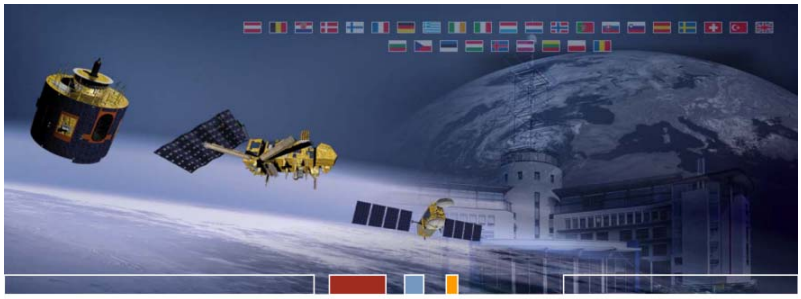

Generation and assimilation of IASI level 2 products

Peter Schlüssel, Thomas August, Arlindo Arriaga, Tim Hultberg,
Nikita Pougatchev, Peter Bauer, Gábor Radnóti

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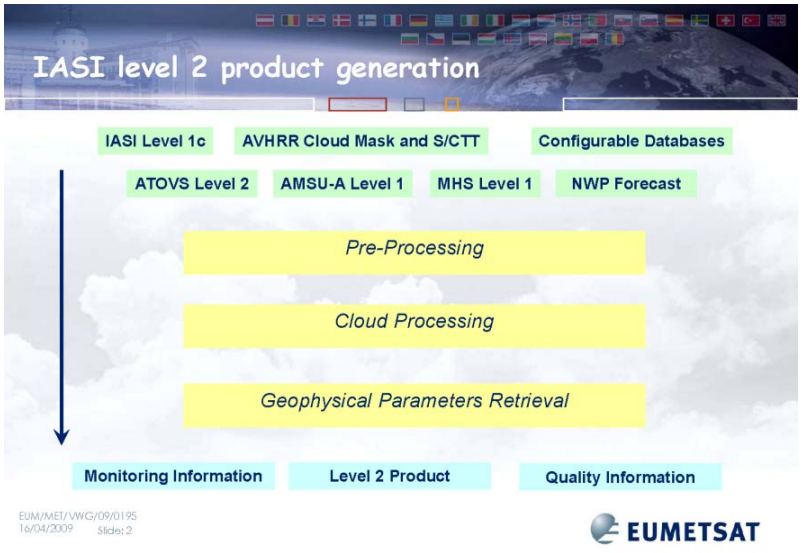

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- For a best use of IASI measurements the level 2 processing combines IASI with concurrent measurements of AVHRR and AMSU-A to detect clouds and to derive cloud parameters
- IASI stand-alone processing is used for geophysical parameters retrieval
- Inclusion of NWP forecast
  - Surface pressure as reference for the profiles to be retrieved
  - Surface wind speed over sea for the calculation of surface emissivity
  - Temperature and water-vapour profiles for cloud detection and CO_2-slicing
  - **No conditioning of profile retrieval with NWP forecast**

