LEIBNIZ-INSTITUT FÜR
TROPOSPHÄRENFORSCHUNG

Biennial Report

Zwei-Jahresbericht

2004 / 2005

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Table of contents

IfT-Intern

Introduction / Einleitung
Synopsis / Übersicht

Introduction

In the “Research Park Leipzig/Permoserstraße” close to the Environmental Research Center, other research establishments and related businesses you find the Leibniz-Institute for Tropospheric Research e.V. (IfT). Its name identifies the IfT as a member of the Leibniz Association. The IfT was founded for the investigation of physical and chemical processes in the polluted troposphere.

Fig. / Abb. 1: *IfT main building. / IfT Hauptgebäude.*

Meanwhile, a well-defined and globally unique research profile of IfT emerged, with a focus on aerosols, i.e. small airborne particles, and clouds. Despite their minute absolute amount, aerosols and clouds are essential parts of the atmosphere because they control the budgets of energy, water and trace substances of the Earth System. Human activities can change these highly disperse systems and thus feed back on human beings. This may happen via health effects caused by inhaled particles and fog droplets and through regional and global climate change.

Despite these strong connections between human beings, aerosols, and clouds important physico-chemical processes of aerosol and cloud formation and the relationships with climate and health are poorly understood. This limitation is mainly due to analytical difficulties with the very small samples and with the complex behavior of tropospheric multiphase systems, in which individual processes seldom can be distinguished. In climate research this limitation is reflected in much larger uncertainties in predicted anthropogenic aerosol and cloud effects in comparison to numbers published by the Intergovernmental Panel on Climate Change for additional greenhouse gases.

Rapid advances in our understanding of tropospheric multiphase processes and an application of this process understanding to the prediction of the consequences of human impacts can only be expected from concerted approaches from several directions. Consequently, the Leibniz-

Einleitung

Auf dem Gelände des „Wissenschaftsparks Leipzig / Permoserstraße“, in guter Nachbarschaft zum Umweltforschungszentrum, anderen Forschungseinrichtungen und verwandten Firmen, befindet sich seit 1992 das Leibniz-Institut für Troposphärenforschung e.V. Sein Name weist es als Mitglied der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz aus. Gegründet wurde

Fig. / Abb. 2: *IfT cloud lab. / IfT Wolkenlabor.*

es zur Erforschung physikalischer und chemischer Prozesse in der belasteten Troposphäre.

Inzwischen hat sich ein klares und weltweit einzigartiges Forschungsprofil herausgebildet, in dessen Mittelpunkt Aerosole, also kleinste luftgetragene Partikel und Wolken, stehen. Trotz geringster absoluter Mengen sind diese wesentliche Bestandteile der Atmosphäre, weil sie den Energie-, Wasser- und Spurenstoffhaushalt des Erdsystems beeinflussen. Menschliche Aktivitäten können die Eigenschaften dieser hochdispersen Systeme verändern und direkt sowie indirekt auf den Menschen zurück wirken. Das kann sowohl über die gesundheitlichen Wirkungen eingeatmeter Partikel und Nebeltröpfchen als auch über regionale und globale Klimaänderungen geschehen.

Trotz dieser wichtigen Beziehungen zwischen Mensch, Aerosolen und Wolken sind die physikochemischen Prozesse von Aerosol- und Wolkenbildung und die Wechselwirkungen mit Gesundheit und Klima noch wenig verstanden. Dies liegt vor allem an Schwierigkeiten bei der Analyse der beteiligten kleinsten Stoffmengen und an dem komplexen Verhalten troposphärischer Mehrphasensysteme, deren Einzelprozesse in der Atmosphäre nicht klar getrennt beobachtet werden können. In der gegenwärtigen Klimadiskussion zum globalen Wandel spiegelt sich diese Kenntnislage in den sehr viel größeren Unsicherheiten in allen zu Aerosol- und Wolkenwirkung veröffentlichten Zahlen im Verhältnis zu Treibhauseffekten der Gase wider.

Institute for Tropospheric Research conducts field studies in several polluted regions parallel to the development of analytical methods for aerosol and cloud research.

These tools are not only applied in field experiments but also in extensive laboratory investigations, which form a second major activity. A third and equally important approach consists of the formulation and application of numerical models that reach from process models to regional simulations of the formation, transformation and effects of tropospheric multiphase systems.

Field experiments

Field experiments elucidate the atmospheric life cycle and related processes of aerosol and cloud particles. This task is vastly more difficult than comparable trace gas studies, in which only one number has to be known for each substance at each point in time and space. Particle sizes in the nano and micrometer size range over more than six orders of magnitude occur in atmospheric aerosols and clouds, all of which play an important role in certain processes. All condensable substances of the Earth System can be found in the aerosol and a large number of them contribute to climate and biospheric effects. As a consequence of this multidimensional system essential aerosol and cloud properties are not well established on a global scale yet.

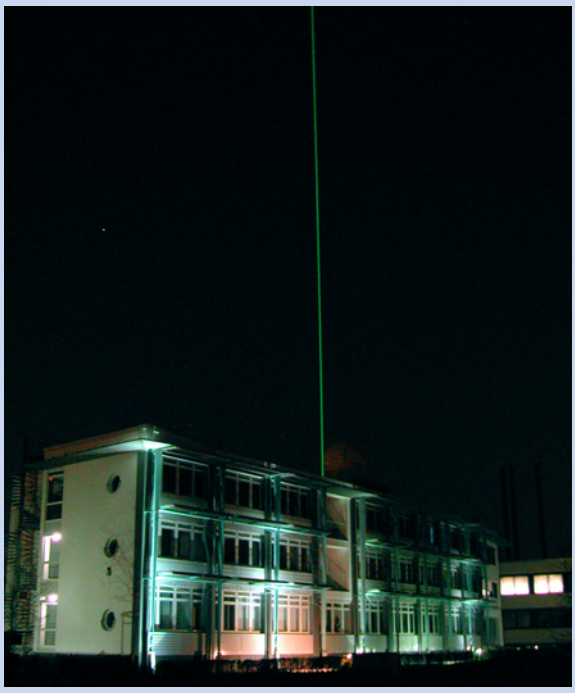

Fig. / Abb. 3: *Multiwavelength Raman lidar measurement after sunset performed in the framework of the European Aerosol Research Lidar Network (EARLINET). / Mehrwellenlängen-Raman-Lidarmessung im Rahmen des Europäischen Lidarnetzwerkprojekts EARLINET.*

Fig. / Abb. 4: *IfT research station Melpitz near Leipzig. / IfT-Forschungsstation Melpitz bei Leipzig.*

Rasche Zuwächse beim Verständnis troposphärischer Mehrphasenprozesse und eine Anwendung dieses Prozessverständnisses auf die Vorhersage der Folgen menschlicher Eingriffe lassen sich nur durch ein konzertiertes Vorgehen in mehreren Richtungen erwarten. Das Leibniz-Institut für Troposphärenforschung betreibt daher neben Feldstudien in mehreren belasteten Regionen auch die Entwicklung eigener analytischer Verfahren zur Untersuchung von Aerosolen und Wolken. Diese Verfahren werden auch in ausgedehnten Laboruntersuchungen eingesetzt, der zweiten Hauptarbeitsrichtung des Instituts. Ein dritter, gleichermaßen wichtiger Arbeitsansatz ist die Formulierung und Anwendung numerischer Modelle von der Prozessbeschreibung bis zur Beschreibung der regionalen Bildung, Umwandlung und Wirkung troposphärischer Mehrphasensysteme.

Der Wissenschaftsrat hat dem Institut bestätigt, dass es insgesamt gute Forschungsleistungen von überregionaler Bedeutung und gesamtstaatlichem Interesse erbringt.

Feldexperimente

Die Feldexperimente des Instituts dienen der Aufklärung des atmosphärischen Kreislaufs der Aerosol- und Wolkenpartikel und der damit verbundenen Prozesse. Die Komplexität des Systems ist dabei dadurch bestimmt, dass in Aerosolen und Wolken Partikel auftreten, deren Größe sich im Nano- und Mikrometerbereich um mehr als sechs Zehnerpotenzen unterscheiden kann, die unterschiedlich prozessieren können. Außerdem kann man alle kondensationsfähigen Stoffe des Erdsystems im Aerosol finden, von denen eine große Zahl das Klima und die Biosphäre beeinflussen. Als Folge dieser Vielfalt und der mengenbedingten analytischen Schwierigkeiten sind wesentliche globale Aerosol- und Wolkeneigenschaften noch wenig bekannt.

Diese Unsicherheit beginnt schon bei den Partikelquellen, die Forschungsgegenstand am

Fig. / Abb. 5: *Arterial road in Leipzig. / Hauptverkehrsader in Leipzig.*

The uncertainty and thus the studies of the Leibniz-Institute for Tropospheric Research start with particle sources. The combustion of fossil and contemporary fuels is one of the most prominent aerosol sources. However, these sources are still poorly characterized in terms of climate-relevant aerosol parameters. In collaboration with car manufacturers the institute establishes size dependent particle emission data of cars at test stands, in particular in the nanometer size range that was not covered by conventional emission studies. According to long-term measurements of the institute in a street canyon the car related emissions of particles and their precursor gases are subject to strong physical and chemical transformations even before they reach the sidewalk. These transformations have been investigated by a unique new mobile aerosol laboratory measuring the exhaust plume from a moving car in traffic.

Dedicated methods have been developed for the analysis of soot components, a major absorber of sunlight. Health related aerosol studies are being expanded in collaboration with the Environmental Research Center with

Fig. / Abb. 6: *Diesel test car with mounted inlet system during the Girl's day 2005. / Diesel-Testfahrzeug mit montiertem Einlasssystem während des Girl's day 2005.*

Leibniz-Institut für Troposphärenforschung sind. Die Verbrennung fossiler und nachwachsender Brennstoffe zur Energieerzeugung und im Verkehr sind wichtigste Aerosolquellen. Wie sich aus Langzeitmessungen des Instituts in einer Straßenschlucht ergab, unterliegen Verkehrsemissionen von Partikeln und deren Vorläufern enormen physikalischen und chemischen Umwandlungen, noch bevor sie den Straßenrand erreichen. Daher hat das IfT ein spezielles mobiles Aerosollabor entwickelt, mit dem die direkte Partikelemission und die Neubildung von Partikeln unmittelbar hinter einem fahrenden Kraftfahrzeug bestimmt werden.

Eigene Analyseverfahren zur Bestimmung von Rußkomponenten wurden entwickelt und sowohl bei Quell- als auch Immissionstudien eingesetzt. Gesundheitsbezogene Aerosol-studien werden in Zusammenarbeit mit dem

Fig. / Abb. 7: *Monitoring station Leipzig-Eisenbahnstrasse (red building). / Messstation Leipzig-Eisenbahnstrasse (rotes Gebäude).*

Umweltforschungszentrum Leipzig/Halle verstärkt, speziell durch gekoppelte Innenraum- und Außenluftmessungen mit gleichzeitiger Bestimmung von Gesundheitseinwirkungen im urbanen Raum Leipzigs.

Selbst die am höchsten verunreinigten Regionen über Nordamerika, Europa, dem indischen Subkontinent und Ostasien sind noch bei weitem nicht hinreichend bezüglich ihrer Aerosolbelastungen und den daraus resul-tierenden Klimawirkungen charakterisiert. Auf diese Regionen konzentrieren sich daher in internationaler Zusammenarbeit die Feldexperimente des Instituts mit guten Erfolgen in der jüngsten Vergangenheit in Europa, über dem Indischen Ozean und in China. Durch Nutzung eines kommerziellen Verkehrsflugzeuges der Lufthansa werden dabei die örtlich und zeitlich begrenzten Einzelexperimente auf regelmäßig beflogenen interkontinentalen Routen in der oberen Troposphäre verbunden.

Daneben werden an Bergstationen, mit Hubschraubern und mit gecharterten Flugzeugen

coupled indoor and outdoor aerosol experiments and concurrent clinical investigations in the urban region of Leipzig.

Not even the largest highly polluted regions in the plumes of North America, Europe, the Indian subcontinent and Eastern Asia are sufficiently characterized in terms of aerosol burdens and ensuing climate effects. Thus, the institute focuses its participation in international field campaigns and dedicated long-term studies on South and East Asia. By means of a commercial aircraft operated by Lufthansa, the results of the regional experiments are connected through regular intercontinental CARIBIC flights.

Process studies are conducted at suitable locations such as mountain observatories, with a helicopter and with a small, chartered aircraft. These experiments are dedicated to particle nucleation, particle processing through clouds and the influence of anthropogenic aerosols on the optical properties of clouds.

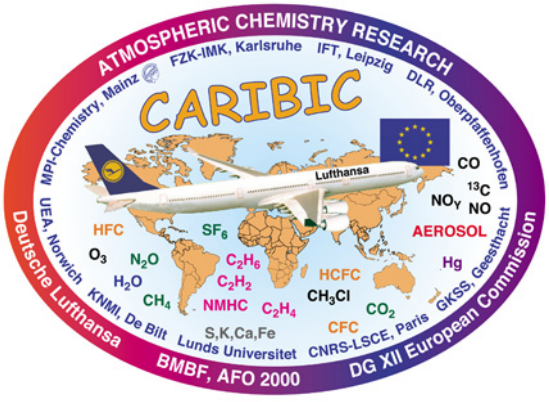

Fig. / Abb. 8: *The logo of the international project CARIBIC (Civil Aircraft for Regular Investigation of the atmosphere Based on a Intrument Container). / Das Logo des internationalen Projekts CARIBIC.*

Laboratory experiments

In atmospheric research, there is a continuous development of physico-chemical models for the description of the most relevant process. These models are based on process parameters, which need to be determined in physical and chemical laboratory experiments.

In the physics section of the institute laboratory experiments cover the development of a large number of methods to characterize atmospheric particles and drops, in particular their size distribution and thermodynamic properties. Complex measuring and sampling systems are being designed for the characterization of cloud drops and interstitial particles.

Spectroscopic techniques such as the Differential Optical Absorption Spectroscopy have

Fig. / Abb. 9: *First application of helicopter-borne ACTOS (Airborne Cloud Turbulence Observation System) in Koblenz/Winningen 2005. / Erster Hubschraubereinsatz mit ACTOS in Koblenz/Winningen 2005.*

Studien durchgeführt, die sich dem Verständnis von Einzelprozessen, wie der Partikelneubildung, der physikochemischen Veränderung des Aerosols beim Wolkendurchgang und dem Einfluss von Aerosolen auf die Strahlungseigenschaften von Wolken widmen.

Laborexperimente

In der Atmosphärenforschung werden kontinuierlich physikochemische Modelle zur Beschreibung der wesentlichen Prozesse entwickelt. Grundlage derartiger Modelle sind stets Prozessparameter, die auch in physikalischen und chemischen Laborexperimenten ermittelt werden.

In der Abteilung Physik wird im Bereich der Laborexperimente eine Vielzahl von Messmethoden entwickelt, die zur Partikelcharakterisierung in boden- und luftgestützten Feldmesskampagnen eingesetzt werden. Im Einzelnen betreffen diese Arbeiten die Weiterentwicklung von „Differential Mobility Analysern (DMA)“ zur Messung von Partikelgrößenverteilungen sowie komplexe Messsysteme zur physikalischen und chemischen Charakterisierung von Wolkentröpfchen und dem interstitiellen Aerosol, also denjenigen Aerosolpartikeln, die innerhalb von Wolken neben den Wolkentröpfchen selbst in der Gasphase suspendiert sind.

Optische Messmethoden werden zur Bestimmung der Extinktion von Partikeln und der Absorption von Spurengasen und Radikalen mittels der differentiellen Absorptionsspektroskopie (DOAS) angewendet. Mehrwellenlängenlidare und ein Windlidar werden zur Bestimmung von Aerosoleigenschaften und meteorologischen Parametern wie Temperatur, Feuchte und Wind im Labor weiterentwickelt und im Felde eingesetzt. Die Anteile „schwarzen Kohlenstoffs“ und mineralischer Aerosolkomponenten in Aerosolproben werden durch spektrale Absorptionsmessungen bestimmt.

been developed for the analysis of trace gases and aerosol particles. Multi-wavelength aerosol LIDAR (Light Detection and Ranging) systems are developed and deployed in the field for measuring atmospheric state parameters such as temperature, wind and relative humidity besides aerosol-optical characteristics. Black carbon and mineral, light absorbing aerosol components are quantified with spectroscopic methods in aerosol and cloud samples.

The physics and chemistry sections in two main areas are carrying out process-oriented laboratory studies jointly. The first of these activities concerns a laminar flow tube reactor in which particle formation from (SO_2) and organic precursors (e.g., terpenes) is being investigated. With the large Leipzig Aerosol Cloud Simulator LACIS and related instrumentation the transition from a moist aerosol to a cloud is simulated in a dedicated.

The chemistry section conducts several process-oriented laboratory studies. Gas phase reactions of the radicals OH and NO_3 are being investigated in flow reactors. These reactions are important for ozone and particle formation caused by biogenic and anthropogenic emissions of volatile hydrocarbons. The chemical identity of atmospheric particles will be characterized in reaction chambers. In a single drop experiment, phase transfer parameters of trace gases and

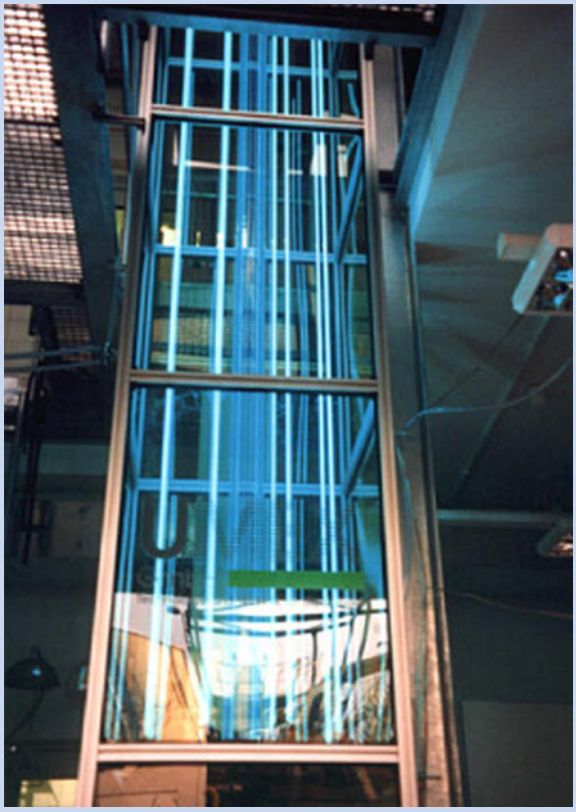

Fig. / Abb. 10: *The IfT laminar flow tube reactor (IfT-LFT). / Der laminare Rohrreaktor des IfT.*

Fig. / Abb. 11: *Mini Raman lidar polly in an air-conditioned cabinet. / Mini Raman lidar polly im klimatisierten Gehäuse.*

In zwei Bereichen werden direkt prozessorientierte Laboruntersuchungen gemeinsam von den Abteilungen Physik und Chemie durchgeführt. Diese abteilungsübergreifenden Aktivitäten betreffen zunächst einen als Laminarströmungsrohr ausgeführten Reaktor, an dem die Bildung von Partikeln aus anorganischen (SO_2) und organischen Vorläufersubstanzen (z.B. Terpenen) untersucht wird. Neben einer kleinen, schon mehrfach eingesetzten kleinen Version befindet sich der große Strömungsreaktor LACIS im Aufbau, in dem das Wachstum von Aerosolpartikeln zu Wolkentröpfchen sowie die chemische Wirkung von Wolken in einem dezidierten Labor untersucht werden.

In der Abteilung Chemie werden Gasphasenreaktionen der Radikale OH und NO_3 in Strömungsreaktoren untersucht. Diese Reaktionen sind von Interesse für die Ozon- und Partikelbildung verursacht durch anthropogen oder biogen emittierte flüchtige Kohlenwasserstoffe. Zur Untersuchung der chemischen Identität von Partikelinhaltsstoffen stehen auch Reaktionskammern zur Verfügung. In einem Einzeltropfenexperiment werden Phasentransferparameter für Spurengase und Radikale untersucht. Die Bestimmung von Phasentransferparametern und reaktiven Aufnahmekoeffizienten wird dabei auf bisher nicht betrachtete chemische Spezies und Oberflächen ausgeweitet. Im Bereich von Flüssigphasenmechanismen werden Reaktionen von nichtradikalischen Oxidantien mittels der sog. Stopped-Flow-Technik mit optischem Nachweis untersucht. Einen besonderen Schwerpunkt bilden schließlich die Experimente mit Radikalreaktionen in wässriger Lösung, die in der Umwelt in den Tröpfchen von Wolken, Regen und Nebel sowie in wässrigen Partikeln ablaufen. Hier werden zum Verständnis der Oxidation organischer Spurengase im troposphärischen Mehrphasensystem eine

radicals are being determined for different chemical species and surfaces. Mechanisms of non-radical oxidations in the liquid phase are being studied with the stopped-flow technique and optical detectors. Experiments with radical reactions in the liquid phase form a core activity of the laboratory experiments because of their importance for processes in haze particles, fogs and clouds. For the understanding of the oxidation of organic trace gases in the tropospheric multiphase system a large number of reactions with the OH and NO_3 radicals are being studied as well as reactions of halogenated oxidants. The latter species are of interest for the emission of reactive halogen compounds from sea salt particles.

Several laboratory experiments are dedicated to the chemical characterization of atmospheric organic aerosol components. Besides the conventional combustion techniques, mass spectroscopic and chromatographic techniques coupled directly to analysis by mass spectrometry or capillary electrophoresis with different sampling and segregation techniques are being developed. The close cooperation of the physics and chemistry section has lead to the development of a patented and commercially exploited sampling method for narrow well-defined particle size ranges that is coupled directly to the mass spectroscopic analyses.

Modeling

For the description of complex atmospheric processes, model systems of varying dimensions and complexity are developed, tested and applied to micro and mesoscale problems. For the modeling of tropospheric multiphase processes cloud modules are developed, which combine a complex multiphase chemistry with a detailed

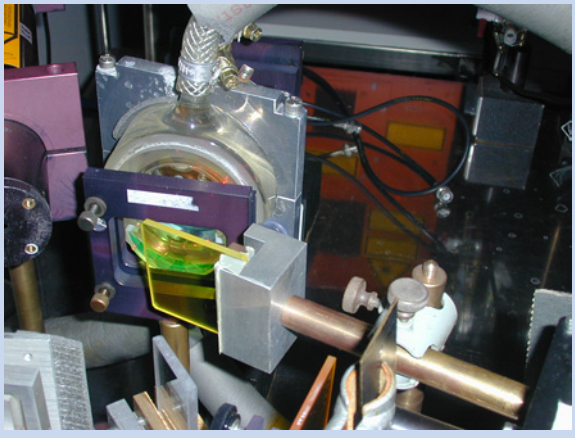

Fig. / Abb. 12: *A laser photolysis-long path laser absorption experiment for the study of nitrate radical kinetics in aqueous solution. / Eine Laserphotolyse-Laserlangwegabsorptionsanordnung zur Untersuchung der Kinetik des Nitrat-Radikals in wässriger Lösung.*

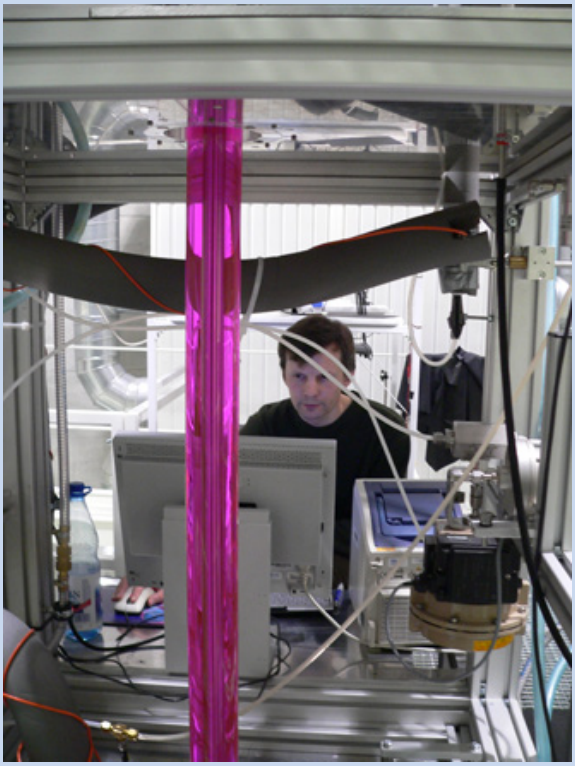

Fig. / Abb. 13: *The "Leipzig Aerosol Cloud Interaction Simulator" (LACIS). / Der Wolkenkanal (LACIS).*

Vielzahl von Reaktionen der Radikale OH und NO_3 sowie Reaktionen von halogenhaltigen Oxidantien untersucht. Letztere Spezies sind von Interesse bei der Freisetzung von Halogenverbindungen aus maritimen Seesalzpartikeln, der sog. Halogenaktivierung.

In der analytischen Messtechnik werden in Laborexperimenten Verfahren zur besseren chemischen Charakterisierung der organischen Bestandteile von Aerosolpartikeln entwickelt und getestet. Diese Techniken beruhen zumeist auf massenspektrometrischen Verfahren, die in verschiedenen Kopplungstechniken eingesetzt werden. Im Bereich der Probenahmetechniken gibt es auch hier eine enge Kooperation mit der Abteilung Physik zur Entwicklung einer gezielten Abscheidung von Partikeln bestimmter Größe und deren kontinuierlicher chemischer Analyse.

Modellierung

Zur Beschreibung der komplexen atmosphärischen Vorgänge werden Modellsysteme verschiedener Dimension und Komplexität für die Mikro- bis Mesoskala entwickelt, überprüft und angewendet. Zur Modellierung von troposphärischen Multiphasenprozessen erfolgen vor allem Arbeiten zur Entwicklung von Wolkenmodulen, die eine komplexe Multiphasenchemie mit einer detaillierten Mikrophysik verbinden. Mit deren Integration in komplexe dreidimensionale Modelle kann man

microphysics. With their integration in complex three-dimensional models the many interactions between aerosol particles, gases and clouds can be described in a coupled three-dimensional meteorology-chemistry-transport model. With this model system as a toolbox scientific as well as legal tasks are addressed.

Models are indispensable tools in the search for efficient and cost-effective possibilities of compliance of relevant limit values for protection of human health for gaseous and particulate air pollutions defined or suggested in directives by the European Commission. As done in the past for the Saxonian government, the Leibniz-Institute for Tropospheric Research will work on this field in the context of national and international projects in the future too.

The most example of this kind of activity is the investigation of the formation and dispersion of secondary aerosol particles caused by the emissions of power plant that are vented through cooling towers. The simulations were conducted with the complex three-dimensional modeling system LM-MUSCAT.

In the area of process studies concerning aerosol and cloud dynamics turbulent mixing processes and their effect on particle formation are studied with the third-order planetary boundary layer chemistry aerosol model TOPCAM. In a similar fashion the planned

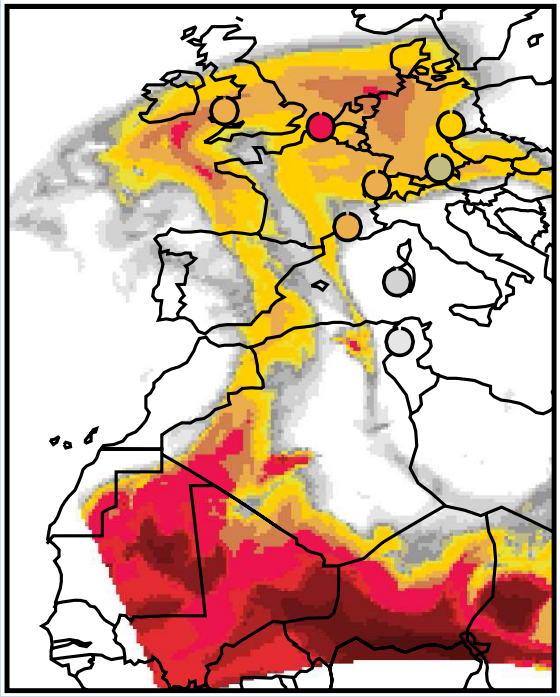

Fig. / Abb. 14: *Saharan dust induced optical thickness over Europe and Africa simulated with regional dust model LM-MUSCAT. / Mit dem regionalen Staubmodell LM-MUSCAT simulierte optische Dicke, verursacht von Saharastaub über Europa und Afrika.*

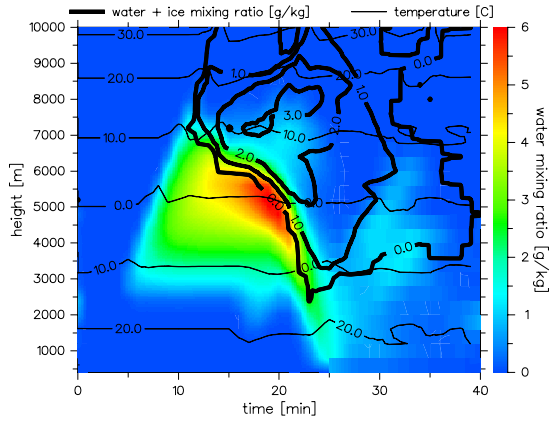

Fig. / Abb. 15: *Time evolution of vertical profiles of liquid and frozen water as well as temperature simulated by a cylinder-symmetric model of the Asai-Kasahara type coupled with spectral mixed phase microphysics. / Zeitentwicklung der Vertikalprofile von Flüssigwasser, Eis und Temperatur, simuliert mit einem zylindersymmetrischen Modell vom Typ Asai-Kasahara gekoppelt mit einer spektralen Mischphasenmikrophysik.*

die vielfältigen Wechselwirkungen zwischen Aerosolpartikeln, Gasen und Wolken in einem gekoppelten dreidimensionalen Meteorologie-Chemie-Transport-Modell beschreiben, und so zu einer Verbesserung des Systemverständnisses der Troposphäre gelangen. Mit einem solchen Modellsystem hat man ein Instrument zur Bearbeitung wissenschaftlicher Aufgaben und gleichermaßen zur Beantwortung von Fragen zur Luftqualität im legislativen Bereich.

Bei der Suche nach effektiven und kostensparenden Möglichkeiten zur Einhaltung bestehender und zukünftiger nationaler und europäischer Grenzwerte für gasförmige Luftbeimengungen und Partikeln unterschiedlicher Größe ist der Einsatz von Modellen unverzichtbar. Nach bisheriger guter Zusammenarbeit mit dem Sächsischen Staatsministerium für Umwelt und Landwirtschaft beabsichtigt das Institut, auch weiterhin auf diesem Gebiet national und international tätig zu sein. Jüngstes Beispiel dafür ist die Untersuchung der Bildung und Ausbreitung sekundärer Aerosolpartikel, verursacht durch die Emissionen von Großfeuerungsanlagen, die über Kühltürme abgeleitet werden. Die Simulationen wurden mit dem komplexen dreidimensionalen Modellsystem LM-MUSCAT ausgeführt.

Im Bereich Prozessstudien zur Aerosol- und Wolkendynamik erfolgen Arbeiten zu turbulenten Mischungsprozessen und deren Auswirkungen u.a. auf die Partikelneubildung. Hierfür wurde in der Abteilung Modellierung das eindimensionale Grenzschichtmodell TOPCAM (Third-Order PBL Chemistry Aerosol Model) entwickelt.

Gleichermaßen erfolgen Simulationen im Zusammenhang mit den geplanten Experimenten am Wolkenkanal LACIS. Insbesondere ist

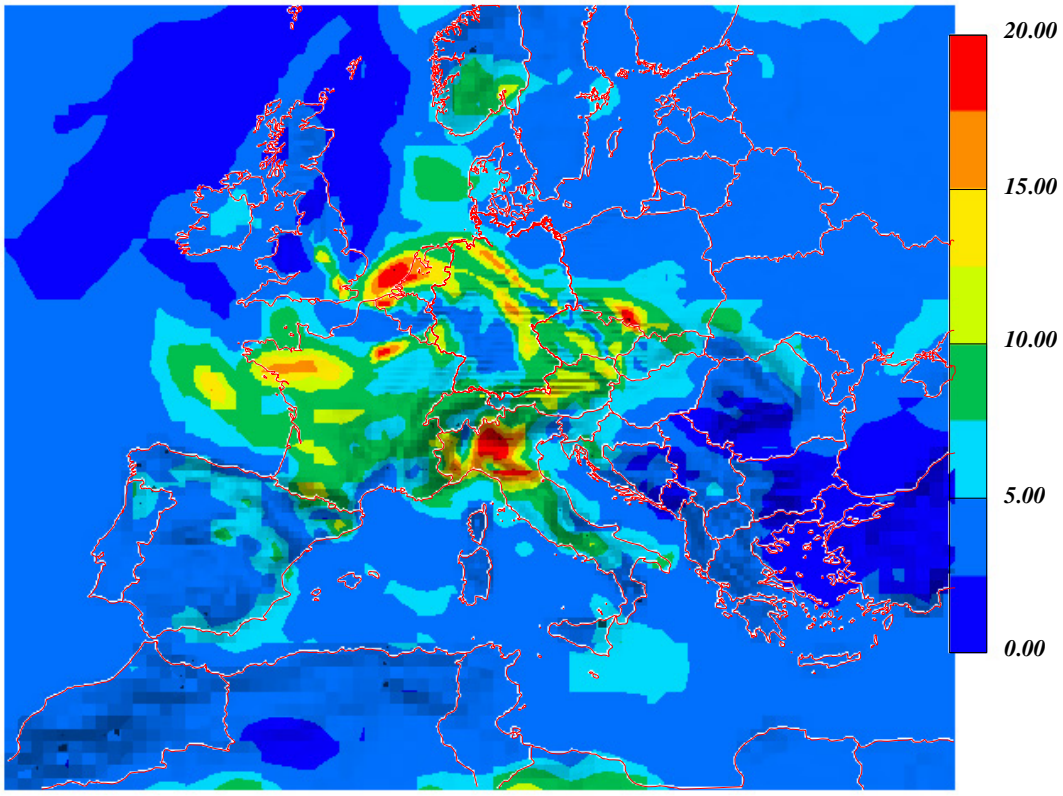

Fig. / Abb. 16: *Simulated PM2.5 concentration over Europe. / Simulierte PM2.5-Konzentration über Europa.*

experiments in LACIS are simulated, in particular the hygroscopic growth as function of the nucleating particles and the carrier gas.

The model simulation of tropospheric multiphase systems is numerically highly demanding. The models need to be sufficiently accurate and numerically efficient to be used productively on existing computer systems. To this end the modeling department conducts an ongoing development.

ein von der chemischen Zusammensetzung abhängiges Diffusionswachstum in Abhängigkeit von der umgebenden Gasphase (einschließlich Wasserdampf) Ziel der Modellierung.

Die modelltechnische Behandlung eines so umfassenden atmosphärischen Systems ist numerisch sehr aufwendig. Die zu entwickelnden Modelle müssen hinreichend genau sein und numerisch sehr effizient auf den jeweils zur Verfügung stehenden Rechnerarchitekturen laufen. Zur Entwicklung auf diesem Gebiet liefert die Abteilung Modellierung wesentliche Beiträge.

Synopsis of the contributions to the report

The medium-term scientific concept of the institute defines the *three major research themes*:

1. *Evolution, transport and spatio-temporal distribution of the tropospheric aerosol*
2. *Influence of the tropospheric aerosol on clouds and on the radiation budget*
3. *Chemical processes in tropospheric multi-phase systems.*

The improvement of the predictability of the evolution and effects of tropospheric multiphase systems is the long-term goal of the research along the lines of the major themes.

The majority of the text contributions in the present report covers *theme one* in which traffic-related emissions of primary particles and the secondary particle formation from traffic emission play a major role. IfT-research concentrates here on urban experiments in Leipzig (Gnauk et al., Rose et al.) and Dresden (Müller et al.) as well as the highly polluted regions Pearl River Delta (PRD) and Beijing, China. In PRD (Cheng et al.) Chinese agencies funded a first field experiment in Fall 2004 whereas in Beijing DFG-funded aerosol investigations take place since March 2004 in cooperation with Peking University (Brüggemann et al., Wehner et al.). IfT developed a unique on-board payload for aerosol measurements in moving traffic from a station wagon (Uhrner et al.). A second prominent subject in *theme one* is the investigation of the climate effect of Saharan dust within the DFG-Research group SAMUM (http://www.tropos.de/samum/, Helmert et al.).

Concerning *theme two* this report presents results of field and laboratory experiments besides numerical cloud simulations. Experiments in the Leipzig Aerosol Cloud Simulator LACIS and with our unique High Humidity Tandem Differential Mobility Analyzer yielded the first material-specific results on hygroscopic growth of aerosol particles beyond 90% r.H. and for atmospheric water vapor supersaturations (Wex et al.). To date the simulation of turbulent cloud processes and ice formation in LACIS are not possible. However, with the new helicopter-borne payload ACTOS we expect new results on turbulent mixing processes, in particular near cloud borders (Siebert et al.). The model contribution by Wendisch et al. yields new quantitative results in radiative transfer in cirrus clouds as a function of crystal shape. Our numerical physico-chemical cloud models are continuously extended to support and complement cloud experiments in the laboratory and in the field (Grützun et al., Heinrich et al., Hinneburg et al., Zoboki et al.).

Übersicht der Einzelbeiträge

Das mittelfristige Arbeitskonzept des Instituts legt folgende übergeordnete *Forschungsthemen fest*:

1. *Evolution, Transport und raumzeitliche Verteilung des troposphärischen Aerosols*
2. *Einfluss des troposphärischen Aerosols auf Wolken und Strahlungshaushalt*
3. *Chemische Prozesse in troposphärischen Mehrphasensystemen.*

Langfristiges Ziel der damit verbundenen Arbeiten ist die Verbesserung der Vorhersagefähigkeit der Entwicklung und der Effekte von troposphärischen Mehrphasensystemen.

Im vorliegenden Jahresbericht trägt ein Großteil der Beiträge zu *Forschungsthema 1* bei, wobei verkehrsbedingte Primäremissionen von Partikeln und die sekundäre Partikelbildung aus Verkehrsemissionen und anderen Verbrennungsquellen eine Hauptrolle spielen. Die Arbeiten des Instituts konzentrieren sich hierbei neben urbanen Experimenten in Leipzig (Gnauk et al., Rose et al.) und Dresden (Müller et al.) auf die beiden hoch verschmutzten Regionen Pearl River Delta (PRD) und Beijing, China. In PRD (Cheng et al.) fand dazu auf chinesische Einladung hin im Herbst 2004 ein erstes Feldexperiment statt während in Beijing schon seit März 2004 kontinuierlich Aerosoluntersuchungen in Kooperation mit Peking University stattfinden (Brüggemann et al., Wehner et al.). Zur Untersuchung von Verkehrsemissionen wurde am IfT ein weltweit einzigartiges mobiles Messsystem entwickelt, das im fließenden Verkehr Aerosolmessungen im Abgasstrom eines fahrenden PKW ermöglicht (Uhrner et al.). Ein zweites wichtiges Teilgebiet in *Forschungsthema 1* sind die Untersuchungen zur Klimawirkung von Saharastaub (Helmert et al.).

Zu *Forschungsthema 2* werden Ergebnisse aus Labor- und Feldexperimenten sowie aus numerischen Simulationen vorgestellt Wolken-simulationen im Leipziger Aerosol Cloud Simulator LACIS und mittels des Hochfeuchte-Tandem-Differentiellen Mobilitätsanalysators HHTDMA lieferten erste materialspezifische Ergebnisse zum Feuchtewachstum von Aerosolpartikeln oberhalb 90% r.F. und bei atmosphärischen Wasserdampf-übersättigungen (Wex et al.). Die Untersuchungen von turbulenten Wolkenprozessen und von Eiswolken sind bisher in LACIS noch nicht möglich. Mit der neuen hubschraubergetragenen Nutzlast ACTOS dagegen werden neue Erkenntnisse zu Mischungsprozessen an Wolkenrändern erwartet (Siebert et al.). Der Modellierbeitrag von Wendisch et al. liefert neue Zahlenwerte zum Strahlungstransport in Zirren in Abhängigkeit

The new multi-purpose experimental hall of IfT allows extended chamber experiments for the chemical understanding of secondary aerosol formation, contributing to *theme three*. Here the article by Böge et al. presents new knowledge in the area of organic aerosol formation. Finally, the contribution by Barzaghi et al. explains further liquid phase reactions in the atmospheric aerosol.

von der Form der Eiskristalle. Zur Stützung und Erweiterung der Wolkenexperimente im Labor und im Feld werden auch die numerischen physiko-chemischen Wolkenmodelle kontinuierlich erweitert (Grützun et al., Heinrich et al., Hinneburg et al., Zoboki et al.).

Die neue Mehrzweckehalle auf dem LACIS-Gelände gestattet erweiterte Kammerexperimente zum chemischen Verständnis sekundärer Aerosolbildung innerhalb *Hauptthema 3*. Hier liefert der Artikel von Böge et al. neue Erkenntnisse auf dem Gebiet der Bildung organischer Aerosolpartikel. Der Beitrag von Barzaghi et al. schließlich klärt weitere Flüssigphasenreaktion im atmosphärischen Aerosol auf.

Articles

SAMUM: Regional Modeling of Saharan Dust Aerosol – A Near-Source and a Far-Field Case Study

Jürgen Helmert, Bernd Heinold, Ralf Wolke, Ina Tegen

Das Saharan Mineral Dust Experiment (SAMUM) hat das Ziel, die Verteilung, mikrophysikalische, chemische sowie optische Eigenschaften von Saharastaubaerosol zu bestimmen, und damit den Einfluss von Staubepisoden auf Wetter und Klima besser als bisher zu quantifizieren. Im Rahmen dieses Projektes wurde ein regionales Staubtransportmodell entwickelt, welches zur Beschreibung von Staubepisoden und deren Einfluss auf den Strahlungshaushalt dienen soll. Hier werden erste Resultate für zwei Fallstudien (in Quellnähe bzw. Ferntransport von Saharastaub) vorgestellt, welche durch vorhandene Beobachtungsdaten zur Modellevaluierung geeignet sind. Die Ergebnisse zeigen, dass das Modell die gemessene atmosphärische Staubverteilung gut reproduziert. Wir zeigen erste Modellergebnisse zur Änderung der Oberflächentemperatur durch erhöhte atmosphärische Staubkonzentrationen.

Introduction

As one of the major components of the atmospheric aerosol, soil dust plays an important role in the Earth's climate system. Aeolian dust emitted by wind-erosion in arid and semi-arid regions can be expected to influence significantly the radiation budget and cloud properties. Since there are still considerable uncertainties in quantifying the highly variable dust distribution and its optical properties, the understanding of magnitude and even the sign of these effects remains poor [*IPCC*, 2001]. Recent remote sensing results of dust optical properties indicate that dust is nearly non-absorbing [*Kaufman et al*., 2002], while earlier laboratory measurements suggested dust to be partly absorbing at visible wavelengths [*Sokolik et al*., 1999]. To quantify radiative forcing by dust from the Sahara, which is by far the largest source of dust worldwide, the DFG Forschergruppe 'SAharan Mineral dUst experiMent (SAMUM)' coordinated by the Leibniz-Institute for Tropospheric Research will investigate dust properties by means of a field campaign in Morocco in spring 2006. The planned measurements include ground-based, air-borne and space-borne remote sensing, as well as microphysical, chemical, and morphological analyses of dust aerosol from field samples. Within the framework of SAMUM we developed a new regional model-system to describe Saharan dust production, transport, deposition, and its effect on the radiation balance. Preceding the actual field experiment, the model performance has been tested in several case studies. Here we present the results of a near-source study for a recent dust episode over the Bodélé depression (Chad) in March 2005 during a field experiment carried out by a group of UK scientists, and of a far-field case study of a Saharan dust outbreak directed to Europe in October 2001 that already has been analyzed earlier [*Ansmann et al*., 2003]. The model results for the far-field study are evaluated by comparison with lidar measurements provided by the European Aerosol Research Lidar Network (EARLINET) and aerosol optical thickness retrievals from sunphotometers at selected Aerosol Robotic Network (AERONET; *Holben et al*. [1998]) stations. The modeled dust aerosol distribution is coupled online to the radiation scheme of the regional model, which allows the change in radiation balance caused by the presence of dust aerosol to feed back upon atmospheric dynamics. This gives first insights into the effects of direct and semi-direct forcing by a Saharan dust episode on a regional scale.

Model description

The regional dust model is based on the 'Lokal-Modell' (LM), which is the operational weather prediction model of the German Weather Service (DWD), the online-coupled Chemistry-Transport-Model MUSCAT, and a dust emission scheme (DES) developed by *Tegen et al*. [2002]. The near-source case study has been performed for a dust event in March 2005 described by *Washington et al*. [in press] and *Todd et al*. [submitted]. The model was run for a period from March 1-13, 2005 to capture this episode. For the far field case study a major Saharan dust outbreak directed to Central Europe in October 2001 has been chosen, which is well documented by, e.g., *Ansmann et al*. [2003]. The event was simulated for the days October 8-16, 2001.

Two model domains have been used for the near-source and far-field case studies (Figure 1). The domain for the October 2001 case has a grid spacing of 14 km and covers major parts of the Sahara desert and Europe, which permits the computation of dust emission from several source regions as well as the transport of dust towards Europe. The second, smaller, domain for the March 2005 case has a horizontal resolution

Fig. 1: Model domain for the far-field study (red border) and the near-source case (blue border). The location of the observation sites used for model evaluation are indicated on the map.

of 7 km and includes the Bodélé depression in Chad, and the mountains Tibesti and Ennedi to the northeast of the Bodélé. One-way grid nesting is applied to zoom from the larger into the smaller domain. The LM is operated with 40 vertical levels of a pressure-based, terrain following vertical coordinate. The vertical coordinate of MUSCAT is limited to 12 km. The model-predicted dust is transported as dynamic tracer in five independent size classes with radius limits at 0.1 μm, 0.3 μm, 0.9 μm, 2.6 μm, 8 μm and 24 μm. Dust is removed from the atmosphere by dry and wet deposition processes. For particles larger than 2 μm the removal from the atmosphere is mainly by gravitational settling. Dust optical thicknesses, which can be compared to remote sensing measurements and are read into the radiation scheme of the LM, are computed from the simulated dust concentrations, particle size distribution and extinction efficiencies.

The parameterization of radiative transfer of short- and longwave radiation in the LM uses a delta-two-stream radiative transfer solver, taking into account effects of scattering, absorption, and emission by aerosols, cloud droplets, and gases. It considers optical properties for all spectral intervals of various climatologically fixed aerosol types [*Tanre et al.*, 1984]. However, such a fixed distribution of aerosols is inappropriate for estimation of radiative impact of particular dust events due to the high variabilities in temporal, spatial, and size distribution of dust aerosol. Uncertainties in optical properties of mineral dust are related to uncertainties in the dust size distribution and in the spectral complex refractive index [*Sokolik et al.*, 2001]. For this study, the constant distribution of desert dust aerosol in the LM radiation scheme is replaced by the size-resolved dust concentration provided by the transport scheme MUSCAT, thus the computation of radiation fluxes accounts for a spatially and temporally varying atmospheric dust load.

