



INSTITUTSBERICHT INSTITUTE REPORT 2003-2004

MAX-PLANCK-INSTITUT
FÜR CHEMIE



MAX-PLANCK-GESELLSCHAFT



BIOGEOCHEMISTRY

ATMOSPHERIC
CHEMISTRY

GEOCHEMISTRY

COSMOCHEMISTRY

CLOUD PHYSICS
AND CHEMISTRY

MAX
PLANCK
INSTITUT

INSTITUTSBERICHT

FÜR
CHEMIE

2003
2004

INSTITUTE REPORT

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VORWORT

VORWORT

Unser Institut erforscht die Erde und ihr Umfeld in unterschiedlichen Größenbereichen, von Ökosystemen bis zum Sonnensystem, von Nanopartikeln bis Supernovae. Beobachtungen von Naturphänomenen in Feldstudien führen zu neuen wissenschaftlichen Fragestellungen. Wir ergänzen die Feldstudien durch Laboruntersuchungen unter kontrollierten Bedingungen, und wir simulieren die Wechselwirkungen und Rückkopplungsmechanismen durch numerische Modellrechnungen. Unser Institut betreibt nicht nur Grundlagenforschung, es fördert auch Wissen und Methoden, die für eine nachhaltige Nutzung der natürlichen Ressourcen und zum Schutz der Umwelt notwendig sind.

Auf Grund des schnellen technologischen Fortschritts müssen wissenschaftliche Methoden ständig weiterentwickelt werden. Das betrifft z.B. hochempfindliche Massenspektrometer, lasergestützte optische Messtechniken, Satelliten zur Erforschung von Erde und Sonnensystem und immer leistungsfähigere Rechner. Wir sind international anerkannt in den Geowissenschaften, insbesondere auf dem Gebiet der Chemie des Systems Erde. Auch sind wir an der wissenschaftlichen Ausbildung beteiligt, z.B. mit unserer International Max Planck Research School. Im folgenden Bericht stellen wir unsere Institution und ihre Tätigkeitsschwerpunkte vor und geben einen kurzen Überblick unserer Forschungsergebnisse des Zeitraums 2003-2004.

PREFACE

PREFACE

Our institute explores the Earth and its environment on a range of scales, from ecosystems to the solar system, and from nanoparticles to supernovae. We conduct field studies of natural phenomena as well as laboratory analyses and experiments under controlled conditions, and we simulate system interactions and feedback mechanisms through computer modelling. Our institute is engaged in basic research, but it also helps supply the knowledge and methods needed for the sustainable use of natural resources and environmental protection.

As a result of rapid technological advances there is a compelling need to continuously upgrade instrumentation and develop new scientific methods. This involves, for example, highly sensitive mass spectrometers, laser-based optical detection techniques, satellites that probe the Earth and solar system, and increasingly powerful computers. We operate at the forefront of the earth sciences, notably in earth system chemistry, and we are also committed to science education, for example, through our International Max Planck Research School. In this report, we present our organisation, its central scientific themes, and brief summaries of some of our research achievements in the period 2003-2004.

Prof. Dr. Jos Lelieveld

(Managing Director)



ALLGEMEINES ZUM INSTITUT

Geschichte und Gegenwart

Das Max-Planck-Institut für Chemie (MPI) ist eines der ältesten unter den derzeit 78 Instituten der Max-Planck-Gesellschaft zur Förderung der Wissenschaften (MPG). Es wurde 1912 in Berlin-Dahlem als Institut der Kaiser-Wilhelm-Gesellschaft, der Vorläuferorganisation der MPG, gegründet. 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.

Wie alle anderen Einrichtungen der Max-Planck-Gesellschaft betreibt das Max-Planck-Institut für Chemie Grundlagenforschung. Um sich den verändernden wissenschaftlichen Erfordernissen anzupassen, haben sich die Forschungsschwerpunkte des Instituts im Laufe seiner 90-jährigen Geschichte mehrfach

GENERAL

History and Present

The Max Planck Institute for Chemistry is one of the oldest among the currently 78 institutes of the Max Planck Society (MPG). It was founded in Berlin-Dahlem in 1912, as an institute of the Kaiser Wilhelm Society, the forerunner organisation of MPG. The institute was rebuilt in 1949 in Mainz on the campus of Johannes Gutenberg University, after it had been destroyed in World War II and temporarily relocated to Tailfingen/Württemberg. Since 1959 it has additionally been named Otto Hahn Institute to commemorate Otto Hahn's great importance for the institute and the discovery of nuclear fission, which was made in 1938 jointly by Otto Hahn, Lise Meitner and Fritz Strassmann in this institute.

Like all institutions of the MPG, the MPI for Chemistry performs basic research. To adapt to the changing scientific demands, the institute's main research has undergone multiple changes during its 90 years of existence. While classical chemistry was practised in the beginning, the focus has later been mainly put on radiochemistry, nuclear physics and mass spectrometry. Since the 1970's the formation and development of our planet and its environment have been the central issues. The

ALLGEMEINES ZUM INSTITUT

GENERAL

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 dabei vorwiegend, aber keineswegs ausschließlich, auf chemischen und physikalisch-chemischen Untersuchungen. Insofern ist der Name MPI für Chemie auch heute noch gerechtfertigt.

Drei Mitgliedern des Instituts wurde der Nobelpreis verliehen: Richard Wildstätter 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).

research covers a wide range of topics including the planets of our solar system, the atmosphere of the Earth and its hot core. Emphasis is predominantly, though by no means exclusively, put on chemical and physical-chemical analysis. Hence, the name MPI for Chemistry continues to be relevant.

Three members of the institute have been awarded the Nobel Prize: Richard Wildstätter 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).



ALLGEMEINES ZUM INSTITUT

GENERAL

Organisation

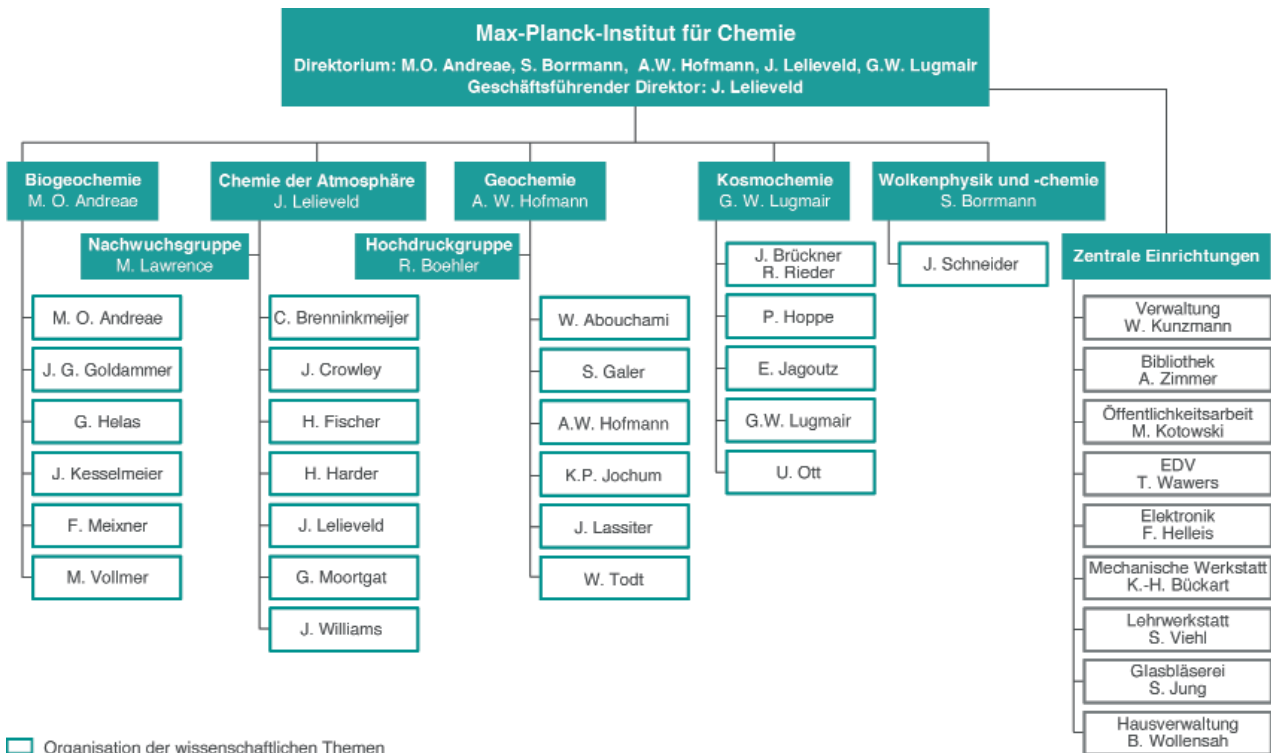
Organisation

Heute besteht das Institut aus fünf Abteilungen, einer selbständigen Arbeitsgruppe 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 five departments, an independent research group 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 the 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. Ein Kuratorium fördert den Kontakt zur Gesellschaft und Öffentlichkeit. Neben Wissenschaftlern gehören dem Kuratorium auch Vertreter aus Politik und Wirtschaft an.

The institute's research is evaluated by an international Advisory Board. The Board of Trustees promotes the relation between the institute, society and the general public. It consists of scientists as well as representatives of politics and economy.



ALLGEMEINES ZUM INSTITUT

GENERAL

FACHBEIRAT

ADVISORY BOARD OF THE INSTITUTE

Prof. Dr. Halliday, Alexander N.	ETH Zürich, Schweiz
Prof. Dr. Hawkesworth, Christopher John	University of Bristol, Bristol, UK
Prof. Dr. Hofmann, Michael R.	California Institute of Technology, Pasadena, USA
Prof. Dr. Hofmann, Thorsten	Universität Mainz
Prof. Dr. Isaksen, Ivar S.A.	University of Oslo, Norway
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

KURATORIUM

BOARD TRUSTEES OF THE INSTITUTE

Dr. Baumgarten, Ludwig	Mitglied des Vorstands Deutsches Zentrum für Luft- und Raumfahrt
Beutel, Jens	Oberbürgermeister der Landeshauptstadt Mainz
Prof. Dr. Felcht, Utz-Hellmuth	Vorstandsvorsitzender Degussa AG, Düsseldorf
Junker, Reinhard	Ministerialdirektor im BMBF
Prof. Dr. Kröner, Alfred	Institut für Geowissenschaften der Universität Mainz
Dr. Leuchs, Hans-Jürgen	Geschäftsführender Gesellschafter C.H. Boehringer Sohn
Prof. Dr. Michaelis, Jörg	Präsident der Universität Mainz
Dr. Quisthoudt-Rowohl, Godelieve	Mitglied des Europäischen Parlaments
Prof. Dr. Spiess, Hans-Wolfgang	Max-Planck-Institut für Polymerforschung
Dr. Ungeheuer, Udo	Mitglied des Vorstands Schott Glas
Utner, Ferdinand	Online-Chefredakteur, Zweites Deutsches Fernsehen
Prof. Dr. Zöllner, Jürgen E.	Staatsminister für Bildung, Wissenschaft und Weiterbildung des Landes Rheinland-Pfalz

ALLGEMEINES ZUM INSTITUT

GENERAL

Forschungsthemen im Überblick

Research Topics

BIOGEOCHEMIE

(Prof. Dr. Meinrat O. Andreae)

ist eine relativ neue wissenschaftliche

Disziplin, die sich mit den Wechselwirkungen zwischen der Biosphäre und der Chemie der Erde beschäftigt. In dieser Abteilung werden eine Reihe von Schlüsselaspekten der globalen Biogeochemie bearbeitet: der Austausch von chemisch und physikalisch wichtigen Spurengasen zwischen dem System Boden/Vegetation und der Atmosphäre, die Bildung von Aerosolteilchen und ihre Wirkung in der Atmosphäre sowie der Einfluss von Vegetationsfeuern auf die Ökologie und Luftverschmutzung.



BIOGEOCHEMISTRY

(Prof. Dr. Meinrat O. Andreae) is a relatively new scientific discipline focusing on the

interactions between biosphere and the chemistry of the Earth. This department investigates a number of key aspects of global biogeochemistry: the exchange of chemically and physically important trace gases between the soil/vegetation system and the atmosphere, the formation of aerosol particles and their effects in the atmosphere, and the impact of vegetation fires on ecology and atmospheric pollution.

Die Abteilung

CHEMIE DER ATMOSPHÄRE

(Prof. Dr. Jos Lelieveld) untersucht

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 mit Hilfe von Computermodellen zur Simulation meteorologischer und chemischer Wechselwirkungen sowie deren Einfluss auf das Klima.



The research in the

ATMOSPHERIC CHEMISTRY DEPARTMENT

(Prof. Dr. Jos Lelieveld) focuses on ozone and

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 these field measurements.

In der Abteilung GEOCHEMIE

(Prof. Dr. Albrecht W. Hofmann) werden

die chemische Beschaffenheit und die zeitliche Entwicklung von Kruste, Mantel und Kern unserer Erde erforscht. Mit Hilfe sehr genauer Messungen von Isotopenhäufigkeiten der natürlichen radioaktiven Zerfallssysteme (wie z.B. Uran - Blei, Rubidium - Strontium) sowie von Spurenelementhäufigkeiten in Gesteinen und Mineralen werden neue Erkenntnisse über geologische Prozesse, wie die Bildung von Vulkaninseln oder die Entwicklung der Weltmeere, gewonnen.



The GEOCHEMISTRY DEPARTMENT

(Prof. Dr. Albrecht W. Hofmann) investigates

the chemical composition and chronological development of the Earth's mantle, crust and core. High-precision measurements of isotopic abundances of natural radioactive decay systems (e.g., uranium - lead, rubidium - strontium) 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 development of the oceans.

ALLGEMEINES GENERAL ZUM INSTITUT

Die Forschungsschwerpunkte in der Abteilung **KOSMOCHEMIE** (Prof. Dr. Günter W. Lugmair) reichen von



Studien zu den physikalischen und chemischen Bedingungen von Prozessen im frühen Sonnensystem und deren zeitlicher Abläufe bis zu Fragen der Synthese von chemischen Elementen in Sternen. Es werden die chemische und zeitliche Entwicklung der Planeten untersucht und verschiedene Aspekte der Meteoritenforschung behandelt. Eine besondere Rolle spielen die Entwicklung und der Einsatz von Experimenten an Bord verschiedener Raumsonden.

The research fields in the **COSMOCHEMISTRY DEPARTMENT**

(Prof. Dr. Günter W. Lugmair) range from studies on physical and chemical conditions of processes in the early solar system and their temporal evolution to questions regarding the synthesis of chemical elements in stars. The chemical and secular evolution of the planets as well as various aspects of meteorite research are treated herein. A special role involves the development and implementation of experiments on board of various space probes and planetary landers.

Die Abteilung **WOLKENPHYSIK UND -CHEMIE** (Prof. Dr. Stephan Borrmann), die im Jahr

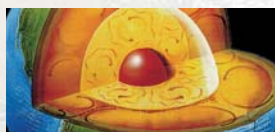


2001 als jüngste Abteilung des Instituts gegründet wurde, ist eine gemeinsame Einrichtung des MPI für Chemie und des Instituts für Physik der Atmosphäre der Universität Mainz. Sie beschäftigt sich mit der chemischen Zusammensetzung und den physikalischen Eigenschaften von Aerosol- und Wolkenpartikeln in der Atmosphäre. Zudem werden die Größe, Anzahl, Strahlungseigenschaften und Bildungsmechanismen des Aerosols und der Wolken untersucht.

The Department of **CLOUD PHYSICS AND CHEMISTRY**

(Prof. Dr. Stephan Borrmann), founded in 2001 as the most recent department of the institute, is a joint institution of the MPI for Chemistry and the Institute for Physics of the Atmosphere of the University of Mainz. Its research focuses on the chemical composition and physical properties of atmospheric aerosol and cloud particles. Also the sizes, number densities, shapes, radiative properties and formation mechanisms of aerosols and clouds are topics of experimental investigations.

