COPS

Convective and Orographically-induced Precipitation Study

An International Field Experiment Within the
Priority Program "Quantitative Precipitation Forecast (PQP)"
of the German Research Foundation

PQP
Praecipitationis
Quantitativae
Praedictio

WWRP RDP Proposal

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Project Summary

The Convective and Orographically-induced Precipitation Study (COPS) is an international field campaign initiated within the German 6-year Priority Program 1167 “Quantitative Precipitation Forecast PQP (Praecipitationis Quantitativae Predictio)”. The German Research Foundation (DFG) provides base funding for PQP. Within this program, 11 universities, 3 research centers, and two meteorological services are working together on 23 projects in connection with surface-atmospheric exchange, orographic effects, convection, cloud microphysics, data assimilation, and parameterization. For the field experiment, a region in southwestern Germany/eastern France has been selected, where, on the one hand, severe thunderstorm activity is frequent in summer with significant amounts of precipitation and risk of flash flood events. On the other hand, the skill of numerical weather forecasts in this region is particularly low.

The objective of COPS is to identify the physical and chemical processes responsible for the deficiencies in QPF over low-mountain regions with the goal to improve their model representation. Correspondingly, the overarching goal of COPS is to

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

Through strong collaboration between modelers, instrument PIs, weather forecast centers, and hydrologists a list of fundamental hypotheses has been developed, which will be addressed by combining three fundamental components of COPS:

1) Synergy of unique in-situ and remote sensing instruments with unique measurement properties on different platforms.

2) Advanced high-resolution models optimized for operation in complex terrain.

3) Data assimilation and ensemble prediction systems.

Intense links to international research programs such as THORPEX and MAP-FDP/D-PHASE have already been established, as these are considered essential to reach the science goals. The first link ensures the improvement of the modeling of the large-scale conditions in the COPS region and studies of the interaction of small-scale and large-scale processes. The latter provides operational deterministic and probabilistic forecasts for the COPS region for mission planning but also for a validation of these forecasts with previously unachieved details.

The strong collaboration between instrument PIs and the modeling community will ensure a long-term, significant improvement of operational QPF. COPS also contains a strong educational component, which ensures that students from schools and universities will get hands-on experience in the performance of measurements during an international field campaign. It is expected that these activities will improve the competence of students in weather and climate education at schools and universities.

If the science goal of COPS is accomplished, advanced process understanding will lead to improved QPF in a critical region where skillful prediction of rain is especially important for economy and society. We expect that the results can also be applied in other regions of interest all over the world.

1 The German Priority Program (PP) 1167 “Quantitative Precipitation Forecast (PQP)”

1.1 Motivation

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

Susceptibility to extreme events, e.g., strong precipitation, hailstorms or storms, will further increase in the industrialized nations due to the increasing accumulation of material assets and the optimization of economic processes (Pielke and Klein 2001). In Europe, this became obvious in 2002 again during the catastrophic flash flood event in Saxonia, which caused an economic loss of 10B US$ (Munich Re Group 2003). Even in the highly industrialized US during the severe hurricane season 2005, loss of life and huge damage took place, which to date cannot be estimated in terms of money.

Quantitative forecast of non-extreme precipitation events is of comparable value, although the avoidable losses mostly do not appear to be that spectacular. Complemented by estimates of their potential uncertainties, such forecasts are of inestimable value as input for hydrological applications or for planning in agriculture and the construction sector.

As precipitation is one of the most important meteorological variables, there is an urgent need to improve forecasting of precipitation from the short-range to the long-range as well as to improve predictions of precipitation anomalies on monthly, seasonal to inter-annual time scales and projections of precipitation changes as a consequence of global climate change. Particularly, an intensification of the global water cycle is expected, which may lead to an increase of extreme weather events in certain regions (e.g., Schär et al. 2004). In the future, climate and weather models will be based on similar parameterizations and model physics. Consequently, any research program leading to an improvement of quantitative precipitation forecast (QPF) will also have a significant positive impact on the performance of regional and global climate models.

1.2 User Requirements

The QPF user community is huge and is it still a subject of research to investigate their respective needs (see e.g., Hense et al. 2004, Fritsch and Carbone 2004). As an example, the demands of the hydrologists for using QPF to extend the lead-time for flash flood forecasting are summarized in Fig.1.1.

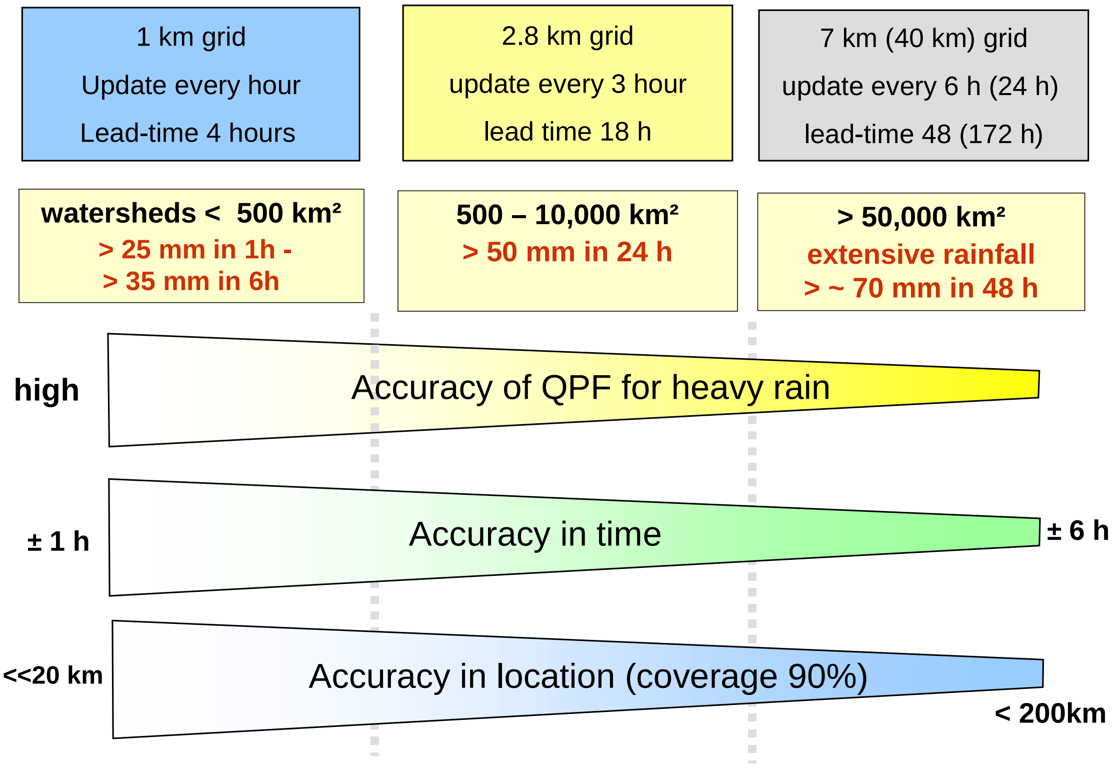

Figure 1.1. Requirements set to QPF for extending the lead time of flash flood forecasting (Courtesy of Werner Schulz, Landesamt für Umweltschutz, Baden-Württemberg, Germany).

These requirements cannot be compressed in a few numbers but depend on the size of the catchment area. For instance, in watersheds with a size of up 500 km^2 the requested accuracy of QPF at rain rates of the order of 30 mm/h is typically 10 %.

The requirements are rising with the complexity of the terrain, as it is becoming more and more essential to predict accurately the spatial/temporal distribution and development of precipitation. Prediction of QPF in complex terrain is obviously most important for many users, as the amount of precipitation is strongly controlled by orography.

1.3 Performance of Current Weather Forecast Models

Weather forecasting and climate models, initialized by basic atmospheric and surface variables like temperature, pressure and wind are able to forecast or calculate precipitation rate and distribution, however, with comparably low skill, especially for convective conditions.

Skill scores of precipitation forecasts are also routinely evaluated at ECMWF and other weather forecast centers. The ability of numerical weather prediction (NWP) models to correctly forecast the amount of precipitation with a certain spatial and temporal resolution has been subject of several studies (Ebert et al. 2003, Hense et al. 2004). Advances in meteorological forecasting methods and observation systems resulted in a constant increase in the quality of short and medium-range weather forecast, e.g., for temperature and wind, in the past years. In contrast, precipitation forecast still has similar deficiencies as some 15 years ago (Ebert et al., 2003). These findings are supported by Fig.1.2, where the improvements in forecast quality (RV: Reduction of variance) of the German Meteorological Service (DWD) are illustrated for various atmospheric variables. In the course of the past 16 years, it was not accomplished to improve the forecast as to whether precipitation will fall in a certain area or not (precipitation yes/no). Ebert et al. (2003) as well as Fritsch and Carbone (2004) confirm that persistent deficiencies in QPF are a problem for all weather services.

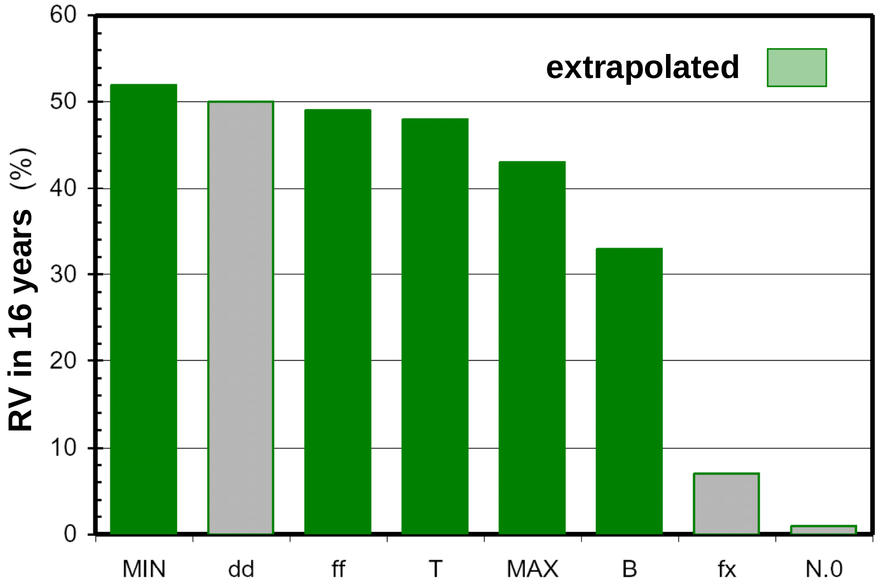

Figure 1.2. Reduction of variance (RV) of the German Meteorological Service (DWD) forecasts during the past 16 years for the model variables of daily minimum temperature (MIN), daily maximum temperature (MAX), average temperature (T), wind direction (dd), wind intensity (ff), cloudiness (B), wind peaks > 12 m/s (fx), and precipitation yes/no (N.0). In fact, no improvement was reached in precipitation forecast (RV = 0.5%) (internal report DWD, Hense et al. 2004).

Comparable comprehensive studies for mesoscale models have been lacking until recently. Preliminary studies indicated that the skill of mesoscale models for short- and medium-range QPF is no better or even degrades in comparison with global models using conventional verification parameters (e.g., Colle et al. 1999, Davis and Carr 2000, Mass et al. 2002). This is confirmed by several studies, which have been initiated within the German Priority Program. A first draft summarizing the results of several verification projects of the DWD mesoscale model Lokalmodell (LM) is available (van Lipzig et al. 2005). These studies show a degradation of skill scores in summer due to more convective precipitation. The results also indicate major problems of QPF in orographic terrain. Furthermore, the diurnal cycle of precipitation is not well reproduced and shows that the initiation of convection is triggered too early in the mesoscale model.

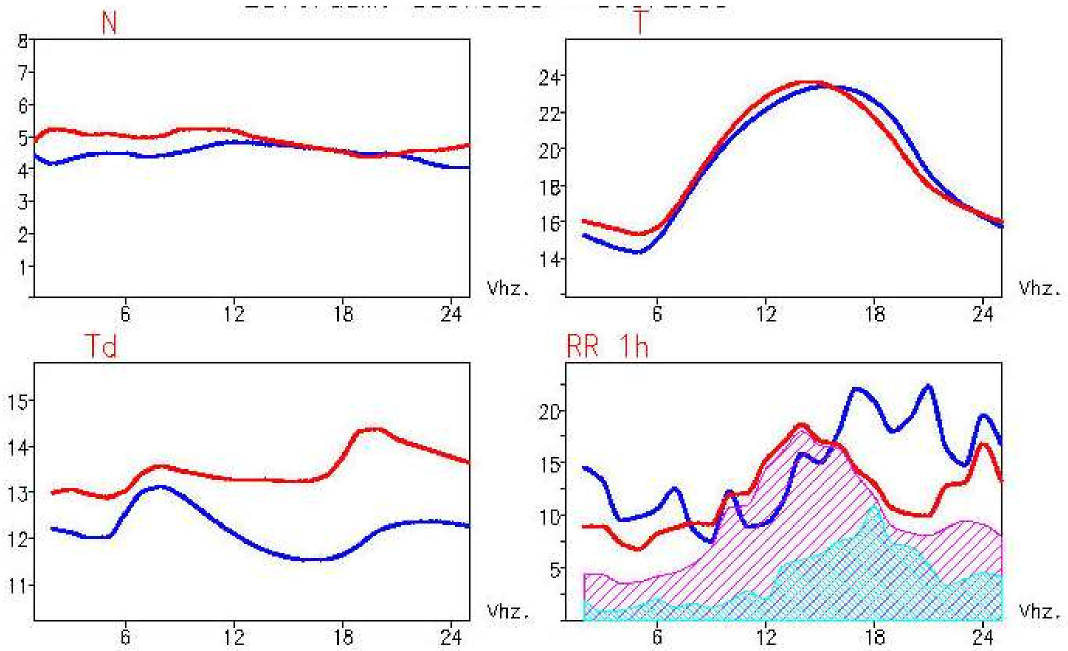

Figure 1.3. Validation of LM forecast of cloud coverage (N), temperature (T), dew point (Td), and rain rate (RR) between 6.5-15E and 47.3-54N between July 03-27, 2003. Blue line: observations, red line: forecast, shaded: contribution of convective precipitation. Courtesy of Ulrich Damrath, DWD, Germany

This finding is substantiated in Fig.1.3, where the forecasts of different variables are compared with observations between July 3 – July 29, 2003. Obviously, in the course of the day, precipitation is predicted too early. These phase errors in the diurnal cycle of precipitation have been reported since more than a decade but the problem remains unresolved (e.g., Guichard et al. 2004). It is likely that this effect is related to incorrect modeling of the diurnal cycle of boundary layer variables such as temperature and dew point. This indicates a general problem with the parameterization of land-surface exchanges processes and/or turbulence closure.

