PP KENDA (km-scale ensemble-based data assimilation) : Contents

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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- 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
- (Task 5: Development of a Sequential Importance Resampling (SIR) filter)

Task 1: General issues in the convective scale (e.g. non-Gaussianity)

- COSMO Newsletter:
  M. Tsyrulnikov: Is the Local Ensemble Transform Kalman Filter suitable for operational data assimilation ?
  (difficulty: assimilate non-local satellite data & achieve good resolution in local analysis)

- COSMO Newsletter:
  K. Stephan and C. Schraff: The importance of small-scale analysis on the forecasts of COSMO-DE
  (small-scale analysis can be beneficial, depends on situation, daytime of analysis)

- COSMO Technical Report:
  D. Leuenberger: Statistical Analysis of high-resolution COSMO Ensemble forecasts, in view of Data Assimilation
  (no clear indication that Gaussian assumption of LETKF will be detrimental
  → COSMO Met Services will (continue to) focus on developing LETKF)

Preliminary study: occurrence of non-Gaussianity ?

by Daniel Leuenberger, MeteoSwiss

- General assumption in Ensemble Kalman Filter methods:
  'Errors are of Gaussian nature and bias-free'
  (prerequisite for 'optimal' combination of model forecast and observation)

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

- How normal are these terms in the COSMO model ?

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

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

  - small deviations from normality for T, u, v, ps (except for 'fat tails')
  - RH, precip: large deviations; small for transformed variables (log(precip) & normalised RH)
  - no larger deviations with higher resolution (Δx = 2.8 km) / increasing forecast time (≤ +12h)

