WG1 Overview

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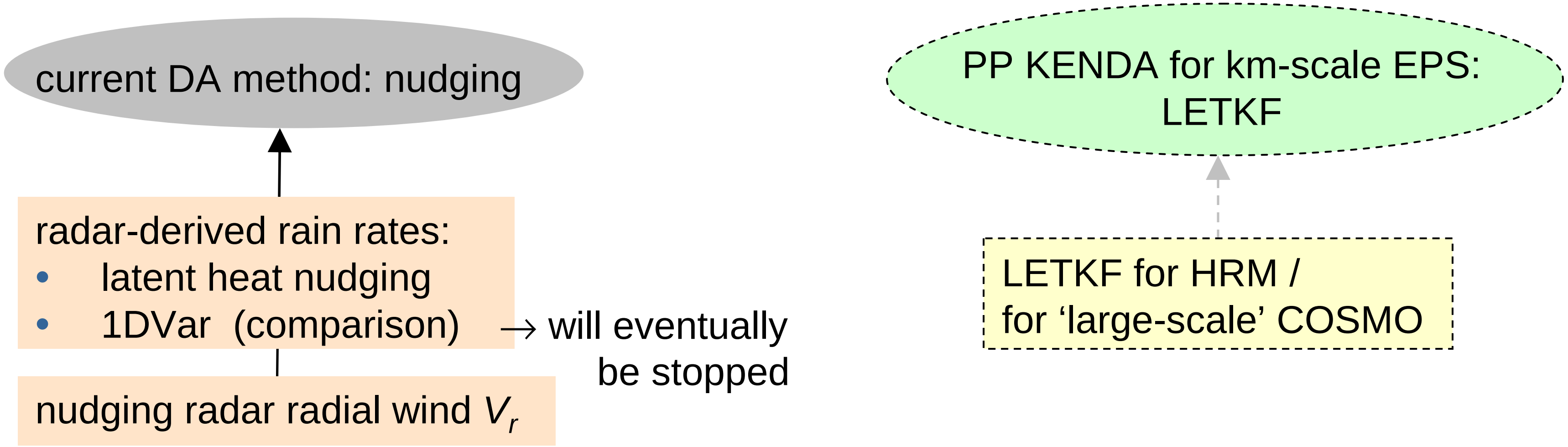


current DA method: nudging

radar-derived rain rates:
- latent heat nudging
- 1DVar (comparison)

→ will eventually be stopped

nudging radar radial wind V_r

PP KENDA for km-scale EPS: LETKF

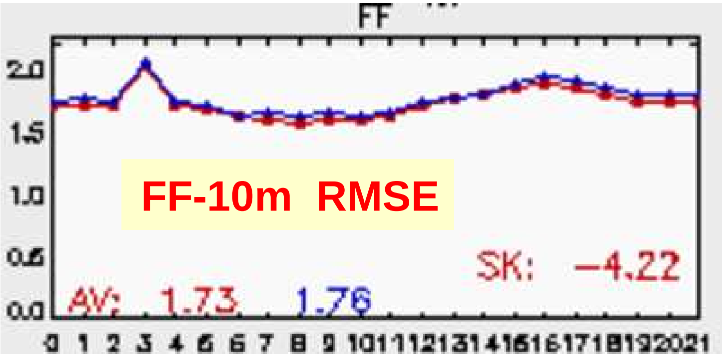
LETKF for HRM / for ‘large-scale’ COSMO

nudging of radar radial velocity ...
... a side-step to verification

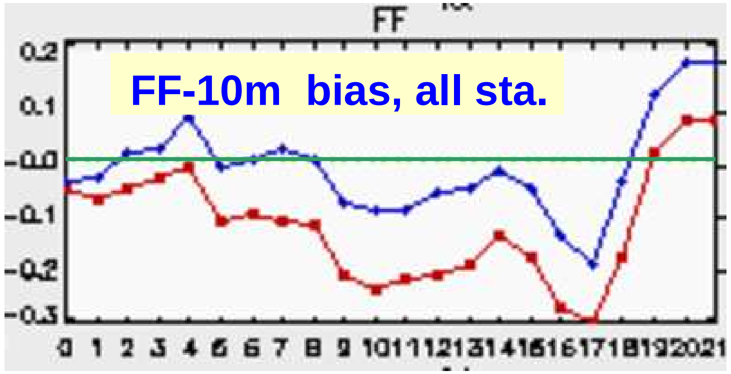
0-UTC runs

control

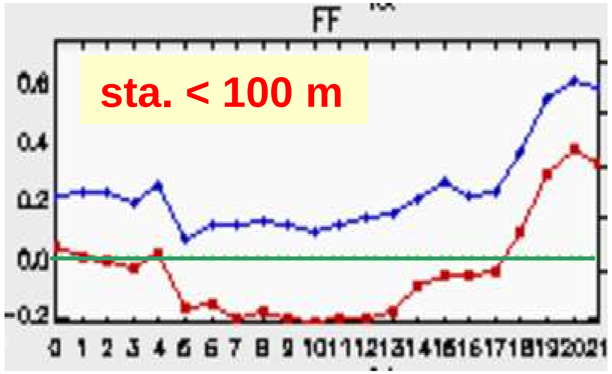
nudge vr



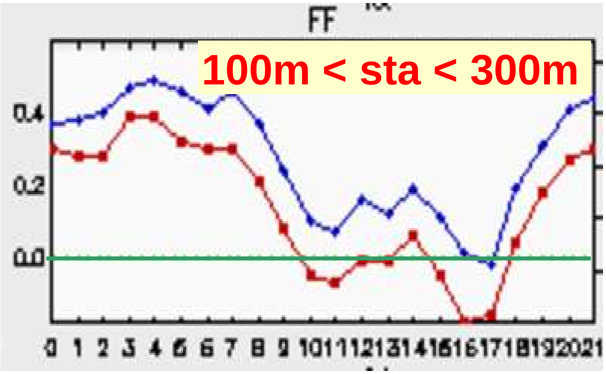
FF-10m RMSE



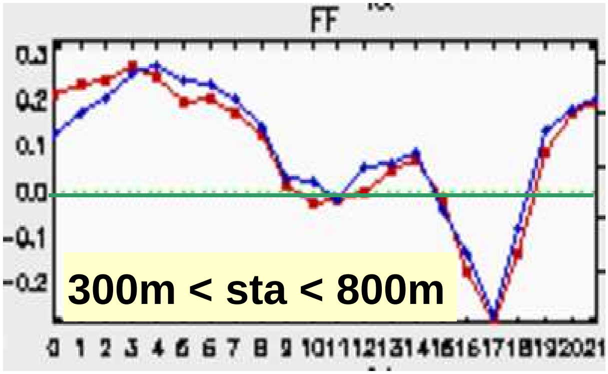
FF-10m bias, all sta.



