Assimilating visible satellite images with COSMO/KENDA

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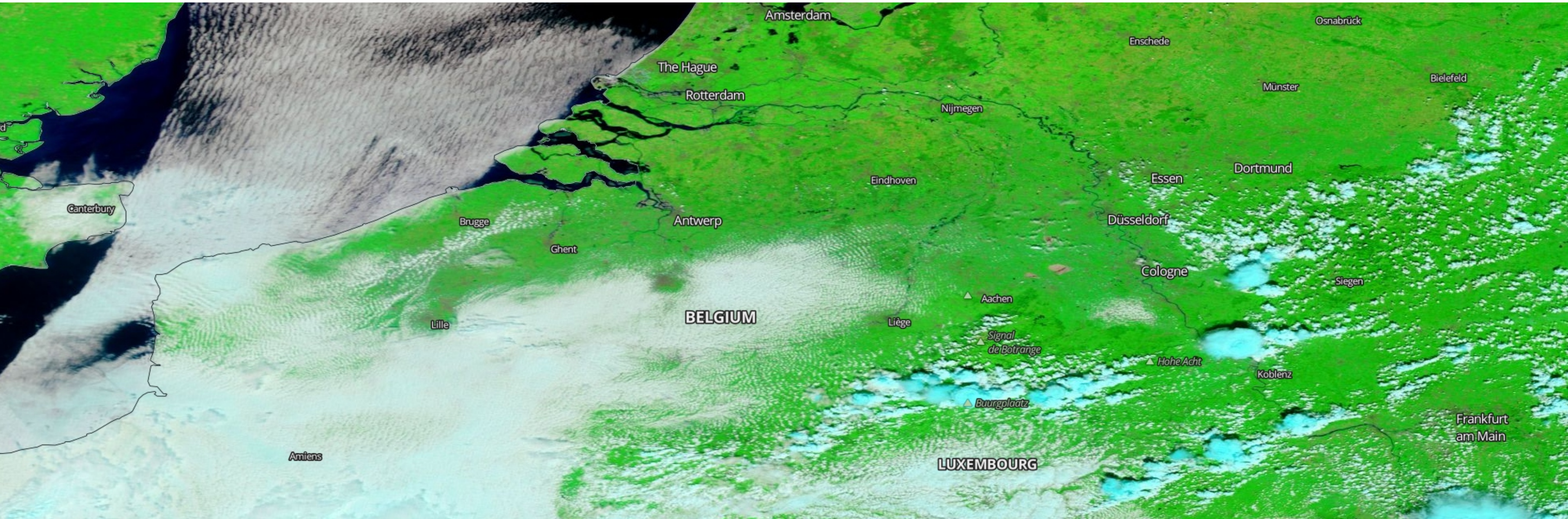


