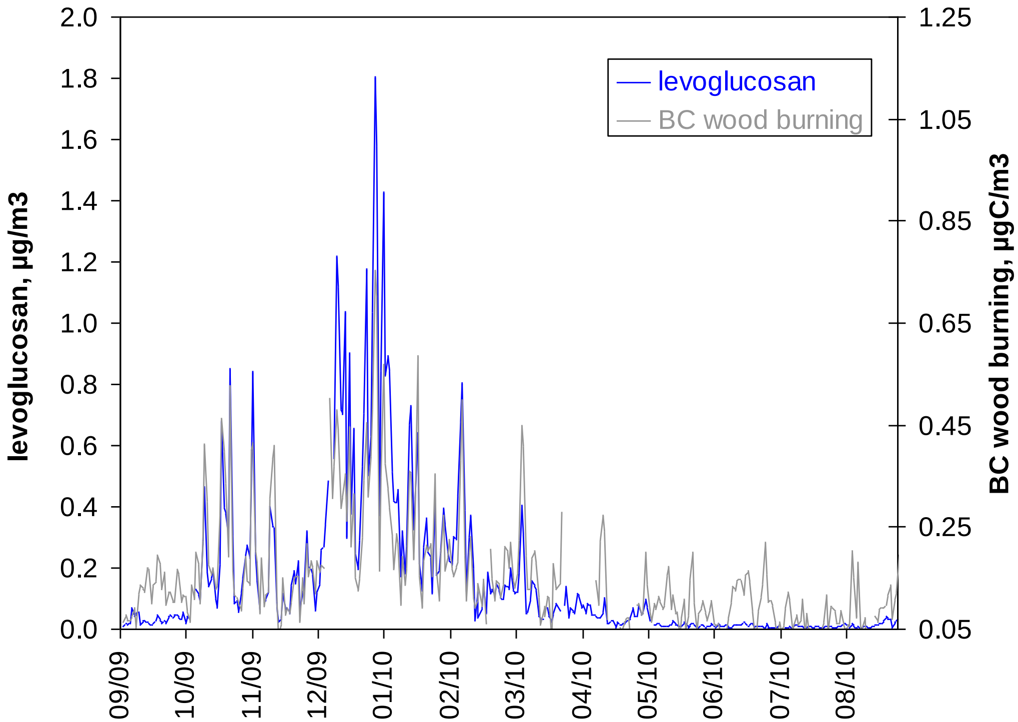
Strong seasonal variations for PM wood burning

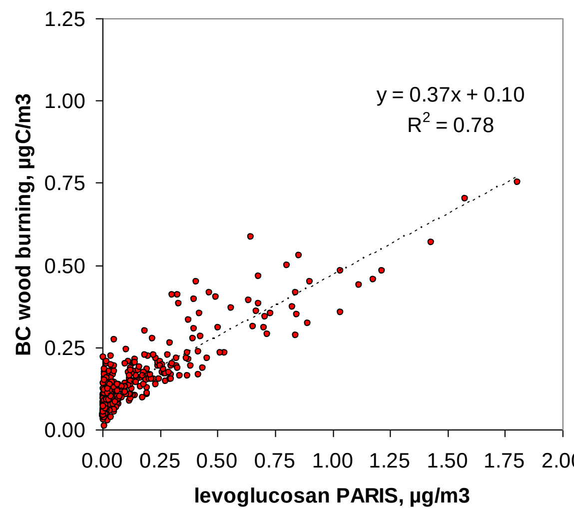
On a yearly basis,

$PM_{wood\ burning}$ = 2.33µg/m³
$PM_{traffic}$ = 3.35µg/m³

* BC_{wb}/PM_{wb} = 0.06; & BC_{ff}/PM_{ff} =0.4; Aethalometer model, **Sciare et al., JGR, 2011, under review**

Comparison between the "Aethalomer" model with the mono-tracer (levoglucosan) approach: A seasonal perspective





