Overview on ongoing work towards to the assimilation of cloud-sensitive data within KENDA

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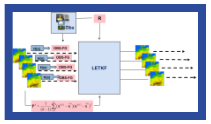
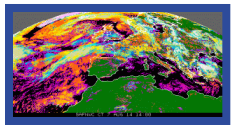
Outline

(Main) motivation: improve the **solar radiation** predictions for the **renewable energy** sector (within the EWeLiNE project)

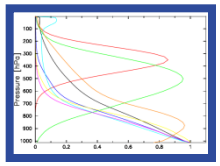


- **KENDA**

- **Assimilation of photovoltaic power**

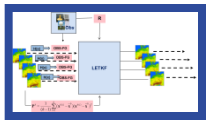


- **Assimilation of SEVIRI satellite cloud products**



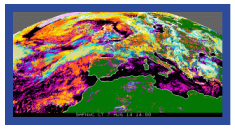
- **Assimilation of SEVIRI satellite radiance**

Outline



- KENDA

- Assimilation of photovoltaic power



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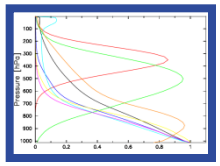
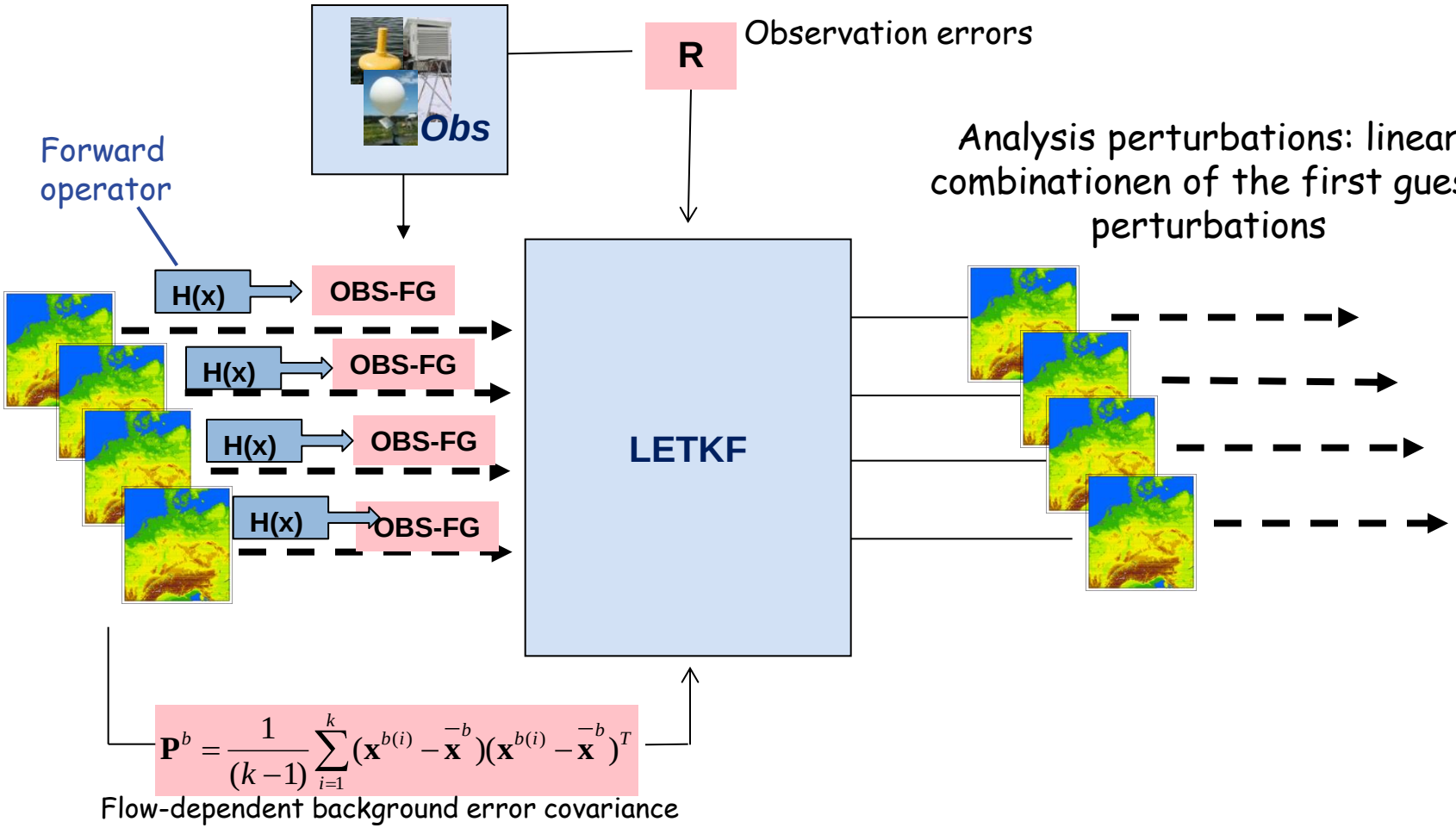


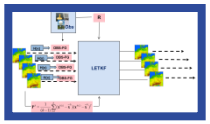
- Assimilation of SEVIRI satellite radiance

Local Ensemble Transform Kalman Filter



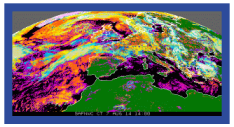
The closer an ensemble member to the observation, the higher it‘s weight in the analysis linear combination. No linear/adjoint model needed!

Outline

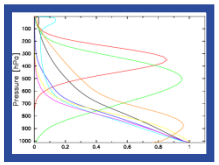


- KENDA

- Assimilation of photovoltaic power



- Assimilation of SEVIRI cloud products



- Assimilation of SEVIRI radiance

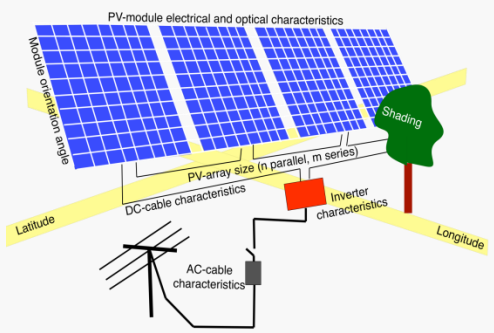
Assimilation of photovoltaic power

Forward operator (to derive the model equivalent for the LETKF):

Model variables:
- Surface irradiance
- 2m temperature
- Albedo

Module meta data:
- Orientation/tilt angle
- Latitude/Longitude
- Temperature coefficients
- Installed capacity

Forward operator for PV module



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- Transform to radiation at tilted plane
- Compute losses (soiling, module temperature, optical losses)

Synthetic PV power H(x)

Data quality

- PV panels yield unexpected power values for example in the case of
  - Meta-data often not given correct!
    - Peak power
    - Orientation / tilt angle
  - Possible failure of single strings
  - Soiling? Dust , leaves….
  - Shading by trees or buildings?
  - Snow on panels
  - Temperature coefficients unknown

→ *Some kind of quality control is essential!! Some bad data can easily spoil the positive impact of a lot of good data in the assimilation process!*

Quality control system

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

CMSAF satellite products:
- Direct surface radiation
- Diffuse surface rad.

