KENDA-O + WG1 overview

Deutscher Wetterdienst

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

- Task 1: further development of LETKF scheme
  - investigation of discrepancies betw. MCH and DWD KENDA performance
  - Mode-S operational at DWD: winter test + revision of QC
  - activities at MeteoSwiss → climatological B
  - HMC: model-error perturbations
- Task 2: extended use of observations (radar, satellite, etc.)
- Task 3: lower boundary: soil moisture analysis using satellite soil moisture data
  (up to now small benefit, fellowship ends 12/18, will continue with little FTE)
- Task 4: adaptation to ICON-LAM, hybrid methods / particle filters

KENDA at DWD: operational setup

(→ Schraff et al. 2016, QJRMS)

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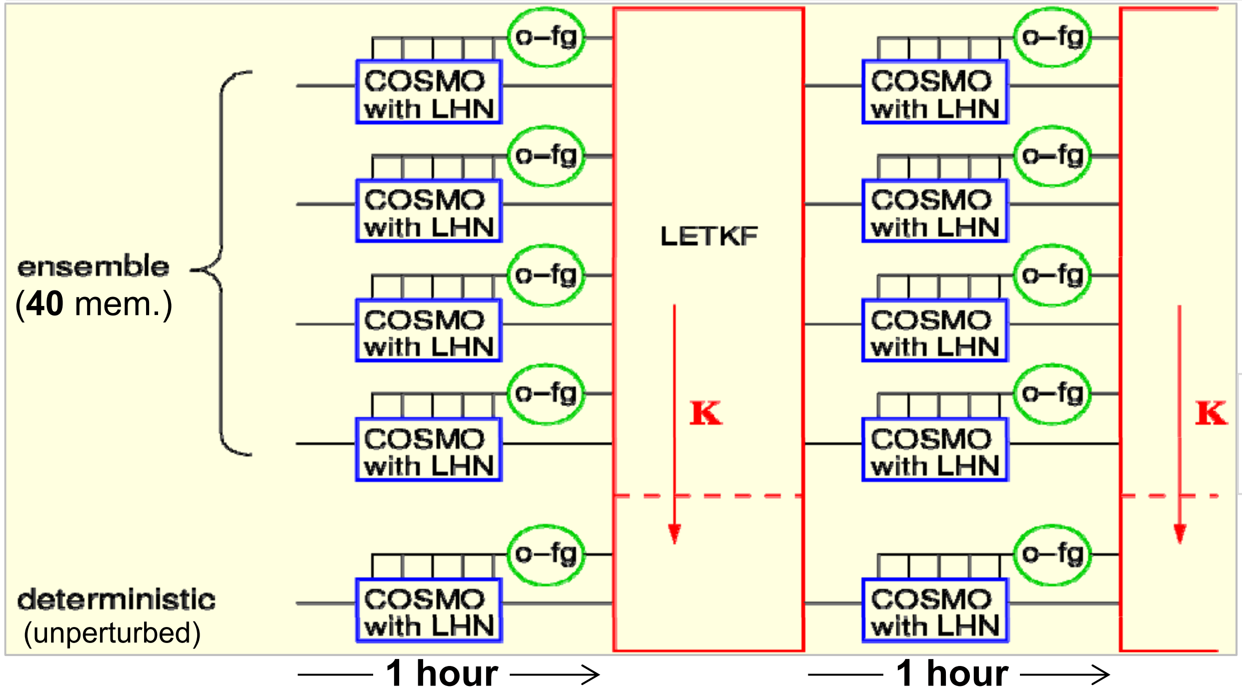
KENDA: 4D-LETKF + LHN (latent heat nudging for assimilation of radar precip)



LETKF: operationally conventional obs only (TEMP, AMDAR, SYNOP, Wind Profiler, (Mode-S))

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

operational settings:

- **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)
- **additive** covariance **inflation** (since Feb. 2017)
- explicit soil moisture perturbations
- lateral **BC**: from **ICON-EnVar/LETKF** (Δx = 20 km / 6.5 km for ensemble / deterministic run)

In Task 1: Investigation of discrepancies between MeteoSwiss & DWD KENDA

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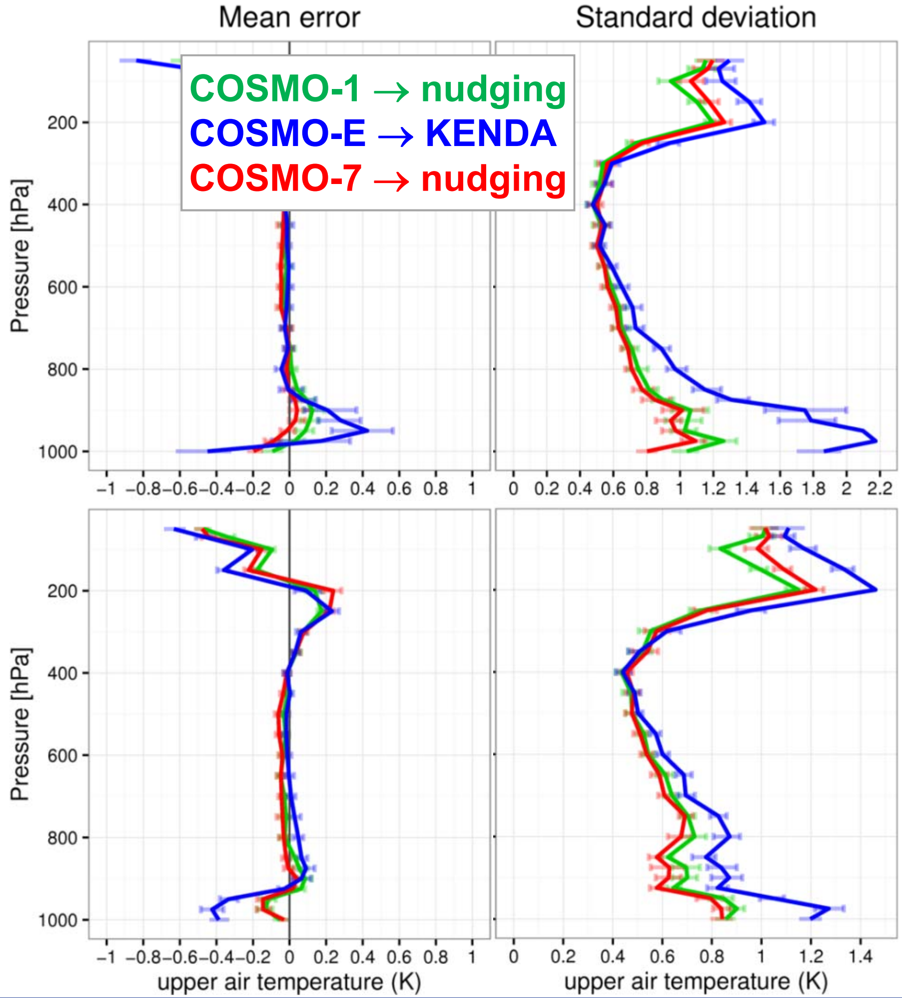
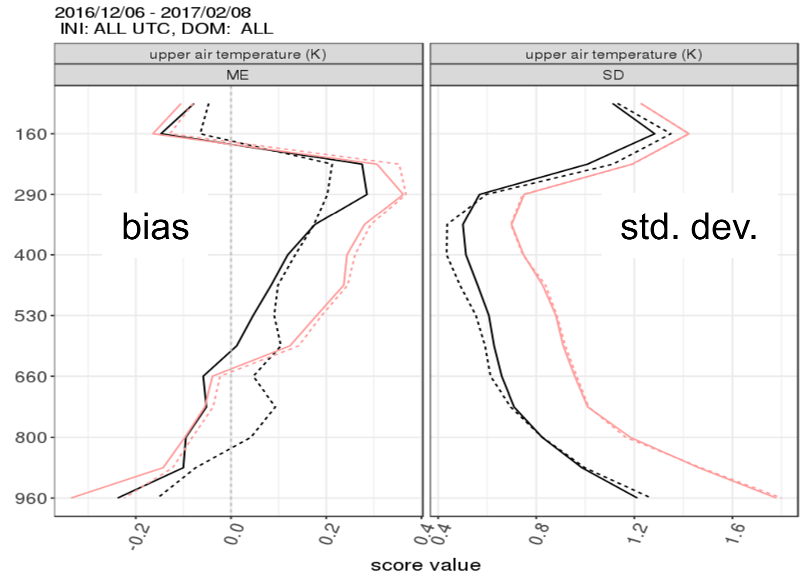
MeteoSwiss analysis verification | temperature | DWD verification

+ 0 h

Winter 2016 (w/o S_SO pert.)

Spring 2017 (with SPPT)





— COSMO-DE → with nudging

--- COSMO-DE-KENDA (without additive inflation)

lead-time [h]

— 000

— 012

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In Task 1: Investigation of discrepancies between MeteoSwiss & DWD KENDA

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generally: same LETKF configurations at MCH and DWD

relevant differences :

	MCH	DWD
model domain	COSMO-E, 2.2 km (16-bit coding of T_SO)	COSMO-DE, 2.8 km
lateral BC	IFS HRES + EPS perturb. age of perturb.: +30h to +36h	ICON EPS
radiosonde obs	BUFR reports (→ 100 % more RS obs), obs time = nominal synoptic time wind obs error: 1.7 – 2.1 m/s	TEMP reports obs time = launch time wind obs error: 1.9 – 2.4 m/s

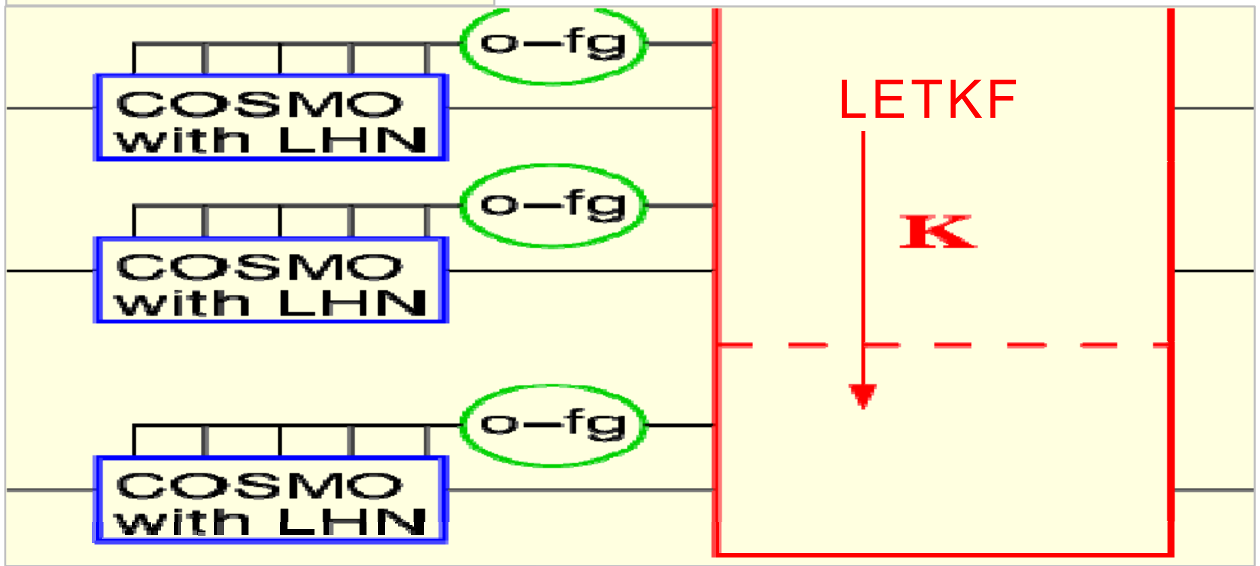
‘**Swiss experiment**’ at DWD: comparison KENDA vs. Nudging for Dec. 2016 (winter, extended low stratus periods)

- DWD setup (KENDA, ICON-LBC, obs (no Mode-S)), but on **COSMO-E domain**
- perform verification as at MCH (vs. at DWD):
  - use BUFR radiosonde reports vs. TEMP radiosonde reports
  - MEC applied to cdfin-files vs. MEC applied to ‘ekf’ fdbk files from LETKF

In Task 1: Investigation of discrepancies between MeteoSwiss & DWD KENDA

first guess check: reject obs y if: $|\,y - H(\mathbf{x})\,| > \Delta y_{thresh}$

KENDA: 4D-LETKF



applied in COSMO:

– obs operator H
  $\rightarrow y - H(\mathbf{x}_{fg})$

– 'COSMO-FG check':
  thresholds Δy_{thresh} **tuned** to cope with low-level inversions

→ 'fof' fdbk files →

applied in LETKF:

– 'LETKF-FG check':
  generic thresholds Δy_{thresh} (see later)
  rejects **additional** obs

→ 'ekf' fdbk files →

'cdfin' observation files ↓

MEC for verif @ MCH

– obs operator H
  $\rightarrow y - H(\mathbf{x}_1)$

– 'COSMO-FG check' applied to first model state $\mathbf{x}_1$ that is read by MEC

MEC for verif @ DWD

→ use analysis flags

→ obs **not** used in verification if either rejected in 'COSMO-FG check' or 'LETKF-FG check'

In Task 1: Investigation of discrepancies between MeteoSwiss & DWD KENDA

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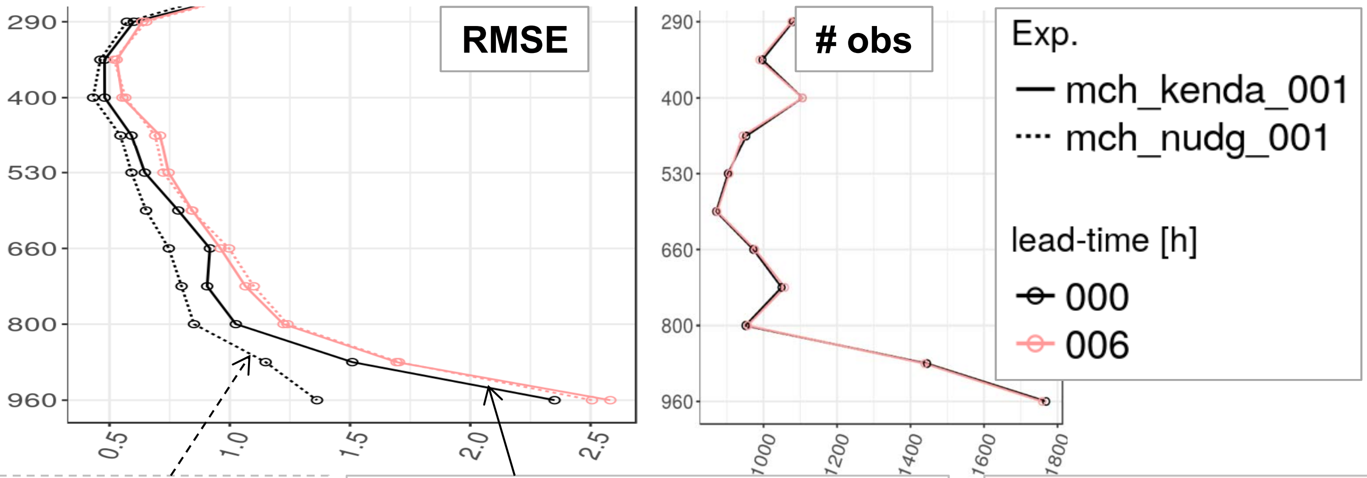
DWD

temperature
1 – 27 Dec 2016

MEC based on DWD cdfin files

→ only 'COSMO' first guess check but no LETKF first guess check



~ all obs being used in verif. also used in nudging analysis

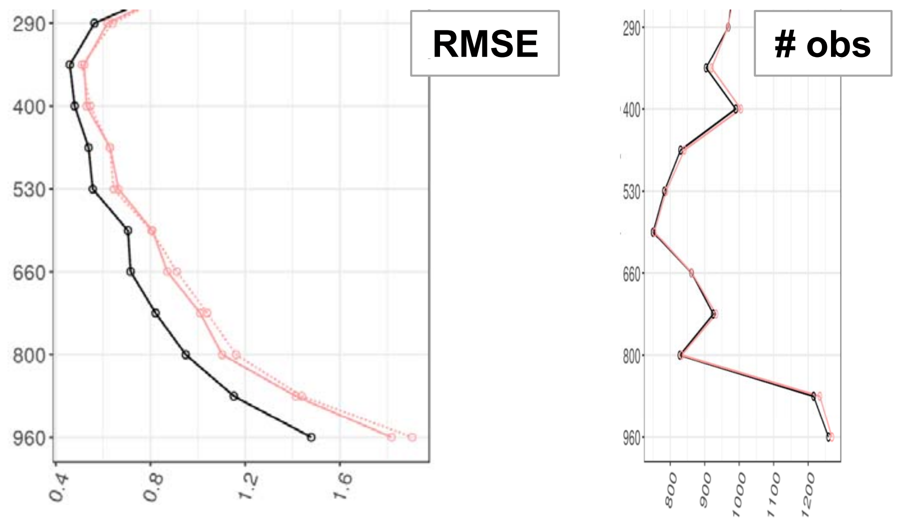
quite a few obs used in verif. not used in KENDA analysis

→ unfair comparison does not tell anything about analysis quality!
… but set of obs in verif is ok to judge forecast quality!

