Towards an operational use of the Kilometre-scale Ensemble Data Assimilation (KENDA)

Christoph Schraff

Deutscher Wetterdienst, Offenbach, Germany

… and many colleagues from CH, D, I, RU …
… in particular Hendrik Reich (DWD), Daniel Leuenberger (MCH)

→ Local Ensemble Transform Kalman Filter (LETKF) system developed

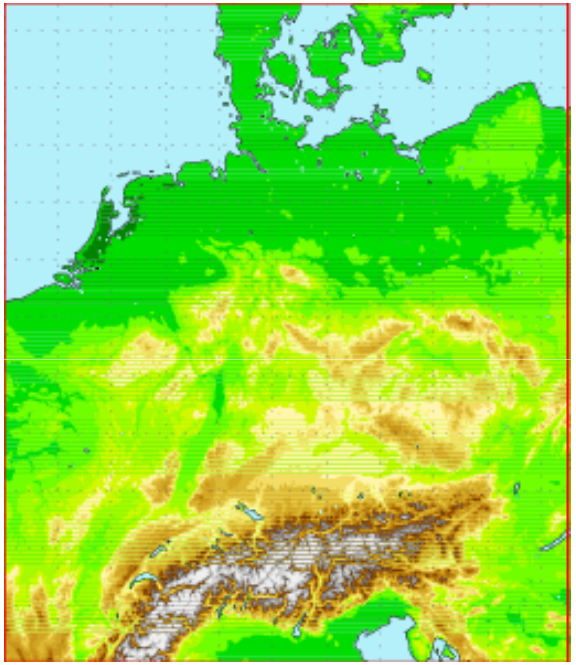
→ reference paper on KENDA: Schraff et al. 2016, QJRMS (doi:10.1002/qj.2748)

(pre-)operational use of KENDA

Deutscher Wetterdienst

- **MeteoSwiss:** **KENDA operational** for **EPS** (COSMO-E : Δx = **2.2** km) since 19 May 2016

- **DWD:** **KENDA** run in **pre-operational suite** for **deterministic + EPS** forecasts with COSMO-DE (Δx = **2.8** km) since May 2016

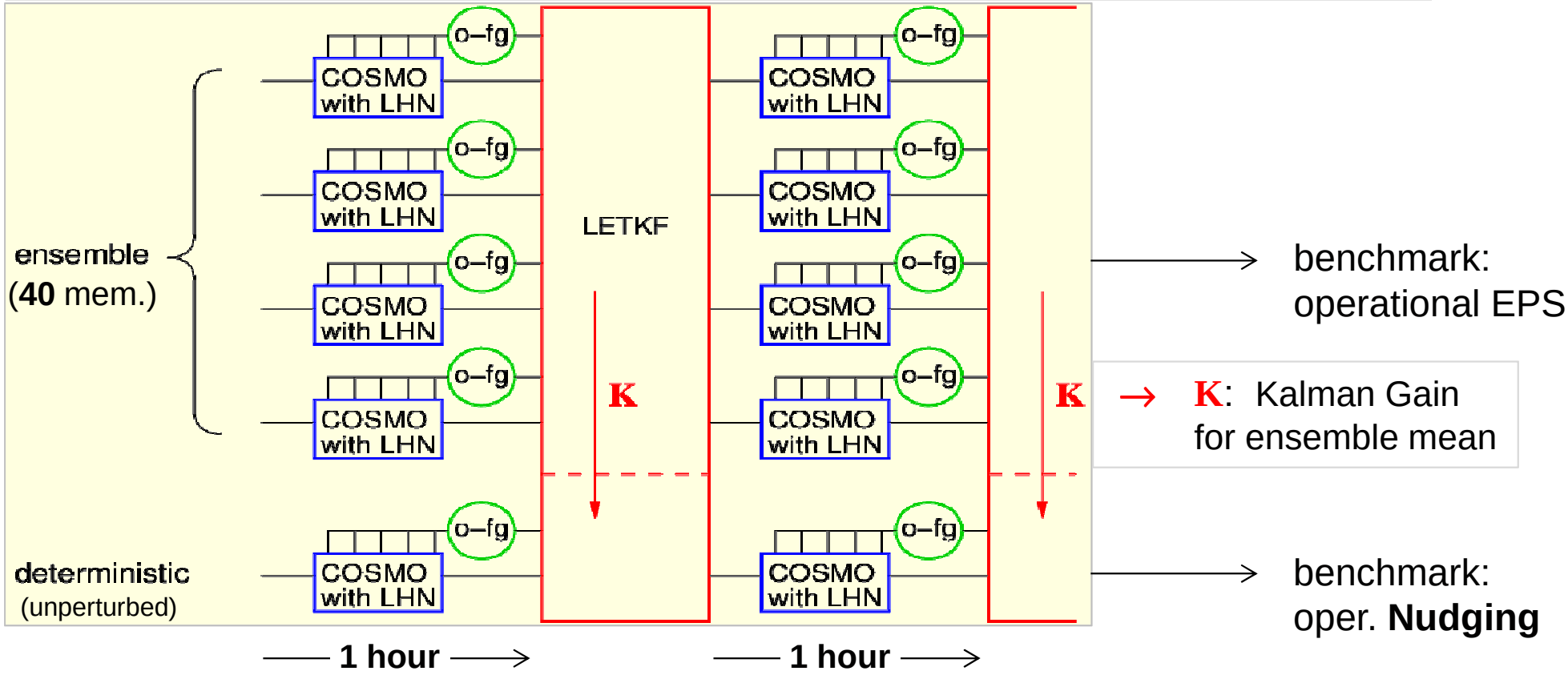


- ARPAE-SIMC: (Italy) start **pre-operational suite** with KENDA-IC for **2.2** km **EPS** soon (Oct.?)
- COMET: (Italy) KENDA code adapted to include required capabilities of COMET system and run in a **parallel suite** (Δx = **10** km)

KENDA-LETKF: (pre-) operational setup, incl. deterministic analysis / forecast

Deutscher Wetterdienst

KENDA: 4D-LETKF + LHN (latent heat nudging for assimilation of radar precip)



(pre-) operational settings:

- conventional obs types only (radiosonde, aircraft, wind profiler, synop)
- adaptive horizontal localisation (keep # obs constant, 50 km ≤ s ≈ std dev ≤ 100 km)
- adaptive mutliplicative covariance inflation (obs-f.g. statistics) + RTPP (α_p = 0.75)
- explicit soil moisture perturbations (only DWD), …

operational KENDA implementation

by Daniel Leuenberger et al.

- lateral BC in EPS (forecast component) : (6 h old) IFS ENS

- lateral BC in DA cycle:

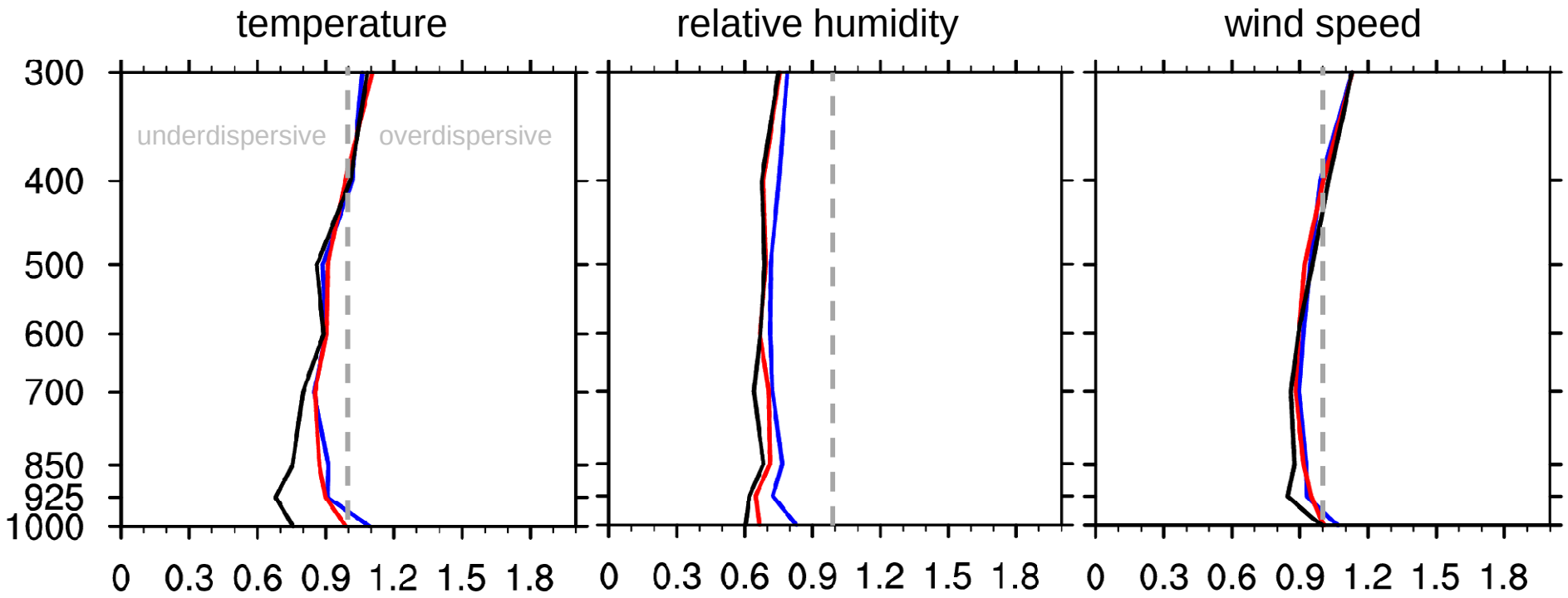
  perturbations from 30 – 42 h old IFS ENS perturbations centred around the latest HRES forecast

KENDA for COSMO-E analysis performance

by Daniel Leuenberger et al.

spread / skill ratio of first guess

(27 July – 28 Aug. 2015)



operational setting
with SPPT (stochastic perturb. of physics tendencies)
with SPPT + soil moisture perturb.