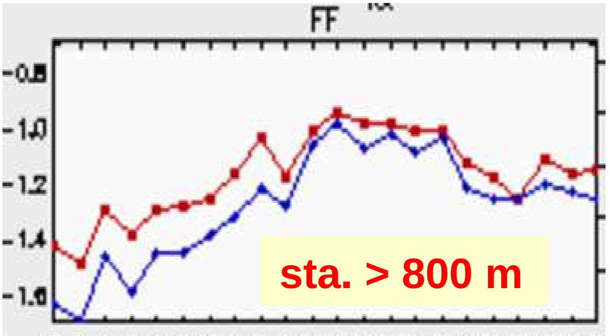
sta. < 100 m



100m < sta < 300m



300m < sta < 800m



sta. > 800 m

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current DA method: nudging

radar-derived rain rates:
- latent heat nudging
- 1DVar (comparison)

nudging radar radial wind V_r

GPS-IWV (ceased)

screen-level:
- scatterometer wind (OSCAT, OceanSat2)
- improved T2m, Q2m assimilation, adapt T_soil, SM

quality control of surface pressure:
new check against fields providing lateral BC

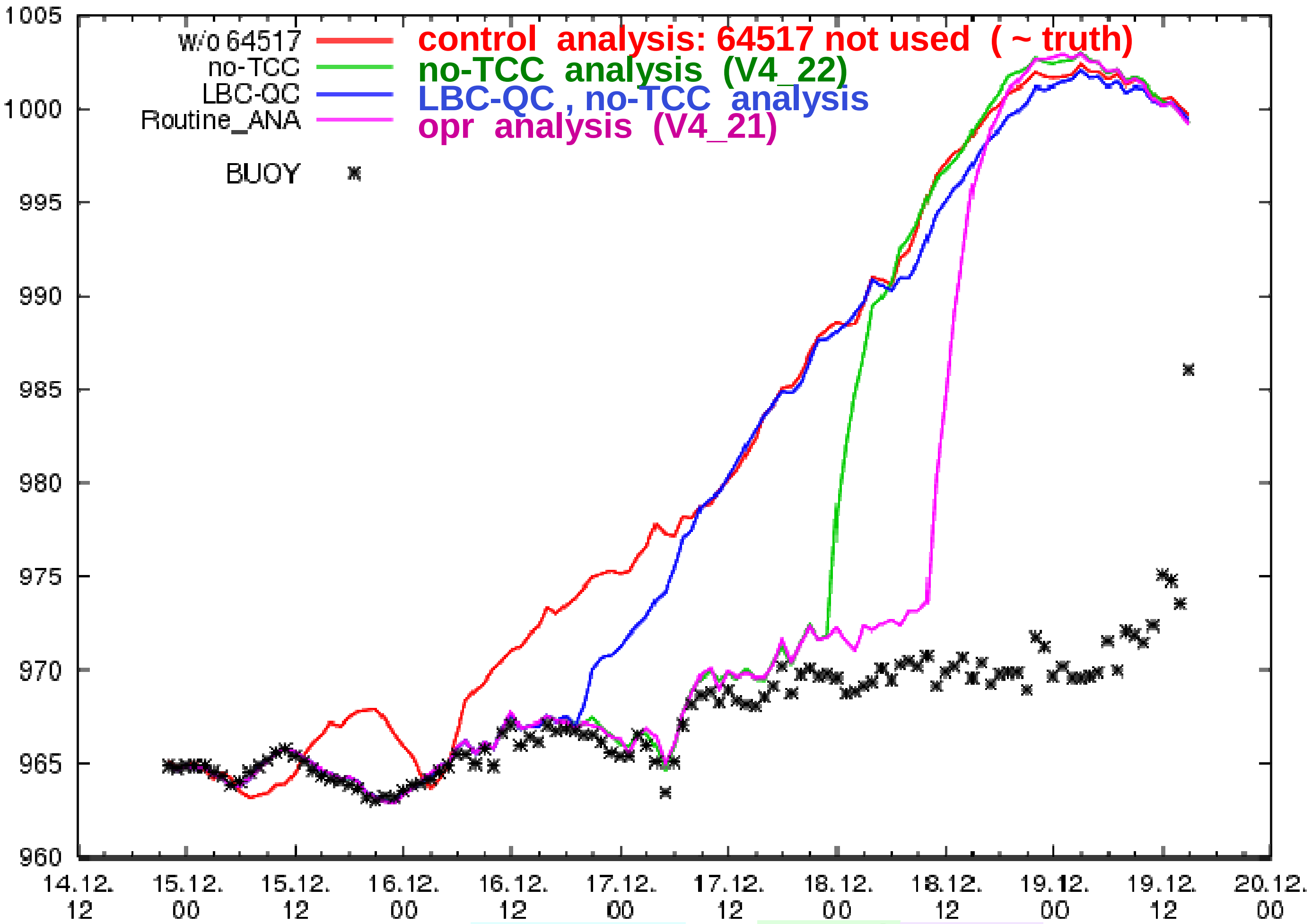
PP KENDA for km-scale EPS:
LETKF

LETKF for HRM /
for 'large-scale' COSMO

quality control of surface pressure p_s :
case 2 : 15 - 19 Dec. 2011

surface pressure

(at the location of buoy 64517)



LBC-QC rej.
16 Dec
20 UTC

SCC rej.
18 Dec
0 UTC

SCC rej.
19 Dec
10 UTC

Status Overview on PP KENDA
Km-scale ENsemble-based Data Assimilation

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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Contributions / input by:

Hendrik Reich, Andreas Rhodin, Roland Potthast, Uli Blahak, Klaus Stephan, Africa Perianez, Michael Bender (DWD)

Annika Schomburg (DWD / Eumetat)

Yuefei Zeng, Dorit Epperlein (KIT Karlsruhe)

Daniel Leuenberger (MeteoSwiss)

Mikhail Tsyrulnikov, Vadim Gorin, Igor Mamay (HMC)

Lucio Torrisi (CNMCA)

Amalia Iriza (NMA)

- Task 1: General issues in the convective scale (e.g. non-Gaussianity)
- Task 2: Technical implementation of an ensemble DA framework / LETKF
- Task 3: Tackling major scientific issues, tuning, comparison with nudging
- Task 4: Inclusion of additional observations in LETKF

SMC: LETKF: implementation

- modifications in COSMO in official code (V4_24)
  (e.g. in order to have a sub-hourly update frequency)

- **COSMO-DE LETKF implemented in NUMEX** and tested
  (e.g. stand-alone 2-day experiment reproduced)

- **GME-LETKF & ensemble INT2LM for DA cycle implemented in NUMEX,**
  being tested, should be available end of Sept.

→ in Oct., start first KENDA experiments in NUMEX over several days/weeks

but:
- direct interpolation from 60 km to 2.8 km !
- deterministic analysis not yet implemented in NUMEX

- ensemble LBC 2013 – 2014 :
  ensemble perturbations of interpolated ensemble GME fields,
  added to deterministic COSMO-DE LBC

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LETKF :
implementation / activities

- in past year, still only preliminary LETKF experiments possible, using Hendrik's scripts:
  - up to 2 days (7 – 8 Aug. 2009: quiet + convective day)
    → 3-hourly (15-min) cycles
  - 32 ensemble members
  - perturbed LBC: COSMO-SREPS, 3 * 4 members

→ therefore
  - theoretical studies, toy model experiments related to adaptive localisation
    → talk by Hendrik Reich
  - benchmark , winter school on DA , support for HErZ centre ,
    testing (e.g. NUMEX) …
  - only few COSMO-DE experiments related to adaptive localisation

LETKF :
implementation of verification

- **tool for production of ‘full’ NetCDF feedback files**
  - make clean interfaces to observation operators / QC in COSMO : done
  - … integrate them into 3DVAR package : in progress
  - and extend flow control (read correct (hourly) Grib files etc.) : to be done

