
Towards Operationalisation of KENDA at DWD

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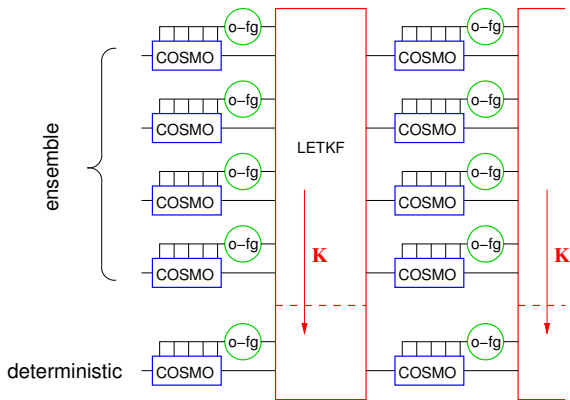
COSMO GM 2016



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- ▶ KENDA setup
- ▶ Verification of parallel routine
- ▶ Remaining problems
- ▶ current experiments
- ▶ Summary & outlook

KENDA system setup



KENDA system setup; 'o-fg' denotes observation minus first guess, 'K' the Kalman Gain for the analysis mean. BC are taken from ICON-EU (20/6.5 km resolution)

KENDA in the preoperational setup

- ▶ Since 2.May the KENDA data assimilation cycle is running in the parallel suite p1 of COSMO-DE.
- ▶ 11.May: Forecasts and time-critical 'main run' analyses are produced twice daily (for 0 and 12 UTC).
- ▶ 20.May: LHN is applied in the ensemble forecast runs and deterministic run with the same cut-off time as for the (pre-)operational EPS runs.
- ▶ 26.May: LHN is applied in the deterministic forecast run with the correct cut-off time for the deterministic run.

KENDA in the preoperational setup

- ▶ 26.May: The mean of the perturbed soil moisture of the ensemble members is relaxed towards the unperturbed soil moisture of the deterministic run to avoid bias of the ensemble mean soil moisture.
- ▶ 21.June: A bug in the assimilation of aircraft data has been fixed, such that now about 30 % more data are used in KENDA.
- ▶ 13.July: The operational COSMO-DE obtains the lateral boundary conditions from ICON-EU instead of COSMO-EU; the operational suites for COSMO-DE and COSMO-DE-EPS are the new benchmarks for the KENDA parallel suite.

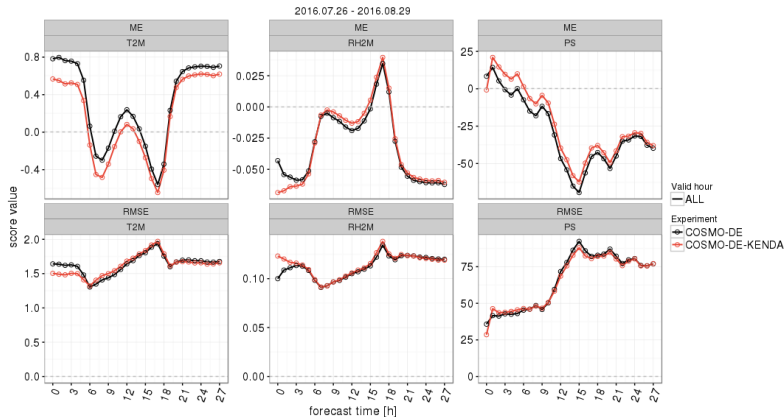
KENDA in the preoperational setup

- ▶ 26.July: The `adjust_SST_SNOW` components have been activated in `KENDA_P` to deliver a fully correct `SNOW` and `SST` analysis at the right point in time.
- ▶ 26.July: The updating of the climatological fields in the ensemble part of `KENDA` has been fixed. Before this fix, the ensemble members used constant climatological fields since 2.May, which resulted in an underestimation of the activity of the vegetation.

