Assimilation of geostationary water vapour clear sky radiances with an Ensemble Kalman Filter

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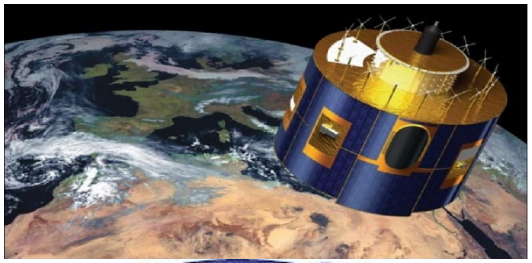
Data Assimilation, DWD



Special thanks to:

Roland Potthast and colleague Stefanie Hollborn
- and to the EUMETSAT fellowship program

Aim of the study

- Assimilation of water vapour clear sky radiances (CSR), especially from MSG/SEVIRI

- Evaluate the ability of ensemble data assimilation system:
  - To extract wind information from a sequence of WV observations
  - Studies within ICON/EnVar system of DWD

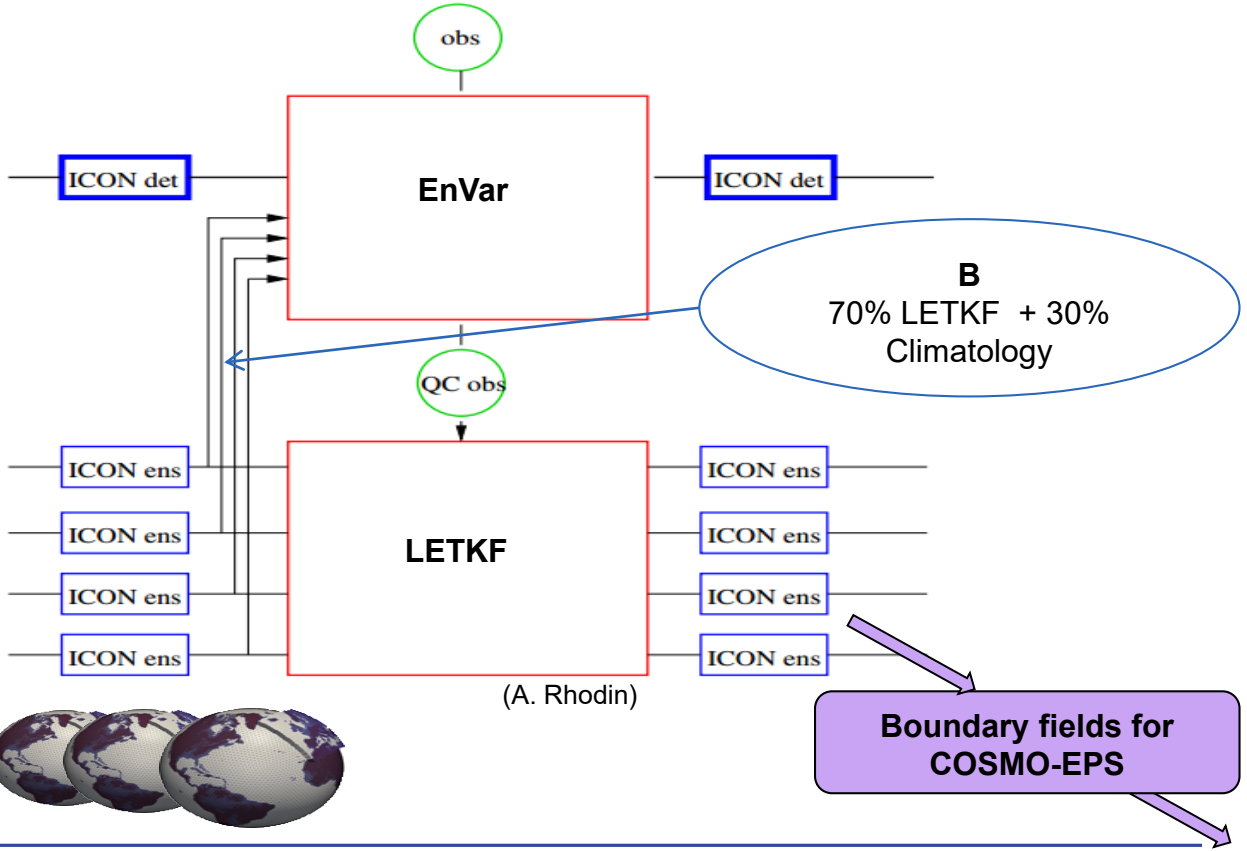
- Context:
  - 4DVar „tracer effect“ [C. Peubey and A.P. Mc Nally, 2009]
  - LETKF: assimilation of AIRS QV retrievals [Liu et al., 2009]

Outline

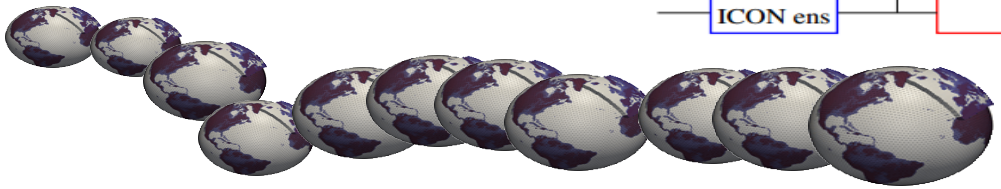
- **Current NWP system at DWD**
- Setup of a framework for idealised experiments
  - Nature run & twin experiments
  - CSR Cycled and non cycled runs
  - Conclusions of the study (overall statistics)
- Assimilation experiments with real SEVIRI data
- Summary and outlook

DWD NWP system: Global

Deterministic ICON:
@ 13 km Global
@ 6.5 km Europe
(two-way nesting)



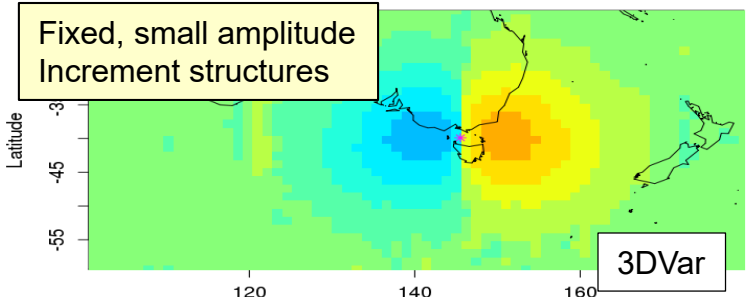
ICON-Ensemble:
40 members @ 40/20km



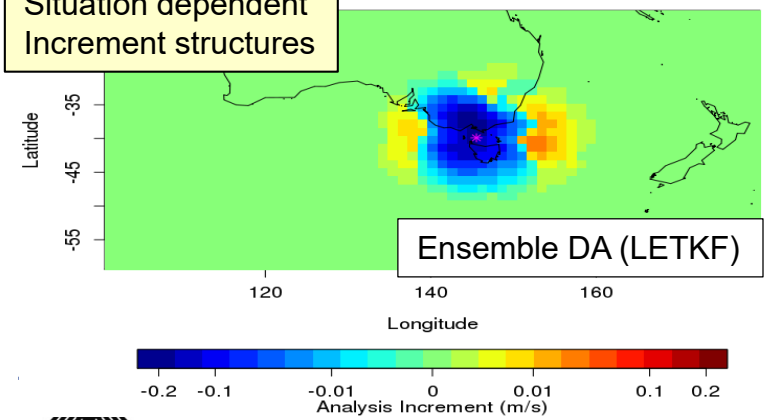
Wind information from humidity sensitive radiances

Example of analysis increments for wind (v-component)
from single WV radiance (HIRS ch11)

