Recent developments in KENDA

Christoph Schraff

Deutscher Wetterdienst

KENDAscope: KENDA from Surface to Cloud Observations Progressive Extension
(Sept. 2020 – Aug. 2025)

- Task 1: algorithmic developments
  - refinements of LETKF → minor improvements
  - EnVar (+ 4D-EnVar) → EnVar for LAM runs technically in prelim. version
  - Particle Filter → success at improving ens. spread, tests with ICON-D2
- Task 2: observations (from surface to clouds)
  - Radar (Z + Vr) → DWD: e.g. adjust for 2-mom. microphysics
  - GNSS ZTD + STD → tech. work tbd. before ICON-D2 impact exp. (limited resources)
  - **all-sky IR WV + VIS** SEVIRI data
  - MTG IRS → project started on 15 March 2021
  - **screen-level obs (T2M, RH2M)** → e.g. in context of fog / low stratus
  - PBL profiling obs (wind lidar, MW radiometer, Raman lidar, drones, towers)
- Task 3: soil / surface → satellite soil moisture: no positive impact yet

\+ ML / NN : research on assimilation cloud info from meteo cam

Radar reflectivity at Arpae (Bologna)

Thomas Gastaldo, Virginia Poli

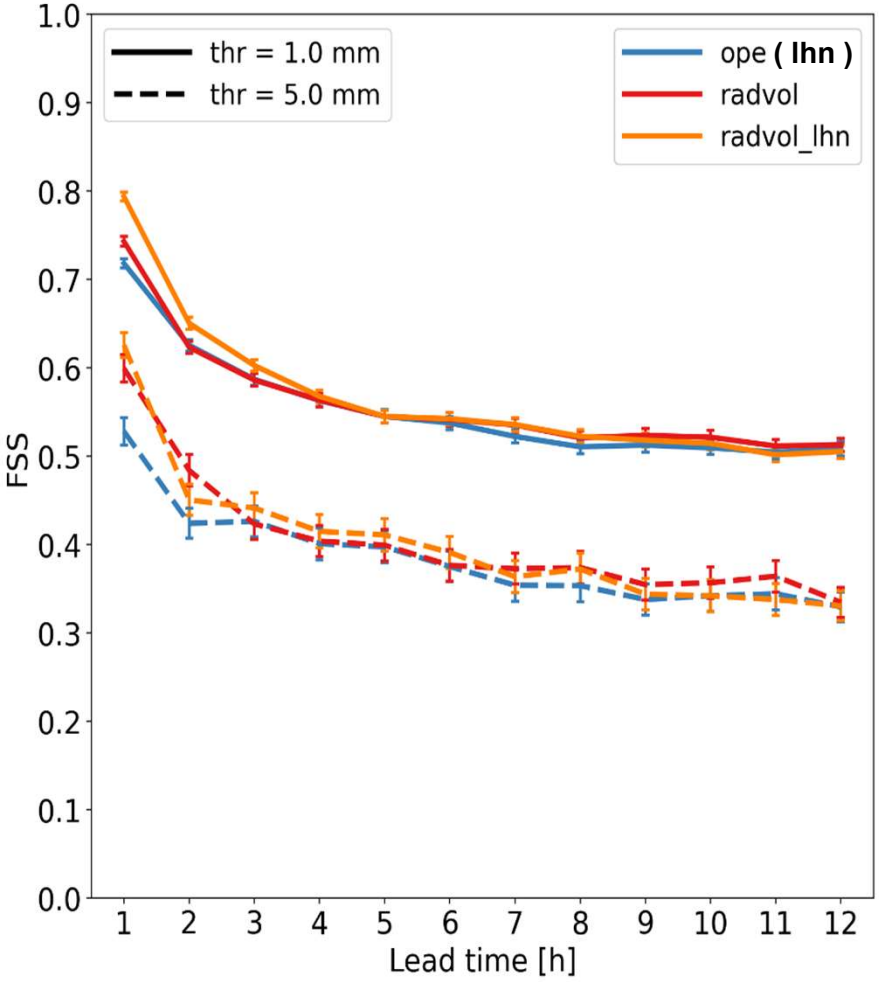
Deutscher Wetterdienst

arpae emilia-romagna

direct assimilation of
3-D reflectivity in LETKF:

- RREFL + LHN > RREFL > LHN
  - precip improved up to +3 h (significant)
    resp. + 9 h (not significant)
  - other variables ~ neutral
- w/o LHN: less precip, drying of soil
- introduced operationally in spring 2021

FSS 22 km against rain-gauge adjusted radar
18/09 – 19/10/2020



2-m temperature + humidity obs: BC + **assimilation**

Elisabeth Bauernschubert, C. Sgoff, C. Schraff, K. Stephan

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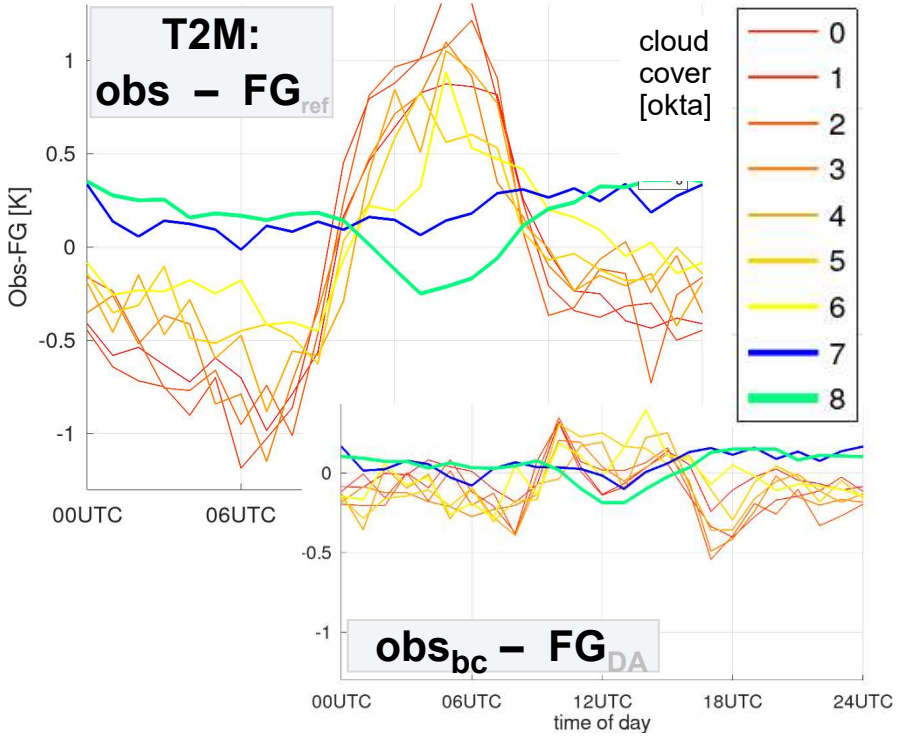
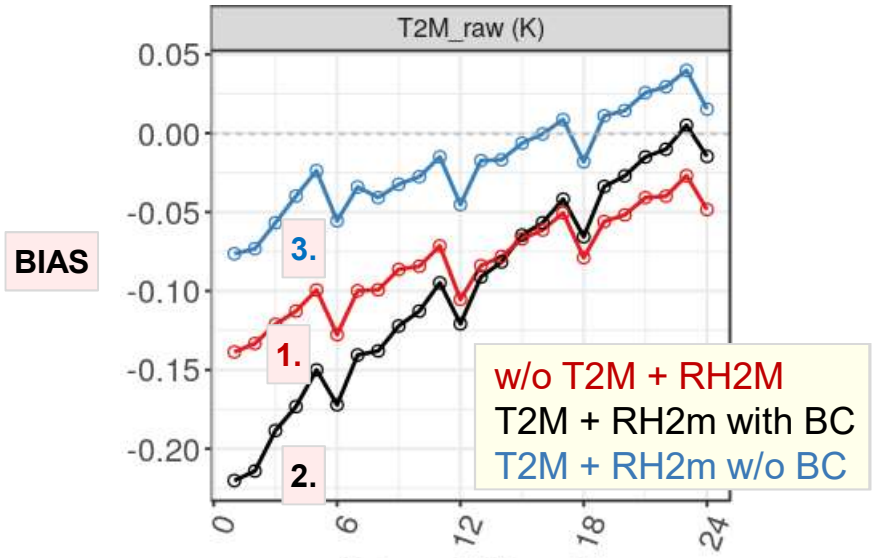
bias correction for T2M, RH2M obs