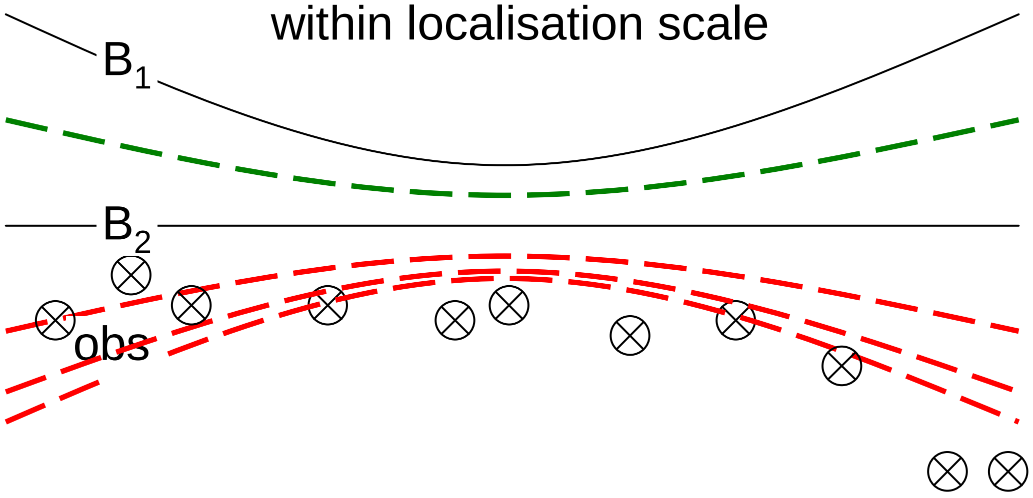
  should be ready by end of 2012 (for VERSUS)

- **ensemble-related diagnostic + verification tool**, using feedback files : (Iriza, NMA)
  - → computes statistical scores for different runs (‘experiments’),
  - → focus: use exactly the same observation set in each experiment !
    - → select obs according to namelist values (area, quality + status of obs, …)
  - implementing ensemble scores (reliability, ROC, Brier Skill Score, (continuous) Ranked Probability Score)
  - main part of documentation written

LETKF (km-scale COSMO) : scientific issues / refinement

- adaptive estimation of obs error covariance $\mathbf{R}$

  (Li, Kalnay, Miyoshi, QJRMS 2009) , but our implementation: in ensemble space !



f.g. mean = $0.5\ B_1 + 0.5\ B_2$

ana $\cong$ f.g.mean + $(B_2 - B_1)$
= $1.5\ B_2 - 0.5\ B_1$
(1 perfect obs)

2 obs → least square fit

add obs, if already $N_{obs} > N_{ens}$:

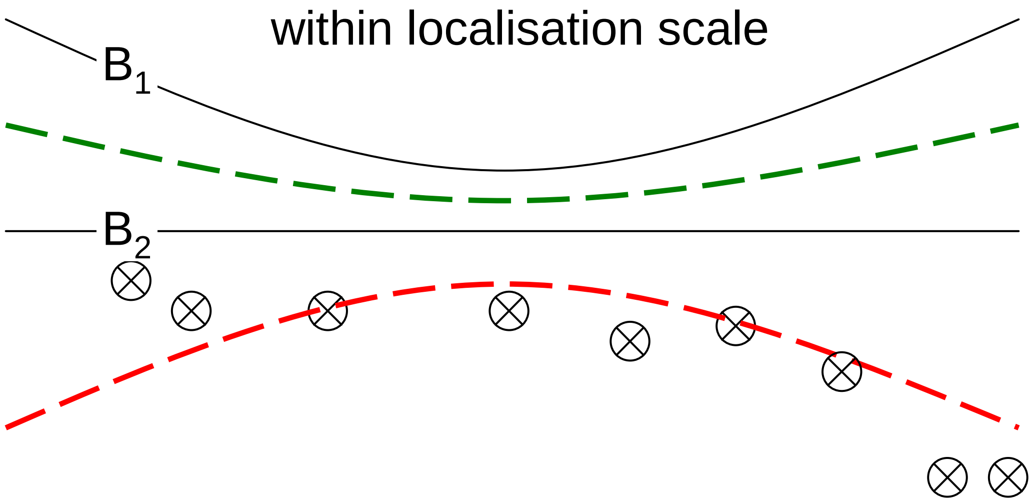
- cannot be fitted well, improve analysis only slightly
- decrease analysis error !

$$\mathbf{P}_w^{\,a} = \left[(k-1)\,\mathbf{I} + \left(\mathbf{Y}^b\right)^T \mathbf{R}^{-1}\mathbf{Y}^b\right]^{-1}$$

→ adaptive $\mathbf{R}$ takes that into account and increases $\mathbf{R}$

LETKF (km-scale COSMO) : scientific issues / refinement

however: large N_{obs} : adaptive increase of $\mathbf{R}$ indicates non-optimal use of obs



f.g. mean = 0.5 B_1 + 0.5 B_2

$N_{obs} > N_{ens}$ → least square fit

→ localisation !

→ see also Hendrik's talk !

(or data selection / superobbing ?)

→ basic idea for adaptive localisation : keep N_{obs} constant (> N_{ens} , not >> N_{ens}) !

LETKF, preliminary results: horizontal localisation

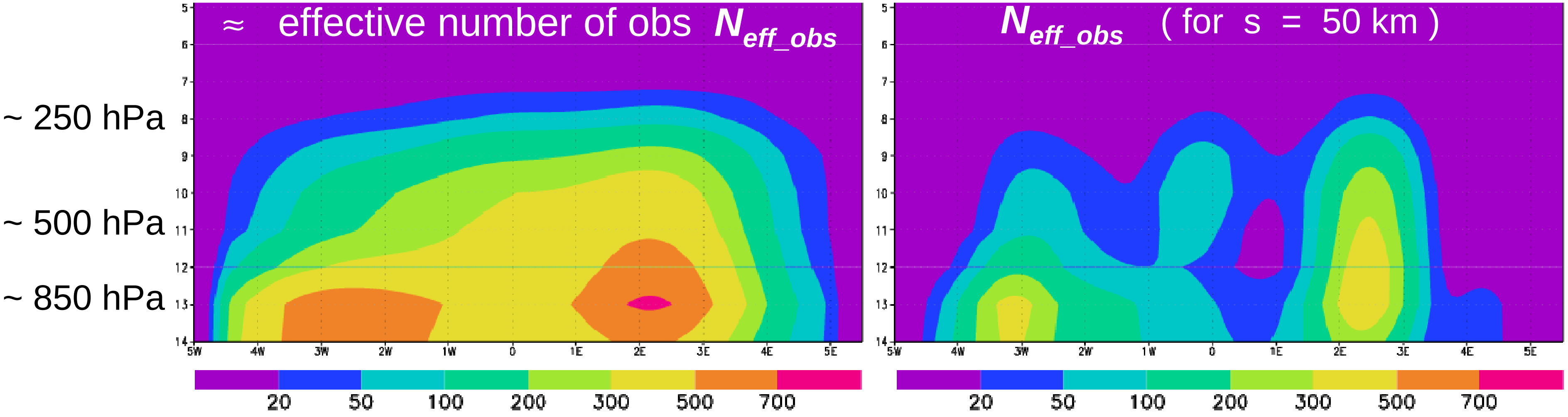
Caspari-Cohn function: scale $s = 100$ km → reduce scale : $s = 50$ km

→ 0.4 at $r \cong (2)^{\frac{1}{2}} \cdot s \cong$ 141 km

→ 0 at $r = 2 \cdot (10/3)^{\frac{1}{2}} \cdot s \cong$ 365 km

vertical cross section
(at rot lat = 2° , 8 Aug 2009 , 12 UTC)

sum of localisation weights of obs



≈ effective number of obs N_{eff_obs}

N_{eff_obs} (for $s = 50$ km)

