Assimilation and Bias Correction of 2-m Temperature Observations and some other Aspects about KENDA

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- assimilation and bias correction of T2M (& RH2M) synop obs

  ***Elisabeth Bauernschubert**, Christine Sgoff, Christoph Schraff, Klaus Stephan, et al.*

- on experimental use of Netatmo citizen data: T2M & RH2M

  ***Walter Acevedo**, Christine Sgoff , Thomas Kratzsch, Roland Potthast*

- steps towards (C)EnVar, port of observation operators to 'global' DACE routines

  Mareike Burba, Sven Ulbrich, Elisabeth Bauernschubert, Hendrik Reich,

  Stefanie Hollborn, Christoph Schraff, Harald Anlauf, et al.

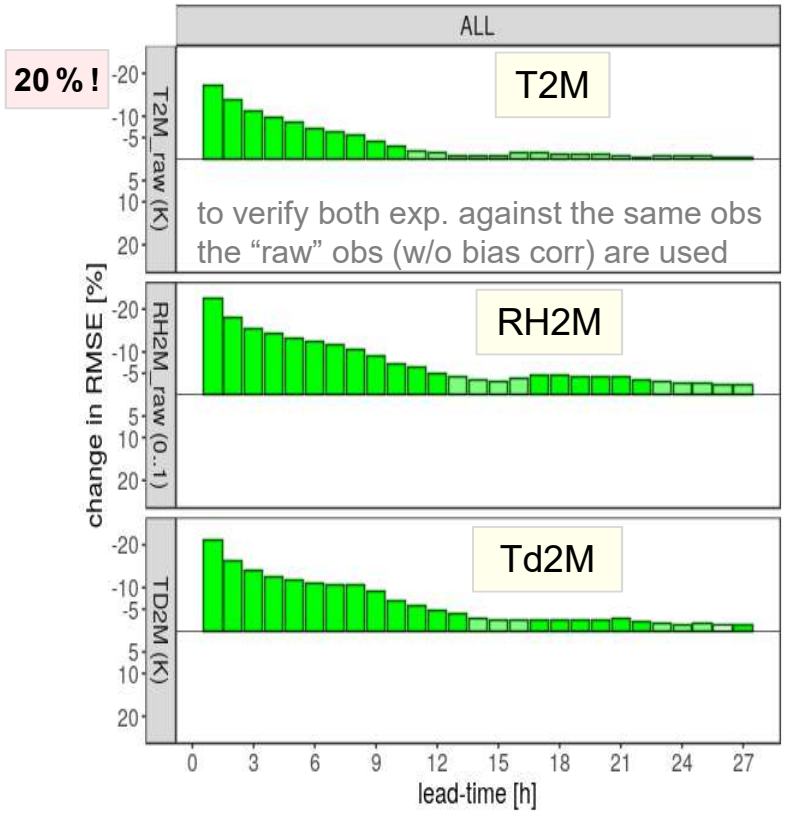
2-m temperature + humidity obs: BC + **assimilation**

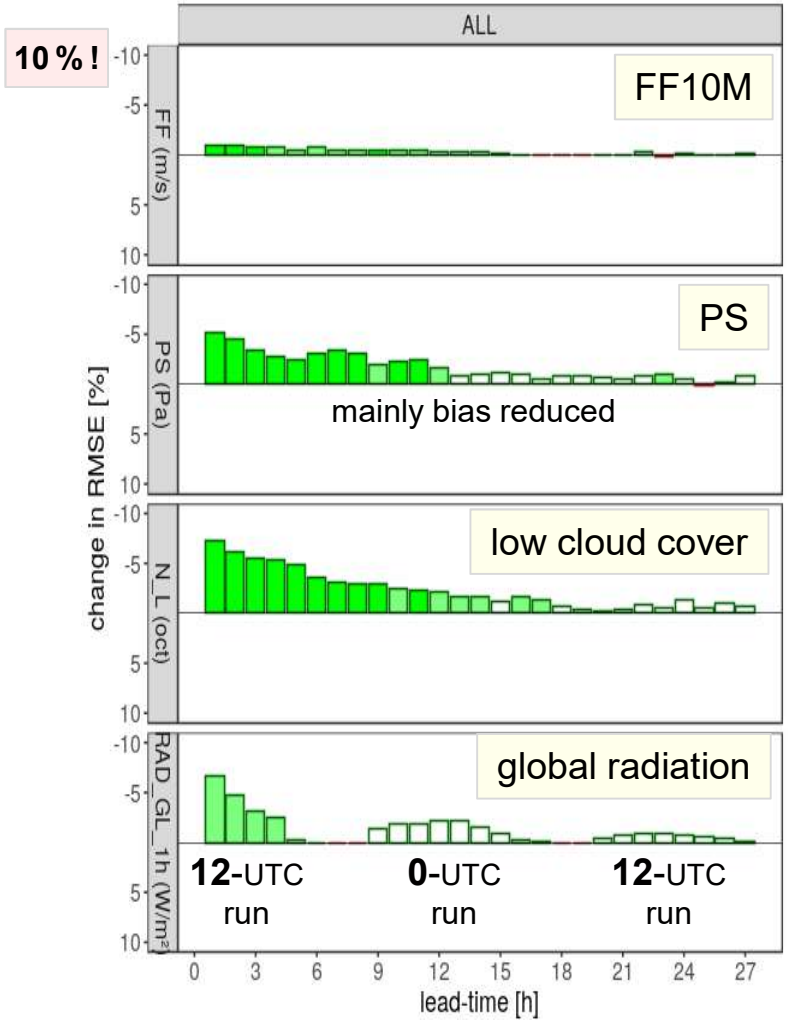
Elisabeth Bauernschubert, C. Sgoff, C. Schraff, K. Stephan **Deutscher Wetterdienst**

winter 21/12/19 – 08/01/20

change [%] of RMSE against synop

ICON-D2
with RH2M + T2M better
w/o RH2M + T2M better





2-m temperature + humidity obs:
bias correction (BC) + assimilation

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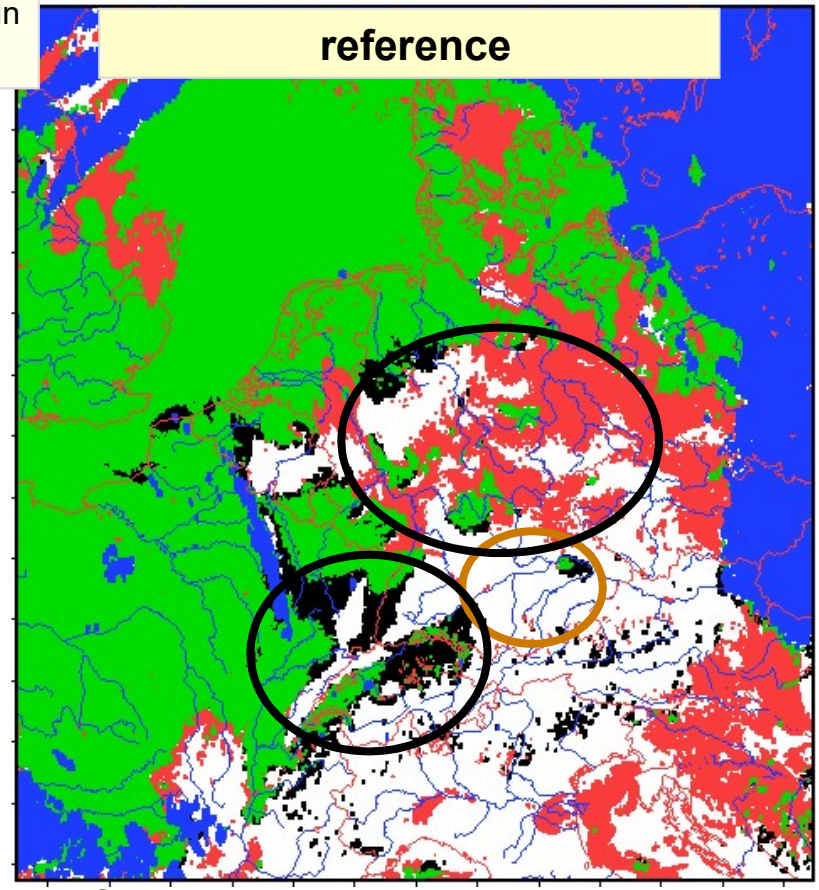
low stratus case study: **1 Jan. 2020** , comparison to **NWCSAF cloud type**

