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Developments in Satellite Radiance Assimilation

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This poster gives a summary of recent upgrades to satellite radiance data use in the operational global ICON/EnVAR system of DWD since ITSC-23 as well as an overview of ongoing developments.
The last years saw global system updates to the radiative transfer setup, the introduction of RTTOV 13 and a revision and enhancement of the assimilation of microwave humidity sounding channels. Current work in the global ICON/EnVAR system focuses on further increasing data use by adding more low peaking channels over land and ice or snow covered surfaces as well as updates to the bias correction approach.

Another focus has been the development of an all-sky assimilation capability for IR water vapour (WV) and visible (VIS) radiances from SEVIRI in the regional convection-resolving ICON-D2/LETKF system. VIS reflectances will become operational in March 2023 and are also used in the pre-operational suite of the new rapid-update-cycle assimilation. This RUC system contributes together with enhanced nowcasting techniques to the new seamless very short-range forecasting system SINFONY. Current focus is the operational introduction of the water vapour channel all-sky use as well as the preparation for the hyperspectral IRS radiances.

1. Global ICON/EnVAR: recent upgrades & developments

The Table shows a summary of satellite radiance assimilation upgrades since ITSC-23.

Instrument	Date	Change
GEO CSR	June 2020 June 2021 June 2022 Dec 2022 Jan 2023	• METEOSAT: Switch to ASR data stream • GOES: Switch to ASR data stream and EUMETCast • Switch of MET-8 to MET-9 for IODC • Switch of Himarari-8 to Himawari-9 • Switch of GOES-17 to GOES-18
IASI	Jan 2022	• Upgrade to CADS v3.1 (McNally&Watts cloud detection)
RTTOV	Mar 2022 May 2022 Jan 2023	• Introduction of RTTOV-v13 code (v7 predictors) • Use of up-to-date O_3 fields from ECMWF forecasts in radiative transfer • Introduction of RTTOV-v13 predictors (including updated optical depth smoothing for humidity sensitive channels) **See Poster 13p.01**
AMSU-A ATMS	May 2022	• Introduction of dynamic emissivity retrieval capability and MW emissivity atlases • Addition of channels AMSU-A ch 7,8 and ATMS ch 8,9 over land, snow and ice surfaces
MHS, ATMS, SSMIS	May 2022	• Update of cloud/rain screening for MW humidity channels • Introduction of constrained bias correction for high peaking MW humidity channels (MHS, ATMS) **See Poster 15p.03**
ICON, ICON-EPS	Nov 2022	• Increase of ICON - EPS resolution to 26 km / 13 km ICON/ ICON-EU model unchanged at 13 km / 6.5 km • Increase of ICON/ICON-EU vertical levels to 120 / 74 levels (120 Levels up to 75 km, ~0.01 hPa)
MWHS-2	Jan 2023	• Addition of MWHS-2 (ch 11,13,15) on FY-3C, FY-3D, FY-3E including extension of constrained bias correction approach **See Poster 15p.03**

Towards an all-surface approach:

MW and IR surface emissivity atlases (CNRM, TELSEM2, UWIRemis, CAMEL) and a dynamic ε_s retrieval capability (e.g. Karbou et al., 2006) have been implemented. The ε_s retrieval uses a MW window channel and atlas values as fall back values.

As a first step MW radiances over land and sea ice from AMSU-A ch 7,8 and ATMS ch 8,9 have been added to operations. The cloud/rain screening uses a FG check at 52.8 GHz and a scattering index, tuned still for a quite strict selection (Fig 1a). Nevertheless, the forecast impact is distinctly positive (Fig. 1c), especially for the SH and SH polar areas (Fig. 1b). Tests are ongoing with adding also AMSU-A ch 5,6 (and ATMS ch 6,7), also testing Lambertian reflection over sea ice and snow as well as a treatment for coastal OBS by averaging ε_s over land and sea parts of the FOVs.
Additionally, experiments with IASI over land (still excluding channels with significant surface contribution) are conducted using CAMEL ε_s and show a modest positive impact and are encouraging for extending the IASI data use.

Evaluation of MWHS-2 and MWTS-2 from FY-3E:

MWHS-2/FY-3E was evaluated to be of good quality and is now used operationally. MWTS-2, however, displays noise patterns that do not allow its introduction yet.

