Overview on Status of KENDA

Deutscher Wetterdienst DWD

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Daniel Leuenberger, Simon Förster, André Walser (MeteoSwiss)

Chiara Marsigli, Virginia Poli, Tiziana Paccagnella (ARPA-SIM)

Lucio Torrisi, Francesca Marcucci (CNMCA)

Amalia Iriza (NMA)

Mikhail Tsyrulnikov, Dmitri Gayfullin (HMC)

PP KENDA: overview

- Task 1: General issues in the convective scale , to decide on LETKF (e.g. occurrence and effects of non-Gaussianity in COSMO-DE-EPS)
- Task 2: Implementation of LETKF system
  → MEC (Model Equivalent Calculator) for feedback files (verification)
- Task 3: Main development (tuning, refinement, testing) of LETKF, comparison with nudging (using conventional obs)
  - Stochastic Perturbation of Physics Tendencies (*Torrisi, CNMCA*)
  - Stochastic Pattern Generator (*Tsyrulnikov, Gayfullin, HMC*)
- Task 4: Use of additional (high-resolution) observations

MEC (Model Equivalent Calculator)

- first version disseminated for testing + use
  - with documentation, test cases for deterministic and ensemble forecasts
  - for verification of conventional obs
- some pending issues
  - verification of time-accumulated quantities
  - need to use same model domain / resolution for first creation of feedback file and for forecasts for which model equivalents are computed
  - technical
- future : extend to non-conventional obs

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3-D radar radial velocity and reflectivity

- obs operator implemented, superobbing, thinning,
- tuning, sensitivity tests with LETKF , impact studies

GPS slant path delay (*Bender, DWD)*

- obs operator implemented, technically ready for DA experiments
- work continues (IAFE-DWD, +3y)

Use of cloud top height (CTH) derived from satellite (SEVIRI) data

- obs operator implemented, LETKF single-obs experiments
- sensitivity tests and impact studies for low-stratus periods

Use of direct satellite radiances for assimilation of cloud information

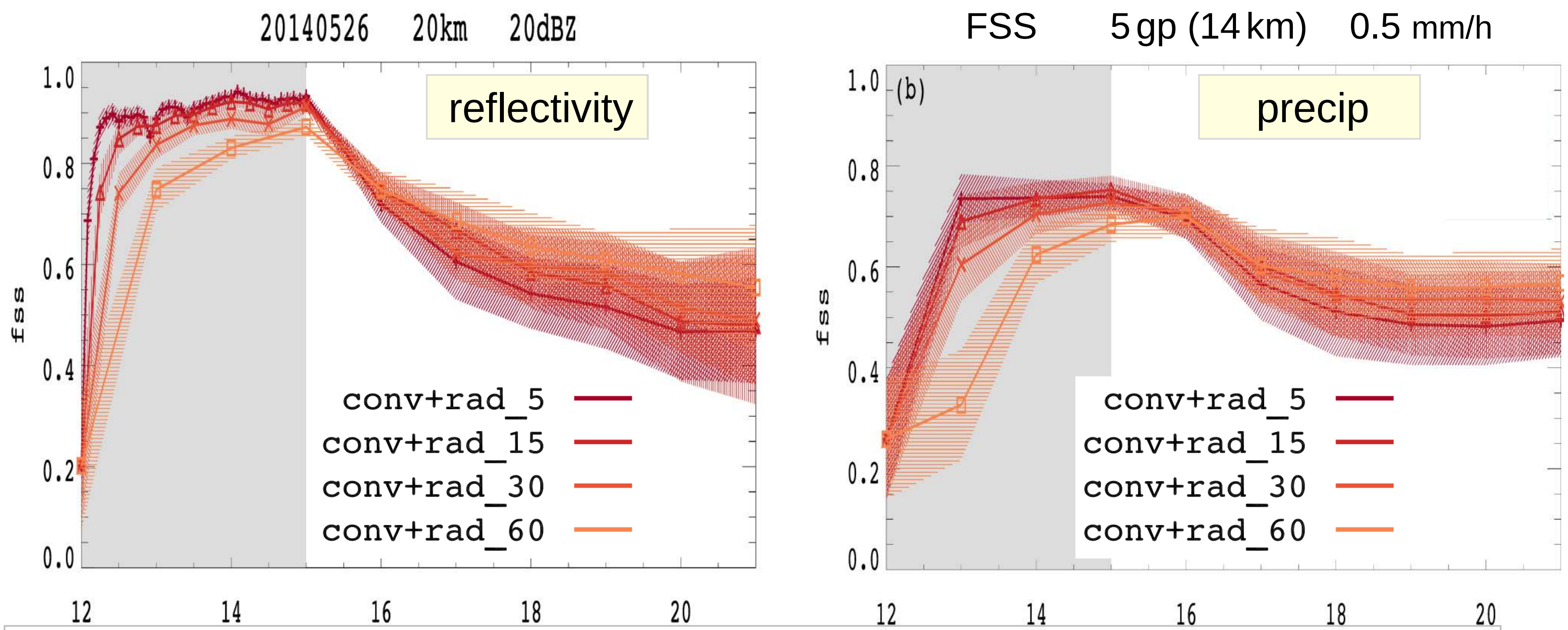
- first DA exp. over several days : benefit for f.g. simulated radiances
- *A. Perianez* left DWD in Nov. 2014; new IAFE 4y will start in late 2015

Raman lidar (qv-profile) & microwave radiometer (T-profile) delay (*Haefele, MCH)*

- innovation statistics of obs at Payerne with COSMO-2 forecasts

LETKF: use of radar reflectivity sensitivity test (single case)

CONV + RADAR-3D with different LETKF cycling frequencies: 5, 15, 30, 60 min.



- ✓ 1-hour LETKF update rate better than higher update rates
- ✓ better to use radar obs at full hours and throw away obs in between

Why ?
- – system flooded with radar obs → influence of other obs reduced ?
- – obs error mis-specified , correlations neglected ?
- – too few ensemble members, LETKF over-confident ?
- – noise ? does not yet level off completely after 5 or 15 min.