Another interesting systematic error, which has been revealed in the COPS region, is the windward/lee problem. Statistical analyses of QPF errors of the Lokalmodell (LM) of the DWD show a clear overestimation of precipitation on the windward site whereas precipitation of precipitation is strongly under-predicted on the lee side. As the major part of precipitation is due to convection, it is reasonable that this problem is due to an inadequate convection parameterization. The strength of this error also depends on model resolution; however, it has been shown by Meißner et al. (2005) that increasing model resolution alone is clearly not sufficient to improve forecast skill.

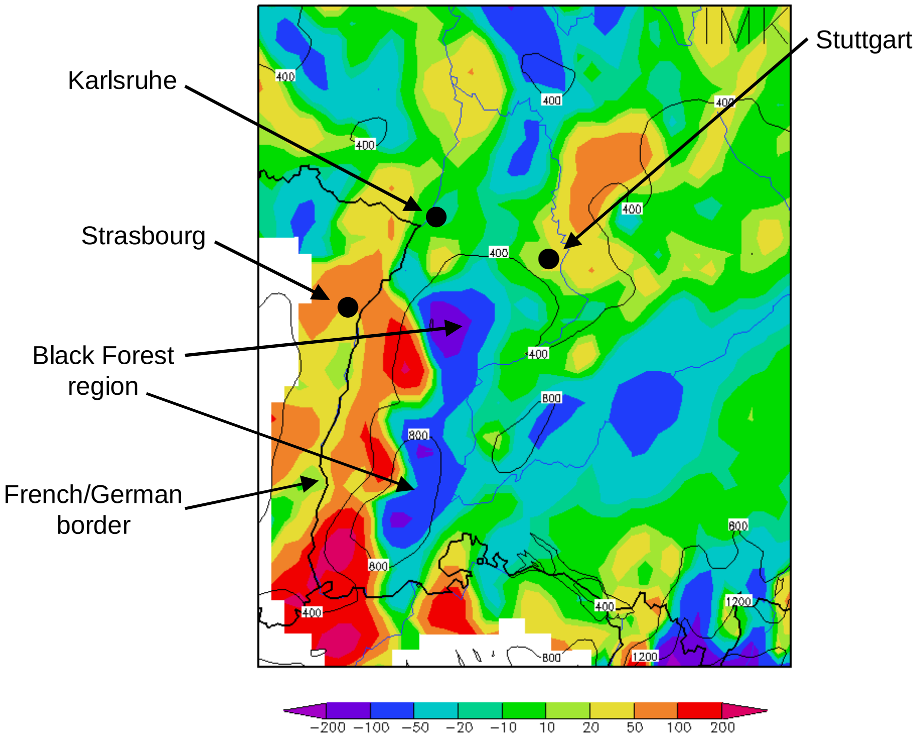

Figure 1.4. Difference in mm between predicted and observed precipitation in the Black Forest Area for August 2004 using the Lokal-Modell of the DWD confirming the windward/LEE problem. The thin black lines indicate the topography. The locations of major cities and the French/German border are also shown. Courtesy of L. Gantner, IMK, Karlsruhe, Germany.

In summary, detailed analyses of the DWD revealed that model deficiencies are particularly large over low mountains and concern the following aspects:

- too frequent forecasts of weak precipitation,
- large errors for strong precipitation /flood forecast,
- wrong positioning and onset of convective precipitation,
- incorrect flow dynamics over mountains,
- enhanced windward/lee precipitation differences,
- deficiencies of soil moisture and water vapor data in the planetary boundary layer (PBL).

Another uncertainty, which is often not considered in NWP models, is the interaction of aerosol and cloud microphysics. In a modeling study employing a new cloud microphysics parameterization scheme it was demonstrated that clouds forming either on maritime or continental cloud condensation nuclei (CCNs) do not only develop differently with respect to their microphysical properties but also the dynamics as well as the resulting rain rates are different (Seifert and Beheng 2005). Figure 1.5 shows a comparison of two precipitating clouds developing in maritime and continental CCNs, respectively, after 48 min modeling time. Relationships between aerosol particles and intensity of precipitation have also been explored in numerous other studies such as Rosenfeld, 2000, Andrea et al. 2004, Segal et al. 2004, Khain and Pokrovsky 2004.

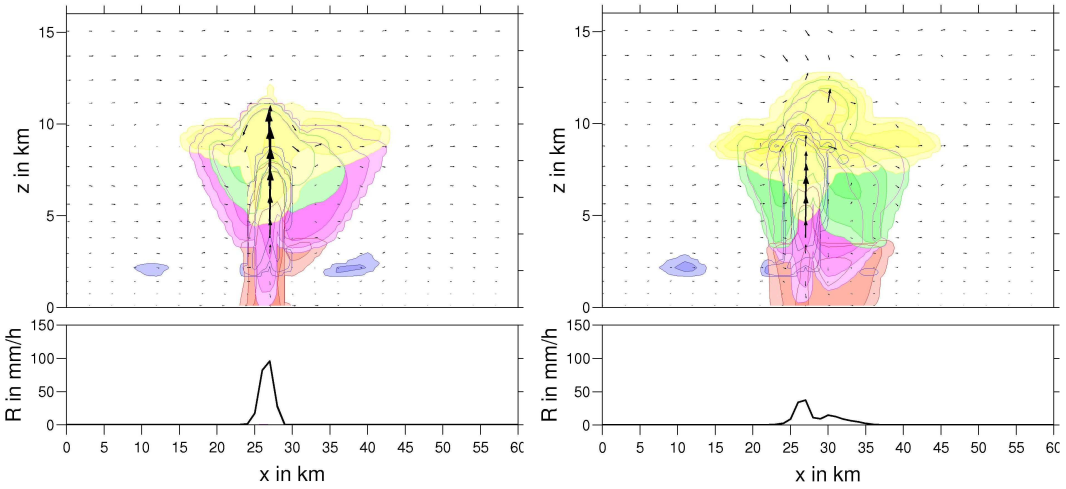

Figure 1.5. Clouds modeled in environments with maritime or continental CCNs including wind vectors. Blue: cloud droplets, red: rain drops, magenta: graupel, yellow: cloud ice, green: snow. Courtesy of Klaus-Dieter Beheng, IMK, Karlsruhe, Germany.

Based on the analyses above, we conclude that the improvement of QPF has not kept up with society's requirements on our forecast systems. Both, global and mesoscale models, are far from fulfilling the needs of many users such as the hydrologists (see Fig.1.1). In Mid-Europe, particularly beneficial for the user community is the improvement of QPF in terrain with significant orography. However, error sources are complex, interwoven, and difficult to separate. The main deficiencies of QPF are considered to be due to errors of the initial fields, sub-optimal methods for the assimilation of observations, inadequate modeling of processes in connection with the water cycle and with aerosol-cloud microphysics as well as fundamental problems in the interpretation of deterministic models. Consequently, it is essential to observe simultaneously the complete process chain of events leading to precipitation in 4 dimensions including some variables, which are not considered in NWP model. This is one of the challenges this research program is taking up.

1.5 The Role of Field Campaigns in Connection with QPF Research

In general, more precise specification of spatial and temporal scales, on which precipitation can be predicted quantitatively, is essential for an improvement of QPF. Moreover, it is necessary to identify the dynamic processes and space-time structures of atmospheric flows that contribute to predictability. However, real structures and processes can only be identified by combining modeling with the aggregation of observation data and only be verified by validating realistic forecasts with high quality observations. These are the theory-based requirements for a comprehensive atmospheric experiment aiming at the improvement of QPF.

When planning a field experiment aimed at improving QPF, one has to know the important influencing factors. However, this requires observing system simulation experiments with models already containing all the processes influencing precipitation formation. This is not possible yet, even for most non-hydrostatic mesoscale models. From long-term meteorological and atmospheric research we know at least five major factors are determining the location and amount of precipitation:

- Large-scale atmospheric dynamics,
- three-dimensional distributions of water in all its phases,
- surface fluxes of momentum, heat, and moisture over inhomogeneous terrain,
- orography, and
- three-dimensional size distribution and chemical composition of tropospheric aerosol.

Two of these factors are strongly influenced by human activities, namely surface fluxes by land use and aerosol content by direct emissions and/or precursor gases.

Under special circumstances, one of these four factors can be the dominating one, but very often all will play a considerable role, for example over moderately complex terrain in an industrialized country, like in most parts of Central Europe, during the summer half year.

This has major consequences for the planning of observations during field experiments and for model development. The following "Gedankenexperiment" may show the difficulties. The situation: Large-scale atmospheric flow across two chains of hills in combination with moderate convective activity, leading to cloud top temperatures of about –12 °C along the first hills. Whether showers develop here, depends on the tiny insoluble portion of the aerosol particles, acting as freezing nuclei already at –12 °C. If they are absent, the second large chain of hills could generate more and more intense showers.

Thus the research tasks ahead for an "ideal" field experiment are:

- Establishment of four-dimensional time series of atmospheric variables in the entire troposphere including as many aerosol, cloud, and precipitation parameters as possible.
- Development of assimilation techniques that allow to incorporate water cycle and aerosol parameters like water vapor, cloud water and aerosol size distribution profiles into mesoscale and cloud resolving models.
- Time series of high spatial and temporal resolution surface flux estimates in a large region, covering at least several hundred by several hundred square kilometers, to be used as lower boundary for the atmospheric models.
- Derivation of new parameterizations for mesoscale weather forecasting models and regional climate models and subsequent test of the skill of these models.

The first three of these tasks can only be accomplished if remote sensing with satellites as well as with ground-based active and passive instruments are utilized.

As the full implementation of the above objectives is beyond the scope of the project PQP, the planning has to include support from interested institutions and other third-party funding, e.g., special research foci of the German Research Foundation (DFG). The organizers are also going through a descoping exercise using knowledge about facilities available to national and international members of the consortium. The known potential of the consortium and the new sensors under construction will be part of the next sections.

The timing for this campaign is excellent, as base funding from DFG is available and the campaign is imbedded in the large German QPF program PQP, and strongly coupled with the activities of weather forecast centers. Therefore, this program will provide a unique focal point for international collaboration and the application of the data set collected during the campaign.

We are proposing a field campaign, which provides a data set for identifying the reasons of deficiencies in QPF and for improving the skill of mesoscale model forecasts with respect to precipitation.

Furthermore the limits of predictability of short-range QPF shall be investigated.

We are focusing on a region with a large amount of rainfall, as this will have the optimum benefit for the user communities.

In Germany, these critical regions are the alpine mountain range and the low-mountain ranges further north. QPF research in regions with significant orography is also essential in many other countries. As this experiment is performed in terrain with significant orography, the name of the experiment is

Convective and Orographically-induced Precipitation Study (COPS).

1.6 Objectives and Set up of the Priority Program 1167 QPF

The Priority Program was initiated as early as 2001 where a large meeting of German scientists took place discussing key topics of future research in atmospheric sciences. The German Research Foundation (DFG) supported the workshop. It was decided to focus on QPF considering its large deficiencies and it fundamental importance for society. A steering group was announced, which included a representative of DWD. From the end of 2001 until the beginning of 2003, a series of meetings took place in order to prepare a proposal to DFG in order to set up a large Priority Program on QPF. The proposal was highly acknowledged and accepted in spring 2003.

This activity led to the set up of the Priority Program (PP) 1167 “Quantitative Precipitation Forecast PQP” by the Deutsche Forschungsgemeinschaft (DFG) in summer 2003 (PQP stands for Praecipitationis Quantitativae Praedictio).

PQP addresses the challenges identified by the user groups with respect to QPF. The program brings together atmospheric scientists at German and Swiss universities and research institutes to combine their knowledge in this research area. In close cooperation with the German Meteorological Service (DWD) their operational forecast systems are used and refined as a basic backbone for model development, testing, and validation. The structure of PQP is depicted in Fig.1.6.

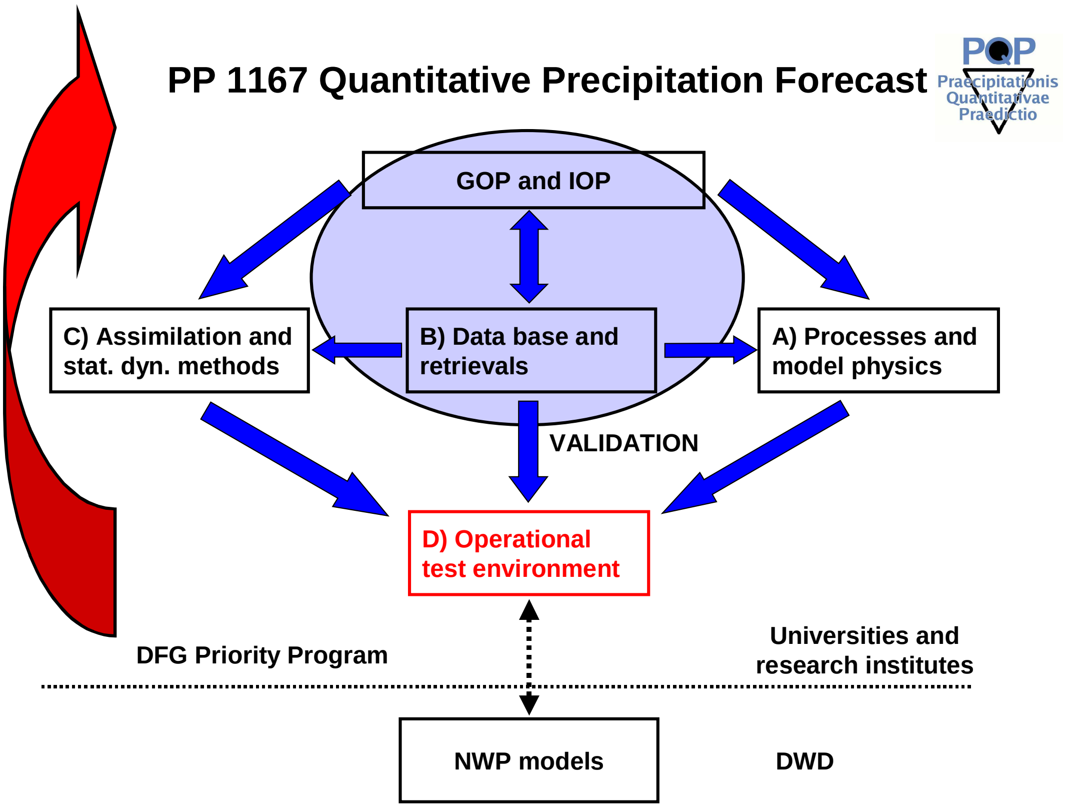

Figure 1.6. Structure of Priority Program 1167 Quantitative Precipitation Forecast - Praecipitationis Quantitativae Praedictio (PQP).

