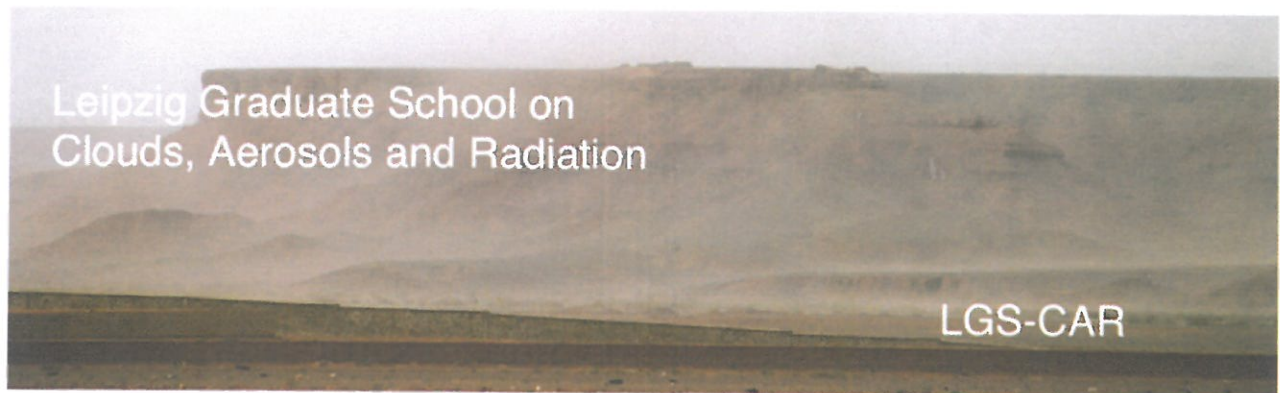


Final report

Leipzig Graduate School on Clouds, Aerosols and Radiation (LGS-CAR)

Leibniz Institute: Leibniz Institute for Tropospheric Research
Reference number: SAW-2012-lfT-4
Project period: 01.06.2012 – 30.11.2016
Contact partner: Prof. Andreas Macke

Leipzig Graduate School on Clouds, Aerosols and Radiation (LGS-CAR)



Prof. Andreas Macke (Speaker), Leibniz Institute for Tropospheric Research

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Executive summary

At the location Leipzig a grown education and research competence exists in the areas of aerosols, clouds and their effects in the climate system. Especially mineral dust particles or volcanic ash particles play a special role in this regard for many reasons. Their contribution to the total tropospheric aerosol is substantial (more the 60% of the atmospheric aerosol mass), and they are subject to strong anthropogenic (key word "desertification") and natural (key word "volcanism") influences.

Because of the non-spherical complex particle shapes new methodologies are required for active and passive remote sensing (key word "polarization"). Complex chemical and physical processes take place on their surfaces, which significantly effect the formation of clouds and precipitation.

In the long term the study of the physical and chemical processes from the molecular to the global scale especially in cooperation with the University partners shall lead to a break through in cloud and precipitation research and their applications, by means of field and laboratory investigations that provide the basis for process oriented modelling.

The Graduate School is the basis for a long-term joint structured PhD education in the field "aerosols, clouds and radiation". Specifically for the PhD works five topical areas are predefined:

- Application of polarization for the remote sensing of non-spherical particles
- Absorbing aerosols: parameterization and effects on atmospheric dynamics on regional and global scale
- Indirect aerosol effect: Combination of ground and satellite-based remote sensing
- Heterogeneous chemistry at modified mineral dust surfaces
- Heterogeneous ice nucleation at mineral dust particles

Based on an initial phase that is focused in the specific topics, the networking of the PhD work represents an essential part of the structured education. To this end numerous instruments like participation in summer schools and conferences, joint workshops, PhD seminars and others are provided. All measures are integrated in the Research Academy Leipzig, which also provides further measures in the fields of soft skills.

