

INSTITUTSBERICHT INSTITUTE REPORT 2007-2008

MAX-PLANCK-INSTITUT FÜR CHEMIE



MAX-PLANCK-GESELLSCHAFT



BIOGEOCHEMISTRY

ATMOSPHERIC
CHEMISTRY

GEOCHEMISTRY

PARTICLE
CHEMISTRY

MAX
PLANCK
INSTITUT

INSTITUTSBERICHT

FÜR
CHEMIE

2007
2008

INSTITUTE REPORT

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VORWORT

VORWORT

Unser Institut erforscht die Erde und ihr Umfeld in unterschiedlichen Größenbereichen, vom Nanopartikel bis zum Planeten und von der Ökosystemdynamik bis zum globalen Klimawandel. Unsere wissenschaftlichen Fragestellungen entstehen oft aus der Beobachtung natürlicher Phänomene in Feldstudien. Wir untersuchen ausgewählte Komponenten des Systems Erde unter kontrollierten Bedingungen im Labor und verwenden Computermodelle, um die Wechselwirkungen im System zu verstehen und die Rückkopplungs-Mechanismen aufzuklären. Wir helfen somit, Wissen und Methoden bereitzustellen, die für eine nachhaltige Nutzung der natürlichen Ressourcen und zum Schutz der Umwelt erforderlich sind. Auch sind wir durch unsere International Max Planck Research School und unser E-Learning-Programm an der wissenschaftlichen Ausbildung beteiligt.

In den beiden vergangenen Jahren hat das Institut seine Neufokussierung auf ein integrales Verständnis chemischer Prozesse im Erdsystem konsequent fortgesetzt. Die drei bestehenden Abteilungen Biogeochemie, Chemie der Atmosphäre und Partikelchemie legen ihren Schwerpunkt auf die Untersuchung von Prozessen auf relativ kurzen Zeit- und Raumskalen. Die im Aufbau begriffene Abteilung Chemie des Erdsystems, gegenwärtig realisiert durch die Gruppe Satellitenfernerkundung, erweitert die räumliche Skala durch den Einsatz satellitengestützter Fernerkundung. Durch eine gemeinsame Berufung mit der Universität Mainz eines Direktors für das Arbeitsgebiet der chemischen Paläoklimatologie soll nun das wissenschaftliche Portfolio des Instituts in Richtung auf längere Zeitskalen erweitert werden. Weiterhin wird die Erdsystemmodellierung durch eine Kooperation mit mehreren Max-Planck-Instituten (u.a. Hamburg, Jena und Mainz) und dem Potsdam-Institut für Klimafolgenforschung ausgebaut.

PREFACE

PREFACE

The Institute explores the Earth and its environment across a range of scales, from nanoparticles to planets, and from ecosystem dynamics to global climate change. Our research questions often arise from observations of natural phenomena in field studies. We investigate selected components of the Earth System under controlled conditions in the laboratory, and explore system interactions through computer modelling to study feedback mechanisms. In this way, we contribute the basic knowledge and methods needed for the sustainable use of natural resources and environmental protection. We are also committed to science education through our International Max Planck Research School and E-learning program.

In the past two years our institute has continued its process of refocusing on an integral scientific understanding of chemical processes in the Earth System. The three Divisions, Biogeochemistry, Atmospheric Chemistry, and Particle Chemistry, place their emphasis on the investigation of processes at relatively short time and space scales. The Division of Earth System Chemistry, which is under development and presently implemented in the form of the Remote Sensing Research Group, expands the spatial scales of our research by the use of satellite remote sensing. The joint appointment with the University of Mainz of a director working in the area of chemical palaeoclimatology is intended to complement the Institute's scientific portfolio in the direction of longer time scales. We are continuing our efforts in Earth System modelling by means of a co-operation with several other Max Planck Institutes (Hamburg, Jena, Mainz and others) and the Potsdam Institute for Climate Impact Research.

In den letzten beiden Jahren wurde das deutsche Forschungsflugzeug HALO für die Anforderungen der Atmosphärenforschung umgebaut. Die Übergabe an die Forschergemeinde wird in der zweiten Jahreshälfte 2008 erfolgen. Das Institut hat sich mit Unterstützung der Max-Planck-Gesellschaft von der ersten Vorschlagsphase an sehr stark für das Zustandekommen des HALO-Projekts eingesetzt und bereitet jetzt die erste Forschungsmission vor. Durch die Übernahme der Forschungsstation in Manaus, Brasilien, und eine Reihe von Expeditionen im Amazonasgebiet baut das Institut seinen Schwerpunkt in der Erforschung der Wechselwirkungen von Biosphäre und Atmosphäre in den Tropen weiter aus.

Im folgenden Bericht stellen wir unsere Institution und ihre Tätigkeitsschwerpunkte vor und geben einen kurzen Überblick unserer Forschungsergebnisse des Zeitraums 2007-2008.

Over the last two years, the new German High Altitude – Long Range (HALO) aircraft has been modified for use in atmospheric research. It will be handed over to the scientific community in the second half of 2008. The Institute, supported by the Max Planck Society, has been strongly committed to the acquisition and development of HALO and is now preparing its first research mission. Research on the interactions of the biosphere and atmosphere in the tropics is a growing scientific focus of the Institute, recently strengthened by a series of expeditions into the Amazon region and by the establishment of a permanent research station in Manaus, Brazil.

In this report we present our organisation, the central themes and a brief summary of our research results achieved in the period 2007-2008.



Prof. Dr. Meinrat O. Andreae
(Managing Director)

ALLGEMEINES ZUM INSTITUT

GENERAL INFORMATION

ALLGEMEINES ZUM INSTITUT

Geschichte und Gegenwart

Die Wurzeln des Max-Planck-Instituts für Chemie reichen zurück ins Jahr 1912 nach Berlin-Dahlem, wo es als erstes Institut der Kaiser-Wilhelm-Gesellschaft, der Vorläuferorganisation der Max-Planck-Gesellschaft zur Förderung der Wissenschaften (MPG), gegründet wurde. Die Max-Planck-Gesellschaft widmet sich vorrangig der Grundlagenforschung und greift insbesondere neue, zukunftssträchtige Forschungsrichtungen auf, die wegen ihres interdisziplinären Charakters oder wegen des großen Aufwandes keinen oder keinen ausreichenden Platz an den Universitäten finden.

Nach der Zerstörung der Institutsgebäude im 2. Weltkrieg und einer provisorischen Übersiedlung nach Tailfingen/Württemberg erfolgte 1949 der Neuaufbau in Mainz auf dem Gelände der Johannes Gutenberg-Universität. Seit 1959 trägt das Institut zusätzlich den Namen 'Otto-Hahn-Institut'. Damit wird die große Bedeutung Otto Hahns für das Institut gewürdigt und an die Entdeckung der Kernspaltung erinnert, die er 1938 zusammen mit Lise Meitner und Fritz Straßmann an diesem Institut gemacht hat.

Um sich den verändernden wissenschaftlichen Erfordernissen anzupassen, haben sich die Forschungsschwerpunkte des Instituts im Laufe



Lise Meitner & Otto Hahn, 1913

GENERAL INFORMATION

History and Present

The roots of the Max Planck Institute for Chemistry can be traced back to Berlin-Dahlem, where it was founded in 1912 as the first institute of the Kaiser Wilhelm Society, the forerunner organisation of the Max Planck Society for the Advancement of Science (MPG). The Max Planck Society focuses on basic research in new and promising science fields. These – mostly interdisciplinary – research areas are usually resource-intensive and are therefore difficult to accommodate at universities.

After its destruction in World War II and a provisional relocation in Tailfingen/Württemberg, the Institute was re-established in Mainz on the campus of Johannes Gutenberg University in 1949. Since 1959 it has additionally been named 'Otto Hahn Institute' to commemorate Hahn's great importance for the Institute, especially the discovery of nuclear fission, which he made together with Lise Meitner and Fritz Strassmann at this institute in 1938.

Adapting to changing scientific demands and interests, the Institute's research priorities underwent multiple changes in its history. While in the beginning classical chemistry had been practised, the focus later shifted to radiochemistry,



Paul J. Crutzen, 1995

ALLGEMEINES ZUM INSTITUT

GENERAL INFORMATION

seiner Geschichte mehrfach gewandelt. Wurde in den Anfangsjahren die klassische Chemie betrieben, so wandte sich das Interesse später vor allem der Radiochemie, Kernphysik und Massenspektrometrie zu. Seit den siebziger Jahren des letzten Jahrhunderts sind die Entstehung, Entwicklung und Zukunft unseres Planeten und seiner Nachbarn die zentralen Forschungsthemen. Der Bogen der Forschungen spannt sich dabei von den Planeten unseres Sonnensystems über die Lufthülle unserer Erde bis zu ihrem heißen Kern. Der Schwerpunkt liegt auf der Chemie des Systems Erde, wobei alle Komponenten des Erdsystems – Ozeane, Atmosphäre, feste Erde, Biosphäre und Menschen – als sich gegenseitig beeinflussende Teile eines integralen Systems erforscht werden.

Drei Mitgliedern des Instituts wurde der Nobelpreis verliehen: Richard Willstätter für seine Chlorophyllarbeiten (1915), Otto Hahn für die Entdeckung der Kernspaltung (1944) und Paul J. Crutzen für die Arbeiten über den Abbau des Ozons in der Stratosphäre (1995). Die Nobelpreisträger Max Delbrück und Heinrich Wieland haben zwar zeitweise am Institut geforscht, die preisgekrönten Arbeiten aber an anderen Institutionen durchgeführt.

nuclear physics and mass spectrometry. Since the 1970s, the formation and development of our planet and its environment have been the central issues. The research covers a wide range of topics, including the planets of our solar system, the atmosphere of the Earth, and its hot core. The main focus is on Earth system chemistry, thus all individual components of the Earth system – i.e. oceans, atmosphere, solid Earth, biosphere, and humans – are studied, since their reciprocal impact and interferences influence the whole system.

Three directors of the Institute have been awarded the Nobel Prize: Richard Willstätter for his work on chlorophyll (1915), Otto Hahn for the discovery of nuclear fission (1944), and Paul J. Crutzen for his work on ozone depletion in the stratosphere (1995). The Nobel Prize winners Max Delbrück and Heinrich Wieland both worked at the Institute for some time, their awarded work and research were conducted in other institutions, however.



Emeriti, 2001: Friedrich Begemann, Albrecht W. Hofmann, Paul J. Crutzen, Günter W. Lugmair, Heinrich Wänke



Direktoren, 2008: Jos Lelieveld, Meinrat O. Andreae, Stephan Borrmann

ALLGEMEINES ZUM INSTITUT

GENERAL INFORMATION

Organisation

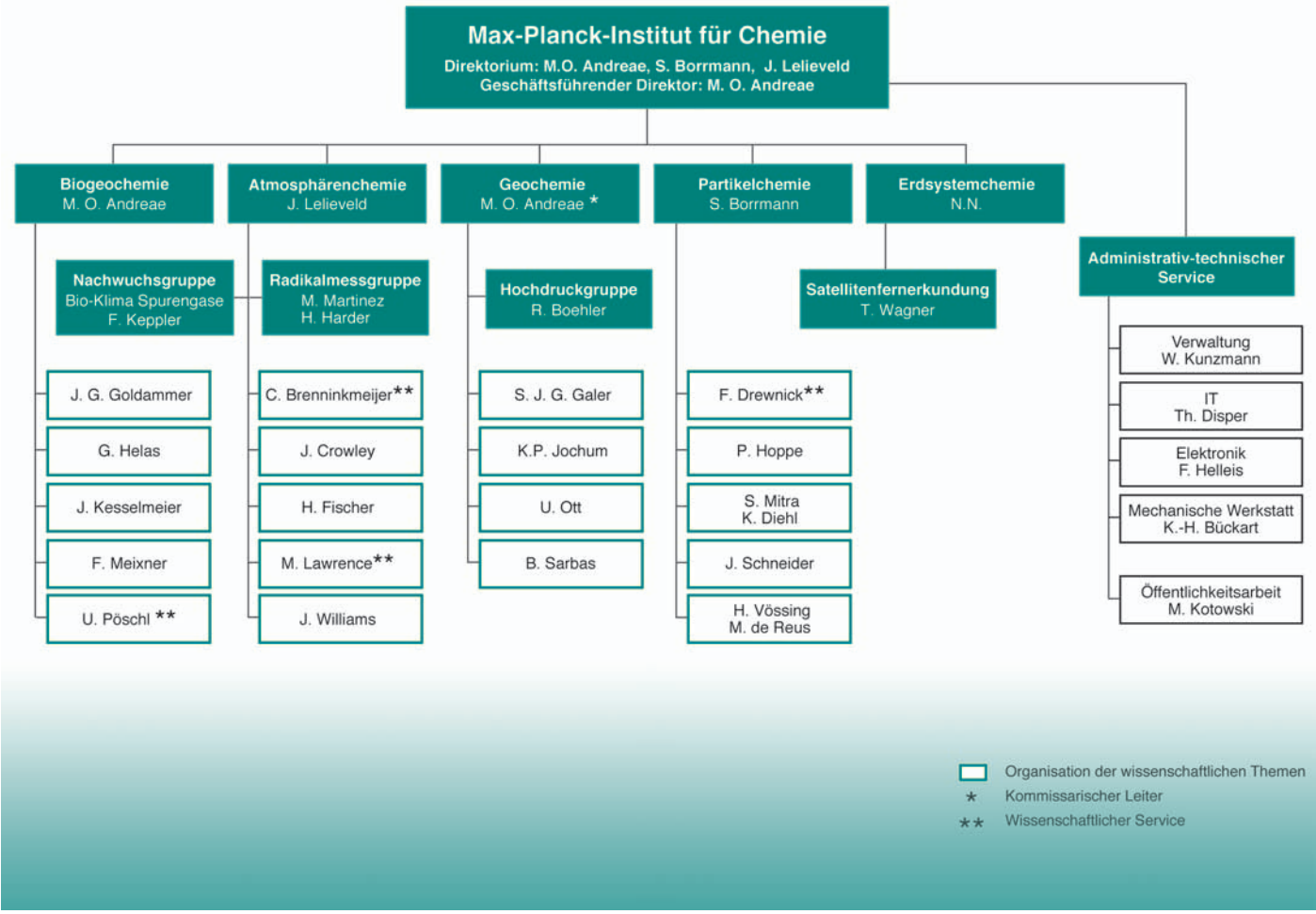
Organisation

Heute besteht das Institut aus vier Abteilungen, drei selbständigen Arbeitsgruppen und einer Nachwuchsgruppe. Jede der Abteilungen wird von einem Direktor geleitet, der als Wissenschaftliches Mitglied der MPG für seine Forschungstätigkeit eigenverantwortlich ist. Die Direktoren entscheiden gemeinsam über die Geschicke des Instituts und wählen aus ihrem Kreis im dreijährigen Turnus einen geschäftsführenden Direktor.

At present the Institute consists of four departments, three independent research groups and a junior research group. Each of the departments is supervised by a director, who, as a scientific member of MPG has sole responsibility for his field of research. The directors decide collectively the Institute's development and elect a managing director out of their circle every three years.

Die Forschungsarbeit des Instituts wird von einem internationalen Fachbeirat begutachtet, der in regelmäßigen Abständen dem Präsidenten der Max-Planck-Gesellschaft berichtet.

The Institute's research is evaluated by an international Scientific Advisory Board, which reports at regular intervals to the President of the Max Planck Society.



Organisation der wissenschaftlichen Themen
 * Kommissarischer Leiter
 ** Wissenschaftlicher Service

ALLGEMEINES ZUM INSTITUT GENERAL INFORMATION

FACHBEIRAT

SCIENTIFIC ADVISORY BOARD OF THE INSTITUTE

Prof. Dr. Halliday, Alexander N.	University of Oxford, Oxford, UK
Prof. Dr. Hawkesworth, Christopher John	University of Bristol, Bristol, UK
Prof. Dr. Hoffmann, Michael R.	California Institute of Technology, Pasadena, USA
Prof. Dr. Hofmann, Thorsten	Universität Mainz
Prof. Dr. Isaksen, Ivar S. A.	University of Oslo, Oslo, Norwegen
Prof. Dr. Levin, Zev	Tel Aviv University, Ramat Aviv, Israel
Prof. Dr. Molina, Mario J.	Massachusetts Institute of Technology, Cambridge, USA
Prof. Dr. Solomon, Sean C.	Carnegie Institution of Washington, Washington, DC, USA



ALLGEMEINES ZUM INSTITUT

GENERAL INFORMATION

Forschungsthemen im Überblick

Research Topics

Die Abteilung **BIOGEOCHEMIE** (Prof. Dr. Meinrat O. Andreae) befasst sich mit Austausch und Wechselwirkungen von

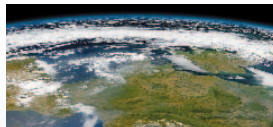


The **BIOGEOCHEMISTRY** Department (Prof. Dr. Meinrat O. Andreae) addresses the exchange and interactions of trace gases and

Spurengasen und Aerosolen zwischen Biosphäre und Atmosphäre. Diese Prozesse werden durch Experimente im Labor, Feldmessungen und Modellrechnungen untersucht. Forschungsschwerpunkte sind: Austausch von chemisch und klimatisch wichtigen Spurengasen zwischen dem System Boden/Vegetation und der Atmosphäre, Bildung von Aerosolteilchen und ihr Einfluss auf das Klima, Einfluss von Vegetationsfeuern auf die Ökologie und Luftverschmutzung und globale Kreisläufe von Spurenstoffen. Ein besonderer Schwerpunkt ist die Untersuchung des Amazonasgebietes.

aerosols between biosphere and atmosphere. These processes are studied by laboratory investigations, field measurements and numerical models. The research topics are: exchange of chemically and climatically important trace gases between the soil/vegetation system and the atmosphere, formation of aerosol particles and their effects on climate, impact of vegetation fires on ecology and atmospheric pollution, and global cycles of trace gases. A special focus is the investigation of the Amazon region.

Die Abteilung **CHEMIE DER ATMOSPHÄRE** (Prof. Dr. Jos Lelieveld) untersucht



The research in the **ATMOSPHERIC CHEMISTRY** Department (Prof. Dr. Jos Lelieveld) focuses on ozone and

chemische Reaktionen und globale Spurenstoffkreisläufe von Ozon und anderen reaktiven Spurengasen in der Atmosphäre. Diese Prozesse werden durch Experimente im Labor sowie Messungen in der Atmosphäre von Bodenstationen, Schiffen, Flugzeugen sowie Satelliten aus untersucht. Diese Feldmessungen werden unterstützt und analysiert mithilfe von Computermodellen zur Simulation meteorologischer und chemischer Wechselwirkungen sowie deren Einfluss auf das Klima.

other reactive trace gases in the atmosphere, their chemical reactions and global cycles. These processes are studied by laboratory investigations and intensive ground-based, ship, aircraft and satellite measurements in the atmosphere. Numerical models that simulate meteorological and chemical interactions are used to support and analyse the field measurements and study human influences on climate.

In der Abteilung **GEOCHEMIE** (Prof. Dr. Meinrat O. Andreae, kommissarisch) werden die chemische



The **GEOCHEMISTRY** Department (Prof. Dr. Meinrat O. Andreae, Acting Head) investigates the chemical composition and

Beschaffenheit und die zeitliche Entwicklung von Kruste und Mantel unserer Erde und anderer Körper des inneren Sonnensystems erforscht. Mithilfe sehr genauer Messungen von Isotopenhäufigkeiten der natürlichen radioaktiven Zerfallssysteme sowie von Spurenelementhäufigkeiten in Gesteinen und Mineralen werden neue Erkenntnisse über geologische Prozesse, wie die Bildung von Vulkaninseln oder die Entwicklung der Weltmeere, gewonnen.

chronological development of the Earth's mantle and crust, as well as of other bodies of the inner Solar System. High-precision measurements of isotopic abundances of natural radioactive decay systems and of trace element abundances in rocks and minerals provide new insights into a wide range of geological processes, including the formation of volcanic islands and the evolution of the oceans.