COSMO-DE analyses:
- T2m
- Albedo

PV panel meta data
- Peak power, lat, lon
- Orientation and tilt angles

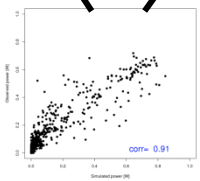
PV Forward operator

"theoretical" PV power

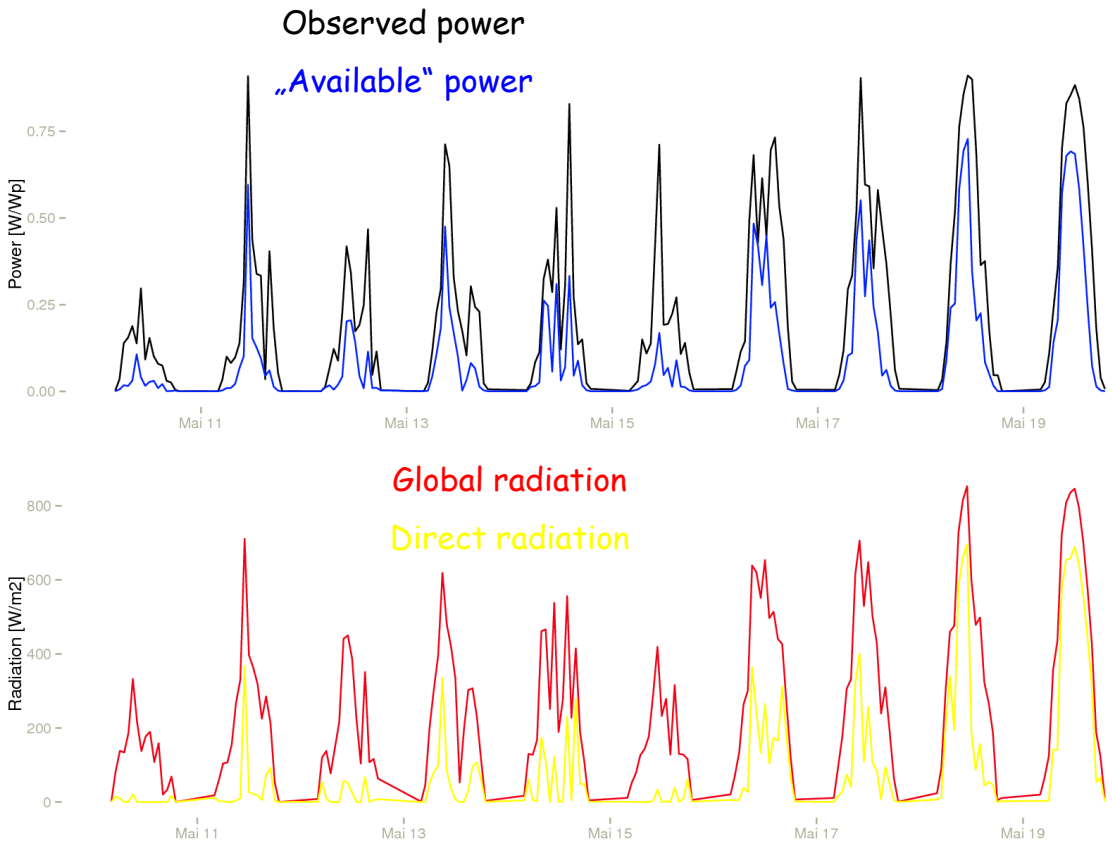
Observed PV power

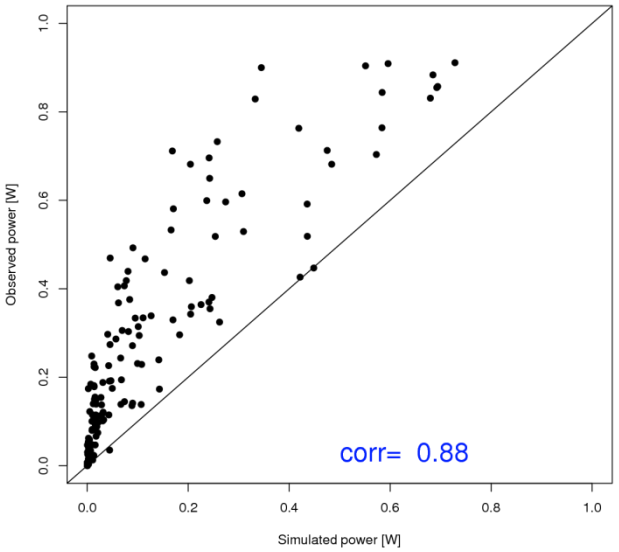
Compute statistics

-Correlation
-Mean error
-RMSE



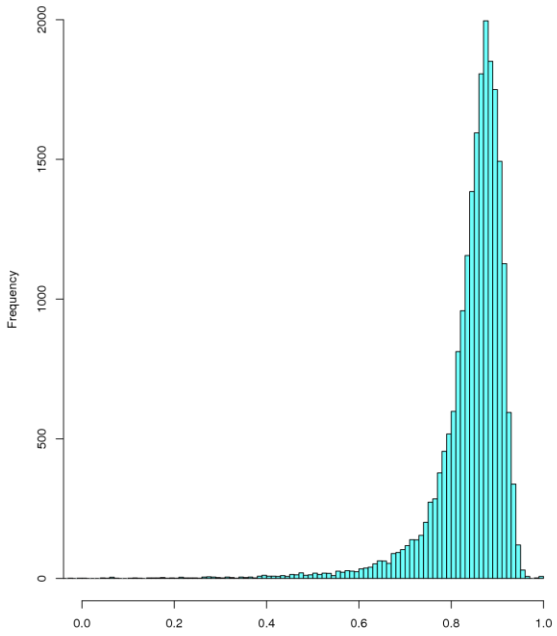
Quality monitoring for single panels



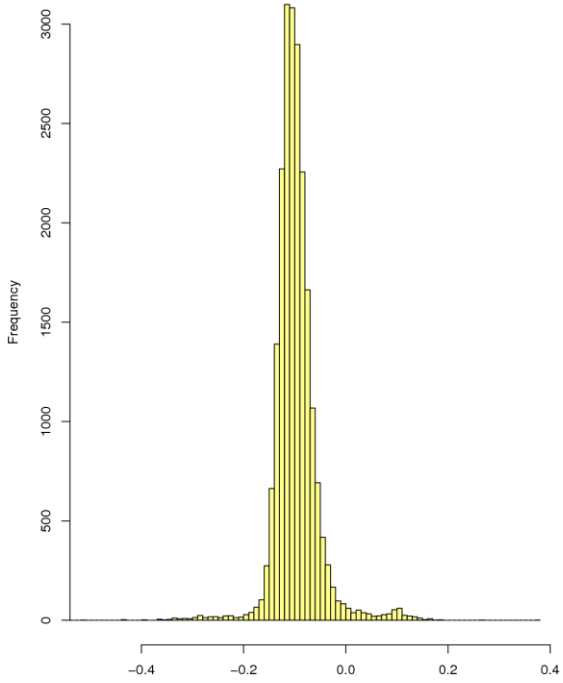


Quality: statistics
(from ~30,000 panels of company XX)