background term: COSMO-DE ensemble forecast perturbations

fixed perturbations of model physics parameters →

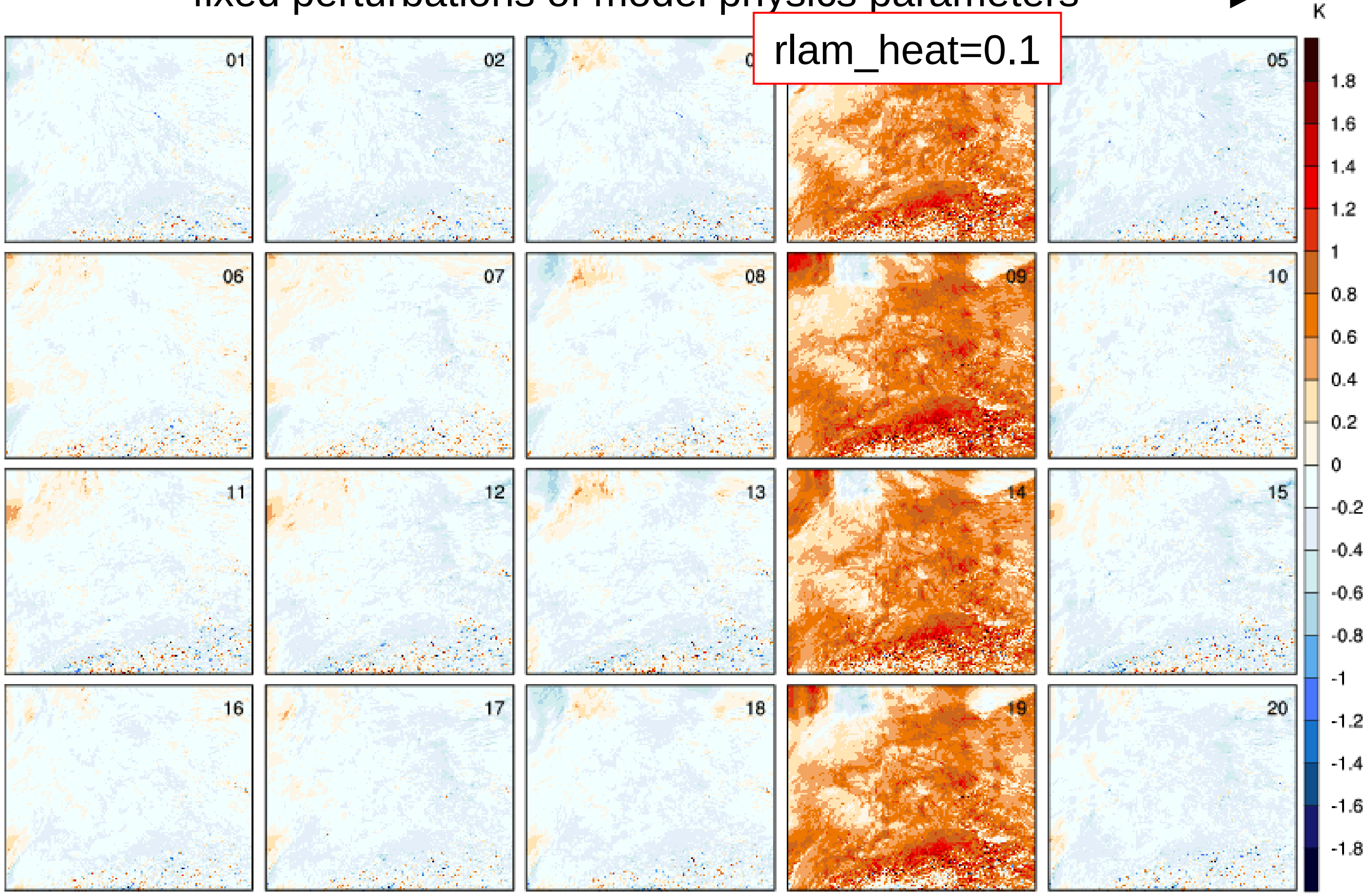
grandfathers for LBC ↓

ECMWF

GME

NCEP

UM

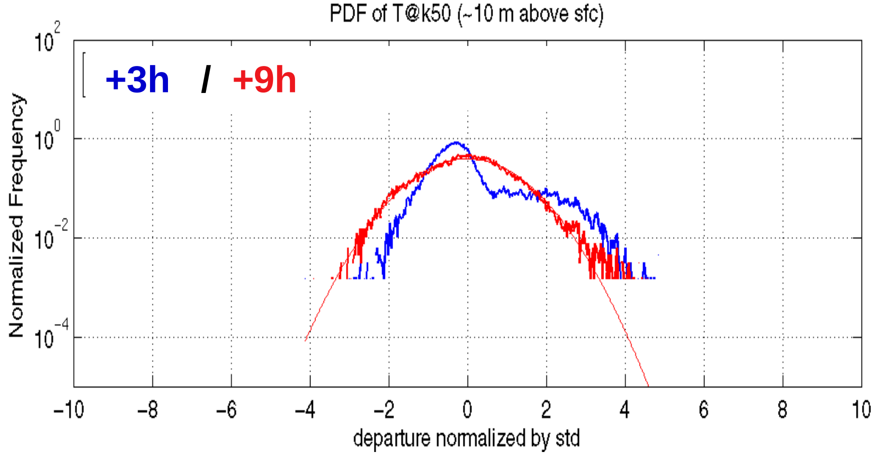


temperature at ~10m, +3h (03 UTC)

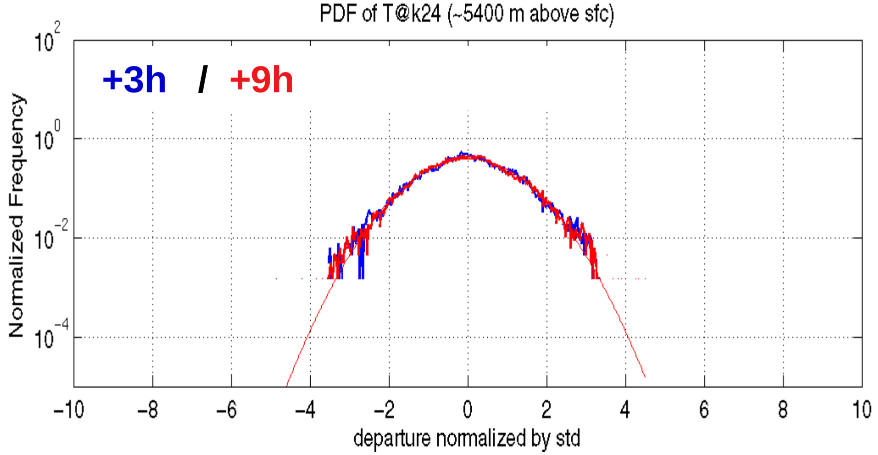
Statistical characteristics (COSMO-DE) : background term (EPS)