ALLGEMEINES ZUM INSTITUT GENERAL INFORMATION

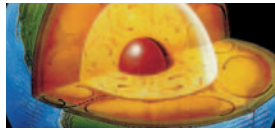
Die Abteilung **PARTIKELCHEMIE** (Prof. Dr. Stephan Borrmann) untersucht physikalische Eigenschaften und chemische



Zusammensetzung atmosphärischer Aerosol- und Wolkenpartikel. Hierzu werden Laborexperimente (z.B. in einem Vertikalwindkanal), Messungen an Boden- und Bergstationen und auf mobilen Messträgern (insbesondere auf Flugzeugen) durchgeführt, sowie Methoden entwickelt zur Erfassung des Aerosols durch Massenspektrometrie. Mithilfe von Isotopenmessungen werden extraterrestrische Partikel wie z.B. präsolare Körner aus Meteoriten und von Kometen analysiert.

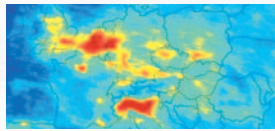
The **PARTICLE CHEMISTRY** Department (Prof. Dr. Stephan Borrmann) is focused on chemical composition and physical properties of atmospheric aerosol and cloud particles. The measurements include laboratory experiments (e.g. in a vertical wind tunnel) as well as ground- and aircraft-based field experiments. Methods for mass spectrometric detection of aerosols are developed. Particles of extraterrestrial origin such as presolar dust grains from meteorites and comets are studied by isotope measurements.

Die Arbeitsgruppe **HOCHDRUCK-MINERALPHYSIK** (Dr. Reinhard Boehler) untersucht Metall- und Mineralphasengleichgewichte, das Schmelzverhalten und thermodynamische Zustandsgrößen bei Druck- und Temperaturbedingungen des tiefen Erdmantels und Erdkerns (bis zu 2 Millionen Atmosphären und 5000 °C).



The **HIGH PRESSURE MINERAL PHYSICS** research group (Dr. Reinhard Boehler) is concerned with the determination of metal and mineral equilibria and thermodynamical properties under conditions of the deep Earth's mantle and core (up to 2 million atmospheres pressure and 5000 °C).

Die Gruppe **SATELLITENFERNERKUNDUNG** (Prof. Dr. Thomas Wagner) befasst sich mit



der Entwicklung und Anwendung von Auswertelgorithmen für neuartige Satelliteninstrumente im ultravioletten, sichtbaren und nah-infraroten Spektralbereich. Solche Messungen erlauben die Untersuchung atmosphärischer Stoffkreisläufe von Schadstoffen, Treibhausgasen, Aerosolen und Wolken.

The **SATELLITE REMOTE SENSING** group (Prof. Dr. Thomas Wagner) is concerned with the development and application of retrieval algorithms for novel UV/vis/near-IR satellite instruments. Based on these observations the atmospheric budgets of pollutants, greenhouse gases, aerosols and clouds are investigated.

Die **RADIKALMESSGRUPPE** (Dr. Monica Martinez) untersucht reaktive Spurengase, insbesondere Hydroxyl- und Hydroperoxyl-Radikale, in Hinblick auf deren Quellen, Senken und Reaktionsketten in verschiedenen Bereichen der Atmosphäre. Es werden Geräte zur laserinduzierten Fluoreszenz-Spektroskopie entwickelt und auf verschiedenen Plattformen vom Boden bis in die untere Stratosphäre eingesetzt.



The **RADICAL MEASUREMENTS** group (Dr. Monica Martinez) investigates hydroxyl and hydroperoxyl radicals focusing on their sources, sinks and reaction chains. Laser-induced fluorescence instruments are developed and deployed on different measurement platforms to investigate the different parts of the atmosphere.

Die Nachwuchsgruppe **ORCAS** (Dr. Frank Keppler) erforscht die Bildung klimarelevanter, leichtflüchtiger organischer



Substanzen und ihren Lebenszyklus. Der Forschungsschwerpunkt liegt auf den Spurengasen Methan, Chlormethan und Brommethan und deren Beitrag zum Treibhauseffekt beziehungsweise zur Ozonzerstörung.

The junior research group **ORCAS** (Dr. Frank Keppler) investigates the formation of climate-relevant volatile organic substances and their life cycle. Its research focuses on the trace gases methane, chloromethane and bromomethane and their contribution to the greenhouse effect and ozone destruction.

ALLGEMEINES ZUM INSTITUT GENERAL INFORMATION

Forschung und Lehre

Research and Education

Das Institut betreibt keine eigenständige Lehre, ist aber insbesondere durch seine Lage auf dem Universitätscampus in vielfältiger Weise in das Leben der Mainzer Johannes Gutenberg-Universität eingebunden, sowohl durch gemeinsame Einrichtungen und Forschungsprojekte als auch durch Lehrtätigkeit an der Universität. So ist die Abteilung Partikelchemie eine gemeinsame Einrichtung des MPI für Chemie und des Instituts für Physik der Atmosphäre der Universität Mainz und die Arbeitsgruppe Satellitenfernerkundung eine Kooperation mit dem Institut für Umweltphysik der Universität Heidelberg.

Die **International Max Planck Research School for Atmospheric Chemistry and Physics (IMPRS)** wurde in enger Zusammenarbeit zwischen dem MPI für Chemie und den Universitäten Mainz, Frankfurt und Heidelberg im Jahre 2003 gegründet. Besonders begabten deutschen und ausländischen Studenten bietet diese Einrichtung die Möglichkeit, sich im Rahmen einer individuell strukturierten Ausbildung, die Vorlesungen, Workshops und Sommerschulen umfasst, auf die Promotion vorzubereiten.

Die IMPRS bietet einen Studienplan in Atmosphären-, Umwelt- sowie Geophysik und -chemie an. Durch die Kombination von exzellenter Forschung, modernster Geräteentwicklung, Feldmessungen und innovativen Unterrichtsmethoden wird die IMPRS zum Anziehungspunkt für talentierte und hoch motivierte junge Wissenschaftler aus der ganzen Welt. Ein Teil der Studenten arbeitet im Labor, viele beteiligen sich an Feldmesskampagnen mit Flugzeugen und Schiffen, und einige verwenden Satellitendaten und entwickeln Computermodelle. Während der jährlich im Sommer durchgeführten IMPRS-Informationstage erhalten die einzelnen Studenten Einblick in andere Labor- und Forschungseinrichtungen und tauschen untereinander Erfahrungen aus.

Während ihrer Ausbildung werden die Studenten durch einen beratenden Ausschuss betreut, der aus mindestens drei Wissenschaftlern

The Institute is not an independent teaching institution. However, it is part of university life, particularly as it is located on the campus of the University of Mainz, through joint institutions and research projects and through teaching activities at the University. The Particle Chemistry Department is a joint institution of the MPI for Chemistry and the Institute for Physics of the Atmosphere of the University of Mainz, and the Satellite Remote Sensing group is a co-operation with the Institute of Environmental Physics, University of Heidelberg.

The **International Max Planck Research School for Atmospheric Chemistry and Physics (IMPRS)** was established in 2003 in co-operation with the Universities of Mainz, Frankfurt and Heidelberg. The school offers talented Ph.D. students from Germany and abroad the possibility to prepare for their Ph.D. exam in an individually structured programme that includes lectures, workshops and summer schools.

The IMPRS offers a Ph.D. curriculum in atmospheric and environmental science, geophysics and geochemistry. Through the combination of high quality research, state of the art instrumentation development, field measurements and innovative education methods it attracts talented and motivated young scientists from all over the world. Some of our students work in the laboratory, many are active in field campaigns using aircraft and ships, and a number use satellite data and develop computer models. During the annual and informal IMPRS Days in summer, the students gain insight in each other's laboratory and research facilities and exchange experiences.

During their studies our students are guided by a Ph.D. advisory committee (PAC), comprising at least 3 scientists (from both, the University and the Institute) with whom the students meet in regular intervals. During the PAC meetings the students present and discuss their scientific work and receive feedback from the senior scientists. The PAC members help the students to complete

ALLGEMEINES ZUM INSTITUT GENERAL INFORMATION

der Universität und des Instituts besteht. Mit diesen treffen die Doktoranden in regelmäßigen Abständen zusammen, stellen dabei ihre wissenschaftlichen Arbeiten vor, diskutieren die Ergebnisse und erhalten Feedback. Die Mitglieder des Ausschusses helfen den Studenten, ihre Promotion innerhalb der vorgesehenen drei Jahre zu vollenden. Zudem berichten die Studenten am Ende des ersten und zweiten Jahres über ihre Fortschritte, die von den Ausschussmitgliedern begutachtet werden.

Die IMPRS vermittelt den Studenten nicht nur das erforderliche Fachwissen in den Geowissenschaften, ausgewählte Kurse zur Verbesserung der Präsentationsfähigkeiten ermöglichen zusätzlich eine Steigerung der Karrierechancen nicht nur in der Wissenschaft, sondern auch in der Wirtschaft oder im Ausbildungswesen.

Zurzeit (Anfang 2008) sind 54 Doktoranden in der IMPRS aufgenommen, davon 25 weibliche. Die Studenten stammen aus 18 verschiedenen Ländern. Seit der Gründung der IMPRS im Jahre 2003 haben 29 Studenten das Studium abgeschlossen, die meisten davon mit hervorragenden Beurteilungen.

the Ph.D. work within the 3 year time frame. Besides the meetings, the students report about progress at the end of the first and second year, and the progress is assessed by the PACs.

In addition to the required knowledge in the earth sciences we offer our students a selection of courses to improve their presenting and writing skills, thus enhancing career opportunities not only in science, but also in industry and education.

To date (early 2008) the IMPRS hosts 54 doctoral students, of which 25 female. The students are from 18 different countries. 29 students have finished since the school's start in 2003, most of them with excellent results.

The screenshot shows the website www.atmosphere.mpg.de/school for the International Max Planck Research School for Atmospheric Chemistry and Physics. The website features a header with the URL and logo, a banner image of Earth, and a navigation menu with links for Contact, Home, Atmospheric Chemistry Department, ESPERE, News, Links, and Impressum. Below the screenshot is a photograph of a group of students sitting around a long table in a meeting room, engaged in discussion.

MAX PLANCK INSTITUT

SELECTED RESEARCH REPORTS

FÜR CHEMIE

BIOGEOCHEMISTRY DEPARTMENT

ATMOSPHERIC CHEMISTRY DEPARTMENT

GEOCHEMISTRY DEPARTMENT

PARTICLE CHEMISTRY DEPARTMENT

HIGH PRESSURE MINERAL PHYSICS GROUP

SATELLITE REMOTE SENSING GROUP

RADICAL MEASUREMENTS GROUP

JUNIOR RESEARCH GROUP

SELECTED PUBLICATIONS

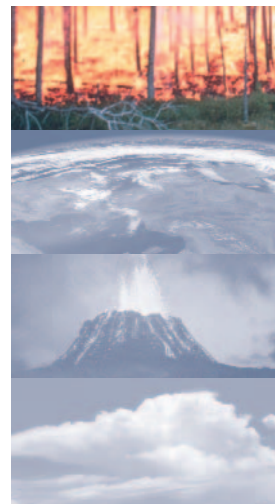
BIOGEOCHEMISTRY DEPARTMENT

Main Research Areas

Meinrat O. Andreae



Born 19 May 1949 in Augsburg. Undergraduate studies in chemistry and earth sciences, Karlsruhe and Göttingen. Ph.D. 1977 in Oceanography, Scripps Institution of Oceanography, University of California, San Diego. 1978-1982 Assist. Professor, 1982-1986 Assoc. Professor, 1986-1987 Professor of Oceanography at Florida State Univ., Tallahassee. Visiting Professor at the University of Antwerp, the University of California, Irvine, and the California Institute of Technology. Since 1987 Director and Scientific Member at the MPI for Chemistry. Member of the scientific steering committee of the 'Large Scale Biosphere Atmosphere Experiment in Amazonia (LBA)' and Chair of the IGBP Core Project 'Integrated Land Ecosystem Atmospheric Processes Study (ILEAPS)'. Editor-in-Chief of Global Biogeochemical Cycles.



Biogeochemistry is the scientific discipline that studies the interactions of the biosphere with the Earth's chemical environment. It is an essential part of the evolving field of Earth System Science, which looks at the Earth as an integral system. Our department investigates a number of key aspects of global biogeochemistry: the role of the terrestrial biota as sources and sinks of climatically important trace gases and aerosols, the exchange of trace gases between the soil/vegetation system and the atmosphere, the effect of vegetation fires on ecology, climate, and atmospheric pollution, and the role of biogenic and other aerosols in the climate system. Our research is closely tied to the International Biosphere/Geosphere Program, and involves a high amount of international collaboration.

Current projects include the study of the exchange of volatile organic compounds by plants in tropical and Mediterranean ecosystems. One of the main objectives is to understand the role of this exchange in the carbon budget of ecosystems and the terrestrial biota as a whole.

The conversion of rainforest and savanna in the tropics into grazing and agricultural lands has a strong influence on the exchange of trace gases, and in particular on the ability of ecosystems to act as sources or sinks for a wide variety of nitrogen-containing trace gases and aerosol species. We study these effects at selected sites in the tropics and in temperate regions.

Vegetation fires are an important determinant in the ecology of many terrestrial systems. We study the role of fire in ecology, climate and atmospheric chemistry, using modelling, remote sensing, and field work in the Amazon and other regions. Gaseous and particulate emissions from vegetation fires and the products of the photochemical processing of these emissions in the atmosphere are being investigated. Our studies show that the numbers of aerosols and cloud condensation nuclei (CCN) over pristine tropical continents are low and resemble conditions found over the oceans. Large-scale burning due to deforestation and clearing fires leads to a strong increase of aerosol and CCN concentrations, which in turn has a dramatic effect on cloud properties. This changes the mechanism of rainfall production and leads to redistribution of the transport of energy and chemical species in the tropical atmosphere. Ultimately, the effects reach far beyond the Amazon Basin and the tropics.

In 2007, the MPI for Chemistry took over the operation of the field station in Manaus from the MPI for Limnology. In collaboration with the Brazilian National Institute for Amazon Research, we are conducting integrated studies on the biogeochemistry and ecology of the Central Amazon.

BIOGEOCHEMISTRY

Molecular Genetics, Diversity and Emissions of Bioaerosols

Biogenic aerosols are ubiquitous in the Earth's atmosphere, and they influence atmospheric chemistry and physics, the biosphere, climate, and public health. They play an important role in the spread of biological organisms and ecosystems, and they can cause or enhance human, animal and plant diseases. Moreover, they can initiate the formation of clouds and precipitation as cloud condensation and ice nuclei. The composition, abundance and origin of biogenic aerosol particles and components are, however, not yet well understood.

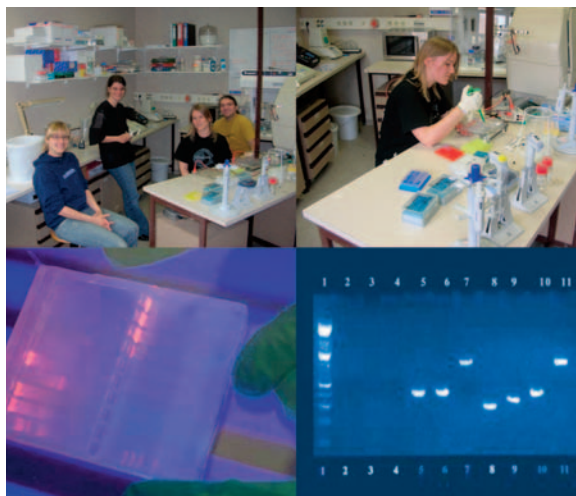
Biogenic volatile organic compounds are the main precursors of secondary organic aerosol formation, and primary biogenic aerosol (PBA) particles and components are emitted directly from the biosphere to the atmosphere. Pollen grains, fern spores, large fungal spores, and other large PBA particles typically belong to the coarse fraction of air particulate matter, with aerodynamic diameters up to one hundred micrometres. PBA particles and components are, however, also found in intermediate and fine fractions of air particulate matter, with aerodynamic diameters less than 10 μm and 2.5 μm , respectively: most fungal spores, bacteria, viruses, carbohydrates, proteins, waxes, ions, etc. are in the micrometre and submicron size ranges.

To identify and quantify PBA particles and components, we develop and apply biological, chemical and physical techniques. By extraction, amplification and analysis of deoxyribonucleic acid (DNA) we have found a wide variety of archaea, bacteria, fungi, plant and animal fragments in filter samples of coarse and fine particulate matter

from urban, rural, high-alpine, tropical rainforest, and marine boundary layer air around the world. Systematic investigations of biodiversity, geographical differences and seasonal trends are under way. Most of the detected bacterial sequences are from the group of Proteobacteria, which includes many pathogens as well as nitrogen oxidising bacteria living in soils and on plants. Most fungal sequences are from Ascomycota and Basidiomycota, many of which actively discharge spores with liquids into the air (ejection by osmotic pressure and surface tension effects). Based on the observed average concentrations of spores and related molecular tracers (sugar alcohols), we have derived a first estimate of the global emission rate of fungal spores ($\sim 50 \text{ Tg yr}^{-1}$, $\sim 200 \text{ m}^{-2} \text{ s}^{-1}$ over land), indicating that fungi are a major source of organic aerosol.

Online fluorescence detection and microscopic analyses show that fungal spores and other PBA particles are especially abundant in tropical regions, where both the biological activity at the Earth's surface and the physicochemical processes in the atmosphere are particularly intense and important for the Earth system and global climate. Further measurements (ground-based and airborne) and model studies are planned to unravel the seasonal and regional variations, vertical profiles, long-range transport, and climate effects of bioaerosols.

Bioanalytical laboratory and electrophoretic separation of polymerase chain reaction (PCR) products in the course of DNA amplification and analysis.



Aerosol-Cloud-Climate Interactions: Measurement and Modelling of Cloud Condensation Nuclei

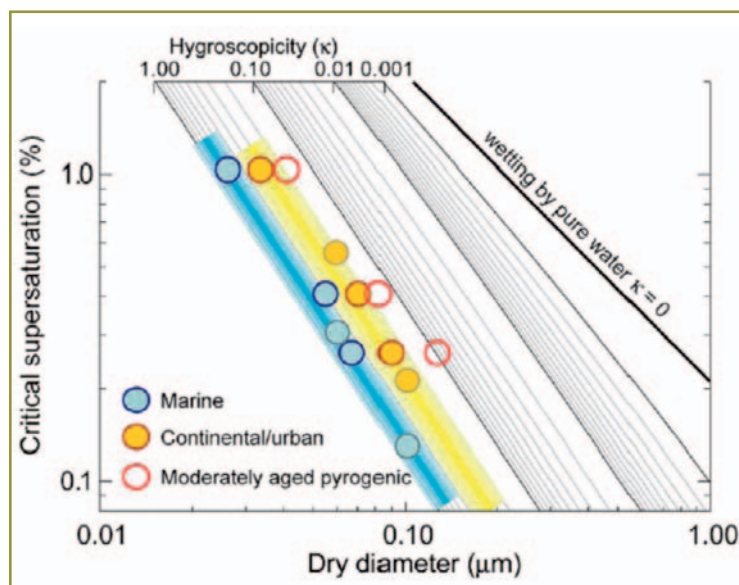
Aerosol particles that enable the condensation of water vapour and formation of cloud droplets are called cloud condensation nuclei (CCN). Elevated concentrations of CCN tend to increase the concentration of cloud droplets and decrease their size. Besides changing the clouds' optical properties and radiative effects on climate, this may lead to the suppression of precipitation in shallow and short-lived clouds but also to greater convective overturning and more precipitation in deep convective clouds. The response of cloud characteristics and precipitation processes to increasing anthropogenic aerosol concentrations represents one of the largest uncertainties in the current understanding of climate change. One of the crucial underlying challenges is to determine the ability of aerosol particles to act as CCN under relevant atmospheric conditions (CCN activity).

We have used a cloud condensation nuclei counter to measure the CCN activity of aerosols as a function of particle size and water vapour supersaturation in different environments around the world: in the vicinity of highly polluted megacities (Beijing, Guangzhou), at rural and high-alpine continental sites (Feldberg, Hohenpeißenberg, Jungfraujoch) as well as in pristine tropical rainforest and marine boundary layer air (Amazonia, Puerto Rico). The measurement results show a high temporal and

spatial variability of CCN concentrations due to differences in the concentration, size distribution and chemical composition of aerosol particles.

The influence of chemical composition on the CCN activity of aerosol particles can be described by an effective hygroscopicity parameter (κ) that relates the dry particle diameter to the so-called critical water vapour supersaturation, i.e. the minimum supersaturation required to form a cloud droplet. As illustrated below, the critical supersaturation generally decreases with increasing particle diameter and hygroscopicity. According to measurements and thermodynamic models (Köhler theory), κ is typically in the range of ~ 0.1 for biomass burning and secondary organic aerosols to ~ 1 for sea spray aerosols. Continental and marine aerosols tend to cluster into relatively narrow ranges of effective hygroscopicity (continental $\kappa = 0.3 \pm 0.1$; marine $\kappa = 0.7 \pm 0.2$) which should facilitate their treatment in climate models.