Die Arbeitsgruppe **HOCHDRUCK-MINERALPHYSIK** (Dr. Reinhard Boehler) untersucht Metall-

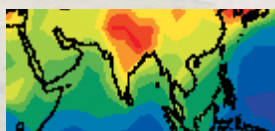


und Mineralphasengleichgewichte, das Schmelzverhalten und thermodynamische Zustandsgrößen bei Druck- und Temperaturbedingungen des tiefen Erdmantels und Erdkerns (bis zu 2 Millionen Atmosphären und 5000 °C).

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 Nachwuchsgruppe **SAPHIRE** (Dr. Mark Lawrence) beschäftigt sich mit der Entwicklung und Anwendung numerischer



Modelle zum Studium physikalischer und chemischer Prozesse, insbesondere in konvektiven Stürmen, die die gegenwärtige und zukünftige chemische Zusammensetzung der Atmosphäre in den Tropen, vor allem in Südasiens und dem Indischen Ozean, beeinflussen.

The junior research group **SAPHIRE** (Dr. Mark Lawrence) focuses on the

development and application of numerical models to study physical and chemical processes especially in convective storms, which affect the present and future chemical composition of the tropical atmosphere, particularly in South Asia and the Indian Ocean.

ALLGEMEINES ZUM INSTITUT

Forschung und Lehre

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 Forschungsprojekte als auch durch Lehrtätigkeit an der Universität.

International Max Planck Research School for Atmospheric Physics and Chemistry (Sprecher: Prof. Dr. Jos Lelieveld) wurde in enger Zusammenarbeit zwischen dem MPI für Chemie, den Universitäten Mainz, Frankfurt und Heidelberg sowie dem MPI für Kernphysik im Jahre 2003 gegründet. Besonders begabten deutschen und ausländischen Studenten bietet diese Einrichtung die Möglichkeit, sich im Rahmen einer strukturierten Ausbildung mit innovativen Unterrichtsmethoden unter exzellenten Forschungsbedingungen auf die Promotion vorzubereiten. Im Zentrum des Forschungsinteresses stehen dabei die chemisch-physikalischen Prozesse in der Atmosphäre sowie der menschliche Einfluss auf globale Klima- und Umweltveränderungen. Thematisch ausgerichtet ist die Forschung unter anderem auf die empfindlichen Regionen der Atmosphäre, die bislang relativ wenig wissenschaftliche Beachtung gefunden haben, zum Beispiel in den Tropen. Zurzeit sind rund 40 Studenten aufgenommen.



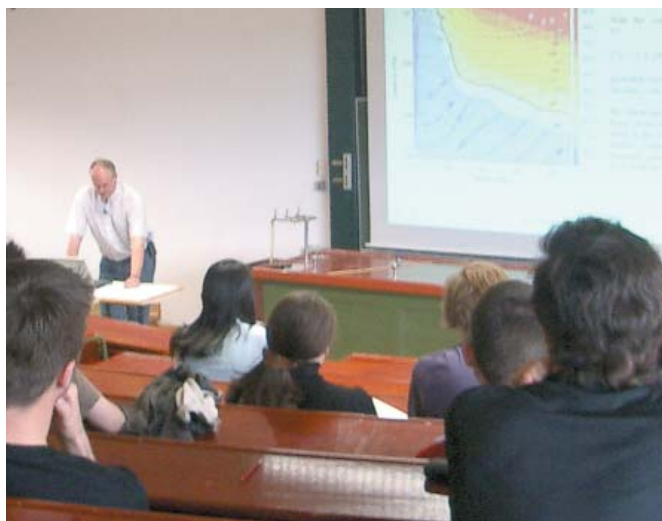
GENERAL

Research and Education

The institute does not practice self-contained teaching. However, it is part of university life, particularly as it is located on the campus of the university of Mainz, through joint research projects and through teaching activities at the university.

The International Max Planck Research School for Atmospheric Chemistry and Physics (Spokesman: Prof. Dr. Jos Lelieveld) was established in 2003 in close cooperation between the MPI for Chemistry, the Universities of Mainz, Frankfurt and Heidelberg, and the MPI for Nuclear Physics in Heidelberg. This institution offers talented students from Germany and abroad the possibility to prepare for their Ph.D. exam in a structured program providing excellent research conditions. The research projects focus on chemical and physical processes in the atmosphere and the anthropogenic impact on global climatic and environmental changes. Thematically the research concentrates on sensitive regions of the atmosphere, which have not attracted much attention so far, for example in the tropics. Currently about 40 students are admitted.

WWW www.atmosphere.mpg.de/school



MAX PLANCK INSTITUT

SELECTED RESEARCH REPORTS

FÜR CHEMIE

BIOGEOCHEMISTRY DEPARTMENT

ATMOSPHERIC CHEMISTRY DEPARTMENT

GEOCHEMISTRY DEPARTMENT

COSMOCHEMISTRY DEPARTMENT

CLOUD PHYSICS AND CHEMISTRY DEPARTMENT

HIGH PRESSURE MINERAL PHYSICS 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 and marine 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, and the effect of vegetation fires on ecology, climate, and atmospheric pollution. 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 emission of trace gases, and on the ability of ecosystems to act as sinks for substances like ozone and nitrogen dioxide. 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 energy, water vapour and chemical species in the tropical atmosphere. Ultimately, the effects reach far beyond the Amazon Basin and the tropics.

BIOGEOCHEMISTRY DEPARTMENT

Smoking Rain Clouds Over the Amazon

Millions of vegetation fires, set for deforestation, agricultural purposes, or ignited by lightning burn each year, releasing some 100 million tons of aerosol particles. Estimates of the number of particles released are close to 1×10^{29} annually. These aerosols affect climate by scattering and absorbing sunlight, and they also interfere with cloud and rainfall formation.

We have been able to show by measurements over remote continental regions that in the natural environment, the number of particles in the atmosphere is rather low. When clouds form, the number of cloud droplets will therefore also be low and raindrops can form easily. On the other hand in polluted air, the number of aerosol particles is much higher, and therefore the number of cloud droplets in clouds over polluted regions will be much higher. In a cloud with a higher number of droplets, the droplets must remain smaller because the amount of condensable water vapour often is a limitation. Clouds with a high number of droplets, but of smaller size, are more efficient in reflecting sunlight, and will thus, in the same way as the direct effect of aerosol particles, have a cooling effect of the Earth.

Furthermore, smaller droplets do not easily collide with one another, which is necessary to form rain. Thousands of cloud droplets have to collide, in order to form a drop that is large and heavy enough to fall down as a raindrop. Our scientific project SMOCC (Smoke, Clouds, and Climate) has focused on this latter aspect, trying to understand more about how the vast amount of aerosol particles in smoke from human induced fires in the Amazon will affect clouds, weather and climate. We have found that the smoke from human induced fires indeed reduced the cloud droplet size dramatically. Due to this, precipitation was suppressed, and when it occurred, the onset of the precipitation was delayed from about 1.5 km above cloud base in unpolluted clouds to more than 7 km above cloud base in pyro-clouds. Also clouds that grew out of the polluted smoke haze, so called smoky clouds, showed considerable

suppression and delayed onset of precipitation.

The delayed onset of precipitation leads to transport of heat to higher layers in the atmosphere. Heat is released to the air when water vapour condenses on the aerosol particles, and when liquid water freezes to ice. At the higher elevations the temperature is cold enough for the water to freeze. The heat released at these higher elevations will reinforce the updraft of the air and lead to more intense turbulence, which will make the clouds more vigorous and can induce stormy weather, thunderstorms, lightning, heavy showers and hail. Hail as large as 2 cm on the ground has been reported from these cloud types, but no reports of hail on the ground could be found for the smoke-free conditions.

Other effects of the suppressed and delayed onset of precipitation are that the heat released at high altitudes can induce substantial changes in the regional and global circulation of air. Also aerosol particles, water vapour, and gaseous pollutants can be transported through these clouds to high elevations in the atmosphere, where they can spread to much larger regions, possibly all over the globe. Thus, these effects can have more global impact, which will be studied in more detail in the future.

Forest fire in the southern part of the Amazon, September 2002. A so-called pyro-cloud forms directly on top of the smoke plume of the fire.



BIOGEOCHEMISTRY DEPARTMENT

Laboratory Studies on Aerosol Emissions from Vegetation Fires

Every year wide-spread natural and man-made fires around the globe emit significant amounts of trace gases and aerosols into the atmosphere. While the impact of trace gas emissions has received significant attention, information on biomass burning aerosols is more sparse. Aerosols may affect climate both directly and indirectly via their optical properties and their role in cloud formation, respectively. To better understand and quantify these effects for biomass burning aerosol, we investigated fire emissions under laboratory conditions using various wood types typical for tropical and boreal regions. This research complements field studies by the Biogeochemistry Department on biomass burning aerosols and their effect on clouds and climate.

For these laboratory experiments, the smoke of laboratory fires was directed through a well-mixed metal container, which served as damping volume to avoid instrumentation problems due to rapid changes in emission concentrations. Typically, we measured numerous aerosol properties such as number density, size distribution, optical properties (absorption and scattering coefficient), the ability to nucleate cloud droplets, and chemical composition as well as carbon dioxide (CO₂) and carbon monoxide (CO) concentrations. Aerosol morphology was studied offline with

techniques such as scanning electron or atomic force microscopy.

Although smoke, i.e. aerosol, is usually the most visible part of fire emissions, our investigations show that fires convert only a few percent of the fuel mass into particulate matter. The rest is emitted mainly as gaseous CO and CO₂. As mentioned above, optical and cloud formation properties determine the impact of biomass burning aerosol on climate related issues. More flaming and hot fires tend to generate "darker", i.e. optically more absorbing, particles due to enhanced soot production. Although this was confirmed for all wood types in our experiments, the aerosol was typically not "dark" enough to produce planetary warming due to absorption of sunlight, and therefore these aerosols have an overall cooling effect on climate. On the other hand, the cloud formation efficiency of biomass burning aerosol showed no major dependence on wood type or burning conditions. On average, the particles behaved like model particles consisting of about 10% of ammonium sulphate and 90% of insoluble material. This relatively simple parameterisation will facilitate computational studies on cloud formation under smoky conditions and its effect on global climate.

Laboratory fire for investigation of climate relevant properties of biomass burning aerosol.



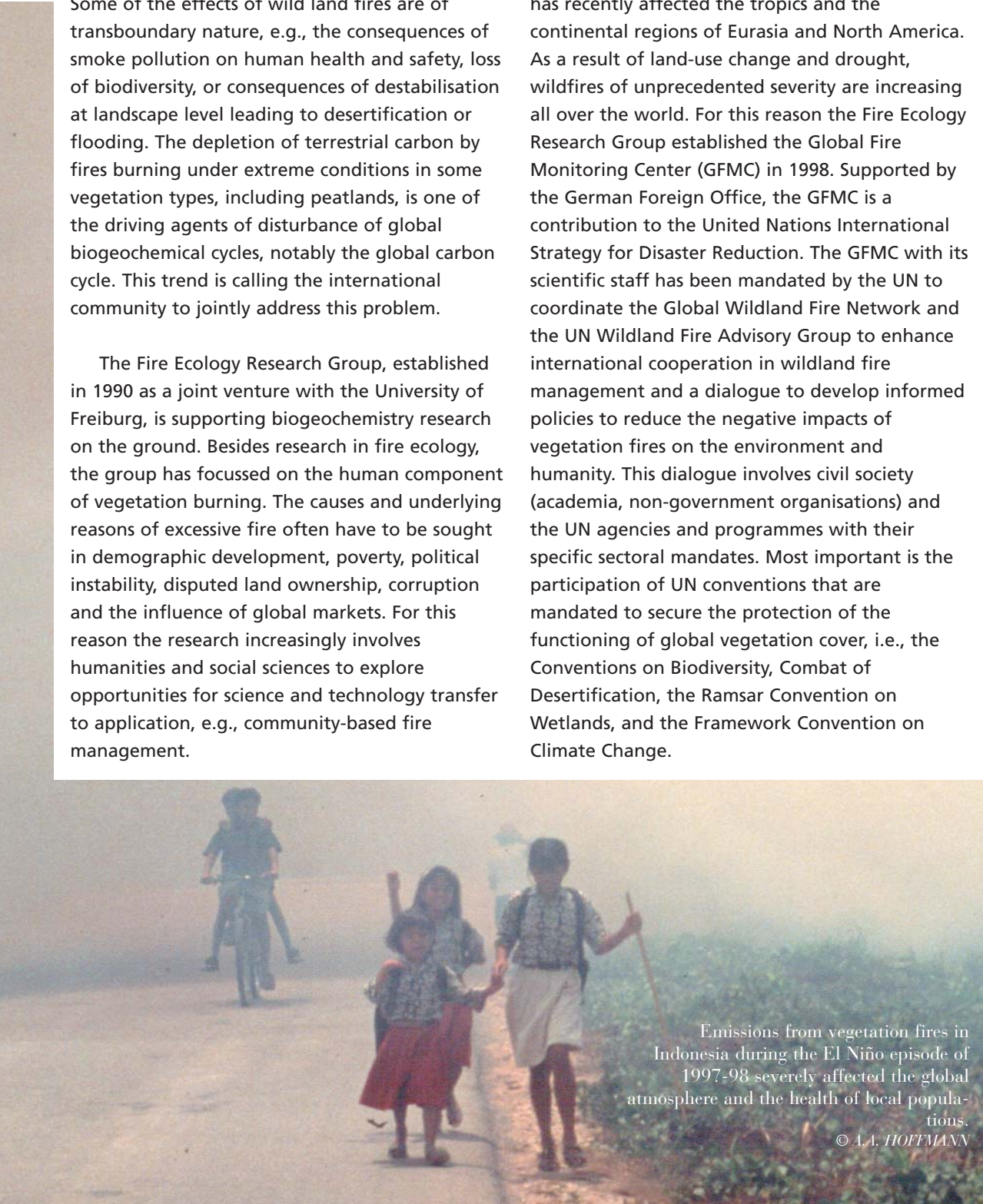
BIOGEOCHEMISTRY DEPARTMENT

Impact of Vegetation Fires on the Global Environment

Over the past decade, 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 severities have been observed in many regions of the world. Some of the effects of wild land 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. This trend is calling the international community to jointly address this problem.

The Fire Ecology Research Group, established in 1990 as a joint venture with the University of Freiburg, is supporting biogeochemistry research on the ground. Besides research in fire ecology, the group has focussed on the human component of vegetation burning. The causes and underlying reasons of excessive fire often have to be sought in demographic development, poverty, political instability, disputed land ownership, corruption and the influence of global markets. For this reason the research increasingly involves humanities and social sciences to explore opportunities for science and technology transfer to application, e.g., community-based fire management.

The increasing magnitude of vegetation cover destruction by fire and its consequences on the planetary system is further driven by the effects of regional climate change. A noted increase of climate variability, involving extreme droughts, has recently affected the tropics and the continental regions of Eurasia and North America. As a result of land-use change and drought, wildfires of unprecedented severity are increasing all over the world. For this reason the Fire Ecology Research Group established the Global Fire Monitoring Center (GFMC) in 1998. Supported by the German Foreign Office, the GFMC is a contribution to the United Nations International Strategy for Disaster Reduction. The GFMC with its scientific staff has been mandated by the UN to coordinate the Global Wildland Fire Network and the UN Wildland Fire Advisory Group to enhance international cooperation in wildland fire management and a dialogue to develop informed policies to reduce the negative impacts of vegetation fires on the environment and humanity. This dialogue involves civil society (academia, non-government organisations) and the UN agencies and programmes with their specific sectoral mandates. Most important is the participation of UN conventions that are mandated to secure the protection of the functioning of global vegetation cover, i.e., the Conventions on Biodiversity, Combat of Desertification, the Ramsar Convention on Wetlands, and the Framework Convention on Climate Change.



