Priority Program SPP 1167 of the DFG

Quantitative Precipitation Forecast

PQP Praecipitationis Quantitativae Praedictio

QUEST – Third Phase

Susanne Crewell[1], Felix Ament[2], George Craig[3], Jürgen Fischer[4], Martin Hagen[3], Nicole van Lipzig[5], Monika Pfeifer[3], Thorsten Reinhardt[1], Axel Seifert[6], Stefan Stapelberg[4]

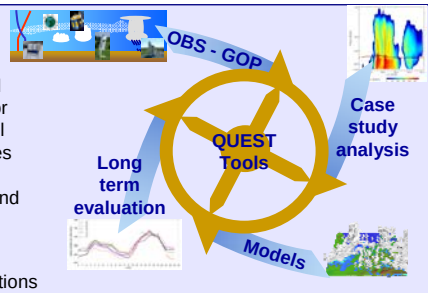
[1)] Institute for Geophysics and Meteorology, University of Cologne (IGMK) [2)] Meteorological Institute, University of Hamburg, [3)] Institute of Atmospheric Physics (DLR), [4)] Institute for Space Sciences, Free University of Berlin (FUB) , [5)] Katholieke Universiteit Leuven (KUL), [6)] German Meteorological Service, Offenbach (DWD)

Objectives

The "Quantitative Evaluation of regional precipitation forecasts using multi-dimensional remote sensing observations" (QUEST) project contributes to the PQP goals:

- **Identification of physical and chemical processes responsible for the deficiencies in quantitative precipitation forecast**
  - *evaluating mesoscale model forecasts of water cycle variables*
  - *combination of detailed case study investigations and long-term model evaluations*
  - *systematic model deficits by averaging out stochastic errors (initial and/or boundary conditions)*
  - *changing model physics in order to attribute the errors to the treatment of specific processes*
- **Determination and use of the potentials of existing and new data and process descriptions to improve quantitative precipitation forecast**
  - *remote sensing data currently not used in routine model verification*
  - *radar/satellite observations with resolution comparable to COSMO-DE (formerly "LMK", ~ 2.8 km)*
  - *polarimetric radar, millimetre wave radiometry to investigate different hydrometeor species*
  - *life cycle of clouds and precipitating cells from model and reality with MSG*

Strategy



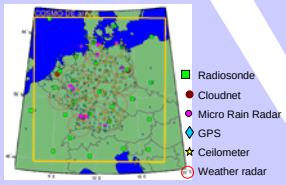
QUEST uses multi-dimensional remote sensing observations for multivariate evaluation of model forecasts with focus on variables of the water cycle - specially water vapor, cloud properties and precipitation.

Focal points of the third phase:

- Exploitation of GOP observations
- Generalization of results by including the D-PHASE models
- Detailed analysis of model deficits already detected during previous phases: i) Case study selection & analysis ii) testing of corresponding model improvements iii) multi-model analysis (D-PHASE)

Observations

- GOP with focus on satellite RS
- D-PHASE OBS
- COPS



Tools

- Forward Operators (SynPolRad, SynSat/-Mic)
- Satellite analysis (Retrievals, tracking,..)
- Data mining tools for models
- Intercomparison tools
  - shape parameters (patchiness)
  - auto- / cross-correlation
  - regional masks & regime def.
- Fuzzy verification

Models

- COSMO-DE and COSMO-EU by DWD + test suites by DWD
- D-PHASE models (right) operated from June to Nov. 07 in the Alpine region.

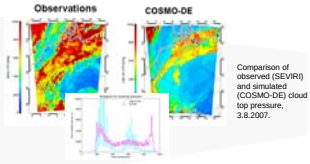
High-resolution deterministic models	Driving deterministic models	Ensemble prediction systems
COSMO-2, Swiss	COSMO-7, Swiss	CLEPS, Italy
COSMO-I2, Italy	COSMO-ME, Italy	MOGREPS, UK
COSMO-I7, Italy	COSMO-I7, Italy	INMSREPS, Spain
COSMO-DE, Germany	COSMO-EU, Germany	CSREPS, Italy
ISACMOL, Italy	QROLAM33, Italy	LAMEPSAT, Austria
ISACMOL2, Italy	QROLAM11, Italy	PEPS, SRNWP
ARPAMOL, Italy	ALADFR, France	MPEPS, SRNWP
MM5_2_CT, Germany	MM5_60, Germany	
MM5_2_4D, Germany	MM5_15, Germany	
MM5_325, Germany	ALADAT, Austria	
AROME, France	CMCGEML, Canada	
CMCGEMH, Canada		

WP 2: Model evaluation

Representation of water vapor

Errors due to advection or evaporation? Consistent representation of humidity and clouds?

- Analysis of additional measurements at super sites (e.g. AMF or Lindenberg)
- MERIS, MODIS and MSG data to assess temporal / spatial evolution and relations to clouds

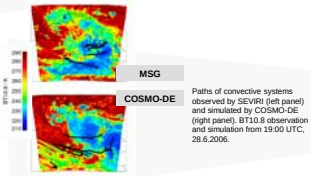


Comparison of observed (SEVIRI) and simulated (COSMO-DE) cloud top pressure, 3.8.2007.