MEC based on DWD ekf files

→ with LETKF first guess check

→ good fit of KENDA analysis to obs (PBL) (like KENDA @ DWD for COSMO-DE)



→ LETKF f.g. check rejects too many obs (near inversions, for verif & analysis)

In Task 1: Investigation of discrepancies between MeteoSwiss & DWD KENDA

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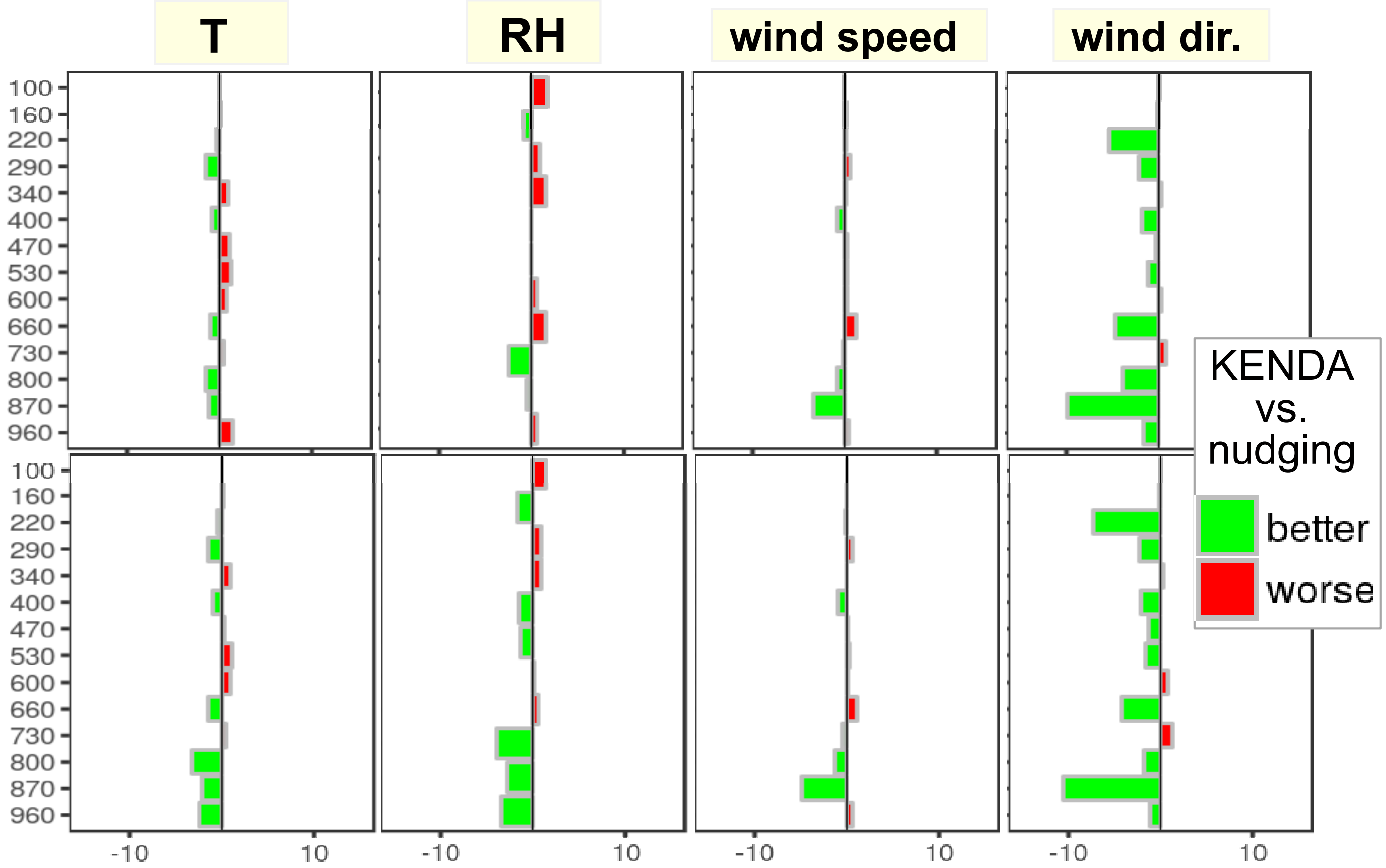
6 – 24 h forecasts:
radiosonde verification

MEC based on DWD cdfin files
→ no LETKF first guess check
1 – 31 Dec 2016

MEC based on DWD ekf files
→ with LETKF first guess check
1 – 27 Dec 2016



→ MEC mode: no effect on wind scores, but affects T + RH at low levels

→ ekf-based MEC gives slightly too optimistic forecast scores in strong inversion periods (as long as the LETKF first guess check is not improved)

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In Task 1: Investigation of discrepancies between MeteoSwiss & DWD KENDA

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✓ COSMO first guess check (as in cdfin-based MEC verif.) rejects very few data

✓ LETKF first guess check rejects about 5% for T, RH and about 2.5% for wind, particularly near inversions (and in stratosphere)

→ too many good obs are rejected (*in the presence of strong systematic model errors*)

→ **discrepancies in upper-air analysis scores at MCH and DWD are** (apparently)

- mainly **not** due to difference in analysis and forecast performance of KENDA as a result of different model domains, ensemble LBC's, data input, etc.
- **but mainly due to different quality control in verification**

→ **solution:**
- **improve model, eliminate systematic model errors**
- **refine first guess check in LETKF analysis** (see later)

Mode-S EHS (Enhanced Surveillance) aircraft data

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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)

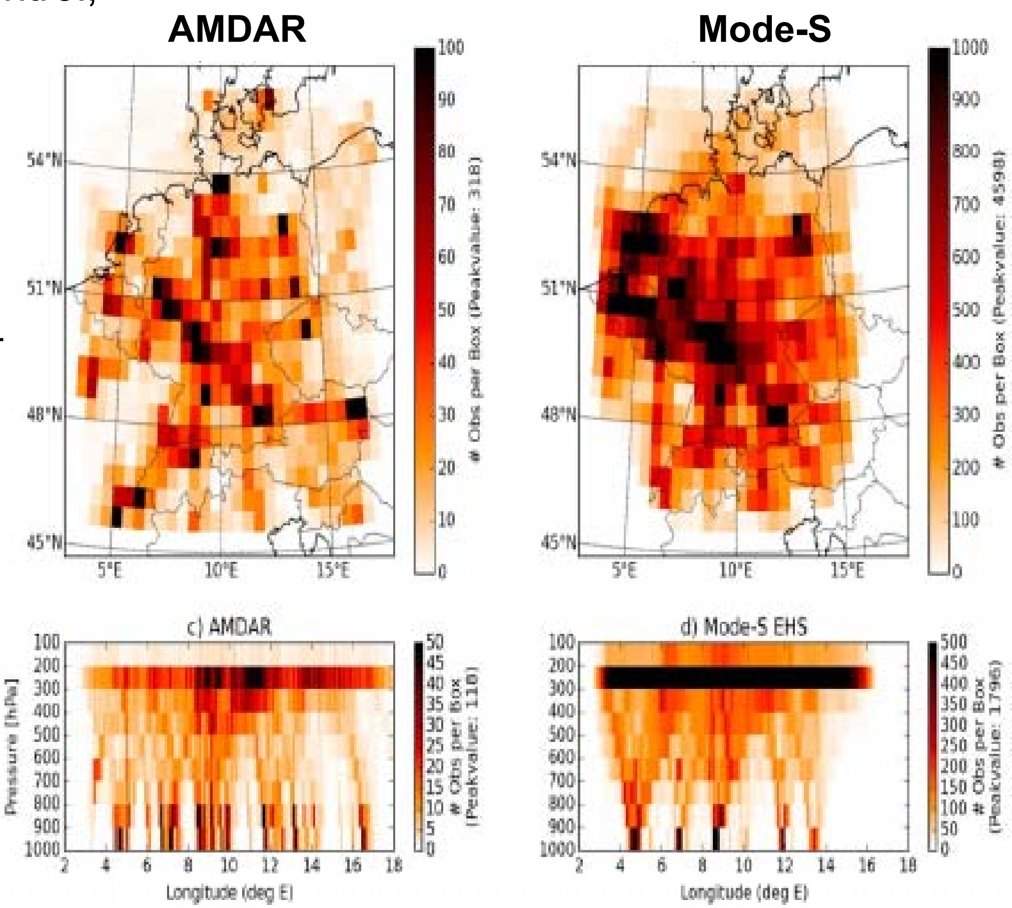
- best results with thinning (40 % active), still 5 times more data than AMDAR

- wind vector (obs error similar as AMDAR) +
  temperature (obs error 50 – 100 % larger at low levels)
  (no humidity)

results shown last year:

- convective period:
  clear + long-lasting positive impact
  (precip, surface + upper-air verif.)
- much smaller positive impact in August

→ winter ?



obs per day – from: *Lange and Janjic, MWR 2016*

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Mode-S aircraft:
winter test (Dec. 2016), verification

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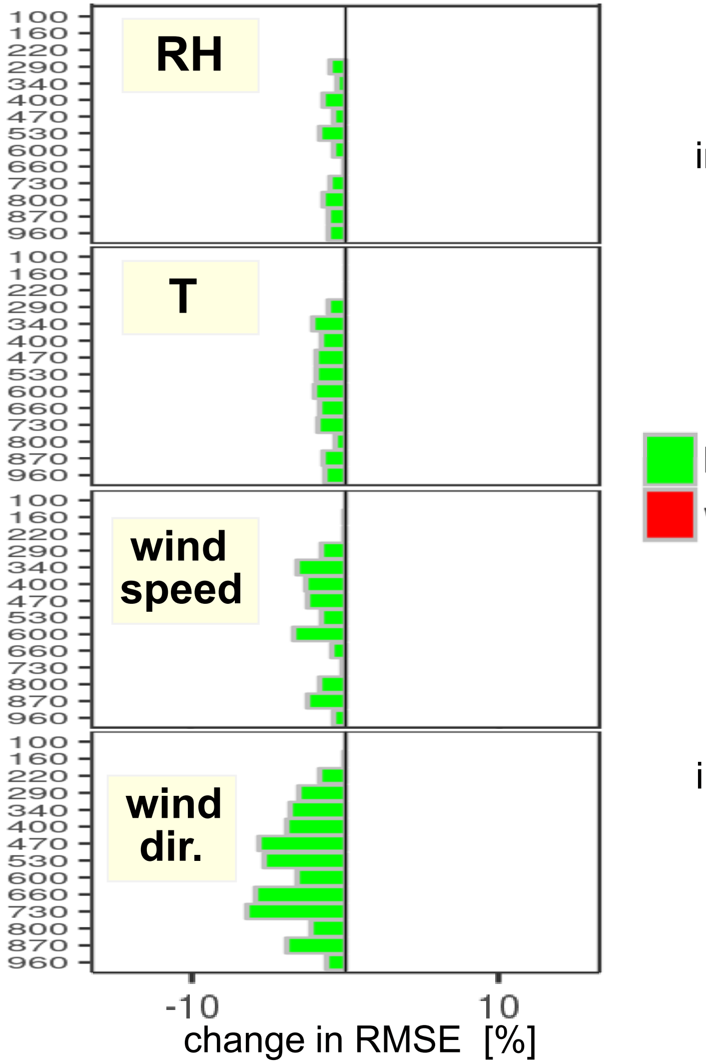
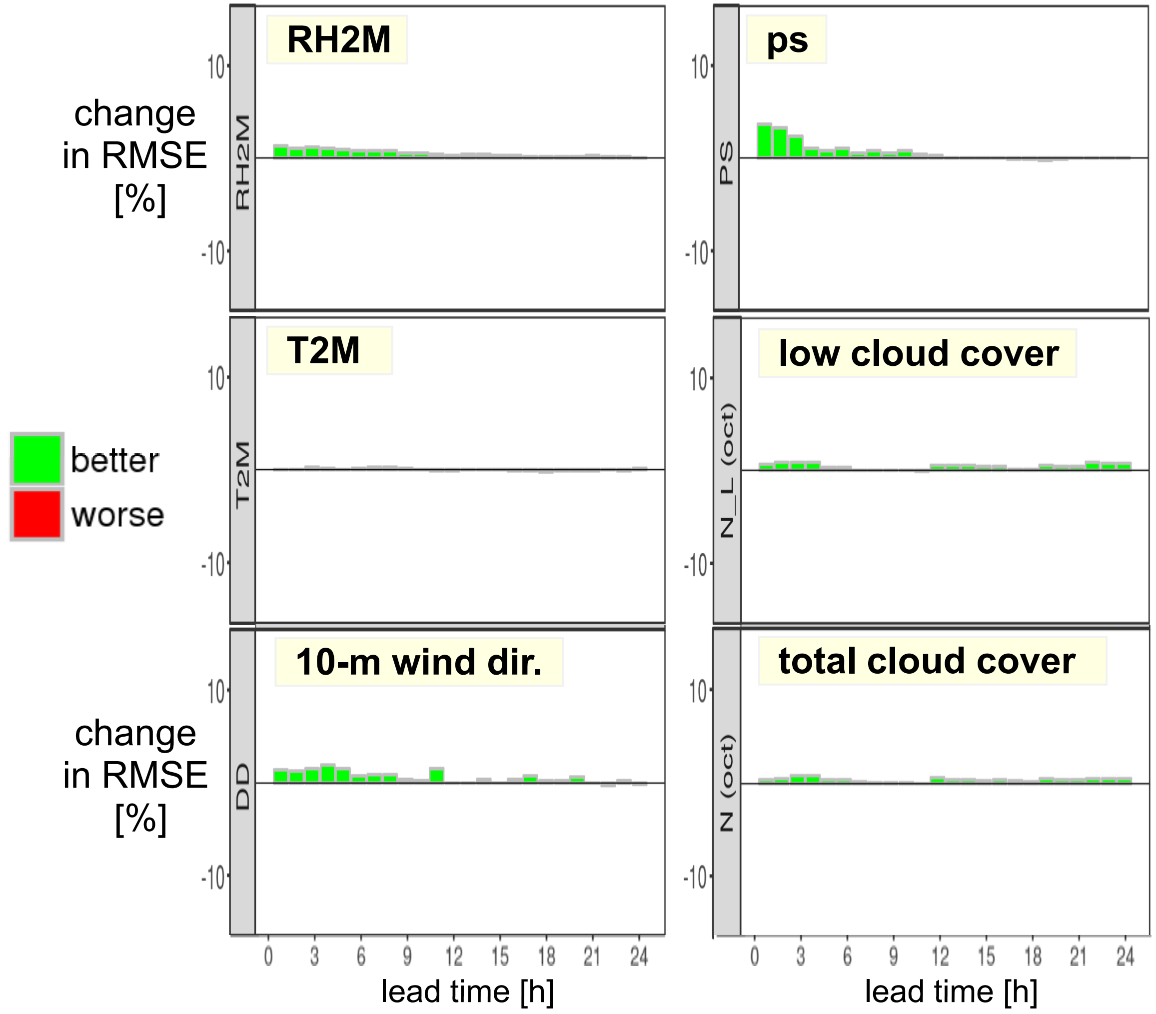
radiosonde verification



averaged over 6-, 12-, 18-, 24-h forecasts

surface verification



✓ Dec. 2016: positive impact (precip neutral)

Mode-S aircraft: radiative low stratus in winter low-level cloud (vs. NWC-SAF)

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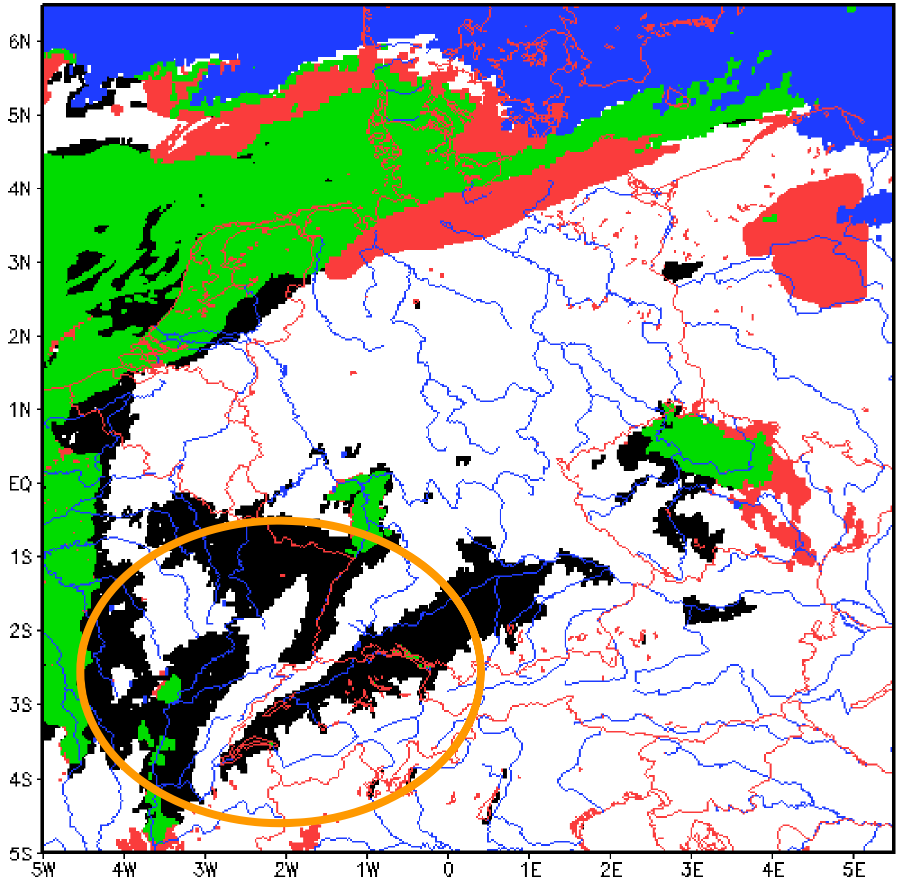
REF

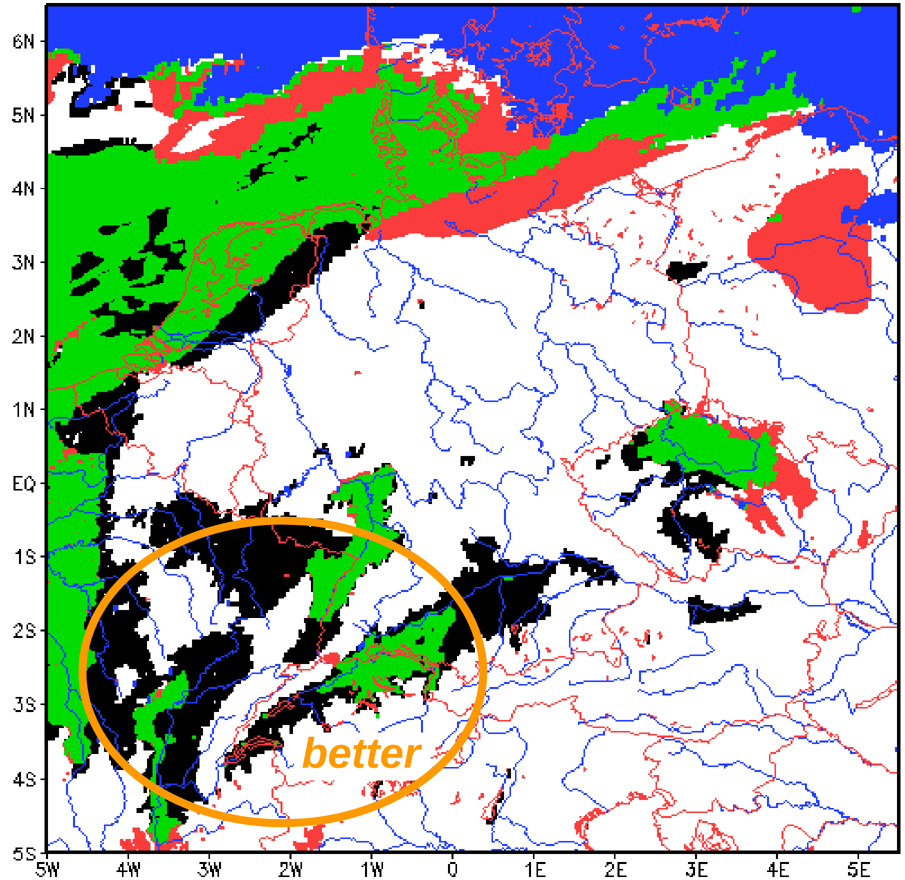
exp_8000.04_HR_det_2016123012+06h
clcl



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

Mode-S

exp_8000.05_HR_det_2016123012+06h
clcl



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

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

Mode-S aircraft: radiative low stratus in winter low-level cloud (vs. NWC-SAF)