To unravel the influence of aerosols on the formation and properties of clouds and precipitation, we use the CCN measurement data and parameterisations as input for numerical simulations of cloud microphysics with parcel models and high-resolution 3-D models. First results show systematic but strongly non-linear dependences of initial cloud droplet number on aerosol properties, CCN activity and meteorological parameters. Further comprehensive investigations of aerosol composition, CCN activity and cloud microphysics will be required for full elucidation of aerosol-cloud-climate interactions – especially for the prediction of cloud properties, precipitation patterns and heavy weather events in the course of global change.



Characteristic relation between minimum water vapour supersaturations and dry diameters of aerosol particles (CCN) required for cloud droplet formation. The coloured dots and bands represent measurement results; the grey lines are model results for different hygroscopicity parameters (κ).

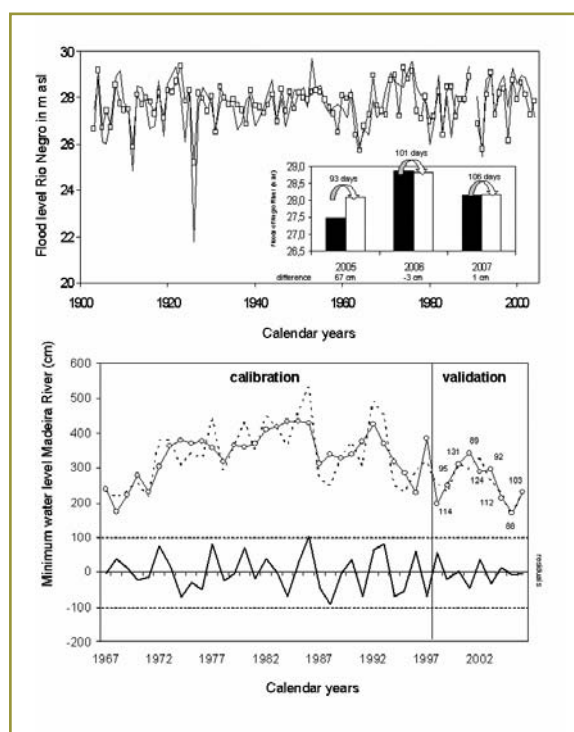
BIOGEOCHEMISTRY

Forecasting the Flood Pulse of Amazonian Rivers by Oceanographic Data

The Amazon Basin comprises about 20% of the world freshwater resources. Because of its importance for general global circulation, biogeochemical cycles, atmospheric chemistry, water resource management, transportation, hydroelectricity production, and economic activities, an understanding of the interannual variability in meteorological and hydrological patterns in Amazonia is of great importance. Sea-surface temperatures (SSTs) of the tropical Atlantic and tropical Pacific are known to trigger the seasonal precipitation regime, inducing a regular annual flood pulse with mean amplitudes of several metres. Within the floodplains, a distinct seasonal cycle between an aquatic phase and a terrestrial phase is induced, affecting biogeochemical cycles, growth rhythms and life cycles. Nutrient-rich floodplains along sediment-loaded, white-water rivers (várzea) have the highest human population densities in rural Amazonia due to their easy accessibility, richness in natural resources and highly productive soils. Agriculture, fishery and timber extraction are directly associated with water level fluctuations. Severe floods and droughts have huge impacts on the ecosystems and socio-economic activity in

these large river-floodplain systems. As there are large uncertainties about how the intensity and frequency of such extreme events will change as a result of regional and global climate change, there is a great interest to develop the capacity to forecast droughts and floods.

Based on multiple regression analysis of Amazonian river water levels and SSTs of the surrounding tropical oceans, a forecast of minimum and maximum water levels about 100 days in advance is possible. So far, forecast models have been developed for the Rio Negro (Manaus) and Rio Madeira (Porto Velho) to predict maximum water levels (Manaus) and minimum water levels (Porto Velho). In the future we will expand the forecast models to other hydrographic basins in co-operation with the National Institute for Amazon research (INPA) and the University of Amazonas State (UEA). Such models are powerful instruments for investigations on climate change as well as for formulating public policies to develop an effective risk management for the populations living in floodplains and urban regions along the Amazonian rivers, and to increase the efficiencies of their economic activities.



Comparison between the observed (solid line) and predicted (line with squares) maximum flood levels of the Rio Negro (Manaus) for the period 1903–2004 (asl: above average sea level). The forecast maximum levels of the Rio Negro from 2005 to 2007, the difference and time lag between forecast (black bars) and observation (white bars) is indicated in the small figure (above). Comparison between observed (solid line) and forecast minimum water levels (dotted line) of the Madeira River at Porto Velho is given for the period of calibration (1967–1997) and validation (1998–2006). Numbers indicate the time lag in days between forecast and observed minimum water levels (below).

BIOGEOCHEMISTRY

Exchange of Trace Gases in Forested Mountain Regions

The ability of forests to absorb trace gases emitted from anthropogenic (traffic, energy production) and from biogenic (soil and plants) sources is an important aspect of tropospheric chemistry. Particularly for the regional distribution of ozone (O_3), the impact of the 'processing' of so-called ozone precursor gases (e.g. nitrogen oxides [NO , NO_2] and volatile organic compounds [VOCs]) by vegetation is a wide open question. Below tall vegetation canopies, especially inside forests, frequent calm wind conditions lead to reduced in-canopy turbulent transport. Consequently, quite long residence times are likely for trace gases that are emitted from the soil surface and the vegetation elements (stem, branches, leaves) to the trunk and canopy air spaces (e.g. NO , HNO_2 , N_2O , CO_2 , CH_4 , VOCs) – they are somewhat 'sheltered' from otherwise fast dilution into the above-canopy atmosphere. On the other hand, there is ample time for (a) their transformation into other species due to fast (photo-)chemical reactions (e.g. with O_3 , OH , ROH), and (b) effective adsorption of the emitted gases and their reaction products to soil surfaces and leaves (stomatal uptake). The orographic and complex structure of mountain forests creates a particular challenge in this direction.

Within the project EGER the Biogeochemistry Department and the University of Bayreuth joined forces to investigate the exchange of energy,

water and trace gases at the 54-year-old montane Norway spruce (*Picea abies*) stand of 'Weidenbrunnen' (Fichtelgebirge/Germany). The biogeochemical focus is concentrated at the most important interfaces of trace gas exchange: forest soil/trunk space and canopy/atmosphere. Spatial and temporal scales of the bi-directional exchange of NO , NO_2 , O_3 , CO_2 , H_2O , ^{222}Rn , ^{220}Rn , as well as NH_3 , HNO_3 , $HONO$, SO_2 , HCl and related aerosol compounds (NH_4^+ , NO_3^- , SO_4^{2-} , Cl^-) are addressed during seasonally distributed intensive observation periods. For that, the full suite of flux measurement instrumentation is applied: dynamic and static soil chambers, leaf and branch enclosures, sap flow devices, highly resolved vertical concentration profiles (ranging from mineral and organic soil layers through the trunk space and canopy to the above-canopy atmosphere), aerodynamic gradient and eddy covariance as well as remote sensing techniques (SODAR/RASS). Data obtained through these field experiments will be used to validate a set of complex models (1D–3D) to describe the microclimate and physiological behaviour of individual trees and the stand, the spatio-temporal distribution of radiation, turbulent transport, thermodynamic stratification and coupling, as well as chemical reactions, biogenic emission and uptake of the above-mentioned non-reactive and reactive trace gases.



Left: Three towers form the central observational tool of the EGER project at the 'Weidenbrunnen' site (Fichtelgebirge/Germany).

Middle: At the interface 'forest canopy/atmosphere': Micrometeorological instrumentation at the main EGER tower for the measurement of fluxes of non-reactive and reactive trace gases by aerodynamic gradient and eddy covariance techniques.

Right: At the interface 'soil/trunk space': Measurements of trace gas fluxes by dynamic and static soil chambers and vertical concentration profiles.



BIOGEOCHEMISTRY

DEPARTMENT
Impact of Vegetation Fires on the Global Environment, Human Health and Security

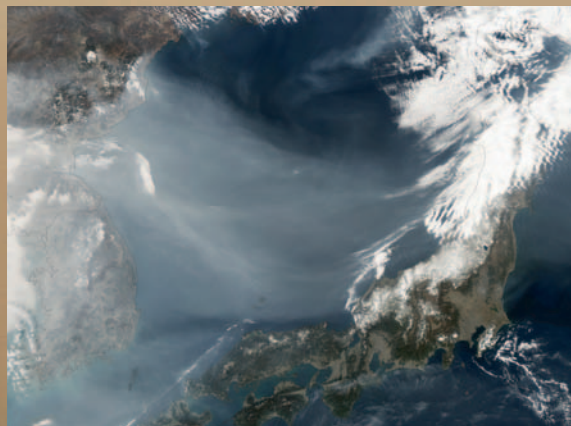
Over the past two decades, a growing trend of excessive fire application in land-use systems and land-use change, as well as an increasing occurrence of wildfires of extreme severity have been observed in many regions of the world. Some of the effects of wildland fires are of transboundary nature, e.g., the consequences of smoke pollution on human health and safety, loss of biodiversity, or consequences of destabilisation at landscape level leading to desertification or flooding. The depletion of terrestrial carbon by fires burning under extreme conditions in some vegetation types, including peatlands, is one of the driving agents of disturbance of global biogeochemical cycles, notably the global carbon cycle. The Fire Ecology Research Group / Global Fire Monitoring Center (GFMC) is instrumental in the development of an internationally concerted approach, developing informed policies and action to reduce the negative impacts of vegetation fires on the environment and humanity. This work includes the co-operation with the United Nations to develop a strategy for international co-operation in wildland fire management and the 'Fire Management Voluntary Guidelines: Principles and Strategic Actions' – a voluntary, legally non-binding tool aimed at enhancing capabilities to reduce the negative consequences of vegetation fires globally.

The research group initiated a major outreach activity through its function as United Nations University (UNU) Associate Institute and in its role as the 'main engine' of the Global Wildland Fire

Network. Critical issues that were addressed included:

- Development of decision-support tools for policy-makers to protect human health and security threatened by vegetation fire smoke (2007)
- Support of an assessment of global wildland fire emissions from 1960 to 2000 (2008)
- Implementation of the UN Fire Management Global Assessment (2006)
- Consequences of fires in armed conflict zones, sites contaminated with unexploded objects from armed conflicts, or radioactively contaminated terrain (2006-2007)
- Socio-economic and cultural changes resulting in land abandonment in Europe and increasing risk of high-severity wildfires

Forward-looking issues to be addressed will include the role of fire management in reducing the transfer of terrestrial carbon stored in live and dead vegetation (e.g., in swamps, wetlands and peat deposits) to the atmosphere. The outcome of the World Climate Conference in Bali in 2007 includes an action plan to include the reduction of deforestation and degradation into an overall concept of stabilising terrestrial carbon pools – a process to be addressed by fire management and supported by the work of this research group.



Right: Severe vegetation fire smoke pollution in the Far East of the Russian Federation on 11 March 2008. The high contamination by pyrogenic aerosol is a result of fires burning in peatlands in the Far East of Russia. Satellite image based on MODIS sensor on the Aqua satellite.

Background: Smoke pollution generated by peat and forest fires in Khabarovsk City, 11 March 2008.

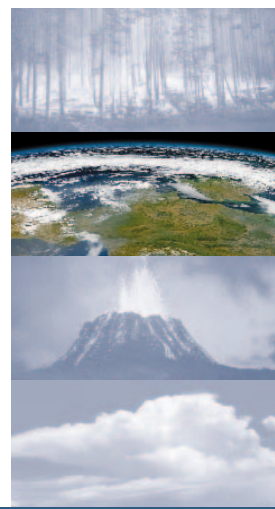
ATMOSPHERIC CHEMISTRY DEPARTMENT

Main Research Areas

Jos Lelieveld



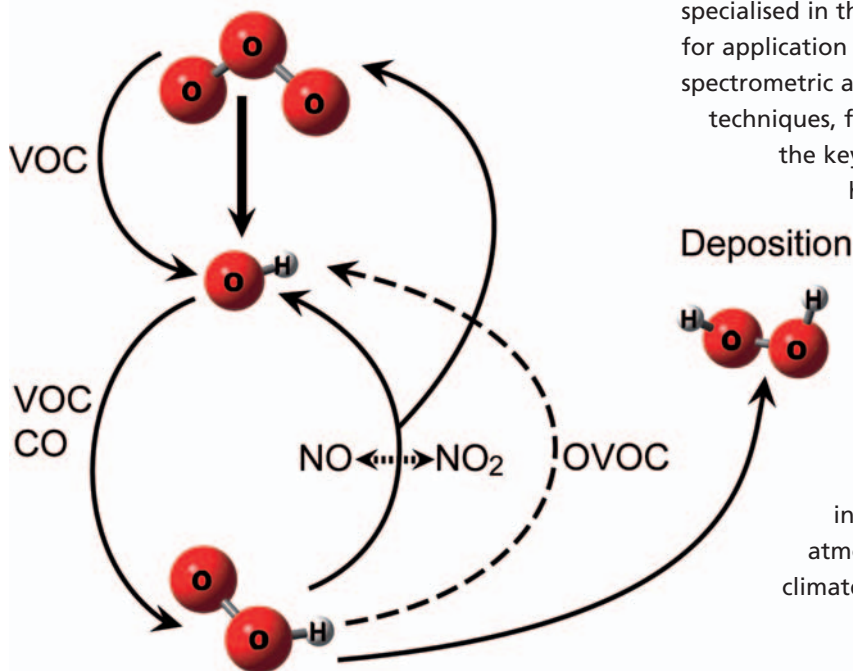
Born 25 July 1955 in The Hague, Netherlands. Undergraduate in Biology, University of Leiden. Ph.D. in Physics 1990, University of Utrecht. Research associate at Geosens B.V. in Rotterdam from 1984-1987. Atmospheric Chemistry Department of the MPI for Chemistry from 1987-1993. Extended visits at Stockholm University (1991) and the University of California, San Diego (1992). Professor in Air Quality at Wageningen University in 1993-1995. Professor in Atmospheric Physics and Chemistry at Utrecht University 1996-2000. Director of the international research school COACH (Co-operation on Oceanic, Atmospheric and Climate Change studies) 1997-2000. Director of the Atmospheric Chemistry Department since 2000. Professor in Atmospheric Physics at Mainz University, Spokesman of the International Max Planck Research School and Deputy Spokesman of the Mainz Geoscience excellence cluster.



The Earth's atmosphere contains 21% oxygen and it is uniquely oxidising. The oxidation processes transform natural and anthropogenic gases into products that can be more easily removed from the atmosphere through wet and dry deposition. This mechanism removes a multitude of gases that would otherwise accumulate and create a hothouse effect – rather than a greenhouse effect – or be toxic for life. This self-cleansing capacity of the atmosphere is regulated by radical reaction cycles that have some resemblance to those in combustion processes, in which hydrocarbons are oxidised to carbon dioxide and water vapour. On a global

scale many gases, notably reactive carbon and nitrogen compounds, can have profound effects on the abundance of atmospheric oxidants. We investigate to what extent natural and anthropogenic emissions influence the self-cleansing capacity, and how they contribute to regional and global changes of our atmosphere and climate.

Our research focuses on ozone and the role of radicals in photo-oxidation mechanisms which play a central role in the self-cleansing mechanism. We develop highly sensitive instrumentation to measure trace gases, and uncover the photochemical reaction chains. We have specialised in the construction of instrumentation for application on aircraft. Laser-optical, mass spectrometric and gas chromatographic techniques, for example, are used to determine the key breakdown products of hydrocarbons and radicals. Our studies include laboratory investigations, field measurements on aircraft and ships, and the use of satellite observations. We develop computer models to simulate the interactions of chemical and meteorological processes, and investigate the influences of atmospheric composition changes on climate.



ATMOSPHERIC CHEMISTRY

New Instruments for Measurement of Nitrogen Trace Gases

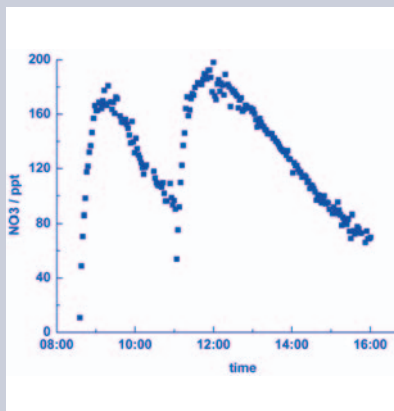
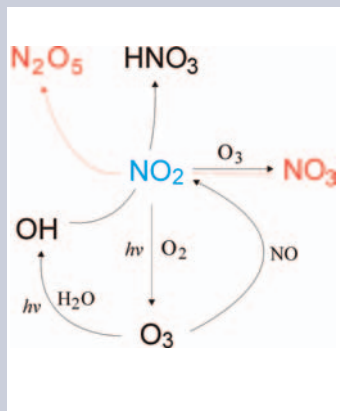
An important aspect of the research carried out in our department is the development of equipment that can selectively detect and monitor atmospheric trace gases at very low mixing ratios in a chemically complex environment and from diverse platforms including ships and aircraft. As commercially available instruments rarely fulfil all the requirements of being transportable, sensitive and reliable, new devices have to be designed, developed and tested. We report on three highly sensitive instruments designed to measure trace gases of the $\text{NO}_x / \text{NO}_y$ families that play important roles in both day- and night-time chemistry. The trace gases in question are the nitrate radical (NO_3), dinitrogen pentoxide (N_2O_5), nitric acid (HNO_3) and nitrogen dioxide (NO_2), all of which are closely linked in photochemical cycles and which impact strongly on e.g. photochemical ozone formation and the capability of the atmosphere to oxidise pollutants.

Our device to measure NO_3 radicals exploits recent advances in both laser and optical coating technology and the fact that NO_3 strongly absorbs red light in a unique absorption feature at 662 nm. By coupling the emission of a cheap, powerful diode-laser (662 nm) into an optical resonator we 'trap' the light between two highly reflective mirrors for hundreds of microseconds during which it travels ≈ 25 km in an instrument just 70 cm length. The absorption of this light by NO_3 is detected, the long light paths meaning that a few ppt of NO_3 (ppt = mixing ratio = molecules of NO_3 per 10^{12} molecules of air) can be detected within in a few seconds. A dataset obtained during an inter-comparison of NO_3 field instruments is displayed below.

N_2O_5 can be detected indirectly with the same device by heating the air to ≈ 90 °C which causes N_2O_5 to thermally decompose to NO_3 . A laser-based optical measurement is also used to detect NO_2 , a central trace gas. In this case absorption of pulsed blue light (again from a recently developed diode laser) causes NO_2 to re-emit (fluoresce) red and infra-red light at an intensity which is proportional to the NO_2 mixing ratio. By keeping the pressure low, the yield of re-emitted photons is high and detection limits of a few ppt are achieved.

HNO_3 is frequently the most abundant NO_y species, yet speciated measurements of HNO_3 at sufficient time resolution for e.g. aircraft measurements are difficult. In collaboration with scientists at the Georgia Institute of Technology we have set up a device that detects HNO_3 following its selective chemical conversion to an ion (NO_3HF^-) which can be detected by mass spectrometer with high sensitivity. The detection limit is presently close to 20 ppt HNO_3 in 2s measurement time. The instrument has been designed to enable integration in aircraft and is shown below complete with Lear-Jet rack. It will be flown on the new High Altitude – Long Range (HALO) research aircraft in 2009.

By combining these new instruments with existing ones for NO , OH and HO_2 radicals, we have a comprehensive suite of NO_x (sum of NO and NO_2) and NO_y ($\text{NO}_x + \text{HNO}_3 + \text{NO}_3 + \text{N}_2\text{O}_5$ etc.) measurements that provide both comparison with predicted distributions from global modelling studies and give us improved insight into the role of nitrogen oxides in controlling the oxidation capacity of the atmosphere, both by day and by night.



Left: Mass spectrometer for airborne measurement of HNO_3 operated by Nicolas Povesle.

Middle: Chemical links between O_3 and $\text{NO}_x / \text{NO}_y$ trace gases.

Right: NO_3 profile measured during an inter-comparison in June 2007 at the SAPHIR environmental chamber in Jülich.

