**Deutscher Wetterdienst** 



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→ Local Ensemble Transform Kalman Filter (LETKF) (Hunt et al. 2007, Physica D)

operational since 21 March 2017 for deterministic + EPS forecasts



this talk:

changes in 2017: - 5 July:

- limiter to soil moisture perturbations
- 8 Feb.: additive covariance inflation
- 4 Oct.:
- Mode-S aircraft observations

 $\rightarrow$  wintertime low

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stratus

+ first guess check thresholds





## KENDA at DWD: operational setup

(→ Schraff et al. 2016, QJRMS)



operational settings:

- adaptive horizontal localisation (keep # obs constant,  $50 \text{ km} \le s \approx \text{ std dev} \le 100 \text{ km}$ )
- adaptive multiplicative covariance inflation (obs-f.g. statistics) + RTPP ( $\alpha_p = 0.75$ )
- additive covariance inflation (since Feb. 2017)
- explicit soil moisture perturbations
- lateral **BC**: from **ICON-EnVar/LETKF** ( $\Delta x = 20 \text{ km} / 6.5 \text{ km}$  for ensemble / deterministic run)





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- KENDA (with additive inflation) vs. old operational nudging
  - deterministic forecasts:
    - ✓ positive for convective precipitation in summer
    - ✓ positive for 2-m temperature
    - neutral & negative periods for low stratus in winter
  - **EPS** (20 members, with lateral BC from ICON-EPS,
    - vs. old approach with IC / BC perturbations based on 4 global models):
    - ✓ very positive (in summer & winter, for precip, wind gusts, ...)

→ operational introduction of KENDA: 21 March 2017

• but: pending issue at that time















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### adding explicit random soil moisture perturbations

(with prescribed horizontal (100 km , 10 km) and temporal (1 day) correlation scales and variance (0.72 SMI/day))

 → accumulate over days, saturate eventually at domain average ~ 20 – 25 % SMI (soil moisture index SMI: 0 at plant wilting point, 1 at field capacity: a kind of relative humidity)

- modification: no further explicit SM perturbations added where spread(SMI) > 15 %
  - → "soft limiter" for SMP





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soft limiter of soil moisture perturbations: impact on a sunny day (23 June 2016)







soft limiter of soil moisture perturbations: impact on **spread** in a sunny day (23 June 2016) **Deutscher Wetterdienst** 



100



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PS

(Pa)

T\_2M **spread** strongly reduced fairly selectively in sunny days as required (by 10 – 40 % at daytime, 5 – 15 % at night, similar for RH\_2M, 5 – 15 % low-level upper-air T, RH, wind) 10-



- ✓ deterministic forecasts: neutral
- EPS: slightly reduced errors (upper-air T, surface pressure, especially bias), slightly improved precip
- hypothesis: due to using of additive covariance inflation (since Feb. 2017), reduction of soil moisture perturbations is even beneficial
- $\rightarrow$  soft limiter to soil moisture perturbations operational since 5 July 2017



6

9

3

0

-10

reduction [%] of CRPS for ps

12

15

18

lead time [h]

21

24



9





KENDA much worse than nudging !

### → additive covariance inflation:

- additional random perturbations in all LETKF analysis ensemble members, based on climatological forecast error covariances from global EnVar for ICON
   (B = L L<sup>T</sup>; y = L x, where x : random vector (with reduced resolution/dimension))
- purpose: account for model errors in a better way,
- → increases ensemble spread, increases (error) space spanned by ensemble, notably where it underestimates uncertainty of first guess in the presence of systematic errors (→ e.g. for low stratus)
- $\rightarrow$  increases weight of observations in analysis





# winter experiment on additive inflation: radiative low stratus









winter experiment on additive inflation: vertical profiles, 50°/10°, 5 Dec. 2016, 12 UTC **Deutscher Wetterdienst** 



additive inflation:

- winter: large positive impact on low stratus + 2-m temperature bias very positive for EPS
- summer (convective period) :
  - ~ neutral impact

(possibly due to larger effect of soil moisture perturbations in summer)

 $\rightarrow$  introduced in KENDA parallel suite on 8 Feb.







