Making KENDA operational

Christoph Schraff, DWD

PP KENDA-O : Km-Scale Ensemble-Based Data Assimilation for the use of High-Resolution Observations (until 2020)

1) further development of LETKF scheme
   - work towards operationalization: additive covariance inflation
   - limiter to soil moisture perturbations

2) extended use of observations (overview)
   - Mode-S aircraft

3) lower BC: soil moisture analysis (by LETKF) using satellite soil moisture data

4) – adaptation to ICON-LAM: LETKF, 3DVar, hybrid EnVar
   – particle filters (hybrid PF-Var with global ICON almost as good as operational EnVar (with LETKF) in 1-month test)

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

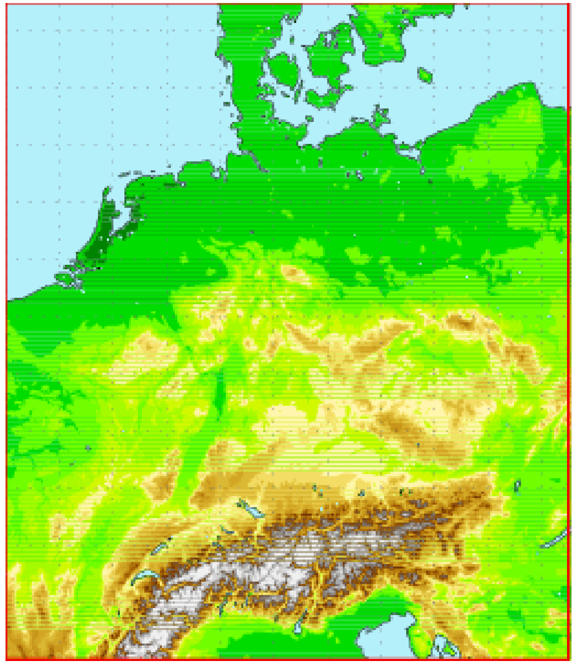
  (Daniel Leuenberger, …)

  KENDA for det. COSMO-1: 2018

  (T,qv in PBL still worse, some problems:

  no additive inflation yet,

  KENDA draws analysis less close to obs than nudging, mainly in winter)



- DWD: KENDA operational for **det. + EPS** since 21 March 2017 (Δx = **2.8** km)

  *(**Hendrik Reich**, Christoph Schraff, Andreas Rhodin, Roland Potthast, Klaus Stephan, …)*

  (→ first to replace observation nudging)

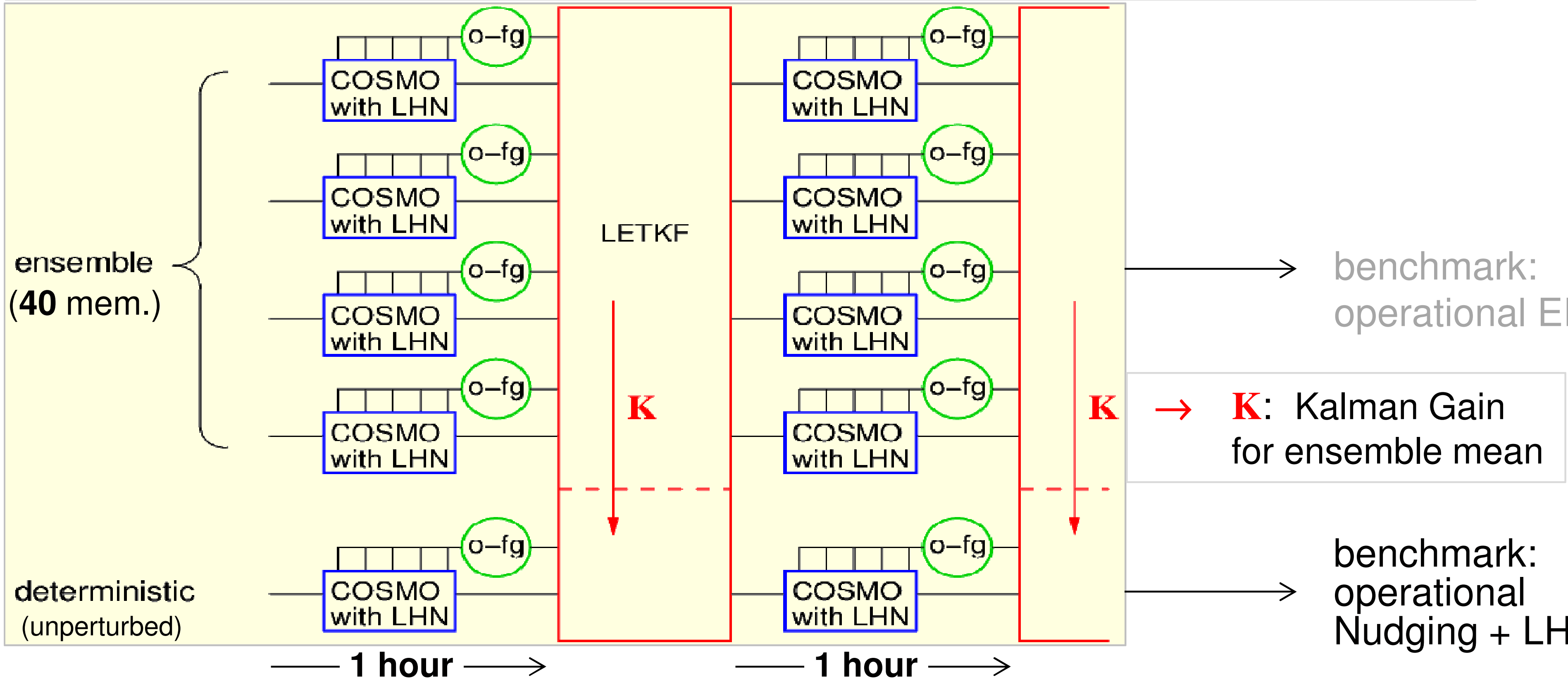
- ARPAE-SIMC: KENDA operational for **det.** forecast since May 2017, for EPS soon (2.2 km)

  (Bologna)

  (Chiara Marsigli, Davide Cesari, …)

KENDA at DWD, MeteoSwiss, …: KENDA-LETKF operational setup

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



(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 ($\alpha_p = 0.75$)
- additive covariance inflation (DWD only → see later)
- explicit soil moisture perturbations
- conventional obs types only (radiosonde, aircraft, wind profiler, synop)

winter test KENDA vs. nudging: larger 2-m temperature cold bias

- bug in model system setup: insufficient Grib precision in analysis for T_SO,
  leading to underestimation of melting of soil ice

  → bug fix operational since mid-Nov. 2016

- **additive covariance inflation**:

  – additional random perturbations in all LETKF analysis ensemble members, based on climatological forecast error covariances from global EnVar for ICON

  ($\mathbf{B} = \mathbf{L}\,\mathbf{L}^T$; $\mathbf{y} = \mathbf{L}\,\mathbf{x}$, where $\mathbf{x}$: random vector (with reduced resolution/dimension))

  – 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

  → experiments: February 2016 (only 8 days)
  December 2016 (with low stratus periods: 03 – 08 Dec, 15 – 21 Dec, 29 Dec – 02 Jan)

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additive covariance inflation using 3DVar-B
(10 – 18 Feb. 2016)

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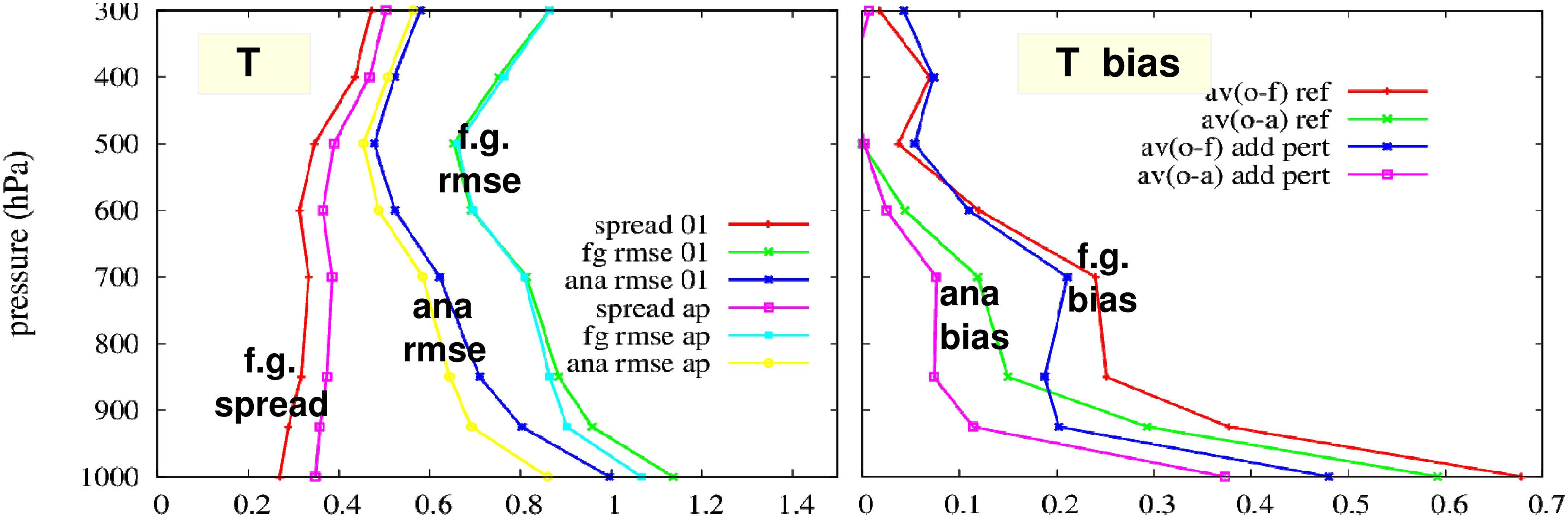
DWD



additive covariance inflation:

- increases f.g. spread
- draws analysis closer to obs
- reduces low-level T rmse in f.g.
- **reduces** low-level T, T2M **bias** !
- little effect on forecast errors in general (T, wind…), but …

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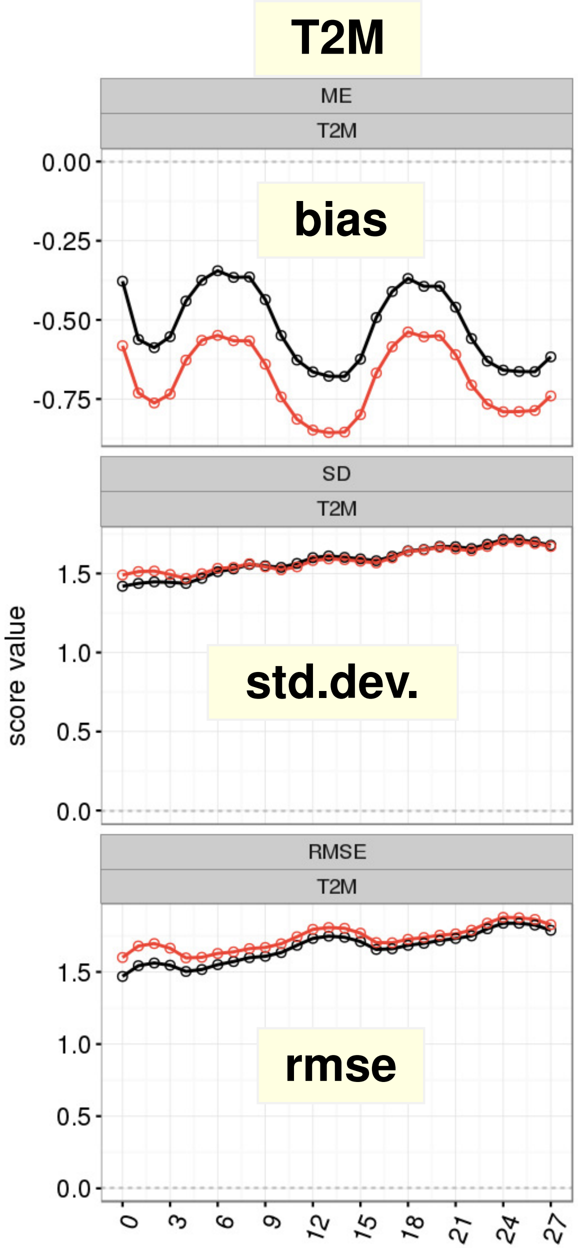
winter experiment (Dec. 2016):
KENDA vs Nudging, surface verification



