APPLICATION FOR A GRANT FOR THE PREPARATION AND REALIZATION OF THE FIELD CAMPAIGNS COPS AND GOP WITHIN THE PRIORITY PROGRAM 1167 PQP

Code name: „COPS and GOP“

Prof. Dr. Volker Wulfmeyer
Institute of Physics and Meteorology (IPM)
University of Hohenheim (UHOH)
Garbenstraße 30, D-70599 Stuttgart, Germany
Tel.: +49 (0)711 459-2150
Fax: +49 (0)711 459-2461
Email: wulfmeyer@uni-hohenheim.de

The COPS WG and GOP Chairs

Prof. Dr. Christoph Kottmeier, Institute of Meteorology and Climate Research (IMK),
University of Karlsruhe / Forschungszentrum Karlsruhe (FZK), Germany

Prof. Dr. Jost Heintzenberg, Leibniz-Institute for Tropospheric Research (IfT), Leipzig, Germany

Dr. Martin Hagen, Institute of Atmospheric Physics (IPA),
German Aerospace Center (DLR) Oberpfaffenhofen, Germany

Dr. George Craig, Institute of Atmospheric Physics (IPA),
German Aerospace Center (DLR) Oberpfaffenhofen, Germany

Prof. Dr. Susanne Crewell, Meteorological Institute,
Ludwig-Maximilians University (LMU), Munich, Germany

Coauthors:

Dr. Andreas Behrendt, COPS Project Office, IPM, UHOH, Stuttgart, Germany
Dr. Ulrich Corsmeier, IMK, University of Karlsruhe / FZK, Germany

Table of Contents

1.2. Topic

Preparation and Realization of the PQP Field Campaigns COPS and GOP

1.3. Code name

COPS and GOP

1.4. Scientific discipline and field of work

Atmospheric sciences, field campaigns, quantitative precipitation forecast, predictability, orographic effects on precipitation, life cycle of precipitation, in-situ measurements, active and passive remote sensing, sensor synergy, data assimilation, parameterization of turbulence, convection, and cloud microphysics, model evaluation

1.5. Scheduled duration in total

The first phase of the COPS project is running from 01.04.2004-31.03.2006. During this phase, which is devoted to the scientific and logistical preparation of COPS, the project is funded by DFG.

This project is intended to continue during the second and the third phases of the Priority Program 1167. For the whole duration of the Priority Program, funding will be necessary.

1.6. Application period

1 April 2006 till 31 March 2008

1.7. Renewal proposal

The previous grant has been funded from 01.04.2004-31.03.2006. Expenditures and consumables will last until 31.03.2006.

1.8. Summary

A comprehensive program aimed at the improvement of QPF depends on a previously unachieved set of high-quality data that cannot be obtained by routine observations. In order to identify and distinguish between different kinds of model deficits and to improve initial conditions and process understanding, two additional levels of observations are required: Firstly, the production of long-term data sets by optimizing the use of existing instrumentation on different platforms within a General Observations Period (GOP). Secondly, high-resolution 4D data sets covering the entire evolution of convective precipitation events, which can only be achieved by a combination of sensors reflecting the most advanced results of meteorological research within an Intensive Observations Period (IOP). Consequently, both a GOP and an IOP have been initiated as international measurement programs within the German Priority Program 1167. Covering central Europe throughout the year 2007, the GOP will investigate all types of precipitation systems with increasing detail towards the IOP region, relating its results to larger scales. The IOP consists of the field experiment Convective and Orographically-induced Precipitation Study (COPS) taking place in the summer of 2007 in a low-mountain area in southwestern Germany/eastern France, which is characterized by high summer thunderstorm activity and particularly low skill of numerical weather prediction models. COPS is linked to several World Weather Research Program (WWRP) research projects and has been endorsed as WWRP Research and Development Project.

2. State of the art, preliminary work

2.1. State of the art

Quantitative Precipitation Forecasting (QPF) on regional scales is still inadequate for many users such as hydrologists (see COPS Science Overview Document (SOD), section 1.2). For this purpose, it is essential to model precipitation accurately down to the size of small catchment areas. Within the frame of the Convective and Orographically-induced Precipitation Study (COPS), we focus on the investigation of the formation and organization of convective precipitation systems in a low-mountain region. We chose this domain, as the Earth's land surface is largely covered with low mountains.

In these regions, several problems in connection with QPF have been identified, which include the windward/lee problem leading to an overestimation and underestimation of precipitation on the windward and lee side of the mountains, respectively (see SOD, section 1.3), and a phase error in the diurnal cycle of precipitation leading to a several hours too early onset of precipitation in model forecasts (see SOD, section 1.3). The latter has been an outstanding issue in numerical weather prediction (NWP) research for a long time (e.g., Guichard et al. 2004). Also aerosol-cloud interaction, which is crudely parameterized in most of the current NWP models, can lead to significant errors in precipitation intensity and distribution (see SOD, section 1.3).

On the one hand, there are efforts to reduce a major part of these errors by high-resolution modeling (about 1 km grid size) without convection parameterization (Buzzi et al. 2004, Walser and Schär 2004). In nearly all weather forecast and research centers, mesoscale ensemble forecast systems are under development (e.g. Molteni et al. 2001). Also here, the trend clearly goes to high model resolution. For instance, the European Centre for Medium-Range Weather Forecasts (ECWMF) is planning to increase their global model resolution to 16 km until 2012 and to 12 km until 2016. On the other hand, in some cases even a degradation of model performance with higher resolution and without convection parameterization has been detected (Barthlott et al. 2005) (see also SOD, section 1.3). While admitting that the next generation of models will certainly make an important contribution to atmospheric research, one should never neglect the importance of high-resolution, high-accuracy data sets these models require for their initialization and verification. Furthermore, it is expected that especially in orographic terrain the deficits of high-resolution models will still be substantial unless the gaps in our understanding of the complex chain of coupled processes leading to precipitation are closed.

Consequently, there is an urgent need to study the performance of state-of-the-art mesoscale models from high to medium resolution. It has to be pointed out that for identification of error sources of QPF, it is not sufficient to validate the end product precipitation only. As errors due to incorrect initialization and model physics are coupled and both important, they need to be separated and quantified. This is only feasible if the whole evolution of processes from initiation of convection to the initiation and development of clouds to the initiation and development of precipitation is observed simultaneously, if possible, in 4D. This can only be achieved within a field campaign such as COPS in combination with a statistically improved data set of the General Observations Period (GOP).

For preparing COPS, the previous experience from related QPF campaigns such as the Mesoscale Alpine Programme (MAP) in Europe, the International Water Vapor Project (IHOP_2002) in the US, and the Convective Storms Initiation Project (CSIP) in the UK will be applied for logistic and scientific preparation (see SOD, section 5.1). Along the series of these QPF campaigns, different forcing mechanisms are likely to be dominant in low-mountain regions so that results of the other campaigns cannot be applied with confidence. Therefore, we are proposing COPS as the first QPF field campaign in a low-mountain region in order to tackle related significant systematic errors of NWP models.

If a corresponding data set is provided, a large research area is opened concerning the predictability of orographically-induced convection. A huge number of mesoscale deterministic and ensemble prediction systems with various resolutions, parameterizations, and data assimilation systems can be tested by scientists within this Priority Program 1167 Precipitationis Quantitativae Praedictio (PQP) of the German Research Foundation (DFG). Further extensive QPF studies are planned in collaboration with World Weather Research Programme (WWRP) Forecast Demonstration Projects (FDPs) such as the Mesoscale Alpine Programme (MAP) FDP Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region (D-PHASE) and The Observing System Research and Predictability Experiment (THORPEX) Interactive Grand Global Ensemble (TIGGE) project.

The current failures of QPF and a discussion of possible reasons are outlined in detail in the COPS SOD. It is shown that especially in four areas the understanding of critical processes has to be improved: convection initiation (CI), aerosol and cloud microphysics (ACM), precipitation processes and their life cycle (PPL), as well as data assimilation and predictability (DAP). Corresponding scientific working groups (WGs) have been founded within COPS. Furthermore, it has been recognized that for a statistically firm model evaluation, a General Observations Period (GOP) is required. In the following, the current state of research with respect to these topics is outlined.

2.1.1. Convection Initiation (CI)

Initiation of convection depends on various atmospheric and surface factors. They can be roughly attributed to differential surface heating, fronts (temperature fronts, differences in the wind/flow field such as gust fronts and gust convergence lines, moisture fronts), and upper tropospheric forcing related to large-scale advection of vorticity, upper level troughs, Rossby waves, and cold advection.

Mesoscale studies in flat terrain during IHOP_2002 demonstrated the potential of high-resolution model runs for process studies (Xue and Martin 2005a, 2005b) and of ensemble forecasts for sensitivity studies (Martin and Xue 2005). Furthermore, the potential of new high-resolution observations for improving the prediction of convection was highlighted (Wulfmeyer et al. 2005).

However, the relevant processes leading to CI in low-mountain regions are still hardly understood. Recent studies confirmed that coarse model resolution and non-representative parameterizations introduce significant biases for both modeled convective precipitation (Barthlott et al. 2005, Meißner et al. 2005) and frontal precipitation, e.g, during the Saxonian flood in 2002 (Zängl 2004a, 2004b) and in the Black Forest (Kunz and Kottmeier 2005a, 2005b). Open questions are related to the relative influence of

a) the convergence and updrafts created by forced lifting on the windward side and thermally-forced anabatic flow,

b) the wind shear profile in the region of the ridges,

c) variations in the depth of the convective boundary layer as well as in moisture, convective inhibition (CIN), and convective available potential energy (CAPE) across the mountain ridges,

d) the presence of gravity waves impinging on the ridges,

e) aerosol loading in the pre-convective environment influencing the diurnal cycle of boundary variables.

The latter topic demonstrates the importance of the interaction between CI and ACM processes.

Consequently, it is essential to perform 4D thermodynamic measurements of atmospheric variables in the troposphere in regions where CI is expected as well as throughout its depth within and upstream of the COPS region to assess its thermodynamic (CAPE, CIN) and dynamic state (sharpness and progression of fronts, vorticity, moisture, and temperature advection). This requires a new synergy of ground-based scanning, airborne, and space borne remote sensing systems.

2.1.2. Aerosol and Cloud Microphysics (ACM)

Although nothing is known about the global impact of aerosol particles on precipitation, evidence for the suppression of precipitation due to enhanced CCN concentrations have been found in clouds contaminated by ship tracks (Ferek et al. 2000), major industrial and urban emissions (Givati and Rosenfeld 2004, Rosenfeld 2000) and biomass burning smoke plumes from large forest fires (Andreae et al. 2004, Rosenfeld 1999).

Indirect aerosol effects on clouds have been investigated increasingly over the past five years both by modeling studies (cf. e.g., Lohmann and Feichter 2005, Seifert and Beheng, 2005) and field experiments (Feingold et al. 2003, Feingold et al. 2005a, Feingold et al. 2005b, Kaufman et al. 2005). In the latter approach, remote sensing systems such as lidars, radars, and microwave radiometers have been combined. For example, accurate observations of cloud liquid water content (LWC) and effective radius (r_e) are crucial (Feingold et al. 2005a) and can be improved by using new multi-channel microwave radiometers (Rose et al. 2005) in conjunction with advanced multi-instrument algorithms developed in the European Union (EU) projects CLOUDNET, Cloud Liquid Water Network (CLIWA-NET), and the European Cooperation in the Field of Science and Technology (COST) 720 “Integrated Profiling”. Furthermore, advanced cloud radar observations can provide the Doppler spectrum with high temporal resolution and allow a better detection of drizzle particles and updraft regions.

The EU project Baltic Sea Experiment (BALTEX) 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 on the Cabauw station in the Netherlands. It was coordinated with the large-scale field experiment BRIDGE of BALTEX. A lesson from the BBC data analysis was the necessity to move from 1D to at least 2D observations to improve the representativeness of a model grid box (e.g., Willen et al. 2005). In this context it was found essential 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.

In all these activities, the focus was on model evaluation with respect to cloud properties. Interaction of aerosol-cloud microphysics and their impact on precipitation was not considered. As it can be expected that aerosol-cloud microphysics has also an important impact on convective precipitation, a corresponding field study in a low mountain region is urgently required applying simultaneous observations of aerosol and cloud properties.

2.1.3. Precipitation Processes and their Life Cycle (PPL)

In Southern Germany, mesoscale convective systems, as well as super- or multi-cells, can live for several hours and propagate during that time for several hundreds of kilometers (e.g. Hagen et al. 1999, Hagen et al. 2000). This holds especially for large systems like squall lines. They are normally related to cold fronts, but develop well ahead of the front (50-200 km). Under these conditions, it is the prefrontal southwesterly flow with warm and humid air at low levels and prevailing cold air in upper levels, which destabilizes the prefrontal air mass and favors the development of organized deep convection (e.g., Meischner et al. 1991, Haase et al. 2000, Haase and Crewell 2000). If the wind field is influences by orography, convective cells will develop differently. The observations by Haase et al. (1997) showed a clear orographic influence on the development of a squall line. As shown above (see also SOD, section 1.3), these systems are not predicted well enough in current mesoscale models.

Several studies demonstrated the importance of a detailed microphysical parameterization of the ice phase (e.g. Richard et al. 2003, Pfeifer et al. 2004) and the autoconversion rate between the particle classes (Xu et al. 2005) in NWP models. Verification of these processes can only be performed by polarimetric weather radar, which allows for retrieving 4D hydrometeor distributions and the flow within a thunderstorm cell. The potential also exists to perform these studies using operational radars (Friedrich and Hagen 2004). The development of hydrometeor classification schemes for polarimetric radars (Höller et al. 1994, Vivekanandan et al. 1999) gained new insight into the microphysical processes of graupel and hail formation. The retrieval of raindrop-size distribution from polarimetric radar observations (e.g. Seliga and Bringi 1976, Zhang et al. 2001) provided additional information on the underlying microphysics governing the initiation of precipitation. Recent progress in radar technology enabled to measure simultaneously surface layer refractivity fields as well as 3D cloud and precipitation fields (Weckwerth et al. 2005, Ellis et al. 2005). Convective systems can also be observed by space borne measurements of radiative temperatures of geostationary satellites.

Lightning detection techniques have been improved during the past few years. It is now possible to obtain a quasi 3D picture of flashes at Very Low Frequency / Low Frequency (VLF/LF) range and thus to discriminate between intra-cloud and cloud-to-ground lightning (Betz et al. 2004). These observations can be used for tracking of thunderstorms and attempts can be made to relate these data to cloud and precipitation microphysics like the simultaneous existence of solid and liquid particles (Fehr et al. 2005).

Within the WWRP, a global study on the lifetime of warm-season precipitation is ongoing. In the US it was found that convection, which was initiated in the Rocky Mountains, can have lifetimes of up to 60 h (Carbone et al. 2002). It was argued that this kind of mesoscale convection becomes correlated and reactivated by the diurnal cycle of boundary layer processes. A subsequent modeling study of this correlation failed to produce the observed lifetime and phase speeds of convective systems (Davies et al. 2003). In Europe, similar studies are ongoing but it seems that long-term coherence of convective systems is mainly present in the high-mountain regions such as the Alps. The organization and lifetime of convection is probably reduced in low-mountain regions. It is uncertain, which degree of coherence will remain. It is important to develop a general theory of the dependence of the lifetime and organization of convection in low-mountain regions on meteorological conditions. For this purpose, it is essential to perform field campaigns with 4D observations of thermodynamic, cloud, and precipitation properties.

2.1.4. Data Assimilation and Predictability (DAP)

As discussed previously (sections 2.1.1 and 2.1.3) the location and timing of convective precipitation depends on the synoptic or mesoscale flow, together with small-scale boundary-layer structures. For Alpine precipitation events, the small-scale flow is strongly constrained by the orography, and the greatest forecast sensitivity comes from the large-scale flow (Lascaux et al. 2004), while in other situations there is a strong sensitivity to perturbations in the model physics that primarily affect the local scales (Zängl 2004a, 2004b). To account for these various sources of uncertainty, regional ensemble forecasting systems have been constructed, using ensembles of global analyses and forecasts as boundary conditions to give variations in the larger scales (Molteni et al. 2001), and stochastic parameterizations or multimodel ensembles to give variations in the smaller scales (Bright and Mullen 2002, Quiby and Denhard 2003). In general it is difficult to know how accurately an ensemble forecast represents these various sources of uncertainty, because many of the significant structures are not well observed operationally, and model errors are poorly quantified. It is therefore essential that a measurement campaign considers both the large and small-scale factors controlling the precipitation in a given event, so that their roles can be identified and distinguished from model errors.

The operation of numerical weather prediction models at high resolution also provides the opportunity to reduce forecast uncertainty by assimilation of remote sensing data such as radar, lidar and passive instruments at full resolution and early results have shown great promise (Gao et al. 2004, Dowell et al. 2004, Wulfmeyer et al. 2005). There will be opportunities during the COPS measurement period, both for preliminary feedback on the performance of data assimilation systems, and to provide guidance for modifications to the observing strategy based on preliminary data impact studies.

2.1.5. Long-term observations of larger domains

Results of PQP verification studies have confirmed deficits of the Lokal-Modell (LM) of the German Meteorological Service (DWD) in all low-mountain areas in correctly predicting intense convective events (internal PQP report, van Lipzig et al. 2005). In addition, on average an overestimation of precipitation in central and northern Germany as well as errors in the Swiss Alps were found. This demonstrates the need to investigate larger domains and to include different types of precipitation events. Because many of the variables related to the development of precipitation have a large temporal and spatial variability, the demands on the observing system are very high and are not fulfilled in operational model verification. In the past, many studies concerning model evaluation and improvement have been limited to other specific regions, for example to the tropics (Bechtold et al. 2004), specific precipitation types, or specific observation periods (Guichard et al. 2003).

One of the problems in forecast evaluation and data assimilation lies in the occasional appearance of phase errors, where a forecasted weather system is displaced in space or time. This is especially true for convective-scale systems, where the errors can be large due to the influence of sub grid-scale processes. Therefore it is beneficial to produce long-term comprehensive data sets at certain locations in conjunction with aerial information as provided by satellite and radar. This combination can separate random errors from systematic displacements. This also holds for the diurnal cycle, which is at mid-latitudes often shadowed by synoptic disturbances and becomes more obvious in mean quantities.

Large difficulties in simulating the different hydrometeor quantities exist leading to gaps in our understanding of cloud microphysics. Recent advances in remote sensing techniques have allowed a thorough evaluation of predicted cloud microphysical properties (for example Hogan et al. 2005) at advanced atmospheric observatories like the US Atmospheric Radiation Measurement (ARM) Program stations and the network of European observatories (Cabauw, Chilbolton, Lindenberg and Palaiseau). For instance, large differences were found in liquid water path (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 observations revealed again large difference in LWP depending also on the convection parameterizations and effect of aerosol (Zhang et al. 2005). Biases in modeled LWP have been previously related to wrong estimates for the threshold for autoconversion (Xu et al. 2005). However, it is unknown how these deficits are related to the representation of the pre-convective environment and to the reduction of QPF skill. This can only be investigated if present data sets are combined with measurements of the thermodynamic environment of clouds as well as of precipitation distribution and microphysics.

A comprehensive data set covering a large domain suitable for testing hypotheses and new modeling techniques is lacking. High spatial and temporal resolution satellite and radar data, profiling stations, rain gauges, lightning, lidar and GPS networks among others are essential. Furthermore, existing instrumentation is often not distributed for optimized observation of precipitation microphysics. An observation period of at least one year will open up the possibility to statistically approach the model problems and better pin down specific model weaknesses: Some problems, e.g., initial and boundary conditions might cancel out when longer time series are considered. A General Observations Period (GOP) with a duration of one year covering Germany and its neighboring countries will be performed to provide the necessary data.

2.1.6. Education

The upcoming annual meeting of the American Association for the Advancement of Science (AAAS) in February 2006 will include under the main topic "Learning and Literacy" a symposium entitled "Strategies for Success in School-University Partnerships" as well as under "Next Generation Pathways" another symposium with the title "What's possible when teachers and researches collaborate". This shows how serious the issue of interactions between schools and university research is taken at the AAAS.

Similar efforts have been started in Europe, as it has been realized that there is still a large space for applying recent results of research on teaching and learning processes for education and schools and universities. Key to a better understanding of science topics seems to be hands-on education that also includes experiments. Furthermore, direct contact between scientists and student in the field is a strong motivation and wakes interest in special science topics as well as in natural sciences in general. Consequently, the field campaigns within PQP provide not only the opportunity to perform key research but also the possibility to be the key to implement science education into schools in order to promote scientific literacy.

2.2. Preliminary work, progress report

2.2.1. Scientific and logistic preparation of COPS

The field campaign COPS was considered as early as October 10, 2002, where a planning meeting of the PQP Steering Committee and representatives of the German Meteorological Service (DWD) took place at the Institute of Physics and Meteorology (IPM) of the University of Hohenheim (UHOH). At this meeting, it was decided to include a field campaign on QPF in orographic terrain in the overarching PQP proposal. During the next months, before the proposal was submitted, this idea was refined to a coupled design of two experiments, COPS (called Intensive Observations Period, IOP, at that time) and the General Observations Period, GOP. The results of this preparatory process became subject of the PQP proposal. In April 2004, the scientific preparation and coordination of COPS gained momentum with the start of the correspondent COPS proposal of IPM and the Institute of Meteorology and Climate Research (IMK) of the University of Karlsruhe / Forschungszentrum Karlsruhe (FZK) in April 2004.

For the scientific and logistic preparation of COPS, a full scientist position for a COPS Coordinator was accepted and made available for the COPS project office at IPM of University of Hohenheim. **Dr. Andreas Behrendt started this work on April 1, 2004.** Furthermore, a half scientist position was funded at IMK for supporting modeling work as well as for further investigations of model deficits and climatologies in the COPS region. **The following results described in sections 2.2-5.6 are mainly based on the extensive work of the IPM COPS Coordinator and the IMK scientist on the scientific and logistical preparation of COPS.**

The achievements of the COPS Project Office at IPM include:

- ➢ **Involvement of the major fraction of the national atmospheric sciences community in the COPS planning process,**
- ➢ **Initiation of a huge international collaboration, particularly with scientists from France, UK, US, and Austria, Italy, among other,**
- ➢ **Coordination of COPS with research programs of the WWRP such as THORPEX and D-PHASE,**
- ➢ **Endorsement of COPS as a WWRP RDP at the 8th Session of the WWRP Science Steering Committee (SSC) in Kunming, China, from October 24-30, 2005,**
- ➢ **Preparation of the COPS Science Overview Document (SOD).**

These achievements within the preparation Phase 1 of COPS were possible by the following steps:

- 1st International COPS Workshop at UHOH in September 2004 with about 70 scientists from more than 10 countries (see COPS webpage http://www.uni-hohenheim.de/spp-iop/ for agendas, copies of presentations, protocols etc.).
- 2nd International COPS Workshop at UHOH in June 2005 (see http://www.uni-hohenheim.de/spp-iop/).

- Strong coordination of COPS with related PQP projects (see sections 2.2.4 and 5.2).
- Analysis and request of the proposed instrumentation (questionnaires were sent to all meteorological and atmospheric sciences institutes within Germany to assess the most excellent German instruments for COPS and the GOP).

Coordination with national activities included the organization and performance of the

- 1st Workshop "Transport and Chemical Conversion in Convective Systems (TRACKS)-COPS, Konzeption eines zu COPS assoziierten Messprogramms zum konvektiven Spurenstoffaustausch", Karlsruhe, April 2004,
- 2nd Workshop "TRACKS-COPS, Konzeption eines zu COPS assoziierten Messprogramms zum konvektiven Spurenstoffaustausch", Karlsruhe, July 2005,
- Workshop concerning collaboration between meteorology and hydrology: „Quantitative Niederschlagsvorhersage, Anforderungen der Hydrologie und Möglichkeiten der Meteorologie", in cooperation with BMBF Research Program Risk Management of Extreme Flood Events (RIMAX), Karlsruhe, October, 2005.

