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DWD

Characterization of MSG-SEVIRI IR satellite observations and their potential for convective-scale ensemble data assimilation

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Observations for convective-scale data assimilation

- Geostationary satellite observations:

  - high temporal (~min) and spatial (~km) resolution

  - major source of atmospheric information:
  strong sensitivity to temperature, water vapour, clouds

→ potential for convective-scale data assimilation

<u>Many challenges for optimal use:</u>

- fast and accurate forward operators
- assimilation of cloud-affected data

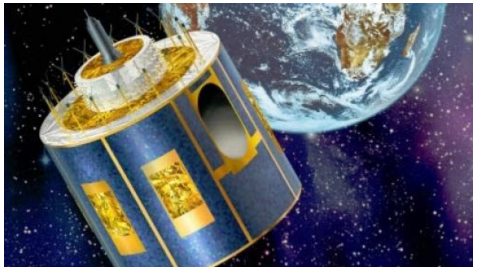
  (e.g., biases, non-Gaussian errors, difficulties in forward modelling)
- using ensemble data assimilation systems

  (e.g., vertical localization, ensemble background errors)

MSG – SEVIRI

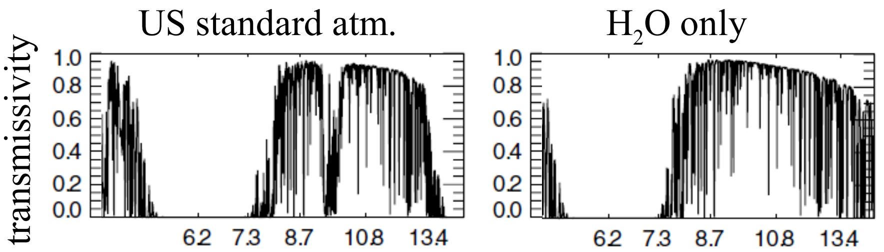
Meteosat Second Generation

Spinning-Enhanced Visible and Infrared Imager

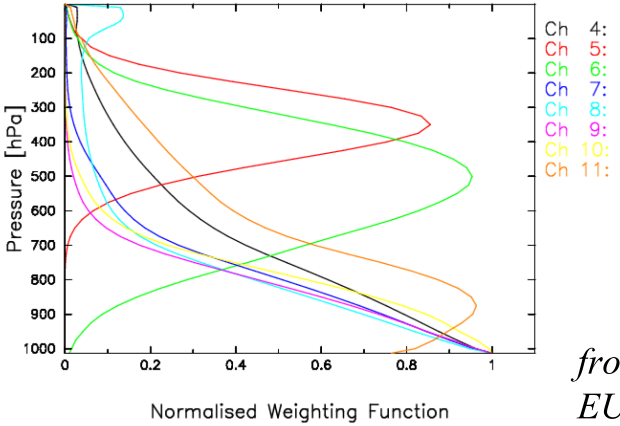


Channel no.		Characteristics of spectral band (μm)			Main gaseous absorber or window
		λ_{cen}	λ_{min}	λ_{max}	
1	VIS0.6	0.635	0.56	0.71	Window
2	VIS0.8	0.81	0.74	0.88	Window
3	NIR1.6	1.64	1.50	1.78	Window
4	IR3.9	3.90	3.48	4.36	Window
5	WV6.2	6.25	5.35	7.15	Water vapor
6	WV7.3	7.35	6.85	7.85	Water vapor
7	IR8.7	8.70	8.30	9.10	Window
8	IR9.7	9.66	9.38	9.94	Ozone
9	IR10.8	10.80	9.80	11.80	Window
10	IR12.0	12.00	11.00	13.00	Window
11	IR13.4	13.40	12.40	14.40	Carbon dioxide
12	HRV	Broadband (about 0.4 – 1.1)			Window/water vapor