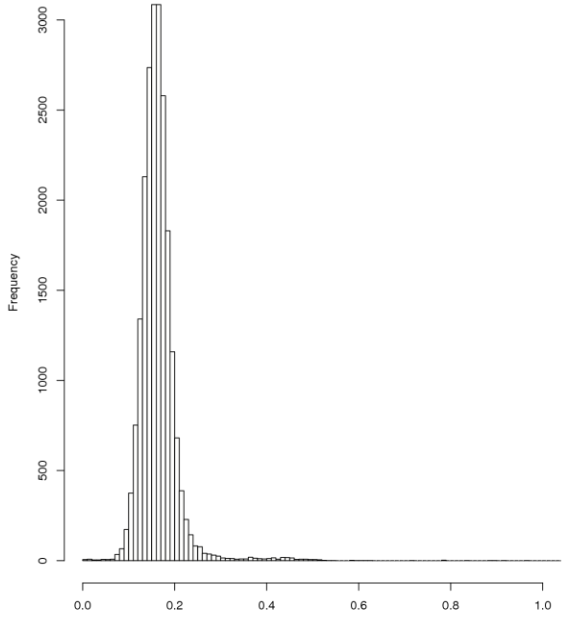
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Correlation



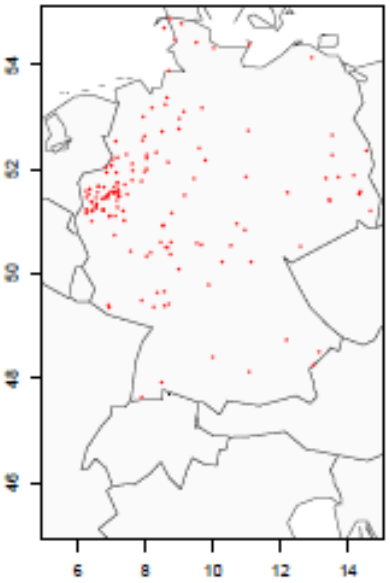
Bias (for W/W_p)



RMSE (for W/W_p)

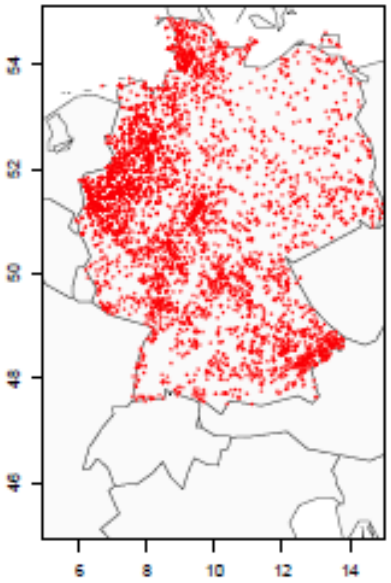
Data with sufficient quality

(out of 30,000 panels)



„best panels“

Corr > 0.9
RMSE < 0.05 * W_{peak}
BIAS < 0.1 * W_{peak}



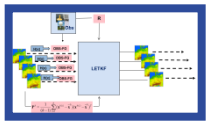
„good panels“

Corr > 0.85
RMSE < 0.15 * W_{peak}
BIAS < 0.15 * W_{peak}

NEXT:

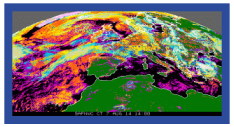
- Write blacklist of panels with bad data quality.
- Technical implementation
- First assimilation experiments.

Outline

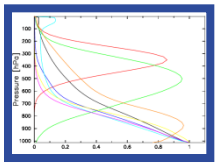


- KENDA

- Assimilation of photovoltaic power



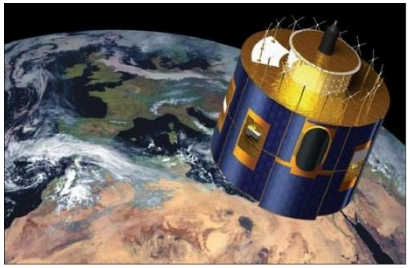
- Assimilation of SEVIRI satellite cloud products



- Assimilation of SEVIRI satellite radiance

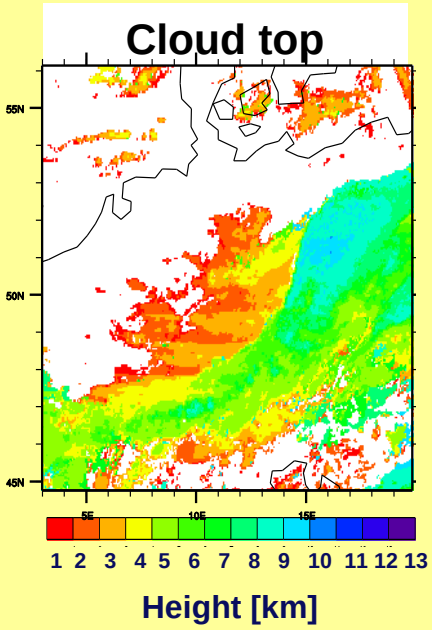
Satellite cloud product information

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



Source: EUMETSAT

NWCSAF satellite product: cloud top height

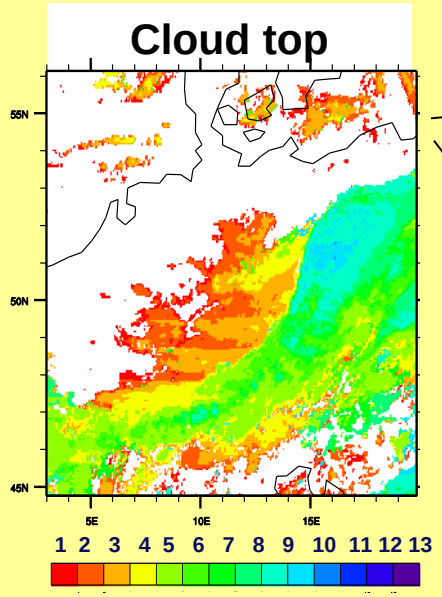


→ contains information on horizontal and vertical distributions of clouds

Method

- Extract information if a pixel is observed as **cloudy:**

OBSERVATION:
Satellite product: cloud top height



Assimilated variables:

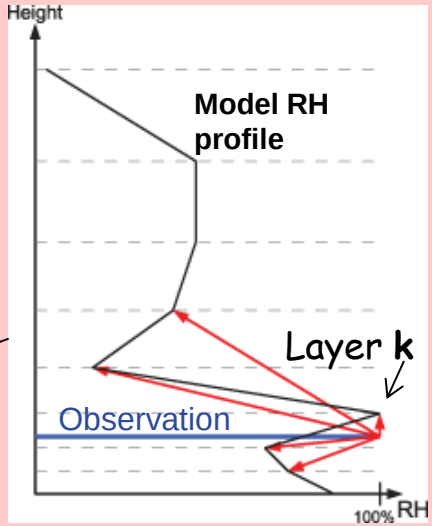
Cloud top height

100% Relative humidity at cloud top height

MODEL EQUIVALENT:
Determine cloud top model equivalent: top of most humid layer k close to observation