The priority program focuses on reaching the following scientific objectives:

I. **Identification of processes responsible for the deficiencies in quantitative precipitation forecast**

II. **Determination and use of the potentials of existing and new data and new process descriptions to improve quantitative precipitation forecast**

III. **Determination of the predictability of weather forecast models by combined statistical and dynamical analyses with respect to quantitative precipitation forecast**

The schedule of PQP is shown in Fig.1.7. The program has been accepted in May 2003 and started in April 2004. The duration shall be 6 years. The program is divided in three 2-year funding periods. More details are found on the PQP webpage (www.meteo.uni-bonn.de/projekte/SPPMeteo/).

To date 23 research projects have been funded by the DFG after an international review process, which took place in winter 2003/2004. These projects are related to surface-atmosphere exchange, convection, aerosol and cloud microphysics, data assimilation, remote sensing, numerical techniques, and verification. More details are presented on the PQP web page. Two projects are concerned with the preparation of two field campaigns, the General Observing Period (GOP) and COPS. Strong collaboration between PQP PIs is fostered by joint workshops. International collaboration is also strongly supported by the DFG. The field campaign COPS, which is subject of this proposal is an example.

	April 2004-2005	April 2005-2006	April 2006-2007	April 2007-2008	April 2008-2009	April 2009-2010
Year	1	2	3	4	5	6
	Period 1		Period 2		Period 3	
GOP				One year		
IOP	Phase 1: Preparation			Phase 2: Performance: Summer 2007	Phase 3: Data analysis	

Figure 1.7. Funding and timing of PQP. GOP: General Observations Period, IOP: Intensive Observations Period (= COPS)

About 1.6M€ have been allocated for the experiments within the scope of the PQP. The GOP and COPS are imbedded in the center of the PQP program so that these activities can be coordinated with all PQP research projects. Furthermore, this permits to perform IOP projects and the corresponding data analysis within the duration of the PQP.

1.7 Experiments Within the Scope of PP 1167

The urgently required improvement of knowledge on the relevant processes as a basis of model optimization with respect to the currently blatant uncertainty of QPF can only be achieved when data are made available, which meet a far higher standard than the measurement values that are routinely recorded for weather forecast and climate investigation. It is therefore indispensable to extend the database by field experiments, where advanced sensors allow for the observation of decisive atmospheric variables. These include the atmospheric dynamics, the water vapor field as well as cloud and precipitation parameters.

The experimental set up takes into account the huge temporal and spatial distribution of precipitation making the analysis of its statistics were difficult. The entire experiment shall comprise a large-area observation phase of one year (General Observations Period, GOP), and a dedicated experiment regarding the precipitation process over several months (Intensive Observations Period, IOP = COPS), providing high-resolution, four-dimensional measurements of atmospheric variables. The latter is the subject of this WWRP RDP proposal.

During the GOP, all available observations routinely performed will be gathered (e.g., rain gauges, three-dimensional radar observations, satellite observations) in the GOP area covering the major part of Europe. Research institutes shall be supported for operating their "standard" instruments. Available instruments shall be redistributed within the GOP area to obtain information on the atmospheric state at certain sites as complete as possible. Strong cooperation with European Observatories (Cabauw, Chilbolton, Lindenberg, SIRTA in Paris) is planned. Additionally, at least one special long-term observation site shall be operated within the COPS area a critical location, which has been identified in the experiment preparation phase. The Atmospheric Radiation Measurement Program (ARM) Mobile Facility (AMF) has been requested for this purpose. This integration of operationally not employed data will result in the presently achievable optimum of information on the state of the atmosphere being supplied to a regional forecast system.

COPS will be performed in summer 2007 in southwestern Germany and eastern France for 3 months. Precipitation processes will be observed by means of a synergy of a new generation of research remote sensing systems operated on ground, aircraft, and satellites. The whole life cycle of convective precipitation from the initiation of convection, via the formation and development of clouds, to the formation and development and decay of precipitation shall be observed in detail.

The combination of the GOP with COPS shall not only give rise to a far improved data set for assimilation into and validation of models, but also to an improved in-depth process-understanding. Evaluation of the data sets obtained under this priority program will lead to a better representation of relevant processes in models and, hence, to improved QPF.

2 COPS Research Proposal

2.1 Science Goals

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

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

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

- Detailed knowledge of the large-scale conditions is a prerequisite for improving QPF in orographic terrain.
- Better understanding and high-resolution modeling of the orographic controls of convection such as embedded convection in convergence lines, secondary circulations, and regional-scale potential instability is essential.
- The initiation of convection depends mainly on the structure of the humidity field in the PBL (e.g., due to land use, soil moisture and vegetation heterogeneity and evaporation).
- Continental and maritime aerosol type clouds develop differently over mountainous terrain, but the connection of the atmospheric aerosol with ice formation and precipitation from convective clouds do not depend on measurable aerosol properties.
- The combination of novel instrumentation during COPS can be designed in such a way that critical parameterizations of sub-grid processes in complex terrain can be improved.
- Real-time data assimilation of key prognostic variables such water vapor and dynamics is routinely possible and leads to a significant better short-range QPF.

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

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

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

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

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

2.2 International Collaboration

The research performed within COPS is strongly linked with international programs, as the investigation of the whole life cycle of convective precipitation requires detailed knowledge of the large-scale environment around the COPS regions as well as of the small-scale processes within the COPS region. The international collaboration established within COPS is demonstrated in Fig.2.1. COPS shall be coordinated with a European THORPEX regional Campaign (ETReC07). In TReCs, targeting shall be performed by identifying areas, which are critical for weather forecasting in certain regions. In the target areas, additional measurements will be made available for improving the quality of NWP forecasts. It is planned to identify target regions for the COPS area, which can lead to a better representation of the large-scale conditions. On the other hand, the excellent validation data sets of the GOP and COPS can be used to study the impact of targeting. This coordination of large-scale and small-scale measurements is a unique feature of COPS, which to our knowledge has not been attempted before.

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

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

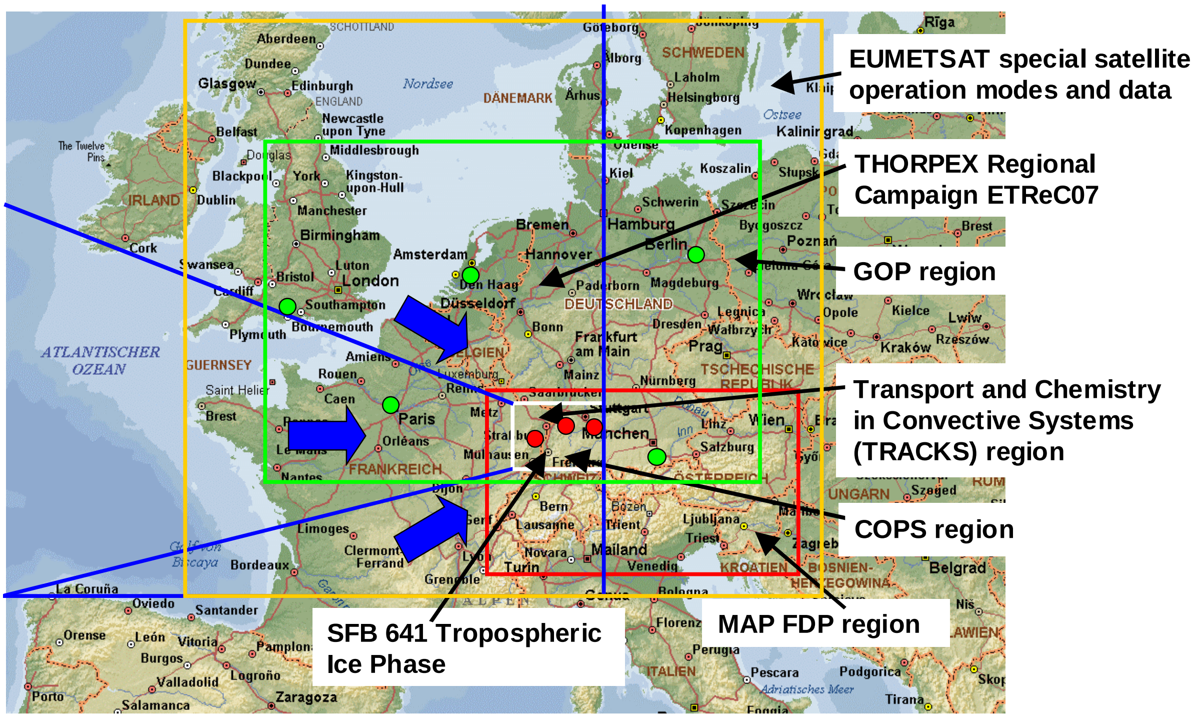

Figure 2.1. Overview of the COPS area (white line) with the planned supersites (red dotes) and its relation to other international research programs. The European observatories are shown by the green dots.

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

3 Scientific Management

A unique property of COPS is its incorporation in an ongoing, funded QPF program with links to several international activities. This ensures that the exploitation of the COPS results within PQP projects as well as scientific studies of other international partners. Additional funding has been or will be requested from other funding agencies such as NSF, PATOM in France, and NERC in UK in order to further strengthen the campaign.

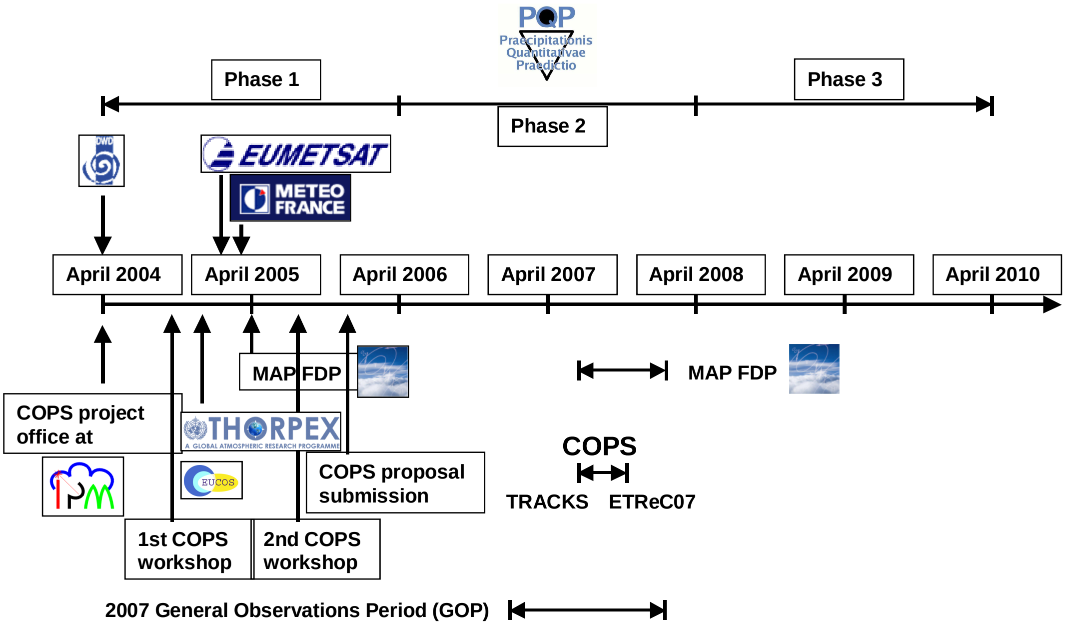

Figure 3.1. Timeline of COPS preparation, performance, and data analysis

The whole project is divided in three phases (see Fig.3.1) according to the set up of PQP. During the preparatory phase, which is currently ongoing, detailed funding of COPS instrumentation will be requested from DFG. This proposal will include planning of operations and logistics, the current mission design, and data archiving issues. The DFG COPS proposal will be based on a Science Overview Document (SOD), which is in preparation. After acceptance of this proposal, which is expected in March 2006, the logistic and scientific preparation of the campaign will be intensified and refined. A detailed Operations Plan (OP) will also be developed.

The second phase is the performance of the campaign during June-August 2007 based on the preparatory work outlined in the SOD and the OP. Particularly critical will be the coordination between COPS, ETReC07, and MAP FDP. For this purpose it is envisioned to set up two operations centers for COPS and ETReC07, respectively. Within ETReC07, medium-range forecasts will be performed and target areas will be detected. The data density in these areas will be increased in order to improve medium-range forecasts in the COPS/GOP area. These results will be used for mission planning in combination with the operational MAP FDP forecasts. These results will be used for guiding aircrafts and for choosing optimized operational modes at the supersites and for mobile instrumentation. It is also planned to ingest a part of the COPS and GOP measurements in BUFR format immediately in the GTS system so that weather forecast centers can use and test additional COPS and GOP observations in real time. To our knowledge this will be the first attempt to demonstrate the available technology and the impact of field measurements on initial fields of mesoscale forecasts in real time.

During the third phase, which starts after the performance of the field campaign and continues at least until April 2010, research based on COPS data will be started. Dedicated studies shall lead to a long-term positive impact on the quality of QPF, and to an improved understanding of the organization and predictability of convective precipitation.