from Schmetz et al. 2012



from Stengel 2005

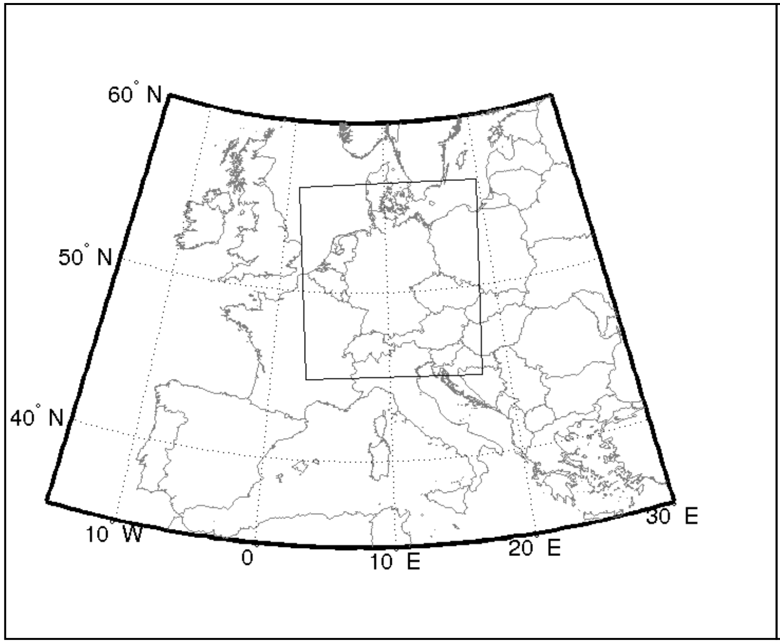


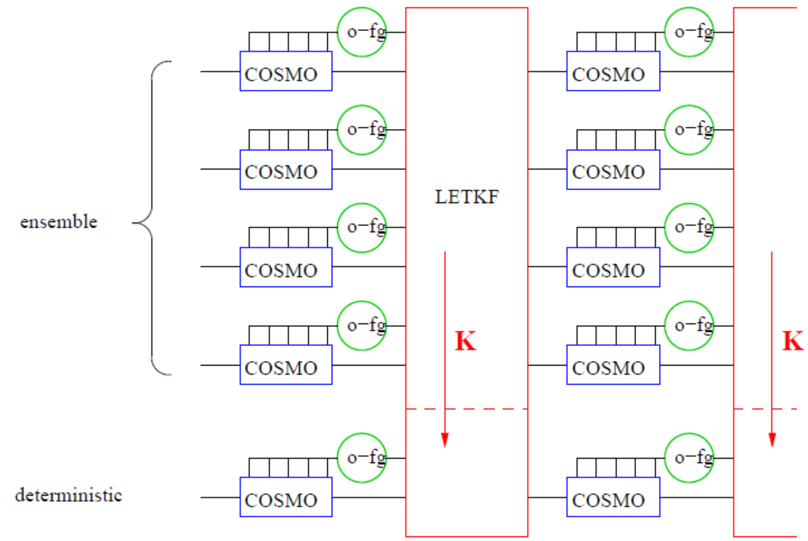
from EUMETRAIN, 2008

Overall goal:

- Direct assimilation of MSG SEVIRI all-sky observations in the experimental kilometre-scale ensemble data assimilation (KENDA) system of DWD

→ Local Ensemble Transform Kalman Filter (LETKF) in the COSMO-DE forecast model at 2.8 km horizontal resolution





from Schraff et al. 2015

Evaluation of satellite observation statistics

Summer time period from 01 – 06 July 2011 over central Europe

Reference experiment:

- Hourly DA cycle 40 ensemble member LETKF + deterministic run
- Assimilation of conventional observations
- Monitoring of brightness temperatures T_B for SEVIRI channels WV6.2, **WV7.3** at reduced horizontal resolution of ~10 km
- Radiative transfer with RTTOV 10:

  (i) multiple scattering scheme for cloudy scenes: fractional cloud clover, cloud liquid and ice water content (LWC, IWC)

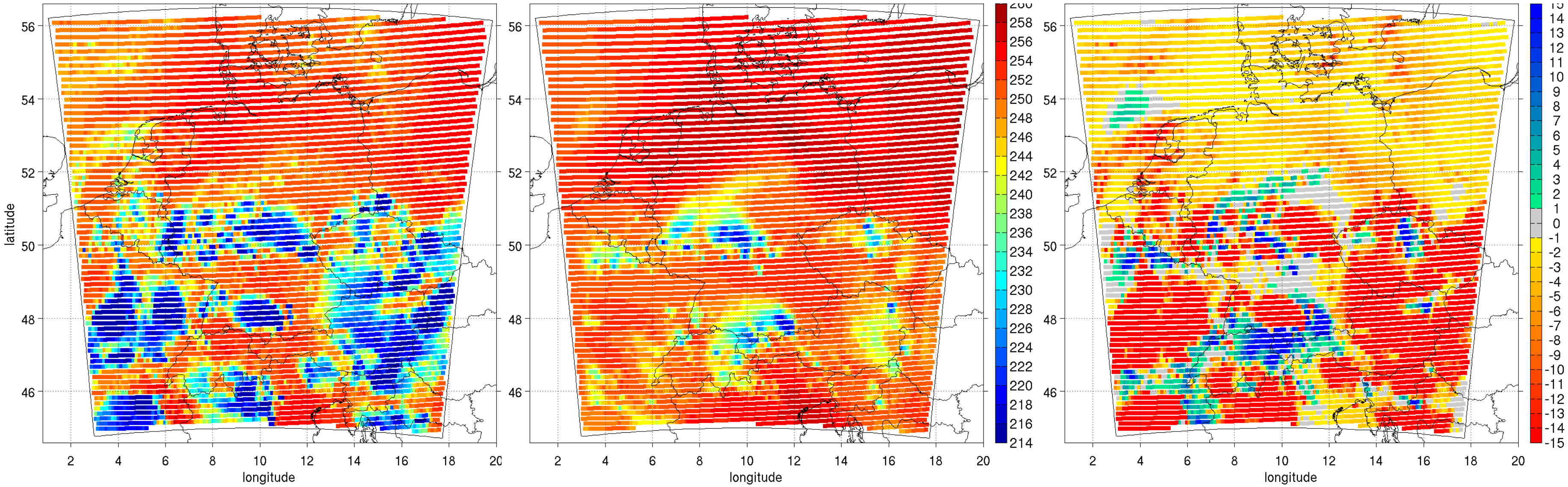
  (ii) Wyser (1998) parametrisation to convert IWC to effective diameter

  → potentially larger errors / biases in cloudy situations

Example case 16 UTC 04 June 2011

WV7.3 T_B (K):

observation **model** **observation - model**



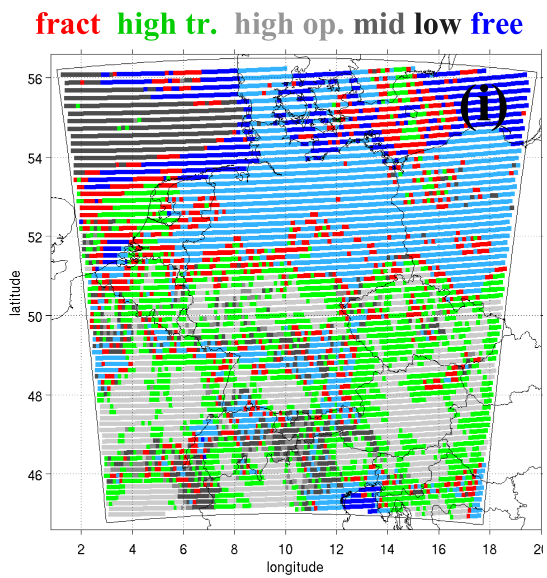
- Significant differences between observed and simulated T_B
- Errors seem to differ for clear and cloudy areas

