# Assimilation of IASI Measurements into the Limited Area Model COSMO-EU: Results and Next Steps

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# I got great support from many people





## special thanks to

- Thomas Hanisch, Klaus Stephan, Ulrich Pflüger, Jochen Förstner
- Christoph Schraff, Francesca Di Giuseppe, and Blazej Krezeminski
- EUMETSAT

# Outline

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# assimilation setup in COSMO



## nudging – current status:

only conventional data is assimilated

## nudging and 1DVar

usage of ATOVS and SEVIRI data via 1DVar scheme (by R. Hess, F. Di Giuseppe, C. Schraff, and B. Krezeminski)

## IASI and nudging

usage of IASI data via 1DVar scheme

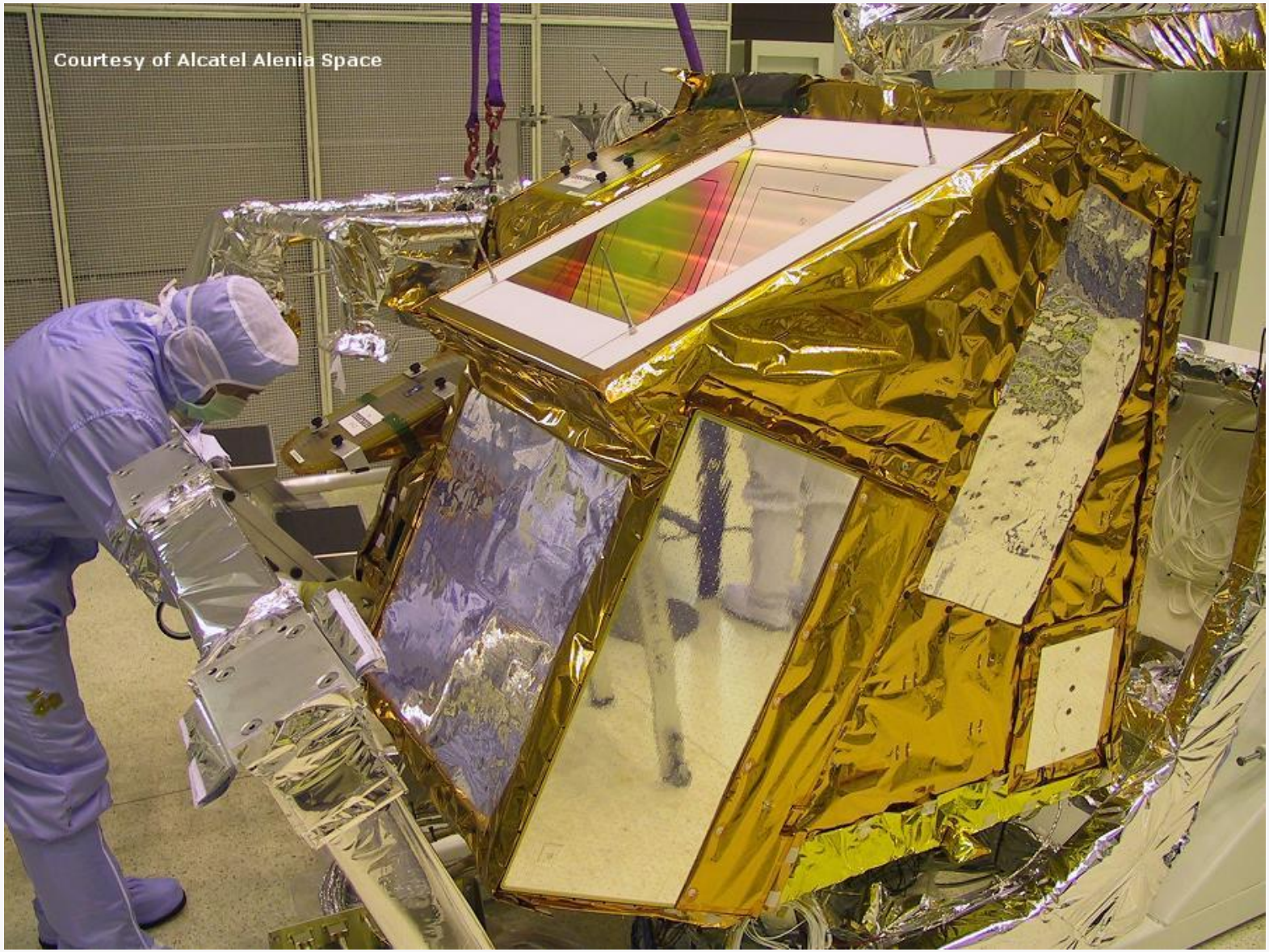
# So – ???



Who or what is IASI?

# IASI on METOP






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

# instruments on board of METOP



Source: http://www.space-technology.com/

## additional instruments

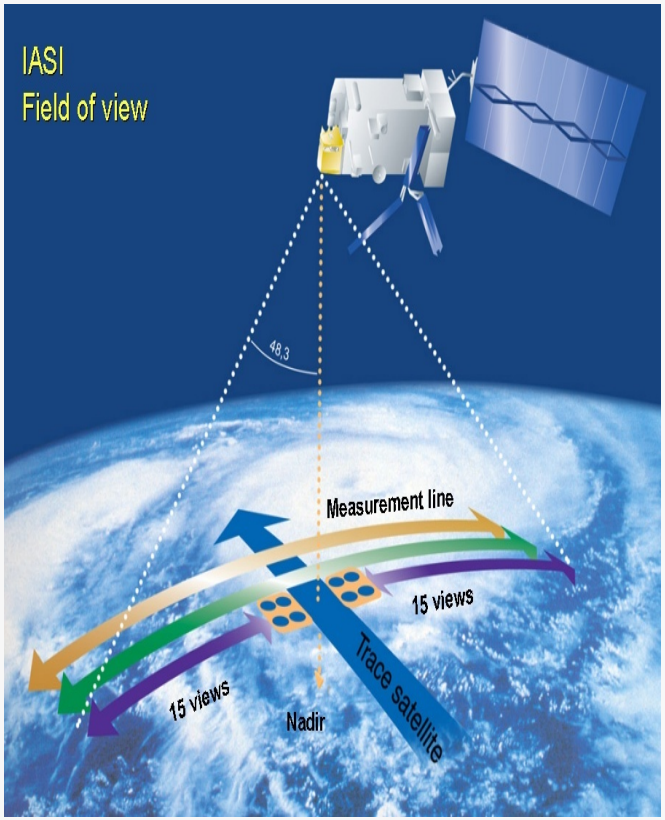
- A/DCS (Advanced Data Collection System)
- SARP-3 (Search And Rescue Processor)
- SARR (Search And Rescue Repeater)
- SEM (Space Environmental Monitor)

## atmospheric instruments

- IASI
- AMSU - A1, A2
- ASCAT
- AVHRR
- GOME-2
- GRAS
- HIRS
- MHS

# IASI – infrared atmospheric sounding interferometer






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

## technical data

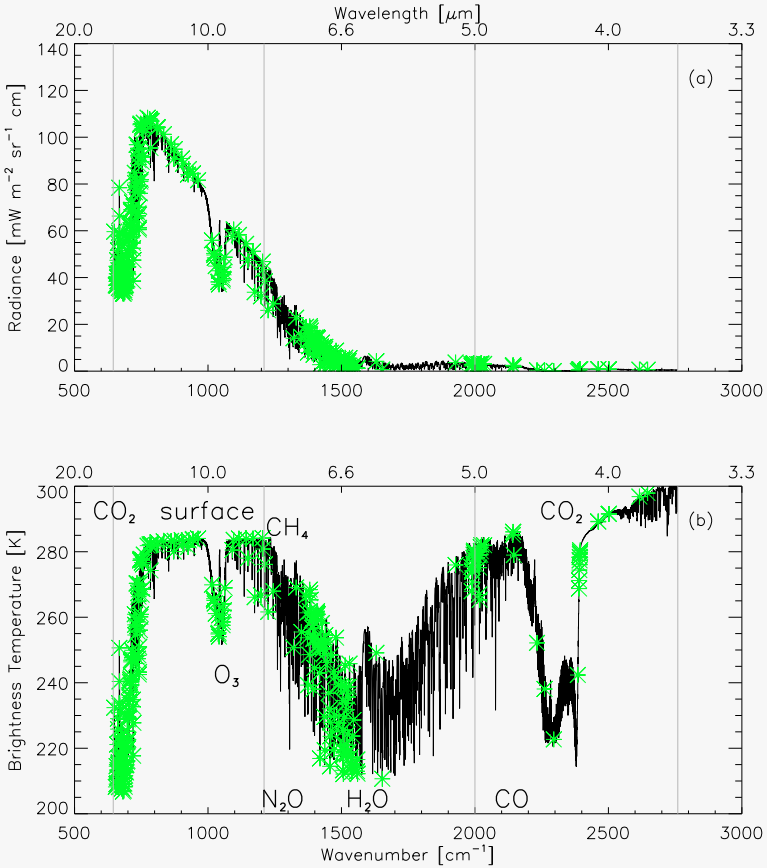
- 30 views/scan with 4 pixels/view
- IFOV: 3.33°(48 km at nadir)
- swath: ±48.3°(±1026 km)
- 3 bands, i. e., 3 interferometers:

| | range [$cm^{-1}$] | range [$\mu m$] | $\delta\nu$ [$cm^{-1}$] |
|---|---|---|---|
| 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 $\mu$m
- spectral res.: 0.35 - 0.5 $cm^{-1}$
- 8461 channels
- radiometric res.: 0.25 - 0.5 K