The latter workshop provides also a very important link to projects of the WWRP where direct contact between meteorologists and end users of forecasts is highly appreciated (see section 2.2.2).

An indispensable part of the preparation of COPS was the scientific analysis of previous results, the identification of gaps in our knowledge on QPF, and the derivation of conclusions concerning key instrumentation and mission design. These activities included the following efforts and conclusions:

I. Detection and analysis of fundamental model deficits, especially confirmation of **deficits** of DWD LM **in all low-mountain areas** (internal PQP verification report, van Lipzig et al. 2005; SOD, sections 1.3 and 1.4), set up of corresponding key science goals of COPS (section 3.1).

II. Analysis of the relevance of different parameterization (section 2.1; SOD, sections 1.3 and 1.4) by evaluation of sensitivity studies leading to the result that all parameterizations are equally critical and have to be investigated simultaneously.

III. Consequently, for detecting deficiencies in QPF, the whole chain of processes leading to precipitation has to be observed simultaneously and in 4D. This requires the application and careful synergy of observing systems for pre-convective, aerosol, cloud, and precipitation measurements, which can only be applied in field campaigns (section 2.2.6; SOD, chapter 7).

IV. Thorough analysis of previous QPF campaigns with respect to their results and remaining gaps in our knowledge (see SOD, section 5.1) leading to the facts that

  - COPS can be considered a part of an international series of QPF campaigns taking place in critical areas of different complexity and forcing. This is one of the explanations of the large international interest in COPS.
  - COPS is the first campaign concentrating on QPF in a low-mountain area.
  - the relative contributions of various factors resulting in deficiencies of QPF are unknown so that they need to be separated. These include the relative impact of small-scale/large-scale processes from boundary layer circulation to convection, to cloud microphysics, to the presence of large-scale features such

as Rossby wave trains. A major conclusion from the Mesoscale Alpine Programme (MAP) experiment was that the simulated precipitation amounts depended as much on the larger-scale specification of initial fields as on the microphysical parameterizations.

- due to the complexity of QPF campaigns, a clear infrastructure for mission design and planning, the decision process, and data archiving has to be constructed (see sections 2.2.2, 3.1, 3.2; SOD, chapter 10).

V. Key science questions, suitable mission designs, and identification of key instrumentation have been derived based on a thorough climatologically and high-resolution analysis of typical weather conditions in the COPS region (see sections 2.2.5, 2.2.6, 3.1).

VI. Data assimilation in combination with the COPS data set has been identified as the key for process and predictability studies. Clear strategies for reaching the overarching COPS goals have been derived (see sections 3.1.5, 3.1.7).

2.2.2. Coordination of COPS with international activities

Right from the beginning it was realized that the ambitious scientific goals of COPS can only be achieved by strong international collaboration. This is due to the complexity of atmospheric processes in orographic terrain but also due to the importance of the knowledge of the large-scale conditions leading to CI in the COPS domain.

The international collaboration was successfully initiated by the set up of the COPS International Science Steering Committee (ISSC, see SOD, Appendix III). 2 ISSC meetings were organized at the COPS workshops and 3 additional telephone conferences (December 2004, March 2005, October 2005). Furthermore, presentations about COPS were given at, e.g.,

- Research Center for a Sustainable Humanosphere (RISH), Kyoto University, Japan, November 2004,
- 1st THORPEX Science Symposium, Montreal, Canada, December 2004,
- Eidgenössische Technische Hochschule (ETH), Zurich, Switzerland, January 2005,
- Meteo France, Toulouse, France, February 2005,
- European Geophysical Union (EGU), General Assembly, invited, Vienna, Austria, April 2005,
- Centre National de la Recherche Scientifique (CNRS), Paris, France, May 2005,
- National Center for Atmospheric Research (NCAR) Earth Observing Laboratory (EOL), Boulder, US, August 2005,
- Royal Meteorological Society, London, UK, June 2005.

The coordination of COPS with international research programs was discussed at:

- 1st THORPEX European Regional Committee (ERC) Meeting, Montreal, Canada, December 2004,

- 2nd THORPEX ERC Meeting, Vienna, Austria, April 2005: Decision on the coordination of COPS with the first summertime European THORPEX Regional Campaign in 2007 (ETReC 2007),
- Meeting of MAP FDP Science Steering Committee, Vienna, Austria, April 2005: Decision on the coordination of COPS with D-PHASE,
- Presentation of COPS at the 8th Meeting of the WWRP Science Steering Committee (SSC), Kunming, China.

In this connection, the following proposals were prepared and submitted:

- Submission of COPS ARM Mobile Facility (AMF) proposal, June 2005,
- Preparation of the first draft of the COPS Science Overview Document (SOD) in collaboration with the COPS ISSC in June 2005,
- Submission of COPS WWRP RDP proposal, October 2005,
- Submission of D-PHASE FDP proposal, October 2005,

This led to the following results:

- Endorsement of COPS as WWRP RDP, October 31, 2005,
- Endorsement of D-PHASE as WWRP FDP, October 31, 2005,
- Decision of the WWRP SSC: THORPEX ERC is the coordinating group concerning the interaction of COPS, D-PHASE, and ETReC 2007,
- The AMF proposal is still pending, a feedback is expected within November 2005.

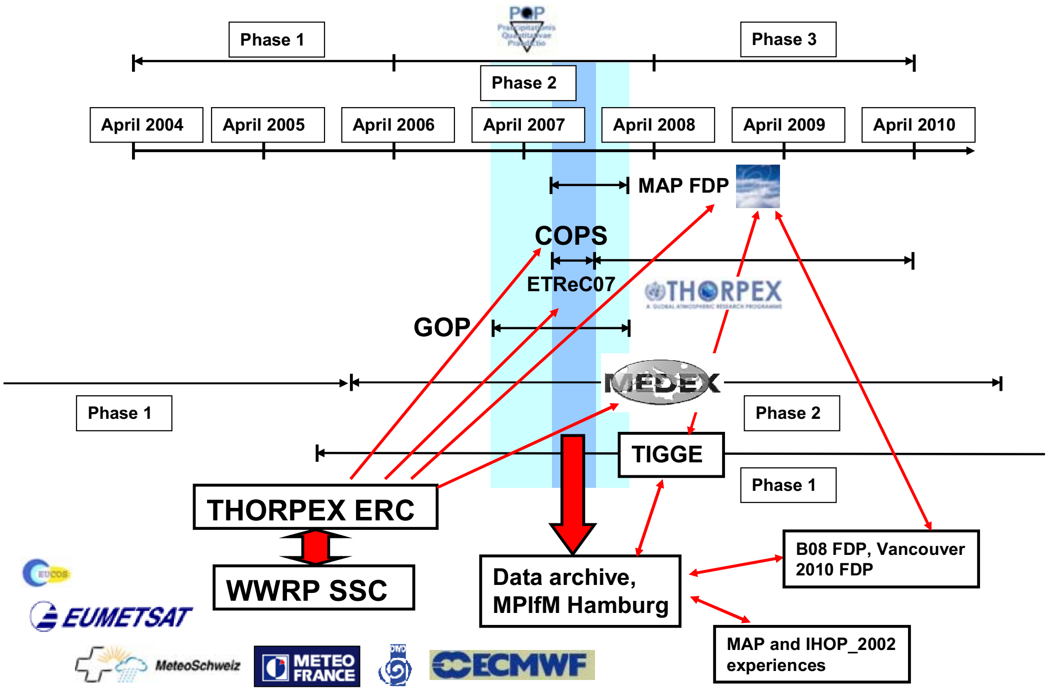


Fig. 2.1. *Time line and relationship of international programs coordinated by WWRP. IPM played a key role in the international coordination of these activities. Core gremium for international coordination will be the THORPEX European Regional Committee (ERC). B08 FDP: Beijing 2008 FDP. Further acronyms are explained in the text below.*

Furthermore, IMK scientists participated in CSIP in summer 2005 and initiated a strong collaboration between UK and German scientists on the performance of QPF field campaigns.

The present status of the coordination of COPS with international QPF research is depicted in Fig. 2.1. COPS became very successfully imbedded in WWRP research programs such as THORPEX and D-PHASE. The European THORPEX Regional Campaign ETReC 2007 is planned to be held in conjunction with COPS, providing links to the global weather forecasting community. The MAP (Mesoscale Alpine Programme) forecast demonstration project D-PHASE, will assemble new high-resolution NWP product from the meteorological services in the Alpine region during the summer and autumn of 2007, and make them available for use in analyzing COPS data. An EU INTERREG II project, RISK-AWARE 2, will conduct a real-time demonstration in August 2007 of an experimental meteorological-hydrological forecasting system for the upper Danube catchment, including the COPS region, providing a framework for evaluating end-user significance of the special observations. Through coordination with the THORPEX ERC, the experience from COPS will built into the planning of the MEDiterranean EXperiment on "Cyclones that produce high impact weather in the Mediterranean" (MEDEX) intensive measurement period that is tentatively scheduled for 2010. The spatial coverage of the major activities during summer 2007 is presented in Fig. 2.2.

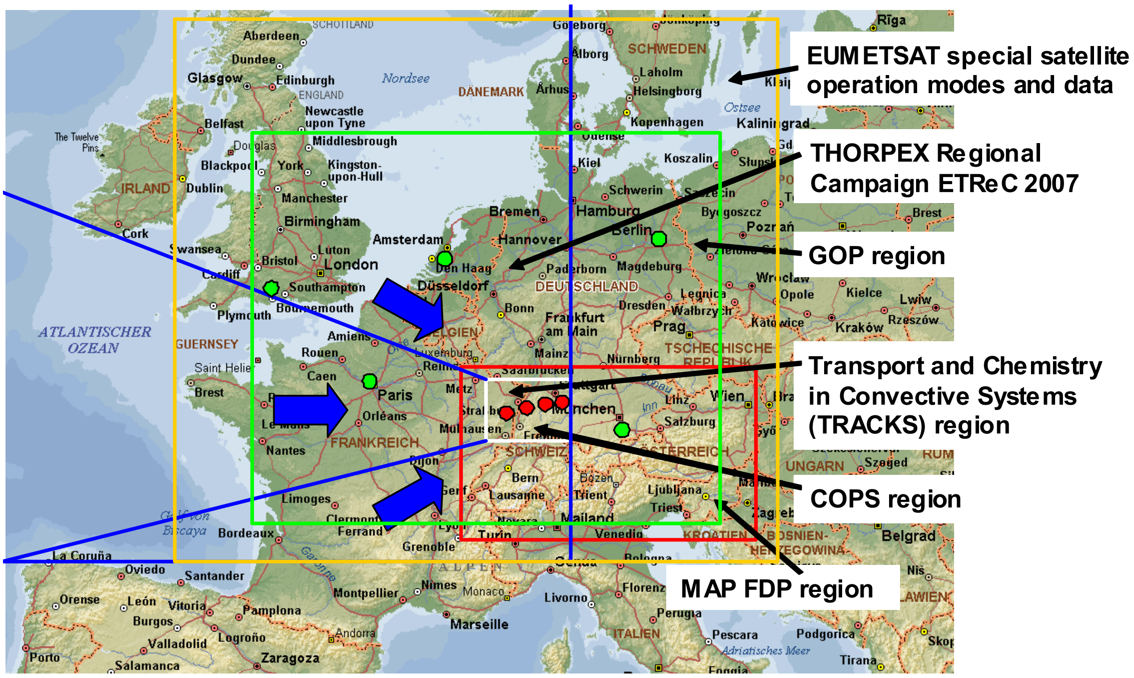


Fig. 2.2. *Spatial coverage of field activities in summer 2007 demonstrating the excellent overlap between their domains. The red circles indicate COPS supersites, which are discussed in sections 2.2.6 and 3.2.2.*

Another important aspect is the fact that data archiving got organized via the department Models & Data at the Max Planck Institute for Meteorology (MPIfM) in Hamburg, Germany. This permits data archiving with quality control at a very experienced data center. The coordination of the storage of COPS, GOP, and D-PHASE data ensures that the overview of the results is kept in one hand. Previous experience in archiving of field experiment data will be used by collaboration with the Joint Office for Science Support

(JOSS) at the National Center for Atmospheric Research (NCAR). The data archiving structure for D-PHASE shall be performed using the ECMWF Meteorological Archive and Retrieval System (MARS) so that the same structure will be used as for the global TIGGE project.

2.2.3. GOP preparation and identification of key instruments

Within the GOP, for one year routine observations covering Europe shall be collected with increasing detail towards the COPS region. Thorough quality control is essential so that these data can be used for model evaluation and data assimilation. At the PQP kick-off meeting in April 2004, Prof. Dr. Susanne Crewell from the Ludwigs-Maximilians University (LMU) in Munich was announced to lead the preparation and performance of the GOP. In-situ data sets, ground-based remote sensing networks, and satellite observations will provide the backbone of the GOP data set.

For the preparation of the GOP, the PQP colloquia and COPS workshops were used to spread the GOP idea by presentations/posters (Crewell et al. 2005) and to discuss its implementation. A web site for providing an overview of the GOP data and the relevant documents has been set up (http://server.meteo.physik.uni-muenchen.de/gop/web_latest/). The preparatory meetings lead to a close collaboration with COPS WGs and PQP projects.

During Phase 1 of PQP, the GOP preparation was supported by the overall PQP coordination project which focused on the standard observation of precipitation by **rain gauges.** Techniques were developed for analyzing systematic errors and quality control schemes for rain gauges. Diverse additional operators of rain gauge networks have been contacted. It is expected that the observations acquired by the Environmental Agencies, water authorities, and municipalities will lead to an independent data set of several hundred stations. An example for the latter is the dense (about 60), high resolution (1 min) Berlin network available through the PQP project STAMPF. Rain gauge data will be completed by stream flow sensors to generate a complete data set for hydrological applications. Most of the DWD stations (~3900) only provide daily precipitation sums. The VERIPREG project within PQP uses a disaggregation method based on radar observations to derive hourly sums for Germany. In order to make full use of these observations, quality control schemes are currently being developed. Also these data shall be made available for the GOP and COPS.

A better spatial and temporal resolution for the observation of precipitating hydrometeors is provided by **weather radars**. Most prominently the DWD radar network and those of neighboring countries can provide information about the 3D distribution of hydrometeors. Though these observations are rather indirect and a wide variety of products (more than 20) is derived from the measurements, this is a unique 3D data set concerning precipitation processes, which so far was not available for the research community. An overview about the different products for the PQP was generated by Yen et al. (2005). In addition, a radar school (http://www.meteo.physik.uni-muenchen.de/~crewell/herbstschule/) was organized in fall 2005 to educate PhD students within the PQP about radar observations, possible error source, as well as the use of radar for a number of applications, e.g., model evaluation and data assimilation among others. For these purposes, the raw 3D radar data set must be collected. The use of these data for determining the best precipitation estimation at the ground is currently investigated by the joint DFG project AQUARADAR. A close collaboration will be kept.

Micro rain radars (MRRs) are a relatively new type of instrument, which provides detailed information on the precipitation microphysics for one column, i.e. the vertically-resolved Doppler spectrum. By assuming a relationship between drop size and the vertical velocity, the drop size distribution (DSD) can be derived. Further products include the vertical profiles of liquid water content (LWC), radar reflectivity factor *Z*, mean vertical velocity of rain drops, and rain rate. Recent long term studies with MRRs in the Baltic sea area have revealed significant height dependences of DSD parameters between surface and melting layer (Peters et al. 2005), which are relevant for future physically based weather radar calibrations. In addition, systematic differences were found over land and sea respectively (Bumke et al. 2005). Currently, a small-scale array (L ~ 10 km) of MRRs is operated in the joint DFG project AQUARADAR in order to explore the structure and life cycle of single precipitation events as well as the spatial structure of rain inside of a weather radar resolution cell.

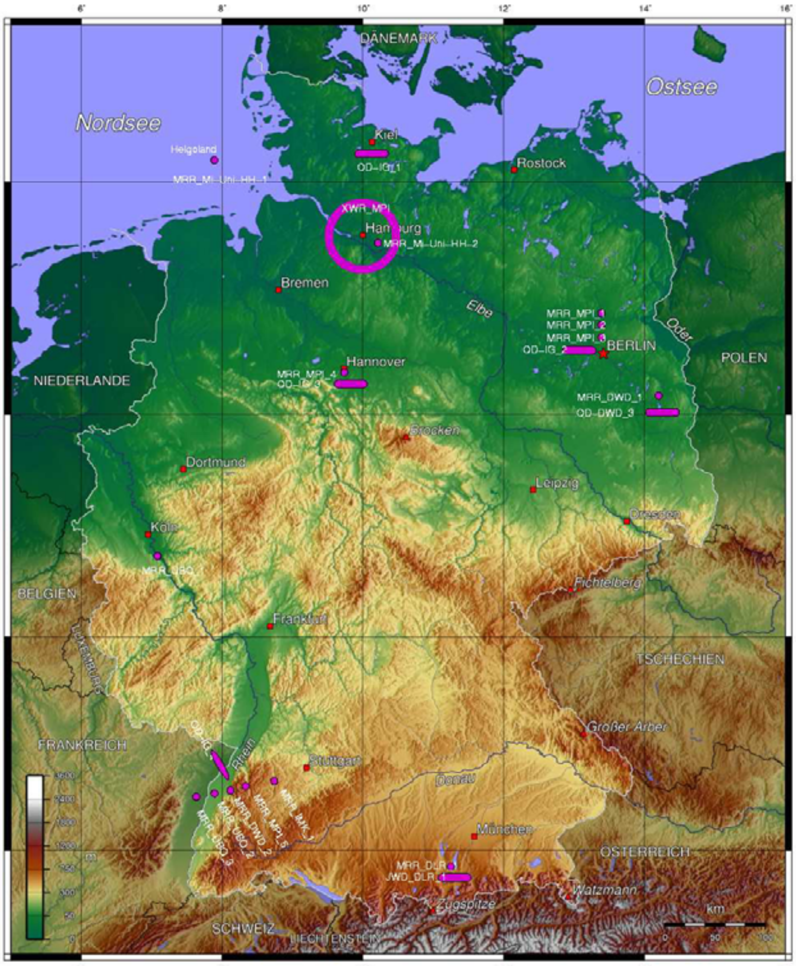


Fig. 2.3. *Planned locations for MRRs (circles), Disdrometers (lines), and low-power X-band radars of the University of Hamburg.*

It is planned to implement a network of micro rain radars (MRRs) in combination with other in-situ and active remote sensing measurements to investigate precipitation microphysics in Germany (see Fig. 2.3). Additional MRRs shall be set up in the COPS region within the scope of joint activities of COPS and GOP scientists. This transsect will be selected in coordination with the set up of the COPS radar network (see Fig. 3.3).

For studying aerosol-cloud interaction, 3D measurements of aerosol optical properties in addition to the cloud and precipitation observations are essential. These can be provided by **lidars**, particularly the European Aerosol Research Lidar Network (EARLINET, Website) network. Within the GOP, it is planned to use not only EARLINET measurement but also data of simpler lidar ceilometer networks. More than 100 lidar ceilometers are operated continuously within Germany at airports and research institutes. The observed cloud base height together with cloud top height derived from satellite measurements is an important variable to better constrain cloud microphysics (for example for the PQP assimilation projects DAQUA).

Precipitation is the result of a complex chain starting with water vapor saturation. An essential data source for humidity observations on a large scale are the zenith wet delay measurements of the Global Positioning System (**GPS**) which can be converted to the integrated water vapor. Access to this data (more than 200 in the GOP area) set turned out to be rather difficult, as GPS receivers are operated by several organizations and institutions. A comprehensive GPS data set will be a very important step towards their extended use for QPF research. A denser network of GPS receiver shall be set up in the COPS region. Furthermore, French research institutes are providing additional GPS data.

Lightning observations have been proposed to have a high potential in nowcasting of severe weather and detailed microphysical thunderstorm studies. It was decided to collect data of European lightning networks, as these can be used for distinguishing between convective and stratiform precipitation. Furthermore, these data can be used for thunderstorm tracking for example by the PQP nowcasting projects.

The weather radar network can only provide information on precipitating hydrometeors. **Satellite** data are complementary in respect to radar because they provide information on water vapor and various cloud properties as well as aerosol information with similar coverage and resolution. This allows for the investigation of the complete development and life cycle of precipitation. While geostationary satellites provide a high repetition time for life cycle studies, sensors on polar orbiters have often more spectral channels (to provide aerosol information) and a much better spatial resolution to allow sub-grid analysis. An overview of the available data sets is given in section 3.2.3.

Meteorological stations play a major role in the standard observation network. In addition to the multitude of in-situ stations advanced observatories operate advanced remote sensing devices for column observations. Continuous observations made by diverse operators will be available. Several observatories in Germany (e.g., Lindenberg, Hohenpeissenberg, especially Hartheim and Tuttlingen in the COPS region, Bonn) and Europe (e.g., Cabauw, Chilbolton, Palaiseau) have already been identified as useful.

2.2.4. Related PQP Results

As shown by the overview of PQP projects in section 5.2, nearly all PQP projects are related to COPS and the GOP. COPS has become a component of these projects with the following aims: COPS will provide a detailed data set for verification and nowcasting. It will make a test data set available for the ongoing studies on parameterizations, land-surface, and orographic effects. Several projects on the interaction of aerosol-cloud microphysics can use COPS data to perform sensitivity studies using real experimental data. Within COPS, a synergy of new observing systems will be applied, which can be used for data assimilation studies. Particularly critical is the link between an operational NWP model and aerosol measurements.

Two data assimilation projects in PQP are particularly connected, as their performance will be tested within COPS and the GOP. Both are aimed at developing new data assimilation techniques for high-resolution numerical models. In the Short-Range QPF (SRQPF) project, forward operators are being developed for vertically pointing and scanning lidar and radar systems, as well as in-situ sounding systems. Nudging, 3DVAR, and 4DVAR will be applied provided by the MM5 and WRF models. Furthermore, this project is striving for closing the gap between aerosol observations and QPF by developing a corresponding aerosol data assimilation system based on the WRF-Chem module.

In the Combined Data Assimilation with Radar and Satellite Retrievals and Ensemble Modeling for the Improvement of Short Range Quantitative Precipitation (DAQUA) project, the Lokal Model (LM) of the German Weather Service is used in a novel ensemble-based data assimilation system that combines Bayesian Monte Carlo methods with latent heat nudging and an ensemble Kalman filter to deal with intrinsic nonlinearity of cloud and precipitation processes and the non-Gaussian behavior of the resulting error statistics. Developmental versions of these two systems will be applied in COPS, as detailed in the work plan.

A further project, which has been initiated in connection with COPS, is the Virtual Reality COPS (VR-COPS) where COPS results shall be generalized by means of Observation System Simulation Experiments (OSSEs).

The PQP project QUEST has investigated the usefulness of multi-dimensional remote sensing data for model evaluation. On the basis of case studies tools were developed to bring observations and model output together in a most effective way. Some of these techniques (radar operator, hydrometeor classification, radar/satellite tracking of convective systems and fronts, patchiness parameters etc) will be transferred to operational GOP environment to routinely compare with model output. QUEST has already identified some model shortcomings (for example cloud microphysics and boundary layer structure), however, a solid data base consisting of several model parameters is needed to better attribute them to certain regimes.

2.2.5. Analysis of typical weather conditions for COPS mission design

The general climatology of weather processes in the COPS region leading to significant precipitation has been studied in the SOD (section 4.3). It was found that three large-scales conditions are typical:

1. Forced/frontal with embedded convection along a surface front in a region of large-scale lifting,
2. Forced/non-frontal with large-scale lifting, but no surface front, so convection breaking out over a wider area (this case will be analyzed below),
3. Air mass convection (non-forced/non-frontal).