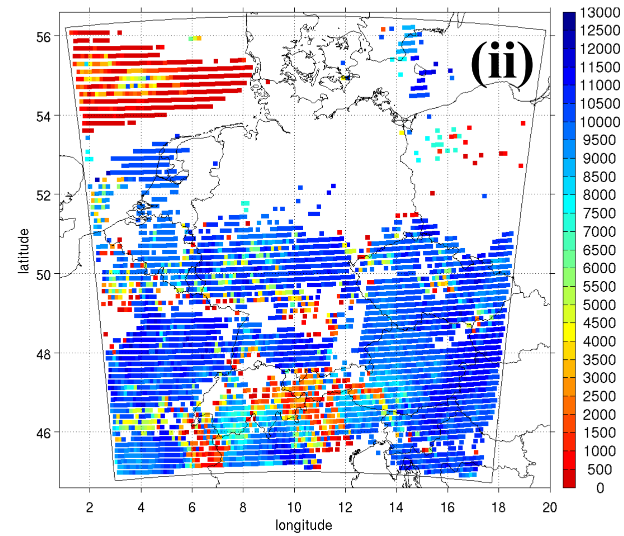
→ Evaluate performance and correct potential bias of simulated T_B

Evaluation of satellite observation statistics

- Nowcasting Satellite Application Facility (NWC SAF):

  (i) cloud type and (ii) **<u>cloud top height</u>** product for MSG-SEVIRI data





- **<u>Model cloud top height</u>** estimation from cloud LWC / IWC:

  model level where cloud water / ice content > 1 mg m^{-3}

Evaluation of satellite observation statistics

- Static bias correction derived from monitoring statistics as function of cloud type:

y^{BC} for T_B (K) at WV 7.3 µm:

-2.9 K	**clear**
-2.9 K	**low (< 2 km AGL)**
-3.1 K	**mid (2-6 km AGL)**
-4.4 K	**high (> 6 km AGL)**

from Perianez 2014

Evaluation of satellite observation statistics

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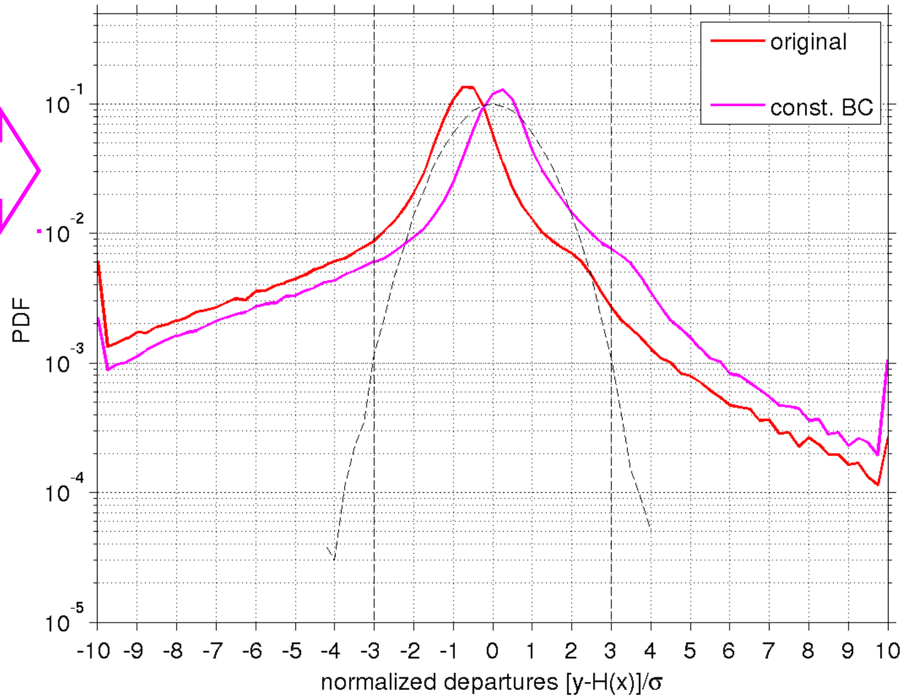
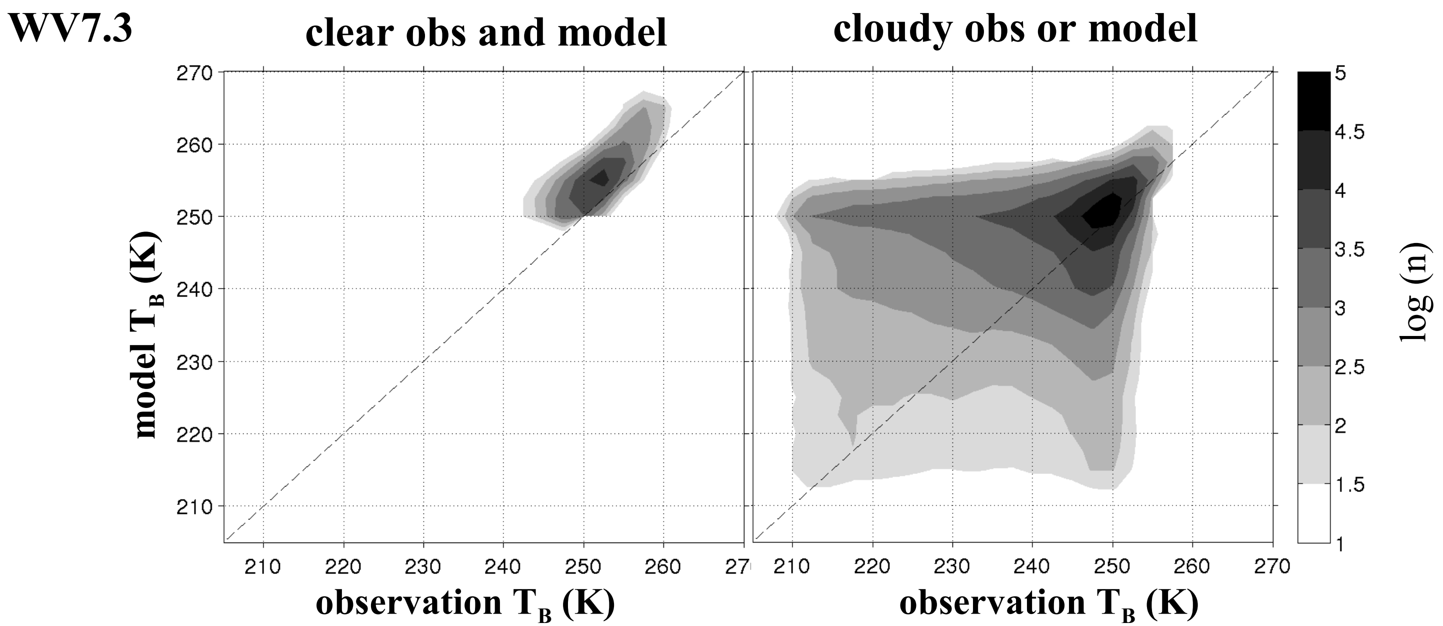
from Perianez 2014