Complex refractive indices of dust have been determined from laboratory measurements and derived from remote sensing retrievals in various spectral ranges from 250 nm to 30000 nm. The advantage of estimating the refractive indices via remote sensing lies in the determination of optical properties of airborne dust under real atmospheric conditions (e.g., *Dubovik et al.* [2002]; *Sinyuk et al.* [2003]). Laboratory experiments determine the complex dust refractive index from bulk dust samples in the shortwave range and in the infrared spectral region [e.g., *Volz*, 1973]. The differences in the spectral distribution of the imaginary part of the complex refractive index n (Figure 2) from these data sources reflect the uncertainties in absorption properties of the mineral dust, which determine its radiative impact. Dust optical properties (extinction efficiency, single scattering albedo, and asymmetry factor) are calculated employing Mie theory based on an algorithm by *Mishchenko et al.* [2002]. Although Mie theory requires spherical particles, an assumption that is not reasonable for most dust particles, errors are small in the hemispherical integration when compared to computations with spheroids. Computed optical properties are adopted in the LM radiation scheme by spectral integration for each solar band and longwave IR band.

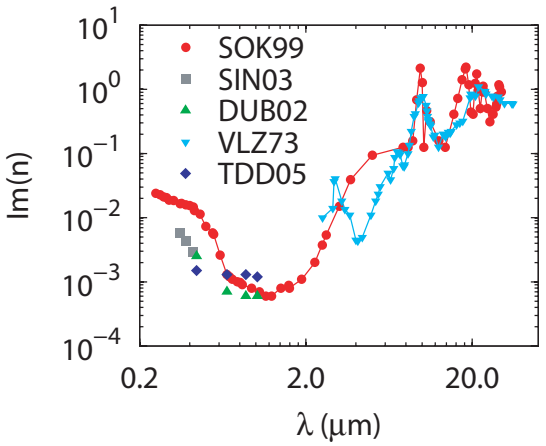

Fig. 2: Imaginary part of the dust refractive index depending on wavelength. Shown are values derived from remote sensing and laboratory studies. Sok99: Sokolik et al. [1999]; Sin03: Sinyuk et al. [2003]; DUB02: Dubovik et al. [2002]; VLZ73: Volz [1973]; TDD05: Todd et al. [submitted].

For the near-source case we carried out two model experiments: (1) A model run including dust aerosol with optical properties derived from sunphotometer measurements taken during the Bodélé field study [*Todd et al.*, submitted] at visible and from *Volz* [1973] at infrared wavelengths and (2) a LM run without including dust aerosol. For the October 2001 far-field case, three model experiments have been carried out: (1) A model run with an online feedback of dust on the LM

radiation scheme using dust optical properties from *Sokolik et al*. [1999], assuming an internal mixture of 2% hematite and 98% kaolinite ('absorbing dust'), characterized by a single scattering albedo at 550 nm of 0.84 for dust particles with 1.5 μm radius; (2) a run with an on-line feedback of a more reflective dust characterized by optical properties from *Volz* [1973], *Dubovik et al*. [2002], and *Sinyuk et al*. [2003] ('reflective dust'), characterized by a single scattering albedo at 550 nm of 0.94 for dust particles with 1.5 μm radius; and (3) a control run without any desert dust aerosol affecting the radiation. The dust optical thickness distribution computed with the transport model MUSCAT is used in the meteorological model the LM radiation routine, which is called once per hour and updates the radiation fields including the changes due to the changed dust distribution.

Near-source study: Bodélé Depression, Chad

During the middle Holocene ca. 6000 years B.P. the paleo-lake Mega-Chad covered a surface area five times larger than the extent of Lake Chad at the late Holocene. A substantial layer of diatomite sediment formed from the shells of freshwater diatoms at the bottom of the former lake (centered near 17°N, 18°E), which is now exposed and forms the most active dust source in the world. Diatomite is a highly porous sediment consisting of ca. 90% silicium dioxide, with bulk densities of ca. 1 g cm^{-3}.

A group of scientists from the UK carried out a field experiment in the Bodélé depression from February 28 to March 13, 2005 ('Bodélé Dust Experiment', BoDEx). The observation site 'Chicha' is located at 16°53'N, 18°33'E at the eastern margin of the large diatomite deposit originating from the paleo-lake Mega-Chad. Surface measurements of meteorological parameters during BoDEx included temperature, wind speed and air pressure [*Washington et al*., in press]. Aerosol optical thicknesses were measured during the field experiment using a Cimel C-318 sun-sky spectral radiometer of the type used in AERONET, measuring sun and sky radiances at four wavelengths. The retrieval algorithm provides aerosol optical thicknesses at the 4 wavelengths as well as refractive index and phase function information, together with aerosol size distribution retrievals between 0.1 and 15 μm. Additional optical thickness measurements were taken by handheld Microtops sun photometers, measuring aerosol optical thicknesses (AOTs) every 30 min [*Todd et al*., submitted]. During the field expedition, individual dust events were observed on the days February 28, March 4 and March 9, while a major dust storm occurred on March 10-12. During the dust storm, with peak 2m-wind speeds reaching 14 m s^{-1}, dust production reportedly occurred by a 'self-abrasion' process of saltating diatomite flakes, which partly disintegrate when colliding mid-air or impact on the ground. At this location fine dust particles are apparently produced by disintegration of the saltators themselves, rather than by dislocation of small particles from soil aggregates at the soil surface through the impact of saltating sand grains. Dust production at the field site occurred when the surface wind speed exceeded 10 m s^{-1} [*Washington et al*., in press], which is a higher threshold value compared to the often observed value of dust production starting at surface wind speeds exceeding 6-7 m s^{-1}.

Regional model results of the near-source case. The emission parameterization in the regional dust model was adapted such that the model results fit the observed optical thicknesses as well as retrieved dust aerosol particle size distribution. The specific density of the particles was set to a value of 2 g cm^{-3}. The kinetic energy of the saltating particles needed to break up diatomite aggregates is 20 times lower than the energy needed for breaking up clay aggregates as determined by wind tunnel experiments [*Alfaro et al*., 1997]. The comparison of the dust optical thicknesses simulated with the regional model during the BoDEx event shows reasonable agreement between the model results and measurements (Figure 3a). On March 4, dust emissions are overestimated by the model, and the strong increase in dustiness observed on March 9 starts earlier in the model than observed. An overestimation of nighttime wind speeds in LM does not affect the dust emissions, since the threshold friction velocity for initiating dust emission is not reached. The total dust emissions for this event computed by the regional model are ca. 250 g m^{-2} at the Chicha site.

When directly comparing the surface temperatures from the regional model LM and the observations at the field site location we find that the nighttime minimum temperatures are overestimated in the model by 3-5 K. This overestimate of nighttime temperatures may be caused by the inability of the regional model to produce a well defined boundary layer. The maximum daytime temperature decrease between the March 9 and March 10 at the beginning of the strong dust storm is about 5 K in the model if the radiative forcing by dust is not included, compared to an actually observed temperature decrease by about 10 K on these days (Figure 3b). For the case where the influence of the computed dust aerosol distribution is coupled to the radiation scheme of LM and the changes in radiation fluxes caused by dust influence the temperature distribution in the model, we find that the measured

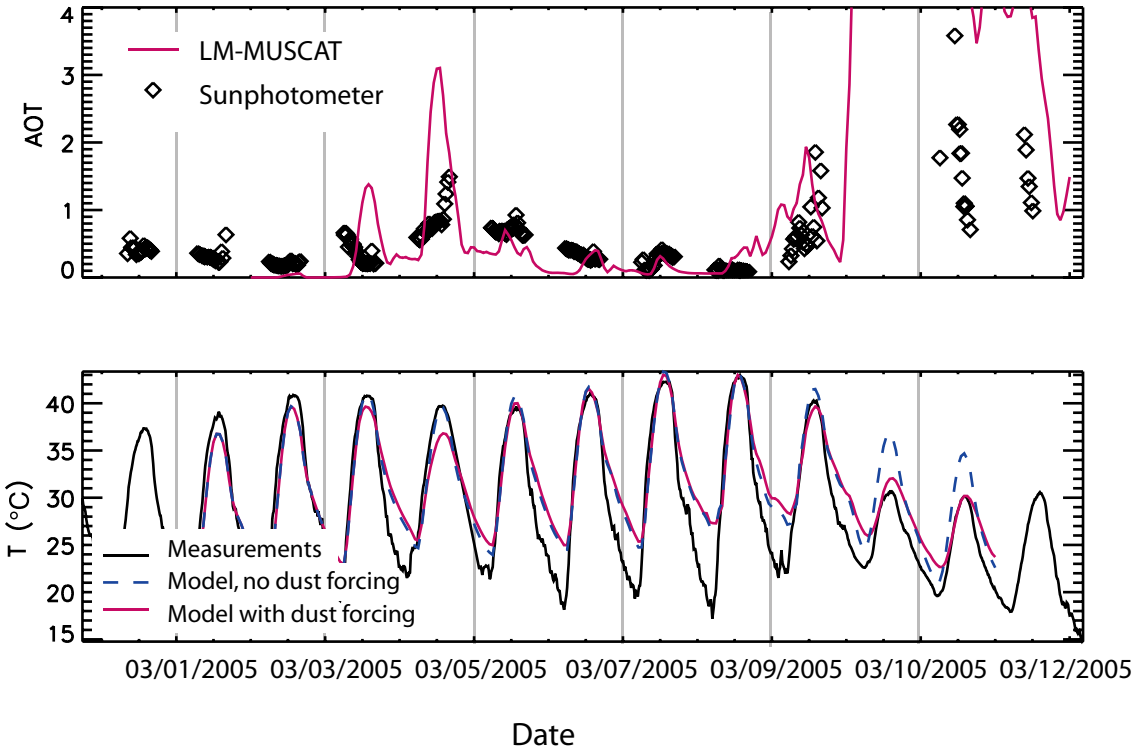

Fig. 3: *Results of the Bodélé case study of the March 2005 dust event. Top panel: Comparison of modeled dust aerosol optical thickness (red line) with sunphotometer measurements (black symbols). Bottom panel: 2m temperature measurements (black line), modeled surface temperatures without dust impact on the radiation (blue dashed line), and model results including dust forcing (red line).*

maximum daytime temperatures and their change with time during the event is much better matched compared to the model results without dust forcing in the regional model (Figure 3b). The decrease in incoming solar radiation at the surface by the strong increase in dust optical thickness between March 9 and March 10 causes about 5 K reduction in surface temperatures, which accounts for about half of the observed decrease in maximum temperature between these days. The change in daytime maximum surface temperatures caused by dust is nearly linearly dependent on the dust optical thickness. Global model results from the offline TM3 tracer model (not shown) indicate that dust from the Bodélé depression contributes less than 5% to the dust optical thickness of the northern Atlantic dust. But this contribution is higher than 50% in the Sahel region in the northern hemisphere winter months, when mixing of dust with biomass smoke is expected. This is of particular interest as diatomite has different surface properties and can be expected to interact much more strongly with atmospheric gases and cloud water compared to clay aggregates or quartz particles.

Far-field study: The October 2001 Saharan dust outbreak

In October 2001 major dust emission occurred in northern Mauritania, Mali, northeastern and southern Algeria, Tunisia and in Chad (Bodélé depression). The northward transport of Saharan dust started on October 8-10, 2001 initiated by a trough of low pressure extending from the Canary Islands to northern Scotland. Under the influence of a low pressure area west of Morocco as well as high pressure over northern Africa and the Mediterranean Sea the dust plume passed over the Iberian Peninsula on October 11, and reached the British Isles, Belgium, the Netherlands and western Germany on October 12. During the following days the dust plume crossed Germany in west-east direction from October 13 to 14, 2001. Figure 4 (left) shows the distribution of the absorbing aerosol index (AI) retrieved by the Total Ozone Mapping Spectrometer (TOMS) satellite instrument on October 13, 2001, indicating the presence of dust aerosol above the Sahara and middle Europe. Blue areas indicate intense cloudiness, especially over northern Europe, inhibiting retrieval of the dust plume below.

The aerosol optical thicknesses provided by AERONET reach values of up to 1.2 at 500 nm at Bordeaux, France, on October 12, 2001. Values up to 0.6 were observed at Leipzig, Germany, on October 14, 2001 (Figure 5).

With more than 20 European lidar stations EARLINET provided a comprehensive dataset of the horizontal and vertical distribution of aerosols in the years 2001-2003. The vertical structure of

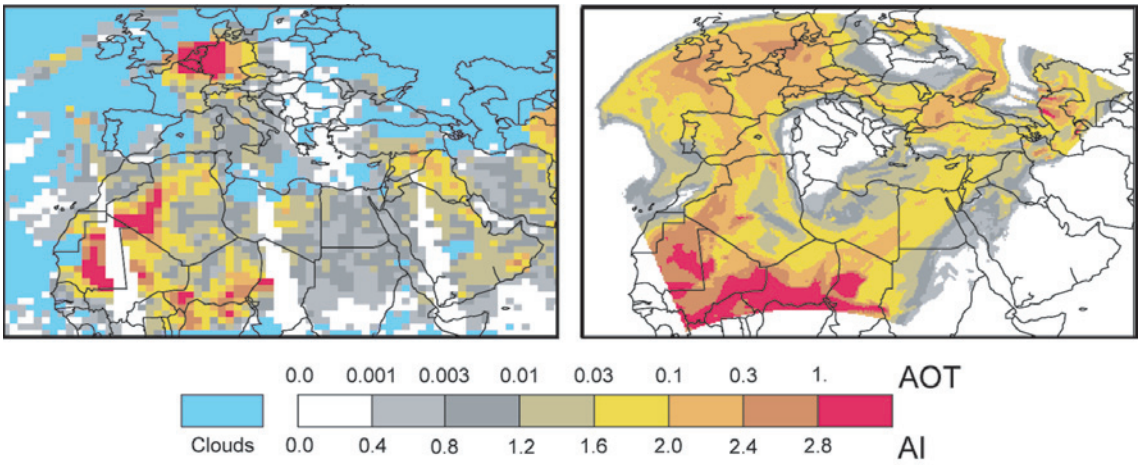

Fig. 4: Comparison of the horizontal distribution of Saharan dust on 13 October 2001. Map of TOMS absorbing aerosol index (AI), (left) and simulated dust aerosol optical thickness at 550 nm (right). Note that the color bar describes different units.

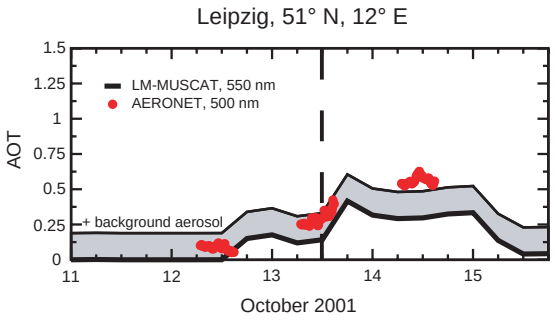

Fig. 5: Comparison of the model-derived dust aerosol optical thickness (550 nm; bold line) with the optical thickness (500 nm; circles) provided by AERONET at Leipzig on 11 – 15 October 2001. The shaded area marks the background aerosol optical thickness added to the model results.

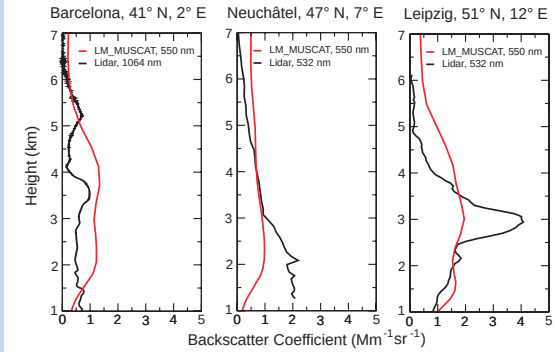

Fig. 6: Vertical distribution of Saharan dust backscatter coefficient above 1 km above sea level above three EARLINET sites: Barcelona on 11 October 2001, 19:15 UTC (left), Neuchatel on 13 October 2001, 16:30 UTC (middle) and Leipzig on 13 October 2001, 18:30 UTC (right). Comparison of modeled profiles (550 nm; red line) with lidar data (black line).

the Saharan dust plume is presented in Figure 6 for selected stations and dates. The lidar profiles of the particle backscatter coefficient ranged from about 1 Mm^{-1} sr^{-1} at Barcelona, Spain, to 4 Mm^{-1} sr^{-1} at Leipzig. While the base of the dust layer corresponded to the top of the boundary layer at Leipzig, over Neuchatel the dust can not be clearly separated from the boundary layer aerosol due to the influence of the nearby Alps. The top of the dust layer extended to heights of 3- 5 km. Dust concentrations were elevated even up to 7-8 km height.

Regional model results of the far-field case. We compared the spatial evolution of the horizontal distribution of the simulated dust aerosol optical thickness at 550 nm with the TOMS AI. While this is only a qualitative comparison which is hindered by extended cloud fields, a good agreement has been found with respect to the location of dust sources and transport patterns. The path of the dust plume from northern Africa to Europe is captured well by the model. Figure 4 shows the map of TOMS AI (left) and the modeled dust optical thickness for the absorbing dust case for October 13, 2001 as an example. High values of optical thickness indicate dust sources in northern and western Mauritania, Mali, southern Algeria and the Bodélé depression. An area of high dust concentrations over southern Niger caused by local dust emission and transport of dust from the Bodélé is more pronounced in the model results than in the TOMS data. Because the sensitivity of the TOMS absorbing aerosol retrieval in the lowest 1-1.5 km of the atmosphere is low, the processes of dust mobilization and vertical lifting are not well represented by the TOMS AI, which may explain this discrepancy.

A good quantitative agreement has been found comparing the model-derived aerosol optical thickness at several sites with that provided by AERONET. As an example the comparison is shown for Leipzig in Figure 5. The sunphotometer measurements represent the optical thicknesses

from both the dust aerosol from the Saharan dust event, as well as the anthropogenic aerosol at this site. A constant value for the background aerosol of 0.19 has been added to the model results, which represents the value of the constant aerosol background optical thickness (excluding dust) used in the LM [*Tanre*, 1984]. While the bold line in Figure 5 represents the dust optical thickness at 550 nm, the shaded area above marks the background aerosol optical thickness. The optical thickness at Leipzig is well reproduced by the model compared to the measurements. On October 14, the modeled aerosol optical thickness remains just below the observed value of about 0.6. Nevertheless, the temporal evolution of the dust event is correctly reproduced by the model, and the discrepancies are in the range of the uncertainties of the climatological optical thickness value for the baseline aerosol optical thickness.

Figure 6 shows the modeled dust vertical structure at Barcelona for October 11, 2001, Neuchatel and Leipzig on October 13, 2001 in comparison with lidar data in terms of particle backscatter coefficients. For this purpose the simulated dust optical thicknesses have been transformed by means of dust optical properties from *Dubovik et al.* [2002] and a extinction-to-backscatter ratio of 50 [*Mattis et al.*, 2002; *Ansmann*, pers. communication] has been applied. The model is quite capable to describe the vertical distribution of Saharan dust at the chosen locations. The locations of the maxima of vertical dust distribution are in agreement with the lidar data at Neuchatel and Leipzig. However, over Neuchatel the comparison is hampered by boundary layer aerosol. At Barcelona, where the vertical aerosol structure is complex, single dust layers are not resolved but the overall distribution is well captured by the model. Except at Barcelona, the maximum backscatter coefficients are underestimated by a factor of 2-3 in the model compared to the observations. These effects are probably due to the coarse vertical resolution of the model, which causes the dust to be 'smeared' over the total column and inhibits a clear separation of dust layers.

Direct and semi-direct effect of dust. Various studies have shown the influence of mineral dust on Earth's climate through the direct effect of scattering of radiation and through indirect effects, where aerosol-induced increase in cloud-condensation nuclei leads to enhanced cloud albedo (first indirect effect) and to enhanced lifetime and cloud reflective properties due to suppression of precipitation (second indirect effect). While these aerosol effects result in cooler surface temperatures, the absorption of radiation by dust aerosol is expected to lead to a warming of atmosphere and suppression of cloud formation (semi-direct effect) (e.g., *IPCC* [2001]).

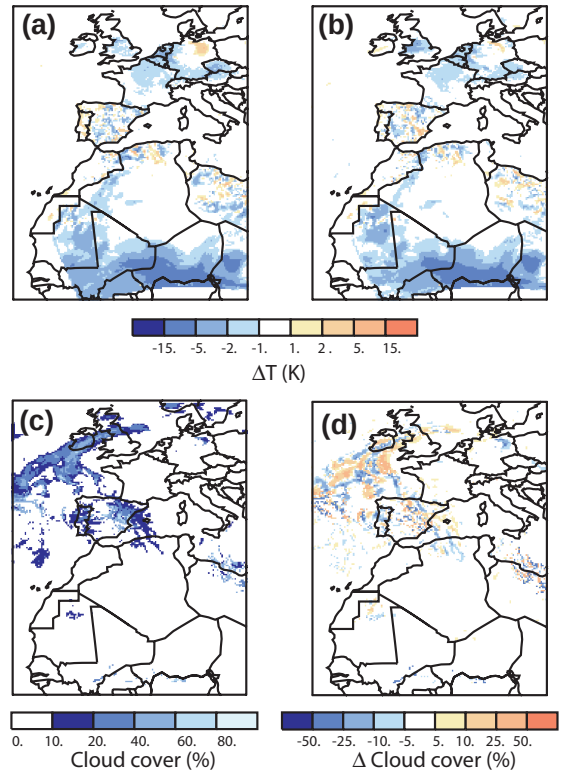

Fig. 7: *Surface temperature difference of model results including dust forcing compared to the control case without dust for 'absorbing' dust (a) and 'reflective' dust (b). Bottom panels: (c) Total cloud cover for the model case without dust forcing and (d) difference in cloud cover of the model experiment including more absorbing dust and the case without including dust. The model results are shown for October 13 2001, 12:00 UTC.*

We investigated the impact of Saharan dust on surface air temperature and the mesoscale cloud coverage using the simulation of the dust event in October 2001. This model study did not include any microphysical interactions between dust particles and cloud droplets, changes in modeled cloud coverage by including dust forcing in the model were thus only caused by changes in the atmospheric dynamics. Figures 7a and 7b show the temperature difference between the LM-MUSCAT surface temperatures between the model experiment including dust radiative forcing for the two different parameterizations of dust optical properties ('absorbing dust' (a) and 'reflective dust' (b)) and the model results without including the interaction of dust aerosol and radiation for October 13, 12:00 UTC. Comparing the temperature differences in the model to the dust optical thickness distribution on this date (Figure 4) we find, as expected, the strongest temperature decrease occurring where the dust optical thickness is highest in the southern Sahara. Here, the presence of dust causes a surface temperature decrease by about 13 K. In Central Europe (parts of France, Belgium and the Netherlands) we find a temperature reduction

of the order of 1-2 K for both parameterizations of dust optical properties that can be attributed to the direct radiative effect of the dust plume with optical thickness of 0.1-0.3 in this area. In eastern Germany the absorbing dust causes a surface warming by 1.2 K (Figure 7a), this effect is much smaller in the case with the reflective dust (Figure 7b). This temperature decrease can be explained by a semi-direct cloud effect of the dust: Figure 7c shows the columnar average of modeled cloud coverage for the simulation without dust impacting the radiation fluxes as control run, and the difference between the simulation with the absorbing dust and the control run for October 13, 2001 (Figure 7d). While major cloud structures occurred over Western Europe, a smaller cloud structure occurred in north eastern Germany and southern Scandinavia. The difference plot of cloud coverage (Figure 7d) gives some indications of an interrelation between the presence of desert dust and cloud coverage that could be attributed to the semi-direct effect of the aerosol. However, the change of the cloud coverage in the simulation with dust feedback is complex, the results may be spurious. While the results of the impact on dust forcing on cloud coverage should be viewed carefully, the results still show that the dust has the potential to influence climate via a semi-direct effect similar to strongly absorbing soot aerosol. However, because this effect is sensitive to the optical properties of dust, care must be taken to prescribe those parameters correctly.

Summary and outlook

We developed a new regional model system consisting of the regional model LM, a dust emission model (DES) and the transport scheme MUSCAT for simulation of dust emission, transport, deposition and radiation effects within the framework of the SAMUM. To test the model performance we carried out a near-source study simulating a dust event during the BoDEx field experiment in March 2005, and a far-field study of a Saharan dust outbreak in October 2001, when large amounts of Saharan dust were transported to Europe. It could be shown that the model is capable of describing Saharan dust events in the mesoscale. For the near-source study, computed emissions from the diatomite deposits in the Bodélé depression result in dust aerosol optical thicknesses and size distributions that are consistent with sunphotometer retrievals during the BoDEx campaign. A 20-fold reduction of the binding energy of the Bodélé soil particles compared to clay aggregates gave a better agreement with the observation. Results from the regional model show that during the dust storm the aerosol causes a daytime temperature reduction by about 5 K, which accounts for about half of the temperature decrease measured in the field at the start of the dust storm event on March 9. Dust from the Bodélé is highly visible in satellite retrievals. It probably contains a large contribution of diatomite particles, which may have quite different surface properties compared to dust observed in e.g. the northern Sahara, which is mostly described by a mixture of clay aggregates. Diatomite particles may have different radiative properties, and different effects on atmospheric chemistry and cloud formation compared to clay and quartz compounds. However, its contribution to global dust optical thickness may be small outside of the direct vicinity of the Bodélé and the Sahel. The role of dust from the Bodélé and the different properties compared to North Saharan dust should be further clarified in upcoming field experiments.

For the far-field study in October 2001, both the location of dust sources and the transport patterns are in agreement with observations. A slightly slower eastward shift of the dust plume in the model results has to be attributed to a slower evolution of the weather situation predicted by the meteorological model LM. A good qualitative agreement has been found comparing the model-derived dust optical thickness with the observed aerosol optical thickness at selected AERONET stations. Also, the vertical distribution of Saharan dust over several EARLINET sites is well captured by the model, especially with respect to correctly placed maxima of the particle backscatter coefficient. Nevertheless, the maxima of the vertical dust distribution are underestimated and secondary maxima are not resolved, which is probably is due to the coarse vertical resolution of the model. While as expected there is strong impact of the dust radiative forcing near the source region in the southern Sahara, the model results show the potential of dust to influence the cloud cover through the influence on the atmospheric dynamics, even though the potential influence of dust particles on cloud microphysical processes is not taken into consideration in these model studies.

In summary, the model-system LM-MUSCAT-DES has been shown to be capable for regional modeling of Saharan aerosol. It will be used to accompany the analysis of the results gained during the SAMUM field campaign in 2006. Results from the measurements during SAMUM will be used to improve the parameterization of the modeled dust processes and to specify the optical properties of Saharan dust.

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Aerosol chamber studies of the formation of secondary organic particulate compounds from biogenics gas phase oxidation products

Olaf Böge, Yoshiteru Iinuma, Thomas Gnauk, Hartmut Herrmann

Es wurden Laborexperimente in einer Aerosolkammer ausgeführt. Dabei wurde die Bildung partikulär gebundener sekundärer organischer Verbindungen ausgehend von α-Pinen und dessen Reaktion mit Ozon und von Isopren und bekannten Reaktionsprodukten des Isoprens untersucht. Schwerpunkt der Experimente war die Untersuchungen des Einflusses acider Partikel auf die Änderung der Partikelmasse und die Art der partikulär gebundenen Produkte. Hierbei zeigte sich, dass saure Partikel zur verstärkten Entstehung oligomer Produkte in der Ozonolyse von α-Pinen führen. Experimente mit Zusatz eines Fängers für die in der Ozonolyse gebildeten OH-Radikale legen den Schluss nahe, dass die Reaktion der OH-Radikale mit α-Pinen oder seinen Produkten die Bildung von Oligomeren entscheidend beeinflusst. Für Isopren und seine Oxidationsprodukte konnte in den Kammerexperimenten ein Mechanismus zur Entstehung partikelgebundener Produkte, der 2-Methyltetrole, validiert werden.

Introduction

Organic matter frequently makes up the largest particulate fraction of the aerosol over continental regions, especially in remote areas [*Andreae and Crutzen*, 1997]. The contribution of secondary organic carbon (SOC) to the total organic particulate concentration remains a controversial issue. The SOC content in tropospheric particles is highly variable and its composition and formation mechanisms are not well understood [*Pandis et al.*, 1992; *Turpin et al.*, 2000]. Because of the large influence of particulate organic compounds on thermodynamic, microphysical and chemical properties [e.g., *Turpin et al.*, 2000] a quantitative description of the impact of organic compounds to particle formation and modification is needed.

Biogenic organic compounds are emitted to the atmosphere in substantial amounts mainly from terrestrial vegetation. Total global biogenic organic emissions are estimated to range from 491 to 1150 Tg year^{-1} exceeding the estimated anthropogenic emissions by as much as an order of magnitude [*Müller*, 1992; *Guenther et al.*, 1995]. After methane the terpenes and isoprene are the organic compounds with the highest global emission.

The identification and quantification of reaction products from the oxidation of terpenes and isoprene in the gas phase has been received great attention over the past two decades. More recently, the formation of secondary organic aerosol (SOA) during the oxidation process of terpenes in the atmosphere has also been investigated [*Pandis et al.*, 1991; *Zhang et al.*, 1992; *Hoffmann et al.*, 1997]. Figure 1 illustrates the SOA formation processes from biogenic organic compounds. The SOA yields of secondary organic products have been normally explained by condensation or partitioning theory [*Pankow*, 1994; *Odum et al.*, 1996; *Hoffmann et al.*, 1997; *Kamens et al.*, 1999]. However, there is also the possibility of further transformation of semi-volatile organic compounds in atmospheric aerosol particles or at their surface.

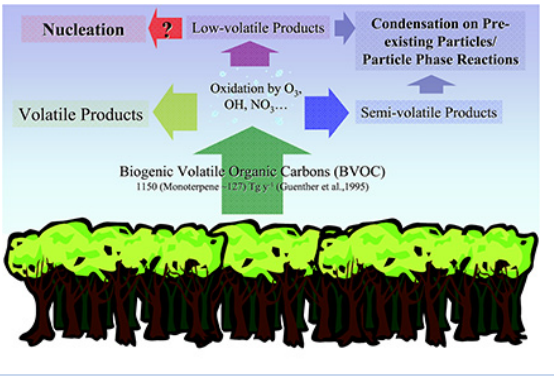

Fig. 1: *POM formation processes from biogenic volatile organic compounds.*

Contrary to the chemistry of terpenes it has commonly been assumed that the photooxidation of isoprene does not contribute to the production of secondary organic aerosol (SOA) under ambient conditions [*Seinfeld and Pandis*, 1998]. Recently, two diastereomeric 2-methyltetrols (2-methylthreitol and 2-methylerythritol) have been identified in natural aerosol particles from the Amazonian rain forest [*Claeys et al.*, 2004a]. The appearance of these compounds was explained by OH radical-initiated photooxidation of isoprene. In a subsequent publication the presence of 2-methyltetrols in natural forest aerosol particles collected at K-puszta, Hungary [*Claeys et al.*, 2004b], has also been reported. It was then suggested that the 2-methyltetrols are formed through acid-catalyzed liquid phase oxidation of isoprene.

The main goal of the chamber experiments was i.) to study the particulate organic matter (POM) formation from the ozonolysis of biogenic

hydrocarbons especially the influence of the particle acidity on particulate products and yields and ii.) to evaluate the mechanisms for the formation of particulate products from isoprene.

Experimental

The experiments were carried out in a 9 m^3 chamber made of Teflon film. The chamber was flushed with particle-free air prior to each experiment for more than 18 h. The humidity of the chamber was achieved by a humidifier which consists of a series of twelve tubes filled with Milli-Q grade water. The relative humidity and temperature were maintained at around 50 % and between 20 - 25 °C for all experiments. Neutral or acidic seed particles were generated using a nebulizer from a solution of Na_2SO_4 (neutral seed experiments) or $(NH_4)_2SO_4/H_2SO_4$ (acidic seed experiments). A bipolar charger was used to neutralize the seed particles.

For α-pinene ozonolysis experiments ozone was generated using a UV-lamp passing through an oxygen stream of 2 l min^{-1}. The initial ozone mixing ratio in the chamber was about 68 - 73 ppb. α-Pinene or a mixture of α-pinene and scavenger were injected into a stream of clean air using a micro-syringe and introduced into the chamber. The initial mixing ratio of α-pinene was 100 ppb exceeding the initial ozone concentration and hence leading to a nearly complete consumption of ozone in order to prevent secondary ozone reactions.

In each experiment, an aerosol particle sample was taken on a 47 mm PTFE filter for chemical analysis of the particulate products or on a 47 mm quartz fiber filter for thermographic total organic carbon (TOC) measurement. Teflon filters were extracted in methanol for CE-MS analysis. The analysis of the individual chemical species was performed using an Agilent capillary electrophoresis instrument coupled to an ion trap mass spectrometer equipped with an electrospray ionization source (CE-ESI-MS). The electrospray was operated at the negative mode to detect deprotonated compounds (M_w-1). Mass ranges scanned were from m/z 50 - 500 for the analysis of smaller compounds (M_w < 400) and m/z 300 - 1500 for the detection of oligomeric compounds.

For the experiments with isoprene or isoprene oxidation products only acidic seed particles and no ozone was introduced into the chamber. Then H_2O_2 was introduced by means of a syringe in an air stream of about 300 l. After this the organic rectants were added in the same manner. After the reaction was run for 150 min filter samples were taken on quartz filters. The quartz fiber filters were Soxhlet-extracted with CH_2Cl_2/MeOH for 22 h and concentrated. For analysis the 2-methyltetrols were silylated with N.O-bis(trimethylsilyl)-trifluoracetamide (BSTFA). The reference compounds mixture of 2-methylthreitol and 2-methylerythritol was synthesized from 2-methyl-2-vinyloxirane according to *Claeys et al.* [2004a].

Secondary organic aerosol formation from ozonolysis of terpenes

Influence of particle acidity on SOA yield

Little is known about the overall significance of the influence of pre-existing particle properties on POM formation, particle growth and aging from biogenic VOC oxidation. In order to assess such effects, α-pinene ozonolysis was carried out in the presence of sulfuric acid seed particles (very acidic) and ammonium sulfate seed particles (slightly acidic).

Table 1 summarizes experimental conditions and particulate organic carbon yields ΔTOC. Average ΔTOC after two and a half hour of the experiments are 52.4 ± 8.5 μgm^{-3} (n=3) and 72.3 ± 14.2 μgm^{-3} (n=4) in the presence of ammonium sulfate seed particles and sulfuric acid seed particle, respectively. High acidity of the sulfuric acid seed particles increased the average particulate organic carbon yield by almost 40 % compared to the mildly acidic ammonium sulfate seed particles.

Date	Particle	$Ozone_0$ [ppb]	R.H. [%]	T [°C]	ΔTOC [μgm^{-3}]
05/11/2002	H_2SO_4	75	45	17.6	54.9
11/25/2002	H_2SO_4	68	41	22.9	83.3
11/26/2002	H_2SO_4	72	43	20.7	66.6
11/29/2002	H_2SO_4	62	42	18.7	84.5
11/28/2002	H_2SO_4	71	43	19.2	PTFE-Filter
01/10/2003	$(NH_4)_2SO_4$	63	50	17.8	62.2
01/14/2003	$(NH_4)_2SO_4$	61	52	17.7	47.1
01/16/2003	$(NH_4)_2SO_4$	67	49	18.7	47.8
01/20/2003	$(NH_4)_2SO_4$	70	48	20.2	PTFE-Filter

Tab. 1: *Initial conditions and TOC yields from the ozonolysis of α-pinene with H_2SO_4 and $(NH_4)_2SO_4$ seed particles.*

Although the particle acidity has influenced the ΔTOC dramatically, it does not show a significant impact on the yield and the fraction of low molecular weight compounds found from both seed particle systems. *cis*-Pinic acid is the most abundant single product for all sets of experiments followed by compounds with a molecular weight (M_w) 172 and 200. *cis*-Pinic acid is typically the most abundant α-pinene oxidation products in the ambient particle. The migration time of a compound with M_w 172 suggests a hydroxy-monocarboxylic acid (e.g. pinolic acid, $C_9H_{16}O_3$) but a possibility of a dicarboxylic acid such as *cis*-norpinic acid cannot be excluded as the known reaction mechanisms

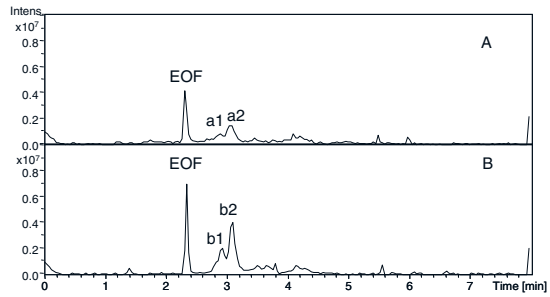

Fig. 2: Extracted ion electropherograms (EIC) for the experiments with (A) ammonium sulfate seed particles and (B) sulfuric acid seed particles (m/z 300-1500). EOF stands for electroosmotic flow.

Figure 4 shows the MS^2 spectra of m/z 369. It shows strong fragments at m/z 167 and 185 followed by a weaker fragment of m/z 169, which are characteristic masses of α-pinene oxidation products. This result confirms that the dimeric compounds detected in this study consist of low molecular weight α-pinene oxidation product units.

Currently, two possibilities are proposed for the formation of the oligomers in monoterpene secondary POM. The first possibility suggests oligomerization/polymerization of multifunctional oxidation products (typically aldehydes and keto-acids) through well established oligomerization/ polymerization reactions such as aldol

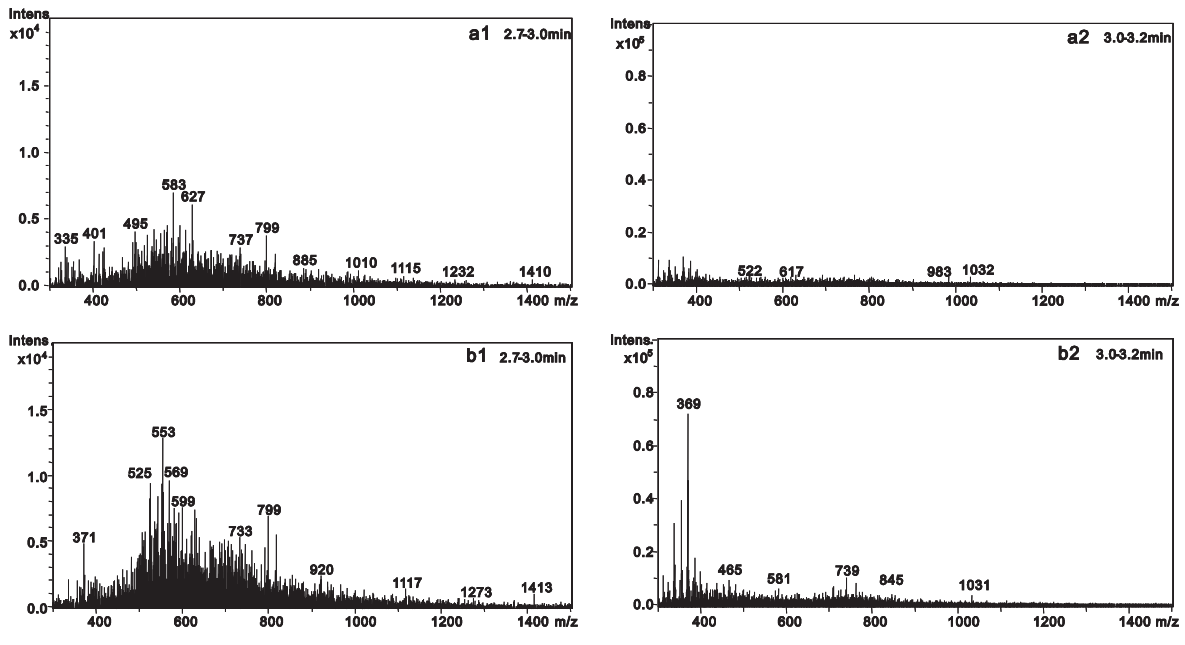

Fig. 3: Background subtracted average mass spectra of peak a1, a2, b1, and b2 in Figure 2.

cannot explain the formation of pinolic acid. The migration time of a compound with M_w with 200 indicates a C10 hydroxy-monocarboxylic acid ($C_{10}H_{16}O_4$).

Figure 2 shows the extracted ion electropherograms (m/z 300 - 1500) of filter extracts from α-pinene ozonolysis in the presence of (A) sulfuric acid seed particles and (B) ammonium sulfate seed particles (B). Two broad peaks between 2.7 to 3.2 minutes are much larger for the experiment with sulfuric acid seed particles. The averaged mass spectra of these peaks show that the peaks a1 and b1 are largely made of compounds with m/z 400 - 800 at the maximum intensity around m/z 550 (Figure 3a1 and 3b1) whereas the peaks a2 and b2 consist of compounds with mainly m/z 300 - 400 (Figure 3a2 and 3b2).

A tandem MS experiment (MS^2) was carried out in order to obtain qualitative information on a functional group of the dimeric compounds.

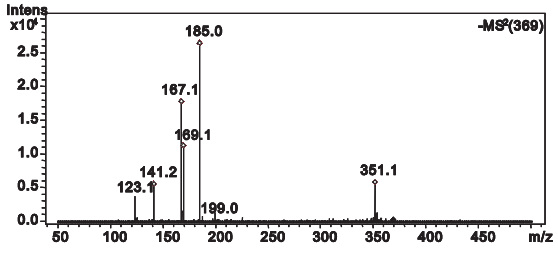

Fig. 4: MS^2 mass spectrum of m/z 369.

condensation, gem-diol reactions, and acid dehydration [*Czoschke et al.*, 2003; *Gao et al.*, 2004a; *Gao et al.*, 2004b; *Iinuma et al.*, 2004; *Jang et al.*, 2003a; *Jang et al.*, 2003b; *Jang et al.*, 2002; *Jang and Kamens*, 2001; *Lee et al.*, 2004; *Tolocka et al.*, 2004]. The second possibility suggests peroxyhemiacetal formation from heterogeneous reactions of hydroperoxides and aldehydes [*Docherty et al.*, 2005]. The oligomer formation

mechanisms in monomoterpene secondary POM may not be mutually exclusive to one pathway as the first possibility can explain higher oligomer yields under acidic conditions well whereas the second possibility can describe the observation of oligomers under neutral or mildly acidic conditions shown in recent work [*Gao et al.*, 2004a; *Gao et al.*, 2004b; *Iinuma et al.*, 2005; *Docherty et al.*, 2005]. More work is necessary in order to better characterize the oligomers from monoterpene ozonolysis.

Influence of OH radical scavengers on SOA yield

Criegee intermediate, which is an intermediate product of α-pinene ozonolysis, decomposes some degree and produces an OH radical. The OH radical is a strong oxidant and it also contributes to the POM formation. Therefore, to separate the contribution of OH radicals to POM produced in α-pinene and ozone reaction, OH scavengers were used for this study.

Figure 5 shows the examples of extracted ion electropherograms (EIC) and mass spectra for m/z 300 - 1000 from the samples of (A) α-pinene ozonolysis with neutral seed particle, (B) α-pinene ozonolysis with the neutral seed particle in the presence of 2-butanol as an OH-scavenger and (C) α-pinene ozonolysis with the neutral seed particle in the presence of cyclohexane as an OH-scavenger. The corresponding electropherograms and mass

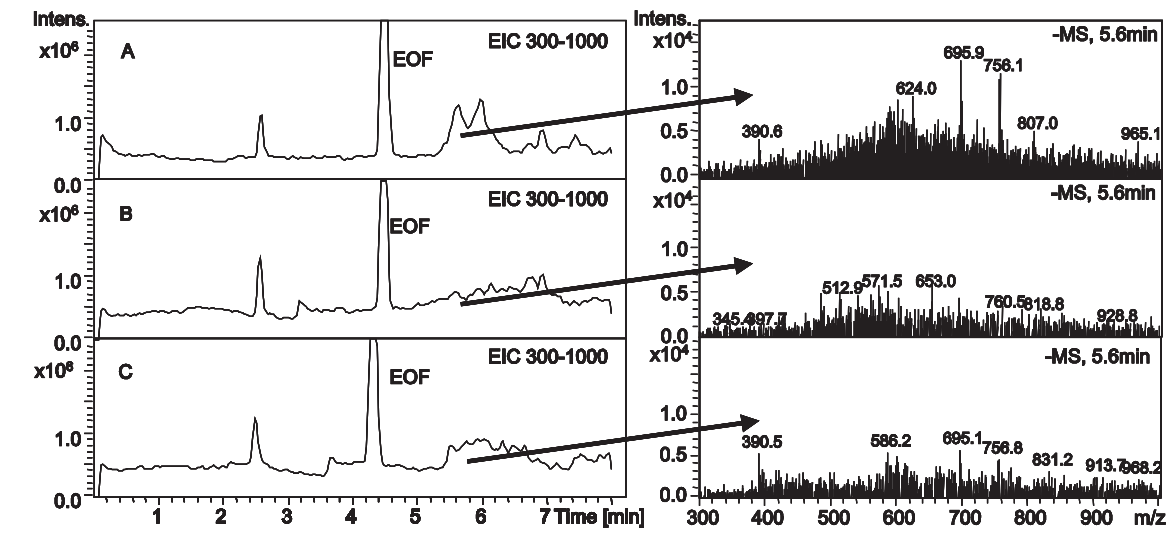

Fig. 5: EIC from the α-pinene ozonolysis in the presence of neutral seed particle. (A) no OH-scavenger; (B) 2-butanol as an OH-scavenger; and (C) cyclohexane as an OH-scavenger.

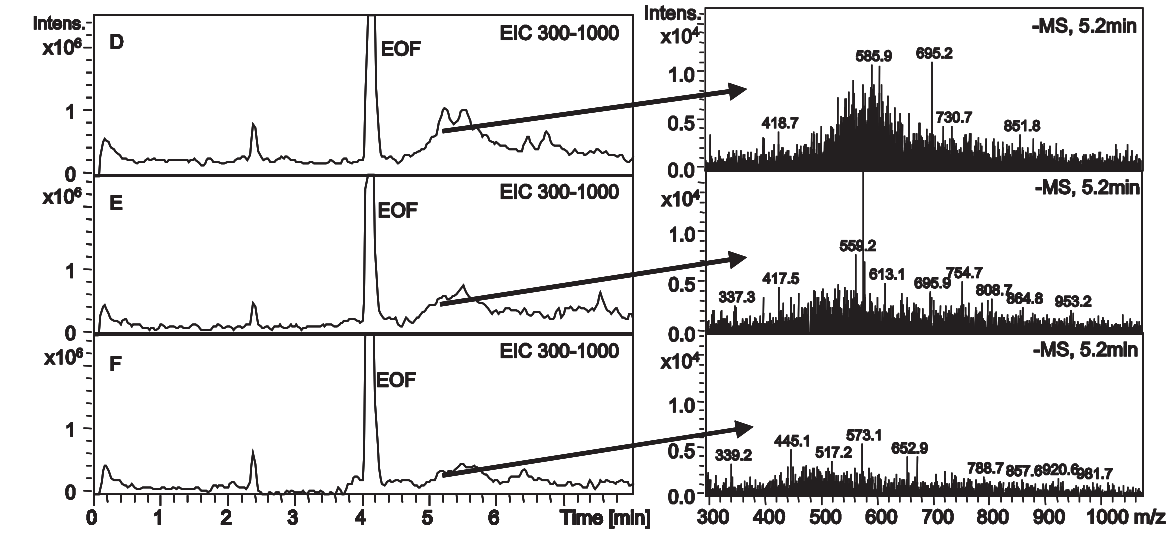

Fig. 6: EIC from the α-pinene ozonolysis in the presence of acidic seed particle. (A) no OH-scavenger; (B) 2-butanol as an OH-scavenger; and (C) cyclohexane as an OH-scavenger.

spectra from the acidic seed particle experiments are shown in Figure 6. Although the peaks in Figures 5 and 6 correspond to the peak a1, a2, b1 and b3 in Figure 2, they migrated much later due to a longer analytical capillary used for this analysis.