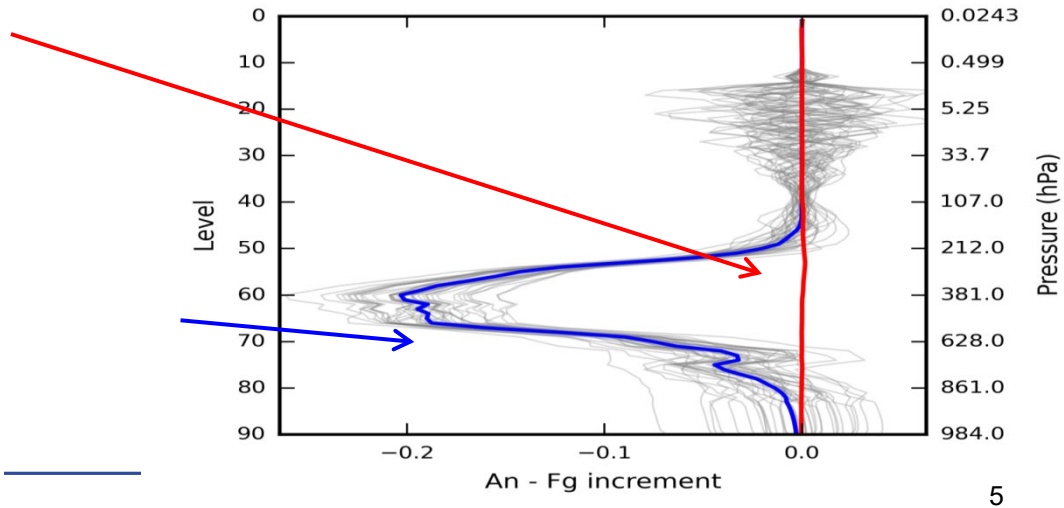
Fixed, small amplitude
Increment structures



Situation dependent
Increment structures



LETKF: Wind increments from single obs
due to cross-correlations in B matrix



Courtesy: Dora Fohring

Outline

- Current NWP system at DWD
- **Setup of a framework for idealised experiments**
  - **Nature run & twin experiments (control and CSR cycled run)**
  - CSR non cycled runs
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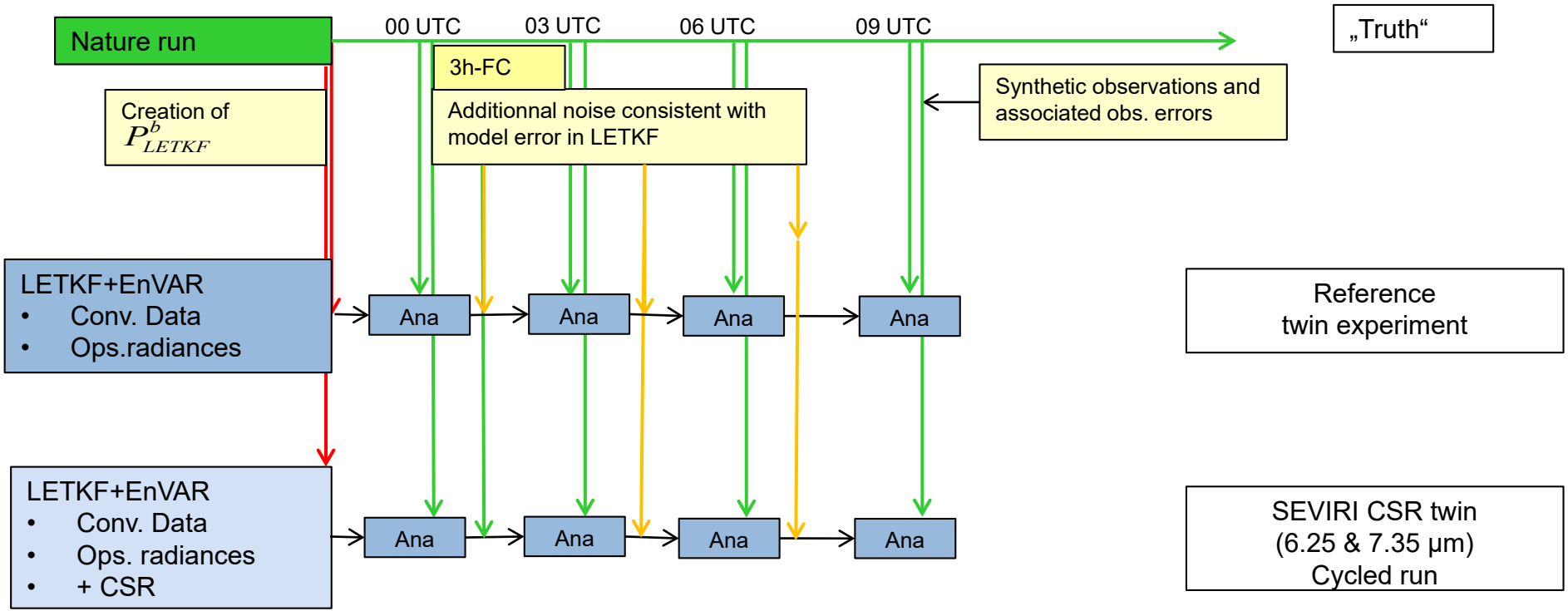
Nature run & twin experiments

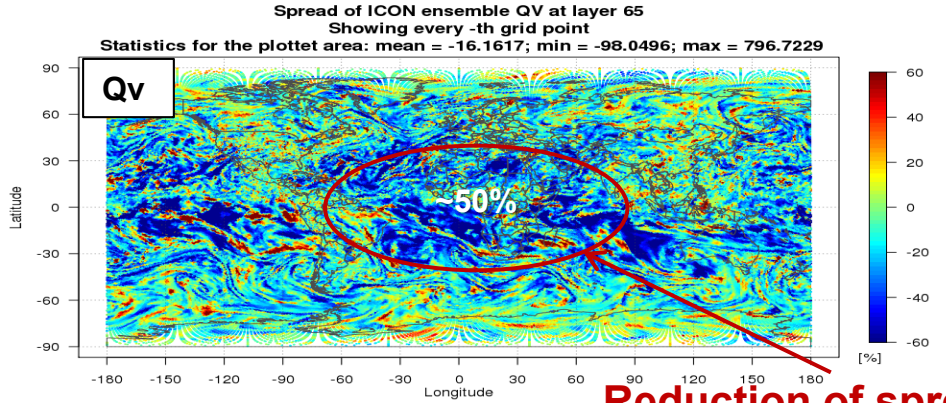
- Nature run: undisturbed integration of the model (01-16.08.2017)
  - Trajectory of the “true atmospheric development” fully consistent with the model formulation
  - Conventional and remote sensing observations simulated by the observation operator

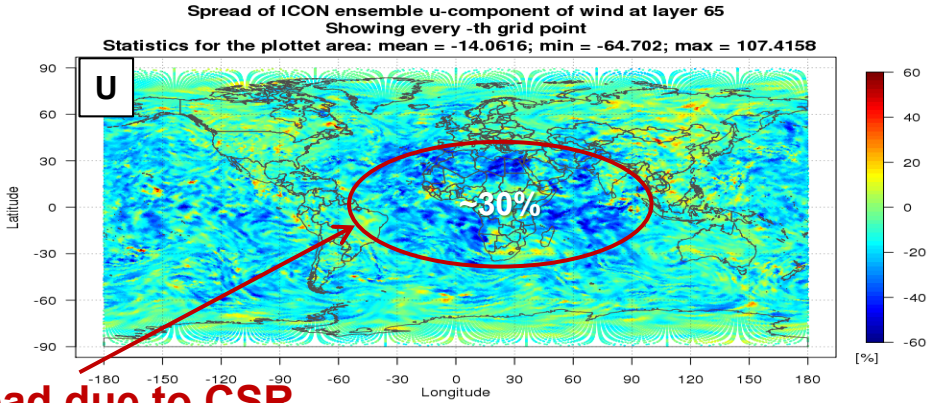
- Twin experiments:
  - Assimilation of synthetic observations
  - Performed under idealised conditions (no model biases, outliers, etc.)
  - Explore the value of the data in LETKF+EnVAR under optimal conditions

