QUEST

Quantitative Evaluation of Regional Precipitation Forecasts using Multi-Dimensional Remote Sensing Observations

S. Eikenberg[1] and the QUEST team

[1] *Institute of Geophysics and Meteorology, University of Cologne*

PQP kick-out meeting, Bonn, Germany, 14-15/04/2010

General Overview QUEST

Validating IWCs in GME, COSMO-EU, and COSMO-DE with CloudSat CPR data

QUEST: 2004-2012

Partnership

- Susanne Crewell, Sonja Eikenberg, University of Cologne (*IGMK*)
- Jürgen Fischer, Stefan Stapelberg, FU Berlin (*FUB*)
- George Craig, Martin Hagen, Christian, Keil, Peter Sinigoj (*LMU, DLR*)
- Felix Ament, Suraj Polade, University of Hamburg (*UH*)
- Axel Seifert, Deutscher Wetterdienst (*DWD*)
- Nicole van Lipzig, Tim Böhme, Katholieke U. Leuven (*KUL*), Belgium

1st Phase	**2nd Phase**	**3rd Phase**
PI Craig/Hagen (DLR) PI Crewell (LMU) PI Fischer (FUB)	PI Baldauf (DWD) PI Craig/Hagen (DLR) PI Crewell (IGMK) PI Fischer (FUB) PI van Lipzig (KUL)	PI Ament (UH) PI Craig/Hagen (DLR) PI Crewell (IGMK) PI Fischer (FUB) PI Seifert (DWD)
van Lipzig (LMU) Ament (LMU) Schröder (FUB) Pfeifer (DLR)	Reinhardt (IGMK) Hünerbein (FUB) Pfeifer (DLR)	Reinhardt (IGMK) Eikenberg (IGMK) Stapelberg (FUB) Polade (UH) Sinigoj (DLR)

QUEST-B PI van Lipzig

Goals

Contributes to PQP goals

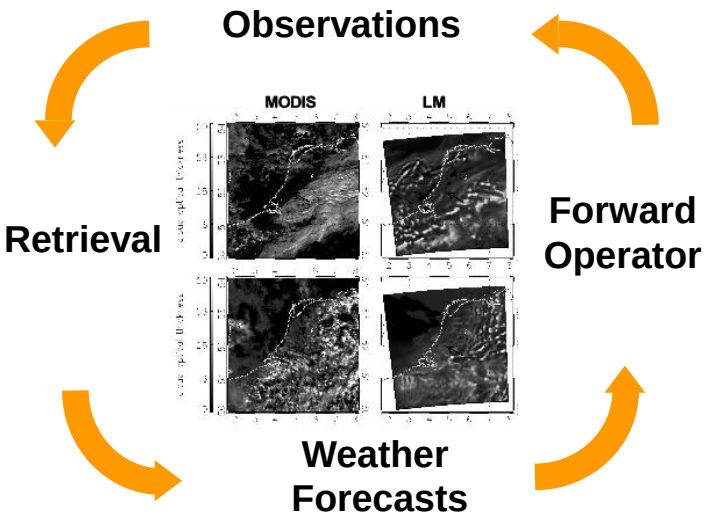
(1) Identification of physical and chemical processes responsible for the deficiencies in quantitative precipitation forecast

(2) Determination and use of the potentials of existing and new data and process descriptions to improve quantitative precipitation forecast

Evaluation of QPF using new remote sensing observations

- Considering the spatial-temporal structure of water in all its three phases
- Studying the whole process chain from the water vapour to surface precipitation
- Identifying weaknesses in the treatment of cloud processes in NWP (COSMO)
- Improving assumptions on cloud and precipitation microphysics (e.g., conversion rates, drop size distributions, particle phase and shape), as well as land surface and radiation parameterizations

Strategy



- Evaluating mesoscale model forecasts (COSMO) of water cycle variables
  - Remote sensing data currently not used in routine model verification
  - Radar/satellite observations with resolution comparable to high-resolution NWP models
  - Polarimetric radar & millimetre wave radiometry for hydrometeors
  - Life cycle of clouds and precipitating cells from model/reality

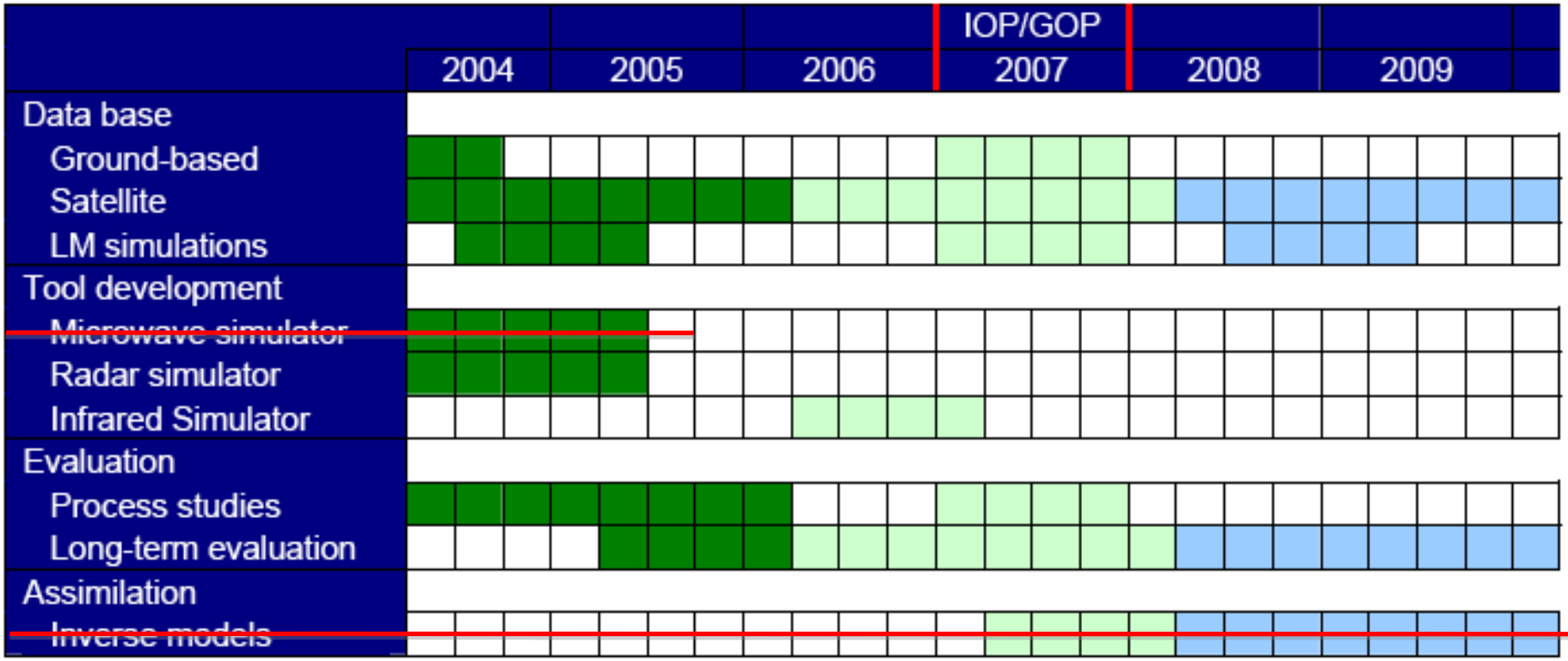
- Combining detailed case study investigations and long-term model evaluations:

  General Observation Period GOP
- Identifying systematic model deficits by averaging out stochastic errors
- Changing model physics (strong cooperation with DWD) in order to attribute the errors to the treatment of specific processes

Time Table

From first proposal:

Table 2: Outline implementation plan for QUEST during the SPP lifetime. Three different colours are used to highlight the threeSPP phases. The first phase (dark green) is described in detail below.



Contribution by Jörg Schulz was not funded

Time Table

Table 1. Summary and time table of work packages of QUEST during the 3rd phase of the SPP.

WP	Tasks	I	II	III	IV	I	II	III	IV
1	**Coordination**								
	Project meetings (all)	x			x			x	
	Implementation: Testbed and tools (IGMK)								
2	**Model Evaluation**								
	Representation of water vapour (FUB, IGMK)								
	Development of clouds (FUB, IGMK)								
	Regime related deficits (IGMK,KUL, DWD)								
	D-Phase generalization (UHH) + third year								
	Error structures hydrological cycle (IGMK,UHH)								
3	**Model Improvement**								
	Boundary layer evolution (IGMK, DWD)								
	Cloud microphysics (DLR, DWD)								
	Cloud radiative interaction (IGMK,DWD)								
	Ensemble evaluation (UHH) + third year								

Publications 1st Phase

Tool development

- **Pfeifer, M.; G. Craig, M. Hagen**, and C. Keil, 2008: A polarimetric radar forward operator for model evaluation. *Journal of Applied Meteorology and Climatology*, 47, 3202-3220.

- Mech, M., **S. Crewell**, I. Meirold-Mautner, C. Prigent, and J.-P. Chaboureau, 2007: Information content of millimeter observations for hydrometeor properties in mid-latitudes. *IEEE Trans. Geosci*. 45(7), 2287-2298

Case Study for WMO International Cloud Modeling Workshop

- **Schröder, M., N. P. M. van Lipzig, ,F. Ament**., J.-P. Chaboureau, **S. Crewell, J. Fischer**, V. Matthias, E. van Meijgaard., A. Walther, and U. Willén, 2006: The representation of low-level clouds in atmospheric models: Part II: Spatial distribution from satellite remote sensing during the BALTEX Bridge Campaigns. *Atmos. Res.* 82(1-2), 83-101.

- **Van Lipzig, N.P.M., M. Schröder, S. Crewell, F. Ament,** J.-P. Chaboureau, **U. Löhnert**, V. Matthias, E. van Meijgaard, M. Quante, U. Willén, and W. Yen, 2006: Model predicted low-level cloud parameters. Part I: Comparison with observations from the BALTEX Bridge Campaigns. *Atmos. Res.* 82(1-2), 55-82.

→ Modeled and observed cloud structure are different (*patchiness, vertical extent, life time, …)*

→ Shallow convection scheme gives no significant benefit.

Publications 2nd Phase

Long-term evaluation

- **Crewell, S.,** M. Mech**, T. Reinhardt,** C. Selbach, H.-D. Betz, E. Brocard, G. Dick, E. O'Connor, **J. Fischer**, T. Hanisch, T. Hauf, **A. Hünerbein**, L. Delobbe, A. Mathes, G. Peters, H. Wernli, M. Wiegner and V. Wulfmeyer, 2008: The General Observation Period 2007 within the Priority Programm on Quantitative Precipitation Forecasting: Concept and first results. *Meteorol. Z.*, 17(6), 849-866.

  → Presentation of GOP observation and COSMO.DE /-EU data set

  → Impact of daytime radiosonde dry bias on COSMO water vapor, MSG SEVIRI BT, and cloud base height …

Case Studies

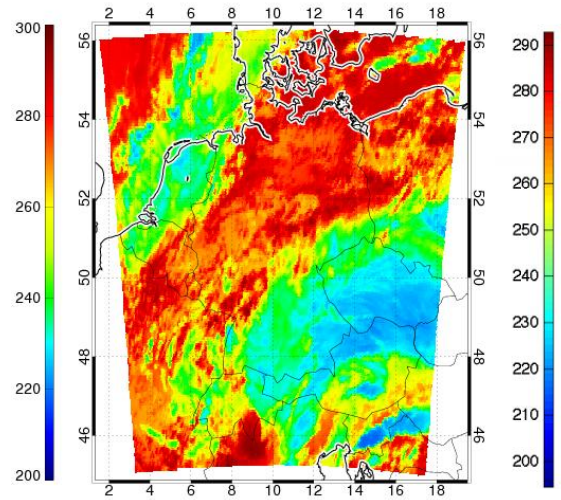
- **Pfeifer, M**., W. Yen, **M. Hagen, G. Craig, T. Reinhardt**, M. Mech, **S. Crewell, A. Hünerbein, J. Fischer, M. Schröder**, and **M. Baldauf**, 2008: Validating precipitation forecasts using sensor synergy: The case study approach, revised 31.3.2010.

  → Inconsistency of high clouds, snow generation, and surface precipitation

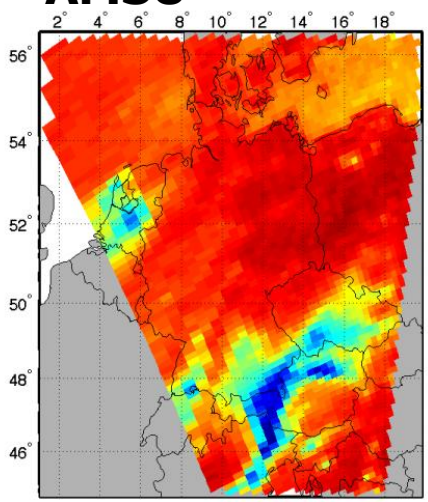
  → Similar number of convective systems but timing difference