ATMOSPHERIC CHEMISTRY DEPARTMENT

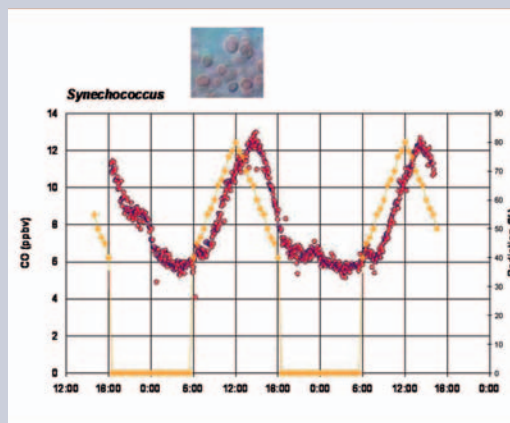
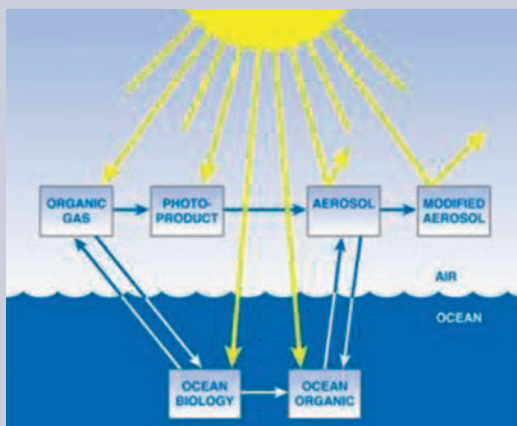
Atmospheric Chemistry at the Air-Sea Interface

For the past years several activities focused on the air-sea interface within the project 'OOMPH'. The project was funded under the European Union sixth framework programme and coordinated by the Atmospheric Chemistry Department (<http://www.atmosphere.mpg.de/enid/oomph>). Considering the size and potential importance of the air-ocean interface, it is surprisingly poorly characterised in terms of organic gases and aerosols. These organic species are known to play important roles in the Earth's atmosphere, impacting ozone chemistry and aerosol formation, thereby influencing the Earth's overall oxidation capacity and radiative budget.

The sunlit regions of the oceans are home to a myriad tiny plant species and bacteria. As these pelagic autotrophs photosynthesise carbon dioxide (CO₂) from the atmosphere into planktonic biomass, a fraction of the carbon 'leaks' out into the surrounding seawater in the form of organic compounds. Some small volatile species with a low solubility are known to escape directly to the atmosphere (e.g. dimethyl sulphide and isoprene) while larger species remain in the liquid phase. Further photo-oxidation in both the air and seawater ensues, generating a multitude

of photochemical breakdown products (see the left figure). Aerosol in the marine boundary layer can potentially be influenced through secondary organic aerosol formation, or by direct injection of organic aerosol from the ocean. Interestingly, in comparison to terrestrial based studies there are very few datasets for organic species over the ocean. This is in spite of the fact that the net primary production of the ocean is comparable to that of the terrestrial biosphere (45 Pg/yr⁻¹).

In the first stage of the OOMPH project laboratory studies were performed on seawater samples and specific phytoplankton types to determine the effect of basic biophysical parameters (e.g. temperature, light) on the emission of organic species. In particular the emission of CO, isoprene and monoterpenes were examined. See the right figure: Shown below is the emission of CO measured from the cyanobacteria *Synechococcus*. The CO emission peak clearly follows that of the light cycle with a time delay of circa 3 hours. This data was taken in collaboration with colleagues from CNRS, France, and IFM-Geomar, Germany. During the studies the first emissions of monoterpenes from phytoplankton were determined by our institute.



ATMOSPHERIC CHEMISTRY DEPARTMENT

Ozone Smog over the Southern Ocean

New measurement systems were developed during the OOMPH project. Of particular note are the flux systems developed in a co-operation with CNR, Italy. With this system it was possible to determine fluxes of CO₂ and acetone directly from on-board the ship. Such new devices were tested first in an up-welling region off the coast of Tropical Africa on board the German research vessel 'Meteor' (see the upper picture). Considerable additional difficulties can be expected when determining fluxes from a ship since the movement of the vessel has an effect on the wind field that must be taken into account.

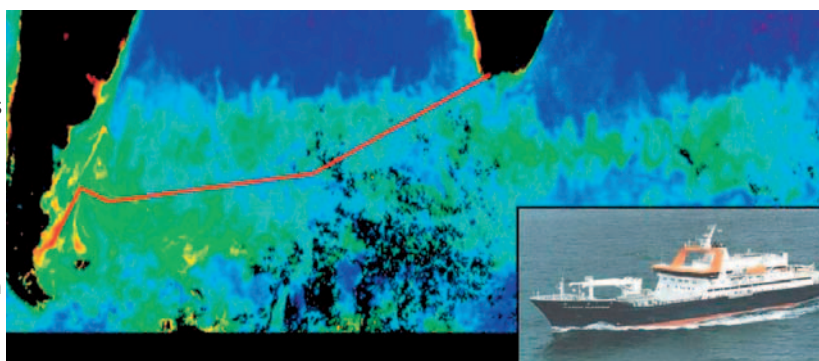
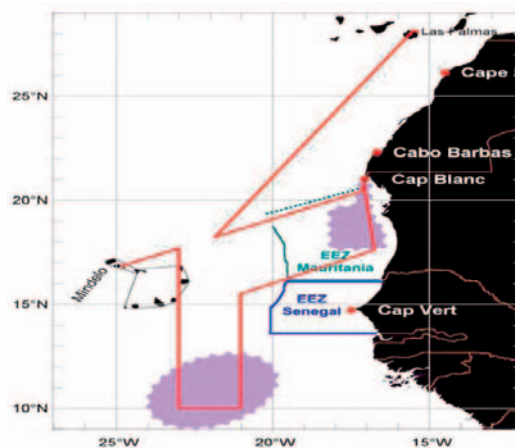
The main OOMPH shipborne campaign crossed the Southern Ocean between South Africa and Chile in January-March 2007. As planned, it encountered a large-scale natural phytoplankton bloom which was characterised in terms of its gaseous emissions (e.g. DMS, organohalogenes, oxygenates, NMHC), water concentrations (e.g. CO) and effects on ambient aerosol. On the return leg several additional instruments from our institute were added to the payload in order to investigate the photochemistry of the remote boundary layer. These included measurements of nitrogen oxides, hydroxyl radicals (HO_x) and total reactivity.

Generally the ship-borne measurements in remote regions showed some of the lowest concentrations of reactive hydrocarbons and NO_x yet observed. This research cruise did, however, encounter two significant emission sources en route: the large scale natural phytoplankton bloom (see the bottom picture) which was found to emit reactive hydrocarbons (e.g. isoprene, DMS, methyl iodide, bromoform, monoterpenes) to the air; and a high seas fishing fleet which represents a strong local NO_x source.

Using an atmospheric chemistry model constrained by *in-situ* measurements, it was shown that strong ozone production ensues from the juxtaposed biogenic and anthropogenic emissions. Furthermore it has been shown that ozone over the Southern

Ocean is particularly sensitive to ship emissions.

Measurements of methanol, acetone and isoprene have been used in conjunction with global models in order to revise their global budgets. The OOMPH data show that in the case of both methanol and acetone the ocean represents an important global sink. In contrast, the ocean is a weak source of isoprene in productive areas but that source is insufficient to account for organic aerosol levels in the remote boundary layer. No evidence of secondary organic particle formation was observed other than that from DMS/MSA/sulphate and thus enhanced organic aerosol levels measured over the bloom regions were assumed to be primary in origin.

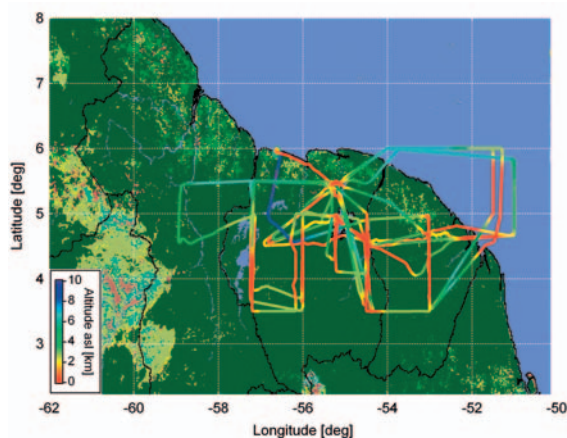


ATMOSPHERIC CHEMISTRY DEPARTMENT

Aircraft Measurements over a Tropical Forest

A focal point of research in the Atmospheric Chemistry Department has been on the hydroxyl radical (OH) and its role in determining the oxidising efficiency of the troposphere. Over the past few years, major steps forward in our understanding of hydroxyl radical chemistry have been made as a joint effort involving much of the Department, including field observations, laboratory experiments and model simulations. This work was kicked off during the field campaign GABRIEL, which took place based out of Suriname, over the east coast of South America and nearby coastal regions, in October 2005 (see figures). The first highlight of this research took place already directly during this campaign: the first ever direct measurements of OH over the tropical rainforests were made with an instrument designed within our institute.

On-site comparisons of the measurements with the output from our atmospheric chemistry-



transport forecasting system, used to help plan the flights, revealed the next highlight: the observed OH concentrations were far higher than simulated, by a factor of 2 to 10, even after the uncertainty in the measurements was taken into account. Afterwards, comparisons with output from the Department's chemistry-climate modelling system made clear that this underestimate applied to other, more advanced models as well. Later comparisons with constrained box model simulations, which also showed this underestimate, then made it evident that there was a fundamental flaw in our understanding of OH chemistry over the pristine forests. This is of great global significance, since the high temperatures and substantial emissions of reactive organic compounds make this region of importance for the global oxidising efficiency.

The race was then on to determine what the source could be for this 'missing HO_x' (where HO_x = OH+HO₂, and the HO₂ radical concentrations were also generally underestimated by the models). After substantial speculation about various highly complex organic compounds (such as monoterpenes, C₁₀H₁₆, and sesquiterpenes, C₁₅H₂₄), attention began to turn to the most abundant hydrocarbon above the forests, isoprene (C₅H₈). This was particularly spurred on by the discovery that in box model simulations in which isoprene chemistry was neglected, the agreement with the observed OH became much better. Furthermore, the ratio of the observed versus simulated OH concentration was plotted as

a function of the isoprene concentration, and was found to become larger with increasing isoprene concentrations.

Above: The Guyanas in South America where the aircraft measurements were performed.

Preparing for the aircraft measurements at Zanderij Airport in Suriname.



ATMOSPHERIC CHEMISTRY

Subtle Balance between Tropical Forest and Atmosphere

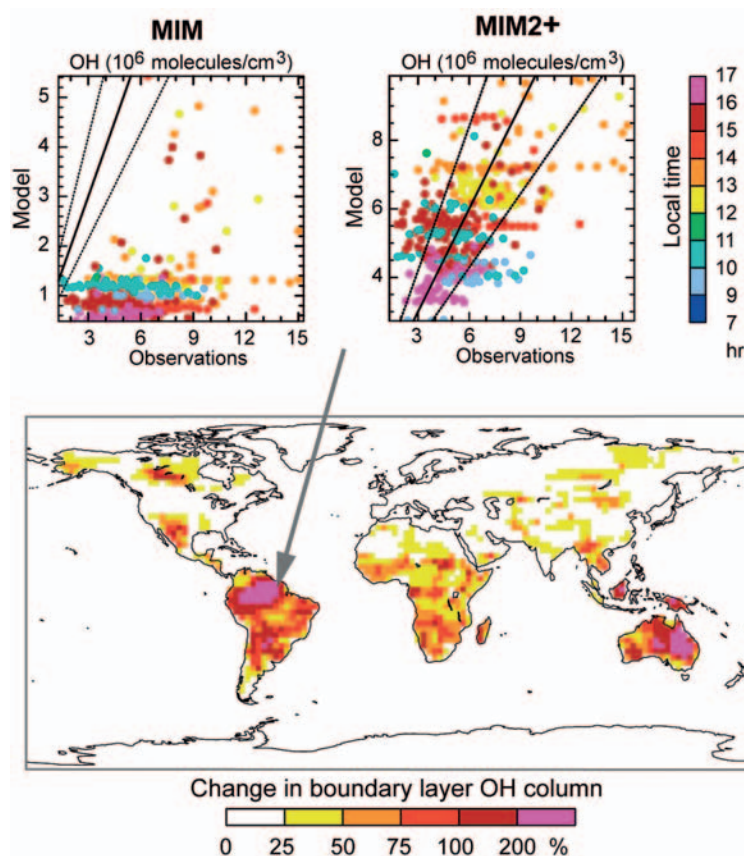
Based on the evidence from the GABRIEL measurement campaign over the Guyanas and the kinetics laboratories results that OH could be recycled during isoprene oxidation, we looked for a mechanism which would explain the high OH observed over the forest. Although our laboratories were indeed able to reveal OH formation through previously unconsidered pathways, and results from other laboratories were combined with various theoretical mechanistic considerations, this has still not yet been enough to explain the discrepancy between models and observations. Nevertheless, with the assurance that there must be some mechanism providing for this within the isoprene oxidation pathways, we conducted several sensitivity simulations to quantify the amount of OH recycling which would be necessary, and to determine what other impacts this would have on atmospheric chemistry.

One particular impact was the realisation that, when sufficient OH was simulated, the simulated isoprene mixing ratios then dropped below the observed levels. It appears that the explanation for this is that there is a substantial degree of 'segregation' between OH and isoprene – that is, OH concentrations are highest where isoprene concentrations are lowest, and vice versa. Although this in itself may not appear too surprising, we showed that the degree of segregation required is at the upper end of any previous estimates made within the literature.

The studies so far have been crowned off by our contemplations that there may be a deeper meaning to all these results: what if there were to be an evolutionary advantage to trees which emit isoprene, provided that the isoprene oxidation efficiently recycles OH? The results of these contemplations, which were published in *Nature*, point to the hypothesis that the biosphere - atmosphere interactions of tropical forest ecosystems maintain a subtle balance. The forest uses the ambient air to transport VOCs for communication and defence, and to dispose of metabolic products without the build-up of toxic compounds. Rather than depleting the atmospheric oxidation capacity, as was believed previously, the photochemistry of VOCs over the

forest recycles OH in a manner that does not contribute to photochemical smog, in contrast to the anthropogenically influenced atmosphere.

The rapid oxidation by OH of biogenic VOCs that carry sulphur, nitrogen or halogens prevents the loss of nutrients from the ecosystem, because they are locally preserved through the deposition of reaction products. The efficient OH recycling may also explain how the atmospheric oxidation capacity could be sustained in geological warm periods with abundant vegetation. It is clear that replacing rainforest by agricultural, urban or industrial areas will be associated with enhanced emissions of carbon dioxide, carbon monoxide and NO, which will strongly enhance photochemical air pollution. However, in the absence of external influence the forest appears to manage its atmospheric sustainability remarkably well.

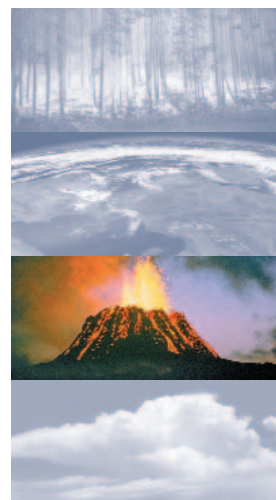


OH measurements over the forest compared with the original (MIM) and the newly improved model (MIM2+). The bottom panel shows the global effects.

Albrecht W. Hofmann
(Director until 2007)



Born 11 March 1939 in Zeitz. Undergraduate studies in Geology at Duke University, Durham, N.C., USA and University of Freiburg i.Br. Ph.D. in Geochemistry at Brown University, Providence R.I. (1969). Scientific Assistant at Labor für Geochronologie, University of Heidelberg (1968-70), Postdoc and Scientific Staff Member at Carnegie Institution of Washington (1970-1980). Director of Geochemistry Department (1980-2007). Awards (Selection): Fellow American Geophysical Union (1994), V.M. Goldschmidt Medal of the Geochemical Society (1996), Foreign Associate of U.S. National Academy of Sciences (1999), Harry H. Hess Medal of the American Geophysical Union (2001).



Geochemistry is concerned with quantitative analysis of major and trace elements, and their isotopic abundances, in rocks, minerals, melts and fluids. We use these data to understand the origin and evolution of our planet and the processes that continue to shape it. The slow decay of radioactive isotopes such as uranium, thorium, potassium, rubidium, samarium and rhenium changes the isotopic abundances of the radiogenic daughter elements. From this, we can measure not only the ages of rocks, but the isotopic abundances of the daughter elements are powerful tracers of many geological processes ranging in scale from microscopic to global.

Much of our research focuses on large-scale terrestrial processes. Solid-state convection continuously turns over the Earth's interior. It is driven by heat generated from natural radioactive decay. It creates continents, ocean basins and mountains, and it causes mantle rocks to melt. These melts migrate toward the surface to create volcanoes and new continental crust. The geochemical 'fingerprints' consisting of chemical and isotopic data from these melts reveal the nature and history of global cycling and recycling processes. In these cycles, oceanic crust and some continental material is returned to the deep mantle and is ultimately recycled in new volcanic eruptions.

One group led by Wolfgang Paul Award winner Alexander Sobolev is studying microscopic melt inclusions trapped in magmatic crystals. This offers a new window on melting, because these melts preserve their primary chemistry formed in the mantle. Another group studies mantle rocks that remain behind after melting and must be dredged from the ocean floor. These studies employ a microanalytical arsenal involving an electron microprobe, an ion microprobe and laser ablation plasma mass spectrometry.

Other studies trace the origin of ancient parts of the continental crust by measuring the ages of minerals such as zircon and garnet separated from the rocks. The radioactive elements and their daughter products, e.g. uranium and lead, are present in microgram or nanogram quantities. Their chemical separation before mass spectrometric analysis requires state-of-the-art clean room facilities.

We also study how global ocean circulation has changed in the geological past. This circulation resembles a global conveyor belt which transports heat from the tropics to the northern ocean. We trace ancient ocean currents by analysing lead isotopes in dated sediments. These lead isotopes are precipitated from the water column above, and this makes it possible to trace the movement of specific water masses.

GEOCHEMISTRY DEPARTMENT

Tracing Metallic Elements Using their Stable Isotopes

The stable isotope fractionations of light elements such as H, O, C and S are a mainstay of isotope geochemistry. What is being measured is, effectively, the preference for 'heavy' over 'light' isotopes of these elements, which can then be used to tell us something interesting about the sample itself. This might be about temperature, evaporation/precipitation (the hydrological cycle), the mass balance of the element in the geochemical cycle or the importance of biological fractionation, for example.

Recently, interest has arisen in exploring the natural mass-dependent stable isotope fractionations of 'non-traditional' elements, such as the transition metals. We have been concentrating our efforts on cadmium, since cadmium possesses many physical attributes that make it promising. The bias in 'heavy' over 'light' isotopes can be measured with a precision of a few ppm per Dalton using a new double spike technique we have developed, in which the isotopic composition is determined by thermal ionisation mass spectrometry (TIMS). We started by doing a survey of Cd stable isotope variations in a wide range of terrestrial materials in order to better understand the geochemical cycle of cadmium in general.

One of the surprising findings is that industrially processed cadmium has an extreme isotopic fractionation, an order of magnitude greater than that found in any natural materials thus far. This means, in effect, that we have a foolproof isotopic fingerprint of man-made cadmium which is extremely useful in tracking environmental pollution of this metal.

In terms of 'natural' cadmium isotope variations, the largest effects we have found are in sulphides from seafloor hydrothermal chimneys where so-called 'black smokers' actively vent hot fluids originating from deep in the ocean crust to

seawater. Using the Cd isotopic composition we can follow the progressive precipitation of sulphide minerals in these hydrothermal systems which form the principal ores and sources of the metals Cd, Zn and Cu.

