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Assimilation of IASI Data over Sea and Land into the Regional NWP Model COSMO-EU

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German Weather Service (DWD), Offenbach, Germany

IASI Conference, January 25-29, 2010

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Local Model COSMO-EU

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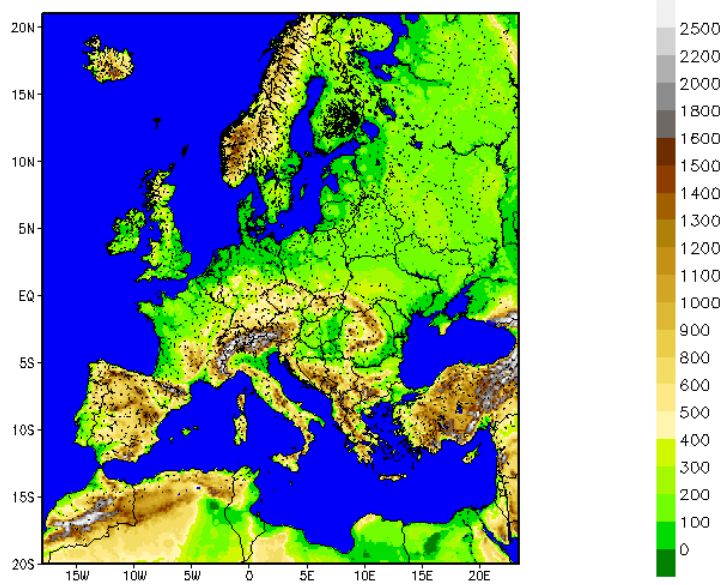

domain of cosmo-eu

COSMO

- non-hydrostatic regional model
- rotated latitude-longitude grid with mesh size 7 km
- hybrid vert. coord. grid with 40 layers up to 20 hPa
- forecast range: 78 h for initial times at 0 and 12.
- cloud ice and rain are prognostic variables
- boundary values from GME

current assimilation scheme of COSMO-EU

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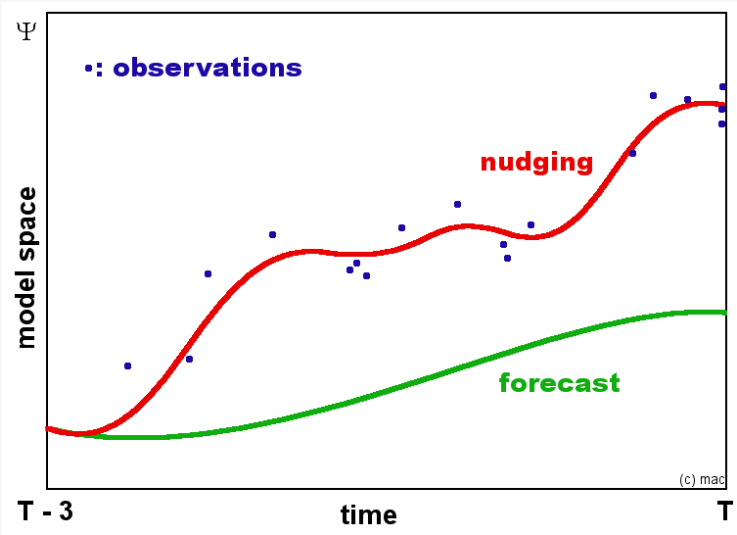

influence of the observations on forecast process.

nudging approach (Newtonian relaxation scheme)

- model trajectory nudged towards obs. at every time step.
- influence according to nudging weights depending on:
  - spatial distance
  - temporal distance

assimilated data within COSMO-EU

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analysis – operational

- **upper-air:**
  TEMP, PILOT, AIRCRAFT, WIND PROFILER
  $\Rightarrow$ horizontal wind, temperature, relative humidity, (geopotential height)
- **Surface-level:**
  SYNOP, SHIP, BUOY
  $\Rightarrow$ station (surface) pressure, (2-m temperature, 2-m humidity, 10-m horizontal wind),
- variational soil moisture analysis
- cutoff: 2 h 30 min

nudging – pros and cons for lam's

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pros

- kind of 4-dimensional assimilation scheme
- possible use of async. and high frequent obs.
- fast method – can provide a punctual forecast
- combination with ensemble methods is possible
- no initialization required

cons

- no mathematical formalism to determine theoretically optimal solution
  $\Rightarrow$ tuning of free parameters required
- cannot include observation error correlations
- observation increments have to be expressed in model space
- no direct use of nonlinear obs. (i. e., satellite obs.)

hence: idea in the COSMO consortium

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combine nudging and 1DVar

usage of satellite radiance data via 1DVar scheme
usage of IASI data via 1DVar scheme (that’s what I am doing)

IASI – infrared atmospheric sounding interferometer

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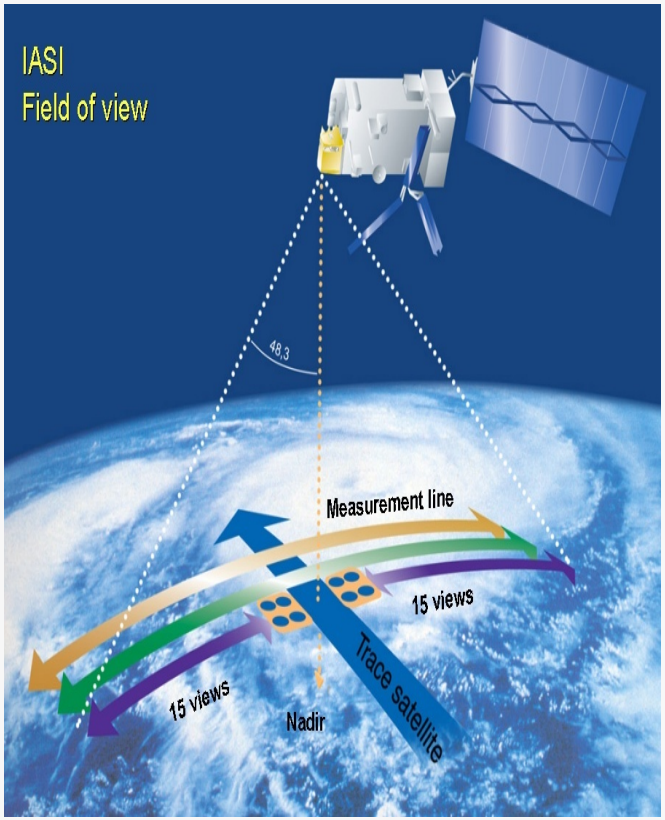

source: http://smc.cnes.fr/IASI/

technical data

- 30 views/scan with 4 pixels/view
- IFOV: 3.33°(48 km at nadir)
- swath: ±48.3°(±1026 km)
- 3 bands, i. e., 3 interferometers:

	range [cm^{-1}]	range [μm]	$\delta\nu$ [cm^{-1}]
1	645 – 1210	15.50 – 8.26	$\leq$ 0.35
2	1210 – 2000	8.26 – 5.00	$\leq$ 0.39
3	2000 – 2760	5.00 – 3.62	$\leq$ 0.50

- spectral range:
  645-2760 cm^{-1}
  15.5-3.6 μm
- spectral res.: 0.35 - 0.5 cm^{-1}
- 8461 channels
- radiometric res.: 0.25 - 0.5 K

interesting parts for metorology

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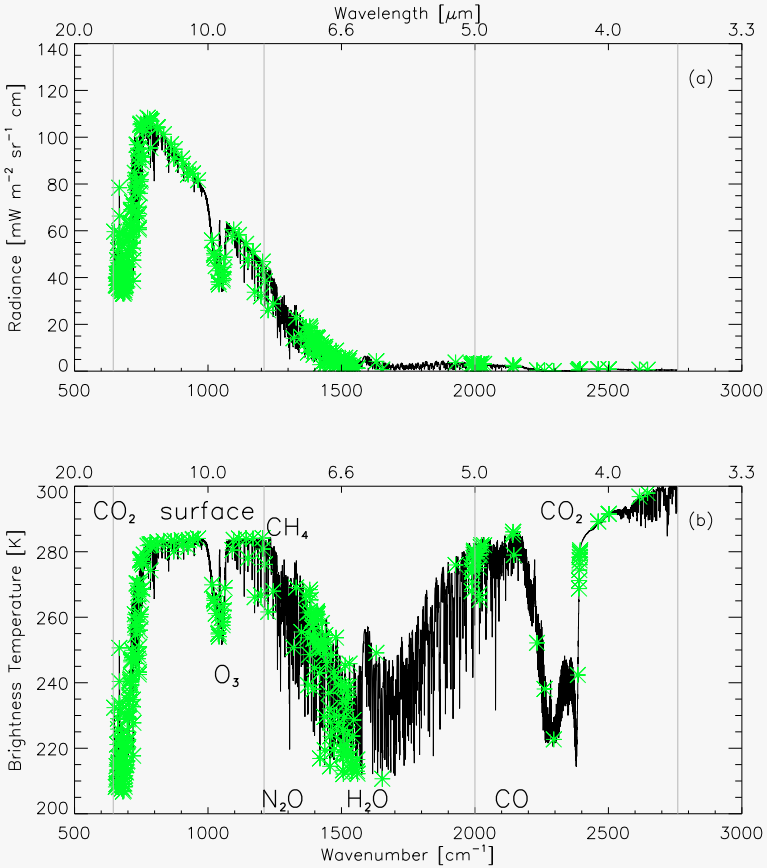

temp, humi surf

Spectral Range	Primary Application
650 - 770 cm^{-1}	T sounding (CO_2 band)
770 - 980 cm^{-1}	surf and cloud props
1080 - 1150 cm^{-1}	surf and cloud props
1210 - 1650 cm^{-1}	Q and T sounding (and N_2O, CH_4, and SO_2)
2150 - 2250 cm^{-1}	T sounding and N_2O column
2350 - 2420 cm^{-1}	T sounding

interesting spectral regions for applications at DWD
(300 channel set selected by IC method (Andrew Collard, 2005))

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Offline Data Preparation and Preprocessing

- mapping of mhs and amsu-a to iasi grid via aapp
- selection of 1 of 4 (warmest and/or most homogeneous iasi subpixel, respectively)
- selection of a predefined set of iasi channels;
- area selection according to lam boundaries and first quality control
- data window: 1 hour before, to 1 $\frac{1}{2}$ after assimilation date.

data preparation

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interesting parts of this step

- bias correction
- cloud detection
- quality control

bias correction

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implementation of model dependent bias predictors after Harris and Kelly (2001)

- scan- and air-mass correction
- cloud flagging using IASI Level 2 cloud flags
- Predictors for air-mass correciton:
  - Layer thickness between 900 hPa and 300 hPa
  - Layer thickness between 200 hPa and 50 hPa
  - surface temperature
  - total column water vapor

bias DNA plot – stdev obs. minus bg.