Illustration of Nature & twin experiment setup

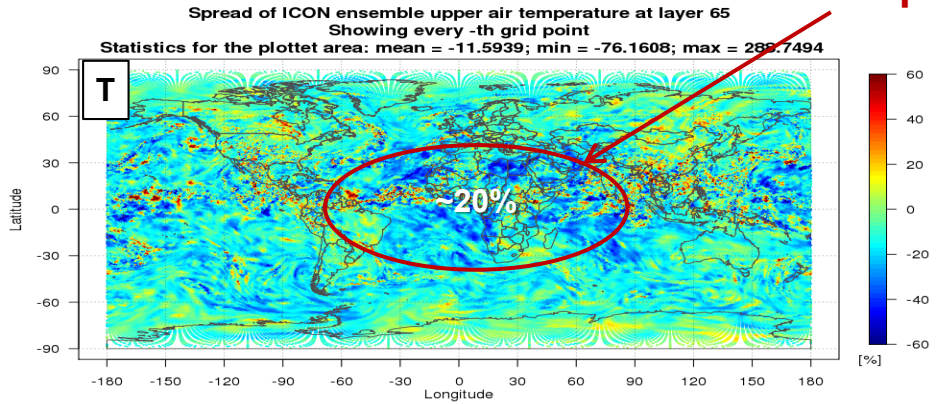


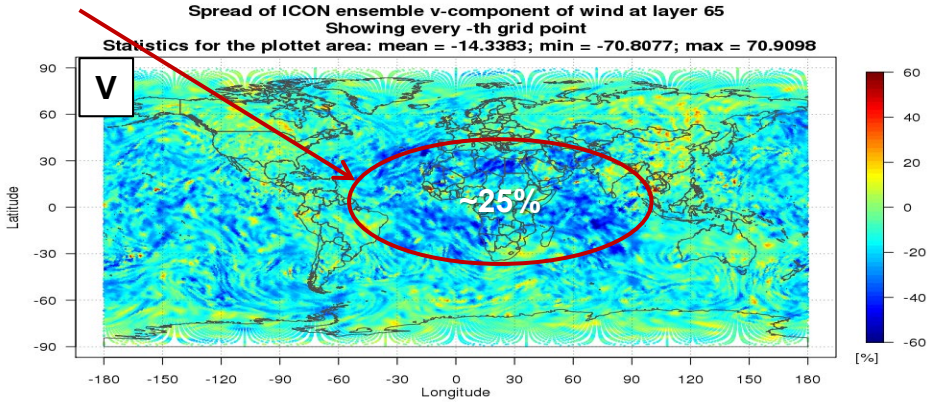
500 hPa forecast ensemble spread (CSR vs. Ref.)



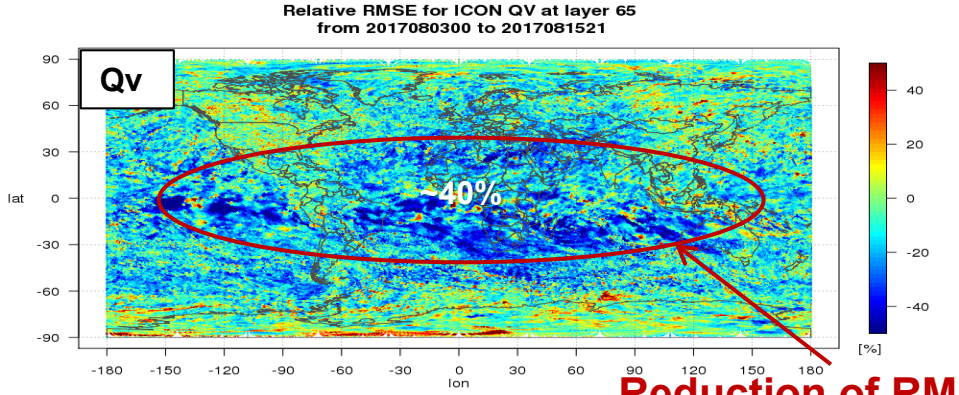


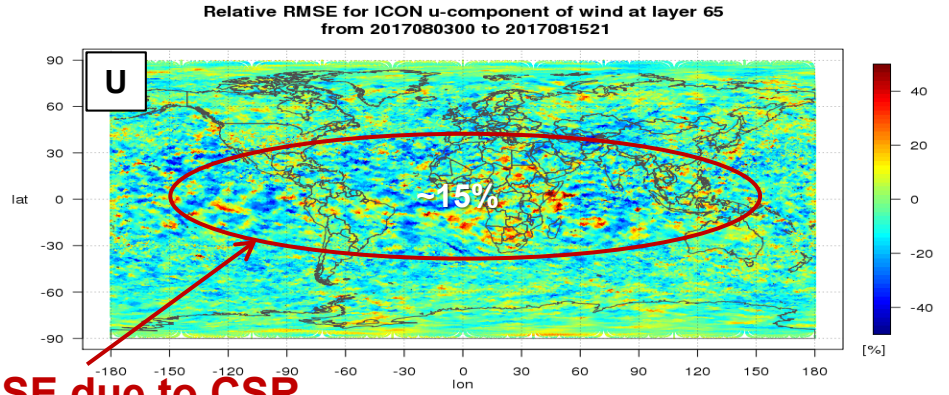
Reduction of spread due to CSR



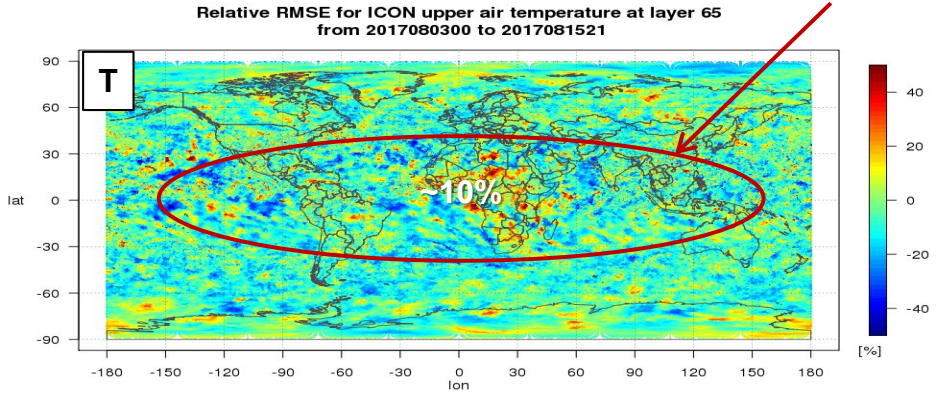


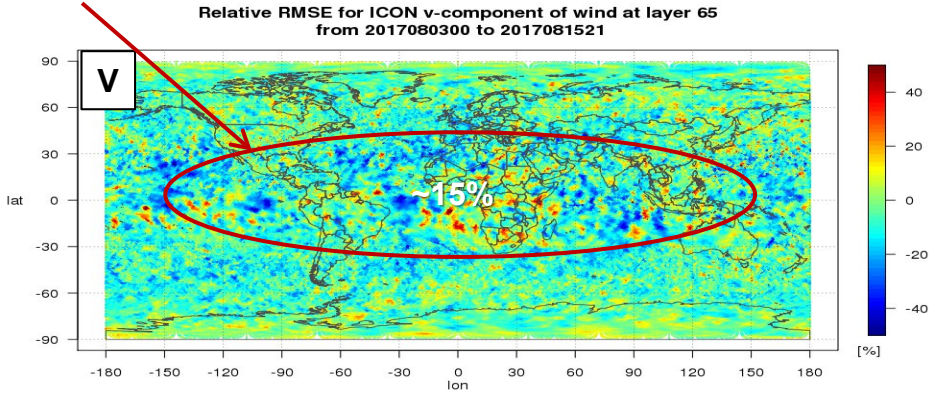
500 hPa analysis RMSE (vs. Nature)
CSR – control





