Recent Developments in KENDA

Deutscher Wetterdienst

PP KENDA-O : Km-Scale Ensemble-Based Data Assimilation for the use of High-Resolution Observations
(Sept. 2015 – Aug. 2020)

- further development of LETKF scheme (conventional obs, operationalisation)

  → KENDA-1 (at **1.1** km) operational at MeteoSwiss (Aug. 20)

- adaptation to ICON-LAM

  → ICON-D2 in parallel suite at DWD (since Nov. 19; planned operational Q1/21)
  → ICON-IT in parallel suite at COMET (since Feb. 20)

- extended use of observations

  → promising results for bias correction + assimilation of T2M + RH2M

  → 3-D radar radial velocity + **reflectivity** operational at DWD (March / June 20)
  (1st direct assimilation of 3-D reflectivity in operational NWP at NWS worldwide ?)

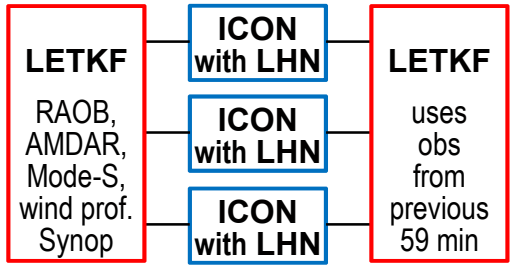
  → radiosonde descent profiles operational at DWD / COMET

KENDA for **ICON-LAM**
ICON-D2 at DWD

Deutscher Wetterdienst

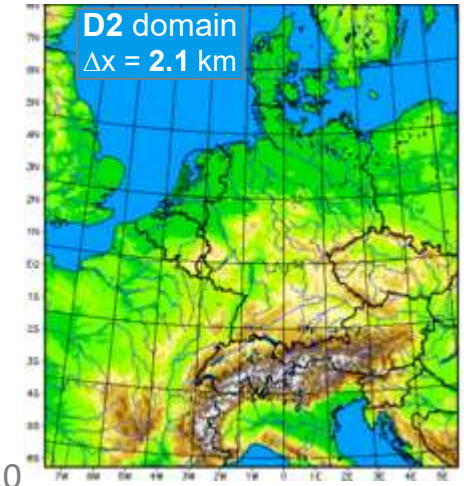
→ ***Hendrik Reich, Christian Welzbacher, Harald Anlauf, Klaus Stephan,***
Thomas Rösch, Martin Lange, Sven Ulbrich, Gernot Geppert, Thorsten Steinert,
Lilo Bach, Uli Blahak, Christoph Schraff, Roland Potthast, … , Günther Zängl, et al. (!)

- LETKF: same settings as for COSMO (e.g. for localization, covar. inflation, soil moisture perturbations, …)
  but with **IAU** (10 min)
- LHN: adjusted + re-tuned for ICON-D2



- **soil moisture nudging** towards interpolated ICON-EU soil moisture added
  (ICON-EU (Δx = 6.5 km) has SM analysis based on T2m obs)
  → to prevent excessive drying in dry summers

- comparison **ICON-D2** with KENDA (no soil moisture nudging yet
  no use of 3-D radar obs yet)
  (00 + 12 UTC forecast runs)
  - vs. **COSMO-D2**
  - vs. **downscaler**: ICON-D2 with interpolated ICON-EU as IC
  - for 3 periods: summer / autumn / winter
    1 – 23/06/19 / 13/09 – 13/10/19 / 26/11/19 – 06/01/20



KENDA for **ICON-LAM**
comparison to COSMO / to downscaler

Deutscher Wetterdienst

1-h precip vs. radar

FSS (15 g.pt. ≅ **30 km**)

0.1 mm/h

0-UTC runs

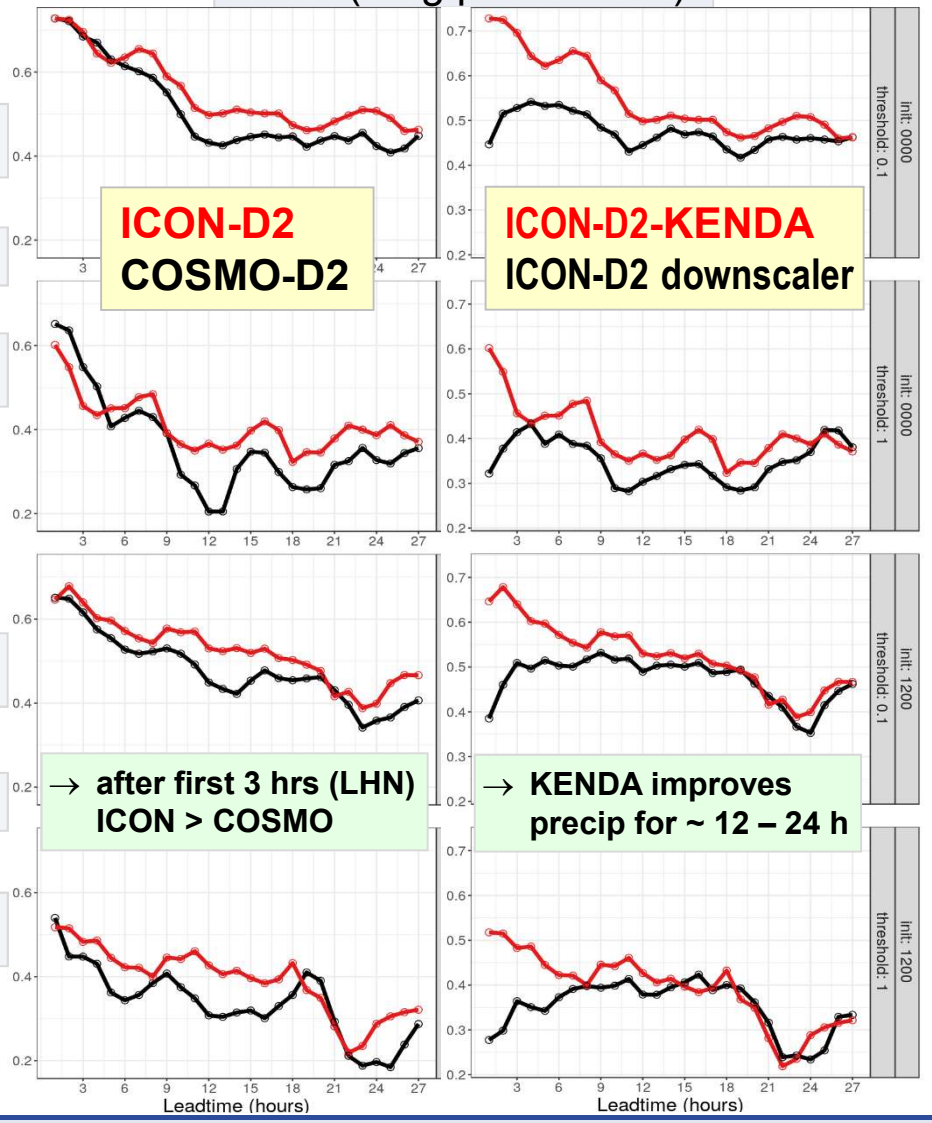
1 mm/h

summer 01 – 24 /06 /19

0.1 mm/h

12-UTC runs

1 mm/h



→ **after first 3 hrs (LHN) ICON > COSMO**

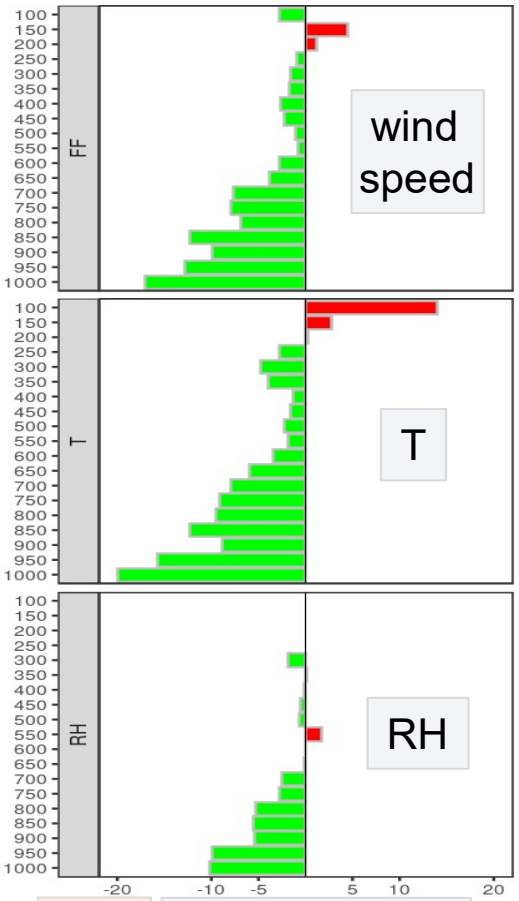
→ **KENDA improves precip for ~ 12 – 24 h**

FSS differs less in autumn, neutral vs. downscaler in winter

KENDA for ICON-LAM comparison to COSMO

Deutscher Wetterdienst

radiosonde verification



-20 % !