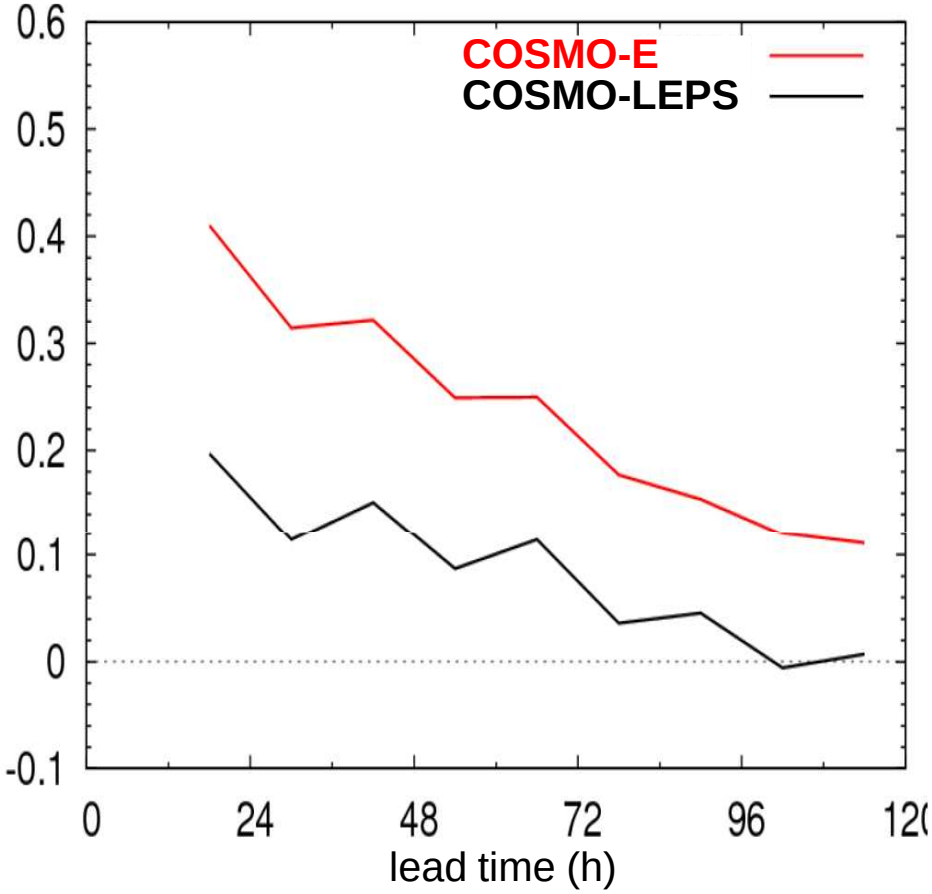
christoph.schraff@dwd.de

COSMO-E outperforms COSMO-LEPS (Δx=7km)

by Daniel Leuenberger et al.

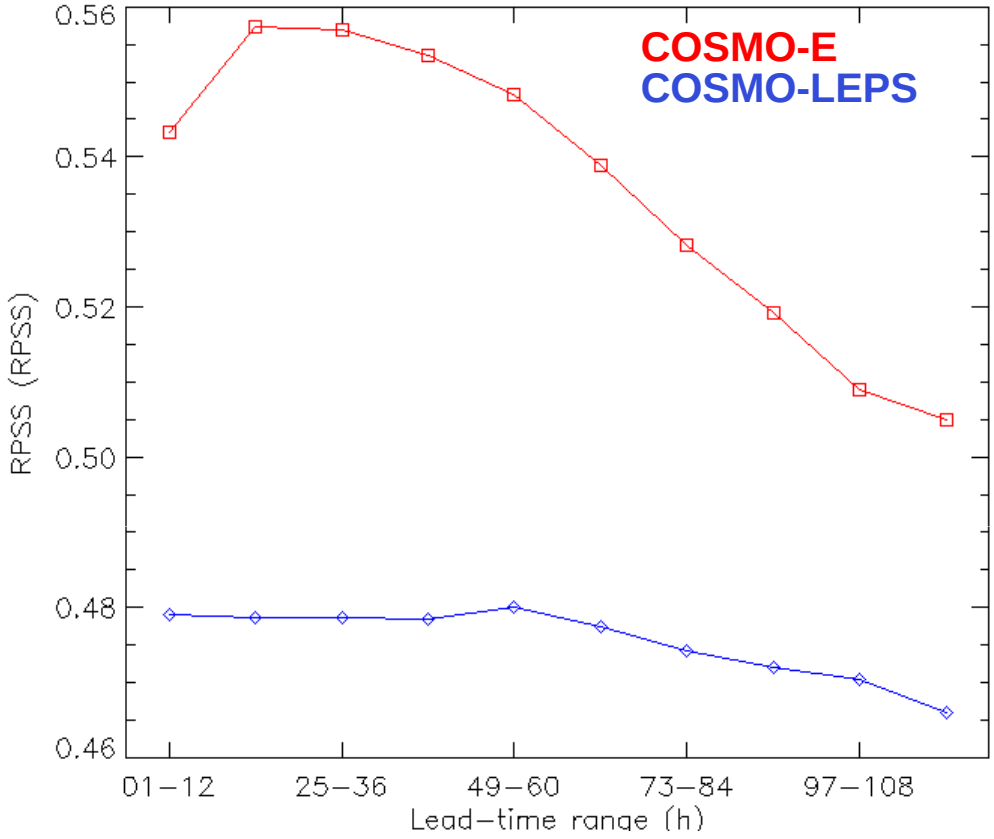
precip > 5 mm/12h
Brier Skill Score

(w.r.t. climatology, 300 stations
July – August 2014)



2-m temperature
RPSS

(w.r.t. climatology,
March – May 2016)



COSMO-E with KENDA IC also better than with IC downscaled from IFS-ENS

christoph.schraff@dwd.de

- **KENDA-LETKF**: conventional obs, plus humidity data from 9 aircrafts,

- benchmark: operational **nudging** uses 2-m humidity data (with limited weight),
  continues to nudge new obs in first 30 minutes of forecast

- lateral BC from operational global ICON EnVar system,
  with resolution: deterministic global 13 km / **EU 6.5 km** ,
  ensemble global 40 km / **EU 20 km**

results shown for:

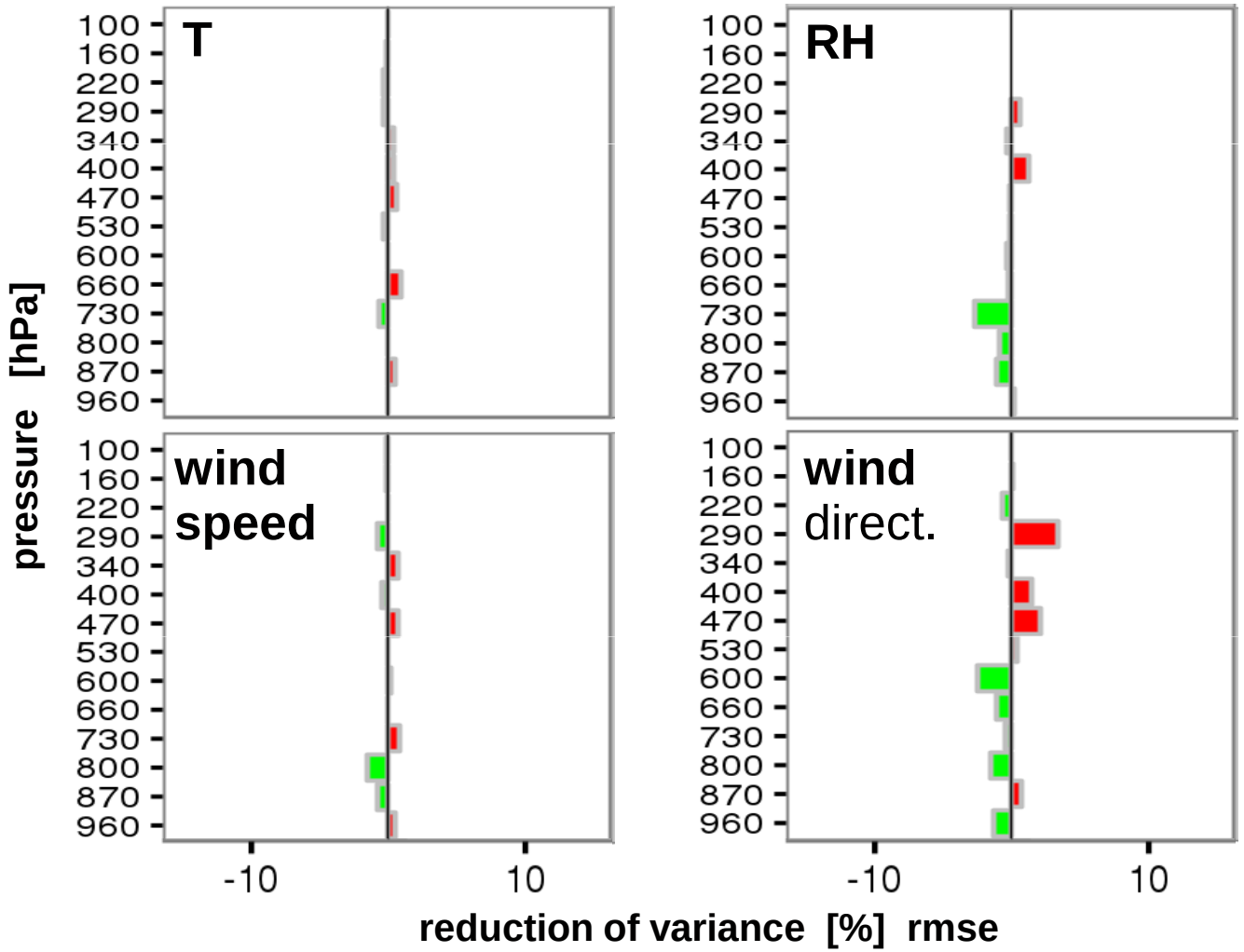
- Period A: ~ August (+ Sept.): mainly **frontal** precip, dry periods
  → meteorologically not too interesting

- Period B: ~ end May – mid June: lots of local, often stationary, **heavy convection** over Germany: **high-impact weather** !

  → meteorologically highly interesting,
  but affected by bugs (expect small degradation of KENDA results)
  - no use of any aircraft obs in 30 % of the hourly analyses
  - in ensemble part: no updating of climatological fields since 2 May
    → activity of vegetation underestimated (evapotranspiration !)

