Assimilation of ground-based microwave radiometer observations into convection resolving ICON model: observing system simulation experiments (OSSE)

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1. Motivation

State-of-the art high resolution, convection resolving NWP models require dense and frequent observations to define detailed initial conditions. Key variables are, among others, the 3-dimensional fields of temperature and humidity. In the boundary layer, both variables are not adequately measured by current observing systems.

- A network of ground-based microwave Radiometer (MWR) has the potential to provide temperature and humidity profile observations.
- **Microwave radiometers** (MWR) measure radiances at 14 channels along absorption lines of water vapor and oxygen (K- and V-band, 22–31 GHz, 51–58 GHz)
- It is essential to evaluate the potential impact of assimilation of MWR observations on the analysis and forecast within operational data assimilation system.
- OSSE's are used to show the potential impact of assimilation of prospective observing systems and networks

2. OSSE 1 (small domain, single obs. experiments, MWR only)

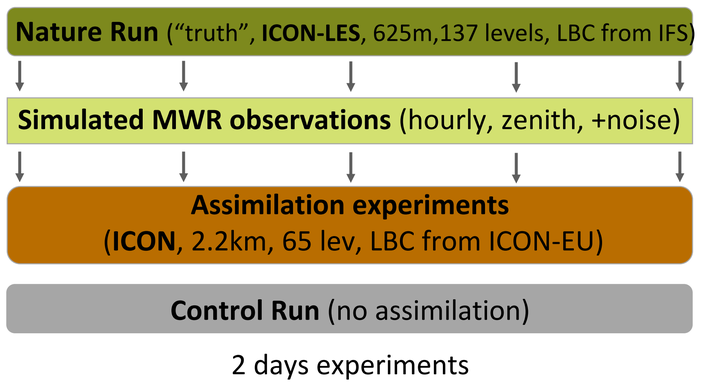

Figure 1: Scheme of the OSSE 1

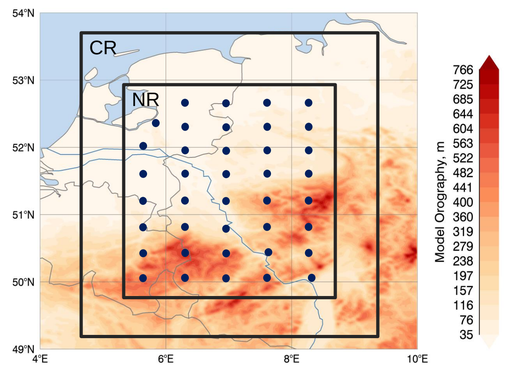

Figure 2: Experimental area in the west of Germany. Dots show the locations of MWR.

To get the first insights into functionality of the assimilation of MWR observations single observation experiments were performed.

- **Nature Run** (NR): to reduce identical twin effect high resolution ICON-LES model for the 150*150 km domain in North Rhine-Westphalia is used (Fig. 2). 2 day period from 12-14. August in 2020.
- **MWR observations** simulated with the fast radiative transfer model RTTOV-gb.
- Only zenith pointing and clear sky observations were assimilated.
- **Assimilation experiments** with **hourly** assimilated MWR observations.
- Kilometer-scale ensemble data assimilation (**KENDA**), Schraff et al. 2016.
- **LETKF** (Local Ensemble Transform Kalman Filter, Hunt et al. 2007) with 40 member and 1 deterministic run.
- Different experiments were carried with **varying localization radius, number of assimilated channels, assigned observation error**.
- The evaluation focuses on the improvements in the accuracy **of temperature and humidity analysis profiles in grid points with MWR** compared to 1h forecast and to the control run**. NR** is considered as "truth".

3. Results of OSSE1

Spatial localization was applied to MWR observations (Figs. 3 and 4):
- **horizontal** with length scale of 5km
- **vertical** using localization functions (Gaspari-Cohn) calculated from temperature and humidity jacobians (Fig. 4)

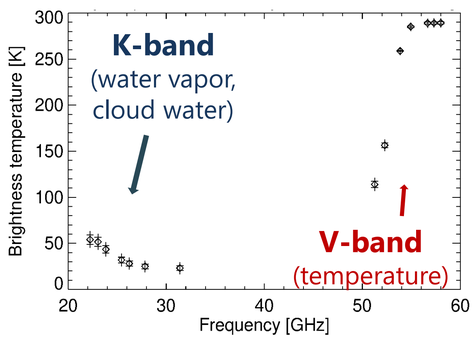

Figure 3: Example of MWR observation: daily mean brightness temperatures at 14 channels.

