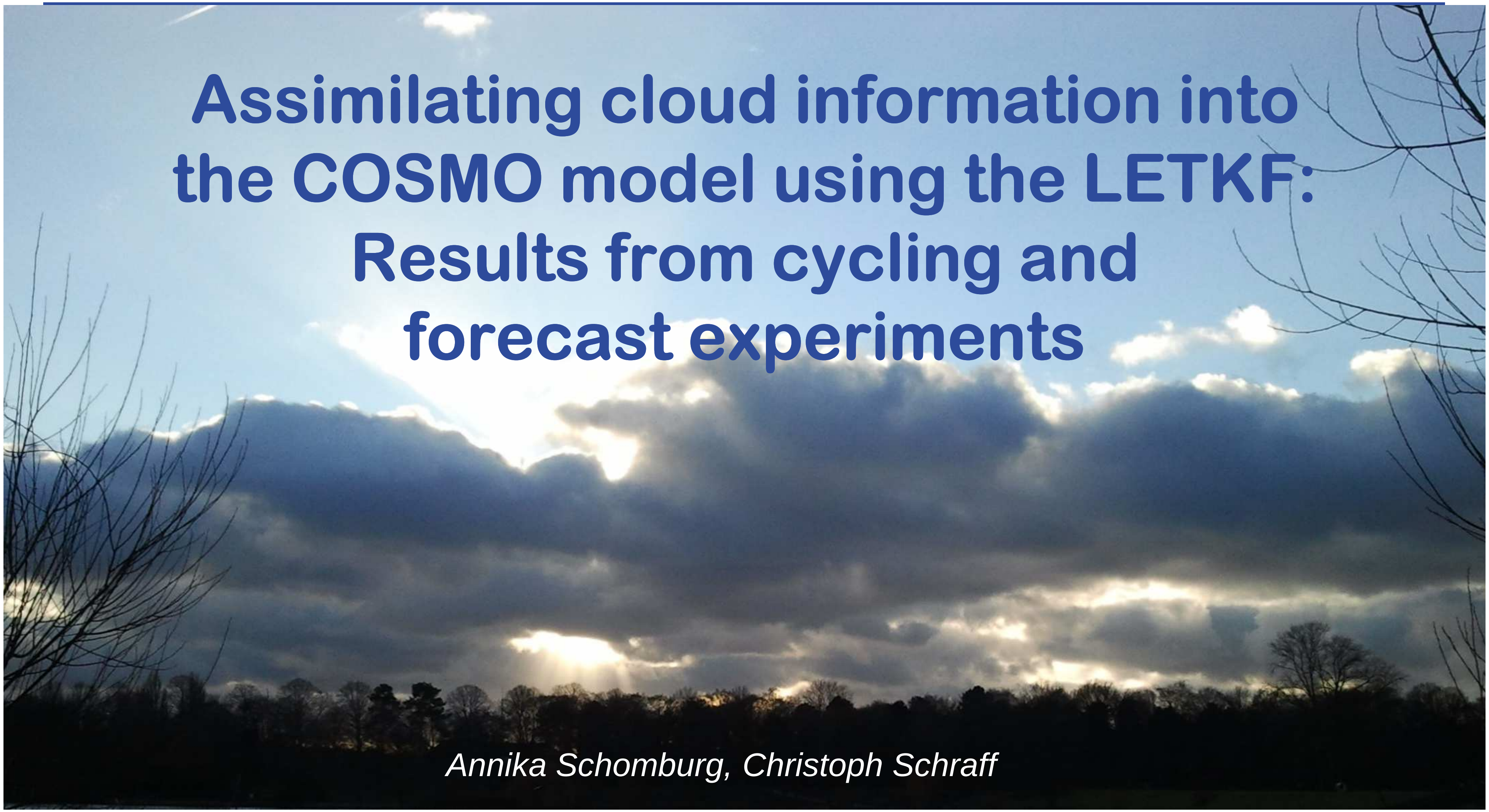
EUMETSAT

DWD
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Assimilating cloud information into the COSMO model using the LETKF: Results from cycling and forecast experiments

Annika Schomburg, Christoph Schraff

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COSMO User Seminar, Offenbach, 17 – 19 March 2014

Observations

- Geostationary satellite data: **Meteosat-SEVIRI**
  (Δx ~ 5 km over central Europe, Δt = 15 min)

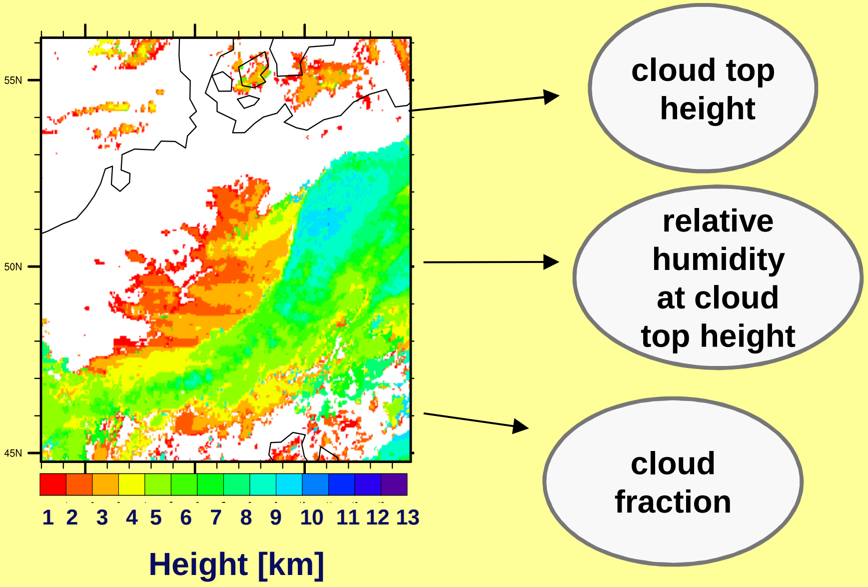
Source: EUMETSAT

NWCSAF Satellite product: cloud top height

retrieval algorithm
uses *T*, q_v profile
from NWP model as input

→ *cloud top height error*
if T model profile
not correct

→ *use also radiosonde*
info where available



cloud top height

relative humidity at cloud top height

cloud fraction

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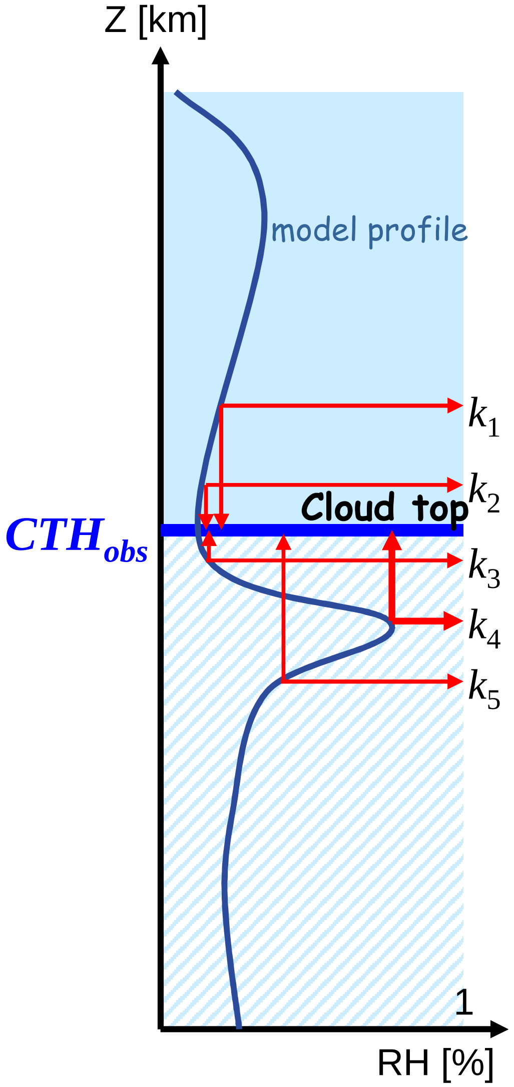
Use of cloud top height (CTH) ‘obs’ in LETKF: Method for cloud-covered pixels



if cloud observed with cloud top height CTH_{obs} ,
what is the appropriate type of obs increment ?