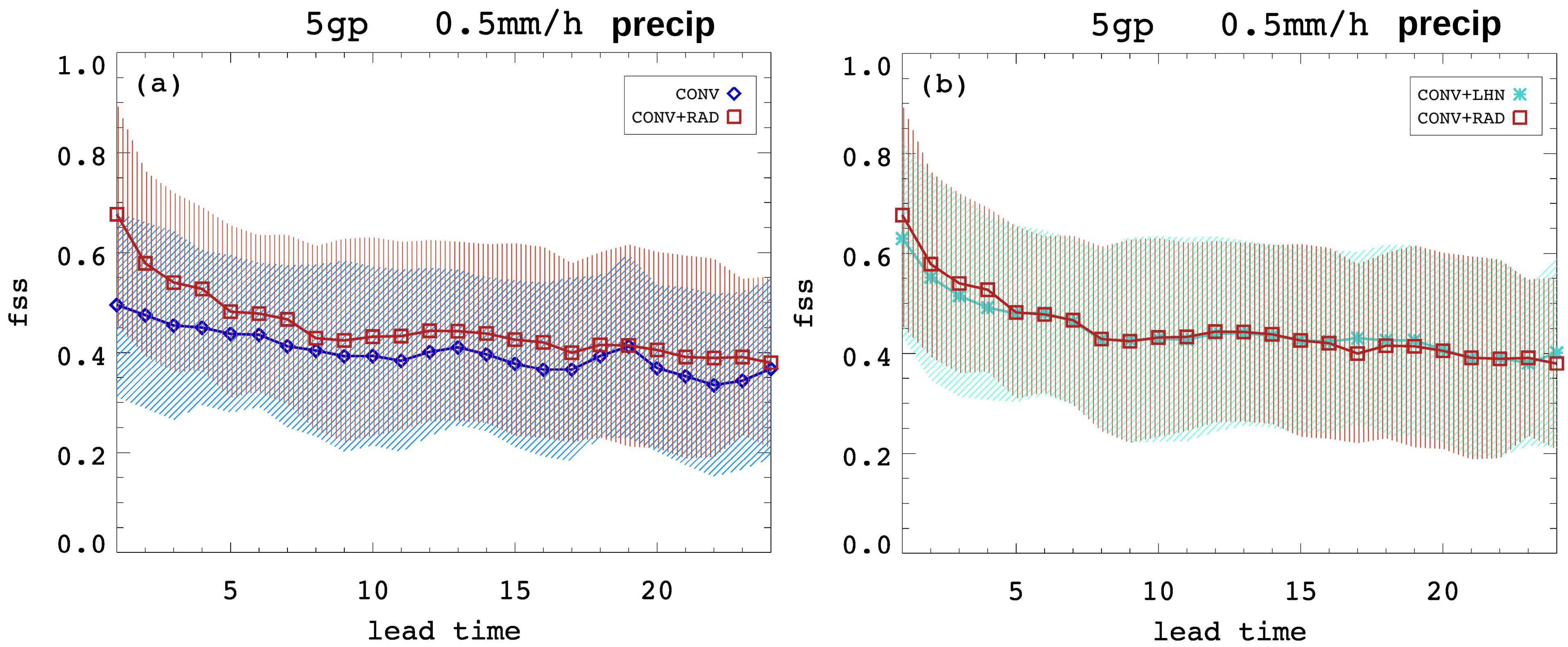
LETKF: use of radar **reflectivity** → *Theresa Bick et al.*
impact study (7 day period)

7 days: 22 – 29 May 2014

- mean FSS (precip) over **19** forecasts
- std dev.

CONV
CONV + RAD

CONV + LHN
CONV + RAD

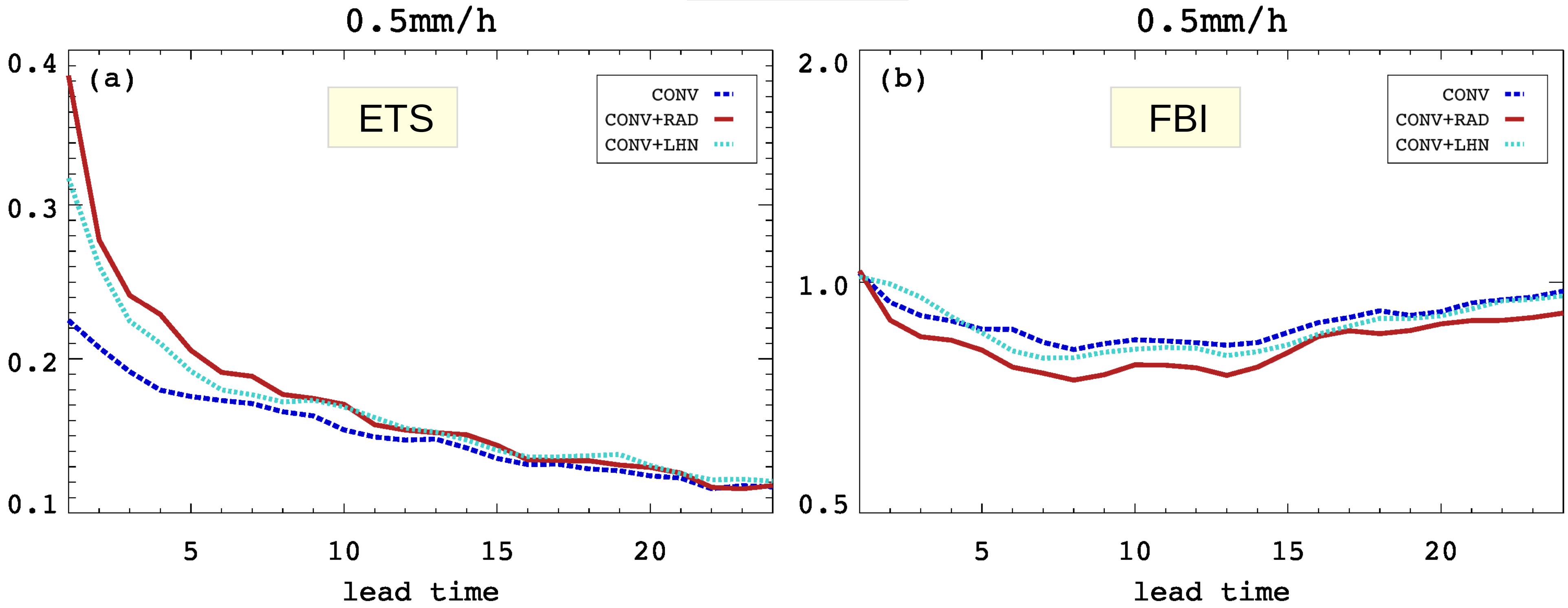


✓ rather large, long-lived positive impact from use of radar reflectivity in LETKF
✓ use of radar reflectivity in LETKF slightly better than LHN in first 4 hours

LETKF: use of radar reflectivity impact study (7 day period)

7 days, 19 forecasts:
22 – 29 May 2014

CONV
CONV + LHN
CONV + RAD



✓ use of radar Z in LETKF gives slightly better score, but worse bias than LHN

LETKF: use of radar reflectivity impact study (7 day period)

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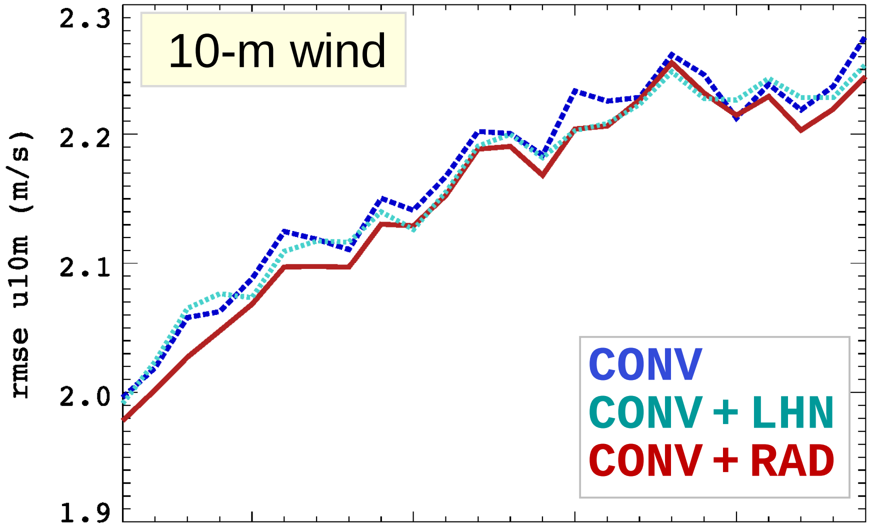

