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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Assimilation of ground-based MWR (microwave radiometer) observations

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Outline

- microwave radiometers and observation operator

- MeteoSwiss
    - ensemble correlations
    - current experiments and results
    - (linear approximation of the analysis model equivalents in the LETKF)
- DWD
    - vertical localization
    - observation error
    - current experiments and results

- summary and next steps

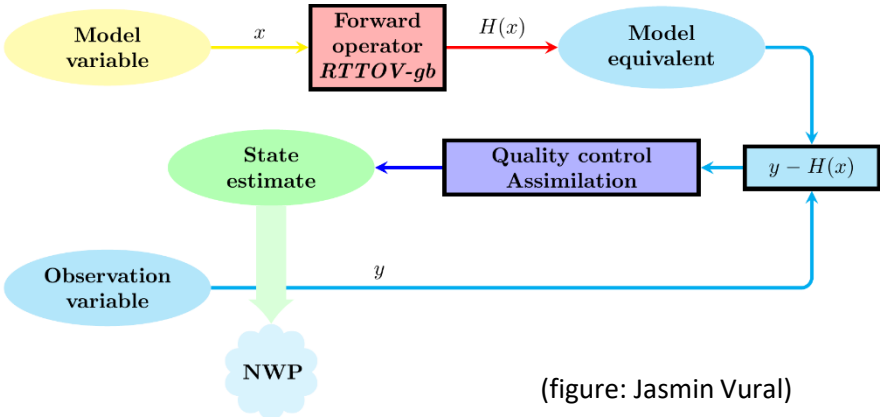
Microwave Radiometers, Observation Operator and Model Equivalents

Microwave radiometer (MWR) observations

- passive remote sensing instrument
- **brightness temperature** for **14 frequency bands**
  - 7 K-band channels (22.24-31.40 GHz) hold mainly **humidity** information
  - 7 V-band channels (51.26-58.00 GHz) hold mainly **temperature** information

Ground-based microwave radiometer (HATPRO)

MWR model equivalents



(figure: Jasmin Vural)

- **direct** assimilation of **brightness temperatures**
- brightness temperature from model state
- **observation operator: RTTOV-gb radiative transfer model**
  (upward-looking version of RTTOV, de Angelis et al., 2016)