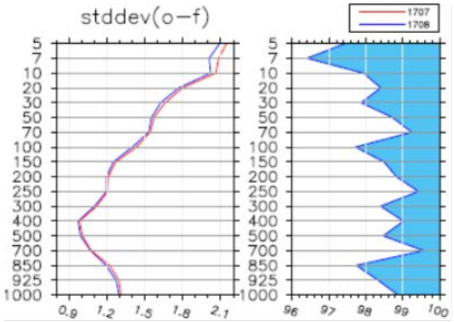
Reduction of RMSE due to CSR



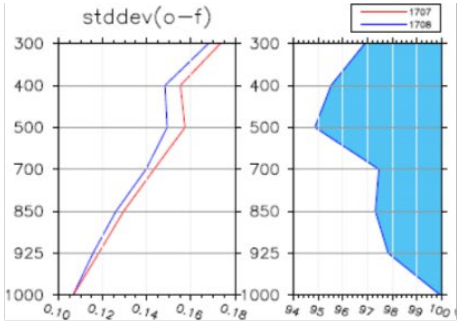


O-B departure statistics

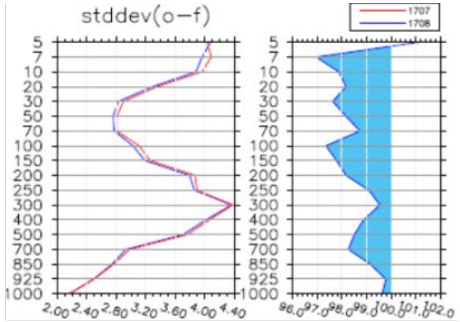
Temperature radiosondes

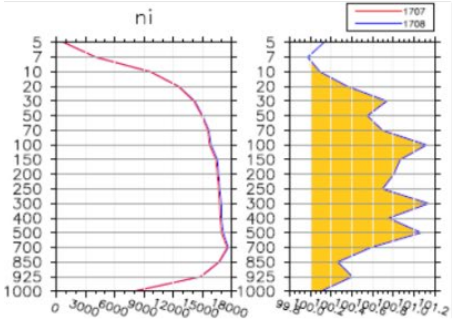


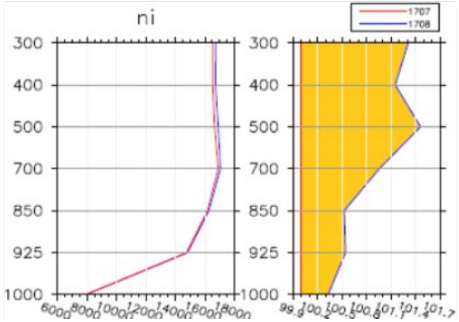
Humidity radiosondes

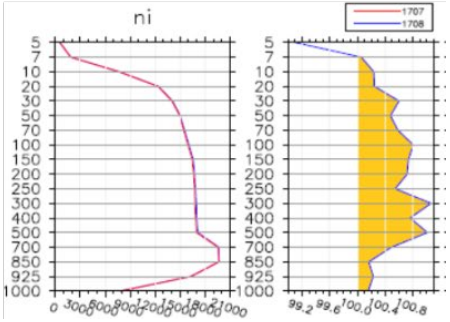


Wind AMV









Outline

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  - **CSR non cycled run**
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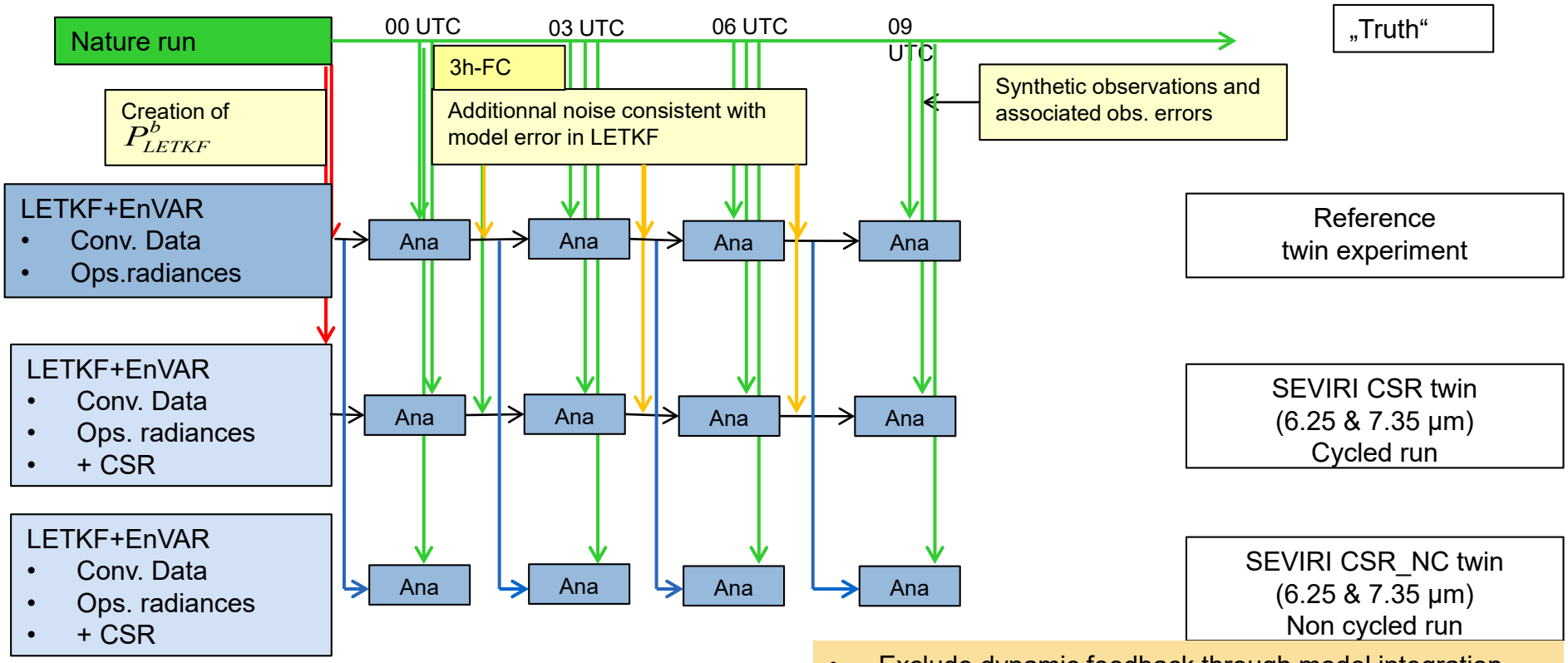
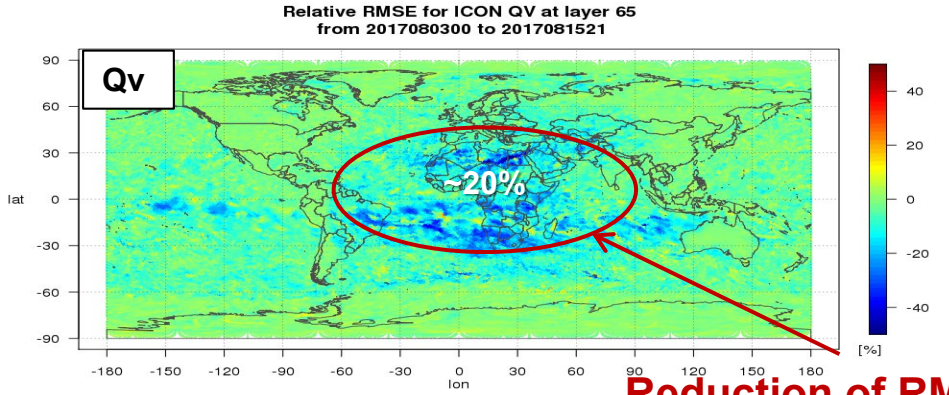
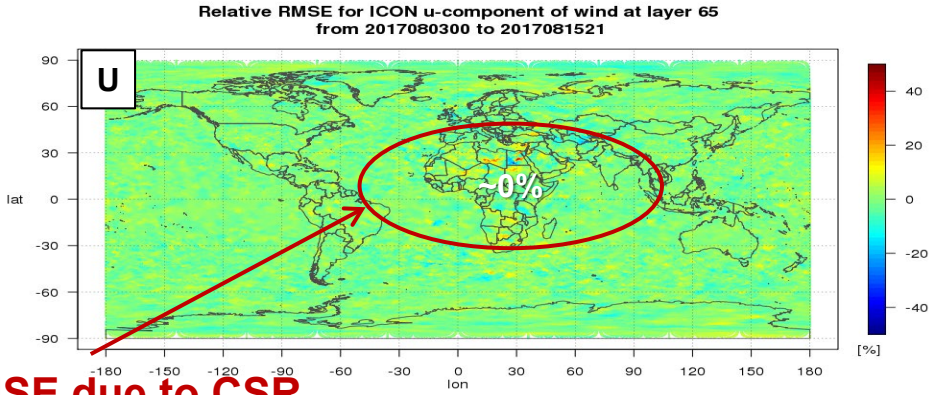
Illustration of Nature & twin experiment setup