# interesting parts for NWP





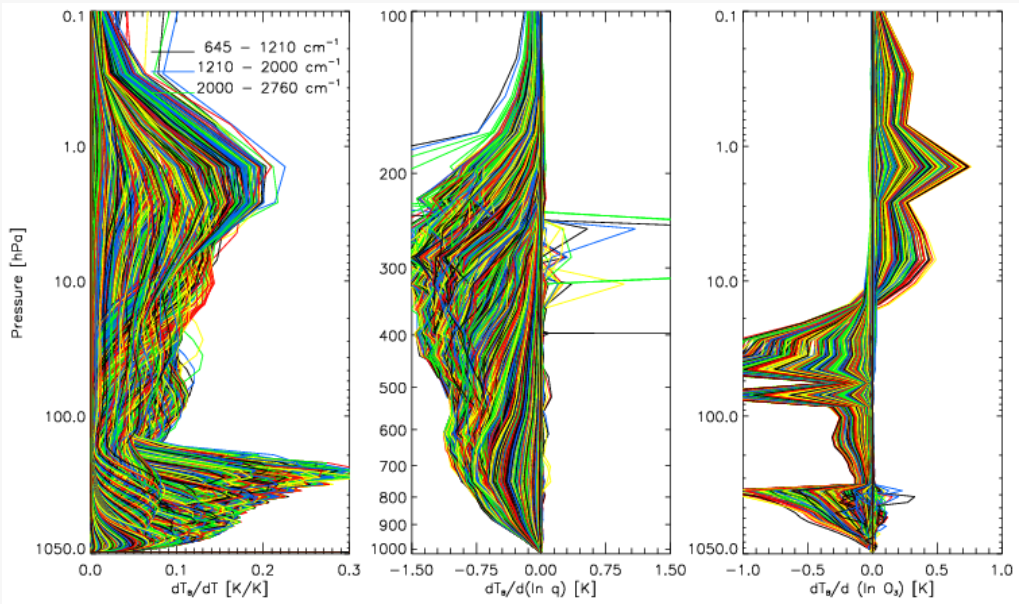

## temp, humi surf

| 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 |

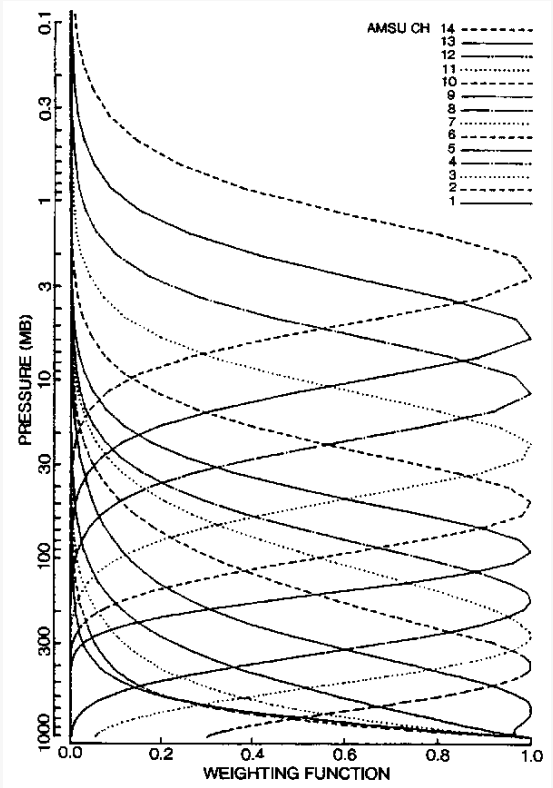
interesting spectral regions for meteorological applications
(300 channel set selected by IC method (Andrew Collard, 2005))

# Information comparison IASI - AMSU-A





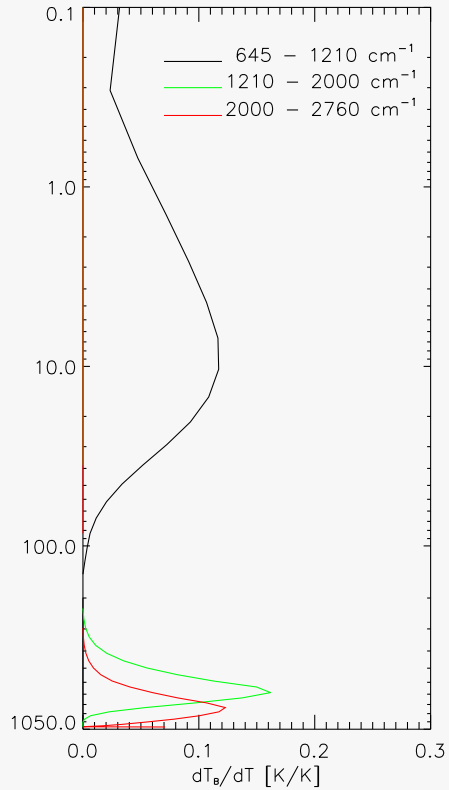

all temp, wv and ozone channels of the iasi instrument




source: http://www.ecmwf.int/

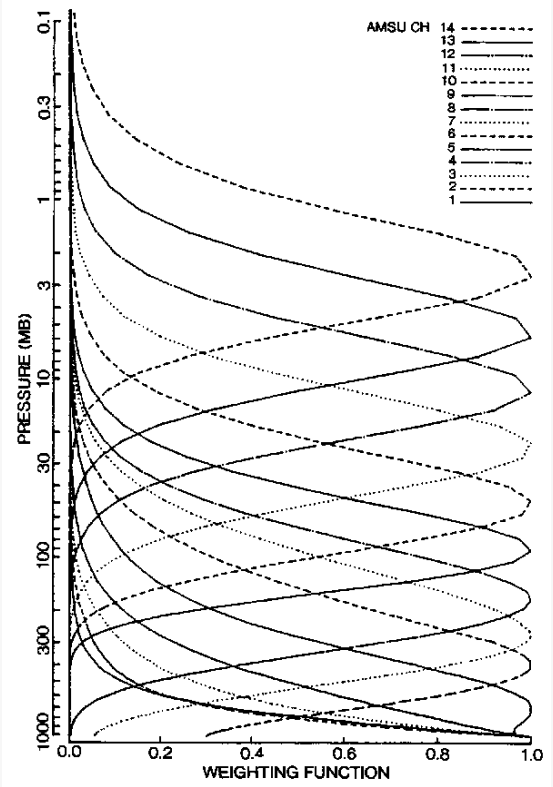
# Resolution comparison IASI - AMSU-A






selected temperature channels

of the iasi instrument




source: http://www.ecmwf.int/

# Outline

# Offline Data Preparation and Preprocessing

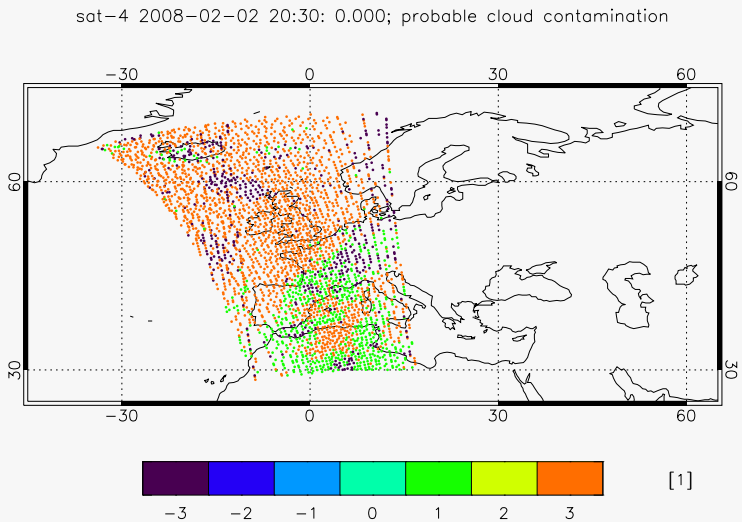


## a script handles

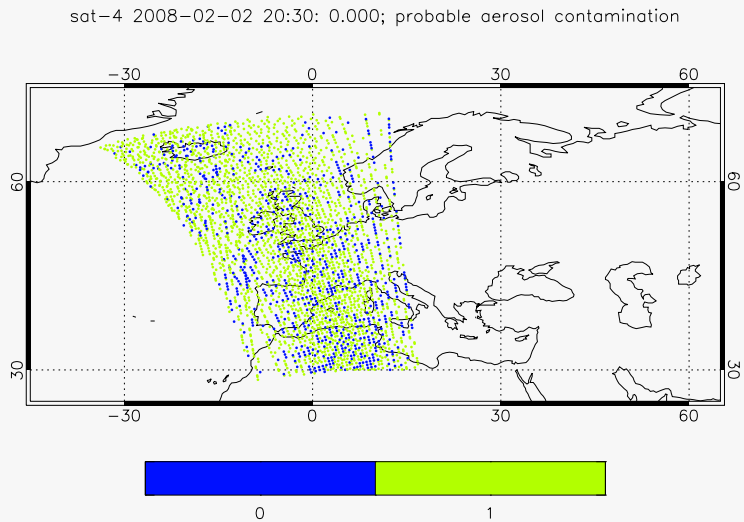
- data extraction from Db for needed time window
- conversion of bufr to aapp-1c format (amsu-a, mhs, and iasi data)
- pre-processing with aapp
- conversion from aapp-1d Format to netCDF as needed by COSMO-EU.

