Status Overview on PP KENDA

Km-scale ENsemble-based Data Assimilation

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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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

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

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- **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, …)
  - problems with observation selection solved
  - implementing ensemble scores (reliability, ROC, Brier Skill Score, (continuous) Ranked Probability Score)
  - main part of documentation written

– lack of spread: (partly ?) due to model error and limited ensemble size which is not accounted for so far

to account for it: covariance inflation, what is needed ?

→ additive (see later)

→ multiplicative $X_b \rightarrow \rho \cdot X_b$

(by tuning, or) adaptive $\left\langle \left(y - H(x_b)\right)\left(y - H(x_b)\right)^T \right\rangle = \mathbf{R} + \rho\, \mathbf{H}\mathbf{P}_b\mathbf{H}^T$

→ pre-specifed $\mathbf{R}$ is used for adaptive ρ :

→ need for careful specification / tuning of obs errors

– observation error covariance $\mathbf{R}$:

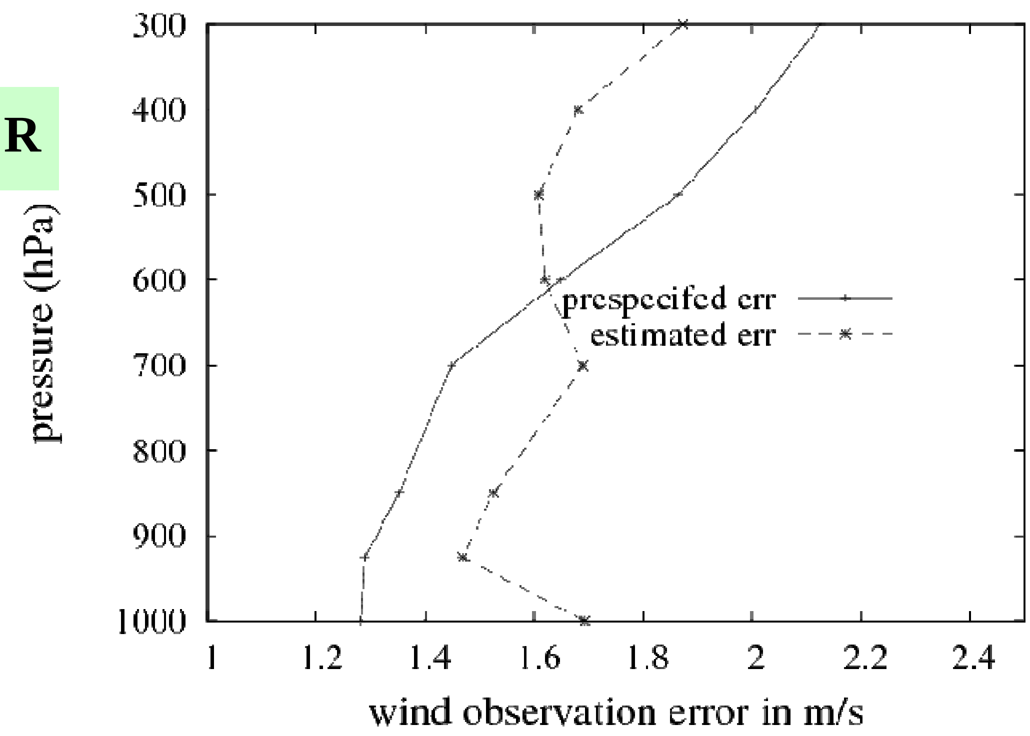
also estimate adaptively (Li, Kalnay, Miyoshi, QJRMS 2009)

$$\left\langle \left(y - H(x_a)\right)\left(y - H(x_b)\right)^T \right\rangle = \mathbf{R}$$

– adaptive observation errors

$$\left\langle \left(y - H(x_a)\right)\left(y - H(x_b)\right)^T \right\rangle = \mathbf{R}$$

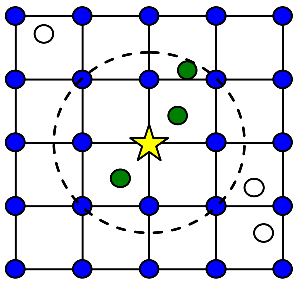
(in observation space)



– adaptive $\mathbf{R}$ in ensemble space:

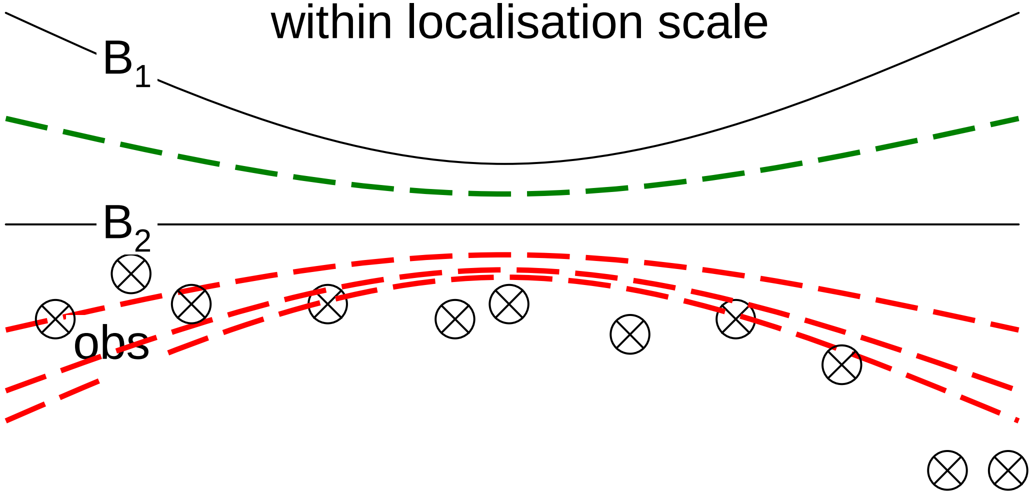
adjusts total weight, not relative weight of obs