Meanwhile the Graduate Scholl is established as the "Leipzig Graduate School for Aerosols, Clouds and Radiation". It currently consists of 30 PhD students at TROPOS and the University partner LIM (Leipzig Institute for Meteorology), and is funded from different budgets, mainly from the Collaborative Research Centre TR 172 "Arctic Amplification" of the German Research Association.

Initial questions and objectives of the project

The overall questions aims at the relations between natural and anthropogenic airborne particles (aerosols), clouds and precipitation, and the radiation budget of your planet. The Graduate School further specifies this on the atmospheric mineral dust, which is both a natural and - due to changing land use - an anthropogenic component of the atmospheric aerosol. The initial questions of the project are:

- To what extend can the shape of mineral particles be accounted for in the active and passive remote sensing resp. in the dust identification?
- How strong does absorbing mineral dust effect the stability of the troposphere and the development of clouds by means of heating effects?
- Is it possible to identify the impact of mineral dust on clouds by combining ground- and satellite-based remote sensing methods?
- What types of chemical aging processes are taking place on the surface of mineral dust particles?
- How do mineral dust particles initiate ice formation in supercooled droplets?
- To what extend are the results of the individual works applicable to neighbouring fields?

The main goal of the Graduate School is the bundling of expertise, competence and infrastructure of specifically selected Institutes at the University of Leipzig (LIM, IPTC, IEP-II) and at the Leibniz Institute in order to establish a joint topic-overarching education of PhD students by means of joint research projects in the area of mineral dust. To this end, the initiative „Leipzig Centre for Clouds, Aerosols and Radiation (LC-CAR)" has been founded, and specific partnerships between the University Leipzig and the Leipzig Institute to individual working areas in the overall topic have been defined. The Graduate School represents the first joint effort to establish a joint PhD education in this field based on interdisciplinary research projects.

The studies aim at an improved process understanding of the tropospheric mineral dust in its initialisation, aging, and interaction with radiation and clouds. The joint scientific denominator is mineral dust as the dominant part of atmospheric particle flux and transport, as carrier of heterogeneous chemical reactions as well as modifier of clouds and precipitation over large areas of our planet. The Graduate Scholl shall initiate the interconnection between the University of Leipzig and the Leibniz Institute by means of specific topics, and shall provide the interconnected education a structure. Existing supervision programmes are synchronized and new supervision elements are created, the latter especially for independent scientific work. In subsequent work, the graduates will be ready to better understand multiphase processes in the troposphere in a larger context in order to provide suggestions for solutions if the retrieval of mineral dust and the interaction with gas, clouds and precipitation

Proceeding of the conducted work including deviations from the original concept, scientific failures, problems in project organization or technical realisation

The structured PhD education has been successfully established. Numerous activities have been performed inland and abroad and will not be listed in detail. However, we emphasize the so-called "Advanced Training Modules" (ATMs). These are two-day teaching series with local and external lectures on a recent topic. Up to know, the following ATMs took place:

15. - 16. October 2013: ATM 1 „Absorbtion“ (Prof. Tegen, Prof. Quaas)

11. - 12. February 2014: ATM 2 „Polarization“ (Prof. Macke, Prof. Wendisch)

01 - 02 July 2014: ATM 3 „Indirect Aerosol Effect“ (Prof. Pospichal, Prof. Deneke)

25 - 26 November 2014: ATM 4 „Heterogeneous Chemistry“ (Prof. Abel, Prof. Herrmann)

22 - 23 April 2015: ATM 5 „Heterogeneous Ice Nucleation“ (Prof. Grundmann, Dr. Stratmann, Prof. Haase)

28 to 29 September 2015: ATM 6 „Clouds in a changing climate system“ (Prof. Macke, Prof. Quaas)

17/18 October 2016: ATM 7 „Cloud droplet number concentration“ (Prof. Quaas)

23-24 February 2017: ATM 8 “Cloud Microphysical Measurements” (Dr. Stratmann)

Planned

04-06 October 2017: ATM 9 “Polar Mid-Latitude Interactions”

The Leipzig ATMs of the LGS-Car have been established as international visible events and will be permanently carried on together with the university partners. Meanwhile, the ATMs are combined with international workshops.

