Status of the KENDA project

Deutscher Wetterdienst

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… and many colleagues from CH, D, I, ROM, RU …
… in particular Hendrik Reich (DWD)

- **K**m-scale **EN**semble-based **D**ata **A**ssimilation : COSMO priority project
- Local Ensemble Transform Kalman Filter (LETKF) system being developed

first goal: replace nudging (+ latent heat nudging) with deterministic LETKF analysis

→ focus on quality of deterministic analysis/forecast

This talk:

- LETKF experiments using conventional obs, comparison to nudging (+ LHN)
- brief overview on use of high-res obs and plans

LETKF (km-scale COSMO) : implementation

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→ ensemble of COSMO runs, collecting obs – f.g. → **4D** -LETKF

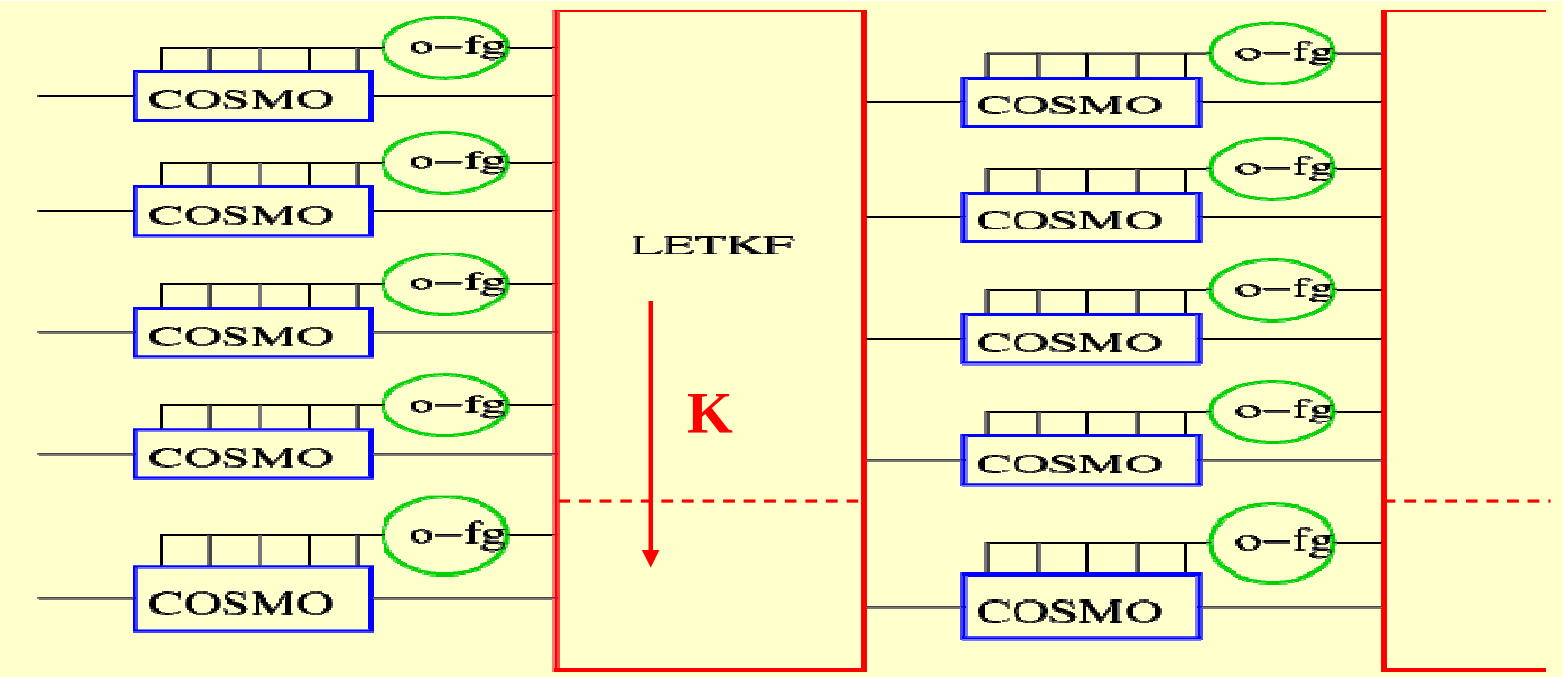
ensemble

ensemble lateral BC from global LETKF/EPS

deterministic

lateral BC from (same !) global deterministic

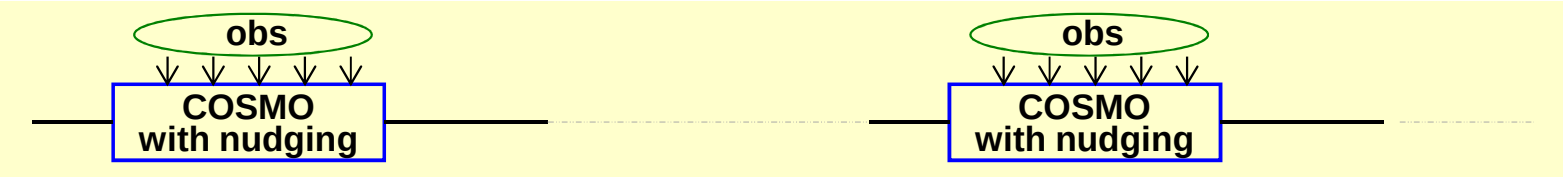
benchmark: Nudging (+ LHN)



use Kalman Gain **K** of analysis mean $\mathbf{x}^A = \mathbf{x}^B + \mathbf{K}\,[\mathrm{y}^o - H(\mathbf{x}^B)]$

→ deterministic run must use same set of obs as ensemble system !

→ deterministic run may have higher resolution



KENDA: testing, tuning, refinement of LETKF using raso, aircraft, wprof, surface

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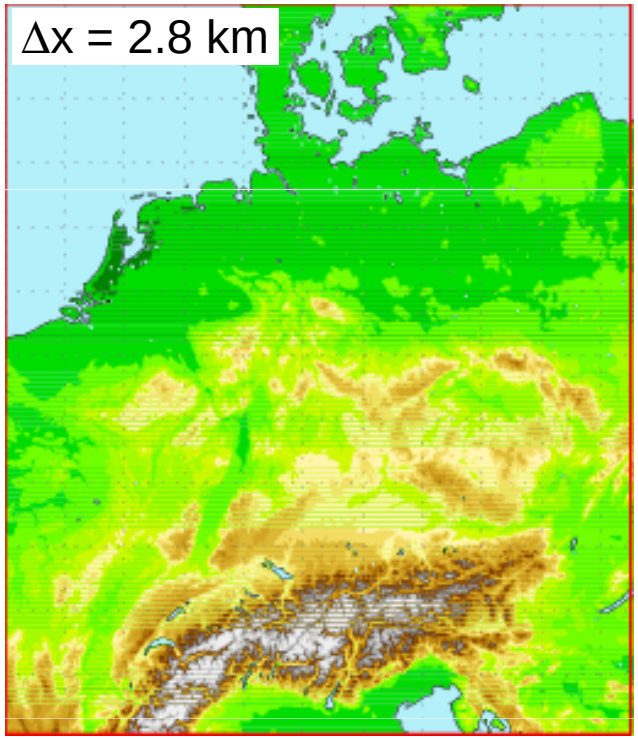
- **DWD**: BACY experimentation environment

  → 1.5 days of **1-hrly** LETKF cycle (N_{ens}=40) with COSMO-DE computed in 1 day real-time

  – adaptive multiplicative covariance inflation (based on innovation statistics) applied to analysis ensemble

  – relaxation to prior spread (RTPP)

  – adaptive horizontal localisation length scale (idea: adapt scale to data density)



- **MeteoSwiss**: similar experiments (→ Poster !), Δx = 2.2 km, smaller domain lateral BC from IFS EPS

