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Initiation of convection and the microphysical properties of clouds in orographic terrain: AMF + COPS

Volker Wulfmeyer and Andreas Behrendt, Institute of Physics and Meteorology, University of Hohenheim, Stuttgart, Germany

Susanne Crewell, Meteorological Institute, University of Munich, Germany

Richard Ferrare, NASA Langley Research Center, USA

Jost Heintzenberg, Institute for Tropospheric Research, Leipzig, Germany

Anthony Illingworth, Department of Meteorology, University of Reading, UK

Alexander Khain and Mark Pinsky, Hebrew University of Jerusalem, Israel

Christoph Kottmeier, Institute for Meteorology and Climate Research, Karlsruhe Research Center, Germany

Ulrike Lohmann, Swiss Federal Institute for Technology, Zurich, Switzerland

Herman Russchenberg, Delft University of Technology, The Netherlands

David D. Turner, Pacific Northwest National Laboratory, Richland, USA

Ed Westwater, University of Colorado, Boulder, USA

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PQP

Praecipitationis Quantitativae Praedictio

Content

1. Abstract

We propose the deployment and operation of the ARM Mobile Facility (AMF) during the Convective and Orographically-induced Precipitation Study (COPS) in the Black Forest area in summer 2007. The COPS region can be characterized by significant orographic precipitation with most of the summertime precipitation being convective. Due to major problems in predicting this type of precipitation the area was chosen as a natural laboratory for convection during the Intensive Observations Period (IOP) of the German priority program on Quantitative Precipitation Forecasting (PQP) funded for a 6 year period by the German Research Foundation (DFG). The aim is to identify the reasons of deficiencies in QPF and to improve the skill of mesoscale model forecasts with respect to precipitation. During the COPS experiment, large efforts will be put on observing the 4 dimensional state of the atmosphere from the pre-convective environment, to the initiation of convection, to the formation of clouds, to the development and decay of precipitation. For this purpose, measurements from several super sites (similar to the AMF) within an area of about 100x100 km^2 will be combined with satellite and radar data. At the super sites, a number of new scanning remote sensing instruments (cloud radar, lidar, microwave radiometer) will be deployed.

In order transfer the COPS results to a larger scale a General Observations Period (GOP) of the PQP will cover the area of central Europe and the full year 2007. Here close cooperation with the CloudNET project (stations Cabauw, Chilbolton and Lindenberg) will take place to derive a set of cloud microphysical parameters using novel synergetic algorithms and to compare those with numerical modeling results. For an improved connection between COPS and the GOP we are requesting continuous measurements of the AMF for a duration of 9 months at a special observation site in the COPS area where often initiation of convection and cloud formation can be expected. As COPS and the GOP have an open data policy, these data are available for all collaborators.

The following science questions shall be investigated by combining the AMF, the COPS, the GOP and the CloudNET data set:

1) **What are the processes responsible for the formation and evolution of convective clouds in orographic terrain?**

2) **What are the microphysical properties of orographically induced clouds and how do these depend on dynamics, thermodynamics, and aerosol microphysics?**

3) **How can convective clouds in orographic terrain be represented in atmospheric models based on AMF, COPS, and GOP data?**

To answer these science questions the observations (ground-based, air- and satellite borne) will be strongly linked with atmospheric models ranging from detailed cloud microphysical models over state-of-the art mesoscale models used in short-range weather prediction to General Circulation models (GCM). Using this set of tools we will investigate how representative are the observations of an atmospheric column by the AMF and the other CloudNET stations for a model grid box (from about 2 to 200 km) in orographic terrain.

The PQP program is coordinated with other international research programs like the MAP Forecast Demonstration Project (FDP) and THORPEX of the World Weather Research Program (WWRP). A strong collaboration between modelers, instrument PIs, weather services within international research programs and organizations has been established. Consequently, the PQP community will provide and study unique data sets of observations and model results for addressing the science questions above.

2. Project Description

2.1 Scientific Background

2.1.1 Motivation of the PQP program

Water is the prerequisite for the major processes of life. The atmosphere regulates the availability of water above all through precipitation. Therefore, predictability of the atmosphere in general and of precipitation in particular is of extraordinary economical and social significance. Its improvement represents a task of crucial importance for our future existence. Agriculture and water resources management, air and shipping traffic, road transport and energy economy directly depend on the state of the atmosphere. Damage caused by extreme precipitation events is extremely costly for the budgets of industry, national governments and international organizations. People affected by extreme precipitation events often face economic ruin.

Advances in meteorological forecasting methods and observation systems resulted in a sustained increase in the quality of short- and medium-range weather forecast, e.g. for temperature and wind, in the past years. In contrast, precipitation forecasts still have the same deficiencies known for about 10 years (Ebert et al., 2003). Also research at the German Meteorological Service (DWD) showed that in the course of the past 16 years there has been no improvement in the ability of models to forecast whether precipitation will fall in a certain area or not (precipitation yes/no) (Hense et al., 2004). Ebert et al. (2003) as well as Fritsch and Carbone (2004) demonstrated that persistent deficiencies in quantitative precipitation forecasts are a problem for all weather services.

To address this urgent issue, a research program on Quantitative Precipitation Forecasting (QPF) has been initiated in Germany, which is called Precipitationis Quantitativae Predictio (PQP). PQP has the following overarching scientific objectives:

I To identify the physical and chemical processes responsible for deficits of QPF

II To explore and to apply existing and new data sets for improved representation of relevant processes

III To determine the predictability of precipitation by statistical-dynamical analyses

The program has been started in April 2004 and has a duration of 6 years. Details on PQP are found at http://www.meteo.uni-bonn.de/projekte/SPPMeteo/.

2.1.2 Analyses of model deficits

Precipitation is especially difficult to model because it results from a complex chain of events with timescales much shorter than those of atmospheric flow systems and with relatively small spatial dimensions. Almost all spatial and temporal scales are involved in precipitation events and need to be treated adequately in atmospheric models. The importance of addressing the whole process chain to improve QPF was pointed out by Fritsch and Carbone (2004), who argue for an improved knowledge of the mesoscale structure of the environment, an adequate understanding and representation of cloud-scale and microphysical processes, as well as a realistic treatment of certain sub cloud-scale processes such as moist turbulence.

Detailed statistical analyses of weather forecast centers revealed that mesoscale model deficiencies are particularly large over low mountains (e.g., DWD, 2001) and concern the following aspects:

- too frequent forecasts of weak precipitation (e.g., Ebert et al., 2003),
- large errors for strong precipitation /flood forecast (e.g., Zängl, 2004 and reference on WMO 2004 cloud modeling workshop),
- wrong positioning and onset of convective precipitation (e.g.,Weckwerth and Parsons, 2005 with further references),

- enhanced windward/leeside precipitation differences (see Fig.1),
- incorrect representation of the diurnal cycle of convection and precipitation (e.g., Bechtold et al., 2004).

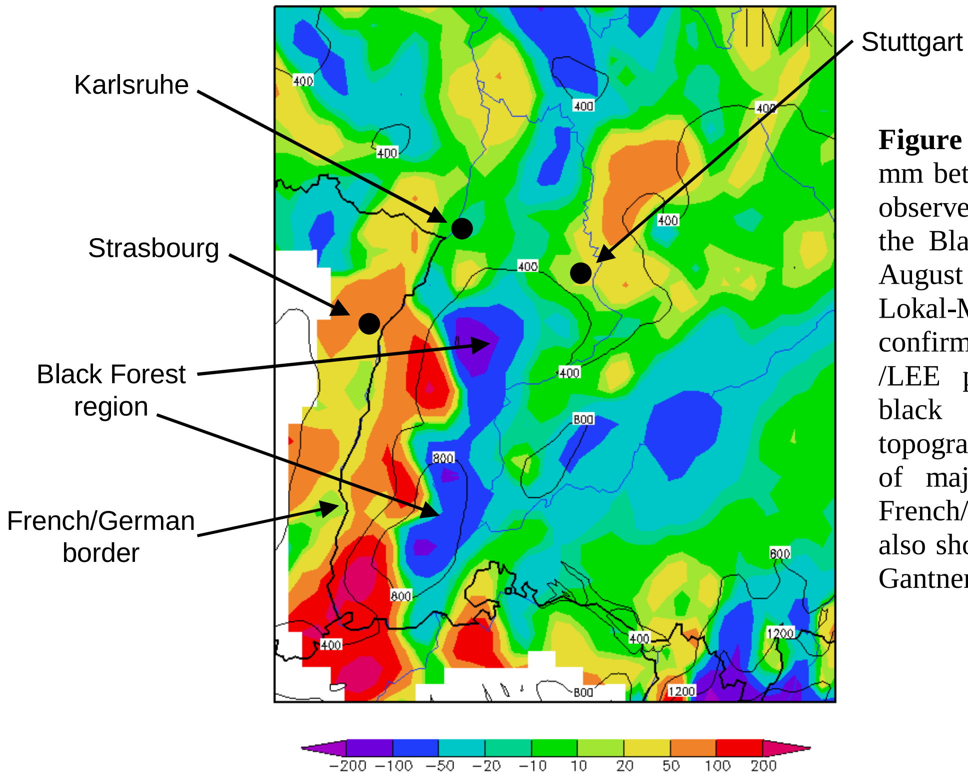

Figure 1. Difference in mm between predicted and observed precipitation in the Black Forest Area for August 2004 using the Lokal-Modell of the DWD confirming the Windward /LEE problem. The thin black lines indicate the topography. The locations of major cities and the French/German border are also shown. Courtesy of L. Gantner, IMK.

These results are based on extended comparisons between operational weather forecast models and observations. With respect to the COPS, Fig.1 illustrates the **Windward/LEE problem in the low-mountain region** Black Forest in southwestern Germany. The precipitation amount at the windward side is overestimated by up to 80% whereas it is underestimated by about 50 % at the lee side. This signature is also observed in other low mountain regions in Germany. As the major component of rain produced by the model is convective precipitation, it is very likely that the convection parameterization is the major source of this model deficit.

The problem of atmospheric models in failing to reproduce the **diurnal cycle of convective precipitation** has been addressed in numerous studies. Recently, Bechtold et al. (2004) investigated different versions of the ECMWF convection schemes using different convective trigger functions and convective closures. Although some improvements are achieved, the model precipitation still peaks too early in the day compared to the observations. Due strongest signals, most studies have focused on the tropical regions. However, the problem is also evident in central Europe (see Fig. 2). Strong deviations between cloud coverage, temperature, and dew point occur in the LM forecasts. Obviously, the phase error in the diurnal cycle of temperature and moisture leads to a too early onset of convection and precipitation.

The treatment of **cloud microphysical process** in atmospheric models has become more complex in the last years for example by including more hydrometeor categories as prognostic variables. The difficulty in parameterizing the complex processes between the hydrometeors becomes obvious when one looks for example at the huge differences in the auto conversion rates used in various models (Xu et al., 2005). Most mesoscale models already start converting cloud to rain water at very low liquid water contents explaining partly the fact that the frequency and duration of precipitation is often over predicted (van Meijgaard and Crewell, 2005).

In the past model intercomparisons have revealed large discrepancies between different models especially for cloud microphysical parameters like the liquid water path (LWP) (Gates et al., 1999). Stephens et al. (2002) report that the predictions of the vertically integrated ice water span an order of magnitude. However, only recent advances in remote sensing techniques have allowed a thorough evaluation of predicted cloud microphysical properties (for example Hogan et al., 2004a, 2004b). Not surprisingly large differences were found in LWP between different weather forecast and climate models and advanced European observatories (van Meijgaard and Crewell, 2005) with the observations being somewhere in between. Comparisons with a single-column version of the ECHAM5 climate model with ARM observation reveal again large difference in LWP depending also on the convection parameterizations and effect of aerosol (Zhang et al., 2005).

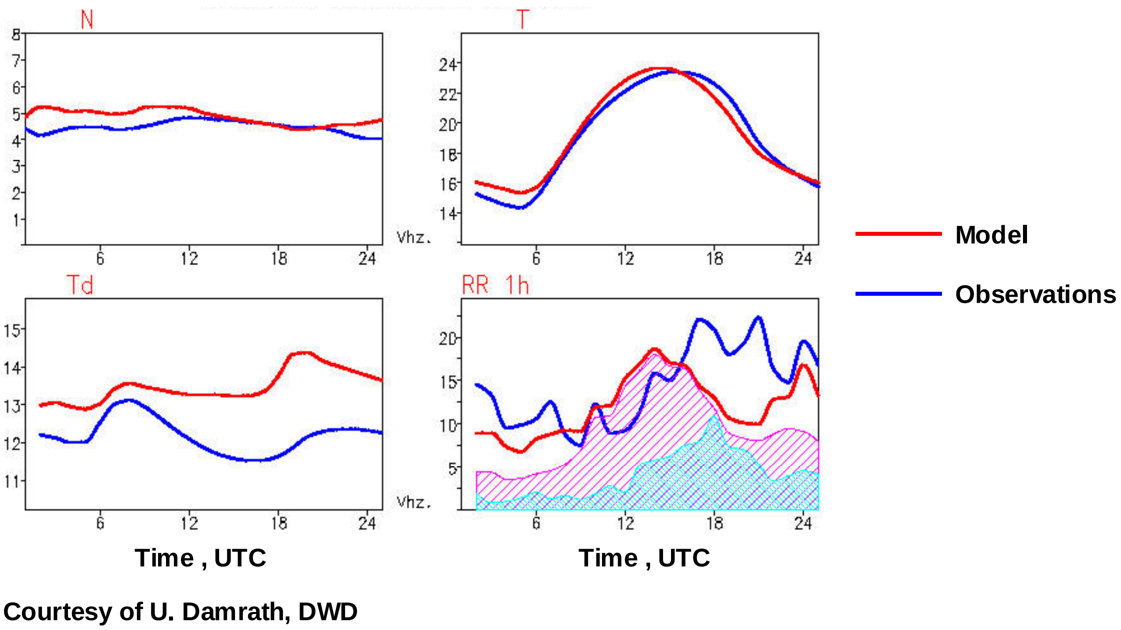

Figure 2. The diurnal cycle of cloud coverage (N) (upper left panel), surface temperature (T) (upper right panel), dew point (lower left panel), and rain rate (lower right panel) averaged between 6.5-15 E and 47.3-54 N from July 3-29, 2003. The shaded areas in the lower right graph correspond to the convective part of the precipitation.

