Status Report for KENDA-O + WG1

Deutscher Wetterdienst

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Mikhail Tsyrulnikov, Dmitri Gayfulin (HMC)

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
  - comparison of MCH and DWD KENDA → QC issue
  - Mode-S winter test + operationalisation
  - activities at MeteoSwiss → climatological B
  - stochastic pattern generator
- Task 2: extended use of observations
  - radar radial winds + reflectivity, (WG1: LHN; SEVIRI VIS)
- 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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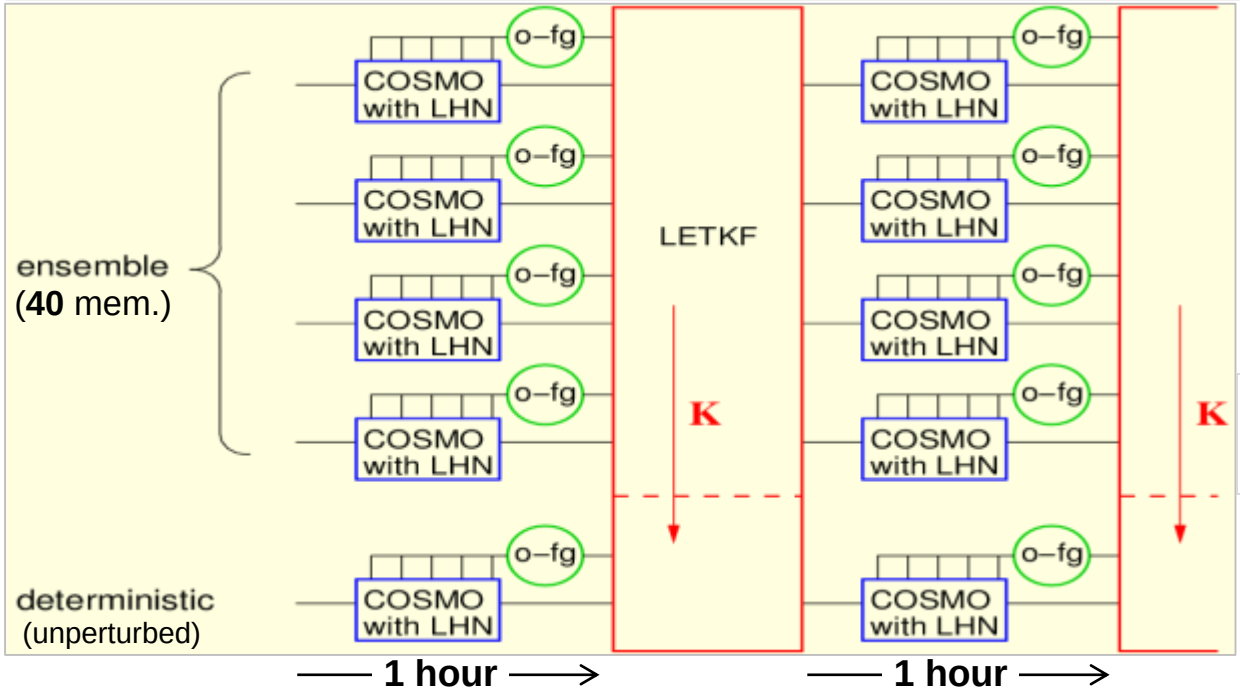
KENDA: 4D-LETKF + LHN (latent heat nudging for assimilation of radar precip)



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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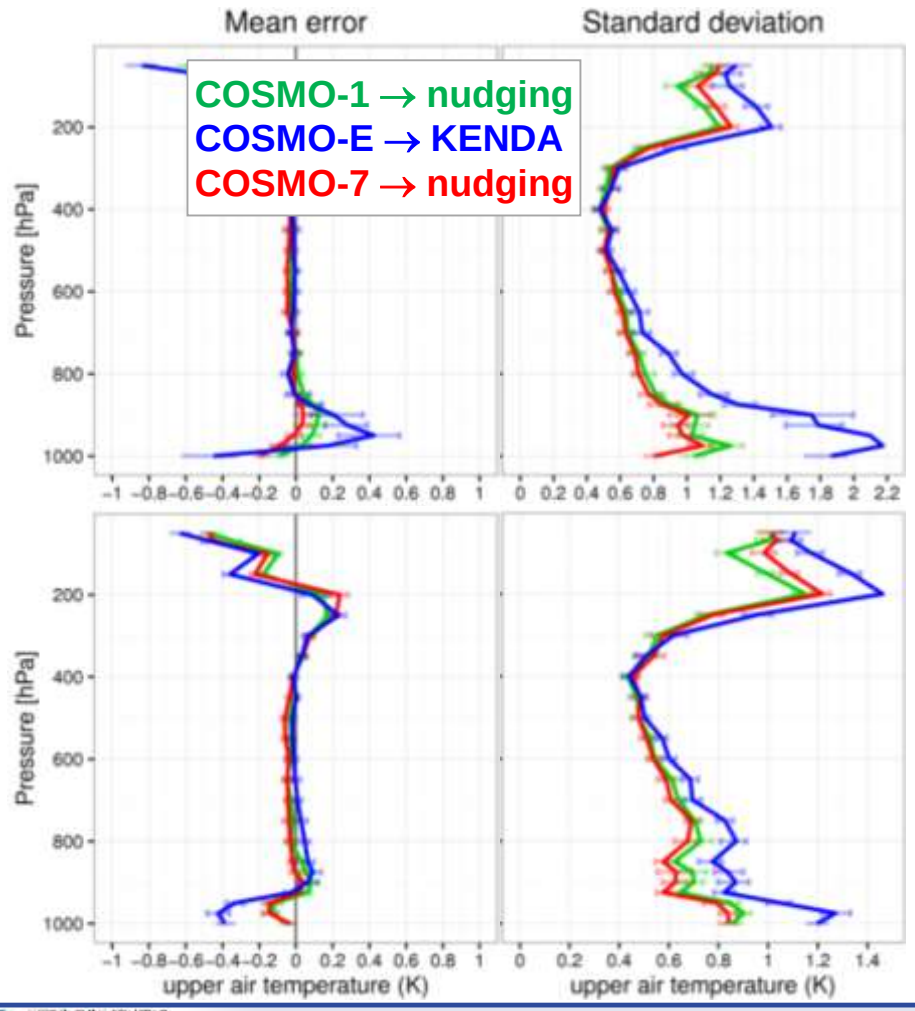
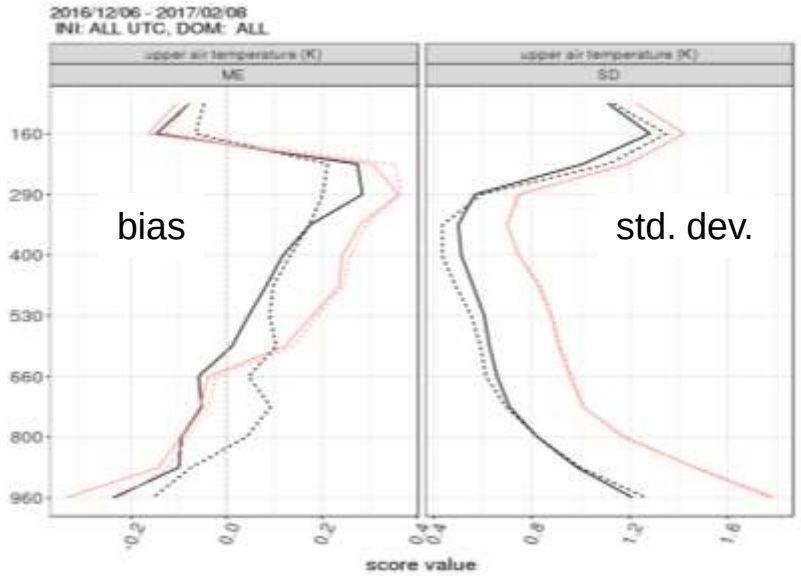
MeteoSwiss analysis verification | temperature | DWD verification

+ 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

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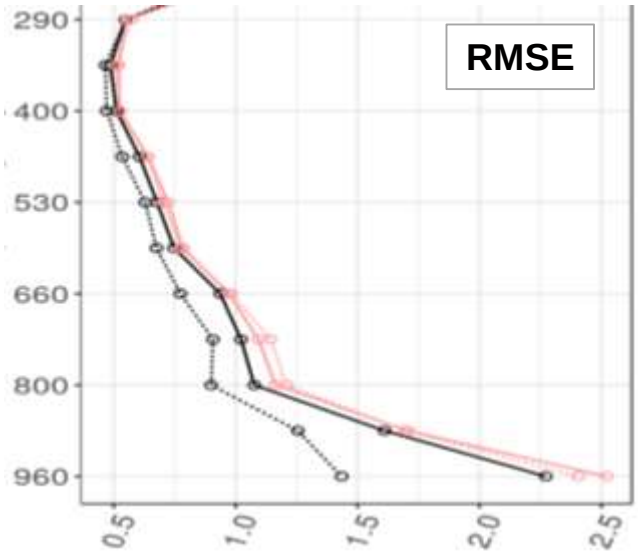
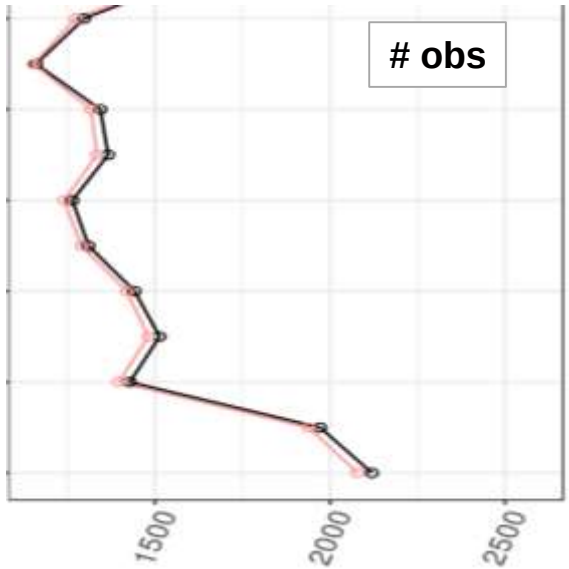
temperature