COSMO-DE ensemble forecast perturbations

T@10 m over Northern Germany (flat)



T@5400 m over N. Germany



- results largely determined by physical perturbation technique

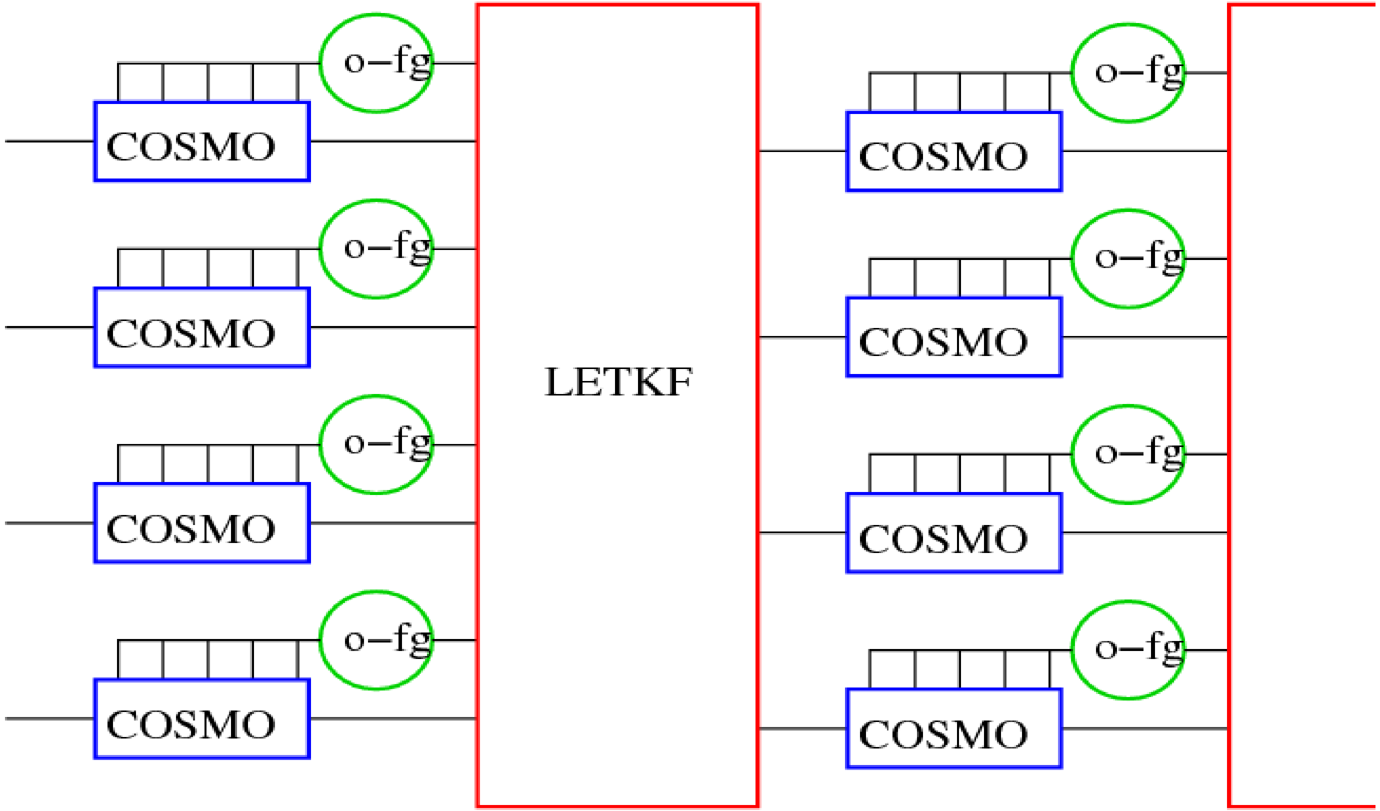
- LETKF ensemble will differ form the current set-up of COSMO-DE EPS
  e.g. Gaussian spread in initial conditions
  → need to re-do such evaluations with LETKF ensemble

- for data assimilation, need perturbations that are more Gaussian
  → physics perturbations: stochastic instead of fixed parameters ?