- avoid too strong penalizing of members with high humidity but no cloud (→ use RH instead of cloud fraction)
- avoid strong penalizing of members which are dry at $\boldsymbol{CTH_{obs}}$ but have a cloud or even only high humidity close to $\boldsymbol{CTH_{obs}}$

→ search in a vertical range Δh_{max} around $\boldsymbol{CTH_{obs}}$ for a ‘best fitting’ model level k, i.e. with minimum ‘distance’ d:

$$\boxed{d = \min_k \sqrt{(RH_k - RH_{obs})^2 + \frac{1}{\Delta h_{\max}}(h_k - CTH_{obs})^2}}$$

relative humidity

= 1

height of
model level *k*

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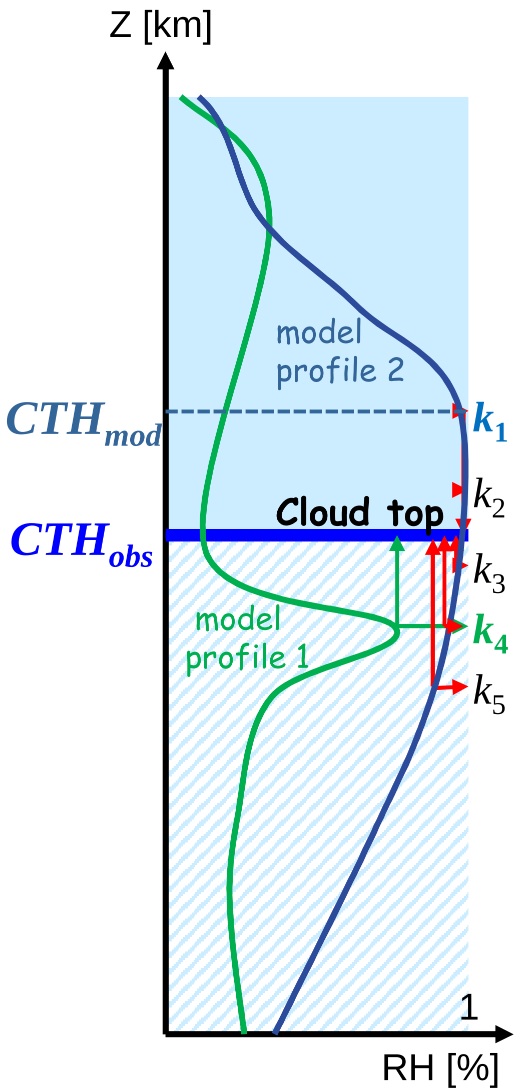
Use of cloud top height (CTH) ‘obs’ in LETKF: Method for cloud-covered pixels



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relative humidity = 1 height of model level k

(but make sure to choose the **top** of the detected cloud)

- use $y = \boldsymbol{CTH_{obs}}$, $H(x) = \boldsymbol{h_k}$
  and $y = \boldsymbol{RH_{obs}=1}$, $H(x) = \boldsymbol{RH_k}$ (over water/ice dep. on T)
  as 2 separate variables assimilated by LETKF

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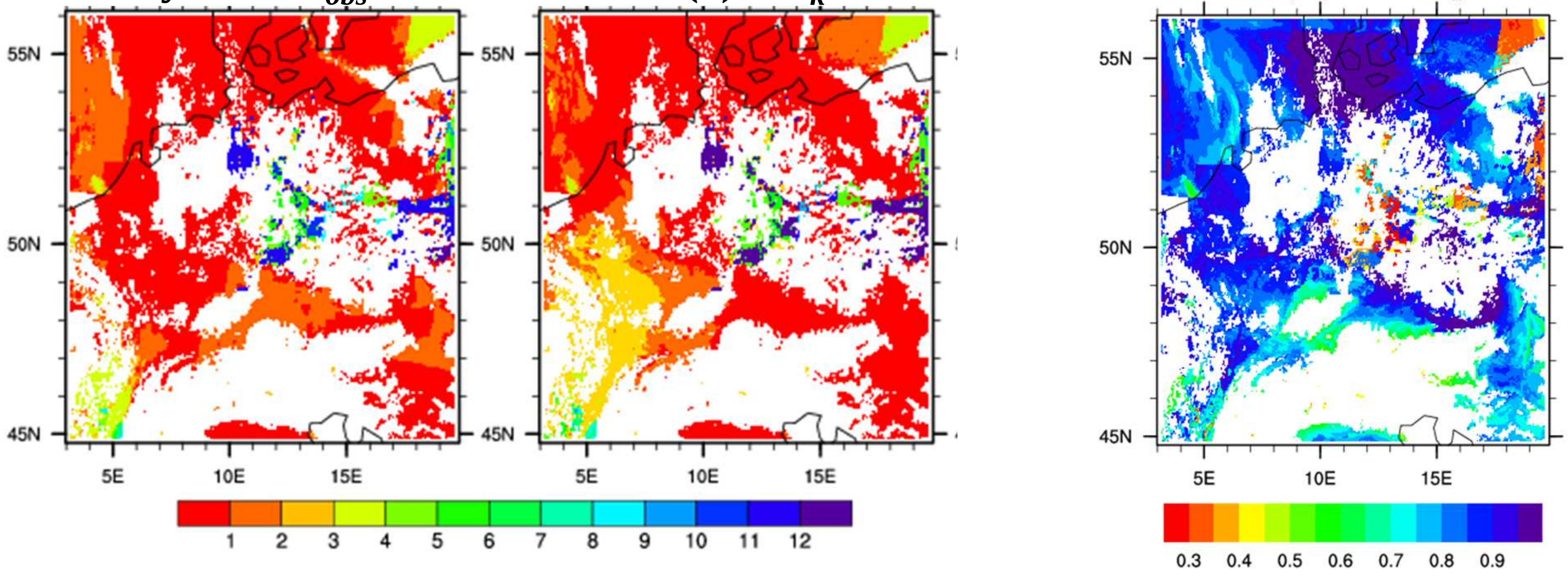
Use of CTH ‘obs’ for cloud-covered pixels : Example for obs / model equivalents