Height (k)

RH(k)

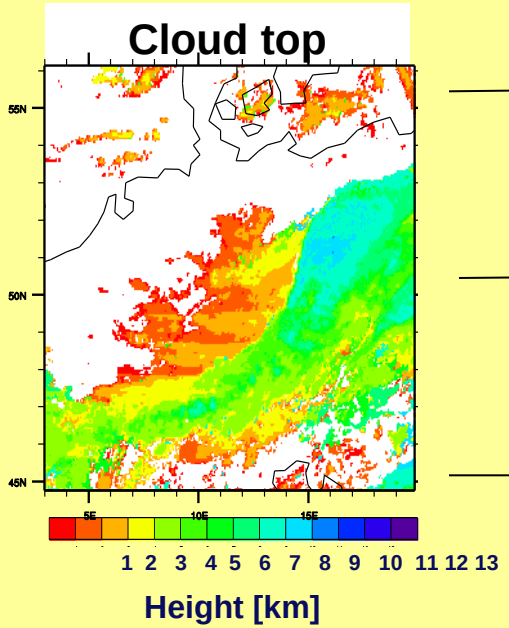


see Schomburg et al., QJRMS, 2014

Method

- Extract information if a pixel is observed as **cloud-free:**

Observation:
Satellite product: cloud top height



Assimilated variables:

0%

Cloud cover high clouds

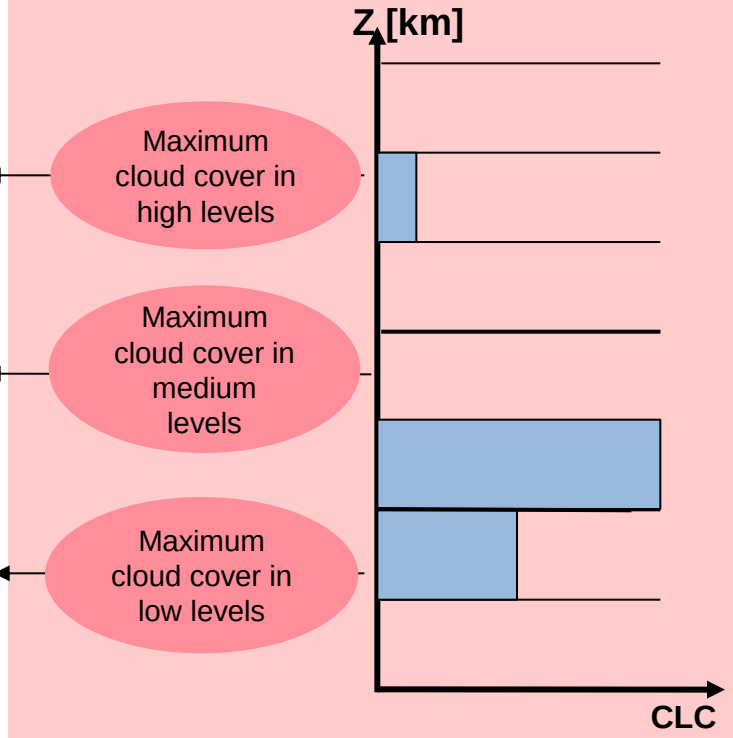
0%

Cloud cover mid-level clouds

0%

Cloud cover low clouds

Model equivalent:

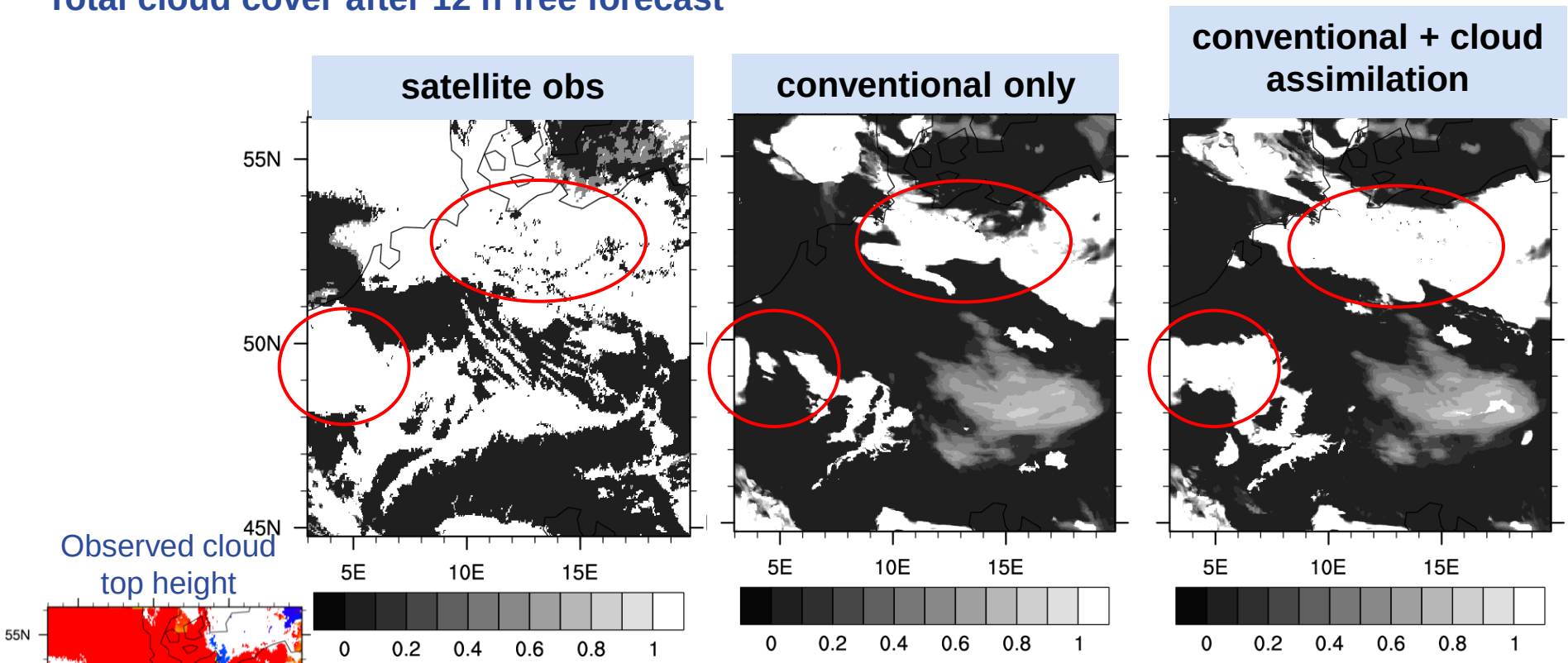


see Schomburg et al., QJRMS, 2014

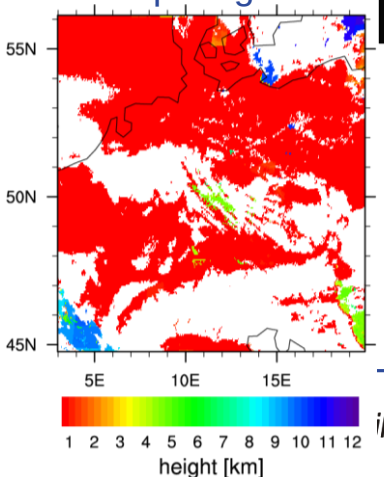
Forecast results: low stratus case

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Total cloud cover after 12 h free forecast