- station-dependent
- non-linear function of time of day
- linear func. of (observed) cloud cover
- online (dynamic)



assimilation of bias-corrected T2M, RH2M:

- strong positive impact in winter
- undesired positive feedback from bias correction in summer:



1. model FG has cold bias (vs. raw T2M obs)
2. **assimilating bias-corrected cold T2M obs increases cold bias of model FG**
   if verified against raw T2M obs (or radiosonde obs)
3. assimilation of T2M + RH2M w/o BC ok

2-m temperature + humidity obs

Elisabeth Bauernschubert, C. Sgoff, C. Schraff, K. Stephan

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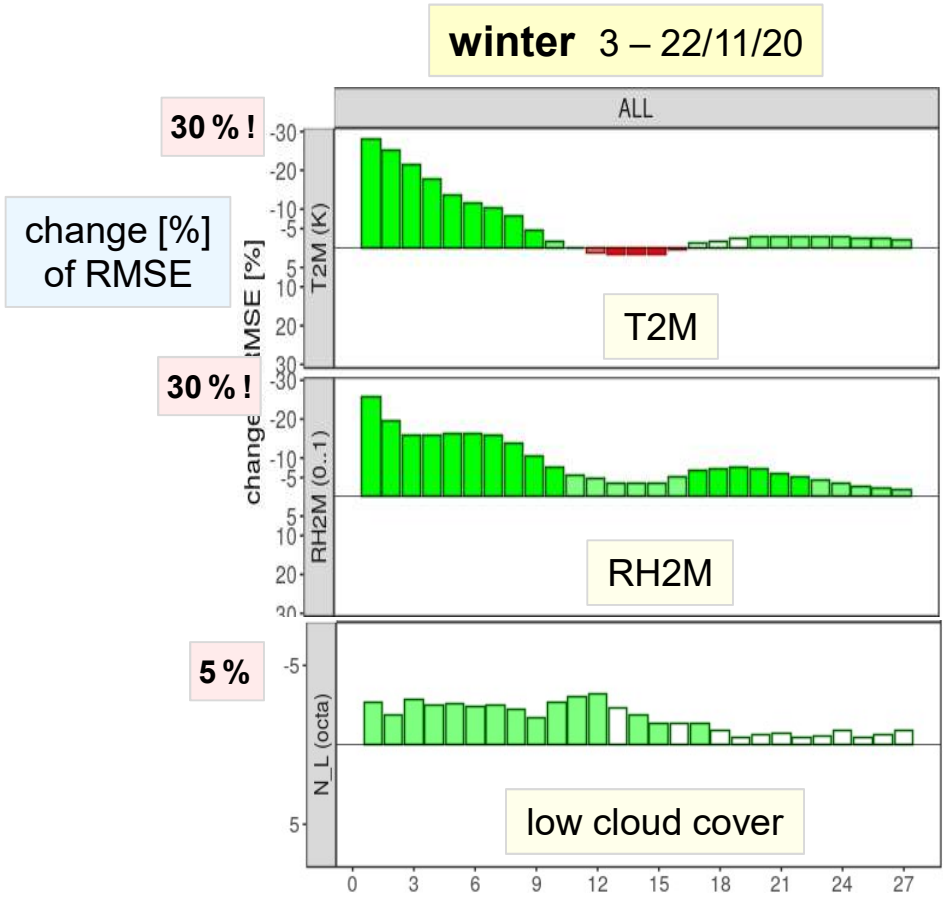
assimilation of T2M + RH2M without bias correction:

- test in winter / for low stratus (Nov. 2020)
- **introduced operationally in ICON-D2 (Q1/21)**

  (… and at COMET IT)
- working on revised bias correction

  (by relaxing large-scale (area-averaged) BC towards zero;
  … satisfactory solution not yet found)



Low stratus, inversions
and the role of **ensemble covariances**

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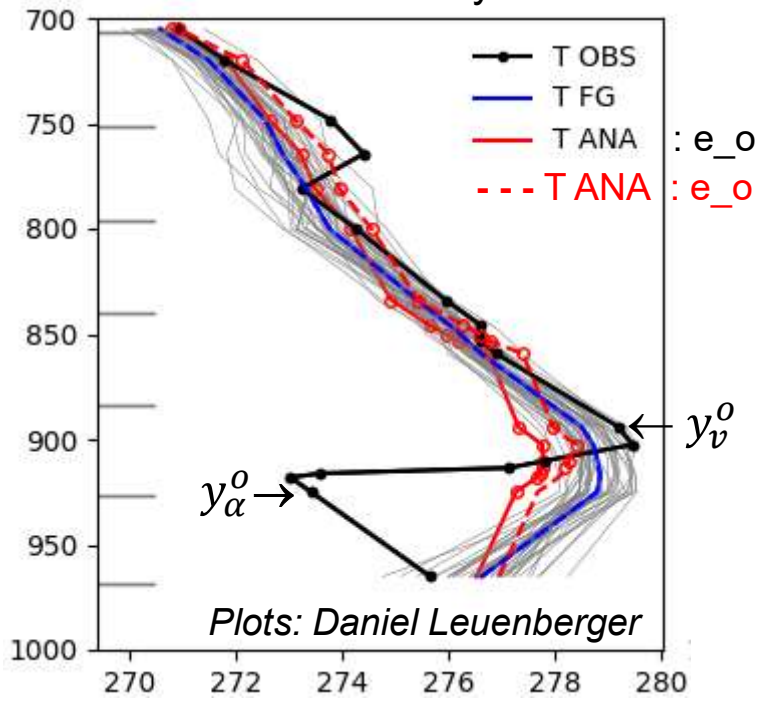
LETKF: problems in case of strong vertical gradients, missing low stratus in Swiss Plat. seen as serious problem at MeteoSwiss after introducing KENDA-1 / **COSMO**1(E)

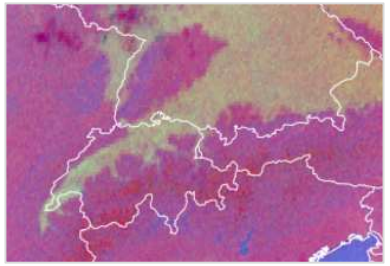
temperature inversion
at radiosonde Payerne



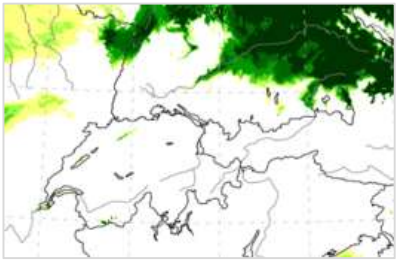
: e_o = e_o(oper)

: e_o = e_o(oper) / 4.