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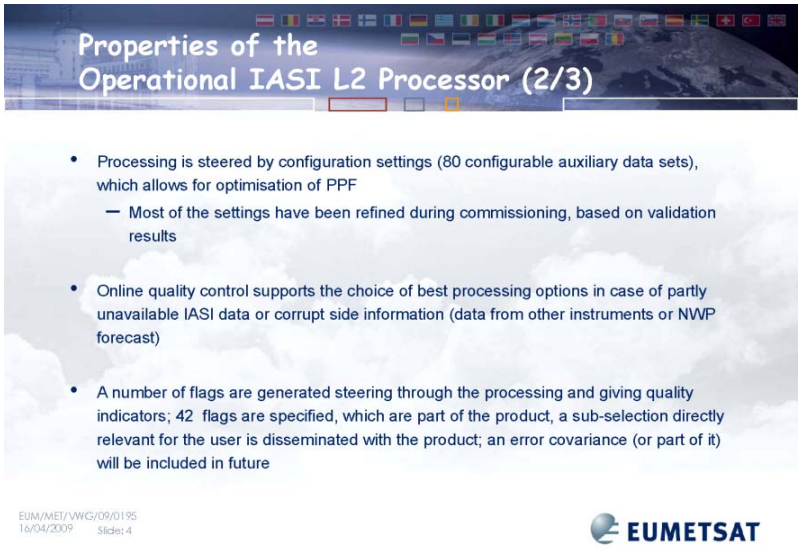
Properties of the
Operational IASI L2 Processor (2/3)
• Processing is steered by configuration settings (80 configurable auxiliary data sets), which allows for optimisation of PPF
– Most of the settings have been refined during commissioning, based on validation results
• Online quality control supports the choice of best processing options in case of partly unavailable IASI data or corrupt side information (data from other instruments or NWP forecast)
• A number of flags are generated steering through the processing and giving quality indicators; 42 flags are specified, which are part of the product, a sub-selection directly relevant for the user is disseminated with the product; an error covariance (or part of it) will be included in future
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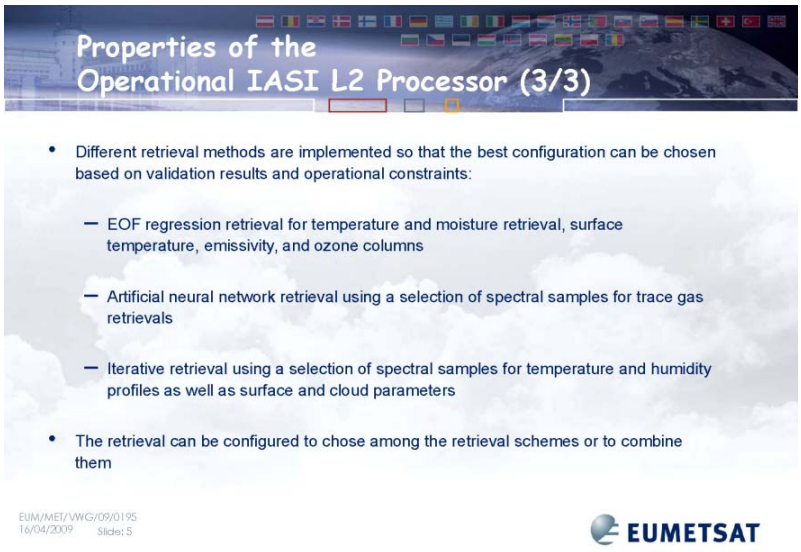
Properties of the
Operational IASI L2 Processor (3/3)
• Different retrieval methods are implemented so that the best configuration can be chosen based on validation results and operational constraints:
– EOF regression retrieval for temperature and moisture retrieval, surface temperature, emissivity, and ozone columns
– Artificial neural network retrieval using a selection of spectral samples for trace gas retrievals
– Iterative retrieval using a selection of spectral samples for temperature and humidity profiles as well as surface and cloud parameters
• The retrieval can be configured to chose among the retrieval schemes or to combine them
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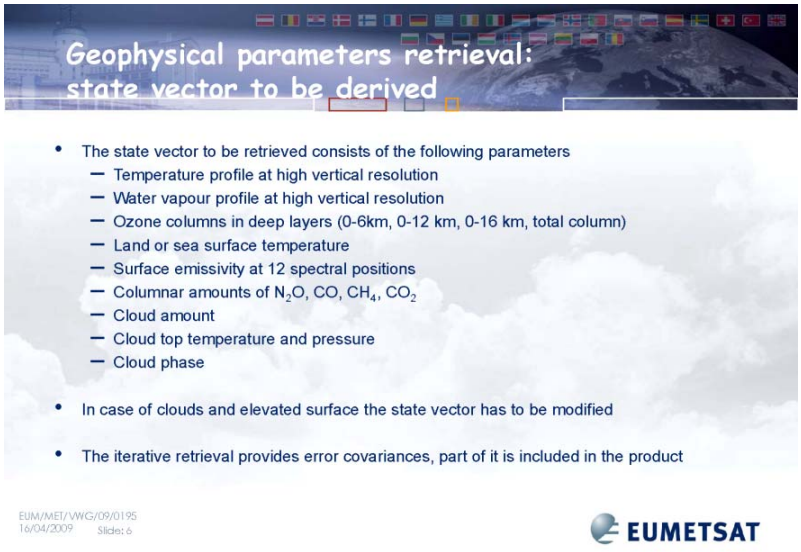
Geophysical parameters retrieval:
state vector to be derived
• The state vector to be retrieved consists of the following parameters
– Temperature profile at high vertical resolution
– Water vapour profile at high vertical resolution
– Ozone columns in deep layers (0-6km, 0-12 km, 0-16 km, total column)
– Land or sea surface temperature
– Surface emissivity at 12 spectral positions
– Columnar amounts of N_2O, CO, CH_4, CO_2
– Cloud amount
– Cloud top temperature and pressure
– Cloud phase
• In case of clouds and elevated surface the state vector has to be modified
• The iterative retrieval provides error covariances, part of it is included in the product
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Preprocessing

