Priority Program SPP 1167 of the DFG

Quantitative Precipitation Forecast

PQP Praecipitationis Quantitativae Praedictio

Current status and first results of the SPP1167 project COPS-GRID

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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 sources of water vapor 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 are important to improve quantitative 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.

Status of the WRF and WRF 4DVAR (IPM)

- The current release is WRF V3.0.1.1 from August 2008 (including 3DVAR FGAT, public 4DVAR follows in release 3.1 planned for March 2009 with the same set of operators).
- Various new physics options (including 2-moment cloud microphysics and updates of earlier schemes) are included.
- Direct initialization from ECMWF model level data (including cloud water and cloud ice)
- Operators are available for upper air observations, surface measurements, GPSPW, GPSREF, GPS ZTD, satellite observations (winds and radiances) and radar measurements (reflectivity and radial velocity).
- Basic quality checking and data thinning is implemented for standard observations.

Experiment coordination and combined data processing

Operator development (IPM)

During the next two years, the assimilation system shall be extended to process observations of scanning lidar systems and radial velocities of the DWD radar network.

Scanning lidar:

$$m = \frac{M_W R_L T N_W}{N_L p - 1.608 M_W R_L T N_W}$$

- N_W water vapor number density (DIAL)
- N_L Loschmidt's number
- M_W molecular weight of water vapor
- R_L gas constant of dry air
- p pressure (MM5)
- T temperature (MM5)
- m water vapor mixing ratio (MM5)

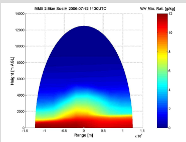


Figure IPM.1: Lidar water vapor mixing ratio [g/kg] derived from MM5 model output using the forward operator for scanning lidar systems.

Impact & Process Studies

GPS slant total delay:

$$H = \int_{rec}^{mtop} \left(c_1 \frac{P}{T} + c_2 \frac{PQ}{(c_3 + Q) T^2} \right) ds + H_0$$

Delay above the model top

- H Slant total delay (GPS)
- T Temperature (MM5)
- P Pressure (MM5)
- Q Mixing ratio (MM5)
- c_x constants

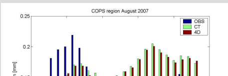


Figure IPM.2: Averaged diurnal cycle of total precipitation [mm] for August 2007. Shown are hourly reporting precipitation stations (blue), MM5 CONTROL (green) and MM5 4DVAR (improved version) at 18 km horizontal resolution.

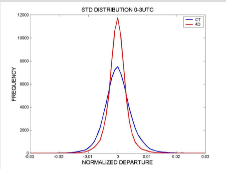


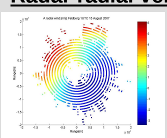
Figure IPM.3: Frequency distribution of the normalized departure Model-Observation for all slants in the assimilation window of August 2007.

Data, Error descriptions

Radar radial velocity:

$$r = u e_1 + v e_2 + w e_3$$

- r Radial velocity (Radar)
- u,v,w Local wind components
- e_x Unit direction vector components



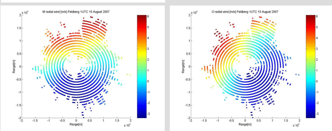


Figure IPM.4: OSSE demonstrating the performance of the radar radial velocity operator developed for the MM5 4DVAR. The lower left panel shows the radial velocity of the model. On the lower right panel the same model wind field was rotated by 45° and then assimilated into MM5. The result of the assimilation experiment is shown in the upper panel. The radar operator is already available in WRF 3DVAR/4DVAR.

The extended WRF 4DVAR will be used to perform process studies for selected COPS IOPs (see poster of Thomas Schwitalla and talk of Florian Zus).

Deliverables:

1. Operators for high-resolution WRF 4DVAR system for the weather forecasting community
2. WWRP data assimilation test bed in the COPS region proposed by the WWRP working group MWF.
3. Suggestions for the improvement of process representations in the convection permitting version of WRF

GPS Meteorology (GFZ)

During the COPS, GFZ provided near real-time GPS-derived tropospheric products to the meteorological community: IWV with a temporal resolution of 15 minutes, STDs with a resolution of 2.5 minutes as well as meteorological observations.