WV7.3 T_B (K): [obs – model] / σ_o



→ Current bias is corrected, but actual values are likely to change

Error model for all-sky data assimilation



- Agreement between obs and model depend on the cloud type / height
- Forecasts are not very accurate in predicting exact cloud type / height at the correct location

Error model for all-sky data assimilation

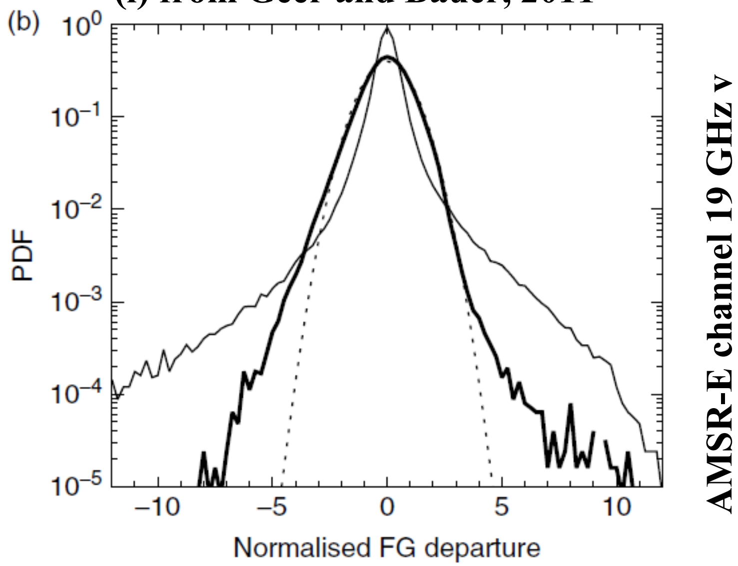
Can we predict how big the cloud impact is on the first-guess departures?

- Different predictors used before for observation errors:

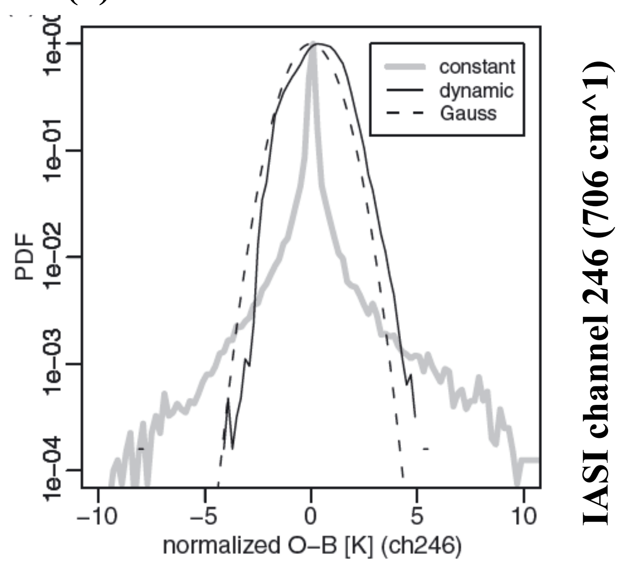
  (i) symmetric cloud amount or (ii) cloud effect average

