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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Data assimilation for a combined ICON/ICON-ART NWP system at DWD

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The global operational NWP system of DWD uses a high-resolution deterministic run and an ensemble at coarser resolution based on the ICON forecast model. We present a planned update that adds a second system using a coarser deterministic run and fewer members, which is based on ICON-ART, an extension to ICON that allows the prognostic forecast of aerosol tracers including their interaction with the atmosphere. By combining both ensembles in the data assimilation system, we are able to compensate for the reduced ensemble size and achieve analysis and forecast qualities comparable to or better than a full ensemble, while at the same time improving the current operational system.

Aerosol Dust at DWD

Mineral dust aerosol is an important factor for atmospheric composition. It changes the radiation balance in the atmosphere and can trigger the formation of clouds. It affects the optical depth of the atmosphere and therefore the production rate of solar power.
Due to its importance, DWD plans to provide ensemble forecasts featuring prognostic mineral dust. Hence we employ ICON-ART, an extension to DWD's ICON model that allows the simulation of **A**erosols and **R**eactive **T**race gases (ART) and their interactions with the atmosphere.
In this work we present the future operational NWP and data assimilation setup used to produce these mineral dust forecasts.

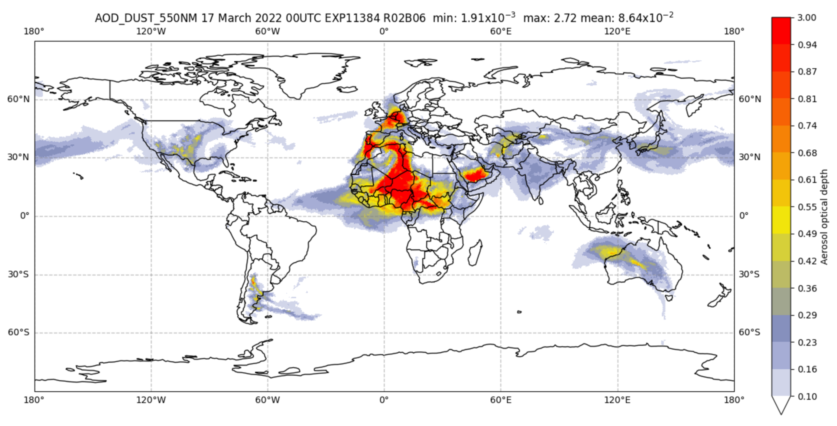

Figure 1: Mineral dust optical depth at 550nm.

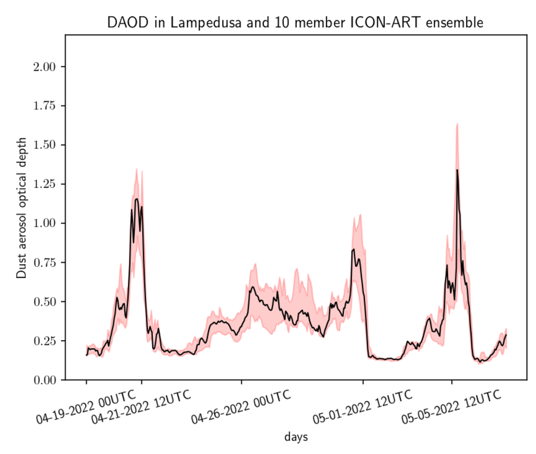

Figure 2: Mineral dust optical depth of det. run + 10 members.

NWP and Data Assimilation Setup

DWD's operational NWP system consists of a deterministic run at 13 km resolution and a 40 member ensemble at 26 km resolution. The system features a nest at higher resolution over Europe.

The data assimilation system is a hybrid method EnVar consisting of a three-dimensional variational analysis (3D-VAR) coupled with an ensemble Kalman filter (LETKF) followed by an ensemble recentering. The covariance matrix in the variational analysis is build from climatological covariances as well as dynamical covariances derived from the ensemble.

