Multi-instrument Optical Closure Study: laboratory and field approaches

J.P. Faria[1], U. Bundke[1], T. Mentel[1], T. B. Onasch[2], A. Freedman[2] and A. Petzold[1]

[1] Forschungszentrum Jülich GmbH, IEK-8, 52425 Jülich, Germany
[2] Aerodyne Research, Inc., Billerica, MA 01821-3976, USA
Keywords: Airborne Aerosol, Single Scattering Albedo, Climate.
Presenting author email: j.de.faria@fz-juelich.de

Airborne aerosols impact climate directly though the interaction with incident solar light by scattering, generating a cooling effect, or by absorbing it and reemitting infrared radiation, having a heating effect. According to Haywood and Shine (1995), the effect of aerosols on the global radiation budget depends on the aerosols optical depth, the single scattering albedo (SSA), and the backscattered fraction. Measuring the SSA involves necessarily measuring two parameters separately since, by definition, the SSA is the relationship between the scattering and extinction coefficients (where extinction is the sum of the scattering and absorption). Therefore, two separate instruments with different principles and uncertainties are commonly used, leading to potential sources of significant errors and biases.

A novel instrument based on cavity attenuated phase-shift technology and incorporating an integrating sphere was recently developed by Aerodyne Research, Inc. The Cavity Attenuated Phase Shift Single Scattering Albedo Monitor (CAPS PM_{ssa}) is capable of simultaneously measuring both the extinction and scattering coefficients, reducing the potential errors of applying two separate instruments (Onasch *et al.*, 2015).

In a previous study (Petzold *et al.*, 2015), the CAPS PM_{ssa} system was assessed in an optical closure study, by comparison with the proven technologies listed in Table 1. A good agreement was found for the extinction channel both with absorbing and scattering aerosols samples. In the case of the scattering channels, the NEPH and the CAPS PM_{ssa} agreed well with scattering aerosol samples (high SSA values), but some inconsistencies when measuring absorbing aerosols (low SSA values) were observed.

In order to better understand these previous results, a new optical closure study has been done with extended instrumentation, utilizing 2 or 3 methods for each aerosol optical property (see Table 1). We have also done a theoretical comparison by calculating the expected extinction coefficient by applying Mie theory using the size distribution of the aerosol measured by an optical particle counter (OPC). The study was carried out in the laboratory with controlled particle generation systems. We used both light absorbing aerosols (Regal 400R pigment black from Cabot Corp. and colloidal graphite – Aquadag – from Agar Scientific) and purely scattering aerosols (ammonium sulphate and polystyrene latex spheres), covering SSA values from approximately 0.4 to 1.0. Figure 1 shows a preliminary result of the intercomparison between the extinction channel of the CAPS PM_{ex} and CAPS PM_{ssa}. We will report on our final results, focusing specifically on the scattering measurements.

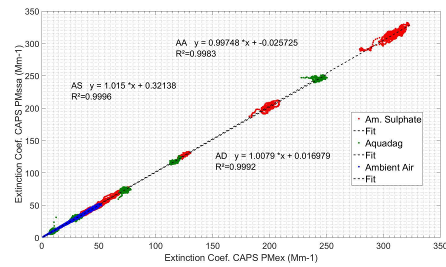

Figure 1 Intercomparison of CAPS PM_{ex} and CAPS PM_{ssa} extinction channels for different aerosol types.

Table 1 List of instruments used for the optical closure study in laboratory

Instrument	Manufacturer	Measured Property	λ (nm)
CAPS PM_{ex} [1,2]	Aerodyne	Ext. Coef.	630
CAPS PM_{SSA} [1,2]	Aerodyne	Ext. + Scat. Coef.	630
Aurora 4000[2]	EcoTech	Scat. Coef.	635, 525 and 450
TSI 3563[1,2]	TSI	Scat. Coef.	700, 550 and 450
PSAP[1,2]	Radiance Research	Abs. Coef.	660, 530 and 467
MAAP[2]	Thermo Scientific	Abs. Coef.	670
OPC[2]	GRIMM	Particle Size Dist.	655

[1] First Campaign
[2] Second Campaign

As the next step, a long-term optical closure study using ambient air has been designed. During this campaign all instruments that have been used in the laboratory study will also be deployed in the field plus a blue wavelength CAPS PM_{ex} and a second automatic PSAP to continuously evaluate the optical closure. With this final configuration we will be able to study the aerosol optical characteristics at the three most optically relevant wavelengths.

The laboratory studies, together with the long-term optical closure campaign and the remote sense techniques (JOYCE (Löhnert et al., 2015)) will, in the long run, give us all necessary parameter to also estimate the local aerosol radiative forcing efficiency.

Haywood, J. and Shine K. (1995) *Geophysical Research Letters*, **22:5**, 603-606.

Löhnert, U., et al. (2015) *Bulletin of the American Meteorological Society*, **96**:10, 1765-1787.

Onasch, T., et al. (2015) *Aerosol Sci. Technol.*, **49**:4, 267-279.

Petzold, A., et al. (2015) *2015 European Aerosol Conf.*.