Operationalisation of KENDA at DWD

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KENDA: Km-scale ENsemble Data Assimilation

→ Local Ensemble Transform Kalman Filter (**LETKF**, Hunt et al. 2007)

talk outline

- introduction
- results from pre-operational suite (since May 2016) & related experiments
  - ensemble forecasts (EPS) → *talk by Tobias Tröndle et al. yesterday*
  - here: deterministic forecasts → comparison: KENDA-LETKF vs. nudging + LHN

(MeteoSwiss: KENDA operational for new EPS system (COSMO-E) since May 2016)

1. provide **perturbed IC for EPS** (COSMO-DE-EPS)

   → *talk by Tröndle et al.:* very successful

2. better suitable than current operational nudging scheme for use of **indirect observations** (**satellite**, **radar**, etc.):
   - nudging requires retrievals (e.g. *T*-, *q*- profiles from satellite radiances)
   - EnKF: apply forward observation operator (→ simulated radiances)

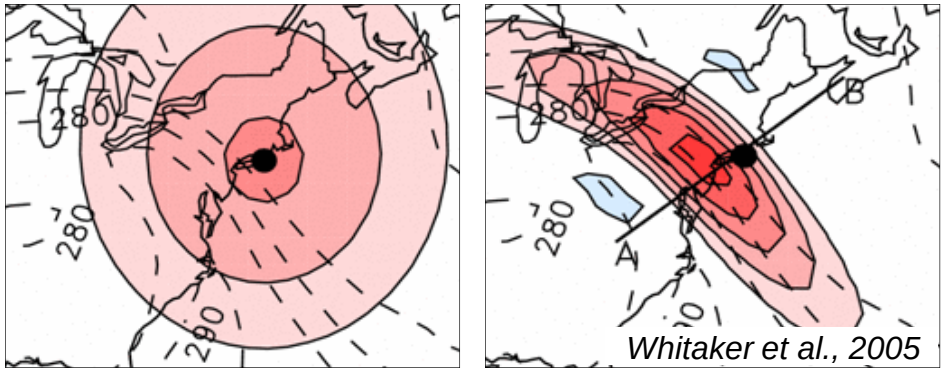
   → in development (radar V_r + Z, SEVIRI WV + cloud, GPS STD, etc.)

3. improved analysis / forecast quality by use of **multi-variate, flow-dependent error covariances** (estimated from first guess ensemble)

   → also for deterministic forecasts, conventional obs only: this talk

nudging ana. increments (climatological errors)

ensemble filter analysis increment



Whitaker et al., 2005

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Introduction:
KENDA-LETKF (pre-) operational setup

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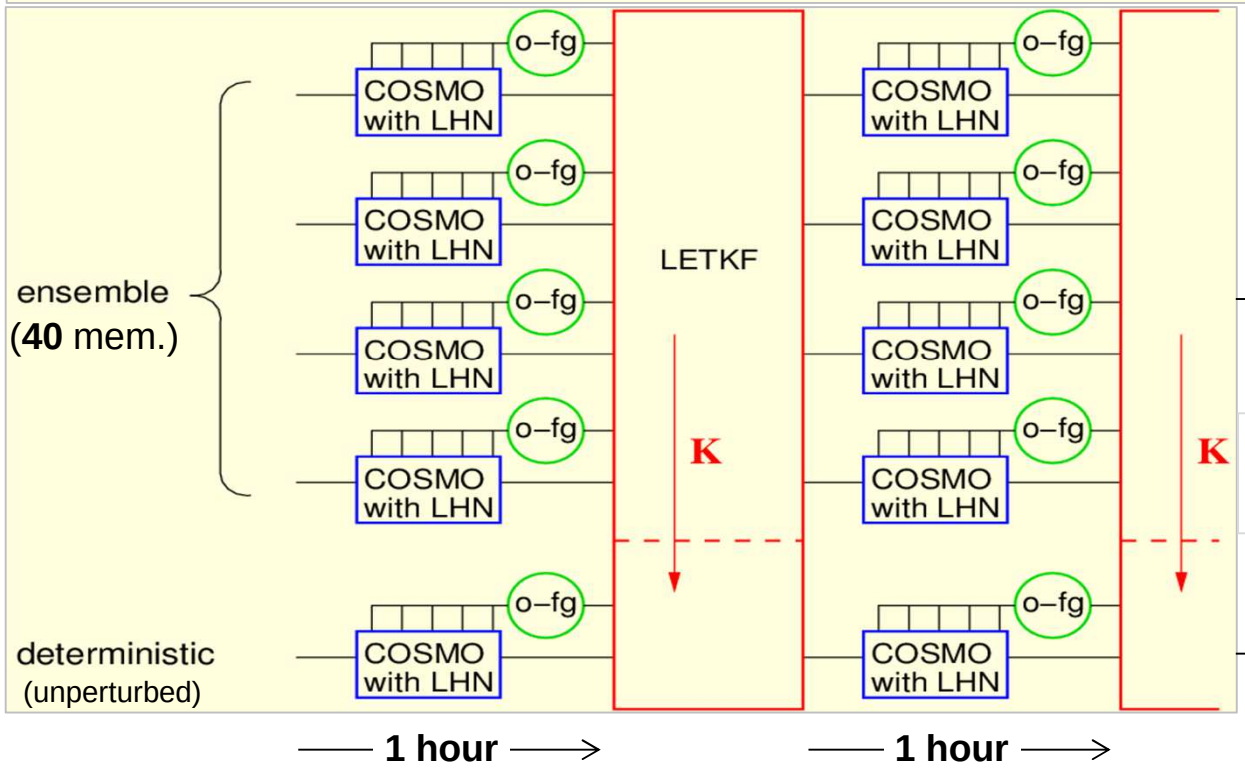
KENDA: 4D-LETKF + LHN (latent heat nudging for assimilation of radar precip)



→ benchmark: operational EPS

→ **K**: Kalman Gain for ensemble mean

→ benchmark: operational Nudging + LHN

(pre-) operational settings (→ *Schraff et al. 2016, QJRMS*) :

- 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
- conventional obs types only (radiosonde, aircraft, wind profiler, synop)

pre-operational KENDA suite at DWD, comparison to operational nudging setup

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- same conventional obs types used, except:
  - KENDA-LETKF: humidity data from 9 aircrafts,
  - operational nudging: 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**

