Proposal for a **Virtual Institute** investigating the

Role of aerosol particles as condensation and ice nuclei in tropospheric clouds (Aerosol-Cloud Interactions ACI)

within the Helmholtz-Gemeinschaft (HGF).
(call from April 7, 2006)

Related to Helmholtz Research Field Earth and Environment / Atmosphere and Climate.
Key topics:

- Role of clouds in climate change and water cycle.
- Impact of aerosols on cloud formation and cloud properties.
- Aerosol related formulation of ice nucleation in cloud and climate models.

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1. Background and Motivation

Clouds are important regulators of the Earth's global temperature, because they scatter shortwave radiation from the sun back to space (cooling effect) and absorb long wave terrestrial radiation from the Earth surface (warming effect). About 60% of the Earth's surface is covered with clouds at any time. The response of cloud characteristics and precipitation processes to changing natural and anthropogenic aerosol sources is one of the largest uncertainties in the current understanding of climate change.

In the atmosphere, water droplets in clouds can only be formed on aerosol particles which provide a surface for water vapour to condense when the relative humidity exceeds 100%. Aerosol particles that lead to the formation of cloud droplets are called cloud condensation nuclei (CCN). An increase of the CCN number by human activities leads to an increase in drop number, but also to a decrease in drop size with unchanged water vapour abundance. Such clouds back-scatter sun light more effectively and thus have a stronger cooling effect than clouds with fewer but larger droplets. This cooling effect also depends on the lifetime of these clouds which is affected by CCN changes. The efficiency of aerosol particles to act as CCN depends on their size, solubility, and, for solid particles, their hygroscopic surface properties. Therefore, any CCN study should include a detailed physical and chemical analysis of the aerosol particles.

In clouds at medium altitudes with temperatures below 0°C, the water droplets remain in a supercooled liquid phase. Only at temperatures below -35°C pure water droplets and supercooled liquid aerosol particles spontaneously freeze and form ice particles (homogeneous freezing). At temperatures between 0 and -35°C, the freezing of supercooled cloud droplets can be induced by certain solid aerosol particles, so-called ice nuclei (IN). The heterogeneous ice nucleation is induced by a particle immersed in the droplet (immersion mode) or colliding with a droplet (contact mode). The same particle can first act as CCN and then as IN (condensation mode). The direct deposition of water vapour to the surface of a solid particle is called deposition mode ice nucleation. The number of ice crystals in mixed-phase clouds is typically much smaller than the number concentration of droplets (100 – 500 cm^{-3}). The ice crystals, however, grow to larger sizes in expense of the liquid droplets (Bergeron-Findeisen process). The ice initiation and related secondary effects like riming forms mixed-phase clouds with rapidly changing internal structure which affects the cloud cooling and warming capabilities. In many cloud cases, ice formation also initiates precipitation events. The IN efficiency of aerosol particles sensitively depends on their physical and chemical surface characteristics.

Pure ice clouds, so-called cirrus clouds, form at high altitudes and temperatures below -35°C, and typically contain ice crystal number densities in the range 0.1 to 10 cm^{-3}. Whether cirrus clouds have a net cooling or heating effect on climate depends, among other factors, on the number concentration, size, and habit of ice crystals and therefore on the cirrus formation mechanisms. While thin and subvisual cirrus clouds are believed to warm the planet, the global effect of cirrus clouds is not fully understood. Both homogeneous freezing of liquid aerosol particles and heterogeneous ice nucleation as described above contribute to the formation of ice crystals in cirrus clouds. Mineral particles originating from desert dust storms, organic particles, and soot particles emitted by aircraft engines have been identified as ice nuclei in the free troposphere. Specific particle surface properties can markedly lower the ice supersaturation threshold for heterogeneous ice nucleation compared to the threshold required for homogeneous freezing, thereby changing not only the frequency of occurrence but also the microphysical and optical properties of cirrus clouds (indirect effect of IN on cirrus clouds).

A complete evaluation of the role of cirrus in climate change must also include the direct effect of persistent, spreading contrails (contrail-cirrus) on cloud fraction, background aerosols and cirrus, and water vapour fields. Contrail-cirrus increase high cloud cover notably, and their contribution to the total is expected to rise strongly in the next few decades. The direct and indirect effects are coupled inasmuch as contrail-cirrus develop in supersaturated air in which ice nucleation on aircraft-emitted or perturbed background aerosols is favoured.

A detailed understanding of aerosol-cloud processes and their numerical implementation is prerequisite for reliable modelling of weather forecast, precipitation development, and climate change. Homogeneous freezing rates of aerosol particles can be parameterised in numerical models as a function of the temperature, cooling rate, and aerosol parameters. In contrast, aerosol-related parameterisations for heterogeneous ice nucleation processes are more difficult to assess. Only recently, new concepts have been suggested to consider specific aerosol properties for parameterisations of heterogeneous ice nucleation in models. These concepts need to be approved for application under variable cloud conditions and with relevant tropospheric aerosol systems. Comparison with results of laboratory cloud simulation experiments is needed to test and improve existing or develop new parameterisations, because it is difficult to constrain formulations of cloud microphysics in models to field measurements.

A major challenge is to determine the ability of aerosols to act as CCN and IN and to develop aerosol-related parameterisations for the representation of CCN and IN processes in cloud, weather forecast, and climate models. The suggested Virtual Institute VI-ACI aims at detailed experimental and modelling investigations of aerosol cloud processes and novel evaluations of the role of clouds in the climate system. Series of closely coordinated laboratory experiments are conducted using the unique cloud simulation facilities AIDA and LACIS in Karlsruhe and Leipzig, the simulation chamber SAPHIR in Jülich, the vertical wind tunnel at the University of Mainz, and the novel ice nuclei counters currently developed at the University Frankfurt (FINCH) and the ETH Zürich (ZINC). Further partners contribute their specific expertise in sensitively detecting water vapour (Uni-HD, ICG-I), investigating aerosols and their potential formation mechanism in the atmosphere (Uni-MZ, ICG-II, IfT), measuring CCN properties (IfT, ICG-II, ETH), and characterising ice particles in mixed-phase and cirrus situations (Uni-HS, Uni-MZ). The model simulations make use of sophisticated fluid dynamics models (IfT), process-oriented parcel, trajectory, and 1D-models (DLR-IPA, IMK-AAF, ICG-I), state-of-the-art cloud-resolving 2D- and 3D-models (Uni-TA, DLR-IPA, Uni-MZ, ETH), and global climate models (DLR-IPA, ETH).

2. Scientific Objectives

In the suggested Virtual Institute on the "Role of aerosol particles as condensation and ice nuclei in tropospheric clouds", three Helmholtz Centres, one Leibniz Institute, and 6 Universities will combine their expertise and efforts in the field of aerosol-cloud interactions to closely cooperate on the following scientific objectives:

- Quantify the efficiency of aerosols from natural (desert dust, secondary organic aerosol, biogenic particles) and anthropogenic (air traffic emissions, ground-based combustion particles) sources to act as cloud condensation nuclei (CCN) and ice nuclei (IN) in mixed-phase and cirrus clouds.
- Quantify the variation of CCN and IN efficiency by particle transformation, e.g. condensed-phase processes, surface modification by heterogeneous chemistry, or coating by condensation of less volatile compounds.
- Study the formation and slow transformation of potential CCN and IN from representative precursor mixtures, natural light, and oxidant levels.
- Perform experiments at simulated cloud conditions to investigate the competition of different aerosol types for cloud droplet formation and heterogeneous freezing.
- Improve existing or develop novel concepts for aerosol-related parameterisations of ice nucleation in cloud and climate models.
- Investigate the sensitivity of precipitation initiation in cloud models to the natural variability of CCN and IN concentrations and their properties measured in the laboratory experiments.
- Investigate the partitioning of water in life cycles of cirrus clouds by cloud chamber simulations, link the observations to field measurements, and reproduce the measurements with model simulations.
- Determine particle composition and mixing state of ubiquitous UTLS aerosol composition (sulphate, organics, soot) by means of process-oriented modelling in support of laboratory measurements of ice nucleation activity of such mixtures.

- Study of cirrus clouds and the contrail-to-cirrus transition with newly developed state-of-the-art cloud-resolving simulation models.
- Interpret field measurements with cloud resolving models using new parameterisation schemes.
- Quantify the global impact of IN on cirrus microphysical properties with realistic IN properties guided by the laboratory experiments.
- Quantify, with general circulation models, the global impact of cirrus and the contribution of contrail-cirrus to high cloud occurrence along with their associated radiative forcing of climate.
- Investigate the sensitivity of the radiation budget and the hydrological cycle in climate model simulations to the new parameterisations of CCN and IN efficiency of relevant tropospheric aerosol particles developed within this project.

3. Work Programme

The work programme is organised in four work packages (WP) of laboratory experiments and three work packages of modelling studies (see flow diagram in Section 4). The laboratory experiments are mainly performed at the aerosol chamber facility AIDA (Aerosol Interactions and Dynamics in the Atmosphere) of Forschungszentrum Karlsruhe (WP-L1), the Leipzig Aerosol and Cloud Interaction Simulator (LACIS) at IfT Leipzig (WP-L2), the Zurich Ice Nucleation Chamber (ZINC) at ETH Zurich (WP-L3), and the SAPHIR facility (Simulation of Atmospheric PHotochemistry In a large Reaction Chamber) of Forschungszentrum Jülich (WP-L4). Supporting measurements are planned with new IN devices of the University of Frankfurt and with the wind tunnel of the University of Mainz (WP-L2). The model studies include process-oriented modelling (WP-M1), cloud modelling (WP-M2) and global climate modelling (WP-M3). Details of the work programme are discussed in the following sections.

3.1 Laboratory experiments

CCN and IN activation of aerosols will be studied intensively in several series of laboratory experiments. Both CCN and IN efficiency depend on specific aerosol properties. Therefore, the detailed chemical analysis of the laboratory generated test aerosols is essential for the interpretation of the laboratory experiments. Similar aerosol systems will be generated for the experiments in the laboratories at FZK, ICG-II, IfT, and ETH.

WP L1: AIDA laboratory experiments at Forschungszentrum Karlsruhe.

Laboratory experiments of ice nucleation are conducted using the AIDA facility. During these experiments, ice supersaturated conditions are achieved by volume expansion, thereby simulating cooling rates of air parcels with updraft velocities between 0.5 and 6 $m\ s^{-1}$. Pristine and aged/coated aerosols can be prepared in a smaller aerosol vessel. The comprehensive instrumentation of the AIDA chamber includes number and size distribution measurements of aerosols, droplets, and ice particles. The fraction of aerosol particles acting as IN is obtained from the ratio of ice to total particles. This IN active fraction is measured as function of the temperature and supersaturation with respect to ice for different ice nucleation mechanisms. A unique combination of in situ measurement methods by Fourier-transformed infrared spectroscopy (FTIR), laser scattering/depolarisation, and tunable diode laser (TDL) spectroscopy provides valuable information about the formation and evolution of the clouds simulated in AIDA experiments. The results of AIDA ice nucleation experiments can directly be used as input to model studies of ice nucleation processes.

Droplets and ice particles can selectively be sampled with a counterflow virtual impactor (CVI). The residual particles remaining after heating the CVI sample flow are also analysed by number concentration and size distribution. The University of Mainz will provide two types of aerosol mass spectrometers: The Aerodyne Aerosol Mass Spectrometer (Q-AMS or ToF-AMS) and the Single Particle Laser

Ablation Time-of-Flight MS (SPLAT). The chemical composition of single aerosol and cloud residual particles will be measured with the PALMS instrument of NOAA, Boulder (currently at ETH). The Forschungszentrum Jülich (ICG-II) will contribute measurements with a novel CCN spectrometer and an Aerosol Mass Spectrometer (Aerodyne AMS). Sensitive, selective, and sampling-free in situ water vapour measurements within the clouds are realized by tunable diode laser (TDL) spectroscopy in co-operation with the University of Heidelberg. Sensitive and fast measurements of the total water concentration are performed with the FISH hygrometer of Forschungszentrum Jülich.

For the experiments at mixed-phase cloud temperatures (-35 to 0°C) it is very important to measure both droplets and ice particles at the same time in the same air mass. This is a major challenge for ice nucleation experiments at these conditions which can be solved with the so-called small ice detector (SID-2) recently developed by the University of Hertfordshire. Uni-HS will also carry out computations using a new scattering model of single scattering properties for different crystal habits (phase functions, 2D scattering patterns, asymmetry parameter, depolarization) to allow the interpretation of measurements at AIDA and to provide input for the modelling of radiative forcing (WP-M3).