The continuous observations at advanced atmospheric observatories like the ARM stations and the network of European observatories (Cabauw, Chilbolton, Lindenberg and Palaiseau) allow for the first time long-term statistics of model forecasts. As an example Figure 3 (from CloudNET) shows the differing performance of two models over a nine month period: ECMWF has a good mean liquid water content (LWC) but stratocumulus clouds occur too frequently, whereas the Met Office model has the correct frequency but the probability distribution function (PDF) of LWP is worse.

Identification of the reasons for QPF failures is a difficult task, as various errors in the prediction of precipitation can occur within the complex chain of processes. Various studies have demonstrated that models deficits are due to

- coarse model resolution,
- inadequate parameterizations,
- incomplete coverage and low quality of observations,
- sub optimal assimilation of existing observations.

Model resolution is a major source of different performance of models. Models perform differently if the resolution is changed while maintaining the same parameterization (e.g., Barthlott et al., 2005). Model runs with about 1 km resolution may perform better with shutdown of the parameterization of convection. However, the optimal set up of high-resolution models and their parameterizations is not clear to date and requires extended comparisons with observations.

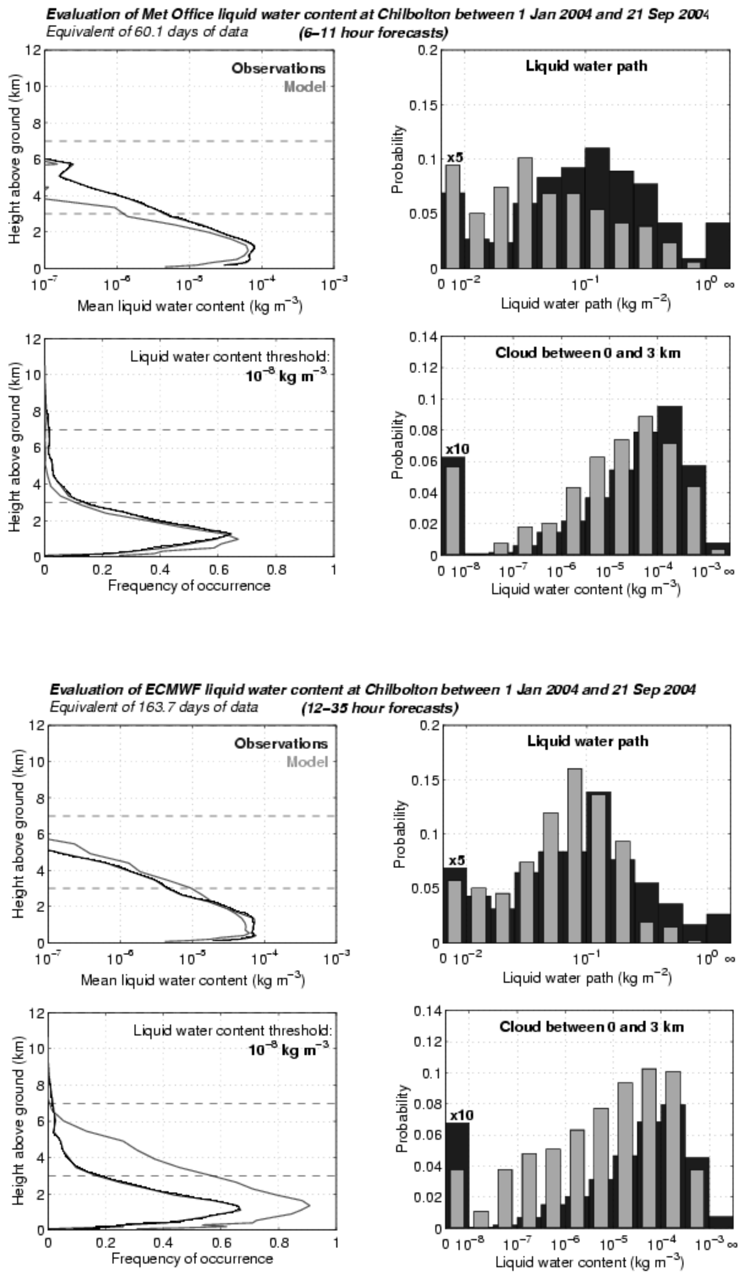

Figure 3: Evaluation of the representation of water clouds in the ECMWF and Met Office models during CloudNET (see http://www.met.rdg.ac.uk/radar/cloudnet).

Parameterization of the variety of sub-grid scale processes is another severe source of forecast errors. Figs.1-3 provide important hints identifying model deficits. As the Windward/LEE problem (Fig.1) occurs mainly if the precipitation produced by the model is due to convection, it is very likely that the main problem is the convection parameterization. The phase error in the diurnal cycle of precipitation is already present in the representation of variables in the pre-convective environment. Therefore, it can be assumed that this problem is at least partly related to the parameterization of surface and entrainment fluxes in the boundary layer (see also Chaboureau et al., 2004, Guichard et al., 2004). Also deviations between cloud coverage and vertical extent revealed in Figure 3 are partly due to boundary layer parameterization but also due to cloud microphysics parameterization.

Another major source of forecast failures are errors in the initial fields, particularly dynamics and water in all its phases. On the one hand, this is due to lack or low quality of existing data. On the other hand, existing data may be assimilated in a sub optimal way into the weather forecast system. Numerous studies are available demonstrating improvements of mesoscale forecasts by additional assimilation of water and dynamics. Recent results demonstrate that the assimilation of range-resolved water vapor measurements using lidar can improve significantly the forecast of hurricane tracks and intensity (Kamineni et al., 2003) and short-range QPF (Wulfmeyer et al., 2005). Furthermore, in the case study by Wulfmeyer et al. (2005), significant errors in initial fields of water vapor provided by ECMWF analysis were detected.

It is extremely difficult to separate corresponding errors, as the real state of the atmosphere and model background errors are uncertain. Furthermore, parameterizations are interwoven in the simulation of the complex chain of events. Consequently, in order to identify more in detail model errors and to develop strategies for their improvements, the whole life cycle of precipitation must be investigated. New data sets must be produced, which contain 3-d knowledge of the pre-convective environment, the initiation of convection, clouds, and precipitation. Simultaneously, the data set must have a good coverage with respect to space and time. This dilemma has been realized right at the beginning of the PQP project. The PQP community decided to accept this challenge by including two field efforts in this research program, a 1-year General Observations Period (GOP) and an imbedded Intensive Observations Period (IOP). The latter is the field experiment Convective and Orographically-induced Precipitation Study (COPS).

2.1.3 Previous field experiments related to QPF and cloud microphysics

The Mesoscale Alpine Programme (MAP) (Bougeault et al., 2001) investigated, among other topics, orographic effects on precipitation in and round the Alps, a terrain characterized by much higher elevations and steeper slops than the COPS region. One of the main MAP results was the fact that the quality of model forecasts depended as large as from initial conditions as from parameterizations (e.g., Lascaux et al., 2004). COPS will benefit from further MAP experiences, as many MAP scientists are also involved in COPS preparation.

The International Water Vapor Project (IHOP_2002) (Weckwerth et al., 2004, Weckwerth and Parsons, 2005) focused mainly on the role of water vapor in the initiation of convection. It took place in another completely different very flat terrain, the Great Plains in Oklahoma, where IC is mainly related to the presence and the properties of the dryline. A special of IHOP_2002 is in print and will appear at the end of 2005. Highlights of this research are the use of high-resolution modeling for process studies (Xue and Martin, 2005), the use of large mesoscale ensembles for predictability and sensitivity studies (Martin and Xue, 2005), as well as the demonstration of a large impact of new observation systems on precipitation forecast (Wulfmeyer et al., 2005).

The Convective Storm Initiation Project, which is currently (summer 2005) underway in the UK, is examining the initiation of convection over the gently rolling terrain of southern England. Several German groups (among them one of the collaborators, Christoph Kottmeier) are participating in CSIP with aircraft and lidar instruments. Again, CSIP takes place in a different, maritime environment. Furthermore, it is not linked with efforts like MAP FDP and THORPEX.

The EU project BALTEX cloud liquid water network CLIWA-NET (Crewell et al., 2002) focused on a systematic observation and model evaluation of water clouds in Europe. The results revealed large model deficits (van Meijgaard and Crewell, 2005) even in reproducing mean liquid water paths. The Baltex Bridge Cloud campaign (BBC) (Crewell et al., 2004) as part of CLIWA-NET emerged to a large experiment in August/September 2001 centered around the Cabauw station in the Netherlands to also study the radiative effects of clouds. It was coordinated with the large scale field experiment

BRIDGE of BALTEX. A lesson from the BBC model evaluation is the necessity to move from 2D (z,t) to at least a 3D (x,z,t) observation to improve the representativeness of a model grid box (e.g., Willen et al., 2005). In this context it was found necessary to get the atmospheric state as complete as possible at one site and therefore prefer less but well equipped sites to more sites with missing instrumentation.

CloudNET led by Anthony Ilingworth is an EU project which involves observing cloud profiles initially at three ground stations (Chilbolton, UK, Palaiseau, F and Cabauw, NL) over a period of several years and comparing these cloud properties with their representation in six operational forecasting models (See Fig 3). Recently, CloudNET has been expanded to include the Lindenberg observatory and the DWD model, in addition the data from the ARM cloud profiling sites in the USA and the tropics is being analyzed using the CloudNET algorithms. During the African Monsoon Multidisciplinary Analysis (AMMA) special observing period 2006 the AMF will be positioned in Niamey, Niger and the observed data processed within the CloudNET system.

2.1.4 PQP field experiments and its research components

The General Observations Period (GOP)

The GOP (http://server.meteo.physik.uni-muenchen.de/gop/web_latest), which shall take place in 2007, is addressing the fact that cloud development and precipitation have a large temporal and spatial variability. Therefore it is crucial to produce long-term comprehensive data sets at certain locations. The data set will consist of routine ground-based observations (rain gauge, GPS, radar, CloudNET stations etc) as well as space borne remote sensing systems and an optimized distribution of existing instrumentation within Germany (e.g., micro rain radars and disdrometers). A long-term model evaluation (similar to figure 3) will be performed to identify systematic model deficits. This data set will be very important for research on cloud development and precipitation, however, it will not be possible to observe the whole complex chain of relevant processes in three dimensions. Therefore, the field campaign COPS will be imbedded in the GOP where a suite of scanning remote sensing systems as well as ground-based networks will be deployed.

The Intensive Observations Period (IOP) COPS

The overarching objective of COPS (www.uni-hohenheim.de/spp-iop) is to identify the physical and chemical processes responsible for the deficiencies in QPF over low-mountain regions with the goal to improve their model representation. Correspondingly, the overarching goal of COPS is to

Advance the quality of forecasts of orographically-induced convective precipitation by 4D observations and modeling of its life cycle

Within strong collaboration between modelers, instrument PIs, and weather forecast centers, a list of fundamental hypotheses has been developed, which will be refined by the international research community in upcoming workshops:

- Detailed knowledge of the large-scale conditions is a prerequisite for improving QPF in orographic terrain.
- Better understanding and high-resolution modeling of the orographic controls of convection such as embedded convection in convergence lines, secondary circulations, and regional-scale potential instability is essential.
- The initiation of convection depends mainly on the structure of the humidity field in the PBL (e.g. due to land use, soil moisture and vegetation heterogeneity and evaporation).
- Continental and maritime aerosol type clouds develop differently over mountainous terrain, but ice formation and precipitation from convective clouds do not depend on measurable aerosol properties.

- The combination of novel instrumentation during COPS can be designed in such a way that critical parameterizations of sub-grid processes in complex terrain can be improved.
- Real-time data assimilation of key prognostic variables such water vapor and dynamics is routinely possible and leads to a significant better short-range QPF.

These science questions are addressed by four working groups (WGs), which have been established during two recent COPS Workshop.

The **WG Initiation of Convection (IC)** is focusing on high-resolution, 3-d observations and modeling of convection in orographic terrain. Dynamical and thermodynamic theories shall be developed to understand the complex flow and the related moisture variability in order to understand the timing and location of the initiation of convection. For this purpose, a unique combination of instruments will be applied to study the pre-convective environment in 3-dimensions including the upper tropospheric forcing and secondary forcing due to orography.

The **WG Aerosol and Cloud Microphysics (ACM**) is exploring the relationship between aerosol properties and cloud microphysics in a low-mountain region. For instance, they will study whether sub-cloud aerosol variability affect convective precipitation. The relation between cloud turbulence and condensation, coalescence, aggregation and thus precipitation is also addressed. Furthermore, the correlation between measurable aerosol properties (IN, depolarization) and ice formation will be determined.

The **WG Precipitation and its Life Cycle (PLC)** is investigating the role of orography on the development and organization of convective cells. A critical point is also the distribution of the condensed water into the different hydrometeor categories (cloud water and ice, graupel, snow, rain water) where big differences between mesoscale models have been noted. To study the development of graupel, hail and the drop size distribution (DSD) of precipitation a combination of polarimetric radars, satellite observations, micro rain radars disdrometers will be used as well as observations supersites to study the onset of full precipitation from drizzle conditions.

The **WG Data Assimilation and Predictability (DAP)** is studying the impact of current and new observations for improving QPF. Data assimilation is the key to separate errors due to initial fields and parameterization, as the model can be forced to reduce forecast uncertainties due to initial fields by means of assimilation of the whole COPS and GOP data set. Therefore, data assimilation is an essential tool for process studies. Furthermore, using a variety of mesoscale models in combination with ensemble forecasting, studies on the predictability of convective precipitation shall be performed. The huge set of models to be applied within COPS is summarized in Appendix II.