  → only scores on precipitation shown

KENDA-LETKF vs. nudging



rmse
(averaged over lead times & initial times)

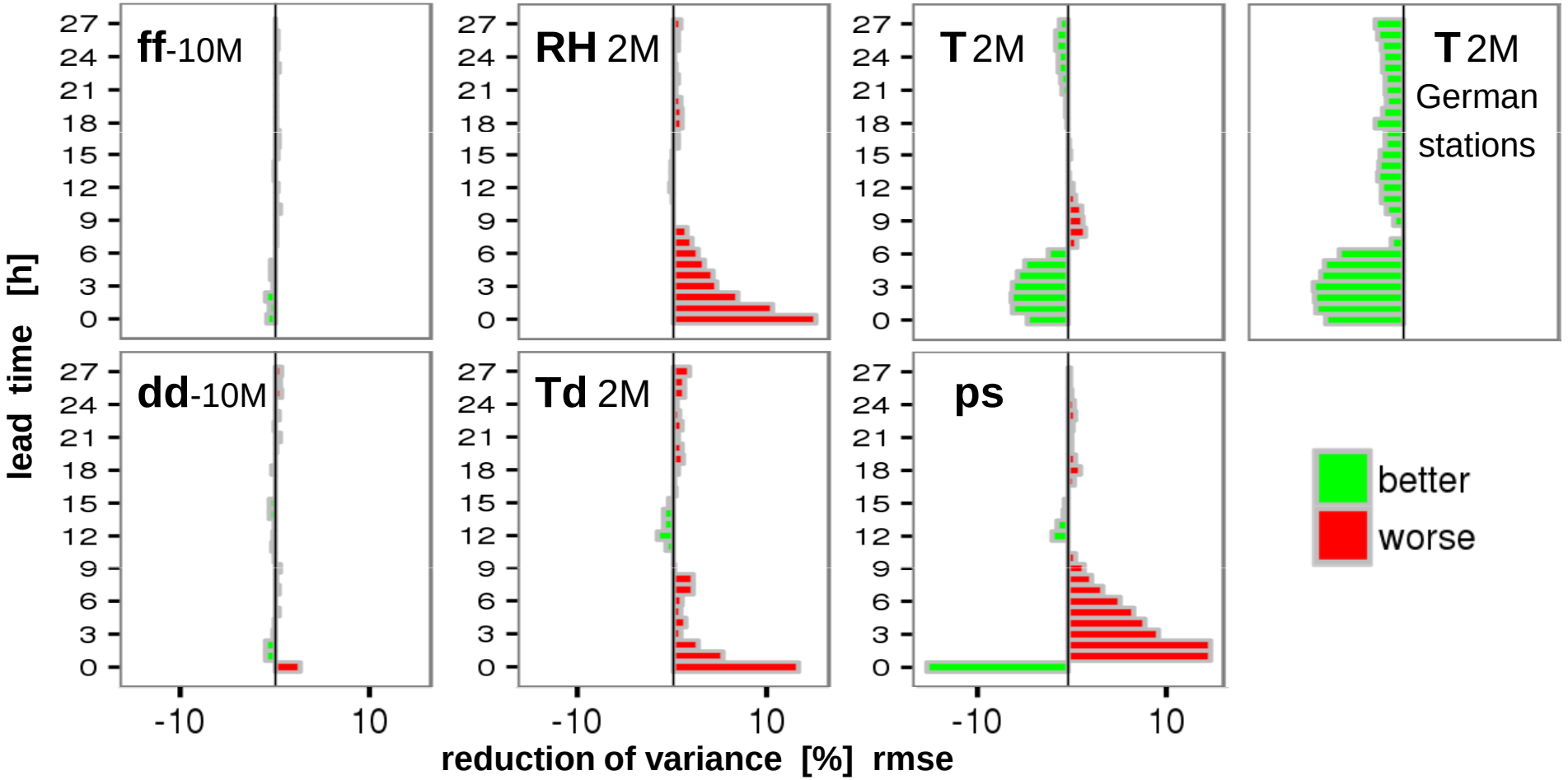
better
worse

✓ KENDA: neutral (similar results for convective period)

pre-operational parallel suite, deterministic: surface verification (26 July – 27 Sept. 2016)

Deutscher Wetterdienst

KENDA-LETKF vs. nudging



- KENDA: worse for 2-m humidity in first 6 hours and for surface pressure 'ps'
  ('ps': mainly bias (lateral BC with bias) : (~ geostrophic) balance issue, under investigation)
  2-m temperature slightly better, otherwise neutral

pre-operational parallel suite, deterministic: radar verification (26 July – 29 August 2016)

Deutscher Wetterdienst

mostly frontal precip, some post-frontal showers

0.1 mm/h

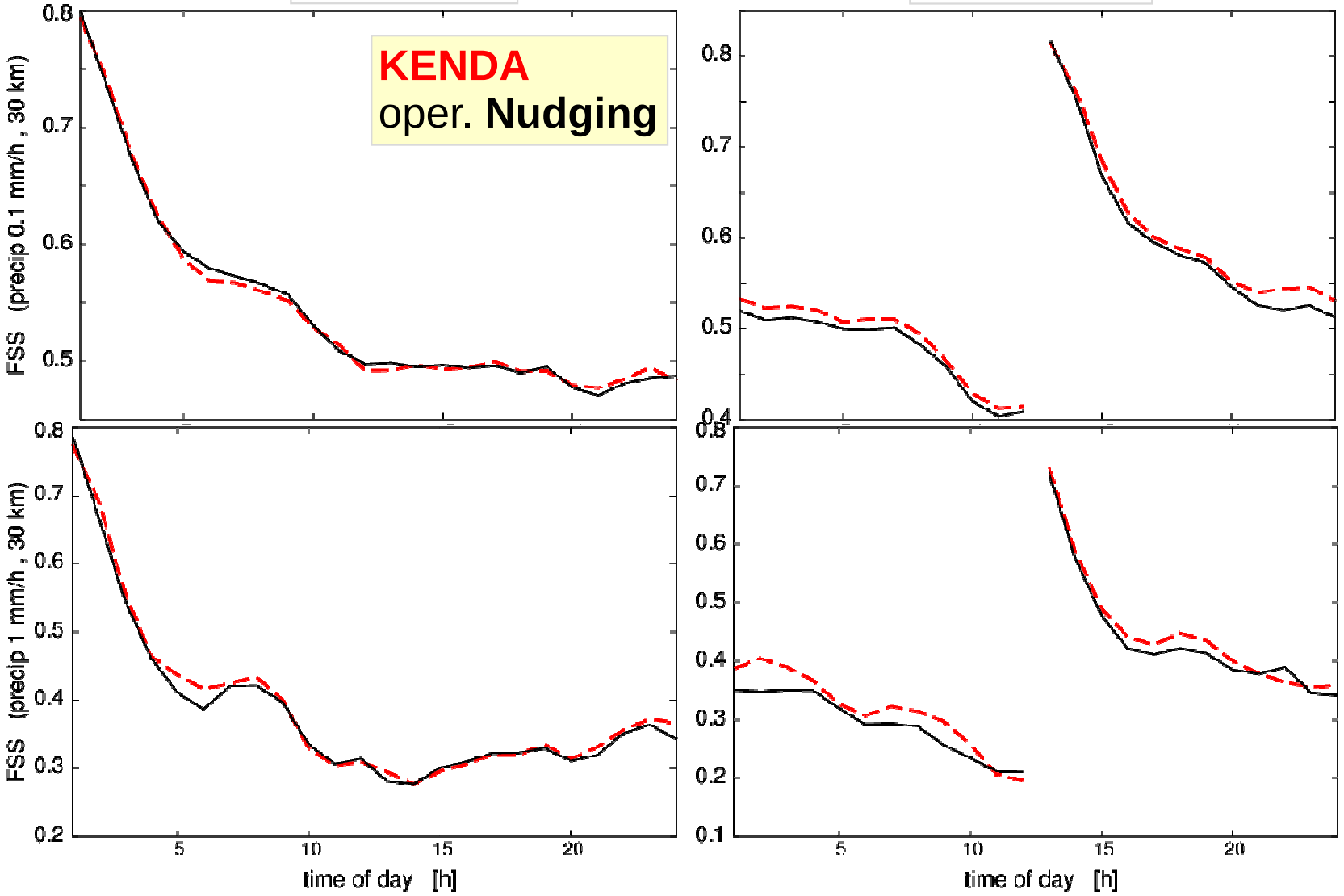
1-hrly precip FSS (30 km)

1 mm/h

0-UTC runs

12-UTC runs

KENDA
oper. **Nudging**



✓ KENDA: only small, but long-lasting improvements in 12-UTC runs

pre-operational parallel suite, deterministic: radar verification (26 May – 12 June 2016)

Deutscher Wetterdienst

lots of local, often stationary, heavy convection (high-impact wea.)

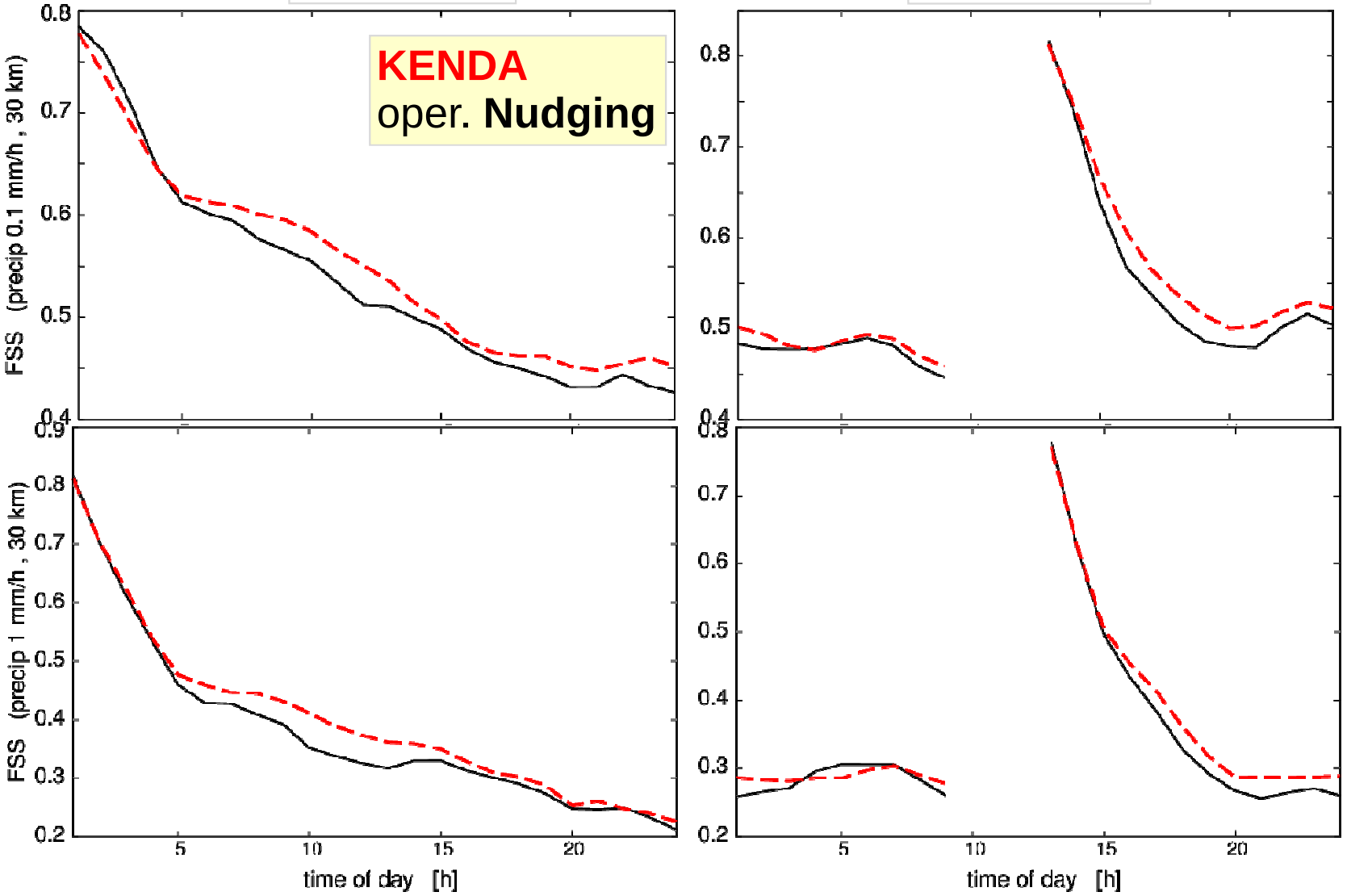
0.1 mm/h

1-hrly precip FSS (30 km)

