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Aerosols in the Atmosphere

Absorption coefficients of aerosols obtained from in situ data in Covilhã, central Portugal

Coeficientes de absorción de aerosoles obtenidos a partir de datos in situ en Covilhã, centro de Portugal

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ABSTRACT:

Since October 2009 an aerosol measurement data set was started at Covilhã, a small town located in the region of Beira Interior (Portugal) in the interior of the Iberian Peninsula. Until July 2010, the ambient light-absorption coefficient, σ_a (470 nm), σ_a (522 nm) and σ_a (660 nm), presented a daily mean value of 14.2Mm^{-1} (StD=8.6Mm^{-1}), 12.1Mm^{-1} (StD=7.3Mm^{-1}) and 9.6Mm^{-1} (StD=5.7Mm^{-1}), respectively. Monthly variations and daily cycle are presented in this work.

Keywords: Aerosols, Absorption, Ångström Exponents, PSAP.

RESUMEN:

En octubre de 2009 se han iniciado una serie de medidas de aerosoles en Covilhã, una pequeña ciudad situada en la región de Beira Interior (Portugal), interior de la Península Ibérica. La estación está destinada a la obtención de datos in situ de absorción y los valores obtenidos hasta julio de 2010 presentan una media diaria de 14.2Mm^{-1} (StD=8.6Mm^{-1}), 12.1Mm^{-1} (StD=7.3Mm^{-1}) y 9.6Mm^{-1} (StD=5.7Mm^{-1}), para las longitudes de onda 470 nm, 522 nm y 660 nm, respectivamente. Se presentan en este trabajo las variaciones mensuales y el análisis del ciclo diario.

Palabras clave: Aerosoles, Absorción, Exponentes de Ångström, PSAP.

REFERENCIAS Y ENLACES / REFERENCES AND LINKS

[1]. C. Wang, "A modeling study on the climate impacts of black carbon aerosols", *J. Geophys. Res.* **109**, D03106 (2004).

[2]. P. Buseck, M. Pósfai, "Airbone minerals and related aerosol particles: Effects on climate and environment", *P. Nat. Acad. Sci. USA* **96**, 3372–2279 (1999).

[3]. C. Lin, M. Baker, R. Charlson, "Absorption coefficient of atmospheric aerosol: a method of measurement", *Appl. Opt.* **12**, 1356–1363 (1973).

[4]. T. Bond, T. Anderson, D. Campbell, "Calibration and intercomparison of filter-based measurements of visible light absorption by aerosols", *Aerosol Sci. Technol.* **30**, 582–600 (1999).

[5]. A. Virkkula, N. Ahquist, D. Covert, W. Arnott, P. Sheridan, P. Quinn, D. Coffman, "Modification, calibration and a field test of an instrument for measuring light absorption by particles", *Aerosol Sci. Technol.* **39**, 68–83 (2005).

[6]. E. Montilla, S. Mogo, V. Cachorro, A. de Frutos, "An integrating sphere spectral system to measure continuous spectra of aerosol absorption coefficient", *J. Aerosol Sci.* **42**, 204-212 (2011).

[7]. J. Heintzenberg, M. Bussemer, "Development and application of a spectral light absorption photometer for aerosol and hydrosol samples", *J. Aerosol Sci.* **31**, 801–812 (2000).

[8]. S. Mogo, V. Cachorro, M. Sorribas, A. de Frutos, "Optical and chemical properties of atmospheric PM fractions related with air masses in the central Iberian Peninsula", *Opt. Pura Apl.* **39**, 331–340 (2006).

1. Introduction

Despite the huge number of studies about the radiative properties of aerosols, their net effect on the climate is still not completely clear. The aerosols can behave as a factor of cooling or warming, depending in what prevails [1]: the light scattering or the light absorption. For that reason, knowledge of the scattering and absorption properties of the atmospheric aerosol is of utmost importance.

While the scattering data is easily found on the bibliography, the absorption data is more scarce, especially spectrally resolved data. However, the absorption coefficient of atmospheric particles is a fundamental optical parameter that needs to be precisely known in order to be included on current models of climate forcing. Data to compute models is scarce and inventories are quite incomplete, leading to a large uncertainty in the models outputs. Because of this reason, more measurements are needed in many different regions of the Earth organized in a global network, as the particle properties show in general a great spatial and temporal variability.

But bearing in mind that anthropogenic aerosols have, in general, the greatest impact near their sources [1,2], this work is focused on the analysis of particles found in the atmosphere of the town of Covilhã (Portugal) in order to study its absorbent characteristics. It does not intend to be a monitoring study for Covilhã but only analyze the optical parameters measured.