– localisation



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

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



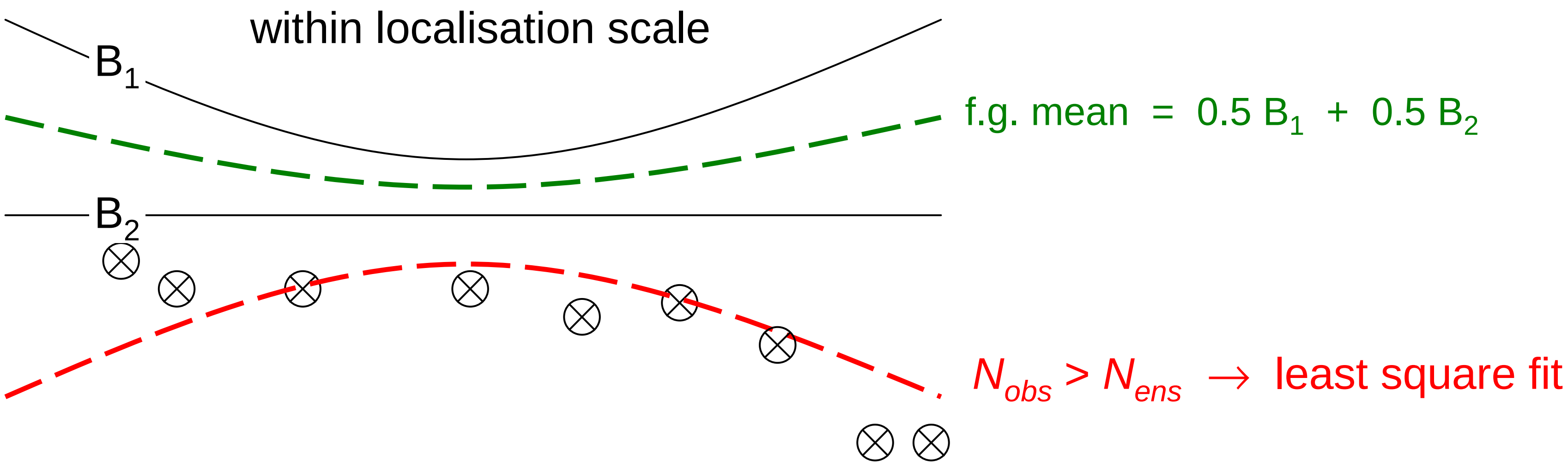
add obs, if already $N_{obs} > N_{ens}$:

- 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 $\mathbf{R}$

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



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

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

vertical cross section

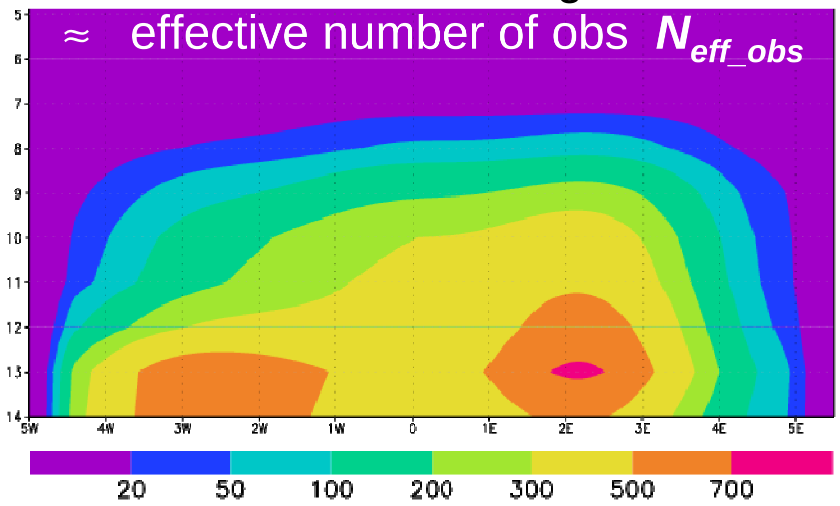
(at rot lat = 2° , 8 Aug 2009 , 12 UTC)