It is clear from Figures 5 and 6 that the broad oligomer peaks in both the electropherograms and mass spectra are reduced significantly when OH-scavengers are used. These observations suggest that not only the acidity of seed particles influence POM yields but also the presence of OH radical can change POM yields. It seems that OH reactions in the gas phase appear to be an important source for precursors of the oligomers identified in α-pinene ozonolysis POM.

Contrary to the findings of our study, *Gao et al*. [2004b] have found oligomeric compounds from α-pinene ozonolysis even in the presence of cyclohexane in high excess**.** Our experiments were much shorter in duration (2.5 h reaction time) compared to their experiments (5 ~ 7 h reaction time) and this could partly have caused the differences. Indeed, the coupled multiphase processes forming oligomeric compounds proceed under certain circumstances in time range of days, as emphasized by *Kalberer et al*. [2004] for the oxidation of aromatic substrates. However, 2.5 h reaction time was sufficient to produce oligomers when no OH-scavenger was used. Therefore, the different reaction times cannot be the sole reason for the observed differences. Excess ozone in the experiment of *Gao et al*. [2004b] might have caused secondary ozone reactions, which could also have contributed to the observed difference. Nonetheless, the reaction of OH radicals with primary ozonolysis products such as pinonaldehyde or α-pinene itself may be also important for the formation of low volatility oligomer precursor compounds.

Formation of secondary organic particle phase compounds from isoprene gas-phase oxidation products

Four sets of aerosol chamber experiments were carried out. The formation of 2-methylthreitol and 2-methylerythritol as result of the reaction of isoprene, 2-methyl-3-butene-1,2-diol or 2-methyl-2-vinyloxirane with H_2O_2 in the presence of acidic particles was examined. Hydrogen peroxide (H_2O_2) is a major atmospheric oxidizing agent especially in the aqueous phase. Parameters influencing the formation of 2-methyltetrols, such as r.h., temperature, aerosol particle number concentration and particle diameter were held nearly constant in all experimental runs.

The identification of the 2-methyltetrols was achieved by their mass spectra and retention times of the reference mixture cf. Figure 7 and Figure 8. Figure 7 in the upper part shows a typical chromatogram from an experimental run with 2-methyl-2-vinyloxirane and H_2O_2. In the lower part of Figure 7 the chromatogram of the reference compounds mixture is shown. Figure 8 shows the background subtracted mass spectra of the peaks with retention time 12.27 min (2-methylthreitol) from the chromatograms in Figure 7.

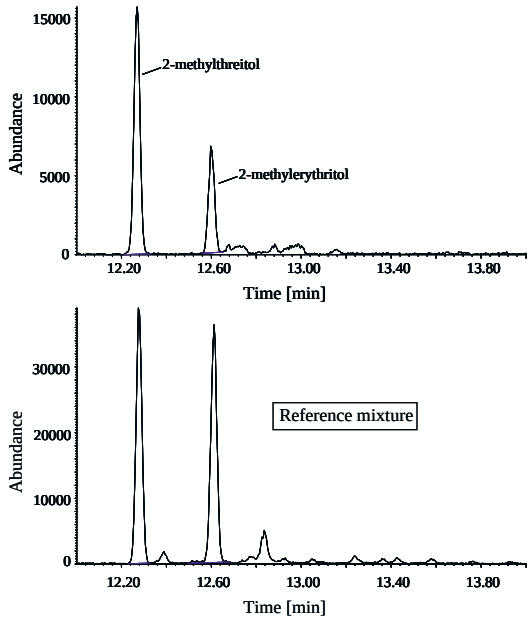

Fig. 7: *Typical EI (m/z 219) chromatograms from experimental run with 2-methyl-2-vinyloxirane and H_2O_2 (upper part) and reference compounds mixture (lower part).*

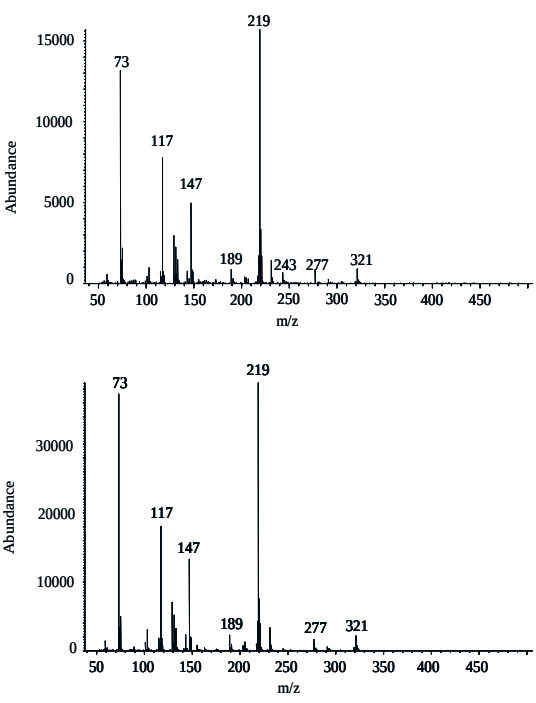

Fig. 8: *Background subtracted mass spectra of the peak with retention time 12.27 min (2-methylthreitol) and from reference compound (lower part).*

2-Methyltetrol precursor	Precursor (ppm)	Hydrogen peroxide (ppm)	2-Methyltetrol yield[a] (ngm^{-3})
 isoprene	1.5 5.0	1.5 1.5	-[b] 6.2 ± 0.9
 2-methyl-3-butene-1,2-diol	1.5	1.5	25.4 ± 10.7
 2-methyl-2-vinyloxirane	1.5	1.5	59.0 ± 12.5

[a] Mean value from three experiments each. Error represents 1σ.
[b] No significant 2-methyltetrol formation measured.

Tab. 2: *Initial concentrations in the aerosol chamber and 2-methyltetrol amounts measured in the particle phase.*

Table 2 summarizes the obtained particulate 2-methyltetrol concentrations (sum of the two isomers). In the first run with 1.5 ppm initial isoprene mixing ratio no significant 2-methyltetrol formation was observed. With increased isoprene mixing ratio the formation of small amounts of 2-methylthreitol and 2-methylerythritol could be detected. The aerosol phase reaction of 2-methyl-3-butene-1,2-diol or 2-methyl-2-vinyloxirane with H_2O_2 yielded noticeable higher particle phase concentrations of the 2-methyltetrols.

Several mechanisms for the oxidation of isoprene have been suggested to explain the occurrence of the 2-methyltetrols in atmospheric particles, cf. Figure 9. The first mechanism

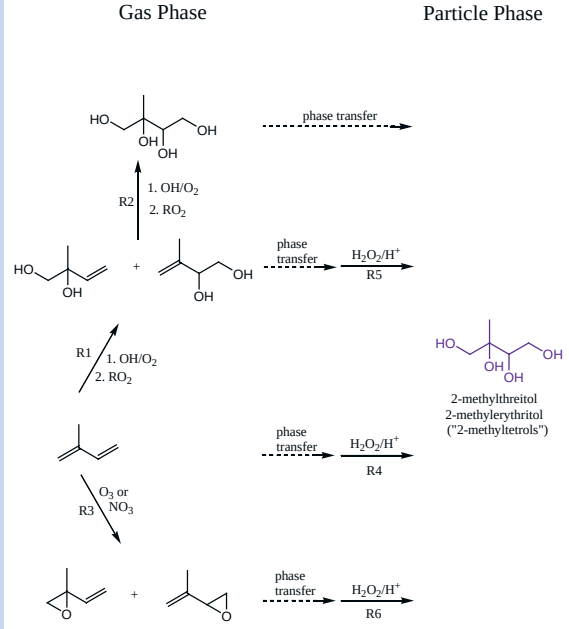

Fig. 9: *Proposed reaction pathways for the atmospheric formation of 2-methyltetrols from isoprene.*

proposed the formation of the 2-methyltetrols in a gas-phase reaction via reaction (1) followed by reaction (2) [*Claeys et al.*, 2004a]. The OH-radical initiated reaction of isoprene leads to the rapid formation of hydroxyl peroxy radicals. There self reaction or cross reaction with other peroxy radicals can lead to 2- and 3-methyl-butene-1,2-diol as well as 2-methyl-2-butene-1,4-diol. The peroxy radicals can also react with HO_2 producing organic hydroperoxides and with NO forming alkoxy radicals or nitrates. The permutation reactions of the peroxy radicals leading to the diols can only be important in remote forested regions where 'low NOx' conditions prevail. For the 'low NOx' case a diol yield of about 1 – 3 % was estimated by *Ruppert and Becker* [2000]. Taking this value also for the second reaction (2) an overall yield of just 0.01 - 0.09 can be estimated for the 2-methyltetrol formation according to reactions (1) and (2).

Results from field measurements have led to a reconsideration of the processes by which 2-methyltetrols are formed from isoprene. The new results showed higher concentrations of the 2-methyltetrols under 'high NOx'conditions during the wet season [*Claeys et al.*, 2004b]. The formation of the 2-methyltetrols in atmospheric particles has been explained through the acid catalized reaction of isoprene with hydrogen peroxide cf. reaction (4) in Figure 9. In the present study an aerosol chamber experiment was performed with acidic ($(NH_4)_2SO_4/H_2SO_4$) particles and the identification of the 2-methyltetrols in the aerosol indicates that the reaction pathway suggested by *Claeys et al.* [2004b] may be relevant to atmospheric conditions. The low amounts of 2-methylthreitol and 2-methylerythritol observed in the two sets of experiments starting with isoprene cf. Table 1 are probably caused by the low Henry coefficient and therefore low isoprene concentration in the particle phase.

A third reaction pathway starting from 2-methyl-3-butene-1,2-diol cf. reaction (5) is proposed and was tested in the aerosol chamber. The yields of the 2-methyltetrols with repect to the reacted educts are higher as in the previous experiment, see Table 2. Taking the formation yield of the diols of 1 – 3 % for reaction (2) in the 'low NOx'case this pathway can be an additional possibility for the occurrence of 2-methyltetrols in atmospheric particles, especially in remote areas.

The last reaction pathway leading to the formation of the 2-methyltetrols starting from isoprene monoxides was studied in the aerosol chamber, i.e. reaction (6) in Figure 9. The isoprene monoxides are known reaction products of the ozone isoprene reaction [*Aschmann and*

Atkinson, 1994] as well as the nitrate radical initiated oxidation of isoprene [*Berndt and Böge*, 1997]. Reaction (6) gave the highest 2-methyltetrol yields in the aerosol chamber studies presented here.

Summary

In the first part of this study, the SOA mass and the formation of oligomeric compounds following α-pinene ozonolysis with and without gas phase OH scavengers in the presence of acidic and nonacidic particles were determined. Compared to the experiments without scavenger, a strong decrease in the formation of oligomeric products was observed in the experiments with OH radical scavenger which was accompanied by a reduction in the concentration of monomeric particle phase compounds. Serious uncertainties exist regarding both the reaction of OH radicals with primary ozonolysis products of α-pinene or α-pinene itself causes these differences. However, the mentioned reactions seem to be more essential for the formation of low vapor pressure oligomer precursor compounds than the primary ozonolysis products themselves. For this reason more detailed studies of the reactions of OH with terpenes and known terpenes oxidation products, especially in the presence of acidic seed particles are needed.

In the second part of this study, the formation of 2-methylthreitol and 2-methylerythritol as particulate products of the atmospheric oxidation of isoprene was examined in the aerosol chamber. It was shown, that the reaction of known isoprene oxidation products as well as isoprene itself with hydrogen peroxide on or in acidic particles can indeed result in the formation of 2-methyltetrols. The reaction of isoprene itself with hydrogen peroxide yields only low amounts of 2-methyltetrols and from the chamber experiment it is difficult to estimate the importance of the reaction for the real atmosphere. The reaction of 2- and 3-methyl-3-butene-1,2-diol was shown to produce 2-methyltetrols in higher yields, but these diols are only produced under 'low NOx' conditions, i.e. this pathway can only in remote regions serve as 2-methyltetrol source.

In order to asses the importance of isoprene monoxides for the formation of 2-methyltetrols the following assumption have been made. Taking the rate constants for the reaction of isoprene with ozone and OH with with isoprene recommended by *Calvert et al*. [2000] and assuming a global average of 50 ppbv for ozone and 2.6 x 10^6 molecules cm^{-3} for OH it can be calculated that 5.6 % of the isoprene in the atmosphere are oxidized by ozone on a global scale. Together with the experimentally obtained yields [*Aschmann and Atkinson*, 1994] of 2-methyl-2-vinyloxirane and 2(1-methyl-vinyl)oxirane of 2.8 % and 1,1 %, respectively, a yield of about 0.22 % can be calculated for the formation of the oxiranes based on the total atmospheric isoprene conversion. An annual global emission of isoprene of approximately 500 Tg C [*Guenther et al.*, 1995] indicates an upper limit for 2-methyltetrols in atmospheric aerosols formed via the reaction of isoprene monoxides of about 1 Tg C, neglecting all other sinks for the isoprene monoxides. Compared to the total estimated SOA formation per year from biogenic sources of 8 to 40 Tg [*Penner et al*., 2001], the source strength of 2-methyltetrols should not be neglected.

However, additional mechanistic and kinetic studies are required to determine the contribution of all studied processes to SOA and especially to the formation of 2-methyltetrols in the atmosphere and to clarify if there exist additional sources for 2-methyltetrols.

Outlook

Based on the fact that biogenics contribute to substantial amount to SOC in atmospheric particles and inspired from the results presented here further experiments are urgently needed. On top of the possible influence of OH reactions with terpenes on POM yield and formation of oligomeric compounds especially in acidic particles some other questions need to be answered: Is their a significant POM increase in the presence of acidic particles for nearly atmospheric reactant concentrations and conversion rates? Could humic-like substances (HULIS) which have been identified in atmospheric particles be formed through acid catalyzed oligomerization? What are the solution phase kinetics and mechanisms of oligomer formation reactions? What is the chemical nature of the oligomers and their precursors? What is the influence of the oligomers on the physical (e.g., vapor pressure, light scattering, hygroscopicity) and chemical properties of the particles?

Fig. 10: *The new IfT aerosol chamber building.*

To tackle this questions and to overcome the disadvantages associated with 9 m^3 aerosol chamber a new chamber in a new building is constructed cf. Figure 10 and Figure 11. Contrary to the old chamber the new chamber permits studies of photochemical reactions (generation of OH radicals), reactions at a controlled temperature and experiments with lower concentrations (closer to atmospheric conditions). The chamber experiments will also be assisted by kinetic and mechanistic studies performed in aqueous phase.

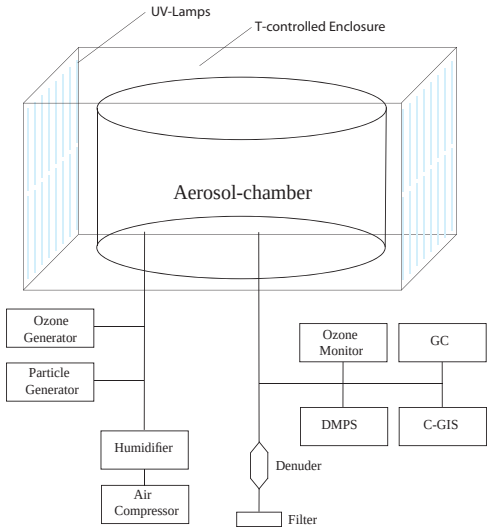

Fig. 11: *Block diagram of the gas- and aerosol-phase instrumentation of the new IfT aerosol chamber.*

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Traffic contribution to Particulate Matter (PM) concentrations in a street canyon

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Das Ziel des Projektes bestand in der Aufklärung der chemischen Zusammensetzung des Aerosols in einer Leipziger Straßenschlucht nach größenselektiver Probenahme mittels Berner-Impaktoren und MOUDI. Der Zusammenhang der Feinstaubbelastung mit direkten und indirekten Verkehrsemissionen sollte untersucht werden. Verkehrsruß und Aufwirbelungen von Straßenstaub sind nicht vernachlässigbare Komponenten des städtischen Aerosols. Besonders in den ultrafeinen Partikeln finden sich erhebliche Anteile primärer Kfz-Emissionen, während vorwiegend in groben Partikeln aufgewirbelter Straßenstaub zu finden ist. In Abhängigkeit von der Verkehrsdichte und meteorologischen Rahmenbedingungen sind Erhöhungen von EC und OC im Aerosol nachgewiesen worden, die auf den Verkehr zurückzuführen sind.

Introduction and Experimental

Recent epidemiological studies in Europe and the US [in *Kappos et al*., 2004] have determined strong correlations between long-term exposure of people to fine and ultra-fine dust and the risk of negative health effects. From Germany the results of investigations in Erfurt show the influence of ultra-fine PM on health [*Wichmann and Peters*, 2000; *Ibald-Mulli et al*., 2002]. The traffic, especially emission of soot from diesel trucks and buses, is an important anthropogenic factor of PM in cities. Fine particles and the associated organic compounds are of current concern because of their putative health effects. Of particular concern are polycyclic aromatic hydrocarbons (PAH) which are mutagenic air pollutants formed as by-products of combustion. Studies of size-segregated analysis of PM from traffic sites already exist [e.g., *Cass et al*. 2000, *Allen et al*.,2001, *Matta et al*., 2002] but the focus of the present project was the investigation of the carbonaceous fraction of fine and nano-particles in a street canyon.

Nano-particles (dp < 50 nm) and their effects on human health depend on their chemical constitution, water solubility or lipid solubility. Insoluble soot particles are suspected to be more toxic than soluble PM.

Size-segregated PM sampling and chemical characterization was carried out using five-stage Berner impactors (0.05 < Dp < 10 μm) and a 11-stage MOUDI (Micro Orifice Uniform Deposit Impactor; 0.056 < Dp < 18 μm) complemented by a three-stage nano-MOUDI (0.01 < Dp > 0.056 μm).

Depending on the size range main PM components were inorganic ions, Organic Carbon (OC) or Elementary Carbon (EC). Associated individual organic compounds from natural and anthropogenic sources like alkanes, PAH or small dicarboxylic acids (DCA) were detected additionally. Background influences of PM were investigated from parallel samples at three differently polluted stations in a street canyon (E - Eisenbahnstraße) at the urban background site (I - top of the IfT-building) and in the rural background (M - Melpitz - 42 km Northeast of Leipzig).

To investigate local and seasonal variations of the size-segregated PM concentration impactor measurements were made at a traffic-site monitoring station in the Eisenbahnstraße during two summers and two winters. During the experiment the Eisenbahnstraße was reconstructed completely. The traffic volume changed within the measuring periods from about 20,000 cars per day via 2,000 during reconstruction works to 10,000 after the reconstruction. Under theses circumstances the traffic has been classified in three major episodes. The MOUDI samples delivered additional information about sources because the greater number of impaction stages.

The Berner-sampling took place on precipitation-free days at all sites in parallel over 24 hours but the MOUDI was operated 96 hours because of its low flow rate. During the Berner collection time two 96-hour back trajectories were calculated at three heights using the NOAA hysplit model (http://www.arl.noaa.gov/ready/hysplit4. html). PM was collected on aluminum substrates in both impactors. After conditioning and weighing the foils were divided into three parts for the different analytical procedures:

1. Analysis of water soluble ions and dicarboxylic acids
2. OC/EC analysis
3. CPP-GC-MS (Curie-Point Pyrolysis Gas Chromatography – Mass Spectrometry) for alkanes and PAH (Polycyclic Aromatic Hydrocarbons)

Results

The investigation was directed mainly at the smallest particles of the Berner impactor (stage 1: 0.05 < Dp < 0.14 μm) which are well known from previous experiments for primary traffic contributions. In nearly all periods of the experiment the determined mass of these ultra-fine particles decreased from Eisenbahnstraße via IfT to Melpitz. A similar observation was made for ions. In Figure 1 the mean mass concentration found in this size class is given for all periods. The main ionic components in all size fractions are sulfate, nitrate and ammonium. All are partially traffic-related after chemical conversions of S, NO_2 and NH_3, which are well known from vehicle emissions. Their concentrations decreased from E via I to M but the percentage of the ionic constituents increased in the same direction.

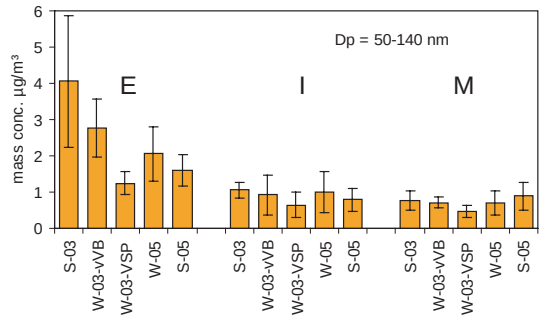

Fig. 1: *Mean mass concentration of Berner impactor stage 1 particles at the three sites (E - Eisenbahnstrasse, I - IfT, M - Melpitz) and the variability between and within periods (S- 03 - summer 2003 before traffic reduction; W-03 vVB – winter 2003 before traffic reduction; W-03VSP – winter 2003 during the reconstruction work; W-05 – winter 2005 after reconstruction; S- 05 – summer 2005 after reconstruction).*

OC and EC concentrations in the smallest particles are strongly correlated with traffic density. In Figure 2 the concentration of OC/EC is presented. A high correlation was found for the EC (R^2 = 0.996) in the nano-particles of the MOUDI measurements (0.018 < Dp < 0.056 μm). For the size range of 0.05 < Dp < 0.14 μm a good correlation with traffic density in the Eisenbahnstraße is given for TC (Total Carbon; R^2 = 0.910). With increasing diameter of PM (Figure 3) the correlation of TC decreased to the R^2-value of 0.463 for the stage 2 particles (0.14 < Dp < 0.42 μm). Similar observation was made for the PM mass concentration ($R^2_{stage\ 1}$ = 0.756 and $R^2_{stage\ 2}$ = 0.446). No correlation was found for the concentration of ions. The decrease of TC between the summer 2003 (traffic volume: 100 %) and the summer 2005 (traffic volume: 50 %) was 40 % in the mean of all measurements.

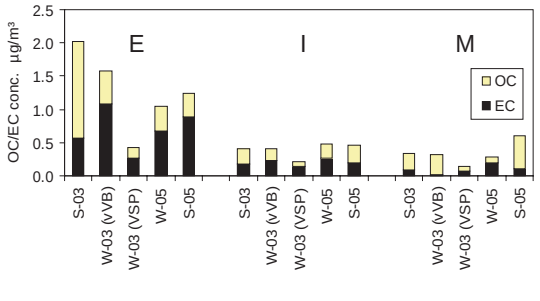

Fig. 2: *Mean OC/EC concentration of Berner impactor stage 1 particles and the variability between and within the measurement periods.*

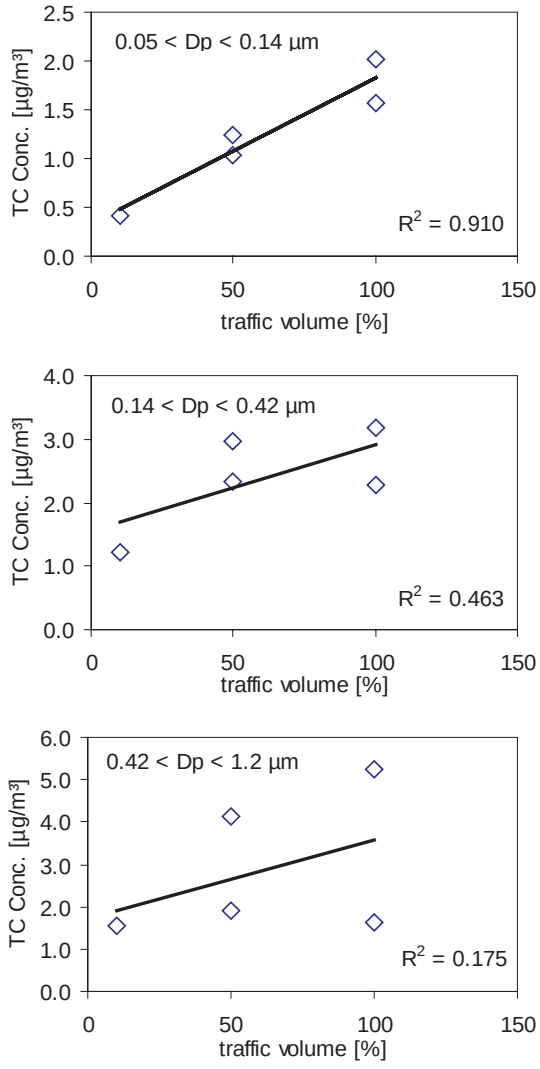

Fig. 3: *Correlation of TC concentration to the traffic volume at the sampling site Eisenbahnstraße on the three smallest Berner impactor stages.*

Besides the Berner impactor measurements in campaigns MOUDI measurements took place at all sites. The pattern of individual organic compounds in the different size classes is an important tool to identify their sources. The

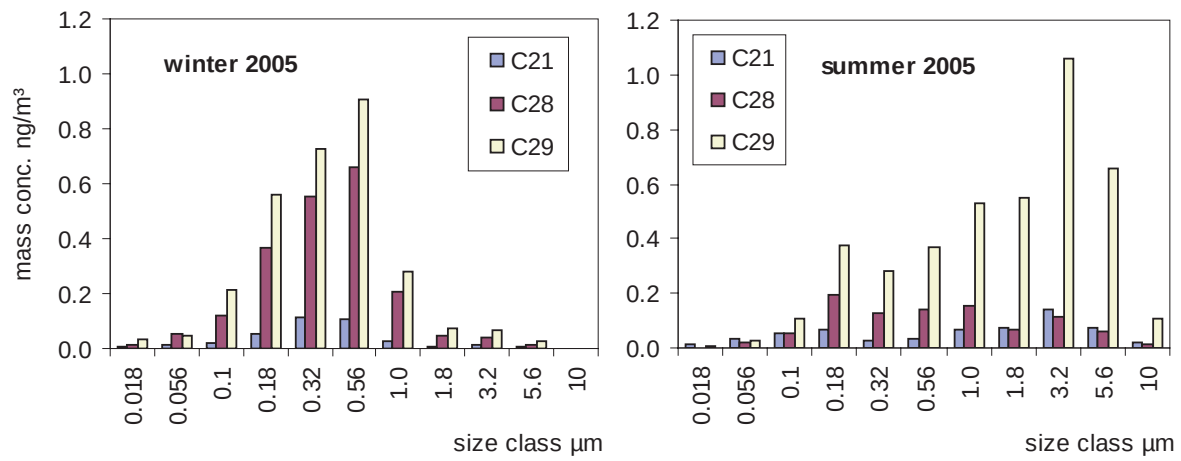

Fig. 4: Pattern of three alkanes in a summer and a winter MOUDI sample.

long-chained alkanes allow to differentiate between traffic emissions (diesel and lubricants), domestic heating and biogenic sources (cuticular waxes). The CPI (Carbon preference index CPI = sum of concentration of alkanes with odd C-number/sum of alkanes with even C-number) is a helpful tool to describe the origin of alkanes. Is the CPI nearly 1 the origin is anthropogenic. At higher CPI-values the biogenic contribution to PM increases because in biogenic materials the number of odd n-alkanes is 5 to 10 times higher than the number of even alkanes. The pattern of three selected alkanes in Figure 4 shows the important differences between summer and winter (proportion of C29 and C28). The winter sample has the maximum of all alkanes in the medium sized particles whereas in the summer the biogenic C29 has its maximum in the coarse mode PM. The more traffic related C21 has two small peaks, one in the direct emission mode and the other in the coarse mode from road dust.

The determination of DCA (dicarboxylic acids), the most abundant class of organic compounds in PM is not connected to traffic emissions. The concentration level of DCA is higher in summer than in winter with a maximum of DCA in the three fractions of the MOUDI between 0.18 and 1.0 μm. During summer measurements a significant increase of DCA in the coarse mode particles was observed.

At the Eisenbahnstraße PM was collected during four episodes using the MOUDI. The high size resolution of the MOUDI delivered some additional data in reference to the sources of constituents. The PAH pattern is quite similar from all sources of burning oil or coal, hence the size distribution of PAH and their concentration in PM are the most important information about sources (Figure 5).

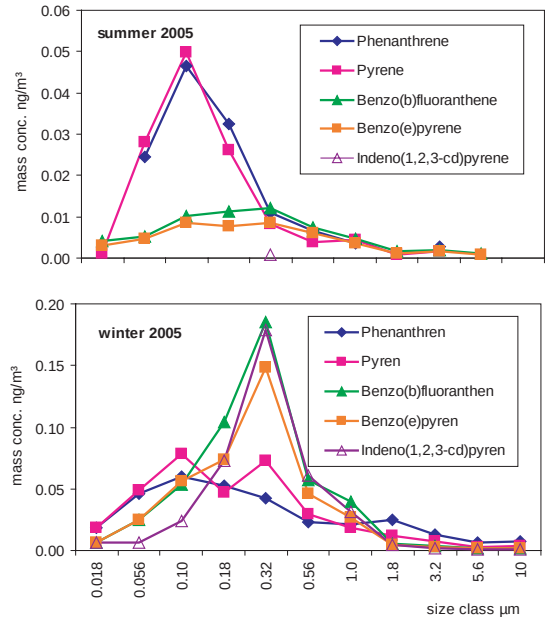

Fig. 5: Comparison of the distribution of selected PAH between stages of the MOUDI in winter versus summer 2005 (mean of all measurements).

During summer only the traffic emissions are the source of PAH but in winter the concentration of the PAH is ten times higher and the peak concentration shifted to the medium sized PM which comes from long range transport and the local emission of domestic heating. In the same size range the winter peak of TC was observed (Figure 6). The TC in the smallest particles is nearly constant in both seasons under equal traffic conditions. The slightly higher summer concentration in the coarse mode is dependent on the re-emission of dry material from the ground (indirect traffic emission).

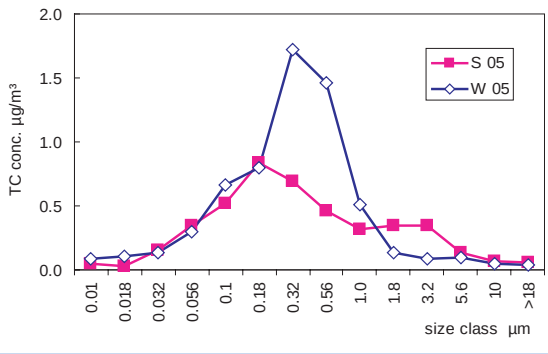

Fig. 6: *Comparison of TC mean values of four winter and summer measurements in 2005.*

Conclusions

From the parallel measurements of Berner impactors in the Eisenbahnstraße, on the roof of the IfT and at the rural site Melpitz the influence of long range transport and the urban background on the PM concentration could be calculated and the traffic contribution in the Eisenbahnstraße was estimated after the method of *Lenschow et al*. [2001]. The PM concentration measured in Melpitz was defined as the rural background. The difference between sites I and M was determined as the urban background including parts of traffic emission. The difference between E and I yields the local traffic influence for the street canyon.

The mass concentration of nano-particles is strongly correlated with the traffic density and decreased during the traffic reduction time to 30 % of the value before. After the reconstruction at a traffic volume of about 50 % the mass concentration decreased to 45 % of the value determined before reconstruction under high traffic volume conditions. For the stage 2 particles a correlation to the traffic delivers 15 to 33 % traffic related PM mass. The main ionic species nitrate, sulfate and ammonium play a minor role in ultrafine particles but a traffic-dependent percentage was found, too.

More significant is the dependence of particulate carbon on the traffic volume (Figure 7). In the nano-particle fraction 48-80 % of TC (total carbon) are traffic emissions, highly correlated with traffic volume ($R^2 = 0.92$). Decreasing but significant parts (24 – 39 %) of the stage 2 ($140 < Dp < 420$ nm) OC/EC are traffic-related. The correlation to the traffic volume decreased to $R^2 = 0.52$ which hints to the increasing influence of other sources (domestic heating and long range transport). The stage 3 ($420 < Dp < 1{,}200$ nm) is mainly influenced by long range transported PM. In this size class the difference between the sites M and E is small. Only during both summers the local traffic contributes to the TC mass (Figure 8). In the two coarse mode fractions no correlations with traffic volume could be determined.

From the organic species a very high correlation ($R^2 = 0.99$) was found for the concentration of C22-C25 alkanes, which are diesel representatives. About 50 % of their concentration are contributions of the local traffic. The highest concentrations of alkanes were found on stages 2 and 3 but here other sources are to be considered than the local traffic.

According to the additional sources during winters only the summers were compared for the total contribution of the local traffic to PM_{10} in the Eisenbahnstraße to 33 % at 100 % traffic volume and to 18 % at 50 % traffic volume. Under high traffic volume conditions in the summer 2003 the traffic related TC in the PM_{10} range amounts to 3.5 $\mu g/m^3$ (37 % of TC, Figure 8). A decreasing traffic volume yields definitely lower PM concentration during summer time.

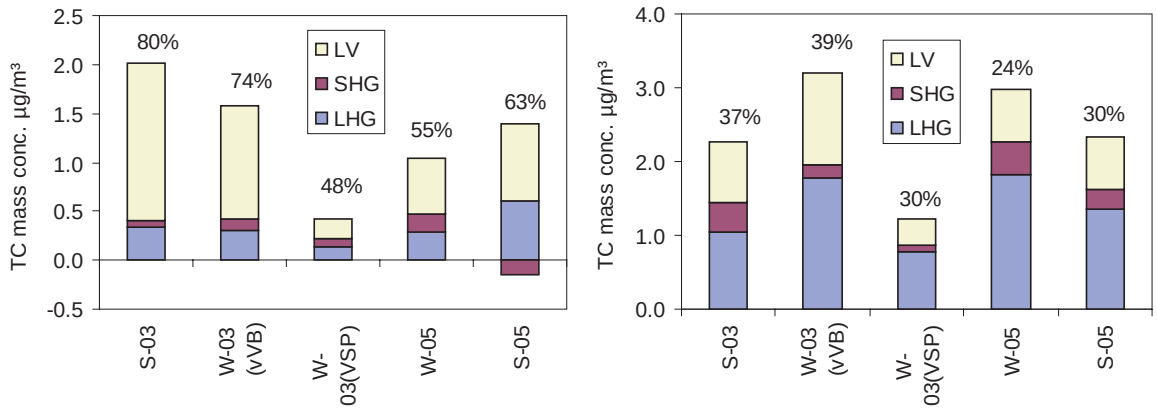

Fig. 7: *TC mass concentration of stage 1 (left) and stage 2 (right) of the Berner measurements in the Eisenbahnstraße, percentage corresponds to local traffic contribution (LHG – rural background contribution, SHG – urban background contribution, LV – local traffic contribution).*

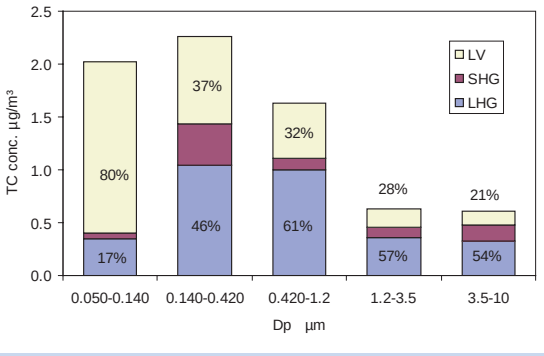

Fig. 8: *TC mass concentration in the summer 2003 Berner samples with respect to the different sources (legend as in Figure 7).*

It has been shown that the mass and the carbonaceous fraction of nano- and fine particles are strongly dependent on the local traffic level in a busy street canyon. From the investigation of single organic components only the alkanes are traffic-related. PAH concentrations are more influenced by domestic heating and long range transports. DCA are mainly formed by photochemical processes in the atmosphere independent of the local traffic.

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Funding

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Soot emission factors and number size distributions of passenger cars and heavy-duty vehicles

Diana Rose, Christa Engler, Jens Voigtländer, Thomas Tuch, Birgit Wehner, Alfred Wiedensohler

Zum ersten Mal wurden in einer Studie Emissionsfaktoren für Russpartikel in einer Straßenschlucht für Personenkraftwagen und bzw. Lastkraftwagen inklusive Kleintransporter und Busse bestimmt. Dazu wurde die externe Mischung von Rußpartikel in einer Straßenschlucht und im urbanen Hintergrund mit einer neuen Methode gemessen. Mittels des „Operational Street Pollution Models" konnten die Faktoren dann aus Messungen an Werktagen und an Sonntagen errechnet werden. Die Rußpartikel-Emissionen von Lastkraftwagen ist 40-50-fach höher pro Fahrzeug und Kilometer als für Personenkraftwagen. Dadurch dass der Anteil von Lastkraftwagen nur 4% am Verkehr ausmacht, tragen Lastkraftwagen und Personenkraftwagen ähnlich stark zur Konzentration der emittierten Rußpartikel in der Straße bei.

Elemental carbon (EC) is one of the most important components in the atmospheric aerosol. First, it is the most efficient particulate light absorber [*Horvath*, 1993], which may lead to atmospheric warming (e.g., *Haywood and Shine*, [1995]) due to a decrease in single scattering albedo of the aerosol. Second, soot with its major compound EC is believed to play a significant role in aerosol-induced health effects (e.g., *Pope and Dockery*, [1999]; *Donaldson et al*., [2001]; *Ye et al*., [1999]). Soot particles are neither water- nor lipid-soluble and have thus a completely different effect on health than water-soluble compounds [*Kreyling and Scheuch*, 2000]. In urban regions, soot, mainly introduced into the atmosphere by traffic emissions, has a significant number fraction in the size range below 100 nm [*Wiedensohler et al*., 2000]. Soot particles are emitted as an externally mixed subpopulation into the atmosphere. During their transport, they either coagulate with other particles or are covered with material such as sulfates, nitrates or organic compounds due to condensation. The main fraction of soot particles close to the source is however externally mixed. For investigating the impact of soot in the atmosphere either on optical properties or on health effects, the partitioning of soot as externally or internally mixed particles is important to know and to quantify for different aerosols.

In the frame of a research project funded by the Forschungsvereinigung Automobiltechnik (FAT), a Volatility Tandem DMA (VTDMA) was used to measure the non-volatile number fraction of submicrometer particles by evaporating volatile material of particles of certain diameters (here 30, 50, 80, and 150 nm). This method even allows differentiating the fraction of externally mixed soot particles from other non-volatile material. The measurements took place in Leipzig at two differently polluted urban areas in summer 2003. The first station was a polluted street canyon near the city-center, Eisenbahnstrasse (EI). The street is in a narrow canyon with five-storied houses on both sides of the road. The car traffic consisted of 4% heavy-duty vehicles (i.e. buses, vans, and trucks). The second site was located on the roof of the Leibniz-Institute for Tropospheric Research (IfT), which is in the north-eastern part of Leipzig and approximately ~2.5 km from the Eisenbahnstraße. This second site represents the urban background aerosol [*Wehner et al*., 2003].

Parallel to the number fraction of externally mixed soot particles, the number size distribution of particles in the range of 3-800 nm was measured parallel with a size spectrometer. The combination of these instruments made it possible to calculate the number concentration of externally mixed soot particles (N_{soot}). It was found that the number concentration of soot particles decreased with increasing distance from source due to a decreasing influence of traffic emissions. In EI the average N_{soot} was 6,400 cm^{-3}, which was approximately ten times higher than at the urban background site. N_{soot} measured in the street canyon is well correlated with the traffic emissions. Furthermore, the N_{soot} is a function of the dilution conditions in the canyon. The dilution in a street canyon depends mainly on the wind speed (the higher the wind speed the lower the N_{soot}) and on the wind direction. The EI is oriented in east-west direction and the monitoring station is located on the north side of the street canyon. When the wind comes from southerly directions, the monitoring station receives less polluted air from the background due to a vortex-like air circulation inside the street canyon. In contrast to that, approximately four times higher soot concentrations are detected when the wind comes from northern directions.

The relationship between street-level concentration of particle number and the meteorological as well as the traffic conditions was investigated by *Berkowicz et al*. [1997]. They developed the Operational Street Pollution Model (OSPM), which describes the source-receptor relationship in a street canyon. The

model calculates the dilution of emissions in a street canyon (dilution function F) taking into account the turbulences induced by the wind (requires knowledge of wind speed and direction at roof level) and the turbulences caused by cars (needs the number and speed of vehicles in the street). The subtraction of N_{soot} at the IfT-site from the concentration in the street canyon equals the N_{soot} resulting only from traffic emissions in the street. Dividing this value by the dilution function F and by the number of cars driving in the street the soot particle emission factor of one vehicle can be obtained. The emission factor (q) describes the number of particles emitted per vehicle and kilometer. Soot particle emission factors q were calculated from the N_{soot} on working days and Sundays. The daytime average of q is $(1.5 \pm 0.4)10^{14}$. Furthermore, it was also possible to separate the emission factors for passenger cars and heavy-duty vehicles. For this purpose, an equation system was set up consisting of two equations, one for working day and one for Sunday conditions (much less heavy-duty vehicles). The emission factors q for heavy-duty vehicles and passenger cars were calculated to $(5.8 \pm 2)10^{13}$ for cars and $(2.5 \pm 0.9)10^{15}$ for heavy-duty vehicles, respectively. Number size distributions of emitted soot particles for heavy-duty vehicles and passenger cars are shown in Figure 1. Taking into account the traffic density of heavy-duty vehicles and passenger cars, the contribution of both on the number concentration of externally mixed soot particles in the street canyon is similar.

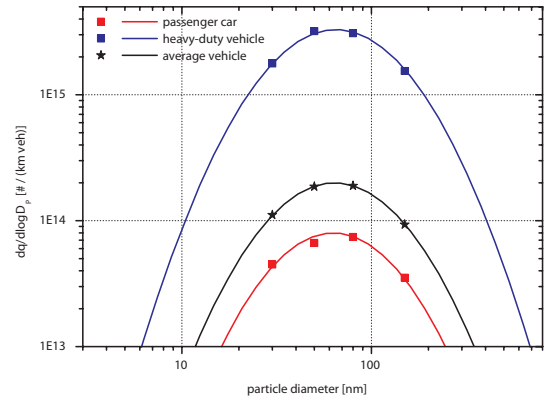

Fig. 1: *Number size distribution of soot particles emitted in a street canyon given per vehicle and kilometre. The black squares represent the average distribution of all vehicles. The grey squares and the stars differentiate between passenger car and heavy-duty vehicles, respectively.*

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Size-segregated PM characterization at a traffic-site in Dresden

Konrad Müller, Erika Brüggemann, Thomas Gnauk, Antje Plewka, Dominik van Pinxteren, Hartmut Herrmann

Das Ziel des Projektes bestand in der Aufklärung der chemischen Zusammensetzung des Aerosols an einer Verkehrsstation in Dresden nach größenselektiver Probenahme mittels Berner-Impaktoren und MOUDI. Im Zusammenhang mit direkten und indirekten Verkehrsemissionen wird in Städten eine Überschreitung der EU-Grenzwerte für Feinstaub erwartet, wenn ungünstige meteorologische Bedingungen vorherrschen. Die Untersuchungen haben gezeigt, dass Verkehrsruß und Aufwirbelungen von Straßenstaub nicht vernachlässigbare Komponenten des städtischen Aerosols sind. Besonders in den ultrafeinen Partikeln finden sich erhebliche Anteile primärer Kfz-Emissionen während vorwiegend in groben Partikeln aufgewirbelter Straßenstaub zu finden ist.

Introduction and Experimental

Emissions of particulate matter from traffic are a well known source of atmospheric soot and trace metals. To investigate the annual variation of the size-segregated PM (Particulate Matter) concentration impactor samples were taken at a traffic-site monitoring station in Dresden (about 55,000 cars per day) using Berner-type five stage impactor and a MOUDI (Micro Orifice Uniform Deposit Impactor). For the Berner-sampling dry days were selected for 24 hour sampling whereas for MOUDI the sampling time was 96 hours. PM was collected on aluminum substrates in both impactors. After conditioning and weighing the foils were divided into three parts for the different analytical procedures:

1. Analysis of water soluble ions and dicarboxylic acids
2. OC/EC (Organic Carbon/Elemental Carbon) analysis
3. CPP-GC-MS (Curie-Point Pyrolysis Gas Chromatography – Mass Spectrometry) for alkanes and PAH (Polycyclic Aromatic Hydrocarbons)

Only on the Berner impactor stages a small piece of polycarbonate foil was placed to collect material for PIXE analysis of trace elements. During the Berner collection three 96-hour back trajectories were calculated using the NOAA hysplit model (http://www.arl.noaa.gov/ready/hysplit4.html). During three sampling episodes small particle probes were collected for scanning electron microscopy (SEM).

Results

Depending on the meteorological conditions, the season, and the biological emission strength the constitution of PM was determined in 15 daily Berner samples (3 from an urban background site) and 12 MOUDI samples (2 from the background site) in the years 2003 and 2004. The traffic was nearly constant during all working day samples. Both, one MOUDI and one Berner sample were collected during a winter weekend.

The comparison of summer and winter means of mass concentration yields the typical differences in stages 2 and 3 with higher winter concentrations. This particle size class is mainly influenced by other sources than traffic, e.g., domestic heating and long range transport. On the other hand, the distribution of semi-volatile compounds between gas phase and PM is shifted between seasons, too.

The OC/EC concentration in PM is a significant indicator of the importance of traffic emissions on the PM constitution. The Figure 1 demonstrates the differences between two sites of PM collection. In the two size classes 0.056 - 0.100 μm and 0.100 - 0.180 μm the differences are the highest, which points to direct traffic emissions in these size classes.