Meteosat



KENDA-1 ana.: low cloud



- decreasing obs errors by factor 4 should have fairly similar effect as increasing ensemble spread by 4
- does not help very much to improve analysis here, i.e. inversion not much enhanced – why?
- reason: across-inversion ensemble covariances $P^{b,\,loc}_{ens(\alpha,v)}$ (> 0) contradict f.g. error 'correlation' $\left(y_v^o - y_v^b\right)\left(y_\alpha^o - y_\alpha^b\right)$ (< 0)

new diagnostics ← *developed by Olaf Stiller*

$$J^b_{\alpha,v} = P^{b,\,loc}_{ens(\alpha,v)}\left(y_v^o - y_v^b\right)\left(y_\alpha^o - y_\alpha^b\right) s^{-1} < 0$$

Low stratus, inversions
and the role of **ensemble covariances**

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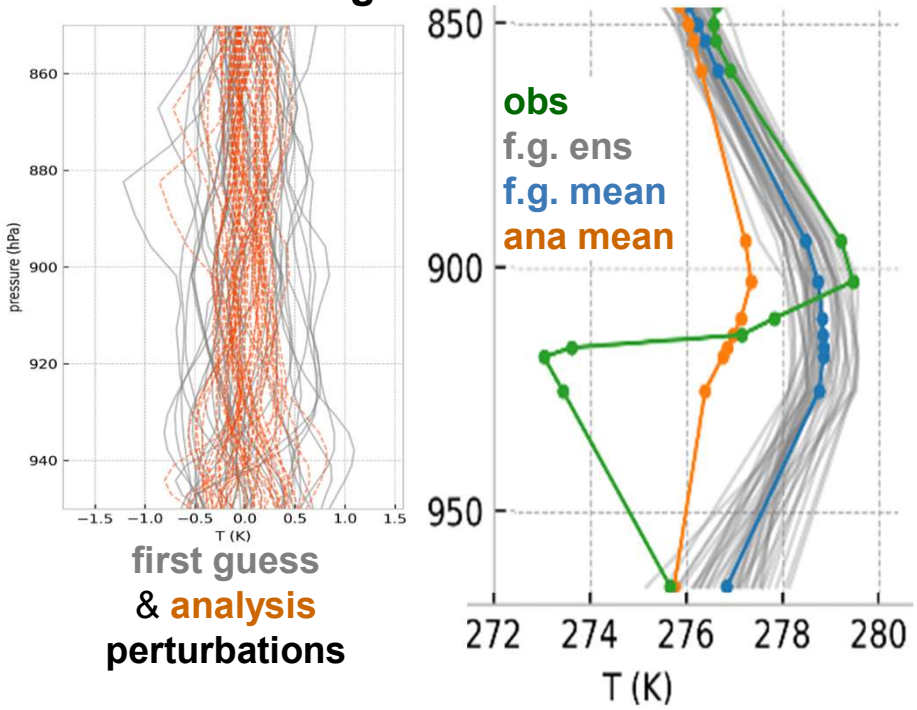
plots by Claire Merker, MeteoSwiss

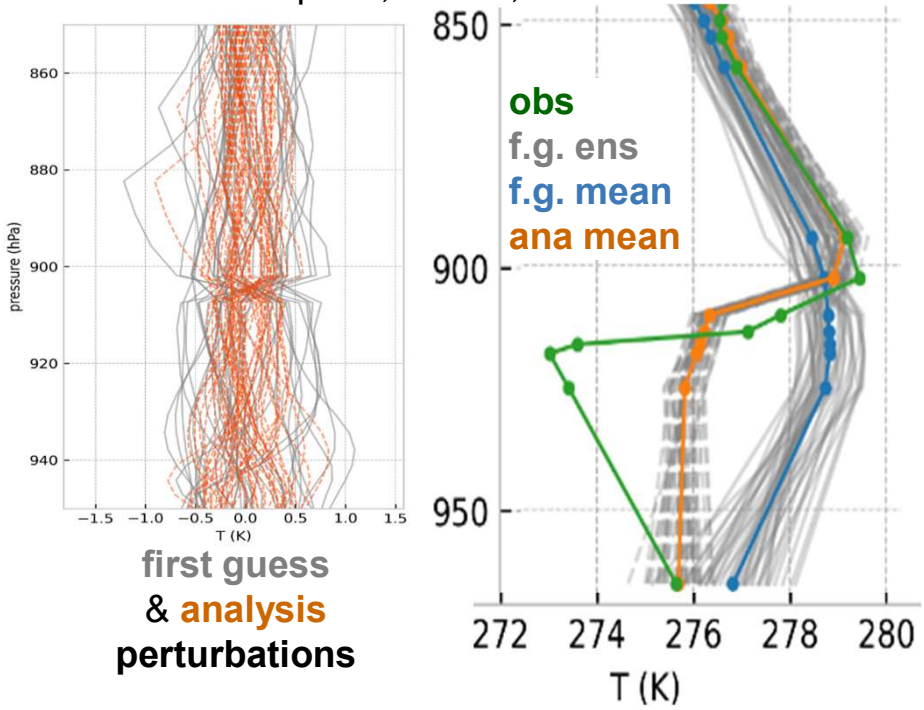
(toy ETKF tool, only 1 model profile)

original ensemble



first guess & analysis perturbations

shuffled ensemble (idealized experiment):
dissect ensemble members at inversion height into 2 parts, shuffle, reassemble



first guess & analysis perturbations

- across-inversion covariances of shuffled ensemble (~ zero) do not contradict f.g. error 'correl.' (negative) → obs below and above do not work against each other → improved analysis
- ensemble covariances crucial in DA → need for better first guess → better model (ICON) → assimilate more obs