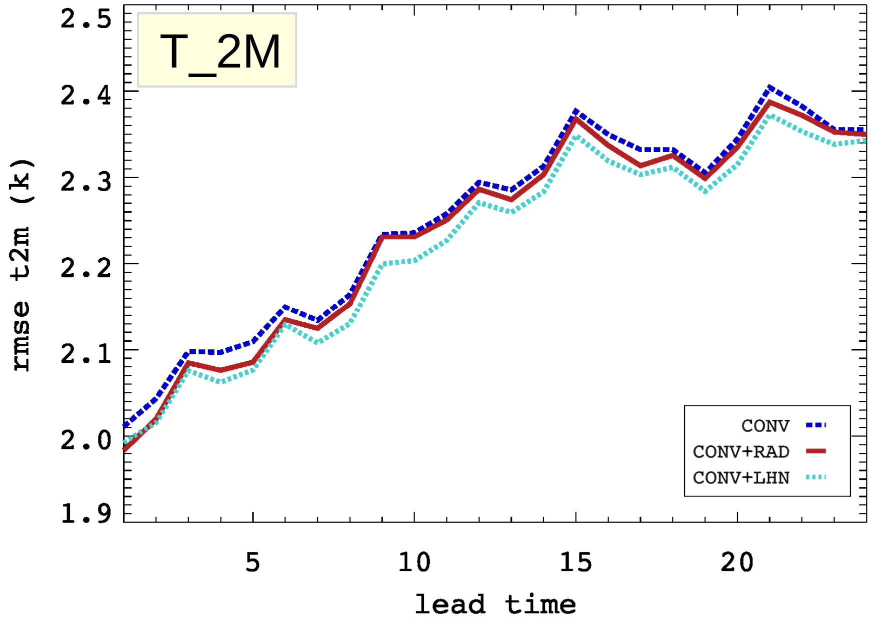

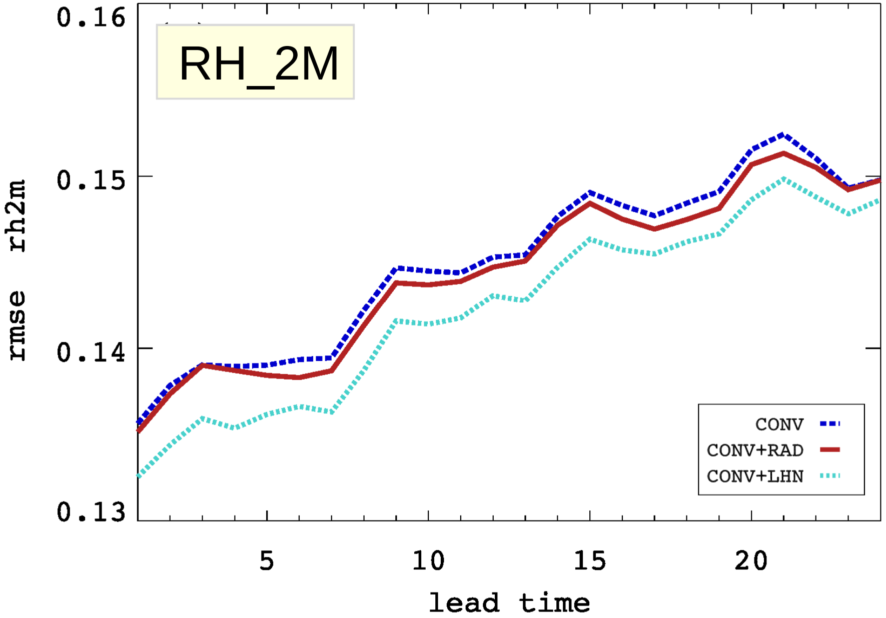

7 days, 19 forecasts:
22 – 29 May 2014

surface verification (RMSE):

✓ slight benefit from use of radar Z in LETKF, but LETKF + LHN is better

LETKF: use of radar reflectivity
impact study (7 day period)

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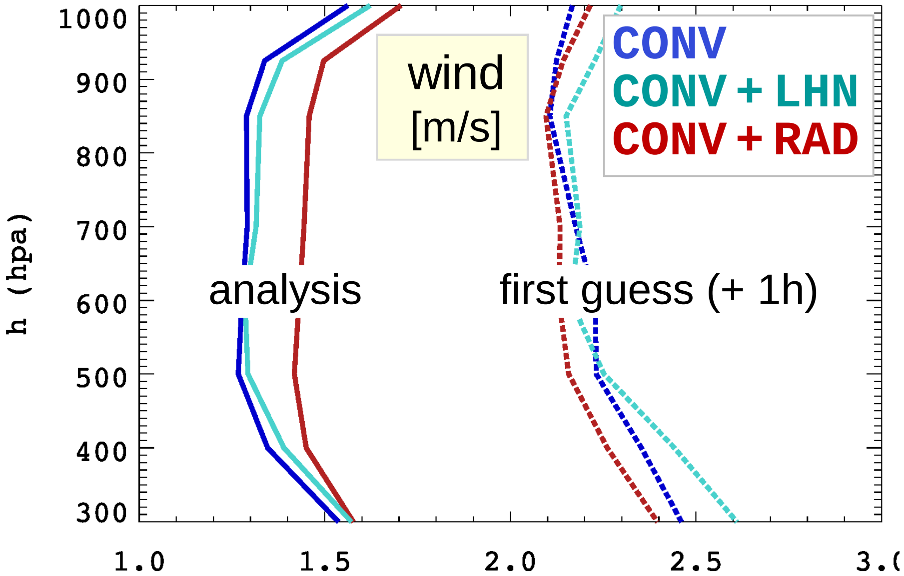