1 mm/h

0-UTC runs

12-UTC runs



✓ KENDA: long-lasting improvements after first 2 – 4 hours in summer convective period

pre-operational parallel suite, deterministic: radar verification (26 May – 29 August 2016)

Deutscher Wetterdienst

complete summer (3 months)

0-UTC runs

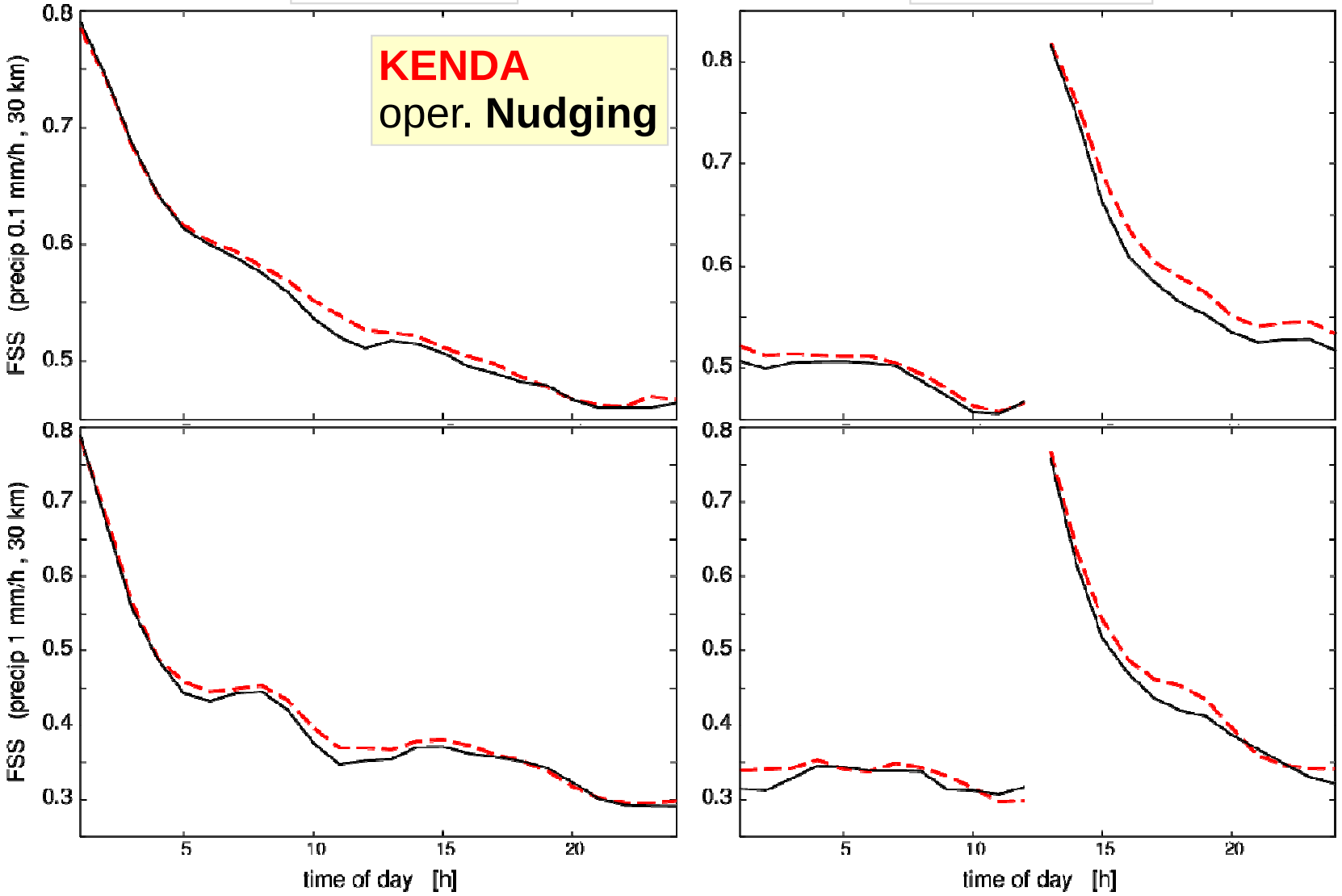
12-UTC runs

KENDA
oper. **Nudging**

0.1 mm/h

1-hrly precip FSS (30 km)

1 mm/h



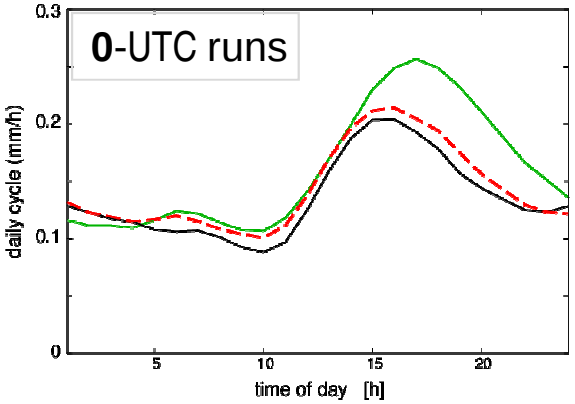
✓ KENDA: on average rather small, but long-lasting improvements in summer

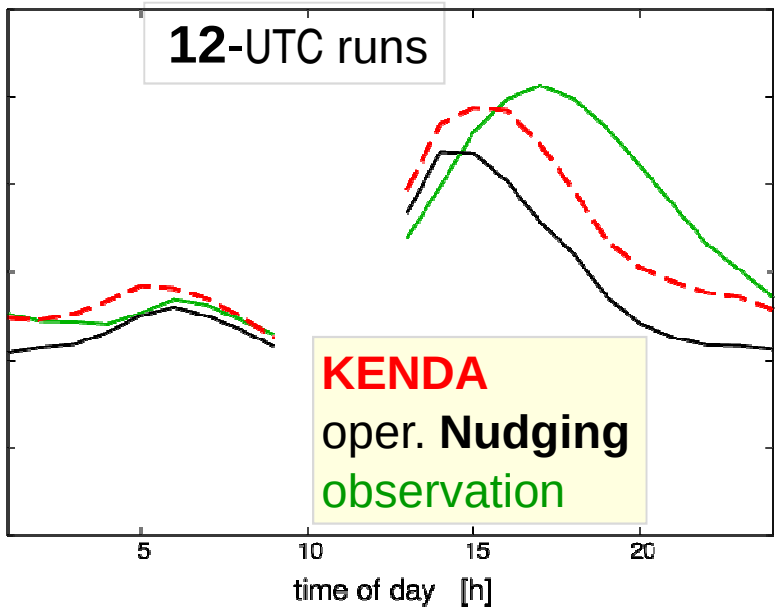
pre-operational parallel suite, deterministic: radar verification (26 May – 12 June 2016)

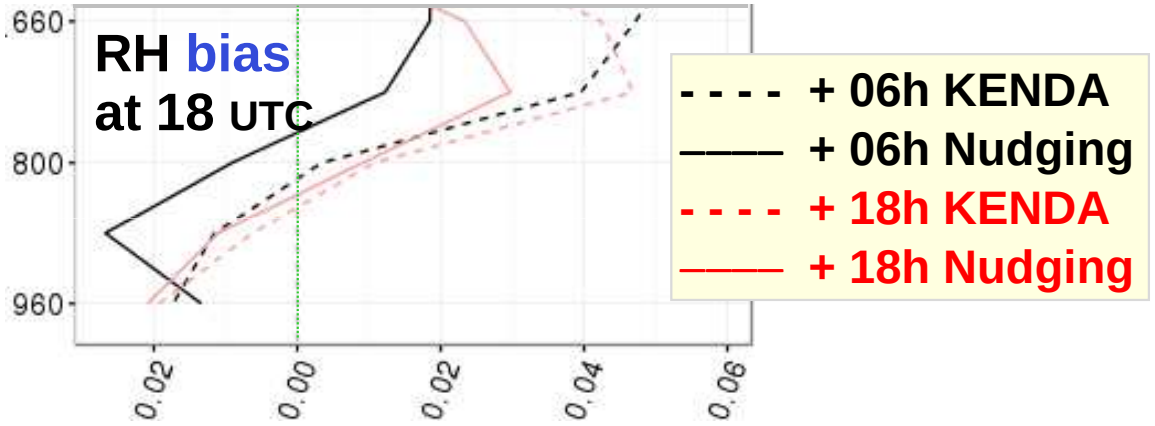
Deutscher Wetterdienst

daily cycle of precip amount

lots of local, often stationary, heavy convection (high-impact weather)







✓ KENDA: better daily cycle of (convective) precip, particularly in afternoon of 12-UTC runs
→ KENDA makes less correction to the moist bias of the model (climatology)

✓ not always good to correct model biases in the analysis !

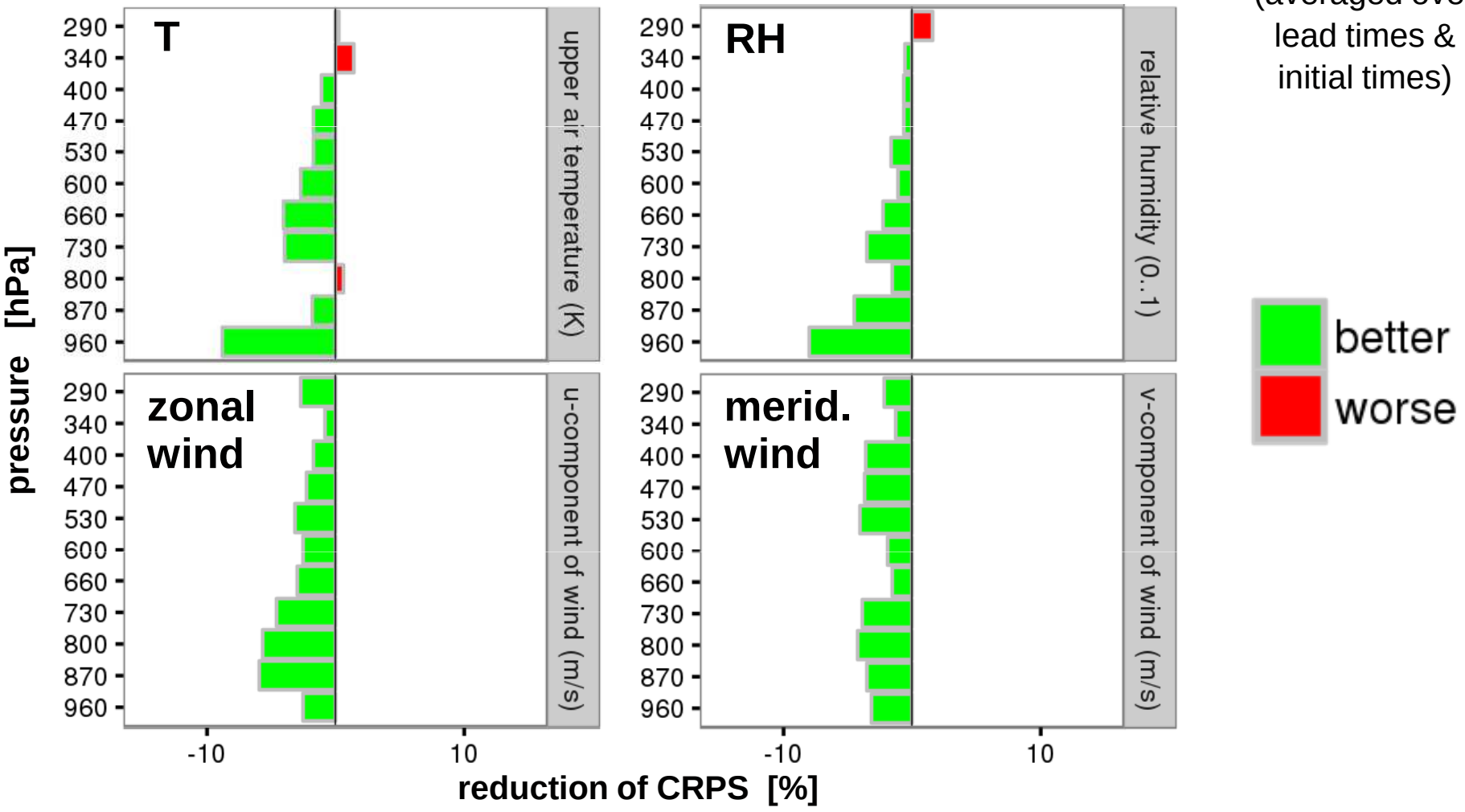
- EPS with KENDA IC vs. EPS with nudg./multi-model IC (operational “COSMO-DE-EPS”)
  - nudg./multi-model: operational deterministic analysis (nudging) + perturbations from 4 global model systems
  - LBC: perturbations from 4 global model systems (“BCEPS”)
  - perturbed physics parameters

