LEIBNIZ INSTITUTE FOR
TROPOSPHERIC RESEARCH

Biennial Report

Zwei-Jahresbericht

2006 / 2007

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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 (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 difficulties with analyzing the very small samples and with the complex behavior of tropospheric multiphase systems, in which individual processes seldom can clearly 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

Einleitung

Auf dem Gelände des „Wissenschaftsparks Leipzig/Permoserstraße“, in 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 Partikel 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.

from several directions. Consequently, the Leibniz 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. The process models in particular derive their parameters from laboratory experiments.

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 diameters in the nano and micrometer size ranging over more than six orders of magnitude occur in atmospheric aerosols and clouds, all of which play an important role in certain processes. All atmospheric condensable substances can be found in the

Fig. / Abb. 3: *Laser beams transmitted at IfT by Polly (2-channel lidar), two Polly XT (6-channel lidars), and the EARLINET lidar (9-channel lidar). / Laserstrahlen über dem IFT von Polly (2-Kanal-Lidar), zwei Polly XT (6-Kanal-Lidar) und dem EARLINET-Lidar (9-Kanal-Lidar).*

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 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 auf der Basis eigens durchgeführter komplexer Laborexperimente.

Feldexperimente

Die Feldexperimente des Instituts dienen der Aufklärung des atmosphärischen Kreislaufs der Aerosol- und Wolkenpartikel und der damit verbundenen Prozesse. Die Komplexität des Systems wird dabei unter anderem dadurch bestimmt, dass in Aerosolen und Wolken Partikel auftreten, deren Größe sich im Nano- und Mikrometerbereich um mehr als sechs Zehnerpotenzen unterscheiden kann, die dem entsprechend auch unterschiedlichen Umwandlungsprozessen unterliegen. Außerdem kann man alle kondensationsfähigen Stoffe des Erdsystems im Aerosol finden, von denen eine große Zahl das Klima und die Biosphäre und deren Wirkung 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.*

aerosol and a large number of them contribute to climate and biospheric effects. Essential aerosol and cloud properties of this multidimensional system are not well established on a global scale yet.

The uncertainty and thus the research efforts 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 urban and rural measurements of the institute emissions of particles and their precursor gases are subject to strong physical and chemical transformations that need to be followed with high-resolution sensors in order to identify the underlying processes.

Not even the largest highly polluted regions in the plumes of North America, Europe, the Indian subcontinent, Amazonia, and Eastern Asia are

Fig. / Abb. 6: *View from the Campus of Peking University on a heavily polluted day. / Blick vom Gelände der Peking Universität an einem stark verschmutzten Tag.*

Leibniz-Institut für Troposphärenforschung sind. Die Verbrennung fossiler und nachwachsender Brennstoffe zur Energieerzeugung und im Verkehr sind wichtigste Aerosolquellen. Wie sich aus Messungen des Instituts an vielen urbanen Stellen und kontinentalen Hintergrundstationen ergab, unterliegen die Emissionen von Partikeln und deren Vorläufern enormen physikalischen und chemischen Umwandlungen, die mit hoher zeitlicher Auflösung verfolgt werden müssen, um die beteiligten Prozesse aufzuklären.

Selbst die am höchsten verunreinigten Regionen über Nordamerika, Europa, dem indischen Subkontinent, dem Amazonasgebiet und Ostasien sind noch bei weitem nicht hinreichend bezüglich ihrer Aerosolbelastungen und den daraus resultierenden Klimawirkungen charakterisiert. Auf diese Regionen konzentrieren sich daher in internationaler Zusammenarbeit die

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

Feldexperimente des Instituts. Seit einigen Jahren nehmen Untersuchungen des Mineralstaubes im Quellgebiet der Sahara aber auch im Fernfeld über dem Atlantik und im Labor wachsenden Raum ein. 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 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 Entwicklung von Wolken widmen.

Laborexperimente

In der Atmosphärenforschung werden kontinuierlich physikalisch-chemische Modelle zur Be-

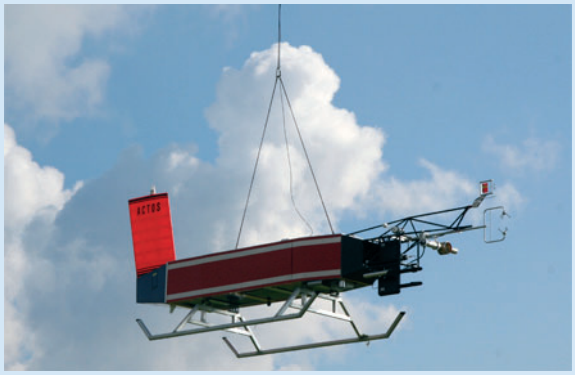

Fig. / Abb. 8: *The helicopter-borne payload ACTOS approaching airport Kiel-Holtenau. / Die hubschraubergstützte Messplattform ACTOS kurz vor der Landung auf dem Flugplatz Kiel-Holtenau.*

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. In recent years the study of mineral dust near its most important Saharan source and in the far field over the Atlantic have gained more weight in the institute's research. 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.

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.

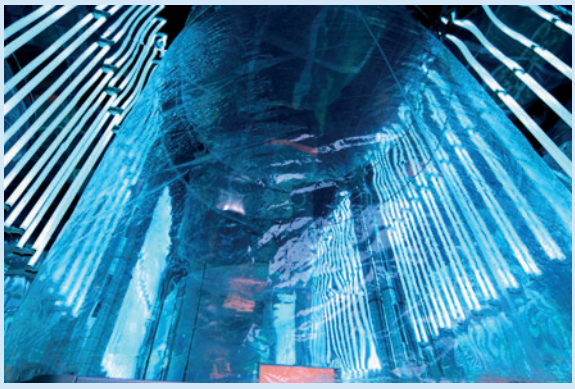

Fig. / Abb. 9: *The IfT aerosol chamber (LEAK) with UV lamps. / Die IfT Aerosolkammer (LEAK) mit UV-LAMPEN.*

schreibung der wesentlichen Prozesse entwickelt. Grundlage derartiger Modelle sind stets Prozessparameter, die in Laborexperimenten ermittelt werden müssen. Laborexperimente auf dem Stand der Basiswissenschaften Chemie und Physik müssen die Basis einer jeden Modellentwicklung sein.

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.

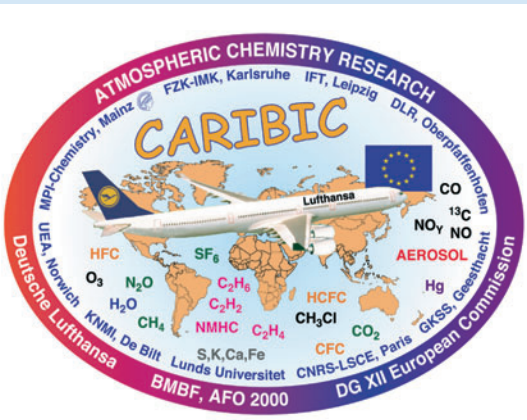

Fig. / Abb. 10: *The logo of the international project CARIBIC (Civil Aircraft for Regular Investigation of the atmosphere Based on an Intrument Container). / Das Logo des internationalen Projekts CARIBIC.*

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, Aerosolflüssen 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.

In zwei Bereichen werden prozessorientierte Laboruntersuchungen gemeinsam von den Abteilungen Physik und Chemie durchgeführt. Diese abteilungsübergreifenden Aktivitäten betreffen zunächst einen als Laminarströmungsrohr

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 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 and aerosol fluxes. 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.

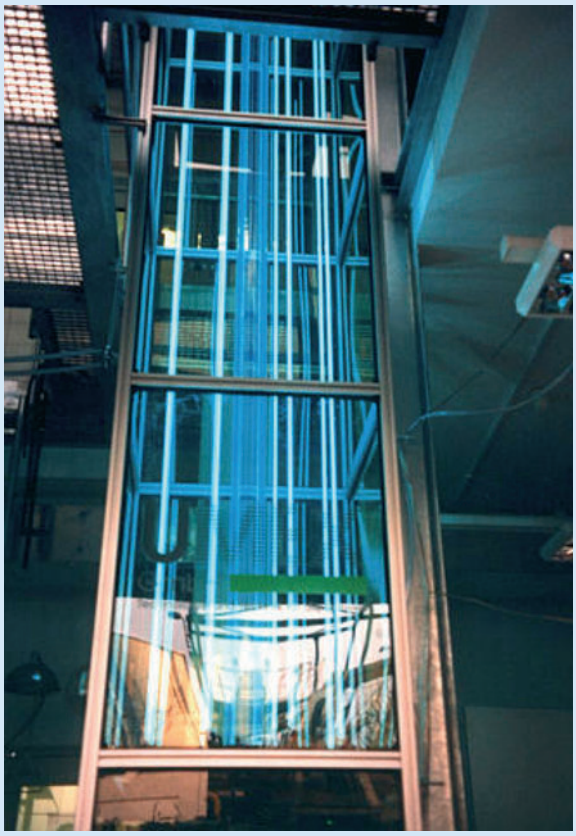

Fig. / Abb. 11: *The IfT laminar flow tube reactor (IfT-LFT). / Der laminare Rohrreaktor des IfT.*

Fig. / Abb. 12: *Mini Raman lidar Polly XT in an air-conditioned cabinet. / Mini-Ramanlidar Polly XT im klimatisierten Gehäuse.*

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 Version befindet sich der große Strömungsreaktor LACIS im Aufbau, in dem das Wachstum von Aerosolpartikeln zu Wolkentröpfchen sowie deren Gefrieren 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 anthropogene oder biogene flüchtige Kohlenwasserstoffe. Zur Untersuchung der chemischen Identität von Partikelinhaltsstoffen steht die Leipziger Aerosolkammer (LEAK) 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 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.

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 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 multi-phase 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.

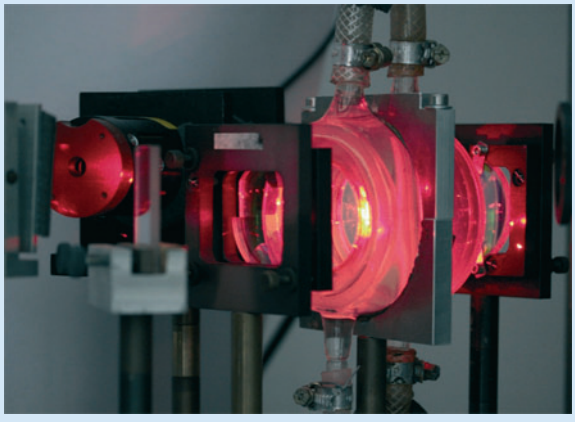

Fig. / Abb. 13: *Experimental set-up including White cell optics, reaction cell and solid state laser for the kinetic investigation of nitrate-radical (NO_3) reactions in aqueous solution. / Versuchsaufbau zur Messung der Kinetik von Nitratradikalreaktionen (NO_3) in wässriger Lösung mit Festkörperlaser, Whitespiegel-Konfiguration und Reaktionszelle.*

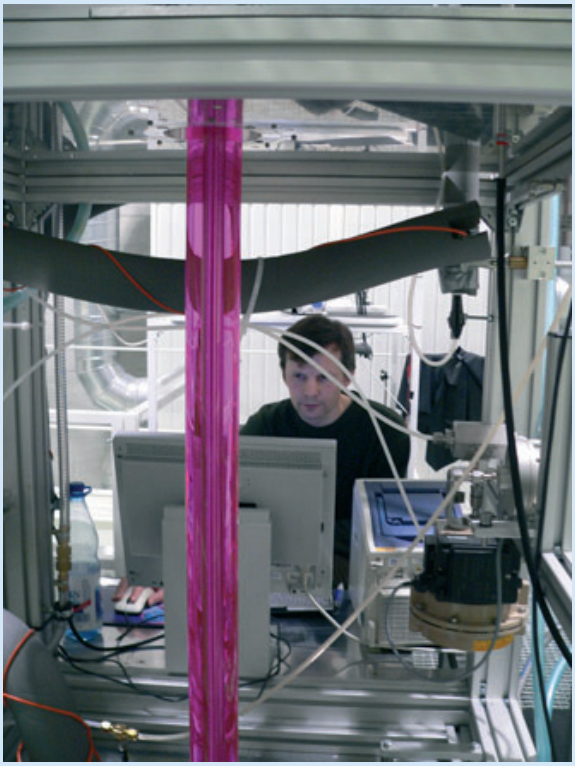

Fig. / Abb. 14: *The "Leipzig Aerosol Cloud Interaction Simulator" (LACIS). / Der Wolkenkanal (LACIS).*

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 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

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 microphysics. With their integration in complex three-dimensional models the manyfold 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 the 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 Federal Environmental Agency and 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 latest example of this kind of activity is the investigation of the formation of secondary aerosol particles in regions with high ammonia emissions, caused from agriculture and livestock husbandry. The simulations were conducted with the complex three-dimensional modeling system COSMO-MUSCAT.

The multiscale model ASAM, developed in the modeling department, was used for simulations in

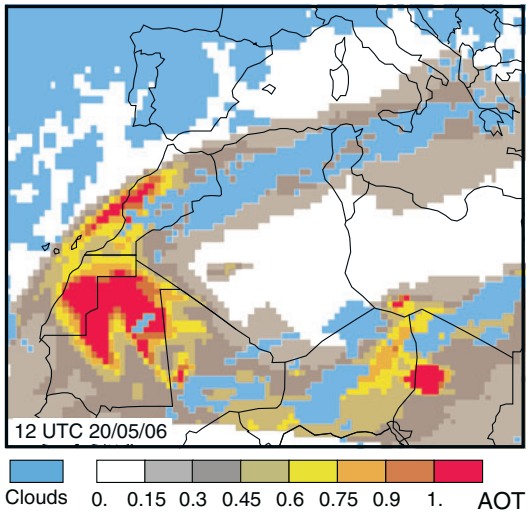

Fig. / Abb. 15: *Horizontal distribution of Saharan dust in terms of model-derived dust aerosol optical thickness (550 nm) on 20 May 2006 at 12:00 UTC. / Horizontale Verteilung des Saharastaubs am 20. Mai 2006, 12:00 UTC. Dargestellt ist die modellierte optische Dicke des Staubs bei 550 nm Wellenlänge.*

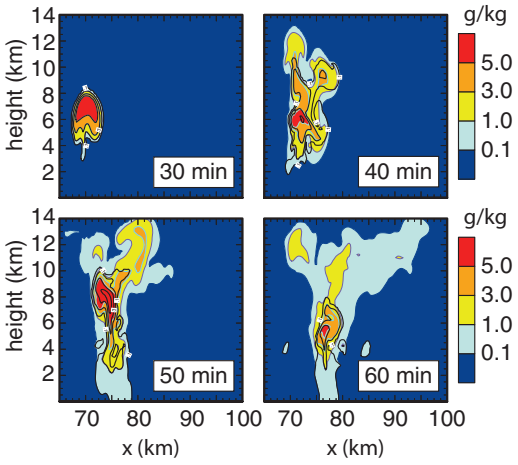

Fig. / Abb. 16: *Modeled convective cloud. Colors: total condensed water mixing ratio; black: liquid water mixing ratio (same levels). / Modellierte konvektive Wolke. Farbe: Mischungsverhältnis des gesamten kondensierten Wassers; schwarz: Mischungsverhältnis des Flüssigwassers (identische Level).*

ein Instrument zur Bearbeitung wissenschaftlicher Aufgaben und gleichermaßen zur Beantwortung von Fragen zur Luftqualität im legislativen Bereich.

Bei der Suche nach effektiven und Kosten sparenden Möglichkeiten zur Einhaltung bestehender und zukünftiger nationaler und europäischer Grenzwerte für gasförmige Luftbeimengungen und Partikel unterschiedlicher Größe ist der Einsatz von Modellen unverzichtbar. Nach bisheriger guter Zusammenarbeit mit dem Umweltbundesamt und 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 anorganischer sekundärer Aerosolpartikel, verursacht durch die Ammoniak-Emissionen bei der Tierhaltung und in der Landwirtschaft. Die Simulationen wurden mit dem komplexen dreidimensionalen Modellsystem COSMO-MUSCAT ausgeführt.

Mit dem in der Abteilung Modellierung entwickelten multiskaligen Modell ASAM (All Scale Atmospheric Model) wurden mikroskalige, gebäudeauflösende Modellsimulationen zum Zwecke der Validierung und weiterführenden Auswertung von Feinstaubmessungen des IfT an der Berliner Stadtautobahn durchgeführt.

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

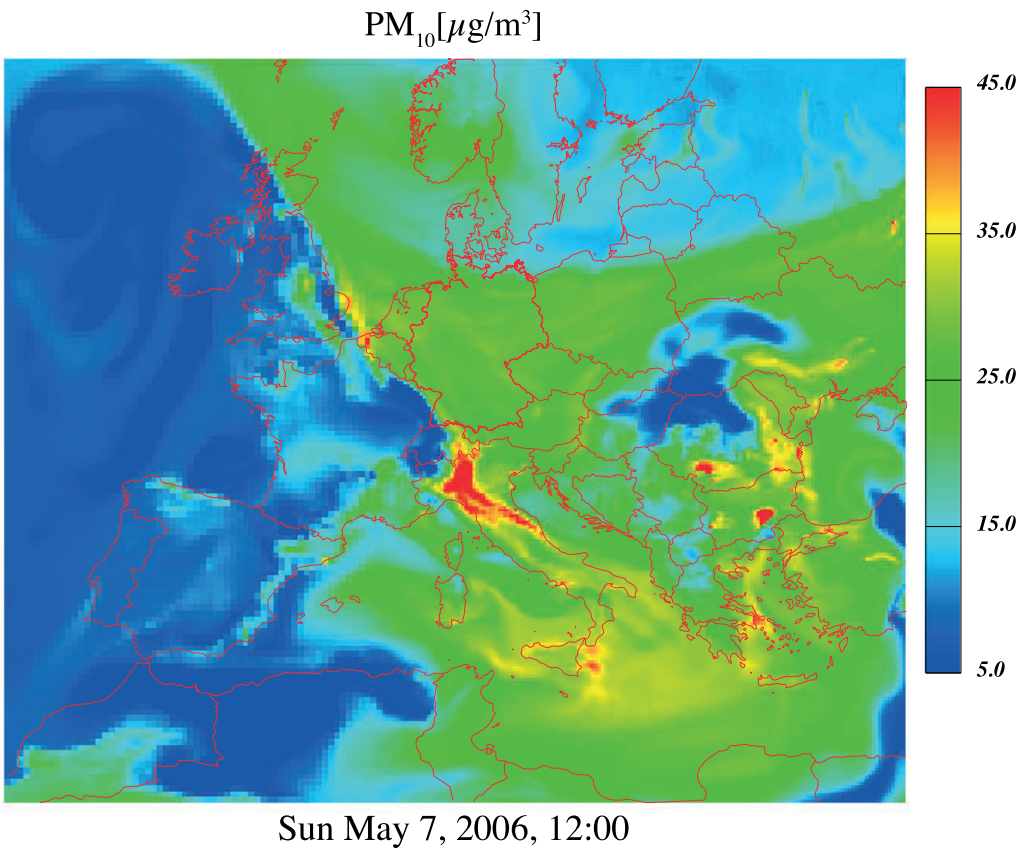

Fig. / Abb. 17: *Simulated PM_{10} concentration over Europe for an episode with "wild-land" fires in South Russia. / Simulierte PM_{10}-Konzentration über Europa für eine Episode mit Flächenbränden in Südrussland.*

the microscale domain "Berliner Stadtautobahn" with concern to particle measurements.

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 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.

am Wolkenkanal LACIS. Insbesondere ist 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.

Overview of 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 multiphase 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 *Research Theme 1* in which particles of the larges source of mineral dust play a central role. Experimental and modeling reports covering this subject are the results over several research projects, which occupy IfT since 2004. The national research group SAMUM (Saharan Mineral Dust Experiment) is funded in part by the German Research Council and lead by IfT focuses on physical – mainly optical – characteristics of Saharan dust. SAMUM conducted a first major experiment in May/June 2006 in southern Morocco as closely as possible to the dust source. The report by **Heintzenberg et al.** covers the experimental work at the two ground stations in Ouarzazate and near Zagora and on the research aircraft Partenavia. This report is complemented by **Tegen et al.**, who developed a regional dust transport model, which they evaluated with the detailed experimental SAMUM data of several dust transport episodes.

The two projects TRACES (funded by the WGL-Pakt) and SOPRAN (funded by BMBF) complement SAMUM by studying the mobilization, transport and deposition of mineral dust on the Cape Verdes, where the physical and chemical characteristics of dust particles are analyzed at a long-term station. Laboratory experiments addressing the photochemistry of iron in marine particles complement the field studies. The influence of the ocean on the atmosphere is studied in project FILGAS, in which the organic film on the ocean surface is characterized. An interdisciplinary internal project adds multiphase modeling to these experimental approaches. **Weller et al.**, summarize first results in these dust-related projects, which also contribute to *Research Theme 3*.

The ongoing discussion of potential health effects of fine and ultrafine particles increases the value of solid long-term aerosol data taken at the IfT research station Melpitz northeast of Leipzig. Since 2004 size-segregated sampling has been

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 die weltgrößte Mineralstaubquelle Sahara die Hauptrolle spielt. Die zugehörigen Berichte entstammen mehreren Forschungsvorhaben, die das IfT seit 2004 beschäftigen. Die vom IfT geleitete und stark getragene DFG-Forschergruppe SAMUM (Saharan Mineral Dust Experiment) führte 2006 ihr erstes Großexperiment in Südmarokko durch, um die physikalischen, vor allem optischen Eigenschaften des Saharastaubes so nahe wie möglich einer seiner Quellen zu charakterisieren. Der Bericht von **Heintzenberg et al.** dazu umfasst die Arbeiten an den beiden Bodenstationen in Ouarzazate und bei Zagora sowie die Strahlungsmessungen auf dem Forschungsflugzeug Partenavia. Dieser Bericht wird durch den Artikel von **Tegen et al.** fortgesetzt, die für SAMUM ein regionales Staubtransportmodell entwickelten und anhand mehrerer gut experimentell erfasster Staubepisoden evaluierten.

Die Projekte TRACES (PAKT-finanziert) und SOPRAN (BMBF-finanziert) untersuchen den Einfluss der Atmosphäre auf den Ozean insbesondere Mobilisierung, Transport sowie Deposition von Saharastaub auf den Kap Verden. Dort laufen auch Feldmessungen zur Charakterisierung der physikalisch-chemischen Eigenschaften von Staubpartikeln neben Laborexperimenten zur Photochemie von Eisen in marinen Partikeln. Auch das Projekt FILGAS beleuchtet den Einfluss des Ozeans auf die Atmosphäre. Dort werden organische Oberflächenfilme charakterisiert, sowie durch Modellierung von atmosphärischen Multiphasenprozessen in einem abteilungsübergreifenden hausinternen IfT Projekt berücksichtigt. **Weller et al.** fassen erste Ergebnisse zu diesen drei Vorhaben zusammen. Die darin geschilderten Laborexperimente zur Photochemie von Eisen in marinen Partikeln sind auch für Hauptthema 3 von Bedeutung.

Die Feinstaubdiskussion erhöht die Bedeutung der Langzeitaerosolmessungen an der IfT-

added to the Melpitz measurements. **Spindler et al.**, present results of the past three years, which complement and widen the data taken since 1993. They demonstrate a substantial influx of particulate mass and anthropogenic aerosol components through long-range transport of air pollution, in particular in winter and from easterly directions. Also related to the Melpitz station **Poulain et al.**, show preliminary results of first field measurements with a High Resolution Time of Flight Aerosol Mass spectrometer during a recent intensive field campaign in January and February 2007.

Due to its high concentrations and its multiple formation processes the urban aerosol remains a major research focus of IfT. Results of related work are presented in several short contributions. With the data of an aerosol experiment near Beijing **Wiedensohler et al.** show that high precursor concentrations and favorable conditions can lead to rapid particle growth within one day from newly nucleated nanoparticles to sizes larger than 100 nm at which they become important for cloud processes. The related particle nucleation from the gas phase still poses many open questions. Mechanistic laboratory simulations on this subject have been conducted for many years at IfT with sulfuric acid as the major component. In a short contribution **Berndt et al.**, present results, which indicate that other SO_2 reaction products besides sulfuric acid, such a products of the $HOSO_2O_2$ radical, may be responsible for the nucleated particles. **Hinneburg and Knoth** report of micro-scale highly resolved model simulations, which they conducted for validating and evaluating aerosol measurements at the inter-urban freeway in Berlin. Finally, **Engelmann et al.**, present a new eddy correlation method for turbulent aerosol fluxes throughout the planetary boundary layer. This method is based on the combination of the IfT aerosol lidar and a Doppler lidar.

The reports concerning *Research Themes 2* and 3 reach from laboratory experiments via ground-based and helicopter-borne field experiments to the evaluation of high-tropospheric intercontinental flights and model simulations of convective cloud systems. **Wex et al.**, combine in their contribution the Leipzig Aerosol Cloud Simulator LACIS with two other particle growth instruments to show how the surface tension of wet particles influence their growth and critical supersaturation. Laboratory experiments are also addressing *Research Theme 3 Chemical processes in tropospheric multiphase systems*. By means of laser-photolysis **Hoffmann et al.**, derive liquid-phase reaction constants of important atmospheric radicals with oxygenated hydrocarbons. The results are used in further developments of the multiphase mechanism

Forschungsstation Melpitz nordöstlich von Leipzig. **Spindler et al.** stellen dazu Ergebnisse einer 2004 bis 2007 umfassenden, größenaufgelösten Charakterisierung der Partikelmasse PM_{10} vor, die die seit 1993 laufenden Langzeitaerosol-messungen ergänzen und erweitern. Sie zeigen einen erheblichen Eintrag von anthropogenen Aerosolkomponenten durch den Ferntransport kontinentaler Luftmassen, besonders im Winter aus östlicher Richtung. Auch auf Experimenten an der Forschungsstation Melpitz basierend zeigen **Poulain et al.** erste Feldergebnisse mit einem Aerosolmassenspektrometer in den Winter-monaten Januar bis Februar 2007.

Wegen seiner hohen Konzentrationen und der vielfältigen Bildungsmechanismen bleibt das urbane Aerosol ein wichtiges Forschungsthema des IfT, dessen Arbeiten dazu in mehreren Kurzbeiträgen vorgestellt werden. **Wiedensohler et al.** zeigen anhand eines Aerosolexperimentes in der Nähe Pekings, dass die anthropogene sekundäre Aerosolbildung dort unter günstigen Bedingungen zu einem so starken Anstieg der Partikelmasse führt, sodass aus der Gasphase gebildete Partikel innerhalb eines Tages bis in den Größenbereich von 100 nm aufwachsen. Diese Partikelnukleation aus der Gasphase wirft nach wie vor viele offene Fragen auf. Die seit Jahren am IfT laufenden mechanistischen Untersuchungen hierzu mit Schwefelsäure als Hauptbestandteil der neu gebildeten Partikel werden von **Berndt et al.** in einem Kurzbeitrag beschrieben. Offenbar spielen Peroxylradikale wie das Peroxymonosulfatradikal $HOSO_2O_2$ in der Partikelbildung eine wichtige Rolle. **Hinneburg und Knoth** berichten von mikroskaligen, gebäudeauflösenden Modellsimulationen zum Zwecke der Validierung und weiterführenden Auswertung von Feinstaubmessungen des IfT an der Berliner Stadtautobahn. Schließlich stellen **Engelmann et al.** eine neue auf der Kopplung zweier Lidarverfahren basierende Eddy-Korrelationsmethode vor, mit der erstmals Vertikalprofile des turbulenten Aerosolmassen-flusses in der gesamten planetaren Grenzschicht bestimmt wurden.

Die Berichte zu den *Forschungsthemen 2 und 3* reichen von Laborsimulationen über Feldexperimente und Auswertungen hochtroposphärischer inter-kontinentaler Flüge bis hin zur Modellsimulation konvektiver Systeme. **Wex et al.** zeigen anhand von Experimenten mit der Kombination des Leipzig Aerosol Cloud Simulator LACIS mit zwei anderen Partikelwachstumsmessungen, wie die Oberflächenspannung der Partikel Wachstum und Tropfenaktivierung beeinflusst. Mit Labor-studien wird auch das *Hauptthema 3* bearbeitet. Mittels Laser-Photolyse ermittelten **Hoffmann**

CAPRAM 3.0 (Chemical Aqueous Phase Radical Mechanism), based on which **Tilgner et al.** present detailed model studies concerning aerosol/ cloud interactions. All results derived to date demonstrate the potential importance of the liquid phase as reactive medium in the troposphere and suggest the implementation of these processes in chemical transport models.

For several years now the heterogeneous ice formation in super-cooled clouds is studied with the Ice-CVI (Counterflow Virtual Impactor) developed at IfT within an international consortium at Jungfraujoch, Switzerland. **Mertes et al.**, found that the ability of atmospheric particles for ice formation begins beyond 200 nm particle diameter, with increasing efficiency at larger sizes. They also found significant chemical differences in particles with ice-forming ability as compared to out-of-cloud aerosol composition. These differences indicate anthropogenic origins of these ice nuclei.

The influence of small-scale turbulence on the dynamics of cloud droplets plays a major role in the drop growth by coalescence and in the generation of large drops, which may cause precipitation. **Siebert and Shaw** report of helicopter-borne measurements of turbulence and dro size distribution in quasi homogeneous stratocumuli and demonstrate a qualitative connection between local turbulence and the occurrence of drops with diameters between 30 and 80 µm.

With a multi-year data set **Weigelt et al.**, investigate statistically the influence of deep convection on particle number in the upper troposphere. They use measurements of the CARIBIC project (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container) complemented by back trajectories and satellite data. The analysis shows that deep tropical convection often contributes to the nanoparticle number while they scavenge larger particles.

Grützun et al., finally report on a model development, in which a spectral microphysical model has been combined with the mesoscale weather model COSMO of the German Weather Service. The present first results based on idealized data of a strong convective cloud over Midland, Texas.

et al. Geschwindigkeitskonstanten von Reaktionen wichtiger atmosphärischer Radikale mit sauerstoffhaltigen Kohlenwasserstoffen in wässriger Phase. Mit den Ergebnissen wird der Multiphasenmechanismus CAPRAM 3.0 (Chemical Aqueous Phase Radical Mechanism) verbessert, mit dem **Tilgner et al.** Modelluntersuchungen zur Aerosol-Wolkenwechselwirkung vorstellen. Ihre Ergebnisse zeigen die potentielle Relevanz der Flüssigphase als reaktives troposphärisches Medium und erfordern daher ihre Implementierung in höherskaligen Chemie-Transport-Modellen.

Mertes et al. untersuchen seit mehreren Jahren die heterogene Eisbildung mittels des am IfT entwickelten Eis-CVI (Virtueller Gegenstromimpaktor) innerhalb eines internationalen Konsortiums am Jungfraujoch, Schweiz und stellen fest, dass die Eisbildungsfähigkeit atmosphärischer Partikel ab etwa einer Größe von 200 nm beginnt und die Effizienz mit steigendem Durchmesser zunimmt. Sie finden deutliche Unterschiede in der chemischen Zusammensetzung der Eis bildenden Partikel im Vergleich zum Hintergrundaerosol, die einen anthropogenen Einfluss auf die heterogene Eisbildung vermuten lassen.

Der Einfluss kleinskaliger Turbulenz auf die Dynamik von Wolkentropfen spielt eine zentrale Rolle für das Tropfenwachstum und die Entstehung großer Wolkentropfen. **Siebert und Shaw** berichten von hubschraubergestützten Messungen von Turbulenz und Tropfengrößenverteilungen in Stratocumuli und zeigen einen Zusammenhang zwischen lokaler Turbulenz und dem Auftreten von Wolkentropfen mit Durchmesser zwischen 30 – 80 µm.

Mit Hilfe eines mehrjährigen Flugmessdatensatzes untersuchten **Weigelt et al.** erstmals statistisch den Einfluss hoher Wolken auf die Anzahlkonzentrationen von Aerosolpartikeln in der oberen Troposphäre (8-12 km Höhe). Dafür wurden Aerosolmesswerte genutzt, die im Rahmen des CARIBIC-Projekts (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container) gemessen wurden. Diese wurden mit Rückwärtstrajektorien und Satellitenbildern auf eine Wolkenbeeinflussung hin überprüft. Eine statistische Analyse zeigte, dass hochreichende tropische Wolken sehr häufig zur Partikelneubildung beitragen.

Grützun et al. schließlich berichten über eine Modellentwicklung, die eine spektrale Wolkenmikrophysik mit dem mesoskaligen Wettermodell COSMO des Deutschen Wetterdienstes vereint und stellen erste Modellergebnisse mit idealisierten Beobachtungen einer hoch reichenden konvektiven Wolke über Midland, Texas, vor.

Articles

The Saharan Mineral Dust Experiment SAMUM-1: Experimental

Jost Heintzenberg, Albert Ansmann, Dietrich Althausen, Eike Bierwirth[1], Nicole Kaaden, Andreas Massling, Detlef Müller, Thomas Müller, Alexander Schladitz, Matthias Tesche, Manfred Wendisch[1], Alfred Wiedensohler

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Die DFG-Forschergruppe SAMUM (Saharan Mineral Dust Experiment) beschäftigt sich seit 2004 mit den physikalischen Eigenschaften und der Verteilung des Saharastaubes und seiner Wirkung auf Strahlungshaushalt und atmosphärische Dynamik. Die erste Dreijahresphase der Arbeit kulminierte in dem Großexperiment SAMUM-1 2006 in Südmarokko, bei dem die Staubeigenschaften nahe an den Staubquellen durch Boden- und Flugzeugmessungen sowie Fernerkundungsmethoden (Boden, Flugzeug, Satellit) aus bestimmt wurden. Der vorliegende Bericht fasst die experimentellen Beiträge des IfT zu SAMUM-1 zusammen. Das IfT betrieb im Mai und Juni 2006 zwei Bodenstationen. Bei Zagora wurden Größenverteilung, optische Eigenschaften und Feuchtewachstum der Staubpartikel gemessen, während am Flugplatz von Ouarzazate mit einem Mehrwellenlängenlidar multispektrale und Polarisationsprofile des Mineralstaubs bestimmt wurden. Von dort startete auch das vom IfT gecharterte Forschungsflugzeug, das neben der spektralen Bodenalbedo Vertikalprofile spektraler Irradianzen registrierte. Mit den experimentellen Ergebnissen von SAMUM-1 stehen die notwendigen Ausgangsdaten zur Verfügung, um die Wirkungen des Staubes in Säulen- und mesoskaligen Modellen wesentlich gesicherter als bisher quantifizieren zu können.

Introduction

Saharan dust contributes significantly to the global aerosol load. The dust changes the global and regional radiative energy balance, thus modifying atmospheric heating rates, atmospheric temperatures and stability, and the hydrological cycle [e.g., *Miller et al.*, 2004; *Pérez et al.*, 2006]. The radiative effects caused by soil dust aerosol are complex, since dust particles not only scatter but also partly absorb incoming solar radiation, and the particles absorb and emit outgoing long wave radiation. The magnitude and even the sign of the dust radiative forcing depends on the optical properties of the dust, its vertical distribution, the presence of clouds, and on the albedo of the underlying surface [*Liao and Seinfeld*, 1998; *Myhre and Stordal*, 2001; *Sokolik and Toon*, 1996; *Tegen et al.*, 1996]. A prerequisite for estimating the radiative effects and interactions of dust and climate is the quantification of atmospheric dust loads and size-dependent optical properties of the dust particles. Large-scale dust distributions can be retrieved from satellite data, although over highly reflective surfaces like most deserts these retrievals so far are mostly just qualitative. This is because of uncertainties in the a-priori assumptions about aerosol optical properties [e.g., *Sokolik et al.*, 2001].

The limited number of existing in-situ measurements of dust particle properties is neither sufficient to constrain realistic estimates of dust loads, which are highly variable in space and time nor to model dust effects on radiation balance, weather and climate. To improve this situation the SAMUM projected was conceived combining the competence of six German research groups in field experiments, satellite retrievals and model developments. The present report focuses on experimental work in the SAMUM-1 field experiment in Southern Morocco, where IfT operated the two ground stations near Zagora and at Ouarzazate airport and the research aircraft Partenavia.

Fig. 1: *The IfT container laboratory at the Zagora station, Morocco during a dust storm (photo courtesy of Konrad Kandler).*

Zagora

Instrumental. In a laboratory container state-of-the-art aerosol instrumentation was deployed for determining physical properties of the Saharan dust downstream of a PM_{10}-inlet (cf. Figure 1). Particle number size distributions were measured with a combination of a Differential Mobility Particle Sizer (DMPS) for the mobility size range of 20 nm to 800 nm and an Aerodynamic

Particle Sizer (APS) (model 3321, TSI Inc., St Paul, USA) for the aerodynamic size range of 850 nm to 10 µm. The set up included an H-TDMA (Hygroscopic Tandem Differential Mobility Analyzer), an H-DMA-APS (Hygroscopic Differential Mobility Analyzer Aerodynamic Particle Sizer) and several other instruments. H-TDMA and H-DMA-APS were used for determination of state of mixture, hygroscopic growth of individual particle groups and their number of particles in the sub-micrometer and micrometer size range. Instrumental constraints limited the measurements to a dry size of one micrometer. This diameter was large enough to cover the maximum of the particle number size distribution occurring in the range of 0.5 to 5 µm. Scattering and hemispheric backscattering coefficients were measured with an Integrating Nephelometer (model 3563, TSI Inc., St Paul, USA) at the wavelengths λ = 450, 550 and 700 nm. The particulate absorption coefficient was determined with a Particle Soot Absorption Photometer (Radiance Research, Seattle, USA) at λ = 537 nm and with a Multi Angle Absorption Photometer (Thermo Fisher Scientific Inc., Waltham, USA) at λ = 637 nm. Additionally, spectral absorption coefficients from 250 to 750 nm wavelength with a spectral resolution of 50 nm were measured with a spectral absorption photometer developed at IfT.

Size distribution of dust particles. Figure 2 illustrates the average particle number and volume size distributions during a strong dust period of May 27th to May 28th, 2006. A mineral dust mode exhibits a number median diameter around 600 nm. For the particle volume the dust mode is clearly dominant with a volume median diameter of 2 – 3 µm. The average particle number concentration in the dust mode is ten times higher during the dust period than during low dust conditions / background aerosol. In contrast, the particle concentration of the accumulation mode for the number size and volume size distribution shows only small variations with number median diameter around 70 nm to 90 nm and a volume median diameter of about 300 nm.

State of mixture and hygroscopic growth of dust particles. Several particle parameters were derived from the hygroscopic measurements, namely the hygroscopic growth factor (GF) of different hygroscopic particle groups, their corresponding number fractions (nf), the total soluble volume fraction (ε) and the dynamic shape factor. Resulting from the evaluation of the H-TDMA data, a more hygroscopic, a less hygroscopic, and a hydrophobic particle group was always present in the sub-micrometer size range. Thus, the sub-micrometer particle population was

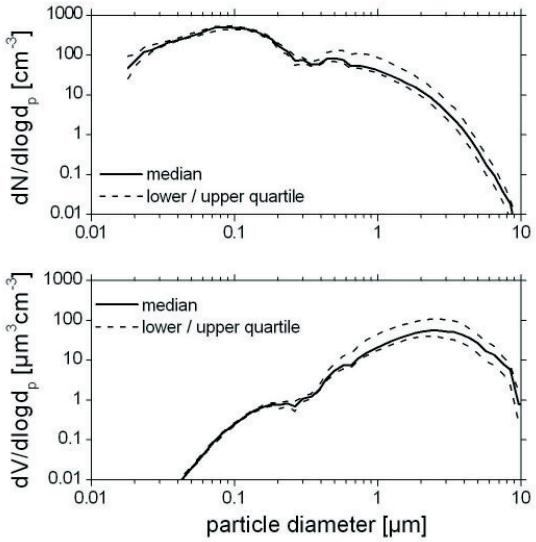

Fig. 2: *Number (top) and volume (bottom) size distributions (medians and quartiles) during a dust period at the Zagora station May 27/28 2006.*

mixed both internally (within each mixed particle) and externally (different particles of a given size having different properties), as particles are not consisting of only one material. In contrast humidified particle number size distributions measured with the H-DMA-APS in the micrometer size range showed only one particle group for every diameter over the complete measurement period. Thus, no externally mixed particle super-micrometer population was observed.

Figure 3 shows the hygroscopic growth factors for the different hygroscopic particle fractions during a dust event at the Zagora station. Theoretical growth factors for ammonium sulfate (black line), calculated based on parameterizations

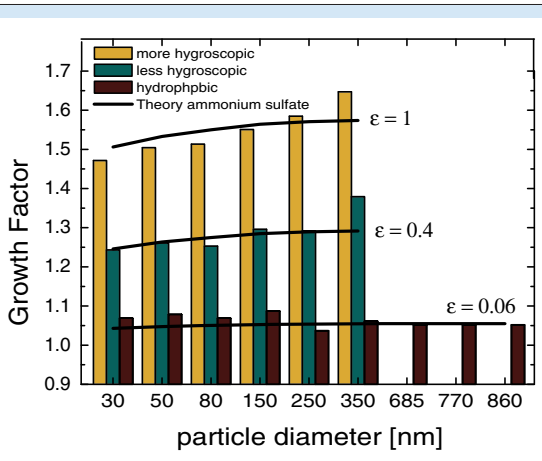

Fig. 3: *Growth factors for hydrophobic, less hygroscopic, and more hygroscopic particles during a dust event at the Zagora station for all measured diameters. For comparison, growth factors for different fractions (ε) of ammonium sulfate and insoluble material are shown.*

of *Tang and Munkelwitz* [1994] for different values of ε are added as a simple compositional model that fits the data well. The value of ε = 1, corresponds to the hygroscopic growth factor of pure ammonium sulfate particles. Less hygroscopic particles are represented by a soluble volume fraction of ε = 0.4 whereas hydrophobic particles by a soluble volume fraction of ε = 0.06. Both latter ε-values describe well the mean growth factors of the respective subpopulations particle fraction for the whole experiment.

In Figure 4 the number fractions of different hygroscopic particle groups are shown for the same dust event as in Figure 3. It is obvious, that the hydrophobic number fraction increases with increasing diameter due to the size of mineral dust particles being mostly in the super-micrometer range. Very small number fractions of hydrophobic particles were found at the particle diameters 30 – 150 nm but a very high number fraction for the more hygroscopic particle fraction with values ranging between 80 and 90% was observed in this size range. The number fraction for the hydrophobic particles for larger sub-micrometer sizes (150 – 350 nm) shows a strong increase. At 250 nm particle size nf exceeds 50% and for 350 nm it already reaches 75%. This indicates clearly, that minerals from the Saharan desert dominate the hydrophobic number fraction above 250 nm particle size.

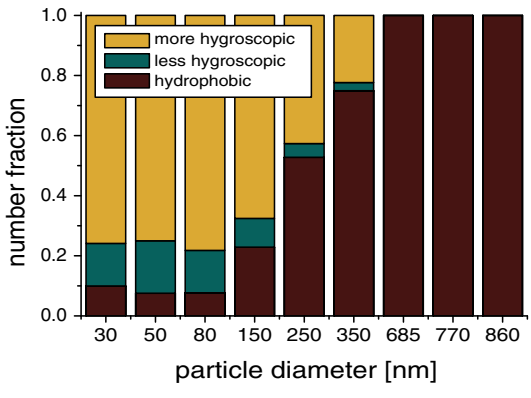

Fig. 4: *Number fraction hydrophobic, less hygroscopic, and more hygroscopic particles during a dust event at the Zagora station for all measured diameters.*

Optical dust properties. Typical scattering and absorption coefficients during the SAMUM-1 experiment are collected in Figure 5. Ambient visibility V was measured with an optical forward scattering sensor (Biral, Bristol, UK). The inverse variation of V and scattering coefficient is clearly visible in Figure 5, in particular during the dustiest period 11. Some 10% of the total scattering is in the backward hemisphere. Due to the absorption discussed below the single scattering albedo of

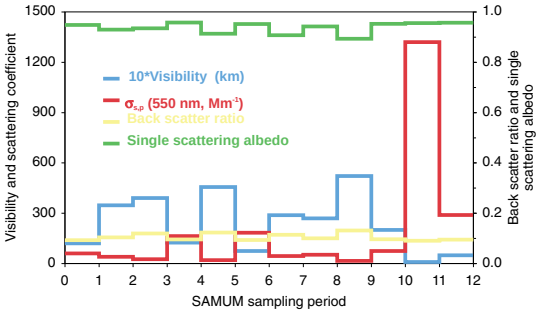

Fig. 5: *Average optical dust properties for 12 SAMUM-1 sampling periods at the Zagora station. Ambient visibility in km (blue); $\sigma_{s,p}$ = dry scattering coefficient at 550 nm wavelength in Mm^{-1} (red); hemispheric back scatter ratio (ß) at 550 nm wavelength (sienna); single scattering albedo (SSA) at 530 nm wavelength (green).*

the dust at 530 nm wavelength consistently lies below one.

The intensive optical property specific mass absorption coefficient (absorption per mass) characterizes the absorptive property of the absorbing material. Besides the measured absorption properties it requires the knowledge of the particle density in order to convert the measured size distributions to mass concentrations. Single particle analysis of filter samples collected during SAMUM-1 by the Institute for Applied Geosciences at the University of Darmstadt yielded the overwhelming majority of the super-micrometer particles consisting of quartz and silicates with a preliminary average particle density of 2.7 g cm^{-3} for particle diameters >500 nm [*Kandler et al.*, 2008].

To obtain an estimate of the complex refractive index, the differences between Mie-calculated and measured scattering and absorption were minimized for given size distributions following a procedure developed by *Wex et al.* [2002]. In Figure 6 the derived average imaginary parts for 12 time periods at 530 and 630 nm are plotted against the mass absorption coefficients. For both wavelengths mass absorption coefficients and imaginary parts correlates excellently and there is a simple parameterisation between both quantities. Using the linear relationship between both quantities the imaginary part can be derived from the mass-absorption coefficient at any time. Its average values for the entire experiment were $4.1 \cdot 10^{-3}$ at 530 nm and $3.1 \cdot 10^{-3}$ at 630 nm wavelength

A correlation analysis elucidates the connection between particle size and optical properties. Size-resolved coefficients of determination (R^2) are shown in Figure 7. The particle scattering correlates well with particle number concentrations larger 1 µm in diameter with a maximum value of R^2 of 0.9 at 1.6 µm. Particles <0.5 µm are not correlated with the particle scattering coefficient. For hematite absorption we get similar size-

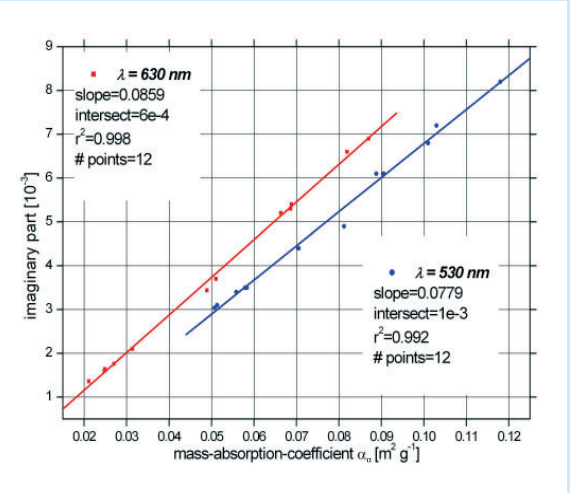

Fig. 6: *Average imaginary parts of dust-refractive index plotted against average mass absorption coefficients for 530 nm wavelength (blue) and 630 nm wavelength (red) at the Zagora station for 12 sampling periods. Parameters of linear fits and respective coefficients of determination (r^2) are added.*

dependent coefficients of determination but with lower values below 0.5. Scattering and hematite absorption spectra are well correlated with the dust mode and there is almost no correlation to the fine mode. With these findings we can identify the dust mode to consist almost entirely of hematite. This is in agreement with size-resolved electron microscopy reported by *Kandler et al.* [2008].

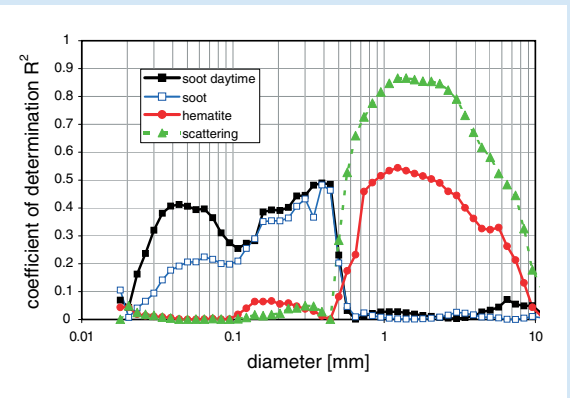

Fig. 7: *Size-resolved correlations of absorption and scattering coefficients with the particle number concentration. Black line with filled squares: daytime (06:00 to 18:00) soot absorption (650 nm); blue line with open squares: soot absorption; red line with filled circles: dust (hematite) absorption (650 nm); dashed green line with open triangles: total scattering (550 nm).*

The soot absorption coefficient correlates with the fine particle fraction with dust and soot absorption maximum values of R^2 around 0.5 indicating that soot and hematite can be found in well-separated modes. During daytime soot and particle number concentration correlate best at particle diameters about 0.04 µm. This suggests that the aerosol was then influenced by an anthropogenic local source of soot.

Details of the Zagora results are discussed in *Kaaden et al.* [2008], *Müller et al*. [2008b], and *Schladitz et al*. [2008].

Ouarzazate

Instrumental. At Ouarzazate airport IfT deployed their mobile six–wavelength aerosol lidar [*Althausen et al.*, 2000]. The system emits laser radiation at six wavelengths from at 355, 400, 532, 710, 800, and 1064 nm wavelength. Besides the elastically backscattered radiation at these wavelengths, inelastically backscattered vibrational Raman signals at 387 nm and 607 nm are detected. This combination allows for an independent determination of backscatter and extinction coefficients at these wavelengths (532 nm and 355 nm). To derive backscatter profiles at the remaining wavelengths the extinction-to-backscatter ratio (also called lidar ratio) needs to be known or estimated [*Fernald*, 1984]. In addition to the vibrational Raman signals, rotational Raman signals at 532 nm were detected even during daytime. However, the detection of these signals is strongly dependent on the laser beam receiver field-of-view overlap. The six beams are aligned onto one optical axis. All laser beams are linearly polarized. At 710 nm, cross and parallel-polarized signals are detected separately. Besides the elastically backscattered light at the laser wavelengths, the vibrational Raman signals of nitrogen at 387 and 607 nm, of water vapor at 660 nm, and rotational Raman signals in two channels around 532 nm are detected. The rotational Raman signals allow determining particle extinction profiles even at daytime. However, due to the very narrow field of view of the rotational Raman channels, accurate results can only be obtained at heights ≥2 km above the lidar. With a careful correction of the overlap effect in the near range in the other

Fig. 8: *SAMUM-1 lidar station at Ouarzazate airport, Morocco. The left container is the Munich lidar (photo courtesy of Markus Garhammer).*

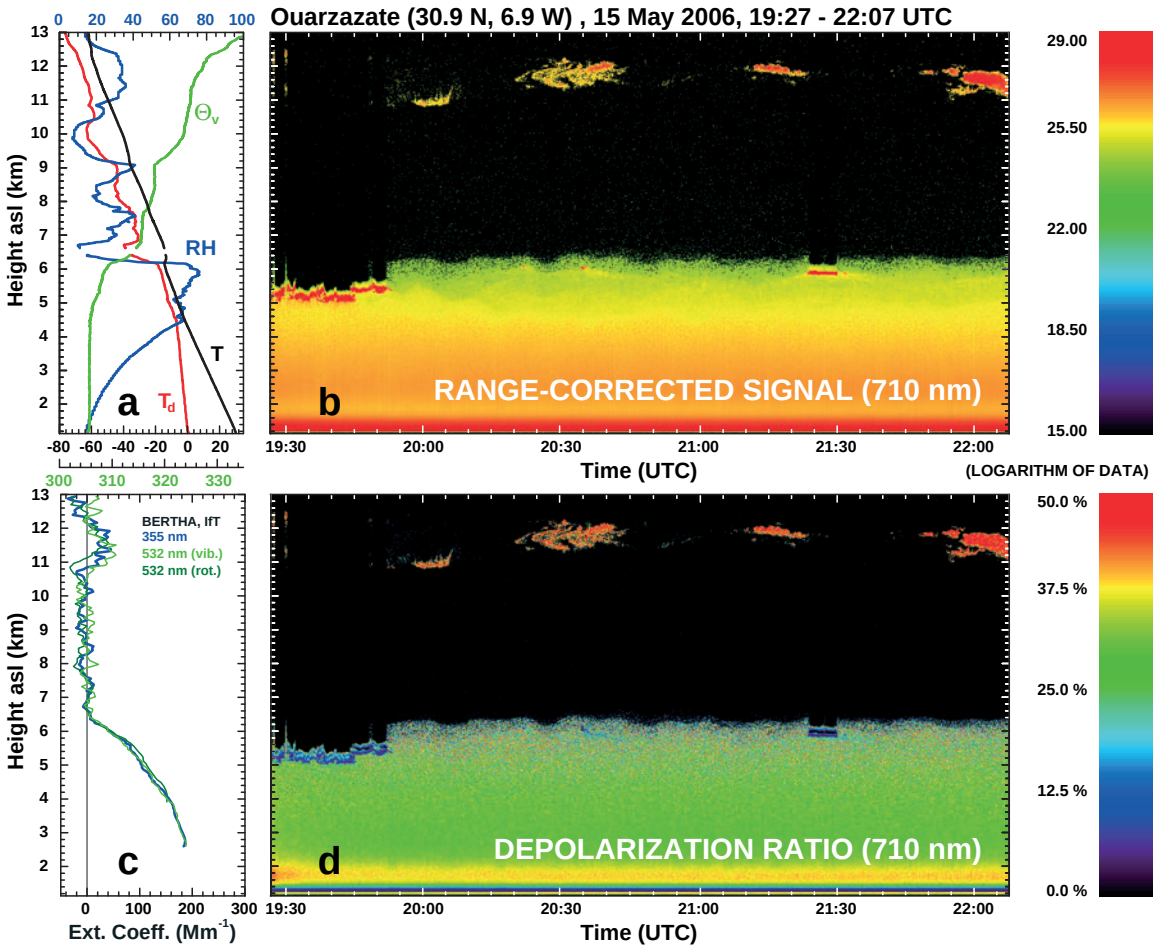

Fig. 9: *a) Meteorological profiles, b) time-height-display of the range-corrected backscatter signals, c) spectral extinction profiles, and d) time-height-display of depolarization ratios signals on May 15 2006 at Ouarzazate.*

channels, accurate measurements are possible down to 700 m above the lidar. The combination of elastic backscatter signals and the nitrogen Raman signals can be used to determine independent height profiles of the dust backscatter coefficient and the dust extinction coefficient, and thus also of the corresponding dust lidar ratios [*Ansmann et al.*, 1992]. 51 Radiosondes were launched by the IfT group during the campaign. Figure 8 gives an impression of the lidar station at Ouarzazate.

