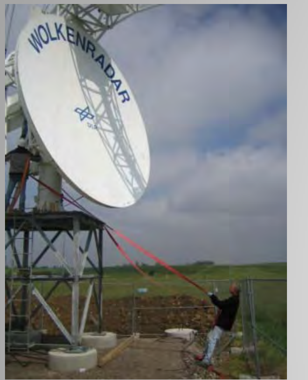
COPS (Convective and Orographically-induced Precipitation Study)

Goal: Advance the quality of forecasts of orographically-induced convective precipitation by 4D observations and modeling of its life cycle

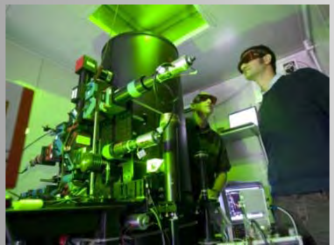


Volker Wulfmeyer

Institute of Physics and Meteorology (IPM)

University of Hohenheim, Stuttgart, Germany

and the COPS International Science Steering Committee

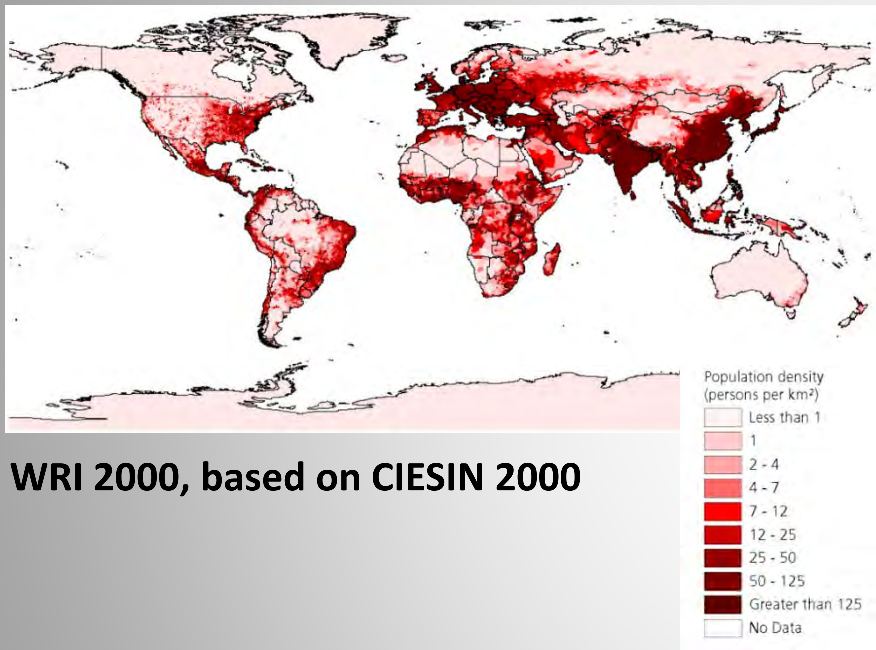


- Motivation and strategy
- Set up and performance
- First highlights
- Ongoing and future projects

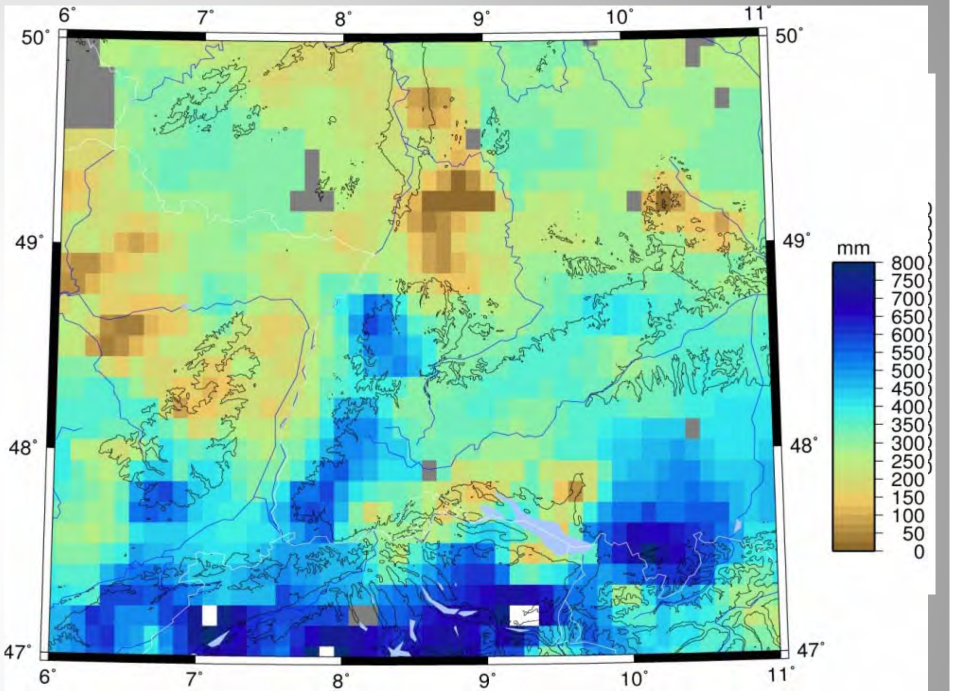
Wulfmeyer et al., Bull. Amer. Meteor. Soc. 89(10), 1477-1486, 2008, DOI:10.1175/2008BAMS2367.1.

The Importance of Orography for Weather and Climate Research

Global population density 1995



WRI 2000, based on CIESIN 2000



(summer 2007) in the D-PHASE domain and in the *COPS domain* (black box)

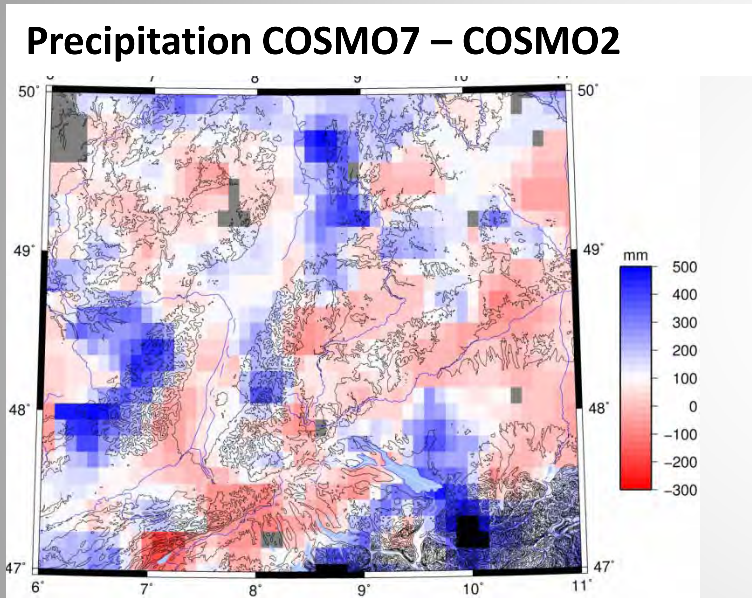
Precipitation amount in the *COPS region*

Reliable regional climate modeling and high-resolution weather forecasting both require a detailed understanding of the process chain leading to precipitation down to the scales of land-use, catchments, and orography.

Status of Quantitative Precipitation Forecasting (QPF) and Regional Climate Modeling

Summer 2007, COPS Domain

Operational models COSMO7 and COSMO2 with grid resolutions of 7km and 2.2km, respectively