thanks to Christoph Gebhardt + Felix Fundel for plots

pre-operational parallel suite, EPS (probabilistic): radiosonde verification (26 July – 31 August 2016)

Deutscher Wetterdienst

KENDA-LETKF vs. nudg./multi-model



CRPS
(averaged over lead times & initial times)

better
worse

✓ KENDA: much better CRPS

pre-operational parallel suite, EPS (probabilistic): radiosonde verification (26 July – 31 August 2016)

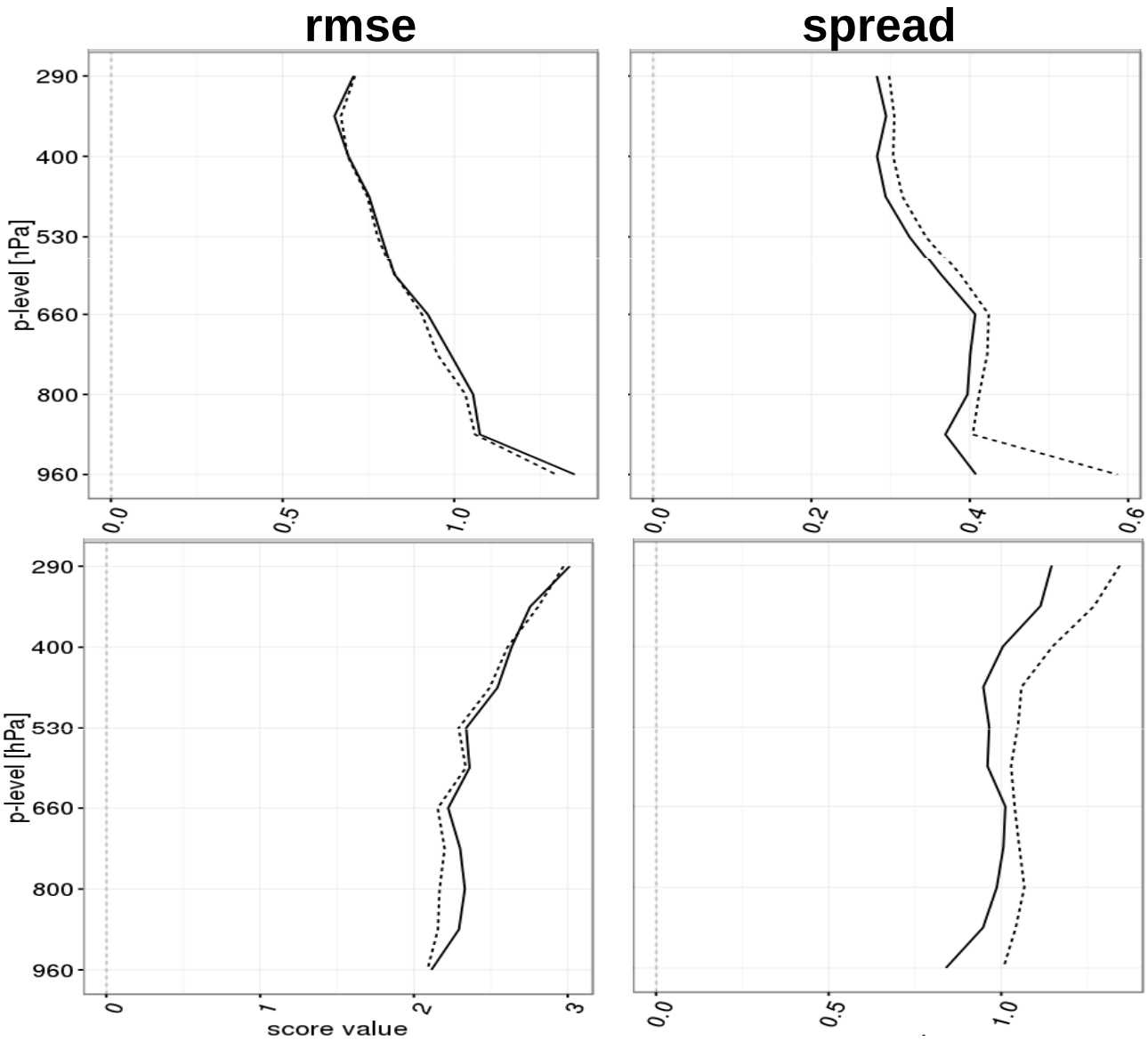
Deutscher Wetterdienst

- - - - KENDA
——— nudg./multi-model

12-h forecasts

temperature

wind speed

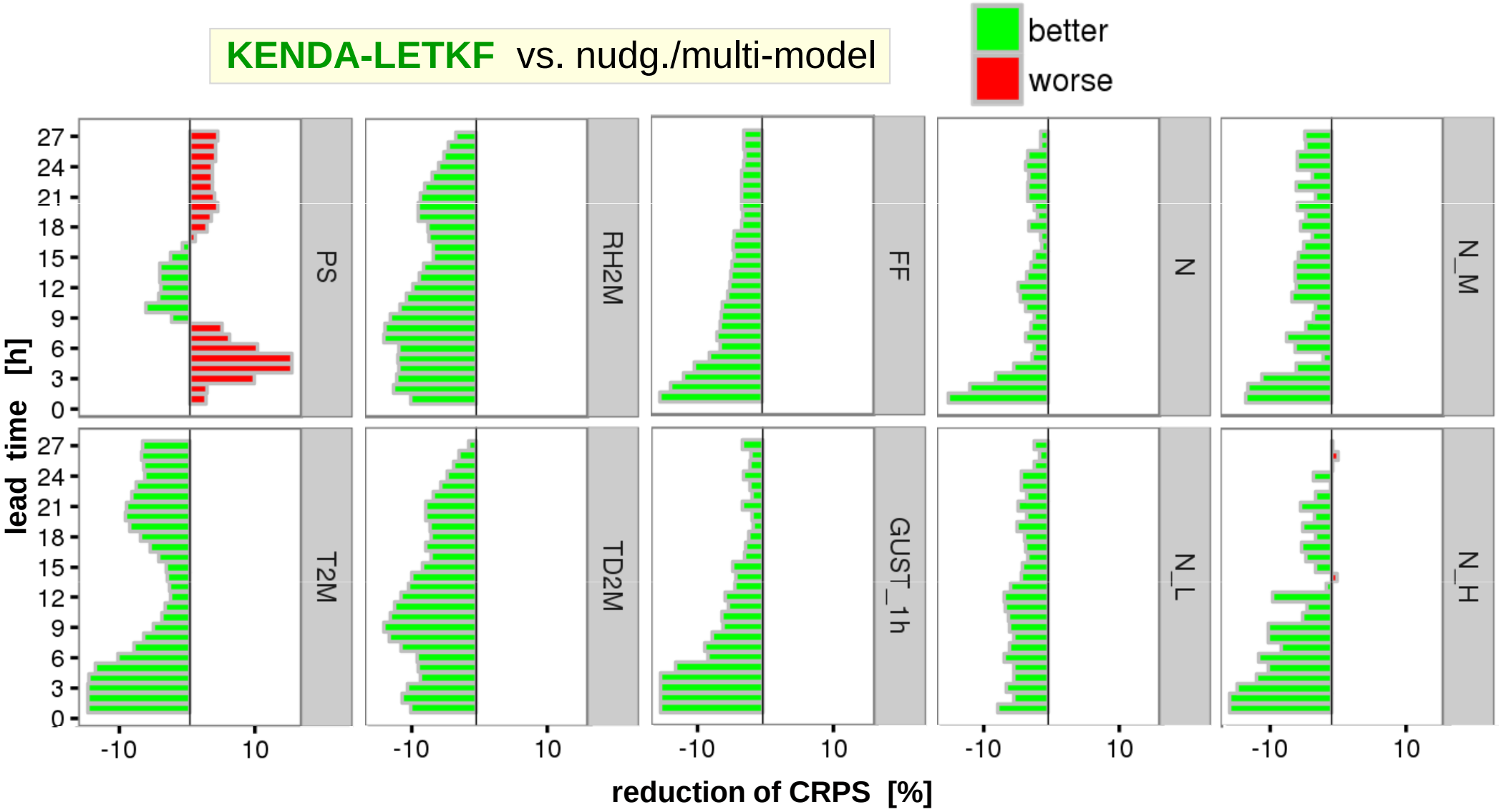


✓ KENDA: much better (larger) spread, also slightly smaller errors (rmse)

pre-operational parallel suite, EPS (probabilistic): surface verification (26 July – 31 August 2016)

