

Assimilation of visible channels in a convective-scale ensemble data assimilation system

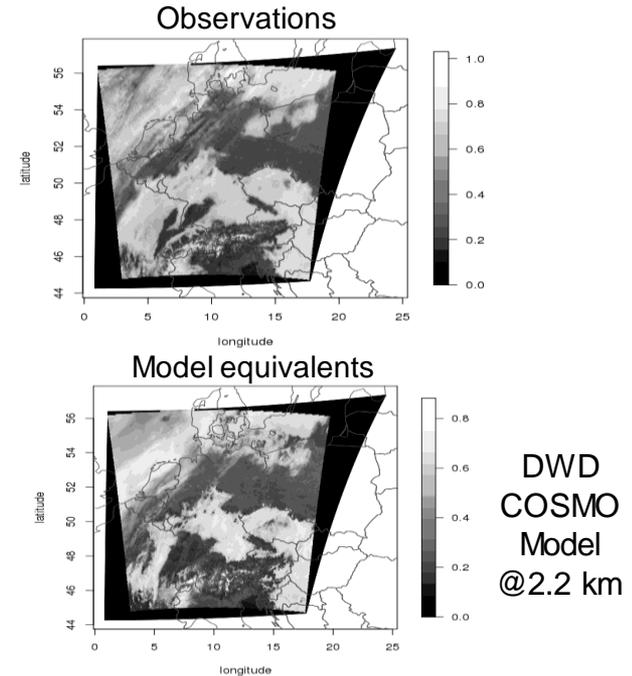
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DWD, Germany

Why assimilate visible channels?

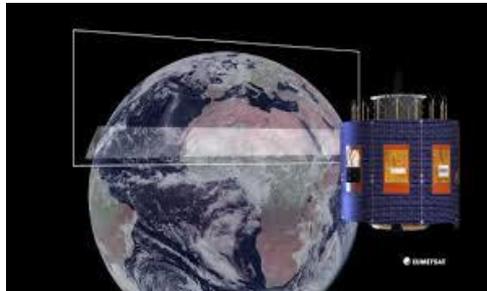
- Added and complementary value to IR / WV channels
 - Visibility of low clouds
 - Only cloud-sensitive
- Aim is to improve
 - cloud analysis & forecast – e.g. low stratus
 - convective-scale processes - capture initial convective stage (convective initiation)
 - representation of cloud related processes such as precipitation, radiation & boundary layer dynamics
- Context:
 - DWD project SINFONY , convection resolving COSMO model
 - Seamless combination of NWP with obs-based nowcasting (extension of the warning horizon)

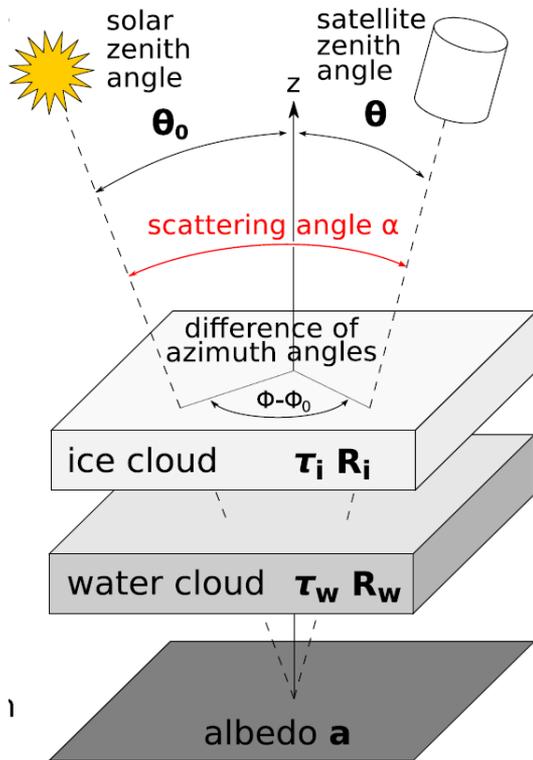
All-sky data assimilation



- Observations and forward operator MFASIS
- Convective scale data assimilation system
- Results:
 - Case study (see poster 11p.07)
 - Single observation experiment (low stratus case)
 - Numerical experiments (low stratus and convective summer period)
- Key challenges
- Summary & outlook

- Cloud-sensitive **visible imager** channels (**0.6 μm**)
- High resolution obs from **SEVIRI** on MSG ($0^\circ/0^\circ$):
 - Temporal resolution: 15 minutes
 - Horizontal: 6 km x 3 km (over German COSMO model domain)
 - **Reflectance** observations





- Very fast forward operator for VIS radiation (reflectance) in presence of clouds
- Uses a look-up table (LUT) approach
- Available in RTTOV (v12.2, v12.3)
- LUTs tuned on DISORT implementation: RTTOV-DOM

LUTs contain:

Fourier coefficients of reflectance

w.r.t. $\theta_0 + \theta$ and $\theta_0 - \theta$

for given conditions of

- scattering angle, optical cloud properties, albedo

• α , τ_w, τ_i, R_w, R_i , a

→ KENDA: 4D-LETKF (using model equivalents at observation time), 40 members

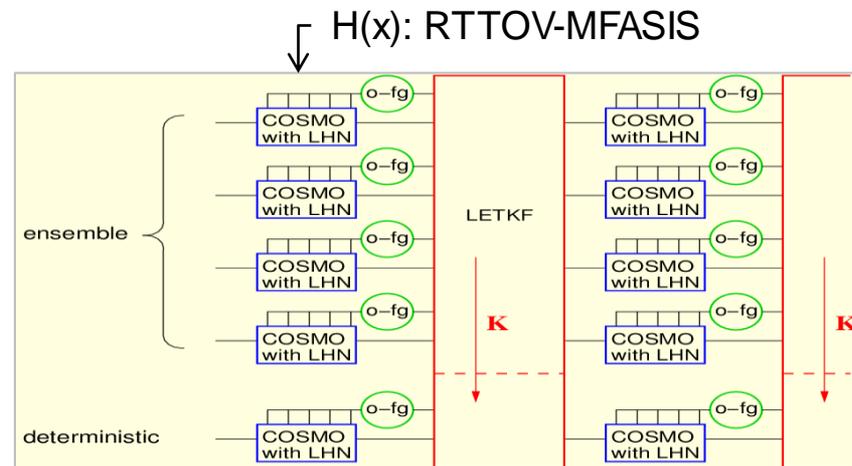
→ State vector consists of

- Temperature
- Specific humidity
- Pressure
- Wind components
- Cloud water
- Cloud ice