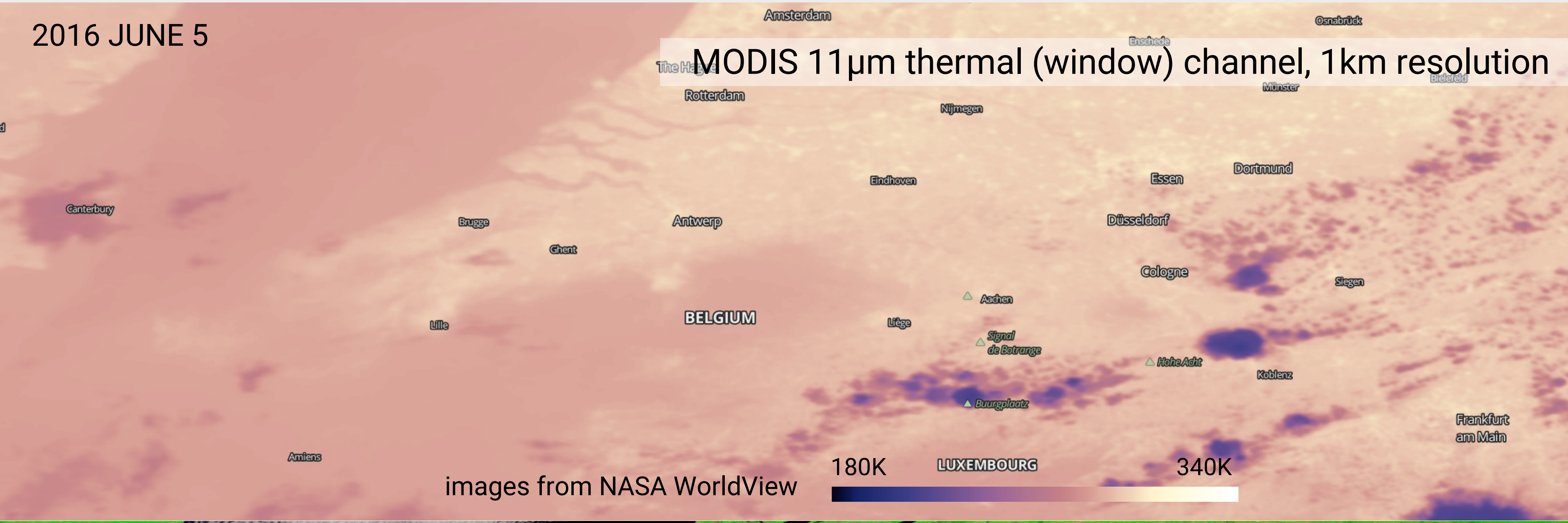
LMU

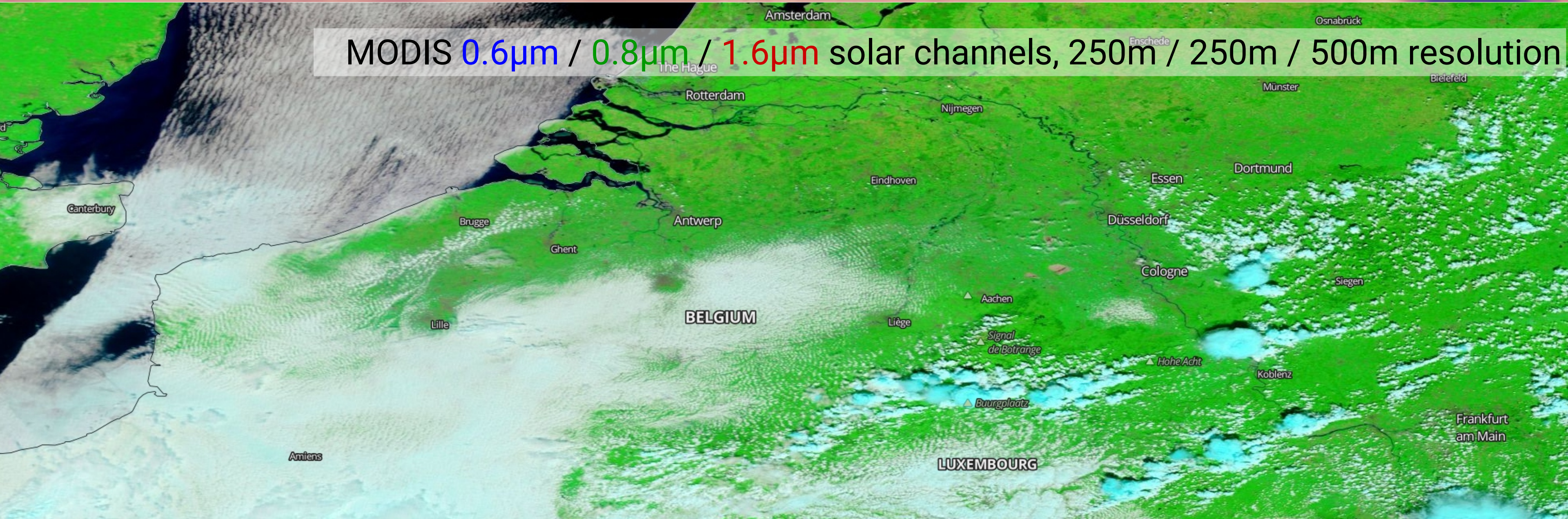
LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

MIM

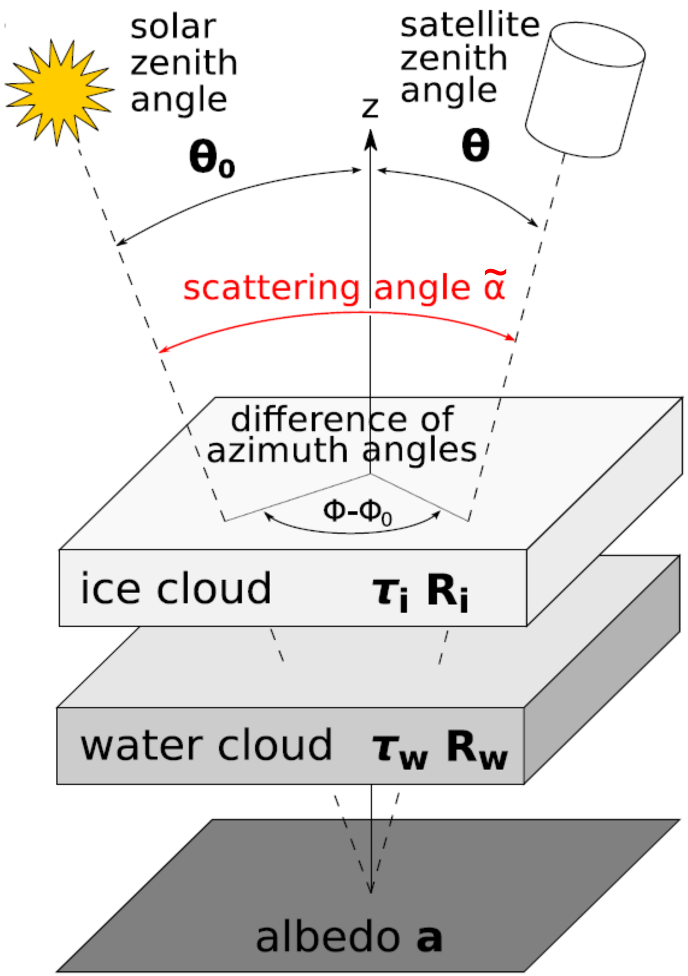
Hans-Ertel-Zentrum für Wetterforschung

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD





Why are we not assimilating solar channels?



- **multiple scattering dominates, 3D effects important**
  - → radiative transfer (RT) is much more **complicated and computationally expensive** than for thermal infrared channels
  - → **forward operators** based on standard RT methods **too slow / inaccurate** for operational purposes

Solution: MFASIS (method for fast satellite image synthesis)

- fast 1D RT method based on a **compressed look-up table** for reflectances computed with standard methods for **strongly simplified vertical profiles**
- **10^4 times faster than standard 1D RT methods**
- integrated into **RTTOV 12.2 by DWD** (+MetOffice, LMU) in the framework of EUMETSAT NWP SAF NUMERICAL WEATHER PREDICTION
- extensions to **account for 3D effects** have been developed and will be further improved

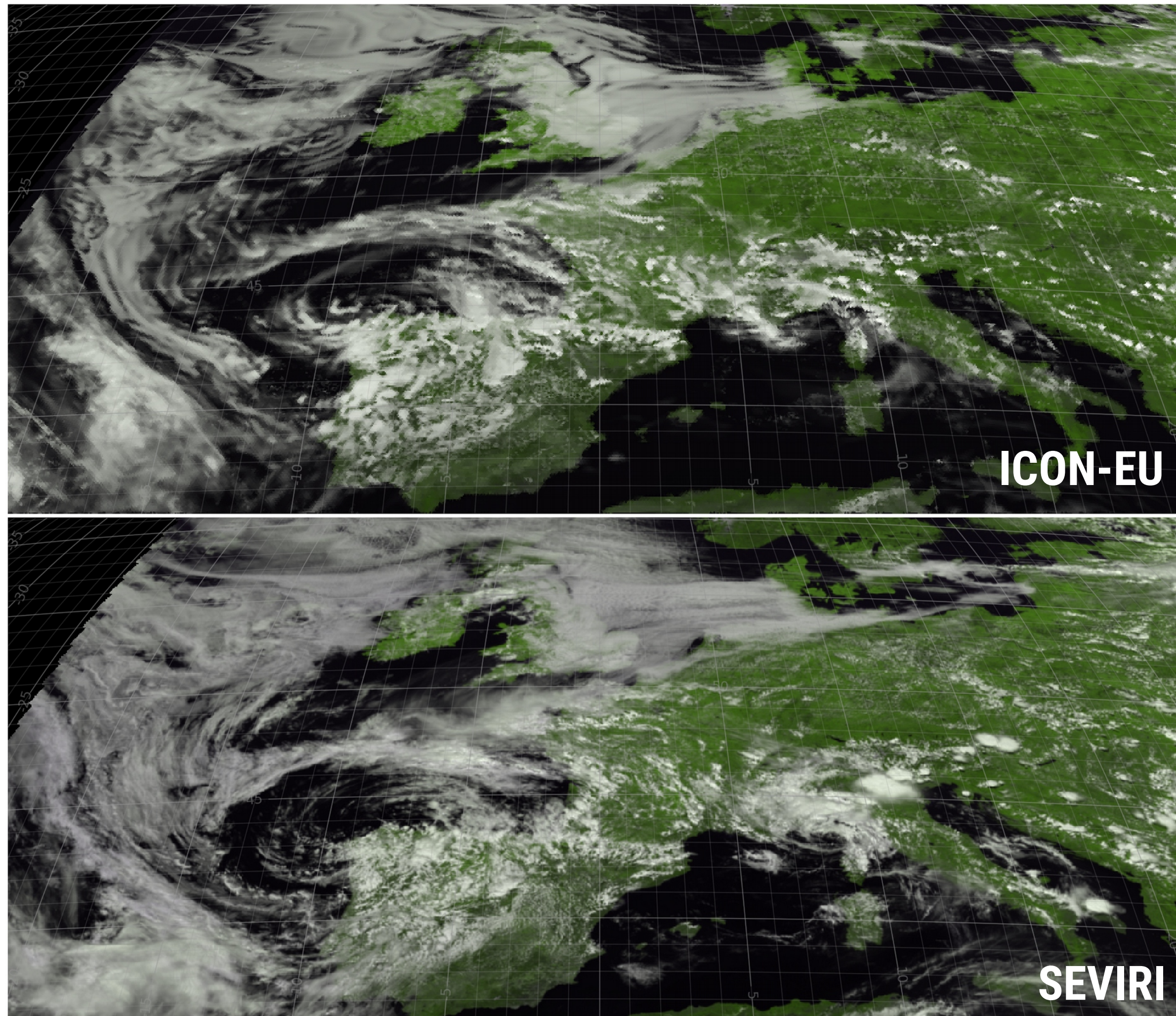
- **observations may be problematic to assimilate**
  - very **nonlinear** (RH=99%→ nothing, RH=100%→cloud)
  - how to perform **vertical localization?**