International Collaboration

The research performed within COPS is strongly linked with international programs, as the investigation of the whole life cycle of convective precipitation requires detailed knowledge of the large-scale environment around the COPS regions as well as of the small-scale processes within the COPS region. The international collaboration established within COPS is demonstrated in Fig.4. COPS shall be coordinated with a European THORPEX regional Campaign (ETReC07). In TReCs, targeting shall be performed by identifying areas, which are particularly critical for weather forecasting in certain regions. In the target areas, additional measurements will be made available for improving the quality of NWP forecasts. It is planned to identify target regions for the COPS area, which can lead to a better representation of the large scale conditions. On the other hand, the excellent validation data sets of the GOP and COPS can be used to study the impact of targeting. This coordination of large scale and small scale measurements is a unique feature of COPS, which to our knowledge has not been attempted before.

The Mesoscale Alpine Program Forecast Demonstration Project (MAP FDP) is one of the acknowledged FDPs of the WWRP. Combining MAP FDP with COPS leads to another win-win situation. Operational forecasts by different models produced by MAP FDP can be used for mission planning and performance. These models can be validated in the COPS regions, and COPS as well as

GOP data may be assimilated in MAP FDP models for investigating the impact of additional observation systems.

The SFB 641 is another DFG research program where new sensors for measuring ice nuclei shall be developed. It is envisioned to operated these sensors for the first time during COPS. The experiment Transport and Chemical Conversion in Convective Systems (TRACKS) is a three-stage large-scale experiment of the German Helmholtz Society. Convective systems shall be studied with regards their capabilities of transporting energy, water, and pollutants as well as with respect to their impact on climate.

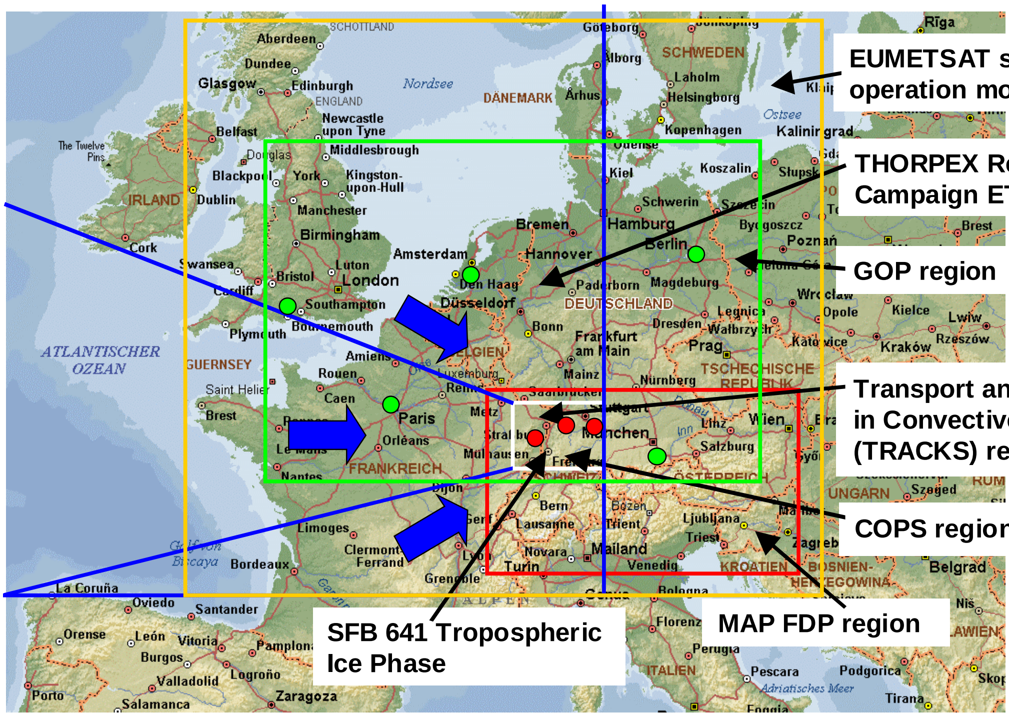

Figure 4. Overview of the COPS area (white line) with the planned supersites (red dotes) and its relation to other international research programs. The CloudNET stations are given by the green dots.

Furthermore, this cooperation will be supported by EUMETSAT, EUCOS, EUMETNET and several weather services such as ECMWF, Meteo France, and DWD ensuring a strong collaboration between instrument PIs and modelers.

2.1.5 COPS research strategy

COPS Observations

In order to categorize and to coordinate all different observation systems at various sites, we are dividing the observation of the life cycle of precipitation in four phases. We are further distinguishing between standard and research observation systems. All full list of the envisioned instrumentation is summarized in Appendix I. Standard observation systems produce continuous measurements during the campaign without changes of the observation strategy. To this category belong meteorological mesonet stations, rain gauges, soil and river runoff stations, flux stations, as well as continuous operating remote sensing systems on ground and in space. Research observation systems have the capability to be mobile or flexible in operation, e.g., by changing the set up of the scanning mode. These systems are usually more complex and are not operated continuously during COPS.

Several standard observation systems will be added in suitable networks during the campaign. These are including additional radio soundings, a dense GPS network, radiometers, and several micro rain radars.

A unique suite of research systems will be applied during COPS. On ground, a novel 3-d scanning water vapor differential absorption lidar (DIAL) system will be applied (Wulfmeyer and Walther, 2001b), which will be able to perform 2-d water vapor measurements up to a range of 15 km within one minute. This system will be combined at least with a scanning Doppler lidar, cloud radar, and microwave radiometer, among other instrumentation forming a package for 3-d atmospheric dynamics and stability, moisture convergence, and budget measurements. This combination will be extended with instrument packages for aerosol, cloud, and precipitation measurements.

This research instrumentation will be deployed within the COPS area (see Fig. 4) spanning about 100 x 100 km^2 at four supersites. Three supersites shall be equipped with PQP instrumentation only. **We are proposing for form a fourth supersite by combining the ARM mobile facility with scanning PQP remote sensing systems (see 2.2.2).**

A potential set up of a supersite and the combination of its measurements with other sensors is depicted in Fig.5. In the low-mountain region we expect that IC is often localized. In fact, we identified already several key regions by means of radar observations and high-resolution model runs. One supersite shall be located in the Vosges mountains, the AMF in an interesting valley in the Black Forest, another supersite in another valley to the south, and another one on the lee side of the Black Forest (see Fig.7).

Several unique aircraft will be operated such as the DLR Falcon with a 2-µm Doppler lidar, water vapor DIAL, and drop sondes (see also Appendix I) for mapping large-scale initial conditions. Finally, these observations will be merged with satellite observations such as from MSG, MODIS, MERIS, AMSU, and IASI.

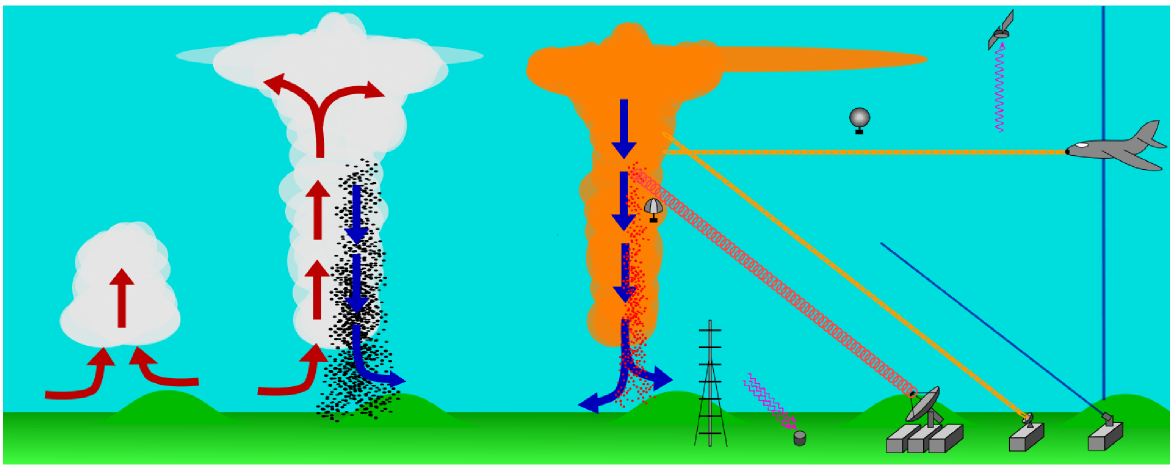

Figure 5. Sensor synergy at COPS supersite based on scanning Doppler lidar, DIAL, cloud radar, and microwave radiometer. These data will be merged with other in-situ and remote observations.

The observation strategy can be divided in four phases (see Fig.5) in order to observe the whole process chain from convective initiation over cloud microphysics to precipitation. **Phase 1** is defined by the presence of a pre-convective situation. During this time, mainly three activities will take place. Within the ETReC07, targeting will be performed for improving large-scale forecasts a few days ahead before IC is taking place. Mesoscale targeting for better characterization of the inflow in the COPS are will take place at suitable located surface stations as well as by airborne and satellite observations. Meanwhile, boundary layer processes will be characterized in great detail in the COPS domain.

During **Phase 2**, IC takes place. The operation mode of scanning remote sensing systems will be adapted for 3-d observations of atmospheric key variables. Aerosol in-situ, scanning cloud radar and microwave radiometer measurements will be added for extending the range of 3-d observations into clouds and for investigation aerosol-cloud interaction.

During **Phase 3**, IC is continuing and precipitation is forming. Clear-air and cloud measurements will be continued to study the organization of convection, and precipitation radars will be added. Tracking of the convective system will be performed with ground-based mobile instrumentation, aircrafts, radar systems with large range, as well as satellite observations.

Phase 4 is defined by the decay of the convective system, which shall also be observed as continuous and detailed as possible. These observations will be surrounded by a preparatory phase based on mesoscale forecasts and an important accompanying activity, the real-time data assimilation of COPS and GOP observations.

Research based on COPS and GOP data

Based on these observations, the COPS science questions will be addressed. Unique model evaluation and process studies will be possible by the 4D observation of the life cycle of precipitation. The data will be compared with the recent generation of high-resolution mesoscale models as well as of global NWP models. Processes can be investigated from sub-grid scale of mesoscale model grid boxes to the scale of climate models.

In order to optimally exploit the diverse multi-dimensional remote sensing observations, two different approaches will be pursued. On one hand, the synergy of multi-wavelength (active/passive) observations can be combined to derive the atmospheric variables using existing or newly developed algorithms (**observation-to-model approach**). For evaluation of model forecasts these variables will be the prognostic model parameters; for development of parameterizations an even more complete set of variables will be necessary to formulate and test parametric assumptions. On the other hand, it can be helpful to convert the model output to the direct observables (**model-to-observation approach**) and perform comparison in terms of observables. This approach avoids uncertainties due to the retrieval process because the so-called “forward” model (operator) can be described much more accurately than the inversion process, which always involves certain assumptions to compensate for the ambiguities of the problem. The need to extent this approach has also been highlighted by the Atmospheric Radiation Measurement (ARM) cloud parameterization and modeling working group. The development of operators, which convert model output to observation space is also an important step towards assimilation since they are a pre-requisite for modern assimilation techniques, including variational methods. The application of a polarimetric radar operator (Pfeifer et al., 2004) developed as part of the PQP has been found quite valuable for investigating cloud microphysical parameterizations.

For the observation-to-model approach, data from cloud radars, lidars, and microwave radiometers will be combined using the synergetic algorithms developed as part of the EU Project CloudNET (http://www.met.rdg.ac.uk/radar/cloudnet). This includes a cloud classification, ice water content, cloud fraction, turbulence levels, and liquid water path with a strict quality control and error estimates. All this products are available every 30 seconds with 60 m vertical resolution. Furthermore, the optimal estimation technique developed by Löhnert et al. (2004) and extended within the COST720 initiative “Integrated Profiling” will continuously provide **profiles of temperature, humidity, cloud liquid water content, drizzle water content, cloud effective radius and the corresponding error estimates**. All these techniques will also be applied to the AMF data. For some of these products the AMF data will be combined with simultaneous microwave radiometer observations provided by the collaborators, which have the necessary specifications in terms of frequency and temporal resolutions.

Data assimilation is another key components of COPS. Data assimilation provides the essential link between observations and model results in order to perform improved process studies (Xue and Martin, 2005, Wulfmeyer et al., 2005). By means of data assimilation, errors due to initial fields and parameterizations can be separated in more detail so that even with a limited data set provided within a field campaign fundamental results can be derived, which can be tested in operational models.

Dedicated studies of the impact of new observations as well as of present and new parameterizations on forecast quality will be possible. Based on ensemble forecast systems, the predictability of clouds and precipitation will be explored on a regional scale (Montani et al., 2003, Martin and Xue, 2005). Figure 6 presents a scheme of the COPS research and Appendix II summarizes the models to be operated during COPS.

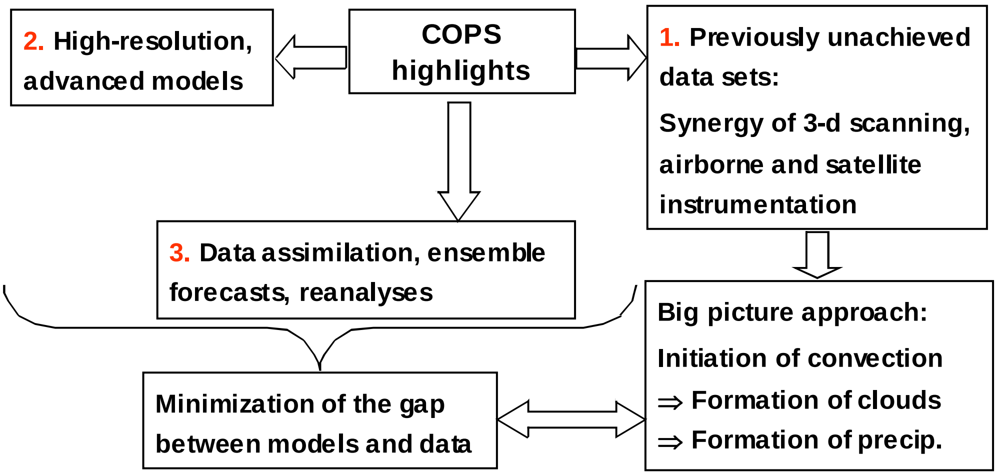

Figure 6. COPS research approach.