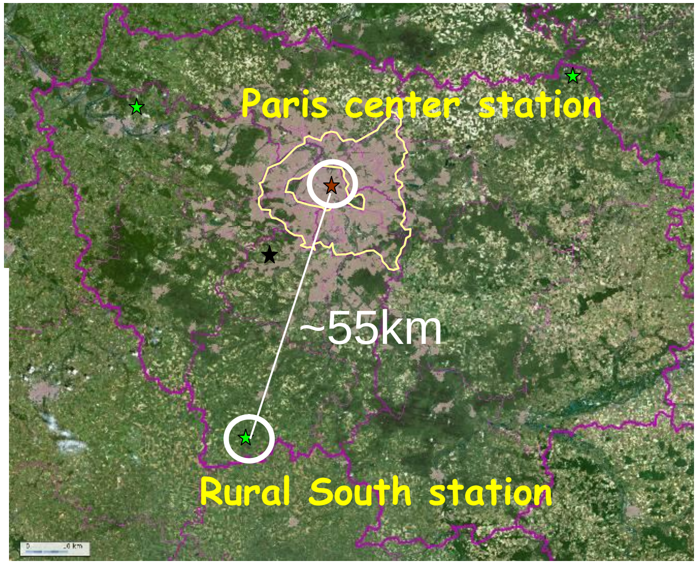
As observed previously from time-limited intercomparisons, the 2 approaches are well correlated over the whole winter period

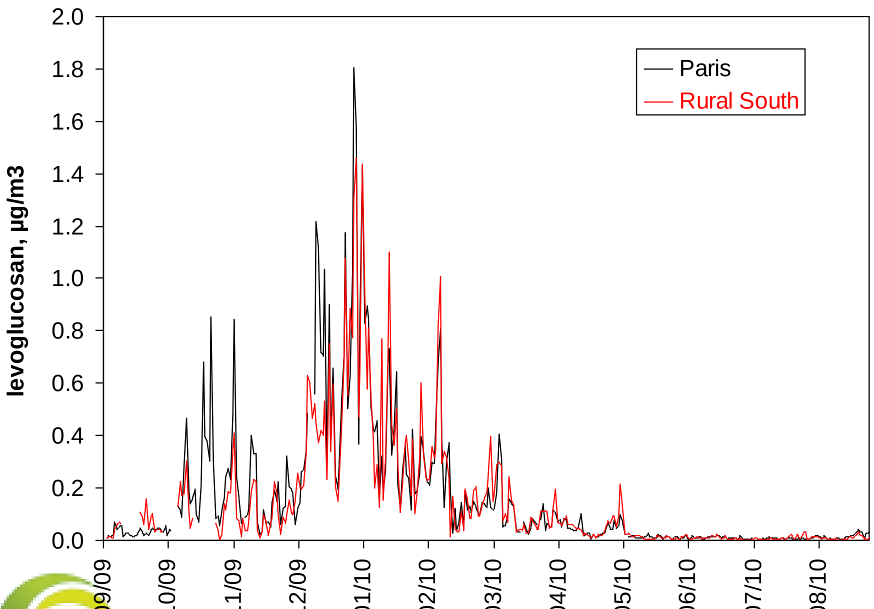
On a yearly basis

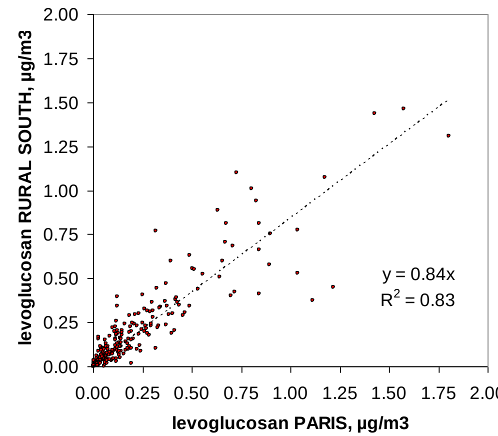
$PM_{wood\ burning}$ = 2.33µg/m^3 (Aethalomer model)
$PM_{wood\ burning}$ = 2.20µg/m^3 (Levoglucosan approach)