Deutscher Wetterdienst

KENDA-LETKF vs. nudg./multi-model



✓ KENDA: much better CRPS in all variables except surface pressure

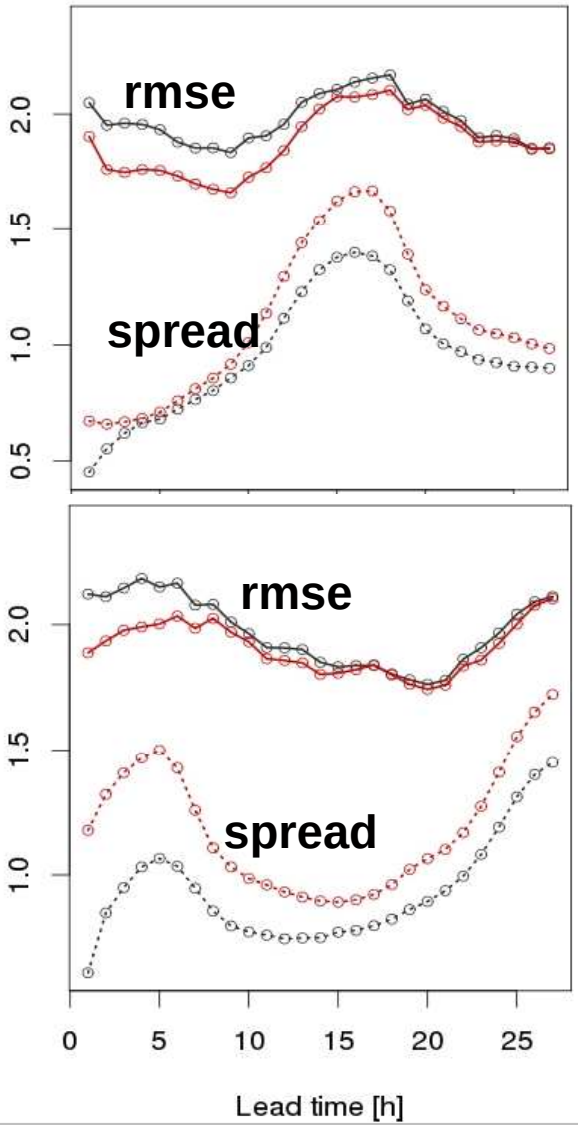
10-m wind gusts

spread / rmse

0-UTC runs

KENDA-LETKF
nudg./multi-model

12-UTC runs



✓ KENDA: better spread + skill + BSS (for 14 m/s + 18 m/s, due to improved reliability)

pre-operational parallel suite, EPS (probabilistic): radar verification (20 May – 21 June 2016)

Deutscher Wetterdienst

1-hrly **precipitation**

Brier skill score (averaged over lead times 1 – 27 h)

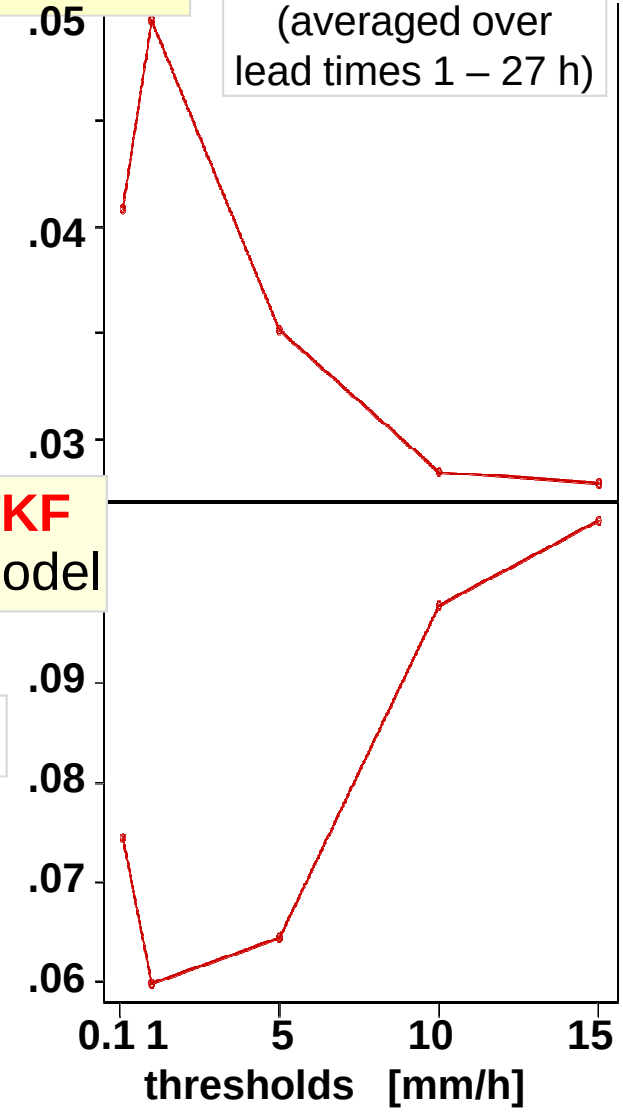
BSS 1 mm/h

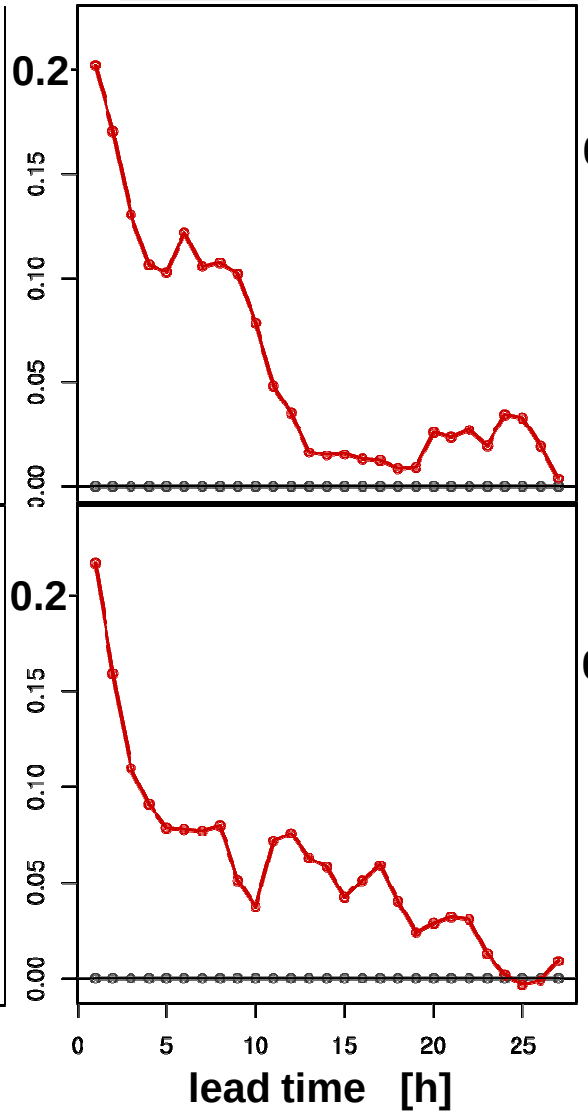
BSS 5 mm/h

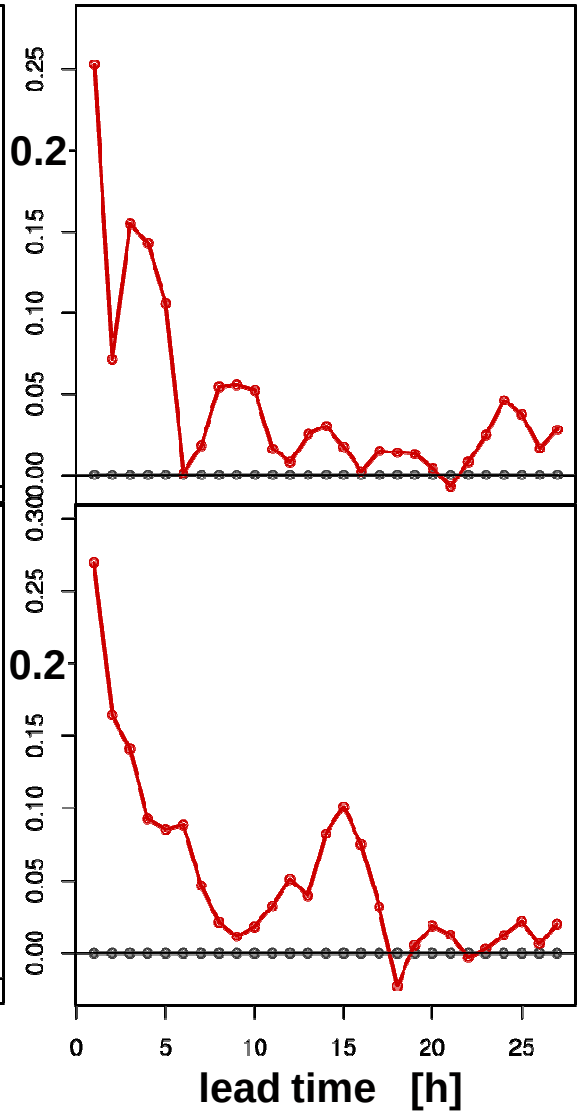
0-UTC runs

KENDA-LETKF nudg./multi-model

12-UTC runs







✓ KENDA: BSS better for all thresholds, long-lasting

pre-operational parallel suite, EPS (probabilistic): radar verification (20 May – 21 June 2016)