2.2 Science questions addressed in this proposal based on AMF data

2.2.1 The relation of COPS and ARM science goals

The ARM program is mainly focusing on the improvement of cloud and radiation processes in global and regional climate models. Inadequate representations of clouds and of radiative transfer in models have been identified as a major source of errors in simulations of the future climate (e.g., IPCC 2001). In this connection it is investigated whether cloud properties in a column of the atmosphere can be predicted from knowledge of larger scale atmospheric properties. Consequently, the representativeness of measurements of atmospheric variables from a single location is a major concern. To reach the goals of the ARM program, not only major improvements of cloud parameterizations have been achieved (e.g., Xie et al. 2004). Also new and improved instrumentation for measurements of water vapor profiles, cloud microphysical properties, and radiation has been developed (e.g., Feltz et al., 2003, Goldsmith et al., 1998, Turner and Goldsmith, 1999, Turner et al., 2000). In different climates, ARM sites have been established for long-term measurements of cloud properties and of atmospheric variables affecting radiative transfer. Current key research areas include the characterization of ice and mixed-phased clouds as well as of the indirect aerosol effect. Based on corresponding data sets, comprehensive tests of atmospheric models with respect to the representation of clouds and their parameterizations shall be performed. This knowledge will be used for improving climate models.

It is obvious that many deficits of climate models and numerical weather prediction models have the same causes, as they are based on the same physics and often on the same parameterizations. It is also clear that a major source of uncertainty in NWP and climate models is the representation of clouds. Understanding of clouds provides the fundamental link between initiation of convection and precipitation. Consequently, there is a large overlap between the science goals of a PQP and the ARM program. Whereas the ARM program is mainly interested in cloud properties and microphysics for understanding radiative transfer, COPS is interested in the same properties in order to model precipitation correctly. Particularly in connection with the timing and the localization of convection in orographic terrain, COPS is addressing a key issue in connection with regional climate modeling, the correct representation of cloud coverage and cloud properties in inhomogeneous terrain. Improvements in this area are of huge interest, as simultaneously the largest amounts of precipitation but also large model deficits have been identified in these regions. Furthermore, it can be expected that cloud microphysical variables have special properties in these areas, as they are strongly linked to the complex dynamical and thermodynamic processes.

2.2.2 The role of the AMF

We are proposing to operate the AMF for 9 months in a region where initiation of convection and cloud formation can be expected. The unique capability of the AMF to operate routinely will provide for an excellent data set of the clear-air environment and of **microphysical cloud properties in orographic terrain**. Due to the long-term operation of the AMF, not only measurements of diurnal cycles of atmospheric variables during the COPS observations period in summer but also a comparison of these results with measurements during spring and fall will be possible. The extension of these continuous measurements beyond the duration of COPS will also enable to reduce the gap between COPS and GOP data.

The location of the supersites is shown in Fig.7. Each supersite will be equipped with various lidar, cloud radar, and passive remote sensing systems as well as with in-situ instrumentation. Supersite 1 is located in a valley where often initation of convection is observed. It is proposed to equip supersite 1 with the AMF. In order to explore the representativeness of AMF measurement in orographic terrain, we are offering to combine the AMF instrumentation with measurements of the new water vapor DIAL, a Doppler lidar, a scanning cloud radar, and a scanning microwave radiometer.

The first part of COPS will be devoted to instrument intercomparisons. Further instrumentation, for example the microwave radiometer (ASUMUWARA), and several lidar systems will be placed at the AMF site allowing a thorough **quality control and error specification** of the instruments. The operation of advanced instrumentation like the newly developed HATPRO instrument can also be exploited to investigate the added value compared to the ARM standard microwave radiometers. For this purpose we will place the microwave radiometer HATPRO (Humidity And Temperature Profiler) (Rose et al. 2005) next to the AMF during the whole period. HATPRO has high temporal resolution and sensitivity. It is also able to derive high-resolution boundary layer temperature profiles.

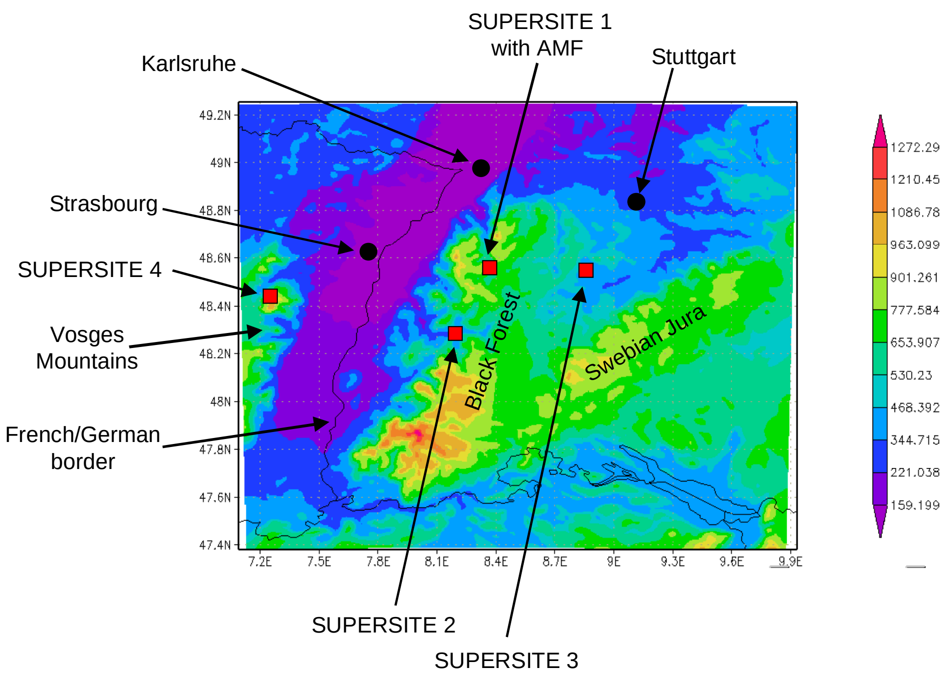

Figure 7. Proposed locations of the supersites in the COPS region.

This combination of instrumentation will permit various intercomparison between passive and active remote sensing systems in clear-air and in the presence of clouds. For instance, comparisons between AERI, DIAL, and in-situ water vapor measurements are possible. Furthermore, lidar backscatter measurements can be compared between the AMF MPL and the ceilometer, as well as the Doppler lidar and the DIAL. The AMF cloud radar can be compared with the PQP cloud radar (likely the GKSS MIRACLE). These are just are few examples.

By means of the unique scanning research instruments available at the AMF site, the 3D structure of wind, water vapor, and clouds will be studied. Consequently, the unique combination of AMF and COPS instrumentation will enable us to get a much better description of **atmospheric variability in all dimensions** as previously possible. As several of the scanning remote sensing systems are not designed to be operated continuously, special observation modes will be developed to cover the diurnal cycle and the 3D variability of atmospheric variables as best as possible. Due to the unique spatial temporal resolution of the various scanning systems, the statistics of the collected data set will be sufficient to investigate the representativeness of the vertical column observations for model grid boxes.

The combination of 3D clear-air measurements using PQP and AMF instrumentation will permit to study the initiation of convection in complex terrain and the processes responsible for formation and evolution of clouds. Furthermore, the AMF consists of a large set of instruments to observe radiation and aerosol properties. These aerosol measurements will be expanded by several PQP airborne in-situ sensors, e.g., on the helicopter borne sensor Helipod, flown close to cloud bases. This will provide for an excellent opportunity to investigate the radiative properties of clouds and how well models can reproduce them. The goal is to study the relation of aerosol and cloud microphysics, which shall give new insights in the aerosol indirect effect.

We are convinced that we are offering a unique synergy for addressing science questions, which are of essential interest for the ARM program.

2.2.3 Key science questions of this proposal and the approach for their solution

A large component of the PQP is devoted to the evaluation of weather forecast models (van Lipzig et al., 2005) and will be extended here by the collaborators to explicit cloud microphysical models (Khain et al., 2004, Khain and Pokrovsky, 2004) and climate models (Zhang et al., 2005).

The proposed combination of instrumentation and of models shall be applied for addressing the following science questions:

1) **What are the processes responsible for the formation and evolution of convective clouds in orographic terrain?**
2) **What are the microphysical properties of orographically induced clouds and how do these depend on dynamics, thermodynamics, and aerosol microphysics?**
3) **How can convective clouds in orographic terrain be represented in atmospheric models based on AMF, COPS, and GOP data?**

Question 1 can be studied in detail by scanning, clear-air observations at the supersites. For the first time, moisture convergence can be mapped in 2 dimensions. The combination of these measurements with airborne and satellite measurements will give us a deep insight in the processes responsible for the initiation of convection in complex terrain. These measurements will be continued when clouds are forming so that the thermodynamic environment of clouds can be studied while cloud microphysical measurements are started. These data will provide a unique basis for studying and deriving convection parameterizations in complex terrain.

Question 2 will be answered using CloudNET analysis of observations from the AMF providing statistics of cloud LWP, profiles of liquid water content (LWC), degree of dilution of clouds, dissipation rate of turbulent kinetic energy within clouds, the formation of drizzle within clouds and the drizzle size spectrum, cloud droplet concentration and size, the evolution of ice and supercooled water, which then can be compared with the parameters used to represent clouds within the various operational models. Such comparisons can be classified by different weather regimes and time periods of weeks, months and seasons. A simple example is given in Fig.3.

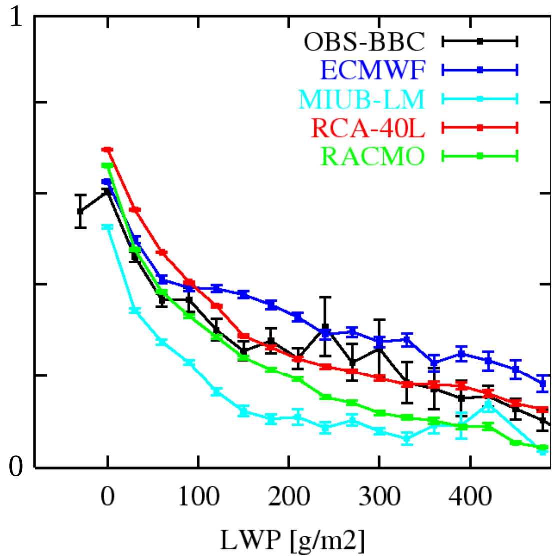

Figure 8. Solar transmission versus LWP for observations and models for 2 months based on CloudNET data.

Another specialty will be the combination of the measurements mentioned above with the AMF radiation instrumentation. First observations of solar transmission of clouds in dependence of LWP over 2 months (Fig. 8) have revealed large discrepancies, which could be narrowed down to certain conditions using the AMF data. Figure 8 makes clear that the largest radiative effects occur at low liquid water paths (LWP) below 100 gm^{-2}. Therefore it is very important to accurately retrieve **cloud properties from clouds with very low amounts of liquid water**. Typically dual channel 23.8 / 31.4 GHz microwave radiometer data are used to derive LWP. Unfortunately, due to the underdetermined retrieval problem the accuracy is not much better than 30 gm^{-2} (Löhnert and Crewell, 2003). The potential of AERI radiance to retrieve LWP, effective radius and optical thickness has been explored by Turner (2005). Combining AERI and other AMF instruments with higher frequency microwave observations provided by the collaborators has high potential to get much higher accuracies (Crewell and Löhnert, 2003). Therefore the combination of AMF and COPS can help to better understand the ARM observations (their accuracies and uncertainties) and thus improve the retrievals for these low LWP clouds at all of the ARM sites.

The excellent data availability of the AMF (>96 %; Kim Nitschke, personal communications) over a time period of 9 months will allow a long-term evaluation of several atmospheric models (see Appendix II) to identify systematic biases and to answer Question 3. These models employ different grid resolutions, which need to be taken into account by assuming certain advection speeds or by probabilistic approaches (Jacob et al., 2004). Within the PQP, case studies have been performed (van Lipzig et al., 2005; Schröder et al., 2005) to combine the vertical column information with horizontal information from satellite (MSG) in order to develop techniques suitable for the long-term evaluation. One goal of this strategy is to identify the conditions in which certain systematic errors are most prominent. By incorporating observations from the dense operational radar network we also want to address the questions to which degree models need to represent clouds and their inhomogeneities in order to get a good forecast of precipitation? They same question can be studied with respect to the modeling of radiation.

2.3 Expected scientific results and anticipated collaboration

This project will provide a unique set of observations and related modeling efforts in order to improve our current knowledge on cloud and precipitation processes. COPS aims at a thorough analysis of the whole process chain producing precipitation. Therefore the microphysical and radiative properties of clouds are a major component, which will be addressed by the collaborators.

Additional support is provided by the activities of the German PQP program where currently 31 projects are ongoing, which perform research on topics like verification, parametrization development, data assimilation, etc. In order to ultimatively improve climate model simulations, the collaborators will apply models ranging from detailed microphysical modeling (for a better process understanding) via short-term weather forecasts (parameterization testing) to climate models.

This proposal will enlarge the current set of observations performed within ARM by operating the AMF for the first time in an environment characterized by significant orography. The coordination with other European observatories will provide a unique data set of cloud and aerosol microphysical properties and radiation. The available data set will be used for evaluating and improving the parameterization schemes used in atmospheric models. The following results can be expected:

- Insight in the performance of AMF measurements, particularly with respect to clear-air water vapor, temperature, and aerosol measurements, as well as to MWR and cloud radar measurements.
- Improved understanding of the representativeness of AMF measurements in orographic terrain on scales of high-resolution mesoscale models to the scale of GCMs.
- Development of strategies for determining cloud climatologies in complex terrain. Comparison of the microphysical properties of convective clouds with maritime locations (Cabauw, The Netherlands; Chilbolton UK) and continental flat regions (Lindenberg).
- Investigation of clouds with low LWP.
- Understanding of the relation between dynamics, thermodynamics, aerosol properties, and cloud microphysics in complex terrain.
- Test and development of novel parameterization schemes for convection in regions with significant orography.
- Test and development of novel parameterization schemes for cloud microphysical variables in regions with significant orography.