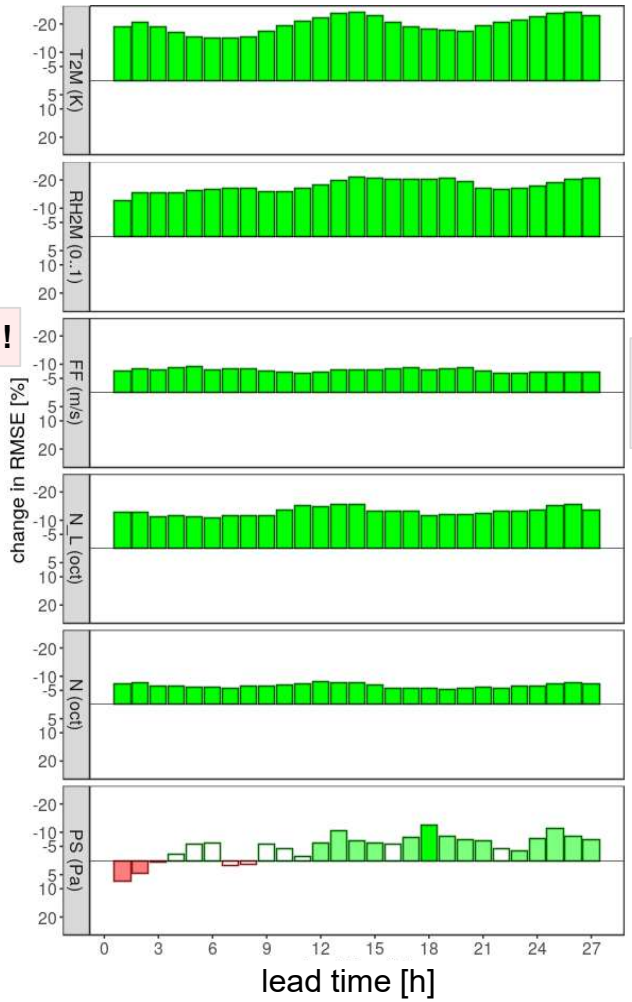
change [%] in RMSE averaged +12h, +24h

winter
26/11/19 – 06/01/20

change [%] in RMSE

ICON -D2 better
COSMO-D2 better

Synop verification



T2M

RH2M

-20 % !

10-m wind speed

low cloud

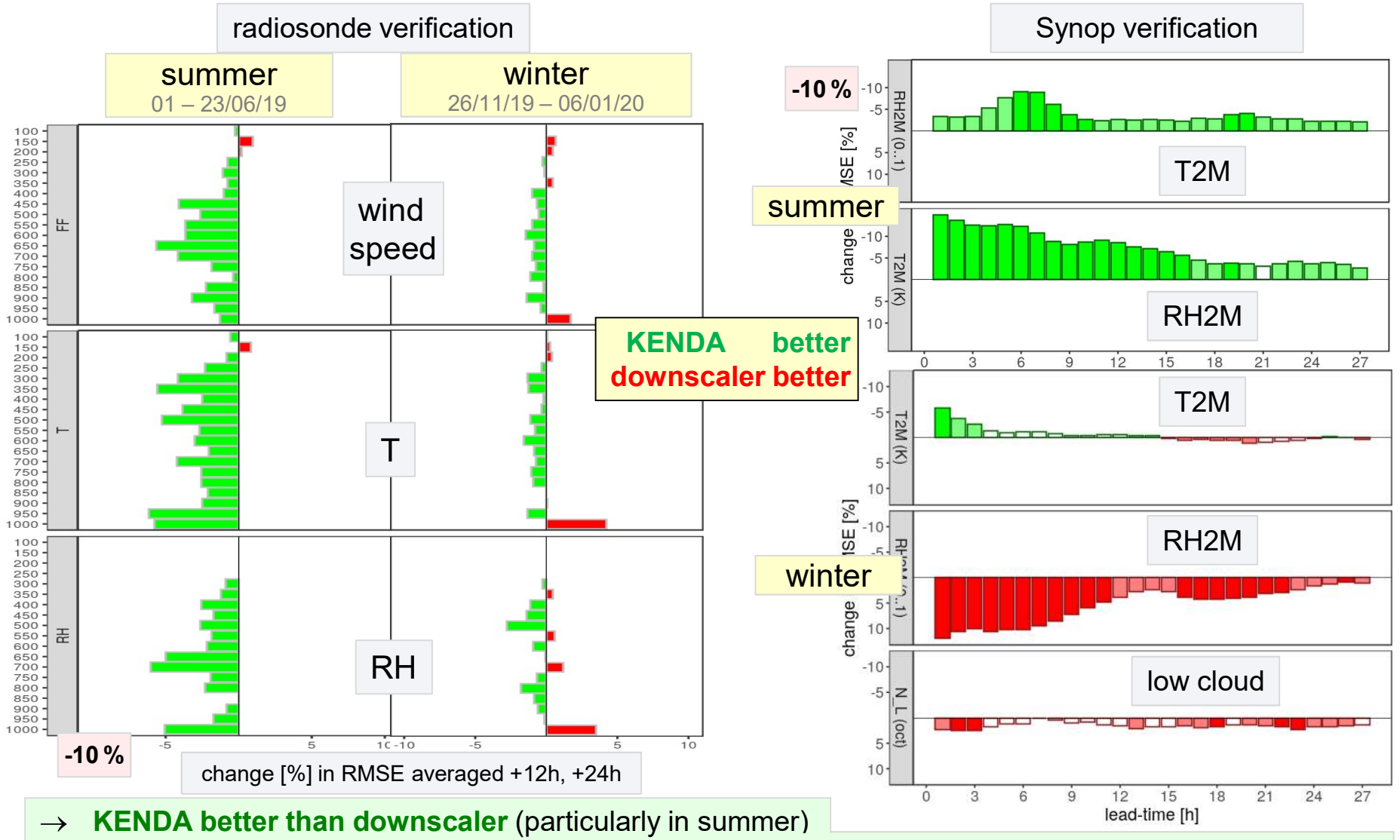
total cloud

PS

→ **ICON-D2 far better** than COSMO in (lower) troposphere, **all seasons**, all variables