Assimilation of T2M + RH2M obs in COSMO-1

Daniel Leuenberger, Claire Merker, Marco Arpagaus

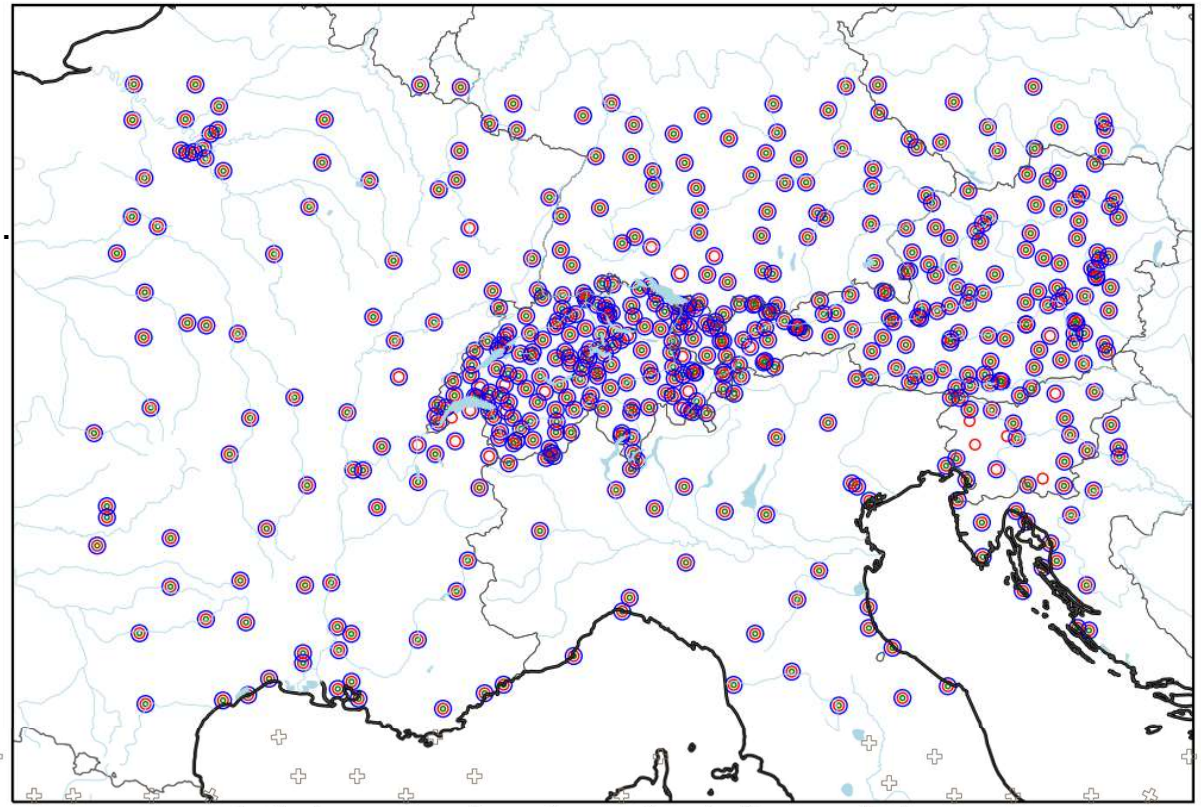
Deutscher Wetterdienst

hourly assimilation of T2M + RH2M obs

… located both below & above the inversion / cloud top

- Period: 21. – 30.11.2020 (10d)
- e-suite KENDA-1 and COSMO-1E (00 and 12UTC)
- **Exp2M**: w. T2M + RH2M assim.
  Ref : operational

locations of active observations



MeteoSwiss

Assimilation of T2M + RH2M obs in COSMO-1 in case of strong inversion / low stratus

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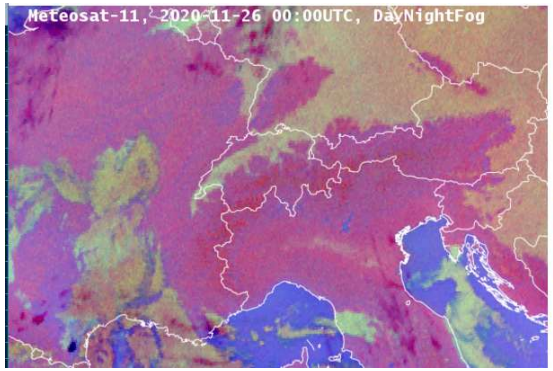
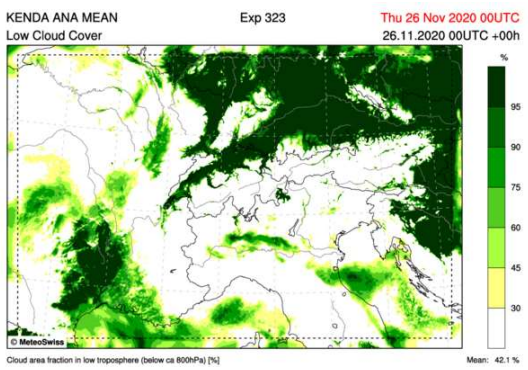
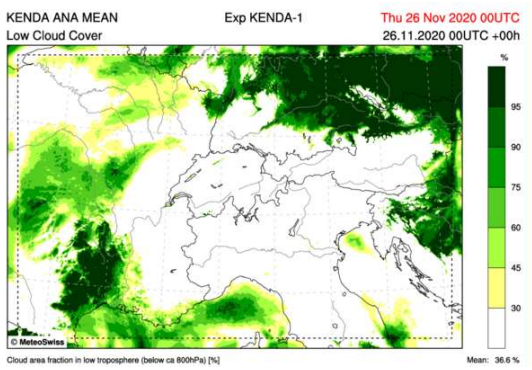
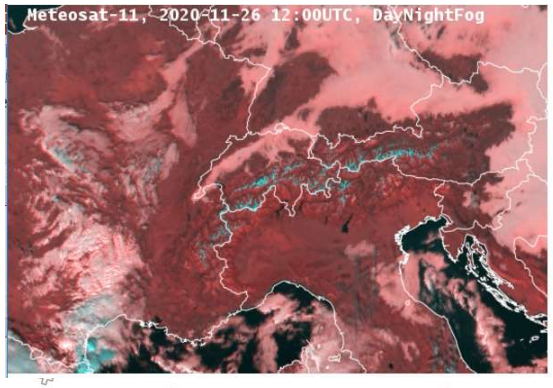
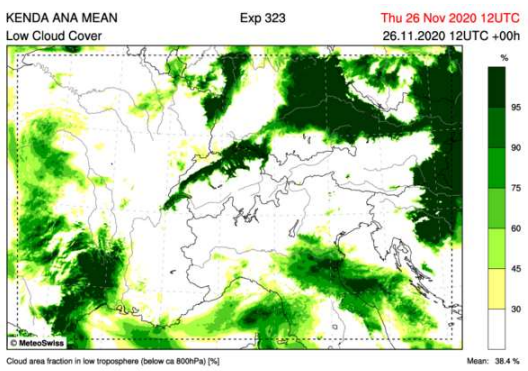
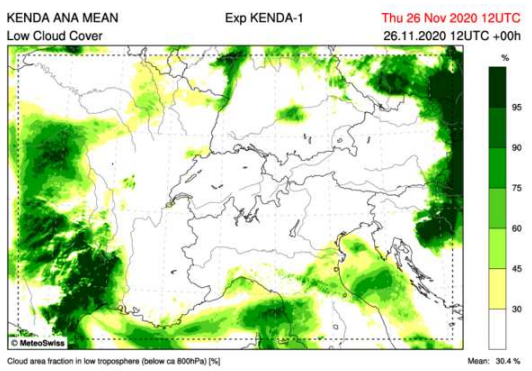
impact on KENDA-1 **analysis** (low clouds)