KENDA setup

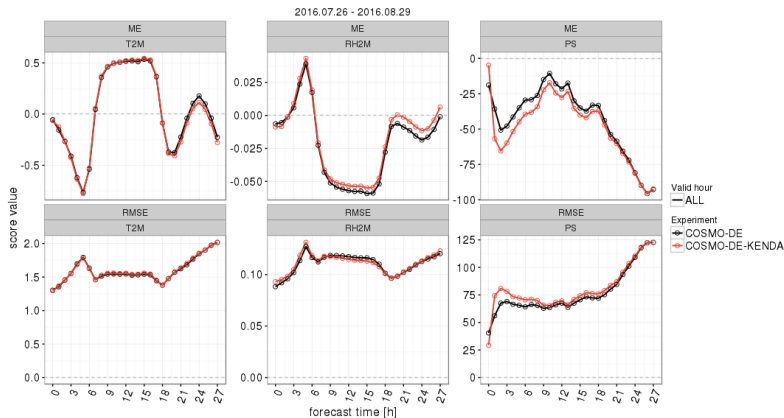
variable / feature	value
ensemble size k	40
deterministic run	1
horiz. resolution ens. + det. run	2.8 km
forecast frequency / length	6 h / 24 h
analysis update frequency	1 h
vert. localis. length scale (ln p)	0.075 - 0.5
horizontal localisation	adaptive
→ target weighted no. obs. N_{loc}^{Oef}	100
→ min. local. length scale r_{loc}^{min}	50 km
→ max. local. length scale r_{loc}^{max}	100 km
multiplicative covariance inflation	adaptive
→ lower / upper limit of ρ	0.5 / 3.0
RTPP relaxation weight α_p	0.75

Verification of parallel routine (SYNOP)

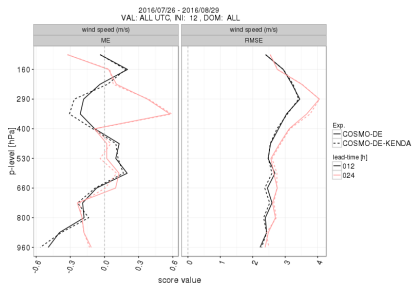
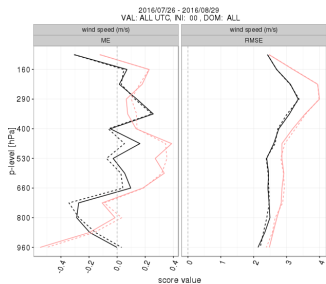
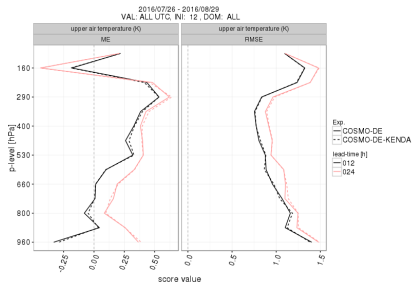
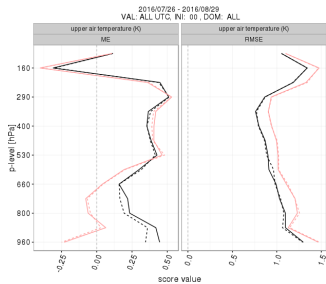


RMSE and ME of COSMO-DE routine (nudging, ICON-EU BC; black) and **parallel routine 1** (KENDA, ICON-EU BC; red), 00 runs

Verification of parallel routine (SYNOP)

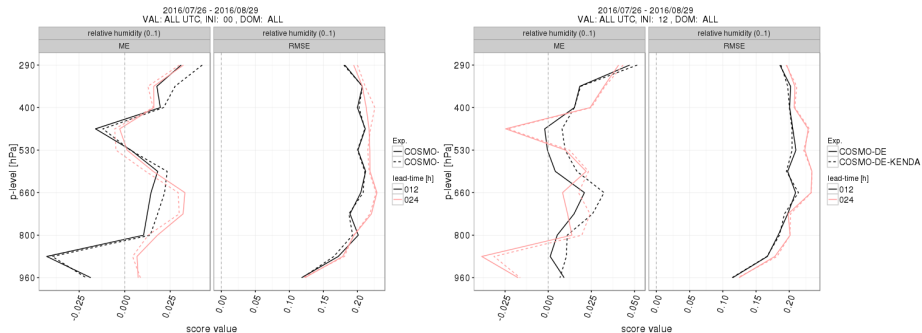


RMSE and ME of COSMO-DE routine (nudging, ICON-EU BC; black) and **parallel routine 1** (KENDA, ICON-EU BC; red), 12 UTC runs

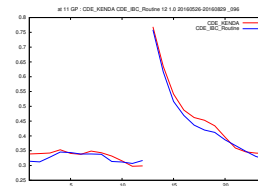
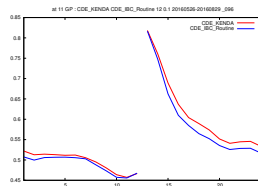
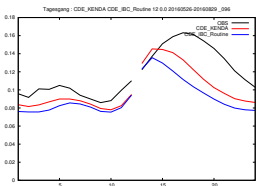
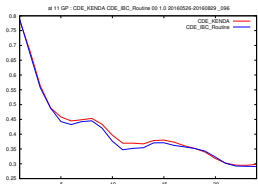
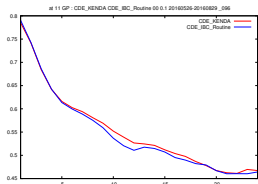
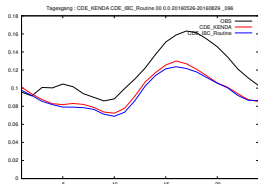