But perhaps the most interesting use of Cd isotopes is in studying the biogeochemical cycling of cadmium in the oceans. Here, cadmium behaves much like phosphorus in that it is a required micronutrient, consumed and incorporated into the shells of phytoplankton living in the upper few 100 m of the water column. When these organisms die, they sink and partially re-dissolve, liberating cadmium back into deeper waters. This 'cycling' results in a pronounced depletion in cadmium in the upper water column. Normally, the availability of micronutrients limits the primary productivity (i.e. rate of biological turnover) in the shallow ocean, and thus, importantly, the rate of uptake of atmospheric CO₂ as calcium carbonate. We have been able to show that the surface water depletions in cadmium are associated with strong enrichments in 'heavy' stable isotopes of cadmium. This enrichment is caused by the incorporation of isotopically 'light' cadmium into the phytoplankton. In deeper waters, the cadmium is no longer 'heavy' due to the re-addition of cadmium derived from sinking phytoplankton. Thus, by using Cd stable isotopes we are able to quantify the vertical cycling of this important micronutrient in the water column. This new tool is also useful for

reconstructing past primary productivity using palaeo-records, such as those stored in sedimentary cores or shallow ferromanganese crusts. This offers the potential of tackling the question of how much different the biological overturn was in the oceans – and by inference the CO₂ 'draw-down' – during ice ages.



An ultraclean sampler for trace metals in seawater emerges from the ocean.
© NIOZ

Giant Siliceous Spicules of Deep Sea Sponges

Sponges are the evolutionary oldest animals, which appeared approximately 800 million years ago as the first metazoans (multicellular animals) on our planet. Special characteristics, such as cell communication, immune system, and a simple body plan qualify the sponges as the basal group of all metazoans. Siliceous sponges are distinguished by one unique feature from all other multicellular animals – their ability to form a siliceous skeleton (composed of spicules). One deep sea sponge, termed *Monorhaphis intermedia*, forms giant spicules, which can reach lengths of 3 m and diameters of up to 8.5 mm; they represent the largest biogenic silica structures on Earth. The unique feature of this silica is its way of synthesis; it is formed enzymatically (using silicatein) from orthosilicate at ambient temperature (between -1°C and 25°C). Hence, this biosilica represents the first inorganic polymer that is formed catalytically by an enzyme.

In co-operation with W.E.G. Müller (Universität Mainz) and Xiaohong Wang (National Research Centre for Geoanalysis, Beijing) we have investigated giant sponge spicules that had been dredged from a depth of 1500 to 2000 m. Scanning electron microscopic inspection of cross sections reveal their lamellar organisation; each lamella is about 3 to 7 µm thick. In the centre of the spicules an axial canal is located. This 0.5 µm wide canal is surrounded by 500 concentrically arranged lamellae, made of biosilica. A complete series of laser ablation – inductively coupled

plasma – mass spectrometry (LA-ICP-MS) analyses has been performed on such a spicule within µm areas. The detection limits of the elements are extremely low and range between 0.3 and 10 ng/g.

The results demonstrate that most trace elements are uniformly distributed within the spicules from the axial canal to the surface of the spicules. Surprisingly, and of prime interest in the field of biomaterials, is the fact that the giant spicules are composed to over 99.5% of pure silica (biosilica). Na (0.15%) and Ca (0.02%) are the ‘most abundant’ trace elements, whereas the 35 remaining elements add only unimportantly to the inorganic composition of the spicules. Thus, the biosilica of the sponge spicule has quartz grade. The impact of this finding becomes highly remarkable with respect to the element composition of the seawater. In contrast to the siliceous spicules, natural seawater contains large amounts of Na and Cl with 32.4% and 58.5% (solid material), respectively, but comparably low levels of Ca with 1.2% and only minute levels of Si (0.006%). Our data show that sponges have the ability to produce almost pure biosilica in an aqueous environment that contains only trace levels of Si; and even more they form this material at 4°C catalytically via silicatein. This finding demonstrates the impressive ability of biological organisms to form such material. For the chemical synthesis of quartz glass, temperatures of above 1600°C and aggressive chemicals are required. The applications of this ability of sponges in biomaterials science are large and range from their potential use in biomedicine to soft lithography.



The giant basal spicule from a siliceous sponge (species *Monorhaphis*). **Left:** Schematic growth pattern of this animal. Small specimens surround the giant basal spicule completely. During growth, the body elongates and grows along the centrally arranged giant spicule to reach finally sizes of 3 m. **Middle:** A 1 metre long spicule is shown, held by a person. **Right:** A polished cross section through a giant basal spicule with its central canal and the surrounding 500 siliceous lamellae.

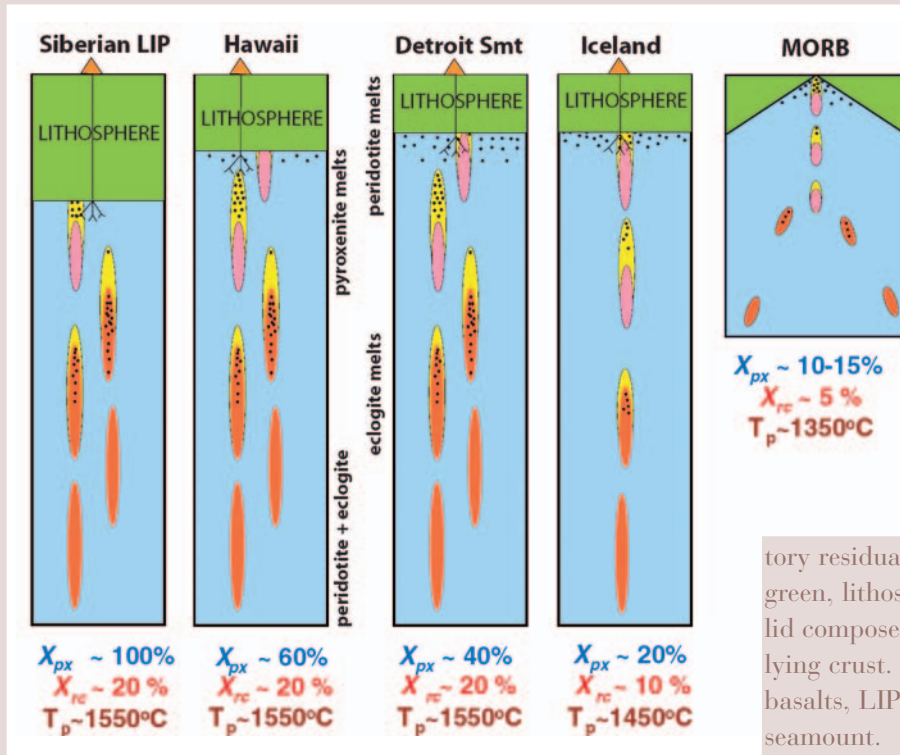
GEOCHEMISTRY DEPARTMENT

Crustal Recycling Quantified

Plate tectonic processes recycle the Earth's basaltic ocean floor back into the mantle. What happens subsequently has profound effects on how our planet's interior functions and evolves. It has long been known that traces of this recycled basalt resurface in oceanic volcanic rocks, especially those produced by 'mantle plumes' such as Hawaii. However, previous geochemical tracers of this process have been qualitative. A new quantitative tracer method using micro-analysis of Ni and Mn in magmatic olivine crystals has been developed in the group led by Alexander Sobolev. The first melt formed from recycled crust forms a SiO₂-saturated melt, which reacts with ordinary, olivine-bearing mantle rock 'peridotite' to form an olivine-free 'pyroxenite' (consisting mostly of the mineral pyroxene). Partial melts formed from this pyroxenite are high in Ni but low in Mn, because unlike olivine, the mineral pyroxene preferentially retains Mn but releases Ni into the melt fraction. Thus, the amount of pyroxenite in the source can

be estimated and distinguished from normal mantle rock (peridotite). Melts from both types of source rock crystallise new olivine at low pressure, and the source composition is calculated from the Ni and Mn contents of these olivines.

Recently this approach has been extended to melts from many mantle-derived volcanic rocks. The smallest amounts of recycled crust (5-10%) are found below mid-ocean ridges. The largest amounts (20%) occur in the largest mantle plumes (e.g. Hawaii). The extreme case (almost 100% pyroxenite) is found for Siberian flood basalts – the giant magmatic event that probably triggered the greatest mass extinction of life on Earth 251 million years ago. The large amount of Si-rich recycled crust explains the extreme amount of melting, because normal peridotite under a thick lithospheric 'lid' could not produce nearly enough melt.



Schematic model illustrating interplay between amounts of recycled oceanic crust (X_{rc}) in the peridotitic mantle, amount of pyroxenite-derived melt in the mixture with peridotite-derived melt (X_{px}), thickness of lithosphere, and temperature of mantle (T_p). Blue, upwelling peridotitic mantle; red, recycled oceanic crust as eclogite (high pressure modification of basalt); black dots, melting; yellow, reaction zones forming hybrid pyroxenite; pink, refractory residual after recycled crust melting; and green, lithosphere - relatively cold and stable lid composed from viscous mantle and overlying crust. MORB - mid-oceanic ridge basalts, LIP - large igneous province, Smt - seamount.

GEOCHEMISTRY DEPARTMENT

Nanodiamonds, Noble Gases and Supernovae

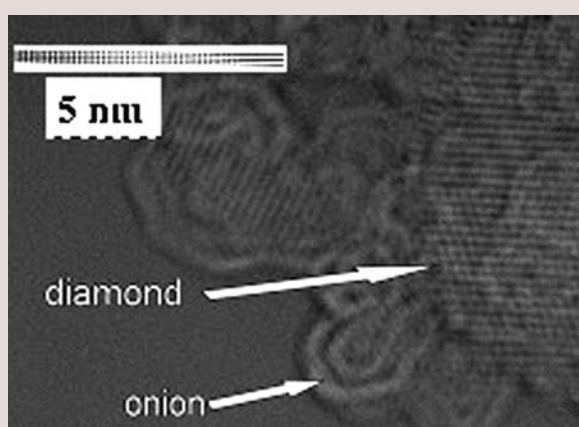
The noble gas elements (helium, neon, argon, krypton and xenon) are extremely rare in solid materials and thus can serve as sensitive tracers – often rivalling the radionuclides – for a variety of processes in geo- and cosmochemistry. We are employing them in a number of contexts, ranging from landscape evolution on Earth to cosmic ray exposure of meteorites, evolution of the atmosphere of Mars, and study of the processes of nucleosynthesis by which elements are synthesised in stars. It is in the context of the latter that the nanodiamonds – particles of diamond dust measured in nanometres – found in meteorites come into play. The link to supernovae is provided by the noble gas xenon that is present in the nanodiamonds. Part of its exotic isotopic composition can only be explained by a process akin to the rapid neutron capture process (r-process) thought to take place during the explosion of supernovae.

Extending our analyses of isotopes, we are studying material properties of the meteoritic nanodiamonds in order to learn more about their formation, history, and the processes by which they acquire and lose the supernova gases. Micro-Raman spectroscopy indicates shifts to lower wavelengths, which could be an indication that the diamonds were formed from graphite by shock transformation, but could also be related simply to the small grain size. The latter also

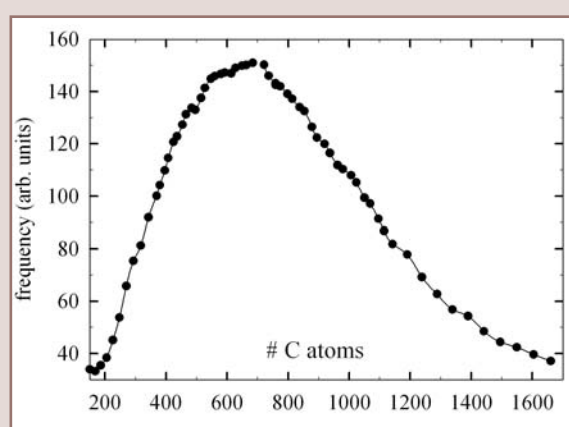
shows up in the form of a quantum confinement effect in their X-ray absorption spectra.

Application of high-resolution transmission electron microscopy (HRTEM) is central because of the small size of only 2.5 nanometres (corresponding to about 1000 carbon atoms) on average (see the left figure). The distribution of sizes around this value is log-normal (see the right figure), as we have determined by laser-ablation time-of-flight mass spectrometry (LA-TOF-MS).

As shown by laboratory experiments using artificial nanodiamonds, implantation of xenon as ions with energy roughly 1 keV is the most likely mechanism for introducing the exotic xenon, while during heating and release of noble gases in the laboratory the nanodiamonds transform into carbon onions (left figure). A favoured scenario for the origin of the isotopically strange xenon found in the nanodiamonds calls for the standard r-process, but requires in addition an early separation between quickly formed xenon and more slowly decaying radioactive precursors of stable xenon isotopes. Astronomers observe dust formed around supernovae on the timescale of months after the explosion. Much earlier formation of a generation of grains that takes up the less volatile precursors of xenon and is destroyed again by the reverse supernova shock may offer a requisite spatial separation mechanism.



High-resolution TEM picture of a nanodiamond separate from the Allende meteorite heated to 1000 °C in vacuum. Some diamonds are still present; others have been transformed into carbon onions.



Mass distribution of nanodiamonds from the Allende meteorite determined by LA-TOF-MS. The maximum occurs at ~700 carbon atoms.

PARTICLE CHEMISTRY DEPARTMENT

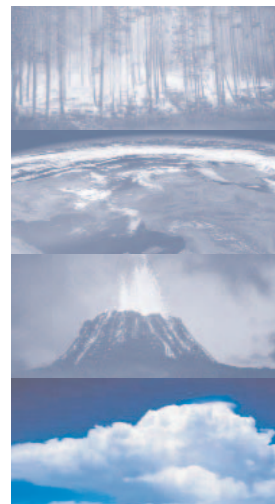
Main Research Areas

Stephan Borrmann



Born 18 January 1959 in Mainz, Germany. 'Diplom' / M.S. degree in Physics in Mainz. 'Adjunct Research Instructor' at the Naval Postgraduate School in Monterey, CA, USA for two years. Ph. D student in Mainz. Postdoc for two years at the NCAR in Boulder, Colorado. Habilitation in Meteorology in Mainz and head of the Aerosol Research Group at the Forschungszentrum Jülich GmbH. Since 2000 professor for Meteorology at the Mainz University. Since 2001 Director (in part-time assignment) and Scientific Member of the Max Planck Institute for Chemistry.

Memberships in Associations: Member of the European Geophysical Society, the German Meteorological Society, the German Physical Society. 2004 and 2005 elected member of the German Science Foundation Review Panel ('DFG Fachkollegium').



The Department of Particle Chemistry of the Max Planck Institute is structurally and conceptually linked to the Institute for Physics of the Atmosphere at the Johannes Gutenberg University in Mainz. This joint assignment of Stephan Borrmann as university professor and MPI director constitutes a close link between both institutions and is a novelty for the location of Mainz.

The research of the group is focused on chemical composition and physical properties of aerosol and cloud particles. Sizes, number densities, shapes, radiative properties and formation mechanisms of aerosols and clouds are topics of experimental investigations. Knowledge concerning clouds and airborne, suspended aerosol particles is of importance for our understanding of climate, climate change, atmospheric chemical processes, as well as anthropogenic influences on the atmosphere. For these reasons emphasis in the department is placed upon: (1) Investigations of aerosols in the troposphere and lower stratosphere, (2) processes and properties of Polar Stratospheric Clouds, which contribute to the ozone holes, (3) the effects of commercial air traffic exhaust emissions on the atmosphere, and (4) the influence of upper tropospheric ice clouds (cirrus) on the chemical composition of the air. In addition there are (5)

studies on the capabilities of cloud droplets, snow crystals, graupel and hail particles to remove ('scavenge') pollutant gases and aerosols from the atmosphere.

The methods employed cover mass spectrometric instruments for the measurement of aerosol and cloud particle chemical composition, optical and thermodynamical instruments, and a worldwide unique vertical wind tunnel. By means of this facility, droplets and hydrometeors are suspended in a vertical air flow for extended periods to become amenable for detailed experiments. *In-situ* atmospheric measurements are performed on board of the converted Russian espionage aircraft M-55 'Geophysika' (reaching altitudes up to 22 km), as well as other research aircraft, ships, ground stations, and the recently designed MPI MOBILE Laboratory for Aerosol research (MOLA). The efforts are aimed at enhancing our understanding of cloud related processes in order to improve weather and precipitation forecast, and also at contributing to climate modelling. The methods developed in the department are applied also to environmental industrial research outside of fundamental atmospheric science. In this way our graduate students become qualified for a large variety of working fields within industry and research.

PARTICLE CHEMISTRY

Characterisation of DEPARTMENT the Remote Marine Aerosol

Oceans are known to be a source for aerosol particles like sea salt and also for volatile organic substances like for example dimethyl sulphide. These gases are produced from marine microorganisms (phytoplankton, bacteria and microalgae) and emitted into the atmosphere, where they can be converted by photochemical processes into species that can be found in aerosol particles. Since not much is known about the formation processes of such secondary aerosol species in the remote marine environment, measurements of gas phase and aerosol components were performed during a ship measurement campaign in the southern Atlantic Ocean. These measurements were part of the OOMPH project, conducted in collaboration with colleagues from the Atmospheric Chemistry Department and research institutes from all over Europe between January and March 2007.

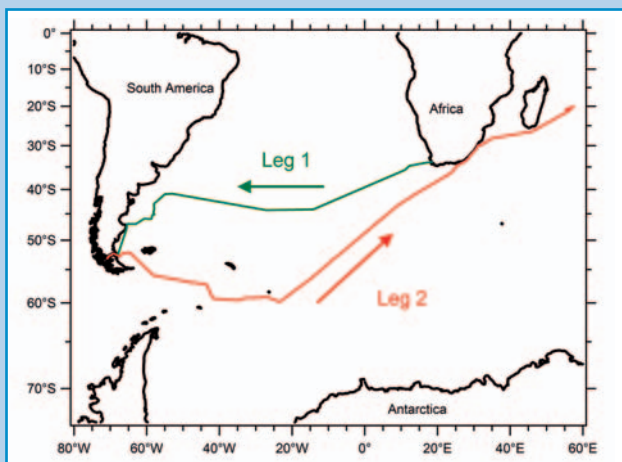
For measurements of the chemical composition and species-resolved size distributions of the non-refractory submicron aerosol particles an on-line high-resolution Aerosol Mass Spectrometer was installed on board the French research vessel 'Marion Dufresne'. In addition a large variety of aerosol and gas phase measurement instruments was deployed during this cruise. The aerosol measurements covered the whole trip from Cape Town (Republic of South Africa) to Punta Arenas (Chile) and back crossing the southern Atlantic Ocean a second time before passing the southern

tip of Africa up to Reunion Island.

For improving the instruments capability to characterise the marine boundary layer, aerosol laboratory experiments were performed and a method was developed to extract information on sulphur-containing organic species expected to be found in marine aerosol particles from the high-resolution aerosol mass spectra.

Mass concentrations and size distributions were calculated for various aerosol species and averaged for times when different distinct air masses from different sources like pure marine origin, arriving from Antarctica or being influenced by continental outflow from South America and Africa were measured. In addition average species concentrations were determined for a time period when a phytoplankton bloom was crossed. Remarkable differences in absolute and relative concentrations of individual aerosol species were identified within the different air masses probed. Together with measurements of the gas phase these results will allow the investigation of aerosol formation and aging processes within the marine environment.

Frequent contamination of the measurements by ship exhaust from the own stack had to be removed from the data set prior to analysis of the marine aerosol characteristics. However, these exhaust-related data provide valuable information on physical and chemical parameters of aerosols from ship traffic, which are known to have an influence on cloud formation over the oceans.



Left: Itinerary of the cruise through the southern Atlantic Ocean.

Middle: Installation of aerosol inlets on atmospheric mast.

Right: Front of research ship with sampling mast.

PARTICLE CHEMISTRY DEPARTMENT

Aerosol Chemistry and Cloud Formation

Aerosols and clouds play an important role in the Earth's atmosphere. The interaction between aerosol particles and clouds is a fascinating research topic that is thoroughly investigated by the scientists of the Max Planck Institute for Chemistry, to a large extent as a collaboration between the different departments but also in large international co-operations.

The size and the chemical composition of an aerosol particle determine its ability to act as a cloud condensation nucleus (CCN). Such a CCN takes up water and grows to cloud droplet size under conditions where the ambience is supersaturated with water. This process is called 'cloud activation'. On the other hand, freezing of cloud droplets is mainly initiated by heterogeneous processes. In such processes an aerosol particle acting as ice nucleus (IN) interacts with a supercooled cloud droplet, thereby inducing the freezing process. The subject of ice formation has raised special interest during recent years and is currently investigated within a Collaborative Research Centre (SFB 641) funded by the DFG.