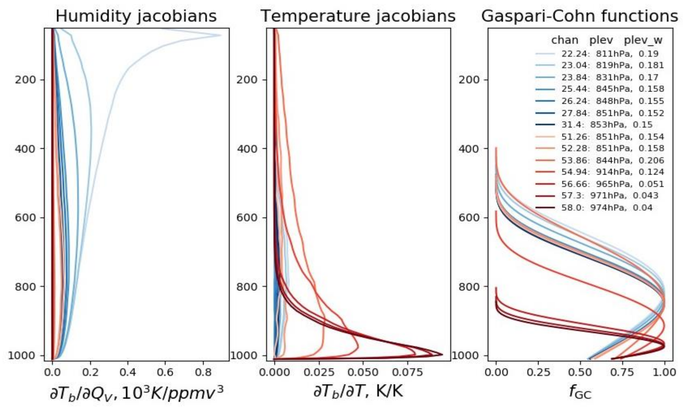

Figure 4: Left and middle: Temperature and humidity Jacobians computed with RTTOV-gb for 14 channels of MWR. Right: Gaspari-Cohn used for vertical localization.

As expected, in observation space the analysis lies closer to observations than the forecast (Fig. 5, example for 3 channels).

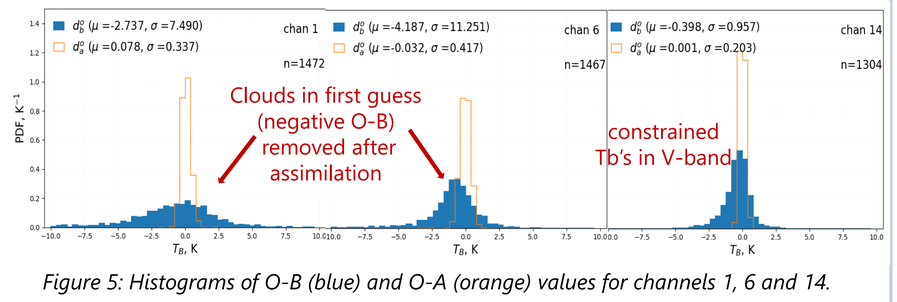

Figure 5: Histograms of O-B (blue) and O-A (orange) values for channels 1, 6 and 14.

Comparison of different assimilation experiments shows the best results for:
- **T profile**: when including the 4 optically thick V-band channels (single or together).
- **QV profile**: when including 7 K-band channels or all 14 channels.

To achieve improvements **in both, T and QV profiles**: **all 14 channels** should be assimilated (Fig. 6).

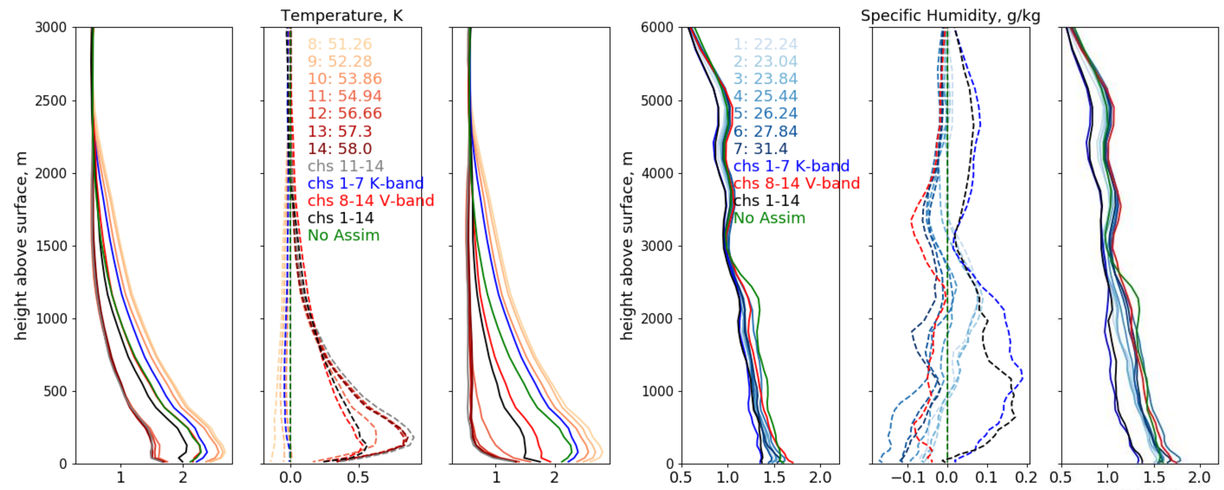

Figure 6: Root-mean-square error (RMSE) of the first guess profiles (1h forecast), improvements in RMSE due to assimilation and RMSE of the subsequent analyse profiles in the grid points with MWR. Each color corresponds to one assimilation experiment (single channels or subsets of channels shown in legend). Left 3 images: temperature, right 3 images: specific humidity. Reference: Nature Run as "truth"