Impact of assimilating additional AMSU-A & ATMS channels over land & ice

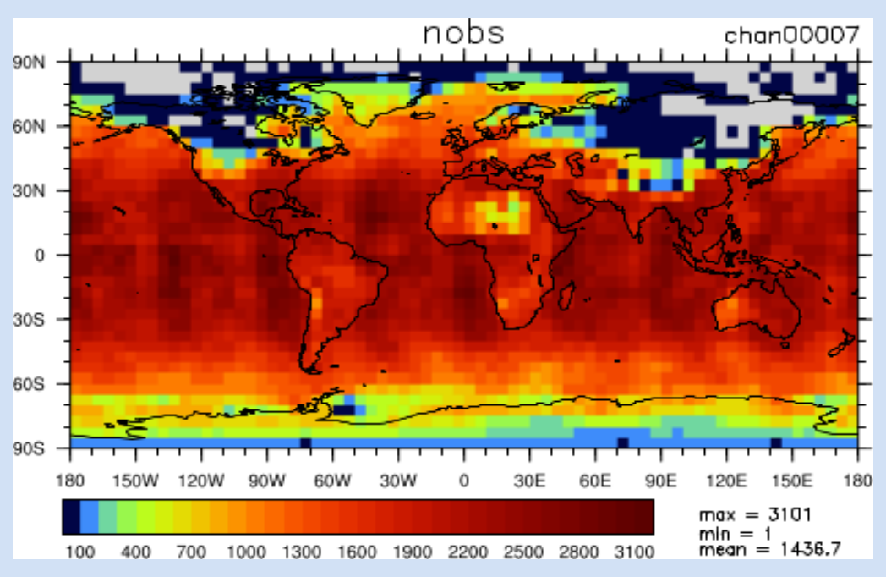
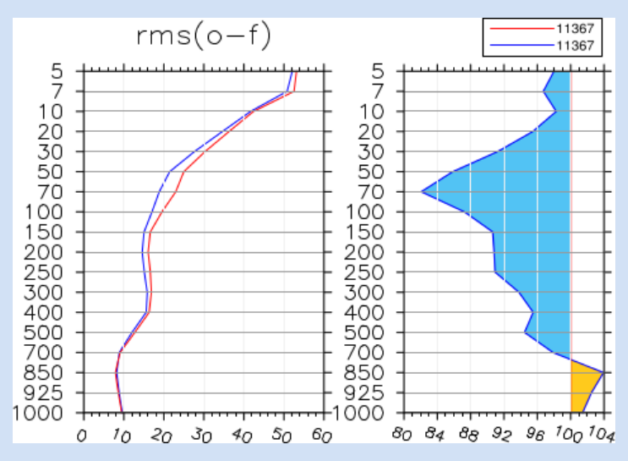


Fig.1a (top left): Number of AMSU-A ch 7 observations used in a 2-month winter experiment in 2021/2022.



RS geop.
for SH
polar area

Fig.1b (bottom left): Impact on radiosonde geopotential for the SH polar area; RMS(obs-fg) and relative change of RMS(obs-fg) for the experiment adding AMSU-A ch7,8 (and ATMS ch8,9) over land and sea ice.