- Validation of incoming data
  - Examination of quality flags in IASI L1C, AMSU-A, MHS, AVHRR Scenes Analysis
  - Check of radiances against valid bounds
  - Check of geolocation against valid bounds
  - Check of NWP forecast against valid bounds and for completeness
- Mapping of AMSU-A, MHS, AVHRR, and NWP to IASI IFOV
- Extraction of land-sea mask and surface topography and mapping to IASI IFOV
- Bias correction of IASI radiances
- Correction for ISRF shift in case of inhomogeneous scenes
- Calculation of IPSF-weighted fractional cloud cover from AVHRR
- Calculation of IPSF-weighted surface and cloud top temperatures from AVHRR

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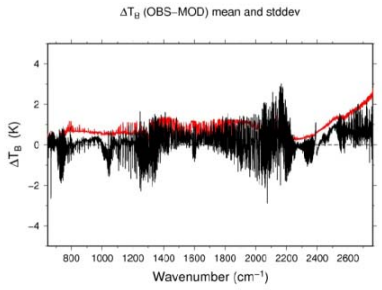
Correction of systematic errors



- Retrieval, CO_2-slicing, and cloud detection use radiative transfer calculations as basis
- Prerequisite for the functionality of the retrieval is a good representativity of the measurements by simulated radiances
- Systematic errors:
  - Approxmations necessary for fast calculations
  - Insufficient knowledge of spectroscopic data
  - Erroneous input data
- Systematic fit of models to IASI measurements

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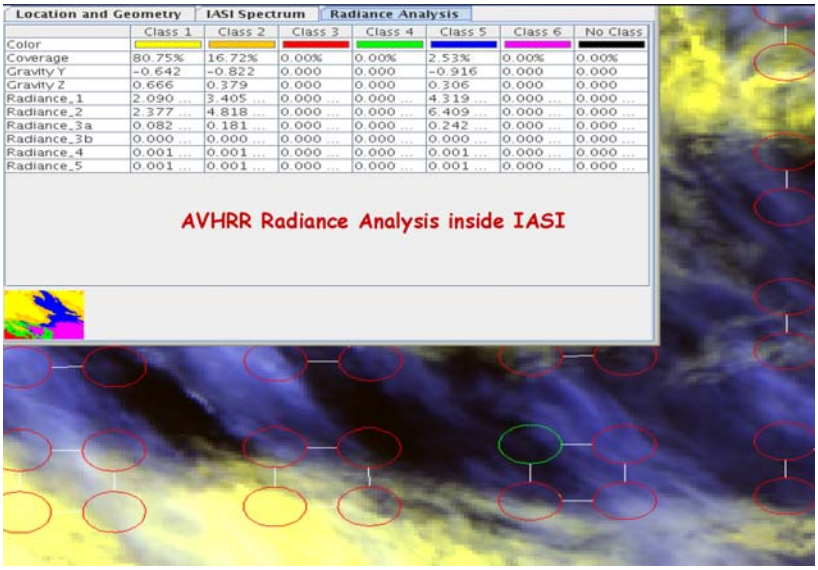
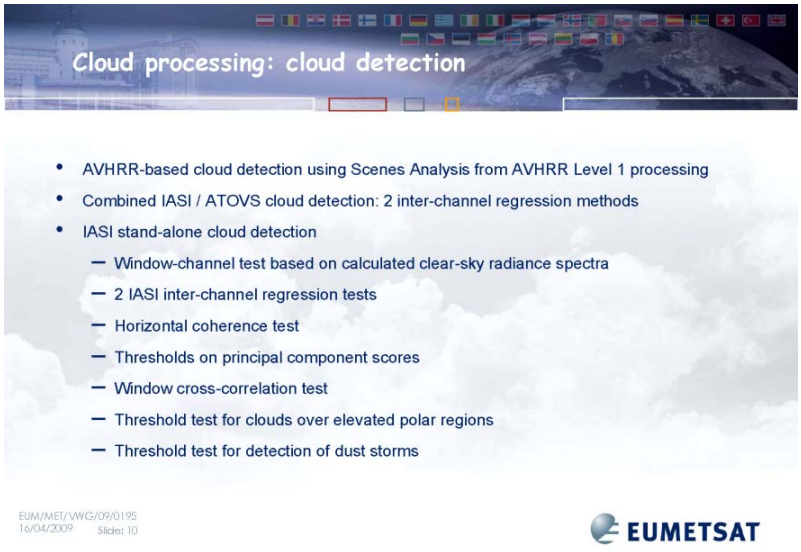