→ $N_{eff\_obs} >> N_{ens}$

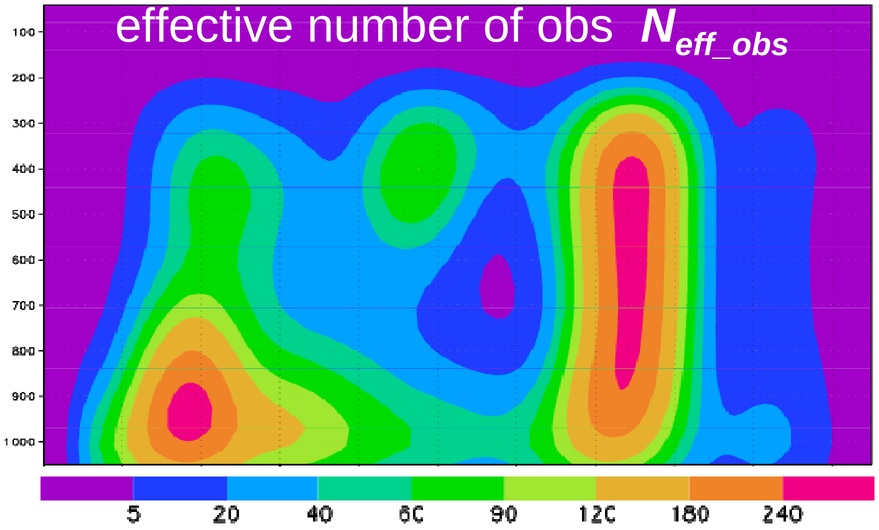
→ too few degrees of freedom in order to fit the observations

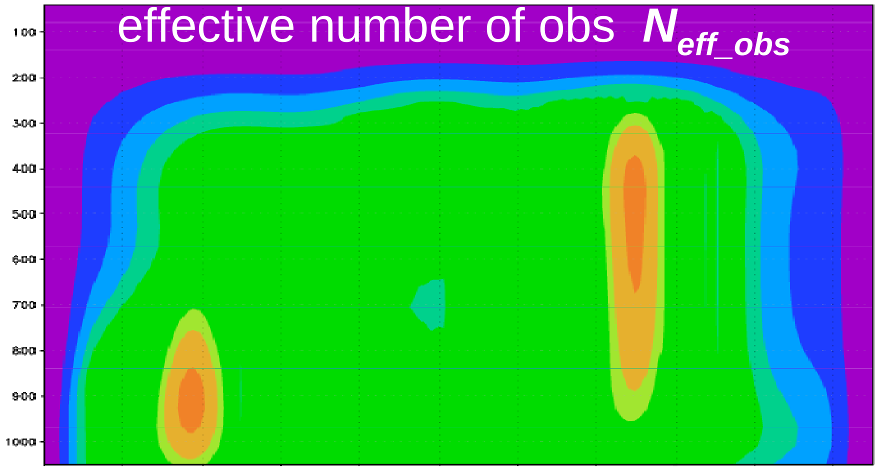
LETKF, preliminary results: adaptive horizontal localisation

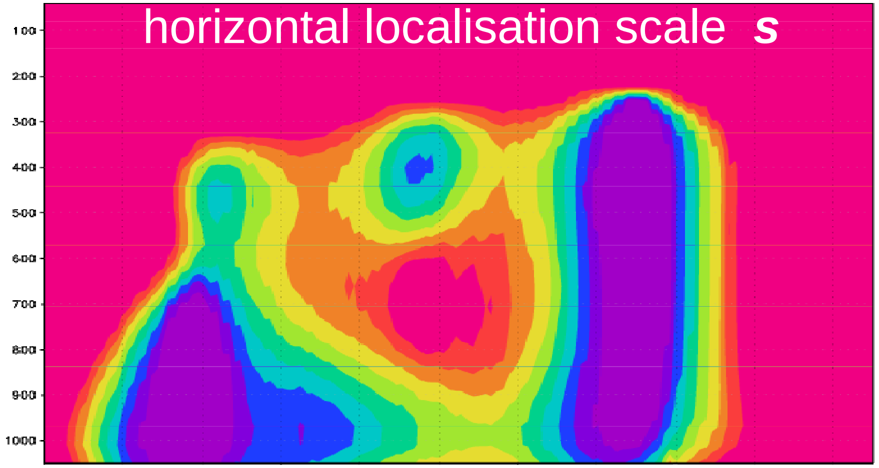
Caspari-Cohn function: scale $s = 50$ km → adaptive scale s :

adapt s such that $N_{eff\_obs} \cong 70$
and $30 \text{ km} \leq s \leq 80 \text{ km}$

vertical cross section
(at rot lat = 2°, 8 Aug 2009 , 12 UTC)





