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ABSORBING PROPERTIES OF BLACK CARBON (BC) OVER EUROPE

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and all ACTRIS station leaders

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1. Introduction

Black carbon (BC) is emitted by incomplete combustion of carbon-based fuels. It is characterized by strong light absorption across the whole visible wavelength range, and is considered the strongest absorber of visible sunlight of the atmosphere. Climate models use the mass absorption cross section (MAC), defined as the ratio between absorption coefficient and BC mass, to estimate light absorption by BC based on modelled BC mass. A lack of knowledge about the MAC values of BC can lead to considerable uncertainty in radiative forcing assessment. Recently, the spatial variabil-ity of the MAC had been investigated by Genberg et al. (2013) for sites in Northern Europe. Complementary to this study, we investigated the spatial and seasonal variability of MAC values over Europe.

2. Methodology

2.1. European supersites included in this study

MAC values have been derived from in-situ measurements of elemental carbon mass concentration and absorption coefficient, performed at 9 European supersites of the ACTRIS network (Fig.1, Tab.1).

Fig.1 ACTRIS superistes used in this work

Station		m_{EC} method	b_{abs} method	Period	Site characteristic
Ispra	(IT)	EUSAAR-2	MAAP (637nm)	2008-2011	Regional polluted background
Melpitz	(DE)	VDI	MAAP (637nm)	2008-2010	Rural polluted background
Montseny	(ES)	EUSAAR-2	MAAP (637nm)	2008-2011	Regional background
Puy de Dome	(FR)	EUSAAR-2	MAAP (637nm)	2008-2010	Regional polluted background
Finokalia	(GR)	EUSAAR-2	Aethalometer (880nm)	2008-10	Mediterranean background
Harwell	(GB)	VDI	Aethalometer (880nm)	2010	Rural background
Birkenes	(NO)	EUSAAR-2	PSAP (522nm)	2010-2011	Continental background
Vavihill	(SE)	EUSAAR-2	PSAP (520nm)	2008-2010	Continental background
Aspvreten	(SE)	EUSAAR-2	PSAP	-	Regional background

Tab.1 Superistes instrumentation and char-

2.2. Data correction

Experimentally, the MAC is obtained from the ratio of absorption coefficient (b_{abs}) and elemental carbon mass concentration (m_{EC}) measurements.

$$\mathrm{MAC}\ [\mathrm{m}^2/\mathrm{g}] = \frac{\mathrm{b}_{abs}\ [\mathrm{Mm}^{-1}]}{m_{EC}\ [\mu\mathrm{g}/\mathrm{m}^3]}$$

Before performing such calculation, raw data from each station had to be harmonized and corrected.
Elemental carbon mass concentration is determined via thermooptical method.

Correction factors for the harmonization of EC measurements from different stations, as determined in a method inter-comparison study by Cavalli et al. (manuscript in preparation), have been applied here. Aerosol light absorption coefficient is measured with filter-based instruments, as the Multi-Angle Absorption Photometer (MAAP, Thermo Fisher Scientific, Waltham, USA) the Aethalometer (Magee Scientific, Berkeley, USA), and the Particle Soot Absorption Photometer (PSAP, Radiance Research, Seattle, USA). These instruments are based on the measure of transmitted light through the collecting filter and the application of a corrective algorithm in necessary to account for different bias. All absorption coefficients in this work are re-calculated using the following corrections.

Petzold et al. (2005) found that the real optical wavelength of the MAAP is 637±1 nm instead 670nm. Muller et al. (2011) defined a corrective factor (CF_{Muller}=1.05) accounting for this wavelength shift.

$$b_{abs}^{637} = b_{abs\,meas.} * \ CF_{Muller}$$

A data analysis algorithm for the Aethalometer had been developed by Weingartner et al., (2004). This correction includes two factor accounting for shadowing ($R(ATN)$) and multi scattering (C) effects.

$$b_{abs} = \frac{b_{ATN}}{C\ R(ATN)}$$

PSAP b_{abs} is corrected following the scheme settled-up by Bond et al., (1999). Corrective factors accounts for inaccuracy of spots size (F_s) and flow rate (F_f), response of the instrument to absorption (K_2) and scattering (K_1). Unit to unit variability (ε_{slope}) is considered, as well as instrument noise (ε_{noise}).

$$b_{abs\,cor} = \frac{F_f\ F_s b_{abs\,meas} - K_1 b_{sp} + \ \varepsilon_{slope} + \varepsilon_{noise}}{K_2}$$

In this work babs measured by Aethalometer and PSAP were interpolated/extrapolated to 637 nm assuming a constant Angstrom exponent.