MEC based on Swiss cdfin files

1 – 26 Dec 2016

→ bad fit of KENDA analysis to obs (PBL) (like KENDA @ MCH)

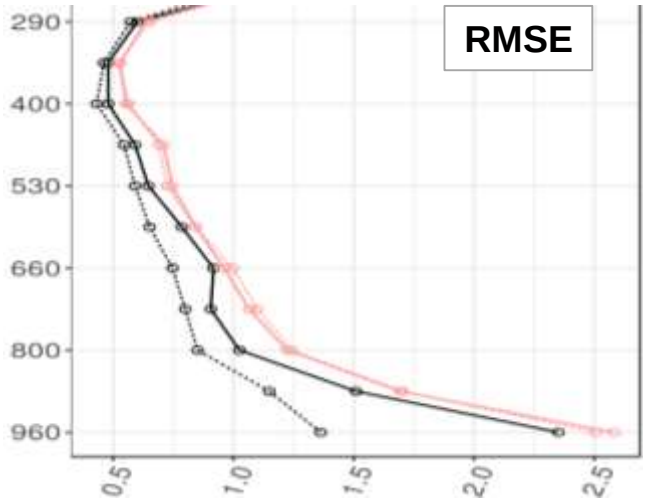


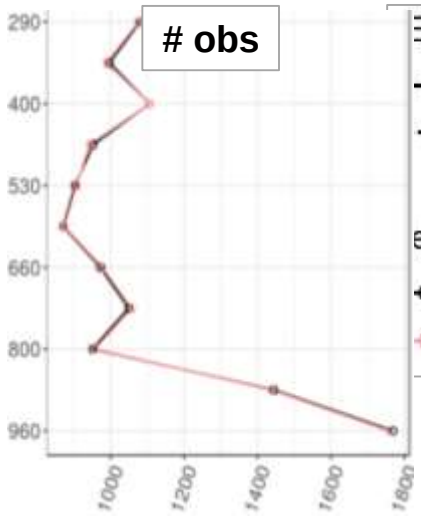


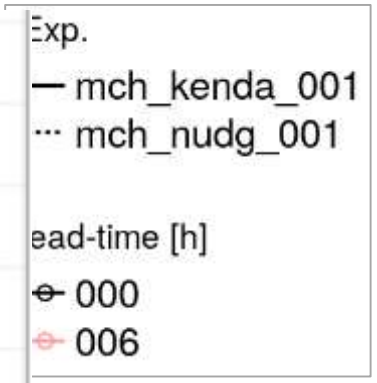
MEC based on DWD cdfin files

1 – 27 Dec 2016

→ no impact from using different cdfin files in verification







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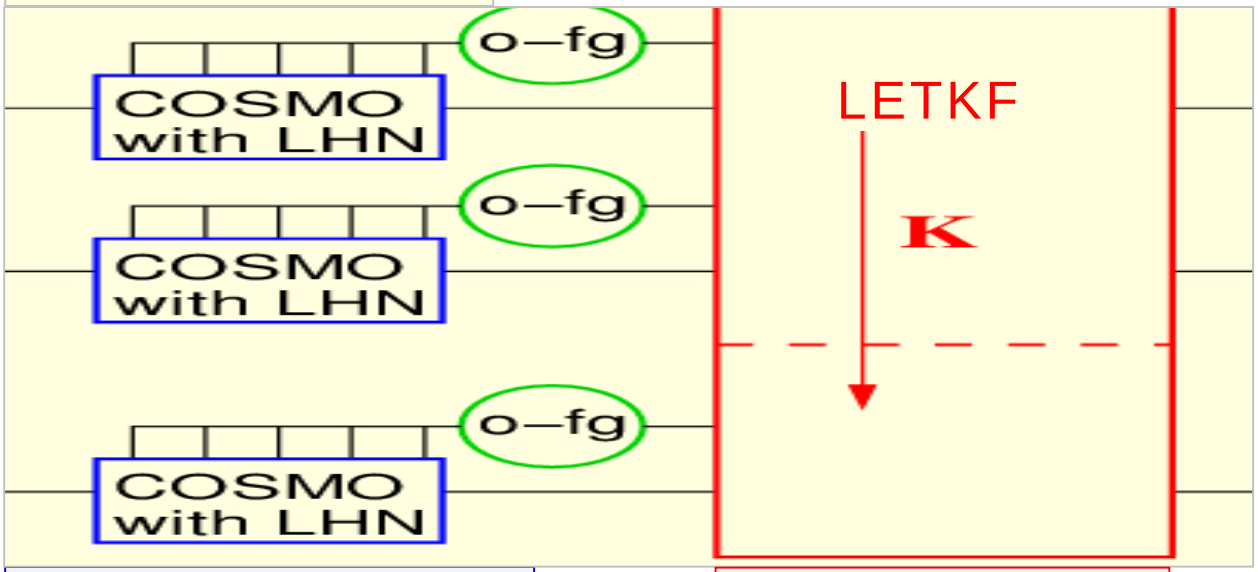
first guess check: reject obs y if: $|y - H(\mathbf{x})| > \Delta y_{thresh}$

KENDA: 4D-LETKF



'cdfin' observation files

MEC for verif @ MCH

- obs operator H → $y - H(\mathbf{x}_1)$
- 'COSMO-FG check' applied to first model state $\mathbf{x}_1$ that is read by MEC

applied in **COSMO**:

- obs operator H → $y - H(\mathbf{x}_{fg})$
- 'COSMO-FG check': thresholds Δy_{thresh} **tuned** to cope with low low-level inversions

'fof' fdbk files

applied in **LETKF**:

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

'ekf' fdbk files

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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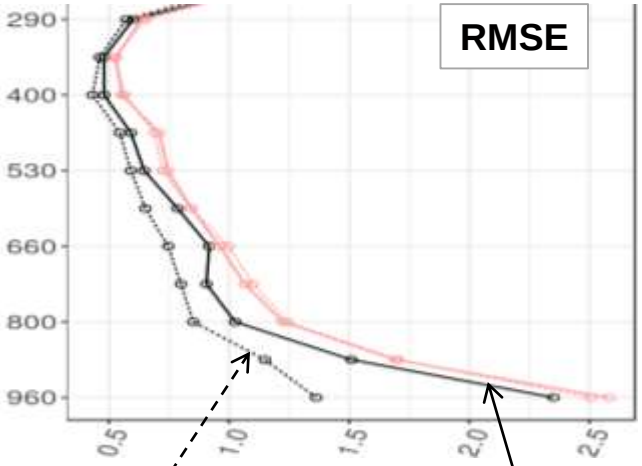
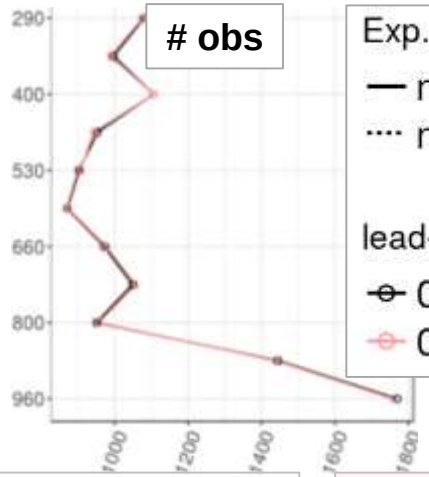
temperature

1 – 27 Dec 2016

MEC based on DWD cdfin files

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





Exp.
mch_kenda_001
mch_nudg_001

lead-time [h]
000
006

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

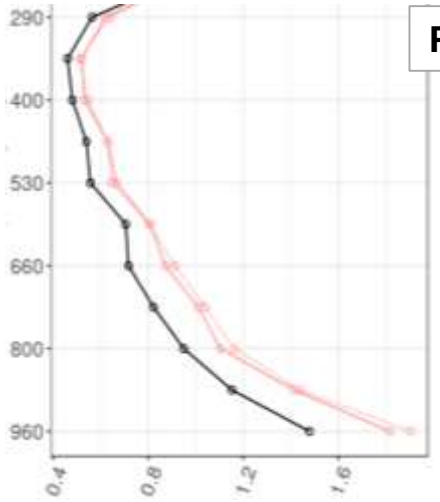
quite a few obs used in verif. not used in KENDA analysis →

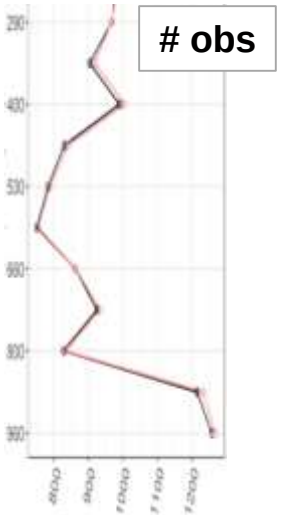
unfair comparison does not tell anything about analysis quality! … but ok to judge forecast quality!

