Developments in KENDA, WG1 and Science Plan Issues

Deutscher Wetterdienst DWD

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Amalia Iriza (NMA)

- WG1 overview
- KENDA (Km-scale ENsemble-based Data Assimilation)
  overview, results from LETKF experiments
- WG1 science plan issues

WG1 Overview

- CNMCA: LETKF for COSMO-ME (7 km)

- RHM:– new hierarchical Bayes approach to ensemble-variational DA
  - assimilation of T2m obs: correction of T in low atm + soil

- ARPA-Piemonte (Giorcelli): FASDAS (Flux Adjusting Surface DA System)
  - assimilation of T2m obs: corrects T in atm + soil (long memory)
  - Exp. Jan – May: shown to improve T2m bias + precip in forecasts

- DWD: Latent Heat Nudging in (7-km) COSMO-EU
  (OPERA precip rate data used outside COSMO-DE domain)

Latent Heat Nudging for COSMO-EU (7km):
influence of lateral BC on COSMO-DE (2.8km)

verification against
Radar precipitation

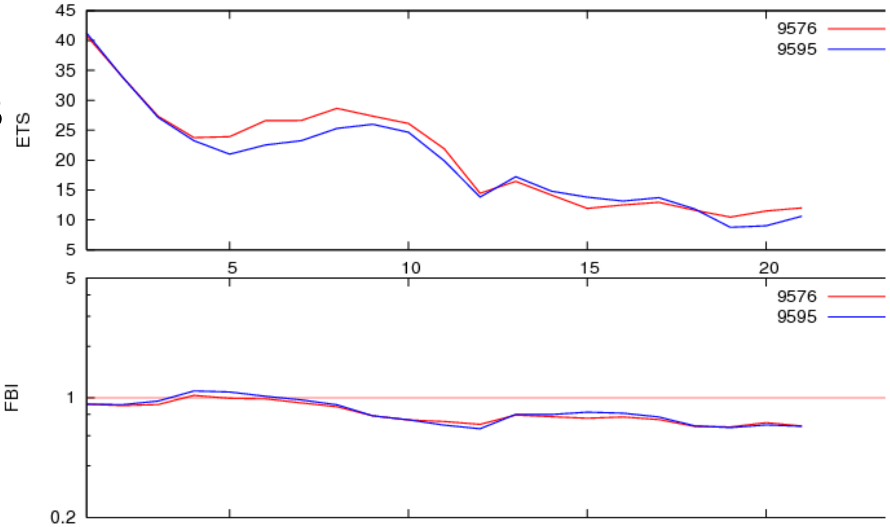
June/July 2013

COSMO-DE with LHN, lateral BC: COSMO-EU with LHN
COSMO-DE with LHN, lateral BC: COSMO-EU no LHN

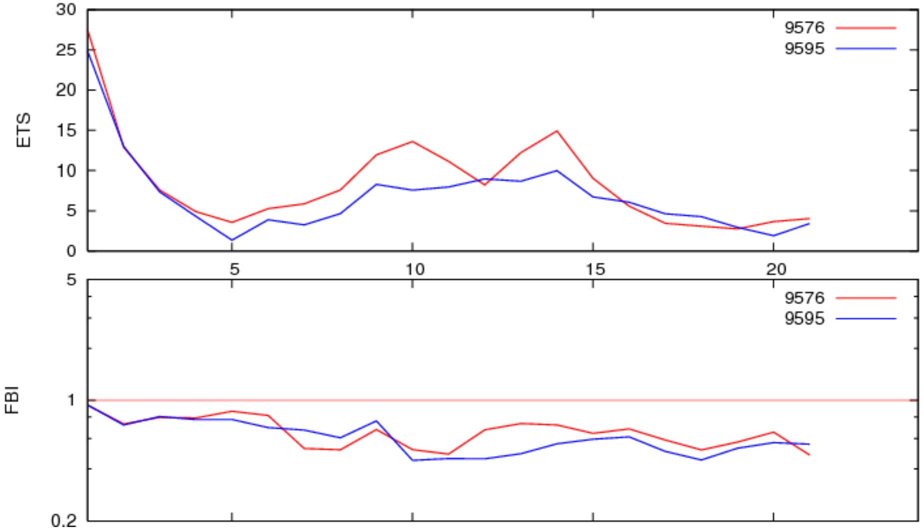
ETS

FBI

0.1 mm/h



5.0 mm/h



→ forecast lead time

→ forecast lead time

✓ small, but long-lasting positive impact on precip

→ introduced operationally last week

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Latent Heat Nudging for COSMO-EU (7km):
influence of lateral BC on COSMO-DE (2.8km)

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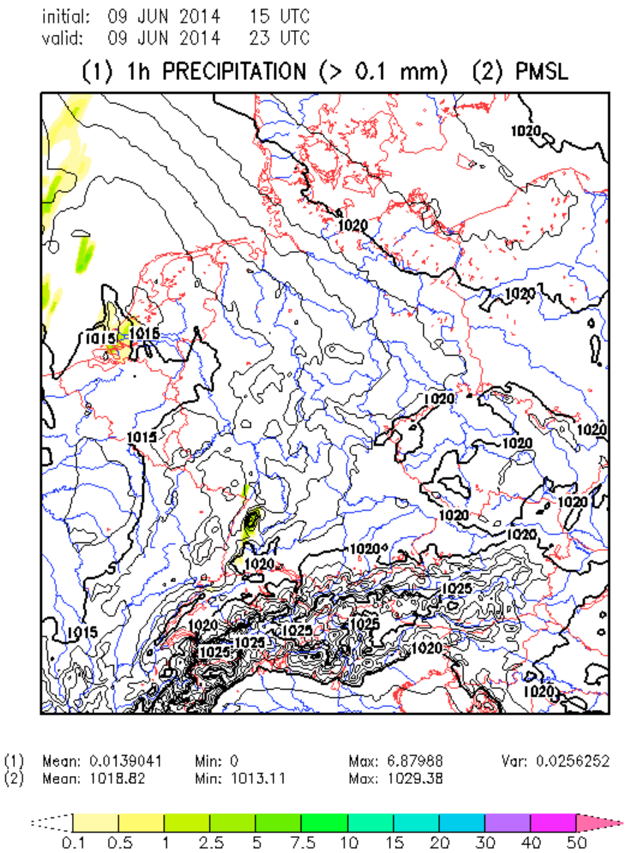
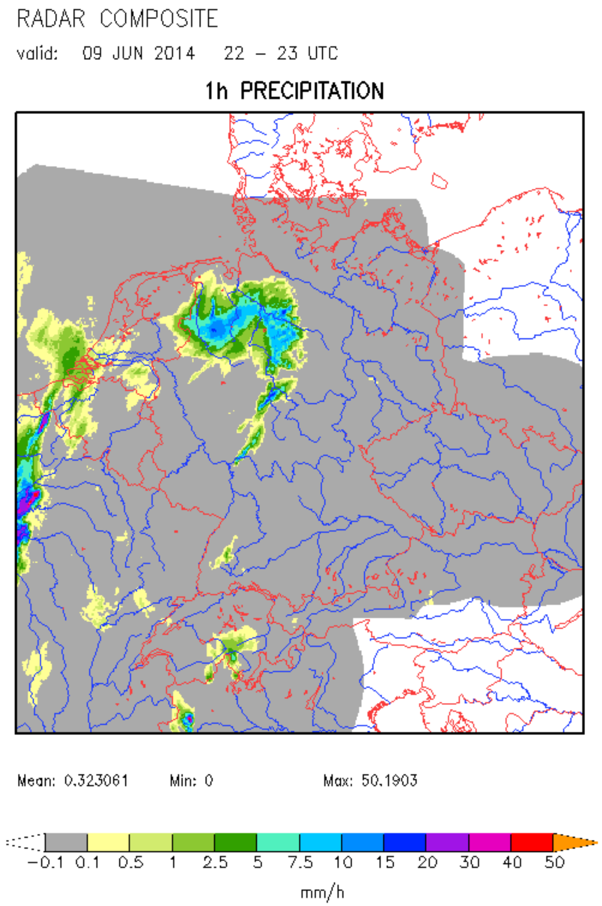
8-h forecast of COSMO-DE with LHN (for 09.06.2014, 23 UTC)