Stereoscopic images and scattering phase functions of individual ice crystals will be provided by the Particle Habit and Polar Scattering Probe (PHIPS) developed by IMK-AAF. These single ice crystal data will be supplemented by polarisation resolved near-forward and near-backward scattering measurements of the ice crystal ensemble. The microphysical and optical data sets will be the basis for modelling investigations of Uni-HS (see above). The results are also valuable for the interpretation of LIDAR data and for upcoming HALO cirrus missions.

The contribution of Uni-HS, Uni-MZ, and FZK will assist in the development of new airborne instruments. In particular, Uni-HS will address issues such as extending the sensitivity of present shape-characterization instruments to include micron-sized and sub-micron aerosols and ice particles, and to permit the detection of the onset of droplet freezing through depolarisation measurements. The results will be relevant to future high-resolution, high-sensitivity instruments for aerosol and ice characterization, including those planned for the HALO aircraft and other airborne platforms.

The University of Frankfurt has recently set up both a continuous flow mixing chamber for IN detection (FINCH= Frankfurt Ice Nucleation Chamber) and a static vacuum diffusion chamber for the activation of ice nuclei collected on 47 mm membrane filters. As part of the VI-ACI both methods will be tested and applied during the AIDA experimental studies. This will provide information on the IN activation properties (e.g. activation spectra) of the different aerosols. Both instruments will also take part in the ice nucleation workshop for intercomparison of various IN instrumentation (see below).

Within the VI-ACI, two AIDA campaigns are planned, one with experiments mainly at mixed-phase cloud temperatures and the other mainly at cirrus cloud temperatures. The AIDA studies will concentrate on the ice nucleation efficiency of mineral particles and soot particles, with special emphasis on the effect of organic and inorganic coating layers. Experiments with selected aerosol components have already been performed in recent AIDA campaigns within the research projects PAZI and SCOUT-O3. Further experiments with dust and soot from other origin and in more complex coated and aged aerosol mixtures (see also WP L4) are needed to obtain a better view of the IN variability with aerosol origin and respective particle properties.

Campaign 1 with experiments at mixed-phase cloud temperatures (0 to -35°C)

During First project year, duration 4 weeks
Aerosols to be studied:

- Pure minerals.
- Mineral dust samples from the Sahara (if possible related to AMMA and SAMUM) and the Dead Sea Area.
- Organic acids.
- Mineral particles coated with sulphuric acid, ammonium sulphate and organics (secondary organic aerosol mass, organic acids).

Campaign 2 with experiments at cirrus cloud temperatures (below -35°C)

During Second project year, duration 4 weeks
Aerosols to be studied:

- Pure minerals.
- Mineral dust samples from the Sahara (if possible related to AMMA and SAMUM).
- Combustion soot with different OC content.
- Internal and external soot and sulphuric acid mixtures to simulate aircraft emissions.
- Mineral and soot particles coated with sulphuric acid, ammonium sulphate and organic acids.

Partners contributing to WP-L1 (AIDA team):

- FZK (IMK-AAF): AIDA facility
- ICG-I: Total water measurements (FISH, only during campaign 2 at low temperatures)
- ICG-II: Aerosol mass spectrometry (see WP-L4).
- Uni-MZ: Aerosol mass spectrometry, aerosol and ice particle characterisation, supporting single particle wind tunnel experiments.
- Uni-FM: IN measurements with static and mixing chamber (FINCH).
- Uni-HD: TDL measurements of water vapour.
- ETH: Single article chemical analysis (PALMS), IN measurements (ZINC, see WP-L3).
- Uni-HS: Droplet and ice particle detection (SID-2), backscattering depolarisation interpretation.

Further partners will be invited, if required. Part of their instrument shipping and travel costs will be reimbursed from the IMK-AAF budget within the VI-ACI.

AIDA ice nucleation workshop 2007:

An ice nucleation workshop was recently suggested with the main purpose of comparing and contrasting ice nucleation measuring systems. The workshop is co-organised by Ottmar Möhler, IMK-AAF, Olaf Stetzer, ETH, and Paul DeMott, Colorado State University, and will be conducted at the AIDA facility, probably in autumn 2007 for the duration of three weeks. It provides a link between laboratory studies of ice nucleation and field measurements of ice nuclei, e.g. on mountain sites or research aircrafts (HIAPER, HALO, FAAM, and others). This workshop will closely be related to the laboratory and modelling activities of the VI-ACI. If funded, part of the FZK budget within the VI-ACI will be spent to support instrument shipping and travel expenses for groups which are not partners of the VI-ACI but participate in the ice nucleation workshop.

Milestones WP L1

MS L1A: AIDA campaign 1 finished and data available for model studies (AIDA team, month 12)
MS L1B: AIDA campaign 2 finished and data available for model studies (AIDA team, month 18)
MS L1C: Report on ice nucleation workshop available (month 24)

WP L2: LACIS laboratory experiments at IfT Leipzig

Laboratory experiments utilizing the Leipzig Aerosol and Cloud Interaction Simulator (LACIS) will be performed to investigate hygroscopic particle growth, activation, droplet dynamic growth and droplet freezing processes under well-defined thermodynamic conditions. LACIS offers instruments and expertise regarding the production of well-defined multi-component, multiphase aerosol particles. For particle generation and coating, instruments such as atomizers, nucleation/condensation type generators and a spark generator are available. For particle characterization with respect to size, structure, and optical properties, expertise and instruments such as differential mobility analyzers (DMAs), condensation particle counters (CPCs), a low pressure impactor (LPI), a thermophoretic particle sampler, optical particle counters, and nephelometers are available. For chemical characterization of the condensation and ice nuclei, different Aerosol Mass Spectrometers (AMS: IfT, ICG-II, Uni-MZ) and/or sampling with subsequent mass spectrometer based chemical analysis (IfT: e.g. LC-MS, CE-MS, CE-TOF/MS) will be applied. The ICG-II and Uni-MZ AMS instruments will be operated at LACIS during selected time periods. The same holds for the ICG-II CCN spectrometer and the Zurich Ice Nucleation Chamber (ZINC: see WP-L3 below). The latter will be used especially in connection with the planned ice nucleation experiments.

Regarding droplet and ice particle detection and sizing, LACIS will be equipped with two White Light Optical Particle Spectrometers (WOPS): One for detection of liquid droplets and the other, a modified WOPS, which is able to distinguish between liquid and frozen droplets by means of an additional depolarization channel.

The main goal of the suggested investigations at LACIS is to provide process understanding and data to support the interpretation of the experimental data gained under WP L1. In addition, microphysical expressions and/or parameterizations for the description of cloud droplet activation and immersion freezing will be provided for use in model calculations (see WP M1).

Measurements of CCN properties

- Performance of CCN-closure studies, i.e., the determination of CCN properties from measurements of hygroscopic growth properties.
- Special focus will be given to the derivation of critical supersaturations needed for droplet activation based on water activities and surface tensions derived from hygroscopic growth measurements at high relative humidities (r.h. < 95%).
- Effects of organic substances (mainly as coatings) on hygroscopic particle growth, activation and droplet dynamic growth will be studied. As insoluble cores both soot and different minerals will be investigated. Aerosol systems similar to those investigated in WP-L1/L3 and characterised in WP-L4 will be used.

Measurements of ice nucleation

- Focussing on immersion freezing processes.
- Special focus will be given on the determination of freezing temperatures as function of the size, the composition, and the shape of the seed particles on which the freezing droplets are formed.
- Effects of organic substances (mainly as coatings), on droplet immersion freezing will be studied. As insoluble cores both soot and different minerals will be investigated. Aerosol systems similar to those investigated in WP-L1/L2 and characterised in WP-L4 will be used.

Within the framework of ACCENT it is planned to perform a measurement campaign in spring 2007 at LACIS. The campaign will deal with the hygroscopic growth, activation, dynamic growth, and freezing of coated soot particles and therefore contribute to the VI suggested here. Furthermore, a mobile LACIS system, developed in the framework of a different project, will be applied at AIDA (WP-L1) and SAPHIR (WP-L4), if necessary.

Milestones WP L2

MS L2A: Achievement of CCN closure for selected aerosol systems and provision of validated microphysical models / expressions and parameterizations (12 month)
MS L2B: Determination of freezing temperatures for selected aerosol systems and provision of validated microphysical models / expressions and parameterizations (24 month)

Partners contributing to WP-L2 (LACIS team):

- IfT: LACIS facility, aerosol mass spectrometry, chemical analysis.
- ICG-II: Aerosol mass spectrometry, CCN activation spectra.
- Uni-MZ: Aerosol mass spectrometry, supporting single particle wind tunnel experiments
- ETH: determination of the IN or CCN efficiencies

WP L3: Laboratory experiments at ETH Zurich

The focus of the activities to be conducted at ETH Zurich will centre on the simultaneous determination of the IN or CCN efficiency and chemical composition of aerosol particles. This focus is encompassed within the first three science objectives outlined in this proposal.

In order to investigate ice nuclei we propose to prepare aerosols within the Aerosol Generation and Characterization Chamber (AGCC) available in our laboratory. This small chamber allows us to prepare internal or external mixtures of aerosol particles from dry powders or aqueous solution. The experimental temperature and relative humidity are determined and the aerosol size distribution, from 3 nm to 20 µm, can be recorded. Produced aerosols are then exposed to controlled temperature and saturation conditions within the Zurich Ice Nucleation Chamber (ZINC) such that ice crystals are formed as a function of these variables. Ice crystals can then be inertially separated from unactivated aerosols using a Pumped Counterflow Virtual Impactor (PCVI).

Alternately, we can select aerosols generated in the same manner according to their hygroscopicity using a Humidified Tandem Differential Mobility Analyzer (HTDMA). In this case activated particles are automatically separated in the second DMA stage.

Chemical analysis can then take place using one or more mass spectrometers: the single particle Particle Analysis by Laser Mass Spectrometry (PALMS) or TSI Model 3800 Aerosol Time Of Flight Mass Spectrometer (ATOFMS) or a small population of aerosols can be analyzed with an Aerodyne Aerosol Mass Spectrometer (AMS). These three instruments are available in our laboratory.

It is also worth mentioning that the aforementioned instruments are all portable. They are thus available for field studies, for example deployments to the AIDA facility. In fact, the PALMS instrument was coupled to the AIDA chamber during 2005 using a counterflow virtual impactor in order to characterize the chemical composition of those aerosols which nucleated ice. Future studies of this sort are anticipated, namely the proposed ice nucleation studies during 2007 and 2008.

Milestones WP L3
MS L3A: Laboratory studies of freezing mechanisms (ETH, month 18)
MS L3B: Conduct mass spectrometry studies of aerosol hygroscopicity (ETH, month 18)

WP L4 Chemical Characterization of CCN and IN

This work package will focus on the chemical characterization of CCN and IN and their chemical formation, transformation and modification under atmospheric conditions. One task of WP-L4 is to characterize the composition of the CCN (and IN) which will be generated and chemically modified for use in WP L1 and WP L2. For that the aerosol mass spectrometers (Q-AMS and W-ToF-AMS) of Uni Mainz and ICG-II will be used in coordinated fashion.

The second task is to investigate the formation and transformation of CCN and IN from the atmospheric chemistry point of view. The objective is to quantify the range of variation of CCN and IN properties of multi-component particles that can be expected after chemical processing the atmosphere. Herein we will focus on in-situ coating of pre-existing CCN and IN by secondary aerosol components generated from representative precursor mixes under natural light, various oxidation and concentration regimes. To improve the process understanding, these processed multi-component aerosols will be compared to typically single component and fresh particles, which are normally used in laboratory studies.

The insights into the formation process are important for quantifying the activation/deactivation potential of atmospheric secondary aerosol components, which alter the CCN and IN properties of pre-existing particles after condensation. In addition, the most important oxidative transformation or photochemically induced condensed phase processes must be characterized which can also occur on primary particles. The focus of this part of WP-L4 will be on representative precursor scenarios and realistic oxidation regimes under which organic coatings are formed that reduce or enhance the CCN activity of the resulting particles or destroy the ice forming properties of particles that are expected to efficiently act as IN. Because of their global importance biogenic precursors will here be primarily investigated. A side aspect of these studies is to narrow down the conditions (if there are) under which secondary organic solids with crystalline domains can be formed, which can potentially act as IN. Here the formation of short chain carboxyl compounds is of main interest. The systems under investigation will be selected in close interaction with WP L1 and WP L2 and will be investigated in the large SAPHIR chamber of the ICG-II at the FZ Jülich. The characterization of the aerosols and the aerosol processing will be performed with Q-AMS and W-ToF-AMS. CCN properties can be directly transferred by using the same CCN spectrometer as in the warm cloud experiments at AIDA and LACIS. ETH ZINC and a mobile LACIS system will support selected studies at SAPHIR, if necessary.