3. Results

A survey conducted on time variability, of b_{abs}, m_{EC} and relative MAC, shows different seasonal patterns from station to station. In addition, as reported from Ispra station, a seasonal trend in b_{abs}, m_{EC} could not reflect a MAC variability (Fig.2)

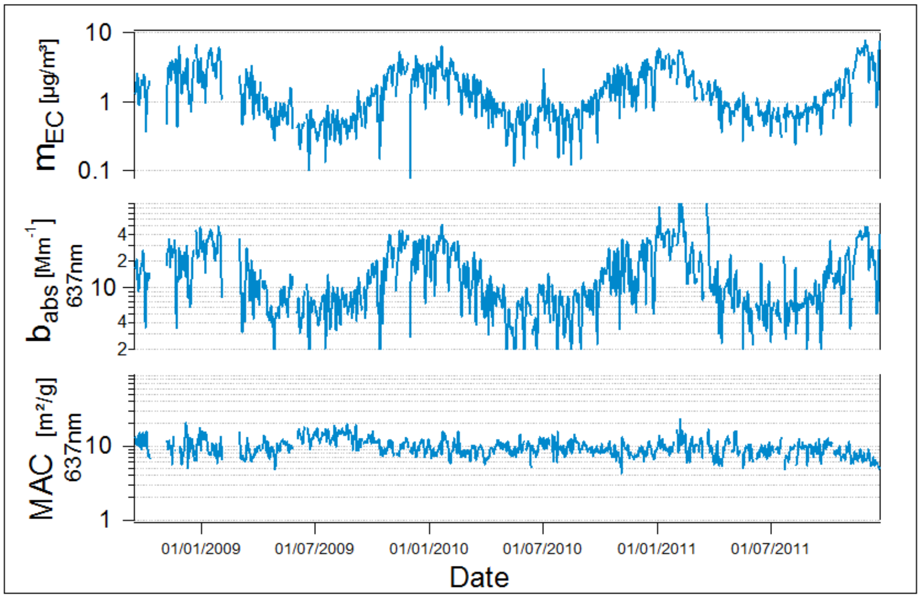

Fig. 2 Ispra time series of a) elemantal carbon mass concetration (m_{EC}), b) absorption coefficient (b_{abs}) and c) mass absorption cross section (MAC)

Figure 3 shows histograms of the MAC values observed at different stations for all data and splitted by season. Depending on location characteristic and aerosol composition, MAC seasonal patterns find their maximum in different periods of the year.

Table 2 shows the geometric mean of the complete sampling period, while geometric standard deviation is considered to represent an upper limit for the atmospheric variability, as it also contains a contribution from random measurement noise.

