Studies with COSMO-DE on basic aspects in the convective scale: Gaussianity and systematic errors

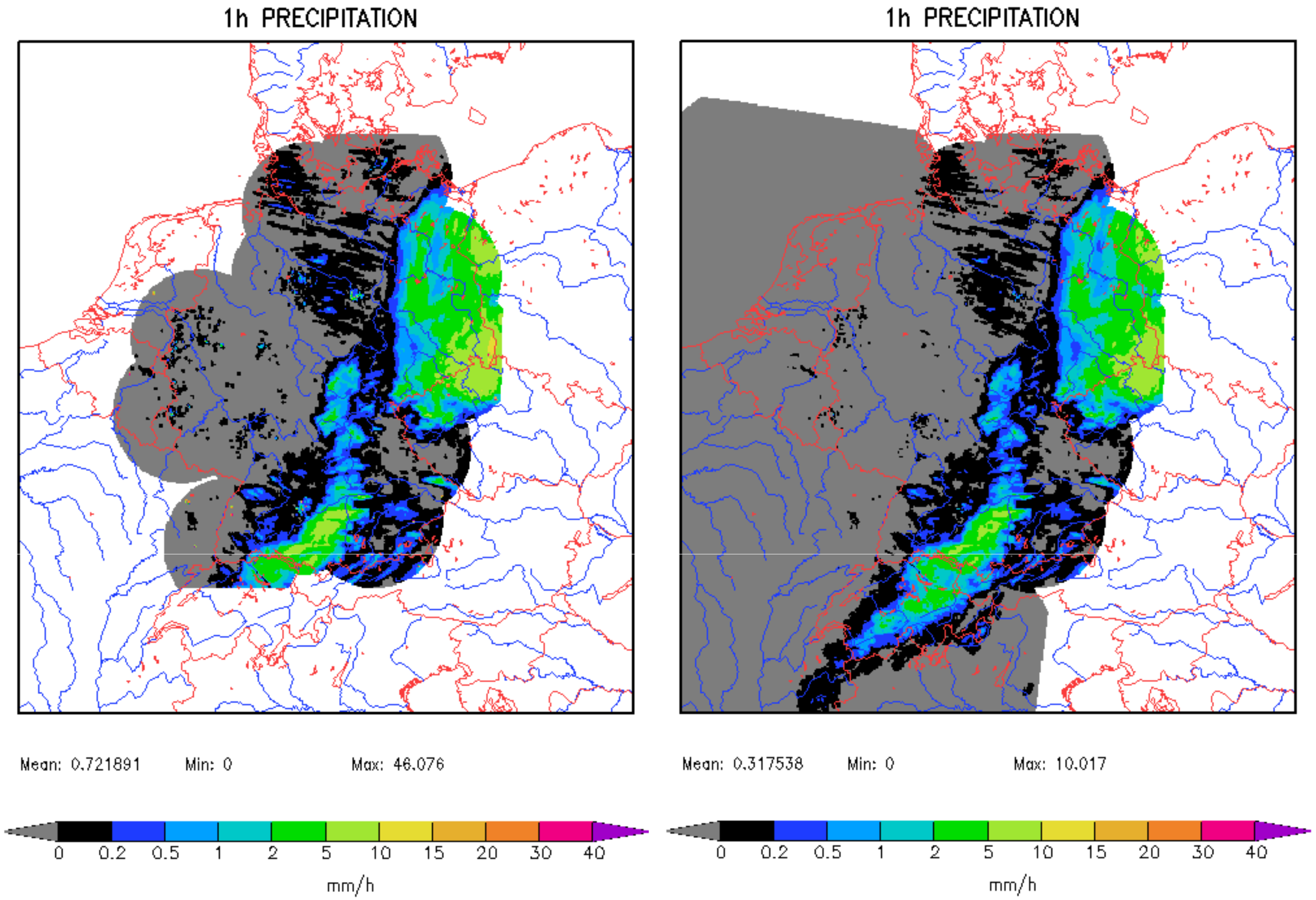
christoph.schraff [at] dwd.de
Deutscher Wetterdienst, D-63067 Offenbach, Germany

COSMO Priority Project KENDA → LETKF : mainly implementation work done

- use of extended radar composite
- statistical study on (non-) Gaussianity of km-scale
- model (and observation) bias

Use of extended composite of radar-derived surface precipitation in LHN

all experiments & plots by Klaus Stephan



with quality control
on single-radar data

+ NL composite (3 Sta.)
+ B composite (2 Sta.)
+ 10 French stations
+ 3 Swiss stations

limited quality control:

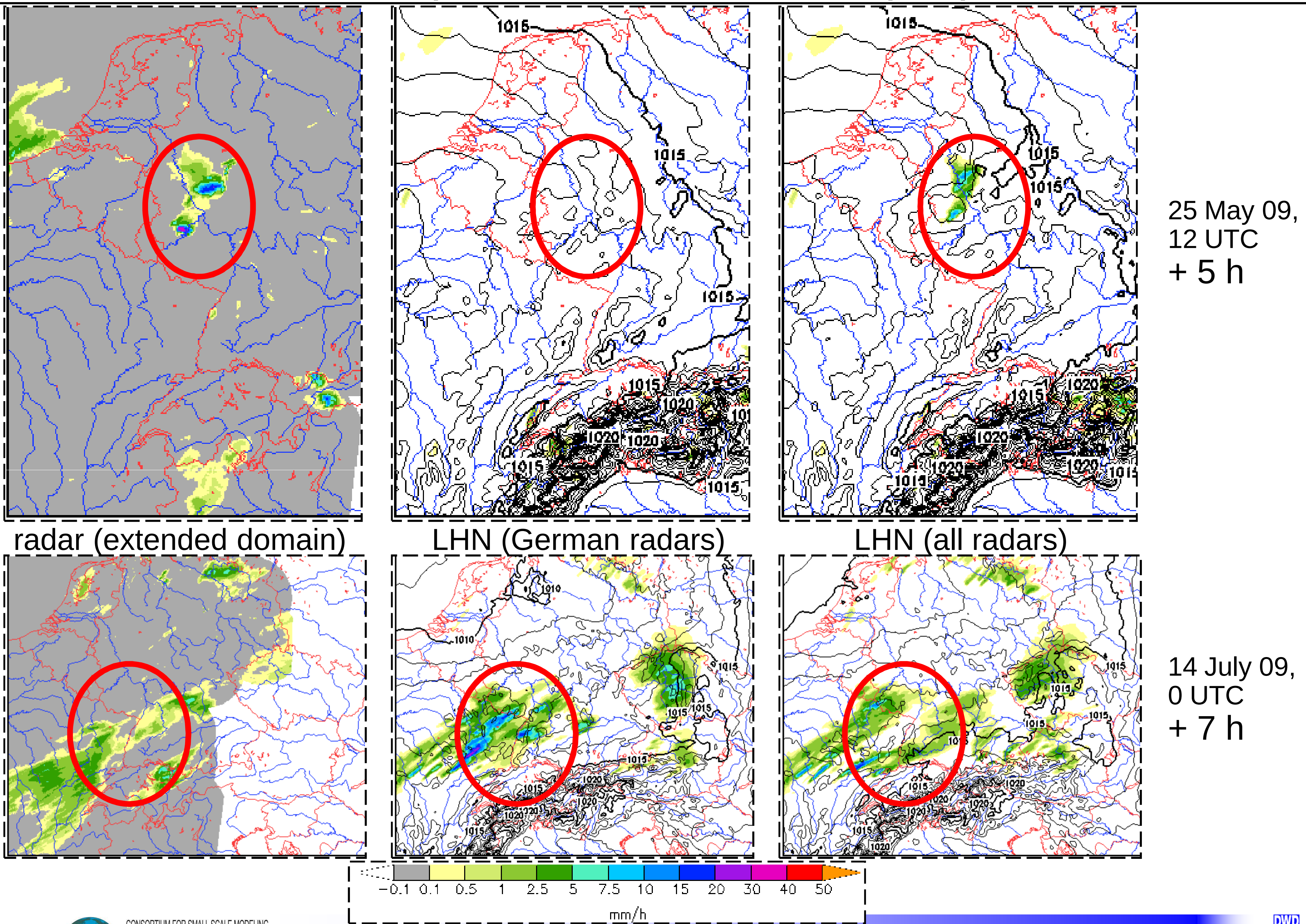
+ filtering of clutter

+ gross error detection (anomalous histogram)

+ blacklist (by comparison to satellite cloud)

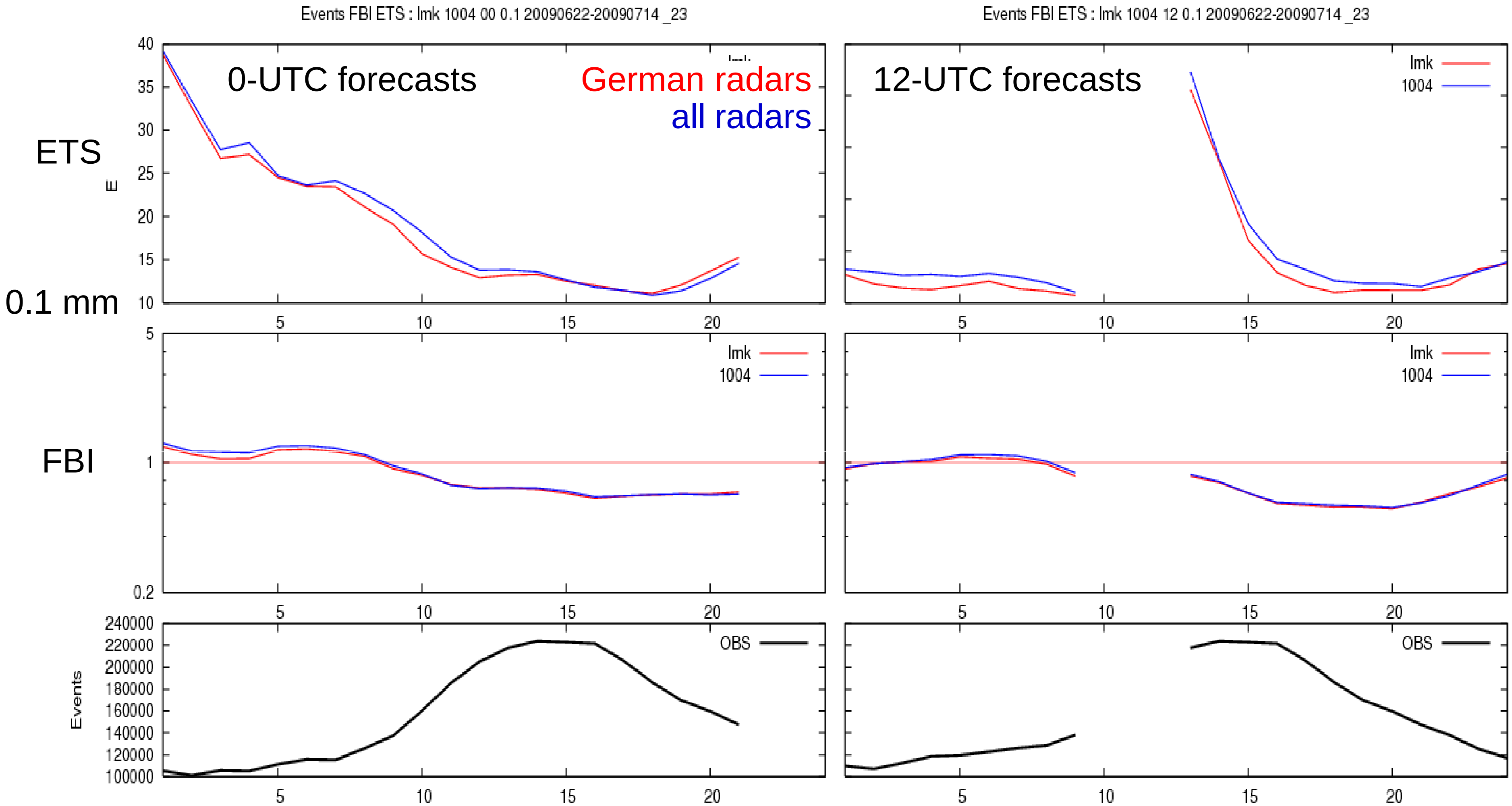
– no radar beam height map for bright band detection