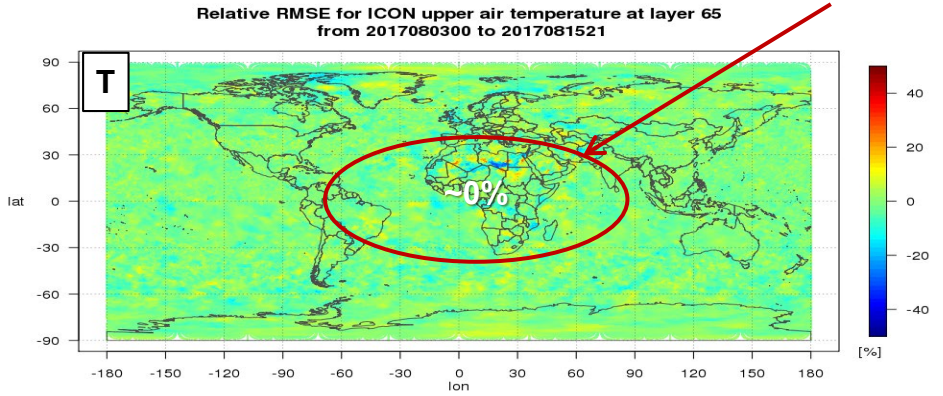
- Exclude dynamic feedback through model integration
- No improvements in B through CSR assimilation

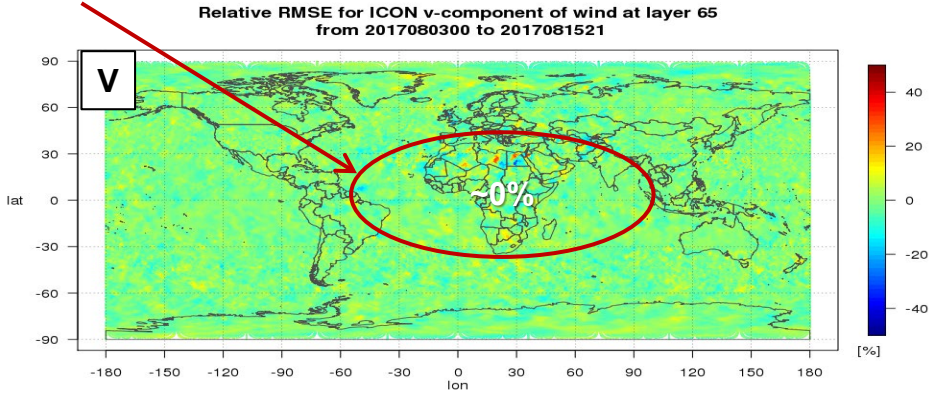
500 hPa analysis RMSE (vs. Nature)
CSR_NC – control





Reduction of RMSE due to CSR





Outline

- Current NWP system at DWD
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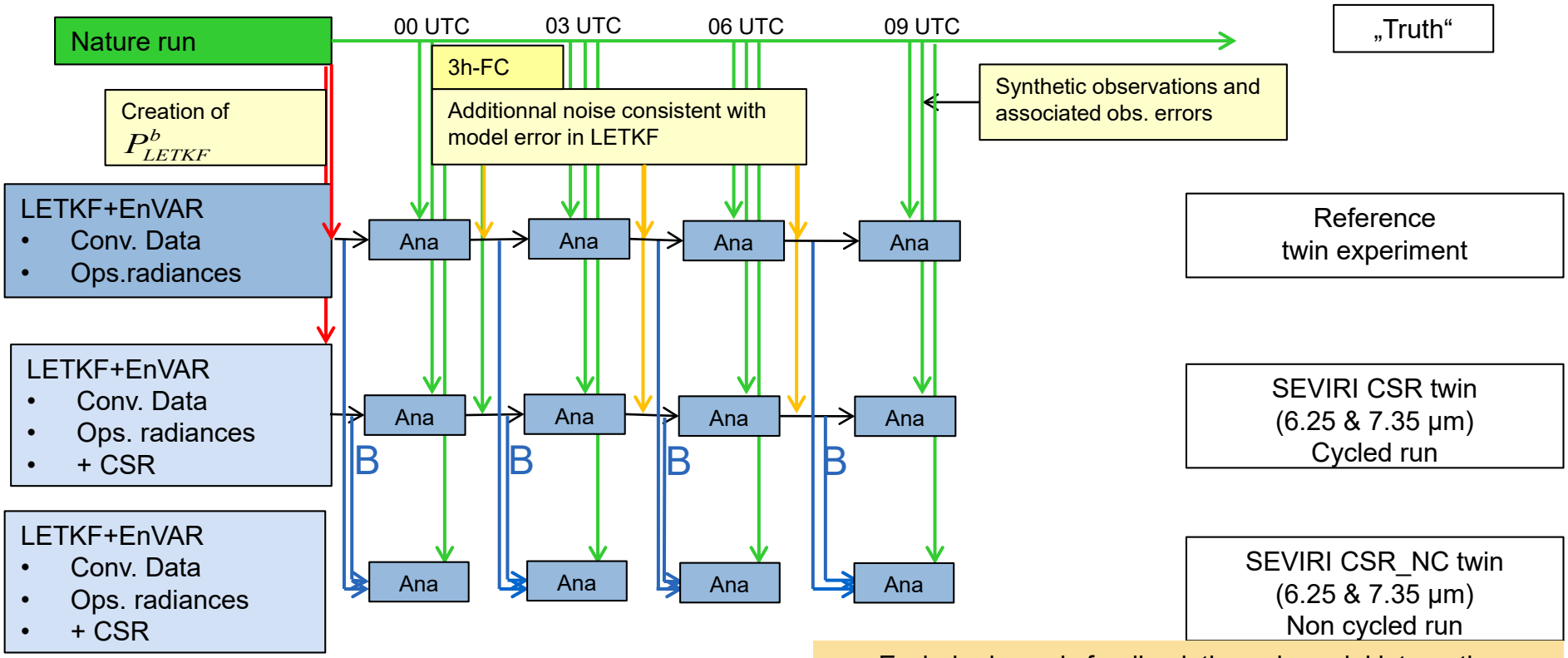
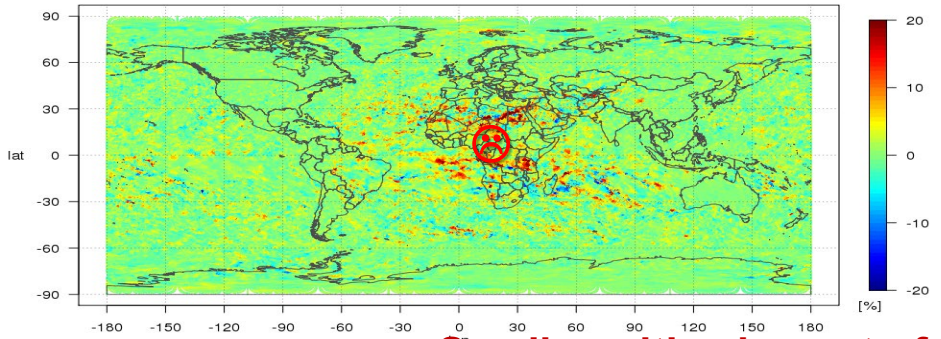
Illustration of Nature & twin experiment setup



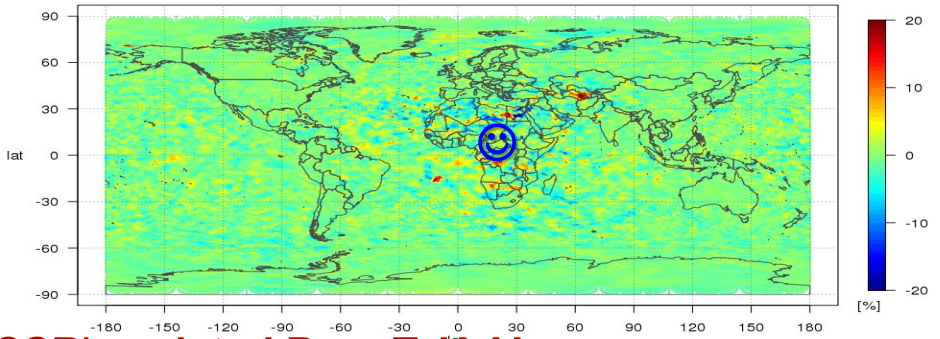
- Exclude dynamic feedback through model integration
- Improvements in B through CSR assimilation