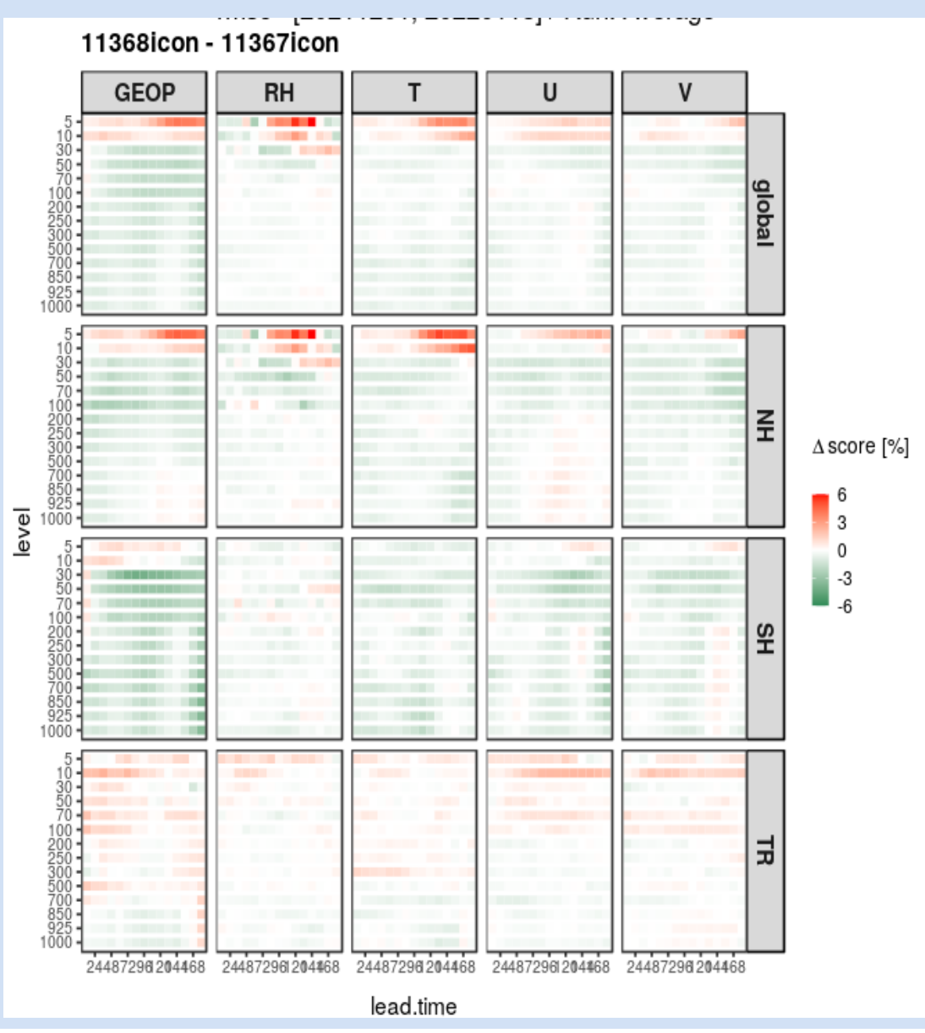


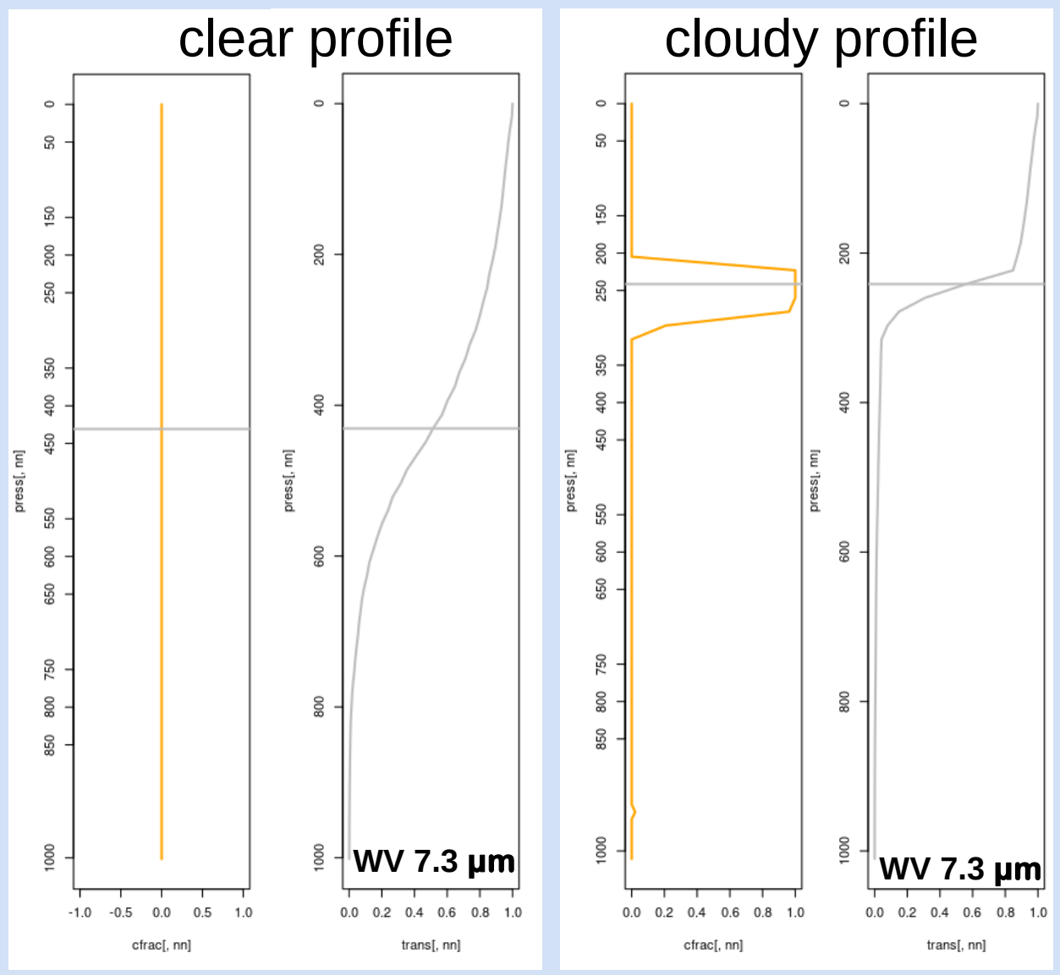
Fig.1c (right): Forecast verification against analyses showing the relative rms(fc-ana) difference versus the control. Green/red indicate improved/degraded forecasts.