# show a frame where IL2 data and AAPP cloud data is compared - to show that aapp cloud detection is useless for iasi






possible cloud contamination – aapp




possible aerosol contamination – aapp

# first quality data selection steps



## throw away

- not in model domain
- neither iasi nor amsu-a nor mhs channels left after evaluating the pre-processing info
- one of four IASI IFOV's is selected

## pre-processing summary word

- iasi quality flag
- overall aapp-1d scanline quality flag
- cloud and aerosol info

# data preparation



## this step contains

- reading of data according to needed time window
- bias correction
- cloud detection
- channel selection
- quality control

# bias correction

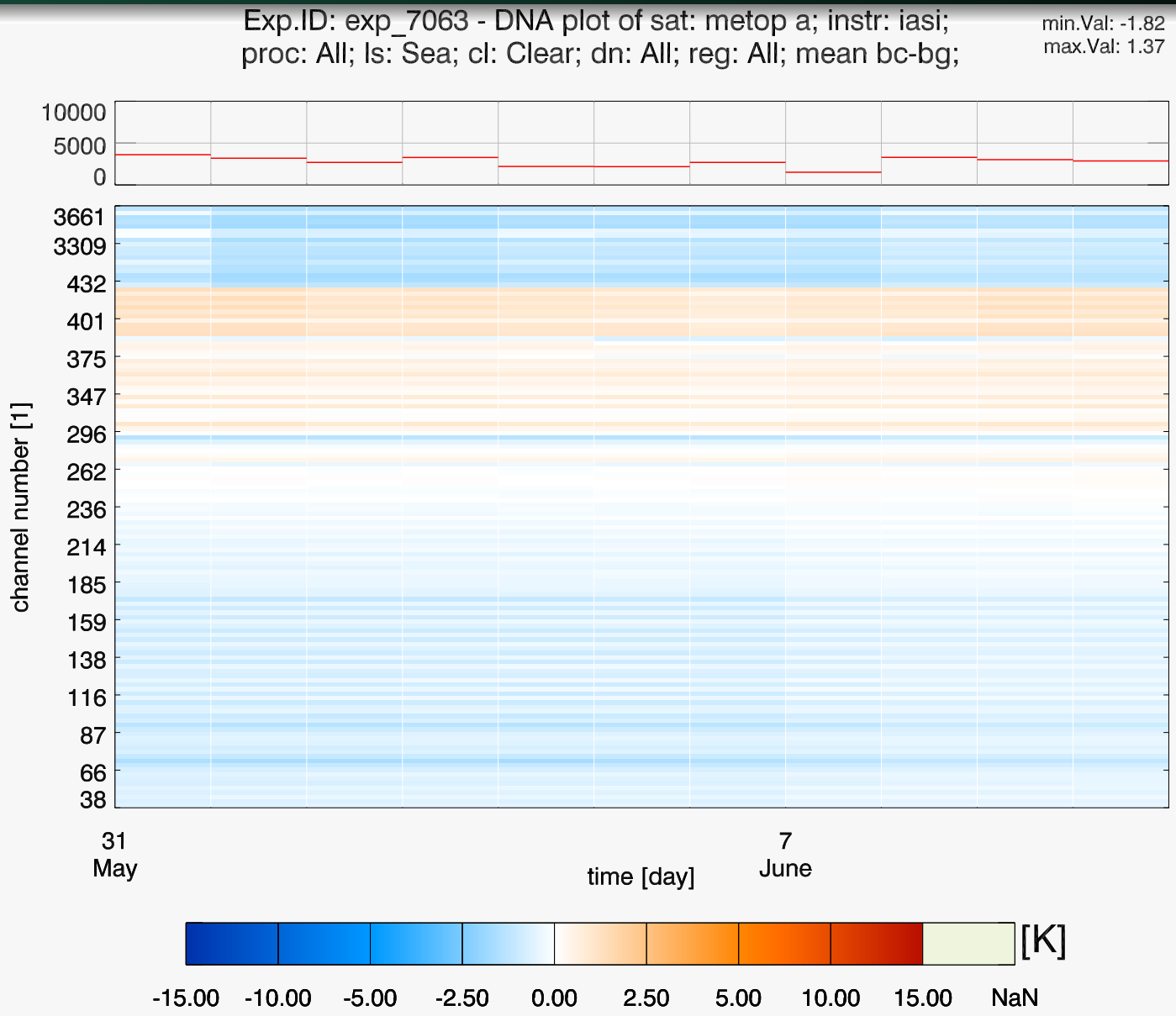


## implementation of model dependent bias predictors after Harris and Kelly (HK) (2001)

- scan- and air-mass correction
- cloud flagging using iasi Level 2 cloud flags
- Predictors:
  - 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 – mean

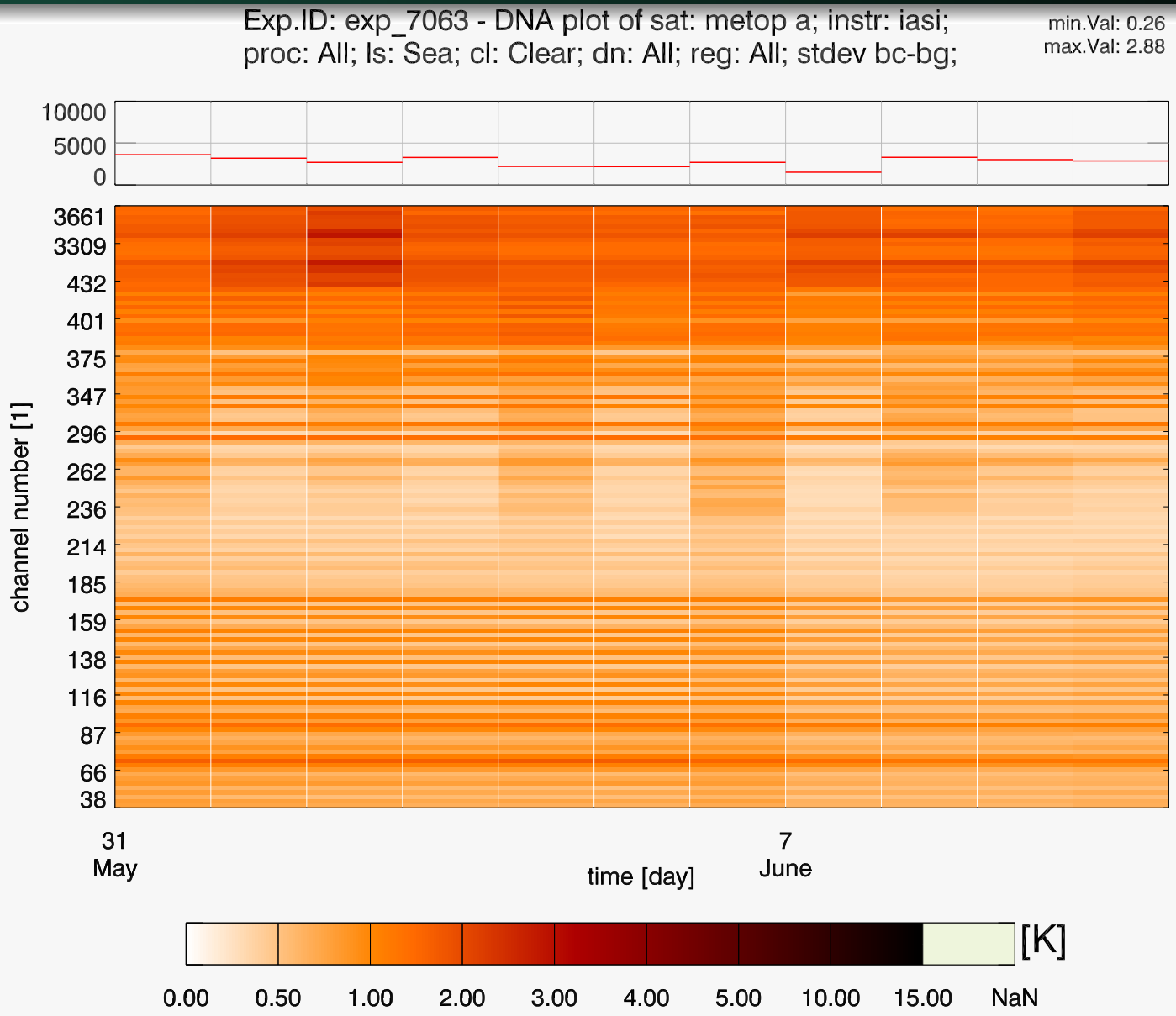





bias corrected minus first guess measurements for IASI data.
for a ten days period in June

# bias DNA plot – stdev






stdev of bias corrected minus first guess measurements for IASI data.
for a ten days period in June

# cloud detection



## iasi level 2 cloud flags

- cloud flags from IASI level 2 (IL2) data
- problem: data cutoff, valid for whole profile
- next year: IL2 cloud flag is deliverd with level 1c.

## implementation of model after McNally and Watts (2003)

- adaption of the limits to COSMO-EU
- adaption to limited area model setup with low model top
- advantage: all channels above a cloud are assimilated $\Longrightarrow$ more information can be assimilated.
- $\Longrightarrow$ next year: combine McNally/Watts and IL2

# channel selection – neue chan sel daten rein



## currently two very raw sets:

- **1:** only 116 temperature channels from the 15 $\mu$m (666.66 $cm^{-1}$) band (649 $cm^{-1}$ to 759,25 $cm^{-1}$) and 18 channels of the 6.25 $\mu$m (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 $\mu$m (1600 $cm^{-1}$) wv band (1212.75 to 1560.25 $cm^{-1}$) – no specific channel selection in the wv band.