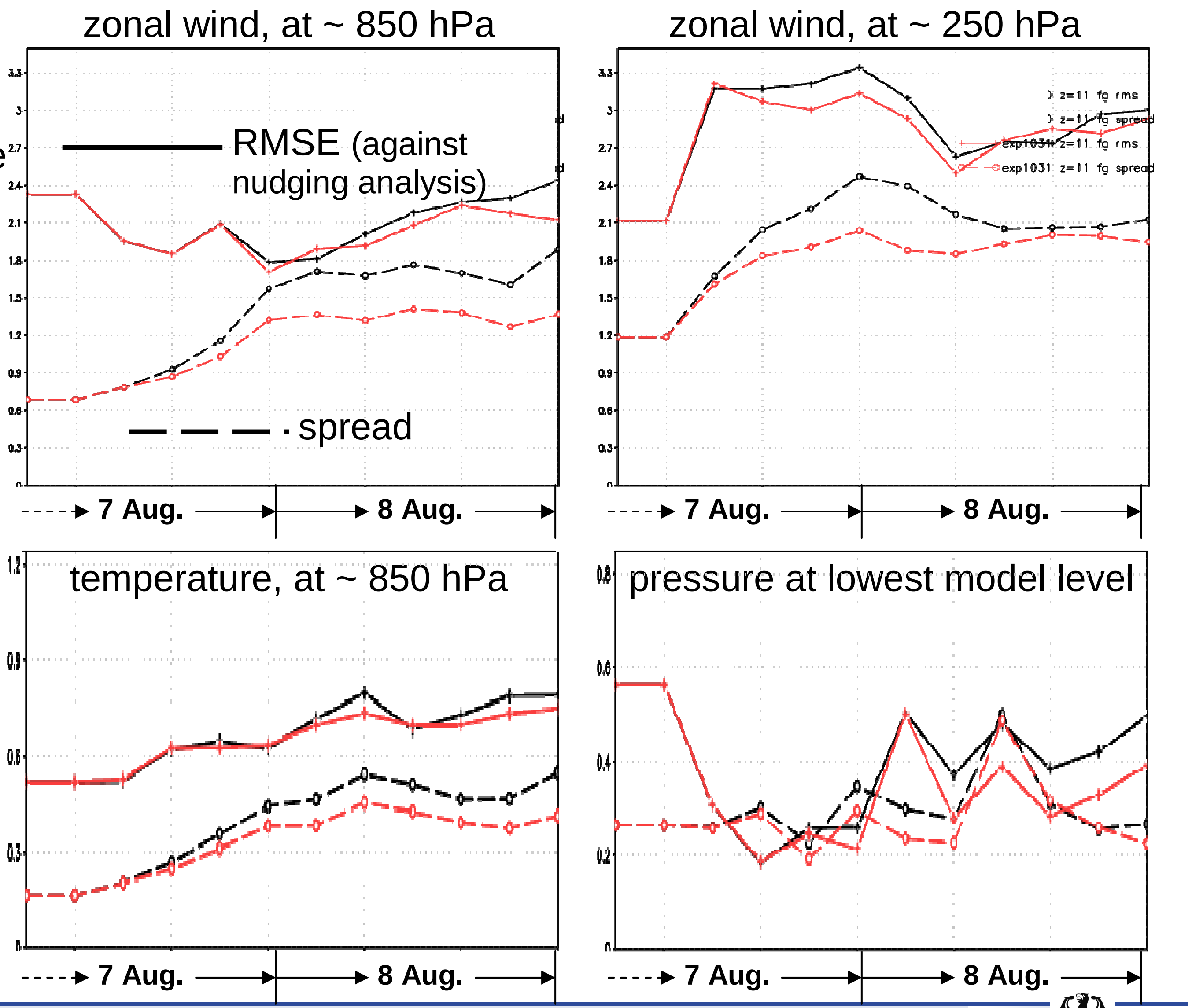


scale s ·· $(10/3)^{½}$

LETKF, preliminary results: adaptive horizontal localisation

first guess mean
(inner domain average)

(variable vertical localisation, adaptive **R** and multiplicative covariance inflation ρ)


zonal wind, at ~ 850 hPa

zonal wind, at ~ 250 hPa

temperature, at ~ 850 hPa

pressure at lowest model level

RMSE (against nudging analysis)

spread

s = 50 km
adaptive *s*

→ smaller spread

→ mostly smaller RMSE

(mixed results in verif vs. upper-air obs (T pos., wind neg.))

LETKF:
account of model error / additive inflation

- **parameterisation of model error using statistics** (Tsyrulnikov, Gorin) :
  - parameterisation: $\underline{e = \mu * F_{phys}(\mathbf{x}) + e_{add}}$
  - estimate parameters by fitting to statistics from forecast ***tendency*** and observation ***tendency*** data (using a maximum likelihood based method)

failed in OSSE setup with simulated ME for finite-time 1 – 6 hr tendencies !!!

main methodological cause of failure : instantaneous ME is contaminated in ***finite-time*** tendencies by other tendency errors :

- trajectory drift as a result of ME themselves
- initial errors (plus the trajectory drift due to initial errors)

→ conclusion: observation accuracy and spatio-temporal coverage far from being sufficient to reliably estimate ME !

→ task is stopped !

LETKF:
account of model error / additive inflation

→ new task for a **pattern generator** (PG)

purely stochastic tool to generate 4-D pseudo-random fields with selectable scales / ampl.,
used to generate additive perturbations / for stochastic physics
(~ 0.4 FTE / y)

- **stochastic physics**: perturbing total physics tendency by a random factor
at any given grid point (Palmer et al., 2009) (Torrisi)
  - modified Buizza version running
    → tuning required
  - perturb all physics tendencies in same way ?

→ 2013 Ekaterina Machulskaya from SFP for (more physically based) stochastic physics !
+ 1 N.N. (renewable energy project)

- additional additive inflation: - by scaled forecast differences (e.g. Bonavita et al.) ?
- 3DVAR – B ?

KENDA: use of additional observations
use of radar obs

- **radar : assimilate 3-D radial velocity and 3-D reflectivity directly**

1. observation operators implemented
   (Uli Blahak (DWD), Yuefei Zeng, Dorit Epperlein (PhD, KIT))
   - full, sophisticated
   - efficient (e.g. lookup tables for Mie scattering)
   - tested for sufficiently accurate and efficient approximations for DA

2. assimilation experiments
   - technical work finished this week
   - 1 - 2 assimilation case studies (Zeng)
   - 2013: Klaus Stephan : test periods, tuning …

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Task 4.3: use of GNSS slant path delay

- **ground-based GNSS slant path delay SPD**
  - produce & use tomographic refractivity profiles (Erdem Altunac, PhD)
  - implement non-local SPD obs operator & use SPD (Michael Bender)

    - first implement SPD obs operator in 3DVAR package
      (environment for work on tomography)
      - implement simple operator (refractivity along straight line)
      - implement complex obs operator with ray tracer
      - monitoring, test e.g. impact of straight line approximation
    - then implement obs operator in COSMO (in 2013)

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Task 4.4: use of cloud info

- **cloud information based on satellite and conventional data**

1. derive incomplete analysis of cloud top + base height, using conventional obs (synop, radiosonde, ceilometer) and NWC-SAF cloud products from SEVIRI

   use cloud top height info in LETKF

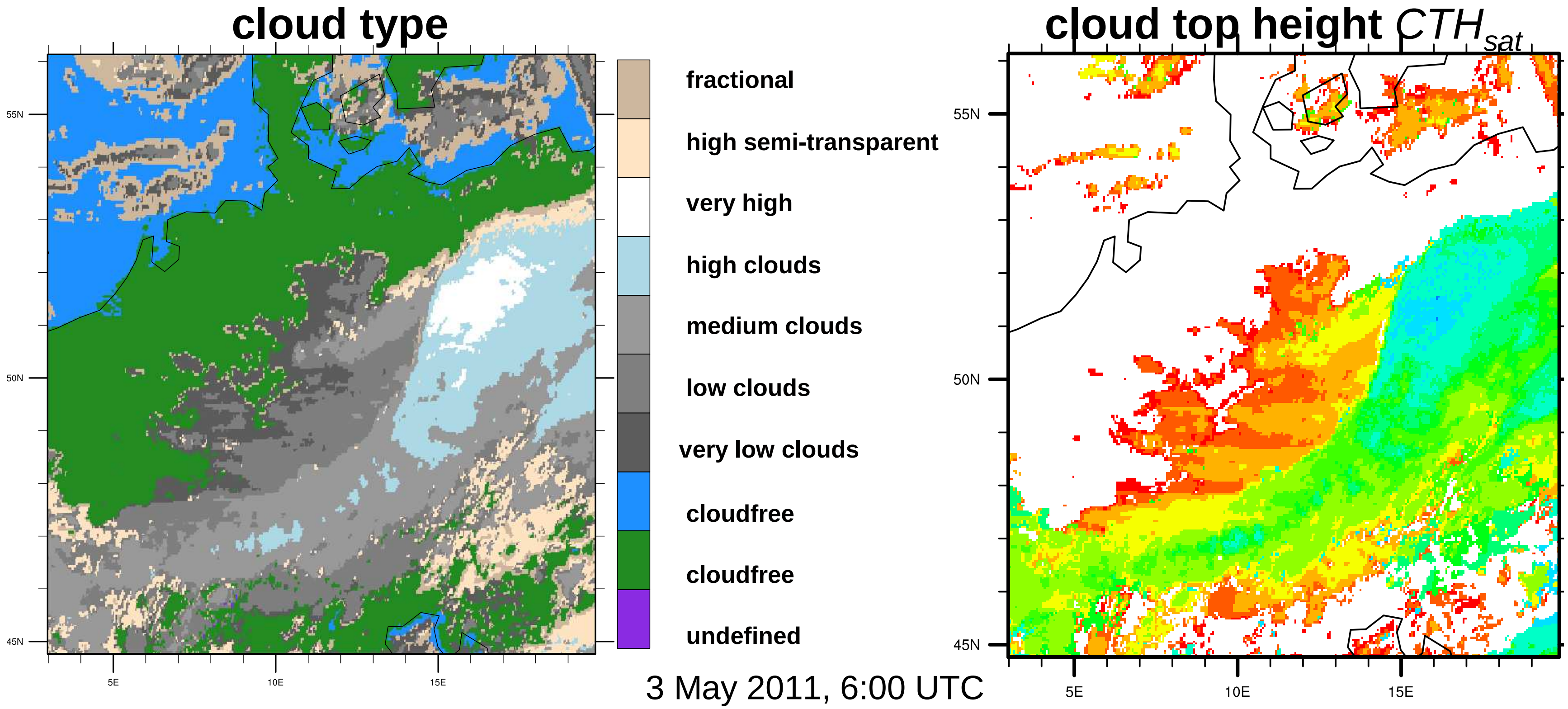
   (Annika Schomburg , DWD / Eumetsat)