KENDA, new series of experiments: influence of **lateral BC (spread)**

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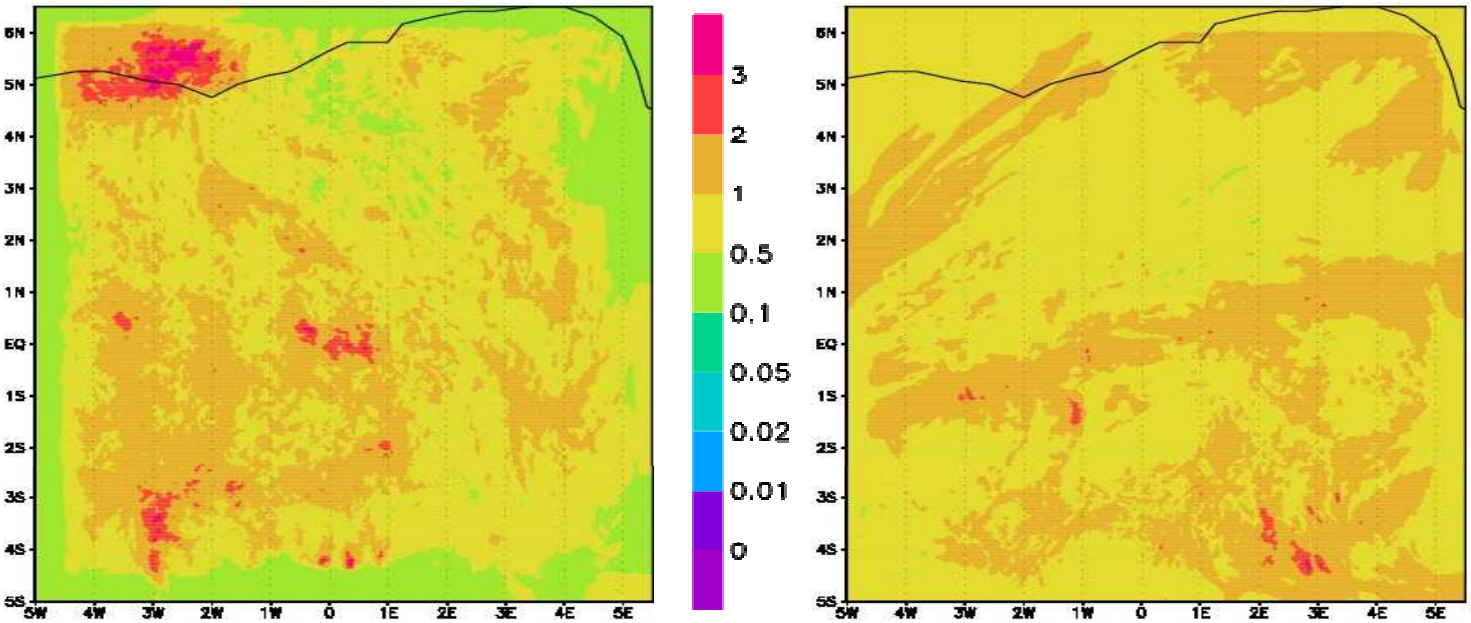
- new period: 19 – 25 July 2012, deterministic 24-h forecasts every 6 hrs
- lateral BC from ICON-LETKF (better spread than GME-LETKF over Europe !)

2011060600
lateral BC from **GME-LETKF**



2012072400
lateral BC from **ICON-LETKF**

f.g. spread
zonal wind
at ~ 500 hPa

→ spread from ICON-LETKF ~ ok

- compare deterministic LETKF forecast with free fc & nudging :
  same obs (except QC), lateral BC, initial state at 19 July (atm. + soil)

→ better spread in lat. BC → LETKF compares more favourably to nudging

introduction of soil moisture (SM) perturbations (+ SST pert.)

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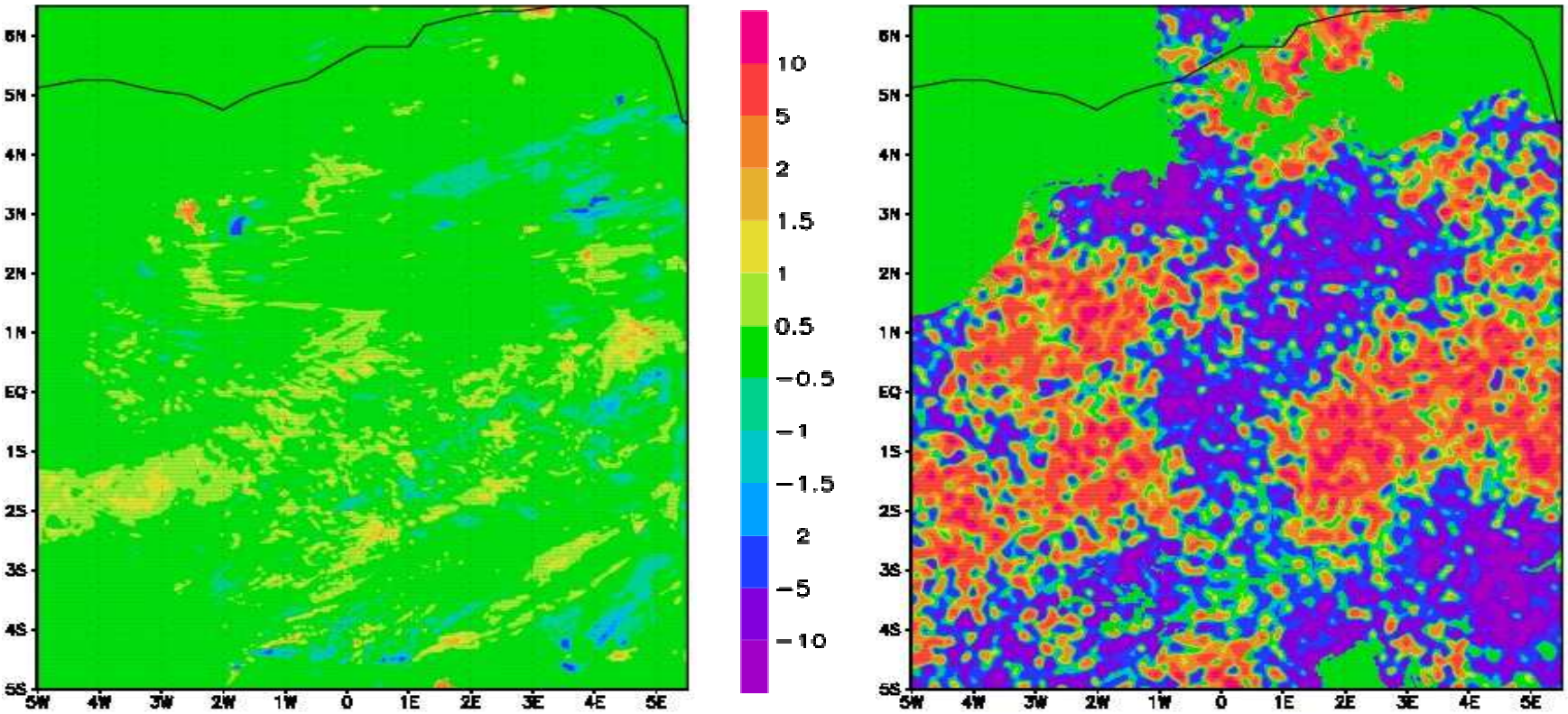
- ✓ simple superposition of Gaspari-Cohn (~ Gaussian) functions at each analysis g.p., with random amplitude and pre-specified horiz. / temporal correlation scale(s)
- ✓ scales : 100 km + 10 km ; 1 day ; std dev of amplitude: 0.1 soil moisture index