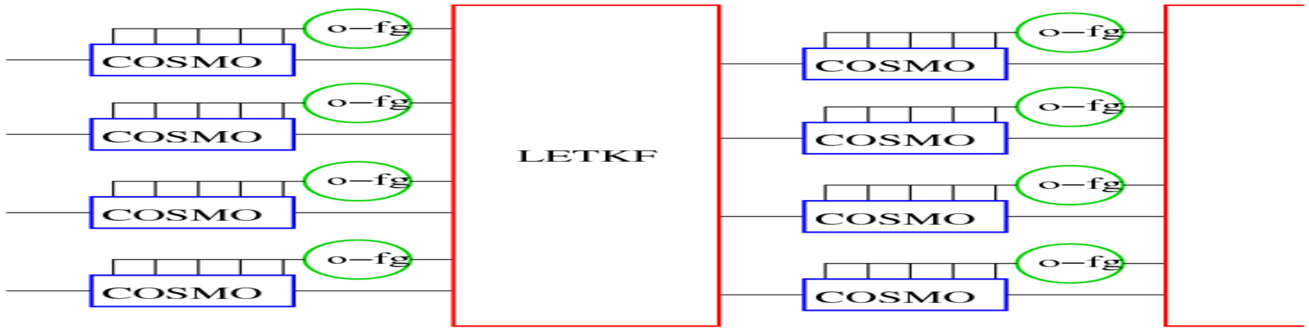
analysis step (LETKF) outside COSMO code

→ ensemble of independent COSMO runs up to next analysis time

→ separate analysis step code, LETKF included in 3DVAR code of DWD



Technical implementation of LETKF



Task 2.4: 1st version not yet available

exp. system

COSMO

Task 2.2: almost finished

- → done: adaptations to start model runs not at full hours
- → compute obs–fg (obs. increm.) + QC (contains obs operator)
- → to do: test (bug fix) writing NetCDF feedback files NEFF (obs + obs–fg + QC flags)

LETKF

Task 2.3: finished

- → read ensemble of NEFF and first guess Grib files
- → perform LETKF (calc. transform matrix and analysis ensemble) (adapt: C-grid, specific variables (*w*), efficiency)
- → write ensemble of analysis Grib files and NEFF (add. QC flags)

However: scripts written to do a few stand-alone cycles with LETKF
→ preliminary experiments (talk by Hendrik Reich)

Technical implementation of verification for KENDA

- **'stat'-utility**: compute model (forecast) – obs for complete NEFF:
  adapt verification mode of 3DVar/LETKF package
  - → need to implement COSMO observation operators with QC ('library 2') in 3DVar/LETKF package
    (+ COSMO modules for reading obs from NetCDF obs files : 'library 1' , for verification against obs not used in DA)
  - → hybrid 3DVar–EnKF approaches in principle applicable to COSMO

  to do: build COSMO modules with clean interfaces and introduce them in LETKF
  - library 1: finished
  - library 2: isolation of COSMO modules started, but no progress in past year
  - extend flow control (read several Gribs, interpolate in time) : not yet started

  → plan: first implement lib 2 + flow control by end of 2010 for upper-air obs (input for VERSUS-2), then do it for other obs

- develop tool to compute and plot scores based on NEFF
  - → Amalia Iriza (NMA) : started work with 8-week stage at DWD

Task 3: tackle major scientific issues

– 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 ?

→ multiplicative $X_b \rightarrow \rho \cdot X_b$ (tuning, or adaptive ($y - H(x) \sim R + H^T P_b H$))

→ additive ((e.g. statistical 3DVAR-B), stochastic physics (Torrisi))

– model bias

– localisation (multi-scale data assimilation, 2 successive LETKF steps with different obs / localisation ?)