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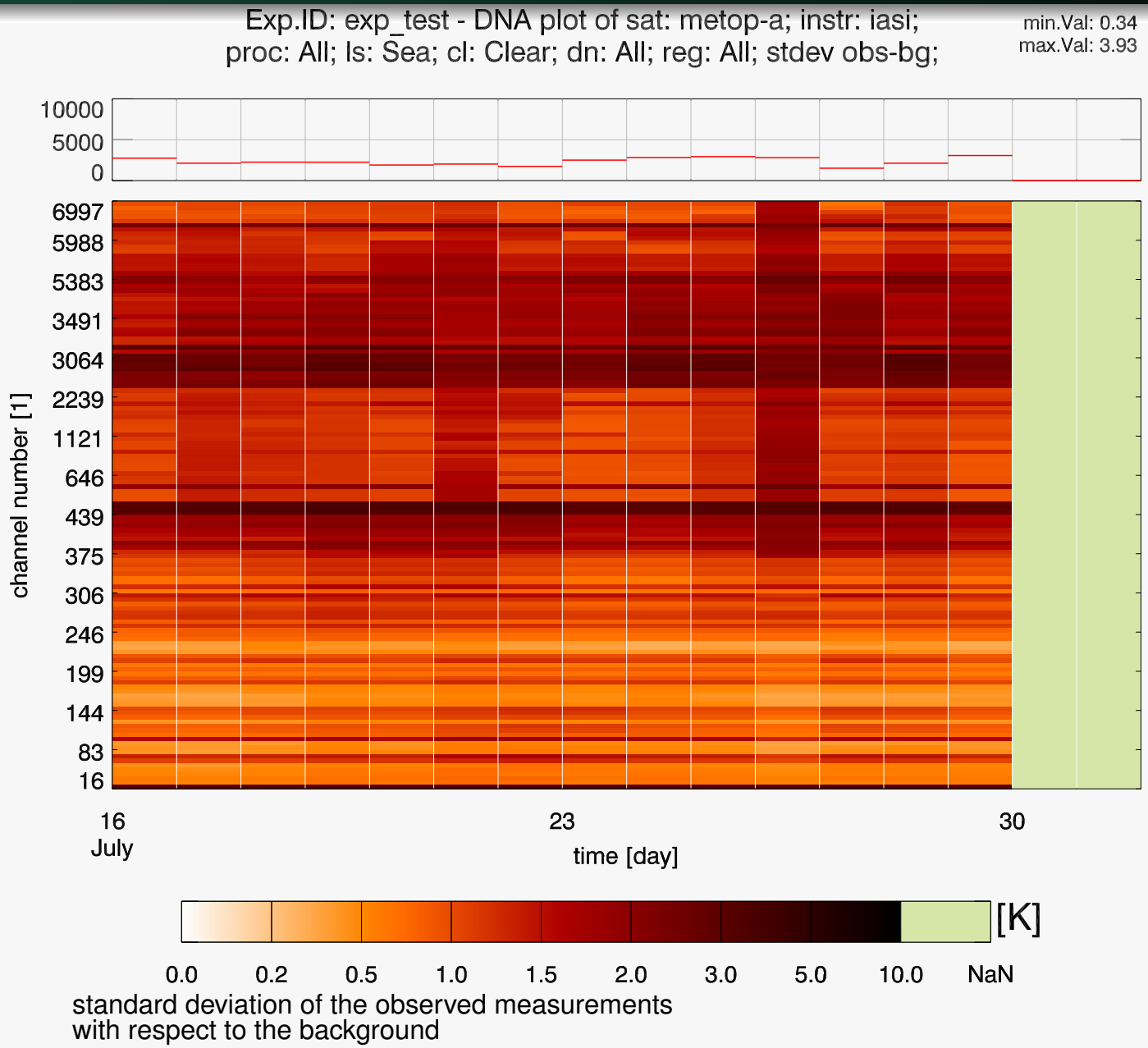

bias DNA plot – stdev bias-corr. minus bg.

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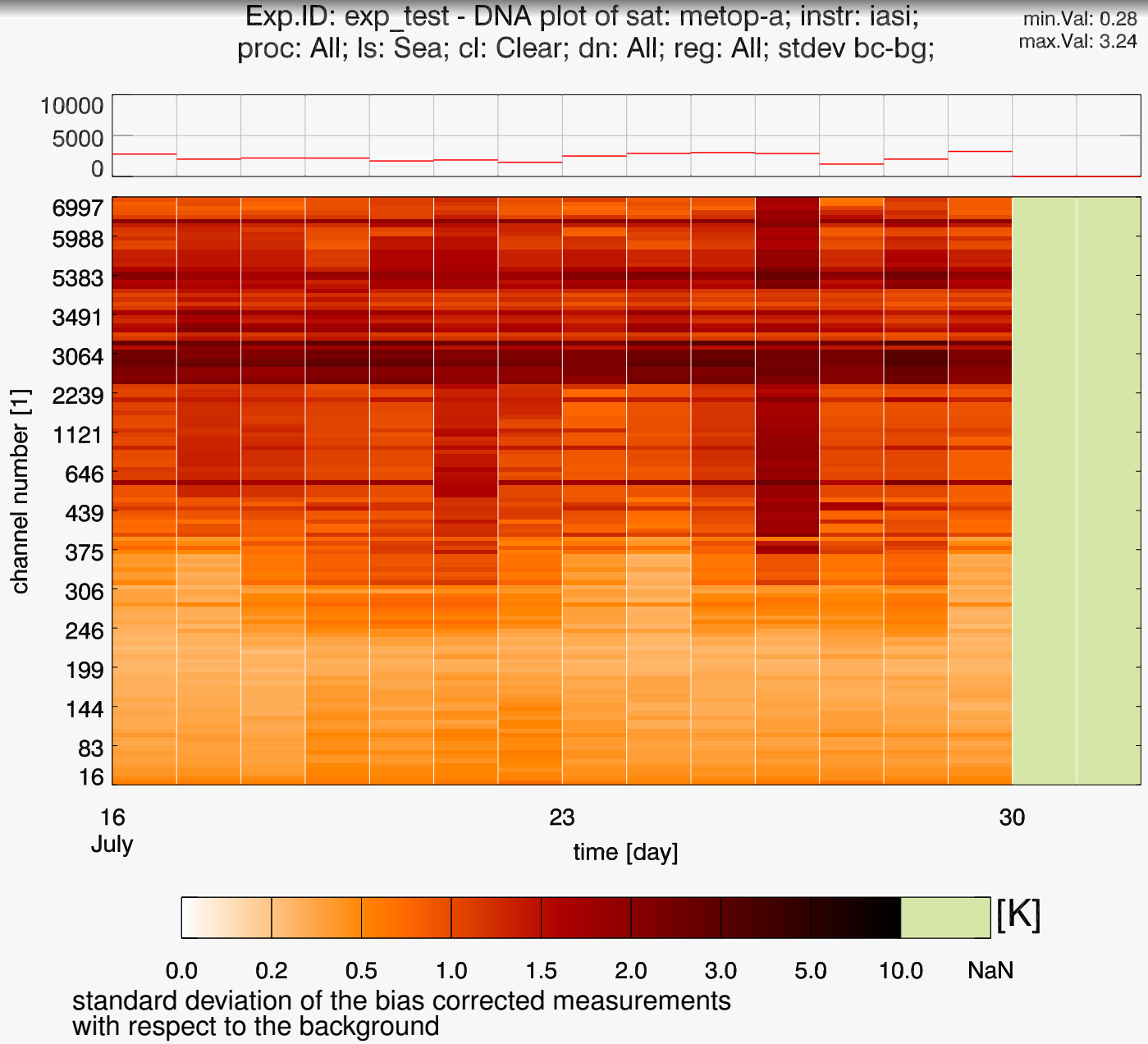

bias DNA plot – mean obs. minus bg.

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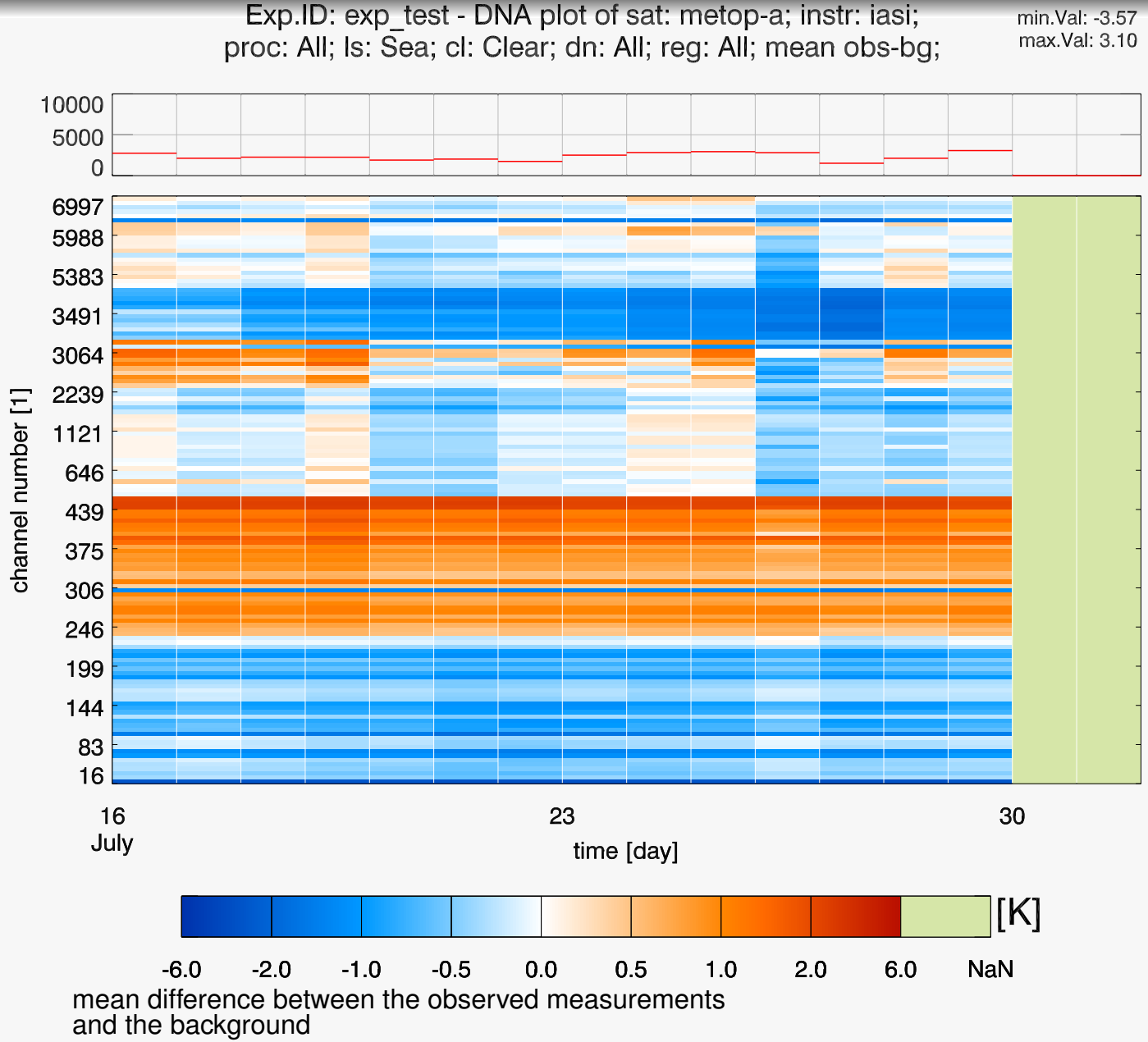

bias DNA plot – mean bias-corr. minus bg.