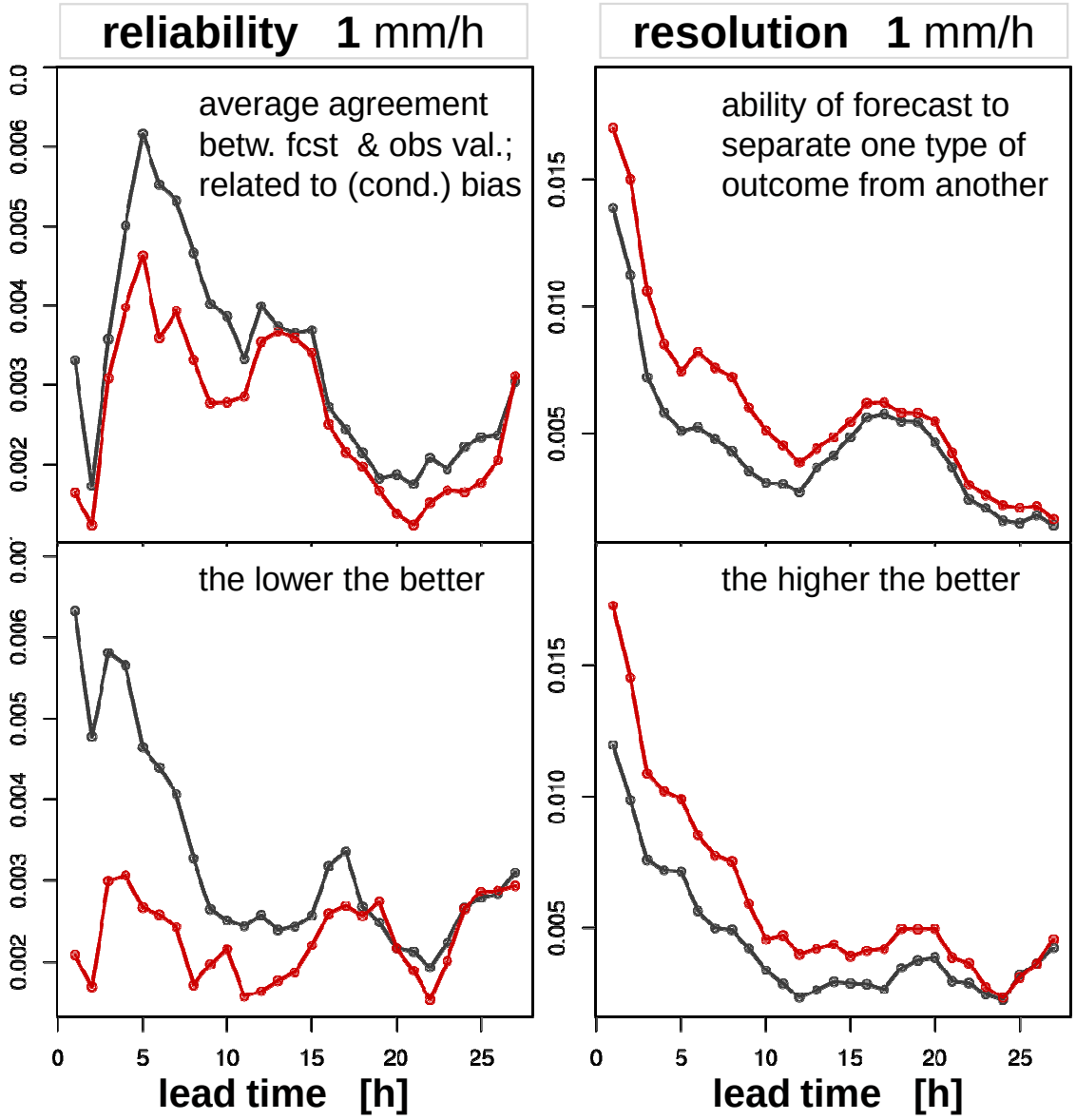
Deutscher Wetterdienst

precipitation

0-UTC runs

KENDA-LETKF
nudg./multi-model

12-UTC runs



✓ KENDA: better reliability and (not susceptible to calibration:) resolution

pre-operational parallel suite, EPS (probabilistic): radar verification (26 July – 31 August 2016)

Deutscher Wetterdienst

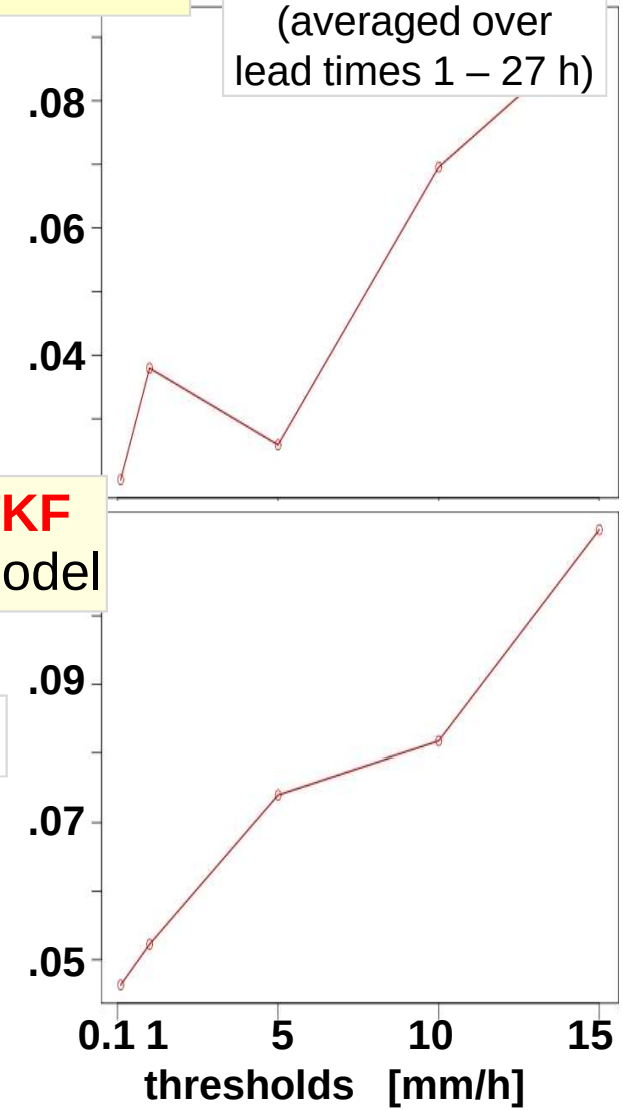
1-hrly **precipitation**

0-UTC runs

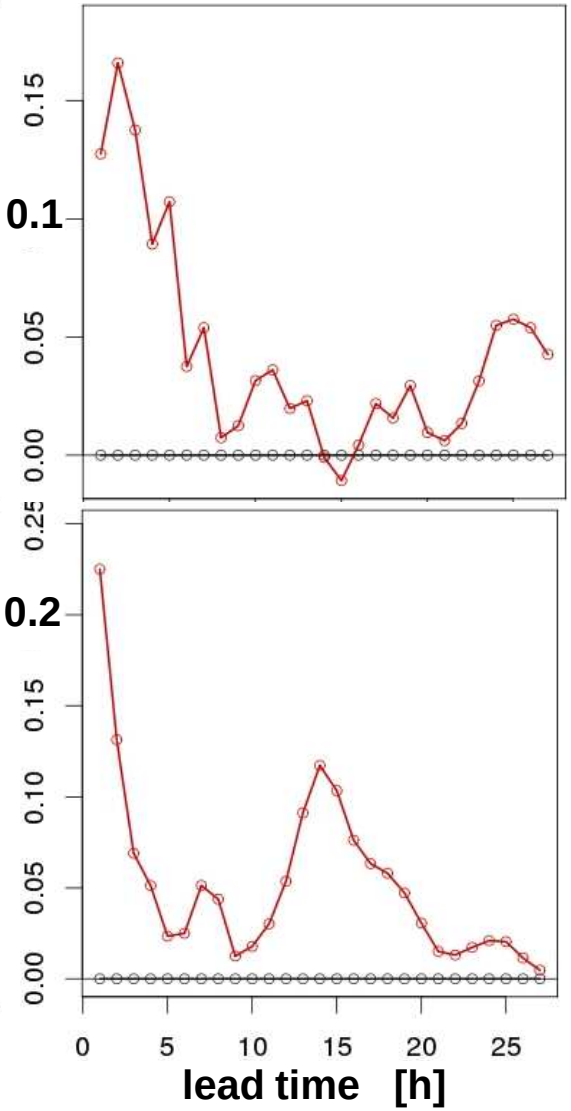
KENDA-LETKF
nudg./multi-model

12-UTC runs

Brier skill score
(averaged over lead times 1 – 27 h)



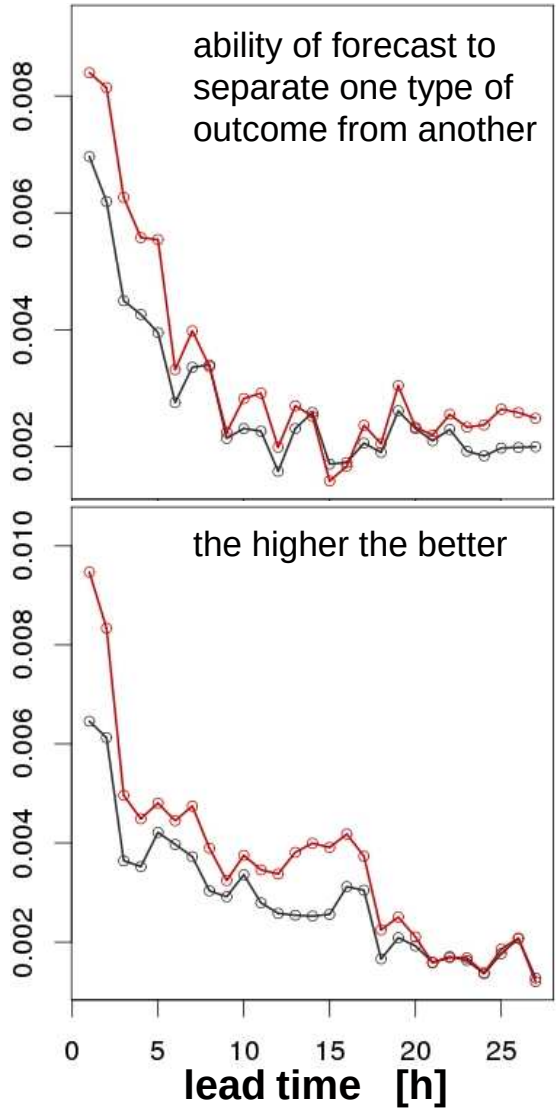
BSS 1 mm/h



resolution 1 mm/h

ability of forecast to separate one type of outcome from another

the higher the better



✓ KENDA: BSS (resolution (neutral for 0.1mm/h) + reliability) better for all thresholds, long-lasting

pre-operational parallel suite: summary of results

Deutscher Wetterdienst

(convective) precip;

EPS overall (spread + errors)

deterministic (overall, vs. nudging)

Td2m

surface pressure (at DWD pre-op, bias in LBC)

pre-operational parallel suite: summary

Deutscher Wetterdienst

→ KENDA operational at DWD (det + EPS) in late 2016 or 1st half 2017, depends on

- data base
- winter period with pre-operational configuration (LBC!)

Further developments on KENDA

use of additional obs:

- GNSS slant total delay (8-day test: positive impact on precip (in addtion to LHN))
- SEVIRI WV all-sky approach for cloud info (cloud dep. obs errors + bias corr.)
- radar reflectivity + radial velocity (sensitivity tests)
- screen-level obs (sensitivity tests)
- Mode-S : tests at DWD & MeteoSwiss soon
- etc.

further tasks

- non-Gaussianity: promising research ongoing with
  - hybrid LETK-PF applied to COSMO (*Sylvain Robert, ETH*)
  - hybrid VarEnKF-PF applied to ICON (*Roland Potthast, DWD*)
- further refinement of LETKF, soil moisture analysis using sat obs in LETKF framework, …

Further developments: KENDA for ICON

- 2017: start porting KENDA from COSMO to **ICON-regional**

  → implement also hybrid (4-D) EnVar , compare with pure 4-D LETKF

  motivated by some advantages:

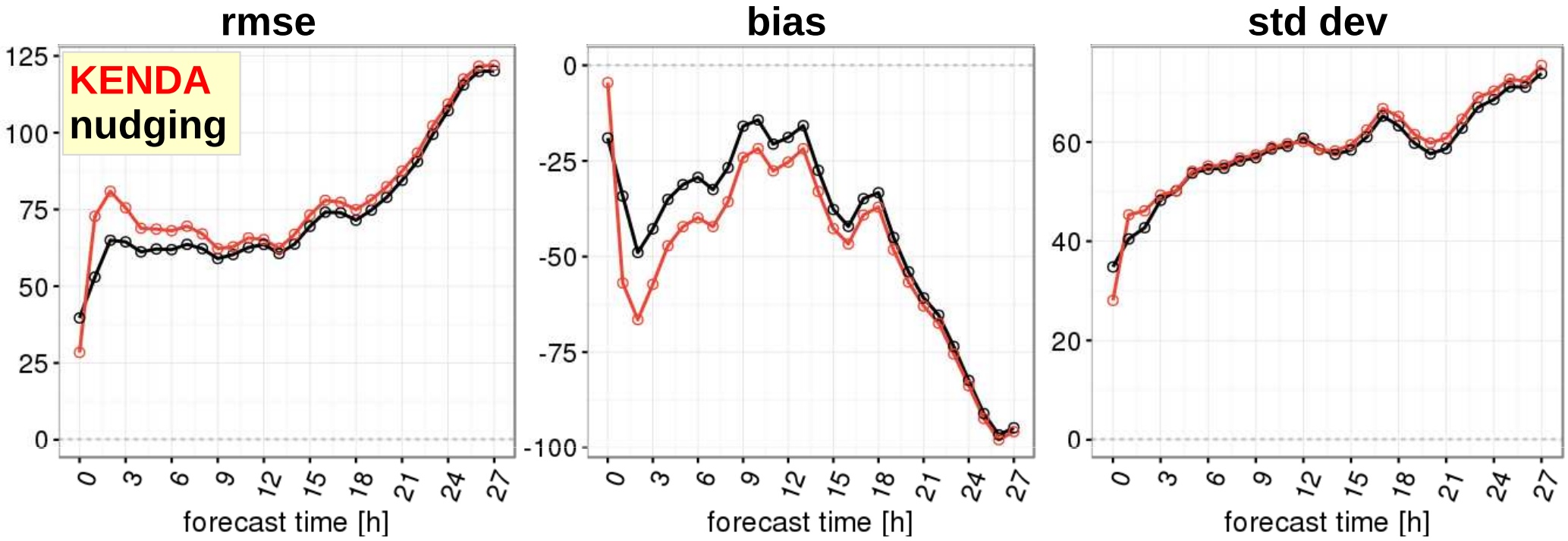
  – very positive experience with (3-D) EnVar for global ICON;
    KENDA 4-D LETKF: large improvement for EPS, not for deterministic
  – conceptual advantages of VAR (localisation, Var-BC / -QC,…) + hybrid (B-matrix)
  – further code unification with global DA at DWD
  – capability to use KENDA code without need to run ensemble (3DVar, poor man's EnVar)

  some disadvantages:

  – trade-off between 4-D capability and the need to interpolate + amount of I/O
  – increased complexity, need of tangent linear / adjoint obs operators

KENDA system: outlook

surface pressure,
12-UTC runs



- surface pressure: (~ geostrophic) balance issue, under investigation
  (lateral BC with bias)

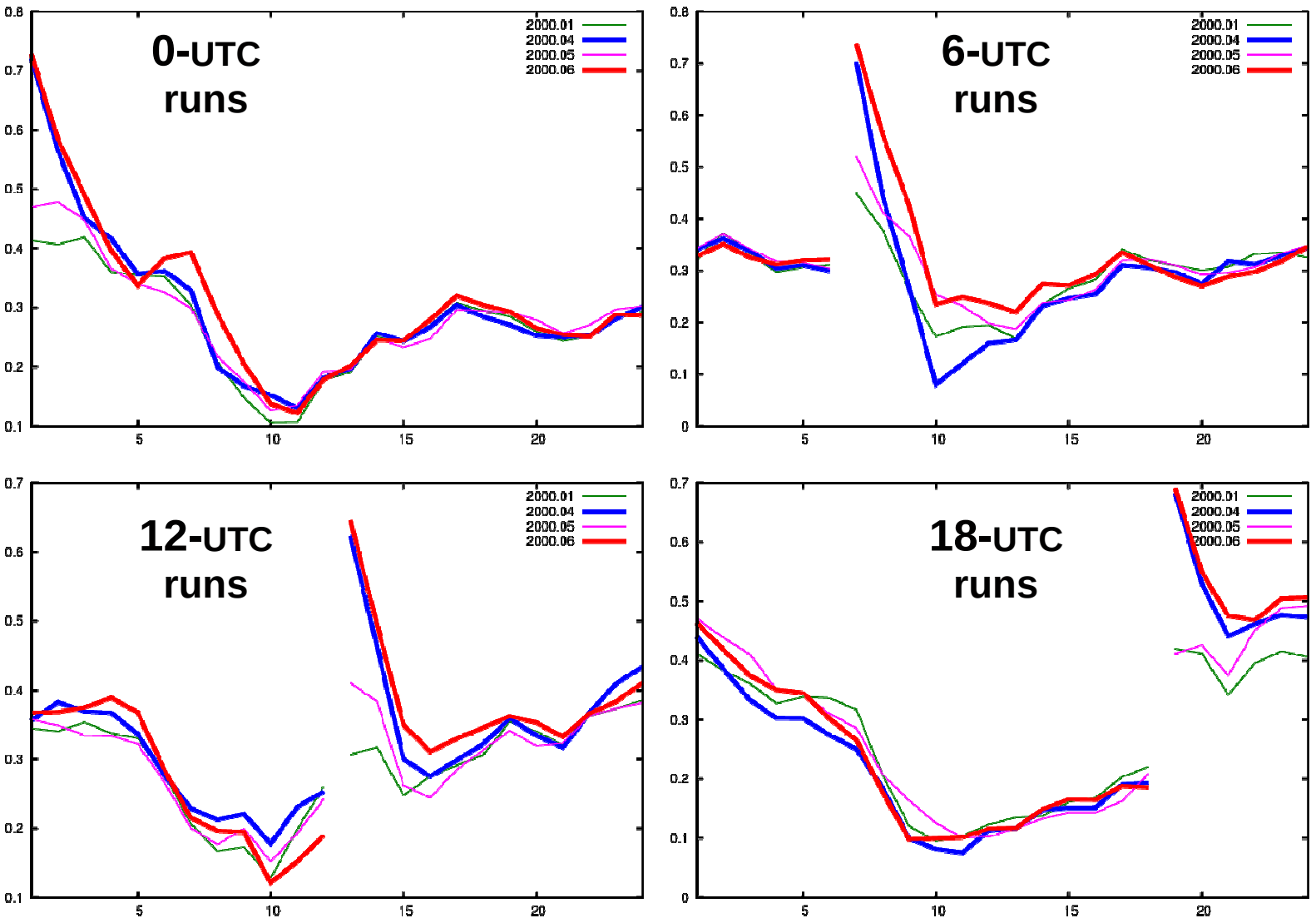
KENDA-O overview, Task 2 (high-res. obs): GNSS-STD, first trial for use in KENDA

Deutscher Wetterdienst

8 days
17 – 24 May 2014

1-hrly precip
FSS (30 km)
1 mm/h

CONV only
CONV + GNSS
CONV + LHN
CONV + LHN + GNSS



✓ 1 mm/h : slightly better for 0-, 6-, 18-UTC runs

pre-operational parallel suite, EPS (probabilistic): surface verification (26 July – 31 August 2016)

Deutscher Wetterdienst

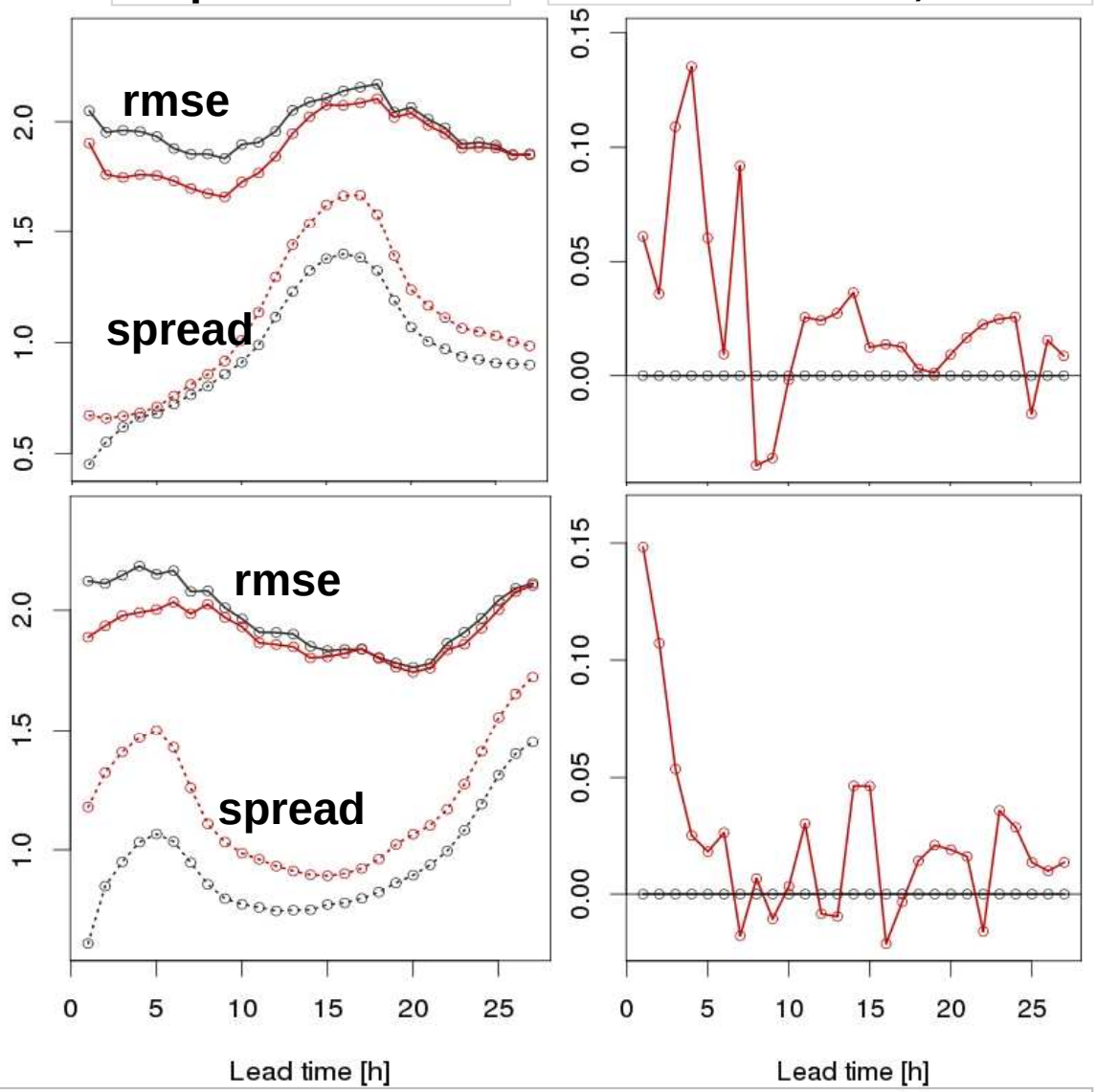
10-m wind gusts

spread / rmse | **Brier skill score , 14 m/s**

0-UTC runs

KENDA-LETKF
nudg./multi-model

12-UTC runs



✓ KENDA: better spread + skill + BSS (for 14 m/s + 18 m/s, due to improved reliability)