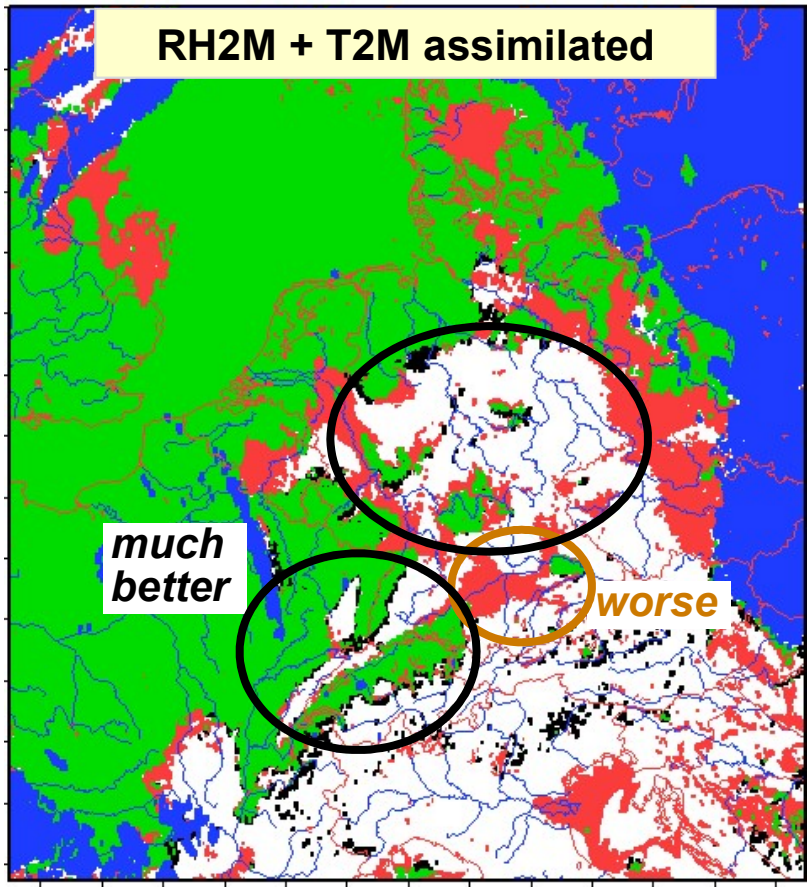
12-UTC run
+ 1 h

reference



ETS: 0.407 FBI: 1.209

RH2M + T2M assimilated



ETS: 0.537 FBI: 1.194

correct cloudy / **correct cloud-free** / **missed events** / **false alarms** / **undefined** (observed higher cloud)

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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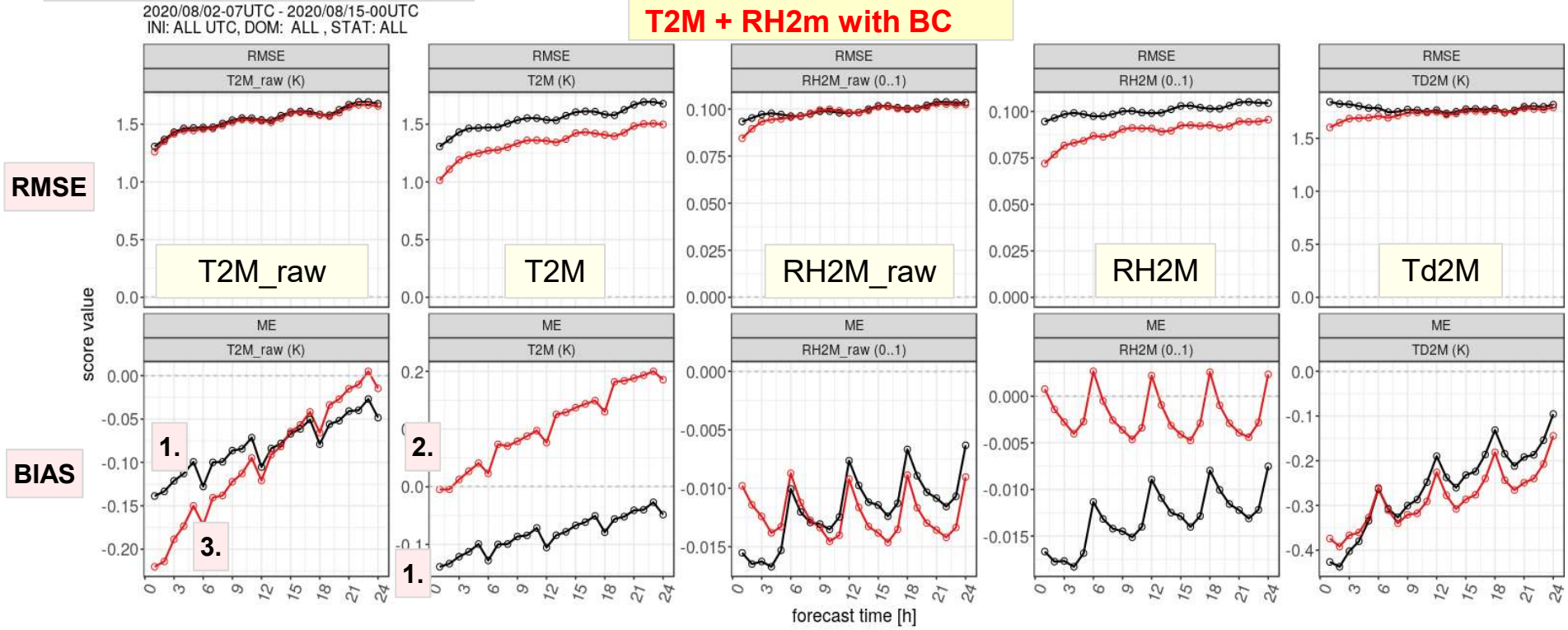
summer 02 – 15/08/20

ICON-D2 **REF**
T2M + RH2m with BC



1. model (at +1h) has cold bias

2. T2M model bias at + 1h against bias-corrected T2M obs ≈ 0 → BC works ok,
   i.e. it adjusts the obs to the cold bias of the model by making the obs colder

3. **assimilating the bias-corrected cold T2M obs increases cold bias of model** (FG)
   if verified against raw T2M obs or radiosonde / aircraft obs → undesired positive feedback