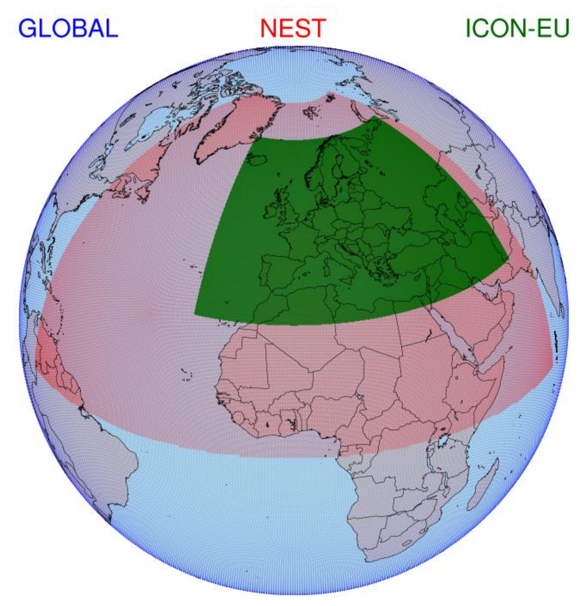

Figure 3: ICON-EU Nest (green) and ICON-NANA-Nest (red)

DWD will introduce a second NWP system based on ICON-ART that uses a similar setup as the original one. Hence the data assimilation updates only the standard set of meteorological variables of the atmosphere and not the dust variables. Since north-Africa and the northern Atlantic are important for the transport of mineral dust to Europe, the system features a larger nest including those regions.

Motivation for a Data Assimilation System with a Combined Ensemble

ICON-ART simulations including the prognostic aerosol tracers and the larger nest are more expensive than regular ICON simulations. To reduce the costs for operational production we must introduce some simplifications for the second system:

- Reducing the deterministic resolution to 26 km
- Reducing the ensemble size to 10 members

The system shows promising first results but has less spread.

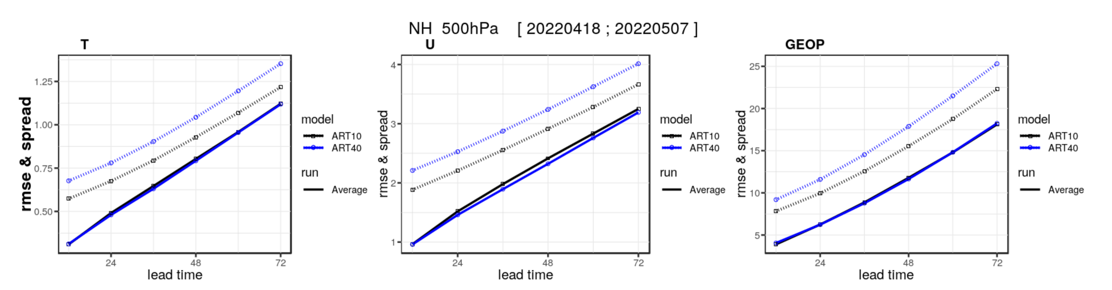

Figure 4: RMSE (full) & spread (dotted) of 10 member vs 40 member ICON-ART

Using only 10 members has a negative impact on the uncertainty estimation of the dynamical part of the covariance matrix. This reduces the quality of the analysis and the resulting weather forecasts of the new NWP system when compared to a system with 40 members.

To improve the quality we couple both systems by adding the members of the original NWP system when building the dynamical covariance matrix, effectively using 50 ensemble members.
Generated by the same NWP model at the same resolution both ensembles feature similar biases, but also differ due to the effects of the prognostic mineral dust and the different nests.