Milestones WP L4

MS L4A Chemical characterisation of particles at AIDA (ICG-II, Uni-MZ, month 24)
MS L4B Chemical characterisation of particles at LACIS (IfT, ICG-II, Uni-MZ, month 24)
MS L4C Process understanding for in-situ coating of pre-existing CCN and IN assessed (ICG-II, month 30).
MS L4D Couple ZINC chamber to mass spectrometers (ETH, Uni-MZ, month 24)

3.2 Modelling

WP M1: Process-oriented modelling

This work package aims at testing and improving parameterisations of ice nucleation and CCN processes. This will be achieved by comparing data sets of AIDA simulation experiments with process modelling results. A process model is available at IMK-AAF which was developed and approved especially for application to aerosol chamber experiments. The model includes a full description of size-bin resolved aerosol physics, gas-particle interactions, and thermodynamics of cloud expansion experiments. Available formulations of CCN and IN activation are also included. The same model was adapted by ICG-I to investigate, on the basis of field observations, the impact of ice nucleation processes on the dynamic water partitioning and supersaturation in cirrus cloud life cycles.

Numerical simulations of coagulation and condensation are performed determining the mixing state of sulphate/organics/soot aerosol in cirrus conditions. The results will be used to select most relevant aerosol systems for the laboratory IN experiments in cirrus conditions. A fully coupled cirrus parameterization scheme, validated by means of the comprehensive microphysical model APSC developed at DLR-IPA and constrained by laboratory and field observations of nucleation properties of heterogeneous IN will be made available to the VI-ACI. This scheme will be updated and tested for later use in the climate model ECHAM.

Evaluations of microphysical expressions/models and parameterizations for cloud droplet activation and growth as well as ice nucleation inside the coupled CFD-particle dynamics model will be carried out at IfT. The model consists of the Computational Fluid Dynamics (CFD) code FLUENT and the Fine Particle Model (FPM) and allows the coupled description of fluid flow, heat/mass transfer and particle/droplet dynamics in LACIS. Inside this model, different microphysical expressions/models and parameterizations can be implemented and evaluated by comparison with experimental data gained at LACIS. The evaluated expressions/models and parameterizations will be provided for use in model calculations within the VI (WP M2, WP M3).

Milestones WP M1

MS M1A Cirrus parameterization scheme available for use in ECHAM (DLR, month 6).
MS M1B Model runs on aerosol mixing state in cirrus finished (DLR, month 12).

MS M1C Validated microphysical models, expressions and parameterizations regarding CCN activation for selected aerosol systems (IfT, month 12)
MS M1D Ice nucleation properties in mixed-phase clouds assessed (FZK, month 18).
MS M1E Ice nucleation properties in cirrus clouds assessed (DLR, FZK, month 24).
MS M1F Process model with new IN schemes applied to cirrus data sets (ICG-I, month 24).
MS M1G Validated microphysical models, expressions and parameterizations regarding freezing temperatures for selected aerosol systems (IfT, month 24)

WP M2 Cloud modelling

A 2D cloud model of the Tel Aviv University (TAU-2D) will be used to test some of the parameterizations of CCN and IN and the effects on the growth of drops and ice crystals. The advantage of this model is in the use of the multi-moment method to accurately calculate the growth and break-up of drops and ice crystals. With the new data on nucleation, this model will need some modifications of drop and ice initiation as well as shapes of ice crystals. These modifications and the application of the model will be performed within the VI in cooperation with IMK-AAF.

DLR-IPA will develop a state-of-the-art cirrus cloud package for the multiscale flow model EULAG. The microphysics package comprises non-equilibrium, size-resolved aerosol processes relevant to ice formation and is capable of representing heterogeneous ice nuclei besides liquid (or mixed liquid/insoluble) particles. The ice phase forms either homogeneously or heterogeneously, leading to individual ice crystals which may be combined to clusters if computational demands become too challenging. Ice formation processes will be treated employing the latest information available from the VI-ACI. The sedimentation and growth of individual ice crystals is followed explicitly while they are transported with the flow field. Dynamics and microphysics will be coupled to a computationally efficient yet accurate radiation module, enabling dynamic-radiation-microphysics feedbacks to be studied.

An advanced bulk ice microphysics module to study the contrail evolution in the vortex and dispersion phase will be developed for EULAG. The vortex phase of a contrail (10-150 sec after formation) determines the initial conditions for the contrail-to-cirrus transition. The contrail properties (e.g., geometrical extent and ice crystal properties) at the end of this period depend sensitively on ambient humidity, on temperature, stratification, turbulence level, and perhaps on aircraft design and fuel properties. For EULAG, we will develop and implement methods for the correct simulation of vortex pairs. Vortex cores will be traced, the circulation of the vortices will be computed and the proper decay of vortices will be achieved by interactively adapting diffusion parameters. After the vortex phase is correctly simulated, the subsequent dispersion phase will be investigated in more detail. Two doctoral theses summarizing these innovative efforts will be submitted to the Department of Physics at the University of Munich.

After extensive testing and validation the cloud-resolving models will be applied to study processes relevant to UTLS microphysics and aviation-induced clouds, among which are ice initiation in cirrus and contrail-cirrus, contrail-to-cirrus transition, cirrus cloud life cycles, and trace gas uptake on ice. Results of these modelling efforts will help represent contrail- and cirrus-related processes in the climate model employed by DLR-IPA within the VI-ACI.

The activities at ETH Zürich in cloud resolving modelling focus on the impact of dynamics and aerosols on the life cycle of cirrus clouds. For our investigations we will use the recently developed and implemented bulk ice microphysics scheme on the basis of the model EULAG. The model contains different classes of ice formed by heterogeneous and homogeneous nucleation. The parameterisations for heterogeneous nucleation have been improved using AIDA results (ICG-I, FZK). The existing model will be used for different studies:

- Interpretation and simulation of measurements obtained during field campaigns (CIRRUS I-III, ICG-I, Uni-MZ, ETH). We have started with a case study on frontal cirrus clouds measured during CIRRUS II and want to continue this work.

- Investigation of the influence of different aerosols on the formation of cirrus clouds and improvement of the existing parameterisations in the model by using laboratory results (FZK, ETH)

Milestones WP M2

MS M2A Lagrangian ice crystal tracking module for small and mesoscale simulations of cirrus clouds developed (DLR-IPA, month 12).
MS M2B Ice microphysics module for small and regional-scale contrail studies developed (DLR-IPA, month 12).
MS M2C Case studies on cirrus clouds obtained during field campaigns (ICG-I, ETH, month 12).
MS M2D TAU-2D model runs finished (Uni-TA, IMK-AAF, month 30).
MS M2E Cloud-resolving model runs using the multi-scale dynamical model EULAG finished (DLR-IPA, month 30).
MS M2F Investigation and interpretation of field measurements (ETH, ICG-I, month 36).

WP M3 Climate modelling

General circulation models (GCM) will be applied to investigate the impact of new parameterisation schemes for CCN/IN processes (WP-M1/M2) and ice crystal single-scattering properties (WP-L1) on the indirect aerosol effect. Climate change due to this indirect effect as well as the direct effect of contrail cirrus will be studied by DLR-IPA and ETH.

The ETH GCM modelling will focus on contact freezing and immersion freezing in stratiform mixed-phase clouds (with temperatures between 0° and -35°C). Respective parameterisations for black carbon and mineral dust assumed to be composed of either kaolinite (simulation KAO) or montmorillonite (simulation MON) were introduced into the ECHAM4 general circulation model. Here, the effectiveness of black carbon and dust as IN as a function of temperature is parameterized from a compilation of laboratory studies. The rather subtle differences between these sensitivity simulations in the present-day climate have significant implications for the anthropogenic indirect aerosol effect. The decrease in net radiation in these sensitivity simulations at the top of the atmosphere varies from 1 ± 0.3 to 2.1 ± 0.1 W m^{-2} depending on whether dust is assumed to be composed of kaolinite or montmorillonite. In simulation KAO, black carbon has a higher relevancy as an ice nucleus than in simulation MON, because kaolinite is not freezing as effectively as montmorillonite. In simulation KAO, the addition of anthropogenic aerosols results in a larger ice water path, a slightly higher precipitation rate, and a reduced total cloud cover. On the contrary, in simulation MON the increase in ice water path is much smaller and globally the decrease in precipitation is dominated by the reduction in warm-phase precipitation due to the indirect cloud lifetime effect. Within the VI-ACI, ETH will extend this approach to other relevant aerosols, such as different types of mineral dust and take into account the effect of chemical ageing on the mineral dust surfaces.

The DLR-IPA contributions concentrate on ice clouds that are prevalent at altitudes above about 8 km. Besides properly representing their formation and dynamical triggering in a climate model framework, the main emphasis will be on the anthropogenic impact on cirrus. This includes effects of heterogeneous IN from aviation and other anthropogenic and natural sources, as well as aviation-induced contrail-cirrus. Because a common treatment of indirect and direct aviation effects within a consistent model version is not yet possible, we start to treat both issues separately. At the end of the VI-ACI, tools will be available to investigate the coupling between direct and indirect effects of aviation-induced particles and those from other sources.

In general circulation models (GCMs) that enable the prediction of number and mass of ice crystals in cirrus clouds, it is possible to study the effect of black carbon and mineral dust particles on cirrus formation with increased confidence. These models need a predictive capability for dust and soot particle abundance, along with ice nucleation parameterizations that include realistic background cirrus formation scenarios. The ECHAM4 climate model operated by DLR-IPA fulfils these requirements after implementation of the updated ice nucleation parameterization. For the first time, it will become possible to study the role of various competing aerosol types in cirrus formation globally. This includes studies of the role of aviation in cirrus modification.

With the help of tools that allow contrail-cirrus to be tracked as a distinct class of cirrus clouds, the direct effect of persistent, spreading contrails on cloud cover and radiative forcing can be studied in the framework of conventional climate models. Such studies will be far more realistic than existing GCM estimates of contrail effects and will lead to an improved prediction of the hitherto poorly quantified global contrail-climate impact. In the VI-ACI, we will develop such a prognostic tool for contrail-cirrus along with a parameterization that accounts for subgrid-scale growth and spreading effects. Implementing and using these tools in ECHAM4 will enable us to study and quantify the climate implications of contrail-cirrus and to investigate interactions between the global water vapour and cirrus fields, affecting the efficacy of IN to indirectly modify cirrus properties.

Milestones WP M3

MS M3A Fully coupled parameterization of cirrus cloud formation implemented in ECHAM (DLR, month 12)
MS M3B Subgrid-scale parameterization for contrail-cirrus ready in ECHAM (DLR, month12)
MS M3C Simulations with varying mineral dust composition (ETH, month 18)
MS M3D Global impact of contrail-cirrus on cirrus cover and properties quantified (DLR, month 30)
MS M3E Impact of natural and anthropogenic ice nuclei (including aviation soot) on global cirrus cloud properties quantified (DLR, month 30)
MS M3F Simulations with changed freezing efficiency due to aged aerosols (ETH, month 36)

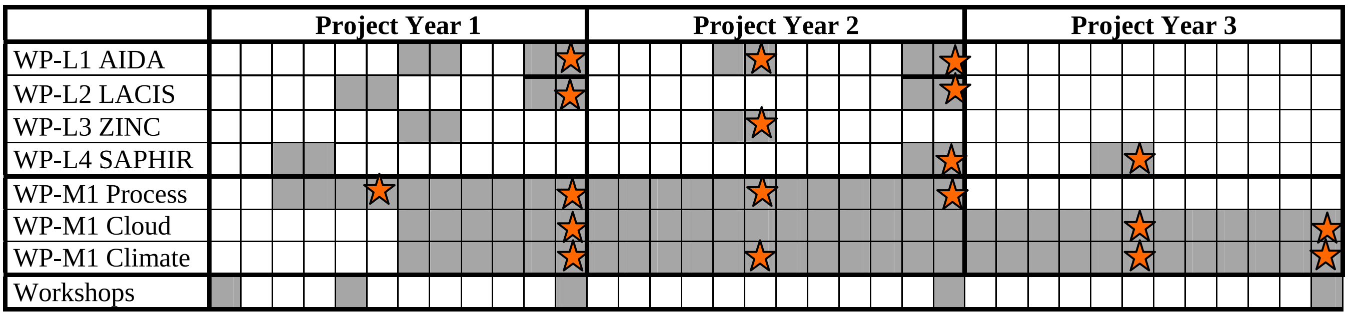
3.3 Workshops and further activities

The cooperation within the Virtual Institute will be started with a kick-off meeting. Progress and further planning will be discussed in two project workshops towards the end of the first and second project years.