3.1 Key Information about COPS

Proposed location: Southwestern Germany, eastern France

Time and duration: June-August 2007

Coverage: About 270 km × 150 km

1st COPS workshop: September 13-14, 2005, Hohenheim University, Stuttgart, Germany

2nd COPS workshop: June 27-28, 2005, Hohenheim University, Stuttgart, Germany

Requested base funding: 2M€ from DFG + 2M€ internal funding of the participating institutes and research centers + international funding

The COPS ISSC agreed on an open data policy between COPS participants.

3.2 COPS Project Office

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3.3 PQP Steering Committee

The overall PQP program has been initiated by

Andreas Hense, Prof. Dr.; Institute of Meteorology, University of Bonn, Bonn, Germany (speaker)

Gerhard Adrian, Prof. Dr.; German Meteorological Service (DWD), Offenbach, Germany

Christoph Kottmeier,	Prof. Dr.; Institute of Meteorology and Climate Research (IMK), University of Karlsruhe/Forschungszentrum Karlsruhe, Karlsruhe, Germany
Clemens Simmer,	Prof. Dr.; Institute of Meteorology, University of Bonn, Bonn, Germany
Volker Wulfmeyer,	Prof. Dr.; Institute of Physics and Meteorology (IPM), Hohenheim University (UHOH), Stuttgart, Germany, Chair

This steering group is working on the coordination of the diverse research projects, which have been funded within PQP, during all three phases of the program. Furthermore, suggestions are made for optimizing the set up of research projects in order to reach the overarching research goals of PQP.

3.4 COPS International Science Steering Committee

For the scientific preparation and performance of COPS a dedicated International Science Steering Committee has been established. It consists of the following members:

Volker Wulfmeyer,	Prof. Dr.; Institute of Physics and Meteorology (IPM), Hohenheim University (UHOH), Stuttgart, Germany, Chair
Christoph Kottmeier,	Prof. Dr.; Institute of Meteorology and Climate Research (IMK), University of Karlsruhe / Forschungszentrum Karlsruhe, Karlsruhe, Germany, Co-Chair
Gerhard Adrian,	Prof. Dr.; German Meteorological Service (DWD), Offenbach, Germany
Alan Blyth,	Dr.; School of Environment, University of Leeds, UK
Ed Browell,	Dr.; NASA Langley Research Center, Hampton, Virginia, USA
Susanne Crewell,	Prof. Dr.; Institute of Meteorology, TU Munich, Munich, Germany
Kenneth J. Davis,	Prof. Dr.; Pennsylvania State University, University Park, Pennsylvania, USA
Hartmut Graßl,	Prof. Dr.; Max-Planck-Institute of Meteorology (MPIfM), Hamburg, Germany
R. Michael Hardesty,	Dr.; Environmental Techology Laboratory, NOAA, Boulder, CO, USA
Jost Heintzenberg,	Prof. Dr.; Leibniz Institute for Tropospheric Research, Leipzig, Germany
Jos Lelieveld,	Prof. Dr.; Max-Planck-Institute for Chemistry, Mainz, Germany
Dave Parsons,	Dr.; NCAR MMM, Boulder, Colorado, USA
Evelyne Richard,	Dr.; Laboratoire d'Aerologie, University of Toulouse, Toulouse, France

Mathias Rotach, PD Dr.; Meteo Swiss, Zurich, Switzerland

Herman Russchenberg, Dr.; International Research Centre for Telecommunications-Transmission and Radar (IRCTR),
Delft University of Technology, Delft, The Netherlands

Peter Schlüssel, Dr.; EUMETSAT, Darmstadt, Germany

Ulrich Schumann, Prof. Dr.; Institute of Atmospheric Physics (IPA),
DLR Oberpfaffenhofen, Germany

Reinhold Steinacker, Prof. Dr.; Department of Meteorology and Geophysics,
University of Vienna, Vienna, Austria

Tammy Weckwerth, Dr.; NCAR ATD, Boulder, Colorado, USA

The terms of reference of the COPS ISSC are as follows:

- Provide scientific guidance for research topics investigated during COPS
- Suggest most important science questions to be addressed
- Develop Science Document (SD) and Science Overview Document (SOD)
- Support the request for scientific instrumentation operated during COPS
- Foster international collaboration with related research programs such as THORPEX, other RDPs and FDPs, as well as CSIP in UK.
- Request and develop links to weather services for preparing and supporting the field phase of COPS.

3.5 COPS Working Groups and Chairs

Chair WG IC: **Christoph Kottmeier,** Prof. Dr.;
Institute of Meteorology and Climate Research (IMK),
University of Karlsruhe/Forschungszentrum Karlsruhe, Germany,

Chair WG ACM: **Jost Heintzenberg,** Prof. Dr.;
Leibniz Institute for Tropospheric Research, Leipzig, Germany,

Chair WG PPL: **Martin Hagen,** Dr.; Institute of Atmospheric Physics (IPA),
DLR Oberpfaffenhofen, Germany,

Chair WG DAP: **George Craig,** Dr.; Institute of Atmospheric Physics (IPA),
DLR Oberpfaffenhofen, Germany.

3.6 COPS Observations

In order to categorize and to coordinate all different observation systems at various sites, the observation of the life cycle of precipitation will be divided in four phases. We are further distinguishing between standard and research observation systems. A full list of the envisioned instrumentation is summarized in Appendix I. Furthermore, set up and operations of instruments will be based on the expected weather conditions (see Appendix II).

Standard observation systems produce generally continuous measurements during the campaign without changes of the observation strategy. To this category belong meteorological stations, rain gauges, soil and river runoff stations, flux stations, as well as continuous operating remote sensing systems on ground and in space. Several standard observation systems will be added in suitable networks during the campaign. These are including additional radio soundings, a dense GPS network, radiometers, and several micro rain radars.

Research observation systems have the capability to be mobile or flexible in operation, e.g., by changing the set up of the scanning mode. These systems are usually more complex and are not operated continuously during COPS. A unique suite of research systems will be applied during COPS. On ground, a novel 3-d scanning water vapor differential absorption lidar (DIAL) system will be applied (Wulfmeyer and Walther 2001b), which will be able to perform 2-d water vapor measurements up to a range of 15 km within one minute. This system will be combined at least with a scanning Doppler lidar, cloud radar, and microwave radiometer, among other instrumentation forming a package for 3-d atmospheric dynamics and stability, moisture convergence, and budget measurements. This combination will be extended with instrument packages for aerosol, cloud, and precipitation measurements providing a unique opportunity for synergetic measurements using this instrument combination.

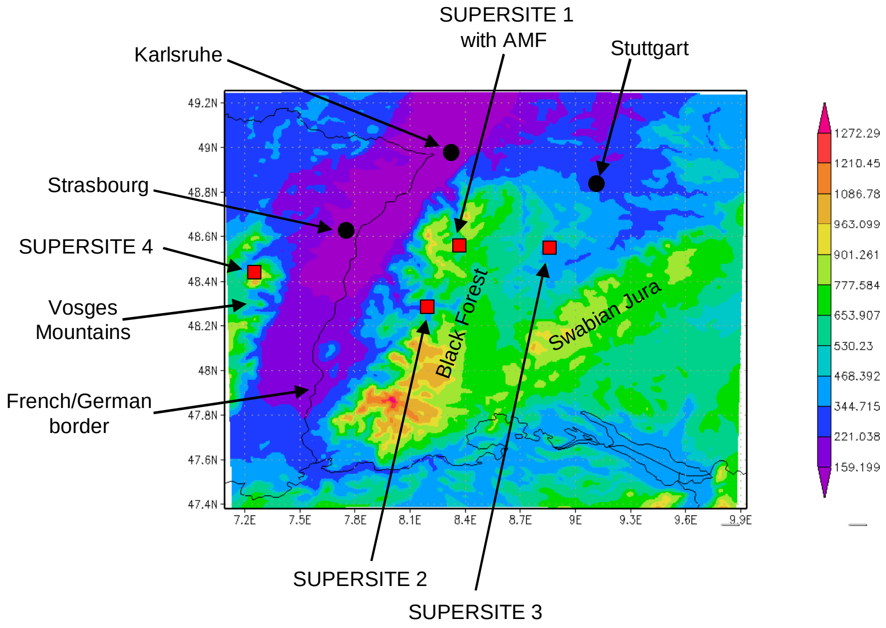

Figure 3.2. Proposed locations of the supersites in the COPS region.

This research instrumentation will be deployed within the COPS area spanning about 100 x 100 km^2 at four supersites. Three supersites shall be equipped with PQP instrumentation only. We are proposing to form a fourth supersite by combining the ARM mobile facility with scanning PQP remote sensing systems. This proposal is currently in review at the ARM program in the US. One supersite shall be located in the Vosges mountains, the AMF in a valley in the Black Forest where often convection initiation takes place, another supersite in a valley to the south, and another one on the lee side of the Black Forest (see Fig.3.2).

A potential set up of a supersite and the combination of its measurements with other sensors is depicted in Fig.3.3. In the low-mountain region we expect that IC is often localized (see Appendix II). In fact, we identified already several key regions by means of radar observations and high-resolution model runs. Thunderstorm and initiation of convection time series demonstrate that it is very likely that several interesting cases can be observed and studied during COPS.

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

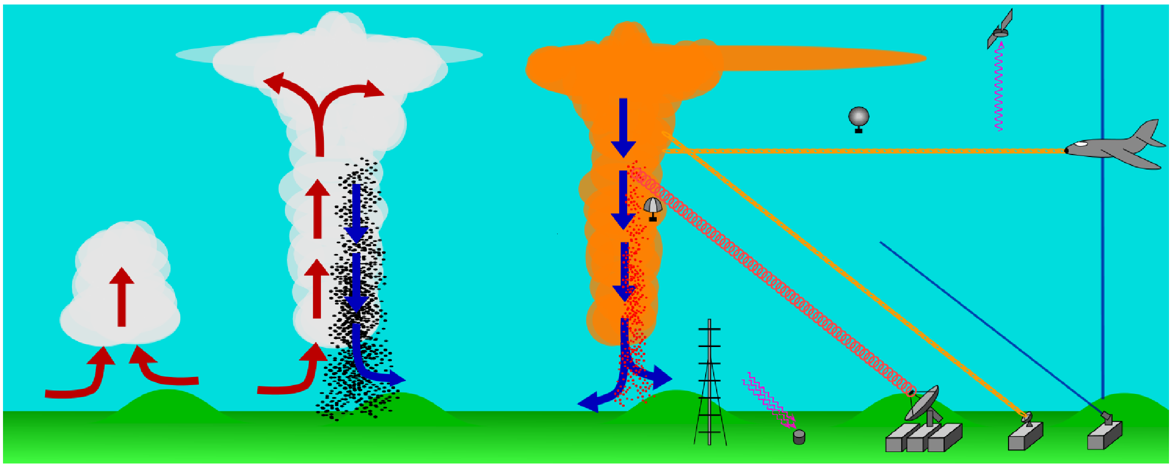

Figure 3.3. Sensor synergy at COPS supersite based on scanning Doppler lidar, DIAL, microwave and precipitation radar, and microwave radiometer. These data will be merged with other in-situ and remote observations.

The observation strategy can be divided in four phases (see Fig.3.3) in order to observe the whole process chain from convective initiation over cloud microphysics to precipitation. **Phase 1** is defined by the presence of a pre-convective situation. During this time, mainly three activities will take place. Within the ETReC07 (see Fig.2.1), targeting will be performed for improving large-scale forecasts a few days ahead before IC is taking place. Mesoscale targeting for better characterization of the inflow in the COPS are will take place at suitable located surface stations as well as by airborne and satellite observations. Meanwhile, boundary layer processes will be characterized in great detail in the COPS domain.

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

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

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

3.7 Research Based on COPS and GOP Data

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

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

For the observation-to-model approach, data from cloud radars, lidars, and microwave radiometers will be combined, e.g., using the synergetic algorithms developed as part of the EU Project CloudNET (http://www.met.rdg.ac.uk/radar/cloudnet) and of BALTEX (Crewell et al. 2004). This includes a cloud classification, ice water content, cloud fraction, turbulence levels, and liquid water path with a strict quality control and error estimates. All this products are available every 30 seconds with 60 m vertical resolution. Furthermore, the optimal estimation technique developed by Löhnert et al. (2004) and extended within the COST720 initiative “Integrated Profiling” will continuously provide profiles of temperature, humidity, cloud liquid water content, drizzle water content, cloud effective radius, and the corresponding error estimates.

The limited representativeness of passive remote sensing systems in orographic terrain due to their low range resolution and limited scanning capability will be extended by various scanning lidar systems, which are considered as key components of COPS (Wulfmeyer et al. 2003). These systems will deliver 3-d fields of humidity

(Wulfmeyer and Walther 2001a, 2001b), wind components (Henderson et al. 1993, Grund et al. 2001), and temperature (Behrendt et al. 2005) in the pre-convective environment or the environment around convective systems. These measurements are considered essential to *understand* the properties of clouds and precipitation, as well as their development and evolution.

All these approaches shall lead to comprehensive data sets, which can be used to improve the process understanding of convective precipitation in complex terrain. The set up of observation systems during COPS will enable to observe critical processes from the pre-convective conditions, to the initiation of convection, to the development and evolution of clouds, to the development, evolution, and decay of precipitation.

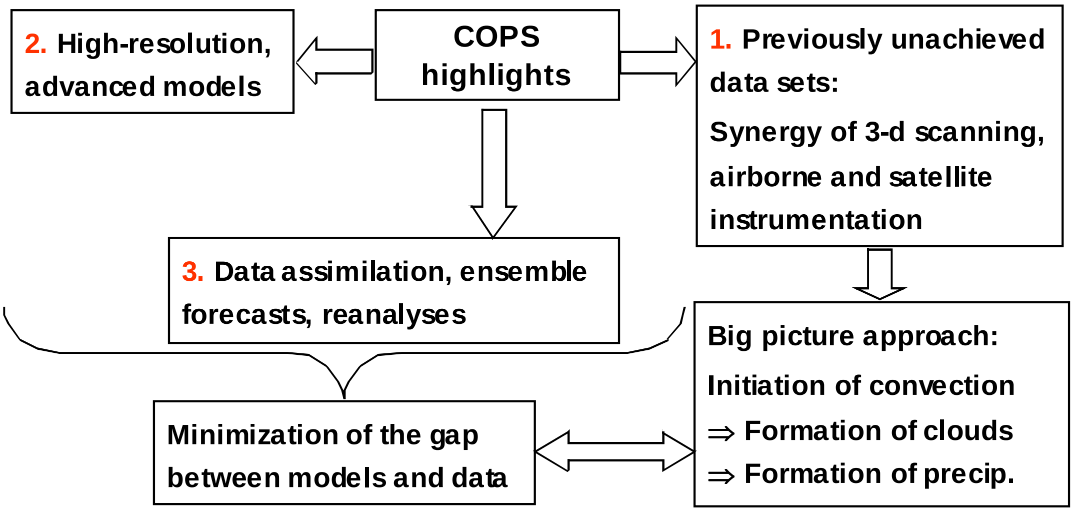

Figure 3.4. COPS research approach.