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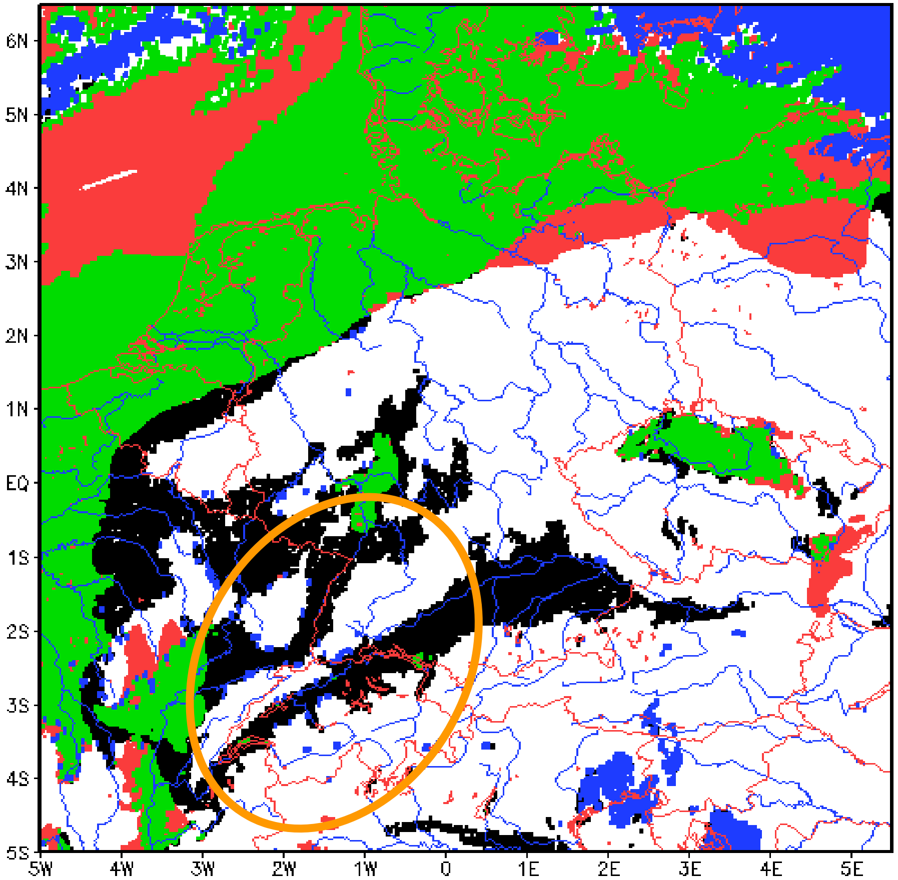

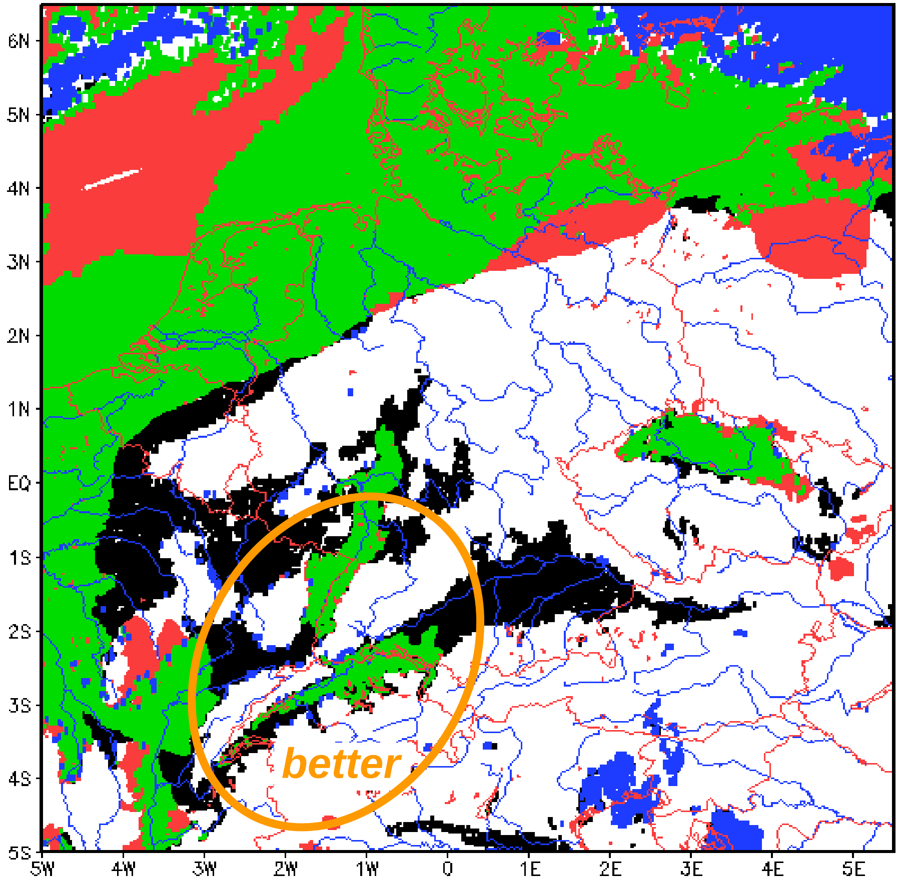

correct cloudy / correct cloud-free / missed events / false alarms / undefined (observed higher cloud)

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: radiative low stratus in winter
low-level cloud (vs. NWC-SAF)

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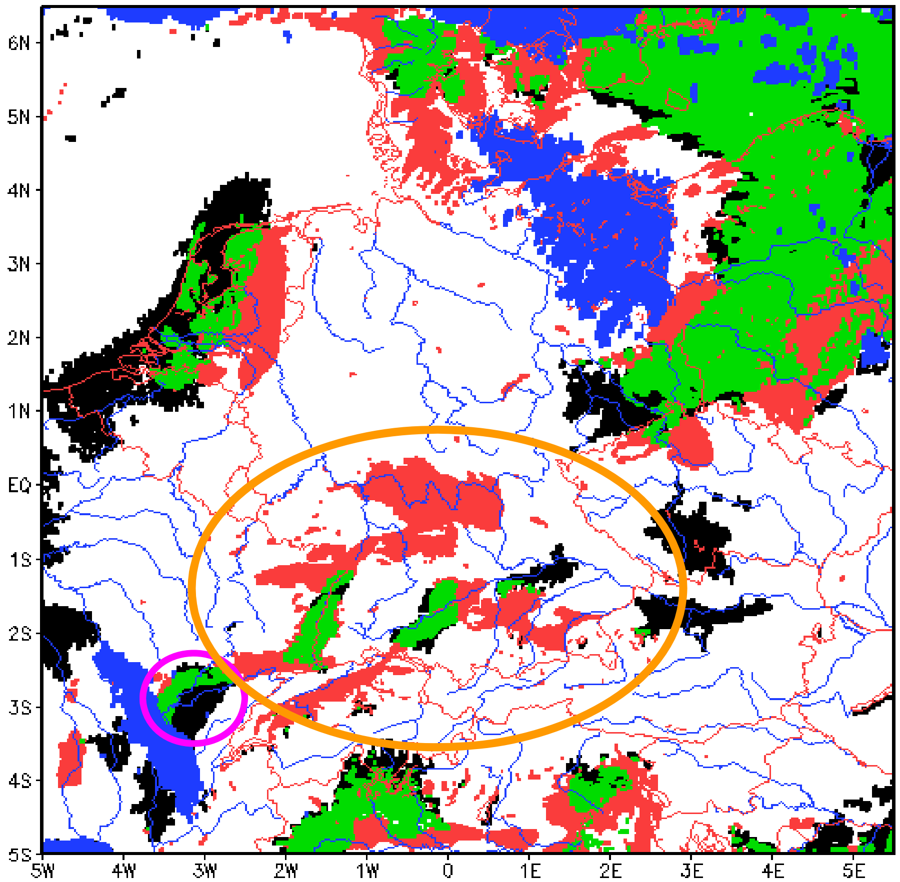
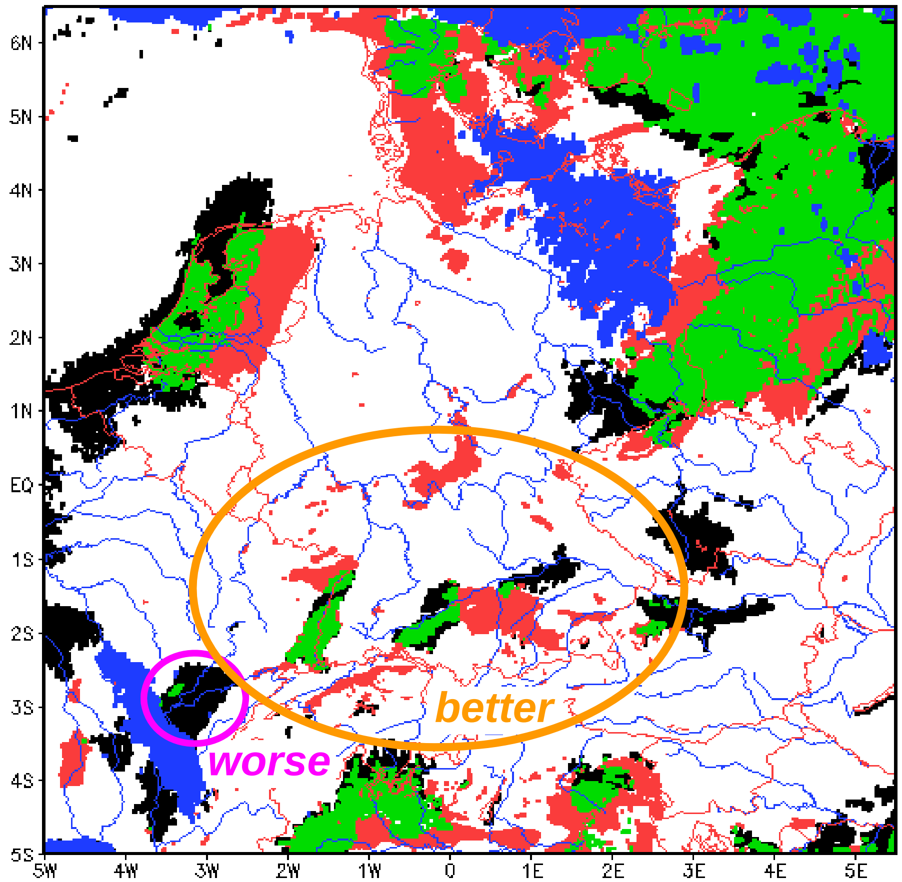
REF

exp_8000.04_HR_det_2016122912+06h
clcl



Mode-S

exp_8000.05_HR_det_2016122912+06h
clcl



correct cloudy / correct cloud-free / missed events / false alarms / undefined (observed higher 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: radiative low stratus in winter
low-level cloud (vs. NWC-SAF)

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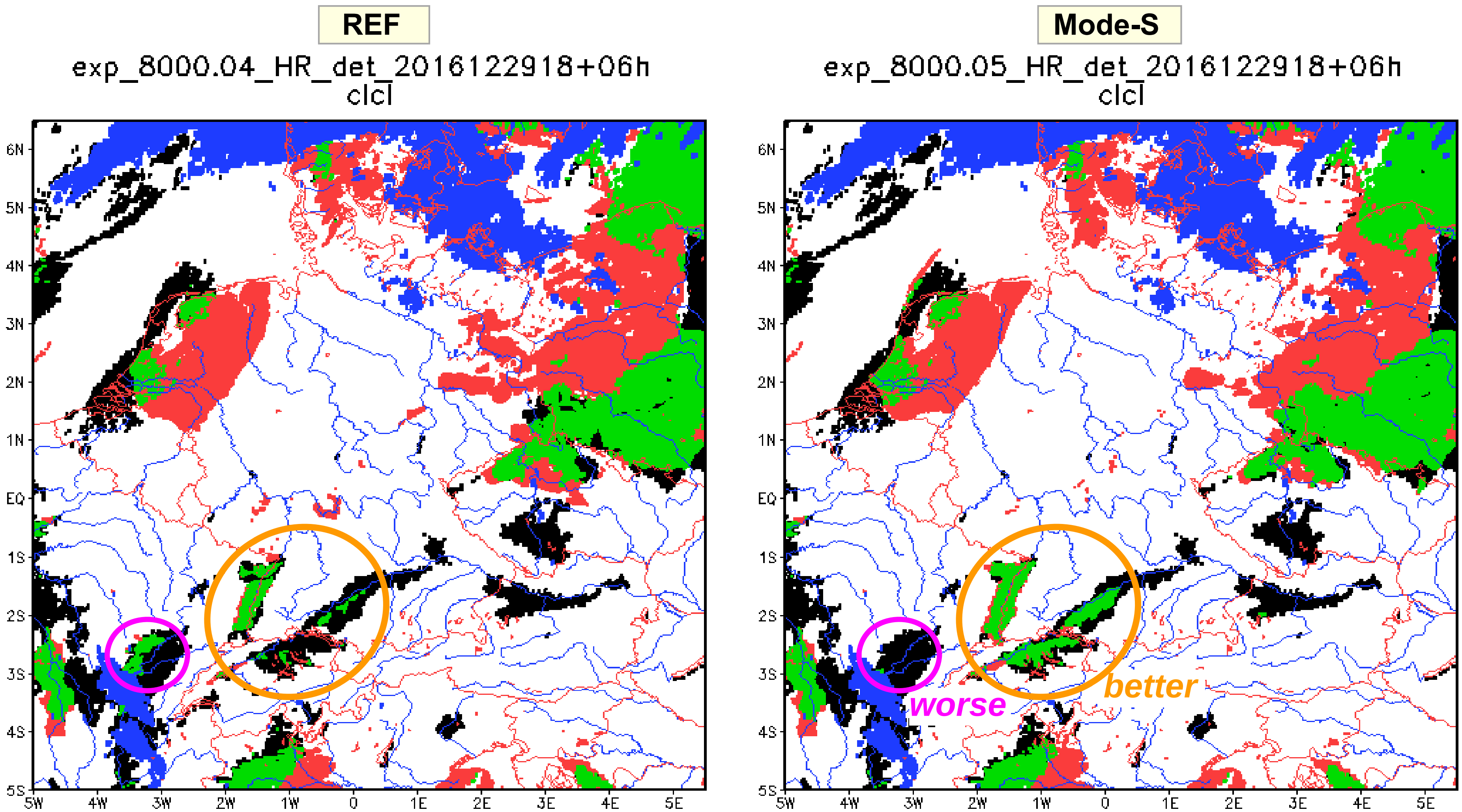


correct cloudy / **correct cloud-free** / **missed events** / **false alarms** / **undefined** (observed higher cloud)

REF	Mode-S
missed (black): 14337 false (red): 18040 hits (green): 14081 unclear (blue): 14042	missed (black): 13105 false (red): 17132 hits (green): 15313 unclear (blue): 14042
ETS: 0.217 FBI: 1.130	ETS: 0.252 FBI: 1.141

Impact of Mode-S aircraft: summary

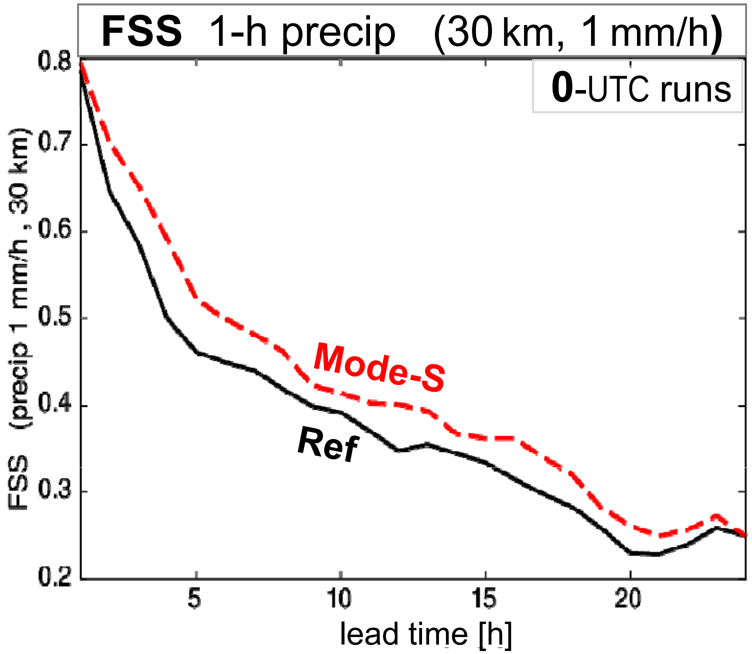
✓ impact of Mode-S depends on weather situation:

from very slightly to

clearly positive for

- (radiative) low stratus
- convective precipitation in summer →

26 May – 10 June 2016



→ Mode-S operational 4 October 2017

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

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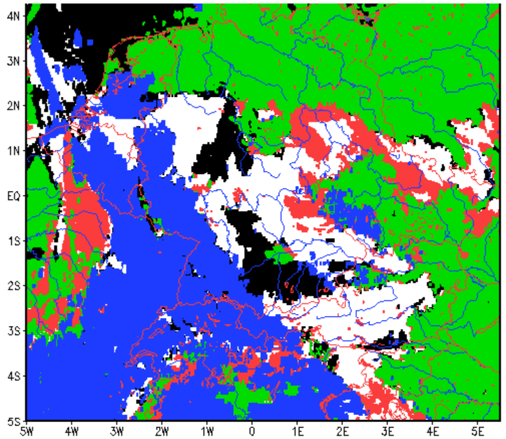
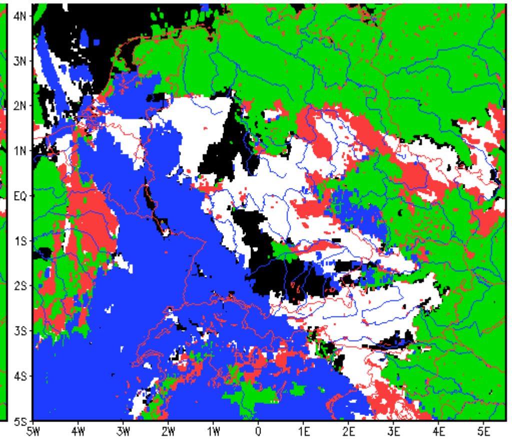
Dec. 2016

