THE CONVECTIVE AND OROGRAPHICALLY-INDUCED PRECIPITATION STUDY: A RESEARCH AND DEVELOPMENT PROJECT OF THE WORLD WEATHER RESEARCH PROGRAM

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ABSTRACT

In summer 2007, the Convective and Orographically-induced Precipitation Study (COPS) was performed in a region covering southwestern Germany/eastern France. The overarching goal of this experiment is the improvement of quantitative precipitation forecasting in low-mountain regions. For this purpose, a unique synergy of in-situ, passive, and active remote sensing systems was operated for a duration of three months in order to capture the whole chain of processes leading to the development, organization, and decay of precipitation. Observations were provided by densified networks, a transect of so-called supersites, as well as by airborne and space borne platforms. Convective precipitation events are presented focusing on the application of lidar systems for studying the pre-convective environment. In coordination with several international activities, the COPS data set will be applied to improve the understanding of the initiation and organization of convection.

INTRODUCTION

Prediction of precipitation in low-mountain regions is of enormous importance for economy and society. On the one hand, the orography causes a critical enhancement of precipitation, which is difficult to be simulated even by the new generation of convection permitting mesoscale models. On the other hand, particularly in these regions, regional climate models have to simulate the future development of weather statistics accurate enough for decision making.

However, two severe systematic errors are still present in atmospheric models: the windward/lee effect and phase errors in the simulation of the diurnal cycle of precipitation [1, 2]. The windward/lee effect causes an over prediction and under prediction of precipitation on the windward and the lee sides of low-mountains, respectively. The phase shift in the diurnal cycle results in a too early onset of precipitation in models. It is obvious that these errors hinder the use of quantitative precipitation forecasting (QPF) for enhancing the lead time of flash flood warnings and for water management under the influence of climate change.

The Convective and Orographically-induced Precipitation Study (COPS)[1] is tackling these challenges by combining three components [2]:

1. Synergy of unique in-situ and remote sensing instruments on different platforms.
2. Advanced high-resolution modeling with mesoscale data assimilation.
3. Ensemble prediction.

Whereas the synergy of observation systems has been designed to study the process chain in 3 dimensions, only by means of data assimilation can the gap between observations and model results be close. We anticipate that the extended assimilation of new observation systems such as Global Positioning System (GPS) [3, 4], lidar [5, 6], and radar [7, 8] will not only lead to improved weather forecasting but also to a refinement of process studies. The latter can be expected by reducing the sensitivity of case studies with respect to initial conditions. Finally, these components in combination with ensemble prediction will enable atmospheric scientists to study the predictability of precipitation.

INTERNATIONAL COOPERATION

A unique coordination of international activities was accomplished in order to merge the three components of COPS mentioned above. The corresponding research programs are depicted in Fig.1. COPS itself was endorsed as Research and Development Project (RDP) of the World Weather Research Program (WWRP) [9, 10]. It is imbedded in a 1-year General Observations Period (GOP)[2] collecting additional, routinely available observations in Europe. Both observational programs, COPS and GOP, are components of the Priority Program 1167 QPF of the German Research Foundation[3]. Additional observations of chemical tracers and their transport were performed during the experiment TRACKS[4]. Further observations were provided by the Atmospheric Radiation Measurement Program Mobile Facility (AMF)[5] and by the Rapid Scan Service (RSS) of Meteosat Second Generation (MSG) operated by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)[6].

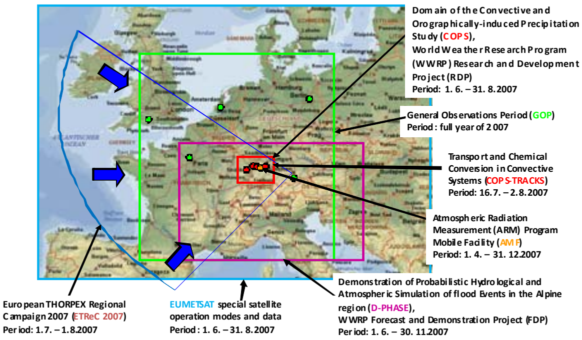

Fig.1. International collaboration within COPS.