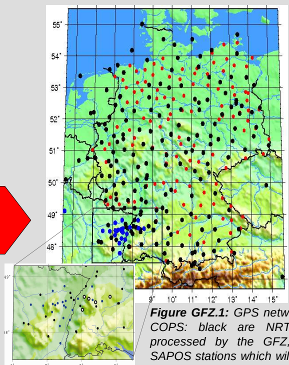


Figure GFZ.1: GPS network during COPS: black are NRT stations processed by the GFZ, red are SAPOS stations which will be made available for re-processing, blue are French post-processed GPS sites.

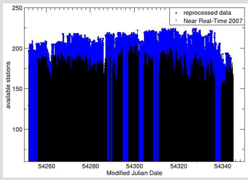


Figure GFZ.2: Current status of reprocessing which has been done in the first run including French post-processed GPS sites.

GPS-derived slants have been validated using the COSMO-DE analyses. Weather prediction models provide all information required to compute the 3D fields of the refractivity (dry + wet), the water vapor and the corresponding delays along any given slant path. A simulation tool developed at the GFZ has been used to compare the observed and the simulated delays (ZTD + STD). The ZTDs generally agree very well (Fig. 4) but there are some cases where the model diverges from the atmospheric state.

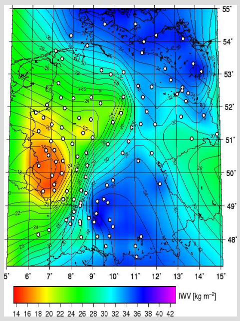


Figure GFZ.3: Example of re-analysis of IWV during IOP 9c (July 20).

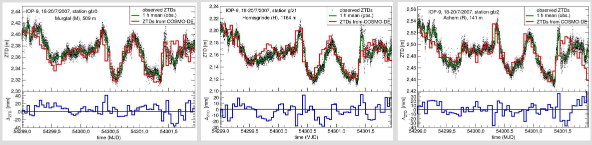


Figure GFZ.4: Observed slant total delays, mapped to zenith direction (black), their hourly mean value (green) and the hourly mean computed from the corresponding COSMO-DE analyses (red) for 3 GFZ GPS sites at different heights. The difference 'Observation - COSMO-DE' is shown in the bottom part in blue.

Data, Error description

Reanalyses Impact studies

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.

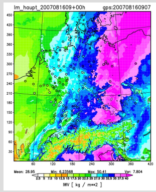


Figure DWD.1: Integrated water vapor from COSMO-DE (shaded) + GPS observations (dots)

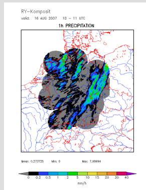


Figure DWD.2: Radar derived 1h-preciptation rate in mm/h

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

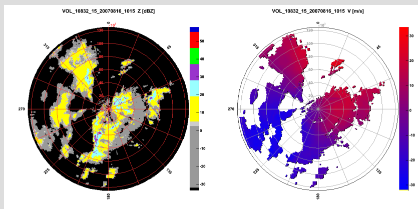


Figure DWD.3: Radar reflectivities (left) and radial winds (right) for elevation 2.5°at Radar Türkheim

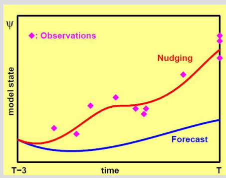


Figure DWD.4: Principle of the nudging assimilation in COSMO-DE

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

Observations \ Experiment	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. For agreement on the format please contact: werner.wergen@dwd.de

Reference:

Stephan, K., S. Klink and C. Schraff, 2008: Assimilation of radar-derived rain rates into the convective-scale model COSMO-DE at DWD.Q.J.R.Meteorol.Soc. **134**:1315-1326