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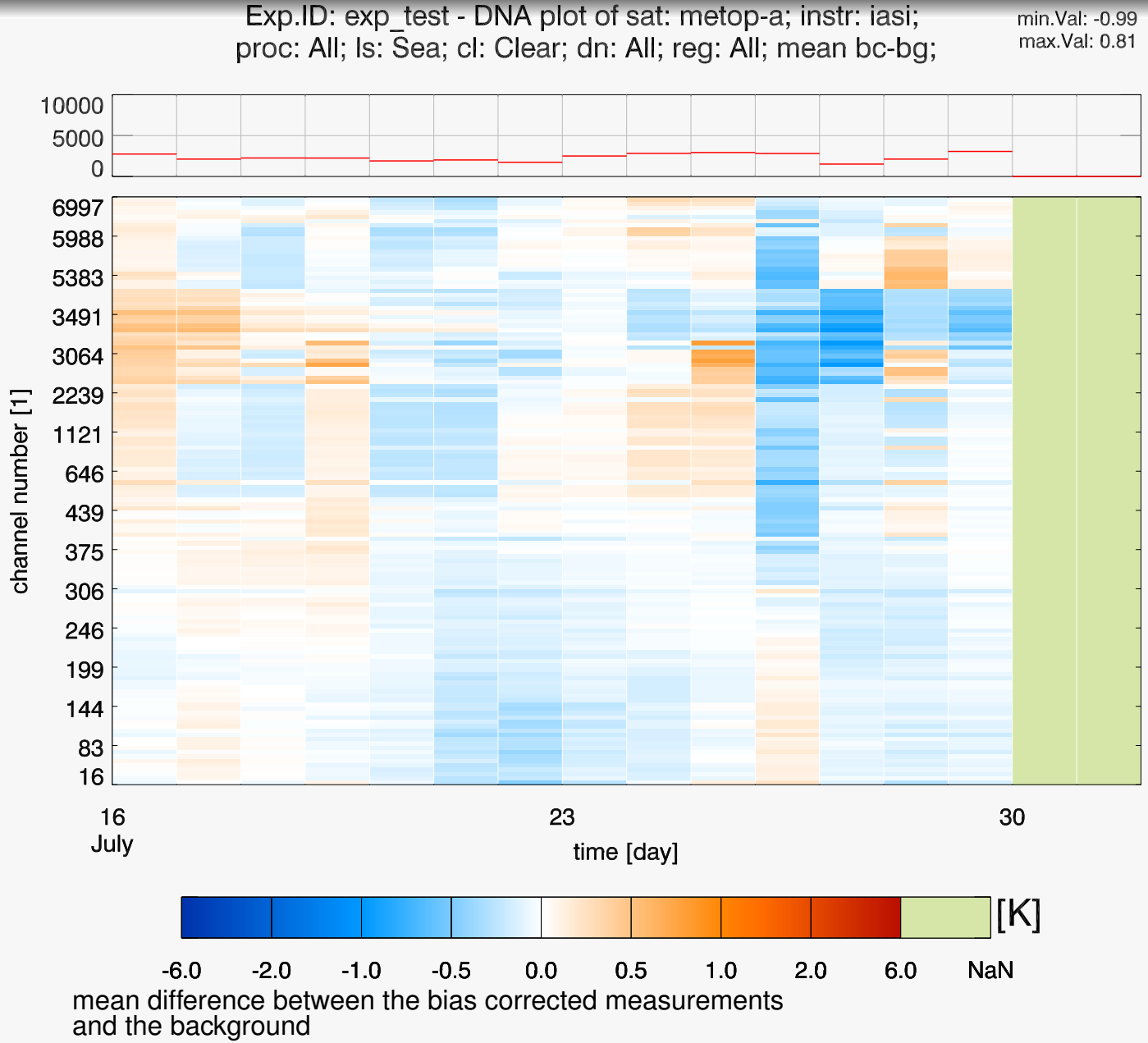

cloud detection

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implementation of model after McNally and Watts (2003)

- takes into account first guess departures
- looks for signature of opacity not included in the clear-sky calculation (i. e. cloud or aerosol)
- by ordering channels according to their height
- reduction of instrument noise by moving-average filter.
- advantage: all channels above a cloud are assimilated $\Longrightarrow$ more observations can be used.

changes in the McNally/Watts Algorithm

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changes with respect to the code distributed by the NWP SAF

- level-to-channel height assignment as proposed by manual
- replacement of the sorting algorithm (heapsort was replaced by quicksort with a modified insertion)

this resulted in

- better/more meaningful height assignment of the channels (problems occured due to putting a foreign model on top of cosmo-eu for RT reasons)
- modified insertion results in a more continuous T_B hence more less channles were deselected.

cloud detection comparison: Seviri cloud mask

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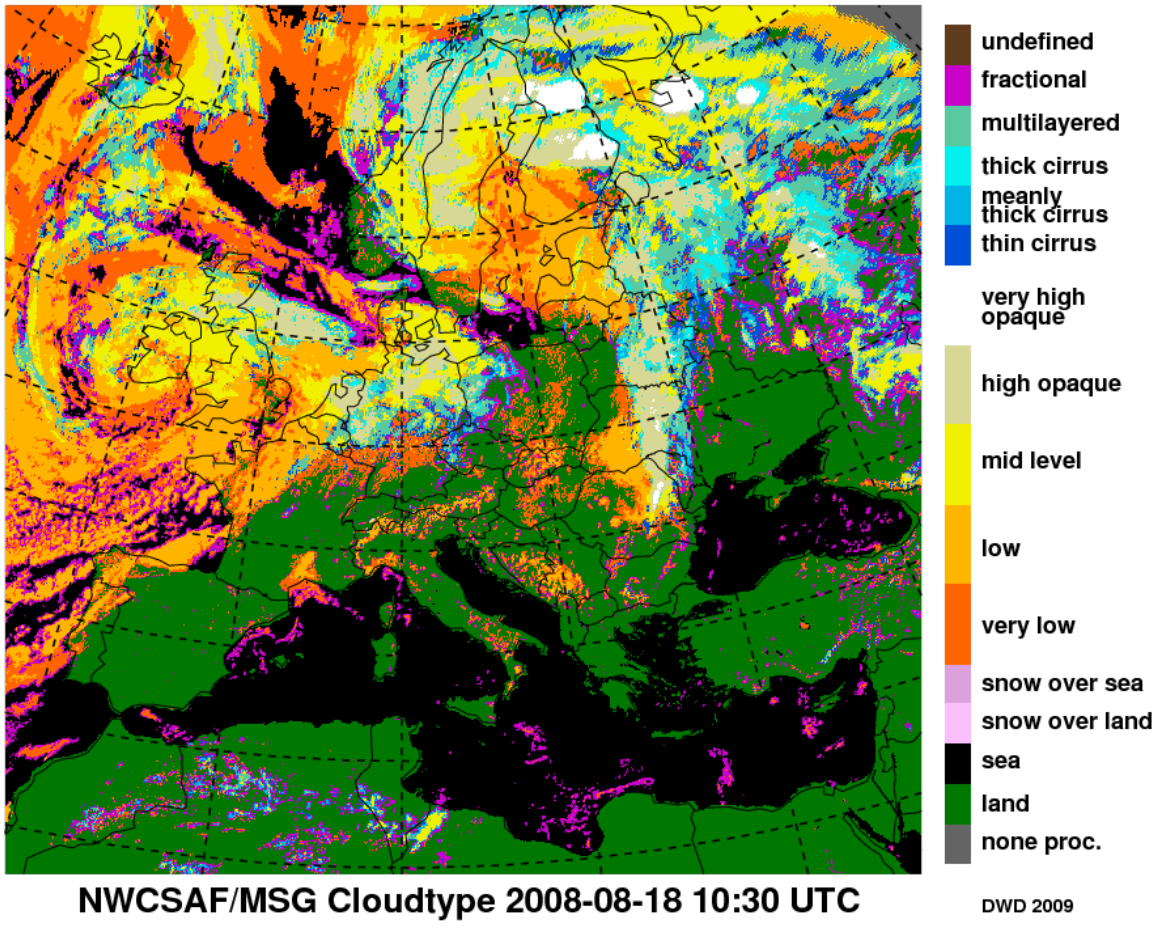

seviri cloud mask at 2008-08-18 10:30 UTC

cloud detection comparison: McNally/Watts

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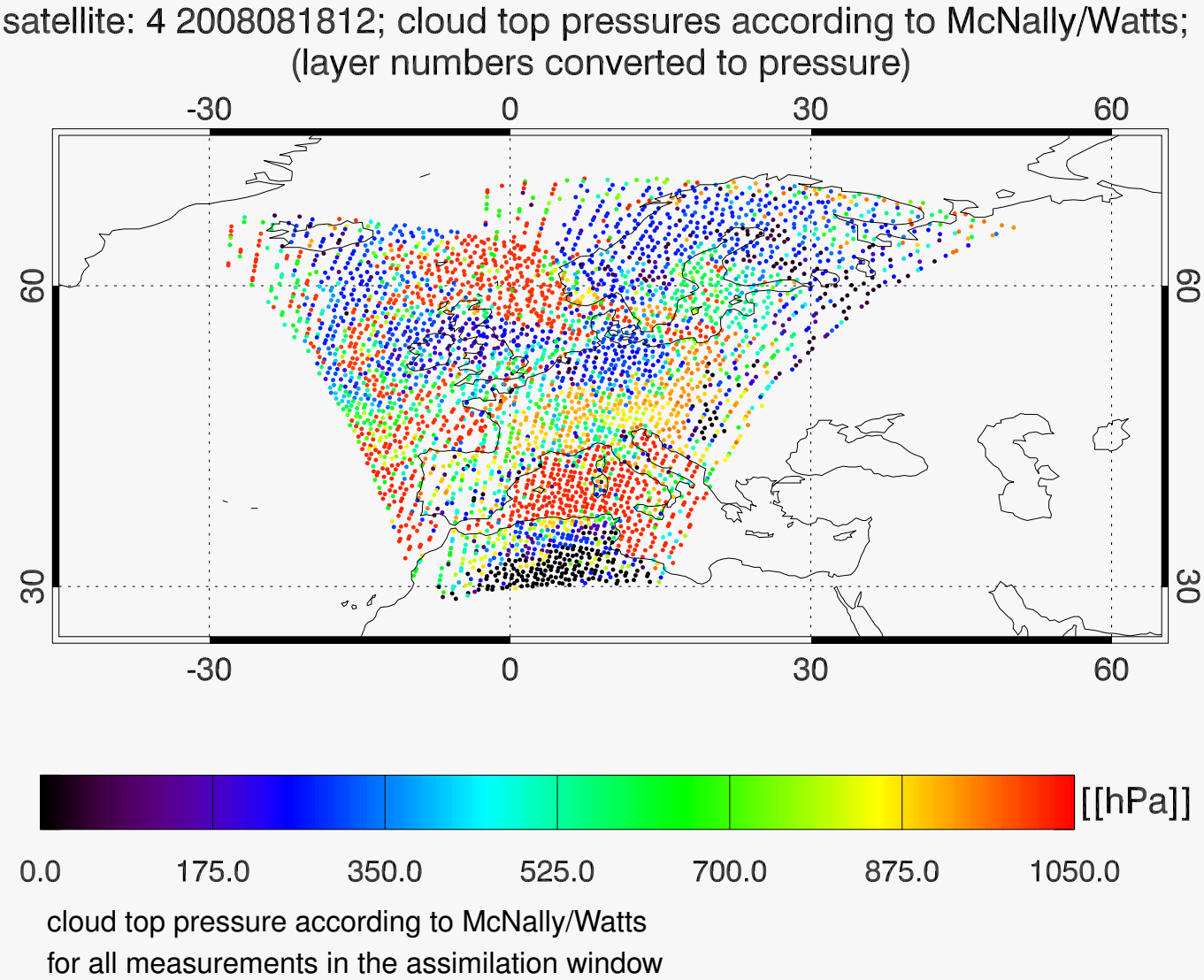

