COPS synthesis:
Which level-2 data products do we need to investigate the COPS science questions and how do we get them?

Andreas Behrendt

Institute of Physics and Meteorology, University of Hohenheim

Goals of the „next phase“:

- An exciting new data set awaits exploitation:
  the comprehensive, 4D, high-resolution remote sensing data of COPS
- Address the science questions of COPS
- Derive new synergetic data which are relevant to process studies at all Supersites
- Evaluate and refine parametrizations in complex terrain

COPS Remote Sensing Instruments

	July																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
IOP	5a	5b		6				7a	7b					8a	8b	8c		9a	9b	9c			10		11a	11b				12	
No. of CI event	2	8		1				0	3					0	1	*		3	0	6			5		0	0				1	
Airborne																* no MSG rapid scan data available on this day															
DLR DIAL								x							x			x	x	x					x	x				x	
Leandre2														x	x	x		x	x	x					x	x				x	x
Mobile																															
DOW1	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
DOW2																					x	x	x	x				x	x	x	x
SuSiH																															
WV DIAL	x						x	x	x				x	x	x	x		x	x	x			x		x	x				x	
RRL	x						x	x	x				x	x	x	x		x	x	x		x	x								
Windtracer	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CloudRadar	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
CNR MWR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiR																															
BASIL	x	x		x				x	x		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x		x	x
Doppler Lidar	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CloudRadar	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
TARA	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x										
MWR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiM																															
BERTHA	x	x		x				x	x			x	x	x	x			x	x	x	x	x	x		x	x				x	x
WiLi	x	x		x				x	x		x	x		x	x	x		x	x	x		x	x	x	x	x				x	x
MPL	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CloudRadar	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HATPRO	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiV																															
TRESS	x	x		x	x	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x
CNRS RL	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiS																															
Ceilometer						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
WTR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
MICCY	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
POLDIRAD	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

24 instruments (in addition to AMF, op. radars, GPS, MRRs, MSG RSS)!

COPS Data Products

Phase 1: 09/07 - 03/08

Level 0: Raw data
not collected in COPS Data Archive,
need to be stored by individual groups (10 years?)

Level 1a: Direct data products (*T, q,* β, α, δ, *Z,* LWP, …),
see instrument forms
are collected in COPS Data Archive, deadline: March 2008

Phase 2: 4/08 – 3/10

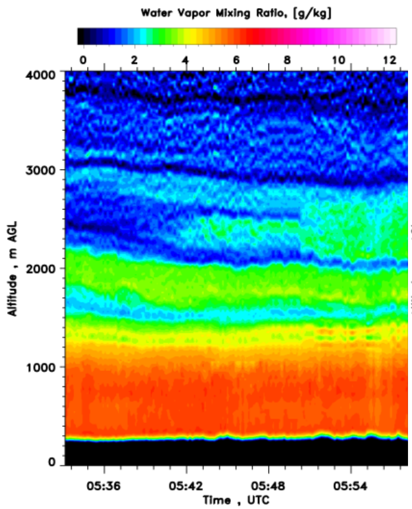
Level 1b: Direct data products of improved accuracy
are also collected in COPS Data Archive

Level 2: Higher-order data products, synergetic data, composites
(RH, *B*, CAPE, CIN, lidar fluxes, CBL height, …)
are invited to the COPS Data Archive