A dust outbreak in the middle of May caused optical depths as high as 0.8 (cf. Figure 12). Figure 9 shows profiles and lidar height-time-sections through part of this outbreak.

A thick and very homogeneous dust layer extended up to a height of 6 km asl. High depolarization ratios due to the nonsphericity of the dust particles. The same – and even more intense – effect can be observed with the cirrus clouds at altitudes of 11 – 12 km asl. The IfT radiosonde (Figure 9a) shows a temperature inversion at the top of the dust layer. The relative humidity increased up to the top of the layer and decreased strongly in the dust–free troposphere.

The multiwavelength lidar provided detailed and consistent spectral profiles through the dust layers. The example in Figure 10 characterizes a homogeneous dust layer extending to 5 km height. Besides the conventional back scatter and extinction coefficients values of the latter at 532 nm derived from rotational Raman scattering (cf. Figure 10b) and ensuing lidar ratios up to 5 km (cf. Figure 10c) were derived with which the back scatter signals could be evaluated more precisely. The Ångström exponents of back scatter are consistent with the independent columnar results from the sun photometer (see below).

The continuous lidar measurements over the whole campaign provided the basis for solid statistics on the structure and properties of dust layers as exemplified in Figure 11 that combines histograms of dust layer depths for 53 lidar measurements and mean extinction coefficients at 500 nm. The latter quantity was obtained by dividing the optical depth of the Sun photometer measurement by the observed the dust layer depth DLD from the lidar measurement for 25 simultaneous measurements.

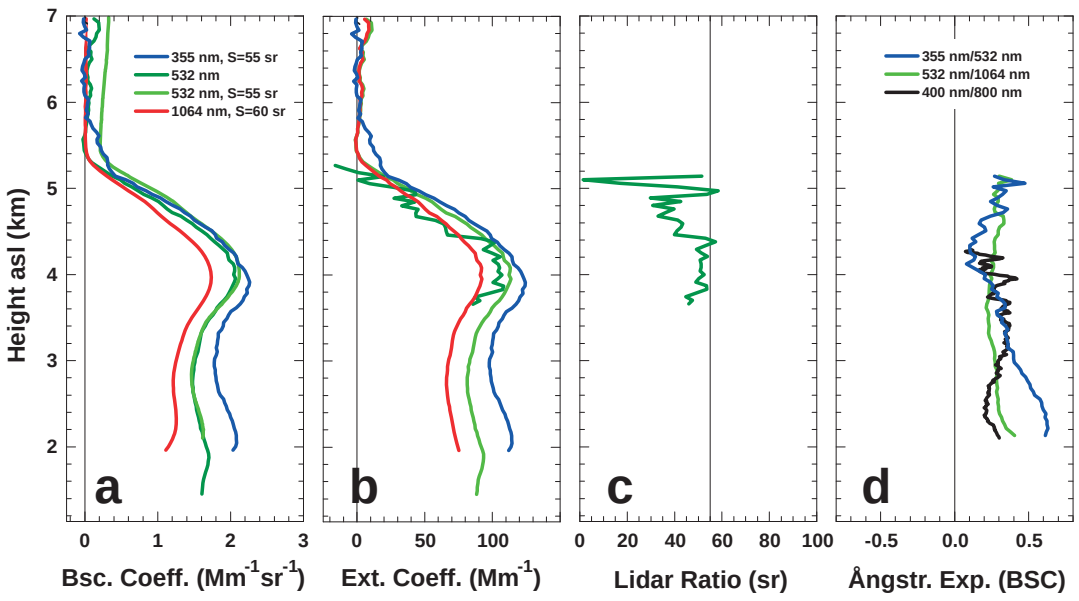

Fig. 10: Spectral daytime lidar profiles through a homogeneous dust layer on May 19 2006 at Ouarzazate airport; a) Back scatter coefficients; b) extinction coefficients; c) lidar ratio; d) Ångström exponents of back scatter.

A detailed discussion of the lidar results can be found in *Tesche et al.* [2008].

Sun photometer. As a columnar complement to the lidar system an AERONET sun photometer was operated on the rooftop of one of the sea-containers that house the lidar instrumentation at Ouarzazate airport. This automatic tracking sun and sky radiometer is part of AERONET, which is a federated international network of sun/sky radiometers [*Holben et al.*, 1998]. The instrument measures the Sun's direct radiation at 339, 379, 441, 501, 675, 869, 1021, and 1638 nm wavelength every 15 minutes. Figure 12 gives an overview of spectral optical depths and their wavelength dependence expressed as Ångström exponents experienced during SAMUM-1.

The inversion algorithm of *Dubovik and King* [2000] is used to retrieved the particle volume size distribution from 0.05 – 15 µm in radius, and the complex refractive index in the range from 1.33 – 1.6 (real part) and 0i – 0.1i (imaginary part). For May 19 2006 Figure 13 gives the derived columnar volume size distribution showing a bimodal distribution as in the surface data in Figure 2 albeit with the coarse particle mode

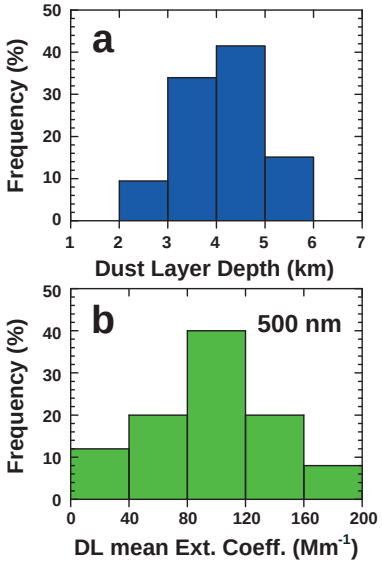

Fig.11: Histograms of the dust layer depth (DLD) derived from 53 lidar measurements (a) and the dust layer mean extinction coefficient (b) at 500 nm wavelength.

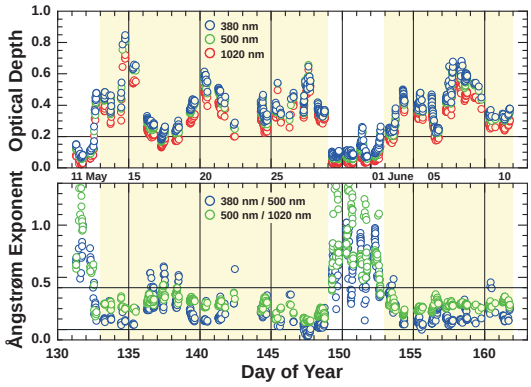

Fig. 12: 30-day AERONET time series of optical depth (upper graph) at three wavelengths (380 nm, (blue), 500 nm (green), and 1020 nm (red) and Ångström exponent (lower graph) for the wavelength pairs 380 nm / 500 nm (blue) and 500 nm / 1020 nm (green). The shaded areas indicate periods that can be considered to represent pure dust conditions.

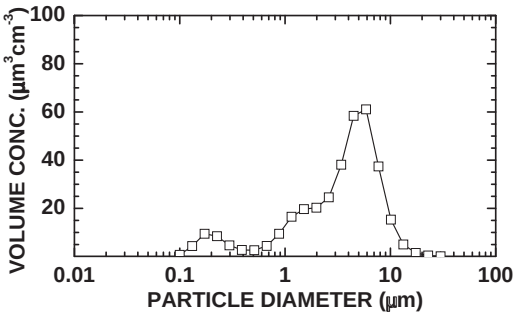

Fig. 13: Particulate volume size distribution derived from AERONET Sun photometer measurements and lidar-derived dust layer depths on May 19 2006.

shifted to somewhat larger sizes because the surface data were derived with a 50% cut-off at 10 µm (PM_{10} inlet).

Real and imaginary parts of the effective refractive index for the same case as shown in Figure 13 are plotted in Figure 14.

A detailed discussion of the AERONET sun photometer results can be found in *Müller et al.* [2008a].

Partenavia

Instrumental. Solar radiation was measured by the Spectral Modular Airborne Radiation Measurement SysTem (SMART)-Albedometer mounted on the Partenavia aircraft. It comprised six spectrometers that covered almost the entire shortwave spectrum of solar radiation (from 290 nm to 2200 nm) with spectral resolutions between 2 nm in the visible (VIS; 290 nm–1000 nm) and 16 nm in the near-infrared (NIR; 1000 nm – 2200 nm). The SMART-albedometer was operated with optical inlets for the detection of upwelling and down welling spectral irradiance F_λ and actinic flux density $F_{\lambda,\alpha}$. These inlets were mounted on a unique horizontal stabilization system that has been developed jointly by IfT and *enviscope GmbH*, Frankfurt am Main, Germany [*Wendisch et al.*, 2001].

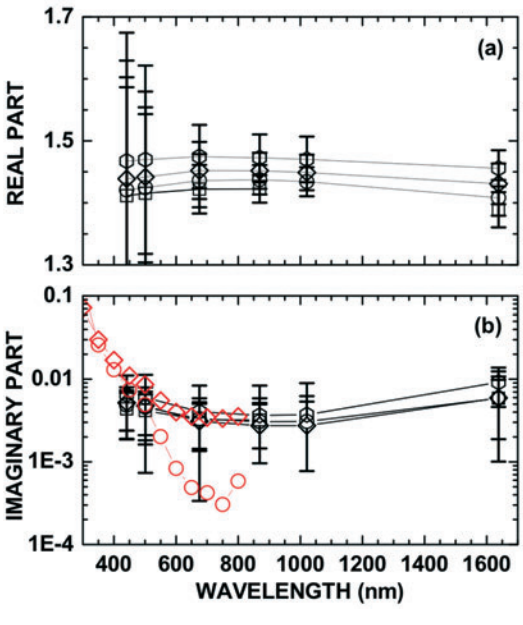

Fig. 14: (a) Real part and (b) imaginary part of the complex refractive index determined from AERONET Sun photometer data (black symbols). Also shown are respective parameters derived from particles were collected at the ground site at the Zagora station, (red symbols). Diamonds represent total absorption, whereas circles give results with soot absorption subtracted.

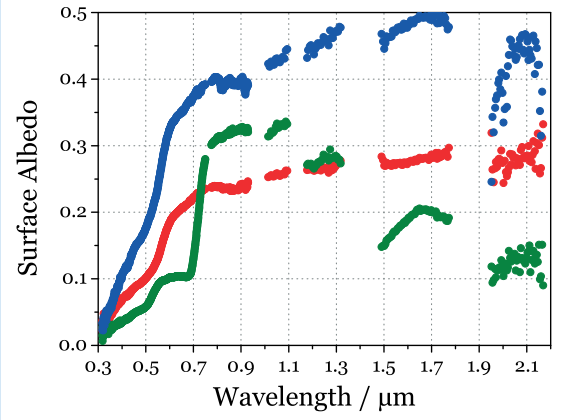

Fig. 15: Surface-albedo spectrum of the red stone-desert Hamada surface (red) in the Zagora basin; over a small oasis in the Atlas mountains (green) – showing the vegetation edge at 700 nm. d) surface-albedo spectrum of the Iriki salt lake (blue).

The Partenavia conducted 13 flights for the determination of spectral surface albedos and vertical irradiance profiles. Albedo spectra from different surfaces are shown in Figure 15. Typical spectral features of barren surfaces include a distinct increase in the red color range (beyond 600 nm), and a plateau from 800 nm to 2200 nm with small slope, which is mostly slightly positive but in a few cases also slightly negative. When flying over vegetation in the oases, characteristic changes occur in the albedo spectrum: A strong slope around 700 nm appears (natural protection against plant damage caused by NIR radiation) and is accompanied by a stepwise decrease of the surface albedo between 1000 nm and 2200 nm (due to water).

Using the measured surface and atmospheric properties, the dust radiative forcing at the top and bottom of the atmosphere has been estimated with a radiative transfer model (cf. Figures 16, 17). The surface albedo has a major impact on the shortwave radiative forcing of Saharan dust. In the SAMUM-1 case of May 19 2006, top-of-atmosphere (TOA) shortwave radiative forcing changes by 12 W m^{-2} when the surface albedo

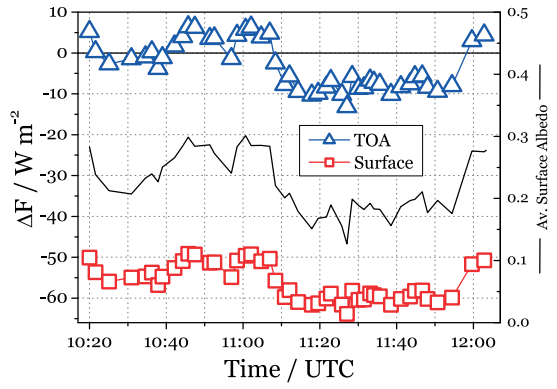

Fig. 16: *Integral shortwave radiative forcing along the Partenavia flight track on May 19 2006, calculated with the solar zenith angle and the surface elevation fixed to average values. Average measured surface albedo beneath the aircraft is shown for comparison.*

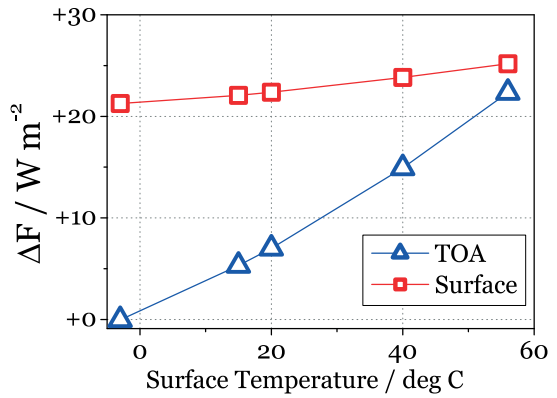

Fig. 17: *Integral long wave (thermal infrared) radiative forcing for the dust conditions of May 19 2006, and for the surface temperature range during SAMUM-1: 15 °C for the coldest night, and 56 °C for a hot day's noon.*

changes by 0.1. The TOA radiative forcing in the long wave spectral range is determined by the temperature difference between the surface and the dust layer. Values of up to +22 W m^{-2} were derived for May 19 2006. A surface albedo of 0.2 leads to an increase in net radiative forcing (shortwave + long wave) at TOA of Saharan dust of 24 W m^{-2} in comparison to -19 W m^{-2} for a non-reflecting surface. Therefore, Saharan dust over bright surfaces always gives rise to a warming. A detailed discussion of the Partenavia results can be found in *Bierwirth et al.* [2008].

Serendipity

SAMUM-1 had the well-defined goal of a comprehensive characterization of optical dust properties, which was reached through the intensive campaign in Southern Morocco. With reliable and sensitive instruments directed with an open mind at the complex atmospheric multiphase system chances are good for interesting unexpected results. In the case of SAMUM-1 two such unexpected results are reported below.

At both stations much of the dust emissions occurred in the form of dust devils, which were readily observed by (but also a nuisance to) the lidars systems. Figure 18 gives an exemplary time series of dust backscatter and depolarization ratios from May 16 2006 together with IfT-radiosonde data. The depolarization ratio, given by the (calibrated) ratio of the cross–polarized to the parallel–polarized 710 nm backscatter signal, permits discriminating, e.g., cloud layers of liquid drops from layers with predominating ice crystal backscattering. The radiosonde indicated light winds blowing from the east prevailing in the dust layer. The relative humidity increased from values around 20% at ground to about 80% in the upper part of the dust layer. The potential temperature indicated a well–mixed boundary layer up to 2 – 2.5 km height agl around 1050 UTC. Slightly stable conditions were observed in the upper part of the developing convective boundary layer. Updrafts reached heights around 2.5 km height above ground to that time as the color plot of the range–corrected signal in Figure 18 indicates.

Distinct plumes are not visible in the depolarization observations before 1045 UTC. Strong updrafts surrounded by areas with downdrafts mark the development of the convective boundary layer. The updrafts steadily increased with time from about 2 km height agl at 1050 UTC to 4 km height two hours later as the height–time display of the range–corrected signal indicates. The updrafts occurred with a frequency of roughly 15 – 20 minutes and triggered the oscillation on the upper boundary of the dust layer. Note that the updraft pumped clear air into the upper part of the dust layer. The yellow updraft signals are smaller than the orange signals in the upper dust layers by almost a factor of three on this day. Only the convective plumes inject dust. The tilt of the plumes to the right with height results from the fact that the plumes were advected from the east and the laser beam was pointed to the west so that the lower part of the plume was detected first before the upper part of the plume crossed the laser beam at greater heights.

For five days with favorable conditions for convective activity detailed statistics in form of frequency of occurrence of convective plumes and plume top–height statistics were derived. The plumes occurred with a mean frequency of 0.5 plumes per minute on these days. Top heights were mainly lower than 1000 m. About 10 – 20% of the plumes were found to reach higher than 2000 m agl. A detailed discussion can be found in *Ansmann et al.* [2008b].

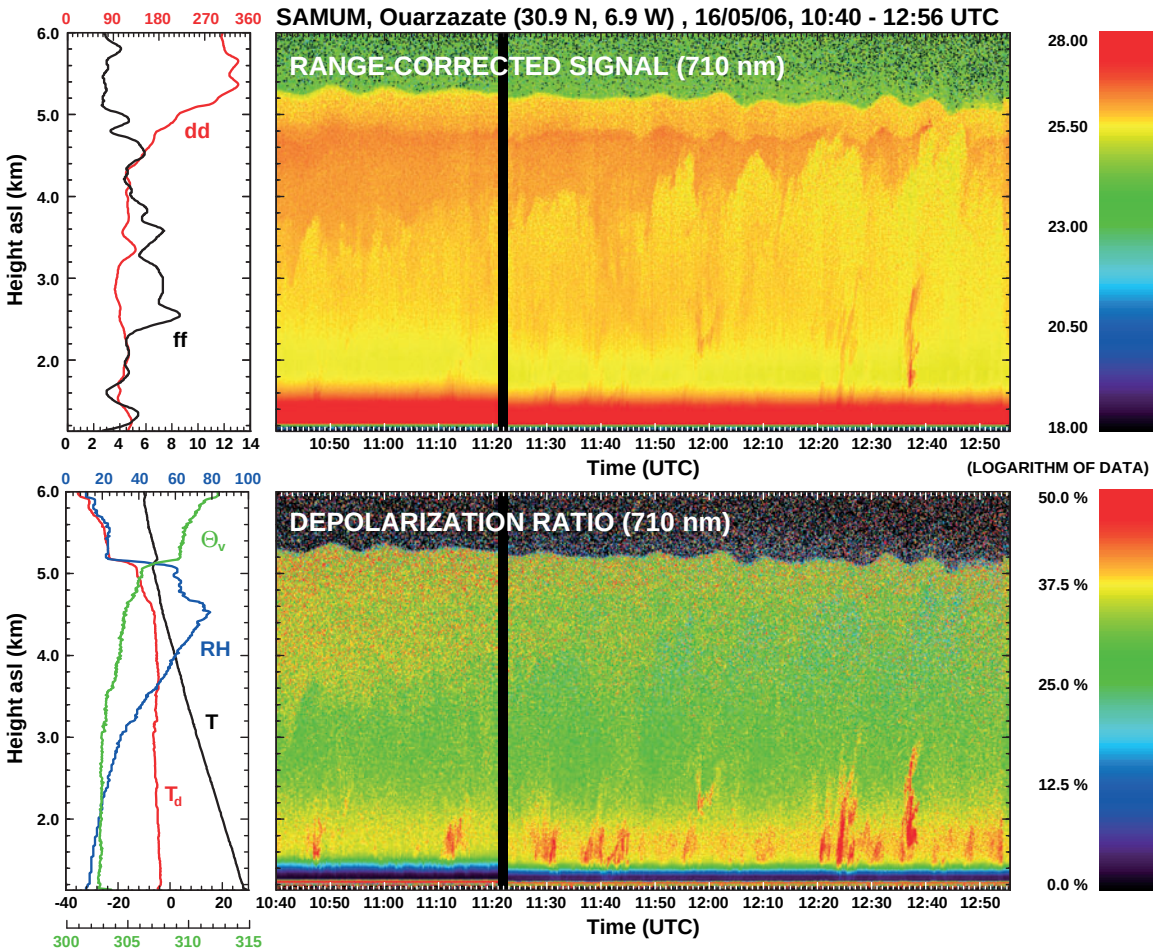

Fig. 18: *Lidar observations of dust devils and convective plumes in the 4 km thick Saharan dust layer on May 16 2006. Range–corrected 710 nm signal (top, arbitrary units) and respective depolarization ratio as a function of height (15 m resolution) and time (here in profile number, each number represents 10 s) are shown. Left panels show IfT radiosonde profiles of relative humidity RH, temperature T, dew point temperature T_d, and virtual potential temperature Θ_v (top) and wind direction (dd) and wind velocity (ff).*

The lidar system also yielded a second unexpected result. Surprisingly, most of the altocumulus clouds that form at the top of the Saharan dust layer, which reaches into heights of 4 – 7 km asl and has layer top temperatures of -8 °C to -18 °C, did not show any ice formation. The presence of a high number of ice nuclei (1 – 20 cm^{-3}) does obviously not automatically result in the generation of ice particles. According to the lidar observations, cloud top temperatures must typically reach values as low as -20 °C before significant ice production starts.

Figure 19 shows the only observation of ice formation in an altocumulus cloud with top temperature above -20 °C. Ice virgae are present at the end of the observational period. The Saharan dust layer is more than 5 km thick with clouds reaching beyond 6 km height asl at the beginning of the measurement period. Extinction coefficients below the cloud layers are high with values of around 200 Mm^{-1}, indicating ice nucleus concentrations of 5 – 20 cm^{-3}. The dust optical depth is almost one during that evening. The 532 nm lidar ratio is close to 40 sr around 5 km height and is probably influenced by residual drops or dust particles that are still wet and round after the cloud segments have dissolved. In the case of pure backscattering by drops, the lidar ratio is around 20 sr. The most interesting feature of Figure 19 is that the virgae mainly consist of drops rather than ice. The liquid-phase virgae reach altitudes below 5 km asl before they evaporate. Virgae at greater heights are obviously not necessarily a clear sign for ice formation as we expected. Ice virgae were only observed at the end of the measurement period. Cloud top temperature was presumably -15 – 16 °C. Ice crystals fell out of an opaque cloud. At this cloud top temperature only the contact-freezing mode was fully activated. Condensation freezing may also contribute weakly to ice formation at temperatures as high as -15 °C. Immersion freezing becomes fully activated at temperatures less than -25 °C. Liquid-phase clouds were

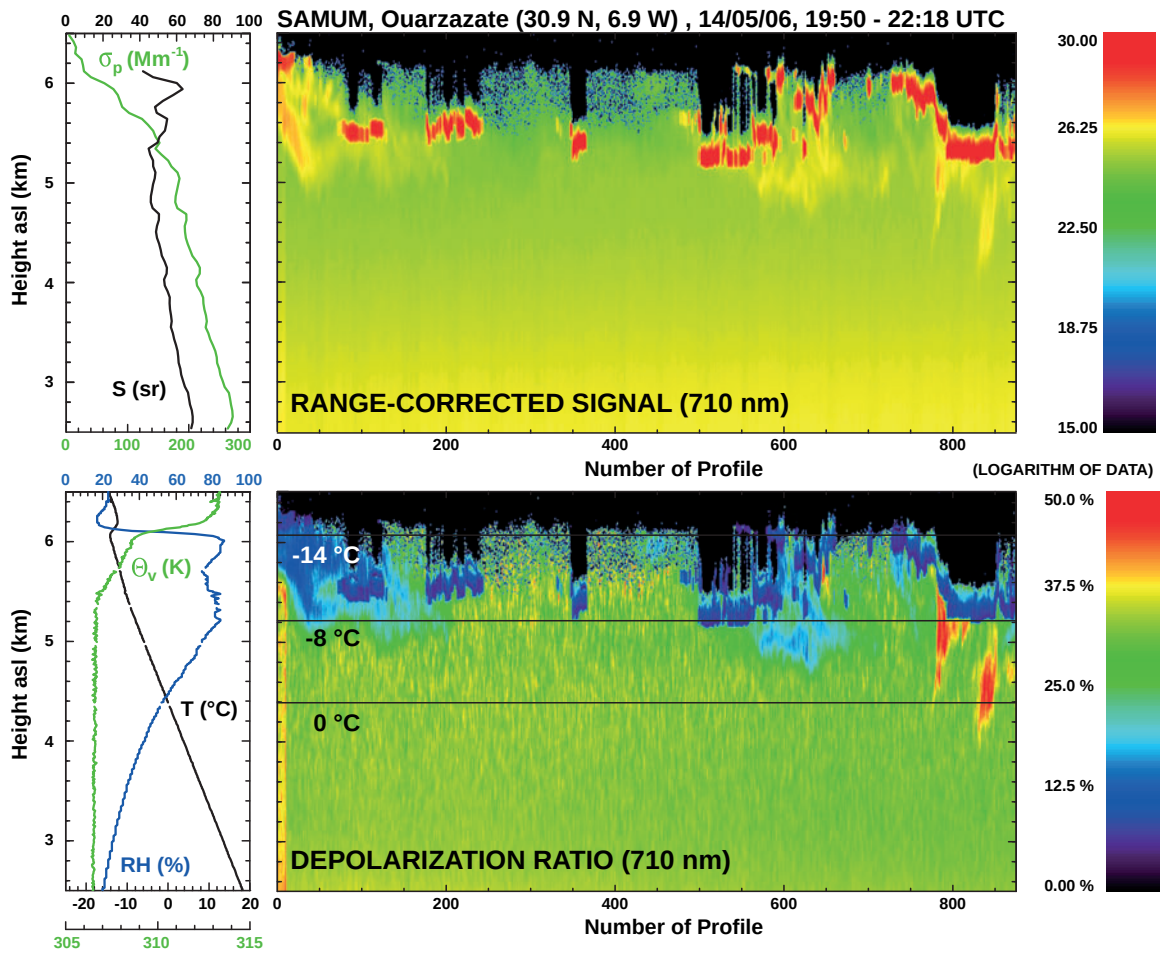

Fig. 19: *Scattered cumulus (red in the upper panel) and virga (yellow) in the dust layer (yellow to green) on May 14 2006. Range-corrected 710 nm signal (top, arbitrary units) and respective depolarization ratio as a function of height (15 m resolution) and time (here in profile number, each number represents 10 s) are shown. Left panels show height profiles of the dust particle extinction coefficient and extinction-to-backscatter ratio S at 532 nm wavelength (top, left) and radiosonde profiles of relative humidity RH, temperature T, and virtual potential temperature Θ_v (bottom, left). Horizontal lines in the depolarization plot indicate 0 °C, -8 °C, and -14 °C temperature height levels as measured with a radiosonde.*

obviously required before ice crystals form via heterogeneous freezing mechanisms, and, as a consequence, deposition freezing was not an important ice nucleation process.

The sharp decrease of the relative humidity and the strong increase of the potential temperature at the top of the dust layer suggest that the top of clouds almost coincided with the top of the dust layer. The relative humidity in the free troposphere is less than 20% up to 8.3 km height asl and generally less than 40% up to the tropopause. The relative humidity of around 80% above 5 km height asl as measured with the radiosonde may suggest some mixing of the moist dust layer air with dry free tropospheric air. Details of this study can be found in *Ansmann et al.* [2008a].

Conclusions

SAMUM-1 had the well-defined goal of a comprehensive characterization of optical dust properties, which was reached through the intensive campaign in Southern Morocco based on two ground stations with in-situ measurements and sampling and remote sensing systems. The ground-based systems were complemented by research aircraft and satellite data analyses [*Dinter et al.*, 2008, not discussed here]. The IfT contributions provided an internally consistent characterization of internal and external dust properties with a focus on multispectral optical parameters, state of mixture and hygroscopic growth characteristics. With a unique ground-based lidar system and spectral radiation data taken on the Partenavia aircraft the detailed dust characterization was extended throughout the depth of the dust layers. Taken as a whole the experimental results provide a solid base for a significant improvement of the quantification of dust effects and feedbacks in columnar and mesoscale models. Unexpectedly, the lidar system allowed for first statistics on dust devil

characteristics and on cloud nucleation properties of mineral particles. A companion article Tegen and co-workers report on the modeling part of SAMUM.

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The Saharan Mineral Dust Experiment SAMUM-1: Regional dust modeling

Ina Tegen, Dietrich Althausen, Bernd Heinold, Benoit Laurent, Detlef Müller, Kerstin Schepanski, Matthias Tesche

Im Rahmen des Saharan Mineral Dust Experiments (SAMUM) wurde ein regionales Staubtransportmodell entwickelt. Die Simulation der Staubepisoden zum Zeitraum des Feldexperiments im Mai und Juni 2006 wurde für Tage evaluiert, an denen eine Vielzahl von Messungen vorliegt. Generell wird die raumzeitliche größenaufgelöste Staubverteilung vom Modell gut reproduziert. Allerdings werden bei Staubereignissen, die durch Feuchtkonvektion ausgelöst werden, Ort und Stärke der Staubemissionen vom Modell nicht korrekt wiedergegeben. Die Beschreibung von Gebieten im Modell, in denen Saharastaubmobilisierung stattfindet, wird durch Fernerkundungsdaten des geostationären Meteosat Second Generation Satelliten verbessert. Danach ist die übliche Modellparametrisierung von topographischen Senken als bevorzugte Staubquellen fehlerhaft; stattdessen treten Staubemissionen bevorzugt im Bereich von Trockentälern und Wadis auf.

Introduction

Soil dust aerosol plays an important role in the climate system. The presence of dust not only influences the atmospheric radiation budget, but dust deposition also provides nutrients for oceanic microorganisms and terrestrial vegetation, thus influencing the global carbon cycle. Considerable uncertainties in quantifications of the highly variable distributions and optical, microphysical and chemical properties of dust particles result in large uncertainties in estimates of the magnitude of dust effects [*Solomon et al.,* 2007]. The magnitude of the dust effects depends on the dust particle properties, which vary with source areas and transport pathways. An adequate description of dust source areas is a prerequisite for realistic estimates of the effects of dust aerosol, as well as for understanding the response of dust emission fluxes to changing climate conditions. It is therefore a special focus in dust model studies.

The Sahara desert is the largest dust source worldwide, providing at least half of the global atmospheric dust load [*Washington et al.,* 2003]. To improve the quantification of optical properties and radiative forcing by Saharan dust, the research group 'SAharan Mineral dUst experiMent' (SAMUM) (supported by the Deutsche Forschungsgemeinschaft) carried out a field campaign in Morocco in May and June 2006 [*Heintzenberg et al.,* this report]. Within the framework of SAMUM a regional dust model system (LM-MUSCAT-DES) was developed to describe Saharan dust emission, transport, and deposition, together with the effect of dust on the radiation balance. Regional-scale modeling allows computing surface properties and transport processes at scales that are small enough to resolve many of the meteorological processes controlling the dust cycle. It provides a spatio-temporal context to individual measurements taken during field experiments and is used for studying the effect of the dust radiative forcing on regional meteorological processes. The measurements allow for a detailed evaluation of the regional dust model system. In addition to the SAMUM study IfT also participates in the Leibniz-Society-network-project TRACES (ocean-atmosphere-land impacts on TRopical AtlantiC EcoSystems) and the BMBF (Bundesministerium für Bildung und Forschung) cooperative project SOPRAN (Surface Ocean PRocesses in the ANthropocene) [*Weller et al.,* this report]. As part of those projects dust deposition into the tropical Atlantic Ocean is characterized for studies of the impact of the micronutrient deposition on nitrogen fixation and the CO_2 cycle. Within these projects the regional dust model system LM-MUSCAT-DES is used to describe dust deposition fluxes for typical meteorological situations.

Model description

The regional dust model system that was developed in the framework of SAMUM is described in detail in *Heinold et al.* [2007]. It 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) [*Tegen et al.,* 2002]. 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 removal from the atmosphere is mainly by gravitational settling. Dust optical thicknesses 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 takes into account effects of scattering, absorption, and emission by aerosols, cloud droplets, and gases [*Tanre et al.,* 1984]. The constant distribution of desert dust aerosol in the LM radiation scheme is replaced by the size-resolved dust optical thickness provided by the transport scheme MUSCAT, thus the computation of radiation fluxes accounts for a spatially and temporally varying atmospheric dust load. Uncertainties in optical properties of mineral dust are related to uncertainties in the dust size distribution and in the spectral complex refractive index of the particles [*Sokolik et al.,* 2001].

For simulations of the dust episodes during the SAMUM-1 field campaign shown here, a horizontal resolution of 28 km is used for the area between 13.86° N, 25.35° W and 47.78° N, 38.16° E. The model domain covers major parts of the Sahara desert and southern Europe, ensuring that synoptic and regional scale weather systems, local dust emissions and transport to the experimental sites are reproduced within the domain. The model is operated with 40 vertical layers of a pressure-based, terrain-following vertical coordinate, the lowest layer being centered at 34 m above surface. Simulations were performed for the period from May 9 to June 5, 2006.

Here, we focus on the results for the days of June 3 and 4 when dust events were observed by many airborne and ground-based measurements during the SAMUM-1 field experiment. The LM simulation of the regional meteorology is initialized using analysis fields from the global model GME (Global Modell of the DWD), and driven by 6-hourly updated lateral boundary conditions from GME. The simulations were carried out in cycles with a re-initialization every 48 hours in order to keep the meteorology of the regional model close to the analysis fields. After a spin-up period of 24 hours the LM is coupled with MUSCAT to compute dust mobilization and transport. The initial dust concentration at the first cycle is set to zero. The following cycles use the modeled dust concentration from the previous cycle as initialization.

SAMUM period: Model results

Observations used for model evaluation. The model results for the SAMUM period were evaluated with observations taken during the field experiment [*Heintzenberg et al.,* this report]. In *Heinold et al.* [2008] the authors make use of the aerosol optical thickness (AOT) measured by Aerosol Robotic Network (AERONET; [*Holben et al.,* 1998]) sunphotometers, which determine sun and sky radiances at several wavelengths between 340 − 1604 nm. Here, only AOTs at 440 nm are considered. In addition, extinction profiles of the corrected 532-nm extinction coefficient from the IfT lidar [*Tesche et al.,* 2008] are used to validate the vertical profile of the modeled dust above Ouarzazate, Morocco (30.94° N, 6.91° W). Several flight experiments were conducted to measure the vertical distribution of dust particle properties above the observation sites. The Falcon aircraft operated by the DLR (Deutsches Zentrun für Luft and Raumfahrt) carried instrumentation for measuring dust particle size distributions [*Weinzierl et al.,* 2008] here taken for comparisons with modeled size distributions at different heights, and soundings of wind speed and thermodynamical properties [*Petzold et al.,* 2008] that are used for validation of the meteorology simulated by the LM.

The spatio-temporal distribution of modeled dust optical thickness is also qualitatively compared to daily satellite retrievals of the absorbing aerosol index from the Ozone Monitoring Instrument (OMI AI, [*Veihelmann et al.,* 2007]), which is an indicator for the presence of absorbing aerosol particles. The recently developed infrared dust index computed from brightness temperature differences of three infrared (IR) channels of the geostationary Meteosat Second Generation (MSG) satellite [http://www.eumetsat.int] is an additional qualitative indicator for the presence of dust. Due to its high spatio-temporal resolution it is particularly useful for identification of dust sources [*Schepanski et al.,* 2007].

Spatio-temporal dust distribution. The dust distribution on June 4 is illustrated in Figure 1, comparing model optical thickness results at 12:00 UTC with OMI AI, the MSG infrared dust index and dust emissions on the previous 24 hours for June 4, 2006. The model simulated dust emissions over central Mauretania, Mali and Algeria, which is in good agreement with the OMI AI. Dust production in the foothills of Ahaggar are identified by the MSG dust index and simulated by the model in the morning of June 4. This dust is transported to the southern border of Algeria. Dust emissions predicted in Libya were probably associated with clouds. While the model did not simulate dust emissions in Niger that were indicated in the OMI AI and MSG dust index retrievals, the modeled dust transport in northerly direction is realistic. Density currents near the southern Atlas Mountains observed by *Knippertz et al.* [2008] on June 2 to 4 were not reproduced by the model. Trajectories for Tinfou and Ouarzazate on this day originated from north-eastern and central Algerian lowlands.

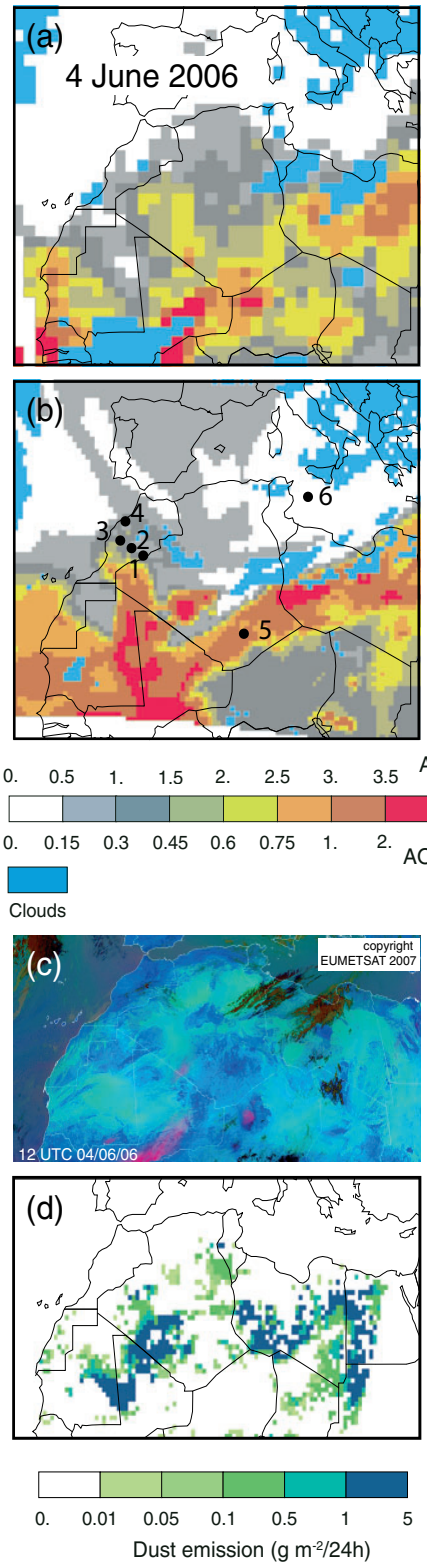

Fig. 1: Comparison of the horizontal distribution of Saharan dust at 12:00 UTC on June 4, 2006. Map of OMI AI (a), model-derived dust aerosol optical thickness at 550 nm (b), MSG dust index (c), and modeled dust emission fluxes for the previous 24 hours (d). Note that the color bar describes different units. In the MSG product, dust is indicated by pink color. Black dots indicate the position of the SAMUM sites Tinfou (1) and Ouarzazate (2), the AERONET stations Saada (3), Tamanrasset (5), and Lampedusa (6), and Casablanca (4).

For the period May 31 to June 4 model results for aerosol optical thickness (AOT) and sunphotometer observations are compared at Lampedusa located in the Mediterranean, 133 km east of the African coast downwind from the Saharan dust sources at (35.52° N, 12.63° E), and Ouarzazate in Morocco [*Müller et al.,* 2008] (Figure 2). It must be noted that only dust aerosol particles are considered in the model, whereas the observations record the total column aerosol. Lampedusa observes long-range transport of Saharan dust where atmospheric dust loads are not very sensitive to the exact location of the source area. Both modeled temporal evolution and the magnitude of dust optical thicknesses agree very well with the sunphotometer measurements at this location. At Ouarzazate, the model overestimates dust optical thicknesses in the beginning of June, as unrealistically large dust emissions were simulated over south-western Algeria on May 30, resulting in considerable dust transport towards the Atlantic. The dust optical thickness is highest on June 3 and 4. On June 3 the model underestimates the optical thickness measurements, as the dust emission sources in Mali and Mauretania were located too far in westerly direction when compared to the satellite dust indicators, following too early activation by wet convection in the model.

Whereas observed dust optical thickness and size distributions are well matched by the model, the spatio-temporal evolution of the dust

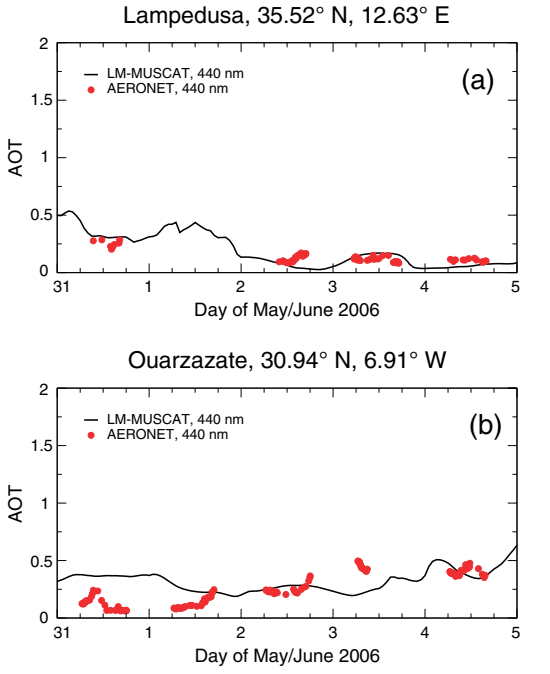

Fig. 2: Comparison of the model-derived dust aerosol optical thickness (440 nm; black line) with the optical thickness provided by AERONET (red symbols) at Lampedusa (a) and Ouarzazate (b).

plumes was not always satisfactorily reproduced. Much of the disagreement of model results with observations is related to the inaccuracies of the placement of dust sources by the model. While the synoptic-scale meteorology is well matched in the model, maximum surface wind speeds are often underestimated. A mismatch between modeled and observed surface wind speed is found in areas characterized by strong variations in small-scale topography that cannot be resolved by the model. Dust emissions in the vicinity of such topographic features such as, e.g., narrow valleys are underestimated in the model. Whereas simulated dust distributions are well matched for dust events caused by dry large-scale dynamics, e.g., extratropical upper-level troughs and large-scale orographic blocking, the model often misrepresents dust emissions related to moist convective events. In particular in comparison with MSG the model emissions often do not occur at the correct location [*Heinold et al.,* 2008].

Vertical structure of the dust layer. Besides the dust optical thickness of the atmospheric column, the vertical distribution of the dust aerosol is an important indicator of the ability of the model to reproduce transport patterns correctly. In addition, the vertical extent of a dust plume affects its impact on weather and climate. Since characteristics of the planetary boundary layer influence the dust vertical structure, first the vertical profiles of wind speed and temperature from the measurements taken during the Falcon flights over Casablanca Airport and radiosonde ascents from Ouarzazate are compared with the model results [*Knipperts et al.,* 2008]. Figure 3a shows profiles for radiosonde measurements at Ouarzazate during the morning hours of June 4. As repeatedly reported for many days during the field campaign, the boundary layer exhibited a layered structure with two or more inversions in the morning hours on this day. The comparisons reveal that whereas the profiles of wind and temperature were generally well reproduced in the model, the observed weak inversions and associated jumps in wind speed are missing. The inability of the model to capture these sharply defined, vertically limited structures can be attributed to a too coarse vertical resolution of the model, but may be also related to numerical diffusion or an inappropriate boundary layer scheme. Modeled dust extinction coefficients were compared with measurements taken at Ouarzazate by the IfT lidar at 532 nm wavelength and to backscatter measurements taken by the DLR during Falcon flights [*Tesche et al.,* 2008, *Weinzierl et al.,* 2008]. The dust model usually correctly places the maximum of the vertical dust layer. For example, on June 4 at 9:45 UTC the measurements with the IfT lidar showed the dust layer with a maximum extinction coefficient at about 190 Mm^{-1} at about 1.7 km above ground level, dust layer reached up to almost 4 km, these features were matched by the model (Figure 3b). However, the well-defined layers of dust extinction coefficients that are observed by lidar are not reproduced, as the dust concentration decreases too gradually with height. The apparently insufficient vertical model resolution leads to an absence of inversions in the model vertical profiles, which is the likely cause for the absence of the observed sharply defined dust layers.

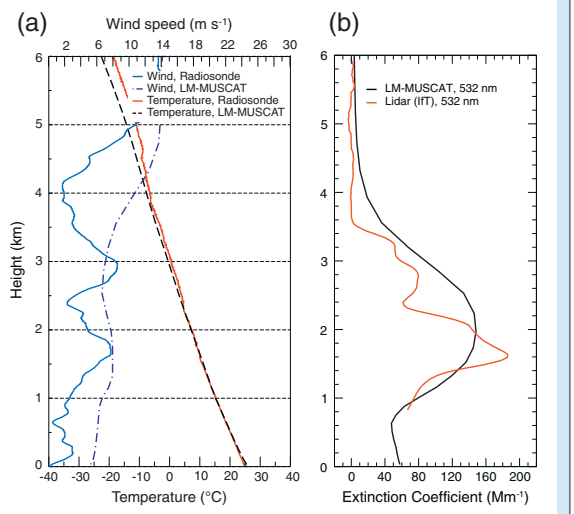

Fig. 3: *(a) Vertical profiles of temperature and wind above ground level measured from a radiosonde on June 4, 2006 (10:39 UTC) in Ouarzazate in comparison with model results; (b) vertical distribution of Saharan dust extinction coefficient (532 nm) above Ouarzazate on June 4, 2006 at 09:47 UTC. Comparison of the modeled dust extinction profile (black line) with the IfT lidar (red line).*

Size distribution. *Heinold et al.* [2008] compare model results with in-situ measurements at the ground site in Tinfou and measurements from the DLR Falcon aircraft on several days. Overall, particle number size distributions in the dust model agree well with the different measurements and the changes in size distribution in the vertical layers as dust transported from different sources is well matched. Figure 4 shows the comparison of particle size distribution from airborne measurements aboard Falcon aircraft above Ouarzazate [*Weinzierl et al.,* 2008] and model results for June 4 at two heights. The number size distribution measured at surface level on this day (not shown) exhibits high number concentrations for particles larger than 30 µm that were likely caused by local dust production by dust devils, which cannot be reproduced by the model. On June 4 larger particles were observed at 3854 m above sea level (fourth log mode of count median

diameter (CMD) = 4.38 µm) than at 1928 m (fourth log mode CMD = 3.2 µm) (Figure 4). The high number of small particles observed at 1928 m on this day is most likely not related to dust concentrations. The differences in size distributions in the vertical layers point to different dust transport histories or transport from different source regions. The agreement between modeled and observed dust number size distribution is reasonable, as the dust distribution was well captured by the model on this day.

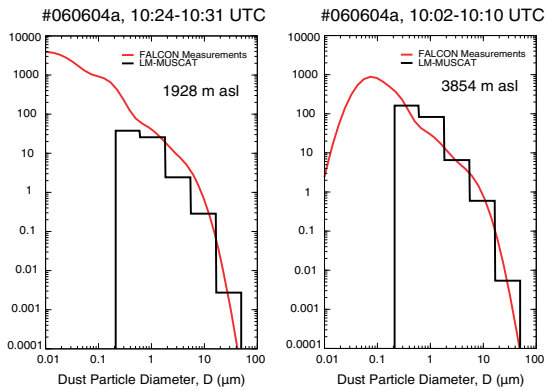

Fig. 4: Comparison of the modeled number size distribution (black line) above Ouarzazate at different heights on June 4, 2006 with airborne measurements taken by the DLR aboard Falcon aircraft (red line).

Dust sources

Not only surface wind speeds, but also soil surface properties must be prescribed correctly in models for computations of realistic dust emission fluxes. Soil properties like grain size distribution and especially aerodynamic surface roughnesses determine the threshold wind speed that must be reached to initialize dust emission in a particular region (e.g., *Marticorena et al.,* [2004]). High roughness lengths in mountainous terrain make dust emission difficult, while flat and smooth terrain provide favorable conditions for dust emission. The 10-m threshold wind speed required for dust emission used in *Heinold et al.* [2007] is shown in Figure 5. The threshold wind velocities are estimated from the surface threshold wind friction velocities and assuming a neutral logarithmic wind profile [*Laurent et al.,* 2008]. For comparison, those areas that were regarded as dust sources for the major dust events during SAMUM by trajectory studies in *Petzold et al.* [2008] are outlined with white dashed lines. The low threshold velocities within these areas confirm that these are potential dust sources when strong surface winds occur, even in the vicinity of the Atlas Mountains. Still, to confirm the potential for dust emission in these regions would require analysis of numerous ground samples, which cannot be easily obtained. With its high spatio-temporal resolution the MSG

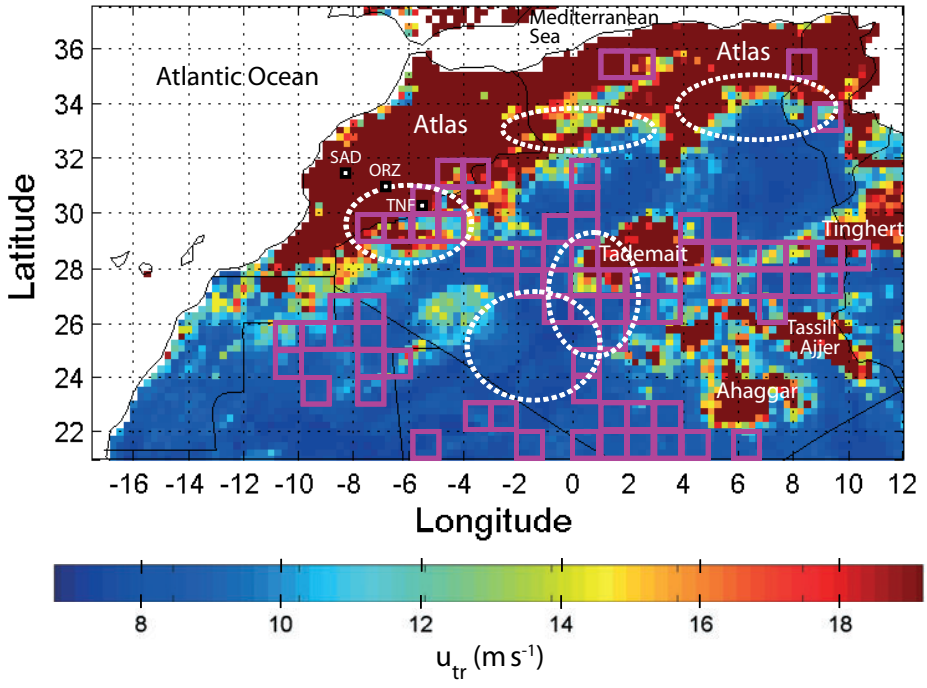

Fig. 5: Map of the 10-m erosion threshold wind velocities over north-western Africa including the SAMUM area. The pink squares correspond to the location of the dust emissions observed during the SAMUM period following Schepanski et al. [2007] (see Figure 1c). The white dotted areas correspond to the estimated source regions of the various dust episodes encountered during the SAMUM research flights [Petzold et al., 2008].