Ensemble correlations and increment structure

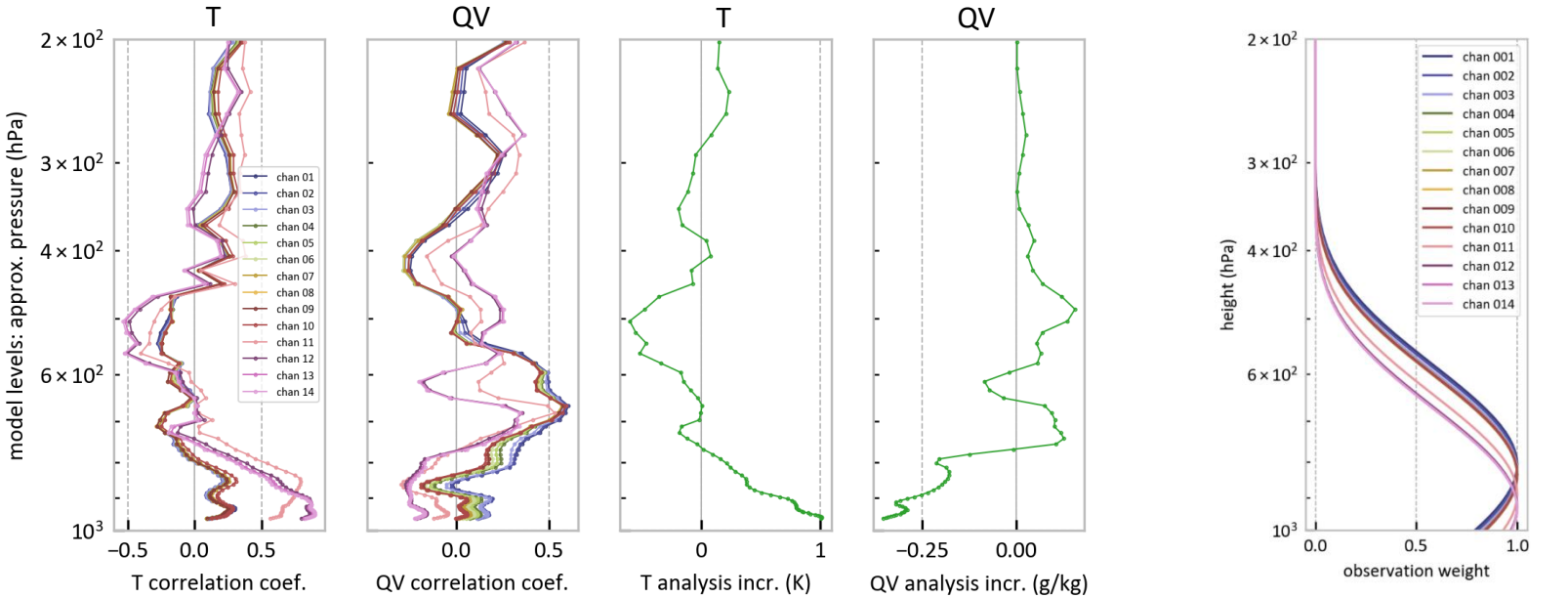
Ensemble correlations and increments

21.07.2019 00UTC analysis step, only MWR DA, Payerne zenith scan

ensemble correlations

analysis increments

default vertical localisation for radiances



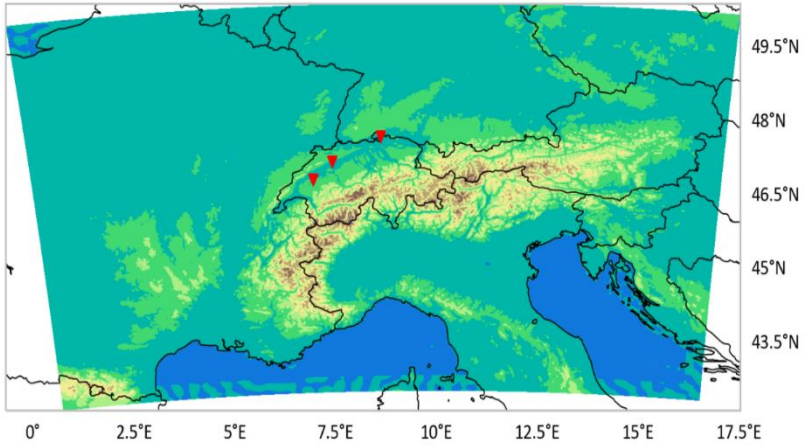
Experiment setups

Current test setups

	MeteoSwiss	DWD
model	COSMO-1E	ICON
resolution	~1.1 km	~2.1 km
KENDA	40 members (also at 1.1 km)	40 members
elevation angles	6 (zenith + scans)	zenith
stations	3	1
vertical localisation	dynamical	dynamical
minimum vert. loc. width	lv = 0.3	lv = 0.075
bias correction	static, determined with FG (station, elevation and channel dependent)	dynamical
observation error		iterative
period	end of July 2019 (10 days)	June 2021 (14 days)

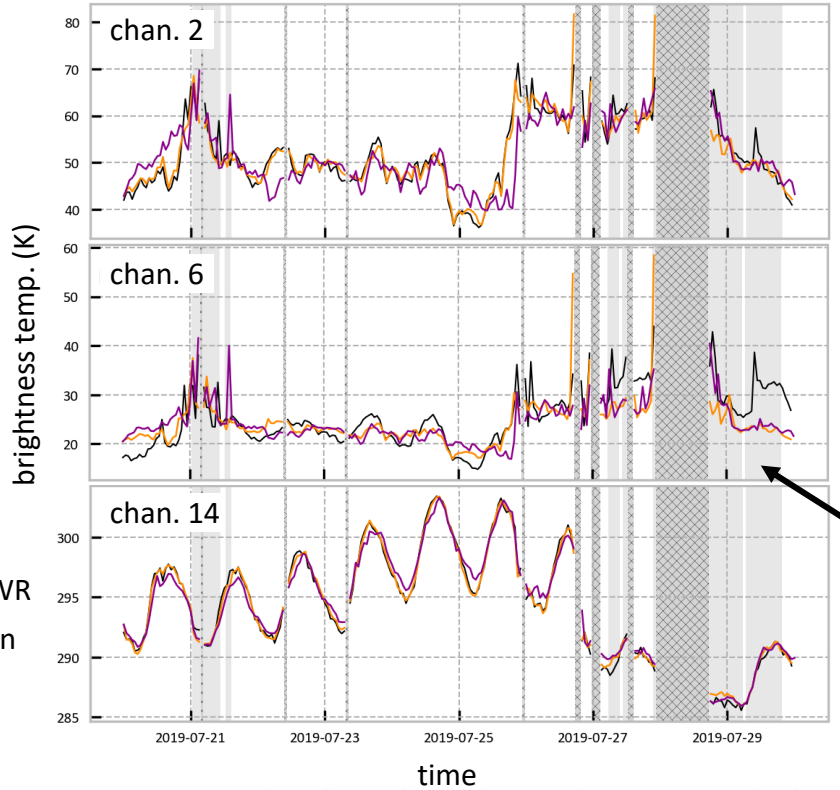
MeteoSwiss work status

Experiment setup



- period: 20.07.2019 – 30.07.2019
- reference: **conv. observations only**
- experiment:
  - **conv. observations + MWR data** (clear-sky)
  - **three MWR** stations: Payerne, Schaffhausen, Grenchen
  - static bias correction and observation error
  - channels:
    - K-band channels only in Payerne and for zenith angle
    - channel 1 in Payerne zenith scan with wrong bias correction