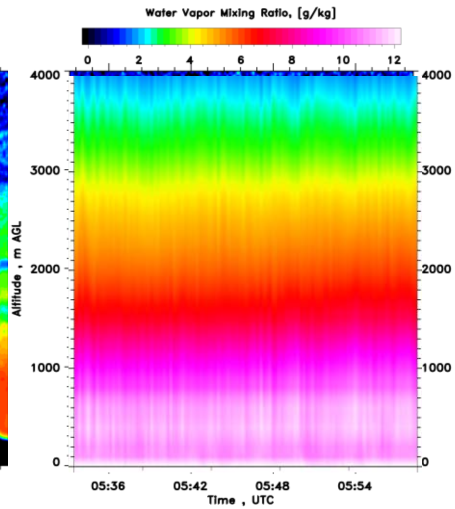
COPS/GOP/D-PHASE Data Policy

1. All investigators participating in COPS, GOP, and D-PHASE must agree to **promptly submit their data** to the joint Data Archive to facilitate the intercomparison of results, quality control checks and inter-calibrations, as well as an integrated interpretation of the combined data set (up to end of phase 2 of PQP, i.e., up to March 2008, the latest).
2. All data shall be **promptly provided to other COPS, GOP or D-PHASE investigators** upon request. A list of investigators will be maintained by the COPS Project Office at University of Hohenheim and will include the principle investigators directly participating in the field experiment as well as collaborating scientists who have provided guidance in the planning of COPS/GOP activities.
3. During the initial data analysis period (up to end of phase 2 of PQP, i.e., **up to March 2008), no data may be provided to a third party** (journal articles, presentations, research proposals, other investigators) without the consent of the investigator who collected the data. This initial analysis period is designed to provide an opportunity to quality-control the combined data set as well as to provide the investigators time to publish their results.
4. All data will be considered **community domain for all COPS/GOP/D-PHASE investigators and PIs of PQP after March 2008** and any use of the data will offer co-authorship at the discretion of the investigator who collected the data.
5. After the end of phase 3 of PQP, i.e., **March 2010, all data will be considered public domain for non-commercial use**. In this phase, any use of the data will include either acknowledgment (i.e., citation) or offer co-authorship at the discretion of the investigator who collected the data.
6. **Commercial use of the data is prohibited at any time, the data may be used for research only.**

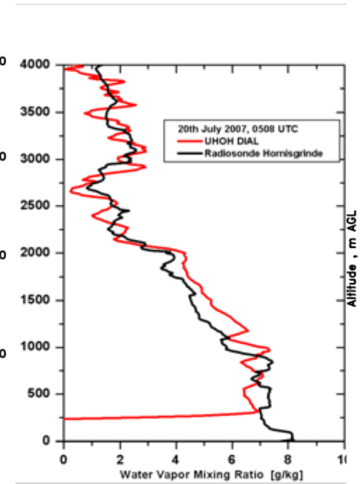
Synergetic measurements of ABL key parameters, COPS IOP 9c



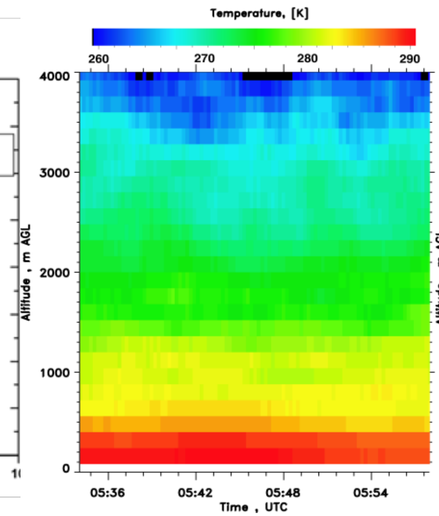
UHOH DIAL
Water Vapor Mix. Rat.



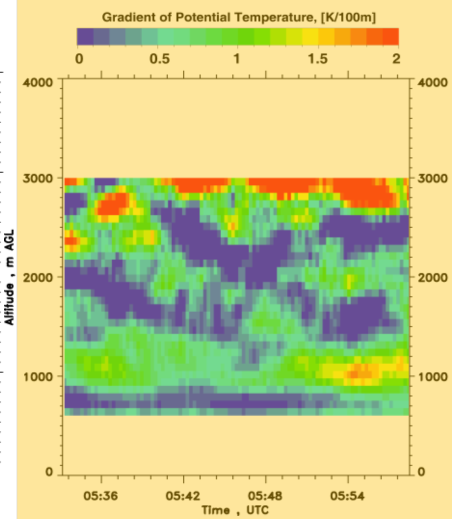
CNR-MWR
Water Vapor Mix. Rat.
Courtesy of F. Madonna
and G. Pappalardo



UHOH DIAL and radiosonde
Water Vapor Mix. Rat.intercomp.

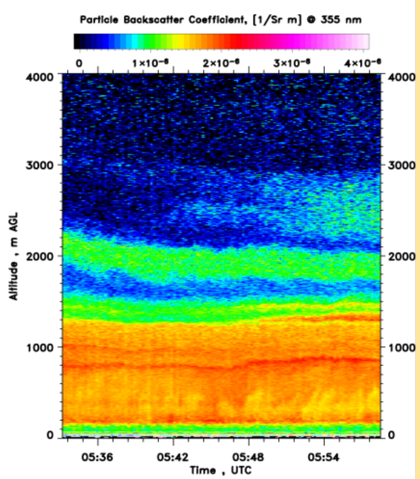


UHOH RRL: Temp.