2. use SEVIRI brightness temperature directly in LETKF in cloudy (+ cloud-free) conditions, in view of improving the horizontal distribution of cloud and the height of its top (2013: Africa Perianez, Annika Schomburg)

→ compare approaches

Particular issues: non-linear observation operators,
non-Gaussian distribution of observation increments

use of cloud info :
NWCSAF cloud products (SEVIRI/MSG)



cloud type **cloud top height CTH_{sat}**

3 May 2011, 6:00 UTC

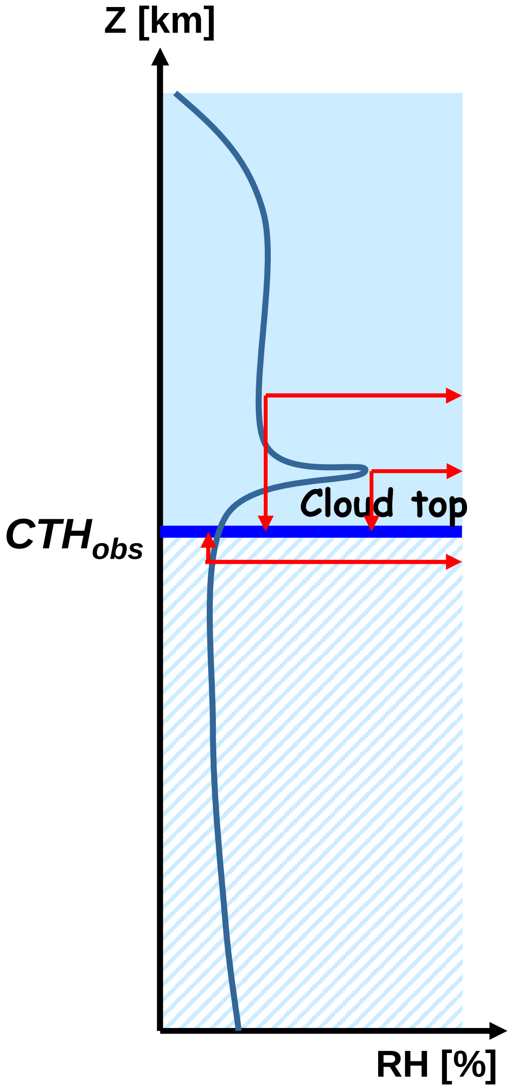
retrieval algorithm needs temperature and humidity profile from a NWP model

→ cloud top height CTH_{sat} wrong if temperature profile in NWP model wrong !

→ combine good horizontal resolution of satellite info
with good vertical resolution of radiosonde info :

use nearby radiosondes with same cloud type to correct CTH_{sat}

use of cloud info :
assimilation of ‘cloud analysis’



if cloud observed with cloud top height CTH_{obs} ,
what is the appropriate type of obs increment ?

- avoid too strong penalizing of members with high humidity but no cloud
- avoid strong penalizing of members which are dry at CTH_{obs} but have a cloud or even only high humidity close to CTH_{obs}

→ search in a vertical range Δh_{max} around CTH_{obs} for a ‘best fitting’ model level k, i.e. with minimum ‘distance’ d:

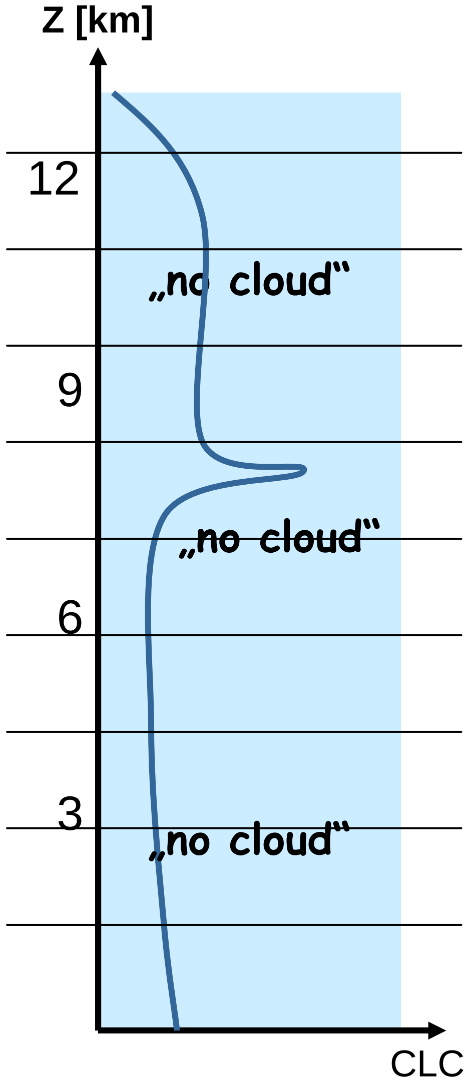
$$\boxed{d = \min_k \sqrt{(f(RH_k) - f(RH_{obs}))^2 + \frac{1}{\Delta h_{\max}}(h_k - CTH_{obs})^2}}$$

function of relative humidity

= 1

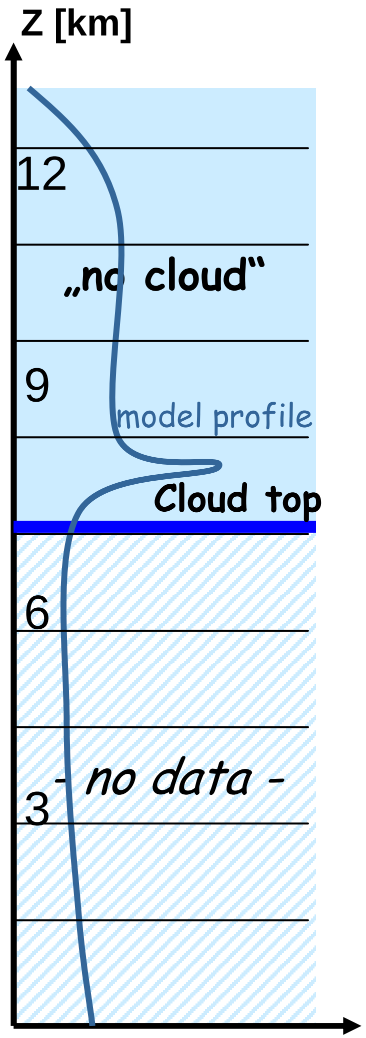
height of model level k

- use $f(RH_{obs}) - f(RH_k) = 1 - f(RH_k)$
  and $CTH_{obs} - h_k$
  as 2 separate obs increments in LETKF