RMSE and ME of COSMO-DE routine (nudging, ICON-EU BC; full line) and parallel routine 1 (KENDA, ICON-EU BC; dotted line); T 00/12 UTC, wind speed 00/12 UTC, 12 and 24 h forecast time

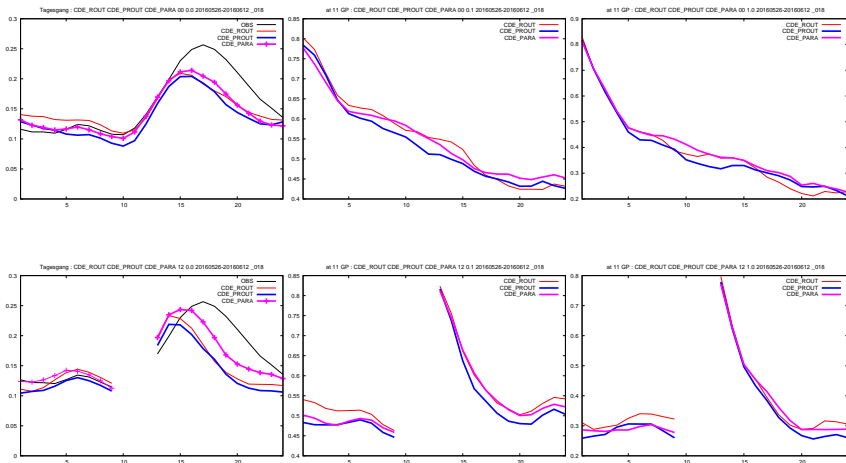
Verification of parallel routine (TEMP)



RMSE and ME of COSMO-DE routine (nudging, ICON-EU BC; full line) and parallel routine 1 (KENDA, ICON-EU BC; dotted line); relative humidity 00/12 UTC, 12 and 24 h forecast time



Radar precipitation verification, **Routine** and **KENDA**; 00/12 UTC runs; diurnal cycle, FSS 0.1 mm 00/12 UTC run, FSS 1.0 mm 00/12 UTC run



Radar precipitation verification for convective period, Routine, parallel routine, KENDA; 00/12 UTC runs; diurnal cycle, FSS 0.1 mm 00/12 UTC run, FSS 1.0 mm 00/12 UTC run

Verification of parallel routine

- ▶ Precipitation: KENDA better than nudging, especially for convective period
- ▶ SYNOP: PS worse, T neutral
- ▶ SYNOP: RH2M worse (during first 3 h); likely due to assimilation of SYNOP-RH2M in nudging
- ▶ TEMP: overall neutral results

Remaining problems

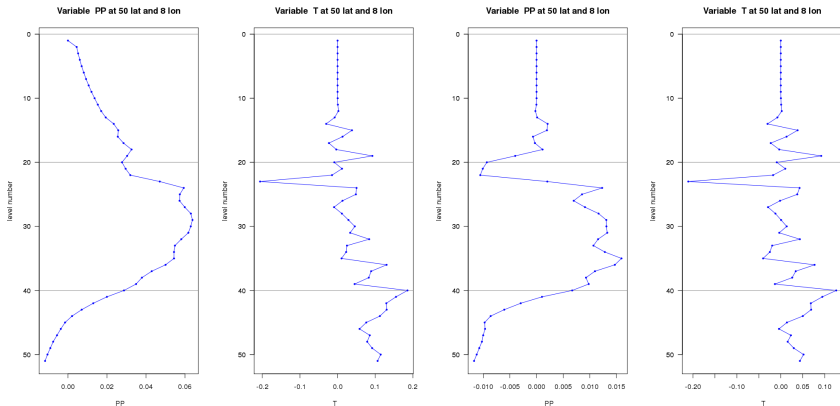
- ▶ PS error: increases strongly bewtween analysis and 1. forecast hour!
- ▶ Remains larger than in nudging for longer forecast times
- ▶ → experiments with hydrostatic balancing