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)

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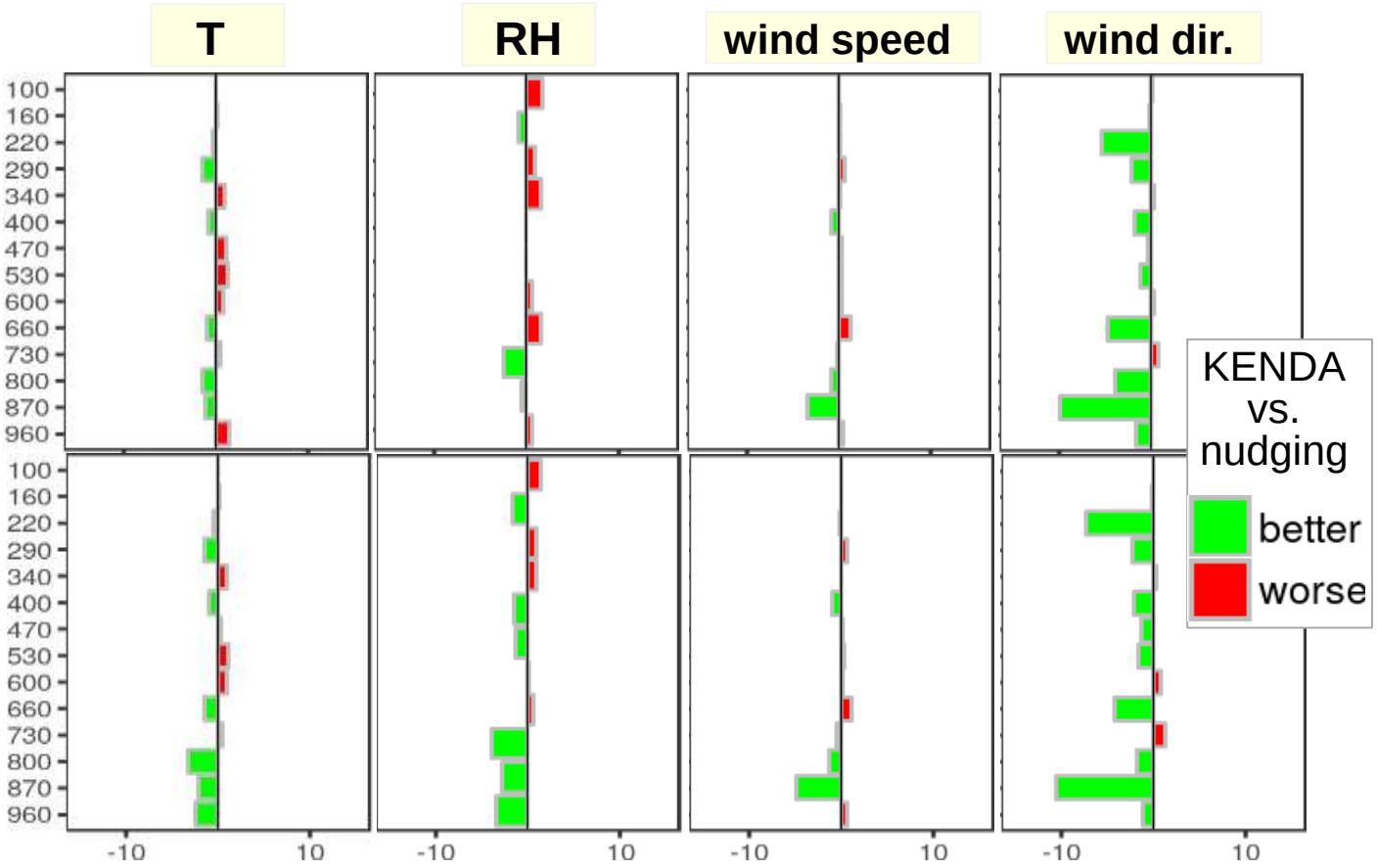
6 – 24 h forecasts:
radiosonde verification

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)