Pfeifer et al., 2010: Case study approach: 3/8/2006 11 UTC

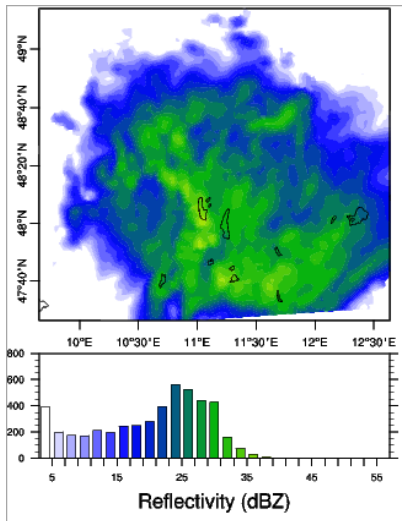
TB@10.8 μm MSG



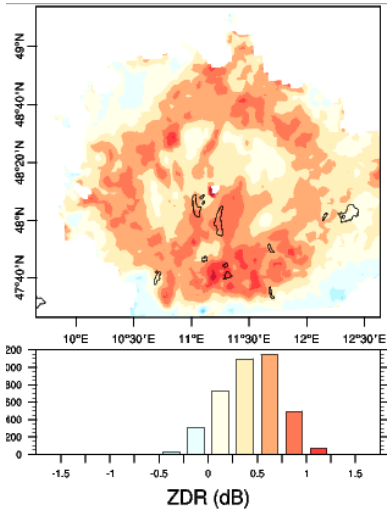
TB@150 GHz AMSU



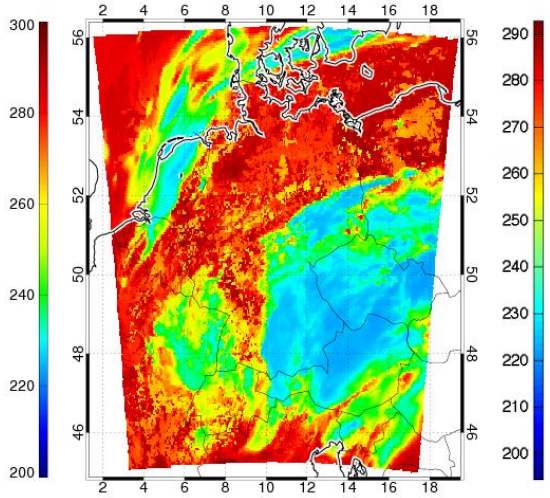
POLDIRAD Z

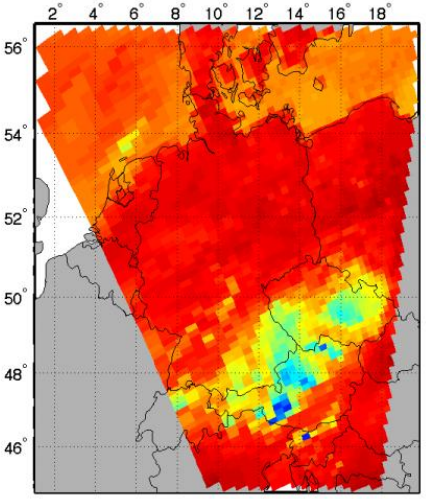


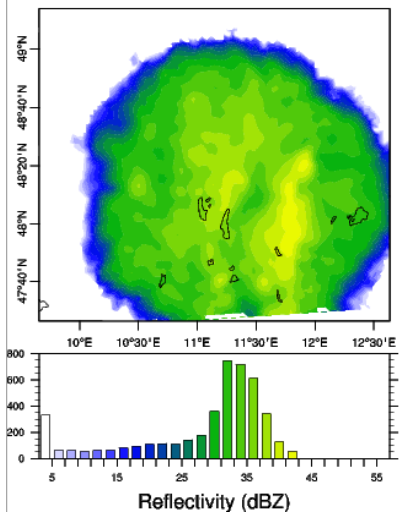
ZDR

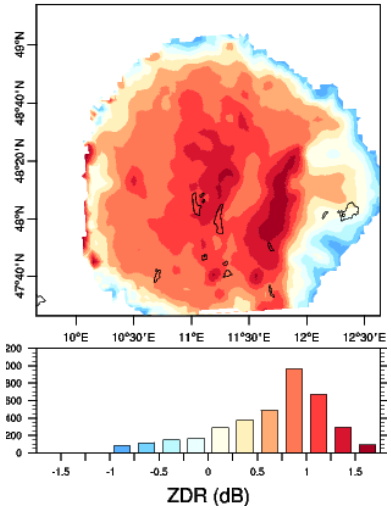


COSMO-DE









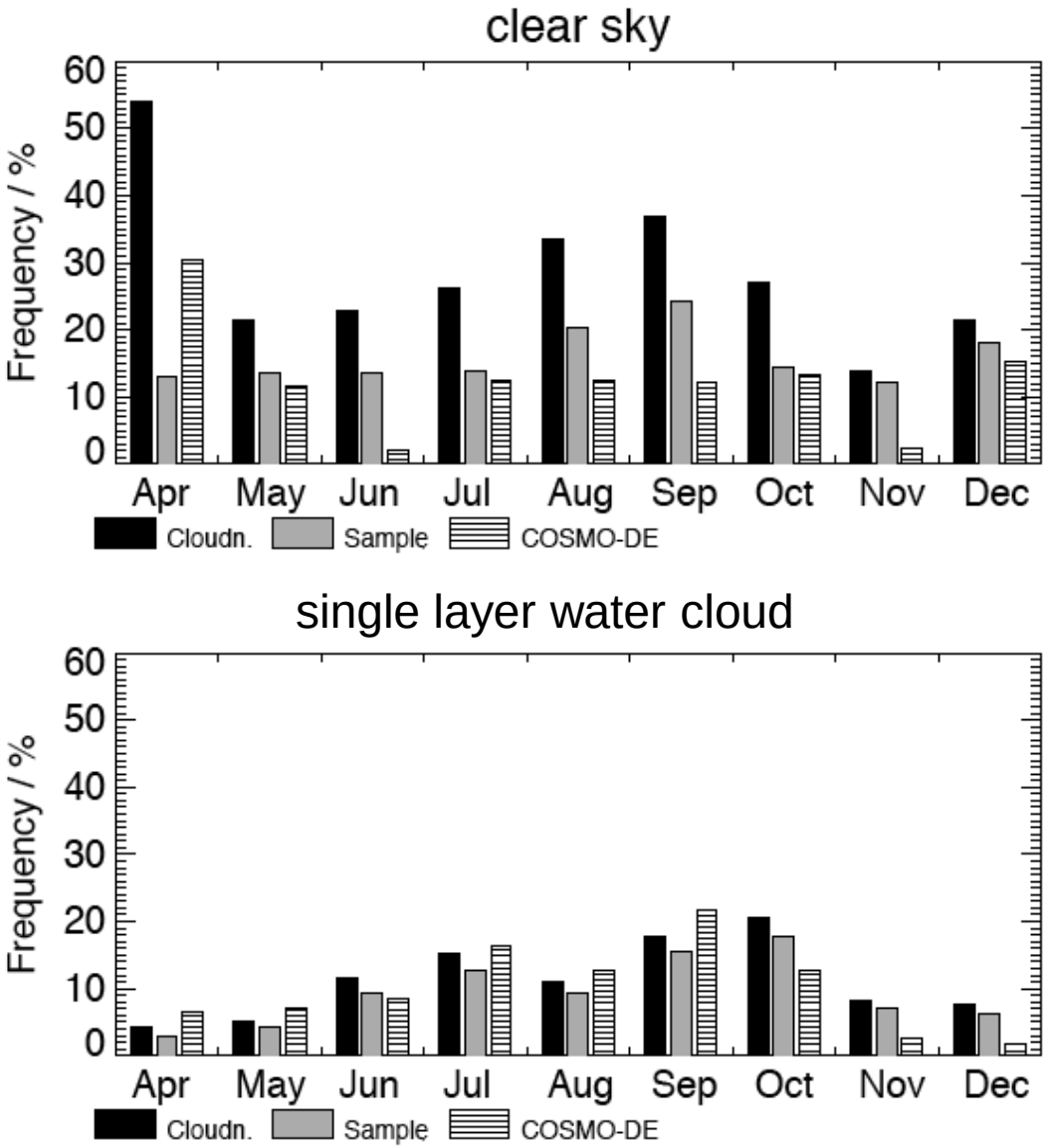
Upcoming publications

- Ebell, K., **S. Crewell**, U. Löhnert, D. D. Turner, E. O'Connor, 2010: Cloud statistics and cloud radiative effect for a low-mountain site, Q. J. Royal. Met. Soc. submitted COPS special issue
- **Akkermans, T.**, **T. Böhme**, M. Demuzere, **S. Crewell**, C. Selbach, **T. Reinhardt, A. Seifert**, and **N. P. M. Van Lipzig**, 2010: Regime-dependent evaluation of accumulated precipitation in the COSMO model to be submitted to Met. Z. next week.

  → Talk by Tim Böhme / Kwinten van Weverberg
- **Stapelberg, S., T. Akkermans, F. Ament, T. Böhme, S. Crewell, J. Fischer, C. Selbach, T. Reinhardt, A. Seifert,** and **N. P. M. Van Lipzig**, 2010: Long-term evaluation of water cycle parameters: Seasonal and diurnal cycles, to be submitted special issue of Met. Z