spread of soil moisture (WSO), layer 3 (3 – 9 cm), after 5 days

cycling without perturbations



cycling with SM perturbations

impact of including in LETKF
(SST +) **soil moisture perturbations**

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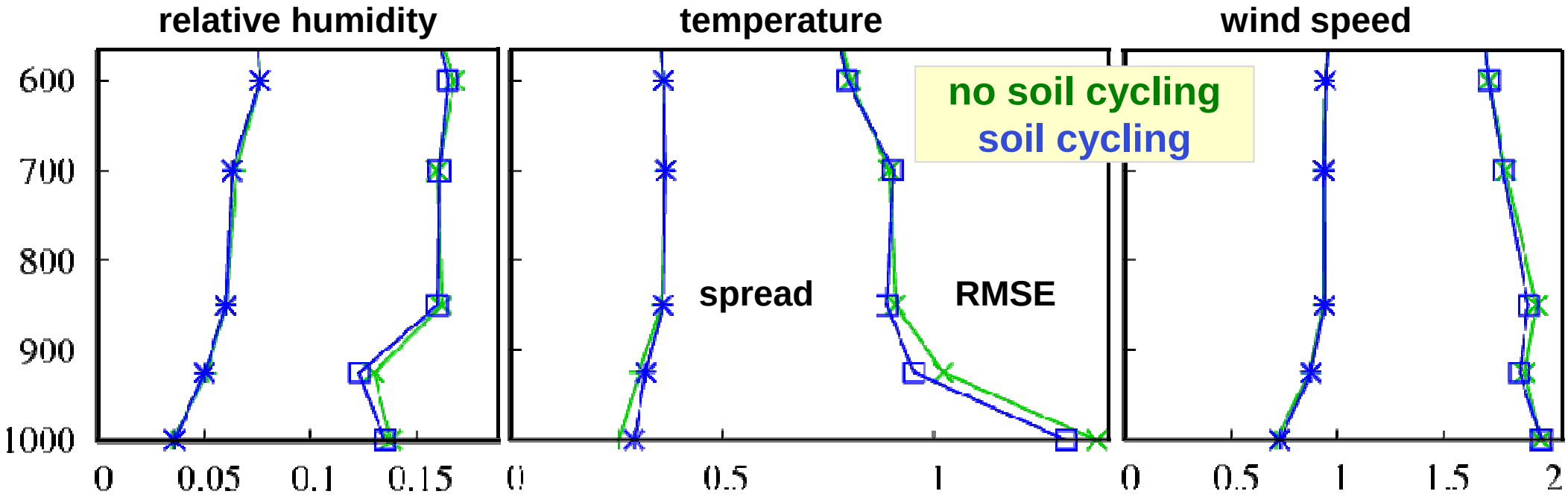
upper-air verification (spread / RMSE) of first guess (1-h forecast)



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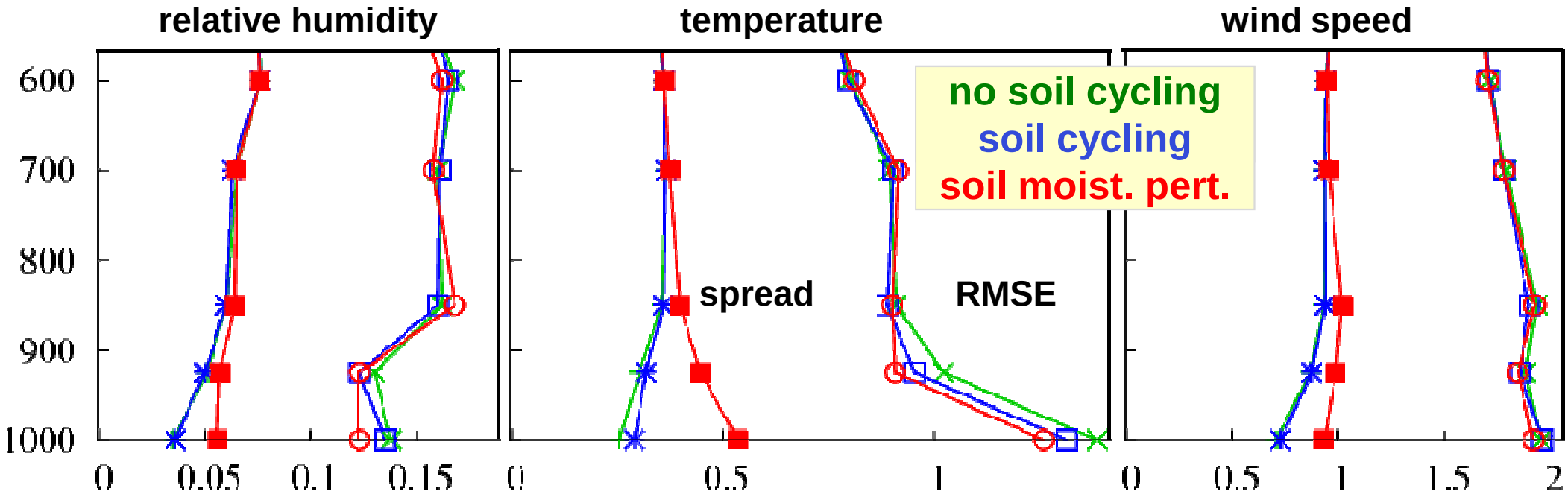
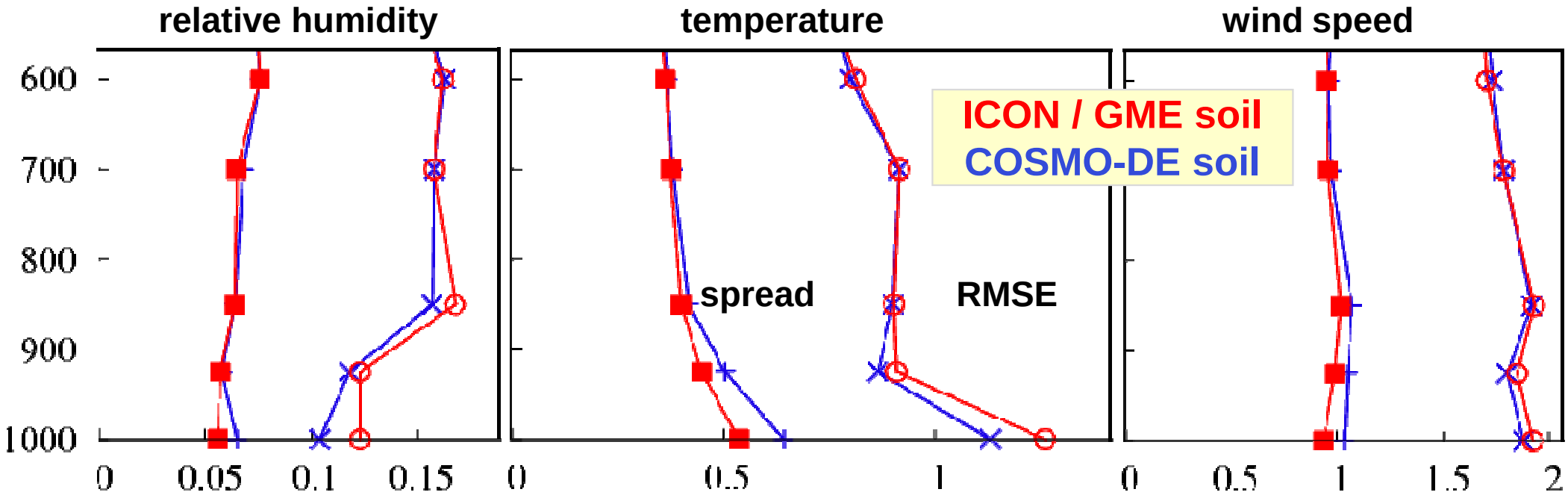


→ RH, T, wind, near surface:
larger spread, smaller errors in f.g. (+ 6 h)

→ slightly smaller errors in ps(!), T2m, Td2m, CLCM forecasts

→ use soil moisture perturbations in following exp.

upper-air verification (spread / RMSE) of first guess (1-h forecast)



→ RH, T, wind, near surface: smaller errors,
larger spread, despite soil moisture perturbations of same size !

Why ?