Analysis time series – observation space

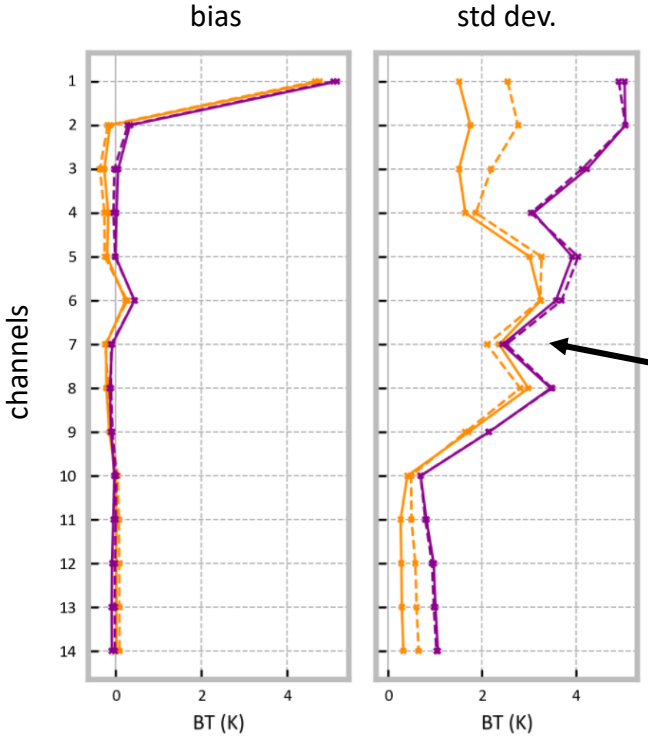


- Payerne, zenith scan
- analysis ensemble mean

- better agreement of conv. + MWR with observations than conv. only

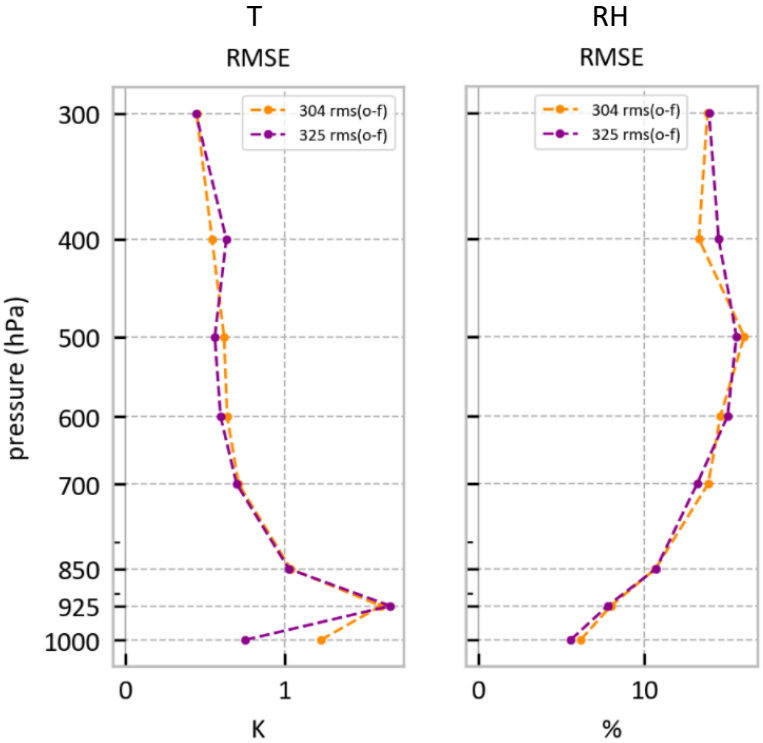
- some channels show larger discrepancies between model and observations: complex processes, and probably data quality issues in this time period

Departure statistics – observation space



- Payerne, zenith scan, active obs.
- bias small (except for channel with wrong correction ;)…)
- standard deviation smaller for conv. + MWR than for conv. only but impact is small for some channels
- standard deviation smaller in analysis than in first guess (conv. + MWR), but not for all channels

Departure statistics – against sounding



conv. only

conv. + MWR

- Payerne, soundings, active obs.
- first guess ensemble mean

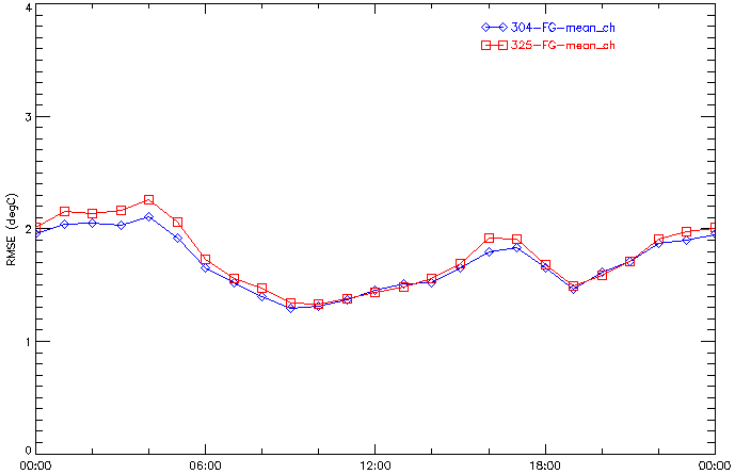
- impact is very small, with a slight tendency towards negative

Synop. verification on domain

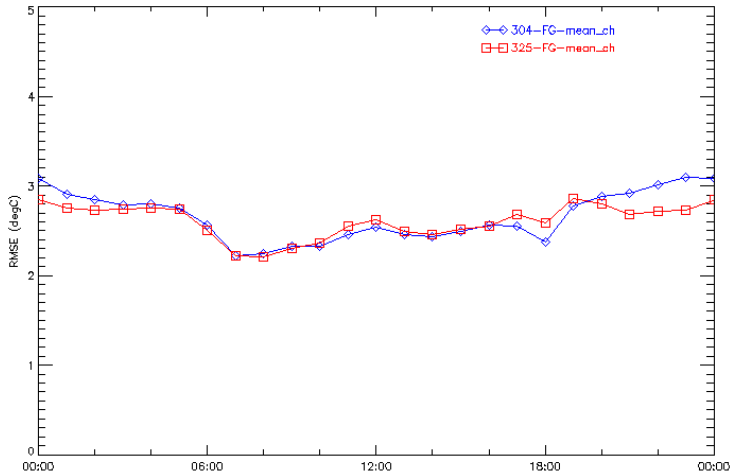
conv. only
conv. + MWR

RMSE

2m temperature



2m dew point temperature



- Payerne, soundings
- first guess ensemble mean
- RMSE diurnal cycles

- slight improvement in 2m temperature
- deterioration in 2m dew point temperature (nighttime)

for the discussion part, or contact me if interested:

Linear approximation of the brightness temperature analysis model equivalents in the LETKF

Linear approximation of model equivalents

Model equivalents for the MWR brightness temperature are computed

- using **RTTOV-gb as an observation operator** (for first guess, prior to assimilation especially – fof_ files)
- performing a **linear approximation within the KENDA/LETKF** code (analysis in the ekf files)

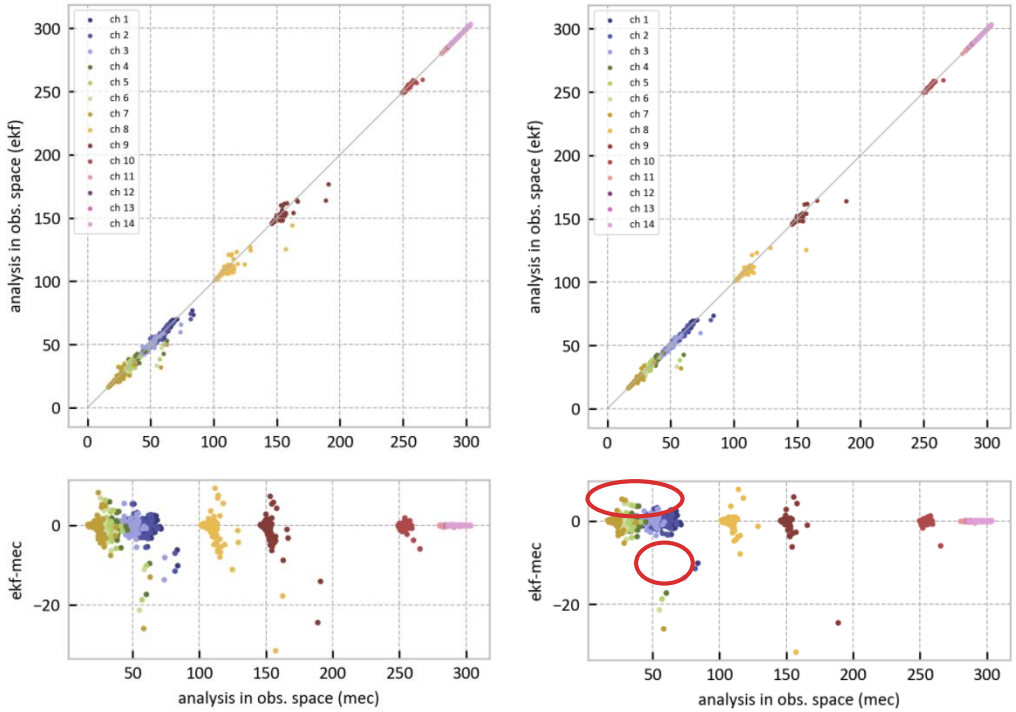
How do those values compare for complex observations with non-linear processes?