# quality control



## rejection of whole measurements

- measurement over land
- first guess departure (15 K)
- cloudy measurements (depends on special experiment)

## rejection of single channels

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

  has unphysical values (for IASI: 180 K – 320 K)
- channels below cloud top (depends on special experiment)

# 1DVar setup



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

# first guess

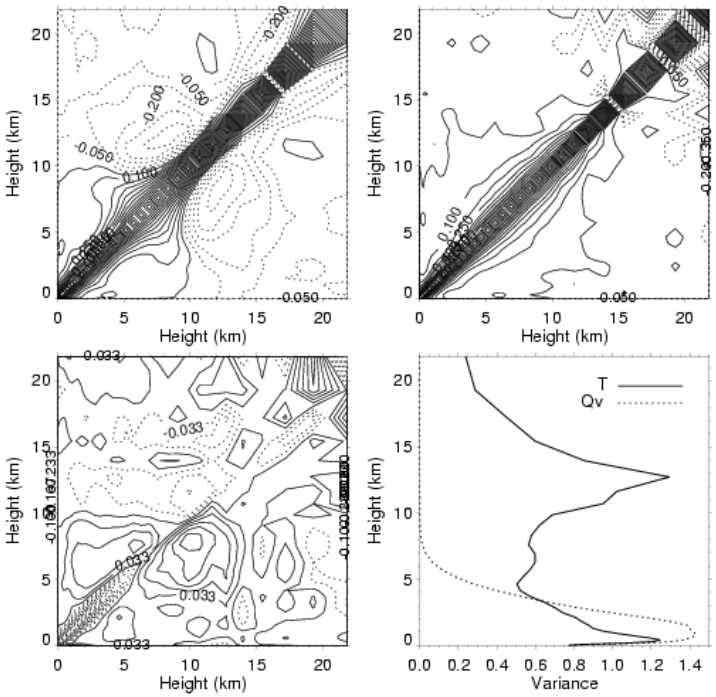


## first guess creation

- bi-linear interpolation using the 4 surrounding grid points
- interpolation points: vertical points over measurement ground point
- above model top: ifs profiles from ifs forecasts (radiative transfer)
- in addition: if too small values in specific humidity they are set to 1.5 $10^{-6}$ kg/kg

# the *a priori* error covariance matrix






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



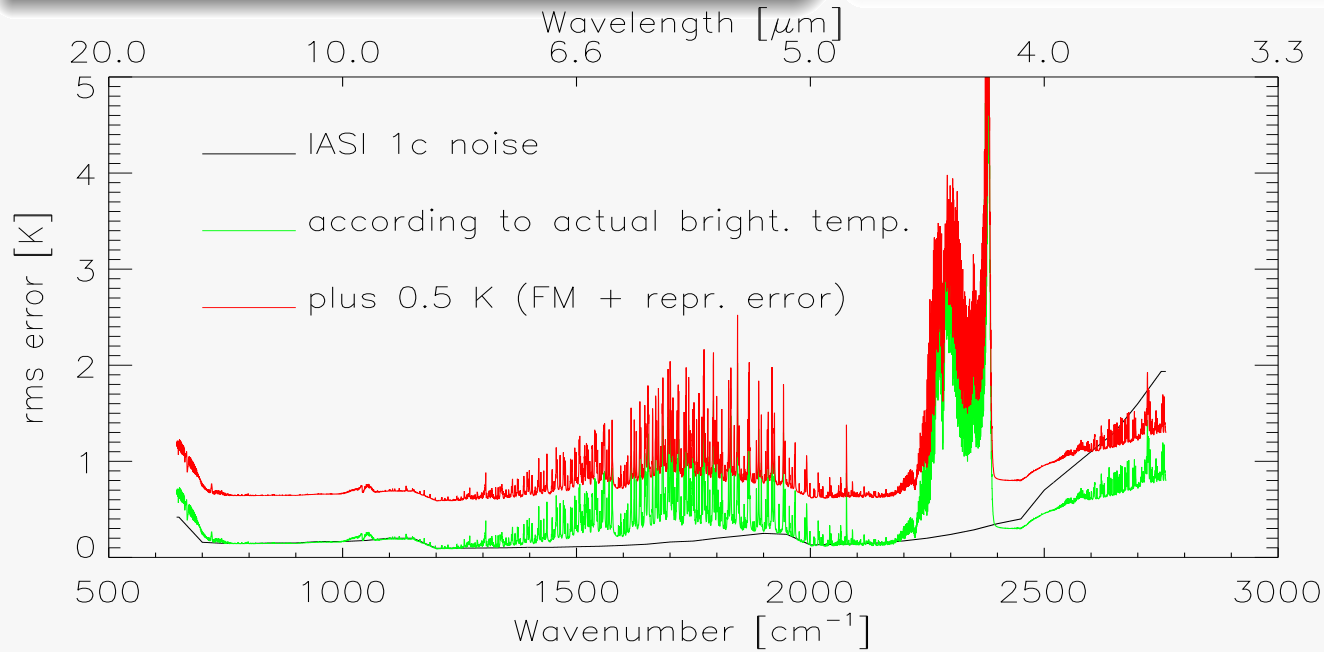
## diagonal elements

- IASI level 1c noise values
- adapted to the actual brightness temperature
- +0.5 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 measurement error covariance matrix



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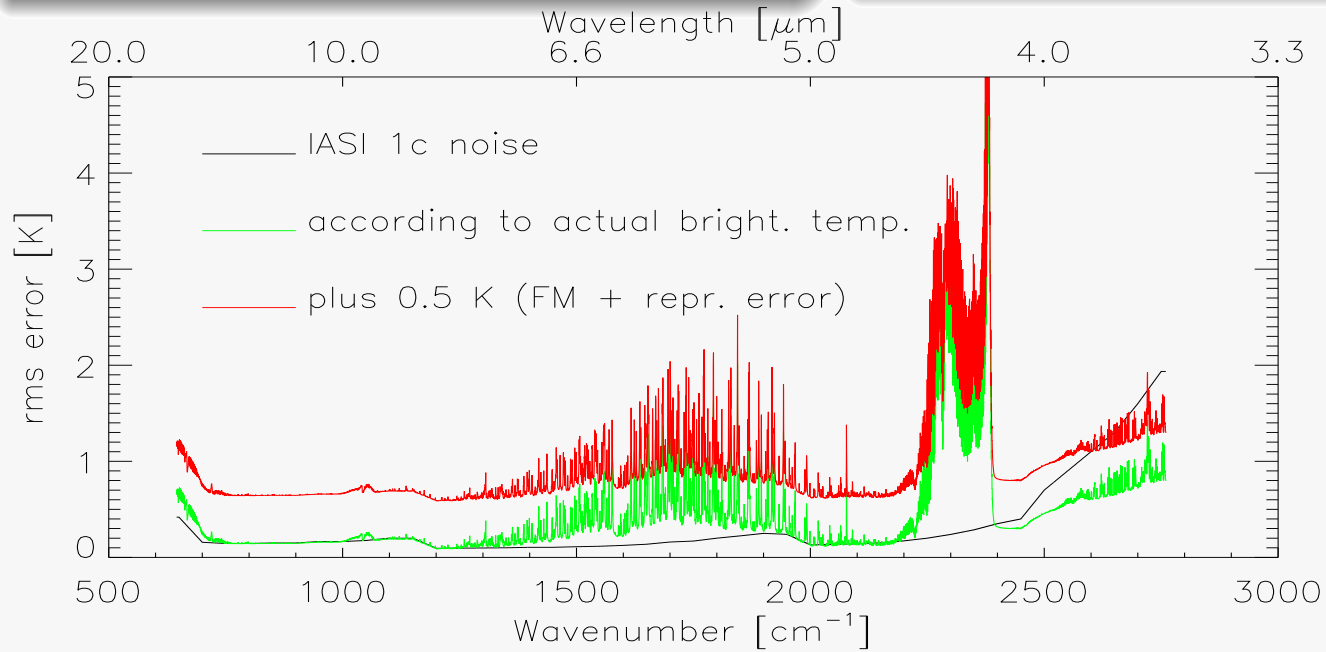


# the forward model and 1DVar scheme



## RTTOV9 - an overview

- simulation of the IASI measurements at 100(43) fixed pressure levels between 0.01(0.1) and 1100.00(1013.25) hPa
- brightness temperatures $\mathbf{T}_B$ (or radiances, respectively).
- tangent linear and adjoint model to calculate jacobians, e.g.,
  for $\mathbf{T}$, $\mathbf{q}$, $\mathbf{O_3}$, and $\mathrm{SST}$ - $\frac{\partial \mathbf{T}_B}{\partial \mathbf{T}}$, $\frac{\partial \mathbf{T}_B}{\partial \mathbf{q}}$, $\frac{\partial \mathbf{T}_B}{\partial \mathbf{O_3}}$, and $\frac{\partial \mathbf{T}_B}{\partial \mathrm{SST}}$
- a new and better interpolation function from user levels to rttov levels