Data assimilation is another key components of COPS. Data assimilation provides the essential link between observations and model results in order to perform improved process studies (Xue and Martin 2005, Wulfmeyer et al. 2005). By means of data assimilation in combination with reanalyses, errors due to initial fields and parameterizations can be separated in more detail so that even with a limited data set provided within a field campaign fundamental results can be derived, which can be tested in operational models. Dedicated studies of the impact of new observations as well as of present and new parameterizations on forecast quality will be possible. Based on ensemble forecast systems, the predictability of clouds and precipitation will be explored on a regional scale (Montani et al. 2003, Martin and Xue 2005). Figure 3.4 presents a scheme of the COPS research and Appendix III summarizes the models to be operated during COPS.

Consequently, we are convinced that during COPS unique research can be performed leading to a long-term improvement of NWP systems. Also future improvements of NWP models are considered such as the implementation of advance data assimilation systems as well as the representation of aerosol-cloud-interaction.

4 Societal Impact

Advanced QPF by deterministic and probabilistic forecasts is a prerequisite for extending the lead-time for flash flood forecasting. Strong collaboration between meteorologists and hydrologists is essential to accomplish this goal, which has already been initiated within COPS and MAP FDP. Furthermore, research on predictability and a better explanation of the results to society will lead to an improved acceptance and understanding of QPF in the public. This can result in advanced planning to improve public safety and to protect the public from high-impact weather events.

Education is another key subject of COPS preparation and performance. COPS provides a unique opportunity to educate students at schools and universities by means of hands-on activities in the fields of weather and climate research. A special part of the COPS proposal will focus on providing personal experience to students during the preparation and performance of COPS. Several student groups from German universities will travel to the COPS region, participate in COPS, and set up their own observation systems, which will be taken into account in mission planning. It is envisioned that students will get the opportunity to design and to suggest their own operations plans during specific missions. A special project called Meteorology In Action (MIA) will be devoted to the education of students at schools. During joint preparatory workshops of teachers and scientists it will be discussed how education on precipitation should be optimized at schools. Groups from different schools will participate in the experiments using their own equipment. Finally, it will be tested whether the personal experience acquired by participation in a field campaign increased the competence of the students in the understanding of problems in atmospheric sciences related to the formation of clouds and precipitation.

Before, during, and after the experiment an intense outreach campaign will be performed in order to inform the public about the activities of the COPS participants. We consider this activity very important in order to demonstrate the status and the role of research on QPF in society and economy.

5 Forecast Demonstration Projects

The link of COPS with MAP FDP/D-PHASE already ensures the coordination of COPS with a WWRP FDP. In the future, it can be expected that COPS research will lead to the further performances of dedicated FDPs. For instance, COPS can contribute to the planning and development of future observing systems based on networks or mobile platforms on ground and/or space borne observations. Target areas will be identified where additional routine observations from ground or space are needed for improving mesoscale QPF by means of data assimilation. It will be identified what kind of observation systems are particularly important. This activity may result in a future **mesoscale targeting FDP for improving short-range QPF.**

COPS research on different data assimilation technique will result in several impact studies. Recommendations on the best choice of data assimilation methods will be derived considering different complexity and required computing power. These results may be used for performing a **mesoscale data assimilation FDP** where operational models based on different data assimilation systems (3DVAR, 4DVAR, FDDA) will be compared with respect to QPF skill.

Development of parameterizations in complex terrain will be incorporated and tested in advanced high-resolution forecast systems. Their performance can be evaluated and compared in future **parameterization FDPs**. We consider as particularly important the comparison of skills of high-resolution models with and without parameterization of convection.

High-resolution ensemble forecasting systems will be tested after COPS and research on the predictability of convective precipitation will be performed. We expect that these activities will lead to improvements of operational probabilistic forecasts to be demonstrated in future FDPs.

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Appendix I List of Candidate Instruments

German Participants

Facility	**Instrument**	**Principal Investigator**	**Anticipated Sponsor**
DLR	DLR Falcon aircraft with in-situ instrumentation, H2O DIAL, Doppler Lidar, and dropsondes	Gerhard Ehret	DLR + DFG
DLR	C-band polarization Doppler radar POLDIRAD	Martin Hagen	DLR + DFG
DLR	2 high resolution automatic rain gauges	Martin Hagen	Internal
DLR	Joss & Waldvogel disdrometer	Martin Hagen	Internal
DLR	Vertical pointing Micro Rain Radar	Martin Hagen	Internal
DLR/AMS-Gematronik	X-Band Compact Polarisation Radar CORA	Ronald Hannesen	DLR + DFG + AMS-Gematronik
DWD	Radar network, radiosonde network, surface network	NN	DWD
FZK	Research Aircraft DO 128 with in-situ mean, turbulent parameter and chemistry sensors	Ulrich Corsmeier	DFG
FZK	Dropsondes	Ulrich Corsmeier	Internal
FZK	Drop-up-sondes	Norbert Kalthoff	Internal
FZK	Karlsruhe C-band precipitation radar	Klaus Dieter Beheng	Internal
FZK	Mobile wind-temperature radar	Siegfried Vogt	Internal
FZK	Doppler lidar WindTracer, mobile	Christoph Kottmeier	Internal
FZK	2 mobile sodars	Norbert Kalthoff	Internal
FZK	2 mobile radiosonde stations	Norbert Kalthoff	DFG
FZK	2 mobile tethered balloon sonde stations	Norbert Kalthoff	Internal
FZK	2 mobile energy budget stations	Norbert Kalthoff	Internal

	stations	Kalthoff	
FZK	9 mobile meteorological surface stations	Norbert Kalthoff	Internal
FZK	4 mobile meteorological masts	Norbert Kalthoff	Internal
FZK	Soil moisture sensors (several)	Christian Hauck	Internal
FZK	Instrumentation at Zugspitze/Garmisch observatories	Ralf Sussmann, Thomas Trickl	Internal + DFG
GKSS	Polarimetric 95 GHz Doppler cloud radar MIRACLE	Markus Quante	GKSS + DFG
IfT	Six-wavelength aerosol, water vapor, temperature Raman lidar	Dietrich Althausen	IfT + DFG
IfT	Wind lidar WILI, scanning	Ulla Wandinger	IfT + DFG
IfT	Helicopter-borne payload ACTOS with sensors for turbulence, thermodynamical and microphysical properties, and aerosol particle measurements	Holger Siebert, Manfred Wendisch	IfT + DFG
IfT	Airborne counterflow virtual impactor (CVI) and interstitial inlet (INT) coupled with physico-chemical particle characterisation	Stephan Mertes	IfT + DFG
Institut für Weltraumwissenschaften Freie Universität Berlin	Cessna 207 T aircraft with lidar (Mathias Wiegner, U. München), Spektrometer FUBIS (0.4-1.7 µm), Spektrometer casi (0.45 – 0.95 µm), Aureole sun photometer	Jürgen Fischer	DFG
LfU	Surface network	NN	LfU
Research Center Jülich	Zeppelin NT with aerosol and meteorological in-situ data instrument.		Research Center Jülich + DFG
U. Bayreuth	3 Energy balance stations	Thomas Foken	DFG

U. Bayreuth	Modified Bowen-Ratio stystem	Thomas Foken	DFG
U. Bayreuth	Laser scintillometer	Thomas Foken	DFG
U. Bayreuth	METEK Sodar-RASS	Thomas Foken	DFG
U. Bayreuth	12-m wind, temperature, and humidity mast	Thomas Foken	DFG
U. Bonn	X-band Doppler radar	Dirk Metschen	Internal
U. Bonn	24 GHz micro-rain-radar (2x)	Malte Diederich	DFG
U. Bonn	Ceilometer CT25	Andreas Schneider	Internal
U. Bonn	AIR (Atmospheric Interferometry Radiomter) sounding system (6 levels)	Günther Heinemann, Andreas Schneider	Internal
U. Bonn	MW radiometer MICCY with IR radiometer KT 19.85	Clemens Simmer, Susanne Crewell	DFG
U. Bonn	3 profiling stations	Günther Heinemann	DFG
U. Bonn	Turbulence station	Günther Heinemann	DFG
U. Bonn	Scintillometer BLS	Andreas Schneider	Internal
U. Bonn	Disdrometer, & 8 tipping buckets	Andreas Schneider	Internal
U. Braunschweig	Helicopter pod with turbulence instr.	Jens Bange	DFG
U. Freiburg	Towers with meteorological instrumentation at the forest sites Hartheim and Tuttlingen	Helmut Mayer	DFG
U. Freiburg	Flat-array SODAR system (Scintec FAS64)	Helmut Mayer	DFG
U. Freiburg	Tethered balloon system	Helmut Mayer	DFG
U. München	Airborne POLIS lidar on Cessna 207 T	Matthias Wiegner	DFG
U. München	Sun and sky photometer, UV radiation	Peter Köpke	DFG

U. München	150 GHz polarimetric microwave radiometer + HATRPRO (RPG)	Susanne Crewell	DFG
U. München	Automatic weather stations	Roger Smith	DFG
U. Hohenheim	Temperature Raman Lidar, scanning	Andreas Behrendt	DFG
U. Hohenheim	X-band radar	Thorsten Schaberl	DFG
U. Hohenheim/ IfT/UP/ DLR	Scanning H2O DIAL	Volker Wulfmeyer	DFG
U. Hohenheim	Aersol particle counters and analysis	Roland Wurster	DFG

French Participants

Facility	**Instrument**	**Principal Investigator**	**Anticipated Sponsor**
CNRS/ SAFIRE	ATR 42 aircraft with in-situ mean and turbulent parameter instruments	NN	CNRS
CNRS/ SAFIRE	Falcon 20 aircraft with in-situ mean and turbulent parameter instruments	NN	CNRS
CNRS	Water vapor DIAL LEANDREII on the NRL P-3 or the SAFIRE Falcon 20	Cyrille Flamant	CNRS
CNRS	Dropsondes on SAFIRE Falcon 20	NN	CNRS
CNRS	Airborne in-situ aerosol sampling instrumentation on SAFIRE ATR 42	Laurent Gomes	CNRS
CNRS	Airborne in-situ cloud microphysical instrumentation on SAFIRE Falcon 20 or ATR 42	Jean-François Gayet	CNRS
CNRS	Airborne Radar/Lidar RALI on SAFIRE Falcon 20	Alain Protat Jacques Pelon	CNRS
CNRS	Ronsard ground-based polarization Doppler radar	Georges Scialom	CNRS
CNRS/IGN	Ground-based Raman lidar	Olivier Bock	CNRS

Meteo-France	Radar network, radiosonde network, surface network	NN	Meteo-France
University of Clermont-Ferrand	X-band local area precipitation radar	Joël Van Baelen	
University of Clermont-Ferrand	UHF multiple receiver boundary layer radar	Joël Van Baelen	
University of Clermont-Ferrand, INSU	GPS observation stations in French COPS region	Joël Van Baelen	

Participants from the UK

Facility	**Instrument**	**Principal Investigator**	**Anticipated Sponsor**
UFAM	BAE 146 aircraft	Alan Blyth/Phil Brown	NERC
UFAM	Cessna aircraft	Martin Gallagher	NERC
UFAM	Wind profiler	Geraint Vaughan	NERC
UFAM	Ozone/aerosol lidar	Geraint Vaughan	NERC
UFAM	Doppler lidar	Chris Collier	NERC
UFAM	Radiometer	Chris Collier	NERC
UFAM	3 sodars	Stephen Mobbs	NERC
UFAM	Tether balloon	Stephen Mobbs	NERC
UFAM	3 sounding stations	Barbara Brooks	NERC

US Participants

Institution or Facility	**Instrument**	**Principal Investigator**	**Anticipated Sponsor**
DOE ARM program	ARM Mobile Facility (microwave radiometers, radiosondes, broadband radiometers, surface pressure/temperature/humidity, millimeter cloud	Mark Miller	US DOE

	radar, micropulse lidar, infrared interferometer)		
NASA	Lidar Atmospheric Sensing Experiment (LASE) on the NASA'DC-8	Ed Browell	NASA
NASA	Raman Airborne Spectroscopic Lidar (RASL) on P-3, DC-8 or Dash-7	Dave Whiteman, Belay Demoz	NASA
NASA	Scanning Raman Lidar (SRL)	Dave Whiteman, Belay Demoz	NASA
NCAR	S-POL	Jim Wilson	NSF/ Deployment pool
NCAR	3 DOWs	Tammy Weckwerth	NSF
U. Wyoming	University of Wyoming King Air (UWKA) with in-situ instrumentation and Wyoming Cloud Radar and Wyoming Backscatter Lidar	Bart Geerts Backscatter Lidar: Zhien Wang	NSF/ Deployment pool
NOAA	Mini-MOPA CO_2 Doppler lidar	Alan Brewer, Christoph Senff	NSF & NOAA

Participants from Austria, Italy, Japan, Switzerland, and The Netherlands

Facility	**Instrument**	**Principal Investigator**	**Anticipated Sponsor**
Basilicata University	Università della Basilicata Lidar (BASIL), aerosols, water vapor, temperature Raman lidar	Paolo Di Girolamo	
Istituto di Metodologie per l'Analisi Ambientale (IMAA)	Aerosol Lidar	Gelsomina Pappalardo	
Istituto di Metodologie per l'Analisi Ambientale (IMAA)	Aerosol, water vapor, temperature Raman Lidar	Gelsomina Pappalardo	
Istituto di Metodologie	Microwave radiometer	Gelsomina Pappalardo	

per l'Analisi Ambientale (IMAA)			
NICT	Airborne Doppler lidar	Kohei Mizutani	
RISH	Water vapor and aerosol Raman lidar	Takuji Nakamura	MEXT Japan
TU Delft	TARA	Herman Russchenberg	
MeteoSwiss	Data use from existing radar, radiosonde, and surface networks	NN	MeteoSwiss
University of Vienna	RASS	Manfred Dorninger, Reinhold Steinacker	
University of Vienna	4 3D-Sonic anemometers	Manfred Dorninger, Reinhold Steinacker	
University of Vienna	3 automatic met. stations	Manfred Dorninger, Reinhold Steinacker	
University of Vienna	1 energy balance system	Manfred Dorninger, Reinhold Steinacker	
University of Vienna	1 mobile radiosonde system	Manfred Dorninger, Reinhold Steinacker	
University of Vienna	1 disdrometer	Manfred Dorninger, Reinhold Steinacker	
University of Vienna	1 micro rain radar	Manfred Dorninger, Reinhold Steinacker	
University of Vienna	10-15 temperature sensors	Manfred Dorninger, Reinhold Steinacker	

Appendix II Logistics, Field and Data Management

II.1 Logistics

The German part of the proposed IOP-Region is characterized by several independent networks measuring meteorological data and in particular precipitation. The density of stations and the different networks are presented in Figure II.1. Networks of the German federal states Baden-Württemberg, Hessen, and Rheinland-Pfalz are measuring precipitation with a time resolution of up to 10 minutes. The 50 SYNOP stations of the German Weather Service (DWD) give hourly values of the standard SYNOP-dataset, while the 34 DWD-MIRIAM stations measure precipitation and other meteorological data automatically in 10-minute intervals. At the approx. 500 DWD-RR24 stations, pricipitation measurements are available every 24 hours. Radiosoundings are made by DWD in Stuttgart on four times a day at 00, 06, 12, and 18 UTC. There are several aerological stations performing radiosonde launches around the COPS region at Munich, Payerne (Switzerland), Nancy (France) and others.