„Cloud top height“

observation $y = CTH_{obs}$

model equivalent $H(x) = h_k$

model equivalent $H(x) = RH_k$



17 Nov 2011, 6 UTC

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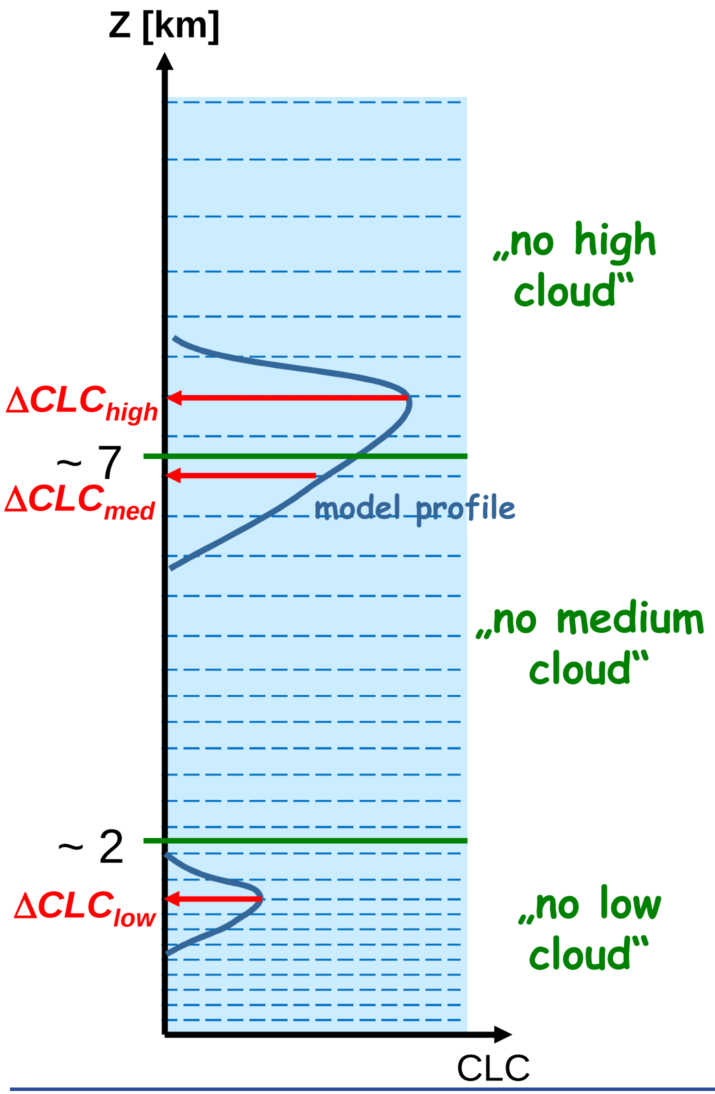
Use of cloud top height (CTH) 'obs' in LETKF: Method for cloud-free pixels



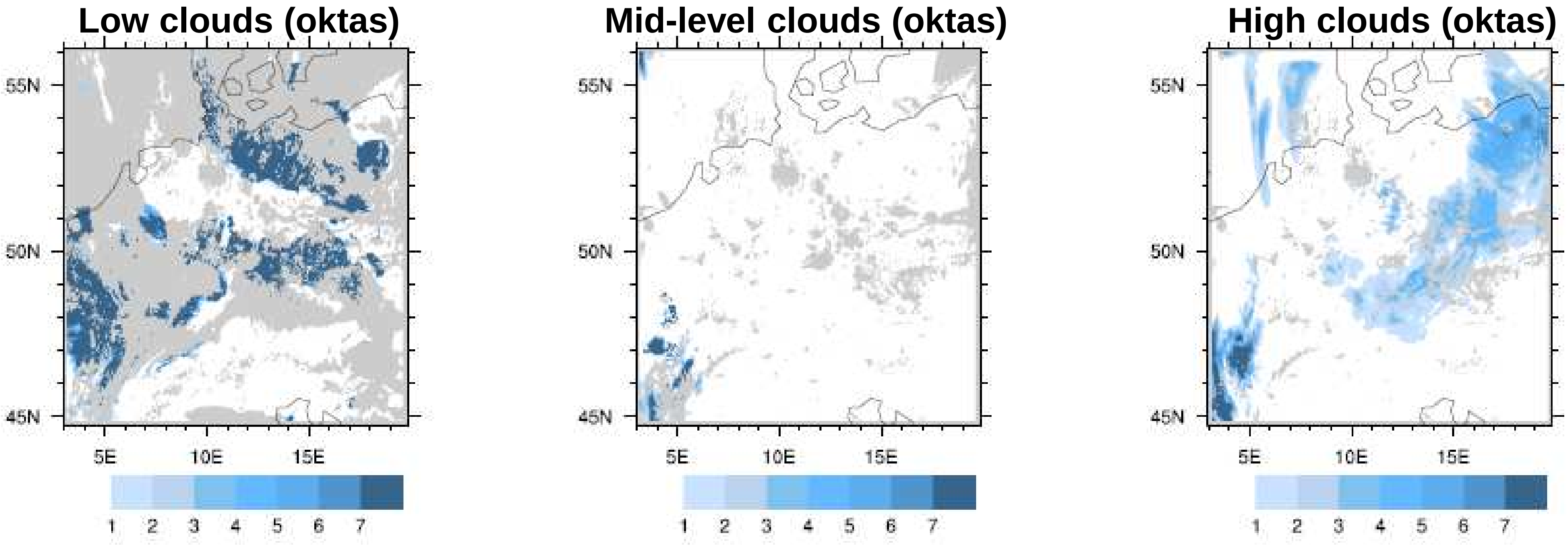
type of obs increment ,
for pixels observed to be **cloud-free** ?

- assimilate cloud fraction $CLC_{obs} = 0$
  separately
  for high, medium, low clouds

- model equivalent:
  maximum CLC within vertical range

Use of CTH 'obs' for **cloud-free** pixels : Example

➔ COSMO cloud fraction where observations "cloudfree"



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Cycling LETKF data assimilation experiment : comparison

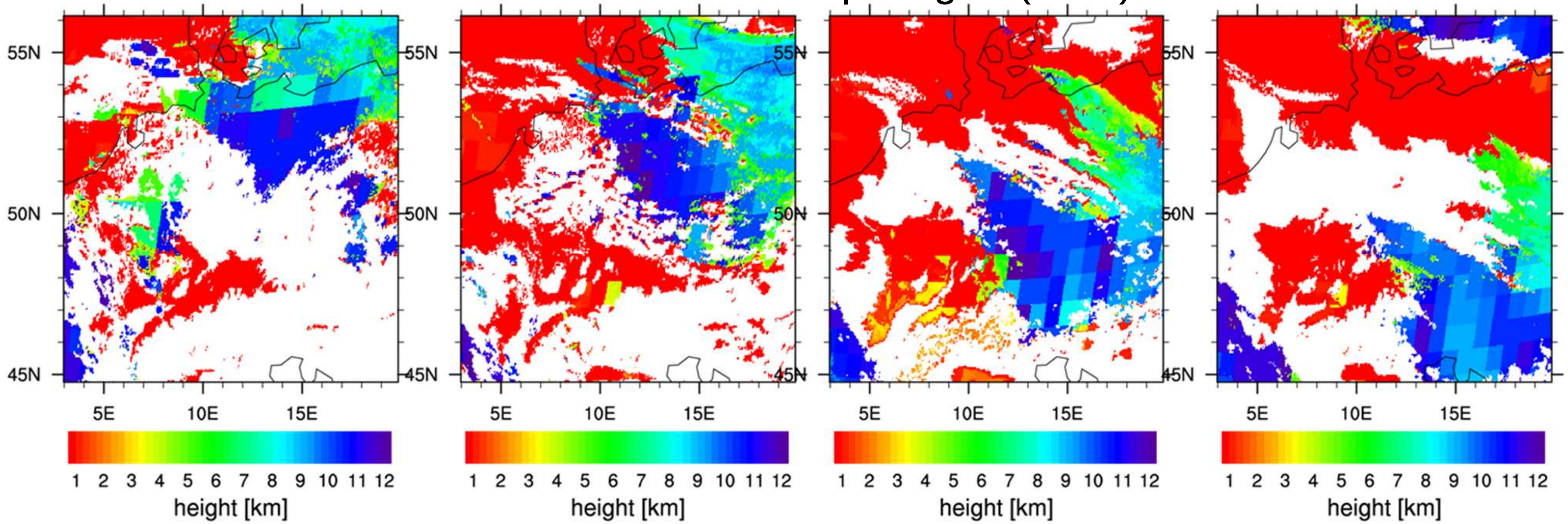
only conventional obs (radiosonde, aircraft, wind profiler, surface)

