First Annual Meeting Particles and Cirrus Clouds (PAZI-2)

Oberpfaffenhofen, IPA, 05-APRIL-2004

- **Goals**

report on work status

inform external project partners

initiate further subtask meetings

start preparation of airborne campaigns

- **Agenda**

09:30 Welcome and Introduction (B. Kärcher)

09:45 Soot emissions from jet engines (P. Gerlinger)
10:00 Global aircraft soot inventory (M. Plohr)

10:15 Discussing HAP 1

10:30 CIRCLE field campaigns (A. Petzold)
10:50 Aerosol precursor gases - SO2 instrument (H. Schlager)
11:00 Global remote sensing (H. Mannstein)
11:15 AIDA freezing experiments (U. Schurath, FZK)

11:30 Discussing HAP 2
11:45 Lunch, Coffee

13:00 Aerosol/cirrus modeling (B. Kärcher)
13:15 Cirrus and radiation (B. Mayer)
13:30 Contrail and cirrus coverage (K. Gierens)
13:45 Global climate modeling (J. Hendricks)

14:00 Discussing HAP 3 and Conclusions

14:30 Adjourn

- **Action items**

Submeeting consolidating ECHAM work plan (already done on 31-MAR-2004 at OP)

Submeeting addressing laboratory aspects of soot processes (Zellner, Schurath, Arnold, Wahl and others); will be organized by P. Gerlinger (DLR-VT)

Submeeting between U MZ / MPI MZ with ITM Stockholm on CVI / AMS issues; will be organized by J. Schneider (MPI-Chemie)

Next PAZI-2 annual meeting will include partner presentations; agenda will be ordered to emphasize science interaction between work packages

- **Further information**

ACCENT European Network of Excellence, with activities connected to PAZI-2 covered by various subgroups (contact: Claire Granier)

- **Detailed report**

AP 1.1 Measurements and modeling of soot formation

- Laboratory experiment soot oxidation and modeling

expand data base for modeling with laminar flame experiments;
study in detail soot oxidation: create well-defined soot size distribution (McKenna burner, D~10-100 nm) and track during oxidation with SPMS probe

- Experiments semi-technical scale

measurements at the high pressure combustion chamber test rig HBK-S built up in PAZI-2;
Laser optical assess to primary combustion zone anbd to secondary air injection, possibility to probe in and end the end of the combustor

- Numerical simulations

improvement of flamelet / soot approach;
detailed chemistry in THETA-code (solve transport for each species);
assumed multivariate beta PDF approach for turbulence closure;
soot caluclation directly in THETA

- Measurements in real engines and combustors

SMPS probe measurements revealing size distribution of soot e.g., at different power settings (take-off, cruise, descent);
continue with measurements in concert with industry partners (Robin DR400180; staged combustor of RR Deutschland)

far goal: form basis for soot reduction tools and enable robust emission simulations

AP 1.2 Global aircraft soot inventory

- Further development of semi-empirical correlations between engine and predicted soot parameters beyond smoke number

Developed soot mass correlation revealed good correlation with measured values (+/- 0.03 g soot per kg fuel, i.e., measurement uncertainty); soot number correlations must be synchronized with physical and empirical correlations and are more uncertain; improvement with data from new measurements (engines and field)

- Produce updated 4D emission inventory for soot mass and number concentrations to replace outdated 1992 data set (with DLR VF-VL)

Inventory procedure comprises several stages:
acquire aircraft movements (real flight paths that often deviate from great circles, time-resolved data and finer spatial resolution 1 x 1 deg x 1 km x 1 hr); representative aircraft engines selection; thermodynamic engine cycle caluclations; applying soot correlation method; create inventory tool (FATE, four dimensional calculations of aircraft trajectories and emissions)

AP 2.1 CIRCLE field campaigns

- 1/ Search for experimental evidence for heterogeneous freezing in ice-supersaturated regions on natural and aviation-related aerosol particles to constrain the role of heterogeneous ice nuclei in cirrus formation

microphysical/chemical characterization of interstitial and activated aerosol particles and precise water measurements required to probe ice initiation stage in background/perturbed conditions

- 2/ Quantification of optical and radiative properties of cirrus ice crystals for improving retrieval algorithms in remote sensing and parameterizations used in global models

microphysical/optical characterization of ice crystals, size distribution, morphology; satellite retrievals from MSG (first choice) or ENVISAT AATSR (second choice); measurements preferably over water without direct emissions (dust, biomass, PBL plumes)

For further details, see minutes of CIRCLE preparatory meeting

AP 2.2 Aerosol precursors and SO_2

- Joint devlopment of a compact airborne ion trap CIMS instrument for SO2 detection

Stengthen collaboration DLR-IPA / MPI-Heidelberg; detection limit of commerically available instruments is too high (0.5 ppbv) for use in UT measurements; in-situ calibration as a novel feature

- Deployment of new instrument during airborne campaigns

Knowledge of UT SO2 concentrations and origin is very poor; aircraft contribution cannot accurately be determined; first test of prototype during ITOP field measurement; miniaturization for use on aircraft is major effort

- Analysis of data with respect to new aerosol particle formation

Combine with CN cascade; focus on nucleation and in particular growth of ultrafine particles; add calibration sources for other molecular species for measuring non-S components