REF | **Mode-S**

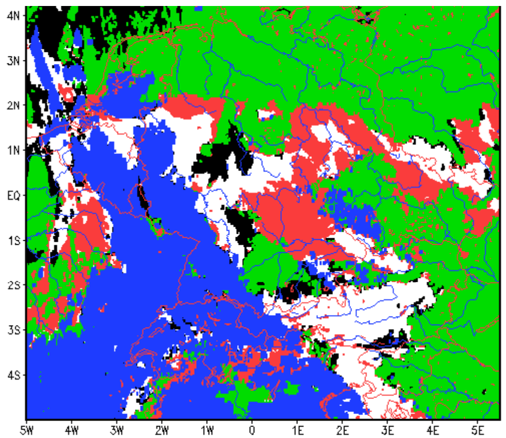
6-h forecasts for 20 Dec., 18 UTC

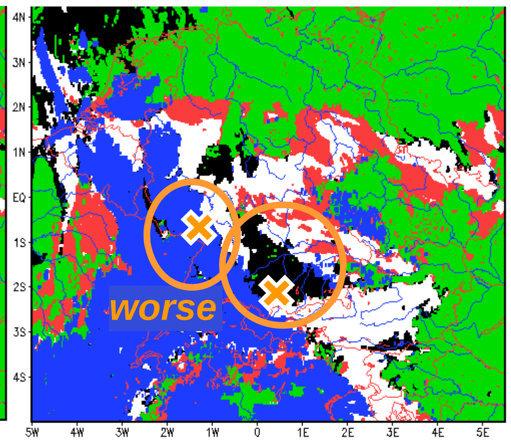
(pseudo first guess w.r.t. radiosondes)





analyses for 20 Dec., 18 UTC





× → radiosonde locations, where humidity obs at cloud top are rejected with Mode-S (T obs are rejected in both exp.)

reason: with Mode-S
- slightly larger o – f.g. (RH)
- slightly smaller spread

correct cloudy / correct cloud-free / missed events / false alarms / undefined

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

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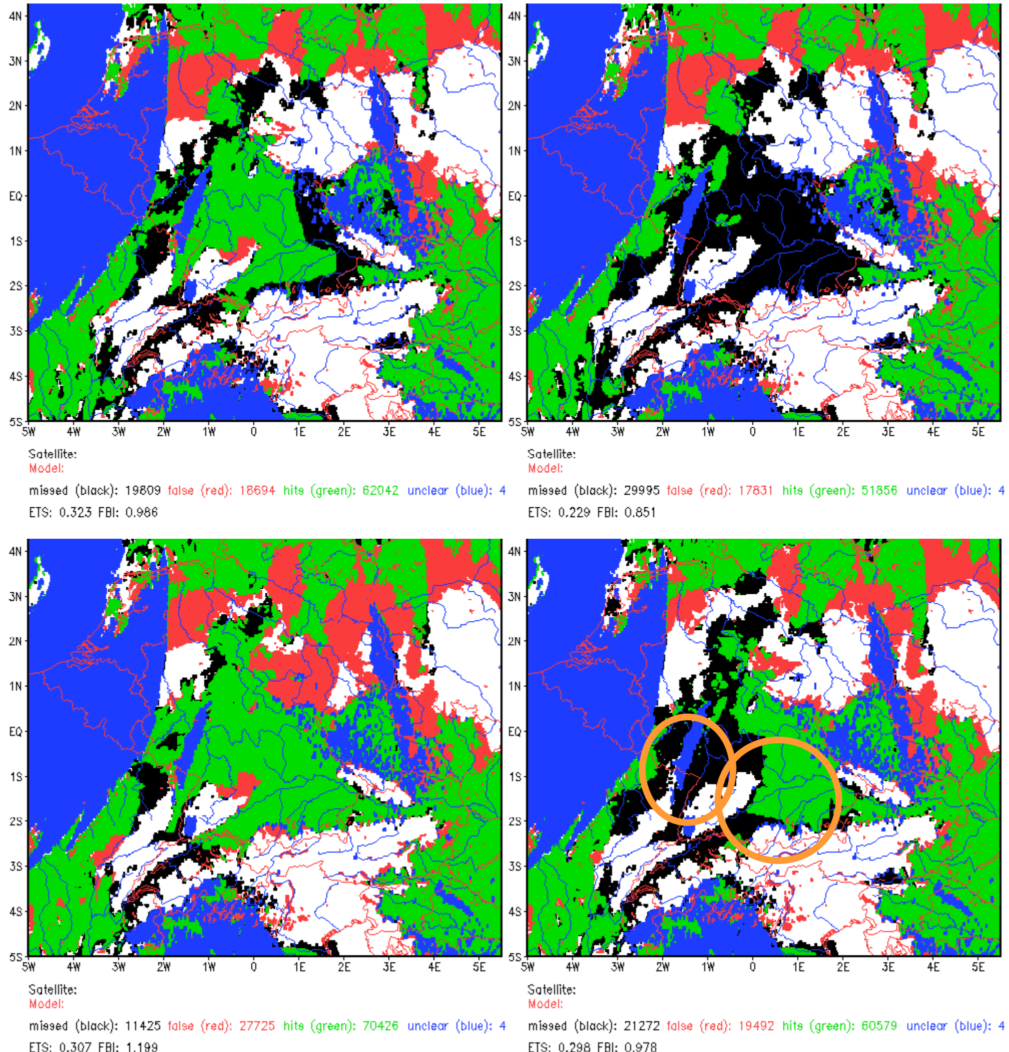
Dec. 2016

12-h forecasts for 21 Dec., 06 UTC

6-h forecasts for 21 Dec., 06 UTC



correct cloudy / correct cloud-free / missed events / false alarms / undefined

→ 1 dramatically degraded forecast

→ next forecast (after using 0-UTC radiosondes) still degraded, but much less

Quality control: Revision of first guess check thresholds

first guess check: reject obs T_o if:

(here: for temperature)

$$|T_o - T_{fg}| > \Delta T_{thresh}$$

up to 12K ≤ 4K

threshold:
(in LETKF)

$$\Delta T_{thresh} = f \cdot \mathrm{std}\{T_o - T_{fg}\} = f \cdot \sqrt{\sigma_0{}^2 + \sigma_{ens}{}^2}$$

$$f = 3$$

≤ 4K ≤ 1K ≤ 1K

→ strong inversions with wintertime low stratus: many correct obs rejected

ensemble spread considers only random errors (as intended)

strong systematic error: not accounted for

revision:

$$\Delta T_{thresh} = f \cdot \mathrm{std}\{T_o - T_{fg}\} = f \cdot \sqrt{\sigma_0{}^2 + \sigma_{ens}{}^2 + \left(\tfrac{1}{f} \cdot \varepsilon_{inv}\right)^2}$$

$$\varepsilon_{inv} \cong 0.8 \cdot \Delta T_{inv}$$

(within 25 hPa; tapering above 800 hPa, ….)

ΔT_{inv} : inversion observed by **radiosonde**

… similar revision for humidity threshold

Revised first guess check thresholds: winter test, low-level cloud (low stratus)

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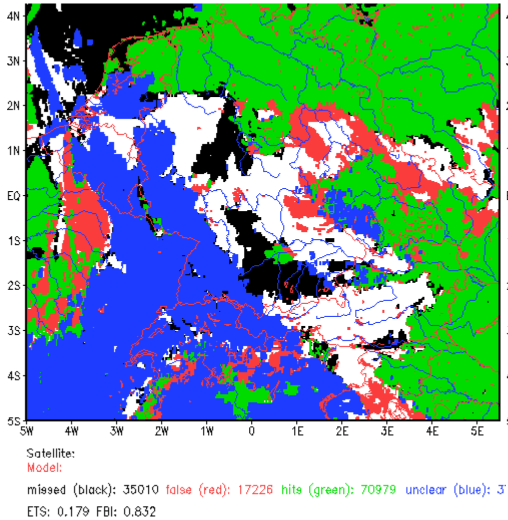
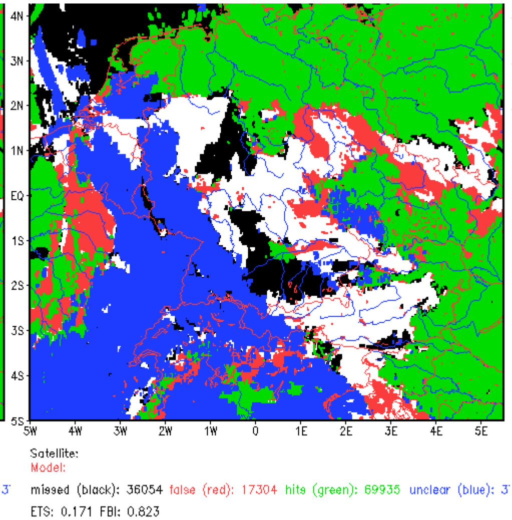
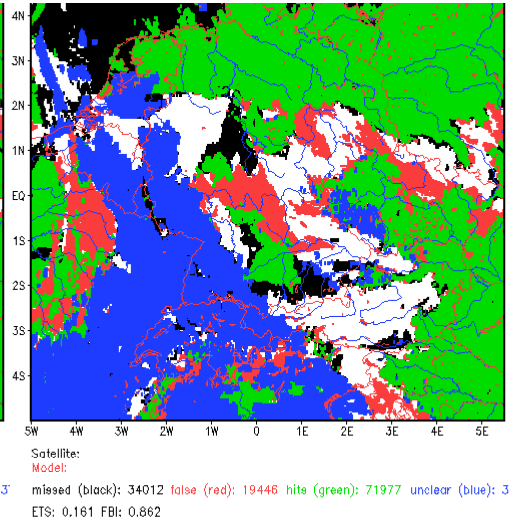
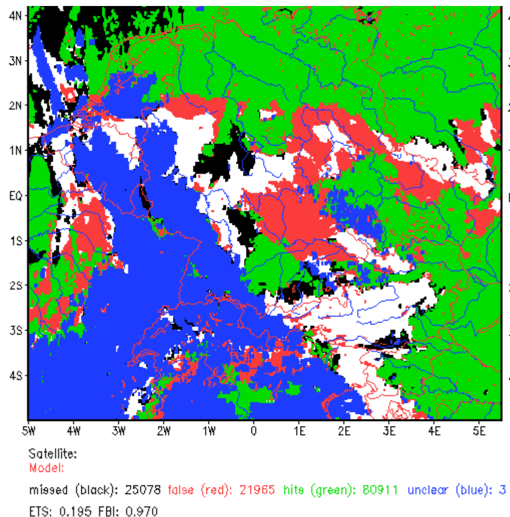
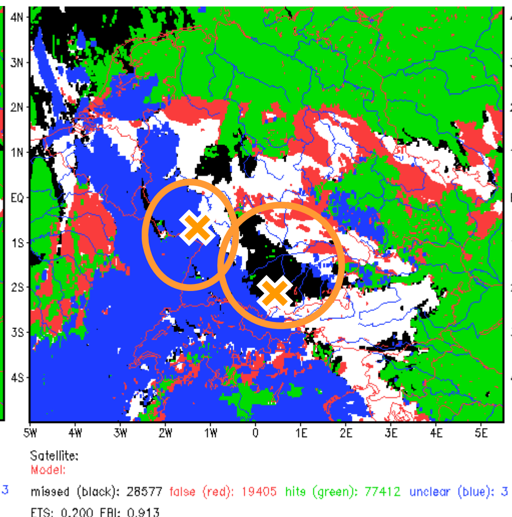
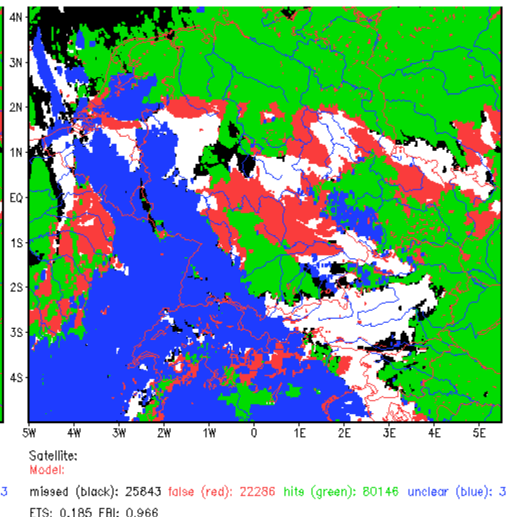
DWD

Dec. 2016

	REF	Mode-S	revised f.g. check
6-h forecasts for 20 Dec., 18 UTC			
analyses for 20 Dec., 18 UTC			

correct cloudy / correct cloud-free / missed events / false alarms / undefined

Revised first guess check thresholds: winter test, low-level cloud (low stratus)

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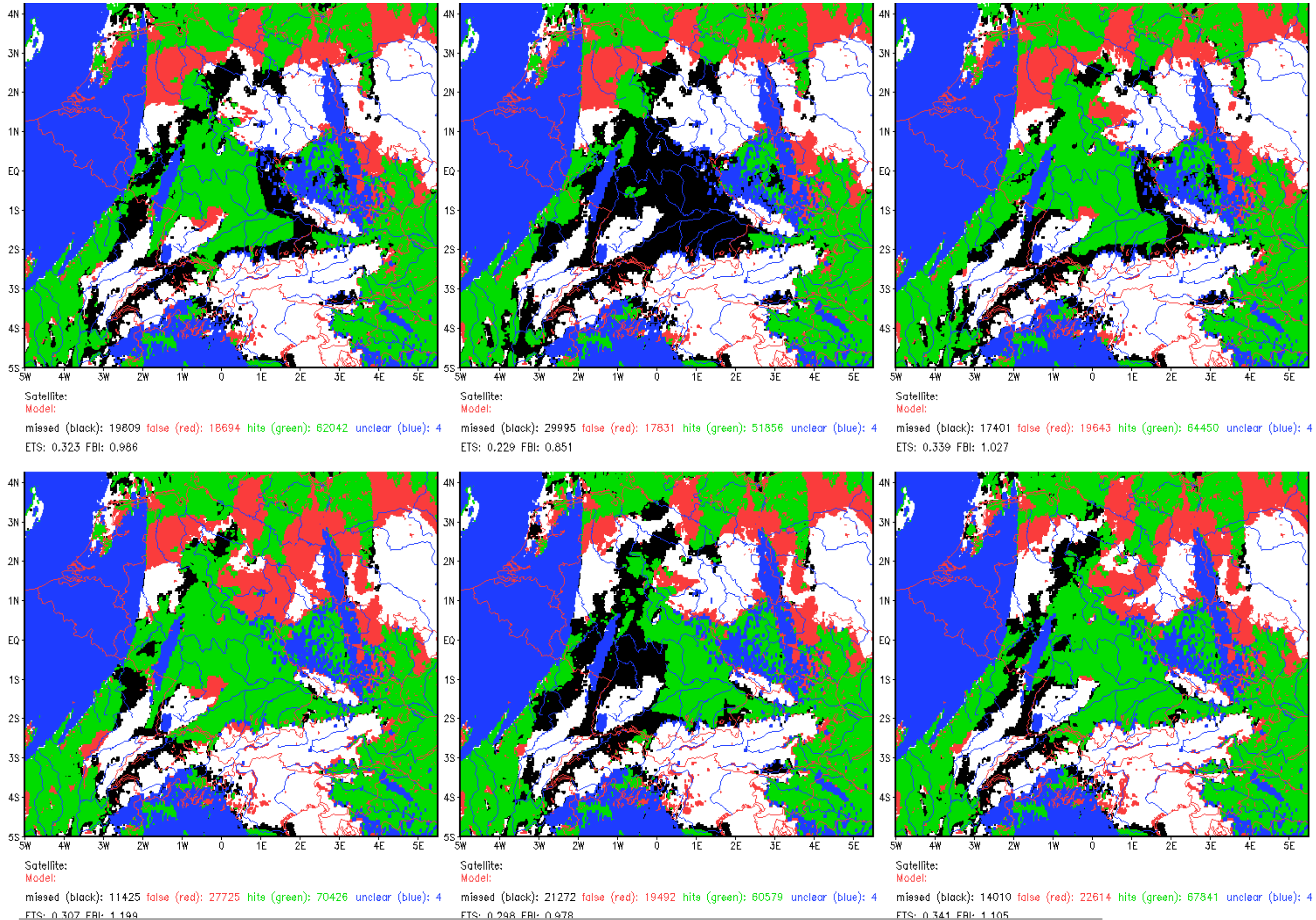
DWD

Dec. 2016

REF | Mode-S | revised f.g. check

12-h forecasts for 21 Dec., 06 UTC

6-h forecasts for 21 Dec., 06 UTC



correct cloudy / correct cloud-free / missed events / false alarms / undefined

Revised first guess check thresholds: winter test

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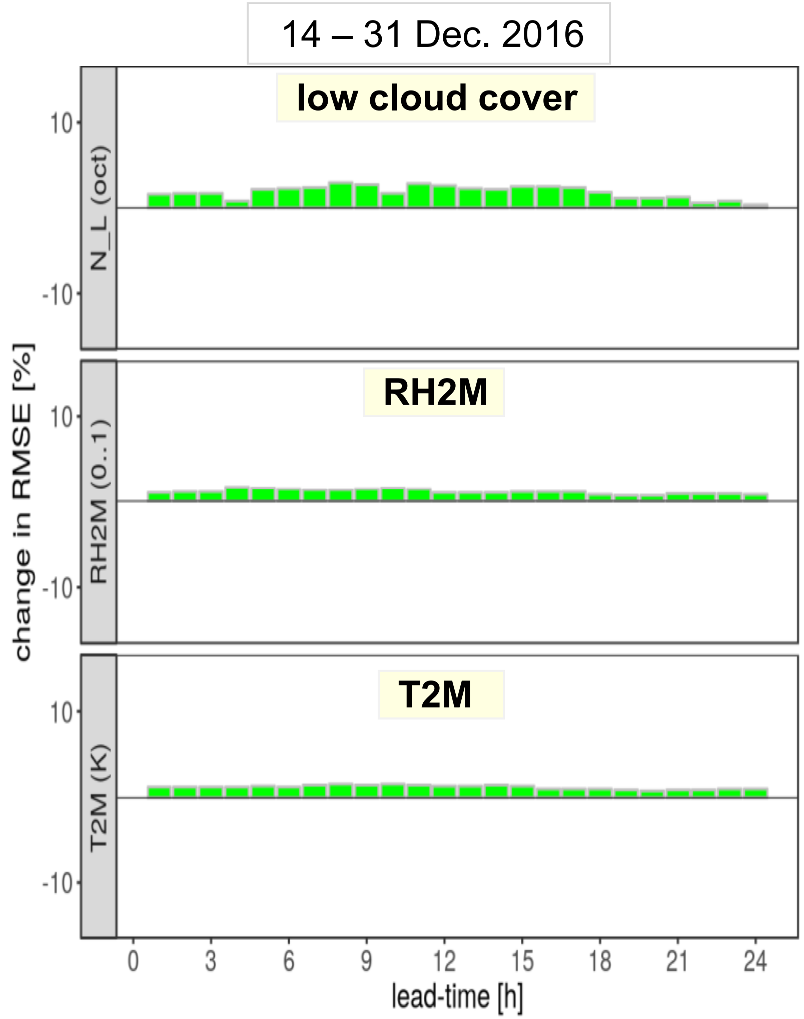
revised first guess check thresholds:

- ✓ positive impact on low stratus
- ✓ slightly positive for T2M, RH2M
- ✓ to be implemented in official code and to be tested further



Summary on LETKF applied to low stratus

important for low stratus / strong inversions (presence of strong systematic errors):

- ✓ additive covariance inflation
- ✓ additional data: Mode-S
- ✓ adjust quality control (for radiosondes)

KENDA Activities at MeteoSwiss (1)

Daniel Leuenberger, Claire Merker, Marco Arpagaus, Alexander Haefele, Giovanni Martucci

- **KENDA** tests with COSMO in **single precision (SP)**
  - SP data assimilation part of COSMO in KENDA mode works fine, (but problems in nudging mode)
  - neutral results in all forecast verifications
  - but: slow drift of soil temperature and moisture in KENDA cycle
    → potential problems in TERRA with SP

- assimilation of temperature and humidity profiles from **Raman Lidar** at Payerne (Task 2.7)
  - large benefit in a case study of convection
  - less impact in a case study of fog

KENDA Activities at MeteoSwiss (2)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Daniel Leuenberger, Claire Merker, Marco Arpagaus, Alexander Haefele, Giovanni Martucci

- KENDA tests with **additive covariance inflation (ACI)**
  (derived from climatological B-matrix of **global** ICON-3DVar of DWD;
  purpose: account for model error and thus improve ensemble spread)
  - large benefit for analyses (closer to observations)
  - benefit in forecasts less clear:
    - neutral or mixed impact already in first guess (more positive in winter)
    - reduction of T_2m and Td_2m spread in summer (?)