Can ekf files be used to perform the common data analysis (departure statistics, Desroziers analysis,…) using obs_err_stat for example?

Linear approximation of model equivalents

all observations
~all-sky

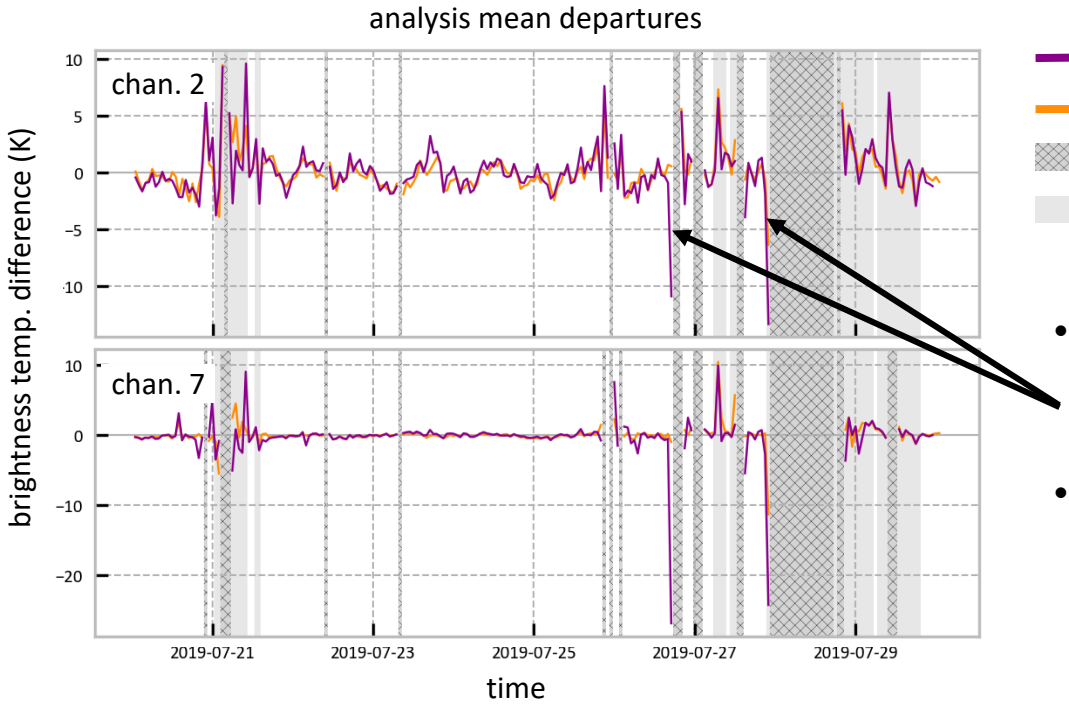
only active observations
~clear-sky



- 10 days
- Payerne, zenith scan
- analysis ensemble mean

- some outliers seem to be connected to cloudy conditions, but not all

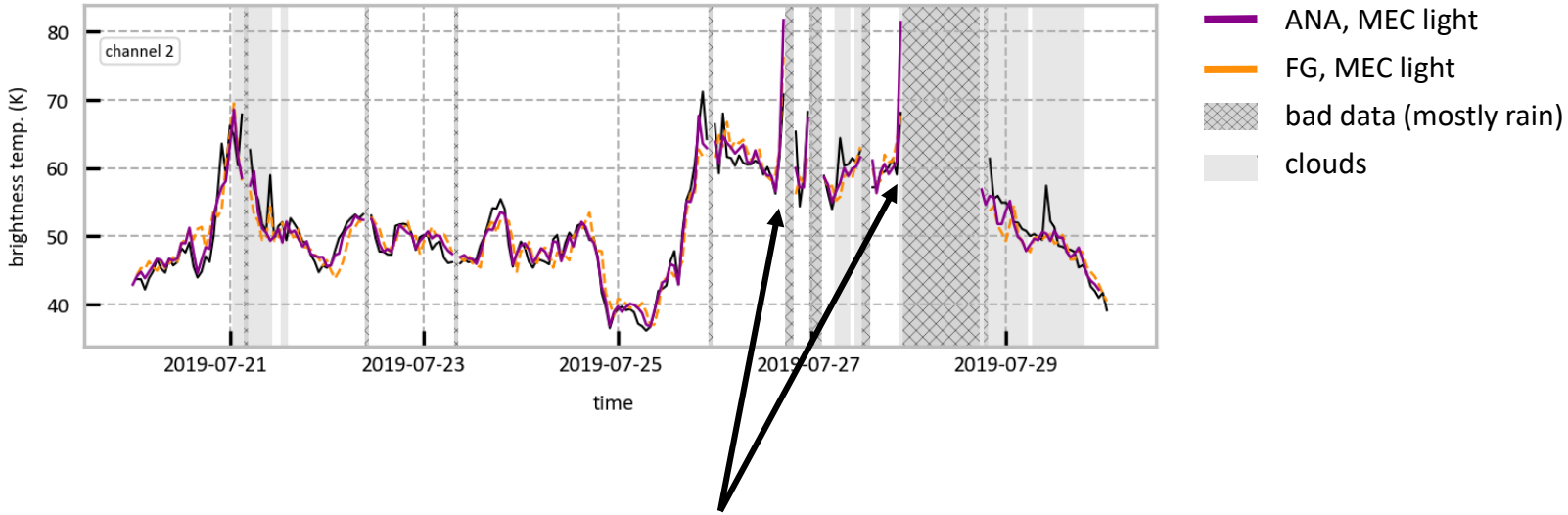
Linear approximation of model equivalents