Use of extended composite of radar-derived surface precipitation in LHN



Use of extended composite of radar-derived surface precipitation in LHN

skill scores 22 June – 14 July 2009



- slight improvement in scores
- large improvement in single cases
- operational in spring 2010

Statistical Characteristics of High-Resolution COSMO Ensemble Forecasts
in view of Data Assimilation

by Daniel Leuenberger, MeteoSwiss

- General assumption in Ensemble Kalman Filter methods:
  'Errors are of Gaussian nature and bias-free'

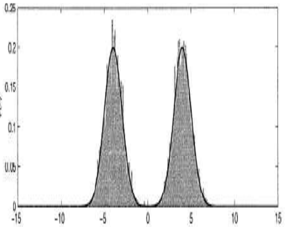
$$J(\mathbf{x}) = \underbrace{\frac{1}{2}[\mathbf{y}-H(\mathbf{x})]^T \mathbf{R}^{-1}[\mathbf{y}-H(\mathbf{x})]}_{\text{observation term}} + \underbrace{\frac{1}{2}(\mathbf{x}-\overline{\mathbf{x}}_b)^T \mathbf{P}_b^{-1}(\mathbf{x}-\overline{\mathbf{x}}_b)}_{\text{background term}}$$

- How normal are these terms in the COSMO model ?

obs - f.g.
(COSMO-DE forecasts,
3 months summer & winter)

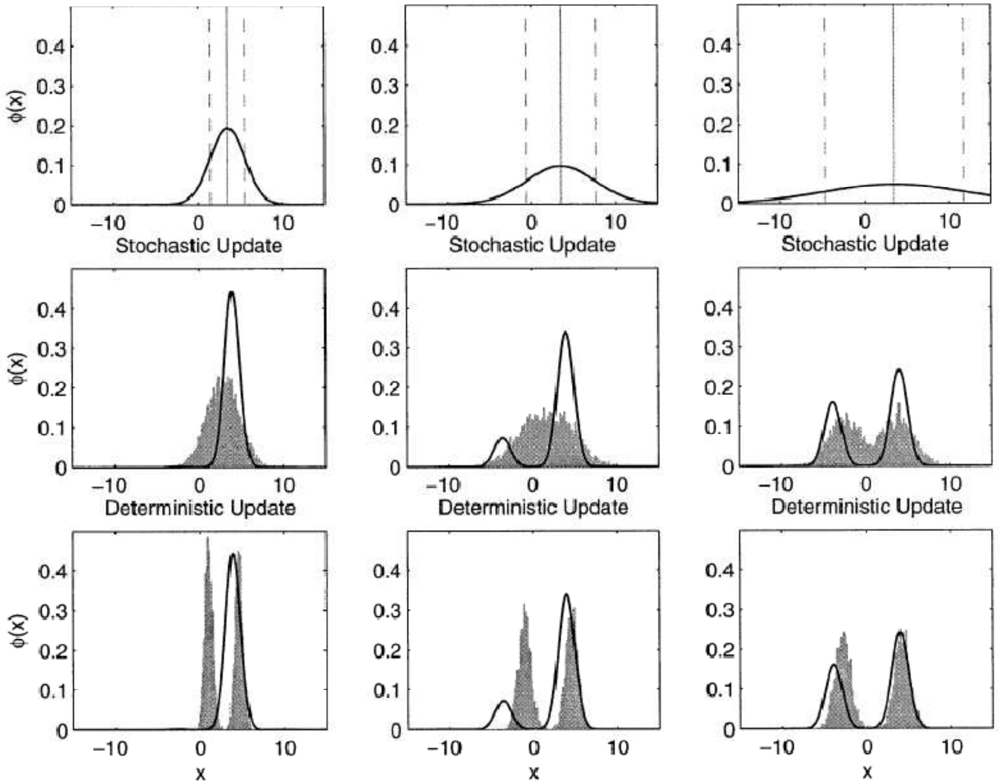
COSMO-DE EPS
ensemble perturbations
(9 cases in August 07)

effect of non-normality on EnKF



background pdf

small obs error | medium obs error | large obs error



observation pdf

shading:
pdf after update with stochastic EnKF

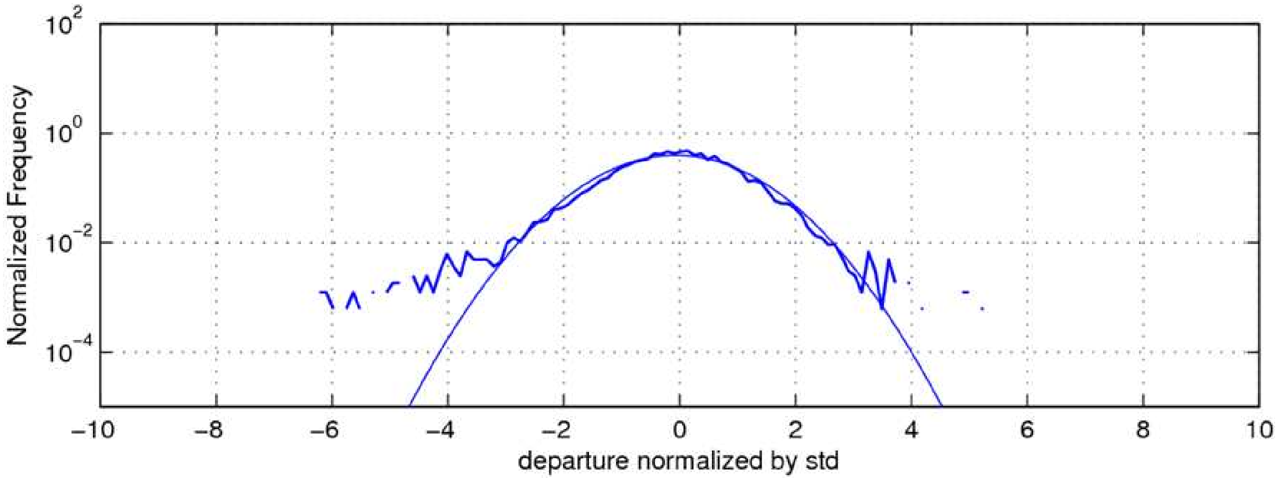
solid line: true pdf

shading:
pdf after update with deterministic EnKF

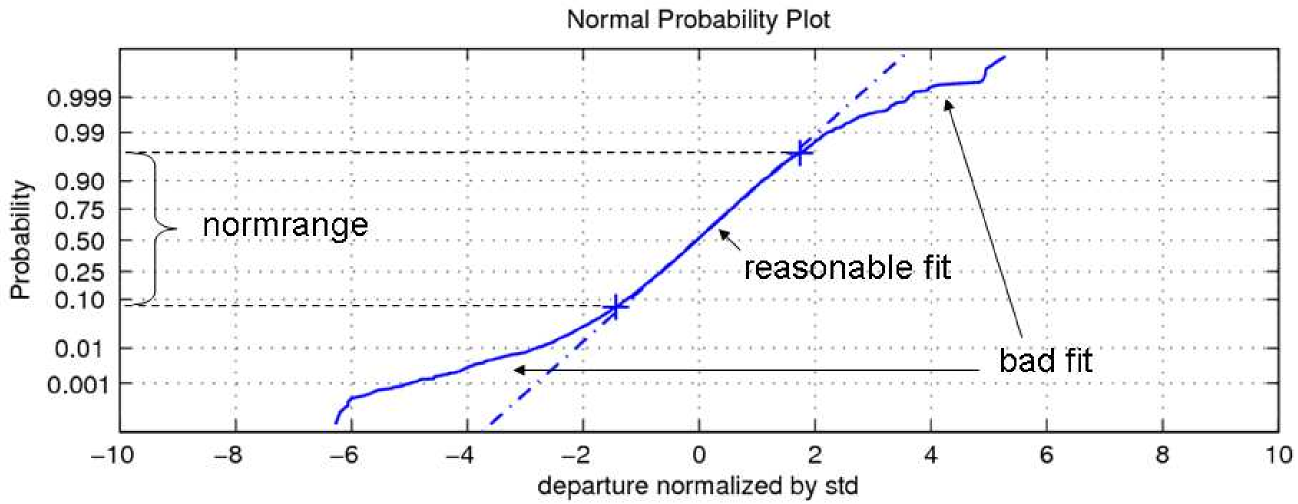
Lawson and Hansen, MWR (2004)

evaluation method

PDF
(qualitative)

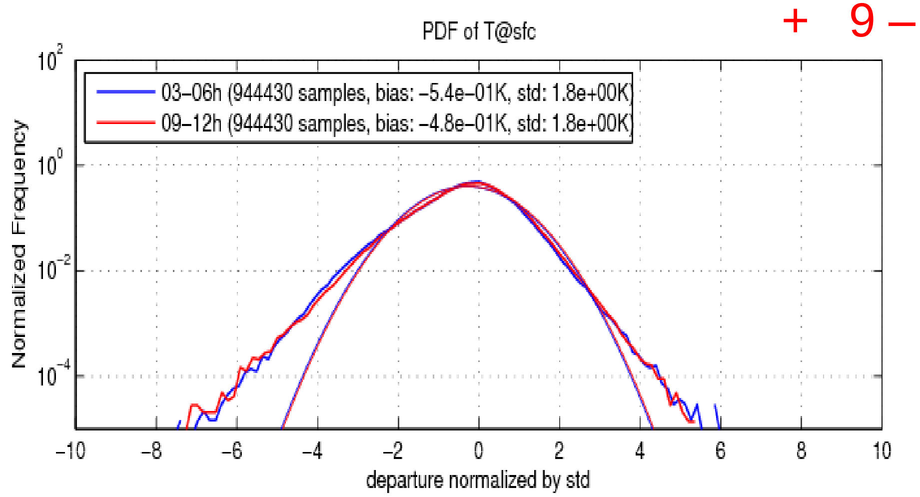


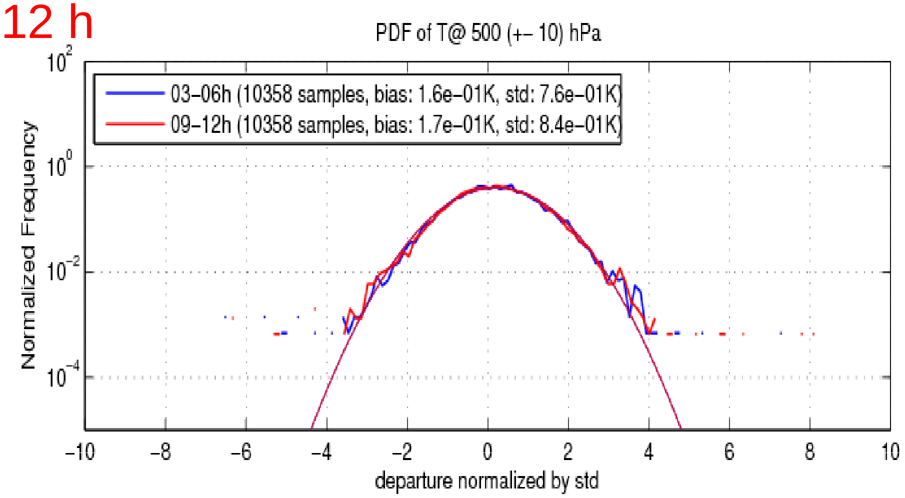
Normal Probability Plot
(more quantitative)