SPATIAL & TEMPORAL CONTRIBUTION OF WOOD BURNING IN PM IN PARIS

The mono-tracer (levoglucosan) approach: A spatial perspective





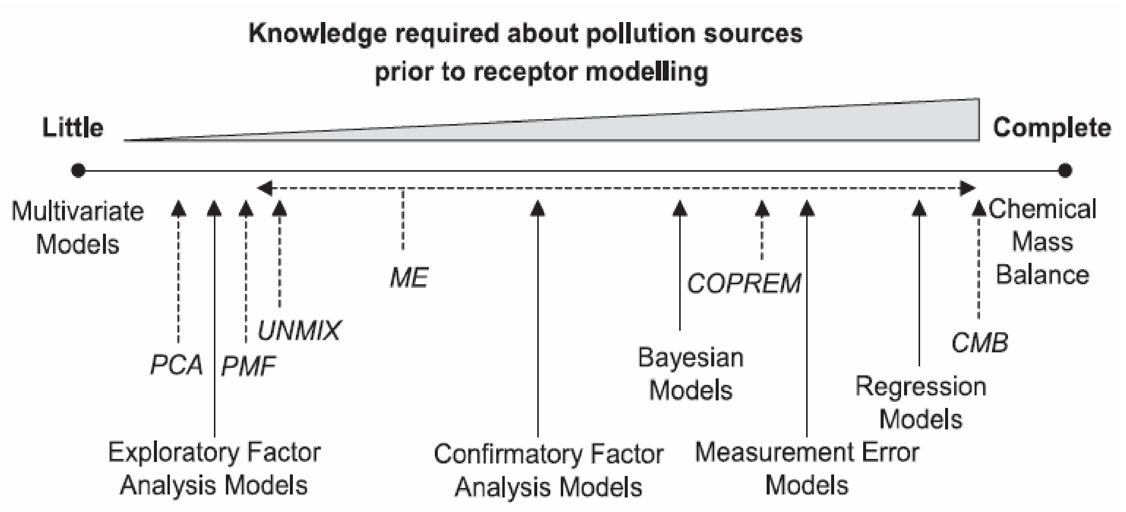


Very homogeneous concentrations of levoglucosan on a regional perspective !
Origin ????

Source Identification and Apportionment of $PM_{2.5}$ and PM_{10} from the urban background of Paris by the Positive Matrix Factorization approach

Receptor Models / Principle

- Aim: Identify and apportion sources of airborne PM in the atmosphere
- Methods based on the statistical evaluation of PM chemical data acquired at receptor sites
- Different methods:



M. Viana et al. / Aerosol Science 39 (2008) 827–849

Source profiles of $PM_{2.5}$ and PM_{10} from the urban background of Paris

Methodology

- Use of the $PMF_{3.0}$ model from EPA (Multilinear Engine method)

- Database: $PM_{2.5}$ and PM_{10} from the urban background of Paris from 11/09/2009 to 27/03/2010

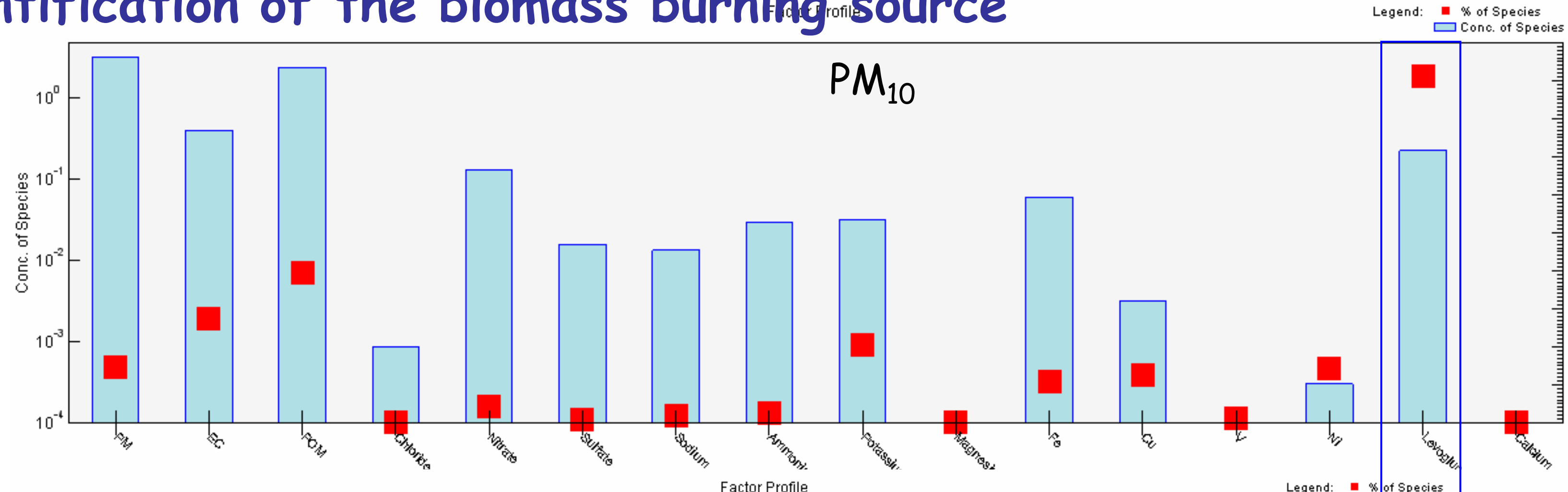
- Chemical species studied:

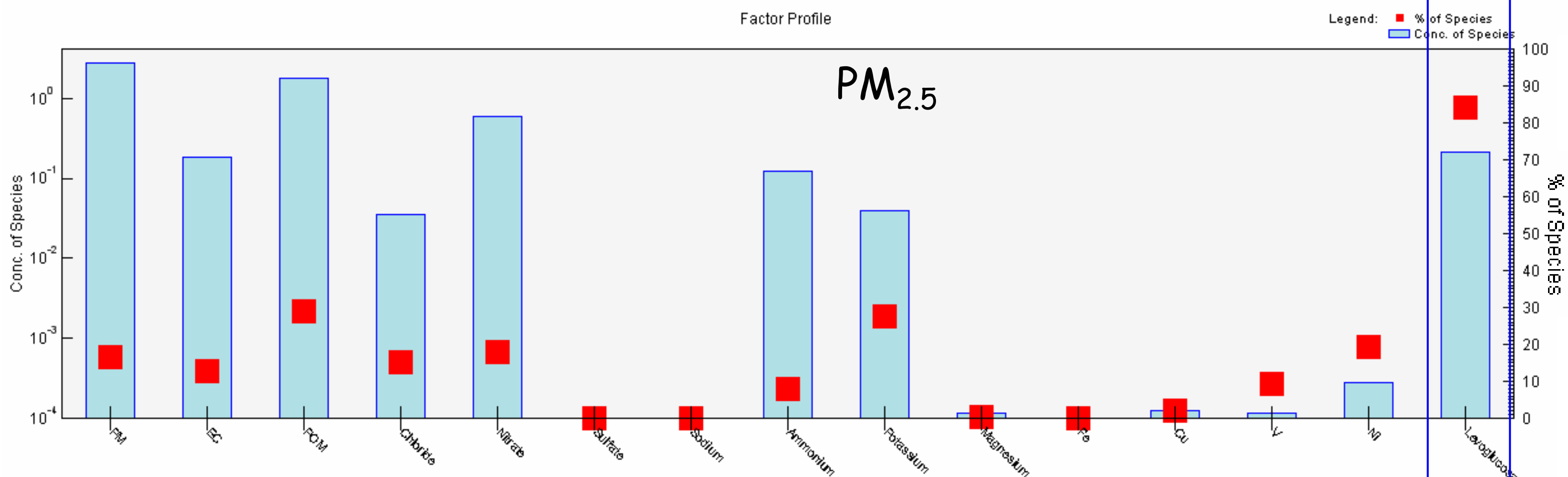
EC, POM, Cl^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+}, Fe, Cu, V, Ni, Levoglucosan for PM_{10} and $PM_{2.5}$. Ca^{2+} for PM_{10} only.

- Number of factor choosen in order to have:
  - mathematically correct results
  - chemically meaningful results

- Numerous PMF runs lead to the choice of:
  - 5 factors for $PM_{2.5}$
  - 6 factors for PM_{10}

Identification of the biomass burning source





Source: Viana et al., 2008

Source signatures	Location	Source interpretation	Study
K, As	Copenhagen (DK)	Biomass burning	Andersen et al. (2007)
K, Carbon, O_3	Monagrega, ES	Biomass burning	Rodríguez (2002)