The design of the field campaign will be matched to these conditions.

Not withstanding the fact that even high-resolution models have shown significant deficits and gaps, here, our working assumption is that their simulations of typical cases can be a valuable aid for mission planning and design. As an example of our planning process, we show high-resolution MM5 simulations (1-km horizontal resolution, no parameterization of convection) in the COPS region to study the model representation of deep convection. In the following, we discuss as an example the case of 19 June 2002, which was well characterized during the campaign VERTIKATOR. This case is related to the above type 2 which is the most common situation in the COPS region. Adaptation of the field design to other conditions will be performed in upcoming workshops.

It turns out that it is reasonable to divide the observation of the life cycle of precipitation in four phases. Furthermore, it is essential to consider the temporal/spatial scales of the relevant processes. Altogether, this leads to a priorization of suitable observing systems, suggestions of their operation, and a suitable design of the observing networks.

Phase 1: Pre-convection, definition of target regions

Phase 1 is defined by the presence of a pre-convective situation. The analysis performed in the SOD (section 4.3) showed that the location of and timing of CI depends in this case on the position and structure of upper-tropospheric synoptic or mesoscale troughs. Therefore, within the ETReC 2007, targeting will be performed for improving large-scale forecasts a few days ahead before CI is taking place. For this purpose, target regions have to be determined by ECMWF, UK Met Office, and Meteo France. Targeting can be performed by more extensive use of satellite and aircraft data in the critical region or by data thinning in the other regions. For this purpose, the DLR Falcon aircrafts has been requested, as this platform carries a water vapor and wind lidar as well as dropsondes.

These measurements will be performed in the context of the **COPS large-scale target region.** It extends up 1000 km upstream and up to 48 hours before the expected convective event. Upper tropospheric forcing is often associated with potential vorticity streamers or mesoscale troughs that can be seen as dry regions in Meteosat water vapor imagery. The intensity of the dynamically forced ascent, and thus the rate of destabilization for moist convection are determined by the strength of the potential vorticity gradient and its rate of movement, and can thus be inferred from the horizontal (geostrophic) wind field, with measurements of the humidity structure testing the link to the routinely available water vapor imagery. If the lifted air mass is potentially instable, convection can develop very rapidly over a wide area, several hundreds of kilometers in extent. The location and timing of individual convective features will be strongly influenced by local orographic features and forcing by surface fluxes of heat and moisture.

Such a large-scale feature could be seen on 19 June 2002, which was a case of deep convection in the Black Forest during the campaign VERTIKATOR. Fig. 2.4 shows a Meteosat image and the upper tropospheric (500 hPa) water vapor field from the high-resolution MM5 simulation. Although the position of the dry air is somewhat too far west in the simulation, the model convection can be seen to begin in the characteristic location on the boundary between the moist and dry air.

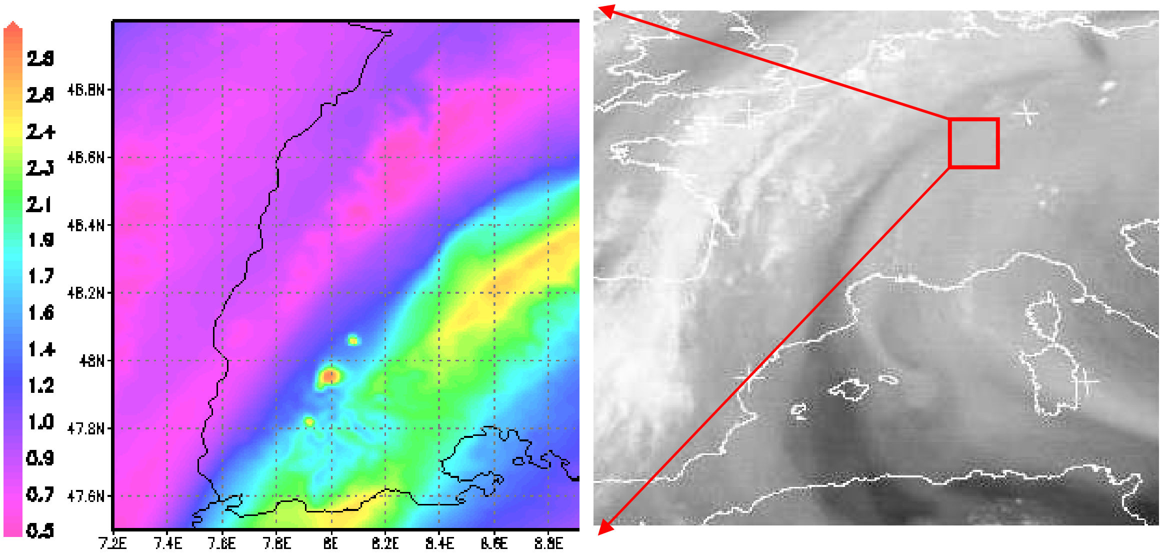


Fig. 2.4. *Left panel: Example of an MM5 simulation in the COPS region with 1 km horizontal resolution. Shown is the horizontal water vapor mixing ratio field in the middle troposphere at 12 UTC, 19 June 2002. Regions where initiation of convection takes place are indicated by strong increase of moisture. Right plot: Water vapor satellite image from Meteosat (same time).*

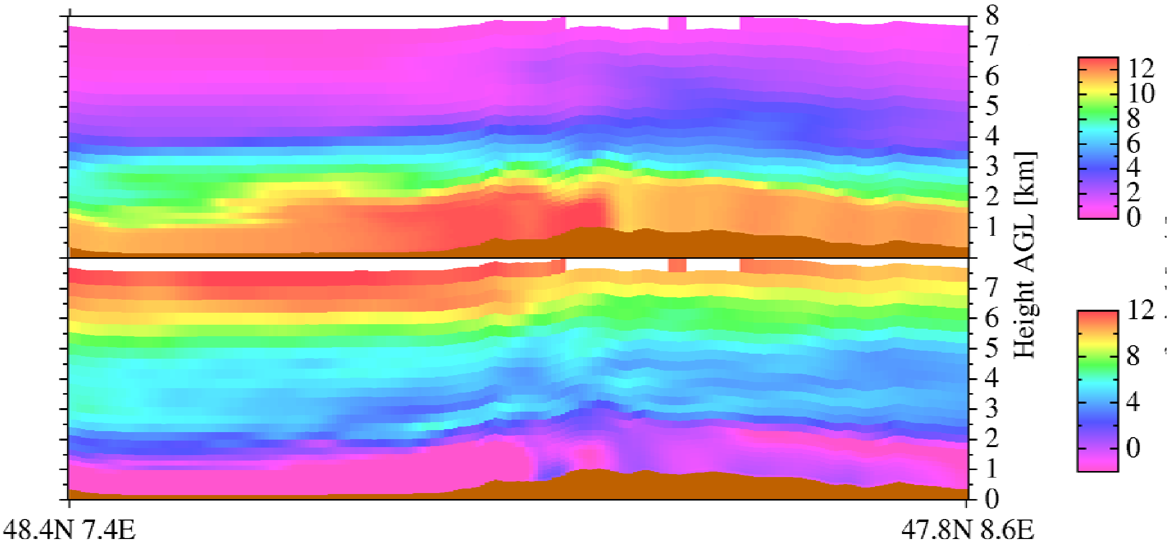


Fig. 2.5. *Vertical cross sections penetrating the Black Forest from NW to SE at 12 UTC, 19 June, 2002. The top panel shows the water vapor mixing ratio (g/kg) while the bottom panel shows horizontal wind speed (m/s) projected to the flight track.*

Fig. 2.5 presents a NW-to-SW cross section of moisture and meridional wind speed through the water vapor feature, showing how the location of CI coincides with the upper level humidity gradient and the leading edge of the upper level jet. Such cross sections can be directly measured by the airborne water vapor lidar. The horizontal wind field in the same section can be measured by scanning Doppler lidar, which will allow for determining the strength of the trough. Coupled with the trough motion, measured from successive sections, this will provide a constraint on the large-scale forcing of vertical motion. Note that although the section shown in Fig. 2.4 passes directly through the convective cloud, the observations for the COPS large-scale target will generally be made in clear sky before the outbreak of convection.

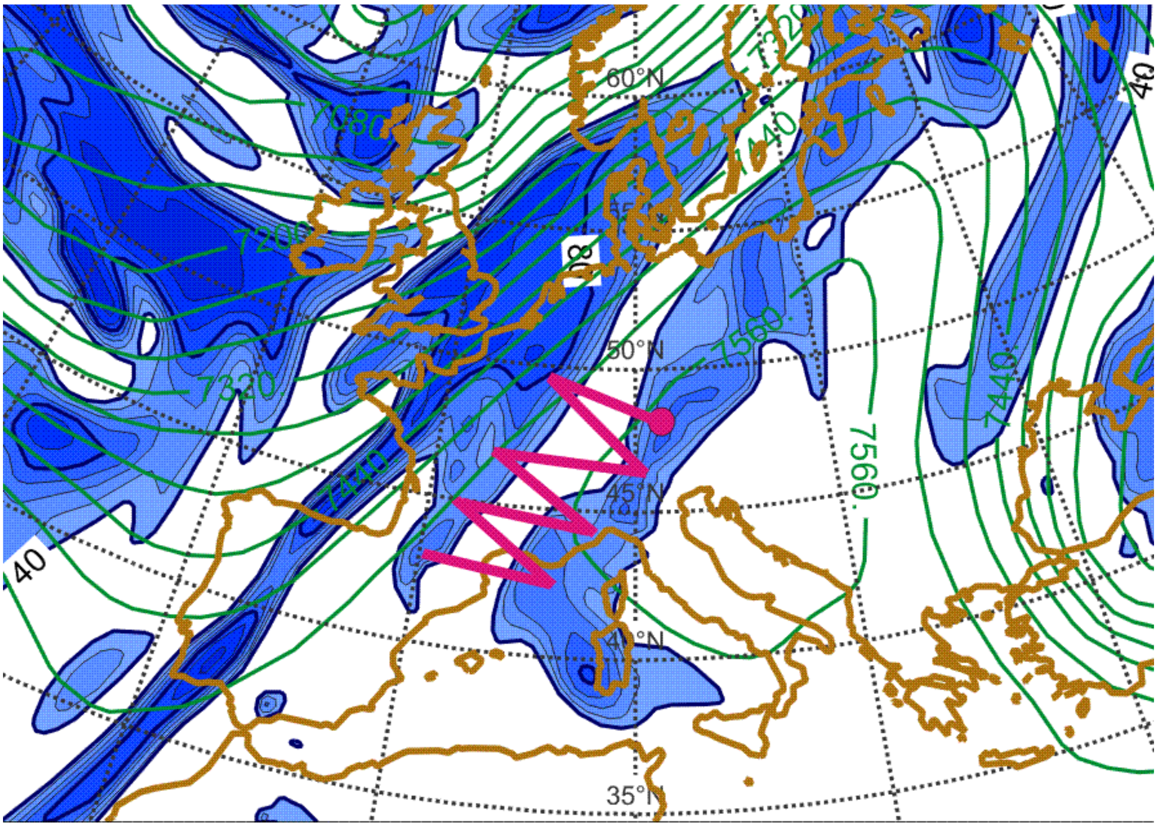


Fig. 2.6. *ECMWF analysis for 19 June 2002, 6 UTC, with contours of geopotential height and specific humidity (color coded) in 400 hPa, overlaid with a DLR Falcon flight route for mapping the stratospheric intrusion.*

Fig. 2.6 shows a possible DLR Falcon flight route for mapping the streamer associated with the dry intrusion overlaid on the ECMWF analysis. The on board wind and water vapor lidars observe the 3D wind and humidity field beneath the aircraft from 12 km flight altitude. By flying a zig-zag pattern across the streamer, the dynamics and the evolution of the streamer will be characterized with high spatial and temporal resolution. The flight route in this example is composed of seven flight legs of approximately 400 km length across the streamer with start in Oberpfaffenhofen and landing in southern France. A second flight with similar pattern some hours later back to Oberpfaffenhofen could serve to observe the streamers' temporal evolution.

It is also important to define a **COPS mesoscale target region**, which shall cover about 200 km x 300 km of the central observational region. Observations in this region are essential for better characterization of the inflow in the COPS region. Mesoscale target regions shall be detected either by calculating backward trajectories and analysis of mesoscale ensemble forecasts within D-PHASE. Furthermore, in this region middle to upper tropospheric instabilities have to be continuously observed. This can be performed with ground-based remote sensing systems, radiosoundings, as well as aircraft and satellite observations. Aircraft flight pattern have to be designed accordingly.

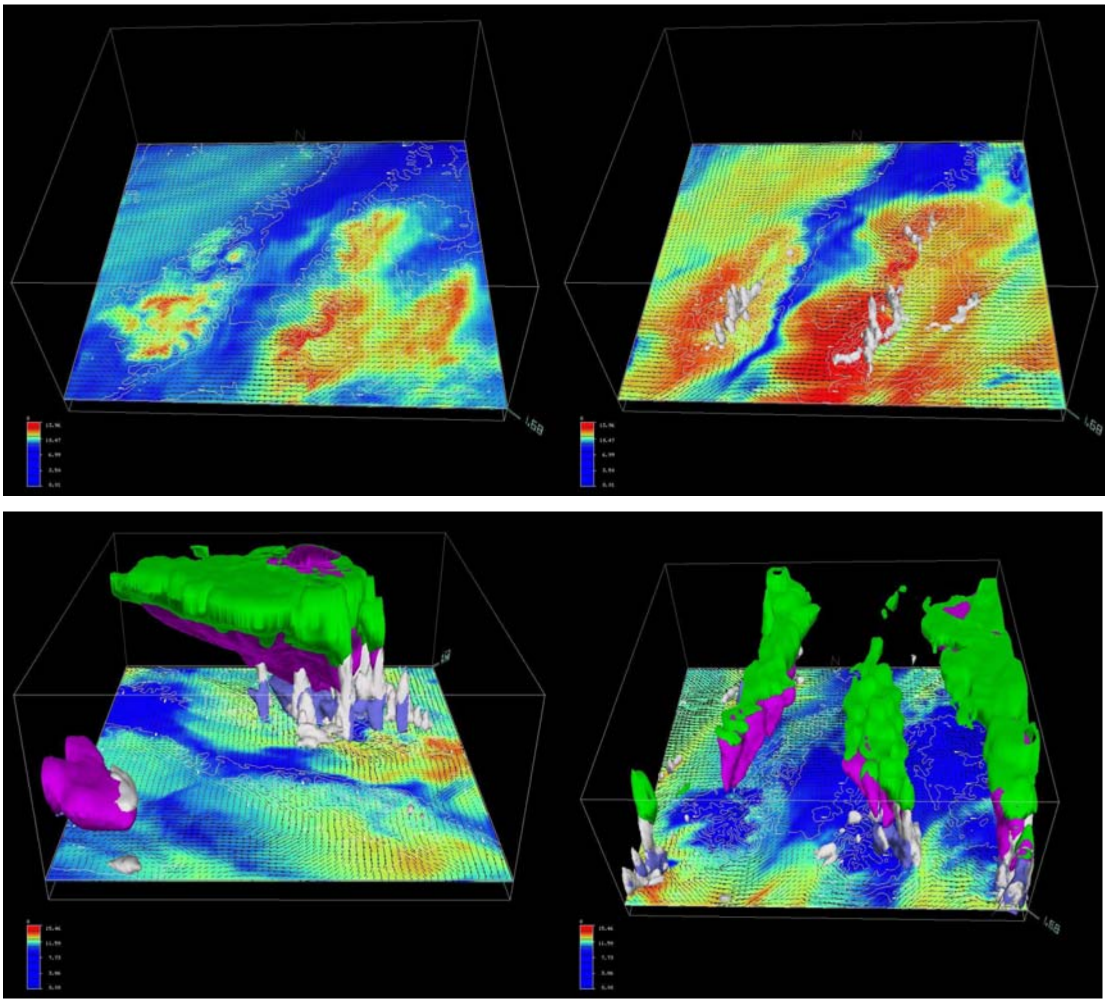


Fig. 2.7. *Dynamics and inhomogeneities of the water vapor field in the COPS region as simulated by the MM5 model with 1 km grid resolution and without convection parameterization.* ***Top left panel:*** *Simulation for 19 June 2002, 9:00 UTC. Water vapor mixing ratio (in g/kg) and wind field in 1.6 km above sea level (ASL), the orography is shown with white is lines in steps of 200 m, view from south.* ***Top right panel****: Initiation of convective clouds at 11:40 UTC. CI takes place near the ridges of the mountain ranges.* ***Bottom left panel:*** *Initiation of convective precipitation at 14:00 UTC, view from west. Different types of hydrometeors and precipitation are indicated (white = cloud water, green = ice clouds, purple = snow, and blue = rain).* ***Bottom right panel:*** *Decay of convective systems at 17:40 UTC, view from south. (courtesy of H.-S. Bauer, UHOH).*

For mesoscale targeting, operational large-scale networks using GPS and radar, additional ground-based observation systems in the critical regions will be very beneficial. Consequently, GOP observations will become important. During Phase 1, measurement of key variables such as dynamics, humidity, and temperature in the pre-convective environment will be essential.

Observations on this scale are also important for the other critical weather conditions such as embedded convection within convergence lines and frontal zones. Prior to the passage of a trough, direct thermal circulation systems develop, sharpening convergence lines and frontal zones. Enhanced instability gives reason for the formation of embedded convection, forming thunderstorms and squall lines with increased risk of severe weather.

It is clear that in the meantime boundary layer processes and aerosol microphysical properties have to be characterized in great detail in 4D in the COPS domain. Therefore, **COPS small-scale target regions** of 20 km x 20 km have to be defined. In these regions, differential heating of the Earth's surface and in moisture uptake by the lowest layers is taking place modified by orographic effects in the low mountain region. The WGs CI and ACM will work closely together, as their measurements of aerosol properties and the thermodynamic environment have to be performed simultaneously in 4D at the locations where CI is expected. Therefore, lidars and radars will provide the backbone for these kinds of observations, as only these systems are able to perform rapid scans and range-resolved measurements with high resolution and accuracy.

Consequently, it is reasonable to combine different kinds of remote sensing systems in so-called **supersites** in order to take advantages of sensor synergy (see SOD, section 7.4). Furthermore, characterization of land surface inhomogeneities with flux and soil moisture networks is critical. Fig. 2.7 shows a series of images of the evolution of dynamics and water components during the life cycle of convective precipitation, confirming the importance of synergetic observations at key locations.

Phase 2: Convection Initiation

During **Phase 2**, CI and cloud formation is expected within a few hours. Development of convection may take place in flat terrain and over low mountain ranges. These are highly QPF-related processes because rapidly growing deep convection is often accompanied by sudden heavy rainfall in a very narrow area. Flash floods and damages can occur.

Particularly, secondary circulation systems developing during daytime in the larger valley systems are responsible for triggering of convection and subsequent precipitation. Our high-resolution MM5 runs show an evolution of convection at the ridges of the COPS low-mountain regions (see Fig. 2.5 and Fig. 2.7). For instance, convergence of air masses takes place due to small-scale circulations around and in the valleys of the Black Forest. Figure 2.2 presents the corresponding cross-section of humidity and vertical velocity. It is clear that the pre-convective thermodynamic environment has to be observed close to ridges. Furthermore, it is important to study the dynamics around and in the valleys.

Consequently, during Phase 2, the measurements will concentrate on the **COPS small-scale target regions.** The operation modes of scanning lidar systems and radiometers will be adapted for 4D observations of atmospheric key variables and aerosols in the expected region of convection. Scanning microwave radar measurements will be added for extending the range of 4D observations into clouds and for investigation aerosol-cloud interaction. WG PPL will get ready for the observation of precipitation.

Simultaneously, targeting on the **mesoscale target region** will be continued in order to characterize the advection of air masses in the COPS domain as best as possible.

Phase 3: Development of Convection and Onset of Precipitation

During **Phase 3**, CI is continuing and precipitation is forming. Now, the COPS measurements are extended by cloud and precipitation measurements focusing of the **small-scale target region.** Suitable remote sensing systems have to be well coordinated to capture the event as accurate as possible. It is planned to measure the thermodynamic environment of clouds, aerosol distributions, as well as cloud and precipitation microphysical properties simultaneously in 4D. Consequently, a strong cooperation between the WGs CI, ACM, and PPL as well as with the GOP PIs will be very important.

As soon as the convective system will leave the coverage of the remote sensing systems at the supersites, observations will be continued in the **mesoscale target regions**. Clear-air and cloud measurements will be used to study the organization of convection, and precipitation radars will be added. Tracking of the convective system will be started with ground-based mobile instrumentation (some of these are available and additional radar systems have been requested in the US), aircrafts, radar systems with large range, as well as satellite observations. Fig. 2.8 shows a sample multi-aircraft mission around the region where CI took place.

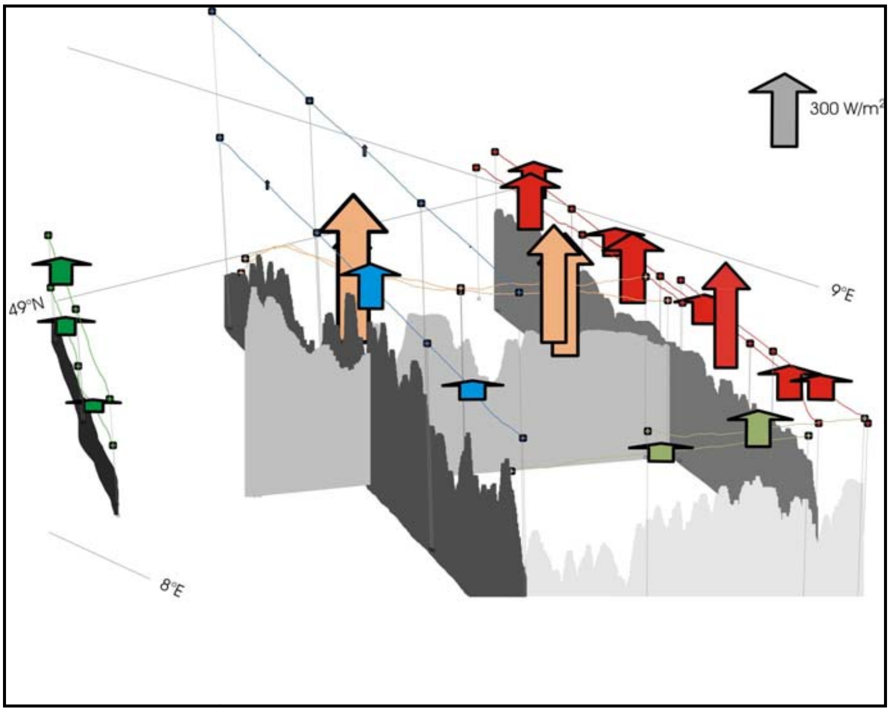


Fig. 2.8. *Example of measurements covering the COPS mesoscale target region: airborne measurements with the DO 128 aircraft and turbulence probing system providing turbulent humidity fluxes (arrows) over the Northern Black Forest on June 19, 2002 around noon (Barthlott et al. 2005). Turbulent fluxes are obtained at different flight levels and are averages over sections of about 30 km. Maximum fluxes are found over the highest mountains. The capabilities of combined water vapor lidar and wind lidar on the DLR-Falcon aircraft shall provide a high-resolution 3D-assessment for such a region during COPS.*

Phase 4: Maintenance and Decay of Precipitating System

This phase is defined by the evolution of the convective system, which shall also be observed as continuous and detailed as possible. It may be necessary to extend the measurements again to the **large-scale target region**.

The choice of operation modes of the synergy of ground-based and airborne systems will be prepared by extensive analyses of model forecasts in the COPS Operations Center (see section 3.2.2). A very flexible ground-based and aircraft mission planning is essential. Is can be expected that convective systems with long lifetime will evolve in direction of the eastern part of Germany and even in the Alpine region so that GOP and satellite data in the lee side of the COPS region will become an important part of this tracking exercise.

