Developments in Satellite Data Assimilation at DWD

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I) Operational NWP system & satellite usage

Global:
- ICON, non-hydrostatic, 13 km, 90 α-ε-levels up to 70 km (~2.6 Pa)
- 3DVAR for conventional and satellite data, 3h cycling
- COSMO-DE: 2.8 km, 50 Levels (non-hydrostatic)
- COSMO-DE-EPS ensemble at 2.8 km, 40 members
- Nudging assimilation scheme for conventional and radar data

Regional:
- COSMO-EU: 7 km, 40 Levels (up to ~22 km, non-hydrostatic)
- To be replaced by ICON-EU-Nest in Q1/2016 (see panel II)
- COSMO-DE-EPS: 2.8 km, 50 Levels (non-hydrostatic)
- COSMO-DE-EPS assimilation ensemble at 2.8 km, 40 members
- Nudging assimilation scheme for conventional and radar data

Satellite data / global ICON:
- AMSU-A (channel 8-14 everywhere, 5/6 only over sea), ATMS (similar, 3/5 superobbing)
- AMSU-B/MHS-pre operational
- GPS-RO bending angles
- IASI (GEOS, LEO), Scatterometer winds
- Monitoring of AMSR-2, Meteosat CSR, JASON-2 winds

Technical aspects:
- RTTOV-10
- Flexible satellite data ingestion & pre-processing package
- Monitoring: Automatic problem detection & alert system
- Online bias correction

Current developments:
- Operational introduction of VarBIC
- Extended IASI usage; introduction of humidity sensitive radiances
- QR/cloud screening: New observation cross-validation method, see Poster 8p.05 and Presentation 11.06 (O. Stiller)
- Analysis of surface emissivity and skin temperature

II) Radiance assimilation in ICON

The ICON model (ICOsahedral Nonhydrostatic modeling framework), developed in cooperation between DWD and the MPI for climate research (Hamburg) is providing global operational forecasts at DWD since 20 Jan 2015 on a 13 km isosahedral grid. The global ICON-EU model runs simultaneously at 7 km on a European domain (ICON-EU) through a two-way nesting. ICON also provides a greatly improved basis for radiance assimilation, especially concerning the assimilation of satellite radiances. The EnVAR/LETKF system so far shows an improved fit to humidity sensitive radiances. The EnVAR/LETKF system is undergoing further parameter tuning, such as the adaptation of observation errors, data thinning, and scale selective localization. The current development focuses on the improvement of (situation dependent) localization and the inclusion of additional radiance data, especially humidity sensitive radiances. The EnVAR/LETKF system so far shows an improved fit to humidity observations compared to the old system. Also, the exploitation of the cross-correlations between variables, e.g. T and Qv, Qv and wind, is further investigated.

The assimilation of high-peaking AMSU & ATMS channels everywhere leads to a consistent improvement in short range forecasts, visible in the fit of the FG to other observations like e.g. IASI, radiosondes. Improvements in forecast scores were visible particularly over northern high latitudes and in some regions in Europe.

![Fig 1: Schematic diagram of ICON grid with regional two-way nest.](image)

The current development focuses on the implementation of the new EnVAR ensemble data assimilation system, which consists of a coupling between a global (lower resolution) LETKF ensemble data assimilation, providing flow dependent background errors, and a full resolution deterministic 3DVAR. The following setup is running continuously in the pre-operational testing and tuning and initial evaluation show significantly improved forecast scores.

- Global LETKF: at 40 km, 40 members, ICON model
- Global EnVAR: at 13 km, deterministic 3DVAR using flow-dependent B matrix from LETKF ensemble blended with a climatological B matrix
- Global EPS: 40 members from global LETKF ensemble, forecasts up to 120 h (~00, 12 UTC), additionally for 24h every 3h to provide boundaries to regional LETKF
- Regional LETKF: at 2.8 km, 40 members, COSMO-DE model
- Regional EPS: COSMO-DE at 2.8 km, 20 Members, (not yet initialized from LETKF analyses)

![Fig 4 (right): Schematic diagram of the interaction between the global ensemble prediction (ICON enu) and analysis (LETKF) and the deterministic forecast (ICON only) with the EnVar analysis.](image)

![Fig 5 (below): Illustration of the flow-dependent background errors provided through the LETKF with the spread of T (left) and the cross-correlations between T and Qv (right) at around 500 hPa for 30 May 2015 as example.](image)

The EnVAR system is able to produce much more localized increments, e.g. located within the areas of higher T uncertainty in the frontal region.

![Fig 6: Example of regional T increments at around 500 hPa of 3DVar (a) in comparison with EnVar (b) together with the spread of the T fields of the ensemble members (c) and the mean T field (d).](image)

Currently, the EnVAR/LETKF system is undergoing further parameter tuning, such as the adaptation of observation errors, data thinning, and scale selective localization.

The high-resolution operational global and regional LETKF runs (Hunt et al., 2007) are based on a single, single-scan approach that exploits the assimilation of state-of-the-art satellite radiances, and then assimilates the high-peaking AMSU & ATMS channels everywhere to provide consistent and high-resolution data assimilation. The LETKF system also provides a means for the assimilation of state-of-the-art satellite radiances, and then assimilates the high-peaking AMSU & ATMS channels everywhere to provide consistent and high-resolution data assimilation.

![Fig 7: Example of analysis increments for wind (z-component) caused by a single radiances observation (HRS channel 11) in 3DVar (left) and the LETKF (right). A non-linear scale is used to enhance small increment values. The 3DVAR wind increment is very small in magnitude and displays the typical dipole pattern from the fixed climatological T(Qv) correlation.](image)

The LETKF wind increments for these single observation tests are generally much more significant and have a highly location dependent shape and structure determined by the local T-Qv and also T(Qv) covariances derived from the ensemble members. These covariances (and increments) vary considerably dependent on the location and meteorological conditions.

![Fig 8: Example of increment profile of z-component of the wind (red) caused by a combination of radiances observations (HRS channel 11) both in 3DVar (red) and in the LETKF for the ensemble mean (blue) and individual ensemble members (green). The LETKF derives wind increments from the predominantly humidity sensitive channel in a least squares regression in the 3DVar model.](image)