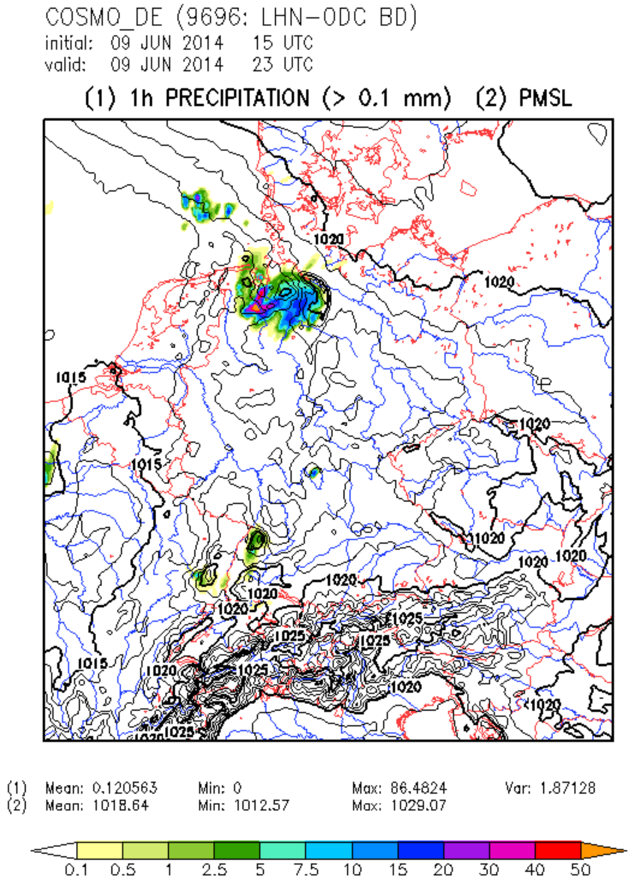
lateral BC without LHN



radar obs (precip)



lateral BC with LHN



- **ARPA-SIM**: OSSE, with humidity $q_v \rightarrow q_v/2$ in some of ens. members

- **MeteoSwiss**: 1-hrly LETKF cycle over 1 month, lateral BC: ECMWF EPS
  → reasonable results (slightly worse than nudging)

  new test (IFS EPS 24 h – 36 h forecast perturbations centred at IFS det.) :
  → better, but still too little spread
  → problems with RH: (too) many RH obs rejected

- **DWD**: BACY (BAsic CYcling) experimentation environment

  → 1.5 days of 1-hrly LETKF cycle (N_{ens}=40) computed in 1 day → Yippee !!)

  first goal: replace nudging with deterministic LETKF analysis
  → focus on quality of deterministic analysis/forecast

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

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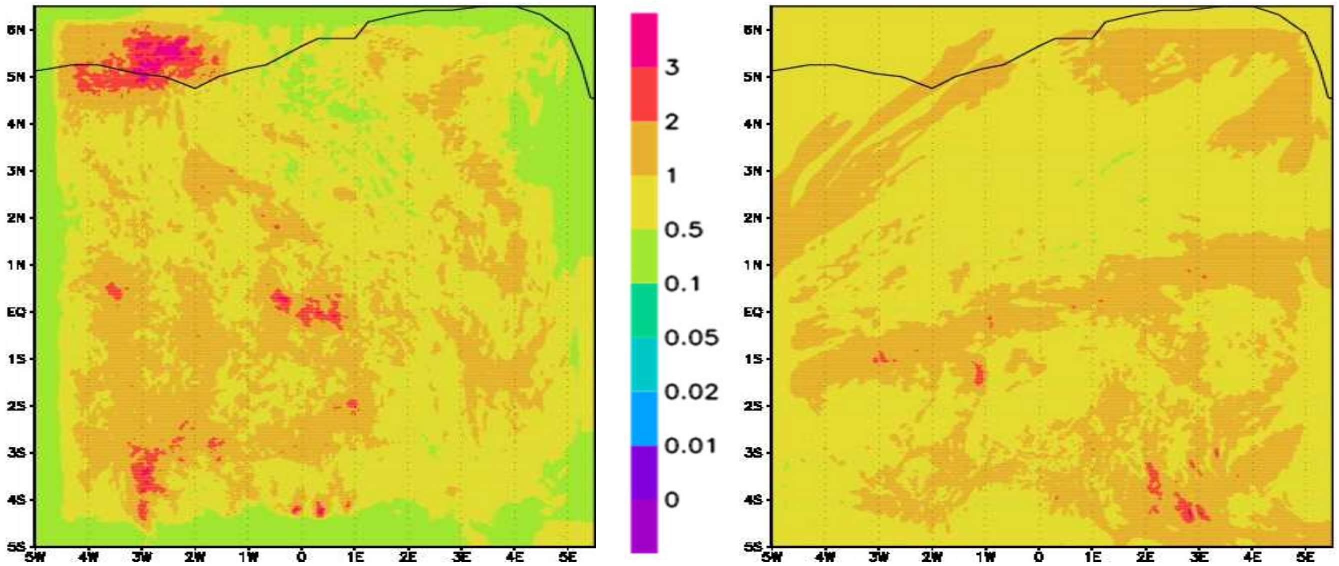
- new period: 19 – 25 July 2012, det. 24-h forecasts every 6 hrs
- lateral BC from ICON-LETKF (better spread than GME-LETKF over Europe !)

2011060600 **lateral BC** from **GME-LETKF** | 2012072400 **lateral BC** from **ICON-LETKF**