During all these phases, some of the observation systems will provide data in real time, which will be used for real-time data assimilation (see section 3.1.5).

2.2.6. Key instrumentation

Based on the scientific goals of COPS (see SOD, sections 3 and 6), a detailed analysis of the performance of current observation systems (see SOD, section 7), and the meteorological analyses above, priorities for suitable systems, which are beneficial for reaching the COPS and the GOP goals have been derived.

Particularly important are remote sensing systems, which are capable of measuring prognostic variables. We are distinguishing between operational and research observation systems, the latter being operated continuously or discontinuously. A full list of the envisioned instrumentation is summarized in the SOD (see section 9).

Operational observing systems include all GOP instruments, surface weather stations operated by national weather services and private weather companies, disdrometer, lightning location, and air-chemical networks, river runoff stations, as well as operational radiosondes. It is clear that these data sources will be extensively used within COPS. Details of the excellent logistics in the COPS region are presented in the SOD, section 10.

Continuous COPS observation systems provide regular measurements during the campaign without changes of the observation strategy. Several continuous observation systems will be added in suitable networks during the campaign. These include additional radiosonde stations, a denser GPS network, soil moisture sensors, radiometers, and several micro-rain radars. meteorological mesonet stations, surface flux and energy balance stations, as well as continuously operating ground-based remote sensing systems also belong to this category (see SOD, section 10).

Discontinuous COPS 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, in particular aircraft and specific remote sensing systems are usually more complex and cannot be operated continuously. A unique suite of such advanced systems, such as airborne wind and water vapor lidar and movable ground-based radiosonde systems for adaptive observations will be applied and is essential to reach the COPS goals. To assess the measurement performance of new instruments, forward operators were derived and observing system simulations were performed (see Fig. 2.9). These results will be used to find the optimal location of these observation systems.

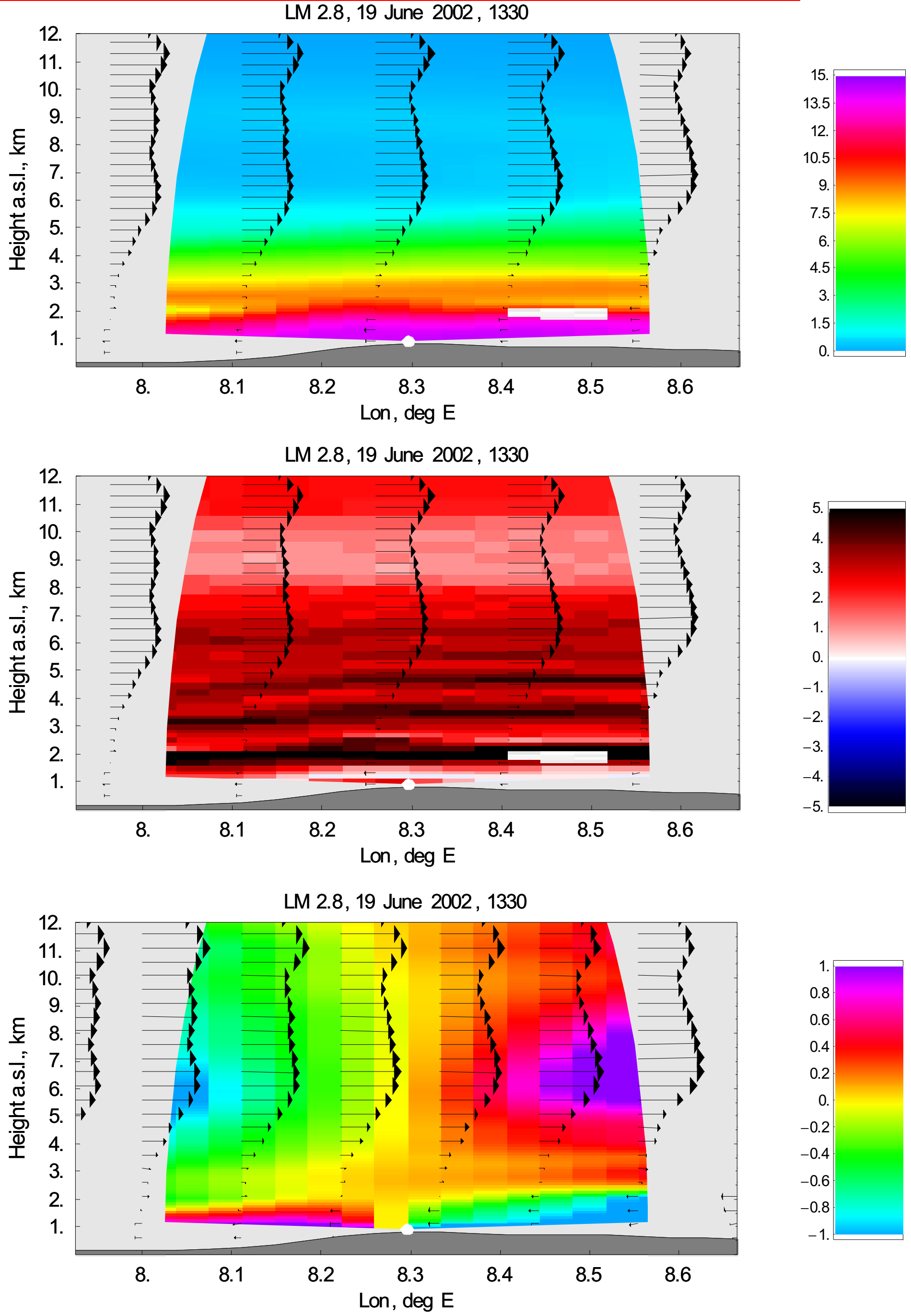


Fig. 2.9. *Example of the expected instrument performance in the COPS region. Range-height-indicator scans in east-west direction with 10-km radius of lidars located at Hornisgrinde, Northern Black Forest, close to where supersite 1 is planned.* ***Top:*** *water vapor DIAL (mixing ratio in g/kg).* ***Middle:*** *rotational Raman temperature lidar (middle, temperature gradient + 9.81 K/km in K/km).* ***Bottom:*** *Doppler lidar (bottom, line-of-sight wind component in m/s). As input, LM data of 2.8 km grid resolution for 19 June 2002 where used. In addition to the fields of the measured parameters shown in colors, also the zonal wind component is plotted (A. Behrendt et al., unpublished).*

Observing system set up

The majority of the instruments will be based on remote sensing, as a high resolution and accuracy of the measurements in 2D or 3D are essential. Furthermore, different kinds of remote sensing systems shall be combined at so-called supersites so that the atmospheric key variables wind, water, and temperature can be observed simultaneously.

Supersites are needed to study the whole life cycle of convective precipitation, to derive synergetic parameters from the combined set of data, and to ensure the quality of the data by intercomparisons (e.g., Behrendt et al. 2005a, 2005b). They have to be set up near locations of high probability for CI. Such locations are known for the COPS low-mountain region where the locations of initiation of convection are rather confined. Scanning multi-wavelength remote sensing instruments for water vapor, wind, temperature, clouds, and aerosol need to be operated combined with energy balance stations, and at least one near-by upwind radiosonde station. The proposed setup of the COPS supersites is described in section 3.2.2, further details on the proposed instrument synergy can be found in the SOD, section 7.4.

Networks combine instruments with similar performance, quality, products, and observation modes. The set up of operational networks of interest covering the COPS region can be found in the SOD, section 10, this proposal Appendix 7.4. Data will be gathered as part of the GOP and are enhanced for COPS. Most prominently the national weather radar networks together with research radars will provide information on the 4D hydrometeor distribution. In addition, the operational GPS and lightning networks will be enhanced during COPS with additional sensors for integrated water vapor and a specialized system for detecting in cloud lightning. Aerosol observation at regular intervals will be contributed by EARLINET. To study the precipitation microphysics in general a network of micro rain radars (MRR) together with disdrometers will be established during the GOP with high density in the COPS area. Detailed planning of radar system set up in combination with COPS observations is under the way (see section 3.1.4 as well as Fig. 3.2 and Fig. 3.3).

Satellites provide continuous information on atmospheric properties over large areas and are indispensable for long-term statistical studies. In addition to geostationary satellite (Meteosat Second Generation MSG) instruments on polar orbiters (e.g., MODIS, MERIS, AMSU, AMSR, SSM/I, CALIPSO/CLOUDSAT) will be used to study subgrid-scale (<500 m) distributions and additional parameters (aerosol) (see also section 3.2.3). The combination of satellite, airborne, and ground based remote sensing is well suited to provide intercalibrated meteorological data sets, which might help to increase our knowledge of physical processes and through evaluation efforts might identify uncertainties in the forecast of NWP models. Our increased understanding of physical processes together with the assimilation of observational data into NWP models will increase their performance and reliability.

2.2.7. Education

The PI of the Coord1167-NUMEX proposal presents meteorology (or atmospheric sciences in the anglo-saxon university culture) regularly to classes from primary and secondary schools (mainly year three to six) with a main emphasis to detrivialize the general understanding of meteorology and transport the vision that meteorology is a science of applied math, applied informatics, and applied physics with the necessity to be studied at university level.

Additionally the Coord1167-NUMEX PI was actively engaged in organizing vocational trainings for meteorologist from universities, weather services, public, and private companies while being the head of the local chapter (ZVR) of the German Meteorological Society DMG. Topics have been aviation meteorology, forecasting of extreme weather events (with Prof. John Snow University of Oklahoma as key note speaker), climate modeling and hydrology or recent advances in oceanography. The NUMEX PI and the PIs of this proposal are actively participating in the development of the new consecutive BSc./M.Sc. for meteorology and other areas.

But in order to effectively promote scientific literacy for learners it is not only important to communicate and implement meteorology / atmospheric sciences at school, we also need to know about the impact of the implementation of science topics. In consequence, we are sure that the process of successful implementation has to be accompanied by educational research. Educational scientists have proven that a science topic is not likely to be understood by learners when it is only transported into schools, e.g. from the meteorologist's point of view. Moreover, it has to be didactically reconstructed to be connectable to learners' perceptions.

The PI of the Meteorology in Action (MiA) proposal researches the possibilities of communicating and transferring scientific knowledge and competence of atmospheric scientists / meteorologists into teacher education at universities and into elementary schools. It is structured to prepare and enable teacher-training students at universities, teachers in-service and learners at school to participate in the scientific discourse by joining the COPS Outdoor Institute of Meteorology during COPS in 2007 as proposed in the Coord1167-NUMEX proposal.

A. COPS Outdoor Institute of Meteorology

For university students wishing to participate in COPS, a summer school is planned in 2007. This event will give national and international well known scientists the opportunity to present lectures on their work in general and their activities during COPS in special to students ("COPS Outdoor Institute of Meteorology"). This summer school will back-up the respective student activities with regard to the student measurement campaigns planned within COPS. The second goal regarding educational affairs is to establish a transfer of knowledge and education to schools via collaboration with the planned project MiA regarding the vocational training of participating teachers and of students in teacher education as well as the educational research on learners' perceptions and learning pathways.

The organization of the planned "COPS Outdoor Institute of Meteorology" will start once the DFG funding of COPS is confirmed. We will contact all PIs and arrange specific lectures on (a) modern measurement techniques, (b) dynamics of convection, (c) data assimilation, (d) predictability and orography in mesoscale meteorology, (e) microphysics in models and observations to cover the scientific hypotheses of COPS and of PQP. University institute from Germany and nearby European countries will be contacted to advertise the summer school as early as possible.

B. Meteorology in Action (MiA)

We propose to contribute to the attempt for transferring knowledge from PQP into public schools. The planning for combining lectures given within the outdoor institute with the vocational training of participating teachers will be coordinated with MiA, a new project proposed for the 2nd phase of PQP. One idea is to ask participating students from the outdoor institute to present lectures for teachers on basic meteorology. Another approach is to organize joint lectures for the training as well as for the outdoor institute regarding more general themes.

International learner-comparison-studies like Programme for International Student Assessment (PISA) or Trends in International Mathematics and Science Study (TIMSS) made it clear how important it is to extend all efforts towards a scientific literacy. When talking about education in connection with COPS there are different levels to take into view. The question where interest and motivation starts from and how it can be taken further is always a concern in the Educational Sciences dealing with school education. Children's perceptions and their concepts, e.g. of a scientific phenomenon, are angles to start from in the field of research of teaching and learning processes. Especially in natural sciences, a lot of research is done that focuses on learners' so-called misconceptions.

Educational scientists know that simply instructing children, pointing out their mistakes to them or telling them the correct answers, is not likely to be successful. Besides, naïve or even incorrect concepts show a great persistence that sometimes lasts for life. Therefore, it is imperative that those concepts are diagnosed and that teachers offer adequate teaching and learning situations that enable children to deconstruct incorrect concepts and to connect topics to their real life.

Not only the content of learning situations, but also the methods and social aspects should be the concern of teachers. A good learning environment that gives orientation and freedom at the same time and in which experiences can be structured by trying out and experimenting, seems to be important for learners in order to be able to prove the correct concepts to themselves.

Natural science education should aim at a conceptual understanding that can also be used outside the classroom. Scientific models and knowledge need to be proven in real situations in order to be able to be connected to the learner's lives and to be satisfactory for them. Structuring and understanding scientific phenomena also includes realizing the systemic character of processes. Only under the condition that systemic thinking and systemic understanding is initiated, learners can develop correct concepts and gain competence that enables them to critically, responsibly and reflectively act in the complex situations of their lives.

The initiation of systemic thinking should start in elementary level. Asking questions, trying, experiencing, and drawing conclusions are examples for a natural science education that focuses on the present and future life of learners.

The COPS campaign is a great possibility to communicate and transfer scientific knowledge and let children in grades 3 and 4 participate in scientific work. That way, the COPS program practices promotion of scientific literacy, which is a great challenge for schools today.

The educational program MiA, a new project proposed for the 2nd phase of PQP, is structured to prepare and enable students of educational sciences, school teachers and young learners to participate in COPS. It also includes empirical research on learner's perceptions on meteorology in general, precipitation in particular and about the work of meteorologists. Furthermore, it researches the development of learners' concepts and their conceptual change while participating in the COPS *Outdoor Institute of Meteorology* and it wants to find out how systemic thinking and understanding can be initiated through a hands-on program.

2.2.8. Relevant literature

Andreae, M.O., D. Rosenfeld, P. Artaxo, A.A. Costa, G.P. Frank, K.M. Longo, and M.A.F. Silva-Dias, 2004: Smoking Rain Clouds over the Amazon, *Science*, **303**, 1337-1342.

Barthlott, C., U. Corsmeier, C. Meißner, F. Braun, and C. Kottmeier, 2005: The influence of mesoscale circulation systems on triggering convective cells over complex terrain. Submitted to *Atmos. Res.*

Bechtold, P., J.P. Chaboureau, A. Beljaars, A.K. Betts, M. Kohler, M. Miller and J.L. Redelsperger, 2004: The simulation of the diurnal cycle of convective precipitation over land in a global model, *Quart. J. Roy. Meteorol. Soc.*, **130 (604)**, 3119-3137.

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, J. Wang: 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. Atmos. Oceanic Technol.*, 2005.

Behrendt, A., V. Wulfmeyer, C. Kiemle, G. Ehret, T. Schaberl, H.-S. Bauer, E. V. Browell, S. Ismail, R. Ferrare, C. Flamant: Intercomparison of water vapor data measured with lidar during IHOP_2002, Part 2: Airborne to airborne systems. Submitted to *J. Atmos. Oceanic Technol.*, 2005.

Betz, H.-D., K. Schmidt, W.P. Oettinger, and M. Wirz, 2004: Lightning Detection with 3D-Discrimination of Intracloud and Cloud-to-Ground Discharges. *J. Geophys. Res. Lett.*, **31**, L11108.

Bright, D.R., and S.L. Mullen, 2002: Short-Range Ensemble Forecasts of Precipitation during the Southwest Monsoon, *Weather Forecast.,* **17**, 1080-1100.

Bumke, K., M. Clemens, H. Graßl, S. Pang, G. Peters, J.E.E. Seltmann, T. Siebenborn, and A. Wagner, 2005: APOLAS More accurate areal precipitation over land and sea, Abschlussbericht, DEKLIM Forschungsprojekt des BMBF 01LD 0029, 60 pp.

Buzzi A., S. Davolio, M. D'Isidoro, and P. Malguzzi, 2004: The impact of resolution and of MAP reanalysis on the simulations of heavy precipitation during MAP cases. *Meteorol. Z.,* **13**, 91-97.

Carbone, R.E., J.D. Tuttle, D.A. Ahijevych, and S.B. Trier, 2002: Inferences of predictability associated with warm season precipitation episodes. *J. Atmos. Sci.*, **59**, 2033-2056.

Crewell, S. C. Simmer, H. Bloemink, A. Feijt, S. Garcia, D. Jolivet, O. Krasnov, A. Van Lammeren, U. Löhnert, E. Van Meijgaard, J. Meywerk, K. Pfeilsticker, M. Quante, S. Schmidt, M. Schröder, T. Scholl, T. Trautmann, V. Venema, M. Wendisch, and U. Willén, 2004: The BALTEX Bridge Campaign: An integrated approach for a better understanding of clouds. *Bull. Amer. Meteorol. Soc.*, **85(10)**, 1565-1584.

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 Environ. Res.*, **7**, 235-245.

Davis, C.A., K.W. Manning, R.E. Carbone, S.B. Trier, and J.D. Tuttle, 2003: Coherence of warm-season continental rainfall in numerical weather prediction models. *Mon. Wea. Rev.*, **131**, 2667-2679.

Dowell, D., F. Zhang, L.J. Wicker, C. Snyder, and N.A. Crook, 2004: Wind and Temperature Retrievals in the 17 May 1981 Arcadia, Oklahoma, Supercell: Ensemble Kalman Filter Experiments. *Mon. Wea. Rev.*, **132**, 1982-2005.

Ellis, S., J. Vivekanandan, K. Goodman, Jr. and C. Kessinger, 2005: Water vapor and liquid water estimates using simultaneous S and Ka band radar measurements. Preprints, *32nd Int. Conf. on Radar Meteorol.*, Amer. Meteor. Soc., Albuquerque, NM, 24-29 October 2005.

Fehr, T., N. Dotzek, and H. Höller, 2005: Comparison of lightning activity and radar-retrieved microphysical properties in EULINOX storms. *Atmos. Res.*, **76**, 167–189.

Feingold G, W.L. Eberhard, D.E. Vernon, and M. Previdi, 2003: First measurements of the Twomey indirect effect using ground-based sensors. *Geophys. Res. Lett.*, **30**, doi:10.1029/2002GL016 633, 2003.

Feingold, G., H. Jiang, and J.Y. Harrington, 2005a: On smoke suppression of clouds in Amazonia. *Geophys. Res. Lett.*, **32**, No. 2, L02804, 10.1029/2004GL021369.

Feingold, G., R. Furrer, P. Pilewskie, L.A. Remer, Q. Min, and H. Jonsson, 2005b: Aerosol Indirect Effect Studies at Southern Great Plains during the May 2003 Intensive Observations Period. *J. Geophys. Res.*, in press.

Ferek, R.J., T. Garrett, P.V. Hobbs, S. Strader, D. Johnson, J.P. Taylor, K. Nielsen, A.S. Ackerman, Y. Kogan, Q. Liu, B.A. Albrecht, and D. Babb, 2000: Drizzle suppression in ship tracks. *J. Atmos. Sci.*, **57**, 2707-2728.

Friedrich, K., and M. Hagen, 2004: On the use of advanced Doppler radar techniques to determine horizontal wind fields for operational weather surveillance. *Meteorol. Appl.*, **11**, 155-171.

Gao, J., M. Xue, K. Brewster, and K.K. Droegemeier, 2004: A Three-Dimensional Variational Data Analysis Method with Recursive Filter for Doppler Radars. *J. Atmos. Oceanic Technol.*, **21**, no. 3, 457-469.

Givati, A., and D. Rosenfeld, 2004: Quantifying Precipitation Suppression due to Air Pollution. *J. Appl. Meteorol.*, **43**, 1038-1056.

Guichard, F., Parsons, D. B., Dudhia, J., Bresch, J., 2003. Evaluating mesoscale model predictions of clouds and radiation with SGP ARM data over a seasonal timescale. *Mon. Wea. Rev.*, **131 (5)**, 926-944.

Guichard, F., J.C. Petch, J.-L. Redelsperger, P. Bechthold, J.-P. Chaboureau, S. Cheinet, W. Grabowski, H. Grenier, C.G. Jones, M. Köhler, J.-M. Piriou, R. Tailleux, and M. Tomasini, 2004. Modelling the diurnal cycle of deep precipitating convection over land with cloud-resolving and single-column models. *Quart. J. Roy. Meteorol. Soc.* **130**, 3139-3172.

Haase, G., and S. Crewell, 2000: Simulation of radar reflectivities using is mesoscale weather forecast model. *Water Resources Res.*, **36**, 2221-2230.

Haase, G., S. Crewell, C. Simmer, and W. Wergen, 2000: Assimilation of radar data in mesoscale models. Physical initialization and laten heat nudging. Phys. Chem. Earth (B), **25**, 1237-1242.

Hagen, M., B. Bartenschlager, and U. Finke, 1999: Motion characteristics of thinderstorms in southern Germany. *Meteorol. Appl.*, **6**, 227-239.

Hagen, M., H.-H. Schiesser, and M. Dorninger, 2000: Monitoring of mesoscale precipitation systems in the Alps and the northern Alpine foreland by radar and rain gauges. *Meteorol. Atmos. Phys.*, **72**, 87-100.

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(3)**, 513-525.

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 evaluation a mesoscale model. *J. Appl. Meteorol.*, in press.

Höller, H., V. N. Bringi, J. Hubbert, M. Hagen, and P. F. Meischner, 1994: Life cycle and precipitation formation in a hybrid-type hailstorm revealed by polarimetric and Doppler radar measurements. *J. Atmos. Sci.*, **51**, 2500–2522.

Kaufman, Y.J., I. Koren, L.A. Remer, D. Tanré, P. Ginoux, and S. Fan, 2005: Dust transport and deposition observed from the Terra-Moderate ResolutionImaging Spctroradiometer (MODIS) spacecraft over the Atlantic Ocean. *J. Geophys. Res.*, **110**, D10S12, doi:10.1029/2003JD004436l.

Kunz, M., and C. Kottmeier, 2005a: Orographic enhancement of precipitation over low mountain ranges, Part I: Model formulation, *J. Appl. Meteorol.*, submitted.

Kunz, M., and C. Kottmeier, 2005b: Orographic enhancement of precipitation over low mountain ranges, Part II: Simulations of heavy precipitation events, *J. Appl. Meteorol.*, submitted.

Lascaux, F., E. Richard, C. Keil, and O. Bock, 2004: Impact of the MAP reanalysis on the numerical simulation of the MAP-IOP2a convective system. *Meteorol. Z.,* **13**, no. 1, pp. 49-54.

Lohmann, U., and J. Feichter, 2005: Global indirect aerosol effects: A review. *Atmos. Chem. Phys.*, **5**, 715-737.

Martin, W.J., and M. Xue, 2005: Initial condition sensitivity analysis of a mesoscale forecast using very-large ensembles. *Mon. Wea. Rev.* accepted.

Meischner, P.F., V.N. Bringi, D. Heimann and H. Höller. 1991: A Squall Line in Southern Germany: Kinematics and Precipitation Formation as Deduced by Advanced Polarimetric and Doppler Radar Measurements. *Mon. Wea. Rev.*, **119**, 678-701.

Meißner, C., N. Kalthoff, M. Kunz, U. Corsmeier and G. Adrian, 2005: Initialisation of deep convection over low mountain ranges, *Meteorol. Atmos. Phys.*, submitted.