A further important element is the regular organization of feedback-workshops with the PhD students and supervisors in order to identify weaknesses and to suggest improvements.

The PhD works that were directly funded by the Graduate School are mostly finished resp. in submission. Two PhD candidates have not finalized their work.

Presentation of the achieved results and discussion with regard to the relevant research topic, possible applications und possible follow-up projects

The Leipzig Graduate School "Clouds, Aerosols, and Radiation" has been established as a permanent structured PhD programme at TROPOS and at the University Leipzig. This programme was a requirement for the successful application of a Collaborative Research Centre (TR 172 "Arctic Amplification").

Statement, if results of the research project are economical viable, and if such an exploitation is practised or planned; specifications regarding possible patents or industrial cooperation

no direct economical utilization

Inputs from possible national and international cooperation partners, who contributed to the realisation of the project results

In the framework of the "Advanced Training Modules" the following guest lecturers have been invited. Beyond their lectures they partly took over supervision tasks and have established cooperation.

Piet Stammes, Royal Netherlands Meteorological Institute (KNMI), Utrecht, The Netherlands

Philip Stier, University Oxford, Department of Physics, UK

Yi Ming, Princeton University, Geophysical Fluid Dynamics Laboratory, USA

Linda Forster, Ludwig-Maximilians-Universität München (LMU), Faculty for Meteorology, Germany

Volker Freudenthaler , Ludwig-Maximilians-Universität München (LMU), Meteorological Institute, Germany

Jerome Riedi, Laboratoire d'Optique Atmosphérique (LOA), France

Brian Cairns, NASA Goddard Institute for Space Studies (GISS), USA

Alexander Kokhanovsky, European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), Germany

Daniel Rosenfeld, Hebrew University in Jerusalem, Israel

Olivier Boucher, Laboratoire de Météorologie Dynamique (LMD), France

Christian George *IRCELYON*- Institut de Recherches sur la Catalyse et l'Environnement de Lyon, France

Bernd Abel, Leibniz-Institut für Oberflächenmodifizierung (IOM) Leipzig, Germany

Knut R. Asmis, Universität Leipzig, Wilhelm Ostwald Institute for Physical and Theoretical Chemistry Leipzig, Germany

Matthias Olzmann, Karlsruher Institut für Technologie (KIT), Institute for Physical Chemistry, Germany

Corinna Hoose, Karlsruher Institut für Technologie (KIT), Institute for Meteorology and Climate Research, Germany

Raymond Shaw, Michigan Technological University (MTU), USA

Dennis Niedermeier, Michigan Technological University (MTU), USA

Benjamin Murray, University of Leeds, School of Earth and Environment, UK

Tapio Schneider, ETH Zürich, Department of Earth Sciences, Switzerland

A. Pier Siebesma, Royal Netherlands Meteorological Institute (KNMI), Utrecht, The Netherlands

Roel Neggers, Universität zu Köln, Institute for Geophysics and Meteorology (IGMK), Germany

Jessica Vial, Laboratoire de Météorologie Dynamique (LMD), France

Herman Russchenberg, Delft University of Technology, The Netherlands

Dan Grosvenor, University of Leeds, School of Earth and Environment, UK

Alexander Khain, Hebrew University of Jerusalem, Israel

Darrell Baumgardener, Droplet Measurement Technologies, Logmont, USA

Qualification works, realised in connection with the research project

see list of publications

List of publications emerged from the project

Finished PhD work

Valileios Barlakas: *A New Three–Dimensional Vector Radiative Transfer Model and Applications to Saharan Dust Fields*

Daniel Merk: *Uncertainties in the Quantification of Aerosol-Cloud Interactions*

Ferdinand Stolz: *Flüssigstrahl-Desorptions-Massenspektrometer für die Integration von CASSIM-Daten*

Matthias Brück: *Evaluation of statistical cloud parameterizations*

Reviewed Publications

Publications

Augustin-Bauditz, S., Wex, H., Kanter, S., Ebert, M., Niedermeier, D., **Stolz, F.**, Prager, A., Stratmann, F. 2014. *The immersion mode ice nucleation behavior of mineral dusts: A comparison of different pure and surface modified dusts*. Geophysical Research Letters 41, 7375-7382.