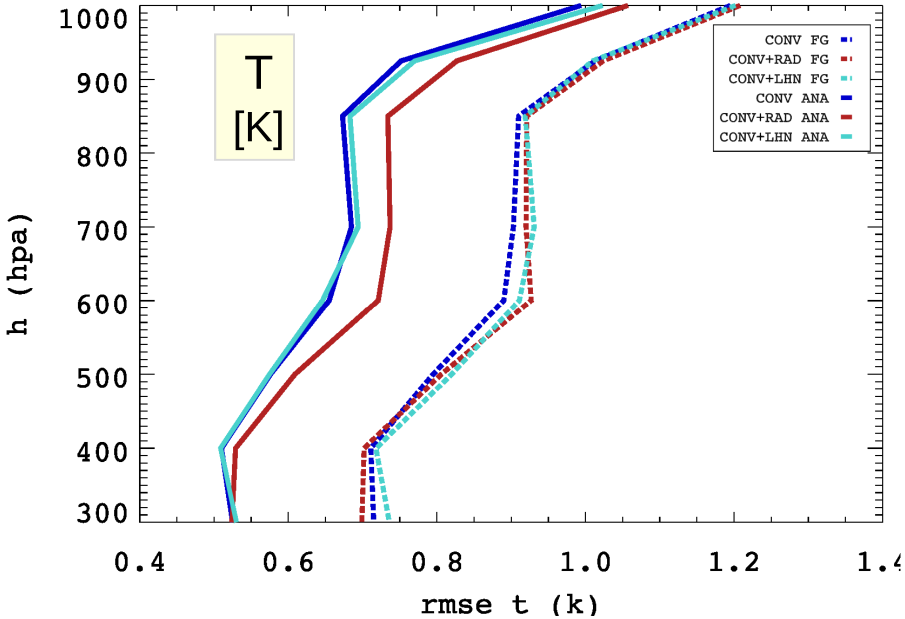

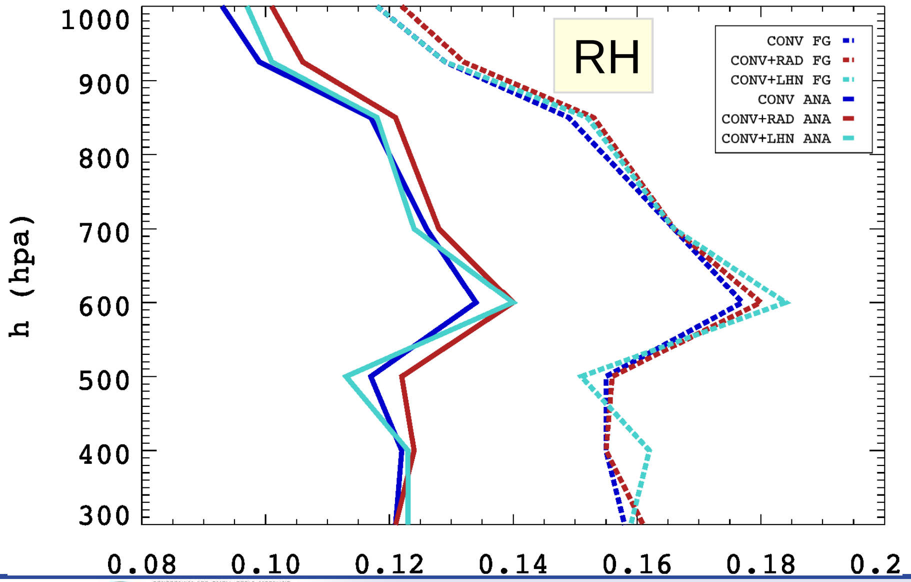

7 days, 19 forecasts:
22 – 29 May 2014

upper-air verification (analysis / f.g. RMSE):

✓ use of radar Z in LETKF improves 1-h wind forecast

LETKF: use of **radar radial velocity** → *Yuefei Zeng et al.*
impact study (5 day period)

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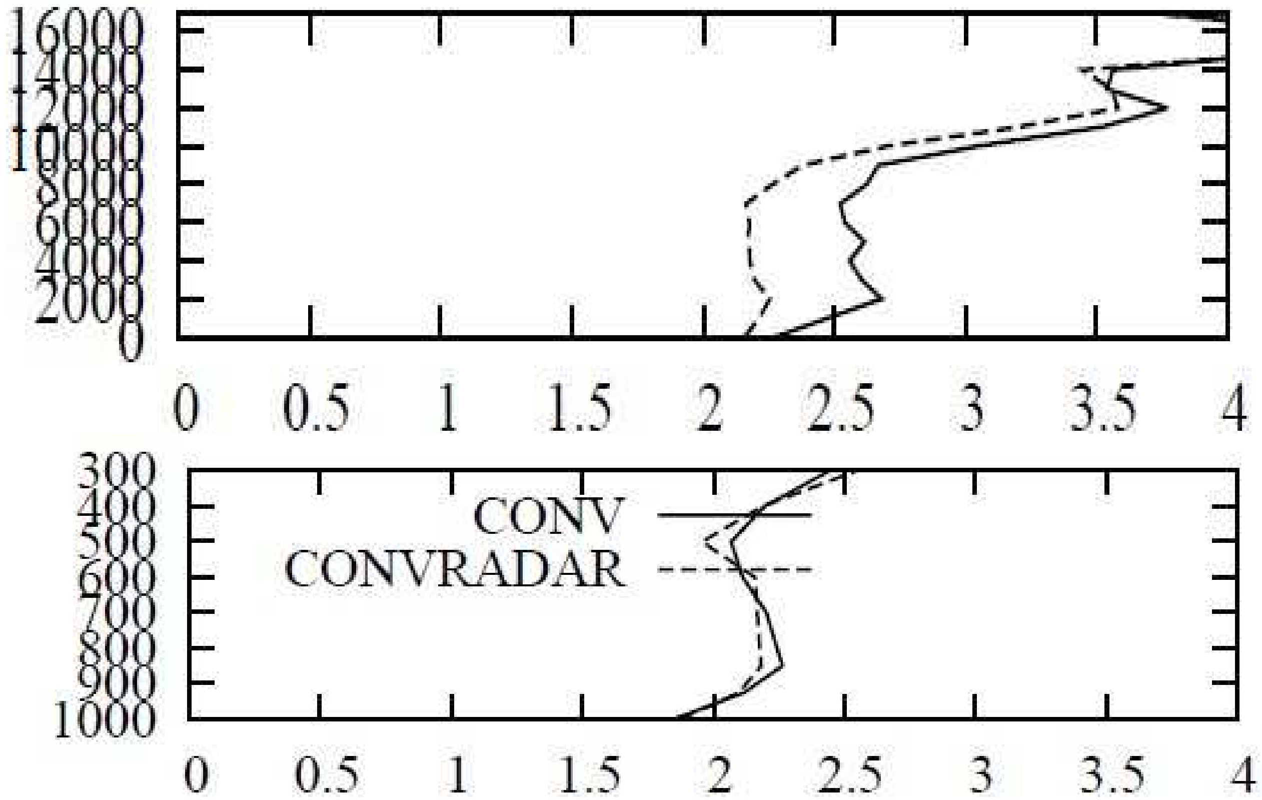
1-hrly LETKF cycling over 5 days (1 – 6 June 2011)

RMSE of first guess (1-hr forecast)



against Radar radial velocity

against radiosonde + aircraft wind speed

LETKF: use of **radar data**
status summary, further steps

radar radial velocity (5-day period)

- (small) positive impact on 1-hr forecast of upper-air wind

radar reflectivity (7-day period)

- (small) positive impact on 1-hr forecast of upper-air wind
- long-lasting positive impact on precip, slightly better than LHN
- small positive impact in surface verification, not as good as LHN

further steps

- quality control
- balance impact of precip vs. non-precip obs / (4-D) radar vs. conventional obs
- thinning / superobbing, obs errors, localization, Gaussianity (variable transform?)
- more test periods

LETKF: use of **satellite cloud top height data**
application to low stratus period

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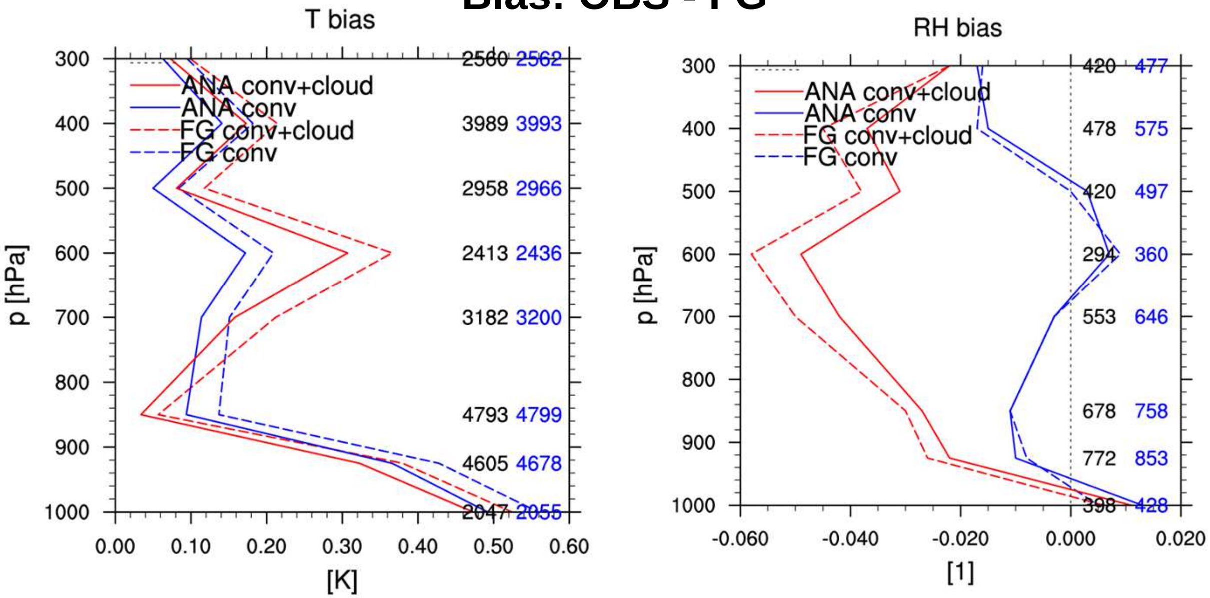
upper-air verification for 83 hours cycled assimilation starting 12 Nov. 2011, 12 UTC

Bias: OBS - FG



assimilation of conventional obs only
assimilation of conventional + cloud obs

→ cold and strong moist bias in mid-levels !
Why ?