– update frequency

– noise control:
  – how to deal with perturbed LBC (limit use of obs ?) (inconsistency of spread structures inside and at LBC, now main source of noise; later: LBC from ICON EnKF)
  – similar problem at upper BC ?
  – hydrostatic imbalance by vertical localisation
  – digital filter initialisation ?

– non-linear aspects, convection initiation (latent heat nudging ?)

(end of 2011: pre-operational LETKF suite)

- **stochastic physics (Palmer et al., 2009)** : by Lucio Torrisi, Jan. 2011
- **build a model-error model (MEM) generator**

→ M. Tsyrulnikov, V. Gorin (Russia, 1.2 FTE / y), for 2 years, start in June 2010

stochastic model (parameterisation) for model error : $e = u * f(M(\mathbf{x})) + e_{add}$

involves stochastic physics ($u * f(M(\mathbf{x}))$) and additive components e_{add} and includes multi-variate and spatio-temporal aspects

– build statistics of forecast tendencies minus observation tendencies d (using pairs of lagged obs (increments) at nearly the same location)

$\mathrm{cov}(d) = (\mathrm{cov}(u) f(M(\mathbf{x}_i)) f(M(\mathbf{x}_j)) + \mathrm{cov}(\delta M(\mathbf{x})) + \mathrm{cov}(e_{add})) * \Delta t^2 + 2 R$

where $\delta M(\mathbf{x})$ = error in the model tendency due to the analysis error, $\mathrm{cov}(\delta M(\mathbf{x}))$ estimated by sample covariance of the ensemble tendencies

Obs: p, T, u,v, q: Synop, ship, buoy; aircraft; wind profiler (?); radar (?)

2. determine parameters for model error by fitting to statistics

3. validate: apply MEM to COSMO forecasts and check resulting EPS spread

- **investigate LETKF in Observing System Simulation Experiments (OSSE)**

  → project plan submitted by MeteoSwiss ,for 2 years, start May 2011

  – apply LETKF to idealized convective weather systems (at the convection permitting scale) , tune LETKF settings (localization, covariance inflation)

  – quantify non-Gaussianity and spin-up time in the evolving LETKF ensemble during the assimilation of a convective storm

  – develop ways to improve Gaussianity of errors and reduce spin-up time of the LETKF → test “running in place” (Kalnay and Yang, 2010) and “outer loop” (Yang and Kalnay, 2010) algorithms

- **radar : radial velocity and (3-D) reflectivity**

→ Research funded by DWD to develop suitably sophisticated + efficient observation operators for radar radial winds + (3-dim.) reflectivity (2 PhD's at KIT, start 1.6. bzw. 1.7. 2010 (PL Uli Blahak)

– Starting point: Implement a simple observation operator for radial velocity by Sept. 2010 (Daniel Leuenberger), based on an offline and tested simple operator of K. Helmert. Includes a parallelisation of the data processing.

– Implement full, sophisticated observation operators

– then develop different approximations and test their validity (both looking at the simulated obs and doing assimilation experiments) in order to obtain sufficiently accurate and efficient operators

Particular issues for use in LETKF: obs error variances and correlations, superobbing, thinning, localisation

Task 4:
inclusion of additional observations

- **ground-based GNSS slant path delay** (after 2010, N.N.)
  - implement non-local obs operator in parallel model environment
  - test and possibly compare with using GNSS data in the form of IWV or of tomographic refractivity profiles

Particular issue: localisation for (vertically and horizontally) non-local obs

Task 4:
inclusion of additional observations

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

  → DWD: **Eumetsat fellowship, vacancy note issued last week !!!**

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

  – use obs increments of cloud or cloud top / base height or derived humidity

  – 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

  – compare approaches

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

- **MeteoSwiss: analysis for deterministic forecast with 1-km resolution**
  - use Kalman Gain of LETKF, interpolate to 1 km, and apply to obs increments to obtain analysis increments, or do full LETKF at 1 km resolution
  - start Oct. 10: first compare approaches with toy model , later with COSMO

- **Posters !**
  - Daniel Leuenberger, Franco Laudanna del Guerra, Andrea M. Rossa:
    Application of an empirical quality function for radar QPE in an NWP model
  - Tanja Weusthoff:
    Best member selection for convective-scale ensembles