Barlakas, V., 2016. *A New Three–Dimensional Vector Radiative Transfer Model and Applications to Saharan Dust Fields*, Ph.D. thesis, University of Leipzig University of Leipzig, Faculty of Physics and Earth Sciences.
[http://www.qucosa.de/recherche/frontdoor/?tx_slubopus4frontend\[jd\]=20746](http://www.qucosa.de/recherche/frontdoor/?tx_slubopus4frontend[jd]=20746).

Barlakas, V., Macke, A., and Wendisch, M. 2016. *SPARTA – Solver for Polarized Atmospheric Radiative Transfer Applications: Introduction and application to Saharan dust fields*. J. Quant. Spectrosc. Radiat. Transfer. 178, 77 – 92.
<https://doi.org/10.1016/j.jqsrt.2016.02.019>.

Barlakas, V., Macke, A., Wendisch, M., and Ehrlich, A. 2014. *Implementation of polarization in a 3D Monte Carlo Radiative Transfer Model*. Wissenschaftliche Mitteilungen aus dem Institut für Meteorologie der Universität Leipzig. 52, 1–14, iSBN: 978-3-9814401-2-6.

Emde, C., **Barlakas, V.**, Cornet, C., Evans, F., Korokin, S., Ota, Y., Labonnote, L. C., Lyapustin, A., Macke, A., Mayer, B., and Wendisch, M. 2015. *IPRT polarized radiative transfer model intercomparison project – Phase A*, J. Quant. Spectrosc. Radiat. Transfer. 164, 8 – 36. <https://doi.org/10.1016/j.jqsrt.2015.05.007>.

Horn, S. 2012. *Speziation und Photolyse von Fe(III)-Carboxylat Komplexen in wässriger Lösung*. M.Sc., Universität Leipzig, Fakultät für Chemie und Mineralogie, 70 pp.

Merk, D. and Zinner, T. 2013. Detection of convective initiation using Meteosat SEVIRI: Implementation in and verification with the tracking and nowcasting algorithm Cb-TRAM. *Atmos. Meas. Tech.*, **6**, 1903-1918. doi:10.5194/amt-6-1903-2013.

Merk, D., Deneke, H., Pospichal, B. and Seifert, P. 2016. Investigation of the adiabatic assumption for estimating cloud micro- and macrophysical properties from satellite and ground observations. *Atmos. Chem. Phys.*, **16**, 933-952. doi:10.5194/acp-16-933-2016.

Stolz, F., Appun, J., Naumov, S., Schneider, C., Abel, B. 2017. *A complex catalytic reaction caught in the act: Intermediates and products online by liquid μ -beam mass spectrometry and theoretical modeling*. *ChemPlusChem* **82**, 233-240.

Weller, C., **Horn, S.** and Herrmann, H. 2013. *Effects of Fe(III)-concentration, speciation, excitation-wavelength and light intensity on the quantum yield of iron(III)-oxalato complex photolysis*. *J. Photoch. Photobio. A*, **255**, 41-49. doi:10.1016/j.jphotochem.2013.01.014.

Weller, C., **Horn, S.** and Herrmann, H. 2013. *Photolysis of Fe(III) carboxylato complexes: Fe(II) quantum yields and reaction mechanisms*. *J. Photoch. Photobio. A*, **268**, 24-36. doi:10.1016/j.jphotochem.2013.06.022.

Wiederschein, F., Vöhringer-Martinez, E., Beinsen, A., Postberg, F., Schmidt, J., Srama, R., **Stolz, F.**, Grubmüller, H., Abel, B. 2015. *Charge separation and isolation in strong water droplet impacts*. *Physical Chemistry Chemical Physics* **17**, 6858-6864.