- towards a **climatological B-Matrix from COSMO data** (Task 1 + 4)

towards a climatological B- (background error covariance) matrix from COSMO data

Claire Merker, Daniel Leuenberger

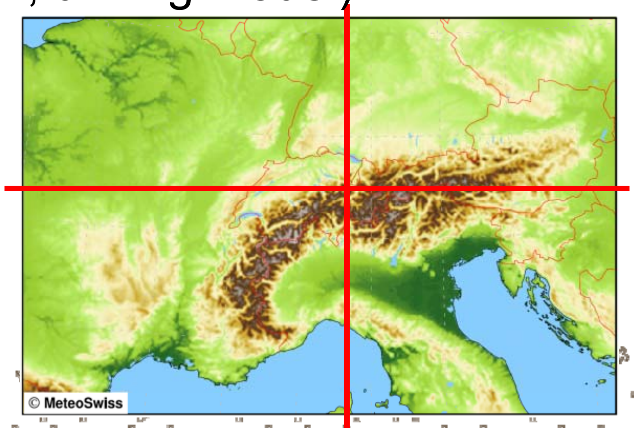
- KENDA additive covariance inflation (ACI) (to account for model error)
  - currently: climatol. background error covariance from global ICON
  - plan: climatol. background error covariance specific to limited-area COSMO

- NMC method: differences between forecasts valid at same time with different lead times
  - as proxy for background errors → for 3DVar for ICON-LAM (→ Task 4)
  - as proxy for model errors: → for ACI in LETKF (→ Task 1)

- comparison COSMO (≈ 2km) with IFS HRES (≈ 9km, driving model)

→ assess differences of error correlation patterns in global and limited area model

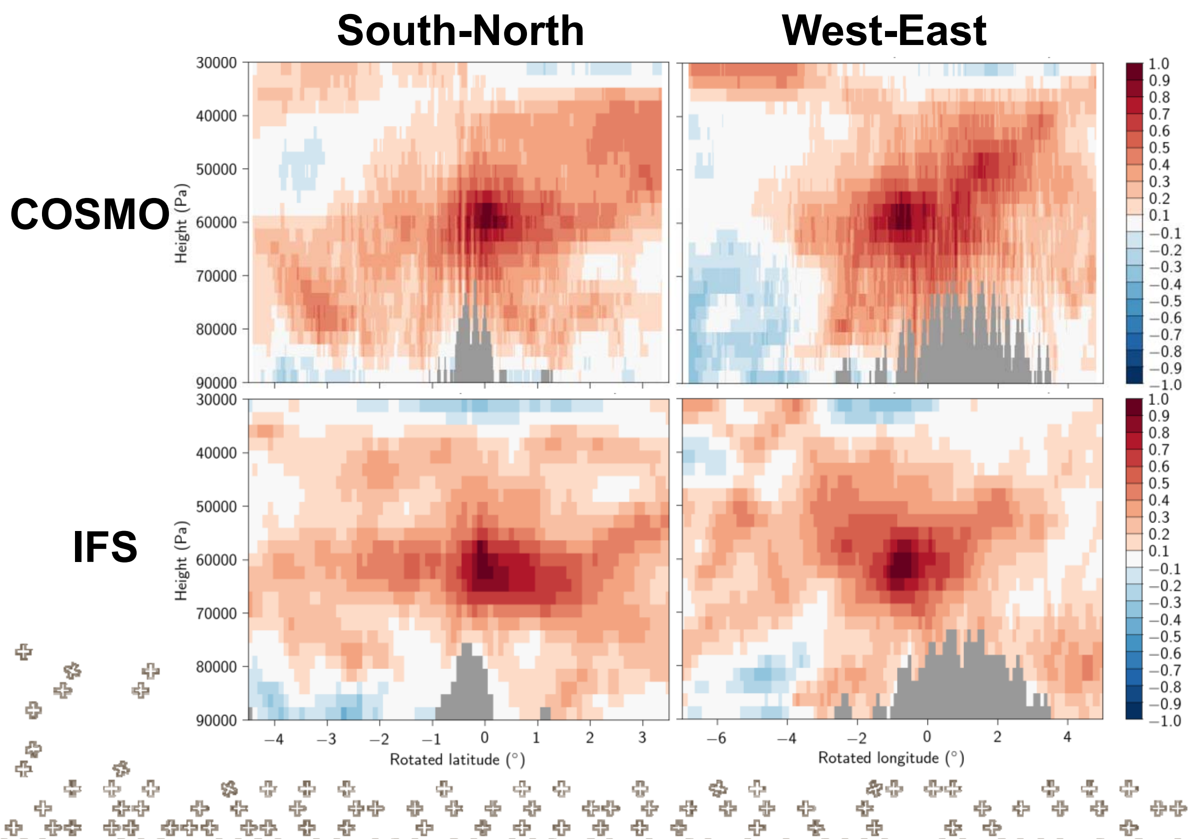
➢ exemplary results along South-North and West-East cross-sections through the COSMO-E domain



towards a climatological B- (background error covariance) matrix from COSMO data

background / model error correlations in COSMO vs. IFS

- lead time difference: $\mathbf{x}^{30h} - \mathbf{x}^{6h}$
- period: March 2017
- (auto-)correlation of temperature, with grid pt. 47.0°N, 8.97°E, 600hPa



- ➢ overall pattern similar
- ➢ higher resolution of COSMO allows representation of more detailed structures around orography (especially at lower levels)

towards a climatological B- (background error covariance) matrix from COSMO data

- expected benefits of climatological background / model error covariance matrix specific to limited area COSMO:
  - better representation of small-scale features
  - better consideration of orographic effects
  - improvements for KENDA especially in boundary layer and for short lead times

- computation of climatological **B**-matrix for limited area domain:
  - more generic approach needed compared to global model (for balances, e.g. height-dependent geostrophic coupling and correlation scales, …)

→ need to identify the relevant balances

➢ work in progress at MeteoSwiss and DWD

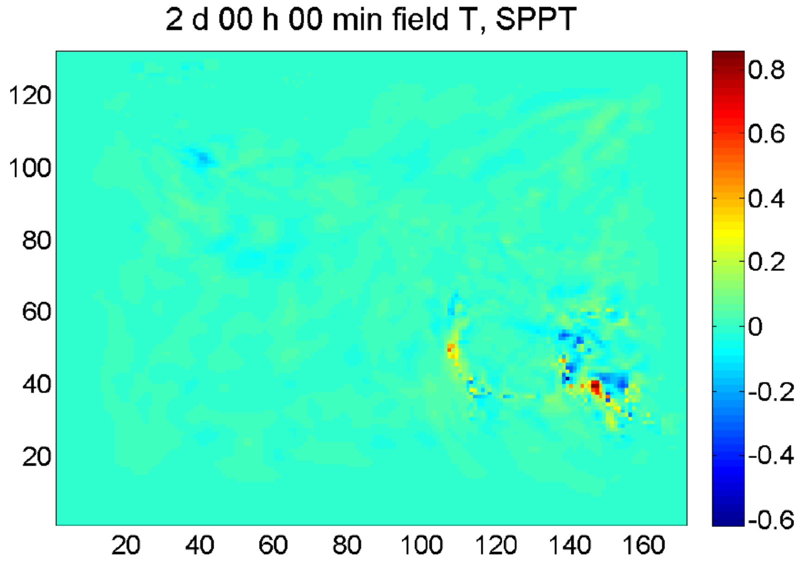
(e.g. velocity potential + stream function calculated with FFT on a limited domain)

Mikhail Tsyrulnikov, Dmitri Gayfulin et al.

SPPT: Stochastic Perturbations of Physical Tendencies

multiplicative → SPPT pert. can be small where errors large (e.g. missing convection)

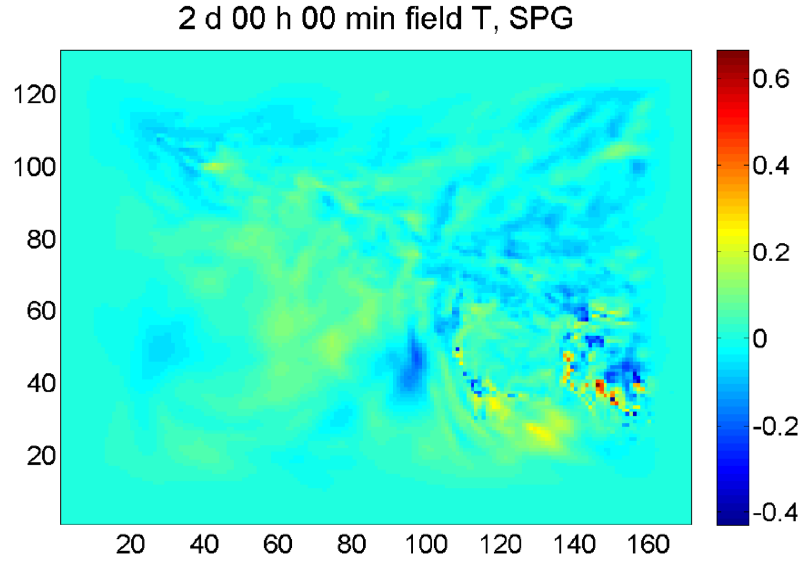
implies that relationships betw. the physical tendencies of different variables are error-free



AMPT: Additive Model-error perturbations scaled by Physical Tendencies

complement with additive perturbations, magnitude depends on average size of phys. tendencies

use independent driving random fields by 4D SPG for different model variables (T, u, v, p, qv, qc, qi)



- AMPT pert. less localized (more spatially uniform) than SPPT pert., magnitudes comparable
- no significant biases due to AMPT pert. detected
- first results (11 days): in ensemble forecasts, the new schemes can outperform SPPT

Task 2: extended use of observations: ongoing

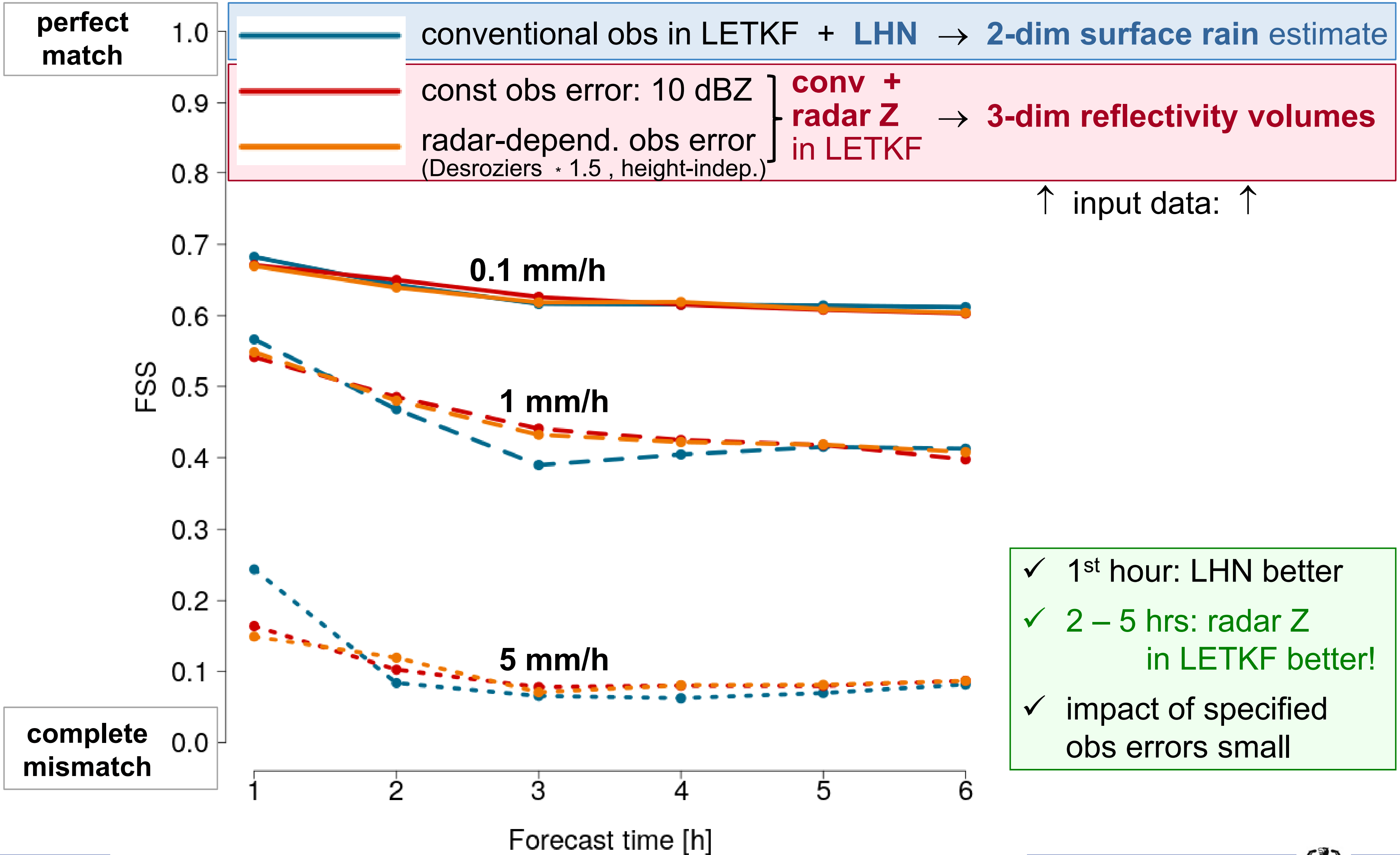
Deutscher Wetterdienst

- ✓ **radar radial winds**: (if also using Mode-S: very) small positive impact (e.g. on precip),
  in parallel suite

- ✓ **radar reflectivity**: slightly better than latent heat nudging for precip after +1h (DWD+ ARPAE)
  better vertical profiles in first guess (with operational LETKF settings)
  → promising

Task 2.1: radar reflectivity

impact experiment (3 – 6 Feb. 2017, 8 daily forecasts)



- ✓ 1st hour: LHN better
- ✓ 2 – 5 hrs: radar Z in LETKF better!
- ✓ impact of specified obs errors small

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Task 2: extended use of observations: ongoing

Deutscher Wetterdienst

- ✓ **radar radial winds**: (if also using Mode-S: very) small positive impact (e.g. on precip), in parallel suite

- ✓ **radar reflectivity**: slightly better than latent heat nudging for precip after +1h (DWD+ ARPAE)
  better vertical profiles in first guess (with operational LETKF settings)
  → promising

- ✓ **GPS slant total delay**:
  - (error-free) bias correction & blacklisting of stations important
  - small positive impact on precip, upper-air wind, 2-m temperature + humidity, cloud

- ✓ **SEVIRI WV**, currently focusing on **clear-sky** (but in future also using cloudy data):
  bias correction important, small consistent positive impact, needs more work

- ✓ **T2M, RH2M**: preparatory work; more resources in 2019

- ✓ **Mode-S aircraft** : operational

- ✓ **Raman lidar** (T-, q- profiles): first case study with positive impact

in WG1:

- ✓ **SEVIRI VIS** (→ cloud): first impact exp. (18 days), slightly improved cloud, precip, T2M, surface pressure, upper-air fields, etc.

