

# European aerosol phenomenology-5: climatology of black carbon optical properties at 9 regional background sites across Europe

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# COMPANION PAPER...

**A European aerosol phenomenology -4: carbonaceous aerosol sampling artifacts, analytical discrepancies, and harmonized concentrations at 10 regional background sites across Europe**

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# MOTIVATION AND GOALS

Absorbing optical properties of black carbon: **mass absorption cross section (MAC)**

$$MAC^\lambda [m^2/g] = \frac{\sigma_{ap}^\lambda [Mm^{-1}]}{m_{EC} [\mu g/m^3]}$$

$\sigma_{ap}^\lambda$  = absorption coefficient

$m_{EC}$  = elemental carbon mass concentration

## MAC is used in

Radiative modelling



$$\sigma_{ap} = BC * MAC$$

Filter based photometers



$$eBC = \sigma_{ap} / MAC$$

## Main concerns

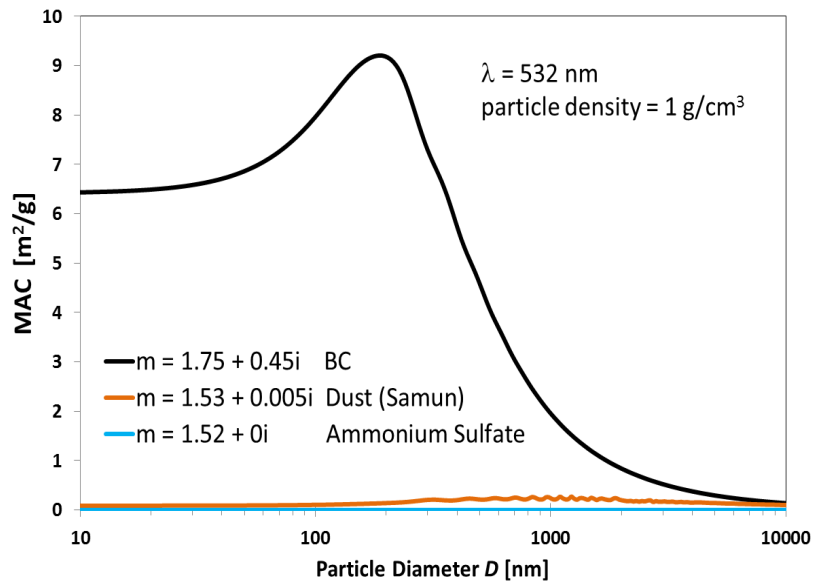
MAC is often assumed as location and season constant → **inaccuracy in RF and eBC**

Wide range of  $MAC^{637}$  values in the literature : **4 – 22  $m^2 g^{-1}$**

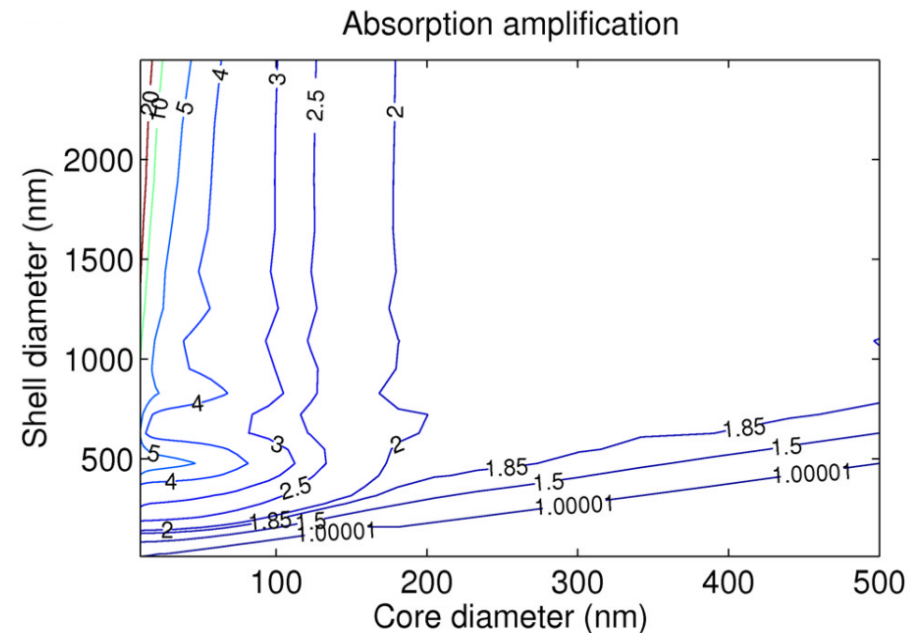
Investigate the **spatial and seasonal variability** of MAC over Europe

# BC ABSORPTION SENSITIVE TO

- **Size** (Bond and Bergstrom, 2006)



- **Mixing state** (Bond et al., 2006)



