Studies of Shallow and Organized Convection With Water-Vapor DIAL and DOW as well as Comparisons with Mesoscale Models during COPS

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1) COPS science goals

The Convective and Orographically-induced Precipitation Study (COPS) was 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.

This required the operation of a sophisticated synergy of remote sensing systems (see Fig. 1 and Wulfmeyer et al. BAMS 2008).

Within this work, the combination of Doppler-on-Wheels (DOW) and water-vapor differential absorption lidar (DIAL) is explored for studying transport processes in complex terrain leading to shallow and organized convection.

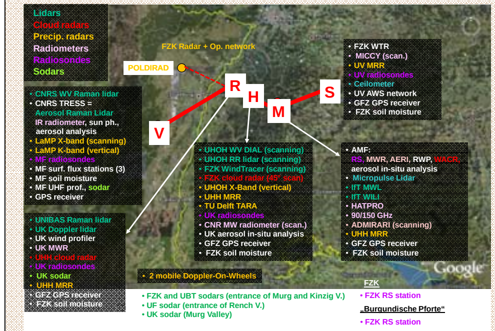

Fig.1. *COPS sensor synergy operated in the COPS domain (southwestern Germany / eastern France). The red letters indicate the location of the supersites.*

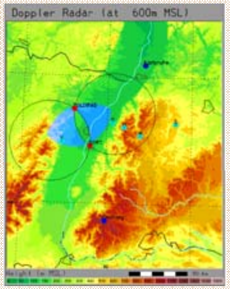

Fig.2. *Location and estimated overlap of dual-Doppler measurements between Poldirad and DOW. The DOW site had a 30km baseline with Poldirad that was at ~345deg. The DIAL operated at supersite H, which was 31km away at 50deg azimuth.*

2) COPS Intensive Observations Period (IOP) 11b, July 26, 2007

Meteorological conditions

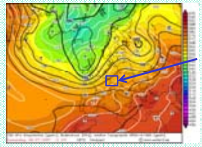

Fig.3. *500-hPa geopotential, surface pressure, and thickness of H500-H1000 layer.*

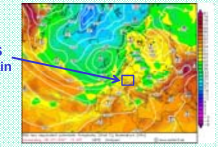

Fig.4. *850-hPa equivalent potential temperature and surface pressure.*

A long-wave trough approached the COPS region from the west and pushed a high-pressure ridge to the east. This resulted in an increasing southwesterly flow during the day. Large-scale forcing remained weak. The day was supposed to stay fair and dry apart from some cumulus clouds (Cu hum to Cu con) mainly over the mountains. Some CAPE developed at the end of the day associated with a weak crossing vorticity maximum so that a slight probability of convection was forecasted in the late afternoon.

D-PHASE data set

For the comparison, the COSMO2 model of Meteo Swiss with 2.2km grid resolution was used. It is one component of the multi-model ensemble operated during COPS and the WWRP Forecast Demonstration Project (FDP) D-PHASE (Wulfmeyer et al. BAMS 2008, Rotach et al. BAMS, submitted).

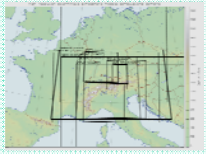

Fig.5. *Domains of D-PHASE ensemble.*

DOW operations and performance

Fig.6. *DOW operating close to the Poldirad site.*

Fig.7. *Poldirad site.*

DOWs are Mobile X-band (3 cm) Doppler radars with a beamwidth of 0.93 deg. We operated them with 120-m range gates. The Neuried site used for this study was at 48 deg 27.134 min N; 7 deg 48.387 min E at an elevation of 152 m. The DOWs were included in COPS to observe the low-level pre-convective wind field to better understand the orographic impact on convection initiation and precipitation enhancement. They are also being used to study the formation and evolution of orographically-induced low-level boundaries.