Emissions from vegetation fires in Indonesia during the El Niño episode of 1997-98 severely affected the global atmosphere and the health of local populations.
 © A.A. HOFFMANN

BIOGEOCHEMISTRY

Exchange of Trace Gases between Forest Ecosystems and the Atmosphere

Forests contribute substantially to atmospheric chemistry by exchange of climatically important trace gases. Our recent studies address the exchange of Volatile Organic Compounds (VOC, e.g., monoterpenes, isoprene, sesquiterpenes, organic acids, and aldehydes) as well as reactive nitrogen oxides (NO , NO_2 , HNO_2 , HNO_3). These trace gases are involved in the atmospheric oxidant cycle (production and consumption of OH and ozone) and in the production of aerosol particles. Forests are complex ecosystems dominated by interactions between vegetation, soil, algae, cyanobacteria, lichens and mosses, as well as a complex fauna. Hence, any research on the role of the forest for atmospheric chemistry and physics is closely related to biological processes, requires an interdisciplinary approach, and the techniques used must be tailored to the various spatio-temporal scales of the interactions within a forest system and between the forest and the atmosphere. Trace gas analysers are mounted at towers (60-70 meters), providing access to the canopy. Basic research tools mounted above the forest are sonic anemometers, which rapidly measure horizontal and vertical wind speeds in order to characterise the turbulent transport of trace gases. Within the canopy, enclosure systems (cuvettes), are placed on tree branches and enclose a leaf or a whole branch to study its role in emission or uptake of trace gases. Finally, soil chambers measure the release or uptake of trace gases from/by soils and soil cover. This allows us to reach our goals: (a) to identify relevant biogenic trace gas species, (b) to understand biological regulations of exchange and how biological, chemical and transport processes are interlinked, and (c) to quantify exchange rates on all relevant spatial and temporal scales.

Recent work in Amazonian and midlatitude forests showed that emission of isoprenoids, including monoterpenes, is highly plant species dependent. The emission fluxes depend both on light and temperature, at least as long as there is no storage of these compounds within leaves as has been reported for conifers. Oxygenated

compounds (short chain acids, aldehydes) usually are taken up by vegetation. However, environmental adaptation, e.g., to flooded root areas in floodplains, may lead to a substantial release of acids, aldehydes and alcohols. Furthermore, developmental aspects, i.e., leaf development, can cause a significant shift in the quantity and quality of VOC emissions. In a recent analysis of the fluxes of different types of carbon in and out of ecosystems, we were able to show that the release of VOC represents a considerable loss of carbon for an ecosystem.

Exchange of reactive nitrogen depends largely on the rates of turbulent transport, chemical interconversion, and biological processes. Nitric oxide (NO) is released from soils, but may not reach the atmosphere above the forest. It is mostly oxidised by ozone in the canopy space to NO_2 , which is partially (up to 50 % of the soil emitted NO) taken up by the soil and vegetation. This has been observed in the remote Amazon, as well as in mid-latitude regions. However, anthropogenic air pollution, including biomass burning, generally leads to deposition of NO_2 which exceeds any release of biogenic reactive nitrogen from forest ecosystems.



A large tower (a) reaching above the canopy top (by more than 10 m) provides access to measure turbulent transport above the forest (by sonic anemometer (b)) and allows to place enclosures (cuvettes) around a leaf or branch (c). At the forest floor, soil chambers (d) are used to study soil gas exchange.

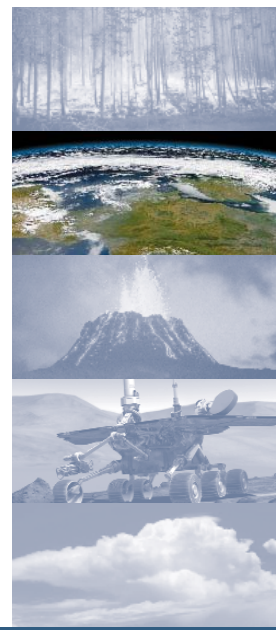
ATMOSPHERIC CHEMISTRY DEPARTMENT

Main Research Areas

Jos Lelieveld



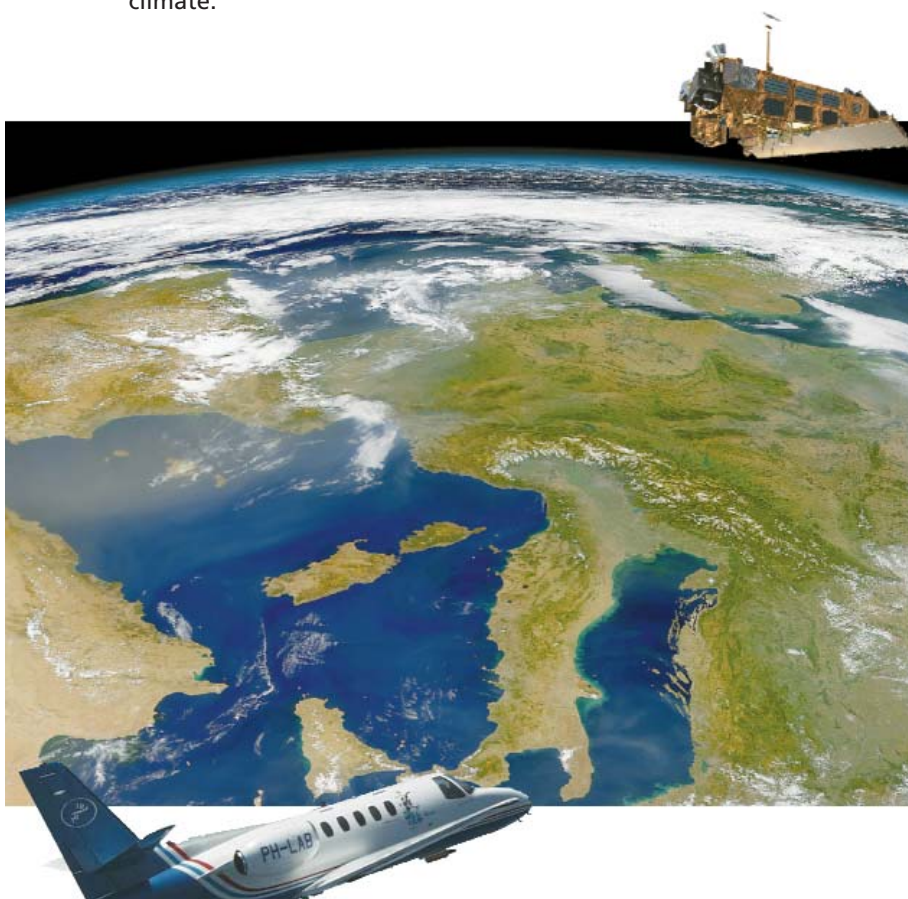
Born July 25, 1955 in The Hague, Netherlands. Undergraduate in Biology, University of Leiden. Ph.D. in Physics 1990, University of Utrecht. Research associate at Geosens B.V. in Rotterdam from 1984-1987. Atmospheric Chemistry Department of the MPI for Chemistry from 1987-1993. Extended visits at the Meteorological Institute of 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 (Cooperation on Oceanic, Atmospheric and Climate Change studies) 1997-2000. Director of the Atmospheric Chemistry Department since 2000. Spokesman of the International Max Planck Research School on Atmospheric Physics and Chemistry since 2002.



The earth's atmosphere contains 21% oxygen, therefore 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-cleaning capacity of the atmosphere is regulated by radical reaction chains that have some resemblance to those in combustion processes, in which hydrocarbons are ultimately 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. Hence we investigate to what extent natural and anthropogenic emissions influence the self-cleaning 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-cleaning capacity of the atmosphere. 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 also develop computer models to simulate the interactions of chemical and meteorological processes, and investigate the influences of atmospheric composition changes on climate.



ATMOSPHERIC CHEMISTRY DEPARTMENT

Atmospheric Chemistry Modelling

Computer modelling plays a central role in the study of feedbacks in the atmosphere-climate system, and in the assessment of global environmental change. We focus on the theoretical understanding of atmospheric transport, photochemistry and links with climate. We develop and apply models ranging from zero-dimensional "box" models which describe large sets of chemical reactions specific to a particular location or problem, intermediate complexity column models, to high-resolution (1x1 degree) global three-dimensional models.

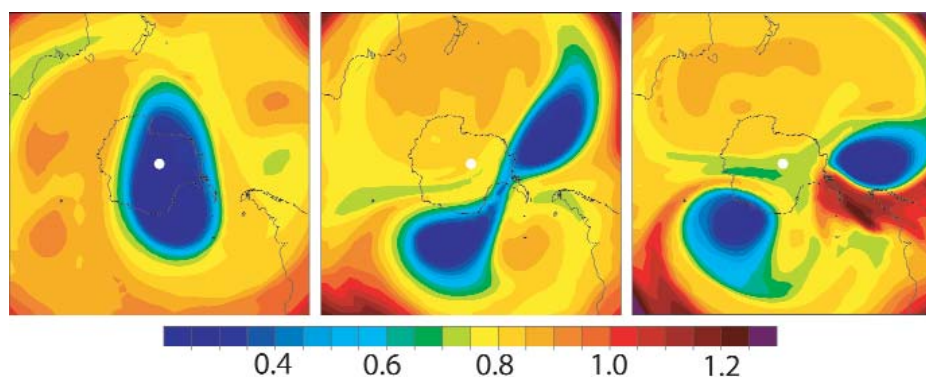
Recent developments towards earth system modelling follow a "top-down" approach, coupling existing models of different domains (land, ocean, atmosphere, ...) by means of a universal coupler. Yet, to study the interactions between bio-physico-chemical processes, the domain specific model itself must be controllable in a transparent and user friendly way. We have developed – not as an alternative, but rather as a complement – a "bottom-up" approach, providing a generalised interface structure for the standardised control of submodels and their interconnections, called Modular Earth Submodel System (MESSy). It has been successfully implemented into the general circulation model ECHAM5 (European Centre Model Hamburg, version 5), thus extending it into a fully coupled chemistry-climate model.

ECHAM5/MESSy provides unique new possibilities to study feedback mechanisms, for

example, of effects of reactive gases and aerosols on the climate and water cycle in the lower and middle atmosphere, including the effects of solar variability and volcanoes, and links between the biosphere and atmosphere. For example, the model has been used to show the strong impact of deforestation on atmospheric oxidation processes. The model successfully reproduces satellite observations of stratospheric tracers and stratosphere-troposphere exchange processes, while operating in a fully coupled chemistry-climate mode. For example, the model simulates the stratospheric and mesospheric water cycle, which includes processes such as methane oxidation and polar stratospheric cloud formation and particle sedimentation.

The ECHAM5/MESSy model also simulates tropospheric aerosols, including sea salt, mineral dust, carbonaceous and inorganic pollution particles. This submodel has been developed within the international (EU supported) project PHOENICS. The aerosols provide sites for heterogeneous reactions that affect ozone, oxidation processes and biogeochemical cycles (e.g. of C, N, S). The particles scatter and absorb solar radiation, so that anthropogenic aerosols contribute to climate change. The particles also affect cloud properties, which can alter solar radiation reflection to space, convection and precipitation processes. We include these processes in MESSy to study their links with atmospheric chemistry and climate.

The Modular Earth Submodel System connects a coupled tropospheric-stratospheric chemistry model to a general circulation model. This graph shows simulated methane mixing ratios (in ppmv) in the stratosphere over Antarctica (at 10 hPa), illustrating that the model can forecast the unusual vortex split observed by satellite from 20-26 September 2002.



ATMOSPHERIC CHEMISTRY

(Natural) Aerosols and DEPARTMENT

Chemistry in the Troposphere

Aerosols are solid or liquid airborne particles that are ubiquitous throughout the atmosphere, and which play an important role not only in the areas of human health (they cause respiratory illness) and visibility (e.g. haze and fog) but also play an important role in modifying the chemical composition of the air. We acquire information about their mechanisms of formation, their physical properties and their chemical reactivity. This information is obtained both by taking aerosol samples in the field, and also in laboratory investigations. Our research has been focussing on the roles of ice particles (cirrus clouds), mineral aerosol (desert dust) and secondary organic aerosols (SOA, formed by photochemical conversion of anthropogenic and biogenic emissions), which are mainly found in the upper troposphere, the free troposphere and the boundary layer, respectively.

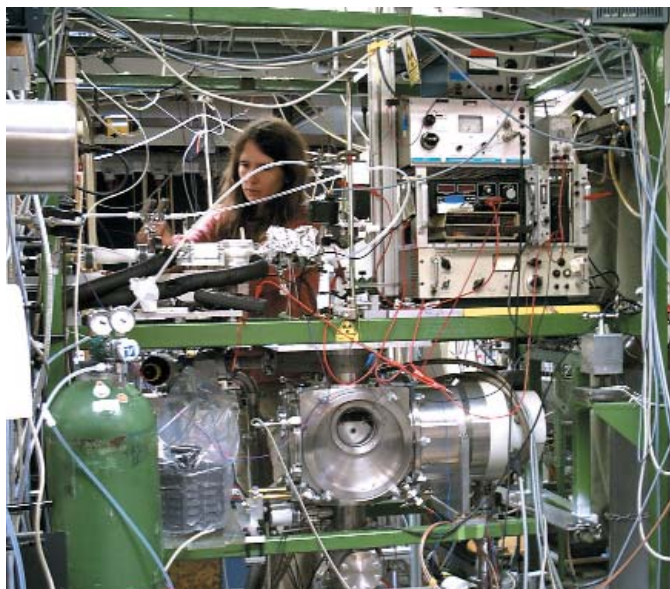
Cirrus clouds are ubiquitous in the cold upper troposphere, where they are known to cover about 25 % of the Earth's surface. In laboratory experiments that investigate the interaction of atmospheric trace gases with ice surfaces, we have shown that cirrus clouds have the potential to scavenge trace gases from the air, and thereby modify their role in photochemical cycles. A prime example is that of nitric acid, HNO_3 , whose high affinity for ice surface means that a large fraction will be absorbed to cirrus clouds. This has important implications for the NO_x and O_3 chemistry of the upper troposphere.

Mineral dust is mobilised into the free troposphere by strong winds over arid regions (e.g. the Saharan and Gobi deserts), and can be transported thousands of kilometres e.g. across the Atlantic Ocean before deposition. The interaction of mineral dust with important trace gases such as ozone and HNO_3 has been investigated in specially designed laboratory experiments using authentic desert dust samples. These experiments show that mineral dust provides a reactive surface for a number of trace gases, and that, during transport, mineral dust can strongly reduce their concentrations, whilst

itself being chemically modified. These observations have important implications for e.g. the ozone chemistry of the free troposphere and the cloud formation properties of mineral dust.

To study the chemical characteristics of SOA, particles are sampled with filters in various locations in Europe and are subsequently analysed in the laboratory. Use of highly sensitive and specific analytical tools enabled us to identify a large number of new organic compounds in the particulate phase, e.g. dicarboxylic acids, oxo-dicarboxylic acids, and nitrophenols. The detailed mechanism and the efficiency of formation of SOA are investigated in laboratory experiments, in which both gas phase intermediates and the particles are chemically characterised. These experiments have shown that oxidation of biogenic hydrocarbons by ozone leads to significantly more SOA than oxidation initiated by reactive species such as OH or NO_3 .

Laboratory work on trace gas interactions with ice particles.



ATMOSPHERIC CHEMISTRY DEPARTMENT

Transport and Chemistry at the Tropopause

The upper troposphere and lower stratosphere (UT/LS), roughly at 7-15 km altitude, have received considerable attention recently because of the importance for large-scale transport of chemical compounds as well as climate change. The chemical composition of the UT/LS is affected by vertical transport of pollution from the boundary layer and by emissions from commercial aircraft that cruise at 10-12 km altitude. To study the distribution of trace gases in the UT/LS airborne in-situ measurements are required, using dedicated research aircraft. The operation of instruments on airborne platforms requires special designs to meet the stringent demands of vibration isolation, shock resistance and minimising of weight, size and power consumption. The high speed of aircraft (150 – 200 m/s) calls for high temporal resolution of the measurements (~ 1 sec) to guarantee high spatial resolution. In addition, the low concentration of several chemically relevant trace gases requires high sensitivities in sub-ppbv range (less than 1 target molecule per 1 billion air molecules). For this purpose, state-of-the-art instruments based on optical spectroscopy methods have been developed to detect CO, CO₂, CH₄, NO, NO_y (total reactive nitrogen), N₂O, O₃, HCHO, H₂O₂ and H₂O. These methods have been successfully deployed on various jet aircraft during several measurement campaigns.