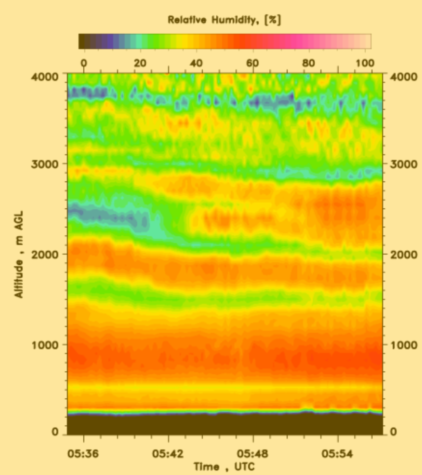


UHOH RRL: dΘ/dz

Level-2 Data

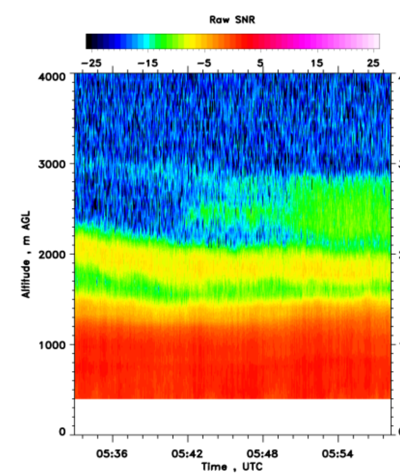


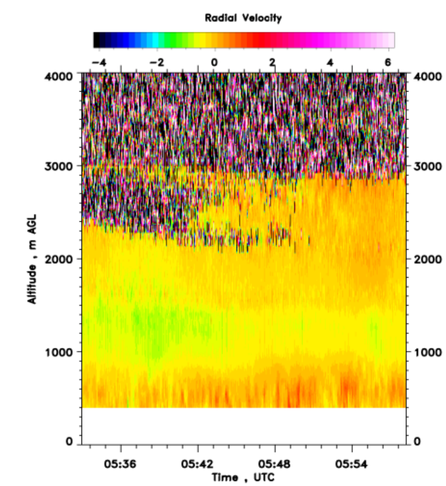
UHOH RRL: $\beta_{par,\ 355\ nm}$



UHOH DIAL and RRL: Rel. Hum.