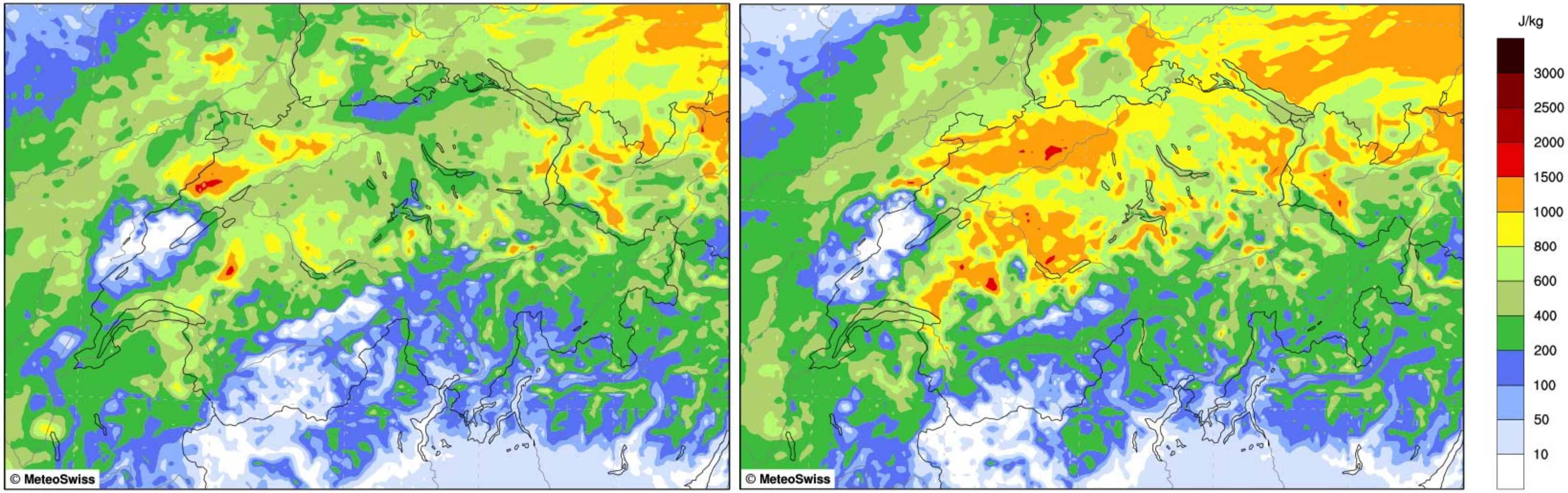
Task 2.7: Ground-based remote sensing observations: **Raman Lidar**

Alexander Haefele, Daniel Leuenberger

- lack of temperature and humidity obs in PBL
- Raman Lidar can provide **temperature** and **humidity profiles** with high temporal and vertical resolution
- at MeteoSwiss: 1 Lidar at Payerne, average availability of 60 %, data quality approaching that of radiosondes
- 2 case studies: 1 low stratus case
  - + 1 convective case:
  - ➢ 12 hours of 1-hrly KENDA assimilation cycle on 24 Aug. 2017, 00 – 12 UTC
    - – CONV (LEKTF with conventional obs + radar precip by LHN)
    - – LIDAR (additional assimilation of Lidar T and RH profiles)
  - ➢ COSMO-E forecasts (CTRL + ensemble) started at 12UTC

Pre-convective Environment:

CAPE of analysis mean valid at 12UTC (IC of forecasts)

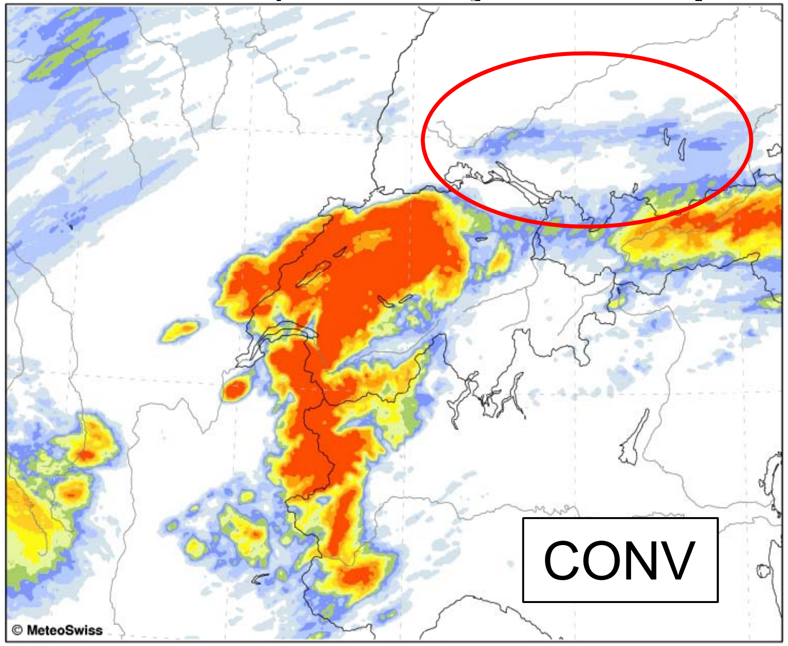


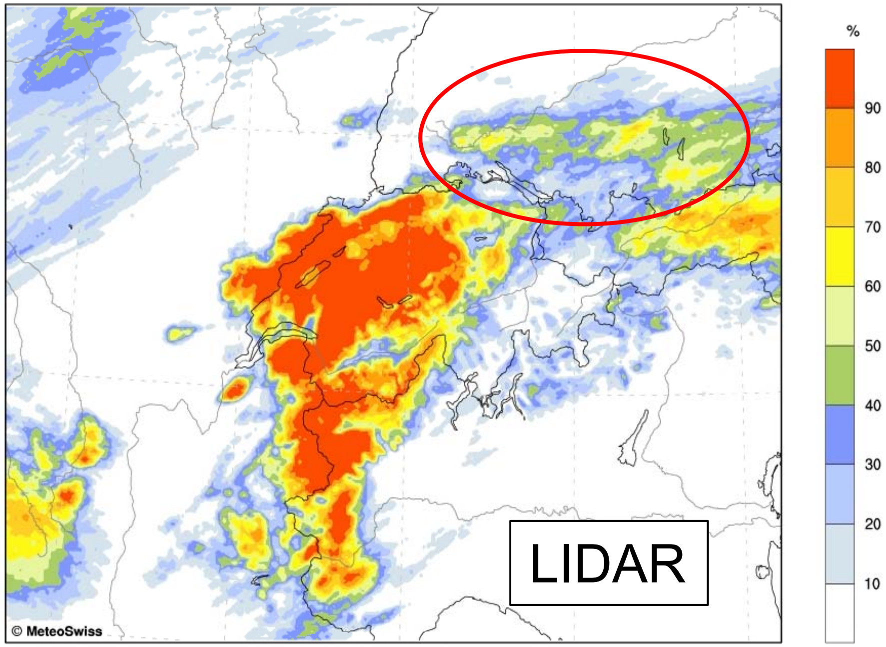
CONV

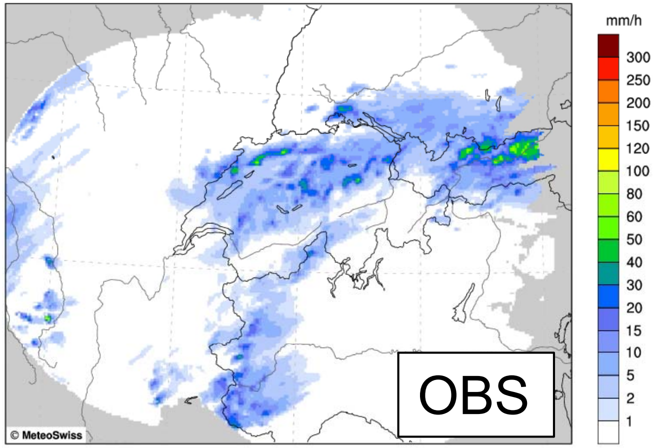
LIDAR

Task 2.7: Ground-based remote sensing obs, Raman Lidar: experiment, impact on precipitation forecast

probability that 24h **precipitation** sum exceeds 1mm







- lidar obs adjust pre-convective environment, resulting in a more skilful precipitation forecast
- low-stratus case: smaller impact (not shown)

WG1: Latent heat nudging

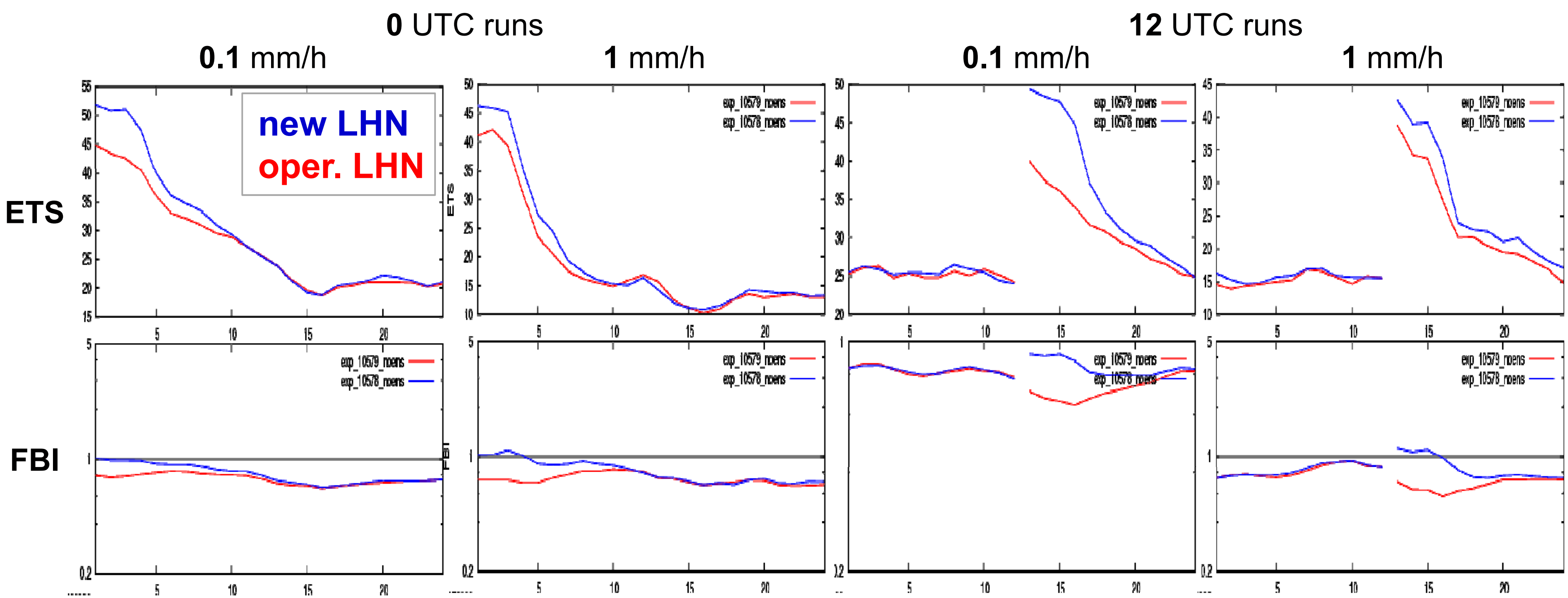
test of revised version

Deutscher Wetterdienst

- revision of LHN for ICON, tested for COSMO for August 2017

  (grid point search removed, much larger amplitude of the climatological latent heat profile)

  → much larger trigger to initiate missing convective precip
  (where convective precip has been produced,
  the climatological profile is not used any more)



✓ large improvements up to + 12 hrs !
✓ also improved surface pressure, T2M, RH2M

✓ neutral impact in winter period
• tested + investigated further

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Task 4.1: KENDA for ICON-LAM (incl. EnVar)

Hendrik Reich, Christoph Schraff, Klaus Stephan, Christian Welzbacher, Lilo Bach, et al.

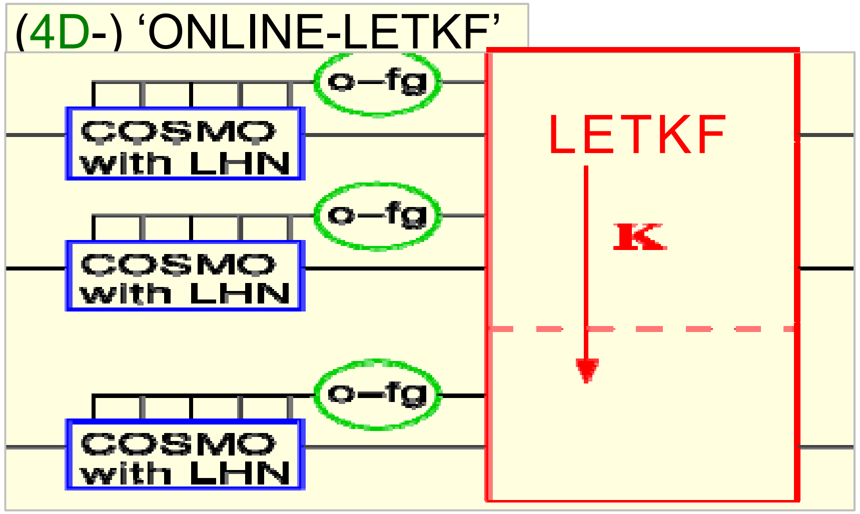
current KENDA: 4-D LETKF + LHN

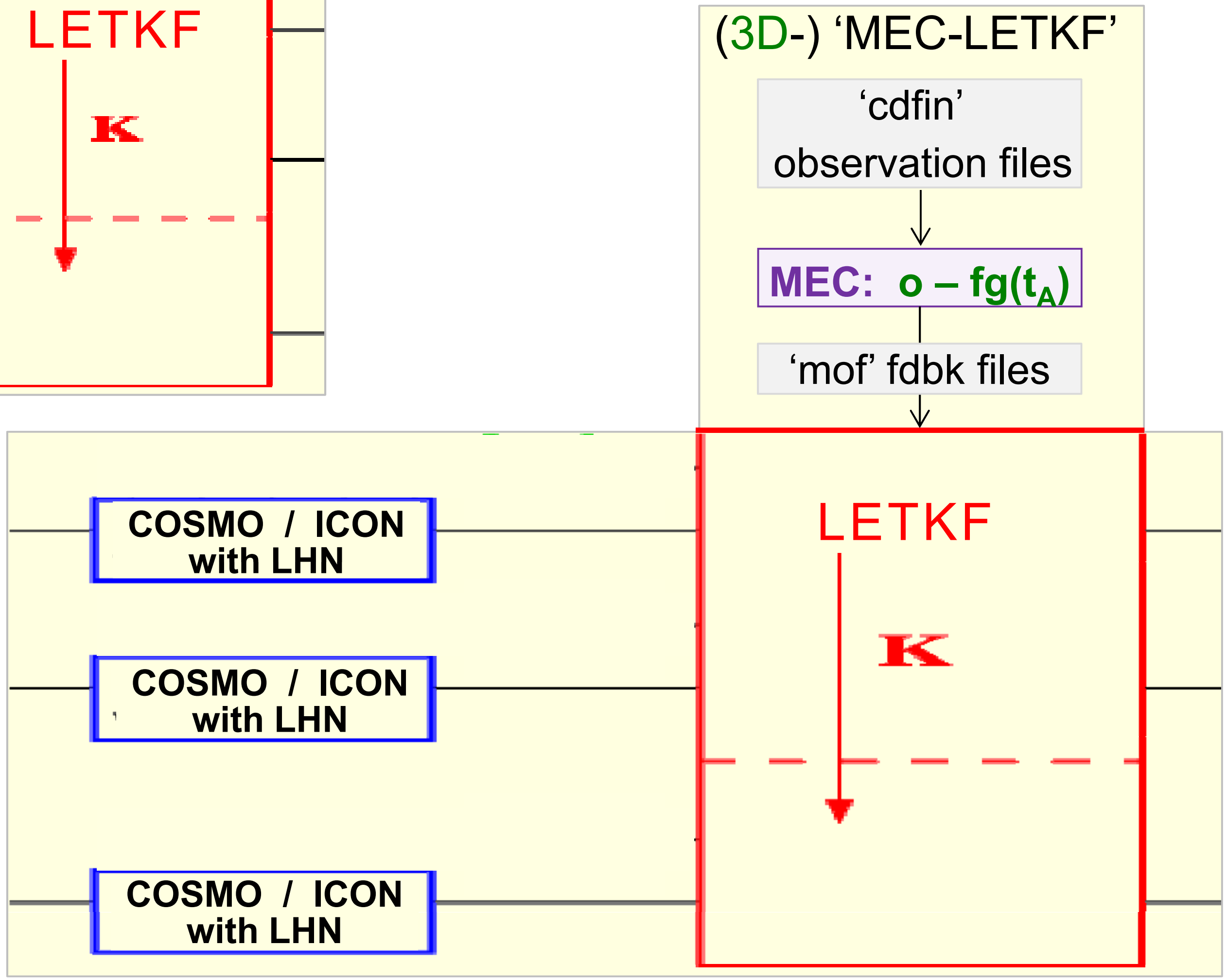
- LHN : technically implemented (without grid point search)
  tuning not yet completed,
  but first tests show positive results

- full 4-D LETKF for ICON-LAM:
  - need to be able to call observation operators from ICON: not yet ready, work in progress
  - **intermediate** solution for first testing + tuning: **'MEC-LETKF'** for ICON-LAM

Task 4.1: KENDA for ICON-LAM
3-D MEC-LETKF

Deutscher Wetterdienst





MEC-LETKF:

$o - fg(t_A)$

model equivalents at analysis time

→ 3-D LETKF

Task 4.1: KENDA for ICON-LAM
ICON-MEC-LETKF

compare LETKF experiments:
- 4-D COSMO-ONLINE (with COSMO-DE, 2.8 km)
- 3-D COSMO-MEC (with COSMO-DE, 2.8 km)
- 3-D ICON-MEC (with ICON-DE 2.5 km)

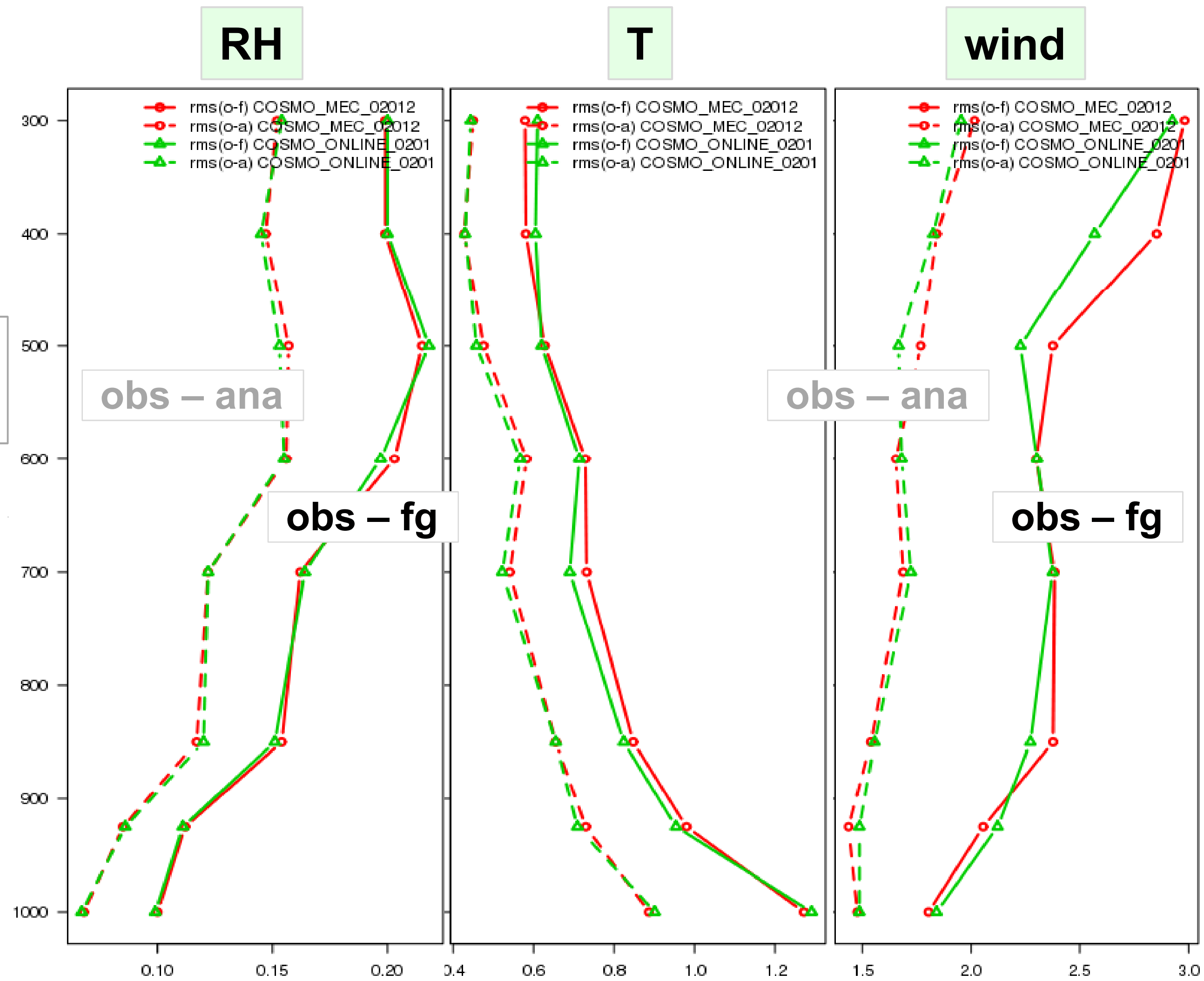
- same lateral BC (from ICON-EU), LETKF settings (incl. Mode-S), etc.
- LHN switched on, but in ICON-LAM not used due to a bug
- period: 26 – 31 May 2016 → ~ 5 days

