Aerosol measurements within the CATCOS Project

A first exchange of general information:

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1. The CATCOS Project

CATCOS (Capacity Building and Twinning for Climate Observing Systems) is a project supported by the Swiss Agency for Development and Cooperation (SDC) with MeteoSwiss as the coordinating partner.

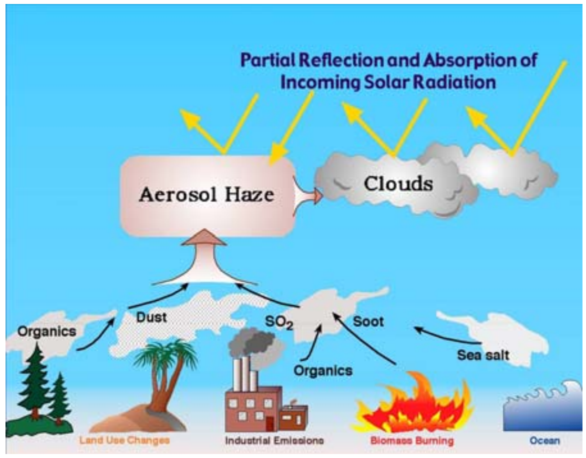
In the context of the Global Climate Observing System (GCOS) and WMO Global Atmosphere Watch Programme (GAW), the project addresses the need to improve climate observations world-wide.

2. The importance of measuring aerosol optical properties

Aerosols influence the atmospheric energy budget through direct and indirect effects:

- Direct radiative effects include the scattering and absorption of solar radiation and the subsequent influence on planetary albedo and the climate system.
- Indirect effects involve the influence of the aerosol on cloud properties, cloud lifetime and cloud cover through acting as cloud condensation nuclei (CCN) and ice nuclei (IN). Anthropogenic changes of the atmospheric aerosol loadings are expected to cause an overall negative climate forcing partially offsetting the positive forcing by greenhouse gases.

However, the aerosol effects are still poorly quantified due to the inhomogeneity of global aerosol loadings and chemical composition as well as the complexity of involved interactions and feedbacks. A major gap in the quantification of the aerosol indirect effect is the poor quantification of the global distribution of CCN.



Therefore, knowledge of aerosol radiative properties is needed for the evaluation of aerosol effects on climate and visibility. The fundamental quantity of interest for these applications is the aerosol light extinction coefficient (σ_{ep}). σ_{ep} is the sum of the light scattering (σ_{sp}) and light absorption (σ_{ap}) coefficients. Another important parameter is the aerosol single-scattering albedo, defined as σ_{sp}/σ_{ep}. It describes the relative contributions of scattering and absorption to the total light extinction. Purely scattering aerosols (e.g. ammonium sulfate or sodium chloride) have values of 1, while very strong absorbers (e.g. soot or black carbon) have values of around 0.3. An analysis of the wavelength dependence of all these parameters allows deriving further information on the aerosol type. For example, biomass burning aerosols or mineral dust are characterized by very distinct different optical properties compared to the background aerosol.

Within the CATCOS project, the aerosol light scattering coefficient, σ_{sp}, will be measured with a multi-wavelength integrating nephelometer (Aurora 3000, Ecotech). This instrument operates at 3 wavelengths and is able to measure total scattering and hemispheric backscattering. The light absorption coefficient (σ_{ap}) will be measured with a multi-wavelength aethalometer (Magee Scientific, AE31). The measurement principle is based on the rate of change of transmission through a fibre filter as particles are deposited.

3. Who we are: The Laboratory of Atmospheric Chemistry at Paul Scherrer Institut, Switzerland

The Paul Scherrer Institute (PSI) is Switzerland's largest research centre for the natural and engineering sciences. Approximately 400 scientists at the Institute are investigating a large variety of scientific questions that can be grouped into three main fields: “Matter and Material”, “Human Health”, and “Energy and Environment”.

The PSI Laboratory of Atmospheric Chemistry in Villigen, Switzerland (LAC, http://www.psi.ch/lac) was founded in 2000. In the years since then, the LAC has developed the following mission:

- Investigation of key processes determining the gas phase and aerosol composition in the polluted atmospheric boundary layer, and the identification of their sources and sinks
- Study of the impact of anthropogenic air pollution to the Alpine region, including the biosphere

To address these issues the LAC has been built up to the current size of about 40 people, about 20 out of these being PhD students.