The determination of trace elements and individual organic compounds in the coarse mode particles in all seasons hints to the re-emission of road dust by the traffic. The concentration of

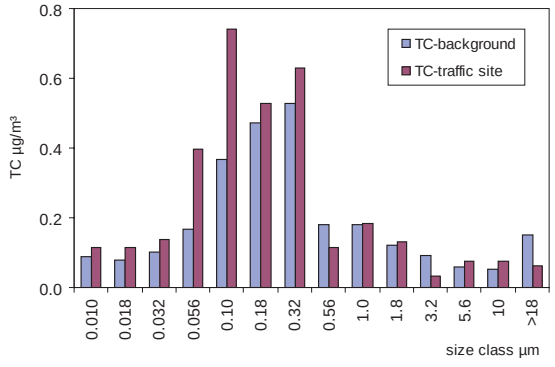

Fig. 1: *Comparison of TC (Total Carbon = sum of emental and organic carbon) content of in parallel collected MOUDI samples (09-12 Feb 2004) from the traffic site and the urban background station.*

biogenic alkanes in the coarse mode samples in summer is typically high from direct emissions of biomass (Figure 2) but in winter they were re-emitted from roads. The alkanes in Figure 2 show low concentrations for the C21 and C22 alkanes in PM but high for the C29 and C30 alkanes. Odd numbered alkanes were emitted from biogenic sources in higher concentration than even numbered. In particular this finding is obvious in the coarse mode particles.

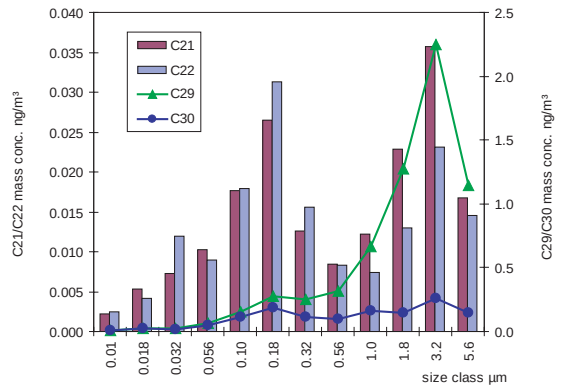

Fig. 2: *Concentration of the mainly traffic-related C21/C22 alkanes and the mainly biogenic C29/C30 alkanes in the MOUDI sample 28- 06 – 01-07 2004.*

The determination of further organic compounds (PAH and dicarboxylic acids) gave only minor traffic contributions. Dicarboxylic acids are mainly secondary compounds formed in the atmosphere by photochemical processes. The distribution over the size classes is similar to the mass distribution. PAH were emitted by traffic but much higher concentrations were found during winter sampling from domestic heating and other sources. Their distribution over the PM size classes has a maximum in the higher submicrometer particles (Berner stage 3: 0.42 - 1.2 μm; MOUDI: 0.32 – 1.8 μm), which do not reflect to traffic emissions. More detailed project results and implications are reported in *Gerwig et al*. [2005].

Summary

The aim of the project was to find the sources of PM_{10} at the traffic-dominated site in Dresden-Neustadt. Up to 70 % of PM_{10} was of anthropogenic origin. Traffic was responsible for 44 % of PM_{10}. Local traffic produced a quarter of the particulate matter (6 – 7 $\mu g/m^3$). This part was made of re-suspended dust, soot from exhaust pipes and tyre abrasion.

The mass fraction of diesel soot in aerosol in the particles increases with decreasing particle diameter. Measurements of smaller particles ($< PM_1$) are more adequate to characterize for this fraction of PM. About 1% of the particle mass at the street level consisted of trace elements of car brake linings, like antimony and copper, which were mostly found in the coarse PM fraction ($PM_{10-2.5}$) and where adverse health effects are also discussed.

PM concentrations higher than of the EU PM limitations are resulting from strong local emissions if they coincide with back-ground air masses already containing high concentrations of secondary aerosol.

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Emissions from passenger cars: on-road measurements and modeling

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Ein neuartiges Messsystem zur Untersuchung der Emissionen eines einzelnen PKW sowie deren Verdünnung und Transformation wurde in den letzten Jahren am IfT entwickelt. Bei Messungen an einem Opel Astra Diesel hat sich gezeigt, dass die Aerosolgrößenverteilung in den meisten Fällen von einem Russmode (D_p ~ 50 nm) dominiert wird. Unter extremen Fahrbedingungen mit hohen Drehzahlen (> 3800 U min^{-1}) wurde ein zusätzlicher Nukleations-Mode beobachtet. Das Besondere an diesen Messungen ist, dass zum ersten Mal das „eigene" Abgas eines auf öffentlichen Straßen fahrenden Pkws gemessen wurde und auch zum ersten Mal signifikante Nukleation während des Betriebs eines Diesel-Pkws mit Niedrigschwefelgehalt gemessen wurde.

Die gekoppelte 3-D Strömungs- und Aerosol-Modellierung bestätigte das Auftreten signifikanter Nukleation nur bei extremen Fahrbedingungen. Zudem konnten wesentliche Charakteristika wie Temperatur und Konzentrationsfelder der Abgasfahne recht gut reproduziert werden. Das Wachstum der Nukleations-Mode Partikel konnte nicht mit reiner H_2SO_4-H_2O Kondensation erklärt werden. Deshalb wurde ein Anteil an (gering) flüchtigen Kohlenwasserstoffen am Kondensationswachstum vereinfacht mitberücksichtigt. Dies führte zu einem Aufwachsen der Nukleations-Mode Partikel bis zu dem gemessenen Durchmesser von ~ 15 nm.

Vehicle particle emissions are studied extensively because of their adverse health effects, their contribution to ambient PM levels and their possible impact on climate. Main sources of ultrafine particles (D_p≤100 nm) are Diesel vehicles. The aim of this work is to obtain a better understanding of dilution and transformation processes within a passenger car exhaust plume for typical atmospheric and on-road conditions.

Particle and exhaust gas measurements were made on public roads. The measurement devices and data acquisition were placed inside the car and the inlet and sensor system was mounted on a bicycle rack behind the car. The motivation for concomitant simulations is to gain insight into several important simultaneous processes affecting new particle formation. Therefore, the dilution and aerosol dynamics within and around the exhaust plume are modeled using computational fluid dynamics software (FLUENT 6, www.fluent.com) coupled with the aerosol model FPM (Fine Particle Model www.particle-dynamics.de).

This work uses a fully coupled (Euler/Euler - FLUENT/FPM) approach. A 3-D geometry of the test-car was created placed in a computational wind tunnel using about 260000 grid cells. A k- ε turbulence model was used. A model system for the simulation of H_2SO_4-H_2O-soot particles (core-mantle) was developed. In order to reduce numerical stiffness and to save CPU time for H_2SO_4-H_2O growth, an equilibrium approach for water was utilized using a parameterization to compute the particle composition (from H. Vehkamäki). Nucleation was calculated according to *Vehkamäki et al*. [2003].

Exhaust gas flow, composition and soot mode particle fluxes were prescribed based on fuel consumption, air/fuel ratio, vehicle operating conditions and exhaust temperature measurements. Exhaust gas composition and fuel/air ratio were chosen according to motor test bench measurements. The exhaust soot-mode particle flux was adjusted to fit number concentrations measurements at 0.45 and 0.9 m distance behind the exhaust tailpipe. The $H_2SO_{4(g)}$ exhaust flux was used as a free parameter and related to fuel sulfur content (FSC) and SO_2-to-SO_3 conversion rate (CR).

V km/h	rpm min^{-1}	N_{nuc} cm^{-3}	$d_{g\text{-}nuc}$ nm	σ_{nuc}	N_{soot} cm^{-3}	$d_{g\text{-}soot}$ nm	σ_{soot}
		-	-	-	9e6	45	1.6
120	2600	-	-	-	4e6	51	1.6
		1e6	10	1.3	8e6	48	1.9
148	3200	-	-	-	3e6	52	1.7
		5e7	6	1.9	1e7	44	1.8
148	4000	2e7	11	1.5	5e6	45	1.6

Tab. 1: *PM Emissions: Data sampled at 0.45 m (upper values) and 0.9 m (lower values) centerline distance behind the exhaust pipe. Mean values were obtained by fitting SMPS size distributions to a log-normal form from 10 scans.*
V is the test car velocity, rpm denotes revolutions per minute, N_{nuc} and N_{soot} are the number concentrations of nucleation and soot mode particles, dg denotes the geometric mean diameter, and σ is the standard deviation.

Particle size distribution measurements at 0.45 m and 0.9 m distance within the exhaust plume indicate a dominant, consistent soot mode at 48 (±4) nm and number concentrations of up to 10^7 cm^{-3} depending on car operating conditions (see Table 1). The test car (2l/74 KW, oxidation catalyst, Euro 3) was run with low sulfur fuel (<10 ppm). High nucleation particle (D_p≤15 nm)

concentrations (>10^7 cm^{-3}) were only recorded under extreme driving conditions such as strong acceleration or high speed (>140 km/h) and high rpm (>3800 rpm), see Figure 1. These conditions were characterized by high exhaust temperature (550 K) and high NO_x concentrations (124 ppm at 0.45 m and 62 ppm at 0.9 m).

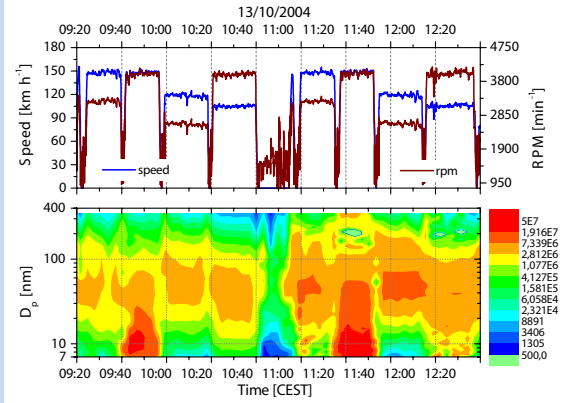

Fig. 1: *Measured vehicle speed and rpm (top), evolution of the size distribution (bottom) on the motorway A38, on 13 October 2004.*

The CFD model was verified against measurements within the exhaust plume. For temperature, humidity and CO_2 a good agreement between measurements and simulation results was obtained. The simulations revealed the importance of an accurate description of turbulent species and particle transport. Due to the short residence time of exhaust particles in the first 10 m of the plume, coagulation has only a minor impact on their fade. In particular, turbulent diffusion of soot and nucleation mode particles is attributable for the measured decrease of number concentrations within the exhaust plume. A soot mode particle flux of 10^{13} s^{-1} ($2.6 \cdot 10^{14}$ km^{-1}) was determined for conditions representing ~150 km/h and high rpm (4th gear, ~4000 min^{-1}).

The simulations showed a strong sensitivity towards $H_2SO_{4(g)}$ fluxes: $9 \cdot 10^{-7}$ mol s^{-1} resulted in up to $2 \cdot 10^7$ cm^{-3} at 0.5 m and $1 \cdot 10^7$ cm^{-3} at 1 m distance behind the exhaust pipe (see Figure 2). Compared with measurements a good agreement with the number concentration pattern was obtained.

Highest nucleation rates are located where gradients of temperature, humidity and $H_2SO_{4(g)}$ are strongest and dilution as indicated by CO_2 (Figure 3) is strongest. The simulated $H_2SO_{4(g)}$ exhaust flux of $9 \cdot 10^{-7}$ mol s^{-1} corresponds to a FSC of 350 ppm at a CR of 0.03 or to a FSC of 10 ppm and a CR of 1. In these simulations ambient humidity was set in good accordance with the measured humidity to 65% RH. However, due to limitations in the parameterizations used (temperature range 300-400 K) the model

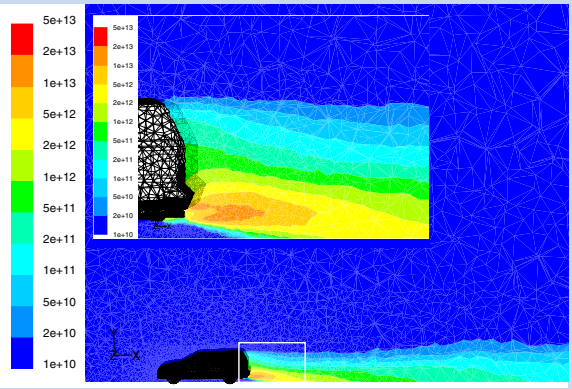

Fig. 2: *Cross section for simulated N (m^{-3}) in the exhaust pipe plane.*

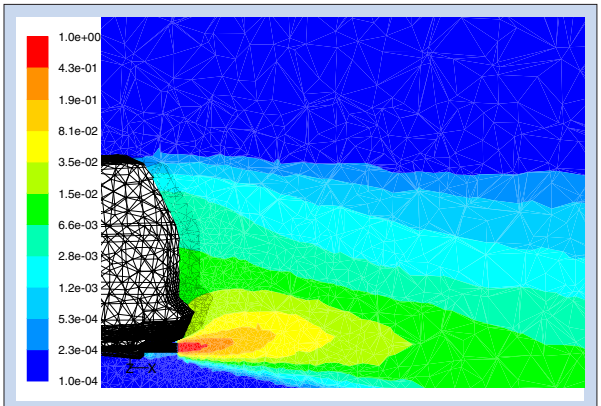

Fig. 3: *Cross section for simulated CO_2 dilution ratio in the exhaust pipe plane.*

ambient temperature was set ~15 K higher than the measured one to 300 K. Extrapolating the parameterization beyond the validated range requires ~$3 \cdot 10^{-7}$ mol s^{-1} $H_2SO_{4(g)}$ exhaust flux to obtain number concentrations similar to measured ones (~ a FSC of 10 ppm and a CR of 0.33).

High nucleation particle number concentrations were recorded only under very high engine load conditions. Our results based on measurements and simulations suggest that this is due to the low sulfur fuel used, strong dilution, high SO_2 to SO_3 conversion rates and additional sulfur contributions from lube oil and purging of stored sulfur. High exhaust temperatures on the oxidation catalyst favor high conversion rates [*Maricq et al.*, 2002]. In turn, high conversion rates of fuel sulfur and additional sulfur as suggested by [*Maricq et al.*, 2002] can justify the $H_2SO_{4(g)}$ fluxes used in our simulations resulting in up to $5 \cdot 10^7$ cm^{-3}.

The simulated growth of H_2SO_4-H_2O nucleation particles was unrealistically low (see Figure 4) to explain measured nucleation particle concentrations. The reason for the simulated insufficient growth is the limited condensable H_2SO_4-H_2O vapor mass opposed to the strong condensational sink of soot mode particles. Hence, other low or semi-volatile condensable species

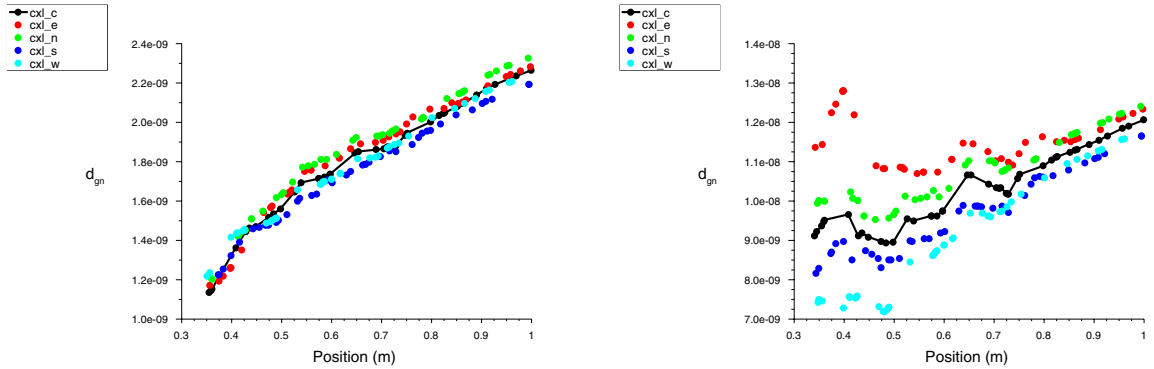

Fig. 4: *Simulated d_g in m near exhaust plume region for nucleation particles consisting of H_2SO_4-H_2O (left) and simplified H_2SO_4-H_2O-HC (right), cxl-c is the centreline of the exhaust pipe, cxl-w, cxl-e, cxl-n, and cxl-s are shifted 2 cm to the left, right, upward and downward. Note the different scale on the y-axis. Measured fitted values at 0.45 m are: 6-10 nm, at 0.9 m: 11-16 nm.*

such as hydrocarbons are required to explain size and number concentration of measured nucleation particles. The simplified condensational growth of octane and gas-oil hydrocarbons between the exhaust pipe exit and ~1 m distance is fast enough to grow particles up to 10 nm and larger in this region (Figure 4).

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Formation and dispersion of secondary particles by cooling tower emissions in Saxonia

Detlef Hinneburg, Eberhard Renner, Ralf Wolke

Der Einfluss der Großkraftwerke Boxberg und Lippendorf auf die Feinstaubbelastung (PM_{10}) in Sachsen wird durch Anwendung eines Meteorologie-Chemie-Transport-Modells simuliert. Schwerpunkt der Untersuchungen ist die zu erwartende Ammoniumsulfat- und -nitratbildung, verursacht durch die beträchtlichen SO_2- und NO_x-Emissionen der Kühltürme.

Introduction

Atmospheric particulate matter (PM) in ambient air has been associated with human health effects. Since respiration is the only route of exposure in this regard and particles with aerodynamic diameters smaller than 10 μm (PM_{10}) are able to pass the larynx, the European air quality standards prescribe a limit for PM_{10}.

Techniques introduced to reduce primary particulate emissions by traffic, industry, agriculture and other sources have led to substantial success. Currently, the focus of environmental sciences and politics includes the secondary formation and growth processes of particles.

To observe the fate of power plant emissions in terms of secondary particles, the inorganic chemical species and first of all the formation of ammonium sulfate and ammonium nitrate have to be investigated. The dominant contribution to increasing particle mass is given by heterogeneous condensation of gaseous compounds on pre-existing aerosol particles. Especially the reactions of ammonia with sulphuric and nitric acids and their generation by several paths from the precursory species SO_2 and NO_x are relevant. An additional effective path of the ammonium sulfate formation results from the direct reaction of emitted free sulfate ions with ammonia.

The complex process of formation, growth, transport and deposition of particulate matter will be strongly influenced by the meteorological conditions and the effective height of the emission sources. These factors essentially modify the original processes and have drastic consequences for the resultant concentrations near the surface.

The present work tries to estimate, to which extent the exhaust of some natural-draft cooling-towers contributes to the formation of secondary particles in the context of overall gas and particle emissions in an industrial region of East Germany. The study is performed for long-term real-weather situations of a summer and a winter period (for details see *Hinneburg et al*. [2005]).

Model description

The parallelized model system consists of two online coupled components:

(1) Meteorological model: The operational weather model LM (Local Model) [*Doms and Schättler*, 1999] of the German Weather Service solves the governing equations of the atmosphere in a limited area with the facility of self-nesting and four-dimensional data assimilation. The model describes the atmospheric flow and phenomena between the meso-β and micro-α scale (i.e., with grid resolutions between 50 km and 50 m), particularly with regard to the near-surface properties, convection, clouds, precipitation, orographical and thermal wind systems.

(2) Chemistry-transport model: Driven by the meteorological model, the model MUSCAT (Multi-Scale Atmospheric Transport Model) [*Wolke and Knoth*, 2000] simulates the transport of the air pollutants, i.e., advection, diffusion, sedimentation, and deposition, together with the chemical reactions. Due to the online-coupling with LM, the calculations are involved in the time loop of the meteorological model, exploiting the current atmospheric conditions. The time integration scheme operates independently from the meteorological model, thus allowing for autonomous time steps and different horizontal grid resolutions in selected regions of the model domain.

The chemical part of MUSCAT comprises the gas phase mechanism of RACM considering 76 reactive gas species (e.g., NO_x, CO_x, O_3, SO_2, NH_3) with 217 chemical and 22 photolytic reactions. The particle phase and appropriate gas-particle interactions are also included. The variable radiation activity, biogenic and anthropogenic emissions (incl. plume rise) as well as the actual cloud cover, temperature, and other meteorological parameters taken from LM are utilized. In case of only annual emission data available, adequate time-split functions are applied for an hourly disaggregation.

This study focuses to the secondary formation (growth) of anorganic particles with sizes below 10 μm (PM_{10}). Dominant contributions are provided by the heterogeneous condensation of gaseous compounds on pre-existing aerosol particles, e.g.,

ammonia and sulfuric or nitric acid. The complex reactions starting from emitted precursor gases are schematized by Figure 1.

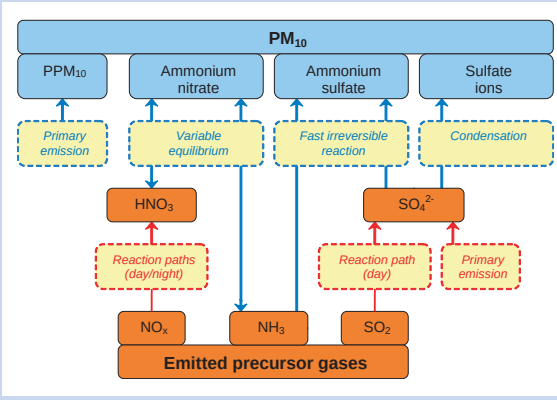

Fig. 1: *Secondary particle formation from emitted precursor gases.*

Simulation setup

The model system LM-MUSCAT was applied in a nested hierarchy with a superior control by the global re-analysis data of GME (Global Model of the Earth). The region of interest (Saxony) resolves an area of 240 km x 156 km by a variable grid space between 2.8 km and 0.7 km with the finest resolution around the dominant emission sites Boxberg and Lippendorf. The outer region (Central Europe) extends over 1200 km x 1000 km largely with a resolution of 8 km. Two typical summer/winter periods of both 36 days in 2002 were chosen for the simulations. The plume rise of the cooling towers in dependence on the meteorological conditions was accounted for by utilizing the adequate model of *Schatzmann and Policastro* [1984]. The simulations were repeated with the cooling tower emissions switched off. The difference between the switch-on/off simulations allows to extract the direct and indirect influences of these emissions on the immission situation in Saxony. The presumed partitioning of the respective SO_2 emissions (88% SO_2, 12% free sulfate ions) determines the results decisively.

Results

The results can be summarized as follows (Figure 2 presents an example):

1.) Significant influence of the cooling tower gas emissions on the particle immission situation can be noticed only within limited zones of very narrow (highly concentrated) plumes and mainly for several hours around noon in summer.

2.) The intrinsic particle formation caused by the considered emission sites frequently reaches peak values of about 10 $\mu g/m^3$ PM_{10} (maximal 20 $\mu g/m^3$), consisting predominantly of ammonium sulfate. Primary particles and ammonium nitrate formation contribute to only 10%.

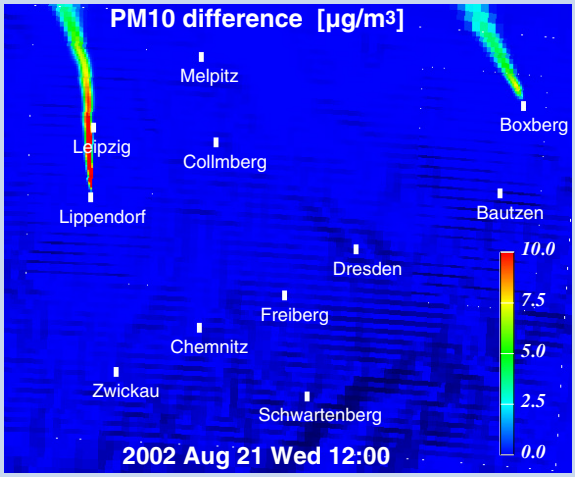

Fig. 2: *PM_{10} concentration in Saxony caused solely by the emissions in Boxberg and Lippendorf at 12:00 on August 21th 2002.*

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Size-segregated chemical characterization of aerosol particles depending on air mass origin at Melpitz (Germany)

Gerald Spindler, Konrad Müller, Thomas Gnauk, Erika Brüggemann, Hartmut Herrmann

Partikelkonzentrationen können bereits außerhalb von Ballungsgebieten in Abhängigkeit von Jahreszeit und meteorologischen Bedingungen kritisch hohe Werte bezüglich des EU-Grenzwertes von 50 µg m^{-3} (Tagesmittel) erreichen. Masse und Zusammensetzung (wasserlösliche Hauptionen und Kohlenstoffgehalt) von Partikeln PM_{10}, $PM_{2.5}$ und PM_1 wurden in Abhängigkeit von der Hauptanströmung (West – maritim und Ost – kontinental) an der Forschungsstation Melpitz ermittelt. Dafür wurden tägliche Proben von Filtersammlern mit großem Volumenstrom verwendet. Die Zuordnung der Anströmung erfolgte mit 96-Stundenrückwärtstrajektorien. Es zeigen sich deutlich erhöhte Massekonzentrationen bei Anströmungen aus östlicher Richtung. Besonders im Winter werden große Anteile Sulfat, Nitrat und Kohlenstoff nachgewiesen. Der relative Massenanteil wasserlöslicher Ionen und von Kohlenstoff an der Gesamtmasse nimmt von PM_{10} zu PM_1 hin zu.

The mass concentration of airborne PM (particulate matter) is in the focus of environmental sciences and policy. Particle sources can be caused naturally and antropogenically by industrial, volcanic and mechanical processes at the earth surface (primary particle formation) or by different tropospheric processes (secondary particle formation).

The main ionic aerosol constituents are ammonium (NH_4^+) nitrate (NO_3^-) and sulphate (SO_4^{2-}). Their source process is the gas-to-particle conversion [*Vayenas et al.*, 2005]. Non-volatile aerosol species (e.g. mainly NaCl, Na_2SO_4, $CaSO_4$ and $(NH_4)_2SO_4$) and semi-volatile inorganic components, such as ammonium nitrate (NH_4NO_3) and ammonium chloride (NH_4Cl), exist. They are formed from the trace gases NH_3, HNO_3 and HCl via reversible phase equilibria [*Pio and Harrison*, 1987; *Plessow et al.*, 2005]. Carbonaceous aerosol particles are of variable composition. Small particles from high temperature combustion contain predominantly EC (elemental carbon) and only a very small fraction of OC (organic carbon). Transformation processes in the troposphere cause to the uptake of hygroscopic material such as gaseous organic compounds and condensation of non-volatile organic compounds produced by photochemical processes and increase the OC/EC ratio by secondary formed OC [*Griffin et al.*, 1999]. Aged particles should show a higher OC/EC ratio than particles in the vicinity of emission sources.

As a consequence, the main components of ambient PM are nitrate, sulphate, ammonium, OC, EC and water-insoluble species, the latter mainly from soil dust. The relative content of these PM components changes with source, distance from source, time of day and season. Particles with different diameter show different chemical distribution. The physical properties of particles e.g. aerodynamic diameter and higroscopic growth – are of relevance for lifetime, cloud processing and transport [*Mertes et al.*, 2005]. PM can influence climate and has varying influences on human health.

An EU-Council Directive [*EU-Commission*, 1999] established 2005 a strong regulation of the atmospheric daily mean mass concentration of PM_{10} to a maximum value of 50 $\mu g\ m^{-3}$ limited to be exceeded no more than 35 days per year. The annual mean for PM_{10} has to be $< 40\ \mu g\ m^{-3}$.

Concentrations higher than the daily maximum mean value for PM_{10} in the cities are caused by complex reasons (e.g. traffic, domestic heating, and resuspension of particles). Also high particle mass concentrations observed over a wide area in the surrounding of a conurbation can be contribute to the number of days with exceeded PM_{10} values in a city. The appearance of such situations depends mainly on meteorological conditions. For a size-segregated chemical characterization of the aerosol outside of an urban area samples from the IfT-research station Melpitz [*Spindler et al.* 2004] are used. The main wind directions are mostly west and secondly east for maritime and continental air masses, respectively. From June

Fig. 1: *High volume filter samplers for PM_{10}, $PM_{2.5}$ and PM_1 at Melpitz site.*

2004 up to October 2005 at Melpitz particle filter samples were collected daily (24 hour samples) for PM_{10} and $PM_{2.5}$ and every six days for PM_1 on quartz fibre filters using high volume samplers (DIGITEL DHA-80). Figure 1 shows the samplers at Melpitz. The particle mass concentration was determined gravimetrically with a micro balance (20 °C, 50% relative humidity). Water-soluble ions were quantified using standard ion chromatography. The determination of OC and EC was performed by a 2-step thermographic method

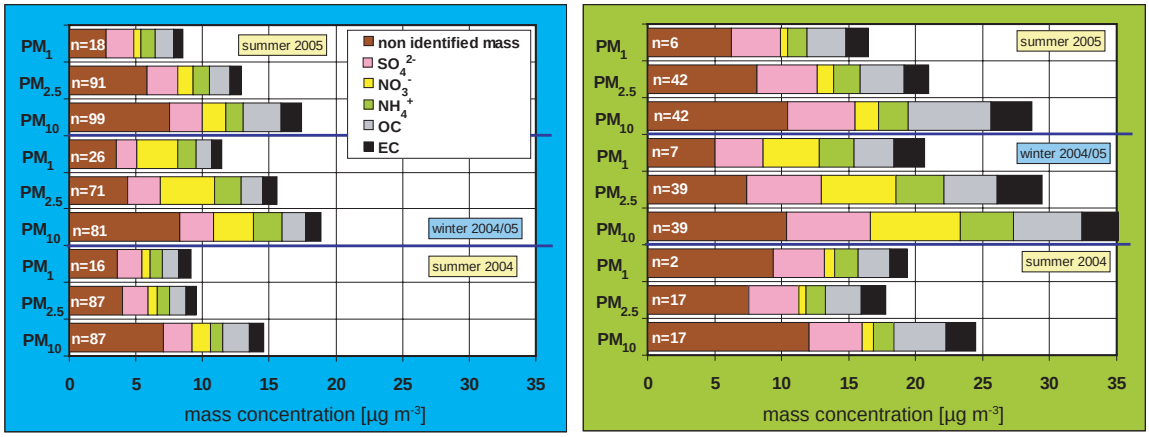

Fig. 2: *Mass concentration means for PM_{10}, $PM_{2.5}$ and PM_1 maritime (blue frame) and continental air masses (green frame) for summer 2004, winter 2004/05 and summer 2005 at Melpitz site (n, number of days included in the mean).*

applying a Ströhlein C-mat 5500 carbon analyzer.

The days for the sectoral averages were selected following the two main air stream directions, west (maritime) and east (continental) from the data set of measurements PM_{10} (495 samples), $PM_{2.5}$ (470 samples) and PM_1 (98 samples) using 96-backward trajectories (level 200, 500 and 1500 m above ground) for 10:00 and 18.00 (CET). A distinction for summer (first of May up to 31 of October) and winter (first of November up to 30 of April) was done additionally.

Figure 2 presents the means distinguished as a function of particle size, air mass origin and season. In principle the concentration means for continental air masses are absolutely higher than for maritime air masses. Reasons are the different meteorological conditions. During days with westerly winds the mean wind velocity is often high and rain showers are frequent, as opposite. During easterly winds high-pressure conditions exist with dry air masses and moderate wind velocities. The main source regions for maritime air masses are Germany, Benelux, France and adjacent sea surfaces, for continental air masses the source regions are Poland, Belarus, Ukraine and the Czech Republic. In these areas, in contrast to Western Europe, coal-fired power plants with little exhaust treatment, old industry and older cars still exist. For the maritime air masses the differences between summer and winter are low but in summer more coarse particles (PM_{10}-$PM_{2.5}$) exist, mostly resuspended from dry soil surfaces. In winter higher mass concentration were detected for SO_4^{2-}, NO_3^-, and NH_4^+ from semi-volatile inorganic components. The highest values for $PM_{2.5}$ and PM_{10} were reached in continental air masses during winter. Then anthropogenic emission rates are the highest and mixing heights are low. In this situation the (PM_{10}-$PM_{2.5}$) fraction is relatively small, that means relatively more particles situated for long range transport with long lifetimes are in the troposphere. Therefore continental weather conditions in winter are often connected with high particle mass concentrations in a wide area. In these situations PM_{10} mass concentrations at Melpitz reach often more than 50 $\mu g\ m^{-3}$ but also concentrations somewhat lower contribute to an urban concentration exceeding the daily maximum value of 50 $\mu g\ m^{-3}$.

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Aerosol Optical Properties in the Pearl River Delta, China

Ya-Fang Cheng, Heike Eichler, Alfred Wiedensohler, Ronny Engelmann, Dietrich Althausen, Albert Ansmann, Thomas Gnauk, Erika Brüggemann, Hartmut Herrmann, Yuan-Hang Zhang, Min Hu, Shang Liu, Ling-Yan He

Im Oktober 2004 beteiligte sich das IfT an dem „Observation Experiment for Regional Air Quality in Pearl River Delta of China". Die Messungen konzentrierten sich auf die optischen Eigenschaften des hoch verschmutzten Aerosols in dieser Region. Hierzu wurden bodengebundene in-situ Messungen als auch Fernkundungsmethoden zur Charakterisierung des Verschmutzungsgrades der gesamten Dunstschicht bis in rund 3 km Höhe eingesetzt. Die Ergebnisse lieferten extreme Werte sowohl für die Streu- und Absorptionskoeffizienten am Boden als auch für die Extinktionskoeffizient-Verteilung in der Säule. Die optische Schließung der Streu- und Absorptionskoeffizienten am Boden konnte durch die Modellierung des Mischungszustandes von schwarzem Kohlenstoff erreicht werden. Messungen des Feuchtewachstums als auch der chemischen Zusammensetzung ermöglichten die Modellierung des Extinktionskoeffizienten und des Lidarverhältnisses bei Außenluftfeuchten. Der Vergleich der vom Ramanlidar gemessen Werte im Vergleich zu den berechneten liegen im Unsicherheitsbereicht der Messungen und Berechnungen. Die Lidarmessungen belegen die enorme Verschmutzung anhand der gemessenen sehr hohen Extinktionswerte und optischen Dicken innerhalb der gesamten Dunstschicht.

Introduction

The region of the Pearl River Delta (PRD) is one of the most densely populated areas of China (more than 50 million inhabitants) and with one of the country's highest concentration of industry. In PRD, there are 10 major cities, including Hong Kong, Guangzhou (Canton), Shenzhen and Macau, and also many small towns and farms interspersed. The rapid industrialization in PRD, as well as the increasing population, is accompanied by significant increases in regional pollution of air, water and soil. The air pollution is especially due to high concentrations of aerosol particles and can be recognized daily by the strong reduction of the visibility.

Tropospheric aerosols affect Earth's climate by altering the radiative properties of the atmosphere through the direct effect of scattering and absorbing sunlight and the indirect effect by changing the properties of clouds [*Intergovernmental Panel on Climate Change (IPCC)*, 2001]. The direct climate forcing of aerosols is difficult to quantify, which is mainly due to: (1) the complex connection between the radiative effects of tropospheric aerosol particles and their physical and chemical properties; (2) their inhomogeneous spatial and temporal distributions [*Seinfeld and Pandis*, 1998; *Quinn and Coffman*, 1998; *Bond et al.*, 1998].

The proposed research strategy to quantify and minimize the uncertainties of climate forcing by anthropogenic aerosols includes ground-based observations of aerosol chemical and physical properties and modeling studies to demonstrate consistency between the observations as well as to provide guidance for determination of the most important parameters [*Swietlicki et al.*, 1999]. To understand the optical behavior of the aerosol in PRD of China, knowledge about the 3-dimensional distribution and properties of the particles is needed. The key parameters are the number and mass size distribution, light scattering and absorption coefficients, and size-resolved chemical composition. Furthermore, information on the vertical distribution such as the vertical distribution of the extinction coefficient is needed to understand the influence of the aerosol pollution in the whole boundary layer.

A substantial part of the direct aerosol forcing is due to black carbon (BC) on the absorption coefficient. Here, the mixing state of BC with other aerosol species and the relative dependence of aerosol optical properties are critical for adequate evaluation of aerosol direct radiative effect and ensuing impacts on climate.

Experimental Design and Location

As part of the *Observation Experiment for Regional Air Quality in Pearl River Delta of China*, measurements of aerosol optical, chemical and physical properties were conducted from 4 Oct to 5 Nov 2004 (278-310 DOY (Day of Year)) at Xinken (22.6°N, 113.6°E, cf. Figure 1), which is located downstream (near the mound) of the Pearl River on the northwest-southeast axis between Canton and Hong Kong (also Shenzhen). The intention was to understand better the regional air quality and radiation transfer for this area. The air pollution at the Xinken site is not only caused by regional transport but also by many local sources, such as biomass burning, cooking and the diesel-fueled shipping on the Pearl River. Moreover, an oil-refinery about 2.5 km northwest of the measurement site might have influenced

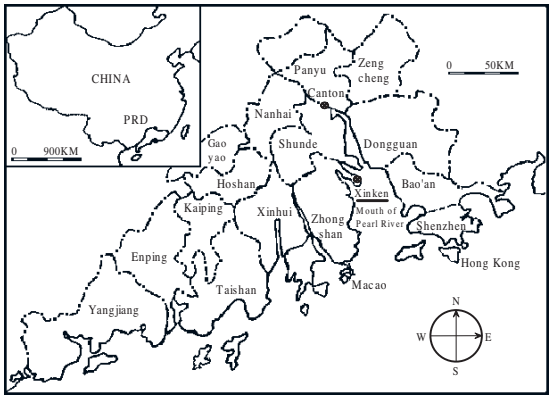

Fig. 1: *Location of Pearl River Delta (PRD) and the measuring site Xinken.*

the measurements during certain meteorological conditions. Traffic on the road leading to the Xinken site is not very dense and therefore does probably not contribute significantly to the local air pollution.

During the campaign, ground-based measurements were taken mainly in a movable container. The measured properties of atmospheric aerosol particles and the instrumentation are summarized in Table 1.

Measured property	Specification	Instrumentation
Number size distribution (dry)	3 nm < Dp< 900 nm	Mobility size spectrometer
	0.8 µm < Dp< 10.0 µm	Aerodynamic particle sizer
Number size distribution (different re. humidities)	22 nm < Dp< 900 nm, RH = 30, 55, 75, 90%	Humidified mobility size spectrometer
Total and back scattering coefficients	PM_{10}, λ = 450, 550, and 700 nm	Integrating nephelometer
Absorption coefficient	PM_{10}, λ = 630 nm	MAAP
Mass size distribution	0,05-10 µm	10-stage MOUDI
Chemical composition	0,05-10 µm	10-stage MOUDI
Vertical extinction profile	532 nm	Raman-Lidar

Tab. 1: *Properties of atmospheric aerosol particles and the instrumentation used for the measurements at Xinken site of Peal River Delta (PRD, China, 2004).*

Ground-based In-situ Measurements

General Observations

Winter and fall are the most polluted seasons in the PRD area [*Wu et al.*, 2005]. During the measurement campaign (278-310 DOY) high aerosol concentrations were found, which were

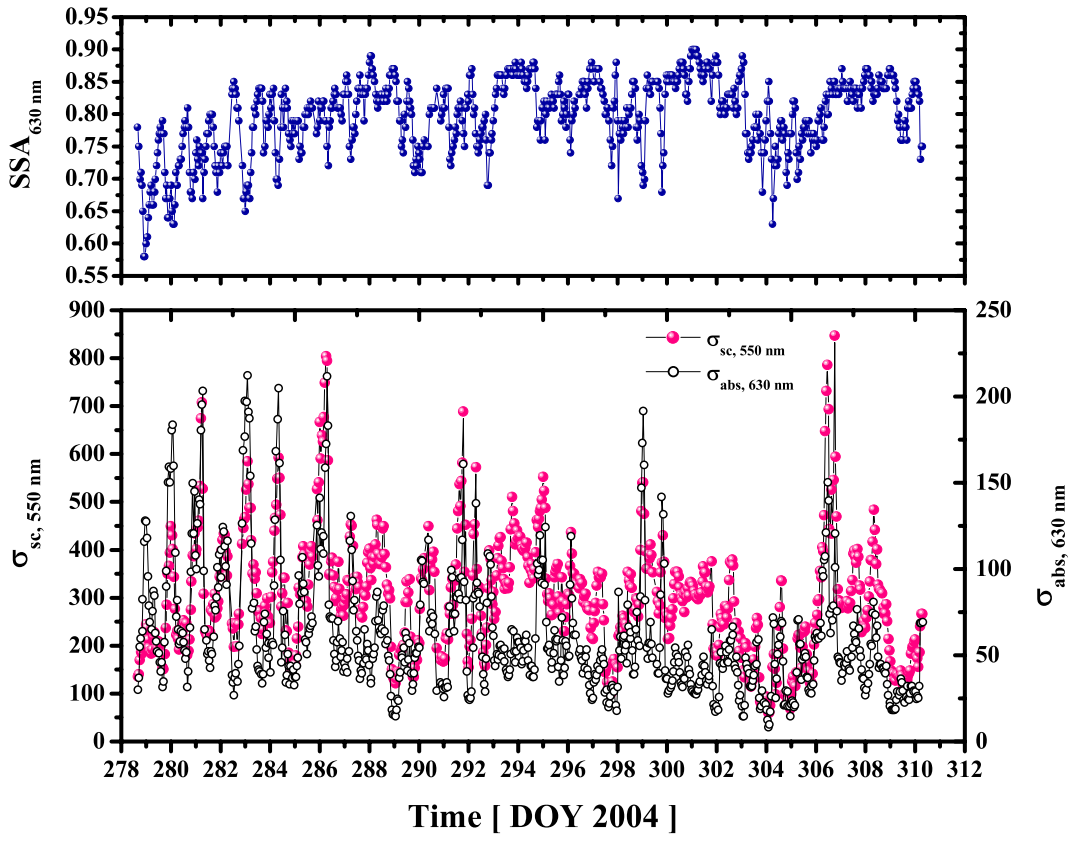

Fig. 2: *Time series of 1h average aerosol light scattering coefficient (550 nm) and aerosol light absorption coefficient (630 nm), as well as the single scattering albedo (SSA 630 nm).*

also clearly seen in the observations of Raman lidar and sun photometer [*Ansmann et al.*, 2005]. The ground-based measurements experienced four pronounced pollution-episodes, around Oct 7-11, 16-19, 24-25 and Nov 1 of 2004 (cf. Figure 2). During October or November in the former years, three to four such meteorology-related pollution episodes in the Hong Kong area were found in previous studies [*Man et al.*, 2001]. Averages and standard deviations of the scattering coefficients ($\sigma_{sc,Neph}$ and $\sigma_{bsc,Neph}$) and the absorption coefficient ($\sigma_{abs,MAAP}$) are summarized in Table 2.

Optical properties of the dry aerosol	Average	Std	Min	Max	N-hour
Scattering coefficient 550 nm (Mm^{-1})	300	122	60	847	737
Absorption coefficient 630 nm (Mm^{-1})	61	36	8	213	737
Single scattering albedo 630 nm	0.80	0.06	0.58	0.90	737

Tab. 2: *Average and extreme values of the scattering coefficient at 550nm, the absorption coefficient at 630nm and the single scattering albedo at 630 nm.*

Closure study on the optical properties of dry particles and the mixing state of black carbon

The microphysical and optical properties of dry aerosol particles at the Xinken site were evaluated with a numerical closure study for the light scattering and absorption coefficients. Furthermore, the influence of the mixing state of BC within the complex aerosol particles was investigated, as an important factor controlling the light absorption coefficient.

A two-component optical aerosol model was assumed for the numerical closure study. The aerosol particles were classified into absorbing and non-absorbing ones. Except for BC, all other particulate compounds were considered to be non-absorbing, including sulfate, ammonium, nitrate, and organic carbon (OC). Based on in situ aerosol microphysical and chemical measurements, the dry aerosol light absorption and total/back scattering coefficients were reconstructed with two extreme mixing assumptions (external and internal mixtures) utilizing a Mie-code, to derive boundary values for the real mixing state. The non-idealities of the nephelometer were incorporated into the Mie-calculations to simulate the actual measurements.

A mass mixing ratio of externally mixed BC to total BC was defined to quantify the mixing state of BC and the non-absorbing particulate matter. The rest of BC was assumed to be internally mixed. An internal consistency algorithm was developed to retrieve the optimum externally mixed mass ratio of BC, which minimized the discrepancies between measured and calculated optical properties. The flow chart of the method is presented in Figure 3.

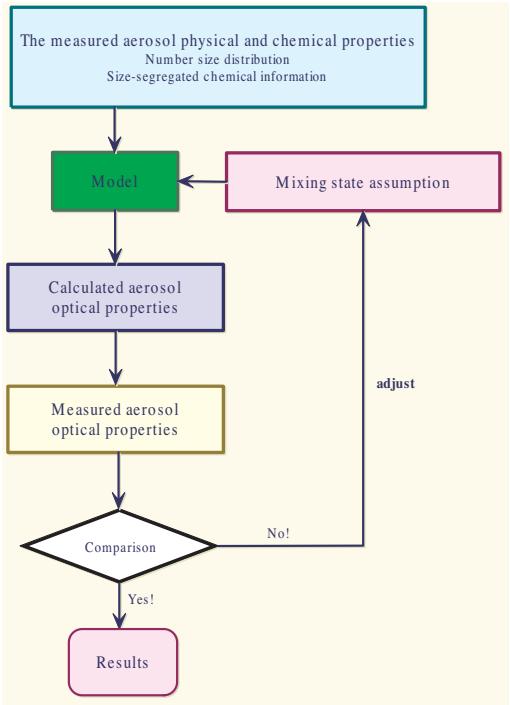

Fig. 3: *Flow chart of the modeling research*

It was found that the measured aerosol optical properties were enclosed by those calculated extreme values, especially concerning light absorption (cf. Figures 4 and 5). The absorption coefficient at 630 nm wavelength calculated by internal mixture was higher than that from external mixture by a factor of 2.3. On the other hand, total/back scattering coefficients for 550 nm from external mixture were a factor of 1.2 higher than those from internal mixture. The single scattering

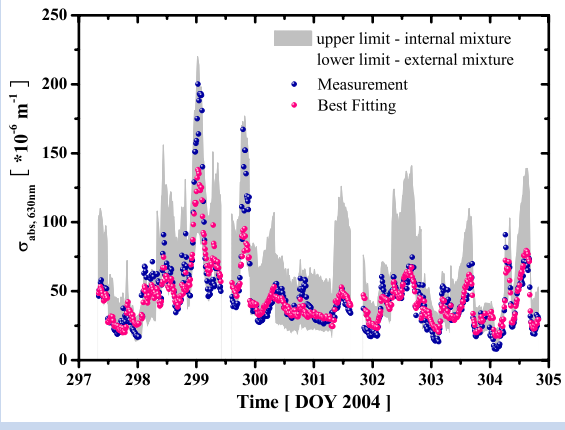

Fig. 4: *Time series of $\sigma_{abs,MAAP}$ and $\sigma_{abs,Mie}$ at 630 nm. The results of the Mie calculation are bounded by the upper and lower limits of the grey area, where the upper and lower limits correspond to calculations for internal and external mixture, respectively. The measured values $\sigma_{abs,MAAP}$ are represented by black solid points, while the $\sigma_{abs,Mie}$ calculated by the retrieved mixing ratio of externally and internally mixed BC are represented by open circles.*

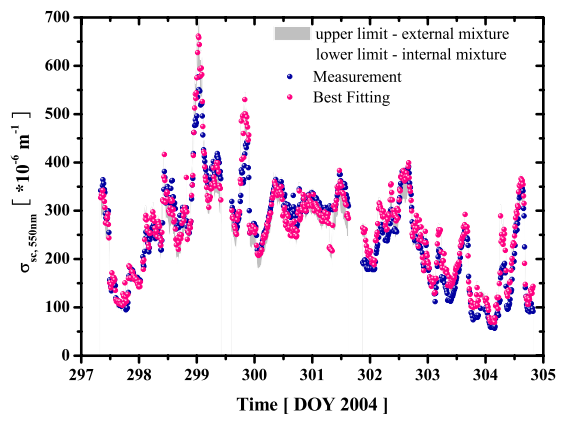

Fig. 5: Time series of $\sigma_{sc,Neph}$ and $\sigma_{sc,Mie}$ at 550 nm. The results of the Mie calculation are bounded by the upper and lower limits of the grey area, where the upper and lower limits correspond to calculations for external and internal mixture, respectively. The measured values $\sigma_{sc,Neph}$ are represented by black solid points, while the $\sigma_{sc,Mie}$ calculated by the retrieved mixing ratio of externally and internally mixed BC is represented by open circles.

albedo calculated from the external mixture was 20% higher than that from the internal mixture. Extinction coefficients and the asymmetry factors showed only a week dependence on the state of mixture.

