Aerosol Absorption and Scattering in Mexico City

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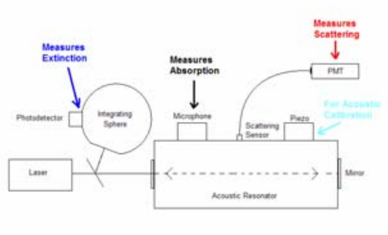
Abstract

Aerosol optical properties are fundamental to establish the effects of aerosols on the planetary radiative balance and therefore to estimate aerosol effects on climate. A fundamental parameter for atmosphere radiative balance models is the aerosol single scattering albedo (SSA). Aerosol SSA values are calculated as the ratio of scattering to total extinction (scattering plus absorption). Optically absorbing aerosol (SSA<1) may contribute to atmospheric warming while cooling the earth surface, while scattering aerosol (SSA~1) may counteract greenhouses gases warming effects by reflecting sun-light in the atmosphere and interacting with clouds. Additionally, aerosol optical properties are strongly related to aerosol chemical composition and size, which conversely have implications for human health and environmental degradation. During the field campaign in Mexico City (MILAGRO March 2006) we measured ensemble aerosol absorption and angle-integrated scattering data. The measurements were performed using the Los Alamos aerosol Photoacoustic instrument with an integrated nephelometer (LAPA) operating at 781 nm. The LAPA was mounted on-board the Aerodyne inc. mobile laboratory which hosted a wide variety of other gases and aerosol instruments, and operated almost continuously between the 3rd and 28th of March 2006. During the campaign the van was moved in different locations to capture pollution dependencies on location, aging, elevation, sources etc. We report here a preliminary analysis of aerosol absorption and scattering values measured in Mexico City.

The Instrument

The LAPA (Los Alamos PhotoAcoustic) instrument (Droplet Measurement Technology, Inc. Boulder, CO) was installed on board the Aerodyne Inc. Mobile Laboratory. The instrument measured simultaneously aerosol absorption and ~180° integrated scattering at 781nm [Arnott et al. 1999, 2000, 2003]. The mobile laboratory carried other instrumentation that measured physical and chemical properties of aerosols and gases. Absorption and scattering calibration of the LAPA was carried out at the factory using absorbing spherocarbs particles and scattering latex spheres and in the laboratory using a kerosene lamp and latex spheres.

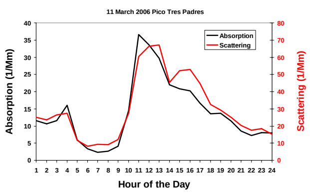
In the LAPA instrument, laser light is modulated to the acoustic resonance frequency of the spectrometer acoustic resonator. The laser light enters the resonator cavity and is then reflected back by a mirror at the end of the resonator to double the intra-cavity laser power. When the laser light hits absorbing gas or aerosol, it is absorbed and converted to an acoustic pressure wave through gas expansion. A high sensitivity microphone can detect this sound signal and make a measurement of light absorption. The angle integrated scattering is measured by a lambertian diffuser detector mounted in the middle point of the acoustic cavity. A measurement of absorption and scattering is performed every ~1.4 seconds. A Piezoelectric disk allows for the finding of the acoustic resonance frequency and Q factor, and is used for calibration every 600 measurements. A zero aerosol absorption is also performed every 600 measurements by filtering the incoming air.



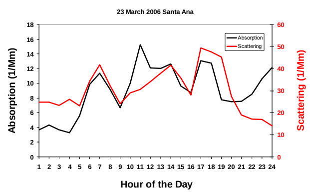
Photoacoustic schematic:

- **Microphone for acoustic signal measurement. Absorption**
- **Integrating sphere for extinction measurement**
- **Lambertian diffuser for scattering measurement**

Examples of Hourly Absorption and Scattering



Daily variations of hourly averaged absorption and scattering at Pico Tres Padres on the 11th of March 2006. An hourly maximum of 37 Mm^{-1} was measured for absorption at 11 AM, while the a maximum of scattering was reached at 1 PM with 67 Mm^{-1}



Daily variations of hourly averaged absorption and scattering at Santa Ana on the 23rd of March 2006. An hourly maximum of 15 Mm^{-1} was measured for absorption at 11 AM, while the a maximum of scattering was reached at 5 PM with 49 Mm^{-1}

Definition of Aerosol Single Scattering Albedo

$$\omega = \frac{K_s}{K_a + K_s}$$

Where Ka is the absorption coefficient and Ks is the scattering coefficient.