  → Talk by Stefan Stapelberg
- **Polade, S., F. Ament**, 2010: Evaluation of the Atmospheric Water Cycle Predicted by MAP D-PHASE Models using GOP Observations, APCD
- **Ludwig, A.:** Evaluation of humidity, clouds, and precipitation in COSMO-CLM and MSG.
- **Ament, F.** and **C. Selbach**: Ceilometer observations for model evaluation: direct vs probablistic assessment.
- **Eikenberg, S**., K. Fröhlich, **A. Seifert**, and **S. Crewell**: GME prognostic ice cloud scheme and evaluation with Cloudsat, to be submitted to Geophys. Res. Lett.
- **Feiertag, N.,** and **S. Stapelberg:** System tracking with radar and satellite.

Ebell et al., 2010: AMF and COPS

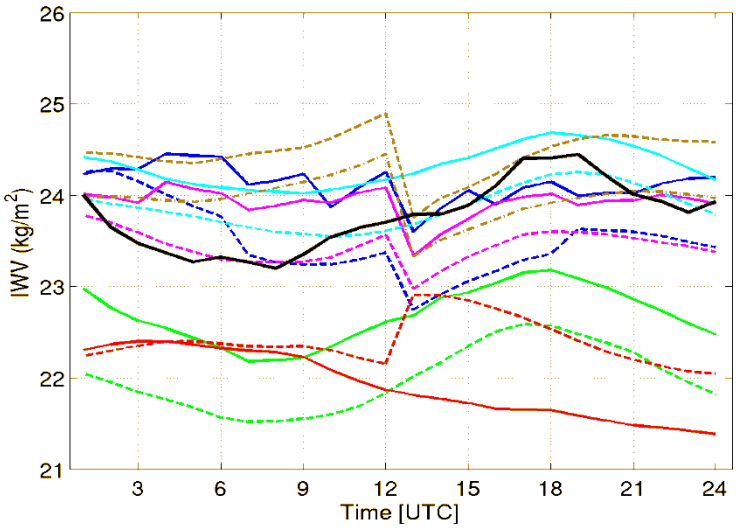


Cloud statistics and cloud radiative effect with long-term cloud observations (CloudNet, 04-12/2007) over orographic terrain (ARM Mobile Facility (AMF) at Murg valley)

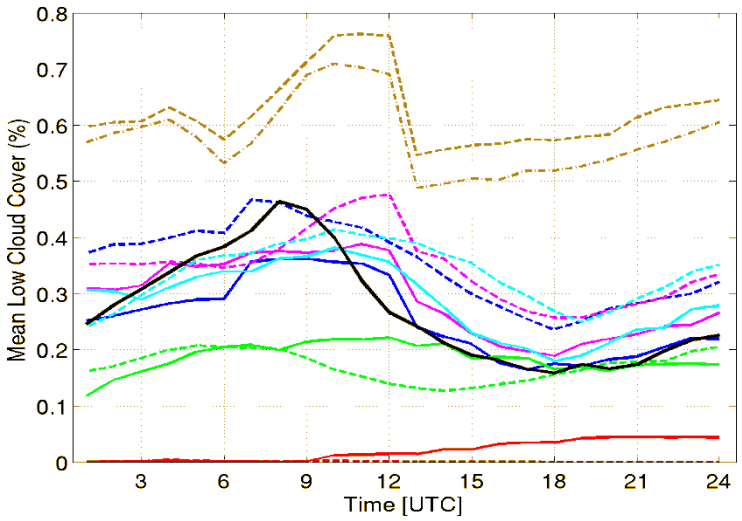
What is the problem with clear sky?