The most recent campaigns have been dedicated to the investigation of intercontinental transport of pollution, the exchange of air masses between the troposphere and the stratosphere and the photochemistry of the UT/LS region, respectively. During the "**Mediterranean INTensive Oxidant Study**" (MINOS) the transport of pollution from North America, Europe and Asia to the Mediterranean basin was studied. It was shown that intercontinental transport significantly contributes to the build-up of pollution in the troposphere, and is often more important than local emissions. The seasonal variation and extent of cross-tropopause transport over Europe was studied within German national SPURT project, demonstrating the existence of a mixing layer around the tropopause, with a composition that characteristically changes with altitude. The effect of aircraft emissions and convective transport on the composition of the UT/LS was investigated during the European UTOPIHAN-ACT project. The measurements have shown that thunderstorms inject near-surface pollution into the tropopause region on time scales of a few hours, without significant dilution by background air. These processes are studied to determine the implications for climate change.

The German research aircraft Falcon and Lear-Jet during the UTOPIHAN-ACT campaign in July 2003.



ATMOSPHERIC CHEMISTRY

Global Observations DEPARTMENT

One of the main challenges in better understanding the complex interplay of physical and chemical processes involving gases and particles in the earth's atmosphere is to obtain comprehensive global scale observational data over extended periods of time. The CARIBIC project develops and deploys an instrumented container on commercial aircraft flying to several long-distance destinations (www.caribic-atmospheric.com). We coordinate this joint effort by four German research institutions, being complementary to surface monitoring networks (e.g. by NOAA) and satellite observations (e.g. by ESA and NASA).

Since 1997, a Boeing 767 passenger aircraft has been used to carry a measurement container on intercontinental flights. Automated measurements have been carried out along routes between Germany and the southern Indian region, South Africa and the Gulf of Mexico. During these flights regular measurements of aerosols, CO, O₃, and later also of NO and NO_y have been conducted. Extensive trace gas and particle measurements were performed by taking air and aerosol samples for detailed analyses in the laboratory, for example, showing trends in halocarbons and hydrocarbons. The results furthermore show strong influences from biofuel use and agriculture on the composition of the upper troposphere during the Indian monsoon, biomass burning over Central Africa and aircraft emissions in the North Atlantic flight corridor.

Thanks to support by the German ministry of research and education (BMBF), the European Union, and a cooperation with Lufthansa, a new even more comprehensive measurement container (1.5 ton) is deployed for a period of 10 years since August 2004. This new system, coupled to a sophisticated air inlet system, is deployed twice per month on long-distance flights using one of Lufthansa's Airbus A340-600 aircraft. In addition to the previous payload, this new system performs in situ measurements of mercury, organic gases and carbonyls, CO₂, BrO, SO₂, and water vapour. Altogether 20 experiments are combined in the new CARIBIC container, comprising a fully equipped research aircraft.

Additional contributions to the global observations include our regular campaigns on the trans-Siberian railroad in the TROICA project (since 1998), showing substantial pollution emissions from high-latitude biomass burning and the mining and extraction of fossil fuels. Furthermore, our recent analysis of routine ozone measurements from ships, combined with an earlier data set of the German Weather Service (DWD), has shown that near-surface O₃ trends over the Atlantic Ocean at northern mid-latitudes since 1977 are relatively small. In contrast, remarkably strong upward O₃ trends over the Atlantic are apparent at lower latitudes and in the southern hemisphere, which contributes to the greenhouse effect.

Automated Container (Boeing 767). The new Airbus A340-600.



The air inlet system.



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ATMOSPHERIC CHEMISTRY DEPARTMENT

Atmospheric Chemistry of Organic Trace Gases

The investigation of organic trace gases in the atmosphere is of growing interest. Despite being found at extremely low concentrations (10^{-12} - 10^{-9} mol/mol), organic trace compounds can have profound effects in the troposphere and stratosphere; their sources, sinks, and lifetimes are the subject of much current research. Tens of thousands of organic compounds have been detected in the air we breathe, and the aim of a new research group is to determine the nature and extent of their effect on air chemistry. Key

species are identified and instrumentation developed to perform quantitative measurements in ambient air. Such instruments are deployed on a variety of platforms such as aircraft, ships and ground based stations in order to establish the spatio-temporal variation in concentration. In cooperation with laboratory based kinetics groups and with modellers the group endeavours to establish the atmospheric chemistry of the species measured, in particular with respect to ozone and the self-cleansing capacity of the atmosphere.



We have investigated the chemistry of the upper troposphere and lower stratosphere as part of the European funded project UTOPIHAN_ACT. In the cold dry upper troposphere, organics such as carbonyls can be important sources of OH and HO₂ radicals. Organics may strongly impact ozone production in this region, especially in convective regions where high concentrations of reactive species have been measured in the upper troposphere.



Ship-borne measurements were performed during a crossing of the Tropical Atlantic. Inter-hemispheric gradients, air-sea fluxes and sea-water concentrations of organics were determined to investigate surface ocean and lower atmosphere interactions. The ocean was found to be a source for some species (dimethyl sulphide, acetone) and a sink for others (e.g. methanol). Anthropogenic and biomass burning tracers were measured downwind from Africa.



We have also performed measurements at ground based sites. For example, the outflow of pollution from Eastern Europe was investigated from Crete, and the effect of Saharan dust on organic species was investigated from a site on Tenerife. In 2003 a program began to measure canisters collected on a weekly basis from Crete (35°N) and Le Croset (35°S) in collaboration with CNRS France and Heraklion University. These long term datasets can be used for the planning of future intensive field campaigns. In 2004 measurements were made at the Deutscher Wetterdienst (DWD) station Hohenpeissenberg.

GEOCHEMISTRY DEPARTMENT

Main Research Areas

Albrecht W. Hofmann



Born March 11, 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 since 1980.

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, rubidium, samarium and rhenium changes the isotopic abundances of the daughter elements. From this, we can measure the ages of rocks, and the isotopic abundances are also 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, thus producing 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 processes. In these cycles, crustal material is returned to the deep mantle and is ultimately recycled in new volcanic eruptions.

One group led by Wolfgang Paul Award winner A. Sobolev studies 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 and other studies employ a micro-analytical arsenal involving electron and ion microprobes and laser ablation plasma mass spectrometry.

Other studies trace the origin of ancient pieces of continent by measuring the ages of minerals such as zircon and garnet separated from the rocks. The radioactive trace elements and their daughter products, e.g. uranium and lead, are analysed by thermal ionisation mass spectrometry.

We 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. The lead is precipitated from the water column above, and this makes it possible to trace the movement of specific water masses in the past.

We have created a global electronic database for chemical and isotopic analyses of volcanic rocks. Access is free over the internet (<http://georoc.mpch-mainz.gwdg.de>). GEOROC currently contains data for about 150,000 rock and mineral samples, and is "visited" by scientists at a rate of over 5000 data searches per month. It is part of an international consortium (<http://www.earthchem.org>).

Anatomy of the Hawaiian Mantle Plume

Mantle plumes are a special form of convection in the Earth's mantle. They resemble mushrooms with broad heads of up to 2000 km diameter and narrow (100 km) stems of hot (but still solid) rock rising, at least in some cases, from the very base of the mantle at almost 3000 km depth. When the top of such a mushroom comes near the surface, it melts and produces vast amounts of lava within a geologically very short time of less than 1 million years. These outpourings are known as flood basalts, the largest of which originally contained at least 2 million cubic kilometres of lava and covered much of Siberia. When a plume erupts in an ocean basin, the lava plateau formed by the plume head is carried to the ocean margin by plate tectonics, but the stem of the plume remains in place and produces a chain of volcanoes as the moving plate carries each volcano away from the plume. The best modern example of such a plume-generated chain stretches 7000 km across the Pacific Ocean from the island of Hawaii toward Kamchatka.

Because plumes come from the deepest mantle, they are particularly interesting to geochemists trying to understand how the Earth works. The study of Hawaiian lavas has therefore occupied us for many years. Recently, the Hawaiian Scientific Drilling Project has drilled a 3000 m deep drill core representing 500 000 years of eruption history of Mauna Kea Volcano, about half of the total growth period of such a volcano. This core and new developments in analytical techniques have given us a new understanding of the internal structure of the Hawaiian Plume. The compositional fine structure of this plume is most sensitively recorded by lead isotopes, which we can now analyse to much higher precision than ever before. The decays of uranium and thorium produce different lead isotopes, so these isotopes leave a record of differences in the ratio of thorium to uranium within the plume.

We can sample the plume both in space and in time, because five active volcanoes (Mauna Loa, Kilauea, Mauna Kea, Hualalai and Loihi) are

located over different parts of the plume, and because of the drill hole. What emerges is a coarse structure superimposed on a more complex fine structure, both of which are vertically elongated over at least hundreds of kilometres within the plume. The fine structure appears to consist of vertical "fibres" perhaps 10 to 20 km wide and is characterised by rather subtle isotopic differences. The coarse structure divides the plume into two isotopically different halves, which are about 50 km wide. One of these is sampled by the more south-westerly chain of volcanoes Loihi, Mauna Loa, Hualalai, and continuing with Kahoolawe and Lanai. The other half is represented by the south-easterly chain of volcanoes Kilauea, Mauna Kea, Kohala and Haleakala. These results show that previous interpretations, which described the plume as concentrically zoned, cannot be correct. The reasons for the bilateral asymmetry is still mysterious, but we think that it reflects much larger-scale fluctuations at the base of the mantle, which are drawn into the vertical "chimney" of the plume and are thereby laterally compressed but vertically elongated.



Kilauea Volcano, Hawaii.

GEOCHEMISTRY DEPARTMENT

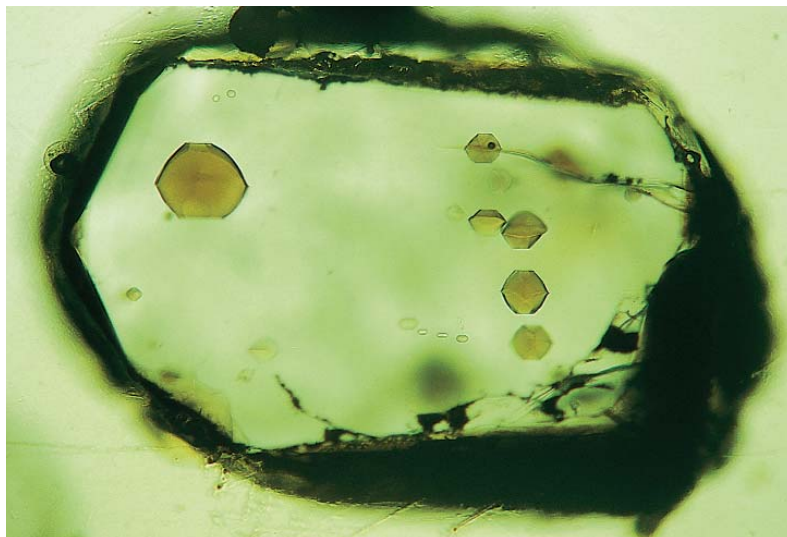
Microscopic Glass Inclusions in Crystals Reveal Secrets of Melting in the Mantle

When rocks melt deep in the Earth's interior, they transmit distinctive geochemical fingerprints of their source composition to the melt, which carries the chemical message from depth to the surface. Along the way, however, such melts are subjected to many processes that can disturb or obliterate the tell-tale information about the Earth's mantle they originally contain. These disturbing processes include contamination by other rocks, mixing of different, initially unrelated melt batches, and crystallisation of various minerals. Fortunately, some of the earliest-formed magmatic crystals, usually of the mineral olivine, frequently trap microscopically small bits of melt before the later processes do their damage. These crystals are then carried to the surface and erupted with the lava. When lava cools quickly, the microscopic melt inclusions are chilled and solidified as glass. Modern micro-analytical methods enable us to measure their trace element and isotopic compositions, and this gives us a wealth of new information about the formation of melts in the mantle and about the composition of the mantle.

To study glassy melt inclusions in olivine crystals, a thin section of the lava sample is prepared to expose the glassy inclusions. This glass is analysed by electron microprobe for major elements, and by secondary ion mass spectrometry

(SIMS) or by laser ablation plasma mass spectrometry for trace elements and isotopes. The results are changing much of our thinking about the rock types present in the mantle and about the nature of the melting processes. For example, we have identified products of melting from specific rock types originally formed in the oceanic crust and recycled through the deep mantle.

One recent project is the study of melt inclusions from diamond-bearing kimberlites, which come from depths greater than 250 kilometres. The true nature of these melts has been enigmatic, because they are heavily altered during passage through the shallower mantle and the continental crust before eruption. Because of this, the primary composition of the melts is very poorly known. Melt inclusions hosted by olivines are now revealing the nature of primary kimberlitic melts. Among other peculiarities, these deep melts are strongly enriched in concentrated salts, alkali chlorides and carbonates, which form mutually immiscible melts at temperatures below 700 °C. Evidently, the high abundances of chlorine and alkalis, along with water and carbon dioxide, have lowered the melting point in the deep subcontinental mantle by hundreds of degrees and are thus responsible for the formation of kimberlitic magmas, the source of all natural diamonds.



Microscopic glassy melt inclusions (30 to 100 μm) in a magmatic olivine crystal.

GEOCHEMISTRY DEPARTMENT

Volcanoes of the Arctic Ocean Sea Floor

Volcanologists have watched with great interest as the secular climatic warming of the last few years has thinned the north polar ice cap. The reason for this is Gakkel Ridge, a gigantic volcanic spreading system stretching across the floor of the Arctic Ocean. Gakkel Ridge is a 2400 km long and 5000 m deep volcanic chain stretching across the Arctic Ocean.

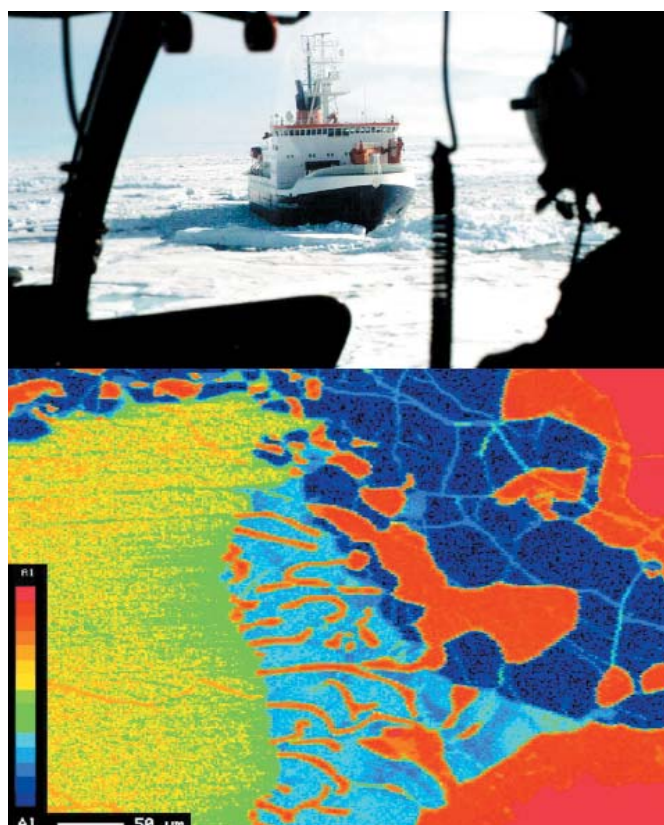
Discovered in the 1960's by the Soviet oceanographer Jakov Jakovitch Gakkel, it is the site of the seafloor spreading that is actively separating Europe from North America. At its fastest-spreading end, it is already the slowest spreading mid-ocean ridge in the world, and the spreading rate decreases from West to East. At its eastern end in Siberia, the spreading and the volcanic activity cease completely. From this follow a number of unique phenomena that have a fundamental bearing on the as yet poorly

understood physics and chemistry of the initial formation of volcanic magma.