3. Relevance to long term goals of the DOE Office of Biological and Environmental Research

The long-term goals of the DOE office related to this proposal are mainly connected with the second goal of the DOE Office of Science Strategic Plan, "Harness the Power of Our Living World". The biological and environmental discoveries necessary to clean and to protect our environment shall be provided. This goal includes a system-level understanding of our Earth's climate system, regional scale prediction of climate change, as well as the design of mitigation and adaptation measures. The latter is summarized in the Program Goal 05.21.00.00.

For climate simulations, which can be used for decision making, it is essential that the water cycle is correctly represented so that changes of temperature and precipitation pattern on a regional scale can be predicted with confidence. Particularly, it is important to model the evolution of temperature and precipitation in inhomogeneous terrain. This is due to the fact that precipitation is enhanced by orographic lifting, which increases the likelihood of strong precipitation events. Furthermore, the temporal/spatial distribution of precipitation is modified in a complex way by orography. Therefore, in these regions, accurate precipitation forecasts and the simulation of future precipitation pattern are fundamental for hydrologists and for water management.

However, the simulation of precipitation is particularly difficult due to the complexity of the terrain. It has been shown in various studies that major uncertainties in the simulation of the future climate of the Earth system are due to limitations in the representation of cloud properties in models. A correct simulation of clouds in inhomogeneous terrain provides the link between the initiation of convection and the development and evolution of precipitation. An improved representation of cloud properties in models will also advance the simulation of radiative transfer. This proposal is intending to contribute to the understanding of the development of clouds including their temporal and spatial variability as well as their microphysical properties particularly in inhomogeneous terrain where the representation of their properties in Earth system models is simultaneously challenging and important.

If the goals of this project are reached, the results can contribute to a reduction of uncertainties in the simulation of the Earth's future climate, particularly in orographic terrain. Furthermore, the research performed in this project will provide techniques to study the predictability of the evolution of the future climate, e.g., by the development and application of data assimilation and ensemble forecast systems. The understanding of the predictability of climate change is also an essential basis for using Earth system models for decision making.

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5. Collaborators

Dr. Andreas Behrendt

Professional Experience:

1996 – 2000	Research associate at GKSS Research Center, Geesthacht, Germany.
2000 – 2003	Post doctoral scientist at Radio Science Center for Space and Atmosphere (RASC), Kyoto University, Japan, with a fellowship of the Alexander von Humboldt Foundation and a research grant of the Japan Society for the Promotion of Science.
Since 2003	Post-doctoral scientist and professorial candidate at University of Hohenheim, Stuttgart, Germany. Management of the ESA project "Verifications of the specifications of WALES" and contributions to two other ESA projects. Head of the lidar group of the Institute of Physics and Meteorology.
Since 2004	Coordinator of COPS (Convective and Orographically-induced Precipitation Study), a field campaign embedded in the Priority Program "Quantitative Precipitation Forecast" (SPP-1167) of the German Research Foundation (DFG)

Internet: http://www.uni-hohenheim.de/~behrendt/

Mayor Research Areas:

Remote sensing of meteorological key parameters and its application for studying the chain of processes of convective precipitation events. Development of advanced lidar systems for temperature, humidity, aerosol and cloud particle measurements and synergetic use of these instruments together with radar and passive remote sensing systems.

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Behrendt, A., V. Wulfmeyer, P. Di Girolamo, H.-S. Bauer, T. Schaberl, D. Summa, D. N. Whiteman, B. B. Demoz , E. V. Browell, S. Ismail, R. Ferrare, C. Kiemle, G. Ehret, and J. Wang, 2005: Intercomparison of water vapor data measured with lidar during IHOP_2002, Part 1: Airborne to ground-based lidar systems and comparisons with chilled-mirror radiosondes. Submitted to *J. Oceanic Atmos. Technol*., 2005.

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The **University of Hohenheim (UHOH)** is the oldest university in Stuttgart, Germany. Research and education is focusing on transdisciplinary Life Science Research performed by its three faculties of Natural Sciences, Agriculture, and Economy. A major topic is the impact of global change on economy and society, which is coordinated by the Life Science Center and the Euroleague for Life Sciences. The university has about 5200 students and 1600 employees including 130 professors.

Prof. Dr. Susanne Crewell

Professional Experience:

1983-90	Diploma in Meteorology, Minor in Geophysics (Universität Kiel)
1990-93	PhD student in Environmental Physics (University Bremen)
1993-94	Postdoc Institute of Remote Sensing (University Bremen)
1994-96	Research Associate, Department of Physics, State University of New York (SUNY) at Stony Brook
1996-2004	Associate Professor, Meteorological Institute (University Bonn)
since 2004	Professor for Experimental Meteorology, Ludwig-Maximilians-Universität München
since 2005	Scientific Director of Environmental Research Station Schneefernerhaus (at Mount Zugspitze)

Internet: www.meteo.physik.uni-muenchen.de/~crewell

Major Research Areas:

Remote Sensing of cloud and precipitation and its application for evaluation/ improvement of weather forecast and climate models. Remote sensing activities include the development of new instruments and techniques from the ground as well as from space; here detailed investigations of scattering properties of hydrometeors (hexagonal ice crystals, dendrites, snow..) are conducted. Organization of major field campaigns in Europe and Africa to study cloud systems using the synergy of different state-of-the art instruments operating in different spectral reasons. Detailed analyses of atmospheric models in respect to their representation of clouds and precipitation and identification of major model deficits on the basis of these observation (satellite, radar, ground-based remote sensing).

5 Selected Publications (2000-2005):

Crewell, S., 2005: Hydrological applications of remote sensing: Atmospheric states and fluxes Water vapor and clouds (passive/active techniques). *Encyclopedia of Hydrological Sciences*, Wiley & Sons, in press.

Crewell, S. et al., 2004: The BALTEX Bridge Campaign: An integrated approach for a better understanding of clouds. *Bull. Amer. Meteor. Soc.* 85(10), 1565-1584.

Crewell, S., and U. Löhnert,2003: Accuraccy of cloud liquid water path from ground-based microwave radiometry. Part II. Sensor accuracy and synergy. *Radio Science* 38, 8042, doi:10.1029/2002RS002634.

Crewell, S, M. Drusch, E. Van Meijgaard, and A. Van Lammeren, 2002: Cloud Observations and Modelling within the European BALTEX Cloud Liquid Water Network, *Boreal Environment Research* 7, 235-245.

Crewell, S., H. Czekala, U. Löhnert, C. Simmer, Th. Rose, R. Zimmermann, and R. Zimmermann, 2001: Microwave Radiometer for Cloud Carthography: A 22-channel ground-based microwave radiometer for atmospheric research. *Radio Science* 36, 621-638.

The **Ludwig-Maximilians-Universität (LMU)** – the oldest university in Bavaria, Germany - has about 48,000 students and 12,000 employees including 700 professors. The LMU covers 18 faculties with a strong emphasis on natural sciences one of which being the faculty of physics. The Meteorological Institute as part of this faculty is divided into three working groups: theoretical meteorology, tropical and meso-scale meteorology and radiation and remote sensing.

Dr. Richard A. Ferrare

Professional Experience:

1982-1985	Graduate Research Assistant, University of Wisconsin, Madison, WI
1985-1989	Faculty Research Assistant, University of Maryland, College Park, MD
1989-1992	Research Associate, Universities Space Research Association, Greenbelt, MD
1992	Meteorologist, National Weather Service, Silver Spring, MD
1992-1997	Principal Scientist, Hughes ST Systems Corporation, Lanham, MD
1997-2003	Research Scientist, NASA Langley Research Center, Hampton, VA
2003-present	Senior Research Scientist, NASA Langley Research Center, Hampton, VA

Internet: http://asd-www.larc.nasa.gov/lidar/bio/ferrare.html

Major Research Areas:

Lidar measurements of atmospheric aerosols and trace gases. Raman and High Spectral Resolution Lidar (HSRL) Measurements of aerosol optical properties. Raman lidar and Differential Absorption Lidar (DIAL) measurements of water vapor. Retrievals of aerosol and trace gas species using combined active and passive remote sensing techniques. Analyses of atmospheric models with respect to their representation of aerosol optical, chemical, and microphysical properties.

5 Selected Publications (2000-2005):

Ferrare, R., D. Turner, M. Clayton, B. Schmid, J. Redemann, D. Covert, R. Elleman, J. Ogren, E. Andrews, J. Goldsmith, and H. Jonsson, 2005: Evaluation of Daytime Measurements of Aerosols and Water Vapor made by an Operational Raman Lidar over the Southern Great Plains, *J. Geophys. Res.*, in press.

Ferrare, R.A., E.V. Browell, S. Ismail, S. Kooi, L.H. Brasseur, V.G. Brackett, M. Clayton, J. Barrick, H. Linné, A. Lammert, G. Diskin, J. Goldsmith, B. Lesht, J. Podolske, G. Sachse, F.J. Schmidlin, D. Turner, D. Whiteman, D. Tobin, H. Revercomb, B. B. Demoz, and P. Di Girolamo, 2004: Characterization of upper troposphere water vapor measurements during AFWEX using LASE. *J. Atmos. Oceanic Technol*. 21, 1790-1808.

Ferrare, R.A., D. D. Turner, L.A. Heilman, W. Feltz, O. Dubovik, and T. Tooman, 2001: Raman Lidar Measurements of the Aerosol Extinction-to-Backscatter Ratio Over the Southern Great Plains. *J. Geophys. Res.* 106, 20333-20347.

Ferrare, R.A., S. Ismail, E. Browell, V. Brackett, M. Clayton, P. V. Hobbs, S. Hartley, J.P. Veefkind, P. Russell, J. Livingston, and D. Tanré, 2000: Comparisons of LASE, aircraft, and satellite measurements of aerosol optical properties and water vapor during TARFOX. J*. Geophys. Res.* 105, 9935-9947.

Ferrare, R.A., S. Ismail, E. Browell, V. Brackett, M. Clayton, S. Kooi, S.H. Melfi, D. Whiteman, G. Schwemmer, K. Evans, P. Russell, J. Livingston, B. Schmid, B. Holben, L. Remer, A. Smirnov, and P.V. Hobbs, 2000: Comparison of aerosol optical properties and water vapor among ground and airborne lidars and sun photometers during TARFOX. *J. Geophys., Res.* 105, 9917-9933.

Researchers in the Science Directorate at **NASA's Langley Research Center** in Hampton, Virginia, study the Earth's atmosphere and how human activities influence it for a better understanding of global change. Their research focuses primarily on the Earth's radiation balance and climate, atmospheric chemistry, and associated data management. They also support NASA's application programs and educational outreach activities.

Prof. Dr. Jost Heintzenberg

Professional Experience:

1969	Diploma in Meteorology, Johannes Gutenberg University, Mainz
1974	PhD in natural sciences, University of Mainz
1977-93	Scientist and Associate Professor, Department of Meteorology, Stockholm University
1993	Director of the Institute for Tropospheric Research, Leipzig
1993	Chair in physics at the University of Leipzig

Internet: http://www.tropos.de/

Major Research Areas:

Present research focus is the connection of aerosols, cloud and radiation and the formation of new aerosols. Author or co-author of more than 180 publications on atmospheric aerosols, clouds and radiation in the atmosphere.

5 Selected Publications (2000-2005):

Heintzenberg, J., 2004: Aerosols and their characteristics. W. Steffen, A. Sanderson, P. Tyson, J. Jäger, P. Matson, B. Moore, F. Oldfield, K. Richardson, J. Schellnhuber, B. L. Turner, and R. Wasson (Ed.), In *Global change and the earth system: A planet under pressure*. Springer, Berlin, 106-107.

Heintzenberg, J., W. Birmili, A. Wiedensohler, A. Nowak, and T. Tuch, 2004: Structure, variability and persistence of the submicrometre marine aerosol. *Tellus B* 56B, 357-367.

Heintzenberg, J., F. Raes, and S.E. Schwartz, 2003: Tropospheric aerosols. G. Brasseur, R. G. Prinn, and A. A. P. Pszenny (Ed.), In *Atmospheric chemistry in a changing world - An integration and synthesis of a decade of tropospheric chemistry research*. Springer, Berlin, Germany: 125-156.

Anderson, T.L., R.J. Charlson, S.E. Schwartz, R. Knutti, O. Boucher, H. Rodhe, and J. **Heintzenberg**, 2003: Climate forcing by aerosols — a hazy picture. *Science* 300, 1103-1104.

Heintzenberg, J., F. Raes, and S.E. Schwartz, 2002: Tropospheric aerosols. G. Brasseur, R. G. Prinn, and A. A. P. Pszenny (Ed.), In *Atmospheric chemistry in a changing world - An integration and synthesis of a decade of tropospheric chemistry research*. Springer, Berlin, Germany: 125-156.

The **Institute for Tropospheric Research (IfT)** was founded in 1991 for the investigation of physical and chemical processes in the polluted troposphere. IfT conducts field studies in several polluted regions parallel to the development of analytical methods for aerosol and cloud research. These tools are not only applied in field experiments but also in extensive laboratory investigations, which form a second major activity. A third and equally important approach consists of the formulation and application of numerical models that reach from process models to regional simulations of the formation, transformation and effects of tropospheric multiphase systems.

Prof. Anthony Illingworth

Professional Experience:

1970	PhD Cambridge (Trinity);
1988	DSc, University of Manchester;
1981	Senior Lecturer, Physics, UMIST
1987-88	Visiting scientist, NCAR, USA;
1989-94	Affiliate scientist NCAR, USA.
1991	Reader in Physics, UMIST
1993	Reader in Meteorology, Reading
2002	Professor of Atmospheric Physics, Reading.