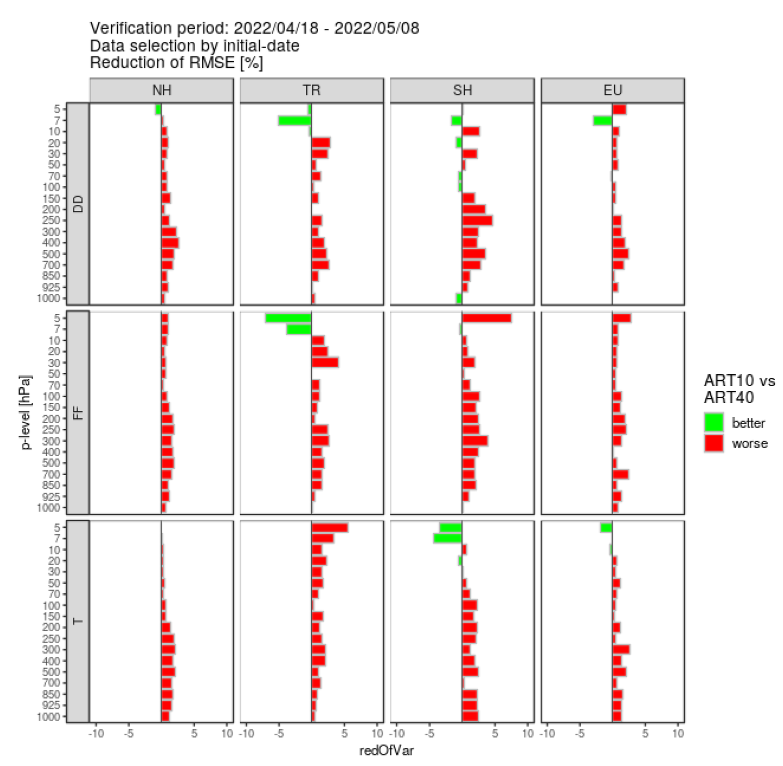

Figure 5: 10 member vs 40 member ICON-ART.

10+40 Member variational Data Analysis

The new system uses the additional members in the 3D-VAR to improve the deterministic analysis (ARTcvar), the LETKF operates only on the 10 ART members. However, the recentering ensures that the improved quality gets transferred to the ensemble.

The resulting forecast quality is comparable to a 40 member ICON-ART system, radiation is comparable to the higher resolved operational ICON runs, cloud cover is improved.

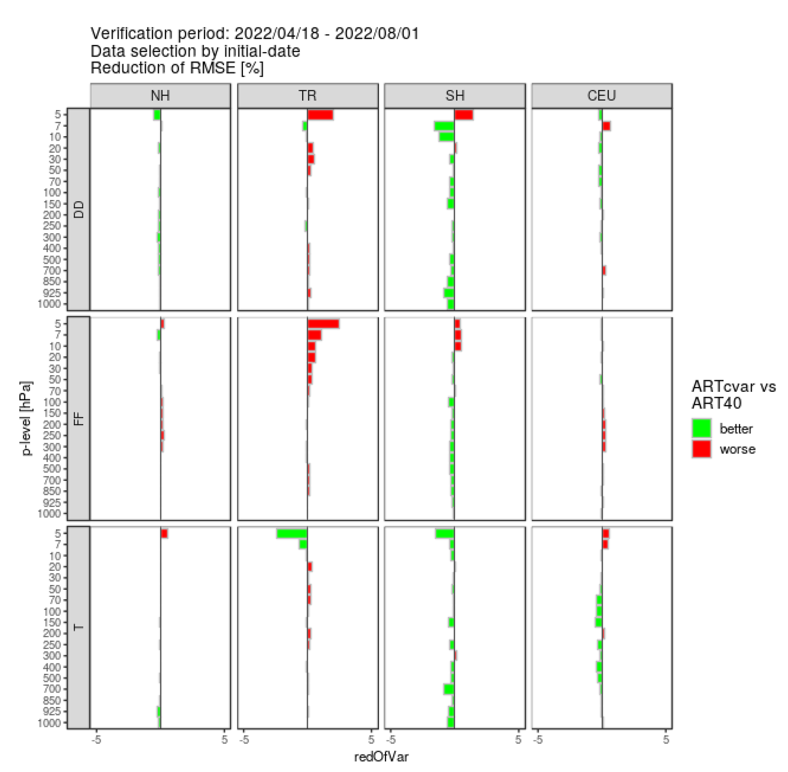

Figure 6: Combined 10+40 member vs 40 member ICON-ART

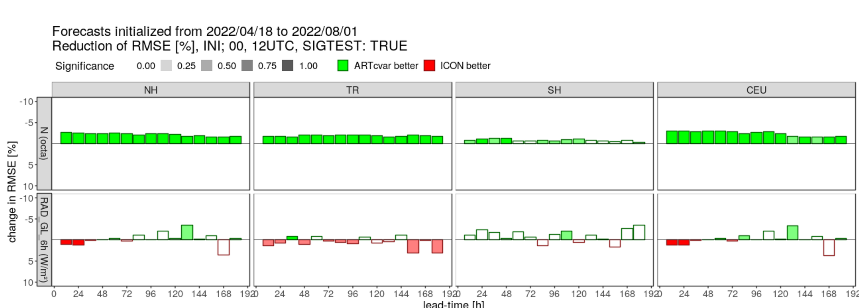

Figure 7: Combined 10+40 member ICON-ART vs operational ICON

Outlook and future developments

Using the combined ensemble also in the ensemble Kalman filter can further improve the quality of the ART-system.