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

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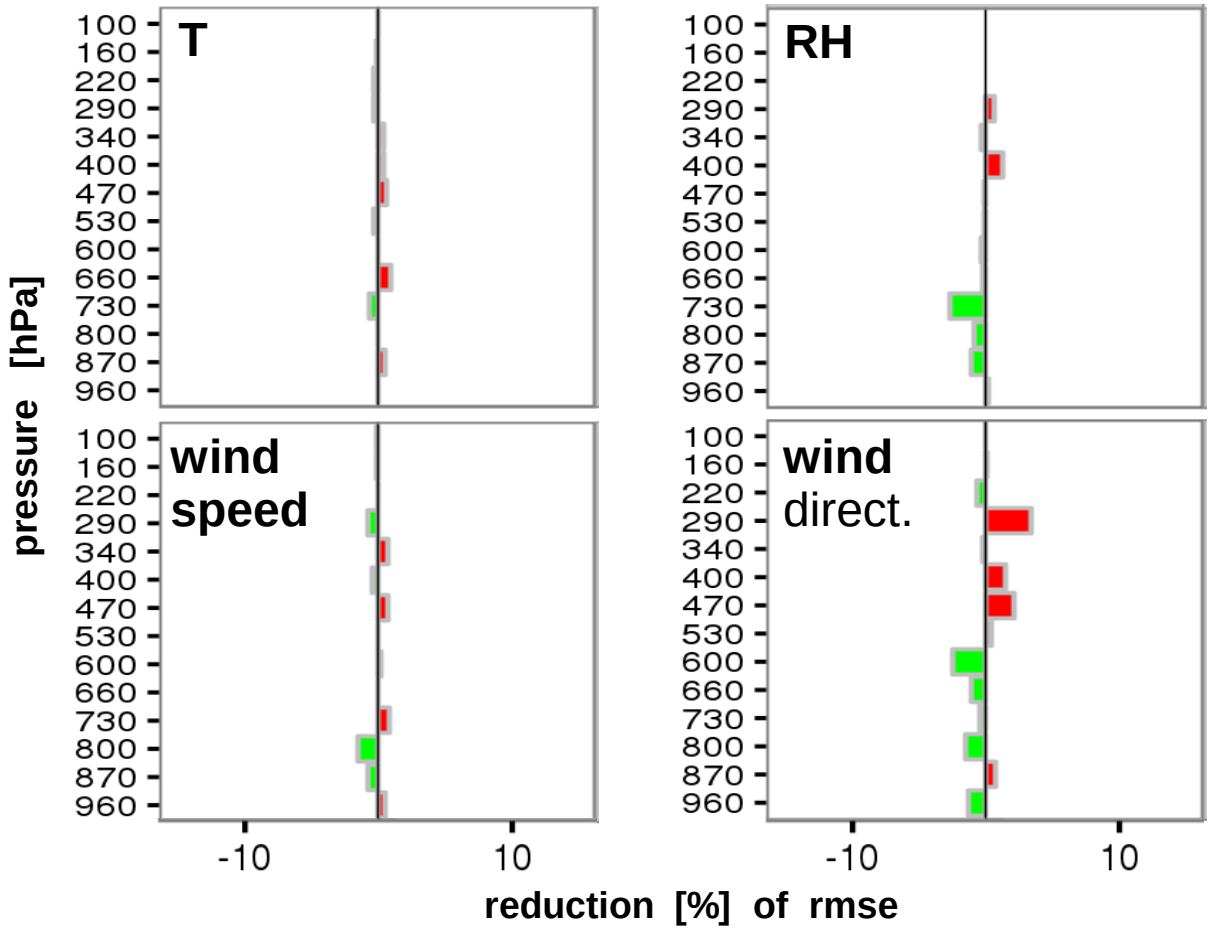
KENDA-LETKF vs. nudging



rmse
(averaged over lead times & initial times)

better
worse

✓ KENDA: neutral (similar results for convective period)

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

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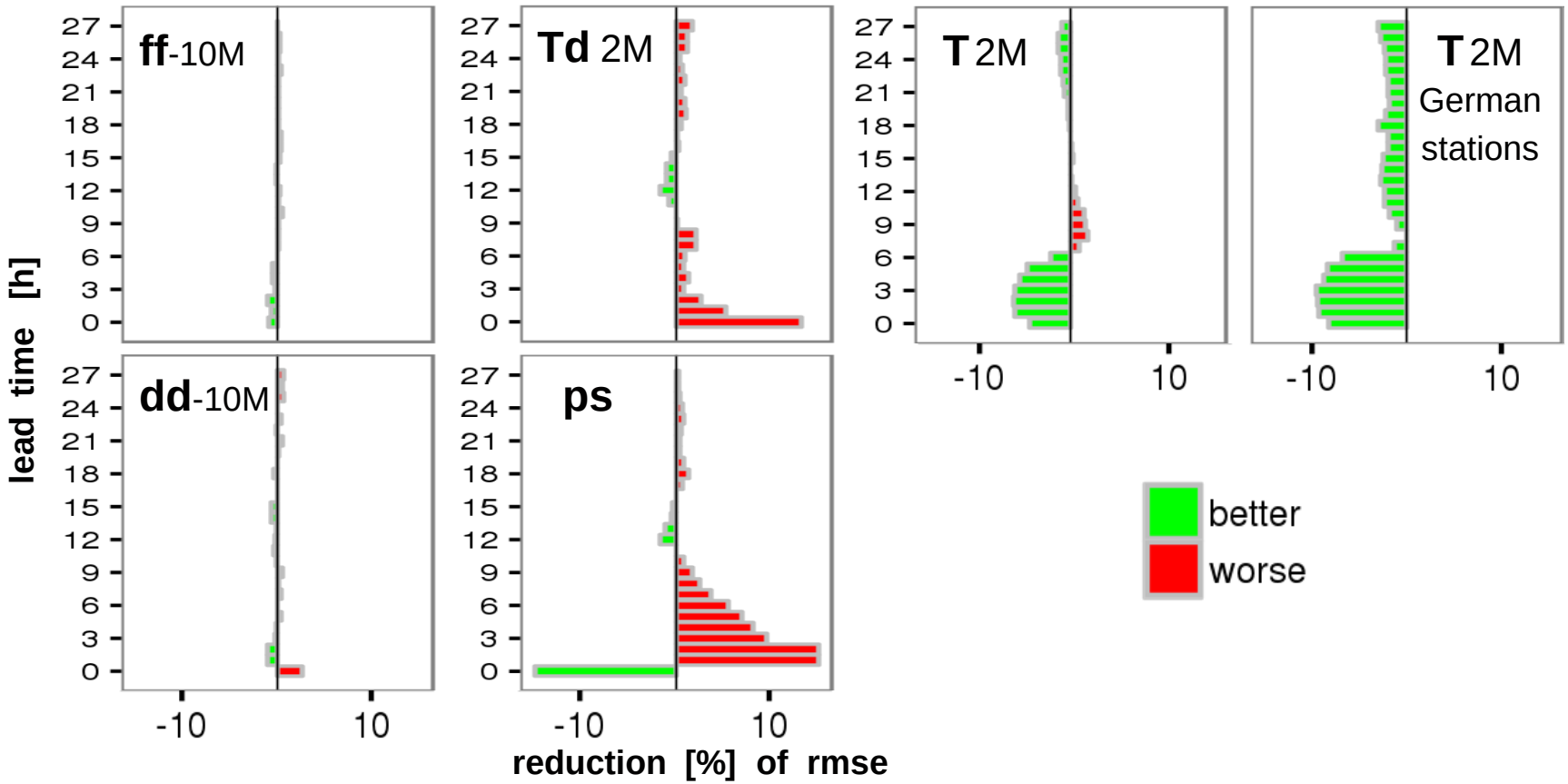
KENDA-LETKF vs. nudging



