Developments in Radiance Data Assimilation at DWD since ITSC-21

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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This poster gives an overview of the recent upgrades to satellite radiance data use in the operational global ICON+EnVAR system of DWD. The DWD system consists of the global icosahedral non-hydrostatic ICON model at 13 km resolution with an embedded European higher resolution area at 6.5 km using a two-way nesting. The data assimilation is a hybrid ensemble-variational approach combining a 40 member ensemble at 40 km resolution providing the flow-dependent background error-covariance matrices with a (currently) 3D-VAR running in 3h cycling. Over the last years, data from several additional satellite instruments have been added - with a particular focus on the inclusion of much of the available humidity sensitive radiances - contributing to further increases in forecast quality. Current developments focus on enhancing the data use from hyperspectral IR sounders, using more data over land and snow/ice surfaces, and the implementation of an all-sky use of infrared, microwave as well as visible radiances.

The use of infrared and visible channels in an all-sky setup is also a particular focus in the context of the convection-resolving model and the development of a very short range prediction system combining nowcasting with NWP approaches to produce seamless forecasts (SINFONY).

In parallel, the EnVAR system is being developed towards a 4D-EnVAR to make better use of the time dependent information in the data.

1. Recent operational upgrades

Satellite data upgrades since ITSC-21 achieved particularly the introduction of a large number of IR and MW humidity radiances, an increase in used data density as well as the use of non-diagonal observation error covariances for IASI. Additionally, technical processing upgrades were introduced and observation errors retuned.

Instrument	Date	Change
RTTOV	14 Mar 2018	• Upgrade to RTTOV-12
Satellite-processing	6 June 2018	• Processing of MWTS-2, MWHS-2, SSMIS, GMI, SAPHIR, AMSR-2, SEVIRI/MVIRI CSR, CrIS-FSR, IASI-PC data to RR, update to data mapping
AMSU-A	11 July 2018	• Increased density (to 160 km thinning) • Retuning of observation errors (Desroziers method)
ATMS	11 July 2018 5 Dec 2018 27 Feb 2019	• Increased density (to 160 km thinning, together with MHS) • Assimilation of humidity channels 18, 20, 22 over sea • Assimilation of channels 20, 22 over land • Introduction of ATMS from N-20
MHS	14 Mar 2018 5 Dec 2019	• Assimilation of humidity channels 3, 4, 5 over sea • Assimilation of channels 3, 4 over land
SSMIS	4 June 2019 22 Oct 2019	• Assimilation of 183 GHz humidity channels (3 chans) • Assimilation of hum. channels over land (2 upper chans)
GMI	4 June 2019	• Assimilation of 183 GHz humidity channels (2 chans)
IASI	14 Mar 2018 11 July 2018 27 Feb 2019 4 June 2019 22 Oct 2019	• Assimilation of 16 humidity channels • Increased density (to 160 km thinning) • Retuning of observation errors (Desrozier method) • Use of full non-diagonal OBS error covariance matrix • Update of McNally&Watts cloud detection • Retuning of OBS errors (adjusted inflation factor)
SEVIRI CSR	11 July 2018	• Assimilation of humidity channels (6.2 and 7.3 µm)
ABI CSR	4 June 2019	• Assimilation of humidity channels (6.15 and 7.4 µm)
AHI CSR	4 June 2019	• Assimilation of humidity channels (6.25 and 7.35 µm)
GOES imager	4 June 2019	• Assimilation of humidity channels (6.55 µm)
METOP-C	10 April 2019 ~ end 2019	• AMSU-A, MHS, ASCAT, RO, AVHRR AMVs • IASI

2. Evolution of forecast scores

The updates in use of satellite radiances (see above) together with numerous physical updates and tuning measures, and updates in the use of other observations types (e.g. AMVs, scatterometer) led to a continuous improvement of forecast scores since the introduction of ICON (Jan. 2015) and EnVAR (Jan. 2016). Fig. 1 and Fig 2. illustrate the improvements which are visible at all levels and forecast ranges, but especially marked for low levels and shorter forecast ranges up to ~3-4 days (the main focus of DWD).