KENDA with additive inflation

nudging

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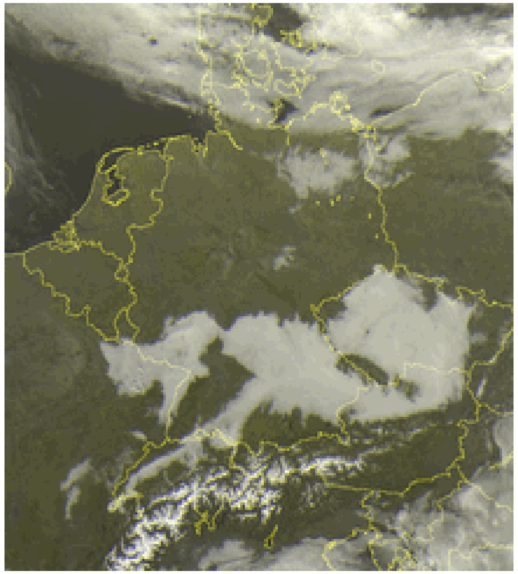
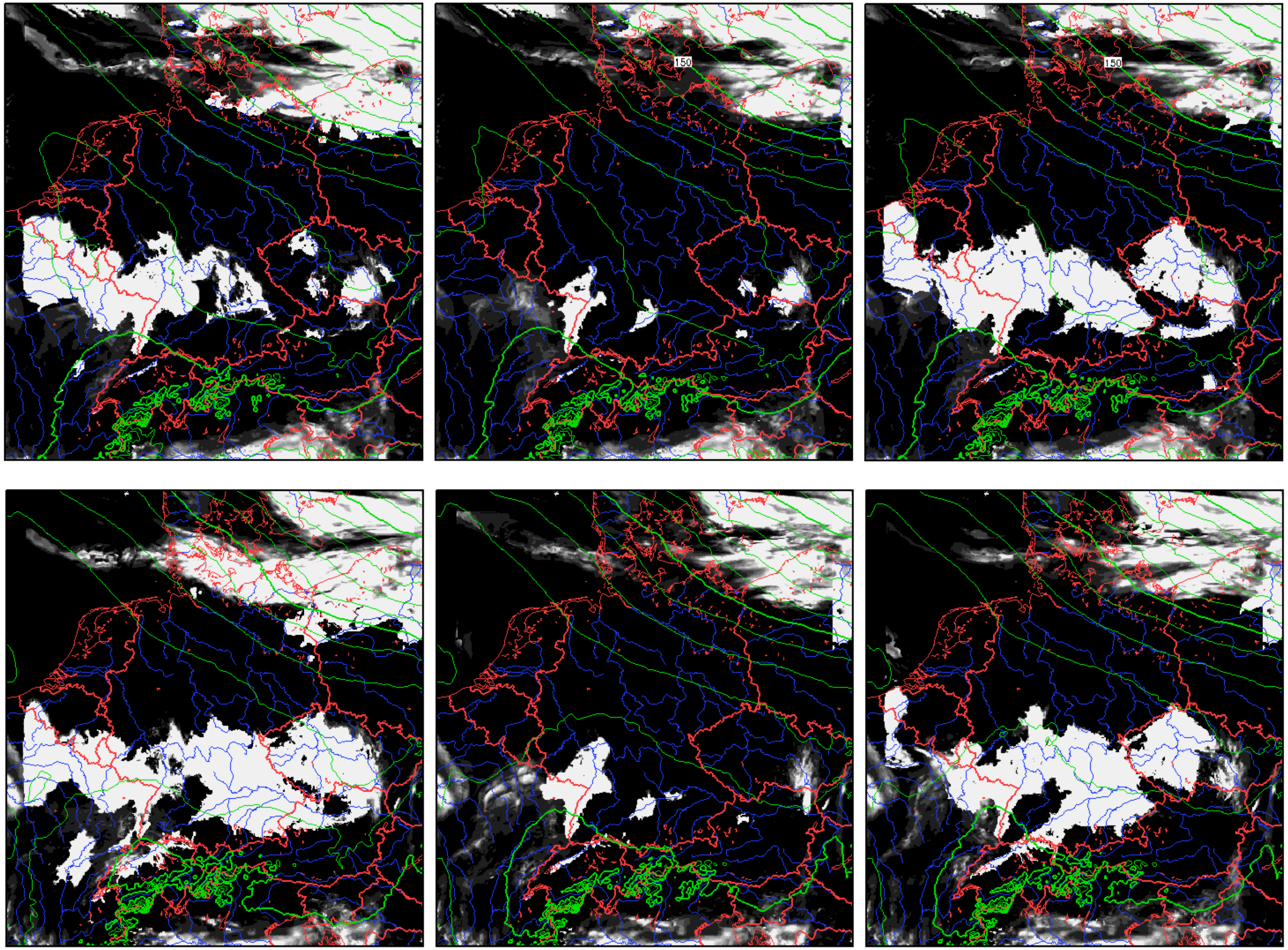
winter experiment: low stratus (cloud), 5 Dec. 2016, 12 UTC

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

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





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

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

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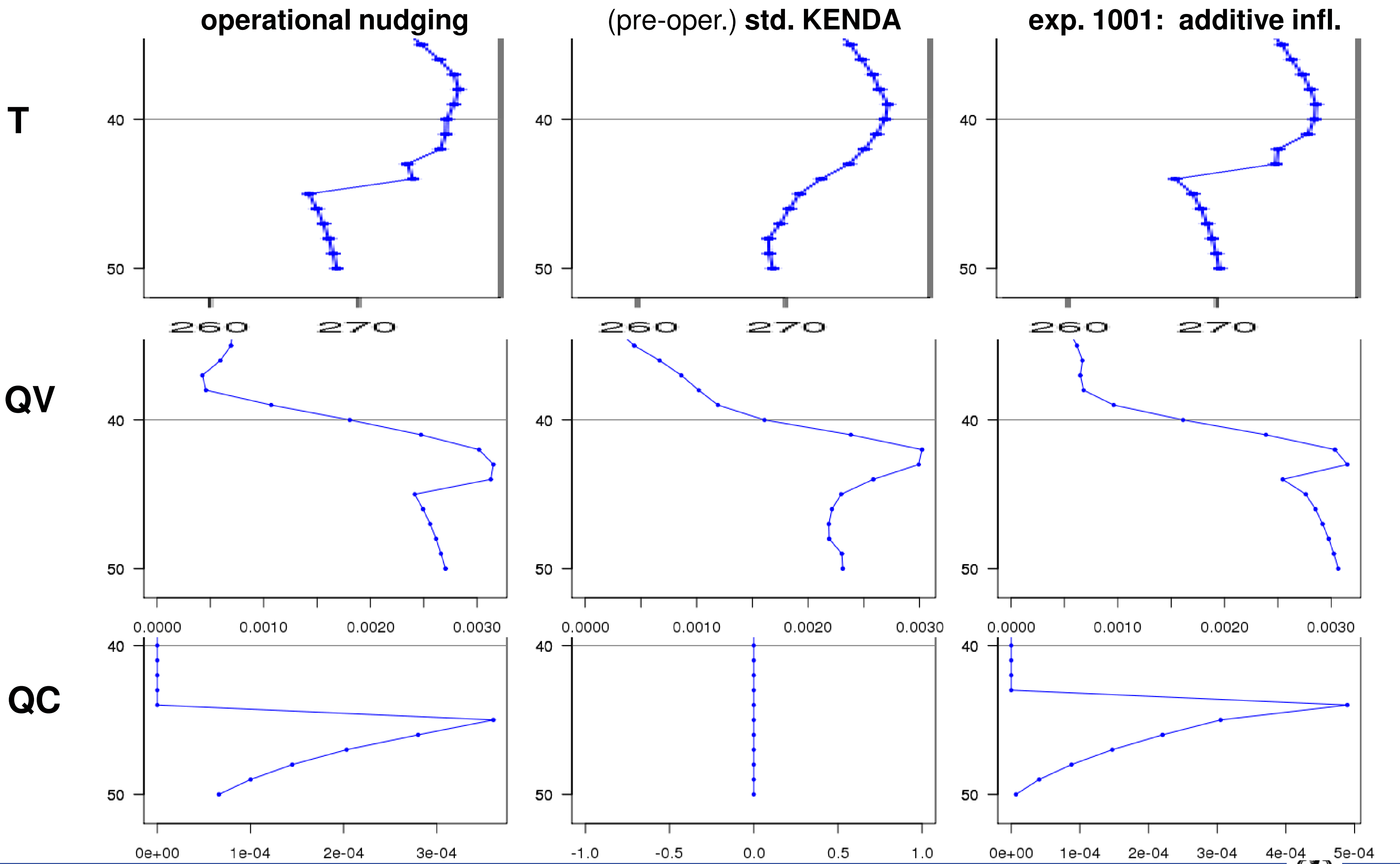

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Summary

- 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.

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Summary

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

  deterministic forecasts: positive for **convective precipitation** in summer
  positive for 2-m temperature
  mixed (negative in 1 period) for low stratus in winter
  negative for surface pressure in summer

  EPS: very positive (in summer & winter, for precip, wind gusts, …)

→ operational introduction of KENDA: 21 March 2017

- but: pending issue, to be solved before summer

pre-operational KENDA suite at DWD in summer 2016: effect of soil moisture perturbations (SMP)

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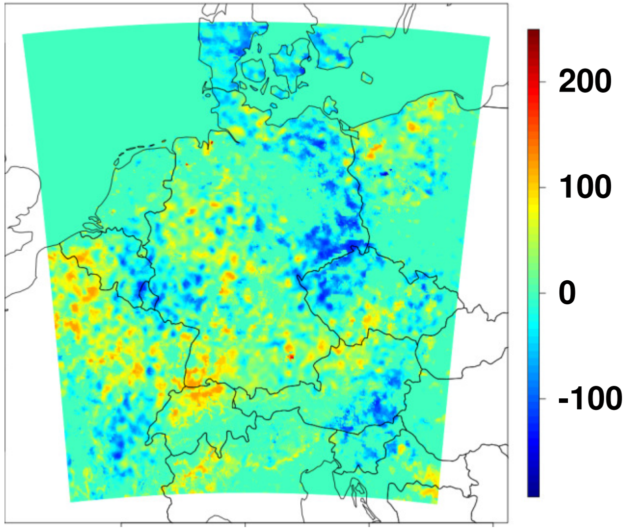
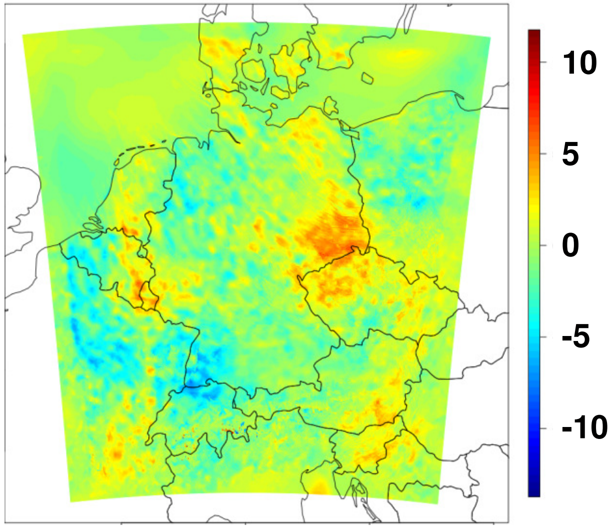
24 Aug. 2016

soil moisture layer 5, diff. betw. 2 mem. (1,8)



T2m at noon, diff. betw. 2 mem. (1,8)



standard soil moisture perturb.:

→ T2m deviations of individual ensemble members unrealistically large in some situations

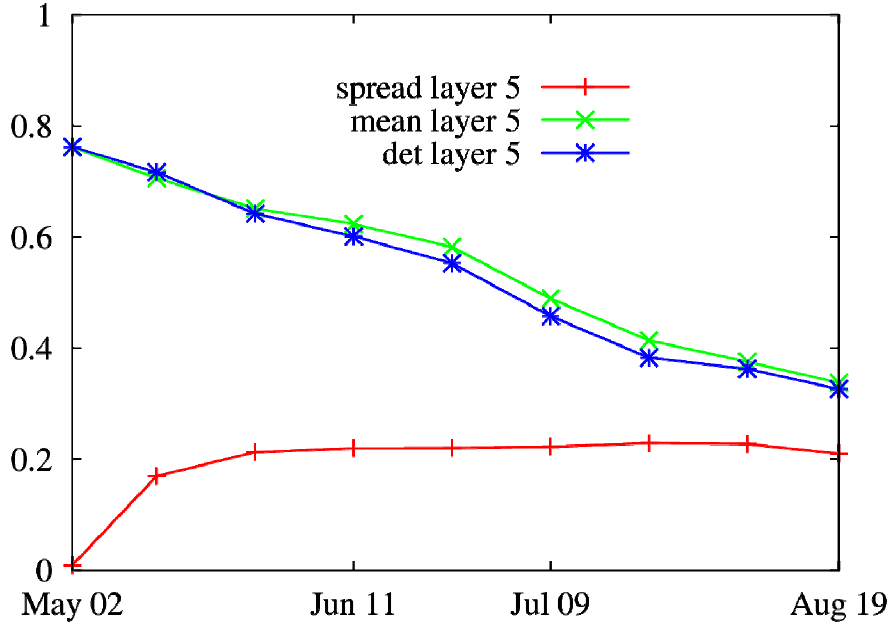
description of new setup with limiter for soil moisture perturbations

- old setup:

  random soil moisture perturbations

  (with prescribed horizontal correlation scales (100 km , 10 km)
  approx. temporal correlation scale (1 day)
  and variance (0.72 SMI/day))

  → accumulate over days, saturate eventually at domain average ~ 20 – 25 % SMI
  (soil moisture index:
  0 at plant wilting point, 1 at field capacity)



- modification: no further explicit SM perturbations added
  where spread(SMI) > 0.15

  → "soft limiter" for SMP

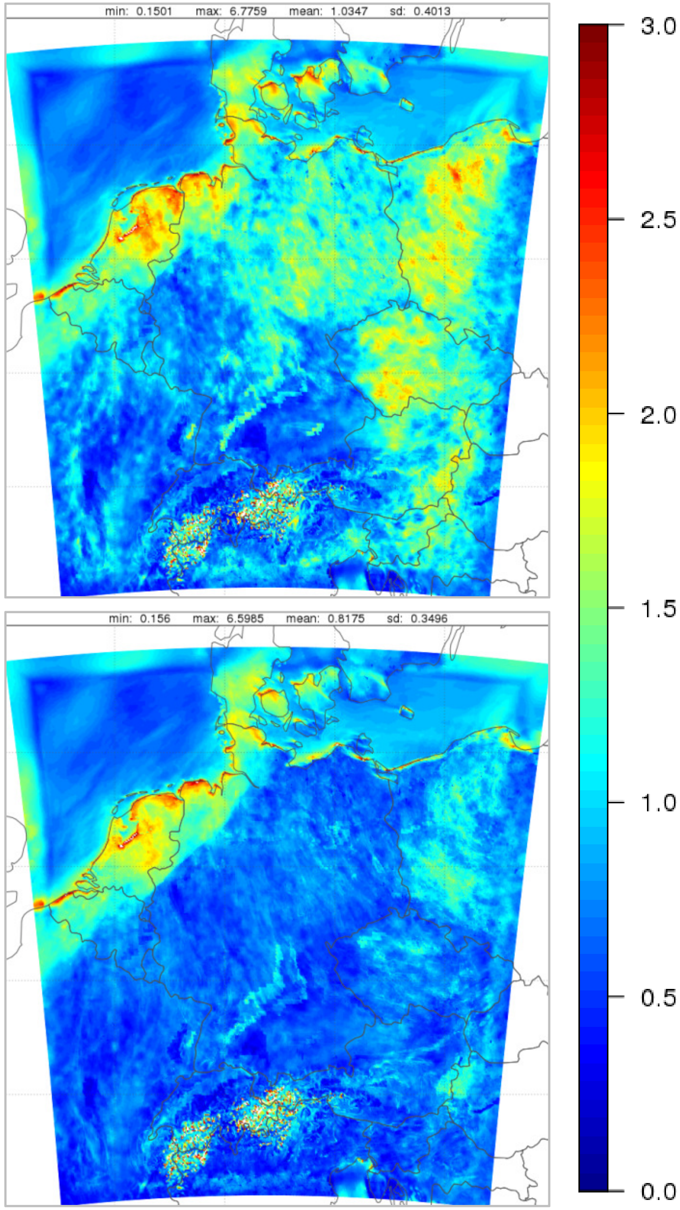
soft limiter of soil moisture perturbations: impact on a sunny day (23 June 2016)

spread of
2-m temperature

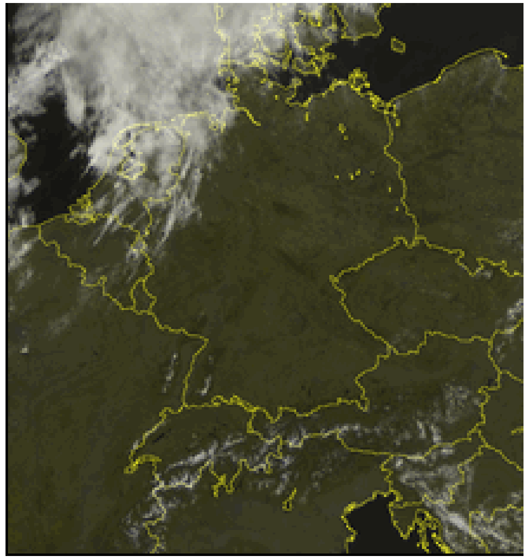
afternoon (14 UTC)

original
(Exp 10396)