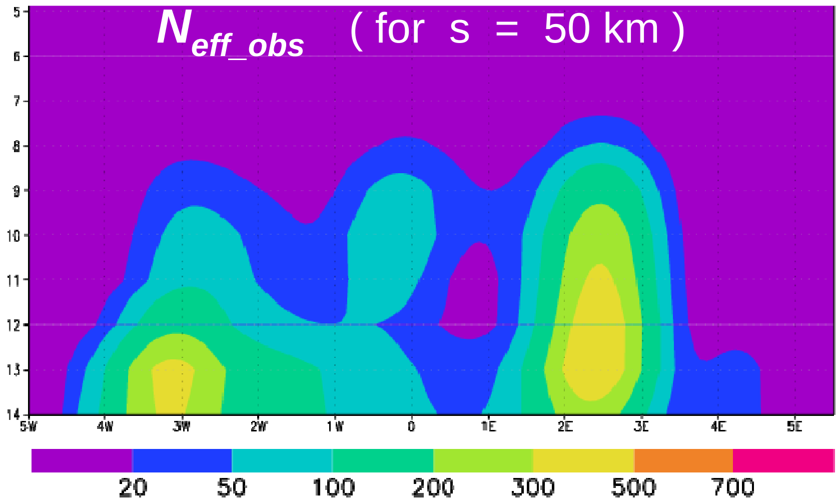
sum of localisation weights of obs

~ 250 hPa

~ 500 hPa

~ 850 hPa





→ $N_{eff\_obs} >> N_{ens}$

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

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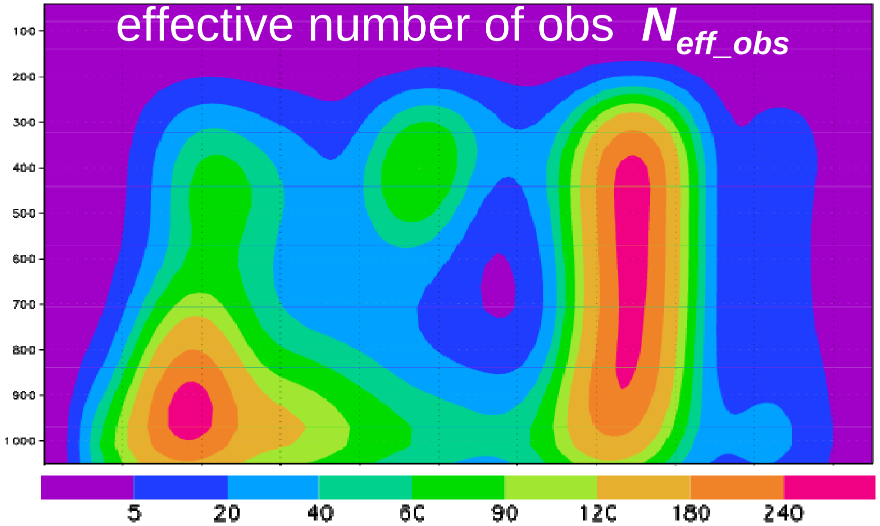
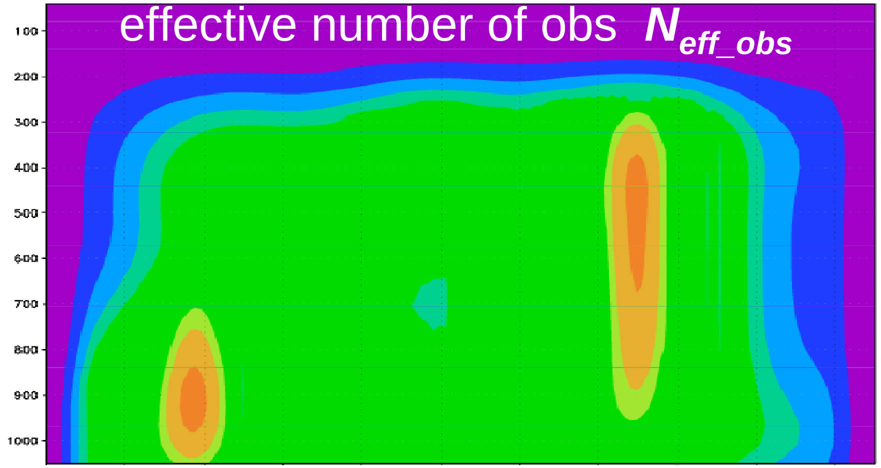
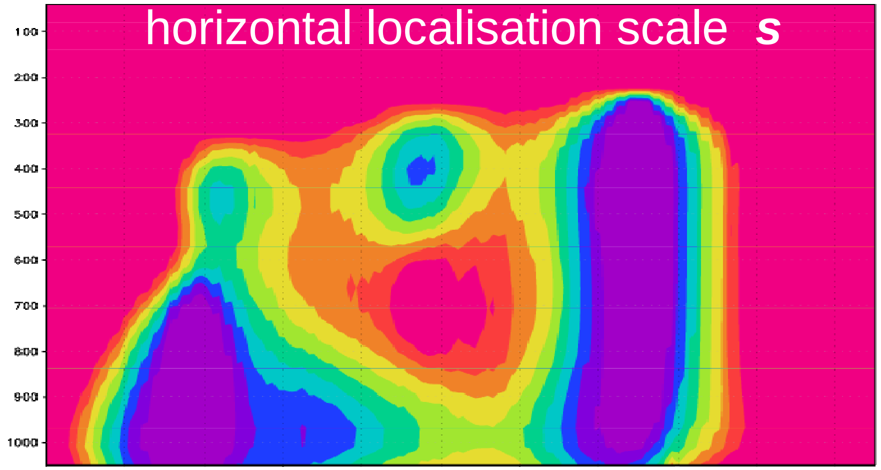
LETKF, preliminary results: adaptive horizontal localisation

Caspari-Cohn function: scale s = 50 km → adaptive scale s :
adapt s such that $N_{eff\_obs} \cong 70$
and 30 km ≤ s ≤ 80 km