Molteni, F., R. Buizza, C. Marsigli, A. Montani, F. Nerozzi, and T. Paccagnella, 2001: A strategy for high-resolution ensemble prediction. Part I: Definition of representative members and global-model experiments. *Quart. J. Roy. Meteor. Soc.,* **127**, 2069-2094.

Peters, G., B. Fischer, H. Münster, M. Clemens, and A. Wagner, 2005: Profiles of rain Drop Size Distributions as retrieved by Micro Rain Radars, *J. Appl. Met.*, accepted.

Quiby, J., and M. Denhard, 2003: SRNWP-DWD Poor-Man Ensemble Prediction System: The PEPS Project. *Eumetnet News*, **8**, (available from http://www.eumetnet.eu.org/WnewLet.htm).

Pfeifer, M., G. Craig, M. Hagen, and C. Keil, 2004. A polarimetric radar forward operator, Proc. Third European Conference on Radar in Meteorology and Hydrology (ERAD), Visby, Sweden, 494-498, 2004.

Richard, E., S. Cosma, P. Tabary, J.-P. Pinty, and M. Hagen, 2003: High-resolution numerical simulations of the convective system observed in the Lago Maggiore area on 17 September 1999 (MAP IOP 2a). *Quart. J. Roy. Meteorol. Soc.*, **129**, 543-563.

Rose, T., S. Crewell, U. Löhnert and C. Simmer, 2005: A network suitable microwave radiometer for operational monitoring of the cloudy atmosphere. *Atmos. Res.*, **75(3)**, 183-200, doi:10.1016/j.atmosres.2004.12.005.

Rosenfeld, D., 1999: TRMM observed direct evidence of smoke from forest fires inhibiting rainfall. *Geophys. Res. Lett.*, **26**, 3105-3108.

Rosenfeld, D., 2000: Suppression of rain and snow by urban and industrial air pollution. *Science*, **287**, 1793-1796.

Seifert, A., and K.D. Beheng, 2005a: A two-moment cloud microphysics parameterization for mixed-phase clouds. Part I: Model description. *Meteorol. Atmos. Phys.*, DOI 10.1007/s00703-005-0112-4.

Seifert, A., and K.D. Beheng, 2005b: A two-moment cloud microphysics parameterization for mixed-phase clouds. Part II: Deep convective storms. *Meteorol. Atmos. Phys.*, DOI 10.1007/s00703-005-113-3.

Seliga, T.A., and V.N. Bringi, 1976: Potential use of radar differential reflectivity measurements at orthogonal polarizations for measuring precipitation. *J. Appl. Meteor.*, **15**, 69-76.

Van Lipzig, N.P.M., H. Wernli, S. Crewell, L. Gantner, and A. Behrendt, 2005: Synthesis of preliminary results of SPP verification projects. *Newsletter PP1167 'Quantitative Niederschlagsvorhersage'* , 25 pages, 26.08.2005,- Nr. 1/2005b.

Van Meijgaard, E. and S. Crewell, 2005: Comparison of model predicted liquid water path with ground-based measurements during CLIWA-NET,*Atmos. Res.*, *Special issue: CLIWA-NET: Observation and Modelling of Liquid Water Clouds*, **75(3)**, Pages 201 - 226, doi:10.1016/j.atmosres.2004.12.006.

Vivekanandan, J., D. S. Zrnic, S. M. Ellis, R. Oye, A. V. Ryzhkov, and J. Straka, 1999: Cloud microphysics retrieval using S–band dual–polarization radar measurements. *Bull. Amer. Meteor. Soc.*, **80**, 381–388.

Walser, A., and C. Schär, 2004: Convection-resolving precipitation forecasting and its predictability in Alpine river catchments. *J. Hydrol.,* **288**, 57-73.

Weckwerth, T. M., C. R. Pettet, F. Fabry, S. Park, M. A. LeMone and J. W. Wilson, 2005: Radar refractivity retrieval: Validation and application to short-term forecasting. *J. Appl. Meteor*., **44**, 285-300.

Weckwerth, T. M., C. R. Pettet, F. Fabry, S. Park, M. A. LeMone, and J. W. Wilson, 2005: Radar refractivity retrieval: Validation and application to short-term forecasting. *J. Appl. Meteor.*, **44**, 285–300.

Willen, U., S. Crewell, H.K. Baltink and O. Sievers, 2005: Assessing Model Predicted Vertical Cloud Structure and Cloud Overlap with Radar and Lidar Ceilometer Observations for the Baltex Bridge Campaign of CLIWA-NET. *Atmos. Res.*, **75(3)**, 227 - 255, doi:10.1016/j.atmosres.2004.12.008.

Wulfmeyer, V., H.-S. Bauer, M. Grzeschik, A. Behrendt, F. Vandenberghe, E.V. Browell, S. Ismail, and R. Ferrare, 2005: Four-Dimensional Variational Assimilation of Water Vapor Differential Absorption Lidar Data: The First Case Study within IHOP_2002. *Mon. Wea. Rev.*, Accepted

Xu, K.-M., M. Zhang, Z.A. Eitzen, S.J. Ghan, S.A. Klein, X. Wu, S. Xie, M. Branson, A.D. Del Genio, S.F. Iacobellis, M. Khairoutdinov, W. Lin, U. Lohmann, D.A. Randall, R.C.J. Sommerville, Y.C. Sud, G.K. Walker, A. Wolf, J.J. Yio, and J. Zhang, 2005. Modeling springtime shallow frontal clouds with cloud-resolving and single-column models. *J. Geophys. Res*., **110 (D15)**, D15S04.

Xue, M., and W.J. Martin, 2005a: A high-resolution modeling study of the 24 May 2002 case during IHOP. Part I: Numerical simulation and general evolution of the dryline and convection. *Mon. Wea. Rev*., Accepted.

Xue, M., and W.J. Martin, 2005b: A high-resolution modeling study of the 24 May 2002 case during IHOP. Part II: Horizontal convective rolls and convective initiation. *Mon. Wea. Rev*., Accepted.

Yen, W., S. Crewell, N. van Lipzig and J. Seltmann, 2005: DWD Radar Products for Model Evaluation in SPP 1167, SPP 1167 Colloquium, Bad Honnef, 10-11 März, Poster.

Zängl, G., 2004a: The sensitivity of simulated orographic precipitation to model components other than cloud microphysics. *Quart. J. Roy. Meteorol. Soc.*, **130**, 1857-1875.

Zängl, G., 2004b: Numerical simulation of the 12-13 August 2002 flooding event in eastern Germany. *Quart. J. Meteorol. Soc.*, **130(7)**, 1921-1940.

Zhang, G., J. Vivekanandan, and E. Brandes, 2001: A method for estimating rain rate and drop size distribution from polarimetric radar measurements. *IEEE Trans. Geosci. Remote Sens*., **39**, 830-841.

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**, in press.

3. Goals and work schedule

3.1. Goals

3.1.1. Overarching goals of COPS

It is the overarching objective of COPS to identify the physical and chemical processes responsible for the deficiencies in QPF over low-mountain regions with the target to improve their model representation. The campaign shall be performed from **June 1 to August 31, 2007** where significant thunderstorm activity can be expected in the COPS region (see SOD, chapter 4). 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.

The determination and use of the potentials of existing and new data sets and of better process descriptions are central issues to improve QPF in this context. In extensive discussions with the COPS ISSC and the PIs of the other PQP projects the following fundamental hypotheses have been developed:

- Upper tropospheric features play a significant but not decisive role for convective-scale QPF in moderate orographic terrain.
- Accurate modeling of the orographic controls of convection is essential and only possible with advanced mesoscale models having a resolution of the order of a few kilometers.
- Location and timing of the initiation of convection depends critically on the structure of the humidity field in the planetary boundary layer.
- Continental and maritime aerosol type clouds develop differently over mountainous terrain leading to different intensities and distributions of precipitation.
- Novel instrumentation during COPS can be designed so that parameterizations of sub-grid scale processes in complex terrain can be improved.
- Real-time data assimilation of key prognostic variables such as water vapor and dynamics is routinely possible and leads to a significant better short-range QPF.

This shall be achieved by combining:

1) **A synergy of unique in-situ and remote sensing instruments,**
2) **Advanced high-resolution models optimized for operation in complex terrain,**
3) **Data assimilation and ensemble prediction systems.**

This requires a sophisticated scientific preparation and a careful coordination between the efforts of the institutions involved.

In the following, the key science questions of each Working Group (WG) of COPS are summarized. The scientific derivation and the importance of these questions have been pointed out in the SOD (see chapter 6) and section 2.1 of this proposal.

Answering these science questions will be performed in two steps. First of all, key instrumentation has to be identified, operation modes for each instrument have to be determined, and the data have to be carefully collected, specified, and archived. Only this step is requested within the PQP Phase 2. Another approach is not possible due to the set up of the PQP. However, as COPS and the GOP are imbedded in the center of PQP, there is the unique opportunity to address all COPS and GOP science questions within Phase 3 of PQP. Consequently, we are illustrating only shortly how the science questions will be addressed in Phase 3, the focus of this proposal is to request the key instrumentation so that corresponding data can be collected within COPS. Our approach is depicted in Fig. 3.1.

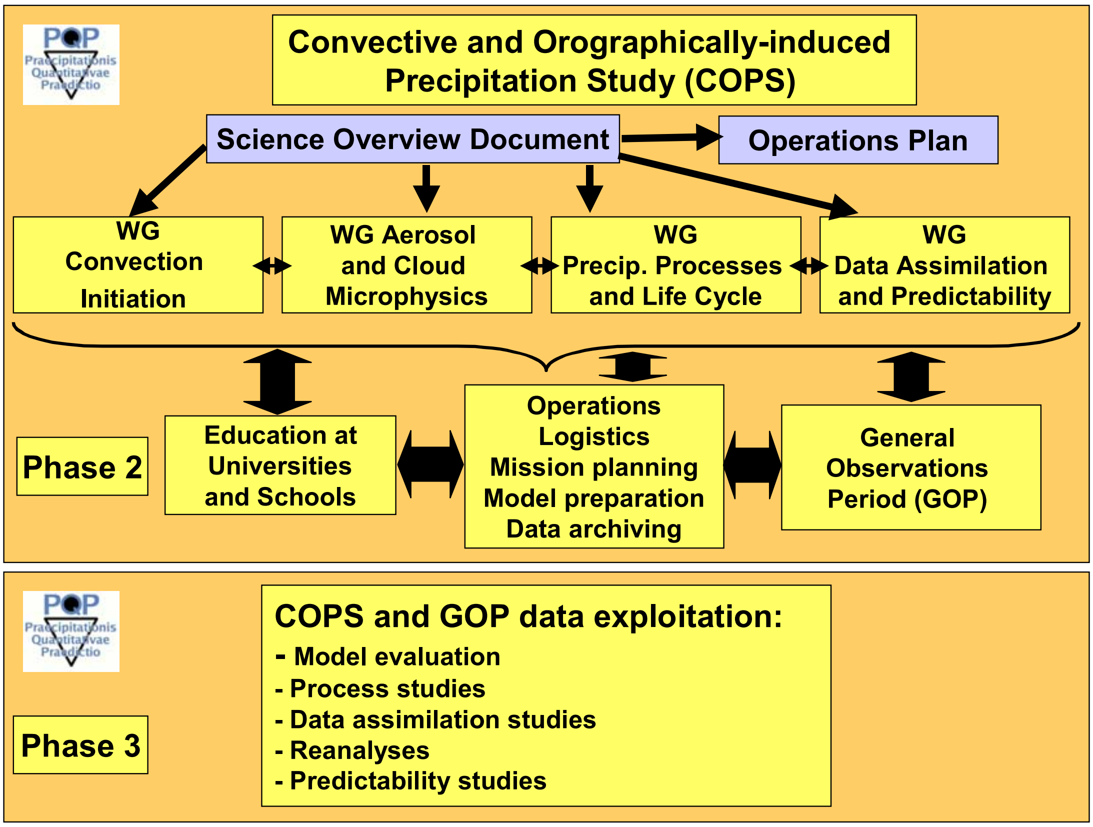


Fig. 3.1. *Structure of COPS and GOP proposal and approach to reach the science goals. Phase 2 of PQP covers April 2006 - March 2008, Phase 3 of PQP covers April 2008 – March 2010.*

3.1.2. WG Convection Initiation (CI): Goals and instrumentation

The CI component of COPS is dedicated to answer the following questions (see also section 2.1.1 and SOD, section 6.1):

CI 1. What is most relevant for the heterogeneity of the boundary layer fields of key prognostic variables (differences in soil moisture, surface parameters, vegetation, orography, etc.)?

CI 2. How are small-scale inhomogeneities of atmospheric humidity, temperature, and wind in complex terrain related to CI?

CI 3. How is the diurnal cycle of CI related to processes at the surface and in the boundary layer and why is the diurnal cycle of convection not represented adequately in the models?

CI 4. To which extent do gravity waves and mountain waves initiate or inhibit convection?

CI 5. What is the relative importance of the large-scale flow versus local orographic and surface driven processes in determining the location, timing and intensity of convection in regions of moderate orography?

CI 6. Do aerosol particles influence CI?

The latter question shall be answered in collaboration with WG ACM. Answering of these questions requires simultaneous measurements of surface properties including soil moisture and vegetation as well as the 4D structure of the diurnal cycle of the boundary layer, particularly in regions where CI is expected. Therefore, networks of surface stations, various ground-based remote sensing systems at the supersites, preferable with scanning capability, and radiosoundings shall be operated.

The COPS **small-scale target regions** are identical to the **supersite locations**, being described in detail in section 3.2. In the region of the supersites, the following instrumentation is requested: For characterization of surface properties; 3 radiation turbulence clusters (RTCs) of the University of Bayreuth; new soil moisture sensors (SISOMOPs), 2 energy balance stations (EBSs) and 5 turbulence towers (TTs) of the Institute of Meteorology and Climate Research (IMK) Karlsruhe are requested. For characterization of the 3D thermodynamic field, the UHOH 3D scanning water vapor differential absorption lidar (DIAL) (UHOH WV DIAL) (see Appendix 7.3.5); the UHOH scanning rotational temperature Raman lidar (UHOH RRL); the scanning Doppler wind lidar (WindTracer), a wind-temperature radar (WTR), 2 sodars, and 1 sodar RASS of IMK are asked for. A unique aspect of the COPS approach is the fact that these supersites will consist of instrumentation, which permits to continue the measurements around and in the cloud as well as in precipitation when CI and rain develops (see WGs ACM and PPL).

Measurements with the helicopter-borne HELIPOD of University of Braunschweig (UBr) (see Appendix 7.3.4) turbulence probe on the scale of 20 km x 20 km provide most valuable data for spatial interpolation of ground-based systems, for area-averaged turbulent fluxes and boundary-layer heights, and complement the 3D data sets for budget calculations.

Atmospheric processes in the **COPS mesoscale target region** have to be observed by networks of ground-based stations as well as by airborne surveys. Various sensors included in the GOP operations are active in the COPS region, such as the operational and research precipitation radars, and micro-rain radars. Two additional radiosonde stations of IMK will be operated at fixed locations in the area. These locations are chosen to catch the upstream stability conditions of air masses entering the region and to complete the aerological information at supersites. Small networks of new low-cost soil moisture sensors of the IMK will be placed at a total of seven locations characteristic of different land-use. Their measurements will be complemented by 4 micro-meteorological masts of IMK. Well-equipped micro-meteorological stations in forested regions with high masts are activated in Eggenstein (IMK), Tuttlingen and Hartheim (University of Freiburg), being upgraded by a flat-array sodar and/or tethered balloon measurements of the University of Freiburg. In addition to an existing network of GPS receivers being used to derive slant path water vapor measurements, five additional stations of GeoForschungsZentrum Potsdam (GFZ) shall be installed for COPS. A network of about 12 automatized weather stations of the University of Munich enables a rather dense coverage by combination with the DWD and Fuldanet station networks (see SOD, chapter 10). An innovative component of COPS is flexible observations, such as for measurements close to large convective cells during their lifetime. This is achieved with mobile teams in the field, which launch radiosondes and drop-up sondes, as well as install met-masts of IMK within 30 minutes at locations of special interest.

The Dornier aircraft Do-128 (see Appendix 7.3.2) is specifically instrumented and suited to cover the full COPS mesoscale target region, such as for getting turbulent and radiative fluxes within and above the PBL as well as the spatial variability of surface temperature, winds, and humidity. It thus provides important capabilities for spatial interpolation and for getting domain-covering surface and boundary layer conditions for CI.

The **COPS large-scale target region** is mainly covered by DLR Falcon measurements (see Appendix 7.3.1). The coincident measurements with water vapor lidar and Doppler wind lidars provide horizontal transects of the wind vectors and humidity as well as their covariances, i.e. turbulent moisture fluxes related to convective and mesoscale processes. Flights in the upstream regions of COPS also give most useful information on the location of fronts and trough lines. In relation to THORPEX ETReC 2007, the Falcon missions provide the possibility of targeted observations, being used to optimize the input data base for data assimilation studies.

Improved understanding of the factors influencing the preferred locations of convective development in complex terrain is the central goal of the WG CI.

3.1.3. WG Aerosol and Cloud Microphysics (ACM): Goals and instrumentation

Building on the 4D thermodynamic fields provided within the WG CI, the WG ACM aims at providing answers to the specific questions (see also section 2.1.2 and SOD, section 6.2):

ACM 1. What is the role of aerosol particles in changing cloud microphysical properties and the initialization of convection?

ACM 2. Does sub-cloud aerosol variability affect convective precipitation?

ACM 3. Does cloud turbulence promote condensation, coalescence and aggregation and thus precipitation?

Conditions with different aerosol characteristics are expected, which will be observed within ACM before onset of convection. Once convection started, ground-based remote sensors analyze the evolution of clouds. With the COPS network of measuring stations the temporal and spatial development of clouds originated from a known aerosol environment can be followed. Moreover, with lidars and airborne measurements the aerosol conditions in the inflow region (cloud base) as well as in the environment influencing clouds by lateral entrainment are investigated. A further important contribution to COPS will be provided by different types of radars yielding distributions of reflectivity, particle shapes, mean velocity, and in-cloud turbulence.

While being of extreme importance for mid-latitude precipitation processes, the issue of ice formation is at the same time one of the most difficult ones to address within COPS. Reasons for the formidable challenges connected with this issue comprise the complexity of potential processes, e.g., the rarity of suspected related aerosol components, and the lack of sensitive and specific measuring techniques. Therefore, the ice-related science questions covered by COPS are more exploratory in nature than other issues addressed by ACM:

ACM 4. Is there a correlation between measurable aerosol properties (e.g., depolarization) and ice formation?

ACM 5. What statistical information about ice formation in COPS can we derive from present satellite sensors?

To answer the science questions, the WG ACM is requesting instrumentation, which comprises five parts:

1. Ground-based aerosol measurements upwind of the potential initialization of convection (Institute for Tropospheric Research, IfT)
2. Ground-based vertical profiling of aerosol characteristics, aerosol fluxes, and cloud microphysical properties through active and passive remote sensing (IfT, Ludwig-Maximilians University Munich, LMU)
3. Airborne mesoscale aerosol mapping (Free University of Berlin (FUB), IfT, LMU)
4. In situ cloud microphysical and dynamical measurements (IfT)
5. Ground-based remote sensing of cloud microphysical properties (IMK, LMU, Institute for Meteorology, Hamburg, UHH)

Aerosol size distribution and hygroscopic behavior require sophisticated instrumentation that will only be available at an upstream supersite, thus in a COPS small-scale target region. These detailed aerosol measurements will be complemented by ground-based active remote sensing of aerosol-optical properties through multi-wavelength lidars at one super site (IfT), at additional sites of COPS participants (UHOH RRL), and from the four German EARLINET lidar stations (see also GOP). Additional aerosol backscatter profiles will be supplied by airborne lidars (DLR, LMU). It is hoped that additional lidars operated by foreign institutes will enlarge the airborne and ground-based aerosol-optical dataset.

The synergy of lidar, cloud radars (FZK, UHH), and microwave radiometers (University of Bonn (UB), LMU) will be exploited to generate a cloud classification which continuously gives the vertical distribution of cloud ice, mixed phase, cloud water, drizzle, and precipitation including the identification of multi-level clouds. 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.

This combination of instruments at supersites does not yield mesoscale coverage yet. The application of scanning instruments (lidar, cloud radar, and microwave radiometer) at the supersite can provide information on the 3D state of the atmosphere within a range of about 10 km. Therefore the data gaps in between supersites will be filled with less sophisticated aerosol airborne measurements by in-situ measurements from UBr helicopter HELIPOD (see Appendix 7.3.4), in-situ and remote sensing from the two aircraft Cessna (FUB, LMU) (see Appendix 7.3.9) and Partenavia (IfT) (see Appendix 7.3.8). Because the microphysical properties of clouds change extremely rapidly (Crewell et al. 2004) the aerial observations by satellites (cloud properties) and weather radar need to be combined with the supersite information.

The helicopter-borne cloud payload ACTOS (see Appendix 7.3.7) will be stationed within 20 nm (~ 35 km) of a supersite not in too complex terrain with convective cloud development. ACTOS measures the three-dimensional wind velocity vector, temperature, and humidity with very high time resolution. In-cloud ACTOS measures liquid water content and drop-size distributions. Aerosol particle number concentrations can be measured in two different size ranges.

ACTOS will be complemented with a counterflow virtual impactor (CVI) and an interstitial aerosol inlet operated onboard the Partenavia aircraft (IfT). The CVI technique has been successfully used in airborne cloud studies to sample and separate cloud droplets from interstitial particles in stratocumulus and cumulus clouds. The interstitial inlet will collect the non-activated particles. Outside clouds, this inlet will sample the ambient total aerosol population and especially the sub-cloud aerosol particles that influence the droplet activation at cloud base. Several sensors downstream of these two inlets will yield size-dependent particle activation data. Additionally, with soot sensors downstream of the inlets, the drop activation of a key anthropogenic aerosol component will be quantified. The Partenavia will also carry a fast optical liquid water sensor. The in-situ cloud microphysical data will primarily serve for process understanding in convective clouds. However, they are of high interest for the validation of cloud-microphysical products from satellites such as MSG, which will be used in COPS and the GOP.

Ground-based aerosol, lidar, microwave radiometer, and cloud radar measurements will be conducted for the full length of COPS, i.e., three months. The result will be a unique extensive 4D dataset of physico-chemical and optical aerosol and cloud characteristics in the COPS region of topographically modulated convective activity. This dataset, complemented with MSG data, can be used to derive statistical relationships between boundary layer aerosol particles, air masses, and ensuing convective clouds. Furthermore, in combination with the project SRQPF, assimilation of aerosol properties in the WRF-Chem system is planned for performing QPF sensitivity studies using real experimental data.

Experiments with the two helicopters and two aircraft can only be utilized during shorter intensive observation periods defined by the COPS operational center. During these periods extensive regional aerosol fields will be derived in the cloudy COPS area by ground-based in situ and lidar measurements and airborne aerosol data from Cessna and Partenavia.

With suitable convective activity near the lidar supersite, the helicopter-borne ACTOS and aircraft-borne cloud measurements will be conducted while vertical aerosol flux measurements with lidars take place. As far as flight regulations allow, coordinated flights of ACTOS and the two aircraft will study the microphysical and dynamical evolution of the same individual convective systems. French scientists expressed their interest to further support aerosol-cloud research among a variety of other science topics (see Appendix 7.7).