Level-2 Data

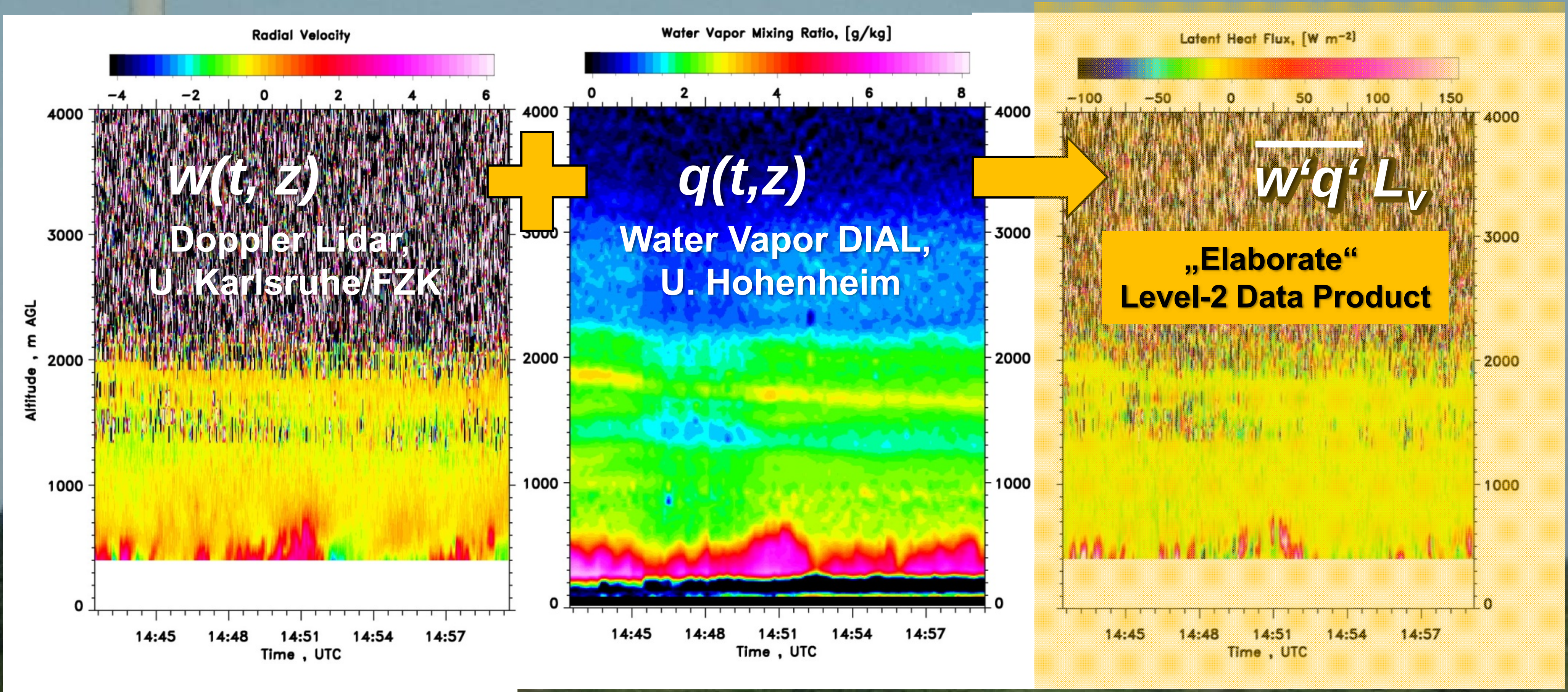




IMK Doppler lidar: Raw SNR and vertical velocity
Courtesy of Katja Träumner. Andreas Wieser, FZK, Karlsruhe

See Poster CI 7, S. Pal et al.

Measurement of Flux Profiles at Supersite H, IOP 8b



See Poster CI 2

DFG Project: CI Remote Sensing

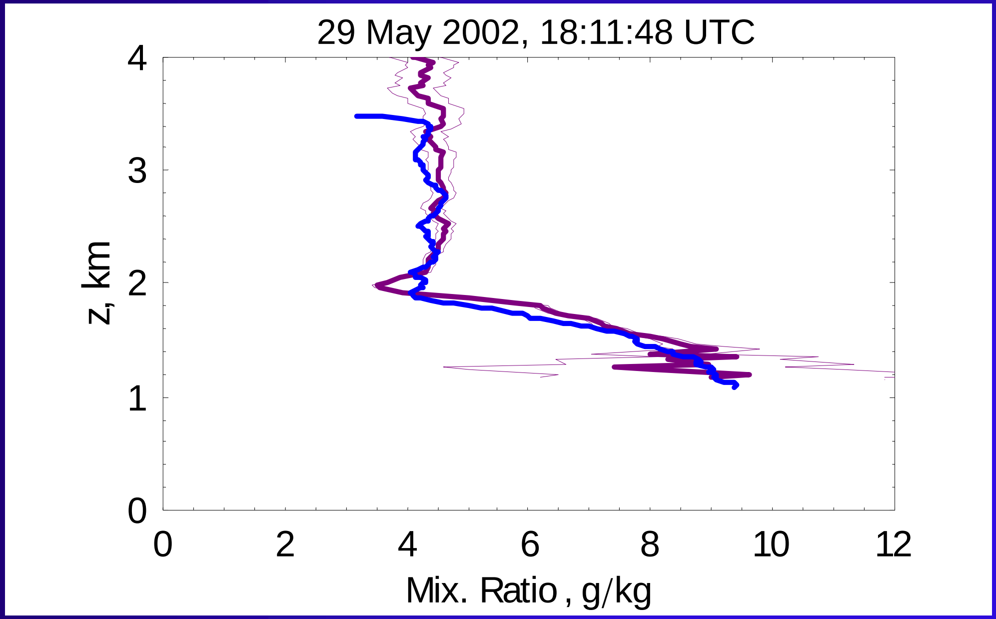
→ Poster CI 2

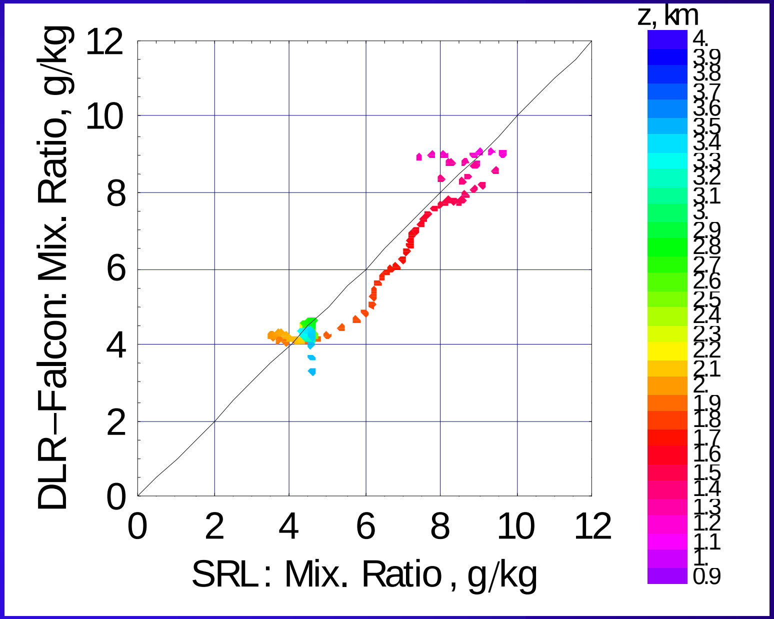
- Support intercomparison of COPS water vapor data, derive bias and RMS errors
- Apply higher-order corrections to water vapor lidar data in order to reach better than 5 % accuracy
- Analyse the diurnal cycle of boundary layer variables and relate the result to QPF deficiencies
- Investigate temperature lids in remote sensing data
- Quantify gravity waves by remote sensing data
- Derive sensible and latent heat fluxes by collocated lidars at Supersites
- Investigate the small scale heterogeneity of water vapor, temperature, wind, clouds, aerosols and their relation to CI
- Combine simultaneous scanning data of water vapor and temperature: RH, θ, θ_v, $d\theta/dz$, $d\theta_v/dz$, buoyancy, CAPE, CIN
- Employ clear-air echos of DOWs and POLDIRAD for CI
- Detailed case studies of CI events and comparison with parameterization concepts
- Compare case study results with D-PHASE model simulations, COPS-GRID re-analyses, and hybrid convection schemes in cooperation with the respective projects