Systematic errors

Investigation of systematic errors for different operator settings and different models (COSMO and ICON with 1-moment and 2-moment microphysics) for a 3 month period is under way…

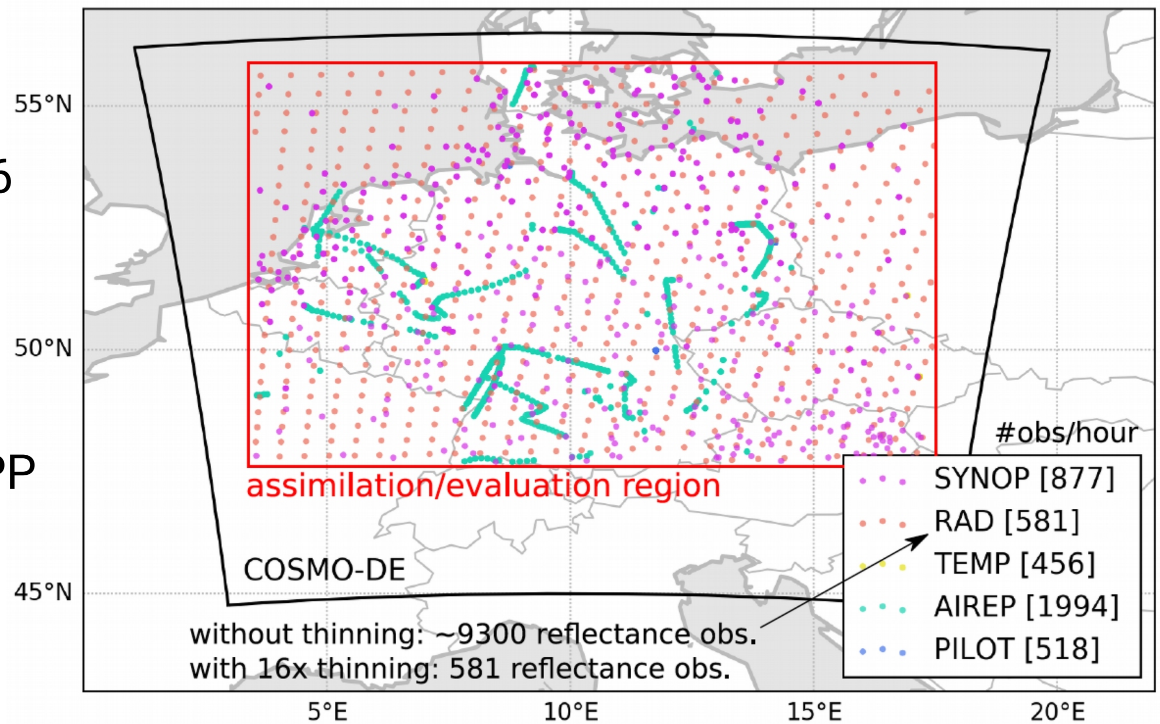
→ Poster P19w by Stefan Geiss, talk by Alberto de Lozar

Potential error sources in the operator: Parameterization of effective droplet / ice particle sizes, Subgrid variation of LWC, 3D RT effects...



LETKF (Local Ensemble Transform Kalman Filter) Assimilation experiments

- **DWD Codes:** KENDA + COSMO-DE (2.8km)
- **Case:** 29 May & 5 June 2016
- **Ensemble:** 40 members
- **Assimilation window:** 1h
- **Covariance inflation:** Additive + multiplicat. + RTPP
- **Conventional obs.:** SYNOP, TEMP, Profiler, AMDAR (no MODE-S, LHN) ~5000 observations/hour