f.g. spread
zonal wind
model level 25

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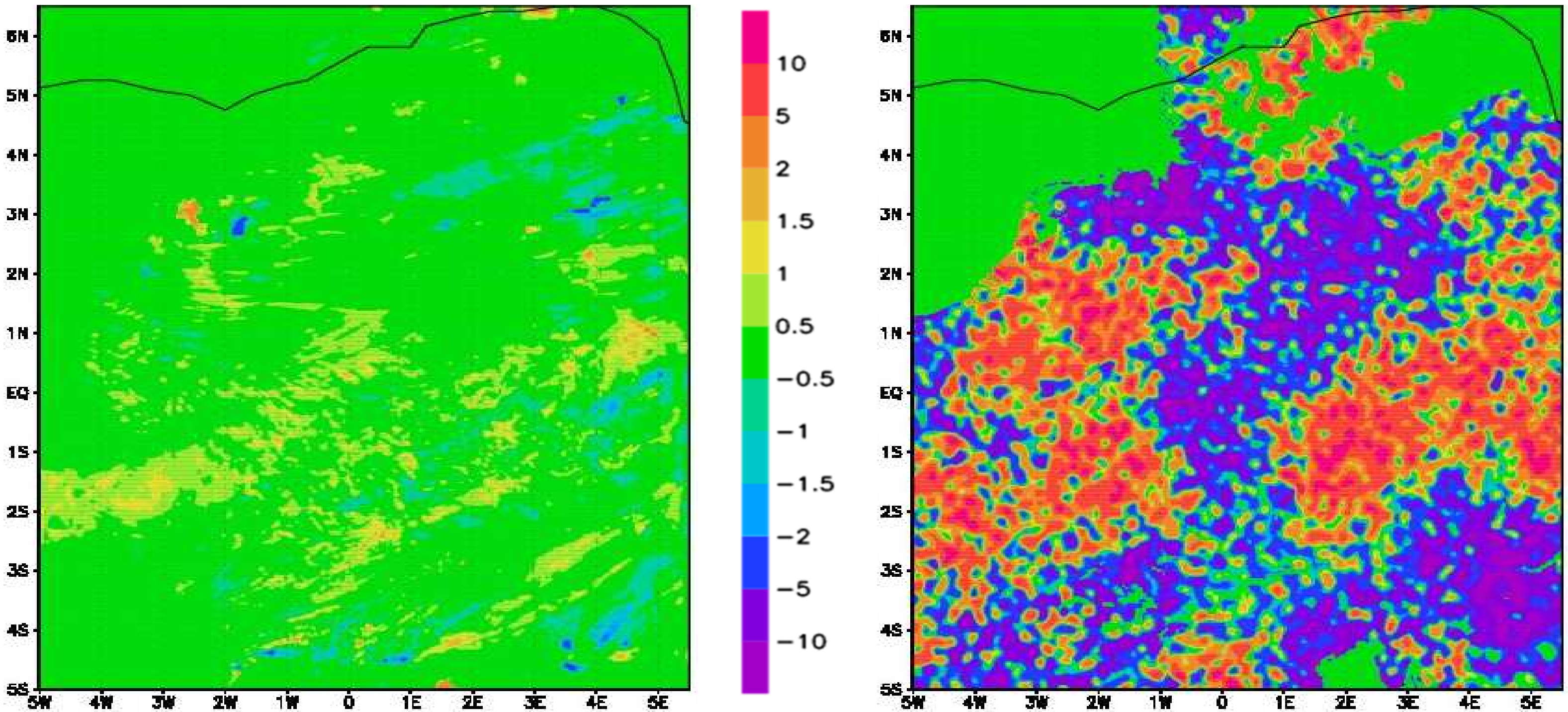
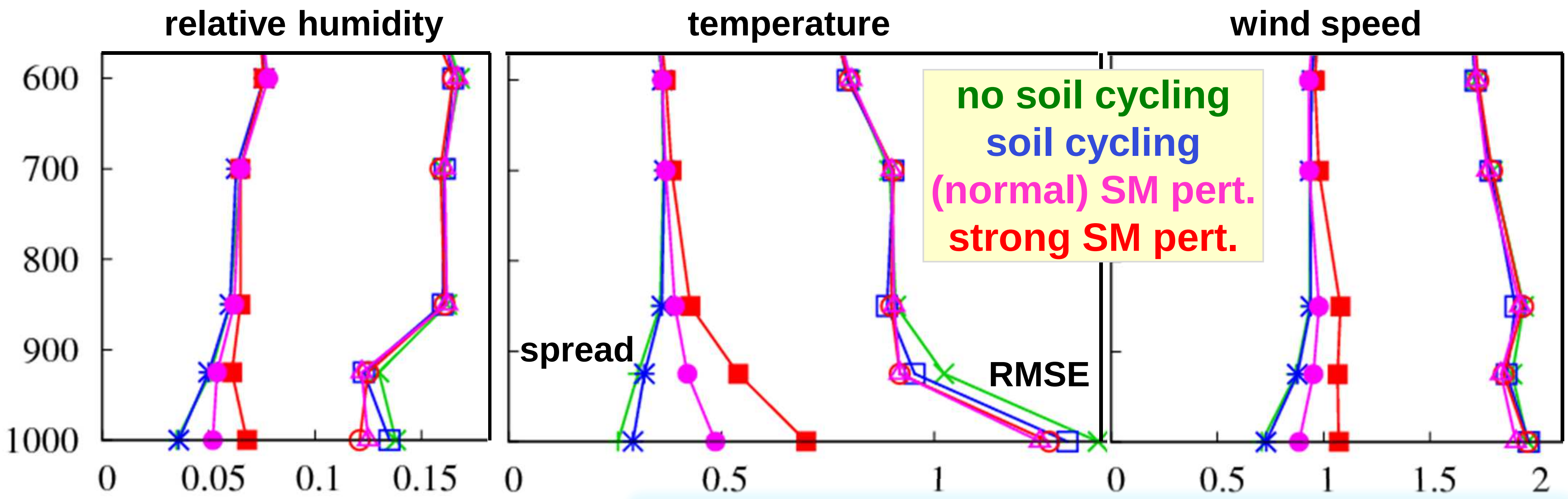
- ✓ simple superposition of Gaspari-Cohn (~ Gaussian) functions at each analysis g.p., with random amplitude and pre-specified horiz. / temporal correlation scale(s)
- ✓ scales : 100 km + 10 km ; 1 day ; std dev of amplitude: 0.1 soil moisture index

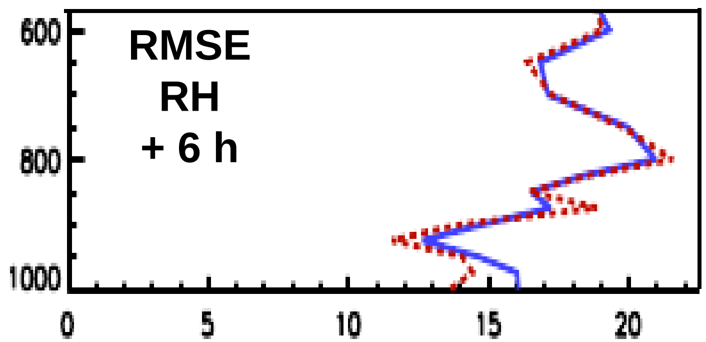
spread of soil moisture (WSO), layer 3 (3 – 9 cm), after 5 days

cycling without perturbations **cycling with SM perturbations**



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





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

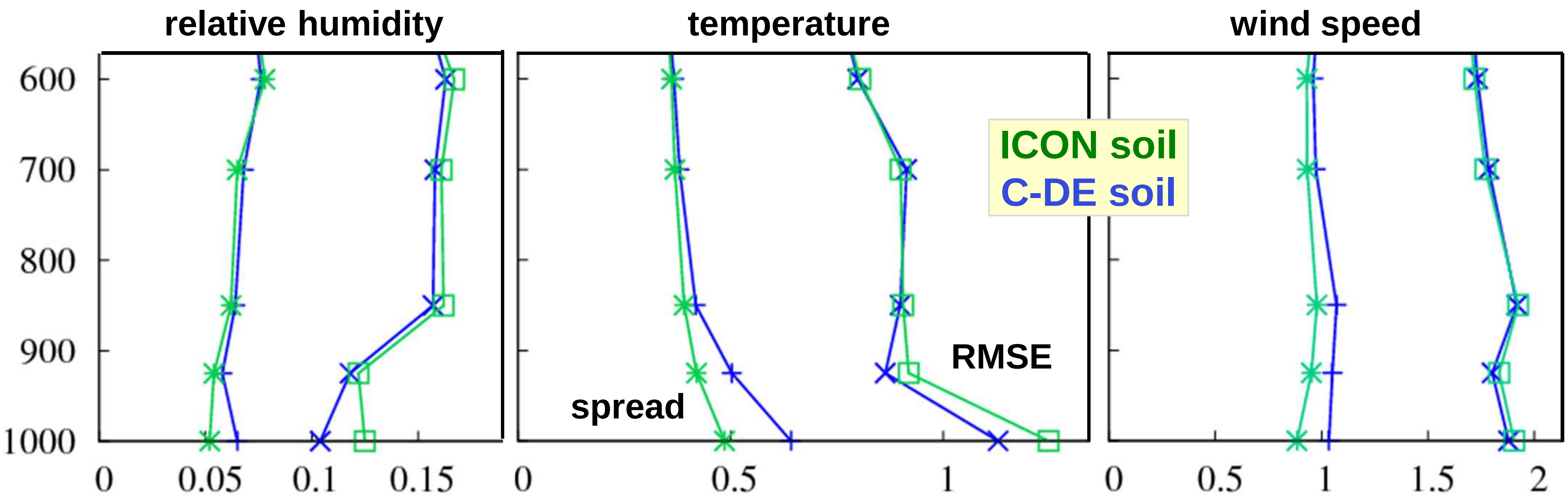
→ strong SM pert.: no further decrease of errors
spread too large ?