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





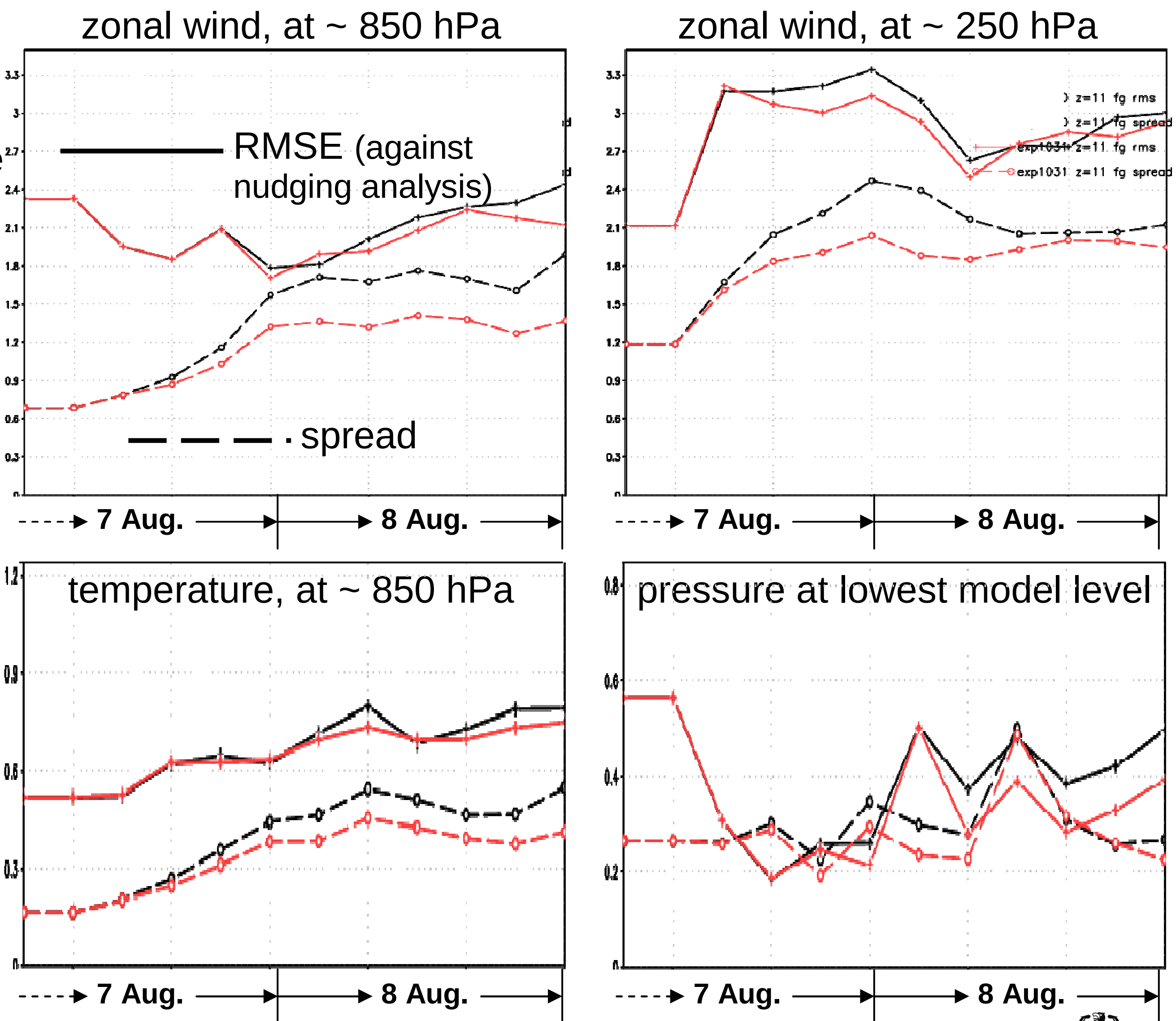


scale s · $(10/3)^{½}$

LETKF, preliminary results: adaptive horizontal localisation

first guess mean
(inner domain average)
(variable vertical localisation, adaptive **R** and multiplicative covariance inflation ρ)

s = 50 km
adaptive *s*



→ smaller spread

→ mostly smaller RMSE

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

- **parameterisation of model error using statistics** (Tsyrulnikov, Gorin) :
  - parameterisation: $e = \mu * F_{phys}(\mathbf{x}) + e_{add}$
  - 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

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→ 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)
  - basic Buizza version running, occas. crashed if microphysics tendencies perturbed
    → 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 ?

- **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
     (e.g. 4/3 earth model for beam propagation)

2. assimilation experiments
   – technical work (feedback files)
   – 1 - 2 assimilation case studies (Zeng)
   – 2013: Klaus Stephan : test periods, tuning …

Task 4.3: use of GNSS slant path delay

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- **ground-based GNSS slant path delay SPD** (Michael Bender, Erdem Altuntac)
  - 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)
      - adjoint (sensitivities needed for tomography)
      - implement complex obs operator with ray tracer
      - monitoring, test e.g. impact of straight line approximation
    - then implement obs operator in COSMO (in 2013)

- **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)

