Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Status of KENDA, plans on DA at DWD

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LETKF: implementation

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

- **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
  40 ensemble members, 3-hourly … 15-minute analysis cycles, …

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

- required in NUMEX for reasonable tests over several weeks (2013 – 2014) :
  - ensemble lateral BC 2013 – 2014 :
    ensemble perturbations of interpolated ensemble GME fields,
    added to deterministic COSMO-DE LBC
    (but no date yet, when available in NUMEX)
  - reasonable lower BC (snow, SST, soil moisture)
  - deterministic run

- benchmarks for system evaluation
  - deterministic nudging analyses / forecasts
  - COSMO-DE EPS forecasts (… also compare IC)

LETKF : implementation / activities

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- up to now, still only preliminary LETKF experiments possible, using Hendrik's scripts:
  - 3-hourly cycles, 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
  - only DA cycle, no forecasts

→ therefore we cannot say 'how good the LETKF system works'

→ … and
  - theoretical studies, toy model experiments related to adaptive localisation
    → talk by Hendrik Reich
  - benchmark , winter school on DA , support for HErZ centre , …
  - only few COSMO-DE experiments related to adaptive localisation

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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

LETKF scientific issues : adaptive methods

- adaptive methods : more important if N_{obs} large

- **strategy for adaptive methods**
  - offline a-priori adaptive estimation of obs errors in obs space
  - online adaptive:
    - multiplicative covariance inflation
    - estimation of obs errors in ensemble space
    - localisation

need to be able to test this in longer DA periods !

(can start soon, (only!) if interpolation 60 km $\rightarrow$ 2.8 km works)

LETKF scientific issues : adaptive methods

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need to be able to test this in longer DA periods !

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

- **update frequency** $\Delta_a t$? $1 \text{ hr} \geq \Delta_a t \geq 15 \text{ min}$
  non-linearity vs. noise / lack of spread / 4D property ?

- **also need additive covariance inflation**

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- **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 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 → no tool to parameterise model errors objectively !
→ empirical techniques , tuning required

LETKF scientific issues: 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 , by GM 2013)

- **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 ff Ekaterina Machulskaya (SFP): (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 ?

LETKF scientific issues / refinements: investigate idealised convection

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- non-linear aspects, convection initiation (running in place, outer loop approaches, latent heat nudging, ... ?)

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

- apply LETKF to idealized convective weather systems, tune LETKF settings (localization, covariance inflation)
- quantify + reduce non-Gaussianity + spin-up time in LETKF during assimilation of convective storm

MeteoSwiss: plan for 2-year project not accepted in 2011

Now: interest to submit revised proposal (for PhD) in D ,
discussed at HErZ meeting in autumn → speculative, not short-term

- **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 …

- **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
   → basic version available

   use cloud top height info in LETKF → first LETKF analysis step done

   (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 other satellite obs ?
work / plans for global DA at DWD

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- already used:
  - AMSU-A temperature
  - GPS RO
  - AMV's

- 2013 operational: ATMS temperature (clear sky, similar to AMSU-A)
- 2013 operational: MW (AMSU-B, MHS) humidity (clear sky)
- 2013 operational: IASI , CrIS temperature, later humidity channels (clear sky)
- work from late 2013: MW sounders / imagers in cloudy (rainy) areas
- work from 2014: IASI , CrIS over land; cloudy rad

not on the 'KENDA' agenda

….

- 2018 MTG-I1, IAS Infrared Sounder
- …

use of other obs ?
work / plans for global DA at DWD

- MSG WV channels ?
- screen-level obs : RH-2m, T-2m, 10m wind
- renewable energy project:
  power data from wind power plants / solar energy devices
- Mode-S aircraft wind (temperature) ?
- SMOS , ASCAT for soil moisture ? soil moisture, see below

Ensemble-based convective-scale data assimilation + use of remote-sensing obs

LMU / DLR : Dr. Martin Weissmann, Prof. George Craig, Dr. Christian Keil,
Prof. Bernhard Mayer, Dr. Oliver Reitebuch