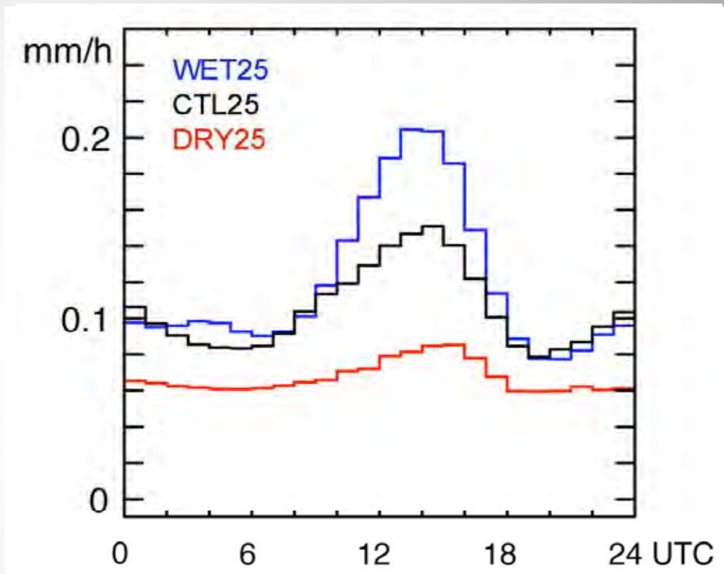


Severe windward/lee effect

Schwitalla et al., Crewell et al., Meteorol. Z. 2008

Summer 2006, ≈D-PHASE domain

Climate COSMO, 25-km grid resolution
Climate COSMO, 2-km grid resolution

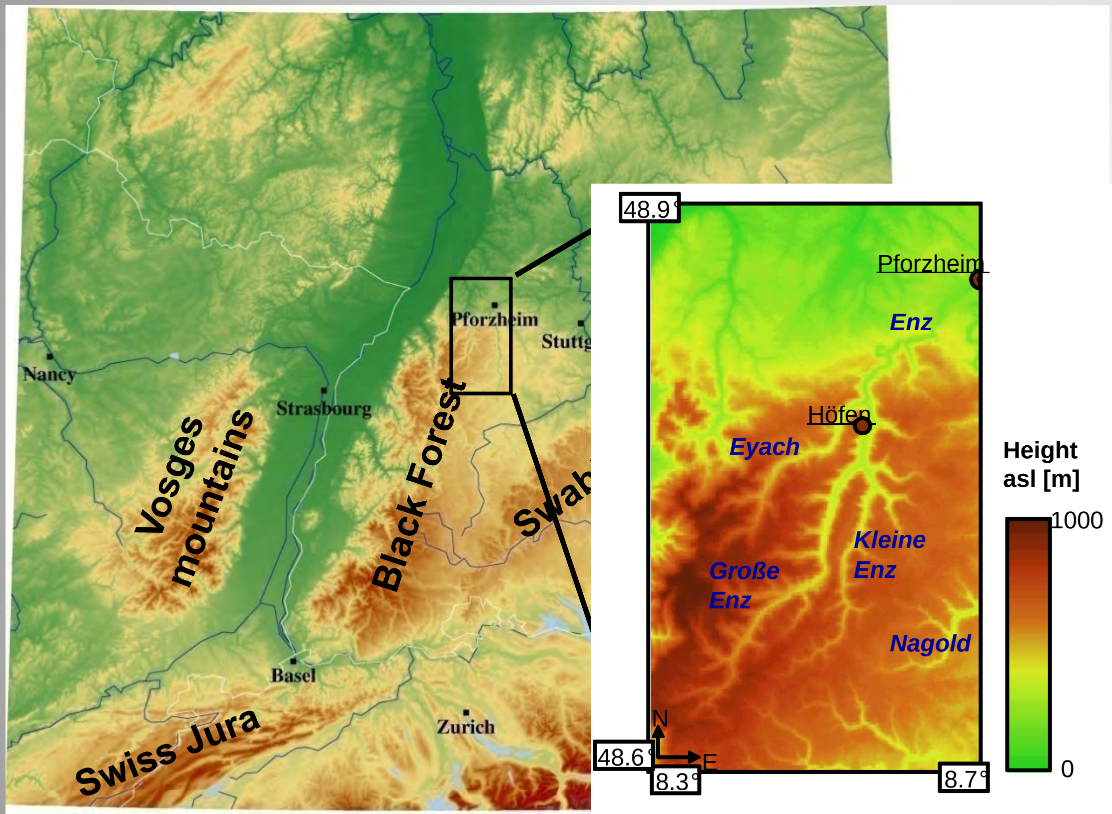


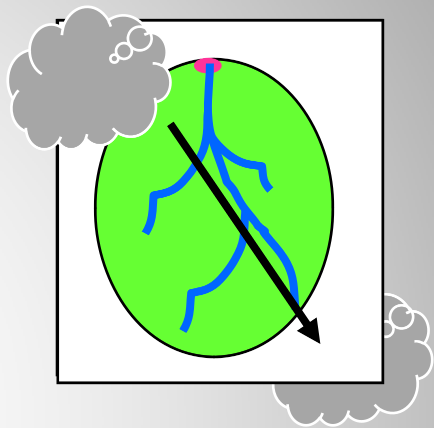
Positive soil moisture-cloud-precipitation feedback
Negative soil moisture-cloud-precipitation feedback

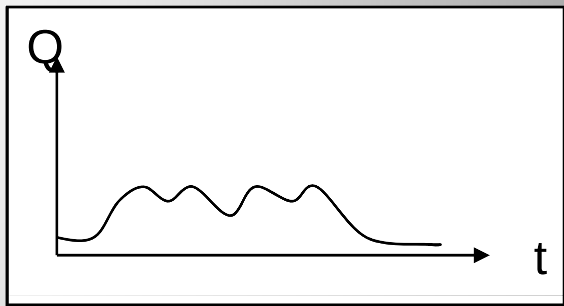
Hohenegger et al., J. Climate 2009

High-resolution, seamless probabilistic simulations of the Earth system are required from nowcasting to centuries.

The Importance of Orography for Weather and Climate Research







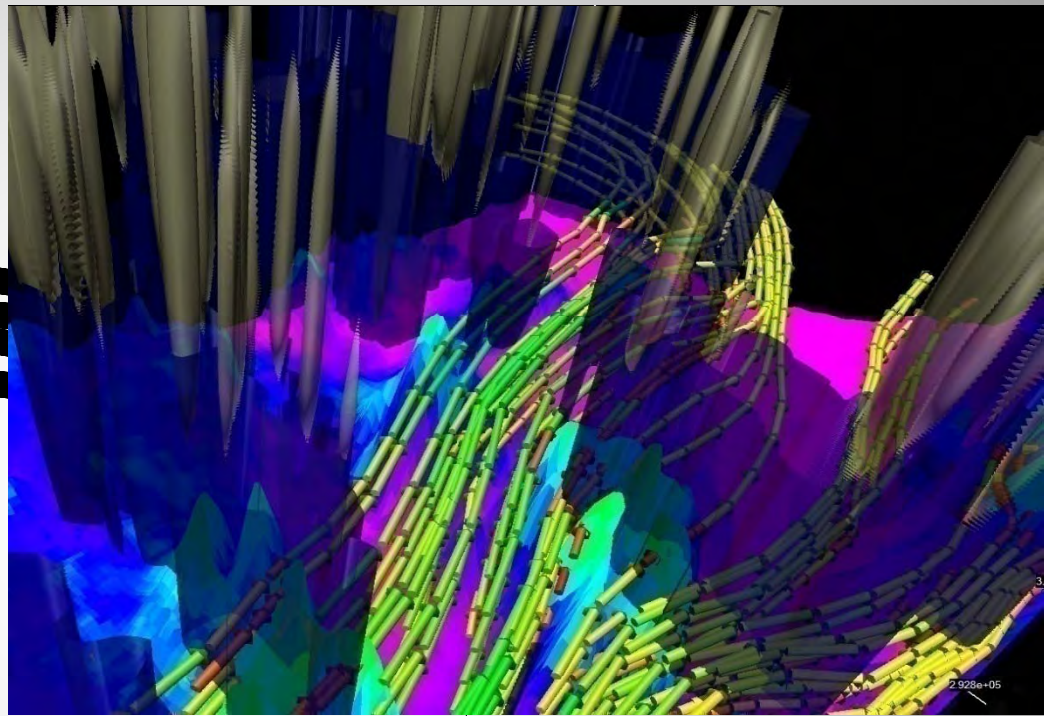
Hydrological forecasts must be *probabilistic* and depend critically on the quality and resolution of *probabilistic quantitative precipitation forecasting* (PrQPF).

Key Physical Processes in Orographic Terrain

Black: Physics, Red: Model requirements (animations with NCAR Vapor)

Orientation and shape of orographic terrain with respect to mean flow, static stability of flow

Correct initial conditions and boundaries of large-scale flow.



