Name of research institute or organization:

Particle Chemistry Department
Institute for Atmospheric Physics, University of Mainz
and Max Planck Institute for Chemistry, Mainz

Title of project:

Mass spectrometric studies of ice nuclei and background aerosol within CLACE 5

Project leader and team:

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Project description:

The identification of ice nuclei is crucial for the understanding of heterogeneous ice nucleation in supercooled clouds, which is the main initiation process of precipitation in mid latitudes. Until today it is not well understood which chemical components (e.g. sulfuric acid, ammonium, nitrate, various organic substances, mineral dust, sea salt, soot, or other materials) contained inside or on the surface of aerosol particles enable a particle to act as an ice nucleus (IN). While water soluble compounds are expected to favour the formation of liquid cloud droplets, insoluble materials like mineral components may favour the formation of ice particles.

Similar to the 3rd and 4th Cloud and Aerosol Characterization Experiments (CLACE-3, CLACE-4) in February/March 2004 and 2005, also in 2006 mass spectrometric measurements of particles were performed at the High Alpine Research Station Jungfraujoch within the frame of the follow-up project CLACE 5. Our CLACE 5 sub-project was embedded into the activities and largely financed by the German Collaborative Research Center 641 "The Tropospheric Ice Phase", sub-project A3 "In situ measurements of the chemical composition of atmospheric ice residuals and ice nuclei by mass spectrometric methods".

During CLACE 5 two different types of aerosol mass spectrometers were operated at the Sphinx laboratory in order to analyze in situ and on-line the chemical composition residuals of supercooled cloud droplets, small ice particles as well as background and interstitial aerosol particles.

The first mass spectrometer, a Time-of-Flight Aerosol Mass Spectrometer (W-ToF-AMS by Aerodyne) is an improved version of the Quadrupole Aerosol Mass Spectrometer that was already deployed to the Jungfraujoch during CLACE 3 and 4. This improved version has a significantly higher sensitivity (only 20 ng/m^3 of arosol mass is needed) and a very high mass resolution of >4000. The mass spectrometer operated very sucessfully and the chemical composition of the non-refractory compounds of the background and interstitial aerosol (sulfate, nitrate, organics and ammonia) was measured quantitatively throughout the campaign at high time resolution. The high mass resolution allowed for the first time to distinguish ions of

different chemical composition but identical integer m/z ratio: for example, the ions of $C_2H_3O^+$ and $C_3H_7^+$ at m/z 43.0184 and 43.0551 were clearly separated and this separation allows to analyze the degree of oxidation of the organic aerosol fraction. The W-ToF-AMS also provided successful measurements of ice residuals. These measurements confirmed our findings from CLACE 3 and 4 that the ice residuals contain only very low amounts of non-refractory material, suggesting that ice nuclei are mainly composed of refractory substances such as mineral dust and soot.

The second mass spectrometer, a Single Particle Laser Ablation Time-of-Flight Mass Spectrometer (SPLAT), analyzes individual particles in the size range of 500-3000 nm diameter. This mass spectrometer has been developed by our group in recent years and it was deployed to the field only for the second time for CLACE 5. Generally, the instrument worked very well and provided mass spectra from more than 1200 individual particles during the campaign. As the instrument is still in a developmental phase its performance was considered very good. The mass spectra revealed various kinds of particles, including mineral dust particles, organic particles, sulfate and nitrate particles, etc.. During CLACE 5 the measurement of ice residuals was not yet successful because the ice residual concentrations were to low for the SPLAT mass spectrometer.

For this reason numerous improvements and optimizations of the SPLAT were implemented during the rest of the year 2006. Here, especially the lowering of the smallest detectable aerosol particle diameter from 500 to below 300 nm represents a substantial improvement. Therefore we are now very confident that we will be able to analyze ice residuals with the SPLAT during CLACE 6.

Key words:

Aerosol chemical composition, ice nuclei chemical composition, aerosol mass spectrometry

Internet data bases:

An FTP server for internal use of CLACE participants has been established

Collaborating partners/networks:

ift Leipzig (Dr. Stephan Mertes), PSI (Dr. Ernest Weingartner), ETH Zürich (Dr. Daniel Cziczo), Tech Univ. Darmstadt (Dr. Martin Ebert),

Scientific publications and public outreach 2006:

Conference papers (for 2006, concerning previous CLACE campaigns)

Bower, K., P. Connolly, J. Cozic, B. Verheggen, E. Weingartner, M. Ebert, A. Worringen, S. Mertes, J. Schneider, and S. Walter, Counterflow virtual impactor based collection of small ice particles in mixed-phase clouds for the physico-chemical characterization of tropospheric ice nuclei, *oral presentation at the International Aerosol Conference, St. Paul, U.S.A.*, 10 - 15 Sept., 2006.

Schneider, J., S. Walter, J. Curtius, S. Borrmann, S. Mertes, E. Weingartner, B. Verheggen, J. Cozic, and U. Baltensperger, Chemical composition measurements of ice nuclei in mixed phase tropospheric clouds during the cloud and aerosol characterization experiments CLACE, *oral presentation at the International Aerosol Conference, St. Paul, U.S.A.*, 10 - 15 Sept., 2006.

E. Weingartner, B. Verheggen, J. Cozic, M. Gysel, S. Sjogren, J.Duplissy, U. Baltensperger, U. Lohmann, S. Mertes, K.N. Bower, M. Flynn, P. Connolly, J.

Crosier, M. Gallagher, H. Coe, T. Choularton, S. Walter, J. Schneider, J. Curtius, S. Borrmann, A. Petzold, M. Ebert, M. Inerle-Hof, A. Worringen, S. Weinbruch, E. Fries, E. Starokozhev, W. Püttmann, W. Jaeschke, M. Vana, A. Hirsikko, E. Tamm, P. Aalto, M. Kulmala, Aerosol-Cloud Interactions in the Lower Free Troposphere as Measured at the High Alpine Research Station Jungfraujoch in Switzerland, *oral presentation at the International Aerosol Conference, St. Paul, U.S.A.*, 10 - 15 Sept., 2006.

Mertes, S., B. Verheggen, S. Walter, M. Ebert, P. Connolly, J. Schneider, K. N. Bower, J. Cozic, A. Worringen, and E. Weingartner, Physico-chemical Characterisation of Ice Particle Residuals in Tropospheric Mixed-phase Clouds, *oral presentation at the 12th Conference on Cloud Physics*, Madison, U.S.A, 10 –14 July 2006.

Walter, S., J. Schneider, N. Hock, J. Curtius, S. Borrmann, S. Mertes, E. Weingartner, B. Verheggen, J. Cozic und U. Baltensperger, Massenspektrometrische Analyse der Residualpartikel von Eiswolken auf dem Jungfraujoch, Fachvortrag DPG-Frühjahrstagung, Umweltphysik, Heidelberg, 2006.

Kamphus, M., M. Ettner-Mahl, F. Drewnick, J. Curtius, und S. Borrmann, Entwicklung und Charakterisierung eines Einzelpartikel- massenspektrometers für die Untersuchung von Eiskeimen, Posterbeitrag 39. Jahrestagung der Deutschen Gesellschaft für Massenspektrometrie DGMS, P5-08, Mainz, 2006.

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