- SEVIRI VIS + NIR cloudy radiances (optical thickness, LWP (or droplet size))
  → fast obs operator, test impact
- AMV → derive height correction using airborne lidar obs (mainly GME)
- observation impact on ana/fcst → test diagnostic methods (Liu, Kalnay, Li…)
- predictability → impact of perturbations (IC, LBC, physics) + obs , flow-dep.
- treatment of non-linearity → evaluate robust state filters
- (lightning)

DA system aspects: Lower BC: SST, snow, soil moisture analysis

- simple approach (1):
  use deterministic analysis for each member → zero spread

- simple approach (2):
  add analysis increment 'determ. analysis minus det. f.g. (or ensemble mean f.g.)' to ensemble member f.g.

- SST enhanced: f.g. is *not* cycled in SST analysis
  → add perturbations with specific amplitude, temporal + spatial correlation to deterministic analysis
  → cycle the perturbations !

- snow enhanced: f.g. *is* cycled in snow analysis
  → run a separate analysis on each ensemble member

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DA system aspects: Lower BC: soil moisture analysis

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- SMA enhanced (1) : apply Kalman Gain from variational SMA for deterministic run to T-2m obs increments of each ensemble member
  (K ~ ratio soil moisture ana incr. / T-2m obs increments)
  or use ensemble to determine K (least squares fit)
- SMA enhanced (2) : separate KF using ensemble of 0-UTC SM and of 12-h forecasts of daytime T-2m;
  ensemble provides backgr. error correl. betw. T-2m , SM
- SMA enhanced (3) : include soil moisture in LETKF control vector
  (LETKF provides background error correlation betw. T-2m , SM)
  (problem: high-frequency LETKF cycling not appropriate for SMA)
- SMA enhanced (4) : include soil moisture in LETKF control vector and use soil moisture obs (SMOS, ASCAT)
  (LETKF provides backgr. error correlation betw. SM, atmosphere)
- SMA enhanced (5) : separate EKF SMA

… or add perturbations with specific amplitude + temp/spat. correlation to det. SM(A)

Outlook

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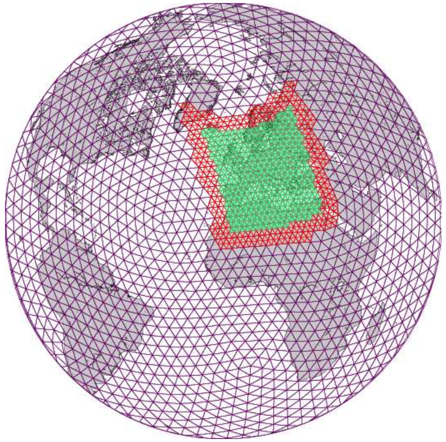
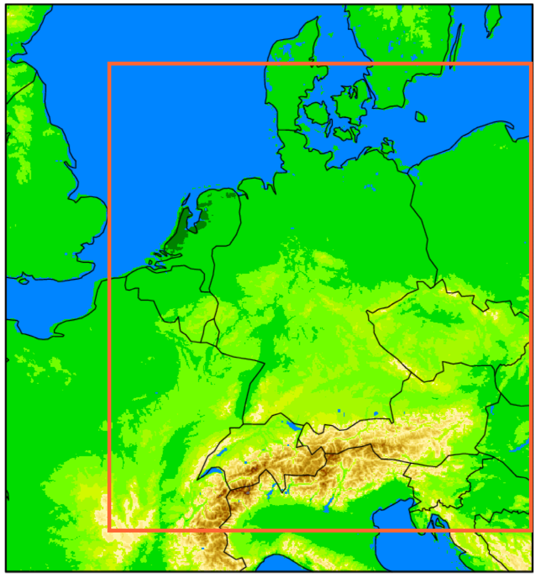
- technical aspects : efficiency, system robustness



schedule towards operational application:

- Q3 2014: global VarEnKF for ICON and KENDA pre-operational
- Q3 2015: global VarEnKF for ICON operational, ensemble resolution 40 km / 10 km
- Q4 2015: KENDA operational, COSMO-DE domain slightly enlarged, resolution ≥ 2 km



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