→ use 'normal' SM pert. in (most) following exp.

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

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

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 soil** (→ GME → SMA)

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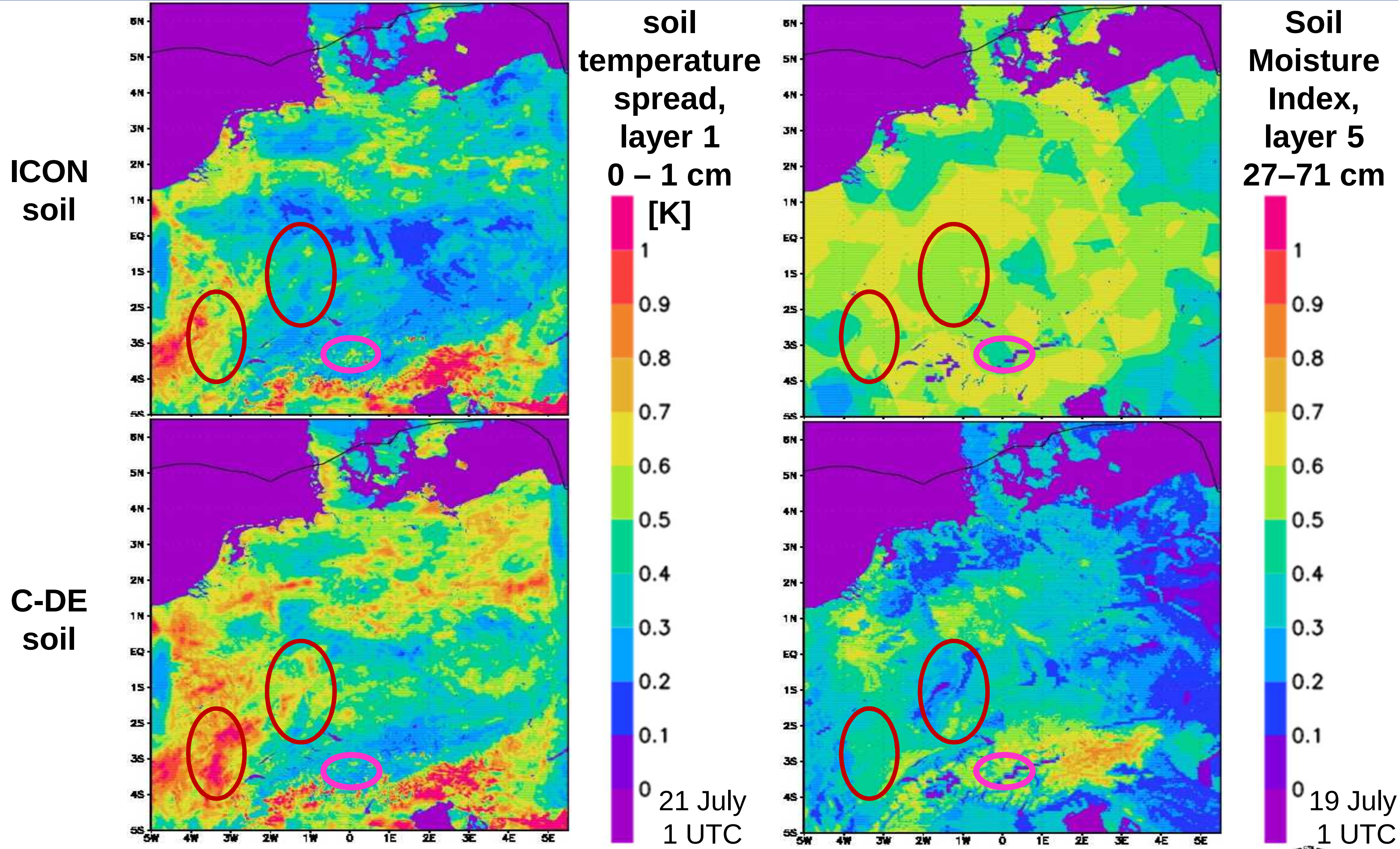

LETKF with **COSMO-DE soil** vs. **ICON soil**:
upper-air verification / summary

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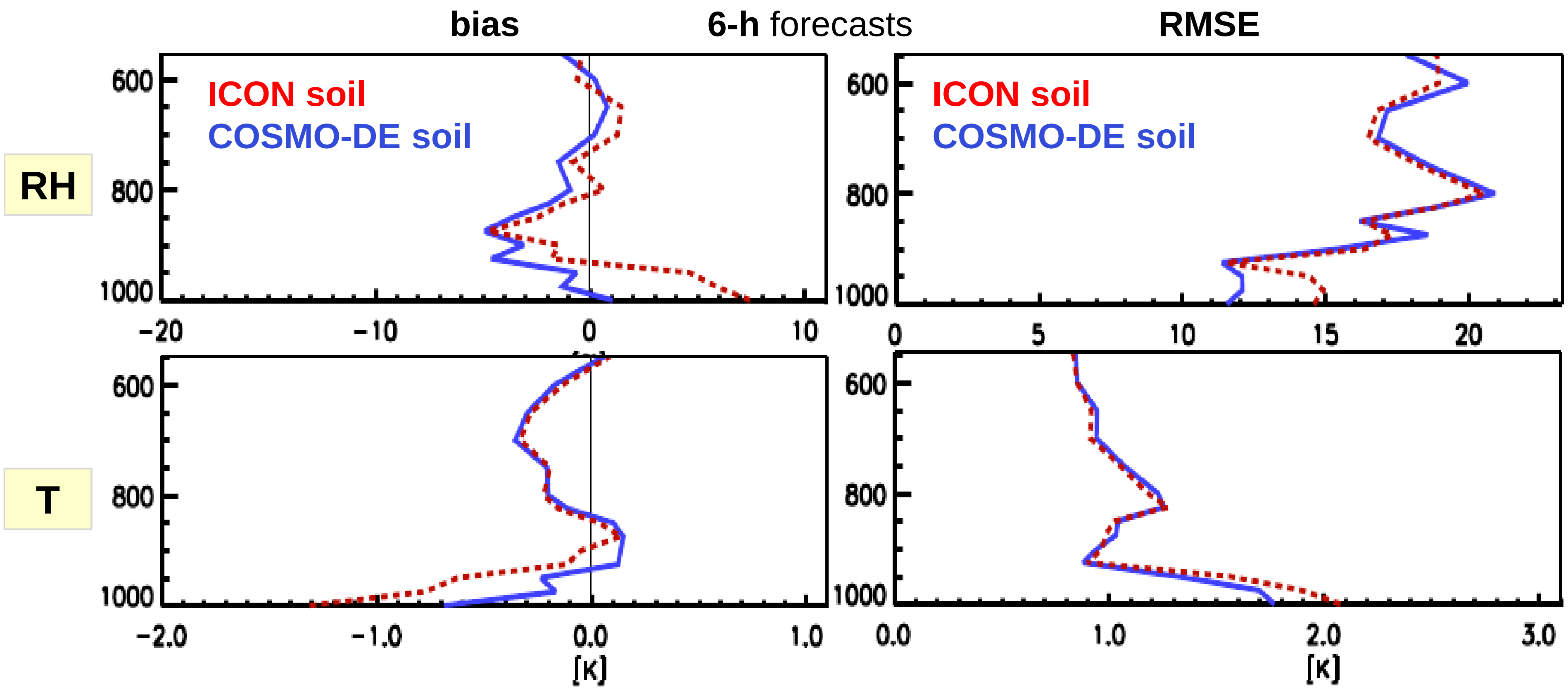