# Outline

# Experiment 7063

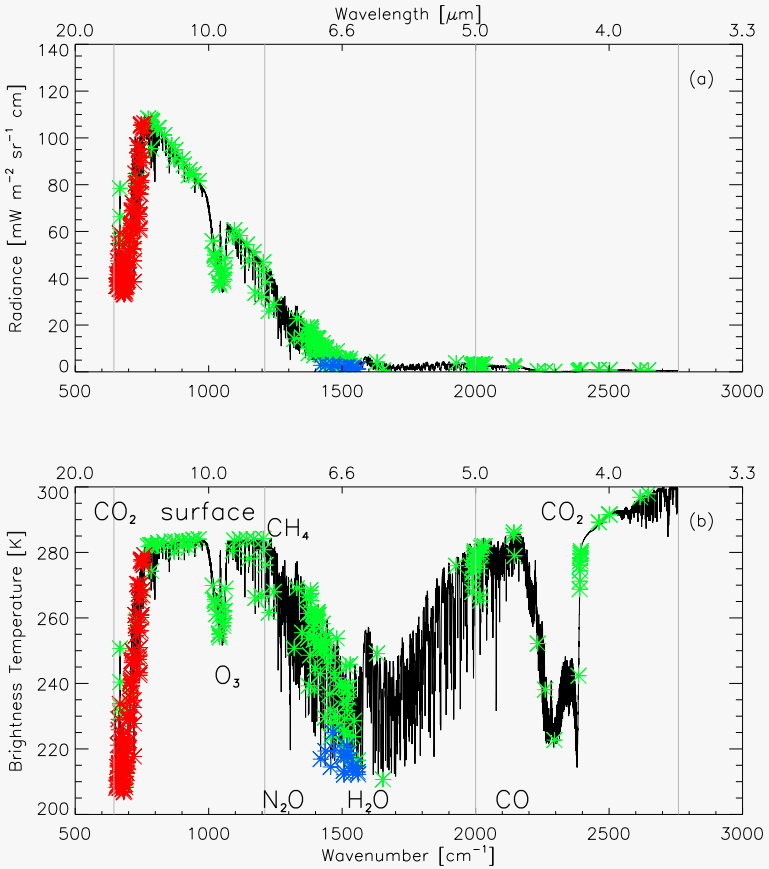


## standard assimilation setup

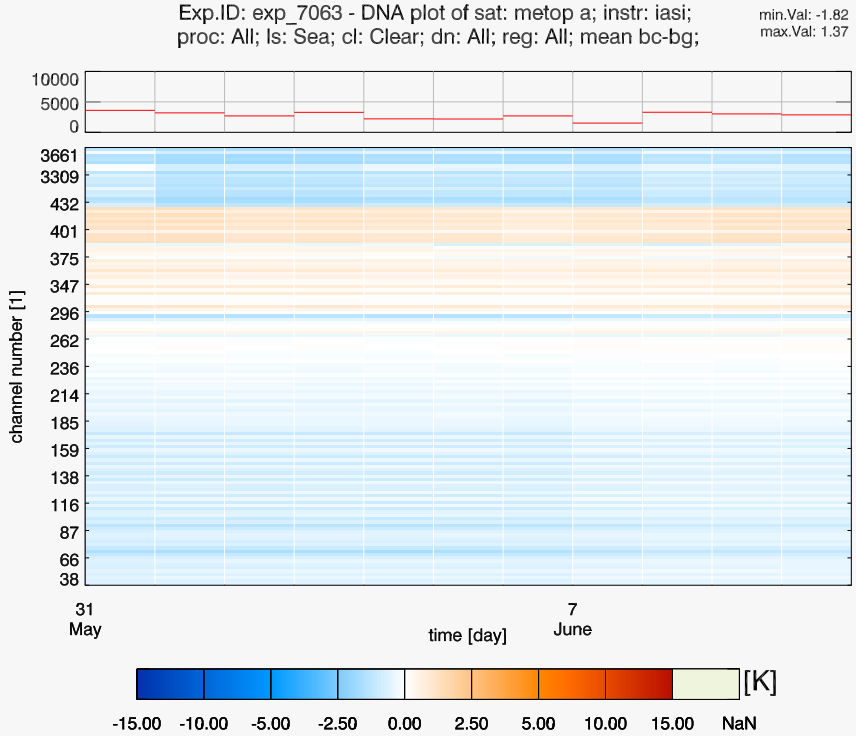
- 99 % of the channel lies above the cloud
- cloud detection via the modified McNally and Watts (2003) algorithm
- $1^{st}$ channel set
- bias correction – HK with IL2 for cloud detection

# selected channels and exemplary bias corrected meas. – 7063






temperature sounding channels (15$\mu$m $CO_2$ band)




bias correction – bias corrected minus background

# Experiment 7065

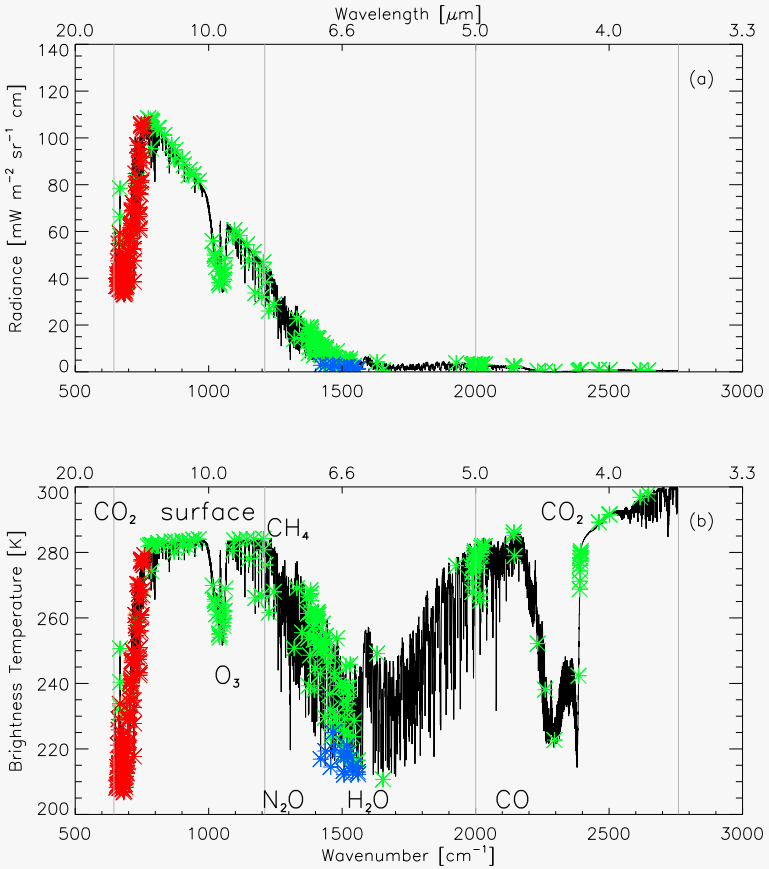


## standared assimilation setup – modified cloud treatment

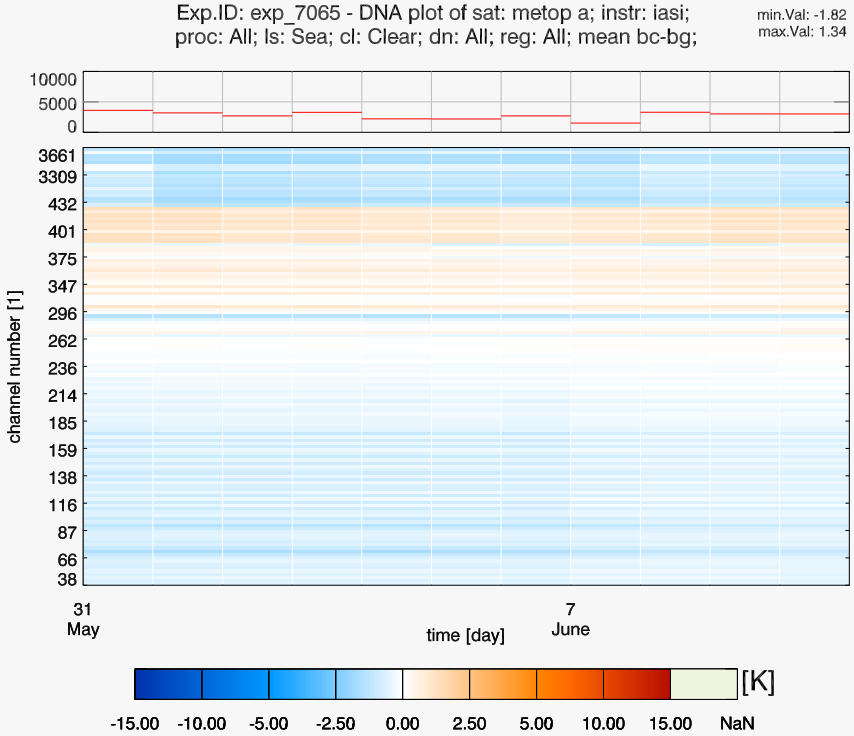
- 95 % of the channel lies above the cloud
- cloud detection via the modified McNally and Watts (2003) algorithm
- $1^{st}$ channel set
- bias correction – HK with IL2 for cloud detection