Discussion meetings open to the interested scientific community will be organised during the first project year (together with a planning meeting for the Ice Nucleation Workshop) and towards the end of the third project year. The latter should summarize the progress made within the VI-ACI, discuss open issues for further collaboration and research, and initiate follow-on networking activities and projects. The VI-ACI may e.g. form a nucleus for new projects within the 7th EU Framework Programme.

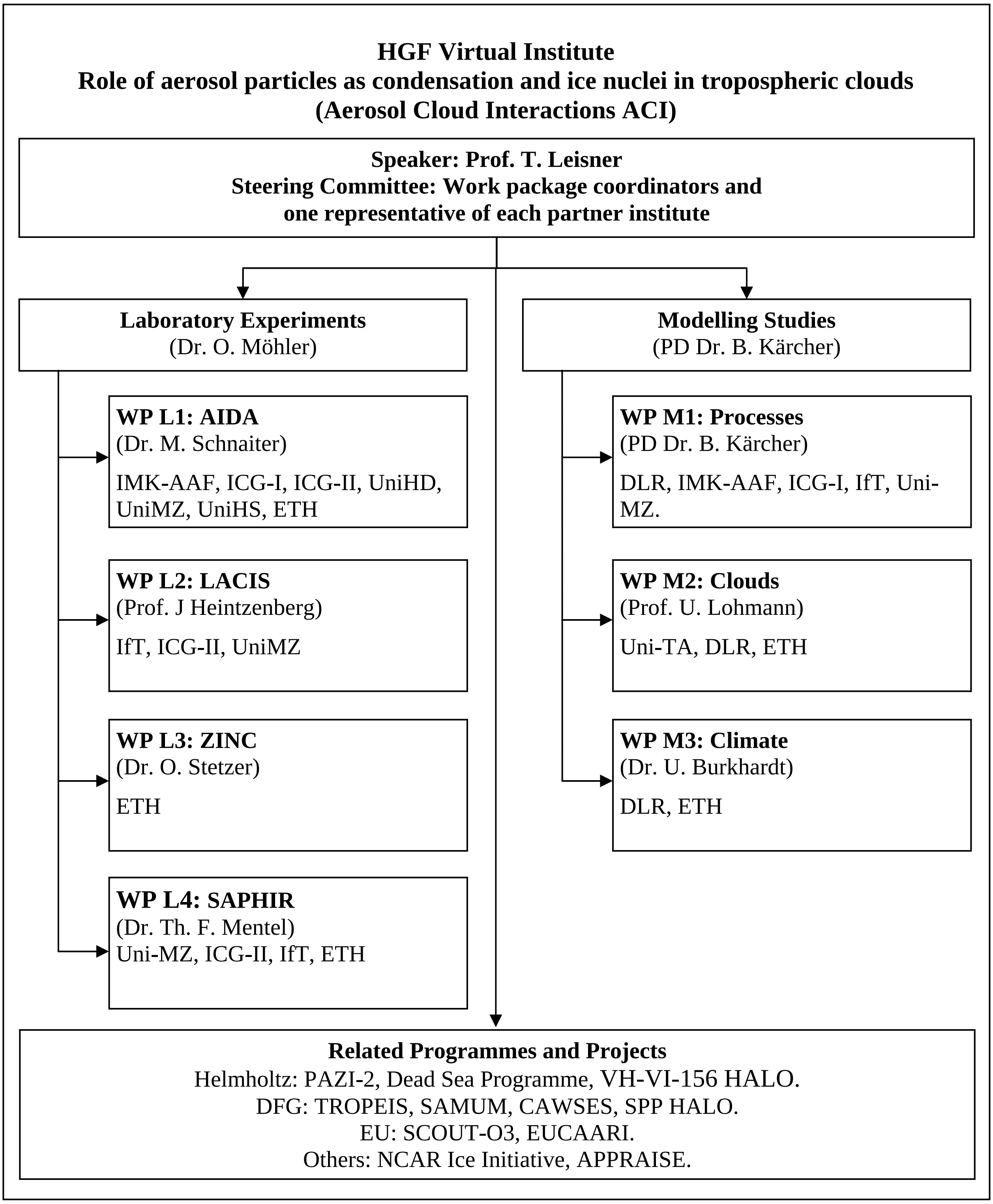
3.4 Time Table of activities and project milestones

The table below gives an overview of the project activities. For the laboratory part, the shaded areas indicate the planned time periods of major experimental activities. The exact time schedule will be discussed and decided during the kick-off and planning workshops. Time periods of major modelling activities are also indicated as shaded areas. The stars indicate times where respective milestones can be found in the work package descriptions (sections 3.1 and 3.2).



4. Management Structure

The flow diagram below displays the management and work programme structure of the VI-ACI. Spokesperson of the Virtual Institute and Chairman of the programme committee will be Prof. Thomas Leisner, who is director of the Institute for Meteorology and Climate Research - Atmospheric Aerosol Research (IMK-AAF) of Forschungszentrum Karlsruhe. The work package coordinators and one representative of each partner institute will constitute a programme committee which is, together with the chairman, responsible for programme decisions, public relations, and relations to other projects and programmes. The work package coordinators support the interaction and close cooperation within their own and with other work packages.



5. Opportunities for young researches

Young researchers will be important team members of the VI-ACI. The Virtual Institute will provide excellent opportunities for students and young researchers to do their undergraduate and graduate work on important and relevant topics of aerosol-cloud interaction and to participate in experimental and modelling studies with international collaboration. A significant fraction of the funding requested from the partners will be spent to PhD students. The VI-ACI offers scientific exchange opportunities to young researchers for doing part of their experimental or modelling research as visitors of partner institutes. If possible, short visits to the partner institutes for discussing specific topics or problems should also be supported. Young researchers will also be encouraged to attend and actively contribute to the workshops of the VI-ACI and to present their results on national and international conferences.

6. Added value of the VI-ACI

The Virtual Institute combines, for the first time, the excellent experimental capabilities of the unique aerosol and cloud simulation facilities AIDA in Karlsruhe, LACIS in Leipzig, SAPHIR in Jülich, and the vertical wind tunnel in Mainz to address open issues of current climate and weather research in a closely coordinated work programme. National and international university partners will use these facilities and contribute a comprehensive set of sophisticated instruments for aerosol and cloud research. All partners of the VI-ACI will benefit from a close cooperation between experimentalists and modellers which is prerequisite to identify most relevant open questions of aerosol-cloud processes, design respective experiments, and develop appropriate parameterisations for use in models. Several groups will contribute their excellent and outstanding experience in process-oriented, cloud-resolved, and climate modelling.

In close interaction with the Helmholtz-Virtual Institute “Atmosphärenforschung mit dem Forschungsflugzeug HALO (VH-VI-156)”, the AIDA facility will be used during the VI-ACI to test and improve new instruments currently developed for science missions with the HALO research aircraft. This includes both optical probes and ice nucleation instruments. Therefore, the preparation of aerosol and cloud missions with the new research aircraft HALO will also benefit from the activities within the VI-ACI.

In 2007, the AIDA group will host an international workshop on the intercomparison of ice nucleation instruments. This workshop involves about 10 European, US, and Japanese groups and can be organized as part of the VI-ACI.

The importance of aerosol-cloud processes and their impact on weather and climate is demonstrated by the fact that several national and international projects cover certain aspects of this research area. However, none of these projects is capable of covering the broad range of topics and methodologies of the VI-ACI. In addition to its own scientific objectives, the VI-ACI will also contribute to strengthen the national and international cooperation in the area of aerosol-cloud interactions. Relations between the VI-ACI and other national and international programmes are briefly outlined in the following section.

7. Relation to other Programmes

The Helmholtz science project **PAZI** (Particles and Cirrus Clouds) has begun as a HGF Strategy-Fund project 2000-2003 under the leadership of DLR-IPA with FZK and FZJ as major partners within the HGF network, and with many other national and international partners from universities and research agencies. PAZI is currently in its second phase (2004-2007). The proposed Virtual Institute will serve to extend the highly successful scientific collaboration between DLR-IPA and its partner institutes beyond the original PAZI research themes.

The research area Atmosphere and Climate of the **Helmholtz Dead Sea Programme** aims at investigating key issues of climate change and related problems in the Dead Sea Area. Major objectives of the suggested programme include (1) Atmospheric Composition, (2) Aerosols, Clouds and Precipitation, and (3) Climate Change, Water Availability and Renewable Energy. The environment in the Dead Sea Area is affected by both local particulate pollution and long range transport of particles such as mineral dust originating from desert areas in the region and in Northern Africa. The chemical transformation and cloud physics of such particles will be investigated in the VI-ACI.

The DFG Sonderforschungsbereich (SFB) 641 "**Die Troposhärische Eisphase – TROPEIS**" aims at investigating the role of ice processes in the troposphere. It is a joint programme of the universities in Frankfurt (lead), Mainz, and Darmstadt and includes 14 subprojects on the formation and characterisation of the ice phase as well as related dynamic effects of chemistry and radiative transfer. There will be a close cooperation and interaction between TROPEIS and the VI-ACI.

The DFG 'Forschergruppe' **SAMUM** involves a team of 7 research groups investigating the local microphysical and chemical properties of Saharan dust, characterise the dust-filled atmospheric column, and assess the regional and global radiative effects of Saharan dust. The VI-ACI will use Saharan dust sampled during the SAMUM field activities to investigate its microphysical (CCN, IN) and direct optical properties (absorption).

HALO - The **H**igh **A**ltitude and **LO**ng Range Research Aircraft will be the new Research Aircraft for atmospheric research and earth observation of the German Science Community. HALO is funded by the Federal Ministry of Education and Research, the Helmholtz-Gemeinschaft and the Max-Planck-Gesellschaft. A DFG 'Schwerpunktprogramm' (**SPP HALO**) will support instrument development. The VI-ACI will investigate basic processes of aerosol-cloud interaction which may be useful to guide and interpret HALO missions and offers unique platforms for testing and improving HALO aerosol and cloud instrumentation.

The **Virtual Institute** "Atmosphärenforschung mit dem Forschungsflugzeug **HALO** (VH-VI-156)" coordinated by Prof. U. Schumann, DLR-IPA, includes 4 Helmholtz centers and 7 university partners. Main goals are the preparation of first science missions with the research aircraft HALO, the modification of existing or development of new instruments required for these missions (including aviation permission issues), and the design of respective inlet ports. The AIDA facility is offered within both the VI HALO and the VI-ACI as a platform for testing of HALO instruments under relevant conditions.

SCOUT-O3 - Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere - is an EU Integrated Project with the aim to provide predictions about the evolution of the coupled chemistry/climate system, with emphasis on ozone change in the lower stratosphere and the associated UV and climate impact, to provide vital information for society and policy use. SCOUT includes an activity of laboratory investigations on the chemistry and microphysics of particles in the upper troposphere and lower stratosphere (UT/LS) region.

The goal of the US project **„Ice Initiation in Clouds"** is to develop a Strategic Initiative of NCAR, Boulder, with considerable input from the university community including graduate students, to advance the understanding and modelling of ice initiation in clouds. The VI-ACI will provide a close link to this activity. Responsible scientists from FZK and DLR-IPA have already contributed their scientific expertise during the preparation of this project.

APPRAISE: The aim of this consortium, including Uni-HS and three further UK universities (Manchester, Reading, Leeds), is to examine indirect effects of aerosols on climate with special emphasis on mixed phase clouds. The role and properties of CCN as well as IN will be investigated in a series of field experiments involving the UK BAe-146 and joint DLR-NERC Dornier 228 aircraft and coordinated with ground-based and satellite remote sensing, as well as laboratory experiments. Partial funding is already available from NERC and further funding is expected from December 2006. It is intended to also include AIDA chamber experiments if possible.

EUCAARI (in negotiation): The European Integrated project on Aerosol Cloud Climate and Air Quality Interactions, EUCAARI, will investigate the role of aerosol on climate and air quality. The main objectives of EUCAARI are reduction of the current uncertainty of the impact of aerosol particles on climate and quantification of the relationship between anthropogenic aerosol particles and regional air quality. One of EUCAARI's workpackages will focus on ice nucleation using the Zurich Ice Nucleation Chamber (ZINC) in mixed-phase clouds and the effects of trace gases on ice nucleation. Another EUCAARI workpackage will focus on characterization of formation and transformation of secondary organic aerosols in the SAPHIR chamber at ICG-II/FZJ.