**Also instrumental artifacts** play a consistent role in MAC calculation

# THE OUTLINE

## 1. Introduction

## 2. Method

a. Definitions

**b. The ACTRIS sites**

c. Experimental method

i. EC determination

**ii. Abs determination and analysis**

**iii. MAC calculation and errors**

## 3. Results and discussion

**a. mEC and abs variability**

**b. MAC spatial variability**

**c. MAC seasonal cycles**

d. MAC spatial homogeneity

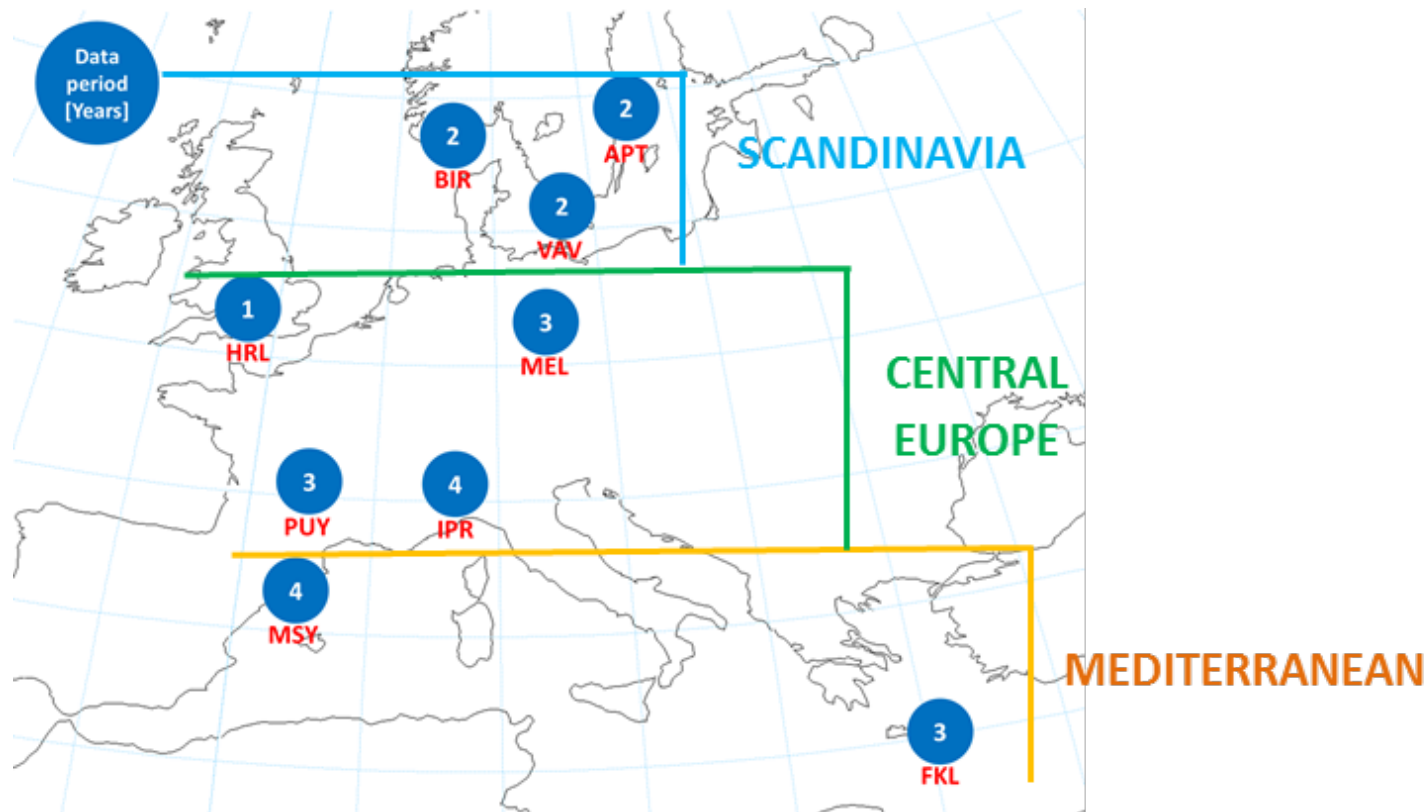
**e. MAC enhancement with mixing degree**

## 4. Conclusion

# THE ACTRIS SITES

Selection criteria:

- Simultaneous mEC and  $\sigma_{ap}$  measurements
- More than 1 year of measurement



**9 ACTRIS sites**, representative of **back ground** air masses, data span **2008-2011**

# THE ABSORPTION PHOTOMETER

Three filter absorption photometer models

- **4 MAAP** → IPR, MEL, MSY, PUY
- **3 PSAP(custom)** → APT, BIR, VAV
- **2 Aethalometer** → HRL, FKL

## Instrument correction procedures

### MAAP (reference)

- Müller correction:
  - ✓ Wavelength shift

### PSAP

- Bond correction:
  - ✓ Response to absorption and scattering
  - ✓ Uncertainty and instrumental errors