# selected channels and exemplary bias corrected meas. – 7065






temperature sounding channels (15$\mu$m $CO_2$ band)




bias correction – bias corrected minus background

# Experiment 7066

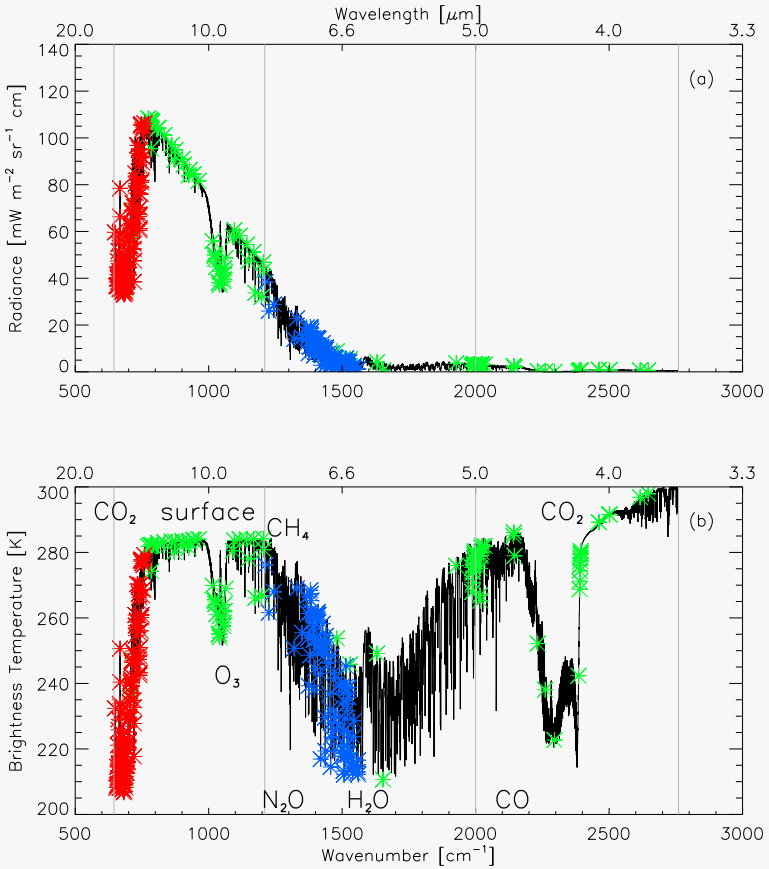


## Level 2 cloud detection – $1^{st}$ channel set

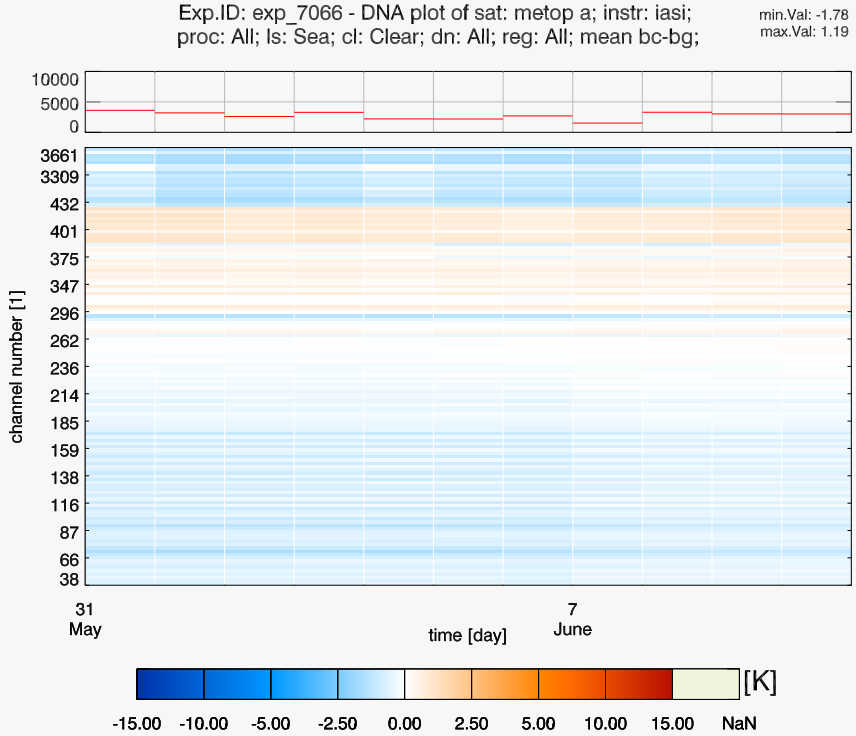
- first guess departure criteria: 15 K
- iasi level 2 flags for cloud detection
- $1^{st}$ channel set
- bias correction – HK with IL2 for cloud detection

# selected channels and exemplary bias corrected meas. – 7066






temperature sounding channels (15$\mu$m $CO_2$ band)




bias correction – bias corrected minus background

# Experiment 7067

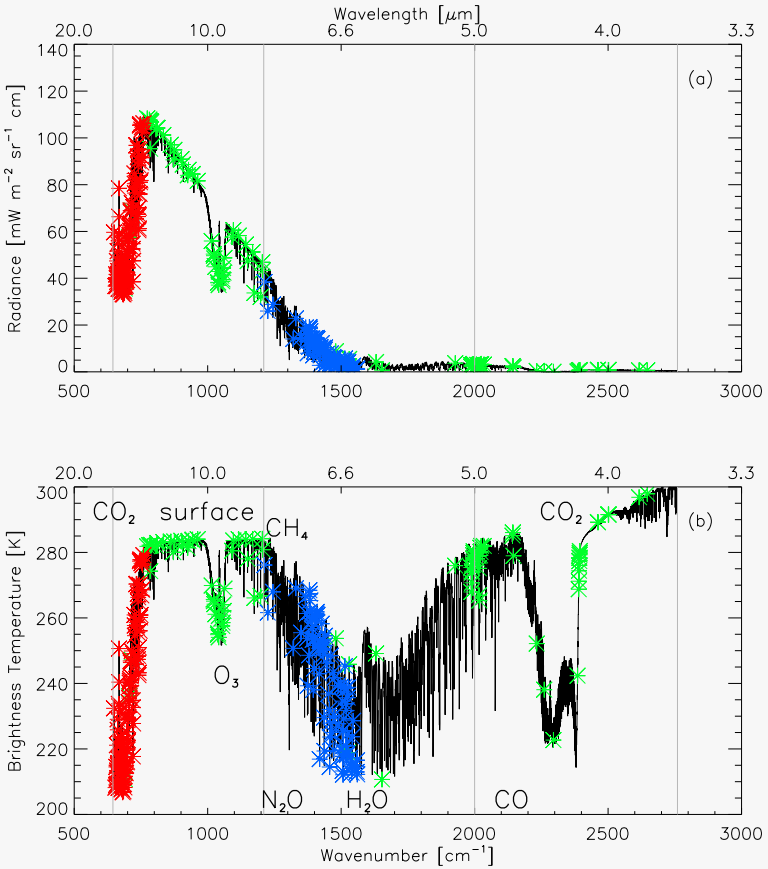


## standard assimilation setup – $2^{nd}$ channel set

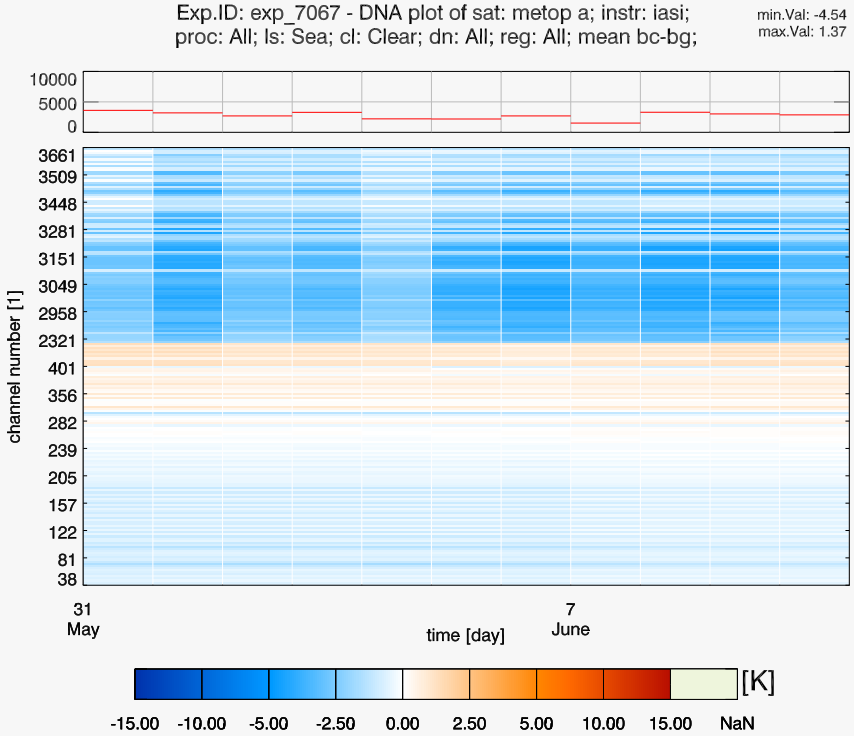
- cloud detection via the modified McNally and Watts (2003) algorithm
- $2^{nd}$ channel set
- bias correction – HK with IL2 for cloud detection