  → used for quality control (QC) and observation error assignment

(i) from Geer and Bauer, 2011



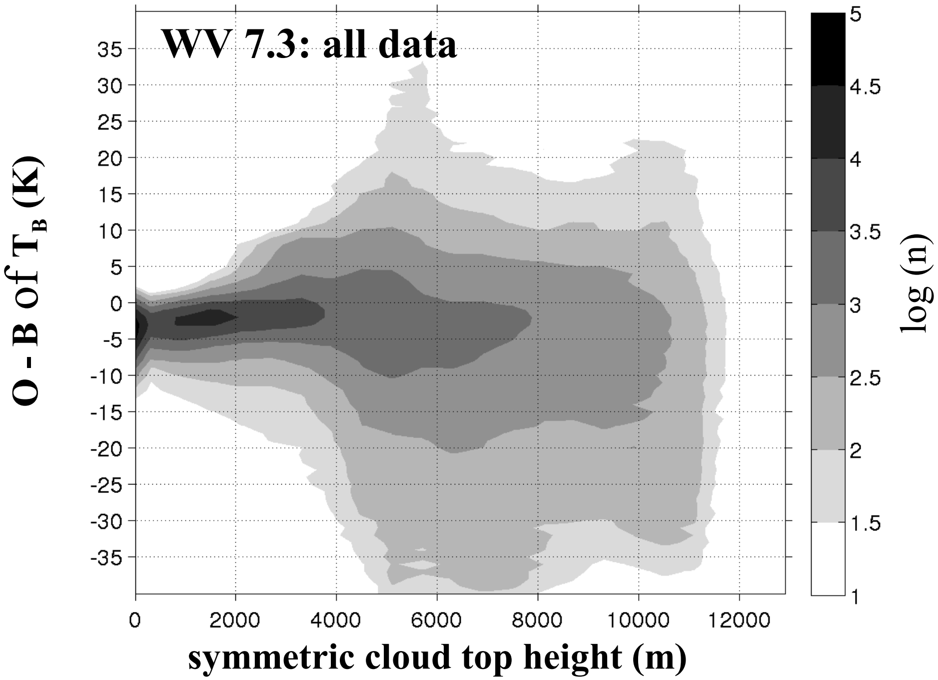
(ii) from Okamoto et al. 2014



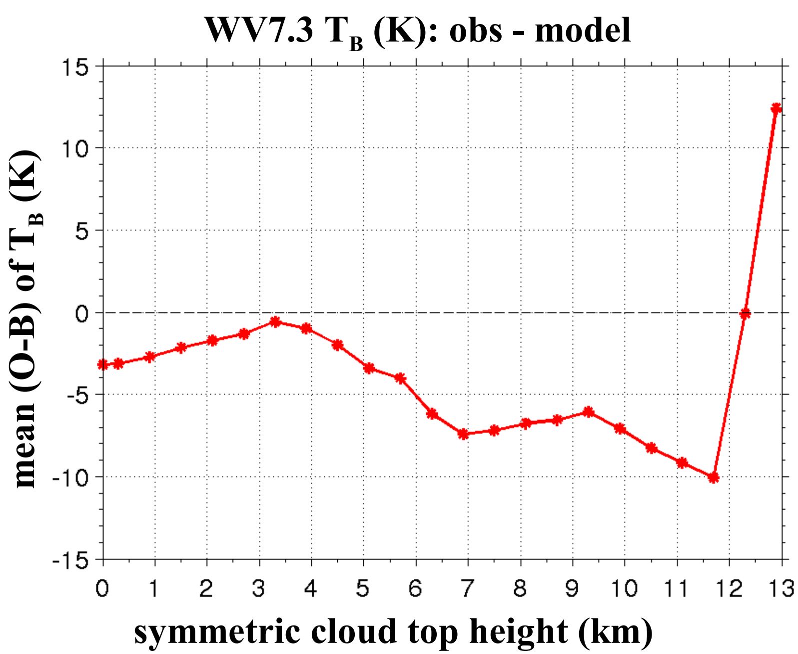
Error model for all-sky data assimilation

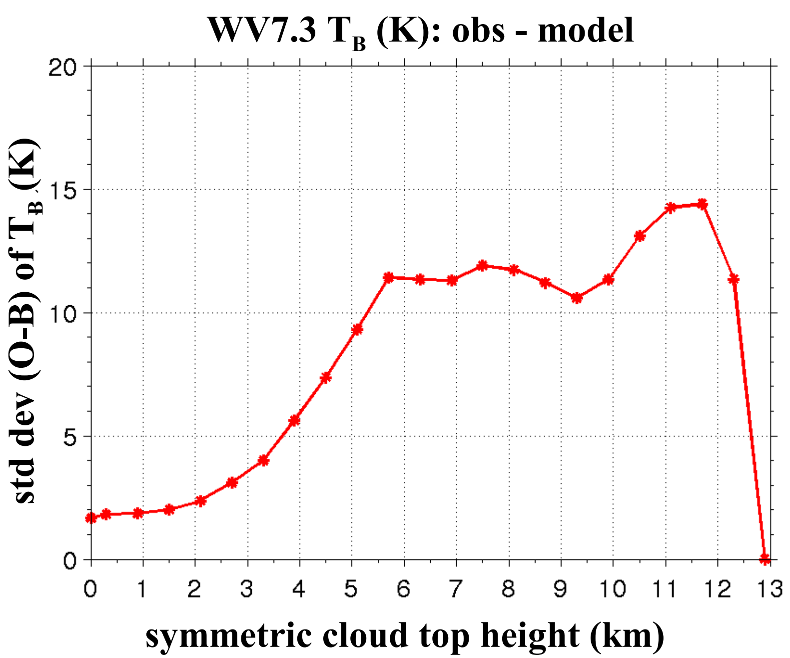
- Use cloud top height information from the observation and the model
- Define symmetric cloud top height