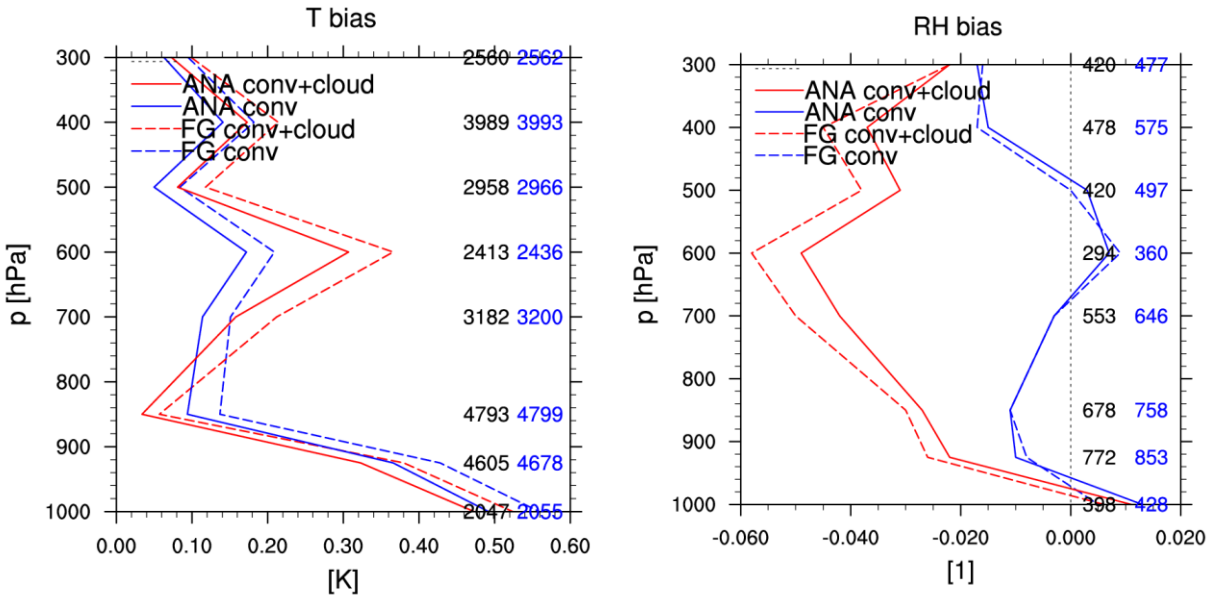
Observed cloud top height



15. Nov 2011, 6:00 UTC

Upper air verification for 83 hours cycling starting at 12 UTC, 12 Nov 2011: bias