	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	No Class
Color							
Coverage	80.75%	16.72%	0.00%	0.00%	2.53%	0.00%	0.00%
Gravity Y	-0.642	-0.822	0.000	0.000	-0.916	0.000	0.000
Gravity Z	0.666	0.379	0.000	0.000	0.306	0.000	0.000
Radiance_1	2.090	3.405	0.000	0.000	4.319	0.000	0.000
Radiance_2	2.377	4.818	0.000	0.000	6.409	0.000	0.000
Radiance_3a	0.082	0.181	0.000	0.000	0.242	0.000	0.000
Radiance_3b	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Radiance_4	0.001	0.001	0.000	0.000	0.001	0.000	0.000
Radiance_5	0.001	0.001	0.000	0.000	0.001	0.000	0.000


Cloud processing: cloud detection
AVHRR-based cloud detection using Scenes Analysis from AVHRR Level 1 processing
Combined IASI / ATOVS cloud detection: 2 inter-channel regression methods
IASI stand-alone cloud detection
Window-channel test based on calculated clear-sky radiance spectra
2 IASI inter-channel regression tests
Horizontal coherence test
Thresholds on principal component scores
Window cross-correlation test
Threshold test for clouds over elevated polar regions
Threshold test for detection of dust storms
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Cloud processing: cloud parameters retrieval
Cloud fraction (CO_2-Slicing)
Cloud top pressure and temperature (CO_2-Slicing)
Cloud phase: examination of slope of window spectra
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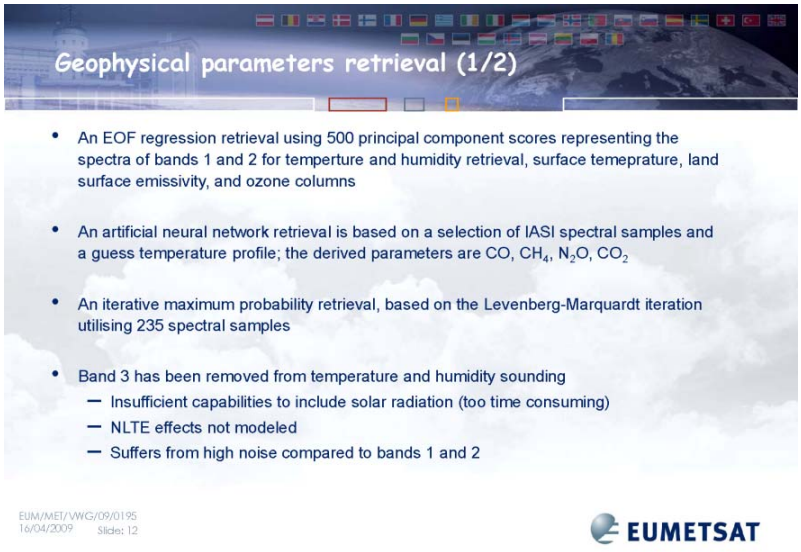
Geophysical parameters retrieval (1/2)
An EOF regression retrieval using 500 principal component scores representing the spectra of bands 1 and 2 for temperture and humidity retrieval, surface temeprature, land surface emissivity, and ozone columns
An artificial neural network retrieval is based on a selection of IASI spectral samples and a guess temperature profile; the derived parameters are CO, CH_4, N_2O, CO_2
An iterative maximum probability retrieval, based on the Levenberg-Marquardt iteration utilising 235 spectral samples
Band 3 has been removed from temperature and humidity sounding