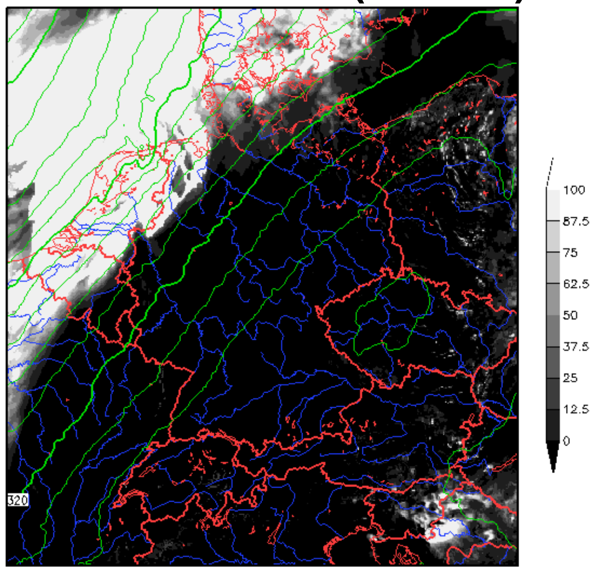
with SMP limiter
(Exp 10416)



Meteosat (12 UTC)

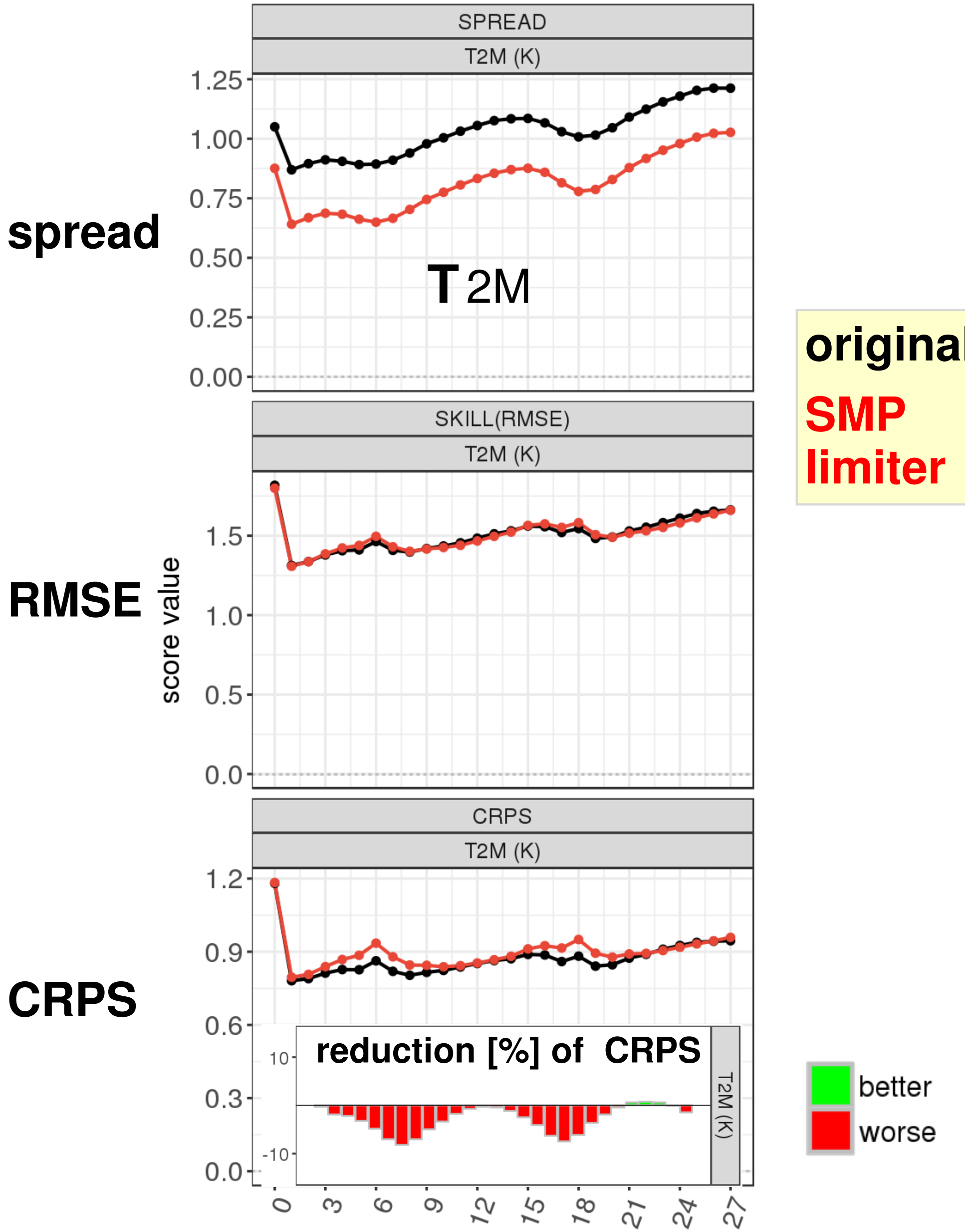


mid-level cloud (12 UTC)

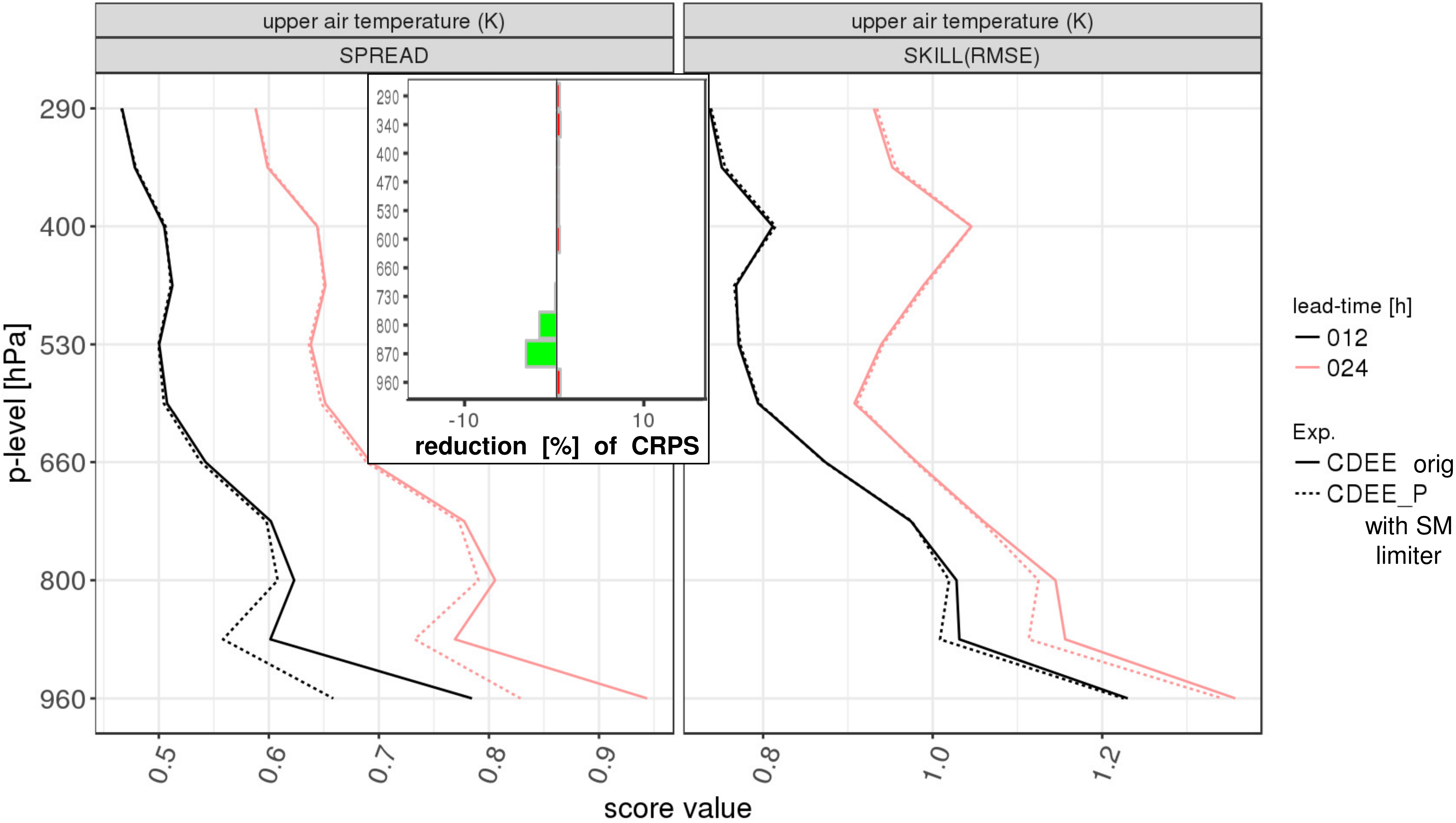


✓ T_2M spread decreased mainly in sunny areas

impact of SMP limiter on scores, **EPS**: surface verification (1 – 25 June 2017)



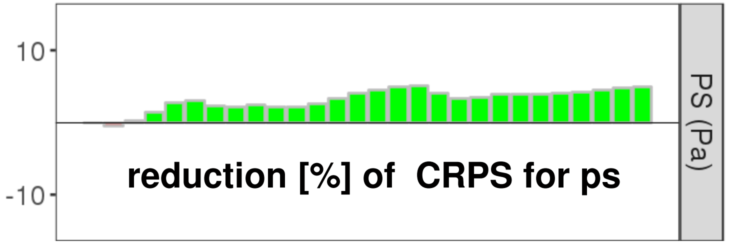
impact of SMP limiter on scores, **EPS**: radiosonde verification (1 – 25 June 2017)



impact of soft SMP limiter: summary

- impact of reduced soil moisture perturbations on scores:
  - ✓ T_2M spread strongly reduced in sunny days as required
  - – T_2M + RH_2M spread moderately reduced in general

    in June 2017 more than in June 2016, because in 2017:
    - – more sunny days
    - – original soil moisture perturbations larger
    - – drier soil



  - ✓ deterministic scores: neutral
  - ✓ EPS: slightly reduced errors (upper-air T, surface pressure, especially bias), slightly improved resolution for precip

  - ➢ hypothesis: due to introduction of additive covariance inflation (in February), reduced soil moisture perturbations can be afforded or are even beneficial

→ soft limiter to soil moisture perturbations operational since early July 2017

Progress in KENDA-O, Task 2:
Extended use of observations: ongoing

✓ **Mode-S aircraft** : DA exp., promising results

✓ **radar radial winds**: DA exp., promising results

✓ **radar reflectivity**: DA sensitivity tests, results mostly preliminary:
- ARPAE-SIMC (≤ 4 radars): 1h / 30'/ 15' cycling, temporal thinning, RTPS, addit. infl.
- DWD: warm bubbles, remapping of Z for Gaussianity, 1.1km, 2-moment microphys.