$$\text{cth\_sym} = (\text{cth\_obs} + \text{cth\_model}) / 2$$



Error model for all-sky data assimilation

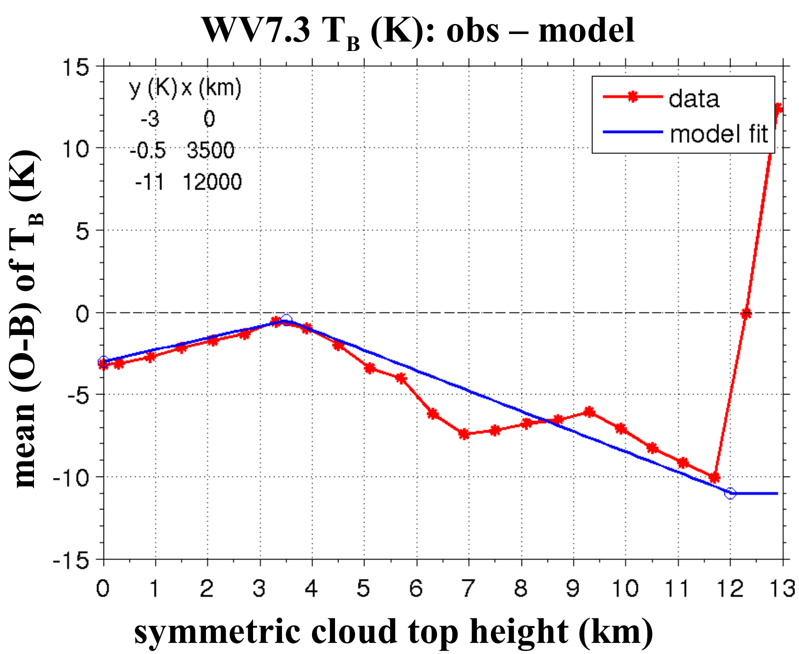


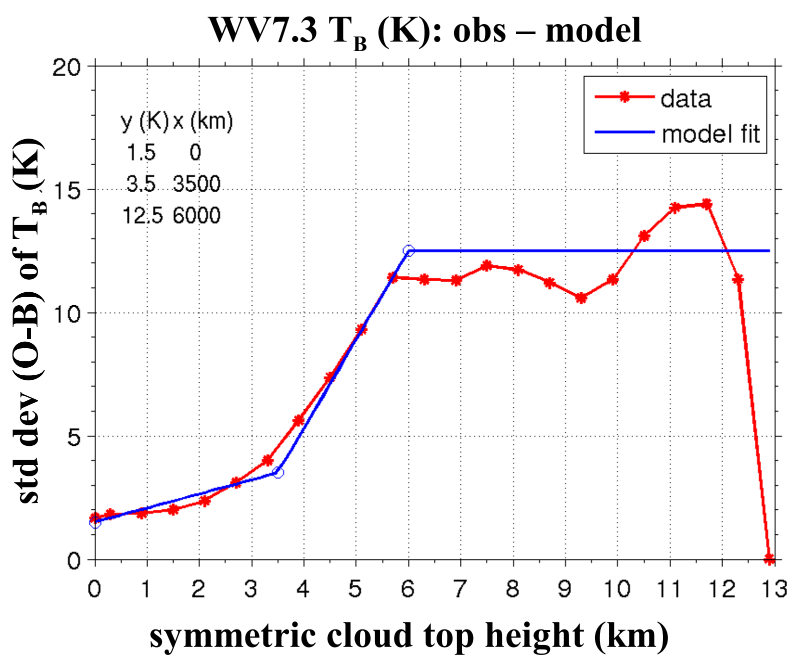


- Compute mean and standard deviation for different cth_sym bins

  → cth_sym can predict bias and standard deviation of O-B departures

Error model for all-sky data assimilation



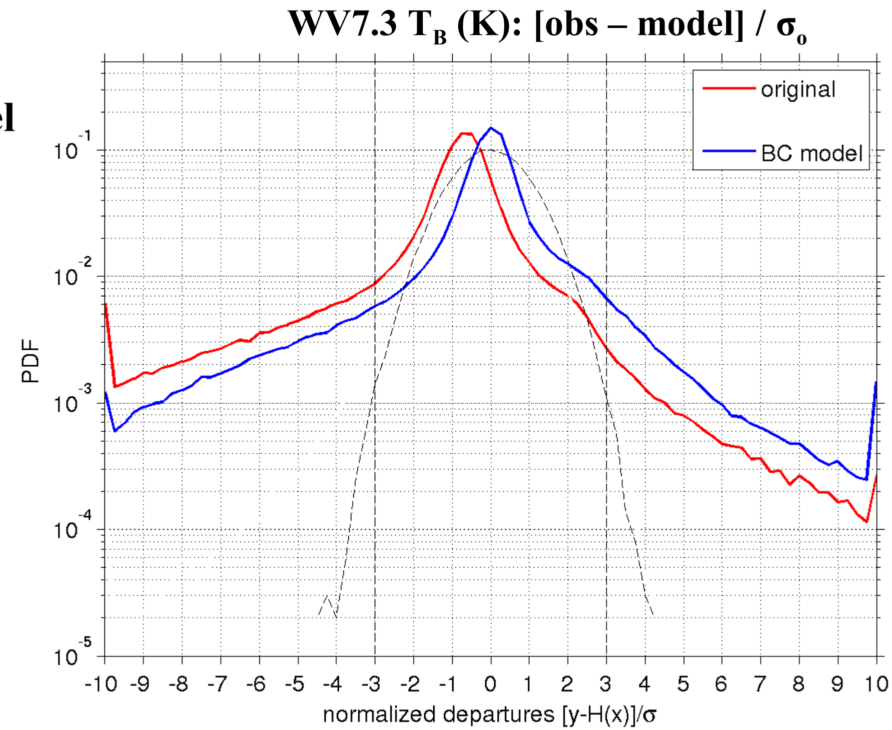


- Compute mean and standard deviation for different cth_sym bins

  → cth_sym can predict bias and standard deviation of O-B departures
- **Linear fit** to model standard deviation and bias as function of cth_sym

Error model for all-sky data assimilation

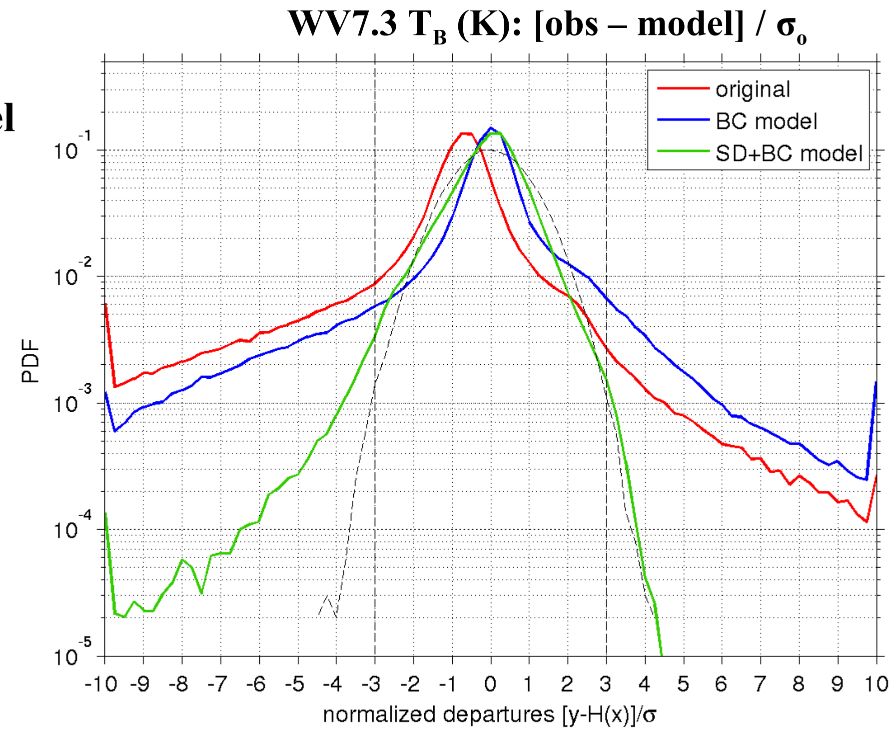
linear model



- Uncorrected O-B departures are non-Gaussian and biased
- Bias correction (BC) as function of cth_sym reduces the bias