Station	Geometric Mean	Geometric St.Dev	Median
Birkenes	11.3	1.82	11.6
Finokalia	16.5	1.78	17.4
Harwell	8.31	1.85	7.96
Ispra	9.40	1.33	9.30
Melpitz	11.0	1.65	10.5
Montseny	7.94	1.87	8.47
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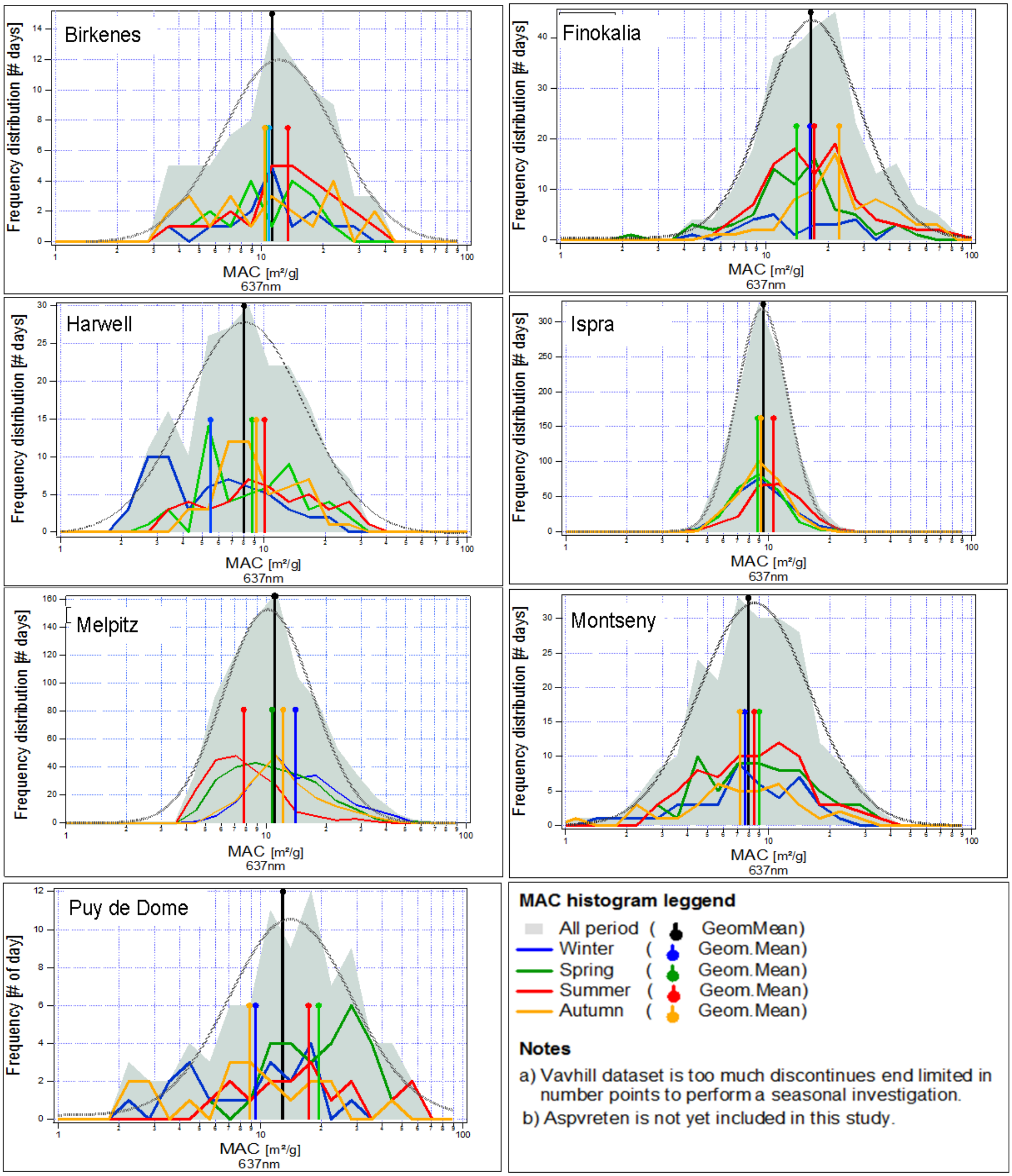
Tab.2 MAC averaged values for each site. Average represents the total sampling period.



Notes

a) Vavhill dataset is too much discontinues end limited in number points to perform a seasonal investigation.

b) Aspvreten is not yet included in this study.

Fig.3 Mass absorption cross-section seasonal variability study. Dust out brakes cause positive artifact at Finokalia site. Synoptic-scale feature of Puy de Dome causes, probably, a wide MAC values distribution.

4. Conclusion

Not all stations show a marked MAC seasonality, as Ispra supersite. Most part of stations display a periodical variability, but seasonal trends change from station to station. Atmospheric condition plays an important role, as at Puy de Dome, where planetary boundary variability leads to higher MAC values during summer, and Spring. Instability of aerosol composition can cause an artefact like in Finokalia, where dust events are responsible for MAC increase. Also meteorology can affects MAC trends, as in Montseny during anticyclonic events.

Optical properties of BC are affected by numerous bias like atmospheric and meteorological condition and aerosol composition, a long term monitoring period is necessary to understand and quantify the effects of these regional and continental variables on optical properties.

Harmonization of in-situ measurement techniques is needed to decrease instrumental uncertainty.