Polade and Ament, 2010: LTE

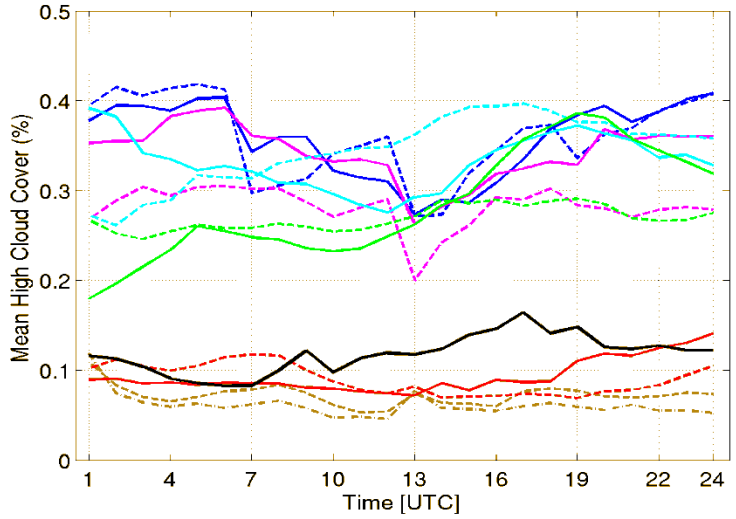
IWV



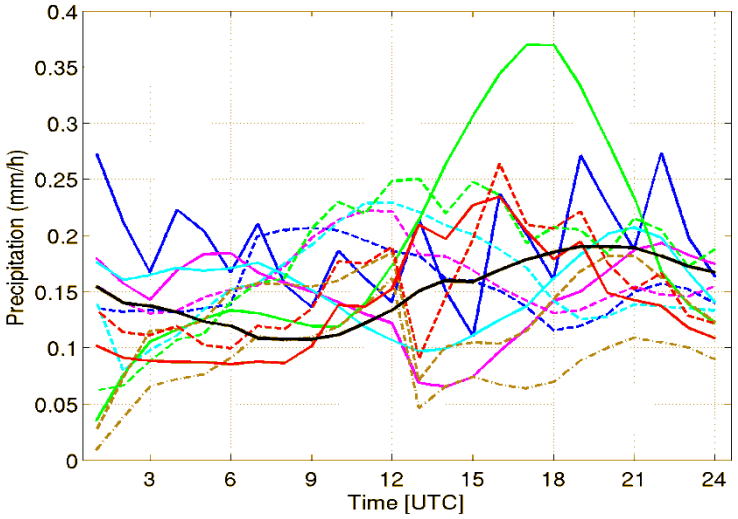
Low cloud cover

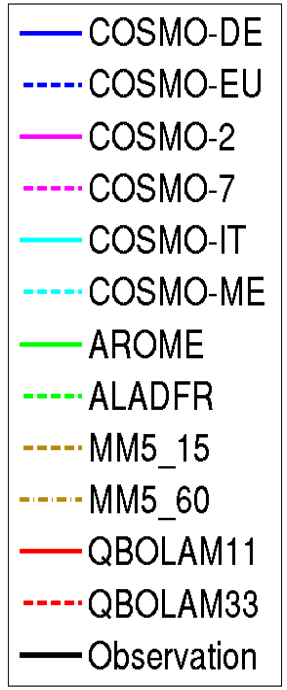


High cloud cover



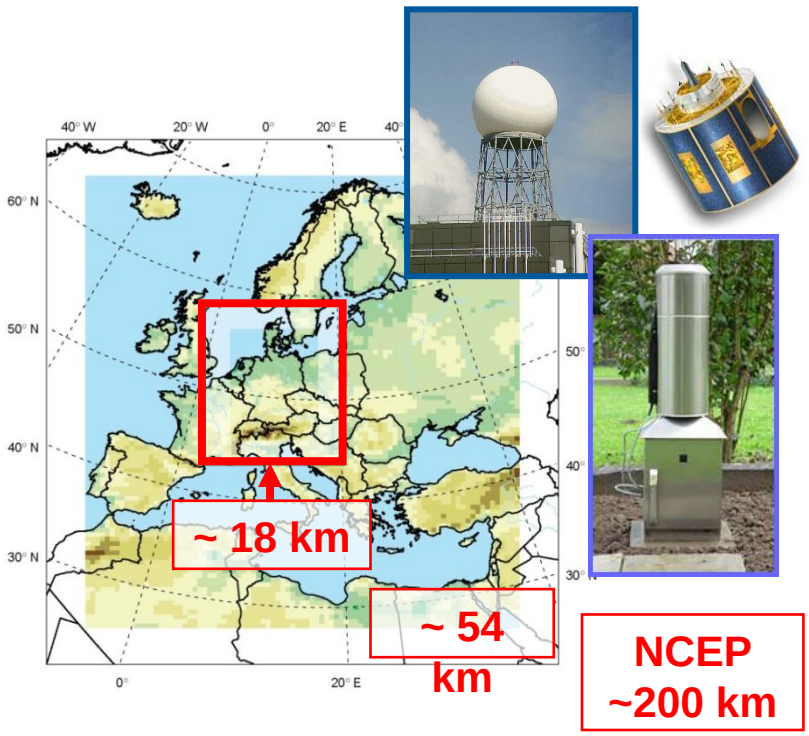
Precipitation

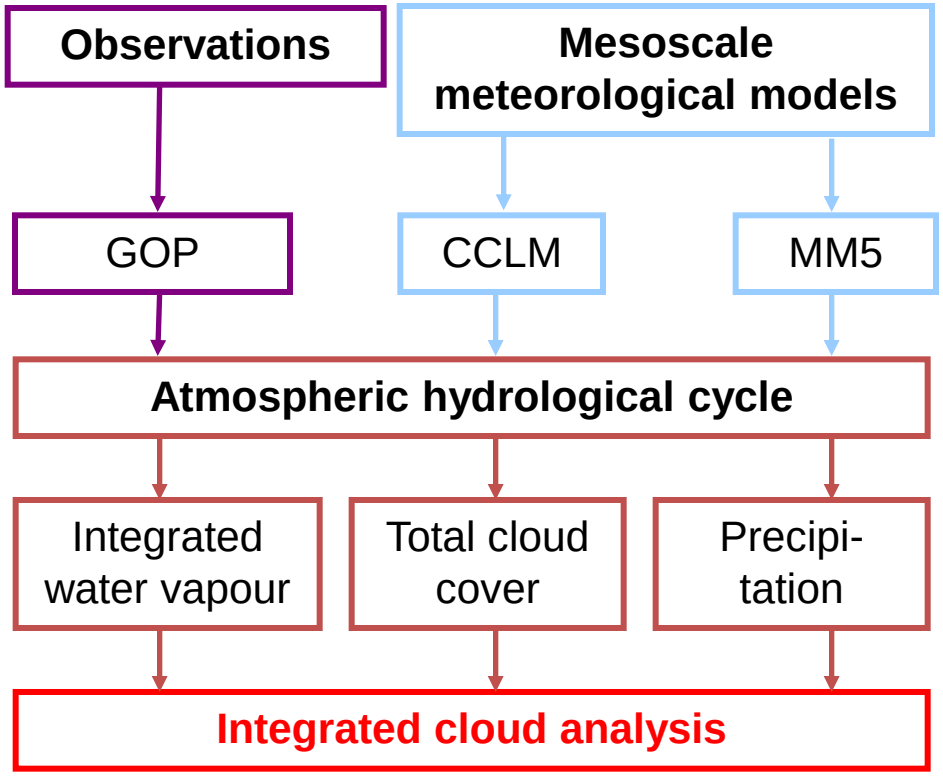




Ludwig, Ament, and Rockel

Evaluation of 2007-08 Humidity, Clouds and Precipitation in COSMO-CLM and MM5





Conclusions

- Typical error structures occure depending on orography, season, and model physics
- MM5 and CCLM show similar bias pattern for IWV and CLCT
- Differences become apparent mainly for precipitation
- CCLM behaves similar to COSMO-DE and COSMO-EU