A time series of this externally mixed mass ratio of BC to total BC was retrieved with a time resolution of 12 h. Good agreement between measured and calculated values was found, on the order of ±15% not only for the total/back scattering but also for light absorption. The discrepancies between calculated and measured optical properties were within the uncertainties of measurements and instruments. So if the state of aerosol mixing was properly accounted for, the model explains the observations.

The mixing state of BC was found to be strongly dependent on local circulation (cf. Figure 6). When north/northeasterly winds prevailed, the air came from the urban and industrial areas of Mainland China and the BC was mainly externally mixed with an average externally mixed BC ratio of 82 ± 14%. When the air flow at the measurement site was controlled by a weak wind system, the mixing state showed a pronounced diurnal variation. During daytime, the wind speed was nearly zero. This favored the increase of local pollution and the average externally mixed BC ratio was higher than 90%. This result, as well as the result conducted in the north/northeasterly winds prevailed period, were coherent with observations and simulations in a number of recent publications. These independent studies were made on the urban aerosols, which were close to the pollution source or only experienced a short transport. However, during nighttime, the mixing state of BC changed to be internally mixed with an average

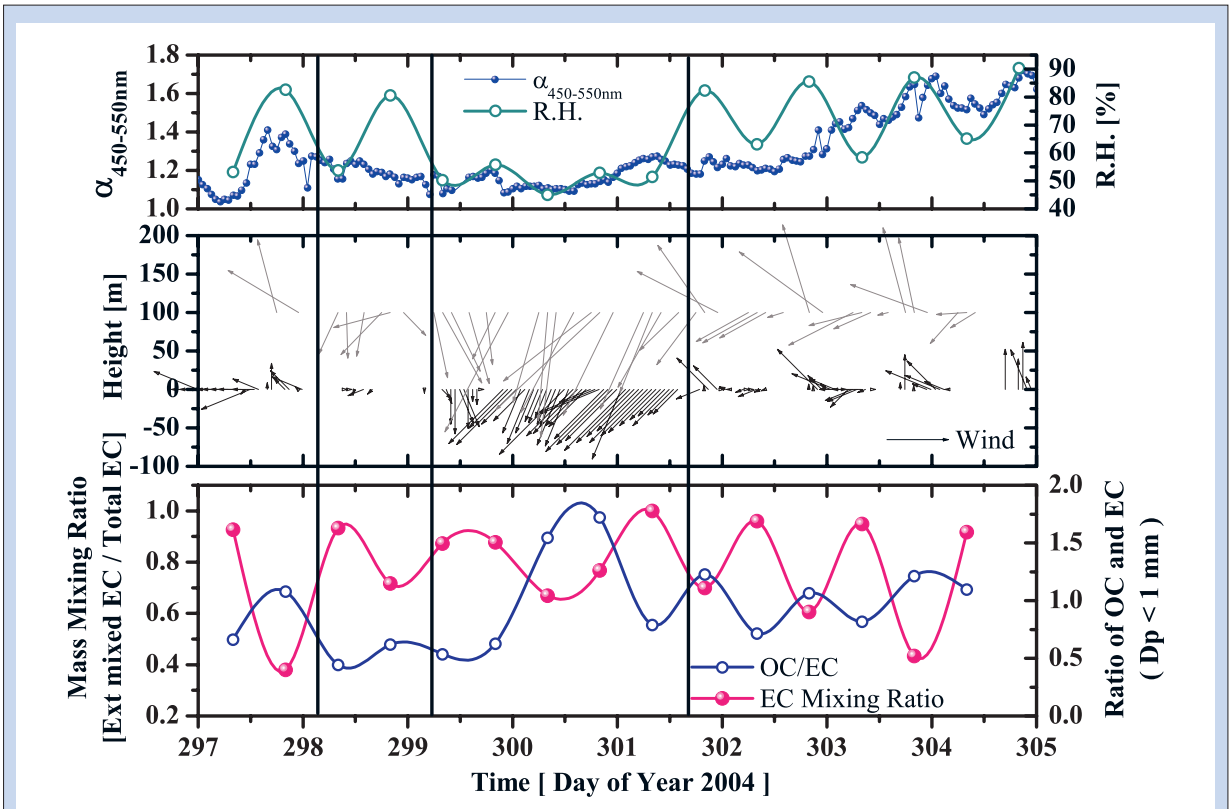

Fig. 6: Time series of the mass ratio of externally mixed BC to total BC with a time resolution of 12 h, as well as 1 h averaged Ångström exponent of 450-550 nm. Wind patterns are presented as vector at two vertical heights (ground level and 100 m), but the wind speed should be divided by 10.

externally mixed BC ratio of 44 ± 17%. There are several possible mechanisms for explaining this transformation of mixing state. One was a local aging of the aerosol particles. This hypothesis was substantiated by the result of the time period from DOY 298 to 299.3, characterized by low wind speeds during both day and night. The mixing state of BC transformed from external to internal mixture from day to night. But the local mixing state transformation was not as strong as that in the period when there were south/southeasterly winds coming from the sea (starting at around 20:00). These south/southeasterly winds coming from the sea were found to cause the most important effect on the transformation of mixing state in the night for our research area, and it indicated that the polluted air mass experienced a relatively longer transport passing the sea and changed to a more aged one.

Comparison between the externally mixed mass ratio of BC and the ratio of OC to EC was made. A pronounced negative correlation was found which means more aged air mass contained more internally mixed BC.

Aerosol hygroscopic growth

Optical properties of atmospheric particles may vary with ambient relative humidity because of hygroscopic growth. In order to know how much a dry particle can grow as a result of increasing ambient relative humidities, a HDMPS [*Nowak*, 2005] was used to measure the particle number size distributions of airborne particles at four controlled relative humidities of between 30 and 90% rh. These data were complemented by concurrent measurements of the TDMPS. With a statistical model, the so-called "quantile-method" [*Birmili*, 2005], the size-resolved descriptive hygroscopic growth factor was determined by relating the dry and humidified particle number size distributions measured with the TDMPS and HDMPS. From the ion-analysis of the impactor measurements the soluble volume fraction of the particles in the size range 100nm – 5.6μm was determined. Using a simple solubility model, the hygroscopic growth factor of each impactor stage was calculated as the sum of the growth factors of each compound multiplied with the corresponding volume fraction. After extrapolating the growth factors derived from both methods to particles with diameters of 22nm–10μm, the particle number size distributions at ambient relative humidities were determined for this size range. As an example, the size-segregated growth factors are presented in Figure 7.

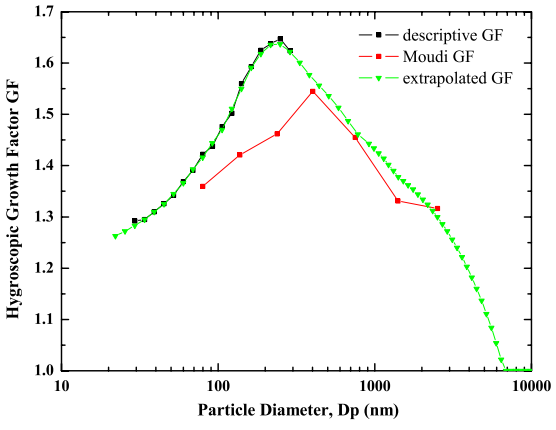

Fig. 7: *An example of the size-segregated hygroscopic growth factors at RH 90% (the daytime of 297 DOY 2004).*

Remote Sensing Observations

For the first time, through extensive profiling of particle optical properties, the vertical extent of the haze layer, aerosol stratification, and the diurnal cycle of vertical mixing were determined over the Pearl River Delta. The observations were performed with Raman lidar and Sun photometer at Xinken (22.6°N, 113.6°W) near the south coast of China throughout October 2004. The lidar ran almost full time on 21 days. Sun photometer data were taken on 23 days, from about 0800 to 1700 local time.

Raman Lidar

The lidar employed was the newly developed small IFT-Raman lidar Polly (*po*rtab*l*e Raman *l*idar s*y*stem). Polly delivers profiles of the particle backscatter and extinction coefficient as well as the height of the planetary boundary layer. Unlike most other Raman lidars Polly has been designed for field sites since it is easy to transport, easy to install and performs its measurements automatically. Polly is shown in Figure 8. The optical table is placed in an air-conditioned cabinet together with the power supply and heat exchanger of the laser and the computers for data acquisition and house keeping.

Lidar and Sun Photometer Observations

Sunny, dry, and mostly cloudless conditions allowed almost continuous lidar observations from October 2-26, 2004. The meteorological situation favored the transport of pollution from the Chinese continent to the field site and the accumulation of locally produced aerosols over the PRD (cf. Section *Closure study on the optical properties of dry particles and the mixing state of black carbon*).

In Figure 9 the temporal development of the range-corrected-signal is plotted for these three days. This plot illustrates the diurnal development

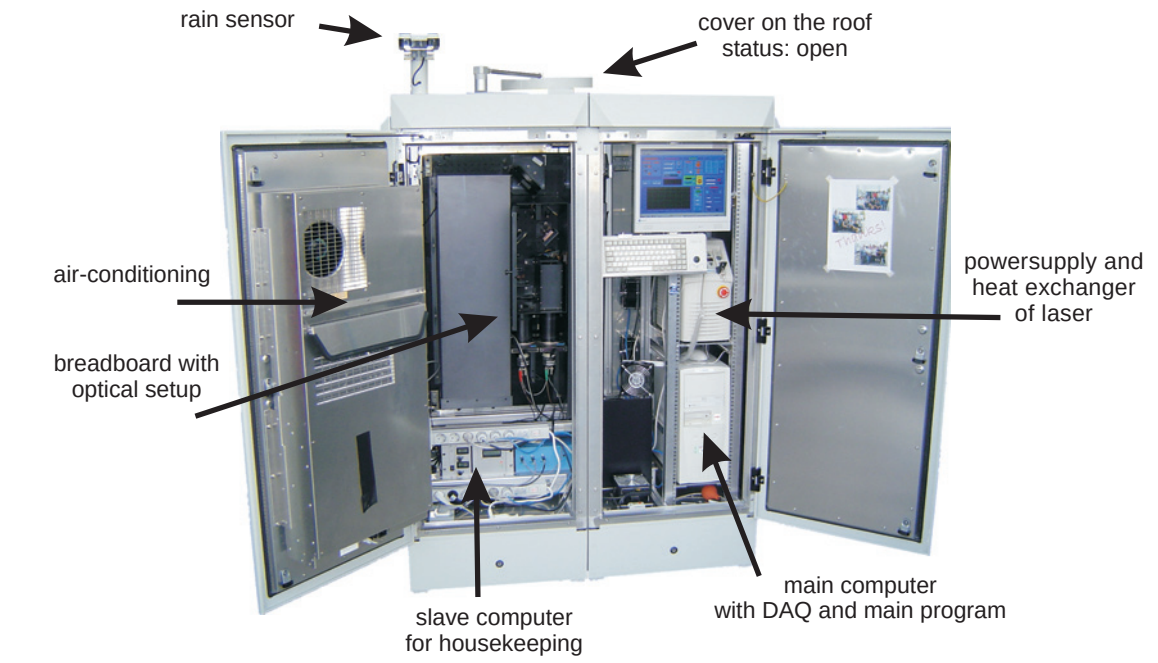

Fig. 8: Polly is a system in an air-conditioned cabinet. The main parts are indicated in the photo.

of the planetary boundary layer during daytime (9-20 local time) and complex aerosol layering up to 2.5 km height during nighttime (21-9 local time). The planetary boundary layer height is also depicted in this plot.

Especially, the day October 23, 2004 showed an almost undisturbed development of the planetary boundary layer during daytime. The extreme high optical depth of around 1.6 before sunrise on DOY 297 (October 23) was caused by high humidity. Strong backscattering (red in Figure 10) occurred in layers with relative humidity > 80 % according to the Hong Kong radiosonde. Some clouds developed at heights from 1.3-1.5 and 2-2.2 km. Aerosol layers are visible above the haze layer. The relative humidity decreased considerably during the morning hours. As a consequence the particle optical depth decreased. The daytime Planetary Boundary Layer (PBL) started to develop about one hour after sunrise. The maximum PBL depth of 1700 m was reached in the evening at 1700-1800 local time. A pronounced diurnal cycle of particle backscattering (and particle concentration) close to the ground with high values during the night and low values in the afternoon is visible and is mainly related to the dilution of pollution by vertical mixing. A diurnal cycle of the haze layer, with

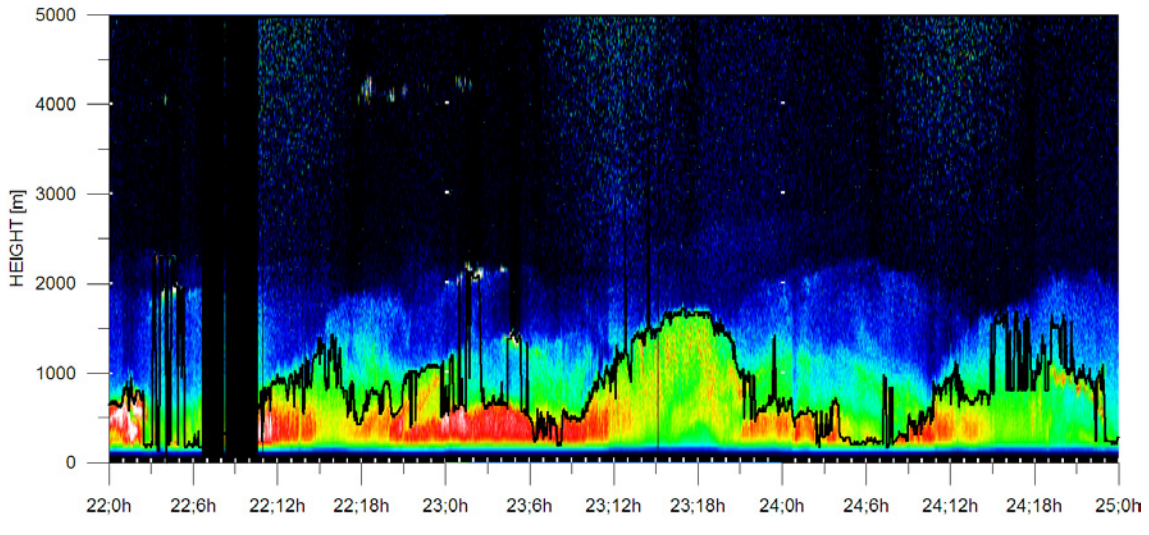

Fig. 9: Time-height plot of the range-corrected signal of the elastic lidar channel from 22-10-04 until 24-10-04.

stable aerosol stratification during the night and convective mixing during the day was observed on 17 of the 21 lidar days.

Figure 10 shows a typical example of a Raman lidar measurement. On October 12, 2004, the haze layer reached up to 2.4 km height. Traces of particles were detected up to 3.6-km height. Particle extinction coefficients σ_{ep} ranged from 200-550 Mm^{-1} in the haze layer yielding a total particle optical depth of τ_p = 1.02. The lidar ratio σ_{ep}/β_p indicates different aerosol characteristics below (40-45 sr) and above 1.2-km height (50-60 sr), and above the haze layer (60-70 sr). The lidar ratio decreases with particle size and increases with relative contribution of light absorption to total extinction of particles. σ_{ep}/β_p is lowest (20-30 sr) for large maritime particles (low light absorption) and largest (70-100sr) for small particles (highly absorbing urban haze) [*Franke et al.*, 2001]. Recent analysis of the combined lidar and photometer observations suggests an increasing relative absorption contribution to light extinction with height.

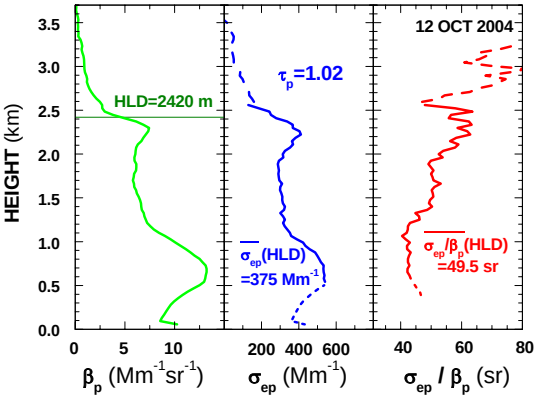

Fig. 10: *Particle backscatter (β_p) and extinction (σ_{ep}) coefficients, and respective lidar ratio (σ_{ep}/β_p) at 532 nm. The top of the haze layer (HLD) is indicated by a horizontal line. Mean profiles for DOY 286 (October 12), 2004, 19-22 local time are shown.*

Figure 11 gives an overview of the October-2004 PRD observations. The total particle optical depth (around 533 nm) typically ranged from 0.6-1.4. The October-2004 mean particle optical depth of 0.92 is 20%-30% higher than the autumn or annual mean optical depth for PRD south of Guangzhou derived from Moderate Resolution Imaging Spectrometer (MODIS) observations from August 2000 - April 2003 [*Li et al.*, 2003]. Note that the annual mean 500-nm particle optical depth was 0.5-0.55 in the Guangdong Province in 1960 and 0.75-0.8 in 1990, according to long-term observations at 750 nm wavelength [*Luo et al.*, 2001]. An Ångström exponent of one is assumed to estimate the 500-nm values from the observations at 750 nm.

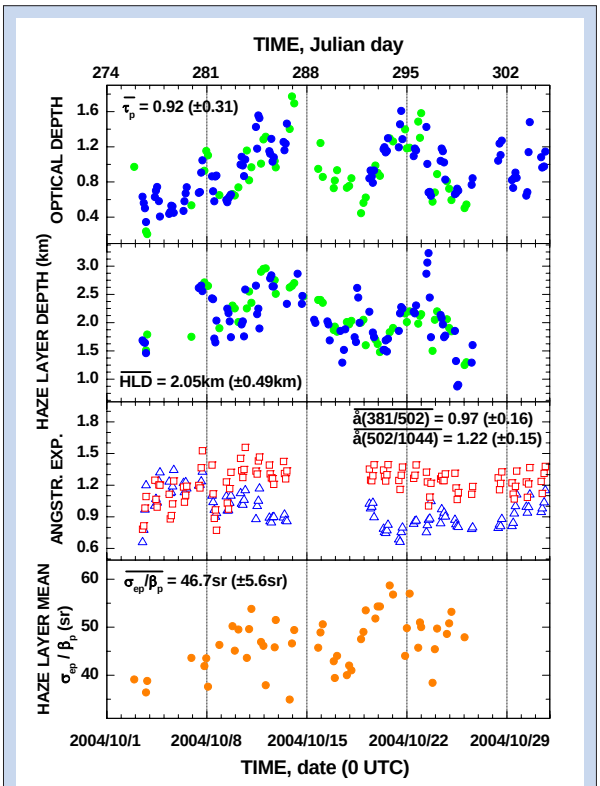

Fig. 11: *Cloud-screened daytime (blue) and night time (green) observations of aerosol optical depth (532-534 nm), haze layer depth (HLD), Ångström exponent å (triangles for 381-502 nm, squares for 502-1044 nm), and column averaged lidar ratio. 1-hour (daytime) and 2-hour mean values (nighttime) are shown. Every second observation is plotted only. Numbers indicate October-2004 mean values and standard deviations (in parenthesis).*

The haze layer depth at the subtropical site was often larger than 2 km. The haze layer mean extinction coefficient (ratio of optical depth to haze layer geometrical depth) varied in most cases from 250-750 Mm^{-1}. The highest values were close to 830 Mm^{-1}. For comparison, extinction coefficients in the Asian outflow region over the eastern Pacific were on average 90 Mm^{-1} (±110 Mm^{-1}) during ACE-Asia [*Anderson et al.*, 2003].

The Ångström exponents were generally low and similar to values found for the pollution outbreaks advected from China over the Pacific [*Anderson et al.*, 2003]. Values around one are also in agreement with the MODIS observations [*Li et al.*, 2003]. Low Ångström values are found in many areas with dense population in China and result from continuous city construction, low plant coverage, ubiquitous local dust and large amounts of soot generated from industrial coal combustion and culinary natural gas [*Li et al.*, 2003].

Lidar ratios were mostly between 40 and 55 sr. The average value of 46.7 sr (± 5.6 sr) is close to the mean value of 45.8 sr (± 9.4 sr) found in the outflow region [*Anderson et al.*, 2003]. Values of 40 and 50 sr are consistent with the presence of large, absorbing particles. Our recent studies indicate effective (area weighted mean) diameters

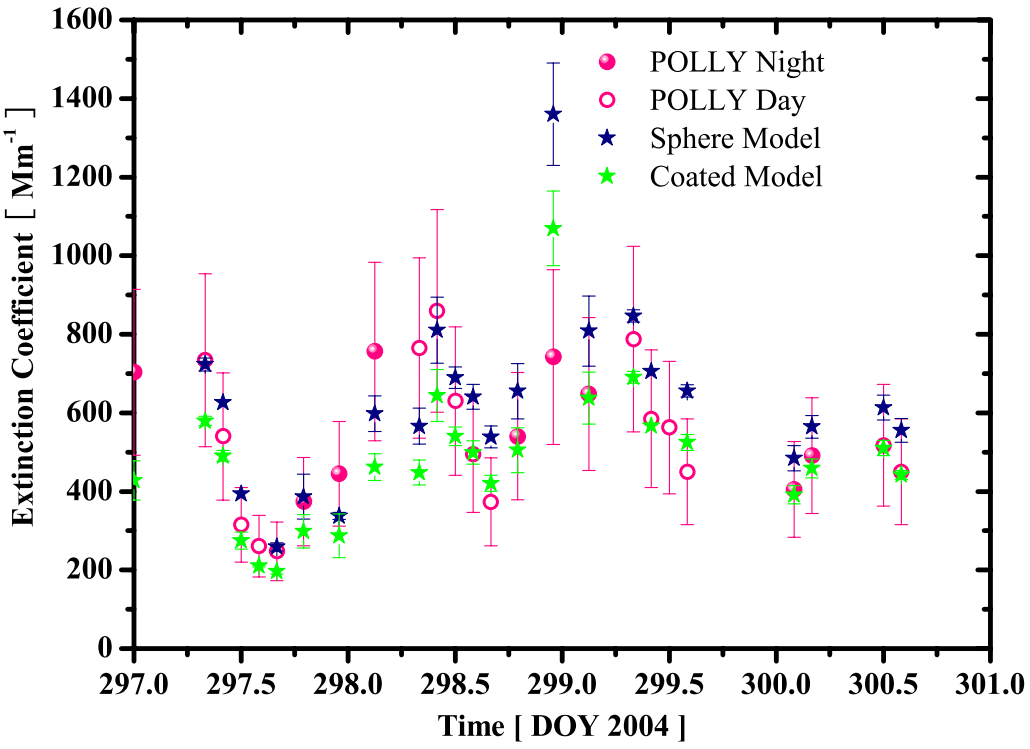

Fig. 12: *Comparison of Mie-modelled ambient aerosol extinction coefficient (coated sphere model and sphere model) with Polly-measured ones (at 150-300m height) along with error bars representing one standard deviation for DOY 297-301 (Oct 23 - Oct 26), 2004 in PRD.*

of the particles around 0.5 μm. Over Leipzig, particle effective diameters are much smaller with values around 0.3 μm.

Closure study of in-situ and remote sensing observations

Two kinds of Mie models were used to evaluate the ambient optical properties. One was the so-called "homogenous model" in which the derived mixing state of BC was applied (see the section *Closure study on the optical properties of dry particles and the mixing state of black carbon*). In this model, the aerosol particle population was assumed to consist of homogeneously mixed particles interspersed with externally mixed BC with certain mass mixing ratio. The other Mie model used is referred to as internally mixed "coated model" in which BC was assumed as a hydrophobic core surrounded by a shell of water and the non-absorbing aerosol component. In general, the extinction coefficient retrieved from the "homogenous model" exceeds the one determined with the "coated model" as obvious in Figure 12.

In a final step, the modeled extinction coefficients were compared with the ones measured by the Raman lidar Polly as presented in Figure 12. Particle extinction coefficients for the lidar data at 60 m were determined by multiplying the backscatter coefficient at 60 m with a constand lidar ratio. Here, the time resolution of 2 h was retrieved from the lidar. In most cases, the calculated values of the extinction coefficient were mostly following the measured ones. It should be emphasized, that the displayed lidar data was observed at 150-300m height whereas the modeled extinction is based on ground measurements and therefore good fitting results can only be expected during times at which a well-mixed boundary layer was observed. An example for such a well-mixed boundary layer is DOY 297.5-297.75 (Oct 23, 12.00-18.00) during which deviations between the modeled and measured extinction coefficient were very small.

As already mentioned, for some cases, the modeled extinction did not fit the measured one. For example, during DOY 299, the modeled value was much higher than the measured one. The difference may be due to the pollution accumulating near the *ground* during that time, which can also be seen in Figures 4 and 5. During DOY 297.95 and 298.13 the values measured by POLLY were higher than the calculated ones. This may be due to a negative temperature gradient. If the temperature decreased with height, the relative humidity would increase resulting in a bigger water uptake of particles at the elevated heights resulting in higher extinction coefficients.

The calculated single scattering coefficient (SSA) of dry particle (630nm) was about 0.80, while the modeled SSA of ambient particle (532nm) was about 0.84 for both sphere and coated model.

The lidar ratio evaluated by POLLY was 45±15. The same values modeled by the sphere model and coated model are 43±9 and 58±6, respectively. Obviously, the closure of lidar ratio is also very good.

Conclusions

During the measurement campaign high aerosol concentrations were found at the Xinken site of PRD, which were clearly seen in the ground-based and remote observations. The mixing state of BC and other aerosol species was defined as the externally mixed BC mass ratio. Based on the two-component optical aerosol model, a time series of this ratio was derived from the ground based measured physical and chemical properties of the dry aerosol through a numerical internal consistency method. It was found that the measured aerosol optical properties were enclosed by those calculated extreme values (external and internal mixtures), especially concerning light absorption. Good agreement between measured and calculated values was found, on the order of ±15% not only for the total/back scattering but also for light absorption. The mixing state of BC was found strongly dependent on the local circulation. When the air mass was mainly come from the Mainland China or the pollutants were accumulated locally due to the calm wind about 85-95% mass of the total BC was mostly externally mixed. While, when there was South-southeast wind coming from the sea at around 20:00 in the nighttime, the mixing state of BC was transformed to be internally mixed with an externally mixing mass ratio of 0.44. Very high aerosol optical depths of the order of one at visible wavelengths together with comparably low values of the spectral slope of the particle optical depth were observed with Sun photometer. The lidar observations showed high particle extinction coefficients throughout the haze layer. The lidar ratio values together with the analysis of the spectral slope of the particle extinction (Angström exponents) indicate highly absorbing, large particles with effective diameters around 0.5 micrometers. Stable aerosol layering during nighttime and pronounced boundary layer development during daytime prevailed during October 2004. The size-segregated hygroscopic growth factors were calculated by TDMPS and HDMPS as well as by MOUDI chemical analysis data. Consequently, the ambient aerosol number size distribution and refractive index were derived. Two kinds of Mie model (sphere homogeneous and coated) were used to evaluate the ambient aerosol extinction coefficients which were found to be good agreed with the POLLY lidar observations. The calculated single scattering coefficient (SSA) of dry particle (630nm) was about 0.80, while the modeled SSA of ambient particle (532nm) was about 0.84 for both sphere and coated model. The lidar ratio evaluated by POLLY was 45±15. The same values modeled by the sphere model and coated model are 43±9 and 58±6, respectively. Obviously, the closure of lidar ratio is also very good. The haze over the PRD has a strong impact on the radiation budget and considerably weakens the vertical exchange of particles by convection and thus augments unhealthy smog conditions near the surface, as our recent simulations clearly show.

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Episodes of high pollution in Beijing, China

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Peking gehört mit seinen momentan ca. 17 Mio Einwohnern zu den so genannten Megacities. Die damit verbundenen Emissionen von Aerosolpartikeln werden zunehmend ein Problem für die menschliche Gesundheit und Lebensqualität in der Stadt. Seit März 2004 werden kontinuierlich Anzahlgrößenverteilungen der Aerosolpartikel von 3 nm bis 10 µm in Peking gemessen. Dabei hat sich gezeigt, dass es eine hohe Variabilität sowohl in der maximalen Konzentration als auch in der Form der Anzahlgrößenverteilung gibt. Saubere Luftmassen werden von Norden her in die Stadt gebracht, dabei tritt häufig die Neubildung ultrafeiner Partikel (< 20 nm) auf. Verschmutzte Luftmassen werden mit wesentlich geringerer Geschwindigkeit und meist von Süden oder Westen herantransportiert. Dabei ist häufig die Sichtweite stark reduziert und die Partikelmassen < 1 µm Partikeldurchmesser können bis zu 450 µg m^{-3} erreichen. Der auffälligste Unterschied zwischen beiden Situationen liegt in der unterschiedlichen Länge der Rückwärtstrajektorien: an sauberen Tagen hat die Luftmasse in den letzten 24 Stunden im Mittel 720 km zurückgelegt, an verschmutzten Tagen sind es dagegen nur 240 km.

Most previous air pollution studies in developing countries have concentrated on particulate mass [*Molina and Molina*, 2004], with little or no information obtained from particle number concentrations, size distributions or chemical composition [*Laakso et al.*, 2006]. Particle number size distribution data are available only from two Asian megacities, New Delhi in India [*Mönkkönen et al.*, 2005] and Beijing in China [*Wehner et al.*, 2004], as well as Mexico City [*Dunn et al.*, 2004]. Those from New Delhi and Mexico City are limited to short field campaigns so far.

In view of the possible impact of fine and ultrafine particles on health, especially below 100 nm, a more detailed characterization is urgently needed. Since March 2004, a joint research measuring site between the Leibniz-Institute for Tropospheric Research and the College of Environmental Sciences of Peking University has been established in Beijing to characterize number size distributions in the size range from 3 nm to 10 µm. First results of the existing number size distributions were published by *Wehner et al.* [2004].

Aerosol number size distributions are measured continuously. A TDMPS (Twin Differential Mobility Particle Sizer [*Birmili et al.*, 1999]) system is used to measure the size distribution from 3 to 800 nm (mobility diameter). Additionally, an APS (Aerodynamic Particle Sizer, TSI model 3321) measures number size distributions between 800 nm and 10 µm (aerodynamic diameter). Size distributions are taken every 10 min. To combine both measurements, the APS-results are transformed from aerodynamic to Stokes diameters using a particles density of 1.5 g cm^{-3}. The number size distributions are used to calculate the total number concentration, N and the volume concentration, V1, from 3 nm to 1 µm and V10 from 3 nm to 10 µm assuming spherical particles: With the same density assumption particle mass concentrations PM1 and PM10 are calculated.

A low flow PM 10 inlet is used to minimize contamination of large dust particles. The aerosol is dried in a diffusion drier before entering the air conditioned laboratory to avoid condensation of water in the inlet systems during warm and humid days in summer time.

Number size distributions measured in Beijing vary significantly in concentration and shape: high concentrations in the ultrafine range (< 20 nm) connected with low concentrations in the accumulation mode range (> 100 nm) occur frequently as well as high number concentrations in the accumulation mode range, resulting in high particle mass concentration. These high pollution events are usually connected with a significant decrease in visibility.

Figure 1 shows one example: March 21, 2004. The number concentration maximum occurs around 100 nm and is nearly stable during the day. The major part of the particle volume was found in the size range below 1 µm. The shape of the number size distribution is typical for an aged aerosol, which was probably transported from other polluted regions in China to Beijing.

One hypothesis is that clean days are mostly connected with air masses coming from north-west to Beijing and polluted days with those coming from the south. To prove this assumption, the data have been classified in terms of air mass origin. First, for every day the mass concentration < 1 µm (PM1) has been calculated. Figure 2 shows the frequency of these PM1 values occurring between March 2004 and February 2005. The 25%, 50%, and 75% quartiles are

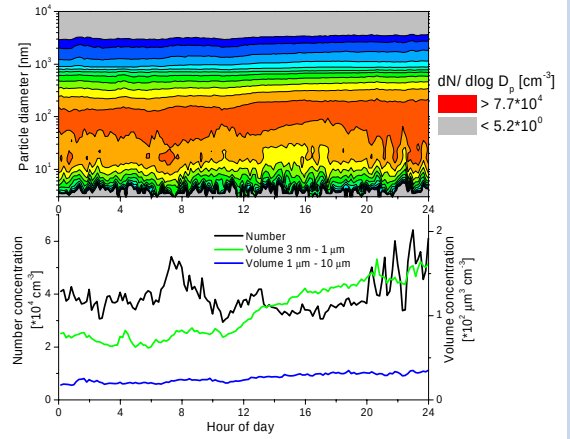

Fig. 1: *Evolution of number size distributions (upper Figure), total number concentration, and volume concentration (lower plot) on March 21, 2004 as example for continental pollution in Beijing.*

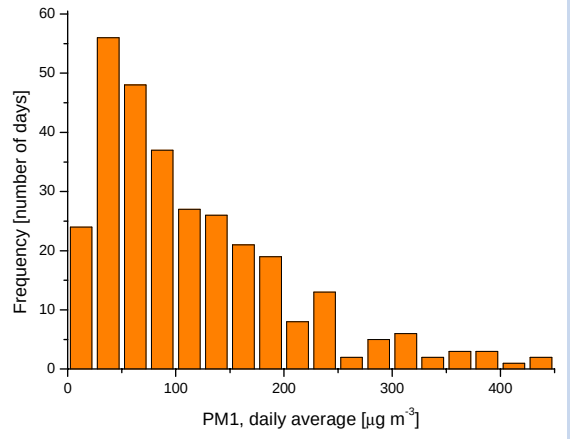

Fig. 2: *Frequency of occurrence of PM1 mean mass concentrations.*

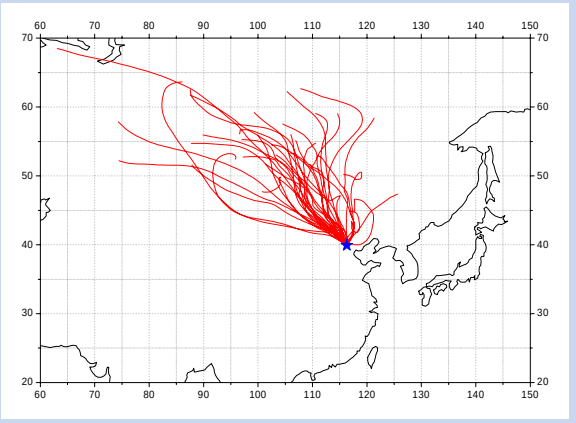

Fig. 3: *72-hour backtrajectories for days with daily average < 50 µg m^{-3}.*

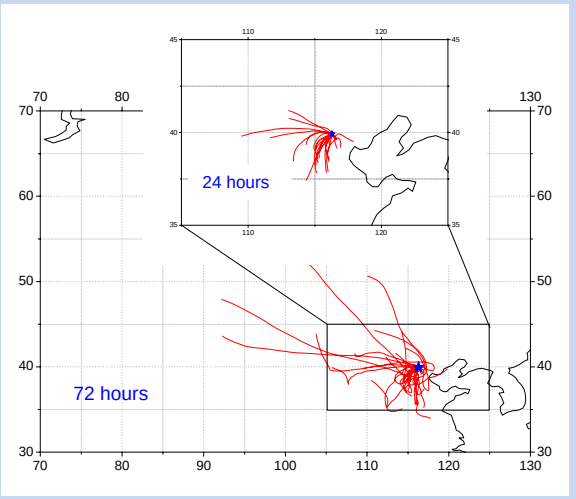

Fig. 4: *72-hour and 24-hour backtrajectories for days with daily average > 160 µg m^{-3}.*

47, 90, and 160 µg m^{-3}. These values were selected as criteria to divide the measurement days into clean (< 50 µg m^{-3}), moderate, and heavily polluted (> 160 µg m^{-3}) cases. For further analysis, only days with nearly constant mass concentration were chosen to ensure that one backtrajectory is representative for the whole day.

Figure 3 shows 72-hour backtrajectories for clean days (< 50 µg m^{-3}). Thus, clean air masses obviously come from northern directions and are moving relatively fast, most of the trajectories reach > 2000 km. Figure 4 shows the corresponding backtrajectories for polluted days (> 160 µg m^{-3}). They are shorter and do not show a predominant direction, meaning the air mass spent more time over the polluted regions around Beijing. To prove this assumption 24-hour backtrajectories of the same days have been plotted (Figure 4, small plot). Here it is obvious that the air masses spent the last day over the industrialized regions south and south west of Beijing.

From Figures 3 and 4 it might be suspected that backtrajectories of heavy polluted days are shorter than those of clean days. Figure 5 shows the mean length of backtrajectories for one, two, and three days of clean and polluted

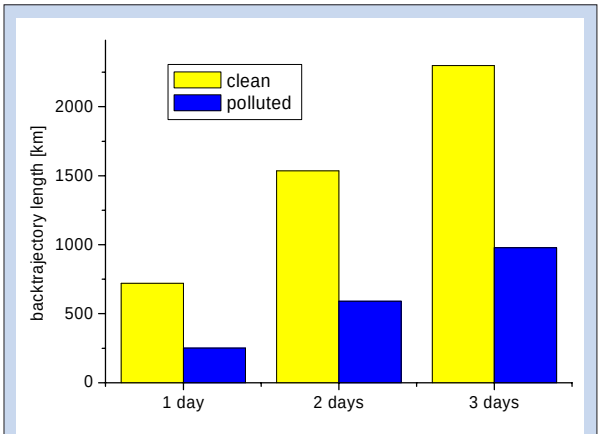

Fig. 5: *Calculated length of backtrajectories for 1, 2, and 3 days divided into clean (< 50 µg m^{-3}) and polluted cases (> 160 µg m^{-3}).*

cases. On clean days, the air masses passed on average 720 km within 24 hours corresponding to a velocity of 30 km h^{-1}. On polluted days the air masses passed only 240 km corresponding to 10 km h^{-1}. Thus, heavy pollution in the Beijing area is connected with slowly moving air masses which have enough time to accumulate pollutants such as primary emitted aerosols but also gaseous pollutants which are able to produce secondary aerosol particles.

Summarizing the results it was found that:

a) Mass concentrations measured in Beijing depend strongly on the air mass origin, but also on the velocity of backtrajectories.
b) Slowly moving air masses (short backtrajectories) passing over polluted regions accumulate primary and secondary aerosol material.
c) Air masses from south passing over downtown Beijing are influenced by long range transport plus urban pollutants.

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Chemical characterization of aerosol particles in Beijing

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Atmosphärische Verschmutzung in China, vor allem in Mega-Städten wie Peking, ist wegen der außerordentlich schnellen Industrialisierung und Verstädterung (schnelles Wachstum der Einwohnerzahl, Vergrößerung der Verkehrsdichte, hoher Verbrauch von fossilen Brennstoffen, stark wachsende Bauaktivität) ein sehr schwerwiegendes Problem. Die damit einhergehende Erhöhung der Verschmutzung der Atmosphäre durch Aerosole ist mit einer vergrößerten Mortalität und Morbidität verbunden. Im Sommer 2004 und im Winter 2005 wurden im Rahmen eines Messprogrammes größenaufgelöste Partikelproben (MOUDI) gewonnen und auf Masse, Hauptionen, elementaren und organischen Kohlenstoff, Dicarbonsäuren und organische Einzelspezies (Alkane, polyzyklische Kohlenwasserstoffe) analysiert. Die Partikelmassenkonzentration betrug bei Nordanströmung unter 50 µg m^{-3} und bei Südanströmung zwischen 170 und 370 µg m^{-3} (EU-Norm: < 50 µg m^{-3}/Tag). Das Maximum der Partikelkonzentration lag im Partikelgrößenbereich 0,32 - 0,56 µm. In einer weiteren Messkampagne sollte eine zweite Messstelle südlich von Peking eingerichtet werden, um den Einfluss der Stadt und des Langstreckentransports während Verschmutzungsepisoden unterscheiden zu können.

Atmospheric pollution in China, especially in Chinese mega-cities like Beijing, is an increasingly severe problem due to rapid industrialization and urbanization. Beijing with approximately 17 million inhabitants is featured by its rapidly expanding population, increasing traffic density, a high consumption of coal and flourishing construction activities. Beijing is situated in a semi-arid region in North China and surrounded by mountains in the west and north. The weather conditions usually do not favor the transport of air pollutants. The pollution by particulate matter (PM) is associated with increased mortality and morbidity. The value of daily mass concentration (PM_{10}) often gets concentrations well over 50 µg m^{-3} (European Standard since 2005). A better understanding of the physical and chemical processes leading to air pollution in Beijing is urgently needed to lower the emission of pollutants.

The urban aerosol in Beijing has been the topic of several recent studies for PM_{10}, $PM_{2.5}$, and individual particles [e.g., *He et al.*, 2001; *Shi et al.*, 2003; *Yao et al.*, 2002, 2003; *Feng et al.*, 2005; *Liu et al.*, 2005; *Chan et al.*, 2005]. In this study the size-segregated chemical characterization of particulate matter in Beijing was performed by an 11-stages MOUDI (Micro Orifice Uniform Deposit Impactor).

The sampling site is located on the campus of Peking University in the northwestern part of Beijing, at the top of a 6-storey building, about 20 m above ground. The campus area is without industrial pollution sources. Sources of particulate matter can be traffic, domestic heating (brown coal), domestic cooking (wood), and construction.

The MOUDI impactor was operated on selected days during the intensive periods (June/July 2004 and January/February 2005) using aluminum foils. The impactor foils were bought and prepared in Germany prior the intensive campaign. The sampling time varied with pollution level between 20 and 48 hours to collect enough particle mass to be analyzed but to prevent overloading of the individual stages.

Weighing of the sampling foils was done under constant relative humidity and temperature (50 % RH and 20 °C) with a microbalance UMT- 2 (Mettler Toledo) with a reading precision of 0.1 µg and a standard deviation of < 1 µg. After the weighing the foils were cut to three parts – for ions and dicarbonic acids (58.9 %), OC/EC (13.7 %) and PAH/alkane (27.4 %).

Foil samples for analysis of main ions and dicarbonic acids were extracted in 1.5 ml ultrapure water (specific resistance ≥ 18.0 MΩ/cm). The main inorganic ion species such as chloride, nitrate, sulphate, and DCAs were analyzed by capillary zone electrophoresis (CE, Spectra Phoresis 1000-Thermo Separation Products, USA) as well as sodium, ammonium, potassium, calcium, and magnesium by ion chromatography (IC, Metrohm-Switzerland).

Particulate carbon determination (elemental (EC) and organic (OC) carbon) was performed with a thermographic method similar to the VDI 2465 (Part 2) Guideline in Germany using a carbon analyzer C-mat 5500 (Ströhlein).

Particulate non-polar organics like alkanes and PAH were analyzed by Curie-Point Pyrolysis GC-MS in a Agilent GC 6890N equipped with a MSD 5973*inert*. The Curie-Point Pyrolyzer was a JAI-350 (Japan Analytical Industries, Ltd.).

Particle samples were collected at 5 events in summer 2004 and 6 events in winter 2005. Figure 1 shows the size-segregated particle mass concentration of the several sampling days. The

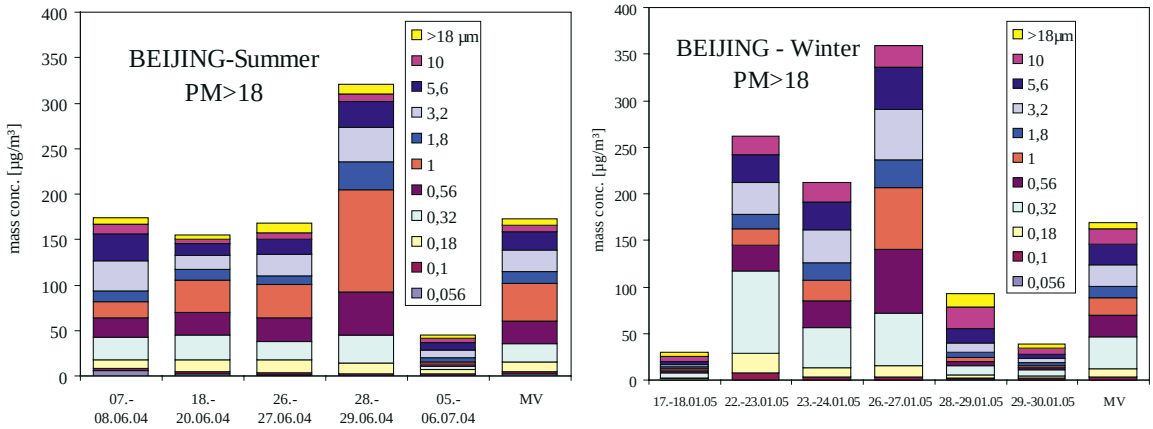

Fig. 1: *Size-segregated particle mass concentration of the individual sampling days (PM: particulate matter; MV: mean value).*

mean total particle mass concentration amounts to about 170 μg m^{-3} in summer and winter. The particulate mass content of the individual events below 50 μg m^{-3} is mainly caused by air mass influence from north and strong over 50 μg m^{-3} from south.

The following discussion represents some selected results of the chemical composition of particles in summer and winter as well as at wind direction from north and south.