LETKF with **COSMO-DE soil** (LHN, no SMA) vs. **ICON / GME soil** (→ SMA)

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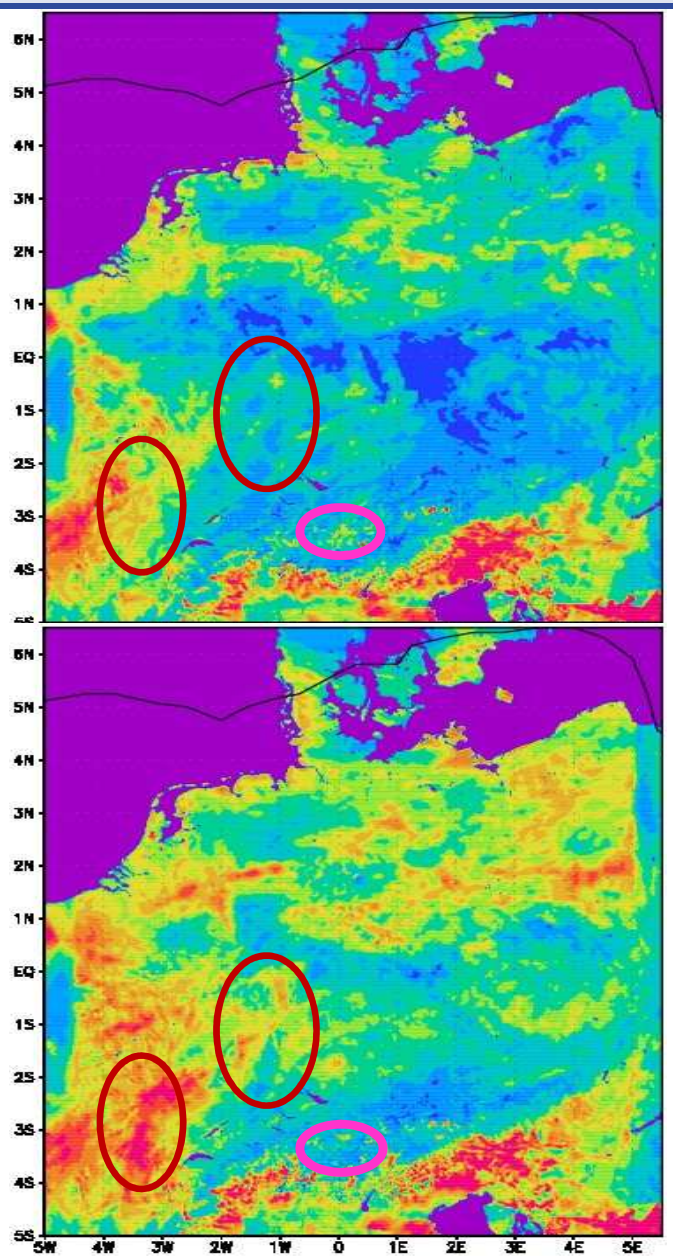
ICON soil

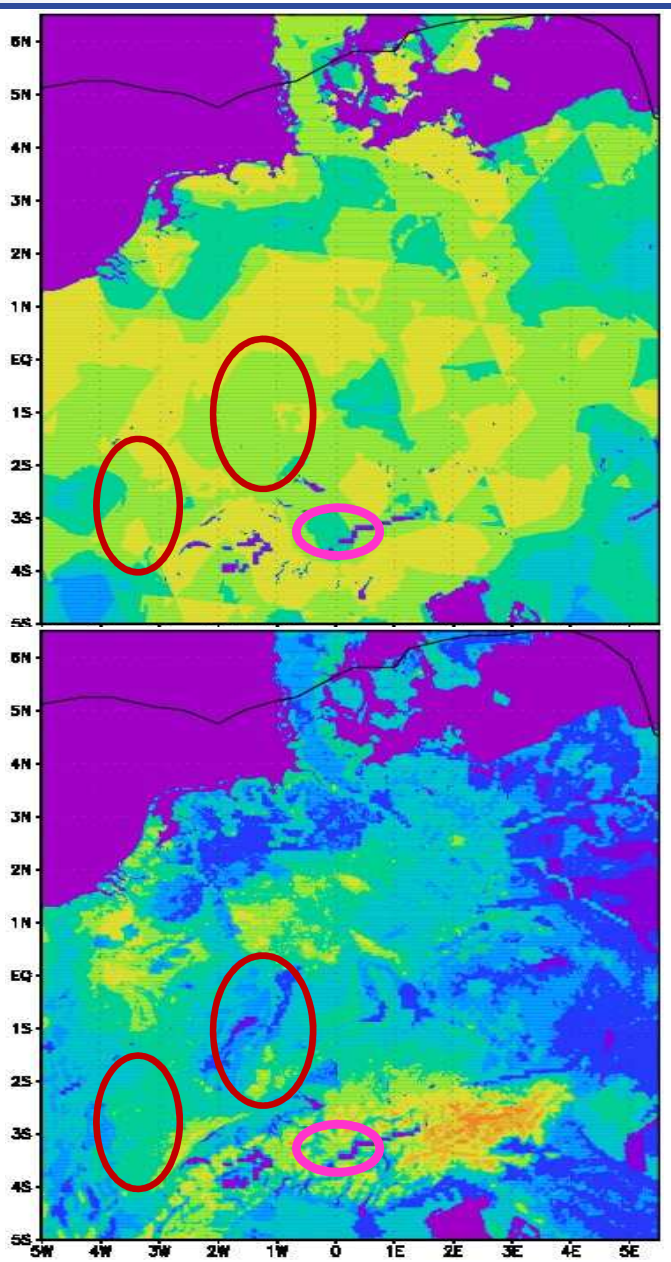
C-DE soil



soil temperature spread, layer 1 0 – 1 cm [K]

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

21 July 1 UTC



Soil Moisture Index, layer 5 27–71 cm

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

19 July 1 UTC

LETKF with **COSMO-DE soil** vs. **ICON / GME soil**: upper-air verification / summary