cloud top pressure according to McNally/Watts
for all measurements in the assimilation window

cloud detection comparison: IASI Level 2 cloud flags

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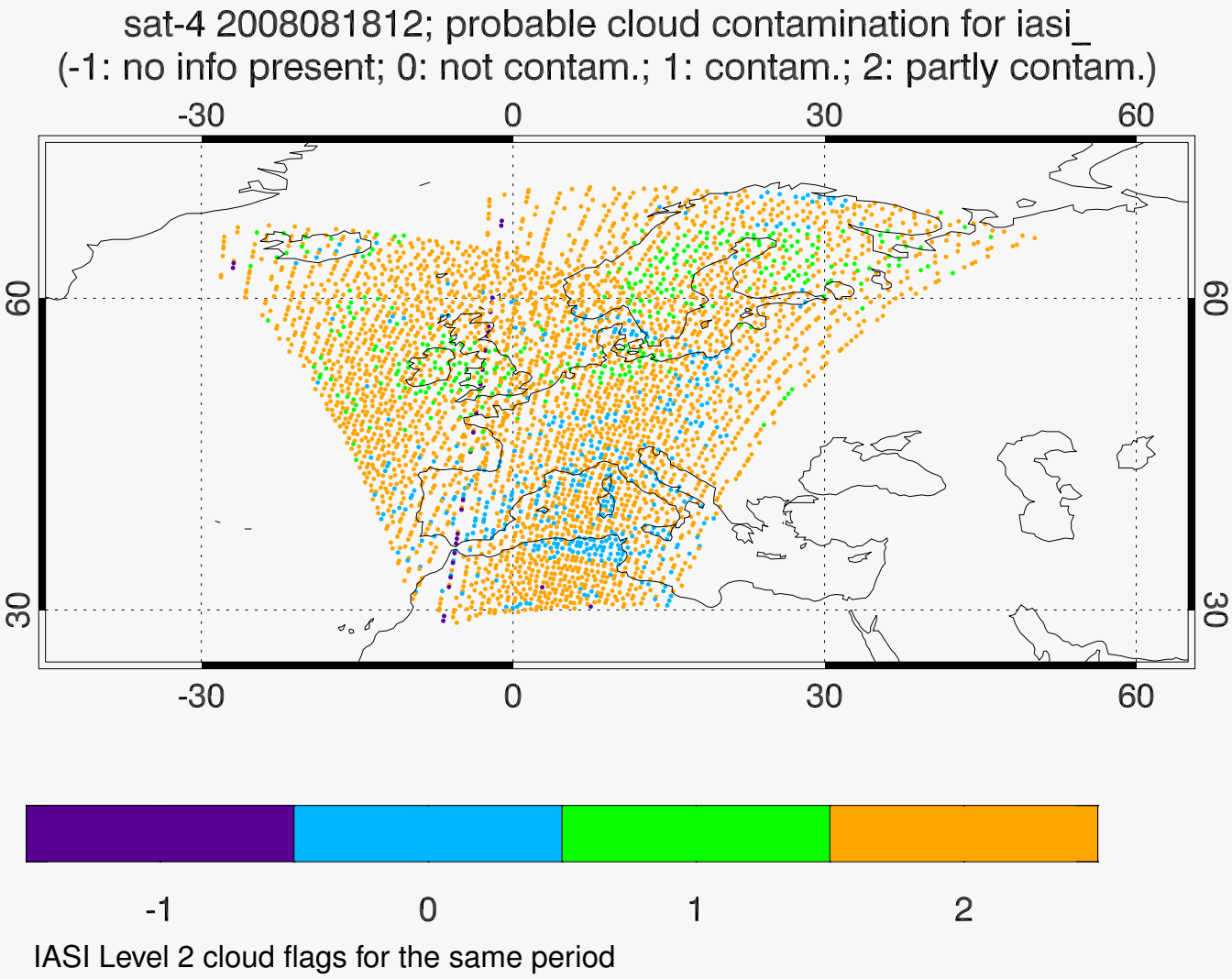

IASI Level 2 cloud flags for the same period

channel selection

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currently two sets:

- **1:** only 116 temperature channels from the 15 μm (666.66 cm^{-1}) band (649 cm^{-1} to 759,25 cm^{-1}) and 18 channels of the 6.25 μm (1600 cm^{-1}) wv band (1212.75 cm^{-1} to 1560.25 cm^{-1}) $\Longrightarrow$ this set was selected by hand.
- **2**: temperature channels as 1 but with 93 additional channels from the 6.25 μm (1600 cm^{-1}) wv band (1212.75 to 1560.25 cm^{-1}) – no specific channel selection in the wv band.
- additional usage of 9 amsu-a channels from metop – but this had no impact.

channel selection - two different sets

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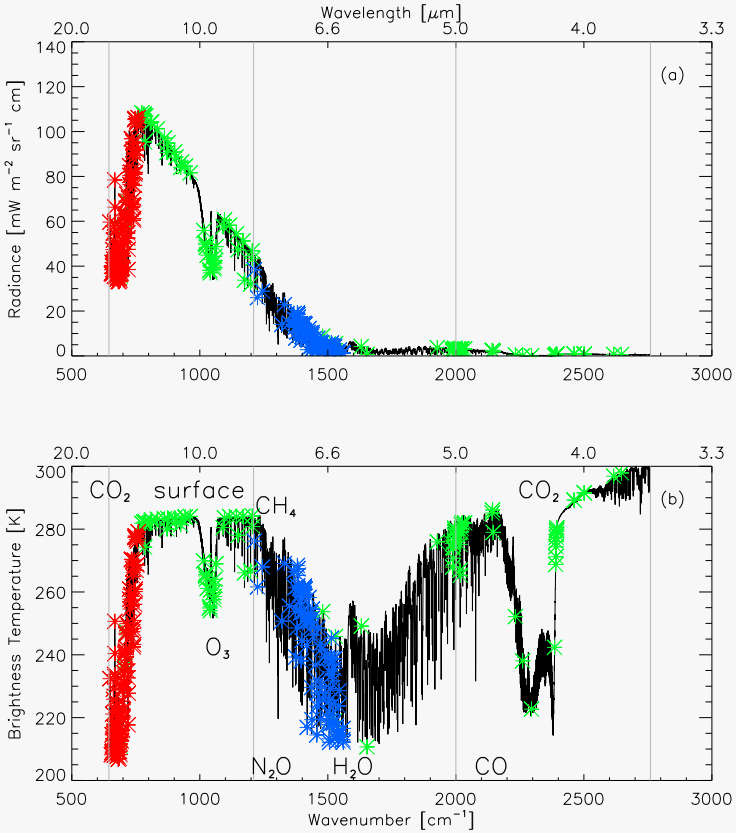

two different channel selection set:
temp channels only as well as some additional humidity channels.

quality control

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rejection of whole measurements

- measurement over land (first studies with usage of land observations are currently started)
- measurements over sea-ice (aapp flag (amsu-a))
- first guess departure (15 K)

rejection of single channels

- if:
  - bias corrected measurement or
  - first guess forward modeled measurement

  has unphysical values (for IASI: 180 K – 320 K)
- channels which are marked as cloudy by the MNW cloud detection

1DVar setup

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- first guess creation
- background error covariance matrix
- measurement error covariance matrix
- used forward model
- final acceptance of the optimized profile
- data thinning

the *a priori* error covariance matrix

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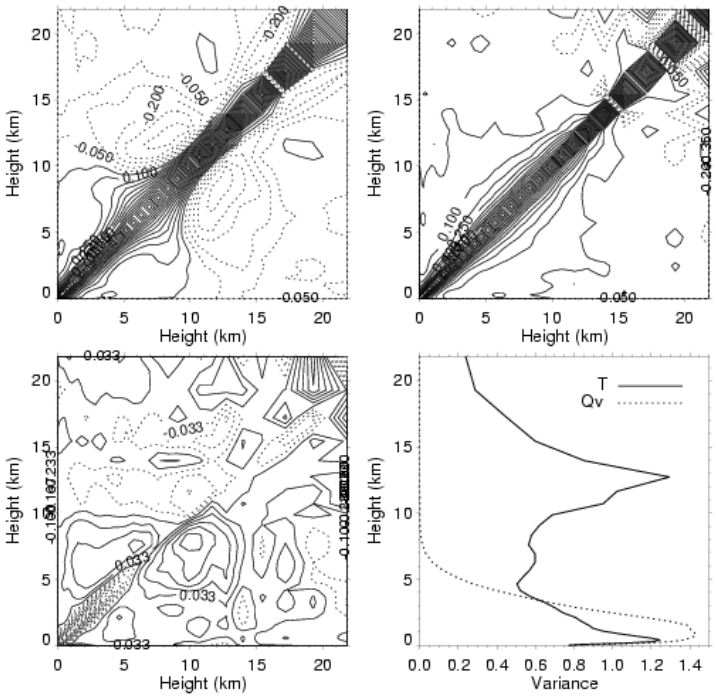

background error covariance matrices for temperature and humidity.

background error cov.