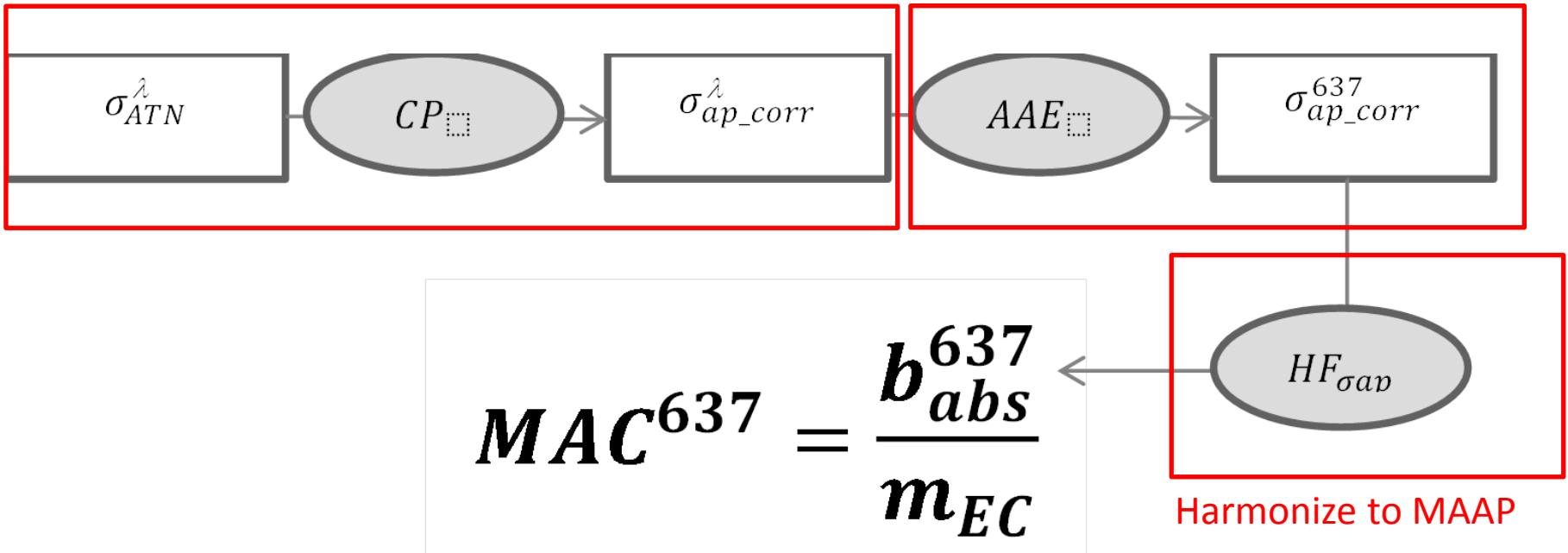
### Aethalometer

- Weingartner correction:
  - ✓ Multiscattering:  $R(ATN)$
  - ✓ Shadowing ( $C=2.14$ )

# ABSORPTION COEFFICIENT DATA TREATMENT

Inst. correction

Adjust to 637 nm



**CP:** Correction procedure

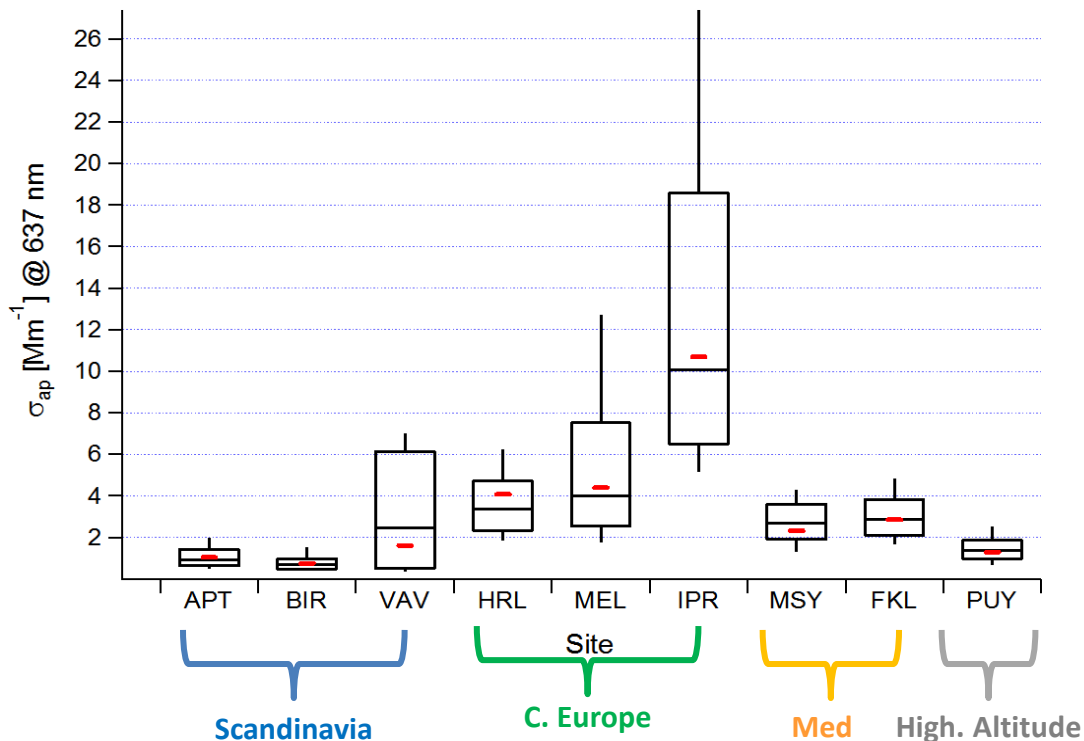
**AAE:** Absorption Ångström exponent = 1 (PSAP& Aethalometer)

**HF:** Harmonization factor (relative sensitivity PSAP-Aethalometer vs MAAP)

- Aethalometer = 1.6 (Müller et al., 2011)
- PSAP = 2 (Personal communication T. Müller & station leaders)