vs

conventional + cloud data

- LETKF: 40 ensemble members, obs thinning 14 km
- 1-hourly cycling over 21 hours, 13 Nov., 21 UTC – 14 Nov. 2011, 18 UTC (wintertime low stratus)

observed cloud top height (CTH)



0:00 UTC **6:00** UTC **12:00** UTC **17:00** UTC

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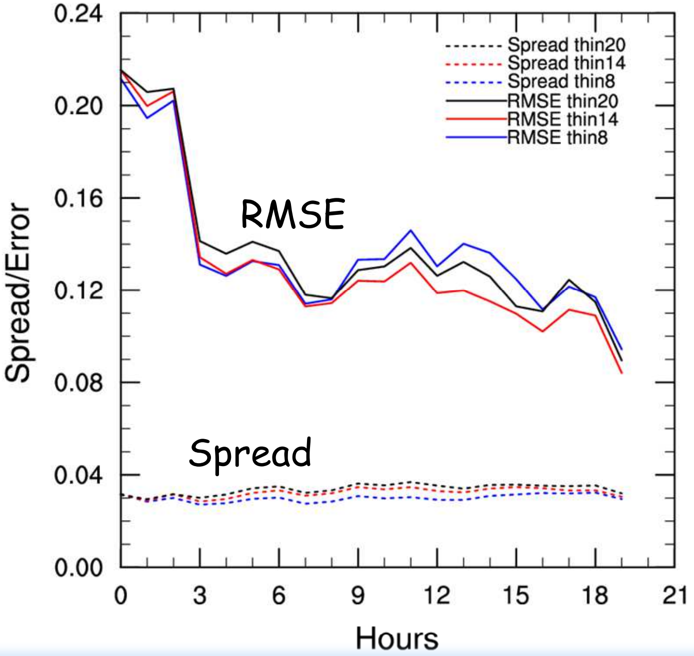
Sensitivity experiment :
data density

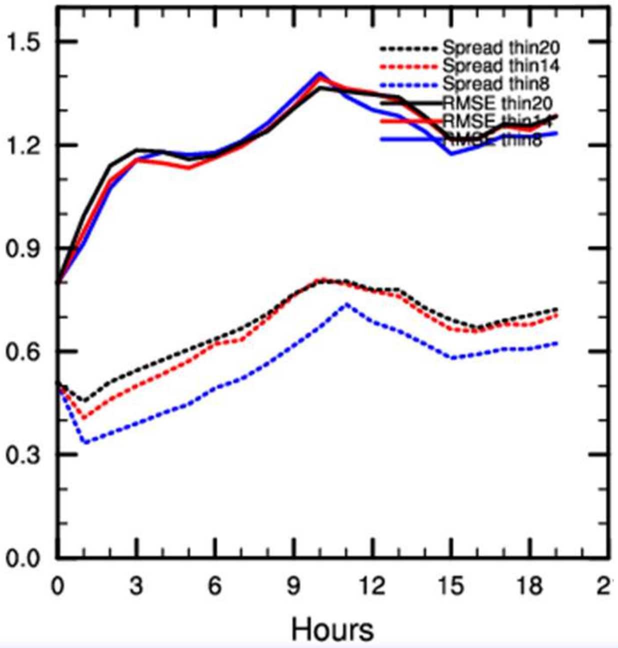
➔ Comparing experiments with different data density:

- 8 km
- 14 km
- **20 km**

RH at observed cloud top
(cloudy obs)



low cloud cover
(cloud-free obs)



➔ *cloudy pixels: best results for a 14 km thinning*
cloud-free pixels: no clear conclusion

➔ *lower spread for 8km thinning experiment (small difference in spread betw. 14 / 20km thinning*

➔ *ensemble is underdispersive, but no sign of a further reduction of spread during the cycling*

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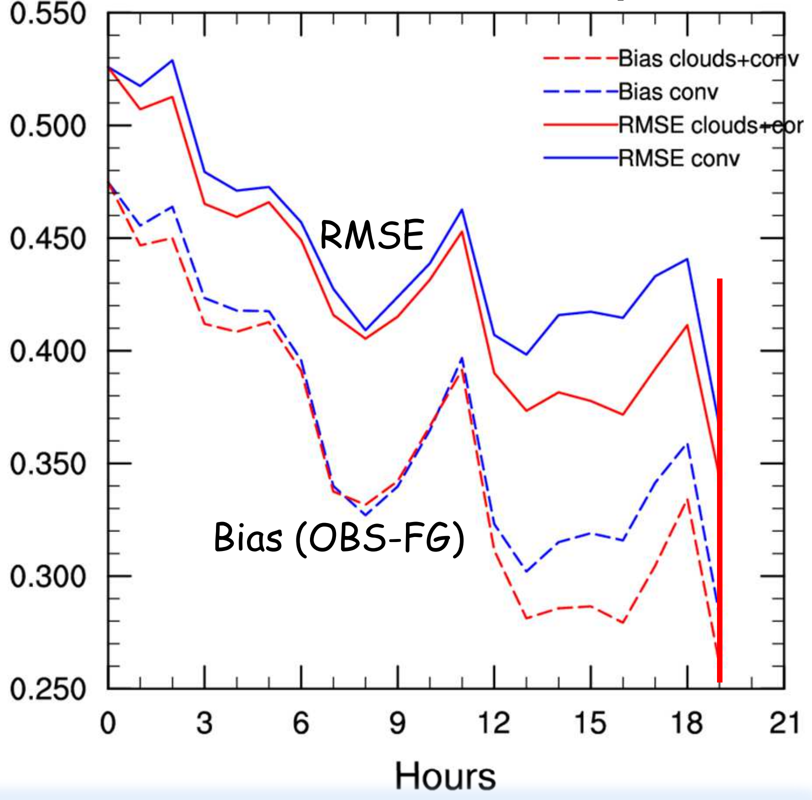
Cycling LETKF: comparison 'only convectional' versus 'conventional + cloud obs'