hydrostatic balancing

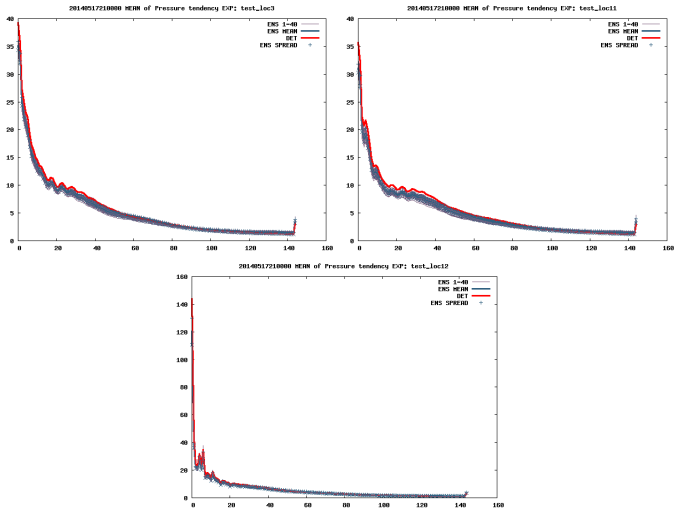
- ▶ analysis *increments* are not hydrostatic balanced
- ▶ → source of vertical velocity
- ▶ not desired, because analysis increments are noisy due to limited ensemble size (and localisation, correlations)
- ▶ → "hydrostatic balancing" of analysis *increments*
- ▶ from nudging:
Integration of hydrostatic equation from surface to top with pressure increments of the lowest level and temperature/humidity increments on all levels
→ pressure increments at upper levels
- ▶ BUT: analysis increments of $P \neq 0$ also at model top, increase of surface pressure RMSE/BIAS between analysis and forecast hour 1

hydrostatic balancing

- ▶ idea: Integration of pressure from top to bottom; adapt T-profile to ensure that surface pressure increment is conserved
- ▶ a similar temperature correction is done in the nudging to correct for surface pressure bias from BC
- ▶ advantage: analysis increment of $P = 0$ at model top; better surface pressure forecast?



Profile of pressure/temperature increments at GP close to OF, balancing of P (left), modified balancing (right)



dps/dt as function of time step, with balancing of P (upper left),
 modified balancing (upper right), no balancing

PS error

```
# PS statistics for SYNOP
```

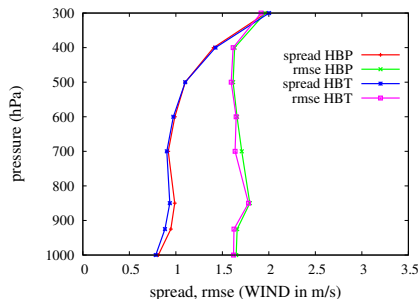
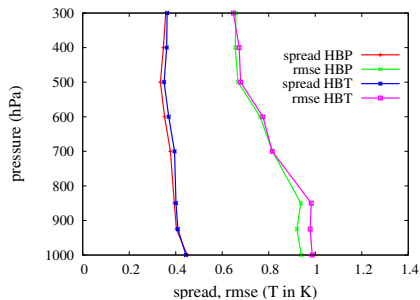
```
# Region: COSMO-DE
```

#	av(o-f)	s(o-f)	av(o-a)	s(o-a)	rms(o-f)	rms(o-a)
HBO	56.890	73.651	6.362	44.311	93.063	44.764
HBP	35.455	49.664	1.546	26.603	61.021	26.647
HBT	12.488	45.824	0.265	27.601	47.495	27.602

HBO: no balancing (old period) HBP: hydrostatic balancing of P

HPT: modified balancing

hydrostatic balancing



HPT: modified balancing
HBP: hydrostatic balancing of P

adjustement of wind field

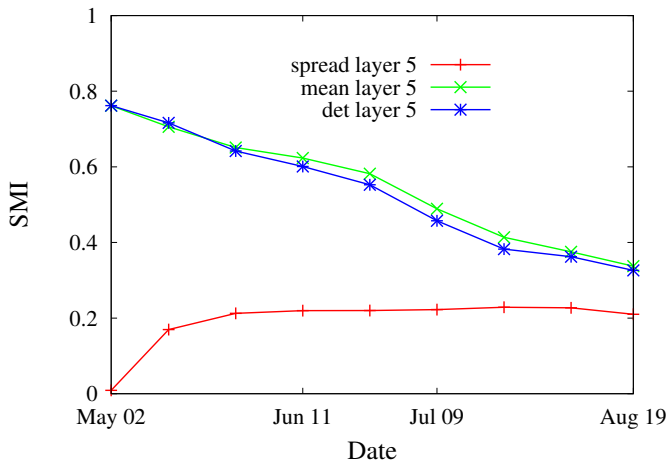
- ▶ also problems with noise in ICON-LETKF
- ▶ Harald Anlauf implemented alternative balancing
- ▶ bases on the adaption of divergent wind field to fulfill continuity equation
- ▶ described in ECMWF-LETKF paper
- ▶ tested within 2 day experiment; reduces the noise by 15 % , but no effect on RMSE
- ▶ Christoph Schraff is currently implementing the IAU (Incremental Analysis Update) in the COSMO code