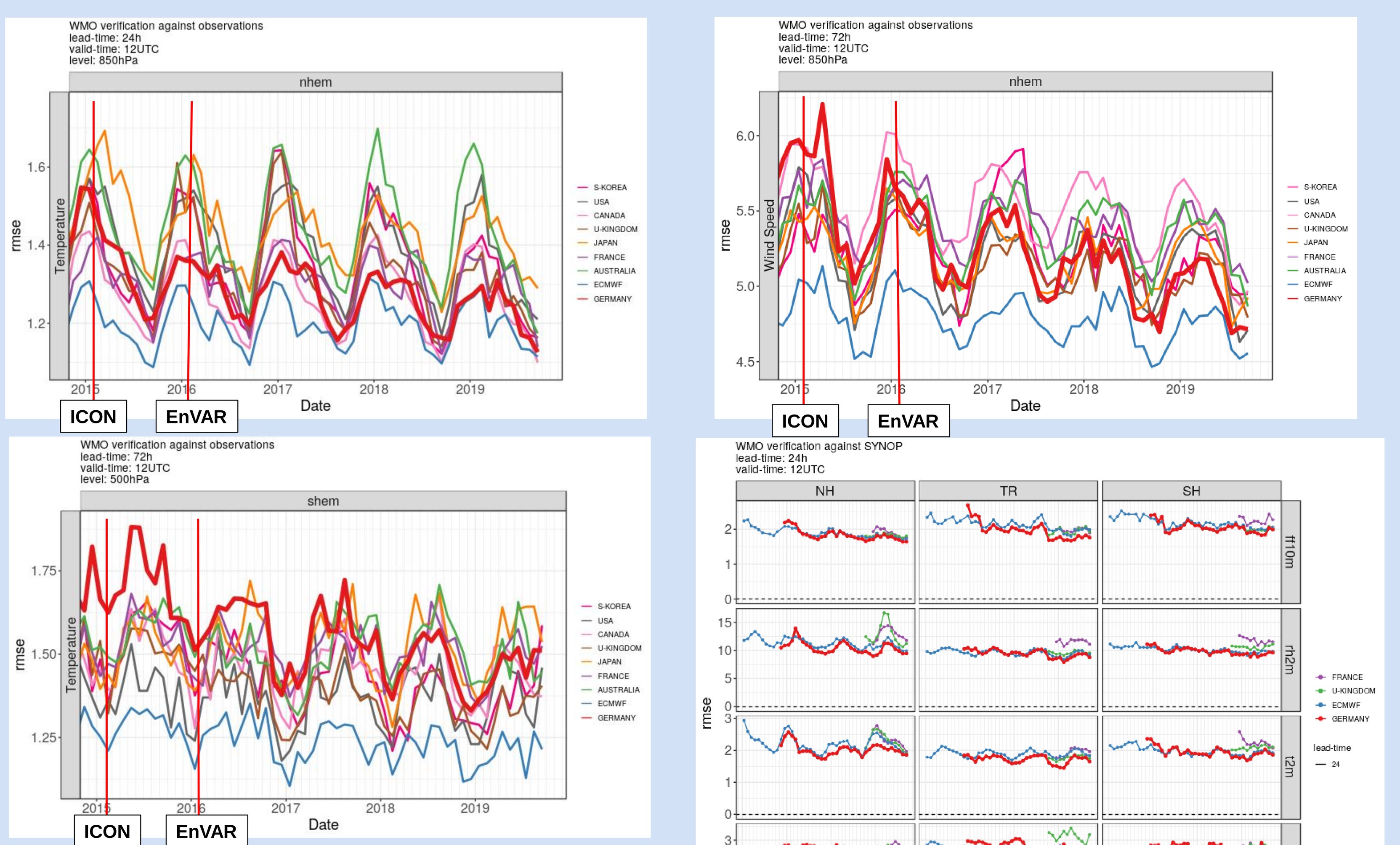


Fig. 1: Evolution of forecast rms since 2015 for DWD (red) and several other global NWP centres: Temperature at 850 hPa, NH, 24h (top left); wind at 850 hPa, NH, 72h (top right); temperature at 500hPa, SH, 72h (bottom left).

Fig 2: (bottom right): Verification for 10m wind speed, 2m relative humidity and temperature and total cloud cover versus SYNOPs since 2016. DWD results are displayed in red.

3. Main ongoing developments

Further upgrades to the use of humidity radiances: Assimilating further humidity sounders and channels on top of the recently implemented ones, as well as tests with non-diagonal observation error covariance matrices for humidity sounders are under way. While this yields improved fits of the first guess short-range forecasts to other observations (e.g. Fig. 3 for MWHS-2 assimilation trial), making these translate into longer range forecast improvements has proven challenging. **Poster 12p.03** describes the issues and the currently tested approach (using a constrained bias correction).

Low peaking MW channels over land (with surface emissivity retrieval) are being tested and MW imagers (technically implemented) are the next data category for assimilation trials.

In parallel, the EnVar system is being prepared for the all-sky assimilation of IR, MW and VIS radiances (see **posters 11p.03, 11p.07 and presentation 9.04**).

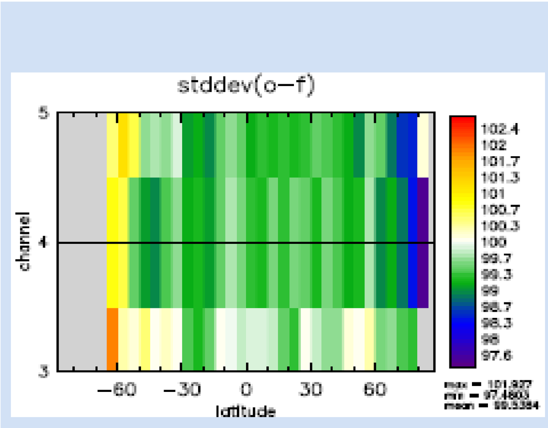


Fig. 3: Improvement in OBS-FG fit to MHS radiances channel 3-5 for assimilation trial of MWHS-2 radiances. Displayed as relative change in stdv(OBS-FG) versus latitude.