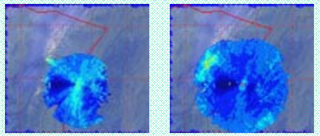

Fig.8. *DOW 260-m and 1250-m reflectivity field plotted on orography and 3-channel MSG composite.*

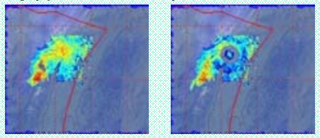

Fig.9. *Same as Fig.8 but Poldirad data.*

DIAL system performance

Fig.10. *Supersite H with unique combination of remote sensing systems.*

Fig.11. *80-cm scanner.*

The new water-vapor DIAL is based on a 6-W laser transmitter operating at 820 nm. The receiver has a diameter of 80 cm and 3D scanning capability. Raw data were collected with resolutions of 15 m and 4 ms, respectively. The DIAL system was operated mainly in the vertically pointing mode. Due to its high accuracy and resolution, we focus on studies of the vertical structure of humidity, atmospheric stability, and mesoscale transport processes including turbulence in the convective boundary layer.

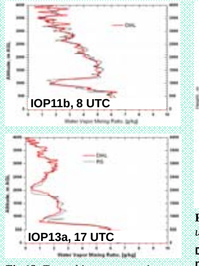

Fig.12. *Two arbitrary comparisons between radio soundings (RS 92) and DIAL measurements with 10s, 150m resolutions, respectively.*

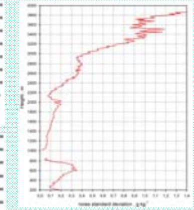

Fig.13. *Daytime DIAL noise error profile using resolutions of 10s and 75m.*

DIAL is very flexible to reduce system noise, as the reduction factor reads for time $\sqrt{\frac{\Delta T_1}{\Delta T_2}}$ **, and for range even** $\left(\sqrt{\frac{\Delta R_1}{\Delta R_2}}\right)^3$.

3) Study of horizontal rolls and convection

DOW and Poldirad

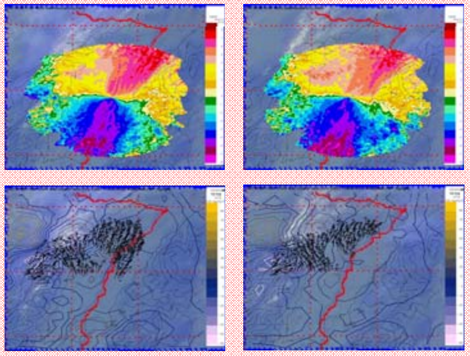

Fig.14. *Upper panels: DOW radial wind speed measurements 600 m above the DOW site at 11 UTC and 12 UTC, respectively. Horizontal rolls were detected in the Rhine valley which were advected to the east during the measurement period.*
Bottom panels: Corresponding dual-Doppler wind fields. The DOW volume scans were synchronized with the Poldirad 10-min timing. After removal of ground clutter and spurious echoes, we interpolated the polar-coordinate data onto a 500 m x 500 m x 500 m Cartesian grid. The dual-Doppler synthesis resulted in a 3D wind field in the dual-Doppler lobes.
These results were overlayed with VERA analyses (University of Vienna) of the surface moisture divergence which show convergence at the northern tip of the Vosges mountains.

VERA and COSMO2

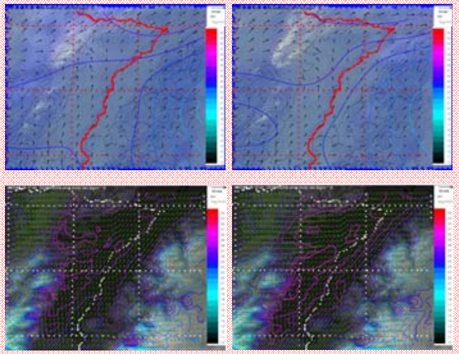

Fig.15. *Upper panels: VERA surface wind field and Geoforschungszemtrum-Potsdam (GFZ) IWV analyses with resolutions of 8km and 1h, respectively. On the one hand, the VERA-analyses do not capture the small-scale variability, on the other hand, they determine the large-scale flow and the humidity distribution over a large domain. The wind analyses agreed reasonably well with the dual-Doppler measurements.*
Bottom panels: Corresponding COSMO2 fields of surface wind and IWV. The model develops a highly variable mesoscale flow with strong channeling in the Rhine valley, which, however, neither agrees with dual-Doppler nor with VERA analyses. The IWV output indicates that the model is too "moist", most likely in the boundary layer.