The Geochemistry Department has been actively involved since 1998 in the exploration of the arctic ridges using such diverse analytical tools as the research icebreaker PFS Polarstern and electron and ion microprobes of the institute.

An exploratory cruise in 1999 by members of the division showed for the first time that hard rock sampling on arctic ridges is possible. Summer 2001 saw the first systematic exploration of Gakkel Ridge by international research teams, one led by the MPI Geochemistry Division aboard the German PFS Polarstern and one aboard the American USCG Healy. The two teams worked in concert to make a map of the largely unknown topography of the Arctic Ocean floor, and took samples of both volcanic rocks and the mantle rocks they are derived from.

Icebreaker and microprobe: The evolution of an 1800 km long volcanic chain is studied in the aluminium distribution in a single crystal of the mineral clinopyroxene.



These rocks show evidence that melt generation and melt reaction are inhomogeneously distributed in the mantle, showing large variations on the scale ranging from entire ridges to microscopic minerals (see figure). This is in stark contrast to normal mid-ocean ridges where melting and melt transport tend to average out mantle compositions. In this way the embryonic stages of the formation of volcanic magmas become observable for the first time. The results imply that initial mantle melts and the mantle that generates them are more chemically diverse than has previously been assumed. This agrees with and confirms the results from the study of melt inclusions in primitive magmatic minerals (also in this department).

The third expedition in this series, a combined US-German team aboard PFS Polarstern, left port for the North in July 2004. The target is the southern continuation of Gakkel Ridge toward what is now the edge of the polar ice. Low-degree partial melts and their residues, and the geochemical makeup of the polar mantle are once again the major research targets.

GEOCHEMISTRY DEPARTMENT

Water, Dust and Climate: The Sedimentary Record of Paleoclimate

Marine sediments are the archives of Earth's climate changes through time. One group in the Geochemistry Department is studying long-lived radiogenic isotopes in marine sediments to unravel the history of climate and its impact on past global ocean and atmospheric circulation. The main pathways of continental input to the oceans are ocean currents, winds and rivers. Climate fluctuations and global tectonic ocean-continent reorganisations (closure and opening of oceanic gateways) occur on time-scales varying from only a few thousand years (for example during the Ice Ages) to millions of years, and they lead to changes in the elemental sources and input magnitudes to the oceans.

Radiogenic isotopes can not only fingerprint the provenance, source and origin of continental material delivered to the oceans, they can also trace deep water circulation patterns and general atmospheric circulation. Because global ocean currents (the "great conveyor belt") act as efficient mixers, only elements with residence times (τ) shorter than the mixing time of the global ocean (1500 years) are useful tracers of ocean circulation. We study the isotopes of two such elements, lead ($\tau = 100$ years), which is produced by decay of uranium and thorium, and neodymium ($\tau = 600$ -1000 years), produced by decay of samarium.

Our laboratory has recently improved the precision of lead isotope measurements by almost

an order of magnitude. We have applied this technical development to unravel the marine record of continental erosion and tectonics, as well as deep water circulation changes, by analysing successive layers of slowly growing marine iron-manganese deposits. Such measurements on deposits from the Atlantic and Pacific Oceans have recorded the effect of the closure of the Isthmus of Panama, the main route of salt exchange between Pacific and Atlantic waters until 3 to 4 million years ago, on the great conveyor belt. Other work on equatorial sediment cores from the Atlantic and Pacific has shown that climate fluctuations during the Ice Ages show up as a "see-saw" pattern in the lead isotope record, caused by inputs from different continental sources during glacial and interglacial intervals. These isotopic fluctuations record the changing intensity of dust storms and wind directions in tropical regions as the global climate changes from warm to cold and back.

Currently we are developing and calibrating new "paleoproxies" for understanding the role of micronutrients in the oceans. These techniques involve measuring stable isotope fractionation of transition metals using our new Multi Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS-Nu Plasma instrument). The transition metals iron, zinc and cadmium are micronutrient elements that limit primary biological productivity in the oceans and are of crucial importance for present and past marine biogeochemical cycles.



Saharan storms deliver dust to the equatorial Atlantic Ocean. Lead isotopes in sediment cores can be traced back to increased storms during Ice Ages.

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Zircons are forever

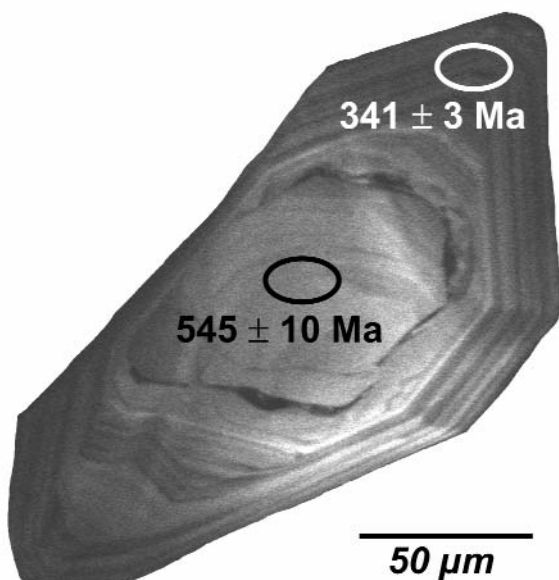
Zircon is a mineral that is not only used in jewellery, it is also one of the most important trace minerals used for measuring absolute ages of rocks. The oldest terrestrial grain of zircon found so far has an age of 4.4 billion years. This is only about 0.1 billion years younger than the age of the Earth. Zircons are found in trace amounts in many rocks, especially in granites but also in sediments. They contain appreciable concentrations of uranium, which decays to "radiogenic" lead. This decay is used as a clock by geochronologists, by measuring the amount of radiogenic lead isotopes relative to the amount of uranium in the crystal.

Many other minerals can also be used for similar radiometric dating, but zircon is special because it retains some or all of its radiogenic lead even when it is heated almost to (or even beyond) the melting point of the rock. Such heating processes, called metamorphism, cause many

mineralogical changes in a rock, for example turning a sediment into a gneiss, and this can cause new zircons to grow. But the original zircons usually persist, and they are then rimmed by new growth. Consequently, a single grain may contain two or more different ages, and it may thus record much of the history of the rock.

In our laboratory, we combine the age measurements with an analysis of the interior structure of single zircon grains using electron microscopy in combination with cathodoluminescence. This luminescence is caused by the interaction of electrons with subtle differences in composition and crystallinity within grains, and under the microscope it reveals the growth history of each grain. The age measurements require separation of nanogram or picogram quantities of lead under clean-room conditions followed by mass spectrometric analysis of the amounts of radioactive uranium and the different radiogenic lead isotopes. In this way, a zircon age can be measured with a precision of about 1 million years in rocks that may be 100 to 4400 million years old.

Precise geochronology is in great demand by geologists who study the collision of continents and the formation of mountain belts. These processes are usually accompanied by melting processes in the crust which produce granitic magmas. Often, this involves remelting of former sedimentary rocks, which also contain zircons, eroded from a previous generation of granites. Frequently, these older zircons did not melt or dissolve in the granitic magma, and they can preserve the original age of the rock that was eroded to form the sediment. Thus we find grains with old cores rimmed by newly grown, magmatic zircon. The different ages can then be measured either by isolating the cores (for example by simply removing the rims) or by "in situ" microanalysis using an ion microprobe. The cathodoluminescence image shown on this page gives an example of such zircons with ancient sedimentary cores and new crystal growth in a granitic magma.



COSMOCHEMISTRY

Main Research Areas

DEPARTMENT

Günter W. Lugmair



Born February 5, 1940 in Wels, Austria. Undergraduate in Physics, University of Vienna, Austria, Doctoral Thesis at Reactorcenter Seibersdorf (1965), Ph.D. 1968, University of Vienna. Scientific Assistant, MPI Chemie, Mainz (1965-1968), Post-Graduate Research Chemist (1968-1971) with H.C. Urey, Assistant, Associate Research Chemist (1971-1984), University of California, San Diego (UCSD), Research Prof., UCSD and Scripps Institution of Oceanography, 1984-present. Director and Scientific Member at the Max Planck Institute for Chemistry, 1996-present. Awards (selection): US-NAS - G. P. Merrill Award, 1987; Fellow AGS, 1997; Fellow EUG, 1998; Member Academia Europaea, 2000; Fellow, AGU, 2000; Leonard Medal of the Meteoritical Society, 2000.



Cosmochemistry is a field of science, which was established by H.C. Urey after World War II. It deals with the chemical and physical aspects of the history and evolution of our solar system. This field now includes the origin of the chemical elements within stars, their transport into the molecular cloud from which our sun and planetary system was born, the time scales of processes in the nascent solar nebula leading to the formation of planetesimals and planets, and their geochemical evolution through time. Meteorites and specific components they contain are the dominant source of samples available for this research area. Thus, understanding their history and place of origin are an important step towards the scientific goals of this field.

Some of the important components within meteorites are exceedingly small. To allow the chemical, mineralogical, and, most importantly, the isotopic analysis of these minute tracers of the earliest history of our solar system new micro analytical techniques were developed during recent years. One of the foremost tools is the NanoSIMS with its spatial resolution down to several tens of nanometres. New insights could be obtained in many areas, such as nucleosynthetic processes within stars, the quantification of a new important radioactive heat source (^{60}Fe) for earliest planetary melting, and the timing of aqueous activity on planetesimals within the first few million years of their existence.

To gain insight into the chemical and geological evolution of our sister planet, Mars, we have contributed two Alpha-Particle-X-Ray-Spectrometers (APXS) to the recent NASA Rover Missions to Mars. The excellent data returned from these instruments contained many surprises. The wealth of new information on the chemical composition of the Martian surface, the distribution of dust in the equatorial regions, and the variety of volcanic and sedimentary rocks on Mars will keep us and our colleagues busy for years to come.

The evolution of the atmospheres on our neighbouring planets is another complicated problem in cosmochemistry. What is their mechanism of origin? When were they established? Why are they fractionated in their elemental composition? What can we learn from gases contained in meteorites?

As we have learned in recent years, the accumulation of dust to eventually form planetesimals was a much faster process than has been previously assumed. These building blocks of the planets were assembled within only a few million years after the birth of our sun. Various methods allow dating of these early events 4.56 billion years ago with a resolution of only 1 million years.

COSMOCHEMISTRY

Radioactive Nuclides in DEPARTMENT Extraterrestrial Matter:

A Window for Stellar Astrophysics and Early Solar System History

Most of the chemical elements are the products of nuclear reactions in the interior of stars. In evolved stars the newly formed nuclides are being dredged-up to the star's envelope and finally ejected into the interstellar medium by stellar winds. Very massive stars explode as supernovae, heavily enriching the interstellar medium with intermediate-mass and heavy elements. A small fraction of the ejected matter condenses into dust grains, thus freezing the nucleosynthetic signatures of their parent star. Important constituents of stellar ejecta are radioactive nuclides. They provide a characteristic fingerprint of their stellar sources and are a useful tool for cosmochemistry.

Our solar system formed from the collapse of an interstellar gas and dust cloud (solar nebula) about 4.57 billion years ago. Only a small fraction of the dust grains survived the earliest solar system history, escaping chemical and isotopic equilibration. Such presolar grains are found in small quantities in primitive meteorites and interplanetary dust particles. The largest fraction of solid solar system matter formed in the solar system itself. Radioactive isotopes, present in minute quantities in the solar nebula, were incorporated into these solids and detection of their decay products in meteorites allows dating of events in the early solar system.

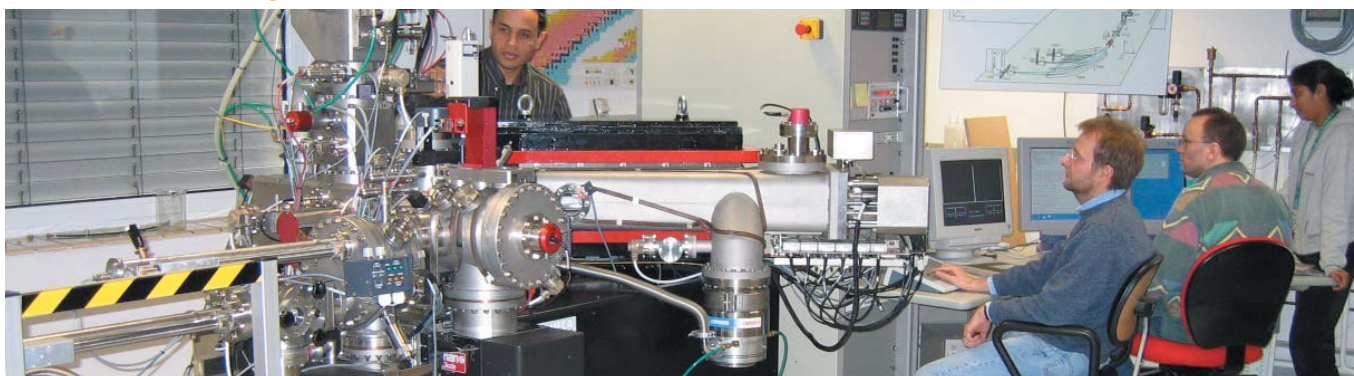
Of particular use for the study of radioactive nuclides in extraterrestrial matter is the NanoSIMS ion microprobe. This instrument is specifically designed for the study of small samples,

submicrometre to micrometre in size, thus being perfectly suited for the study of presolar grains and meteoritic minerals.

Our studies of presolar grains (silicon carbide, spinel) have revealed the presence of the decay products of radioactive isotopes of aluminium, titanium, and vanadium. While the decay product of radioactive aluminium is found in almost all presolar grains, those of radioactive titanium and vanadium are seen only in a small fraction of the grains. These rare grains must have formed in a supernova explosion. Our studies have shown that the supernova grains formed from well-mixed ejecta, involving matter from the whole supernova, and that the short-lived (half-life 11 months) radioactive vanadium must have been alive at the time of grain formation. The latter observation suggests that grain formation in supernova ejecta occurs only several months after the explosion.

Our measurements of meteoritic minerals with solar system origin have clearly established the former presence of radioactive manganese in carbonates and of radioactive iron in iron sulphide, with the following implications for the solar system history: (i) The carbonates apparently formed in a time span of 7 to 11 million years after solar system formation, testifying to early and extended hydrothermal activity on at least one meteorite parent body. (ii) Radioactive iron, injected into the solar nebula from a nearby supernova explosion shortly before the birth of our solar system, must be considered a potential heat source for planetary melting.

The NanoSIMS ion microprobe.



COSMOCHEMISTRY

Planetary Gases: DEPARTMENT

Compositions and Origin

The atmospheres of the "terrestrial planets" (Venus, Earth, Mars) share common features, but there are also a number of differences. Main constituents are the elements carbon, nitrogen, and oxygen, either in elemental form, or in chemical compounds (such as CO₂). Additional "atmosphile elements" include the noble gases (helium, neon, argon, krypton, and xenon). Common to all these elements is that a significant fraction of the planetary inventory occurs in the atmospheres and that in planets these elements are significantly depleted compared to their cosmic (solar) abundances. An important question, which we try to address in our work, is the origin of the existing inventory.

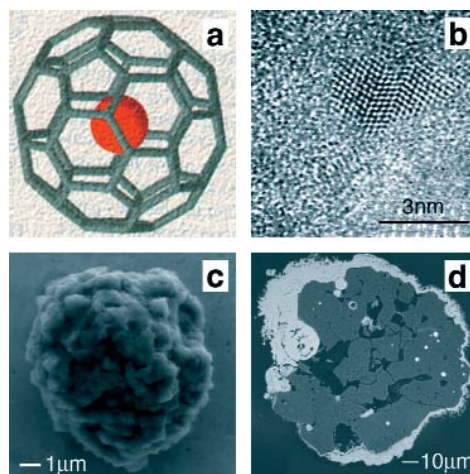
In our approach we investigate possible materials that may have served as vehicles delivering the gaseous elements to the planets. Drawing conclusions regarding the original inventory, from what is observed today, is most straightforward in the case of the chemically inert noble gases. For this reason, we concentrate especially on the investigation of abundances and isotopic compositions of noble gases. In addition, we recently installed analytical capabilities for the analysis of small (nanogram) amounts of nitrogen. Analysis of meteorites from Mars allows comparison between Earth and Mars.