Error model for all-sky data assimilation

linear model

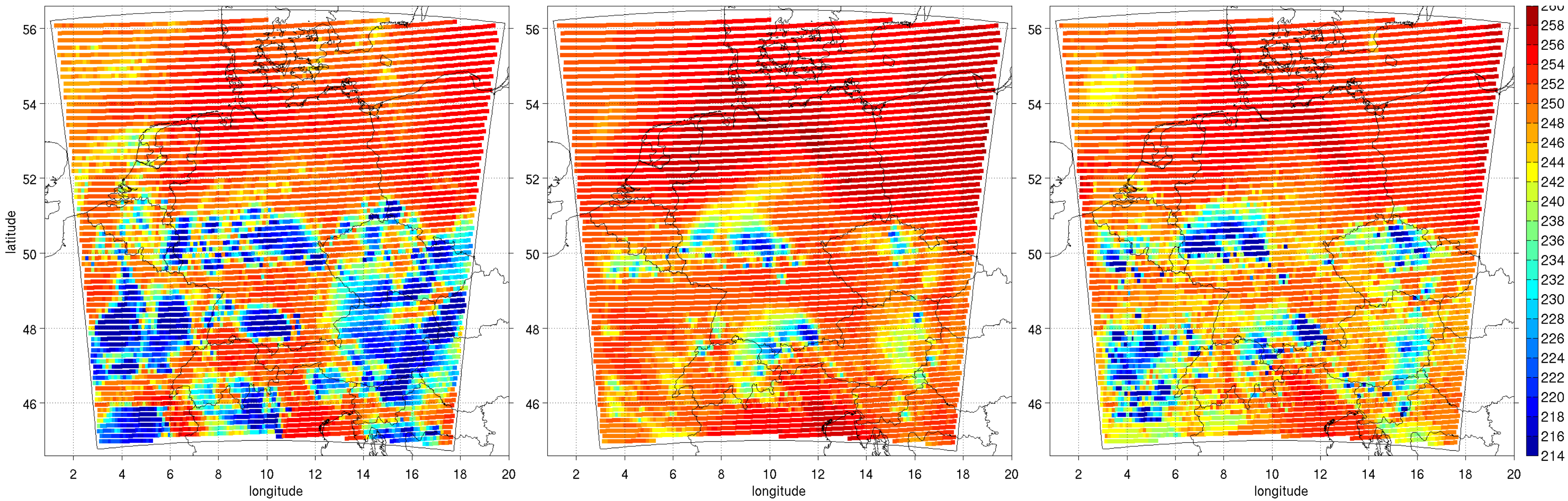


- Uncorrected O-B departures are non-Gaussian and biased
- Bias correction (BC) as function of cth_sym reduces the bias
- Dynamic observation error produces more Gaussian O-B departures

Bias correction on 16 UTC 04 June 2011

WV7.3 T_B (K):

observation **model** **bias corrected model**



- Model background seems to produce too few high-level clouds
- Overestimation of brightness temperatures, model is too warm
- BC model tries to reduce the warm model bias (clear sky & cloudy)

Bias correction of T_B in ensemble data assimilation

- Biases depent on the presence of a cloud and the cloud type

  → cloud dependent bias correction needed

- Bias correction is usually applied to the observations: $\mathrm{y} + \mathrm{y}_{\mathrm{bc}}$

- Different ensemble members might forecast different cloud situation

  → apply the bias correction to the model instead of the observation

$$\boxed{H(\mathbf{x}_b^l) + y_{bc}^l} \longrightarrow$$

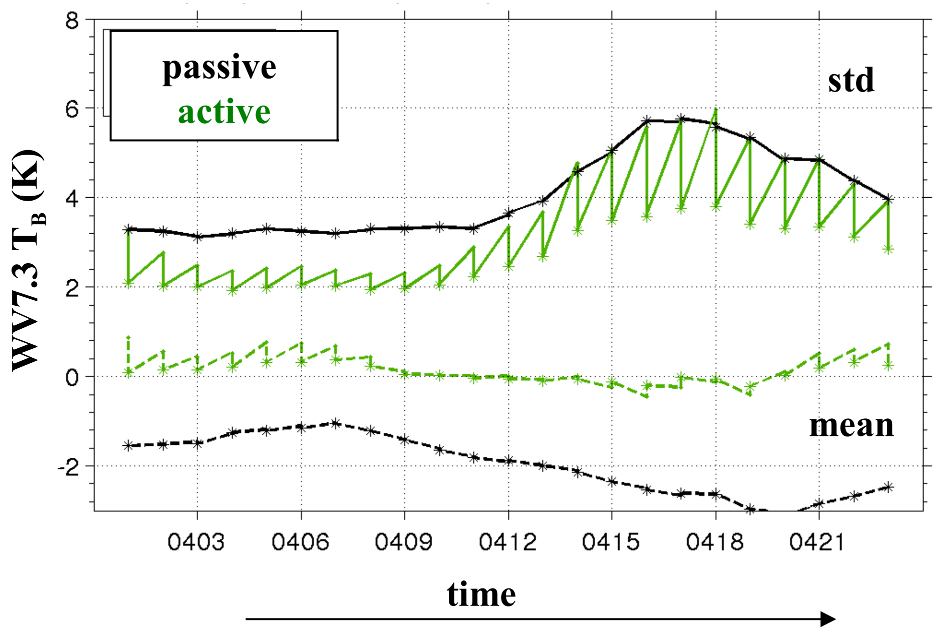
$$\overline{\mathbf{x}}_a = \overline{\mathbf{x}}_b + \mathbf{K}\left[\mathbf{y} - H(\overline{\mathbf{x}}_b)\right]$$

$$\overline{\mathbf{x}}_a = \overline{\mathbf{x}}_b + \mathbf{K}\left[\mathbf{y} - \frac{1}{L}\sum_{l=1}^{L}\left(H(\mathbf{x}_b^l) + y_{bc}^l\right)\right]$$

$$\overline{\mathbf{x}}_a = \overline{\mathbf{x}}_b + \mathbf{K}\left[\mathbf{y} - H(\overline{\mathbf{x}}_b) - \frac{1}{L}\sum_{l=1}^{L} y_{bc}^l\right]$$