MEC light
lin. approx. (ekf)
bad data (mostly rain)
clouds

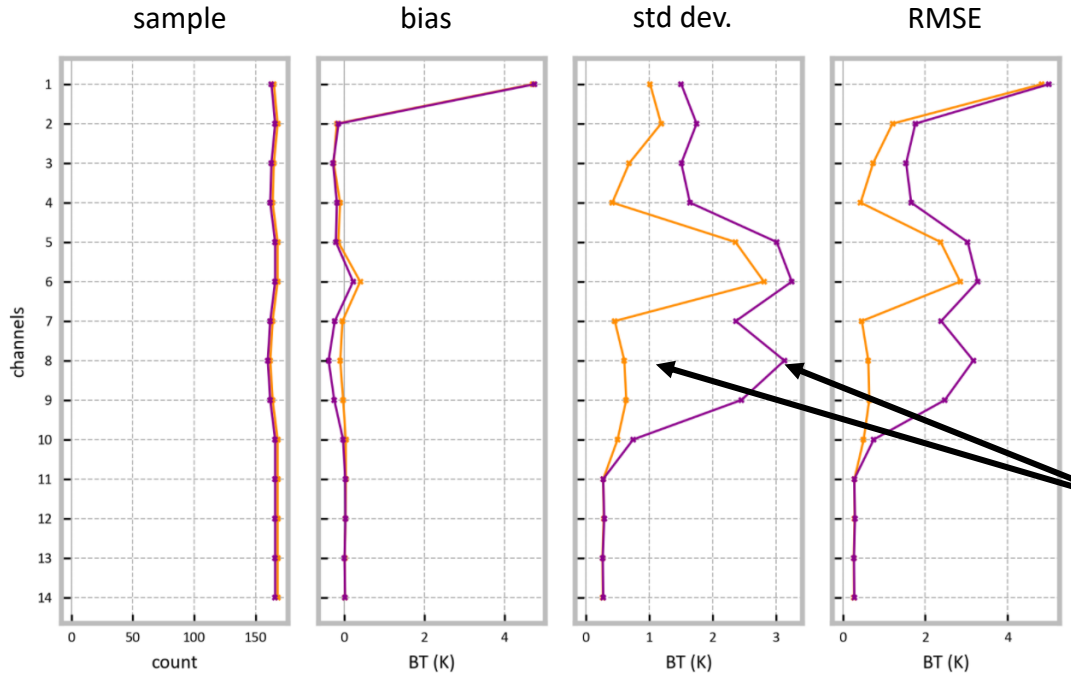
- outliers: mostly cases at the transition between clear-sky and cloudy/rainy conditions
- first guess model state produces better brightness temperature than analysis in these cases, also using MEC-light (next slide)

Linear approximation of model equivalents



T, QV… in model ➔ first guess T_B ➔ DA ➔ updated T, QV… in model ➔ worse analysis T_B ?

Linear approximation of model equivalents



MEC light

lin. approx. (ekf)

- Payerne, zenith scan, active obs.
- analysis ensemble mean

- large discrepancies in standard deviation / RMSE caused by very few outliers at ‘phase’ transition

Current test setups

	MeteoSwiss	DWD
model	COSMO-1E	ICON
resolution	~1.1 km	~2.1 km
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Vertical localisation

- Localise each channel vertically to limit increments

- p-level:

$$p_{\mathrm{loc}} = \frac{\sum_i w_i p_i}{\sum_i w_i}$$

- p-level width:

$$dp_{\mathrm{loc}} = \frac{\sqrt{\frac{\sum wp^2}{\sum w} - \left(\frac{\sum wp}{\sum w}\right)^2}}{p_{\mathrm{loc}}}$$

Vertical localisation

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- p-level width:

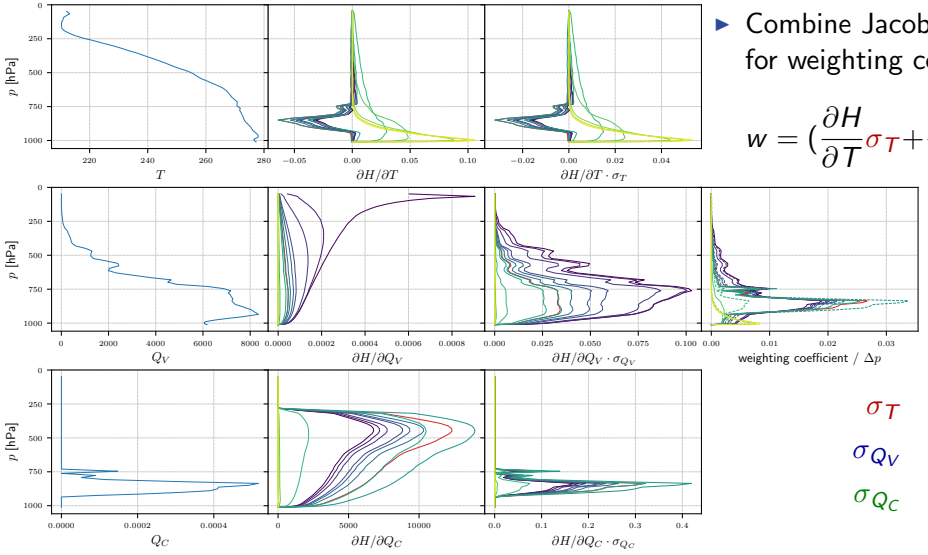
$$dp_{\mathrm{loc}} = \frac{\sqrt{\frac{\sum w p^2}{\sum w} - \left(\frac{\sum w p}{\sum w}\right)^2}}{p_{\mathrm{loc}}}$$

- Combine Jacobians of T, Q_V, Q_C for weighting coefficients:

$$w = \left(\frac{\partial H}{\partial T}\sigma_T + \frac{\partial H}{\partial Q_V}\sigma_{Q_V} + \frac{\partial H}{\partial Q_C}\sigma_{Q_C}\right)$$

$$\begin{aligned} \sigma_T &= 0.5 \\ \sigma_{Q_V} &= 0.1 Q_V \\ \sigma_{Q_C} &= 0.1 Q_C \end{aligned}$$