The most accessible cosmochemically relevant materials that may resemble the building blocks, from which the planets formed, are meteorites. In the so-called "primitive" types that are comparably rich in volatiles, carbon and nitrogen occur mostly in the form of a macromolecular material; the noble gases argon, krypton, and xenon are concentrated in a sub fraction. Most of the helium and neon, on the other hand, have been found to be trapped within diamonds of only about 2.5 nanometre in size (corresponding to about 1000 carbon atoms); a smaller fraction of noble gases occurs trapped in micrometer-sized grains of silicon carbide and graphite. These three minerals represent "stardust". Investigations we have performed on them allow drawing conclusions concerning the nuclear processes by

which the noble gases were synthesised in stars.

Other investigations in which we are actively involved at this time concern the potential of fullerenes – with their cage structure – as carrier materials for noble gases. First results indicate that the C₆₀ fullerene incorporates helium rather efficiently, but less so the other noble gases with their larger atomic radii.

A project we are planning for the near future is the study of micrometeorites. Micrometeorites (size range 0.04 to 2 mm) currently dominate the infall of extraterrestrial material (30,000 tons per year) onto Earth. Hence, the volatiles that micrometeorites contain may be even more representative than those in the larger meteorites for the inventory the Earth accreted in its early history. Because of analytical limitations, noble gas analyses of micrometeorites so far were mostly restricted to helium only. We aim – using a new mass spectrometer with high detection efficiency and equipped with a new type of detector system – to extend these studies to the full suite of noble gases.



Some objects for noble gas analysis:
 a) Fullerenes (schematically; adapted from M. Saunders, Yale University); b) stardust-nanodiamond (transmission electron-microscope picture; F. Banhart, MPI für Metallforschung); c) stardust-silicon carbide (secondary electron microscope picture; J. Huth); d) Micrometeorite (G. Kurat, Naturhistorisches Museum, Wien).

NASA Rovers on Mars deploy Alpha-Particle X-Ray Spectrometers (APXS)

In January 2004 two rovers landed successfully on the Martian surface. On board are two APXS, which were developed and built in our department. The performance of both instruments after landing on Mars was excellent. For the first time trace elements like Ni, Zn, and Br, in addition to major and minor rock-forming elements, could be measured.

The landing sites, Gusev Crater and Meridiani Planum, are located close to the equatorial plane on opposite sides of planet Mars. Their selection was driven by safety reasons – flat and crater-poor areas – and the primary goal of the Mission: "The search for traces of surface water in Mars' past". The south rim of Gusev Crater (150 km in diameter) is crosscut by Ma'adim Valley, one of the largest valley structures on Mars, which possibly could have served as water inflow. Meridiani Planum is a smooth plain covered with grey hematite, a mineral that often – although not exclusively – forms under wet conditions.

After landing in Gusev Crater a desert area was encountered. Soil compositions were measured by the APXS. They are characterised by high S and Cl concentrations with major and minor element compositions very similar to those measured during earlier missions. This confirms that, at least in equatorial latitudes, recurrent huge dust storms homogenise and globally distribute soil material. Individual dust-crust covered and fragmented

rocks are sitting on the surface. Brushing and grinding into three of these with the Rock Abrasion Tool removed layers of adhering material. After each cleaning step, the freshly exposed areas were analysed by the APXS. However, even after the final abrasion, fresh surfaces showed alteration veins and alteration zones. High abundance of Br (up to 170 ppm) in these areas may be indicative of surface alterations during a past aqueous environment in Gusev Crater. The interiors of the rocks resemble primitive basalts with low SiO₂ and high MgO contents. Low concentrations of incompatible elements (e.g., K, Ti) and P indicate that these basalts formed by a large degree of partial melting.

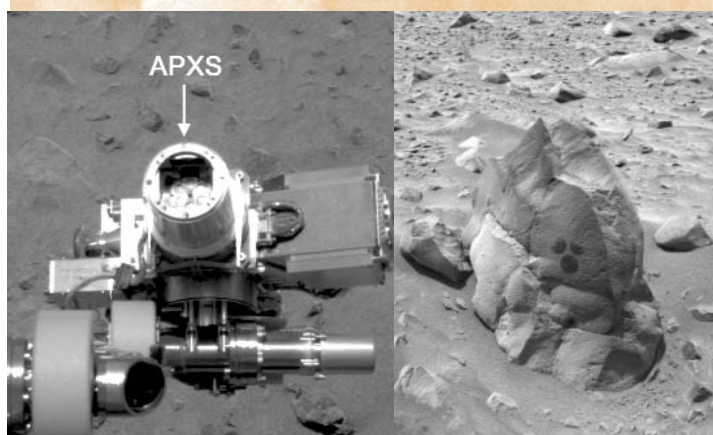
At Meridiani Planum the rover landed in Eagle crater, where fortunately white bed forms were exposed. APXS measurements revealed that these rocks are extremely rich in SO₃ (up to 25 wt.%). Sulphates, probably mostly MgSO₄, are major constituents. A very low Cl/Br ratio of < 50 is typical for these rocks. Only processes involving water can account for the low ratios found in these bedrocks. During evaporation of water, sulphate deposits can form and Cl/Br ratios can be fractionated. The chemical composition of these rocks is direct evidence for past surface water on Mars.

Not far away from the crater rim an isolated individual rock, named Bounce Rock, sits on the surface of the plain. Bounce Rock has the composition of more evolved basalts and key elements at concentration levels that are typical for Martian meteorites: a high P₂O₅ content, S of 0.2 wt.%, and a Fe/Mn ratio of 36.2. In general, element concentrations fall well within the range of basaltic shergottites (a subgroup of Martian meteorites), except for lower FeO and higher CaO and Br.

The APXS results provided the critical data, which allowed to trace the watery past of Mars. In addition, the discovery of a rock compositionally so similar to "Martian" meteorites leaves little doubt that these indeed do come from Mars.

The APXS on Mars.
© NASA

Brush Marks on Rock
Humphrey, © NASA



COSMOCHEMISTRY

Geochemical and DEPARTMENT Isotopic Evolution on Mars

The recent operation of the two Mars Exploration Rovers (MER), Spirit and Opportunity, with their special equipment provide us the opportunity to study the geology and chemistry of the Martian surface remotely. Direct laboratory studies of planetary samples yield complementary information of very high precision.

We explored the geochemical and isotopic evolution of Mars using a special group of meteorites, which are generally believed to represent magmatic Martian rocks. From their chemistry and cosmochemical constraints we developed a model for the chemical composition of the Martian mantle and core. This widely accepted model was later substantiated by measurements of the momentum of inertia of Mars. Martian meteorites suggest that chalcophile elements are depleted in the Martian mantle. This was one of the reasons why our model postulates a sulphur-rich core. A special feature of this model is a high P content of the Martian mantle. Measurements by the Rovers on the Martian surface confirmed a high P content for rocks and soils, also supporting the general validity of our model.

Isotopic data are a powerful tool for the study of planetary evolution. Our mass spectrometric measurements of the radiogenic isotope systematics of Sm-Nd, Rb-Sr, and U-Pb in the Martian meteorites reveal the time of the silicate differentiation in mantle and crust of this planet.

The Rb-Sr isotope systematics of the Martian meteorites indicates a very early differentiation process forming 3 isotopically distinct reservoirs on Mars, which remained isolated for a period of 4.3 ± 0.2 Ga (billion years). These reservoirs are the crust, the residual mantle, and an unfractionated mantle. However, the latter could also be formed by a mixing process of crust and residual mantle. The requirement to keep three isotopically distinct reservoirs isolated for a period of up to 4.5 Ga places severe constraints on the tectonic activity of the planet. Thus, plate tectonic activity and crustal recycling back to the mantle, as we have on Earth, seems to be absent on Mars.

The initial Pb data from plagioclase separates of the Martian meteorites also strongly suggest an early silicate differentiation process of their parent planet about 4.5 Ga ago. The early formation of the enriched crust has caused the depletion of the mantle, indicated by the primitive initial Sr isotopic values and the low μ value ($^{238}\text{U}/^{204}\text{Pb}$) of mantle derived rocks.

Although ^{146}Sm existed at the beginning of the solar system, with a half life of 103 Ma it is an extinct isotope today. ^{146}Sm decays to ^{142}Nd . Anomalous ^{142}Nd is only expected in rocks, which differentiated very early in solar system history. The measured excess of ^{142}Nd in all our analysed Martian meteorites reveals a $^{146}\text{Sm}/^{144}\text{Sm}$ ratio of 0.006 at the time of the differentiation of Mars. Since a $^{146}\text{Sm}/^{144}\text{Sm}$ ratio of 0.008 was determined for the beginning of our solar system, 4568 Ma ago, a crust-mantle differentiation on Mars could not have occurred much later than 30 Ma after planet formation. This estimate is in very good agreement with the differentiation interval derived from ^{182}W , the decay product of ^{182}Hf , another now extinct isotope.

Martian meteorite found in Oman.



Main Research Areas

Stephan Borrmann



Born 18. Januar 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 and Associations: Member of the European Geophysical Society, the German Meteorological Society, the German Physical Society. Since 2004 elected member of the German Science Foundation Review Panel ("DFG Fachkollegium").



The Department of Cloud Physics and Chemistry of the Max Planck Institute for Chemistry 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 and ground stations. The efforts are aimed at enhancing our understanding of cloud related processes in order to improve weather and precipitation forecast, and also contributing to climate modelling. The methods developed in the department are applied also to environmental, industrial research outside of fundamental atmospheric science. At this way our graduate students become qualified for a large variety of working fields within industry and research.

DEPARTMENT OF CLOUD PHYSICS AND CHEMISTRY

Cloud Droplet Formation Ability of Aerosol Particles

Aerosol particles are liquid or solid particles suspended in the air with size diameters ranging from a few nanometres to tens of micrometres. The particles contain sulphuric acid, water, ammonium, nitrate, various organic substances, mineral dust, sea salt, soot, or other materials. Their number concentration is usually in the order of a few hundreds to several thousands of particles per cubic centimetre of air. However, only a small percentage of these aerosol particles is able to act as cloud condensation nuclei (CCN), which means that only few particles allow water to condense on them such that formation of cloud droplets results. Special interest is paid to ice nuclei (IN) that are triggering the formation of ice cloud particles. This is focus of current research because as much as 80% of the rainfall comes from clouds containing ice particles. Pure water droplets do not freeze in the atmosphere at temperatures above $-35\text{ }^{\circ}\text{C}$, but ice nuclei of certain chemical composition are able to increase this freezing temperature. Which chemical components contained inside or on the surface of aerosol particles enable a particle to act as CCN or IN is not well understood. Water soluble compounds are expected to favour the formation of liquid cloud droplets, while insoluble materials like mineral components may favour the formation of ice nuclei.

We are investigating these processes in detail during various *in situ* field measurements as well as in laboratory studies:

In summer 2003, a field study was conducted in collaboration with the University of Stockholm on the Swedish mountain Areskutan (1400 m). Liquid

cloud droplets were collected through a counter flow virtual impactor, which is a specially designed inlet system that differentiates between cloud droplets and aerosol particles. The residual particles (which are the original cloud condensation nuclei) were analysed with an aerosol mass spectrometer (middle picture). We could show that nitrate particles were activated to become cloud condensation nuclei more efficiently than other species as sulphate, ammonium, and organics.

During CLACE-3 (Cloud and Aerosol Characterization Experiment) at the high alpine research station Jungfraujoch (JFJ, Switzerland, 3580 m above sea level; 46.55°N , 7.98°E , left picture), a specially designed aerosol inlet was used to separate liquid cloud droplets from frozen ice crystals with subsequent evaporation of the ice fraction. Here, the residual particles are expected to be the original ice nuclei and are analysed with the aerosol mass spectrometer.

Also in 2003, an aircraft based experiment in collaboration with the German Aerospace Centre (DLR, right picture) was conducted, aiming for investigation of the possible influence of aircraft exhaust particles on cirrus cloud formation in the upper troposphere. This was the first employment of this type of aerosol mass spectrometer on a jet aircraft. We could measure vertical profiles of aerosol components like sulphate, nitrate, and organics from ground level up to the tropopause. Also, aircraft exhaust particles were sampled and analysed. Aerosol and cloud particle mass spectrometry by using *in situ*, real time techniques has turned out to be one of the most promising tools for cloud physics and chemistry research for the future and we attempt to implement our instruments on high altitude research aircraft as well as the new German research aircraft "HALO".



DEPARTMENT OF CLOUD PHYSICS AND CHEMISTRY

Diesel Exhaust Particle Analysis

Understanding the processes of particle formation in Diesel exhaust is of great importance because of the discussion on adverse effects that



Diesel particles may have on human health. Diesel exhaust typically contains fine and ultra fine soot particles as well as nucleation particles, the latter having diameters smaller than $0.05 \mu\text{m}$. Since smaller particles reach deeper into the lungs, they are of special interest. Furthermore,

particles from combustion processes may influence the radiation budget of the atmosphere. We performed mass spectrometric measurement of size and composition of Diesel exhaust particles under various conditions: Chassis dynamometer tests, field measurements near a German motorway, and individual car chasing. We found that nucleation particles are only formed under certain conditions (high engine load, high fuel sulphur content) and are composed of sulphuric acid (which is the nucleating agent) and organic compounds that originate from incomplete fuel combustion as well as from lubrication oil and condense on the sulphuric acid droplets. The formation of nucleation particles can be suppressed even at high engine loads by using low sulphur fuel.

Tropical Upper Tropospheric Clouds and Stratospheric Aerosols

High clouds play major roles in a variety of atmospheric contexts. Polar stratospheric clouds (PSC) for example convert inactive chlorine containing gases into forms capable of destroying ozone. Ice clouds in the upper troposphere influence the Earth's radiative budget and – especially in the tropics – remove water vapour from the atmosphere by "freeze drying" the air, which means the water is "frozen out" condensing onto the ice particles. Whether these

cirrus clouds alter the air chemistry by chemical reactions occurring at the surface of the ice particles is matter of intense debate. In order to reach polar stratospheric or high tropical ice clouds, which exist at altitudes between 16 and 22 km, specialised aircraft are needed because conventional air planes can not climb high enough. Worldwide three research aircraft with such capabilities exist, and the only platform available for European scientists is the converted Russian espionage plane M-55 "Geophysica". The Department of Cloud Physics and Chemistry supplies in collaboration with the Institute for Atmospheric Physics of the Mainz University four specially designed and engineered aerosol and cloud particle instruments for "Geophysica" to perform research on PSC and tropical clouds. In 2003 two field campaigns were conducted from Kiruna (Arctic Sweden) and further campaigns are planned for tropical Brazil. Our department currently modifies one of the aerosol particle mass spectrometers for use on "Geophysica" such that in-situ, real time measurements of volatile and semi-volatile chemical components of nanometer sized aerosol particles can be performed at high altitudes.