8. Science Team of the VI-ACI

IMK-AAF	Prof. T. Leisner	Leader and spokesperson of the Virtual Institute
	Dr. O. Möhler	Coordinator Laboratory Experiments, cloud microphysics
	Dr. M. Schnaiter	Coordinator WP AIDA experiments, ice characterisation
	Dr. H. Saathoff	TDL water vapour measurements
	Dr. R. Wagner	IR spectroscopy of aerosols, droplets, and ice particles
DLR	Prof. U. Schumann	Representative of DLR, link to aviation aspects
	PD Dr. B. Kärcher	Coordinator modelling studies, cirrus modelling supervisor.
	Dr. U. Burkhardt	Coordinator WP climate modelling.
	Dr. K. Gierens	Contrail Modelling Supervisor
	Dr. J. Hendricks	Climate Modelling
	I. Sölch	Cirrus Modelling
	S. Unterstrasser	Contrail Modelling
ICG-I	Prof. M. Riese	Representative ICG-I, link to upper tropospheric studies
	Dr. M. Krämer	Total water measurements, process-oriented modelling
ICG-II	Prof. A. Wahner	Representative ICG-II, link to tropospheric chemistry aspects
	Dr. Th. F. Mentel	Coordinator WP SAPHIR experiments, CCN activation spectra
	Dr. A. Kiendler-Scharr	Aerosol mass spectrometry
IfT	Prof. J. Heintzenberg	Representative IfT, link to atmospheric aerosol aspects.
	Dr. F. Stratman	LACIS experiments, cloud microphysics
Uni-MZ	Prof. S. Borrmann	Representative University of Mainz
	Dr. J. Schneider	Aerosol mass spectrometry, aerosol characterisation
	Dr. K. Diehl	Wind tunnel studies.
Uni-FM	Prof. U. Schmidt	Representative of Univ. Frankfurt and SFB 641 (TROPEIS)
	Dr. H. Bingemer	Ice nuclei filter processor
	Dr. U. Bundke	Ice nucleation mixing chamber
Uni-HD	HD Dr. V. Ebert	TDL water vapour measurements.
ETH	Prof. U. Lohmann	Representative ETH, coordinator WP cloud modelling.
	Dr. O. Stetzer	Ice nucleation measurements (ZINC), co-organiser IN workshop
	Dr. D. Cziczo	Single particle mass spectrometry (PALMS)
Uni-HS	Prof. P. H. Kaye	Droplet and ice particle characterisation.
	Dr. Z. J. Ulanowski	Calibrations using ice analogues and particle classification.
	Dr. E. Hesse	Light scattering modelling of ice particles.
Uni-TA	Prof. Z. Levin	Representative Tel Aviv University, Israel; cloud modelling

9. Budget Plan

The project duration is three years. For the VI-ACI we request a total amount of 300000 Euro per year (110000 Euro/yr for the Helmholtz centers, 140000 Euro/yr for the WGL and national university partners, 50000 Euro/yr for the international university partners. Most of the budget covers personal costs for PhD students working on the objectives of the VI-ACI. It is obvious that only part of the total costs for the planned experiments and model studies is covered by the funding available within the VI. All partners bring in significant amount of funding from own sources. The suggested budget plan includes a minimum which is needed to establish an international network and workprogram on aerosol-cloud interaction as suggested in the present proposal. A detailed budget plan for the international partners with total and requested costs is given in separate tables.

Partner		**Year 1**	**Year 2**	**Year 3**	**Total**
Helmholtz Centers					
FZ Karlsruhe (IMK-AAF, coordinator)	PC[a]	35000	35000	35000	105000
	CS	5000	5000	5000	15000
	DE	0	0	0	0
	Tot	**40000**	**40000**	**40000**	**120000**
DLR Oberpfaffenhofen (DLR-IPA)	PC	30000	30000	30000	90000
	CS	5000	5000	5000	15000
	DE	0	0	0	0
	Tot	**35000**	**35000**	**35000**	**105000**
FZ Jülich (ICG-I, ICG-II)	PC	0	0	0	0
	CS	35000	35000	35000	105000
	DE	0	0	0	0
	Tot	**35000**	**35000**	**35000**	**105000**
Leibniz Institute and National Universities					
IfT Leipzig (IfT)	PC	25000	25000	25000	75000
	CS	10000	10000	10000	30000
	DE	0	0	0	0
	Tot	**35000**	**35000**	**35000**	**105000**
University of Mainz (Uni-MZ)	PC	30000	30000	30000	90000
	CS	5000	5000	5000	15000
	DE	0	0	0	0
	Tot	**35000**	**35000**	**35000**	**105000**
University of Frankfurt (Uni-FM)	PC	30000	30000	30000	90000
	CS	5000	5000	5000	15000
	DE	0	0	0	0
	Tot	**35000**	**35000**	**35000**	**105000**
University of Heidelberg (Uni-HD)	PC	25000	25500	26000	76500
	CS	10000	9500	9000	28500
	DE	0	0	0	0
	Tot	**35000**	**35000**	**35000**	**105000**
International Partners					
ETH Zürich (ETH)	Tot	20000	20000	20000	60000
University of Hertfordshire (Uni-HS)	Tot	15000	15000	15000	45000
Tel Aviv University (Uni-TA)	Tot	15000	15000	15000	45000
Total VI-ACI		**300000**	**300000**	**300000**	**900000**

[a] PC = Personal Costs, CS = Consumables, DE = Durable Equipment, Tot = Total requested costs

As outlined in the work programme of the proposal, the contributions of all three international partners are necessary to achieve the overall objectives of the Virtual Institute. The three institutes contribute significant amount of work on the basis of own funding but request financial support for part of the travelling expenses and personal costs for PhD students. This support is a minimum needed by all three partners to afford their full integration in the science programme of the VI-ACI. The respective total and requested costs are listed in the following table.

Budget plan ETH Zurich:

	Year 1		Year 2		Year 3	
	VI[a]	**ETH**	**VI**	**ETH**	**VI**	**ETH**
Travel costs (workshops, campaigns)	1000	1000	1000	1000	1000	1000
Partial Salary (Cziczo, Spichtinger, Stetzer)	19000	25000	19000	25000	19000	25000
Total per year	**20000**	**26000**	**20000**	**26000**	**20000**	**26000**

[a] Requested grant

Budget plan University of Hertfordshire (Uni-HS):

	Year 1		Year 2		Year 3	
	VI[a]	**Uni-HS**	**VI**	**Uni-HS**	**VI**	**Uni-HS**
Travel costs (workshops, participation in AIDA campaigns)	2000		2000		2000	
Studentship and partial academic staff costs	12500	40000	13000	40000	13500	40000
Total per year	**14500**	**40000**	**15000**	**40000**	**15500**	**40000**

[a] Requested grant

Budget plan Tel Aviv University (Uni-TA):

	Year 1		Year 2		Year 3	
	VI[a]	**Uni-TA**	**VI**	**Uni-TA**	**VI**	**Uni-TA**
Exchange visit to Karlsruhe for preparation and continued development of cloud modelling studies	7000	7000	3500	3500	3500	3500
Exchange visit of PhD student from IMK-AAF to Tel Aviv University for modification and application of cloud model			4500		4500	
Masters student help with model runs at Tel Aviv University	5000	5000	5000	5000	5000	5000
Attend project workshop in Karlsruhe	2000	2000	2000	2000	2000	2000
Miscellaneous	1000	1000	0	0	0	0
Total per year	**15000**	**15000**	**15000**	**10500**	**15000**	**10500**

[a] Requested grant

Appendix - Expertise of partner institutes and leading scientists

Forschungszentrum Karlsruhe, IMK-AAF
Prof. T. Leisner, Dr. O. Möhler

Expertise of Institute

The Institute for Meteorology and Climate Research (IMK-AAF) at Forschungszentrum Karlsruhe runs the large aerosol and cloud chamber AIDA (Aerosol Interactions and Dynamics in the Atmosphere), which can be operated at variable conditions of the troposphere and stratosphere. The AIDA facility provides an excellent infrastructure in terms of optical, physical, and other instrumentation to carry out, with international partners, comprehensive experimental investigations of aerosol-cloud interactions, aerosol optical properties, and heterogeneous aerosol chemistry. The IMK-AAF also runs well advanced process oriented models of aerosol physics and chemistry.

Contribution to the VI

Overall coordination and coordination of the laboratory studies.
AIDA laboratory experiments of CCN and IN efficiency of aerosols.
Microphysical and optical characteristics of ice particles.
Process-oriented modelling studies, parameterisations of ice nucleation processes.

CV and expertise of leading scientists

Prof. Th. Leisner

Since 2006	Director of IMK-AAF, Forschungszentrum Karlsruhe Professor at Institute for Environmental Physics, University of Heidelberg
2000-2006	Professor for Environmental Physics, TU Ilmenau, Germany
1992-2000	Research Scientist at Freie Universität Berlin
1991	Postdoctoral Fellow at University of New Hampshire, Durham NH
1991	Doctorate in Physics from University of Konstanz

Over 60 peer reviewed publications.

Dr. O. Möhler

2004	Visiting scientist at NCAR, Boulder, CO.
Since 1997	Leader of research group “Atmospheric Aerosols and Clouds” at Forschungszentrum Karlsruhe, IMK-AAF.
1993-1997	Research Scientist at Forschungszentrum Karlsruhe, IMK-AAF.
1989-1992	Postdoctoral fellow at Max-Planck-Institut für Kernphysik Heidelberg (MPI-K).
1989	Doctorate in Physics from University of Heidelberg/MPI-K.

30 peer-reviewed papers, Principal Investigator (PI) of EU research projects CIPA and SCOUT-O3 and HGF projects PAZI-1, PAZI-2, Coordinator of BMBF AFO2000 project cluster POSTA, Steering Committee Member of NCAR Strategic Initiative on “Ice Initiation in Clouds”.

Selected publications

Achtzehn T, Müller R, Duft D. and **Leisner T.**, The Coulomb instability of charged microdroplets: dynamics and scaling, European Physical Journal D, 34, 1-3, (2005)

Möhler, O., S. Büttner, C. Linke, **M. Schnaiter**, **H. Saathoff**, **O. Stetzer**, **R. Wagner**, **M. Krämer**, A. Mangold, **V. Ebert**, and U. Schurath, 2005, Effect of sulphuric acid coating on heterogeneous ice nucleation by soot aerosol particles, Journal of Geophysical Research, 110 (D11210), doi:10.1029/2004JD005169.

Stöckel P., Weidinger I.M., Baumgartel H. and **Leisner T**., Rates of homogeneous ice nucleation in levitated H_2O and D_2O droplets, J. Phys. Chem A, 109, 2540-2546 (2005)

Duft D. and **Leisner, T.,** Laboratory evidence for volume-dominated nucleation of ice in supercooled water microdroplets, Atmos. Chem. Phys. 4, 1997 – 2000, (2004)

Möhler, O., **O. Stetzer**, S. Schaefers, C. Linke, **M. Schnaiter**, R. Tiede, **H. Saathoff**, **M. Krämer**, A. Mangold, P. Budz, P. Zink, J. Schreiner, K. Mauersberger, W. Haag, **B. Kärcher**, and U. Schurath, Experimental investigation of homogeneous freezing of sulphuric acid particles in the aerosol chamber AIDA, Atmos. Chem. Phys., 3, 211-223, 2003.

Deutsches Zentrum für Luft- und Raumfahrt, Institute of Atmospheric Physics, DLR-IPA
Prof. U. Schumann, Priv. Doz. Dr. B. Kärcher

Expertise of Institute

The Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) is the German national research establishment for aeronautics, astronautics, and energy technology. DLR is also responsible for the management of the German national space programme. The DLR-Institut für Physik der Atmosphäre (DLR-IPA) performs research in the following areas: large-scale, meso-scale, and micro-scale modelling of atmospheric dynamics, aerosols, clouds, and chemistry, in situ air-borne measurements of chemical species, aerosols, and meteorological quantities, radiative transfer modelling, development and application of tools for passive and active remote-sensing including air-borne Lidar instruments, polarimetric Radar, processing of satellite output, and analysing and forecasting the impact of weather on aircraft operations. DLR-IPA has many years experience in co-ordinating research projects including major field campaigns, e.g., the EC projects AERONOX, POLINAT, EULINOX, METRIC, TROCCINOX, QUANTIFY and national research programmes funded by BMBF and DFG.