SEVIRI (Spinning Enhanced Visible and Infrared Imager) infrared dust index (see Figure 1c) allows discerning the origin of major dust emission events in a qualitative way. For the SAMUM period, the 1° × 1° gridcells where dust source activation are observed by MSG SEVIRI are outlined in Figure 5 as pink squares. These results suggest that dust emissions occur preferentially in the vicinity of mountain sides rather that in flat, smooth terrain. In some cases they are located upwind of areas identified as dust sources by backtrajectory studies.

Satellite based dust source retrieval. Atmospheric dust can be detected during daytime and nighttime with a high temporal and spatial resolution using infrared (IR) wavelength channels. Here, the brightness temperature (BT) converted from radiances measured by the SEVIRI instrument on board the geostationary MSG satellite is used. With a sampling rate of 15 minutes and a spatial resolution of 3 km at nadir, SEVIRI BT are available at a high spatio-temporal resolution, which we use to identify activated dust sources. The IR dust index is composed of the BT differences (BTD) at 12.0 µm − 10.8 µm and 10.8 µm − 8.7 µm, as well as the BT at 10.8 µm. Several effects lead to dust detection in the thermal IR spectrum (e.g., *Ackerman et al.*, [1997]). The thermal emissivity of desert surface is low in the 8.7 µm wavelength band compared to the 10.8 µm wavelength band. Compared to clear sky conditions dust decreases the BTD between the 10.8 µm and 12.0 µm wavelength bands (BTD (12.0,10.8)), as it does for the 8.7 µm and 10.8 µm wavelength bands (BTD (10.8,8.7)).

Composite pictures using the BTD (12.0,10.8), BTD (10.8,8.7) and BT (10.8) are computed for March 2006 to September 2007 for each 15-min SEVIRI scan. Because of the high resolution of MSG, dust source activation can be observed and localized by visually tracing dust plume patterns back to their origin, in particular by inspecting consecutive images during dust mobilization and transport events. Dust emitting areas are visually determined and marked as dust source activation event on a 1° × 1° gridded map for the Saharan region between 5° N 20° W and 40° N 40° E. The monthly or annual frequencies of source activation events are then calculated for each grid cell [*Schepanski et al.,* 2007].

For one year of analyzed data, the retrieved spatial dust source activation frequency (DSAF) pattern is shown in Figure 6. The main source areas partly agree with source areas described by *Prospero et al.* [2002]. The areas of most frequent dust emission events are located in the south-easterly part of the Sahara, mainly the Bodélé Depression (16 − 19° N, 16 − 18° E) that is most active in December 2006 to February 2007, where dust activations occur at up to 65% of all days during some months. The second strongest source area are the southern foothills of Massif l'Aïr (15 − 18° N, 5 − 9° E). During summer (June to August 2006), dust is most frequently lofted in the western foothills of the Red Sea Mountains (16 − 19° N, 34 − 36° E) (up to 27% of days), the foothills around Massif l'Aïr (17 − 20° N, 6 − 8° E) (up to 26% of days), the area west of the Adrar Mountains (20 − 21° N, 1 − 0° W) (up to 25% of days) and in the area of Sebkhas Mekherrane and Azzel Matti (25 − 27° N, 0 − 3° E) (up to 20% of days). An obvious result of this analysis is that topographic depressions are not always preferential dust sources, which is a modification of the results shown by *Prospero et al.* [2002]. Instead, high frequencies of dust emission are found at foothills of mountain areas where fine sediment is available in wadis and fluvial outwash, and the meteorological situations favor high wind speeds required to initiate dust emission.

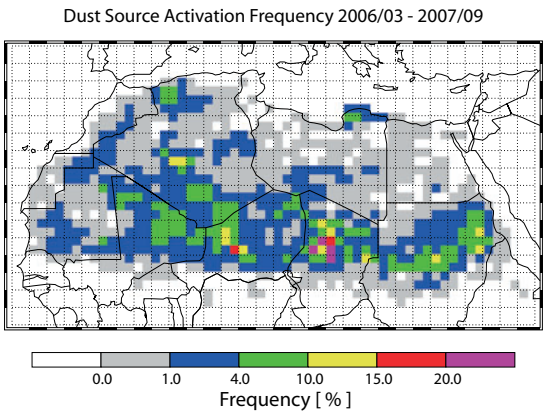

Fig. 6: *Annual frequency of dust source activation on a 1° × 1° grid derived from MSG infrared dust index for March 2006 to September 2007.*

The seasonal and diurnal patterns of dust emission observed by MSG SEVIRI help to understand the meteorological processes controlling the spatio-temporal patterns of dust emission in the different regions of in the Saharan desert. Areas with similar topographic features and seasonal changes in dust source activation can be summarized. In Figure 7 we show the monthly changes in the number of activated 1° × 1° grid cells from *Schepanski et al.* [2007] in two particular Saharan regions: The Atlas region (enclosing approximately the area between 28° N and 36° N, 8° W and 6° E) and the Aïr (between15° N and 28° N, 1° W to 10° E. This includes the Aïr, Ahaggar, and the Plateau de Tademaït). For each month the fraction of the time of the day when the dust source activation occurs is indicated.

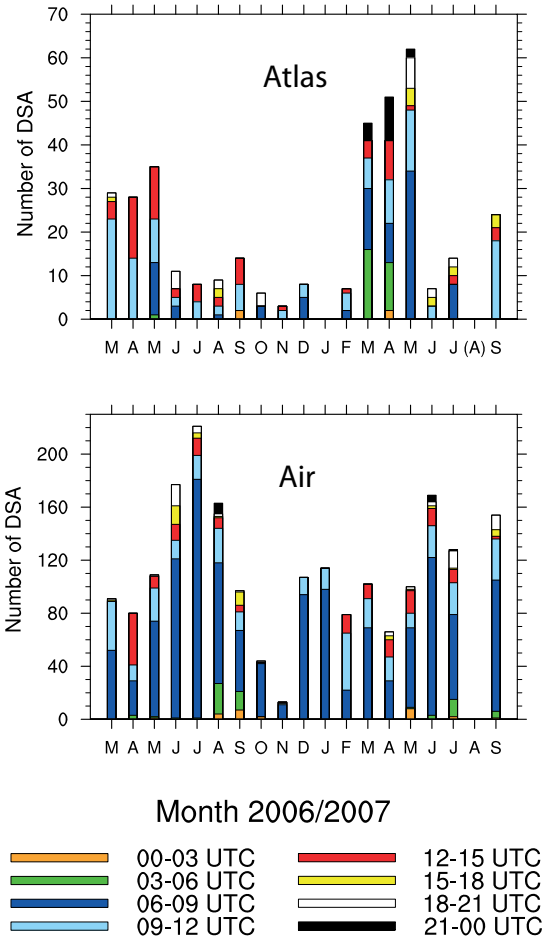

Fig. 7: *Monthly dust source activation frequencies for the dust source regions Atlas and Aïr Mountains (see text) for March 2006 to September 2007. The color indicates the fraction of the time of day (UTC) of dust source activation.*

Dust source activation in the Atlas area is most frequent during spring time, with a minimum in winter. Whereas in most parts of the Sahara dust mobilization is most frequent in the morning hours, here dust mobilization frequently occurs during mid-days and afternoons. Orographic clouds may develop above the Atlas that reach their maximum in the afternoon, leading to precipitation and associated density currents that frequently activate dust sources in this region [*Knippertz et al.,* 2007]. Especially in spring time, the temperature contrast between the North African coast and the Mediterranean Sea cause the development of lee cyclones (Sharav Cyclone or Khamsin Depression) [*Alpert and Ziv,* 1989]. These cyclones quickly move eastward and may cause the activation of dust sources south of the Atlas.

The Aïr region exhibits maximum dust source activation frequencies in the summer months and a minimum in late fall. Approximately 70% of the dust emissions take place in the morning hours between 7:00 and 10:00 local time. Here, the dust emissions appear to be predominantly related to the occurrence of nocturnal low level jets. After sunrise high wind speeds are caused by the breakdown of the nocturnal stable boundary layer due to downward mixing of momentum (e.g., *Lenschow and Stankov,* [1979]). Similar mechanisms of dust mobilization have been observed for the Bodele region, where the strongest surface winds are observed in the morning hours when momentum is mixed down from a persistent low level jet to the surface by turbulence induced by radiative heating in the morning hours [*Washington et al.,* 2006].

Model test of MSG-derived dust sources. While computations of the dependencies of dust emission fluxes on soil, surface properties and friction wind velocity are meanwhile quite sophisticated in large-scale models (e.g., *Marticorena et al.,* [1997]), the accuracy of such computations is limited by the available input data. The Saharan DSAF map provides a new mask for potential dust source areas useful for models of the Saharan dust cycle. In *Schepanski et al.* [2007] the new source area map derived from MSG data was used as input field for the LM-MUSCAT-DES in the regional dust transport model to test how using the new sources changes the model results for a case study of a Saharan dust event from March 5 – 10, 2006. For a first test, dust emission was set to zero at those grid cells where source activation was observed less than 4 times a year in the MSG data set. For Test case 1, soil texture was held at fixed values and the surface roughness was set to z_0 = 0.001 cm for the entire model region. For Test case 2 the surface roughnesses used as input parameters in the dust emission code were set to satellite-derived values [*Marticorena et al.,* 2004]. A simulation of the same period with the original model that prescribes topographic depressions as preferential dust sources [*Heinold et al.,* 2007] was used as reference case. Compared to AERONET AOTs the use of the new source area map clearly improves the modeled AOT for both test cases compared to the reference case, both in AOT magnitude and timing of dust events. As example for the improvement in model performance when comparing AOTs with measurements from AERONET sunphotometer stations we find that at the location of the Dakar (14.39° N, 16.96° W) the results of Test case 2 shows best agreement with the observations (Figure 8).

These results using the new source area map as a mask for potential dust sources represent a first test; further refinements of the source formulation are needed. However, for this case study the implementation of the new derived dust source areas already show a promising improvement of the model performance.

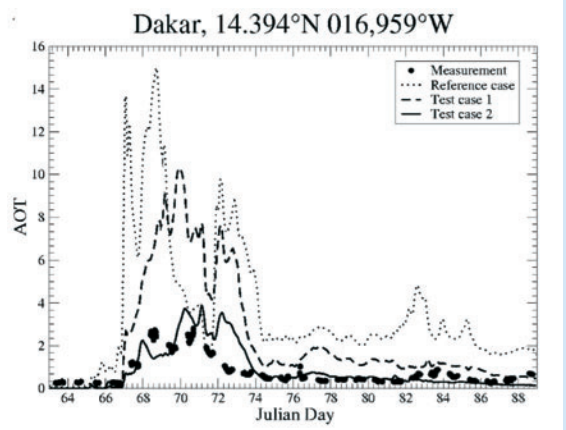

Fig. 8: *Comparison of modeled (550 nm) and measured AOT (440 nm) at AERONET station Dakar, for March 4 – 29 (shown as Julian Days) for different dust source area masks.*

Summary and outlook

The performance of the regional dust model system LM-MUSCAT-DES was evaluated with measurements of optical thicknesses, extinction coefficients, and particle size distribution, as well as satellite dust indices and standard meteorological parameters during the 2006 SAMUM-1 field campaign. The evaluation focused on days when many co-located measurements were available. Dust optical thickness and size distributions are mostly well matched by the model. However, the spatio-temporal evolution of the dust plumes is not always satisfactorily reproduced. Much of the disagreement of model results with observations is related to the inaccuracies of the placement of dust sources by the model. A strong mismatch between modeled and observed surface wind speed is found in areas characterized by strong variations in small-scale topography that cannot be resolved explicitly. Whereas simulated dust distributions are well matched for dust events caused by dry large-scale dynamics, the model often misrepresents dust emissions related to moist convective events. The standard LM moist convection may not be suitable for the conditions in desert regions. While the model usually places the maximum of the vertical dust layer correctly, the well-defined layered structure of dust extinction coefficients observed by lidar instruments is not reproduced. The still insufficiently fine resolved spacing of the vertical model layers leads to an absence of inversions in the model vertical profiles, which is the likely cause for the absence of sharply defined dust layers. The evaluation with the large number of available observations in proximity to dust source regions demonstrates the limits of the regional dust model system.

The difficulties in specifying the exact locations of dust source regions, which in turn are a prerequisite for realistic descriptions of dust transport pathways and particle properties, motivate a specific focus on dust emissions. Here we make use of three thermal IR wavelength channels of the SEVIRI instrument on board the geostationary MSG satellite to detect atmospheric dust over land. The high spatio-temporal resolution makes the detection of individual dust emission events possible. Using this information we compiled a new monthly 1° × 1° map of dust source activation frequencies for the Sahara and Sahel region from MSG IR composite pictures for March 2006 up to September 2007. In the presence of clouds, localization of dust emission is limited. Uncertainties in localization and misinterpretation of the MSG-signal are the main error sources. Results from the application of the dust source map as a mask to describe dust emission areas in a dust model indicate that this observation-based dust source distribution potentially improves the model performance of regional scale Saharan dust transport. The MSG data set will be extended to include results for upcoming years, and additional case studies will be performed to test possible improvements in dust models from the use of the new source parameterization.

The generally good model performance makes it a useful tool for the study of direct radiative effects and feedbacks of Saharan dust. While such regional models are well-suited for investigations of dust transport during individual case studies that cannot be reproduced by global models, the studies with the high-resolved regional model will ultimately help to improve the parameterisations of global dust models as well.

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Atmosphere-Ocean interactions

Christian Weller, Hartmut Herrmann, Yoshi Iinuma, Nicole Kaaden, Sandra Lehmann, Conny Müller, Thomas Müller, Kerstin Schepanski, Andreas Tilgner, Alfred Wiedensohler

Massenaustausch zwischen den Ozeanen und der Atmosphäre kann über den Austausch von Gasen sowie die Bildung und Aufnahme von Aerosolpartikeln stattfinden. Der Schwerpunkt der Arbeiten am IfT zur Wechselwirkung der Ozeane mit der Atmosphäre liegt auf Untersuchungen von Prozessen, die Partikel betreffen. Die Ozeane bilden einerseits die global wichtige Quelle für Seesalzpartikel, andererseits beeinflussen eingetragene Staubpartikel aus der Atmosphäre chemische und biologische Prozesse im Ozean durch ihre Inhaltstoffe wie z. B. Eisen. In den Projekten TRACES und SOPRAN werden im Hinblick auf den Einfluss der Atmosphäre auf den Ozean Mobilisierung, Transport sowie Deposition von Saharastaub untersucht. Weiterhin finden Feldmessungen zur Charakterisierung der physikalisch-chemischen Eigenschaften von Staubpartikeln und Laborexperimente zur Photochemie von Eisen in marinen Partikeln statt. Der Einfluss des Ozeans auf die Atmosphäre wird im Projekt FILGAS beleuchtet, welches den organischen Film auf der Ozeanoberfläche und an marinen Partikeln charakterisiert, sowie durch die Modellierung von chemischen und physikalischen Prozessen im atmosphärischen Mehrphasensystem unter besonderer Berücksichtigung der Halogenchemie und der Umsetzung organischer Substanzen.

Atmosphere-ocean interactions - an overview

More than 70% of Earth's surface is covered by oceans. Therefore, the interaction between the ocean and the troposphere is important for many processes in either system and is hence linked to the global climate and its change. The exchange of mass, i.e., trace gases and particles between the atmosphere and the ocean occurs in many different sub-systems. The ocean influences the tropospheric budgets of important trace gases such as CO_2 and DMS (dimethylsulfide, [*Ayers et al.*, 1995]). Water vapor from the ocean surface controls the global water cycle and therefore the atmospheric water content as well as cloud formation in the troposphere. Sea salt particles are generated at the ocean surface and affect the atmosphere, but atmospheric particles from continental sources are also deposited into the ocean importing a variety of trace substances including nutrients into the ocean. The complex processes are treated in several ongoing projects at IfT and are described in this contribution.

When particulate matter is deposited on the ocean surface, it affects the surface water chemistry as well as the oceanic ecosystems. Here, work at IfT focuses on the impact of desert dust particles deposited on the tropical Atlantic. Micro-nutrients, in particular iron, transported by dust, fertilize the marine biota and support nitrogen fixation in tropical ocean regions [*Jickells et al.*, 2005] which in turn is important for the drawdown of atmospheric CO_2. Furthermore, atmospheric processes at the surface of the dust particles such as chemical weathering, water uptake, phase transfer of organic compounds from the gas phase and subsequent photochemical reactions can considerably change the physical and chemical properties of the emitted dust particles. Dust components can catalyze chemical reactions and alter the chemical composition of the marine troposphere. Recent studies discuss e.g., the photochemical dissolution of ferrihydrite, an abundant form of iron in weathered and reprocessed dust particles, together with oxidation products of DMS [*Johansen*, 2006].

Whether dust deposition is dominated by dry sedimentation or wash-out by precipitation might influence the chemical state of micro-nutrients in the mineral particles. This is crucial for the availability of the nutrients for marine biota. To estimate effects of oceanic deposition of mineral dust on the climate system, detailed information about dust emission, atmospheric transport processes, (photo-) chemical processing of the transported dust and its specific chemical components such as iron-minerals and the regional distribution of dust deposition is needed. Especially, the chemical processes during the transport of dust and after the deposition of the dust into the ocean are of interest, with focus on the complexation and photochemical reactions of iron.

DMS is the most important reduced sulfur compound emitted from the ocean [*Andreae*, 1990]. It has been proposed that the oxidation of DMS and its oxidation intermediates in the atmosphere could play an important role in marine atmospheric chemistry as well as in climate processes due to new particle formation and growth processes, thus affecting the albedo of the cloudy atmosphere and the solar radiation budget at the Earth's surface [*Charlson et al.*, 1987]. In marine environments particularly sea salt particles act as CCN and determine the optical properties

of the marine clouds. Chemical multiphase processes in and on marine particles initiate complex chemical conversions influencing (i) the oxidation capacity of the atmosphere, (ii) the sulfur cycle, (iii) the budgets of organic compounds in either phase in the marine environment and (iv) new particle formation involving iodine compounds and/or organics. Because of the complexity of such multiphase processes and interactions, improved chemical mechanisms and models are needed to enhance the understanding of specific field observations as well as the system as a whole.

Primary sea salt particles are formed by both wave-braking and a bubble-burst mechanism [*Pruppacher and Klett*, 1997]. Marine aerosol particles are not solely composed of inorganic components such as sodium chloride (NaCl). Recent chemical analyses have shown that the particles also include a variety of organic compounds [*O'Dowd et al.*, 2004]. These organics may be constituents of the particle bulk phase or may exist at the particle surface. With regard to the latter, marine aerosol particles could be pictured as a brine core covered with an organic layer [*Dobson et al.*, 2000]. This layer may contain surface-active compounds such as fatty acids. The surface layer can be formed by air bubbles which rise through the water column and adsorb organic material [*Saint-Louis and Pelletier*, 2004]. Additionally to the probably omni-present surface microlayer, increased biological activity during algae blooms could lead to slick formation on the ocean surface. In such case, the main part of the organic microlayer which covers the ocean as the so-called ocean surface microlayer (OSM, [*Hardy and Word*, 1986]) is of biogenic origin. Compounds from the OSM may then lead to the coverage of generated sea spray particles [*Creamer and Wright*, 1992]. If such organic films also occur on particles this will influence the water evaporation rate and also the phase transfer of trace gases and radicals. Since an organic layer changes the optical properties of the aerosol particles, Earth's radiation budget will also be influenced [*Facchini et al.*, 1999].

In summary, the mentioned areas of the study are crucial for a better understanding of atmospheric processes such as cloud formation, marine tropospheric multiphase chemistry, new particle formation, oxidation capacity and finally Earth's radiation budget. To investigate the abovementioned issues of atmosphere-ocean interaction concerning tropospheric aerosol, IfT presently is conducting the following four projects:

Atmospheric impact on the ocean

- SOPRAN (Surface Ocean Processes in the Anthropocene), BMBF Project
- TRACES (Ocean-Atmosphere-Land Impacts on Tropical Atlantic Ecosystems), WGL-SAW-Project

Oceanic impact on the atmosphere

- FILGAS (the function of the film formation at the boundary ocean-atmosphere for the transport of trace gases), WGL-SAW-Project
- Modeling of phase transitions of mixed phase particles together with the development of the CAPRAM-MARINE mechanism (AÜP)

Atmospheric impact on the ocean

Modeling of Saharan dust deposition towards the tropical Atlantic (TRACES)

To study dust transport towards and deposition in the tropical North Atlantic, the regional dust transport Model LM-MUSCAT [*Heinold et al.*, 2007] is used. It consists of the regional meteorological model Lokal-Modell (LM) from the Deutscher Wetterdienst (DWD) and the Multi-Scale Chemical Aerosol Transport Model (MUSCAT). The model simulations were performed for an area covering 0.2° N; 32.3° W – 41.3° N; 33.3° E with a horizontal resolution of 28 km and 40 vertical layers. The study includes the determination of dust source areas, relevant for the atmospheric transport and deposition towards the Atlantic. To model dust mobilization, dust emission was excluded for grid cells, where dust source activations were observed less than two times during the period 03/2006 − 02/2007, based on satellite observations [*Schepanski et al.*, 2007]. To describe dust emission, soil texture and surface roughness were held at fixed values. Dust transport and deposition is computed for five size classes between 0.1 µm and 24 µm radius.

Dust emission areas and fluxes as well as transport paths and deposition fluxes change with season. Three case studies have been performed to capture seasonal differences of transport and deposition: March 2006, July 2006 and December-January 2006/2007. All three periods are characterized by large dust plumes extending over the tropical Atlantic.

Over the Atlantic, the dust particles are transported within a more or less well-defined layer, characterized by low relative humidity (<40%) and high dust particle concentration (Saharan Air Layer, SAL). During boreal winter and spring, this layer is located near the surface. During summer, the dusty layer is elevated above the marine air layer, with maximum dust concentrations at 3 − 5 km height. Dust deposition depends on the amount of transported dust, the size distribution of the particulate matter, the height of transport and the occurrence of clouds

and precipitation. Near source regions, the main mechanism for dust particle fluxes towards the surface is dry deposition (Figure 1). Precipitation distribution determines the scavenging of dust particles and is the most efficient way of removing dust from the atmosphere. This wet deposition occurs most frequently in regions dominated by moist convection like the monsoon regions over the Atlas Mountains due to their blocking effect, as well as the regions affected by cyclonic activities. The amount of local wet deposition varies with the season as cyclonic activities especially over the Atlantic and the extent and location of the monsoon region vary seasonally (Figure 1).

Over the tropical North Atlantic, only ocean regions characterized by moist convection due to monsoon season are dominated by wet deposition. The area dominated by dry dust deposition over the Atlantic is an extension of the Saharan dust plume entering the Atlantic from the African continent. Seasonal distribution of dust sources as well as wind fields varying with the season mainly affect the extent of the plume regarding longitude as well as latitude and structure.

To capture the dust emission areas as well as the dust deposition areas, which are hundreds of kilometers apart of each other, modeling studies are necessary to investigate relevant processes

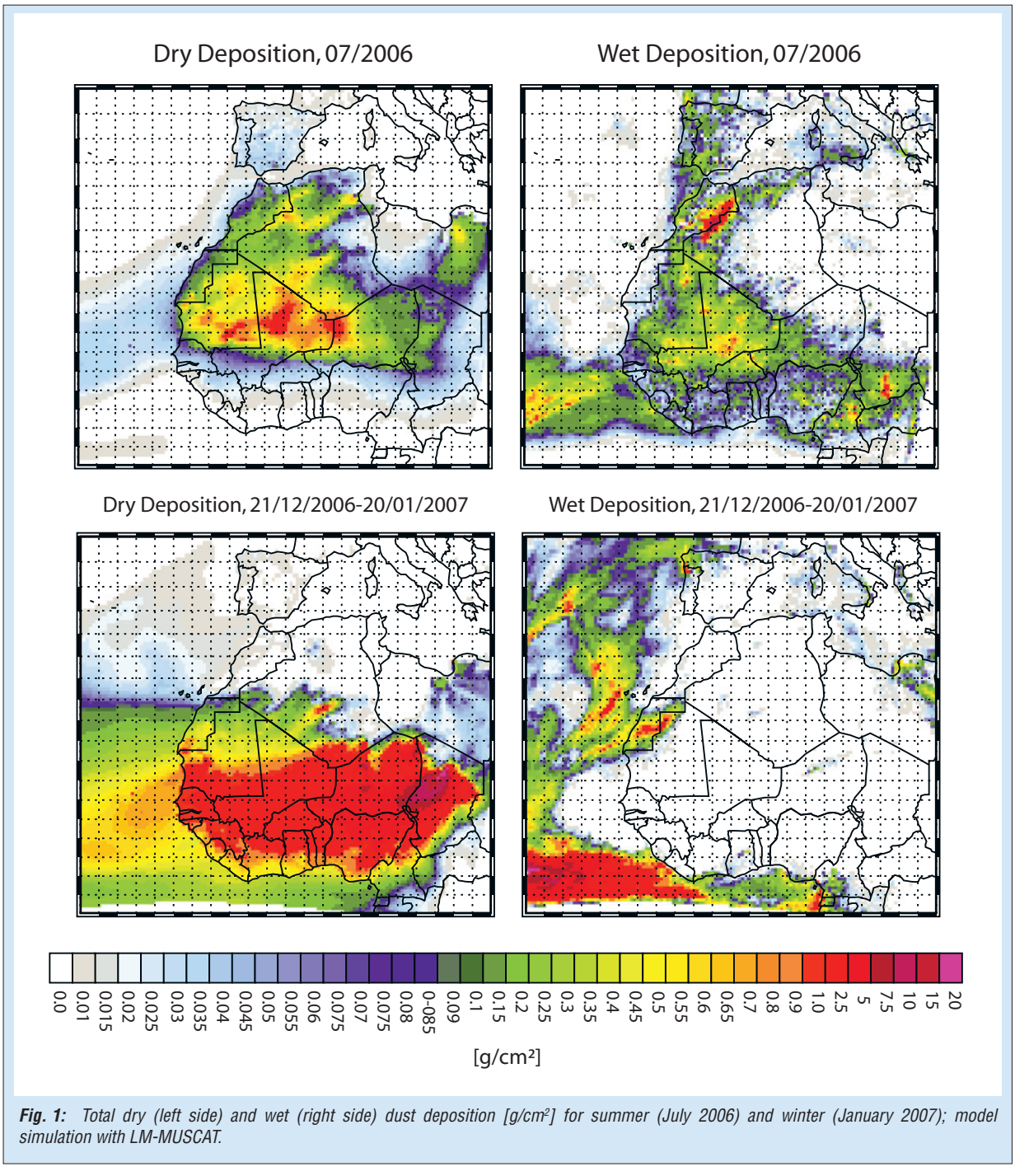


Fig. 1: *Total dry (left side) and wet (right side) dust deposition [g/cm²] for summer (July 2006) and winter (January 2007); model simulation with LM-MUSCAT.*

for emission, transport and deposition of dust. In the future, the model results will be compared with experimental results for the chemical and physical characterization of particles on the Cape Verde Islands in both the projects SOPRAN and SAMUM, cf. the SAMUM contributions in this volume.

Surface Ocean Processes in the Anthropocene (SOPRAN)

The BMBF-supported project SOPRAN started in the beginning of 2007 as an interdisciplinary cooperation of 12 German research institutes with atmospheric, marine and biological foci. The main focus of the project is to better understand ocean-atmosphere exchange processes under anthropogenic influence. Research at IfT is focused on Theme 1 of the SOPRAN-project: "Oceanic response to atmospheric dust". Chemical and physical field measurements in the different particle-size fractions, hygroscopic and optical characterizations are conducted at the Cape Verde Oceanic and Atmospheric Observatory (Figure 2) which was established in a joint effort of UK SOLAS, IfM Kiel, IfT and the MPI for Biogeochemistry in Jena. The volcanic archipelago of the Cape Verdes is located in the Atlantic Ocean off the west coast of Africa. Saharan dust is transported over large distances westwards and southwards over the north tropical and equatorial Atlantic Ocean [*Carlson and Prospero*, 1972]. Especially during winter months (November – February) it reaches Cape Verde with the north-eastern trade winds.

The development of the station infrastructure and equipment is also funded by the EU-project TENATSO (Tropical Eastern North Atlantic Time-Series Observatory). Local support and close cooperation is provided by the INMG (Instituto Nacional de Meteorologia e Geofísica) and the INDP (Instituto Nacional de Desenvolvimento das Pescas). The observatory is of crucial importance for the SOPRAN studies. For the IfT, the site is used for aerosol sampling with subsequent chemical analysis and direct physical measurements of the aerosol. Instruments for chemical aerosol analysis and physical aerosol measurements are present at the site since the beginning of 2007. Some instruments are running throughout the year, whereas others are only operated during intensive campaigns for several weeks. The first such campaign took place from May 10th to June 14th, 2007, synchronized with the UK SOLAS RHAMBLE projects intensive campaign. The second started on November, 28th 2007 and lasted until January 5th, 2008.

Chemical measurements and analysis. To reduce the influence of the local sea spray at the site, the instruments for the chemical sampling were installed on the top of a 30 m-tower. A high volume Digitel DHA-80 sampler is routinely operated, complemented by a 5-stage BERNER-impactor which is run during intensives. The filters and foils from the field sampling are extracted in the lab for further analysis. The sea salt fraction of the particles is analyzed by ion-chromatography as a sum parameter. Bromide ions are of special concern because of the key role of bromine atoms being formed from particle bromide in marine multiphase chemistry.

Figure 3 gives an overview of the first results for the particle ion content derived from Digitel-filters for the period January to October 2007. High peaks in the mass concentration with simultaneous low ion concentrations indicate dust events. Five examples for events with high and low dust loading during the normal and intensive campaigns are given in Figure 4. The dust

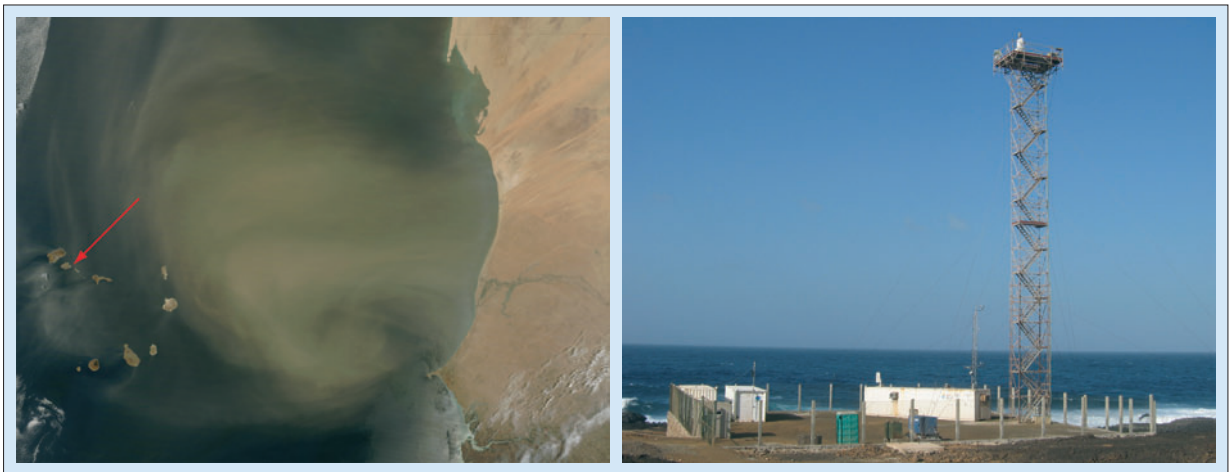


Fig. 2: *Left: Saharan dust emissions from the African continent heading towards of Cape Verde, red arrow: sampling site, MODIS Terra Satellite image, using Band 1, 4 and 3 (670 nm, 565 nm, 479 nm) for true-color composite picture, 9th of May 2007, 11:50 UTC, Right: The atmospheric sampling site of the Cape Verde Oceanic and Atmospheric Observatory on São Vicente with its 30 m tower.*

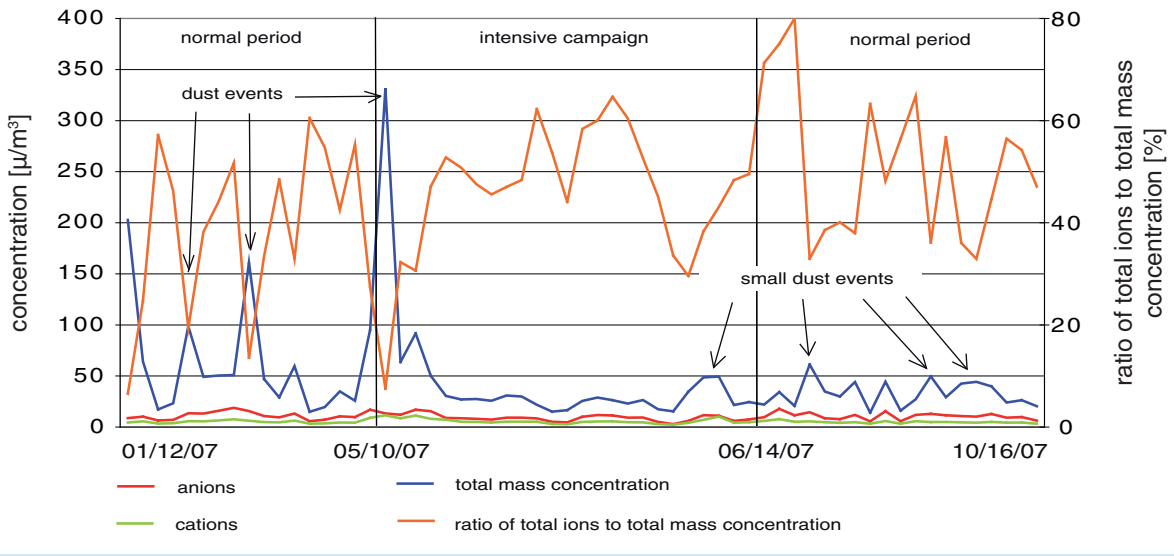


Fig. 3: *Ion concentrations from Digitel-samples taken between January 12th and October 16th, 2007 at the Cape Verde Atmospheric Observatory.*

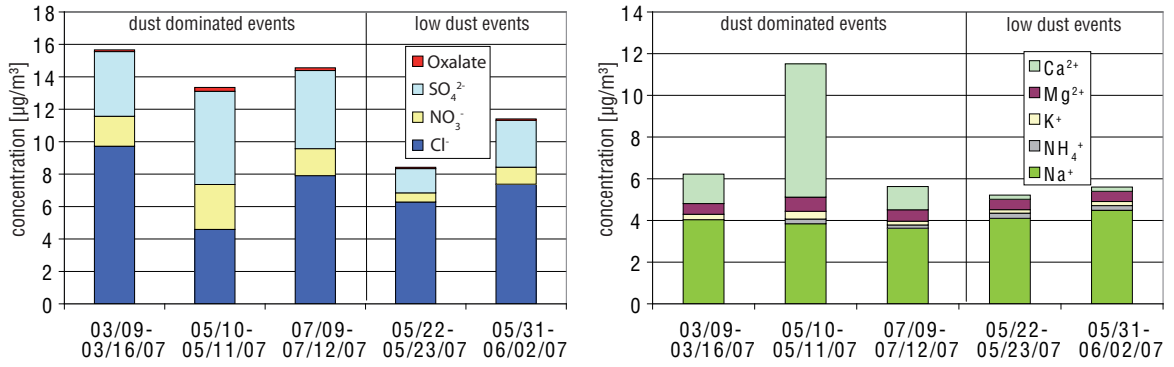


Fig. 4: *Detailed anion and cation concentrations for 5 examples of Digitel-samples.*

events show a higher concentration of calcium, probably caused by the mineral origin of the dust. Elevated sulfate and nitrate levels could be due to anthropogenic influence and long range transport over the Atlantic Ocean.

Organic tracers can give information about the particle sources such as the mobilization of Saharan dust or biomass burning events. In combination with back trajectories, the sources of the dust events can be estimated. It is of interest, how areas under strong anthropogenic pressure (e.g., Sahel) have an influence on the current dust mobilization and transport [*Chiapello et al.*, 1997].

Figure 5 illustrates a typical chromatogram for summer samples taken at the Cape Verde Atmospheric Observatory. Although the intensities of peaks are relatively low, a number of sugars and sugar alcohols are found in the summer samples. The sugar alcohols mainly originate from biological sources such as leaves, fungi and algae (arabitol and mannitol) or from isoprene oxidation (methyltetrols). A small influence of biomass burning can be seen on this particular sample from the biomass burning tracer compounds levoglucosan and mannosan.

Besides improving the knowledge of dust transport and its composition, this wide spectrum of chemical analyses can provide important information about Saharan dust as nutrient supplier for the upper layer of the Atlantic Ocean. Two more years of SOPRAN with more intensive campaigns are planned. This will provide basic knowledge to be used for further modeling studies or laboratory experiments to understand the complex aerosol influence on atmospheric chemistry and the upper ocean.

Physical measurements. The mixing of the marine aerosol and transported mineral dust is also monitored by physical aerosol measurements. Particle number size distributions in the range from 10 nm to 10 µm give information about the aerosol type and thus some information about the origin of aerosols. In general, the marine

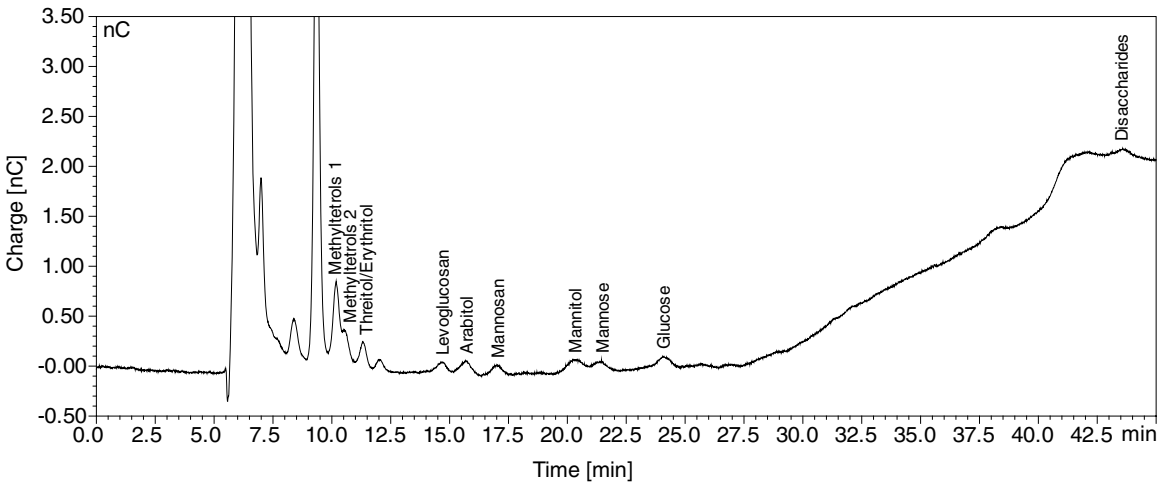


Fig. 5: A chromatogram obtained from the sample taken between June 21st and June 24th, 2007 at the Cape Verde Atmospheric Observatory.

aerosol consists of different modes, two sub-micrometer (sulfate-dominated), and one super-micrometer (sea salt). Long-range transport of Saharan dust will elevate the concentrations in the super-micrometer size range. Light absorption measurements at wavelengths between 300 and 800 nm give additional information about the iron content of the mineral dust. All measurements are limited by an upper size cut of 10 µm and are performed under dry conditions.

Particle number size distributions show changes in the super-micrometer size range between clean marine periods and episodes with additional mineral dust as plotted in Figure 6. Here, average particle number size distributions are given for periods of approximately 5 hours from DOY 135.8 − 136.0 and 136.2 − 136.4 representing a (1) dust-influenced and a (2) clean marine period. For the sub-micrometer size range, the number size distributions are almost identical, while for the super-micrometer range the curves clearly differ. The yellow area represents additional number concentrations of super-micrometer dust particles.

The spectral light absorption coefficient was measured using a spectral optical absorption photometer. The photometer collects particles on a fiber filter while the sample spot is illuminated by a white light source. The transmission and reflection of light of the particle-filter system are measured using an optical spectrometer in the wavelength range from 350 to 800 nm with an optical resolution of 25 nm. Using a radiative transfer model the particle absorption coefficient is determined.

For the same time periods as described above, high and low light absorption for wavelengths smaller than 600 nm was observed indicating iron-rich mineral dust. Light absorption of Saharan

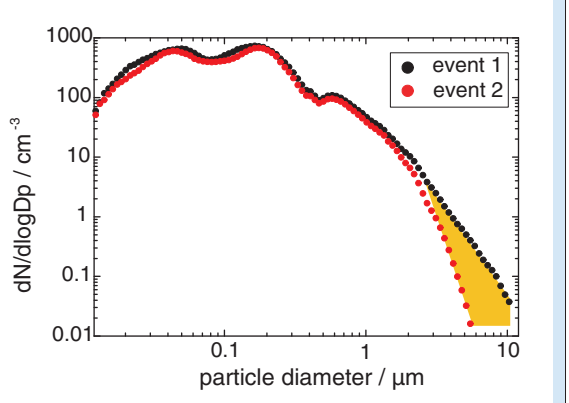


Fig. 6: Averaged number size distributions of an episode of clean marine conditions (red dots) and a period with additional mineral dust (black dots) in the super-micrometer size range. The yellow area describes the additional number concentration due to dust.

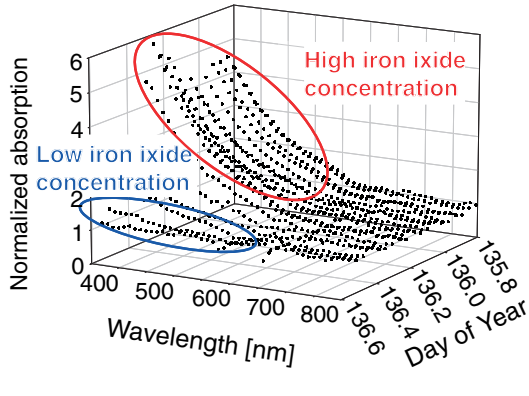


Fig. 7: Time series of spectral optical absorption coefficient measured for wavelengths from 350 to 800 nm. The absorption spectra are normalized to the absorption coefficient at 550 nm in order to point out qualitative differences in the absorption spectra caused by different iron oxide concentrations.

dust is dominated by iron oxides. While the light absorption in the UV is relatively high, the absorption drops above 600 nm wavelength. For the time period 135.8 − 136.0, the normalized absorption spectrum plotted in Figure 7 shows a high iron concentration indicating mineral dust with iron oxide. During day 136, the iron concentration decreased significantly indicating the end of this dust event as shown in the particle number size distribution.

Iron photochemistry in marine tropospheric particles and the surface ocean (TRACES)

The investigations in TRACES aim at clarifying the interactions of important organics with iron in marine particles and clouds, and, when applicable, at the ocean-surface layer. This project contribution deals with iron-organic-interactions to form complexes which could undergo photochemical conversions. By the study of iron-chemistry at the molecular level it complements studies at the regional level on iron deposition into the ocean and studies of chemical particle composition at the microscale level. In both the atmospheric aqueous phase and the ocean there is a huge potential for organic iron-complexation due to the presence of numerous organic ligands [*Deguillaume*, 2005; *Powell and Donat*, 2001]. Photochemistry of iron-complexes can initiate radical production in the atmospheric aqueous phase and in the ocean surface layer. Radical chain reactions could then drive chemical transformation processes in both compartments. In oceanic oxic environments iron is mostly present as iron(III) but the form iron(II) which is formed by iron(III)-complex photochemistry is biologically more important for marine organisms.

Model ligands in the categories polycarboxylates, keto-carboxylates, hydroxymates and catecholates were chosen according to their environmental relevance [*Okochi and Brimblecombe*, 2002; *Santana-Casiano*, 2000] for iron-complexation to measure their light absorption features, radical and iron(II) quantum yields and organic products from iron complex photolysis in laboratory experiments.

Absorption spectra of the organic-iron complexes have been measured for various ligands in the UV-VIS range to determine their sensitivity to the actinic UV-radiation (Figure 8). At the lower end of the actinic UV-range the iron(III)-malonate complex is the most strongly absorbing complex. Photolysis experiments of the iron(III)-malonate complex at pH = 5 have been performed with excimer laser single wavelength flash photolysis at 248 and 308 nm. A pH of five was chosen as representative for marine clouds. The first experiments at wavelength 248 nm

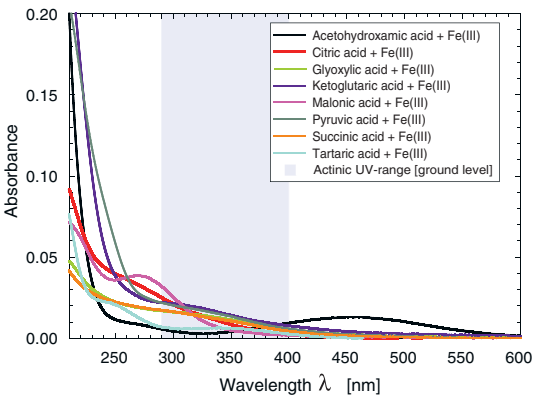


Fig. 8: *Absorption spectra of a series of organic-ligand-iron(III) complexes at pH = 5.*

are not directly of tropospheric relevance since this light is not available in the troposphere. These experiments, however, can give valuable information about the overall wavelength dependence of the quantum yield and served as a test series to develop the measurement method. In the course of the experiment, UV-spectra of the iron(III)-malonate complex are recorded before and 2 ms after the laser flash photolysis with a deuterium lamp as an analytical light source and a transient spectrophotometer. Two effects are noticed in the spectrum after the photolysis in comparison to the reference spectrum before photolysis (Figure 9). First, the green curve shows a lower absorbance between 230 and 290 nm compared to the red one because a certain amount of iron-malonate has been destroyed (photo-bleaching). Secondly, the green curve crosses the red one and is higher between 290 and 370 nm due to absorbance caused by product build up. The wavelength range of the photo-bleaching effect can be used to calculate how

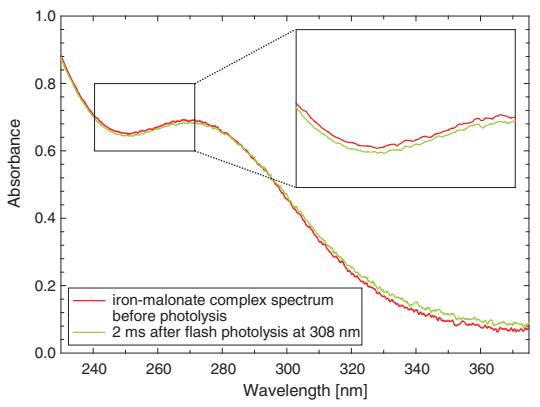


Fig. 9: *UV-Spectra of iron-malonate complex before and 2 ms after excimer laser flash photolysis at λ = 308 nm. Values from 70 experiments have been averaged. The insert highlights the photo-bleaching effect.*

much of the iron-malonate has been photolysed. This is specifically done from 240 to 270 nm where the difference between the two spectra is constant (see zoom-insert of Figure 9) which indicates that no overlap with product absorbance takes place. Using the concentration difference together with the pulse energy of the excimer laser, the quantum yield can be calculated.

From the abovementioned experiments first determinations of effective quantum yields (Φ) at the respective wavelengths can be given to Φ_{248nm} = 0.09 and Φ_{308nm} = 0.03. The quantum yield can be used to gain more insight into the complicated iron redox-chemistry in cloud water via modeling studies with mechanisms such as CAPRAM [*Herrmann et al.*, 2005]. The cloud water chemical processes can change the composition of the precipitation and therefore the chemical speciation of iron-input into the ocean.

Oceanic impact on the atmosphere

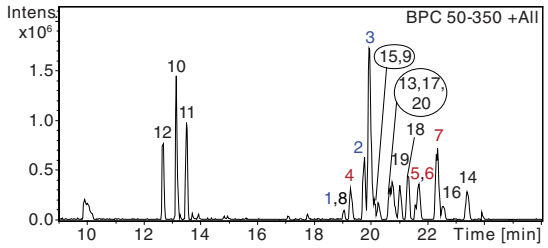
Ocean surface microlayer (FILGAS)

The aim of the FILGAS ("The function of the film formation at the boundary ocean – atmosphere for the transport and the production of trace gases") WGL-supported project is the characterization of the interface between the ocean and the atmosphere (ocean surface microlayer) and its role for the gas exchange. This project includes the determination and identification of polar organic compounds in the ocean surface microlayer and marine aerosols. As mentioned earlier, polar organic compounds in these matrices are mainly of biogenic origin; i.e. amino acids, carboxylic acids, fatty acids and carbohydrates are main target compounds.

CE/ESI-ITMS (capillary electrophoresis coupled to electro spray ionization ion trap mass spectrometry) and a method adapted from *Soga et al*. [2004] (see Figure 10, Table 1) was modified and used for the amino acid analysis.

The base peak chromatogram for all 20 amino acids shows base line separation except for leucine and isoleucine (Figure 10). Retention times, calibration correlation coefficients and detection limits for twenty amino acids using the modified method are summarized in Table 1. Capillary electrophoresis is also used for carboxylic acids measurements with our standard method, which allows the separation of smaller substituted carboxylic acids in about 40 min.

Here, the base peak chromatogram (Figure 11) shows base line separation of linear mono and dicarboxylic acids in the C_4–C_9 range. Retention times, calibration correlation coefficients and detection limits for the analysis of twelve carboxylic acid using CE/ESI-ITMS method are



aliphatic amino acids
1 Alanine
2 Isoleucine
3 Leucine
4 Valine

aromatic amino acids
5 Phenylalanine
6 Tryptophan
7 Tyrosine

polar amino acids
8 Serine
9 Threonine
10 Arginine
11 Histidine
12 Lysine
13 Proline
14 Prolin OH
15 Asparagine
16 Aspartic acid
17 Glutamine
18 Glutamic acid
19 Cysteine (dimer)
20 Methionine

Fig. 10: *CE/ESI-ITMS base peak chromatogram for a standard mixture of 20 proteinogenic amino acids. Chromatogram shows base line separation except for leucine and isoleucine.*

amino acids L-form	retention time [min]	correlation coefficient	detection limit [µmol l^{-1}]
Alanine	16.2 ± 0.4	1.000	7.0 ± 1.8
Isoleucine	17.7 ± 0.4	0.999	3.0 ± 0.9
Leucine	17.9 ± 0.4	0.999	3.0 ± 0.8
Valine	18.2 ± 0.5	1.000	2.4 ± 0.7
Phenylalanine	19.3 ± 0.4	0.999	1.2 ± 0.5
Tryptophan	20.3 ± 0.7	1.000	18.1 ± 9.2
Tyrosine	21 ± 0.7	1.000	1.6 ± 0.5
Serine	18.0 ± 0.5	0.998	5.0 ± 1.4
Threonine	19.1 ± 0.6	1.000	5.3 ± 2.3
Arginine	12.6 ± 0.3	1.000	2.6 ± 0.8
Histidine	13 ± 0.3	0.999	1.2 ± 0.5
Lysine	12.2 ± 0.2	0.999	3.7 ± 1.6
Proline	19.5 ± 0.6	1.000	42.1 ± 7.8
Proline OH	21.9 ± 0.7	0.999	25.8 ± 11.4
Asparagine	18.9 ± 0.6	0.999	4.8 ± 2.8
Aspartic acid	21.0 ± 0.7	0.999	5.4 ± 2.4
Glutamine	20.0 ± 0.6	0.999	9.8 ± 3.8
Glutamic acid	20.0 ± 0.6	0.999	2.7 ± 1.0
Cysteine (Dimer)	19.7 ± 0.6	0.999	7.3 ± 2.8
Methionine	19.5 ± 0.6	0.999	1.3 ± 0.4

Tab. 1: *Analytical quality parameters of the amino acid CE/ESI-ITMS method: Retention times, correlation coefficients and detection limits.*

summarized in Table 2. Carbohydrates, which can be analyzed using derivatization GC/MS or IC-PAD (ion chromatography-pulse amperometric detection), are also expected in the microlayer [*Medeiros et al.*, 2007, *Engling et al.*, 2006]. One of the advantages of the GC/MS method is structural elucidation of unknown compounds. On the other hand, the IC-PAD method requires no prior derivatization which is time consuming and labor intensive. Similar to the results which

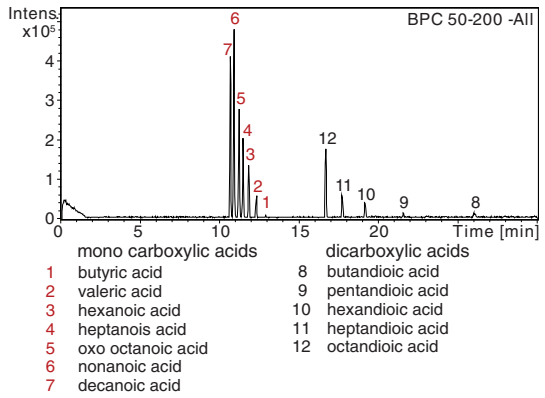


Fig. 11: *CE/ESI-ITMS base peak chromatogram for a standard mixture of 12 linear carboxylic acids. Chromatogram shows base line separation for all carboxylic acids.*

carboxylic acids	retention time [min]	correlation coefficient	detection limit [µmol l^{-1}]
Butyric acid	13.5 ± 0.8	0.995	14.2 ± 3.7
Valeric acid	12.9 ± 0.7	1.000	2.8 ± 1.1
Hexanoic acid	12.3 ± 0.6	0.999	3.8 ± 1.4
Heptanois acid	11.9 ± 0.9	0.999	2.8 ± 1.0
Oxo octanoic acid	11.3 ± 0.5	1.000	1.7 ± 0.7
Nonanoic acid	11.2 ± 5.6	1.000	2.4 ± 1.3
Decanoic acid	11.1 ± 0.5	0.998	2.7 ± 1.1
Butandioic acid	26.5 ± 4.8	1.000	11.6 ± 3.9
Pentandioic acid	23.6 ± 2.3	0.999	15.4 ± 6.3
Hexandioic acid	20.7 ± 0.7	1.000	5.9 ± 1.1
Heptandioic acid	19.0 ± 1.5	0.999	5.4 ± 1.5
Octandioic acid	11.8 ± 1.3	1.000	4.9 ± 1.5

Tab. 2: *Analytical quality parameters of the carboxylic acid-CE/ESI-ITMS method: Retention times, correlation coefficients and detection limits.*

have been shown in detail for the amino acids and the monocarboxylic acids, the IfT FILGAS contribution for carbohydrates is also available. These compounds have been separated and detected using GC/MS after derivatization with *N,O*-bis-(trimethylsilyl)trifluoroacetamide (BSTFA) containing 1% trimethylsilane (TMS). This method converts non-volatile carbohydrates to highly volatile trimethylsilyl derivatives by derivatizing OH groups into carbohydrates. In order to fully derivatize multiple OH groups into carbohydrates, the derivatization conditions must be carefully evaluated. With the derivatisation procedure used in this study only aldopentoses and aldohexoses produced two isomers with base line separation in the gas chromatogram.