Feiertag and Ament

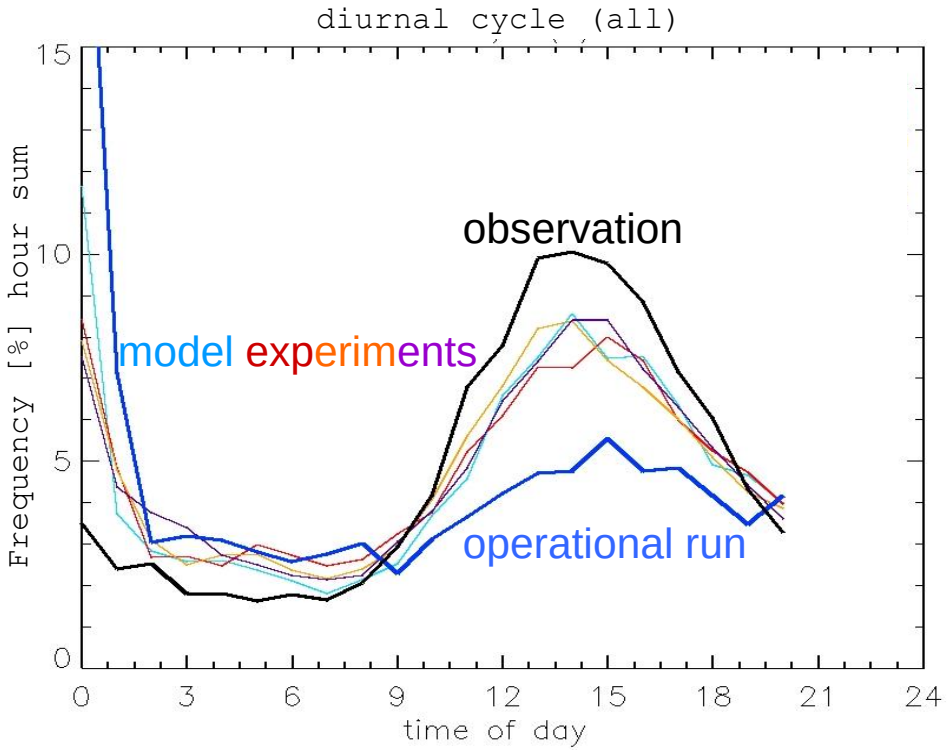
How precise can the model predict the characteristics of convective cells of precipitation? → number and size of cells, lifetime, …

COPS-Periode (06-08/2007)

Observations
German radar network of DWD

Model
COSMO-DE operational data & 4 model experiments

Rad-TRAM
(written at the DLR) tracking & nowcasting



Model changes are visible in cell characteristics:

- Operational version can not predict the diurnal cycle of onset
- Model experiments shows a clear improvement

General Overview QUEST

Validating IWCs in GME, COSMO-EU, and COSMO-DE with CloudSat CPR data

Motivation

- Better prediction of clouds improves quantitative pecipitation forecast and radiation scheme
- Challenge: ice microphysics
- Problem: sparse good observations of ice water contents (ISCCP, AMSU, MLS, MODIS, …)
  → passive sensors are not height-resolving
- CloudSat CPR is first satellite-based cloud radar
- Good quality of radar reflectivity factor (*Protat et al., 2009*)
  → CloudSat well suited for model evaluation

Goals

Both
- Case studies
- Statistical long-term evaluation

Two approaches:
- Observation-to-model (CloudSat “radar-only” retrieval)
- Model-to-observation (radar simulator QuickBeam, *Haynes et al., 2007*)

Various scales:
- GME: 40 x 40 km
- COSMO-EU: 7.5 x 7.5 km
- COSMO-DE: 2.5 x 2.5 km

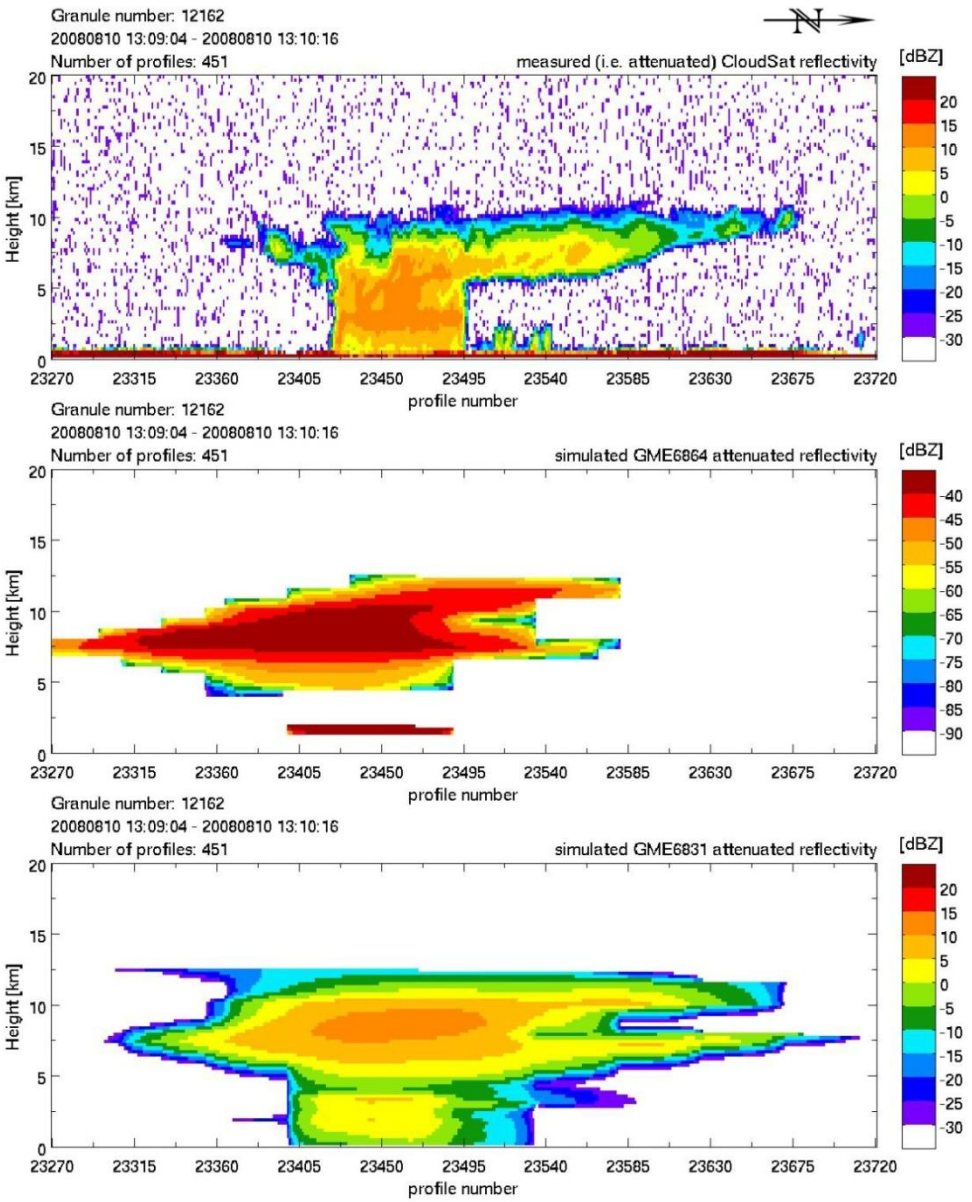
Various regimes:
- Mid-latitudes
- Tropics
- Cumulus trade regime
- Convective/stratiform events
- …