LETKF: use of **satellite cloud top height data** application to low stratus period

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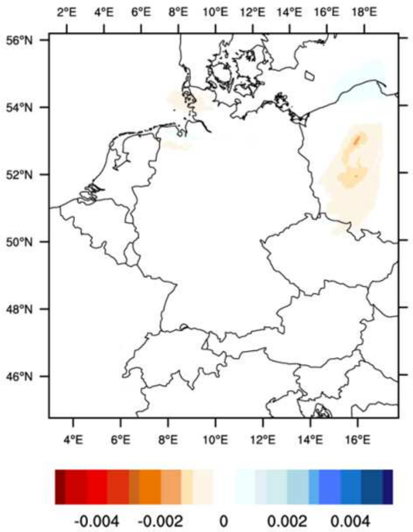
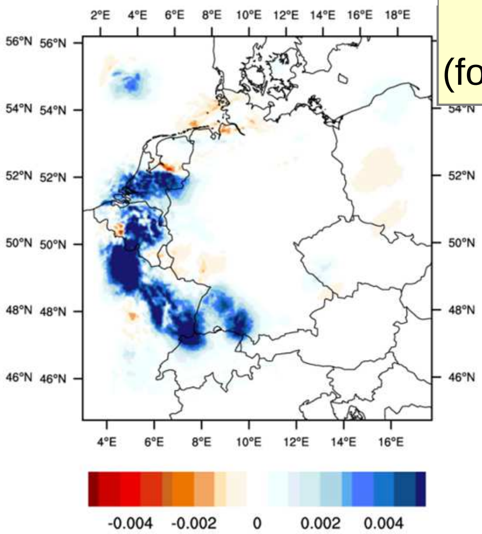
mid-level moisture analysis increment (for 13 Nov. 2011, 12 UTC)

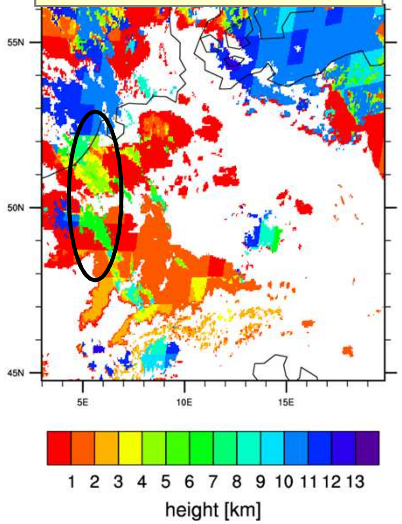
conventional only



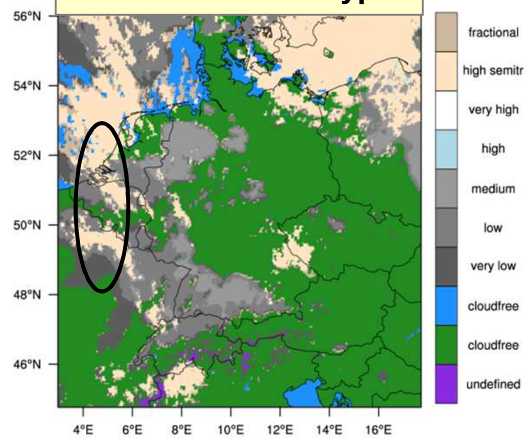
conv + cloud



'observed' cloud top height



observed cloud type



→ mid-level moisture increment in low-stratus situation ! Why ?

→ problems caused by incorrect cloud top height in NWCSAF cloud top height product

LETKF: use of **satellite cloud top height data** application to low stratus period

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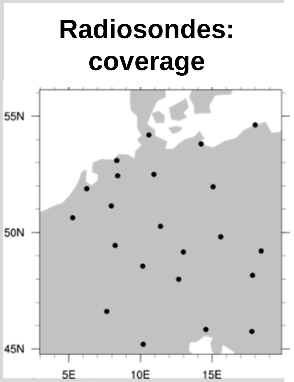
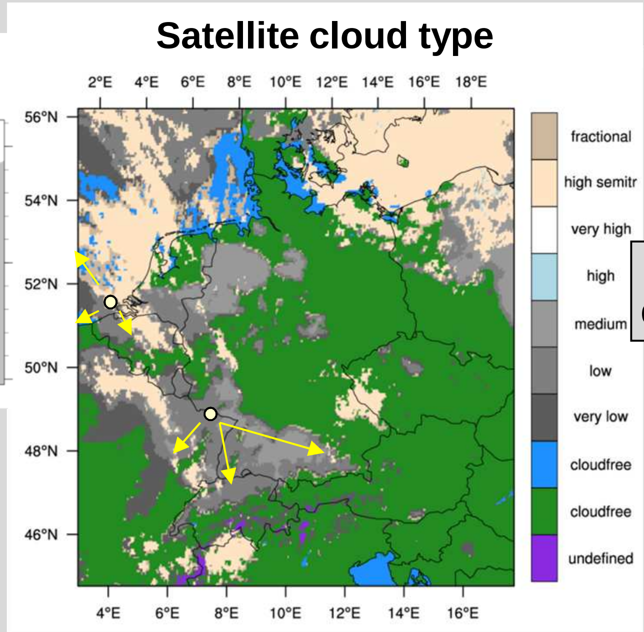
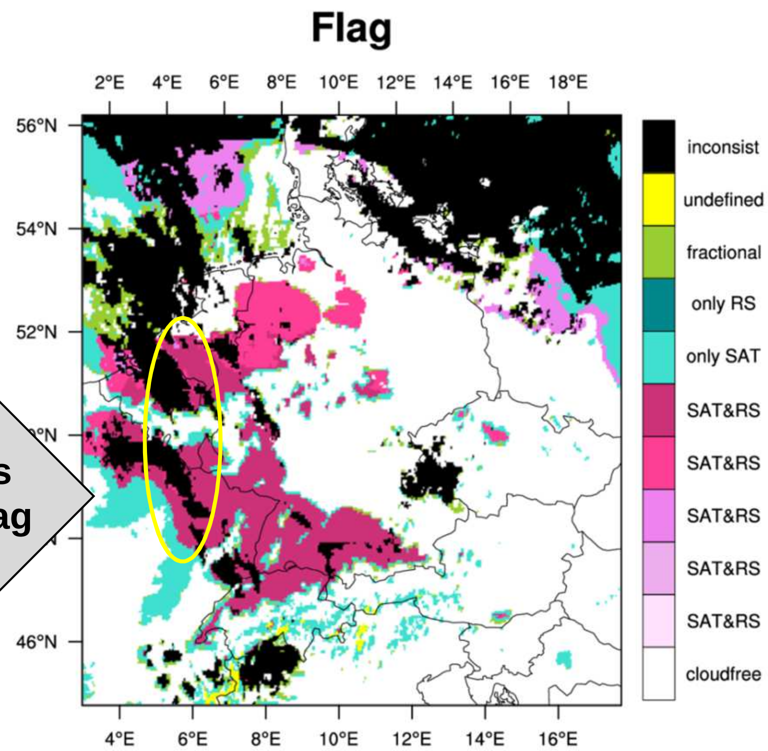
pre-processing to merge satellite and radiosonde cloud top height information (cloud analysis):