Direct, i.e., in-situ, investigations of ice particles or icing of whole clouds is a very challenging task only possible by sophisticated instrumentation of aircraft or other airborne facility. In COPS this is out of reach with instrumentation from Germany only. A contribution from UK scientists is in preparation (see Appendix 7.6). So far, as an alternative in COPS, information on ice in clouds is gained from the three radars (IMK cloud radar, UHH cloud radar, DLR POLDIRAD) all having polarization capability. The use of two wavelengths (IMK, UHH: K-Band; DLR: C-Band) is of advantage since the cloud radar detects preferably small particles whereas the C-Band radar registers large particles. In looking into the same sample volume, the data from both radars can be used to derive properties of small and large ice particles via evaluation of polarization-related parameters as LDR, ZDR etc. In case of having collocated aerosol measurements and owing to various air masses with different aerosol load to be expected during COPS, the effect of aerosols can be inferred from a combination of aerosol and radar data.

3.1.4. WG Precipitation Processes and their Life Cycle (PPL): Goals and instrumentation

Most observations of deep convection have been performed in relatively flat terrain. The question as to which degree orography can influence the evolution of convective cells must be considered unanswered to date. It has been observed that orography can trigger the development of cells; however, it is unknown whether convection is suppressed in the subsiding flow in the lee of hills. It is assumed that the life cycle of single cells can be modulated by orography, but it is unclear whether orography like Vosges Mountains or Black Forest can have a significant influence on the formation and propagation of multi- or super-cells or even mesoscale convective organizations. How significant is this influence if the cells have already been formed before they interact with orography? Especially windward/lee effects so far are poorly represented in NWP systems (see SOD, section 1.3).

Another fairly open question is the role of embedded convection triggered by orography. Formerly stable stratified precipitating clouds may be destabilized by the forced uplift through mountains, which leads to stronger precipitation than expected from the stratiform precipitation.

The goal of the working group precipitation processes and life cycle is to perform observations with high spatial and temporal resolution of convective precipitation systems. The following scientific questions shall be answered (see also section 2.1.3 and SOD, section 6.3):

PPL 1. What is the role of orography for the development of convective cell? To what extent does this affect organized convection?

PPL 2. Does orography affect the hydrometeor distribution, development of graupel and hail, and the precipitation rain drop size distribution (RDSD)? Is this different for orographically induced and non-orographically affected convective precipitation?

PPL 3. How does RDSD change during the cloud life cycle?

PPL 4. What triggers the transfer of drizzle (virga) into full precipitation?

PPL 5. What is the reason for the windward/lee problem and can it be solved by high-resolution mesoscale modeling without convection parameterization?

The purpose of the measurements is also to confirm the following hypothesis:

The life cycle of single cells is affected by orography
but not the one of larger systems.

The observational basis will consist of ground-based instrumentation such as radars and disdrometers. The life cycle of precipitation can be studied by scanning weather radars. Operational radars provide volume measurements of reflectivity and Doppler velocity with a spatial resolution of about 1 km^3 and a temporal resolution of 5–15 minutes. The COPS region is covered by 8 operational Doppler radars (DWD: Neuheilenbach, Feldberg, Frankfurt, Türkheim; MeteoSwiss: Albis; MeteoFrance: Nancy, Montancy; FZ Karlsruhe). This dense network provides a complete coverage of the COPS region with maximum ranges from the radars of about 100 km (see SOD, section 10).

While frequent reflectivity measurements give a detailed image of the 4D precipitation structure and to a certain degree also of the cloud structure, the Doppler velocity gives additional information on dynamics. Due to the high degree of overlapping Doppler information, it is possible to retrieve the 3D wind vector field from precipitation and to a certain degree also from clear-air echoes in the boundary layer. Since the Doppler radar coverage is limited close to the surface in mountainous regions, we propose to deploy additional mobile Doppler radars (DOWs from NCAR, USA, see Appendix 7.5) to get a better multiple Doppler coverage close to "hot-spots" for convection or in the inflow region of the larger Black Forest valleys (e.g. Murg valley, near the city of Rastatt; Kinzig valley near the city of Lahr). These additional radars are necessary since the radar on top of the Feldberg (1500 m ASL, 1350 m above the Rhine valley) has limited view down to the boundary layer within the Rhine valley.

In order to retrieve microphysical parameters like hydrometeor type or the size distribution of raindrops it is necessary to use polarimetric weather radars. According to the current planning, only the radar at Montancy will be polarized by 2007 (see Fig.3.2). Additional radars are necessary to cover the COPS region, especially the Rhine valley between the Vosges Mountains and the Black Forest. We propose the DLR C-band polarimetric Doppler radar (POLDIRAD) (see Appendix 7.3.3) and the US S-Pol radar (see Appendix 7.5) for additional coverage. The locations for these additional polarimetric radars have not been decided yet, Strasbourg airport is considered preliminarily for POLDIRAD, S-Pol shall be located in the Rhine valley in the northern part of the COPS region (Fig.3.3). Simultaneous operation of both radars would provide additional dual-Doppler measurements, dual-polarization measurements, and additional surface refractivity measurements from S-Pol. Furthermore, S-Pol provides 3D dual-wavelengths observations of clouds and precipitation.

To investigate the life cycle of precipitating clouds and their RDSDs relative to orography and the state on the lee side, we suggest to set up a transsect across the Black Forest with rain gauges, disdrometers, and vertical pointing Doppler radars (e.g., the micro rain radar, MRR) along a radial direction from a polarimetric radar (see Fig.3.3). This transect shall also cover the lee side, and would provide an optimum strategy for observing the modification of the RDSD by orographic effects. Preferably, this MRR transect should be set up during the complete GOP. Currently four MRRs are assigned for this. Since the retrieval of MRR drop size distributions assumes no vertical air velocity, it is necessary to develop procedures in synergy with other radar measurements to overcome this limitation and to be able to retrieve the RDSD even in the presence of orographic or convective induced vertical wind flow. This is planned for Phase 3 of PQP. The vertical X-band radar of UHOH and the holographic particle recorder (HODAR) of University of Mainz shall be placed at supersites. Also the DO 128 shall contribute to PPL by the release of chaff to investigate dynamics within clouds before precipitation starts.

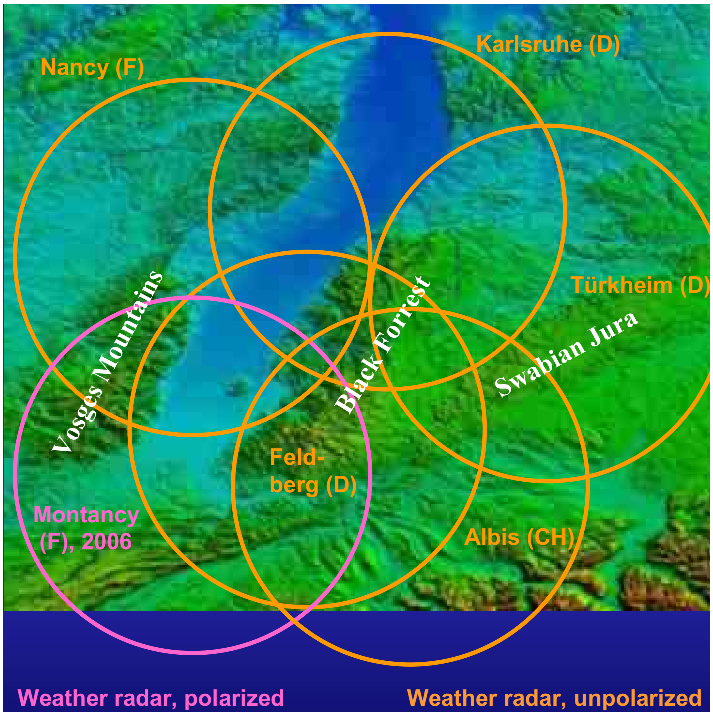


Fig. 3.2. *Network of operational weather radars covering the COPS region in 2007. Of these radars, only the Meteo France radar in Montancy will be polarized in 2007. It should be noted, however, that the coverage of the operational-radar network is affected close to the ground by orographic shielding.*

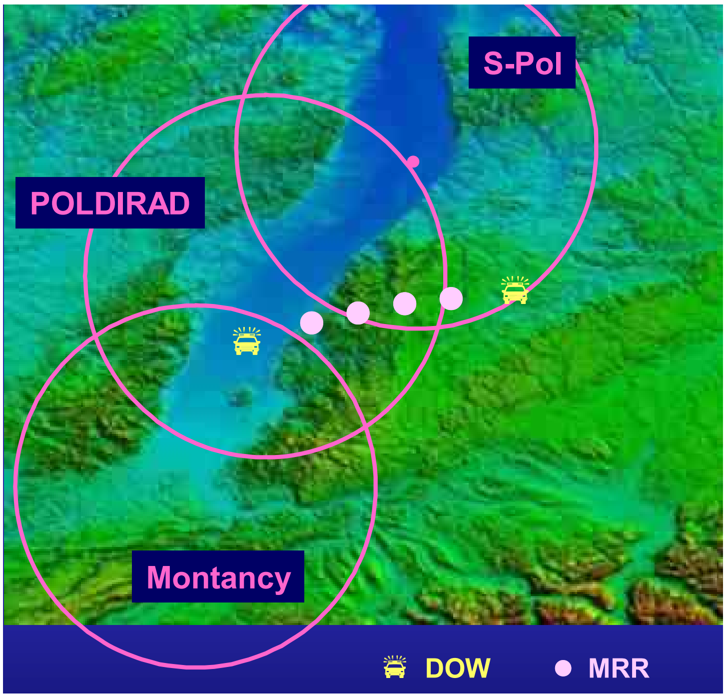


Fig. 3.3. *Envisioned set up of polarization weather radars during COPS (magenta circles). Support for funding of POLDIRAD is requested from DFG. In addition, we propose a transect of Micro Rain Radars (MRRs). S-Pol and two mobile Doppler On Weels (DOWs) will be requested at the National Science Foundation (NSF) in the USA supported by DFG. With this set up of radars an almost complete coverage of the regions of highest interest will be possible also close to the ground.*

While the operational radars and the MRRs run continuously, the other systems (POLDIRAD, S-Pol, HODAR, and the vertical X-band radar) require manual operation. The operation therefore has to be coordinated with the COPS operation center. For POLDIRAD an operation of up to 16 hours per day is anticipated.

Radar reflectivity and Doppler velocity are available in real time and can be transferred to the database directly from the operational radars, making data sets available for real time assimilation. For the DLR radar, high-speed data links are necessary. Preliminary polarimetric data products are also available in real time. Final polarimetric products require quality control and post-processing of the data.

In preparation of the COPS campaign it is necessary to optimize the location of the DLR (and additional foreign) radars considering beam blockage by hills. Site surveys will be performed in 2006 and the sites will be prepared with electrical power and data lines in due time that the operation can start with the beginning of the COPS.

The LINET lightning detection network is operated in a co-operation by DLR and LMU: a deployable version of 6 stations is provided by DLR and an already existing permanently installed network is made available by LMU. The DLR stations will enhance resolution and thus provide especially an improved vertical resolution of the data. An optimum deployment of these stations during the summer 07 is around a polarimetric radar site (radius 100 km around POLDIRAD).

3.1.5. WG Data Assimilation and Predictability (DAP): Goals and modeling efforts

The COPS/GOP data set will provide a unique opportunity to evaluate and improve all aspects of the Numerical Weather Prediction system. The over-arching goal is to quantify and extend the limits of predictability of convection through high-resolution ensemble forecasting and advanced data assimilation. The key scientific issues where progress is expected are:

DAP 1. What are the relative roles of upper and mid-tropospheric forcing versus local orographic and surface flux influences on the predictability of convective precipitation in a region of moderate orography?

DAP 2. What is the impact of the assimilation of high resolution remote sensing data on short-range forecasts of convective precipitation, and what data assimilation methods are best suited for this task?

DAP 3. What is the impact of model errors on forecast accuracy, in comparison to error in initial fields, and can a synergetic use of observations lead to a characterization and reduction of model error?

To achieve this, the following program has been initiated:

1. *(Preparation for COPS)* High-resolution simulations and ensemble forecasts are being applied to typical weather event in the COPS region to identify an observing strategy that lead to maximum impact in numerical simulations.
2. *(During COPS)* As described below, preliminary studies using COPS data will be carried out in near real time to provide feedback to the operations centre. Funding is requested in this proposal for this work.

3. *(Phase 3 of SPP)* Following the experimental period, there will be systematic analysis using a wide array of models, data assimilation systems, ensemble strategies and verification techniques, applied to selected case studies and longer measurement periods. International partners will be involved through the ETReC 2007, D-PHASE and RISK-AWARE II projects.
4. *(Phase 3 of SPP)* In the framework of a virtual reality simulation (VR-COPS) that has been carefully validated against COPS/GOP data, observing system simulation experiments will be carried out to generalize the initial results to a wider range of meteorological situations and to potential future operational observing and forecasting systems.

During the COPS campaign itself, new real-time mesoscale model forecast products for use in the daily COPS briefings and assimilation of COPS data in near real time in mesoscale models for improved NWP shall be performed. The idea of "near real-time data assimilation" is to perform impact studies by assimilating COPS data as soon as possible after the measurements. This will provide positive feedback on the success of the observations as the COPS missions can be planned in the best possible way. This strategy should be especially beneficial for airborne observations, which are the most mobile platforms. The specific scientific questions to be addressed by the work during the COPS measurement period are as follows:

DAP 4. Is there an obvious impact of COPS measurements on model forecasts?

DAP 5. If reasons for lack of positive impact can be identified, can a better measurement strategy be devised?

DAP 6. Which assimilation systems best handle the data and which may be practical for real-time use (nudging, 3DVAR, 4DVAR, ensemble-based)?

DAP 7. Is such a system a valuable tool to support mission planning?

Data assimilation work during the COPS period will be carried out by scientists at UHOH and at DLR, with many other groups becoming involved in the third phase of the Priority Program, as outlined in section 2.2.7 above.

At UHOH, most of the work necessary for setting up a real-time assimilation system for the most-advanced novel observing systems of COPS has been requested in the parallel project **SRQPF** (Short-Range Quantitative Precipitation Forecast) (2nd phase). This includes operator developments for assimilation of several COPS observing systems (e.g. scanning lidar for water vapor, wind, and temperature measurements, GPS, wind profiler, and radar Doppler radial velocity). If possible, the real-time data assimilation system shall be used for mission guidance. The real-time forecast process starts at the point the analysis of ECMWF is available. From then a chain of scripts is initiated calling each other in a row so that the whole preprocessing, forecast, and post-processing tasks including the series of plots provided to the forecaster in the COPS operations center is automated.

Furthermore, after the performance of COPS, a novel aerosol data assimilation system shall be made available to test the impact of aerosol-cloud microphysics based on real experimental data.

At DLR, two applications are proposed for the mesoscale ensemble forecasting system under development within the **DAQUA** project. The first effort is concerned with real-time provision of ensemble forecast information. This will allow forecasters to evaluate the objectively determined best members of the ensemble, and make a comparison between the best members of the ensemble, which is based on earlier data, with newer deterministic forecasts. The best members of the older ensemble may be better, since the model is fully spun up, but may be worse if none of the ensemble members captures the real event, but a forecast that has the benefit of newer data does capture it.

The second effort is the application of near real-time ensemble data assimilation providing a preliminary assessment of the impact of COPS observations on model forecasts. This will be based on nudging of best ensemble members and on an ensemble Kalman filter if available. Feedback can then be provided for use in the planning of subsequent measurements. This will be particularly significant in aircraft flight planning. Although this preliminary work will involve only a very few cases, there is potential for immediately visible impacts since the observation coverage will be dramatically improved on the mesoscale. Since the measurements are addressed to particular meteorological features, as described in the CI section of the COPS SOD, judgments of the appropriateness of the measurement strategy will be based on whether those features were observed as expected, and how their observation could be improved. In particular, it will be investigated whether airborne lidar observations targeted at interesting features, have an obvious impact on the forecast, addressing some of the key objective of the THORPEX Science Plan.

An agreement is being made within the Consortium On Small Scale MOdelling (COSMO) consortium, a group of European meteorological services responsible for the development of the Lokal Modell, to output Synthetic Satellite Images in LM (LM-SYNSAT) from the operational COSMO- Local Ensemble Prediction System (LEPS) ensemble forecasting system. Scripts will be prepared to access this data in real time, and evaluate them using the image matching software. Close cooperation with the COPS operations center will be required to enable delivery of these products to the forecasters. Cases for preliminary impact studies will be selected manually, based on availability of additional data. Initial and boundary condition data will come from the operational COSMO-LEPS system.

Table 3.1 shows a list of data, assembled at the COPS workshop in June 2005 that could potentially be assimilated, along with a list of additional data that could probably not be assimilated directly but would be important for verification. The data for assimilation would need to be available in a quality-controlled form within a day or two of the measurement period in order to be used for near-real time studies.

Table 3.1. *Data sets for data assimilation validation efforts.*

Verification (in addition to assimilation data)	**Assimilation**
Rain Gauges All kinds of ground based instruments providing data at least in near-real time Soil moisture	Analyzed data Special data collected during the campaign (lidar data for water vapor, wind, and temperature, dropsondes, …) GPS (real time) Microwave radiometer (MWR) Polarization radar (reflectivities and more) GTS observations providing conventional meteorological observations

3.1.6. General Observations Period (GOP): Goals and model evaluation efforts

The main goal of the General Observations Period (GOP) is to gather a comprehensive data set suitable for testing hypotheses and new modeling techniques developed within PQP. The GOP encompasses COPS both in time and space to provide information of all kinds of precipitation types and to relate the COPS results to a broader perspective (longer time series and larger spatial domain). The duration of one year will open up the possibility to statistically approach model problems and better pin down specific model weaknesses: Some problems e.g. initial and boundary conditions might cancel out when longer time series are considered. The GOP will therefore provide a basis for reaching the PQP goal: **Determination and use of the potentials of existing and new data as well as process descriptions to improve QPF.**

To achieve this goal the GOP will

GOP 1. gather as many data about the atmospheric state as possible within an area covering Germany and it neighboring states. The Alpine states (e.g. Austria and Switzerland) are of special interest to include the complex orography and to connect with D-PHASE,

GOP 2. optimize the exploitation of existing instrumentation by gathering routine measurements normally not available to the scientific community,

GOP 3. focus on continuous/coordinated observations using existing instrumentations which are suitable for statistical evaluation,

GOP 4. focus on measurements, which are available in near real-time to enable a timely use within the PQP,

GOP 5. perform a rigorous quality control, cross-checking, and error estimation of the data,

GOP 6. tailor the observations to model output (e.g., LM, D-PHASE forecasts),

GOP 7. enable an easy access to data, quicklooks and first order analysis to the PQP.

The GOP will support the four COPS WGs by:

- Providing additional water vapor observations by GPS and satellite data to WG CI. In addition, the formation of clouds and precipitation will be observed by high temporal resolution measurements (MSG, weather radar).
- Providing information on aerosol and cloud life cycle for WG ACM.
- Helping to answer the question how orography affects the hydrometeor distribution as well as development of graupel and hail and of the RDSD within WG PPL.
- Providing observations for data assimilation within WG DAP.

3.1.7. Future efforts to reach the COPS and GOP science goals in Phase 3 of PQP

Due to the set up of PQP, within Phase 2 the performance of COPS and GOP measurements, data archiving, and data quality control is requested. During this phase, WG DAP will already yield a major part of their scientific results in connection with the real-time data assimilation efforts. Furthermore, first results are expected using GOP data, as near real-time first order model evaluations will be disseminated via several PQP projects (see Table 5.1).

The processing of the GOP data including a first order model evaluation will be performed in a near-real time environment in order to provide PQP participants already in Phase 2 with a suitable data set to perform rigorous model verification (VERIPREG, STAMPF, QUEST), data assimilation (DAQUA, SRQPF), and process studies.

The analysis of the expected huge and high-quality COPS and GOP data sets has to be performed within Phase 3 of PQP. Already, the main part of PQP proposals within Phase 2 has been connected with COPS and the GOP, as demonstrated by the list of related projects given in section 5.2. Within Phase 3, PQP projects will concentrate on the analysis of COPS and GOP data. This provides a unique opportunity for an extensive data analysis of a field project imbedded in an ongoing QPF program.

A comprehensive research approach has been developed for scientific work with the COPS data set, which is depicted in Fig. 3.4. This figure demonstrates the interplay between observations, modeling and data assimilation efforts, as well as the role of theories concerning QPF related processes. Further aspects are discussed in the SOD, chapter 8.

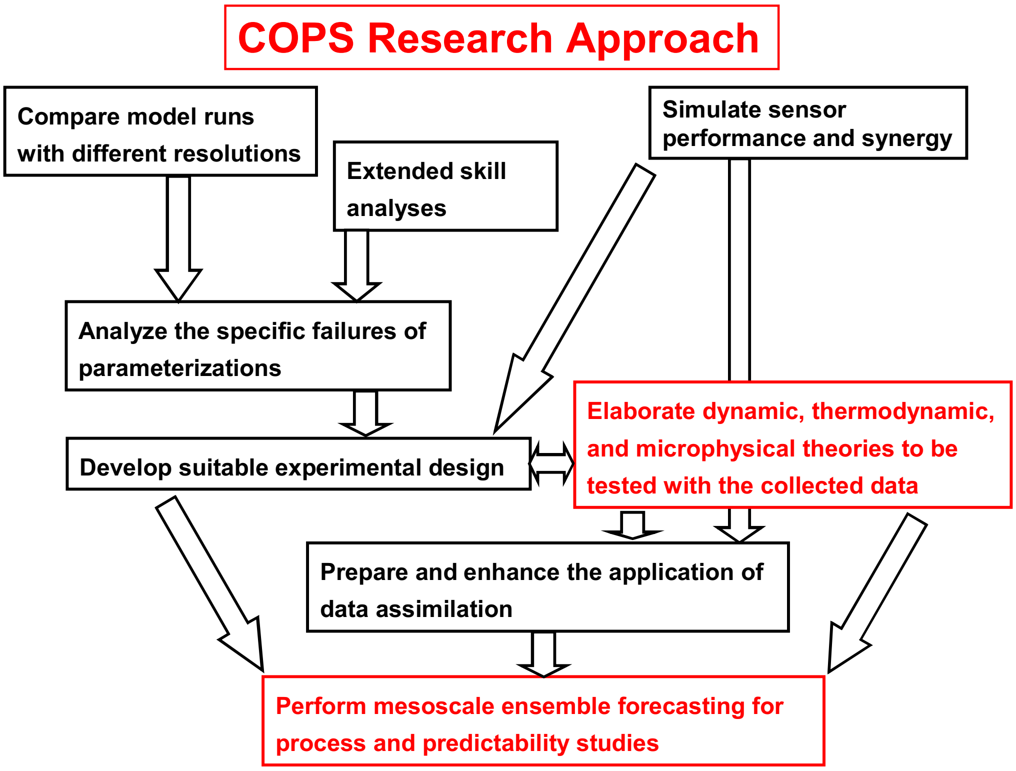


Fig. 3.4. *COPS research approach.*

Particularly, we expect scientific work in the following research areas:

1. Model evaluation: Results can be compared with performance of a variety of deterministic mesoscale models and ensemble prediction systems. Again, in this connection, it is very valuable that corresponding verification projects are already running within PQP. The long-term evaluation of GOP data will reveal cases with

especially poor/good model performance. These cases will be well suited for detailed process studies.

2. Process studies: Due to the comprehensive, 4D, and high-resolution COPS data set, research can be performed on land-surface exchange processes as well as boundary layer and convection parameterizations in complex terrain. The diurnal cycle of boundary layer variables can be studied and related to QPF deficiencies. The interaction of aerosol and cloud microphysics can also be investigated. The initiation and organization of convection can be observed and compared with corresponding theories.
3. Data assimilation studies: The impact of different observing systems on the quality of QPF can be explored. Large-scale and mesoscale targeting can be investigated. Forward operators for indirect measurements can be considered and permit studying the impact of aerosol and cloud observations on QPF.
4. Reanalyses: The whole COPS data set assimilated in mesoscale models during a certain time window can be used for determining a gridded data set resembling nature as close as possible. This can be very helpful for separating QPF errors due to initial conditions and model physics. Furthermore, different parameterizations can be tested.
5. Studies on the predictability of convective systems can be performed. The role of small-scale/large-scale error growth on the quality of QPF can be studied.