We present data obtained at Covilhã, a small town in the interior of the Iberian Peninsula. The measurements took place from October 2009 to July 2010 and for this purpose different instruments were simultaneously installed in the University of Beira Interior facilities. However, in this work we will focus solely on the absorption coefficients of aerosols. The light absorption coefficient of the aerosols, σ_a, was measured continuously using a three-wavelength Particle Soot Absorption Photometer (PSAP), in near real time.

2. Methods

The particles analyzed in this study were collected within the urban environment of Covilhã, a town with ~36.700 inhabitants, located in central Portugal, Fig. 1. The sampling site is located on the terrace of a six-story building on the University of Beira Interior facilities, 150m from the city center. The climate in Covilhã is temperate, moderately cold in the winter and relatively warm in the summer.

Two methods were used for determination of the absorption coefficients: an automated method, the PSAP, and a manual system named IS3 (Integrating Sphere Spectral System).

For the automated method, the light absorption coefficients were measured at three wavelengths (470, 522 and 660 nm) with a PSAP working with the air flow set to 1.5 l/min. The instrument uses a filter-based technique in which aerosols are continuously deposited onto a glass fiber filter at a known flow rate. The change in the transmitted light is related to the optical absorption coefficient using Beer's law. The instrument is an improved version of the integrating plate method [3] and is described in detail by [4] and [5].

Fig. 1: Map of the region.

For the manual system, the IS3, the particles are collected over Millipore polycarbonate membrane filters using an in-line filter holder. Subsequently, the filters with their aerosol loads are dissolved in chloroform to produce a liquid suspension of the deposited particles. This suspension is placed in the center of the sphere into a quartz cell, where it is irradiated both with direct light from the source and uniformly distributed light within the sphere. If an absorbing substance is present in the sample, the signal decreases. Using the measurement of the light transmitted intensity, the absorption coefficients are determined assuming that the attenuation of the beam follows the Beer-Lambert law. The system is fully described in [6].

The PSAP data is nearly continuous but not scattering corrected while the IS3 data is only 24 h resolved but is scattering corrected. Both together allow for a nearly continuous data series with a good estimation of the influence of scattering. Maximum and minimum differences observed during the whole period of measurement were used to perform the correction.

Since we have spectral information, an analysis of the spectral shape of the absorption coefficient can be carried out. In order to evaluate the slope of the absorption spectra we use the absorption Ångström exponent obtained from the empirical expression:

$$\sigma_a(\lambda) = K\left(\frac{\lambda}{\lambda_0}\right)^{-\alpha_a} \qquad (1)$$

where K is a constant, λ is the wavelength, λ_0 is an arbitrary reference wavelength usually taken as 1 μm and α_a is the absorption alpha exponent. This power law expression characterizes the steepness of the slope of the curve σ_a versus λ.

Absorption coefficients and absorption Ångström exponents data are available from 9th October 2009 to 31st July 2010. Except for the analysis of the daily cycle, the statistical data are calculated based on the daily averages.

3. Results and discussion

During our observations, the daily mean σ_a at 470 nm, 522 nm and 660 nm ranged from 1.6 to 81.4 Mm^{-1}, 1.3 to 67.9 Mm^{-1} and 1.1 to 53.0 Mm^{-1} (average 14.2, 12.1 and 9.6 and standard deviation 8.6, 7.3 and 5.7 Mm^{-1}), respectively. The daily mean values of α_a (450-650 nm) ranged from 0.85 to 1.49 (average 1.17 and standard deviation 0.10). For σ_a the median value is lower than the mean while for α_a (450-650 nm) the median equals the mean. Thestatistics on σ_a and α_a values is presented in Table I and a time series representing over 274 days of measurement is shown in Fig. 2.

Though the magnitude of σ_a and α_a depend on many factors, our results were compared with literature values of some other areas and Table I suggests that the magnitude of aerosol absorption coefficients and absorption Ångström exponents in Covilhã are comparable to those in other urban not heavily populated regions, such as those presented by [7] at Melpitz and [8] at Valladolid.

The monthly mean values of σ_a are delineated in Table II. The table shows a seasonal cycle in the monthly-averaged values, with higher values registered during cold seasons and smaller values registered during the warm seasons. This fact is probably related to the domestic heating.

TABLE I

Evaluation of the overall ranges and median values of the absorption coefficients and the Ångström exponents obtained from the data set measured at Covilhã.

	nm	Min	Max	Mean	Median	StD
	470	1.6	81.4	14.2	12.5	8.6
σ_a [Mm^{-1}]	522	1.3	67.9	12.1	10.8	7.3
	660	1.1	53.0	9.6	8.5	5.7
$\alpha_{a(450-650)}$		0.85	1.49	1.17	1.17	0.10

TABLE II

Monthly-averaged aerosol absorption coefficients at 522 nm.