use nearby radiosondes within the same cloud type to determine quality flag





provides quality flag

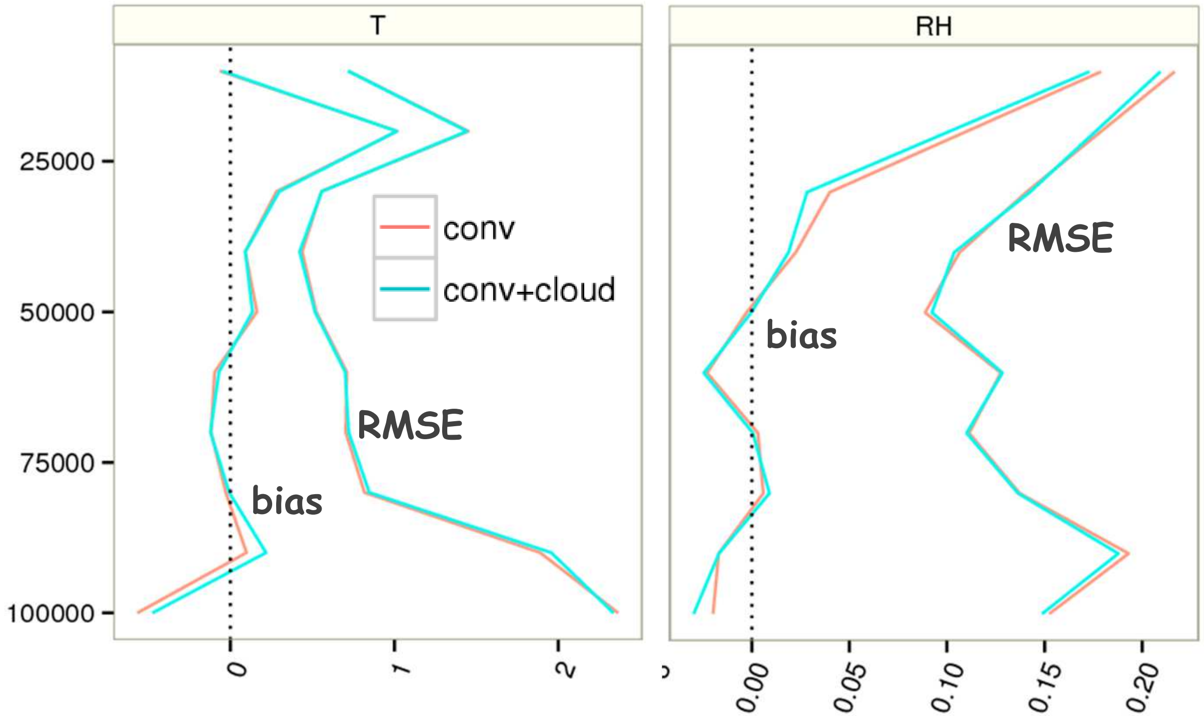


→ discard data flagged as 'inconsistent'

→ applied to new experiment

LETKF: use of **satellite cloud top height data**
application to low stratus period

results of new experiment with rigid quality control:
upper-air verification for several 6-h forecasts from 13 – 15 Nov. 2011



→ no detrimental effect of cloud assimilation any more

→ but sometimes a lot of cloud data are discarded by new QC

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LETKF: use of **satellite cloud top height data**
application to low stratus period

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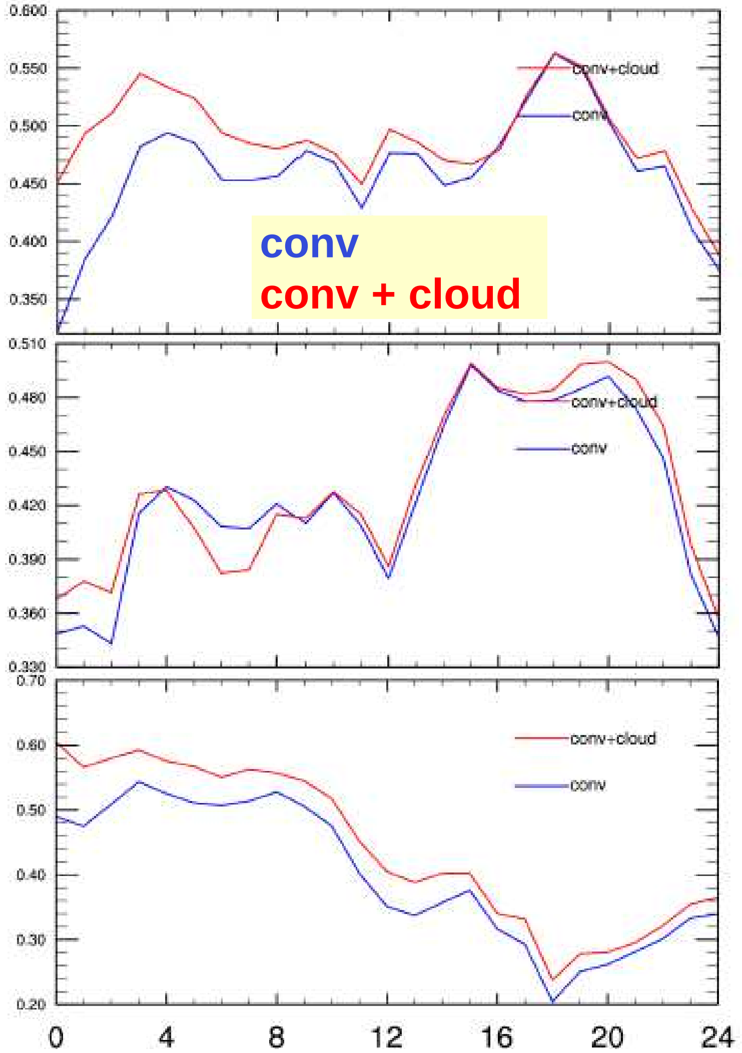
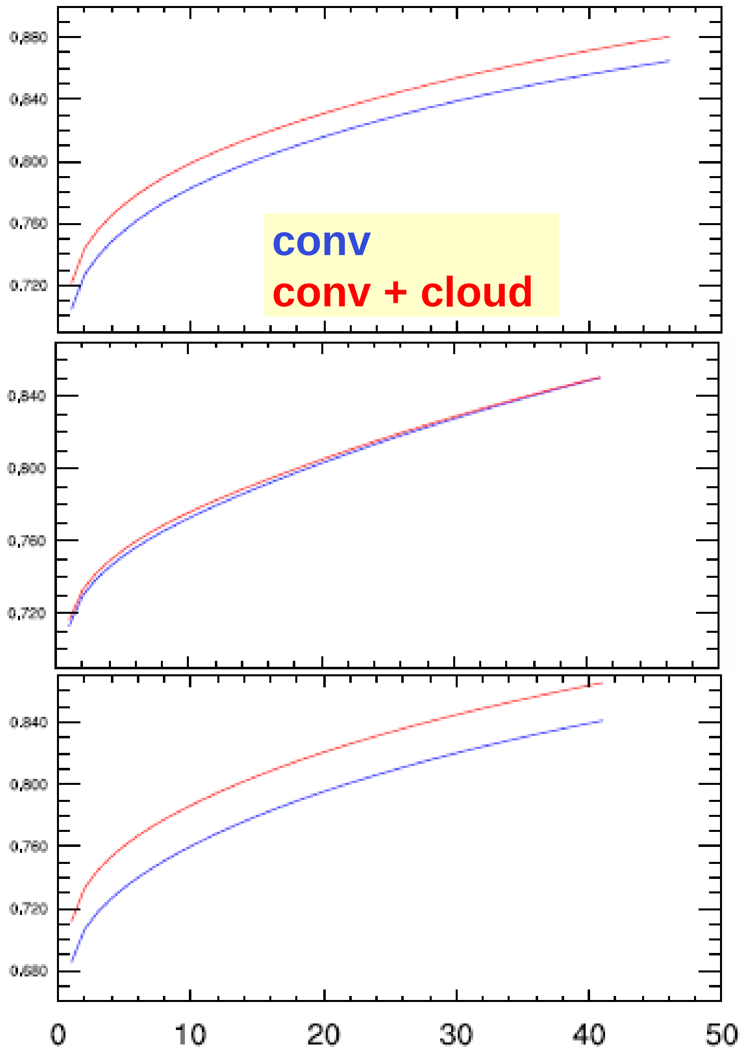
Correlation coefficient for total cloud cover