These are just a few examples.

The PQP and COPS community is clearly committed to perform QPF research based on COPS and GOP data according to this scheme. The COPS organizational structure will remain at least during the whole duration of PQP if not longer in connection with COPS research as a WWRP RDP. This includes the COPS ISSC and their WG Chairs, the COPS Project Office with its coordinator as well as the GOP Chair so that smooth organization of the analysis phase is ensured. The overwhelming international interest in COPS shows the strong demand for the unique data set available in Phase 3 of PQP.

3.1.8. Education

The goal is to link COPS with innovative approaches for education of students at universities and schools. The educational projects are explained in section 2.2.7. Within this proposal, we are requesting support for a workshop in connection with the project MiA and for student excursions of meteorological institutes in Germany for performing practical work during COPS.

The MiA-Workshop shall gather COPS scientists, MiA co-operative partners, students of teacher education from Bremen and Baden-Württemberg, schools teachers from Baden-Württemberg who participate in COPS in 2007, and teachers from Bremen who are active in MiA (funding requested within PQP).

3.2. Work schedule

3.2.1. Requested instrumentation for COPS

In section 3.1, the goals of COPS and its WGs have been explained and summarized. The requested instrumentation as well as its operation and applications have been motivated. In principle, the work schedule in the operation of instrumentation is the same for each device. The work schedule has to cover transportation to the measurement site and back, staff costs for operation and data analysis, operation of the instrument at the site, consumables for the instrument. Therefore, we are just summarizing the work packages for each instrument in a single table, which contains all these expenses.

Table 3.2. *Proposed instruments for COPS listed according to type.**TBD**: to be determined. **WG IC**: COPS Working group "Initiation of convection", **WG ACM**: "Aerosol and cloud microphysics", **WG PPL**: "Precipitation processes and their life cycle"; **WG DAP**: "Data assimilation and predictability"; **GOP**: "General observations period". x: Red crosses mark main contributions to WGs and GOP, respectively.*

Instrument	Type	PI	Institution	WG CI	WG ACM	WG PPL	WG DAP	GOP
Airborne								
DLR Falcon	Aircraft + H2O Lidar + Doppler Lidar + Dropsondes	Ehret	DLR	x	x		X	
DO 128	Aircraft	Corsmeier	FZK	x		x		
ACTOS	Helicopter + payload	Siebert	IfT		x			
CVI+INT	Aircraft + payload	Mertes	IfT		x			
CASI+POLIS	Cessna aircraft + payload	Fischer, Wiegner	FUB, LMU		x			
HELIPOD	Helicopter + payload	Bange	U. Braunschweig	x				

Ground-based Lidars								
UHOH WV DIAL	Lidar, H2O DIAL, IR, scanning	Wulfmeyer	U. Hohenheim + IfT + U. Potsdam + DLR	x	x		X	
UHOH RRL	Lidar, Rotational Raman, UV, temperature & aerosols, scanning	Behrendt	U. Hohenheim/ COSI-TRACKS	x	x		X	
WindTracer	Doppler lidar, scanning	Wieser	FZK	x	x		X	
MWL & WiLi	Multi-wavelength Raman lidar (vertical) + Doppler lidar (vertical)+ radiosondes	Althausen	IfT	x	x			
Radiometers								
HATPRO	MW radiometer	Crewell	U. Munich	x	x			
MICCY	MW + IR radiometer,	Simmer	U. Bonn	x	x			
Radars								
POLDIRAD	Polarization Radar, C-band, scanning	Hagen	DLR			x		

Karlruhe Radar	Weather Radar, C-band, scanning	Beheng	FZK			x		x
UHOH X-Band	Precip radar	Schaberl	U.Hohenheim			x		
IMK Cloud Radar	Cloud Radar	Beheng	FZK		x			
UHH Cloud Radar	Cloud radar	Peters	U. Hamburg		x			
MRRs	Micro Rain Radars	Peters	U. Hamburg			x		x
Hydrometeor Imager								
HODAR	Holograhic Hydrometeor Imager	Vössing	U. Mainz			x		
GPS								
GPS Network	GPS, 5 additional stations for COPS	Gendt	GFZ	x			X	x
WTR + Sodar + RASS								
WTR	Mobile wind temperature radar	Vogt	FZK	x				
2 Sodars	Sodar	Kalthoff	FZK	x				

Sodar-RASS	Sodar, RASS	Foken	U. Bayreuth	x				
Flat array sodar	Sodar	Mayer	U. Freiburg	x				
Surface in-situ								
2 Energy balance stations		Kalthoff	FZK	x			TBD	
5 Turb. Towers		Kalthoff	FZK	x				
SISOMOP	Soil Moisture sensors	Hauck	FZK	x			TBD	
Rad.-Tur. Cluster	3 Energy balance stations + Bowen ratio system + Scintillometer	Foken	U. Bayreuth	x				
12 Automatic Weather Stations		Smith	U. München	x		x	TBD	
Aerosol container	Aerosol analysis	Wiedensohler	IfT		x			
Masts + tethered balloons								
4 MMM	Micro-Meteorology-masts, comb. w. Drop-up sondes	Kalthoff	FZK	x				
12-m Mast		Foken	U. Bayreuth	x				
Hartheim site		Mayer	U. Freiburg	x	x	x	TBD	x
Tuttlingen site		Mayer	U. Freiburg	x	x	x	TBD	x

Tethered Ballon		Mayer	U. Freiburg	x				
Radiosonde stations								
2 Mobile RS Stations		Kalthoff	FZK	x			X	
Drop-up sondes	Advanced radiosondes (30 sondes, 5 kits)	Corsmeier	FZK	x			TBD	

3.2.2. COPS preparation, coordination, and management

A. Work package IPM: COPS coordination and COPS project office

Staff requested by IPM: 1 BATIIa position for 24 months for COPS Coordinator

At IPM, the preparation of COPS and its realization in the field shall be performed by the COPS coordinator. Furthermore, the collection and quality control of the data will be organized. The COPS coordinator organizes the COPS project office.

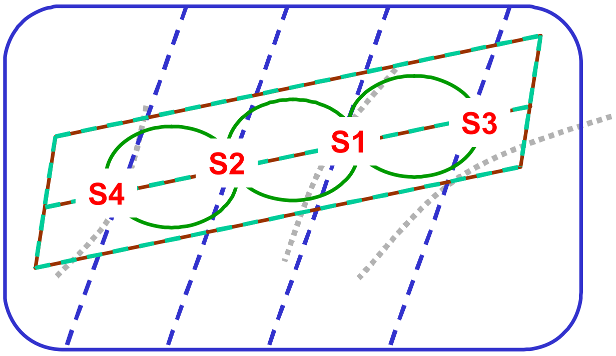
The work package of the COPS coordination and the COPS project office at IPM comprises the following:

- Organization of international **workshops**,
- Scientific exchange with **COPS ISSC**, organization of meetings and telephone conferences,
- Design and set up of COPS **supersites**, based on an analysis of the optimal synergy of available instruments,
- Refine the development of COPS **missions** according to current research results,
- Coordinate the development of the COPS missions and, **COPS Operations Plan** (OP), and its continuous update up to the field phase,
- Scientific supervision and performance of **real-time data assimilation**,
- Coordination of COPS with **ETReC 2007** and **MAP FDP/D-PHASE**,
- Continuous scientific exchange with related **PQP projects** for coordination of COPS,
- Cooperation and information exchange with **DWD**,
- Supervision of the set up and coordination of the **COPS data archive** with Max Planck Institute for Meteorology (MPIfM),
- Organization and coordination of **data quality control**, of data intercomparisons, and of the generation of synergetic data products,
- Providing a link to the **public media**,
- Coordination of **education** activities for students, schoolchildren, teachers, collaboration with the respective PIs,
- Responsibility for and coordination of the comprehensive **COPS Field Phase Report** (after the COPS field phase).

Some aspects of the extensive required efforts are highlighted in the following.

Mission design: According to the goals of COPS, the developed hypotheses will be investigated in different missions. The deployment of all non-continuous and adaptable instruments will depend on the type of mission – these instruments comprise all airborne instruments, soundings, and those ground-based systems with adaptable operation modes.

The involvement of air traffic control authorities will be intensified as soon as Phase 2 of PQP has been started. The decisions processes for the type of mission to be performed will be described in the COPS Operations Plan. Figure 3.5 shows a pre-convection multiple aircraft sample mission, which is currently in preparation.



✈ DLR Falcon (2 - 6 km AGL): WV DIAL, Doppler lidar (conical scanning), dropsondes, turb. fluxes

✈ Do128 (0.3 – 3 km AGL): T surface, upwelling & downwelling radiative and turb. fluxes

✈ Paternavia: aerosol & cloud particles ; *T, p, RH* in-situ

✕ Helipod: Turb. fluxes, surface temp.

✕ ACTOS: aerosol & cloud particles, turb. fluxes

Fig. 3.5. *Sample of the envisioned flight pattern for a pre-convection mission. While the Falcon aircraft performs measurements at the boundary of the COPS region with transects over the supersites, the DO 128 and Paternavia aircrafts perform observations also with transects of the supersites but on a smaller scale. The two helicopters are operated close to the supersites - during the pre-convective stage, preferably close to supersite 1, which will be equipped with the most sophisticated scanning remote sensing instruments but also close to the other supersites, especially when convection activity is progressing. The grey lines denote the locations of ridges.*

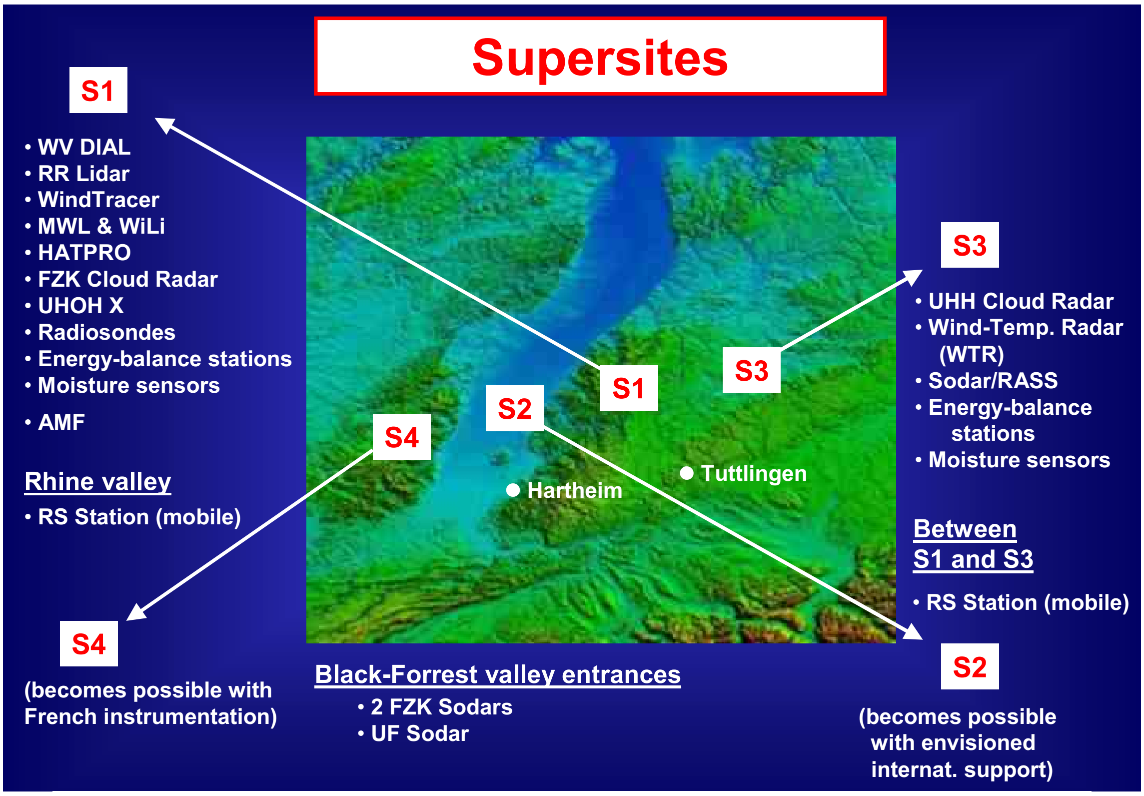
Operations Plan: The scientific and logistic management of the COPS campaign will be subject of the COPS Operations Plan (OP). The OP will contain all information necessary and critical for the successful operations (see, e.g., MAP Implementation Plan, http://www.map.meteoswiss.ch/map-doc/mip.htm, IHOP_2002 Operations Plan, http://www.atd.ucar.edu/dir_off/projects/2002/IHOPdocs/opsplan.doc) and will be updated continuously until the field phase.

The OP will contain the following information

- Descriptions of the COPS missions with typical meteorological situations,
- Description of all instruments with measured parameters, operation modes, logistical requirements (for the German instruments proposed here, this information has already been collected),
- Briefing and debriefing procedures,
- Communication plan for sites, operation center, airbase, aircraft, and scientists,
- Communication plan for data flow (operational and COPS-specific data),
- Forecasting system, responsible forecasters,
- Air traffic control issues,
- Alerting procedures for the investigators in the field,
- Names and responsibilities of operation manager, missions leaders, supersite managers,
- Details of the Operation Center Data Management System (see below),
- Procedures for decision making.

Set up of supersites: The ground-based instruments of COPS shall be concentrated in supersites in order to make optimum use of possible instrument synergies. Each supersite shall be equipped with different types of state-of-the-art remote sensing instruments (various types of lidars, cloud radars, and radiometers), which shall be combined with in-situ sensors.

In the COPS workshops, a concept of 4 supersites was developed. These 4 sites form an east-west transect of the COPS area (Fig. 3.4). Supersite 1 and 3 are the backbone of the ground-based instrumentation. The equipment to set up these two sites is requested within this proposal. Various surface in-situ and remote sensing systems contributed by partner institutions from Austria, England, USA, Netherlands, France, and Italy shall be arranged to complete the supersite instrumentations. The optimum distribution of instruments is to be discussed as soon as the funding is confirmed and will be the main topic of the next COPS workshops planned in 2006.



Supersites

S1

- **WV DIAL**
- **RR Lidar**
- **WindTracer**
- **MWL & WiLi**
- **HATPRO**
- **FZK Cloud Radar**
- **UHOH X**
- **Radiosondes**
- **Energy-balance stations**
- **Moisture sensors**
- **AMF**

Rhine valley

- **RS Station (mobile)**

S4

(becomes possible with French instrumentation)

Black-Forrest valley entrances

- **2 FZK Sodars**
- **UF Sodar**

S3

- **UHH Cloud Radar**
- **Wind-Temp. Radar (WTR)**
- **Sodar/RASS**
- **Energy-balance stations**
- **Moisture sensors**

Between S1 and S3

- **RS Station (mobile)**

S2

(becomes possible with envisioned internat. support)

Fig. 3.6. *Envisioned set up of COPS supersites (S1 to S4) with instrumentation. Each supersite shall be equipped with a synergy of state-of-the-art remote sensing instruments (different types of lidars, radiometers, cloud radars). Supersite 1 and 3 form the backbone of the ground-based instrumentation. The equipment to set up these 2 supersites (S1 and S3) is requested within this proposal. Instruments for an even denser investigation of atmospheric processes have been offered by international partners, so that Supersite 2 in the Rhine valley and Supersite 4 in the Vosges Mountains shall become reality, too, with their support. The optimum distribution of instruments is to be discussed as soon as the funding for the participating instruments is confirmed. This will be the main topic of the next COPS workshops planned in 2006.*

Supersite 1 shall be arranged around the mountain crest of a high mountain range in the Northern Black Forest (Hornisgrinde or Musbach/Freudenstadt), where a novel 3D scanning water vapor differential absorption lidar (DIAL) of UHOH shall be applied. This instrument will be able to perform 2D water vapor measurements within one minute and shall be collocated with the Rotational Raman Lidar of UHOH. The synergy of these systems provides water vapor and temperature measurement from close to the ground up to a range of 15 km. In the boundary layer, turbulent processes and convection can be resolved. The scanning Doppler lidar WindTracer of IMK shall be placed properly to get coincident water vapor and wind measurements to calculate vertical turbulent water vapor fluxes, and to localize the initiation and timing of convection onset. The new scanning cloud radar of IMK shall be operated to monitor the transition from dry convection to clouds and to get information on cloud particles. For analyzing cloud microphysical properties, the Multi-wavelength Raman lidar of IfT and a radiometer shall be added. As part of the micro rain-radars, one instrument is placed on the mountain top to obtain the initiation of precipitation and vertical profiles of rain rate. To derive the mass and moisture budgets (convergence) of the anabatic wind regimes, two sodars, as well as three turbulence and wind met stations are installed on the slopes. An energy balance station on top and a setup of soil moisture sensors provides information on the importance of soil moisture, evapotranspiration and sensible heat fluxes for the surface induced convection. Measurements with the helicopter-borne HELIPOD turbulence probe on the scale of 20 km x 20 km provide most valuable data for spatial interpolation of ground-based systems, for arially averaged turbulent fluxes and boundary-layer heights, and complement the 3D data sets for budget calculations.

An application for the ARM mobile facility to be operated during COPS has been placed. This ARM instrument system with an precipitation radar, an automatic radiosonde launcher and various remote sensing would perfectly complement Supersite 1 and shall be placed in a valley.

Operation of **Supersite 2** is planned for the lowlands of the Rhine valley. In contrast to the Hornisgrinde site, the location is characteristic for rather homogeneous surfaces, the only landscape differences arising from land use differences.

We are proposing to establish **Supersite 3** to the east of the Black Forest, south of Stuttgart near the climate station Hohenheim and radiosonde station Stuttgart, a region where lightning data prove that the probability of occurrence of mature convective cells which were formed over the Black Forest is high. The instrument setup focuses on the surface energy balance. Continuous information on the vertical wind and temperature structure is derived from wind-temperature-radar from both inside and outside of clouds and from a Sodar/RASS for the PBL. Three energy balance stations will be arranged at the supersite to cover different typical types of land-use. A network of low-cost innovative soil moisture sensors is installed at the same location to study the role of moisture storage from previous rainfall and of transpiration on the sensible and latent heat fluxes. These data shall provide insight into the documented shortcomings of LM to get the diurnal cycle of surface air temperatures and moisture correctly. The cloud radar of University of Hamburg shall complement this site.

Supersite 4 in the Vosges Mountains shall become possible with the proposed French instruments (see SOD, chapter 9).

The supersites are the preferred locations of flight with ACTOS helicopter aerosol probe. Further selection and set up of supersites shall be performed in collaboration with IMK. For the envisioned set-up of supersites with the international participation in COPS envisioned, see SOD, section 10.

B. Work package IMK: COPS Operations Center and Operational Data Management System

Staff requested by IMK: 0.5 BAT 2 – position for 24 months (12 person months)

The work package of IMK comprises the organization of the COPS Operations Center and of a Web-based data management system for a successful conduction of COPS. Specific tasks are

- **Organization of the COPS Operations Center,**
- **Organization of a web-based data management system for COPS, also providing the base for the COPS Field Phase Report**
- **Guidance on the selection of supersite locations and the locations of all instruments**
- Cooperation and information exchange with DWD,
- COPS design and preparation in liaison with IPM,
- Responsibility for all operational issues regarding the COPS Operations Plan,
- Proceeding with detailed studies of typical QPF failure cases using state-of-the-art models.

The **COPS Operations Center** shall collect and distribute all information necessary for guiding COPS, i.e., the closely coordinated operation of all participating measurement systems. It also is the interface between modelers and experimentalists. The OC tasks are defined to:

- Monitor meteorological conditions and alerting all COPS investigators
- Allow decisions about missions,
- Collect all data and information needed to make decisions,
- Distribute all operational information to the COPS investigators
- Inform all COPS investigators about ongoing activities on intensive observations periods within COPS,
- Assist COPS investigators logistically,
- Manage an advanced information system (see below).

Members of the OC will be the WG Chairs, the COPS coordinator, members of the ISSC, Principal Investigators, and other experienced scientific and technical staff. The center will be either located at the IMK or at the airport Karlsruhe Baden-Baden. The center will be equipped with state-of-the-art communication technique.

Web-based data management system (DMS): A Data Management System (DMS) for guiding the COPS missions, for real-time visualization of the measured data of automated and semi-automated instruments, and for assessing the potential success of a mission quickly by collecting information about the operations of all instruments and about all available data will be organized. The DMS will have a user-friendly web interface. For instance all decisions of the OC will immediately be announced via email, SMS, and web-page in addition to standard communication ways. All information available at the OC, such as model forecasts and satellite images, will be placed in the DMS to allow access for all investigators involved in COPS. All instrument operators shall inform regularly about the status of their systems. Operators of distinct instruments will provide their data in near real time. These data will be used for data assimilation.

Setting up of the DMS will begin with the start of Phase 2 of PQP, so that it will already be tested in summer 2006, i.e., one year before COPS. The DMS will be the fundament of the COPS Field Phase Report, which will describe all field activities and meteorological conditions during COPS.

Guidance on the selection of supersite locations and the locations of all instruments: The locations of the COPS supersites and the locations of all ground based instruments participating in COPS will be selected in such a way that scientific and logistical requirements are coordinated. These questions are subject to the COPS workshops. For each supersite a manager will be appointed. From former projects IMK has great experience to select suitable sites in the COPS region. The available instruments will be distributed to the different sites in an optimum way for reaching the COPS science goals.

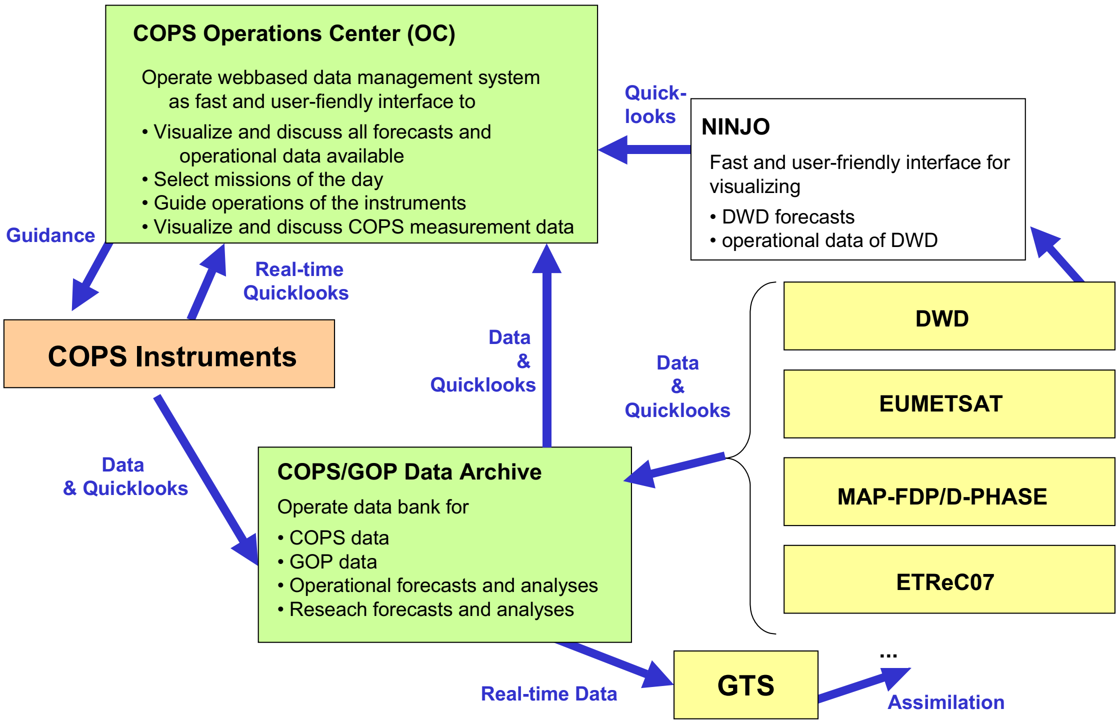


Fig. 3.7. Interplay between the COPS Instruments, the COPS Operations Center, and the COPS Data Archive with DWD and related international organizations and activities.