Despite all these issues we determined an averaged European continental Mass Absorption Cross-section of 10.1 ± 13%.

References

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Acknowledgments

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Light absorbing properties of Black Carbon (BC) over Europe

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Results and discussion

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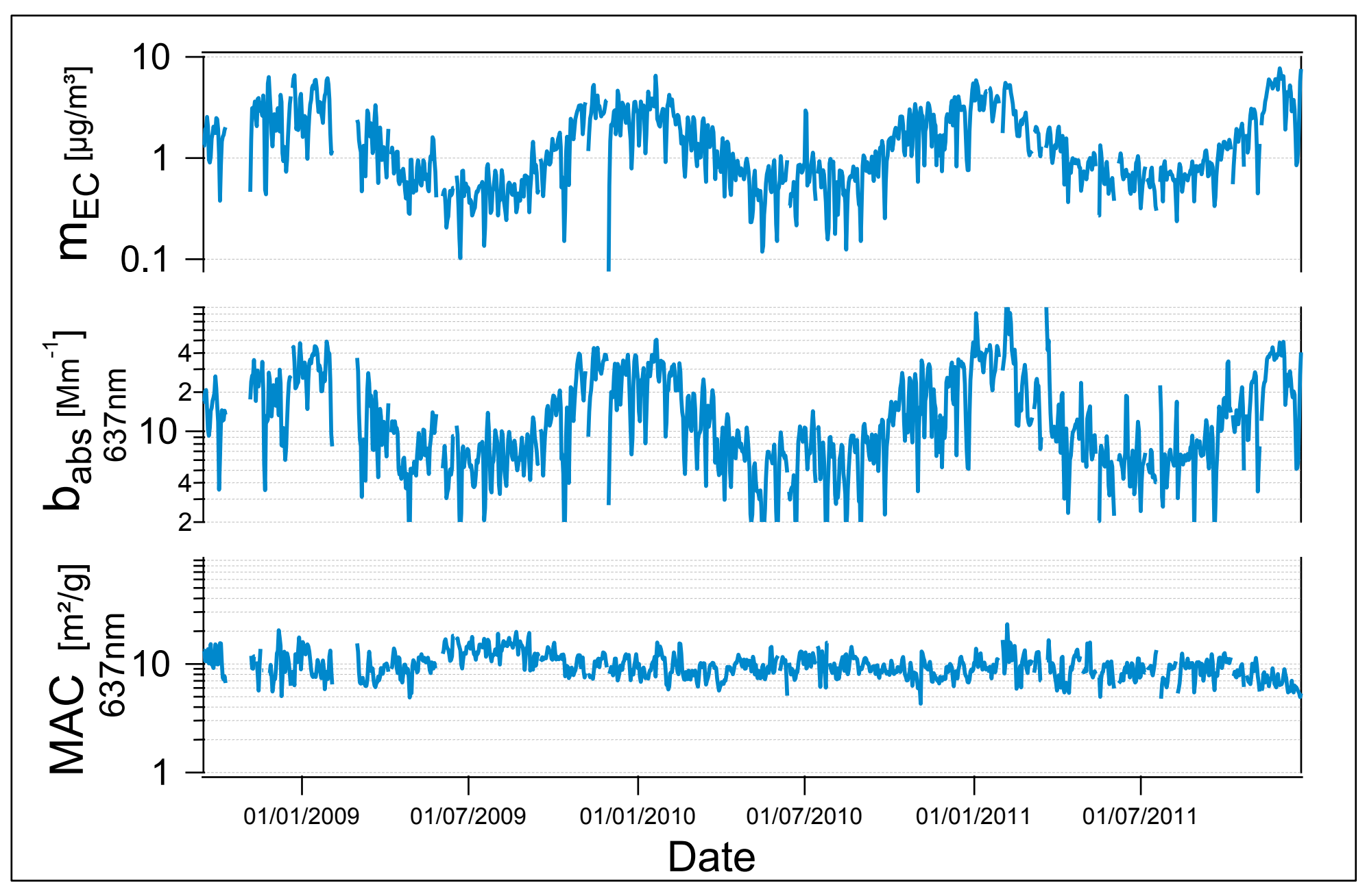