- calculated via NMC method
- using forecast comparisons between 12 h and 36 h forecast using an average over 3 month (by F. Di Giuseppe)

the measurement error covariance matrix

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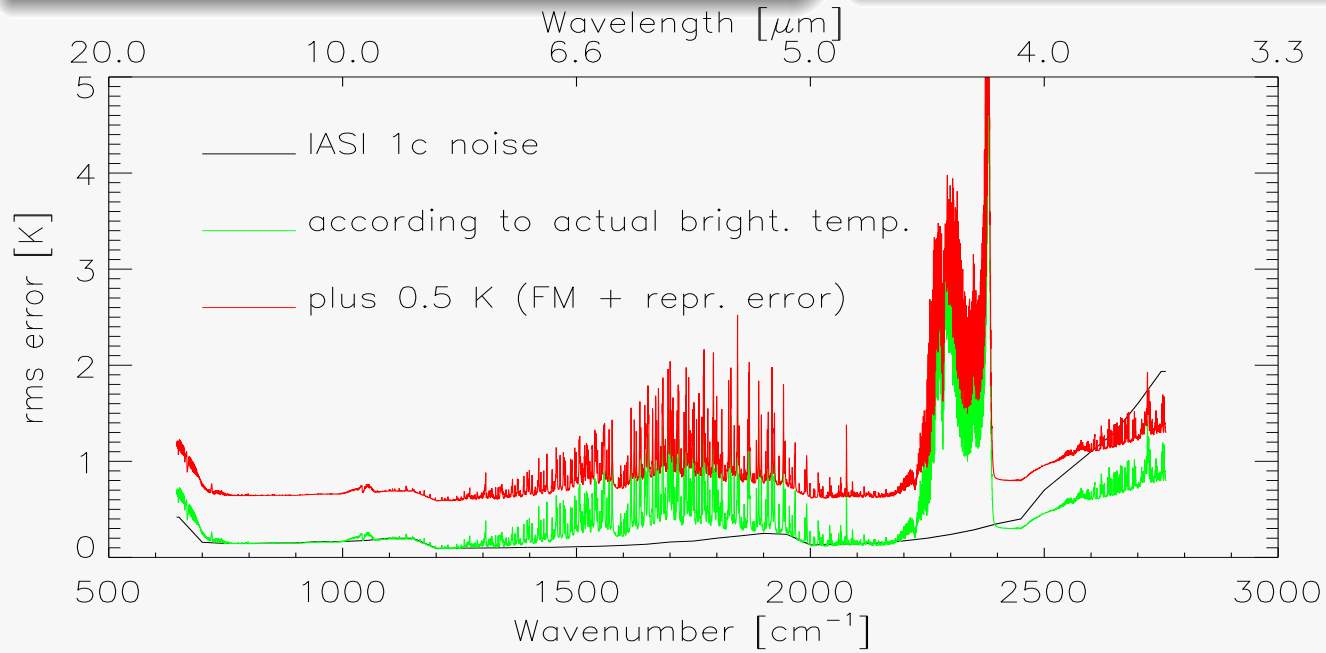
diagonal elements

- IASI level 1c noise values
- adapted to the actual brightness temperature
- +0.2 K forward model error + repres. error

off diagonal elements

correlation of the three nearest neighbor channels:

1	0.75
2	0.25
3	0.04



the forward model and 1DVar scheme

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RTTOV9 - an overview

- simulation of the IASI meas. at 100 fixed press. levels between 0.01 and 1100.00 hPa
- calculates $\mathbf{T}_B$ (and radiances).
- tangent linear and adjoint model to calculate jacobians, e.g., for $\mathbf{T}$, $\mathbf{q}$, $\mathbf{O_3}$, and SST - $\frac{\partial \mathbf{T}_B}{\partial \mathbf{T}}$, $\frac{\partial \mathbf{T}_B}{\partial \mathbf{q}}$, $\frac{\partial \mathbf{T}_B}{\partial \mathbf{O_3}}$, and $\frac{\partial \mathbf{T}_B}{\partial \mathrm{SST}}$
- a new and better interp. function from user levels to rttov levels

the forward model and 1DVar scheme

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RTTOV9 - performance

- due to performance tuning (vectorization) a factor of 2 could be gained in case of the adjoint code
- still too slow $\Longrightarrow$ further work has to be done.

final acceptance tests

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convergence

- the number of simulations and iterations, respectively, must be below maximum
- The cost function has to decrease at least 10% from it's initial value
- the finally obtained bias corr. minus first guess T_B's. have to be smaller than 3 sigma of the measurement error covariance.
- the finally obtained state vector has to be smaller than 3 sigma of the background error cov. in all levels.

1DVar processing flags – arbitrary chosen example

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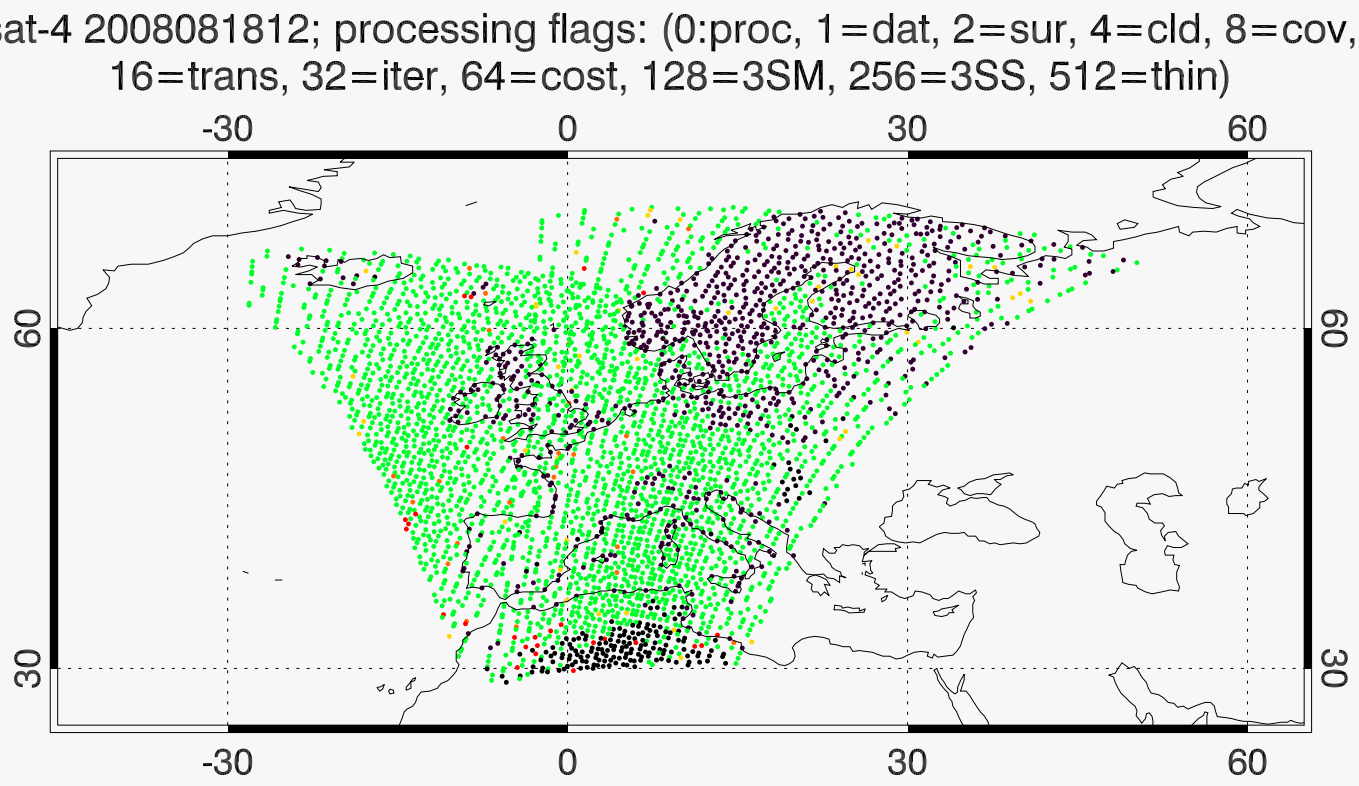

processing flags of the 1DVar process incorporated in the COSMO model without data thinning

1DVar processing flags – including horizontal thinning

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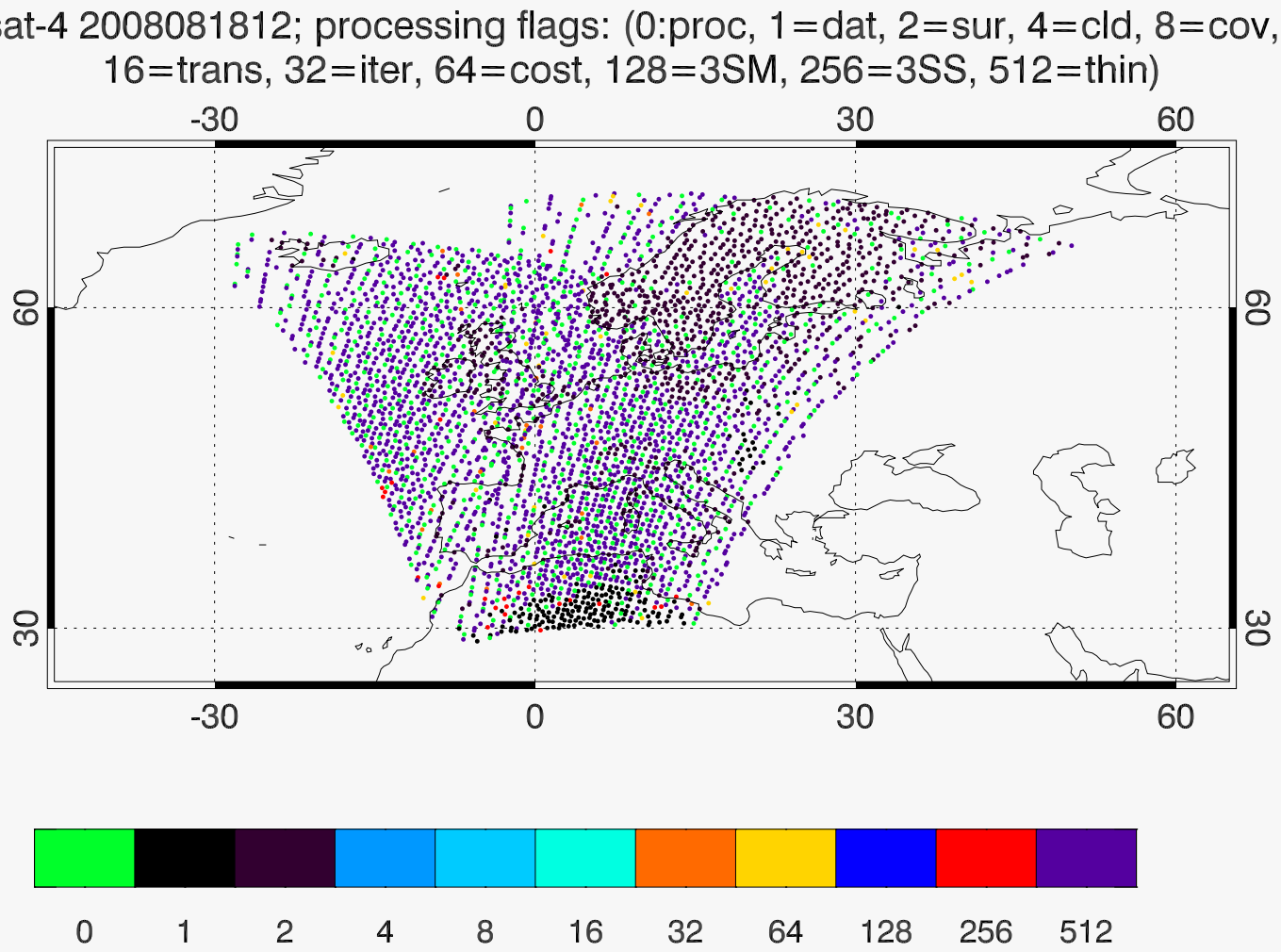

processing flags of the 1DVar process incorporated in the COSMO model after horizontal data thinning