Contribution to the VI

Coordination of modelling activities within the VI-ACI
Parameterization schemes of subgrid-scale processes for use in climate models
Process- and cloud-resolving modelling of ice clouds
Global modelling of contrail-cirrus and cirrus clouds and climate impact

CV and expertise of leading scientists

Prof. Ulrich Schumann

Since 1986	Professor (Theoretical Meteorology) at the University of Munich
Since 1982	Director of the Institute of Atmospheric Physics of DLR
1978	Habilitation and Venia Legendi, University of Karlsruhe
1974/75	Post-doc National Centre for Atmospheric Research in Boulder, Colorado, USA
1973	Doctorate in Fluid Mechanics from the University Karlsruhe

Professor Schumann's research areas include a wide range of topics in atmospheric physics and climate research, most notably turbulence modelling, mesoscale dynamics, and airborne measurements of trace gases. He acted as PI in several European and national research projects. He is author of over 100 peer-reviewed publications, and received numerous awards such as the Alfred-Wegener Medal of the German Meteorological Society (2001) and the Aachen and Munich Prize for Technique and Applied Natural Sciences (2005). He is member of numerous panels such as the EC Science Panel on Stratospheric Ozone of the European Commission, DG XII/D-1, the Scientific Advisory Council of the German Weather Service, the Scientific Steering Group of the World Climate Research of GEWEX (Global Energy and Water Cycle Experiment), and the Scientific Advisory Committee of the German Climate Computer Centre (DKRZ).

Priv. Doz. Dr. Bernd Kärcher

Since 2000	Adjunct Professor (Privat-Dozent) at the University of Munich
Since 1997	Research Scientist at DLR-IPA, Department "Atmospheric Trace Gases and Aerosols"
1999	Habilitation and Venia Legendi in Theoretical Physics, University of Heidelberg
1992-1997	Research Assistant (C1) at the University of Munich, Work with Prof. Peter Fabian
1988-1992	PhD-Student and Post-Doc at the MPI for Quantum Optics, Garching; Doctorate (1991) in Physics from the Technical University Munich

Dr. Kärcher has many years of experience in developing atmospheric process models, understanding the microphysical and chemical behavior of airborne particles, and developing parameterization schemes for climate models. He was awarded the Research Prize 1996 of the German Meteorological Society (DMG) for his work on the Formation of Aerosols and Ice Crystals in the Upper Troposphere**.** He actively participated in several EU projects and numerous field campaigns, and was the responsible scientist in various national research projects. As a lead author, he contributed to IPCCs Aviation Assessment (1999) and SPARCs Assessment of Stratospheric Aerosols (2006). He has published over 60 peer-reviewed papers and serves as an Editor for Atmospheric Chemistry and Physics (since 2001).

Selected publications

Haag, W., **B. Kärcher**, S. Schaefers, O. Stetzer, O. **Möhler**, U. Schurath, **M. Krämer**, and C. Schiller: Numerical simulations of homogeneous freezing processes in the aerosol chamber AIDA. Atmos. Chem. Phys. 3, 195-210, 2003.

Kärcher, B.: Simulating gas-aerosol-cirrus interactions: Process-oriented microphysical model and applications. Atmos Chem Phys. 3, 1645-1664, 2003.

Hendricks, J., **B. Kärcher**, **U. Lohmann**, and M. Ponater: Do aircraft black carbon emissions affect cirrus clouds on the global scale? Geophys. Res. Lett. 32, L12814, doi:10.1029/2005GL022740, 2005.

Kärcher, B., **J. Hendricks**, and **U. Lohmann**: Physically-based parameterization of cirrus cloud formation for use in global atmospheric models. J. Geophys. Res. 111, D01205, doi:10.1029/2005JD006219, 2006.

Schumann, U.: Formation, properties and climatic effects of contrails. C. R. Physique 6, 549-565, 2005.

Forschungszentrum Jülich, ICG-I
Prof. M. Riese, Dr. M. Krämer

Expertise of Institute

The research activities of the Institute for Chemistry and Dynamics of the Geosphere I: Stratosphere (ICG-I) at Forschungszentrum Jülich are placed in the upper troposphere and the stratosphere. They cover aircraft in-situ and remote observations as well as model studies. One focus are in-situ H_2O measurements of UT/LS gas phase water and cirrus clouds coupled with process modeling of cirrus life cycles.

Contribution to the VI

Laboratory measurements and process modelling of H_2O partitioning in cirrus clouds
Testing ice nucleation properties from laboratory measurements for field observations.

CV and expertise of leading scientists

Prof. Martin Riese

Since 2002 Director of ICG-I, Forschungszentrum Jülich,
Professor for Atmospheric Physics, University of Wuppertal.
1994-2002 Research scientist at University of Wuppertal, Atmospheric Physics.
1994 Doctorate in Physics from University of Wuppertal, Atmospheric Physics.

50 peer reviewd publications. Since 2004, spokesman of the virtual Helmholtz institute „Ice cloud formation and dehydration at the tropical tropopause (centre tropical tropopause, ZTT)“, since 2004, spokesman of programme topic „Stratosphere and tropopause in a changing environment“ of Helmholtz programme „Atmosphere and climate“

Dr. Martina Krämer

Since 2001 Head of Cloud group at Forschungszentrum Jülich, ICG-I.
1997–2001 Research scientist at Forschungszentrum Jülich, ICG-I.
1992–1996 Postdoctorate fellow at University of Mainz, Institute of Physics of the Atmosphere.
1992 Doctorate in Meteorology from University of Mainz, Institute of Physics of the Atmosphere.

26 peer reviewed papers. Coordinator of CIRRUS I,II,III aircraft field experiments, Co-Pi of DFG research programs CAWSES, Co-PI of EU research projects TROCCINOX and SCOUT-O3, HGF project PAZI-1+2.

Selected publications

Krämer, M., Schiller, C., Ziereis, H., Ovarlez, J. and **H. Bunz** (2006): Nitric acid partitioning in cirrus clouds: the role of aerosol particles and relative humidity. Tellus B, Vol. 58, 141-147, doi:10.1111/j.1600-0889.2006.00177.x

MacKenzie, A.R. C. Schiller, Th. Peter, A. Adriani, J. Beuermann, O. Bujok, F. Cairo, T. Corti, G. DiDonfrancesco, I. Gensch, C. Kiemle, **M. Krämer**, C. Kröger, S. Merkulov, A. Oulanovsky, F. Ravegnani, S. Rohs, V. Rudakov, P. Salter, V. Santacesari9, L. Stefanutti, V. Yushkov (2006): Tropopause and hygropause variability over the equatorial Indian Ocean during February and March 1999. JGR, accepted.

Mangold, A., Wagner, R., Saathoff, H., Schurath, U., Giesemann, C., Ebert, V., **Krämer, M**. and **O. Möhler** (2005): Experimental investigation of ice nucleation by different types of aerosols in the aerosol chamber AIDA: implications to microphysics of cirris clouds. Meteorol. Z., Vol. 14, No. 4, 485-497.

Offermann, D.; Schäler,B.; **Riese,M**.; Langfermann,M.; Jarisch,M.; Eidmann,G.; Schiller,C.; Smit,H. G. J.; Read,W. G.,Water vapor at the tropopause during the CRISTA2 mission, J. Geophys. Res., 107, 8176, 10.1029/2001JD001303, 2002.

Riese, M.; Manney, G.L.; Oberheide, J.; Tie, X.; Spang, R., Küll, V.: Stratospheric transport by planetary wave mixing as observed during CRISTA-2, J. Geophys. Res., 107, 8179, 10.1029/2001JD000629, 2002.

Spang, R.; Eidmann,G.; **Riese,M**.; Offermann,D.; Pfister,L.; Wang,P.H., CRISTA observations of cirrus clouds around the tropopause, J. Geophys. Res., 107, 8174, 10.1029/2001JD000698, 2002.

Forschungszentrum Jülich, ICG-II
Prof. Dr. A. Wahner, Dr. Th. F. Mentel, Dr. Astrid Kiendler-Scharr

Expertise of Institute

The Institute for Chemistry and Dynamics of the Geosphere II: Troposphere (ICG-II) of has an over 25 year experience in the field of Atmospheric Chemistry. The focus of the research is to quantitatively understand the atmospheric transformation of trace compounds in gas- and particulate phase produced by human activities and natural processes and how they influence the chemical composition of the atmosphere and earth's climate. Experimental field studies, simulation experiments and model calculations are used to investigate the processes that control the chemical transformation, spatial distribution of trace compounds, and their ultimate removal from the atmosphere.

Contribution to the VI

Chemical characterization of CCN and coated IN at AIDA and LACIS
CCN Spectrometry at AIDA and LACIS
Process Studies of Formation and Transformation of CCN (and IN)

CV and expertise of leading scientists

Prof. Andreas Wahner

Since 200 Director of Institut für Chemie und Dynamik der Geosphäre II: Troposphäre, Forschungszentrum Jülich
1991-2001 Deputy of the director, Prof. Dr. D. H. Ehhalt
1988-2001 Head of the "Heterogeneous Chemistry" group at the FZJ, ICG-3
1983-1988 Research associate at CIRES and at NOAA ERL with Dr. C. Howard and Dr. A. R. Ravishankara
1983-1985 Research scientist at Fraunhofer Institut für Toxikologie und Aerosolforschung, Hannover
1984 Doctorate in Chemistry at the Ruhr-Universität Bochum

Over 52 of peer reviewed publications, lead author and reviewing editor of several IPCC reports, member in over 10 comitees, editor of J. Atmos. Chem.

Dr. Thomas Mentel

Since 2006 In charge of the "Aerosols" research section at the FZ-Jülich, ICG-II
Since 2001 Head of the "Heterogeneous Reactions" group at the FZJ, ICG-II
1991-2001 Research Scientist at the FZJ, ICG-3, with Prof. D.H. Ehhalt
1989-1991 Postdoctoral Fellow at Dept. of Chem. Princeton University with Prof. G. Scoles
1988 Doctorate in Physical Chemistry at Philipps University in Marburg with Prof. W.A.P. Luck

Over 40 publications, over 20 peer reviewed publications. Coordinator in EU Project CASOMIO and HECONOS (with Prof. A. Wahner), WP-leader and PI in EU integrated Project EUCAARI, Organized several aerosol sessions at AGU and EGU conferences.

Selected publications

Anttila, T., A. **Kiendler-Scharr**, R. Tillmann, and Th. F. **Mentel**, On the reactive uptake of gaseous compounds by organic-coated aqueous aerosols: Theoretical analysis and application to the heterogeneous hydrolysis of N2O5 . J. Phys. Chem. A (2006), (accepted)

Anttila, T., A. **Kiendler-Scharr**, Th. F. **Mentel** and R. Tillmann, Size dependent partitioning of organic material: direct evidence for the formation of organic coatings on aqueous aerosols, *J. Atm. Chem.*, 2006 (submitted)

Dinar, E., I. Taraniuk, E. Graber, S. Katsman, T. Moise, T. Anttila, Th. F. **Mentel**, and Y. Rudich, Cloud Condensation Nuclei Properties of Model and Atmospheric HULIS, *Atmospheric Chemistry and Physics Discussions*, 6, 1073-1120, 2006

Karl, M., T. Brauers, H.P. Dorn, F. Holland, M. Komenda, D. Poppe, F. Rohrer, L. Rupp, A. Schaub, and A. **Wahner**, Kinetic Study of the OH-isoprene and O3-isoprene reaction in the atmosphere simulation chamber, SAPHIR, Geophysical Research Letters, 31 (5), 2004.

Folkers, M., Th. F. **Mentel**, and A. **Wahner**, Influence of an organic coating on the reactivity of aqueous aerosols probed by the heterogeneous hydrolysis of N_2O_5, *Geophys. Res. Lett.*, **30**, 10.1029/2003GL017168, 2003

Leibniz-Institut für Troposphärenforschung (IfT)
Prof. J. Heintzenberg, Dr. F. Stratmann

Expertise of Institute

The IfT runs the Leipzig Aersol Cloud Interaction Simulator (LACIS), a unique facility for the study of aerosol cloud interactions. With LACIS, the IfT offers a facility for the investigation of complex phase transition processes such as particle/droplet hygroscopic growth, activation, and ice nucleation. Instruments and expertise regarding the production of well-defined multi-component, multiphase aerosol particles and their characterization are available. A coupled computational fluid dynamics (CFD) and particle/droplet dynamics model for interpretation of experimental data, development and test of microphysical expressions and parameterisations is available at IfT. Furthermore, the new LACIS building offers laboratory space for setup, calibration, etc. of guest experiments and instruments.