4. OSSE 2 (ICON-D2 domain, MWR, CONV, LHN, RADAR)

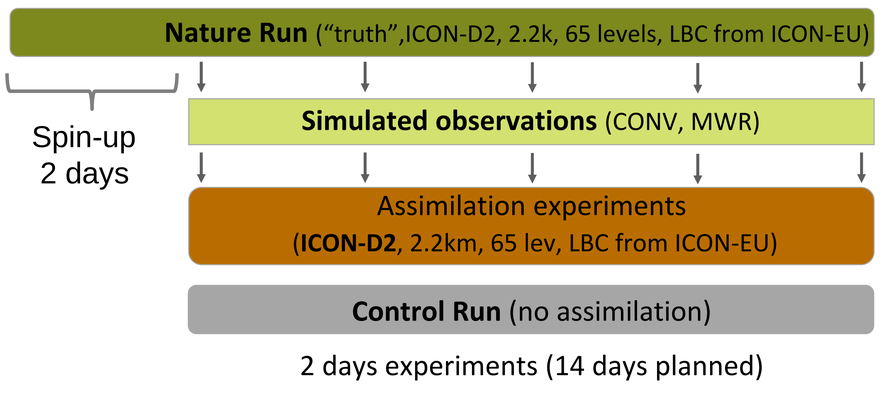

Figure 7: Scheme of the OSSE 2

- **Nature Run** (NR): ICON-D2, 2 days from 18-20 June 2021 with 2 day spin-up period to introduce differences to assimilation and control runs.

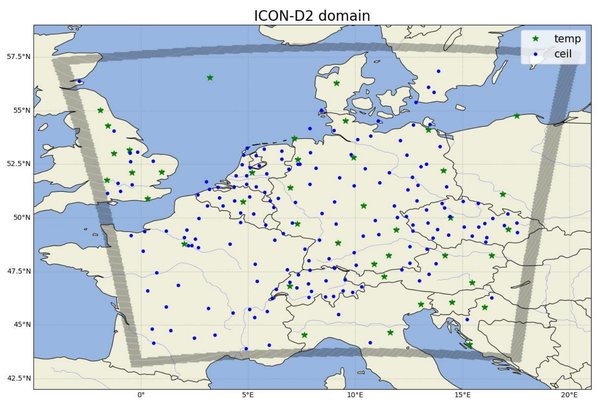

Figure 2: Experimental area of OSSE 2. Green stars and blue dots show the locations of MWR which are assumed to be collocated with currently operational radiosonde stations and stations with E-PROFILE ceilometers

- **Assimilation experiments** with zenith, clear sky **MWR** observations (all 14 channels, **218** Instruments) **and conventional (AIREP, SYNOP, TEMP), latent heat nudging available.**
- For MWR observations: diagonal R-matrix used→ Observation errors inflated by 1.5 to account for correlations.
- Horizontal localization with length scale of 10km.

5. Preliminary results of OSSE2

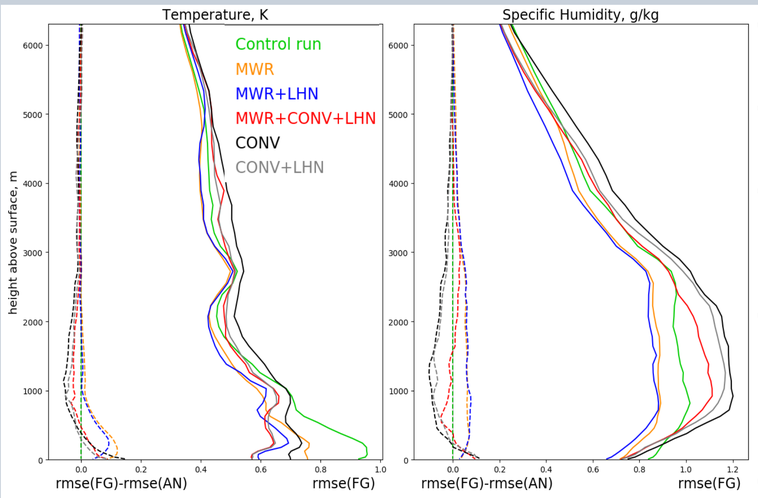

Figure 7: Root-mean-square error of the first guess (1h forecast) profiles of temperature and specific humidity (solid lines) and improvements after assimilation (dashed lines) for experiments performed within ICON-D2 domain.

- Evaluation performed in the grid points with MWR (218).
- **MWR**: positive impact on T and QV profile accuracy.
- **+LHN**: further improvements for T below 2 km and for QV up to 7km height.
- **+LHN+CONV**: degradation for QV profile and for T profile above 500 m. Positive impact on T below 600 m.
- **CONV+LHN**: beneficial only in the lowest 1.5 km for T and 500 m for QV.

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