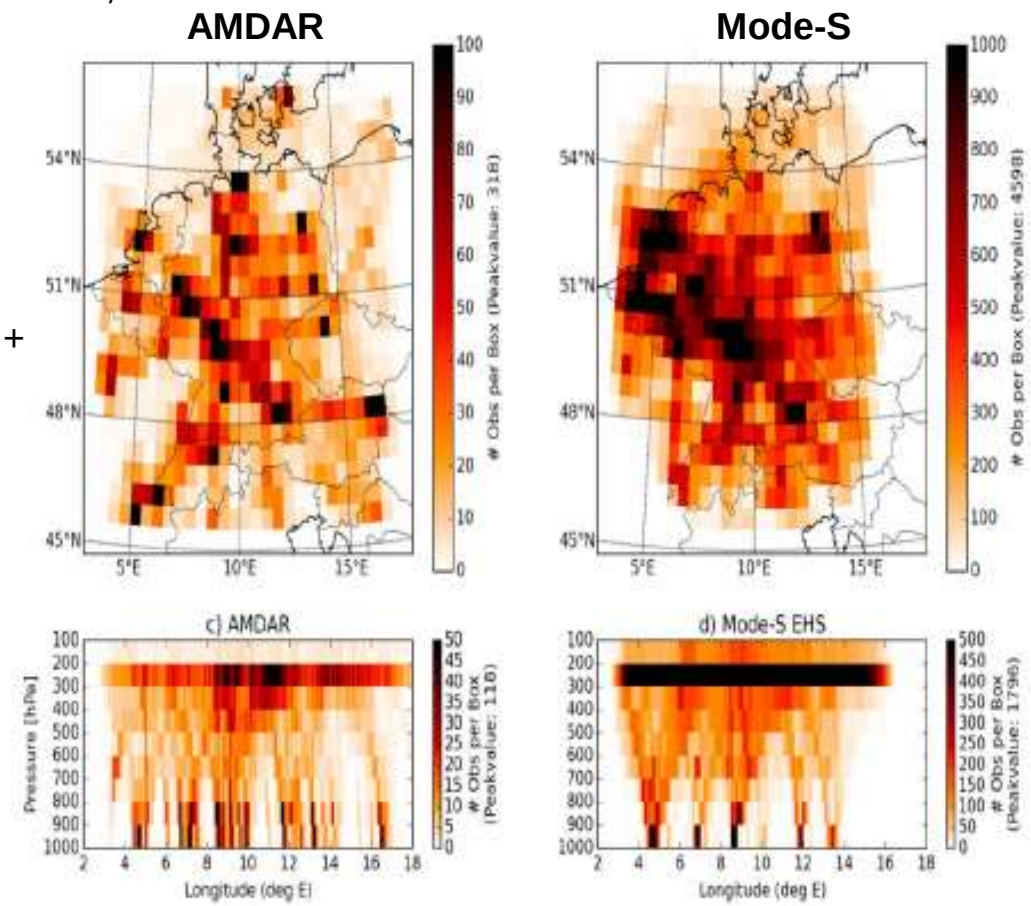
Mode-S aircraft

- 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*

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

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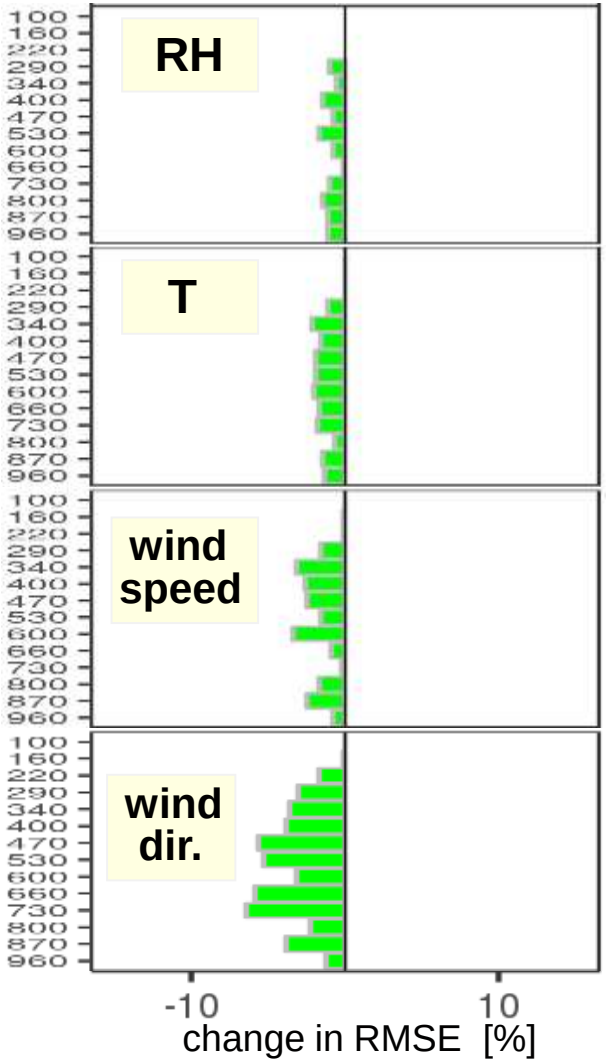
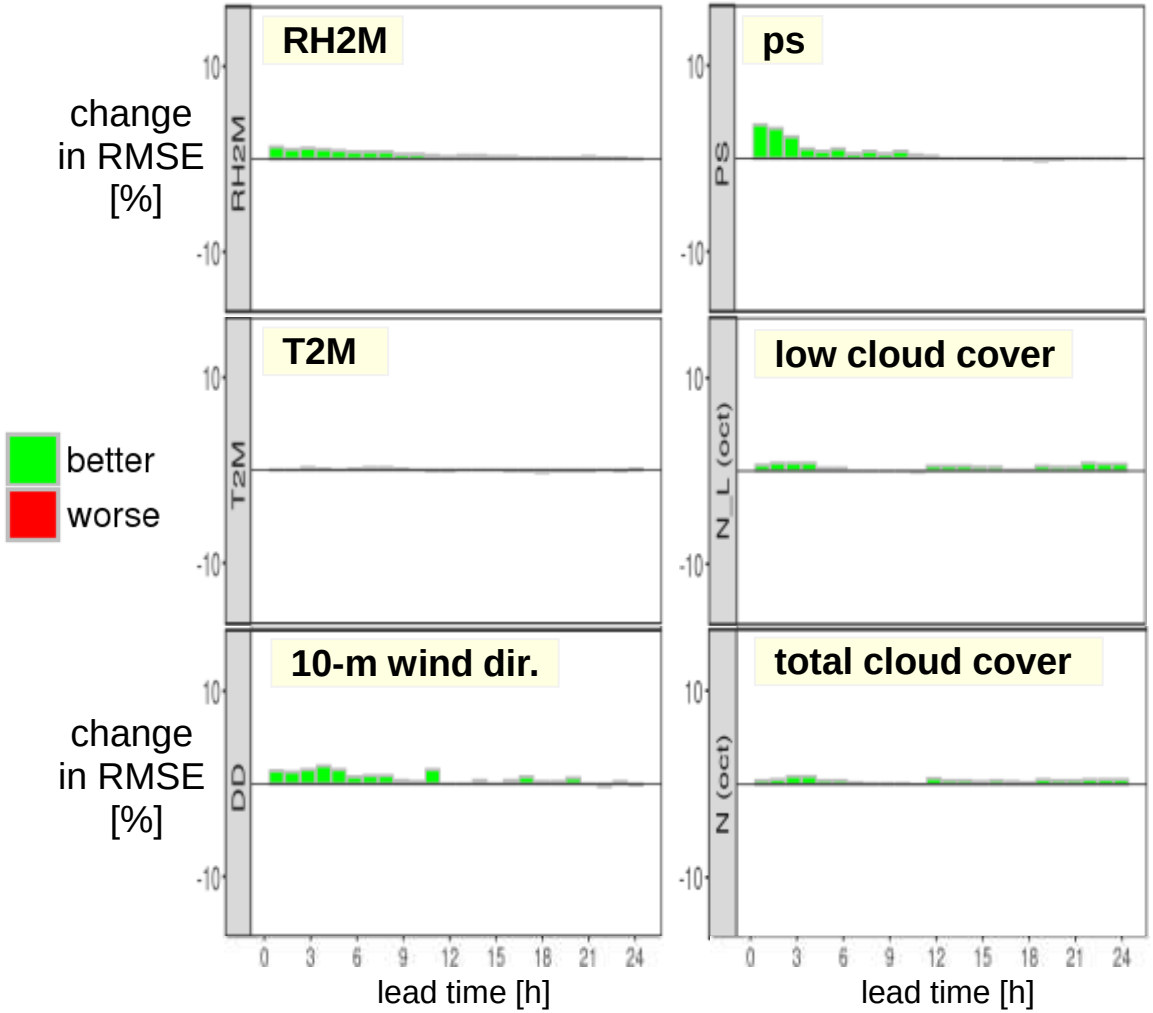
radiosonde verification



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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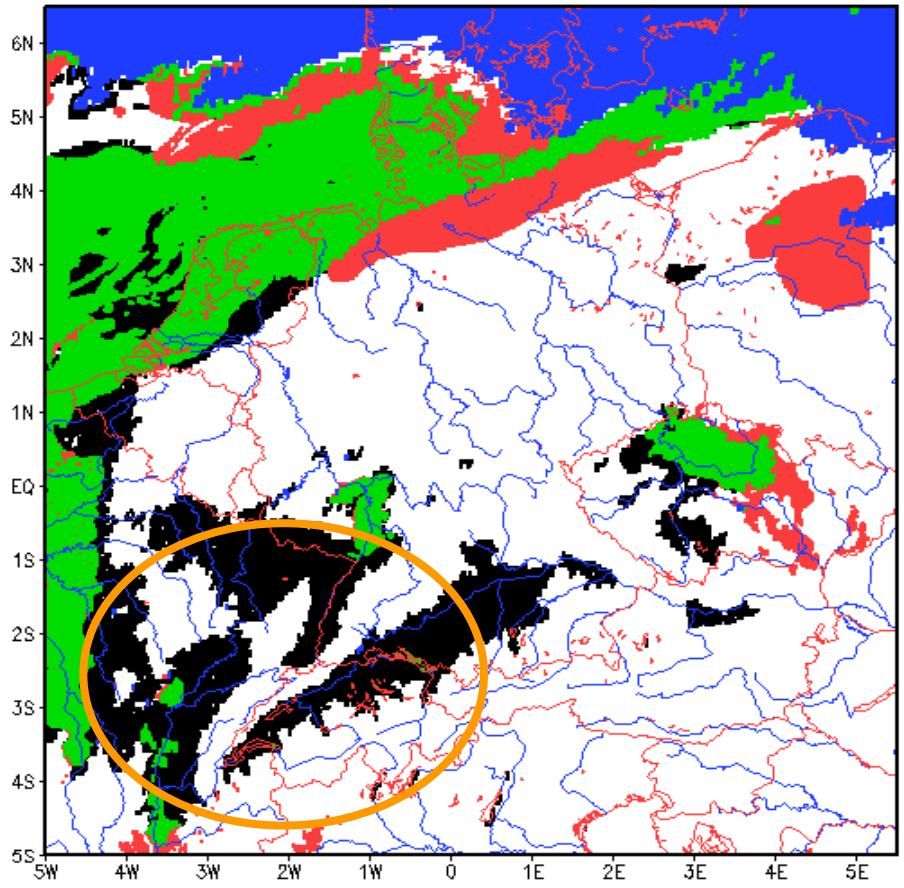
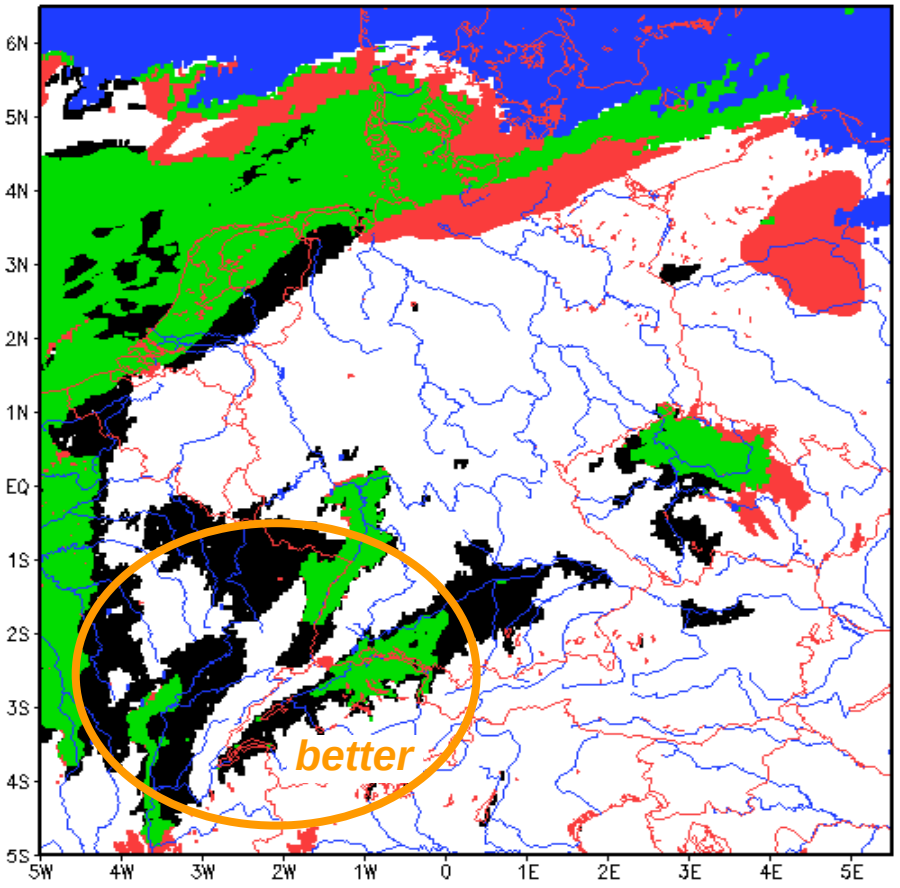
REF