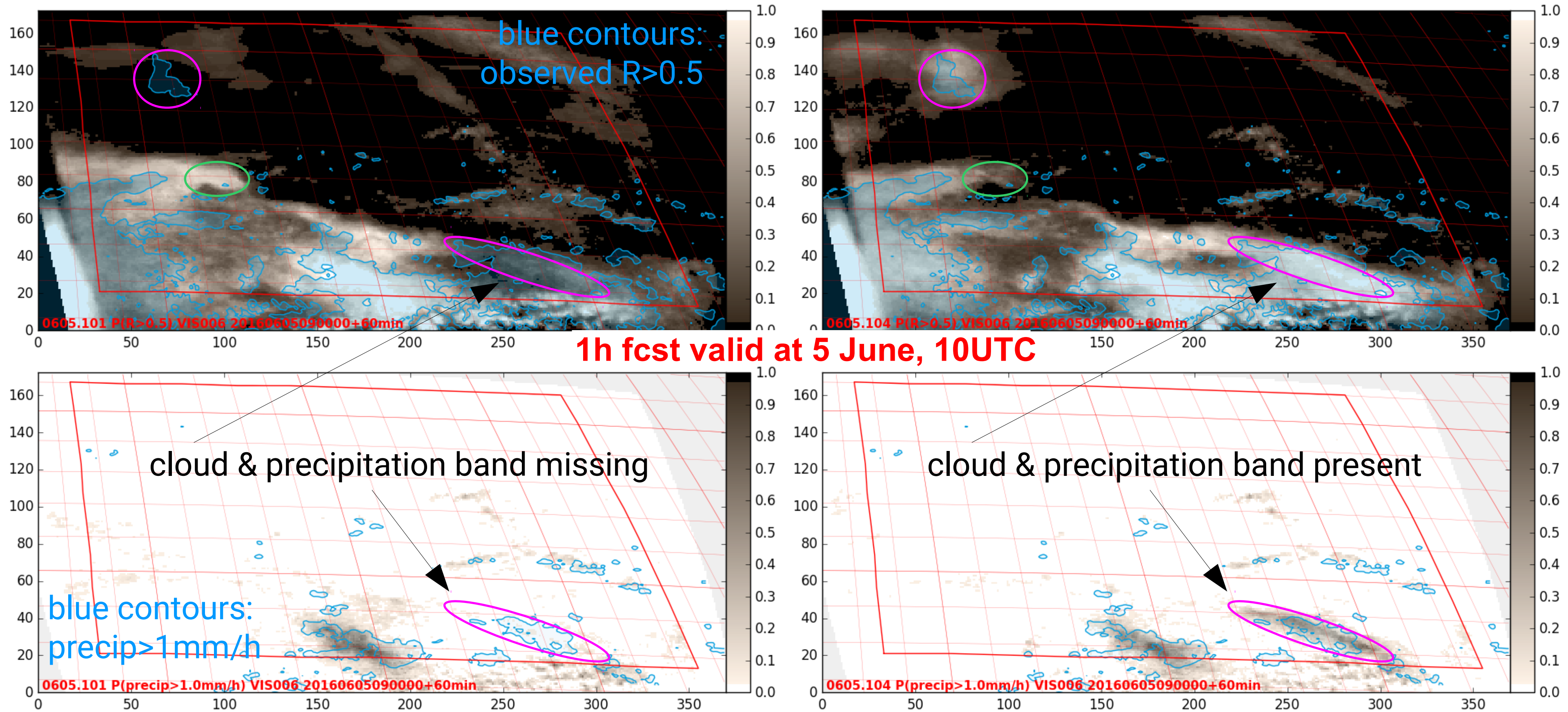


- **Reference runs:** Conventional obs. only, cycling 21UTC – 18UTC next day
- **Run with conv. obs. + visible sat. images:** Branched from ref. run at 5UTC
- **Visible reflectances:** 0.6µm SEVIRI, superobbed to $(18\text{km})^2$, optionally thinned

Cloud cover and precipitation forecast improvements

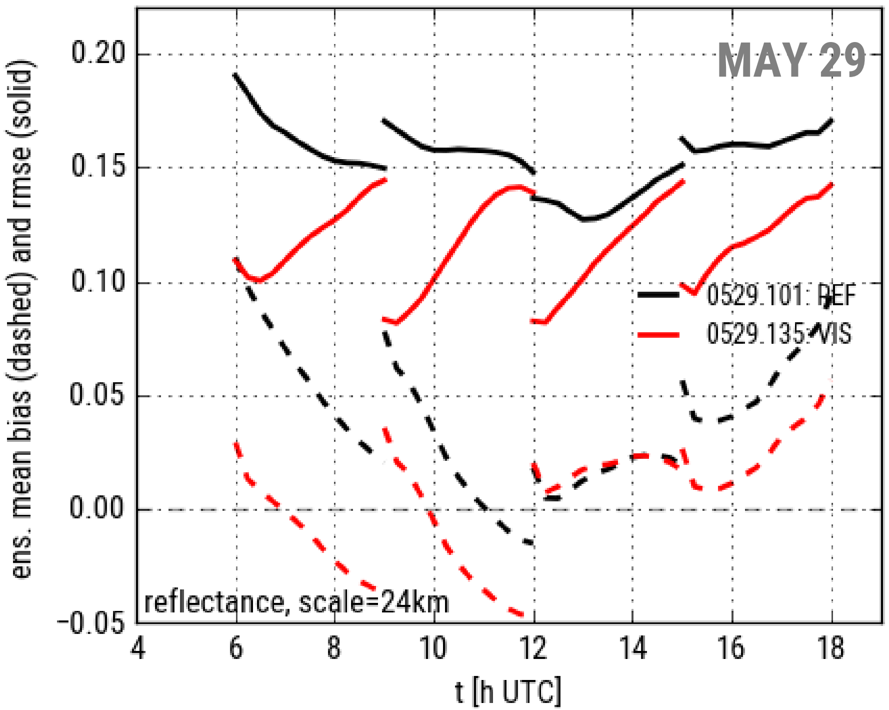
Fraction of ens. members exceeding reflectance>0.5 (top) or precip. >1mm/h (bottom).

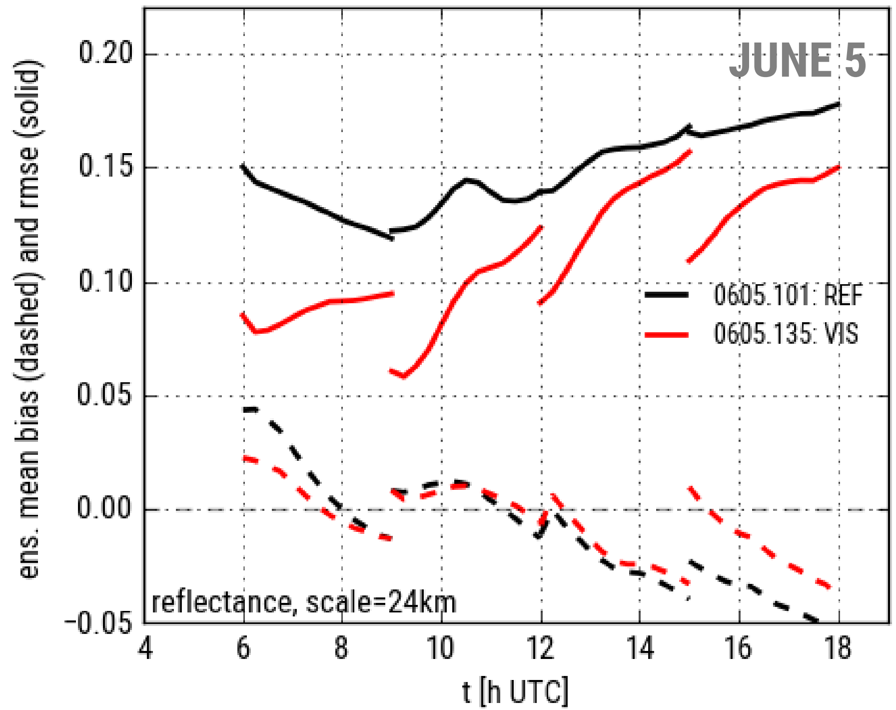
P(R>0.5) only conventional obs. **P(R>0.5)** conventional + SEVIRI 0.6mu