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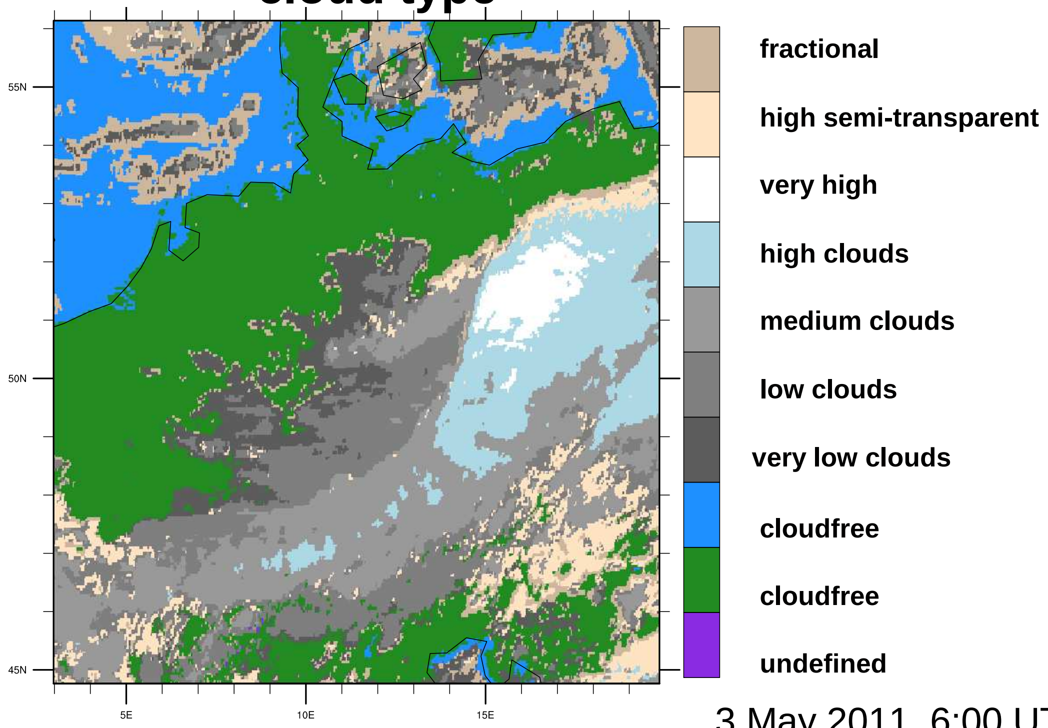
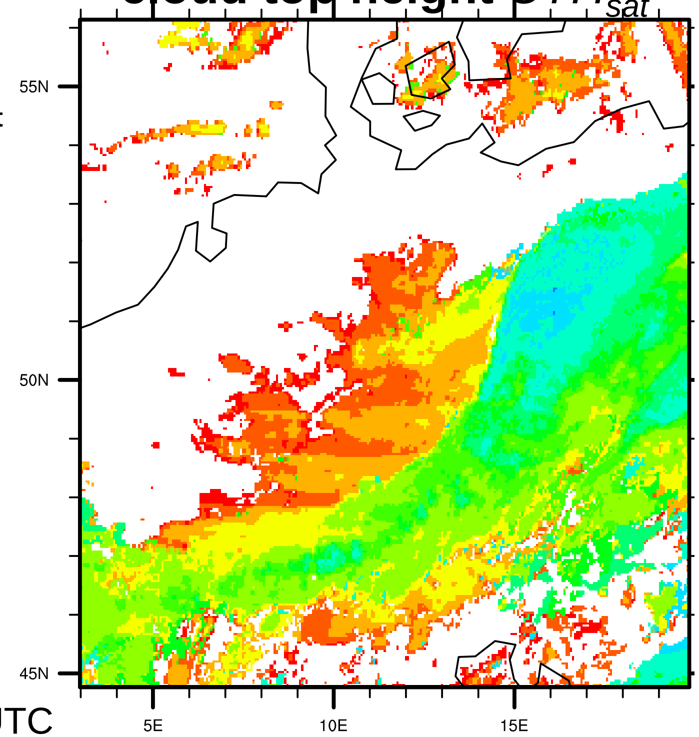
cloud type



cloud top height CTH_{sat}



3 May 2011, 6:00 UTC

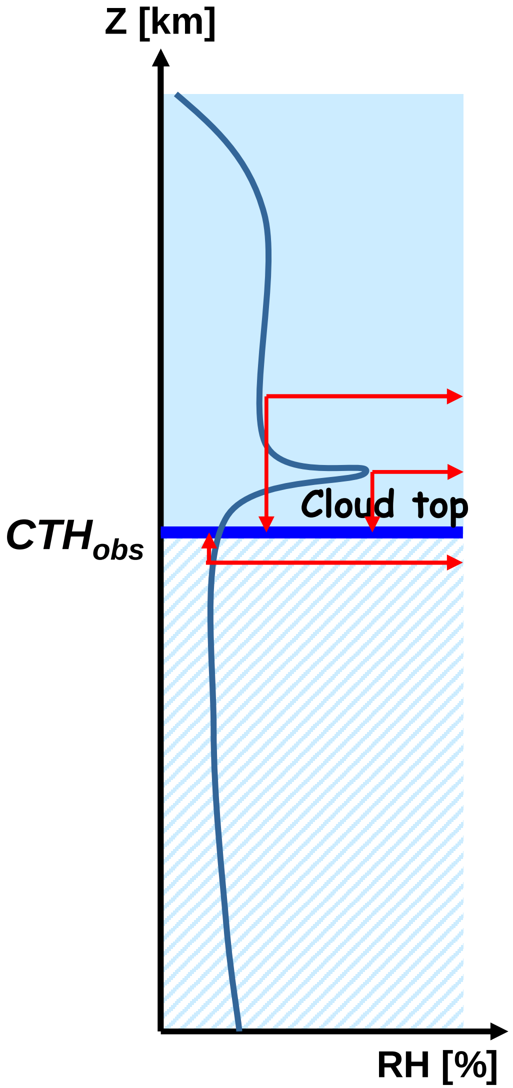
retrieval algorithm needs temperature and humidity profile from a NWP model

→ 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'



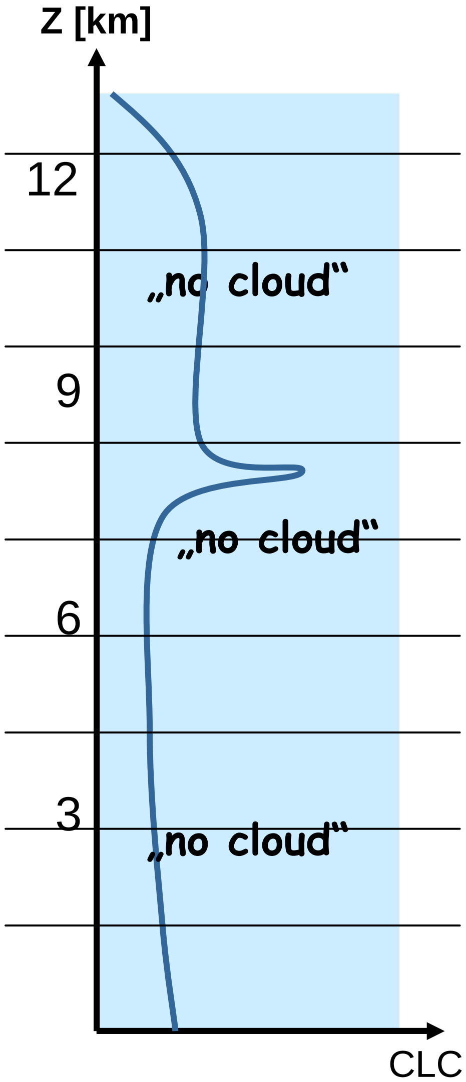
if cloud observed with cloud top height $\boldsymbol{CTH_{obs}}$, what is the appropriate type of obs increment ?