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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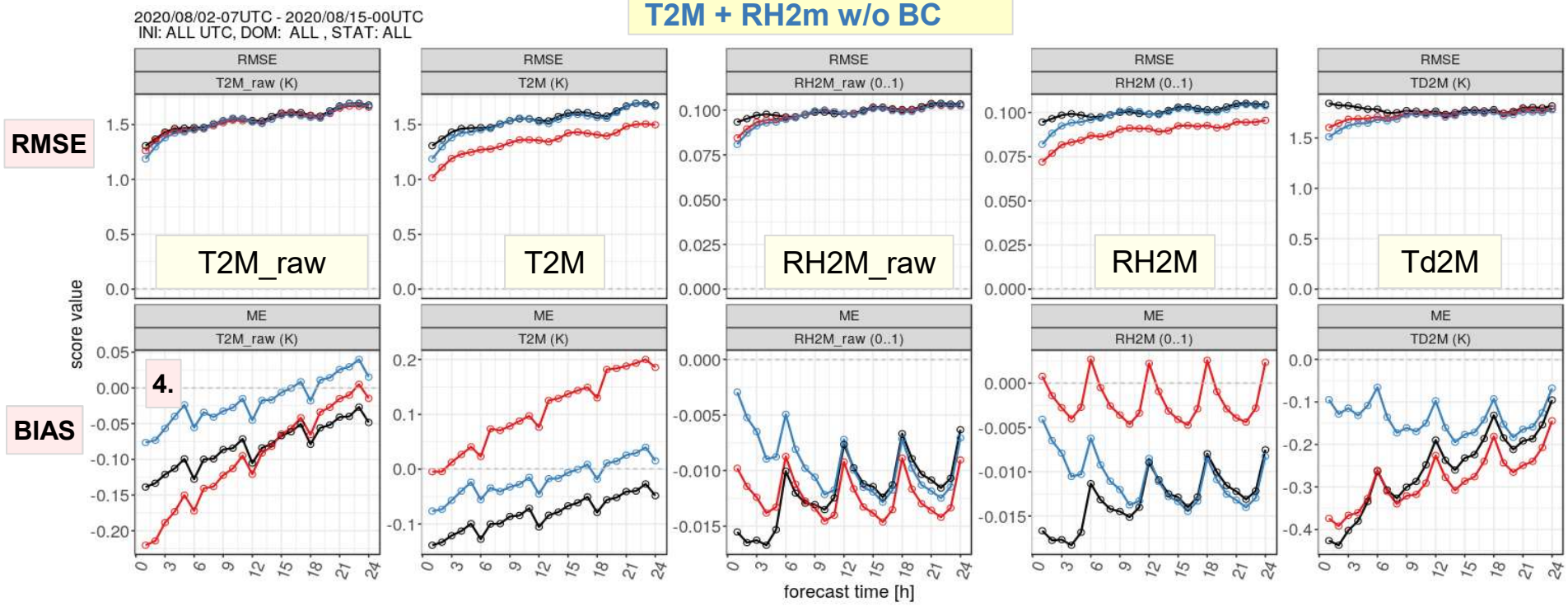
summer 02 – 15/08/20

ICON-D2 **REF**
T2M + RH2m with BC
T2M + RH2m w/o BC



assimilation of T2M + RH2M without bias correction:

- avoids increase of cold bias and even decreases T2M bias (averaged over all stations!!)
- still improves T2M + RH2M forecasts (against raw obs)
  (but loses small positive impact on low cloud / precip)

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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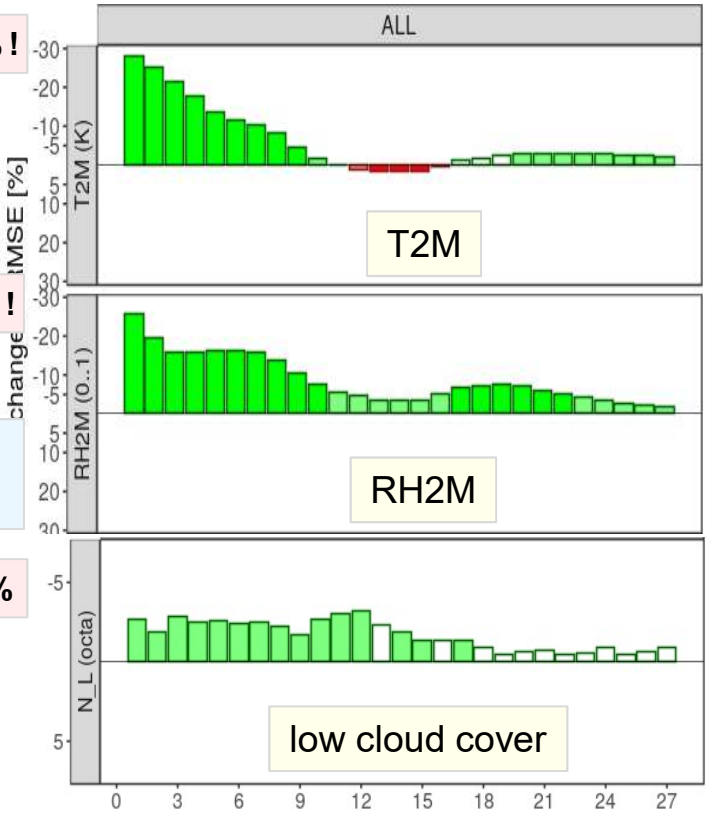
assimilation of T2M + RH2M without bias correction:

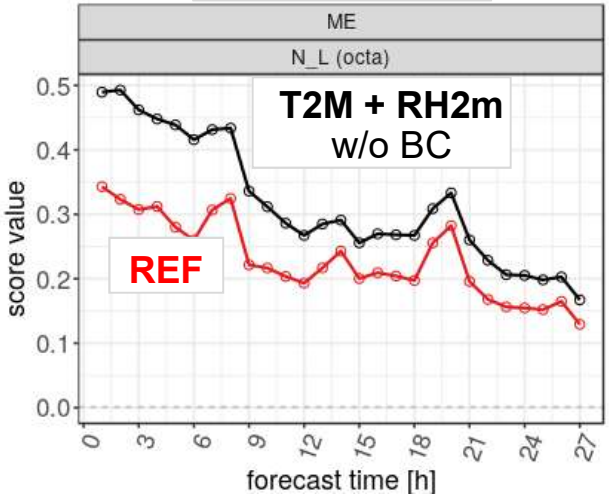
- test in winter / for low stratus (Nov. 2020)
- assimilation of T2M + RH2M w/o BC introduced (pre-/)operationally in ICON-D2
- working on revised bias correction (by relaxing area-averaged BC towards zero)

winter 3 – 22/11/20



change [%] of RMSE against synop

low cloud cover bias



→ impact on low cloud:
improves RMSE
but increases overestimation

→ more narrow distribution for subgrid-scale cloud under testing

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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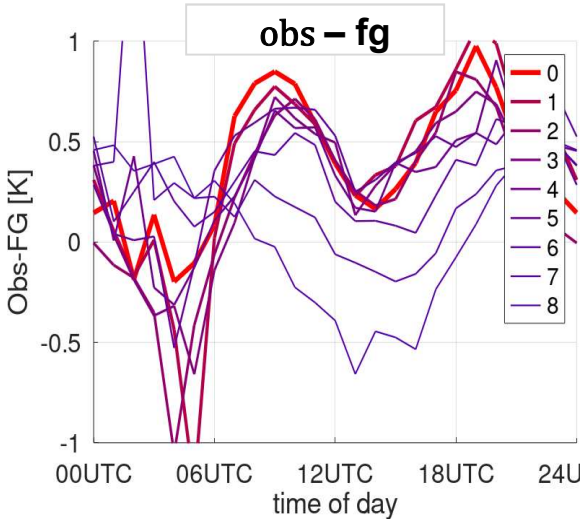
concept of non-linear bias correction

