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.
- Radiosonde, 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.

**Improvement of the assimilation system (IPM)**

The MMS 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 will 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 (Arnth-Keu → e.g. Grell).
- Application 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 POP the assimilation system shall be extended to use observations of scanning lidar systems and radial velocities of the DWD radar network.

**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 will be operationally during D-PHASE are promising (see above).

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

**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.

**Improved GPS analyses with error estimates**

- 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 $\Delta$ (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.

**Evaluation**

- New observing networks, such as radar and GPS stations provide important additional information improving mesoscale precipitation forecasts.
- Sensitive locations exist, where the effect of these observations on the forecast quality is largest.
- Convexion 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.

**Convection**

**Deliverables**
2. Consistent reanalyses data sets for the scientific community.

**Figures**

- Figure IPM.1: Flood event after a severe precipitation event.
- Figure IPM.2: Radar reflectivities (left) and radial winds (right) for elevation 1.5° of Radar Teltow.
- Figure DWD.1: Observations of GPS stations. Figures DWD.2 and DWD.3 show radar observatons planned to be used for the reanalyses.

**Tables**

- Table of the relative difference $\Delta$ (STD) (%) between the observed STDs and delays computed from the LMK for different elevations.

**Impact Studies**

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

**Data, Error description**

GPS Meteorology (GFZ) G F Z P O T S D A M

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.

- New stations ($\times$) will complement the existing (e) network at Germany. Data from French and Swiss stations including about 20 temporal data sets for the whole COPS/GOP period.

**Experiment coordination and data processing**

- Planned observing system experiments and observations used in the reanalyses.

**Figures**

- Figure DWD.4: Principle of the nudging description in COSMO-DE.
- Figure DWD.5: Planned observing system experiments and observations used in the reanalyses.

**Data, Error description**

- Data processing

**High-resolution process studies**

The results of the system will be operationally during D-PHASE are promising (see above).

**Figures**

- Figure IPM.4: Comparison of a radiosonde launched at Surupas in normally with the MM5 model at the corresponding grid box.

**Figures**

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

**Figures**

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