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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INTRODUCTION

The mass fraction of black carbon (BC) in the atmospheric aerosol 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).

RESULTS

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 (CVI) (Mertes *et al.*, 2005). A wide variety of physical and chemical parameters was determined downstream of these inlets. The BC concentration behind the inlets was measured by two Multi-Angle Absorption Photometers (Petzold and Schonlinner, 2004) and two Particle Soot Absorption Photometers (Reid *et al.*, 1998). 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 submicron aerosol size distribution (SMPS). In-situ measurements of cloud microphysical parameters (Particulate Volume Monitors and Cloud Particle Imager) allowed for the determination of the cloud liquid water content (LWC) and ice water content (IWC).

A mass closure of the Jungfraujoch aerosol was performed in winter and summer 2005 for total suspended particles (TSP) and PM1 (Cozic *at al.*, 2006b). The major aerosol mass was found to be internally mixed and present in the submicrometer size range except during Sahara dust events. OC is an important component with a larger contribution in summer (~50%) compared to winter (~30%). Black carbon represents ~4% of the total aerosol mass in winter.

The scavenged fraction of black carbon is defined as the ratio of BC mass 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 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. At the Jungfraujoch the scavenged BC fraction increases with increasing ambient temperature from 10% at -25°C up to 61% at +5°C (Cozic et al., 2006a). 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 a clear dependence of the cloud ice mass fraction, defined as IWC/(IWC+LWC), on the scavenged BC fraction was observed (Figure 1).

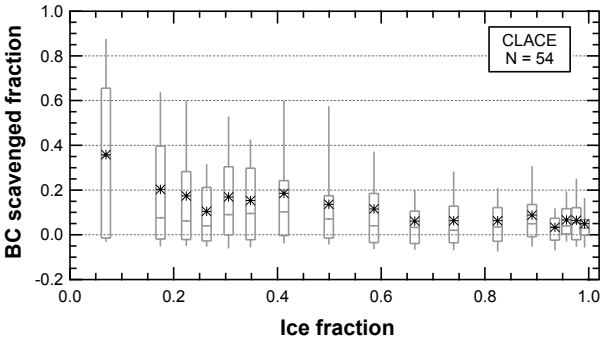

Figure 1. Scavenged BC fraction vs. cloud ice mass fraction.

A similar analysis was performed for the scavenged BC fraction in ice crystals which is defined as the ratio of BC incorporated in small ice particles (diameter < 20 µm) over the total BC mass concentration. It was found that this fraction is low (< 0.01) for mixed phase clouds with an ice mass fraction < 0.4. The observed increase of this fraction with increasing ice mass fraction suggests an enrichment of BC particles in the ice residuals. This enrichment is also seen in Figure 2 where the BC mass fraction in the ice residual phase

(i.e. the ratio of the BC mass concentration to the submicrometer particle mass concentration downstream of the CVI) is compared with the corresponding fraction in the total phase.

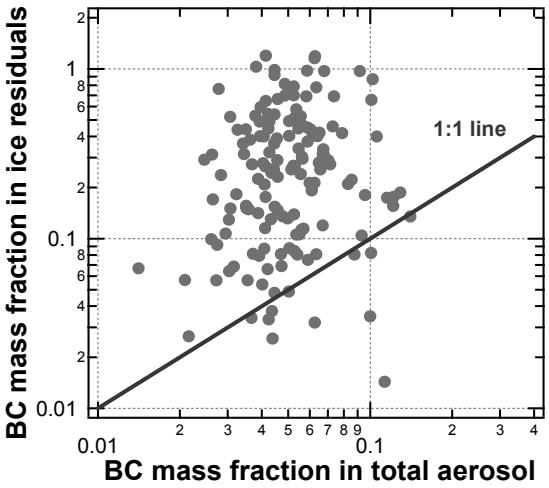

Figure 2. Comparison of the fraction of BC in the ice residual phase with the fraction of BC in the total aerosol phase (44h of in cloud data, mass concentrations were derived from SMPS submicrometer size distributions assuming a density of unity).

CONCLUSIONS

Measurements of black carbon (BC) were made in winter, summer 2004 and winter 2005 at the high Alpine site Jungfraujoch in order to study the scavenging of BC into cloud droplets and ice crystals. Main results showed that the scavenged fraction represents 61% in summer and that for a large temperature range between -25°C and 5°C, the scavenged BC fraction increases with increasing temperature and increasing liquid water content. BC has been found enriched in ice residual particles compared to total particles.

Keywords: *Carbonaceous Aerosol, Cloud/Fog Aerosol Interactions, Free Tropospheric Aerosols*

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