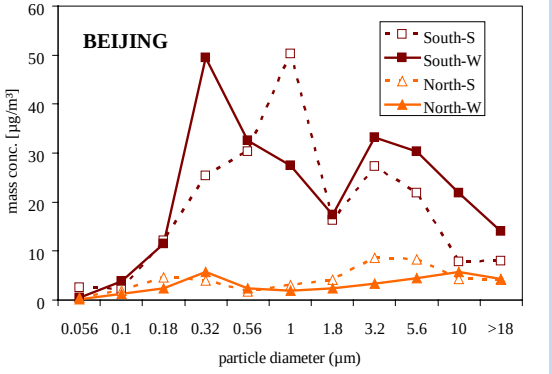

Fig. 2: *Size-segregated mean mass concentration in summer (S) and winter (W) at south and north wind direction.*

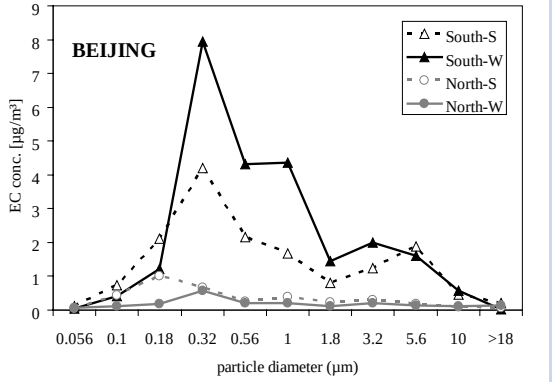

Fig. 3: *Size-segregated mean EC concentration in summer (S) and winter (W) at south and north wind direction.*

For the main components the maximum value of concentration lies in the size range 0.32 - 0.56 μm in winter. In summer the maximum value is removed to the size range 1.0 - 1.8 μm. The mean total particulate summer concentrations of nitrate, sulfate, and ammonium (12.6, 25.5, 10.4 μg m^{-3}, respectively) are higher as in winter (8.8, 15.9, 8.5 μg m^{-3}, respectively). The mean particle sulphate concentration is about twice higher as the nitrate concentration in summer and winter. The mean ammonium concentration corresponds with the nitrate concentration. Surprisingly, the mean nitrate concentration is higher in summer than in winter. The mean total OC concentration is higher in summer (16 μg m^{-3}) as in winter (14 μg m^{-3}). The mean total particulate EC concentration is higher in winter (16 μg m^{-3}) than in summer (13 μg m^{-3}). The OC/EC ratio in summer amounts to 1.2 (biogenic emissions) and in winter to 0.8 (domestic heating).

The size-segregated mean particle mass, EC, and OC concentration are presented in Figures 2, 3, and 4, respectively. All components show at north flow clearly lower concentration than at south flow. The concentration distribution is roughly similar for the respective component

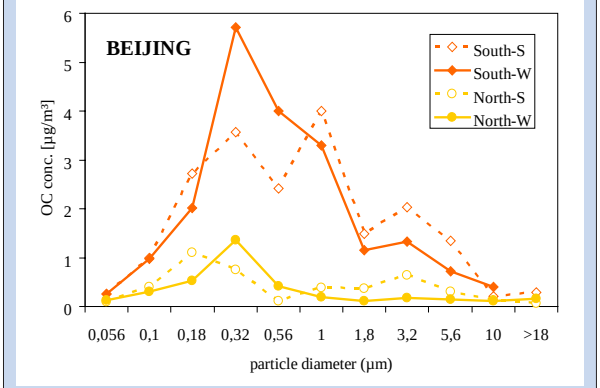

Fig.4: *Size-segregated mean OC concentration in summer (S) and winter (W) at south and north wind direction.*

at north wind direction in summer and winter. The founded higher concentration of mass, EC, and OC (and other components) in winter than in summer at south wind direction is caused by the domestic heating. A distinction between long range transport of pollutants and local urban influence (south wind direction) from the measurement results is not possible since the measurement site is located northwest of downtown Beijing. In a next measurement campaign a second measurement site south of Beijing should be established to determine the fraction of urban influence as well as of long range transport.

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LACIS: hygroscopic growth and activation for different kinds of particles

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In den Jahren 2004 und 2005 wurden mit der bereits existierenden Version von LACIS (Leipzig Aerosol Cloud Interaction Simulator), „LACIS-klein“, Messung von hygroskopischem Wachstum und Aktivierung von atmosphärischen Aerosolpartikeln und von organischen Substanzen (Bernsteinsäure und Levoglucosan) durchgeführt. Der Neubau des Wolkenlabors wurde 2005 bezogen, und mit dem Aufbau von „LACIS-gross“ begonnen. Im Oktober 2005 wurden, nach erfolgreichen Tests des ersten Abschnitts von „LACIS-gross“, erste Messungen zum hygroskopischen Wachstum und zur Aktivierung von HULIS-Partikeln (Humic-Like Substance) durchgeführt. Ende 2005 wurde an „LACIS-gross“ eine internationale Messkampagne (LExNo – LACIS Experiment in November), erfolgreich durchgeführt. Dabei wurde das hygroskopische Wachstum und die Aktivierung von Russpartikeln, beschichtet mit Ammoniumsulfat und/oder Levoglucosan, untersucht. Während LExNo wurden zusätzlich zu LACIS drei CCN (Cloud Condensation Nucleus) Zähler, ein HTDMA (Hygroscopicity Tandem Differential Mobility Analyzer), spezialisiert für Messungen bei relativen Feuchten bis zu 98%, ein Niederdruckimpaktor und zwei Aerosol-Massenspektrometer betrieben.

Overview

In the years 2004 and 2005, the existing version of LACIS (Leipzig Aerosol Cloud Interaction Simulator) [*Stratmann et al.*, 2004, *Wex et al.*, 2005a, *Kiselev et al.*, 2005], i.e. “LACIS-short”, was used to measure the hygroscopic growth and activation of atmospheric aerosol particles and of laboratory generated particles consisting of succinic acid (a slightly soluble dicarboxylic acid) and of levoglucosan (a tracer for biomass burning).

In 2005, the new cloud laboratory building was completed. The buildup of “LACIS-long” was started and, after testing the functionality of the first section of “LACIS-long”, first measurements were performed on hygroscopic growth and activation of particles generated from a HULIS-sample (Humic-Like Substance).

LACIS-short

Atmospheric Aerosol. The hygroscopic growth of atmospheric aerosol particles with dry sizes of 150, 300, and 350nm was measured with “LACIS-short” for relative humidities (RH) above 98%. Figure 1a shows measured growth factors for 99% RH during the course of 24 hours. It was found that particles with larger dry diameters (300 and 350nm) had growth factors more similar to those of pure ammonium sulfate than the 150nm particles. LACIS was also used to measure the critical diameter or, respectively, the critical super-saturation, for the activation of atmospheric aerosol particles. For this, either the dry diameter of the selected particles was kept constant, while the super-saturation in LACIS was varied from 0.3% to 1% super-saturation. Alternatively, the super-saturation in LACIS was kept constant while the dry size of the particles was varied. Figure 1b

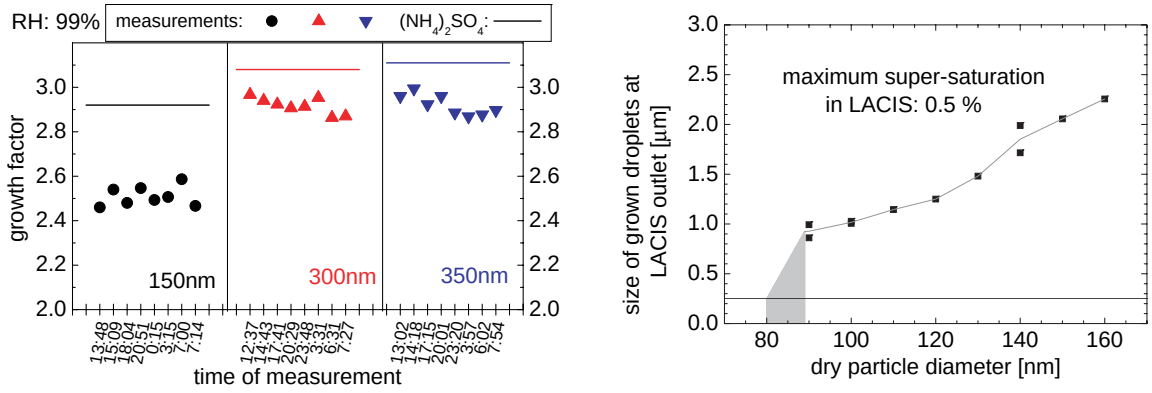

Fig. 1: ***a)*** *(left side) hygroscopic growth factors for atmospheric aerosol particles for 24 hours, measured at 99% relative humidity with LACIS and* ***b)*** *(right side) measured sizes of atmospheric aerosol particles after their passage through LACIS, at 0.5% maximum super-saturation inside the flow tube.*

shows the size of the grown droplets at the LACIS outlet for different dry diameters, at 0.5% super-saturation, where the critical dry diameter at 0.5% super-saturation was 85nm (+/-5nm). For another set of measurements the critical super-saturation for particles with a dry diameter of 75nm was found to be 0.52%. The measurement of the hygroscopic growth and of the critical super-saturation clearly shows that LACIS is suitable for examining atmospheric aerosol particles [*Wex et al.*, 2005b].

Organics. The hygroscopic growth and activation of particles consisting of pure succinic acid and pure levoglucosan was measured for different initial dry sizes. As an example, the results of measurements of the hygroscopic growth of succinic acid are shown here (Figure 2). Succinic

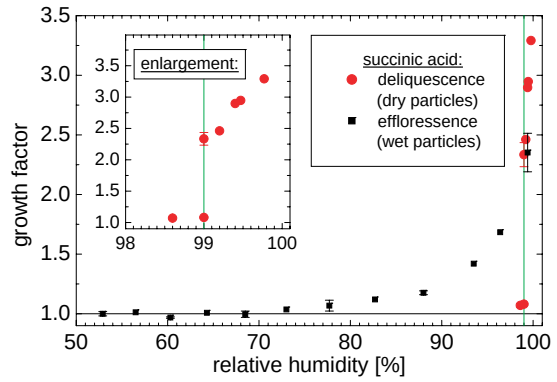

Fig. 2: *Hygroscopic growth factors for succinc acid particles at different RHs. Deliquescence of dry particles was found at 99% RH (enlargement). Efflorescence measurements show a gradual shrinking of the wet particles towards lower RHs, but no steplike point of efflorescence.*

acid, a dicarboxylic acid, belongs to the group of slightly soluble compounds, which deliquesces at very high RHs. To date, a determination of the deliquescence RH of succinic acid by the measurement of the hygroscopic growth of succinic acid particles has not been published. In 2005, LACIS was used for this kind of measurement. Figure 2 shows that dry succinic acid particles did not show hygroscopic growth up to 99% RH. At 99% (+/-0.2%) RH they deliquesced. No time delay was found for the deliquescence process. When measuring the efflorescence of wet succinic acid particles, hygroscopic growth was found for RHs of about 70% RH and larger, but no clear efflorescence was observed.

LACIS-long

HULIS-sample. A sample of an atmospheric humic-like substance (HULIS) provided by Imre Salma from the Eötvös University, Budapest, Hungary, was used to generate particles. A high humidity HTDMA [*Hennig et al.*, 2005] was used to measure the hygroscopic growth of HULIS particles with a dry diameter of 100nm for RHs up to 98%, while LACIS measured the hygroscopic growth for 200nm particles at three RHs between 98% and 100%. LACIS also measured the activation of HULIS particles with dry diameters of 50, 75, 100, and 125nm. The measured data were used in a CCN closure. For this purpose, Köhler theory was used to simulate the measured hygroscopic growth factors. The parameters derived from this simulation, i.e. basically the number of moles in solution that were necessary to reproduce the measured hygroscopic growth factors, were used to model the critical super-saturations (S_{crit}) for different dry particle sizes. Calculations were done twice, once using the surface tension of water, and a second time using the surface tension of the HULIS sample, which had been measured at the Eötvös University, Budapest, Hungary (58mN). Measured and modeled values of S_{crit} are shown in Figure 3. Measurement and model are in good

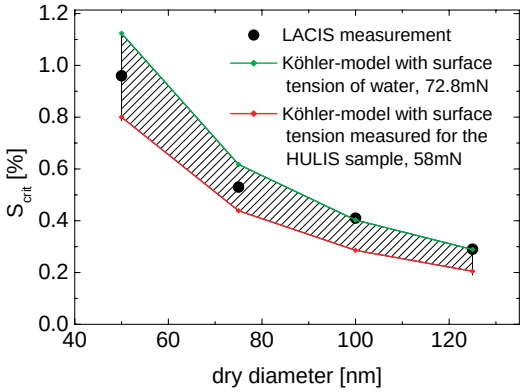

Fig. 3: *S_{crit} for HULIS particles with different dry diameters, measured with LACIS and derived according to Köhler theory, for different surface tensions of the droplets.*

agreement. S_{crit} measured for HULIS particles with dry diameters of 100 and 125nm agree with the simulations which used the surface tension of water. S_{crit} for HULIS particles with dry diameters of 50 and 75nm are between the results of the calculations with the different surface tensions, indicating an influence of HULIS on the surface tension of the droplet. These results are consistent with the fact that, in general, larger particles have a lower critical super-saturation, but a larger growth factor at the point of activation.

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Time-resolved laser-based laboratory studies of aqueous phase reactions relevant for tropospheric chemistry

Paolo Barzaghi, Saso Gligorovski, Dirk Hoffmann, Kshama Parajuli, Hartmut Herrmann

Temperaturabhängige Geschwindigkeitskonstanten für die Reaktionen wichtiger atmosphärischer Radikale mit sauerstoffhaltigen Kohlenwasserstoffverbindungen wurden in wässriger Phase mittels Laser-Photolyse-Langwegabsorptionanordnungen ermittelt. Die ermittelten Geschwindigkeitskonstanten wurden in das Multiphasenmodel CAPRAM eingebunden.

Introduction

Free radicals play an important role in the chemistry of the aqueous tropospheric particle phase [*Herrmann*, 2003]. In order to understand the impact of free-radical chemistry in the tropospheric aqueous phase kinetic data with relevant organic compounds are required. In this work the reactions of OH, NO_3 and Br towards different oxygenated organic compounds have been studied between 278 and 318 K in aqueous solution using a laser flash photolysis – longpath absorption (LP –LPA) technique.

Experimental

The radicals were generated by laser photolysis of adequate precursors and the absorption signals of these radicals were detected.

The temperature dependency of the rate constant has been investigated for the reaction of OH with oxygenated organic compounds using a direct method based on RO_2 build-up kinetic (Figure 1). The formation of the OH radicals was initiated by excimer laser photolysis of H_2O_2 at λ = 248 nm.

Using as analytical light source an Ar^+ laser at λ = 244 nm, time resolved absorption profiles at one single wavelength can be followed using a photodiode as a detector.

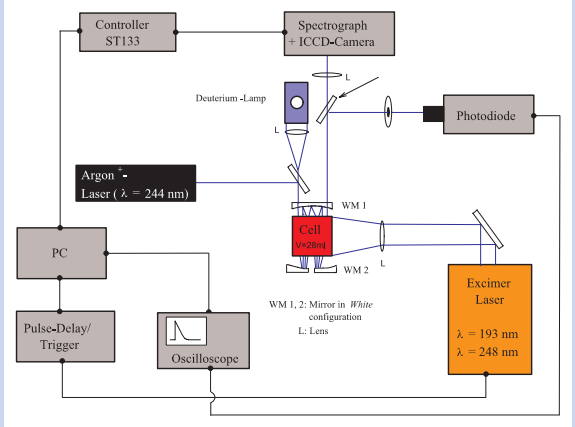

Fig. 1: *Schematic of the laser flash photolysis experimental setup used for the study of OH-kinetics with a direct method.*

For the kinetic investigations carried out by competition kinetics thiocyanate (SCN^-) has been used as reference substance. The temperature-dependent rate constant on reaction OH + SCN^-, reported by Chin and Wine ($k = 1.24 \cdot 10^{10}$ $M^{-1}s^{-1}$ at 298 K) has been applied as reference data.

NO_3 radicals were generated by flash photolysis of nitrate anions at λ = 248 nm under acidic conditions (pH = 0.5). The temporal change of the NO_3 concentration was followed using a He-Ne laser operated at λ = 632.8 nm.

Br-atoms in aqueous solution have been generated by photolysis of bromoacetone operating at λ = 248 nm by an excimer laser. A high pressure mercury xenon lamp has been used as an analytical light. The decay of Br-atoms followed by using its absorption at λ = 297 nm which is close to the absorption maxima of Br-atoms.

Normally, eight measurements were performed and averaged for every reactant concentration. The errors stated throughout this work are statistical errors using the t-student distribution for a confidence interval of 95 %.

Results and Discussions

The kinetic data obtained in this study with the semi-direct method show a good agreement with the data obtained from kinetic competition method and recent literature studies [*Ervens et al.*, 2003; *Gligorovski and Herrmann*, 2004, *Herrmann*, 2003]. The obtained results are reported in Table 1.

Reactions with alcohols. Considering available literature and the data presented here, alcohols appear to react with OH radicals with rate constants increasing with the increasing of the length of the carbon atom linear chain carrying the hydroxyl group. The reactions of OH with alcohols proceed three order of magnitude faster than the reactions with Br-atom, whereas Cl-atom has a comparable reactivity to OH [*Wicktor et al.*, 2003].

Reactions with carbonyl compounds. In the aqueous phase, carbonyl compounds are also

Compound	Radical	k_{2nd} / $M^{-1}s^{-1}$	A / M^{-1} s^{-1}	E_a / KJ mol^{-1}	Remarks
Alcohols					
2-propanol	OH	$(2.1 \pm 0.2)\cdot10^9$	$(6.1 \pm 0.3)\cdot10^{10}$	8 ± 2	a
		$(2.1 \pm 0.9)\cdot10^9$	-	-	b
	Br	$(1.8 \pm 0.4)\cdot10^6$	$(7.8 \pm 1.2)\cdot10^{10}$	26 ± 10	
1-butanol	OH	$(4.1 \pm 0.8)\cdot10^9$	$(1.0 \pm 0.1)\cdot10^{11}$	8 ± 1	a
2-butanol	OH	$(3.5 \pm 0.4)\cdot10^9$	$(7.4 \pm 0.3)\cdot10^{10}$	8 ± 3	a
	Br	$(1.5 \pm 0.2)\cdot10^6$	$(2.0 \pm 0.1)\cdot10^9$	18 ± 4	
Carbonyl Compounds					
Propionaldehyde	OH	$(2.8 \pm 0.3)\cdot10^9$	$(2.6 \pm 0.1)\cdot10^{11}$	11 ± 3	a
	Br	$(5.7 \pm 2.0)\cdot10^7$	$(1.1 \pm 0.1)\cdot10^9$	5 ± 2	
	NO_3	$(5.8 \pm 1.6)\cdot10^7$	$(3.0 \pm 0.5)\cdot10^{11}$	22 ± 11	
Butyraldehyde	OH	$(3.9 \pm 1.0)\cdot10^9$	$(8.1 \pm 0.3)\cdot10^{10}$	8 ± 3	a
	Br	$(1.0 \pm 0.2)\cdot10^8$	$(4.7 \pm 0.6)\cdot10^9$	7 ± 6	
	NO_3	$(5.6 \pm 2.3)\cdot10^7$	$(5.0 \pm 0.4)\cdot10^{10}$	17 ± 4	
Isobutyraldehyde	OH	$(2.9 \pm 1.0)\cdot10^9$	$(3.0 \pm 0.1)\cdot10^{10}$	6 ± 3	b
	Br	$(1.0 \pm 0.2)\cdot10^8$	$(6.7 \pm 2.2)\cdot10^8$	5 ± 17	
Acetone	OH	$(1.3 \pm 0.1)\cdot10^8$	$(8.4 \pm 0.4)\cdot10^{10}$	16 ± 3	a
		$(2.1 \pm 0.6)\cdot10^8$	$(3.4 \pm 0.4)\cdot10^{11}$	18 ± 11	b
2-butanone	OH	$(1.5 \pm 0.7)\cdot10^9$	$(5.1 \pm 0.6)\cdot10^{11}$	15 ± 8	b
	NO_3	$(2.2 \pm 0.4)\cdot10^7$	$(4.0 \pm 0.9)\cdot10^{11}$	24 ± 15	
Diacetyl	OH	$(2.8 \pm 0.6)\cdot10^8$	$(4.3 \pm 0.3)\cdot10^{12}$	24 ± 5	b
Acetonylacetone	OH	$(7.6 \pm 1.1)\cdot10^8$	$(1.1 \pm 0.1)\cdot10^{11}$	12 ± 5	b
Acetoin	OH	$(2.9 \pm 1.0)\cdot10^9$	$(2.9 \pm 0.1)\cdot10^{11}$	11 ± 3	a
Dicarboxylic acids and corresponding dianions					
Mesooxalic acid	OH	$(1.8 \pm 0.3)\cdot10^8$	$(3.8 \pm 0.8)\cdot10^{10}$	13 ± 13	b
D,L-Malic acid		$(7.1 \pm 1.3)\cdot10^8$			a
D,L-Maleate dianion		$(8.4 \pm 1.0)\cdot10^8$			a
Glutaric acid		$(6.0 \pm 2.0)\cdot10^8$			a
Glutarate dianion		$(1.0 \pm 0.2)\cdot10^9$			a
Adipic acid		$(1.7 \pm 0.3)\cdot10^9$			a
Adipate dianion		$(2.4 \pm 0.2)\cdot10^9$			a
Pimelic acid		$(2.4 \pm 0.7)\cdot10^9$			a
Pimelate dianion		$(2.9 \pm 0.8)\cdot10^9$			a
Suberic acid		$(5.0 \pm 0.4)\cdot10^9$			a
Suberate dianion		$(5.8 \pm 0.3)\cdot10^9$			a

a) kinetic data obtained with the semi-direct method; b) kinetic data obtained with the competition kinetics method.

Tab. 1: *Kinetic data for the reactions of OH, NO_3 and Br with oxygenated organic compounds in aqueous solution.*

reacting through an H-abstraction mechanism with OH, NO_3 and Br. It can be seen that OH radicals represent also in the case of aldehydes and ketones the most reactive species. However smaller differences in rate coefficients respect to Br have been observed.

Whereas OH and Br show activation energies (E_A) activation similar, NO_3 radical presents a stronger influence of the temperature on the rate constants (Table 1).

Reactions with dicarboxylic acids. In this work only the reactions at 298 K of OH with different dicarboxylic acids have been reported. The rate constant obtained for the not dissociate form of the diacids are in good agreement with existing literature [*Herrmann*, 2003]. To the best knowledge of the authors, the rate constants for the reactions of OH with the anionic form of the acids have been measured for the first time.

It can be seen that the dianionic form reacts always faster than the corresponding acid, furthermore even if an increase in the rate coefficient is observed with the increase of the length of the carbon atom chain, this difference in the reactivity seems to become smaller with the increase of the number of the carbon atoms (Table 1).

Summary

The rate constants for the aqueous phase reactions of important atmospheric radicals with oxygenated organic compounds have been measured using a laser-photolysis-long-path-laser-absorption (LP-LPLA) technique The kinetic data obtained here has been used as input parameters in the latest versions of our multiphase reaction mechanisms CAPRAM (Chemical Aqueous Phase Radical Mechanism, Herrmann et al., 2005).

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Treatment of non-ideality in the multiphase model SPACCIM

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Verschiedene chemische Komponenten der Atmosphäre existieren sowohl in der Gas- als auch in der Partikelphase. Die Verteilung zwischen den Phasen hängt dabei nicht nur von der Konzentration der jeweiligen Spezies ab sondern auch vom Wasseranteil und der Konzentration anderer chemischer Komponenten. In solchen Multikomponentensystemen finden kontinuierlich Phasentransferprozesse statt, die Partikel- und Tropfenbildung und -wachstum beeinflussen. Bei der Modellierung derartiger Multiphasenprozesse ist es notwendig, nicht-ideale Lösungen in den Partikeln anzunehmen. Hier findet man hochkonzentrierte Lösungen, die typisch für die Anfangsphase der Tropfenbildung sind und nur geringe Mengen Wasser zur Verfügung haben. Das Verhalten solcher nicht-idealen Lösungen aus Elektrolyten und Nicht-Elektrolyten, die sowohl anorganische, als auch organische Spezies enthalten, ist in den vorhandenen Modellen bisher nicht zufrieden stellend beschrieben worden. Das Ziel unserer Arbeit ist die verbesserte Beschreibung solcher komplexen Systeme durch die Implementierung verschiedener Methoden zur Berechnung von Aktivitätskoeffizienten in das Spectral Aerosol Cloud Chemistry Interaction Model [SPACCIM, Wolke et al., 2005]. Die hier gezeigten Ergebnisse erster Modellrechnungen machen den Einfluss nicht-idealer Bedingungen auf Multiphasenprozesse deutlich.

Introduction

Many chemical compounds in the atmosphere can exist in both gas and particle phases. The partitioning of the species between the phases depends on the concentration of the species itself, as well as on the concentration of water and other chemical compounds. In this multi-component system phase transfer processes take place, which can influence the particle and droplet formation as well as particle growth. In the modeling of such multiphase processes it is necessary to consider non-ideal conditions in deliquescent particles. Here we find highly concentrated solutions which are typical in the initial stage of the droplet formation, when only small amounts of water are available. The behavior of these non-ideal mixed solvent-electrolyte solutions including inorganics and organics is not yet described satisfyingly in existing multiphase models. The aim of our work is to improve the description of such complex systems by the implementation of different activity coefficient calculation methods into the Spectral Aerosol Cloud Chemistry Interaction Model (SPACCIM) [*Wolke et al.*, 2005].

The Model and the model studies

SPACCIM has been developed for the description of cloud microphysical processes with the consideration of complex multiphase chemistry for a size-resolved particle/drop spectrum. A microphysical model is coupled with a chemical model, so meteorological and microphysical parameters needed for the chemistry can be taken from the microphysical model. Changes in the chemical composition feed back on the microphysical processes. Up till now, the model was able to describe the transformation and growth of particles and droplets only from shortly before cloud forming, through the cloud life time and until shortly after cloud evaporation. This limitation results from non-ideal behavior of solutions when the concentrations are high and thus a well diluted solution can not be assumed. The influence of the dissolved molecules and ions on each other is not negligible any more. The non-ideality of highly concentrated solutions can be described with the so called activity coefficients. In ideal (well diluted) case this measure is unity. An extended version (included ions) of the UNIFAC-Dortmund (Universal Quasi-Chemical Functional Group Activity Coefficient) method [*Fredenslund*, 1977, e.g., *Aznar et al.*, 2001] coupled with the Pitzer method [*Pitzer et al.*, 1974] was implemented. The new version of the model is able to simulate the physico-chemical processes of the particles/ droplets also at lower relative humidities.

The interactions among electrolytes and non-electrolytes are based on different mechanisms. Deviations from the ideality in ionic solutions exist mainly due to the long range electrostatic interactions. The activity coefficient of a component of an electrolyte is a complex function of the concentration of the species in the solution and the Coulombic interactions of the ions. The most accepted ion interaction approach is the Pitzer method. In non-electrolytes the deviations from non-ideality are caused mainly by the dipole-dipole relations. These short range interactions are typical in organic solutions. For modeling the non-ideality in organic solutions, group contribution models (e.g., UNIFAC) are often used, in which the organic solutions are not treated as a mixture

of components, but as a mixture of functional groups. The advantage of these methods is that the number of functional groups can be much lower than the number of the organic molecules. So it is possible to describe complex systems with only few parameters. Beside ion-ion and organic-organic interactions, also ion-dipole interactions have to be considered.

For the model studies, the gas phase mechanism RACM [*Stockwell et al.*, 1997] with about 261 reactions has been coupled to a reduced aqueous phase mechanism. The reduced mechanism is based on the reduced version of the Chemical Aqueous Phase Radical Mechanism - CAPRAM 2.4 [*Ervens et al.*, 2003] and a deduced reaction scheme of the most up-to-date mechanism CAPRAM 3.0 [*Herrmann et al.*, 2005]. In the organic reaction scheme only oxidations of C_1 and C_2 by the OH radical are considered. Other radical reaction pathways are neglected. The deduced aqueous phase mechanism contains a detailed oxidations scheme of inorganic as well as organic compounds with about 155 species and 218 reactions.

Results

The simulations were carried out for a meteorological scenario in which an air parcel moves along a predefined trajectory including three cloud passages and intermediate aerosol state at a 90 % relative humidity level. Simulations have been performed for three cases: (1) without feedback between the microphysical and chemical model and without consideration of non-ideal solutions; (2) without feedback, but with consideration of non-ideal solutions; (3) with feedback and consideration of ideal solutions.

As shown in Table 1 the deviations from ideal solutions are not negligible in this scenario. However, the deviations from ideal behavior strongly depend on the species regarded. The activity coefficients do not change linearly to droplet size or relative humidity. This fact is caused by a non-linear change of activity coefficients in terms of the molality due to the different types of interactions in the solution. Furthermore the concentrations depend on the droplet size because smaller droplets growth faster as larger ones (surface to volume proportion is bigger).

The concentration of HO_2 radical and the pH-value for the three simulations are compared in Figure 1. The effect of implementing activity coefficients is noticeable especially in the intermediate aerosol state. The time evolution plots of the activity coefficient of water and ammonium show also the dependence of these measures on the particle/droplet size (Figure 2). Additionally, the activation of the particles is

	Aerosol conditions, 90% relative humidity			Cloud conditions, 100% relative humidity		
Mean dry radius	72 nm	460 nm	2900 nm	72 nm	460 nm	2900 nm
HSO_3^-	0.89	0.91	0.92	0.99	1.00	1.00
HSO_4^-	0.33	0.36	0.43	0.59	0.96	0.88
NH_4^+	0.39	0.40	0.43	0.63	0.96	0.94
CH_3COOH	1.32	1.27	1.22	1.03	1.00	1.00
$(CH(OH)_2)_2$	1.83	1.70	1.55	1.06	1.00	1.00
water	0.91	0.92	0.94	0.99	1.00	1.00

Tab. 1: *Mean activity coefficients of selected species in and after the first cloud passage in different drop size classes during case (3). In ideal solutions the activity coefficients are always defined as unity.*

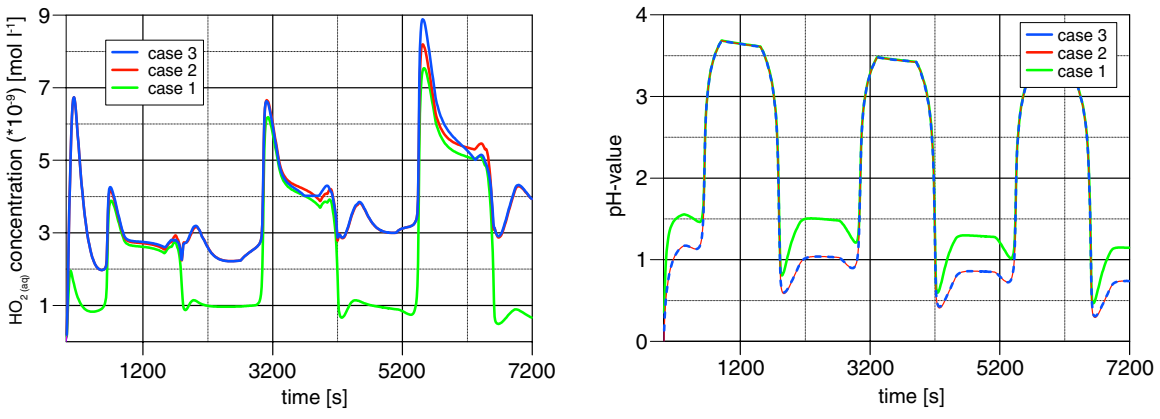

Fig. 1: *Comparison of the HO_2 concentration (left) and the pH-value (right) during the three cases.*

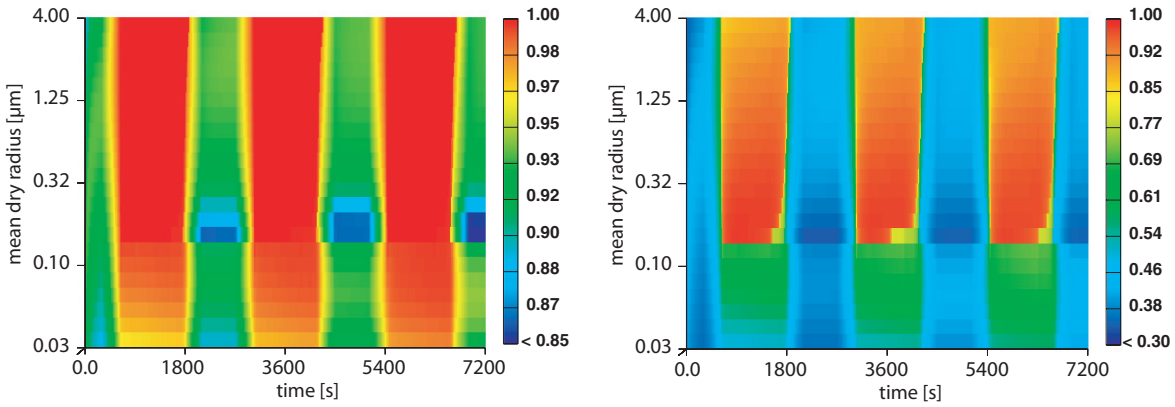

Fig. 2: *Activity coefficient (colored scale) of water (left) and ammonium (right) for case (3) over the whole size spectrum.*

clearly visible. The simulation results emphasize the consideration of non-ideality in multiphase models especially for aerosol processing in deliquescent particles and droplet activation. The proposed approach which combines UNIFAC and the Pitzer method leads to an appropriate modeling.

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Spectral Microphysics in the regional Forecast Model Lokal-Modell

Verena Grützun, Oswald Knoth, Martin Simmel, Ralf Wolke

Das mesoskalige Lokal-Modell des Deutschen Wetterdienstes wurde mit einem expliziten spektralen Mikrophysikmodell gekoppelt. Die schnellen mikrophysikalischen Prozesse sowie die Advektion der betroffenen Größen werden in einem kleinen Zeitschritt von höchstens 1 s berechnet. Die dynamischen Tendenzen von Druck, Temperatur und Wind werden hingegen in einem größeren Zeitschritt von 10 s bis 100 s berechnet. Um numerische Instabilitäten zu vermeiden, wird eine massenerhaltende Advektion aus dem Modellsystem LM-MUSCAT verwendet. Eine Modellstudie anhand einer Wärmeblase zeigt den großen Einfluss, den die Aerosoleigenschaften auf den Niederschlag haben. So wird durch eine höhere Anzahldichte der Partikel der akkumulierte Niederschlag deutlich verringert.

Introduction

The quantitative prediction of precipitation is one of the most uncertain parts of weather forecast models. The formation of precipitation is strongly connected to the available aerosol in the atmosphere through droplet nucleation. Droplet number and size depend on number, size and chemical composition of the aerosol particles. These droplets grow by condensation and subsequently by coalescence finally leading to the formation of rain drops. Furthermore, below 0°C droplet freezing can take place. This is a key process in precipitation formation, which depends on e.g., included aerosol mass and insoluble aerosol particles. To comprehend the mechanisms leading to the formation of precipitation, we combine a detailed spectral microphysics model and the three-dimensional mesoscale Lokal-Modell. First results from a warm convective cloud are presented.

Models

Lokal-Modell (LM). The LM [*Doms and Schättler*, 1999] is the regional (mesoscale) part of the operational model system of the German Weather Service. It is non-hydrostatic and fully elastic and operates on scales of 1 km. The formation of grid-scale precipitation is based on Kessler-type formulation.

Microphysics. The spectral bin microphysics model developed by *Simmel et al*. [2002] and *Simmel and Wurzler* [2006] is used. Aerosol particles as well as cloud and rain drops are described in a joint field of 66 size bins ranging from 1 nm to several mm. In each size bin, particle number mixing ratio (n^{bin}), liquid water mixing ratio and the mixing ratios of soluble and insoluble aerosols ($q^{bin}_{c,a,s}$) are considered explicitly. This offers the possibility to investigate detailedly the influence of aerosol particle number, size and composition on the formation of precipitation. Furthermore, the evaporation of drops leads to a restoration of aerosol particles. Through the use of a joint field, the nucleation of cloud droplets is included explicitly rather than through a parameterization. The model includes condensation/evaporation, coalescence using the Linear Discrete Method by *Simmel et al*. [2002], and spontaneous drop break-up.

Methods

Coupling scheme. A new data type was included into the LM representing the hydrometeors. As the time scales of the dynamical processes and of the microphysical processes strongly differ, two different time steps have been implemented. In the large time step (10 s up to 100 s), the dynamical tendencies of pressure p, temperature T, and the wind fields u, v, w are calculated within the framework of the original LM. The fast microphysical processes and the dynamical tendencies of the related variables (n^{bin}, $q^{bin}_{c,a,s}$ and water vapor mixing ratio q_v) are calculated within a time step of 1 s or smaller. The physical quantities T, p and density ρ driving the microphysics are approximated linearly to be used in the small time step (see Figure 1).

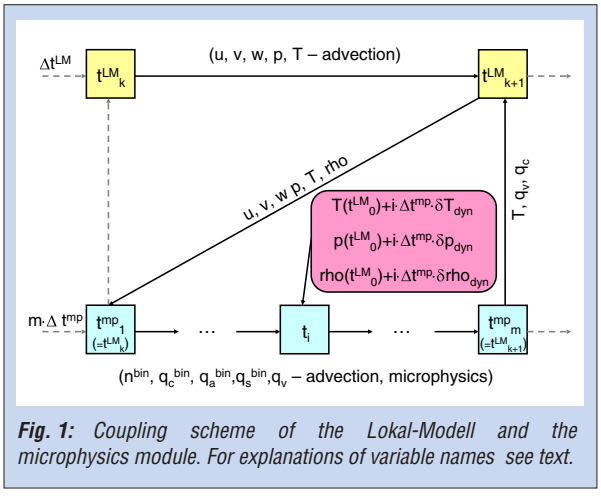

Fig. 1: *Coupling scheme of the Lokal-Modell and the microphysics module. For explanations of variable names see text.*

Conservative transport. The LM advection scheme is not mass conserving which leads to numerical instabilities in the microphysics model. Thus, the conservative transport scheme of the model system LM-MUSCAT was used. Here, before advection is done, the wind fields $\tilde{U}$ are recalculated such that the continuity equation

$$\frac{\rho_{k+1} - \rho_k}{\Delta t^{LM}} = -DIV\left(\tilde{U}\right)$$

is fulfilled. Then in each microphysical time step the continuity equation with the given $\tilde{U}$ is applied again to calculate a new density $\tilde{\rho}$. The advection is done in the flux form then and mass is conserved.

Results

The model system was tested on an artificial case. A model domain of 80 km x 80 km was used with a horizontal resolution of 1 km and 40 height levels. A temperature disturbance up to 2 K was applied to induce a convective cloud. The initial wind was set to zero. As initial distribution of the aerosol particles, a unimodal lognormal function as in *Kreidenweis et al.* [2003] was used. Presented are the results from a sensitivity study with respect to the initial number concentration of the aerosol particles (N_0=200 cm^{-3} (N200), N_0=566 cm^{-3} (N566) and N_0=4000 cm^{-3} (N4000)).

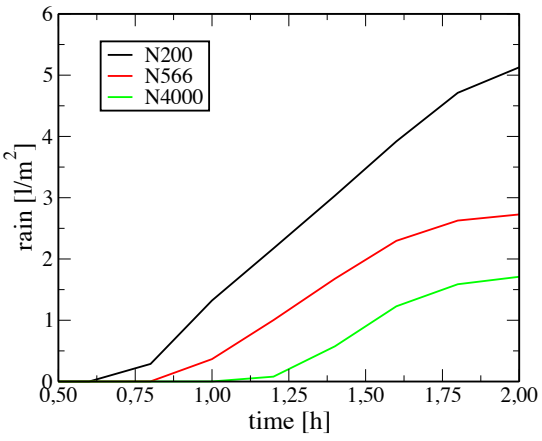

Fig. 2: *Reduction of rain with increased particle number. Shown is the accumulated rain in the center of the model domain (i.e. below the cloud center) for the three cases N200 (N_0=200 cm^{-3}), N566 (N_0=566 cm^{-3}) and N4000 (N_0=4000 cm^{-3}).*

Figure 2 shows the influence of the different initial particle numbers on the accumulated precipitation. It is clearly visible that an increase of the particle number leads to a decrease of the precipitation.

The particle and drop height profiles are shown in Figure 3 (solid: drops only, dashed: all particles and drops). For N200 and N566, a depletion of cloud nuclei (CN) can be seen,

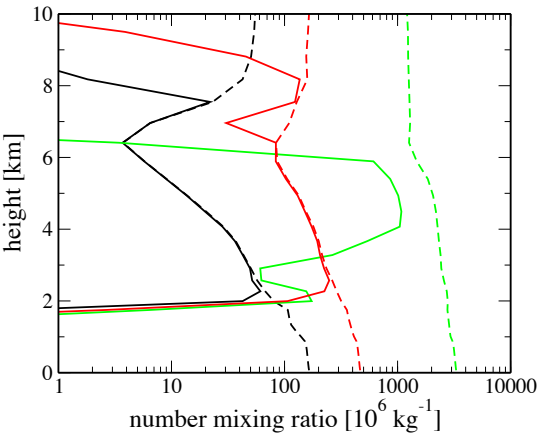

Fig. 3: *Number mixing ratio of drops (solid) and particles plus drops (dashed; colors as above). For the cases N200 and N566, all particles are activated inside the cloud, while in N4000 still many CNs remain unactivated.*

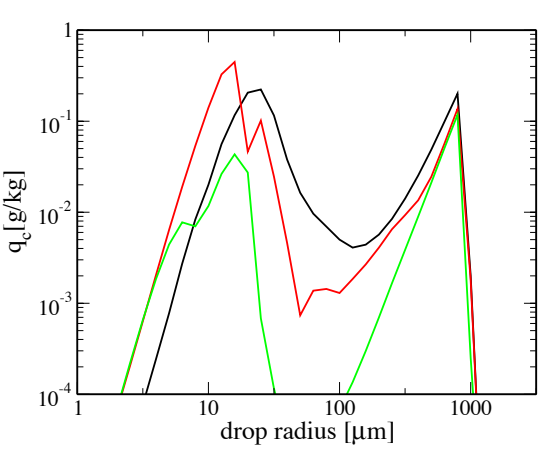

Fig. 4: *Size distribution of droplets in the center of the cloud near cloud base (2.9 km). The fewer particles lead to larger drops (first peak shifted to the right) and to a more effective coalescence (high q_c between the two peaks).*

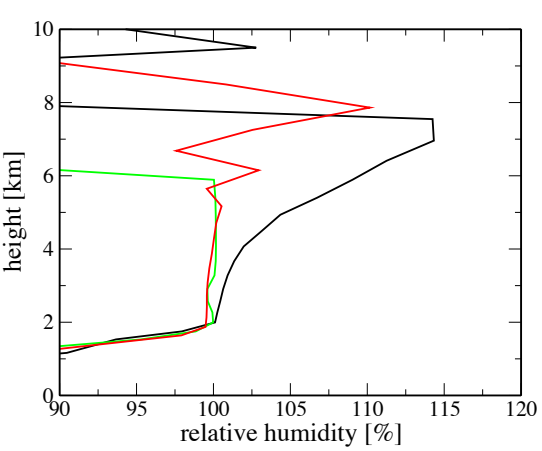

Fig. 5: *Vertical profile of the relative humidity in the center of the cloud. Due to the depletion of particles in N200 and N566, the relative humidity rises to 115 %.*

whereas in N4000 only the larger part of the CN spectrum is activated. This results in larger particles in the first two cases (see Figure 4) and in large supersaturations of up to 15 % inside the cloud (see Figure 5), as the small amount of droplets cannot take up the water fast enough. In N4000, the supersaturation is always near to 0 % as enough CNs are left to be activated once the relative humidity exceeds 100 %. The particles here stay smaller, so that coalescence is not as effective anymore which is the reason for the above mentioned reduction of precipitation.

Conclusions and Outlook

A spectral microphysics model was successfully coupled to the LM of the German Weather Service. Sensitivity studies with respect to the microphysical parameters show the huge impact of aerosol properties on the resulting amount of rain and offer insights into the droplet nucleation process. The results build a strong basis for a further development of the model system, physical as well as numerical, which will finally lead to the investigation of selected realistic episodes.

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Numerical examination of interactions between insoluble particles and tropospheric mixed-phase clouds

Harald Heinrich, Martin Simmel, Eberhard Renner

Die Hauptniederschlagsmasse über den Kontinenten fällt aus Mischphasenwolken, die aus unterkühlten Tropfen und Eispartikeln bestehen. Entscheidend für die Niederschlagsbildung in Mischphasenwolken ist die Eisphase, die bei troposphärischen Temperaturen meist über unlösliche Aerosolpartikel eingeleitet wird. Um die Effekte der unlöslichen Partikel auf den Niederschlag zu untersuchen, erfolgte eine Weiterentwicklung eines spektralen Wolkenmikrophysikmodells im Bereich der Eisphase, d.h. der Wechselwirkungen zwischen unlöslichen Aerosolpartikeln, Tropfen und Eispartikeln. Die ein- und zweidimensionale Version dieses mikrophysikalischen Modells wurde mit einem zylindersymmetrischen Dynamikmodell gekoppelt. Im Folgenden werden Simulationsergebnisse der eindimensionalen Modellversion für eine Mischphasenwolke vorgestellt.

Introduction

Mixed-phase clouds play a crucial role in the formation of precipitation. Although many clouds reside completely or partially above freezing level, cloud droplets do not freeze instantaneously as they are exposed to subzero temperatures. Ice forming mechanisms, being of primary importance for cloud evolution, are poorly understood. Observational and theoretical studies suggest that insoluble aerosol particles (AP) provide the nuclei for ice crystal generation. To examine the interactions between insoluble AP and clouds in the context of ice-phase initiation, we implement a spectral microphysical model into a radially symmetric cylindrical dynamic model. With this model configuration we test the influence of drop freezing and melting mechanisms on cloud and precipitation development.

Model

Dynamics. The dynamic model consists of two concentric air columns, the inner column corresponding to an updraft (cloud) region and the outer concentric annular column to the surrounding downward motion (cloudless) region. The model combines the vertical equation of motion, the first law of thermodynamics, the equation of mass continuity, the equation of continuity of water vapor and prognostic equations for the microphysical values. The equations are formulated in one dimensional space similar to *Asai and Kasahara* [1967]. All quantities represent average values of the parameters over the cross section of the air column per unit mass of air and are understood to be functions of both the spatial location in the vertical column and time. Interactions between the inner and outer columns are considered through the buoyant force which depends on temperature differences between the air in the ascending area and the air in the descending area. We also consider entrainment and turbulent mixing through the lateral boundary between the inner and outer cells.

Microphysics. The model includes sectional microphysics with an iterative calculation of the saturation ratio [*Simmel et al.*, 2002; *Simmel and Wurzler*, 2006]. The AP are simulated as an external mixture of partially soluble and purely insoluble particles. As microphysical processes the model considers: condensation and evaporation of drops, collision/coalescence of drops, collision of insoluble AP and drops, immersion freezing [*Diehl and Wurzler*, 2004], contact freezing induced by insoluble AP [*Diehl et al.*, 2006], heterogeneous ice nucleation [*Pruppacher and Klett*, 1997], melting of frozen drops [*Pruppacher and Klett*, 1997], collision of frozen drops, collision of drops and frozen drops, freezing of drops. The prognostic variables for liquid drops are number, water mass, soluble mass and total aerosol mass concentrations. Frozen drops can convert ice into water mass by melting when they fall through regions of the atmosphere with temperatures greater than 0°C. Therefore, we introduce the total (water + ice) mass concentration as an additional variable for ice particles. The prognostic values for the frozen drops are number, total mass, ice mass, soluble mass and total aerosol mass concentrations.