KENDA for **ICON-LAM**
comparison to downscaler

Deutscher Wetterdienst



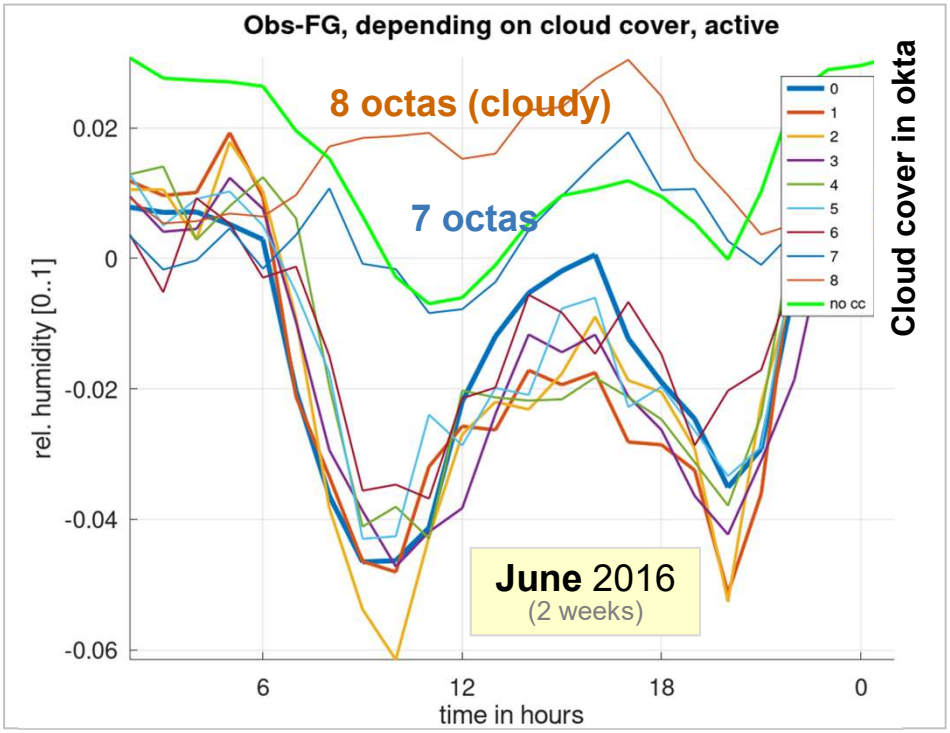
→ **KENDA better than downscaler** (particularly in summer)
except in **winter**: T, RH near surface, low cloud, **RH2M** ← KENDA w/o vs. EnVar with use of RH2M

bias correction and assimilation of **2-m temperature** and **humidity** obs

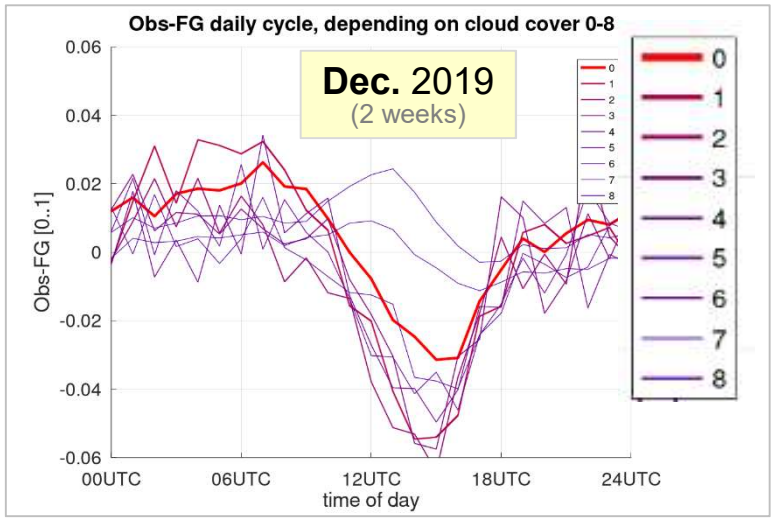
Deutscher Wetterdienst

Christine Sgoff, Elisabeth Bauernschubert, Roland Potthast, Christoph Schraff (DWD)

bias (O – FG) of RH2M, averaged over stations



- small diurnal cycle of bias if very cloudy
- diurnal cycle otherwise



→ bias correction for LETKF assimilation
- station-dependent
- dependent on time of day
- dependent on (observed) cloud cover
- online (dynamic)
- (parameterized non-linear)

bias correction and assimilation of **2-m temperature** and **humidity** obs

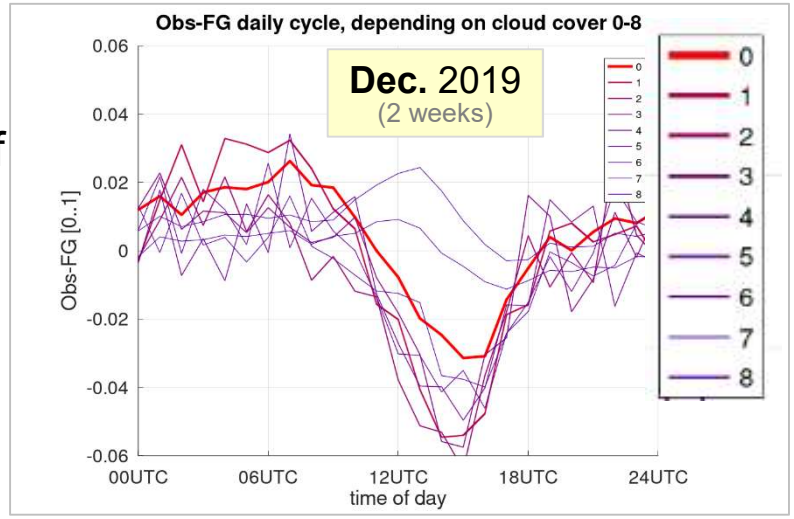
Deutscher Wetterdienst

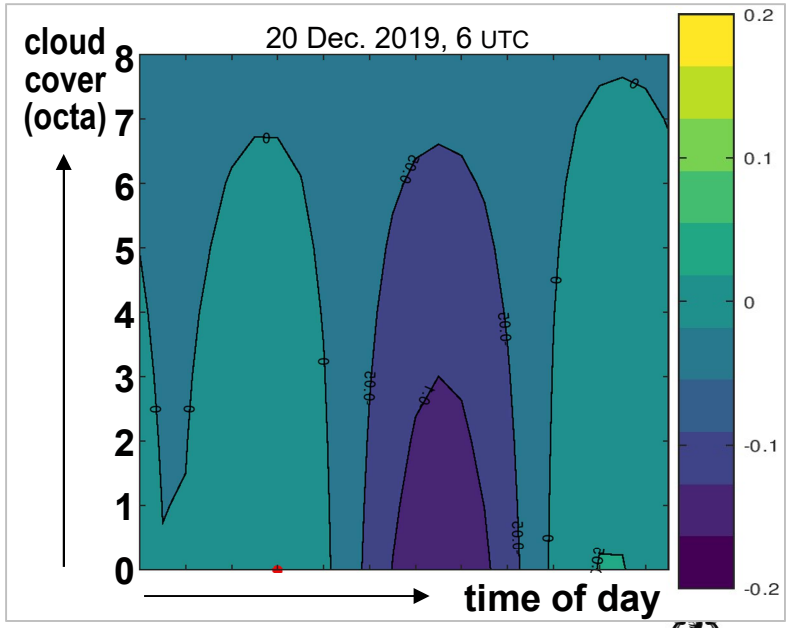
bias correction concept

- bias: described (approx.) by scalar product of
  vector A of basis functions and
  vector c of coefficients : $\text{bias} = A \cdot c$

- each element of A is the product of
  - 1 of 5 (7) trigonometric fn. of time of day t
    $1\,, \sin nt\,, \cos nt\,, \sin 2nt\,, \cos 2nt\,\ldots$
    $n = 2\pi/24$
  - 1 of 2 (3) polynomial fn. of cloud cover N
    $1\,, 9 - N\,, (9-N)^2$