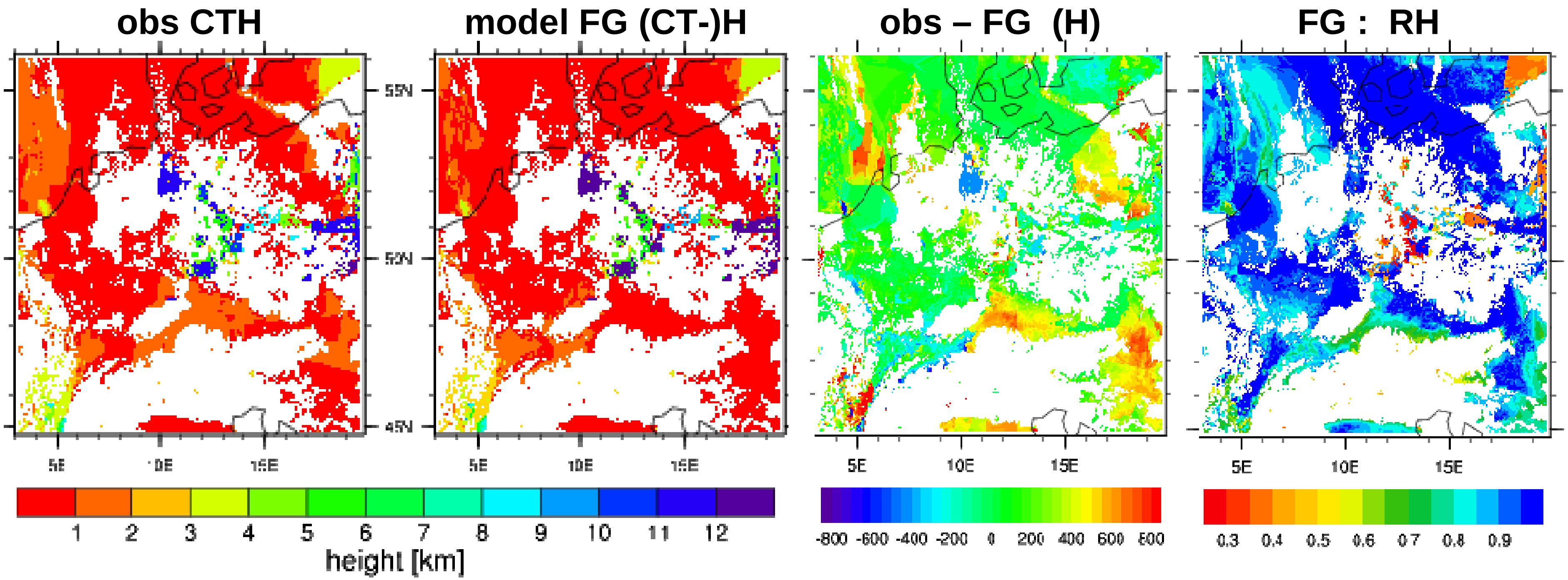
type of obs increment , if **no cloud** observed ?

- assimilate *CLC* = 0 separately for high, medium, low clouds
- model equivalent: maximum CLC within vertical range



use of cloud info :
assimilation of ‘cloud analysis’ : example

17 Nov 2011, 6 UTC (low stratus case)
pixels where observation has clouds
(output from feedback files)



obs CTH

model FG (CT-)H

obs – FG (H)

FG : RH

use of cloud info :
first assimilation experiment

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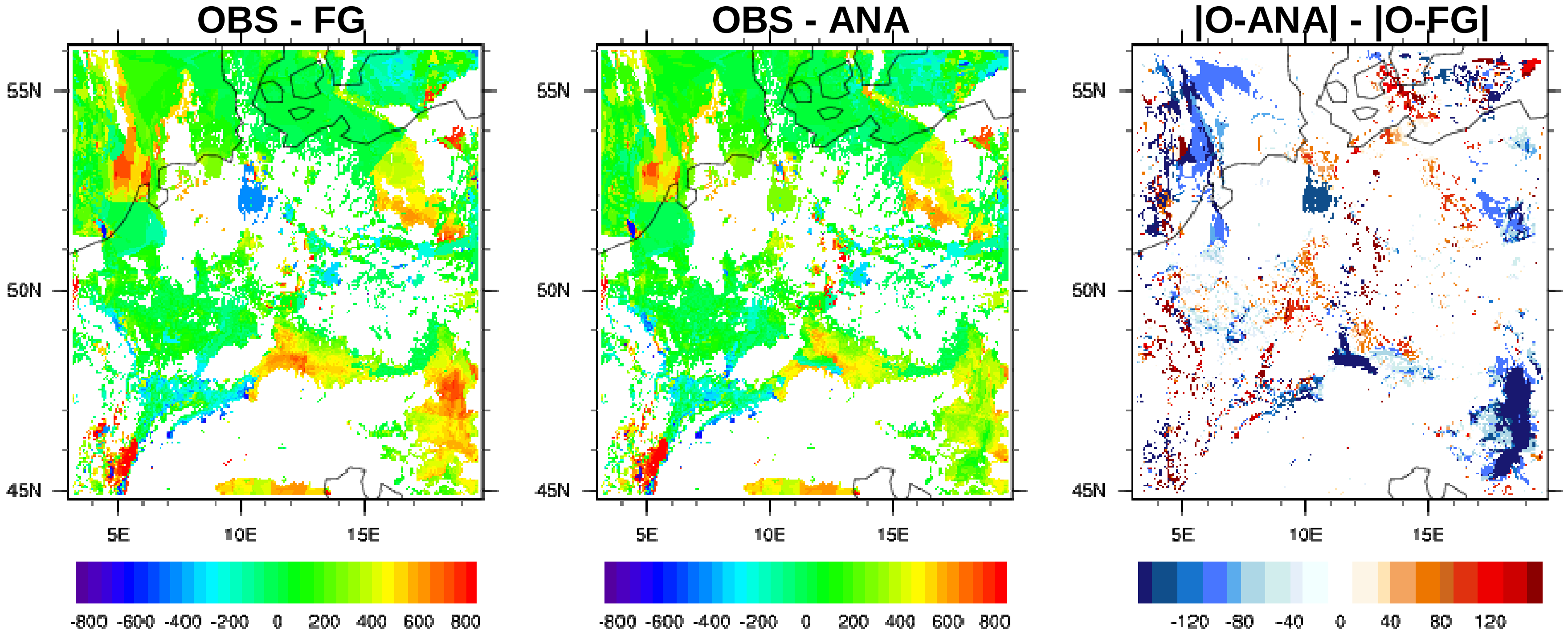
‘cloud‘ top height



blue means ANA is better

Here: results of **deterministic** run in LETKF framework

(Kalman gain matrix applied to standard (unperturbed) model integration)