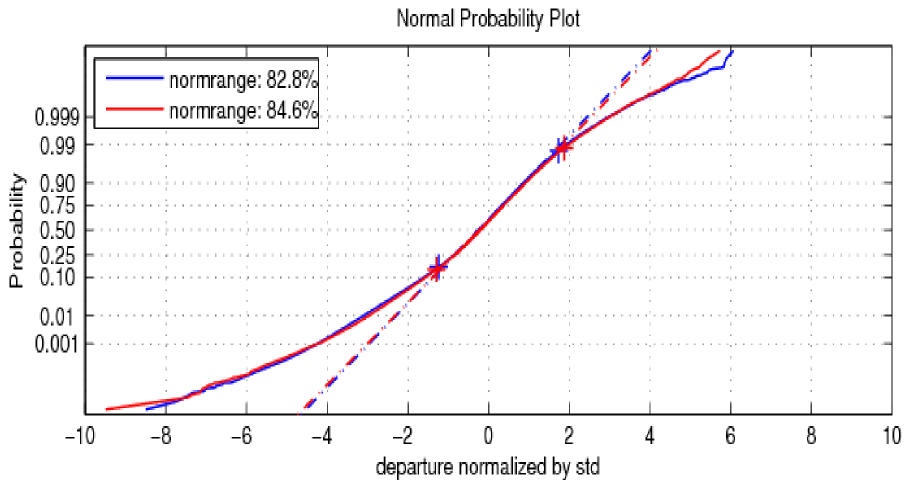


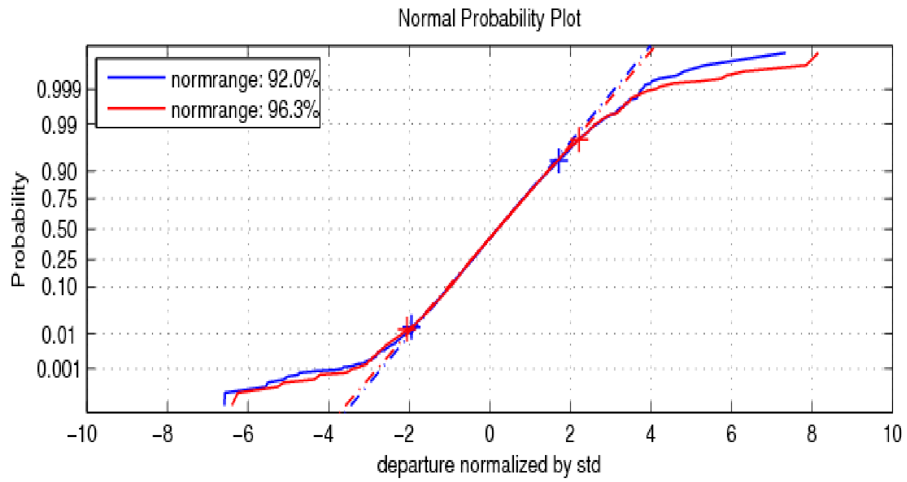
example 1: temperature

T2m from SYNOP + 3 – 6 h + 9 – 12 h T@500hPa from aircraft obs







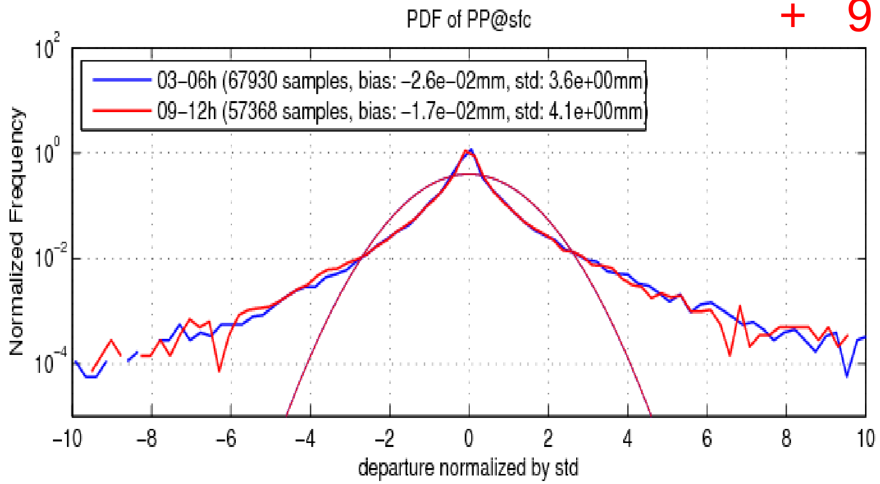


example 2: precipitation

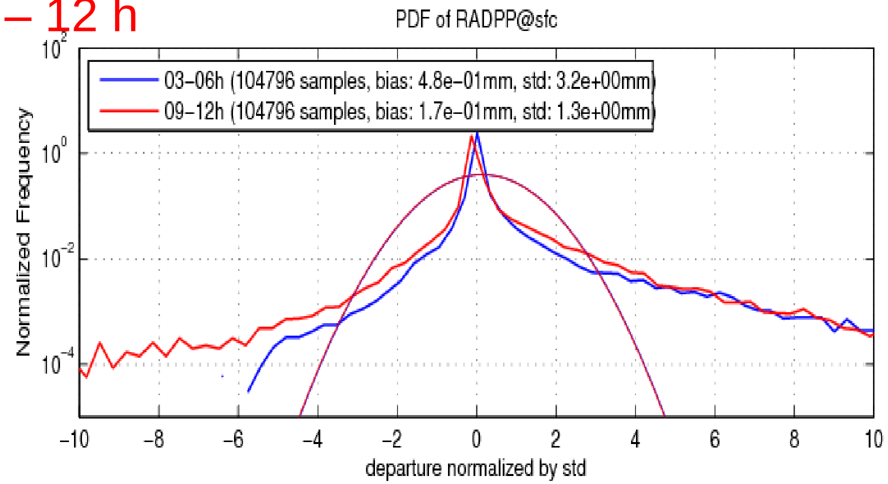
+ 3 – 6 h

+ 9 – 12 h

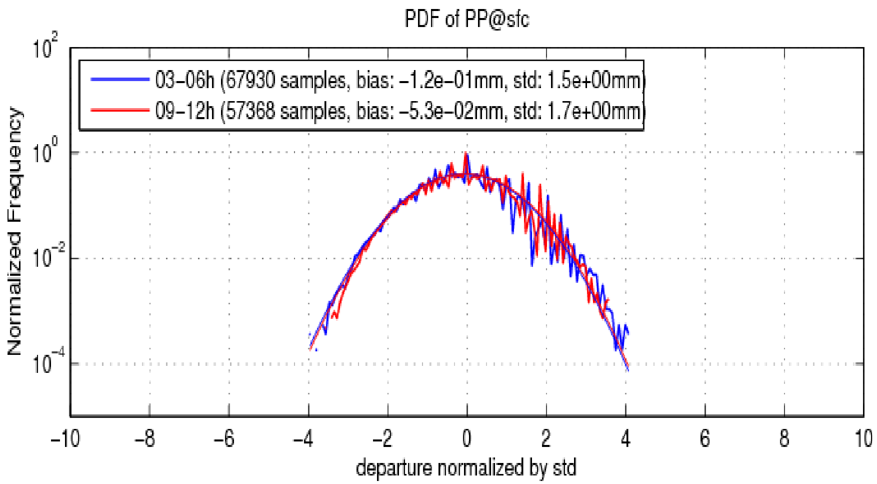
precip from SYNOP



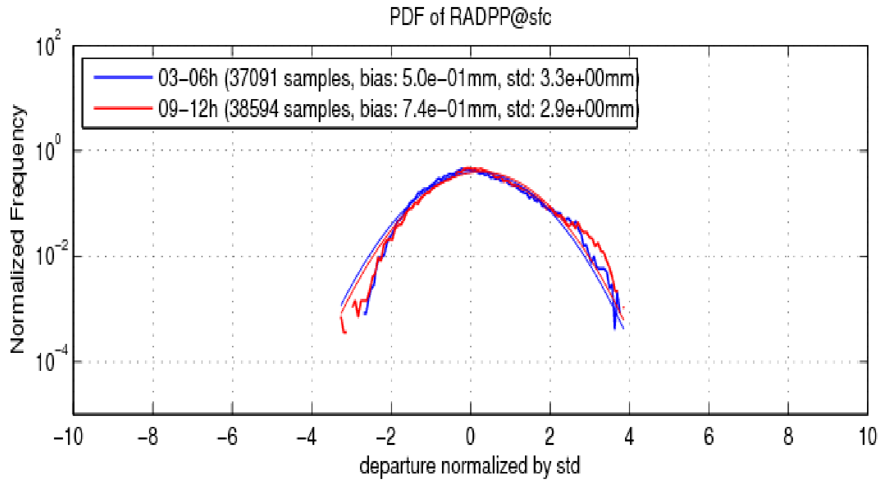
precip from radar



log(precip) from SYNOP



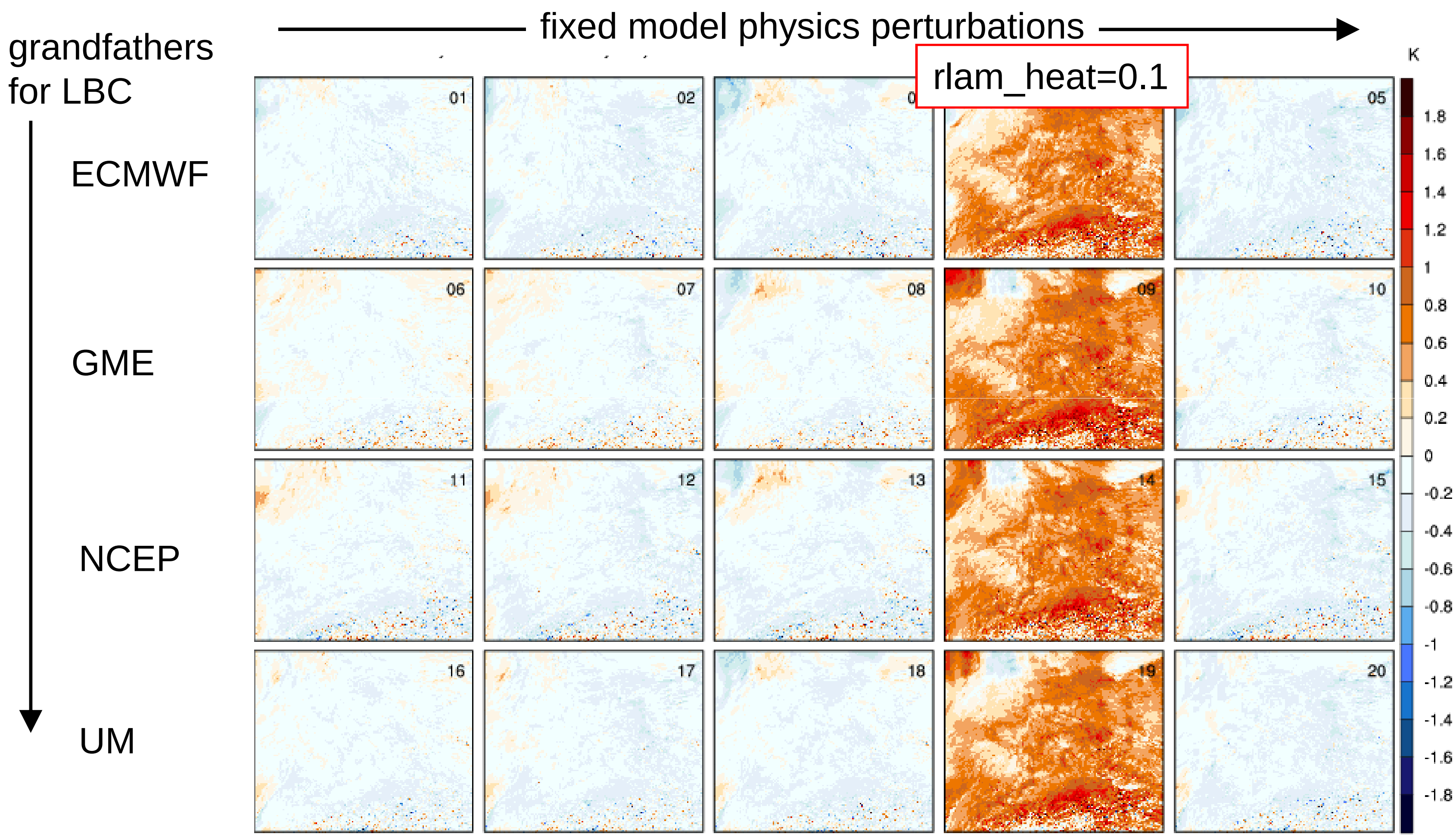
log(precip) from radar



general findings for observation term

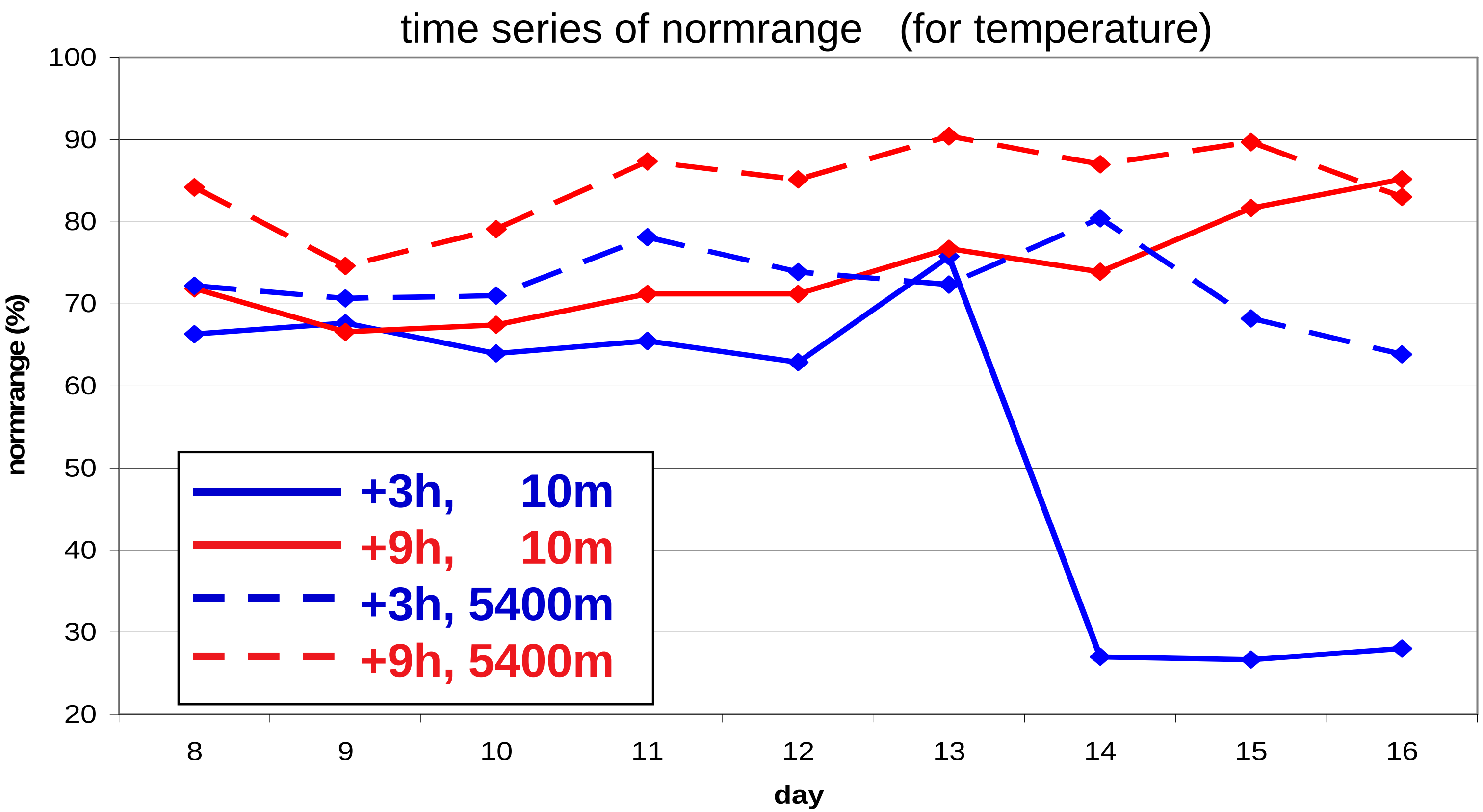
- Small deviations from normality for T, u, v, ps (normranges 80 - 95%)
  - → „fat tails“ (large departures occur more often than in a Gaussian distribution)
- Better fit in free atmosphere than near surface
- No decrease of normrange with increasing forecast lead time (up to + 12 h)
- Negligible differences COSMO-DE (Δx = 2.8 km) vs. COSMO-EU (Δx = 7 km)