	Satellite	Exp2M	Ref
26.11.2020 00 UTC			
26.11.2020 12 UTC			

side remark: in pre-operational **ICON**-D2 at DWD Swiss Plateau etc. was covered with low cloud even without T2M + RH2M assimilation

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Assimilation of T2M + RH2M obs in COSMO-1 in case of strong inversion / low stratus

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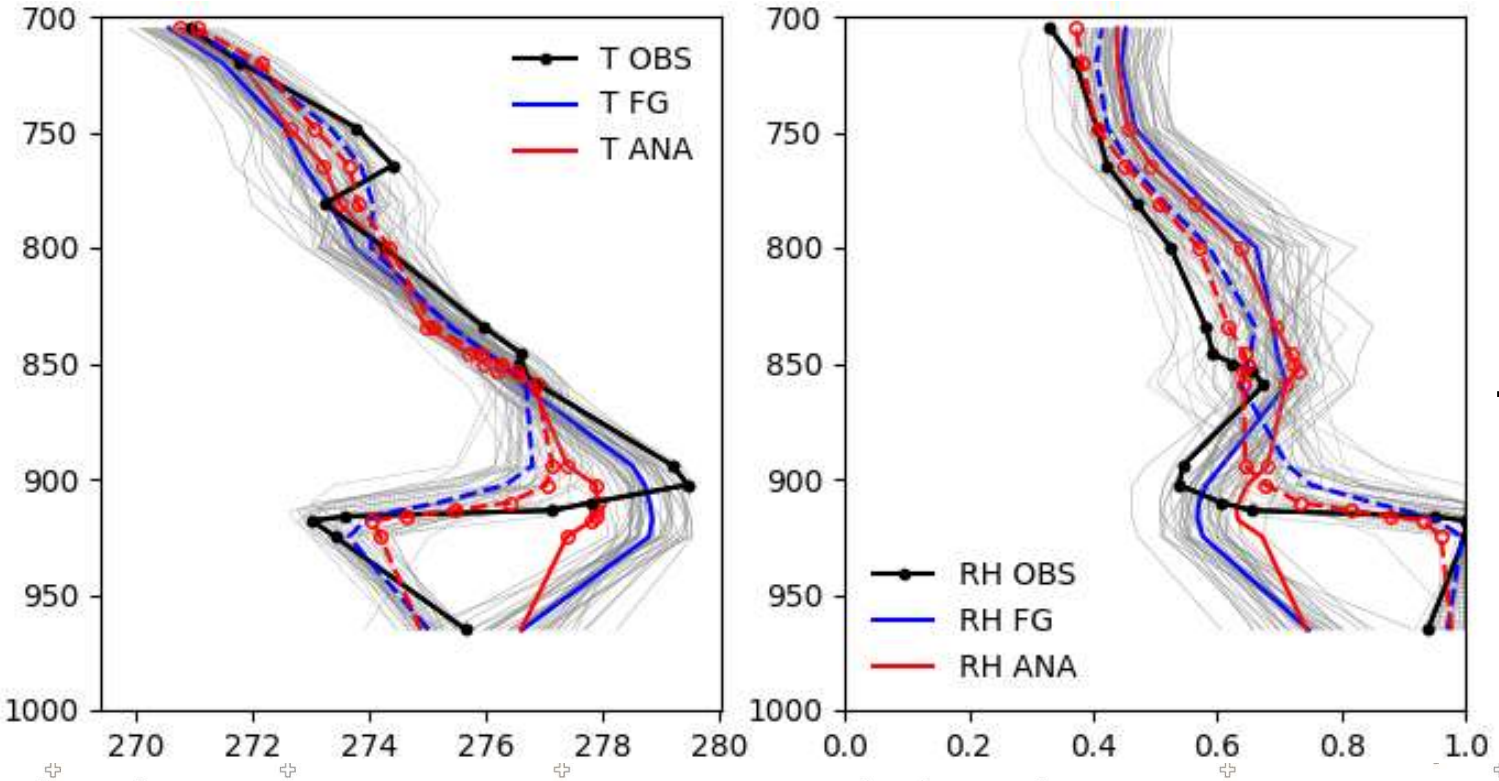
impact on KENDA-1: **vertical structure**

Radiosonde Payerne, 26.11.2020 00UTC



— Ref
--- Exp2M

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Assimilation of T2M + RH2M obs in COSMO-1(E) in case of strong inversion / low stratus

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deterministic forecasts

Parameter	RMSE	Bias	STDE
Precipitation	similar	similar	similar
Cloud Cover	better	better	better
Global Radiation	slightly better	better	slightly better
Sunshine Duration	better	better	better
Temperature	better	slightly better	better
Dewpoint	better	better	better
Relative Humidity	much better	much better	much better
Wind Speed	similar	similar	similar
Wind Gusts	similar	similar	similar
Wind Direction	similar	similar	similar
Station Pressure	similar	similar	similar
Sea Level Pressure	slightly better	slightly better	slightly better
Parameter	Freq. Bias	POD	FAR
Precipitation > 0.2 mm/6h	slightly worse	similar	slightly worse
Precipitation > 5 mm/6h	worse	better	slightly better
Cloud Cover > 2.5 okta	worse	better	similar
Cloud Cover > 6.5 okta	better	better	slightly better
Wind Gusts > 12.5 m/s	similar	similar	similar

virtually no rain in this period

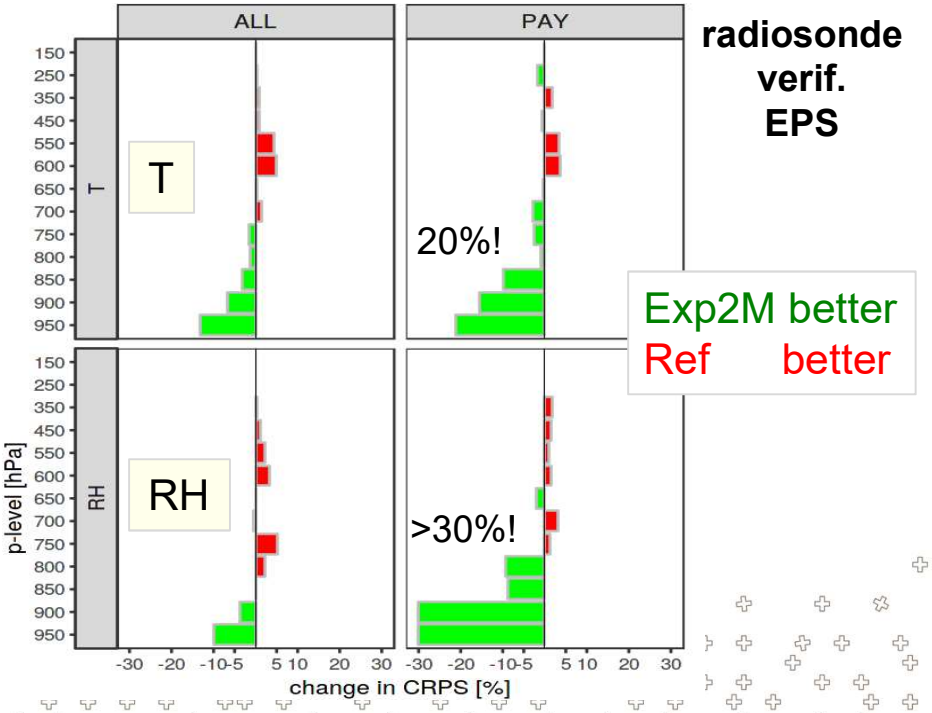
Synop verif.