→ plant evapotranspiration more sensitive to SM changes/perturb., if SM low
→ C-DE soil: higher spread in soil temperature & in f.g. T, RH at low levels
→ reduced bias & RMSE of T, RH at low levels
→ reduced bias of T2m, Td2m, improved T2m, low cloud

LETKF vs. **Nudging** (using COSMO-DE soil): surface verification

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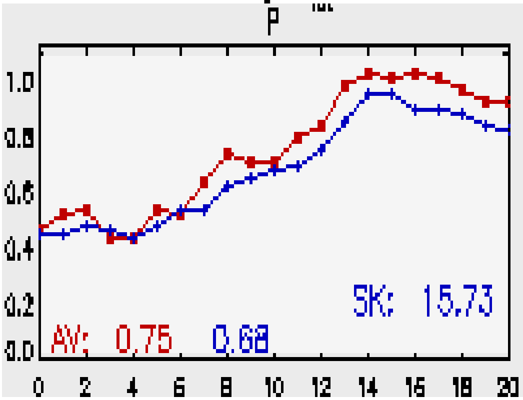
experiment
operational

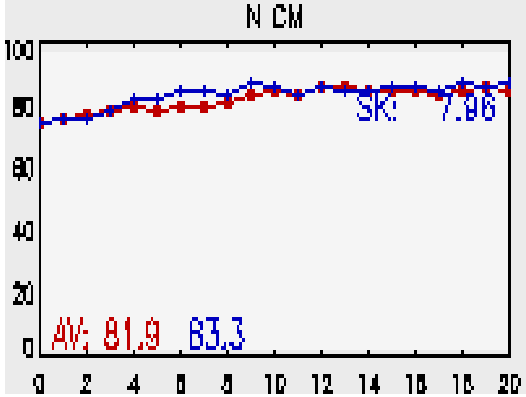
RMSE **surface pressure**

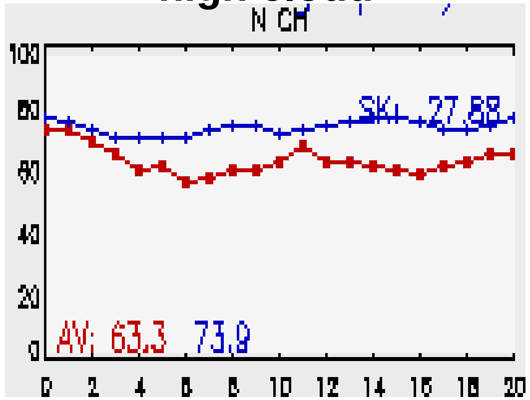
hit rate **mid-level cloud**

hit rate **high cloud**

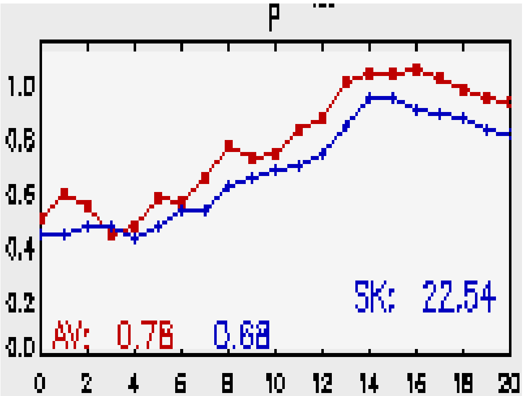
Nudg.

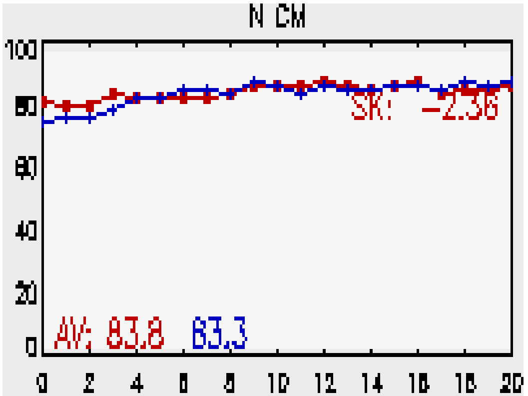


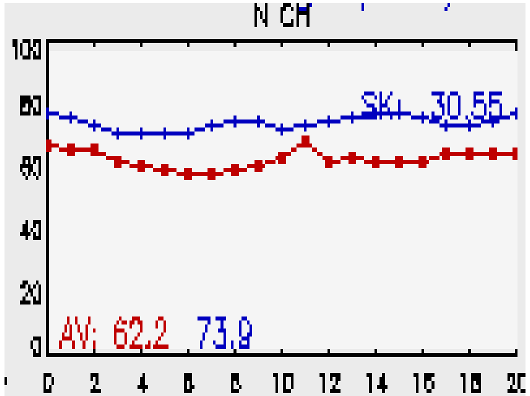




LETKF







LETKF worse

LETKF better

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

LETKF vs. Nudging (using COSMO-DE soil): KENDA score chart

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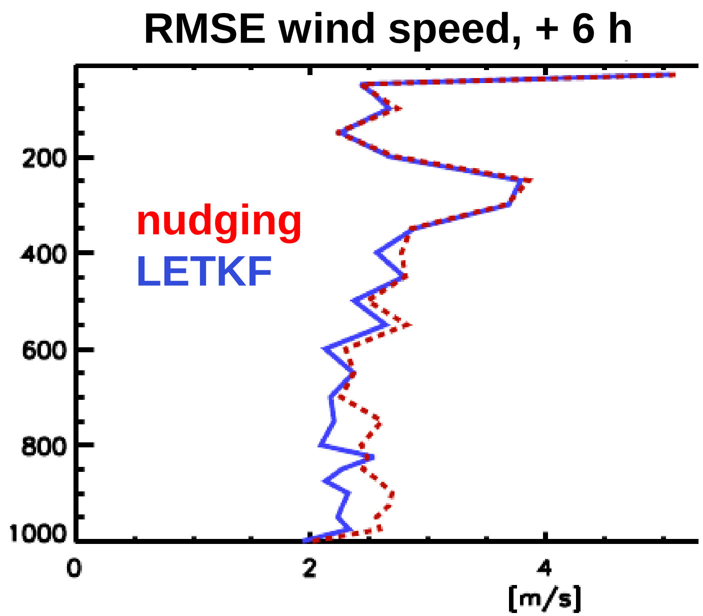
	LETKF vs. Nudging		
	Variable	RMSE	bias
upper air	geopotential	=	=
	temperature	=	=
	(relative humidity)	+	=
	wind speed	+	=
	wind direction	(+)	=
surface	2-m temperature	(+)	=
	2-m dew point temp.	=	=
	10-m wind	=	=
	surface pressure	-	=
	total cloud	=	=
	low cloud	(+)	(+)
	mid-level cloud	+	(+)
	high cloud	(-)	(-)



LETKF used fewer RH obs than nudging, due to stricter QC !!

impact of including **LHN in LETKF DA cycle** : verification against radar precipitation