- estimate coefficients c :
  by hourly re-adjustment based on a 3DVar





bias correction and assimilation of **2-m temperature** and **humidity** obs

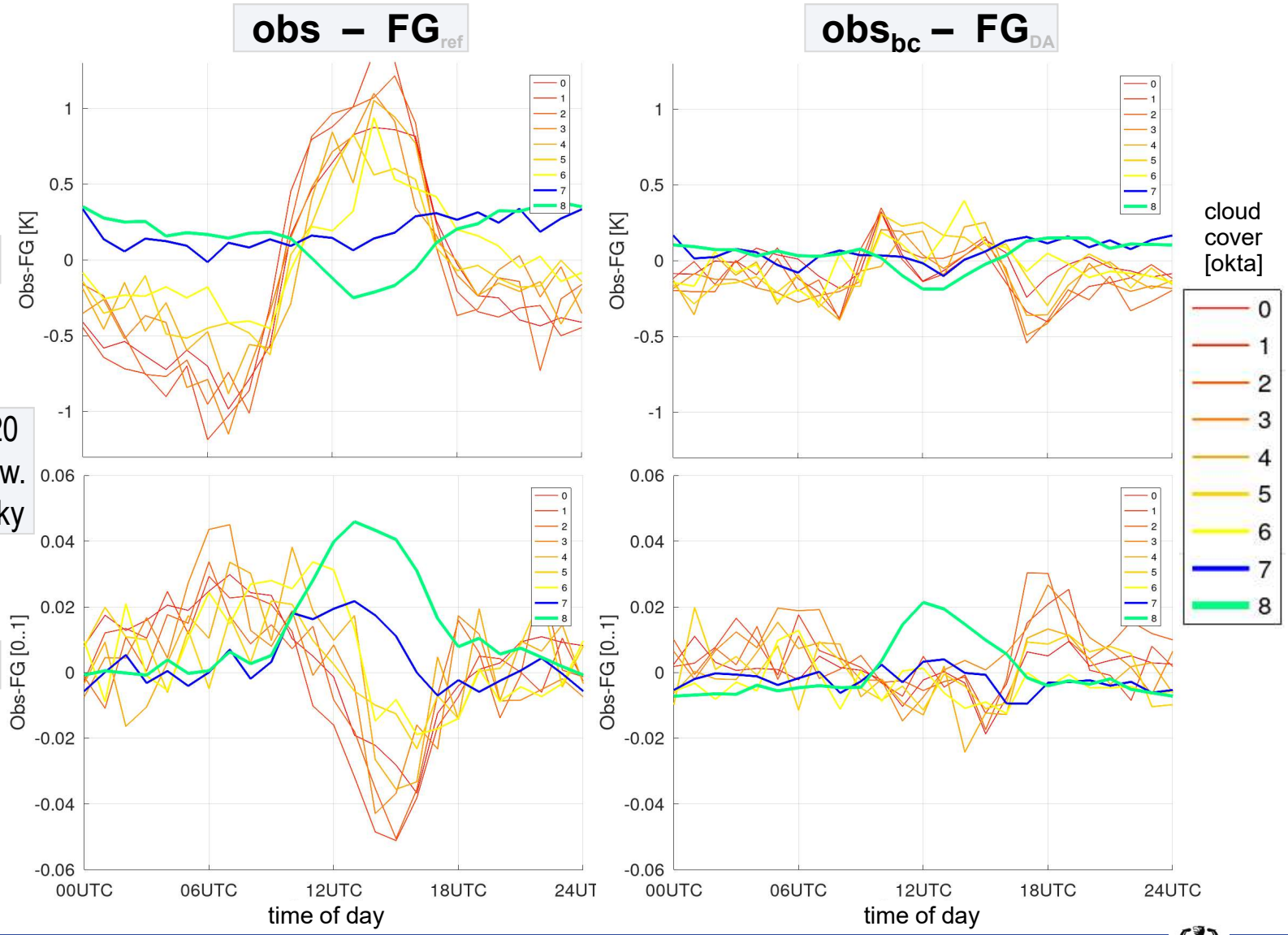
Deutscher Wetterdienst

bias
(mean difference) averaged over stations

T2m

27/12/19 – 08/01/20
winter, incl. cases w. low stratus /clear sky

RH2m



christoph.schraff@dwd.de

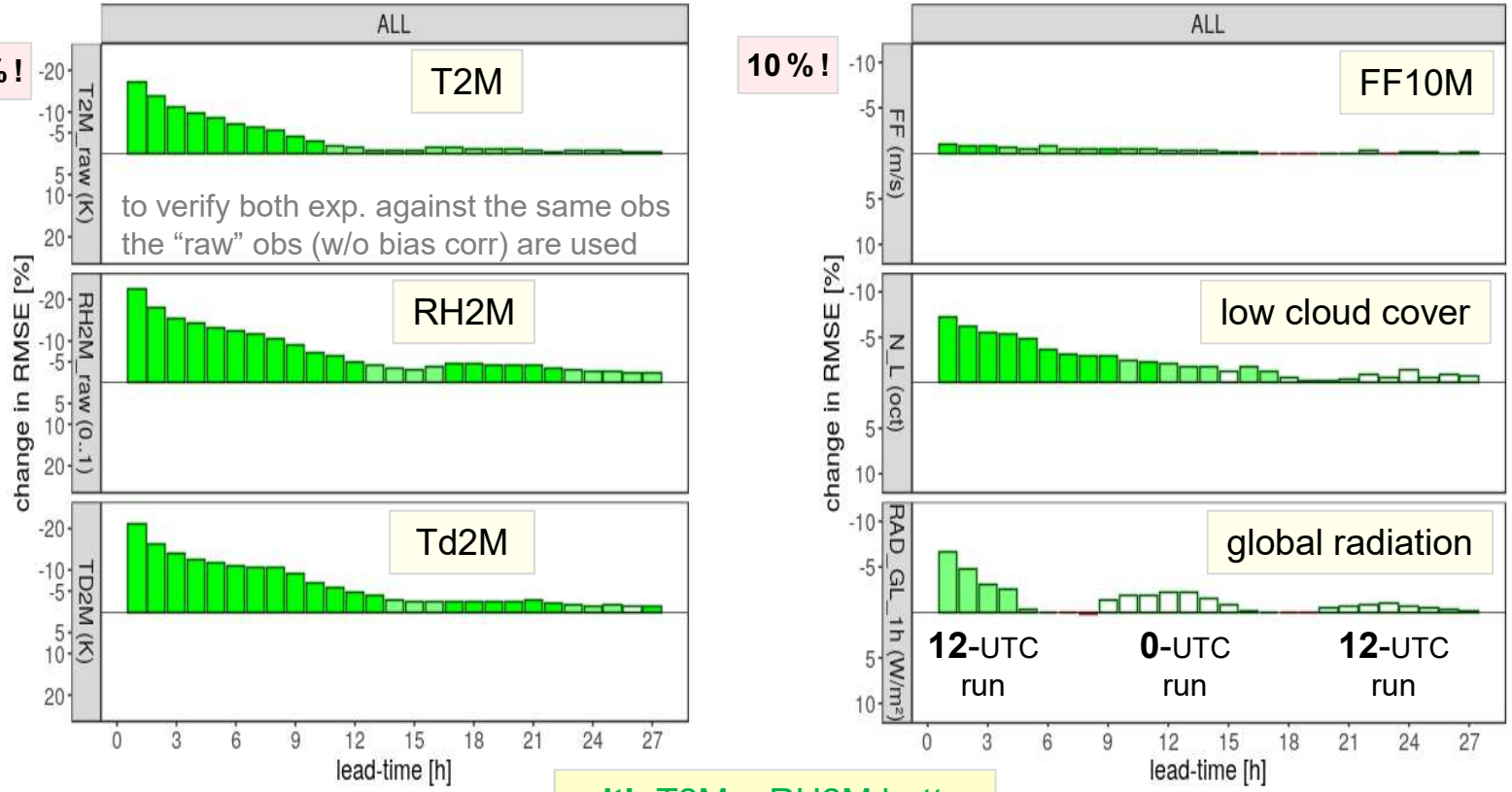
bias correction and **assimilation** of **2-m temperature** and **humidity** obs