Time series of first guess errors, averaged over **cloudy** obs locations

assimilation of conventional obs only
assimilation of conventional + cloud obs

RH (relative humidity) at observed cloud top



→ Cloud assimilation reduces RH (1-hour forecast) errors

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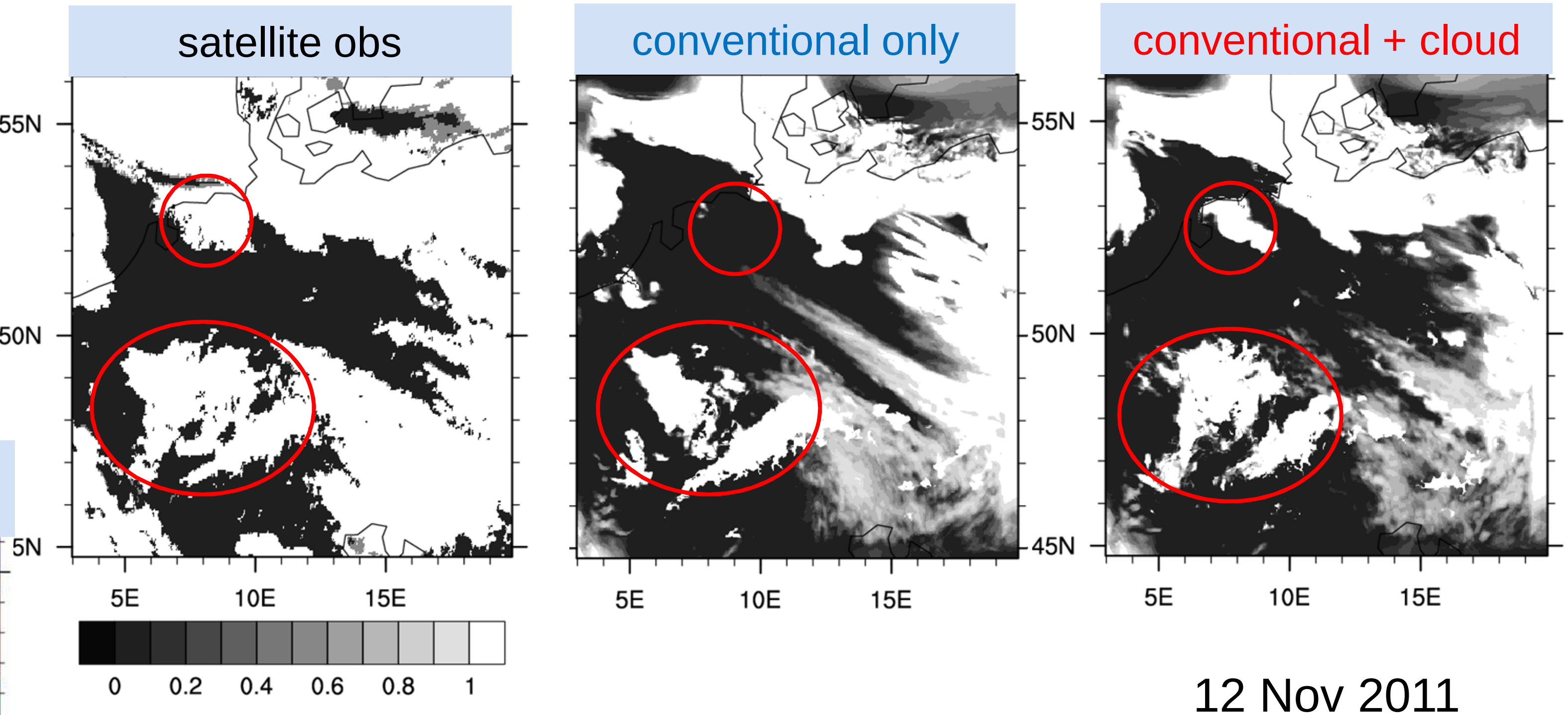
Cycling LETKF: comparison ‘only convectional’ versus ‘conventional + cloud obs’

Total cloud cover of first guess fields after 20 hours of cycling

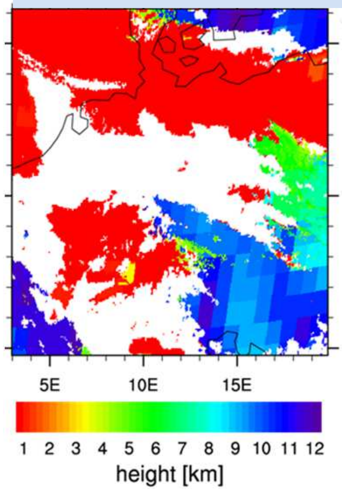

satellite obs

conventional only

conventional + cloud

12 Nov 2011
17:00 UTC

Satellite cloud top height



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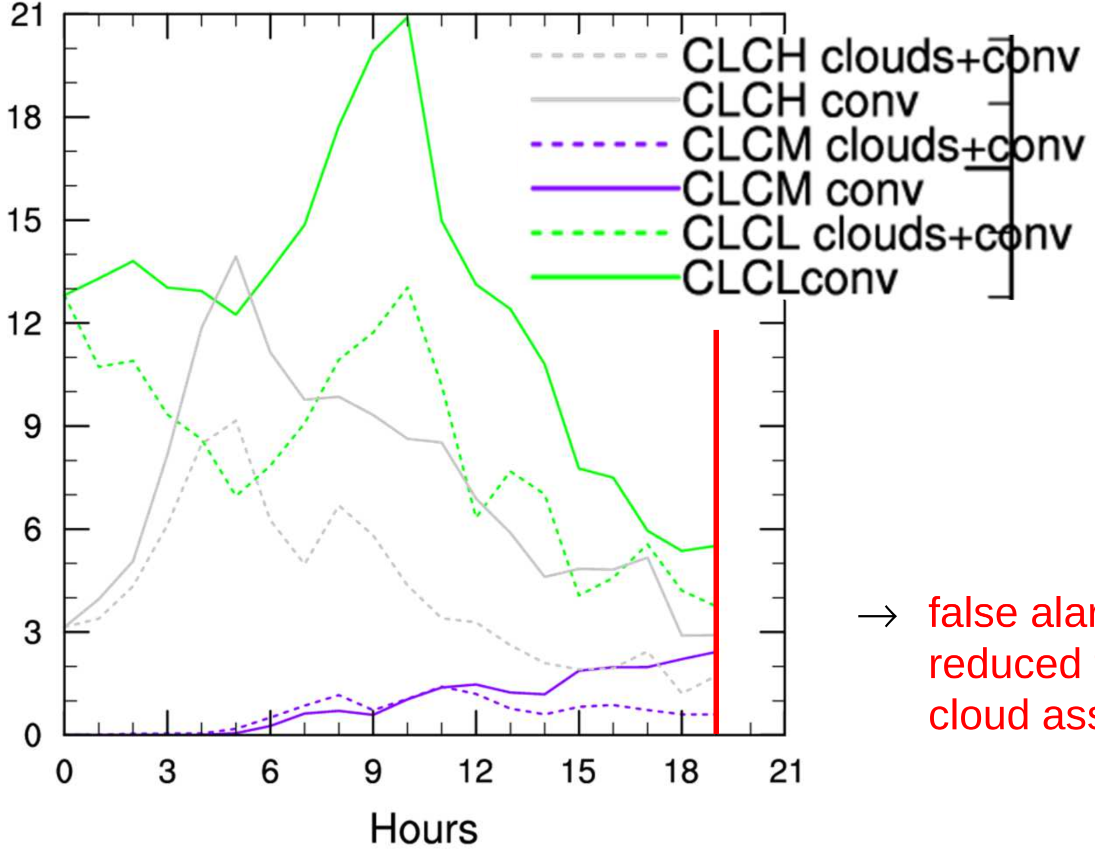
Cycling LETKF: comparison 'only convectional' versus 'conventional + cloud obs'

time series of first guess errors, averaged over **cloud-free** obs locations
(errors are due to false alarm cloud)

mean square error of cloud fraction [octas]