use of cloud info :
first assimilation experiment

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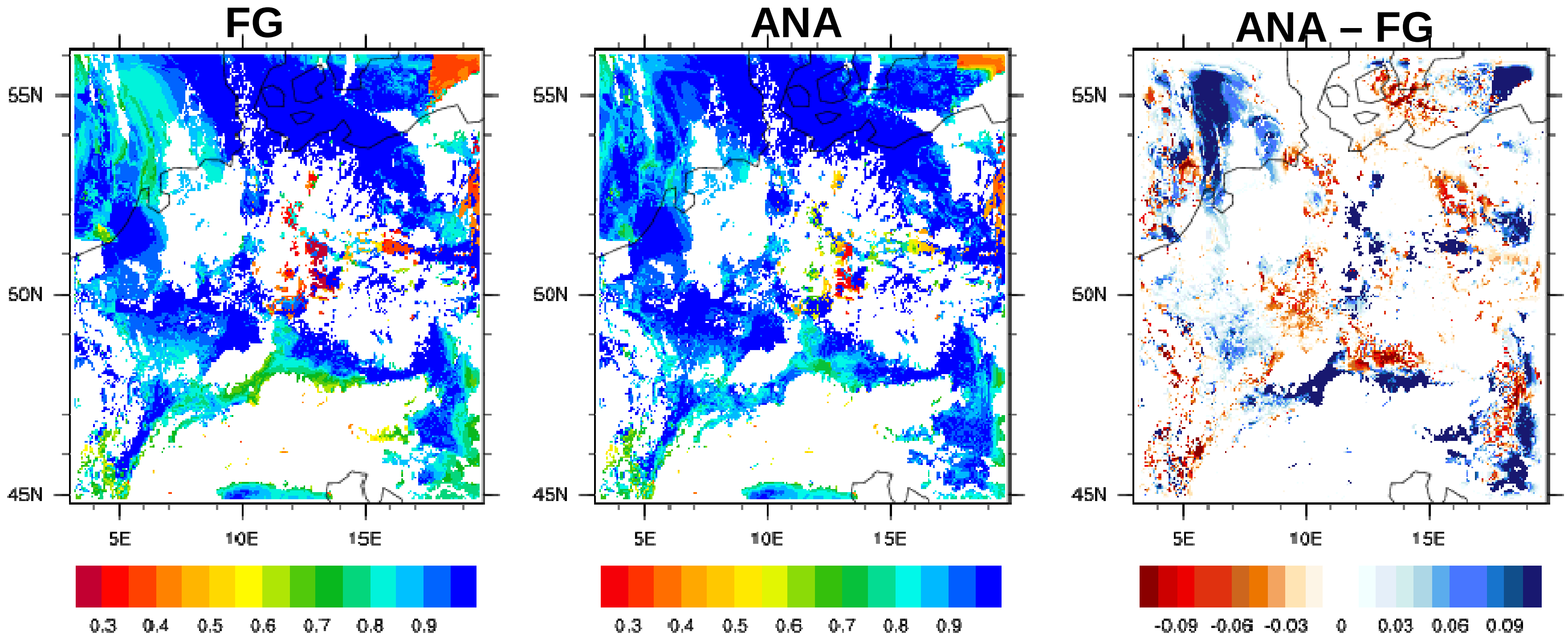
Relative humidity at 'cloud' level



Here: results of **deterministic** run in LETKF framework

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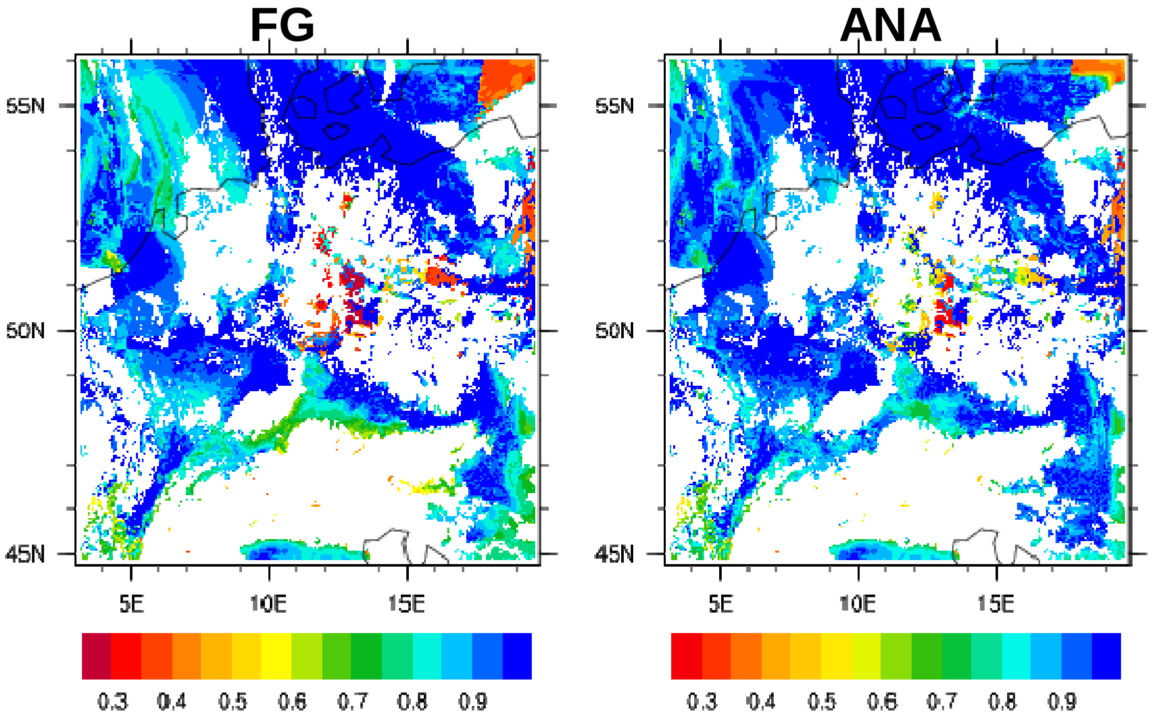
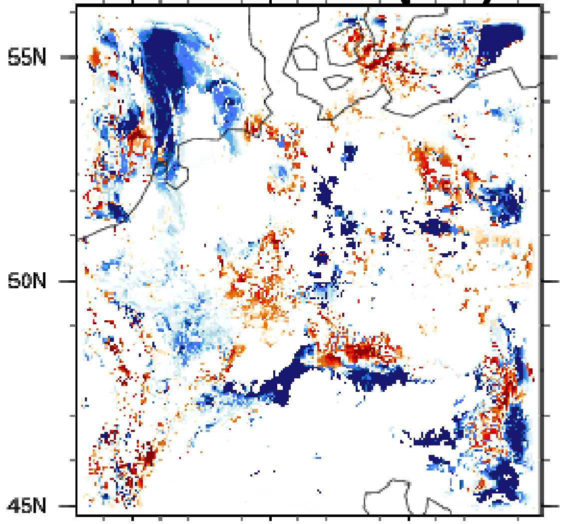
use of cloud info :
first assimilation experiment

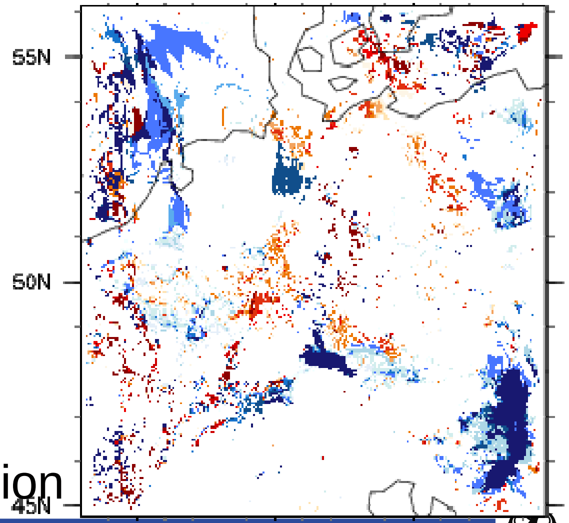
Relative humidity at cloud level



ANA – FG (RH)



|O-ANA| - |O-FG| (‘CTH’)



→ LETKF draws model cloud tops closer to obs

next :
- detailed evaluation (cross section, profiles…)
- single observation experiments
- tuning of observation error, thinning, localization

Overview WG1 / KENDA

thank you for your attention

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