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

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

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

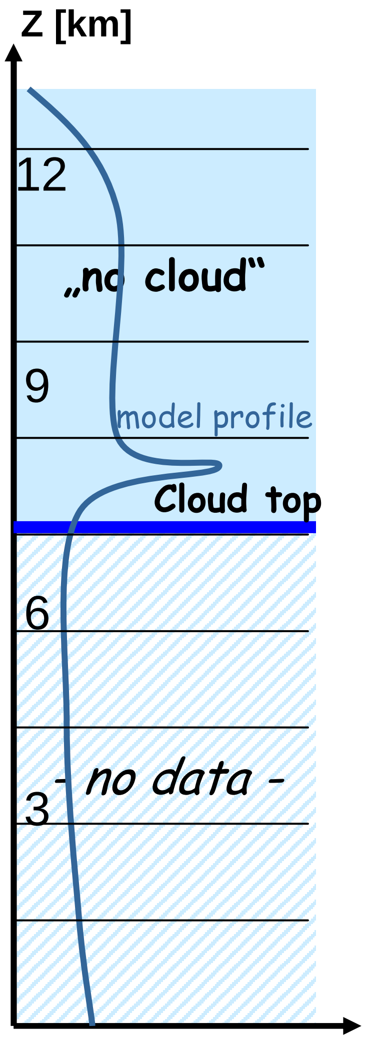
- use $f(RH_{obs}) - f(RH_k) = 1 - f(RH_k)$
  and $CTH_{obs} - h_k$
  as 2 separate obs increments in LETKF



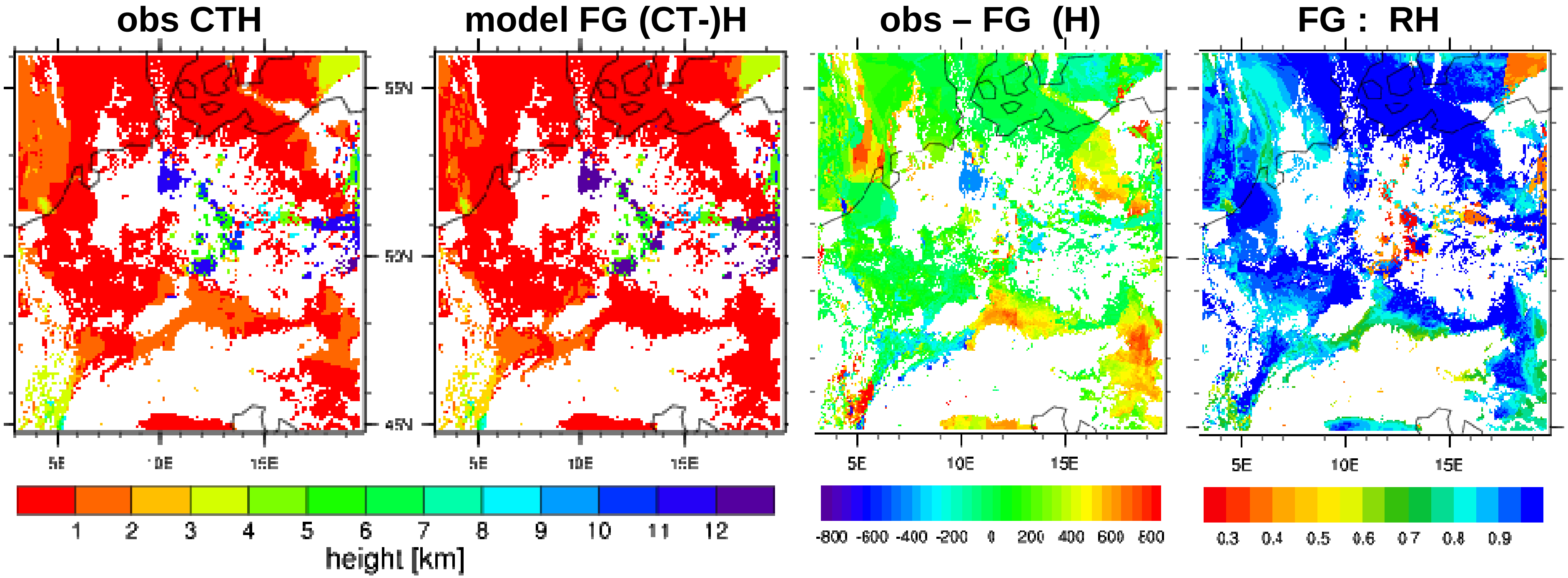
type of obs increment ,
if **no cloud** observed ?