Enhanced use of hyperspectral IR sounders: After the successful implementation of non-diagonal observation error matrices for IASI, assimilation trials with CrIS data and a larger number of IASI channels are being conducted. Also, the use of reconstructed radiances based on EUMETSAT principal components data sets has been tested (see **poster 7p.03**) and is being developed further. A scheme for the retrieval of skin temperature and surface emissivity (based on a principal components based representation of emissivity spectra) is implemented and explored to extend data use also to lower peaking channels over land surfaces.

Data assimilation developments: An extension of the currently used EnVAR+LETKF scheme to a 4D-EnVAR+LETKF is under way. The current 3D implementation already allows the derivation of wind information from humidity radiances (see **presentation 4.03**), but a 4D formulation should allow even more dynamical information being gained from using a sequence of observations throughout the assimilation time window. Additionally, a particle filter is being tested in the operational environment with the aim to better assimilate observations with non-Gaussian error characteristics.

For a regular analysis of observation impact in the system, a diagnostic scheme based on the ensemble increments and characteristics is being studied with the aim to further improve our understanding of observation use and tuning in the DWD system (see **poster 11p.08**)

4. Data impact study (July 2018 system)

A series of OSEs were run in summer 2019 (in the context of the radio-frequency interference workshop, see presentation b.01) to document the impact of various observation types in the DWD system. Please note, that the NWP system has evolved significantly since then, especially in MW data use and IR GEO and hyperspectral data use (see Table). Fig. 4 shows the relative difference in rms for a set of denial experiments compared to the full data use control setup. Results for IR hyperspectral are not included here as the IASI use was undergoing several changes at the time.

While conventional data are still the most important data type on the NH, satellite data by far outweigh this on the SH. MW radiances as well as AMVs have the most significant impact of all satellite data on both hemispheres. For MW data impact will have increased further due to the use of additional humidity radiances over sea and land. Also, ongoing developments of 4D-EnVAR and all-sky assimilation will further enhance the impact of satellite radiances.

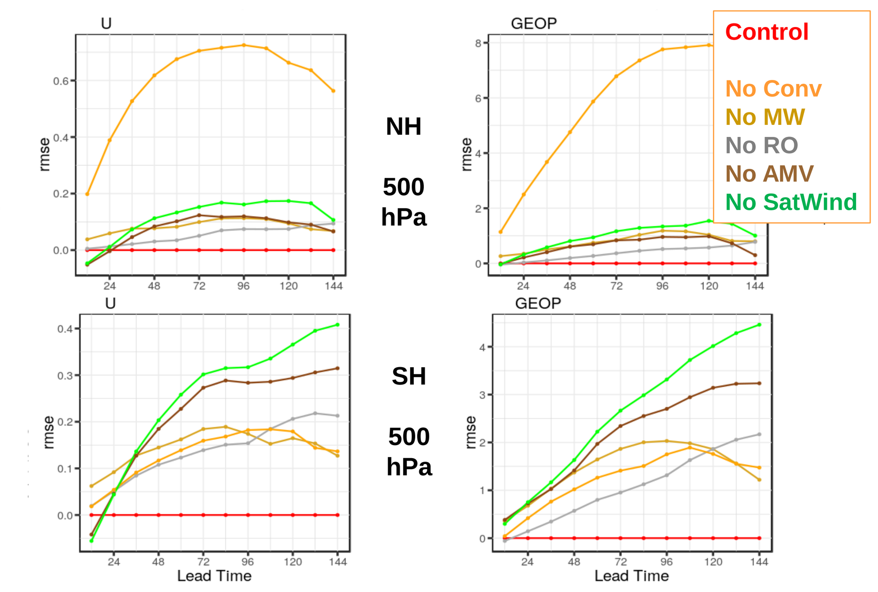
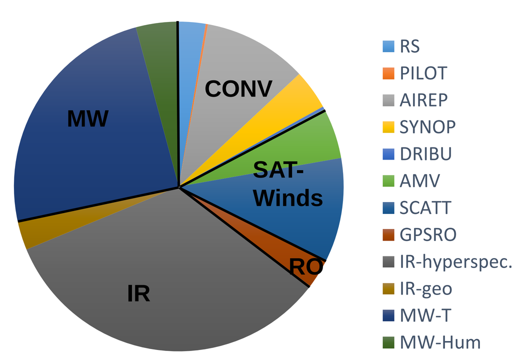


Fig. 4: Difference in rms-error between denial experiments and control as a function of forecast lead time for wind (left) and geopotential (right).

5. Current operational data use

Fig. 5 gives a snapshot of the current operational data use. About 5.3 million data items are assimilated per 24 h (in eight 3h assimilation windows). Satellite data represent 67.4 % (with 36.3 % IR and 28.4 % MW) of the data. With the inclusion of additional instruments based on current work this percentage will be increasing further over the next years.



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