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Two Years Past the Field Phase of CLEOPATRA

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It is now just two years that CLEOPATRA (the Cloud Experiment Oberpfaffenhofen and Transports) May–July 1992 has been performed in southern Germany 50 km north of the Alpine foothills. The experiment was designed as a national contribution to GEWEX (Global Energy and Water Cycle Experiment within the World Climate Research Programme). The general goal, the objectives, the experimental setup, the missions as well as first observational results have been described in Meischner et al. (1993). The time in between has been used for more detailed data analysis by all participating groups and some results are to be presented in this special issue of the Contributions to Atmospheric Physics. It might be the time for a more general review of the outcome of the experiment.

Shortly summarized, the goal of CLEOPATRA was to quantify elements of the hydrological cycle on a regional scale and the special objectives were

- a more quantitative description of deep convective systems in southern Germany, their formation and organization depending on synoptic conditions, the associated vertical mass transport, the precipitation formation process, and interactions with the environment;
- the understanding of transport, modifications of air pollutants, and their scavenging by clouds;
- to determine the conditions for the formation of broken stratocumulus cloud layers at the top of the boundary layer;
- the quantification of water vapor transports from soil and vegetation to the atmosphere in dependence on precipitation events and the state of vegetation for a given test area;
- to improve and compare remote-sensing methods from ground, aircraft, and space for observing elements of the hydrological cycle;
- to quantify the impact of weather elements on satellite communication links.

Sixteen scientific missions were defined and performed depending on the respective favorable weather condition. They were:

Hail
Squall Line
Gravity Waves
Tracer Transports by Thunderstorms
Chemistry in Stratus Clouds
Chemistry in Cumulus Clouds
Microphysics and Entrainment
Boundary Layer Stratus
Humidity Transport
Lifted Inversion
Validation of Apollo
Radar Polarimetric Measurements
Satellite Path

For most of the objectives interesting and detailed observational data of high quality have been collected. Only the objective of investigating the conditions for the formation of broken stratocumulus cloud layer was not covered at all because an appropriate weather situation did not occur during the observational period.

An overview on all measurements performed are compiled in Meischner (1993).

The scientific results of CLEOPATRA can be summarized under the headings

- Deep convective systems
- Transport and modifications of air pollutants and their scavenging by clouds
- Quantification of water transports
- Improvement of remote sensing methods

which will be discussed in some detail below.

Deep Convective Systems

Some interesting thunderstorm cell types including several squall lines and a supercell storm on 31 July were observed and documented. Selected cases are under more detailed investigations or were published partly.

A most interesting, excellent and detailed documented squall line event took place on 21 July 1992. It developed over eastern France and Switzerland and passed southern Germany and the CLEOPATRA operational area in the course of the day.

The squall line caused tremendous damage and even some fatalities. Ahead of the eastward propagating squall line mesoscale phenomena like thunderstorms, gravity waves and convergence lines developed. Measurements were performed by the 'mesonet' of meteorological surface stations of the Meteorologisches Institut der Universität München und objective analyses were performed. Gravity waves were detected by the DLR microbarometric measuring system in Lichtenau. The temporal evolution of the boundary layer depth was monitored by SODAR observations of the FhG Institut für Atmosphärische Umweltforschung and the Geographisches Institut der Universität München operated a surface energy balance station near Weilheim. Temporarily dense radar observations were obtained from the DLR polarimetric Doppler radar at Oberpfaffenhofen. The results of DLR motorglider flights complement radiosonde ascents at Penzing performed by the Meteorological Institut der Universität München and DLR, as well as the routine soundings of the weather services. Time – height analyses of these soundings were performed.

Ozone probes and meteorological measurements in a cumulonimbus anvil and its surroundings were taken by the DLR Falcon-20 jet.

The documentation further takes advantage from meteorological data that were not specially gained during CLEOPATRA, such as from the meteorological mast at Garching, Ozone soundings from the Deutscher Wetterdienst and Schweizer Meteorologische Anstalt, radar observations from the ETH Zürich and METEOSAT satellite images of EUMETSAT.

Numerical simulations with the Deutschland Modell of the Deutscher Wetterdienst and the subsynoptic scale environment analysis were performed.

The very comprehensive, possibly one of the best documentations of a storm of this type in the region is being printed as a DLR Forschungsbericht at present (Haase-Straub et al., 1994).

It was the aim of the complementing measurements in 1994 (SETEX-Severe Thunderstorm Experiment) to additionally study the genesis of such kind of storms.

Transport and Modification of Air Pollutants and Their Scavening by Clouds

Three airplanes – a Piper-Chieftain from the Zentrum für Umweltforschung of the J. W. Goethe-Universität Frankfurt/Main, a DO 228 from DLR and a DO 128, equipped by the Institut für Meteorologie and Klimaforschung together with the Universität Mainz, Institut für Physik der Atmosphäre – flew with similar cloud physics and cloud chemistry instrumentation on board. It was the first time that – by the use of three similarly equipped aircraft – cloud physical together with cloud chemical processes could be measured in time and space. The measurements were complemented by coordinated collection of rain at the ground for further analyses. Stratus clouds, stratocumulus clouds as well as a single cumulus in different altitudes were sampled. These measurements mainly were an experimental contribution by the Sonderforschungsbereich 233 of the Deutsche Forschungsgemeinschaft „Dynamik und Chemie der Hydrometeore".

Quantification of Water Transports

Four surface energy balance stations were operational extending the observational period of CLEOPATRA, measuring water vapor and energy fluxes of fields with different vegetation types. Meteorological profiles were measured up to 10 m above ground as well as the humidity of the soils. During the growing season all indicators describing the state of the vegetation were measured. Additionally new methods for estimation of soil moisture, wind and temperature profiles by acoustic means were tested. All ground truth measurements are used to verify remote sensing from satellites as with ERS-1, JERS-1 the European and Japanese Earth Resource Satellites or to prepare for them (PRIRODA – the forthcoming earth observation module, to be adapted to the Russian space station MIR). From multifrequency, multitemporal and multipolarization E-SAR measurements vegetation type classifications become applicable.

The test area 'humidity transport' of about 100 km^2 was included into a geographical information system enabling model calculations.

Improvements of Remote Sensing Methods

Quantitative rain estimation by radar is increasing in importance for the objectives of GEWEX as well as for hydrology. Three different radar systems, an X-band Doppler radar together with a distrometer from ETH Zürich, a CW-FM Doppler radar fromthe Meteorologisches Institut Universität Hamburg and the polarimetric Doppler radar (POLDIRAD) from DLR simultaneously measured rain events, and investigations for evaluation of different methods have already been finished or have still been going on making use of polarimetric measurements as well as Doppler measurements. Rain gauge and distrometer measurements are used as references.

Rain and water vapor measurements from space platforms are urgent for GEWEX. One commonly discussed and applied method is the multifrequency microwave radiometry. The comparison of water vapor and rain rate measurements by microwave radiometers similar to those flown on the forthcoming PRIRODA mission with active radar (POLDIRAD) and a Differential Absorption Lidar DIAL were used to test and improve the algorithms for measurements from space.

The collaborative and integrated effort of CLEOPATRA by a broad spectrum of different disciplines and different observational systems including remote sensing clearly improved basic knowledge for most of the scientific objectives for which the experiment was designed. Scientific results are going to be presented in journals and at conferences.

We are grateful to the 'Contributions to Atmospheric Physics' for giving us the opportunity to present collected results in this special issue and in forthcoming volumes.

We hope that these publications will stimulate to discuss the results of CLEOPATRA and to make use of them.

CLEOPATRA should have been one step forward for GEWEX as well as for future observational projects.

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