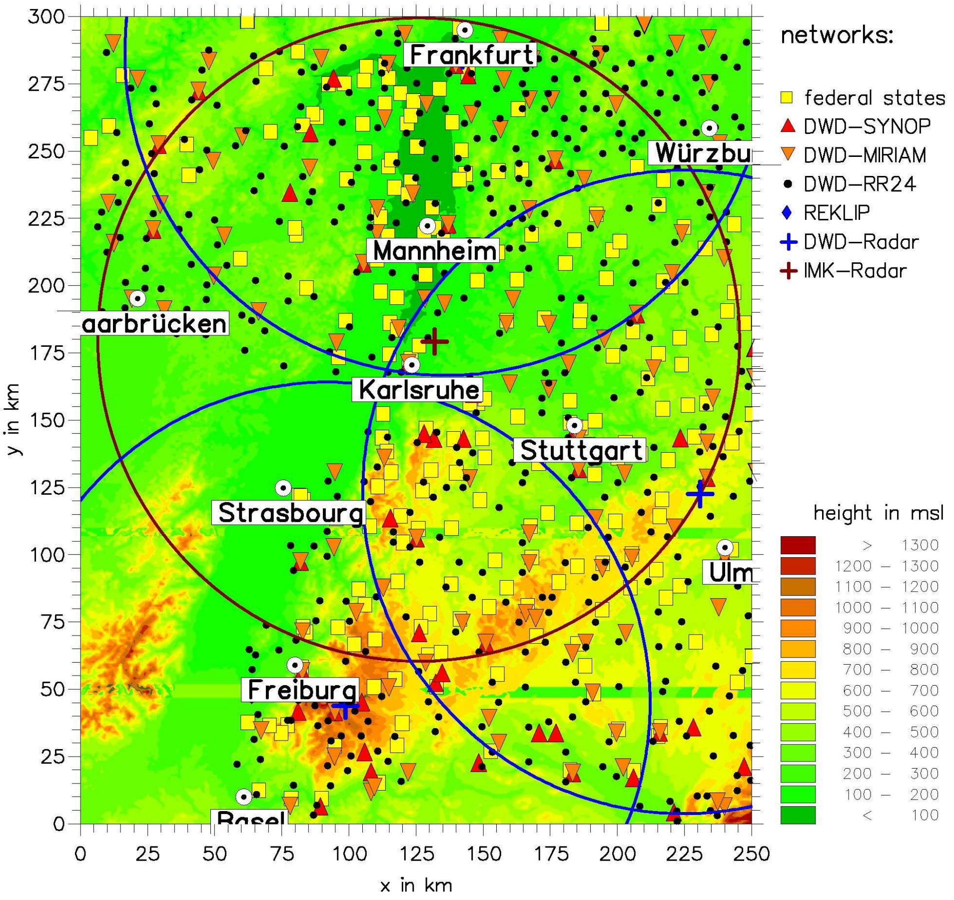


Figure II.1. Networks for precipitation measurements operated by DWD and environmental protection agencies. Radius of view (120 km) of the IMK-precipitation-radar located at the Forschungszentrum Karlsruhe (red circle) and radii of DWD-radars at Frankfurt (north), Türkheim (east), and Feldberg (south), (Kunz, 2004). The networks in the French part of the IOP-region, operated by METEO FRANCE and others will be included.

Additionally the ranges of four precipitation radar systems are indicated in Fig.II.1. The IMK radar located at the Forschungszentrum Karlsruhe approx. 12 km north of

Karlsruhe (red circle), and three radars of the DWD-radar network located at Frankfurt, the summit of the Feldberg (1483 m) in the southern Black Forest and at Türkheim near Ulm (blue circles). The ranges of the radar systems are approx. 120 km. Two French radar systems are also overlapping with the COPS domain. A dense lightning network is operated by the Siemens AG in Germany. The data are open to the public and can be used in COPS.

For research aircraft operations there are several airports in the area, which can be used as COPS airbase, e.g., Freiburg/Lahr, Karlsruhe/Baden-Baden, Stuttgart, and several German military air bases. The former Canadian military airbases Freiburg/Lahr and Karlsruhe/Baden-Baden are good choices for aircraft operations. Lahr, located 50 km north of Freiburg in the Rhine valley, is open for freight flights only and a special permit is necessary for others than cargo aircraft.

Karlsruhe/Baden-Baden, as well a former Canadian military airbase is located 30 km south of Karlsruhe in the Rhine valley. It's now a regional airport with international traffic, open 24 h a day (if necessary), hangar space and offices are available, it's within
the area of operation (no ferry), full landing equipment is available, no restrictions due to weather are to expect in summer. The traffic is quite low at Karlsruhe/Baden-Baden. In former campaigns there was a very good cooperation between the scientists and the crews on the one hand and the airport administration and the tower on the other hand.

II.2 Campaign Management

The scientific and logistic management of the COPS campaign, including pre and post campaign activities is subject of the COPS Operations Plan (OP), which will be elaborated at the beginning of 2006. An important subject of this document will be the preparation of a large variety of model forecasts to be used for mission planning. For this purpose, access to the results of MAP FDP forecasts has to be ensured. Currently, it is discussed to store these results at ECMWF. Other model forecasts such as the European PEPS shall also be used. At the COPS Operations Center (OC), the major information of these forecasts will be visualized. The COPS OC will be most likely located at the airport Karlsruhe/Baden-Baden where several aircrafts can be operated.

Furthermore, the COPS OP will include the location of each instrument and its operations modes during each mission. A key part will be the joint set up of different observation systems at the supersites. Each mission will be explained and labeled in a playbook, which will provide the basis for the combination and performance of different missions. A special section will deal with aircraft operations.

The COPS OP will contain detailed plans for mission design, preparation, and performance including the set up of briefings and debriefings including corresponding times, agendas, and members. During each briefing, one or more forecasters will provide a detailed introduction in the weather situation for all scientists based on the huge amount of information provided by operational forecasts including MAP FDP and ETReC07 results. The NINJO operation system of the DWD will be used for visualization of most forecast results overlaid on additional observations from different platforms.

A clear path for the decision process will be proposed announcing the involved scientists and their responsibilities. A communications plan will be derived in order to include all COPS scientists even at remote locations in the decision process. After a discussion between COPS Lead Scientists in the OC, missions of the day will be selected. For each mission, a PI will be announced who will be responsible for ground and aircraft operations. The information content of real-time satellite data will be used for last minute detailed mission planning. This includes strong communication with air traffic control. An alert system for field teams will be available in order to optimize the operation of mobile instrumentation during all missions.

Finally, the results will be uploaded in form of quicklooks and in well-specified raw data formats to the COPS field catalogue. Two categories of data will be provided. One set of data will be available for real-time data assimilation (see II.3), which sets high demands to data quality and documentation. The other data will be used after the performance of COPS for research on QPF. The COPS field catalogue shall be designed similar as during IHOP_2002 in the US (see www.joss.ucar.edu/ihop/catalog/). After the performance of the campaign, all data will be delivered to the COPS archive in a previously specified format containing all critical information about the data including an extended error analysis.

II.3 Data management

The Model and Data group of the Max Planck Institute will organize the data archive for COPS and GOP data for Meteorology 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) and satellite data. Access to the data will be provided both by file as provided by the instrument PIs and by a data bank structure, which allows to extract data by a range of selection criteria. The latter is especially useful for model data in order to select data of interest.

Measuring atmospheric parameters by a set of new and advanced research instruments like it is planned for COPS, will cause challenges for data-assimilation systems if the data format is not suited for the preprocessing and processing in that system. To allow flexible, simple, and efficient access, all data, which are to be assimilated in real-time during COPS, will be encoded in BUFR, the standard format for observation data handling as defined by WMO. The use of BUFR will probably not be possible for all instruments and all platforms used during COPS and the GOP, but actions have been taken to allow this even for instruments where BUFR tables are yet to be defined. For almost all instrument types, which are planned for COPS and GOP, the required BUFR tables are already defined or will soon be available by WMO. Exceptions are lidar systems. COPS participants have started to work on the definition of the missing BUFR tables. For introducing BUFR software interfaces and data handling routines, the COPS participants will come together on a programming & implementing workshop in early 2006. For real-time data assimilation, the timely delivery of the observation data needs to be prepared thoroughly; this includes the definition of error characteristics. Initial testing, monitoring and data-assimilation system tuning will to be performed well before the field phase of COPS in summer 2007.

II.4 Precipitation Initiation Statistics in the COPS Region

For the preparation and performance of COPS it is essential to consider the typical weather conditions and its statistics. The mean temporal and spatial distributions of thunderstorms in the COPS region are given in Fig.II.2. SYNOP-observations between 1995 and 1998 were used to calculate the annual (left) and the diurnal cycle (right) of thunderstorms, respectively. From May to August the probability of thunderstorms is significantly higher than during the rest of the year. As in the second half of August the thunderstorm activity is reduced (not shown), a three-month campaign should take place from June to August. The daily thunderstorm cycle is characterized by the minimum at 09:00 and the maximum at 16:00 local time. In summer, sunrise is at 04:00 and sunset at 22:00 local time in the area of interest. Thus is possible to operate aircrafts between sunrise and sunset and to measure the pre-convective atmospheric environment as well as during the most pronounced thunderstorm activity.

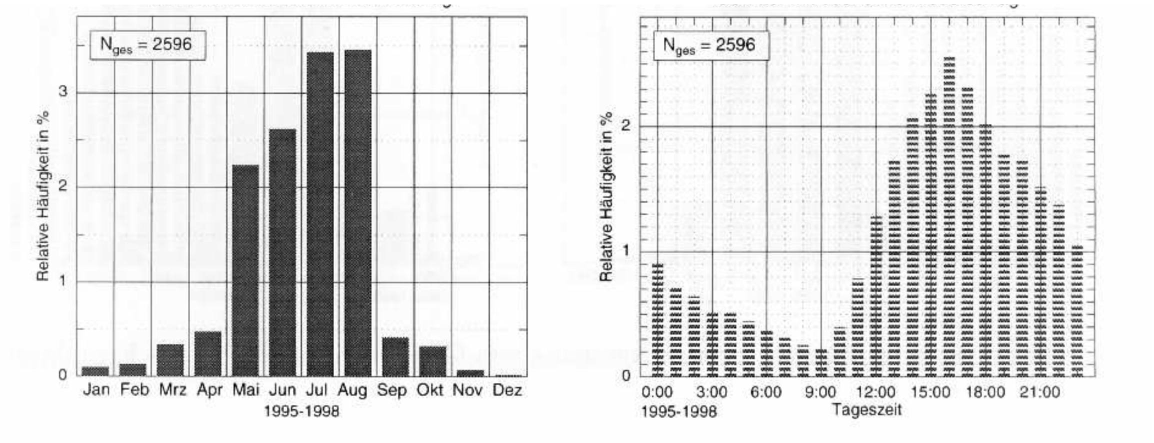


Figure II.2. Frequency distribution of thunderstorms with and without precipitation on the basis of 2596 DWD-synop-data between 1995 and 1998 for the area of the Black Forest and the Swabian Jura. Annual cycle (left) and diurnal cycle (right).

European composite radar reflectivity datasets have been used to assess the summertime climatology of precipitation initiation (PI) in the COPS region (Wilson and Weckwerth, unpublished). Precipitation is seen in the Black Forrest region on more than 50 % of all days in summer (Figure II.3). Figure II.4 shows the initiation of precipitation (PI) in this area. The data indicate a bi-modal distribution of summertime PI with maxima of PI events in early June and early August, and a minimum at early July. The fraction of days with PI events is about 45 % for the maxima and 10 % for the minimum. The diurnal cycle of PI shows a broad distribution at daytime with a maximum in the early local afternoon.

For the full COPS region, data of the years 2003 and 2004 have been used to investigate the diurnal cycle of different types of convective precipitation and the locations of the initiation of convection. The analyses identified a daytime peak in rainfall development from 0800-1700 UTC (Figs. II.4, II.5). This initiation was mostly in the form of a line of new cells popping up. About 33 % of the time, however, the new convection formed in the same area with no apparent organization to the structure. About 19% of the time solitary cells formed.