500 hPa analysis RMSE (vs. Nature)
CSRNC_Bcsr – CSR_NC

Relative RMSE for ICON specific humidity at 500 hPa

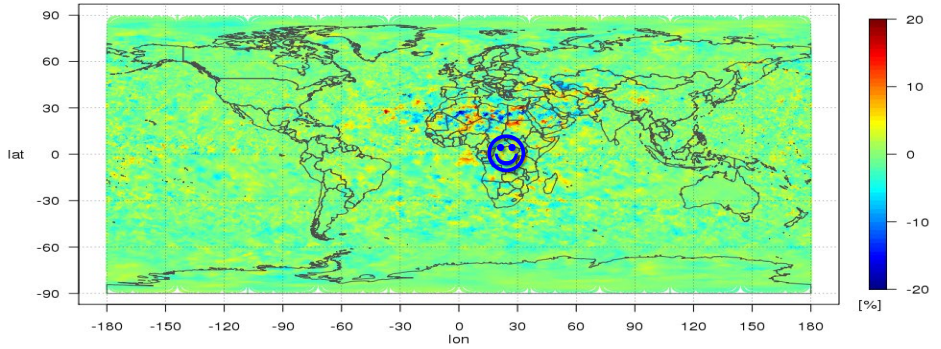


Relative RMSE for ICON zonal wind at 500 hPa

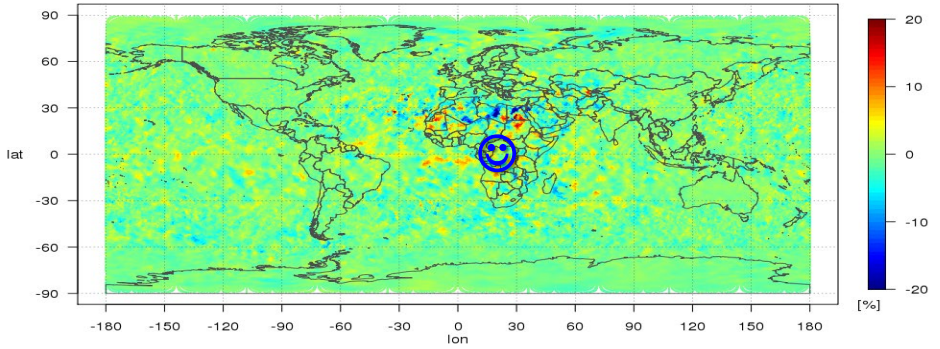


Small positive impact of (CSR) updated B on T, U, V

Relative RMSE for ICON upper air temperature at 500 hPa



Relative RMSE for ICON meridional wind at 500 hPa



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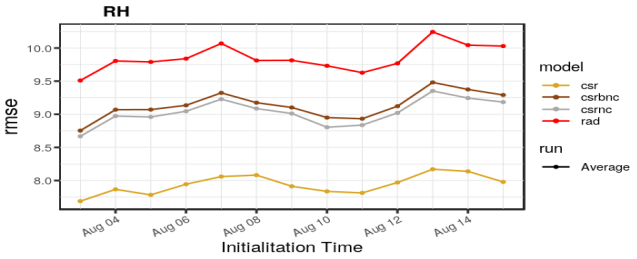
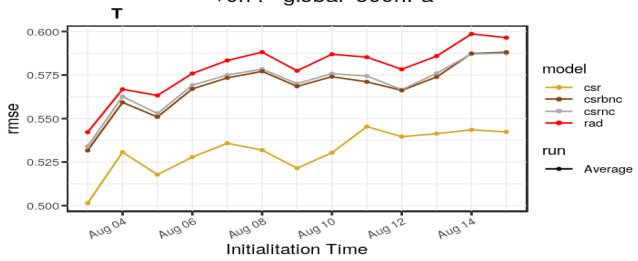
Analysis verification scores (Time series)

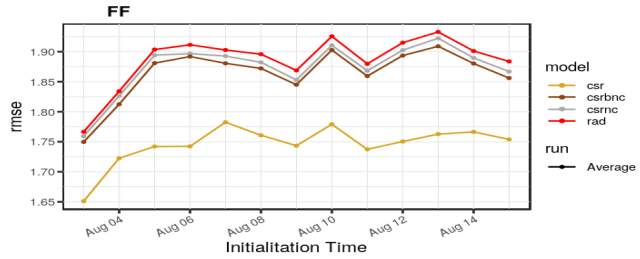
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

500 hPa

+0h : global 500hPa

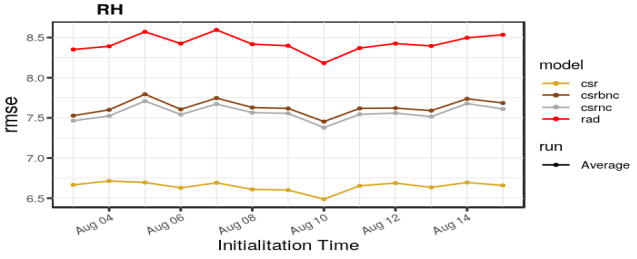


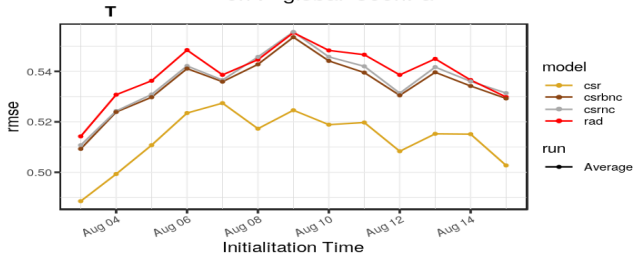


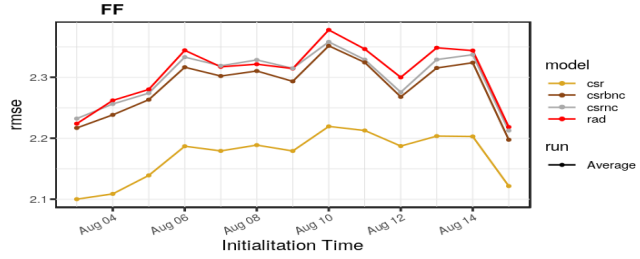


300 hPa

+0h : global 300hPa



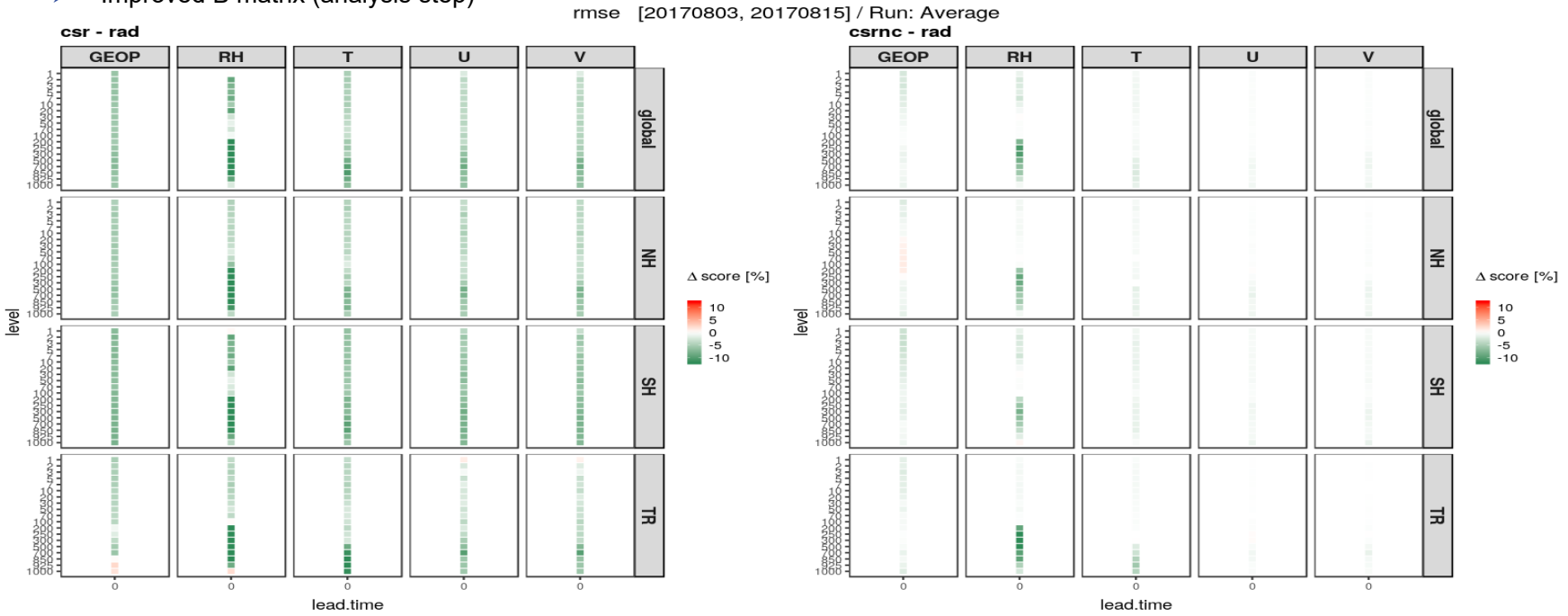




Control run
CSR cycled run
CSR non cycled run
CSR non cycled run with CSR updated B