4. Our expertise in climate relevant aerosol research

In 1988, PSI initiated an aerosol research program at the high Alpine Research Station Jungfraujoch (JFJ, 3580 m a.s.l.). Since 1995 PSI has been responsible for the continuous aerosol measurements performed at JFJ within the Global Atmosphere Watch (GAW) program of the World Meteorological Organization. By the end of 2011 we have reached 17 years of continuous measurements. Nowadays, the aerosol monitoring programme at the JFJ is among the most complete aerosol monitoring programs worldwide. The following aerosol parameters are measured on a continuous basis at the JFJ: particle number concentration (with a particle diameter Dp>10 nm) and size distribution (Dp=20 nm - 20 μm), number concentration of cloud condensation nuclei (CCN) at various supersaturations, light scattering and absorption coefficient at various wavelengths, PM1 mass concentration and aerosol major ionic composition (PM1 and TSP). These continuous measurements were complemented by a series of intensive field campaigns where the interactions of aerosol particles with the cloud particles were explored. The aerosol monitoring and research activities at JFJ have been and are embedded in numerous EC projects, such as EUSAAR (European Supersites for Atmospheric Aerosol research), EUCAARI (European Integrated Project on Aerosol Cloud Climate and Air Quality Interactions), GEOMON (Global Earth Observation and Monitoring of the Atmosphere), and most recently ACTRIS (Aerosols, Clouds, and Trace Gases Research Infrastructure Network).

5. Planned CATCOS aerosol instrumentation

Aethalometer: The aerosol light absorption coefficient, σ_{ap}, will be measured with a multi wavelength aethalometer (Magee Scientific, AE31). This instrument is capable of measuring aerosol light absorption with a high time-resolution at seven wavelengths, from 370 nm (UV) to 950 nm (IR). The measurement principle is based on the rate of change of transmission through a fiber filter as particles are deposited on the filter. Calibration of these filter-based methods is complex and is required because the relationship between change in light transmission and aerosol absorption optical depth on the filter depends on many factors, including the particular filter medium and the light-scattering nature of the particles. Recent publications have presented successful approaches for this calibration, which require simultaneous nephelometer measurements to correct for substantial effects of light scattering by the particles on the filter. The light absorption measurements will be connected to the same inlet system as the rest of the aerosol sampling system. The filter-based methods yield erratic results when the humidity changes, particularly at high relative humidity. For this reason, a supplemental heater at the inlet of the instrument may be needed to ensure that the sample RH is kept low in air-conditioned laboratories (see below). As the aethalometer models perform the filter change automatically, routine maintenance checks are typically minimal. Because the final measurement results are expressed in terms of a aerosol cross-section for light absorption per unit volume of air (units of m^2 m^{-3}), the sample flow rate and the sample area of the filter deposit must be checked periodically (typically every 1-2 month).

Nephelometer: The aerosol light absorption coefficient, σ_{sp}, will be measured with a multi-wavelength integrating nephelometer (Aurora 3000, Ecotech). This instrument operates at wavelengths of 525nm (green), 450nm (blue) and 635nm (red), and has the added feature of being able to measure σ_{sp} over two angular ranges: total scattering (9-170° degrees) and hemispheric backscattering (90-170°, denoted as σ_{bsp}). The high sensitivity, multiple wavelengths, and backscatter capability of this instrument makes it suitable for monitoring aerosol light scattering properties in support of radiative climate studies. Calibration is achieved by filling the instrument with a particle-free gas that has a known scattering coefficient. Filtered, ambient air is used as the downscale calibration point, and CO_2 as the upscale point. Generally, calibrations with filtered air are performed automatically every few hours. Manual calibrations with CO_2 should be done typically every 1-2 month. It should be made clear that the schedule for air calibrations controls the precision of the determination of the Rayleigh scattering coefficient of air, which is subtracted from the measurements to obtain the aerosol light scattering coefficient; any error here gravely affects the detection limit of the instrument.

Planned setup of instruments: An omni-directional high efficiency dedicated air inlet is required for aerosol sampling (cover to exclude precipitation, vertical stack, laminar sampling flow, high aerosol transmission efficiency, conductive and non-corrosive tubing material, etc) such that an undisturbed aerosol is delivered to the aerosol instruments. Sampling sites that are frequently in clouds or fog will be equipped with a heated whole air inlet to sample and evaporate cloud or fog droplets. The instruments plus the other hardware components will be integrated in a rack.

A detailed sketch of the planned design will be sent as separate document.

6. Contacts

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