Poster

Barlakas, V., Macke, A., Wendisch, M. 2014. *Implementation of Polarization into a 3D Monte Carlo Radiative Transfer Model: Results and Applications*. AMS, Boston, USA, 07 – 11 July 2014. (Poster)

Bieligk, H., Voigtländer, J., Herenz, P., Chou, C., Ulanowski, Z. J. and Stratmann, F. 2013. *Laboratory measurements of ice surface roughness*. INUIT Summer School on "Atmospheric Ice Nucleation and its Implications". Braunfels, Germany. 15-20 September 2013. (Poster)

Bieligk, H., Völker, G. S., Clauss, T., Grundmann, M. and Stratmann, F. 2014. *A new optical ice particle counter at LACIS*. EGU General Assembly 2014, Vienna, Austria, 27 April - 2 May 2014. (Poster)

Can, Ö., Tegen, I., Quaas, J. and Stier, P. 2013. *Effects of aerosol absorption on climate dynamics in idealized Aquaplanet simulations*. EGU General Assembly 2013, Vienna, Austria, 7-12 April 2013. (Poster)

Can, Ö., Tegen, I. and Quaas, J. 2015. *Evaluating direct radiative effects of absorbing aerosols on atmospheric dynamics with aquaplanet and regional model results*. 2015 AGU Fall Meeting, San Francisco, CA, USA, 14-18 December 2015. (Poster)

Can, Ö., Quaas, J. and Tegen, I. 2014. *Impacts of absorbing aerosols on clouds and dynamics in idealized sensitivity studies using the ECHAM6 General Circulation Model*. EGU General Assembly 2014, Vienna, Austria, 27 April - 2 May 2014. (Poster)

Can, Ö., Tegen, I., Quaas, J., 2013.. *Effects of absorbing aerosols on climate dynamics – A modeling study*. ERCA Winter School 2013, Grenoble, France, 07 Januar – 08 February 2013 (Poster)

Horn, S. and Herrmann, H. 2013. *Knudsen cell: Investigations about the uptake of important traces gases on ambient airborne mineral dust.* EGU General Assembly 2013, Vienna, Austria, 7-12 April 2013. (Poster)

Merk, D., Ansmann, A., Deneke, H., Pospichal, B. and Seifert, P. 2013. *Investigation of the adiabatic cloud model combining SEVIRI data and ground site measurements from Leipzig.* EGU General Assembly 2013, Vienna, Austria, 7-12 April 2013. (Poster)

Merk, D., Ansmann, A., Deneke, H., Pospichal, B. and Seifert, P. 2013. *Accuracy of the adiabatic cloud model as diagnostic for the first indirect aerosol effect based on MSG SEVIRI and ground observations.* 13th EUMETSAT Meteorological Satellite and 19th American Meteorological Society Satellite Conference, Vienna, Austria, 16-20 September 2013. (Poster)

Merk, D., Deneke, H., Pospichal, B., Seifert, P. and Ansmann, A. 2014. *Investigation of key quantities for the first indirect aerosol effect.* EGU General Assembly 2014, Vienna, Austria, 27 April - 2 May 2014. (Poster)

Senf, F., Bley, S., **Merk, D.** and Deneke, H. 2016. *Meteosat-based characterization of the initiation and growth of severe convective storms over Central Europe.* 17th International Conference on Clouds and Precipitation (ICCP), Manchester, UK, 25-29 July 2016. (Poster)

Stolz, F., Horn, S., Herrmann, H., Abel B. 2013. *Chemistry at Dust Particle Surfaces.* INUIT Summer School on Atmospheric Ice Nucleation and its Implications. Braunfels, Germany, 15 – 20 September 2013.