- predictors: **time of day t** , **cloud cover N**
- basis functions: **5 trigonometric + 2 polynomial** fn.

$$\mathrm{A(t,N)} = (1, \sin st,\ \cos st,\ \sin 2st,\ \cos 2st, (9-\mathrm{N}), (9-\mathrm{N})\sin st,\ (9-N)\cos st,\ (9-N)\sin 2st,\ (9-N)\cos 2st)$$

- bias is approximated by: $bias(t,N) = A(t,N) \cdot c$
- need to specify / estimate coefficients *c*



- how to compute vector c and apply bias correction ? $\rightarrow$ at analysis step k:
  - bias correction : $bcor = -bias^{estimated} = -A \cdot c^{k-1}$
  - bias-corrected obs: $obs_{bc} = obs + bcor$
    … used in LETKF: $\mathbf{x}^{\mathrm{a}} = \mathbf{x}^{\mathrm{b}} + K\left(obs_{bc} - H(\mathbf{x}^{\mathrm{b}})\right)$
    … and to update c: $c^k = c^{k-1} + K_c\left(obs_{bc} - H(\mathbf{x}^{\mathrm{b}})\right)$ $\quad K_c = BA^t(R + ABA^t)^{-1}$

  example: 3D-Var with $B = I$ and $R = \alpha I$, α = damping/ regularization parameter

- BC: apply to each synop station separately $\rightarrow$ $c = c_{sta}$

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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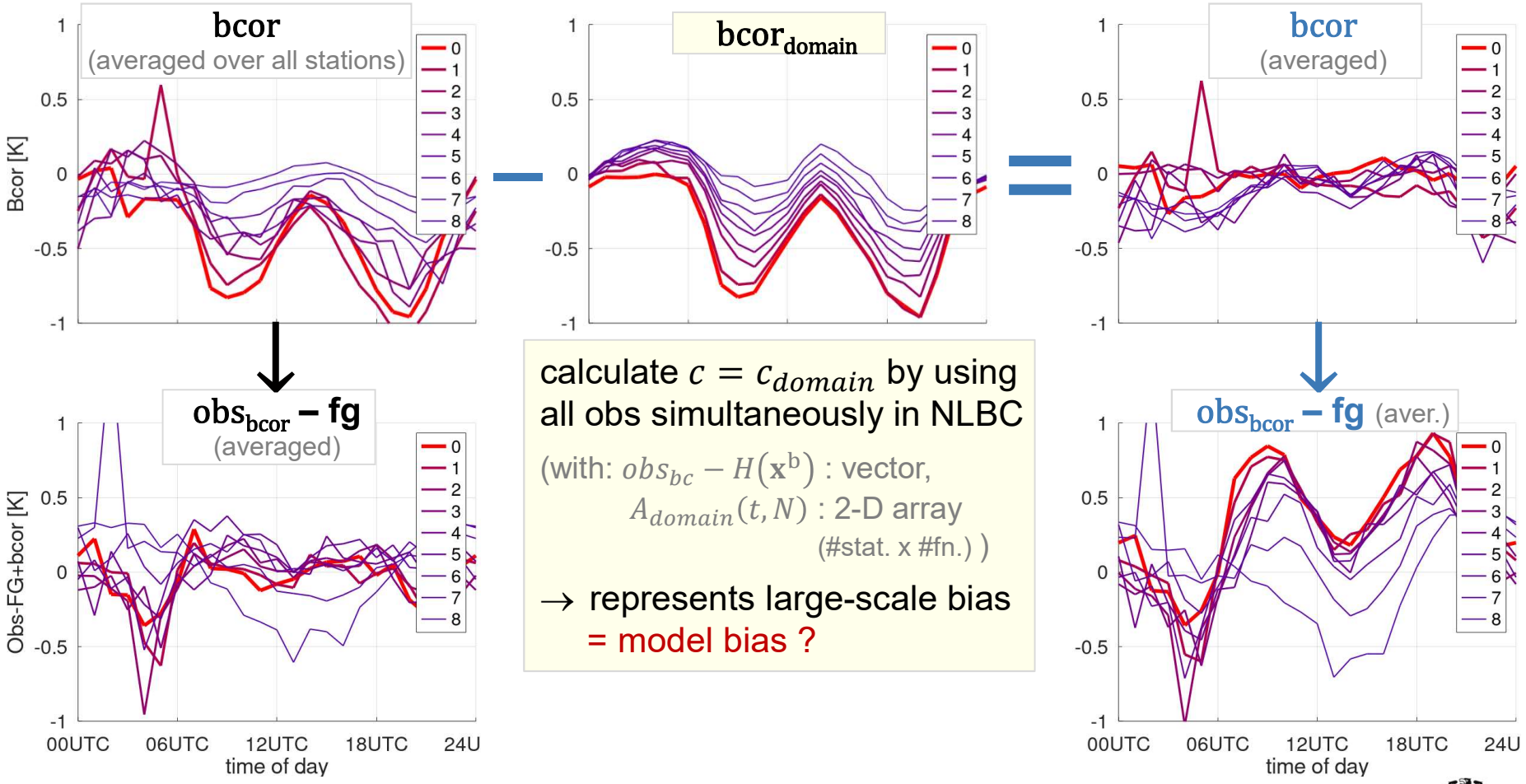
concept of non-linear bias correction (NLBC)

"BC": apply NLBC to each synop station separately



calculate $c = c_{domain}$ by using all obs simultaneously in NLBC

(with: $obs_{bc} - H(\mathbf{x}^{b})$: vector,
$A_{domain}(t, N)$: 2-D array
(#stat. x #fn.))

→ represents large-scale bias
= model bias ?

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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concept of non-linear bias correction (NL-BC)

- BC → $bcor = -A \cdot c_{sta}$: corrects for difference of obs – model bias
- BC_c1 → $bcor = -A \cdot (c_{sta} - c_{domain})$: subtracts large-scale (model?) bias from BC
- BC_c2 → $bcor = -(A \cdot c_{sta} - bcor_{conv})$: subtracts 'global' bias from BC

where $bcor_{conv}$: conventional online BC

non-linear bias correction	BC	BC_c1	BC_c2	BC_c3
station dependent	✓	✓	✓	✓
accounting for diurnal cycle	✓	(–)	✓	✓
dep. on (observed) cloud cover	✓	(–)	✓	✓
online (dynamic)	✓	✓	✓	✓

- BC_c3 → $bcor = -A \cdot (c_{sta} - s \cdot (c_{domain} - c_{dom.,clim}))$

where: $c_{dom.,clim}$: pre-computed from an experiment w/o T2M, RH2M assimilation;
$0 \leq s \leq 1$: tuning parameter for relaxation towards 'climatological' bias
(BC_c3 currently under testing)

: subtracts only difference of current to 'climatological' large-scale bias from BC