**Mode-S** EHS (Enhanced Surveillance) aircraft data

### Mode-S aircraft





# Mode-S aircraft: winter test (Dec. 2016), verification

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correct cloudy / / missed events / false alarms / undefined (observed higher cloud)

missed (black): 21309 false (red): 12950 hits (green): 27447 unclear (blue): 18832 ETS: 0.321 FBI: 0.828

missed (black): 19905 false (red): 12150 hits (green): 28851 unclear (blue): 18832 ETS: 0.352 FBI: 0.840



6N

5N

4N

3N

2N

1N

ΕQ

1S

2S

3S



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missed (black): 19956 false (red): 19707 hits (green): 52658 unclear (blue): 8240 ETS: 0.380 FBI: 0.996 missed (black): 17496 false (red): 19482 hits (green): 55118 unclear (blue): 8240 ETS: 0.412 FBI: 1.027





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 missed (black): 14148 false (red): 18256 hits (green): 24156 unclear (blue): 10744
 missed (black): 14429 f

 ETS: 0.320 FBI: 1.107
 ETS: 0.337 FBI: 1.042

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- impact of Mode-S depends on weather situation:  $\checkmark$ from very slightly to
  - clearly positive for

summary

Impact of Mode-S aircraft:

- (radiative) low stratus
- convective precipitation in summer  $\rightarrow$

- Mode-S operational 4 October 2017
- $\rightarrow$





26 May – 10 June 2016







first guess check: reject obs  $T_o$  if: (here: for temperature) threshold:  $\Delta T_{thresh} = f \cdot \operatorname{std}\{T_o - T_{fg}\} = f \cdot \sqrt{\sigma_0^2 + \sigma_{ens}^2}$   $\leq 4K$ f = 3

→ strong inversions with wintertime low stratus: many correct obs rejected ensemble spread considers only random errors (as intended)

#### strong systematic error: not accounted for

revision:

$$\Delta T_{thresh} = f \cdot \operatorname{std} \{ T_o - T_{fg} \} = f \cdot \sqrt{\sigma_0^2 + \sigma_{ens}^2 + \left(\frac{1}{f} \cdot \varepsilon_{inv}\right)^2}$$

$$\varepsilon_{inv} \cong 0.8 \cdot \Delta T_{inv} \qquad \text{(within 25 hPa; tapering above 800 hPa, ....)}$$

$$\Delta T_{inv} : \text{ inversion observed by radiosonde}$$

... similar revision for humidity threshold





#### DWD Revised first guess check thresholds: winter test, low-level cloud (low stratus) **Deutscher Wetterdienst** revised f.g. check REF Mode-S Dec. 2016 analyses for 20 Dec., 18 UTC Satellite: Satellite: Satellite: Model Model missed (black): 25078 false (red): 21965 hits (green): 80911 unclear (blue): 3 missed (black): 28577 false (red): 19405 hits (green): 77412 unclear (blue): 3 missed (black): 25843 false (red): 22286 hits (green): 80146 unclear (blue): 3 ETS: 0.195 FBI: 0.970 ETS: 0.200 FBI: 0.913 ETS: 0.185 FBI: 0.966 12-h forecasts for 21 Dec., 06 UTC Satellite: Satellite: Satellite: missed (black): 19809 false (red): 18694 hits (green): 62042 unclear (blue): 4 missed (black): 29995 false (red): 17831 hits (green): 51856 unclear (blue): 4 missed (black): 17401 false (red): 19643 hits (green): 64450 unclear (blue): 4 ETS: 0.323 FBI: 0.986 ETS: 0.229 FBI: 0.851 ETS: 0.339 FBI: 1.027 / missed events / false alarms / undefined correct cloudy /



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# Revised first guess check thresholds: winter test

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Revised first guess check thresholds:

- $\checkmark$  positive impact on low stratus
- ✓ slightly positive for T2M, RH2M

✓ to be tested further









important for low stratus (presence of strong systematic errors):

- ✓ additive covariance inflation
- ✓ additional data: Mode-S
- ✓ adjust quality control (for radiosondes)











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