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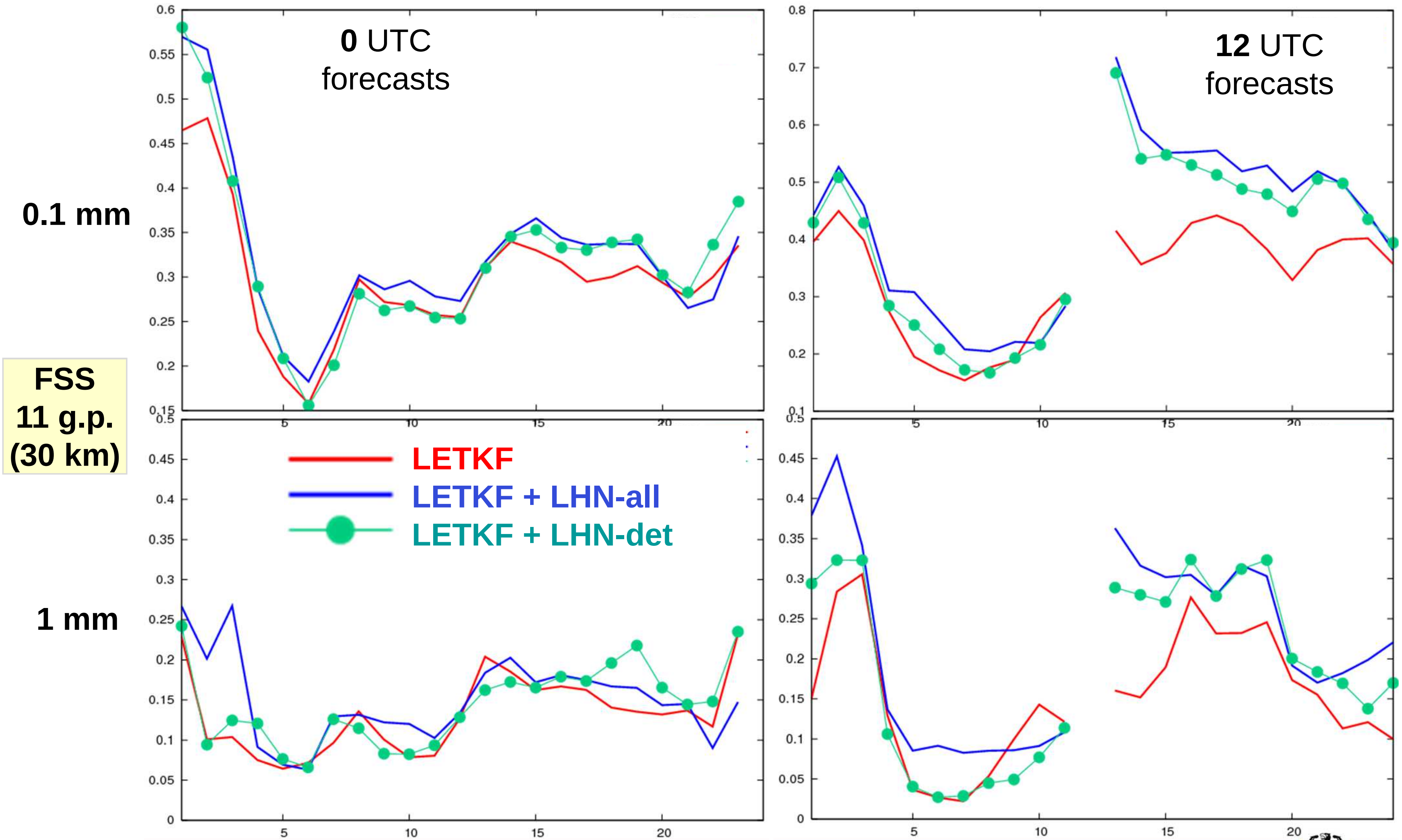

impact of including **LHN in LETKF DA cycle** (with ICON soil): score chart

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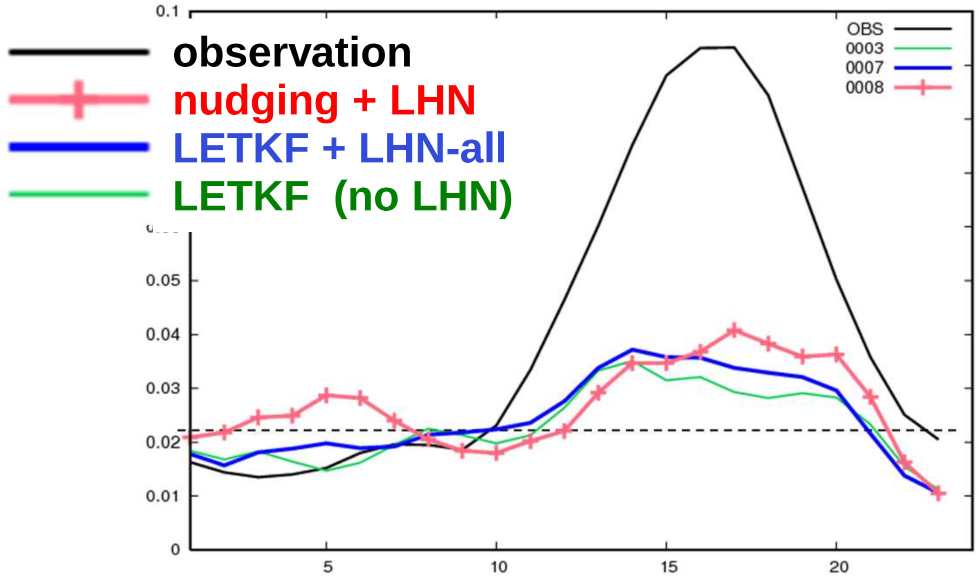
	LETKF **LHN-det** vs. no-LHN		LETKF **LHN-all** vs. LHN-det	
variable	RMSE ETS / FSS	Bias FBI	RMSE ETS / FSS	Bias FBI
upper-air	=	=	=	=
surface	=	=	=	=
precip 0 UTC , 0.1 mm	(+)	(+)	(+)	=
precip 0 UTC , 1 mm	=	=	(+)	=
precip 12 UTC, 0.1 mm	**+**	**+**	**+**	=
precip 12 UTC, 1 mm	**+**	=	**+**	=

→ benefit from adding LHN small for 0-UTC runs, large for 12-UTC runs
→ deterministic forecast improves if LHN also added to all ens members in LETKF

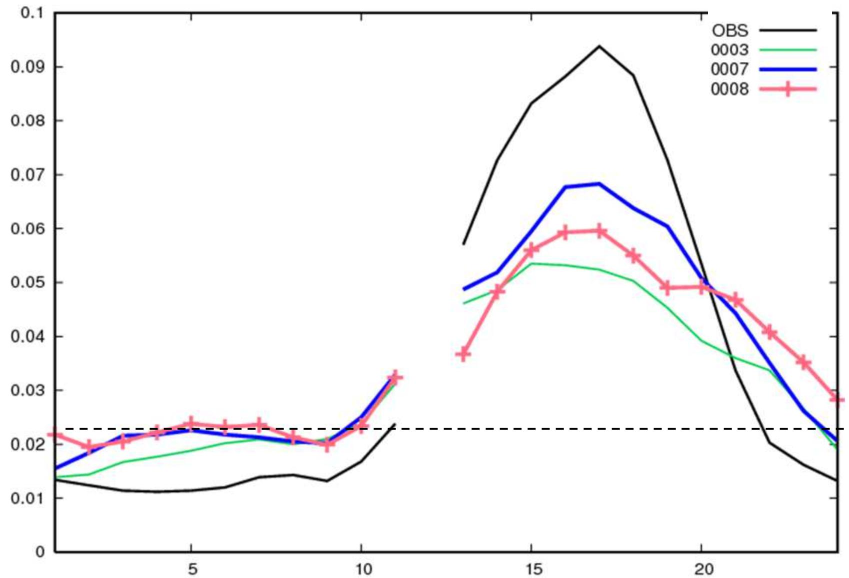
daily cycle of domain average precip → info on bias