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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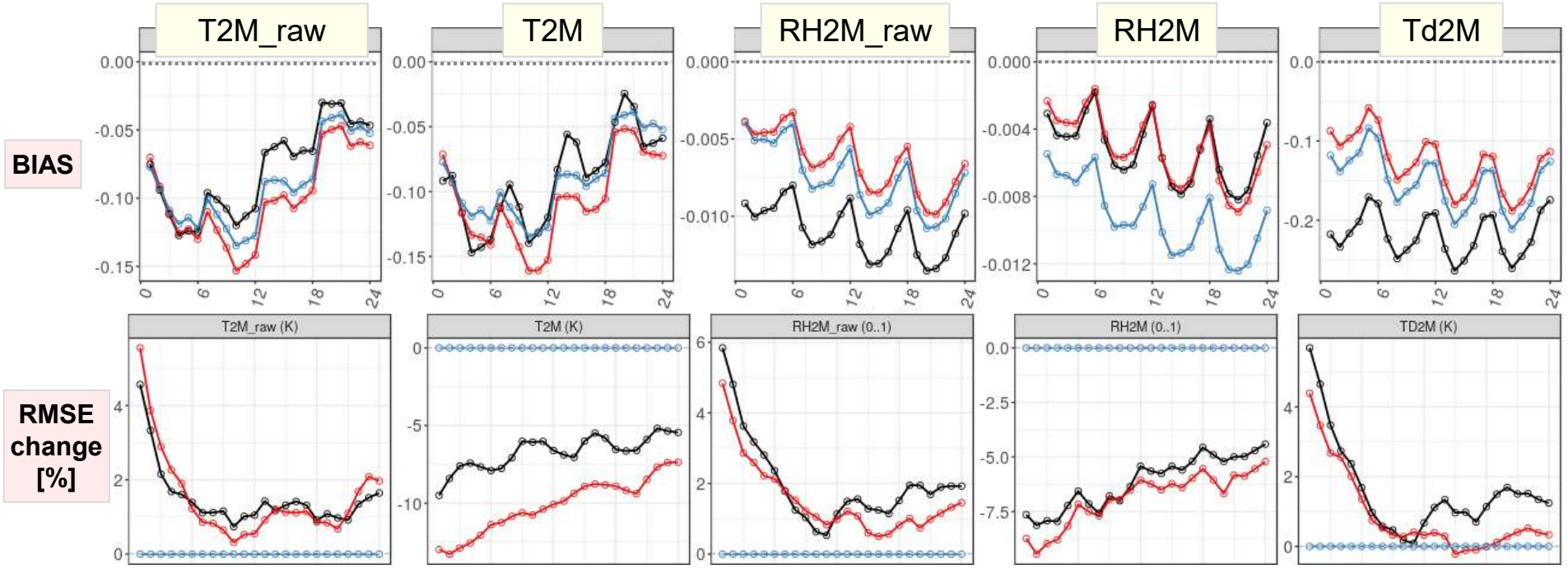
summer 04/08 – 04/09/20

T2M + RH2m w/o BC (ref) | **T2M + RH2m with BC_c1** | **T2M + RH2m with BC_c2**



- **BC_c1** vs. **no-BC**: **bias** against raw 2-m humidity larger
- **BC_c1,2** vs. **no-BC**: **rmse** ag. raw obs larger (no-BC loses 4% of advantage in first 6 hrs),
  ag. bcor obs much smaller (lose only 2 % of advantage in first 6 hrs)
  → assimilating bias-corrected obs more model-compatible (?)
- **BC_c2** vs. **BC-c1**: T2m **bias** slightly larger after +6h, raw 2-m humidity bias smaller
  rmse: generally slightly smaller (particularly bcor T2m)

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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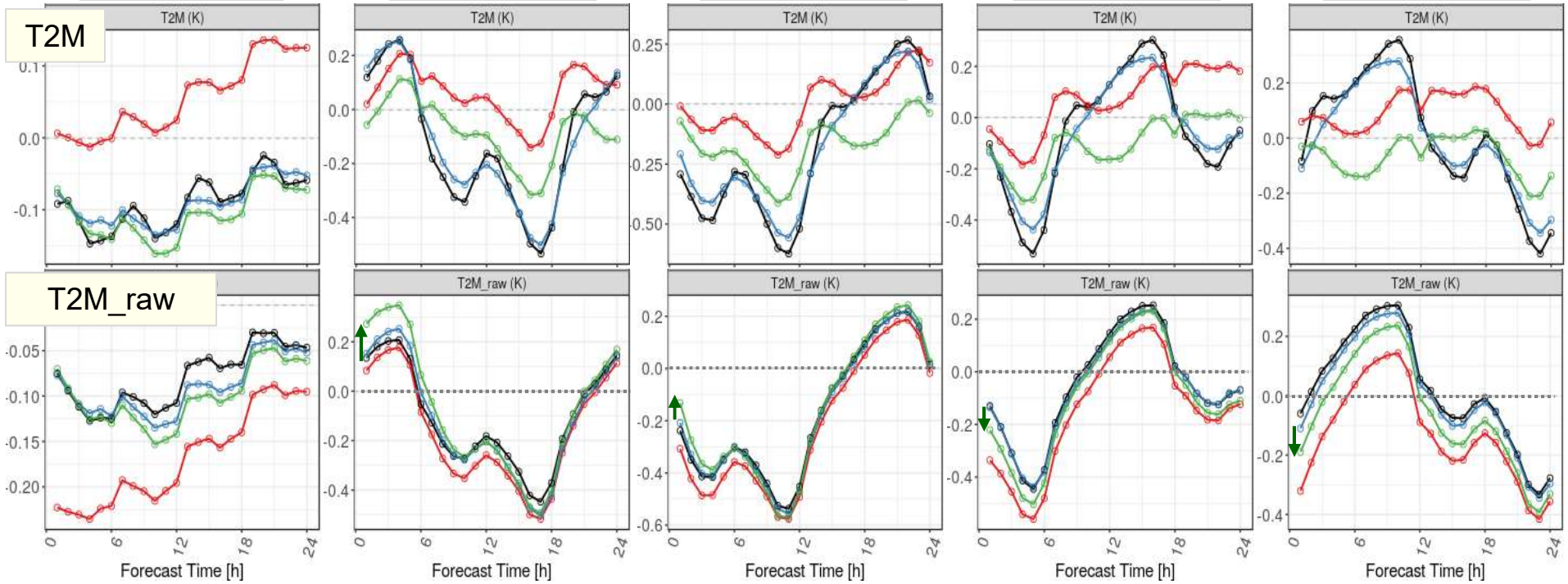
summer 04/08 – 04/09/20

bias

T2M + RH2m w/o BC (ref) | T2M + RH2m with BC_c1
T2M + RH2m with BC | T2M + RH2m with BC_c2

all forecasts | **0**-UTC runs | **6**-UTC runs | **12**-UTC runs | **18**-UTC runs



- **BC_c1**: bias very similar to **noBC** (no bias correction) (in statistics, averaged over stations)
- **BC_c2**: bias ag. bias-corr. T2m: diurnal cycle in forecast reduced vs. noBC (similar to BC)
  F.G. bias ag. raw T2m: much reduced vs. BC if averaged over all times,
  but diurnal cycle vs. noBC increased (feedback effect)