✓ **GPS slant total delay**: technical work incl. monitoring, in V5.04d, new DA exp. running
(old exp: benefit on precip, elsewhere mixed (negative at low levels))

✓ **SEVIRI WV**: many (mostly clear-sky) sensitivity DA tests, inconclusive, no benefit yet

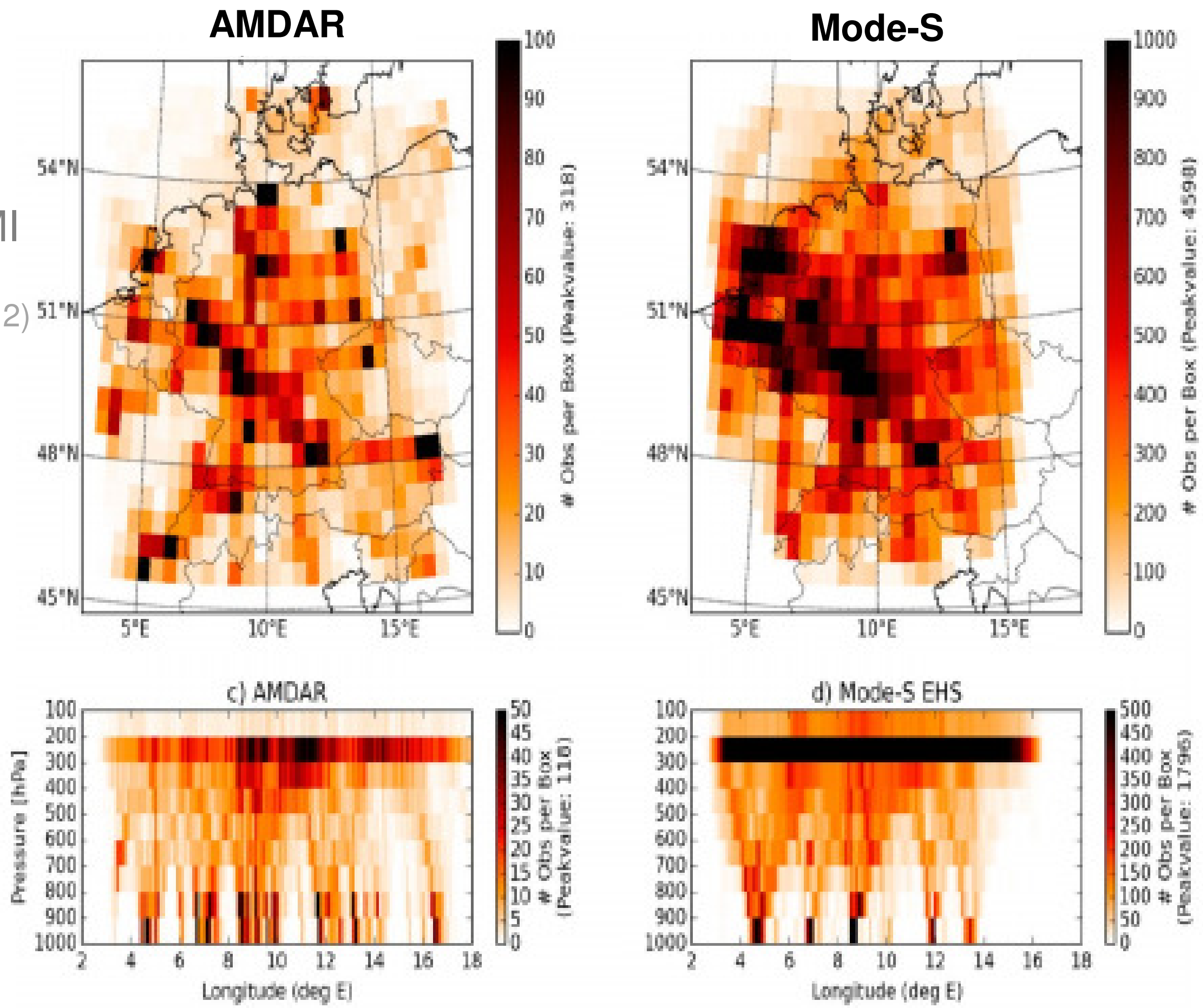
✓ **Raman lidar** (T-, q- profiles): quality of Payerne T-obs improved, DA being set up

✓ **T2M, RH2M**: delayed (resources at MCH/DWD in 2018)

✓ 3 new projects at DWD (→ WG1): **SEVIRI VIS**, **lightning**, (nowcast) **objects**

Mode-S aircraft

- derived from radar data from air-traffic control, processed + provided by KNMI
  (de Haan, *Geophys. Res.*, 2011;
  de Haan and Stoffelen, *Wea. Fcst.*, 2012)
- wind vector + temperature,
  T derived from Mach number
- every 4 – 15 sec
- compared to AMDAR:
  >10 x more data
  no humidity, larger T error
- apply thinning (40 % active)

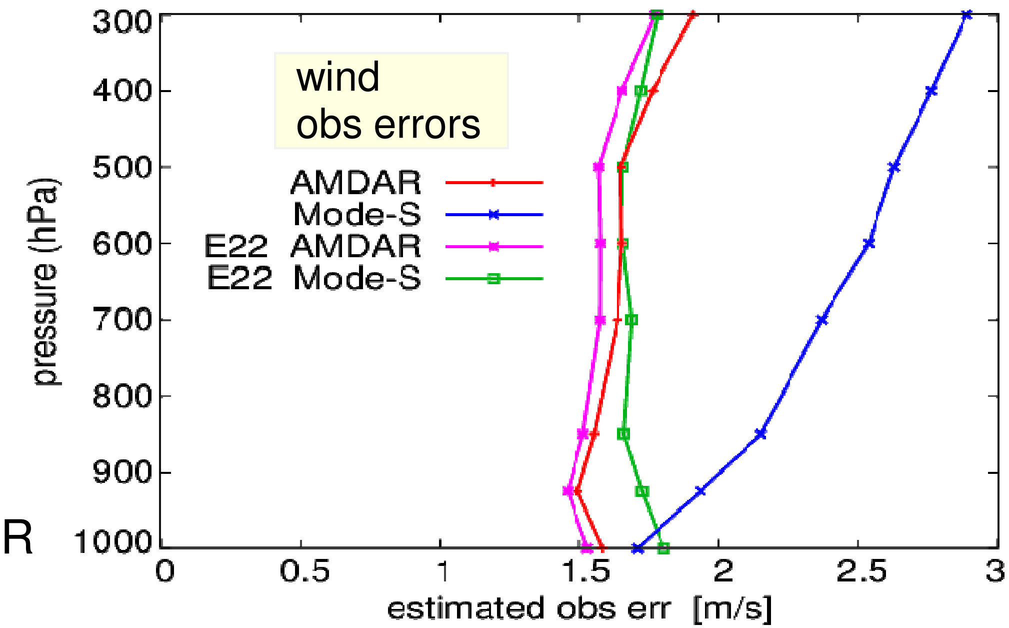


obs per day – from: Lange and Janjic, MWR 2016 experiment 26 May – 10 June 2016

– a-posteriori Desroziers statistics from DA experiment for estimation of obs errors:
unexpected large Mode-S wind errors

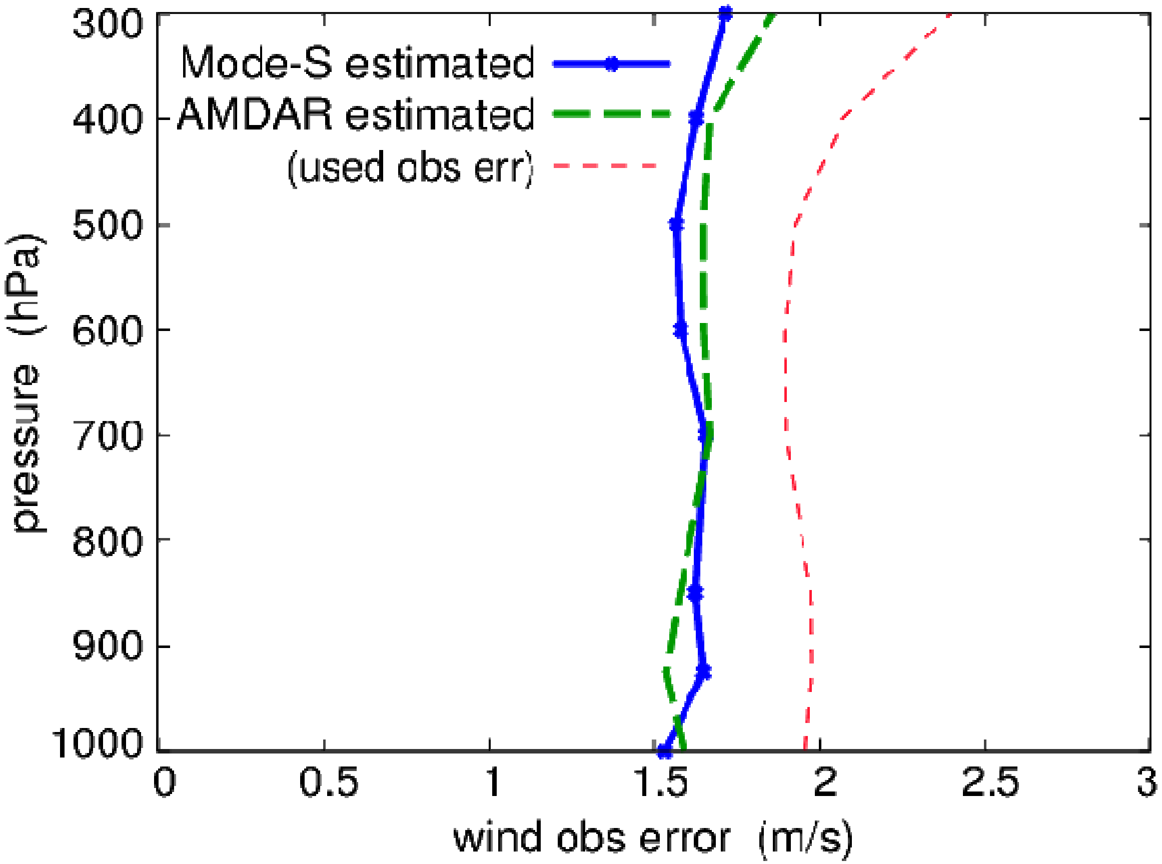
→ data processing corrected by KNMI since 15 May 2017,
re-processed historical data on request

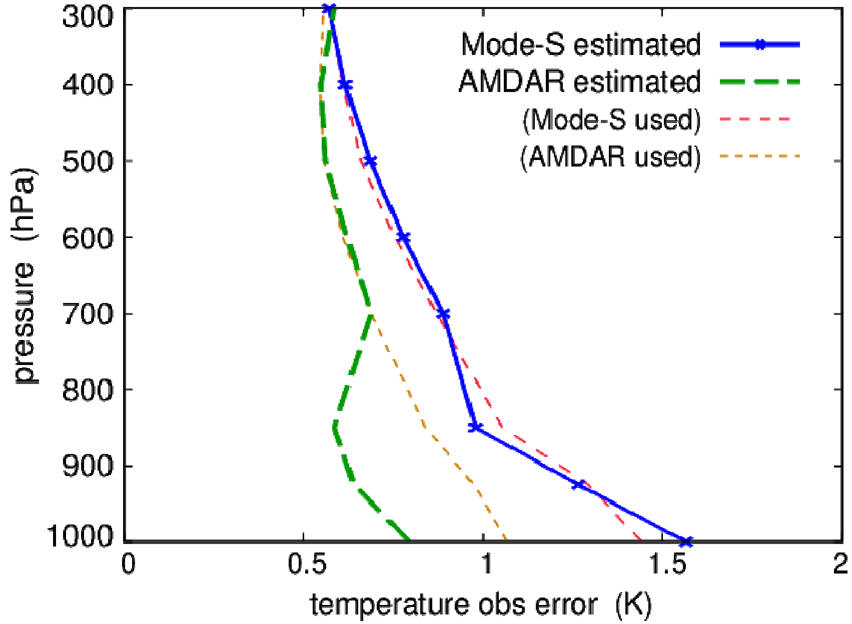
→ new exp. 'E22' with re-processed data:
Mode-S wind obs errors similar to AMDAR
(but specified obs error variance still large)



Mode-S aircraft:
new obs errors (specified / estimated)

1 – 24 Sept. 2017 (trial in parallel suite)





✓ in comparison to AMDAR: Mode-S data quality at least as good as for re-processed data