- KENDA: worse 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 KENDA suite, deterministic: radar verification (26 May – 29 August 2016)

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complete summer (3 months)

0-UTC runs

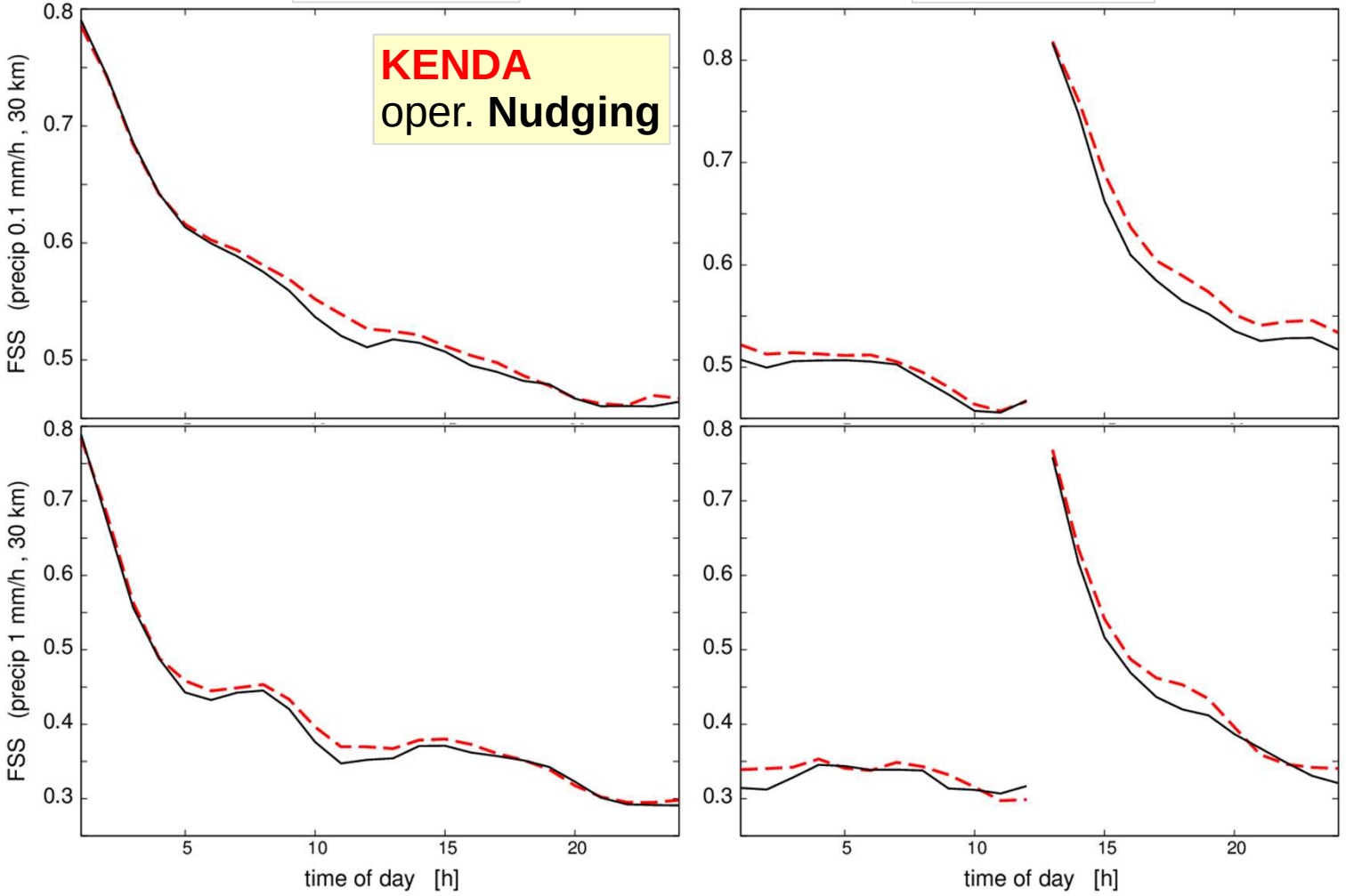
12-UTC runs

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-oper. suite, deterministic:

radar verif. 26 May – 12 June 2016

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

0.1 mm/h

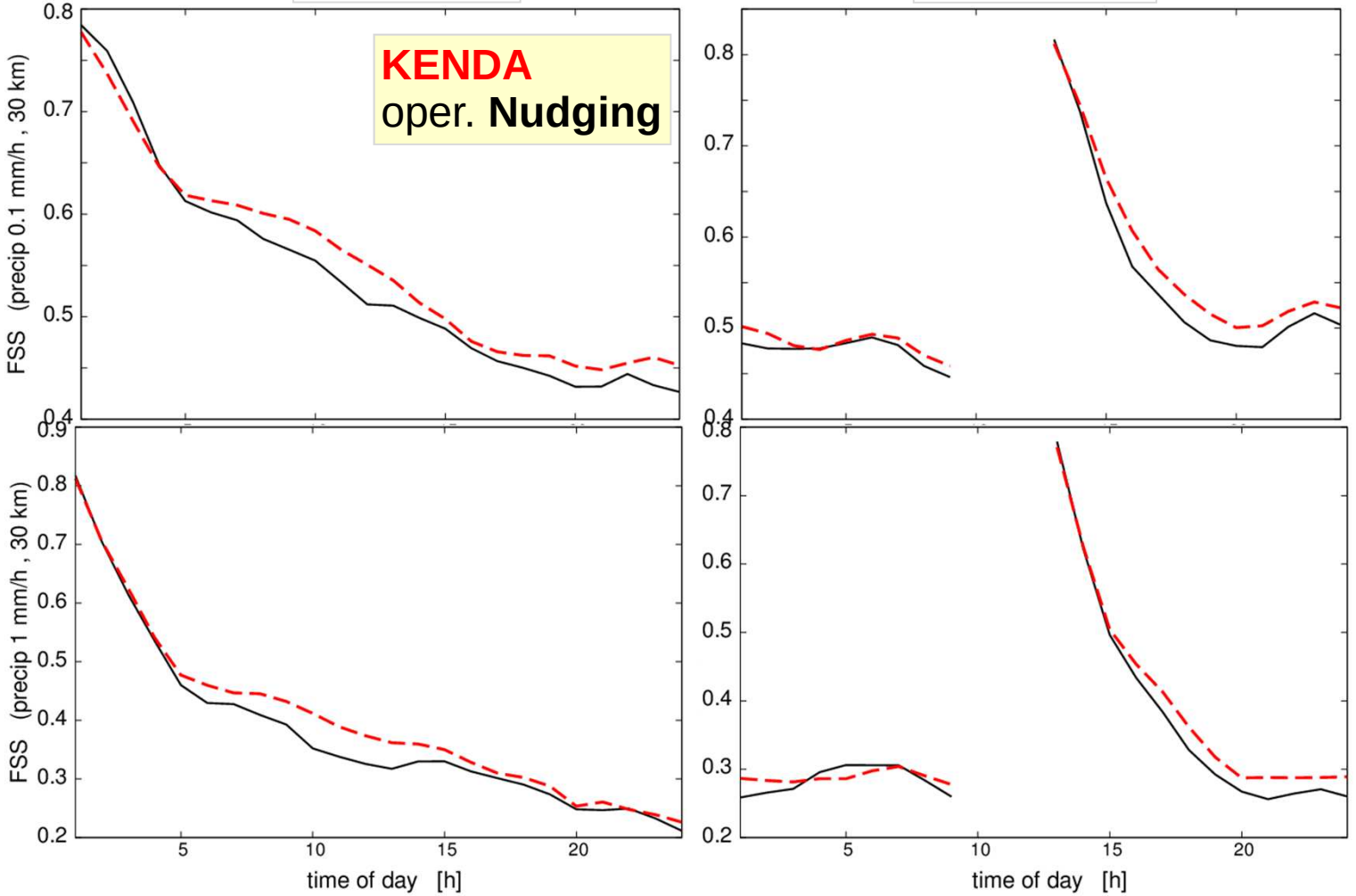
1-hrly precip FSS (30 km)