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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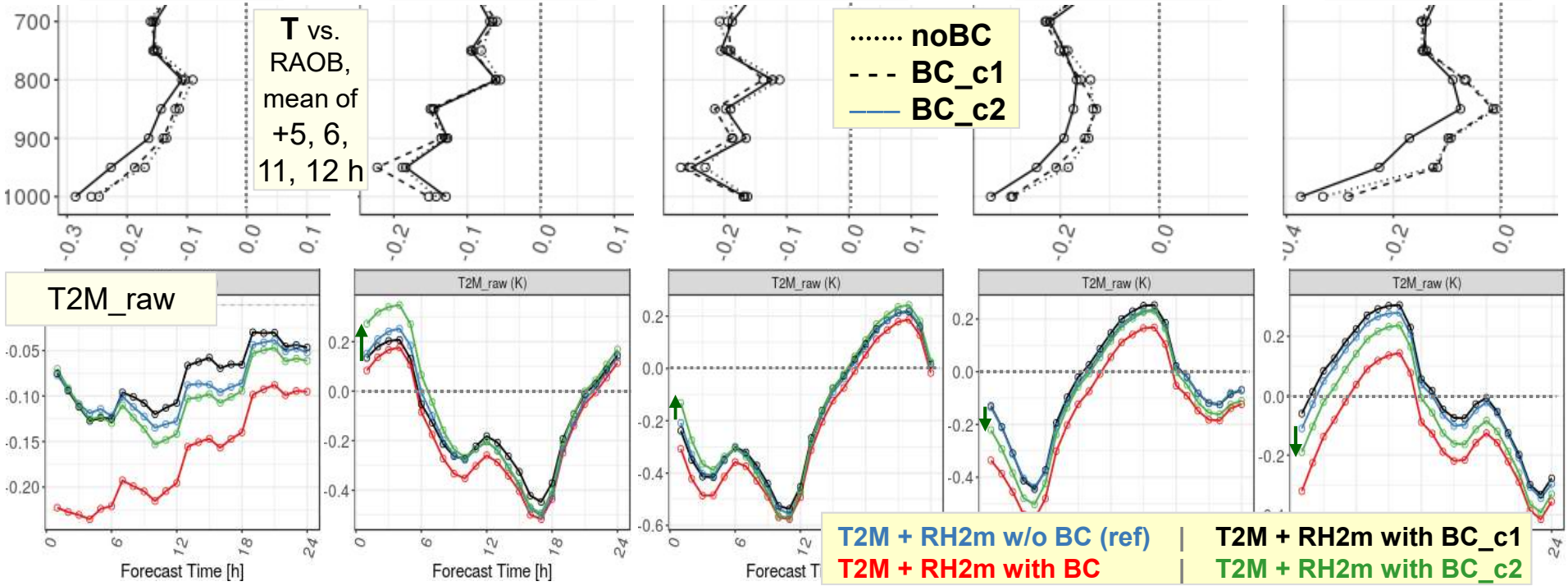
summer 04/08 – 04/09/20

bias

T bias vs. RAOB
mean of +5, 6, 11, 12 h

all forecasts | **0**-UTC runs | **6**-UTC runs | **12**-UTC runs | **18**-UTC runs



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2-m temperature + humidity obs:
bias correction (BC) + assimilation

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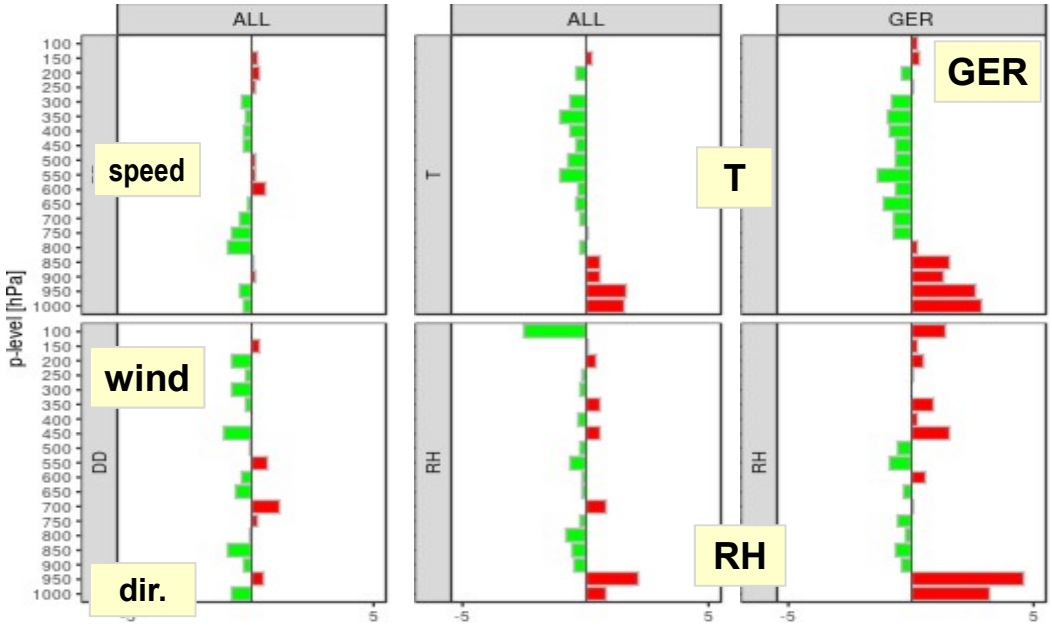
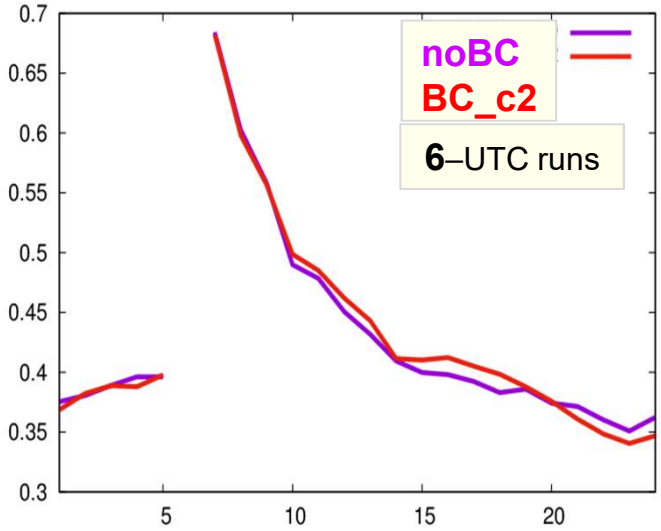
summer 04/08 – 04/09/20

radiosonde verification BC_c2 vs. noBC



Precip FSS (**23** km, **1** mm/h)



summary **BC_c2 vs. noBC:**

- feedback effects of BC: overall increase of negative T2M bias avoided,
  however conditional diurnal biases increased;
  → **increased cold T2M bias at 12, 18 Z** leads to **increased cold bias up to 800 hPa**
- indications of (slightly) improved model-compatibility of bcor T2M & balance
  (precip, T2M, RH2M, upper-air wind, upper-level T)

2-m temperature + humidity obs:
bias correction (BC) + assimilation

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concept of non-linear bias correction (NL-BC)

- BC → $bcor = -A \cdot c_{sta}$: corrects for difference of obs – model bias
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- BC_c3 → $bcor = -A \cdot (c_{sta} - s \cdot (c_{domain} - c_{dom.,\,clim}))$
  : subtracts only the difference of current to 'climatological' large-scale bias from BC

non-linear bias correction	BC	BC_c1	BC_c2	BC_c3
station dependent	✓	✓	✓	✓
accounting for diurnal cycle	✓	(–)	✓	✓
dep. on (observed) cloud cover	✓	(–)	✓	✓
online (dynamic)	✓	✓	✓	✓
no bias increase by feedback	–	✓	✓ / –	?

