Priority Program SPP 1167 of the DFG

Quantitative Precipitation Forecast

PQP Praecipitationis Quantitativae Praedictio

High-Resolution Reanalyses and Impact Studies for Improving Process Understanding and Precipitation Forecast Skill based on the COPS Data Set

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Motivation

- Precipitation has a strong influence on our economy and general livelihood. The forecast of small-scale severe precipitation events is among the most difficult tasks in meteorology.
- Radiosondes, active and passive remote sensing are the major source of water vapour observations used operationally.
- Nevertheless, severe gaps exist in the observation network of atmospheric dynamics and the hydrological cycle. This is especially true for the mesoscale.
- More sophisticated observing systems, e.g. polarization Doppler radar, GPS or lidar, will be available operationally in the future. The preparation of the assimilation systems for these systems is an important task.

Figure 1: *Flooding after a severe precipitation event. (Source: http://www.jcema.org)*

Hypotheses

- New observing networks, such as radar and GPS stations provide important additional information improving mesoscale-γ precipitation forecasts.
- Sensitive locations exist, where the effect of these observations on the forecast quality is largest.
- Convection permitting simulations important to improved precipitation forecasts and process understanding.
- Sophisticated 4-dimensional assimilation systems like Nudging and 4DVAR, used in convection permitting models, are essential for improving QPF on the mesoscale.

Improvement of the assimilation system (IPM)

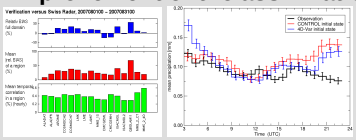


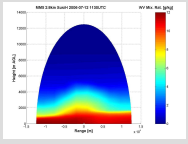
Figure IPM.1: *Left: Validation of the deterministic D-PHASE models with Swiss radar data for August 2007 (courtesy Felix Ament). Right: Averaged daily cycle of precipitation for the three month period August to October 2007.*

The MM5 4DVAR system was used operationally to assimilate GPS slant path delay data (STDs) during the 6 months of D-PHASE. First analyses demonstrate a positive impact on the forecast of precipitation. Runs with improved model physics shall be performed in phase three of PQP.

Planned improvements

- Improve model physics in the assimilation system in cooperation with the MM5/WRF and JMA assimilation groups. This includes a more accurate horizontal diffusion, and a more sophisticated convection scheme (Anthes-Kuo → e.g. Grell).
- Implementation of a digital filter to damp high-frequency waves caused by observations.
- Spin-up run to remove imbalances in the assimilation window.

Operator development (IPM)



In the third phase of PQP the assimilation system shall be extended to use observations of scanning lidar systems and radial velocities of the DWD radar network.

Figure IPM.2: *Lidar water vapour mixing ratio [g/kg] observation derived from MM5 model output using a prototype of a forward operator for scanning lidar systems.*

Exchange results

High-resolution process studies for selected COPS IOPs (IPM)

The improved and extended assimilation system will be used to perform process studies for selected COPS IOPs. First results of the system used operationally during D-PHASE are promising (see above).

Figure IPM.3: *Time-height cross sections of water vapour mixing ratio [g/kg] of the IPM DIAL system (top) and MM5 (2 km resolution) initialized with ECMWF forecast and GPS slant path delay data (bottom).*

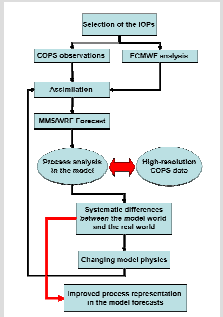


Figure IPM.5: *Steps to be carried out for the high-resolution process studies*

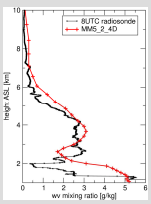


Figure IPM.4: *Comparison of a radiosonde launched at Supersite Hornisgrinde with the MM5 profile of the corresponding grid box.*

Deliverables:

1. High-resolution 4DVAR system for the weather forecasting community
2. WWRP data assimilation test bed in the COPS region
3. Suggestions for improvement of process representation in the convection permitting versions of MM5/WRF

Experiment coordination and combined data processing

Reanalyses and Observing System Experiments for COPS with COSMO-DE (DWD)

Aim of the project is the evaluation of different observing networks using the DWD model chain consisting of GME, COSMO-EU and COSMO-DE. Consistent reanalysis data sets for the three month COPS period shall be provided to the scientific community.