AP 2.3 Global remote sensing

Main concern are contrails and their transition into contrail cirrus

Counting only linear contrails underestimates aircraft-induced cloudiness; transition is difficult to track with in situ measurements unless satellites could be used online as pathfinders; here, a remote sensing based-approach is chosen, combined with flight routing information

Robust detection of linear contrails with previous developed algorithms; however, during wind shear-induced spreading, algorithms will no longer apply;

Use high resolution images from polar orbiters to detect linear contrails and combine them with MSG to track spreading

Global analysis of AVHRR data (e.g., cloud cover) within NOAA/DLR collaboration possible

AP 2.4 Freezing experiments in AIDA

Main focus on ice nucleation properties of soot and other aerosols with emphasis on chemical composition and aging processes

AIDA provides unique environment to study systematically the impact of soot properties of supersaturation, ice yield, crystal morphology

One important new feature is the TDL water vapor measurement combined with chilled mirror frost point for total water or, alternatively, FISH (FZJ); PhD-thesis is devoted to the development of a new 3D ice particle imager with 1 μm resolution (5 times better than commercial imager used now)

FTIR spectrometry has been further developed for accurate tracking of optical depth of the ice phase and inferring ice water content; use of Mie and T-matrix calculations

CAST burner has been modified to produce soot particles, allows variation of yield, ratio EC/OC (chemical composition) and size distribution by varying air/fuel (C/O) ratio; key preliminary result is that ice particle nucleation is a strong function of the OC content on soot particles

Link to the laboratory studies in Essen:
kinetics of adsorption of water on soot and ice nucleation properties of soot and dust particles is investigated experimentally with a Knudsen cell

- focus on initial stages of water interaction with heterogeneous surfaces
- study systematically effect of surface coatings
- control soot combustion conditions with premixed laminar burner; DRIFT spectra from soot surfaces to detect composition and surface structure

AP 3.1 Aerosol/cirrus modeling

- Extending parameterization of cirrus cloud formation for use in climate models

Competition between multiple ice-forming aerosol particle types;
Subgrid-scale temperature fluctuations

- Understanding the indirect aerosol effect on cirrus clouds

Extend trajectory process model APSC*m* to a 1D column version;
Interpret lab and field measurements (CIRCLE, AIDA, ...)

- Analyzing trace gas adsorption and trapping in ice crystals

In depth analysis of CRYSTAL/FACE data with emphasis on HNO_3;
Physical model for gas burial in growing ice crystals

Link to laboratory studies by AWI:
FTIR spectroscopy and quantum-mechanical calculations of trace gas interactions with ice surfaces, including the systems O3 + ice, leading to H2O2; SO2 and SO3 + ice

AP 3.2 Cirrus and radiation

- Validation of new remote sensing methods for optical/microphysical cirrus properties

Aim at implementing a consistent parameterization for the entire solar and thermal spectral range, for radiance and flux computations in libRadtran

Focus on MSG (SEVERI, GERB), routine operations since January 2004; first products available at DLR-IPA; optical thickness and effective radius can be derived and algorithm will be improved during the project

- Interpretation of remote sensing with respect to radiative forcing in cirrus and contrails and improve radiation parameterization of cirrus in ECHAM

Currently used in ECHAM and other global models: Mie calculation for ice spheres, empirical correction factor for asymmetry parameter, original parameterization not suited for thin cirrus

Plan is to couple of radiation physics to ice cloud microphysics and validate radiation scheme with libRadtran

AP 3.3 Contrail and cirrus coverage

- Preparatory work on ice supersaturation in the ECMWF forecast model

Cloud cover is a prognostic variable in the Tiedtke stratiform cloud scheme, this has been adjusted to allow supersaturation as well as cloud dissipation (at subsaturations) to occur

- Implement contrail cover in ECMWF model building on a Gaussian plume diffusion model

Main spreading mechanism of persistent contrails is wind shear; need to superimpose effects of multiple contrails on fractional coverage within a model grid box (effects of overlap and horizontal advection); back-up development of a prognostic parameterization for coverage due to contrail-cirrus with cloud-resolving cirrus simulations of the contrail-to-cirrus transition

AP 3.4 Global climate modeling

Quantify global impacts of aviation on cirrus microphysics and coverage and provide new estimate for climate impact

- Update emission inventories

Aviation: BC mass and number inventory for 2000 or 2002; update surface sources of various aerosol types within AEROCOM activity

- Aerosol module and radiation in ECHAM5 and model validation

Aerosol size distributions and composition now available with modal aerosol module MADE (alternatively M7 maintained by MPI-Hamburg); needs to be extended to cover UTLS region properly

Parameterization of subgrid-scale cirrus and including contrail dispersion; new radiative transfer parameterization taking microphysical variability into account

Model validation in regard to freezing properties of ice nuclei from CIRCLE and AIDA; aerosol from AEROCHEM, CARIBIC, SO2 measurements; contrail dispersion from AP 2.3

- Final simulations

Require careful set-up of freezing scenarios with and without aircraft based on then still existing uncertainties

OP, 06-APR-2004, B. Kärcher