Deutscher Wetterdienst

winter 22/12/19 – 08/01/20

ICON-D2

change [%] of RMSE against synop



with T2M + RH2M better
w/o T2M + RH2M better

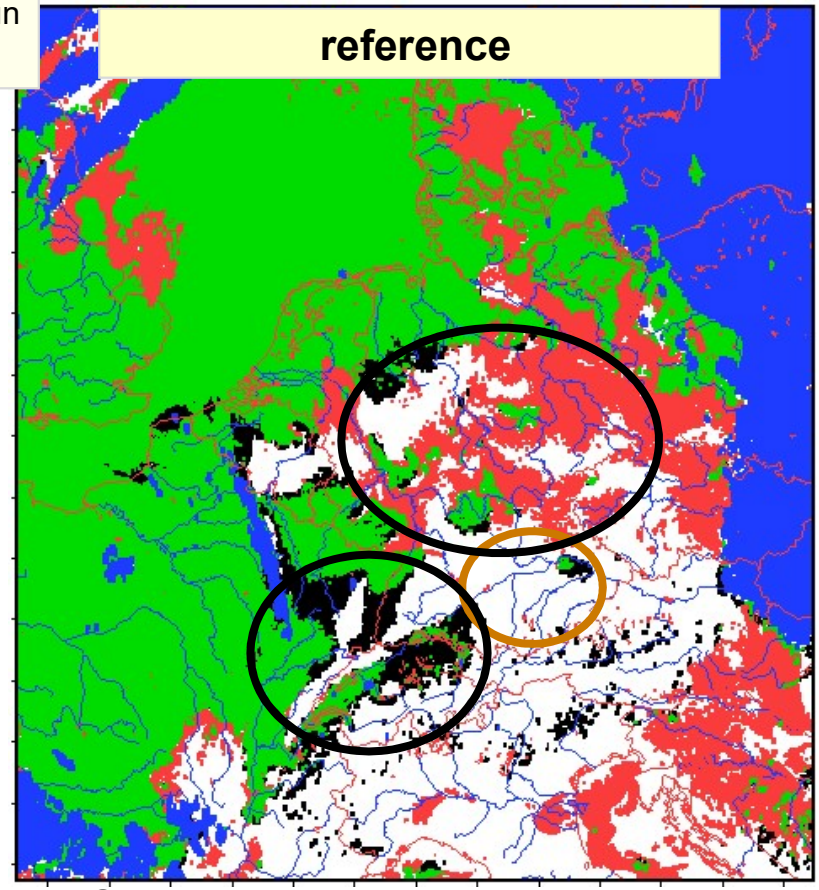
christoph.schraff@dwd.de

bias correction and **assimilation** of **2-m temperature** and **humidity** obs

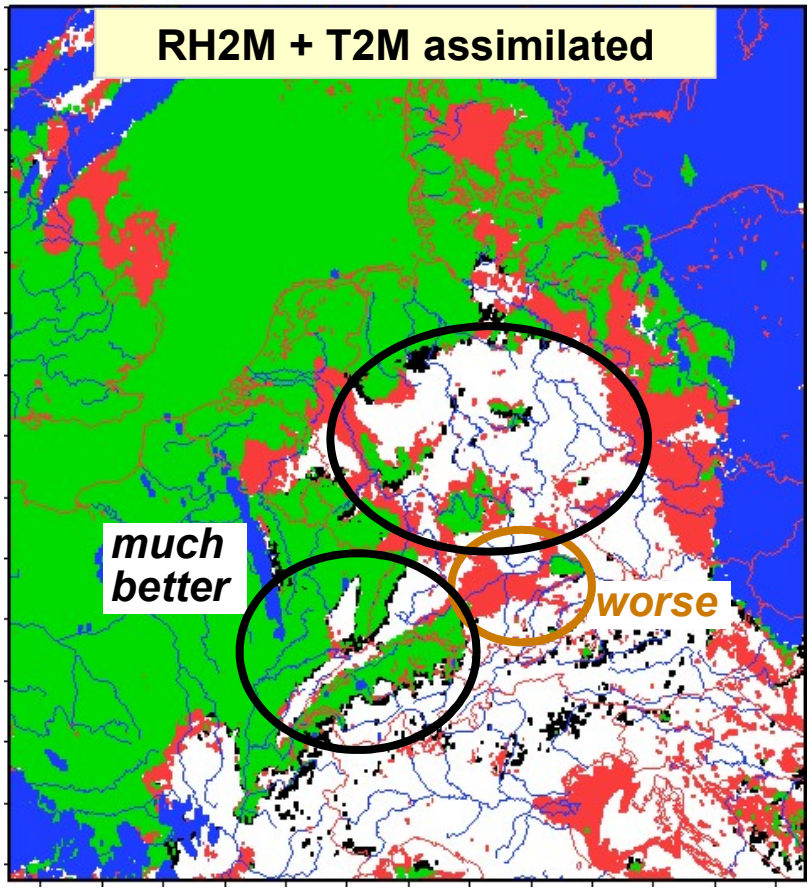
Deutscher Wetterdienst

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

12-UTC run
+ 1 h



ETS: 0.407 FBI: 1.209



ETS: 0.537 FBI: 1.194

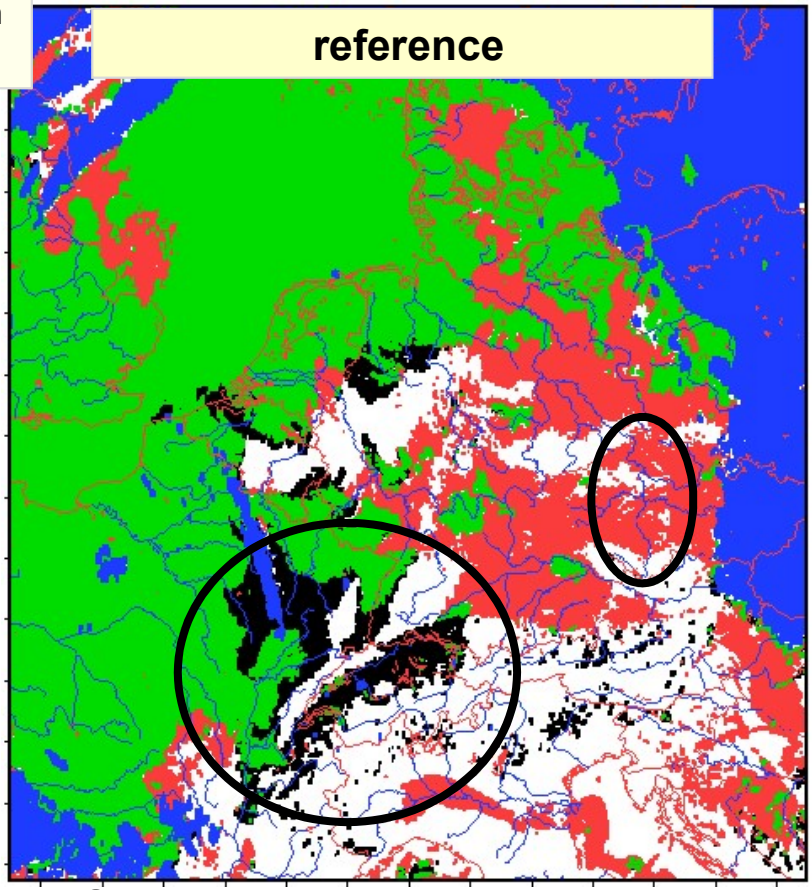
correct cloudy / **correct cloud-free** / **missed events** / **false alarms** / **undefined** (observed higher cloud)