Finally, another compound-class which can be measured with a derivatization GC/MS method is fatty acids. Unlike carbohydrates, fatty acids are derivatized using boron trifluoride in methanol to form methyl ester derivatives instead of trimethylsilyl derivatives. In order to analyze these compounds in saline matrices, sample preparation steps are necessary to extract and enrich target analytes. To this end, a synthetic sea salt solution spiked with standard compounds was used for the development of a sample preparation procedure. Carboxylic acids and fatty acids are both extracted using a SPE (solid phase extraction) method from the salt solution. The recovery for fatty acids is as high as 85%. However, this method is not suitable for very polar compounds such as carbohydrates because they are not trapped in the cartridge and washed away together with the salts. Therefore, the extract from the washing step of the SPE method is collected and the salts and carbohydrates are separated using an ion exchange method. Since the investigated carbohydrates also interact with the ion exchange resin, various washing solvents were tested in order to remove all carbohydrates effectively from the ion exchange resin. Acetonitrile as a washing solvent additive gave the best recovery values (>85%). Amino acids would be also extracted by cationic SPE after the elimination of all inorganic ions by an anion exchange resin. Currently, this sample preparation step is under development.

To summarize the IfT FILGAS work, within this project different methods for the determination of carboxylic acids, fatty acids, sugars and amino acids have been developed. Additionally, different sample preparation schemes were tested for the extraction of the target analytes from synthetic sea salt solutions. The next step will be the evaluation and characterization of the analytical quality parameters (recovery values, reproducibility) of the developed extraction methods. Finally, all methods will be used for the measurement of the target analytes in field samples, i.e., sampled oceanic microfilm material, and, correspondingly, for particles from aerosol chamber studies where marine chemical conversions are simulated.

Modeling of the multiphase chemistry in the marine troposphere

The present knowledge of multiphase chemistry processes in marine regions such as DMS oxidation and its couplings to halogen radical and organic chemical processes and therefore the implementation of these processes in numerical models is limited despite certain progress over the last decade of studies. Potentially important species such as the bromine atom (Br) and the $BrCl^-$ radical anion are poorly represented or even fully missing. The completion and extension of halogen-radical chemistry in state-of-the-art multiphase models is hence the goal of the work described here.

An advanced mechanism should include a detailed description of both non-radical (NRHA) and radical (RHA) halogen activation, a multiphase DMS oxidation scheme and processes describing interactions with other important chemical subsystems in marine coastal and remote regimes. New chemical mechanisms should cover the aqueous phase chemistry in cloud droplets and deliquescent particles as well as the heterogeneous surface chemistry on aerosol particles. The extension of the aqueous phase mechanism will be based on the currently used mechanism CAPRAM 3.0 [*Herrmann et al.*, 2005] which incorporates an explicit description of the aqueous phase chemistry of inorganic and organic species as well as the existing IfT halogen chemistry module [*Herrmann et al.*, 2003].

OH, SO_4^- as well as particularly Cl_2^- are important. These radical pathways are not fully considered or completely neglected in current mechanisms. Furthermore, only little is known on the reactivity of Br and Br_2^- radicals at present.

The first outcome of the current development is a multiphase DMS oxidation mechanism with about 100 reactions which is presented schematically in Figure 12. This scheme includes the main multiphase oxidation paths based on most recent kinetic data and connects to other organic and inorganic chemical subsystems.

Future work will be focused on the update and extension of the multiphase halogen radical and non-radical chemistry module including chlorine, bromine and iodine chemistry based on laboratory measurements as well as the latest

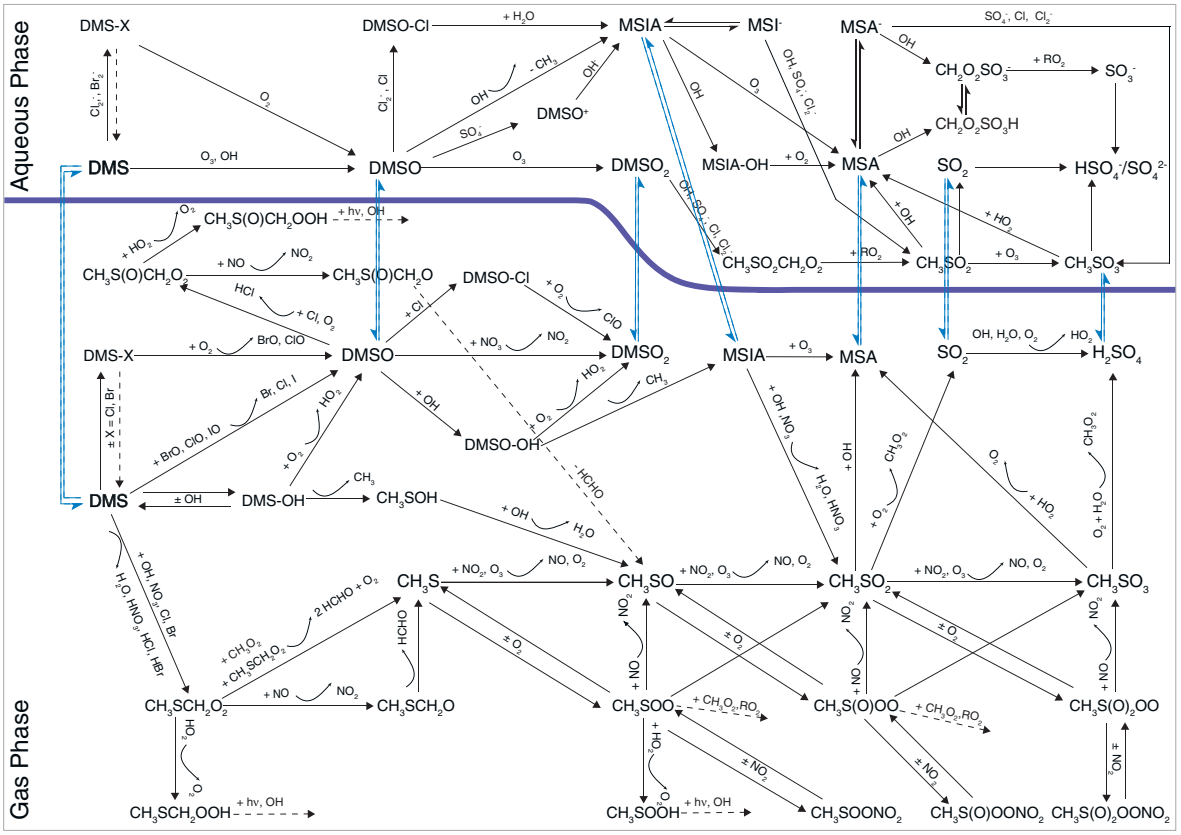


Fig. 12: *Schematic representation of the new developed multiphase DMS oxidation module, under development for CAPRAM-MARINE.*

A detailed multiphase description is needed to study effects of chemical conversions on the entire marine troposphere in either phase. Hence, in the first step of continuing mechanism development extensive literature studies regarding the most recent kinetic chemical as well as phase transfer data has been performed to develop a new comprehensive multiphase DMS oxidation scheme. Recent kinetic studies of *Zhu et al.* [2005] implicate that the radical oxidations of some DMS oxidation products in the particle phase including available chemical kinetic and phase transfer data. Finally, process studies with the new comprehensive marine chemical mechanism will be carried out using the improved SPACCIM (SPectral Aerosol Cloud Chemistry Interaction Model, [*Wolke et al.*, 2005]) model focusing particularly on important tropospheric oxidizing pathways, multiphase chemistry interactions and the influence of organic surface films on the multiphase chemistry, phase transfer as well as CCN activation and growth.

As mentioned before, in addition to the mechanism developments, the new mechanism should be applied in parcel model studies using the spectral multiphase chemistry model SPACCIM. According to the mentioned targets, the multiphase model SPACCIM will also be further developed describing the following issues (i) different particle compartments such as the surface layer, bulk-phase and solid core as well as their interactions, (ii) formation of surface layers on deliquescent particles as well as heterogeneous reactions on the surface, (iii) chemistry in non-ideal solutions like omnipresent in deliquescent sea salt particles and (iv) deliquescence and efflorescence processes.

The IfT internally funded project “Modeling of phase transitions of mixed phase particles” is part of the larger effort described here. In conclusion, it will allow studying complex systems with models based on measured process parameters up to the level of predictions of future developments. The treatment of physico-chemical processes for marine particles described here in a first step will be extended to develop a chemical mechanism module (an extended CAPRAM-MARINE) and a physical model framework (an extended SPACCIM). It will also consider the role of mineral dust particles being transported into a marine environment. Bringing together an updated model of pure marine chemistry and a process module for particle and surface chemistry of dust particles and their chemical processing (‘aging’) will enable us to compare model predictions such as from the SOPRAN modeling with the actual field measurements east of Africa at the Cape Verde Atmospheric Observatory.

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- SOPRAN: Leibniz Institute of Marine Sciences (IFM-GEOMAR), University of Hamburg, University of Bremen, University of Heidelberg, Leibniz Institute for Baltic Research (IOW), Max-Planck Institute for Chemistry, Max-Planck Institute for Biogeochemistry, Alfred Wegener Institute for Polar and Marine Research, GKSS, Oktopus GmbH.
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A three-year study of size-segregated characterization of particles depending on air mass origin at Melpitz

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Es werden Ergebnisse einer drei Jahre (2004 bis 2007) umfassenden größenaufgelösten chemisch-physikalischen Charakterisierung von Partikelmasse PM_{10} an der Forschungsstation des Institutes in Melpitz vergleichend mit dort vorhandenen Langzeitmessungen vorgestellt. Eine einfache saisonale Klassifizierung für Sommer- und Winterhalbjahr mit Unterscheidung der zwei Hauptanströmungsrichtungen mit Quellgebieten im Westen oder Osten unter Zuhilfenahme von Rückwärtstrajektorien zeigt einen erheblichen Eintrag von Partikelmasse bedingt durch Ferntransport kontinentaler Luftmassen, besonders im Winter aus östlicher Richtung. Die physiko-chemischen Eigenschaften dieser Partikel lassen auf einen erheblichen Anteil primärer anthropogener Emissionen und sekundärer Partikelmassebildung aus Vorläufersubstanzen während des Transportes schließen. Mit bis über 90% ist der $PM_{2,5}$ Anteil am PM_{10} in Melpitz erheblich und unterscheidet sich deutlich von Stationen im Westen Deutschlands. Die Ergebnisse belegen, dass es insbesondere im Winter im Osten Deutschlands bedingt durch Ferntransport kontinentaler Luftmassen mit anthropogen emittierten Spurenstoffen zu großräumigen Überschreitungen des Tagesgrenzwertes von 50 μgm^{-3} für PM_{10} kommen kann, gegen die administrative Maßnahmen in den Ballungsräumen unwirksam sind.

Introduction

In the 1980s the region around the city of Leipzig was one of the most polluted areas in central Europe. With the decrease of regional anthropogenic emissions since 1990 the influence of long-range transport of trace gases and particles, especially from Eastern Europe, became more and more apparent as a cause for distinct episodes with elevated particle concentrations, mostly in wintertime. The main source regions for these mostly dry continental air masses are located outside (Russia, Belarus and Ukraine) and inside (Poland, Czech Republic and Slovakia) the European Union. Such situations with long-range transport of continental air masses from the East occur particularly in wintertime with daily PM_{10} concentrations >50 μgm^{-3}. These events increase the number of days with mean PM_{10} concentrations >50 μgm^{-3} [limited to 35, *EU-Commission,* 1999] in wide areas and Saxon cities. In a three year study (spring 2004 till spring 2007) size-segregated particles were characterized chemically and physically in the whole range from 3 nm to 10 µm diameter using high-volume samplers, five-stage BERNER-type impactors and physical online instruments at the research site of the Leibniz Institute for Tropospheric Research (IfT). The main aim of the study is to show the differences in particle mass concentration, chemical distribution and physical properties by classification of daily particle characterization results for long range transported air masses from the West (maritime and/or continentally influenced) and the East (continentally influenced) using backward trajectories with a distinction between winter and summertime (November till April and May till October, respectively) for a representative site.

Measuring site and methods

All measurements were performed at the IfT-research station Melpitz (12° 56' E, 51° 32' N, 86 m a. s. l., Figure 1). This grassland site is located about 50 km north-east of Leipzig near the city of Torgau in a representative region for a rural site in the German low-lands. The distance to the Polish border in the East is about 120 km. The Melpitz site is a EMEP level 3 station (Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe) and provides results of complex scientific evaluation of measurements (cp. *Particulate Matter Assessment Report* [2007]). During several national and international projects the Melpitz site was characterized meteorologically (e.g., *Spindler et al.*, [1996, 2001]), for trace gases (e.g., *Gnauk et al*., [1997]; *Spindler et al.*, [2001]; *Spindler et al.*, [2003]) and for PM concentrations (e.g., *Heintzenberg et al.*, [1998]; *Neusüss et al.* [2002]; *Plewka et al*., [2004]; *Herrmann et al.*, [2006]). Comparisons to other European sites are given in [*Putaud et al.*, 2004] and [*Kruit et al.,* 2007]. For long-term measurements 1993 till 2003, [cf. *Müller*, 1999; *Spindler et al.*, 2004] daily samples were taken by a modified Sierra-Anderson-PM_{10} high-volume-sampler (Anderson Samplers Inc., USA). Since 2004 three identical samplers, DIGITEL DHA-80 (Walter Riemer Messtechnik, Germany),

Fig. 1: *Measuring field of the IfT research station Melpitz (view towards North). The three DIGITEL High-volume-samplers for PM_{10}, $PM_{2.5}$ and PM_1 are in the foreground.*

were used in parallel to determine PM_{10}, $PM_{2.5}$ and PM_1 (Figure 1). PM_{10} and $PM_{2.5}$ were sampled every day and PM_1 every sixth day on prefired quartz fiber filters (MUNKTELL, Sweden).

For a finer size-segregated PM sampling five-stage BERNER type impactors were used. The impactors consist of six successive stages for decreasing aerodynamic particle diameters (D_{pa}: 10, 3.5, 1.2, 0.42, 0.14, and 0.05 µm). Aluminum foils were used as substrate. The selection of measuring days follows the weather forecast. Sampling was carried out during days with stable air mass transport (cp. Figure 2). On stage 1 (0.05 – 0.14 µm) freshly emitted or recently formed particles were typically found (e.g., traffic-derived soot). On stages 2 and 3 aged particles from long range transport and particles from domestic heating dominated. In the coarse mode fractions 4 and 5 modified sea salt particles, primary biogenic material, and re-suspended crustal material were found. The chemical composition of the particles in different size classes varies with sources of PM and the meteorological conditions during the sampling periods. A high-time-resolution PM_{10} mass concentration (half-hourly-means) was measured additionally using a TEOM® 1400a (Rupprecht & Patashnick Co., Inc., USA). The TEOM was operated at 50 °C collecting particles on an oscillating microbalance. The relatively high operating temperature (50 °C) is necessary to avoid the condensation of water vapor (positive artifact) but can also generates systematic errors by evaporating volatile compounds (negative artifacts) such as ammonium nitrate [*Charron et al.*, 2004]. Therefore, the mean mass for 24 hours is corrected by a daily comparison with the mean PM_{10} mass from high-volume sampler. Particulate mass, concentrations of main ionic species (Cl^-, SO_4^{2-}, NO_3^-, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+}), elemental carbon (EC), and organic carbon (OC) in all size fractions were determined from PM_1, $PM_{2.5}$ and PM_{10} and all impactor samples. The filters and impactor foils were equilibrated for 48 hours under controlled temperature and relative humidity (20 °C and 50% RH.). The filters and impactor foils were weighed using a microbalance AT-261 and a UMT-2-type microbalance (both Mettler-Toledo GmbH, Germany), respectively. Anions (filter samples) and cations (filter samples and impactor samples) were analyzed after water extraction by IC (ion chromatography, Metrohm, Switzerland). Anions in the impactor samples were analyzed by capillary zone electrophoresis (Spectra Phoresis 1000-Thermo Separation Products, USA).

OC/EC separation can be achieved in different ways as reviewed by *Penner and Novakov* [1996]. In this study the particulate carbon fraction was determined by a two-step thermographic method using a carbon analyzer of the type C-mat 5500 (Ströhlein, Germany), following the VDI guideline [*VDI 2465, Part 2,* 1999]. In a first step nitrogen was used as carrier gas for the OC volatilization at 650 °C. Carbon compounds that evaporated were converted to CO_2 by a catalyst and attributed to OC. In a second step the remaining carbon was transformed to CO_2 by combustion with oxygen at 650 °C and attributed to EC. The method is discussed in detail in *Neusüß et al.* [2002]. The method was intercompared in an International Round Robin Test for Carbon [*Schmid et al.*, 2001].

The determination of selected Polycyclic Aromatic Hydrocarbons (PAH) was carried out by Curiepoint pyrolysis gas chromatography mass spectrometry (CPP-GC-MS) directly from the impactor foils. The CPP system (JPS-350, Japan Analytical Industry, Ltd.) acts as a fast thermal desorption injector. From the PAH measurements the anthropogenic influence on the particle mass can be estimated.

A tandem differential mobility particle sizer (TDMPS) was used for continuous online particle number concentration determination (time resolution 10 minutes) in the size range from 3 to 800 nm (twin differential mobility particle sizer [*Birmili et al.*, 1999]). The TDMPS system consists of two Hauke type DMAs (differential mobility analyzer) in combination with two CPCs (condensation particle counter) for 3 to 22 nm and 22 to 800 nm mobility size, respectively. Both systems start the measurements stepwise up- and downwards to their upper and lower limits with a size resolution of 16 channels per diameter. An inversion routine is used afterwards to calculate the real number size distributions using the real DMA transfer function (e.g., *Stratmann and Wiedensohler*, [1996]). The number size distribution between 0.8 and 10 µm was measured using an aerodynamic particle sizer (APS, model 3321, TSI Inc., USA).

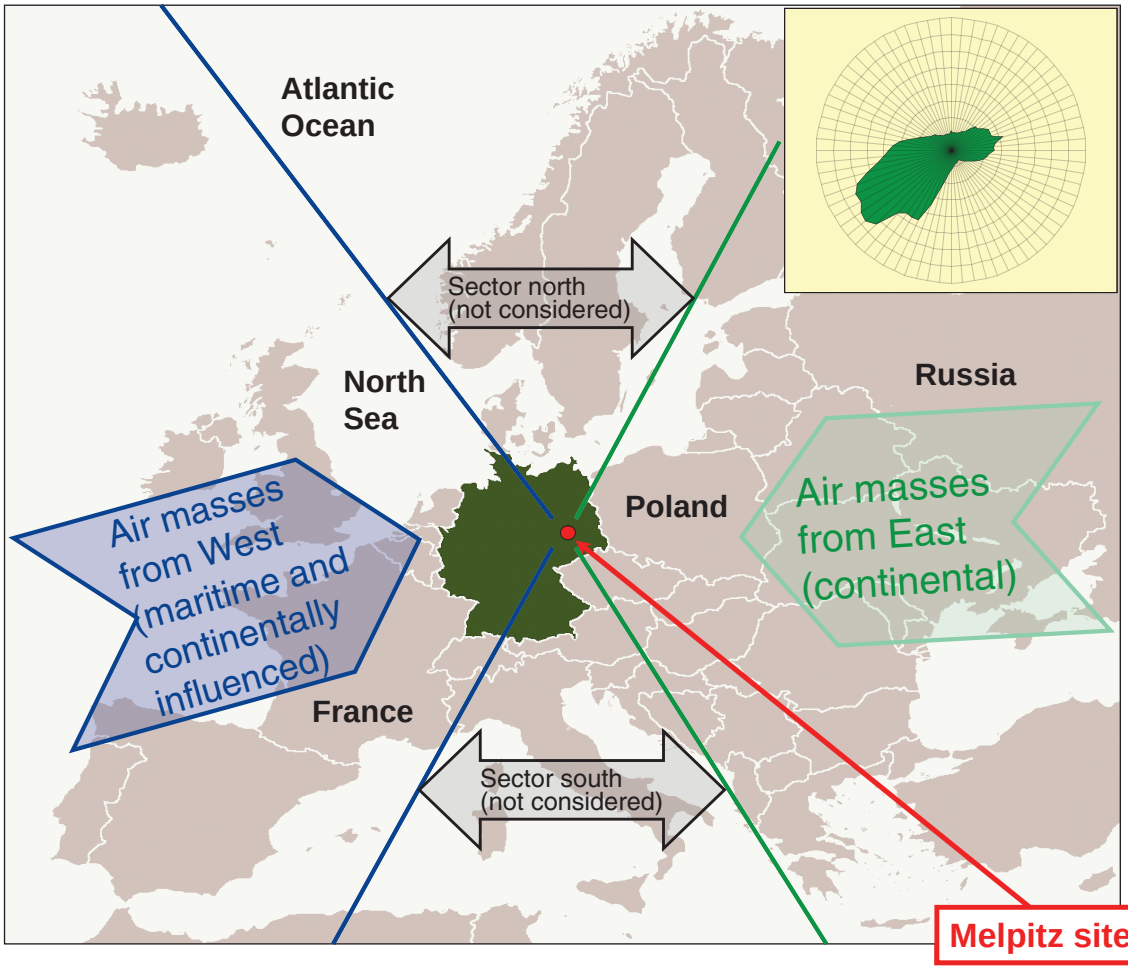

Fig. 2: *Classification of daily samples for two major long-range transport patterns – air masses from the West and air masses from the East and wind rose for the Melpitz site.*

The determination of air mass origin based on 96-hour backward trajectories from the NOAA-Hysplit-Model (source: http://www.arl.noaa.gov/ready/hysplit4.htm). Backward trajectories were plotted twice a day (10:00 and 18:00 CET) and for 200, 500 and 1500 m above ground level. Figure 2 shows the two broad sectors used for the classification of long-range transported air masses.

The course of average half-yearly particle mass concentration of PM_{10} for winter and summer over the past 15 years is plotted in Figure 3. The elevated PM_{10}-concentration (1993 till 1997) was mostly caused from local emission in the Saxon cities and surroundings. A decreasing PM_{10} mass concentration can be observed till about 1998/99. The winters show the higher inter-annual deviations caused by long inversion periods (cf. R^2 values in Figure 3). Since about 1999 the influence of long-range aerosol transport, especially from Eastern Europe, became more apparent. This means that the general influence of meteorological conditions at PM_{10} concentrations is more pronounced in winter than in summer. The correlation with the total precipitation is weak but winters with relatively high mass concentrations show low total precipitations during a more continentally influenced transport pattern.

Long-time measurements of particles – seasonal characterization for air mass transport from West or East

The time series are plotted together with an indicator for air mass direction in Figure 4 starting in May 2004. Mostly in winters PM_{10} but also $PM_{2.5}$ at the rural Melpitz site exceed the limit value of 50 μgm^{-3} for PM_{10} (8 times in winter 04/05, 9 times in winter 05/06 and 7 times in winter 06/07). These days with large area exceeding of the regional PM_{10} concentration exceeding the limit of 50 μgm^{-3} contribute to the maximum number of allowed 35 days in nearby cities. The additional days with elevated concentrations higher above 30 μgm^{-3} aggravate urban air quality problems. The elevated

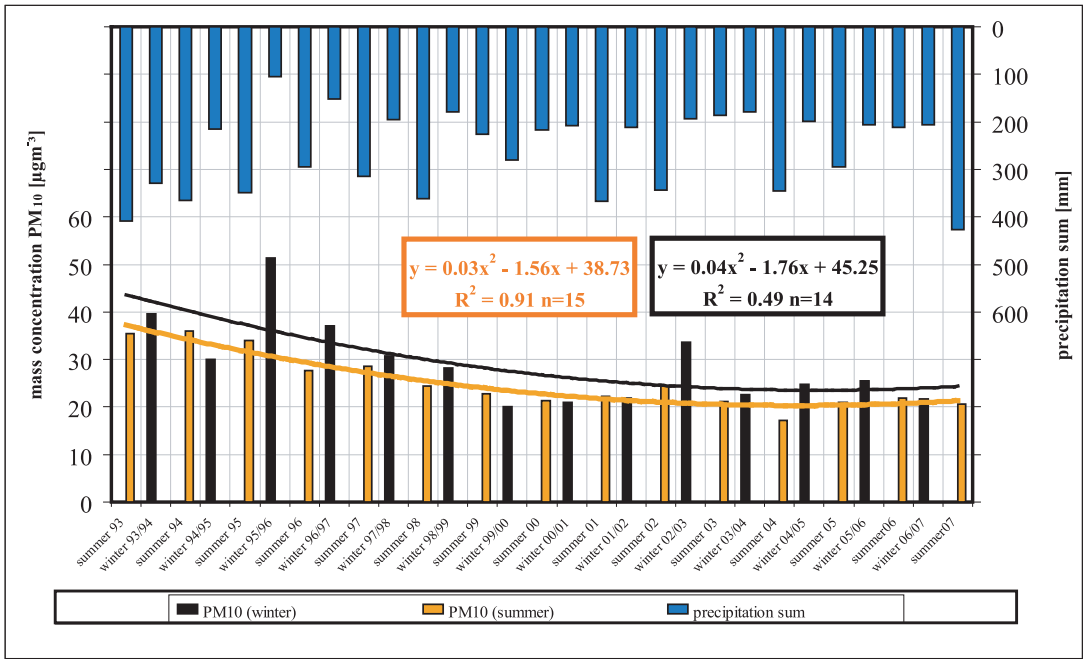

Fig. 3: *Evolution of half-hourly PM_{10} mass concentration and precipitation in winter (November until April) and summer (May until October) at Melpitz in the last 14 years. The half yearly precipitation sum is plotted on inverse scale. Quadratic regressions are plotted for all summers and winters separately.*

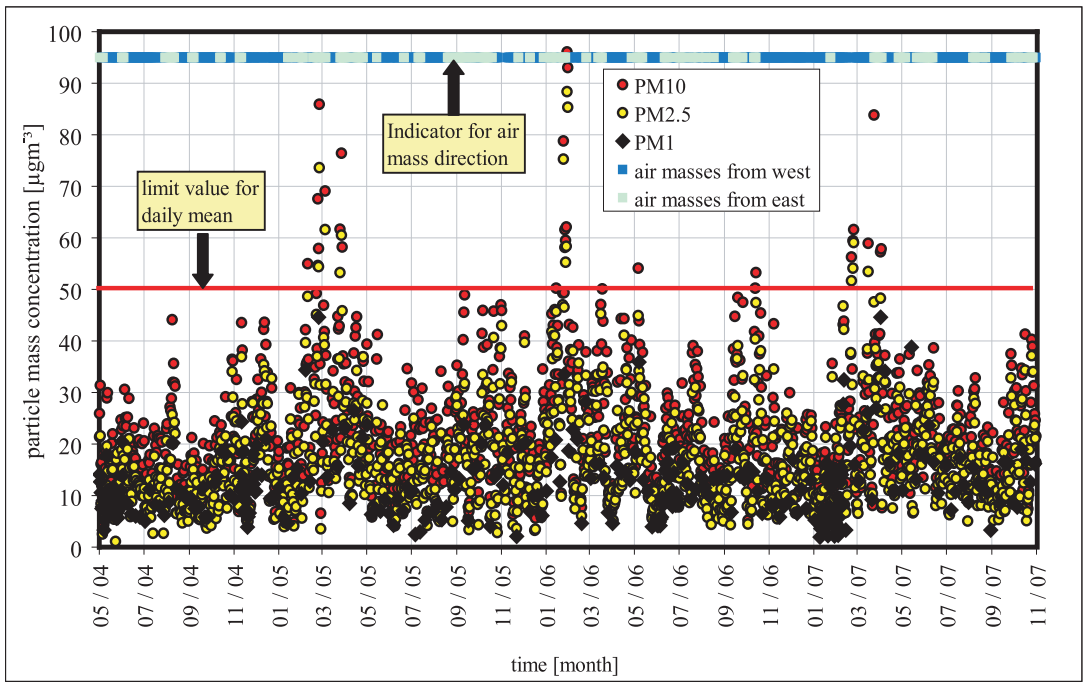

Fig. 4: *Time series of daily particle mass concentration PM_1, $PM_{2.5}$ and PM_{10} (May 2004 until October 2007) with indicator for air mass origin. The red line marks the European PM_{10} limit value of 50 µgm^{-3}.*

PM_{10} values in the very hot and dry July 2006, the warm and dry October 2006 and in the extreme dry spring 2007 are easily recognized.

The high PM concentrations for some days in May 2006 were caused by a long-range transport from partly anthropogenic caused vegetation fires in Russia. Also the isolated high PM_{10} concentration on March 24, 2007 was due to long-range transport from a dust event over the southern Ukraine [*Birmili et al.* 2007].

Figure 5 shows the annual pattern of daily and monthly percentages of $PM_{2.5}$ in PM_{10} since May 2004. The highest percentage of $PM_{2.5}$ in PM_{10} at Melpitz was found with 92 to 96% during a smog

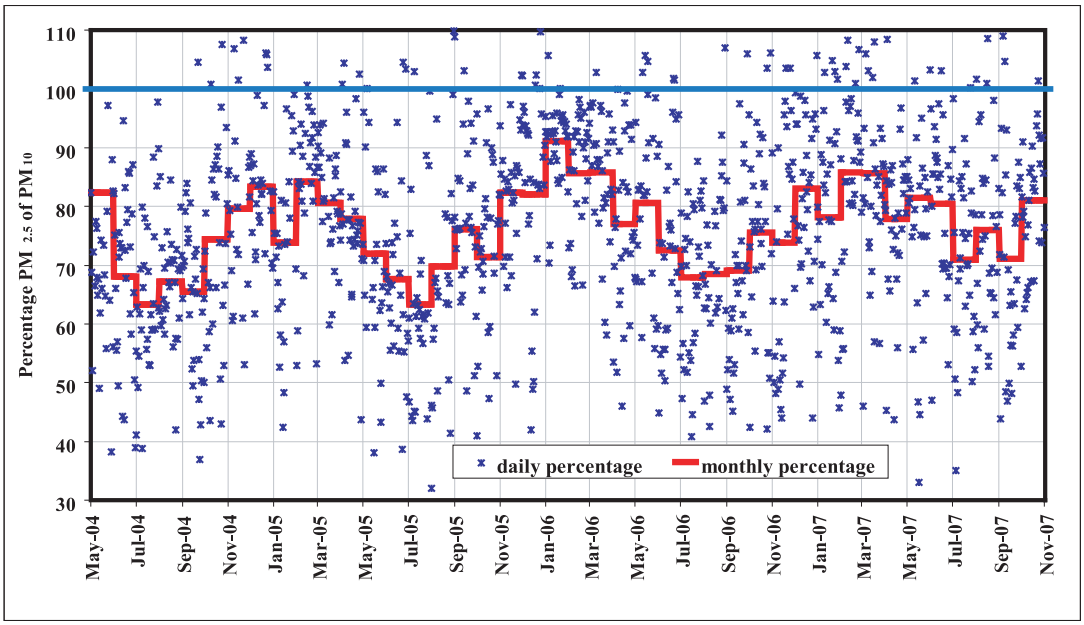

Fig. 5: *Time series of daily and monthly percentage of $PM_{2.5}$ in PM_{10} from high volume samplers (values beyond 100% indicate the range of experimental uncertainties).*

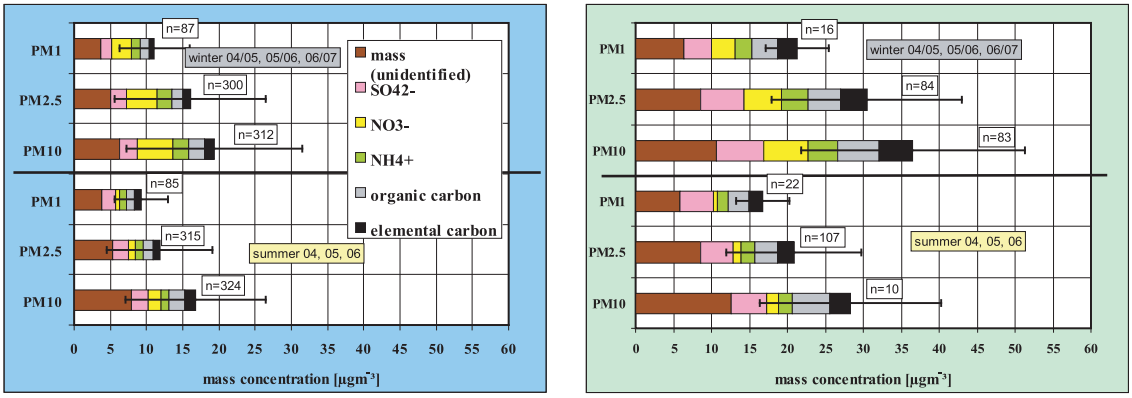

Fig. 6: *Mean PM_1, $PM_{2.5}$ and PM_{10} mass, main ions (nitrate, sulfate and ammonium), OC, and EC in winter and summer. Only days with air mass transport explicitly from the West (blue frame) or from the East (green frame) are considered. The error bars are the standard deviation for the particle mass concentration. "n" is the number of measurement days. Averages of three winters (2004/05 till 2006/07 and summers (2004 till 2006) are shown.*

episode over Germany in winter 2006 (January 22 till February 7, surface snow covered). At the same time the respective percentage of $PM_{2.5}$ was 67% (average of 6 sites) in North-Rhine-Westphalia [*Bruckmann et al.* 2006]. This comparison shows that the air masses in Melpitz were negligibly influenced by local coarse particle emissions and the percentage of $PM_{2.5}$ in PM_{10} decreases in other parts of Germany, where locally produced coarse particles were added to the same air masses.

Average summer and winter particle mass concentrations are shown for the main water-soluble ions (nitrate, sulfate and ammonium), organic, and elemental carbon (OC and EC) in PM_1, $PM_{2.5}$ and PM_{10} for days segregated by air mass transported from East and West in Figure 6. The average particle mass concentrations in Melpitz were higher in winter than in summer. The highest PM concentrations observed during air mass transport from East in winter were caused by long-range transport but also from a low mixing height during high pressure meteorological situations. The main source regions for these air masses are located in Russia, Belarus, Ukraine, Poland, Czech Republic and Slovakia. The high content of sulfate, OC and EC indicate that they come from anthropogenic emissions (e.g., power plants, industry, households and older automobiles).

The wintertime OC/EC ratio was lower than in summer, especially in air masses from the East, possibly caused by emissions from combustion

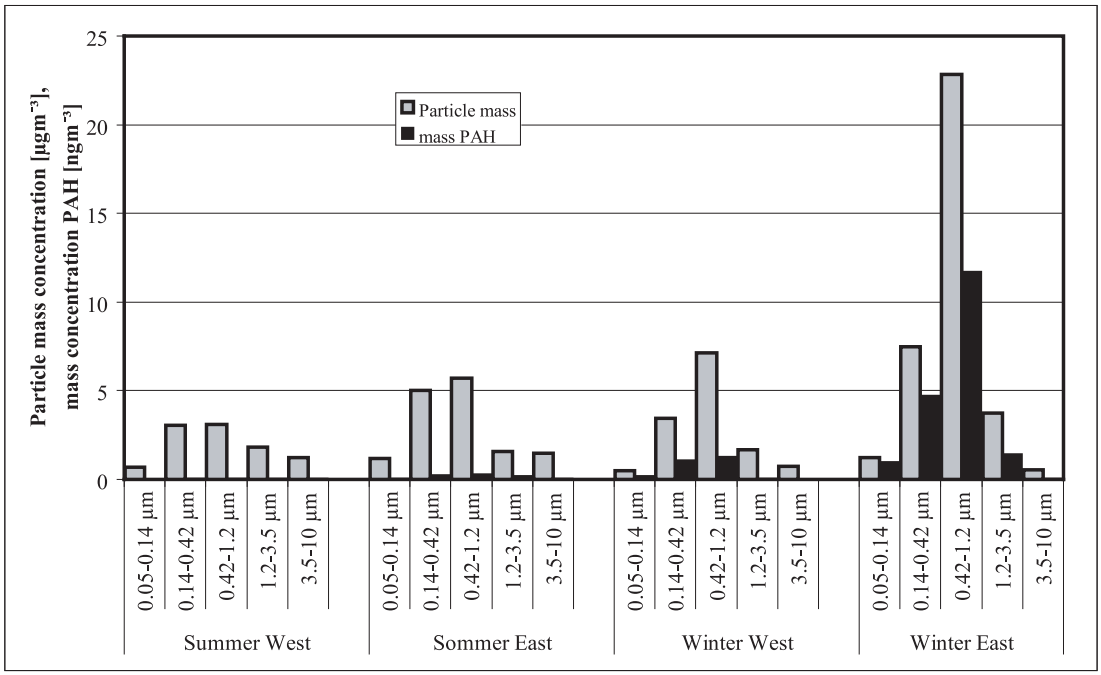

Fig. 7: *Mean PM concentration and mean mass concentration of PAH from the five stages of BERNER-type impactor, divided for winter and summer and air mass transported from West or East. Averages for selected days in three winters (2004/05 till 2006/07 and summers (2004 and 2006) are shown.*

processes (cf. Figure 7). The difference in nitrate concentration between winter and summer was mainly caused by the volatility of ammonium nitrate in summers. The fraction of water-soluble ions was higher in PM_1 than PM_{10} and also higher in the summer samples than in the winter samples. One reason is the re-suspension of coarse particles by agricultural activities and wind-blown dust nearby. The re-emission preferentially occurs in summer where surfaces are drier and also dry much faster after precipitation events than in winter. Generally, PM is lower during air mass transports from the West because they are often combined with precipitation (wet deposition) and more turbulent mixing processes. PM sampling with the BERNER-type impactor was carried out during selected days (24-hour-samples) with stable air mass transport from West or East according to Figure 2. During the three years measurements were done in summer for 20 days with air mass transport from the West and 14 days with source regions in the East, for the winter these number of days are 17 and 18, respectively. The analysis for PAH and n-alkanes were done for 6 selected days each season and air mass source region. Figure 7 shows the means of determined particle mass concentration and the mass concentration of the sum of PAH. Differences between seasons and source regions are evident. Summer concentrations are lower than winter concentrations and air masses transported from Eastern Europe carry higher amounts of PM. The highest concentration of PM was typically found in the size fraction 0.42 – 1.2 µm which is known for their atmospheric stability. This PM fraction is characteristic for long-range-transported particles. During wintertime also aged PM from domestic heating using coal was found mainly in this fraction and can be identified by the high PAH content. PAH are a disproportionately high part in particle mass in winter, especially for the source region East. They were mostly emitted from anthropogenic combustion processes. The percentage of coarse mode particles (size fraction 3.5 – 10 µm) was higher during summers because of the natural dust re-suspension and the anthropogenic re-suspension of PM from dry surfaces by agricultural activities near the sampling site.

The mean daily variation of number size distributions measured with TDMPS and APS is shown in Figure 8. The significant differences between summer and winter and for air masses from West or East are caused by variations in natural and anthropogenic aerosol sources but also by meteorological conditions. Continental dry air masses are usually connected with weather conditions dominated by long-term high pressure influence without precipitation, higher amplitude of the diurnal temperature. During summer months the APS-measurements show higher concentration of coarse particles due to re-suspension of crustal material from dry areas. Concentrations of very small particles (<10 nm)

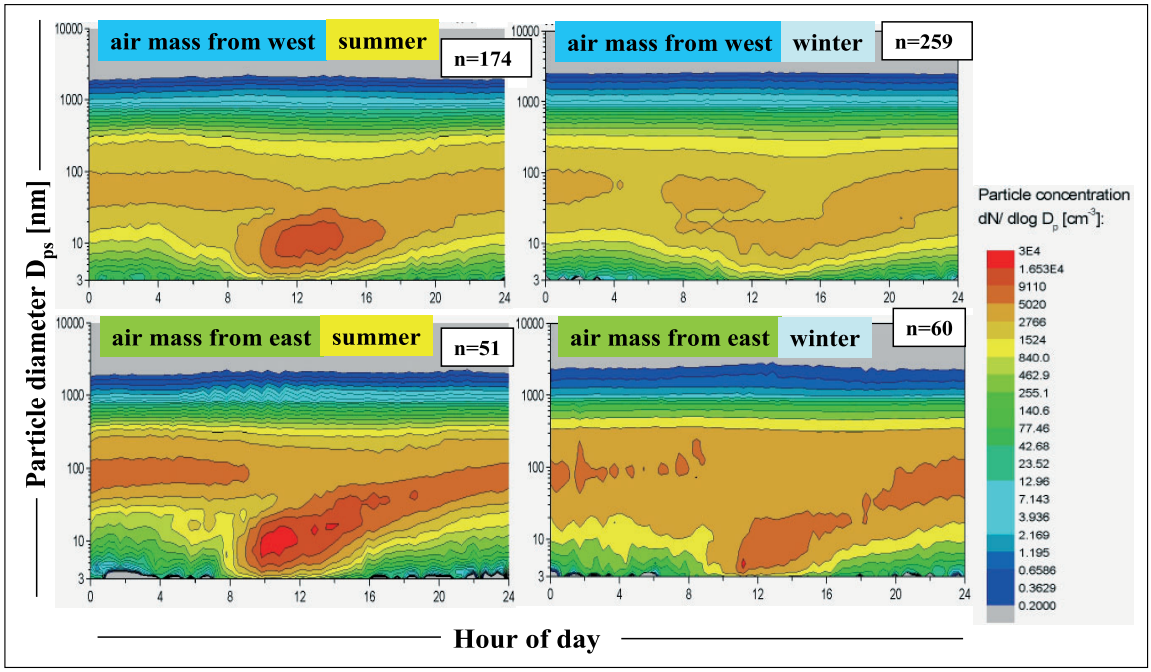

Fig. 8: *Mean daily evolution of number size distributions of ambient aerosols measured with TDMPS and APS (n = number of days). Averages for air masses from West and air masses from East divided for summer and winter days for three winters (2004/05 till 2006/07 and summers (2004 and 2006) are shown. (D_{ps}: Stokes diameter).*

show on average a maximum around noon and are due to "new particle formation events" which occur frequently mainly under influence of high global radiation. New particles were detected in summer after the removing of the nocturnal inversions (9:00 – 10:00 CET) and the formation of a well-mixed boundary layer. Later on the particles grow up to sizes of 100 nm in diameter. Air masses arriving from western directions are typically characterized by higher wind speeds and higher chance for precipitation compared to continental air masses coming from the East. Here, especially in winter, new particle formation events are rarely to observe.

Summary

Long-time measurements of PM_{10} started in 1993 at the IfT research site Melpitz located downwind of Leipzig near the city of Torgau. The measured PM_{10} concentration in 1993 was about 38 µgm^{-3} in summertime and about 44 µgm^{-3} in wintertime. The PM_{10} level decreased to 24 µgm^{-3} and 28 µgm^{-3} for winter and summer in 1998 and 1999, respectively. The yearly variation of the mean concentration was lower in summer than in winter.

Particles were physically and chemically characterized after size-segregated sampling in a three-year-study funded by the Umweltbundesamt. The main results of this project are differences in the mean particle mass concentration, chemical distribution and physical properties of particles distinguished for air masses transported from the West or the East in summer and winter. These differences show the possible influence of long-range transport of air pollution from Eastern Europe, mostly in wintertime. Mean concentrations at the Melpitz area of PM_{10}, $PM_{2.5}$ and PM_1 were 20, 15 and 13 µgm^{-3} in 2004, 22, 18 and 13 µgm^{-3} in 2005 and 24, 19 and 12 µgm^{-3} in 2006, respectively. In the winters 2004/05, 2005/06 and 2006/07 the PM_{10} at Melpitz exceeded the limit value of 50 µgm^{-3} on 8, 9 and 7 days, respectively. These days contributed to the 35 days exceeding the limit value of 50 µgm^{-3} allowed in cities. $PM_{2.5}$ is lowest in summer time and can reach more than 90% of the PM_{10} in wintertime. Reasons are re-emission of coarse particles in the surroundings in summer and long-range transport in winter.

The detailed investigations also give clues to anthropogenically emitted species (e.g., PAH) especially in winter. The mean sources regions for anthropogenically influenced air masses are inside and outside of the European Union. Nucleation events were mostly detected during summer on days with easterly winds.

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Particle characterization by an Aerosol Mass Spectrometer

Laurent Poulain, Hartmut Herrmann, Alfred Wiedensohler

Um die zeitliche Variabilität der Partikelgrößenverteilung und der dazugehörigen chemischen Zusammensetzung zu untersuchen, wurden Feldmessungen mit einem High Resolution Time of Flight-Aerosolmassenspektrometer an der Forschungsstation des IfT in Melpitz in den Wintermonaten Januar bis Februar 2007 durchgeführt. Die Resultate zeigen eine alternierende Struktur von Perioden mit geringen und hohen Partikelmassenkonzentrationen in Abhängigkeit von der Luftmassenherkunft (maritim/kontinental). Unter maritim geprägten Bedingungen sind Ammonium und Sulfat die wichtigsten Partikelmassenkomponenten. Im Gegensatz dazu tragen organische Verbindungen und Nitrat bei kontinental geprägten Luftmassen am meisten zur Gesamtmasse bei. Darüber hinaus war der organische Anteil der Partikelmasse über die gesamte Zeit der Messungen charakteristisch für sekundäre und nicht primäre organische Partikel.

Introduction

Atmospheric particulate matter (PM) has important impacts on human health, atmospheric visibility, and climate forcing. Traditionally, the chemical composition of the PM is measured after filter or impactor sampling. These samples are then analyzed 'offline' in a laboratory using conventional analytical methods such as GC/MS and HPLC/MS after extraction of the compounds. Although these methods provide better insight into a chemical composition, their time resolution is limited to several hours to days due to the necessary mass for the analysis. Recently, a new generation of instruments has been developed providing real-time size resolved chemical information on PM composition. The Aerodyne High Resolution Time of Flight Aerosol Mass Spectrometer (HR-ToF-AMS or just AMS), which is designed to provide such information, was deployed at Melpitz during the last EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe) winter intensive campaign from January 12th to February 12th 2007.

Instrumentation

The measurement took place at the IfT research station Melpitz (Germany) 45 km north-east of Leipzig. Melpitz is considered to be mostly under rural conditions with intermediate urban influences mainly from the city of Leipzig. The AMS is an on-line instrument allowing real time measurements of the particle size distribution together with their chemical composition. The AMS has been previously described in detail by *Canagaratna et al.* [2007] and more specifically the HR-ToF-AMS used during this campaign has been described by *DeCarlo et al.* [2006]. Due to the nature of the instrumental design, only the non-refractory fraction of the particles, i.e. components which can be evaporated from sampled particles, is measured. As a consequence, crustal material, sea-salt, and soot are not detected. The aerodynamic lenses have a transmission efficiency of 100% in the range of 70 to 700 nm with decreasing transmission efficiency below and above this range. Therefore, the AMS is commonly considered a non-refractory PM_1 (NR-PM_1) analyzer. For the duration of measurements, the AMS was connected to a $PM_{2.5}$ inlet located on the roof of the container where the AMS was installed.

Results

The main results are summarized in Figure 1. This Figure shows the wind direction and velocity in the top panel, the time profiles of the mass concentrations of organics, nitrate, sulfate, ammonium and chloride during the campaign in the middle and the relative contribution of each component to the particles mass fraction at the bottom. Results show an alternating pattern of low and high particle concentration periods. Under low particle concentration conditions, particles are mostly made of ammonium and sulfate. In contrast, at higher concentrations, particles are mostly made of organics and nitrate. Ninety six hours backward air trajectories have been calculated twice a day at 9 h and 17 h UTC. A comparison with the AMS results shows that during low particle concentration periods, air masses have an oceanic influence while the events with higher particle concentrations appear to be more correlated with continental air masses coming mainly from south-west.

Figure 2 shows the concentration of the ammonium cation measured compared to a predicted concentration assuming NH_4NO_3, $(NH_4)_2SO_4$ and NH_4Cl being only form present in

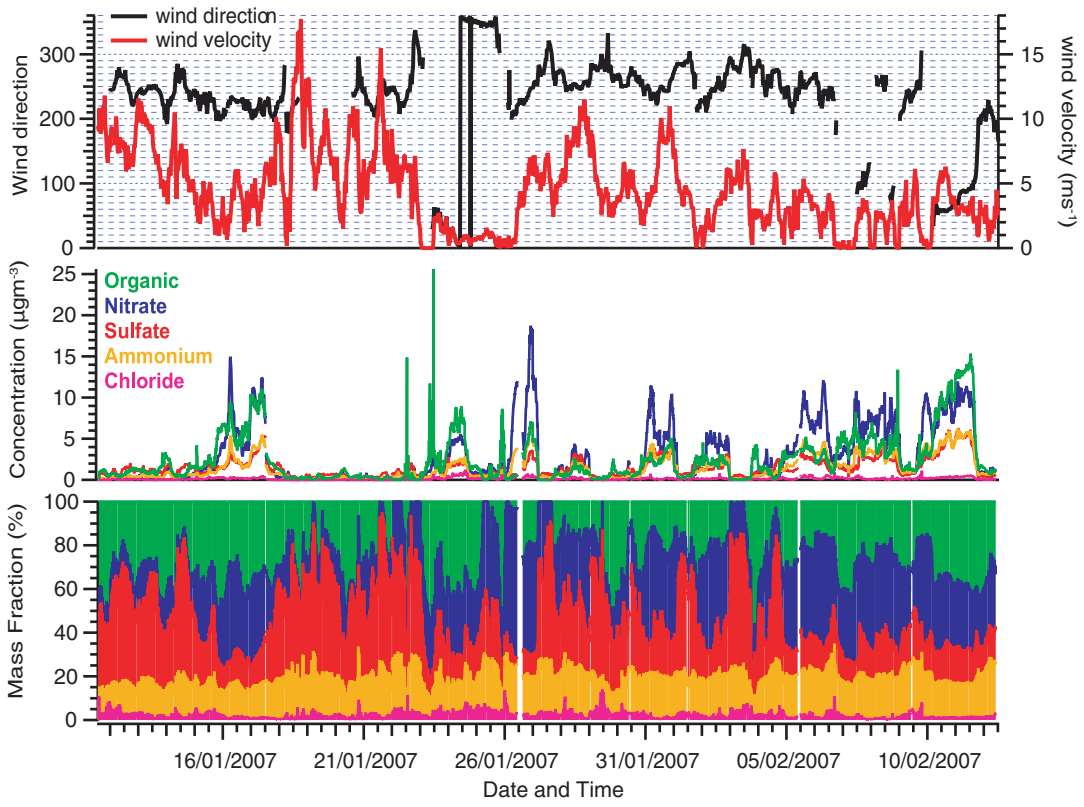

Fig. 1: *Top panel: time series of wind direction and velocity at Melpitz in January and February 2007. Center panel: mass concentrations of major particle components. Bottom panel: mass fractions of major particle components to the total mass measured with a time resolution of 5 min.*

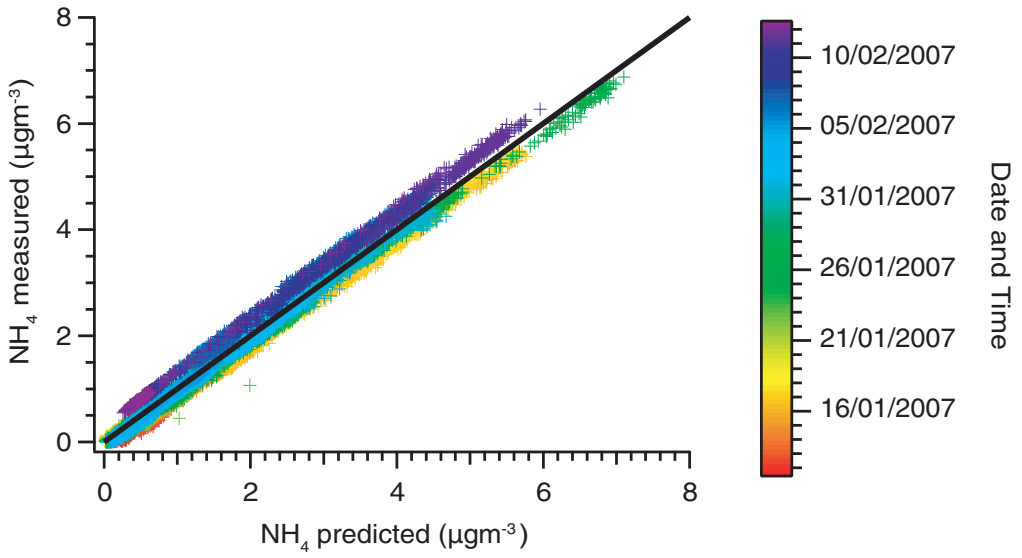

Fig. 2: *Mass concentrations of measured ammonium versus predicted ammonium assuming that ammonium is fully neutralized by NH_4NO_3, $(NH_4)_2SO_4$ and NH_4Cl (in black the line 1:1).*

the particles. During the whole campaign, the correlation between measured and predicted ammonium is close to the 1:1 line, suggesting that sulfate is completely neutralized by ammonium.