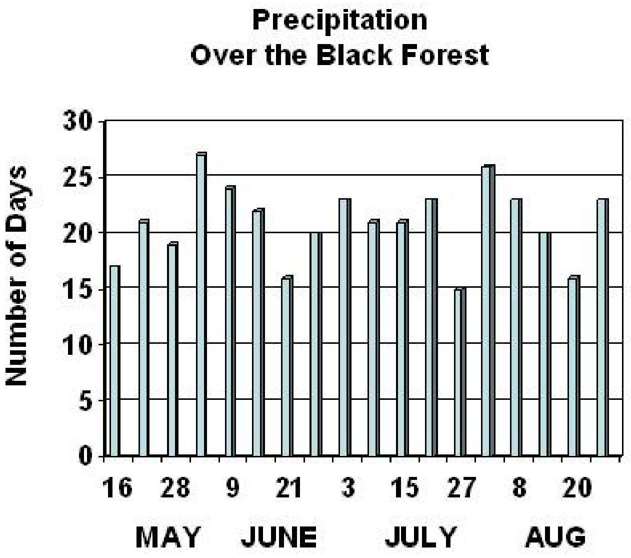


Figure II.3. Precipitation statistics in the Black Forrest region using radar composites of the five years of 2000 to 2004 (Wilson and Weckwerth, unpublished). Number of days in the period of 16 May to 31 August with initiation of precipitation in the Black Forest region. Each column is for a 6-day period starting at the date indicated. The total number of days investigated for each column is 30.

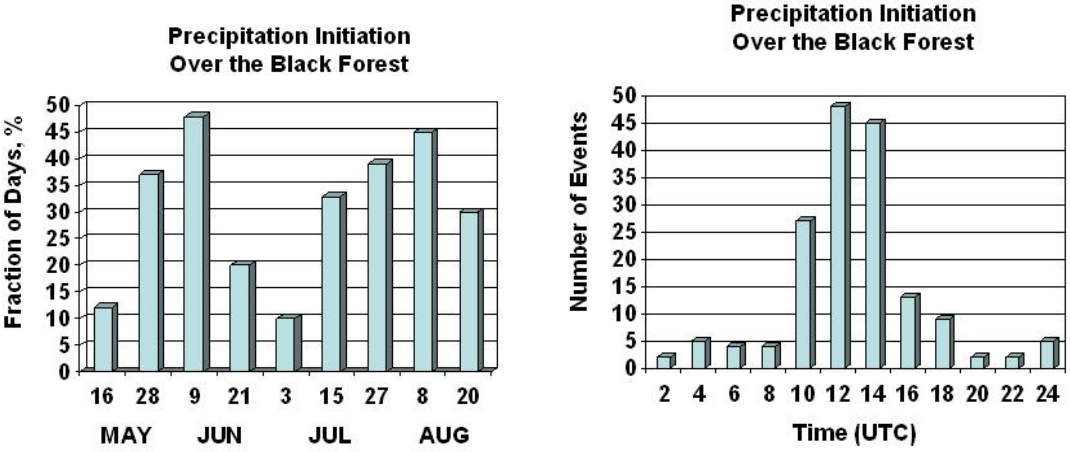


Figure II.4 Precipitation initiation statistics in the Black Forest region using radar composites of the five years of 2000 to 2004 (Wilson and Weckwerth, unpublished). Left panel: Fraction of days in the period of 16 May to 31 August with initiation of precipitation in the Black Forest region. Each column is for a 12-day period starting at the date indicated. Right panel: Diurnal variation of precipitation initiation. Each column is for a 2-hour period staring at the time indicated. Local noon is at ~12:35 UTC. The total number of days investigated in this study is 540.

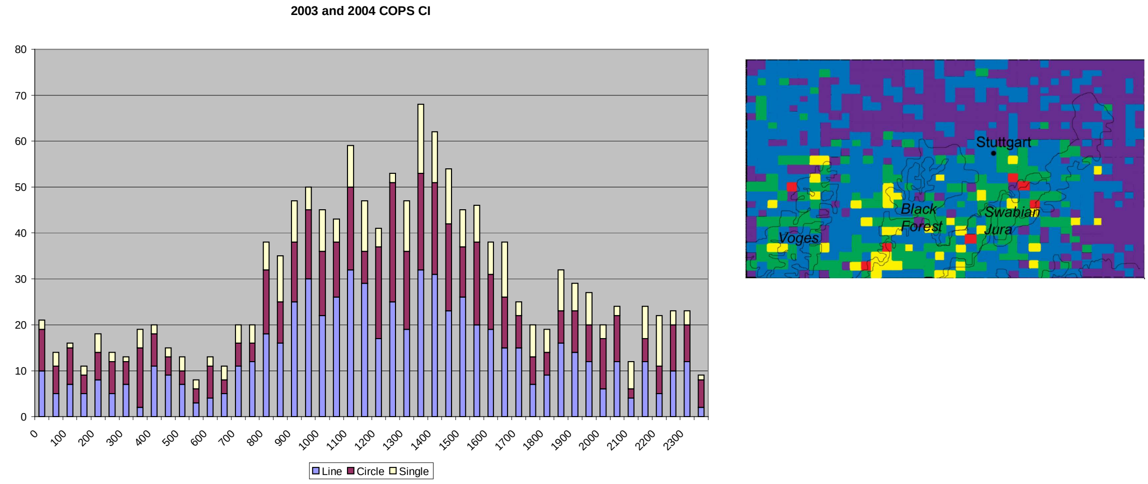


Figure II.5. Convection initiation statistics in the COPS domain using radar composites of June to August of the years 2003 and 2004 (Wilson and Weckwerth, unpublished). Left panel: Diurnal variation. Blue indicates linearly-organized convection; maroon is cluster form organization and yellow is single-cell initiation. Local noon is at ~12:35 UTC. Right panel: Initiation distribution. Purple is 0-3; blue is 4-7; green is 8-11; yellow is 12-15 and red is 16-20 CI events. Black lines indicate topography.

These investigations raised several science questions, which shall be addressed within COPS in the WG PLC. Key research topics are the understanding of the diurnal cycle of convection and of the mesoscale organization of convection.

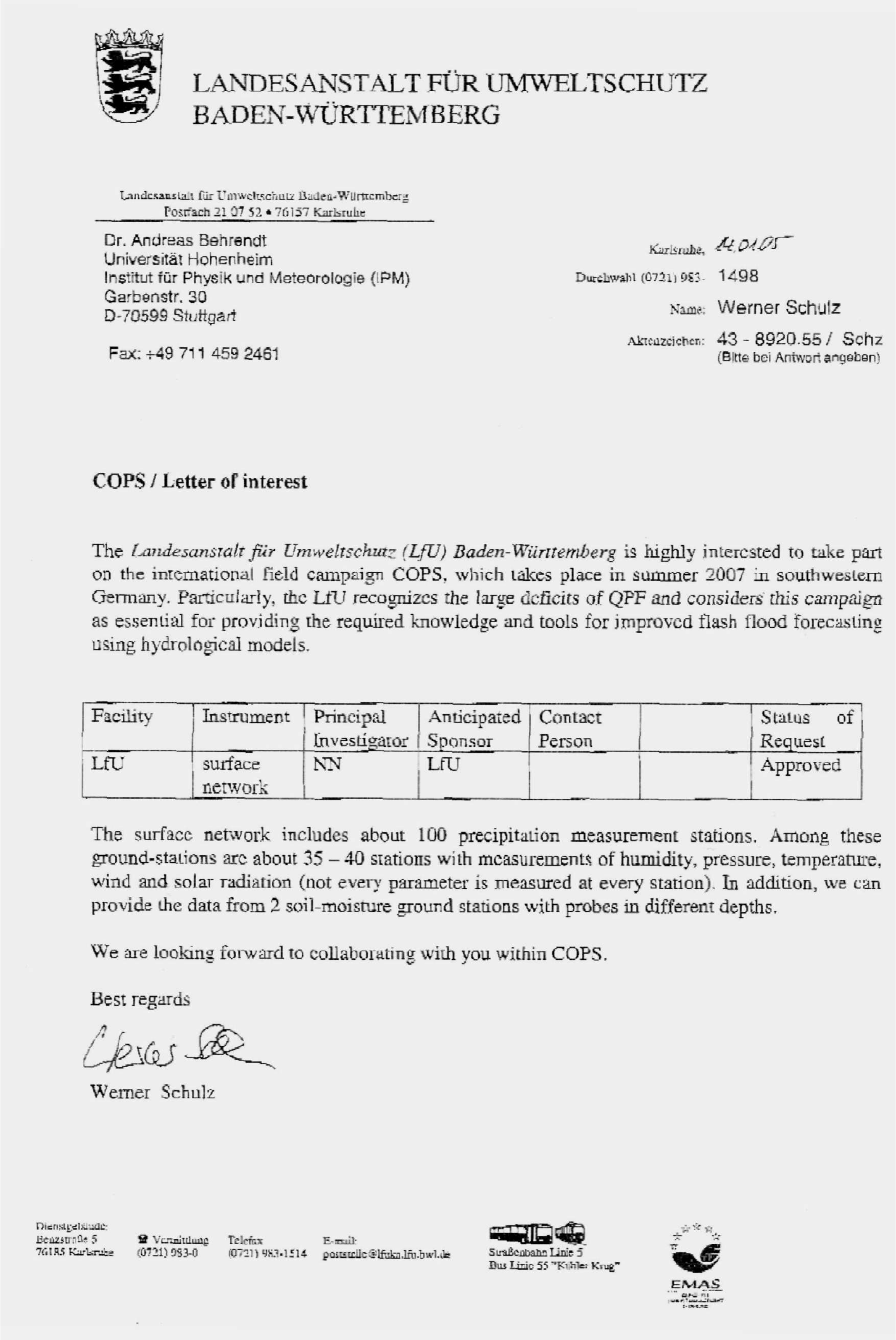
Appendix III Atmospheric Models and Data Assimilation Systems to be Used Within COPS

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

LM	DWD, FZK	- 7 km resolution - 325x325 grid points - 40 s time step - 35 vertical levels - 00Z,12Z,18Z forecast for 48 hours		no	Nudging	GME ECMWF
aLMo	Meteo Swiss	7 km resolution 385 x 325 grid points 40s time step 45 vertical levels 00Z, 12Z forecast	same	no	nudging	ECMWF
aLMo2.2	Meteo Swiss	2.2km resolution 480x350 grid points, 10-40 s approx. 60-80 vertical levels forecast every 3 hrs. over 18 hrs	same	no	nudging	ECMWF, aLMo(7)
MM5 (global version available)	NCAR/ PennState	Used for real time numerical weather prediction in various configurations	- global to 1 km resolution - arbitrary domain & time step - idealised simulations	1-way, 2-way, moving	Nudging (obs+ana) 3DVAR, 4DVAR	ECMWF NCEP
WRF under development	NCAR/…	Real-time tests in different configurations	- global to 1 km resolution - arbitrary domain & time step - idealized simulations	1-way, 2-way, moving	3DVAR, Nudging (?) 4DVAR under development	ECMWF NCEP
MC2	MSC	Various high-resolution real-time applications (e.g. McGill, MAP, …) - 3 km horizontal resolution - 400x490 grid points - 35-60 vertical levels - 12-18 hour forecasts	Various idealized applications using different model configs.			
Arôme	Meteo-France	Under development, pre-operational tests with 2.5 km resolution starting in 2006, operational usage planned for 2008	same			
Meso-NH	Meteo-France	6 – 50 km horizontal resolution	Usable with resolutions from mesoscale to microscale	yes		
COSMO-LEPS quasi operational	ARPA-SIM	- Based on LM version 3.9 resolution 10 km - 306x258 grid boxes - 60 s time step	idem	no		ECMWF

		- 32 vertical levels - forecast range 120 h				
ARPS	CAPS Oklahoma University		Many – down to 150m horizontal resolution	1-way	3DVAR	ECMWF, NCEP (others?)
METRAS with an aerosol/cloud model (MITRAS)	MI Hamburg	No	Idealized simulations with resolution 50 m – 2 km		Nudging	
RAMS	Colo State Univ	operational upon request	Many	2-way	?	various

Appendix IV Letters of Interest



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Karlsruhe, 14.01.05
Durchwahl (0721) 983- 1498
Name: Werner Schulz
Aktenzeichen: 43 - 8920.55 / Schz
(Bitte bei Antwort angeben)

COPS / Letter of interest

The *Landesanstalt für Umweltschutz (LfU) Baden-Württemberg* is highly interested to take part on the international field campaign COPS, which takes place in summer 2007 in southwestern Germany. Particularly, the LfU recognizes the large deficits of QPF and considers this campaign as essential for providing the required knowledge and tools for improved flash flood forecasting using hydrological models.

Facility	Instrument	Principal Investigator	Anticipated Sponsor	Contact Person		Status of Request
LfU	surface network	NN	LfU			Approved

The surface network includes about 100 precipitation measurement stations. Among these ground-stations are about 35 – 40 stations with measurements of humidity, pressure, temperature, wind and solar radiation (not every parameter is measured at every station). In addition, we can provide the data from 2 soil-moisture ground stations with probes in different depths.

We are looking forward to collaborating with you within COPS.

Best regards

Werner Schulz

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EMAS

Deutscher Wetterdienst
Der Präsident

DWD

Deutscher Wetterdienst - Postfach 10 04 65 - 63004 Offenbach

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Universität Hohenheim
Institut für Physik und Meteorologie
Garbenstr 30
70599 Stuttgart

Ansprechpartner:
Prof. Dr. Gerhard Adrian
Geschäftszeichen:
FE/40.11
E-Mail:
gerhard.adrian@dwd.de

Telefon:
069 8062 2720
Fax:
069 8062 3721
Internet:
http://www.dwd.de
UST-ID: DE221793973
UST-Nr.: 03522606073

Offenbach, 11. Februar 2005

Support of COPS by the Deutscher Wetterdienst

Dear Dr Wulfmeyer,

We confirm here with our great interest in a cooperation between COPS and the German Meteorological Service (DWD). COPS is addressing key scientific questions, which are essential for improving Quantitative Precipitation Forecast (QPF) in complex terrain.

COPS is the largest subproject of the Priority Programme 1167 PQP. DWD is already a partner in this programme, and supports the research community by providing an operational high-resolution model (Lokalmodell LM) with a resolution of 2.8 to 7 km including a cooperation concerning the operation and maintenance of this model. Furthermore, DWD is making its data sets available, such as precipitation networks and radar data.

