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Black carbon contribution to the aerosol phase and its scavenged fraction in mixed phase clouds at the high alpine site Jungfraujoch (3580m asl)

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The mass fraction of black carbon (BC) and its mixing state are important for the direct aerosol climate effect. These properties also determine if BC is incorporated into cloud hydrometeors (i.e. droplets and ice crystals) and are important because the microphysical and optical properties of the cloud are altered (indirect aerosol effect). Measurements were performed during several Cloud and Aerosol Characterization Experiments, in winter 2004 (CLACE3), summer 2004 (CLACE3.5), winter 2005 (CLACE4) and summer 2005 (CLACE4.5) at the high Alpine research station Jungfraujoch (3580 m asl).

The aerosol was sampled by three well characterized inlets, discriminating between the total aerosol particles (including the residuals of the hydrometeors) using a heated inlet, the interstitial (unactivated) particles within a cloud using a PM2 cyclone, and the ice crystal residuals using a counterflow virtual impactor. A wide variety of physical and chemical parameters was determined downstream of these inlets and complemented by in-situ measurements of cloud microphysical parameters (Particulate Volume Monitors and Cloud Particle Imager). The BC concentration behind the inlets was measured by two Multi-Angle Absorption Photometers and two Particle Soot Absorption Photometers. These measurements were complemented by ion determination on filters (TSP and PM1) on the total inlet, EC/OC concentrations (thermo-optical analyzer), Aerosol Mass Spectrometer data and total submicron aerosol mass concentration (SMPS).

A mass closure of the Jungfraujoch aerosol was performed in winter and summer 2005 for total suspended particles (TSP) and PM1. The major aerosol mass was found to be present in the submicrometer size range except during Sahara dust events. OC is an important component with a larger contribution in summer ($\sim$50%) compared to winter ($\sim$30%). Black carbon represents $\sim$7% of the total aerosol mass in winter (1 μg/m^3) and $\sim$6% in summer (5 μg/m^3). The Jungfraujoch aerosol is predominately internally mixed with a better mixing in summer than in winter.

The scavenged fraction is defined as the ratio of BC in the cloud droplets (total minus interstitial) to the total BC mass concentration. The measurements showed that the scavenged BC fraction increases with increasing liquid water content (LWC) for values of LWC up to 0.13 g/m^3, and decreases with increasing BC mass concentration for a total BC concentration up to 35 ng/m^3. For a large temperature range (between -25˚C and 5˚C) the scavenged BC fraction increases with increasing temperature, up to 61% in summer. This behavior can be explained by the evaporation of liquid droplets in the presence of ice crystals (Bergeron-Findeisen process). This was confirmed by the microphysics studies where an influence of the ice mass fraction on the scavenged BC fraction was observed. A similar measurement was performed for the BC fraction in ice crystals which is defined as the ratio of BC incorporated in ice particles over the total BC mass concentration. It was found that there is a low activated fraction which can be explained by the low concentration of ice crystals but with an increase for high ice mass fraction which could suggest the enrichment of BC particles in the ice nuclei. The ice residual phase is enriched in BC as suggested by comparing the scavenged BC fraction with the total scavenged aerosol volume in the CVI.