Development of clouds

Do modeled and observed cloud characteristics (life time, extent, origin, …) agree?

- Tracking of cloud systems in satellite observations and model simulations
- Detailed studies to COPS IOPs by combining SEVIRI rapid scans and AMSU observations

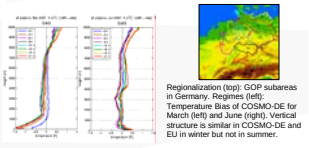


Paths of convective systems observed by SEVIRI (left panel) and simulated by COSMO-DE (right panel). BT10.8 observation and simulation from 19:00 UTC, 28.6.2006.

Regime related model deficits

Are certain model deficits connected with specific regions or weather situations?

- Conditional verification
- Data base already established during GOP

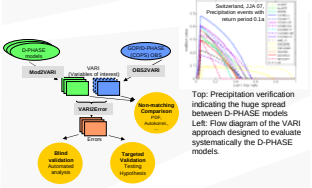


Regionalization (top): GOP subareas in Germany. Regimes (left): Temperature Bias of COSMO-DE for March (left) and June (right). Vertical structure is similar in COSMO-DE and EU in winter but not in summer.

GOP generalization towards D-PHASE

Are COSMO deficits common to other models?

- Adaptation of QUEST methods to D-PHASE models
- "Variable of interest" approach
- Analysis of error structure in the resulting data set

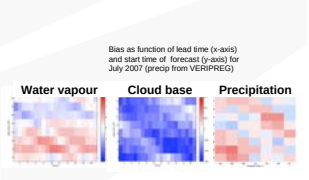


Top: Precipitation verification indicating the huge spread between D-PHASE models Left: Flow diagram of the VARI approach designed to evaluate systematically the D-PHASE models.

Error structure in the hydrological cycle

Are there multivariate error patterns?

- Development of multivariate verification methods (error cross correlation, conditioned evaluation …)
- Pinpointing at important model improvements



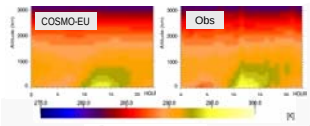
Bias as function of lead time (x-axis) and start time of forecast (y-axis) for July 2007 (precip from VERIPREG)

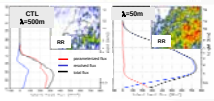
WP 3: Model Improvement

Boundary Layer evolution / daily cycle

Why does COSMO moisten and cool the PBL? How much variability is / needs to be resolved?

- Optimization of the PBL scheme for high resolution (e.g. turbulent length scale)
- Evaluation of reforecasting experiments with modified PBL parameterizations



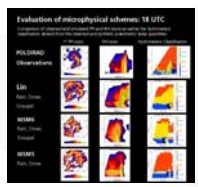


Top: Diurnal temperature cycle for 20 summer days at Lindenberg. Model underestimates cooling in stable boundary layer and cools too quickly in the late afternoon. Left: Sensitivity study altering the turbulent length scale λ, 12.7.06.

Cloud microphysics

Are QPF deficiencies related to representation of the ice phase (snow versus graupel)? – to long lifetime due to incorrect size distributions?

- Analysis of cloud radar, polarimetric radar, AMSU and SMM/I measurements
- Case study analysis of COPS IOPs simulated with 2-moment scheme (with Univ. Karlsruhe) and Meso-NH

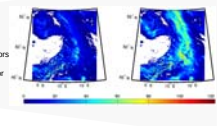


Case Study 12th August 2004: Different Experiments with the WRF (Weather Research and Forecasting) model Version 2.1.2.

Cloud radiation interaction

Does a consistent representation of clouds and radiation improve QPF?

- Testing of the radiation scheme forced by AMF observations
- Testing of improved coupling between precipitating particles and radiation scheme

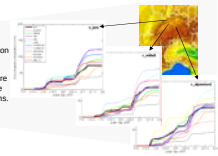


Cloud optical depth diagnosed without precipitating hydrometeors (left) and with (right). COSMO-DE forecast for 7.1.2008, 12 UTC.

Evaluation of ensembles

Do today's limited-area ensemble systems describe the forecast uncertainty – in a multivariate sense?

- Evaluation of spread-skill-relation for all variables of the hydrological cycle during GOP
- Verification of the error cross-correlations (needed by EnKF data assimilation planed for COSMO)



Accumulated precipitation predicted by the ensemble of D-PHASE models during the severe August 07 flood in three adjacent warming regions.

Expected outcome

- New verification tools implemented at DWD:
  - novel observations: ceilometer, satellite retrievals, …
  - novel operators: SynPolRad, SynSatMic,Tracking, …
  - novel methods: conditional verification, cross correlations,…
- Assessment of today's ability of models to represent the hydrological cycle
- Guidance for QPF improvement by
  - Identification of error patterns
  - Selection of case studies
  - Verification of sensitivity experiments

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)								
	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*)								

*) to be continued in the third year, funding will be requested during the second year in the framework of the "Individual Grants Program".