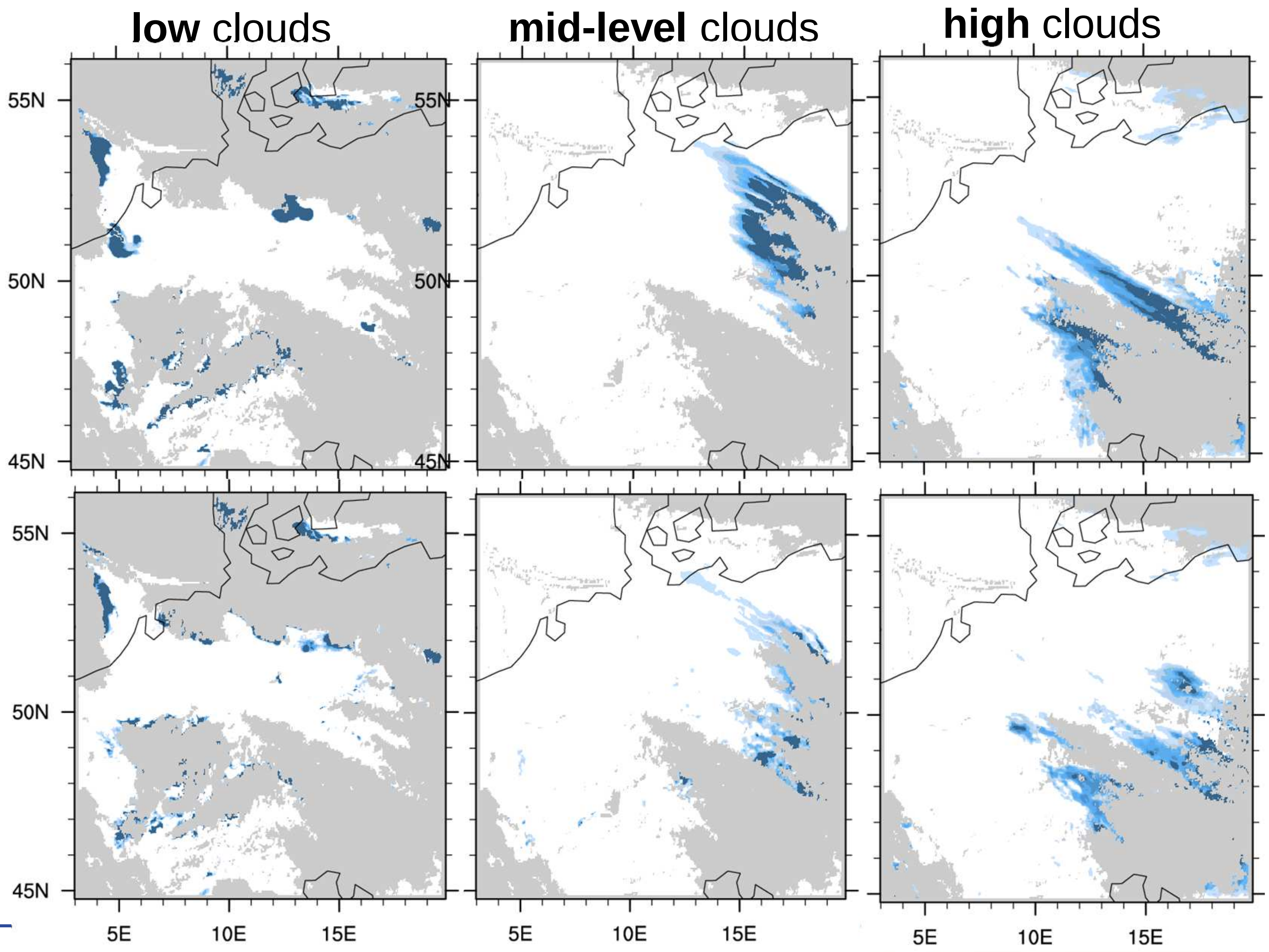


→ false alarm clouds reduced through cloud assimilation

Cycling LETKF: comparison 'only convectional' versus 'conventional + cloud obs'

'false alarm'
cloud cover
(after 20 hrs cycling)

**conventional
obs only**



[octa]

**conventional
+ cloud**

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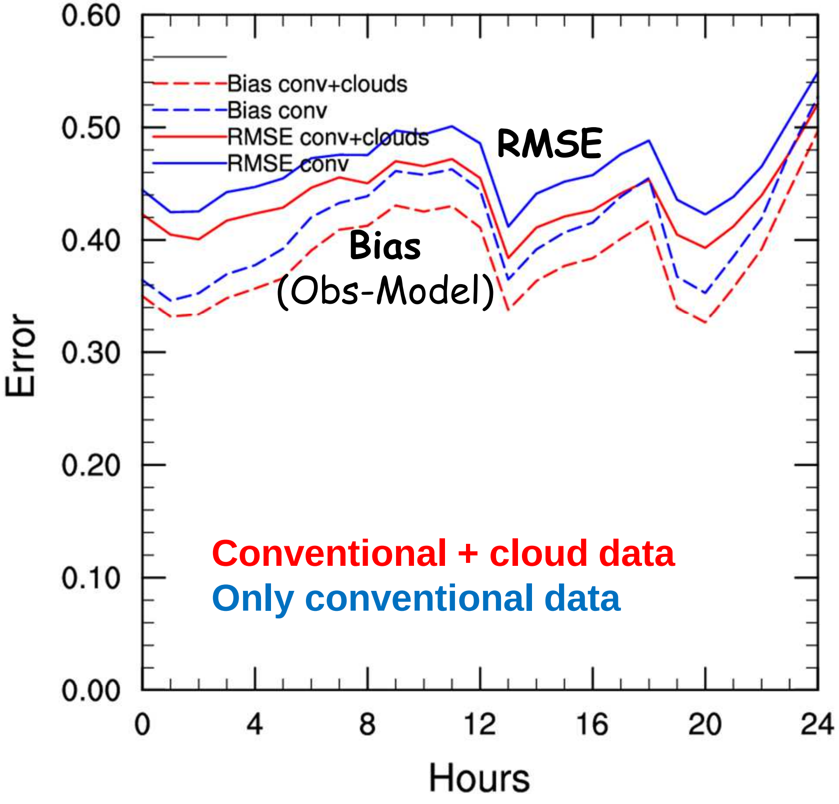
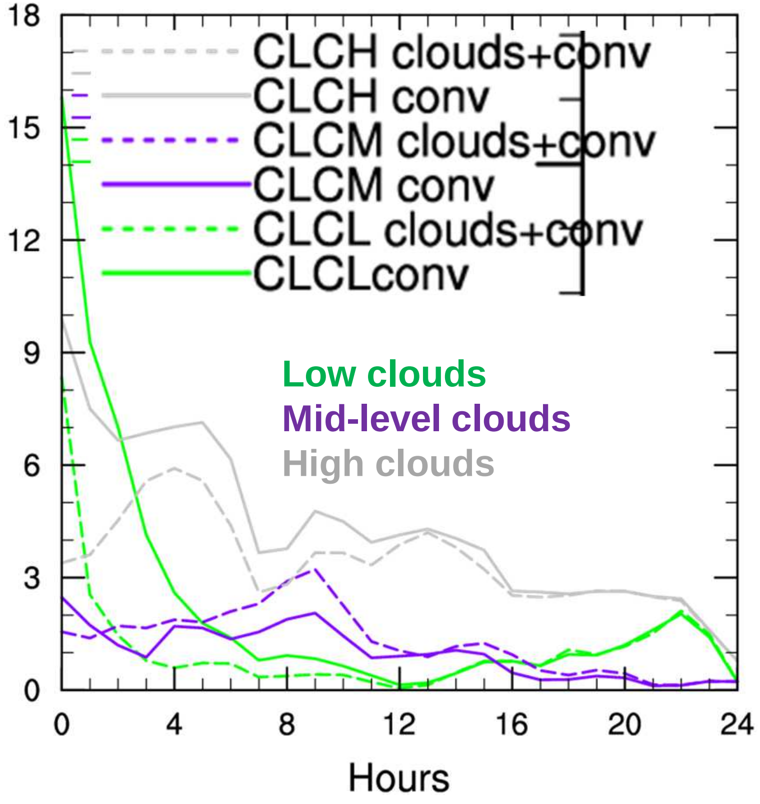
Comparison of free deterministic forecast (after 12 hrs DA): time series of errors