Contribution to the VI

LACIS laboratory experiments on CCN and IN efficiency of aerosols

Coupled CFD and particle/droplet dynamics modelling of particle/droplet growth and freezing

CV and expertise of leading scientists

Prof. Jost Heintzenberg

Since 1993	Professor in physics of the atmosphere at Leipzig University
Since 1993	Director and head of the Physics Section of the Leibniz-Institute for Tropospheric Research (IfT), Leipzig
1983-1993	Associate professor in chemical and physical meteorology at Stockholm University

Dr. Frank Stratmann

Since 1998	In charge of research group "Clouds and Radiation" at Leibniz-Institute-for-Tropospheric-Research, Leipzig
1994-1998	Research Scientist at Leibniz-Institute-for-Tropospheric-Research (IfT), Leipzig
1982-1994	Postdoctoral fellow at University of Duisburg
1992	Doctorate in Electrical Engineering from University of Duisburg

More than 50 peer-reviewed papers.

Selected publications

Heintzenberg, J. et al. (2006), Intercomparisons and aerosol calibrations of 12 commercial integrating nephelometers of 3 manufacturers. J. Atmos. Oceanic Technol.* accepted*.

Heintzenberg, J. et al. (2006), Aerosol number-size distributions during clear and fog periods in the summer high Arctic: 1991, 1996, and 2001.Tellus B* 58B*, 41-50.

Wex, H., Kiselev, A., **Stratmann, F**., Zoboki, J., **Heintzenberg, J.**, Brechtel, F. (2005), Measured and modeled equilibrium sizes of NaCl and (NH4)2SO4 particles at relative humidities up to 99.1%, J. Geophys. Res., 110(D21):Art. No. D21212 NOV 12.

Heintzenberg., J., Okada, K., Trautmann, T. & Hoffmann, P. (2004), Modeling of the signals of an optical particle counter for real non-spherical particles. Appl. Opt.* 43*, 5893-5900.

Stratmann, F., Kiselev, A., Wurzler, S., Wendisch, M., Heintzenberg, J., Charlson, R.J., Diehl, K., Wex, H., Schmidt, S. (2004) Laboratory studies and numerical simulations of cloud droplet formation under realistic super-saturation conditions, J. Atmos. Oceanic Technol., 21(6), 876-887.

Stratmann, F.,Siebert, H. Spindler, G., Wehner, B., Althausen, D.**, Heintzenberg, J.,** Hellmuth, O., Rinke, R., Schmieder, U., Seidel, C., Tuch, T., Uhrner, U., Wiedensohler, A., Wandinger, U., Wendisch, M., Schell, D., Stohl, A. (2003), New particle formation events in the continental boundary layer: First results from the SATURN experiment, Atmos. Chem. Phys., 3, 1445-1459.

Institute for Physics of the Atmosphere, Johannes-Gutenberg-University of Mainz and Department for Particle Chemistry, Max-Planck-Institute for Chemistry Mainz
Prof. S. Borrmann, Dr. J. Schneider, Dr. K. Diehl

Expertise of Institute

The Department of Particle Chemistry of the Max Planck Institute is structurally and conceptually linked to the Institute for Physics of the Atmosphere at the Johannes Gutenberg University in Mainz. The research of the group is focused on chemical composition and physical properties of aerosol and cloud particles. 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 facilty. In situ atmospheric measurements are performed on board of the converted Russian high altitude aircraft M-55 "Geophysika", as well as other research aircraft, ships and ground stations.

Contribution to the VI

Mass spectrometric in-situ, real-time chemical analyses of aerosol and small cloud residual particles.

Instrument development (e.g. holography) for ice and hydrometeor measurements in AIDA.

Wind tunnel experiments of IN efficiency in immersion and contact modes - single drop observations.

CV and expertise of leading scientists

Prof. Stephan Borrmann

2001-pres. Director of the Particle Chemistry Department at the MPI-C , Mainz, Germany.
2000-pres. Professor (C-4) Institute of Physics of the Atmosphere (IPA), University of Mainz.
1998-2000 Leader of the Aerosol Research Group, ICG-I, Research Center Jülich, Germany.
1993-1998 Physics Dept. of University of Mainz: "Habilitation" on aerosol and clouds in tropopause region
1991-1993 Postdoc at Atmospheric Technology Division, NCAR, Boulder, CO, USA.
1991 PhD at the University of Mainz, Physics Department.
1985-1986 Adjunct Research Instructor at the Naval Postgraduate School Monterey, CA, USA.

Dr. Johannes Schneider

2001–pres. Leader of research Group "Atmospheric Aerosol Chemistry" of the Particle Chemistry Department (S. Borrmann), Max Planck Institute for Chemistry, Mainz, Germany.
1998-2001 PostDoc at the Leibniz Institute for Atmospheric Physics, Kühlungsborn, Germany.
1998-1998 PostDoc at the Max Planck Institute for Nuclear Physics, Heidelberg, Germany.
1994-1997 PhD at the Max Planck Institute for Nuclear Physics, Heidelberg, Germany.

Selected publications

Kürten, A., J. Curtius, B. Nillius and **S. Borrmann**: Chracterization of an Automated, Water-based Expansion Condensation Nucleus Counter for Ultrafine Particles. Aerosol Science & Technology 39, 1174-1183, 2005.

Dusek, U., G. P. Frank, L. Hildebrandt, J. Curtius, **J. Schneider**, S. Walter, D. Chand, F. Drewnick, S. Hings, D. Jung, **S. Borrmann** and M. O. Andreae: Size matters more than chemistry for cloud nucleating ability of aerosol particles. Science 312, 1375-1378, 2006.

Curtius, J., R. Weigel, H.-J. Vössing, H. Wernli, A. Werner, C.-M. Volk, P. Konopka, M. Krebsbach, C. Schiller, A. Roiger, H. Schlager, V. Dreiling and **S. Borrmann**: Observations of meteoritic material and implications for aerosol nucleation in the winter Arctic lower stratosphere derived from in situ particle measurements. Atmospheric Chemistry and Physics 5, 3053-3069, 2005.

Diehl, K., S. Matthias-Maser, S.K. Mitra, and R Jaenicke, 2002: The ice nucleating ability of pollen. Part II: Laboratory studies in immersion and contact freezing modes. *Atmos. Res.*, **61**, 125-133.

Diehl, K., M. Simmel, and S. Wurzler, 2006: Numerical simulations of the impact of aerosol particle ice nucleation efficiencies on drop freezing. *J. Geophys. Res.* **111,** D07202, doi:10.1029/2005JD005884.

Schneider, J., **S. Borrmann**, A. G. Wollny, M. Bläsner, N. Mihalopoulos, K. Oikonomou, J. Sciare, A. Teller, Z. Levin, D. R. Worsnop, Online mass spectrometric aerosol measurements during the MINOS campaign (Crete, August 2001), Atmos. Chem. Phys., 4, 65-80, 2004.

Schneider, J., N. Hock, S. Weimer, **S. Borrmann**, U. Kirchner, R. Vogt, V. Scheer, Nucleation particles in Diesel exhaust: Composition inferred from in-situ mass spectrometric analysis, Environ. Sci. Technol., 39, 6153-6161, 2005.

University of Frankfurt, Institut für Atmosphäre und Umwelt
Prof. U. Schmidt, Dr. H. Bingemer

Expertise of Institute

The institute has a long experience in the measurement of cloud-active aerosols, ice nuclei and cloud condensation nuclei. New and improved technologies for ice nuclei measurement are currently under development. A continuous flow mixing chamber for the fast in situ-detection of ice nuclei (FINCH = Frankfurt Ice Nuclei Chamber) has been set up (Bundke et al., 2005a, b). In addition we have improved a static vacuum diffusion chamber for the semi-automatic “activation” of ice nuclei collected on filters. The former will address basically the same nucleation modes as the filter method, but it is aimed to tune this chamber to addressing also the immersion- and contact-freezing modes.

Contribution to the VI

Analysis of ice nucleating efficiency of test-aerosols at the AIDA facilities, as well as of natural aerosols sampled from the atmosphere; verification and intercalibration of ice nuclei detection techniques during intercomparison workshop held by the VI; analysis of the natural variability (i.e. a climatology) of IN number concentration in air masses over Central Europe and of their effect on precipitation development (jointly with Tel Aviv University)

CV and expertise of leading scientists

Prof. U. Schmidt

2004–pres. Speaker of DFG Sonderforschungsbereich 641
1995–pres. Full Professor for Atmospheric Physics, University of Frankfurt

1976-1995 Research Scientist, Deputy Director, ICG, Research Centre Jülich
1974-1976 Research Scientist, Air Chemistry Dept., MPI for Chemistry, Mainz
1974 Doctorate in Meteorology from University of Mainz

Dr. H. Bingemer
1990-pres. Senior Scientist (Akademischer Oberrat), University of Frankfurt
1987-1990 Research Scientist, Biogeochemistry Dept., MPI for Chemistry, Mainz
1984-1987 Post-doctorate at Air Chemistry Dept., MPI for Chemistry, Mainz
1984 Doctorate in Meteorology from University of Frankfurt

Selected publications

Bundke, U., T. Wetter, **H. Bingemer**: Development of a new fast ice nuclei counter: The Frankfurt Continuous Flow Mixing Chamber, Geophysical Res. Abstracts, 7, 05119, EGU, 2005a..

Bundke, U., T. Wetter, **H. Bingemer**: Development of a new fast ice nuclei counter: The Frankfurt Continuous Flow Mixing Chamber, Proc. Europ. Aerosol Conf., Gent, 2005b.

Notholt, J., **Bingemer, H**. (lead authors) et al.: Precursor gas measurements, SPARC asessment of stratospheric aerosol properties, Chapt.2., WCRP-124, 2006.

Otto, P., H.-W. Georgii and **H.G. Bingemer**, Development and first application of a 3-stage continuous flow CCN counter, in: Dynamics and chemistry of hydrometeors, R. Jaenicke (Ed.), Wilex-VCH, 306-314, 2001.

Otto, P., H.-W. Georgii and **H.G. Bingemer**, A new 3-stage continuous flow CCN counter, Atm. Res., 61, 299-310, 2002.

Ruprecht-Karls-Universität Heidelberg, Physikalisch-Chemisches Institut
Hochschul. Doz. Dr. V. Ebert

Expertise of Institute

Laser-based gas-phase diagnostic techniques (Laser induced fluorescence, excimer laser induced fragmentation fluorescence, non-linear frequency mixing, Raman, CARS, absorption spectroscopy) for gas-kinetic studies (e.g. NO_x-formation), technical combustion processes (engines, power plants, turbines) and environmental applications (water sprays for combustion suppression, stratospheric water budget, homogenous/heterogeneous cloud formation, aerosol-cloud interaction).

Contribution to the VI

Fast, selective and sensitive measurement of the water vapour, resp. H_2O supersaturation, within the cloud by open-path diode laser *in situ* absorption spectroscopy. Additionally, precision measurements of spectral line parameters, special algorithms for absolute and calibration-free *in situ* water measurements, possible extension to isotope selective water detection.

CV and expertise of leading scientists

Hochschul. Doz. Dr. Volker Ebert
since 2005 Member of the Post-Graduate-Program (DFG-Graduiertenkolleg 1114) “Optical diagnostics for the characterization of transport processes across interfaces”.
since 2003 Associate Professor (Hochschuldozent), Phys. Chem. Inst., Univ. Heidelberg.
2003 Tenure (Habilitation) in Physical Chemistry, Univ. Heidelberg.
2001-2003 Adjunct Professor (Privatdozent), Phys. Chem. Inst., Univ. Heidelberg.
since 1998 1-2 research visits per year at the Naval Research Laboratory, Washington DC.
1995-2000 Organization of the IR-Spectroscopy group at the Heidelberg Academy of Sciences.
since 1993 Set-up/Management of the research group *In situ Process diagnostics and Trace Gas Detection*, Phys. Chem. Inst., Univ. Heidelberg.
1997 Doctorate in Chemistry, Univ. Heidelberg, supervised by Prof. Dr. J. Wolfrum.

125 publications (52 peer reviewed, 6 book contrib., 3 patents pend.), coordinator of the joint BMBF projects „Diode lasers in external resonators“ and „Gas analysis with NIR diode lasers“, Vice Chair of the "OPTAM" committee in the German Engineering Society (VDI), Co-initiation and -organization of the VDI-conferences „Application and Trends in Optical Analysis Technology“ (2000, ‘02, ‘04 and ‘06), Program Chair “Laser Applications to Chemical, Security and Environmental Analysis, 2007”.

