Light Absorption of $PM_{2.5}$ and PM_{10} Biogenic Aerosol Particles in Amazonia measured using several techniques

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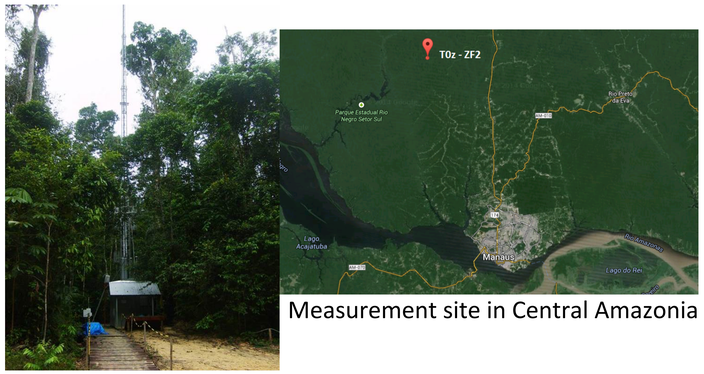
Introduction

The Amazon Basin, during the wet season, has one of the lowest aerosol concentrations worldwide, with air masses covering thousands of kilometers of pristine forest with very low or negligible human impact. The atmosphere in such regions is strongly coupled with the biosphere through primary biological aerosols, biogenic salts and secondary aerosols from oxidation of biogenic VOCs.

Aerosol absorption is a key aerosol property and critically important for the proper calculation of aerosol radiative forcing. Especially in the tropics with the dominance of natural biogenic aerosol and the so-called brown carbon, the anomalous absorption is of particular interest.



Measurement site in Central Amazonia

Methodology

A special experiment was designed to study the wavelength dependence of aerosol absorption for PM2.5 as well as for PM10 particles during the wet season in Central Amazonia. Aerosol analysis began in the 8th of May of 2014 in the ZF2 ecological reserve, located about 55 km North of Manaus, usually in pristine conditions, and was carried out until late in August when the dry season had already started, with the impact of long range transported biomass burning aerosols.

In this experiment, four aerosol absorption instruments were used to measured the concentration of Equivalent Black Carbon (BCe). Two sets of 7 wavelengths AE33 Aethalometers, and MAAPs (Multiangle Aerosol Absorption Photometer) were operated in parallel using $PM_{2.5}$ and PM_{10} inlets, characterizing both coarse and fine aerosol optical properties. Aerosol light scattering for 3 wavelengths was measured using a TSI Nephelometer with PM_{10} inlet. Particles were measured under dry conditions using diffusion dryers. A detailed protocol comparing MAAP with AE33 for both PM10 and PM2.5 inlets was used.

These instruments are all filter based absorption photometers, but differ in the measurement technique: AE33 measurements are based on the transmission of light (7 wavelengths) through two sample spots with different flow rates, whereas the MAAP is based on the transmission and scattering of light (637nm) at two different angles to derive the BCe concentration. All data measured by the Aethalometer was corrected for the multiple scattering effects.

Results

Black carbon equivalent (BCe) concentrations were measured by two sets of MAAPs and Aethalometers, both with inlets PM_{10} and $PM_{2.5}$, and the whole time series can be observed on figure 1. At a first sight, all the instruments show very similar behavior, measuring BCe concentrations of about 0.11 μg/m³ from May to June, and increasing to values of 4 μg/m³ in August, when the dry season has already started.

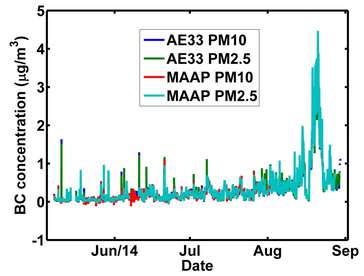


Figure 1– *BCe concentration time series of two sets of MAAPs and two Aethalometers with PM10 and PM2.5 during the experiment in the T0z site.*

During the whole experiment at the ZF2 sampling site, the two Aethalometers AE33 and the two MAAPs were compared to each other at the same inlet and same dryer for careful comparison.

The regression between MAAP PM_{10} and MAAP $PM_{2.5}$ is shown in figure 2. The instruments show a significant correlation (R^2=0.93) and they agree each other within 1%, a very good result.

In figure 3, it is shown the comparison of AE33 measurements with PM_{10} and $PM_{2.5}$ inlets. The Aethalometers are well correlated in the period (R^2 = 0.98), and forcing the linear regression line through the origin, they agree within the estimated instrument accuracies.

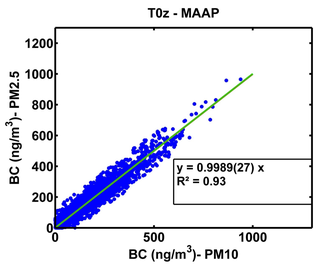


Figure 2 *– Correlation of the BCe concentration measured by MAAPs with PM10 and PM2.5 inlets, showing 30 min averages of data.*

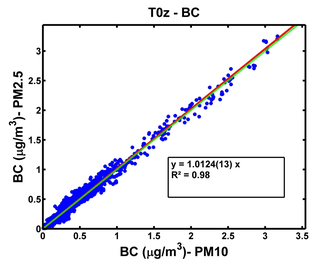


Figure 3 *– Comparison of the BCe concentration measured by AE33 with PM10 and PM2.5 inlets, showing 30 min averages of data compensated for the loading effect and multiple scattering.*

BCe measured by the MAAP and AE33 with PM_{10} and $PM_{2.5}$ inlets are shown in figure 4 and 5, respectively. The correlation between the instruments is significant at the 95% level (R^2=0.93 and R^2=0.97) and they agree within 10% for PM_{10} and 8% for $PM_{2.5}$. This agreement works well for the whole data set spanning all measured values.