→ Flow-dependent increments depend on covariances and inter-variable cross-covariances from ensemble

→ Localization in observation space



LETKF implementation described in Schraff et. al, 2016



Single observation experiment: Low stratus



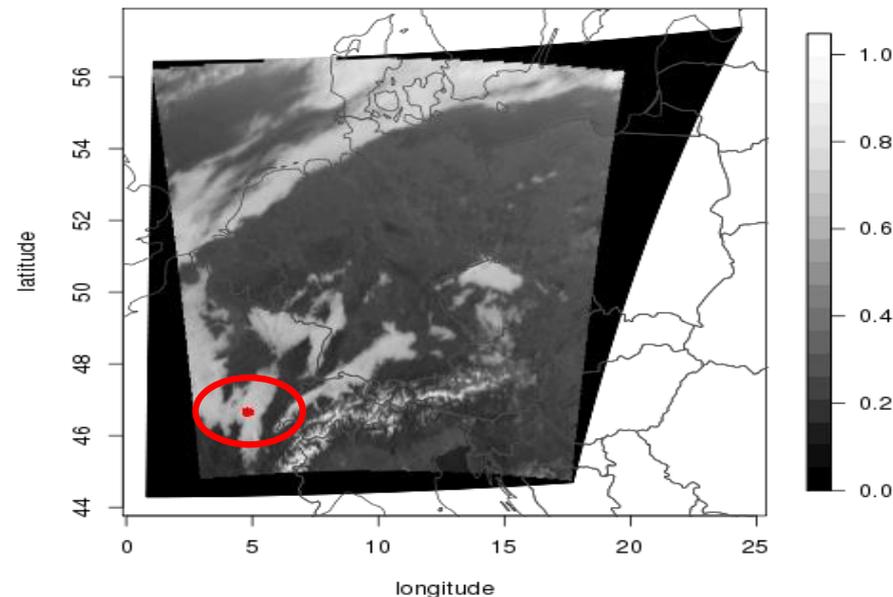
Single Observation Experiment

- December, 30th (2016)
- Low stratus in Southern Germany/France

Two Experiments

1. Position 950 hPa + narrow vertical localization
2. No vertical localization

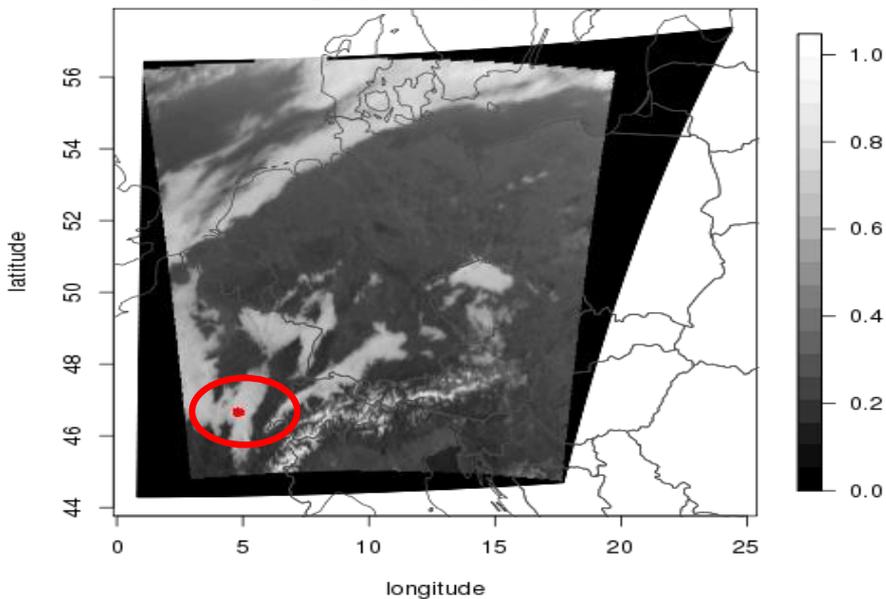
Can we improve the representation of low stratus in the ensemble mean and ensemble members?



Cloud water in the first guess ensemble?

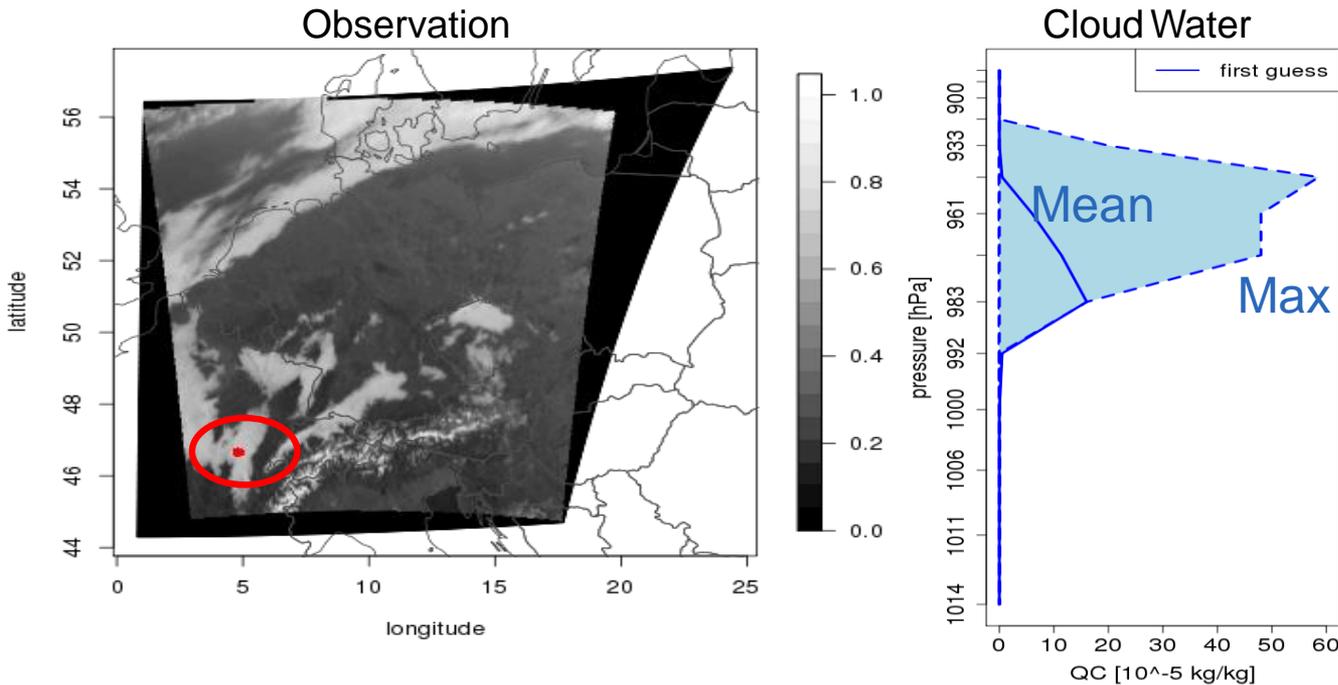
Cloudy observation: high reflectance

Observation



Cloud water in the first guess ensemble?