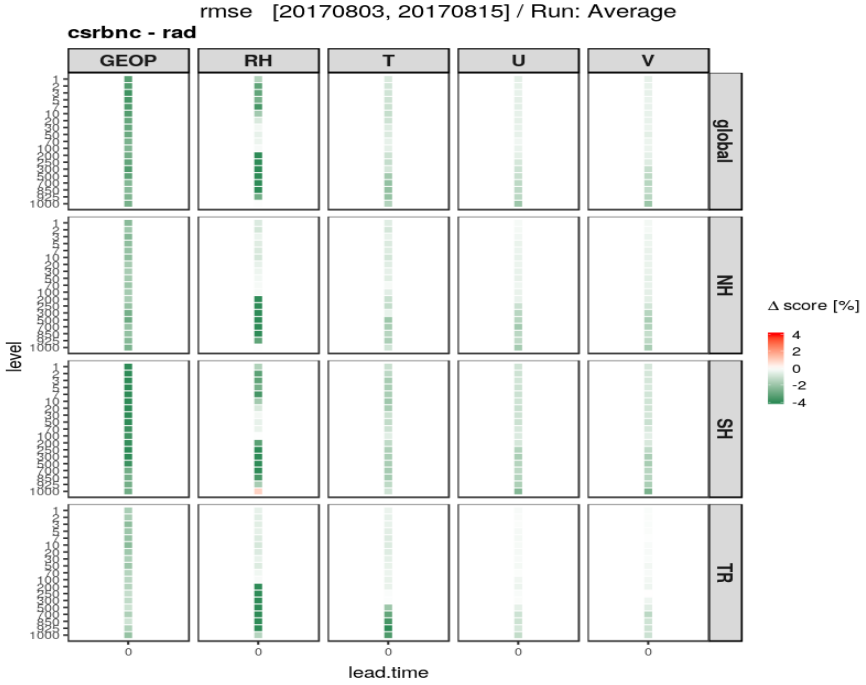
Analysis verication scores (score cards)
CSR cycled vs. Non cycled run

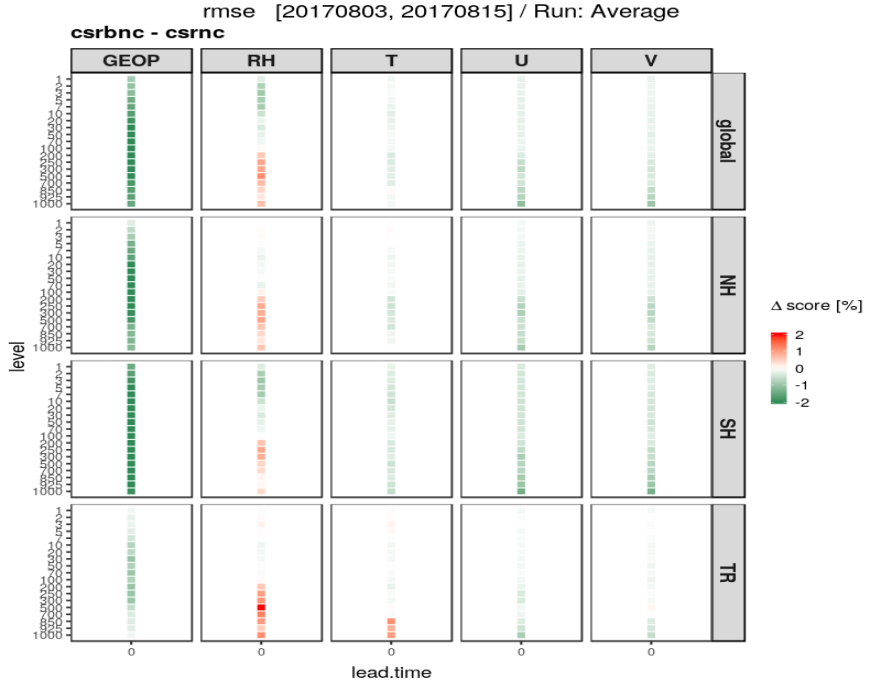
- Positive impact of CSR assimilation (cycled and non cycled runs) on QV analysis
- CSR twin experiment (cycled run): more accurate T, U, V analysis and forecasts due to interactions of T/QV/U/V:
  - Model physics & dynamics (forecast step)
  - Improved B matrix (analysis step)



Global Score Cards
CSR non cycled runs

- Positive impact of CSR assimilation with updated B matrix on T, U, V analysis (improved T/QV/U/V correlations)
- Degradation of QV analysis due to updated B matrix:
  - Strong reduction of QV STD and cross-correlations implies tuning of inflation factor





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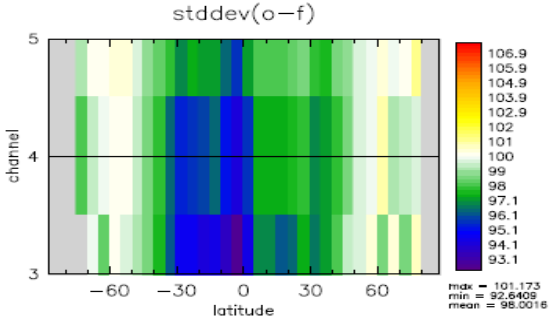
Setup of the experiment

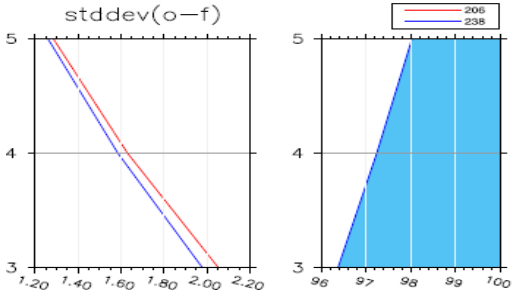
- Assimilation method: EnVar
- Time period: 01.11.2017 – 28.02.2018
- Reference experiment:
  - Assimilation of operational data (conv + AMV + satellite)
  - Includes assimilation of IASI, MHS, ATMS water vapour channels
- CSR assimilation experiment:
  - Adding SEVIRI CSR (6.25 & 7.35 µm) from MET-8, MET-10
  - EnVar (LETKF-covariances from reference experiment)
  - Bias correction using 3 thickness predictors
  - Data up to zenith angle < 60°
  - Additional QC: window channel check, %cloudy pixels in CSR-obs < 70%

O-B BT departure statistics for MHS (CSR vs. Reference)