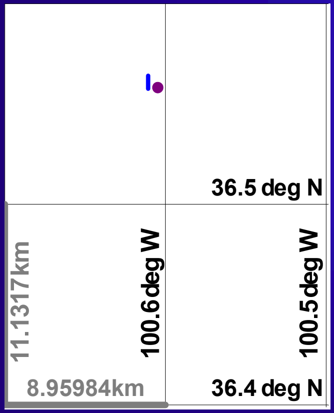
Quality Ensurance

Example: IHOP_2002 Intercomparison Project of ESA

DLR DIAL to NASA SRL







Overall result of 9 cases:

RMS = 0.60 ± 0.25 g/kg or 9.2 ± 2.5 %
Bias DLR – SRL = -0.30 ± 0.25 g/kg or -4.3 ± 3.2 %

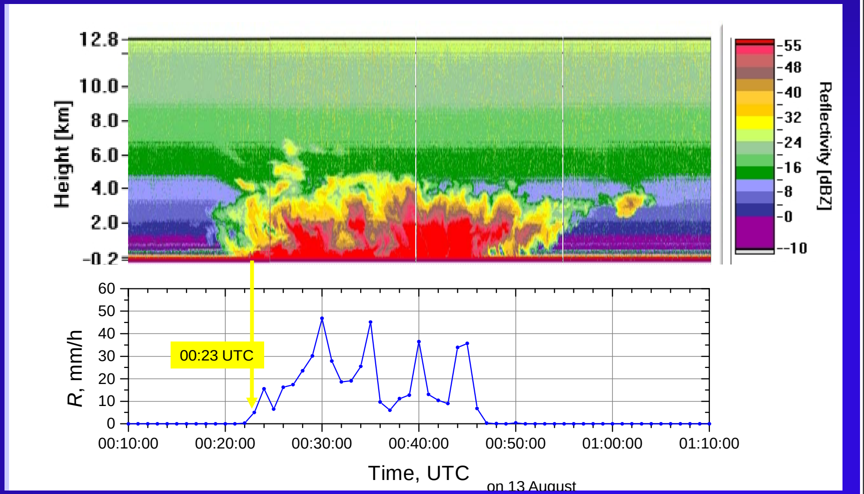
A. Behrendt, V. Wulfmeyer, P. Di Girolamo,
Ch. Kiemle, C. Flamant et al., JTech, 2007a,b.