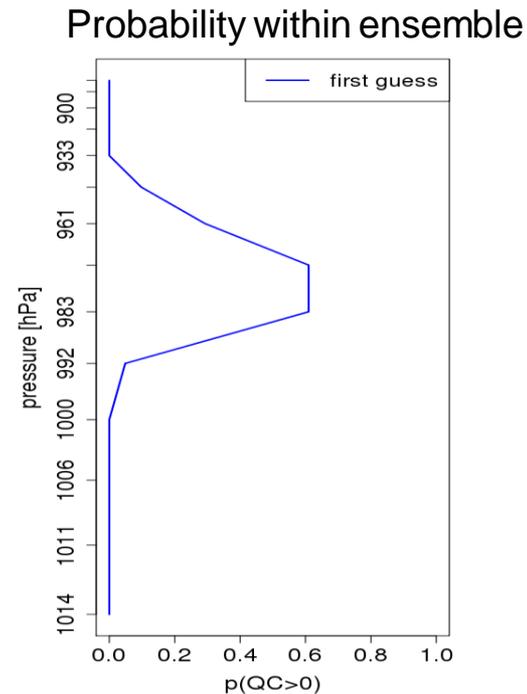
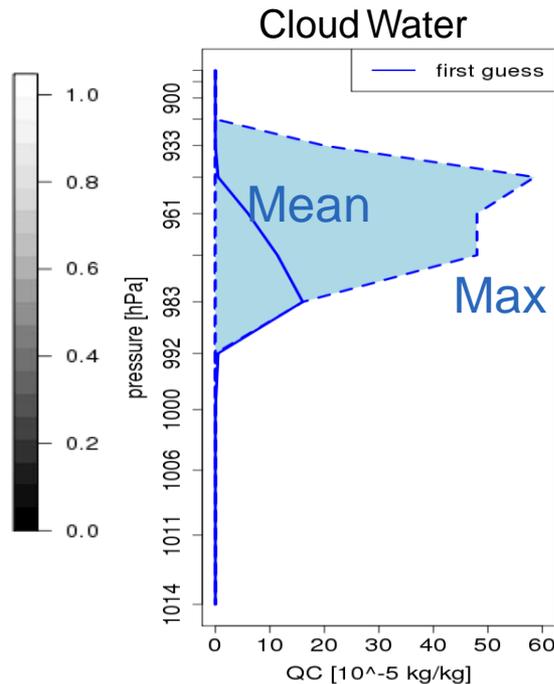
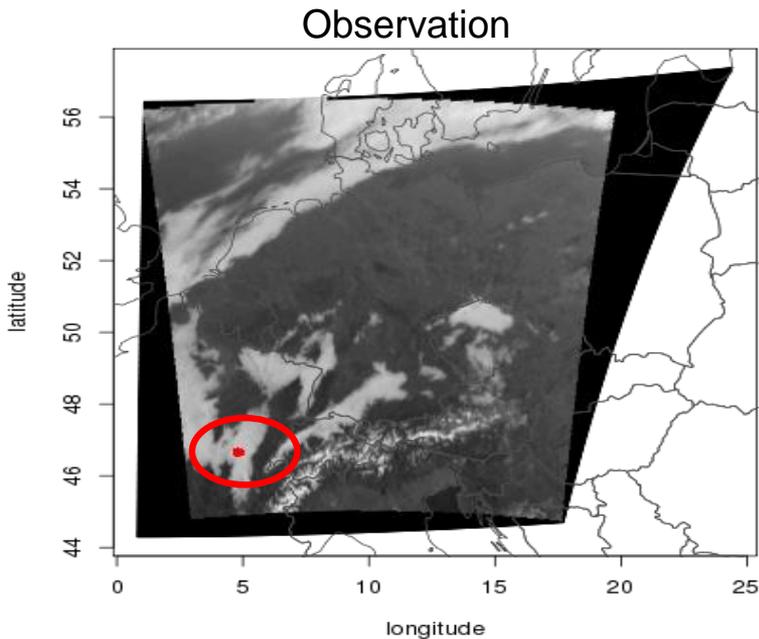
Cloudy observation: high reflectance



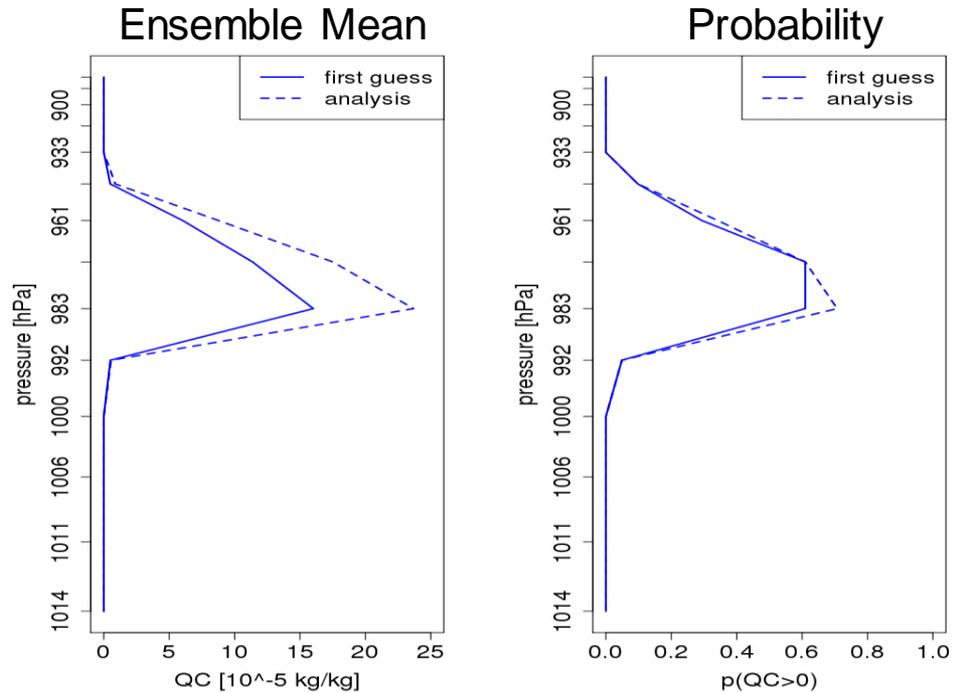
Cloud water in the first guess ensemble?