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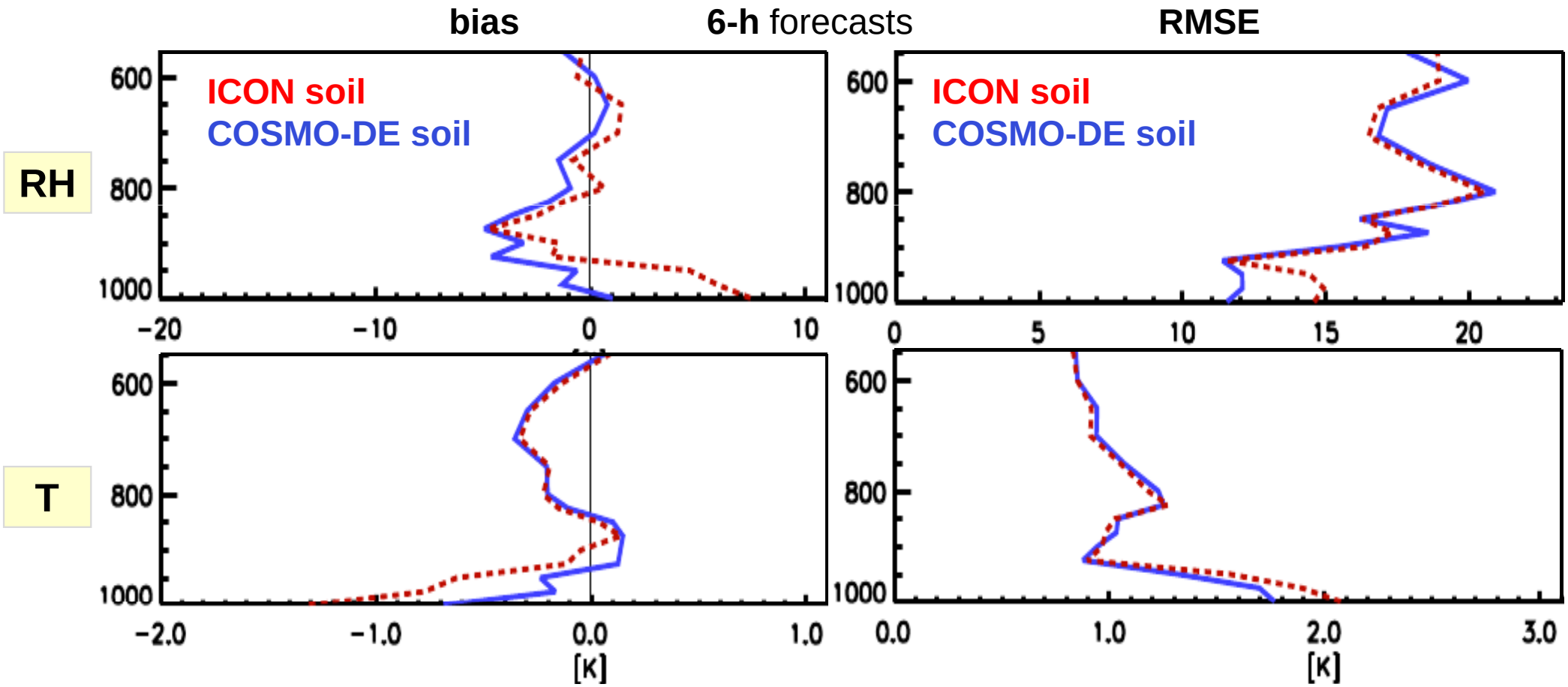
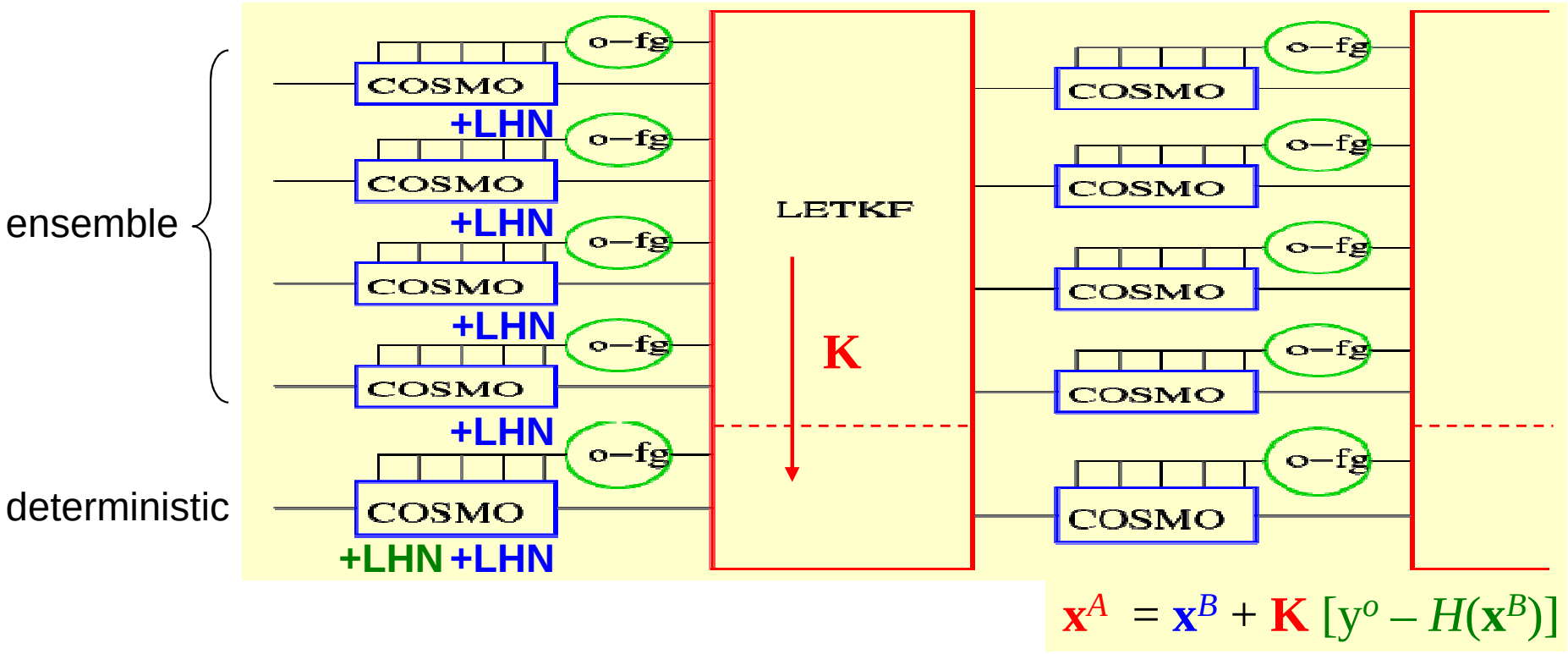


→ plant evapotranspiration more sensitive to SM changes/perturb., if SM low
→ C-DE soil: higher spread in soil temperature & in f.g. T, RH at low levels
→ reduced bias & RMSE of T, RH at low levels
→ reduced bias of T2m, Td2m, improved T2m, low cloud

including **LHN in LETKF DA cycle** (for use of radar-derived precip)



$$\mathbf{x}^A = \mathbf{x}^B + \mathbf{K}\,[\mathrm{y}^o - H(\mathbf{x}^B)]$$

LETKF + LHN-det : LETKF unaffected; but Kalman Gain K not optimal ?

LETKF + LHN-all : f.g. ens. deviations (B-matrix !) 'destroyed' by LHN ?

benchmark:
Nudging
+ LHN

including **LHN in LETKF DA cycle**: verification against 1-hrly radar precipitation

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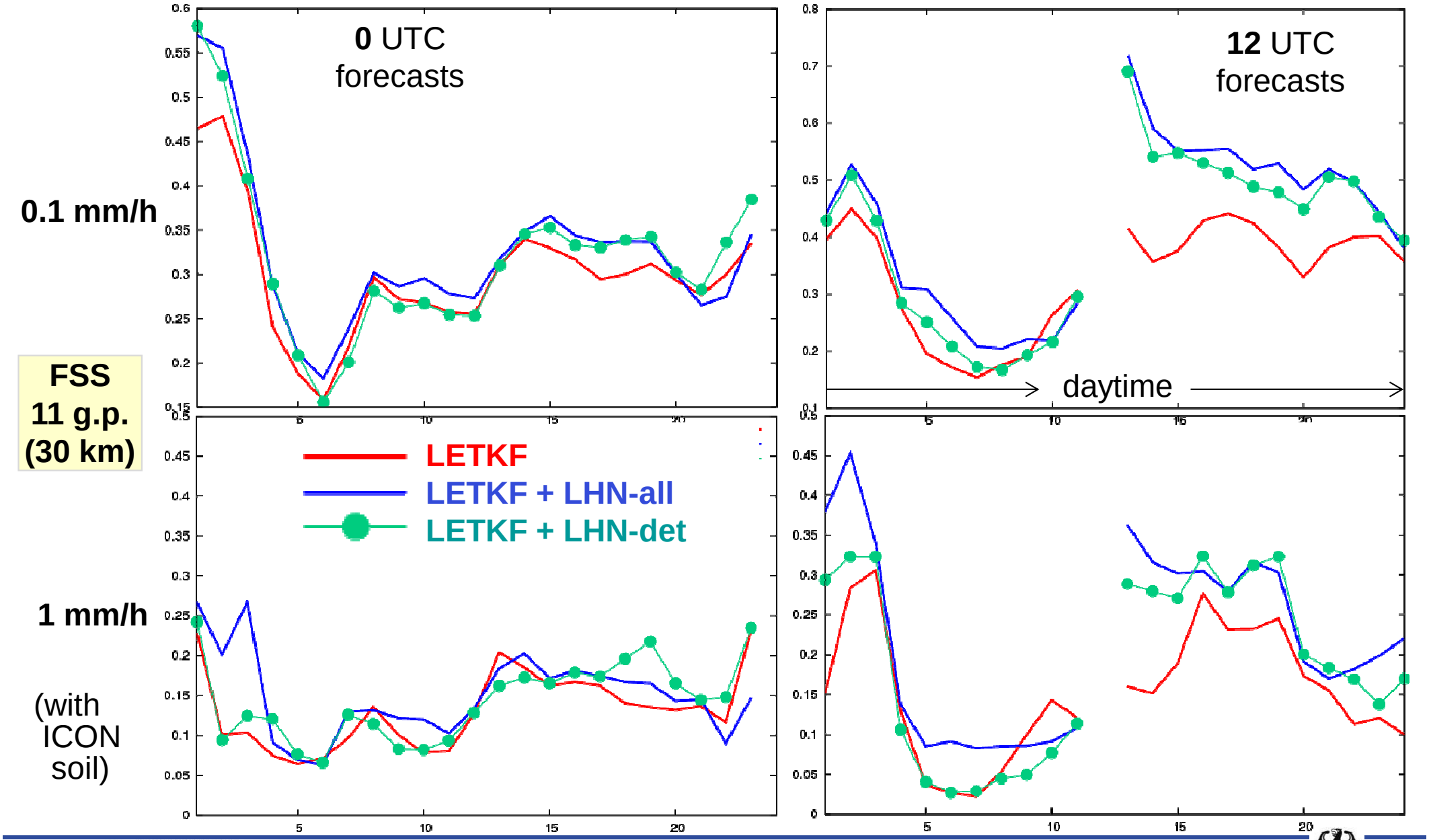