COPS was coordinated with the first summertime THORPEX regional campaign (ETReC07) and the WWRP Forecast Demonstration Project (FDP) D-PHASE[7]. This unique collaboration allowed for the use of targeting for studying the sensitivity of large-scale conditions on the weather development in the COPS region. A huge suite of ensemble forecasts, forecast models with convection parameterization, and convection permitting models was operated during D-PHASE. Their results were provided in real-time to the COPS Operations Center for mission planning. Detailed model evaluation efforts were started in order to study their performance in low-mountain regions.

This overall design provided for a very close cooperation between instrument principal investigators, experts of atmospheric processes, and modelers.

SENSOR SYNERGY

In total, 9 airborne platforms were operated, which carried a variety of remote and in-situ sensors. Their remote sensing systems consisted of advanced Doppler and water-vapor lidar systems observing the pre-convective environment in great detail.

Existing observation networks were enhanced with weather stations, soil moisture, turbulence, and GPS sensors, as well as the set up of a transect of supersites in the COPS domain (see Fig.2). The supersites were

[1] www.uni-hohenheim.de/cops, www.cops2007.de, and www.wmo.int/pages/prog/arep/index_en.html

[2] gop.meteo.uni-koeln.de/gop/doku.php

[3] www.meteo.uni-bonn.de/projekte/SPPMeteo

[4] www-fzk.imk.uni-karlsruhe.de/english/417.php

[5] www.arm.gov/sites/amf/blackforest/

[6] www.eumetsat.int

[7] www.map.meteoswiss.ch/map-doc/dphase/dphase_info.htm

equipped with the current generation of passive and active remote sensing systems, e.g., microwave radiometers, GPS, Doppler lidar, water-vapor and temperature lidar, cloud radar, and micro rain radar, partly with scanning capability. A new scanning rotational Raman temperature lidar and the use of sensor synergy for studying convection initiation at supersite H are presented in dedicated contributions to this conference [12, 13].

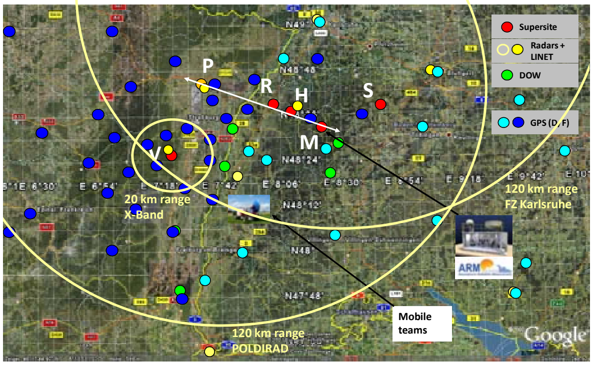

Fig.2. COPS ground-based network. The yellow lines indicate the range of a variety of research radar systems. P: DLR Poldirad S-band polarization radar site. Supersites V: Vosges mountain, R: Rhine valley, H: Hornisgrinde, M: Murg valley, where the AMF was operated, S: Stuttgart.

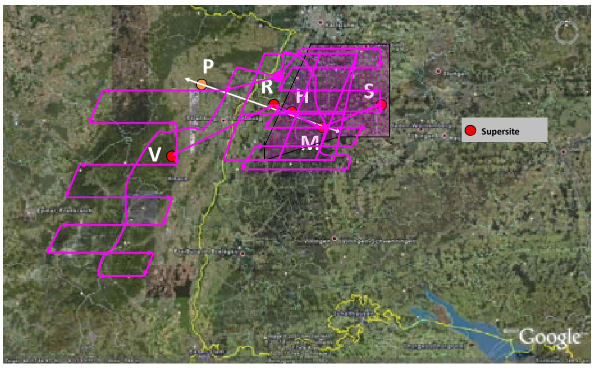

Fig.3. DO-128 flight pattern for flux measurements over the low-mountain regions Vosges (left pattern) and Black Forest (right pattern). The purple shaded area shows the region where the operation of ground-based drop up and airborne drop sondes was permitted by air traffic control.

Figure 3 presents an example of a flight pattern designed for COPS using the DO-128 aircraft operated by the Karlsruhe Institute of Technology (KIT). By means of aircraft measurements, gaps between observations at the supersites were closed as well as the validation of turbulence and aerosol-cloud microphysical measurements by ground-based remote sensing systems became possible.

OVERVIEW AND FIRST RESULTS

During the 3-month field phase of COPS, 18 Intensive Observing Periods (IOPs) were declared, which consisted partly of 2-day or even 3-day measurement periods adding up to 35 IOP days. Furthermore, 8 Special Observing Periods (SOPs) were performed in connection with additional European Fleet for Airborne Research (EUFAR) activities.

