Studies of Convection Initiation and Clouds During COPS

Volker Wulfmeyer[1], Andreas Behrendt[1], Susanne Crewell[2], Hans-Stefan Bauer[1], and Dave Turner[3]
1: University of Hohenheim, Stuttgart, Germany; 2: University of Cologne, Germany; 3: University of Wisconsin – Madison, USA

1) COPS and AMF science goals

The Convective and Orographically-induced Precipitation Study (COPS) is an international field experiment, which was endorsed as Research and Development Project (RDP) of the World Weather Research Program (WWRP). 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.

High-quality quantitative precipitation forecasting (QPF) requires the correct representation of the whole process chain from the pre-convective environment to convection initiation, to the development and organization of clouds and precipitation.

Therefore, the AMF observations provide a key data set for process studies and model validation. The COPS-AMF collaboration is addressing the following sciences questions:

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

Fig.1. *Set up of AMF site in Murg valley of Black Forest*

Fig.2. *Students of Hohenheim University at AMF site. COPS was combined with a variety of educational activities such as practical training for students from universities and for students from elementary schools, as well as an international summer school.*

2) International collaboration, COPS-GOP-D-PHASE data set

To address these topics, a series of research programs has been initiated, which combines the application of the new generation of remote sensing instruments, data assimilation systems, and an ensemble of high-resolution models.

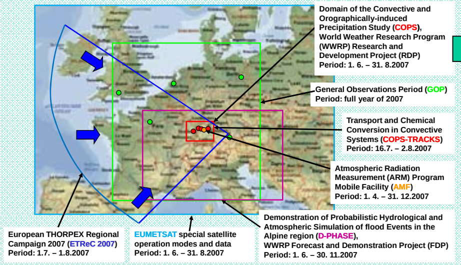


Fig.3. *Coordination of research programs related to COPS.*

D-PHASE data set:

- 6 ensemble forecast systems
- 12 deterministic models with convection parameterization
- 9 deterministic convection permitting models
- 10,000 model runs
- 50,000,000 graphic files
- 50,000,000 model fields in COPS domain

Fig.4. *D-PHASE model domains.*

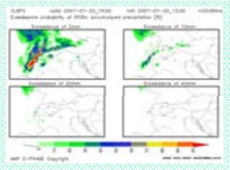


Fig.5. *Example of probabilistic forecast result.*

Observing network:

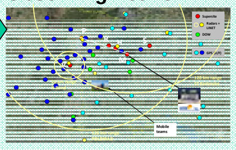


Fig.6. *Network of observations in COPS domain.*

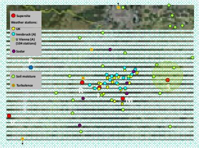


Fig.7. *Zoom in Northern Black Forest.*

Fig.8. *Example of flight pattern of DLR Falcon.*

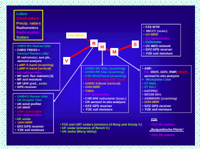


Fig.9. *Sensor synergy at supersites.*

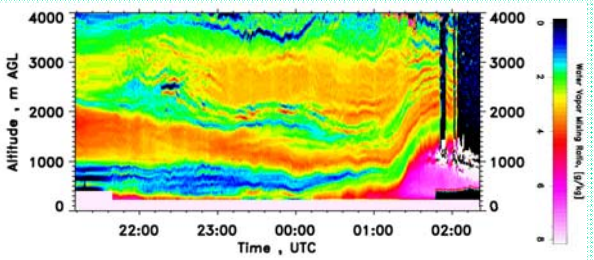


Fig.10. *University of Hohenheim water-vapor DIAL measurement during August 1-2, 2007 (1OP13). At 0:10 UTC the approach of an outflow boundary ahead of colt front was observed in detail with resolutions of 10s and 300m, respectively. The moist layer at 3000 m was advected from the Mediterranean and imbedded in a Saharian dust outbreak.*

Fig.11. *Supersite H with unique combination of remote sensing systems.*

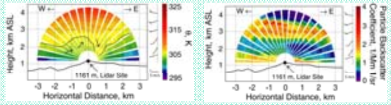


Fig.12. *First 2-d rotational Raman temperature lidar measurement during August 15 (IOP16).*

COPS Highlights

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

3) Meteorological conditions

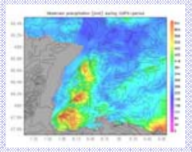


Fig.13. *Precipitation climatology during COPS.*

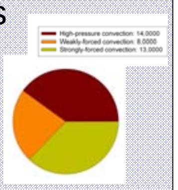


Fig.14. *35 IOP days with various forcing conditions.*

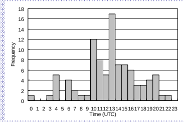


Fig.15. *Diurnal cycle of convection initication demonstrating the importance of land-surface processes.*