1DVar statistics – arbitrary chosen example

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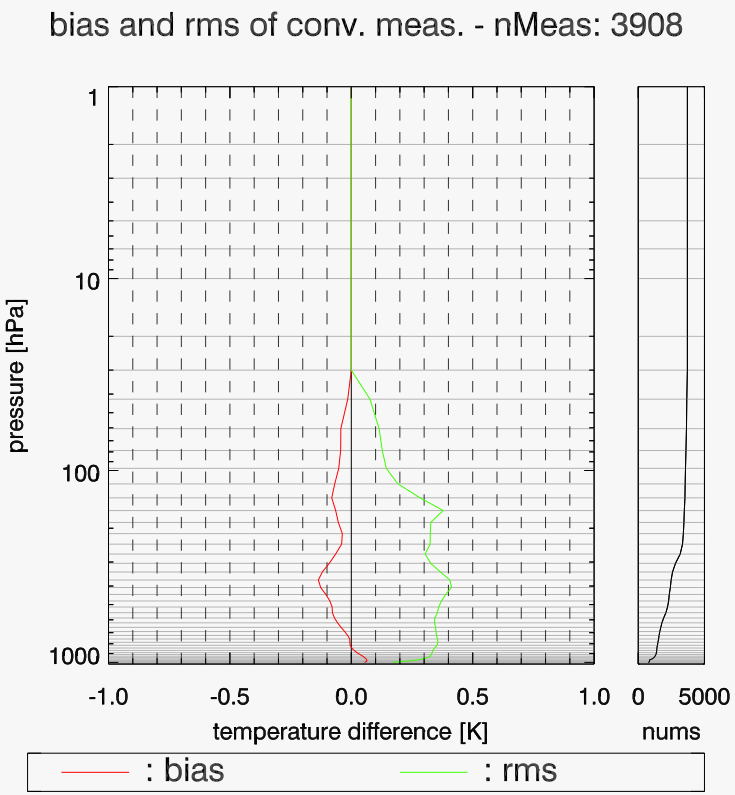
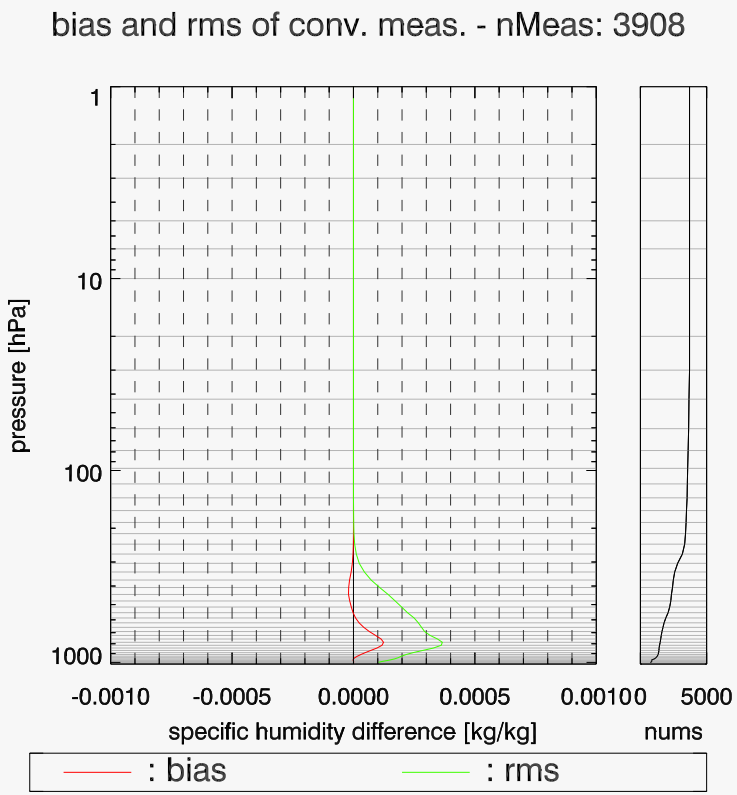


1DVar temperature statistics for this example run



1DVar humidity statistics for this example run

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period: 2. 10. 2008 – 10. 10. 2008

- 7185: control run
- 7185: IASI ass. using standard channel set

period: 17. 11. 2009 – 22. 12. 2009

- 7258: control run
- 7259: ass. run: standard channles
- 7262: ass. run: standard channles, including channel 4 - 12 from amsu-a on metop
- 7264: ass. run: additional humidity channles

upper air verification – Exp 7186 – geopotential

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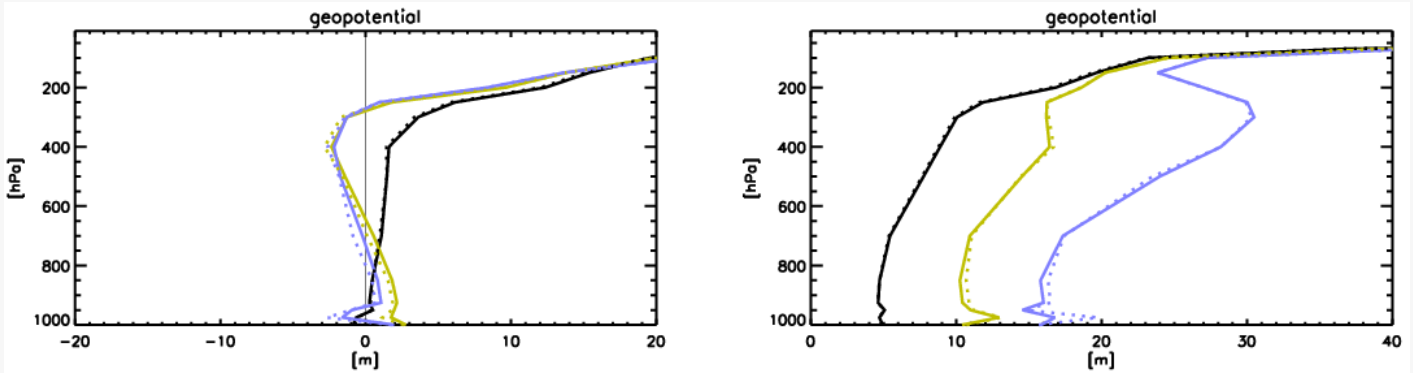

time period 10 days

dotted: reference, solid: experiment

upper air verification – Exp 7259 – geopotential

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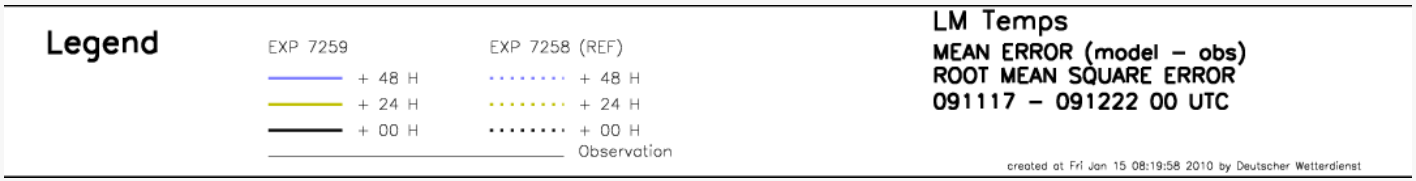

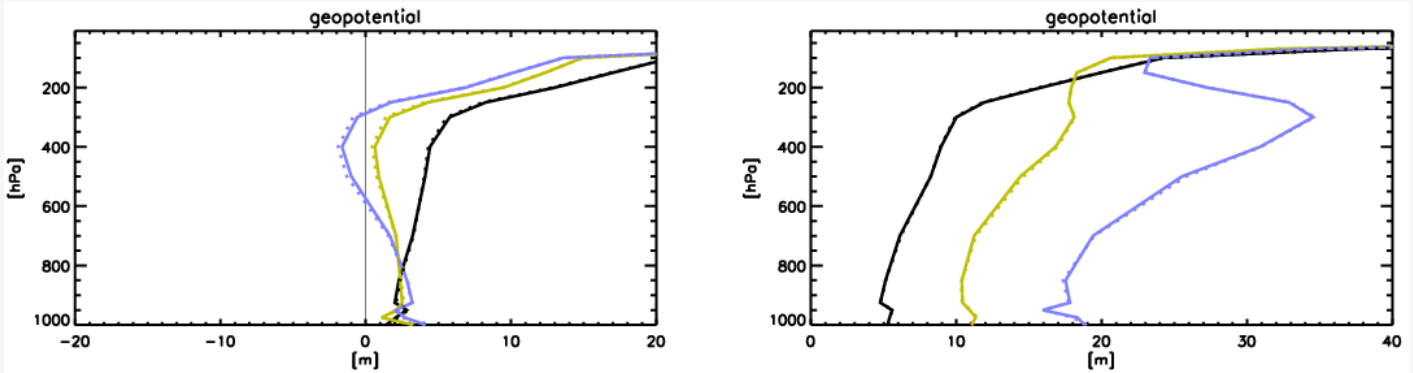

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7262 – geopotential

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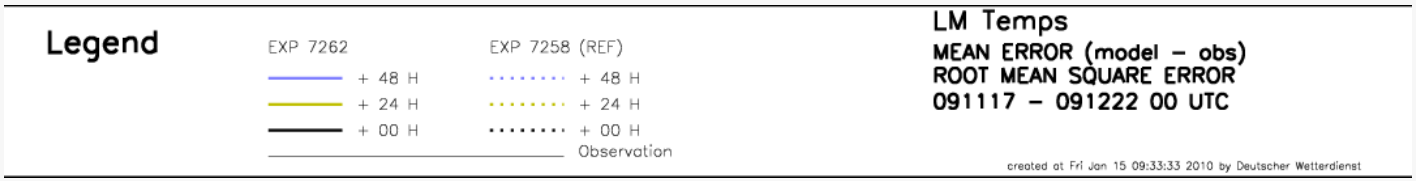

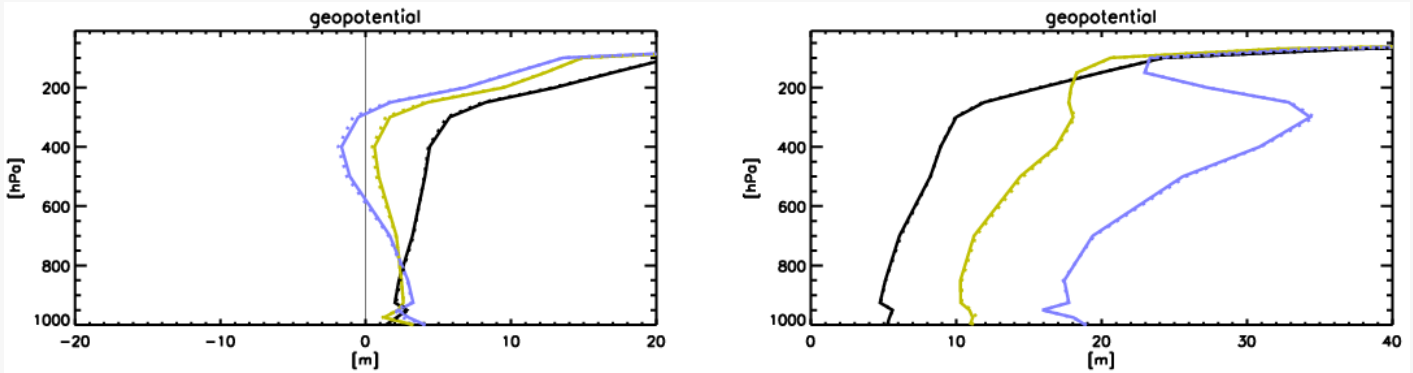

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7264 – geopotential

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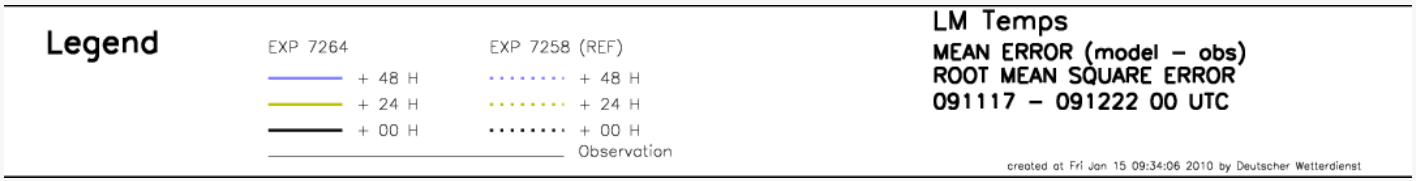