Royal Meteorological Society Awards: 1972 – L. F. Richardson Prize, 1992 – Hugh Robert Mill Medal.

Major research areas:

Remote sensing of clouds and precipitation using radar and lidar. AJI co-ordinates the EU CloudNET project at the University of Reading, in which seven operational models (ECMWF, Met Office mesoscale and global models, Meteo France, KNMI RACMO, DWD and SMHI Hirlam) are being evaluated over three European sites (Chilbolton, Cabauw and Paris). It has recently been agreed with the Chief Scientist of the US Atmospheric Radiation Measurement (ARM) programme that the CloudNET algorithms would be applied to data from the various ARM sites in the framework of a new GEWEX Working Group on Cloud and Aerosol Profiling. AJI is the European scientist leading this joint Japanese/European mission EarthCARE in which ESA/JAXA (formerly NASDA) will fly a Doppler cloud radar and a high spectral resolution lidar on a common platform. He presented the case for this mission at the ESA selection meeting in Frascati (2004); subsequently EarthCARE has been approved for launch in 2012 as the sixth “Explorer” mission.

5 Selected Publications (2000-2005):

Hogan, R.J., M.P. Mittermaier, and A.J. **Illingworth**, 2005: The retrieval of ice water content from radar reflectivity factor and temperature and its use in evaluating a mesoscale model. *J Appl. Meteorol*. accepted.

Hogan, R.J., A.J. **Illingworth**, J.P.V. Poiares Baptista, and E.J. O’Connor, 2003: Characteristics of supercooled clouds: Part II A climatology from ground-based lidar. *Quart. J. Roy. Met. Soc*. 129, 2117-2134.

Hogan, R.J., C. Jakob, and A.J. **Illingworth**, 2001: Comparison of ECMWF winter -season cloud fraction with radar derived values. *J. Appl. Meteorol*. 40, 513-525.

Hogan, R.J., and A. J. **Illingworth**, 2000: Cloud overlap statistics from long-term radar observations. *Quart. J. Roy. Met. Soc*. 126, 2903-2909.

Illingworth, A.J., and C.-L. Liu, 2000: Towards more accurate retrievals of ice water content from radar measurements of clouds. *J. Appl. Meteorol*. 39, 1130-1145.

The **Department of Meteorology at Reading** is the largest in Europe with over 20 teaching staff, 50 research staff and around 50 PhD students. It has received the highest research rating of 5* in all UK Research Assessment Exercises, indicating an international reputation in all aspects of research. The Department hosts three NERC-funded research centres and several Met Office research groups.

Prof. Dr. Alexander Khain

Professional Experience:

1970-1974	Scientific researcher, The Moscow Instrument Development Research Institute
1974-1986	Scientific researcher, The Scientific Hydrometeorological Center, Moscow, the USSR
1986-1991	Senior scientific researcher, Chief of a scientific group, The Scientific Hydrometeorological Center, Moscow, the USSR
1991-2001	Associate Professor, permanent position, The Institute of Earth Sciences, The Hebrew University of Jerusalem
Since 2001	Full Professor, The Institute of Earth Sciences, The Hebrew University of Jerusalem

Internet: http://www.huji.ac.il

Major Research Areas:

Cloud dynamics and microphysics; Cloud-aerosol interactions; Motion and interaction of inertial particles in a turbulent flow; Tropical cyclones and their interaction with the ocean, binary tropical cyclones; Atmospheric boundary layer, cellular convection; Breezes, coastal circulation; Numerical modelling of atmospheric processes.

5 Selected Publications (2000-2005):

Lynn *B*., A.P. **Khain**, J. Dudhia, D. Rosenfeld, A. Pokrovsky, and A. Seifert, 2005: Spectral (bin) microphysics coupled with a mesoscale model (MM5). Part 1. Model description and first results. *Mon. Wea. Rev.* 133, 44-58.

Khain, A.P., and A. Pokrovsky, 2004: Effects of atmospheric aerosols on deep convective clouds as seen from simulations using a spectral microphysics mixed-phase cumulus cloud model Part 2: Sensitivity study. *J. Atmos. Sci.* 61, 2983-3001.

Khain A.P**.**, A. Pokrovsky and M. Pinsky, A. Seifert, and V. Phillips, 2004: Effects of atmospheric aerosols on deep convective clouds as seen from simulations using a spectral microphysics mixed-phase cumulus cloud model Part 1: Model description. *J. Atmos. Sci.* 61, 2963-2982.

Pinsky M.B., and A.P. **Khain**, 2004: Collisions of small drops in a turbulent flow. Part 2. Effects of flow accelerations. *J. Atmos. Sci*. 61, 1926-1939.

Pinsky, M., and A.P. **Khain**, 2002: Effects of in-cloud nucleation and turbulence on dropletspectrum formation in cumulus clouds. *Quart. J. Roy. Met. Soc*. 128, 1-33.

The **Hebrew University of Jerusalem** is the oldest university in Israel. It has about 24,000 students, 1,200 tenured academic faculty and 1,500 administrative and technical staff. The University has 4 campuses, 7 faculties and several schools. The Institute of the Earth Sciences is one of the six institutes that compose the sciences faculty. It is divided into 3 departments: Geology, Oceanography and Atmospheric sciences.

Prof. Dr. Christoph Kottmeier

Professional Experience:

1977	Diploma in Meteorology, University of Hanover
1981	PhD in natural sciences, University of Hanover
1990	Assistant Professor, Physics of the Atmosphere, University of Bremen
1997	Professor for Meteorology, University of Karlsruhe
Since 2003	Head of the Institute of Meteorology and Climate Research, Research Center Karlsruhe and University of Karlsruhe

Internet: http://www.tropos.de/

Major Research Areas:

Atmospheric boundary layer turbulence and transport processes, initiation of convection, quantitative precipitation forecast, development of advanced in-situ sensors, mesoscale modeling, extreme weather events and natural disaster research.

5 Selected Publications (2000-2005):

Hasel, M., Ch. **Kottmeier**, U. Corsmeier, and A. Wieser, 2005: Airborne measurements of turbulent trace gas fluxes and analysis of eddy structure in the convective boundary layer over complex terrain. *Atmos. Res*. 74, 1-4, 381-402

Kunz, M., and Ch. **Kottmeier**, 2004: Orographic enhancement of precipitation over low mountain ranges, Part I: Model formulation. *J. Appl. Meteorol*., in press.

Kunz, M., and Ch. **Kottmeier**, 2004: Orographic enhancement of precipitation over low mountain ranges, Part II: Simulations of heavy precipitation events. *J. Appl. Meteorol*., in press.

Kottmeier, Ch., T. Reetz, P. Ruppert, and N. Kalthoff, 2001: A new airological sonde system for dense meteorological soundings. *J. Atmos. Oceanic Technol*. 18, 1495-1502.

Kottmeier, Ch., P. Palacio-Sese, N. Kalthoff, U. Corsmeier, and F. Fiedler, 2000: Sea breezes and coastal jets in southeastern Spain. *Int. J. Climatol*. 20, 1791-1808.

In the area of troposphere research, the **Institute of Meteorology and Climate Research (IMK)** performs fundamental studies with regard to the climate, water cycle, and trace substance budgets. For this purpose, atmospheric processes, such as turbulence, convection, cloud formation, aerosol physics, precipitation formation, and exchange processes on the Earth's surface are investigated in detail by measurements and theoretical methods. The results are incorporated in models of the atmosphere to adequately represent processes in climate system and weather phenomena. Research activities focus on influences of orography on the wind and precipitation distribution, transports and conversions of water, energy, trace gases, and aerosols in convective systems, regional climate variability, and weather hazards due to storms, heavy rains, and thunderstorms. Particular attention is paid to the further development of own model systems and instruments. The results of all activities are taken into account when studying the influence of man on the chemical composition of the atmosphere and climate as well as when assessing weather hazards.

Prof. Dr. Ulrike Lohmann

Professional Experience:

1993	Diploma in Meteorology from Hamburg University, Germany
1996	Doctorate in Meteorology from Hamburg University, Germany
1996 – 1997	Postdoctoral fellow at the Canadian Centre for Climate Modelling and Analysis at University of Victoria
1997 – 2001	Assistant Professor in Atmospheric Science at Dalhousie University
Summer 2001	Adjunct Professor in Lamont-Doherty Earth Observatory, Columbia University, New York
Fall 2003	Visiting Professor in the Department of Physics at University of Toronto
Spring 2004	Visiting Scientist at the Max Planck Institute for Meteorology, Hamburg,
2001 – 2004	Associate Professor in Atmospheric Science at Dalhousie University
Since 2004	Full Professor in Atmospheric Science at the Swiss Federal Institute for Technology, Zurich, Switzerland

Internet: http://www.iac.ethz.ch/people/ulohmann

Major Research Areas:

The role of aerosols and clouds in the climate system. Radiative effects of anthropogenic aerosols such as sulphate and carbonaceous aerosols and their influence on the microphysical properties of clouds; implication for the hydrological cycle. Investigation using a combination of field measurements, laboratory experiments on ice nucleation and theoretical modeling of aerosol-cloud interactions.

5 Selected Publications (2000-2005):

Zhang, J., U. **Lohmann**, and P. Stier, 2005: A microphysical parameterization for convective clouds in the ECHAM5 climate model: 1. Single column results evaluated at the Oklahoma ARM site, *J. Geophys. Res*. 110, doi:10.1029/2004JD005128.

Lohmann, U., 2004: Can anthropogenic aerosols decrease the snowfall rate? *J. Atmos. Sci*. 61, 2457-2468.

Lohmann, U., 2002: A glaciation indirect aerosol effect caused by soot aerosols. *Geophys. Res. Lett.* 29, doi: 10.1029/2001GL014357.

Lohmann, U., and B. Kärcher, 2002: First interactive simulations of cirrus clouds formed by homogeneous freezing in the ECHAM GCM. *J. Geophys. Res*. 107, doi: 10.1029/2001JD000767.

Lohmann, U., N. McFarlane, L. Levkov, K. Abdella and F. Albers, 1999: Comparing different cloud schemes of a single column model by using mesoscale forcing and nudging technique, *J. Climate* 12, 438-461.

The **Swiss Federal Institute of Technology Zurich** is a science and technology university with an outstanding research record. Excellent research conditions, state-of-the-art infrastructure and an attractive urban environment add up to the ideal setting for creative personalities. 18'000 people from Switzerland and abroad are currently studying, working or conducting research at ETH Zurich. The Institute for Atmospheric and Climate Science is part of the Department of Environmental Sciences (D-UWIS) at the ETH Zürich.

Dr. Mark Pinsky

Professional Experience:

1975-1985	Researcher, Upper atmospheric department. The Central Aerological Observatory, Moscow, USSA
1985-1992	Researcher, Radar meteorology department. The Central Aerological Observatory, Moscow, USSR
1992-1994	Researcher, The Institute of Earth Sciences, The Hebrew University of Jerusalem (HUT), Israel
1994-1997	Post. Doc., The Institute of Earth Sciences, HUT
1997-1998	Senior Scientist "C", The Institute of Earth Sciences, HUT
1998-2003	Senior Scientist "B", The Institute of Earth Sciences, HUT
Since 2003	Senior Scientist "A", The Institute of Earth Sciences, HUT

Internet: http://www.huji.ac.il

Major Research Areas:

Cloud Physics, Microphysical processes in clouds, Cloud modeling, Theory of turbulence, Turbulence-particle interaction, Radar Meteorology, Doppler radar meteorology, Signal processing, Symmetry, Continuous symmetry measure.

5 Selected Publications (2000-2005):

Pinsky M.B., and A.P. Khain, 2004: Collisions of small drops in a turbulent flow. Part 2. Effects of flow accelerations. *J. Atmos. Sci*. 61, 1926-1939.

Pinsky M.B., and A.P. Khain, 2003: Fine structure of cloud droplet concentration as seen from the Fast-FSSP measurements. Part 2: Results of *in-situ* observations. *J. Appl. Met.,* 42,65-73.

Pinsky, M.B., and A.P. Khain, 2002: Effects of in-cloud nucleation and turbulence on droplet spectrum formation in cumulus clouds. *Quart. J. Roy. Met. Soc*. 128, 1-33.

Pinsky, M.B., A.P. Khain, and M. Shapiro, 2001: Collision efficiency of drops in wide range of Reynolds numbers: Effects of pressure on spectrum evolution. *J. Atmos. Sci.* 58, 742-764.

Pinsky, M.B., A.P. Khain, and A. Tsinober, 2000: Accelerations in isotropic and homogeneous turbulence and Taylor's hypothesis. *Phys. Fluids* 12, 3195-3204

The **Hebrew University of Jerusalem** is the oldest university in Israel. It has about 24,000 students, 1,200 tenured academic faculty and 1,500 administrative and technical staff. The University has 4 campuses, 7 faculties and several schools. The Institute of the Earth Sciences is one of the six institutes that compose the sciences faculty. It is divided into 3 departments: Geology, Oceanography and Atmospheric sciences.

Dr. Hermann Russchenberg

Professional Experience:

1986 – 1992	Project researcher, temporary position at Delft University of Technology (DUT), The Netherlands
1992 – 1996	Assistant professor, research and education at DUT
Since 1995	Head of Remote Sensing Sector of the International Research Centre for Telecommunications and Radar (IRCTR) at DUT
Since 1996	Associate professor at TU Delft

Internet: http://www.irctr.tudelft.nl/

Major Research Areas:

Extensive experience in remote sensing of clouds and precipitation with ground-based radar, lidar and microwave radiometry - initiating this kind of this work in The Netherlands. Experiences in system development, theoretical and experimental research of the scattering process as well as the retrieval of geo-physical parameters from synergetic remote sensing observations. Development of the very advanced Doppler-polarimetric radar system TARA, which is now at the premises of the observatory at Cabauw. Key role in the Cabauw experimental site for atmospheric research (Cesar) consortium in The Netherlands, and PI of the initiative to set up the European network of atmospheric observatories EurAt Observatory.