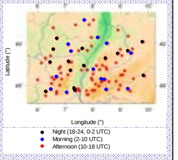


Fig.16. *COPS convection initiation statistics derived using MSG rapid scans.*

4) First model evaluation results

Precipitation:

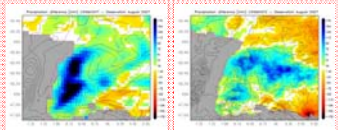


Fig.17. *Comparison of spatial model performa nce of convection permitting model COSMOCH2 and model with convection parameterization COSMOCH7. Convection parameterization causes severe systematic errors called windward/lee effect.*

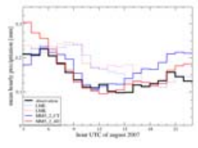


Fig.18. *Improvement of forecast of diurnal cycle of precipitation by University of Hohenheim 4DVAR with European GPS slanth path data..*

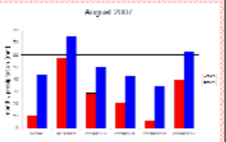


Fig.19. *D-PHASE model evaluation in COPS domain confirming better performance of convection permitting models.*

Clouds:

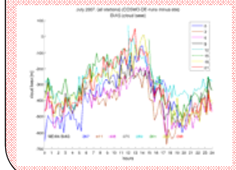


Fig.20. *Diurnal bias of COSMO-DE cloud base vs. ceilometer cloud base (only data where a cloud was detected by the ceilometer and simulated by the model) for July 2007.*

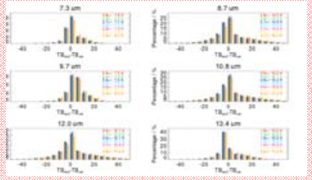


Fig.21. *Probability distribution of difference between observed and simulated brightness temperatures for six different wavelengths for July 2007 over the AMF site. Different colors indicate the lead time of model with red being the closest and orange the longest model run.*

5) Case Study: IOP 9c

In the night from July 19-20, 2007, cyclogenesis took place in southwestern France. The related frontal system reached the COPS domain around 10 UTC on July 20.

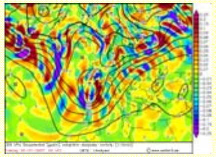


Fig.22. *GFS large-scale analysis. Cyclogenesis was captured reasonably well.*

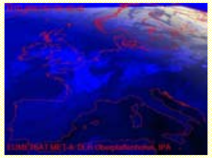


Fig.23. *MSG Rapid Scan Service composite showing the development of deep convection over France.*

Ahead of the front, a sharp and severe squall line developed, which caused flooding events in Germany. Almost all D-PHASE models failed to simulated the related organization of convection.

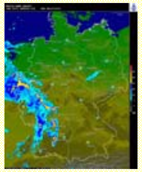


Fig.24. *Squall line slowing down over the Rhine valley and being reactivated on the lee side of the Black Forest.*

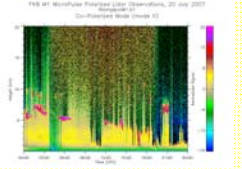
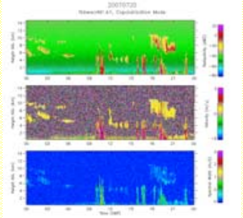


Fig.25. *Passage of squall line at AMF site as observed by micropulse lidar and cloud radar. Depth of convection within mixed-phase cloud reached only 6 km here.*



First conclusions and future work

- **AMF gives unique insight in microphysical properties of convective clouds. Aerosol-cloud-microphysics will be studied more in detail with sensor synergy.**
- **Significantly improved representation of clouds and precipitation by new generation of convection permitting models.**
- **However, these models still often fail to simulate pre-frontal convergence lines and isolated deep convection.**
- **Separation of errors due to initial fields and model physics feasible by advanced data assimilation systems. This will be extended in future projects for testing and improving parameterizations.**

Important links: **COPS:** ***www.uni-hohenheim.de, www.cops2007.de***, **COPS Field Report:** ***www.uni-hohenheim.de/spp-iop/further_reading/further_reading.htm***, **Data archive:** ***cera-www.dkrz.de/WDCC/ui/Index.jsp***
WWRP: ***www.wmo.int/pages/prog/arep/index_en.html***, **GOP:** ***gop.meteo.uni-koeln.de/gop/doku.php***, **D-PHASE:** ***www.map.meteoswiss.ch/map-doc/dphase/dphase_info.htm***

Acknowledgement: **This research program is supported by ARM, DFG, WWRP, HGF, ANR, CNRS, NERC, NCAS, DWD, Meteo France, Meteo Swiss, EUMETSAT, EUFAR, the COPS ISSC, and the D-PHASE SSC.**