Cloudy observation: high reflectance

There is room for improvement of the ensemble...



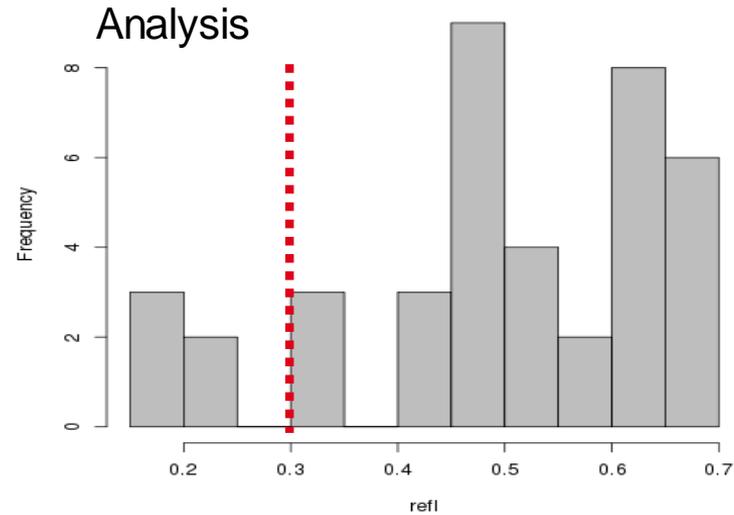
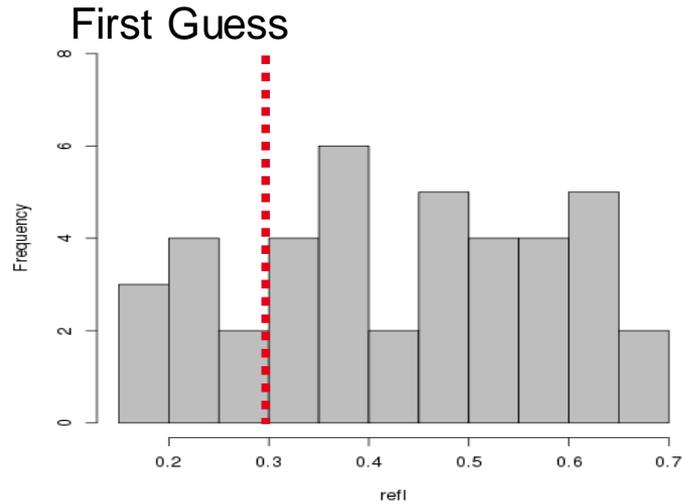
Can we generate cloud water?



*LETKF improves
both ensemble mean
and ensemble*

How does the distribution of reflectance change?

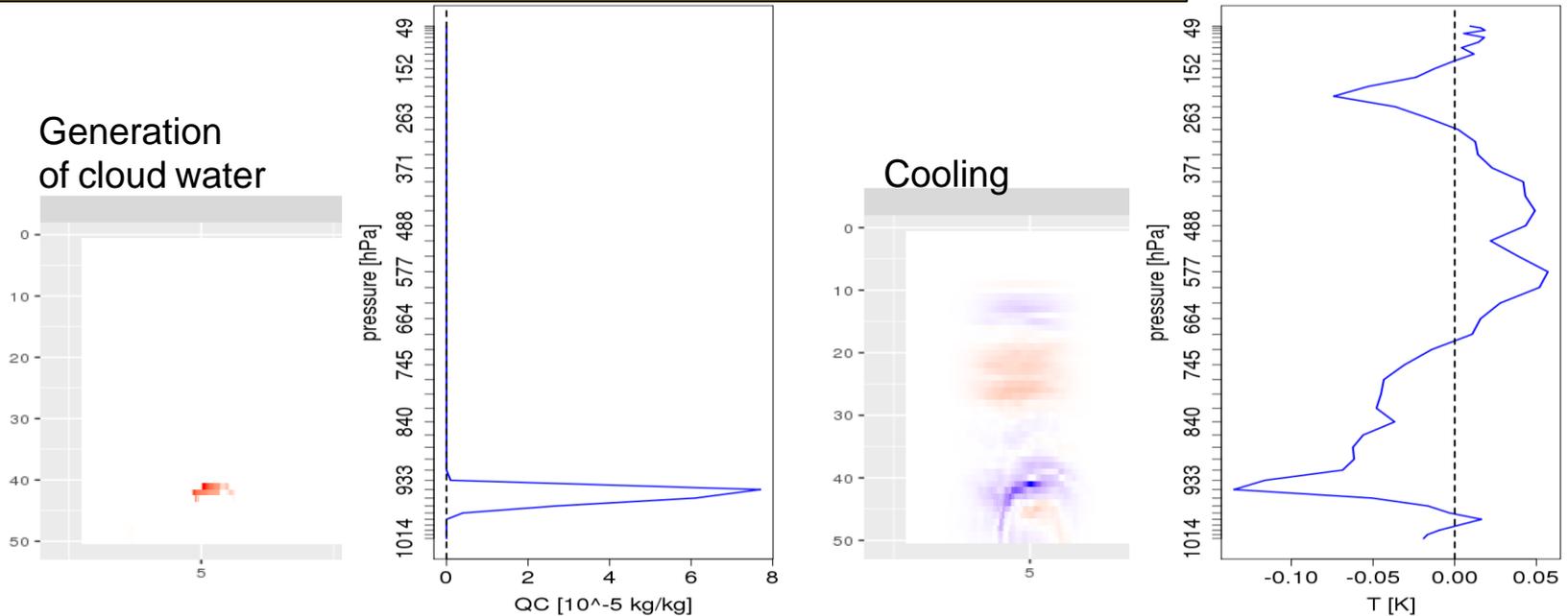
Ensemble:



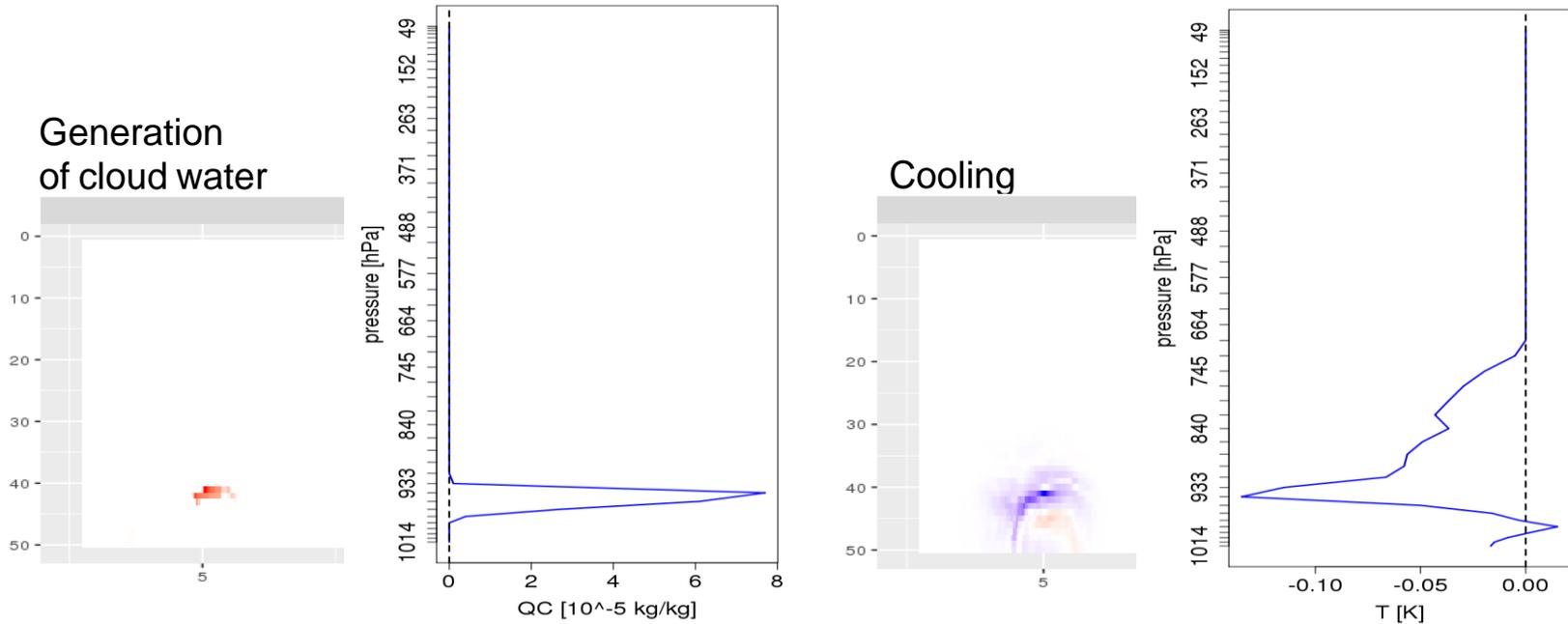
Analysis increments without vertical localization

Assimilation of reflectance obs leads to physically consistent increments

- Cloud water
- Corresponding humidity and temperature increments (cooling)



Vertical localization: Key challenge!

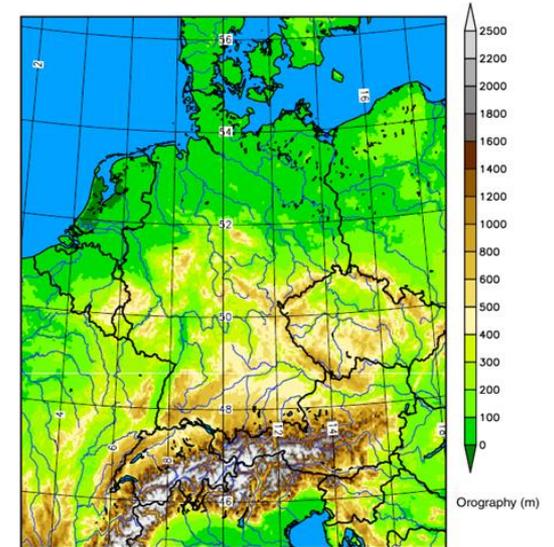


Numerical experiment

Convective period



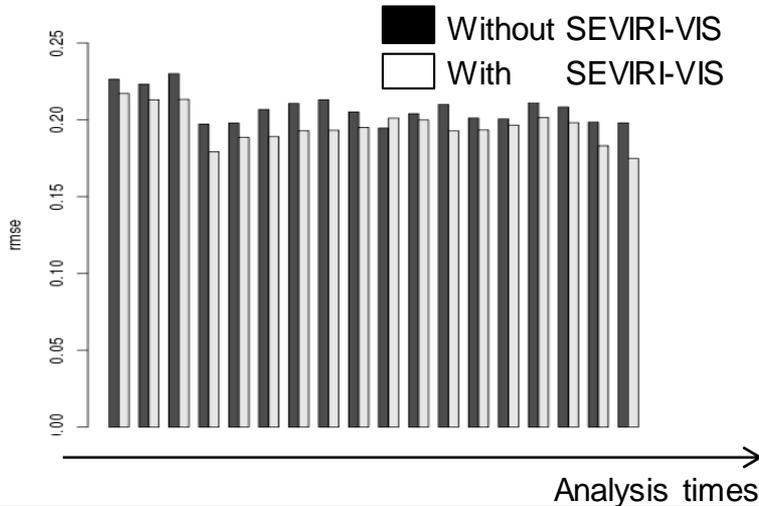
- Here: convective period (2 weeks in May/June 2016)
- COSMO-DE ($\Delta x=2.8$ km)
- KENDA routine set-up:
 - conv. OBS + MODE-S and radar (via latent heat nudging)
 - Hourly DA cycle
 - Hourly SEVIRI $0.6 \mu\text{m}$, 18 km superobbing
 - Reflectance OBS error: 0.2
 - Horizontal localization: 35 km; no vertical localization
 - Very-short range forecasts: 12h (here every 6h)