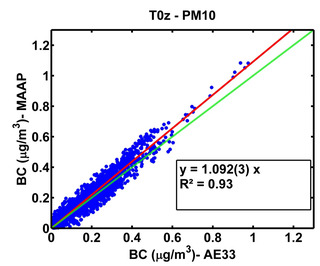


Figure 4– *Comparison of the BCe concentration measured by AE33 and MAAP with PM10 inlet, showing 30 min averages of data.*

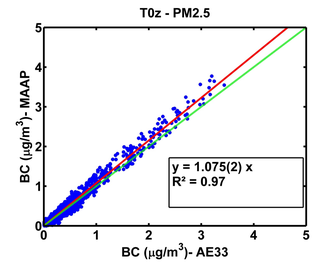


Figure 5– *Comparison of the BCe concentration measured by AE33 and MAAP with PM2.5 inlet, showing 30 min averages of data.*

As such regression coefficients and correlations are dominated by high values of BCe, the correlation slope was re-calculated, but applying upper cut-offs in the considered data. The results of this analysis is shown in figure 6, clearly depicting an absorption threshold in which coarse particles (linked to primary biogenic aerosol) start to play a significant role on the light absorption. Above such value (~0.2 μg m^{-3} of BCe) no significant contribution of coarse aerosol is observed.

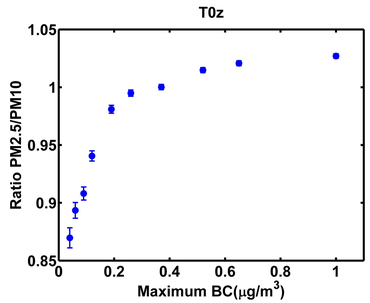


Figure 6 *– Slopes of the correlation between BCe measured by AE33 with PM10 and PM2.5 inlets, as a function of the maximum BCe used in the linear regression.*

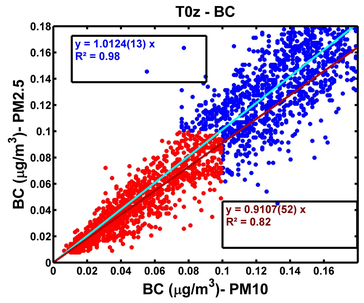


Figure 7 *– Linear regression between AE33 with PM10 and PM2.5 inlets using all data (blue line), and after applying an upper cut-off of 0.1μg/m³ (red line).*

In order to highlight the absorption of biogenic particles, we correlated PM_{10} and $PM_{2.5}$ considering only the cases when BCe is lower then 0.1μg/m³. This correlation is shown in figure 7 (red) and is compared with the general case (blue).

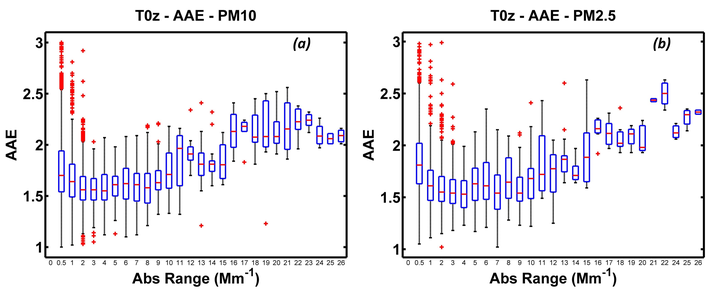


Figure 8– *Plots of AAE for different ranges of absorption coefficients for PM 10 (a) and PM2.5 (b) inlets.. The central line represents the group median, the vertical boxes represent data points between 25th- and 75th- percentiles, the whiskers represent data points between 5th- and 95th- percentiles.*

The Absorption Angstrom Exponent (AAE) was calculated for several ranges of absorption coefficients values during the experiment. As shown in figure 8, Angstrom exponent is about 1.6 for lower absorption values, increasing to values up to 2 for absorption greater than 11 Mm^{-1}, approximately. Absorption Angstrom values of 2 is related with biomass burning emissions.

The Scattering Angstrom Exponent (SAE) was calculated from January to August in T0z site and a histogram containing its values for wet (Jan-May) and dry (Jun-Aug) seasons are in figure 9. The reason for reduced Angstrom exponents during the wet season can be attributesd to the increase of particle size, with larger presence of primary biological particles (PBA).

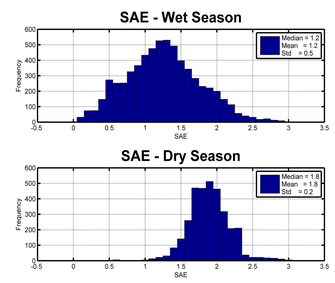


Figure 9 *– Histograms of Scattering Angstrom exponents for the experiment.*