LETKF + LHN-all vs. **Nudging + LHN** (with C-DE soil) : verification against radar precipitation

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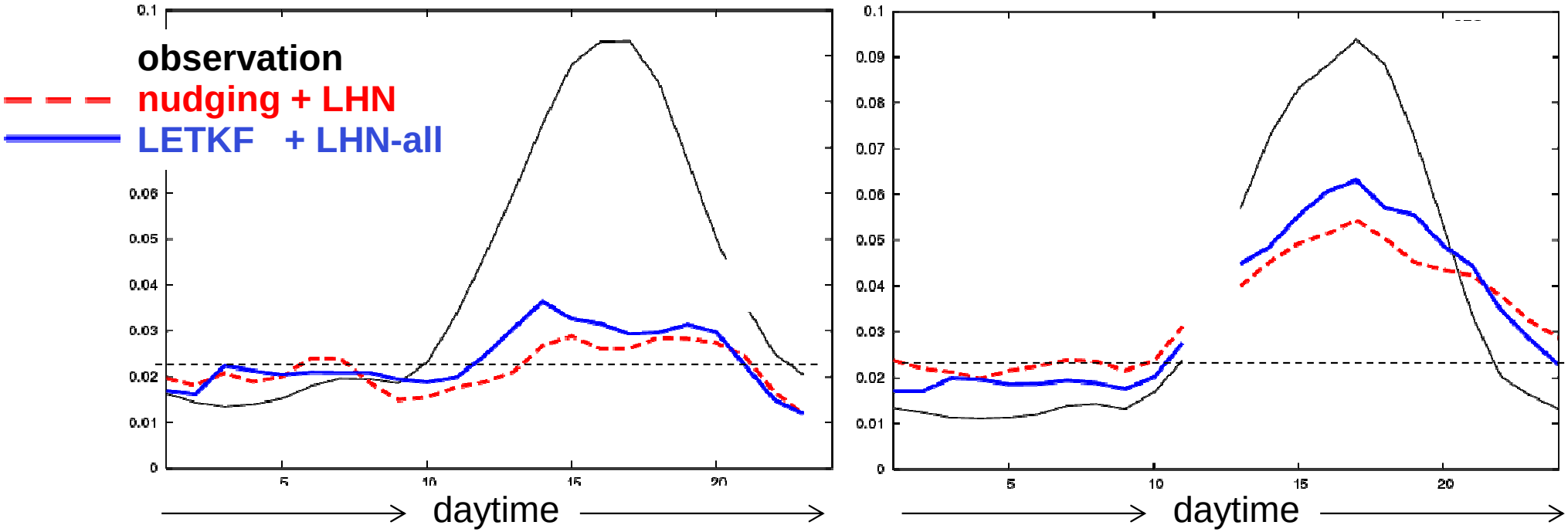
daily cycle of domain average precip → info on bias

0 UTC forecasts

12 UTC forecasts



LETKF + LHN-all vs. **Nudging + LHN** :
verification against radar precipitation

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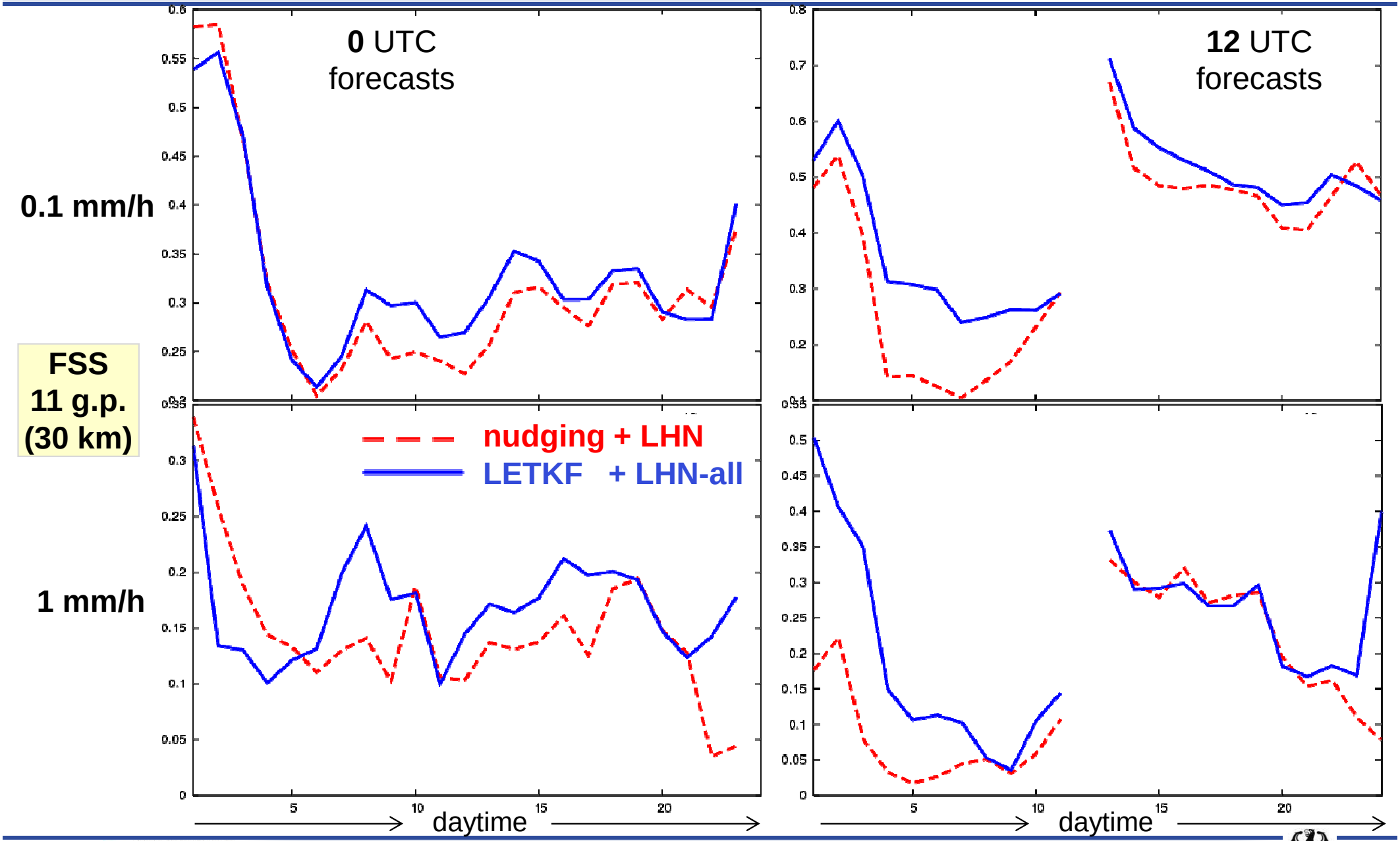

