Name of research institute or organization:

Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland

Title of project:

Cloud condensation nuclei-activity of black carbon particles during the CLoud and Aerosol Characterization Experiment 2016 (CLACE)

Part of this programme:

ERC consolidator grant (ERC-CoG-615922-BLACARAT), EU FP7 project BACCHUS (project number 603445) and GAW-CH (GAW+)

Project leader and team:

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Project description:

The CLACE 2016 campaign, with the broader aim of investigating the behavior of black carbon (BC) particles during cloud formation, took place at the Sphinx observatory from June 2nd to August 8th 2016. BC particles, which are emitted by combustion processes, are of peculiar interest as they are mainly of anthropogenic origin. A larger number fraction of freshly emitted BC particles are hydrophobic. The transport of these particles from the sources within the planetary boundary layer to the Jungfraujoch occurs over hours to days. During transport, condensation of organic and inorganic compounds can lead to substantial coatings around the BC cores, thereby increasing their hygroscopicity and potential to form cloud droplets.

A first research goal is to assess how the cloud droplet activation of BC particles depends on their size and mixing state and how it compares to BC-free particles. A second goal, which is not further discussed in this report, is to characterize the physical properties of the aged BC particles encountered at a high-altitude site, focusing on their size distribution and mixing state. Both goals are addressed with in-situ measurements of different aerosol fractions. For this purpose, three specific air inlets were operated during in-cloud periods:

- An interstitial inlet for selective sampling of interstitial particles, i.e. those that did not form cloud droplets (hydrometeors are removed by impaction).
- A cloud droplet residual particle inlet selectively sampling those particles that did form a cloud droplet (using a counter-flow virtual impactor to remove the interstitial particles).
- A total inlet, for sampling the whole particle population, i.e. both the interstitial and cloud droplet residual particles (part of the continuous GAW aerosol monitoring program).

For the characterization of these three aerosol fractions, the aerosol instrumentation permanently operated at the Jungfraujoch was complemented by additional instruments including a Single Particle Soot Photometer (SP2). The SP2 measures the black carbon mass and optical size of individual particles. This provides the BC mass concentration, BC core size distribution, optical particle size distribution with distinction between BC-containing and BC-free particles, and the thickness of non-refractory coatings of internally mixed BC cores.

The left panel in Figure 1 shows the fraction of particles that formed a cloud droplet for all BC-containing particles compared with the subset of thickly coated BC particles for an example cloud event. The fact that the thickly coated BC particles have a higher activation ratio than the whole population of BC particles, when comparing at equal BC core size, shows that the acquisition of coatings through atmospheric aging processes increases the ability of BC cores to form cloud droplets (particularly for small BC cores). The right panel

of Figure 1 shows the fraction of particles that formed cloud droplets as a function of total particle size. The data from the scanning mobility particle sizer (SMPS) show that large particles readily form cloud droplets while small ones don't. There is no significant difference between BC-free and BC-containing particles in the size range above 200 nm according to the SP2 data, which can be explained by the fact that the vast majority of the BC particles have acquired thick coatings of hygroscopic material by the time they reach the Jungfraujoch. Further analyses aim at quantifying the threshold coating thickness as a function of BC core size required that a BC particle can form a cloud droplet at a certain cloud supersaturation.

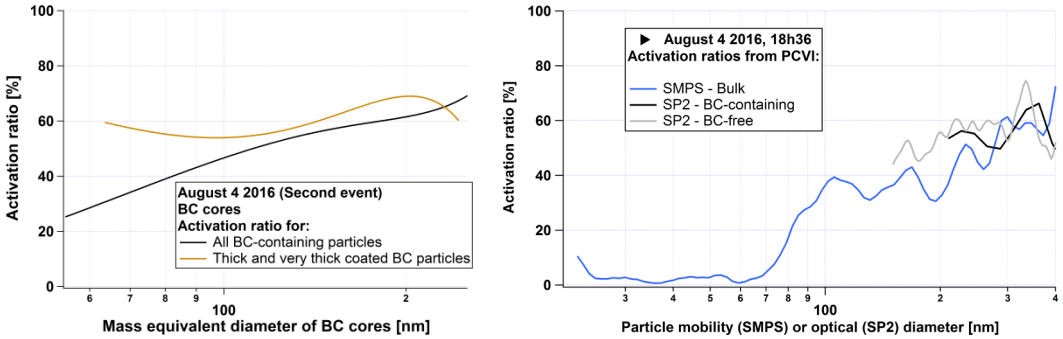

Figure 1. Left panel: cloud droplet activation ratio as a function of BC core size for all BC-containing particles compared with thickly-coated BC particles; right panel: cloud droplet activation ratio as a function of total particle size of BC-containing particles compared with BC-free particles and the total aerosol population (right).

Key words:

Clouds, CCN-activation, black carbon, mixing state, in-situ observation

Internet data bases:

http://www.psi.ch/lac

Collaborating partners/networks:

Dr. C. Hüglin, Dr. S. Henne, Dr. M. Steinbacher, and Dr. S. Reimann, EMPA, Dübendorf
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Scientific publications and public outreach 2016:

Refereed journal articles and their internet access

Hoyle, C.R., C.S. Webster, H.E. Rieder, A. Nenes, E. Hammer, E. Herrmann, M. Gysel, N. Bukowiecki, E. Weingartner, M. Steinbacher, U. Baltensperger, Chemical and physical influences on aerosol activation in liquid clouds: a study based on observations from the Jungfraujoch, Switzerland, Atmos. Chem. Phys., **16**, 6, 4043-4061, doi: 10.5194/acp-16-4043-2016, 2016. http://dx.doi.org/10.5194/acp-16-4043-2016

Kupiszewski, P., M. Zanatta, S. Mertes, P. Vochezer, G. Lloyd, J. Schneider, L. Schenk, M. Schnaiter, U. Baltensperger, E. Weingartner, M. Gysel, Ice residual properties in mixed-phase clouds at the high-alpine Jungfraujoch site, Journal of Geophysical Research – Atmospheres, **121**, 20, 12343-12362, doi: 10.1002/2016jd024894, 2016. http://dx.doi.org/10.1002/2016JD024894

Vochezer, P., E. Jarvinen, R. Wagner, P. Kupiszewski, T. Leisner, M. Schnaiter, In situ characterization of mixed phase clouds using the Small Ice Detector and the Particle Phase Discriminator, Atmos. Meas. Tech., **9**, 1, 159-177, doi: 10.5194/amt-9-159-2016, 2016. http://dx.doi.org/10.5194/amt-9-159-2016

Conference papers

Gysel, M., C.R. Hoyle, C.S. Webster, H.E. Rieder, A. Nenes, E. Hammer, E. Herrmann, N. Bukowiecki, E. Weingartner, M. Steinbacher, and U. Baltensperger, Measured and modelled cloud droplet activation of aerosol particles at the high-alpine research station Jungfraujoch, AAAR 35th Annual Conference, Portland, Oregon, USA, October 17-21, 2016.

Gysel, M., P. Kupiszewski, M. Zanatta, S. Mertes, P. Vochezer, G. Lloyd, J. Schneider, L. Schenk, M. Schnaiter, U. Baltensperger, and E. Weingartner, Size distribution and black carbon content of ice residual particles in mixed-phase clouds at the high-alpine site Jungfraujoch, European Aerosol Conference, Tours, France, September 4-9, 2016.

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