Differential heating inducing mesoscale circulations

Limited-area modelling (LAM):

- Orography, land use, and radiative transfer
- Mesoscale data assimilation

Slope/shading effects on radiation leading to valley flows and specific convergence lines

Land-surface exchange, rad., turbulence

Special environment for aerosol-cloud-precipitation processes

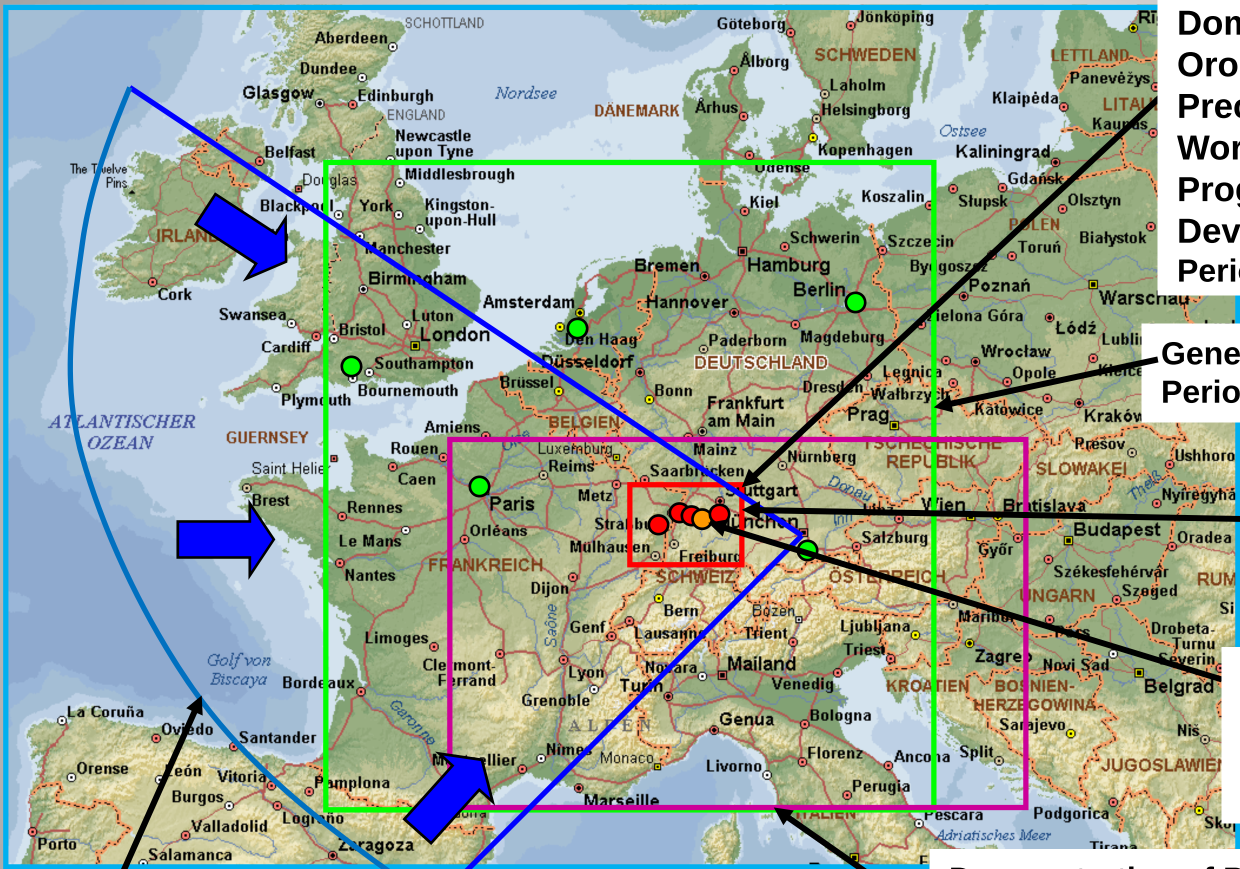
Detailed aerosol-cloud-precipitation physics

Diurnal cycle and specific properties of clouds and precipitation expected.

Limited predictability:

Mesoscale ensemble modeling

European Coordinated Experiments 2007



Domain of the Convective and Orographically-induced Precipitation Study (COPS), World Weather Research Program (WWRP) Research and Development Project (RDP)
Period: 01.06. – 31.08.2007

General Observations Period (GOP)
Period: full year of 2007

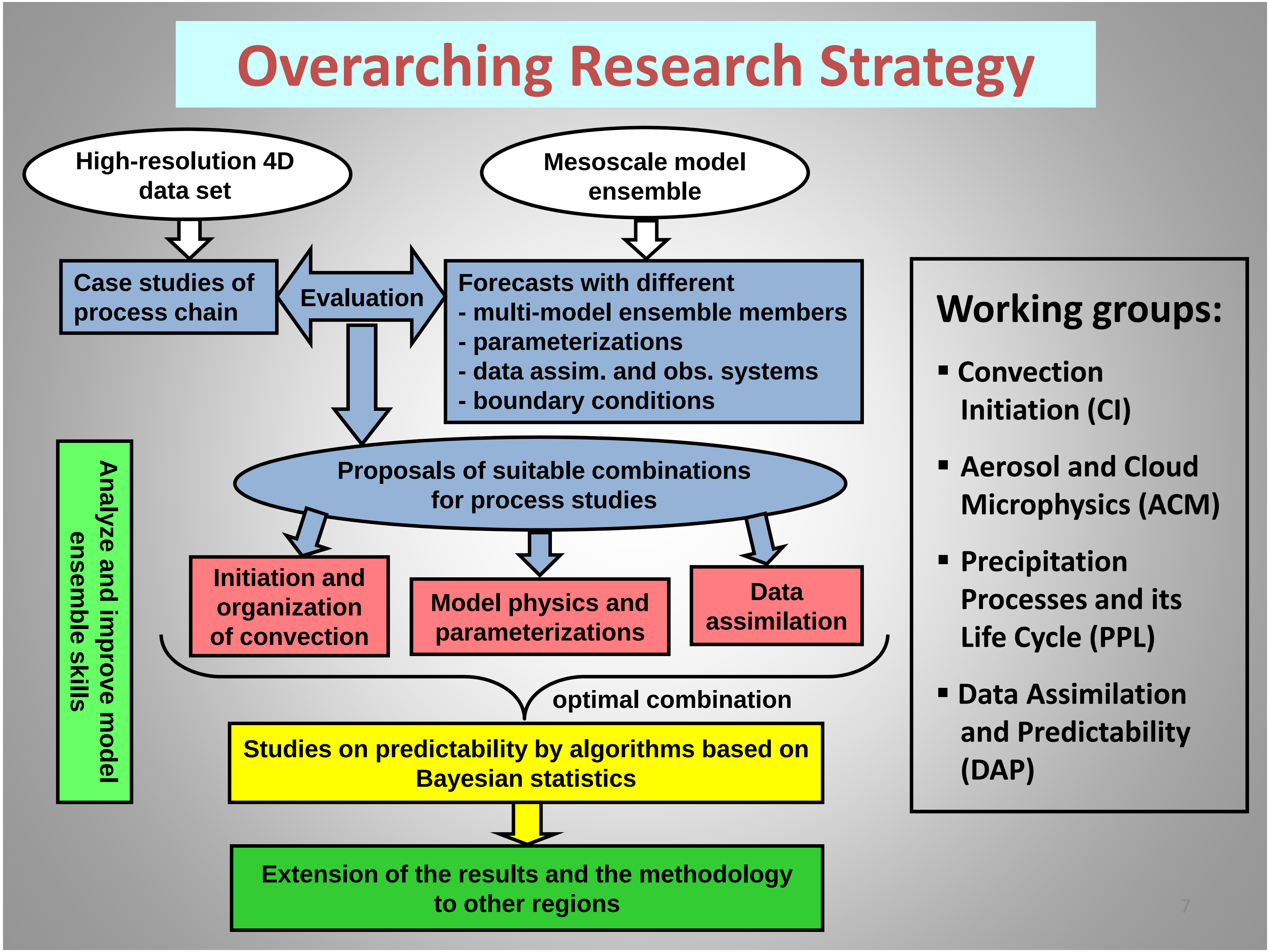
Transport and Chemical Conversion in Convective Systems (COPS-TRACKS)
Period: 16.07. – 02.08.2007

Atmospheric Radiation Measurement (ARM) Program Mobile Facility (AMF)
Period: 01.04. – 31.12.2007

Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region (D-PHASE),
WWRP Forecast Demonstration Project (FDP)
Period: 01.06. – 30.11.2007