(forecast starts 14 Nov., 9 UTC)

RH at observed cloud top
averaged over **cloud-covered** obs



mean square error of cloud fraction
averaged over **cloud-free** obs



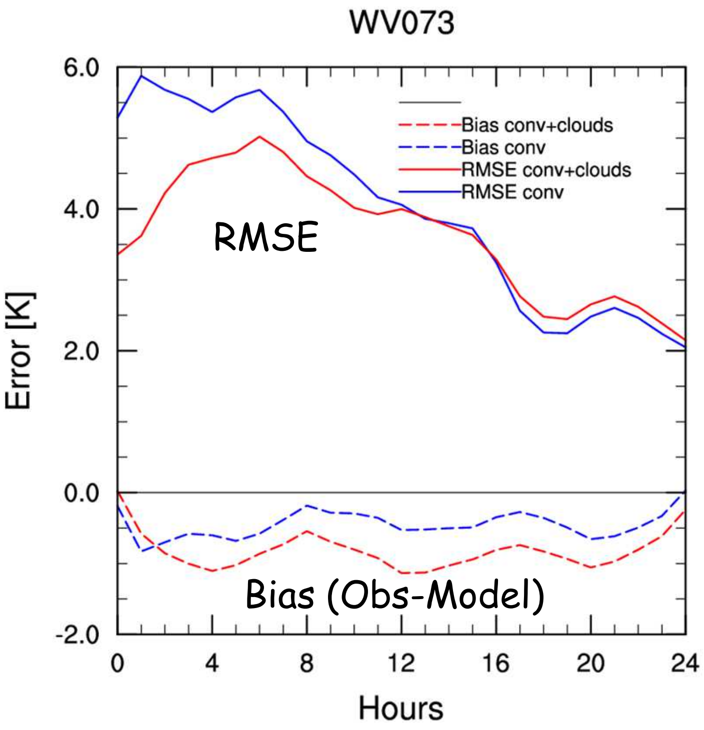
➔ *The forecast of cloud characteristics can be improved through the assimilation of the cloud information*

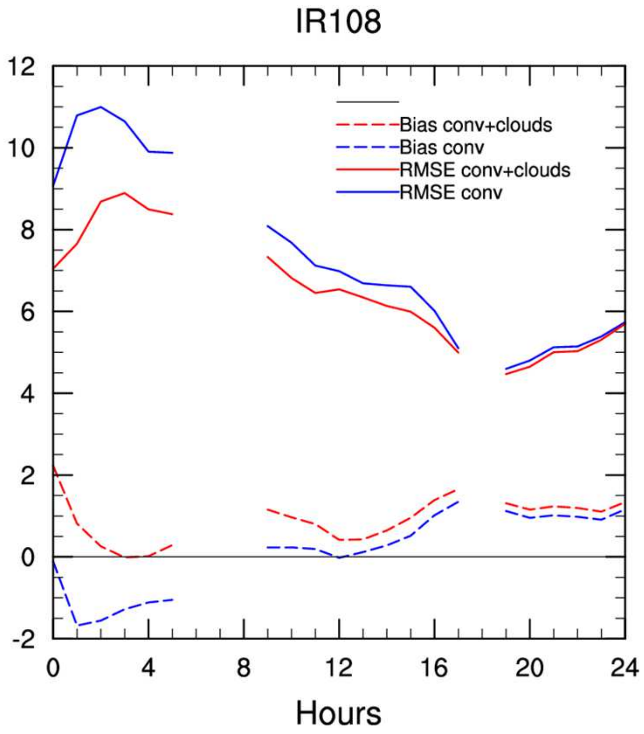
Verification of free deterministic forecast against independent observations

Errors for SEVIRI infrared brightness temperatures

(model values computed with RTTOV)

Conventional + cloud data
Only conventional data





→ RMSE is smaller for first 16 hours of forecast for cloud experiment, bias varies

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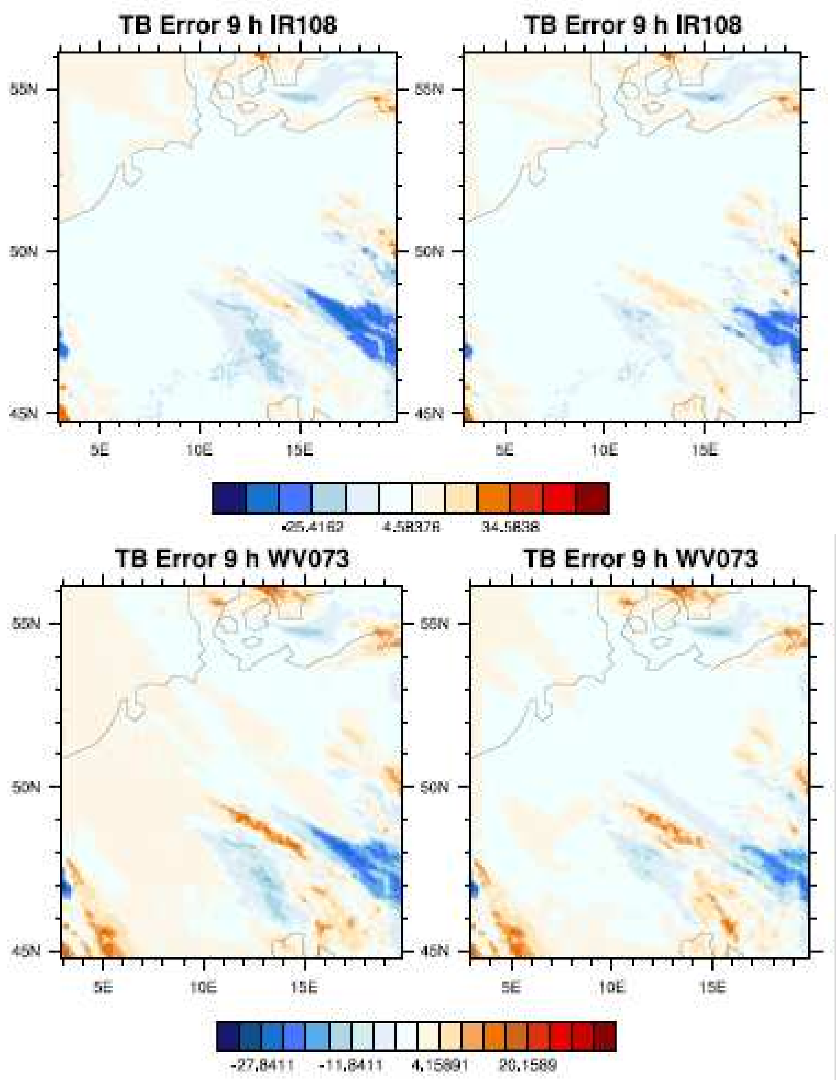
Verification of 9-h forecast against indep. obs: SEVIRI brightness temperature