Different fragments of the organic mass spectra can be used to characterize the organic fraction of the particles. Primary and aged or secondary organic aerosols (SOA) can be followed by the fragments m/z = 57 (HOA, Hydrocarbon like-Organic Aerosol) and m/z = 44 (OOA, Oxygenated like-Organic Aerosol), respectively [*Zhang et al.*, 2005]. Moreover, the biomass burning aerosol

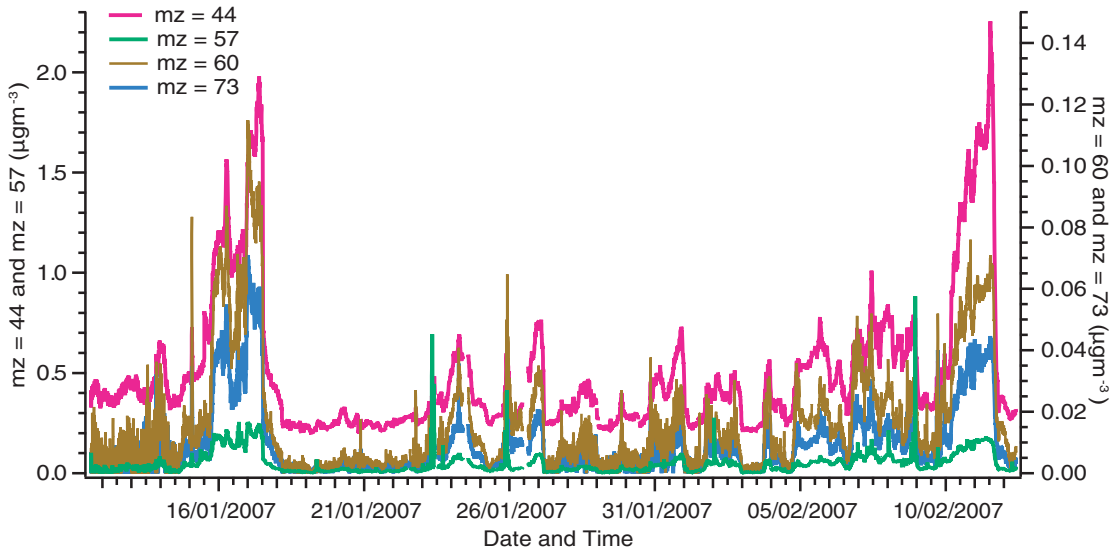

Fig. 3: *Time series of characteristic organic fragments: m/z = 44 (OOA), m/z = 57 (HOA) and m/z = 60 and m/z = 73 (BBOA).*

may also be traced by two specific fragments m/z = 60 and m/z = 73 which originate from levoglucosan a biomass burning tracer compound (BBOA, Biomass Burning like-Organic Aerosol, [*Schneider et al.* 2006]). Time series of these fragments are presented in Figure 3. During the whole experiment, mainly aged or SOA particles were present as m/z = 44, which is commonly found in these types of particles, dominates the time series. BBOA also contributed to the aerosol composition and shows a maximum at the last days of measurements. Moreover, primary particles were observed only during brief periods, which can be attributed to local sources.

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Cooperation
- EMEP project.

Secondary particle formation and growth of nucleated particle into the CCN size range in a polluted region of North-Eastern China

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Durch rasantes Wirtschafts- und Bevölkerungswachstum haben sich in China in den letzten Jahrzehnten besonders dicht besiedelte und verschmutze Regionen entwickelt. Dazu gehört der Nordosten Chinas, die Region um die Hauptstadt Beijing. Die schlechte Luftqualität ist mittlerweile ein ernstes Problem für die Gesundheit der Menschen. Maßnahmen wie die Reduzierung des Individualverkehrs sowie die Umsiedlung von Kraftwerken und Industrien wie Stahlwerken reichen nicht aus, weil die regionale Verschmutzung oft die lokale bei Weitem übersteigt.
Im Sommer 2006 fand in der Region Beijing die internationale Feldkampagne CAREBeijing statt, um den Einfluss des regionalen Aerosols zu bestimmen und um daraus konkrete Maßnahmen zur Verbesserung der Luftqualität ableiten zu können. Im Rahmen der CAREBeijing Messungen wird an einem Fallbeispiel gezeigt wie in einer Luftmasse die anthropogene sekundäre Aerosolbildung zu einem deutlichen Anstieg der Partikelmasse und damit des direkten Klimaeffektes führen kann. Das Wachstum der Partikelmasse ist hierbei eng mit den Konzentrationen von elementarem Kohlenstoff und SO_2 korreliert, die direkte Indikatoren für anthropogene Partikel- und Gasemissionen sind. Frisch gebildete Partikel wachsen im gleichen Zeitraum bis in den CCN-Größenbereich von 100 nm auf.

Introduction

North-Eastern China with the Capital Beijing suffers regularly under pollution events with high aerosol mass concentrations. Particle mass concentrations of 200 µg m^{-3} and more are common especially in the urban area of Beijing. There is a great national interest to reduce these high particle mass concentrations especially for the upcoming Olympic Games to be held in Beijing in summer 2008.

In summer 2006, an international field study (CAREBeijing) was organized by Peking University to identify the sources of primary and secondary aerosol sources. The goal was to advise the local government on taking actions to reduce local particulate pollution during the Olympic Games. Beside actions to be taken in the city of Beijing such as reduction of car traffic or relocating power and industrial plants, the influence of the regional aerosol on the urban pollution has to be minimized. Previous studies indicated that the regional aerosol dominates the particle mass concentration under certain meteorological conditions.

North-Eastern China (Beijing area) is bordered by mountains to the west and north. Depending on large-scale meteorology, air masses from westerly and northerly directions transport relatively clean air to the Beijing area with high wind speeds. This process removes the previous pollution resulting in relatively low particle mass concentration and clear sky. After this removal, the meteorological conditions frequently change to slowly moving air masses mainly from southerly directions. Under these conditions direct particle emissions and secondary aerosol formation from precursor gases can lead to an accumulation of particulate mass within the air mass during the following days.

The Leibniz Institute for Tropospheric Research was involved together with the Peking University, the Research Centre Jülich, the Max-Planck-Institute Mainz, the University Tokyo, and other Chinese institutes in the CAREBeijing project characterizing the regional aerosol and their precursors in Yufa, a small city 80 km south of Beijing. This field study was conducted in summer 2006 to study the regional aerosol under the expected meteorological conditions of the Olympic Games.

Methods and Observations

In-situ aerosol measurements have been performed in an air-conditioned laboratory at the local University in Yufa. The aerosol was sampled via a low-flow PM_{10} inlet and dried in a diffusion dryer keeping the relative humidity below 30%. Particle number size distributions were measure with a 10 min resolution (mobility size spectrometer, MSP), while light absorption (multi angle absorption photometer, MAAP) and scattering coefficients (nephelometer) were recorded on a minute base.

At 9.00 a.m. on August 23, 2006, the near-ground inversion layer broke up due to solar heating and cleaner air from aloft was mixed with more polluted air near ground left from the previous day. This mixing can be clearly seen in Figure 1. While the wind speed increased up to a

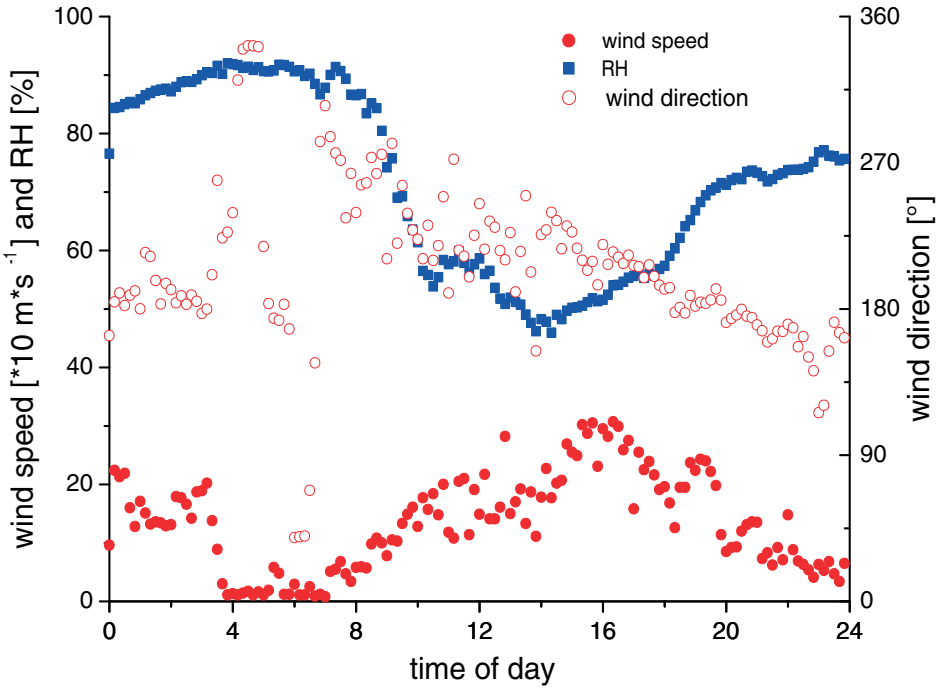

Fig. 1: *Time series of wind speed (red dots), wind direction (open circles) and relative humidity (blue squares) measured on ground in Yufa south of Beijing on August 23, 2006 during the CAREBeijing field study.*

few m/s and the wind direction shifted to south-westerly directions, the relative humidity dropped significantly indicating mixing with drier air from aloft. Homogenous particle nucleation started immediately due to the rapid decrease in particle mass concentration (Figure 3, blue triangles) and increasing global radiation. The new particle formation was followed by condensational growth within the slowly moving air mass indicated by the banana-shaped temporal development of number size distribution shown in the contour plot of Figure 2. Due to slight shifts in wind direction, emission plumes influenced the particle growth as shown in Figure 3 by two distinct maxima in the SO_2 concentration (Figure 3, brown dots). Particle number concentration (red triangles), total particulate mass (calculated from the MSP-measurements, density was estimated to 1.6 g/cm^3 from the chemical composition), and elemental carbon (MAAP-derived, black squares) were elevated during the first SO_2 maximum as plotted in Figure 3. After 6.00 p.m., the wind direction

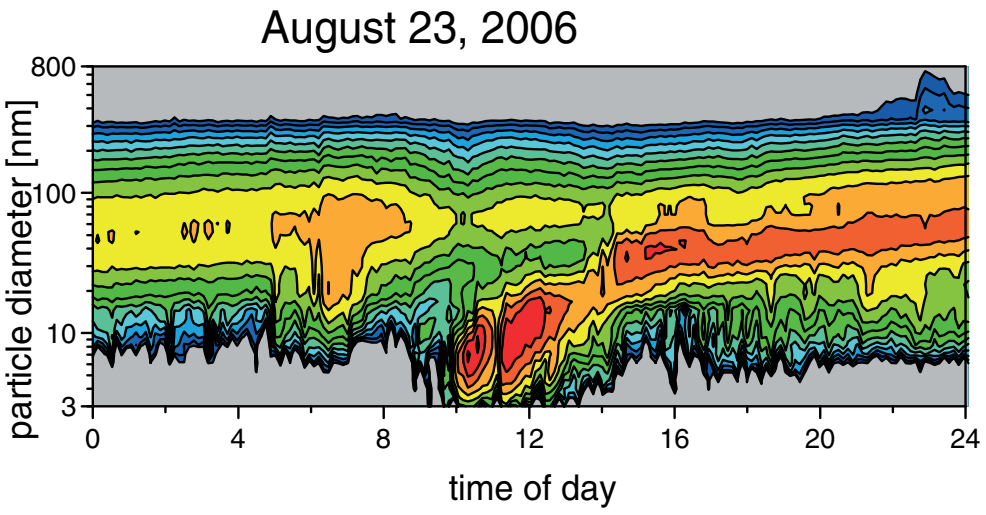

Fig. 2: *Yufa August 23, 2006: Diurnal variation of the number size distribution.*

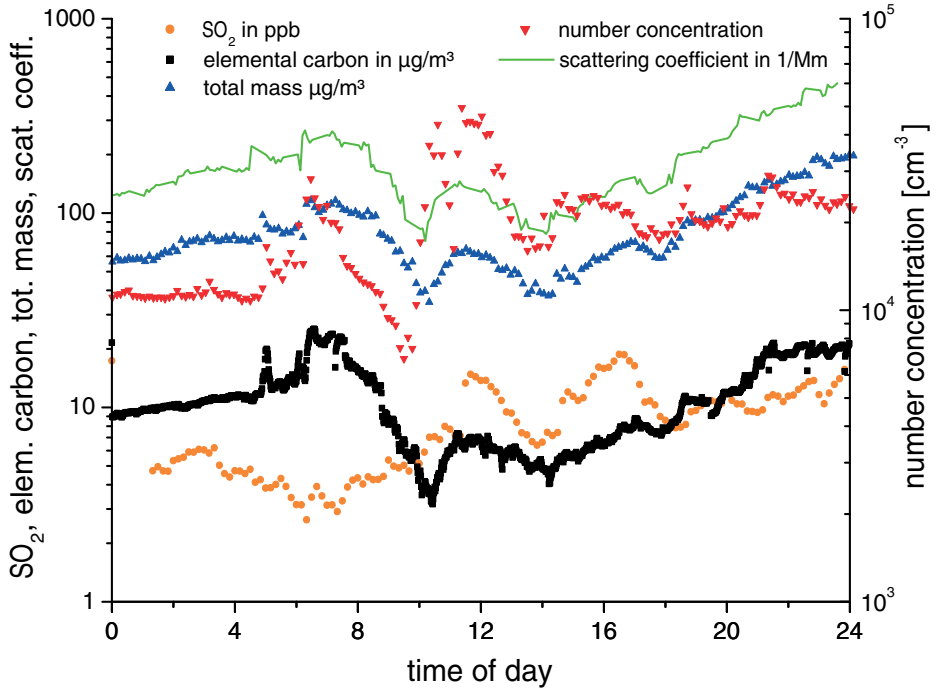

Fig. 3: *Yufa August 23, 2006: Time series of SO_2 (brown dots), total number (red triangles), EC mass (black squares), particulate mass (blue triangles), and scattering coefficient (green line).*

became more stable and the particle growth more homogeneous as illustrated in the contour plot of the particle number size distribution.

At midnight, the particulate mass increased approximately to 200 µg/m³ by continuous growth, while elemental carbon (approx. 10% of the total mass) followed this increase in total mass. A similar picture can be seen when calculating the scattering coefficient from the submicrometer number size distribution. Due to the strong particle growth, the scattering coefficient (here for 550 nm wavelength calculated with a Mie-model) increased from a value below 100 Mm^{-1} up to more than 400 Mm^{-1} (Figure 3, green line). Furthermore, the peak diameter of the nucleation mode peak increased continuously over the whole day and reached a size of about 100 nm at midnight.

Conclusion

The presented case study from Northern China is typical for new particle formation events in this polluted area, when clean air is transported via advection or mixed from aloft in the morning after the break up of the inversion layer.

The growth of the nucleation mode peak (banana-shaped curve in the contour plot) indicates a sustained growth on regional scale within one air mass. In this case, nucleated particles grow within 12 h from nanometer size up to the CCN size range of 100 nm. Due to concurrent high precursor gas emissions and oxidation capacity, secondary aerosol mass is produced continuously over the whole day. This increase in aerosol mass continues also during night linearly on logarithmic scale.

Direct particle emissions such as elemental carbon go hand in hand with the formation of secondary aerosol indicating that the precursor gases are also of anthropogenic origin. Finally, particle emissions and secondary aerosol formation within 12 h lead to significant reduction in the air quality and increase in the direct aerosol effect on the regional climate.

Cooperation
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Atmospheric particle formation starting from OH + SO_2

Torsten Berndt, Sylvia Bräsel, Frank Stratmann

Gegenstand der Studie sind mechanistische Untersuchungen zur Partikelneubildung in der Atmosphäre ausgehend von H_2SO_4/H_2O. H_2SO_4 wird entweder mittels Mitführung von einer flüssigen Probe bezogen oder in-situ über die Reaktion von OH Radikalen mit SO_2 in Gegenwart von H_2O erzeugt. Hier steht ´´H_2SO_4´´ für alle SO_2 Oxidationsprodukte. Experimentell konnte gezeigt werden, dass bei gleichzeitiger Verwendung von H_2SO_4 von einer flüssigen Probe und in-situ produzierter ´´H_2SO_4´´ (über OH + SO_2) ´´H_2SO_4´´ den Prozess der Partikelbildung und des Wachstums steuert. Weiterhin wurde gezeigt, dass NO_x (NO und NO_2) die Partikelbildung inhibieren kann. Diese Befunde lassen den Schluss zu, dass andere SO_2 Oxidationsprodukte als Schwefelsäure (möglicherweise Produkte des $HOSO_2O_2$ Radikals) für die Partikelbildung in der Atmosphäre verantwortlich sind.

Introduction

The formation of new aerosol particles in the atmosphere has been the subject of intense studies in the field and in the laboratory. The mechanisms and the participating substances, however, have not been resolved yet. In previous investigations under near-atmospheric conditions, experimental evidence for the formation of new particles in the system H_2SO_4 / H_2O was found for H_2SO_4 concentrations of ~10^7 molecule cm^{-3} [*Berndt et al.*, 2005] if ´´H_2SO_4´´ was produced in-situ via the reaction of OH with SO_2 (´´H_2SO_4´´ here stands for all products of converted SO_2). In contrast, taking H_2SO_4 from a liquid reservoir concentrations of 10^9 – 10^{10} molecule cm^{-3} are needed for new particle formation [*Ball et al.*, 1999]. Subject of this study are mechanistic investigations on H_2SO_4 / H_2O particle formation explaining the different threshold H_2SO_4 concentrations needed for nucleation.

Experimental

The experiments have been performed in the atmospheric pressure flow-tube *IfT*-LFT (i.d. 8 cm; length 505 cm) at 293 ± 0.5 K using synthetic air as the carrier gas. OH radicals needed for SO_2 oxidation were produced either via photolysis of O_3 in the presence of water vapor or via ozonolysis of trans-butene (dark reaction). Furan or CO has been chosen for OH radical titration. Resulting OH and ´´H_2SO_4´´ concentrations were calculated with a kinetic model using measured O_3 decays. Taking H_2SO_4 from a liquid reservoir, H_2SO_4 concentrations have been determined by means of a denuder system with subsequent analysis of SO_4^{2-} ions using ion chromatography. A butanol-based UCPC (TSI 3025) as well as a H_2O-based UCPC (TSI 3786) for integral particle measurements, and a differential mobility particle sizer (Vienna-type DMA with UCPC, TSI 3025) for monitoring of size distributions have been utilized.

Results

In a first set of experiments in-situ formation of ´´H_2SO_4´´ via OH + SO_2 was coupled with the evaporation of H_2SO_4 from the liquid reservoir as background in order to investigate the role of H_2SO_4 for the new particle formation and growth process. Initial H_2SO_4 concentration from the liquid reservoir was (1 – 2) · 10^9 molecule cm^{-3}, i.e., close to the threshold concentration needed for binary H_2SO_4 / H_2O nucleation in our experiment. In Figure 1 results from a typical measurement are depicted. After turning on the flow through the H_2SO_4-saturator, a small increase of particle number above the noise level was visible with a subsequent slight rise up to 2 – 3 particles cm^{-3} after more than 5 hours on stream. These particles are due to binary nucleation of H_2SO_4 / H_2O. The particle number was not affected by the presence of O_3 and the photolysis products (OH radicals, HO_2, and H_2O_2) after switching on UV irradiation. With addition of SO_2 (time = 235 min), in-situ particle precursor formation in the gas phase started and a constant particle number of 5 · 10^4 cm^{-3} was observed for in-situ ´´H_2SO_4´´ concentration of 2.3 · 10^8 molecule cm^{-3}. Immediately after switching off UV (time = 330 min), particle number went down to the level being attributed to binary H_2SO_4 / H_2O nucleation. At 360 min the supply of H_2SO_4 from the liquid reservoir was stopped resulting in a decrease of particle number down to background noise level. Switching on UV, i.e., restarting the in-situ ´´H_2SO_4´´ production without background H_2SO_4, led to a particle number of 5 · 10^4 cm^{-3} again. This behavior is a strong indication that H_2SO_4 from the liquid reservoir (now absent) did not participate in the nucleation process. Measured size distributions recorded in the presence and absence of background H_2SO_4

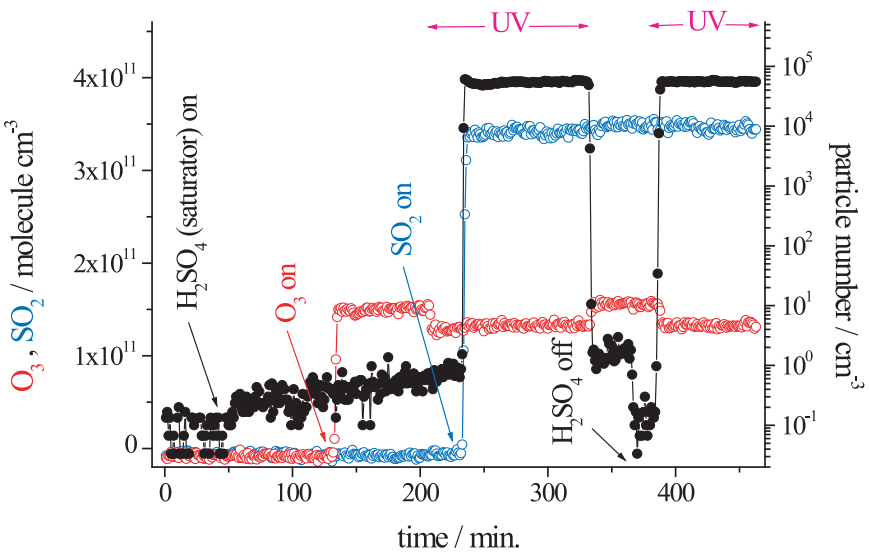

Fig. 1: *Temporal behavior of O_3 and SO_2 concentration and particle number for an experiment using H_2SO_4 from the liquid reservoir as well as in-situ formation of ´´H_2SO_4´´ (SO_2 products) with CO for OH radical titration, r.h. = 22%, gas flow: 10 sl min^{-1}. Initial concentrations were (unit: molecule cm^{-3}); H_2SO_4 (saturator): (1 – 2) · 10^9; O_3: 1.6 · 10^{11}; CO: 1.0 · 10^{14}; SO_2: 3.5 · 10^{11}.*

showed that H_2SO_4 from the liquid reservoir did not significantly contribute to particle growth.

From mechanistic point of view, this behavior can be explained by extension of the currently accepted mechanism of gas-phase SO_2 oxidation

$$\mathbf{OH + SO_2 \rightarrow HOSO_2} \quad (1)$$

$$\mathbf{HOSO_2 + O_2 \rightarrow SO_3 + HO_2} \quad (2)$$

$$\mathbf{SO_3 + 2\,H_2O \rightarrow H_2SO_4 + H_2O} \quad (3)$$

assuming pathway (2a) to be responsible for the formation of the particle precursors.

$$\mathbf{HOSO_2 + O_2 + M \rightarrow HOSO_2O_2 + M} \quad (2a)$$

$HOSO_2O_2$ is a peroxy-type radical and, analogous to organic peroxy radicals, it can react with HO_2, other peroxy radicals or with NO and NO_2 or with SO_2. If the reaction of $HOSO_2O_2$ with HO_2, other peroxy radicals or SO_2 is responsible for the formation of particle precursors, addition of NO and/or NO_2 should reduce or inhibit new particle formation as a part of the available $HOSO_2O_2$ radicals will be consumed by NO and/or NO_2.

To test this hypothesis, experiments were carried out, with NO_x (NO + NO_2) being present

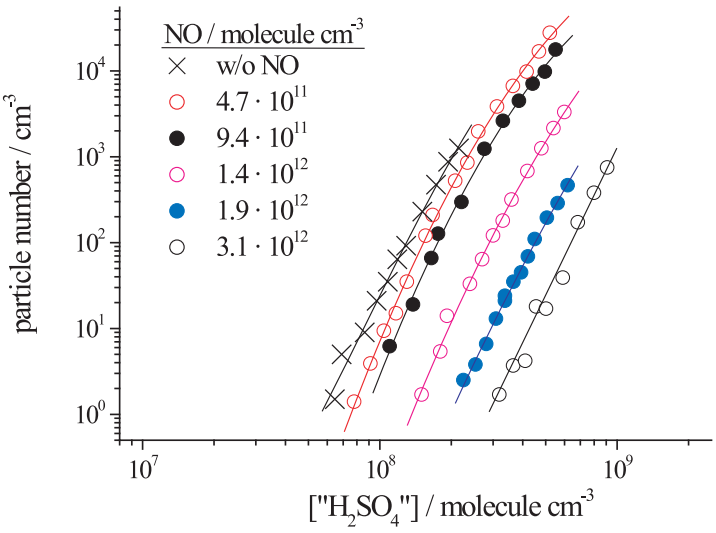

Fig. 2: *Experimentally observed particle number as a function of in-situ produced ´´H_2SO_4´´ (or SO_2 oxidation products) concentration for different NO additions in the carrier gas using furan for OH radical titration, OH radical formation via O_3 photolysis, r.h. = 22%, gas flow: 30 sl min^{-1}. Initial concentrations were (unit: molecule cm^{-3}); O_3: (1.5 – 1.6) · 10^{11}; furan: 6.2 · 10^{11}; furan conversion: 2.1 – 5.3%; SO_2: (1.2 – 16) · 10^{11}.*

in the carrier gas. Figure 2 shows a result of measurements performed for different initial NO concentrations. In the course of the overall reaction, NO was significantly converted to NO_2, e.g., for the lowest initial NO concentration, 32% of NO reacted to NO_2. It is clearly seen that with increasing amounts of NO_x being present in the reaction gas, new particle formation is inhibited. It is to be noted that NO_x cannot effect H_2SO_4 formation as described by pathways (1 – 3). There were also no indications that NO_x inhibited new particle formation using H_2SO_4 from the liquid reservoir. Consequently, these results represent an indication that reaction products from a sulfur-containing peroxy-type radical (most likely $HOSO_2O_2$ formed via pathway (2a)) represent possible particle precursors.

In conclusion, this study shows, that it is not necessarily sulfuric acid triggering atmospheric new particle formation and growth and that other compounds formed during the gas-phase reaction of OH radicals with SO_2 may play an important role.

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Cooperation
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- University of Kuopio, Finland.

Urban dispersion modeling for motorway emissions in Berlin

Detlef Hinneburg and Oswald Knoth

Zum Zweck der Validierung und weitergehenden Auswertung von Feinstaubmessungen des IfT an der Berliner Stadtautobahn wurden Simulationen mit dem institutseigenen mikroskaligen, gebäudeauflösenden Modell ASAM (All-Scale Atmospheric Model) in diesem innerstädtischen Messgebiet durchgeführt. Als Ergebnis steht ein Satz von Simulationen zur Verfügung, der die möglichen Anströmungsverhältnisse und Verkehrsintensitäten prinzipiell vollständig abdeckt. Die Konzentrationsfelder dienen dazu, die an verschiedenen Orten gemessenen Partikelkonzentrationen gegenseitig in Beziehung zu setzen, deren räumliche Verteilung und meteorologische Abhängigkeit zu überprüfen und widersprüchliche Situationen gegebenenfalls von der weiteren Analyse auszuschließen. Letztendlich machen die simulierten Relationen zwischen Emissionsdichte und Konzentrationsverteilung es erst möglich, aus den gemessenen Konzentrationen im Umkehrschluss die unbekannte reale Emissionsdichte des Straßenverkehrs abzuleiten und dank der Verkehrszählungen sogar mittlere Emissionsfaktoren pro Fahrzeug zu berechnen. Der Algorithmus dieser Methode, die eine Vereinfachung der anerkannten inversen Modellierung darstellt, wird hier beschrieben.

Introduction

The Berlin urban motorway A 100 represents one of the most busy roads in Germany. The motorway traverses densely built residential areas within Berlin and appears in these regions as the main source of human exposure to traffic-related exhaust particles. It has been included in the communal air quality monitoring system for a long time. In order to qualify the experimental data for further evaluations, during summer 2005 the IfT has supplemented the roadside measuring station by two nearby background sites and by traffic counting equipment. The intensive measuring campaign 'Particles in the urban atmosphere (PURAT)' comprised the quantitative determination of the size-resolved particle distributions, the meteorological parameters, the interaction with the background, and the dispersion and dilution effects in the immediate vicinity of the road. Only the combination of the extended experimental base with the current micro-scale dispersion simulations provides for the derivation of traffic emission rates and even of fleet emission factors under realistic conditions (inverse modeling). The application of the obstacle resolving model to the considered period, some numerical results as well as the formulae of a simplified inverse modeling scheme are presented in the following.

Modeling region

The model domain includes an area of 500 m x 500 m around the measuring sites and extends vertically to 100 m above the base area or 60 m above the obstacle layer, respectively. The model grid with mesh sizes of 5 m horizontally and 2 m vertically (in the obstacle layer) resolves the relevant buildings, obstacles, streets, bridges, ramps, and

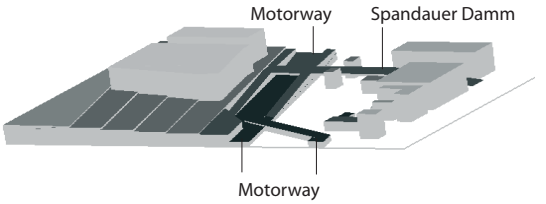

Fig. 1: *Model region with raised surface in the western part.*

the orographic structure (Figure 1). The motorway runs parallel with the urban railway through a 100 m wide south-north directed canyon which is framed by high building blocks. The westerly border of the motorway is adjacent to an orographic step of 10 m. The lanes of the motorway pass above and under two bridges on varying levels and split up in the southern part. Moreover, a second main road, the very busy and emissive 'Spandauer Damm', is crossing the canyon on a long bridge from west to east with sloped branches down to the motorway. Altogether, the orographic situation, the arrangement and the geometrical form of the buildings and emitting lanes let expect complex patterns of the resulting concentration distributions.

Ensemble of wind situations and emission scenarios

The obstacle-resolving 'All-Scale Atmospheric Model (ASAM)' [*Hinneburg et al.*, 2005; website: http://asam.tropos.de/wiki] is applied to the model domain as specified in Figure 1. The dynamic atmospheric forcing is realized by defined values

of the wind direction D and speed U on the top of the domain (100 m). Open lateral in- and outflow boundary conditions and a neutral temperature profile valid for wind speeds above about 1 m s^{-1} are adopted. The 3-dimensional fields of the wind vectors, turbulent kinetic energy and dissipation as well as two separately transported tracers (emitted from the motorway and the Spandauer Damm) have to be calculated for each situation.

The complete treatment of all possible situations would normally require the natural variations of at least three parameters: wind direction D, wind speed U, and emission density per road line Q {particles m^{-1} s^{-1}}. Unlike the general inverse modeling method [*Ketzel et al.*, 2003], the simplified scheme replaces the time series of the meteorological conditions by a discrete set of these parameters. Ten different directions D of the wind (wind rose) have actually been selected for the whole set. The other parameters U and Q, however, are not varied (but are fixed in the simulations) because of approximate interrelations with the local wind speed and concentration, as is shown in the following.

The nearly linear dependence of the local wind speed u(x,y,z) on U (diagnosed for not too low wind speeds) is used to define an unaffected normalized local wind speed u*(x,y,z):

$$u^* = u / U \qquad (1)$$

Since the local concentration c(x,y,z) {particles m^{-3}} scales linearly with the line source density Q of the emitting road and inversely with the wind speed U, the following definition of a normalized local concentration c*(x,y,z) {m^{-1}} is appropriate under the condition mentioned above:

$$c^* = c\, U / Q \qquad (2)$$

Although u* and c* are defined such that they are approximately independent of the amount of U, the vertical position of U has an indirect influence. Thus, any comparison between the simulated and observed normalized quantities implies the assumption that U and D are given at the same height both in the model (here 100 m) and the experiment. In general, however, there is a discrepancy which can be circumvented either (case A) by using c* but correcting for the vertical wind profile if known in model and experiment or (case B) by applying the product c*u* instead of c* solely (multiplication of eqs. (1) and (2)):

$$c^* u^* = c\, u / Q \qquad (3)$$

Indeed, the product c*u* involves only quantities at the observation sites and no reference to U (and hence to the turbulence state) does appear. Even the uncertainties as for the proportionality with the parameter U are expected to cancel out within the term c·u.

Simulation results

The normalized quantities u*(x,y,z) and c*(x,y,z), which are nearly independent of the large-scale wind speed U and the emission density Q, were made available by means of a set of simulations with ten wind directions D and two separately emitting roads (motorway or Spandauer Damm). These results when rescaled with any U and Q according to the equations above yield the 3-dimensional fields of the local wind speed u(x,y,z) and concentration c(x,y,z) for each desired situation. Figure 2 shows the horizontal distribution of the normalized concentration c* with traffic emissions from the motorway for eight different directions of the incoming flow. The concentration patterns are obviously dominated by vertical and horizontal eddies caused by the irregular arrangement of the artificial and orographic obstacles. For comparisons with the experimental data and for more complex calculations (see next section), the simulated quantities u*, c*, and d (local wind direction) are tabulated for the measuring sites C and T (positions see Figure 2) as a function of the wind direction D and the emitting road.

Inverse modeling for the derivation of emission factors

The quoted equations and quantities apply for modeled and observed data likewise. Henceforth, all observed (real) quantities are underlined in distinction from the simulated ones. The functional dependence of the concentrations on the emission density as expressed by eq. (2) is now inversely used to derive the unknown real emission density $\underline{Q}$ from the observed concentration $\underline{c}$.

In the case A (see context of eq. (2)) of available measured wind speed data at the model top height (here 100 m), the simulated normalized concentrations must be equal to the measured ones ($c^* = \underline{c}^* = \underline{cU}/\underline{Q}$) and the following expression is obtained:

$$\underline{Q} = \underline{c}\, \underline{U} / c^* \qquad (4)$$

Thus, the combination of the measured concentration $\underline{c}$ with the simulated normalized value c* (belonging to the same wind situation) leads to the underlying real road emission $\underline{Q}$, provided the measured data $\underline{U}$ of the large-scale wind speed are really available at the considered region and height [*Ketzel et al.*, 2003].

In the general case B (see context of eq. (3)), simulated and observed quantities can only be identical for the product of c* and u* ($c^*u^* = \underline{c}^*\underline{u}^* = \underline{cu}/\underline{Q}$) which results in:

$$\underline{Q} = \underline{c}\, \underline{u} / c^*u^* \qquad (5)$$

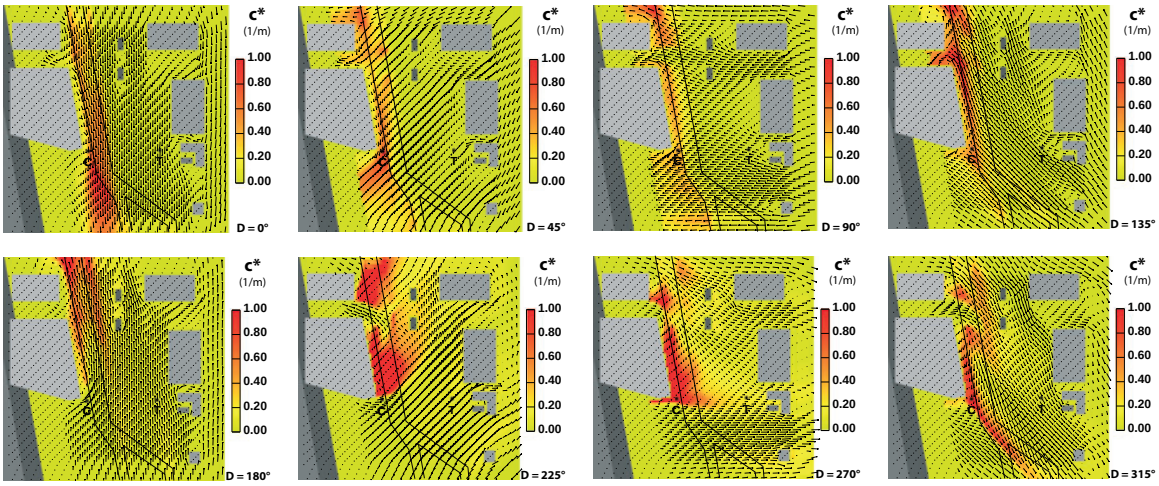

Fig. 2: *Normalized concentration field c* at a height of 13 m above the base area for 8 directions of the incoming flow; C – roadside site (cemetery), T – background site (taxi garage).*

Instead of the large-scale wind speed U, this formula needs the local wind speed u, which has been measured during the intensive campaign at all sites together with the particle concentration c.

The concentrations used in the equations exclude any background pollution. Since the measuring site T is nearly unaffected by the traffic emissions from the motorway and the street Spandauer Damm (see Figure 2), T is utilized as the reference or background station. The corresponding simulated and measured concentrations have to be subtracted from the ones of the site C before applying the equations ($\rightarrow \Delta c, \Delta c^*, \underline{\Delta c}$).

If traffic counts M {vehicles s^{-1}} are available, then the mean emission factor E {particles per vehicle and meter driven} can be determined pursuing the general case B (eq. (5)):

$$E = Q / M = \underline{\Delta c}\ u / (\Delta c^*\ u^*\ M) \qquad (6)$$

Conclusion

The actual investigation represents the first application of the model ASAM to observational data sets. Comparisons of the local wind speed and direction between measurement and model, between the two sites and a large-scale measurement station, as well as others served to confine the number of situations and to obtain a consistent and reliable data set for the derivation and validation of emission factors (preliminary results see in [*Birmili et al.*, 2007]). Accounting for the varying fleet compositions at different times of day, even the specific fleet emission factors for passenger cars and freight vehicles can be deduced. It is emphasized, that the derivation of emission factors under realistic atmospheric dilution conditions is only possible by exploiting micro-scale simulation results. In contrast to the general inverse modeling method [*Ketzel et al.*, 2003], suitable results can be obtained with much less experimental and modeling effort.

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Cooperation
- The Federal Environment Agency (Umweltbundesamt), Dessau, Germany.

Vertical aerosol flux throughout the planetary boundary layer

Ronny Engelmann, Albert Ansmann, Detlef Müller, Ulla Wandinger, Birgit Wehner

Der turbulente Transport von Partikeln zwischen der Erdoberfläche und der unteren Atmosphäre spielt für das Verständnis zahlreicher atmosphärischer Prozesse eine große Rolle. Er nimmt Einfluss auf Wolkenbildungsprozesse und auf die Luftqualität am Boden. Einträge von Partikeln aus der Grenzschicht in die freie Troposphäre bestimmen den Ferntransport von Aerosol. Die Mechanismen des Vertikalaustauschs in der planetaren Grenzschicht und der Entrainmentzone, ihre Abhängigkeit von der Bodenbeschaffenheit und den meteorologischen Bedingungen, sind bisher nur unzureichend verstanden und demzufolge in Modellen schlecht repräsentiert. Entsprechende Beobachtungen sind daher von großem Interesse. Mit den am IfT entwickelten Lidarsystemen können wir sowohl Vertikalwind als auch Aerosoleigenschaften mit hoher räumlicher und zeitlicher Auflösung erfassen. Durch Anwendung der Eddy-Korrelationsmethode konnten wir damit erstmals Vertikalprofile des turbulenten Aerosolmassenflusses in der gesamten planetaren Grenzschicht bestimmen. Im folgenden Beitrag werden die Methode und eine Messung vorgestellt.

Introduction

The turbulent transport of aerosol particles between the surface and the lower troposphere has a strong influence on atmospheric composition, long-range aerosol transport, and cloud formation as well as on smog and haze conditions at the ground. Vertical exchange depends in a complicated way on surface characteristics and meteorological conditions in the planetary boundary layer (PBL). The mechanisms within the PBL and in the entrainment zone are not well understood and thus are not well parameterized in atmospheric models. Therefore, respective observations are of high interest. With the IfT lidar instrumentation we can determine the vertical wind as well as aerosol properties with high spatial and temporal resolution. In this way, we could derive vertical profiles of the turbulent aerosol mass flux throughout the PBL for the first time. Here, we briefly describe the method and a measurement example.

Method

The determination of the vertical aerosol flux is based on the eddy correlation technique. This method requires time series of vertical wind speed and aerosol scattering data at specific height levels with a resolution of <10 s. The accuracy of the vertical wind speed should be <0.1 m s^{-1}. With our advanced lidar systems we are able to measure such datasets in the entire PBL. For the experiment presented here the institute's Doppler wind lidar [*Engelmann et al*., 2007] was set up close to the stationary IfT three-wavelength Raman lidar [*Mattis et al*., 2002]. The horizontal distance between the laser beams was <10 m. The data acquisition was synchronized to assure correlative observations.

For ground-based profile observations Taylor's frozen turbulence hypothesis must be applied, i.e., it is assumed that the temporally resolved datasets well represent the spatial average. Then the turbulent flux F_b of an atmospheric parameter b is given by the covariance of b and the vertical wind speed w, $F_b = \langle b' w' \rangle$. The prime indicates deviations from the mean value and the brackets represent the temporal average. By definition, updrafts have a positive sign, and positive values of F_b imply upward fluxes. In the case of turbulent aerosol fluxes the parameter b should represent the particle number, volume, or mass concentration. However, from lidar observations we can only determine particle backscattering with sufficient temporal resolution. Therefore, we use the time series of the 532-nm particle backscatter coefficient β with a resolution of 5 s. Thus the primary output of the flux calculation is the covariance $\langle \beta' w' \rangle$.

In a second step, we use multiwavelength Raman lidar observations (extinction coefficients at 355 and 532 nm, backscatter coefficients at 355, 532, 1064 nm) and retrieve microphysical particle parameters with our inversion scheme [*Müller et al*., 2001; *Ansmann and Müller*, 2005]. In this way, among other quantities, we obtain profiles of the particle volume concentration with low temporal resolution, from which we can estimate the mean particle mass concentration m by assuming a typical particle density. In the third step, we assume that the obtained relationship between β and m holds for the entire measurement region, so that any change of β with height and any fluctuations β' are caused by respective changes in the mass concentration m and its fluctuations m'. Then the turbulent aerosol mass flux at a given height is $F_m = \langle m' w' \rangle = (m/\beta) \langle \beta' w' \rangle$. The simplification of a height- and time-

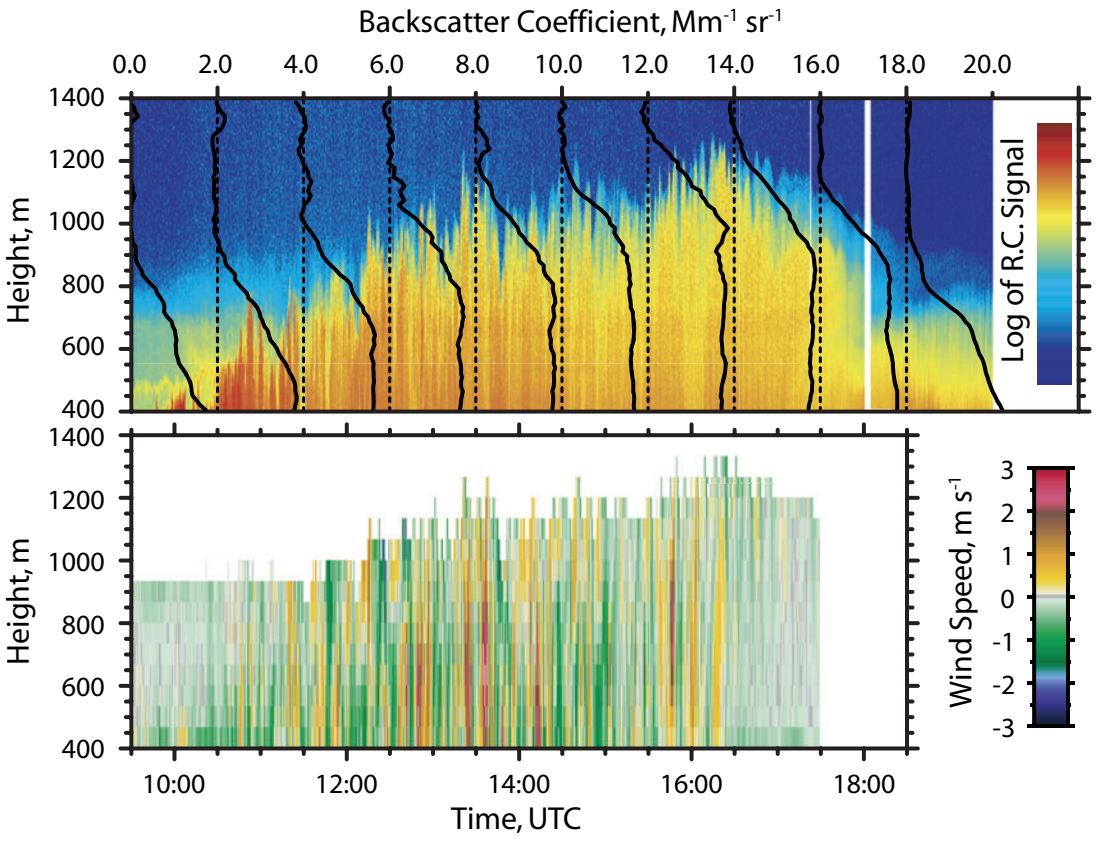

Fig. 1: *Development of the planetary boundary layer observed with aerosol Raman lidar and Doppler wind lidar on September 12, 2006. Top: Range-corrected elastic-backscatter signal (532 nm; resolution 7.5 m, 5 s) and one-hour-averaged profiles of the backscatter coefficient at 532 nm. The profiles are shifted by 2 $Mm^{-1}sr^{-1}$ or 1 hour. Bottom: Corresponding vertical wind speed (resolution 75 m, 5 s).*

independent conversion factor m/β implies that the aerosol size distribution and the particle chemical composition do not vary in the convective PBL.

Results

The data presented here were taken in a very dry PBL (humidity <50% at all heights) on September 12, 2006. The aerosol Raman lidar and the Doppler wind lidar were used to measure the datasets of aerosol backscatter coefficients and vertical wind speed during daytime. The measurement with the Raman lidar was continued after sunset to obtain accurate data under low-background conditions for a characterization of microphysical particle properties. Figure 1 presents the PBL development during daytime between 0930 and 1730 UTC. The range-corrected signal of the 532-nm channel in the Raman lidar and the vertical wind speed show very good correlations. Thermal updraft regions (yellow and red) can be clearly distinguished from downward mixing processes (dark green).

The typical –5/3 slope for the inertial subrange of turbulence could be observed in the power spectra of the vertical wind and backscatter time series (see Figure 2. for a selected time series). This behavior shows that the fluctuations in our

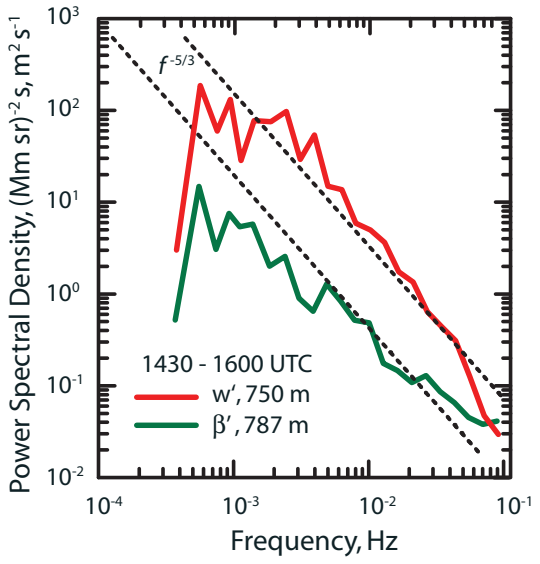

Fig. 2: *Power spectral density functions of the backscatter coefficient and the vertical wind speed at a height level of about 750 m for the time period 1430–1600 UTC. The expected $f^{-5/3}$ roll-off for the inertial subrange of turbulence is indicated. For the β' spectrum a very small noise floor can be recognized at the high frequency end of the spectrum.*

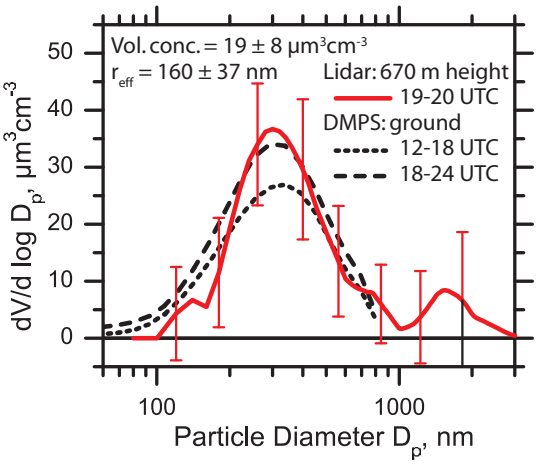

Fig. 3: *Aerosol volume distributions derived from lidar data inversion and from in-situ measurements with DMPS.*

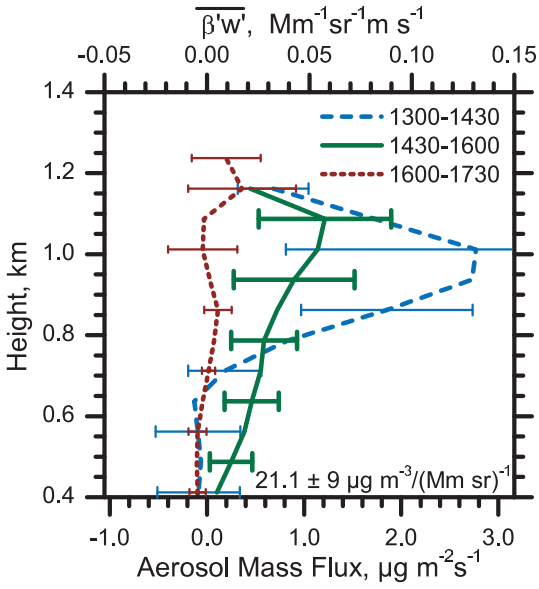

Fig. 4: *Profiles of aerosol mass flux for three time periods on September 12, 2006. The upper axis shows the covariance of the backscatter coefficient and the vertical wind speed. The error bars indicate the sampling error.*

datasets are mainly caused by turbulence and are affected very little by stochastic noise.

A result of the lidar data inversion is shown in Figure 3. The derived particle volume distribution at 670 m height agrees very well with data obtained from regular *in situ* measurements with a differential-mobility particle sizer (DMPS) at ground. A mean particle volume concentration of 19 ± 8 $\mu m^3\,cm^{-3}$ was found from the lidar data. With the related mean backscatter coefficient of 1.44 $Mm^{-1}\,sr^{-1}$ and a particle density of 1.6 g cm^{-3} a backscatter-to-mass conversion factor of 21.1 µg m^{-3} Mm sr is obtained. This value has been applied in Figure 4 to calculate aerosol mass flux profiles for three selected time periods.