→ bias correction can be quite tricky (at least if not enough anchor data)

→ open question whether / which BC will be introduced operationally

2-m temperature + humidity from Netatmo stations

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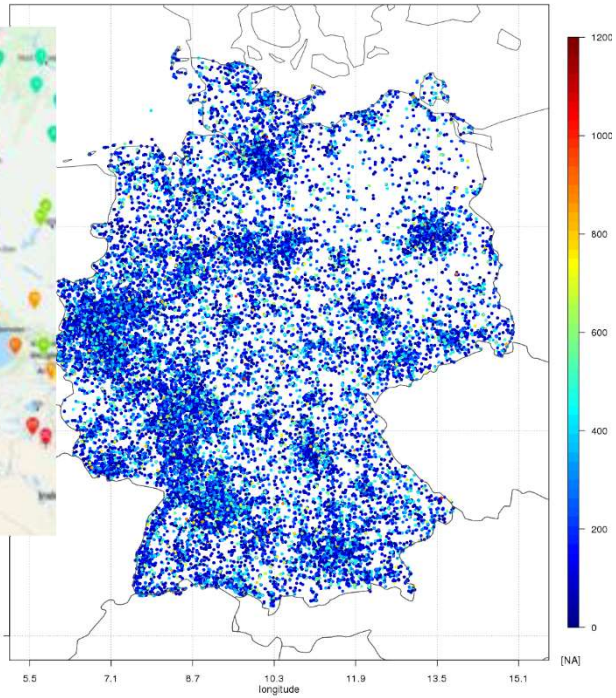
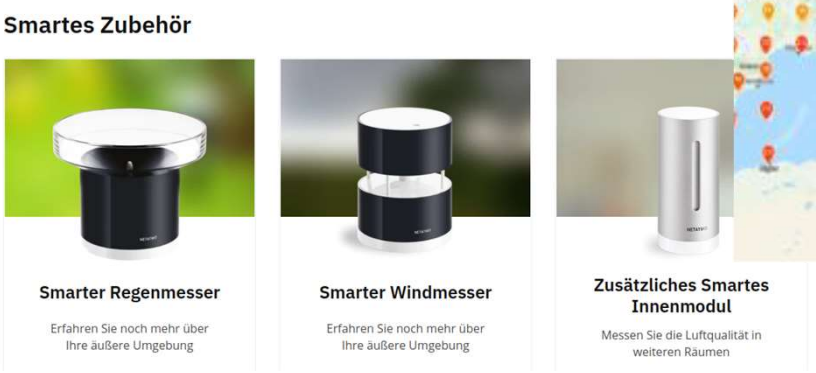
Netatmo: privately owned automatic weather stations worldwide





- data set **purchased** in DE for 17 – 30 Sept. 2018
- observed: T2M, RH2M, pressure, wind speed / direction / gusts, precip
- 10000 stations → 5000 randomly selected → 3000 active (vs. 1200 synop in D2 area)
- plausibility control (altitude (at given lat / lon), T2M outliers (e.g. room temperature), etc.)
- every 5 min → hourly averaging over last 15 min

2-m temperature + humidity from Netatmo stations

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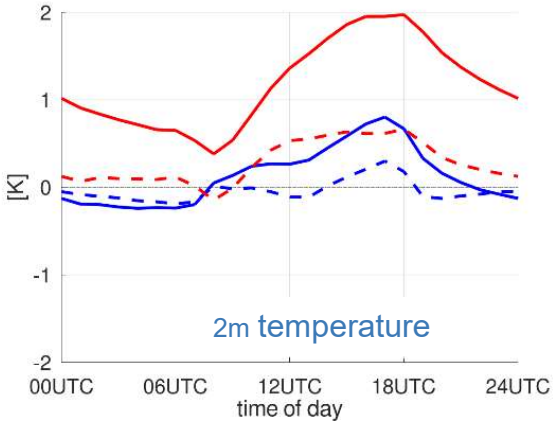
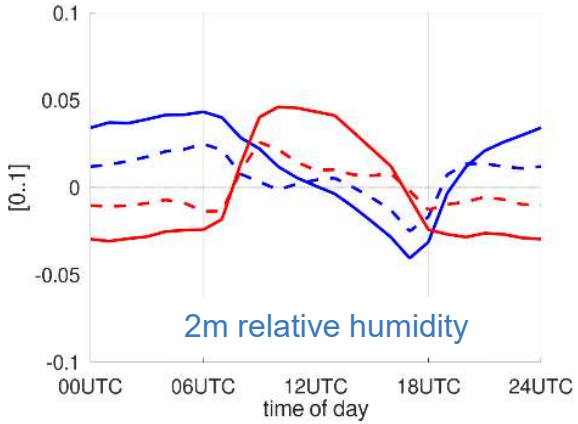
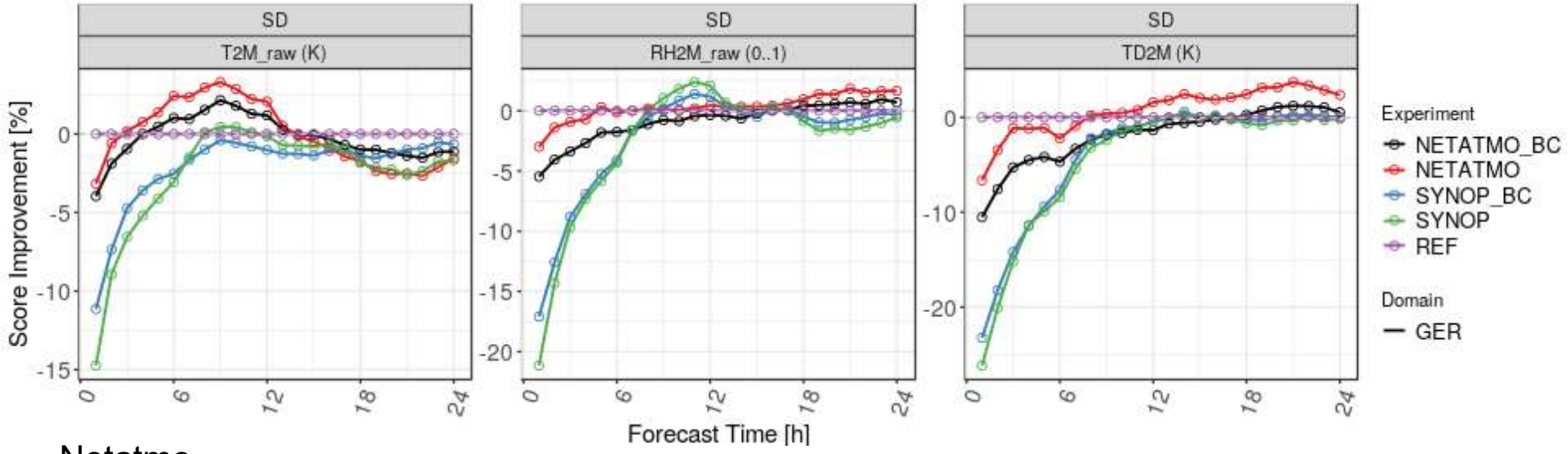




SYNOP – w/o bias correction
SYNOP – with bias correction
NETATMO – w/o bias correction
NETATMO – with bias correction

e_o	T2M	RH2M
Synop	1K	10%
Netatmo	3K	30%



Netatmo

- larger biases (mainly T2M), larger random error (O – FG)
- bias correction important / beneficial, impact much smaller than from Synop