Model setup and initial conditions

The vertical domain is 12 km with a resolution of 400 m. A 1 s time step is used, and the model integrates over 40 min. The environment in which the cloud developed was taken from calculations with the regional model REMO for an area in Indonesia. Convection was initiated by a pulse which made the temperature lapse rate dry adiabatic in the lowest 2 km. The motion-initiating pulse was maintained for 15 minutes. The initial soluble AP spectrum was assumed to be of

maritime type [*Jaenicke*, 1988]. The insoluble AP spectrum consists of a lognormal distribution. The initial number concentration of soluble and insoluble AP decreases exponentially with height in the lowest 2 km of the model domain. The concentration above 2 km remains constant. We assume that the soluble particles contain a water soluble fraction of 50 %, consisting of $(NH_4)_2SO_4$. The contact freezing nuclei and the insoluble part of the cloud condensation nuclei consist only of organic material (bacteria).

Results

Figure 1 shows cross sections of the vertical velocity, supersaturation and temperature for the inner column of the model. The updraft velocity at cloud base is 6-7 m/s at the time of cloud formation and decays after the motion-initiating pulse was shut off. After 19 min, downward motion starts replacing upward motion in the lower model atmosphere. The supersaturation has a double peak: one after 5 min at 2500 m and the other after 18 min at 6500 m. The former affects the early development of the droplets at cloud base.

In Figure 2 cross sections of the liquid water mixing ratio, total (water + ice) mixing ratio and temperature are plotted. This Figure shows the evolution of a mixed-phase cloud with cloud base 2500 m above the ground and the cloud top reaching a height of 10000 m after about 25 min. The glaciation of the cloud starts after an integration time of 10 min at 7000 m. The peak water mixing ratio of 6 g/kg and the peak total mixing ratio of 3 g/kg occurred after 19 min at 5000 m and after 23 min at 8000 m above the ground, respectively. The frozen drops start to fall after 20 min through the 0°C level and melt completely 2500 m above the ground. The rain falls to the ground as a sudden warm shower which starts approximately after 23 min. The rain intensity reaches a maximum value of 1 mm/min at 26 min and decreases rapidly thereafter.

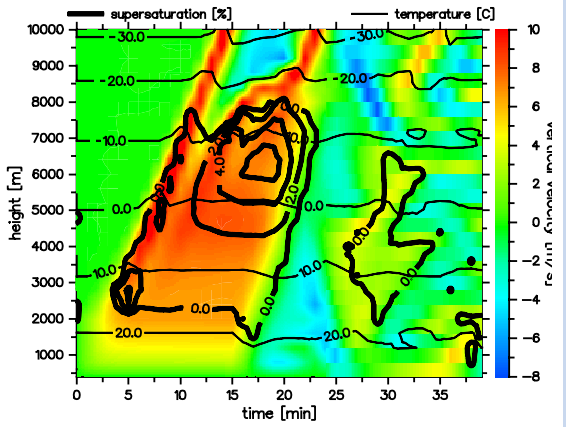

Fig. 1: *Time-height cross sections of vertical velocity, supersaturation and temperature.*

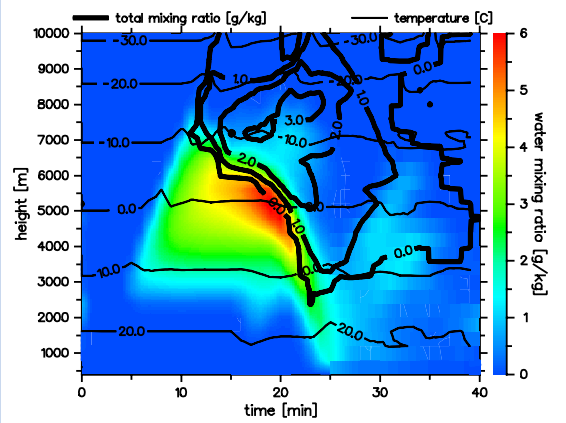

Fig. 2: *Time-height cross sections of liquid water and total (water + ice) mixing ratio and temperature.*

Outlook

The present results suggest that the coupled model describes the dynamics and thermodynamics of a mixed-phase maritime cloud rather well. For future work it is planned to improve the heterogeneous nucleation of ice, the collisions of frozen drops and contact freezing. Furthermore, comparisons with experimental data and simulations of observed hail events will be carried out.

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Turbulent Mixing Near Cloud Edges

Holger Siebert, Katrin Lehmann, Ewe Wei Saw, Raymond A. Shaw, Manfred Wendisch

Die neue hubschraubergetragene Messnutzlast ACTOS (Airborne Cloud Turbulence Observation System) wurde nach erfolgreichen Testflügen im Dezember 2004 in einer ersten Messkampagne im April 2005 in Koblenz/Winningen eingesetzt. Neben weiteren Erprobungen des Systems wurde der Einfluss von turbulenten Mischungsprozessen an Wolkenrändern auf wolkenmikrophysikalische Parameter wie Tropfengrößenverteilung in Cumuluswolken untersucht.

Introduction

A new helicopter-borne version of the Airborne Cloud Turbulence Observation System (ACTOS) is used to investigate small-scale turbulence and microphysical properties in cumulus clouds. In particular the dynamics at cloud edges is investigated where downward motion (subsidence) and up-drafts are located close together. Therefore, at the cloud edges of freshly evolving cumulus clouds shear-induced turbulence and mixing is expected be be dominant. The importance of this shear-induced mixing on the the cloud droplet population is discussed in this short report.

Fig. 1: *The new helicopter-borne ACTOS in front of the BELL 206 LR (Long Ranger).*

Observations

With ACTOS suspended beneath a helicopter, cumulus clouds in the free atmosphere have been investigated up to a height of 3000 m during a measurement campaign near Winningen, Germany in April 2005. Here, we focus on a level flight taken in a height of 2200 m above ground during the Winningen'05 experiment. ACTOS was dipped into the cloud from above, therefore, the measurements were done about 50 to 100 m below cloud top. The helicopter speed relative to the environmental air (true air speed, *TAS*) was 15 m/s. With a sampling frequency of 100 Hz the raw data presented here were collected with a spatial resolution of 15 cm which is unique for airborne cloud investigations. A picture of the new helicopter-borne ACTOS is shown in Figure 1.

In this analysis, the vertical component of the wind vector w (corrected for payload attitude and lateral motion) and the liquid water content (*LWC*) are used to characterize the small-scale cloud structure. To quantify the turbulence, so-called local energy dissipation rates ε_r are estimated with help of 2nd-order structure functions of the longitudinal wind velocity component and averaged over a flight path of length r [*Siebert et al.*, 2006]. In this analysis, ε_r is derived from 1 s long subsequences (100 samples) yielding an estimate of ε_r every 15 m.

In Figure 2 an 800 m long flight path is shown including a cloud penetration of about 350 m length indicated by the *LWC* (black curve). The cloud edges are characterized by strong fluctuations between zero and typical in-cloud values. This behavior is an indication for strong lateral mixing of cloudy and cloud-free air parcels (so-called "lateral entrainment"). Inside the cloud the *LWC* is around 1 g m^{-3} with a few sharply-bounded regions with decreased *LWC*, obviously due to cloud-top entrainment.

In the same Figure the vertical velocity w is shown (red curve) which is close to zero outside the clouds but reveals updrafts in the cloud regions and significant down-drafts near cloud edges.

In Figure 2-Ia a 60 m long sub record is enlarged showing w increasing from – 4 m s^{-1} to + 4 m s^{-1} within a horizontal distance of about 25 m yielding a horizontal gradient in flight direction of $\partial_x w = 0.3$ s^{-1}.

Figure 2-II depicts the series of ε_r. Whereas inside the clouds $\varepsilon_r \sim 10^{-3}$ m^{-2} s^{-3} is comparatively small, in the shearing zone around the cloud edges ε_r shows maximum values of 10^{-1} m^{-2} s^{-3} which is about two order of magnitude higher compared to values inside or outside the clouds and indicates strong turbulent mixing at the cloud edges.

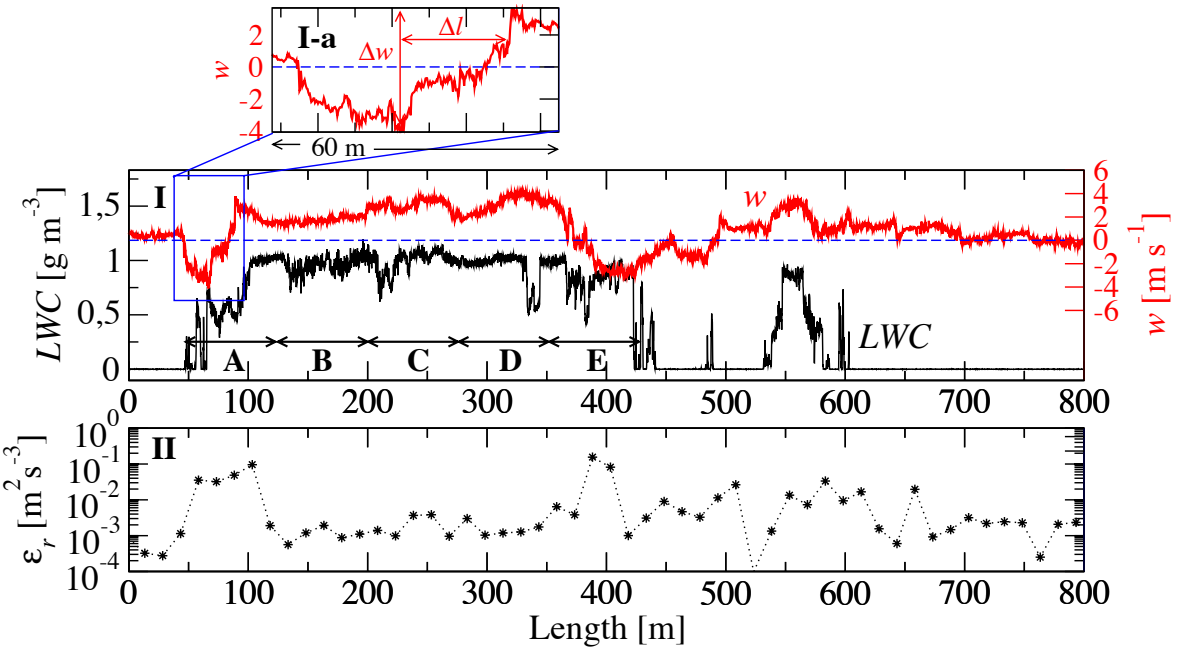

Fig. 2: Observations of a cloud penetration in a height of 2200 m close to cloud top. Shown are the liquid water content LWC, vertical wind velocity w (panel I), and the local energy dissipation rate ε_r in panel II. An enlarged part of w at the cloud edge is shown in panel I-a. The cloud is divided into five sub-records (A to E) for further analysis.

In Figure 3 the probability density functions (PDFs) of the droplet sizes for five cloud regions (indicated in Figure 2-I with the capitals A,B,C,D,E) are presented in a semi-logarithmic plot. The droplet sizes are measured with the Phase-Doppler Interferometer for Cloud Turbulence (PICT) system. All five PDFs have a similar shape with a mean diameter of around 17.5 μm. The PDFs also reveal a few larger droplets with diameters up to about 30 μm. For small droplets with a diameter below 10 μm a slight increase of the PDF for both cloud edges (region A and E) is evident compared to the core of the cloud (region B,C, and D). This behavior is more significant in the cumulative sum of the PDF shown in the lower panel of Figure 3 where curve A and E are higher than curve B, C, and D for diameters below 10 μm.

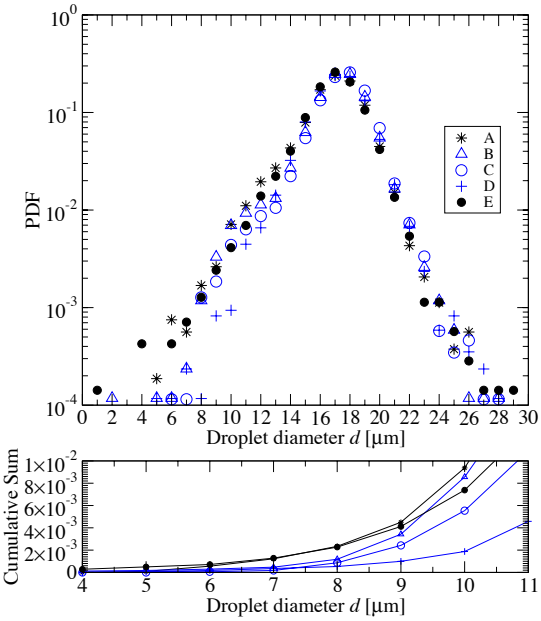

Fig. 3: Probability density function (PDF) of droplet sizes derived from PICT data. The five PDFs are estimated from 5 s long sub-records (e.g., 75 m length), the capitals (A,B,C,D,E) correspond to the cloud regions marked in Figure 2-I. The lower panel shows the cumulative sum of the five PDFs for droplet diameters below 11 µm.

Discussion

Assuming steady-state conditions and assuming furthermore that the horizontal gradient in flight direction $\partial_x w$ is dominating at the cloud edges in comparison to other velocity gradients it can be shown that the shear contribution for ε can be written as $\varepsilon = K\ (\partial_x \langle w \rangle)^2$. Here, K is the eddy diffusivity coefficient which can be approximated by using Hanna's formulation [*Hanna*, 1968]: $K = 0.3\ \sigma_w\ l$ with σ_w is the standard deviation of the vertical wind velocity and l is the spatial dimension of typical structures (e.g., length of the peaks in *LWC*). With $l = 5$ m and $\sigma_w = 0.5$ m s^{-1} we find $K \sim 1$ m^2 s^{-1}.Taking the approximation of the mean gradient from above we find $\varepsilon \sim 0.1$ m^{-2} s^{-3} which agrees well with the observations of local ε_r in that regions. That is, for this case shear stress alone gives the right order of magnitude for ε_r at cloud edges.

Due to this shear-induced lateral mixing of dry and cloudy air at the cloud edges cloud parcels with new thermodynamic conditions are created.

The time scale for mixing such a structure with dimension l at a given ε_r ($\sim 0.1\ m^{-2}\ s^{-3}$) is $\tau_T = (l^2 / \varepsilon_r)^{1/3} \sim 6$ s. The timescale for evaporation of droplets is short compared to the timescale for mixing. Thus, some droplets can completely evaporate, and the droplet concentration is diminishing by dilution and evaporation (inhomogeneous mixing). The increased probability of finding smaller droplets at the cloud edges indicates the activation of freshly entrained CCN (cloud condensation nuclei).

This example demonstrates the unique possibilities of the combined measurements of turbulence and microphysical parameters with a slow flying platform such as a helicopter.

Acknowledgment

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Radiative impact of non-spherical crystal shape in cirrus clouds

Manfred Wendisch, Sebastian Schmidt, Evelyn Jäkel, André Ehrlich, Eike Bierwirth

Üblicherweise werden Kugeln als Form für die Eiskristalle angenommen, aus denen Zirruswolken bestehen. Die Auswirkungen dieser unrealistischen Voraussetzung auf die von Zirren reflektierte Sonnenstrahlung werden in diesem Beitrag untersucht. Dazu werden mikrophysikalische und Strahlungsmessungen in, über und unterhalb von subtropischen Zirruswolken mit Hilfe eines Modells analysiert. Die Daten wurden während eines internationalen Experimentes (CRYSTAL-FACE) im Juli 2002 in der Nähe von Florida gewonnen. Es zeigte sich, dass die Berücksichtigung der nicht-kugelförmigen Eiskristallform wichtig ist für die Berechnung der reflektierten Sonnenstrahlung über optisch dünnen Zirren, insbesondere bei hoch stehender Sonne. Unter diesen Bedingungen können die von der Wolke reflektierten Strahlungsflussdichten, welche unter der Annahme kugelförmiger Eiskristalle berechnet wurden, von denen die mit nicht-sphärischen Kristallgeometrien simuliert wurden, um bis zu 70% abweichen. Für niedrige Sonnenstände und optisch dicke Zirruswolken hingegen ist der Einfluss der Kristallform auf die von den Zirren reflektierte solare Strahlungsflussdichten meist kleiner 10% (außerhalb der Eis-Absorptionsbanden). Somit kann in diesen Fällen die Kugelform bei den Berechnungen benutzt werden. Der prinzipielle Unterschied in der Wirkung der angenommenen Kristallform auf die reflektierte Strahlung liegt im Grad der Mehrfachstreuung begründet. Häufigere Streuprozesse (wie in optisch dicken Zirren bei niedrigem Sonnenstand) waschen die Unterschiede in den Streueigenschaften von unterschiedlich geformten Eiskristallen aus und verringern somit den Einfluss der Kristallform auf die Strahlungseigenschaften der Zirren.

Introduction

Cirrus clouds play an important role in weather processes and in the Earth's climate [*Lynch et al*., 2002]. They scatter/absorb solar radiation, and absorb/emit infrared radiative energy. The scattering effect reduces the solar radiation reaching Earth's surface and thus results in a surface cooling. The upwelling infrared radiation emitted by the surface and lower atmosphere is absorbed by the cirrus clouds and re-emitted at much lower temperatures than at Earth's surface. Thus cirrus clouds effectively reduce the infrared energy escaping the Earth-atmosphere system and consequently warm the atmosphere beneath. The resulting net temperature effect of cirrus clouds depends on several factors including cloud height and geometrical thickness, as well as microphysical properties (ice crystal size and shape). Perhaps the least known of these factors, ice crystal shape, makes it very complicated to quantify the combined (solar and terrestrial) radiative impact of cirrus clouds on global climate. Therefore, we attempt in this short contribution to quantify the influence of crystal habit on solar spectral irradiances above subtropical cirrus clouds. We include airborne microphysical in situ measurements (crystal number size distribution) into radiative transfer calculations in order to simulate the spectral radiative effects due to the usually non-spherical shape of ice crystals in cirrus clouds. More detailed results are given in *Wendisch et al*. [2005].

Methods

Microphysical (crystal size distribution) and radiation (solar spectral irradiance) measurements from the Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) are analyzed [*Jensen et al*., 2004]. Data were collected around Florida and the Caribbean Sea in July 2002 from six aircraft and several surface sites. Measurements from the NASA ER-2 and WB-57F aircraft are the focus of this report. The WB-57F carried a suite of microphysical instruments to probe the cloud characteristics. The ER-2 was equipped with solar spectral irradiance sensors to measure downwelling and upwelling irradiance spectra above the cirrus clouds. Two cirrus cloud cases (26 July 2002: optically thin cloud with a visible optical thickness of $\tau \approx 1$; and 23 July 2002: cirrus of moderate optical thickness with $\tau \approx 7$) were analyzed.

For the simulations we used the following strategy:

(a) The spectral single-scattering optical properties of the individual ice crystals were calculated [*Yang and Liou*, 1996] assuming several crystal shapes (spheres, columns, hollows, plates, bullets, and aggregates).

(b) The single-scattering optical properties were combined with the observed profiles of ice crystal number size distributions to calculate the vertical distribution of the spectral volumetric optical properties of the ice crystal populations for the different crystal shapes.

(c) The volumetric optical properties were used as input for a radiative transfer model [*Mayer and Kylling*, 2005] to simulate the solar spectral irradiance above the cirrus in the flight level of the ER-2 aircraft assuming the different crystal habits.

Results

Figures 1a and 1b show the ratio of calculated upwelling irradiance spectra for each of the non-spherical ice crystal habits to that for spheres at the ER-2 flight level for the two selected days (26 and 23 July 2002). The non-sphericity effects may reach up to 70% for the optically thin cirrus (Figure 1a). Outside the ice absorption band (centered at ≈ 1490 nm wavelength) the non-spherical shape effects on reflected irradiances are much less (≈ 10%) for the optically thick cirrus (Figure 1b). Even the most unlikely of crystal shape, spherical, can sufficiently reproduce the observed spectra at wavelengths less than 1400 nm within the variability of the measurements over this time period. For larger wavelengths, however, effects due to crystal shape become more significant and this is due to the variability in single-scattering albedo. For multiple scattering media these absorption effects are further amplified. This is a fundamental difference between the non-sphericity effects on atmospheric scattering and absorption. Enhanced multiple scattering smoothes out the non-sphericity effects for wavelengths where scattering dominates, but amplifies the non-sphericity impact within the ice absorption bands.

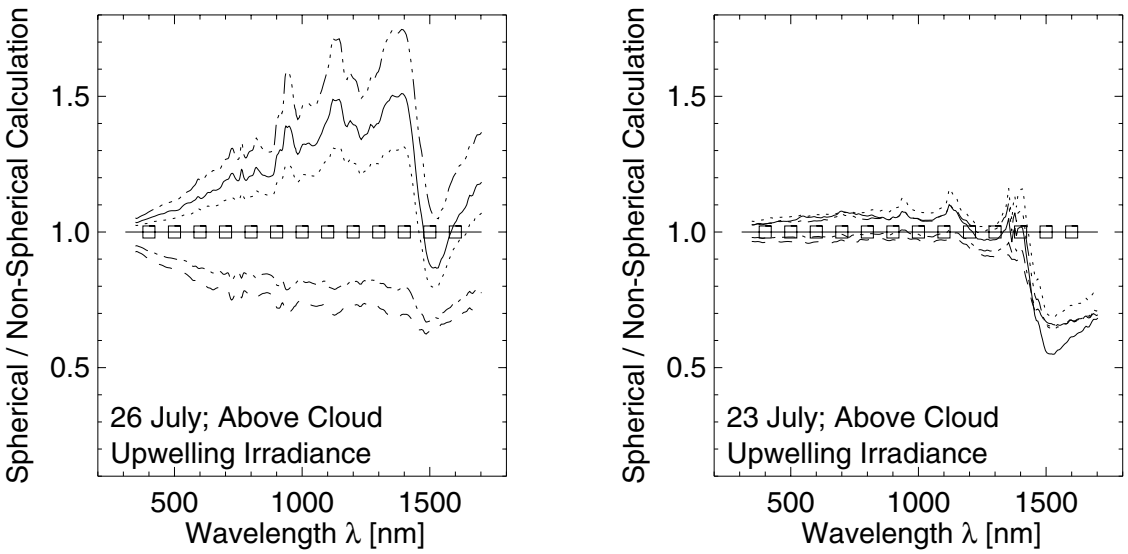

Fig. 1: ***a)*** *(left panel): Ratio of calculated upwelling irradiance assuming spherical and non-spherical ice crystal shapes for the flight level of the ER-2 (19.9 km) above the cloud for 26 July 2002 (optically thin cirrus). The solar zenith angle was θ = 21°. The curve notation is as follows: Solid lines with open squares for SPHERES; dashed lines for COLUMNS; dash-dotted lines for HOLLOWS; dash-dot-dot-dotted lines for PLATES; solid lines for BULLETS; dotted lines for AGGREGATES.* ***b)*** *(right panel): The same as Figure 1a but for 23 July 2002 (flight level of the ER-2: 20.7 km; θ = 78°).*

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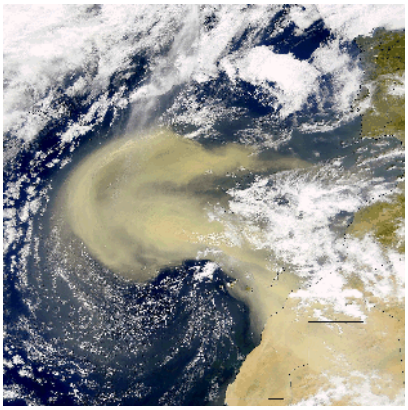
- Center for Atmospheric Research, University of Mexico (UNAM), Mexico City, Mexico.
- German Aerospace Center (DLR), Institute for Physics of the Atmosphere, Oberpfaffenhofen, Germany.



Appendices

Publication statistics

Total number and per department *)

		2004	2005
Total number of publications		**204**	**174**
1.	Books (author)	0	0
2.	Book sections	4	5
3.	Conference proceedings	89	65
4.	Publications, peer-reviewed	51	53
5.	Publications, other	0	8
6.	Lectures, invited	13	25
7.	Lectures, other	47	18
Department of Physics		**110**	**83**
1.1	Books (author)	0	0
1.2	Book sections	1	3
1.3	Conference proceedings	55	27
1.4	Publications, peer-reviewed	27	23
1.5	Publications, other	0	5
1.6	Lectures, invited	11	16
1.7	Lectures, other	16	9
Modeling Department		**33**	**25**
2.1	Books (author)	0	0
2.2	Book sections	2	0
2.3	Conference proceedings	7	6
2.4	Publications, peer-reviewed	7	11
2.5	Publications, other	0	1
2.6	Lectures, invited	0	5
2.7	Lectures, other	17	2
Department of Chemistry		**61**	**66**
3.1	Books (author)	0	0
3.2	Book sections	1	2
3.3	Conference proceedings	27	32
3.4	Publications, peer-reviewed	17	17
3.5	Publications, other	0	4
3.6	Lectures, invited	2	4
3.7	Lectures, other	14	7

*) Each publication is counted only once and assigned to one department.

Publications: Department of Physics

Book sections

2004

Heintzenberg, J. 2004. *Aerosols and their characteristics*. W. Steffen, A. Sanderson, P. Tyson, J. Jäger, P. Matson, B. Moore, F. Oldfield, K. Richardson, J. Schellnhuber, B. L. Turner, and R. Wasson (Ed.), In: *Global change and the earth system: A planet under pressure*. Springer, Berlin, p. 106-107. (IGBP Global Change Series)

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Müller, K., Brüggemann, E., Gnauk, T., van Pinxteren, D., Tilgner, A., Barzaghi, P. and Herrmann, H. 2005. *An integrated effort for a better understanding of atmospheric multiphase chemistry: Laboratory, modeling and field studies*. Ecological Chemistry 2005, Chisinau, Republic of Moldova, 20-21 May. ***)**

Parajuli, K. and Herrmann, H. 2005. *Reactivity study of Br-atoms with tropospherically important oxygenated organic compounds in aqueous solution*. General Assembly of the European Geosciences Union (EGU), Vienna, Austria, 24-29 April.

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Schütze, M. and Stratmann, F. 2005. *Modelling of a cloud tank*. European Aerosol Conference (EAC), Ghent, Belgium, 28 August - 2 September. 503.

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***) invited**

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Lectures, invited

2004

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2005

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Herrmann, H., Böge, O., Brüggemann, E., Gnauk, T., Hofmann, D., Iinuma, Y. and Plewka, A. 2004. *Particle modification and formation from BVOC emissions above coniferous forests in Germany.* AFO 2000. The German Atmospheric Research Programme. Final Symposium. Bad Tölz, Germany. 22-24 March.

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Gerwig, H., Herrmann, H. and Bittner, H. 2005. *Korngrößendifferenzierte Probenahme von chemischen Inhaltsstoffen zur Quellgruppenquantifizierung vom PM10.* 40. Messtechnisches Kolloquium. Aachen, Deutschland. 2.-4. Mai.

Herrmann, H. 2005. *Partikelcharakterisierung und Prozessuntersuchungen zur troposphärischen Multiphasenchemie.* Kolloquium TU Ilmenau. Ilmenau, Deutschland. 25. Oktober.

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Herrmann, H., Iinuma, Y., Böge, O., Gnauk, T., Plewka, A. and Müller, K. 2005. *Laboratory and field studies on SOA formation from BVOC precursors.* Faraday Discussion 130: Atmospheric Chemistry. University of Leeds, UK. 11-13 April.

Spindler, G., Brüggemann, E., Gnauk, T., Grüner, A., Herrmann, H., Müller, K., Tuch, T., Wehner, B., Wiedensohler, A. and Wallasch, M. 2005. *Größenaufgelöste physikalisch-chemische Parti kelcharakterisierung an einer Station im Messnetz des Umweltbundesamtes (Melpitz).* 40. Messtechnisches Kolloquium. Aachen, Deutschland. 2.-4. Mai.

Spindler, G., Helbig, R. and Petzold, H. 2005. *Einsatz eines PAC mit LabVIEW RT zum Monitoring von Klimadaten.* National Instruments Technologie- und Anwenderkongress „Virtuelle Instrumente in der Praxis – VIP 2005“. Fürstenfeldbruck, Deutschland. 27.-28. April.

van Pinxteren, D. 2005. *Bestimmung organischer Säuren in atmosphärischen Partikeln.* 15. Doktoranden-Seminar, AK Separation Science. Kloster Banz, Deutschland. 9. Januar.

Awards

2005

Group Achievement Award of the National Aeronautics and Space Administraion (NASA)
to International Chemical Transport Experiment North America Science Team In recognition of outstanding accomplishments with the extremely successful Intercontinental Chemical Transport Experiment conducted in Illinois and New Hampshire 2005-04-05 M. Wendisch (IfT)

Poster Prize (6 out of 500) **European Aerosol Conference (EAC)**
in Ghent, Belgium, 2005-08-28 – 2005-09-02 “Hygroscopic growth of atmospheric accumulation mode particles in continental boundary layers through H-DMPS and H-TDMA measurements” W. Birmili, K. Schwirn, A. Nowak, K. Haustein, A. Massling, K. Lehmann, A. Wiedensohler, E. Brüggemann, J. Petäjä, M . Baóy and M. Schulz

Publication award of the Leibniz-Institute for Tropospheric Research 2004

Rapid Formation of Sulfuric Acid Particles at Near-Atmospheric Conditions
Torsten Berndt, Olaf Böge, Frank Stratmann, Jost Heintzenberg, and Markku Kulmala Science 4 February 2005: 698-700.

Aerosol-chamber study of the α-pinene/O_3 reaction: Influence of particle acidity on aerosol yields and products
Iinuma, Y., B O., Gnauk, T. and Herrmann, H. Atmospheric Environment, 38, 2004, 761-773.

Publication award of the Leibniz-Institute for Tropospheric Research 2005

Atmospheric Environment – special issue: FEBUKO and MODMEP: A combined Study of Aerosol-Cloud Interaction by Field Experiments and Model Development
H. Herrmann, R. Wolke, K. Müller, E. Brüggemann, T. Gnauk, P. Barzaghi, S. Mertes, K. Lehmann, A. Massling, W. Birmili, A. Wiedensohler, W. Wieprecht, K. Acker, W. Jaeschke, H. Kramberger, B. Svrcina, K. Bächmann, J. L. Collett Jr., D. Galgon, K. Schwirn, A. Nowak, D. van Pinxteren, A. Plewka, R. Chemnitzer, C. Rüd, D. Hofmann, A. Tilgner, K. Diehl, B. Heinold, D. Hinneburg, O. Knoth, A. M. Sehili, M. Simmel, S. Wurzler, Z. Majdik, G. Mauersberger, F. Müller, W. Haunold, R. Auel, D. Möller, J. Valverde-Canossa, G. K. Moortgat, H. Chang, R. Junek, S. Gligorovski, L. Poulain, A. Monod

University courses

Winter semester 2003/2004

University Leipzig Faculty for Physics and Geosciences
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J. Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols I Atmospheric Aerosols I Lab	2 HPW 1 HPW
Heintzenberg, J.	Frontlines of Atmospheric Research	
Herrmann, H.	Atmospheric Chemistry I Atmospheric Chemistry Seminar Atmospheric Chemistry Lab	2 HPW 2 HPW block course
Renner, E.	Modeling of transport and chemical transformation of air pollutants	2 HPW
Althausen, D.	Optical Measurement Techniques	1 HPW
Ms. Wandinger, U.	Atmospheric Optics	1 HPW

Summer semester 2004

University Leipzig Faculty for Physics and Geosciences
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J. Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols II Atmospheric Aerosols II Seminar	2 HPW 1 HPW
Heintzenberg, J.	Modern Meteorological Instruments I	1 HPW
Herrmann, H.	Atmospheric Chemistry II Atmospheric Chemistry Seminar	2 HPW 2 HPW
Renner, E. Hellmuth, O. Knoth, O. Wolke, R.	Mesoscale Meteorological Modeling	2 HPW

*) Hours per Week

Winter semester 2004/2005

University Leipzig Faculty for Physics and Geosciences
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J. Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols I Atmospheric Aerosols I Lab	2 HPW 1 HPW
Heintzenberg, J.	Frontlines of Atmospheric Reserarch	1 HPW
Ms. Ziemann, A. (Univ. Leipzig) Heintzenberg, J. Herrmann H.	Cloud Physics	2 HPW
Herrmann, H.	Atmospheric Chemistry I Atmospheric Chemistry Seminar Atmospheric Chemistry Lab	2 HPW 2 HPW block course
Renner, E.	Modeling of transport and chemical transformation of air pollutants	2 HPW
Althausen, D.	Optical Measurement Techniques	1 HPW
Ms. Wandinger, U.	Atmospheric Optics	1 HPW

Summer semester 2005

University Leipzig Faculty for Physics and Geosciences
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J. Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols II Atmospheric Aerosols II Seminar	2 HPW 1 HPW
Heintzenberg, J.	Modern Meteorological Instruments I	1 HPW
Herrmann, H.	Atmospheric Chemistry II Atmospheric Chemistry Seminar	2 HPW 2 HPW
Renner, E. Knoth, O. Wolke, R. Hellmuth, O. Simmel, M. Ms. Tegen, I.	Mesoscale Meteorological Modeling/ Regional Climate Modeling	2 HPW
Ansmann, A.	LIDAR – Atmospheric research	1 HPW

*) Hours per Week

Guest lectures: Summer semester 2005 — **University Stockholm, Sweden**

Lecturer	Course	HPW*)
Heintzenberg, J.	Biogeochemical Cycles (part of)	1 HPW

Winter semester 2005/2006 — **University Leipzig Faculty for Physics and Geosciences**
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J. Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols I Atmospheric Aerosols I Lab	2 HPW 1 HPW
Heintzenberg, J.	Modern Meteorological Instruments II	1 HPW
Herrmann, H.	Atmospheric Chemistry II Atmospheric Chemistry Seminar Atmospheric Chemistry Lab	2 HPW 2 HPW block course
Renner, E.	Modeling of transport and chemical transformation of air pollutants	2 HPW
Althausen, D.	Optical Measurement Techniques	1 HPW
Ms. Wandinger, U.	Atmospheric Optics	1 HPW

Guest lectures: 2005

Ms. Tegen, I.	Lecture “Atmospheric dust sources” SOLAS Summer School Cargese, France, Sept. 2005
Hellmuth, O.	Lecture “Weather Prognosis (NWP) within the scope of the programmme lectures ‘Sources, Pathways, and Receptors of Extreme Floods’” (FLOODmaster Programme) Technische Universität Dresden, June 2005
Wiedensohler, A.	Aerosol Course “Measurements of atmospheric aerosols:Basics in aerosol physics, sampling and measurement techniques” University Peking, China, December 2005

*) Hours per Week

Master theses

Master thesis 2004

University Leipzig Faculty for Physics and Geosciences	
König, Korinna	Erzeugung und Charakterisierung von unbeschichteten und beschichteten Rußpartikeln zur Anwendung als Kondesationskeim in einem Wolkenströmungsrohr
Rhone, Peter	Development of the data acquisition and analysis systems for a portable Raman lidar and a doppler wind lidar
Rincke, Rayk	Die Entwicklung eines Aktivität basierenden Tropfenwachstums-modell für den Leipzig Aerosol Cloud Interaction Simulator
Sonntag, Andre	Vergleich des mobilen radioakustischen Sondierungssystems MODOS mit in-situ-Messverfahren in der atmosphärischen Grenzschicht
Tilgner, Andreas	Modellrechnungen zur Modifikation der physiko-chemischen Eigenschaften des atmosphärischen Aerosols bei orographischen Wolkenereignissen
Heinold, Bernd	Charakterisierung der Gebirgsüberströmung bei aufliegender Bewölkung im Thüringer Wald

Martin-Luther-University Halle Wittenberg Section Ingeneering Sciences	
Schwirn, Kathrin	Feuchtewachstum von Größenverteilungen atmosphärischer Aerosole

Technical University Dresden Faculty of Traffic Sciences Institute for Combustion Motors and Vehicles	
Bergmann, Maik	Differenzierung des flüchtigen und nichtflüchtigen Anteils bei der Partikel-Messung mit Hilfe von physikalischen und chemischen Analysen bei Emission und Immission

Master thesis 2005

University Leipzig Faculty for Physics and Geosciences	
Wennrich, Chistina	Morphologische und optische Charakterisierung von laborerzeugten luftgetragenen Rußpartikeln zur Verwendung im Leipzig Aerosol Cloud Interaction Simulator (LACIS)
Ehrlich, André	Hochaufgelöste Turbulenzmessungen in der atmosphärischen Grenzschicht mit einer ballongetragenen Messplattform

University Leipzig Faculty for Physics and Geosciences	
Voigtländer, Jens	Abschätzung des Verkehrseinflusses auf die Partikelgrößenverteilung in einer Straßenschlucht unter Berücksichtigung meteorologischer Parameter
Rose, Diana	Variabilität von nicht-volatilen Bestandteilen im atmosphärischen Aerosol : Eine Analyse für verschieden belastete Standorte und die Bestimmung von Emissionsfaktoren
Engler, Christa	Größenverteilungen nicht-volatiler Aerosolbestandteile: eine Studie im Hinblick auf lokale urbane und großräumige meteorologische Einflüsse
Radlach, Marcus	Messung von Temperaturprofilen in der unteren Troposphäre mit einem Rotations-Raman-Lidar
Haustein, Karsten	A New Parametrization Method for the Hygroscopic Growth of Atmospheric Aerosol Particles
Lieber, Matthias	Die Optimierung der Kopplung von Simulationsmodellen mit unterschiedlichen Gitterstrukturen auf Parallelrechnern

Doctoral theses

Doctoral thesis 2004

University Leipzig Faculty for Physics and Geosciences	
Schmidt, Sebastian	Influence of cloud inhomogeneities on solar spectral radiation

Doctoral thesis 2005

University Leipzig Faculty for Physics and Geosciences	
Jäkel, Evelyn	An airborne system for fast measurements of upwelling and downwelling spectral actinic flux densities
Zeromskiene, Kristina	Physical characterization of laboratory-produced biomass burning aerosol particles
Gligorovski, Saso	Laser based Studies of OH radical Reactions in Aqueous Solution
Sehili, Aissa-Mounir	Coupling between complex multiphase chemistry and detailed microphysics in a size-resolved cloud model
Sedello, Cornelia	Bestimmung der Konzentrationen und vertikalen Flüsse von Carbonylverbindungen über Grasland

Guest scientists

Guest scientists 2003/2004

Name	Period of stay	Institution
Ms. P. Rezacova	2003-10-01 / 2004-01-31	Charles University Prag, Czech Republic
A. Kolgotin	2003-11-01 / 2004-04-30	Moscow State Technical University, Russia

Guest scientists 2004

Name	Period of stay	Institution
Dr. Y. Arshinov	2004-02-08 / 2004-04-08	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
Dr. S. Bobrovnsikow	2004-02-08 / 2004-04-08	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
I. Serikov	2004-02-08 / 2004-04-08	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
Prof. R. J. Charlson	2004-04-27 / 30	University of Washington, Department of Atmospheric Sciences Seattle, USA
Prof. C. S. Kiang	2004-05-03 / 04	Peking University, College of Environmental Sciences, China
Dr. A. Weber	2004-05-02 / 05	Universität Karlsruhe, Institute of Mechanical Process Engineering and Mechanics
N. Kalivitis	2004-05-05 / 2004-06-18 2004-10-20 / 2004-11-03	University of Crete, Heraklion, Greece
Prof. Y. Miao	2004-05-15 / 2004-12-31	Peking Institute of Chemistry and Pharmacy, China
S. Liu	2004-07-20 / 2004-08-20	Peking University, College for Environmental Sciences, China
Ms. Prof. M. Hu	2004-08-06 / 2004-09-06	Peking University, College for Environmental Sciences, China
Prof. S. Slanina	2004-08-09 / 13	Energy Research Foundation of the Netherlands, Petten, The Netherlands
Prof. I. Morozov	2004-10-24 / 2004-12-19	Russian Academy of Sciences, Institute for Chemical Physics, Moscow, Russia
Dr. M. Boy	2004-11-08 / 12	University Helsinki, Finland
Dr. A. Nadeev	2004-11-21 / 2004-12-18	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
A. Simakov	2004-11-21 / 2004-12-18	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
Ms. Y. Cheng	2004-11-29 / 2004-12-31	Peking University, College for Environmental Sciences, China

Name	Period of stay	Institution
Dr. G. Pisani	2004-12-06/31	Complesso Universitario di Monte Sant'Angelo, Napoli, Italy
A. Kolgotin	2004-12-06/31	Moscow State Technical University named by Bauman, Department of Applied Physics, Russia

Guest scientists 2004/2005

Name	Period of stay	Institution
Prof. Y. Miao	2004-05-15/2005-05-14	Peking Institute of Chemistry and Pharmacy, China

Guest scientists 2005

Name	Period of stay	Institution
Dr. R. Shaw	2005-01-15/2005-05-31	Michigan Technological University, Department of Physics, Houghton, MI, USA
Ms. Y. Cheng	2005-01-01/2005-12-31	Peking University, College for Environmental Sciences, China
G. Pisani	2005-01-01/2005-03-01	Complesso Universitario di Monte Sant'Angelo, Napoli, Italy
Ms. A. Frey	2005-02-01/2005-07-31	Finnish Meteorological Institute, Helsinki, Finland
E. Engström	2005-02-02/2005-03-31	University Stockholm, Sweden
Z. Wu	2005-04-07/2005-05-23	Peking University, China
Dr. L. He	2005-04-15/2005-07-14	Peking University, Shenzhen School, China
Prof. Dr. C. S. Zhao	2005-04-16/23	Peking University, China
Dr. L. He	2005-04-15/2005-07-14	Peking University, Shenzhen School, China
Dr. A. Nadeev	2005-04-16/2005-06-14	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
A. Simakov	2005-04-16/2005-06-14	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
Ms. K. Cho	2005-04-30/2005-05-04	National Center for AgroMeteorology Republic Korea
Ms. M. Sorribas	2005-05-01/2005-07-31	ESAT "El Arenosillo"/INTA, Spain
Prof. J. Francisco	2005-05-02/04	Purdue University, Department of Chemistry, West Lafayette, Indiana, USA
Ms. Dr. J.-Y. Sun	2005-05-07/14	Peking University, China
N. Kalivitis	2005-05-03/2005-06-17	University of Crete, Heraklion, Greece

Name	Period of stay	Institution
Prof. S. Slanina	2005-07-02/05	Energieonderzoek Centrum Postbus, The Netherlands
Ms. Prof. M. Hu	2005-06-21/2005-07-09	Peking University, China
Ms. S. Urban	2005-06-18/2005-07-01	Malaysian Meteorological Service, Environmental Studies Divistion, Jalan Sultan, Malysia
Prof. R. J. Charlson	2005-09-28/30	University of Washington, Deptartment of Atmospheric Sciences, Seattle, USA
Prof. T. Nakajima	2005-10-12/14	University of Tokyo, Center for Climate System Research, Tokyo, Japan
Ms. Dr. J.-Y. Sun	2005-11-01/20	Peking University, China
Ms. A. Frey	2005-11-08/2005-12-08	Finnish Meteorological Institute, Helsinki, Finland
Dr. J. Ogren	2005-11-12/23	U.S. Department of Commerce NOAA Climate Monitoring and Diagnostics Lab. Boulder, USA
A. Kolgotin	2005-11-15/2005-12-15	Moscow State Technical University.named by Bauman, Department of Applied Physics, Russia
Prof. I. Morozov	2005-10-15/2005-12-22	Russian Academy of Sciences, Institute for Chemical Physics, Moscow, Russia

Visits of IfT scientists at other research institutions

Year	Name	Period of stay	Institutions
2003/04	Dr. M. Wendisch	2003-07-01/ 2004-07-31	NASA Ames Research Center, Moffett Field, USA
2004	Dr. O. Hellmuth	2004-04-05/08	University Helsinki, Finland
	Dr. A. Maßling	2004-07-01/ 2004-12-13	Lund University, Institute of Technology, Department of Physics, Sweden
2005	Dr. A. Maßling	2005-02-01/ 2005-08-04	Lund University, Institute of Technology, Department of Physics, Sweden
	Prof. Dr. J. Heintzenberg	2005-02-27/ 2005-03-01	Peking University, China
	Prof. Dr. J. Heintzenberg	2005-03-02/13	Meteorological Research Institute Tsukuba, Japan
			Research Institute for Humanity and Nature, Kyoto, Japan
	Prof. Dr. J. Heintzenberg	2005-06-04/06	Universidade Evora, Departamento de Fisica, Portugal
	Dr. A. Maßling	2005-09-05/ 2005-12-31	Lund University, Institute of Technology, Department of Physics, Sweden
	Prof. Dr. J. Heintzenberg	2005-11-11/16	Sino-German-Center Peking, China
	Prof. Dr. J. Heintzenberg	2005-12-07/15	Stockholm University, Department of Meteorology, Sweden

External scientific meetings

Organization and chairmanships 2004

meetings	place / date	number of participants
EFEU-Projekttreffen	Leipzig 16.-18.02.04	16 national
Atmosphärenforschungs-Schwerpunkt (AFO) Abschlussseminar	Bad-Tölz 22.-24.03.04	300 national
MODMEP-Projekttreffen	Leipzig 02.06.04	15 national
FAT (Forschungsvereinigung Leipzig Automobiltechnik) - Sitzung mit BMW, Arbeitsgruppe „Umwelt und Gesundheit“	Leipzig 07.10.04	12 national
Vergleichsworkshop „Größenspektrometer“	Leipzig 29.11.-03.12.04	10 national
VDI (Verein Deutscher Ingenieure) Treffen der Arbeitsgruppenational „Partikelzählung in der Außenluft“	Leipzig 01.-02.12.04	10 national
Workshop Atmospheric Chemistry	Aachen 07.10.04	14 national

Organization and chairmanships 2005

meetings	place / date	number of participants
Workshop Atmospheric Chemistry	Frankfurt/M. 23.03.05 Frankfurt/M. 22.07.05 Frankfrut/M. 22.11.05	12 national 14 national 8 national
Verkehrsbedingte Feinstäube in der Stadt (in Kooperation mit UFZ Leipzig-Halle)	Leipzig 14.-15.02.05	14 national
Project-Planning meeting Frame Programme 6 EU	Leipzig 31.10.-01.11.05	12 international
WMO - Gobal Aerosol Watch/Aerosol - Scientific Advisory Group Meeting	Leipzig 18.-19.11.05	8 international
GAW Intercomparison workshop for absorption photometers	Leipzig 12.-21.11.05	17 international
UFIPOLNET-Meeting (Ultrafine praticle size distributions in air polution monitoring networks)	Leipzig 06.12.05	10 international
European Geosciences Union / Session Recent developments in tropospheric aerosol and cloud chemistry	Wien 29.04.05	110 international