The obtained values of the aerosol mass flux of 0.5 – 2 µg $m^{-2}\,s^{-1}$ in the active upper PBL are reasonable. A simplified budget estimate, which may give us an idea on the magnitude of the entrainment flux, can show that. From Figure 1 it can be seen that the backscatter coefficient between 800 and 1000 m increased from values close to 0 in the morning to values around 1.8 $Mm^{-1}\,sr^{-1}$ in the afternoon. According to our inversion results this corresponds to an increase of the mass concentration of 38 µg m^{-3}. We assume that this change is only caused by convective mixing of particle-rich air from the lower PBL with clean air from the free troposphere, where the aerosol flux is zero. Then, a mass flux in the entrainment zone of 2 µg $m^{-2}\,s^{-1}$ would fill an atmospheric column of 200 m depth with the respective amount of particles within one hour. This corresponds very well with the observed PBL growth rate of about 150 – 200 m per hour before 1300 UTC. Later (1430 and 1600 UTC) the mass flux in the upper PBL was of the order of 0.5 – 1 µg $m^{-2}\,s^{-1}$ which again is consistent with the observed increase of the PBL height of 50 – 75 m per hour after 1400 UTC.

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Influence of surface tension on the connection between hygroscopic growth and activation

Heike Wex, Tabea Hennig, Andreas Massling, Dennis Niedermeier, Erik Nilsson, Frank Stratmann, Alfred Wiedensohler, Markus Ziese

In mehreren Messkampagnen an LACIS (Leipzig Aerosol Cloud Interaction Simulator) wurde das hygroskopische Wachstum und die Aktivierung von im Labor generierten Aerosolpartikeln unterschiedlichster chemischer Zusammensetzung untersucht. LACIS-Messungen wurden dabei ergänzt durch Messungen des institutseigenen HH-TDMA (High Humidity Tandem Differential Mobility Analyzer) und eines CCN-Zählers (Cloud Condensation Nuclei) der Firma DMT (Droplet Measurement Technologies). Es wurde gefunden, dass sich das hygroskopische Wachstum im Hochfeuchtebereich (oberhalb 95% relative Feuchte) und die Aktivierung mit Hilfe der Köhler-Gleichung konsistent darstellen lassen, wenn bei oberflächenaktiven Substanzen eine konzentrationsabhängige Oberflächenspannung berücksichtigt wird.

Introduction

In the past, it often has been tried to connect the hygroscopic growth of aerosol particles with their activation to cloud droplets using the Köhler equation (e.g., *Covert et al.* [1998], *Brechtel and Kreidenweis* [2000], *Svenningsson et al.* [2006]). In these past studies, measurements of the hygroscopic growth were only possible up to 95% relative humidity (RH). In general, connecting the hygroscopic growth of particles to their activation by using the Köhler equation was successful more often when relatively simple substances (e.g., ammonium sulphates) were examined, while it frequently failed for atmospheric aerosol particles and for mixtures of substances including organic compounds.

During four measurement campaigns at the ACCENT (Atmospheric Composition Change – the European NeTwork of Excellence) infrastructure site LACIS (Leipzig Aerosol Cloud Interaction Simulator, [*Stratmann et al.*, 2004]), hygroscopic growth up to very high RHs (above 99%) and activation were measured for different types of aerosol particles. This article gives an overview of the results obtained during these campaigns regarding the possibilities to establish connections between hygroscopic growth and activation behavior.

Measurements

The following substances were used as particle material: (a) NaCl and three different seawater samples; (b) soot particles (generated with a spark-generator) that were coated with either ammonium sulfate or levoglucosan (during the ACCENT campaign LExNo (LACIS Experiment in November)); (c) two different HULIS (HUmic Like Substances) samples, collected and prepared in Budapest.

Besides LACIS, which measured hygroscopic growth and activation for the samples given in (a) and (c), a HH-TDMA (High Humidity Tandem Differential Mobility Analyzer, [*Hennig et al.*, 2005]) and a continuous-flow streamwise thermal-gradient CCNc (Cloud Condensation Nucleus counter [*Roberts and Nenes*, 2005]) were used to quantify hygroscopic growth and activation during LExNo, respectively. LACIS and the HH-TDMA, measured the hygroscopic growth at high relative humidities (RHs) above 95%, with the HH-TDMA measuring up to 98% and LACIS up to 99.5% RH.

Modeling

The modeling followed the approach described in *Wex et al.* [2007], using a parameter ρ_{ion} defined as: $\rho_{ion} = (\Phi \nu \rho_{sol}) / M_{sol}$ (with the osmotic coefficient Φ, ν being the number of ions the substance dissociates to in solution, the density ρ_{sol}, and the molecular weight M_{sol} of the solute). This parameter ρ_{ion} is included in the water activity term in one of the possible formulations of the Köhler theory. The description is given in detail in *Wex et al.* [2007].

ρ_{ion} combines all parameters of the solute which occur in the water activity term and for which values are possibly not known. With this approach, the number of unknowns in the Köhler equation is reduced to two: ρ_{ion} in the water activity term and the surface tension σ in the Kelvin term.

In a first step, for the data analysis of all the different particle types, ρ_{ion} was derived from measured hygroscopic growth together with using the surface tension of water (σ_w = 72.8mN/m). ρ_{ion} was adjusted such, that the Köhler equation reproduced the measured particle sizes at the respective RHs. Then, the activation was modeled using the values of ρ_{ion} derived at RHs above 95%, together with σ_w and the resulting calculated critical super-saturations needed for activation were compared to the measured ones.

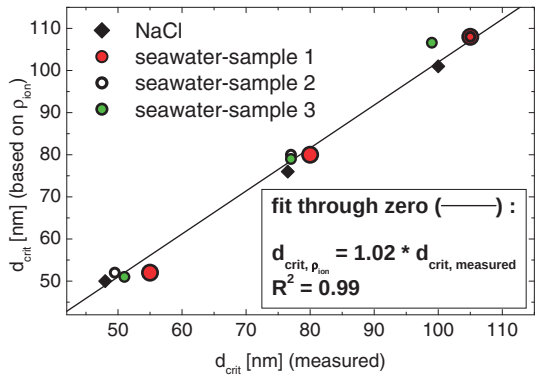

Fig. 1: *Measured and modeled critical diameters for the NaCl particles and for the particles generated from seawater samples.*

Comparison of measured and modeled activation behavior

Particles generated from NaCl and seawater and coated soot particles. For these substances, good agreement between measured and modeled activation behavior was obtained when using the surface tension of water. This was found for both, particles from seawater samples (see Figure 1) and coated soot particles (see Figure 2). The slopes of the fits (which were forced through zero) and the correlation coefficients are also given in Figures 1 and 2. Details on the examination of the seawater samples can be found in *Niedermeier et al.* [2007].

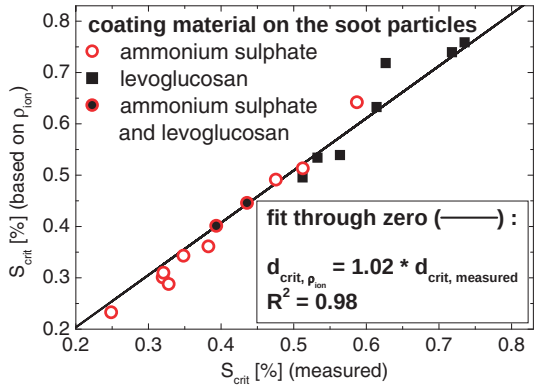

Fig. 2: *Measured and modeled critical super-saturations for the coated soot particles examined during LExNo.*

HULIS particles. Two HULIS samples were investigated, both extracted from urban aerosol samples from Budapest. Measurements were performed for dry particle sizes in the range from 40 to 160 nm. HULIS has been described as a surface-active substance in the past [*Salma et al.*, 2006]. When using the surface tension of water, the critical super-saturations (S_{crit}) predicted from the hygroscopic growth behavior exceeded

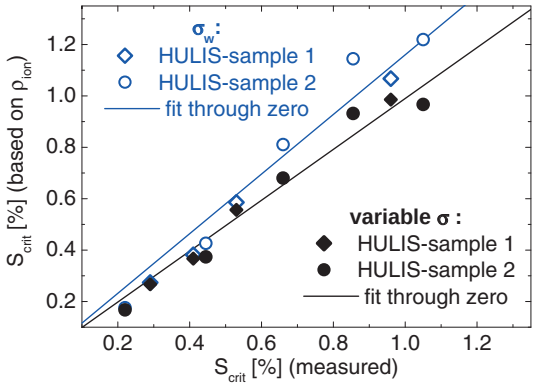

Fig. 3: *Measured and modeled critical super-saturations for the HULIS particles, for the two approaches, one using σ_w and the other one using a variable σ.*

the measured values for S_{crit} above 0.6%, which corresponds to dry particle sizes below 70 nm. This can be seen in Figure 3. For a fit through zero, a slope of 1.16 is obtained for this dataset. Also shown in Figure 3 are values of S_{crit} that were obtained using a variable, i.e., concentration-dependent surface tension. This variable σ was determined following *Szyszkowski* [1908], who suggested a variable σ for droplets containing surface-active substances, depending on the concentration of this substance. Particles with smaller dry diameters have a smaller growth factor at the point of activation, and so they are more concentrated and can have a smaller σ. By using a variable σ, the agreement between measured and modeled S_{crit} was improved, compared to using σ_w, as can be seen in Figure 3. The slope of the fit through zero when using a variable σ is 0.99. Figure 4 shows the derived variable σ for the two HULIS samples, together with the values for σ for the droplets activating on the different

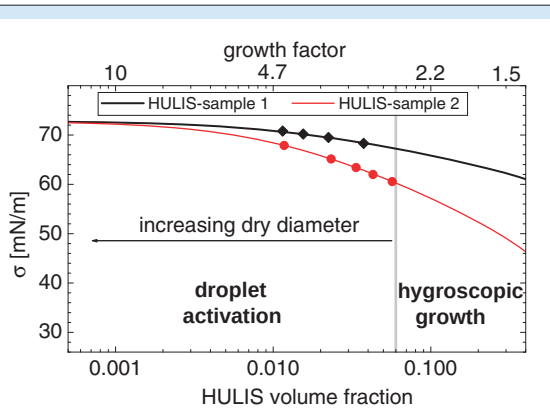

Fig. 4: *Values for σ varying with concentration for the two different HULIS samples. The straight grey line roughly divides the concentration range in a hygroscopic growth and an activation regime. The symbols indicate the values of σ for the droplets activating on the different dry particle sizes in the range from 40 nm to 160 nm.*

dry particle sizes. This study on a concentration-dependent σ for HULIS particles is described in detail in *Ziese et al.* [2007].

The results gained in the course of the experiments described above clearly indicate that a usage of the surface tension of water in the Köhler equation may result an erroneous prediction of the activation behavior, if surface-active substances are present in the droplet. However, it can be concluded that Köhler theory, when used appropriately, is able to describe simultaneously and consistently both, the hygroscopic growth at high RHs and the activation behavior.

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Cooperation

- Eötvös University, Institute of Chemistry, Budapest, Hungary.
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Kinetic measurements of OH and NO_3 radical reactions in the aqueous phase

Dirk Hoffmann, Hartmut Herrmann, Thomas Schaefer, Christian Weller

Mittels Laser-Photolyse wurden Geschwindigkeitskonstanten von Reaktionen wichtiger atmosphärischer Radikale mit sauerstoffhaltigen Kohlenwasserstoffen in wässriger Phase ermittelt. Dabei wurden Effekte der Temperatur, der Ionenstärke und des pH Wertes auf die Geschwindigkeitskonstanten untersucht. Weiterhin wurde eine Analysenmethode ausgearbeitet, um die Produktverteilung bei der Oxidation phenolischer Verbindungen in wässriger Phase zu untersuchen. Die erhaltenen Daten werden in den Ausbau und die Verbesserung des Multiphasenmechanismus CAPRAM 3.0 (Chemical Aqueous Phase Radical Mechanism) eingebunden.

Introduction

Atmospheric chemistry and thus many atmospheric processes are affected by radical reactions. Reactive radicals in the troposphere are OH, NO_3 and halogenated radicals [*Herrmann*, 2003]. Reactions of these radicals contribute to the transformation and degradation of organic compounds in the gas and aqueous phase. In order to describe these processes in models, kinetic data as well as information on the reaction products are needed. Whereas the gas phase chemistry is relatively well described, the aqueous phase chemistry is much less characterized. Therefore, reactions of OH, NO_3 and halogenated radicals with atmospheric relevant organic compounds (acids, phenols, carbonyls, alcohols) were studied within the DFG project ACETOX and the EU project EUCAARI (European Integrated project on Aerosol Cloud Climate and Air Quality Interactions). Experiments were done at room temperature (T = 298 K) and as a function of temperature, ionic strength and pH using Laser-Photolysis – Long-Path-Absorption (LP – LPA) technique (Figure 1).

Experimental

OH radicals were produced using the photolysis of hydrogen peroxide at λ = 248 nm. Rate constants were measured via competition kinetics applying the thiocyanate (SCN^-) reference system [*Gligorovski and Herrmann*, 2004]. NO_3 radicals were generated by photolysis of nitrate anions at λ = 248 nm under acidic conditions (pH = 0.5). The decay of the NO_3 concentration was measured at λ = 632.8 nm using a He-Ne laser [*de Semainville et al.*, 2007].

In order to study the products of radical oxidation reactions with phenolic compounds the LP – LPA setup (Figure 1) was coupled to a combination of Liquid Chromatography / Mass Spectrometry (LC/MS). Additionally, a Solid Phase Extraction (SPE) step was done to purify and enrich the samples prior to the analysis [*Hoffmann*, 2007].

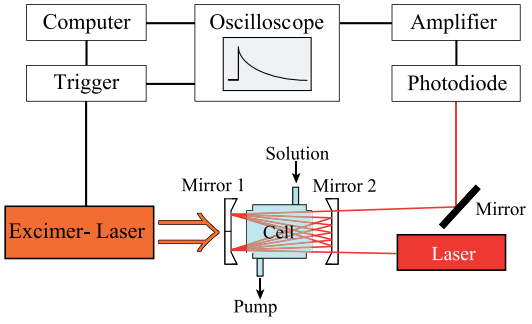

Fig. 1: *Laser-Photolysis – Long-Path-Absorption set-up for the kinetic investigations in aqueous solution.*

Results – Kinetic studies

Isoprene oxidation products. Recent observations of isoprene oxidation products in ambient particles suggested the contribution of isoprene and its oxidation products to the formation of secondary organic aerosol (SOA). Therefore, oxidation reactions of methacrolein, methyl vinyl ketone and methacrylic acid with OH radicals were studied as a function of the temperature in aqueous solution. The rate constants and activation parameters obtained are summarized in Table 1.

Carboxylic acids. Due to the ubiquity and the relatively high solubility of carboxylic acids, OH radical reactions with these compounds in aqueous solution were studied. Within the kinetic measurements the effect of temperature and pH was investigated. Table 1 summarizes the results showing that the dissociation stage has a noticeable influence on the rate constants in case of dicarboxylic acids. This has implications for the modeling of aqueous phase chemistry under changing acidity.

Phenolic compounds. Phenols represent important anthropogenic pollutants as well as tracer compounds of natural and anthropogenic

compound	$k_{OH,\ 298\ K}$ [$M^{-1}\ s^{-1}$]	E_A [kJ mol^{-1}]	A [$M^{-1}\ s^{-1}$]	pH
OH + dicarboxylic acids				
tartronic acid	$(3.4 \pm 0.1) \cdot 10^8$	9.3 ± 3.7	$(1.5 \pm 0.1) \cdot 10^{10}$	1
glutaric acid	$(5.1 \pm 1.2) \cdot 10^8$	9.4 ± 2.2	$(2.2 \pm 0.08) \cdot 10^{10}$	1
adipic acid	$(1.6 \pm 0.4) \cdot 10^9$	12.3 ± 6.4	$(2.5 \pm 0.2) \cdot 10^{11}$	1
pimelic acid	$(3.4 \pm 0.06) \cdot 10^9$	11.1 ± 4.6	$(2.95 \pm 0.2) \cdot 10^{11}$	1
tartronic acid	$(5.0 \pm 0.6) \cdot 10^8$	9.5 ± 3.9	$(2.1 \pm 0.1) \cdot 10^{10}$	9
glutaric acid	$(8.2 \pm 0.9) \cdot 10^8$	19.6 ± 8.5	$(2.5 \pm 0.3) \cdot 10^{12}$	9
adipic acid	$(1.4 \pm 0.4) \cdot 10^9$	16.5 ± 5.2	$(1.2 \pm 0.09) \cdot 10^{12}$	9
pimelic acid	$(2.1 \pm 0.5) \cdot 10^9$	20.9 ± 8.4	$(1.1 \pm 0.1) \cdot 10^{13}$	9
OH + isoprene oxidation products				
methacroleine	$(1.0 \pm 0.1) \cdot 10^{10}$	10 ± 6	$(6.2 \pm 0.6) \cdot 10^{11}$	7
methylvinylketone	$(7.4 \pm 0.7) \cdot 10^9$	8 ± 6	$(2.5 \pm 0.2) \cdot 10^{11}$	7
methacrylic acid	$(1.2 \pm 0.1) \cdot 10^{10}$	11 ± 4	$(1.2 \pm 0.1) \cdot 10^{12}$	3
methacrylic acid	$(1.2 \pm 0.1) \cdot 10^{10}$	12 ± 5	$(2.1 \pm 0.1) \cdot 10^{12}$	8
NO_3 + phenolic compounds				
syringaldehyde	$(1.7 \pm 0.3) \cdot 10^9$	18 ± 4	$(2.8 \pm 0.2) \cdot 10^{12}$	0.5
syringic acid	$(1.4 \pm 0.6) \cdot 10^9$	19 ± 10	$(2.8 \pm 0.4) \cdot 10^{12}$	0.5
vanillin	$(1.1 \pm 0.2) \cdot 10^9$	16 ± 4	$(7.8 \pm 0.4) \cdot 10^{11}$	0.5
vanillic acid	$(1.0 \pm 0.3) \cdot 10^9$	15 ± 4	$(3.8 \pm 0.3) \cdot 10^{11}$	0.5

Tab. 1: *Kinetic data and activation parameters of investigated OH and NO_3 reactions with organic compounds in aqueous solution.*

combustion processes. In order to study their atmospheric stability, reactions of the NO_3 radical with different substituted phenols in aqueous solution were studied as a function of the temperature. The results obtained are also summarized in Table 1.

Results – Product studies

Atmospheric oxidation processes are a source of new compounds, which might have different toxic properties or may affect atmospheric processes (e.g., formation of SOA). Furthermore, product studies are necessary for the development of oxidation mechanisms in atmospheric models. Therefore, the oxidation of 4-methylphenol in presence of OH, NO_2 and NO_3 was studied in aqueous solution. 2-Nitro-4-methylphenol was clearly identified as the main reaction product in the presence of NO_3/NO_2/OH radicals. Besides nitro-substituted compounds also the formation of polymerization products was observed as can be seen in the chromatograms in Figure 2. The formation of these high-molecular-weight

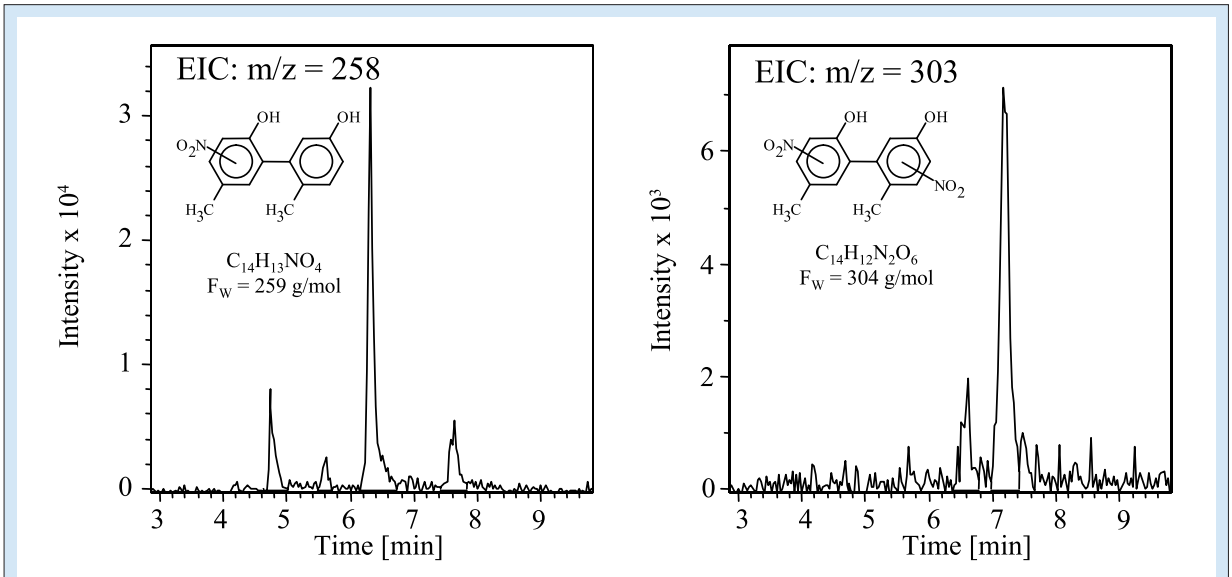

Fig. 2: *Formation of polymerization products by the oxidation of 4-methylphenol in the presence of OH/NO_2/NO_3 radicals in aqueous solution. EIC = Extracted Ion Chromatogram.*

compounds could be important in terms of SOA formation due to the source strength of aromatic compounds. However, a quantification of the polymerization-product-yields was not yet possible due to missing standard compounds.

Summary

The results obtained show the importance of a better description and characterization of tropospheric aqueous phase chemistry in atmospheric models. Therefore, the data obtained will be used as input parameters for the further development and actualization of CAPRAM 3.0 [*Herrmann et al.*, 2005].

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CAPRAM modeling of aqueous particle and cloud chemistry

Andreas Tilgner, Hartmut Herrmann, Ralf Wolke

Heterogene und Mehrphasenprozesse in Wolken haben das Potential, die chemische Zusammensetzung der Troposphäre auf globaler Skala zu modifizieren. Aufgrund der Umweltrelevanz des atmosphärischen Aerosols ist es bedeutsam, physiko-chemische Prozesse und Wechselwirkungen zu verstehen. Dazu können insbesondere detaillierte Modelluntersuchungen beitragen. In den neusten Modellstudien zur Aerosol-Wolken-Wechselwirkung konnte herausgestellt werden, dass die Flüssigphasenchemie einen signifikanten Effekt auf das troposphärische Oxidationsbudget sowohl unter schwach als auch stark anthropogen verschmutzten atmosphärischen Bedingungen haben kann. Dabei kann die Flüssigphase als Senke und Quelle für troposphärische Oxidantien in der Gasphase wirken. Weiterhin konnte gezeigt werden, dass in der Flüssigphase selbst insbesondere in feuchten Aerosolpartikeln OH-Radikale produzieren kann. Dieses Resultat impliziert die potenzielle Bedeutung von deliqueszenten Partikeln als reaktives Medium innerhalb des troposphärischen Multiphasensystems. In guter Übereinstimmung zu den vorher durchgeführten Wolkenchemiestudien [Herrmann et al., 2005; Tilgner et al., 2005] konnte gezeigt werden, dass die Oxidationen in der Flüssigphase zur Bildung von substituierten Mono- und Dicarbonsäuren führt, die zur organischen Partikelmasse beitragen können. Dabei wurde u. a. die Oxidation von Methylglyoxal und 1,4-Butendial unter urbanen Umweltbedingungen als neue wichtige OH Senke erkannt. Abschließend lässt sich sagen, dass alle bisher gewonnenen Ergebnisse die potentielle Relevanz der Flüssigphase als reaktives Medium innerhalb der Troposphäre widerspiegeln und deren Berücksichtigung sowie Implementierung in höherskaligen Chemie-Transport-Modellen erfordern.

Introduction

Clouds and deliquescent particles play a crucial role in the entire tropospheric multiphase system. Tropospheric clouds are a complex multiphase and multi-component environment with simultaneously occurring gas and aqueous phases as well as heterogeneous chemical transformations. Even if the volume of clouds is rather small, multiphase processes can potentially alter the physico-chemical composition of the tropospheric aerosol on global scale [*Ravishankara*, 1997]. However, the understanding of physico-chemical modifications of the aerosol properties is currently still limited chiefly because of the high complexity of multiphase interactions. In order to improve the understanding of the system, a proper knowledge and description of both microphysical and multiphase chemical processes are therefore crucial to appraise the role of the aerosol processing in the troposphere. In this context, tropospheric multiphase models provide a very convenient instrument for studying individual physico-chemical processes in detail. Consequently, models can help to enhance the understanding of the aerosol cloud processing and to assess the relevance of multiphase tropospheric chemical processes. In context of an inorganic and organic multiphase environment, the Chemical Aqueous Phase RAdical Mechanism (CAPRAM; *Herrmann* et al., 2005) has been developed for the application in multiphase models. For more realistic studies of the physico-chemical aerosol cloud interactions as well as processing, the SPectral Aerosol Cloud Chemistry Interaction Model (SPACCIM; *Wolke* et al., 2005) has been applied to investigate the effects of the multiphase aerosol cloud interaction on tropospheric aerosol particles and trace gases using a more realistic non-permanent cloud model scheme.

Model outline and results

The applied parcel model SPACCIM includes a complex microphysical and a detailed multiphase chemistry model. In multiphase chemistry model, the newly developed multiphase chemistry mechanism RACM-MIM2ext/CAPRAM 3.0i with about 1100 processes has been applied incorporating a detailed description of the tropospheric multiphase chemistry. This multiphase chemistry mechanism consists of an extended version of the gas phase mechanism RACM-MIM2 [*Karl* et al., 2006] coupled to the detailed aqueous phase mechanism CAPRAM 3.0i. The chemical mechanism comprises a detailed description of the multiphase chemistry based on time-dependent size-resolved aerosol/cloud spectra. The model was initialised with chemical and physical aerosol data [*Poppe* et al., 2001] for three different atmospheric conditions (urban, remote, marine). Simulations were carried out for a meteorological scenario including 8 cloud passages and an intermediate aerosol state at a 90% relative humidity level by neglecting the

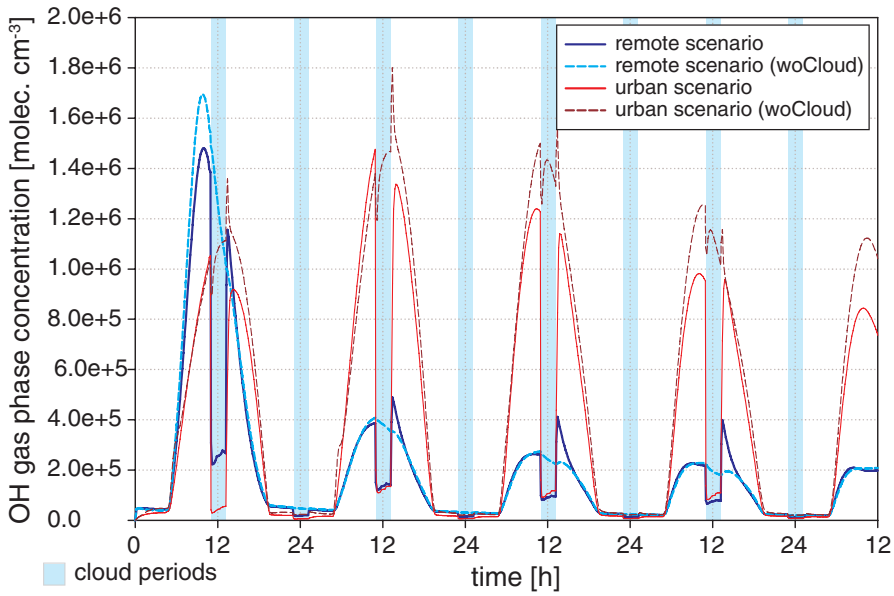

Fig. 1: *Modelled gas phase concentrations of the OH radical for the urban and remote scenario with and without aqueous phase chemistry interaction.*

effects of non-ideal solutions. Simulations have been performed with and without aqueous phase chemistry to study the effect of aerosol cloud interaction on the tropospheric multiphase system. The model results have been analysed including time resolved source and sink studies focused particularly on multiphase phase radical as well as non-radical oxidants and multiphase oxidations of C_2–C_4 organic compounds.

The model studies show significant effects of multiphase cloud droplet and aqueous aerosol interactions on the tropospheric oxidation budget (see Figure 1) for polluted and remote environmental conditions as well as influenced VOC's oxidation due to the changed oxidation budget within the clouds.

Furthermore, the simulations implicate the potential role of deliquescent particles to act as a reactive chemical medium due to the in-situ aqueous phase production of radical oxidants such as OH (see Figure 2) and no-radical oxidants such as H_2O_2. Moreover, the model study shows the importance of the aqueous phase for the formation of higher oxidised organic compounds such as substituted mono- and diacids such as pyruvic acid and tartaric acid (see Figure 3).

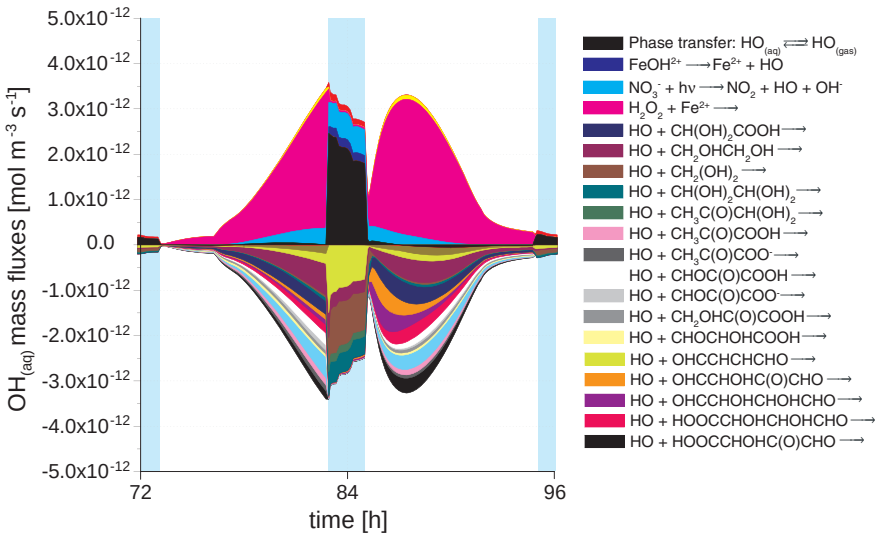

Fig. 2: *Chemical analysis of the most important aqueous phase sink and source processes of OH radical in mol m^{-3} s^{-1} under urban conditions.*

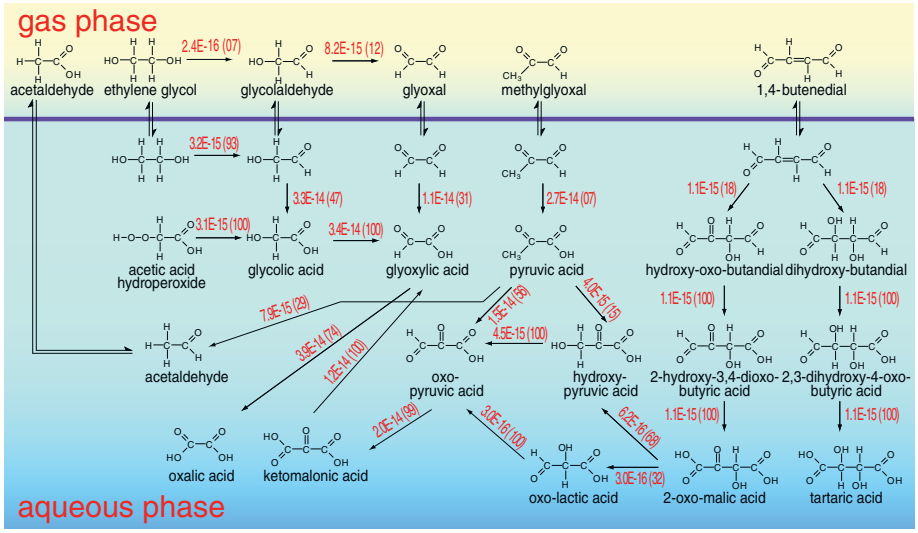

Fig. 3: *The most important aqueous phase oxidation pathways of C_2–C_4 organics contributing to the particulate organic mass production for the remote case (fluxes in mol m^{-3} s^{-1} percentages in brackets).*

In particular, the aqueous phase oxidations of methylglyoxal and 1,4-butenedial have been identified as important OH radical sinks under polluted environmental conditions contributing to the production of less volatile organic compounds and thus the organic aerosol particle mass. Further, the in-cloud oxidation of methylglyoxal and its oxidation products represents an efficient sink for NO_3 radicals in the aqueous phase particularly under urban as well as remote conditions.

Moreover, the model studies have been focused on the total organic mass productions resulting from the aerosol cloud chemistry interactions. The model results show in-cloud organic mass productions up to about 1 µg m^{-3} preferably under polluted day time cloud conditions mainly due to OH initiated multiphase oxidation processes. Finally, the sum of the results implicates the importance of the aqueous phase processes to be considered in future higher scale chemistry transport models.

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Identification of ice nuclei embedded in ice particles collected in tropospheric mixed-phase clouds

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Die heterogene Bildung von Eispartikeln in Wolken der mittleren und unteren Troposphäre kann Niederschlagsprozesse auslösen und die optischen Wolkeneigenschaften verändern. Oberhalb von ca. -38 °C wird die Eisbildung durch spezielle atmosphärische Aerosolpartikel, den Eiskeimen (engl.: ice nuclei, IN) induziert. Besonders bzgl. der Eisnukleation in Mischphasenwolken ist über die physiko-chemischen Eigenschaften der IN wenig bekannt, da hier experimentelle Untersuchungen aufgrund der Koexistenz von unterkühlten Tropfen erschwert werden. Deshalb wurde am IfT ein neuartiges bodengebundenes Sammelsystem, der Ice-Counterflow Virtual Impactor (Ice-CVI), entwickelt, welches gezielt kleine Eispartikel sammelt und alle anderen Wolkenkomponenten vorabscheidet [Mertes et al., 2007]. Nach der Verdunstung werden die Residuen dieser Eispartikel, die als IN interpretiert werden, in Kooperation mit anderen Forschungsinstitutionen identifiziert. Der Ice-CVI wurde mehrfach im Rahmen der Cloud and Aerosol Characterization Experimente (CLACE) auf der hochalpinen Forschungsstation Jungfraujoch eingesetzt. Dabei wurde festgestellt, dass die Eisbildungsfähigkeit atmosphärischer Partikel ab etwa einer Größe von 200 nm beginnt und die Effizienz mit steigendem Durchmesser weiter zunimmt. Deutliche Unterschiede wurden in der chemischen Zusammensetzung der IN im Vergleich zum Hintergrundaerosol gefunden, welches vor, während oder nach einem Wolkendurchgang über einen totalen Aerosoleinlaß gesammelt wurde. Dies lässt einen anthropogenen Einfluss auf die heterogene Eisbildung vermuten.

Introduction

The nucleation of ice particles in middle and lower tropospheric clouds can initiate precipitation and change cloud optical properties and thus affecting the radiative forcing of tropospheric supercooled clouds [*Lohmann and Feichter*, 2005]. In the lower and middle troposphere heterogeneous nucleation which is triggered by a subset of atmospheric particles, named ice nuclei (IN), is the dominant process initiating ice formation in supercooled clouds at temperatures above -38 °C. The heterogeneous ice formation can proceed via different mechanisms [*Cantrell and Heymsfield*, 2005] which include the creation of new frozen hydrometeors by deposition and condensation freezing or icing of existing cloud drops via contact and immersion freezing.

Closely related to the heterogeneous ice nucleation process is the question of the physico-chemical IN properties. Our knowledge about atmospheric particles that act as ice nuclei in tropospheric mixed-phase clouds is incomplete, because the ice phase develops in between super-cooled drops, which complicates the experimental and theoretical investigation.

For this reason a ground-based sampling device was developed at the IfT in order to extract small ice particles from tropospheric mixed-phase clouds and to identify the size and chemical composition of their residual particles that are attributed to the original IN by state-of-the-art analysis methods in collaboration with other research institutions. These measurements have been carried out within the cloud and aerosol characterization experiments (CLACE) at the high alpine research station Jungfraujoch (Swiss Alps, 3580 m asl).

Experimental

This sampling system is based on a counterflow virtual impactor (CVI), which cannot distinguish between frozen and liquid hydrometeors of the same aerodynamic size and which additionally samples large ice crystals, so that in mixed-phase clouds the residues include cloud condensation nuclei (CCN) and scavenged interstitial particles besides the desired IN. Thus, the novel inlet, called Ice-CVI, is supplemented with further components to avoid the collection of supercooled drops and large ice particles. A vertically oriented inlet horn in combination with a virtual impactor (VI) removes the precipitating ice particles larger than 20 µm. This upper size limit assures a collection efficiency of nearly one for the sampled smaller ice particles. Downstream of the VI a pre-impactor (PI) segregates the supercooled drops by their freezing at contact on cold impaction plates. The remaining ice particles bounce off without

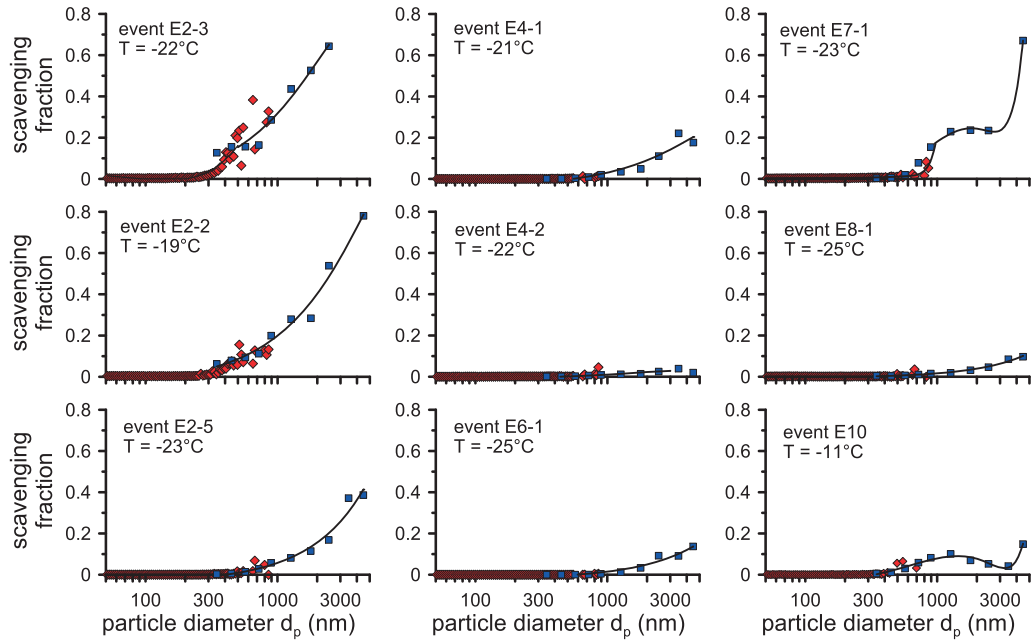

Fig. 1: *Scavenged number fractions of IN as a function of their particle size. Diamonds and squares present SMPS and OPC measurements, respectively.*

significant shattering due to their small size and low velocity and remain in the sample airflow. The CVI itself is located downstream of the PI to reject interstitial particles smaller than 5 µm by a controlled counterflow. Inside the CVI the small ice particles are injected into a particle-free and dry carrier air leading to their complete evaporation, so that the released dry residual particles can be analyzed in collaboration with other research institutions by means of dedicated instrumentation.

In a first field test within the CLACE-3 campaign in 2004 at the high alpine research station Jungfraujoch, it was verified by comparing Ice-CVI measurements with corresponding results obtained from other inlets or with in-situ instrumentation that the small ice particles are collected whereas all other mixed-phase cloud constituents are effectively suppressed [*Mertes et al.*, 2007].

Results

During the reporting period two field campaigns (CLACE-5 and CLACE-6) were carried out in February/March 2006 and 2007, respectively, coordinated by the Institute for Atmospheric Physics (University of Mainz) as activities of the collaborative research centre “The Tropospheric Ice Phase” (TROPEIS). Two former field experiments (CLACE-3 and CLACE-4) were extensively analyzed during this time.

The background aerosol particles were sampled before, during and after a cloud event by means of a total aerosol inlet and analysed in the same way as the ice particle residues in order to identify special features of the IN physico-chemical properties.

Residual particle number size distributions were obtained from a scanning mobility particle sizer (SMPS) and an optical particle counter (OPC) downstream of the Ice-CVI. Dividing these distributions by those of the background particles yields the number fraction of IN as a function of particle size (Figure 1). From this fraction it is found that super-micrometer particles preferentially serve as IN although in absolute terms the IN concentration is dominated by sub-micrometer particles larger than 200 nm.

The black carbon (BC) mass concentration of the ice particle residues was determined with a particle soot absorption photometer (PSAP). A BC mass fraction in the IN was calculated by relating

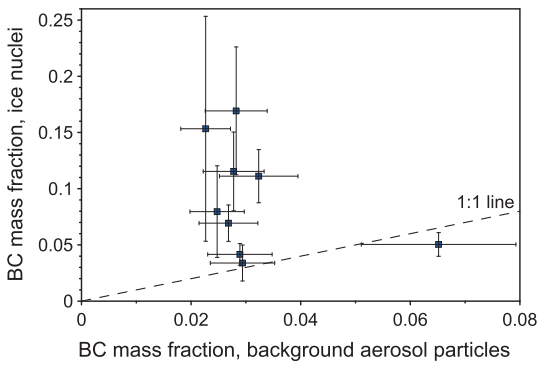

Fig. 2: *Scatterplot of BC mass fractions derived for ice nuclei and background particles sampled simultaneously with the Ice-CVI and total inlet, respectively. The dotted line indicates the 1:1 relation.*

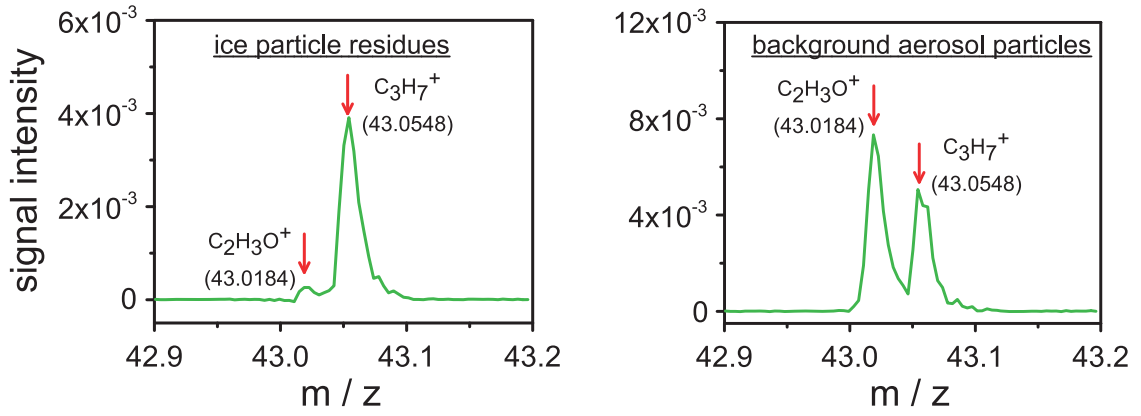

Fig. 3: Relative contributions of hydrocarbon-like and oxygenated organic aerosol particles (represented by $C_3H_7^+$ and $C_2H_3O^+$) to the ice particle residues and background particles.

its mass to the total residual mass inferred from the SMPS results. The correlation of this fraction to the BC mass fraction in the background aerosol, shown in Figure 2, reveals an enrichment of BC in the IN. This enrichment suggests that BC plays an active role in heterogeneous ice nucleation.

Another indication of an anthropogenic influence on heterogeneous ice nucleation in the lower troposphere was observed with a high-resolution, time-of-flight aerosol mass spectrometer (HR-ToF-AMS). In the ice particle residues only the hydrocarbon-like organic compound ($C_3H_7^+$) that has primary anthropogenic sources but hardly any secondary generated oxygenated organic compound ($C_2H_3O^+$) was detected in contrast to the background aerosol particles (Figure 3).

Since the importance of the particle ice nucleating capability is mainly a number and no mass related phenomenon one main effort was to couple single particle mass spectrometers to the Ice-CVI to permit the in-situ analysis of single ice nuclei. This coupling was successfully carried out with the single particle laser ablation time-of-flight spectrometer (SPLAT) and the commercial aerosol time-of-flight mass spectrometer (ATOFMS). A result of the SPLAT measurements during CLACE-6 is illustrated in Figure 4. The pie charts show the percentage of particles (regardless of the particle size) that belong to different particle groups. It is evident that the IN composition differs strongly from the background aerosol composition. Mineral dust is by far the dominating substance in the ice residues. But also carbonaceous particles

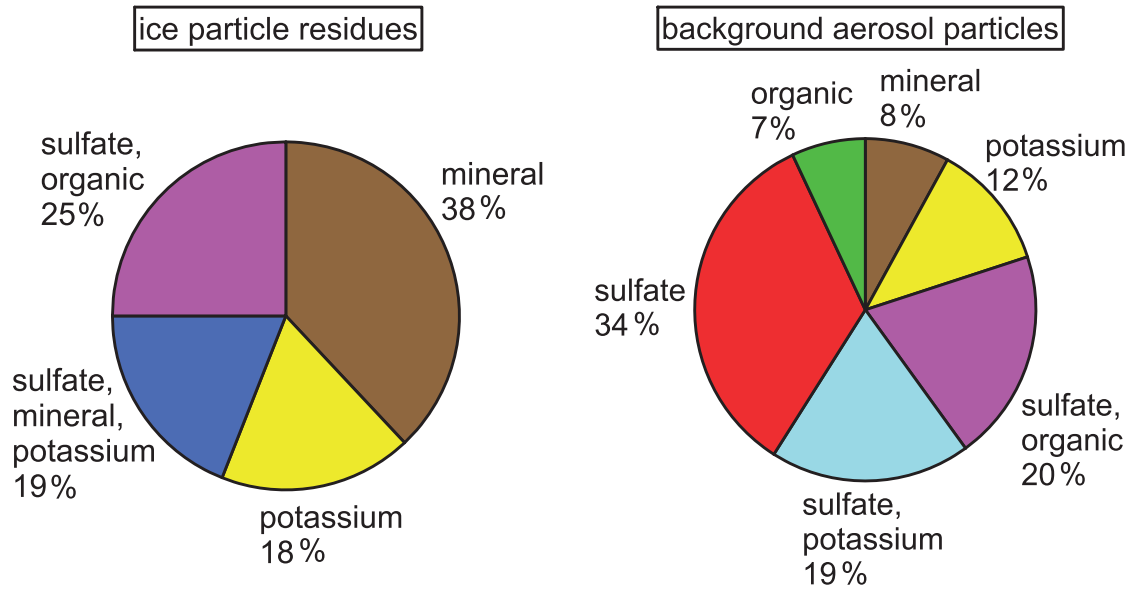

Fig. 4: Relative distribution of different particle classes in background aerosol particles and in ice particle residues obtained from single particle SPLAT measurements.

were present whereas sulfate is depleted. These findings were supported by results from the ATOFMS and by an off-line impactor sample analysis with an environmental scanning electron microscope (ESEM).

During CLACE-6 the Frankfurt IN chamber FINCH was connected to the Ice-CVI in order to activate the ice particle residues by deposition and condensation freezing to which all IN counters are restricted to. FINCH could activate only 1 of 100 residues implying that immersion and contact freezing are much more important ice particle formation processes in the investigated clouds.

It is intended to continue the investigation of ice formation in atmospheric clouds using the IfT CVI technology in cooperation with other research institutions within the second phase of TROPEIS and onboard the new German high altitude long range research aircraft HALO.

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- Institute of Applied Geosciences, Technical University of Darmstadt, Darmstadt, Germany.
- Department of Geosciences, Johann Wolfgang Goethe University, Frankfurt, Germany.
- Laboratory of Atmospheric Chemistry, Paul Scherrer Institute (PSI), Villigen, Switzerland.
- Institute for Atmospheric and Climate Science, ETH Zürich, Zürich, Switzerland.
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The influence of small-scale turbulence on droplet dynamics in stratocumulus clouds

Holger Siebert and Raymond A. Shaw

Der Einfluss kleinskaliger Turbulenz auf die Dynamik von Wolkentropfen spielt eine zentrale Rolle für das Tropfenwachstums durch Koaleszenz und bei der Entstehung von großen Wolkentropfen bis hin zur Niederschlagsbildung. Hubschraubergestützte Messungen von Turbulenz und Tropfengrössenverteilungen in quasi homogenen Stratocumuluswolken zeigen einen qualitativen Zusammenhang zwischen lokaler Turbulenz und dem Auftreten von großen Wolkentropfen mit Radien zwischen 15 – 40 µm.

Introduction

The impact of small-scale turbulence on droplet growth due to the coalescence process and the production of drizzle or precipitation in stratocumulus-like clouds is investigated. Turbulent fluctuations of the wind velocity can enhance droplet growth by different processes like the modification of the spatial droplet size distribution on smallest scales (e.g., droplet clustering at mm-scales) or increasing the collision kernel when Lagrangian acceleration becomes comparable to the gravitational acceleration [*Shaw,* 2003]. For example, when two droplets with different masses (or different diameters) are accelerated due to gravity the resulting droplet speeds (terminal velocities) will be different and the chance of colliding will be increased. If in addition to the gravity the droplets are accelerated by three-dimensional turbulence this effect is thought to increase the droplet growth due to collision/coalescence [*Pinsky and Khain*, 2004]. A key question is if we can find a correlation between local turbulence and the occurrence of large droplets in stratocumulus clouds where the energy dissipation rates (a measure for the degree of the turbulence intensity) are comparably low.

The helicopter-borne measurement payload ACTOS (Airborne Cloud Turbulence Observation System) allows simultaneous measurements of turbulence and cloud microphysical parameters as droplet sizes and concentration with sub-meter resolution. This tool was deployed in a field experiment performed from the end of September until mid October 2007 in marine stratocumulus clouds in the vicinity of Kiel, Germany.

Observations

The ACTOS payload is an autonomous measurement system which is carried as external cargo by a helicopter. To overcome the influence of the helicopter's downwash ACTOS is fixed with a 140-m-long tether to the helicopter. ACTOS is equipped with sensors to measure the three dimensional wind vector, temperature, and humidity but also the microphysical cloud properties and the interstitial aerosol. More detailed information about ACTOS can be found in *Siebert et al.* [2006] and references given therein.

From 26th of September till 12th of October 2007, several research flights were conducted from the airport Kiel-Holtenau. The flights were performed partly over land and/or the Baltic Sea in stratocumulus or shallow cumulus clouds. Since the helicopter had to remain outside of the clouds ACTOS was dipped in from above and therefore the measurements were mainly taken in the cloud-top region.

In this work we present a case study from the 30th of September. The cloud situation was not well-defined with multi layers of shallow cumulus clouds/stratocumulus including single convective cells and an overcast stratocumulus layer above. A 60-s-long (nearly 1 km) cloud penetration was sampled at 09:17 UTC at a nearly constant height of 1492 m. A picture from the on-board camera of ACTOS shortly before the cloud penetrations is shown in Figure 1.

The static air temperature at this height was at 5.2 deg C. Around this level a cloud sheet with a homogeneous cloud top had developed. In Figure 2

Fig. 1: *Picture taken with the on-board camera of ACTOS shortly before entering the analyzed cloud layer.*

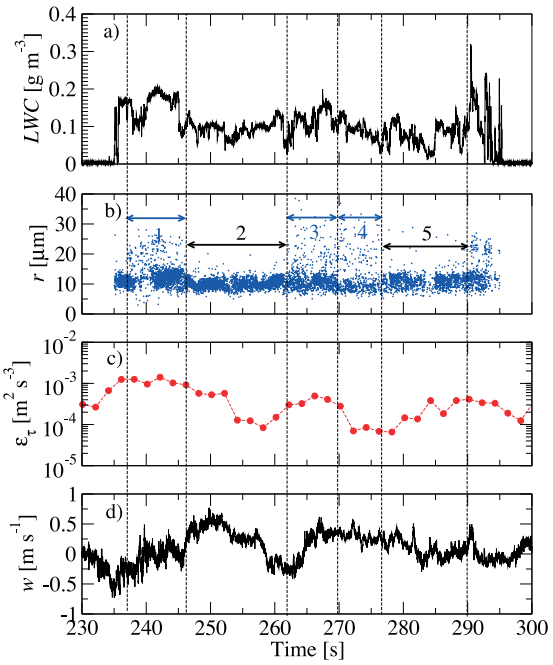

Fig. 2: *Time series of liquid water content (LWC), droplet radius (r), local energy dissipation rate ε_τ, and vertical velocity w during a 60s-long cloud penetration.*

the time series of selected parameters which describe the cloud and turbulence characteristics are shown. The general cloud structure is described by means of the liquid water content (*LWC*) which was measured with a Particle Volume Monitor (PVM-100A). The *LWC* (see Figure 2a) varies between 0.1 and 0.2 g m^{-3} and shows regions with increased fluctuations surrounded by sections with nearly uniform *LWC*. The individual droplet sizes are measured with a Phase Doppler Interferometer (PDI) [*Chuang et al.*, 2008]. In Figure 2b the time series of the droplet radius measured with PDI is shown. The PDI signal indicates regions with droplet sizes ranging from about 6 to 14 µm with a few single bigger droplets up to 20 µm (labeled with 2 and 5) but also regions with significant increased number of bigger droplets up to 40 µm (labeled with 1, 3, and 4). The two different types of regions within the same cloud indicate a complete different microphysical structure; the size distributions of both types are depicted in Figure 3 in terms of a probability density function (PDF). Even if the peak radius is slightly shifted from 9.7 to 11.2 µm the main mode of the two PDFs is quite similar. However, the PDF of type II shows a much longer positive tail indicating the increased probability of finding larger droplets.