probabilistic (EPS) forecasts

Parameter	Spread/Error	RPSS	BSS (low thr.)	BSS (high thr.)
Precipitation (6h)	similar	slightly worse	slightly worse	slightly better
Cloud amount	better	much better	much better	much better
Temperature	better	much better	much better	similar
Dewpoint	better	much better	much better	much better
Wind speed	similar	slightly better	slightly better	similar
Gusts	similar	slightly better	slightly better	better

virtually no rain in this period

radiosonde verif. EPS



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Assimilation of T2M + RH2M obs summary

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- strong vertical gradients: challenge for the model & DA system → bad FG + ana
- **1-hourly** assimilation of T2m + RH2m a game changer
  - T2m + RH2m improved, **better FG** for assimilation of radiosonde
  - fog much better represented in analysis
  - positive impact up to +24h
  - operational since 27 Sept. 2021
  - put more efforts on station selection + quality control

outlook

- use more obs: wind lidar, Raman lidar, MWR, meteodrones, RAOB descents
- ICON (low stratus (in Nov. 2020) much better in ICON-D2 @ DWD)

MeteoSwiss

All-sky assimilation of **SEVIRI** satellite data
In KENDA: mainly information on cloud

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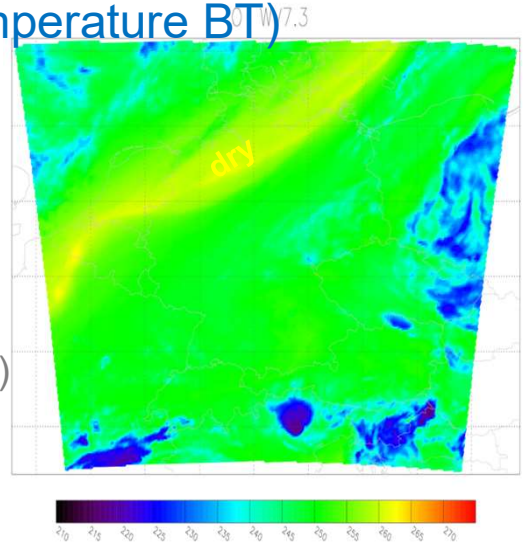
- Infrared (**IR**) water vapour (**WV**) radiance (as brightness temperature BT)

  ***Annika Schomburg**, Lilo Bach, Christina Stumpf, Christoph Schraff, et al.*

  – vertical localization around cloud top height (← transmission)

  – observation error: 6 K fixed for both channels
  → info on high + mid-level cloud
  very small influence of clear-sky WV info
  (obs incr. + backgr. error, WV: few K; high cloud: 20 / 40 K)
  (obs error revised in most recent sensitivity exp., not shown)



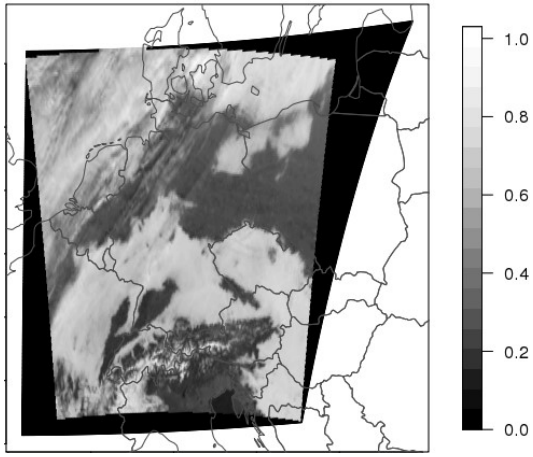
- Visible (**VIS**) reflectance

  ***Lilo Bach,** Thomas Deppisch, Christina Stumpf, Leonhard Scheck, et al.*

  – no vertical localization (because no info on vertical position;
  sensitive from high to low cloud)

  – reflectance obs error = 0.2 fixed , superobbing 12 km

  – sensitive to larger range of LWP / IWP (→ cloud thickness)
  & cloud optical properties (liquid / ice; effective radii, etc.)



- 1 scan per hour, no bias correction, … , 3 – 25 August 2020 (23 days)

All-sky assimilation of SEVIRI IR **WV** radiances: Impact experiments

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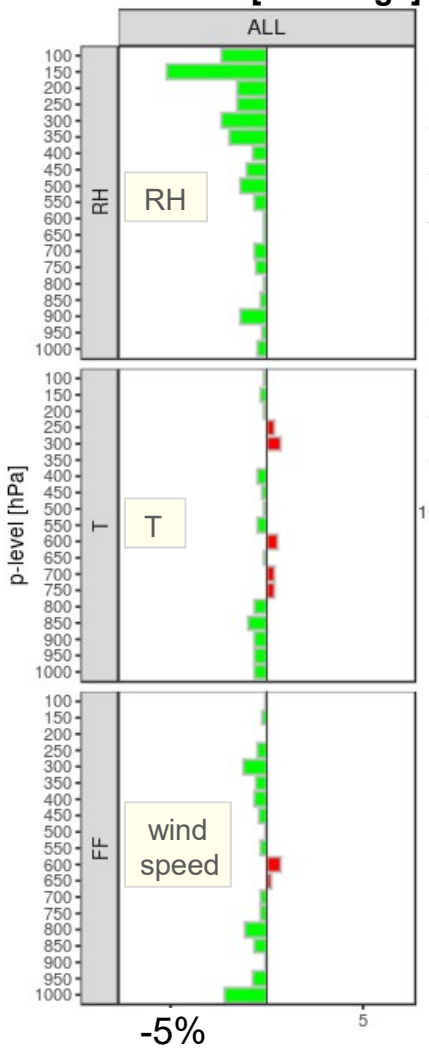
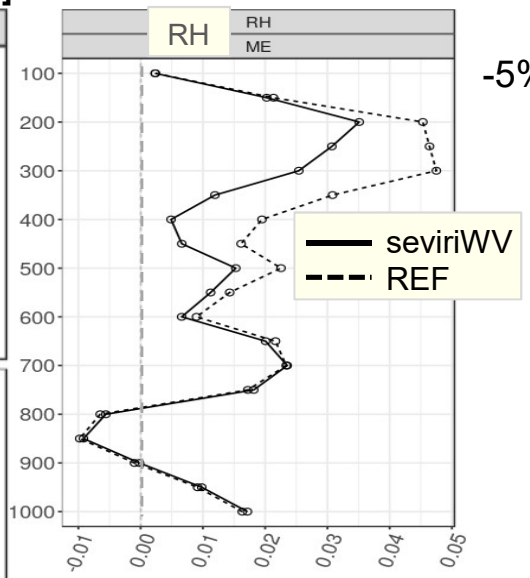
radiosonde verification

stdev [% change]