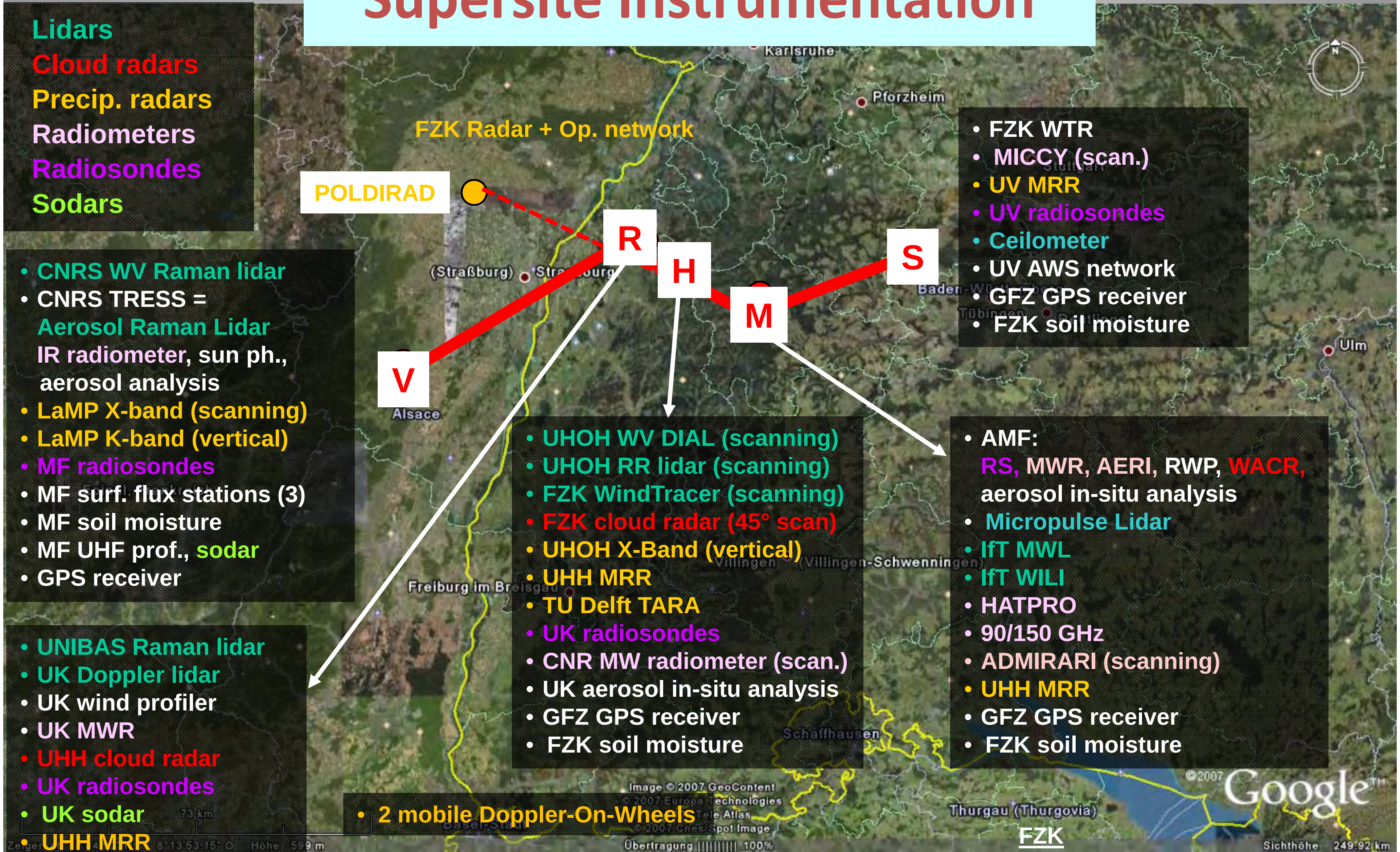
European THORPEX Regional Campaign 2007 (ETReC 2007)
Period: 01.07. – 01.08.2007

EUMETSAT special satellite operation modes and data
Period: 01.06. – 31.08.2007



Overarching Research Strategy
High-resolution 4D data set
Mesoscale model ensemble
Case studies of process chain
Evaluation
Forecasts with different
- multi-model ensemble members
- parameterizations
- data assim. and obs. systems
- boundary conditions
Analyze and improve model ensemble skills
Proposals of suitable combinations for process studies
Initiation and organization of convection
Model physics and parameterizations
Data assimilation
optimal combination
Studies on predictability by algorithms based on Bayesian statistics
Extension of the results and the methodology to other regions
Working groups:
▪ Convection Initiation (CI)
▪ Aerosol and Cloud Microphysics (ACM)
▪ Precipitation Processes and its Life Cycle (PPL)
▪ Data Assimilation and Predictability (DAP)
7

Supersite Instrumentation



• GFZ GPS receiver
• FZK soil moisture

• 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

AMF Supersite in the Murg Valley

COPS Supersite Hornisgrinde

Data Sets (see cera-www.dkrz.de/WDCC/ui/BrowseExperiments.jsp)

Radiation: Energie balance network, AMF, CM-SAF, and Land-SAF retrievals

Land-surface exchange: Soil moisture, turbulence, and weather stations

ABL and CI: Active-passive VIS-IR-MW remote sensing synergy, soundings, GPS network, MSG Rapid Scan Service (RSS)

ACM: In-situ, AERI-MWR-lidar-radar synergy, MSG RSS

Precip: In-situ, micro rain radar, DOW, polarization and weather radar

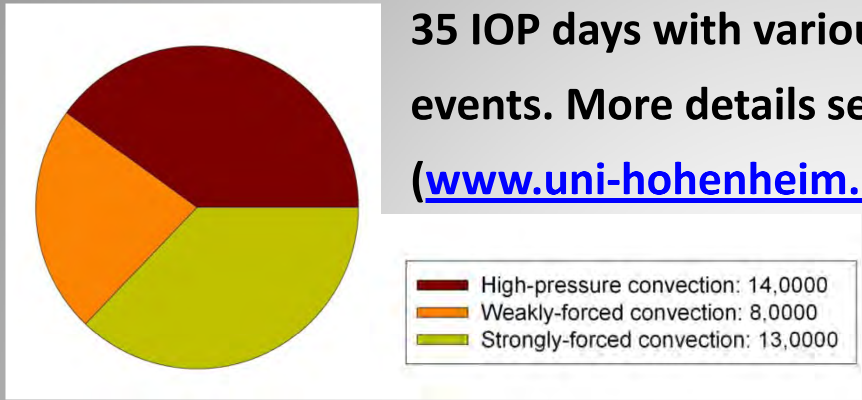
D-PHASE Model Ensemble:

- 6 LAM ensemble forecast systems
- 12 deterministic models with convection parameterization
- 9 convection permitting deterministic models
- Harmonized and extended data set in GRIB1 following the so-called TIGGE+ table

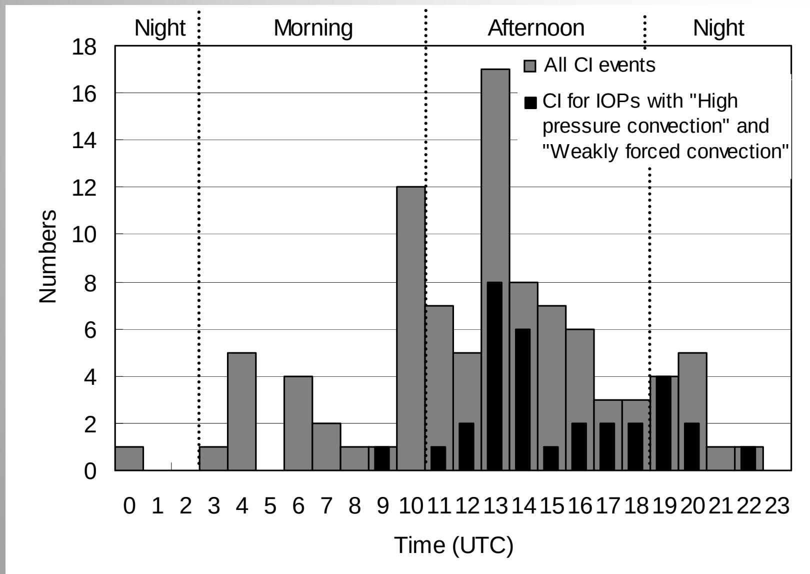
Short COPS statistics:

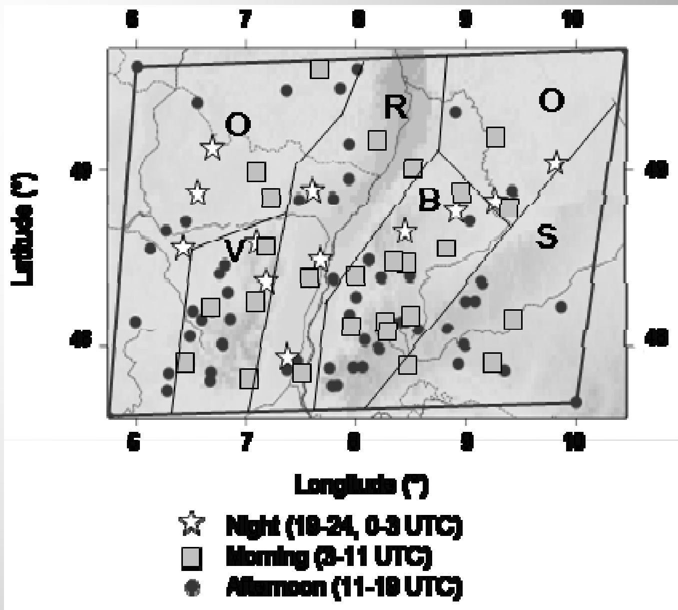
- 2,700 soundings
- 11,000 h of lidar operation
- 10 aircraft with 400 flights hours
- 10,000 model runs with 50,000,000 model fields and plots (COPS domain)
- 60TB of data

COPS Overview



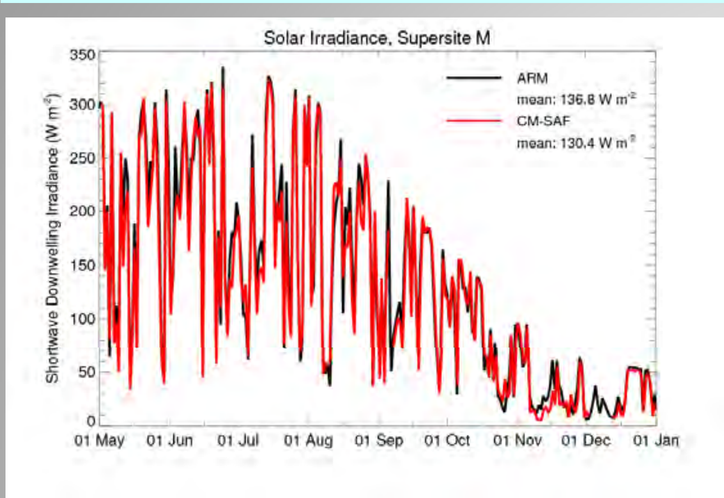
35 IOP days with various forcing conditions and several extreme events. More details see COPS Field Report and COPS web sites (www.uni-hohenheim.de/cops, www.arm.gov/sites/amf/blackforest).