# ABSORPTION SPATIAL VARIABILITY

**Latitude gradient:**  $\sigma_{ap}$  increases approaching central Europe



**Max**  
IPR:  $10.7 \text{ Mm}^{-1}$

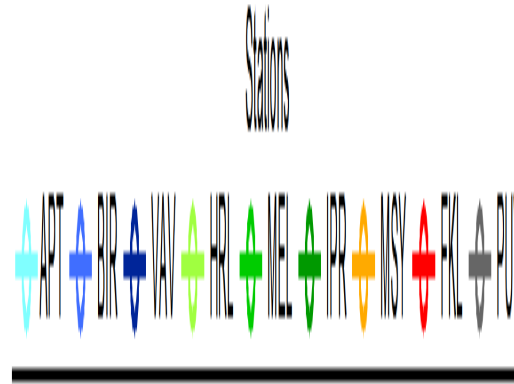
**Min**  
BIR:  $0.750 \text{ Mm}^{-1}$

High impact of urban area and industrial activities

# ABSORPTION SEASONAL VARIABILITY

**Common seasonal trend:** minimum during warm season

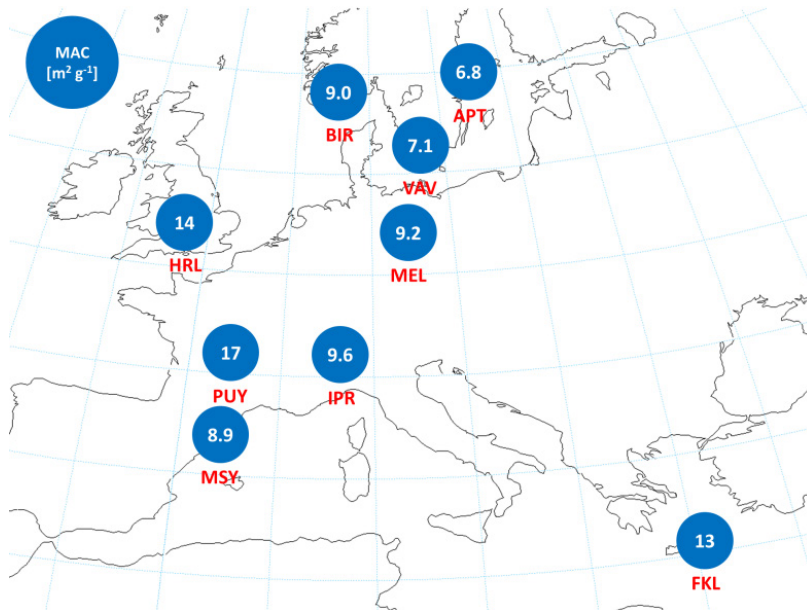
Stations  
—○— APT —○— BIR —○— VAV —○— HRL —○— MEL —○— IPR —○— MSY —○— FKL —○— PUY



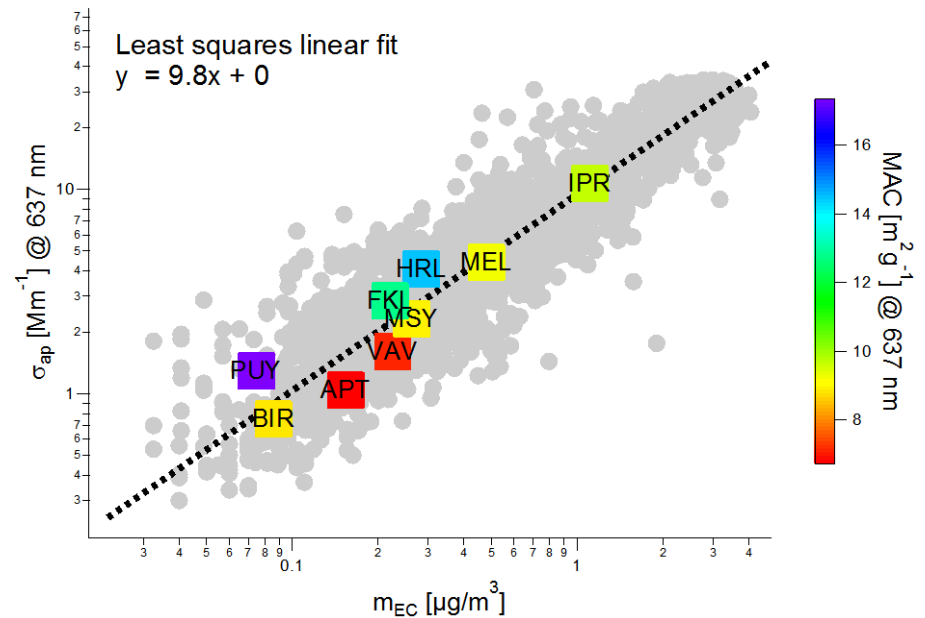
More intense BC emission and lower PBL height  
Exceptions: Mediterranean and high altitude sites