HIGH PRESSURE MINERAL PHYSICS GROUP



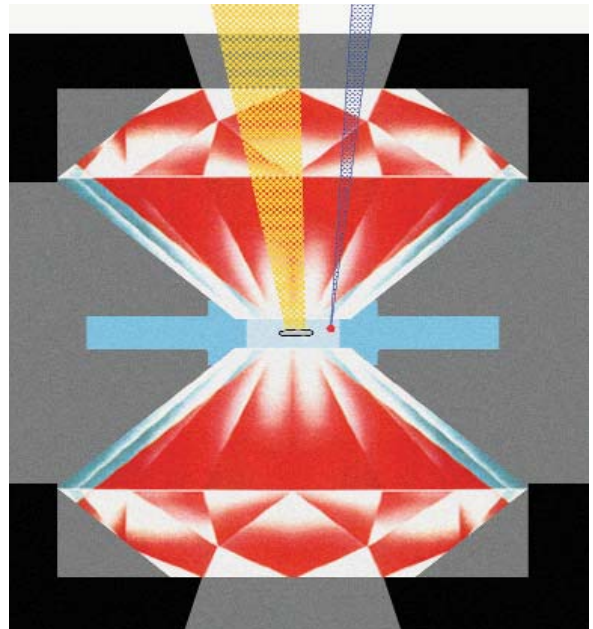
Research of Extreme Conditions: Planetary Interiors

Research at extreme pressure and temperature conditions (millions of atmospheres and several thousand degrees) allows the investigation of material properties at conditions of the interior of the Earth and other planets. Knowledge of these properties is important for the understanding of geophysical observations such as magnetism, plate motion and seismic velocities. Moreover, this research also allows the study of fundamental pressure induced changes in atomic and molecular structures.

We have developed techniques to simultaneously use diamond anvils to generate the high pressures and high power infrared lasers to generate the high temperatures. Because this apparatus is transparent, it allows a large variety of spectroscopic measurements including those of pressure and temperature.

Exploring the physical properties of **iron**, which makes more than a quarter of the Earth's mass, and in particular, its melting behaviour at Earth's core conditions (above 1.3 Million atmospheres) has been a major goal of the high pressure group. This led to the first reliable estimate of the temperature in the centre of the Earth (about 5000 K).

High pressure and temperature cause fundamental changes in the physical properties of materials that are well known to us: **Iron** becomes non-magnetic but in spite of this the Earth's core is responsible for the magnetic field of the Earth. **Water** at high pressure turns into an ionic solid such as rock salt and at higher pressures and temperatures, it may become metallic. Research on water is important in view of modelling the thickness of conductive ice layers and the associated magnetism in the giant planets Uranus and Neptune. **Nitrogen**, subjected to high pressure and high temperature, loses its molecular structure and turns into a polymeric, cubic form where the nitrogen atoms are connected with single covalent bonds. Such a material could be attractive as a potential energetic material because a large amount of energy is released during back transformation to the triple bonded



Schematic view of a diamond anvil press. The sample in the center is contained by a metallic gasket and an inert gas pressure medium. The sample is heated with high power IR laser (yellow) and the pressure is measured using the shift of the ruby fluorescence line which is excited with a blue argon-ion laser.

state. The high-pressure behaviour of the simplest element, **hydrogen**, is of particular theoretical and experimental interest because it has been predicted that it could transform to a metallic, superconducting state at very high pressures of several megabars (million atmospheres) which have now become accessible in our laboratory. One of the goals of the high pressure group is to find novel ways to develop techniques to rapidly heat the extremely reactive hydrogen at very high pressure and measure its optical and electrical properties. **Diamond** is the hardest known material. Recently, however, we have found changes in its optical and structural properties at high pressure indicating the onset of plastic deformation. One of our goals is to synthesise materials with even superior crystal structures. New, cubic forms of silicon nitride and germanium nitride synthesised in our laboratory show extraordinary hardness, however, inferior to that of diamond, but superior temperature stability. The goal is to synthesise a theoretically predicted cubic form of C_3N_4 or similar materials in the carbon-boron-nitrogen family which may have higher hardness than diamond.

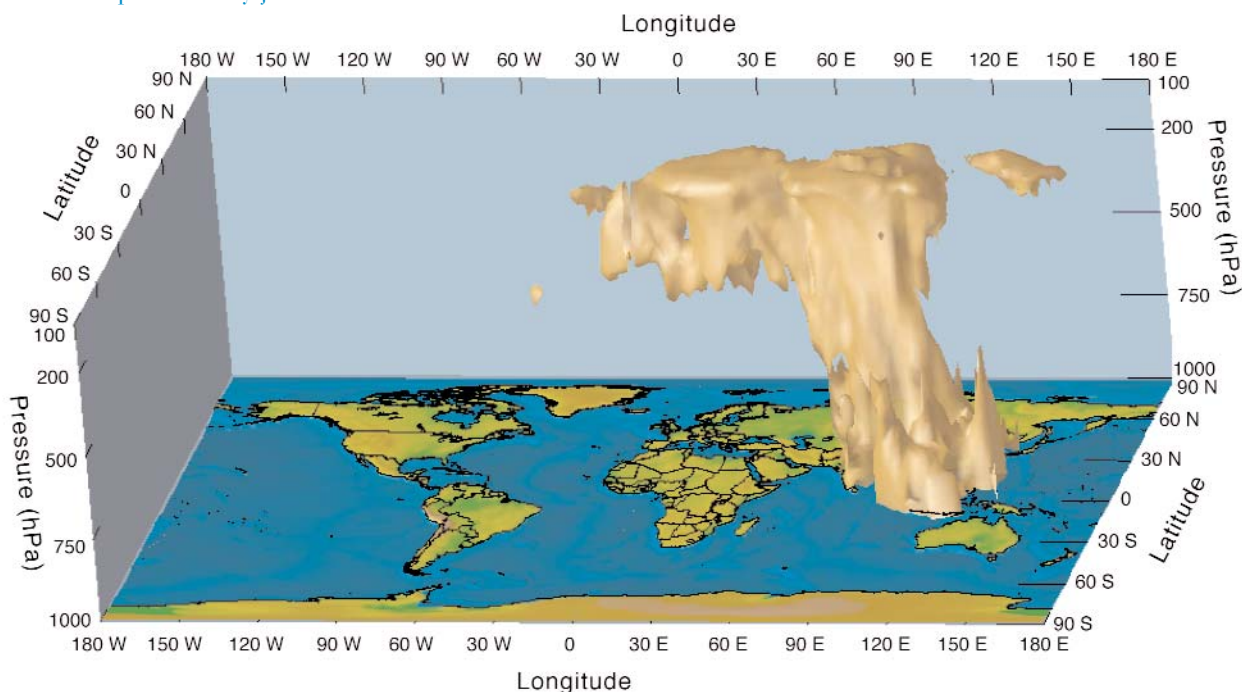


Intercontinental Pollution Transport

Three of the main research activities of the junior research group are: investigating the effects of pollutant emissions from southern Asia on atmospheric chemistry; examining how storm clouds help to transport pollutants away from their source regions; and developing the technique of "chemical weather forecasting", that is, predicting the short-term changes in the concentrations of gases like ozone and carbon monoxide. All three of these topics came together during the Mediterranean Intensive Oxidants Study, known as MINOS. Atmospheric chemistry measurements were made on board a research aircraft based out of Crete, along with measurements at stations on the island. MINOS had several objectives, especially examining the outflow of pollution from Europe in the lowest few kilometres of the atmosphere. One of the objectives which inspired MINOS was to measure

pollution from southern Asia which was predicted to be present at high altitudes, around 10 km, over the eastern Mediterranean Sea. During the summer, storm clouds over southern Asia – the same that produce the famous, torrential monsoon rains – rapidly transport pollutants like carbon monoxide to higher altitudes. This pollution is then transported westwards towards Africa, and finally northwards towards the Mediterranean and Europe. Our chemical weather forecasts indicated on which days the "plume" of pollution would be within reach of the aircraft. On three occasions, these forecasts guided the aircraft into air which was far more polluted than normal for such altitudes over the Mediterranean Sea, and which clearly carried the character of southern Asian emissions. This demonstrated the existence of a previously undocumented pathway for intercontinental pollution transport.

Calculations with the Model of Atmospheric Transport and Chemistry ("MATCH") of the transport of carbon monoxide pollution from southern Asian up to higher altitudes (lower pressures) through storm clouds and northwest towards the Mediterranean by the winds of the "tropical easterly jet".



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MAX PLANCK INSTITUT

FÜR CHEMIE

ÖFFENTLICHKEITSARBEIT
PUBLIC RELATIONS

SCHÜLERPROGRAMM
STUDENTS PROGRAM

EVENTS
EVENTS

ZENTRALE EINRICHTUNGEN
SERVICE UNITS

PERSONAL UND BUDGET
STAFF AND BUDGET

ABKÜRZUNGEN
ABBREVIATIONS

ANFAHRT
HOW TO REACH THE INSTITUTE

Die primäre Aufgabe der Öffentlichkeitsarbeit ist die Schnittstelle zwischen den Wissenschaftlern am Institut, den Medien und dem zentralen Pressereferat der MPG zu bilden sowie die interessierten oder zu interessierenden Gruppen der Gesellschaft (z.B. Schüler, Lehrer, Studenten, Medienvertreter, Politiker, Unternehmer) über die wissenschaftlichen Arbeiten am Institut zu informieren. In den Jahren 2003 und 2004 wurden rund 20 Pressemitteilungen über herausragende Ergebnisse, über neue Techniken oder anlässlich der internationalen Expeditionen herausgegeben. Oft resultierten daraus ausführliche Berichte im Wissenschaftsmagazin „MaxPlanckForschung“, in der lokalen und überregionalen Presse sowie in Rundfunk und Fernsehen.

Das PR-Team erstellt Informationsmaterial wie z.B. Broschüren und Faltblätter über das Institut. Es bereitet die Institutsbeiträge für verschiedene Periodika der Max-Planck-Gesellschaft und des rheinland-pfälzischen Ministeriums für Bildung, Wissenschaft und Weiterbildung 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 (Schulklassen, Studenten- und andere Gruppen), Beantwortung der Anfragen von Journalisten und Vermittlung von Gesprächspartnern sowie Kontaktpflege zu lokalen Medienvertretern und überregionalen Wissenschaftsjournalisten.

Das Jahr 2003 wurde vom Bundesforschungsministerium zum "Jahr der Chemie" erklärt. Es hat dazu beigetragen, die Bedeutung und den Nutzen dieser Wissenschaft einer größeren Öffentlichkeit bewusst zu machen und den Dialog zwischen Wissenschaftlern und Öffentlichkeit zu fördern. Das MPI für Chemie beteiligte sich dabei an verschiedenen Veranstaltungen.

Besuchergruppe bei der Vorstellung des APXS und der erfolgreichen Mars-Erkundungs-Mission 2004.

Visitors listen to a presentation of the APXS and the Mars Exploration Rover Mission 2004.

The primary merit of the public relations work is to establish an interface between scientists, media and the central press department of MPG, and to inform interested societal groups (e.g., school/university students, teachers, journalists, politicians, companies) about the scientific work at the institute. In 2003 and 2004 about 20 press releases on remarkable results, new techniques or on the occasion of international expeditions, have been published. Detailed reports in the science magazine "MaxPlanckForschung", in local and national press or broadcasting and television are often based on these reports.

The PR team produces promotional materials about the institute such as brochures and flyers. It prepares the institute's contributions to various periodicals of the Max Planck Society and of the Ministry of Education, Science and Continuing Education in Rhineland-Palatinate. 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 (e.g., school classes and other groups), arranging contacts between journalists and scientists, and replying to inquiries from journalists, students and other parties.

The year 2003 has been proclaimed as "The Year of Chemistry" in Germany with the intention to improve the dialogue between scientists and the public. The MPI for Chemistry was involved in various events during this year.



SCHÜLER-PROGRAMM

Das Max-Planck-Institut für Chemie beteiligt sich an verschiedenen Projekten für Schülerinnen und Schüler mit dem Ziel, den naturwissenschaftlichen Unterricht in den Schulen zu fördern und Schüler für naturwissenschaftlich-technische Studiengänge zu motivieren. Dazu gehören unter anderem das **Ada-Lovelace-Projekt** und das **NaT-working Schüler/innenlabor** der Universität Mainz. 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 und Schülern Experimente selbst durchführen, wie z.B. die Messung von Methankonzentrationen mit einem Gaschromatographen, die Bestimmung von optischen Eigenschaften von Mineralen mit dem Binokular und Polarisationsmikroskop oder die Dichtentrennung von Mineralen mit

STUDENTS PROGRAM

The institute participates in various projects for school students, aiming at the promotion of natural sciences at schools and the encouragement of students to take scientific-technical courses. Among others, the **Ada-Lovelace-Projekt** and the **NaT-working Schueler/innenlabor** of the University of Mainz are two of these projects. The **Ada-Lovelace-Projekt**, a mentor-network for women in science and technology, has "What I Want, I Can do" as its motto and is mainly directed at schoolgirls. Groups of students are given the opportunity to undertake experiments, as e.g. the measurement of methane concentrations with a gas chromatograph, the definition of optical characteristics of minerals with a binocular- or polarisation-microscope or the density separation of minerals with heavy liquids. These experiments take place in the institute's laboratories, guided by young scientists.



Schülerinnen bei der chemischen Dichtentrennung mit Schwereflüssigkeiten.

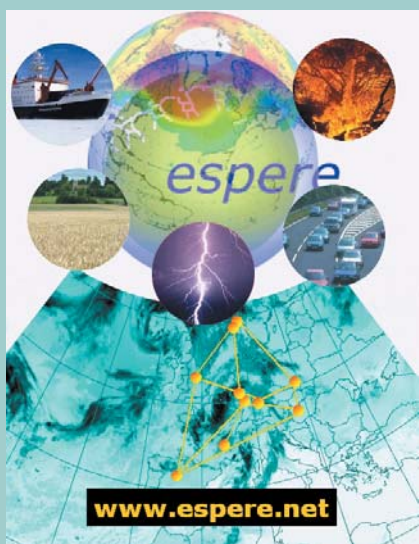
Schoolgirls perform a density separation with heavy liquids.

SCHÜLER-PROGRAMM

Schwereflüssigkeiten. Diese Versuche finden in Institutslaboratorien unter der Anleitung von jungen Wissenschaftlerinnen statt.

Für einzelne Schüler bietet das Institut sowohl in den wissenschaftlichen Abteilungen als auch in der mechanischen Lehrwerkstatt Betriebspraktika an.

Das Projekt **ESPERE** ist ein Klimainformationsnetz für Schüler, Lehrer und die breite Öffentlichkeit. An diesem Projekt mit der zentralen vielsprachigen Webseite (www.espere.net) arbeiten derzeit Wissenschaftler und Lehrer aus sieben europäischen Ländern. Das Max-Planck-Institut für Chemie koordiniert das Projekt und betreut den deutschsprachigen Raum. Diese Webseite ist eine attraktive Ergänzung zum Schulunterricht und eine Quelle zuverlässiger Klimainformationen. Dazu gehören Hintergrundtexte, Aufgabenblätter sowie Anleitungen zum Experimentieren. Die Seiten sind interaktiv, sie entstehen und verändern sich unter Mitwirkung von Schülern und Lehrern.



STUDENTS PROGRAM

For specific school students the institute offers courses both in the scientific departments and in training workshops.

The **EsperE** project is an information-network on climate for students, teachers and the public. Scientists and teachers from seven European countries currently work for this project, with its central, multilingual website (www.espere.net). The MPI for Chemistry coordinates the project and is responsible for the German-speaking part. The website supplements school activities and is a reliable source of information about the atmosphere and climate. It contains background text, exercises and instructions for experiments. The website is interactive, since it is developed and changed in cooperation with students and teachers.

WWW

www.nat-schuelerlabor.de
www.uni-mainz.de/Organisationen/ALP
www.espere.net

Schülerinnen des Gymnasiums Nieder-Olm bereiten die Methanmessung am Gaschromatographen vor.

Schoolgirls prepare methane measurements by gas chromatography.



EVENTS

Mitte September 2003 fand in Mainz der Wissenschaftssommer statt – als Höhepunkt zum Jahr der Chemie. Das Max-Planck-Institut für Chemie war an den folgenden Veranstaltungen beteiligt:

Das NanoCAMP 2003

Unter dem Motto „Wissenschaft als Abenteuer erleben“, einer Kooperation von 3Sat, „Bild der Wissenschaft“ und „Wissenschaft im Dialog“, verbrachten sechzehn Jugendliche aus dem gesamten Bundesgebiet eine Woche an der Mainzer Universität und den beiden Max-Planck-Instituten. Der Projekttag am MPI Chemie war dem Thema „Atmosphärenchemie“ gewidmet. Auf den Spuren des Treibhausgases Methan und anderer Spurengase gingen die Camper mit dem Fesselballon in die Luft. Abends lud Prof. Paul Crutzen die Camper zum Kamingsgespräch ein. Alle Aktivitäten wurden von einem Fernsehteam begleitet, das kontinuierlich in der allabendlichen Sendung darüber berichtete.