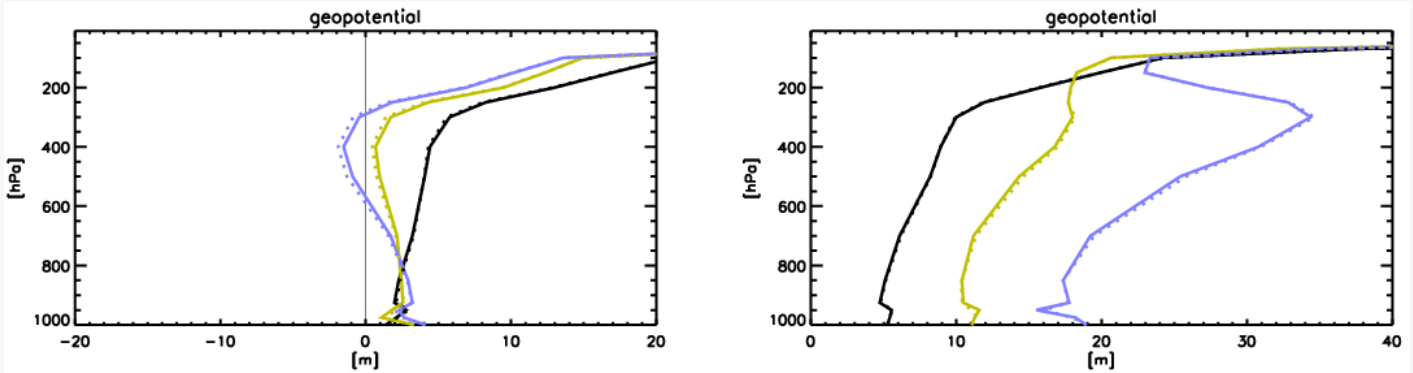

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7259 – temperature

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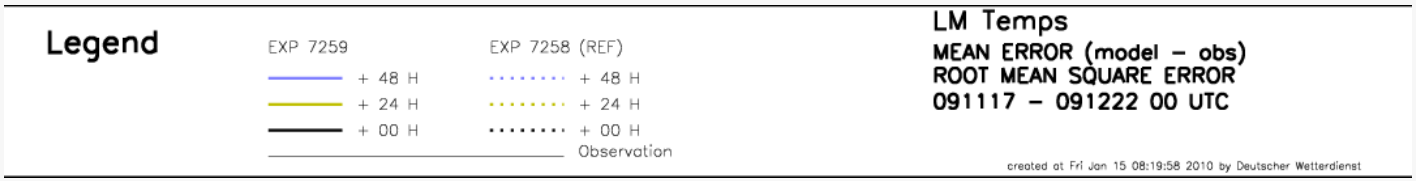

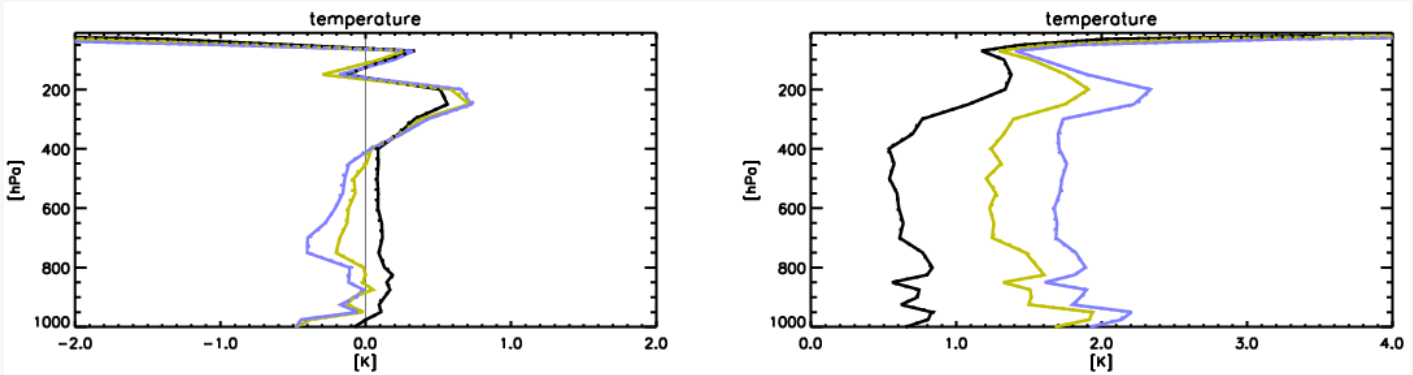

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7262 – temperature

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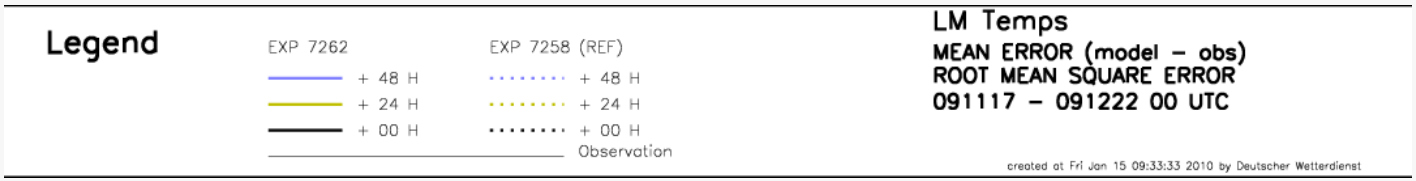

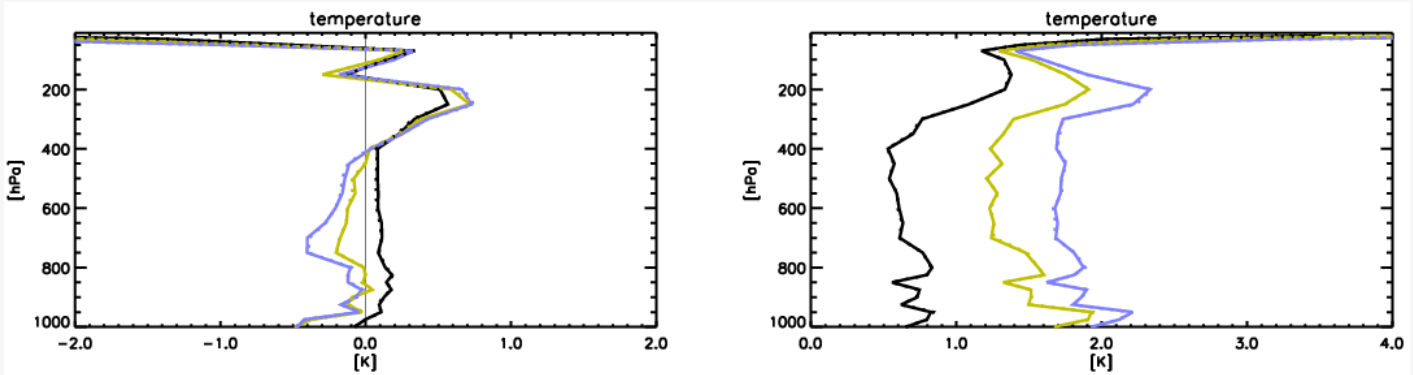

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7264 – temperature

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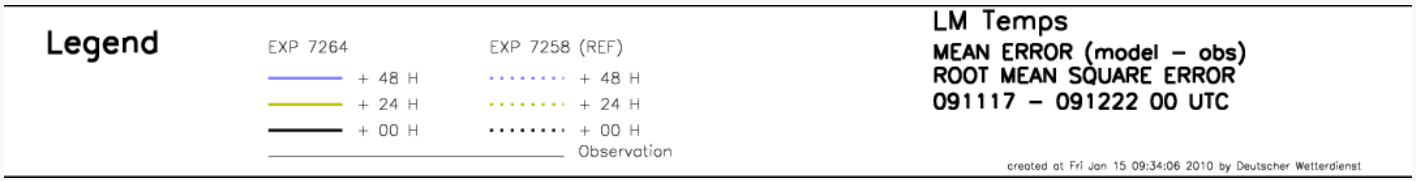

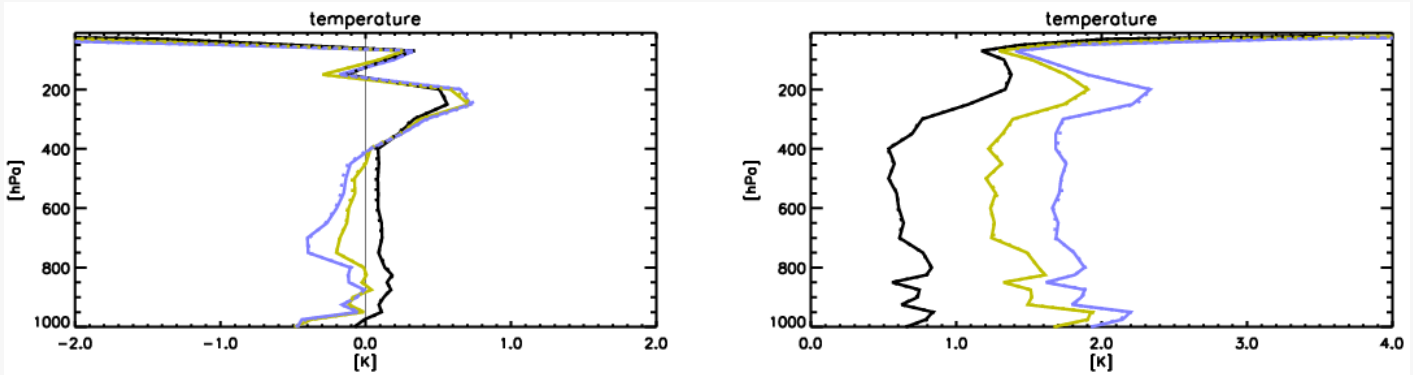

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7259 – relative humidity

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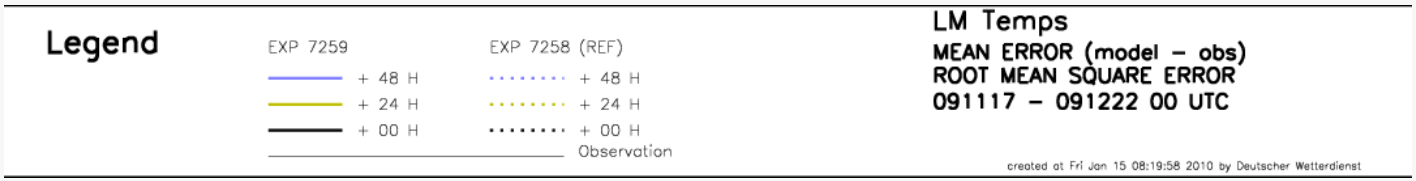