Vertical localisation



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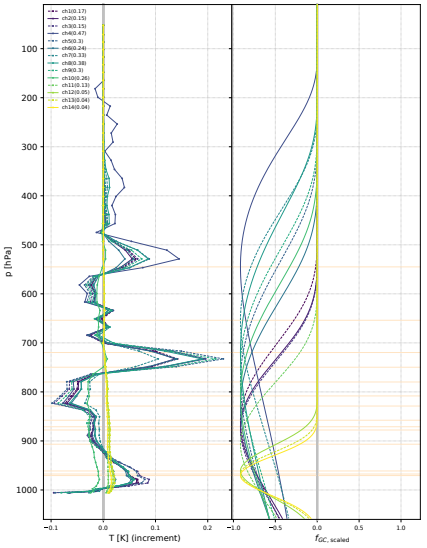
$$\begin{aligned} \sigma_T &= 0.5 \\ \sigma_{Q_V} &= 0.1 Q_V \\ \sigma_{Q_C} &= 0.1 Q_C \end{aligned}$$

Vertical localisation – increments

- Temperature increments only take effect in lower atmosphere
- Humidity increments are wider spread
- Gaspari-Cohn functions shown with theoretical localisation widths
- Lower limit of 0.075 used for increments



Bias correction

- dynamical BC: $$\mathrm{bias}_k = (1 - w) \cdot \mathrm{bias}_{k-1} + w \cdot (d_b^o)_k \quad (1)$$

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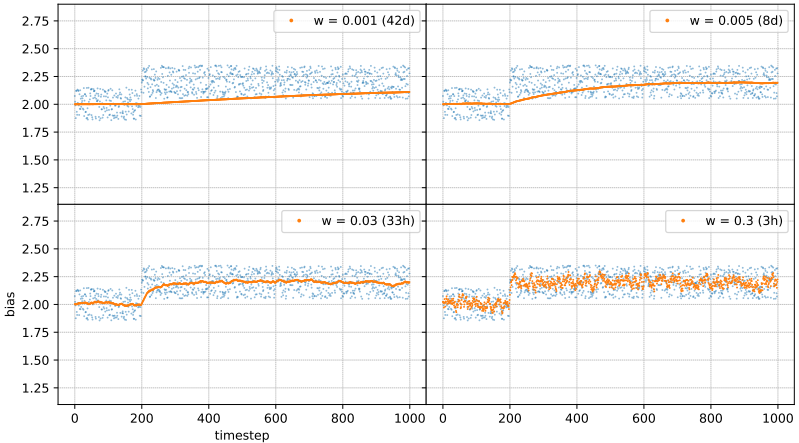
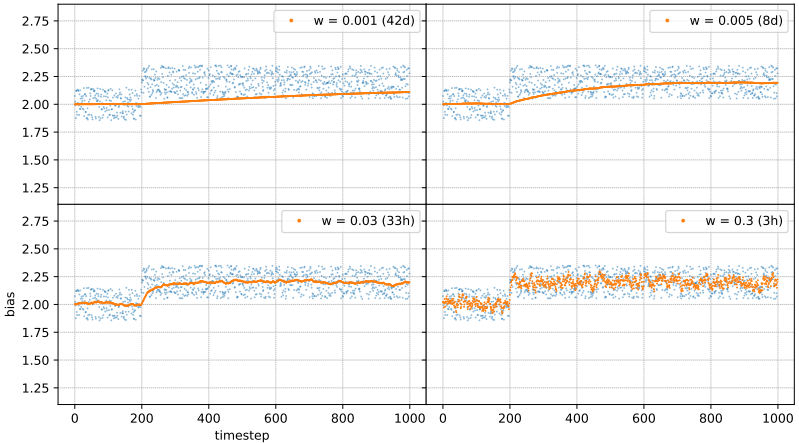


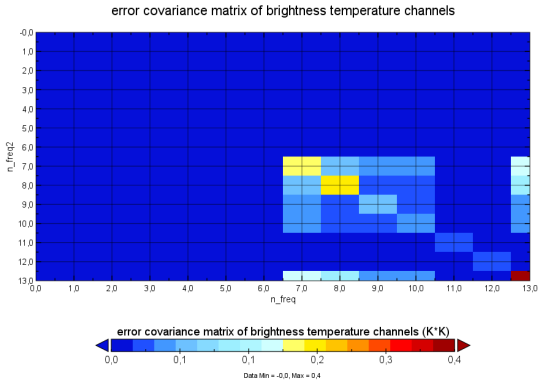
Bias correction

- dynamical BC: $$\mathrm{bias}_k = (1 - w) \cdot \mathrm{bias}_{k-1} + w \cdot (d_b^o)_k \quad (1)$$
- $w = 0.03$ did not correct bias well enough in some channels $\Rightarrow w = 0.005$



Observation error

- ignore cross-correlations → only diagonals



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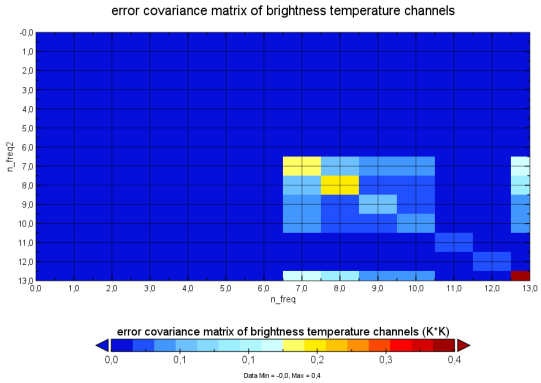

- Iterative method by Desroziers et al. 2005:

K band:	1.6	→	0.25	→	0.15
V band:	7.2	→	0.16	→	0.09

Observation error

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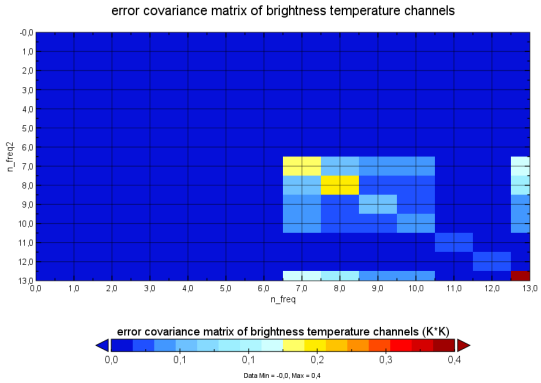