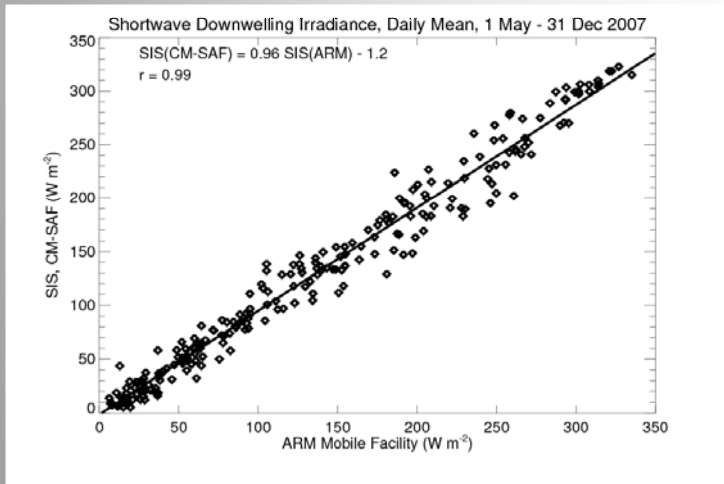


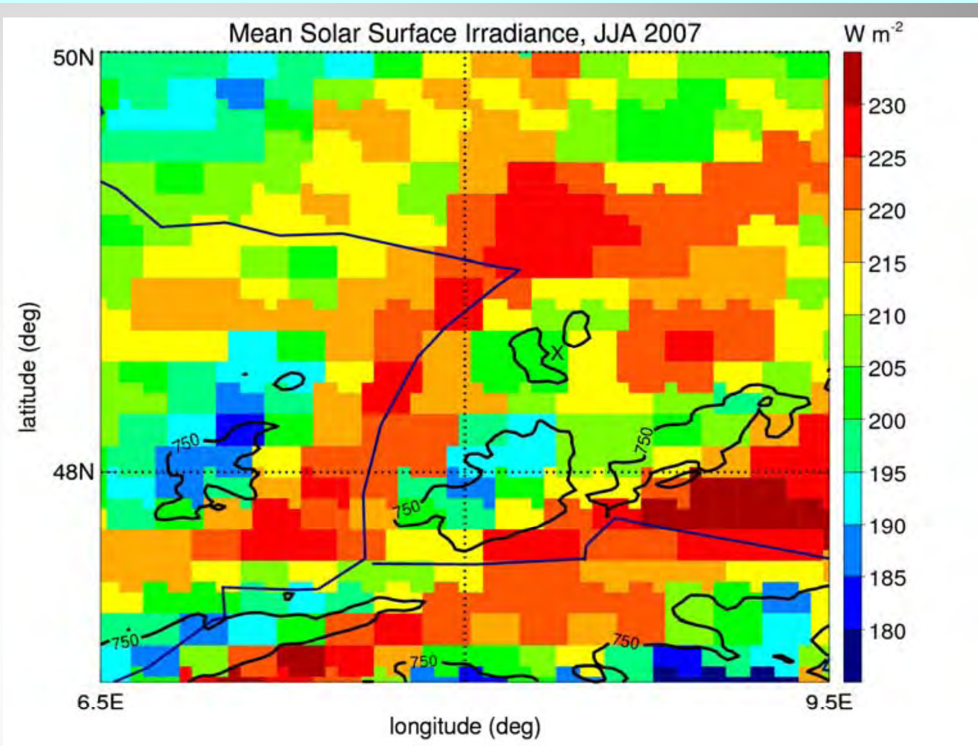


Diurnal cycle and spatial distribution of convection (*Aoshima et al., Meteorol. Z. 2008*)

Validation of CM-SAF (MSG)-Retrieved Incoming Solar Irradiance at AMF Site





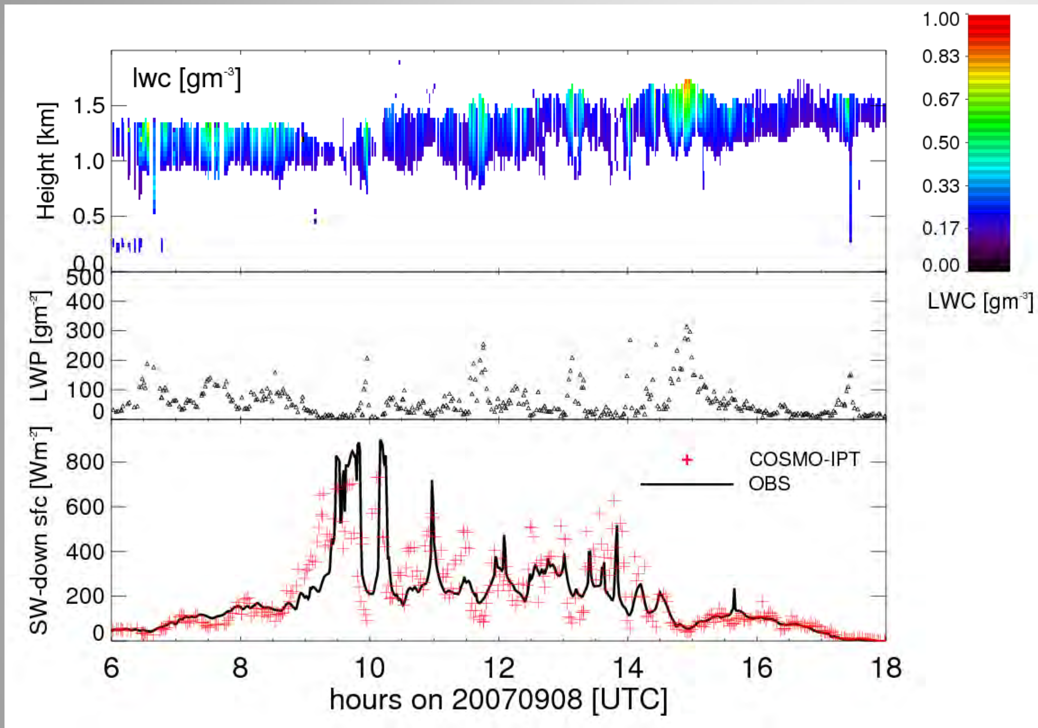


- **Excellent correlation of CM-SAF-derived solar irradiance with AMF observations**
- **Further details about CM-SAF products: www.cmsaf.eu at EUMETSAT and Schulz et al. ACP 2009; Mueller et al. RSE 2009**
- **Cloud microphysics: see Ayers, poster D10**

Courtesy Jörg Trentmann, DWD

Retrieval of Cloud-Microphysics and Radiation

1DVAR retrievals using Integrated Profiling Technique (IPT) over AMF site



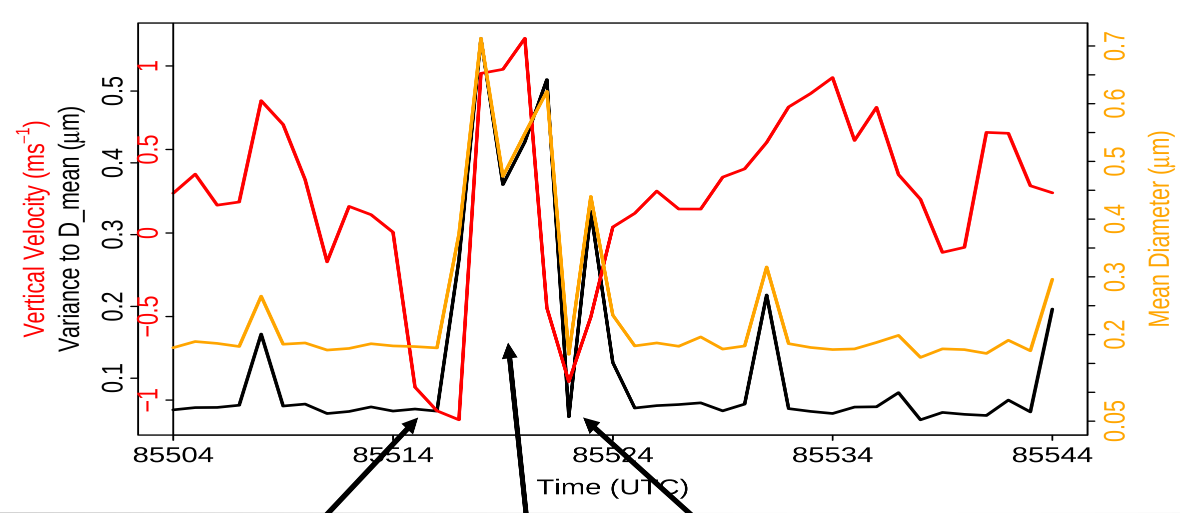
Courtesy Kerstin Ebell, University of Cologne, see also corresponding poster J1, and Löhnert et al. JTECH 2008.