→ data quality **very unlikely** reason of minor impact in parallel suite

→ forecast impact of Mode-S apparently dependent on weather regime

Mode-S aircraft: forecast verification for convective period with weak advection

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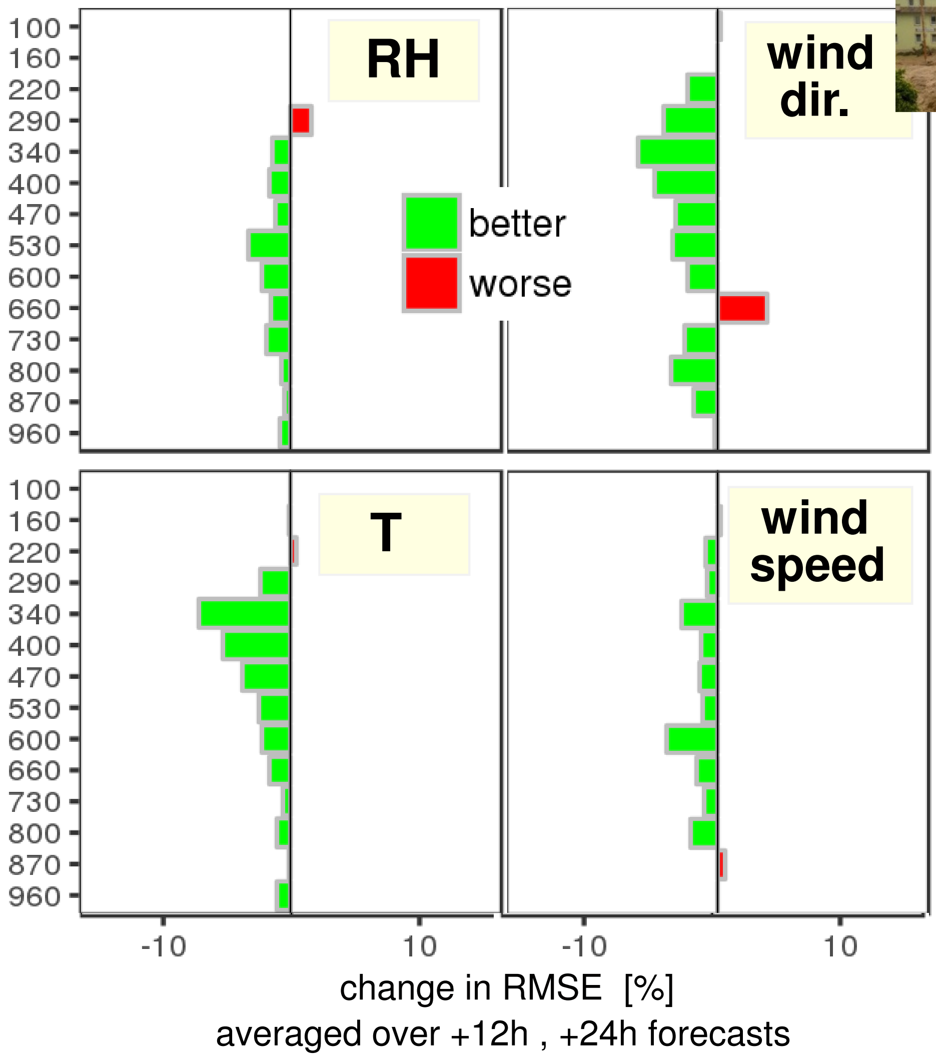
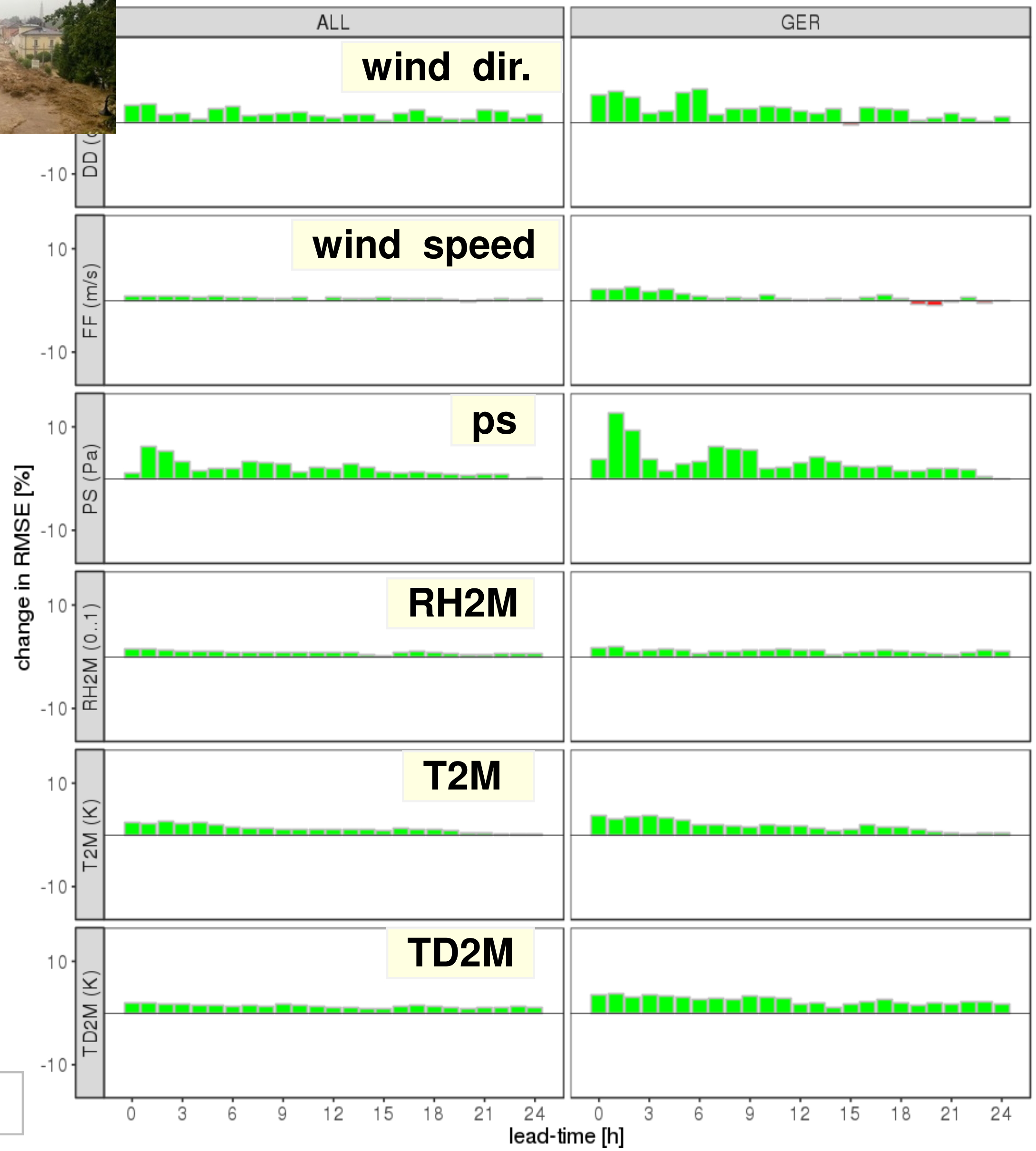
radiosonde verification (26 May – 10 June 2016) surface verification





✓ positive impact from Mode-S throughout

Mode-S aircraft: BACY test
for convective period with weak advection

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DWD

26 May – 10 June 2016

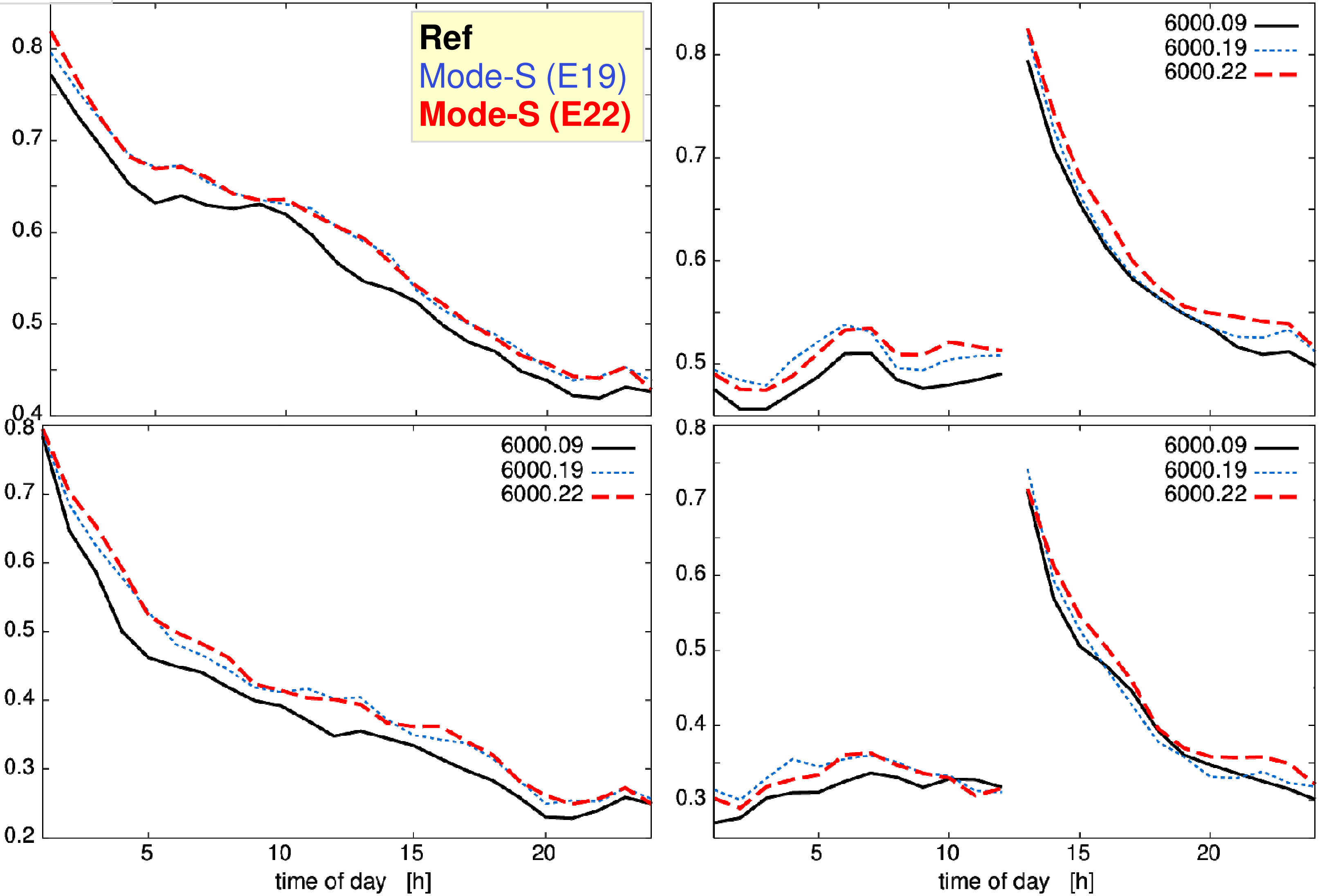
0.1 mm/h

1-hrly precip
FSS
(30 km)

1 mm/h

0-UTC runs

12-UTC runs



✓ Mode-S: clear long-lasting positive impact

Mode-S aircraft:
parallel trial (with adjusted wind obs error)

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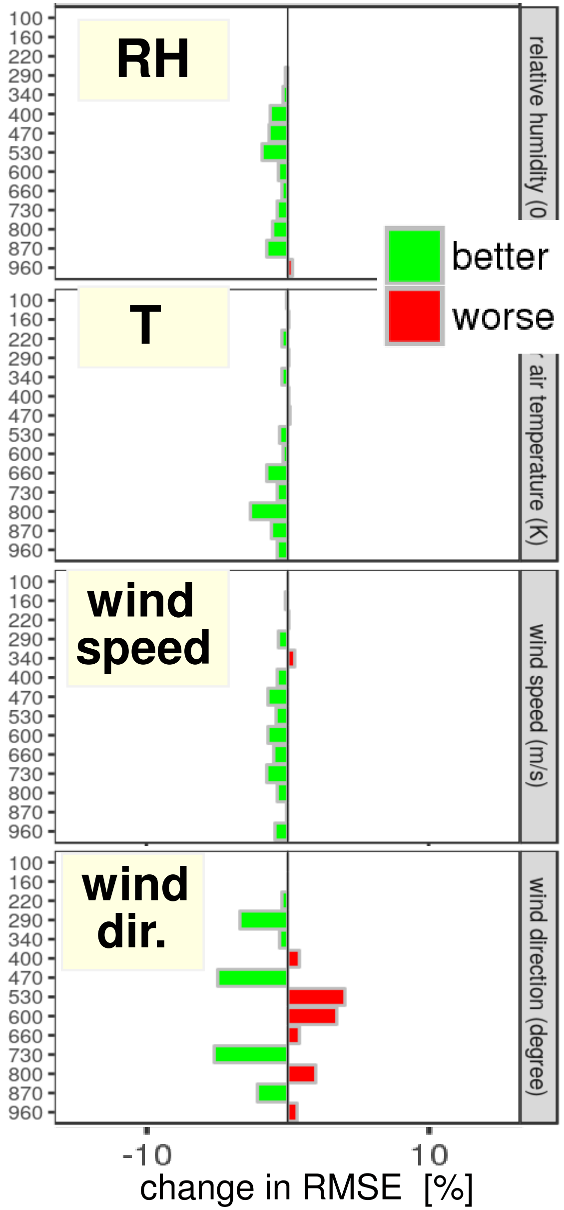
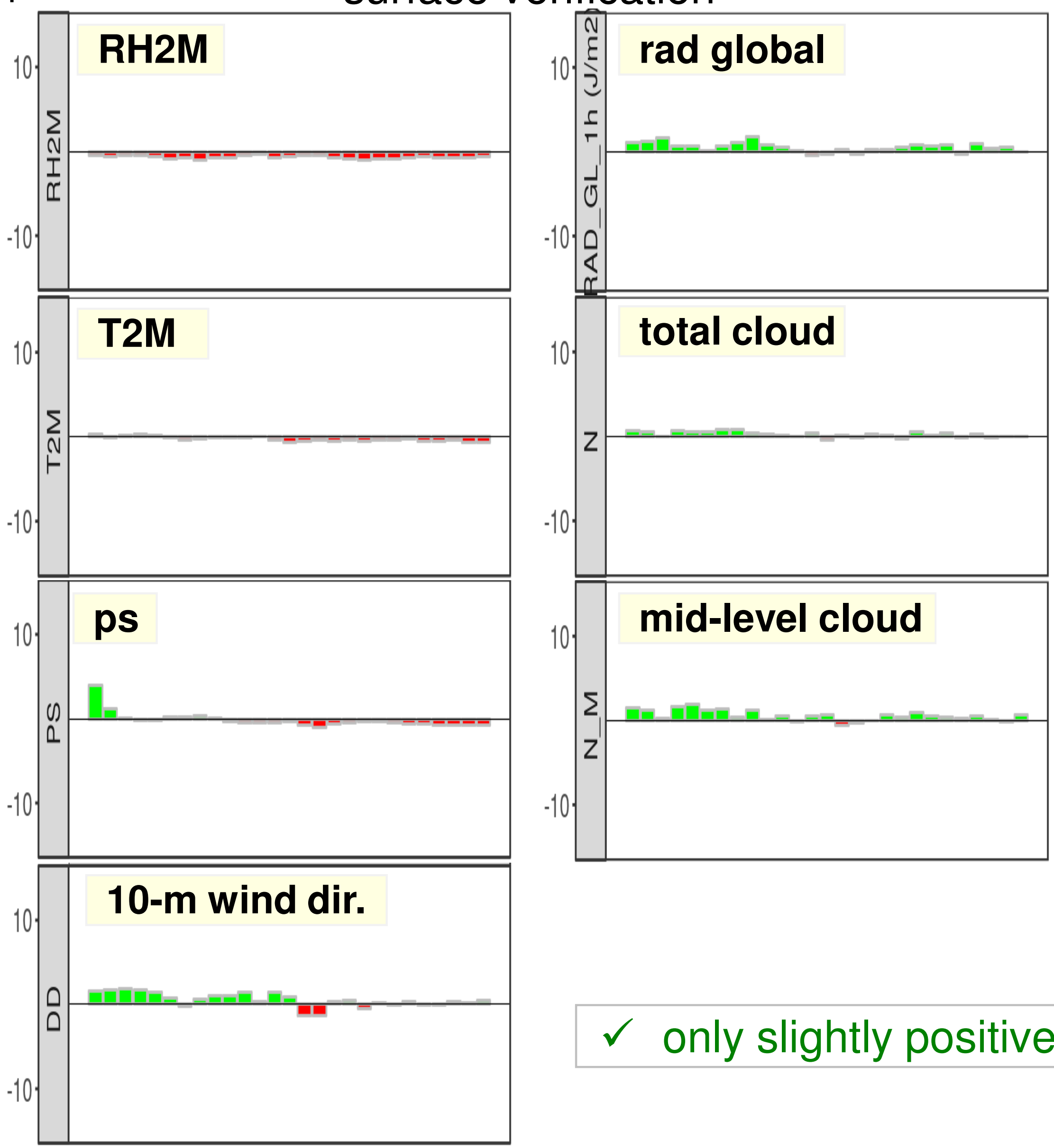
radiosonde verification