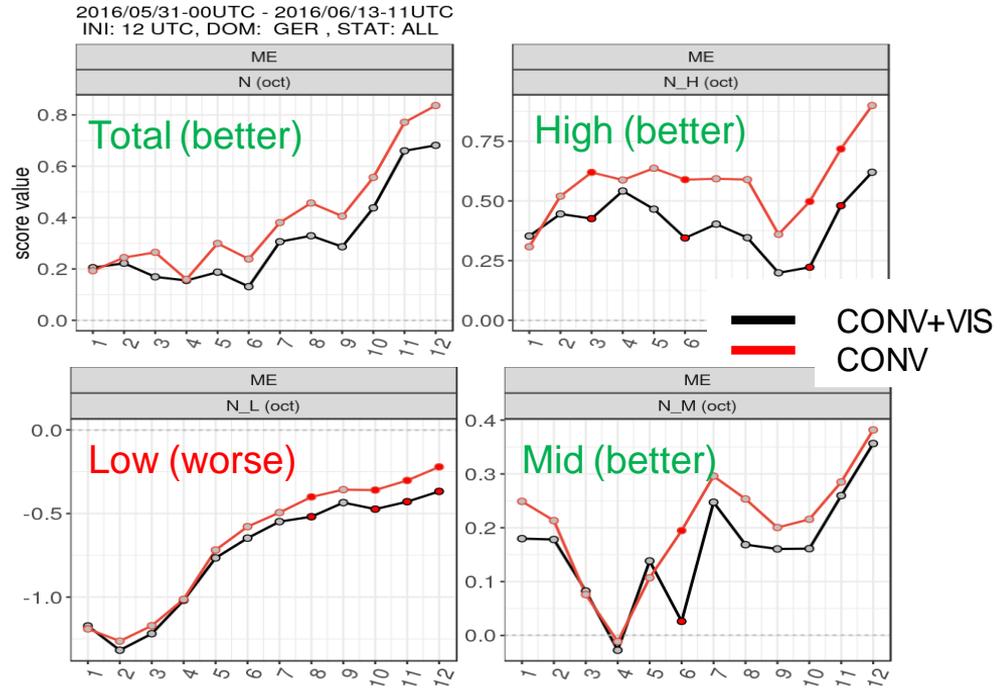
CONV : Conventional obs + Mode-S
CONV+VIS: Conventional obs + Mode-S+ SEVIRI-VIS

12-hour forecasts
06,12,18,00
31.05.2016 to 13.06.2016

Reflectance RMSE for FG (versus SEVIRI)



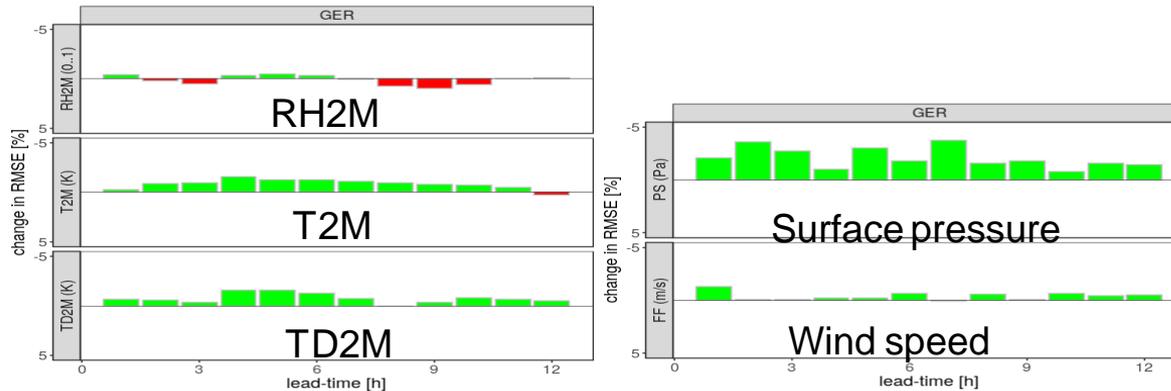
Forecast cloud cover BIAS (versus SYNOP)



12-hour forecasts
06,12,18,00
31.05.2016 to 13.06.2016

0h - 12h forecast versus SYNOPs

RMSE: percentage improvement

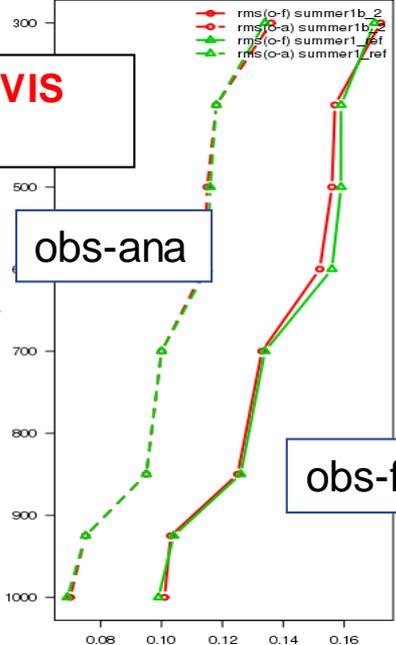


Better with SEVIRI-VIS

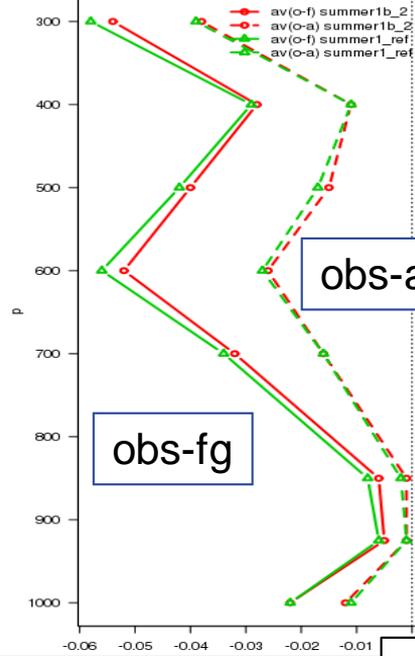
Evaluation: Moisture fields – relative humidity

12-hour forecasts
06,12,18,00
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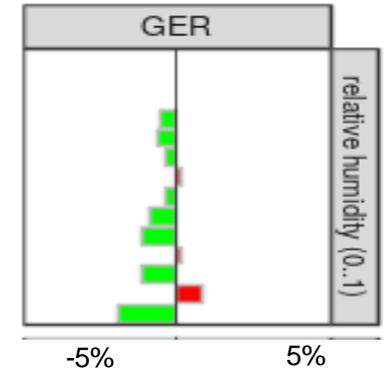
rel. Humidity RMSE (versus RS)



Rel. Hum. BIAS (versus RS)



rel. RMSE difference
(12h forecast versus RS)