forecast time [h]

FSS for cloud cover of 15-h forecast



scale [# grid pts.]

new experiment with rigid quality control

13 Nov. 2011 6 UTC

14 Nov. 2011 12 UTC

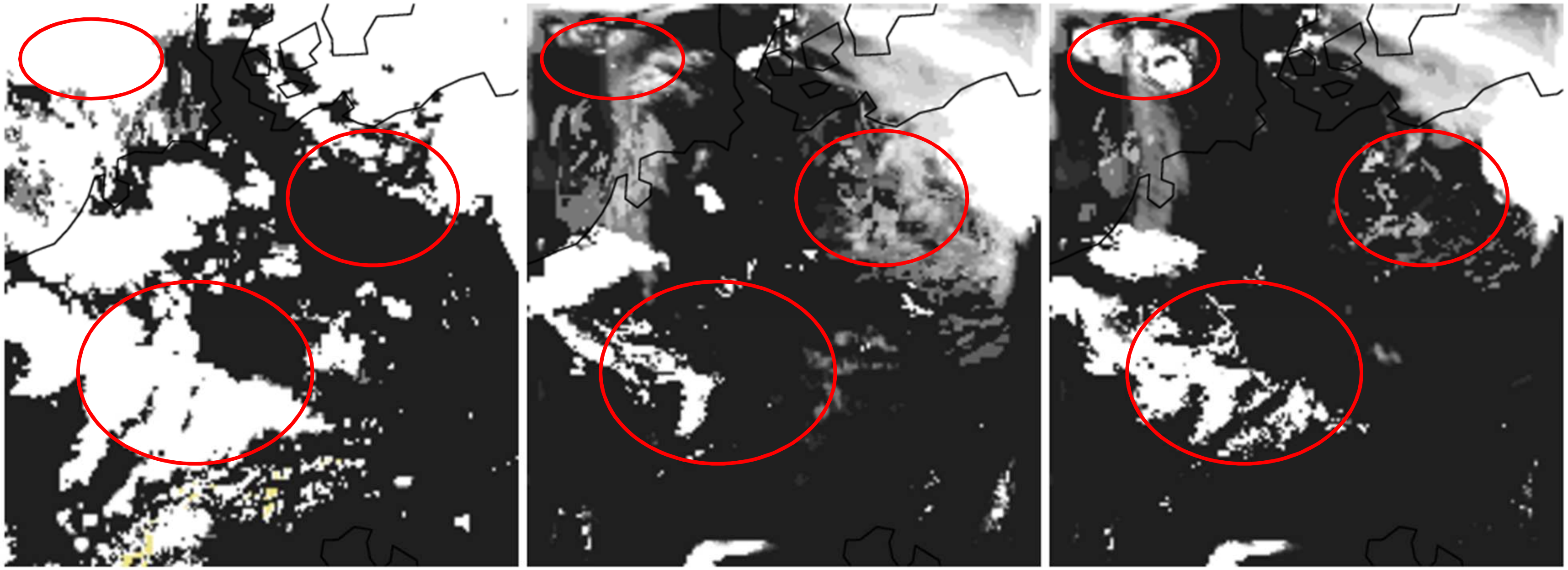
15 Nov. 2011 0 UTC

→ long-lasting small (?) benefit in some cases

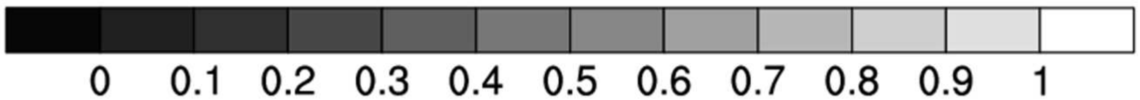
LETKF: use of **satellite cloud top height data** application to low stratus period

results of (new experiment with rigid quality control:
total cloud cover of first guess fields (1-h forecast) after 24 hours of cycling

satellite obs	**conventional only**	**conventional + cloud**



13 Nov 2011, 12:00 UTC



→ better match with observed cloud cover

LETKF: use of **satellite cloud top height data** status summary, further steps

status

- problem with mid-tropospheric cold / moist bias solved;
  with new QC, less data are used in LETKF
- some positive impact on cloud cover remains

further steps

- quality control
- balance impact of cloudy (which may be flagged by QC)
  vs. cloud-free obs (which are never flagged)
- localization (dep. on observed cloud ?), thinning / superobbing, obs errors
- alternative use of Optimal Cloud Analysis (Watts et al., 2011) ,
  which can detect multi-layer clouds ?
- more test periods, other weather types

MeteoSwiss: summary + outlook

- real-time KENDA assimilation cycle runs very stably since mid-January 2015
- verification results from first months are encouraging
- deterministic 2.2km analysis performance similar to nudging
- COSMO-E forecasts started from KENDA compare mostly favourably to those downscaled from IFS-ENS (reduced spin-up effect)
- approaching to meet benchmark, but some problems in PBL humidity and temperature, still lack of spread there *(soil moisture perturbations not applied !)*
- COSMO-1 deterministic analysis under development
- COSMO-E plans to use KENDA IC when going operational in Spring 2016, (COSMO-1 will first use nudging IC)

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LETKF: main development + testing
comparison to Nudging + LHN