C. Work package MPIfM: Joint COPS/GOP, D-PHASE Data Archive

Staff requested by MPIfM: 0.5 BAT IIa–position for 24 months (12 person months)

The data archive for COPS and GOP data will be organized by the Models & Data group of the Max Planck Institute for Meteorology (MPIfM), Hamburg, who is also hosting the World Data Center for Climate (WDCC, http://www.mad.zmaw.de/wdcc/). After syntax quality checks, the observation data acquired within COPS and GOP will be archived with quicklooks and together with related model outputs (forecasts and analyses of models of weather services and research models). Access to the data will be by a data bank structure, which allows for extracting data by a range of selection criteria. JOSS at NCAR offered consultancy work for applying their tools for data archiving and visualization, too.

Due to the unique collaboration with D-PHASE within WWRP and ETReC 2007 within THORPEX, an archiving structure for D-PHASE data which is fully compatible to TIGGE at ECMWF shall be used. ECMWF already promised to provide the corresponding MARS data archiving system for MPIfM. This strategy will ensure large international interest and compatibility with international programs for a long time.

Table 3.3. *Time schedule for performing the work packages by IPM, IMK, and MPIfM. All these work packages cover the two years, for which funding is requested.*

WP	**2006**			**2007**				**2008**
IPM	II	III	IV	I	**II***	**III***	IV	I
WP_IPM	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦
IMK								
WP_IMK	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦
MPIfM								
WP_MPIfM	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦

* *Time frame of COPS field phase: June – August 2007*

3.2.3. GOP preparation and performance

The GOP observations will include high spatial and temporal resolution satellite and radar data, profiling stations, rain gauges, micro rain radar/disdrometer, lightning, and GPS networks as well as further data sources to be explored. Existing instrumentation will be redistributed for optimized observation, e.g., of water vapor and precipitation microphysics. For the optimal performance and exploitation of the GOP the following work packages are defined:

WP-GOP-1: Rain gauge observations

Rain gauge data from the diverse sources will be assembled within the coordination project (A. Hense), quality controlled and combined to precipitation maps for various integration times which take into account the varying temporal resolution of the data. Real-time available observations should be delivered in near-real time to be used by *WP 9* for an “online evaluation” of the LM(K) forecasts.

WP- GOP-2: Weather radar observations

All DWD radar products and original 3-D radar measurements will be made available. A quicklook inventory will allow the PQP participants to pick case studies easily. The PQP project VERIPREG (Paulat et al. 2005) will produce hourly precipitation maps from a combination of radar (composite of precipitation scans) and in situ rain gauge data. The PQP project QUEST will use the 3D radar reflectivities to evaluate the forecasted hydrometeor distributions via forward simulation by a polarimetric radar operator.

WP- GOP-3: Drop size distribution observations

The GOP will contribute to the WG PPL of COPS by providing observations of the RDSD using ground-based disdrometers and vertically pointing MRRs. At least 11 MRRs will be located at selected sites in order to study differences of RDSDs over flat terrain including maritime conditions on one hand and over orographically structured terrain on the other hand (see Fig. 2.3). A transect of MRRs will be deployed in the COPS area and coordinated with polarimetric radar (POLDIRAD/DLR) observations during COPS (see Fig. 3.3). On this transect perpendicular to the west slope of Black Forest the polarimetric radar data and the Doppler data of the MRRs provide independent estimates on RDSD parameters. Another cluster will be established in Berlin with its high-resolution rain gauge network to investigate the RDSD in flat terrain. Due to the spatial coverage and fine time resolution (10 s), the data set will provide a unique basis to study the spatial rain structure and the microphysical processes in orographically induced rain events. An effort will be made to convince more MRR owners to participate in this activity. The continuous operation of the network over a full year cycle and the aerial distribution of instruments will help to identify diverse precipitation types and its relation to dynamical and microphysical processes.

Different surface based disdrometers are used as well: A Joss Waldvogel Disdrometer (JWD), 4 Optical Disdrometer ODM470, and 2 Parsivals. These instruments are based on different physical principles and methods for retrieving DSDs and will thus help to keep the major uncertainty of MRR-based DSDs under control, namely potential bias due to vertical wind.

WP GOP-4: Lidar Observations

Lidar instruments can provide measurements of a number of atmospheric parameters and will be heavily involved in COPS. However, continuous observations, which are the focus of the GOP, are difficult to obtain with the state-of-the-art systems. Therefore the GOP includes 1) a cooperation with European Aerosol Research Lidar Network (**EARLINET**) and 2) the use of lidar ceilometers which are based on much simpler techniques compared to research radars but operate continuously.

EARLINET will provide range-resolved aerosol profiles on a regular basis, approximately three times a week. The data (from all EARLINET stations across Europe) will be available in a data base open for the COPS community. These data include the height of the planetary boundary layer, aerosol backscatter and extinction coefficient profiles typically for one or two wavelengths (355 nm / 532 nm). Cloud boundaries are not evaluated routinely, but can be extracted from the data upon request. German EARLINET stations include Hamburg, Leipzig, München, and Garmisch. The regular EARLINET schedule should allow us to derive statistical properties of aerosol in coordination with cloud observations.

Measurements from lidar ceilometers at more than 100 stations within Germany are available through DWD. Furthermore, data from several institutes (for example Meteorological Institutes in Bonn, Hannover, Kiel, and DLR) will be acquired. It will be investigated whether more stations can archive the backscatter profile in addition to the standard cloud base height. Whenever possible, mixing layer height will be derived as part of *WP 9*.

WP-GOP-5 GPS Observations

The GeoForschungsZentrum Potsdam (GFZ; http://www.gfz-potsdam.de/pb1/GASP/) will provide the zenith wet delay (ZWD) with 30 minutes time resolution, an accuracy of 5-10 mm and a precision of 5 mm as well as the integrated water vapor (IWV) with the same temporal resolution, an accuracy of 1-2 kg m^{-2} and a precision of 1 kg m^{-2} for all available GPS stations in the German network (SAPOS, EUREF & GFZ networks) over the duration of the GOP. Currently this amounts to more than 200 stations. Collaboration with IAP Bern (Christian Mätzler) will provide us with the data of the Swiss network. French GPS network, which will also be analyzed within COPS, will also be considered. In order to achieve a better coverage of the COPS area GFZ will install 5 stations in Southern Germany for a t least 6 months. This will help in conjunction with the precipitation and cloud information help to better analyze the water cycle in that area. All observations will be available in near real-time for use in WP-GOP-9.

WP-GOP-6 Lightning networks

Continuous observation by three networks will be made available to PQP: The **EUCLID** (European Cooperation for Lightning Detection) – a compound of national lightning detection networks; the **SAFIR** (Surveillance et Alerte Foudre par Interférometrie Radioélectrique) total lightning detection system in Northern Germany of the University of Hannover and the joint lightning location system of DLR and University of Munich (**LINET,** http://www.pa.op.dlr.de/linet/) operating about 15 stations in Southern Germany. The latter two separate between cloud to ground (CG) and intra cloud (IC) lightnings. Linet can also give the vertical position of lightning. Climatologies of lightning activities will be generated by WP 9 (LMU).

WP-GOP-7 Satellite Observations

FUB will provide MSG, MODIS and MERIS observations by implementing a near real time (NRT) processing. This will provide an excellent overview of the current weather situation, on a larger scale and for the GOP and COPS area. The information is online (http://wew.met.fu-berlin.de/nrt) with a delay of 2 hours, and therefore can help during flight mission planning. Furthermore, the satellite data can be used for near real time assimilation in an online LMK evaluation system. Level 1 data include for MSG the 11 spectral channels from 0.6 to 14 µm, for MODIS 36 channels from 0.4 to 14.4 µm, and for MERIS 15 channels from 0.4 to 1 µm. The calibrated satellite data are processed automatically to provide higher-order, level 2 products, such as water vapor and cloud top pressure (see Table 1.). In order to carry out subgrid-scale analysis for LMK, quality control for SEVIRI products and a near real time processing, the NRT processor needs to be extended for two reasons: 1) Currently, the NRT processing of MERIS data results in images only, and not in product files due to the large storage space needed. 2) MODIS products were transferred for further processing via ftp to FUB within the CLOUDMAP2 EU-project until summer 2004 and will be ordered now via internet for GOP. A second system needs to be developed due to discontinuous data receiving.

The NRT processing change of SEVIRI products will be adopted to monitor atmospheric products at meteorological stations within the LMK domain, e.g. Cabauw and Lindenberg, but also at COPS experimental sites, MAP stations and Berlin. In addition to the production of time series, averages of selected regions will be compared to LMK output on a regular, operational basis together with WP-GOP-9. Depending on the status of the upcoming satellites CLOUDSAT, CALIPSO, and METOP 1, other satellites as well as ground based and airborne observations might be utilized for validation purposes. Special observations with high resolution about stability indices will be available through EUMETSAT.

Table 3.4. Overview on satellite sensors and the respective products for the GOP. Table A: Overview of satellite spatial resolution Δx and available products (TCI: near true color image, CM: cloud mask, BT: brightness temperature, IWV: integrated water vapor, CTP: cloud top pressure, τ: cloud optical thickness, r_{eff}: effective radius of liquid water droplets, LWP: liquid water path, N: number concentration of cloud droplets, H: geometric cloud thickness, τ_A: aerosol optical thickness, A: Angstroem coefficient) In addition a typical accuracy estimate σ is given which might vary significantly with environmental conditions.

Instrument	**Technical**	**Products**	**Information**
SEVIRI / Meteosat-8	Δx~5 km over Europe, Δx~3 km nadir, whole disc every 15min.	TCI, CM, clear sky BT, IWV, CTP	BT accuracy σ~3.3 K IWV σ~0.7 kg m^{-2} (day, clear sky, land) σ~52/121 hPa (high/low cl),
MODIS / TERRA	overpass Europe ~10:30 am, resolution at nadir 0.3 - 1 km	TCI, CM, τ, LWP, r_{eff}, N, H, 6 IWV, τ_{A}, A	microphysics for ocean and warm boundary layer clouds IWV clear sky land surfaces and above clouds, σ~0.2 kg m^{-2} τ_A σ~0.05-0.3
MODIS / AQUA	as MODIS/ TERRA but overpass ~1 pm	Similar to MODIS/TERRA	
MERIS / Envisat	overpass ~10 :30 local, resolution at nadir 0.25 - 1 km	TCI, CM, τ, CTP, IWV	CTP: σ~183 m (single low-level) clear sky, ocean, land and above clouds
CPR / CLOUDSAT	Scheduled launch autumn 2005		

WP-GOP-8 Meteorological stations

The observations from meteorological stations (DWD, Meteorological and Geographical Institutes, research organizations, etc.) provide continuous information on the atmospheric state. In particular we will use data from

- DWD observatories (Hohenpeissenberg, Lindenberg); especially at Lindenberg a wealth of remote sensing (radiation, microwave radiometer, ceilometer, Raman lidar, cloud radar, wind profiler, GPS etc) and in situ instrumentation is available as well as 4 radiosoundings per day. The observations will allow the characterization of the atmospheric state (in particular the boundary layer and clouds) as complete as possible.
- Further observatories of diverse operators can provide information from interesting locations (UFS Schneefernerhaus; Schwarzwald Observatories Hartheim and Tuttlingen).
- Observatories of foreign weather services including for example the Cloudnet

sites Cabauw, Chilbolton and Palaiseau which provide information on the vertical cloud distribution;

- Meteorological and also geographical institutes operate a rather complete set of instrumentation; as an example the available instruments at the Meteorological Institute Bonn consists of lidar ceilometer, microwave radiometer MICCY, infrared radiometer, micro rain Radar, X-Band Radar, Scintillometer, rain gauges, weather station. This also includes foreign institutes like the IAP Bern.

Auxiliary sites like the wind profiler network operated at nuclear power plants will be also be explored.

WP-GOP-9 GOP management

The overall coordination and organization of the GOP will be performed by LMU. This will include:

- The data organization, distribution, and quality control of radar observations (WP-GOP-2).
- The contact with meteorological/geographical institutes, research organizations, weather services, etc., to explore further data sources.
- The control of timely data delivery from all other WP including data formatting issues.
- The optimal exploitation of ceilometer data (WP-GOP-4) by trying to get backscatter profiles and determination of mixing layer height estimates as well as aerosol classification.
- The performance quality checks by cross correlating data from different WPs.
- The setup and maintenance of a web site giving an overview of the GOP data.
- The performance of a “dry run” in advance of the GOP to guarantee a smooth data management and timely data availability.
- The coordination of data archiving and the subsequent access (together with MPIfM in Hamburg).
- The generation of quicklooks including basic products (time series, maps) and value-added products like monthly means, diurnal cycle, probability density distributions, etc. The latter products will be generated together with a data inventory at the end of each month.
- The tailoring model output to the observations for joint archiving.
- The use of near real time observations for an “online evaluation” of the LM(K) forecasts (and possible other model data). This includes rain gauges (WP-GOP-1), precipitation vertical structure (WP-GOP-3), the cloud base height (WP-GOP-4), vertical water vapor columns (WP-GOP-5).
-

3.3. Not applicable

3.4. Not applicable

7. List of appendages

7.1. Abbreviations

7.2. Résumés and references of applicants and instrument PIs including separate cost tables

7.3. Overview of large research instruments proposed for COPS

7.4. Background information on GOP instruments

7.5. Proposed US Contribution

7.6. Proposed UK Contribution

7.7. Proposed French Contribution

7.8. Proposed Austrian Contribution

7.9. Letters of Interest

7.1. Abbreviations

1D, 2D, 3D, 4D	1-Dimensional, 2-Dimensional, 3-Dimendional, 4-Dimensional
3DVAR	3 Dimensional Variational Assimilation
4DVAR	4 Dimensional Variational Assimilation
AAAS	American Association for the Advancement of Sciences
ACM	Aerosols and cloud microphysics, working group of COPS
ACTOS	Airborne Cloud Turbulence Observation System
AMF	ARM Mobile Facility
AMSU	Advanced Microwave Sounding Unit
AMSR	Advanced Microwave Scanning Radiometer
AQUARADAR	Advances in Quantitative Areal Precipitation Estimation by Radar, DFG project
ARM	Atmospheric Radiation Measurement
Arome	New French mesoscale forecast model
ARPA-SIM	Agenzia Regionale Prevenzione e Ambiente Dell'Emilla-Romagna – Servizio Idro Meteo
ASL	Above Sea Level
BBC	BALTEX Bridge Cloud Campaign
B.Sc	Bachelor of Science
BALTEX	Baltic Sea Experiment
BAT	Bundesangestelltentarif
BMBF	Bundesministerium für Bildung und Forschung
BRIDGE	Cloud campaign during BALTEX, Baltic Sea, 2001
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation, satellite
CAPE	Convective Available Potential Energy
CASI	Compact Airborne Spectrographic Imager
CCN	Cloud Condensation Nuclei
CI	Convection initiation, working group of COPS
CIN	Convective Inhibition
CLIWA-NET	Cloud Liquid Water Network
CloudNET	Research project supported by the European Comission (EC)
CLOUDSAT	NASA Earth System Pathfinder Satellite mission
CNRS	Centre Nationale de la Recherche Scientific
COPS	Convective and orographically-induced precipitation study (= intensive observations period (IOP) of PQP)
COPS-TRACKS	A joint project to COPS on the convective trace substance transport

COSI-TRACKS	Convective Storms Virtual Institute of the Helmholtz Society (http://www.imk.uni-karlsruhe.de/seite2256.php)
COSMO-LEPS	Consortium On Small Scale MOdelling-Local Ensemble Prediction System
COST-720	European Cooperation in the Field of Science and Technology, Action 720: Integrated Ground-Based Remote Sensing Stations for Atmospheric Profiling
CSIP	Convective Storm Initiation Project (UK, summer 2005)
CVI	Counterflow Virtual Impactor
DAP	Data assimilation and predictability, working group of COPS
DAQUA	Combined Data Assimilation with Radar and Satellite Retrievals and Ensemble Modelling fort he Improvement of Short Range Quantitative Precipitation, project within PQP
DFG	Deutsche Forschungsgemeinschaft
DIAL	Differential Absorption Lidar
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DMG	Deutsche Meteorologische Gesellschaft
DMS	Data Management System
DOW	“Doppler on Wheels”, mobile radar system
D-PHASE	Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region; MAP Forecast Demonstration Project
DSD	Drop Size Distribution
DWD	Deutscher Wetterdienst, German Meteorological Service
EARLINET	European Aerosol Research Lidar Network
EBS	Energy Balance Station
ECHAM5	ECMWF model HAMburg version, release 5
ECMWF	European Centre for Medium-Range Weather Forecasts
EGU	European Geophysical Union
ETH	Eidgenössische Technische Hochschule, Zürich
ETL	Environmental Technical Laboratory
ETReC07	European THORPEX Regional Campaign 2007
EUCLID	European Cooperation for Lightning Detection
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUREF	European Reference System (permanent network of GPS stations)
FDDA	Four Dimensional Data Assimilation
FDP	Forecast Demonstration Project
FUB	Freie Universität Berlin, Free University of Berlin
FZK/UKa	Forschungszentrum Karlsruhe, Universität Karlsruhe
GFZ	GeoForschungsZentrum Potsdam, Research Centre for Geosciences Potsdam

GOP	General Observations Period of PQP
GPS	Global Positioning System
GTS	Global Telecommunication System
HATPRO	Humidity and Temperature Profiler
HELIPOD	Helicopter-borne Turbulence Probe, University of Braunschweig
HODAR	Holographic Particle Recorder, University of Mainz
IAP	Institute of Applied Physics, University of Bern
IFS	Integrated Forecast System of ECMWF
IfT	Institute for Tropospheric Research
IHOP_2002	International Water Vapor Project 2002 (USA, 2002)
IMK	Institut für Meteorologie und Klimaforschung, Karlsruhe
INT	Interstitial Inlet
IOP	Intensive Observations Period = COPS
IPM	Institute of Physics and Meteorology, University of Hohenheim
ISSC	International Science Steering Committee
ISSC	International Science Steering Committee of COPS
IWV	Integrated Water Vapor
JOSS	Joint Office for Science Support, UCAR, USA
LAUNCH	Field experiment (Germany & Italy, 2005)
LINET	Lightning Detection Network of DLR and LMU
LM	Lokalmodell of DWD
LMK	Lokal Modell Kürzestfrist
LM-SYNSAT	Synthatic Satellite Images in LM
LMU	Ludwig-Maximilians Universität München, University of Munich
LWC	Liquid Water Content
LWP	Liquid Water Path
M.Sc	Master of Science
MAP	Mesoscale Alpine Project
MARS	Meteorological Archive and Retrieval System, ECMWF, UK
MEDEX	Mediterranean Experiment, a WWRP RDP project
MERIS	Medium Resolution Imaging Spctrometer
METEK	Meteorologische Messtechnik GmbH
METOP	European polar orbiting Satellite mission, European Space Agency
MiA	Meteorology in Action, educational project proposed for PQP in phase 2
MICCY	Microwave Radiometer for Cloud Cartography
MPIfM	Max-Planck-Institute for Meteorology, Hamburg
MM5	Mesoscale Model Release 5
MMM	Micro Meteorological Masts

MODIS	Moderate Resolution Imaging Spectroradiometer
MOS	Model Output Statistics
MPI	Max-Planck-Institute
MRR	Micro rain radar
MSC	Meteorological Service of Canada
MSG	Meteosat Second Generation
MWL	Multi-Wavelength Raman Lidar of IfT
MWR	Microwave Radiometer
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NINJO	Meteorological workstation of DWD
NRT	Near Real Time
NSF	National Science Foundation (USA)
NUMEX	Numerisches Experimentier-System, LM
NWP	Numerical weather prediction
NWP	Numerical Weather Prediction
OC	Operations Center
ODM470	Optical Distrometer
OP	Operations Plan
OSSE	Observation System Simulation Experiment
PBL	Planetary boundary layer
PI	Principal Investigator
PISA	Programme for International Student Assesment
PhD	Philosophiae Doctor (lat.), Doktor der Philosophie
PM	Person months
PO	Project Office
POLDIRAD	Polarization Diversity Doppler Radar, DLR Oberpfaffenhofen
PP	priority program (= SPP1167, Schwerpunktprogramm1167 = PQP)
PPL	Precipitation processes and life cycle, working group of COPS
PQP	Praecipitationis Quantitativae Praedictio (Latin for "quantitative precipitation forecast"), Priority Program 1167 of DFG
QPF	Quantitative precipitation forecast
QUEST	Quantitative Evaluation of Regional Precipitation Forecasts Using Multidimensional Remote Sensing Observations, project within DFG SPP1167
RASS	Radio Acoustic Sounding System
RDP	Research and Development Project
RDSD	Rain Drop Size Distribution
RIMAX	Risikomanagement extremer Hochwasserereignisse

RISH	Research Center for a Sustainable Humanosphere
RS	Radiosonde
RTC	Radiation Turbulence Cluster
SAFIR	Surveillance et Alerte Foudre par Interférometrie Radioélectrique; Blitz-Ortungssystem des Instituts für Meteorologie und Klimatologie, Universität Hannover
SAPOS	Satelliten-Positionierungsdienst der deutschen Landesvermessung
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager
SISOMOP	Simple Soil Moisture Probe
SMS	Short Message Service
SOD	Science Overview Document of COPS
Sodar	Sonic Detecting and Ranging
S-Pol	S-Pol radar of NCAR
SPP1167	Schwerpunktprogramm 1167 = Priority Program 1167 of DFG = PQP
SRQPF	Short-Range QPF, project within PQP
SSC	Science Steering Committee
SSM/I	Special Sensor Microwave Imager
STAMPF	Statistical-Dynamical Methods for Scale-Dependent Model Evaluation and short term Precipitation Forecasting, project within DFG SPP1167
STICCA	Simulation of Topography-Induced Convection in the COPS Area, PQP project
STREAMDATA	Streamflow data assimilation for NWP models, project within PQP
THORPEX	The Observing System Research and Predictability Experiment
THORPEX ERC	THORPEX European Regional Committee
TIGGE	THORPEX Interactive Grand Global Ensemble
TIMSS	Trends in International Mathematics and Science Study
TT	Turbulence Tower
UB	University of Bonn
UBr	University of Braunschweig
UFS	Umwelt Forschungsstation Schneefernerhaus, Environmental Research Station Schneefernerhaus
UHH	Universität Hamburg, University of Hamburg
UHOH	Universität Hohenheim, University of Hohenheim
UHOH RRL	Rotational Raman Lidar of University of Hohenheim
UHOH WV DIAL	Water Vapor DIAL of University of Hohenheim
UK	United Kingdom
US	United States
UTC	Universal Time Coordinated

VERIPREG	VERIfication of PREcipitation over Germany, project within DFG SPP1167
VERTIKATOR	Vertikaler Transport und Orographie, Field experiment, see http://www.vertikator-afo2000.de/ (Germany, 2002)
VLF/LF	Very Low Frequency / Low Frequency
VR-COPS	Virtual Reality COPS, project within PQP
WDCC	World Data Center for Climate, see http://www.mad.zmaw.de/wdcc
WG	Working Group of COPS
WiLi	Wind Lidar of IfT
WindTracer	Scanning Doppler Wind Lidar from IMK/FZK
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting Model, mesoscale model
WTR	Wind-Temperature Radar
WWRP	World Weather Research Programme
ZDR	Differential Reflectivity
ZWD	Zenith Wet Delay