Water-vapor DIAL

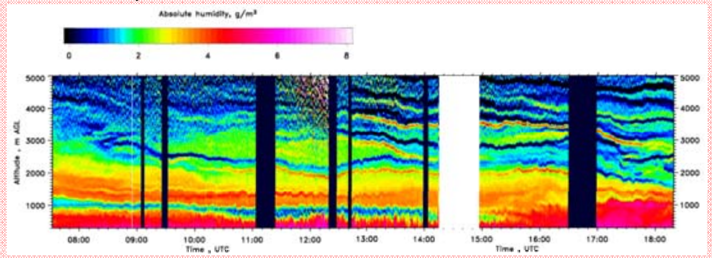

Fig.16. *Time-height cross section of absolute humidity measured with resolutions of 10s and 150m, respectively. The data show a tremendous vertical variability. Data in the region of aerosol gradients may require Rayleigh-Doppler correction but comparisons with soundings incdicate already a high accuracy. A shallow convective boundary layer was detected between 10:30-15:30 UTC.*

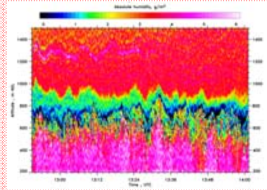

Fig.17. *Humidity measurement with extraordinary resolutions of 1s and 15m. Effect of horizontal rolls around 13:45 UTC and 13:58 UTC?*

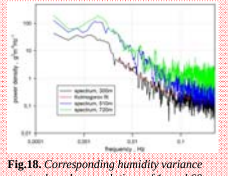

Fig.18. *Corresponding humidity variance spectra based on resolutions of 1s and 60m determined at three different height levels. The frequency distribution of temperature and wind fluctuations may be used for boundary layer parameterization.*

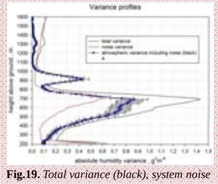

Fig.19. *Total variance (black), system noise variance (red), and atmospheric humidity variance profile including noise and sampling error bars. Two peaks occur due to the presence of the dry layer at ABL top.*

4) Summary

Combination of DOW, VERA, and GPS

- **Structure and dynamics of organized convection were studied, horizontal rolls were detected by contrast of 1-2 m/s in radial wind component.**
- **Convergence in northern part of Vosges mountain is consistent with DOW and VERA data.**
- **GPS IWV fields are probably too smooth as to detect orographically-induced moisture convergence.**
- **But GPS IWV suitable for detecting model deficits.**
- **The potential of DOW, VERA, and GPS synergy for studying water-vapor transport and budget will be explored.**

DIAL

- **Excellent tool for studying small-scale moisture variability. Most of the vertical variability likely caused by weak lids.**
- **Resolution sufficient for investigating turbulence in the convective boundary layer.**
- **It is very likely that the DIAL measurements show interaction between turbulence and horizontal rolls.**

COSMO2

- **Mesoscale flow deviates from VERA and dual-Doppler measurements.**
- **Boundary layer moisture likely too high, which was also detected in other convection permitting models.**

Important links and references: COPS: *www.uni-hohenheim.de/cops, www.cops2007.de, cera-www.dkrz.de/WDCC/ui/Index.jsp;* WWRP: *www.wmo.int/pages/prog/arep/index_en.html*; D-PHASE: *www.map.meteoswiss.ch/map-doc/dphase/dphase_info.htm; Wulfmeyer et al., Bull. Amer. Meteor. Soc. 89, 1477-1486, 2008; Rotach et al., Bull. Amer. Meteor. Soc. , submitted.*

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