- Deviation from normality in humidity and precipitation
  - → transformed variables (log(precip) & normalised RH) have better properties concerning normality and bias
- Slightly larger deviation from normality in a sample of rainy days (27 out of 92)
  - → for single cases, non-Gaussianity is expected to be (far ?) more significant

background term: COSMO-DE ensemble forecast perturbations



temperature at ~10m, +3h (03UTC)

background term: COSMO-DE ensemble forecast perturbations



- need to re-do such evaluations with LETKF ensemble
  → Gaussian spread in initial conditions
- for data assimilation, need perturbations that are more Gaussian
  → physics perturbations: stochastic instead of fixed parameters ?

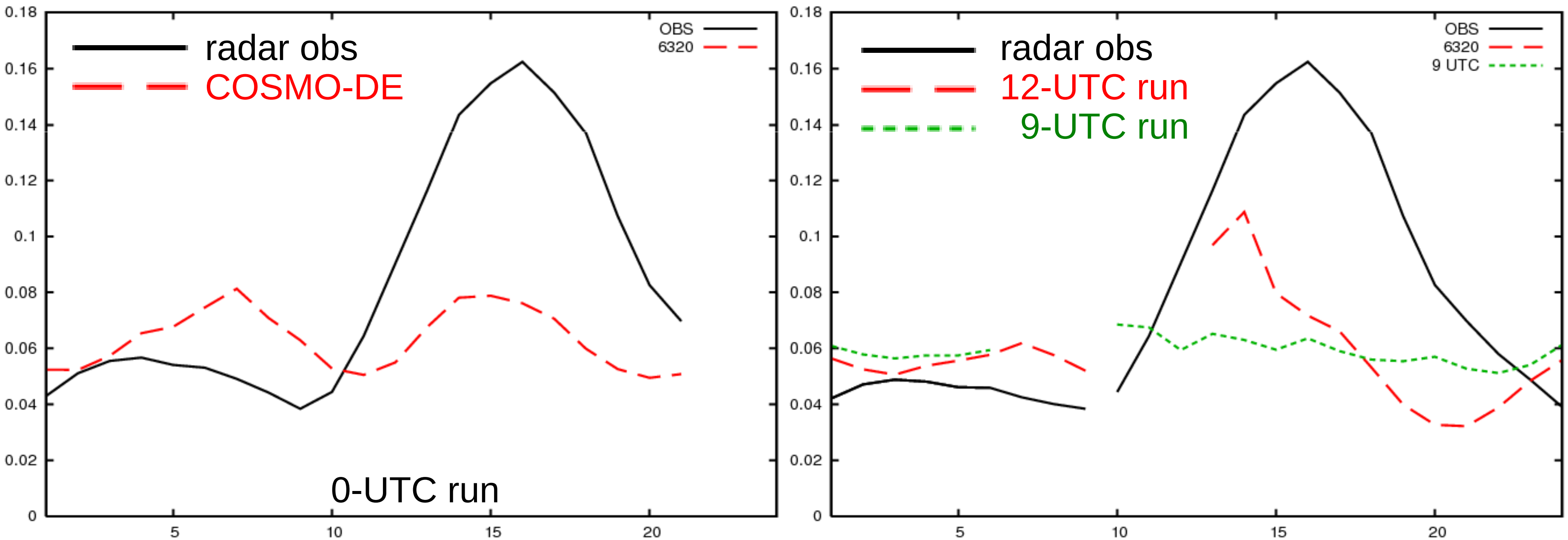
Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

all experiments by Klaus Stephan

Starting point:

convection-permitting COSMO version as operational in summer 2007
strongly underestimates diurnal cycle of precipitation
in convective conditions