Better with SEVIRI-VIS

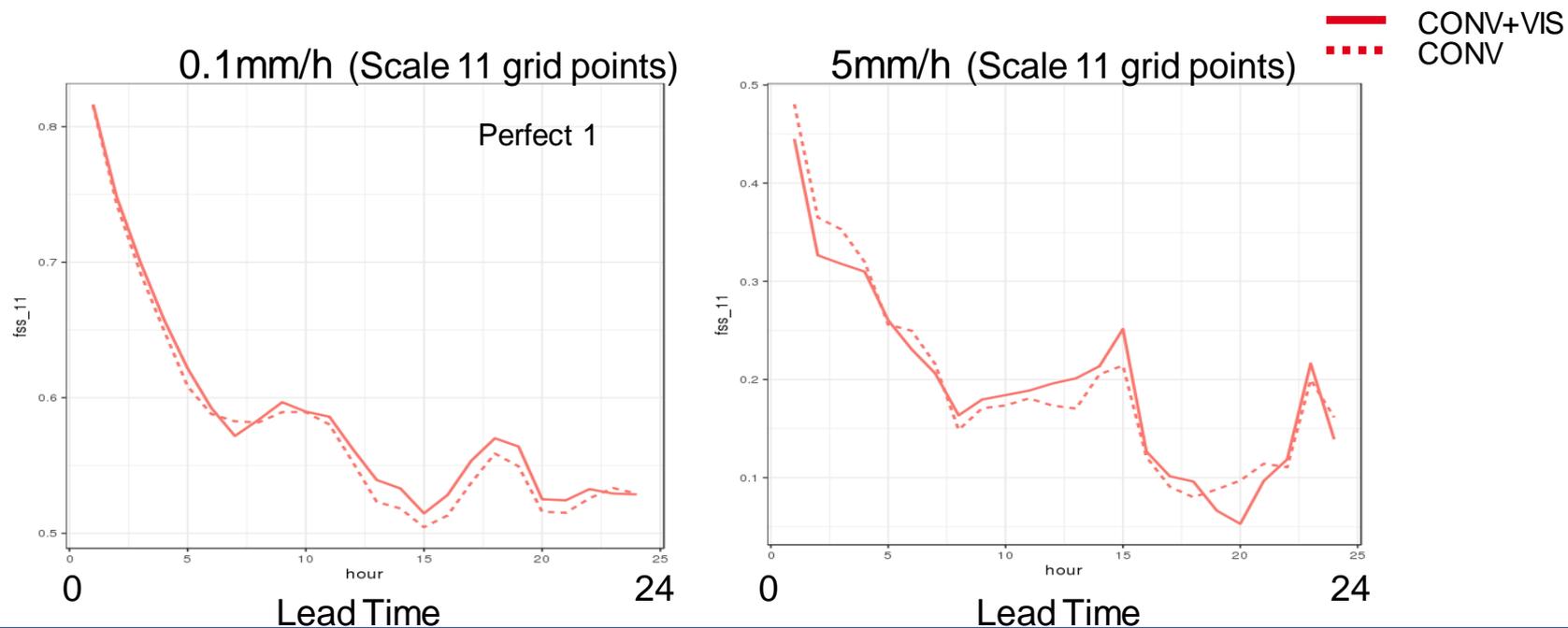


0.0

Evaluation: Convective precipitation

12-hour forecasts
06,12,18,00
31.05.2016 to 13.06.2016

Precipitation forecast FSS (versus radar)



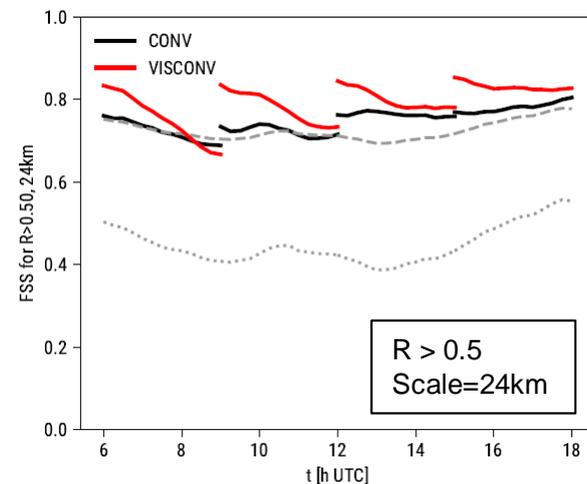
(I) Volume of assimilated satellite observations

- Balancing high-resolution satellite data & conventional data
- Fit of analysis vs. induced forecast spin-up / error-growth
- Target: improve up to 6 to 12 hour forecasts

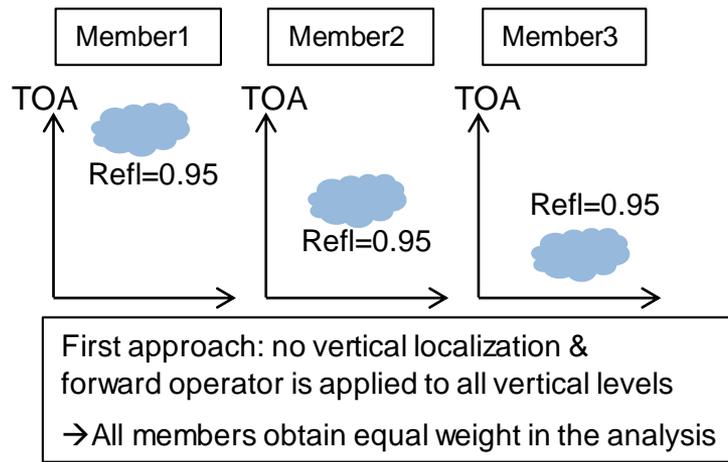
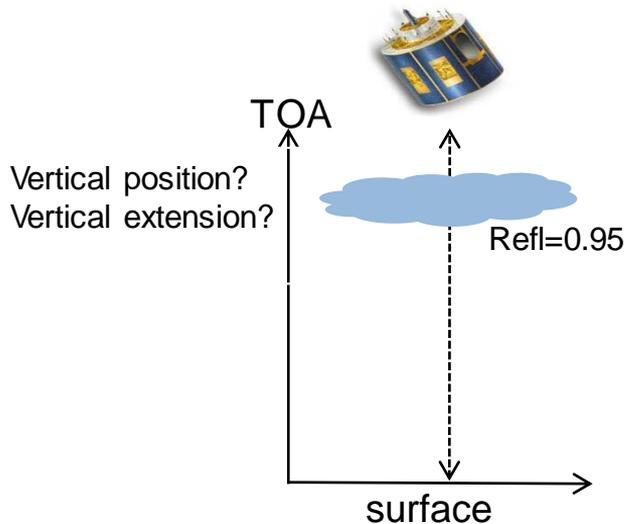
Solution: Tuning experiments regarding