LETKF + LHN-all vs. **Nudging + LHN** : upper-air verification

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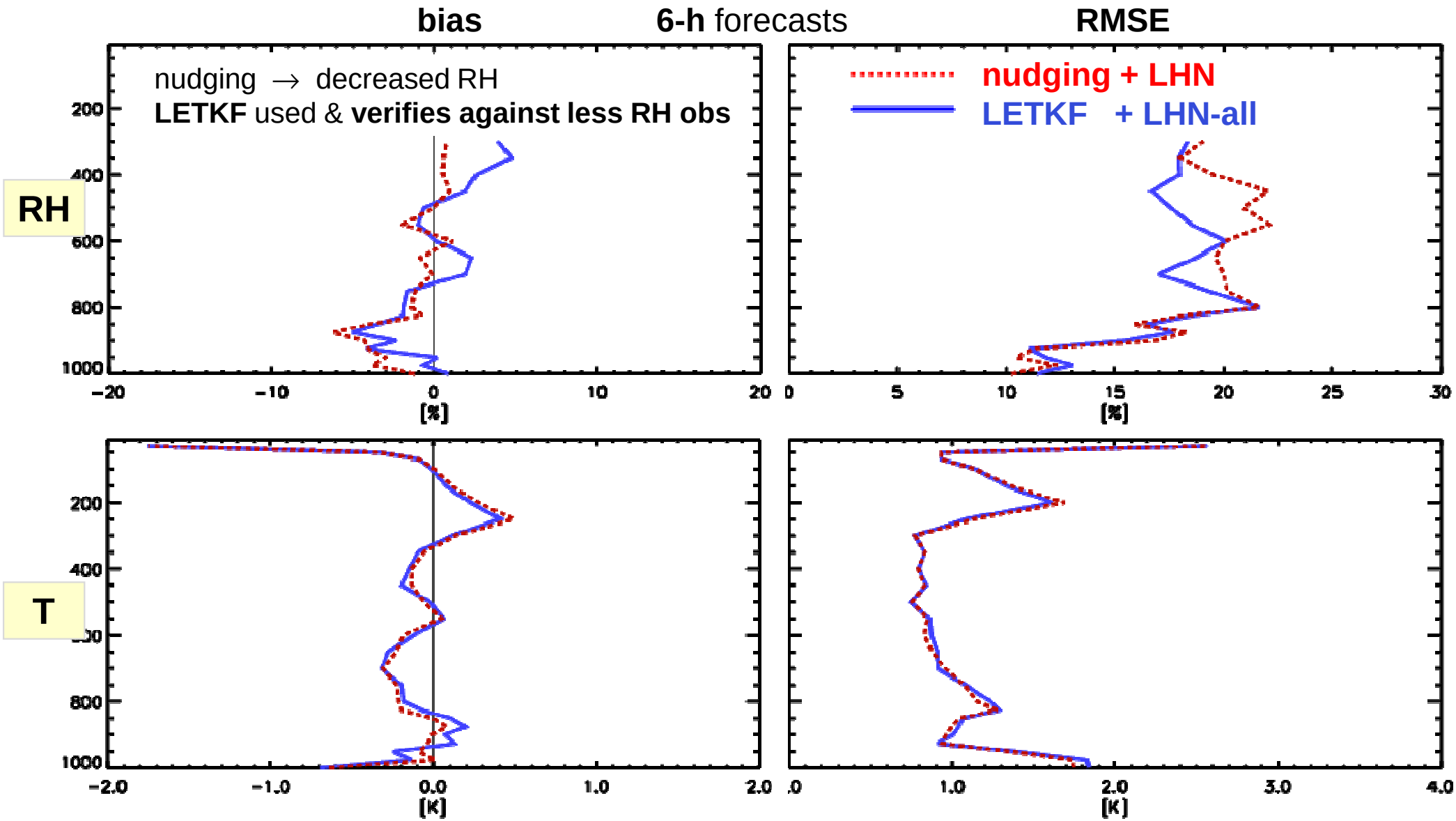

LETKF + LHN-all vs. **Nudging + LHN** : surface verification

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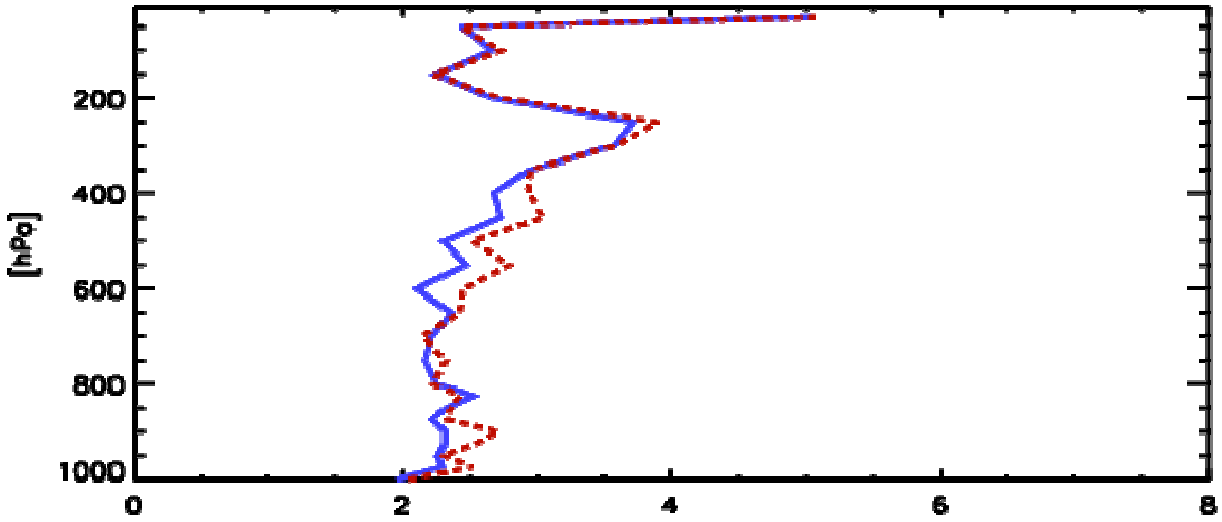
6-h forecasts **RMSE**