Voigtländer, J., **Bieligk, H.**, Niedermeier, D., Clauss, T., Chou, C., Ulanowski, Z. and Stratmann, F. 2013. *A new experimental setup to investigate nucleation, dynamic growth and surface properties of single ice crystals.* EGU General Assembly 2013, Vienna, Austria, 7-12 April 2013. (Poster)

Voigtländer, J., Chou, C., **Bieligk, H.**, Clauss, T., Herenz, P., Niedermeier, D., Ulanowski, J. Z. and Stratmann, F. 2013. *A new device for the investigation of nucleation, dynamic growth and surface properties of single ice crystals.* European Aerosol Conference (EAC), Prague, Czech Republic, 1-6 September 2013. (Poster)

Voigtländer, J., Herenz, P., **Bieligk, H.**, Niedermeier, D., Clauss, T., Chou, C., Ritter, G., Ulanowski, J. Z. and Stratmann, F. 2014. *Investigation of nucleation, dynamic growth and surface properties of single ice crystals.* EGU General Assembly 2014, Vienna, Austria, 27 April - 2 May 2014. (Poster)

Talks

Barlakas, V., Macke, A., Wendisch, M. 2015. *Solar Radiative Transfer Simulations in Saharan Dust Using a New 3D Monte Carlo Radiative Transfer Model Including Polarization.* LS-XV-2015, Leipzig, Germany 21 – 26 June 2015 (Vortrag)

Barlakas, V., Macke, A., Wendisch, M. 2015. *A new 3D Monte Carlo Radiative Transfer Model Including Polarization: Validations and Applications.* AGU-GAC-MAC-CGU, Montréal, Canada 03 – 07 May 2015 (Vortrag)

Merk, D., Zinner, T. and Mannstein, H. 2012. *Detection of convective initiation using the METEOSAT tracking and nowcasting algorithm Cb-TRAM.* 2012 EUMETSAT Meteorological Satellite Conference, Sopot, Poland, 3-7 September 2012. (Vortrag)

Merk, D., Deneke, H., Pospichal, B. and Seifert, P. 2015. *On the reliability of geostationary satellite observations for diagnosing indirect aerosol effects* SPIE Europe: Remote Sensing 2015, Toulouse, France, 23 September 2015. (Vortrag)

Merk, D., Deneke, H. and Pospichal, B. 2016. *Optimal estimation retrieval of cloud droplet number concentration for synergistic ground-based observations*. 17th International Conference on Clouds and Precipitation (ICCP), Manchester, UK, 25-29 July 2016. (Vortrag)

Schepanski, K., Heinold, B., **Can, O.**, Deneke, H., Simmel, M., Tegen, I. and Vogelsberg, U. 2014. *Modelling desert dust*. 1st Leipzig Mineral Dust Workshop. Leipzig, Germany. 6 March 2014. (Vortrag)

Stolz, F., Abel, B., Postberg, F. Srama, R., Trieloff, M. 2013. *Liquid beam ion desorption mass spectrometry for evaluating CASSINI data*. Bunsentagung 2013, Karlsruhe, Germany, 9 – 11 May 2013. (Vortrag)

Stolz, F., R. Reviol, R., Srama, R., Trieloff, M., F. Postberg, F., Abel, B. 2013. *Liquid beam ion desorption mass spectrometry for evaluating CASSINI data*. EGU 2013, Vienna, Austria, 7 – 12 April 2013.

Stolz, F., Abel, B. 2013. *Towards an Ice Particle Accelerator*. Dusty Visions, Stuttgart, 17 – 19 July 2013.

Measures for protection and availability of the produced data during the research project

All data are available by national or international permanent research databases resp. by institutional databases.

List of press releases and media reports

"Neue Graduiertenschule: Einrichtung widmet sich dem Mineralstaub": Leipziger Volkszeitung, 1. 8. 2012

Electronic releases about the Graduate School and web presence:

<http://www.tropos.de/aktuelles/pressemitteilungen/details/neue-graduiertenschule-untersucht-wirkung-von-mineralstaub-in-der-atmo/>

<http://www.tropos.de/aktuelles/pressemitteilungen/details/wuestenstaub-sorgt-fuer-mehr-schwefelsaeure-in-der-atmosphaere/>

<http://www.lgs-car.tropos.de/>

https://www.eurekaalert.org/pub_releases_ml/2013-12/aft-pbd121813.php

<http://www.ral.uni-leipzig.de/de/research-academy-leipzig/struktur/graduiertenzentrum-mathematik-informatik-und-naturwissenschaften/#klassenmin>