bias correction and **assimilation** of **2-m temperature** and **humidity** obs

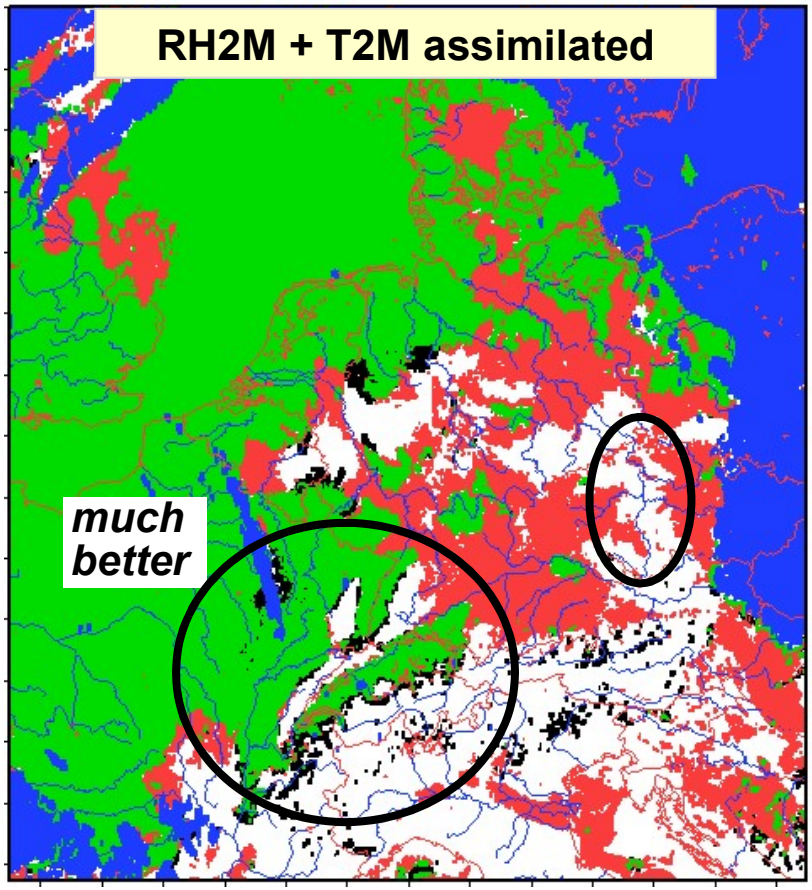
Deutscher Wetterdienst

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

0-UTC run
+ 13 h



ETS: 0.352 FBI: 1.224



ETS: 0.408 FBI: 1.302

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

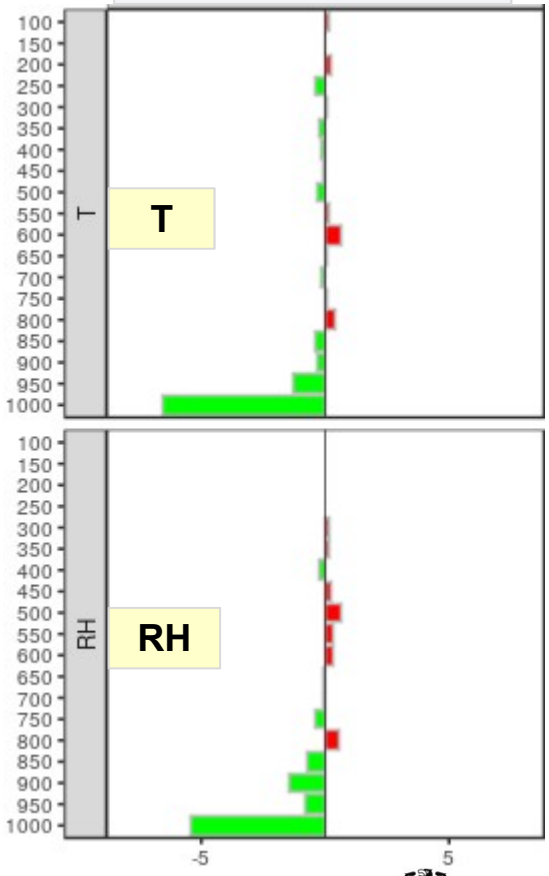
bias correction and assimilation of 2-m temperature and humidity obs

Deutscher Wetterdienst

- station-dependent, conditional, non-linear online bias correction developed

- assimilation of RH2M + T2M with bias correction
  (without having adjusted obs errors, QC, vertical localization …!)
  - improves clearly T2M, RH2M (mainly first 9 hrs),
    T + RH in PBL (up to 24 hrs, only winter),
    radiative low stratus (in winter, esp. in prone valleys),
  - increases low cloud (sometimes too much)
  - (assimilating only RH2M w/o bias correction degraded T2M)

TEMP verif
averaged +12h, +24h
22/12/19 – 08/01/20



next steps

- further investigation of the low clouds
- longer experiment periods, investigate impact on precip
- estimate station-dependent observation errors

3-D radar radial velocity + reflectivity assimilation in KENDA

Deutscher Wetterdienst

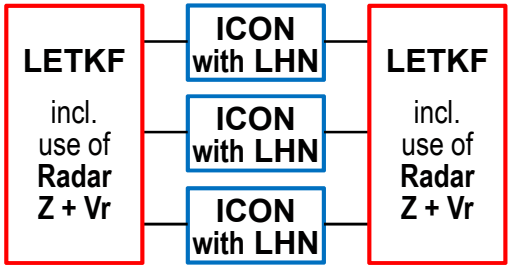
Christian Welzbacher, Klaus Stephan et (many) al. (DWD)

from German radar network

- direct assimilation in LETKF of
  3-D reflectivity Z (from 5 elevations) +
  3-D radial velocity Vr (from 3 elevations)
  from **1** volume scan per hour ('at' analysis time)

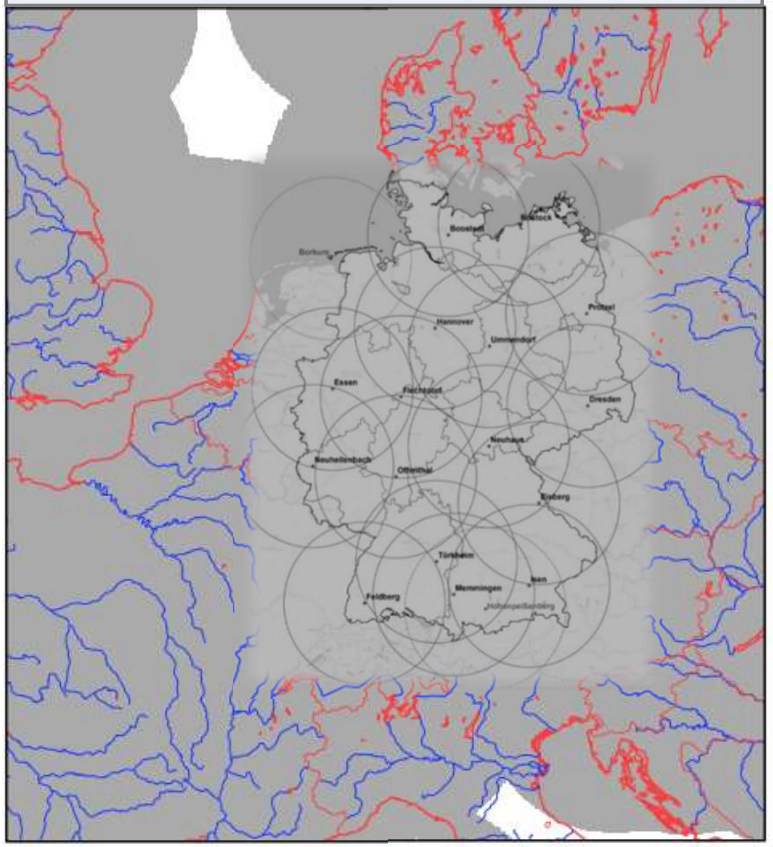
- latent heat nudging (LHN)
  of 'surface' precipitation rates derived from
  2-D 'precipitation scans' every 5 min (DE)

→ complementary data sources, schemes can be combined



other radars (OPERA or others):
- LHN of 'surface' precip rates every 5 – 15 min

– **circles:** **DWD radar** network for **reflectivity** assimilation
– **grey:** radar composite for **LHN** on **D2** domain