5 Selected Publications (2000-2005):

Russchenberg, H.W.J., and R. Boers, 2003: Radar sensor synergy for cloud studies; case study of water clouds, In: *Weather Radar- principles and advanced applications*, Springer, Physics and Astronomy Series, isbn 3-540-000328-2, pp 235-252

Skaropoulos, N.H., and H.W.J. **Russchenberg**, 2002: Light scattering by arbitrarily oriented rotationally symmetric particles, *J. Opt. Soc. Am. A*, 19, 1583-1591.

Baedi, R., R. Boers, and H.W.J. **Russchenberg**, 2002: Detection of boundary layer water clouds by space borne cloud radar. *J. Atmos. Oceanic Technol*. 19, 1915-1927.

Erkelens J.S., V.K.C Venema., H.W.J. **Russchenberg**, L.P. Ligthart, 2001: Coherent scattering of microwaves by particles: Evidence from clouds and smoke. *J. Atm. Sci*. 58, 1091-1102.

Boers, R., H.J.W. **Russchenberg**, H.J. Erkelens, V. Venema, A. van Lammeren, A. Apituley, and S. Jongen, 2000: Ground-based remote sensing of stratocumulus properties during CLARA 1996. *J. Appl. Meteorol*. 39, 169-181.

Founded in 1842, **Delft University of Technology** is the oldest, largest, and most comprehensive technical university in the Netherlands. With over 13,000 students and 2,100 scientists (including 200 professors), it is an establishment of both national importance and significant international standing. The International Research Centre for Telecommunications and Radar at DUT is a project driven organization. The IRCTR is part of the Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS). Staff resources in IRCTR come from different research groups of the Faculty EEMCS. The IRCTR has established an international network of research institutions working on related related topics and projects.

Dr. David D. Turner

Professional Experience:

1992-1994 Masters of Science in Mathematics (Eastern Washington University)

1994-1998 Research Scientist, Pacific Northwest National Laboratory

1998-2000 Senior Research Scientist I, Pacific Northwest National Laboratory

2000-2003 Ph.D. student in Atmospheric Sciences at the University of Wisconsin – Madison

2003-current Senior Research Scientist II, Pacific Northwest National Laboratory

Internet: http://engineering.arm.gov/~turner

Major Research Areas:

- Microphysical properties in mixed-phase clouds, and investigating the importance of the two phases on the radiative energy budget, with a focus on Arctic clouds
- Radiative transfer and light scattering in ice clouds, and appropriately accounting for the shape (habit) of the ice particles
- Life cycle of clouds with very low liquid water paths (< 100 g/m^2) and their impact on the radiative energy budget of the atmosphere
- Longwave radiative transfer, especially at low water vapor amounts in the Arctic and upper troposphere
- Characterization of water vapor observations from Raman lidar, microwave radiometer, and radiosondes
- Raman lidar observations of tropospheric aerosols, and utilizing this data to understand the indirect effect of aerosol

5 Selected Publications (2000-2005):

Ghan, S.J., T. Rissman, R. Elleman, R.A. Ferrare, D.D. **Turner**, C.J. Flynn, J. Wang, J. Ogren, J. Hudson, H.H. Jonsson, T. VanReken, R.C. Flagan, and J.H. Seinfeld, 2005: Use of in situ cloud condensation nuclei, extinction, and aerosol size distribution measurements to test a method for retrieving cloud condensation nuclei profiles from surface measurements. *J. Geophys. Res.*, accepted.

Turner, D.D., 2005: Arctic mixed-phase cloud properties from AERI-lidar observations: Algorithm and results from SHEBA. *J. Appl. Meteorol.* 44, 427-444.

Turner, D.D., D.C. Tobin, S.A. Clough, P.D. Brown, R.G. Ellingson, E.J. Mlawer, R.O. Knuteson, H.E. Revercomb, T.R. Shippert, and W.L. Smith, 2004: The QME AERI LBLRTM: A closure experiment for downwelling high spectral resolution infrared radiance. *J. Atmos. Sci.* 61, 2657-2675.

Turner, D.D., S.A. Ackerman, B.A. Baum, H.E. Revercomb, and P. Yang, 2003: Cloud phase determination using ground-based AERI observations at SHEBA. *J. Appl. Meteorol.* 42, 701-715.

Turner, D.D., B.M. Lesht, S.A. Clough, J.C. Liljegren, H.E. Revercomb, and D.C. Tobin, 2003: Dry bias and variability in Vaisala radiosondes: The ARM experience. *J. Atmos. Oceanic Technol.* 20, 117-132.

Pacific Northwest National Laboratory (PNNL) is a multi-disciplinary national laboratory with over 3,900 researchers and staff. PNNL has extensive computational resources, laboratories, and equipment which are used to advance the fundamental understanding of complex chemical, physical, and biological systems.

Dr. Edgeworth Westwater

Professional Experience:

1959	BA in Physics and Mathematics, Western State College of Colorado
1962	MS in Physics, University of Colorado
1970	PhD in Physics, University of Colorado
1960-78	Research Physicist, US Department of Commerce, Boulder Laboratories
1978-87	Supervisory Physicist, NOAA Wave Propagation Laboratory
1987-1994	Division Chief, NOAA Environmental Technology Laboratory
1994-1995	Senior Scientist and Research Physicist, NOAA Environmental Technology Laboratory, Ocean Remote Sensing Division
Since 1995	Cooperative Institute for Research in Environmental Sciences, University of Colorado/NOAA, Environmental Technology Laboratory, Research Scientist Emeritus

Internet: http://www.etl.noaa.gov/~ewestwater

Major Research Areas:

Remote Sensing of water vapour and clouds; accuracy analysis of radiosondes, microwave technology and calibration improvement.

5 Selected Publications (2000-2005):

Westwater, E.R., S. Crewell, and C. Matzler, 2004: A Review of surface-based microwave and millimeter wave radiometric remote sensing of the troposphere. *Radio Science Bulletin of URSI*, RSB-310, September 2004, **59-80**, ISSN 1024-4530.

Westwater, E.R., B.B. Stankov, D. Cimini, Y. Han, J. A. Shaw, B. M. Lesht, and C. N. Long, 2003: Radiosonde Humidity Soundings and Microwave Radiometers during Nauru99. *J. Oceanic Atmos. Technol.* 20, 953-971.

Westwater, E.R., 2002: Profile retrieval/estimation techniques. Chapter I in *Remote Sensing of atmosphere and ocean from space: models, instruments, and techniques*. Ed. By F. S. Marzano and G. Visconti, Advances in Global Change Research, Martin Beniston, ed. Kluwer Academic Publishers, Dordrecht, The Netherlands , pp. 35-48.

Westwater, E.R., Y. Han, M.D. Shupe, and S.Y. Matrosov, 2001: Analysis of integrated cloud liquid and precipitable water vapor retrievals from microwave radiometers during SHEBA. *J. Geophys. Res.* 106, 32,019-32,030.

Han, Y. und E.R. **Westwater**, 2000: Analysis and improvement of tipping calibration for ground-based microwave radiometers. *IEEE Trans. Geosci. Remote Sens*. *38*, 1260-1276.

The **University of Colorado** was founded in 1876 at Boulder, at the base of the Rocky Mountains. It offers 3,400 courses in about 150 fields of study and nearly 100 research centers, institutes and laboratories focusing on everything from music entrepreneurship to determining the causes of school violence. It is one of 34 U.S. public research universities invited to join the prestigious Association of American Universities.

Prof. Dr. Volker Wulfmeyer

Professional Experience:

1986-1991	Diploma in Physics at the University of Göttingen performed at the Max Planck Institute for Flow Research, Göttingen
1991-1995	PhD study at the Max Planck Institute for Meteorology and the University of Hamburg
1995-96	Postdoc at the Meteorological Institute of the University of Hamburg
1996-2000	Postdoc research at NCAR and NOAA in Boulder, USA, within the scope of a scholarship of the Alexander von Humboldt Foundation
Since 2001	Full University Professor and Director of the Institute of Physics and Meteorology, University of Hohenheim, Stuttgart
Since 2001	PQP Steering Committee
Since 2003	NCAR Affiliate Scientist
Since 2003	Scientific Advisory Committee of the German Meteorological Service
Since 2004	Chair of COPS ISSC
Since 2005	MAP FDP Steering Committee

Internet: http://www.uni-hohenheim.de/www120/

Major Research Areas:

Development and application of 3-d scanning water vapor, temperature, and wind active remote sensing systems, boundary layer turbulence and transport, investigation of aerosol microphysical properties using active remote sensing, initiation of convection, ground-based, airborne, and space borne remote sensing using a synergy of passive and active systems, data assimilation.

5 Selected Publications (2000-2005):

Wulfmeyer, V., H.-S. Bauer, M. Grzeschik, A. Behrendt, F. Vandenberghe, E.V. Browell, S. Ismail, and R. Ferrare, 2005: 4-dimensional variational assimilation of water vapor differential absorption lidar data: The first case study within IHOP_2002. *Mon. Wea. Rev.* 2005, in press.

Wulfmeyer, V., H. Bauer, P. Di Girolamo, and C. Serio, 2005: Comparison of active and passive remote sensing from space: an analysis based on the simulated performance of IASI and space borne differential absorption lidar. *Remote Sens. Environ*. 95, 211-230.

Wulfmeyer, V., et al., 2003: Workshop Report Lidar Research Network Water Vapor and Wind. *Meteorol. Z.* 12, 5-24.

Wulfmeyer, V., and C. Walther, 2001: Future performance of ground-based and airborne water vapor differential absorption lidar. Part II: Simulations of the precision of a near-infrared, high-power system. *Appl. Opt.* 40, 5321-5336.

Wulfmeyer, V., and G. Feingold, 2000: On the relationship between relative humidity and particle backscattering coefficient in the marine boundary layer determined with differential absorption lidar. *J. Geophys. Res.* 105 D4, 4729-4741.

The **University of Hohenheim (UHOH)** is the oldest university in Stuttgart, Germany. Research and education is focusing on transdisciplinary Life Science Research performed by its three faculties of Natural Sciences, Agriculture, and Economy. A major topic is the impact of global change on economy and society, which is coordinated by the Life Science Center and the Euroleague for Life Sciences. The university has about 5200 students and 1600 employees including 130 professors.

6. Resources Required

All AMF core instruments and the Aerosol Observation Suite (AOS) listed below will be requested and enhanced by instrumentation of the collaborators. The AMF will be deployed on a small airfield providing security, power, and water supply as well as an internet connection. It should be mentioned that some of the collaborators have extensive experience in the organization of major field campaigns. Furthermore, the region is well known from minor field campaigns of the FZK Karlsruhe so that any logistical issues can be well handled.

- ☐ **SKYRAD**
- Precision Spectral Pyranometer (PSP)
- Precision Infrared Radiometer (PIR)
- Shaded Precision Spectral Pyranometer (PSP)
- Shaded Precision Infrared Radiometer (PIR)
- Normal Incidence Pyrheliometer (NIP)
- Infrared Thermometer (IRT)
- MultiFilter Rotating Shadowband Radiometer (MFRSR)

- ☐ **GNDRAD**
- Precision Spectral Pyranometer (PSP)
- Precision Infrared Radiometer (PIR)
- Infrared Thermometer (IRT)

- ☐ **Surface Meteorological Tower**
- Optical Rain Gauge (ORG)
- Anemometers (WND)
- Temperature/Relative Humidity Sensor (T/RH)
- Barometer (BAR)

- ☐ **Stand-Alone Instruments**
- Microwave Radiometer: dual channel and profiler (MWR)
- Micropulse Lidar - High Resolution (MPL-HR)
- Ceilometer (CEIL)
- Balloon Borne Sounding System (BBSS) – PC-Cora III
- Total Sky Imager (TSI)
- Millimeter Cloud Radar (MMCR) 95Ghz
- Atmospheric Emitted Radiance Interferometer (AERI)

- ☐ **Aerosol Observing System (AOS)**
- TSI 3563 Nephelometer at low RH (TSI Neph)
- Radiance Research 3 wavelength Particle soot absorption photometer (RR PSAP)
- Condensation nuclei counter (CCN TSI 3010)
- DMT Cloud condensation nuclei counter (CCNC)
- Nephelometer + humidograph system for scanning RH (TSI neph + humidograph)
- Mass Spec, part analysis
- CNN Aerosol
- Cadenza

- ☐ **Instrumentation provided by the collaborators during COPS**
- Scanning water vapor DIAL (UHohenheim)
- Scanning Doppler lidar for wind observations (FZK Karlsruhe)
- Scanning polarimetric cloud radar MIRACLE (GKSS – to be confirmed)
- Wind profiler (FZK Karlsruhe)
- Scanning Microwave Radiometer HATPRO (Rose et al., 2005) – full 9 months
- Polarimetric 90 and 150 GHz microwave radiometer for low LWP (UMunich)

Appendix I

List of candidate instruments. The corresponding PIs expressed their interest to participate in COPS. The feasibility of the deployment of foreign instruments is currently being explored by the COPS International Science Steering Committee and the individual PIs. German instrumentation will be supported by DFG.