1 mm/h

0-UTC runs

12-UTC runs

KENDA
oper. **Nudging**



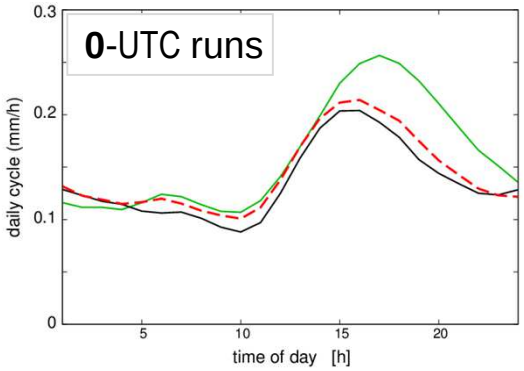
✓ KENDA: long-lasting improvements after first 2 – 4 hours in summer convective period

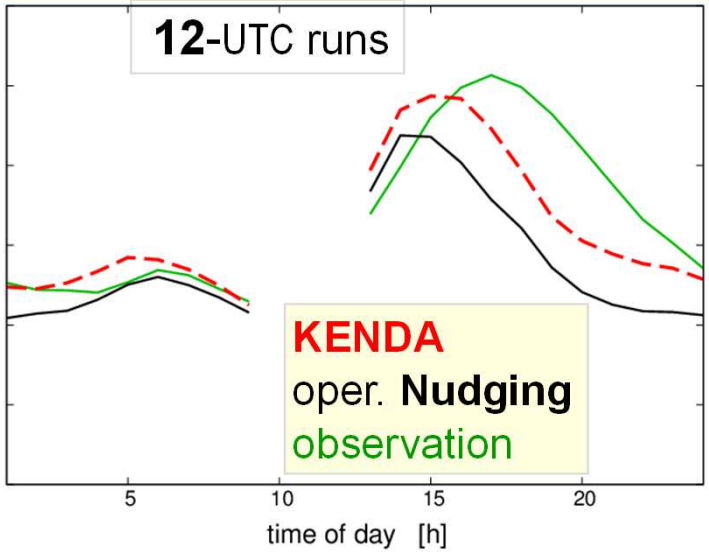
pre-oper. suite, deterministic:

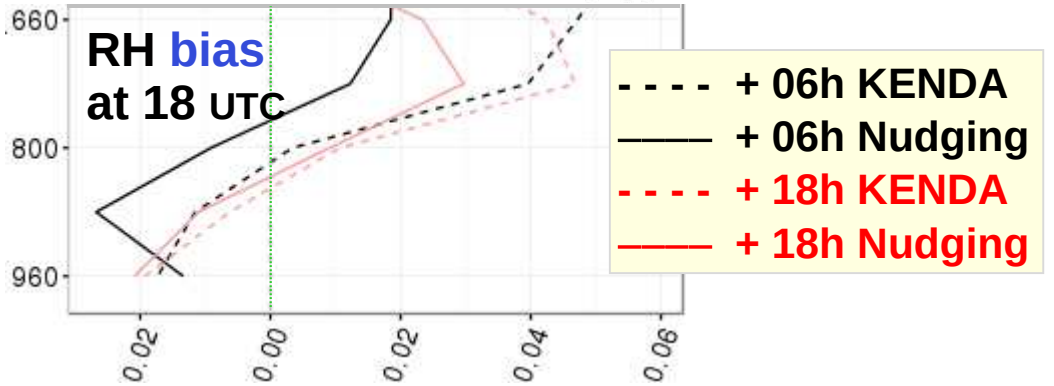
radar verif. 26 May – 12 June 2016

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 !

pre-operational KENDA (setup) vs. operational nudging:
winter test (22 Jan. – 24 Feb. 2016) , det.

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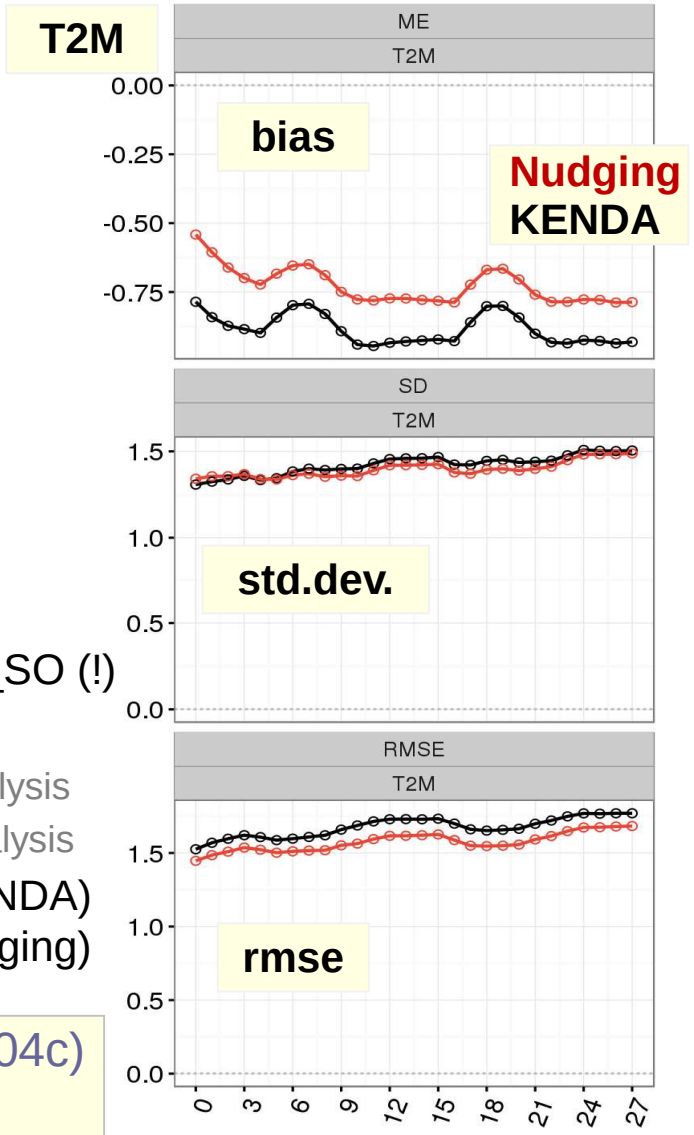
deterministic forecasts:

~ neutral (precip, upper-air, surface verif.),

except negative: – 2-m temperature

– low stratus (cloud)
(2 out of 3 cases)



increased 2-m temperature bias:

→ due to underestimation of melting of soil ice in KENDA

→ due to insufficient Grib accuracy for soil temperature T_SO (!)

when melting of soil ice, very small T_SO increase only

T_SO : Grib accuracy too small → same as in previous analysis

soil ice: diag. from T_SO, W_SO → same as in previous analysis

melting of soil ice underestimated, more in 1-h cycling (KENDA)
than in 3-h cycling (nudging)

✓ Grib accuracy for T_SO increased (COSMO V5.04c)
operational since mid-Nov. 2016

pre-operational KENDA (setup) vs. operational nudging:
winter test (23 Jan. – 24 Feb. 2016) , det.

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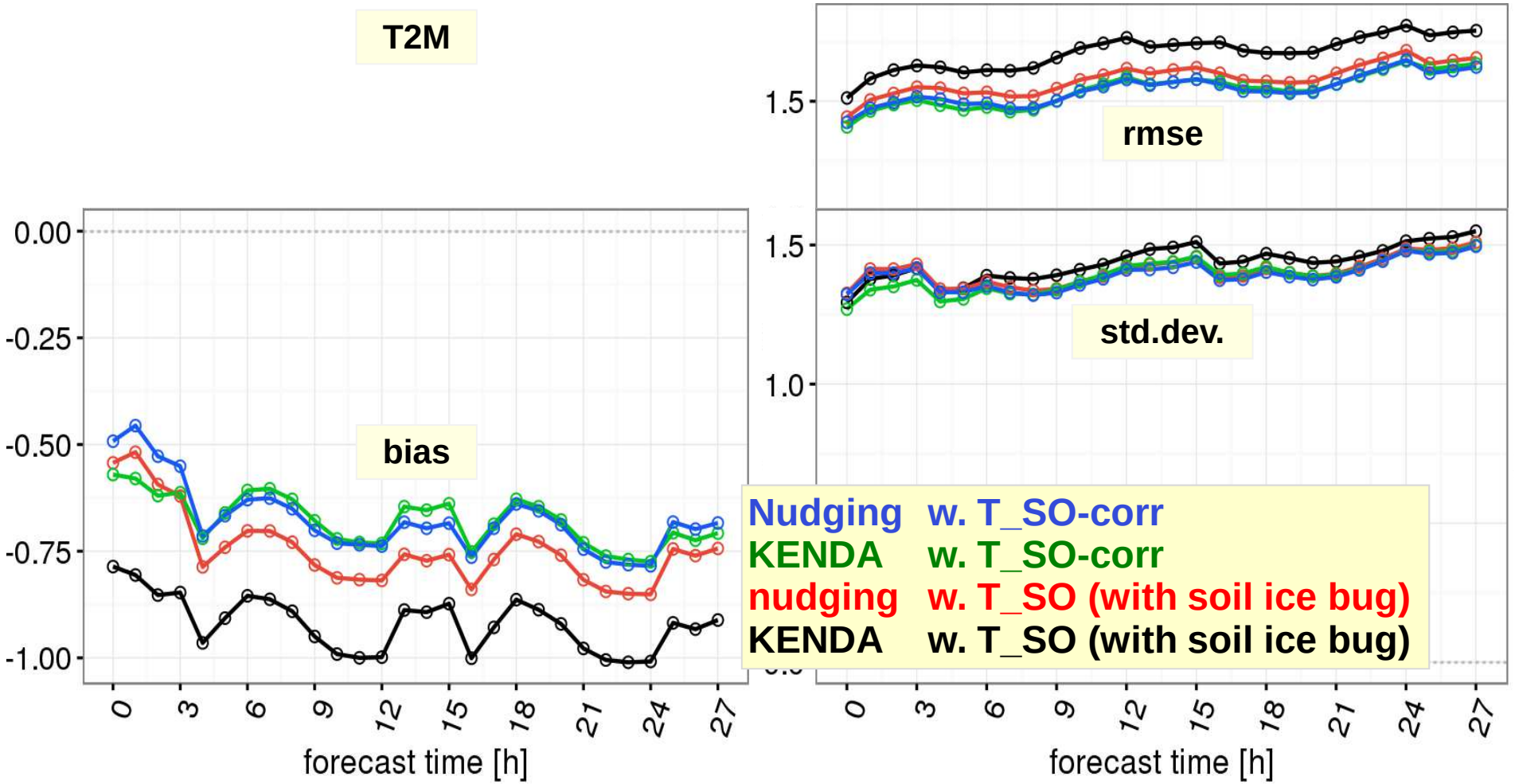

KENDA in winter: problem solving

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- increased Grib accuracy for soil temperature, operational since mid-Nov. 2016

- **„additive covariance inflation“**:
  - additional perturbations in all LETKF analysis ensemble members, based on climatological forecast error covariances from global EnVar for ICON
  - purpose: account for model errors in a better way, so that 1-h forecast ensemble differences (covariances) provide a more complete description of the true errors of the 1-h forecast

  → increases ensemble spread, increases (error) space spanned by ensemble

  → increases weight of observations in analysis

  → experiment: December 2016 (with low stratus periods: 03 – 09 Dec, 15 – 21 Dec, 29 Dec – 02 Jan)