2. High-resolution ICON-D2/LETKF: use of all-sky radiances

The short-range forecasts at DWD are based on the convection-resolving ICON-D2 model at currently 2.2 km and an ensemble LETKF assimilation. It allows an update not only of the dynamic variables but also of model clouds (e.g. cloud water and ice). With the implementation of radiance assimilation we want to take advantage of the high time resolution of geostationary SEVIRI data and aim at improving particularly the forecasts of surface parameters and precipitation. The assimilation of visibile 0.6 µm reflectances (VIS) in ICON-D2 uses RTTOV v13.1 and will become operational in March 2023. VIS assimilation is also part of the RUC system **(see Presentation 3.01)**.

In parallel an all-sky assimilation of the SEVIRI WV channels at 6.2 µm and 7.3 µm has been developed using an observation error model based on a symmetric cloud impact parameter and using vertical localization around the level with transmission 0.5 (see illustration in Fig. 2) and Gaspari-Cohn type vertical localization with 0.3 in ln(p).

SEVIRI WV all-sky assimilation: Vertical localization and observation error model



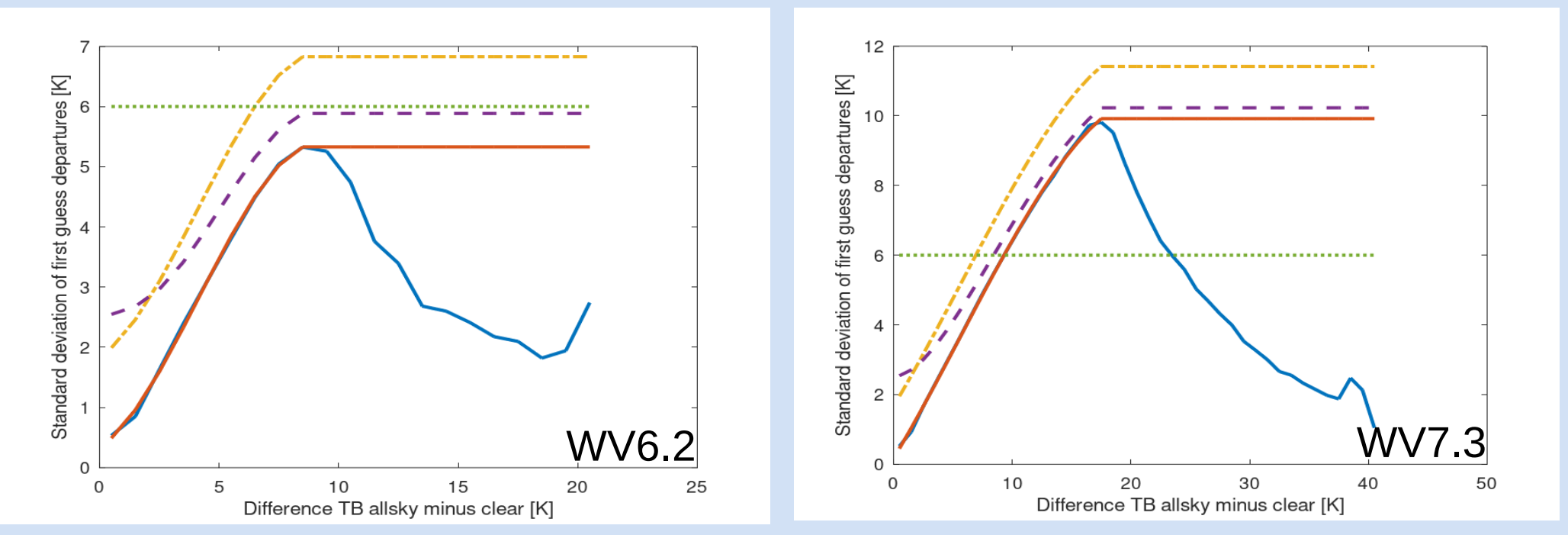


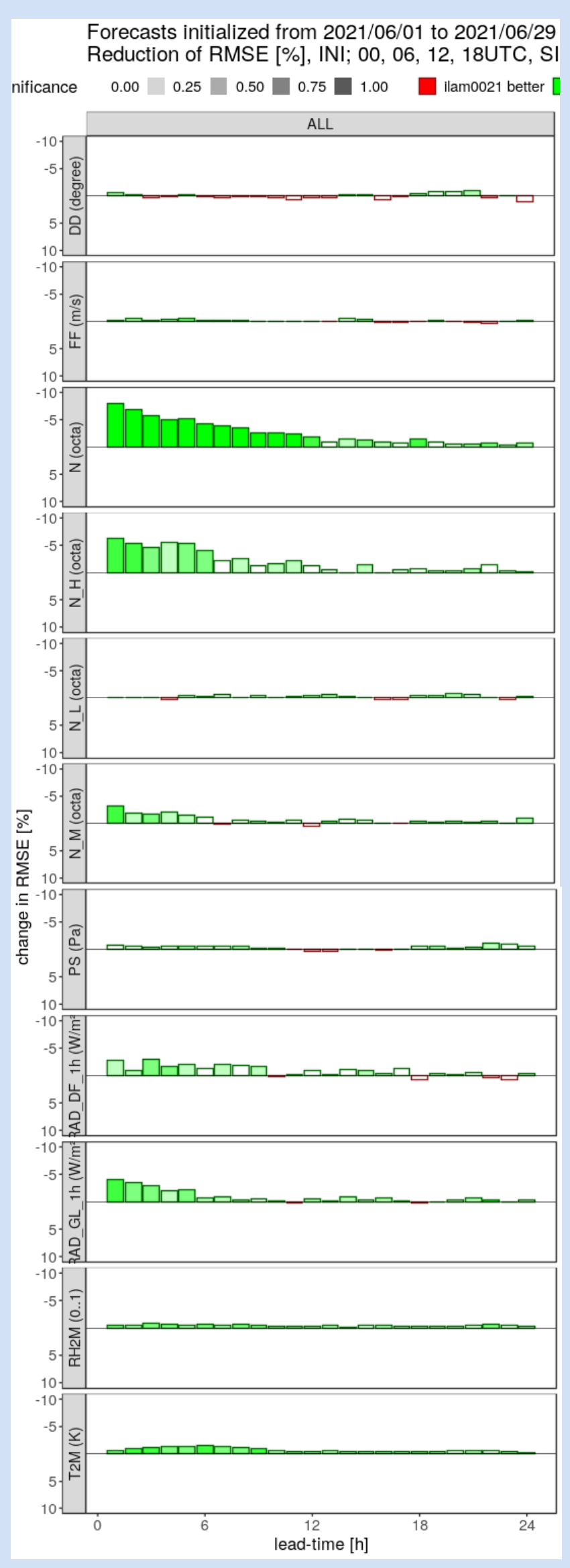
Fig.2a (left): Vertical localization level used for LETKF as a function of transmittance for a clear and a cloudy profile example for 7.3 µm.

Fig.2b (top): Error model basd on symmetric cloud impact (see Okamoto et al. 2014) with stdv(obs-fg) as blue lines, polynomial fit as red lines, and tuned inflated error model as dashed lines.

The forecast impact of the WV channels has been studied with a series of experiments. Other data used comprise radiosondes, SYNOPs, aircraft data, and 3D radar reflectivities. The tests resulted in a setup using an inflation of the parameterized observation error (Fig. 2b), a thinning taking every 4th pixel in both directions, and a horizontal localization of 35 km. There is a clear forecast impact from this WV all-sky assimilation (see Fig. 3) which is only slightly smaller when the WV channels are added on top of a control using also the VIS channel as well as high-resolution MODE-S data (not shown).