The Particle Chemistry Department focuses on the *in-situ* measurement of the chemical composition of aerosol particles. The main research instruments are aerosol mass spectrometers of various types. The measurements include analysis of the aerosol particles before they have been activated to become cloud droplets, but also analysis of the residuals from liquid droplets and ice crystals. These residuals can be sampled from the clouds by rejecting the small, not-activated aerosol

particles by a special inlet (a so-called 'counterflow virtual impactor') and evaporating the liquid or frozen water from the droplet or crystal. With this method it is possible to study the size and chemistry of the original CCN or IN that was incorporated into a cloud droplet or crystal. Field measurements devoted to this research topic were conducted in recent years on mountain sites (Areskutan/Sweden, Jungfrauoch/Switzerland, Kleiner Feldberg/Germany, Hohenpeißenberg/Germany, and East Peak/Puerto Rico) as well as in the Amazonian rain forest near Manaus/Brazil.

These field data are complemented by laboratory studies in cloud simulation chambers, e.g., at the 'AIDA' facility at the Research Centre Karlsruhe, the 'SAPHIR' chamber at the Research Centre Jülich and the 'LACIS' Chamber at the Institute for Tropospheric Research, Leipzig. These cloud simulation chambers allow the design of experiments where the cloud activating ability of well characterised particles is investigated, with special emphasis to particle coating, i.e. pure substances (as mineral dust or soot) that are coated with thin layers of one inorganic or organic substance. The framework of these studies is the Helmholtz Virtual Institute 'Aerosol Cloud Interaction'. The results are used to interpret and understand the field measurements and to improve atmospheric models in order to better predict cloud formation.

Future measurements will also include aircraft based measurements, especially on board the new German research aircraft HALO that will be operational from fall 2009 onwards.



Field station close to Manaus/Brazil.



Counterflow virtual impactor inlet system at the Jungfrauoch research site.

Monsoon in West-Africa: Aircraft *In-Situ* Measurements of Clouds in 20 km Altitude

The West-African monsoon clouds belong to the largest on the planet. Covering areas as large as France and reaching altitudes as high as 18 km these clouds are major components of the tropical climate system. Investigations on such 'Mesoscale Convective Systems' or 'Squall Lines' are of importance for understanding the precipitation development in the Sahel and Sub-Sahel. These regions suffer from a so-far unexplained drought with severe deficiencies in precipitation amounts since 30 years. Also disturbances introduced into the wind patterns by such cloud systems can trigger origin and development of hurricanes over the Atlantic.

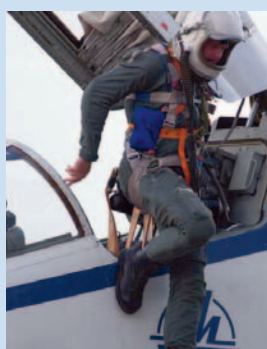
During the European AMMA (African Monsoon Multidisciplinary Analyses) field campaign in Ouagadougou, Burkina Faso, *in-situ* measurements in the highest parts of such clouds and their outflow regions were performed utilising the Russian M-55 high altitude research aircraft 'Geophysika'. This converted espionage aircraft was equipped with a variety of trace gas, aerosol and cloud instruments and performed coordinated research flights together with the instrumented German research aircraft 'Falcon' from DLR. Scientists from 8 European countries, Africa, Russia, and Canada were involved in the instrumentation of the aircraft. Our department contributed 5 out of 18 instruments for 'Geophysika' with the objective to measure aerosol particle number concentrations covering ultrafine aerosols of nanometre size to large cloud ice particles with sizes up to 1.5 mm. The resulting data are used for describing the physical and chemical processes occurring in cloud particle

populations with the aim of improving the capability to numerically simulate clouds, cloud processes and formation of precipitation. Also the measurements are important to characterise the influence of such cloud systems on the surrounding atmosphere. For example the clouds very effectively transport trace substances, aerosols and pollutants from the ground level air into the stratosphere. Six highly successful research flights were performed where the single seated aircraft reached the upper tropical troposphere and lower stratosphere at 20 km altitude. It could be shown by means of the data that biomass burning products from the Cameroon region were transported towards high altitudes in detectable amounts. Also an unexpected increase of ultrafine aerosol particle number concentrations at high altitudes was found which does not appear in our measurements on 'Geophysika' during similar tropical campaigns in Darwin, Australia and Aracatuba, Brazil. The ultrafine particles detected below the stratosphere in the tropical troposphere contained a surprisingly large component of non-volatile constituents which most likely are of organic origin.

Since Burkina Faso is among the five poorest nations worldwide, according to UN statistics, the performance of these experiments involved major logistical and organisational challenges. However, thanks to the support of the local authorities and people we returned with highly valuable data sets and long lasting personal impressions of a beautiful country with a colourful, lively, hospitable population.



The instrumented Russian M-55 'Geophysika' aircraft.



The pilot Oleg Shepetkov.



Look 'They are making rain for us'.

HIGH PRESSURE MINERAL PHYSICS GROUP



Squeezing Hydrogen Dominant Materials: a Way to Metallic Hydrogen?

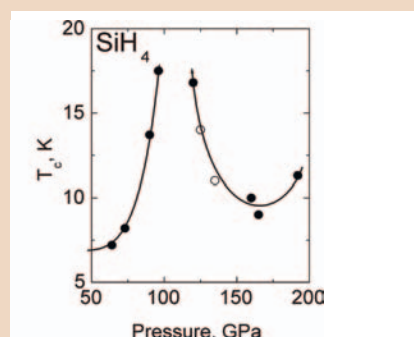
Under high compression hydrogen may be transformed from a molecular to a monoatomic solid where protons (the nucleus of hydrogen) form a crystal lattice. This would be the simplest metal with fascinating properties and therefore of fundamental importance to modern physics of condensed matter. It has been predicted to be a superconductor with a very high critical temperature of $T_c \approx 200$ K. Moreover, this superconductor may exist at ambient pressure in a metastable state. Metallic hydrogen may also acquire a new quantum state: a metallic superfluid and a superconducting superfluid. For astrophysics the study of metallic hydrogen is important because it is a major constituent of giant planets and stars.

However, both experimental and theoretical investigations on dense hydrogen have proved to be extremely difficult. The principal difficulty is the unexpectedly high pressure of metallization. As early as 1935, the pressure of hydrogen metallization was predicted as 25 GPa (about 250 000 atm), which is now considered a low pressure in ultra-high pressure research. Since then there has been no convincing evidence of the achievement of metallic hydrogen to the highest reported pressures of 320 to 340 GPa. Difficulties have been encountered in theoretical investigations, too: hydrogen is one of the few systems for which a simultaneous quantum treatment of both nuclei and electrons is necessary. Modern calculations set the metallization pressure at ≈ 400 GPa, outside the possibilities of current techniques of generating high pressures with diamond anvil cells.

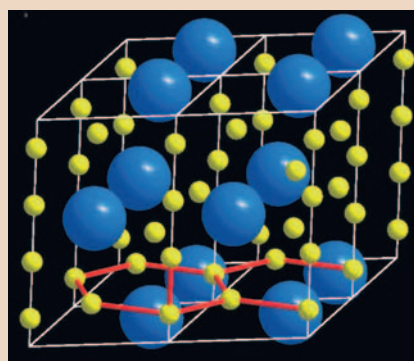
To circumvent this problem, it was proposed to compress hydrogen-rich compounds such as CH_4 , SiH_4 and GeH_4 in which the electron density on the hydrogen atoms is equivalent to pure hydrogen compressed to megabar pressures. These materials are expected to metallize at much lower pressures than pure hydrogen.

We studied silane, SiH_4 , and found that this molecular insulating material transforms to a metal at relatively low pressures of 50 GPa. We found that metallic silane is a superconductor with a notable critical temperature of $T_c \approx 20$ K. At

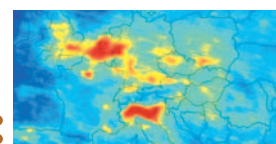
higher pressures we also observed an unusual transformation of metallic silane to an insulator with an increase of volume. All these intriguing phenomena apparently are governed by the dense hydrogen sub-lattice. We performed extensive X-ray diffraction measurements with bright synchrotron sources (at the Advanced Photon Source, Chicago, and European Synchrotron Radiation Facility, Grenoble) and determined the structure of metallic silane. It has a hexagonal close-packed (hcp) structure. This arrangement of the silicon atoms provides the unique set of positions for eight hydrogen atoms in the interstices of the unit cell. The resulting sub-lattice of hydrogen atoms is a regular three-dimensional network with considerable electronic hybridisation due to short H-H distances. The most striking is the average density of the hydrogen atoms: it corresponds to the density of pure molecular hydrogen at 500 GPa, the density of the predicted metallic hydrogen. Thus metallic hydrogen dominant materials obtained at accessible pressures can be a good model of metallic hydrogen. The present work opens a wide perspective for the study of metallic hydrogen. In particular, superfluidity of fluid metallic hydrogen may be simulated in the melted hydrogen sub-lattice.



Pressure dependence of the critical temperature of superconductivity in metallic silane.



Crystal structure of the metallic phase of SiH_4 as determined from X-ray diffraction. Blue and yellow spheres represent silicon and hydrogen atoms, respectively. The hydrogen sub-lattice is shown by red lines.

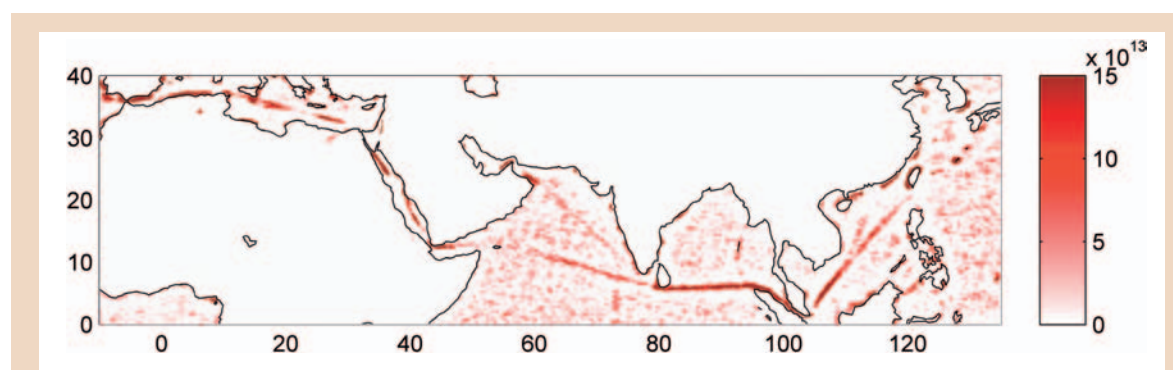


Satellite Observations: Spies for Ship Pollution

One specific advantage of satellite observations is that they yield information on the global distribution of atmospheric trace gases. From such data sets it is possible to identify different emission categories by their characteristic spatial patterns. The large numbers of individual observations (about 70 million measurements per year from the SCIAMACHY instrument) allow to reduce statistical uncertainties by averaging over selected periods of time. Even very weak signals, impossible to detect in individual observations, can be clearly identified in these long term averages (e.g., over several years).

We investigated the NO_2 distributions over the oceans, where one important and steadily growing source of atmospheric nitrogen oxides is ship traffic. Even though these NO_2 ship emissions are small compared to those over the continents, they significantly contribute to marine environmental pollution. Therefore, it has been both a necessity and a challenge to determine such very small local concentrations. So far, the associated emissions were usually quantified by up-scaling of individual emissions according to the global ship traffic density. Using satellite data, it recently became possible to derive a new and completely independent estimate on ship emissions. From observations of the SCIAMACHY satellite instrument we calculated the four-year average (2003-2007) of the global tropospheric NO_2 distribution. In a second step, a high-pass filter in both horizontal directions was

applied to the data over the oceans, to better discriminate the spatial patterns from ship emissions. Part of the resulting map of this procedure is shown in the figure below. Several lines with enhanced NO_2 concentrations can be clearly identified. By comparison with the global inventory of ship traffic, these enhancements can be clearly attributed to ship emissions. The highest signal is found between the southern edge of Sri Lanka and the northern edge of Sumatra. Here the ship routes are concentrated to a very narrow corridor with very high traffic density. Also several other ship routes can be identified in the satellite NO_2 measurements. Lines of high NO_2 concentrations are in particular found in the Red Sea and the Mediterranean. Based on the measured trace gas distributions, it is possible to quantify the associated emission strengths. For this purpose, however, information on the atmospheric lifetime of the trace gas is needed as well. We were able to obtain this information from our satellite data also by comparing the observed spatial patterns to average wind fields. A value of a few hours was obtained, in good agreement with values obtained from atmospheric models. With this information we could estimate the global NO_x emissions ($\text{NO}_x = \text{NO} + \text{NO}_2$) from ships to be about 26 gigagrams of nitrogen per year, in good agreement with existing inventories. Besides NO_2 , enhanced values of formaldehyde over ship tracks were also recently detected by satellite observations.



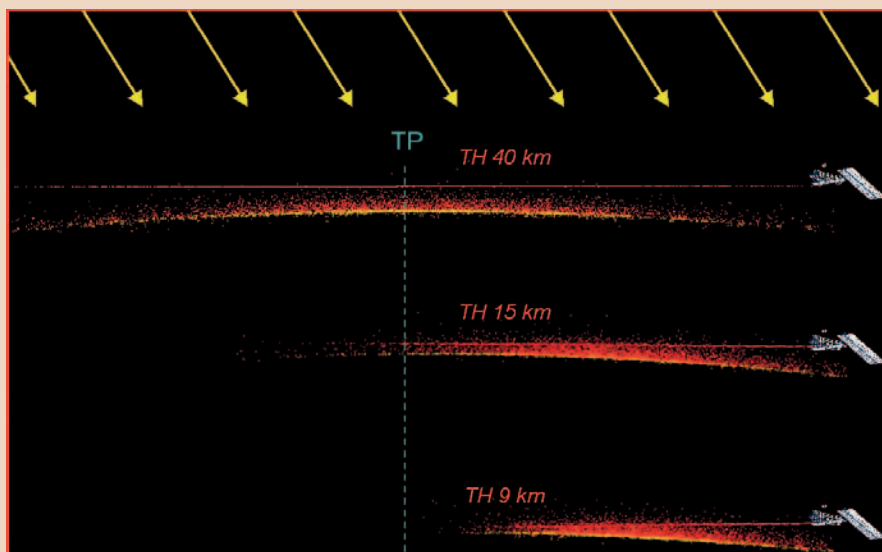
Vertically integrated tropospheric NO_2 concentration (in molecules/ cm^2) analysed from observations of the satellite instrument SCIAMACHY on ENVISAT (only data over oceans are shown). Enhanced emissions over several highly frequented ship tracks can be identified. Note that the NO_2 values over the continents are masked out, because they are typically more than one order of magnitude larger than those over the oceans.

Solar Photons in the Atmosphere: Sky Travellers with Complex Pathways

From an altitude of about 800 kilometres, the SCIAMACHY satellite instrument observes the Earth and its atmosphere in different viewing geometries. In limb viewing mode, the scattered solar photons are observed in nearly horizontal direction during a sequence with slightly varying elevation angles. From such limb sequences, it is possible to analyse the vertical concentration profiles of several stratospheric trace gases like ozone (O_3), nitrogen dioxide (NO_2), chlorine dioxide (OCIO), or bromine monoxide (BrO) on a global scale. Such observations are important for the investigation of the stratospheric ozone chemistry. Global data sets from satellite observations are especially useful to discriminate the effects of chemistry and meteorology. The SCIAMACHY observations of OCIO and BrO constitute the first global 3-dimensional stratospheric data sets.

For the interpretation of the SCIAMACHY limb measurements, detailed radiative transfer simulations have to be performed, which allow quantification of the spatial variability of the sensitivity of the measurements. For this purpose, a 3-dimensional, fully spherical Monte Carlo radiative transfer model (McArtim) was developed

in our working group. It allows simulation of individual processes like scattering, reflection and absorption for a large ensemble of photons. In the figure, photon paths are indicated by atmospheric scattering events (red points) and reflection on the Earth's surface (yellow points). A high density of these events characterise areas with high measurement sensitivity, which is typically highest along the line of sight. Due to multiple scattering, the observed photons can also have penetrated into deeper atmospheric layers. The location at which the line of sight is parallel to the Earth's surface is called tangent point (TP): the altitude of the line of sight at TP is the tangent height (TH). For observations with high TH (e.g. 40 km, see figure), the observed photons are scattered nearly symmetrically from both sides of the TP. For observations at low TH, the observed photons are scattered almost exclusively from the atmosphere between the TP and the instrument. The variation of the horizontal sensitivity with elevation angle is especially important for cases with strong trace gas concentration gradients, e.g. at the edge of the polar vortex.



Simulation of the atmospheric photon paths, which contribute to satellite limb observations for different viewing angles (indicated by different tangent heights, TH). The sensitivity of the measurements is characterised by the density of atmospheric scattering events (red points) and surface reflection (yellow points). The measurement sensitivity varies not only with altitude, but also horizontally.



Oxidation Pathways from the Marine Boundary Layer to the Tropopause

Reaction with radicals is the main self-cleansing mechanism in the atmosphere. A large variety of chemical compounds emitted by human activities such as industrial processes and traffic, but also by natural ecosystems, are oxidised by reactions with OH, O₃ or NO₃, ultimately leading to their removal from the atmosphere. This removal takes place either through a chain of reactions in the gas-phase, for example decomposing hydrocarbon molecules into CO₂ and water, or by the formation of soluble components, enhancing loss through deposition. In addition, the formation of soluble compounds can lead to the formation of aerosols, which influence the atmospheric radiation budget and thus our climate.

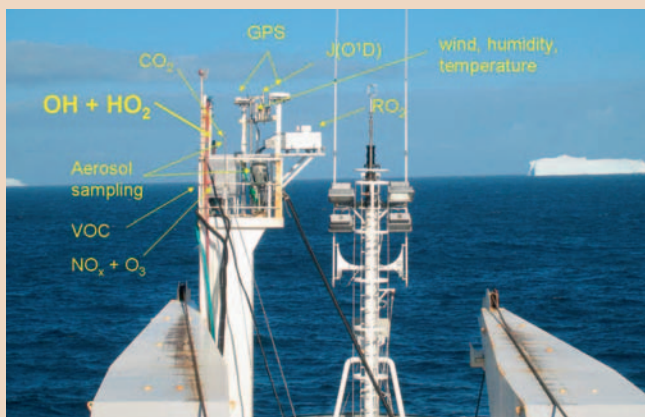
Hydroxyl (OH) is the most reactive of the three radicals mentioned above, therefore it is intrinsically difficult to measure and, despite of its importance, it is present in the atmosphere only in very small amounts of less than a part per trillion.

We have developed an instrument to measure OH and the related HO₂ radicals based on Laser-Induced Fluorescence (LIF). In March 2007 we participated in OOMPH campaign in the South Atlantic, which took place on the French research vessel 'Marion-Dufresne'. Measurements of OH and HO₂ (together called HO_x), combined with other relevant trace gas concentration data and photolysis frequencies, allow studies of the photochemistry in remote marine areas, the

oxidation of marine volatile organic compounds (VOCs) and its impact on aerosol formation and ozone chemistry.

In July of the same year, we deployed the same instrument on a Learjet aircraft, contributing HO_x measurements to the HOOVER summer campaign (HOOVER is HO_x over Europe). The aim is to study the seasonal and latitudinal dependencies of photochemistry in the free troposphere over Europe. During the summer campaign an additional focus was placed on convective transport and processing in thunderstorm clouds as well as the oxidation capacity in the Arctic during the long polar daylight. Very high OH mixing ratios were detected in the outflow of a convective system over central Germany, together with equally enhanced nitric oxides, indicative of enhanced photochemistry in the upper troposphere induced by lightning.

The experience gained so far deploying the LIF instrument on the Learjet is of great value for the next task at hand: the integration on HALO, the new German research aircraft. The first science campaign on HALO is scheduled to take place in July 2009, and the LIF instrument for HO_x measurements is part of the planned scientific payload. Additionally, two new LIF-based instruments are being developed for HALO in our group. Nitric dioxide (NO₂) will be detected directly allowing fast, highly sensitive and interference free measurements. Organic peroxy radicals, which are closely related to the HO_x budget, will be measured by conversion and subsequent detection of OH.