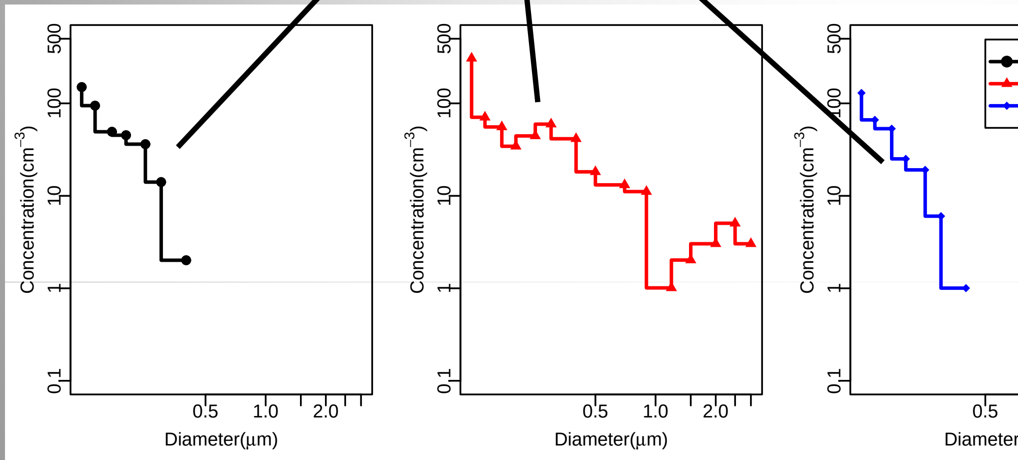
Further data sets:

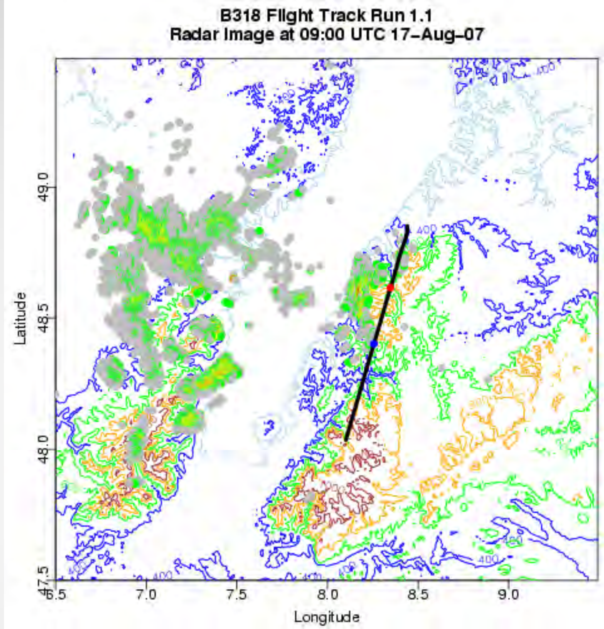
- **IPT retrievals: Ulrich Löhnert**
- **Cloudnet retrievals: Ewan O'Connor and Robin Hogan (www.cloudnet.org/quicklooks/arm-murgtal_products.html#classification)**
- **LWP and PWC: Dave Turner (iop.archive.arm.gov/arm- iop/0pi-data/turner) and Ulrich Löhnert (gop.meteo.uni-koeln.de/hatpro/doku.php)**
- **AOT: Dave Turner**

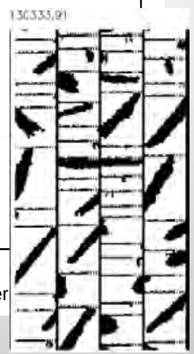
Aerosol Transport and Microphysics

BAE 146 measurements during SOP7, August 17, 2007





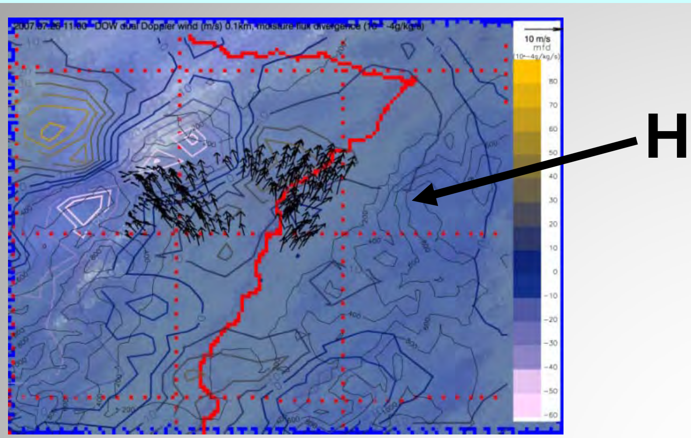




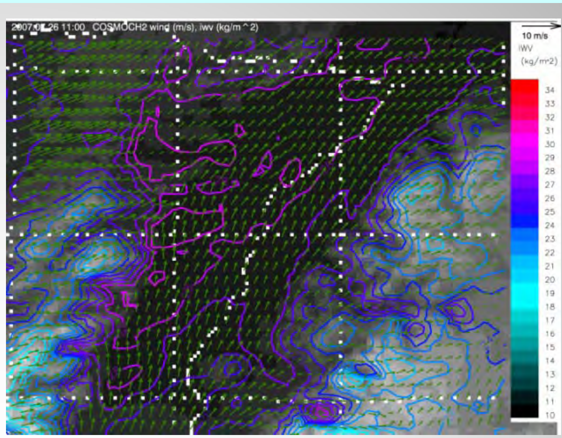
- **Aerosol venting causes special microphysical properties.**
- **Huge data set available for relating these to cloud and precipitation properties.**

Courtesy Alan Blyth, University of Leeds

Shallow and Organized Convection Study With Radar and Water-vapor Lidar (IOP11b, July 26, 2007)



DOW radial and dual Doppler wind field (Tammy Weckwerth, NCAR)

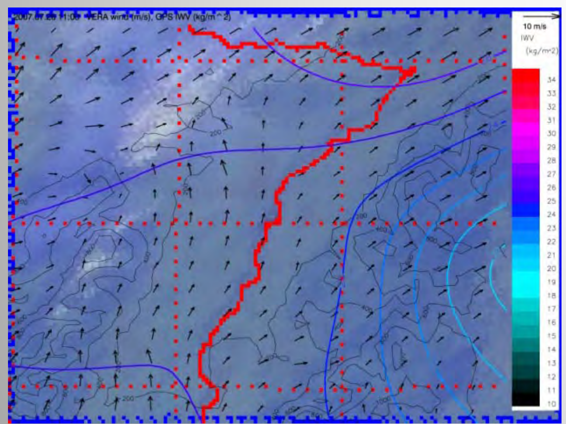


COSMO2, Meteo Swiss

COSMO models too moist, surface wind field agreed neither with VERA nor with radar.