P(PRECIP>1mm/h) only conv. obs. **P(PRECIP>1mm/h)** conv. + 0.6mu

Reflectance RMSE and bias for 3h forecasts

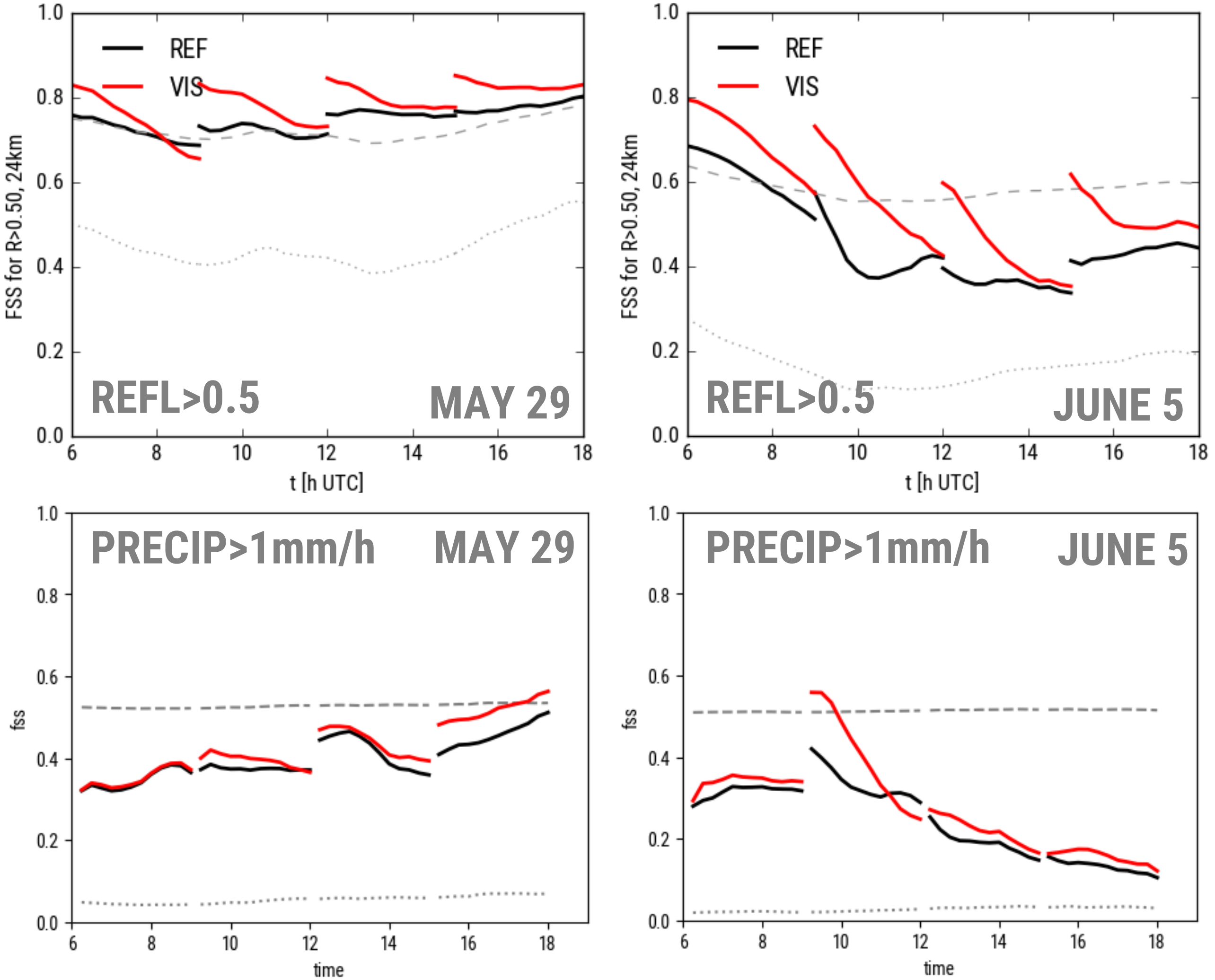




Black: Forecasts started from reference experiment (only conventional obs.)
Red: Additionally SEVIRI 0.6µm reflectance assimilated

RMSE reflectance error (solid) of ensemble mean is strongly reduced in every analysis. Impact is visible for >3 hours in highly convective situation.
Reflectance bias (dashed) is also improved (domain cloud fraction improved).

Fractions Skill Score for Reflectance and Precipitation



Mean FSS of ens. members for

← Reflectance >0.5 on 24km scale

← Precip. > 1mm/h on 30km scale

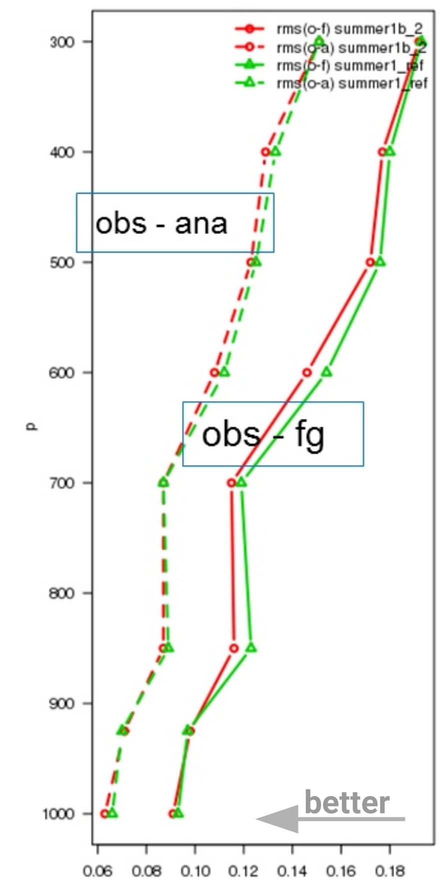
Both improved by assimilation of 0.6 µm SEVIRI in almost all cases

Can we improve moisture?