Preliminary results of data assimilation

conv. obs.	active, as in reference
SEVIRI T_B	WV7.3 active (Δx~10 km)
bias correction	cth_sym (km) = [0,3.5,12] y^{bc} (K) = [-3,-0.5,-11]
obs. error	3.5 K
localization	l_h = 35 km, l_v = 0.7 log p



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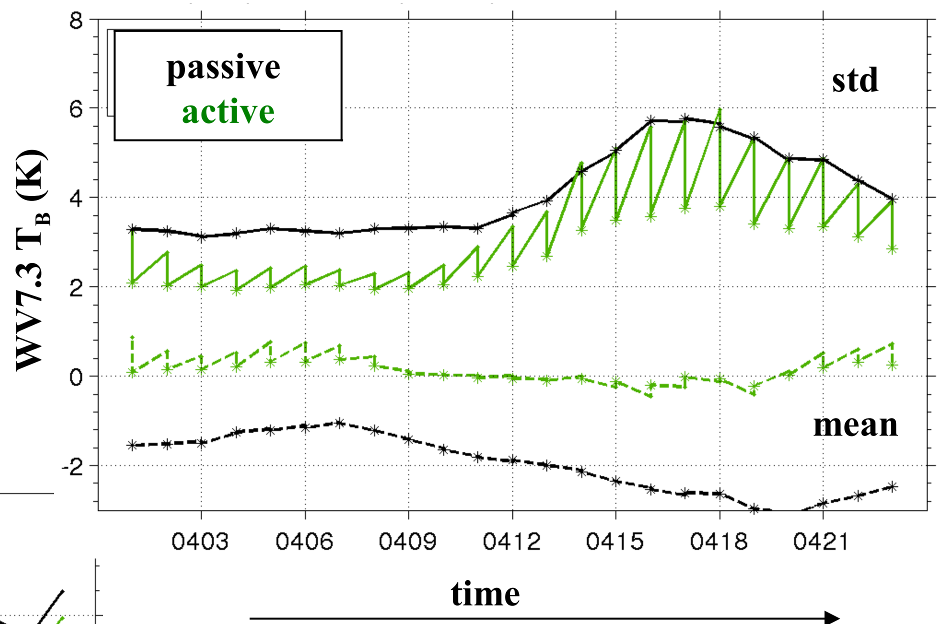

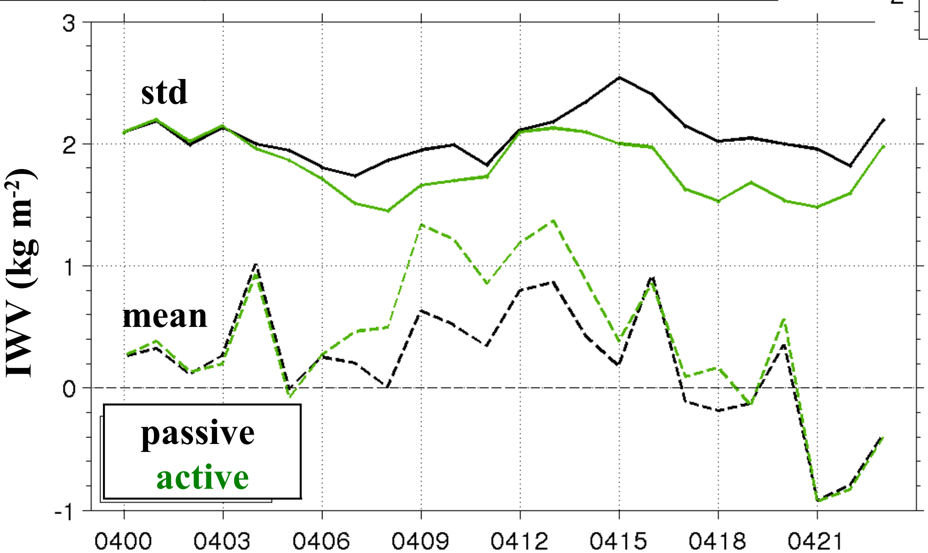

1-h FC of Integrated Water Vapour verified against GNSS surface stations

Summary

- Direct assimilation of all-sky MSG-SEVIRI brightness temperatures requires careful pre-processing before assimilation

  → large cloud dependent biases and observation errors

- Error model for assimilation of all-sky observations:
  use cth_sym to predict the expected observation statistics

  → bias / observation error can be modelled as function of cth_sym

  → cloud dependent bias correction shows good results

  → predicted observation error estimate can be used in the QC and data assimilation and should lead to more Gaussian statistics

- Preliminary results show that all-sky data assimilation of WV7.3 channel works in principle …

Outlook

- Include the observation error estimate in the QC and data assimilation

  → several observation error estimates possible in the ensemble
- Single-observation experiments: investigate the behaviour of the LETKF for different szenarios (e.g, cloudy in obs, clear in ensemble)
- Alternative predictors for the observation error model

  → different way to determine cth in model and obs, not optimal
- Super-obbing of SEVIRI observations → try to reduce non-linearities
- Sensitivity of simulated COSMO-DE T_B to changes in the parametrization (i) of microphysics and (ii) subgrid scale effects

  → impact on cloud properties, cloud cover, LWC/IWC, …
- Compare findings between VIS and WV (IR) channels for same period

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