1 – 24 Sept. 2017



surface verification



✓ only slightly positive

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Mode-S aircraft:
winter test,   low-level cloud (low stratus)

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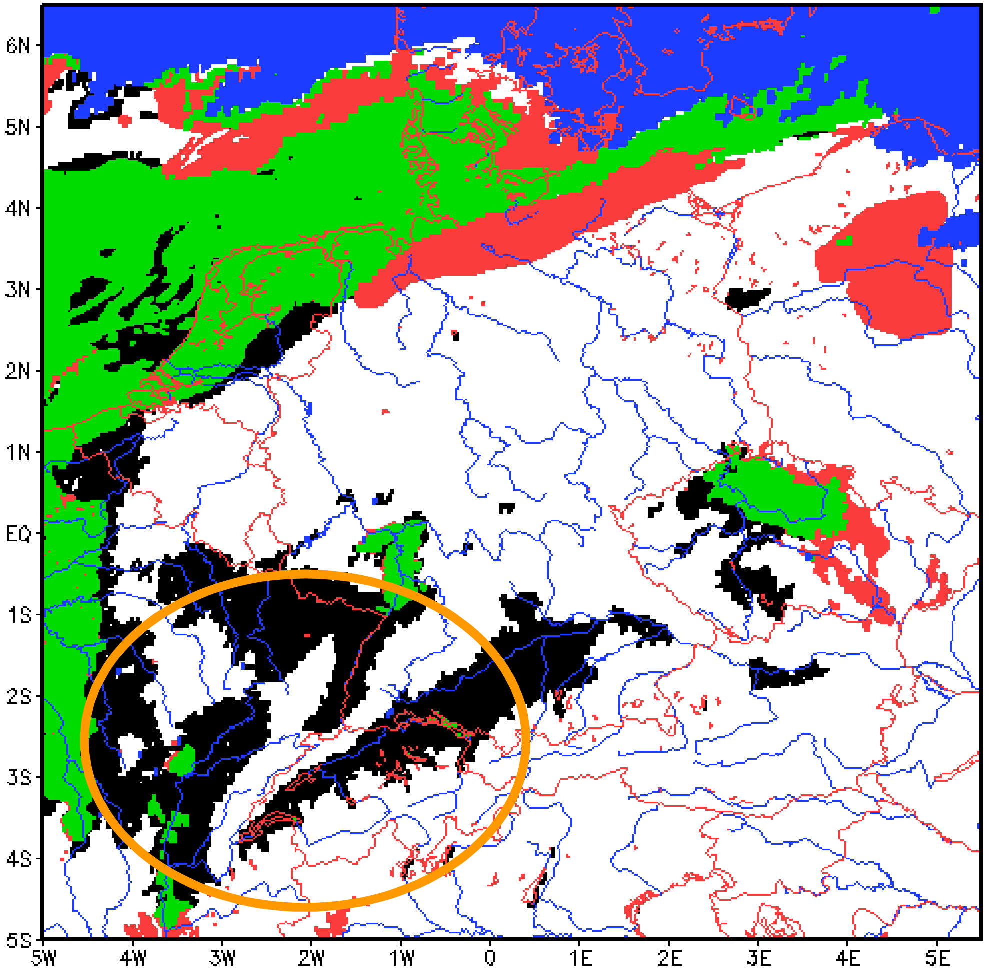
DWD

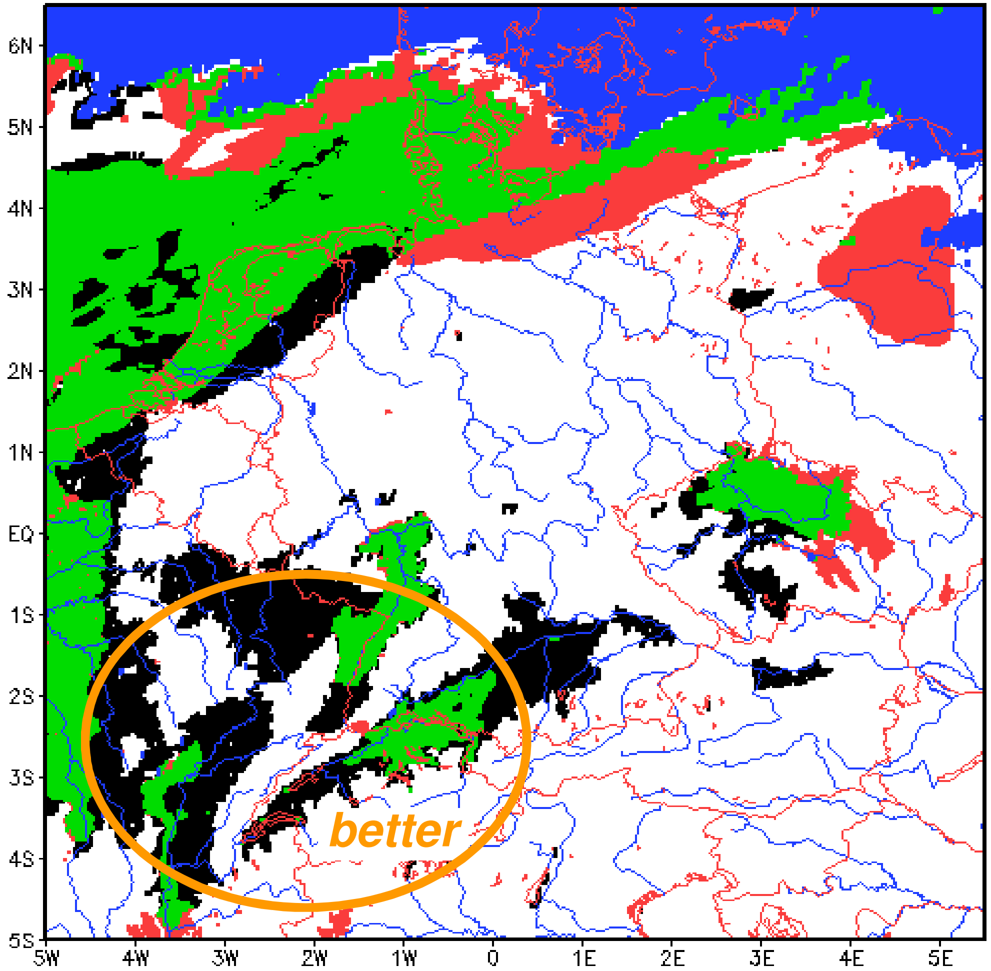
REF

exp_8000.04_HR_det_2016123012+06h
clcl



Mode-S

exp_8000.05_HR_det_2016123012+06h
clcl



Satellite:
Model:

hits / **missed events** / **false alarms** / **undefined** (observed mid-level, high, or fractional cloud)

missed (black): 21309 false (red): 12950 hits (green): 27447 unclear (blue): 18832
ETS: 0.321 FBI: 0.828

missed (black): 19905 false (red): 12150 hits (green): 28851 unclear (blue): 18832
ETS: 0.352 FBI: 0.840

Mode-S aircraft:
winter test, low-level cloud (low stratus)

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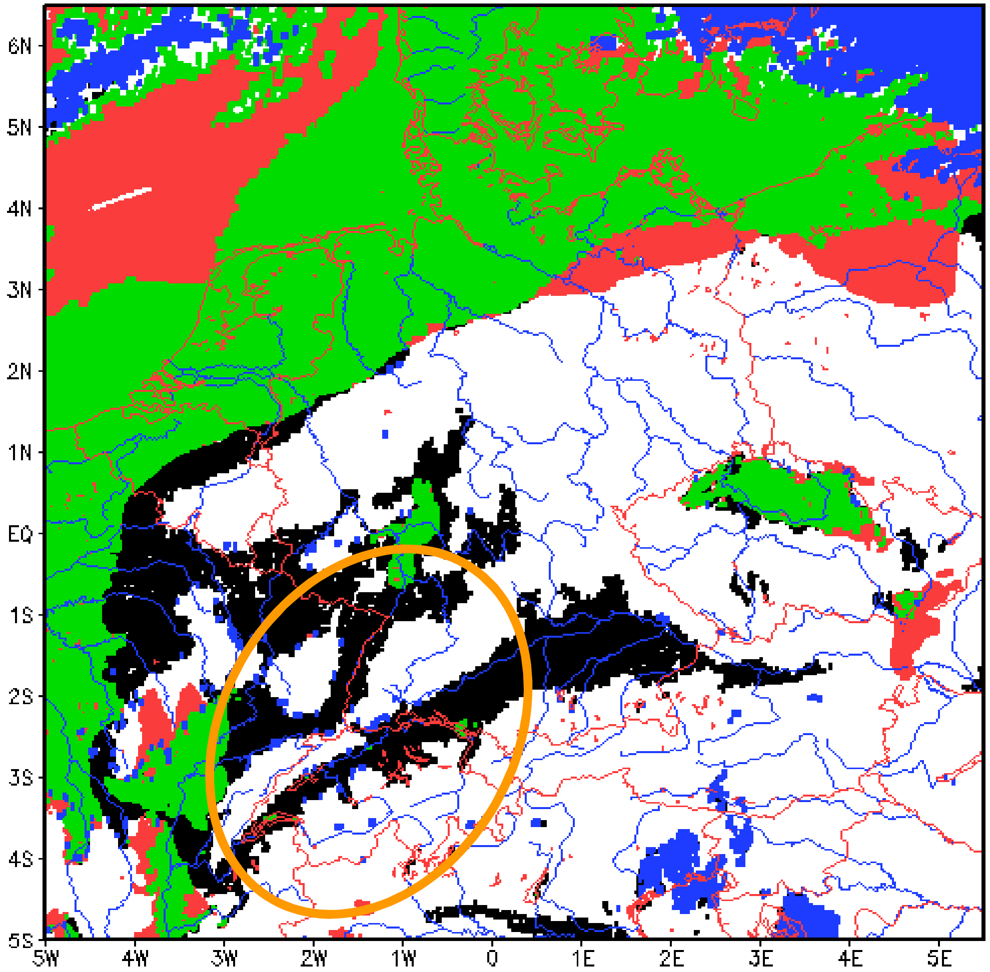
DWD

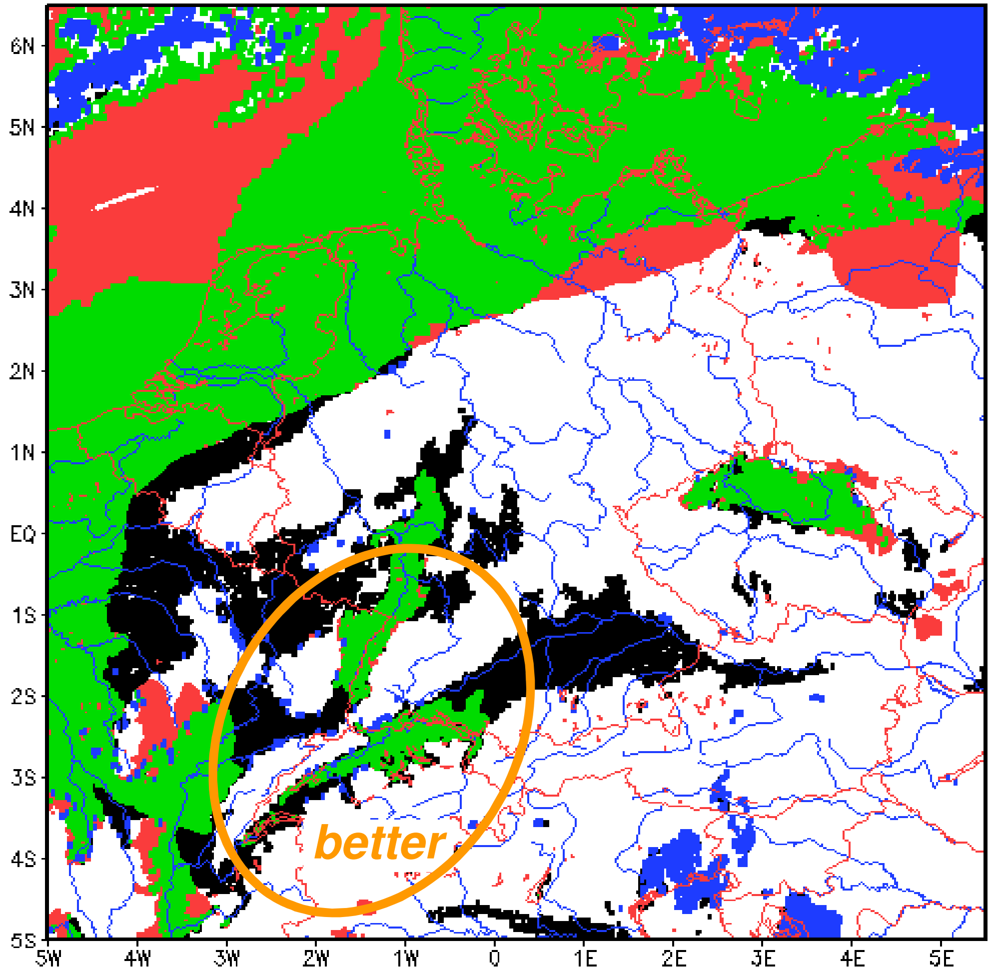
REF

exp_8000.04_HR_det_2016123012+18h
clcl



Mode-S

exp_8000.05_HR_det_2016123012+18h
clcl



Satellite:
Model:

hits / **missed events** / **false alarms** / **undefined** (observed mid-level, high, or fractional cloud)

missed (black): 19956 false (red): 19707 hits (green): 52658 unclear (blue): 8240
ETS: 0.380 FBI: 0.996

missed (black): 17496 false (red): 19482 hits (green): 55118 unclear (blue): 8240
ETS: 0.412 FBI: 1.027

Mode-S aircraft:
winter test, low-level cloud (low stratus)