German Participants

Facility	**Instrument**	**Principal Investiga-tor**	**Anticipated Sponsor**
DLR	DLR Falcon aircraft with in-situ instrumentation	NN[1]	DLR + DFG
DLR	H2O DIAL on the DLR Falcon aircraft	Gerhard Ehret	DLR + DFG
DLR	Airborne Doppler Lidar (ADL)	NN	DLR + DFG
DLR/ CNRS/ CNES	Airborne Doppler Lidar WIND	Oliver Reitebuch Alain Dabas	tbd
DLR	C-band polarization Doppler radar POLDIRAD	Martin Hagen	DLR + DFG
DLR	2 high resolution automatic rain gauges	Martin Hagen	Internal
DLR	Joss & Waldvogel disdrometer	Martin Hagen	Internal
DLR	Vertical pointing Micro Rain Radar	Martin Hagen	Internal
DLR/AMS-Gematronik	X-Band Compact Polarisation Radar CORA	Ronald Hannesen	DLR + DFG + AMS-Gematronik
DWD	Radar network, radiosonde network, surface network	NN	DWD
FZK	Research Aircraft DO 128 with in-situ mean, turbulent parameter and chemistry sensors	Ulrich Corsmeier	DFG
FZK	Dropsondes	Ulrich Corsmeier	Internal
FZK	Drop-up-sondes	Norbert Kalthoff	Internal

[1] No PI identified at this point

		Kalthoff	
FZK	Karlsruhe C-band precipitation radar	Klaus Dieter Beheng	Internal
FZK	Mobile Wind-temperature radar	Siegfried Vogt	Internal
FZK	Doppler Lidar WindTracer, mobile	Christoph Kottmeier	Internal
FZK	2 mobile sodars	Norbert Kalthoff	Internal
FZK	2 mobile radiosonde stations	Norbert Kalthoff	DFG
FZK	2 mobile tethered balloon sonde stations	Norbert Kalthoff	Internal
FZK	2 mobile energy budget stations	Norbert Kalthoff	Internal
FZK	9 mobile meteorological surface stations	Norbert Kalthoff	Internal
FZK	4 mobile meteorological masts	Norbert Kalthoff	Internal
FZK	Soil moisture sensors (several)	Christian Hauck	Internal
FZK	Instrumentation at Zugspitze/Garmisch observatories	Ralf Sussmann, Thomas Trickl	Internal + DFG
GKSS	Polarimetric 95 GHz Doppler cloud radar MIRACLE	Markus Quante	GKSS + DFG
GKSS	Airborne in-situ cloud and aerosol instrumentation on the U. Braunschweig DO 128-6 aircraft, Aerosol sondes on U. Braunschweig Helicopter pod	Dagmar Nagel, Uwe Maixner	GKSS + DFG
IfT	Six-wavelength aerosol, water vapor, temperature Raman lidar	Dietrich Althausen	IfT + DFG
IfT	Aerosol Raman lidar POLLY	Dietrich Althausen	IfT + DFG
IfT	Wind lidar WILI, scanning	Ulla Wandinger	IfT + DFG
IfT	Helicopter-borne payload ACTOS with sensors for turbulence, thermodynamical and microphysical properties	Holger Siebert, Manfred Wendisch	IfT + DFG

	microphysical properties, and aerosol particle measurements		
IfT	Airborne counterflow virtual impactor (CVI) and interstitial inlet (INT) coupled with with physico-chemical particle characterisation	Stephan Mertes	IfT + DFG
Institut für Weltraum-wissenschaften Freie Universität Berlin	Cessna 207 T aircraft with lidar (Mathias Wiegner, U. München), Spektrometer FUBIS (0.4-1.7 µm), Spektrometer casi (0.45 – 0.95 µm), Aureole sun photometer	Jürgen Fischer	DFG
LfU	Surface network	NN	LfU
Research Center Jülich	Zeppelin NT with aerosol and meteorological in-situ data instrument.		Research Center Jülich + DFG
U. Bayreuth	3 Energy balance stations	Thomas Foken	DFG
U. Bayreuth	Modified Bowen-Ratio stystem	Thomas Foken	DFG
U. Bayreuth	Laser scintillometer	Thomas Foken	DFG
U. Bayreuth	METEK Sodar-RASS	Thomas Foken	DFG
U. Bayreuth	12-m wind, temperature, and humidity mast	Thomas Foken	DFG
U. Bonn	X-band Doppler radar	Dirk Metschen	Internal
U. Bonn	24 GHz micro-rain-radar (2x)	Malte Diederich	DFG
U. Bonn	Ceilometer CT25	Andreas Schneider	Internal
U. Bonn	AIR (Atmospheric Interferometry Radiomter) sounding system (6 levels)	Günther Heinemann, Andreas Schneider	Internal
U. Bonn	MW radiometer MICCY with IR radiometer KT 19.85	Clemens Simmer, Susanne Crewell	DFG

U. Bonn	3 profiling stations	Günther Heinemann	DFG
U. Bonn	Turbulence station	Günther Heinemann	DFG
U. Bonn	Scintillometer BLS	Andreas Schneider	Internal
U. Bonn	Disdrometer, & 8 tipping buckets	Andreas Schneider	Internal
U. Braunschweig	Micro Airplane with in-situ instrument.	Jens Bange	DFG
U. Braunschweig	Helicopter pod with turbulence instr. And GKSS aerosol sondes	Jens Bange	DFG
U. Freiburg	Towers with meteorological instrumentation at the forest sites Hartheim and Tuttlingen	Helmut Mayer	DFG
U. Freiburg	Flat-array SODAR system (Scintec FAS64)	Helmut Mayer	DFG
U. Freiburg	Tethered balloon system	Helmut Mayer	DFG
U. München	POLIS Lidar airborne operation possible	Matthias Wiegner	DFG
U. München	MULIS Lidar scanning	Matthias Wiegner	DFG
U. München	Sun and sky photometer, UV radiation	Peter Köpke	DFG
U. München	150 GHz polarimetric MW radiometer+ HATRPRO (RPG)	Susanne Crewell	DFG
U. München	Automatic weather stations	Roger Smith	DFG
UHOH/ NCAR	H2O DIAL & Temperature Raman Lidar, scanning	Volker Wulfmeyer, Andreas Behrendt, Shane Mayor	DFG
UHOH/ IfT/UP/ DLR	Scanning H2O DIAL	Volker Wulfmeyer	DFG

US Participants

Institution or Facility	Instrument	Principal Investigator	Anticipated Sponsor
DOE ARM program	ARM Mobile Facility (microwave radiometers, radiosondes, broadband radiometers, surface pressure/temperature/humidity, millimeter cloud radar, micropulse lidar, infrared interferometer)	Mark Miller	US DOE
Arizona State University	Doppler lidar, surface energy budget equipment, meteorological towers, and in situ aerosol sampling equipment	Ron Calhoun	NSF
NASA	Lidar Atmospheric Sensing Experiment (LASE) on the NASA'DC-8	Ed Browell	NASA
NASA	Raman Airborne Spectroscopic Lidar (RASL) on P-3, DC-8 or Dash-7	Dave Whiteman, Belay Demoz	NASA
NASA	Scanning Raman Lidar (SRL)	Dave Whiteman, Belay Demoz	NASA
NCAR	S-POL	Jim Wilson	NSF/ Deployment pool
NCAR	3 DOWs	Tammy Weckwerth	NSF
NCAR	REAL (eye-safe aerosol lidar)	Shane Mayor	NSF
U. Wyoming	University of Wyoming King Air (UWKA) with in-situ instrumentation and Wyoming Cloud Radar and Wyoming Backscatter Lidar	Bart Geerts Backscatter Lidar: Zhien Wang	NSF/ Deployment pool
NOAA	High-Resolution Doppler Lidar (HRDL)	Michael Hardesty, Sara Tucker	NSF & NOAA
NOAA	Mini-MOPA CO_2 Doppler lidar	Alan Brewer, Chrisoph Senff	NSF & NOAA

U. of Colorado /NOAA	CODI water vapor DIAL	Janet Machol	NSF & NOAA

French Participants

Facility	**Instrument**	**Principal Investiga-tor**	**Anticipated Sponsor**
CNRS/ SAFIRE	ATR 42 Aircraft with in-situ mean and turbulent parameter instruments	NN	CNRS
CNRS/ SAFIRE	Falcon 20 aircraft with in-situ mean and turbulent parameter instruments	NN	CNRS
CNRS	Water vapor DIAL LEANDRE-2 *on the NRL P-3 or the SAFIRE Falcon 20*	Cyrille Flamant	CNRS
CNRS	Dropsondes on SAFIRE Falcon 20	NN	CNRS
CNRS	Airborne in-situ aerosol sampling instrumentation on SAFIRE ATR 42	Laurent Gomes	CNRS
CNRS	Airborne in-situ cloud microphysical instrumentation on SAFIRE Falcon 20 or ATR 42	Jean-François Gayet	CNRS
CNRS	Airborne Radar/Lidar RALI on SAFIRE Falcon 20	Alain Protat Jacques Pelon	CNRS
CNRS	Ronsard ground-based polarization Doppler radar	Georges Scialom	CNRS
CNRS/IGN	Ground-based Raman lidar	Olivier Bock	CNRS
DLR/ CNRS/ CNES	Airborne Doppler Lidar WIND	NN	tbd
Meteo-France	Radar network, radiosonde network, surface network	NN	Meteo-France
University of Clermont-Ferrand	X-band local area precipitation radar	Joël Van Baelen	
University of Clermont-Ferrand	UHF multiple receiver boundary layer radar	Joël Van Baelen	

University of Clermont-Ferrand, INSU	GPS observation stations in French COPS region	Joël Van Baelen	

Participants from Italy, Japan, Switzerland, and The Netherlands

Facility	Instrument	Principal Investiga-tor	Anticipated Sponsor
Basilicata University	Università della Basilicata Lidar (BASIL), aerosols, water vapor, temperature Raman lidar	Paolo Di Girolamo	tbd
Istituto di Metodologie per l'Analisi Ambientale (IMAA)	Aerosol Lidar	Gelsomina Pappalardo	tbd
Istituto di Metodologie per l'Analisi Ambientale (IMAA)	Aerosol, water vapor, temperature Raman Lidar	Gelsomina Pappalardo	tbd
Istituto di Metodologie per l'Analisi Ambientale (IMAA)	Microwave radiometer	Gelsomina Pappalardo	tbd
NICT	Airborne Doppler Lidar	Kohei Mizutani	tbd
RISH	Water vapor and aerosol Raman lidar	Takuji Nakamura	MEXT Japan
TU Delft	TARA	Herman Russchen-berg	tbd
Meteo-Swiss	Radar network, radiosonde network, surface network	NN	Meteo-Swiss

Appendix II

Models to be used within COPS

	Provider	Configuration		Nesting	Data assimilation	Boundary forcing
		Operational	research			
IFS (global)	ECMWF	T511 (40 km) resolution 60 vertical levels	same	no	4DVAR with 12 hour assimilation window	no
ECMWF EPS (global)	ECMWF	Ensemble prediction system with 51 members, ca 80km (T256)	same	no		
Unified Model Global (UM-G)	UK Met Office	- 40 km horizontal resolution in mid latitudes - 432x325 grid points - 38 vertical levels - 48 hr forecasts every 6 hr - 144 hr forecast every 12 hr	same	no	6 hourly 3DVAR data assimilation cycle (planned to be 4DVAR by 2005)	no
UM-ELA (European limited Area)	UK Met Office	- 20 km horizontal resolution, covers whole North Atlantic and Europe - 48 hr forecasts every 6 hr (currently under testing)	same		3 hourly 3DVAR data assimilation cycle	UM (global)
UM-M (mesoscale)	UK Met Office	- 11 km horizontal resolution (this will improve to 4 km by 2005) - - 146x182 grid points centered over the UK - 38 vertical levels - 48 hr forecasts every 6 hr	same		3 hourly 3DVAR data assimilation cycle plus cloud and rainfall assi-milation using nudging	UM (global, limited area)
GME (global)	DWD	- 60 km resolution - 31 vertical levels - 200 s time step - 00Z forecast for 78 hours - 12 Z forecast for 174 hours	same	no	OI soon 3DVAR	no
LME under develop-ment	DWD	- 7 km resolution - 665x657 grid points - 40 s time step - 40 vertical levels	Simulations with variable horizontal and vertical resolution from real and artificial initial conditions are possible	no	Nudging	GME ECMWF
LMK under develop-ment	DWD, FZK	- 2.8 km resolution - 421x461 grid points - 30 s time step - 50 vertical levels - 18h forecasts every 3 hours		no	Nudging Latent heat nudging of radar data	GME ECMWF
LM	DWD, FZK	- 7 km resolution - 325x325 grid points - 40 s time step - 35 vertical levels - 00Z,12Z,18Z forecast for 48 hours		no	Nudging	GME ECMWF

aLMo	Meteo Swiss	- 7 km resolution - 385 x 325 grid points - 40 s time step - 45 vertical levels - 00Z, 12Z forecast	same	no	nudging	ECMWF
aLMo2.2	Meteo Swiss	- 2.2 km resolution - 480x350 grid points, 10-40 s - approx. 60-80 vertical levels - forecast every 3 hrs. over 18 hrs	same	no	nudging	ECMWF, aLMo(7)
MM5 (global version available)	NCAR/ PennState	Used for real time numerical weather prediction in various configurations	- global to 1 km resolution - arbitrary domain & time step - idealized simulations	1-way, 2-way, moving	Nudging (obs+ana) 3DVAR, 4DVAR	ECMWF NCEP
WRF under development	NCAR/…	Real-time tests in different configurations	- global to 1 km resolution - arbitrary domain & time step - idealized simulations	1-way, 2-way, moving	3DVAR, Nudging 4DVAR under development	ECMWF NCEP
MC2	MSC	Various high-resolution real-time applications (e.g. McGill, MAP, …) - 3 km horizontal resolution - 400x490 grid points - 35-60 vertical levels - 12-18 hour forecasts	Various idealized applications using different model configs.			
Arôme	Meteo-France	Under development, pre-operational tests with 2.5 km resolution starting in 2006, operational usage planned for 2008	same			
Meso-NH	Meteo-France	6 – 50 km horizontal resolution	Usable with resolutions from mesoscale to microscale	yes		
COSMO-LEPS quasi operational	ARPA-SIM	- Based on LM version 3.9 resolution 10 km - 306x258 grid boxes - 60 s time step - 32 vertical levels - forecast range 120 h	idem	no		ECMWF
ARPS	CAPS Oklahoma University		Many – down to 150m horizontal resolution	1-way	3DVAR	ECMWF, NCEP (others?)
METRAS with an	MI Hamburg	No	Idealized simulations		Nudging	

aerosol/ cloud model (MITRAS)			with resolution 50 m – 2 km			
RAMS	Colo State Univ	operational upon request	Many	2-way	Tbd	various