exp_8000.04_HR_det_2016123012+06h
clcl



Mode-S

exp_8000.05_HR_det_2016123012+06h
clcl



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

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

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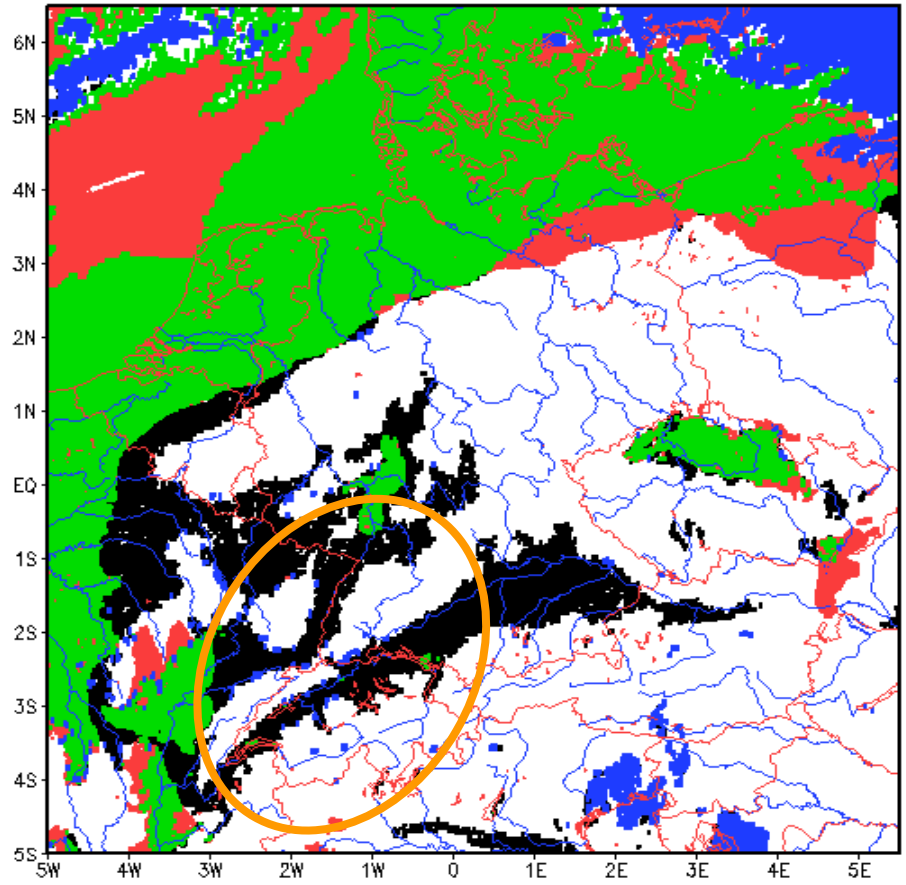
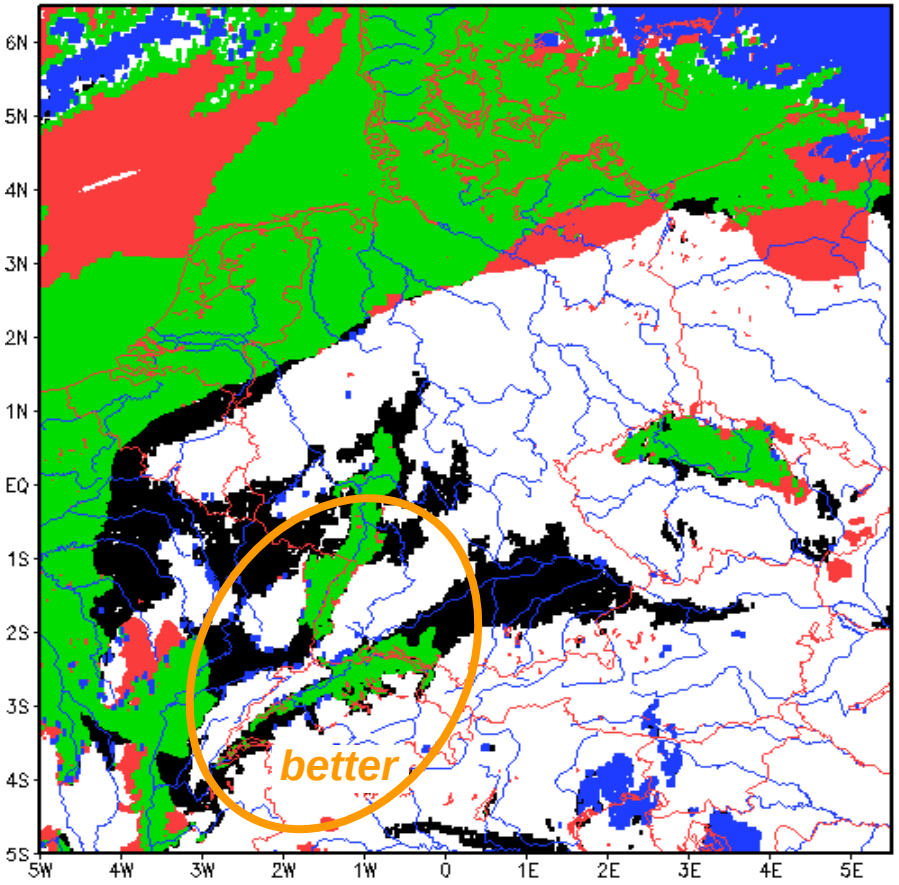
REF

exp_8000.04_HR_det_2016123012+18h
clcl



Mode-S

exp_8000.05_HR_det_2016123012+18h
clcl



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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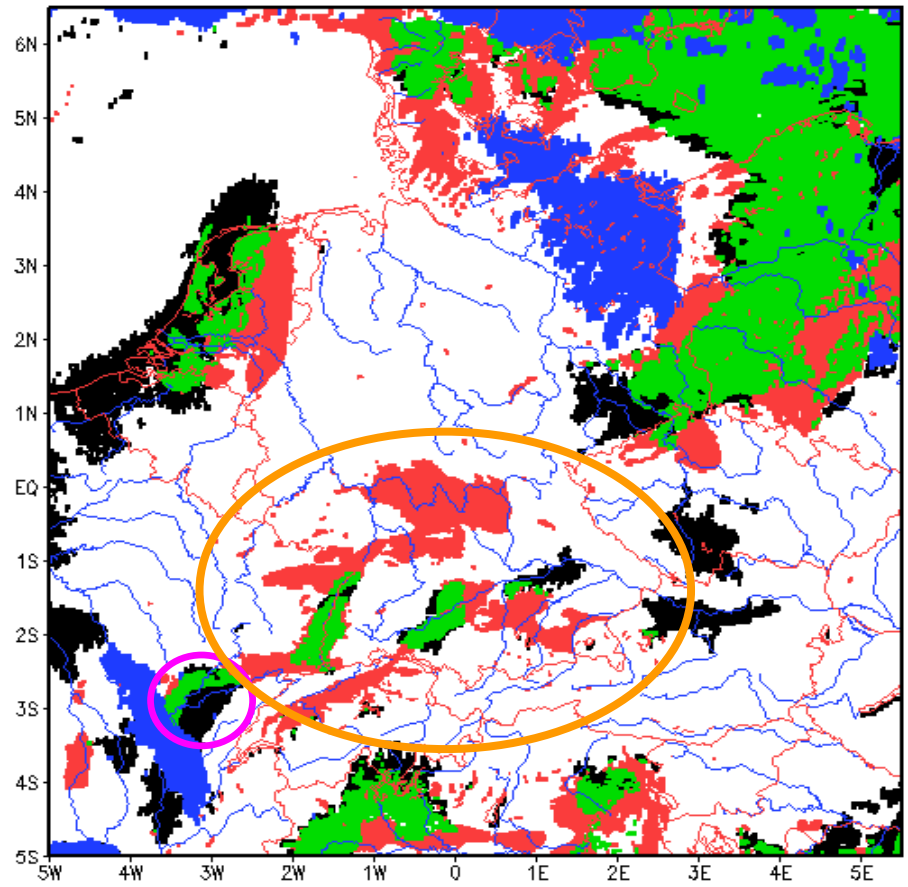
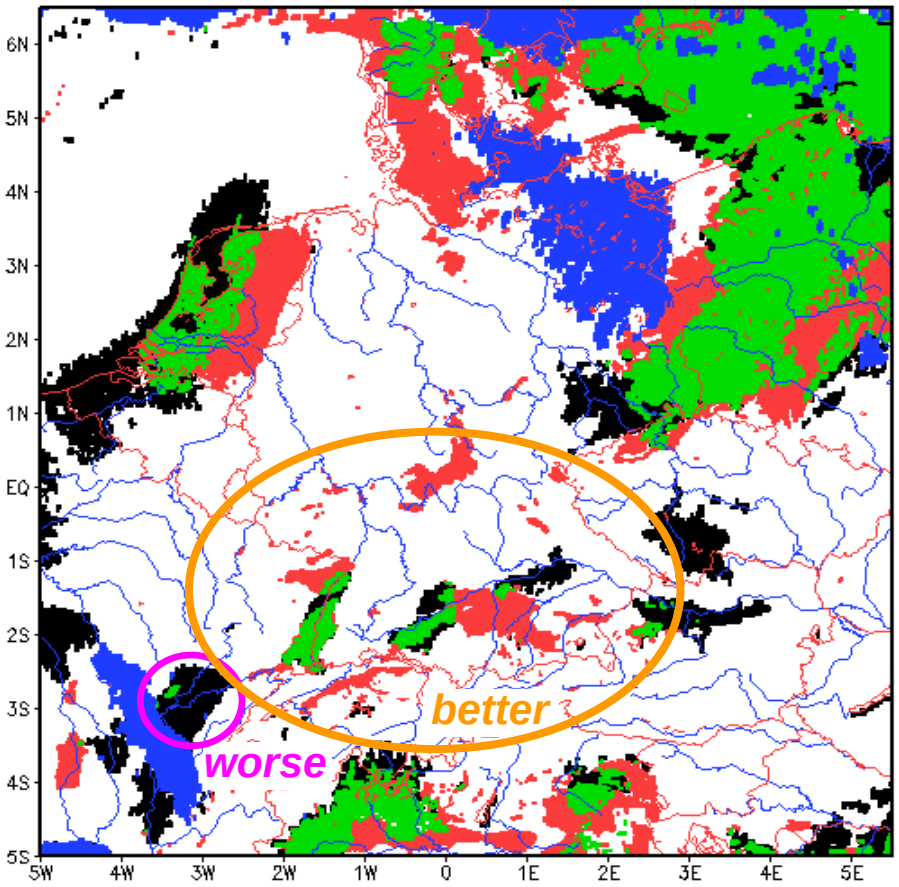
REF