winter experiment (Dec. 2016): KENDA vs Nudging, surface verification

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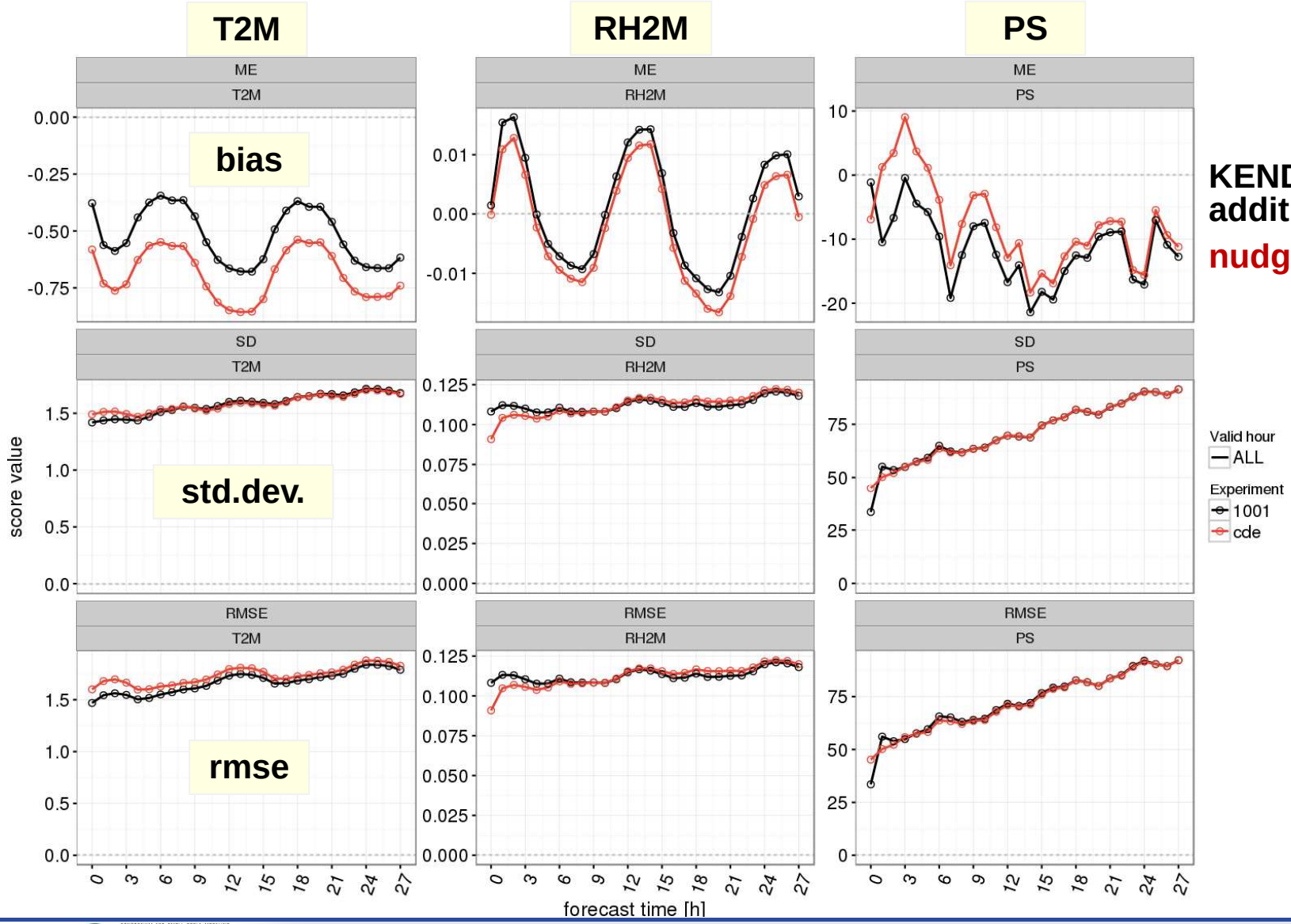

KENDA with additive inflation

nudging

winter experiment (Dec. 2016)
verification against radiosondes

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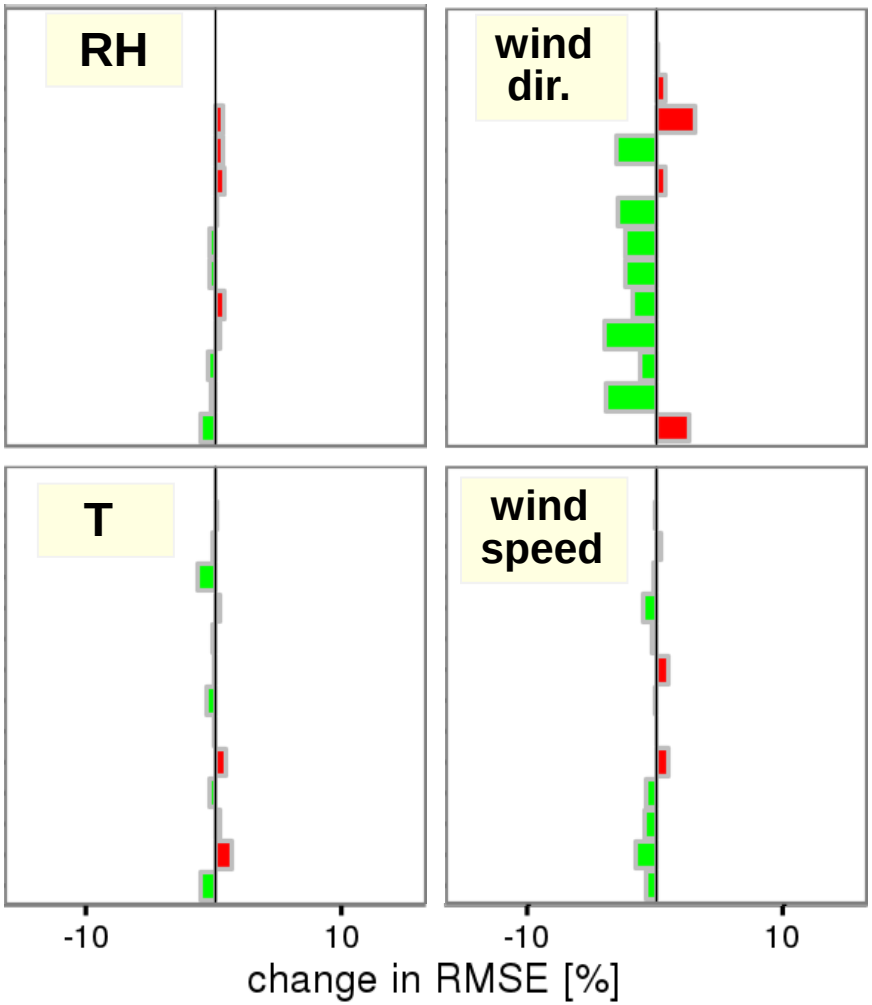
KENDA (additive infl.) vs. nudging