# selected channels and exemplary bias corrected meas. – 7067





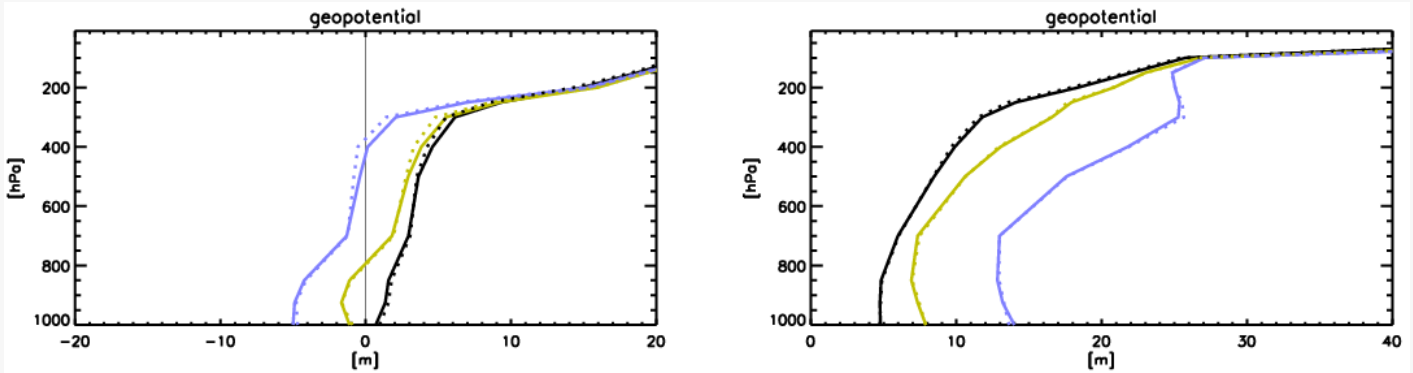

temperature sounding channels (15$\mu$m $CO_2$ band)