JUNIOR RESEARCH GROUP



Vegetation as a Source of Climate-Relevant Trace Gases

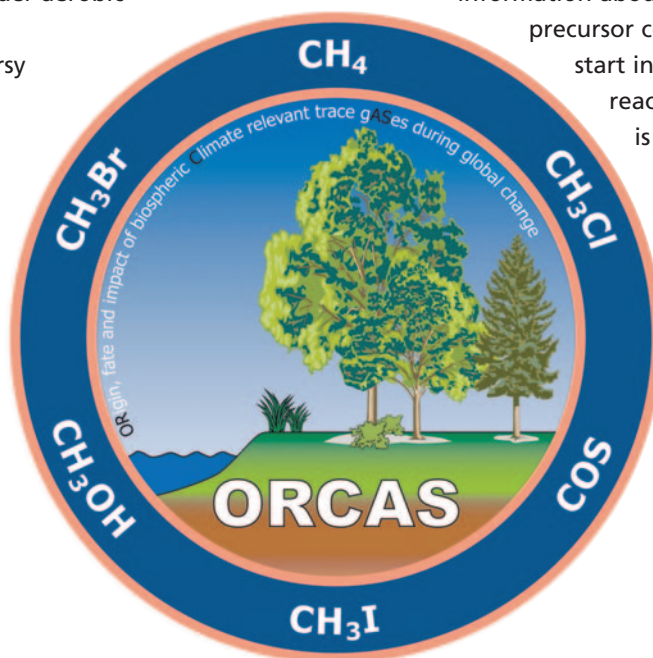
The overall goals of the ORCAS research group are to explore the formation of biospheric climate-relevant volatile organic compounds (VOCs) and to study their life-cycle utilising a stable isotope approach. Stable isotope analysis has become a powerful tool for atmospheric scientists, plant biologists, ecologists and geochemists studying global elemental cycles or past climatic conditions. We focus mainly on the three gases – methane (CH_4), chloromethane (CH_3Cl) and bromomethane (CH_3Br) – known to play a key role in the natural cycles of global warming and ozone depletion. Additionally, other VOCs such as iodomethane (CH_3I), methanol (CH_3OH), carbonyl sulphide (COS) and bromoform (CHBr_3) which are also known to play a role in atmospheric chemistry are of interest. Particular emphasis is given to the fact that biospheric emissions of these gases are expected to drastically change in the 21st century as a response to global change.

Up to now the degree to which the terrestrial biosphere, particularly vegetation contributes to the atmospheric burden of these compounds is not well understood and thus their global budgets are poorly constrained. For instance, the observation that plants (living plants and plant litter) produce CH_4 under aerobic conditions has caused considerable controversy within the scientific community and the general public. It not only led to much discussion and debate on its contribution to the

global CH_4 budget but also on the authenticity of the observation itself. Beyond the observation that vegetation releases methane, the mechanism involved in its formation remains unknown. Thus, elucidation of the underlying biochemical pathway for aerobic CH_4 formation is crucial for gaining full understanding of its role and possible global significance. In a first step it is important to gather information on plant precursor compounds that lead to methane formation.

We have investigated important cell wall components of plants such as pectin with varying degrees of deuterium labelled esterified methyl groups to prove our hypothesis that methoxyl groups are a source of methane in an oxic environment. The stable hydrogen isotope values of the methane released in experiments with deuterium labelled compounds were very different from those with non-labelled compounds. Our results provide unambiguous isotope evidence that specific groups of pectin can act as a source of atmospheric CH_4 under aerobic conditions. We further show that emissions of CH_4 from pectin strongly depend on temperature and exposure to light, in particular in the UV range. Although the mechanism is still unknown, our study is an important first step to gain more information about potential plant

precursor components and thus to start investigating the reaction mechanism which is needed to understand the environmental importance of aerobic methane formation.



MAX
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PUBLICATIONS

SELECTED PUBLICATIONS

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MAX PLANCK INSTITUT

FÜR CHEMIE

ZENTRALE EINRICHTUNGEN
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Die Mitarbeiter der Verwaltung, der Bibliothek, der IT-Gruppe, der Elektronikgruppe, der Werkstätten und der Hausverwaltung bilden das infrastrukturelle Rückgrat des Instituts. Sie unterstützen die Wissenschaftler bei der Erfüllung ihrer Aufgaben und tragen wesentlich zur technischen und organisatorischen Weiterentwicklung des Instituts bei.

BIBLIOTHEK

Die Bibliothek stellt die benötigte Literatur und sonstige wissenschaftliche Informationen in jedweder Form bereit. Während klassische Printmedien (Bücher, Zeitschriften) nach wie vor eine wertvolle Informationsquelle darstellen, wächst die Bedeutung elektronischer Medien, insbesondere Online-Zeitschriften, in den letzten Jahren ständig an. Literatur-Datenbanken (Georef, Web of Science etc.) wie auch Dokumentlieferdienste stellen weitere wichtige Bestandteile des Informationsangebotes dar.

Der Bibliotheksbestand umfasst wissenschaftliche Literatur aus einem weiten Bereich an Fachgebieten: Physik, Chemie, Biologie, Mathematik, Meteorologie, Geowissenschaften, Astronomie, Ökologie und Kernphysik. Im Einzelnen sind rund 28.000 Bände (Zeitschriften, Monographien, Forschungsberichte, Dissertationen) sowie zahlreiche Mikrofiche-Ausgaben, CD-ROMs und Videos vorhanden.

IT-GRUPPE

Zu den Hauptaufgaben der IT-Gruppe gehören die Bereitstellung einer modernen IT-Infrastruktur sowie kompetente Unterstützung der Nutzer im Anwendungsbereich. Um dies zu erreichen, wurden in den Jahren 2007/2008 umfassende Konsolidierungsmaßnahmen im Bereich der Massendatenhaltung und der zentralen Dienste (E-Mail, Internetzugang, Druckdienste, WLAN, etc.) beschlossen und zum Teil bereits umgesetzt.

Zu den geplanten Maßnahmen zählen etwa die Anschaffung eines leistungsstarken zentralen Massenspeichersystems, die Virtualisierung unserer Server mit VM-Ware und der Aufbau einer Windows-Infrastruktur. Im Rahmen dieser Maßnahmen wird auch eine engere Zusammenarbeit mit der Universität Mainz angestrebt, die künftig beispielsweise unsere

The staff of the administration, the library, the IT-group, the electronics group, the workshops and the in-house maintenance staff are the infrastructural backbone of the Institute. They continuously support the researchers and contribute to the technical and organisational development of the Institute.

LIBRARY

The library provides the scientists with media and scientific information in many forms. While the collections of printed material (books, journals) remain a valuable source of information, the importance of electronic media (especially online journals) has been steadily increasing in recent years. Literature databases (Georef, Web of Science etc.) represent another important source of information, as do various document delivery services.

The library collections cover various subject areas (physics, chemistry, biology, mathematics, meteorology, geosciences, astronomy, ecology, nuclear physics) and contain approximately 28,000 volumes (periodicals, monographs, reports, theses), as well as various microforms, CDs and video tapes.

IT-GROUP

The provision of a modern IT-infrastructure and qualified user support in the application range are among the main tasks of the IT-group. To accomplish these tasks, extensive consolidation activities in the fields of mass data management and central services (e-mail, internet access, printing services, wireless local area network [WLAN], etc.) have been initiated in 2007/08 – and in part already been realised.

Among the planned arrangements are the purchase of a high-performance mass storage device, the virtualisation of our servers with VM-ware, and the installation of a Windows infrastructure. This reorganisation also aims at a closer co-operation with the University Mainz, which in the future will provide for our archive data backup.

Due to our scientists' frequent stays at other institutions, at conferences, or measuring campaigns, new services and possibilities regarding network access and the use of mobile devices are being planned.

ZENTRALE EINRICHTUNGEN

SERVICE UNITS

Datensicherung und Archivierung übernehmen wird.

Bedingt durch die häufigen Aufenthalte der Wissenschaftler an anderen Institutionen, bei Tagungen oder Messkampagnen sind auch neue Dienstangebote im Bereich der Netzwerkzugänge und der Nutzung mobiler Endgeräte geplant.

ELEKTRONIKGRUPPE

Der Schwerpunkt der Arbeitsgruppe ist die Instandhaltung des umfangreichen elektronischen Geräteparks sowie zunehmend die Entwicklung von Hard- und Software zur Durchführung oder Unterstützung von wissenschaftlichen Experimenten. Die kommerziell erhältlichen Geräte sind nur in Ausnahmefällen für die speziellen Anwendungen z.B. bei Atmosphärenmessungen geeignet. Vielfach müssen zusätzliche Prozessregler für Temperaturen, Drücke oder Flüsse implementiert werden, um die Prozessparameter der Geräte trotz Änderung der Umgebungsparameter konstant zu halten.

Da es sich bei solchen Systemen meist um Neuentwicklungen handelt, die im Verlauf ihrer Entstehung vielen Änderungen unterworfen werden müssen, nahm in den letzten Jahren die Nachfrage nach modularen, hochgradig flexiblen und skalierbaren Prozesssteuerungen zur Regelung, Datenerfassung, Archivierung und Visualisierung stark zu. Nach Bedarf müssen diese Prozesssteuerungen auch ohne den Operator den sicheren Ablauf von Prozessen steuern und überwachen können. Solche Anwendungen werden mithilfe eines modularen Baukasten-

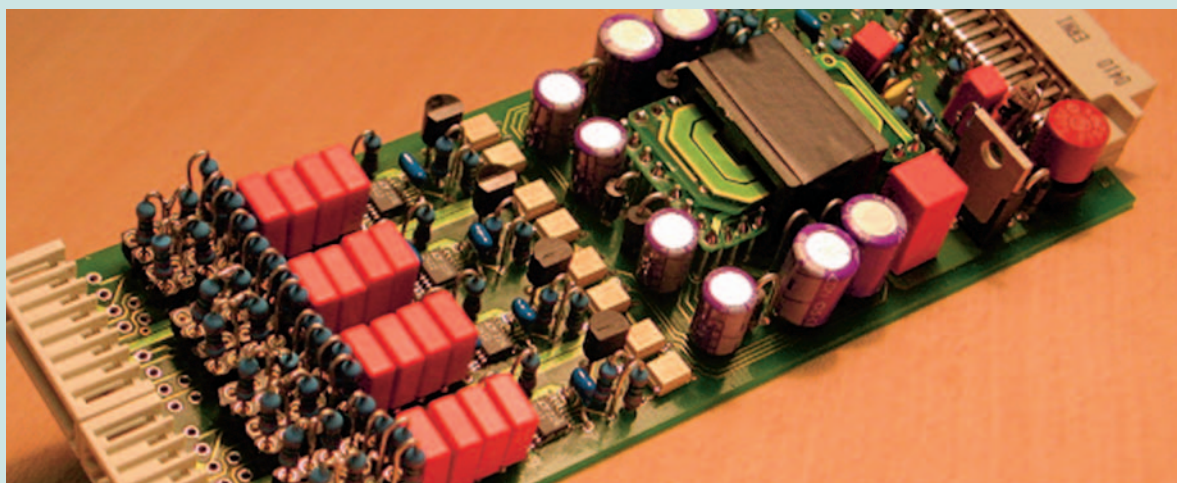
ELECTRONICS GROUP

The main task is the maintenance of various instruments. In addition, the group increasingly deals with hard- and software development needed to support the realisation of scientific experiments. Commercially available equipment rarely meets the special demands of scientific work, e.g., of field measurements. To stabilise the instruments' process parameters, despite changing environmental conditions, additional process controls for temperature, pressure or flux have to be implemented.

Since these systems are often newly developed and modified, there has been an increasing demand for highly flexible and scalable process control hard- and software. Although primarily needed for control, data management, archiving and visualisation, the equipment is also used in automated process control, i.e. without the operator. The realisation of such applications is based on a modular system consisting of various processors, input/output modules and software modules.

WORKSHOPS

Many of the measurement devices needed for the Institute's research are not commercially available. Therefore, they must be produced in the Institute, requiring well-equipped workshops. In the workshop for fine mechanics, new instruments are designed and built in co-operation with scientists. These instruments have to comply with stringent requirements, such as usage on board of satellites, aircraft or ships. The employees of this workshop perform a wide range of operations, such as



systems – bestehend aus unterschiedlichen Prozessoren, Ein-/Ausgabekomponenten und Softwaremodulen – realisiert.

WERKSTÄTTEN

Viele Messapparaturen, die für die Forschungsvorhaben des Instituts benötigt werden, sind nicht auf dem Markt erhältlich. Sie müssen also selbst gebaut werden, dazu sind gut ausgerüstete Werkstätten notwendig. So besitzt das Institut eine feinmechanische Werkstatt, in der in Zusammenarbeit mit den Wissenschaftlern Messinstrumente entstehen, die auch spezielle Anforderungen, wie sie beispielsweise durch die Verwendung in Satelliten, Flugzeugen oder Schiffen auftreten, erfüllen. Ein breites Tätigkeitsspektrum, vom Schweißen spezieller Werkstoffe über das Verspannen aller gängigen Metalle bis zur Galvanik, wird von den Mitarbeitern dieser Werkstatt gefordert.

Die zum Teil sehr komplizierten Glasapparaturen werden in der glastechnischen Werkstatt gefertigt. Grafische und fotografische Arbeiten für die wissenschaftliche Dokumentation werden im Zeichenbüro durchgeführt.

Das Institut beteiligt sich seit 1949 auch an der Lehrlingsausbildung. Die Ausbildung zum Maschinenbaumechaniker erfolgt heute in der separaten Mechaniklehrwerkstatt. Im Rahmen der Ausbildung werden Übungswerkstücke angefertigt und institutsinterne Auftragsarbeiten ausgeführt. Die Auszubildenden erhalten weiterhin Fachausbildungen in CNC-Technik, Pneumatik/Hydraulik und Schweißtechnik, zum Teil in überbetrieblichen Lehrgängen. Die Mechaniklehrwerkstatt ging aus den Leistungswettbewerben der Handwerkerjugend bisher mit elf Kammer Siegern, sieben Landessiegern und zwei Bundessiegern hervor. Im Jahr 2007 ist Christian Barth zweiter Landessieger geworden.

Kommunikationselektroniker, die in der Elektronikgruppe ausgebildet werden, erhalten in der mechanischen Lehrwerkstatt die metalltechnische Grundausbildung. Des Weiteren werden in der Lehrwerkstatt Betriebspraktika für Schüler und Grundpraktika für verschiedene Studiengänge durchgeführt.

welding of special materials, bracing metals, and electroplating.

Complex instruments involving glass are produced in the glass-technical workshop. Graphic and photo-optical work for scientific documentation is carried out in the drawing office.

The Institute has been training apprentices since 1949. The training of mechanics is currently done in a separate workshop. The apprentices not only craft practice pieces, they also carry out machining tasks for the scientific departments. In addition, the apprentices are specially trained in CNC-technique, pneumatics/hydraulic systems and welding technology, partly in inter-institutional courses. The mechanics training workshop has been quite successful in the competitions of the Handwerkerjugend, contributing eleven prize winners at regional, seven at state and two at federal level contests. In 2007 Christian Barth finished as runner-up on state level.

IT technicians, who are qualified in the electronics group, are provided with basic education in metal technique as well. In addition, the training workshop offers industrial courses for schools and various types of education.

Mechaniklehrwerkstatt, mechanics-training workshop.



ÖFFENTLICHKEITSARBEIT PUBLIC RELATIONS

Die Themen Klima, Umwelt und Nachhaltigkeit sind endlich in Politik, Wirtschaft und Gesellschaft zum Durchbruch gelangt und werden nun kontinuierlich und flächendeckend in den Medien behandelt. Aufgrund der zunehmenden Aufmerksamkeit für diese Themen steht das Institut vermehrt im besonderen Licht der Öffentlichkeit. Die primäre Aufgabe der Öffentlichkeitsarbeit ist es, die Schnittstelle zwischen den Wissenschaftlern am Institut und den Medien zu bilden sowie die interessierten oder zu interessierenden Gruppen der Gesellschaft – Schüler, Lehrer, Studenten, Medienvertreter, Politiker, Unternehmer – über die Forschungsarbeiten am Institut zu informieren. Jährlich wird rund ein Dutzend Pressemitteilungen über herausragende Ergebnisse, über neue Techniken oder anlässlich internationaler Expeditionen herausgegeben. Oft resultieren daraus ausführliche Berichte im Wissenschaftsmagazin 'MaxPlanckForschung', in der lokalen und überregionalen Presse sowie in Rundfunk und Fernsehen.

Das PR-Team erstellt Informationsmaterial wie Institutsberichte, Imagebroschüren, Faltblätter und interaktive Präsentationen. Es kooperiert eng mit dem zentralen Pressereferat und bereitet die Institutsbeiträge für verschiedene Periodika und die Internetseiten der Max-Planck-Gesellschaft vor. Das Team ist zuständig für die Erstellung und Aktualisierung der allgemeinen, abteilungsübergreifenden Webseiten des Instituts. Zu den wiederkehrenden Aktivitäten gehören außerdem: Organisation und Durchführung von Gruppenführungen, Diskussionsveranstaltungen, Workshops und Ausstellungen, Beantwortung der Anfragen von Journalisten und Vermittlung von Gesprächspartnern sowie Kontaktpflege zu lokalen Medienvertretern und überregionalen Wissenschaftsjournalisten.

WISSEN VERMITTELN

Das Max-Planck-Institut für Chemie nimmt an verschiedenen europäischen Bildungsinitiativen teil mit dem Ziel, den derzeitigen Wissensstand über Erdsystem und Klima allgemein verständlich darzustellen. Die umfassenden Inhalte sprechen eine breite Zielgruppe an – von Grundschulern über Lehrer bis zu Wissenschaftsjournalisten. Die Arbeiten im Rahmen verschiedener Projekte, die

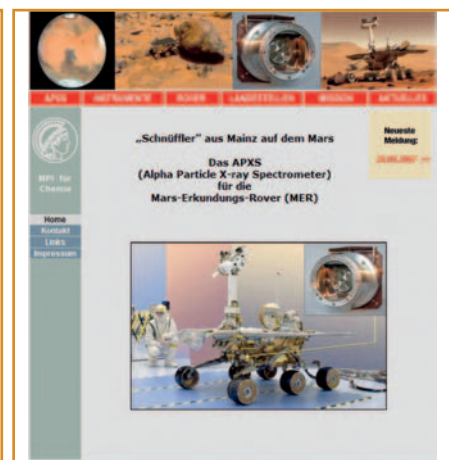
The topics climate, environment, and sustainability have attracted the attention of politics, economy, and society at large. Due to continued and ubiquitous media coverage, the Institute finds itself increasingly in the public eye. The primary purpose of the public relations work is to establish an interface between scientists and media and to inform interested societal groups – e.g., school/university students, teachers, journalists, politicians, companies – about the scientific work at the Institute. Every year about one dozen press releases on remarkable results, new techniques, or on the occasion of international expeditions have been published. Detailed reports in the science magazine 'MaxPlanckResearch', in local and national press, or broadcasting and television are often based on these releases.

The PR team produces promotional materials about the Institute such as Institute reports, brochures, flyers and interactive presentations. It works closely with the central press department and prepares the Institute's contributions to various periodicals and the website of the Max Planck Society. The team is responsible for updating the general pages of the Institute's website. Other regular activities comprise, for example, organising and realising guided tours, discussion meetings, workshops and exhibitions, arranging contacts between journalists and scientists, and replying to inquiries from journalists, students and other parties.

KNOWLEDGE TRANSFER

The Max Planck Institute for Chemistry takes an active part in various – mostly EU-sponsored – educational initiatives, which aim at a generally understandable illustration of the current standard of knowledge on climate and the Earth system. These activities are interlinked with one another on the web presences of the climate encyclopaedia ESPERE, of the school magazine ACCENT, the climate and traffic project QUANTIFY and the oceanographic initiative OOMPH. The current progress in Mars research is given on the Institute's website too. These wide-ranging matters address a broad target group, including elementary school students, teachers and scientific journalists.

ÖFFENTLICHKEITSARBEIT PUBLIC RELATIONS



überwiegend durch die Europäische Union gefördert werden, sind miteinander im Internet vernetzt. Hierzu gehören die ESPERE-Klima-Enzyklopädie, das ACCENT-Schulmagazin sowie die Webseiten des QUANTIFY- Projekts zu Verkehr und Klima und des Ozeanforschungsprojekts OOMPH. Auch über die aktuelle Entwicklung in der Marsforschung wird ausführlich und allgemein verständlich auf der Institutswebseite berichtet.