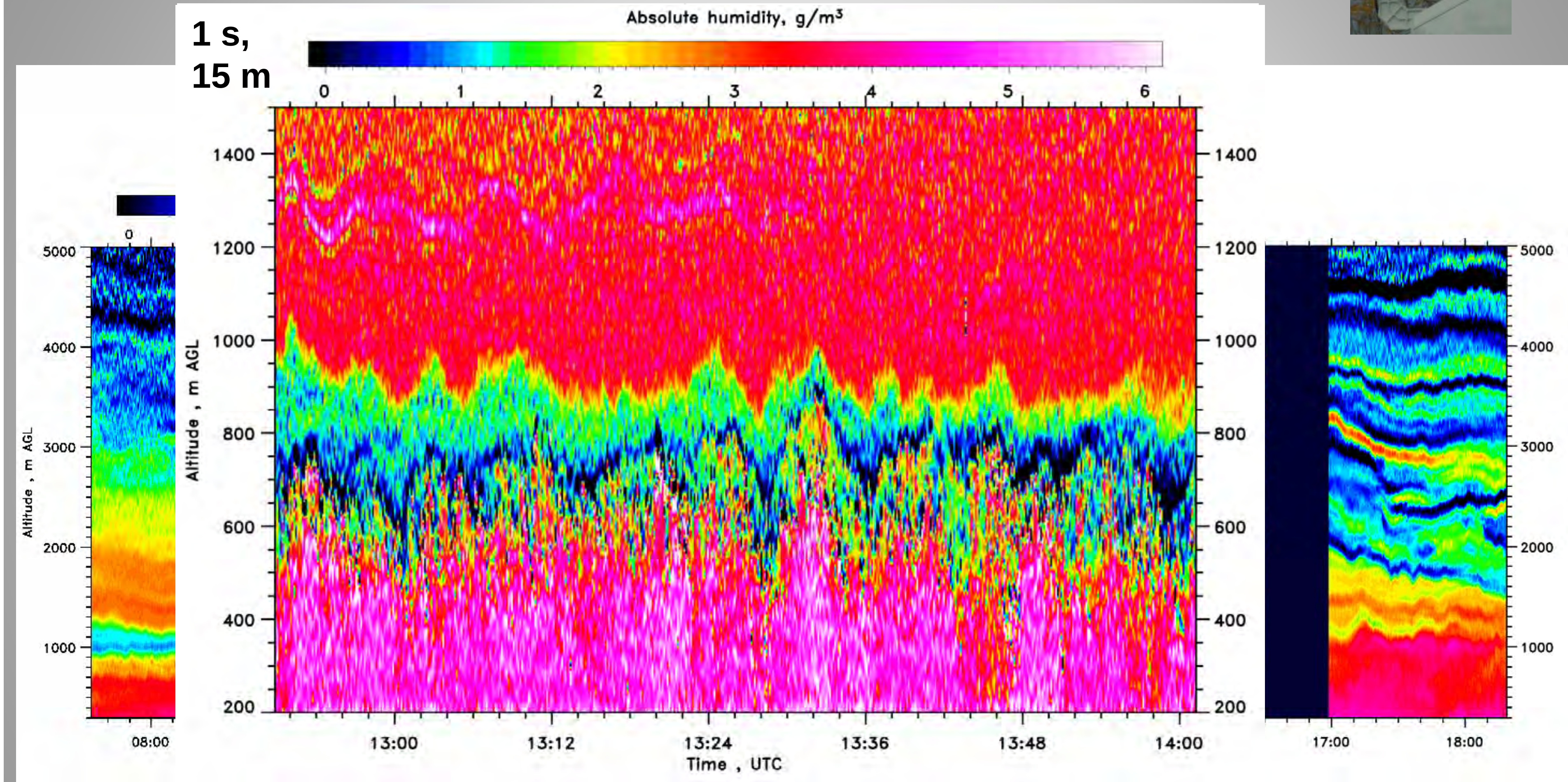
European radar data set (LOS and dual Doppler of DWD, Meteo France, and Meteo Swiss) will also be applied.

LOS wind comparison and data assimilation efforts in preparation using forward operator.



University of Vienna VERA analysis, Manfred Dorninger
GPS IWV field: Galina Dick, GFZ, Potsdam

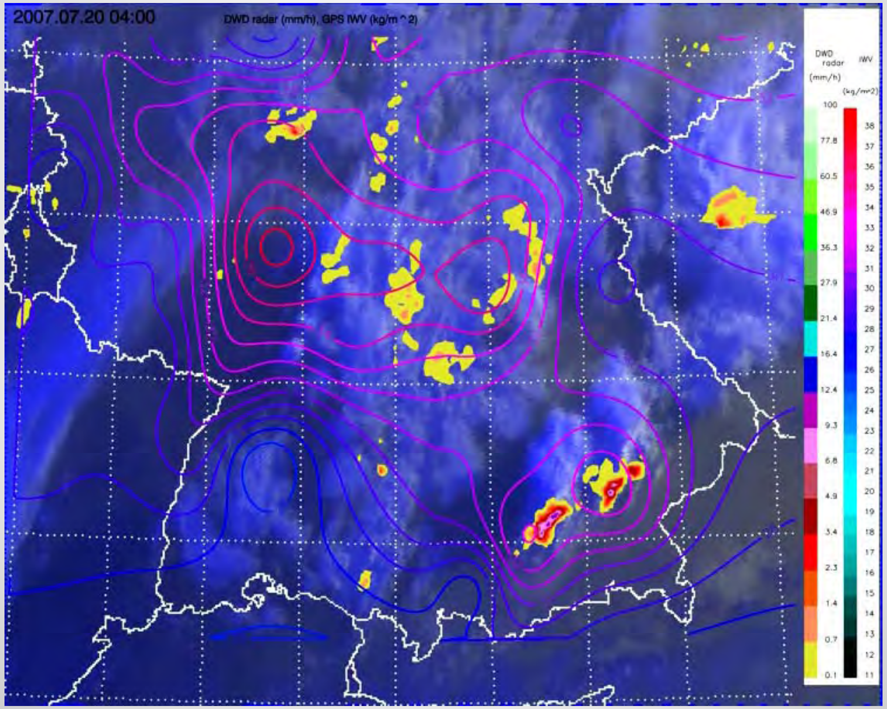
IPM Water-vapor Differential Absorption Lidar Measurement During IOP11b, July 26, 2007



More details on DOW and DIAL see Wulfmeyer, poster D13
Comparison with ACRF Raman lidar: Wagner, poster J7

CI Study During Extreme Event: IOP9c, July 26, 2007

Orographically-induced transformation of a mesoscale convective system with prefrontal convergence line