Back-coupling the ART members to the operational NWP system can improve the forecast quality of the original system.

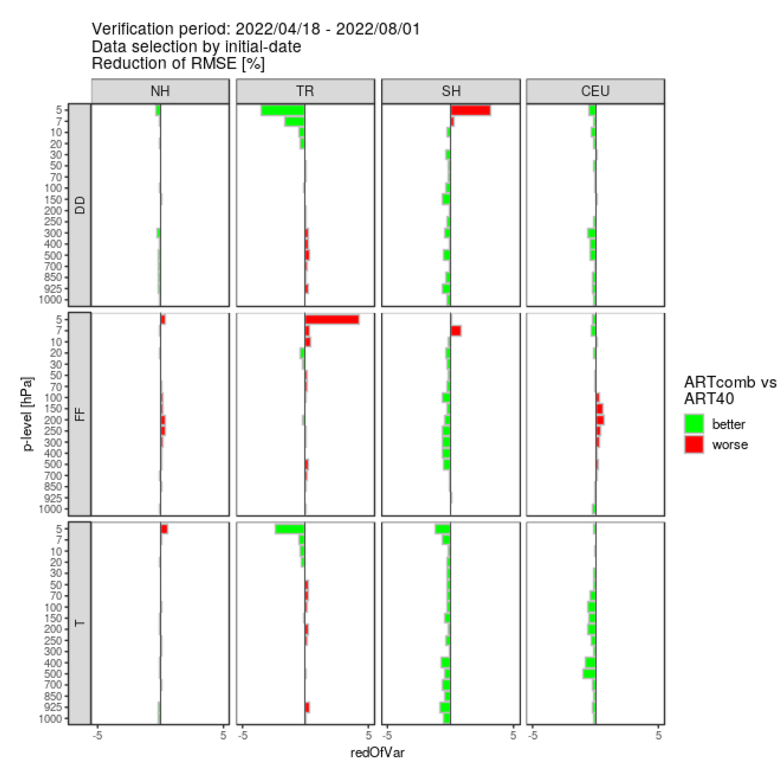

Figure 8: Full combined 10+40 member ICON-ART vs 40 member ICON-ART

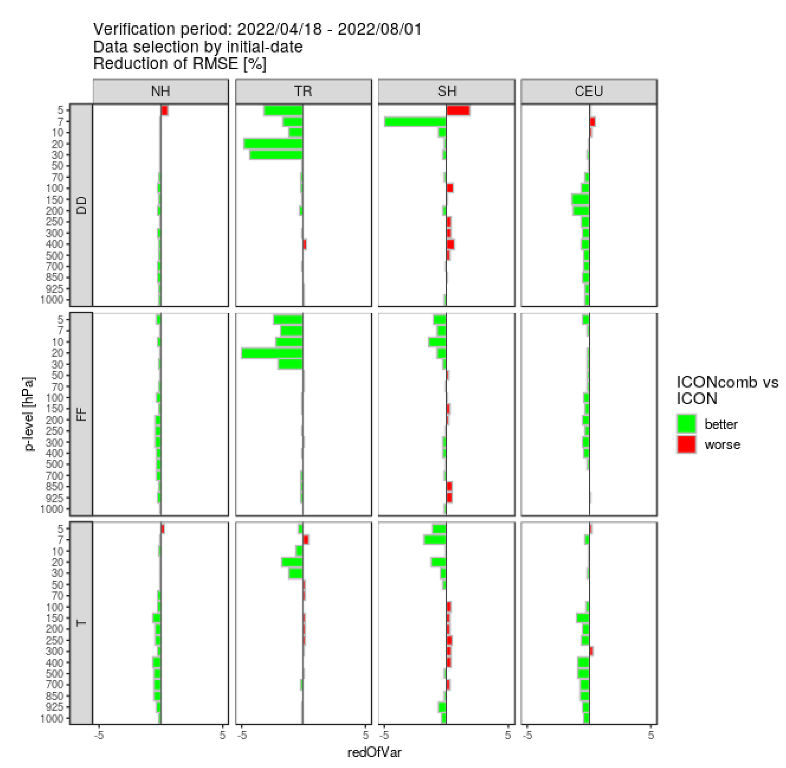

Figure 9: Full combined 40+10 member ICON vs operational ICON

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