Cold Front 10/08/2008: Cross Sections Z

CloudSat

GMErouti
QC, QI prognostic
QR, QS diagnostic

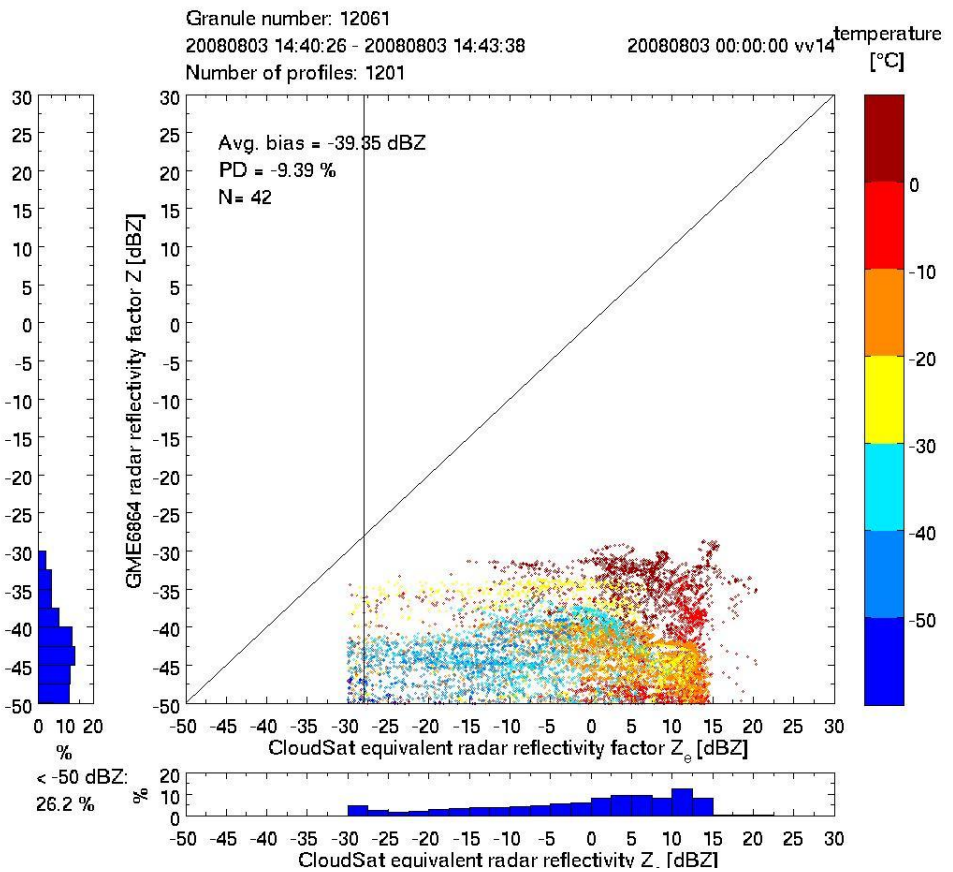
GMEexp
all prognostic



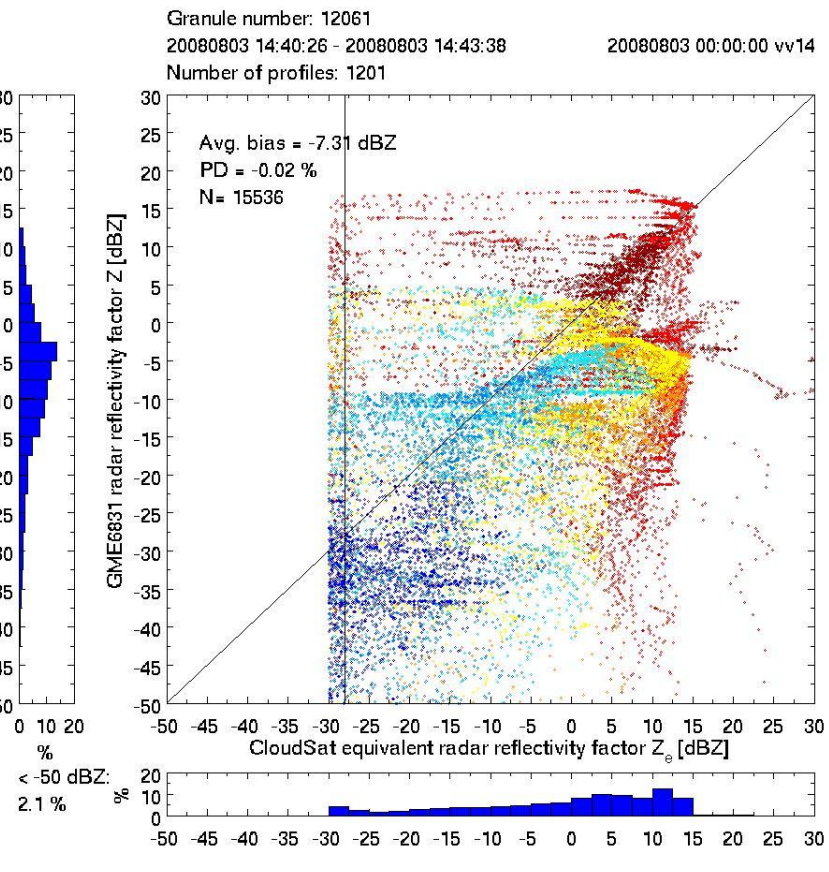
Scale!