# MAC SPATIAL VARIABILITY

## Spatial distribution



## Mean European MAC

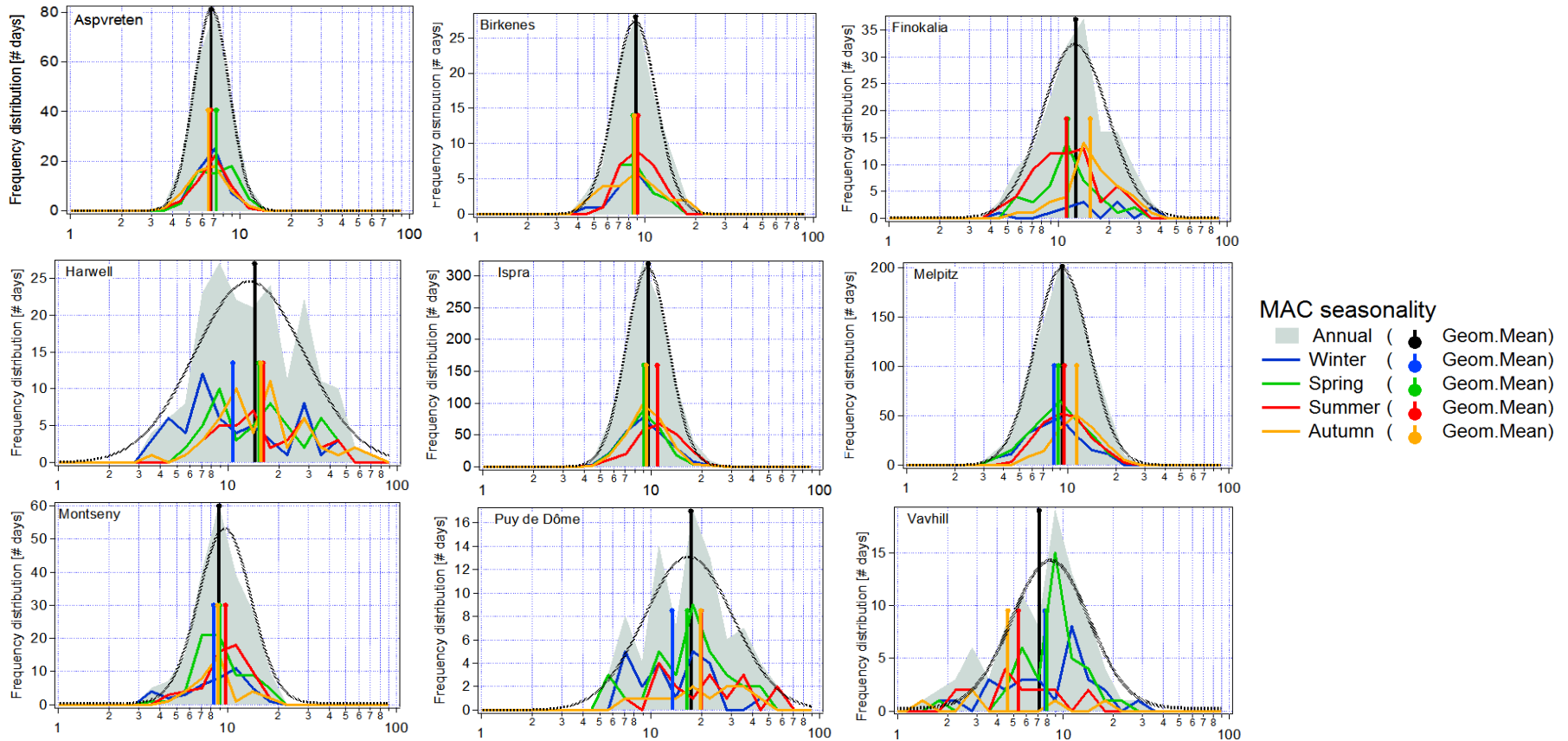


Span of MAC values: **6.8 – 17  $\text{m}^2 \text{g}^{-1}$**

MAC **homogeneously distributed**: encouraging coefficient of divergence

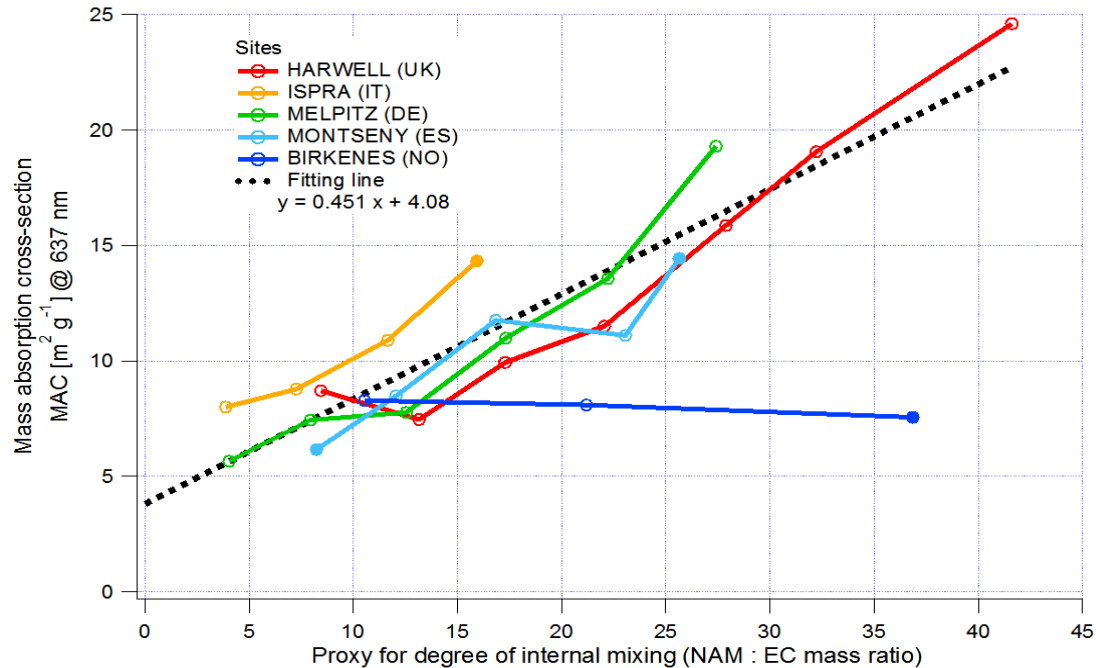
Common European MAC values : **9.5  $\text{m}^2 \text{g}^{-1} \pm 2$**