Selected publications

V. Ebert, H. Teichert, C. Giesemann, **H. Saathoff**, U. Schurath, “Fiber-coupled In situ-Laser Absorption Spectrometer for the selective Detection of Water Vapor Traces down to the ppb-Level ”, *Techn. Messen* 72, 1, 23-30 (2005)

A. R. Awtry, J. W. Fleming, and **V. Ebert**, "Simultaneous diode-laser-based in situ measurement of liquid water content and oxygen mole fraction in dense water mist environments," *Opt. Lett.* 31, 900-902 (2006)

W. Gurlit, J.P. Burrows, R. Zimmermann, U. Platt, C. Giesemann, J. Wolfrum, **V. Ebert**, "Light-Weight Diode Laser Spectrometer 'CHILD' for Balloon-Borne Measurements of H_2O Vapor and CH_4", *App. Opt.* 44, 91-102, 2005

O. Möhler, S. Büttner, C. Linke, **M. Schnaiter**, **H. Saathoff**, **O. Stetzer**, R. Wagner, **M. Krämer**, A. Mangold, **V. Ebert**, and U. Schurath, "Effect of sulfuric acid coating on heterogeneous ice nucleation by soot aerosol particles", *J. Geophys. Res.*, 110, D11210, doi:10.1029/2004JD005169. (2005),

A. Mangold, R. Wagner, **H. Saathoff**, U. Schurath, C. Giesemann, V. Ebert, **M. Krämer**, **O. Möhler**, "Experimental investigation of ice nucleation by different types of aerosols in the aerosol chamber AIDA: implications to microphysics of cirrus clouds", *Meteorologische Zeitschrift*, Volume 14, Number 4, August 2005, pp. 485-497(13)

ETH Zürich, Institute for Atmospheric and Climate Science
Prof. U. Lohmann, Dr. O. Stetzer

Expertise of Institute
Laboratory studies on ice nucleation; field experiments on aerosol and ice nuclei chemical composition; climate modelling of aerosol-cloud-interactions

Contribution to the VI
Laboratory studies on ice nucleation; climate modelling of aerosol effects on mixed-phase clouds

CV and expertise of leading scientists
Prof. Ulrike Lohmann

2004-pres. Full Professor in Atmospheric Science at ETH Zurich, Switzerland
2001-2004 Associate Professor in Atmospheric Science at Dalhousie University
2002-2004 Canada Research Chair Tier II at Dalhousie University
2001-2003 Adjunct Professor in Lamont-Doherty Earth Observatory, Columbia University, New York
1997-2001 Assistant Professor in Atmospheric Science at Dalhousie University,
1996-1997 Postdoctoral fellow at the Canadian Centre for Climate Modelling and Analysis at University of Victoria
1996 Doctorate in Meteorology from Hamburg University/Max Planck Institute for Meteorology

Over 80 peer-reviewed papers
Lead author for chapter 7 (Couplings Between Changes in the Climate System and Biogeochemistry), the technical summary and the summary for policy makers of the Forth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) scientific report.
Editor for Atmospheric Chemistry and Physics (ACP).
Guest editor for Atmospheric Research for a special issue from the 14th International Conference on Clouds and Precipitation, 2005.
Member of the Editorial Advisory Board for Atmospheric Environment.
Member of the GEWEX Radiation Panel (GRP).
Member of the Commission for Atmospheric Chemistry and Global Pollution (CACGP) of the International Association for Meteorology and Atmospheric Science (IAMAS).
Member of the International Commission of Clouds and Precipitation (ICCP) of IAMAS.

Dr. Olaf Stetzer

2004–pres. Research Associate at ETH Zurich, Switzerland
2004 Visiting Scientist at Dalhousie University, Halifax, Canada
2001–2004 PostDoc at IMK-AAF, Research Centre Karlsruhe, Germany
1998–2001 Doctorate in Chemistry at Univerity of Mainz/European Institute for Transuranium Elements in Karlsruhe, Germany

Selected publications
Cziczo, D. J. et al., A Method for Single Particle Mass Spectrometry of Ice Nuclei, *Aero. Sci. Tech.*, 37, 460-470, 2003.

Cziczo, D. J., D. M. Murphy, P. K. Hudson, and D. S. Thomson, Single particle measurements of the chemical composition of cirrus ice residue during CRYSTAL-FACE, *J. Geophys. Res*., 109, D04201, doi:10.1029/2003JD004032, 2004.

DeMott, P. J. et al., Measurements of the concentration and composition of nuclei for cirrus formation, *P.N.A.S.,* 100, 14655-14660, 2003.

Lohmann, U. and **K. Diehl**, Sensitivity studies of the importance of dust ice nuclei for the indirect aerosol effect on stratiform mixed-phase clouds, J. Atmos. Sci. 63, 968-982, 2006.

Lohmann, U. and J. Feichter, Global Indirect Aerosol Effects: A Review, Atmos. Chem. Phys. 5, 715-737, 2005.

Lohmann, U., Possible aerosol effects on ice clouds via contact nucleation, J. Atmos. Sci. 59, 647-656, 2002.

Salam, A., **U. Lohmann**, B. Crenna, G. Lesins, P. Klages, D. Rogers, R. Irani, A. MacGillivray and M. Coffin, Deposition ice nucleation studies of mineral dust particles with a new Continuous Flow Diffusion Chamber. Aerosol Sci. Tech. 40, 134-143, 2006.

University of Hertfordshire (Uni-HS), Science and Technology Research Institute (STRI)
Prof. P. H. Kaye, Dr. Z. J. Ulanowski

Expertise of Institute
Instrumentation for atmospheric aerosol and cloud measurement, laboratory and theoretical studies of scattering properties of atmospheric ice particles and aerosols.

Contribution to the VI
Provision of instruments for ice and aerosol particle shape measurement, measurement and modelling of scattering and depolarisation properties of ice and aerosol particles, provision of ice analogues for the calibration of AIDA instruments, interpretation of data from AIDA instruments.

CV and expertise of leading scientists
Prof. Dr. Paul H. Kaye
Head of STRI, leader of Particle Instruments Research Group.
1998 Co-director of Science and Engineering Research Centre, UniHS
1993 Professor
1990 Head of Engineering Research and Development Centre, UniHS
1978 PhD in Physics, CNAA.
Led the development of many instruments for aerosol measurement, among them the Aerosol Shape Analyser (ASPECT), the Small Ice Detector (SID 1, 2, 2H, 3 and PPD), a single-particle multichannel bio-aerosol fluorescence sensor (WIBS).

Dr. Z. J. Ulanowski
Leader of Light Scattering Research Group.
1998 Senior Research Fellow, UniHS.
1988 Doctorate in Physics, CNAA.
Among recent achievements relevant to the VI are: an electrodynamic trap for studying single microparticles, a laser diffractometer for light scattering measurements on single trapped microparticles, measurement of the scattering asymmetry parameter of a single microparticle, analogues for atmospheric ice crystals, Single-Particle Raman Spectrometer (SPaRS), a technique for the measurement of light scattering from single microparticles in randomized orientation, new theory of scattering on faceted objects such as ice crystals.

Selected publications
Clarke A.J.M., **E. Hesse**, **Z. Ulanowski**, and **P.H. Kaye** 2006 A 3D implementation of ray tracing combined with diffraction on facets. *J. Quantit. Spectr. Rad. Transf.* **100**, 103.

Hesse E. and **Z. Ulanowski** 2003 Scattering from long prisms using ray tracing combined with diffraction on facets. *J. Quantit. Spectr. Rad. Transf.* **79-80C**, 721-732.

Hirst E., **Kaye PH.**, Greenaway RS., Field P., and Johnson DW. 2001 Discrimination of micrometre-sized ice and supercooled droplets in mixed-phase cloud. *Atm. Env.* **35**, 1, 33-47.

Kaye P. H., Barton J. E, Hirst E., and Clark J. M. 2000 Simultaneous light scattering and intrinsic fluorescence measurement for the classification of airborne particles. *Appl. Opt.* **39**, 3738-3745.

Ulanowski Z., E. Hesse, P.H. Kaye and Anthony J. Baran 2006 Light scattering by complex ice-analogue crystals. *J. Quantit. Spectr. Rad. Transf.* **100**, 382.

Tel Aviv University (Uni-TA), Cloud and Precipitation Physics Laboratory
Prof. Zev Levin

Expertise of Institute
Field measurements of aerosols and clouds, modelling of cloud processes using a 2D cloud model with detailed microphysics, cloud field simulations using RAMS (Regional Atmospheric Modelling System)

Contribution to the VI
Helping parameterize ice and drop formation based on laboratory measurements and simulations to evaluate these changes on cloud processes.

CV and expertise of Prof. Zev Levin

Education and professional experience:

1966 BS (honour) in Physics, California State University, Los Angeles California.
1970 PhD in Atmospheric Sciences, The University of Washington, Seattle, Washington.
1986-1987 Chairman Dept. of Geophysics & Planetary Sci., Tel Aviv University.
1987-1992 Dean of Research and Vice President of Research, Tel Aviv University.
1992-1993 NRC Associateship - Senior scientist - NASA Goddard Space Flight Center.
1994 The J. Goldemberg Chair in Atmospheric Physics, Tel Aviv University.
1999 Visiting Professor - Institute for Atmospheric Physics, ETH, Zurich, Switzerland.
2000-2004 Director of The Porter School for Environmental Studies. Tel Aviv University.
1999-2004 PI of The Israeli First Astronaut Experiment on board the space shuttle Columbia.

Committees (since 2000):

1995-2005 WMO Committee on Cloud Physics, Chemistry and Weather Modification.
Since 1991 Tel Aviv University Representative to the UCAR International Affiliate Program.
1997-2004 President, Israeli Association for Aerosol Research.
1999-2002 Member of the AMS committee on weather modification.
Since 1998 Member of the International Commission on Cloud Physics.
2000-2004 Vice President of the International Commission on Cloud Physics.
Since 2000 Scientific Board of the Institute for water research, Technological Institute, Haifa, Israel.
Since 2001 Chairman of Israel Academy of Science Committee for IGBP.
Since 2003 Chairman and Chief Editor, IUGG/WMO group on aerosols-precipitation interactions.
Since 2004 Member of Scientific Advisory Board, Max Planck Institute for Chemistry, Mainz.
Since 2004 President of International Commission on Clouds and Precipitation.

Awards:

1981 NRC Associateship -Senior scientist - NASA Ames Research Center.
1985 ASEE-NASA - Stanford Fellowship.
1989 Japan Society for the Promotion of Science - A Visiting Distinguished Scientist.
1992 NRC Associateship - Senior scientist - NASA Goddard Space Flight Center.
1994 Chair Professor, J. Goldemberg chair in Atmospheric Physics, Tel Aviv University.
1997 The Landesbausparkassen Baden-Württemberg Prize on Environment and life, University of Konstanz.

Selected publications

Yin, Y., Z. **Levin, T. G**. Reisin and S. Tzivion,: The effects of giant cloud condensation nuclei on the development of precipitation in convective clouds - A numerical study. Atmos. Res. 53, 91-116, 2000.

Wurzler, S., T. G. Reisin and **Z. Levin**: Modification of mineral dust particles by cloud processing and subsequent effects on drop size distributions. J. Geophys. Res. 105 , 4501, 2000.

Krichak, S. O. **Z. Levin**: On the cloud microphysical processes during the November 2, 1994 hazardous storm in the southeastern Mediterranean as simulated with a mesoscale model. Atmos. Res., 53, 63-89, 2000.

Yin, Y., S. Wurzler, **Ze. Levin** and T. Reisin: Interactions of mineral dust particles and clouds: Effects on precipitation and cloud optical properties. J. Geophys. Res., 107(D23), 4724, 2002.

Israelevich PL, Ganor E, **Levin Z,** Joseph JH.: Annual variations of physical properties of desert dust over Israel, J. Geophys. Res. -Atmospheres, 108 (D13): art. no. 4381 Jul. 5 2003

Levin, Z., A. Teller, E. Ganor, B. Graham, M. O. Andreae, W. Maenhaut, A. H. Falkovich and Y. Rudich: Role of aerosol size and composition in nucleation scavenging within clouds in a shallow cold front. J. Geophys. Res. – Atmospheres, 108 (D22), 4700, doi:10.1029/2003JD003647, 2003.

Levin, Z., A. Teller, E. Ganor and Y. Yin, On the interactions of mineral dust, sea salt particles and clouds – A Measurement and modeling study from the MEIDEX campaign, J. Geophys. Res. D20202, doi:10.1029/2005JD005810, 2005.

Teller A. and **Z. Levin,** The effects of aerosols on precipitation and dimensions of subtropical clouds; a sensitivity study using a numerical cloud model. Atmos. Chem. Phys. 6, 67–80, 2006.

Jiang, H., H. Xue, A. Teller, G. Feingold, **Z. Levin**, Aerosol Effects on the Lifetime of Shallow Cumulus. Geophys.. Res. Lett., In Press, 2006.