Results for a 6-day test period (Lilo Bach, DWD)

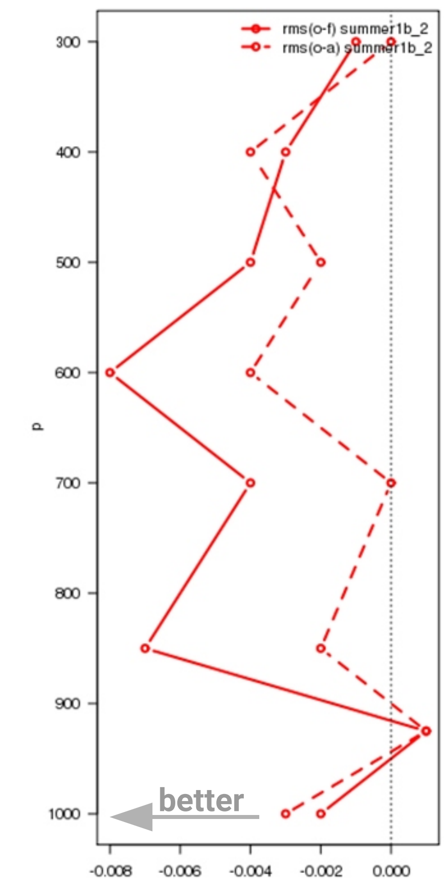
Difference to the setup used so far: **reference run** contains now also MODE-S and radar (LHN) data! **VIS run = reference+VIS**