Bias: OBS - FG

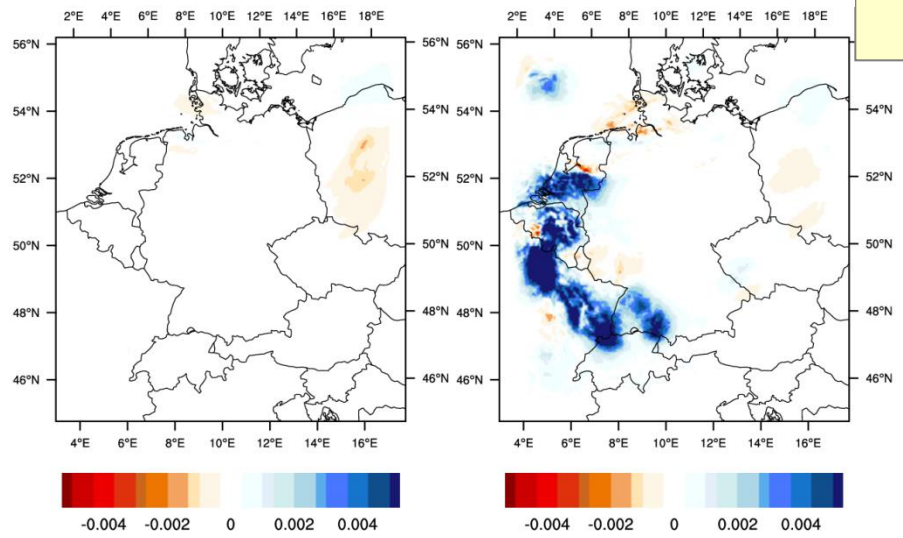


assimilation of conventional obs only
assimilation of conventional + cloud obs

→ **Strong bias in mid-levels…?**
- **FG too cold and much too humid**

Moisture increment for 12 UTC, 13 Nov 2011

Conventional only

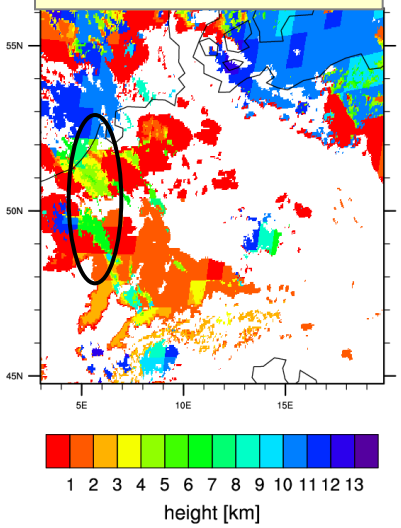


Conv+cloud

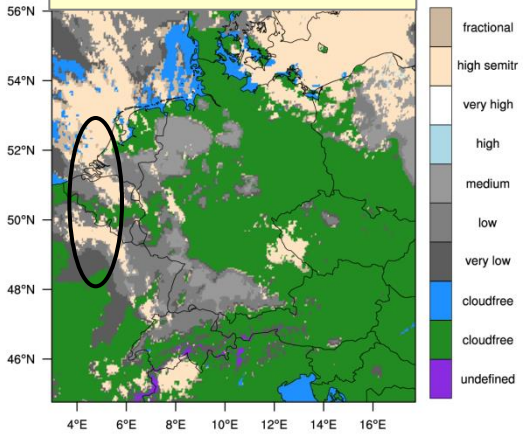
Mid-level moisture increment

- *mid-level moisture increment in low-stratus situation?!?*

Observed cloud top height



Observed cloud type

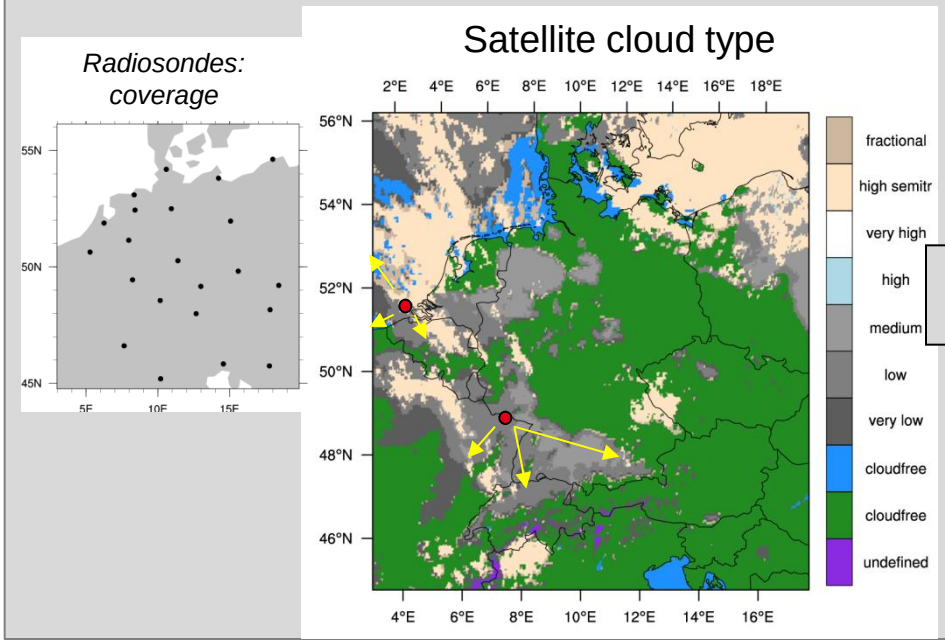


→ **Problems caused** by **incorrect cloud top height** in NWCSAF cloud top height products

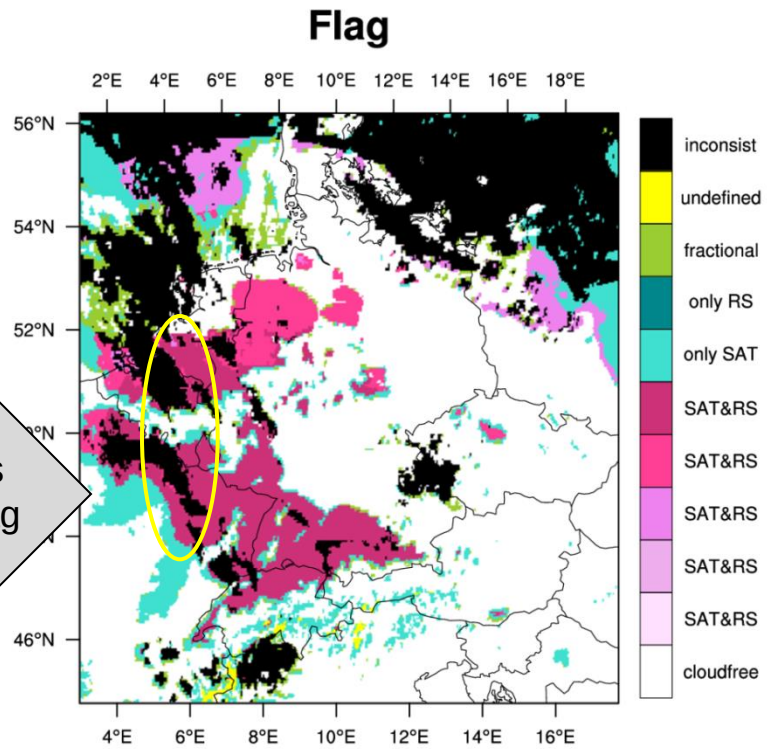
Eliminate suspicious observations

→ *Use flag from cloud analysis to throw away data flagged as "inconsistent"*

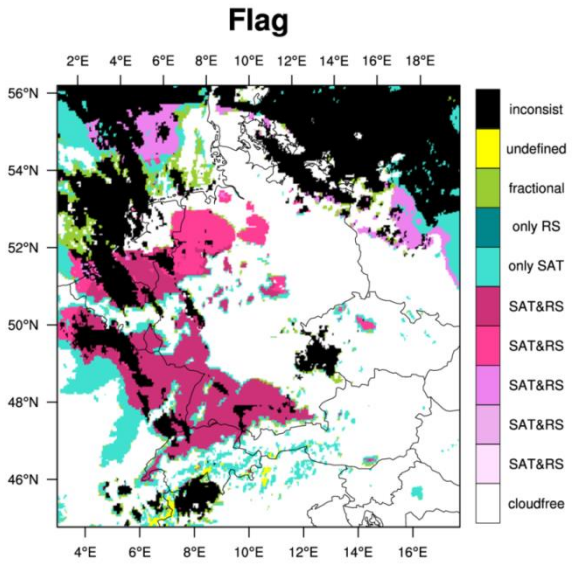
Preprocessing to merge satellite and radiosonde cloud top height information (Cloud analysis): Use nearby radiosondes within the same cloud type to determine quality flag



Provides quality flag



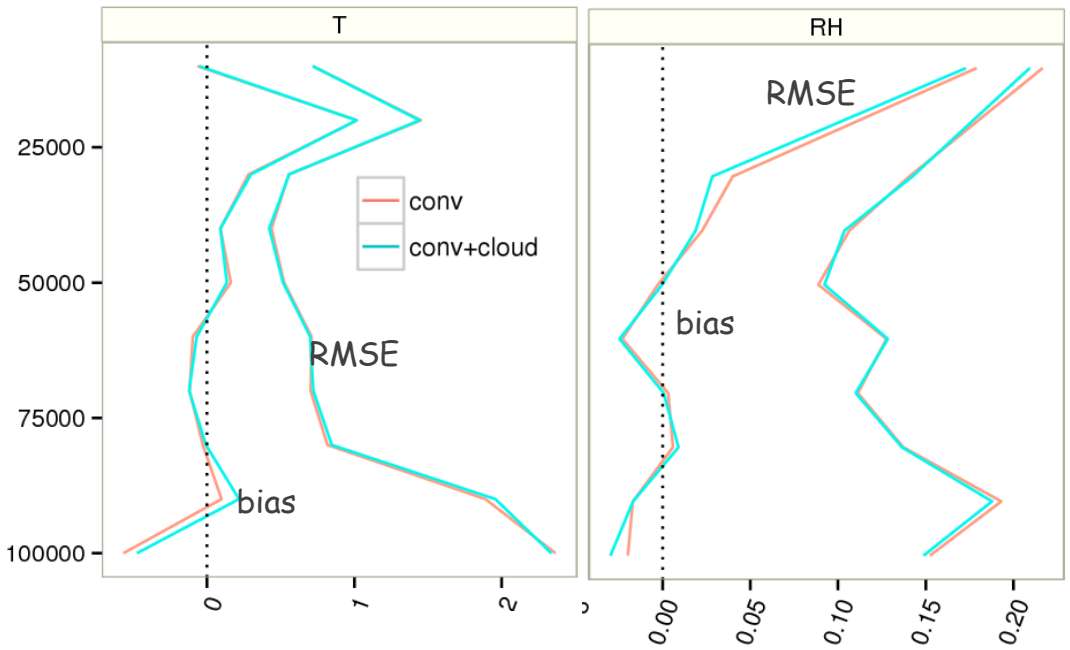
New experiment



→ **New simulation**

- with more strict data elimination

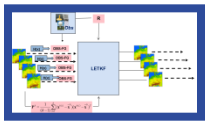
Results of new experiment with rigid quality control: Upper air verification



Scores computed based on several 6h-forecasts from 13-15 November 2011:

→ No detrimental effect of cloud assimilation visible any more, but sometimes a lot of cloud data has to be screened out

Outline



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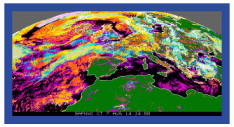

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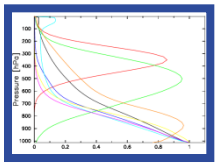
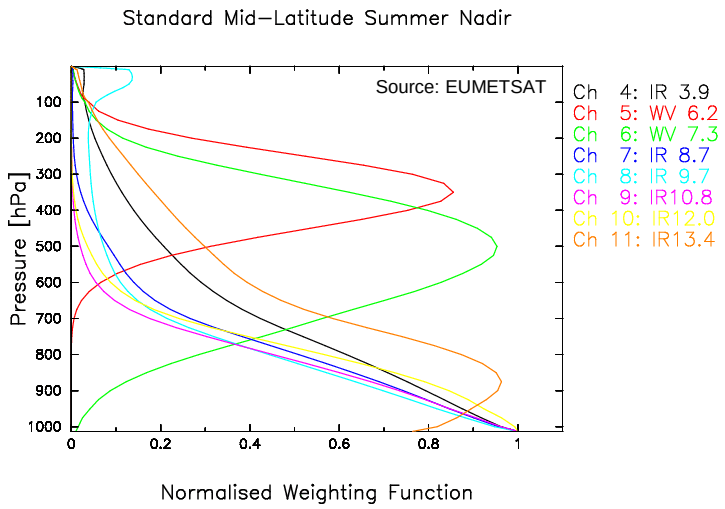
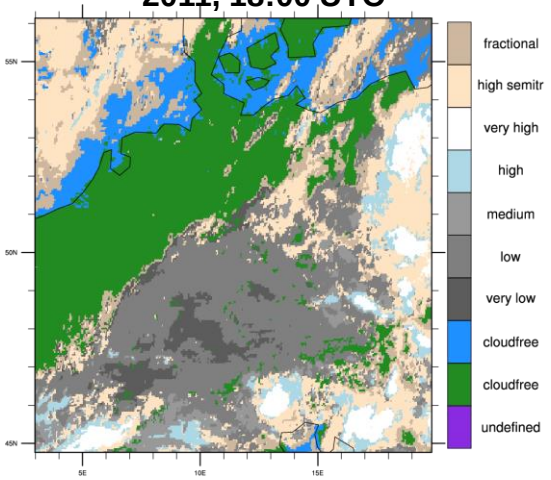


- Assimilation of SEVIRI satellite radiance

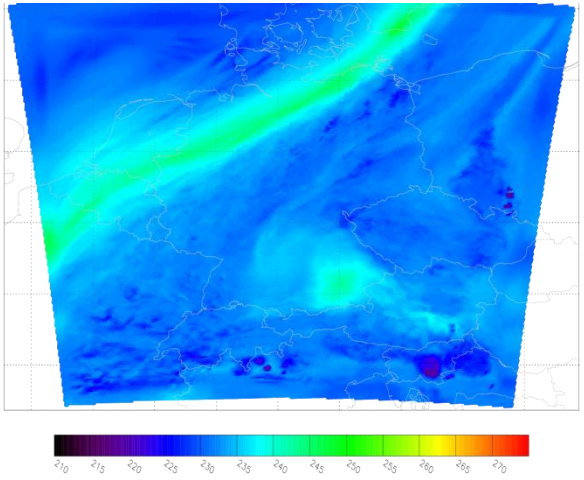
Sensitivities of SEVIRI channels



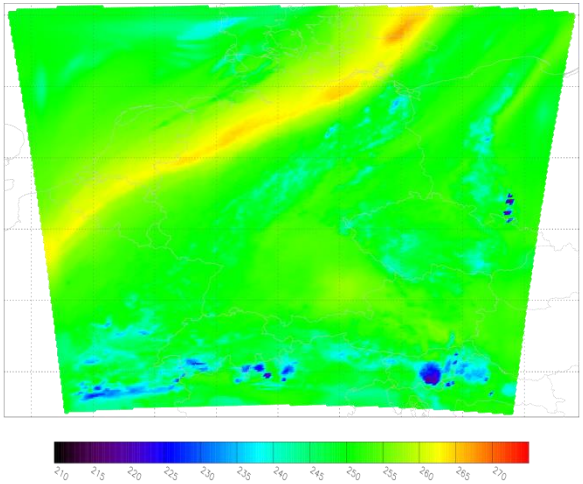
Cloud classification at 1 June 2011, 18:00 UTC