(C-)EnVar for ILAM

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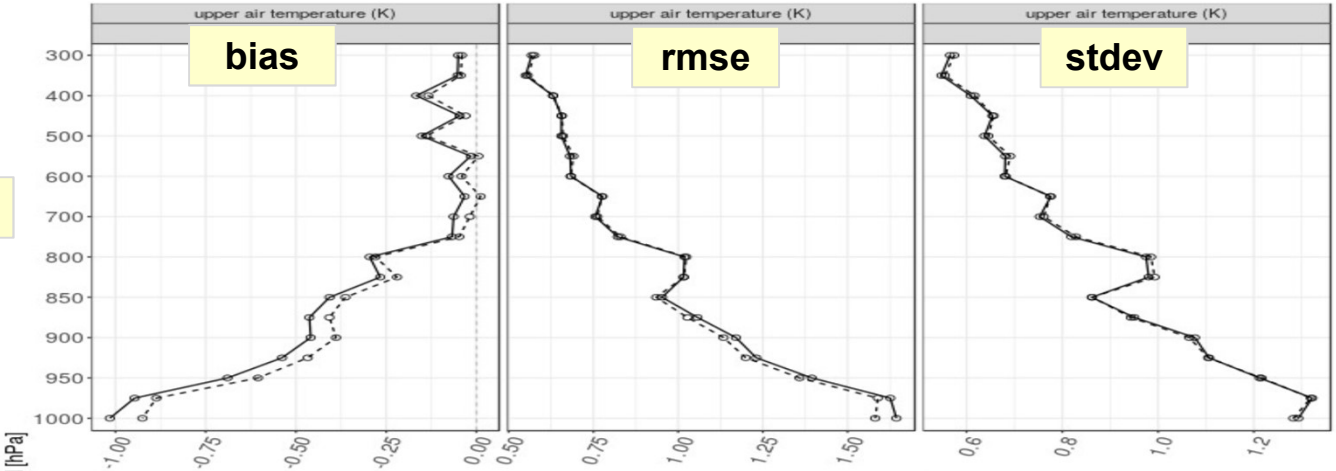
- **EnVar**: runs technically in a preliminary version (with DACE obs operators);
  (Mareike Burba et al.) for testing and comparing to LETKF, need to use similar set of obs
  → careful study obs processing chains & checks to reject obs (no VarQC, thinning, FG check..)
  → using aircraft T obs only: differences in 1-step analysis exp. (mostly) understood

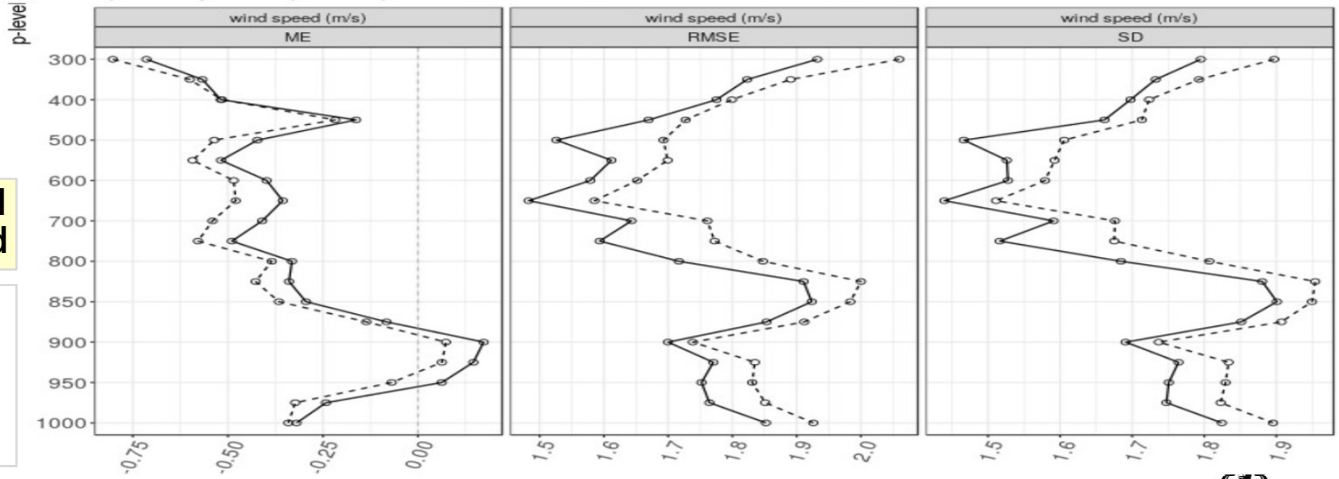
experiment:
- 1 day,
- 4 24-hr forecasts

T



EnVar
LETKF

wind speed



EnVar vs. LETKF
- T slightly worse (bias)
- wind clearly better
  → cross-covariances!

(C-)EnVar for ILAM

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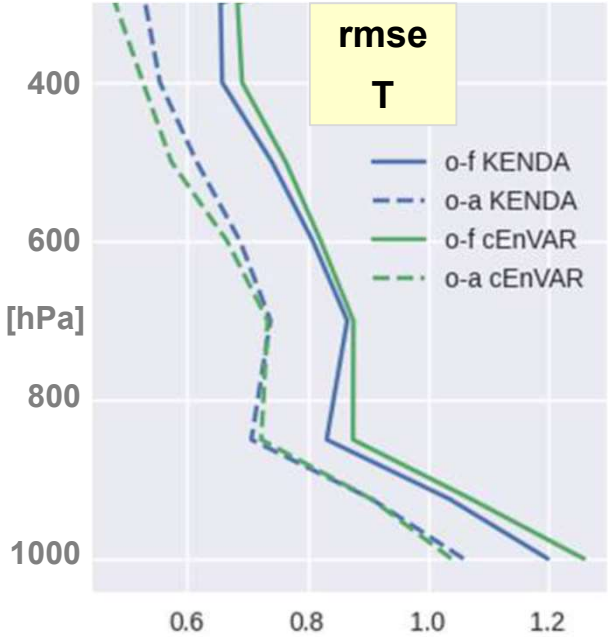
- **CEnVar**: runs technically in a preliminary version
  (with ensemble-B from ICON-EU; with B from ICON-global yet to be checked)
  - C-EnVar for Romanian domain:
    DA cycle runs technically (only very few obs)
  - next step: in order to reduce data amount
    to be transferred:
    - crop target domain from ICON-EU / -global fields,
    - test / adapt DACE to process
      and use them for B-matrix in CEnVar



- **Hybrid EnVar / 3DVar**, i.e. with additional use of **climatological B-matrix**:
  - **global** climatological B-matrix is applicable
  - aim to develop **regional** clim. B-matrix: required very well-trained resources currently not available
    (due to other high-priority work, e.g. 4D-EnVar)

(C-)EnVar for ILAM

re-write of convective-scale forward **operators** (+TL +adjoint) for conventional obs:

- ongoing, for **aircraft** obs technically done, being tested *(Bauernschubert, Reich, Schraff)*

- general: namelist switch '**use_global**': use 'global' DACE routines only for selected obs types
  - setting (temporarily) **obs errors** in MEC (also for cdfin-based verif.), overridden in LETKF
  - applying **blacklist** check, yet only for obs types processed by global routines
- aircraft: (code or namelist) adaptations of ('global') DACE operator for KENDA purposes:
  - **pre-thinning** (for high-res. Mode-S, already includes optional conditions such as time (closeness to analysis time), number of active obs (wind + temperature), etc.)
  - **roll angle** called in MEC, with effect only on wind (not T as in global EnVar)
  - Namelist: lower limit of pressure above surface pressure (KENDA: 3 hPa)
  - **no flight track check** of COSMO operator (very few rejections): not (yet?) implemented, incl. associated thinning of AMDAR along flight tracks
  - **no redundancy check** any more (obsolete if thinning applied)
  - **interpolation**, global settings by namelist: vertically spline instead of linear in ln(p) (as in COSMO operators), horizontally bi-linear interpolation instead of nearest neighbour
- 10-day+ trial started: COSMO routines vs. DACE routines vs. global interpolation