- assimilate *CLC* = 0 separately
  for high, medium, low clouds

- model equivalent:
  maximum CLC within vertical range



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



use of cloud info :
first assimilation experiment

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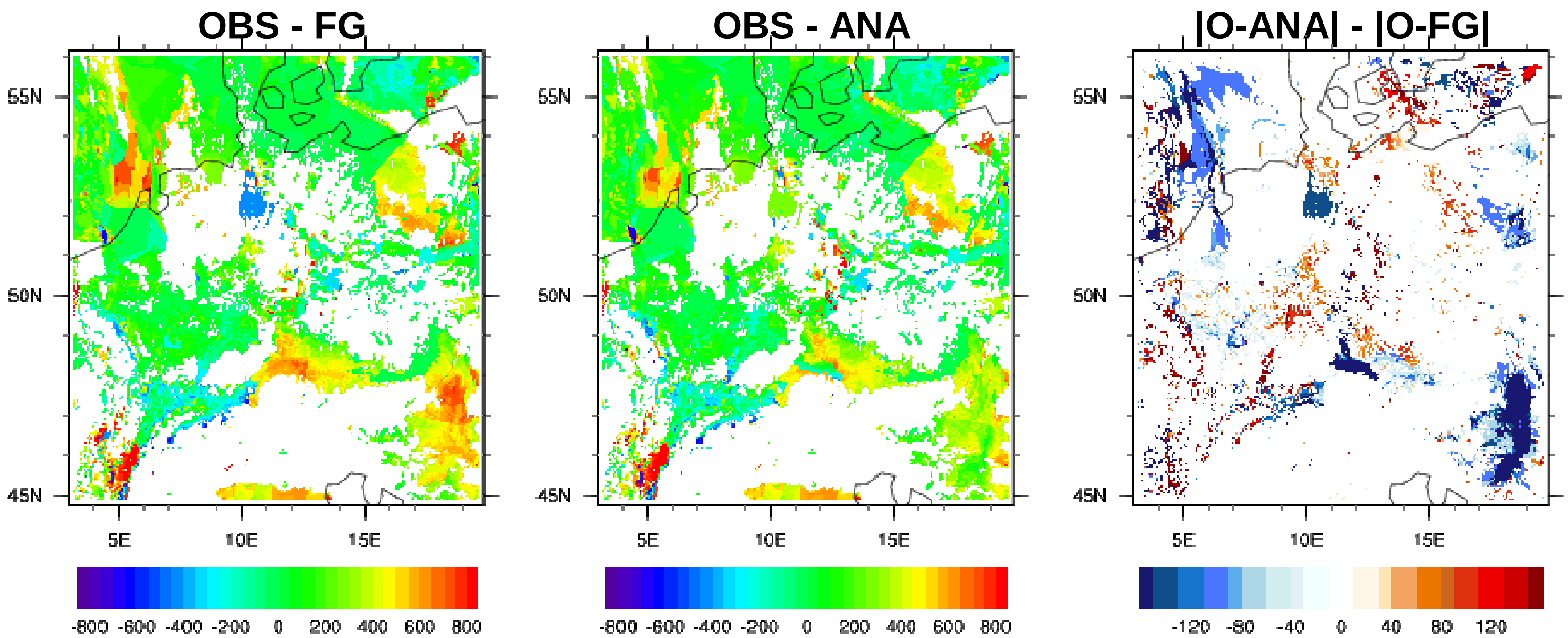
'cloud' top height



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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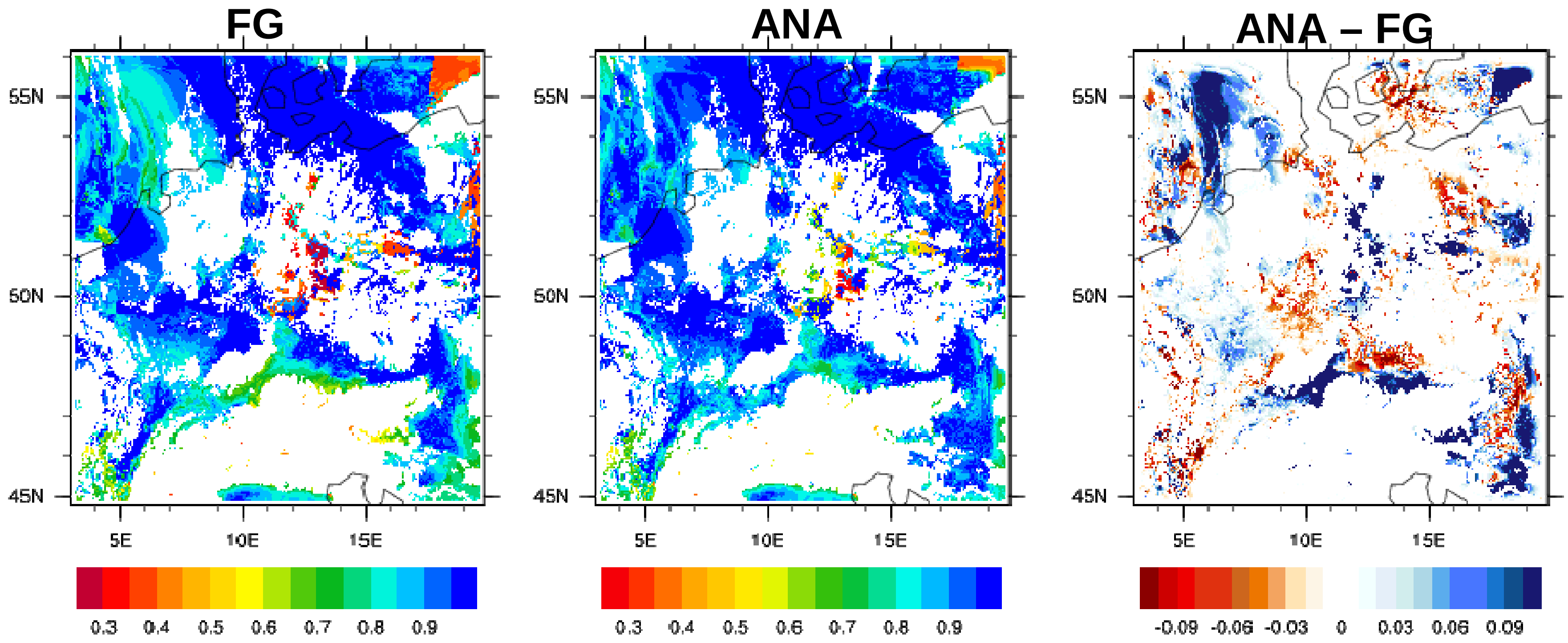
Relative humidity at 'cloud' level