σ_a (522 nm)				
Month	Min	Max	Mean	Std
Oct	5.8	23.6	11.0	4.6
Nov	4.8	37.3	12.9	7.1
Dec	2.4	67.9	17.9	15.3
Jan	4.8	43.8	17.0	9.1
Feb	1.3	18.5	10.4	4.7
Mar	1.9	18.5	11.4	4.5
Apr	4.3	15.1	9.9	2.8
May	3.5	20.0	10.0	2.9
Jun	3.3	15.6	7.9	3.6
Jul	9.7	15.7	12.3	2.2

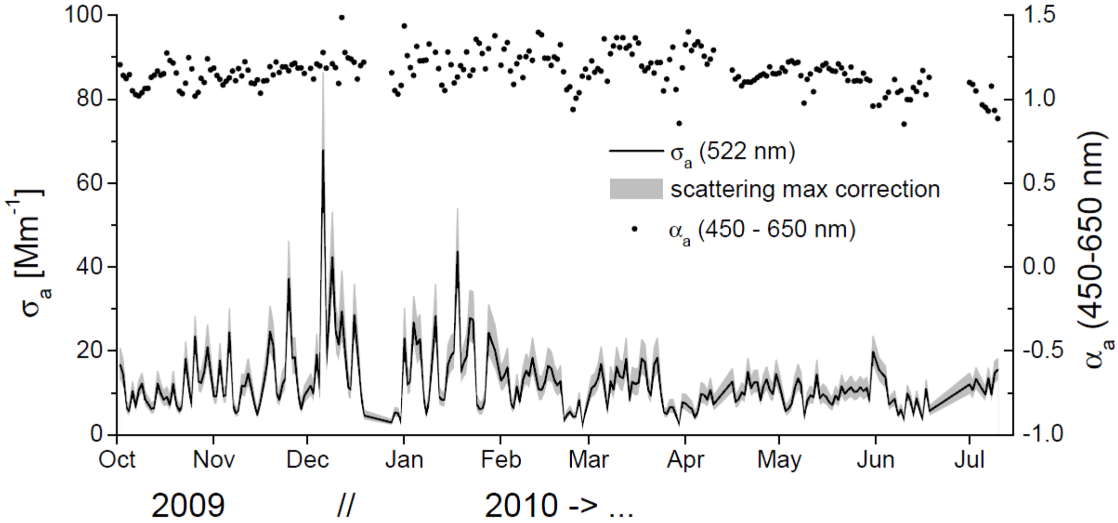

Fig. 2: Time series of the σ_a (522 nm) and the α_a (450-650 nm) for all data set (24 h averages).

The diurnal variation of σ_a at 522 nm during October 2009 is shown in Fig. 3. The higher values of σ_a during the morning can be attributed to traffic peaks, as the maximum value of the curve coincides with the morning rush-hour and, as already mentioned, there is a main road immediately next to the building. Afterwards, the values decrease gradually during the day and in the afternoon they increase again. The afternoon peak is less marked than the morning one as most people go to work every morning at nearly the same time but schedules to return home in the afternoon are differ, so the evening rushhour in not so well-defined. The values of σ_a during the night are low.

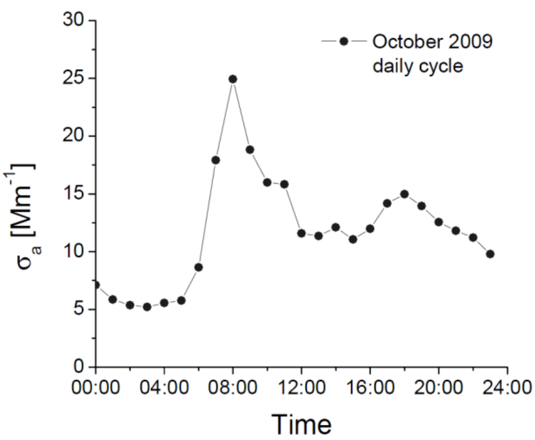

Fig. 3: Daily cycle. Work days.

4. Conclusions

We have initiated a database of aerosol properties for Covilhã, where no previous studies had been performed. The PSAP and the IS3 were used together, allowing an automated measurement of the absorption coefficients corrected from scattering. The daily means σ_a values registered at 522 nm ranged from 1.3Mm^{-1} to 67.9Mm^{-1} during the cold months and from 1.9Mm^{-1} to 20.0Mm^{-1} during the warmer months. The α_a values for the pair of wavelengths 450-650 nm, ranged from 0.94 to 1.49 during the cold months and from 0.86 to 1.37 during the warmer months.

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