In order to find the reason for these two different size distributions dynamical parameters like the local energy dissipation rate ε_τ and the vertical wind velocity *w* are depicted in Figure 2c and 2d. The time series of ε_τ are estimated from

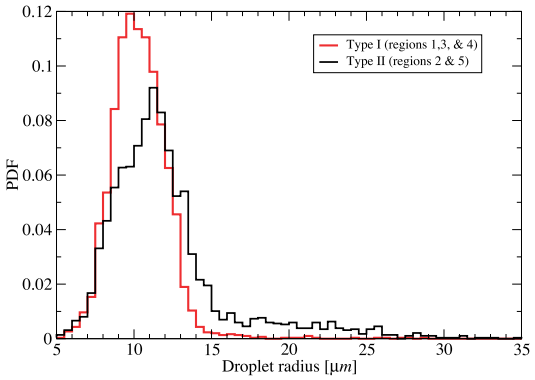

Fig. 3: *Droplet size distributions of two different types as found during the 60s-long cloud penetration. The regions refer to Fig. 2.*

2-s-long subsequences as described in *Siebert et. al* [2006]. While the absolute value of *w* shows no correlation with the droplet sizes the fluctuations of *w* and, therefore, the time series of ε_τ show increased values in the regions with large droplets and local minimums in the area with sharp size distributions. The different regions do not correlate perfectly and possible reasons will be discussed in the following. It has to be pointed out that other thermodynamic parameters such as temperature or humidity do not show any structure comparable to the droplet sizes.

Discussion & Summary

The influence of increased turbulence on the production of large droplets (broadening of the droplet size distribution) has been investigated. Cloud regions with an increased number of larger droplets (>15 µm) show a qualitative correlation with regions of increased turbulence. However, two points have to be considered: i) the regions of increased turbulence seems to be somehow shifted relative to regions with large droplets which could be caused by the different time scales of the turbulent motion and droplet growth due to coalescence and ii) even though there seems to be a correlation, the absolute values of ε_τ are quite small and from classical coalescence theory one would not expect any significant influence of turbulence on droplet growth since gravitational acceleration is about one order of magnitude higher compared with shear-induced acceleration on the observed length scales. To understand this phenomenon the turbulence on scales comparable to the droplet sizes (or at least on cm-scales) has to be investigated. High-resolution turbulence data as proposed by *Siebert et al*. [2007] could shed light on this issue. Such turbulence data are now available from the Kiel '07 campaign and are currently under analysis.

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Influence of high clouds on aerosol particle numbers in the upper troposphere

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Die Wechselwirkung zwischen Aerosolpartikeln und Wolken ist zur Zeit eines der wichtigsten Forschungsgebiete der Atmosphärenforschung. Als ein Teilaspekt dieses komplexen Themas, wurde mit Hilfe eines mehrjährigen Flugmessdatensatzes erstmals statistisch der Einfluss hoher Wolken auf die Anzahlkonzentrationen von Aerosolpartikeln in der oberen Troposphäre (8-12 km Höhe) untersucht. Dafür wurden mehr als 10.000 gemittelte Aerosolmesswerte genutzt, die im Rahmen des CARIBIC – Projekts (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container) gemessen wurden. Diese konnten mit Hilfe von Rückwärtstrajektorien und Satellitenbildern auf eine Wolkenbeeinflussung hin überprüft werden. Die durchgeführte statistische Analyse zeigte u. a., dass hochreichende tropische Wolken sehr häufig mit Partikelneubildung verknüpft sind. Gleichzeitig bestätigen die Ergebnisse diese als Senke für Aitken- und Akkumulationsmodepartikel.

Introduction

The knowledge of atmospheric aerosol processes and life cycles is still not good enough for an adequate modeling of global aerosol fields [*Textor et al*., 2007]. Whereas progress has been made in near-surface conditions [*Spracklen et al*., 2007], aerosol interaction with clouds is highly unknown and hence is poorly represented in climate models [*IPCC*, 2007]. Aerosol particles do not only influence cloud microphysics, but inversely clouds also influence the particle number concentration and chemical composition (see e.g., *Tilgner et al*., this report). Concerning particles in the free troposphere, clouds can act as a source of new particles by supporting homogeneous nucleation, as vertical transporter for aerosol particles from the boundary layer, or as sink for particles (e.g., *Perry and Hobbs* [1994]; *Zhang et al*. [1998]; *Ekman et al*. [2006]). These processes are particularly relevant in the upper troposphere (UT), where sources of primary particles are rare. However, there are only a few reports on experimental studies, which investigated the influence of clouds on aerosol particles. Moreover, these studies represent only individual case studies in small areas and short time periods (e.g. *de Reus et al*. [2001]).

In the CARIBIC project (Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container) a passenger aircraft is deployed for in situ and retrospective laboratory measurements of trace gases and aerosol particles in the UT and lower stratosphere (LS) [*Brenninkmeijer et al*., 2007, www.caribic-atmospheric.com]. Since 1997, more than 150 measurements flights have been conducted on five different flight routes. With this unique data set, for the first time a statistical analysis of the influence of clouds on the particle number concentration in different size bins became possible.

CARIBIC aerosol data

The present study is based on measurements on two flight routes of the first phase of CARIBIC (CARIBIC-1) between 1997 and 2002. The “Indian” route extends between Germany and Sri Lanka/Maldives in the Indian Ocean, and the “Caribbean” route between Germany and the Caribbean crossing the North Atlantic Ocean.

In CARIBIC-1 the number concentrations of nucleation mode particles (4 nm < d_p < 12 nm, $N_{4\text{-}12}$) and Aitken mode particles (12 nm < d_p, N_{12}) were measured using modified Condensation Particle Counters [*Hermann and Wiedensohler*, 2001]. Besides the particle measurements, also trace gases, like O_3 or CO were measured. In order not to distort the analysis, stratospheric samples were removed from the data set by applying an ozone tropopause definition given by *Zahn and Brenninkmeijer* [2003].

Cloud contact analysis

To analyze the history of the measured air parcels, five day back trajectories were calculated every three minutes along the CARIBIC flight tracks by the Royal Netherlands Meteorological Institute (KNMI, http://www.knmi.nl/samenw/campaign_support/CARIBIC/). For the calculation “first guess” wind fields (6 hours forecast) from the ECMWF hybrid sigma-pressure model as well as analyzed fields were used as input. To account for the spatial uncertainties of long trajectories, we analyzed each trajectory only over the two days preceding the measurement.

To examine the back trajectories for cloud contacts, we used a cloud analysis product provided by the International Satellite Cloud Climatology Project (ISCCP) (http://isccp.giss.nasa.gov). The ISCCP-DX data product contains a Cloud Top Temperature (CTT) as well as a Cloud Top Height (CTH), which could be directly compared to the trajectory height.

To combine the trajectories with the satellite pictures, a FORTRAN-algorithm was developed which puts the trajectories and the satellite images on top of each other. If there is a cloud at the trajectory node, the algorithm compares the cloud top pressure to the trajectory pressure. Due to the different temporal resolution of trajectories (1 h) and satellite pictures (3 h), the analysis algorithm contains a linear interpolation of the CTH between two pictures. Furthermore, the algorithm contains a wind-direction-dependent search function, finding the closest pixel of the satellite picture to the analyzed trajectory node. If the satellite picture was recorded prior to the trajectory node, the program searches against the wind direction. If the satellite picture was recorded after the trajectory node, the program searches downwind.

To evaluate the linear time-interpolation procedure, we compared our interpolated CTT data to non-interpolated data with a temporal resolution of 15 min. Therefore, we used satellite data of GOES-east from the National Oceanic and Atmospheric Administration (NOAA) (http://www.class.noaa.gov/saa/products/welcome). These data were processed to CTTs at the Max-Planck-Institute for Chemistry in Mainz. In summary, we found a good agreement with no systematic discrepancies.

Applying the whole cloud analysis algorithm to the back trajectories, the following questions could be answered for all measurement points:

- Had the air parcel been in contact with a cloud within the previous 48 hours?
- If so, at which local time did this occur?
- How long was the last cloud contact?
- How much time elapsed between the last cloud contact and the measurement?

The particle number concentrations of the air parcels were defined by the average ±30 sec around the starting points of the backward trajectories. The data for each of the two routes were analyzed separately for the tropics, the subtropics, and mid-latitudes to account for differences in cloud types. Here we present only some results for the tropics over the Arabian Sea as an example. More specific analyses of all regions are in progress and will be published in 2008.

First results

To visualize the time-dependent influence of clouds on the number concentrations, the measured values were plotted as mean and median versus the time elapsed between the last cloud contact and measurement (Figure 1). In this figure, all measurements for which the last cloud contact occurred within the last 24 hours were used to calculate the mean and median concentration at 24 h. This “integral” time presentation was used to get smoother curves (more data points) compared to a representation which includes only concentrations with cloud contact at a given time. The disadvantage is, however, that a potential dependency on cloud contact time is damped. In each graph, at long time differences many more cloud cases (>400 at 47 h) were available compared to the short time differences (20 at 0 h). Each cloud case includes on average three concentration values. In both diagrams blue squares represent the cloud influenced means and red triangles the cloud influenced medians. Uninfluenced background

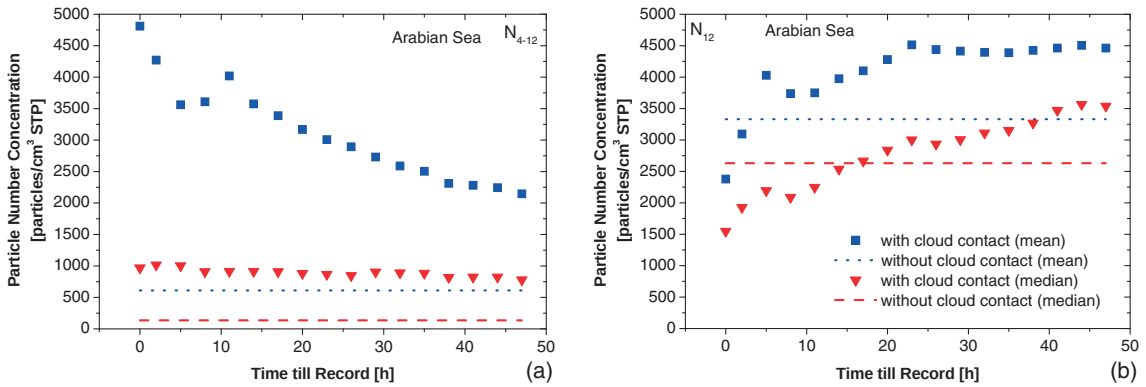

Fig. 1: *Dependency of particle number concentrations on the time between the last cloud contact and the measurement, (a): N_{4-12}, (b): N_{12}. Each point includes all values for which the last cloud contact fell into the time period indicated at the x-axis.*

values are indicated as dotted and dashed lines in the same color.

As it can be seen in Figure 1, the shorter the time between the last cloud contact and measurement, the higher is the mean number concentration of nucleation mode particles and the lower is the mean concentration of Aitken mode particles. The nucleation mode particles are likely formed in the outflow region of convective clouds, because of the lifetime of such particles is too short to transport them from the boundary layer to the UT [*Seinfeld and Pandis*, 1998; *Williams et al*., 2002]. In the outflow region, the temperature is low, the relative humidity is high, actinic fluxes are high, preexisting particle surface area is low, and if emitted in the boundary layer oxidized precursor gases are available. These all are conditions, which favor particle nucleation (e.g., *Kojima et al*. [2004]; *Kulmala et al*. [2006]).

A comparison between the cloud influenced $N_{4\text{-}12}$ values in Figure 1a shows that in contrast to the mean the median decreases much less with increasing time elapsed between cloud contact and measurement. The $N_{4\text{-}12}$ median at time lag 47 is about 20% lower than the $N_{4\text{-}12}$ median at time lag zero. However, in comparison to the $N_{4\text{-}12}$ median background, the cloud-influenced $N_{4\text{-}12}$ medians were almost six times higher. Hence, a strong influence of clouds is apparent. This behavior of mean and median of $N_{4\text{-}12}$ indicates that most of the tropical clouds over the Arabian Sea contribute to particle formation. Thereby few clouds cause large particle bursts, which raise the overall mean number concentration to almost 5000 particles/cm³. The $N_{4\text{-}12}$ mean strongly decreases with increasing time difference, because in air parcels with a high particle number concentration, also the coagulation is enhanced.

The picture of new particle formation in spatial and temporal vicinity of clouds is supported by the behavior of the Aitken mode particles. First, clouds act as particle sink (data points to the left in Figure 1b), which leads to mean and median number concentrations below the non-cloud influenced background (dotted and dashed line). However, with increasing time between cloud contact and measurement, the Aitken mode number concentrations increase above these background values. This increase is probably caused by condensational growth from the nucleation mode particles to Aitken mode size. As the mean and the median behave in parallel, most of the tropical clouds over the Arabian Sea seem to act as sink for Aitken mode particles.

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Simulation of deep convective clouds using the model system COSMO-SPECS

Verena Grützun, Oswald Knoth, Martin Simmel

Das Modellsystem COSMO-SPECS wurde am IfT Leipzig entwickelt und vereint eine spektrale Wolkenmikrophysik mit dem mesoskaligen Wettermodell COSMO des Deutschen Wetterdienstes. In den letzten zwei Jahren wurde es weiterentwickelt, insbesondere wurde eine Gemischtphasenmikrophysik in das Modell eingeführt und anhand idealisierter Modellfälle, wie der einer Wärmeblase über flachem Gelände, getestet. Diese Tests führten zu einem weitgehend zufriedenstellenden Ergebnis, so dass COSMO-SPECS nun für die Modellierung realistischer Fälle und zur Untersuchung des Einflusses von atmosphärischem Aerosol auf die Entwicklung von Niederschlag verwendet werden kann. Erste Modellergebnisse basierend auf idealisierten Daten einer hochreichenden konvektiven Wolke, die über Midland, Texas beobachtet wurde, werden hier vorgestellt. Das Modellsystem reproduziert die wesentlichen Eigenschaften der Wolke, wie einen hohen Flüssigwasseranteil im Aufwindbereich und einen komplett vereisten Amboss. Eine Sensitivitätsstudie bezüglich der Anzahlkonzentration der Aerosolpartikel macht den Einfluss des atmosphärischen Aerosols auf den Niederschlag deutlich. So führt eine Erhöhung dieser Anzahlkonzentration zu geringerem Niederschlag. Weitere Entwicklungen des Modells sind geplant, insbesondere der Gemischtphase, sowie realistische Fallstudien anhand von Daten, die im Rahmen der COPS Messkampagne 2007 erhoben wurden.

Introduction

The formation and the amount of precipitation are directly influenced by aerosol particles in the atmosphere. It depends on their number, size and composition, which number, size and aerosol content the resulting cloud droplets have. Those cloud droplets grow further by condensation and coalescence, which eventually leads to the formation of warm rain. Also, at temperatures below 0 °C, droplet freezing can take place, being dependent on the availability of suitable ice nuclei. This cloud ice can further influence the precipitation.

To better comprehend the mechanisms leading to precipitation and to understand the influence of atmospheric aerosols on the amount of precipitation, we combined a spectral cloud microphysics considering the aerosol particles explicitly with the mesoscale weather model COSMO [formerly “Lokalmodell” (LM), *Steppeler et al.*, 2003]. During the last years this model system has been further developed, especially a mixed phase microphysics was introduced. First results from a realistic case study on a deep convective cloud, which was observed in Texas in 1999, are presented here.

The model system COSMO-SPECS

COSMO is the non-hydrostatic mesoscale weather forecast model of the German Weather Service (“Deutscher Wetterdienst” DWD). The spectral bin microphysics by *Simmel and Wurzler* [2006] and *Diehl et al.* [2007] explicitly describes partly soluble and completely insoluble aerosol particles, liquid hydrometeors and mixed phase hydrometeors in size resolved spectra with currently 66 size bins ranging from a radius of 10^{-3} µm up to 4.2 x 10^{3} µm. The microphysical processes being included in the model are:

- Condensation/vapor deposition
- Collisions between the various hydrometeors
- (Spontaneous) Break-up
- Heterogeneous freezing (contact and immersion)
- freezing/melting of mixed phase particles.

The performance of the model system has been tested on idealized test cases such as a heat bubble over flat terrain and an idealized mountain overflow. Now, COSMO-SPECS is applied to realistic cases.

Case setup

Presented are results from 2D simulations of a deep convective mixed phase cloud having been observed on August 13th, 1999 over Midland/ Texas [*Rosenfeld and Woodley*, 2000]. The model domain is 125 km in horizontal direction with a resolution of 250 m. The model top is at 22 km, the vertical resolution 125 m. The atmosphere is initialized with an idealized vertical sounding [*Khain et al.*, 2001; edited by *Blahak*, 2007]. The temperature, dewpoint, wind speed and water vapor mixing ratio (MR) of this sounding are illustrated in Figure 1. The dynamics has been calculated with a time step of 2 s. For the microphysics as well as the dynamical tendencies of the moist quantities, a time step of 1 s has been used. Convection was initialized by a differential

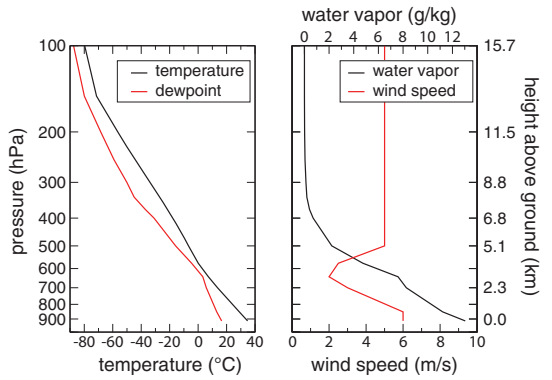

Fig. 1: *Idealized sounding data, Texas, August 13th, 1999.*

heating of the boundary layer with a heating rate of 0.0042 K/s for 10 min. A uni-modal lognormal distribution was used to initialize the aerosol spectra.

Results

Figure 2 shows the development of the modeled cloud. The total water MR, which is a sum of the water in the liquid and in the mixed phase particle spectrum, is illustrated by the colored contours. Black contours (same levels) only represent the water from the liquid particle spectrum including rain. After 30 min, a purely liquid cloud has formed. The cloud base is located at a height of about 4 km.

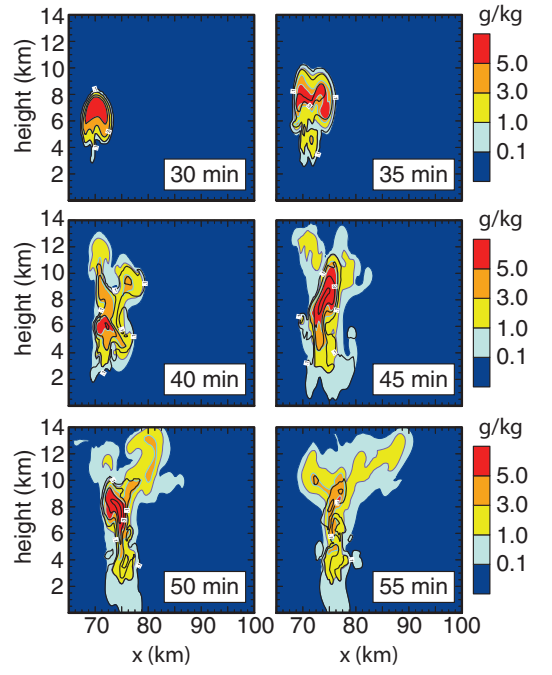

Fig. 2: *Time evolution of the Texas cloud. Colors: total condensed water MR; black: liquid water MR (same levels).*

After 35 min, ice has formed, yet in all parts of the cloud the liquid phase is still present. The rather symmetric structure of the cloud starts dissolving due to the westerly wind. In the following, water is transported further up, the cloud top is found at about 14 km. In the upper part, only mixed phase particles are present after 40 min. At 45 min, in a region of strong updraft in the cloud centre, much liquid water is formed. This water partly freezes and is transported further up as ice, and partly falls out as precipitation. At 55 min, a glaciated anvil has formed, meaning a further horizontal distribution of the water. These results compare well with other model studies of the Texas cloud by *Seifert et al.* [2006], which shows that COSMO-SPECS is performing reasonably well under realistic conditions.

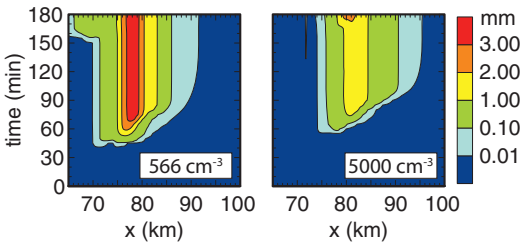

Fig. 3: *Time space evolution of precipitation for clean (left) and polluted case (right).*

Figure 3 shows the time space development of the accumulated precipitation for the cloud presented above ("clean case", initial particle number density N_{init} = 566 cm^{-3} [*Kreidenweis et al.*, 2003]) in comparison with a "polluted case", (N_{init} = 5000 cm^{-3}). In the latter case, the maximum precipitation is much less pronounced than in the cleaner case. Also, the precipitation reaches the ground later and thus, due to the horizontal transport of the cloud, further to the East. This is due to smaller cloud droplets evolving from a larger number of aerosol particles. With the smaller radii, coalescence is less efficient, so that the onset of precipitation is delayed and its amount is reduced. After 150 min, some water falls out of a secondary cloud evolving at about 65 km. This secondary cloud, respectively the resulting precipitation, is much more pronounced in the clean case than in the polluted one.

Conclusions and Outlook

The model system COSMO-SPECS has been further developed. Especially, the mixed phase microphysics has been introduced and was tested in detail on idealized cases. Presented were first results from a realistic case study, which based

on observations of a deep convective cloud over Texas in August 1999. The model system reproduces the basic characteristics of the cloud. Also, a strong increase of the initial aerosol particle number density led to a decrease of the resulting accumulated rain, which points to the importance of including a proper description of aerosols for the correct prediction of precipitation. Though the model initialization with regard to the aerosol particle spectrum was rather simple, the results already compare well with results from other modeling groups [*Seifert et al.*, 2006]. Thus, a first validation of COSMO-SPECS was achieved.

Further improvements of the model system are planned. This includes an extension of the mixed phase particle spectrum to larger particles and also the association of differing ice particle characteristics with different parts of the mixed phase spectrum to represent a wider range of ice particle types. Further case studies are planned in cooperation with the PP 1167 "Quantitative precipitation forecast" using a variety of data from the recent COPS field campaign [*Wulfmeyer et al.*, 2007]. Finally, COSMO-SPECS will serve to investigate in detail the influence of aerosol particles on the formation of precipitation. The knowledge gained here may serve to improve the currently used one- and two-moment bulk parameterizations with regard to a better inclusion of aerosol particles.

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Cooperation

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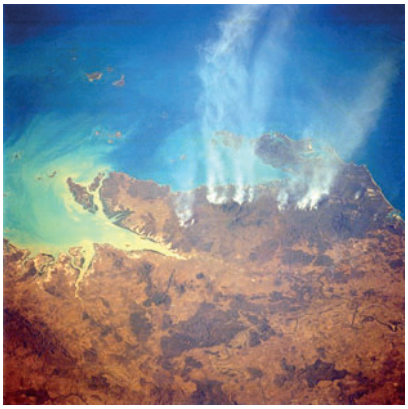

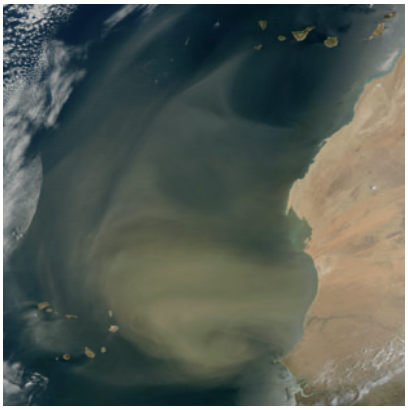

Appendices

Publication statistics

Total number and per department *)

		2006	2007
Total number of publications		**216**	**219**
1.	Books (author, editor)	0	1
2.	Book sections	6	7
3.	Conference proceedings	60	61
4.	Publications, peer-reviewed	48	50
5.	Publications, other	4	3
6.	Lectures, invited	22	18
7.	Lectures, other	76	79
Department of Physics		**131**	**109**
1.1	Books (author, editor)	0	0
1.2	Book sections	1	1
1.3	Conference proceedings	43	44
1.4	Publications, peer-reviewed	25	32
1.5	Publications, other	4	3
1.6	Lectures, invited	13	10
1.7	Lectures, other	45	19
Department of Chemistry		**43**	**62**
2.1	Books (author, editor)	0	0
2.2	Book sections	0	0
2.3	Conference proceedings	11	10
2.4	Publications, peer-reviewed	10	11
2.5	Publications, other	0	0
2.6	Lectures, invited	5	4
2.7	Lectures, other	17	37
Modeling Department		**42**	**48**
3.1	Books (author, editor)	0	1
3.2	Book sections	5	6
3.3	Conference proceedings	6	7
3.4	Publications, peer-reviewed	13	7
3.5	Publications, other	0	0
3.6	Lectures, invited	4	4
3.7	Lectures, other	14	23

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

Publications

Legend: Department of Physics
Department of Chemistry
Modeling Department

Books (author, editor)

2007

Borrego, C. and Renner, E. (Eds.) (2007), Air pollution modeling and its application XVIII, xxxviii, 866 pp., Elsevier, Amsterdam. (Developments in environmental science ; 6)

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2006

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Weller, C., Dänhardt, S., Hoffmann, D. and Herrmann, H. 2007. *Untersuchungen zur Reaktivität des OH Radikals gegenüber Mono- und Dicarbonsäuren in wässriger Lösung.* DPG-Frühjahrstagung. Regensburg, Deutschland. 26-30 März.

Weller, C., Taenza, P., Daenhardt, S., Hoffmann, D. and Herrmann, H. 2007. *Reactivity of the OH-radical towards mono- and dicarboxylic acids in aqueous solution*. 8th Informal Conference on Atmospheric and Molecular Science, Helsingør, Denmark, 8-10 June.

Wex, H., Stratmann, F., Bilde, M., Dusek, U., Frank, G., Hennig, T., Henning, S., Kiendler-Scharr, A., Kiselev, A., Kristensson, A., Mentel, T., Pöschl, U., Rose, D., Schneider, J., Snider, J., Tillmann, R., Walter, S. and Wennrich, C. 2007. *LExNo ^ Hygroscopic growth and activation of laboratory-generated aerosol particles imitating combustion aerosols*. 2nd ACCENT Symposium 2007: Atmospheric composition change - Causes and Consequences - Local to Global, Urbino, Italy, 23-27 July.

Wolke, R. 2007. *Das Modellsystem COSMO-MUSCAT.* Workshop „Chemie und Aerosole in COSMO“. Karlsruhe, Deutschland. 9. Oktober.

Wolke, R., Hinneburg, D. and Renner, E. 2007. *The influence of local emissions and long-range transport on PM10 h otspots in Saxony*. ACCENT/GLOREAM Workshop / 20th Workshop on Tropospheric Chemical Transport Modelling, Berlin, Germany, 28-30 November.

Ziereis, H., Schlager, H., Stock, P., Schumann, U., Brenninkmeijer, C. A. M., Slemr, F., Zahn, A. and Hermann, M. 2007. *Large scale ditribution of nitrogen oxides in the UTLS - Results of the NO and NO_y measurements during CARIBIC*. EGU General Assembly 2007, Vienna, Austria, 15-20 April.

Awards

Publication award of the Leibniz Institute for Tropospheric Research 2006

Hellmuth, O. (2006), Columnar modelling of nucleation burst evolution in the convective boundary layer - first results from a feasibility study - Part I - IV, *Atmos. Chem. Phys.*, *6*(12), 4175-4274.

Publication award of the Leibniz Institute for Tropospheric Research 2007

Heinold, B., J. Helmert, O. Hellmuth, R. Wolke, A. Ansmann, B. Marticorena, B. Laurent, and I. Tegen (2007), Regional modeling of Saharan dust events using LM-MUSCAT: Model description and case studies, *J. Geophys. Res.-Atmosp.*, *112*(D11), D11204, doi:11210.11029/12006JD007443.

University courses

Winter semester 2005/2006

University Leipzig
Faculty of Physics and Earth Science
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J.	Atmospheric Aerosols I	2 HPW
Heintzenberg, J.	Modern Meteorological Instruments II	1 HPW
Heintzenberg, J.	Postgraduate Seminar	1 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
Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols I Lab	1 HPW
Wandinger, U.	Atmospheric Optics	2 HPW

Summer semester 2006

University Leipzig
Faculty of Physics and Earth Science
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J. Tegen, I. Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols II	2 HPW
Heintzenberg, J.	Postgraduate Seminar	1 HPW

*) Hours per week

Lecturer	Course	HPW*)
Herrmann, H.	Atmospheric Chemistry II Atmospheric Chemistry Seminar	2 HPW 2 HPW
Renner, E. Knoth, O. Wolke, R. Hellmuth, O. Simmel, M. Tegen, I. Helmert, J.	Mesoscale Meteorological Modeling/ Regional Climate Modeling	2 HPW
Ansmann, A. Müller, D. Wandinger, U.	LIDAR: Laser Remote Sensing in the Environment and Atmospheric Science Atmospheric Chemistry Seminar	1 HPW

Guest lectures: summer semester 2006

Lecturer	Course	
Heintzenberg, J.	Lecture: “Optical and Climate Effects of the Atmospheric Aerosols”	Summer school of the University Warsaw, Jastarnia, Poland, June 2006
Hellmuth, O.	Lecture: “Weather Prognosis (NWP) within the Scope of the Program Lectures ‘Sources, Pathways, and Receptors of Extreme Floods’” (FLOODmaster Program)	Technical University Dresden, May 2006

Winter semester 2006/2007

University Leipzig
Faculty of Physics and Earth Science
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J.	Frontlines of Atmospheric Research Modern Meteorological Instruments I Modern Meteorological Instruments II	1 HPW 1 HPW 1 HPW
Heintzenberg, J.	Atmospheric Aerosols I	2 HPW
Heintzenberg, J.	Postgraduate Seminar	1 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
Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols Lab	1 HPW
Wandinger, U.	Atmospheric Optic	2 HPW

*) Hours per week

Summer semester 2007

University Leipzig
Faculty of Physics and Earth Science
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J. Tegen, I. Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols II Lab	block course
Heintzenberg, J. Tegen, I. Wiedensohler, A.	Atmospheric Aerosols II	2 HPW
Heintzenberg, J. Wiedensohler, A.	Atmospheric Aerosols II Seminar	2 HPW
Heintzenberg, J. Dubois, R. Klugmann, D. Siebert, H. Spindler, G.	Modern Meteorological Instruments I	1 HPW
Heintzenberg, J.	Postgraduate Seminar	1 HPW
Herrmann, H.	Atmospheric Chemistry II Atmospheric Chemistry Seminar	2 HPW 2 HPW
Renner, E. Knoth, O. Wolke, R. Hellmuth, O. Simmel, M. Tegen, I.	Mesoscale Meteorological Modeling/ Regional Climate Modeling	2 HPW
Ansmann, A. Müller, D. Wandinger, U.	LIDAR: Laser Remote Sensing in the Environment and Atmospheric Science	1 HPW

Guest lectures: summer semester 2007

Lecturer	Course	HPW*)
Hellmuth, O.	Lecture: “Weather Prognosis (NWP) within the Scope of the Program Lectures ‘Sources, Pathways, and Receptors of Extreme Floods’” (FLOODmaster Program)	Technical University Dresden, June 2007

*) Hours per week

Winter semester 2007/2008

University Leipzig
Faculty of Physics and Earth Science
Meteorology

Lecturer	Course	HPW*)
Heintzenberg, J. Stratmann, F. Wiedensohler, A.	Atmospheric Aerosols Lab	block course
Heintzenberg, J.	Modern Meteorological Instruments II Frontlines of Atmospheric Research	1 HPW 1 HPW
Heintzenberg, J.	Postgraduate Seminar	1 HPW
Wandinger, U.	Atmospheric Optics	2 HPW
Ziemann, A. (Univ. Leipzig) Heintzenberg, J. Herrmann, H.	Fundamentals of Cloud Physics	2 HPW
Renner, E.	Modeling of Transport and Chemical Transformation of Air Pollutants	2 HPW
Herrmann, H.	Atmospheric Chemistry I Atmospheric Chemistry Seminar Atmospheric Chemistry Lab	2 HPW 2 HPW block course

Guest lectures: winter semester 2007

Lecturer	Course	HPW*)
Heintzenberg, J.	Lecture: “Frontlines in Earth System Science”	Chinese Academy of Sciences, Institute for Geography and Natural Resources, September 2007

*) Hours per week

Master theses

Master thesis 2006

University Leipzig Faculty of Physics and Earth Science	
Bauer, Stefan	Partikelneubildung und Wachstum ultrafeiner Partikel in Peking, China
Eichler, Heike	Hygroscopic behavior and simulation of the aerosol extinction in South East China at ambient conditions
Grein, Matthias	Charakterisierung und Erweiterung der Empfängeroptik des IfT-Ramanlidars MARTHA für kombinierte Aerosol- und Wolkenmessungen
Meier, Jessica	Untersuchung des hygroskopischen Partikelwachstums des urbanen Aerosols in Peking/China und die Simulation der Sichtweite
Seifert, Patric	Seasonal dependence of geometrical and optical properties of tropical cirrus determined from lidar, radiosonde, and satellite observations over the polluted tropical Indian Ocean (Maldives)
Stock, Maria	Hygroskopische Eigenschaften und Mischungszustände des sommerlichen ostmediterranen Aerosols in Abhängigkeit von der Luftmasse auf Kreta
Tesche, Mattias	Optische und mikrophysikalische Charakterisierung anthropogener Partikel in Südchina (Pearl River Delta) und Nordchina (Peking) anhand von Ramanlidar- und Sonnenphotometermessungen
Ziese, Markus	Untersuchung des hygroskopischen und dynamischen Wachstums organischer Aerosolpartikel am Leipzig Aerosol Cloud Interaction Simulator

University Leipzig Faculty of Chemistry and Mineralogy	
Müller, Conny	Aerosolkammeruntersuchungen und CE/ESI-MS Analyse partikulärer Produkte der Ozonolyse von Alkenen

Technical University Bergakademie Freiberg Interdisciplinary Ecological Center	
Lupa, Kristina	Schnelle Bestimmungen der korngrößenabhängigen Deposition luftgetragener Umweltpartikel in der menschlichen Lunge
Weigert, Barbara	Lasergestützte Untersuchungen von Reaktionen des OH-Radikals in wässriger Lösung
Weller, Christian	Reaktivität des NO_3-Radikals gegenüber atmosphärenchemisch relevanten substituierten Phenolen in wässriger Lösung

University of Applied Sciences Jülich	
Pelzer, Johannes	Aufbau und Erprobung eines spektralen Online-Absorptionsphotometers

University of Applied Sciences of Zwickau	
Stopfkuchen, Katja	Untersuchung zu Verlusten an Aerosolpartikeln in langen rohrförmigen Probenahmensystemen

Master thesis 2007

University Leipzig Faculty of Physics and Earth Science	
Baars, Holger	Continuous monitoring of the planetary-boundary layer depth with LIDAR
Filaus, Elmar	Reibungsbehaftete Überströmung quasi-zweidimensionaler Hindernisse
Kaaden, Nicole	Hygroskopische Eigenschaften feiner und grober Aerosolpartikel über Nordwestafrika
Klose, Susan	Bestimmung von Emissionsfaktoren feiner und ultrafeiner Partikel unter Umweltbedingungen
Merkel, Maik	Emission, Transformation und Transport verkehrsemittierter Partikel in der kleinräumigen Umgebung einer Straßenschlucht
Niedermeier, Dennis	Aufbau und Inbetriebnahme einer mobilen Version des Leipzig Aerosol Clud Interaction Simulators und dessen Einsatz zur Untersuchung des hygroskopischen Wachstums und der Aktivierung von Seesalz-Partikeln erzeugt aus verschiedenen Meerwasserproben
Nordmann, Stefan	Messung von graphitischem Kohlenstoff in atmosphärischen Partikelproben unterschiedlicher Messorte und Aerosolreservoire zur Charakterisierung lichtabsorbierender Partikel
Schladitz, Alexander	Optische Eigenschaften des feinen und mineralischen Aerosols über dem nordwest-afrikanischen Kontinent
Weigelt, Andreas	Modifikation von Aerosolpartikeln in der oberen Troposphäre durch Wolken
Weinhold, Kay	Einflüsse meteorologischer Parameter auf die Feinstaubbelastung in urbanen und ländlichen Regionen des Freistaates Sachsen

University Leipzig Faculty of Chemistry and Mineralogy	
Schaefer, Thomas	Kinetik von Reaktionen des NO_3-Radikals mit polysubstituierten Phenolen in wässriger Lösung

Chair in Geoecology Interdisciplinary Ecological Center Technical University Bergakademie Freiberg	
Heinke, Katja	Größenverteilung der Gesamt- sowie nichtflüchtigen Bestandteile luftgetragener Partikel in der städtischen Atmosphäre von Augsburg

Freie Universität Berlin Department of Earth Sciences	
Reinfried, Franziska	Density currents in the Atlas Mountains leading to dust mobilization: A model sensitivity study

Martin Luther University Halle-Wittenberg Faculty for Natural Sciences Institute for Computer Science	
Schlegel, Martin	Implementation of multirate Runge-Kutta methods for air pollution models

Doctoral theses

Doctoral thesis 2006

University Leipzig Faculty of Physics and Earth Science	
Nowak, Andreas	Das feuchte Partikelgrößenspektrometer: Eine neue Messmethode zur Bestimmung von Partikelgrößenverteilungen (< 1 µm) und größenaufgelösten hygroskopischen Wachstumsfaktoren bei definierten Luftfeuchten
von Löwis of Menar, Sibylle	Measurements within the exhaust plume of a passenger car under real-atmospheric dilution and on-road driving conditions

University Leipzig Faculty of Chemistry and Mineralogy	
van Pinxteren, Dominik	Organische Säuren in troposphärischen Partikeln und Wolkenwasser: Feldmessungen und analytische Methodenentwicklung

Doctoral thesis 2007

University Leipzig Faculty of Physics and Earth Science	
Lehmann, Katrin	Experimental Investigations of the Influence of Turbulent Mixing on Cloud Microphysical Processes
Reichelt, Manuela	Entwicklung und atmosphärische Anwendung eines optischen Partikelzählers für Tropopausenbedingungen

University Leipzig Faculty of Chemistry and Mineralogy	
Hoffmann, Dirk	Multiphasenchemie substituierter Phenole: Analytik und Prozessstudien
Parajuli, Kshama	Laser-based Kinetic Investigations of Halogen Radicals in Aqueous Solution

Habilitation

Habilitation 2007

University Leipzig Faculty of Physics and Earth Science	
Müller, Detlef	Characterization of Free-Tropospheris Particles With Multiwavelength Raman Lidar: Geometrical, Optical, and Microphysical Properties of Aerosol Pollution From Europe, North Africa, South Africa, and North America

Guest scientists

Guest scientists 2006

Name	Period of stay	Institution
A. Frey	06-01-16/30	Finnish Meteorological Institute Helsinki, Finland
N. Joungmin	06-01-28/ 06-07-30	Gwangyu Institute of Science and Technology, Korea
R. Soto Ayala	06-02-01/ 06-05-05	University of Mexico City, Mexico
I. Morozov	06-03-15/ 06-05-14	Russian Academy of Sciences, Moscow Institute of Chemical Physics, Russia
M. Komppula	06-04-01/ 06-12-31	Finnish Meteorological Institute Helsinki, Finland
E. Engström	06-04-03/ 06-07-28	Stockholm University, Sweden
Y. Cheng	06-04-06/ 06-06-26	Peking University, China
A. Malinka	06-05-08/ 06-07-31	National Academy of Science of Belarus, Stepanov Institute of Physics Minsk, Belarus
J. Barret	06-05-15/20	HMS Sultan, Nuclear Department, United Kingdom
B. Alaviippola	06-06-01/ 06-12-31	Finnish Meteorological Institute Helsinki, Finland
A. Nadeev	06-06-11/ 06-08-10	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
A. Simakov	06-06-11/ 06-08-10	Russian Academy of Sciences, Institute for Atmospheric Optics, Tomsk, Russia
A. Apituley	06-06-20/25	National Institute of Public Health and the Environment, Bilthoven, The Netherlands
Y. Dufornet	06-06-20/25	National Institute of Public Health and the Environment, Bilthoven, The Netherlands
E. Nilsson	06-07-01/ 06-09-30	Lund University, Division of Nuclear Physics, Lund, Sweden
P. Villani	06-09-01/ 06-11-30	Blaise Pascal University, Clermont Ferrand, France
E. Engström	06-09-04/ 06-11-30	Stockholm University, Sweden
St. Leinert	06-09-14/ 06-10-06	EPA Dublin, Ireland
E. Szeremeta	06-10-01/ 06-12-03	Polish Academy of Sciences, Institute of Physical Chemistry, Warsaw, Poland
Y. Cheng	06-10-01/ 06-12-31	Peking University, China

Name	Period of stay	Institution
P. Tenza	06-10-01/ 06-12-31	University of Alicante, Spain
E. Skonlhkarth	06-11-05/17	University of Crete, Heraklion, Greece
N. Kalivitis	06-11-13/24	University of Crete, Heraklion, Greece
A. Kolgotin	06-12-25/31	Moscow State Technical University named by Bauman, Department of Applied Physics, Moscow, Russia

Guest scientists 2007

Name	Period of stay	Institution
A. Kolgotin	07-01-01/25	Moscow State Technical University named by Bauman, Department of Applied Physics, Russia
P. Tenza	07-01-01/ 07-06-30	University of Alicante, Spain
	07-10-01/ 07-12-31	
A. Hamed	07-01-08/ 07-02-08	University of Kuopio, Department of Physics, Finland
M. Sipilä	07-01-21/26	University of Helsinki, Finland
R. A. Shaw	07-02-02/09	Michigan Technological University, USA
E. Giannakaki	07-02-03/ 07-12-17	Aristotle University of Thessaloniki, Laboratory of Atmospherics, Greece
E. Tetushkina	07-02-08/ 07-08-08	Immanuel Kant State University of Russia, Russia
O. Marx	07-02-09/16	Max Planck Institute for Biogeochemistry Jena, Germany
G. Song	07-02-26/ 07-03-25	Peking University, China
Y. Dingli	07-02-26/ 07-03-25	Peking University, China
A. Panov	07-03-01/31	IFOR-RAS Krasnojarsk, Russia
L. Deguillaume	07-03-01/ 07-08-31	Versailles Saint-Quentin-en-Yvelines University, Bátiment d'Alembert, Versailles, France
K. Teinilä	07-03-07/11	Finnish Meteorological Institute, Department of Air Quality Research, Helsinki, Finland
D. Covert	07-03-10/30	University of Washington, Department of Atmospheric Sciences, Washington, USA
W. Ya-Qiang	07-03-10/24	Chinese Academy of Meteorological Sciences, Centre for Atmosphere Watch and Services, Beijing, China
P. Sheridan	07-03-10/23	U.S. Department of Commerce, Boulder, USA
G. Sachin	07-03-11/22	Max Planck Institute for Chemistry Mainz, Germany

Name	Period of stay	Institution
A. Marinoni	07-03-11/22	ISAC-CNR Institute for atmospheric and climate sciences, Bologna, Italy
R. Garland	07-03-11/22	Max Planck Institute for Chemistry Mainz, Germany
A. Virkkula	07-03-17/23	Finnish Meteorological Institute, Air Quality Research Helsinki, Finland
S. Goel	07-05-08/ 07-07-25	Indian Institute of Technology Kanpur, Department of Civil Engineering, India
J.-Y. Sun	07-05-12/19	Chinese Academy of Meteorological Science, Beijing, China
J. L. Jin	07-05-12/19	Chinese Academy of Meteorological Science, Beijing, China
T. Mendes Pauliquevis	07-06-16/24	Instituto Nacional de Pesquisas de Amazonia, Manaus, Brazil
J. Pienaar	07-06-20/26	North-West University, School of Chemistry and Biochemistry, Potchefstroom, Republic of South Africa
K. Kohfeld	07-07-03/09	Simon Fraser University, Vancouver, Canada
P. Ivanov	07-07-24/ 07-08-09	Mladost, Sofia, Bulgaria
R. A. Shaw	07-08-01/ 07-12-31	Michigan Technological University, USA
P. G. van Zyl	07-09-23/ 07-10-13	North-West University, School of Chemistry and Biochemistry, Potchefstroom, Republic of South Africa
K. Ferguson	07-09-23/ 07-10-13	University of the Witwatersrand, Johannesburg, Republic of South Afrika
M. Petters	07-09-28/ 07-10-22	Colorado State University, Department of Atmospheric Science, USA
D. Covert	07-10-08/26	University of Washington, Department of Atmospheric Sciences, USA
M. Laborde	07-10-14/19	Eco-Tech Australia Pty Ltd, Australia

Visits of IfT scientists at other research institutions

Year	Name	Period of stay	Institution	Country
2006	A. Maßling	06-01-01/ 06-01-19	Lund University, Institute of Technology, Department of Physics	Sweden
	C. Engler	06-01-01/ 06-06-30	Finnish Meteorological Institute, Helsinki	Finland
	W. Birmili	06-01-01/ 06-06-30	University of Helsinki, Department of Physical Sciences	Finland
	A. Maßling	06-02-20/ 06-03-31	Lund University, Institute of Technology, Department of Physics	Sweden

Year	Name	Period of stay	Institution	Country
2006	J. Heintzenberg	06-02-28/ 06-03-12	Meteorological Research Institue Tsukuba Ibaraki	Japan
	D. Müller	06-03-18/ 06-04-05	Tokyo University of Marine Science and Technology	Japan
	B. Wehner	06-04-18/ 06-05-12	National Center for Atmospheric Research, Boulder	USA
	O. Hellmuth	06-04-19/ 06-04-25	Joint Institute for Nuclear Research, Dubna	Russia
	St. Bauer	06-05-02/ 06-07-26	National Center for Atmospheric Research, Boulder	USA
	L. Poulain	06-05-21/ 06-05-28	Aerodyne Research, Inc., Boston	USA
	S. Klose	06-06-12/ 06-06-24	National Environmental Research Institute, Roskilde	Denmark
	F. Stratmann	06-08-08/ 06-12-22	University of Helsinki, Division of Atmospheric Sciences	Finland
2007	C. Weller	07-01-08/ 07-02-02	Université Joseph Fourier de Grenoble	France
	H. Siebert	07-01-25/ 07-01-26	University of Helsinki, Department of Physical Sciences	Finland
	C. Weller	07-02-03/ 07-02-10	Observatoire de Haute Provence	France
	J. Heintzenberg	07-02-03/ 07-02-22	Stockholm University, Department of Meteorology	Sweden
	T. Müller	07-02-26/ 07-03-02	Stockholm University, Department of Meteorology	Sweden
	J. Heintzenberg	07-02-26/ 07-03-10	Research Institute for Humanity and Nature, Kyoto	Japan
	O. Hellmuth	07-04-17/ 07-04-25	Joint Institute for Nuclear Research, Dubna	Russia
	D. Müller	07-09-03/ 07-09-15	Aristotle University of Thessaloniki, Laboratory of Atmospherics	Greece
	J. Heintzenberg	07-09-22/ 07-09-30	Peking University	China
	O. Hellmuth	07-10-14/ 07-10-19	Institute of Thermal Physics, Ekaterinburg	Russia

Meetings and chairmanships

Meetings and chairmanships 2006

Meeting	Place/ date	Number of participants	National/ international
H-TDMA Workshop	Leipzig 06-02-06/10	15	international
28th NATO/CCMS International Technical Meeting on Air Pollution Modeling and its Application	Leipzig 06-05-15/19	120	international
UFIPOLNET-Meeting	Leipzig 06-05-16/17	18	international
Treffen des Arbeitskreises Atmosphärenchemie (AKAC) der GdCH	Frankfurt/M. 06-07-19	15	national
Treffen des Arbeitskreises Atmosphärenchemie (AKAC) der GdCH	Kloster Johannisberg 06-10-24	20	national
EUSAAR Workshop	Leipzig 06-11-12/21	20	international

Meetings and chairmanships 2007

Meeting	Place/ date	Number of participants	National/ international
Joint French-German Projects on Innovative Basic Research in Atmospheric Chemistry, Roundtable	Bonn 07-01-16/17	46	international
1. Arbeitsgespräch Messung von Ultrafeinstaub in der Atmosphäre	Leipzig 07-03-05/06	20	national
Nephelometer and Absorption Photometer Intercomparison EUSAAR Workshop	Leipzig 07-03-12/22	36	international
3rd UFIPOLNET Workshop	Leipzig 07-05-31	15	international
Treffen des Arbeitskreises Atmosphärenchemie (AKAC) der GdCH	Frankfurt/M. 07-07-25	10	national
EUSAAR Workshop	Leipzig 07-10-15/19	59	international
FILGAS-Meeting	Leipzig 07-11-20	20	national
Air monitoring instrumentation, Workshop - Symposium	Schagen, NL 07-12-10/12	50	international

International and national field campaigns

International field campaigns 2006

Field Campaign	Project partner
EARLINET (permanent experiment) *European Aerosol Research Lidar Network*	EARLINET-Consortium
Melpitz **EMEP** *Co-operative Program for Monitoring and Evaluation of the Long-range Transmission of Air pollutants in Europe* (intensive summer field campaign, June 2006)	Switzerland Czech Republic Denmark Spain Ireland Italy The Netherlands Norway United Kingdom
CALIPSO Validation *Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations* (since June 2006)	NASA EARLINET-Consortium
CAREBEIJING Peking, China	China Hong Kong Taiwan Germany Japan South Korea
CLACE 5 *Cloud and Aerosol Characterization Experiment in the free Troposphere* Jungfraujoch, Switzerland	Switzerland
Pearl River Delta China	China Hong Kong Taiwan Germany Japan South Korea
SAMUM-1 *Saharan Mineral Dust Experiment*	Germany USA Morocco
ZOTTO *Zotino Tall Tower Facility*	ZOTTO-Consortium

International field campaigns 2007

Field Campaign	Project partner
ACCENT-SOA *Atmospheric Composition Change - A European Network, Secondary Organic Aerosol*	USA

Field Campaign	Project partner
CLACE 6 *Cloud and Aerosol Characterization Experiment in the free Troposphere* Jungfraujoch, Switzerland	Germany Switzerland United Kingdom
DFG-COPS *Convective and Orographically-induced Precipitation Study*	Germany France Italy USA United Kingdom The Netherlands Switzerland
Melpitz **EMEP** *Co-operative Program for Monitoring and Evaluation of the Long-range Transmission of Air pollutants in Europe* (intensive winter field campaign, Jan. - Feb. 2007)	Switzerland Czech Republic Denmark Spain Ireland Italy The Netherlands Norway United Kingdom
SOPRAN (BMBF) *Surface Ocean Processes in the Anthropocene* Cape Verde (May - June 2007)	USA United Kingdom
ZOTTO *Zotino Tall Tower Facility*	ZOTTO-Consortium

National field campaigns 2006

Field Campaign	Project partner
LfUG III (summer/winter field campaign) IfT: Physics and Chemistry Depts.	LfUG (Landesamt für Umwelt und Geologie) Dresden
Melpitz (April - June 2006) IfT: Chemistry Dept.	GAA (Gewerbeaufsichtsamt) Hildesheim
Bösel (July - Oct. 2006) IfT: Chemistry Dept.	GAA (Gewerbeaufsichtsamt) Hildesheim