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

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

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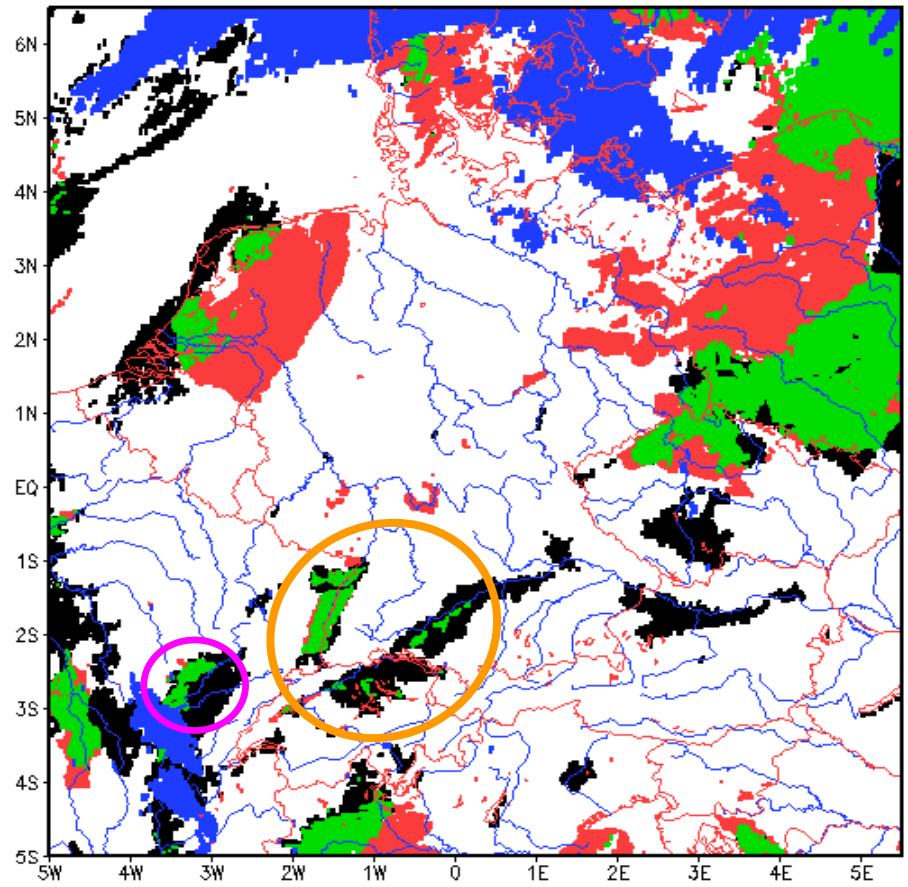
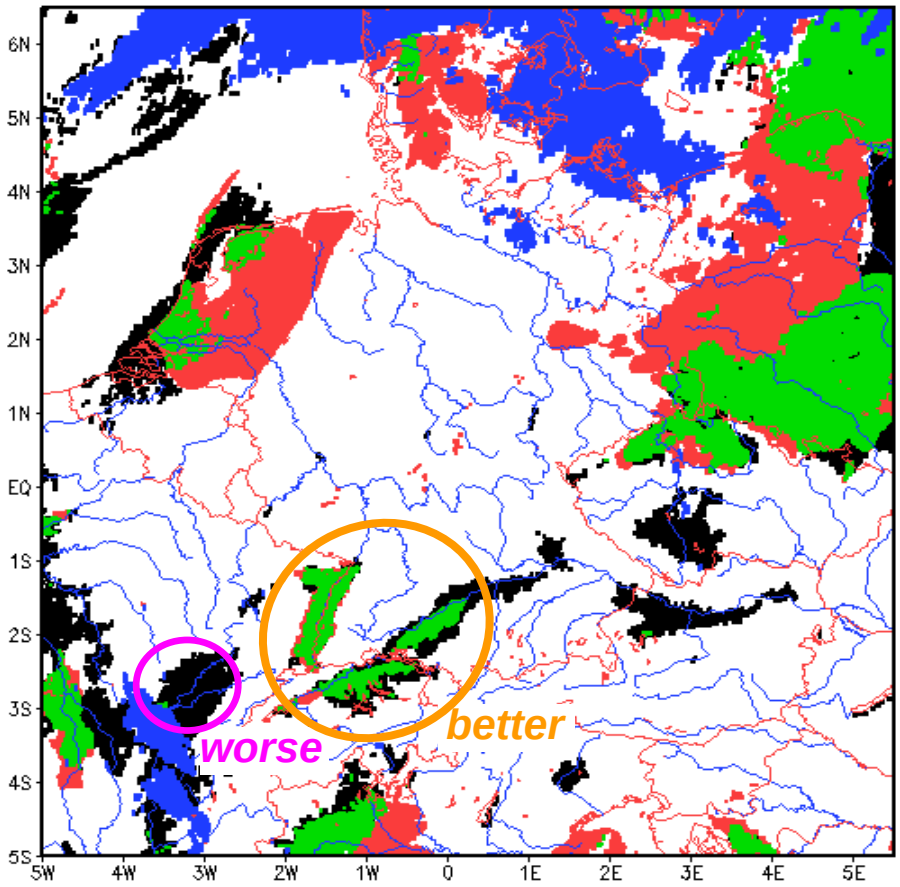
REF

exp_8000.04_HR_det_2016122918+06h
clcl



Mode-S

exp_8000.05_HR_det_2016122918+06h
clcl



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

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

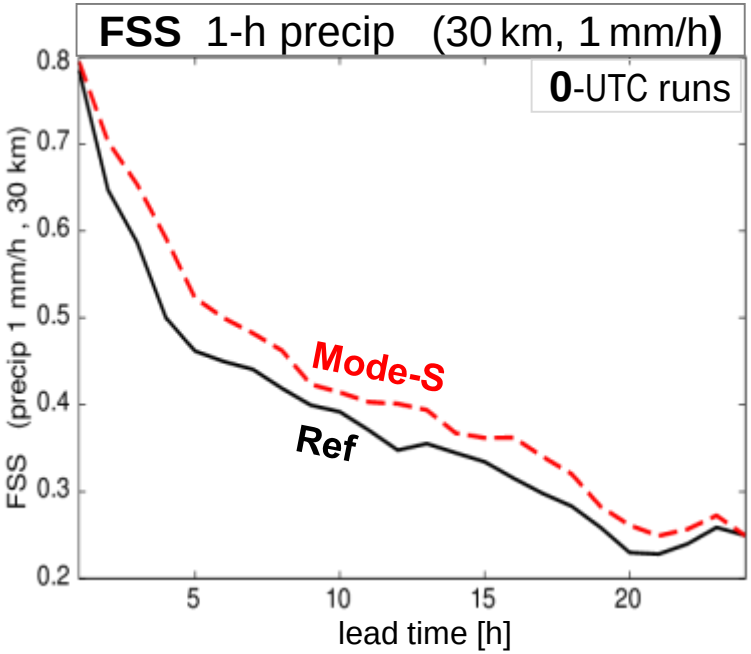
missed (black): 13105 false (red): 17132 hits (green): 15313 unclear (blue): 14042
ETS: 0.252 FBI: 1.141