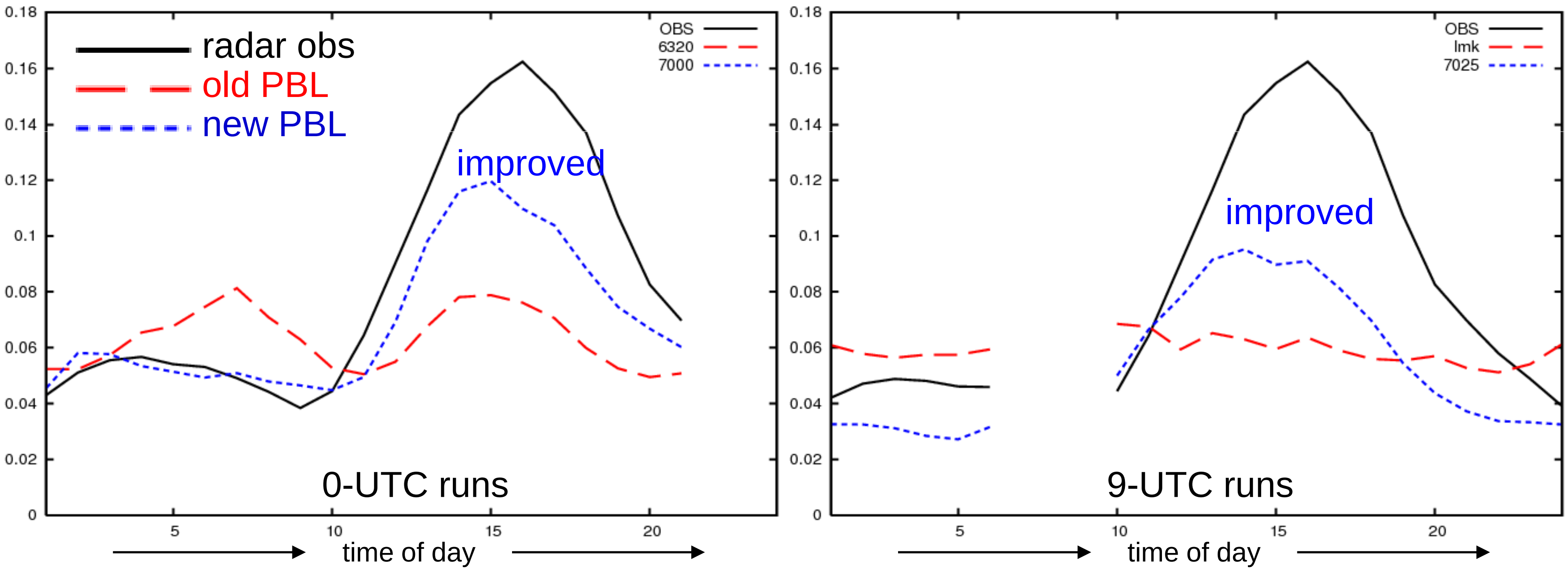
test period : 31 May – 13 June 2007: weak anticyclonic, warm and rather humid, rather frequent and strong air-mass convection



'diurnal cycle':
areal mean precip over radar domain

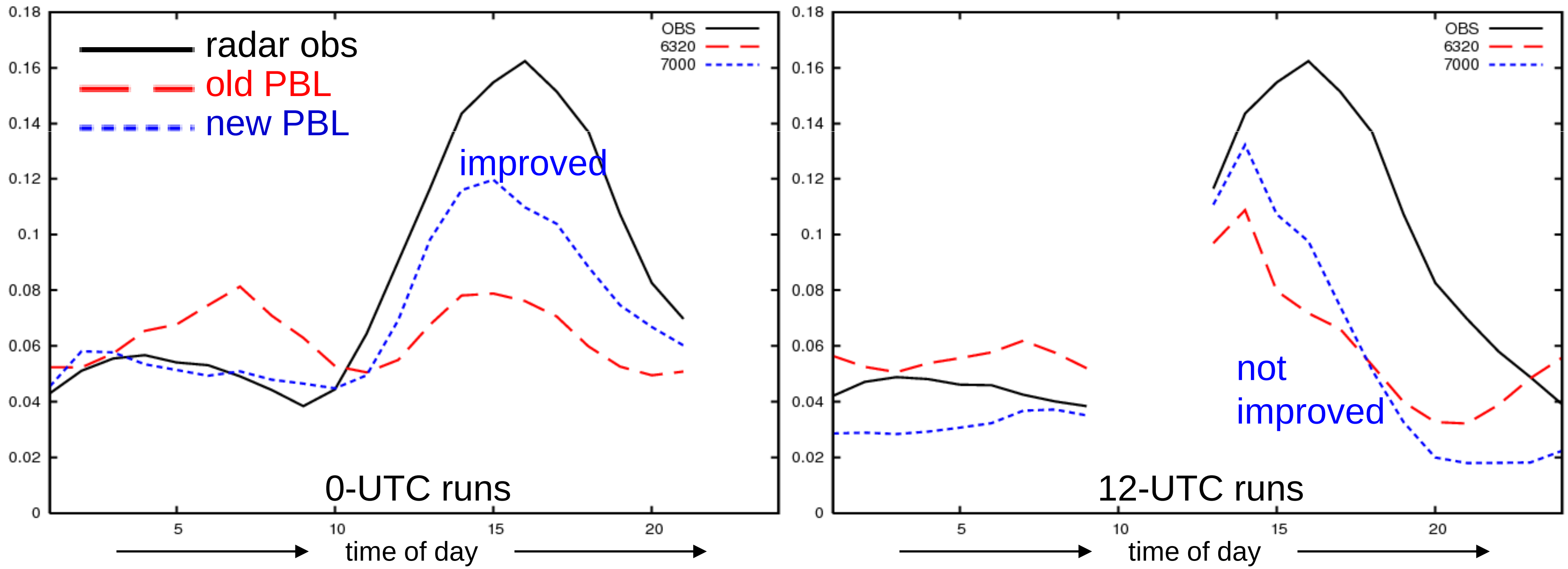
Model changes

- ‘old PBL’ : COSMO V4_0 , ‘original’ model version (operational in summer 2007)
- ‘new PBL’ : COSMO V4_8 , with reduced turbulent mixing (opr. summer 09):
  - reduced max. turbulent length scale (Blackadar length : 200 m → 60 m)
  - reduced sub-grid cloud fraction in moist turbulence



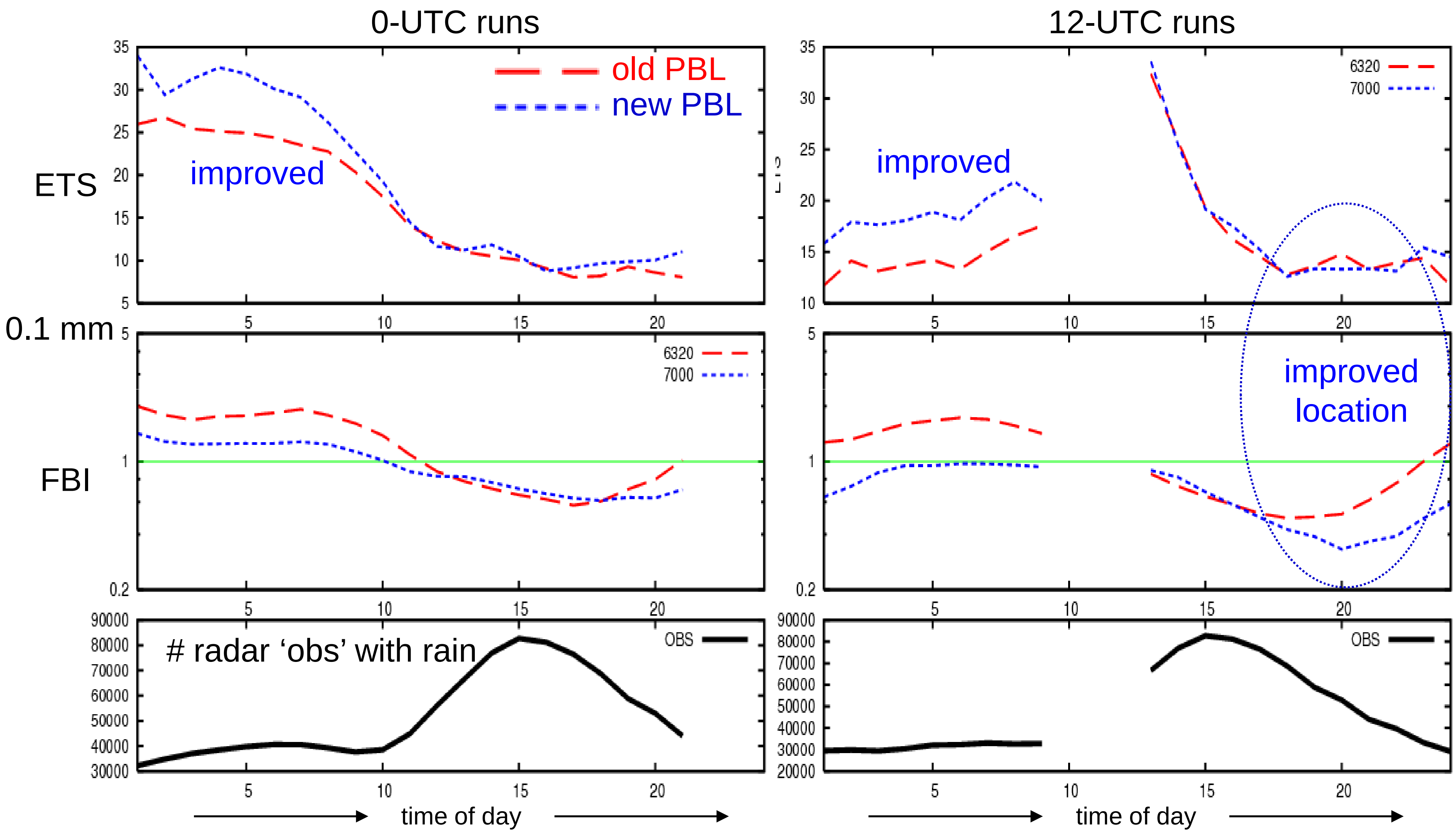
Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

‘new PBL’ : improves diurnal cycle of precip, except for first 12 hrs of 12-UTC runs



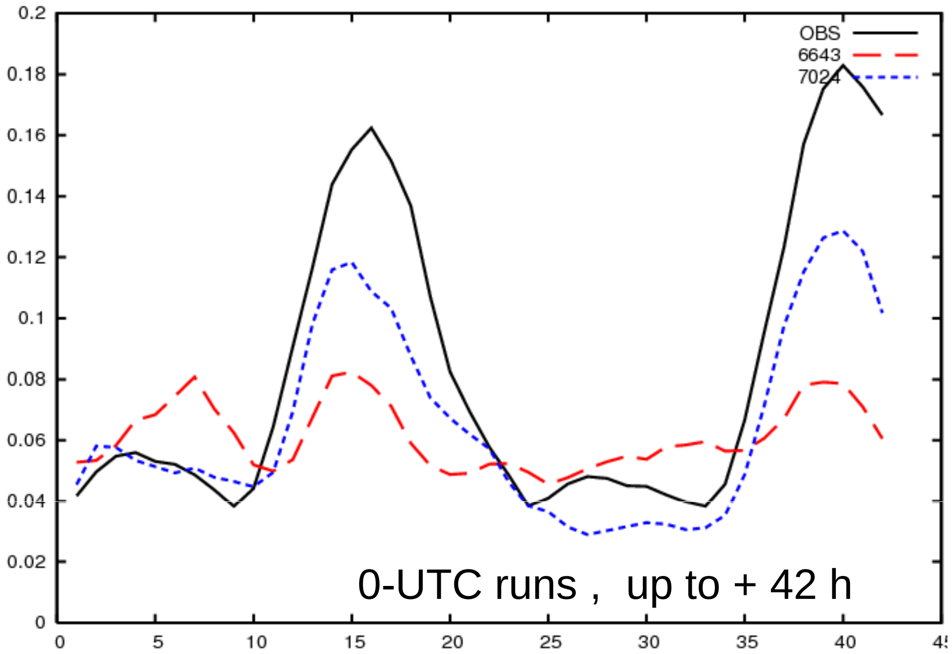
Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