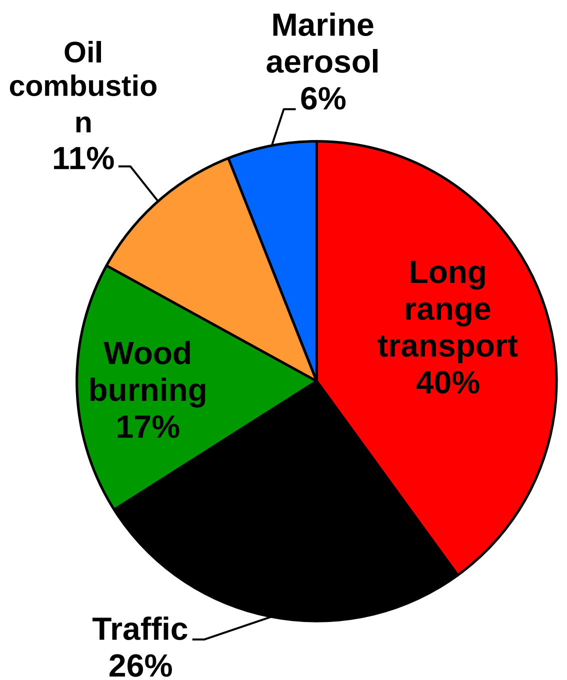
Source: Bruinen de Bruin, 2006

Wood burning	K, volatile C, elemental C, levoglucosane	Huang et al., 1994; Janssen et al., 1997; Ojanen et al., 1998; Chan et al., 1991

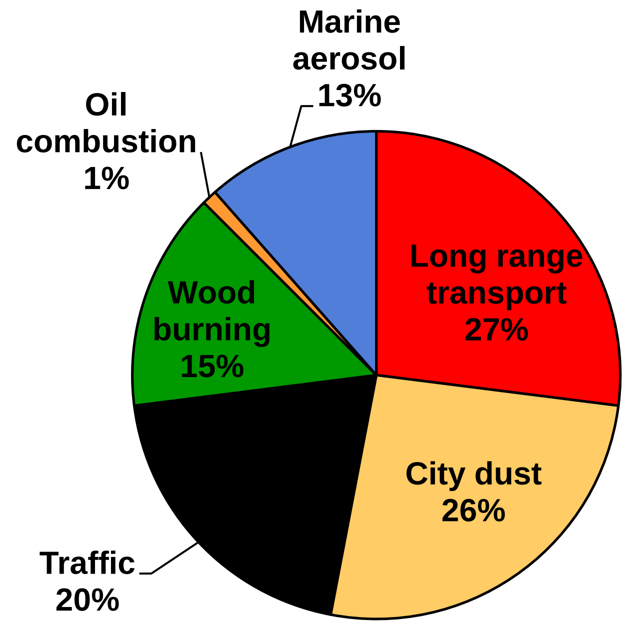
SPATIAL & TEMPORAL CONTRIBUTION OF WOOD BURNING IN PM IN PARIS

Average contribution from 11/09/2009 to 27/03/2010

$[PM_{2,5}]=16,9 \mu g/m^3$



$[PM_{10}]=23,8 \mu g/m^3$



PMF_3 approach

~2.9 µg/m³ of $PM_{2.5}$ for wood burning

Aethalometer model approach

~3.1 µg/m³ of $PM_{2.5}$ for wood burning

Mono-tracer (levoglucosan) approach

~3.5 µg/m³ of $PM_{2.5}$ for wood burning

CONCLUSIONS

+ New and promising techniques developed recently to estimate in near real-time wood burning aerosols (AMS, Aethalometer, …). But, no "perfect" tool to quantify them.

In the region of Paris:

- Different approaches (PMF_3, Aethalometer model, mono-tracer "levoglucosan" approach) used in Paris leading to consistent estimates of PM wood burning

- Significant temporal variations of wood burning having a significant impact on PM during 7 months of a year

- Large & homogeneous signal of wood burning in the region of Paris making difficult to evaluate local-to-advected contributions

PERSPECTIVES

+ Implementation of a regional (EU FP7 ACTRIS network) supersite for long term observation of PM sources (incl. biomass burning)
→ End of 2011

+ Construction of a "Black Carbon network" (~ 10 to 15 stations) in Great Paris & data assimilation leading to realistic maps of BC from traffic and wood burning
→ Beginning of 2012

+ Expected spatial changes in BC (traffic) concentrations in Paris through the implementation of a "Low Emission Zone" in Paris city
→ Beginning of 2013

THANKS FOR YOUR ATTENTION