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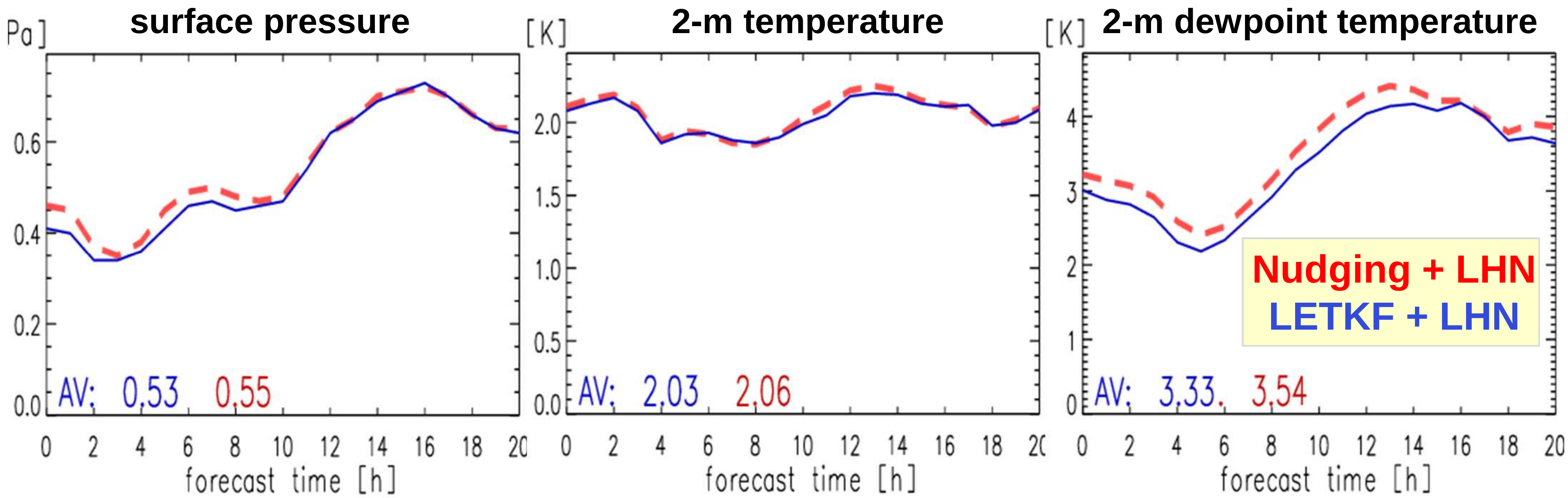
DWD

surface verification (RMSE) of **0-UTC** forecast runs , 28 days (18.05. – 15.06. 2014)



- ✓ LETKF: smaller errors, particularly pressure and humidity
- ✓ (also slightly smaller error for 10-m wind, neutral for cloud cover)

LETKF: main development + testing comparison to Nudging + LHN

DWD : **LETKF outperforms nudging** , in particular if both **combined with LHN**, in test periods

most critical criterion for operationability fulfilled (still more periods required)

(also encouraging results on use of KENDA for IC of COSMO-DE-EPS (possibly in combination with other perturbations))

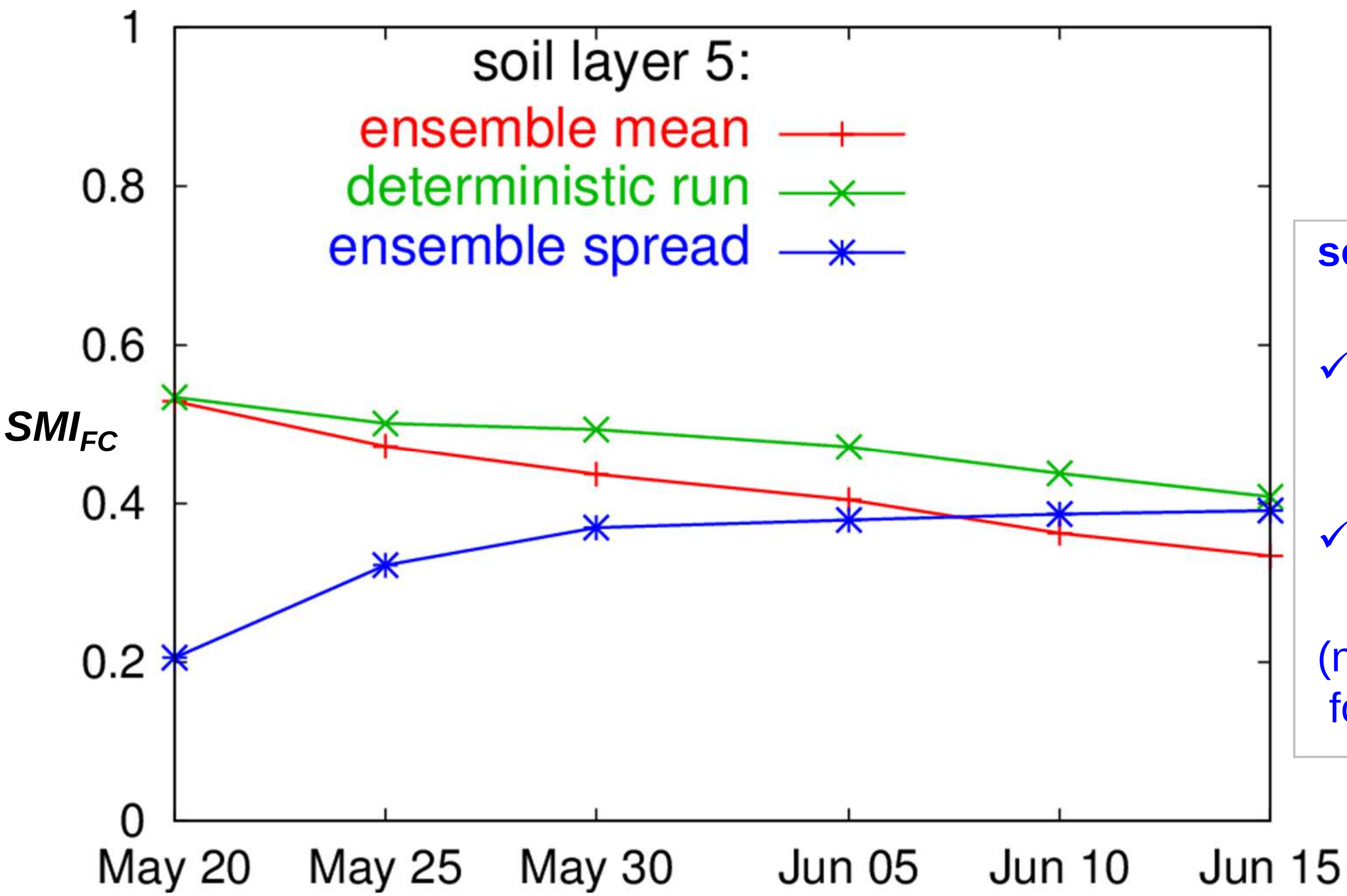
MeteoSwiss : mostly only neutral results for deterministic forecast

→ possible reasons for different performance:

- model configuration + model domain (smaller at MCH!),
- test period (summer period with little advection vs. spring),
- lateral boundary conditions (ICON-LETKF vs. ECMWF),
- soil state, soil moisture perturbations, etc.

LETKF: main development + testing
remaining problems

- explicit soil moisture perturbations:



soil layer 5 (27 – 81 cm) (and 4):

✓ **drift** (**bias**) of mean of perturbed ensemble vs. unperturbed det.

✓ **spread** becomes (too) large

(no problems for soil layers 1 - 3)

- explicit soil moisture perturbations:

  – spread: (small) perturbations are added at each hour to existing perturbed values → perturbations accumulate

    → possible solution: re-scaling of perturbations

  – bias: non-linear response of model to soil moisture perturbations
    → different feedback for positive resp. negative perturbations, particularly near soil field capacity (FC) & plant wilting point (PWP)

    → symmetric limiter to perturbations near FC & PWP

    → re-centering of ensemble mean to (unperturbed) deterministic soil moisture

LETKF: main development + testing
remaining problems

- explicit soil moisture perturbations: bias (drift), too large spread
  - → solutions: symmetric limiter, re-scaling & re-centering of soil perturbations
- upper-air humidity verifies slightly worse, mainly in PBL
  - → should be investigated (sampling noise in LETKF cross-covariance ?)
  - → tolerable, considering benefits for other variables (precip !) (DWD)
- LETKF less able than nudging to correct (temperature, humidity) model biases
  - → inherent, difficult to solve in LETKF
  - → needs improvement of model itself
- technical issues:
  - → robustness: creation of new ens members if few have crashed
  - → continuous online estimation of observation errors (weather dependent)

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