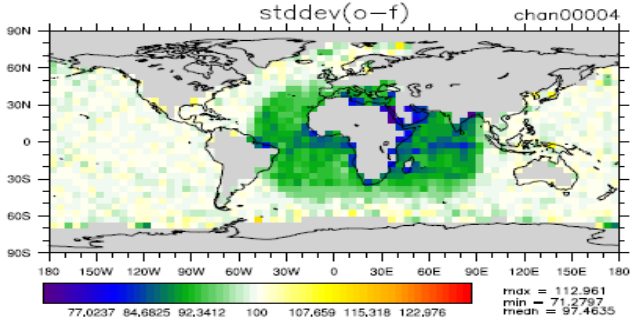
Zonal mean

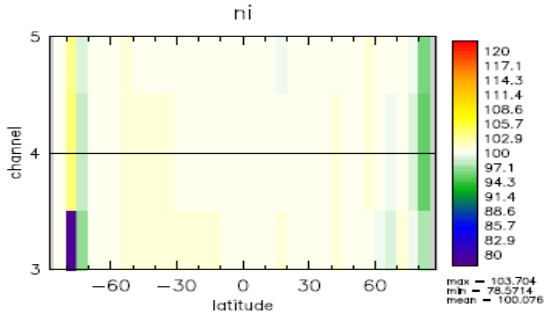


Global

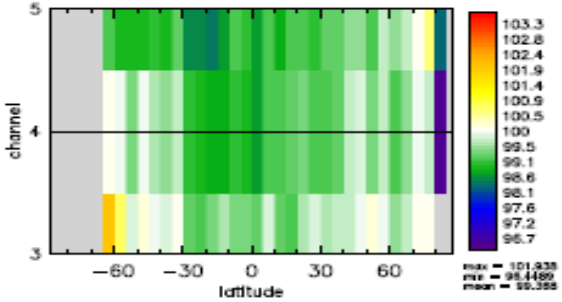


Colocated BT

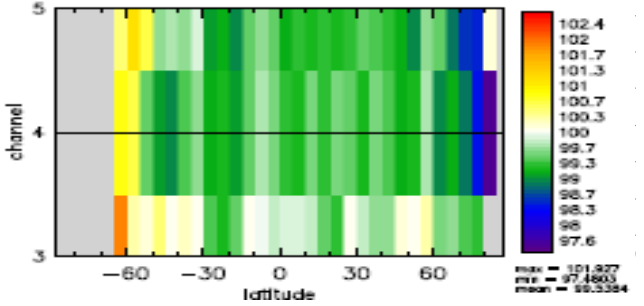




GPM/GMI stddev(o−f)

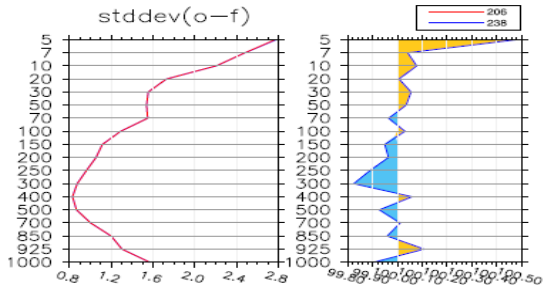


FY/MWHS2 stddev(o−f)

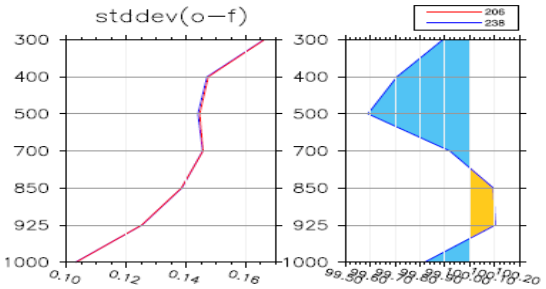


O-B radiosonde departure statistics (CSR vs. Reference)

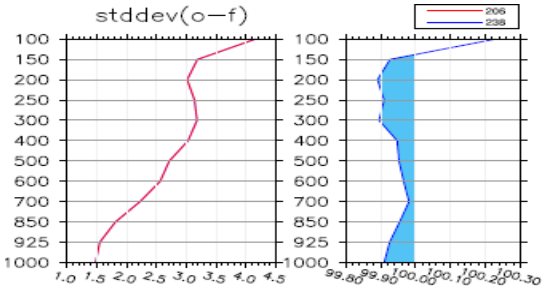
Temperature radiosondes

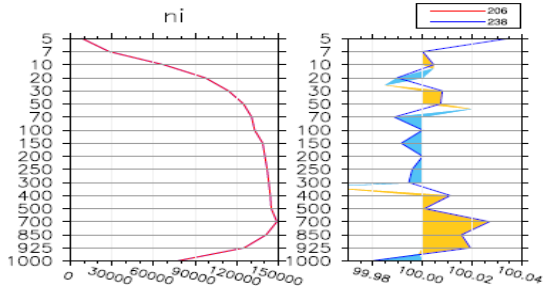


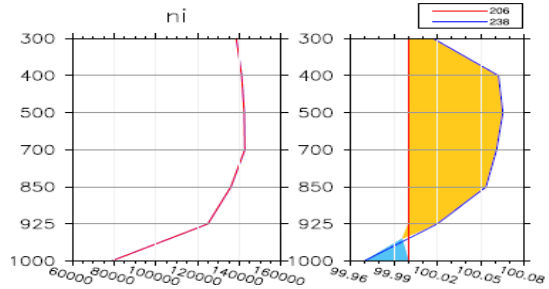
Humidity radiosondes

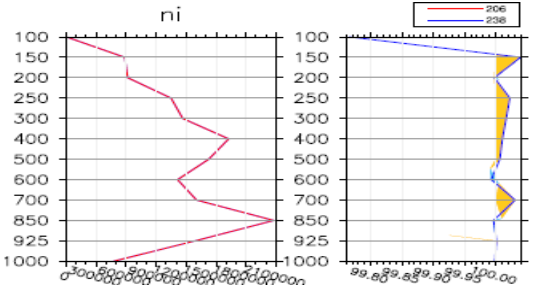


Wind AMV

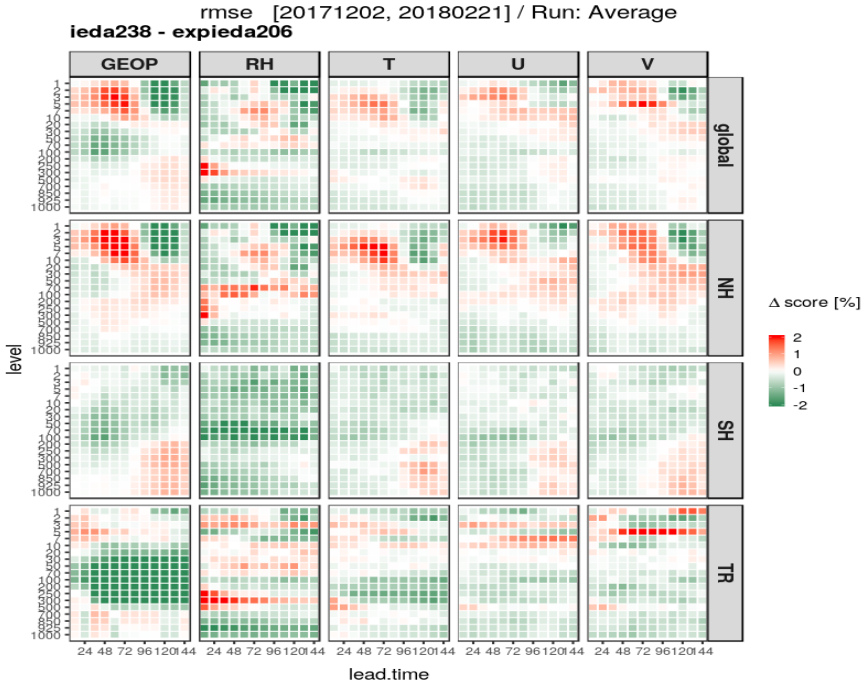








Score Cards (vs. analysis)



- Positive impact of CSR assimilation from SEVIRI on QV/T/U/V forecasts
- Small degradation of QV forecasts in tropical UTLS (to be investigated…)

Outline

- Current NWP system at DWD
- Setup of a framework for idealised experiments
  - Nature run & twin experiments
  - CSR non cycled run
  - Conclusions of the study (overall statistics)
- Assimilation experiments with real SEVIRI data
- **Summary and outlook**

Summary and outlook

➔ Analysis/forecast improvements and extraction of wind information in ICON / EnVar+LETKF have been achieved by using MSG/SEVIRI CSRs.

I. A series of CSR assimilation experiments performed under idealised conditions has allowed to identify the different mechanisms of the impact on the wind:

- Improvements in analyses and forecasts are due to the interaction of T/Q and U/V analysis increments through:
  - ✓ model dynamics & physics during the forecast step;
  - ✓ improved (cross-)correlations of the CSR updated B matrix from the LETKF used in the analysis step.
- The height assignment in LETKF needs further investigation.

II. Implementation and tests with real CSR data:

- Operational assimilation of SEVIRI CSRs (MET-8 and MET-11) since 11th July 2018;
- Operational assimilation of GOES/ABI, Himawari/AHI CSRs since 4th June 2019.

➔ The implementation and use of a 4D-EnVar will improve the wind increment derived from assimilating a sequence of WV radiances.

Deutscher Wetterdienst
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DWD

Thank you for your attention!

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