Ausstellung „Chemie in den Geowissenschaften“

Was bewegt die Erde im Innersten? Wie entstehen Kontinente und Ozeane? Was treibt Vulkane an? Woraus bestehen Meteoriten? Warum verändert sich das Klima? Wie beeinflussen atmosphärische Schadstoffe unsere Gesundheit und lebenswichtige Ökosysteme? Die erlebnisreiche Ausstellung „Chemie in den Wissenschaften“, die das Max-Planck-Institut für



EVENTS

The Summer of Science (Wissenschaftssommer), the highlight of the Year of Chemistry, took place in Mainz in the middle of September 2003. The MPI for Chemistry was involved in all major events:

NanoCamp 2003

Based on a cooperation with 3Sat, "Bild der Wissenschaft" and "Wissenschaft im Dialog", called "Experiencing Science as an Adventure", sixteen school students from all over Germany spent a week at the University of Mainz and the two MPIs. The project day at our institute was devoted to atmospheric chemistry. In search of methane and other trace gases the campers boarded a hot-air balloon. In the evening Prof. Paul Crutzen invited the campers to a discussion by the fireside. All activities were accompanied by a camera-team, reporting every evening on TV.

Exhibition "Chemistry in Geosciences"

What moves the innermost Earth? How do continents and oceans originate? What drives volcanoes? What are meteorites composed of? Why does climate change? In which way do atmospheric pollutants influence our health and vitally important ecosystems? The adventurous exhibition „Chemistry in Geosciences“, staged by MPI, offered answers to these questions. Visitors could discover the multifaceted interrelations of the dynamic System Earth. Exhibits, models, interactive media-stations as well as commentaries in text and vision made the exhibition an exciting event.



EVENTS

Chemie im Kurfürstlichen Schloss zu Mainz veranstaltete, bot Antworten auf diese Fragen. Die Besucher konnten hier die vielfältigen Zusammenhänge im dynamischen „System Erde“ entdecken. Attraktive, selten öffentlich zu sehende Exponate, Modelle, interaktive Medienstationen sowie Erläuterungen in Text und Bild machten die Ausstellung zu einem spannenden Abenteuer.

Wissenschaftsmarkt 2003

„Wissenschaft zum Anfassen und Mitmachen“ präsentierte die Johannes Gutenberg-Universität rund um den Gutenbergplatz in Mainz im Rahmen von Präsentationen in Pavillons, auf der Bühne oder auf dem Platz. Das Max-Planck-Institut für Chemie war mit dem Thema „Chemie in der Luft“ präsent. „Ozon – echt reizend“ überschrieben die Atmosphärenforscher den Spielautomaten, der im Institut für den Wissenschaftssommer umgebaut wurde. Spielend konnten die Besucher die Bildung von Sommersmog simulieren: Über Drehknöpfe konnten sie die wichtigsten Faktoren wie Verkehr, Jahres- und Tageszeit variieren und dabei verfolgen, wie sich die bodennahen Ozonwerte verändern. Wer mehr über das komplexe Thema Klima wissen wollte, hatte außerdem die Gelegenheit auch das Projekt ESPERE kennen zu lernen.

EVENTS

Science Market 2003

Around Gutenbergplatz in Mainz, in pavilions, on stage and on the square itself, the Johannes Gutenberg University presented "Participating in Science". The MPI for Chemistry contributed to the market with the subject „Chemistry in the Air“. With a "pinball" machine, adapted at the institute, visitors could simulate the formation of summer smog: By turning knobs one could vary ozone determining factors like traffic, season or time of day, and observe how these alter the ozone concentration. Those who wanted to gain more knowledge of the atmosphere and climate also had the opportunity to get involved in the project ESPERE.



ZENTRALE EINRICHTUNGEN

SERVICE UNITS

Die Mitarbeiter der Verwaltung, der Bibliothek, der EDV-Gruppe, 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.

The staffs of the administration, the library, the computer 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.

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 (Zeitschriftenbände, Monographien, Forschungsberichte, Dissertationen) sowie zahlreiche Mikrofiche-Ausgaben, CD-ROMs und Videos vorhanden.

EDV-GRUPPE

Die Bereitstellung einer modernen, problemorientierten EDV-Infrastruktur gehört zu den Hauptaufgaben der EDV-Abteilung. Dazu gehört die Serverlandschaft mit zentralen Diensten (E-Mail, Internetzugang, Datenspeicherung, PC-Services und Druckdienste) genauso wie die Sicherstellung des lokalen Netzbetriebs (LAN). Hier sind sowohl Betriebszuverlässigkeit als auch Datensicherheit gefragt. Insbesondere wird der Schutz von Ressourcen und sensiblen Daten immer komplexer und bekommt einen immer höher werdenden Stellenwert. Zu den Aufgaben gehört deshalb auch die Sensibilisierung der Nutzer gegenüber den Herausforderungen, die mit der modernen Kommunikation verbunden sind.

Auf Grund der Heterogenität der eingesetzten Endgeräte (Windows, Mac OS, Unix True64, Linux) wächst der Bedarf an Optimierung. Außerdem

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.

ELECTRONIC DATA PROCESSING (EDP) GROUP

The provision of a modern and problem-oriented EDP-infrastructure is the main task of the EDP-department. This includes the server area with central services (e-mail, internet access, data storage, PC services, print services) as well as securing of the local area network (LAN). In this context operational reliability and data security are of special importance. Particularly the protection of resources and sensitive data becomes more and more complex and gains significance. These demands therefore also include the sensitisation of the users to the challenges associated with modern communication.

The heterogeneous structure of the terminals being used (Windows, Mac OS, Unix True64, Linux) requires increased optimisation. Furthermore, connections with supercomputers (massive parallel and vector machines) are maintained. Due to the visits of the scientists at other institutions, conferences or field measurements, the use of mobile terminals becomes increasingly significant.

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werden Verbindungen mit einer Reihe von Großrechnern (Massiv-Parallel- und Vektorrechner) bereitgestellt. Durch die häufigen Aufenthalte der Wissenschaftler an anderen Institutionen, bei Tagungen oder Messkampagnen nehmen Problemstellungen im Zusammenhang mit der Nutzung mobiler Endgeräte einen immer größeren Raum ein.

ELEKTRONIKGRUPPE

Der Schwerpunkt 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

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 of 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 (see figure).

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 cooperation with scientists. These instruments have to comply with



ZENTRALE EINRICHTUNGEN SERVICE UNITS

überwachen können. Solche Anwendungen werden mit Hilfe eines modularen Baukastensystems – bestehend aus unterschiedlichen Prozessoren, Ein-/Ausgabekomponenten und Softwaremodulen – realisiert (s. Abbildung auf S. 47).

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, Schneiden großer Eisenmeteorite, 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. Graphische und fotografische Arbeiten für 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 zehn Kammerseigern, sechs Landessiegern und einem Bundessieger hervor.

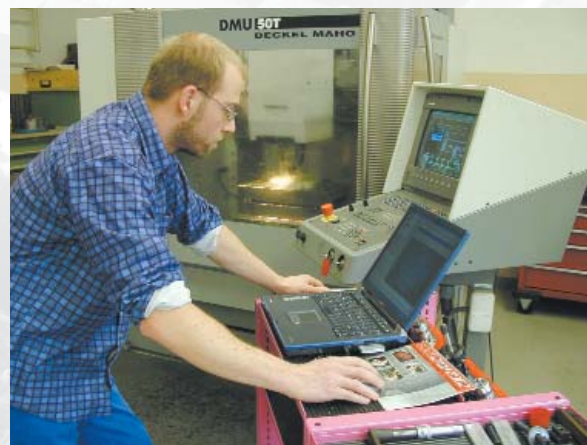
Kommunikationselektroniker, die in der Elektronikgruppe ausgebildet werden, erhalten in der mechanischen Lehrwerkstatt die metalltechnische Grundausbildung. Des Weiteren werden in der Lehrwerkstatt Betriebspraktika für Schüler und Grundpraktika für verschiedene Studiengänge durchgeführt.

stringent requirements, such as usage on board of satellites, aeroplanes or ships. The employees of this workshop perform a wide range of operations, such as welding specific materials, cutting big iron meteorites or 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 for mechanics is currently done in a separate workshop. The apprentices not only craft practice pieces, they also carry machining tasks for the scientific departments. In addition, the apprentices are specially trained in CNC-technique, pneumatics/hydraulic systems and welding technology, partly in interplant courses. The mechanics-training workshop has been quite successful in the competitions of the "Handwerkerjugend", contributing ten prize winners at regional, six at state and one at federal level contests.

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.



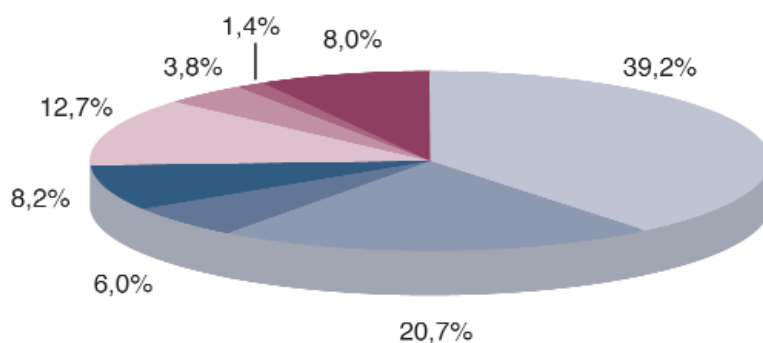
PERSONAL UND BUDGET STAFF AND BUDGET

Anfang 2004 waren insgesamt 226 Mitarbeiter am Institut tätig, darunter 55 Wissenschaftler, 67 Nachwuchswissenschaftler und 13 Auszubildende; hinzu kamen 51 Drittmittelbeschäftigte und 7 Gastwissenschaftler

Early 2004 a total of 226 persons were employed at the institute, among them 55 scientists, 67 junior scientists and 13 apprentices; furthermore 51 scientists with third-party funding and 7 guest scientists were hosted.

AUSGABEN / EXPENDITURE 2003

19,5 Mio EUR



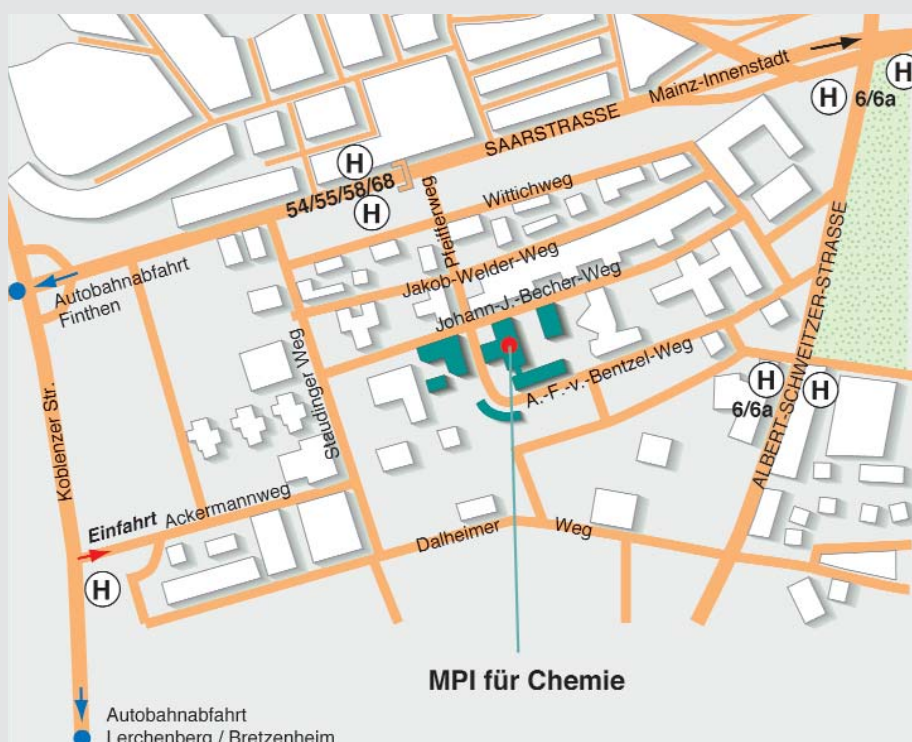
- Personalkosten Institut / staff costs institute
- Sachkosten Institut / consumables institute
- Nachwuchsförderung Institut / junior scientist funding institute
- Investitionen Institut / investments institute
- Personalkosten Drittmittel / third-party staff costs
- Sachkosten Drittmittel / third-party consumables
- Investitionen Drittmittel / third-party investments
- gebundene Restmittel Drittmittel / third-party special funding

ABKÜRZUNGEN

ABBREVIATIONS

APXS	Alpha-Particle-X-Ray-Spectrometer
BMBF	Bundesministerium für Bildung und Forschung
ESA	European Space Agency
CARIBIC	Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container
CCN	Cloud Condensation Nuclei
CLACE-3	Cloud and Aerosol Characterization Experiment
DWD	Deutscher Wetterdienst
ECHAM5	European Centre Model Hamburg, version 5
GEOROC	Geochemistry of Rocks of the Oceans and Continents
GFMC	Global Fire Monitoring Center
ILEAPS	Integrated Land Ecosystem Atmospheric Processes Study
LBA	Large Scale Biosphere Atmosphere Experiment in Amazon
MESy	Modular Earth Submodel System
MINOS	Mediterranean INTensive Oxidant Study
NOAA	National Oceanic and Atmospheric Administration
PHOENICS	Particles of Human Origin Extinguishing Natural solar radiation In the Climate System
SAPHIRE	Southern Asian Photochemistry and Impacts of the Redistribution of Emissions
SOA	Secondary Organic Aerosols
SPURT	SPURengastransport in der Tropopausenregion
VOC	Volatile Organic Compounds
UT/LS	Upper Troposphere and Lower Stratosphere
UTOPIHAN-ACT	Upper Tropospheric Ozone: Processes Involving HOx And NOx. The Impact Of Aviation And Convectively Transported Pollutants In The Tropopause Region

ANFAHRT HOW TO REACH THE INSTITUTE



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.

PER FLUGZEUG

Von Frankfurt Flughafen mit der S-Bahn (S 8) 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.

IMPRESSUM

HERAUSGEBER

Max-Planck-Institut für Chemie
Joh.-J.-Becher-Weg 27
55128 Mainz

REDAKTION

Mirjana Kotowski
Wolfgang Huisl

LAYOUT

Mieke Pijfers

DRUCK

Kerckebosch

MIT BEITRÄGEN VON

Wafa Abouchami · Meinrat O. Andreae · Reinhard Boehler · Stephan Borrmann · Carl Brenninkmeijer · John Crowley · Gerlind Dreibus-Kapp · Horst Fischer · Johann J. Goldammer · Günter Helas · Frank Helleis · Albrecht W. Hofmann · Peter Hoppe · Emil Jagoutz · Jürgen Kesselmeier · Mirjana Kotowski · Wolfgang Kunzmann · Jos Lelieveld · Mark Lawrence · Günter W. Lugmair · Franz Meixner · Ulrich Ott · Johannes Schneider · Otmar Schmid · Jonathan Snow · Theo Wawers · Jonathan Williams · Andreas Zimmer · Jutta Zipfel

TITELBILD

Renate Reifert

FOTOS

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

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**MAX-PLANCK-INSTITUT FÜR CHEMIE
(OTTO-HAHN-INSTITUT)**

Joh.-Joachim-Becher-Weg 27
55128 Mainz
Postfach 30 60
55020 Mainz

TELEFON (+49 6131) 305-0
TELEFAX (+49 6131) 305-388

E-MAIL pr@mpch-mainz.mpg.de
INTERNET www.mpch-mainz.mpg.de