Warm Front 03/08/2008: Z_{GME} versus $Z_{CloudSat}$

GMErouti



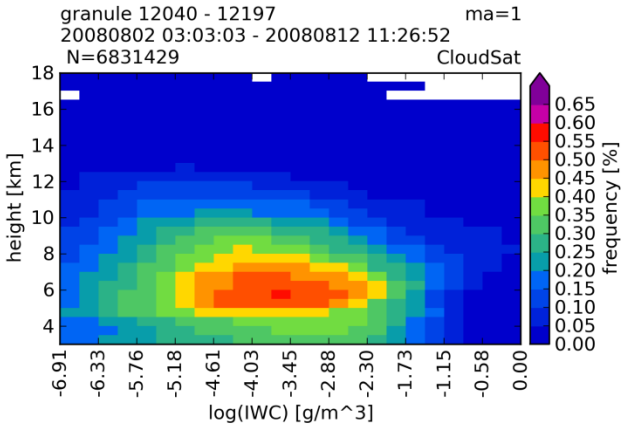
GMEexp

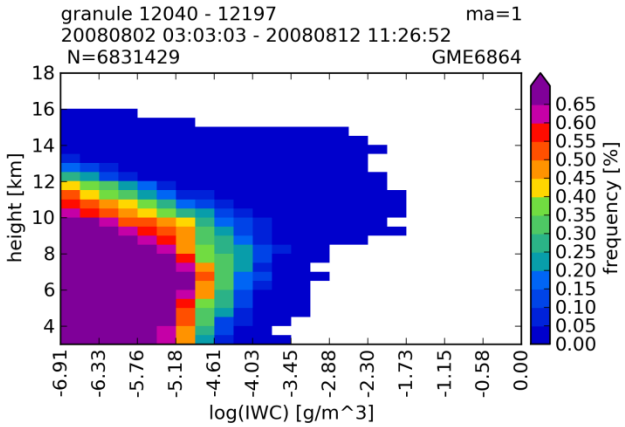


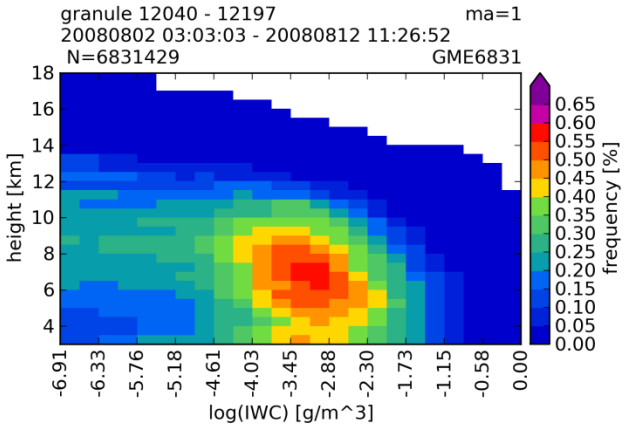
11-day-statistics: PDFs height-log(IWC)

CloudSat **GMErouti** **GMEexp**

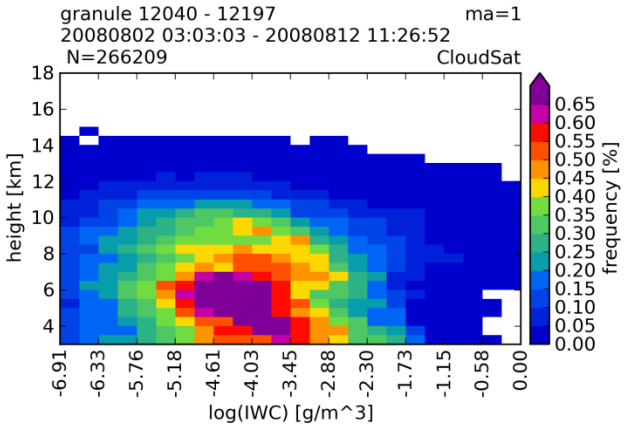
No criteria, N=6,831,429, m=1, all

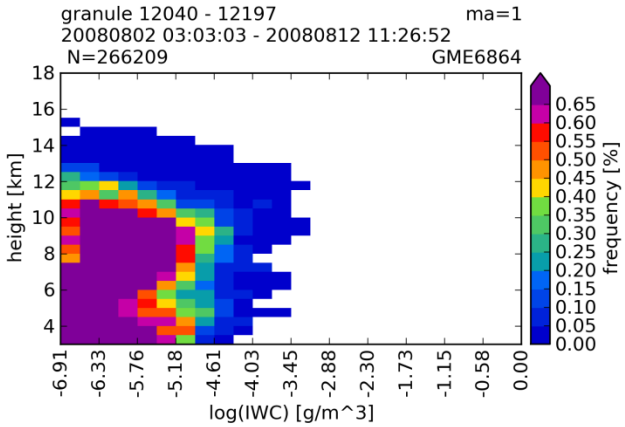


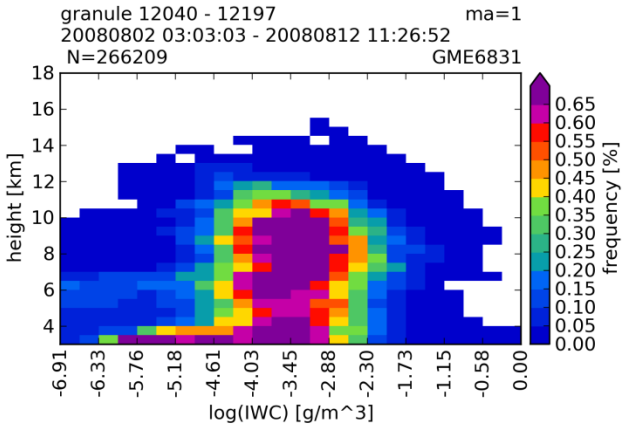




TCH, N=2,008,082, m=1, all







Summary & Outlook

- ↗ Extent and position of clouds is determined better in new GME version → also compare MSG SEVIRI T_Bs with simulated model T_Bs
- ↗ Magnitude of IWCs is better represented in new GME version
- ↘ Cloud top sometimes too high in GME → check with CALIPSO CALIOP data
- ↘ IWC in GME still smaller than in observations → consider sub-grid scale IWC

→ extend analysis to longer time period

Observation-to-model approach

- ↘ 1 value (IWC) is determined from 3 unknowns (D_g, N_T, ω) which are constrained by a priori profiles → error hard to estimate
- ↘ A priori profiles dependent on T and Z → not independent of measurement vector

Model-to-observation approach

- ↗ Offers better control, e.g. profiles with much attenuation can be filtered out (*Waliser et al., 2009*)
- ↘ Unknown particle size: all hydrometeors are modeled as soft spheres in QuickBeam; influence of aggregates? → include other particle shapes in QuickBeam

Thank you for your attention!