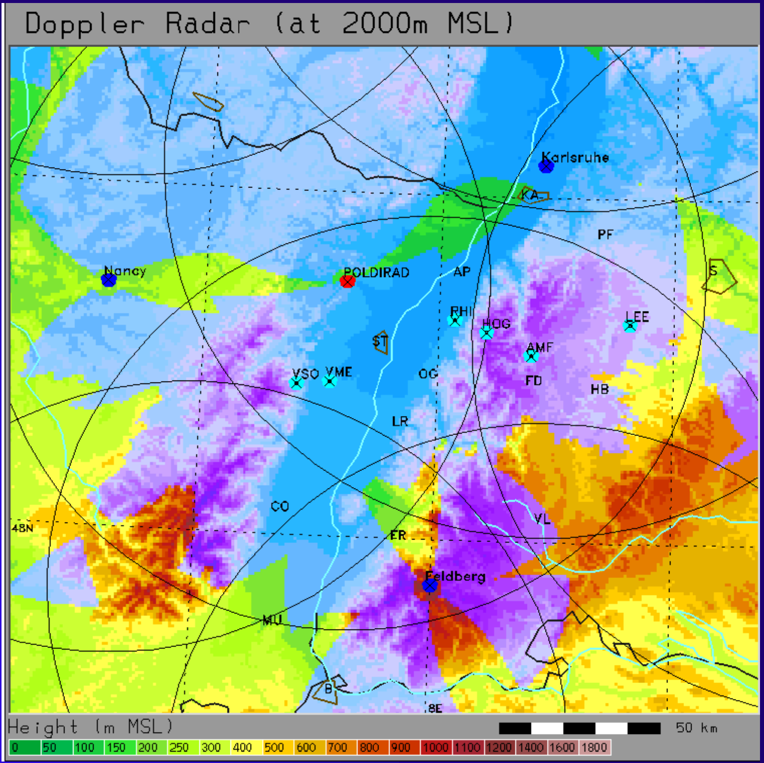
Radar/Precip Composite

= „Elaborate“ Level-2 Data Product

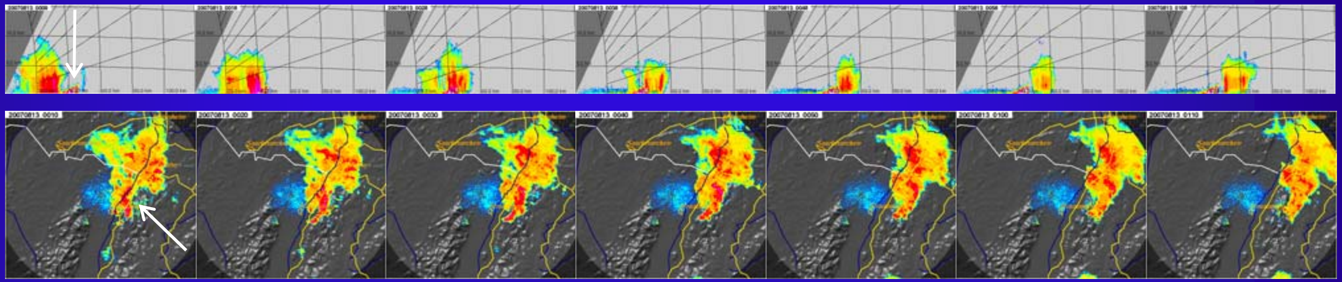
UHOH X-Band Radar

Dirsdrometer

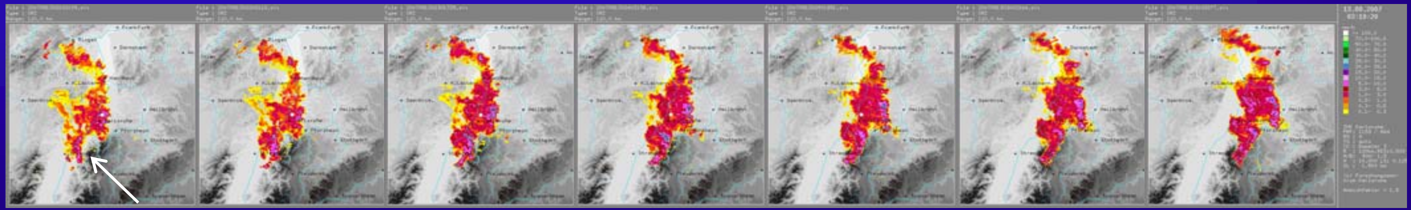




POLDIRAD



IMK C-Band Radar



See Poster PPL 7, A. Riede et al.

Conclusions

Let‘s foster cooperations so that level-2 data products are generated in a coordinated way in order to

- avoid double-work & use resources most efficiently
- use well documented and consistent algorithms
- learn from each others expertise
- benefit science!

Shall we adapt our data policy for „elaborate“ level-2 data products?

	June																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
IOP					1a	1b	1c	1d				2		3a	3b				4a	4b										
No. of CI events					5	6	6	18				4		*	*				*	*										
Airborne														* no MSG rapid scan data available on this day																
DLR DIAL																														
Leandre2																														
Mobile																														
DOW1																			x	x	x	x	x	x	x	x	x	x	x	x
DOW2																														
SuSiH																														
WV DIAL																			x											x
RRL					x	x	x	x			x	x		x	x				x	x					x					x
Windtracer	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CloudRadar	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TARA																			x	x	x	x	x	x	x	x	x	x	x	x
CNR MWR	x						x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiR																														
BASIL				x	x	x	x	x				x		x	x				x	x										x
Doppler Lidar													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CloudRadar		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
MWR													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiM																														
BERTHA			x	x	x	x		x			x	x	x	x				x	x	x										x
WiLi		x	x	x	x	x	x							x					x	x										x
MPL	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CloudRadar	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HATPRO	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiV																														
TRESS																														
CNRS RL																														
SuSiS																														
Ceilometer																														
WTR														x	x	x	x	x	x	x	x	x	x				x	x	x	x
MICCY																												x	x	x
POLDIRAD				x	x	x	x	x	x	x	x	x	x	x								x	x	x	x	x	x	x	x	x