RMSE



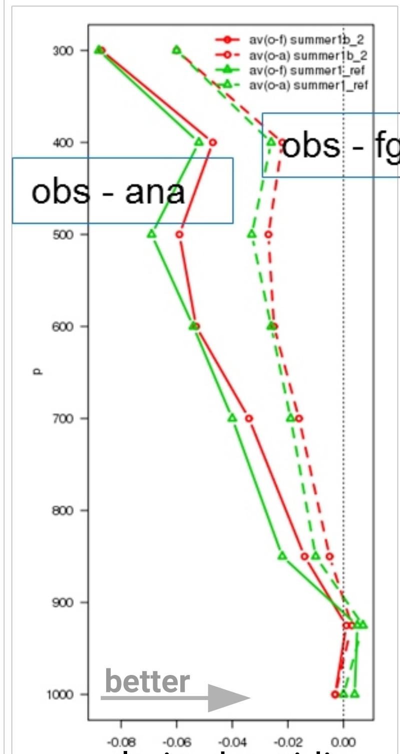
relative humidity

ΔRMSE



relative humidity

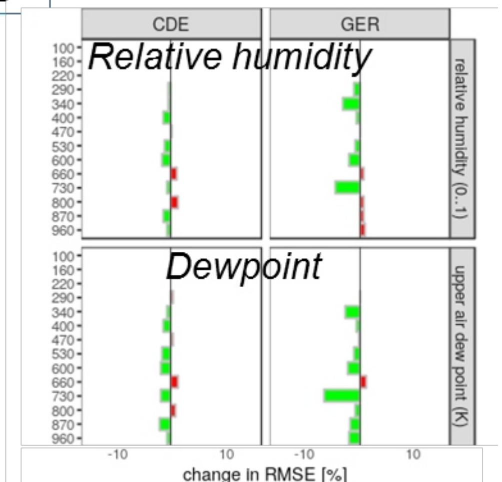
BIAS



relative humidity

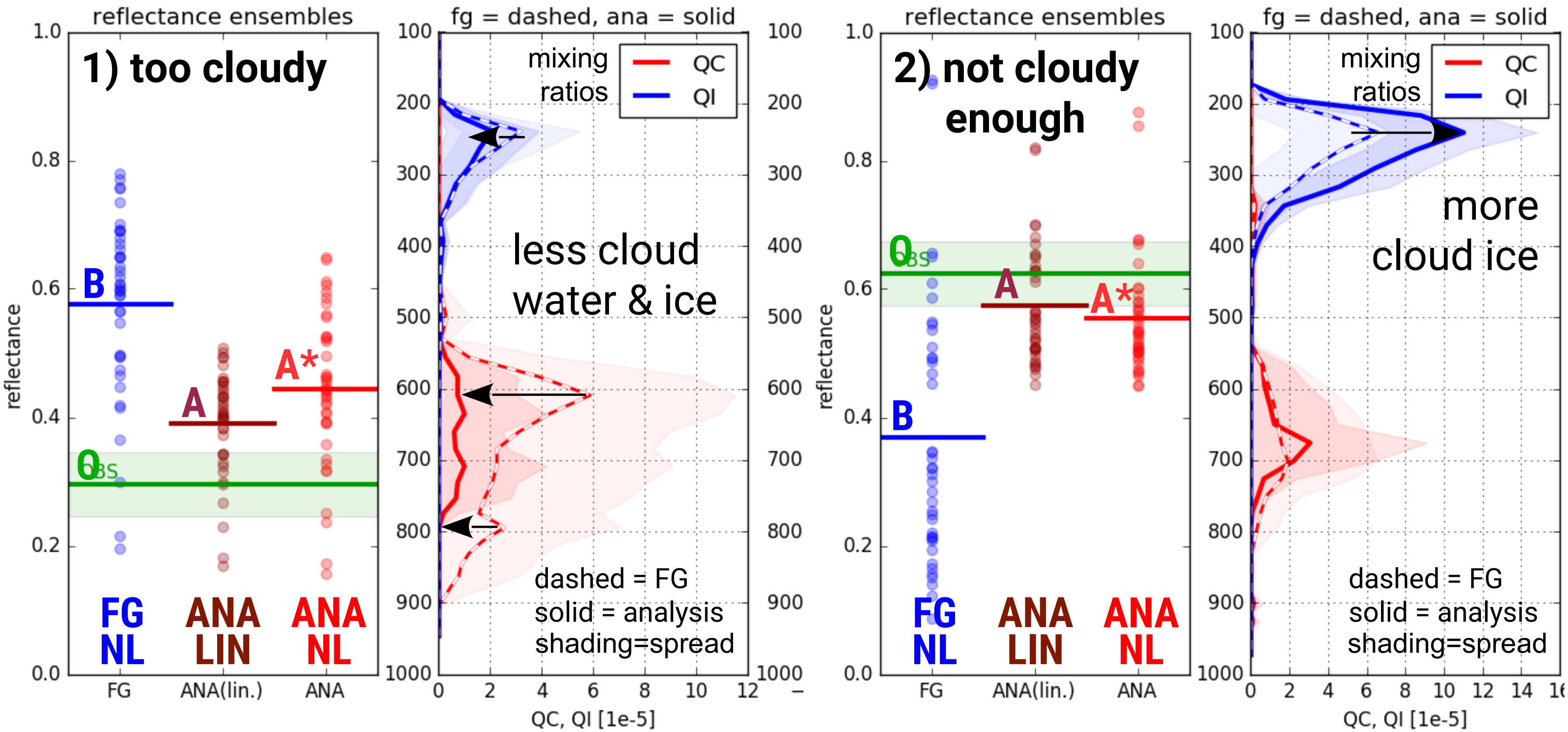
26 – 31 May 2018

RMSE FORECASTS



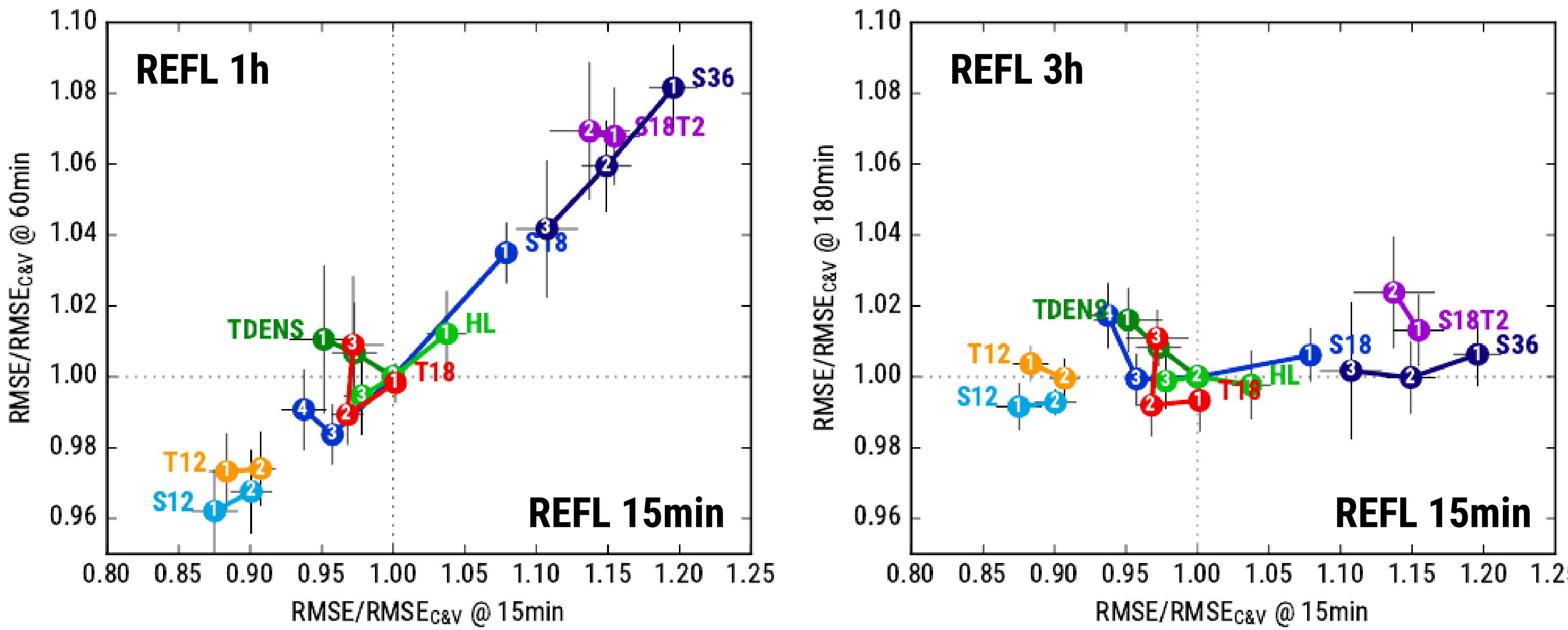
→ **RMSE and moist bias improved.**

Single observation experiments



- Analysis model equiv.: **linear LETKF estimates** differ from exact **nonlinear operator results**
- **Ambiguity**: Reflectance depends on LWC, IWC, RH and cloud fraction. Which should be modified? → resolve using additional channels? **→ Poster p13-w by Weißmann et al.**
- **No vertical localization** → we can get increments related to spurious correlations... L. Bach: Use cloud top height retrievals for localization?

Sensitivity to assimilation parameters



We varied observation error, superobbing/thinning scale and horizontal localization

Advantages gained by pulling ensemble closer to observations mostly gone after 3h (more pronounced imbalances → faster error growth).

From a Sinfony (fusion of nowcasting and NWP forecasting) perspective: Analysis can be pulled close to observations without ruining the 3h forecast.

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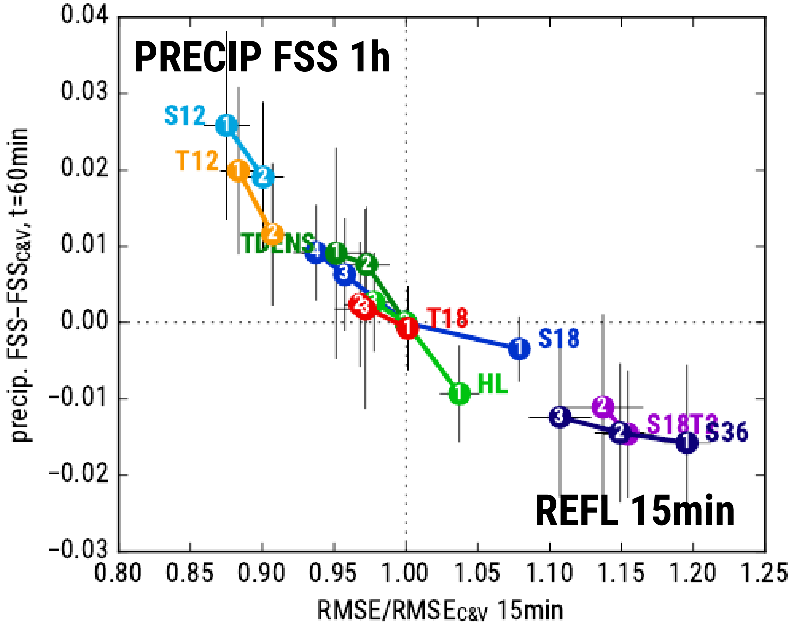