In addition, DWD is supporting COPS in the following activities:

- DWD is member of the COPS ISSC for supporting the scientific preparation of the campaign.
- DWD fosters the collaboration between instrument PIs and modellers.
- DWD provides access to key data sets, such as high-resolution precipitation networks and radar data, in the COPS regions.
- DWD supports the collaboration between the COPS community and other research programmes such as MAP FDP and ETReC07.
- DWD facilitates the logistic preparation and the performance of the campaign with operational high-resolution weather forecasts for mission planning and by analysis of weather situations.
- DWD will provide scientists with weather forecasts for mission planning during the COPS field phase.

We are convinced that the field campaign COPS will lead to an improvement of operational mesoscale forecasts in the near future. Particularly, we are excited about the international collaboration, which has been initiated in connection with COPS.

We are looking forward to a strong and successful collaboration.

Yours sincerely,

U. Gärtner

Dienstgebäude: Kaiserleistraße 29/35 - 63067 Offenbach am Main, Tel. 069 / 8062 - 0
Kontoverbindung: Bundeskasse Trier - Deutsche Bundesbank - Filiale Trier - Kto-Nr.: 58501003 - BLZ: 585 000 00
Der Deutsche Wetterdienst ist eine teilrechtsfähige Anstalt des öffentlichen Rechts im Geschäftsbereich
des Bundesministeriums für Verkehr, Bau- und Wohnungswesen
Das Qualitätsmanagement des DWD ist zertifiziert nach DIN ISO 9001:2000 (Reg.-Nr. 274357 QM)

EUMETSAT

EUMETSAT · Postfach 10 05 55 · D-64205 Darmstadt

European Organisation for the Exploitation of Meteorological Satellites
Organisation européenne pour l'exploitation de satellites météorologiques

Prof. Dr. rer. nat. Volker Wulfmeyer
Universität Hohenheim
Institut für Physik und Meteorologie
BIO I Labor 090
Garbenstrasse 30

70593 Stuttgart

Your reference Votre référence	Your letter dated Votre lettre du	Our reference Notre référence	Darmstadt
		EUM/MET/LET/04/0295	26 November 2004

Dear Prof. Wulfmeyer,

We understand, that under your chairmanship, a major international experiment, the Convective and Orographically – induced Precipitation Study (COPS), is planned for 2007. For the first time, pre-convective atmospheric state, cloud formation and the development of precipitation will be studied with advanced instrumentation.

EUMETSAT has great interest in the findings of COPS as the scope of this study is in line with EUMETSAT's operation activities. From the Meteosat Second Generation satellites, EUMETSAT operationally produces a so-called Global Instability Index (GII) product, which describes the static stability of the atmosphere in a pre-convective state. As the GII is a novel application within the Meteosat programme, the COPS experiment will provide a good opportunity to assess the nowcasting potential of the GII data. A further novel application for the new Meteosat satellite is the derivation of cloud microphysical parameters, which will be operational by 2007, i.e. by the time of this experiment. These special cloud parameters will be optimal estimates of cloud top height, cloud phase, and cloud particle size. A specific application of this product could be to describe the life cycle of convective clouds.

Furthermore, by the time of the Intensive Observations Period of COPS the first Metop satellite, flown in the frame of the EUMETSAT Polar System, will be operational. The remote sensing and in situ data to be gathered during COPS will constitute a valuable data set for the validation of new instruments such as IASI, GRAS and MHS, which will be flown as meteorological payload onboard of Metop.

We strongly encourage pursuance of this important research activity, and we look forward to an opportunity for a cooperation. We think that our operational satellite data and products are a very useful, may be an essential complement to the experiment. Vice versa we are interested in an evaluation of our satellite products as part of the experiments.

I kindly request you to keep us informed about further progress of COPS.

Yours sincerely,

Ernst Koenemann
Director of Programme Development

Toulouse, 14 January 2005

François BOUTTIER
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to whom it may concern

LETTER OF INTENT: NUMERICAL MODELLING AND DATA ASSIMILATION IN THE FRAMEWORK OF THE COPS FIELD EXPERIMENT

The CNRM/GMAP is the R&D group of Météo-France for operational Numerical Weather Prediction (NWP) using global and regional models and their associated data assimilation systems. This 40-people group has developed the global variable resolution ARPEGE model (4D-Var data assimilation), the regional hydrostatic ALADIN model (3D-Var data assimilation), and the regional non-hydrostatic AROME model (3D-Var data assimilation). These systems have been developed in close cooperation with ECMWF and many weather forecasting offices in Europe and elsewhere. ARPEGE and ALADIN are used operationally with very good performance records, and AROME will be operational by 2008. The CNRM/GMAP staff comprises software developers and scientists, with frequent publications in the open literature, and hosts visiting scientists on topics of interest. Research programmes are conducted in cooperation with the rest of the 150-person strong CNRM (Centre National de Recherches Météorologiques), notably on NWP-related field experiments such as FASTEX, PYREX, THORPEX, and soon AMMA and MAP-FDP.

The COPS field experiment is of particular interest to our group because of its emphasis on QPF, simulation of strong convective events, and radar meteorology, which are top priorities for the development of our new AROME NWP system. The AROME non-hydrostatic model and variational data assimilation system will be in preoperational stage in our institute at the time of the COPS Intensive Observing Period, with a horizontal resolution of 2.5km and a capability to assimilate operational satellite and radar data. **Our intention** is to perform near real time data assimilation over the COPS area (at least SW of Germany and NE of France) for two to three months at 2.5km resolution and to broadcast the assimilated and forecasted fields free of charge to the research community, within the limits of available resources in our institute. Operational observations will be assimilated, which is expected to include much of the COPS real-time observations sent over the GTS network. It is believed that subsequent scientific work on COPS will help in the evaluation and further improvement of the forecast performance of the AROME system. Visiting scientists are welcome in our institute to experiment with mesoscale reassimilation using the AROME system. Relevant results will be published in scientific journals and presented at workshops.

In the future, Météo-France may express further commitments in support of COPS, e.g. related to radar deployment and data distribution.

François Bouttier

Zürich, 15.02.2005

MeteoSchweiz

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Re: COPS and MAP FDP

Dear Dr Wulfmeyer

Hereby I confirm our strong interest in a cooperation between COPS and the Forecast Demonstration Project (FDP) of the WWRP Project MAP (Mesoscale Alpine Programme), D-PHASE. This project name, D-PHASE, stands for ***D****emonstration of* ***P****robabilistic* ***H****ydrological and* ***A****tmospheric* ***S****imulation of heavy precipitation in the* ***E****uropean Alps* and thus its goals are to developing strategies for forecasting heavy precipitation events, to couple capabilities between atmospheric and hydrological models with suitable evaluation protocols and to make the value of all these forecasts accessible to end users. Clearly, all these products will be available to the COPS community.
D-PHASE and COPS are strongly related, as both projects deal with precipitation, its observation and forecast, and both are tied to complex terrain. Similar tools will be applied, such as high-resolution atmospheric modeling [O(1 km)] optimized for operation in steep terrain, ensemble prediction, and state-of-the-art data assimilation. On the one hand, the participants in COPS will benefit from the experience and results of MAP D-PHASE. For instance, model runs performed by the MAP FDP community can be applied for mission planning. On the other hand, unique observation systems will be operated during COPS, which are very interesting for the MAP FDP community for real-time data assimilation and for model validation.
Participants of D-PHASE have proposed to perform a forecast demonstration during the COPS experiment in summer 2007, i.e. to extend the MAP FDP towards the season of COPS. The managing bodies of the two projects should do everything possible to make this happen. In any case – and as a first step - COPS modelers are very welcome to join the D-PHASE community, in order to share experience during the forecast period.

We are looking forward to a strong and successful collaboration.

Yours, Sincerely
MeteoSwiss

PD Dr .Mathias Rotach
Head Research and Development
MAP D-PHASE Project Coordinator

Bundesamt für Meteorologie und Klimatologie (MeteoSchweiz)
Office fédéral de météorologie et de climatologie (MétéoSuisse)
Ufficio federale di meteorologia e climatologia (MeteoSvizzera)
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14 January 2005

Dear Volker,

Subject: COPS

We strongly support the coordination of a European Thorpex Regional campaign in summer 2007 (ETReC07) with COPS. This will provide a unique possibility to investigate the impact of the interaction between large scale and small processes on Quantitative Precipitation Forecast (QPF) in complex terrain.

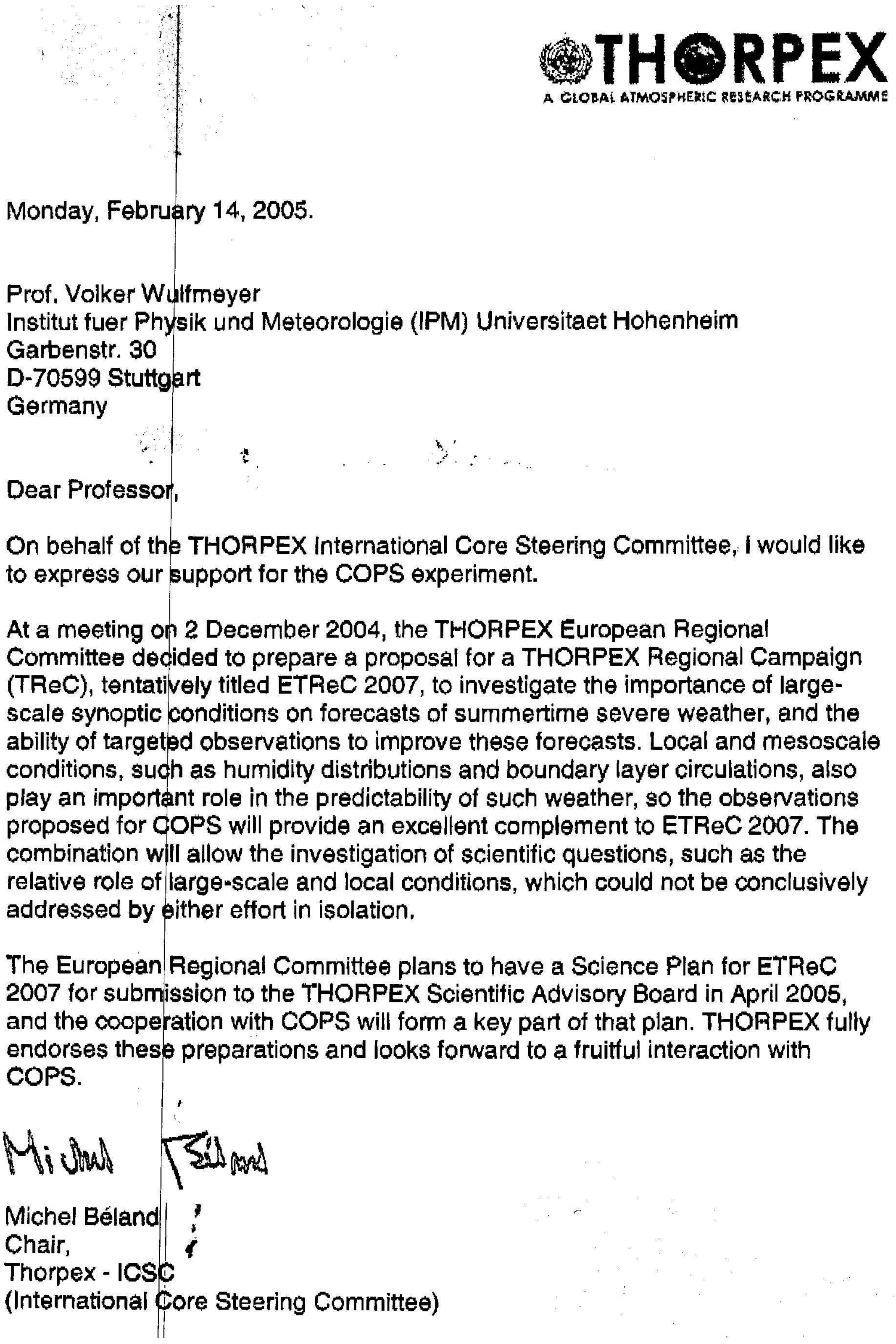
EUCOS is willing to support a corresponding proposal submitted to the Thorpex ICSC and, if the proposal is successful, to help organise and contribute to providing additional observational data during the field campaign either on a targeted or non-targeted basis. This will be subject to the formal agreement of the Programme Board for Observations in EUMETNET and if necessary the COUNCIL of EUMETNET.

We also appreciate the intensions to combine COPS with MAP FDP. If both of these activities took place around the time of the suggested ETReC07 it would improve overall efficiency and facilitate EUCOS involvement.

We look forward very much to following up these activities in the near future.

Kind regards,

Dr Jim Caughey
EUCOS Programme Manager



THORPEX
A GLOBAL ATMOSPHERIC RESEARCH PROGRAMME

Monday, February 14, 2005.

Prof. Volker Wulfmeyer
Institut fuer Physik und Meteorologie (IPM) Universitaet Hohenheim
Garbenstr. 30
D-70599 Stuttgart
Germany

Dear Professor,

On behalf of the THORPEX International Core Steering Committee, I would like to express our support for the COPS experiment.

At a meeting on 2 December 2004, the THORPEX European Regional Committee decided to prepare a proposal for a THORPEX Regional Campaign (TReC), tentatively titled ETReC 2007, to investigate the importance of large-scale synoptic conditions on forecasts of summertime severe weather, and the ability of targeted observations to improve these forecasts. Local and mesoscale conditions, such as humidity distributions and boundary layer circulations, also play an important role in the predictability of such weather, so the observations proposed for COPS will provide an excellent complement to ETReC 2007. The combination will allow the investigation of scientific questions, such as the relative role of large-scale and local conditions, which could not be conclusively addressed by either effort in isolation.

The European Regional Committee plans to have a Science Plan for ETReC 2007 for submission to the THORPEX Scientific Advisory Board in April 2005, and the cooperation with COPS will form a key part of that plan. THORPEX fully endorses these preparations and looks forward to a fruitful interaction with COPS.

Michel Béland

Michel Béland
Chair,
Thorpex - ICSC
(International Core Steering Committee)