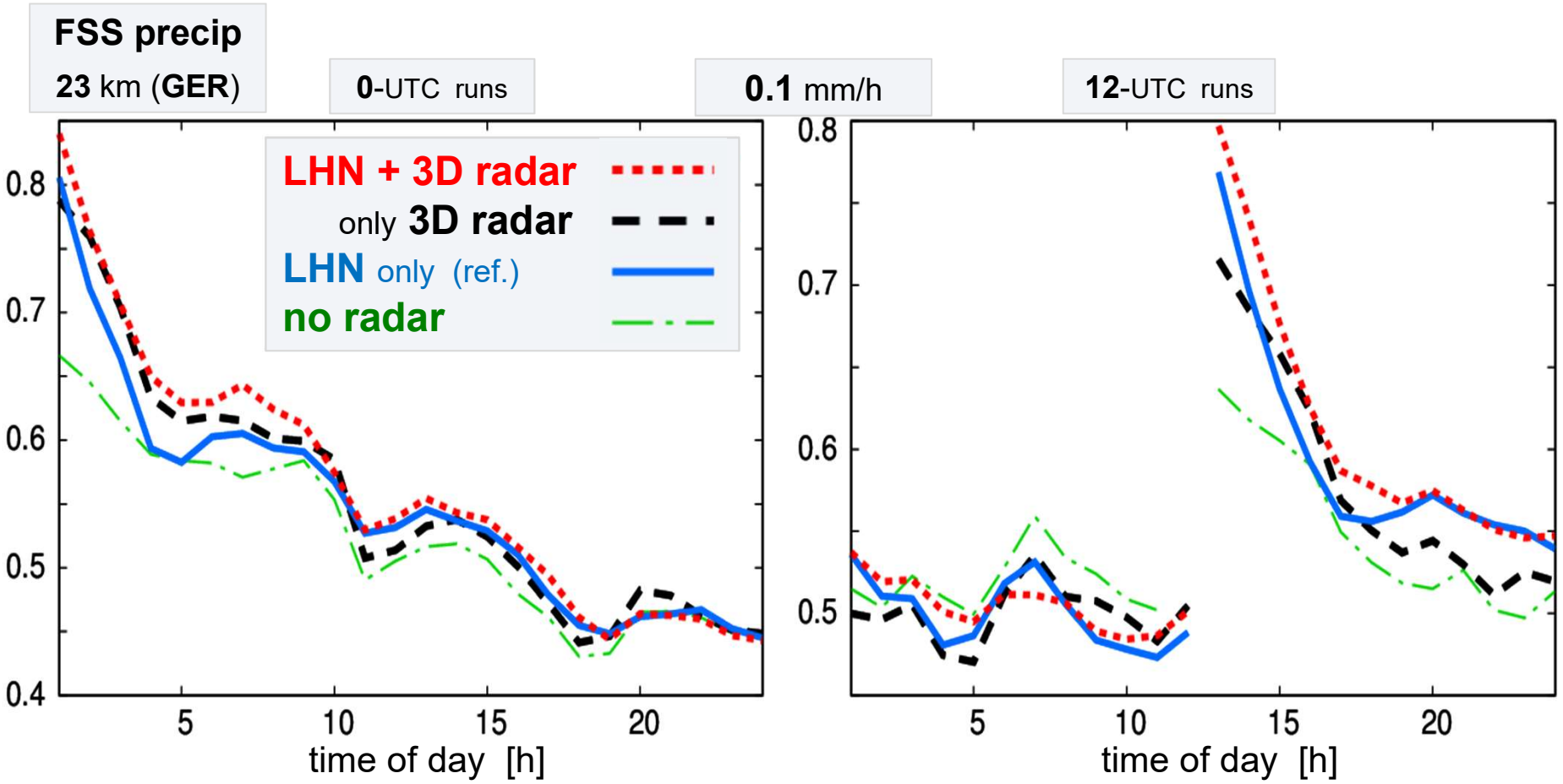


3-D radar radial velocity + reflectivity assimilation in ICON-D2

Deutscher Wetterdienst

combined use of radial velocity + reflectivity tested for ICON-D2: 2 – 22 June 2019

(by accident)



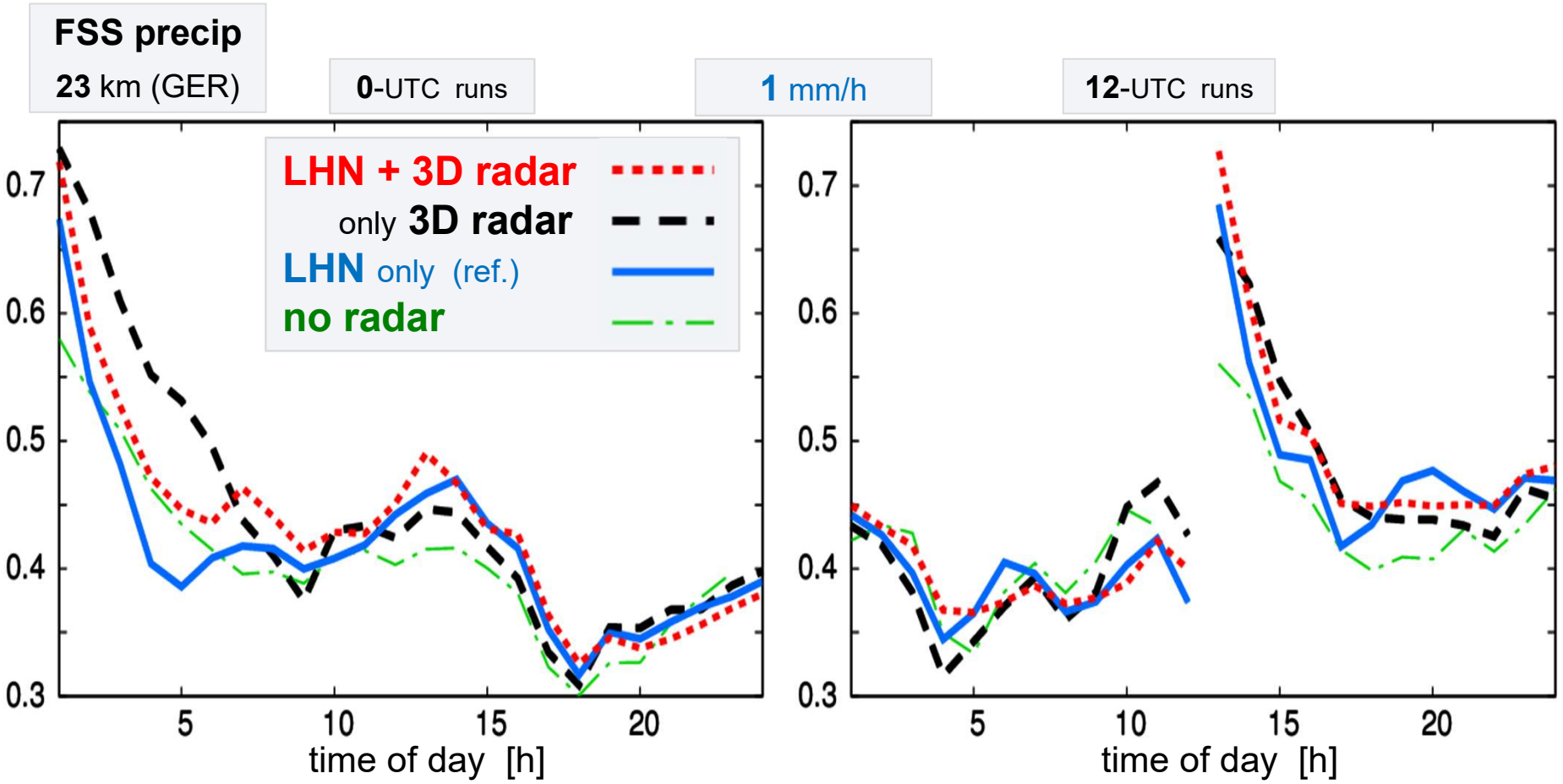
→ **LHN + 3D radar** > **LHN** only ~ **3D radar** only > **no radar**

christoph.schraff@dwd.de

3-D radar radial velocity + reflectivity assimilation in ICON-D2

Deutscher Wetterdienst

combined use of radial velocity + reflectivity tested for ICON-D2: 2 – 22 June 2019