# MAC SEASONAL VARIABILITY



Evident seasonal variability at all sites  
 Different **sources** and atmospheric **processing**

# MAC AND MIXING DEGREE



Non absorbing matter (NAM)= sum of non-sea salt sulfate, nitrate and organic matter

**Correlation** between optical properties and aerosol composition

Not possible to discriminate between **effective enhancement** and enhancement due to **instrumental artifacts**

Contribution of **OM absorption is negligible (<10%)**

# CONCLUSION

- **Homogeneous dataset** obtained through a correction and harmonization procedure for  $\sigma_{ap}$  and  $m_{BC}$ .
- Error associated to MAC exceeded in some case the **50%**
- Statistical analysis revealed a **discrete homogeneity** of considered optical properties, an overall **MAC mean of  $9.5 \text{ m}^2 \text{ g}^{-1} \pm 20\%$**  at 637 nm might be representative of BC at European background locations
- The **dominance of seasonal cycle** is an indication of a change in morphology or mixing degree of BC with other species.
- **Correlation between optical properties and non absorbing aerosol** was found and provides a simple tool to estimate roughly BC optical properties as a function of non-absorbing aerosol presence.

# CONSIDERATION ON THE EBAS DATABASE

## The dataset needs many technical information

ACTRIS EMEP EUSAAR GAW-WDCA NOAA-ESRL						
end_time of measurement, days from the file reference point						
aerosol_absorption_coefficient, 1/Mm, Wavelength=524.3 nm						
aerosol_absorption_coefficient, 1/Mm, Wavelength=524.3 nm, Statistics=percentile:15.87						
aerosol_absorption_coefficient, 1/Mm, Wavelength=524.3 nm, Statistics=percentile:84.13						
pressure, hPa, Location=instrument internal						
temperature, K, Location=instrument internal						
Data definition: EBAS_1.1						
Timezone: UTC						
File name:						
Startdate: 20101201000000						
Revision date: 20141111						
Statistics: arithmetic mean						
Data level:						
Period code: 1mo						
Resolution code: 1h						
Station code:						
Platform code:						
Station name:						
Station latitude:						
Station longitude:						
Station altitude:						
Regime: IMG						
Component: aerosol_absorption_coefficient						
Unit: 1/Mm						
Matrix: pm10						
Instrument type: filter_absorption_photometer						
Laboratory code:						
Instrument name: Radiance-Research_PSAP-1W_XXX						
Instrument manufacturer: Radiance-Research						
Instrument model: PSAP-1W						
Method ref: XX01L_abs_coef						
Originator:						
Submitter:						
starttime	endtime	aerosol_absorption_coefficient	aerosol_absorption_coefficient	aerosol_absorption_coefficient	P	temperature flag

### Here is missing

- Level
- **Sampling flow**
- **Size of the spot**
- Noise or detection limit
- **Info on the data treatment**

In this case the user must contact the responsible person not only for scientific discussion but also for basic technical information

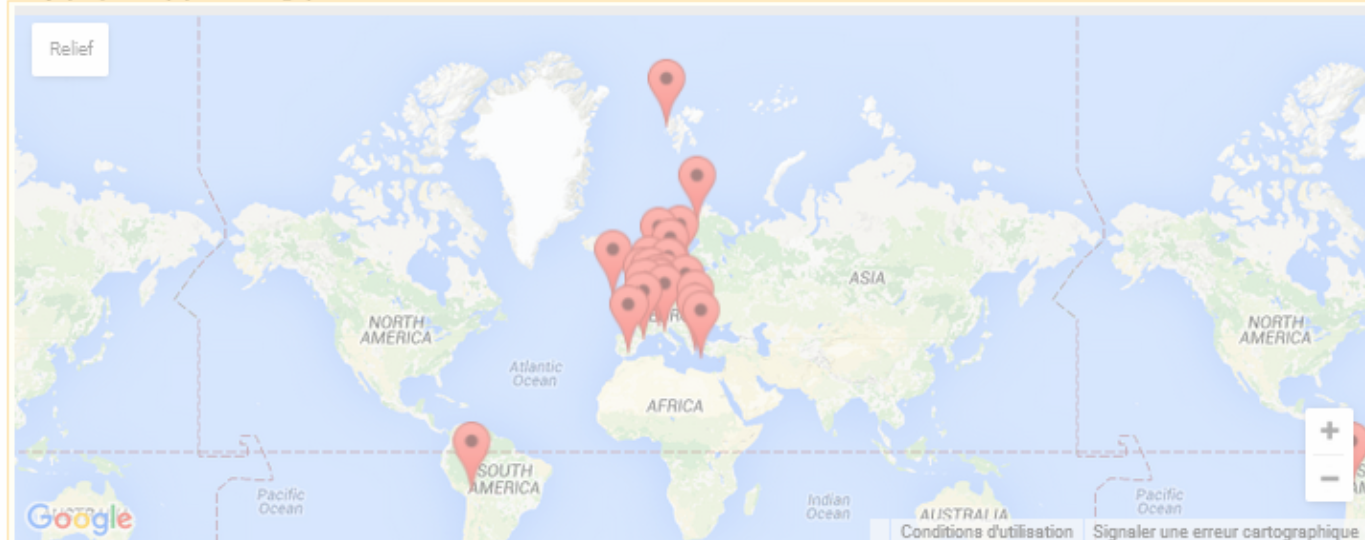
**A BIG LOSS OF TIME AND ENERGY FOR BOTH SIDES**