bias



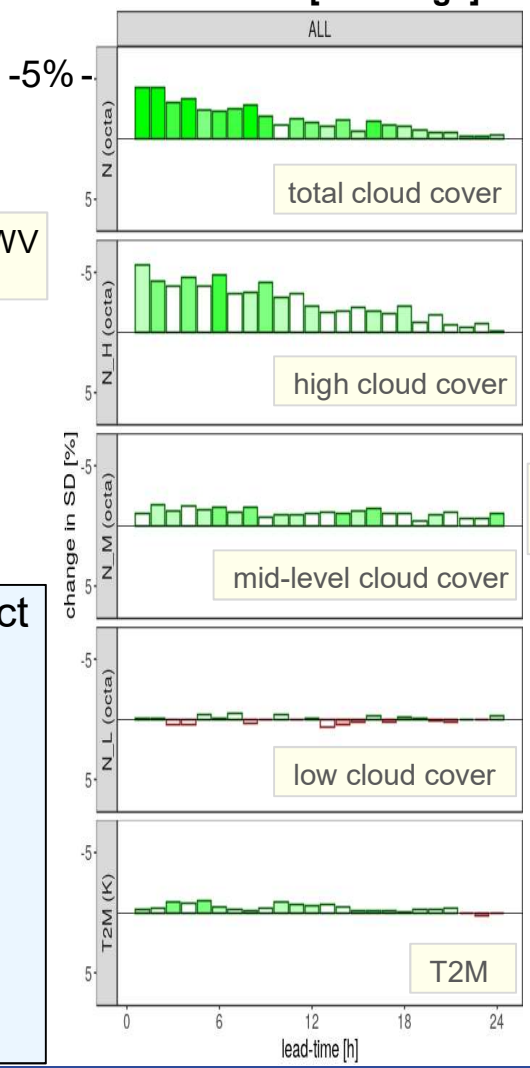
- small positive impact also on precip, no show stopper

further steps:

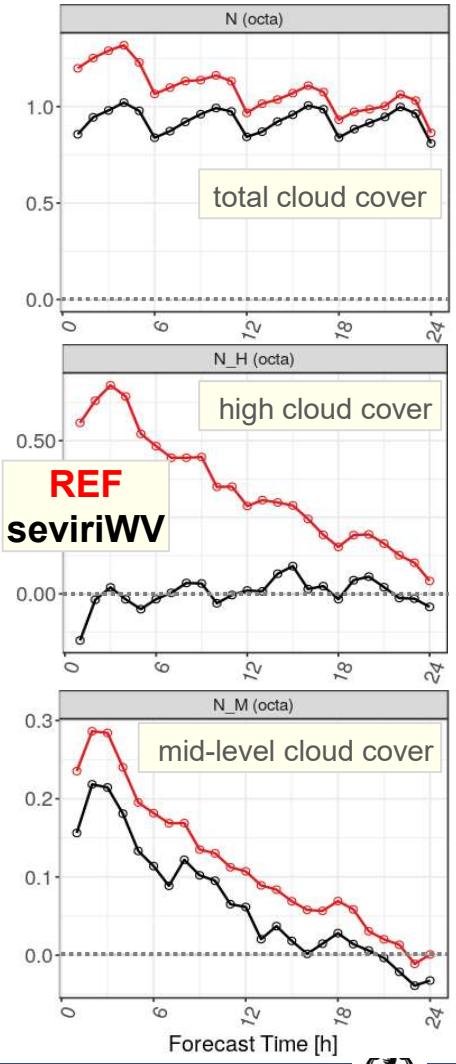
- obs error (→ WV)
- bias correction
- obs op.: slant path, super'modding'

synop verification

stdev [% change]



bias



All-sky assimilation of SEVIRI **VIS** or **WV**: Impact experiments (all-sky) : results

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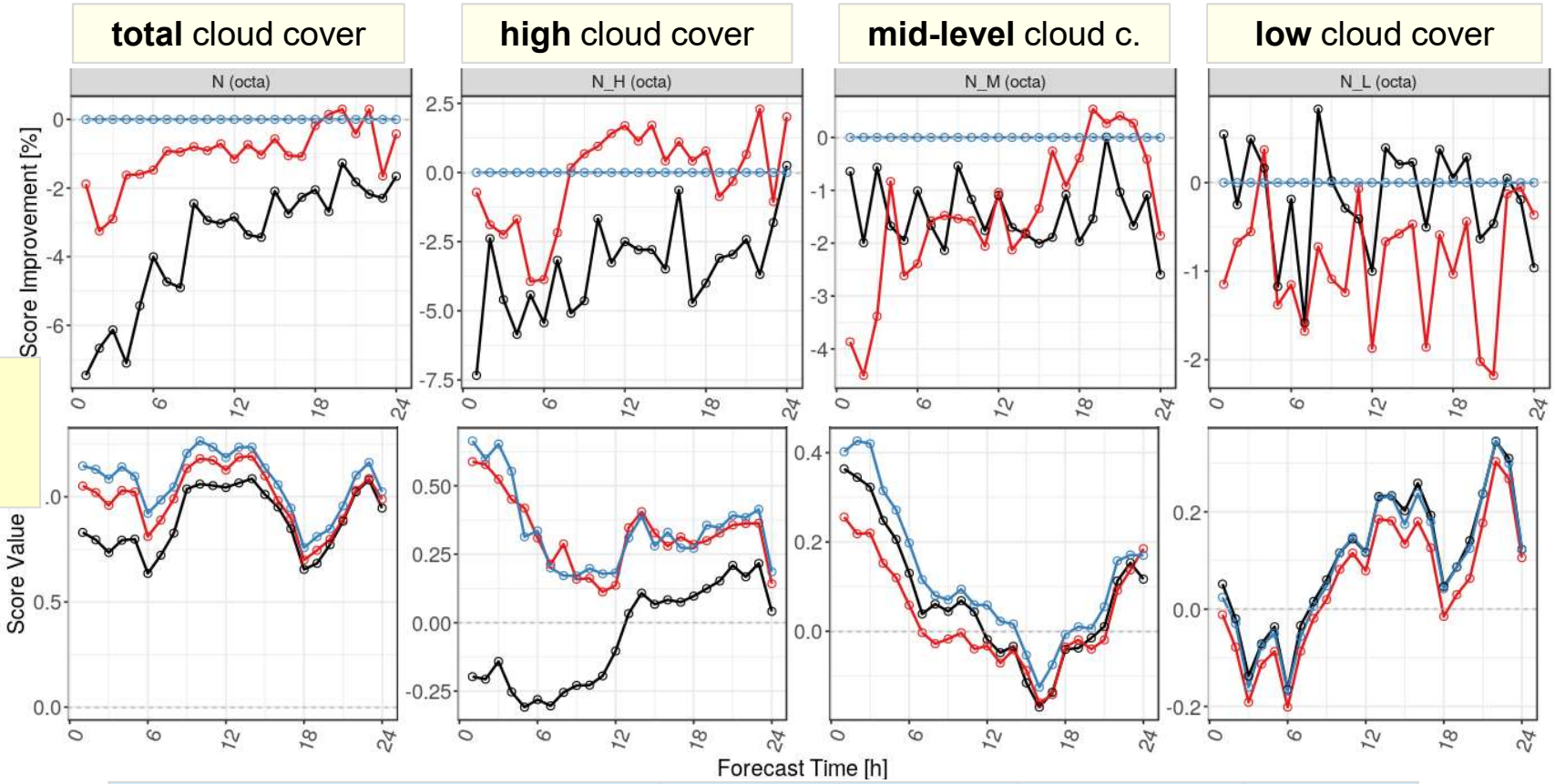
summer 03 – 26/08/20