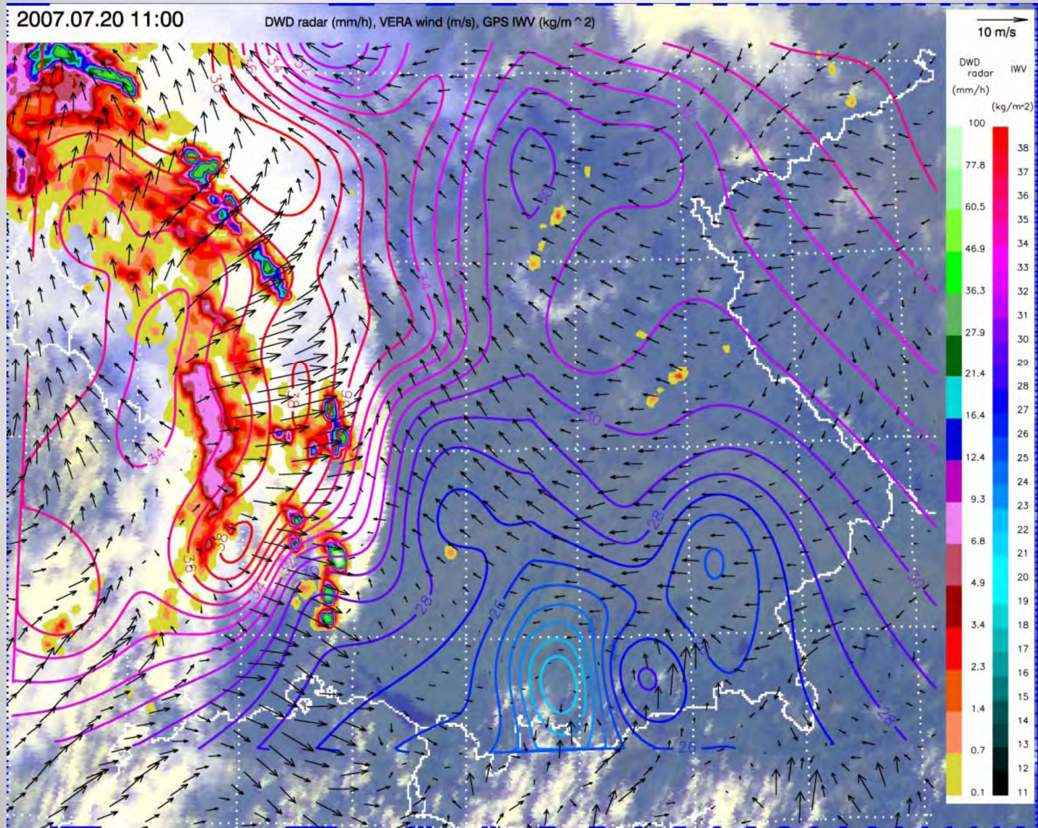


Overlay of GPS IWV, MSG RSS three-channel composite, DWD radar network

Fumiko Aoshima, IPM

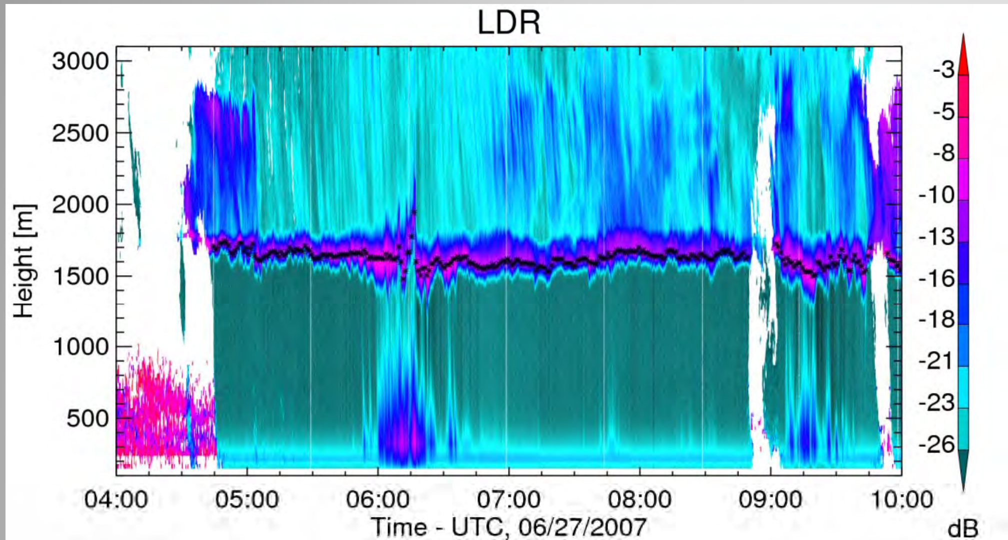
CI Study During Extreme Event: IOP9c, July 26, 2007

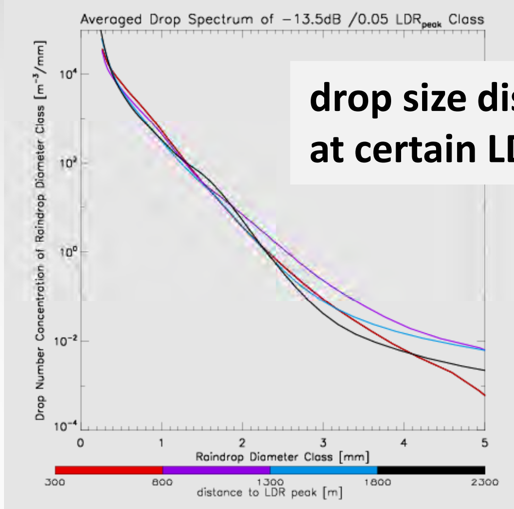
MSG RSS, GPS IWV, DWD radar + VERA surface wind field



Further observation overlays in preparation: MSG all channels and its combinations, VERA surface analyses to be compared with D-PHASE model outputs.

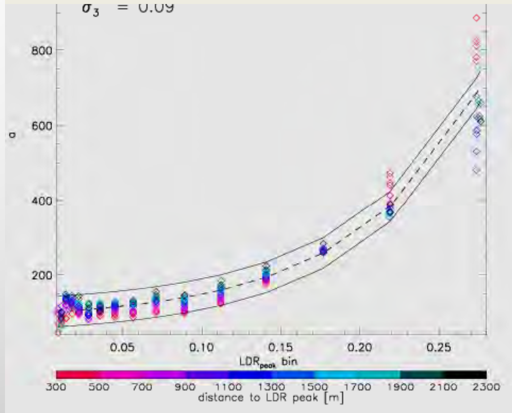
Precipitation-Microphysics
35-GHz cloud radar / 24.1-GHz micro rain radar synergy





drop size distribution at certain LDR class

$$a = (6079 \cdot 10^{3LDR} + 81.35)\frac{\mathrm{mm}^6}{\mathrm{m}^3}\left(\frac{mm}{h}\right)^{-b}$$



Combination of cloud-radar linear depolarization ratio (LDR) measurement with rain drop size distribution measurement from MRR delivers new relationship for stratiform rain:

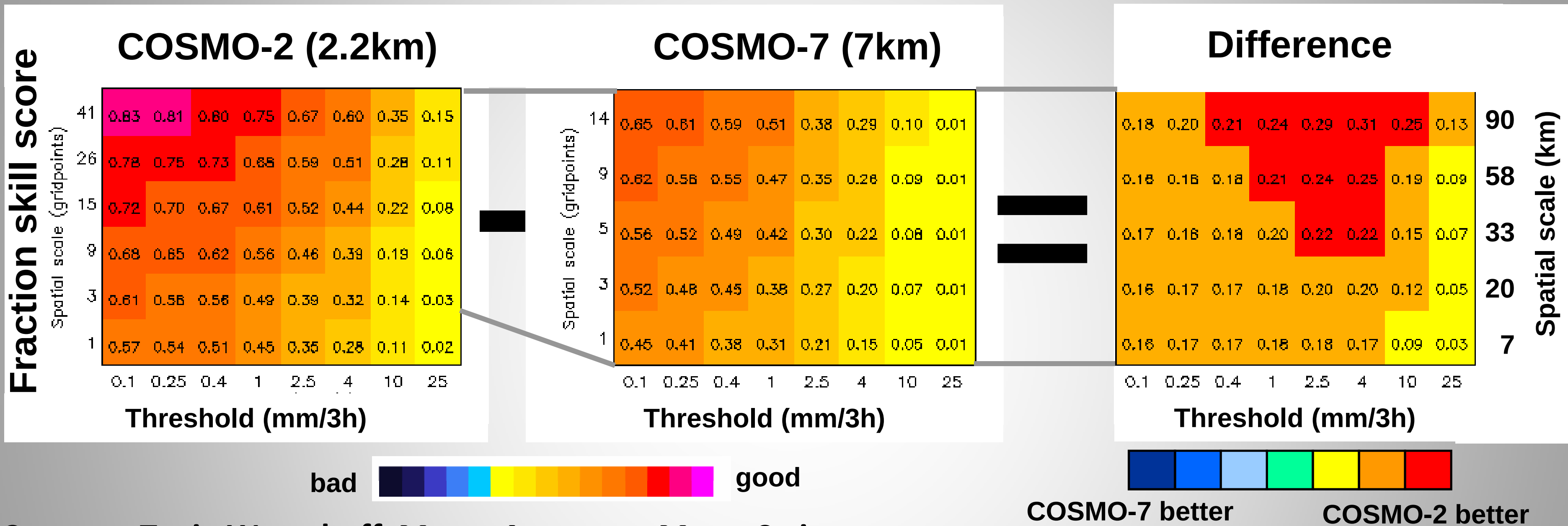
$$Z = a(LDR) \cdot R^{b(LDR)} \text{ with } b \approx 1$$

Courtesy Gerhard Peters, S. Kowalewski, University of Hamburg, 2009

For WACR see also Luke, poster B7

D-PHASE Model Verification Over Switzerland

JJA 2007, Verification against Swiss Radar Composite,
3 hourly accumulations, rain events only



Courtesy Tanja Weusthoff, Marco Arpagaus, MeteoSwiss

+ Clear improvement of diurnal cycle of precipitation

+ Substantial reduction of windward/lee effect

Huge model verification efforts ongoing in COPS and D-PHASE domains

See WWRP website of JWGV and Hogan, poster F4

COPS Publications and Links

- Website: www.uni-hohenheim.de/cops/
- Central data archives: cera-www.dkrz.de/WDCC/, with publication data base (12 refereed pubs, 100 at conferences), www.archive.arm.gov, gop.meteo.uni-koeln.de
- Recent highlight: Dec. 2008 Special Issue on QPF of published in Meteorologische Zeitschrift see www.metzet.de
- 32 externally funded projects (mainly COPS-France, COPS-UK, DFG)
- 8 Master and Diploma theses, 17 PhD theses and 19 Postdocs
- COPS Special Issue in QJRMS in preparation
- Huge potential for further joint ARM-European projects
- Further details: COPS Breakout Session, today, 1-3 pm

COPS Highlights

ACM: Emerging picture of orographically-induced microphysical properties of clouds and precipitation

CI: Thermally induced flows critical for initiation and organization of convection under all forcing conditions.

PPL: New sensor synergy applied, e.g., for the determination of Z-R-relationships

New remote sensing technology and its synergy demonstrated

DAS: Indispensable tool for improvement of QPF and evaluation of model physics on the mesoscale

Large number of new, harmonized data sets in complex terrain

Superior performance of convection permitting models. Strong implications on the development of forecast systems and regional climate models expected.