Task 4.1: KENDA for ICON-LAM

ICON-MEC-LETKF, first guess statistics

RMSE of **1-h** forecast vs. TEMP

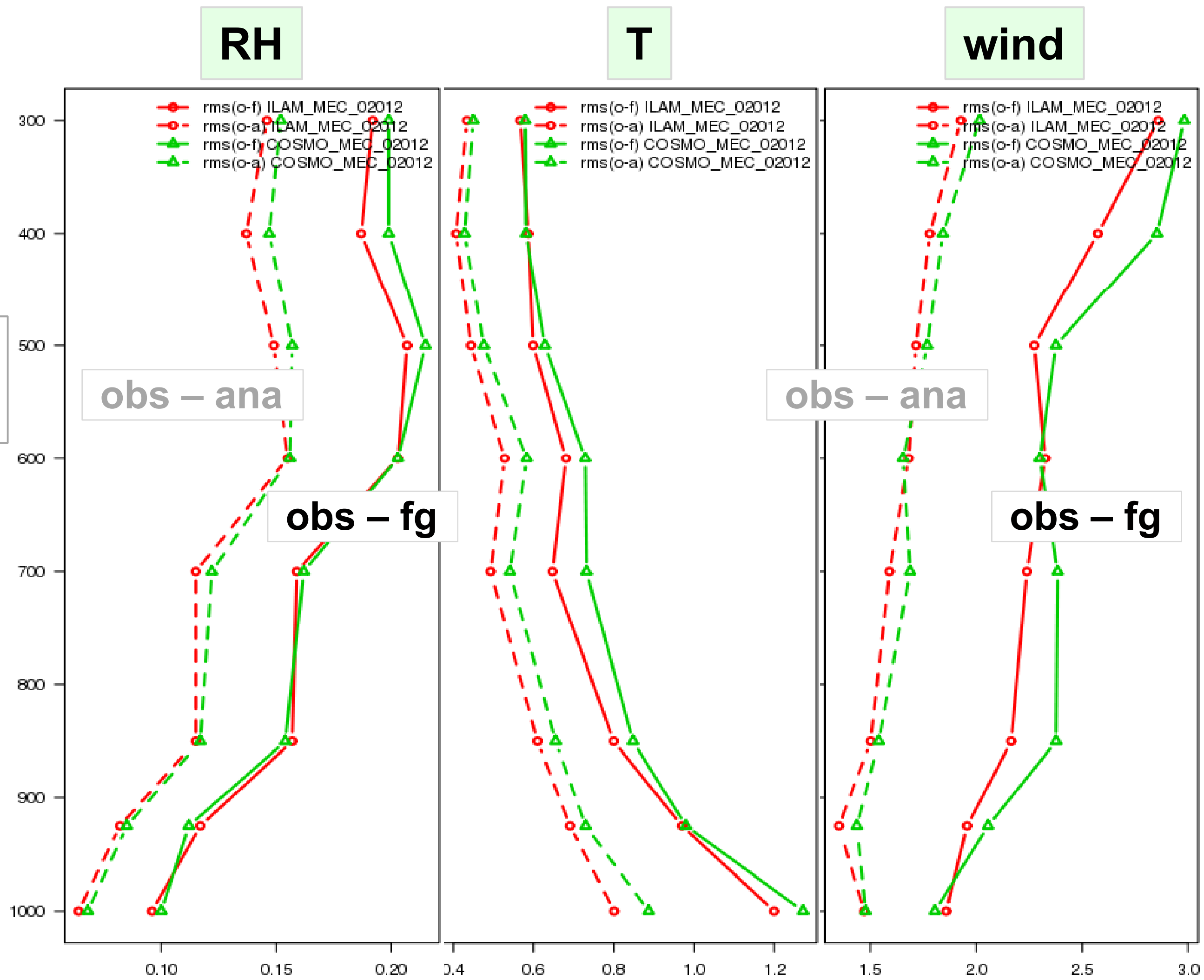
3D COSMO-**MEC**
4D COSMO-**ONLINE**



✓ 4-D online LETKF (slightly) better than 3-D MEC-LETKF for T, wind

RMSE of **1-h** forecast vs. TEMP

3D **ICON**-MEC
3D **COSMO**-MEC



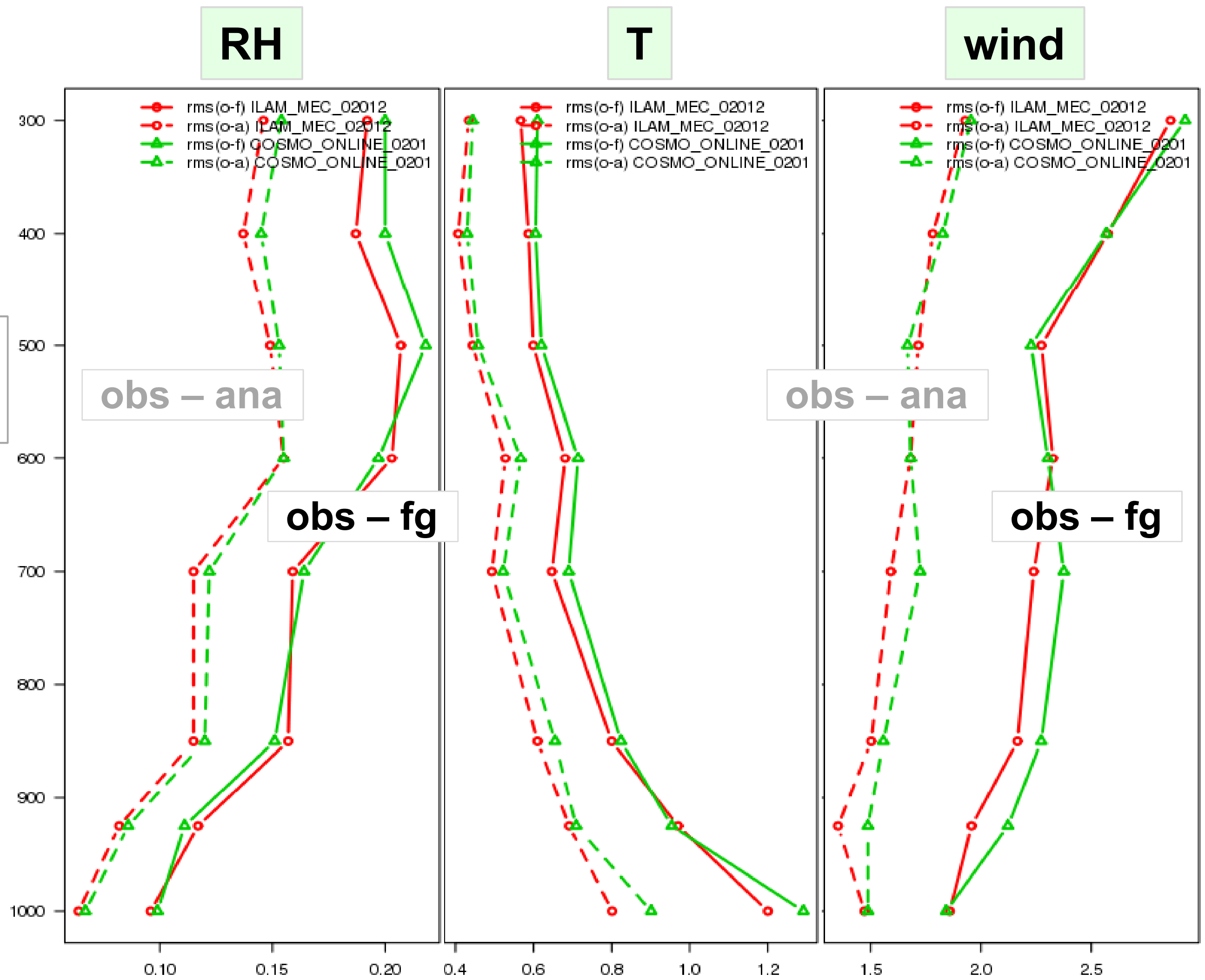
✓ ICON-MEC-LETKF better than COSMO-MEC-LETKF

ICON-MEC-LETKF, first guess statistics

Deutscher Wetterdienst

RMSE of **1-h** forecast vs. TEMP

3D ICON- MEC
4D-COSMO-ONLINE

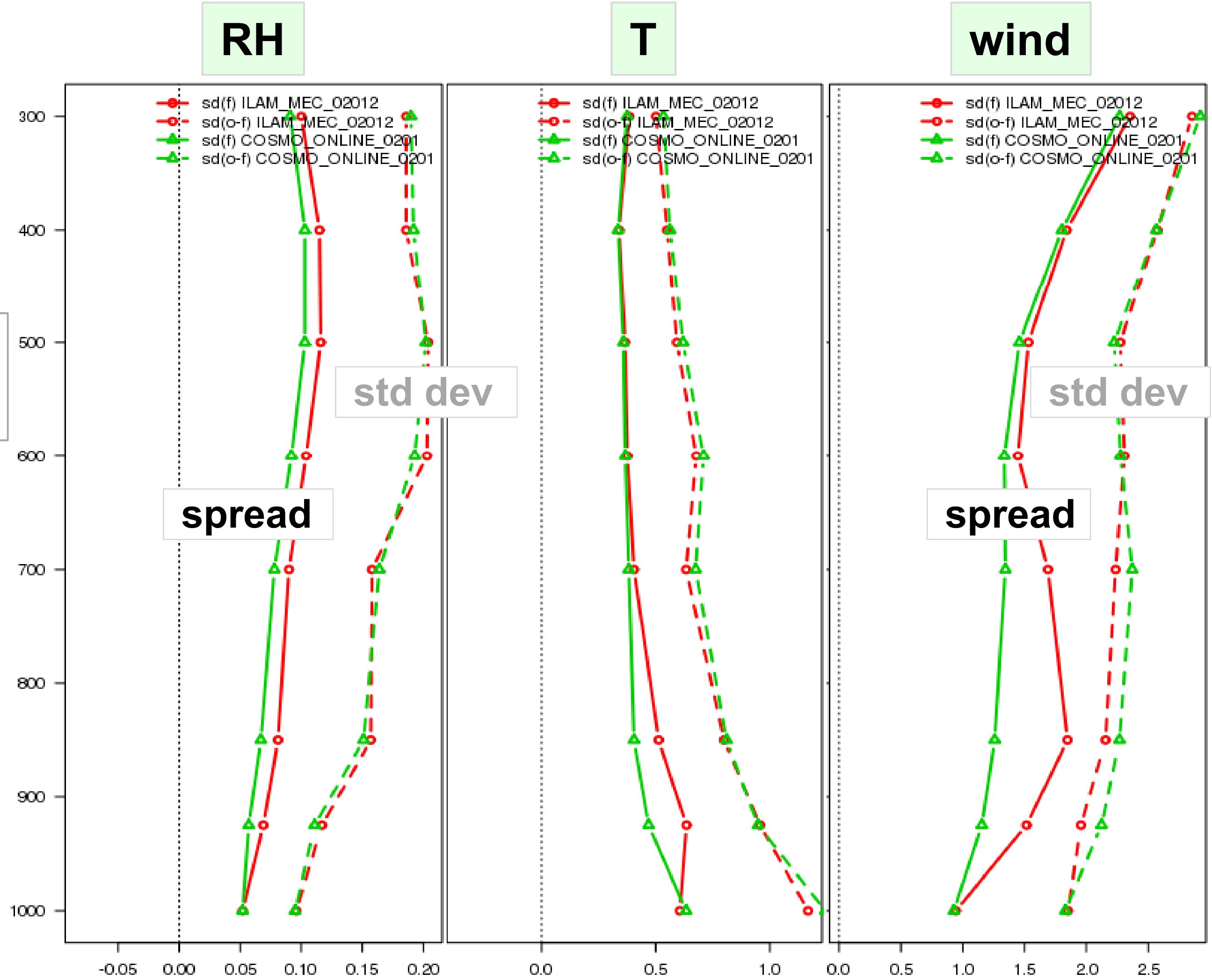


✓ 3D ICON-MEC mostly better 4D COSMO-ONLINE for T, wind; neutral for RH

Task 4.1: KENDA for ICON-LAM
ICON-MEC-LETKF, first guess statistics

spread of **1-h** forecast
& std dev. vs. TEMP

3D ICON-MEC
4D-COSMO-ONLINE

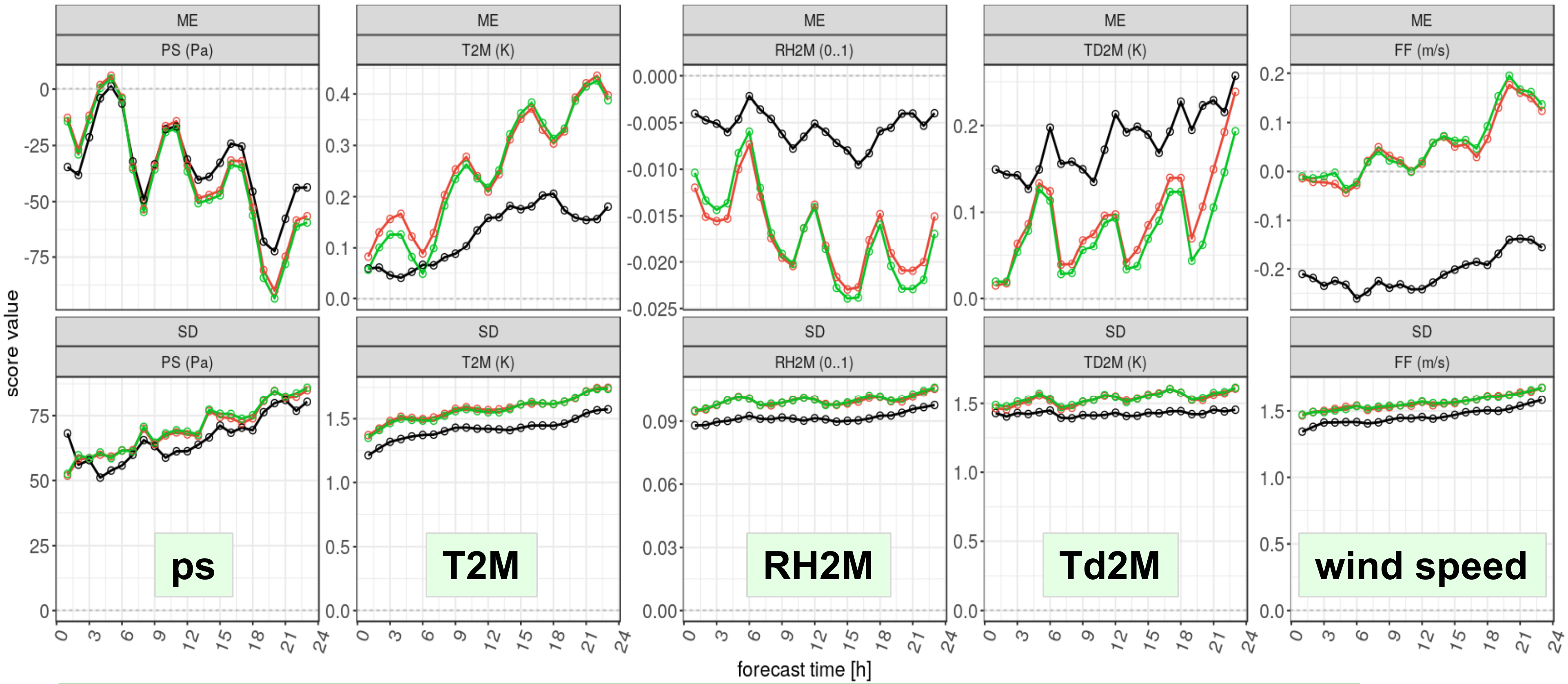


✓ ICON-LETKF has more spread than COSMO-LETKF

Task 4.1: KENDA for ICON-LAM
ICON-MEC-LETKF, surface verification

3D ICON-MEC
3D COSMO-MEC
4D-COSMO-ONLINE

2016/05/26-13UTC - 2016/06/01-13UTC
INI: ALL UTC, DOM: ALL , STAT: ALL



- ✓ ICON-LAM has smaller bias for T2M, RH2M, larger bias for Td2M, 10-m wind
- ✓ ICON-LAM has consistently far smaller random errors