National field campaigns 2007

Field Campaign	Project partner
ACTOS Campaign, Kiel 2007 *Airborne Cloud Turbulence Observation System* IfT: Physics Dept.	Johannes Gutenberg University, Mainz Rotorflug GmbH, Friedrichsdorf enviscope GmbH, Frankfurt/Main
LfUG III Remote transport of particulate matter into the conurbanization of Dresden IfT: Physics Dept.	LfUG (Landesamt für Umwelt und Geologie) Dresden
LfUG IV (winter 2007) Influence of domestic heating appliances on PM concentration in Seiffen, Saxony IfT: Physics and Chemistry Depts.	LfUG (Landesamt für Umwelt und Geologie) Dresden
NH_3 measurements (Nov. 2006 - Jan. 2007) IfT: Chemistry Dept.	GAA (Gewerbeaufsichtsamt) Hildesheim

Reviews

Reviews	Number	
	2006	***2007***
Journals	175	132
Projects	40	41
Others	30	5
Total	**245**	**178**

Memberships

Name	Board	Year
Althausen, D.	Lidar Expert Network “Laser Remote Sensing of Water Vapor and Wind”	2006
Ansmann, A.	NASDA-ESA EarthCARE Joint Mission Advisory Group	2006/2007
Berndt, T.	Gesellschaft Deutscher Chemiker	2006/2007
Böge, O.	Gesellschaft Deutscher Chemiker (AK Atmosphärenchemie)	2006/2007
Heintzenberg, J.	ESF Scientific User Committee for EUFAR (European Fleet for Atmospheric Research)	2006
	DFG-Fachkollegium „Ozeanographie und Atmosphärenforschung“	2006/2007
	Ordentliches Mitglied der Sächsischen Akademie der Wissenschaften	
	Außerordentliches Mitglied der Berlin-Brandenburgischen Akademie der Wissenschaften	
	Wissenschaftlicher Beirat des Deutschen Wetterdienstes	
	Sprecher der Sektion E der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz	
	Editorial Board “Tellus B”	
	Editorial Board “Atmospheric Research”	
	Scientific Advisory Board of the Research Institute for Humanity and Nature, Kyoto, Japan	
	Permanent Scientific Advisory Committee of the Centro de Geofisica de Evora, Portugal	
	Advisory Board of the Indian Institute of Technology (IIT) in Porkee, India for the Max Planck Partner Group IIT	
Herrmann, H.	Vorsitz des Arbeitskreises „Atmosphärenchemie“ in der GDCh-Fachgruppe „Umweltchemie und Ökotoxikologie (AKAC)“	2006/2007
	DECHEMA/GDCh/Bunsengesellschaft Gemeinschaftsausschuss „Chemie der Atmosphäre“	
	DECHEMA/GDCh/KRdL Expertengruppe Feinstaub (Mitglied der Lenkungsgruppe)	
	Mitglied des wissenschaftlichen Beirats der „Kommission zur Reinhaltung der Luft“ (KRdL) des Vereins Deutscher Ingenieure (VDI)	
	Fellow of the International Union of Pure and Applied Chemistry	

Name	Board	Year
Mertes, S.	Assoziiertes Mitglied des DFG-Sonderforschungsbereichs 641 „Die troposphärische Eisphase“	2006/2007
Renner, E.	DECHEMA/GVC-Arbeitsausschuss „Schadstoffausbreitung“	2006/2007
	Scientific Committee of the NATO/CCMS ITM conference series, German member	
Stratmann, F.	Mitglied des Komitees der „17th International Conference on Nucleation & Atmospheric Aerosols“, 13.08.-17.08.2007, Galway, Irland	2006/2007
Wandinger, U.	Topical Editor “Applied Optics”	2006/2007
	Mitglied des Verwaltungsausschusses von COST-720, European Cooperation in the field of Scientific and Technical Research 720: Integrated Ground-Based Remote Sensing Stations for Atmospheric Profiling	2006
	Member of the ESA-JAXA EarthCARE Joint Mission Advisory Group	2007
	Member of the EARLINET Council	
Wehner, B.	Mitglied des Vorstandes des Zweigvereins Leipzig der DFG	2007
Wendisch, M.	Koordinator (Aerosol Mikrophysik) im EUFAR (European Fleet for Atmopheric Research) Projekt	2006/2007
Wiedensohler, A.	„Scientific Advisory Group“ für Aerosole innerhalb des „Global Watch“-Programms der World Meteorological Organization	2006/2007
	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 Program Committee“ der Europäischen Aerosolkonferenz	
	Board member of the GAeF (Association for Aerosol Research)	
	“Technical Program Committee” IAC (International Aerosol Conference)	
	Member of the Scientific Steering Committee (SSC) and Work Package (WP) Leader of the EU project ACCENT	
	Member of the SSC for EU project EUSAAR	
	Gastprofessur „Peking University“, Department of Environmental Science, China	

Name	Board	Year
Wiedensohler, A.	Leiter Weltkalibrierzentrum für Aerosolphysik im Rahmen von WMO-GAW	2006/2007
	Editorial Board Member “Atmospheric Chemistry and Physics”	
	Sprecher der Arbeitsgruppe „Atmosphärische Aerosole“ innerhalb der EAA (European Aerosol Assembly)	
Wolke, R.	Gesellschaft für Angewandte Mathematik und Mechanik (GAMM) Dresden	2006/2007
	European Geoscience Union (EGU)	

Cooperations

International Cooperations

Research Project	Cooperation Partners
HIAPER *High-performance Instrumented Airborne Platform for Environmental Research* Atmospheric Radiation Package (HARP) for spectrally resolved actinic flux and irradiance measurement instrumentation for HIAPER	National Science Foundation (NSF), USA
LACIS *Leipzig Aerosol Cloud Simulator*	Denmark, Finland, USA, Germany
INSPECTRO *Influence of Clouds on the Spectral Actinic Flux in the Lower Troposphere*	United Kingdom, Norway, Greece, Austria, Germany
CLACE *Cloud and Aerosol Characterization Experiment in the free Troposphere*	Switzerland, United Kingdom, Finland, Denmark, Germany
ACTOS *Airborne Cloud Turbulence Observation System*/ Interaction between turbulent mixing processes and cloud micro-physical characteristics in stratiform boundary layer clouds	Michigan Technological University, Department of Physics, Houghton, USA
AERONET *Aerosol Robotic Network*	National Aeronautics and Space Administration (NASA), USA
Polly XT (Compact Lidar Development)	Finnish Meteorological Institute, Finland
NASA-CALIPSO *Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations* (Lidar ground truth, EARLINET)	National Aeronautics and Space Administration (NASA), USA
ESA-ADM *European Space Agency, Atmospheric Dynamics Mission*	European Space Research and Technology Centre (ESTEC), The Netherlands

Research Project	Cooperation Partners
COST-720 (a. o. Measurement Campaign LAUNCH-2005); Integrated Ground-Based Remote Sensing Stations for Atmospheric Profiling	The Netherlands, Italy, United Kingdom, France, Portugal, Spain, Switzerland, Austria, Greece, Poland, Germany, Ukraine, China/Macao
Multiple scattering in Raman Lidar signals	National Academy of Science of Belarus, Institute of Physics, Minsk, Republic of Belarus
Anthropogenic influence of Asian aerosols on tropical cirrus clouds	National Center for Atmospheric Research, (NCAR), Boulder, USA
AIE *Atmospheric Environmental Impacts of Aerosol in East Asia*	30 project partners
ZOTTO *Zotino Tall Tower Facility* (sources and budgets of tropospheric aerosols over Siberia)	MPI for Biological Geochemistry, Jena, Germany MPI for Chemistry, Mainz, Germany IFOR-RASS, Krasnojarsk, Russia
Pearl River Delta (Integrated Measurement for Pollution Complexes in the Pearl River Delta, China)	Peking University, China Guangdong Provincial Environmental Monitoring Center, China Chinese Research Academy of Environmental Science, China Zhongshan University, China
Long range transport analysis analysis of long-distance transport for atmospheric aerosols in the Alps region	Umweltbundesamt, Dessau, Germany NILU, Kjeller, Norway
CELTIC *Chemical Emissions, Losses, Transformations and Interactions in Canopies*	NCAR Atmospheric Chemistry Division, Boulder, USA University of Helsinki, Finland
Carebeijing (Research on transfer and conversion of the pollutants in Beijing and the adjacent area on the air quality in Beijing)	Peking University, Chinese Academy of Sciences, Institute of Atmospheric Physics Beijing University of Technology, China Chinese Research Academy of Environmental Sciences
ARIADNE *Aerosol Physical and Chemical Identification on Crete*	University of Crete, Heraklion, Greece
Twinning Partnership with GAW-Stations	Korean Meteorological Service Global Atmosphere Watch (GAW), Anmyeon, South Korea Malaysian Meteorological Service, Danum Valley, Malaysia Bulgarian Academy of Sciences, BEO-Moussala, Bulgaria
INTROP Measurement of organic Acids in the natural laboratory of Mexico City	Laboratoire de Combustion et Systèmes Réactifs, Centre National de Recherche scientifique, Orléans, France
Secondary new particle formation in Europe	Universities of Helsinki and Kuopio, Finland
Particulate emissions of a modern waste incinerator	Landesagentur für Umwelt, Bozen, Italy
BodEx *Quantification of near source dust emission and dust properties in the Bodele Depression*	Oxford University, Great Britain University College London, Great Britain NASA Goddard Space Flight Center, USA

Research Project	Cooperation Partners
Evaluation of dust aerosol parameterization and climate feedback in a global climate model	NASA Goddard Institute for Space Studies, USA
Measurement methods and techniques for the quantification of gaseous carbonyl compounds	Germany, United Kingdom, Switzerland, Norway, Austria, USA, Spain
Cooperation partners involved in research projects at the IfT Research Station Melpitz	Germany, Sweden, Italy, Bulgaria, Belgium, United Kingdom, Czech Republic, Finland, France, Greece, Ireland, Lithuania, The Netherlands, Norway, Spain, Switzerland, Austria, Denmark, Hungary, Latvia, Poland, Portugal
Development and evaluation of methods for the quantification of trace compounds produced by biomass burning	Academy of Science (Academia Sinica), Taipei, Taiwan
Laboratory investigations in the field of liquid phase chemistry	National Institute of Chemistry Ljubljana, Slovenia University of Lyon, France
Relations between directly emitted wood burning emissions and ambient particle concentration in the Melbourne region	Commonwealth Scientific and Industrial Research Organization (CSIRO), Melbourne, Australia
Isoprene multiphase oxidation studies	IPC Warsaw, Poland
Construction of an international measuring station on the Isle of Sao Vincente (Cape Verde Islands)	Germany, United Kingdom, Cape Verde
DFG-COPS *Convective and Orographically-induced Precipitation Study*	Germany, France, The Netherlands, United Kingdom, Italy, Switzerland, USA
Virtual Institute Role of aerosol particles as condensation and ice nuclei in tropospheric clouds (Aerosol-Cloud Interactions ACI)	Germany, Switzerland, United Kingdom, Israel

European Union - Cooperations

Research Project	Cooperation Partners
EUFAR *European Fleet for Airborne Research in the Field of Environment and Geo-Science*	Germany, United Kingdom, France, Ireland, Sweden
CARIBIC *Civil Aircraft for Remote Sensing and In situ measurement in Tropospheric and Lower Stratosphere based on the Instrumentation Container Concept*	Germany, United Kingdom, France, The Netherlands, Switzerland, Sweden
ACCENT *Atmospheric Composition Change: A European Network*	United Kingdom, The Netherlands, Finland, Belgium, Switzerland, Austria, Norway, France, Greece, Spain, Bulgaria, Denmark, Hungary, Ireland, Latvia, Lithuania, Poland, Portugal, Germany, Sweden, Italy

Research Project	Cooperation Partners
PURAT *Particles in the Urban Atmosphere* Behavior of fine and ultrafine particles, their spatial variation and relationships with local policy action	Germany, Denmark, Sweden, United Kingdom
EUSAAR *European Supersites for Atmospheric Aerosol Research*	Germany, France, Switzerland, Italy, The Netherlands, Norway, Finland, Ireland, Greece, Czech Republic, Bulgaria, United Kingdom, Lithuania, Sweden, Spain
UFIPOLNET *Ultrafine article size distribution in air Pollution monitoring Networks*	Germany, Sweden, Czech Republic
EARLINET *European Aerosol Research Network*	Germany, Italy, Greece, Switzerland, Sweden, Spain, Portugal, Poland, Belarus, United Kingdom, France, Bulgaria
EARLINET-ASOS: *European Aerosol Research Network-ASOS*	Italy, Germany, Spain, Greece, Switzerland, Sweden, Poland, Belarus, France, Bulgaria, Romania, Norway, The Netherlands
EUROCHAMP *Integration of European Simulation Chambers for Investigating Atmospheric Processes*	Germany, Italy, Spain, United Kingdom, Ireland, France, Switzerland, Sweden
IAGOS *Integration of routine Aircraft measurements into a Global Observing System*	Germany, France, United Kingdom
EUCAARI *European Integrated Project on Aerosol, Cloud, Climate and Air Quality Interactions*	Germany, Finland, France, Switzerland, The Netherlands, United Kingdom, Sweden, Hungary, Norway, Ireland Greece, Denmark, India, Brazil, Czech Republic, South Africa, India, Estonia, Austria, China, Poland, Portugal
Comparison of LM and RAMS modeled surface winds to simulate mineral dust emissions	France
Implementation of dust aerosol parameterization in a global transport model	Italy
Chemistry transport model intercomparison	The Netherlands, France, Germany
TNO/UBA Strategies for the reduction of fine particles	The Netherlands, Germany
AEROTOOLS *Tools for the Physical and Chemical Characterization of the Environmental Aerosol*	France, Greece, Finland, Sweden, Spain, Italy, Czech Republic

National Cooperations

Research Project	Cooperation Partners
DWD-Raman-Lidar	Kayser-Threde GmbH, München DWD, Offenbach Meteorologisches Observatorium, Lindenberg inqbus it-consulting, Leipzig Loritus GmbH, München

Research Project	Cooperation Partners
DFG-Wasserdampf-Dial	Universität Hohenheim Universität Potsdam DLR Oberpfaffenhofen Kayser-Threde GmbH, München Deckwerth Fahrzeugbau und Entwicklungswerk, Wurzen
Pro Inno II (Entwicklung des modular zu gestaltenden messtechnischen Teils einer mobilen Dienstleistungseinheit)	Fahrzeugbau und Entwicklungswerk Deckwerth, Wurzen
TROPEIS Sammlung und physiko-chemische Charakterisierung troposphärischer Eiskeime in Zusammenarbeit mit dem DFG-Sonderforschungsbereich 641	MPI für Chemie, Mainz Johannes Gutenberg-Universität, Mainz Johann Wolfgang Goethe-Universität, Frankfurt/M. Technische Universität, Darmstadt
Modellierung mesoskaliger Chemie-Transport-Prozesse	John von Neumann-Institut für Computing (NIC), Jülich
TRACES (WGL-PAKT) *Ocean-Atmosphere-Land Impacts on Tropical Atlantic Ecosystems* Subproject: Transport and transformation processes in the atmosphere of the tropical Atlantic	Leibniz-Institut für Meereswissenschaften IFM-GEOMAR, Kiel Institut für Ostseeforschung Warnemünde, Rostock Potsdam-Institut für Klimafolgenforschung (PIK)
FAT Größenaufgelöste physikalische und chemische Bestimmung von elementarem und organischem Kohlenstoff in Nanopartikeln	Helmholtz-Zentrum für Umweltforschung UFZ Leipzig
GC/MS Bestimmung polarer mittelflüchtiger organischer Substanzen aus größenaufgelöst gesammelten Aerosolpartikeln mittels Thermodesorption und Methylierung	Universität Leipzig, Prof. Engewald
SOA *Sekundäres organisches Aerosol* Temperaturabhängigkeit der Bildung von sekundärem organischen Aerosol	Forschungszentrum Karlsruhe
Kooperation zur Halogenchemie	Universität Heidelberg, Institut für Umweltphysik
Short-term Health Effects of Fine and Ultra-fine Particle Pollution in Beijing, China (DFG)	GSF Nationales Forschungszentrum, Institut für Epidemiologie Helmholtz-Zentrum für Umweltforschung UFZ Leipzig, Abteilung Expositionsforschung und Epidemiologie
Strahlungseigenschaften von stratiformen Wolken	Johannes Gutenberg-Universität, Mainz
DFG-SPP HALO *High Altitude and Long Range Research Aircraft* Counterflow Virtual Impactor (CVI) for the collection of hydrometeors and identification of CCN and IN onboard HALO	16 deutsche Projektpartner

Research Project	Cooperation Partners
Cross cutting activities of **DFG-Priority Program SPP-1294 HALO**	16 deutsche Projektpartner
Quality assurance and evaluation of particle size distribution measurements from the UBA network	Umweltbundesamt, Dessau
Influence of domestic wood stoves on particulate concentrations in rural areas of Saxony	Sächsischen Landesamt für Umwelt und Geologie, Dresden
Development of a mobile aerosol standard	Sächsischen Landesamt für Umwelt und Geologie, Dresden
Non-volatile components of particulate air pollution in Augsburg, Germany	TU Bergakademie Freiberg GSF Neuherberg
DFG-Forschergruppe SAMUM SAharan Mineral dUst ExperiMent	9 deutsche Projektpartner
DFG-SPP-Niederschlagsvorhersage Spektrale Mikrophysik in Vorhersagemodellen unter besonderer Berücksichtigung der Tropfennukleation	21 deutsche Projektpartner
Paralleles Kopplungs-Framework und moderne Zeitintegrationsverfahren für detaillierte Wolkenprozesse in atmosphärischen Modellen	TU Dresden Universität Halle/S.
SOPRAN (BMBF) *Surface Ocean Processes in the Anthropocene*	8 deutsche Projektpartner
DFG-SPP MetStroem Gebietszerlegungsverfahren für positiv definite Helmholtz-Gleichungen	4 deutsche Projektpartner
Ammonisax *Einfluss erhöhter NH_3-Konzentration auf die Partikelmassebildung PM10 - Vergleich von NH_3-Messverfahren an drei Standorten mit unterschiedlichen Spurengaskonzentrationen in Niedersachsen und Sachsen*	Staatliches Gewerbeaufsichtsamt Hildesheim
Einfluss des Ferneintrages auf die Feinstaubbelastung im Ballungsraum	Sächsisches Landesamt für Umwelt und Geologie, Dresden
Pflanzenkammerexperimente (Jülich)	Institut für Chemie und Dynamik der Geosphäre, Forschungszentrum Jülich
FILGAS (WGL-PAKT) (Oberflächenfilme und Gasaustausch)	Leibniz-Institut für Ostseeforschung an der Universität Rostock (IOW), Warnemünde Institut für physikalische und theoretische Chemie an der Universität Rostock (URO) Leibniz-Institut für Meereswissenschaften an der Universität Kiel (IFM-GEOMAR)
Feinstaubmessung; Charakterisierung des Aerosols im Messnetz des Umweltbundesamtes	Umweltbundesamt Dessau
WGL-Pakt: Hochauflösende Modellierung von Wolken und Schwerewellen: Skalenanalyse, Numerik, Validierung	Leibniz-Institut für Atmosphärenphysik e.V. an der Universität Rostock (IAP), Kühlungsborn Potsdam-Institut für Klimafolgenforschung (PIK)

Boards

Scientific advisory board

Name	Institution
Prof. Dr. G. Adrian	Deutscher Wetterdienst, Geschäftsbereich Forschung und Entwicklung, Offenbach
Prof. Dr. T. Benter	Bergische Universität Wuppertal, Physikalische Chemie – FB 9
Prof. Dr. P. Builtjes	TNO – Environment, Energy and Process Innovation, Apeldoorn, The Netherlands
Ms. Prof. Dr. S. Crewell	Institut für Geophysik und Meteorologie, Köln
Dr. R. Delmas	Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE), Saint Martin d'Hères, France
Ms. Prof. Dr. A. Flossmann	Observatoire de Physique du Globe de Clermont-Ferrand, Université Blaise Pascal (UMS833), Aubière, France
Prof. Dr. P. Lemke	Stiftung Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven
Prof. Dr. F.-J. Lübken	Leibniz-Institut für Atmosphärenphysik an der Universität Rostock, Ostseebad Kühlungsborn
Prof. Dr. T. Peter **(Chair)**	ETH Zürich, Institut für Atmosphäre und Klima, Switzerland

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Name	Institution
MinR´in Dr. P. Karl	Sächsisches Staatsministerium für Wissenschaft und Kunst, Dresden
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Prof. Dr. C. Simmer	Rheinische Friedrich-Wilhelms-Universität, Meteorologisches Institut, Bonn

Member of the IfT-Association

Name	Institution
MinR´in Dr. P. Karl	Sächsisches Staatsministerium für Wissenschaft und Kunst, Dresden
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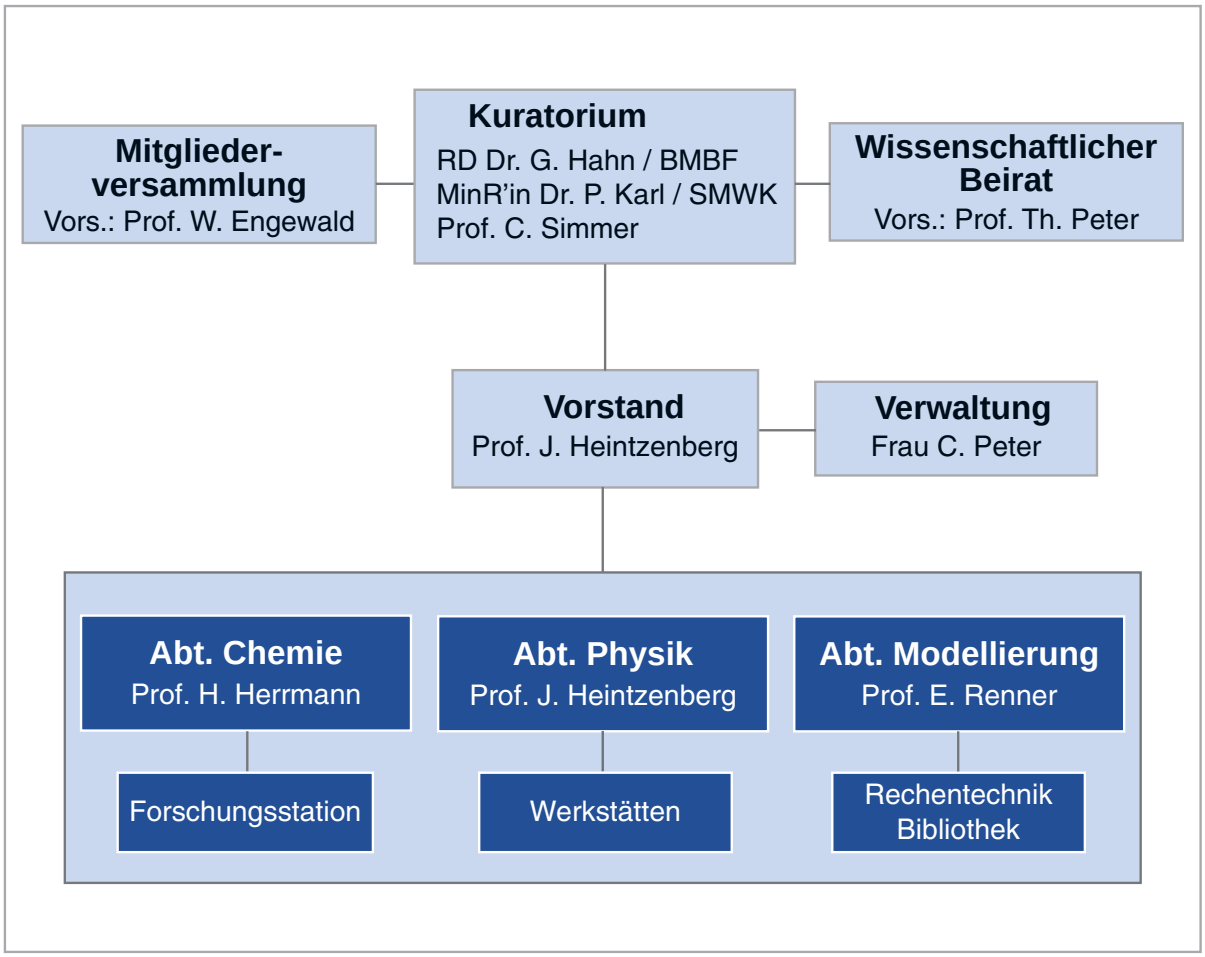
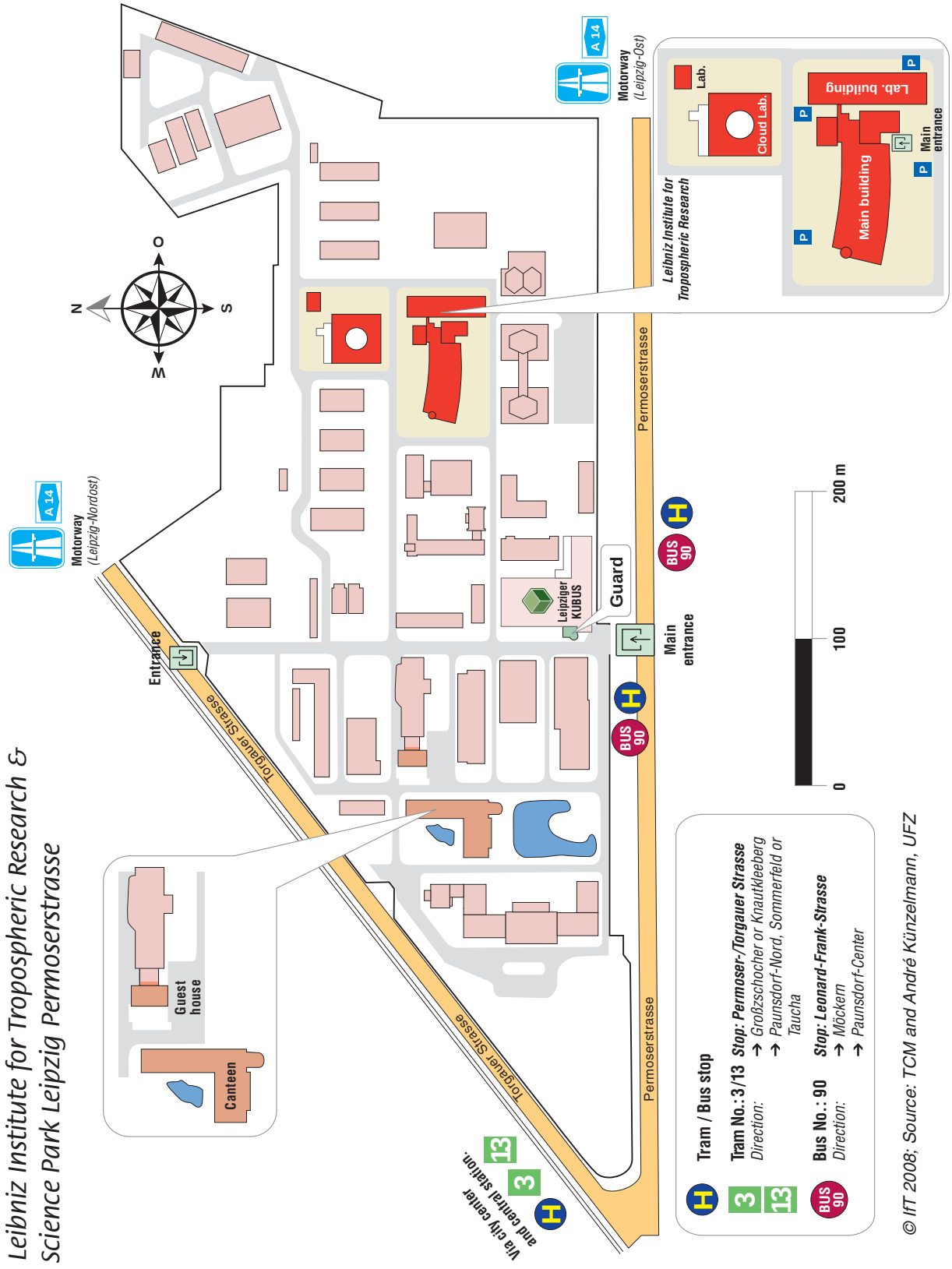
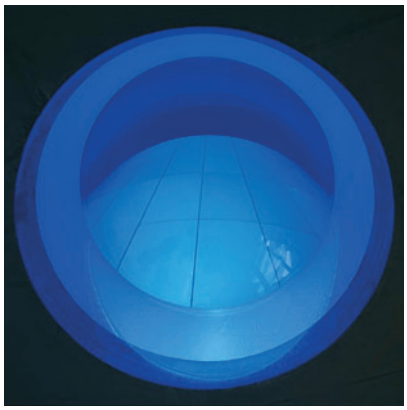
Prof. Dr. P. Warneck	Mainz
Prof. Dr. B. Brümmer	Universität Hamburg, Meteorologisches Institut
Prof. Dr. W. Engewald **(Chair)**	Universität Leipzig, Fakultät für Chemie und Mineralogie

Leibniz-Institut für Troposphärenforschung e.V.



Research area Permoserstrasse





IfT-Intern

Öffentlichkeitsarbeit

Auszeichnungen 2007

Auszeichnung	Ort	Datum
Architektur-Preis 2007 vom Bund Deutscher Architekten Landesverband Sachsen e.V.	Neues Rathaus, Leipzig	27.04.2007
Architekturpreis der Stadt Leipzig 2007	Neues Rathaus, Leipzig	30.10.2007
Deutscher Architekturpreis 2007	München	04.12.2007

Präsenz in Printmedien 2006

Zeitung/Journal	Titel	Datum	IfT-Interview *Jounalist/in*
regional			
Leipziger Volkszeitung Hochschule und Wissenschaft	Wer forscht wo - abseits der Hochschulen? Wolken aus der Retorte	31.12.05/ 01.01.06	*Mario Beck*
Leipziger Volkszeitung	*Von den Inkas geht es zum Wolkenturm* (Lesung zur Leipziger Buchmesse im Kubus - Wissenschaftspark)	15.03.06	*Mario Beck*
Leipziger Blätter Ausgabe 48	Die Vermessung der Wolken - Wolkenlabor des Leibniz-Instituts für Troposphärenforschung	Frühjahr 06	*Anette Menting*
Leipziger Volkszeitung Hochschule und Wissenschaft	Land der Ideen - Wolkenlabor ziert Reiseführer	06./07.05.06	Prof. J. Heintzenberg *Mario Beck*
Leipziger Volkszeitung Hochschule und Wissenschaft	Expedition Samum - Wissenschaftler analysieren Flugstaub der Wüste	10./11.06.06	Prof. J. Heintzenberg *Mario Beck*
Darmstädter Echo Rüsselsheim/Groß Gerau/ Ried/Starkenburger/ Odenwalder (Magazin am Wochenende)	Der Wolkenbau ist keine Hexerei Am Puls des Wetters - Das Leibniz-Institut für Troposphärenforschung in Leipzig simuliert das Geschehen am Himmel und beobachtet die Realität per Hubschrauber	08.07.06	Dr. F. Stratmann *Wolfgang Horn*
Leipziger Volkszeitung Lokalteil Muldenthaler Kreiszeitung	Klimaforscher beim Kirchengespräch *Vortrag zum Klimawandel*	10.07.06	Dr. D. Althausen
Leipziger Volkszeitung Hochschule und Wissenschaft	Partikeljagd am Perlenfluss Troposphärenforscher sondieren chinesische Luft	15./16.07.06	Prof. A. Wiedensohler *Mario Beck*
Leipziger Studentenzeitung „student“	Borkenkäfer und Wolken *Der Wissenschaftspark Leipzig bietet auch für Studenten Serviceleistungen* (IfT - LACIS)	Juni-Ausgabe	Prof. J. Heintzenberg *Eva Haar*

Zeitung/Journal	Titel	Datum	IfT-Interview *Jounalist/in*
regional			
Rhein-Zeitung	Wissenschaftler untersuchen Wolken hoch über Koblenz	02.10.06	*Christian Döring*
Leipziger Volkszeitung Hochschule und Wissenschaft	Troposphärenforschung *Wolkenturm wartet auf Wissensdurstige*	07./08.10.06	IfT *Mario Beck*
LVB - Kundenmagazin Traffix plus (Leipziger Verkehrsbetriebe)	Vom Wolkenlabor bis zur Nanotechnologie Hinter die Kulissen vom Wissenschaftspark in der Permoserstraße geschaut	Dezember-ausgabe	IfT *Helge-Heinz Heinker*
national			
Der Dumont-Reiseführer	365 Orte im Land der Ideen (Deutschland - Land der Ideen)	01.01.06	IfT- Wolkenlabor
gasette - Das e.on Ruhrgas Magazin Technologie und Zukunft	Leibniz-Institut Perspektiven der Wolkenforschung	Ausgabe 1-06	Dr. F. Stratmann *Dr. Eva Caspers*
WETTER-magazin Wissen	*Fliegende Spürnase* CARIBIC-Projekt (Mit dem fliegenden Messlabor CARIBIC wird die Zusammensetzung der Erdatmosphäre erforscht)	Ausgabe 03/06	*Helmut Broeg*
Frankfurter Allgemeine Sonntagszeitung / Wissenschaft	*Steht Wolke hoch, zum Herrlichsten geballt* - Und wenn am Himmel nichts zu messen ist? Dann bauen Forscher Wolken im Labor	04.06.06	Prof. J. Heintzenberg Dr. F. Stratmann *Georg Rüschemeyer*
HÖRZU - Ausgabe 39	*Grüße aus der Wüste* Sandstürme reichen bis nach Übersee und Europa. Deutsche Forscher untersuchen nun die Auswirkungen des Staubs auf das Weltklima	22.06.06	Prof. J. Heintzenberg *Uwe Clausen*
db deutsche bauzeitung	*Ein Ort für flüchtige Phänomene* (Wolkenlabor des IfT)	Ausgabe 10/06	*Annette Menting*
DIE ZEIT	Deutschland Land der Ideen - Ort des Tages: *Wolke sieben* (Wolkenlabor des IfT)	09.10.06	*FC Deutschland GmbH Berlin*
international			
Gazette du Maroc	Projet SAMUM: Des scientifiques allemands au Sahara	22.05.06	Pressekonferenz IfT in Rabat/ Marokko Messkampagne SAMUM
Le Matin (marokkanische Tageszeitung)	Le SAMUM, fruit de la coopération scientifique germano-marocaine	25.05.06	Pressekonferenz IfT in Rabat/ Marokko Messkampagne SAMUM

Zeitung/Journal	Titel	Datum	IfT-Interview *Jounalist/in*
international			
Sonntagszeitung Zürich/ Schweiz WISSEN	Die Wolke verstehen In einem neuen Simulator erforschen Leipziger Meteorologen die Geheimnisse von Kumulus, Zirrus und Stratus	28.05.06	Prof. J. Heintzenberg Dr. F. Stratmann *Ivo Marusczek*
GEO/GEOSKOP (Deutschland, Schweiz, Österreich)	Nachrichten aus Wissenschaft und Forschung: Wolkenforschung/Wetter aus der Röhre	07.07.06	Prof. J. Heintzenberg *Frau Krohn/ Markus Seewald*
GEOlino - Das Erlebnisheft (Deutschland, Schweiz, Österreich)	Wolken - Kunstwerke aus Wind und Wasser / Wolkenlabor	Nr. 7, Juli-Ausgabe	Prof. J. Heintzenberg *Kattharina Beckmann*
GEOkompakt - Die Grundlagen des Wissens (Deutschland, Österreich, Schweiz, Benelux, Finnland, Frankreich, Griechenland, Italien, Portugal, Spanien)	Wetter und Klima: „Der Stoff, aus dem die Wolken sind“	Nr. 9, Juli-Ausgabe	Dr. H. Wex *Jürgen Bischoff* *Andreas Weber*
Test & Messtechnik Magazin der YOKOGAWA Measurement Technologie GmbH Herrsching (Schweiz, Österreich)	Titelbild: Wolkenlabor REPORTAGE: „*Leicht bewölkt*“ Leibniz-Institut für Troposphärenforschung untersucht Wolkenbildung im Reagenzglas	Ausgabe 2, IV. Quartal 06	Dr. H. Wex *Dietmar Gulich - Yokogawa*
LEIBNIZ-Gemeinschaft			
Leibniz-Nachrichten Nr. 23	Ein Leibniz-Institut steht für das „Land der Ideen“ (Kampagne Deutschland - Land der Ideen“)	Jan./Febr. 06	Wolkenlabor auf Deckblatt zum Dumont-Reiseführer
Leibniz-Journal Nr. 2/06	Wolken im Reagenzglas	Juli 06	Inbetriebnahme Wolkensimulator (LACIS) - IfT

Präsenz in Printmedien 2007

Zeitung/Journal	Titel	Datum	IfT-Interview/ *Jounalist/in*
regional			
Leipziger Volkszeitung Forschung und Hochschule	Partikelfang über Sibirien *Leipziger Troposphärenforscher machen bei Großprojekt in der Taiga mit*	15.01.07	Prof. J. Heintzenberg Dr. W. Birmili *Mario Beck*
BILD-Zeitung	Kommentar zum Erscheinen des 4. Klimaberichts des IPCC der Vereinten Nationen	02.02.07	Prof. J. Heintzenberg *Eberhard Au*

Zeitung/Journal	Titel	Datum	IfT-Interview/ *Jounalist/in*
regional			
Leipzig EXPRESS Das Magazin der Marketing Leipzig GmbH	Weltweit einmalig - Leibniz-Institut für Troposphärenforschung / Wolkenlabor	März/April 07	
SAXONY Das Magazin der Sachsen LB	Wetter aus der Dose	April 07	Prof. J. Heintzenberg
Leipziger Volkszeitung	Spritztour durch die Forschungs-landschaft (IfT-Wolkenlabor)	09.05.07	Prof. J. Heintzenberg *Mario Beck*
Freie Presse	Besuch am IfT: Ministerpräsident Milbradt und EU-Kommissar Potočnik	24.05.07	Prof. J. Heintzenberg
Leipziger Volkszeitung	Leipziger blitzen mit Lichtradar im Schwarzwald	11.06.07	Dr. U. Wandinger Dr. D. Althausen *Mario Beck*
Leipziger Volkszeitung	Dem Himmel ein Stück näher (Wolkenlabor)	08.08.07	*Peter Krutsch*
Leipziger Volkszeitung Leipzig	*5 aus 23* Heute vergibt die Stadt ihren Architekturpreis: 3 Gewinner, zwei lobende Erwähnungen, aber kein Star-Bau	30.10.07	*Peter Krutsch*
Leipziger Volkszeitung Lokales	*Lorbeeren für Labor, Laden und Landschaft* Stadt vergibt zum fünften Mal ihren Architekturpreis	01.11.07	*Peter Krutsch*
Leipziger Volkszeitung Schkeuditz/Taucha	*Luftverkehr geringer Faktor des Klimawandels* Troposphärenforscher Markus Hermann erläutert in Taucha den Prozess der Erderwärmung	26.11.07	Dr. M. Hermann *Kristin Jurack*
SachsenSonntag	*Unterwegs auf der Spur der Wolken* Biografieartikel J. Heintzenberg	23.12.07	Prof. J. Heintzenberg *Jens Wagner*
national			
DFG forschung Das Magazin der Deutschen Forschungsgemeinschaft	*Naturwissenschaften* Wenn Europa verstaubt (SAMUM-Projekt)	02.07.07	Prof. J. Heintzenberg
Medical Tribune	*Forschung an künstlichen Wolken* Indikatoren für Wetter- und Klimaveränderungen		Prof. A. Wiedensohler *Richard E. Schneider*

Zeitung/Journal	Titel	Datum	IfT-Interview/ *Jounalist/in*
national			
Zeitschrift „Schattenblick“	Wenn Europa verstaubt Quelle: Forschung 2/07 - Das Magazin der Deutschen Forschungsgemeinschaft, S. 8 - 11	26.09.07	Prof. J. Heintzenberg *Dr. Susanne Schöning*
international			
IGACtivities Newsletter	The CARIBIC aircraft system for detailed, long-term, global-scale measurement of trace gases and aerosol in a changing atmosphere In-service Aircraft for Global Observations - the future	Nr. 37, November-Ausgabe	Dr. M. Hermann, Prof. J. Heintzenberg Dr. M. Reichelt A. Weigelt

Präsenz im Fernsehen 2006

Sender	IfT/Name/*Thema*	Datum Aufnahme	Sendung
regional			
Leipzig Fernsehen Sendung XCAM	Dr. F. Stratmann *Forschung im Wolkenlabor*	05.12.05 21.12.05	11.02.06
national			
MDR Aktuell	Prof. J. Heintzenberg *Forschung im Wolkenlabor*	18.01.06	14.03.06, 21.45 Uhr
SAT 1 N 24	Dr. M. Hermann CARIBIC-Projekt *Mit fliegendem Messlabor wird die Zusammensetzung der Erdatmosphäre erforscht*		Forschen und Fliegen 25.03.06, 16:30 Uhr
Bayerisches Fernsehen	Prof. J. Heintzenberg *Globale Klimaerwärmung*	15.05.06 14.06.05	
ZDF 3sat hitec	Prof. J. Heintzenberg *Die Wüste lebt* Bericht zur Messkampagne SAMUM / Marokko	29.03.06/ 18. - 23.05.06	01.10.06, 16:00/16:30 Uhr 02.10.06, 19:30/20:00 Uhr
ARD W wie Wissen	Forschung im Leipziger Wolkenturm *Flug ins Innere der Wolken*		29.10.06, 17:03 Uhr
ZDF 3sat hitec	*Wolken - Der X-Faktor der Klimaforschung*	06.09.06	12.11.06, 16:00 Uhr, 02:00 Uhr 17.11.06, 15:30 Uhr 20.11.06, 22:15 Uhr
RBB	Wiederholung		09.12.06, 07:00 Uhr

Sender	IfT/Name/*Thema*	Datum Aufnahme	Sendung
national			
SWR	Wiederholungen 11.12.06 - 15.12.06		09:05 Uhr
SF1			10:30 Uhr
WDR			10:45 Uhr
Bralpha			14:30 Uhr
MDR			15:30 Uhr

Präsenz im Fernsehen 2007

Sender	IfT/Name/*Thema*	Datum Aufnahme	Sendung
regional			
MDR Sachsen Spiegel	Prof. J. Heintzenberg *„Alle Wetter“*	19.07.07 *Patricia Klieme*	05.09.07, 21:15 Uhr
national			
3 sat nano RBB, SWR, SF, DRS, WDR, BRalpha, MDR	Prof. J. Heintzenberg *Wüstensand in der Atmosphäre „Wüstenstaub der Sahara beeinflusst das Klima erheblich“*		29.01.07, 18:30 Uhr
WDR 5 Leonardo - Wissenschaft und mehr	Prof. J. Heintzenberg/ Dr. W. Birmili *„Zotto - Ein Stahlriese misst das Klima über Sibirien“*	*Annegret Faber*	24.04.07, 16:05 Uhr
ZDF Abenteuer Wissen	*Das Sahara-Paradox: Die Wüste wird grün/Staubwolken aus der Wüste*		13.06.07, 22:15 Uhr
Pro7	Prof. J. Heintzenberg Dr. F. Stratmann Galileo Mystery *„Wetter“*	11.06.07 *Robin Senger*	16.11.07, 23:00 Uhr
Bayerisches Fernsehen Faszination Wissen	Prof. J. Heintzenberg *Interview Wolkenlabor Feinstaub – der Gegenspieler des Treibhauseffekts*	23.10.07 *Hr. Trümper*	15.11.07, 21:15 Uhr
international			
NZZ Format Fernsehsendung der Neuen Zürcher Zeitung	Prof. J. Heintzenberg Dr. H. Wex *„Wolken - Klimafaktor und Wettermaschine“*	22.05.07 *Basil Gelpke*	**SF2:** 01.07.07, 21:30 Uhr **Vox:** 09.07.07, 23:00 Uhr
MDR aktuell	Dr. I. Tegen Dr. F. Stratmann *Klimakonferenz: Problematik Wolken - Klima*	03.12.07 *Hr. Ackner*	03.12.07, 20:00 Uhr und folgende Nachrichten

Präsenz im Rundfunk 2006

Sender	IfT/Name/*Thema*	Datum Interview	Sendung
regional			
MDR Regional Nachrichten	Prof. J. Heintzenberg *Aktionsplan „Luftreinhaltung der Stadt Leipzig“ - Feinstaubeintrag*	14.02.06	14.02.06
national			
Deutschlandradio Kultur	Prof. J. Heintzenberg FEATURE *Der Wolkenforscher*	2004	11.02.06, 18:05 Uhr
MDR 1 Radio Sachsen	Dr. F. Stratmann Buchmesse Leipzig *Vorstellung der Forschung im Wolkenlabor*	01.03.06	16.03.06, 11:46 Uhr
WDR-3	Prof. J. Heintzenberg FEATURE *Der Wolkenforscher*		23.04.06
Berliner Rundfunk 91.4	Prof. J. Heintzenberg Telefon-Interview Thema Wolkenforschung		06.09.06
MDR 1 Radio Sachsen	Dr. Heike Wex Wolkenlabor	29.08.06	07.09.06, 20:45 Uhr
international			
Schweizer Radio DRS2 (Wiss. Magazin Kontext)	Prof. J. Heintzenberg *Weltweit erster Wolken-Simulator am Leibniz-Institut für Troposphärenforschung in Leipzig*	10.05.06/ 17.12.06	21.06.06, 09:05 Uhr 12-Minuten-Beitrag/ 20:30 Uhr

Präsenz im Rundfunk 2007

Sender	IfT/Name/*Thema*	Datum Interview	Sendung
national			
MDR Figaro	Prof. J. Heintzenberg *„Science Fiction gegen Klima-wandel?“*	14.11.06 *Stefan Römermann*	09.01.07
BBC Sachsenmagazin World	Prof. J. Heintzenberg Dr. W. Birmili *Messstation Zottino/Russland Projekt ZOTTO*	17.01.07 *Annegret Faber*	18.01.07
WDR 5	Prof. J. Heintzenberg Dr. W. Birmili *Leonardo - Wissenschaft und mehr „Ein Stahlriese misst das Klima über Sibirien“*	17.01.2007 *Annegret Faber*	24.04.07

Sender	IfT/Name/*Thema*	Datum Interview	Sendung
national			
BR	Prof. J. Heintzenberg *Faszination Wissen „Feinstaub - der Gegenspieler des Treibhauseffekts“*	23.10.07 *Herr Trümper*	15.11.07
MDR 1 Radio Sachsen	Dr. W. Birmili Dr. K. Müller *Holzheizungen - eine neue massive Quelle von Feinstaubbelastung?*	26.11.07	26.11.07, ca. 18:00 Uhr

Präsenz im Internet 2006

Adresse	Thema
DW-WORLD.DE Deutsche Welle	Mädchen ohne Grenzen: *Girls‘Day in Deutschland* *Bundesland Sachsen - Institut für Troposphärenforschung*
student-leipzig.de Wissenschaft	Borkenkäfer und Wolken *Der Wissenschaftspark Leipzig bietet auch für Studenten Serviceleistungen* (IfT - LACIS: Prof. Heintzenberg)
paschal.de PASCHAL Schalung + Rüstung	Wolkenlabor Leipzig in Betrieb gegangen - Der Wolkenturm
daserste.de/wwiewissen	Flug ins Innere der Wolken
DIE WELT.de Wissenschaft	Die Sonne als globaler Klimakiller (*Experiment in CERN Genf - IfT)*
DW - WORLD.de Deutsche Welle	Die Wüste schwebt - Sandforschung in der Wüste
MDR.DE ECHT! Das Wissenschafts-magazin	Die Wolkenstürmer von Leipzig

Präsenz im Internet 2007

Adresse	Thema
stefanroemermann.de	Science Fiction gegen Klimawandel?
pr-inside.com freiepresse.de	*Internationale Klima- und Umweltkonferenz* 500 Teilnehmer werden in Leipzig erwartet Besuch des sächsischen Ministerpräsidenten Georg Milbradt und des EU-Kommissars Janez Potočnik
planet-wissen.de	Die Wolke im Turm
zdf.de	Staubwolken aus der Wüste
superleipzig.de	*Größtes* Größter Wolkensimulator

Adresse	Thema
sachsen.de	Ausstellung zum Architekturpreis 2007
zdf.de	*Abenteuer Wissen* Das Sahara-Paradox: Die Wüste wird grün
dfg.de	Wenn Europa verstaubt/Bericht zum SAMUM-DFG-Projekt
ard-tagesschau.de	Niederschlagsvorhersage: Weltgrößte Niederschlagsmessung im Schwarzwald gestartet
nzz.ch/format	Wolken - Klimafaktor und Wettermaschine
schattenblick.de	Wenn Europa verstaubt
girls-day.de	Mädchen-Zukunftstag 2007
sachsenlb.de	SAXONY April/2007 Wetter aus der Dose
mdr.de	Alle Wetter
wdr.de	*Leonardo - Wissenschaft und mehr* Zotto - Ein Stahlriese misst das Klima über Sibirien
3sat.de	Wüstenstaub der Sahara beeinflusst das Klima erheblich

Allgemeine Aktivitäten 2006

Anlass	Ort, Datum	Aktivität
Leipziger Buchmesse	IfT, 16.03.06	*Dr. F. Stratmann* Besuch des Wolkenlabors von 120 Teilnehmern der Buchmesse - Lesung im KUBUS - Wissenschaftspark
Deutsche Bank (Leitende Angestellte. Sachsen / Thüringen / Sachsen-Anhalt)	IfT, 30.03.06	*Dr. F. Stratmann, Dr. Heike Wex* Vorstellung der Arbeiten im Wolkenlabor
Institut für Energetik und Umwelt Leipzig (Bereich Biogastech-nologie)	IfT, 11.05.06	*Dr. Heike Wex* Vorstellung der Arbeiten im Wolkenlabor
ACHEMA	Aachen, 15./19.05.06	*Dr. T. Berndt* Präsentation: „Herstellung von Epoxiden: Eine neue effiziente Syntheseroute“
Institut für Energetik und Umwelt Leipzig (Senioren-Gruppe)	IfT, 19.06.06	*Dr. F. Stratmann* Vorstellung der Arbeiten im Wolkenlabor
Friedrich-Schiller-Gymnasium Bad Lausick	Bad Lausick, 19.06.06	*Dr. M. Wendisch* Vortrag zum Thema: „Ursachen und Wirkung der globalen klimatischen Veränderungen“ fächerverbindender Unterricht Klasse 8
Macherner Kirchen-gespräche	Machern, 10.07.06	*Dr. D. Althausen* Vortrag: Klimawandel
MDR Ausbildung Journalisten	Leipzig, 13.07.06	*Dr. F. Stratmann* Telefoninterview zum Thema „Wolkenlabor“

Allgemeine Aktivitäten 2007

Anlass	Ort, Datum	Aktivität
Vortrag	Johannes-Kepler-Gymnasium Leipzig, 09.01.2007	*Prof. J. Heintzenberg* Die Atmosphäre und die atmosphärische Zirkulation in den Tropen und Mittelbreiten und deren Wirkung auf das Leben in beiden Gebieten
Besichtigungen Wolkenlabor		
BSZ1 Leipzig (Berufl. Gymnasium)	IfT, 16.01.07, 08:00 Uhr - 10:00 Uhr	*Dr. F. Stratmann* Vorstellung der Arbeiten im Wolkenlabor
Freie Waldorfschule	IfT, 16.01.07, 10:30 Uhr - 11.30 Uhr	
Senioren SEFA e.V.	IfT, 07.02.07, 10:30 Uhr	
Girls'Day 2007	IfT, 26.04.07	*Mädchen in die Wissenschaft* Meteorologinnen, Physikerinnen und Chemikerinnen führen mit den Mädchen Experimente durch und geben dabei Einblicke in verschiedene Arbeitsgebiete der Atmosphärenforschung am IfT
STUMETA (Studentische Meteorologen-Tagung)	IfT, 17.05.07	*Prof. J. Heintzenberg* Vorstellung der Forschungsarbeiten am IfT
Studentengruppe der FH Nürnberg	IfT, 18.05.07	*Prof. J. Heintzenberg* Vorstellung der Forschungsarbeiten am IfT
Vortrag Institutsgründung LEGUT	Hochschule für Wissenschaft, Technik und Kunst, Leipzig, 30.05.07	*Prof. J. Heintzenberg* Aerosol- und Wolkenforschung am Leibniz-Institut für Troposphärenforschung
Vortrag	Neue Nikolaischule Leipzig, 22.10.07	*Prof. J. Heintzenberg* Anthropogene Klimaänderungen
Vortrag	Galerie für zeitgenössische Kunst Leipzig, 09.11.07, 19:00 Uhr	*Prof. J. Heintzenberg* Von der Wolke in der Röhre bis zum vereisenden Saharastaub: Wolkenforschung am Leibniz-Institut für Troposphärenforschung
Vortrag	Tauchaer Diakonat, 24.11.07	*Markus Hermann* Luftverkehr geringer Faktor des Klimawandels