<b>Framework [14]</b> >>All ACTRIS CAMPAIGN CREATE EMEP EUCAARI EUSAAR EUSAAR_NRT	<b>Country [14]</b> >>All Bolivia Bulgaria Finland France Germany Greece Hungary	<b>Station [25]</b> >>All Aspvreten BEO Moussala Birkenes II Cabauw Zijdeweg DEM_Athens Finokalia Granada	<b>Matrix [5]</b> >>All aerosol instrument pm1 pm10 pm25
<b>Instrument type [1]</b> >>All filter_absorption_photometer	<b>Component [12]</b> >>All aerosol_absorption_coefficient attenuation_coefficient bypass_fraction equivalent_black_carbon flow_rate pressure reference_beam_signal		

# THANKS FOR THE ATTENTION...QUESTIONS ?

Available datasets: 502

## Map (Populate) (Show large)



## Additional resources

- European Monitoring and Evaluation Programme (EMEP-CCC)
- Site descriptions - EMEP
- WMO Global Atmosphere Watch (GAW)
- Site descriptions - GAW
- Air mass trajectories
- Data submission
- Contact persons
- About EBAS
- EBAS User Feedback Tracker
- Social media



# Errors

Standard propagation error procedure: 2 contributors

- Absorption: correction parameters, instrumental noise, harmonization factors

$$\Delta\sigma_{ap} = \sqrt{\Delta\sigma_{apNoise}^2 + \Delta\sigma_{apU2U}^2 + \Delta\sigma_{apCalib}^2 + \Delta\sigma_{apHarm}^2}$$

- EC concentration: harmonization factor

$$\Delta m_{EC Harm} = \sqrt{\Delta m_{EC EUSAAR}^2 + \Delta m_{EC/m_{TC}}^2}$$

- Total error

$$\Delta MAC = \sqrt{\left(\frac{\Delta\sigma_{ap}}{\sigma_{ap}}\right)^2 + \left(\frac{\Delta m_{EC}}{m_{EC}}\right)^2}$$

	$\Delta\sigma_{ap}$ [%]	$\Delta m_{EC}$ [%]	$\Delta MAC$ [%]
APT	25	58	63
BIR	26	19	32
FKL	38	32	50
HRL	41	70	81
IPR	4	23	24
MEL	6	50	50
MSY	10	35	36
PUY	17	39	43
VAV	24	25	35

# HF EC

Site	HF <sub>mEC</sub>
Aspvreten	1.35
Birkenes	1.02
Finokalia	1.19
Harwell	1.45
Ispira	0.93
Melpitz	1.79
Montseny	0.97
Puy de Dome	1.23
Vavihill	0.74

# Station characteristics

Site	Coordinates	Altitude [m asl]	Period	Method		Aerosol Fraction	Area
				m <sub>EC</sub>	σ <sub>ap</sub>		
Aspvreten	(SE) 58 48N, 17 23E	30	2010-11	EUSAAR-2	PSAP (522nm)	PM10	Scandinavia
Birkenes	(NO) 58 23N, 8 15E	190	2010-11	EUSAAR-2	PSAP (525nm)	PM10	Scandinavia
Finokalia	(GR) 35 20N, 25 40E	250	2008-10	EUSAAR-2	Aethalometer (880nm)	PM10	Mediterranean
Harwell	(GB) 51 34 N, 1 19 W	60	2010	QUARTZ	Aethalometer (880nm)	PM10	British Isles
Ispira	(IT) 45 49N, 8 38E	209	2008-11	EUSAAR-2	MAAP (637nm)	PM2.5	Continental Europe
Melpitz	(DE) 51 32N 12 54E	87	2008-10	VDI	MAAP (637nm)	PM10	Continental Europe
Montseny	(ES) 41 46N, 2 21E	720	2008-11	EUSAAR-2	MAAP (637nm)	PM10	Mediterranean
Puy de Dôme	(FR) 45 46N, 2 57E	1465	2008-10	EUSAAR-2	MAAP (637nm)	PM10	Continental Europe
Vavihill	(SE) 56 01N, 13 09E	172	2010-11	EUSAAR-2	PSAP (520nm)	PM10	Scandinavia