- Observation superobbing scale
- Horizontal localization radius
- Observation error
- Number of used 'images' per assimilation window

Reflectance forecast FSS (versus SEVIRI)



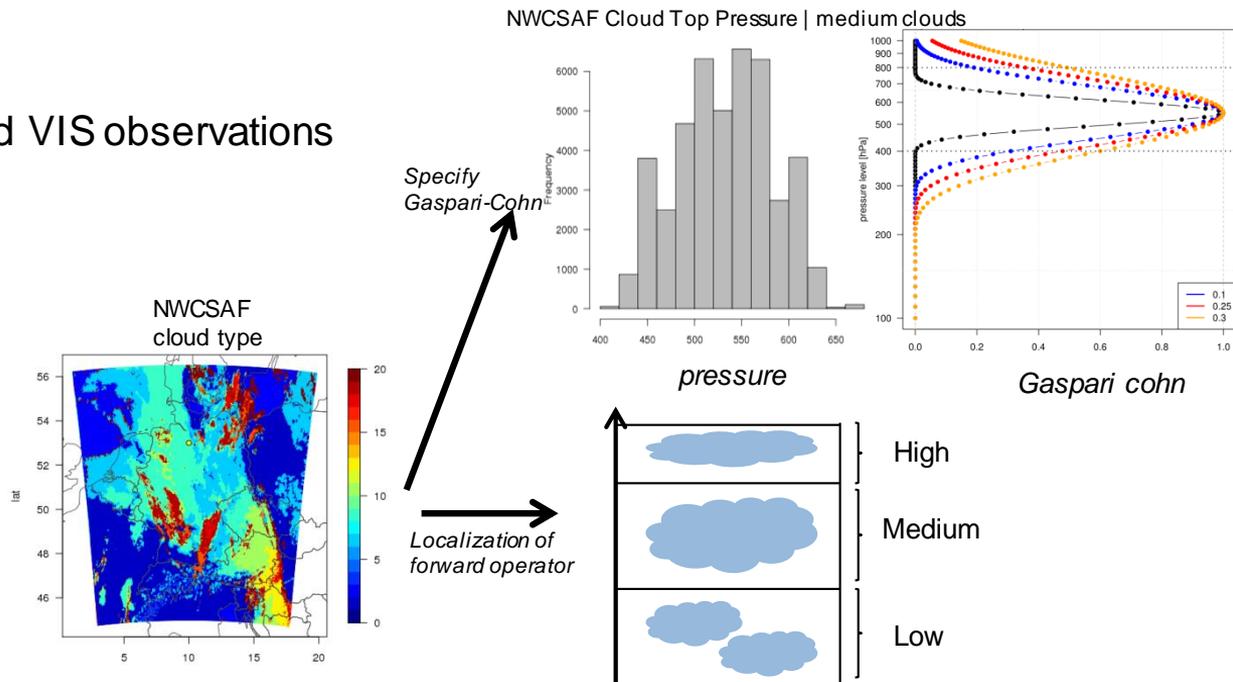
(II) Unknown vertical position & extension of observed cloud



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Solutions we are working on

→ Vertical localization of H(x) and VIS observations

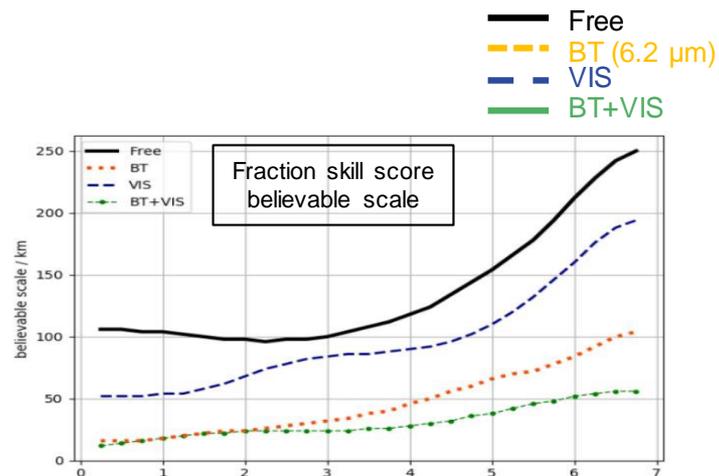


(II) Unknown vertical position & extension of observed cloud

Solutions we are working on

- Vertical localization of H(x) and VIS observations
- Combination with infrared channels: ~ cloud top height

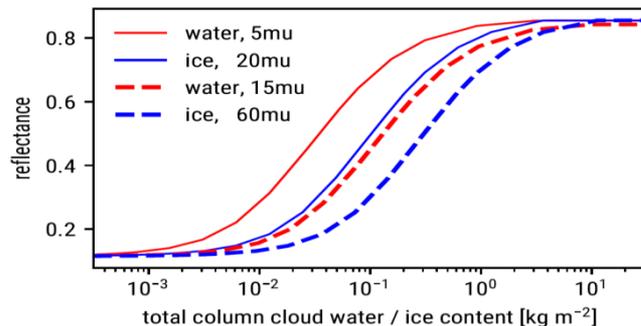
First OSSEs with combination of IR + VIS yield positive results for FSS (precipitation rate > 1 mm/hh)



From Schröttele, Weissmann, Scheck, Hutt: "Assimilating visible and thermal radiances in idealized simulations of deep convection", in preparation.

(III) EnKF assumes linearity and Gaussianity

- Relationship between cloud particles and reflectance is non-linear
- First guess-departures can be non-Gaussian



Possible solution: Application of particle filters

- May raise efficiency of all-sky assimilation in the future
- Particle filter DA in development/testing at DWD

- Use of visible GEO reflectances : cloud ice and cloud water information
- Promising for better prediction of convection and low stratus

- Promising impact in trial set-up with ensemble DA (LETKF)
- State vector contains cloud water and cloud ice
- Key challenges to obtain a more efficient data assimilation are being adressed

Outlook

- Towards operationalisation with new high resolution model version ICON-LAM for seamless forecasting system SINFONY and SRNWP
- Work ongoing for:
 - Vertical localization using additional cloud products
 - Combination with WV / IR channels (all-sky) to reduce ambiguities
 - Work towards use of 2-Moment-scheme to better represent cloud micro-physics