International and national field campaigns

International field campaigns 2004

Field Campaign	Project partner from
CLACE-3 Cloud and Aerosol Characterisation Experiment Jungfraujoch, Swiss	Germany Switzerland UK Denmark
PRACS-RICO Puerto Rico Aerosol and Cloud Study Pico del Este, Puerto Rico	Germany Mexico UK Puerto Rico
FIGARO Finnish-German Atmospheric Research Co-Operation on New Particle Formation in the Boreal Forest Region	Finland
Pearl River Delta regional air quality study	China Taiwan Hong Kong Germany
Characterization of the number and chemical size distributions as well as hygroscopicity of fine and ultrafine particles in Beijing	China

International field campaigns 2005

Field Campaign	Project partner from
Characterization of the number and chemical size distributions as well as hygroscopicity of fine and ultrafine particles in Beijing	China
ARIADNE AeRosol PhysIcal and ChemicAl IDeNtification on CretE	Greece
Winningen‘05 Helicopter-borne cloudexperiment with ACTOS	USA
CLACE-4 Cloud and Aerosol Characterisation Experiment Jungfraujoch, Schweiz	Germany Switzerland UK Finland
LexNo LACIS Experiment in November	Germany Denmark USA

National field campaigns 2005

Field Campaign	Project partner from
Physical and chemical particle characterization in the area of Leipzig Project of the German Automobile Research Association (FAT)	IfT / Dept. Physics, Chemistry
Particle characterization at the IfT-Field measurement station Melpitz	Bundesumweltamt Berlin IfT / Dept. Chemistry

IfT Reviews

Reviews for	Number	
	2004	*2005*
journals	58	53
projects	20	16
Total	**78**	**69**

Memberships

Memberships 2004

Name	Board
Althausen, D.	• Lidar Expert Network “Laser Remote Sensing of Water Vapor and Wind” • Member of the steering committee, Speaker of the Working Group “Reference system” (together with G. Ehret/DLR)
Ansmann, A.	• NASDA-ESA EarthCARE Joint Mission Advisory Group
Heintzenberg, J.	• DFG-Fachkollegium „Ozeanographie und Atmosphärenforschung“ • Ad hoc-Arbeitsgruppe „Koordinierung der Forschungen zum Globalen Wandel“ des Nationalen Komitees für Global Change Forschung • Ordentliches Mitglied der Sächsischen Akademie der Wissenschaften • Außerordentliches Mitglied Berlin-Brandenburgische Akademie der Wissenschaften • Wissenschaftlicher Beirat des Deutschen Wetterdienstes • Sprecher der Sektion E der Wissenschaftsgemeinschaft „Gottfried Wilhelm Leibniz“ • Editorial Board Tellus B, Atmospheric Research • Scientific Advisory Board of the Research Institute for Humanity and Nature, Kyoto, Japan • ESF Scientific User Committee for EUFAR (European Fleet for Atmospheric Research) • Permanent Scientific Advisory Committee of the Centro de Geofisica de Evora, Portugal
Herrmann, H.	• Deutsche Bunsengesellschaft für Physikalische Chemie • Gesellschaft Deutscher Chemiker (GDCh) • Fachgruppe Photochemie der GDCh • Fachgruppe Wasserchemie der GDCh • Fachgruppe Umweltchemie und Ökotoxikologie der GDCh • Arbeitskreis Atmosphärenchemie in der GDCh-Fachgruppe Umweltchemie und Ökotoxikologie (Vorsitz) • Sprecher der Gruppe „Mehrphasenprozesse“ im BMBF-Programm AFO 2000 • IUPAC Committee “Aqueous Solution Kinetics Data for Atmospheric Chemistry” • Mitglied des wiss. Beirats der Komission „Reinhaltung der Luft“ (KRdL) des Vereins Deutscher Ingenieure (VDI)

Name	Board
Renner, E.	• DECHEMA/GVC-Arbeitsausschuss „Schadstoffausbreitung“ • Scientific Committee of the NATO/CCMS ITM conference series, German member
Stratmann, F.	• Gasteditor für Atmospheric Environment
Ms. Wandinger, U.	• International Coordination-group on Laser Atmospheric Studies (ICLAS) • Committee on Laser Atmospheric Studies of the American Meteorological Society (CLAS) • Mitglied des Verwaltungsausschusses von COST-720, • European Co-operation in the field of Scientific and Technical Research - 720: Integrated Ground-Based Remote-Sensing Stations for Atmospheric Profiling
Wendisch, M.	• Koordinator (Aerosol Mikrophysik) im EUFAR (European Fleet for Atmospheric Research) Projekt
Wiedensohler, A.	• „Scientific Advisory Group“ für Aerosole innerhalb des „Global Watch“-Programmes der World Meteorological Organization • Editorial Board Member “Atmosphere, Water, Air and Soil Pollution” • VDI-Ausschuss „Partikelzählung in der Atmosphäre“ • Sprecher der Aerosol-Arbeitsgruppen innerhalb der EAA (European Aerosol Assembly) • „Scientific Programm Committee“ der Europäischen Aerosolkonferenz • Board member of the GAeF (Association for Aerosol Research)

Memberships 2005

Name	Board
Althausen, D.	• Lidar Expert Network “Laser Remote Sensing of Water Vapor and Wind” • Member of the steering committee, Speaker of the Working Group “Reference system“ (together with G. Ehret/DLR)
Ansmann, A.	• NASDA-ESA EarthCARE Joint Mission Advisory Group
Heintzenberg, J.	• DFG-Fachkollegium Ozeanographie und Atmosphärenforschung • Ad hoc-Arbeitsgruppe „Koordinierung der Forschungen zum Globalen Wandel“ des Nationalen Komitees für Global Change Forschung • Ordentliches Mitglied der Sächsischen Akademie der Wissenschaften • Außerordentliches Mitglied Berlin-Brandenburgische Akademie der Wissenschaften • Wissenschaftlicher Beirat des Deutschen Wetterdienstes • Sprecher der Sektion E der Wissenschaftsgemeinschaft „Gottfried Wilhelm Leibniz“ • Editorial Board Tellus B, Atmospheric Research • Scientific Advisory Board of the • Research Institute for Humanity and Nature, Kyoto, Japan

Name	Board
Heintzenberg, J.	• ESF Scientific User Committee for EUFAR (European Fleet for Atmospheric Research) • Permanent Scientific Advisory Committee of the Centro de Geofisica de Evora, Portugal
Herrmann, H.	• Deutsche Bunsengesellschaft für Physikalische Chemie • Gesellschaft Deutscher Chemiker (GDCh) • Fachgruppe Photochemie der GDCh • Fachgruppe Wasserchemie der GDCh • Fachgruppe Umweltchemie und Ökotoxikologie der GDCh • Arbeitskreis Atmosphärenchemie in der GDCh-Fachgruppe Umweltchemie und Ökotoxikologie (Vorsitz) • DECHEMA/GDCh/Bunsengesellschaft Gemeinschaftsausschuss „Chemie der Atmosphäre“ • Fellow of IUPAC • Mitglied des wiss. Beirats der „Komission zur Reinhaltung der Luft“ (KRdL) des Vereins Deutscher Ingenieure (VDI) • German member of the Scientific Steering Committee of the ESF programme INTROP
Renner, E.	• DECHEMA/GVC-Arbeitsausschuss „Schadstoffausbreitung“ • Scientific Committee of the NATO/CCMS ITM conference series, German member
Stratmann, F.	• Gasteditor für „Atmospheric Environment“
Ms. Wandinger, U.	• Topical Editor “Applied Optics” • Committee on Laser Atmospheric Studies of the American Meteorological Society (CLAS) • Mitglied des Verwaltungsausschusses von COST-720, European Co-opertion in the field of Scientific and Technical Research 720: Sensing Stations for Atmospheric Profiling
Wendisch, M.	• Koordinator (Aerosol Mikrophysik) im EUFAR (European Fleet for Atmospheric Research) Projekt
Wiedensohler, A.	• „Scientific Advisory Group“ für Aerosole innerhalb des „Global Watch“-Programmes der World Meteorological Organization • Editorial Board Member “Atmosphere, Water, Air and Soil Pollution” • VDI-Ausschuss „Partikelzählung in der Atmosphäre“ • Sprecher der Aerosol-Arbeitsgruppen innerhalb der EAA (European Aerosol Assembly) • “Scientific Programm Committee” der Europäischen Aerosolkonferenz • Board member of the GAeF (Association for Aerosol Research) • “Technical Programm Committee” IAC (International Aerosol Conference)

Cooperation

International Cooperation

Research Project	Cooperation Partners*)
Atmospheric Radiation Package (HARP) for spectrally resolved actinic flux and irradiance measurement instrumentation for HIAPER (High-performance Instrumented Airborne Platform for Environmental Research)	National Science Foundation (NSF), USA
Cirrus cloud optical properties in the visible and near infrared - Aircraft measurements and radiative transfer calculations	National Aeronautics and Space Administration (NASA), USA
Analysis of the load of fine dust particles in Germany: Determination of the aerosol concentration of ultrafine particles	4 project partners Germany one project partner each: Sweden Denmark UK
Channel for the measurement of temperature and particle extinction with the multiwavelength Lidar	Institute for Atmospheric Optics Tomsk, Russia
BodEx (Quantification of near source dust emission and dust properties in the Bodele Depression)	Oxford University, UK University College London, UK NASA Goddard Space Flight Center, USA
Evaluation of dust aerosol parameterization and climate feedback in a global climate model	NASA Goddard Institute for Space Studies (USA)
Leipzig Aerosol Cloud Simulator (LACIS)	University of Copenhagen, Denmark Universtiy of Helsinki, Finland
INSPECTRO Influence of Clouds on the Spectral Actinic Flux in the Lower Troposphere	three project partners each: Germany UK 2 project partners Norway one project partner each: Greece Austria
European Union - Projects	
EUFAR European Fleet for Airborne Research in the Field of Environment and Geo-Science	2 project partners Germany one project partner each: UK France Ireland Sweden

*) cooperations are listed explicitely with up to five partners

Research Project	Cooperation Partners*)
European Union - Projects	
CARIBIC Civil Aircraft for Remote Sensing and In-situ measurements in Tropospheric and Lower Stratosphere based on the Instrumentation Container Concept	6 project partners Germany one project partner each: UK France Netherlands Switzerland Sweden
CREATE Construction, Use and Delivery of an European aerosol database	two project partners each: Germany Finland Netherlands one project partner each: France Italiy Ireland Norway Switzerland
ACCENT Atmospheric Composition Change: An European Network	6 project partners Germany 6 project partners UK 4 project partners Netherlands 3 project partners Finland two project partners each: Belgium Switzerland Austria Norway France Greece one project partner each: Spain Bulgaria Denmark Ungary Ireland Latvia Lithuania Poland Portugal

*) cooperations are listed explicitely with up to five partners

Research Project	Cooperation Partners*)
European Union - Projects	
PURAT Particles in the Urban Atmosphere: Behavior of fine and ultrafine particles, their spatial variation, and relationships with local policy action	4 project partners Germany 1 project partner Denmark
MOST Multiphase chemistry of Oxygenated Species in the Troposphere	3 project partners France two project partners each: Germany Ireland one project partner each: Switzerland Greece Spain

National Cooperation

Research Project	Cooperation Partners*)
Feinstaubmessung; Charakterisierung des Aerosols im Messnetz des Umweltbundesamtes	Umweltbundesamt, Berlin
Langfristige Beobachtung von Energie- und Spurenstoffflüssen über Grasland am Beispiel einer Ankerstation (Forschungsstation Melpitz) und Parametrisierung von atmosphärischen Widerstandsmodellen	Technische Universität Dresden Technische Universität, Bergakademie Freiberg
Felduntersuchungen von Budgets und Konversion organischer Partikelinhalts-stoffe in troposphärischen Wolkenprozessen (FEBUKO)	Brandenburgische Technische Universität Cottbus Zentrum für Umweltforschung Frankfurt Technische Universität Darmstadt
Chemische und physikalische Charakterisierung des Aerosols aus Biomasseverbrennung	Universität Leipzig, Institut für Meteorologie MPI für Chemie, Biochemie Mainz MPI für Meteorologie Hamburg
Modellierung troposphärischer Mehrphasenprozesse: Werkzeuge und chemische Mechanismen (MODMEP)	MPI für Meteorologie Hamburg, Brandenburgische Technische Universität Cottbus
Spektrale Mikrophysik in Vorhersagemodellen unter besonderer Berücksichtigung der Tropfennukleation (Niederschlagsvorhersage)	21 deutsche Projektpartner
Flugzeuggetragene Messungen von mikrophysikalischen und Strahlungseigenschaften von inhomogenen Wolken in der unteren Troposphäre (4D-Wolken)	9 deutsche Projektpartner

*) cooperations are listed explicitely with up to five partners

Research Project	Cooperation Partners*)
Wasserdampf-DIAL Referenzsystem	Universität Hohenheim, Universität Potsdam, DLR Oberpfaffenhofen Fa. Kayser & Threde, München Fa. Deckwerth, Wurzen
Einfluss von Vegetationsfeuern auf die Zusammensetzung und die Zirkulation der Atmophäre (EFEU)	Universität Leipzig, Institut für Meteorologie MPI für Chemie, Biochemie Mainz MPI für Meteorologie Hamburg
DFG-Forschergruppe SAMUM (SAharan Mineral dUst ExperiMent)	9 deutsche Projektpartner
Partikelmodifizierung und -neubildung aus BVOC-Emissionen von Nadelwaldbeständen in Deutschland (BEWA 2000)	Institut für Meteorologie und Klimaforschung - Institut für Atmosphärische Umweltforschung (IMK-IFU), Garmisch-Partenkirchen Bayreuther Institut für Terrestrische Ökosystemforschung (BITÖK) Bergische Universität Gesamthochschule (BUGH) Wuppertal
Konzentrationsmessungen von BVOC-Carbonylen über einem Nadelwaldbestand (BEWA 2000)	Institut für Meteorologie und Klimaforschung - Institut für Atmosphärische Umweltforschung (IMK-IFU), Garmisch-Partenkirchen Bayreuther Institut für Terrestrische Ökosystemforschung (BITÖK) Universität Freiburg Universität Innsbruck, Österreich
Korngrößen-Zusammensetzung des Schwebstaubs in Dresden	Landesamt für Umwelt und Geologie, Dresden TÜV Sachsen Universität Lund, Schweden Umweltforschungszentrum (UFZ) Leipzig-Halle
Einfluss erhöhter NH_3-Konzentrationen auf die Partikelmassebildung PM_{10} - Vergleich von NH_3-Messverfahren an drei Standorten mit unterschiedlichen Spurengaskonzentrationen in Niedersachsen und Sachsen (Ammonisax)	Staatliches Gewerbeaufsichtsamt Hildesheim (Land Niedersachsen)
TROPEIS Sammlung und physiko-chemische Charakterisierung troposphärischer Eiskeime in Zusammenarbeit mit dem DFG-Sonderforschungsbereich 641	Universität Mainz Universität Frankfurt Universität Darmstadt MPI für Chemie, Mainz
DEKLIM-KLIMEX (Interactions and Feedbacks of Biosphere and Climate on Interannual to Centennial Timescales and Future Trends)	MPI für Biogeochemie Jena MPI für Meteorologie Hamburg Leibniz-Zentrum für Agrarland-schaftsforschung Müncheberg

*) cooperations are listed explicitely with up to five partners

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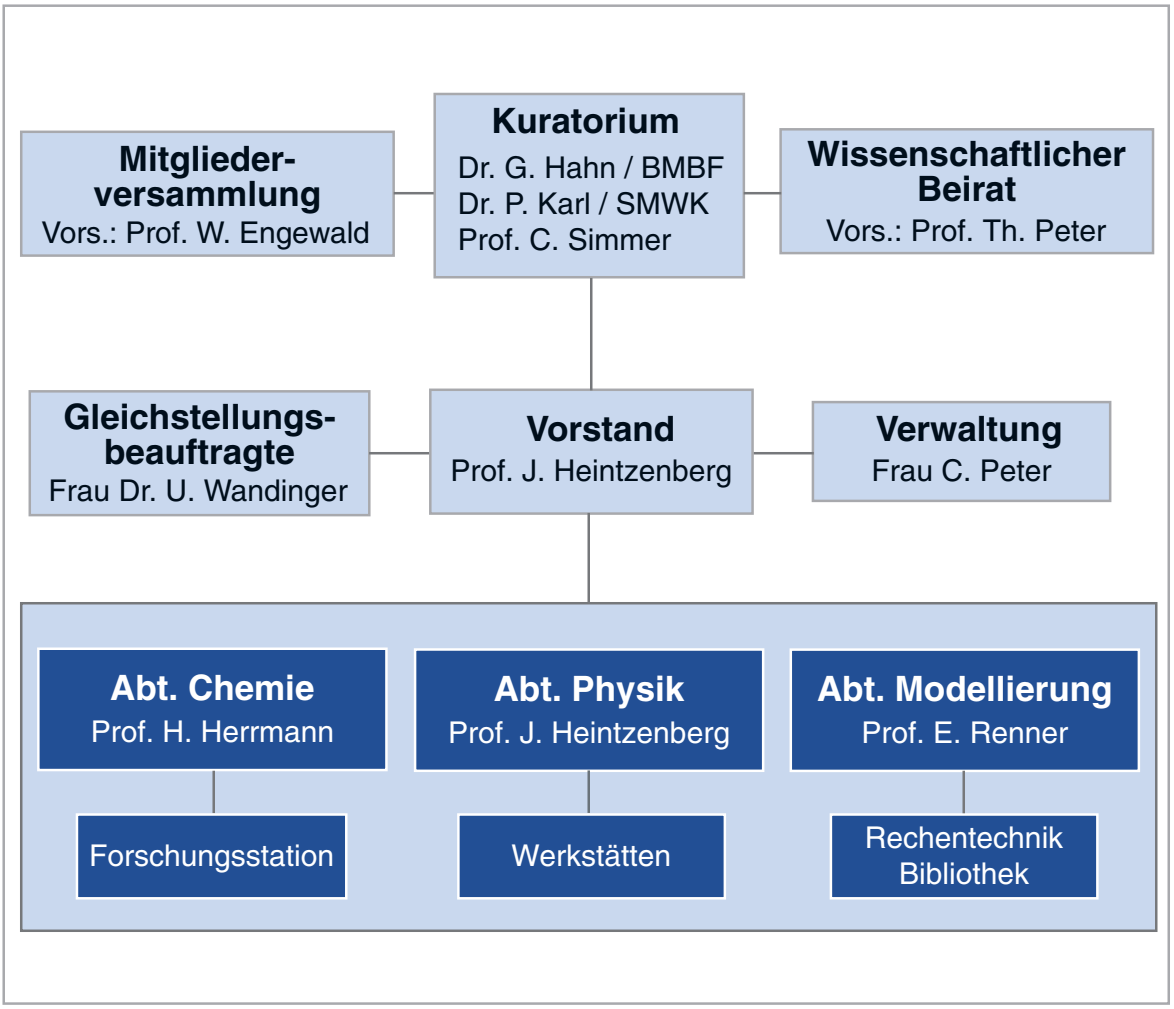
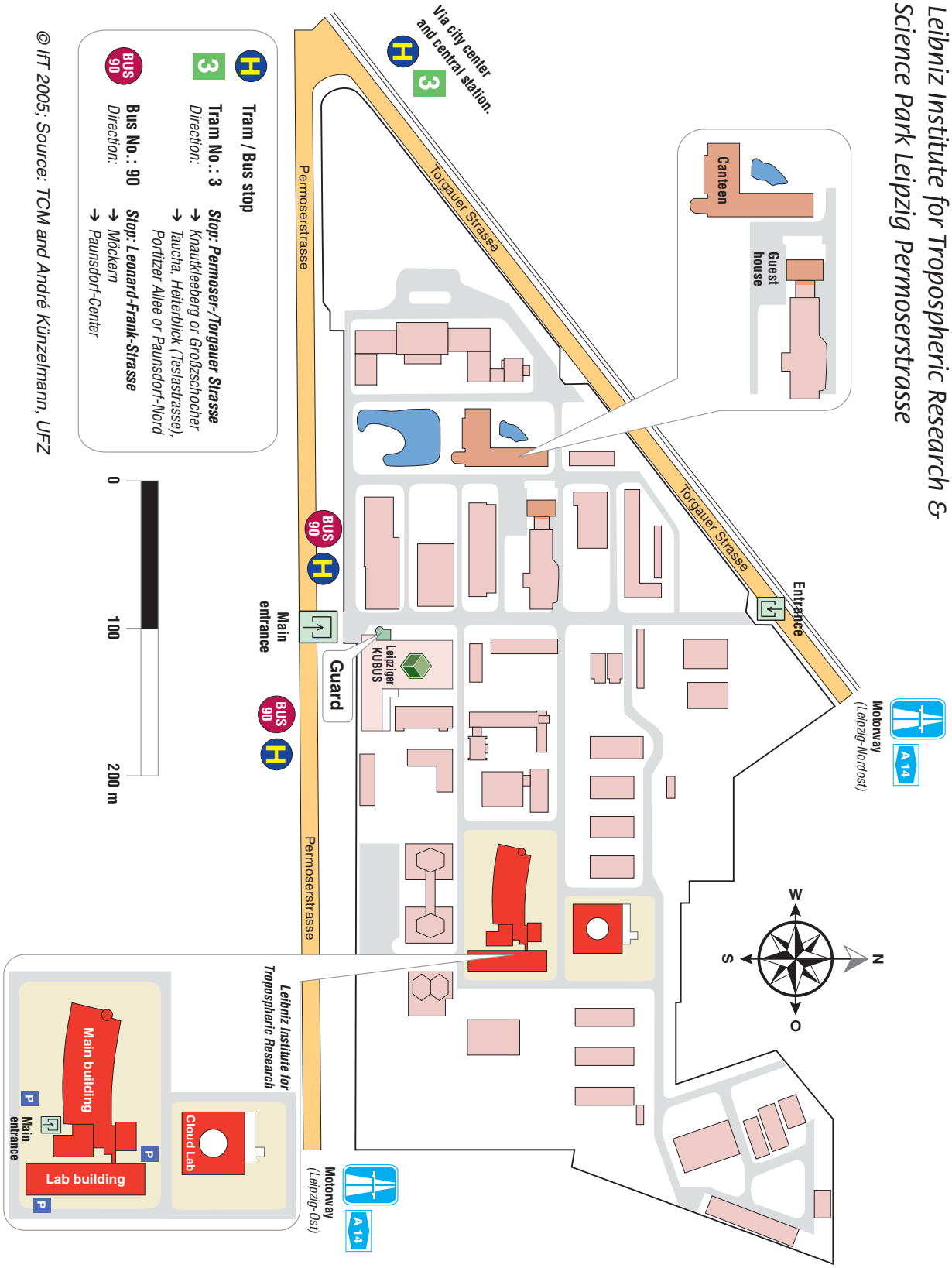
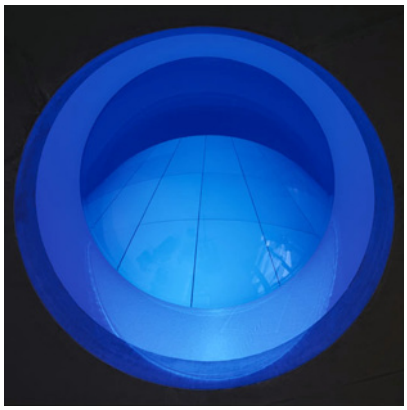


Research area Permoserstrasse





IfT-Intern

Öffentlichkeitsarbeit

Präsenz in Printmedien 2004

Zeitungen

ZEITUNG	DATUM	Titel	IfT - Interview (JournalistIn)
international			
Tages-Anzeiger Zürich	07.04.04	*CLACE-3 Kampagne (Jungfraujoch /Schweiz)* Von Forschern, die sich Wolken wünschen *Auf dem Jungfraujoch untersuchen Forscher, wie Wolken entstehen, Die erhobenen Daten sollen Klimamodelle verbessern*	Dr. Stephan Mertes (Daniel Bächtold)
national			
DIE WELT (*Wissenschaft*)	19.01.04	Vom Winde verwehte Klima-Akteure *Aerosol-Partikel: Forscher erkunden gegensätzliche Effekte - Staub kühlt - Ruß wärmt*	Prof. J. Heintzenberg (Axel Bojanowski)
PM Magazin Welt des Wissens Wissenschaft Aktuell	01.08.04	KLIMAFORSCHUNG *Wetter aus dem Wolkenlaobr*	Dr. F. Stratmann (Gerhard Wagner)
BILD am SONNTAG (*Leben und Wissen*)	15.08.04	Weltweit einmalig *Wolken aus der Wetterküche*	IfT – Öff.Arbeit (Herr Klostermann)
regional			
Freie Presse Chemnitz (*Zwickau-Annaberg*)	03.02.04	Leipziger Forscher kommen den Wolken ein Stück näher *Am Leibniz-Institut für Troposphärenforschung entsteht ein 14 Meter hohes Wolkenlabor*	Prof. J. Heintzenberg (Samira Sachse)
Westfalenpost	20.03.04	Ein Himmel voller Sand *320 Kilometer breite Wolke aus der Sahara verwandelt Tiroler Bergwelt in eine gelb-orangene Landschaft*	Prof. J. Heintzenberg (Joachim Karpa)
DER TAGESSPIEGEL Berlin	11./12.04.04	In 17 Tagen um die Welt *Der schöne Sand an Karibikständen stammt aus der Sahara. Luft kennt keine Grenzen.*	Dr. Albert Ansmann (Christine Wetzel)
Plattlinger Anzeiger	10.05.04	*Europ. Atmosph. Experim. „Inspectro“Messkampagne* Ein Wetterballon am Himmel über Ruckasing *Leibniz-Institut untersucht bei EU-Atmosphärenexp. die Wechselwirkung zwischen Wolken und Strahlung*	IfT (Sepp Schiller)

ZEITUNG	DATUM	Titel	IfT - Interview (JournalistIn)
regional			
Plattlinger Anzeiger	12.05.04	Fesselballon im Gewerbepark von Osterhofen	Dr. Holger Siebert
Plattlinger Anzeiger	14.05.04	Wetterballon MAPS-Y wartet auf Startfreigabe *Heute läuft „Atmosphären-Experiment“ an*	Dr. Holger Siebert Katrin Lehmann
Plattlinger Anzeiger	18.05.04	Atmosphärenexperiment über Osterhofen *Fesselballon schwebt über Osterhofener Gewerbepark*	Dr. Holger Siebert
Freie Presse Chemnitz (*Zwickau Annaberg*)	19./20.04.04	Der Wolkenforscher aus Leipzig *Ankündigung* *Feature, MDR Figaro*	Prof. J. Heintzenberg
Süddeutsche Zeitung	26.05.04	*CLACE-3 Kampagne* *(Jungfraujoch/Schweiz)* Zwischen den Wolken *Wie Schweb- und Schadstoffteilchen das Klima beeinflussen, untersuchen Forscher am Jungfraujoch*	Dr. Stephan Mertes (Eva Opitz)
hallo! LEIPZIG	19.06.04	Wann wird es denn endlich wieder richtig Sommer? *Keine Endzeithektik bei Leipziger Klimaforschern*	Dr. A. Ansmann (Andreas Krüger)
Leipziger Volkszeitung	25.06.04	Rohbau für himmlische Forschungsanlage fertig *Richtkranz tanzt im Wind über dem Wolkensimulator*	Pressemitteilung Richtfest Wolkenlabor (Mario Beck)
hallo! Leipzig	03.07.04	Der Blick nach Wolkenkuckuksheim *Leipziger erforscher rätselhafte Himmelsobjekte im Labor*	Prof. J. Heintzenberg (Svenia Teichmann)
Leipziger Volkszeitung (*Hochschule und Wissenschaft*)	14./15.08.04	Lichtradar späht in Hongkongs Himmel *Mit Hightech rücken Experten des Leipziger Instituts für Tropo-sphärenforschung nach China aus*	Dr. A. Wiedensohler (Mario Beck)
Leipziger Volkszeitung (*Hochschule und Wissenschaft*)	25./26.08.04	Vom Winde verweht *Wie Sahara-Staub das Klima beeinflusst, wollen Leipziger Forscher herausfinden / Eine heiße Sache*	Pressemitteilung (Mario Beck)
Leipziger Volkszeitung (*Hochschule und Wissenschaft*)	24./25.12.04	Düsen und Saugen *Ein Airbus wird zum Fluglabor – und Leipzigs Troposphärenforscher sind bei dem Projekt an Bord*	Pressemitteilung (Mario Beck)
Leipziger Volkszeitung (*Hochschule und Wissenschaft*)	31.12.04	Gastprofessur der Uni Peking	Pressemitteilung (Mario Beck)

Journal

der Wissenschaftsgemeinschaft
Gottfried Wilhelm Leibniz

Ausgabe Leibniz – Journal	Titel	Autor
Nr. 1/2004 / NACHRICHTEN	*Vom Wind verweht* DFG / SAMUM-Projekt	Pressemitteilung IfT
Nr. 4/2004 / NACHRCHTEN	*Saubere Luft für Olympia* Kooperation Univ. Peking	Pressemitteilung IfT

Präsenz in Printmedien 2005

Zeitungen

ZEITUNG	DATUM	Titel	IfT - Interview (JournalistIn)
international			
Ingenioren (Dänemark)	30.09.05	Skylaboratorium	Prof. J. Heintzenberg Jens Ramskov
national			
FLUG REVUE	Feb-05	Lufthansa unterstützt Umweltprojekte Airbus forscht für CARIBIC	Prof. J. Heintzenberg Sigrun Rittrich
MORGENWELT Hamburg magazin für wissenschaft und kultur	05.02.05	Wie Schwefelsäure die Wolkenbildung unterstützt	Dr. Thorsten Berndt Jan Oliver Löfken
FINANCIAL TIMES Deutschland (*Technik + Medien / Forschung + Entwicklung*)	30./31.03.05	EU-Richtlinie basiert nur auf groben Grenzwerten für Luftqualität *(Feinstaub) Feinstaub – Die unsichtbare Gefahr*	Prof. A. Wiedensohler Jan Oliver Löfken
Neues Deutschland	18.04.05	Mit gutem Gewissen Gas geben? Erdgasautos blasen keinen Ruß in die Luft, doch auch ihr Brennstoff wächst nicht nach	Prof. A. Wiedensohler Benjamin Haerdle
Frankfurter Allgemeine Sonntagszeitung	31.07.05	Die Regenmacher	Prof. J. Heintzenberg Jenny Niederstadt
regional			
Leipziger Volkszeitung (*Wissenschaft Kompakt*)	05./06.03.05	Veröffentlichung des IfT *(Dr. T. Berndt) im Magazin SCIENCE*	Pressemitteilung Mario Beck
Leipziger Volkszeitung (*Politik und Nachrichten*)	31.03.05	Effekt durch Dieselfilter kommt erst in fünf bis zehn Jahren (Feinstaub)	Dr. A. Wiedensohler Martin Wachtelborn
Leipziger Volkszeitung	30.04.05	Helikopter schleppt Messkomplex ins Wolkeninnere	Prof. J. Heintzenberg Mario Beck
Leipziger Volkszeitung	28./29.05.05	Wolkenturm erhält Innenleben	Pressemitteilung Mario Beck
Leipziger Volkszeitung (*Hochschule und Wissenschaft*)	12./13.11.05	Troposphärenforschung Sahara-Expedition verschoben	Prof. J. Heintzenberg Mario Beck

Journale / Bücher

Ausgabe	Titel	Autor
international		
Dänisches Journal ILLUSTRERE VIDENSKAB Nr. 3/2005	Artikel zum Wolkenlabor	Pressemitteilung IfT
national		
WirtschaftsWoche Nr. 12 (06.01.05)	Fliegendes Labor (CARIBIC-Projekt)	Pressemitteilung IfT
Umwelt P.M.– Perspektive Nr. 1/2005 Das Magazin für kompaktes Wissen	Sand im Klima-Getriebe *Wüstenstaub* (LIDAR-Messungen; Projekt SAMUM des IfT)	Dr. A. Ansmann ; Frau Dr. I. Tegen
FOCUS - Deutschland Nr. 13/2005	Feinstaub *Stinker sollen raus – Diesel-Fahrverbote*	Dr. W. Birmili
Bauwelt Nr. 07/05	Wolkenlabor	Prof. J. Heintzenberg Nils Ballhausen

Journal / Nachrichten

der Wissenschaftsgemeinschaft
Gottfried Wilhelm Leibniz

Ausgabe Leibniz – Journal	Titel	Autor
Nr. 1 /2005 / PERSONEN	Von Leipzig nach Peking *Gastprofessur Dr. A. Wiedensohler an der Universität Peking*	Pressemitteilung IfT
Nr. 2 /2005 / Zwischenruf	Feinstaub in Deutschland *Was sind Quellen von Aerosolpartikeln, in welchen Größenklassen sind sie zu finden und wie ist ihre chemische Zusammensetzung*	Prof. A. Wiedensohler

Leibniz – Nachrichten	Titel	Autor
Nr. 20, September 2005, Seite 2	Leibniz-Experten warnen vor feinem Feinstaub *Zweiter Zwischenruf gibt umweltpolitische Empfehlungen für die politische Praxis*	Prof. A. Wiedensohler

Präsenz im Rundfunk / Fernsehen / Internet 2004

RUNDFUNK	FERNSEHEN / INTERNET	JournalistIn / RedakteurIn	IfT / Name / Thema	Datum Interview / Aufnahmen	Sendung
national					
	Bayerischer Rundfunk TV	Sabine Denninger	Prof. J. Heintzenberg Saharastaub	01.03.04	04.03., 19:00 Uhr Faszination Wissenschaft
Leipzig 97.6 Uni-Radio Mephisto		Stine Eckert	Dr. F. Stratmann Wolkenlabor	22.03.04	23.03.,10:00 Uhr Tag der Meteorologen
Radio JUMP		Markus Ehm	Dr. F. Stratmann Wolkenlabor	22.03.04	23.03. Tag der Meteorologen
Bayerischer Rundfunk 2			Prof. J. Heintzenberg Eiskzeit in Bayern: Wenn das Klima verrückt spielt		17.05., 21:20 Uhr
MDR Mitteldeutscher Rundfunk		Heidi Mühlenberg	Prof. J. Heintzenberg Feature „Der Wolkenforscher“		19.05., 22:00 Uhr MDR – Figaro
MDR 1 RADIO SACHSEN 93.9		Heike Fiedler	Dr. F. Stratmann Dr. Heike Wex Wolkenlabor	26.05.04	27.05., 07:46 Uhr Wolkenforschung
MDR Figaro		Stefan Römermann	Prof. J. Heintzenberg Klimawandel	15.07.04	27.06., 06:15 Uhr
	Leipzig Fernsehen www.leipzig-fernsehen.de	Sabine Köppe	Dr. K. Müller Forschung am IfT	09.12.04	09.12.,18:00 Uhr, und jede volle Stunde bis 22:00 Uhr
international					
	Deutsche Welle TV	Andrea Wiese	Prof. J. Heintzenberg Projekt Zukunft Tomorrow Today		05./06./07.09. Täglich zwei- bis viermal in Deutsch und Englisch

Präsenz im Rundfunk / Fernsehen 2005

RUNDFUNK	FERNSEHEN	JournalistIn / RedakteurIn	IfT / Name / Thema	Datum Interview / Aufnahmen	Sendung
national					
MDR Figaro		Stefan Römermann	Prof. J. Heintzenberg Dr. F. Stratmann Wolkenlabor	03.02.05	04.02.05, 06:30 Uhr
	ZDF – 3SAT		Prof. A.Wiedensohler Rußmessungen mit Diesel-Pkw	30.03.05	31.03./01.04.05, 18:30 Uhr Sendung Nano
MDR Info		Frau Tesch	Prof. A.Wiedensohler Feinstaubmessung	31.03.05	03.04.05
	PRO 7		Prof. A.Wiedensohler Rußmessungen mit Diesel-Pkw	01.04.05	03.04.05, 22:00 Uhr FOCUS - TV
	RTL		Prof. A.Wiedensohler Rußmessungen mit Diesel-Pkw	01.04.05	10.04.05, 22:00 Uhr SPIEGEL – TV
Deutschland-funk Forschung aktuell		Hartmut Schade	Holger Siebert Wolkenlabor	10.05.05	13./14.05.05, 16:35 Uhr
Deutschland-funk Forschung aktuell		Volker Mrasek	Ina Tegen Staubige Atmosphäre	12.05.05	01.06.05, 16:35 Uhr
	FAKT/ MDR Magazin	Inga Klöver	Prof. A.Wiedensohler Feinstaub-Hysterie	23.05.05	13.06.05, 21:05 Uhr
	MDR Sachsen-spiegel	Frau Hanisch	Prof. A.Wiedensohler Feinstaub	23.08.05	26.08.05
MDR 1 Radio Sachsen		Silke Stadler	Prof. A.Wiedensohler Feinstaub		14.09.05, 07:45 Uhr
Deutschland-funk Forschung aktuell		Volker Mrasek	Dr. A. Ansmann Rauchgaswolke über London	13.11.05	13.11.05, 16:35
international					
Deutsche Welle (dw-world.de)		Rafael Heiling	Prof. J. Heintzenberg Wolken sind Diven aus Dampf		10.05.05

Präsenz im Internet 2005

www-Adresse	Datum	IfT Name / Thema
Allgemein		
flug-revue-rotor.com	Feb-05	Prof. J. Heintzenberg Lufthansa unterstützt Umweltprojekte Airbus forscht für CARIBIC
pro-physik.de morgenwelt.de sciencemag.org	04.02.05	Dr. T. Berndt Wolkenbildung durch Schwefelsäure Rapid Formation of Sulfuric Acid Particles at Near-Atmospheric Conditions
Feinstaub		
		Prof. A. Wiedensohler
onmeda.de	15.03.05	Wissenschaftler erforschen die Wirkung von gesundheitsschädigenden Feinstäuben
kompetenznetze.de	17.03.05	Feinstäube – eine ernste Gefahr für die Gesundheit
medicalnewstoday.com	18.03.05	Background: Particulates – ever tinier particles are coming under the research' microscopes
oebis.net interconnections.de medizinauskunft.de umweltschutz-news.de	18.03.05	Feinstäube – eine ernste Gefahr für die Gesundheit
de.biz.yahoo.com	30.03.05	Feinstaub – Die unsichtbare Gefahr
ftd.de (Financial Times Deutschland) (*Technik + Medien / Forschung + Entwicklung*) feinstaub.twoday.net	30.03.05	EU-Richtlinie basiert nur auf groben Grenzwerten für Luftqualität
3sat.de	31.03.05	Feinstaub in den Städten: Je kleiner desto gefährlicher
de.biz.yahoo.com gesundheit.de	31.03.05	Feinstaub - Die unsichtbare Gefahr
tagblatt.de	10.04.05	Feinstaub: Grenzwerte in Tübingen und Reutlingen an acht Tagen überschritten
laboratorytalk.com	Jun-05	Learn about environmental nanoparticles
processingtalk.com	Jun-05	Environmental Nanoparticle measurement in the air
uni-protokolle.de chemlin.de umweltschutz-news.de neuematerialien.de	31.08.05	Leibniz-Experten warnen: Feiner Feinstaub ist gefährlicher als grober Feinstaub
scienzz.de	31.08.05	Feinstaub - Je feiner desto gefährlicher
dradio.de	31.08.05	Feiner Feinstaub ist gefährlicher als grober Feinstaub

www-Adresse	Datum	IfT Name / Thema
Feinstaub		
		Prof. A. Wiedensohler
pressetext.ch medsana.ch innovationsreport.de apotheke.com info-ruegen.de	01.09.05	Feinstaubpartikel als tödliche Gefahr Experten fordern Senkung der Grenzwerte – Kleinste Teilchen am schädlichsten
ngo-online.de	02.09.05	„Maßlos überschätzt“ Dieselpartikelfilter sollen für Feinstäube ungeeignet sein
kommunikationssystem.de	02.09.05	Feinstaub-Forscher: Grenzwerte stark senken, Partikelfilter ungeeignet
naturkost.de	04.09.05	Feinstaubpartikel als tödliche Gefahr Experten fordern Senkung der Grenzwerte
ne-na.de	05.09.05	Feinstaubpartikel als tödliche Gefahr: Experten fordern Senkung der Grenzwerte – Kleinste Teilchen am schädlichsten
analytik-news.de	05.09.05	Feinstaubdiskussion: Kleinste Teilchen sind am schädlichsten

Wolkenlabor (Inbetriebnahme)

Pressemittelung vom 17.10.05
Die Wolke im Reagenzglas: Weltweit einzigartiger Wolkensimulator in Betrieb genommen.

Pressespiegel 2005

ZEITUNG Nachrichtenagentur	DATUM	Titel	IfT - Interview (JournalistIn)
international			
„EL PAIS“ (Madrid)	30.11.05	Alemania construye un simulador de nubes para mejorar la predicción meteorológica	dpa-Meldung (Waltraud Grubitzsch; Magdalena Ruiz des Elvira)
national			
dpa – Deutsche Presse-Agentur	19.10.05	Inbetriebnahme Wolkenlabor	Dr. Heike Wex (Waltraud Grubitzsch)
Financial Times Deutschland (*Forschen + Entwickeln / Wissenswertes*)	20.10.05	Wetter-Simulant	dpa-Meldung (Waltraud Grubitzsch)
DIE ZEIT (*Wissenschaft*)	03.11.05	*Der Wolkenturm* In einem neuen Simulator erforschen Leipziger Meteorologen die Geheimnisse von Kumulus, Zirrus und Stratus	Dr. F. Stratmann (Ivo Marusczyk)

ZEITUNG Nachrichtenagentur	DATUM	Titel	IfT - Interview (JournalistIn)
regional			
Leipziger Volkszeitung (*Hochschule und Wissenschaft*)	20.10.05	*Regenmacher aus Leipzig* Erste Tests am weltweit einmaligen Wolkensimulator laufen	dpa – Meldung (Waltraud Grubitzsch)
DRESDNER NEUESTE NACHRICHTEN	20.10.05	*Wolken aus dem Rechner* Erste Tests am weltweit einmaligen Wolkensimulator laufen	dpa – Meldung (Waltraud Grubitzsch)
Sächsische Zeitung (*Wissen*)	20.10.05	Labor voller Wolken	dpa – Meldung (Waltraud Grubitzsch)
BILD	20.10.05	Weltpremiere für Leipziger Wolkenrohr	dpa-Meldung (Waltraud Grubitzsch)
Wetterauer Zeitung	21.10.05	Weltweit einziger Wolkensimulator	dpa-Meldung (Waltraud Grubitzsch)
hallo! Leipzig (*Leipzig Aktuell*)	29.10.05	*Wolken selbst gemacht* Weltweit einzigartiges Wolkenlabor wird in Berlin vorgestellt	Dr. Heike Wex (Sandra Kunze)
Leipziger Volkszeitung (*Hochschule und Wissenschaft*)	05./06.11.05	*Es braut sich etwas zusammen* Troposphären-Forscher haben weltweit ersten Wolkensimulator angeworfen	Prof. Heintzenberg Dr. F. Stratmann (Mario Beck)
Berliner Zeitung (*Wissenschaft*)	17.11.05	*Himmelsdunst im Labor* Leipziger Forscher beobachten in einem Simulator, wie sich aus kleinsten Partikeln und Wasserdampf Wolken bilden	Dr. F. Stratmann (Frau S. Noatsch)
DER TAGESSPIEGEL Berlin	21.11.05	*Dem Eisregen auf der Spur* Leipziger Forscher haben ein neues Wolkenlabor	Dr. F. Stratmann (Frank Jaeger)

Allgemeine Aktivitäten 2004

Anlass	Ort, Datum	Aktivität
Institut für Energetik und Umwelt Leipzig (Seniorengruppe)	Leibniz-Institut für Troposphärenforschung (IfT), 04.02.04	Prof. Dr. J. Heintzenberg Dr. M. Hermann Dr. F. Stratmann Frau Dr. Ulla Wandinger • Vortrag zum Institutsprofil • Vortrag Flugzeugmessungen • Vorstellung der Arbeiten im Wolkenlabor und Laserlabor
Girl's Day 2004 Schülerinnen aus Leipziger Gymnasien	IfT , 22.04.04	Praktische Einblicke in die Berufe: • Dipl.-Physikerin • Dipl.-Meteorologin • Dipl.-Chemikerin • Umwelt-Ingenieurin • Phys.-Techn. Assistentin • Chem.-Techn. Assistentin • Feinmechanikerin Tätigkeiten • Messen der Staubbelastung von Innen- und Außenluft • Radiosondenaufstieg Ablauf • Vorstellung des Instituts und der Betreuerinnen • Praktische Arbeiten in Labors • Diskussionsforum mit Studentinnen und jungen Wissenschaftlerinnen
Institut für Energetik und Umwelt Leipzig (Seniorengruppe)	IfT, 14.05.04	Dr. F. Stratmann Wolkenlabor
ROTARY CLUB 5. Schülerkongress Leipzig-Brühl	Stadtbibliothek Leipzig, 05.11.04	Prof. Dr. J. Heintzenberg Referent zum Thema: „Studium der Naturwissenschaften" vor Schülern der Leipziger Gymnasien
Humboldt-Gymnasium Klassenstufe 8	IfT, 13.12.04	Dr. M. Wendisch Vorstellung der Forschungsarbeiten am IfT zum Thema „Atmosphäre"

Allgemeine Aktivitäten 2005

Anlass	Ort, Datum	Aktivität
Lehrerfortbildung	Geschwister-Scholl-Gymnasium Taucha, 25.04.05	Dr. M. Wendisch Vorlesung zum Thema: Anthropogene Klimaänderungen
Lehrerfortbildung	Humboldtschule Leipzig (Gymnasium), 28.04.05	Dr. M. Wendisch Vorlesung zum Thema: Anthropogene Klimaänderungen
Girl's Day 2005 Schülerinnen aus Leipziger Gymnasien	Leibniz-Institut für Troposphärenforschung (IfT), 28.04.05	Praktische Einblicke in die Berufe: • Dipl.-Physikerin • Dipl.-Meteorologin • Dipl.-Chemikerin • Umwelt-Ingenieurin • Phys.-Techn. Assistentin • Chem.-Techn. Assistentin • Feinmechanikerin Tätigkeiten • Messen der Staubbelastung von Innen- und Außenluft • Radiosondenaufstieg Ablauf • Vorstellung des Instituts und der Betreuerinnen • Praktische Arbeiten in Labors • Diskussionsforum mit Studentinnen und jungen Wissenschaftlerinnen
Uni Campus	Universität Leipzig, 07.05.05	Der Beitrag des IfT beim Tag der Universität Leipzig Demonstrationsversuch zur Messung von CO_2 und Wasserdampf in der Atmosphäre (Prinzip: On-line Messung mit dem IR_Detektor Typ LI-7500)
Vorstellung der Forschungsarbeiten	IfT, Wolkenlabor, 07.06.05	Dr. F. Stratmann Mitglieder des Vereins Deutscher Ingenieure (VDI)
Projektwoche in Klassenstufe 8	Gustav-Hertz-Schule (Gymnasium), 05.12.05	Dr. M. Wendisch Vortrag zum Thema: Klimawandel