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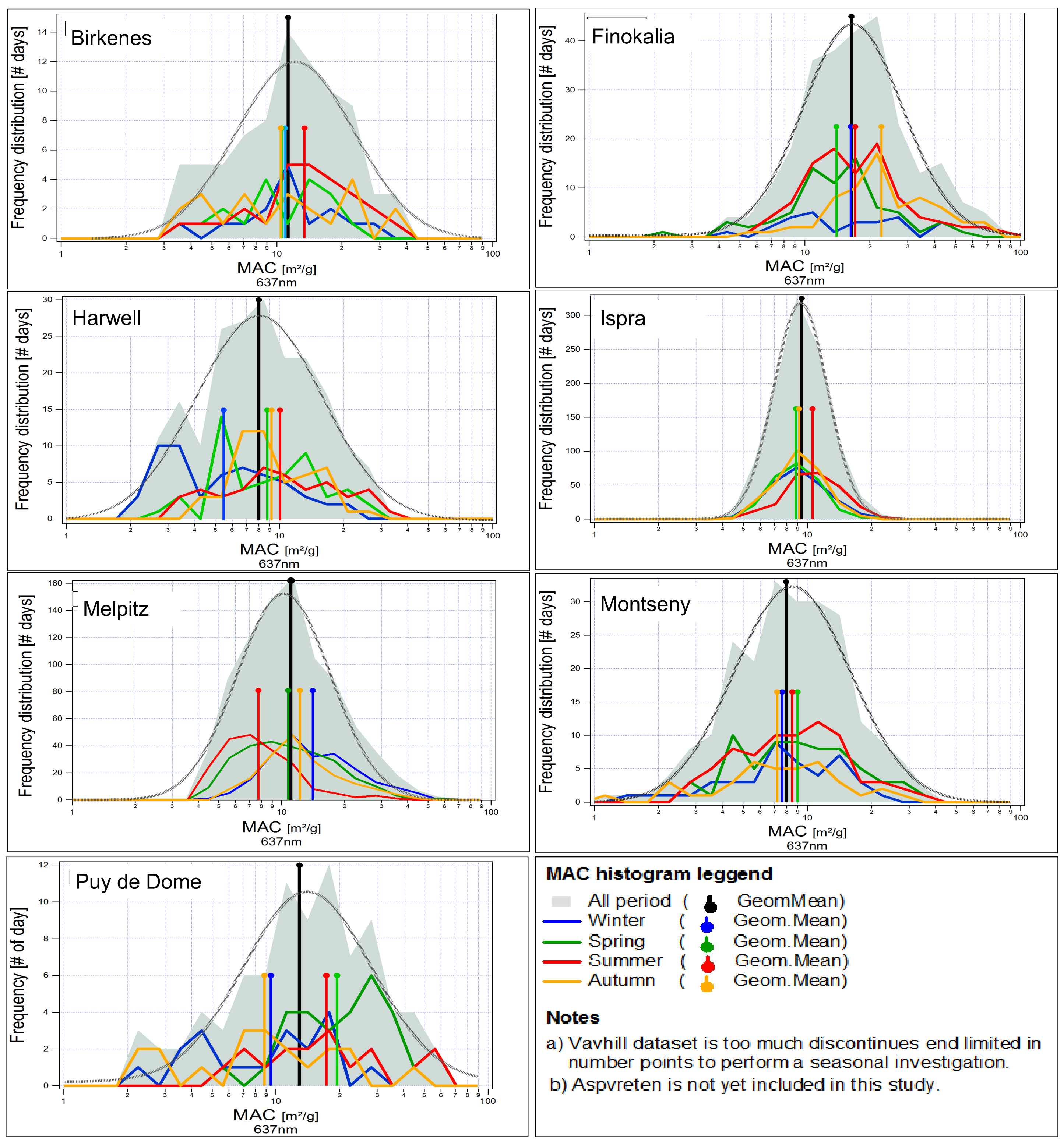

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Tab.2 MAC averaged values for each site. Average represents the total sampling period.

Conclusion

- Not all stations show a seasonality of MAC values.
- Seasonal MAC patterns are different from station to station
- Influence of aerosol sources and composition (dust positive factor at Finokalia).
- Averaged continental European MAC value: 10.11 ± 13%

References

Bond T. C. et al., 1999, Aerosol Science and Technology, 30:6, 582-600

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