Additionally to all-sky experiments with real VIS and WV data, the response of the ICON-D2/LETKF system to different observation types including satellite radiances is investigated using an OSSE setup (**see Presentation 15.09**)

SEVIRI WV all-sky: forecast impact



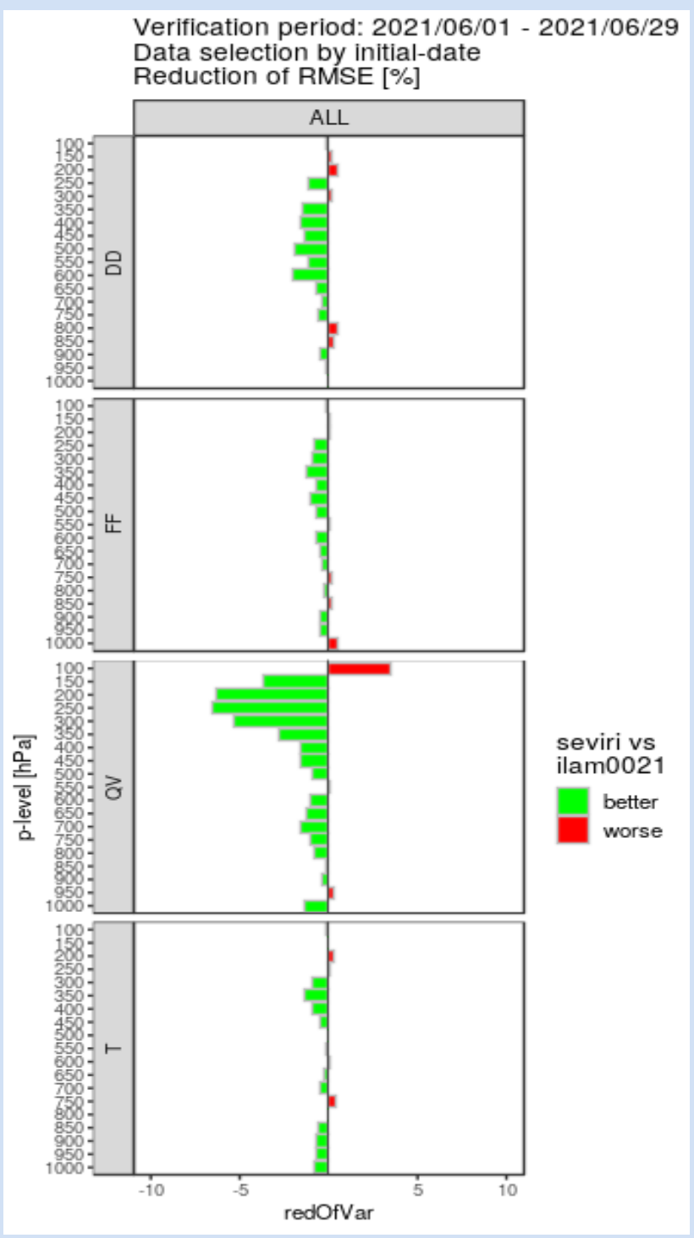


Fig.3a (left): Relative RMS change of surface parameters vs SYNOPs for WV all-sky experiment versus control for a 4 week summer period.

Fig.3b (top): Relative RMS change of T, Qv, and u/v wind components vs radiosondes.

Preparation for IRS

The ICON and regional ICON-D2 systems are also being prepared for the geostationary hyperspectral IRS data. Apart from a range of technical aspects this includes developments for using surface sensitive radiances through implementation and evaluation of the benefit of surface emissivities from the CAMEL atlas as well as of a Ts retrieval functionality. Additionally, a channel selection tool has been developed for hyperspectral data which can also take interchannel correlations into account **(see Poster 12p.06).** Current developments use both simulated IRS as well as current IASI data as proxy for the future IRS spectra.

Karbou et al., 2006: Microwave land emissivity and skin temperature or AMSU-A and –B observations over land. *Q.J.R. Meteorol. Soc.* 132, 2333-2355, doi:10.1256/qj.05.216.
Okamoto, K. et al, 2014: Progress towards the assimilation of all-sky infrared radiances: an evaluation of cloud effects. *Q.J.R. Meteorol. Soc.*, 140, 1603-1614, doi: 10.1002/qj.2242.

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