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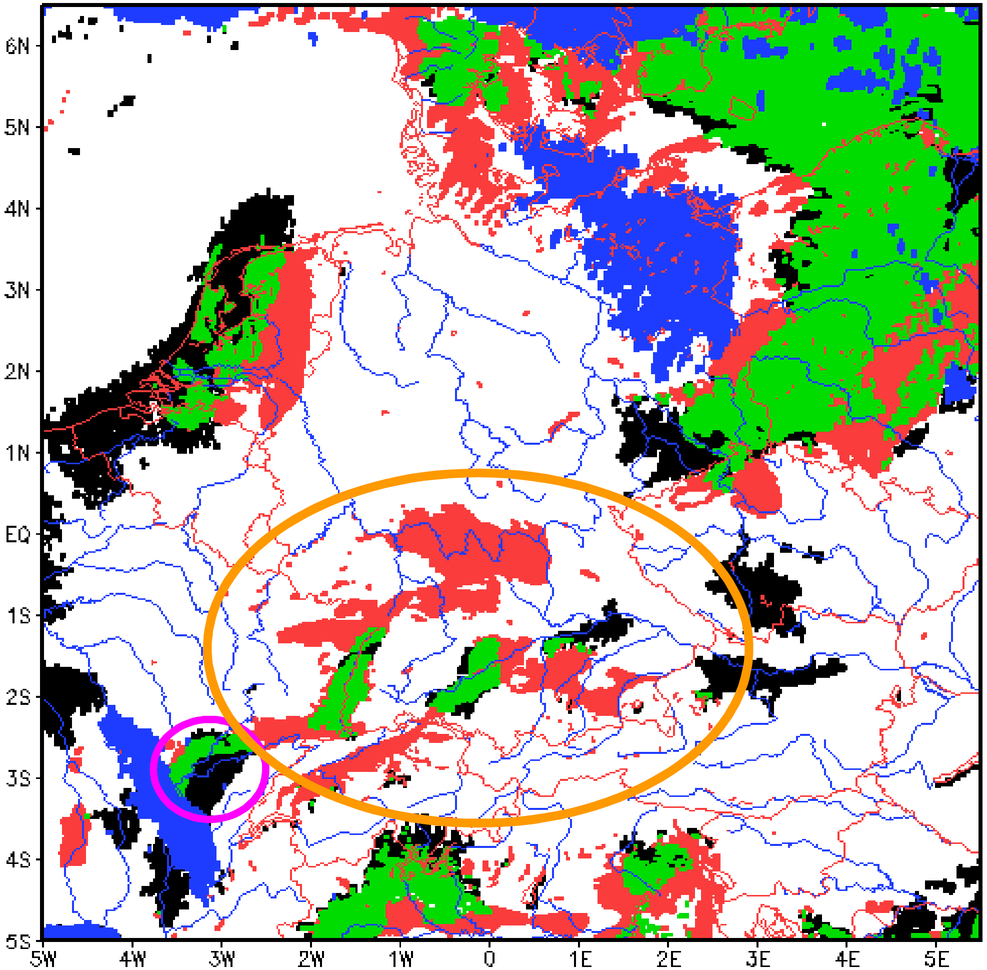
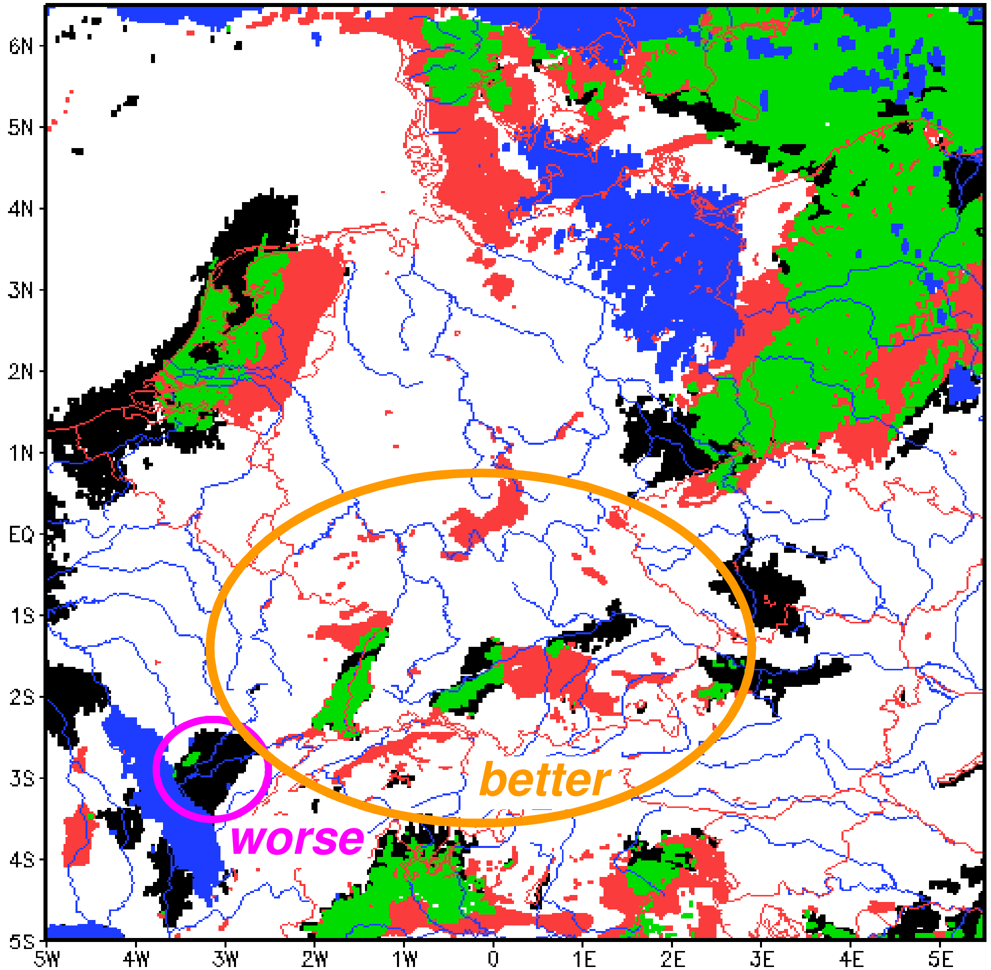
REF

exp_8000.04_HR_det_2016122912+06h
clcl



Mode-S

exp_8000.05_HR_det_2016122912+06h
clcl



Satellite:
Model:

hits / **missed events** / **false alarms** / **undefined** (observed mid-level, high, or fractional cloud)

missed (black): 14148 false (red): 18256 hits (green): 24156 unclear (blue): 10744
ETS: 0.320 FBI: 1.107

missed (black): 14429 false (red): 16065 hits (green): 23875 unclear (blue): 10744
ETS: 0.337 FBI: 1.042

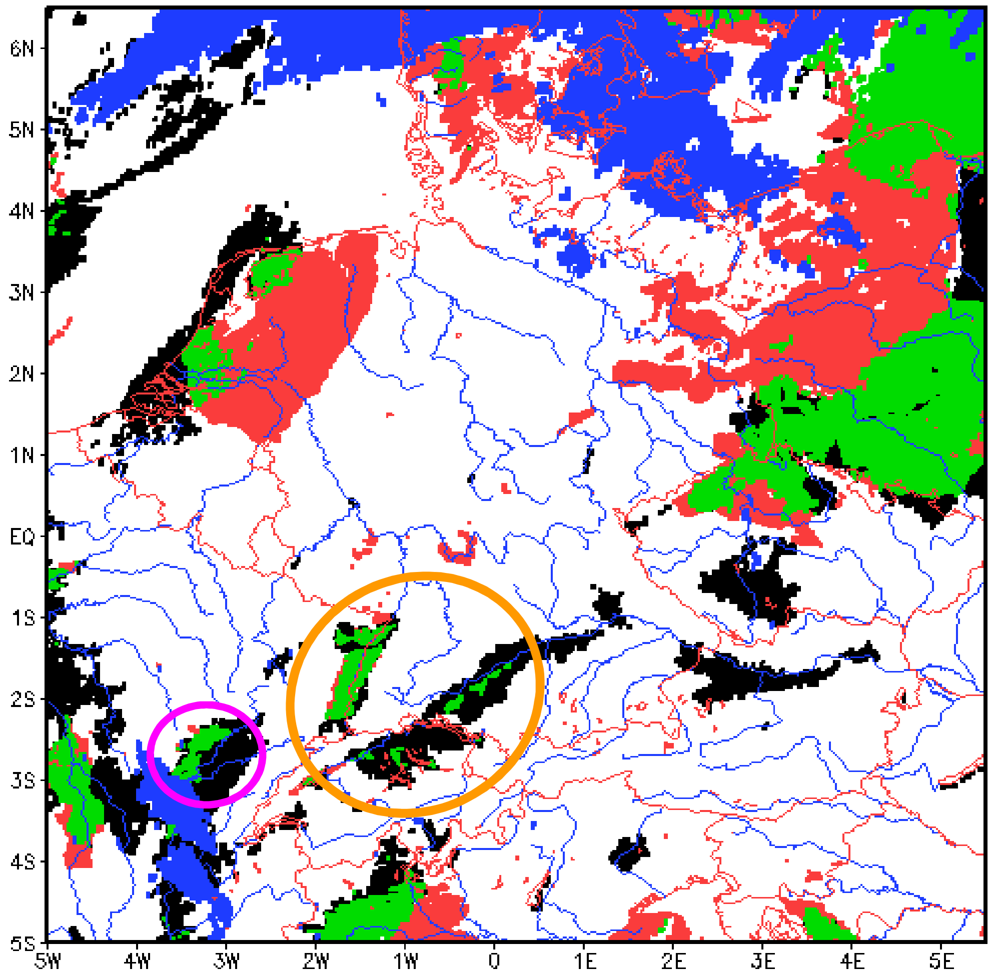
Mode-S aircraft:
winter test, low-level cloud (low stratus)

Deutscher Wetterdienst

DWD

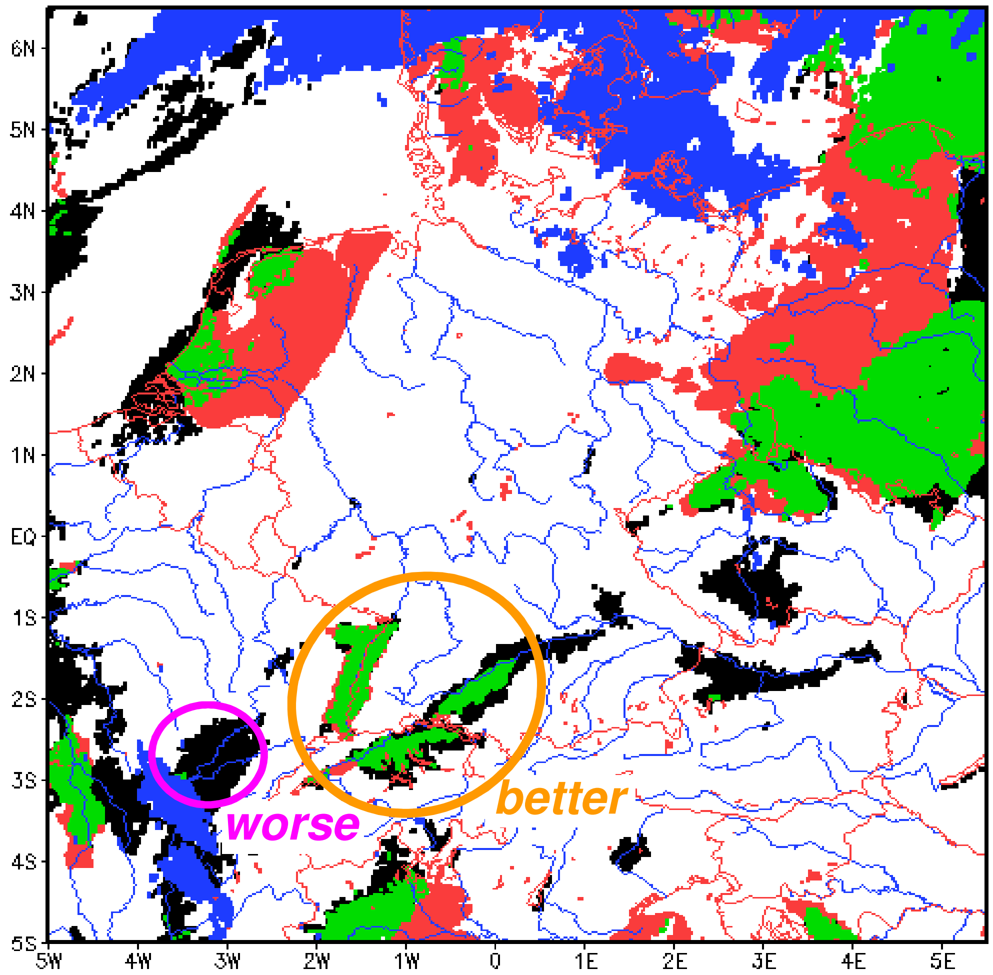
REF

exp_8000.04_HR_det_2016122918+06h
clcl



Mode-S

exp_8000.05_HR_det_2016122918+06h
clcl



Satellite:
Model:

hits / **missed events** / **false alarms** / **undefined** (observed mid-level, high, or fractional cloud)

missed (black): 14337 false (red): 18040 hits (green): 14081 unclear (blue): 14042
ETS: 0.217 FBI: 1.130

missed (black): 13105 false (red): 17132 hits (green): 15313 unclear (blue): 14042
ETS: 0.252 FBI: 1.141

Mode-S aircraft: summary

- ✓ impact tested in summer + winter,
  in BACY experiments (data cut-off time not taken into account) + in parallel suite
- ✓ impact varies between neutral and clearly positive
  (no single parameter in any test period worse)
- ✓ impact depends on weather situation: clearly positive for
  - precipitation in convective situations with weak advection / large-scale forcing
  - (radiative) low stratus

→ Mode-S operational 4 October 2017 (tomorrow)