0 UTC forecasts



daytime

12 UTC forecasts



daytime

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

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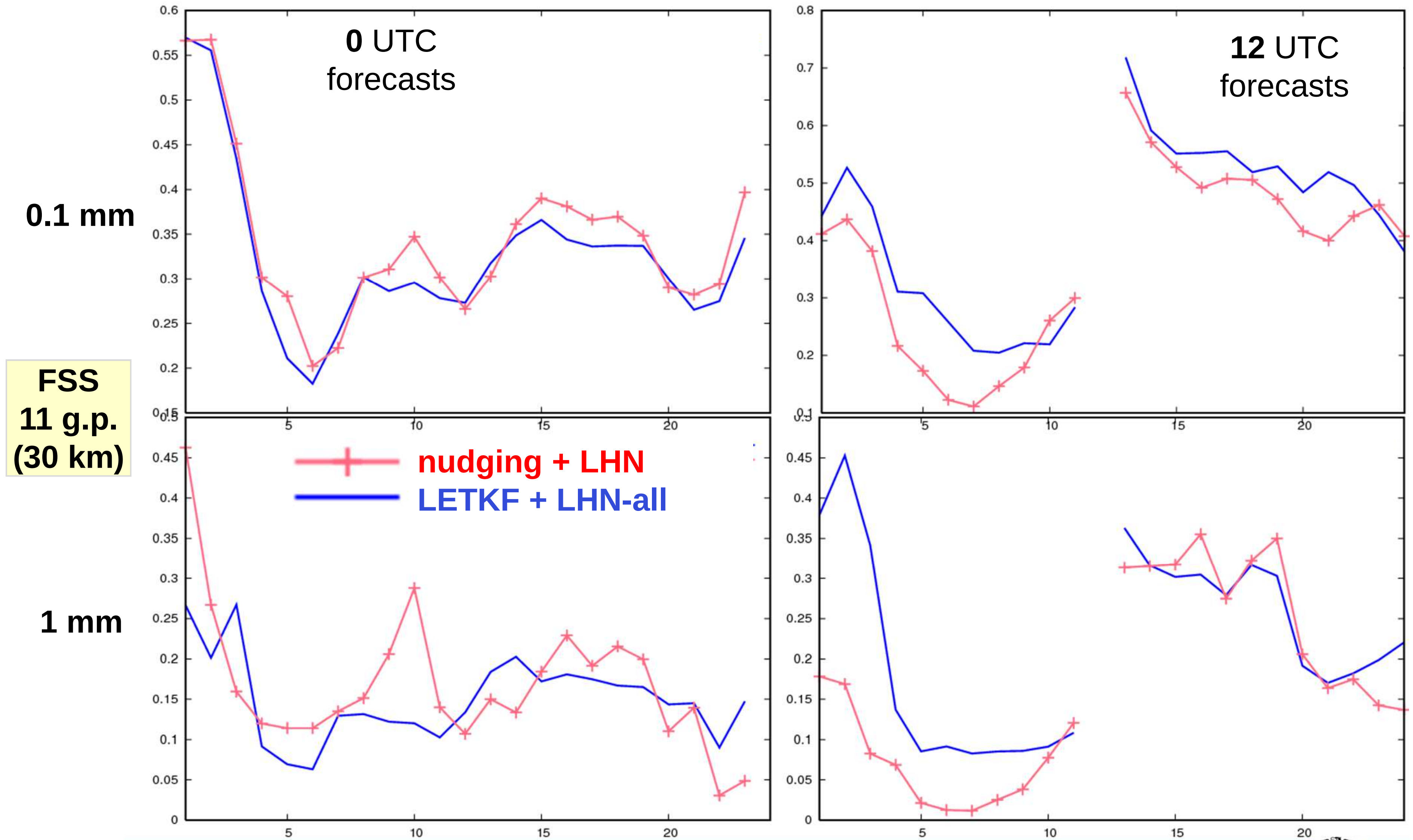
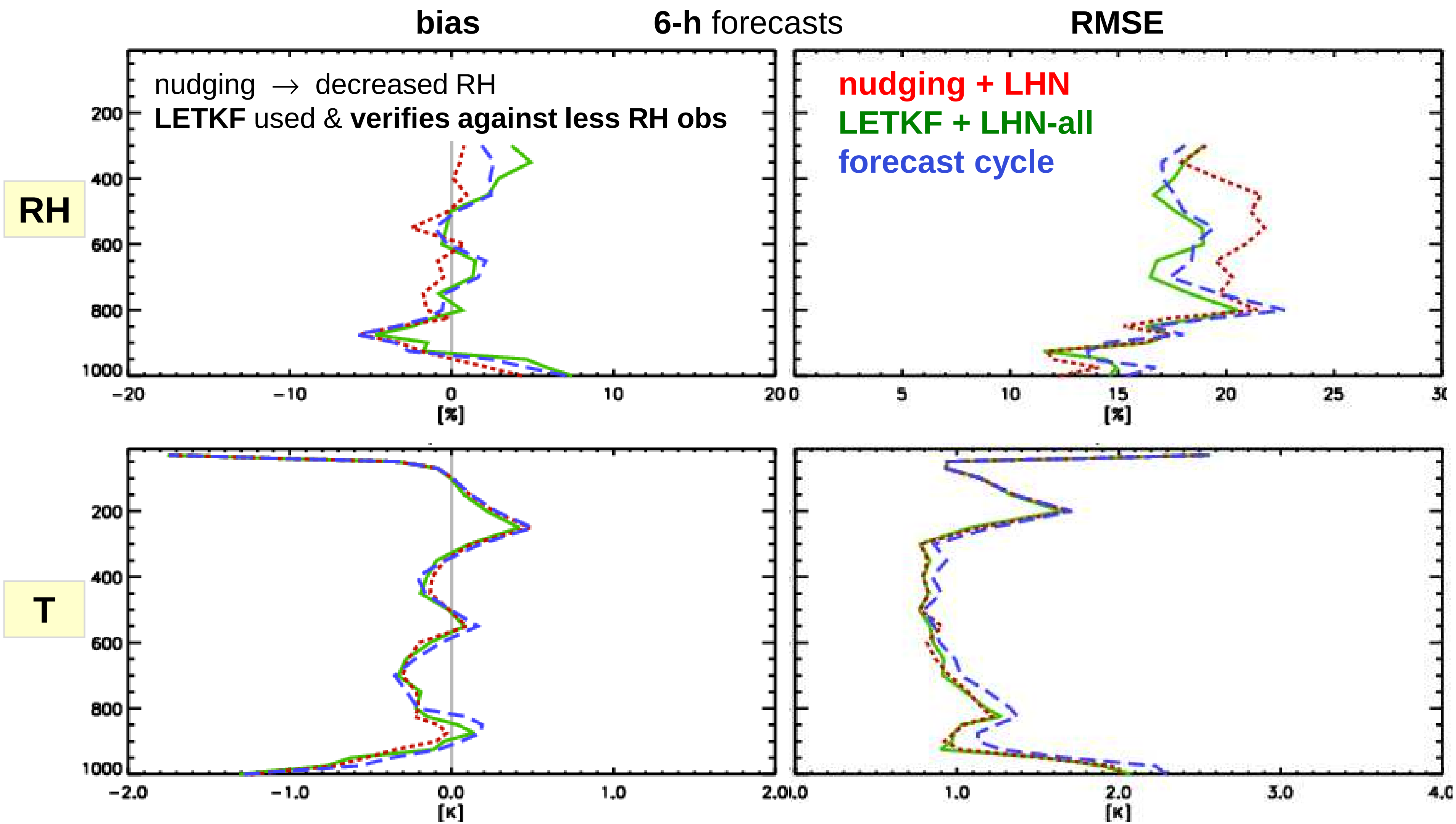