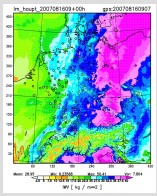


Figure DWD.1: *Integrated water vapour from COSMO-DE (shaded) + GPS observations (dots)*

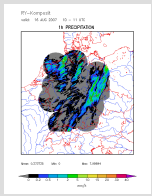


Figure DWD.2: *Radar derived 1h-preciptation rate in mm/h*

Figure DWD.1 contains observations of GPS stations. Figures DWD.2 and DWD.3 show radar observations planned to be used for the reanalyses.

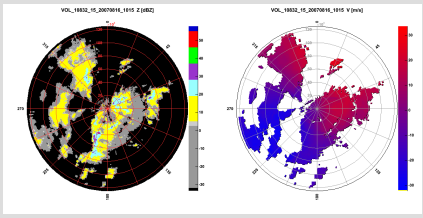


Figure DWD.3: *Radar reflectivities (left) and radial winds (right) for elevation 2,5°at Radar Türkheim*

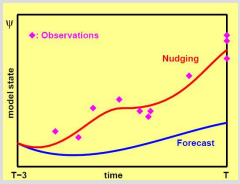


Figure DWD.4: *Principle of the nudging assimilation in COSMO-DE*

In addition to the reanalyses, impact studies for selected IOPs are planned using the research data collected during the COPS campaign.

Experiment / Observations	Operations	Base line	Radar winds	GPS	All
Synop/Ship/Metar	✓	✓	✓	✓	✓
Temp/Pilot	✓	✓	✓	✓	✓
Aircraft	✓	✓	✓	✓	✓
Wind profile	✓	✓	✓	✓	✓
Radar refl.	✓	✓	✓	✓	✓
Radar winds			✓		✓
GPS TD				✓	✓
Real time COPS	✓				✓

Figure DWD.5: *Planned observing system experiments and observations used*

Deliverables:

1. Scientific report on the impact of different observing networks on analysis and forecast quality
2. Consistent reanalyses data sets for the scientific community

GPS Meteorology (GFZ)

GFZ Potsdam

Data, Error descriptions

Impact Studies

GFZ Potsdam provides vertically Integrated Water Vapour (IWV) and Slant Total Delay data (STD) from GPS over Germany in near real-time. IWV and STD are a valuable input to weather models and allow the 3D-reconstruction of the water vapour with high temporal resolution.

Data, Error description

Reanalyses Impact studies

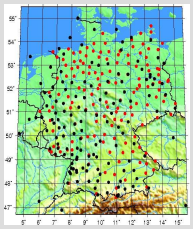


Figure GFZ.1: *Network of GPS stations containing existing (•) and new (•) sites.*

- New stations (•) will complement the existing (•) network at Germany. Data from French and Swiss stations including about 20 temporal sites in the Black Forest will be made available.
- The data of this extended network (~ 400 sites) will be reprocessed in a consistent way making use of the improvements described below for the whole COPS/GOP period.

Improved GPS analyses with error estimates

Data, Error descriptions

Process Studies

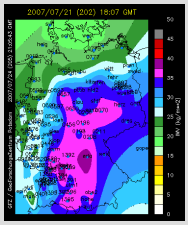
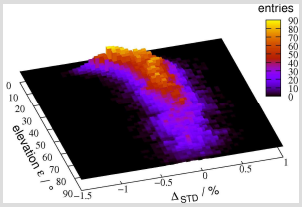


Figure GFZ.2: *Analysis of the integrated water vapour (IWV) field from GPS measurements on July 21 2007, 18:07 GMT.*

- The analyses of IWV (see left, Germany) and STD need further improvements. In particular the quality of slants for low elevation angles (high information content) will benefit from the application of the new techniques:
- Absolute GPS antenna phase centre models
- Reducing multipath effects
- Multipath models for individual stations
- Statistical error estimation for data assimilation.



The relative difference Δ_{STD} (%) between the observed STDs and delays computed from the LMK is rather small for elevations above ~30° but increases significantly below 15°. These data need to be improved and validated carefully. The colour code indicates the number of entries in a 2°interval.

Figure GFZ.3: *Relative difference Δ_{STD} between the observed STDs and the corresponding values computed from the LMK model for different elevations (Δ_{STD}= 100 (STD_{obs}-STD_{LMK})/STD_{obs}).*

cooperation

GPS based data (STD, IWV) as well as the results of the different simulations will be provided to other groups of PQP via the COPS / D-PHASE data archive at the World Data Centre for Climate (WDCC) in Hamburg. Furthermore, cooperation with other groups during planning and performance of the impact studies is planned.