Use of SSA in Aerosol Forcing Calculations

The single scattering albedo of aerosols is one of the parameters used to calculate aerosol forcing as seen in the equations below. SSA is represented by ω.

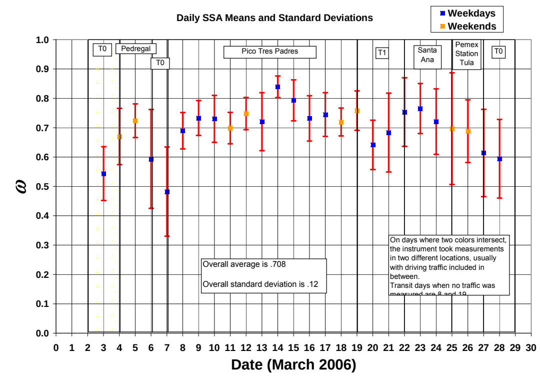
$$\Delta F_R = -\frac{S_0}{4} T_{atm}^2 (1-N)\left[(1-a)^2 2\beta\tau_{sc} - 4a\tau_{abs}\right]$$

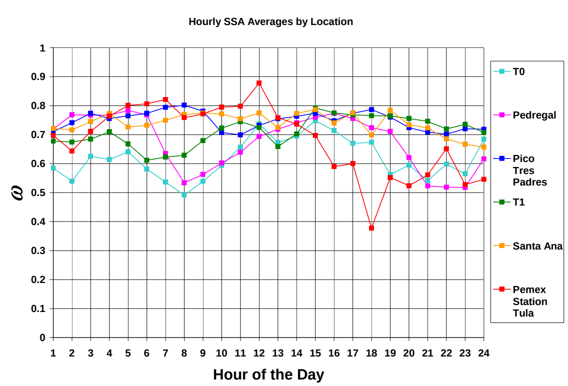
Where

$$A = 2\tau(1-\omega) = 2\tau_{abs}$$

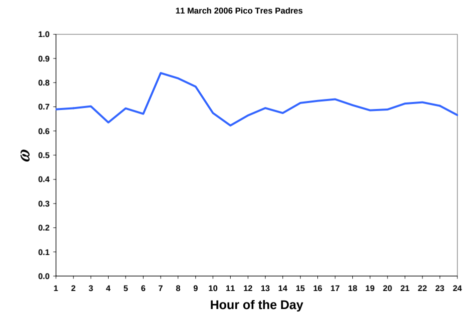
During the field campaign the aerosol single scattering albedo (SSA) measurements ranged between about 0.5 and 0.9, with an overall average of 0.708.

Analysis of SSA in Mexico City





Example of Daily variation of SSA at Pico Tres Padres



Some General Conclusions:

The Los Alamos Photoacoustic instrument collected data almost continuously between March 3rd and March 28 in 6 different locations and also on freeways in heavy traffic conditions.

The preliminary data analysis of our hourly data clearly shows the time dependence of absorption, scattering and single scattering albedo during the day.

More remote sites show generally higher SSA values than T0 or T1. T0 seems to have the lowest SSA values due to higher absorbing aerosol concentrations probably because of more traffic-dominated sources. The highest SSA values occur at Pico Tres Padres.

Pedregal and T0 share similar SSA shapes by the hour, for both sites. The SSA peaks in the morning, drops down around 8 AM in correspondence of the morning rush hour, peaks again in the early afternoon, drops again but slower at the evening rush hour, and rise again at the end of the day. Pico Tres Padres SSA values show a delayed minimum (around 11 AM) due to the boundary layer dynamic during the day. Santa Ana stays relatively level all day, while at Pemex Station and Tula, there is a drastic peak at noon and a reversed peak around 6:00 PM due to the transit measurements in heavy diesel-dominated Traffic conditions.

The overall average of single scattering albedo in Mexico City from March 3-28 was 0.71, with a standard deviation of 0.12.

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