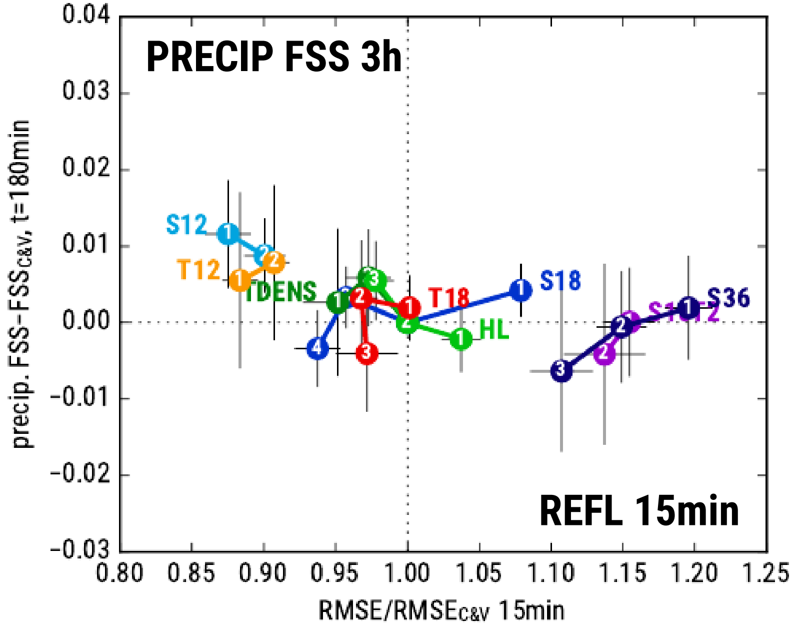

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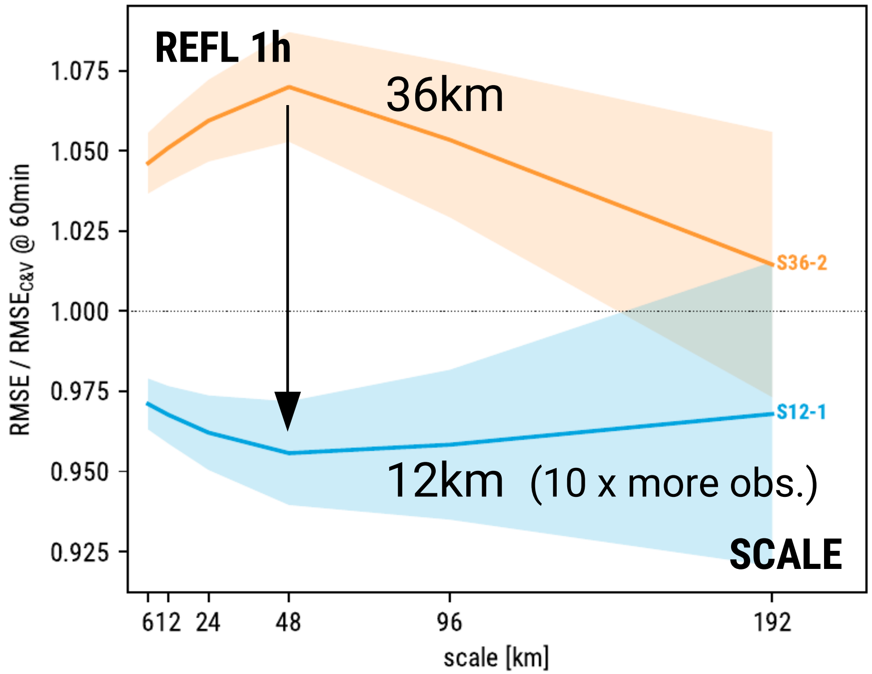
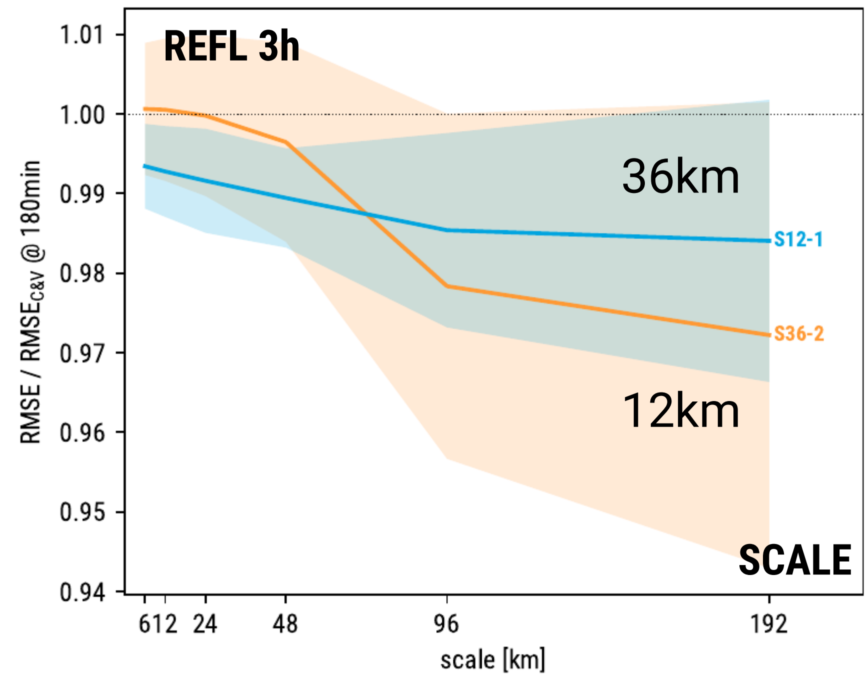
Superobbing / thinning / horizontal localization scale





Short-term error on smaller scales can be reduced by chosing a smaller superobbing or thinning radius together with a smaller localization radius (such that the number of observations influencing each grid point is constant)

Superobbing and thinning lead to similar results – there is no clear winner…

Summary

- A sufficiently **fast and accurate forward operator for visible reflectances** based on the MFASIS RT method is available
- Experiments with the LETKF implemented in DWD's KENDA system for two convective summer days show that **cloud cover and precipitation can be improved for several hours** by the assimilation of visible 0.6µm SEVIRI images
- Longer test periods are being investigated at DWD, first results show a **beneficial impact on the moisture fields**
- **Sensitivity to assimilation settings:** Short-term small-scale error can be reduced without creating problems for the 3h forecasts

Publications:
Scheck, Frerebeau, Buras-Schnell, Mayer (2016): *A fast radiative transfer method for the simulation of visible satellite imagery*, Journal of Quantitative Spectroscopy and Radiative Transfer, 175, p. 54-67.
Scheck, Hocking, Saunders (2016): *A comparison of MFASIS and RTTOV-DOM*, NWP-SAF visiting scientist report, http://www.nwpsaf.eu/vs_reports/nwpsaf-mo-vs-054.pdf
Scheck, Weissmann, Mayer (2018): *Efficient methods to account for cloud top inclination and cloud overlap in synthetic visible satellite images*, JTECH, Vol. 35, Issue: 3, p. 665-685
Scheck, Bach, Weissmann (2019): *Assimilating visible satellite images for convective scale weather prediction* QJRMS, in preparation