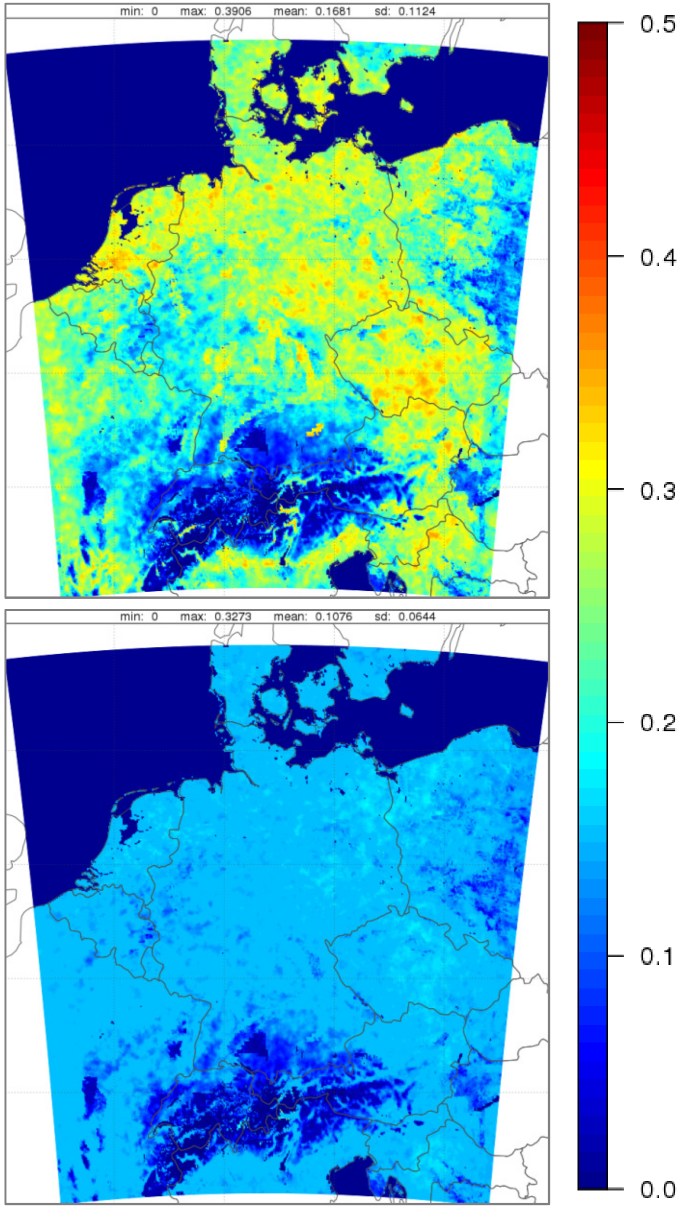
soft limiter of soil moisture perturbations: impact on a sunny day (23 June 2016)

spread of
soil moisture index
(14 UTC)

soil level 5 : 27 – 81 cm

original
(Exp 10396)

with SMP limiter
(Exp 10416)



✓ soft limiter: SMI spread limited to ~ 0.15 SMI

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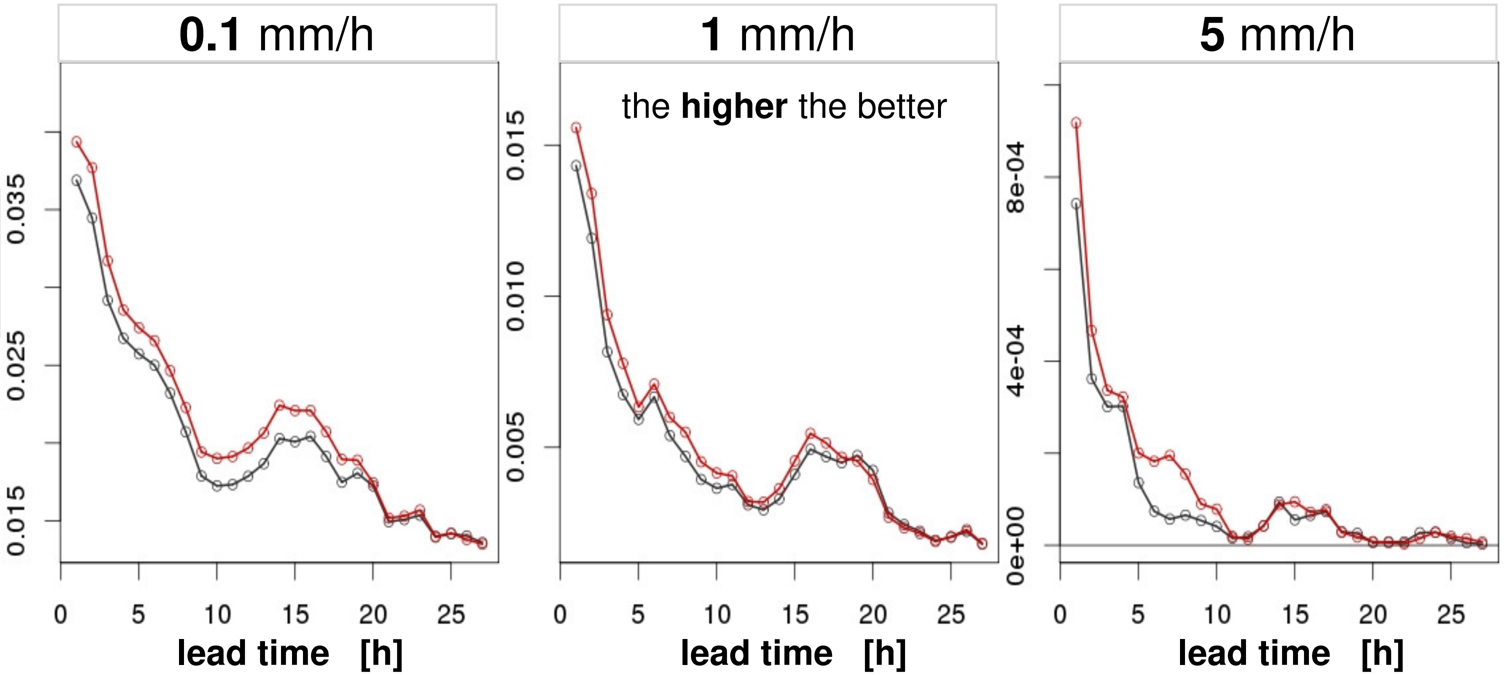
0-UTC runs

Brier Score decomposition

resolution:
ability of forecast to separate one type of outcome from another

original
SMP limiter

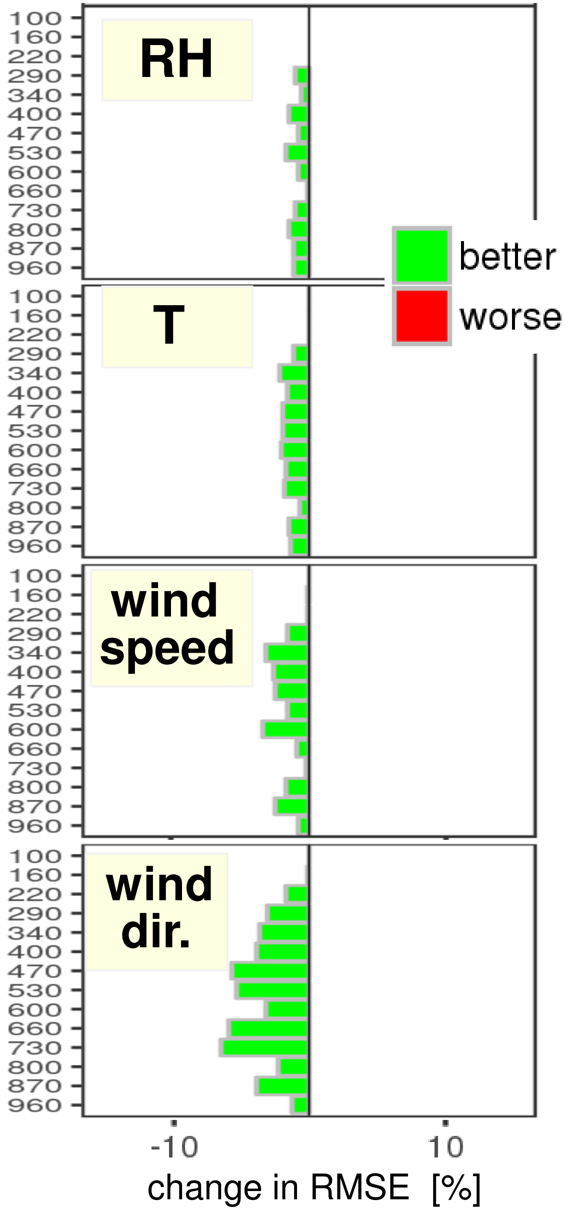


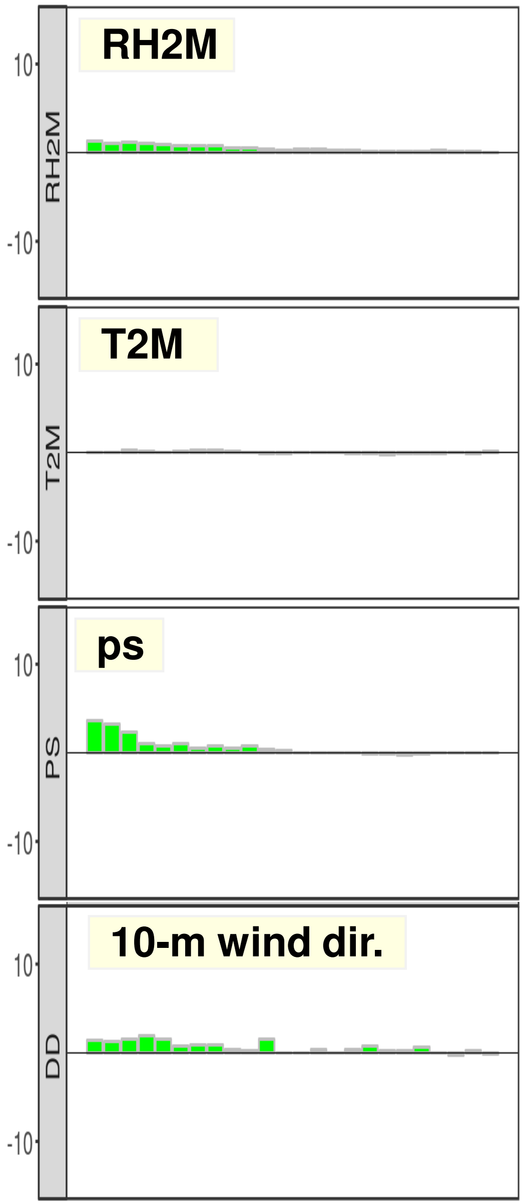
- ✓ better resolution (not susceptible to ensemble calibration)
- ✓ slightly better reliability (except high threshold, not shown)

reliability:
average agreement betw. fcst & obs val.; related to (cond.) bias

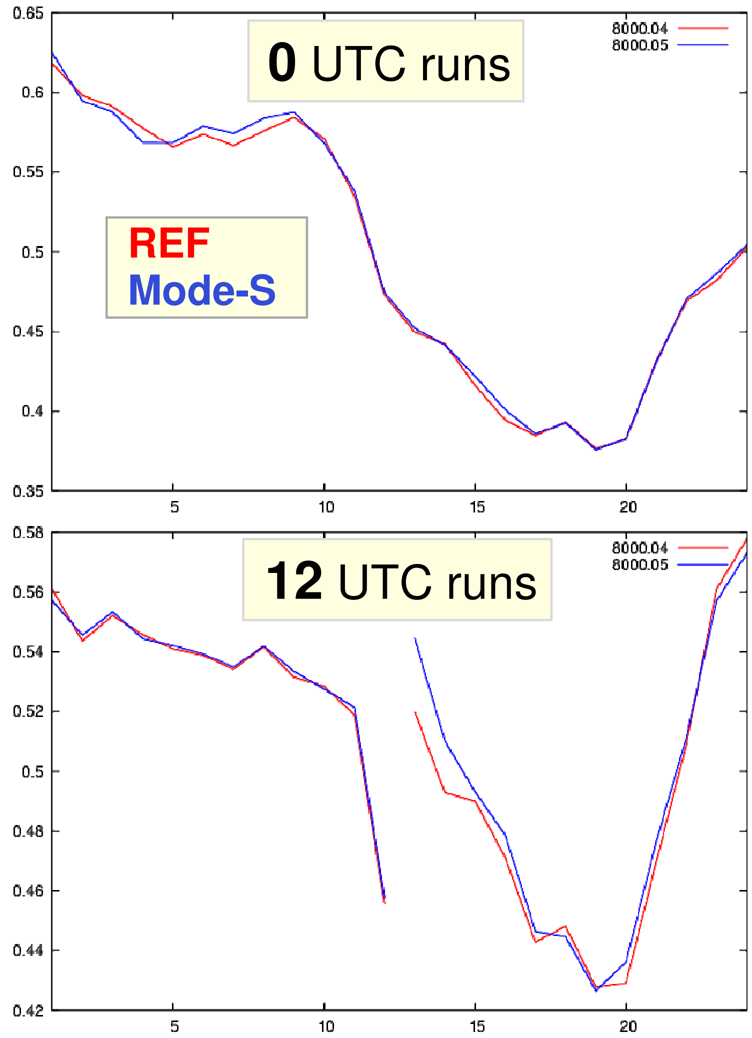
Mode-S aircraft: winter test, upper-air / surface / radar verif.

Dec 2016 (1 Dec. 2016 – 1 Jan. 2017)





FSS (precip 0.1 mm/h , 30 km)



✓ Dec. 2016: positive impact in upper-air + synop verif.

Task 4.2: Particle Filter (PF) methods
(to account for non-Gaussianity)

- hybrid ETKPF (Sylvain Robert (ETH) et al., study finished):
  - 1-week DA with PF for conv. obs in COSMO: f.g. (+1h) slightly improved over LETKF
  - studying several algorithms for adaptive choice for weight of EnKF and PF in analysis
    (idea: use PF where useful, fall back on EnKF where Gaussian or PF does not work well)
  - QJRMS: "A local ensemble transform Kalman particle filter for convective scale DA"

- Local adaptive PF (Roland Potthast et al., ongoing):
  - work with global ICON
    (improved resampling to create new members)
  - PF runs stably in 1-month tests
    scores still about 20% worse than LETKF
  - hybrid PF-Var: using PF ensemble in EnVar
    for deterministic analysis:

    → forecasts only slightly worse than
    operational EnVar with ensemble B from LETKF
    (promising!)

global TEMP verif, 2–24 May.2016