LETKF + LHN-all vs. Nudging + LHN : upper-air verification



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

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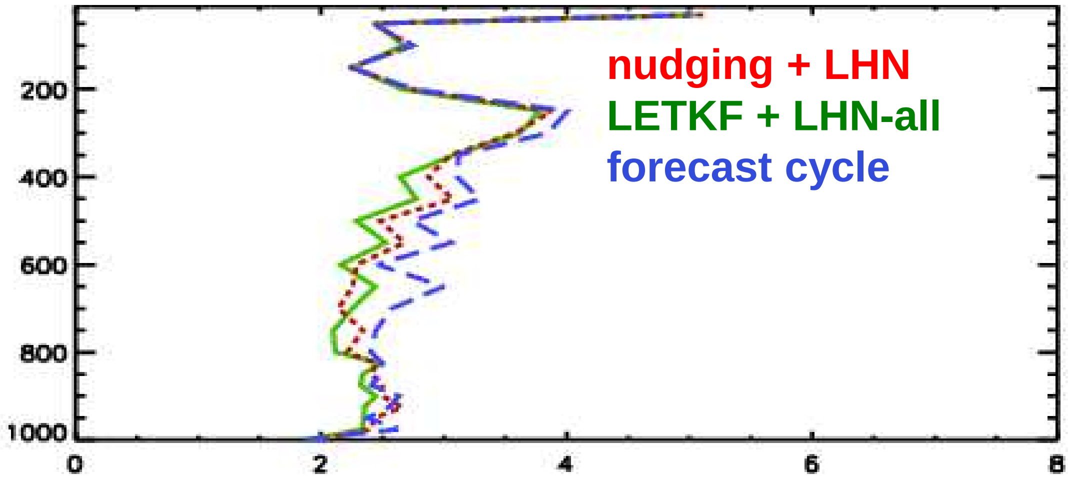
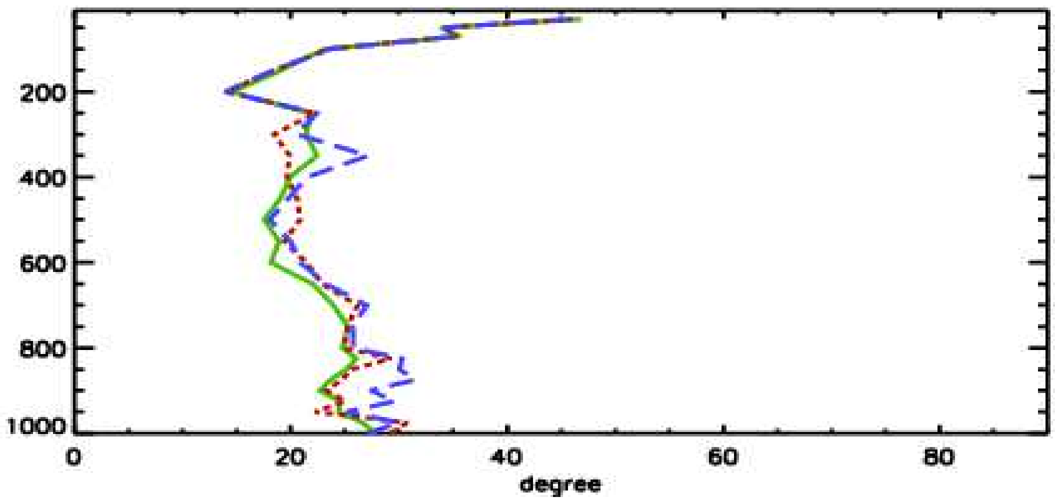
6-h forecasts **RMSE**

wind speed



wind direction



(ICON 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
- ✓ 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 (YIPPEE !)

  negative: surface pressure → reducing ps obs errors helps a bit (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: other tasks

- SPPT (stochastic physics) : adapted for use in cycled DA, in COSMO V5_1
- Pattern Generator (3D, 2D) : incorporated into COSMO, almost finished (RHM)
  - → soil moisture perturbations (ARPA-Piemonte)
  - → additive covariance inflation

KENDA: verification tasks

- MEC (model equivalent calculator), for production of 'full' NetCDF feedback files (input for verification: NEFFprove, VERSUS)
  - preliminary (still slightly buggy) version developed
  - planned end of Oct.: basic working version
    - ✓ conv. upper-air obs / surface obs used in DA (ps, T2m, RH2m, uv10m)
  - thereafter: add additional variables which are not actively assimilated (cloud, precipitation, gusts, MSLP, Td2m, radiation, etc.)

- NEFFprove ensemble-related verification tool, using feedback files (Amalia Iriza):
  - basic version exists, needs to be tested thoroughly
  - further testing / more diagnostic output + docu / revisions dep. on users needs

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

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

- **GPS slant path delay**: pure obs operator implemented
  (Bender) to do: testing, writing feedback files …

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

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

- novel ground-based remote sensing (Haefele, MCH)
  Raman lidar (T + qv profile), **microwave radiometer** (T + qv prof., IWV, ql, BT):
  - report written on new profiler obs with potential use in COSMO
  - working on O-B statistics for radiometer and LIDAR obs at Payerne

KENDA plan

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

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DWD

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 forecasts with larger forecast lead time to IFS det. (MCH); optimize ICON-LETKF (DWD)
  - additive covariance inflation: SPPT, (perturbed physics ? Self-evolved pert.? Incremental perturbations with prescribed spatio-temporal correlations ?)
- complete DA cycle: soil: add SST and snow depth analysis
- technical issues

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

- 4D-LETKF, or (3D-) EnVar (for deterministic ana/fcst) ?

reviews

- Onvlee: main point is quality / ability to extract meaningful info from the obs
  - need flow-dep B
  - get large scale info correct, avoid (evolving unpredictable) small scale noise
  - big effort to handle obs
  - surface DA important

COSMO Science Plan on DA: Overview

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 humidty / weather parameters, also surface
- ✓ towards nowcasting

→ need for high quality and efficiency

– **3D radar – radial velocity** → (Zeng ??)
  – **reflectivity** → Poli (ARPA-SIM); (Bick ??)
  → DWD 2016+ ?; (Würsch, H. Lange, LMU)

– **GPS Slant Path Delay** (/ Zenith PD) → IAFE 2015 – 2018 (+ HErZ)

– **Cloud Top Height** (CTH) derived from SEVIRI → Schomburg: ~ 0.4 FTE / y (?)

– direct use of **SEVIRI WV/ IR window** channels for assimilating **cloud** info
→ IAFE 2015 – 2018; (+ HErZ: WV; **VIS+NIR**)

– direct use of **SEVIRI WV** channels, **clear-sky** for T, qv → HErZ 2016

– **Mode-S** (high-resolution) wind and temperature data (from aircraft)
→ H. Lange (HErZ)

– **screen-level** observations (T2m, q2m, uv10m) → Schraff (0.3 FTE/y), MCH?)

– ground-based remote-sensing data, e.g. microwave radiometer & Raman lidar
T, qv profiles, Doppler lidar wind profiles; ceilometer cloud base height

COSMO Science Plan on DA: action items

- Integrated Forecasting System (IFS) towards Nowcasting
  - analysis + forecast RUC, dx ≤1 km (technical + tuning)
  - tuning and extension of LETKF (→ 1st action item)

  → IAFE projects
    - ➢ assimilation of LLWAS (wind lidar + X band radar) for airport model COSMO-MUC
    - ➢ LES test bed: characterization of model error and of obs representation error

- adaptation to ICON-regional
  - technical implementation of e.g. obs operators in ICON, also re-tuning
  - review decision on DA method: 4D-LETKF, or (3D-) EnVar