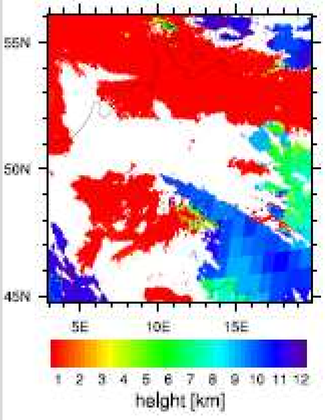
Only CONV experiment

14 Nov 2011,
18 UTC



CONV+CLOUD experiment

Cloud top height



→ *Also the high clouds are simulated better in the cloud experiment*

Conclusions

Use of (SEVIRI-based) cloud observations in LETKF:

- Tends to introduce humidity / cloud where it should
- Tends to reduce ‘false-alarm’ clouds
- Improvement on cloud characteristics in free forecast for a stable wintertime high-pressure systems
- May also be useful for convective situations
  - If convective clouds are captured better while developing, convective precipitation may be improved → needs to be tested

Next steps

- Evaluate other variables and other cases, longer time series
- Application in project EWeLiNE: Improving the forecast for renewable energy sector (clouds particularly important for photovoltaic power production)
- Also work on direct SEVIRI radiance assimilation
  (together with Africa Perianez, Robin Faulwetter)

Thank you for your attention!

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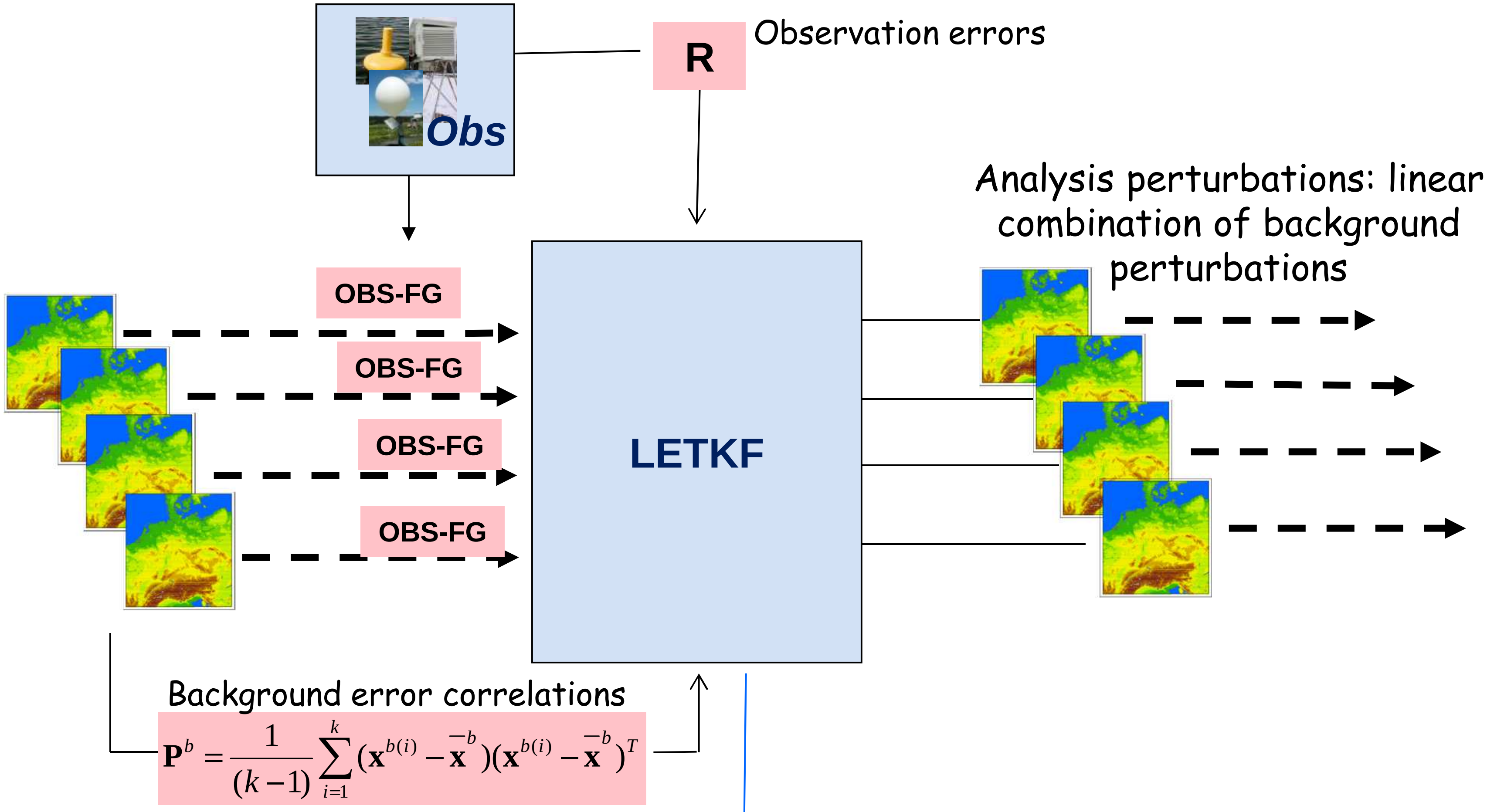
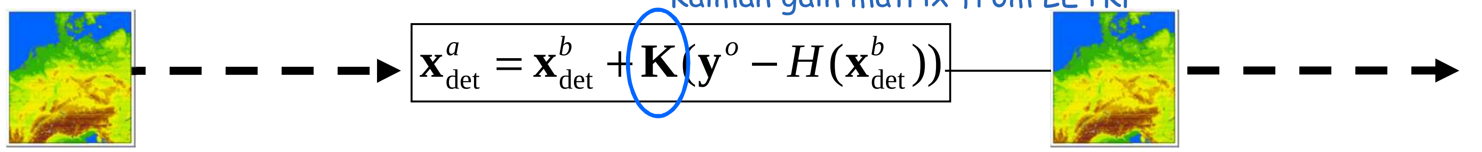
Local Ensemble Transform Kalman Filter



$$\mathbf{P}^b = \frac{1}{(k-1)} \sum_{i=1}^{k} (\mathbf{x}^{b(i)} - \overline{\mathbf{x}}^b)(\mathbf{x}^{b(i)} - \overline{\mathbf{x}}^b)^T$$

Additional: one deterministic run:



$$\mathbf{x}^a_{\text{det}} = \mathbf{x}^b_{\text{det}} + \mathbf{K}(\mathbf{y}^o - H(\mathbf{x}^b_{\text{det}}))$$