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  ⇒ inflate errors by factor of 2

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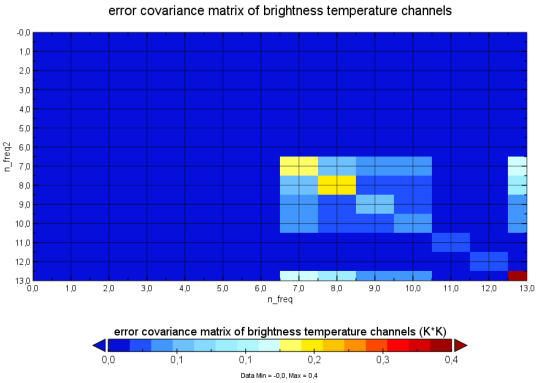

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  K band: 1.6 → 0.25 → 0.15
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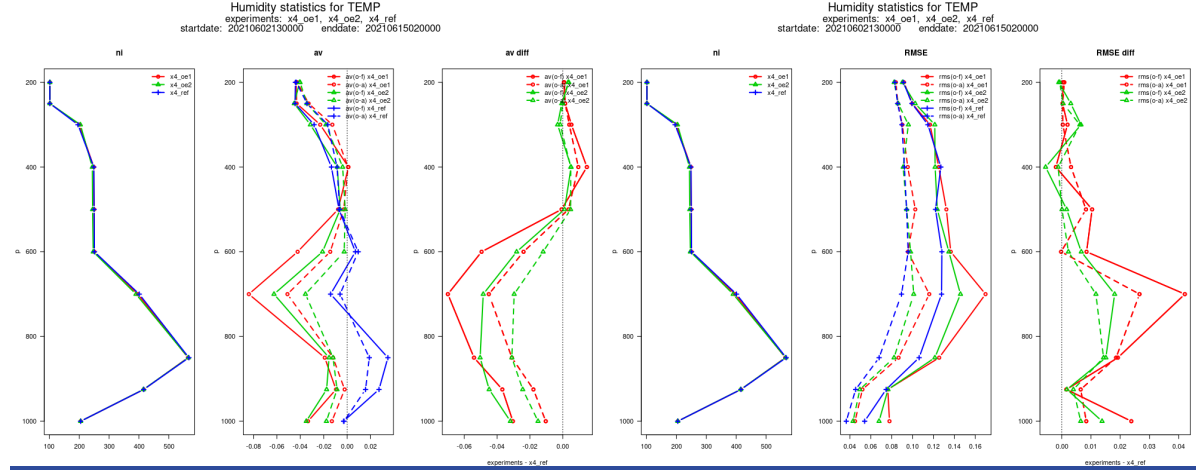
  ⇒ inflate errors by factor of 2

- possibly increase observation error for potential assimilation during cloudy conditions

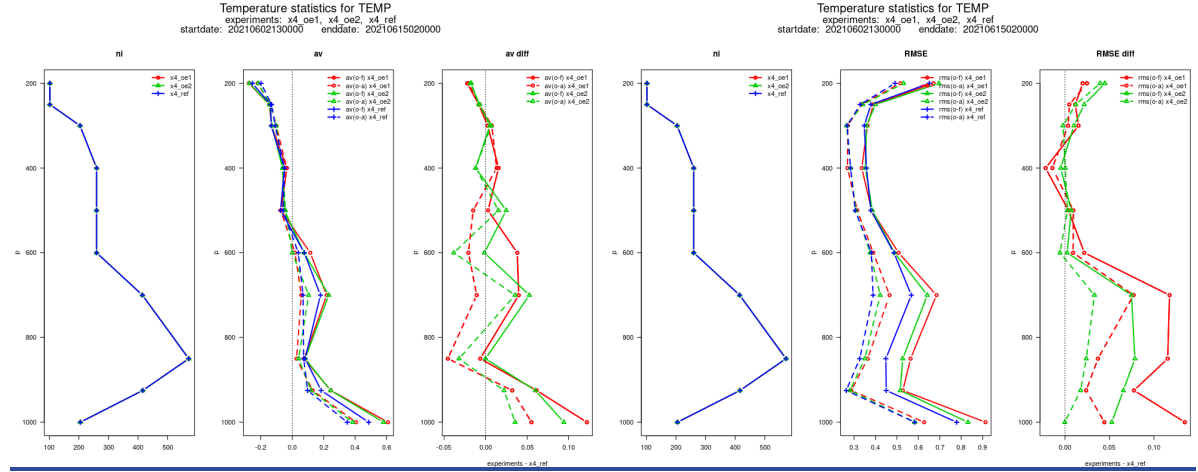
Assimilation statistics (humidity)

- RMSE & bias (mostly) degrade for lower levels
- Inflated observation error (oe2) better than pure Desroziers (oe1)



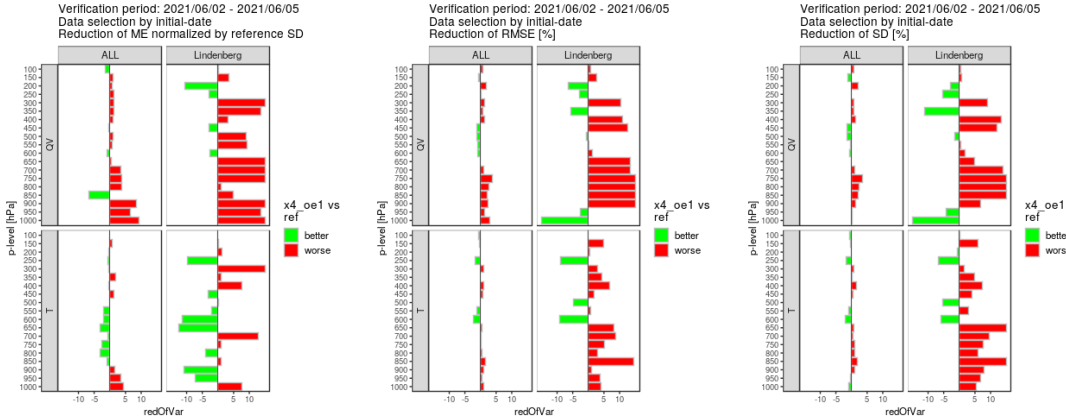
Assimilation statistics (temperature)