Insbesondere die Projekte ACCENT und ESPERE haben dabei den Anspruch, die aktuelle Forschung für den Schulunterricht greifbar zu machen. Das Themenangebot orientiert sich an den Lehrplänen der Fächer Biologie, Chemie, Geographie und Physik mit dem Ziel, die

Particularly ACCENT and ESPERE attempt at adapting the latest research results to school education. Thematically, these projects follow an interdisciplinary approach and relate to the curricular of the school subjects biology, chemistry, geography and physics. Numerous teaching materials and work sheets – compiled in co-operation with teachers – are provided for school lessons. The climate encyclopaedia and the school magazine are available online as well as on CD (PDF files). Besides, the Institute is involved in further education for teachers, offering in-house and external training.

Individual school students are offered work placements at the Institute. Trainees have the opportunity to work together with scientists and



ÖFFENTLICHKEITSARBEIT PUBLIC RELATIONS

fächerübergreifende Zusammenarbeit zu stärken. Für die Anwendung im Schulunterricht stehen auch zahlreiche Arbeitsblätter zur Verfügung. Die Erstellung von geeigneten Schulmaterialien erfolgt im Austausch mit Lehrern. Die Klimaenzyklopädie und das Schulmagazin sind als Informationsplattform im Internet und als vollständige CD-Version im PDF-Format vorhanden. Das Institut engagiert sich zudem bei Lehrerfortbildungen, extern wie auch im eigenen Haus.

Für einzelne Schüler bietet das Institut Betriebspraktika an. Die Praktikanten können – in direkter Zusammenarbeit mit Wissenschaftlern und Technikern – in verschiedenen Laboren und Werkstätten selbständig experimentieren. Sie bekommen zusätzlich die Gelegenheit, eine eigene Webseite zu erstellen und die Erfahrungen, die sie während ihres Praktikums gesammelt haben, im Internet zu veröffentlichen.

Ein Schwerpunkt des Schulprogramms ist es, junge Mädchen für naturwissenschaftlich-technische Studiengänge zu motivieren. Das Ada-Lovelace-Projekt, ein Mentorinnen-Netzwerk für Frauen in Technik und Naturwissenschaften, steht unter dem Motto 'Was ich will, das kann ich' und wendet sich insbesondere an interessierte Schülerinnen. Hier können Gruppen von Schülerinnen Experimente selbst durchführen, wie z.B. die Messung von Methankonzentrationen mit einem Gaschromatographen. Diese Versuche finden in Institutslaboratorien unter der Anleitung von jungen Wissenschaftlerinnen statt. Auch ein spannendes und abwechslungsreiches Programm am Girls' Day findet bei naturwissenschaftlich interessierten Mädchen großen Zuspruch.

EVENTS

European Researchers' Night: Mainzer Wissenschaftlerinnen und Wissenschaftler öffneten am 28. September 2007 ihre Türen auf dem Universitätscampus bis spät nach Mitternacht und gewährten Einblicke in die faszinierende Welt des Wissens und Experimentierens. Diese europaweite Forschungsnacht ist ein Projekt der Europäischen Union.

technicians and to experiment independently. Additionally, they can design their own website, on which they can publish experiences gathered during their work placement.

One of the main goals of the initiatives is to get girls enthused about natural scientific and technical degree courses. The Ada-Lovelace-Project, a mentoring network for women in science and technology, has 'What I Want, I Can Do' as its motto and is particularly directed at schoolgirls. Groups of students, supervised by young female researchers in the Institute's laboratories, can conduct experiments, e.g. measuring methane concentrations in a gas chromatograph. Furthermore, Girl's Day offers an exciting and diverse range of activities that are well received by girls interested in natural sciences.

EVENTS

European Researchers' Night: Friday 28 September 2007 was declared Researchers' Night by the European Commission. The public – and in particular young people – had the opportunity to meet the researchers from Mainz and could gain insights into the world of knowledge and experimenting. The appeal to pursue a scientific career was highlighted.



ÖFFENTLICHKEITSARBEIT PUBLIC RELATIONS



Woche der Umwelt 2007: Bundespräsident Horst Köhler hatte gemeinsam mit der Deutschen Bundesstiftung Umwelt (DBU) herausragende Unternehmen und Institutionen zur Präsentation innovativer Umweltschutztechnologien und -projekte in den Park von Schloss Bellevue nach Berlin eingeladen. Das MPI für Chemie beteiligte sich an dieser wichtigen Umweltausstellung, die etwa 12.000 geladene Gäste aus den Bereichen Wirtschaft, Wissenschaft und Politik besuchten, mit dem Projekt 'Luftqualität und Klimawandel'.

Week of the Environment 2007: Federal President Horst Köhler and the Deutsche Bundesstiftung Umwelt (DBU) had invited outstanding companies

and institutions to present their innovative environmental-protection-technologies, products, and campaigns. The MPI for Chemistry exhibited the project 'Air Quality and Climate Change'. Approximately 12,000 scientific, political and industrial experts visited this important exhibition in the park of Schloss Bellevue.

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Erfahrungsaustausch mit der chinesischen Delegation des Wetterdienstes Tibet.

Experience exchange with the Chinese delegation of the Tibetan meteorological service.



Prominente Besucher in Manaus: Max-Planck-Wissenschaftler informieren Bundespräsident Horst Köhler (linkes Bild) und den Staatssekretär des BMBF, Prof. Dr. Frieder Meyer-Krahmer (rechtes Bild) über ihre Forschungen im Amazonasgebiet und erklären, was Politiker in Deutschland und weltweit tun können, um die Folgen des Klimawandels zu mildern.



VIP visits in Manaus: Max Planck researchers inform the Federal President Horst Köhler (left) and State Secretary, Prof. Dr. Frieder Meyer-Krahmer (right) on the status of their research in Amazonia and elucidate what politicians in Germany and worldwide can do to mitigate the effects of our changing climate.



Feier anlässlich der Emeritierung und des 68. Geburtstages von Professor Albrecht Hofmann.

The Institute celebrates the 68th birthday and retirement of Professor Albrecht Hofmann.

ÖFFENTLICHKEITSARBEIT PUBLIC RELATIONS



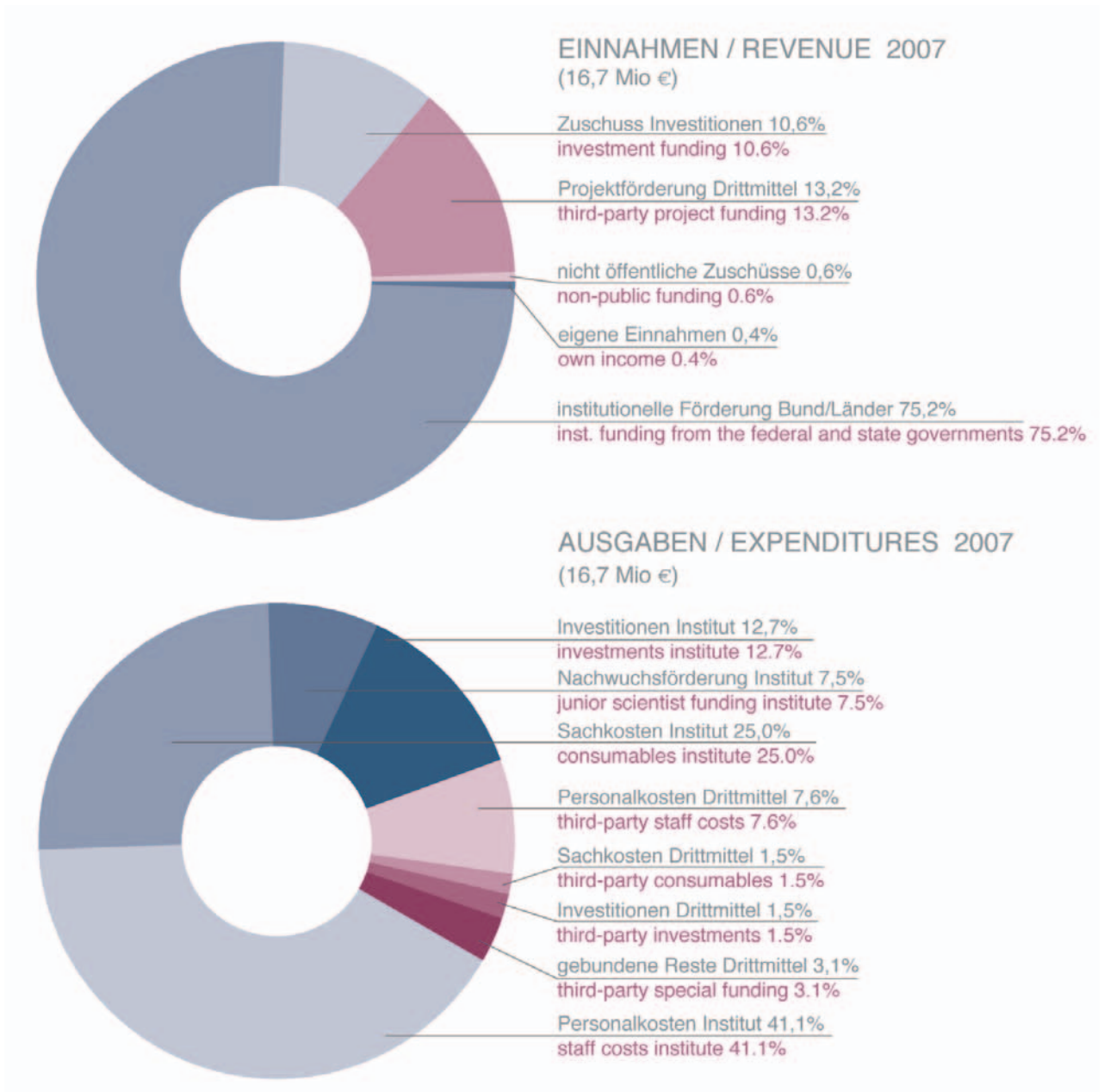
Interne Kommunikation: Für gute Forschungsergebnisse ist auch ein gesundes Arbeitsklima unerlässlich. Im Juni 2007 fand erstmalig ein internes Institutskolloquium statt. Neben Laborbesichtigungen, Posterpräsentationen und Expeditionsberichten gehörte zum Erfahrungsaustausch auch ein Zeltfest mit der institutseigenen 'Crazy Ozone Band'.

Internal communication: To obtain good research results, among other factors, a positive atmosphere at the workplace is necessary. In June 2007 an Institute's colloquium was held for the first time. Thoughts and experiences were shared not only during laboratory visits, poster presentations, and expedition reports, but also on a party with the Institute's in-house 'Crazy Ozone Band'.

PERSONAL UND BUDGET STAFF AND BUDGET

Anfang 2008 waren insgesamt 242 Mitarbeiter am Institut tätig, darunter 101 Wissenschaftler, 39 Nachwuchswissenschaftler, 92 Nichtwissenschaftler und 10 Auszubildende; 214 Mitarbeiter wurden aus institutioneller Förderung und 28 Mitarbeiter aus Mitteln der Projektförderung finanziert.

Early 2008 a total of 242 persons were employed at the Institute, among them 101 scientists, 39 junior scientists, 92 non-scientific staff and 10 apprentices; 214 staff members were paid from institutional funds and 28 scientists were paid from third-party project funding.



ABKÜRZUNGEN

ABBREVIATIONS

ACCENT	Atmospheric Composition Change – the European Network of Excellence
AIDA	Aerosol Interactions and Dynamics in the Atmosphere
AMMA	African Monsoon Multidisciplinary Analyses
CCN	Cloud Condensation Nuclei
CNR	Consiglio Nazionale delle Ricerche, Italy
CNRS	Centre National de la Recherche Scientifique, France
COACH	Co-operation on Oceanic, Atmospheric and Climate Change Studies
DMS	Dimethyl Sulphide
DNA	Deoxyribonucleic Acid
DFG	Deutsche Forschungsgemeinschaft
DLR	Deutsches Zentrum für Luft- und Raumfahrt e. V.
EGER	Exchange Processes in Mountainous Regions
ENVISAT	Environmental Satellite
ESPERE	Environmental Science Published for Everybody Round the Earth
GABRIEL	Guyanas Atmosphere-Biosphere Exchange and Radicals Intensive Experiment with the Learjet
GFMC	Global Fire Monitoring Centre
HALO	High Altitude – Long Range Research Aircraft
HOOVER	HO _x over Europe
HRTEM	High-Resolution Transmission Electron Microscopy
IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften
IGBP	International Geosphere-Biosphere Programme
ILEAPS	Integrated Land Ecosystem Atmospheric Processes Study
LACIS	Leipzig Aerosol Cloud Interaction Simulator
LA-ICP-MS	Laser Ablation Inductively Coupled Plasma Mass Spectrometry
LA-TOF-MS	Laser Ablation Time-Of-Flight Mass Spectrometry
LBA	Large Scale Biosphere Atmosphere Experiment in Amazon
LIF	Laser-Induced Fluorescence
LIP	Large Igneous Province
MIM	Mainz Isoprene Mechanism
MODIS	Moderate Resolution Imaging Spectroradiometer
MOLA	Mobile Laboratory for Aerosol Research
MORB	Mid-Oceanic Ridge Basalts
MSA	Methanesulphonic Acid
NCAR	The National Center for Atmospheric Research
NMHC	Non-Methane Hydrocarbons
OOMPH	Organics over the Ocean Modifying Particles in both Hemispheres
ORCAS	Origin, Fate and Impact of Biospheric Climate-Relevant Trace Gases during Global Change
PBA	Primary Biogenic Aerosol
QUANTIFY	Quantifying the Climate Impact of Global and European Transport Systems
SAPHIR	Simulation of Atmospheric Photochemistry in a large Reaction Chamber
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SODAR-RASS	Sonic Detection and Ranging - Radio Acoustic Sound System
TIMS	Thermal Ionisation Mass Spectrometry
VOCs	Volatile Organic Compounds

DER WEG ZUM INSTITUT HOW TO REACH THE INSTITUTE

PER FLUGZEUG

Von Frankfurt Flughafen mit IC/ICE (Fernbahnhof) oder mit der S-Bahn (S8) Richtung Wiesbaden bis Mainz Hauptbahnhof.

PER BAHN

Es verkehren pro Tag mehrere IC-, EC- und ICE-Züge über Mainz Hauptbahnhof.

PER BUS

Vor dem Mainzer Hauptbahnhof, an der Bushaltestelle 'G' Nr. 54, 55, 58 oder 68 bis Haltestelle 'Friedrich-von-Pfeiffer-Weg', dann über die Fußgängerbrücke auf den Campus, geradeaus den Pfeifferweg und Strassmannweg entlang bis Johann-J.-Becher-Weg, dann links zum Institut.

PER AUTO

Von Süden über die Autobahn A 60, Ausfahrt Mainz-Lerchenberg. Von dort rechts in die Koblenzer Straße, auf der linken Spur bleiben. Direkt vor der 5. Ampel nach rechts zur Haupteinfahrt der Universität.

Von Norden über die Autobahn A 60, Ausfahrt Mainz-Finthen. Folgen Sie der Hinweisbeschilderung 'Innenstadt'. Nach dem 'Europaplatz' nach rechts Richtung 'Bretzenheim' und 'Universität'. An den beiden nächsten Ampeln jeweils links abbiegen zur Haupteinfahrt der Universität.

BY PLANE

From Frankfurt Airport, take the IC/ICE trains (*Fernbahnhof*) or the S8 train (*S-Bahn*) heading towards Wiesbaden until Mainz Central Station (*Mainz Hauptbahnhof*). From the station take a taxi or a bus to the Institute.

BY TRAIN

Mainz Hauptbahnhof is serviced daily by many Intercity (IC), Eurocity (EC) and Intercity Express (ICE) trains.

BY BUS

Exit the Mainz Hauptbahnhof through the main hall and go to the right. At bus stop 'G', take bus line 54, 55, 58, or 68 to the third stop *Friedrich-von-Pfeiffer-Weg*. Cross the pedestrian bridge and follow the *Friedrich-von-Pfeiffer-Weg* and the *Strassmannweg* to the *Joh.-J.-Becher-Weg*. Turn left and you will see the main building of the Institute on your right.

BY CAR

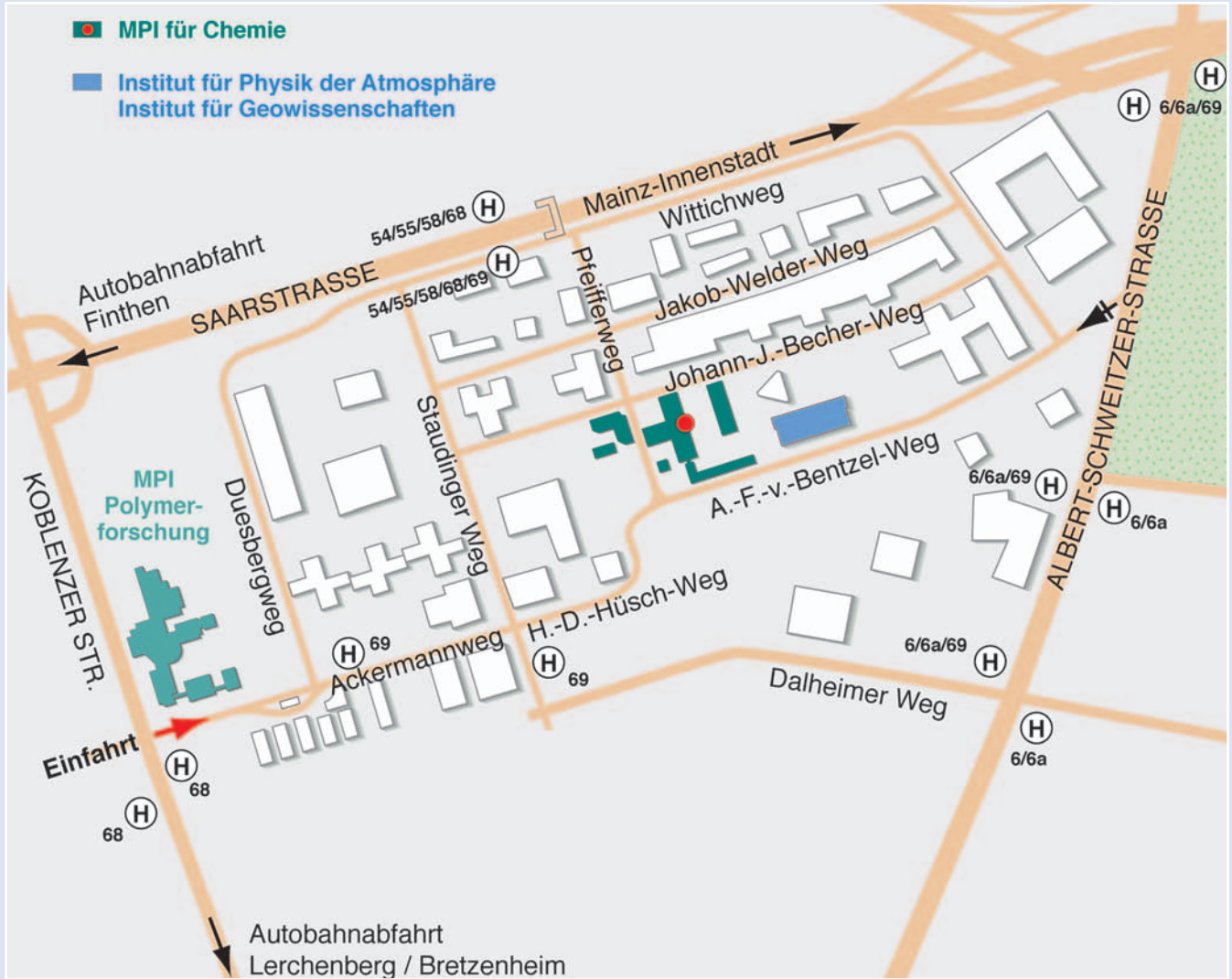
From the south via the *Autobahn A60*. Take the exit Mainz-Lerchenberg, turn right onto Koblenzer Straße and keep the left lane. Before the fifth traffic light, turn right in the direction *Universität* to arrive at the main entrance of the University.

From the north via the *Autobahn A60*. Take the exit Mainz-Finthen and follow the sign *Innenstadt*. After passing the roundabout *Europaplatz* take the next exit in the direction of *Bretzenheim* and *Universität*. Turn left at the traffic light and again at the next traffic light to arrive at the main entrance of the University.



Das Institut liegt auf dem Gelände der Johannes Gutenberg-Universität.

The institute is located on the campus of the Johannes Gutenberg University in Mainz.



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FOTOS

Max-Planck-Institut für Chemie. Bildbearbeitung durch Iris Bambach und Gerhild Feyerherd.

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MAX-PLANCK-INSTITUT FÜR CHEMIE



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