# Literature MAC

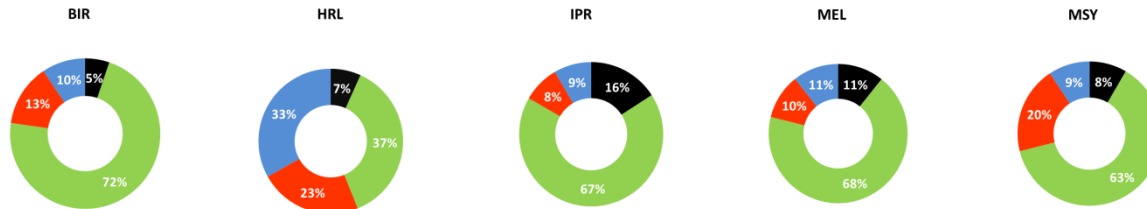
Source-location	MAC [m <sup>2</sup> g <sup>-1</sup> ]	Wavelength [nm]	MAC 637 nm [m <sup>2</sup> g <sup>-1</sup> ]	Reference
Remote areas	5	550	4.3	Liousse, Cachier & Jennings, 1993
Mediterranean	18		15.5	
Savannah	20		17.3	
Urban	12		10.4	
Biomass burning (Brazil)	12.1	550	10.5	Vanderlei Martins et al., 1998
High altitude winter	7.6	630	7.5	Cozic et al., 2008
High altitude summer	11.1		11	
Traffic	9.1	530	7.6	Schwarz et al., 2008
Biomass burning	13		10.8	
High altitude spring	10.2	630	10.1	Liu et al., 2010
Regional background	10.4	635	10.4	Pandolfi et al., 2011
Urban (Barcelona)			9.2	Reche et al., 2011
Traffic (Bern)			10.3	
Industrial (Huelva)			9.8	
Urban (Paris)	13.6	550	11.7	Laborde et al., 2013
Aspvreten	16.3	550	14.1	Genberg et al., 2013
Birkenes	25.9		22.4	
Harwell	9.14		7.9	
Melpitz	4.55		3.9	
Vavihill	26.2		22.7	
High altitude			10.9	Pandolfi et al., 2014

# Coefficient of divergence (COD)

$$COD_{A,B} = \sqrt{\frac{1}{p} \sum_{i=1}^p \left[ \frac{MAC_{iA} - MAC_{iB}}{MAC_{iA} + MAC_{iB}} \right]^2}$$

	ASP	BIR	FKL	HRL	IPR	MEL	MSY	PUY	VAV
ASP		<b>0.14</b>	0.33	0.36	<b>0.18</b>	<b>0.18</b>	<b>0.14</b>	0.44	<b>0.11</b>
BIR	<b>0.14</b>		0.21	0.24	<b>0.04</b>	<b>0.07</b>	<b>0.03</b>	0.32	<b>0.20</b>
FKL	0.33	0.21	0.00	<b>0.15</b>	<b>0.19</b>	<b>0.19</b>	<b>0.22</b>	<b>0.18</b>	0.37
HRL	0.36	0.24	<b>0.15</b>		0.21	0.21	0.24	<b>0.10</b>	0.41
IPR	<b>0.18</b>	<b>0.04</b>	<b>0.19</b>	0.21		<b>0.07</b>	<b>0.04</b>	0.29	0.25
MEL	<b>0.18</b>	<b>0.07</b>	<b>0.19</b>	0.21	<b>0.07</b>		<b>0.07</b>	0.30	0.25
MSY	<b>0.14</b>	<b>0.03</b>	0.22	0.24	<b>0.04</b>	<b>0.07</b>		0.32	0.21
PUY	0.44	0.32	<b>0.18</b>	<b>0.10</b>	0.29	0.30	0.32		0.48
VAV	<b>0.11</b>	<b>0.20</b>	0.37	0.41	0.25	0.25	0.21	0.48	

# Compostion



Mass concentration  $\pm$  StDev [ $\mu\text{g m}^{-3}$ ]

	BC		OM		Sulfate		Nitrate	
BIR	0.10	$\pm$ 0.05	1.32	$\pm$ 0.60	0.25	$\pm$ 0.17	0.17	$\pm$ 0.15
HRL	0.41	$\pm$ 0.35	2.27	$\pm$ 1.26	1.40	$\pm$ 1.10	2.02	$\pm$ 2.33
IPR	1.43	$\pm$ 1.32	6.06	$\pm$ 6.10	0.74	$\pm$ 0.59	0.76	$\pm$ 1.21
MEL	0.96	$\pm$ 1.79	6.08	$\pm$ 5.89	0.94	$\pm$ 1.06	0.95	$\pm$ 0.94
MSY	0.24	$\pm$ 0.13	1.76	$\pm$ 0.68	0.55	$\pm$ 0.36	0.26	$\pm$ 0.26

# OM absorption

Any absorption enhancement at wavelength longer than 532 nm is to be attributed to a lensing effect driven by internal mixing of BC with organic matter and other non-absorbing species (Lack et al., 2012).

**OM mass concentration was converted into  $\sigma_{\text{ap-OM}}$  using a MAC of 0.0297 m<sup>2</sup> g<sup>-1</sup> at 532 nm of wavelength (Utry et al., 2013)**, the latter is representative of humic like substances at European background locations.

**$\sigma_{\text{ap-OM}}/\sigma_{\text{ap}}$  was found to follow a seasonal trend with maximum during summer (<10%).**