- Bias mixed, RMSE degradation
- Inflated observation error (oe2) better than pure Desroziers (oe1)



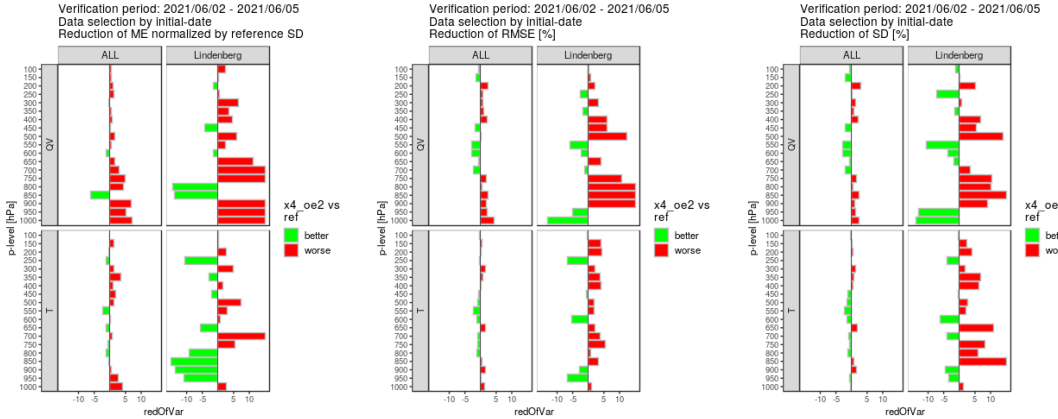
Upper air verification

Observation error obtained with Desroziers method [oe1]

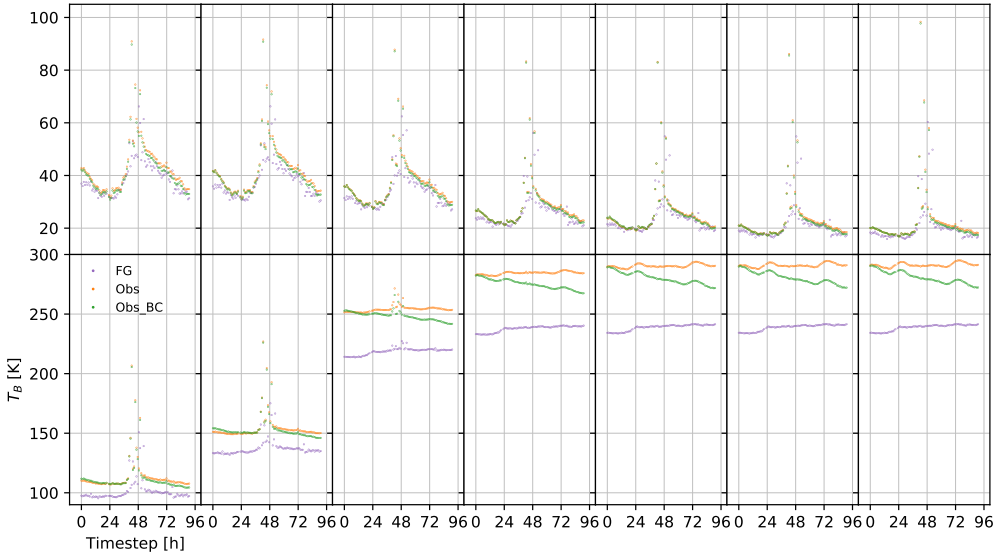


Upper air verification

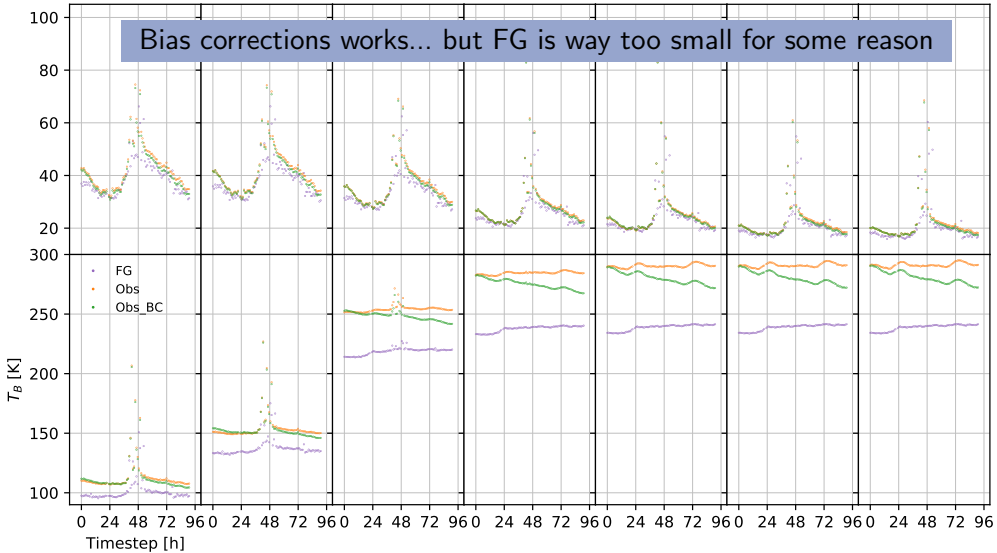
Inflated (2x oe1) observation error [oe2]



First guess problem??



First guess problem??



Conclusion & outlook

- Assimilation experiments ongoing
- Statistics look good in observation space...
- ... but model space is more problematic

$\Rightarrow$ Use observations of G5 instead of G2 devices with better data quality (MCH)

$\Rightarrow$ Use more elevation angles (DWD)

$\Rightarrow$ Use less channels (lower V band?!)

$\Rightarrow$ Replace radio sonde by MWR in assimilation

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⇒ Use observations of G5 instead of G2 devices with better data quality (MCH)

⇒ Use more elevation angles (DWD)

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