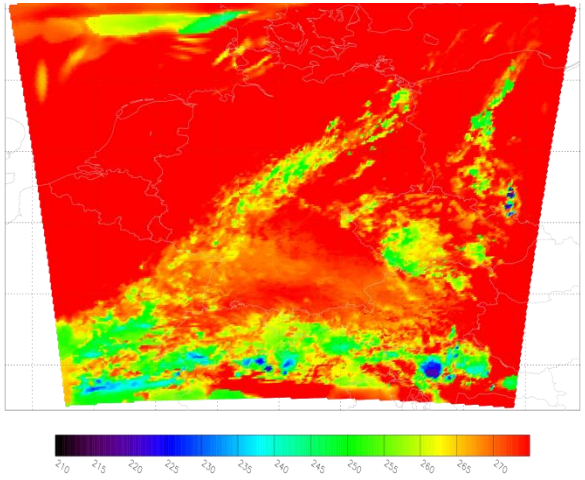
Observed BT WV6.2



Observed BT WV7.3

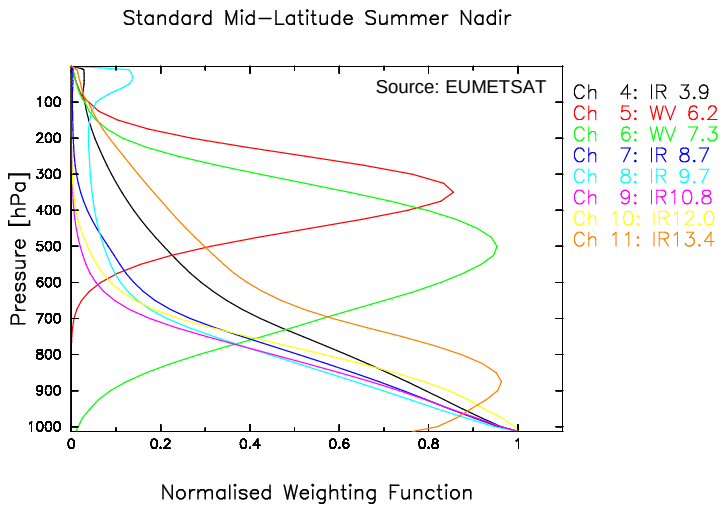


Observed BT IR8.7



Sensitivities of SEVIRI channels:
FG computed with RTTOV

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



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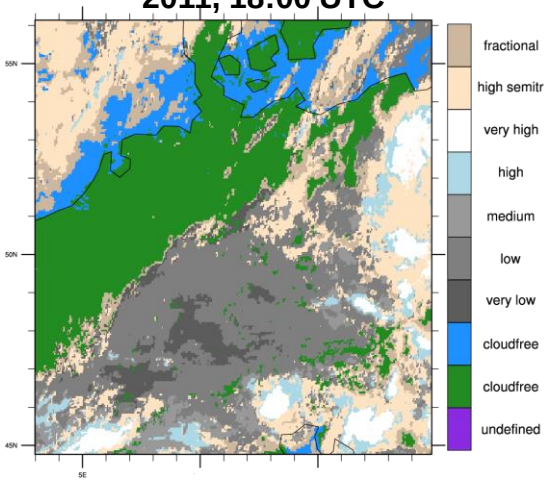
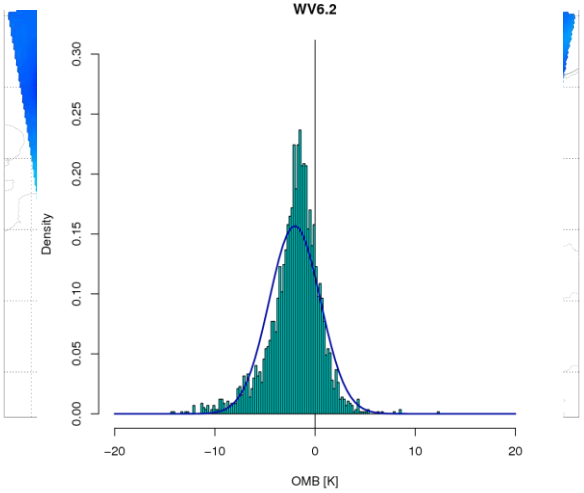
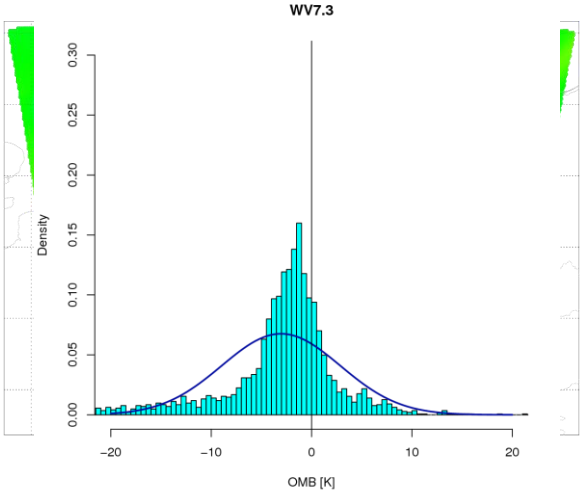


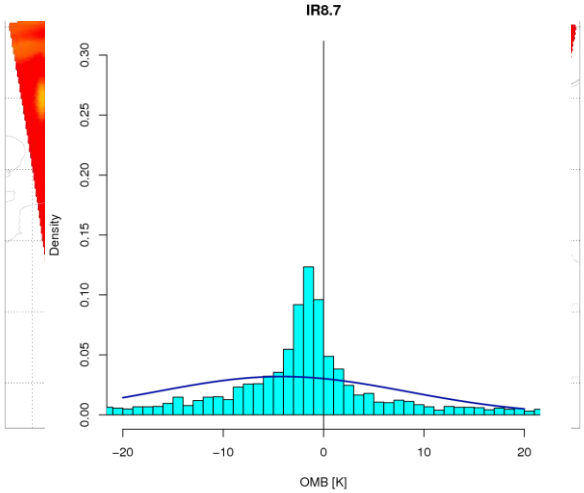
OBS –FG WV6.2



OBS –FG WV7.3

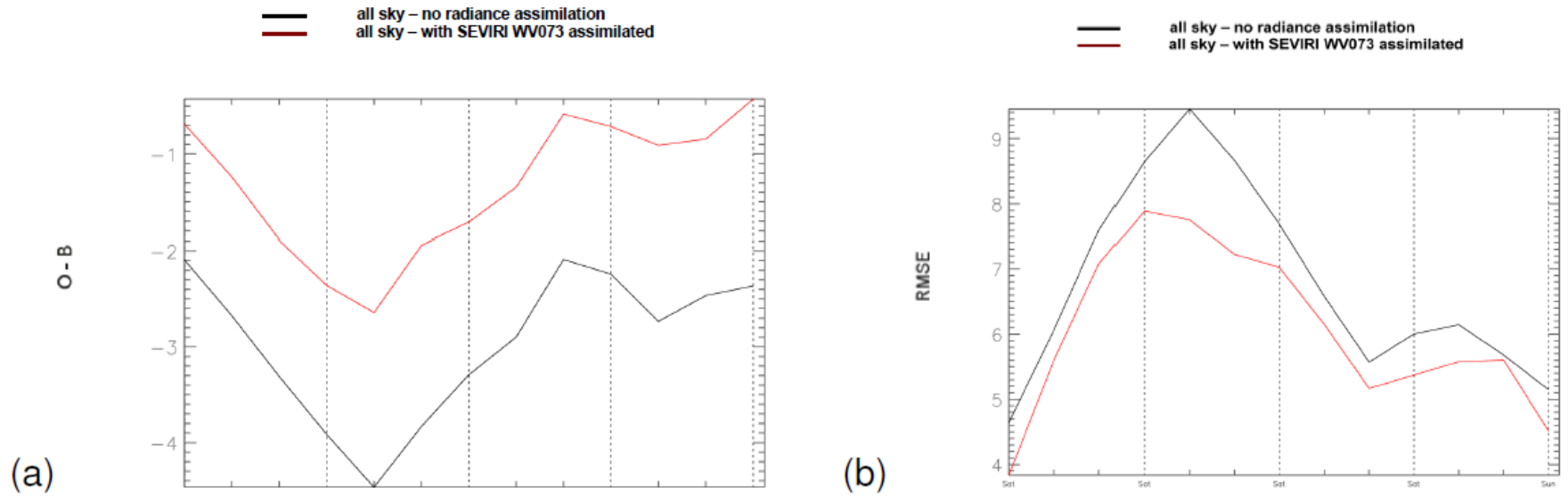


OBS-FG IR8.7



SEVIRI radiance assimilation: channel WV7.3

First assimilation experiment by former DWD colleague Africa Perianez and visiting scientist Jason Otkin (University of Wisconsin-Madison):

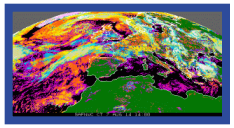


BIAS and RMSE time series for all sky during the 12 hour assimilation period for the Control (black lines) and SEVIRI (red lines) assimilation cases. With parameter values, Observation error $\sigma_{obs} = 3.5$, horizontal localization radius $l_h = 35$ Km and vertical localization radius $l_v = 0.7$.

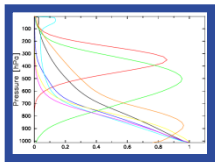
Summary

- Progress towards the assimilation of cloud-sensitive data:

Photovoltaic power: Quality control running → blacklist ”bad panels“ → implementation of usage of the data in KENDA → experiments



SEVIRI cloud products: detected and solved problem with false cloud top heights in satellite product



SEVIRI radiances: very first experiments have been run, more will follow

Thank you for your attention.