Geophysical Research Abstracts
Vol. 17, EGU2015-6073, 2015
EGU General Assembly 2015

Modified cavity attenuated phase shift (CAPS) method for airborne aerosol light extinction measurement

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Monitoring the direct impact of aerosol particles on climate requires the consideration of at least two major factors: the aerosol single-scattering albedo, defined as the relation between the amount of energy scattered and extinguished by an ensemble of aerosol particles; and the aerosol optical depth, calculated from the integral of the particle extinction coefficient over the thickness of the measured aerosol layer. Remote sensing networks for measuring these aerosol parameters on a regular basis are well in place (e.g., AERONET, ACTRIS), whereas the regular in situ measurement of vertical profiles of atmospheric aerosol optical properties remains still an important challenge in quantifying climate change.

The European Research Infrastructure IAGOS (In-service Aircraft for a Global Observing System; www.iagos.org) responds to the increasing requests for long-term, routine in situ observational data by using commercial passenger aircraft as measurement platform. However, scientific instrumentation for the measurement of atmospheric constituents requires major modifications before being deployable aboard in-service passenger aircraft.

Recently, a compact and robust family of optical instruments based on the cavity attenuated phase shift (CAPS) technique has become available for measuring aerosol light extinction. In particular, the CAPS PM_{ex} particle optical extinction monitor has demonstrated sensitivity of less than 2 Mm^{-1} in 1 second sampling period; with a 60 s averaging time, a detection limit of less than 0.3 Mm^{-1} can be achieved. While this technique was successfully deployed for ground-based atmospheric measurements under various conditions, its suitability for operation aboard aircraft in the free and upper free troposphere still has to be demonstrated.

Here, we report on the modifications of a CAPS PM_{ex} instrument for measuring aerosol light extinction on aircraft, and subsequent laboratory tests for evaluating the modified instrument prototype: (1) In a first set of tests, the robustness of the method was demonstrated down to pressure levels below 200 hPa, using air and CO_2 as test gases. Rayleigh scattering cross-section values for both gases deviated by less than 5 % from literature data for all investigated pressure levels.(2) The measurement of aerosol particles at lower pressure levels required the modification of the air flow handling. A new flow scheme using mass flow controllers and a revised vacuum pump set-up was developed and successfully tested. The overall reduction of the instrument noise level to values less than 0.15 Mm^{-1} was achieved. (3) Polydisperse laboratory-generated ammonium sulphate particles and monodisperse polystyrene latex spheres where used to evaluate the instrument operation for the pressure range from 1000 hPa to less than 200 hPa against an optical particle counter. Reference aerosol extinction coefficients were calculated from measured size distributions, using Mie theory. We found less than 10 % deviation between the CAPS PM_{ex} instrument response and calcuated extinction coefficients over the investigated pressure range.