12-UTC forecast runs

RMSE change [%]

I-D2 **Ref**
seviriWV
seviriVIS

BIAS



cloud		total	high	mid-level	low
VIS	12-UTC runs	+	(+)	+	(+)
IR-**WV**	(all runs (0,6,12,18))	++	++	(+)	0

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All-sky assimilation of SEVIRI **VIS** reflectance in ICON-D2

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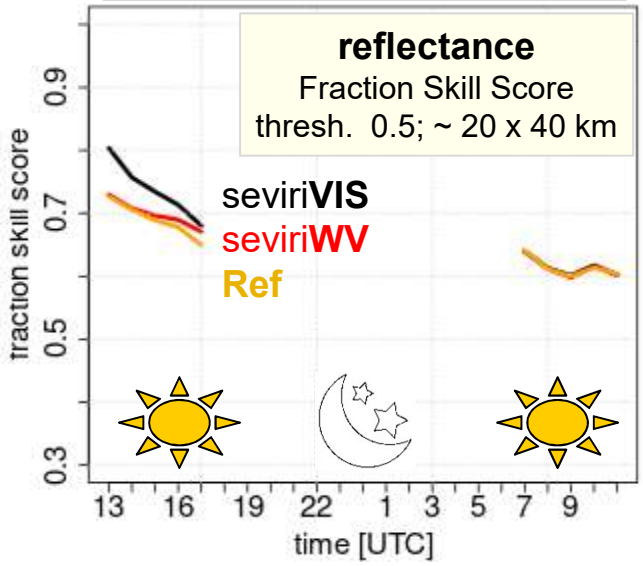
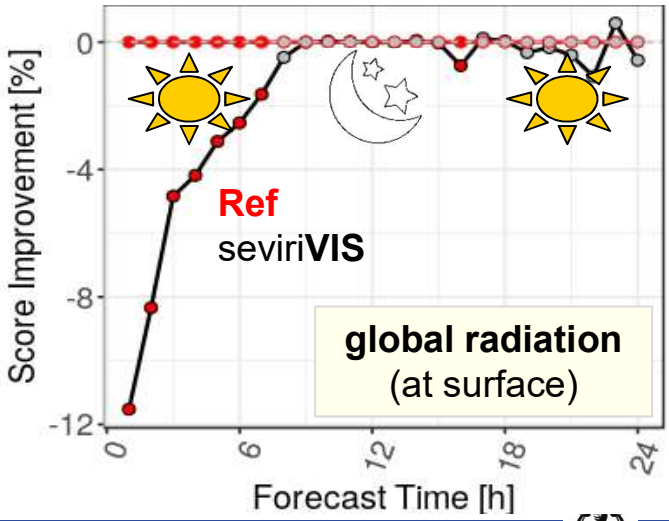
- positive impact on reflectance, (mid-level + low) cloud, global radiation (+ T2M, RH2M) in 12-UTC forecast runs
- little impact on other variables (incl. precip)
- little impact in 0-, 6-, 18-UTC forecast runs
- results depend highly on consistency betw. simulated and observed reflectance histograms and on model version →
  - (ICON) model tuning
  - consistency MFASIS obs op. / ICON
  - bias correction, …
- introduction in SINFONY-RUC & ICON-D2 parallel suites pursued in near future
- combination VIS + WV

12-UTC forecast runs

FSS REFL



RMSE change [%]



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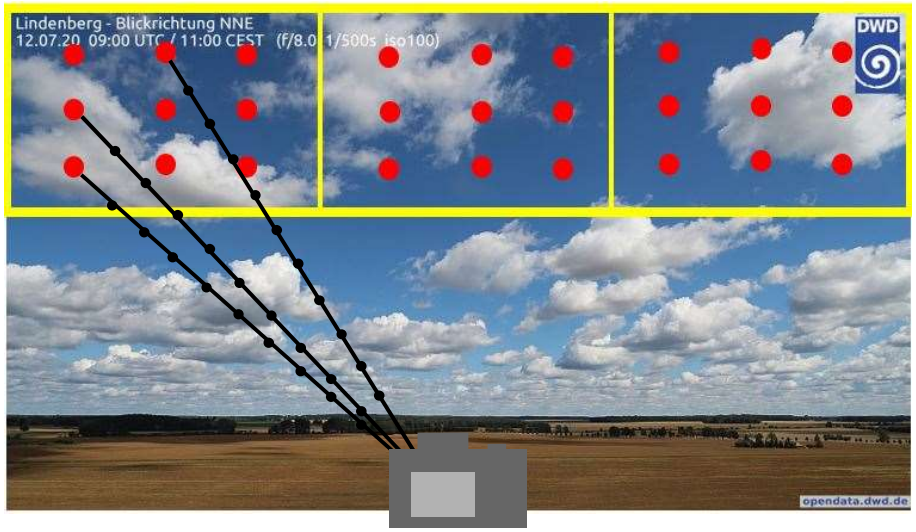
Assimilation of cloud info from meteo / web cams

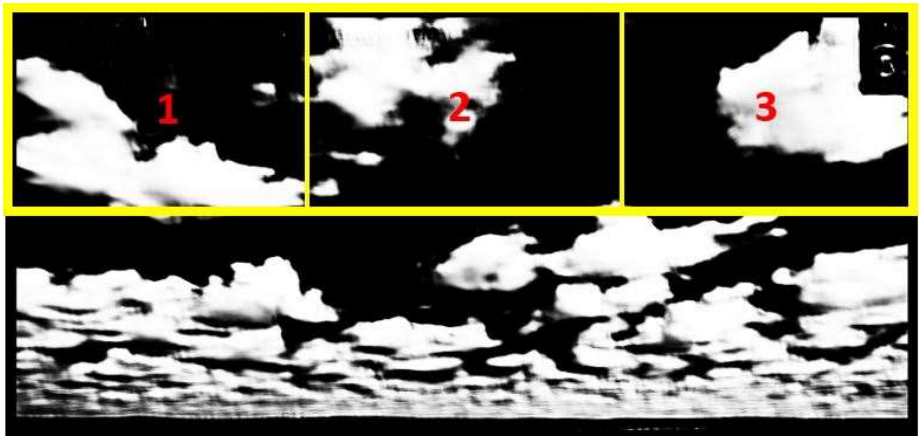
Maria Reinhardt, Roland Potthast et al.

Deutscher Wetterdienst

- **image** from meteo-cam (Lindenberg)
- **cloud detection with CNN**
  (5 convolutional layers + 1 dense layer;
  input: 20 x 20 pixels (sliding window),
  output: 1 value: cloud yes / no);

  stratus detection with CNN (using whole image)
- **superobbing**:
  obs = cloud fraction in 3 boxes
- **observation operator** (model equivalent):
  - 3x3 rays per box
  - model cloud fraction interpolated
    to points along ray
  - maximum cloud fraction along ray
  - average over 9 rays
- monitoring: very little bias
- **assimilation** (1 day): T850 FG **improved**





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