winter experiment:
low stratus (cloud), 5 Dec. 2016, 12 UTC

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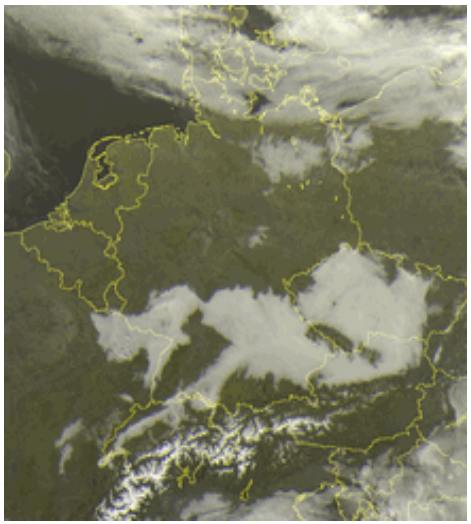
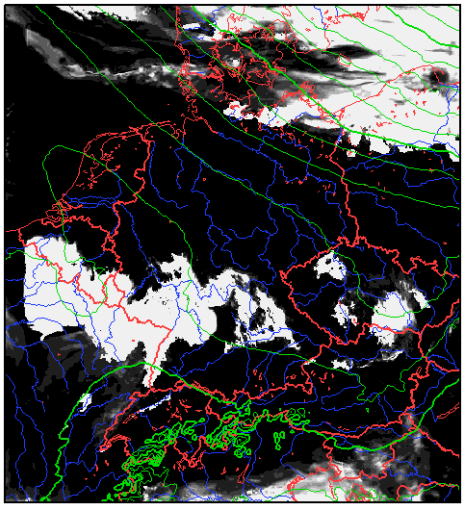
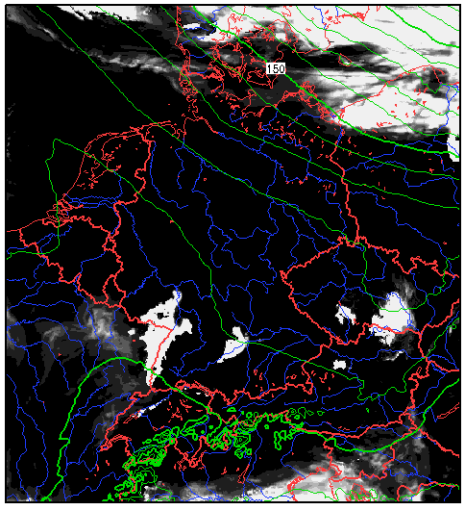
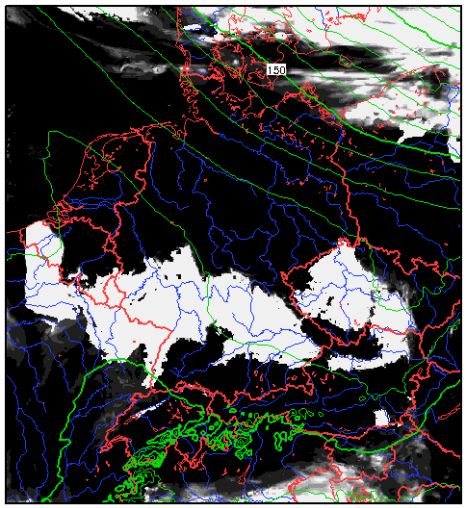
operational nudging | (pre-oper.) **std. KENDA** | **exp. 1001: additive infl.**

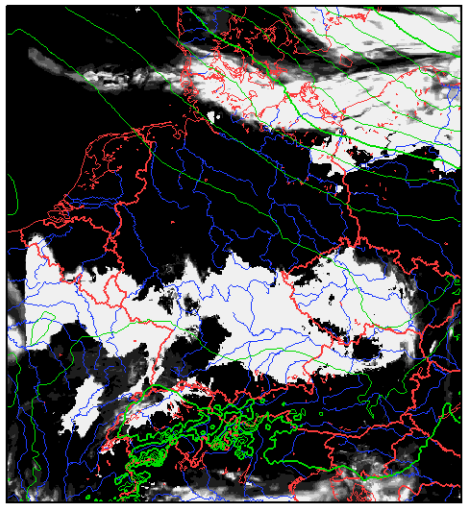
5 Dec 2016,
0 UTC **+ 12 h**

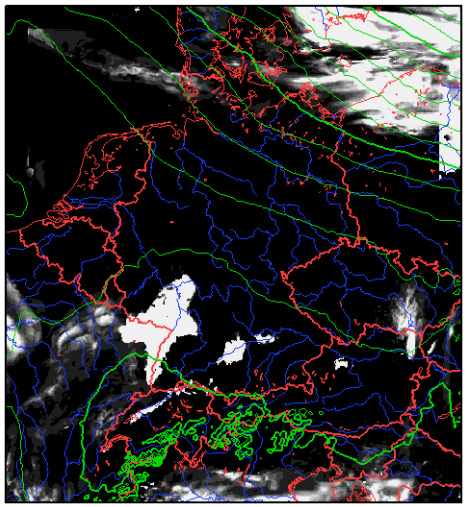


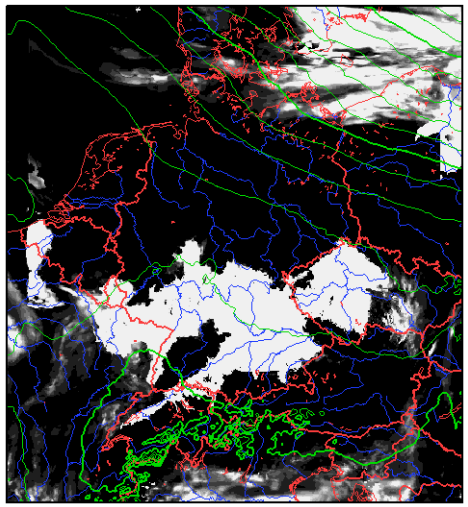












5 Dec 2016,
12 UTC **+ 0 h**

winter experiment:
vertical profiles, 50°/10°, 5 Dec. 2016, 12 UTC

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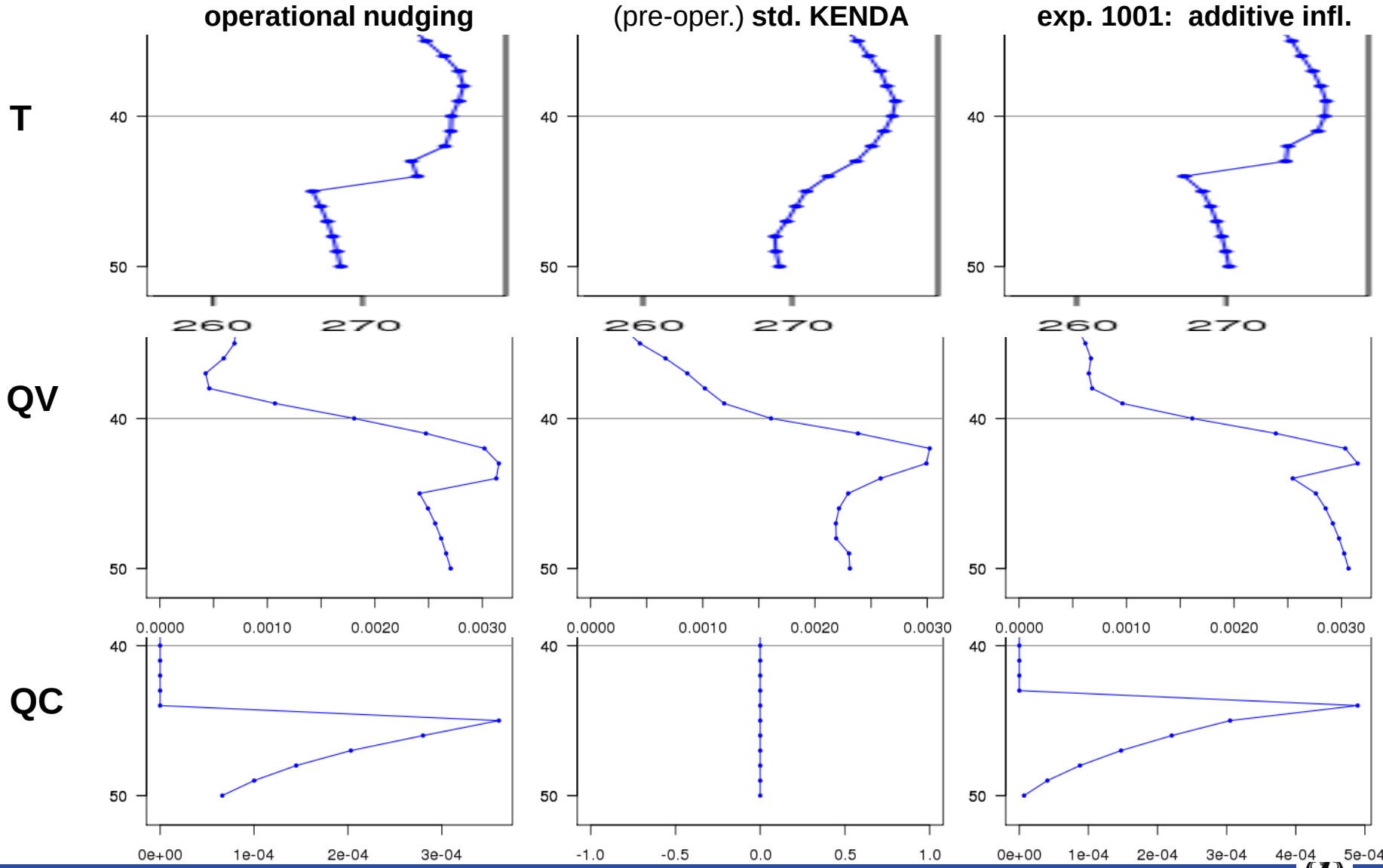