Soil moisture perturbations

- ▶ perturb soil moisture (and SST) with defined spatial and temporal length scales and amplitude
- ▶ soil moisture: 2 length scales, 100 km (synoptic), 10 km (convection)
- ▶ limit perturbation amplitude to “available capacity”
- ▶ relax ensemble towards the unperturbed soil moisture of the deterministic run to avoid bias

```
name = 'W_SO'           ! disturb soil moisture
scales = 0.002 100 1 24 ! 0.004 of soil capacity, 100km,
                        ! 1m vertical, 24 hour
          0.002 10 1 24 ! 0.004 of soil capacity, 10km,
                        ! 1m vertical, 24 hour
name = 'SST'           ! disturb SST
scales = 1 100 0 24 ! 1K + 100 km length scale pattern,
                  ! 24 hour
adj_wso    = .5 .5 .5 .5 .5 .5 .5 .5
```

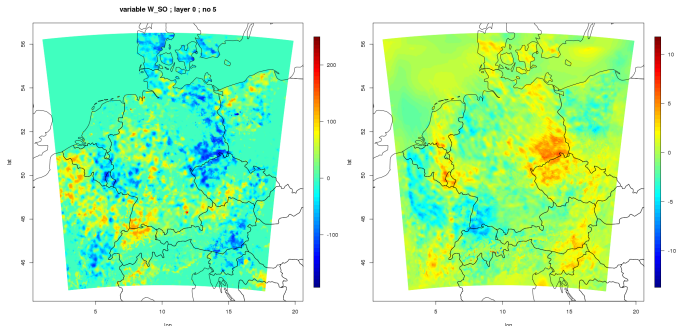
Soil moisture Index (SMI)



time series of W_{S0} at 27-81 cm layer for ensemble mean, ensemble spread and det run

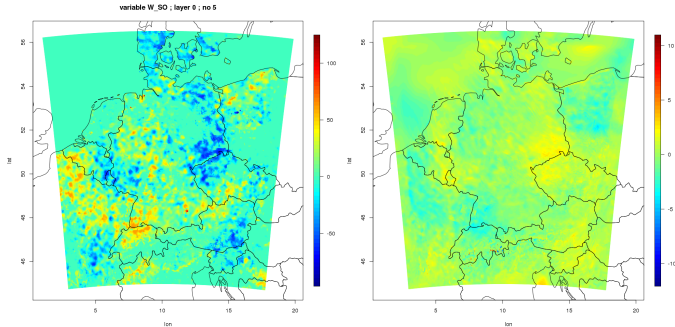
Soil moisture perturbations

- ▶ no bias, but too strong soil moisture perturbations lead to large T2M differences in ensemble members:



difference between ensemble member 1 and ensemble member 8 at 2016082400, W_SO (analysis, left), T_2M (12 hour forecast, right), for standard perturbations

- ▶ to check the sensitivity of T2M to W_SO perturbations, we reduced the perturbations by a factor 0.5:



difference between ensemble member 1 and ensemble member 8 at 2016082400, W_SO (analysis, left), T_2M (12 hour forecast, right), for reduced perturbations

- ▶ experiment shows nearly linear response of T_{2M} differences to W_{S0} perturbations
- ▶ → implement spread limiter to W_{S0} perturbation subroutine
- ▶ test effect on assimilation cycle & forecast quality

next steps in parallel routine

- ▶ before operationalisation of KENDA:
- ▶ compute winter experiment
- ▶ already done in bacy (with neutral results), but with old (BC) setup

KENDA Experiments: overview

- ▶ KENDA-BACY: BC from (pre)operational ICON-EU
- ▶ setup very close to parallel routine; switched to grib2
- ▶ 20160525-20160701 is new test period
- ▶ intense convection, esp. during first 2 weeks

- ▶ test spread limiter, hmodified hydrostatic balancing; Mode-S experiments (runs technically), adaptive inflation with estimated obs errors, pattern generator

Summary

- ▶ KENDA is running in the parallel routine since 2.May
- ▶ SYNOP: PS worse, related to hydrostatic balancing, experiments running
- ▶ alternative balancing (adaption of wind field), IAU?
- ▶ TEMP: neutral
- ▶ Precipitation: KENDA better than nudging

- ▶ Christoph Gebhardt will talk about KENDA ensemble results