	August																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
IOP	13a	13b				14a	14b	14c	14d			15a	15b		16a	16b					17a	17b		18a	18b						
No. of CI event	0	5				*	*	*	2			2	0		5	4					0	5		2	0						
Airborne						* no MSG rapid scan data available on this day																									
DLR DIAL	x																														
Leandre2	x																														
Mobile																															
DOW1	x	x	x	x	x	x	x	x	x	x	x	x	x	x																	
DOW2	x	x	x	x	x	x	x	x	x	x	x	x	x	x																	
SuSiH																															
WV DIAL	x	x				x						x	x	x	x		x				x	x	x	x	x			x		x	
RRL												x	x	x	x	x	x				x	x		x	x					x	
Windtracer	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
CloudRadar	x	x	x																						x	x	x	x	x	x	x
CNR MWR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiR																															
BASIL	x	x				x					x	x	x	x	x	x	x				x	x	x	x	x			x	x	x	
Doppler Lidar	x	x	x	x	x	x	x	x				x	x	x	x	x															
CloudRadar	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TARA		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
MWR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																
SuSiM																															
BERTHA	x	x			x	x						x	x		x							x	x	x	x		x	x			
WiLi	x	x			x	x						x	x		x		x				x	x		x	x						
MPL	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CloudRadar	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HATPRO	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SuSiV																															
TRESS																															
CNRS RL																															
SuSiS																															
Ceilometer	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
WTR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
MICCY	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
POLDIRAD	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	

Lidars

Ground-based at supersites:

- UNIBAS Raman lidar
- UK Doppler lidar (scanning)

R H M S V

- Ceilometer

- IfT MWL
- IfT WILI (scanning)
- Micropulse Lidar

- CNRS WV Raman lidar
- CNRS Aerosol Raman Lidar

- UHOH WV DIAL (scanning)
- UHOH RR Lidar (scanning)
- FZK WindTracer (scanning)

13 Lidars (platforms) with

6 H_2O Lidars

3 Temperature Lidars

4 Aerosol Raman Lidars

4 Doppler Lidars

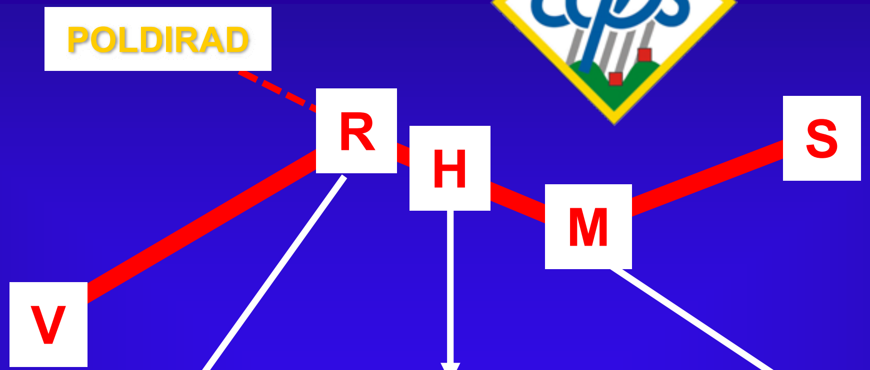
Airborne:

- WV DIAL
- Doppler Lidar (scanning)

- LEANDRE2

Supersite Instrumentation

Lidars
Cloud radars
Precip. radars
Radiometers
Radiosondes
Sodars



- FZK WTR
- MICCY (scan.)
- UV MRR
- UV radiosondes
- Ceilometer
- UV AWS network
- GFZ GPS receiver
- FZK soil moisture

- CNRS WV Raman lidar
- CNRS TRESS = Aerosol Raman Lidar IR radiometer, sun ph., aerosol analysis
- LaMP X-band (scanning)
- LaMP K-band (vertical)
- MF radiosondes
- MF surf. flux stations (3)
- MF soil moisture
- MF UHF prof., sodar
- GPS receiver

- UHOH WV DIAL (scanning)
- UHOH RR lidar (scanning)
- FZK WindTracer (scanning)
- FZK cloud radar (45° scan)
- UHOH X-Band (vertical)
- UHH MRR
- TARA
- UK radiosondes
- CNR MW radiometer (scan.)
- UK aerosol in-situ analysis
- GFZ GPS receiver
- FZK soil moisture