Summary

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- additive inflation:
  - winter: large positive impact on low stratus + 2-m temperature bias
    very positive for EPS
  - summer (convective period) :
    minor mixed impact
    (possibly due to larger effect of soil moisture perturbations in summer)

→ introduced in KENDA parallel suite on 8 Feb.

Summary

- KENDA (with additive inflation) vs. operational nudging:

  deterministic forecasts: positive for **convective precipitation** in summer
  positive for 2-m temperature
  mixed for low stratus in winter
  negative for surface pressure in summer

  EPS: very positive (talk by Tobias Tröndle)

→ **operational introduction of KENDA: 21 March 2017**

Thank you for your attention

Summary

- KENDA (with additive inflation) vs. operational nudging:

  deterministic forecasts: positive for **convective precipitation** in summer
  positive for 2-m temperature
  mixed for low stratus in winter
  negative for surface pressure in summer

  EPS: very positive (talk by Christoph Gebhardt)

→ **operational introduction of KENDA: 21 March 2017**

- pending issue: T2M forecast differences betw. EPS members too large in cloud-free summer days

  → being tested: soil moisture perturb. reduced
  & soil temperature perturb. added

Thank you for your attention

KENDA with additive inflation, deterministic: radar verification (26 May – 12 June 2016)

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

0.1 mm/h

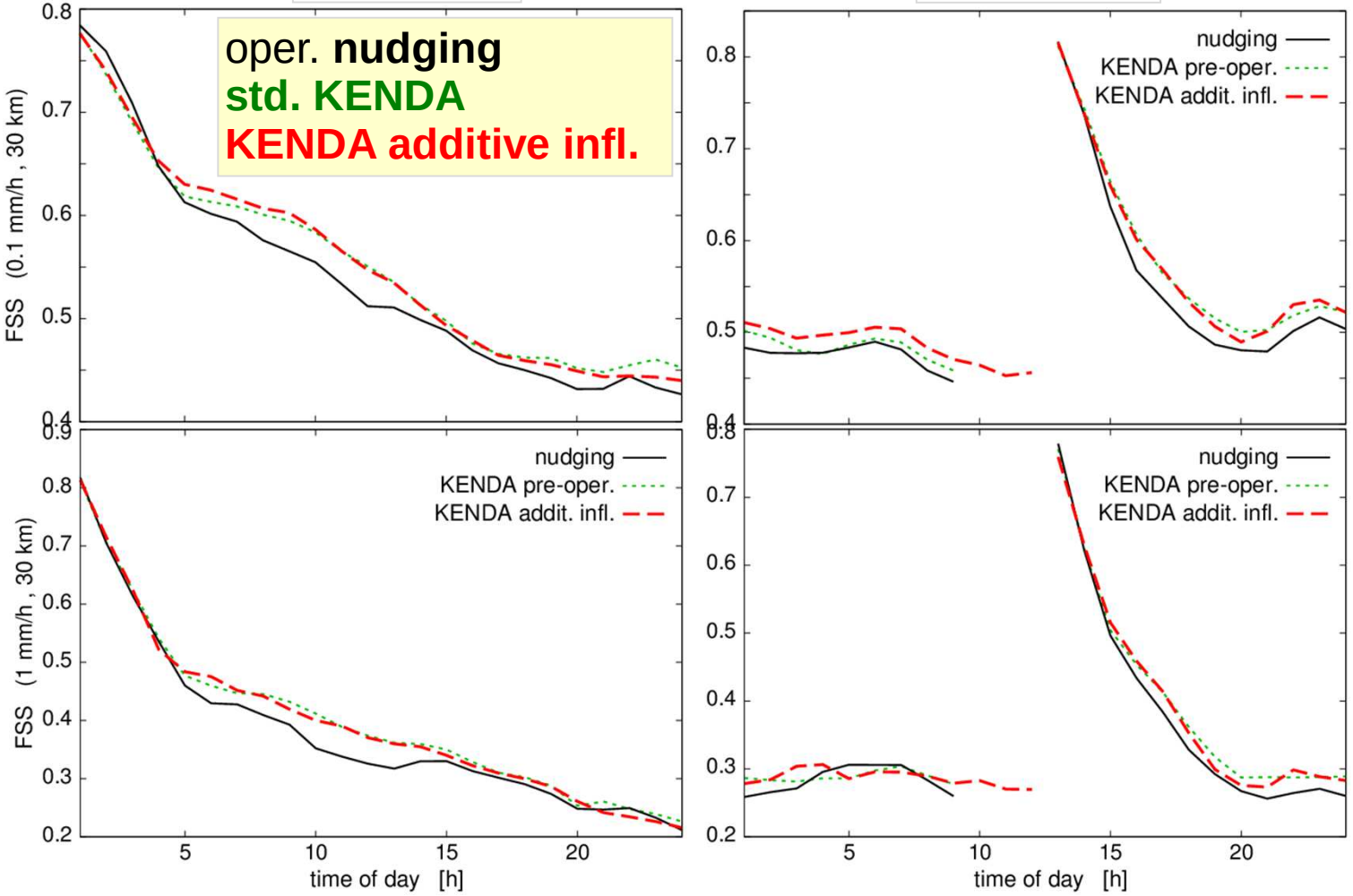
1-hrly precip FSS (30 km)

1 mm/h

0-UTC runs

12-UTC runs

oper. **nudging**
std. KENDA
KENDA additive infl.



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

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