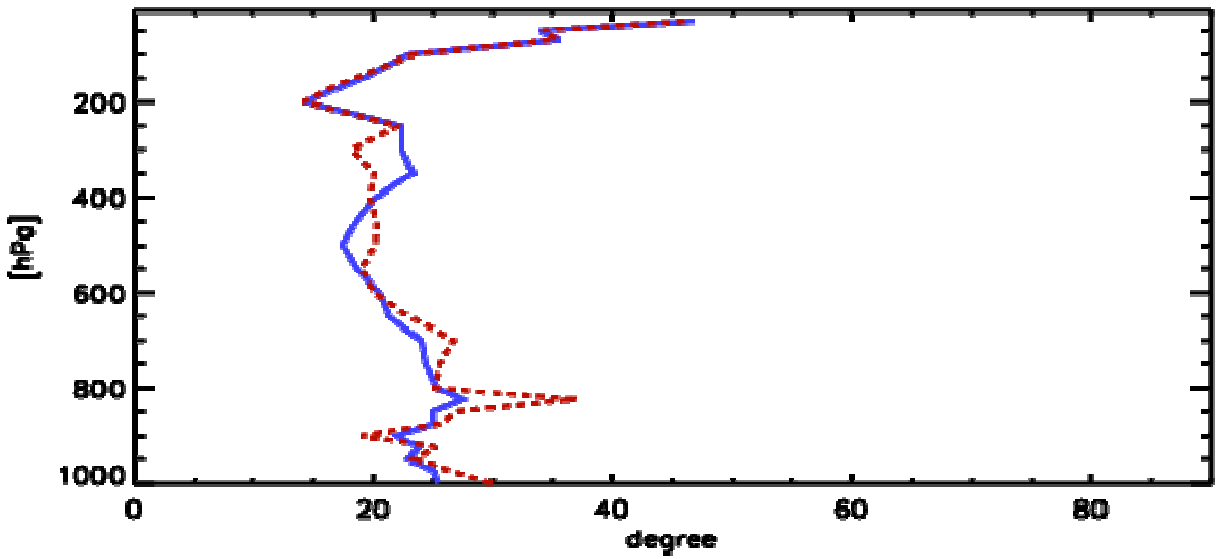
wind speed



nudging + LHN

LETKF + LHN-all

wind direction



LETKF + LHN-all vs. **Nudging + LHN** :
upper-air verification

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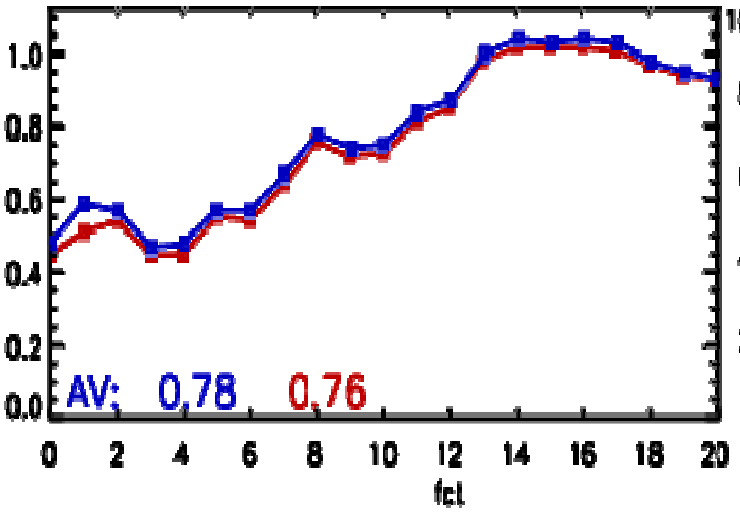
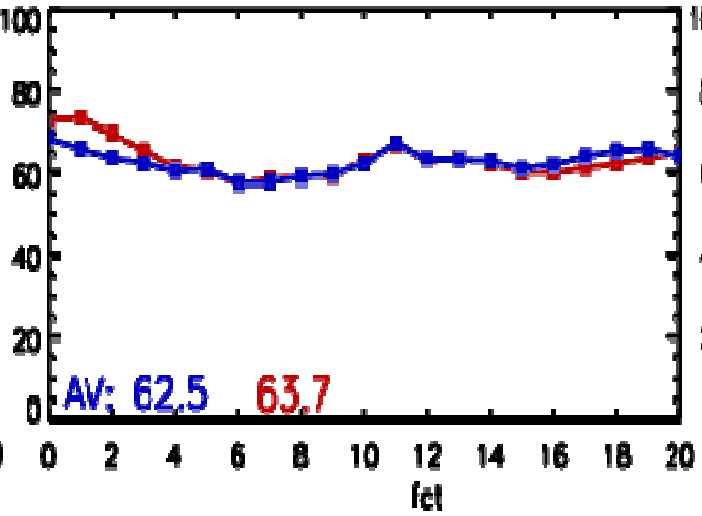
nudging + LHN
LETKF + LHN-all

RMSE
surface pressure



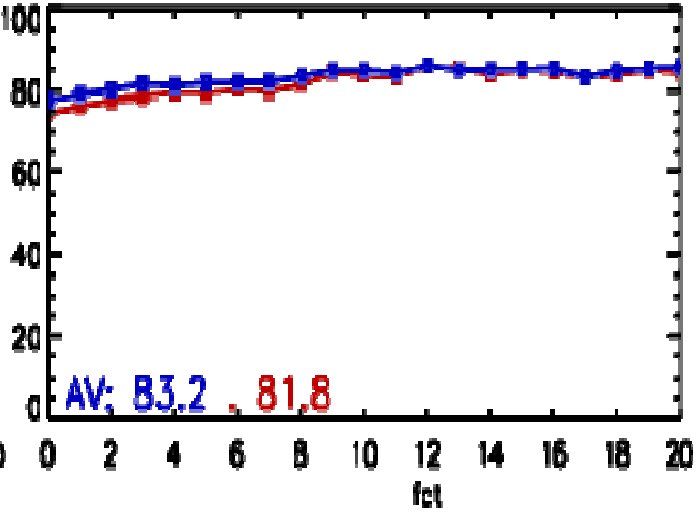
LETKF worse

hit rate
high cloud



LETKF worse in first 3 hours
(too little high cloud)

hit rate
mid-level cloud



LETKF better

(C-DE soil)	**LETKF + LHN-all** vs. **Nudging + LHN**		
	variable	RMSE	bias
upper air	geopotential	=	=
	temperature	(-/=)	=
	(relative humidity)	+	(-)
	wind speed	+	=
	wind direction	(+)	=
surface	2-m temperature	=	=
	2-m dew point temp.	=	=
	10-m wind	=	=
	surface pressure	-	=
	total cloud	=	=
	low cloud	(+)	(+)
	mid-level cloud	(+)	(+)
	high cloud	(-)	(-)
radar	precip 0 UTC	(+/-)	(+)
	precip 12 UTC	+	+

LETKF:

→ overall comparable / better results

→ problem with surface pressure

KENDA, new series of experiments: **summary**

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- ✓ lateral BC spread (+ quality) important (also seen in MeteoSwiss experiments)
- ✓ soil moisture perturbations beneficial near surface;
- ✓ large sensitivity of results to level of soil moisture
- ✓ no very obvious problems with combining LETKF & LHN
- ✓ deterministic forecasts: LETKF comparable / better than nudging

  negative: surface pressure (→ need more spread of ps in lateral BC)

  needs attention: precip (exp. 0-UTC runs) ; high cloud

BUT, results are preliminary !!

– only 6 days → need longer periods, different weather situations

– quality control of RH too restrictive in LETKF (assim. + verif.)

KENDA: extended use of (high-res.) obs

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- **GPS slant path delay**: pure obs operator implemented
  (Bender) some technical work before DA exp.

- **Radar** : **3-D radial velocity V_r** & **reflectivity Z**
  (Zeng, Bick)
  – thinning, superobbing strategies implemented, monitoring set up
  – first DA cycles run

- **SEVIRI cloudy radiances**: first cycled DA experiments,
  (Perianez) different (cloud-type dep.) bias correction
  → positive impact on simulated radiances in first guess

- SEVIRI **cloud top height** : tuning experiments on thinning, localisation...
  (Schomburg) → positive impact on cloud cover, negative on upper-air T, RH

- Microwave radiometer + Raman lidar (Haefele, MCH)

A lot of work yet to be done, everywhere !

KENDA plan

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SMC meeting Feb 2014: **extend PP KENDA** (by ~ 1 y, Sep. 2015)

reason: clear project **aim: operationability**

- Background: KENDA pre-operational at MeteoSwiss in mid 2015

  KENDA pre-operational at DWD in Oct. 2015 (for det. forecasts)

KENDA plan

Aim: **operationability of KENDA by ~ Aug. 2015**

- **quality**: match quality of current operational nudging + LHN
  - recommended setup: update frequency, (ensemble size), specified obs errors, adaptive methods (inflation, localisation,..), multi-scale analysis with variable localisation, (possibly noise control by incremental analysis update)…
  - LBC with realistic spread, e.g. add ECMWF EPS forecast perturbations with larger forecast lead time to IFS det. (MCH); optimize ICON-LETKF (DWD)
  - additive covariance inflation: SPPT (stochastic perturbation of physics tendencies), stochastic physics, (perturbed physics parameter ?)
    incremental random perturbations with prescribed spatial-temporal correlation scales; self-evolved perturbations ?)
- complete DA cycle: soil: add SST and snow depth analysis
- technical issues

COSMO Science Plan on DA: Overview

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main strategy: develop EnDA (EnKF) for IC for det.+ EPS forecast at convective scale

- ✓ further optimize / refine LETKF
- ✓ use of dense obs:
  radar, satellite, related to humidity / weather parameters, also for surface
- ✓ towards nowcasting

  → need for high quality and efficiency

\+ porting COSMO to ICON-regional

Thank you for your attention !