The meteorological conditions did not deviate much from the expected situations based on the last 30-year climatology. The main difference was enhanced cyclonic activity over France and Spain due to the presence of large-scale upper level troughs. This can even be considered as an advantage of the COPS data set. Summertime severe precipitation is often related to the development of small-scale low-pressure systems and their interaction with orography leading to high-impact weather events.

As intended, convection and precipitation could be observed under a variety of forcing conditions. 14 IOP days were performed during high-pressure convection, weakly-forced convection was studied during 8 IOP days, whereas the remainder was related to strongly-forced convection.

A typical example was the weather situation during IOP 8b on July 15, 2007. Ahead of a large-scale trough over the eastern Atlantic, a frontal zone extended from Portugal across the Bay of Biscay to southern England. Large parts of central and eastern Europe were under the influence of a broad ridge extending from the Baltic Sea southward to the central Mediterranean. Depending on the exact location of the frontal zone, surface-forced convection was expected to be initiated in the COPS region. Most of the D-PHASE models did not predict convection but considering forecast uncertainty, a "high-pressure IOP" was performed with extensive aircraft operation of the German DO-128, German DLR Falcon, French Safire Falcon, and UK BAe 146. Pre-convective conditions observed by aircraft will be presented and discussed at the conference.

Starting around 12:30 UTC, shallow convection was observed in the northern and southern Black Forest. Doppler radar radial velocities showed convergence lines oriented from southwest to northeast. However, whereas no deep convection was initiated in northern Black Forest, a deep convective cell developed in the southern part at 14:30 UTC. Its rapid development and decay was observed in detail by the large suite of lidar and radar systems.

Only two D-PHASE models (MesoNH and AROME) were able to simulate this event with acceptable skill. Therefore, this IOP is an excellent opportunity for process studies and for investigating the representation of convection in mesoscale models in dependence of their respective combinations of parameterizations.

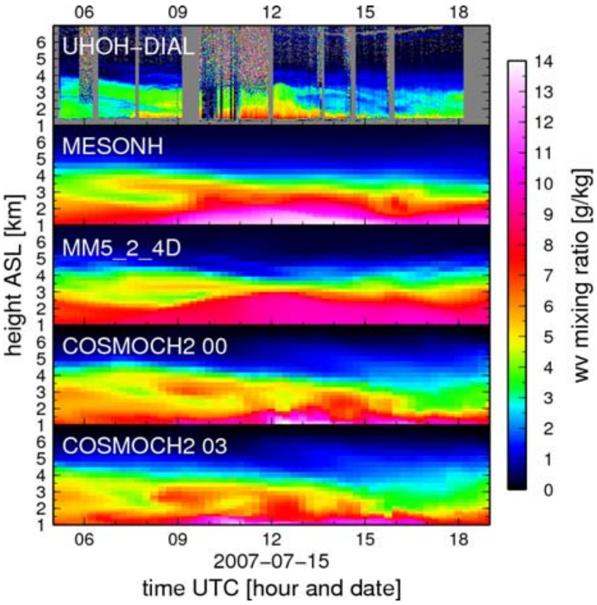

Fig.4. Vertically pointing water-vapor DIAL measurement with resolutions of 10 s and 300 m, respectively, during IOP 8b at supersite H. Mixing ratio was determined using collocated temperature radio soundings. The data are compared with three mesoscale models: MesoNH (Meteo France), MM5 (University of Hohenheim), COSMOCH2 (Meteo Swiss) with two different initial times.

Extended model comparisons have been initiated. Figure 4 shows a time-height cross section of water-vapor mixing ratio measurements in comparison with model forecasts at the same grid point. In particular, strong deviations are detected in the atmospheric boundary layer where all model outputs are far too humid. Further results of model evaluation are presented at the conference.

SUMMARY

In summary, COPS provides observations with the following capabilities:

1. Area-wide and synergetic measurements of the process chain.
2. High-resolution, 4-dimensional data set for process studies.
3. High-end data set for data assimilation and model validation studies.
4. Coordination with D-PHASE for advanced process and predictability studies.

Consequently, the COPS campaign in combination with the other international projects can be considered a treasure chest for atmospheric sciences. First process and data assimilation studies focusing on the applications of lidar systems will be presented at the conference.

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