→ **LHN + 3D radar** ~ **3D radar** only > **LHN** only > **no radar**

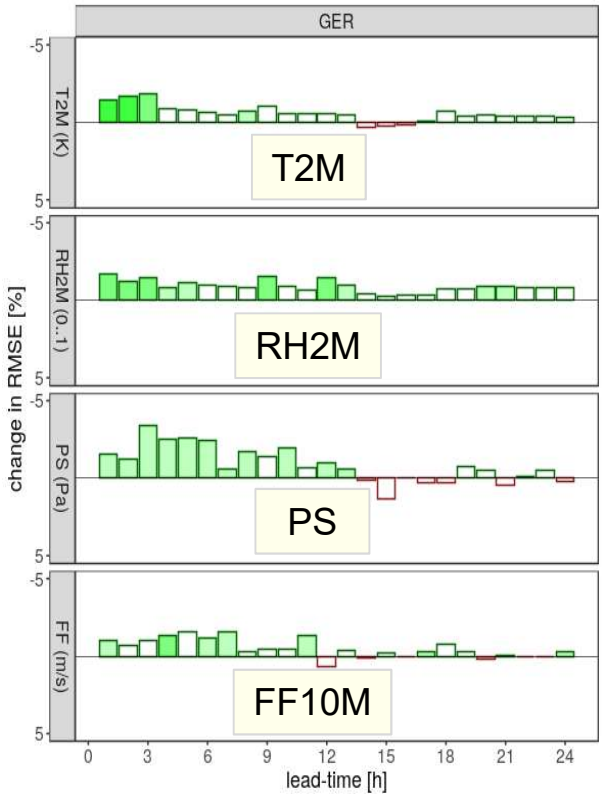
christoph.schraff@dwd.de

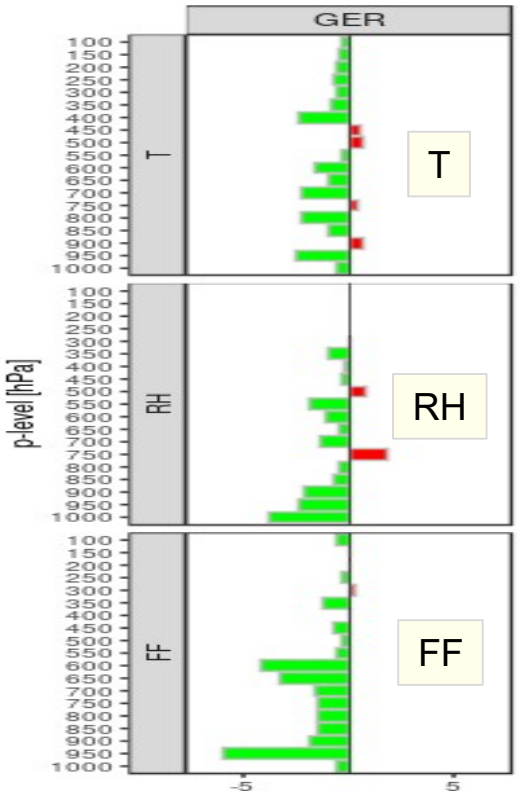
3-D radar radial velocity + reflectivity assimilation in ICON-D2

Deutscher Wetterdienst

combined use of radial velocity + reflectivity tested for ICON-D2: 2 – 23 June 2019

LHN + 3D radar better
LHN (ref.) better





change in RMSE [%]
TEMP verif
averaged +6, 12, 18, 24h

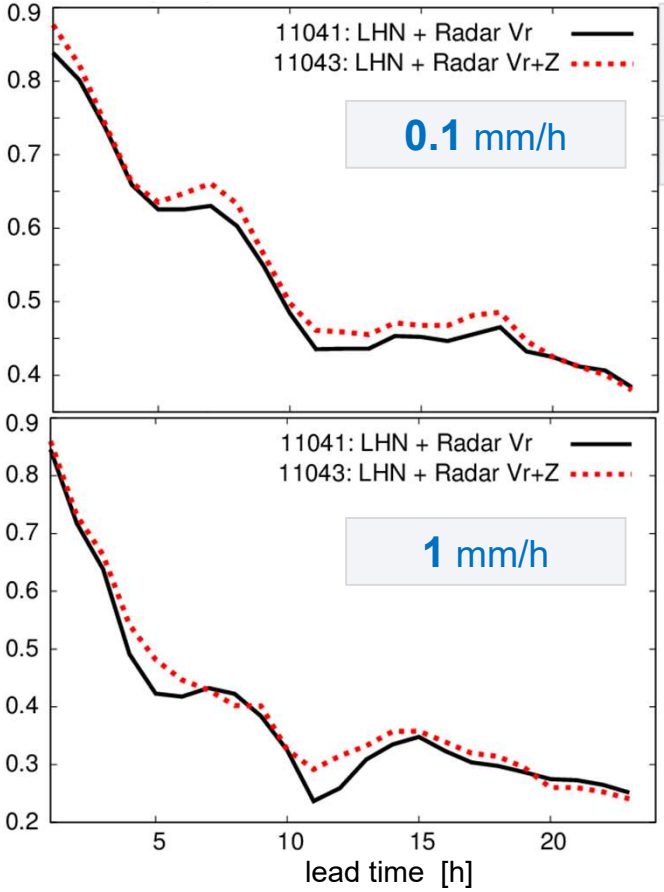
→ **radar Z + Vr** in **ICON-D2 parallel suite** since 22 June 2020
due to clear positive impact

christoph.schraff@dwd.de

3-D radar reflectivity assimilation in COSMO-D2

Deutscher Wetterdienst

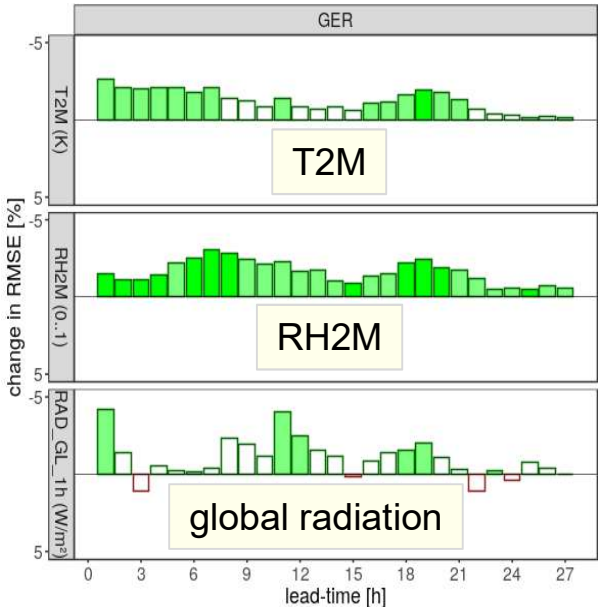
use of 3-D reflectivity tested for COSMO-D2: 2 – 22 June 2019

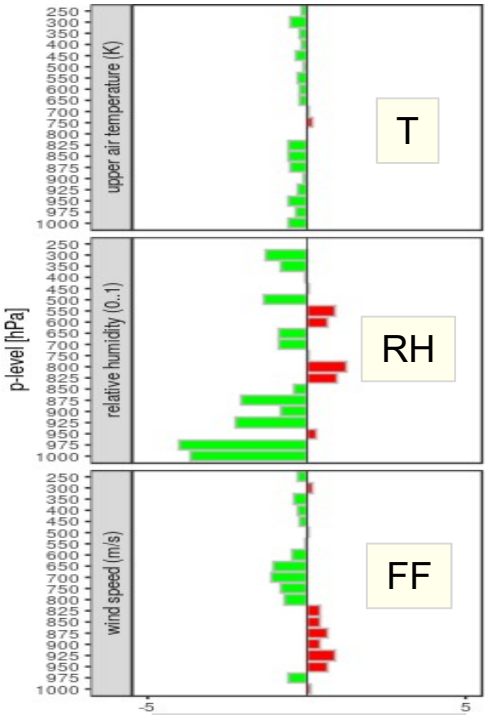


FSS precip
23 km (GER)

0-UTC runs

LHN + 3D **radar** Vr + **Z** better
LHN + 3D radar Vr better





change in RMSE [%]
TEMP verif
averaged +12h, +24h

→ **radar Z operational** in **COSMO-D2** since 17 June 2020
due to moderate positive impact

christoph.schraff@dwd.de

- further development / operationalization of LETKF scheme (conventional obs)

  KENDAscope → algorithmic developments
  - 3D-EnVar (3DVar), 4D-EnVar, exploring Particle Filter
  - bias correction, obs errors, QC, etc.

- adaptation to ICON-LAM (successful pre-operational applications) → done

- extended use of observations: project goals mostly met, continued
  - operational: aircraft Mode-S, radar radial velocity, radar reflectivity
  - close to operational: GPS STD / ZTD; screen-level obs (T2M, RH2M)
  - ground-based remote sensing: some implementations and first tests as intended
    (MWR, wind lidar, Raman lidar, drones, …)
  - some delay on all-sky SEVIRI IR WV (new resources available)

KENDAscope → additionally SEVIRI (FCI) VIS ; MTG IRS