bias correction – bias corrected minus background

# upper air verification – Exp 7063 – geopotential



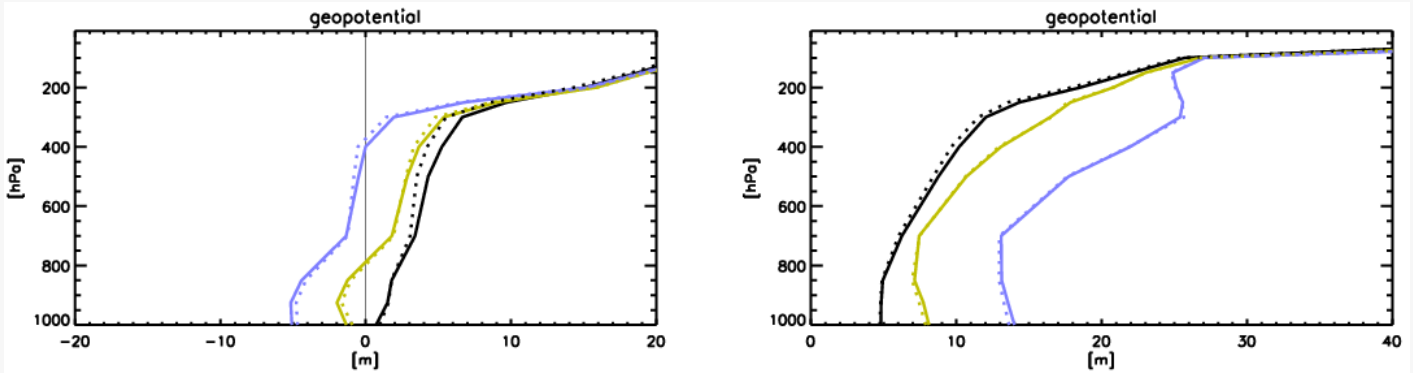




time period 10 days

dotted: reference, solid: experiment

# upper air verification – Exp 7066 – geopotential



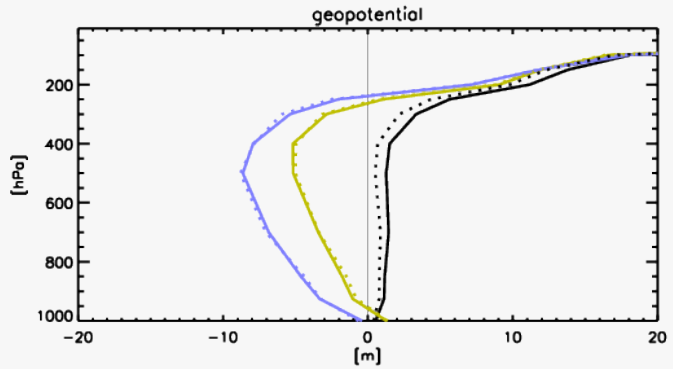



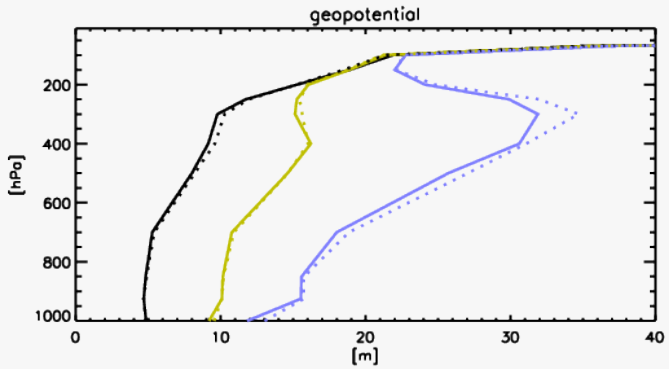

time period 10 days

dotted: reference, solid: experiment

# upper air verification – Exp 6751 – geopotential



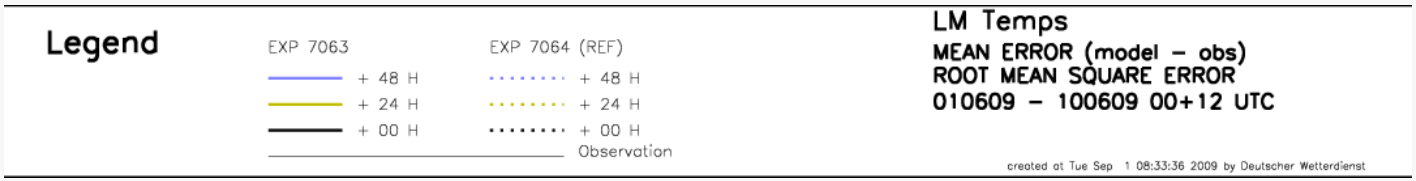



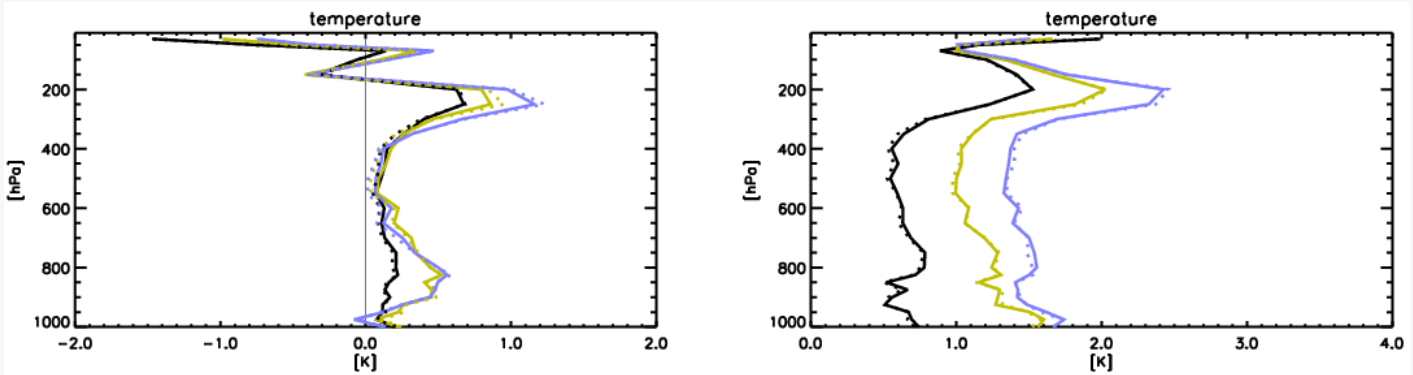

time period 6 days

dotted: reference, solid: experiment

# upper air verification – Exp 7063 – temperature





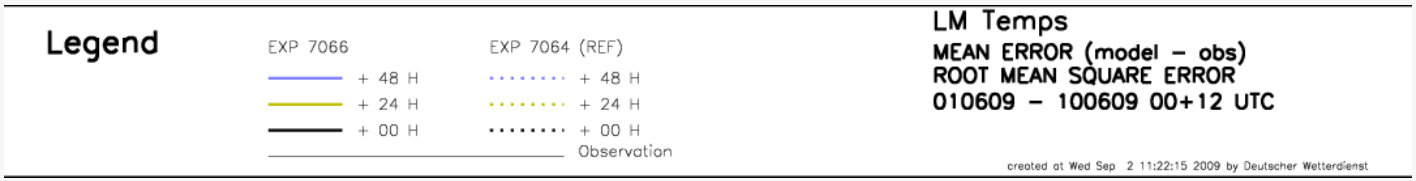



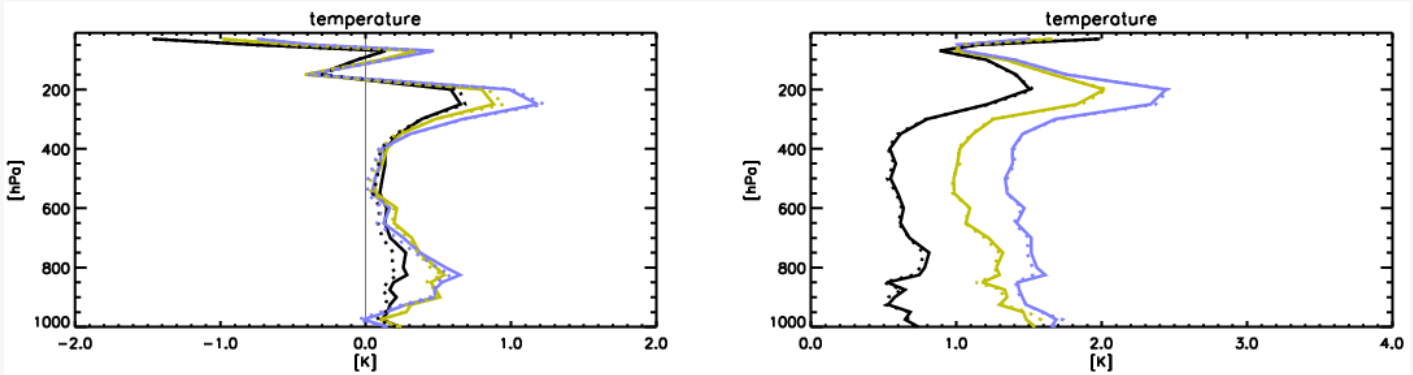

time period 10 days

dotted: reference, solid: experiment

# upper air verification – Exp 7066 – temperature





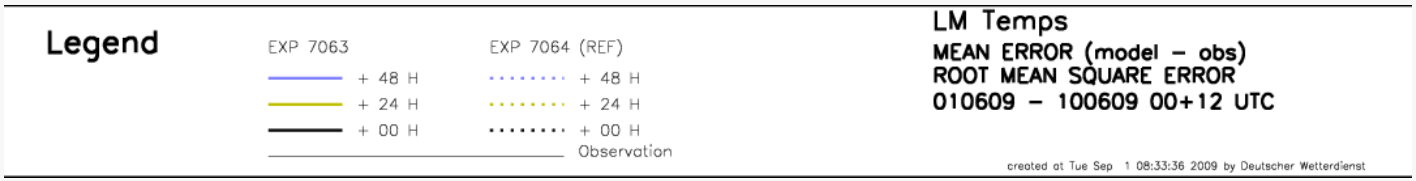



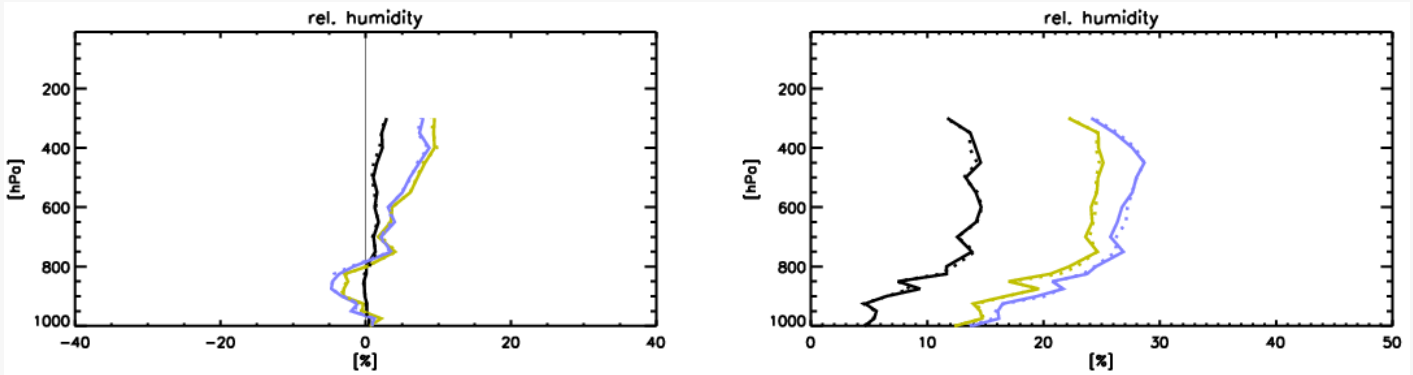

time period 10 days

dotted: reference, solid: experiment

# upper air verification – Exp 7063 – relative humidity





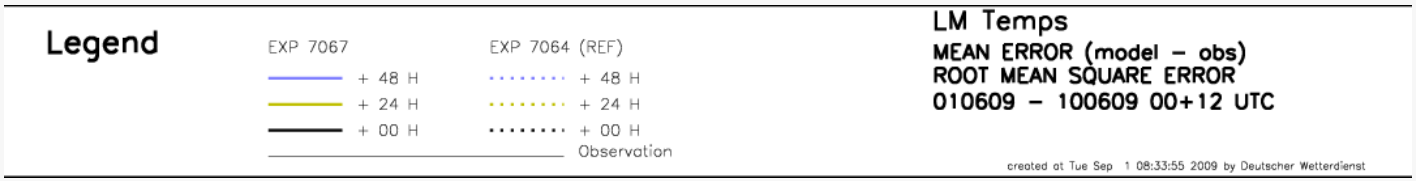



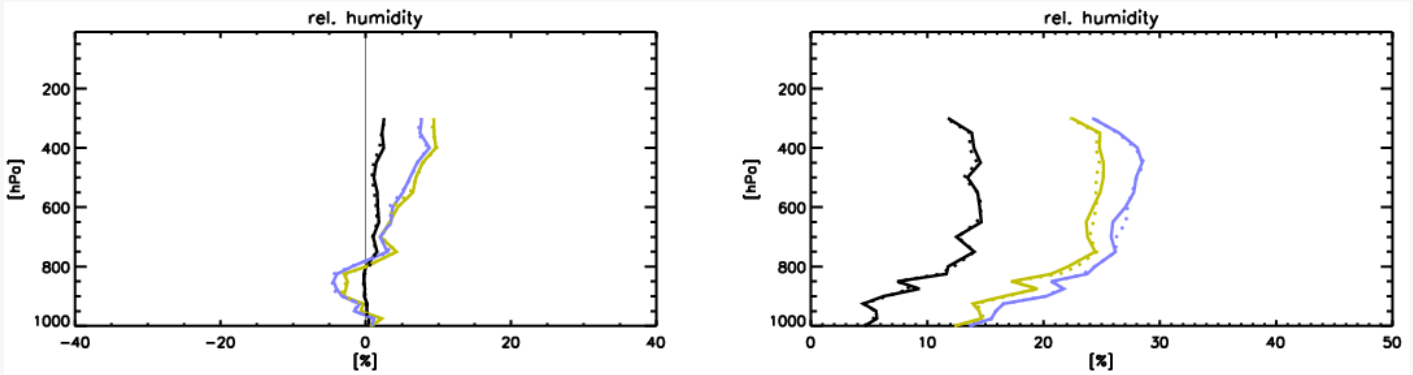

time period 10 days

dotted: reference, solid: experiment

# upper air verification – Exp 7067 – relative humidity





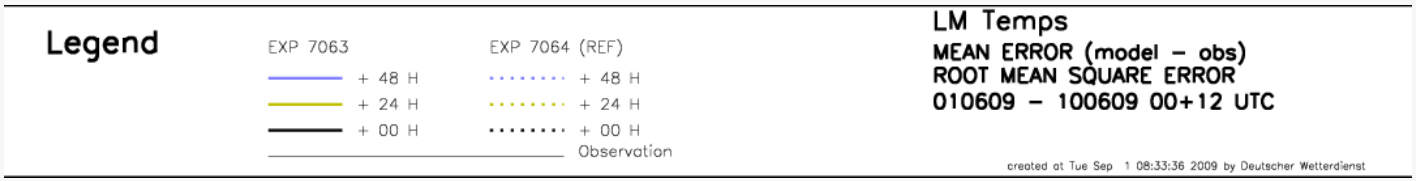



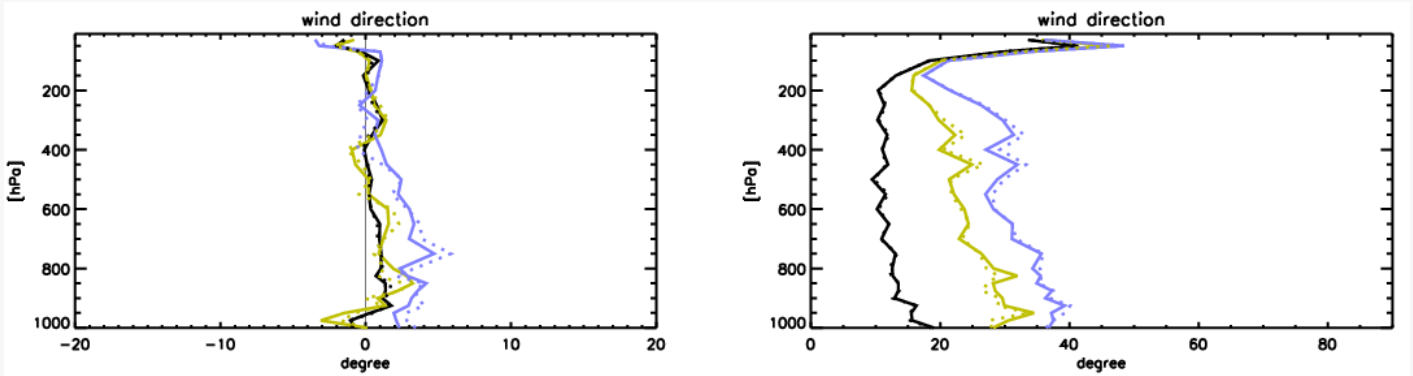

time period 10 days

dotted: reference, solid: experiment

# upper air verification – Exp 7063 – wind direction






time period 10 days

dotted: reference, solid: experiment

# Outline

# Summary



## positive

- it works and gives positive impact results
- upper air verification: enhancements especially in the std. dev. partly also in bias
- previous experiments with more interesting weather showed stronger impact

# Summary



## further investigation

- **optimize channel selection** with regard to the treated vertical COSMO region
- implementation of the new regression coefficients of rttov for IASI.

# outlook



## outlook

- combination with amsu-a and mhs
- **tuning of the data thinning algorithm** optimize with respect to a single-instrument and an inter-instrument thinning, respectively.
- **tuning of nudging coefficients** – in cooperation with Christoph Schraff

# ThanX!

for your attention!