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 →

→ Mode-S operational 4 October 2017

26 May – 10 June 2016



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

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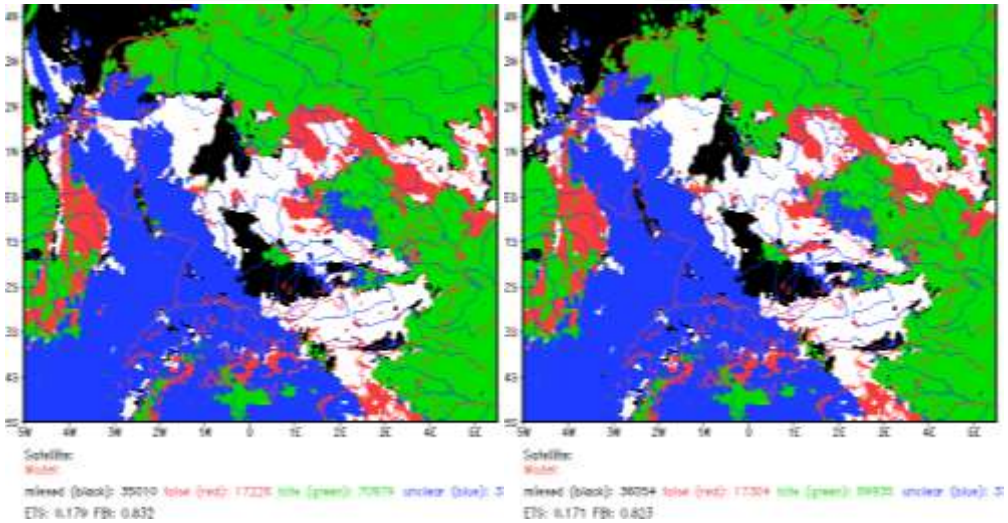
Dec. 2016

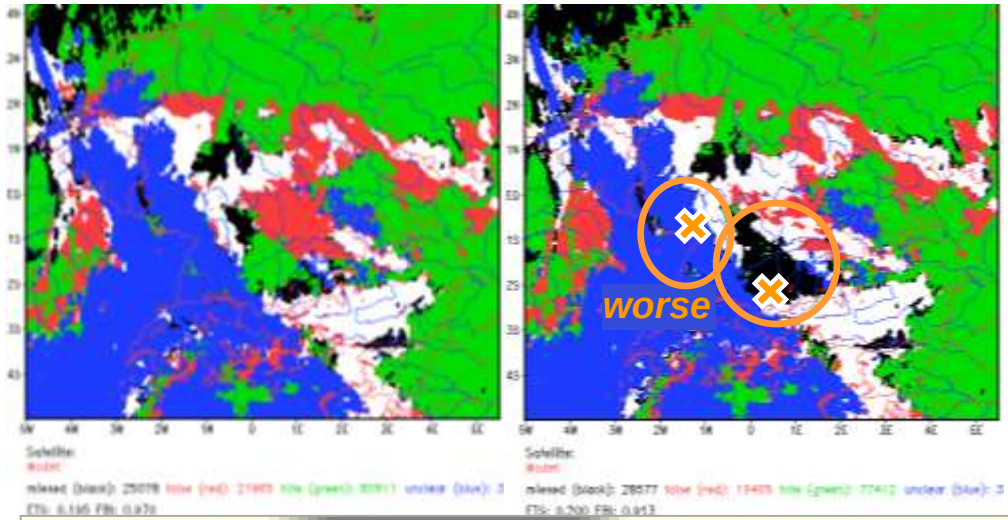
REF **Mode-S**

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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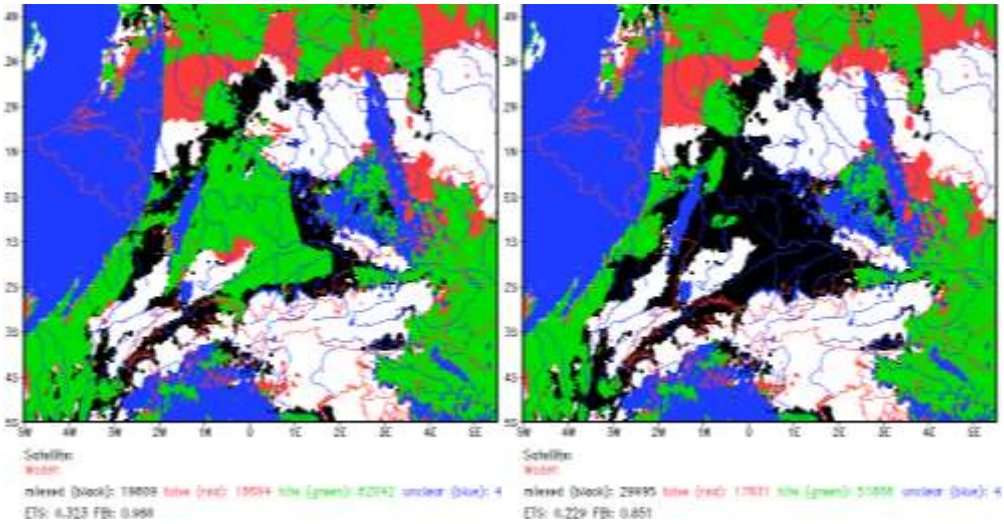
Dec. 2016

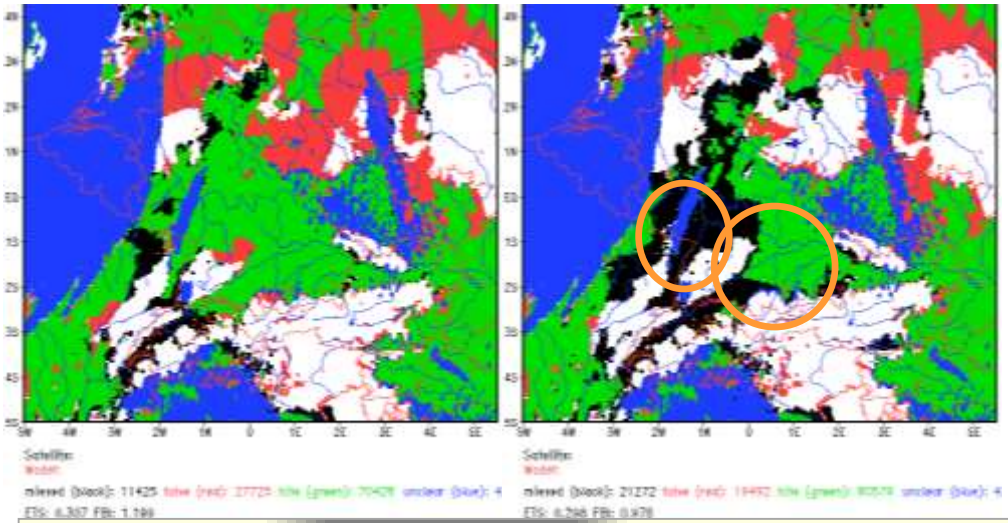
REF **Mode-S**

12-h forecasts for 21 Dec., 06 UTC



→ 1 dramatically degraded forecast

6-h forecasts for 21 Dec., 06 UTC



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

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

Quality control:
Revision of first guess check thresholds

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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:

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

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

(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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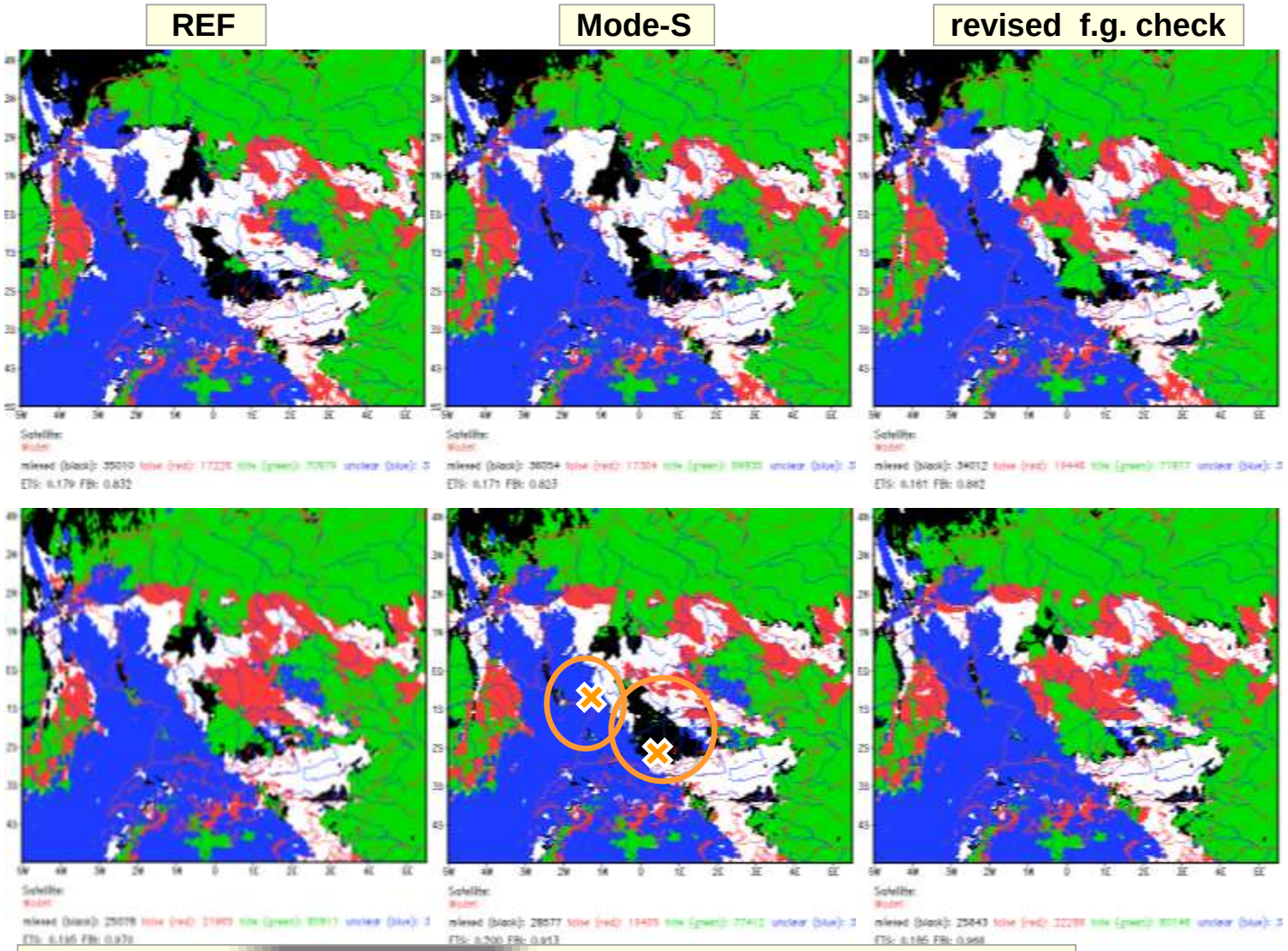
Dec. 2016

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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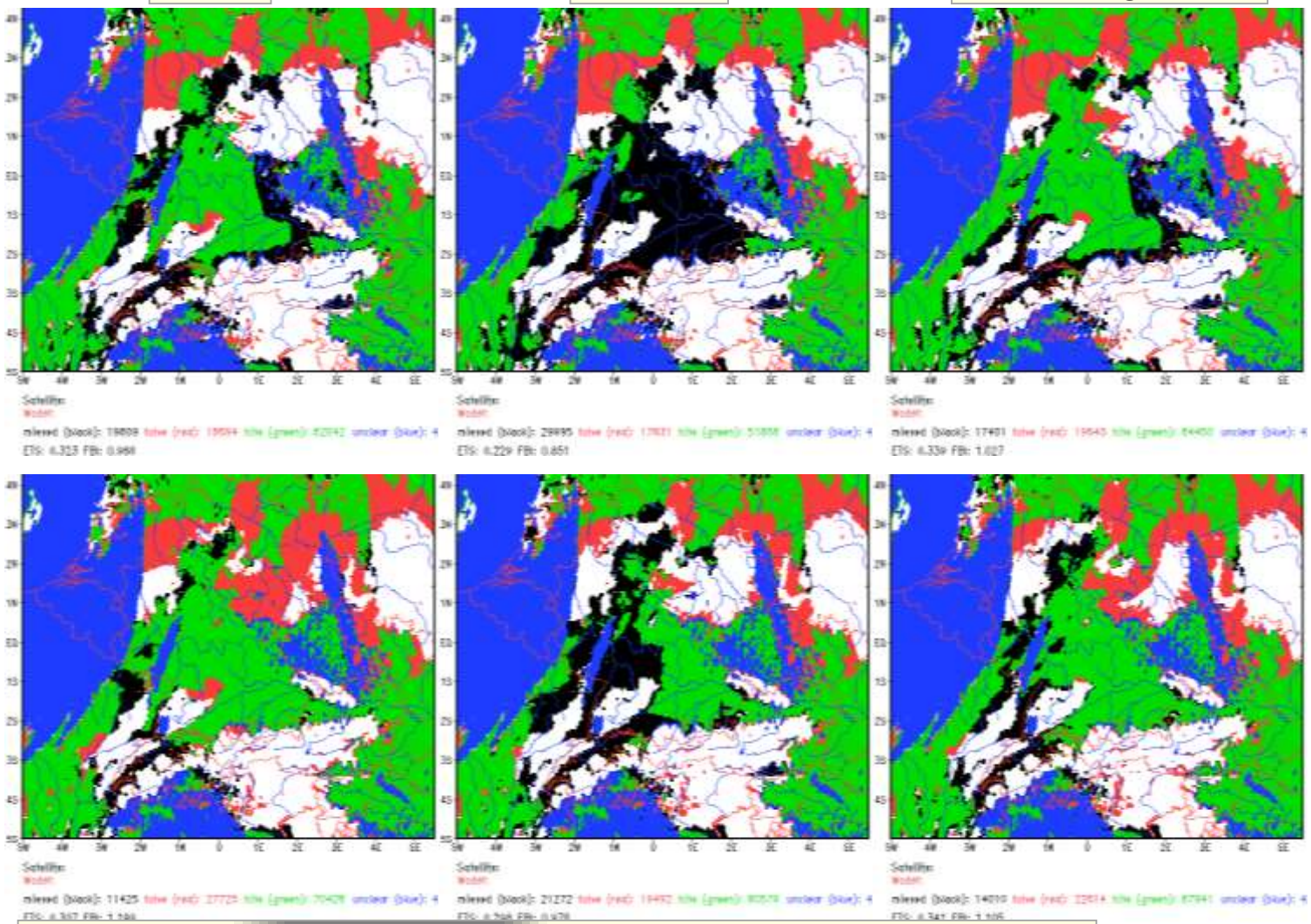
Dec. 2016

REF	Mode-S	revised f.g. check
12-h forecasts for 21 Dec., 06 UTC		
6-h forecasts for 21 Dec., 06 UTC		



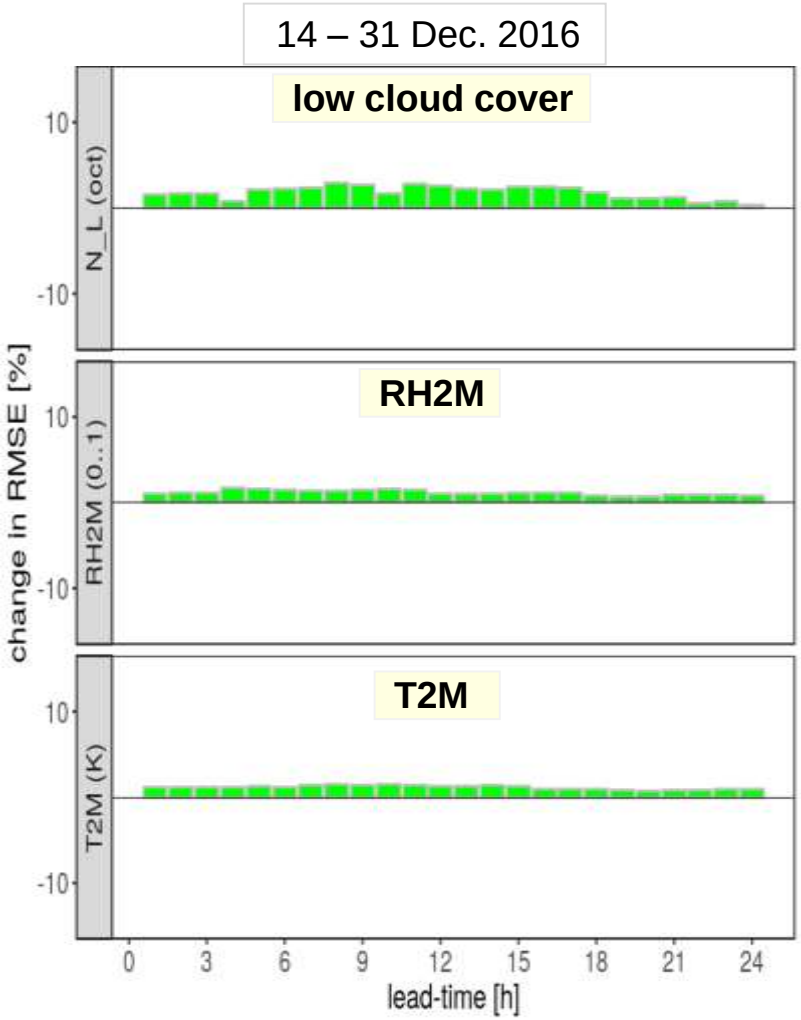
correct cloudy / correct cloud-free / missed events / false alarms / undefined

Revised first guess check thresholds: winter test

Deutscher Wetterdienst

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



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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)