ICON-MEC vs. COSMO-MEC

3D-ICON-MEC vs. 4D-COSMO-ONLINE

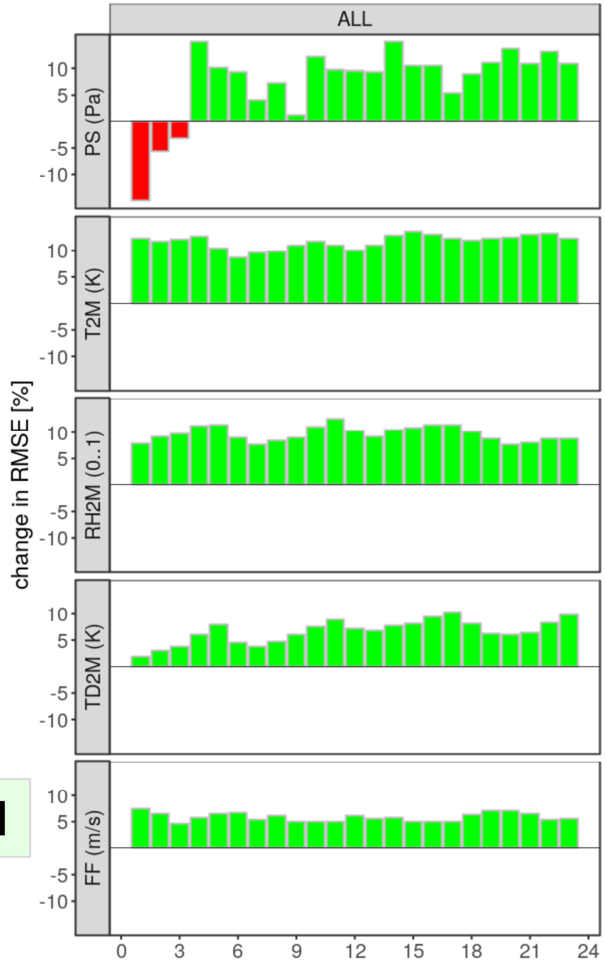
ps

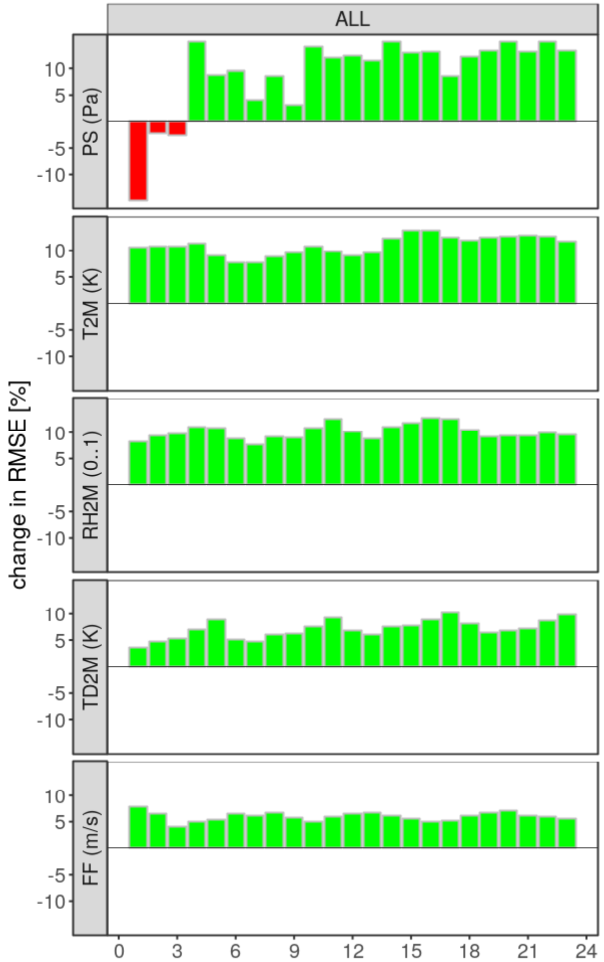
T2M

RH2M

Td2M

wind speed





✓ ICON-LAM much better than COSMO

Task 4.1: KENDA for ICON-LAM

ICON-MEC-LETKF, radiosonde verification

ICON-MEC vs. COSMO-MEC

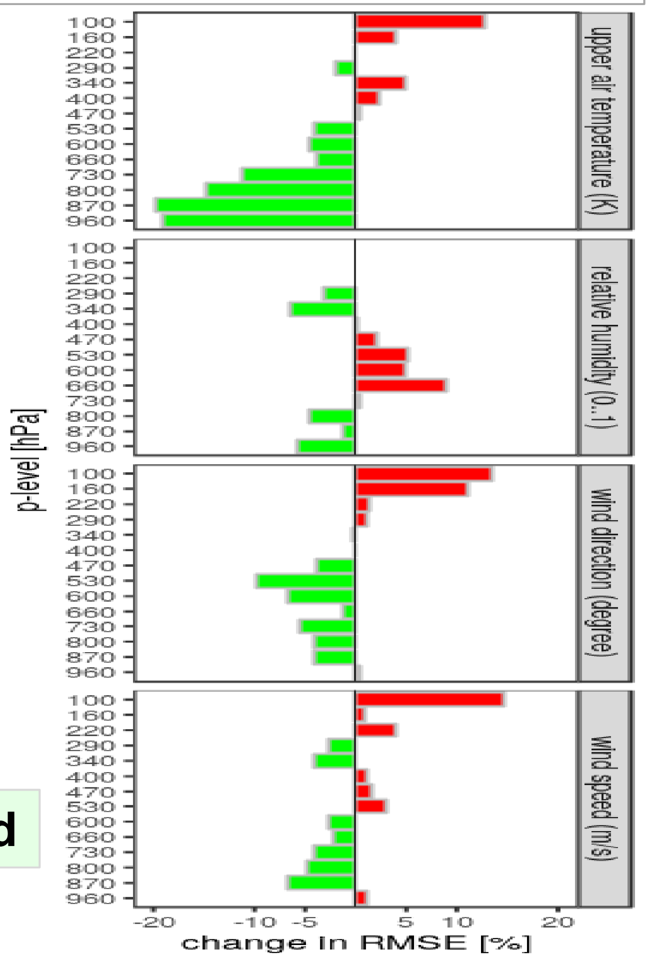
3D-ICON-MEC vs. 4D-COSMO-ONLINE

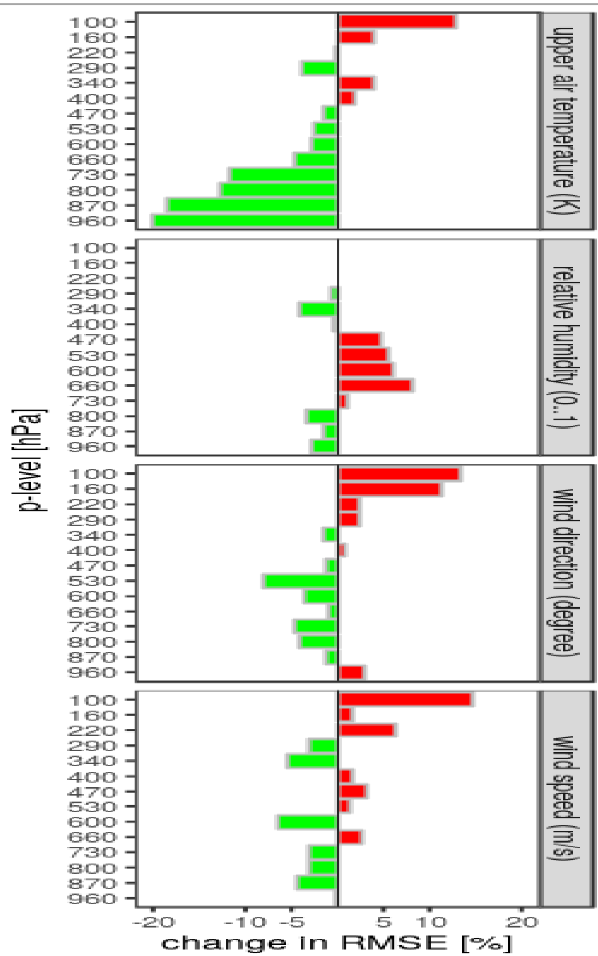
T

RH

wind dir.

wind speed



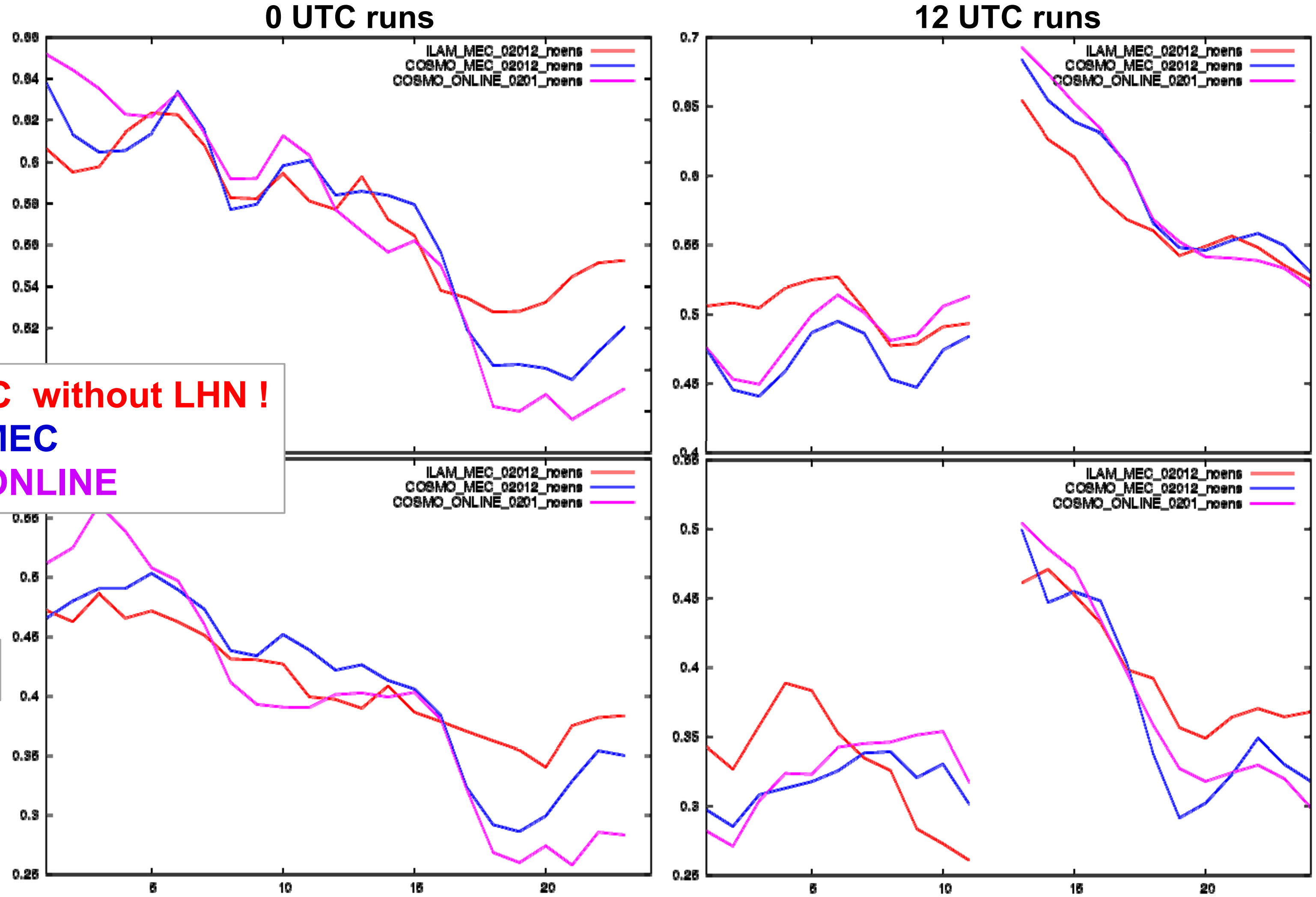


- ✓ ICON-LAM much better than COSMO in troposphere, esp. temperature (bias !)
- ✓ ICON-LAM worse in stratosphere, as no relaxation in upper sponge layer to driving model

FSS
(11 g.pt.)

0.1 mm/h

1 mm/h



3D ICON-MEC without LHN !
3D COSMO-MEC
4D-COSMO-ONLINE

✓ ICON-LAM comparable to COSMO, despite being penalised without LHN in first few hours

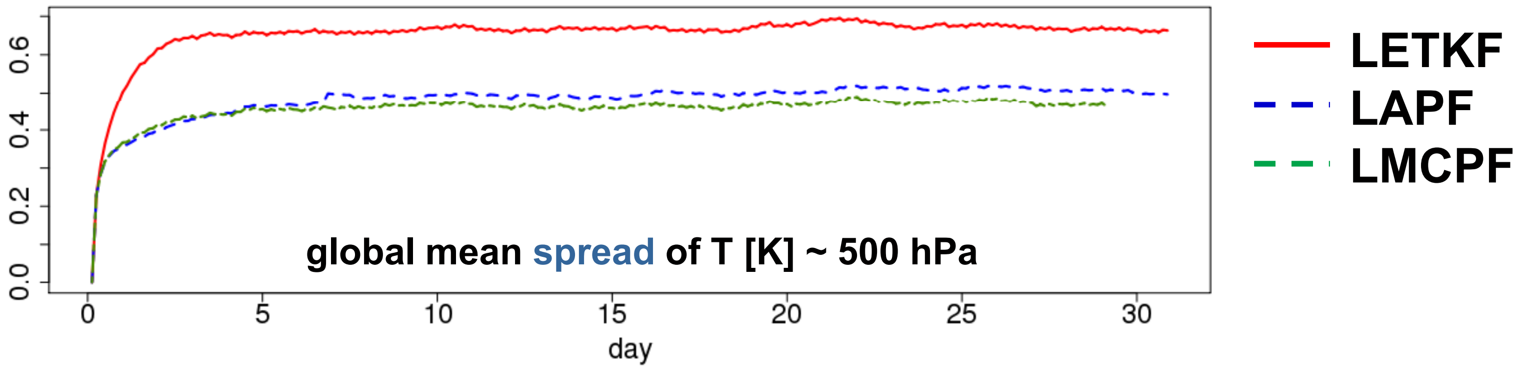
Task 4.1: KENDA for ICON-LAM – summary

- ICON-LAM-LETKF:
  - ICON-LAM with MEC-LETKF already outperforms COSMO for most variables; precipitation should be improved with LHN (currently running)
  - test IAU, hydrostatic balancing of analysis increments to reduce noise
  - tuning of model (e.g. lateral boundary relaxation, …) and DA settings
- implement ICON-LAM-ONLINE for **4D-LETKF**: obs operators called by ICON
- first version of **3DVar** / **EnVar** runs technically, to be tested + refined, e.g. use of LAM **B**-matrix
- ICON-LAM with KENDA in parallel suite end of 2019

Anne Walter, Roland Potthast)
Deutscher Wetterdienst

- Localised Adaptive Particle Filter (**LAPF**) and
  Localised Markov Chain Particle Filter (**LMCPF**)
  implemented in an operational NWP system (global ICON)

- both Particle Filters are able to provide reasonable atmospheric analyses and are **running stably over a period of one month !**



- LMCPF outperforms LAPF but still worse (not much!) than LETKF
  (probably due to smaller spread; further tuning to improve this is in progess)

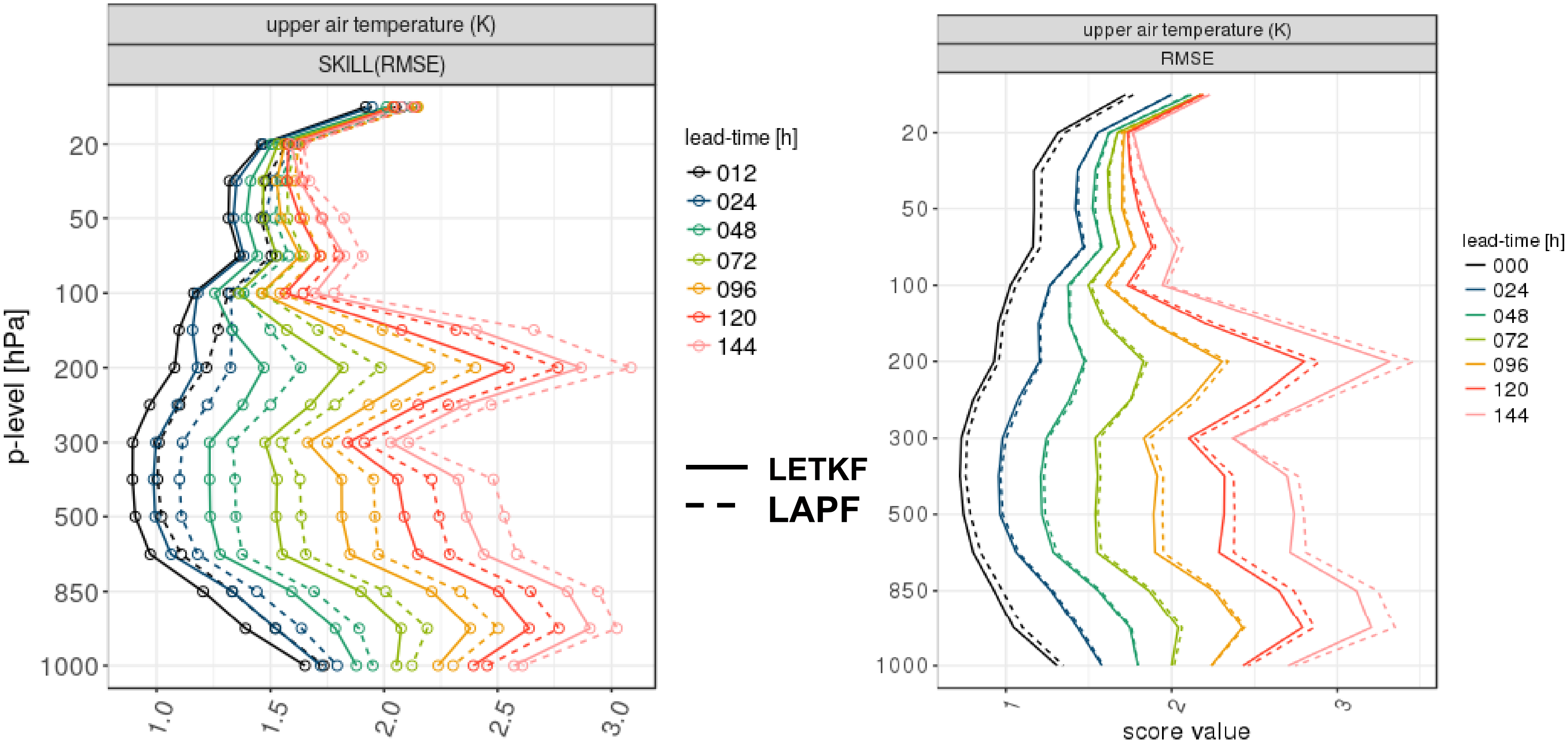
- paper accepted with minor revisions for MWR:
  Potthast et al.: "A Localised Adaptive Particle Filter within an Operational NWP Framework"

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

Deutscher Wetterdienst

RMSE of **temperature** vs. global radiosondes, 2 – 24 May 2016

ensemble **deterministic**



DWD only Met Centre with a **stable** Particle Filter for an (operational) NWP model!
→ strong interest from international science community

thank you for your attention !

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