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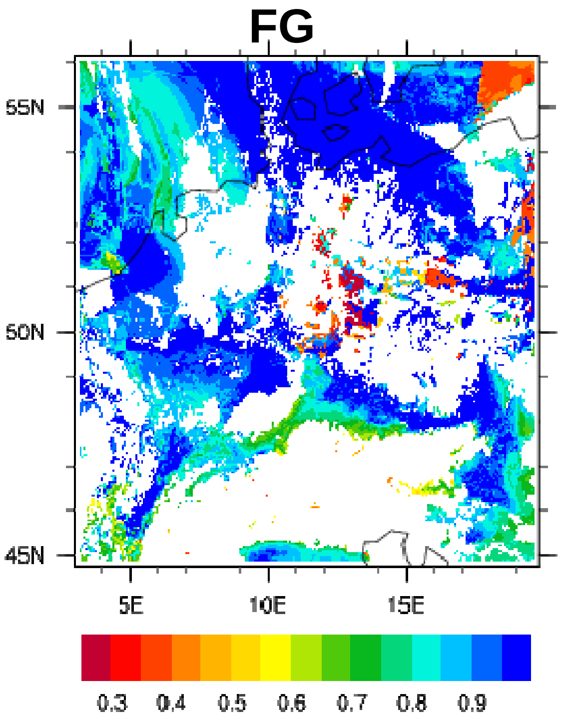
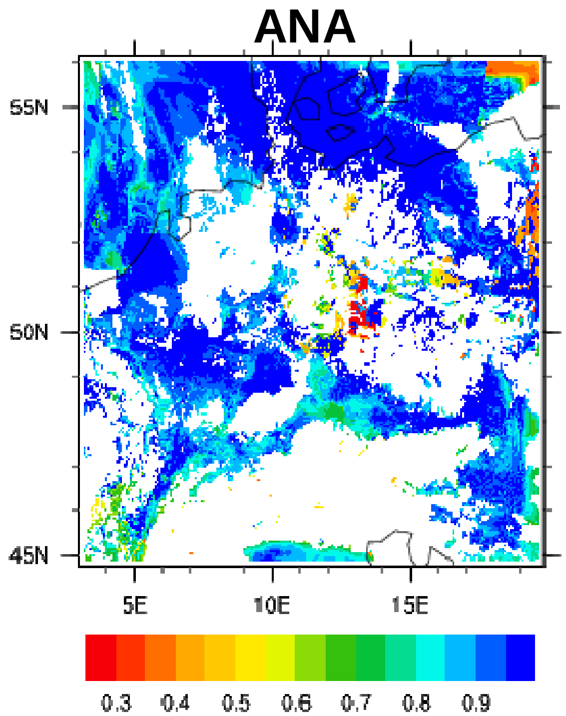
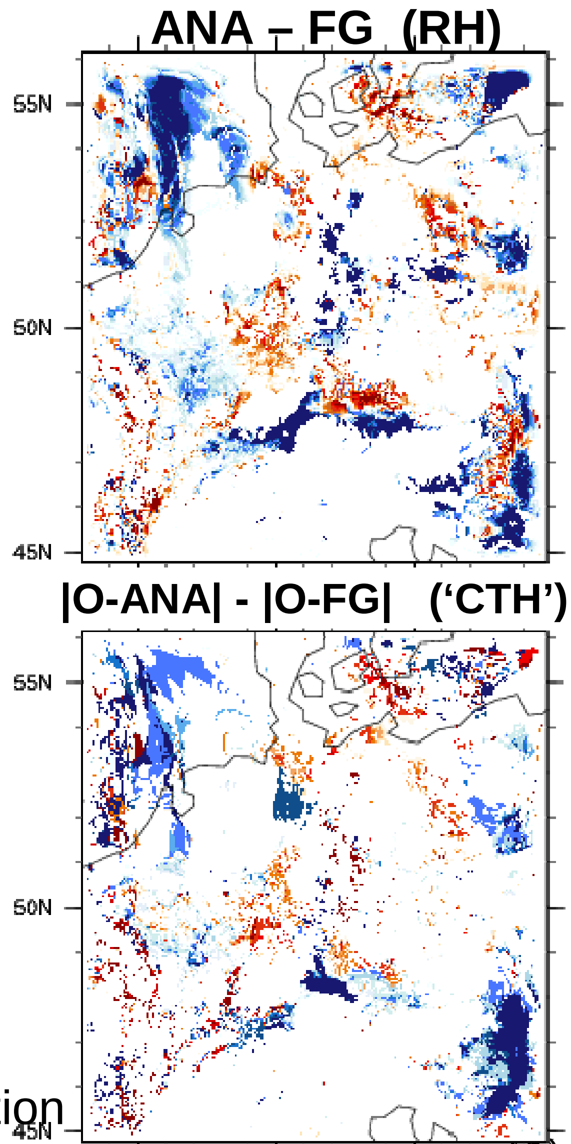
use of cloud info : first assimilation experiment

Relative humidity at cloud level







→ LETKF draws model cloud tops closer to obs

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

thank you for your attention