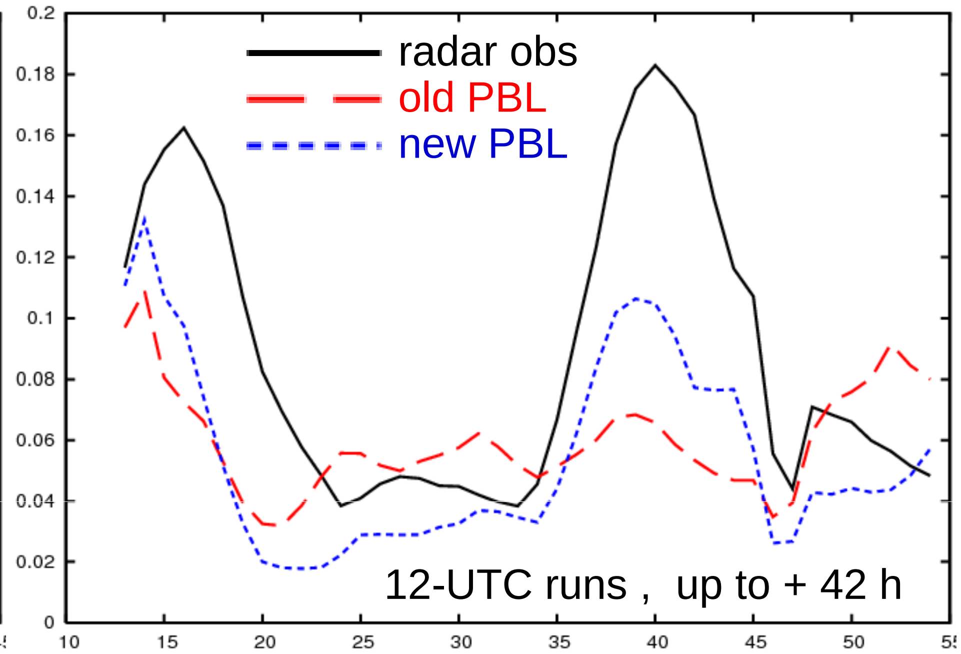
'new PBL' : improves scores mainly at night (both 0- and 12- UTC runs)
(spatial location also in the evening)



Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

42-hour forecasts: ‘new PBL’ greatly improves diurnal cycle of precip,
except for first 12 hours (incl. peak in afternoon) of 12-UTC runs





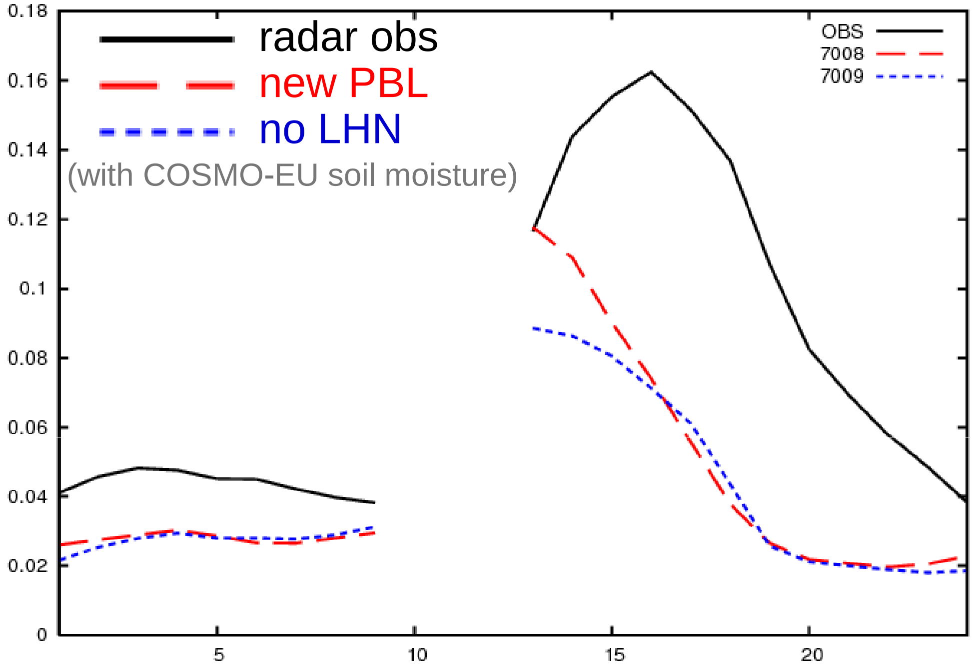
Possible reasons for problems with 12-UTC runs:

- Latent Heat Nudging ?
- radiosonde humidity (daytime RS92 dry bias) ?
- radiosonde / aircraft temperature ?
- other ?

Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

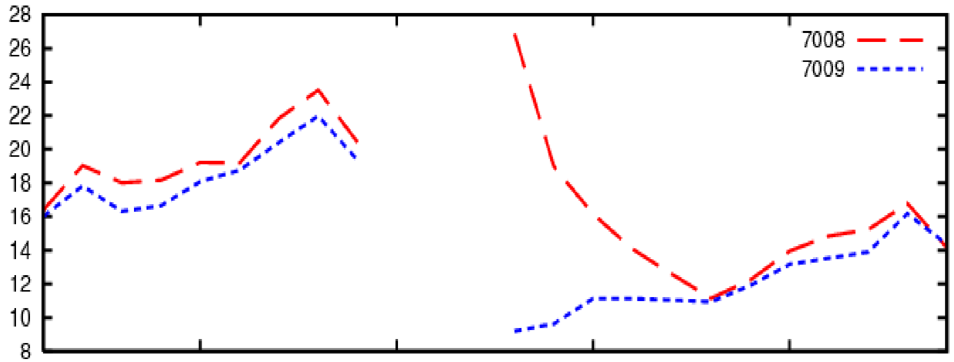
LHN : impact on diurnal cycle negligible
(improves scores mostly during first hours)