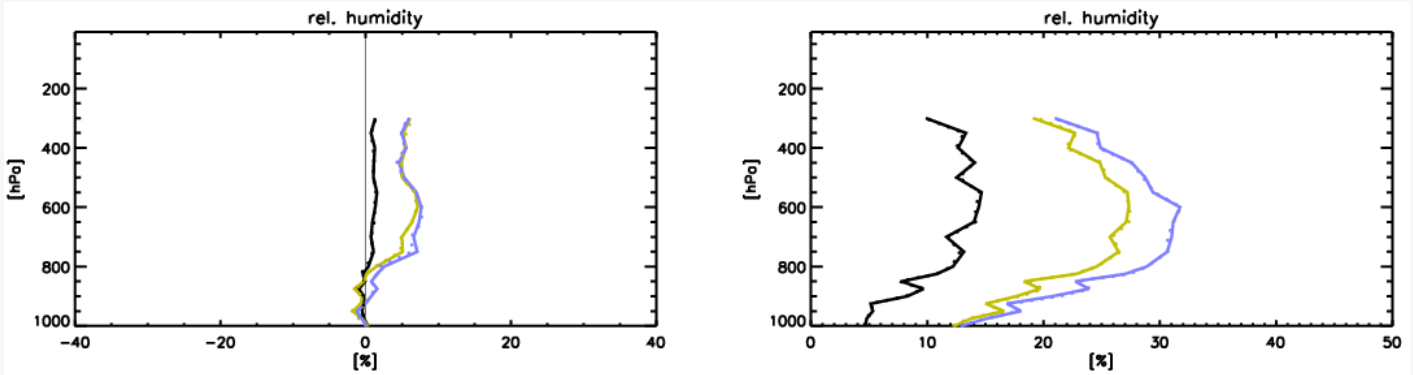

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7262 – relative humidity

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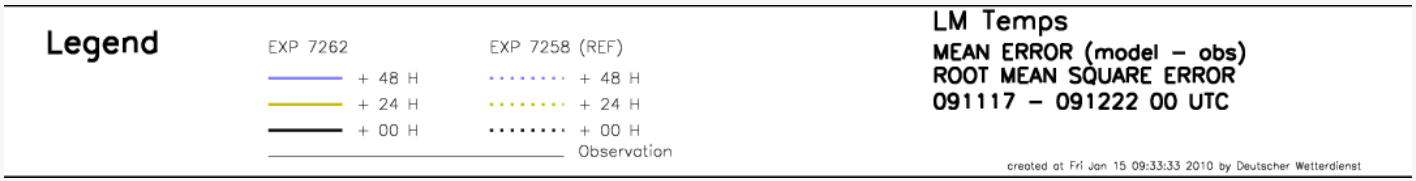

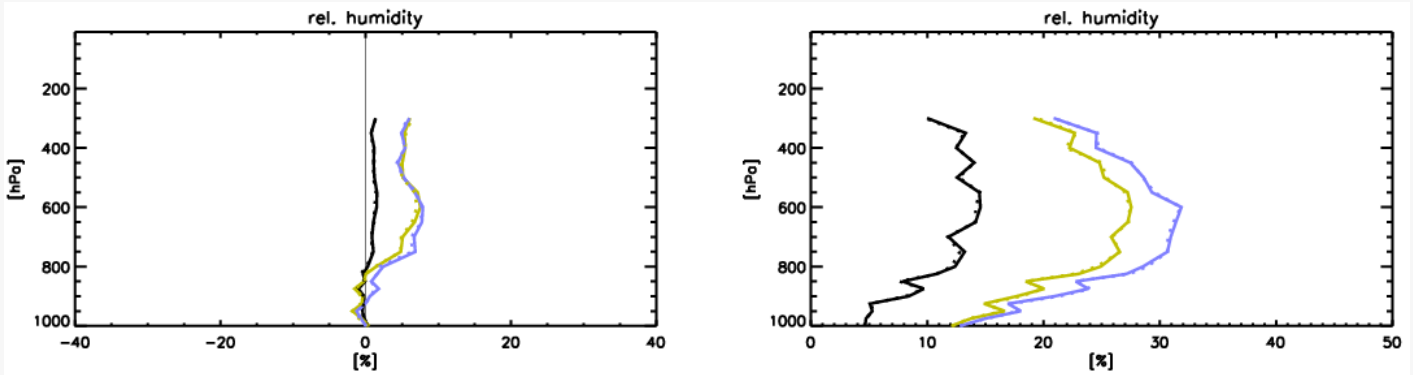

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7264 – relative humidity

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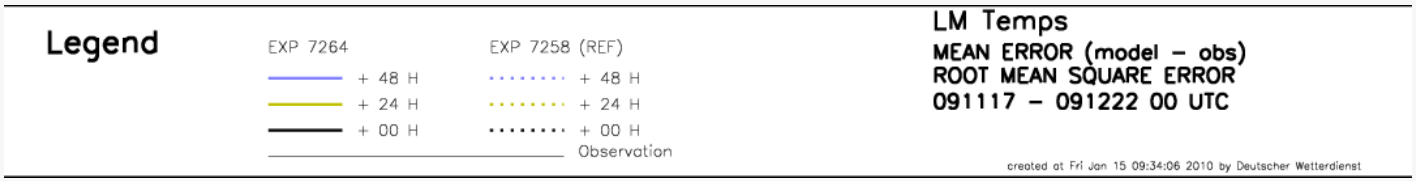

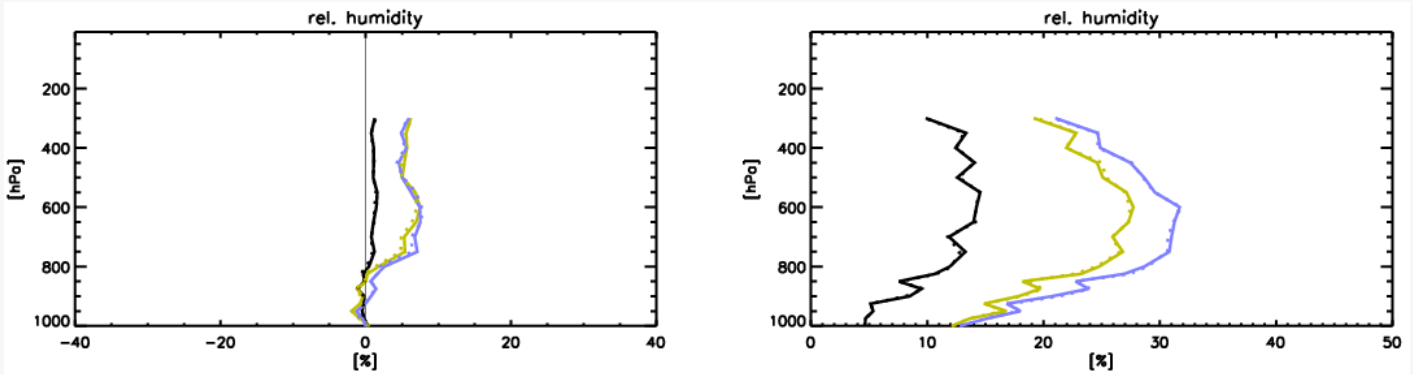

time period 35 days

dotted: reference, solid: experiment

upper air verification – Exp 7265 – relative humidity

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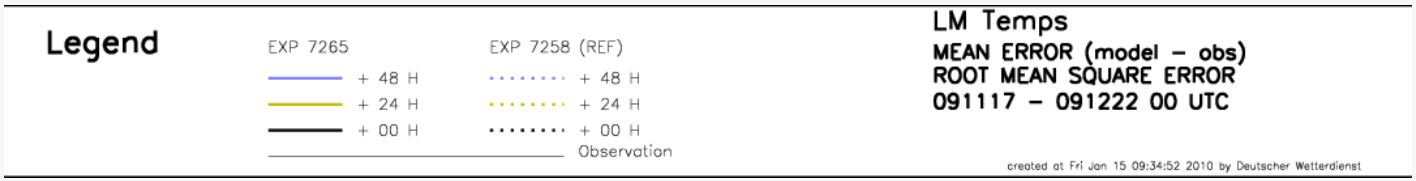

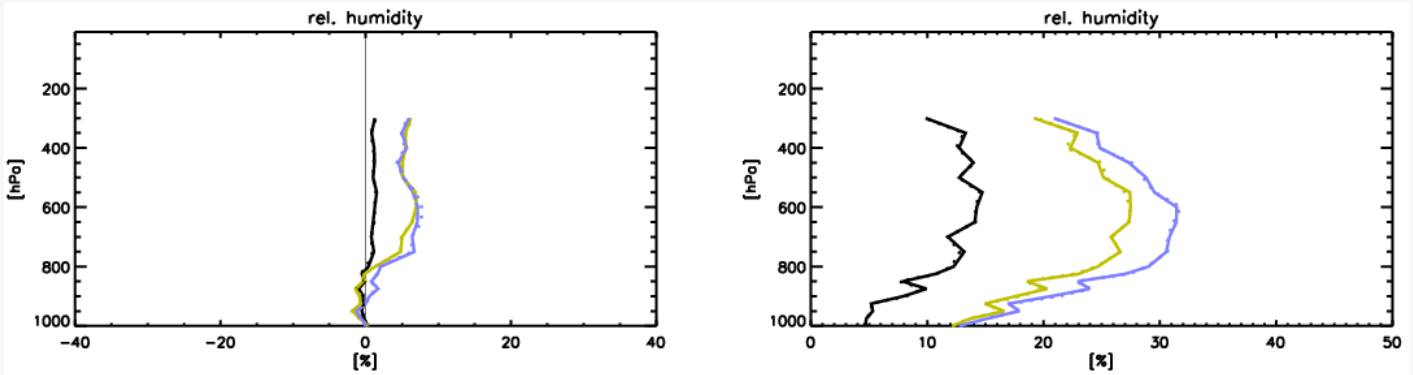

time period 35 days

dotted: reference, solid: experiment

experiment results – summary

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in general

- positive impact if stable weather situation (exp 7186)
- neutral impact if there is a westerly flow situation
- 0 UTC runs perform a little bit better then the 12 UTC runs

experiment differences

- geopotential and temperature becoming better if amsu-a or additional channels in humidity band
- not true for humidity.
- inclusion of surface obs.: small ehancements in humidity.
- in general no significant change.

Outline

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positive

- it works – neutral to positive impact depending on the synoptic situation
- meaningful impact in the 1DVar results
- cloud detection works and gives meaningful results
- assimilation over land works and changes the forecast – not yet clear if positive or negative impact

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further investigation

- **bias correction**: still runs with IASI Level 2 data for cloud detection – currently changed to use MNW data.
- **neutral impact**:
  - more sophisticated data thinning
  - tuning of the nudging coefficients
  - inclusion of the retrieved humidity profile in the nudging.

outlook

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- tuning of the assimilation of land-surface observations
- combination with amsu-a and mhs of noaa satellites
- implementation of a adaptive bias correction

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ThanX!

for your attention!