- AMF: RS, MWR, AERI, RWP, WACR, aerosol in-situ analysis
- Micropulse Lidar
- IfT MWL
- IfT WILI
- HATPRO
- 90/150 GHz
- ADMIRARI (scanning)
- UHH MRR
- GFZ GPS receiver
- FZK soil moisture

- UNIBAS Raman lidar
- UK Doppler lidar
- UK wind profiler
- UK MWR
- UHH cloud radar
- UK radiosondes
- UK sodar
- UHH MRR
- GFZ GPS receiver
- FZK soil moisture

- 2 mobile Doppler –On-Wheels

- FZK and UBT sodars (entrance of Murg and Kinzig V.)
- UF sodar (entrance of Rench V.)
- UK sodar (Murg Valley)

FZK

- FZK RS station

„Burgundische Pforte“

- FZK RS station

COPS Science Hypotheses

- Upper tropospheric features play a significant but not decisive role for convective-scale QPF in moderate orographic terrain. (ETReC07, COPS, GOP)
- Accurate modeling of the orographic controls of convection is essential and only possible with advanced mesoscale models having a resolution of the order of a few kilometers (D-PHASE, COPS)
- Location and timing of CI depends critically on the structure of the humidity field in the planetary boundary layer (ARM, COPS, GOP)
- Continental and maritime aerosol type clouds develop differently over mountainous terrain leading to different intensities and distributions of precipitation (TRACKS, ARM, COPS)
- Novel instrumentation during COPS can be designed so that parameterizations of sub-grid scale processes in complex terrain can be improved (ALL)
- Real-time data assimilation of key prognostic variables such as water vapor and dynamics is routinely possible and leads to a significant better short-range QPF (COPS, GOP)

CI Hypotheses

- What is most relevant for the heterogeneity of the boundary layer fields of key prognostic variables (differences in soil moisture, surface parameters, vegetation, orography, etc.)?
- How are small-scale inhomogeneities of atmospheric humidity, temperature, and wind in complex terrain related to CI?
- How is the diurnal cycle of CI related to processes at the surface and in the boundary layer and why is the diurnal cycle of convection not represented adequately in the models?
- To which extent do gravity waves and mountain waves initiate or inhibit convection?
- What is the relative importance of the large-scale flow versus local orographic and surface driven processes in determining the location, timing and intensity of convection in regions of moderate orography?
- Do aerosol particles influence CI?

ACM Hypotheses

- What is the role of aerosol particles in changing cloud microphysical properties and the initialization of convection?
- Does sub-cloud aerosol variability affect convective precipitation?
- Does cloud turbulence promote condensation, coalescence and aggregation and thus precipitation?
- Is there a correlation between measurable aerosol properties (e.g., depolarization) and ice formation?
- What statistical information about ice formation in COPS can we derive from present satellite sensors?

PPL Hypotheses

- What is the role of orography for the development of convective cell? To what extent does this affect organized convection?
- Does orography affect the hydrometeor distribution, development of graupel and hail, and the precipitation rain drop size distribution (RDSD)? Is this different for orographically induced and non-orographically affected convective precipitation?
- How does RDSD change during the cloud life cycle?
- What triggers the transfer of drizzle (virga) into full precipitation?
- What is the reason for the windward/lee problem and can it be solved by high-resolution mesoscale modeling without convection parameterization?

The life cycle of single cells is affected by orography but not the one of larger systems.

DAP Hypotheses

- What are the relative roles of upper and mid-tropospheric forcing versus local orographic and surface flux influences on the predictability of convective precipitation in a region of moderate orography?
- What is the impact of the assimilation of high resolution remote sensing data on short-range forecasts of convective precipitation, and what data assimilation methods are best suited for this task?
- What is the impact of model errors on forecast accuracy, in comparison to error in initial fields, and can a synergetic use of observations lead to a characterization and reduction of model error?
- Is there an obvious impact of COPS measurements on model forecasts?
- If reasons for lack of positive impact can be identified, can a better measurement strategy be devised?
- Which assimilation systems best handle the data and which may be practical for real-time use (nudging, 3DVAR, 4DVAR, ensemble-based)?
- Is such a system a valuable tool to support mission planning?

AMF Proposal Science Questions

- What are the processes responsible for the formation and evolution of convective clouds in orographic terrain?
  CI + ARM + D-PHASE + PQP scientists

- What are the microphysical properties of orographically induced clouds and how do these depend on dynamics, thermodynamics, and aerosol microphysics?
  ACM + ARM + GOP + PQP scientists

- How can convective clouds in orographic terrain be represented in atmospheric models based on AMF, COPS, and GOP data?
  Coordination of all efforts