diurnal cycle



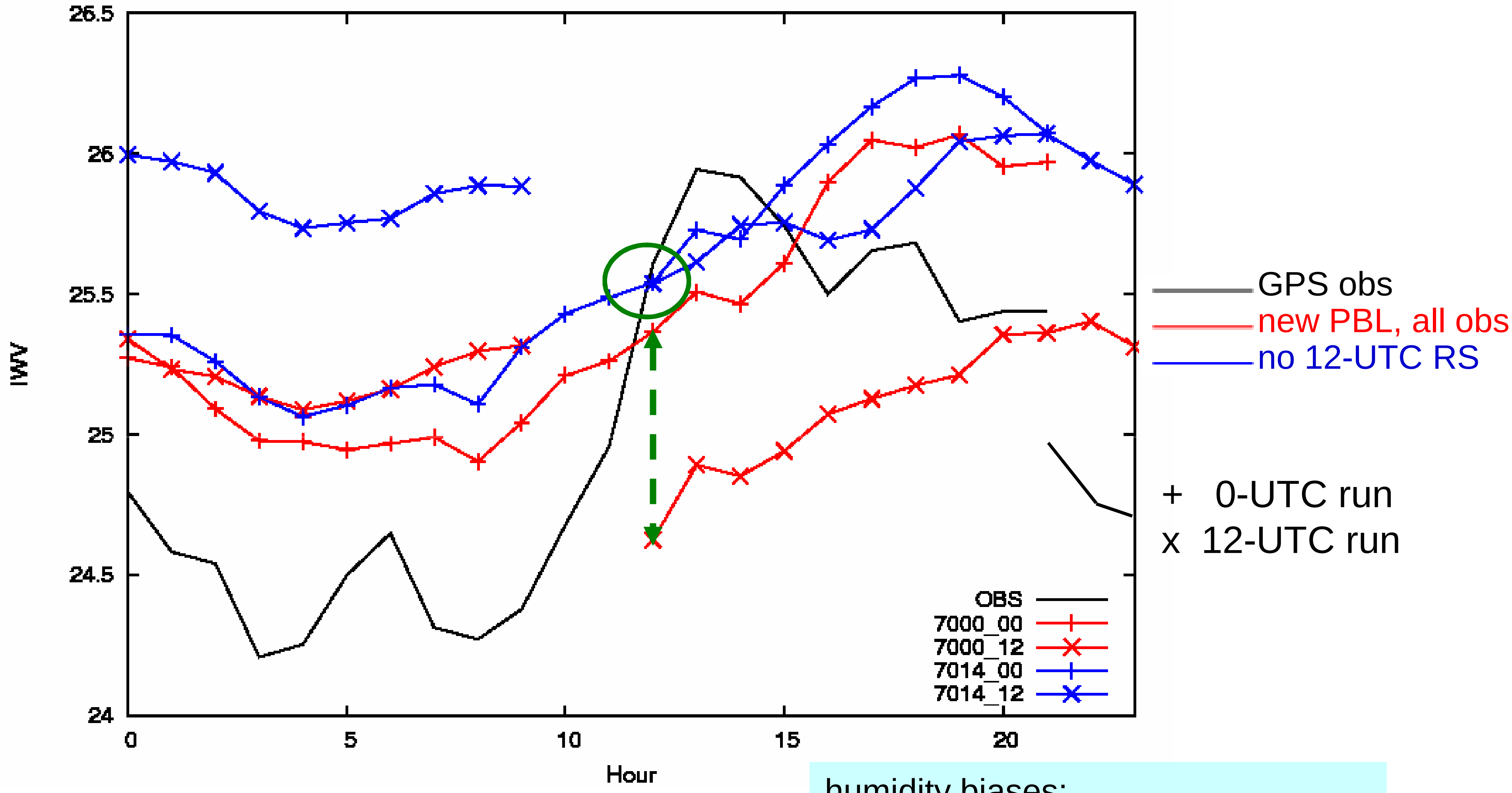
ETS

0.1 mm



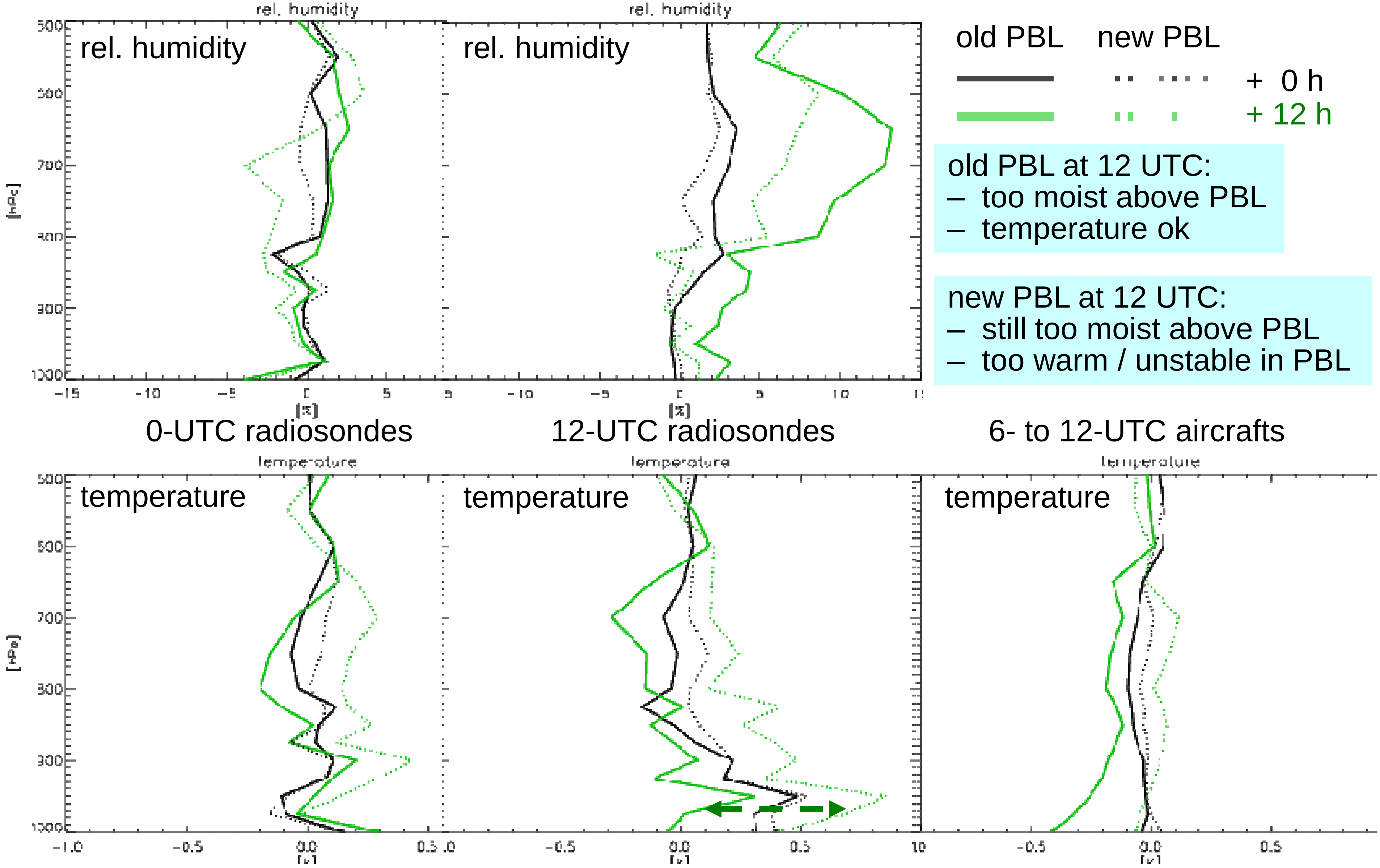
Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

integrated water vapour (at ~ 25 GPS stations near radiosonde stations)



humidity biases:
- daytime dry bias of Vaisala RS92
- moist bias of model

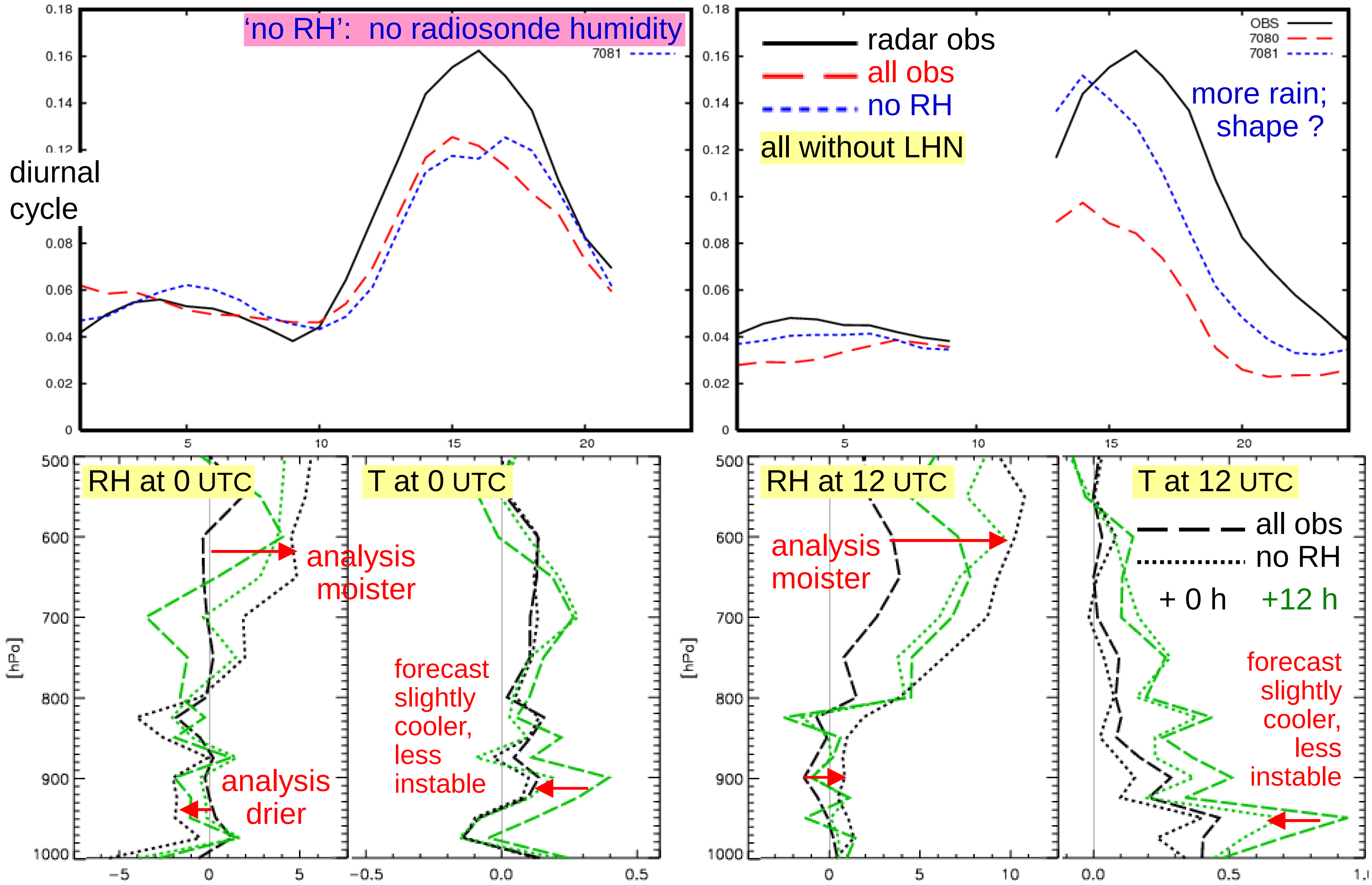
Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?



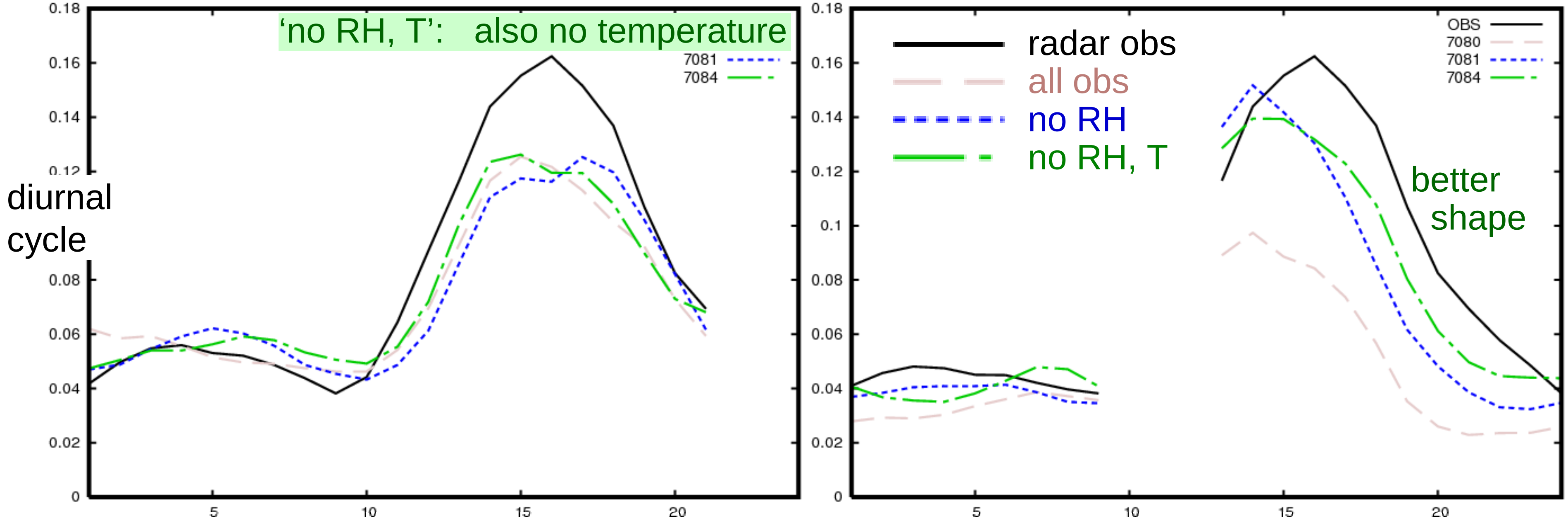
old PBL at 12 UTC:
– too moist above PBL
– temperature ok

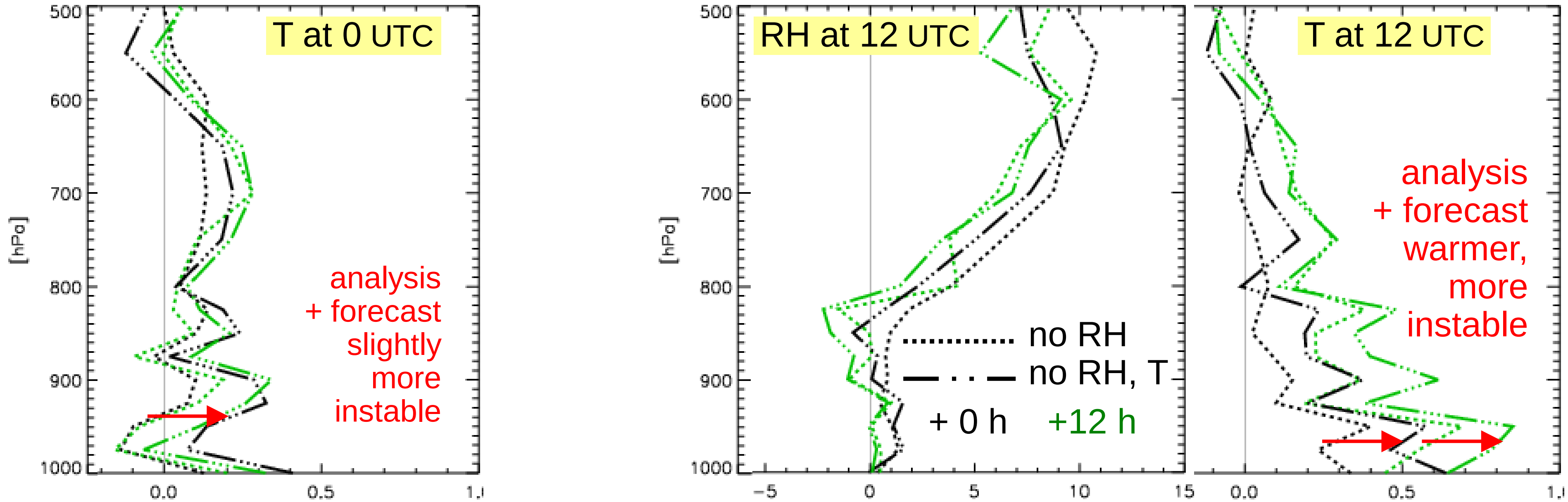
new PBL at 12 UTC:
– still too moist above PBL
– too warm / unstable in PBL

Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

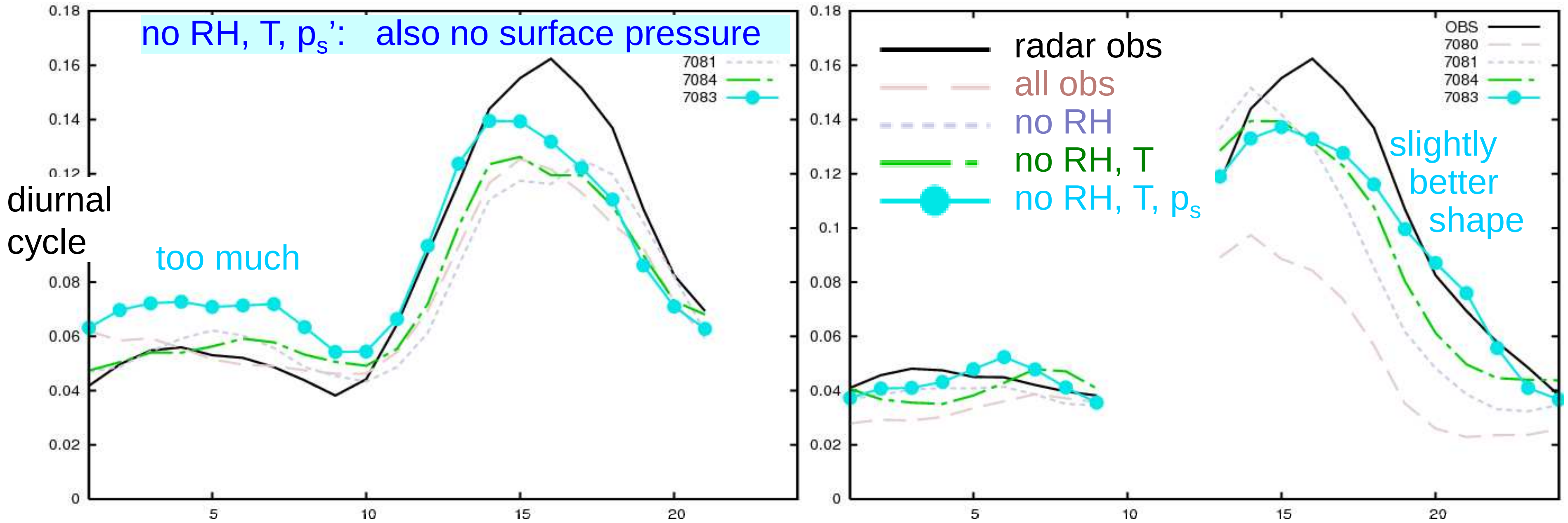


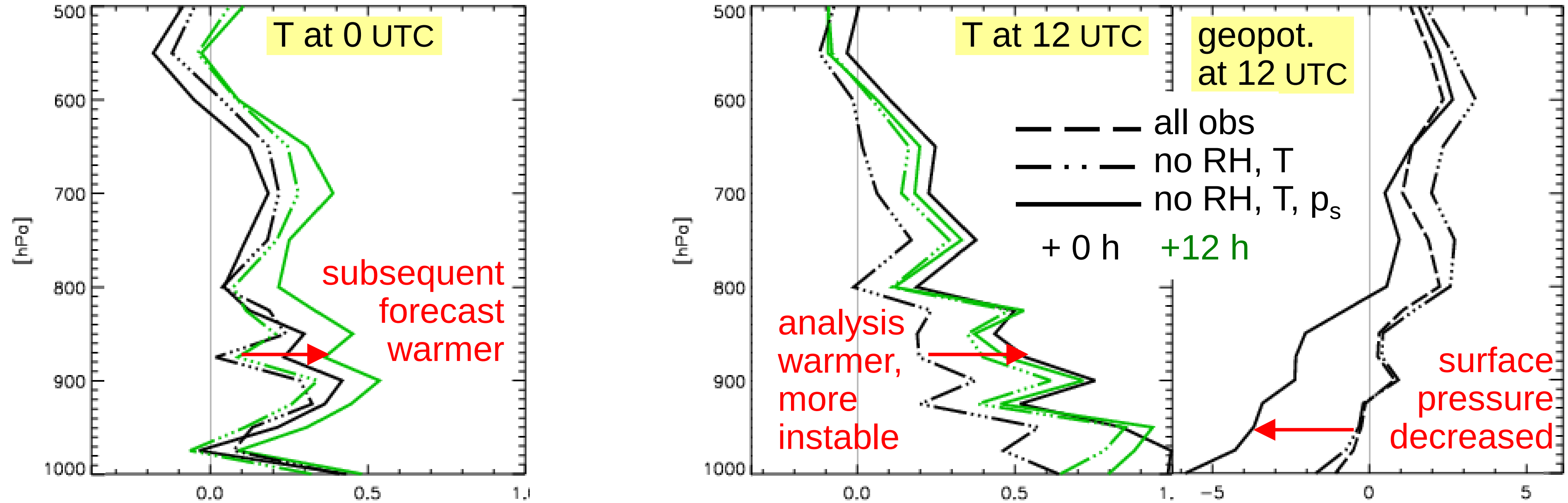
Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?



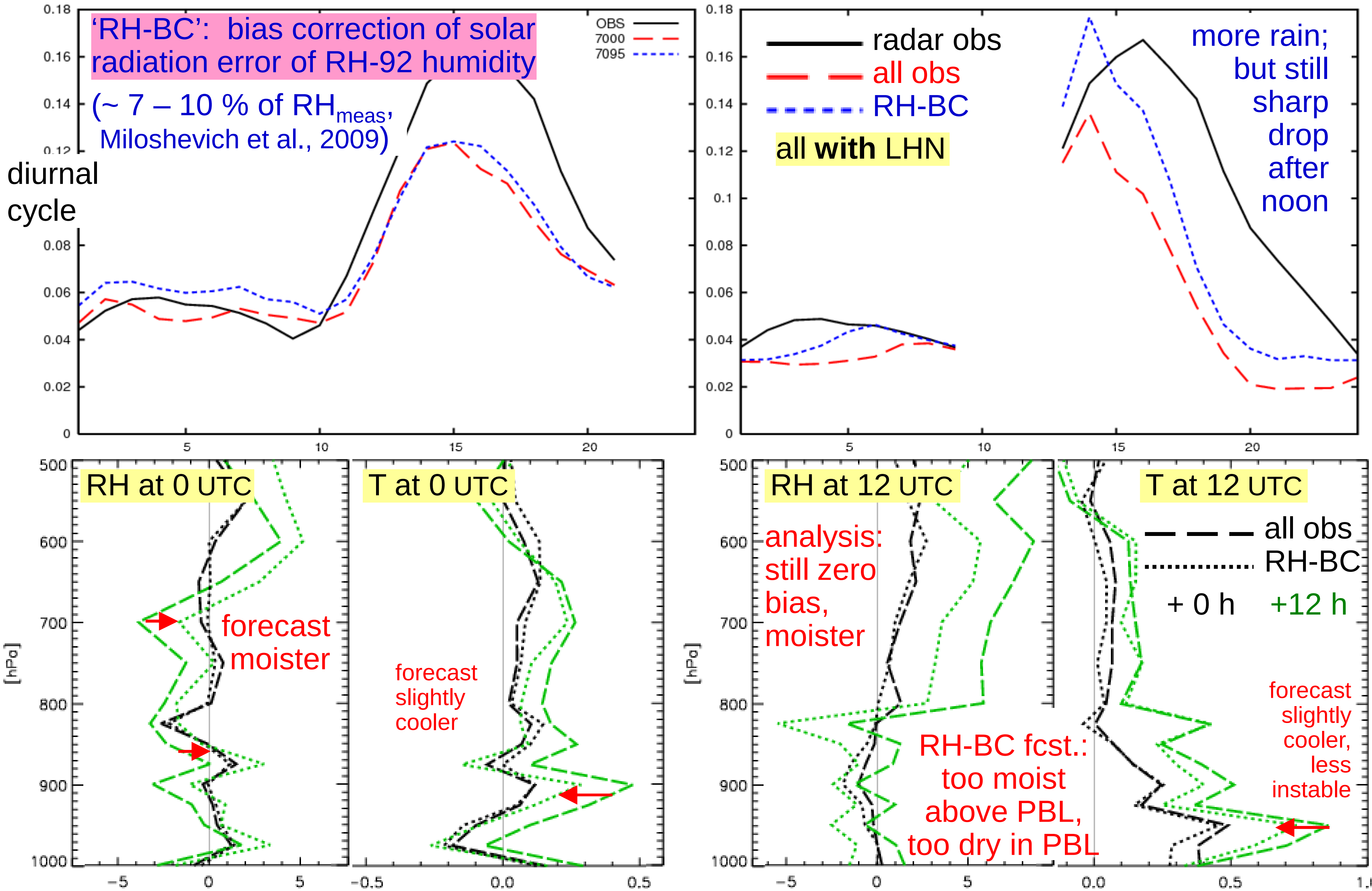


Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?





Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?



Summary

- obs biases
  – Vaisala RS92 : dry bias at daytime
  – aircraft : warm bias (mainly ascents, dep. on aircraft type)

- model biases:
  – old PBL:
    – diurnal cycle of precip far too weak, dep. on initial time of forecast
    – much too humid above PBL , little T-bias
  – new PBL:
    – much better diurnal cycle of precip (still too weak), except first 12 h of 12-UTC runs
    – still too humid above PBL
    – too warm and instable in low troposphere at daytime

- sensitivity tests done, impact on diurnal cycle of 12-UTC runs:
  – little impact of LHN on biases
  – no RS humidity: limited improvement, generally more rain
  – further improvement without temperature, surface pressure
  – RS92 humidity bias correction: limited improvement

Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

- need to test other periods.   If results confirmed:
- what to do with T-obs ?   – correct obs bias : aircraft-T (→ worse ?)
  - – adjust T-obs to model T-bias ? (→ hides model problems)
  - – omit daytime T-obs at low troposphere (up to which height ?)
    (→ loss of info)
- model biases: make the job for data assimilation very hard,
  will not get better with advanced DA methods that make stronger use of the NWP model (LETKF)

→ (should we investigate) reason for these model biases ?

- – insufficient resolution (to resolve convection) ?
  → invest in resolution ≤ 1 km ? (and vertical resolution ?)
- – parameterisations: could they still be improved at current resolution ?
  (also have biases in PBL in absence of convection (small dep. on resolution))

→ EWGLAM / SRNWP : do other convection-permitting model have similar problems ?

Thank you for your attention