Insufficient capabilities to include solar radiation (too time consuming)
NLTE effects not modeled
Suffers from high noise compared to bands 1 and 2
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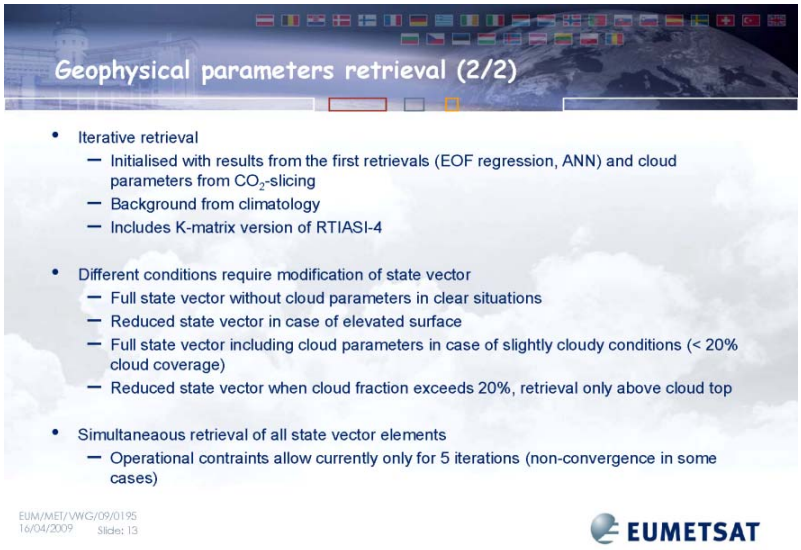
Geophysical parameters retrieval (2/2)
• Iterative retrieval
– Initialised with results from the first retrievals (EOF regression, ANN) and cloud parameters from CO_2-slicing
– Background from climatology
– Includes K-matrix version of RTIASI-4
• Different conditions require modification of state vector
– Full state vector without cloud parameters in clear situations
– Reduced state vector in case of elevated surface
– Full state vector including cloud parameters in case of slightly cloudy conditions (< 20% cloud coverage)
– Reduced state vector when cloud fraction exceeds 20%, retrieval only above cloud top
• Simultaneaous retrieval of all state vector elements
– Operational contraints allow currently only for 5 iterations (non-convergence in some cases)
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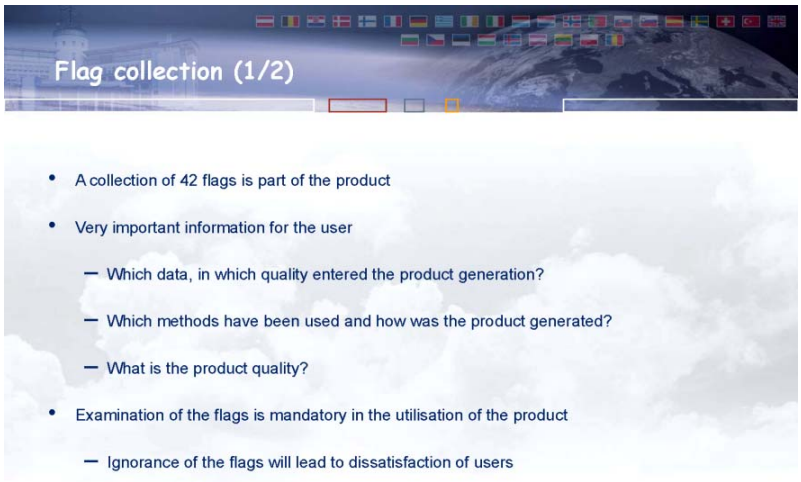
Flag collection (1/2)
• A collection of 42 flags is part of the product
• Very important information for the user
– Which data, in which quality entered the product generation?
– Which methods have been used and how was the product generated?
– What is the product quality?
• Examination of the flags is mandatory in the utilisation of the product
– Ignorance of the flags will lead to dissatisfaction of users
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Flag collection (2/2)
• Validity and quality of the input data: 13 flags
• Information on cloud processing: 9 flags
• Information on day/night, sun-glint, land/sea: 3 flags
• Retrieval choice and settings: 8 flags
• Retrieval quality: 9 flags
• Definition of flags is given in
– Annex D of the IASI L2 Product Generation Specification
– Section 4.3.3 of the IASI L2 Products Guide
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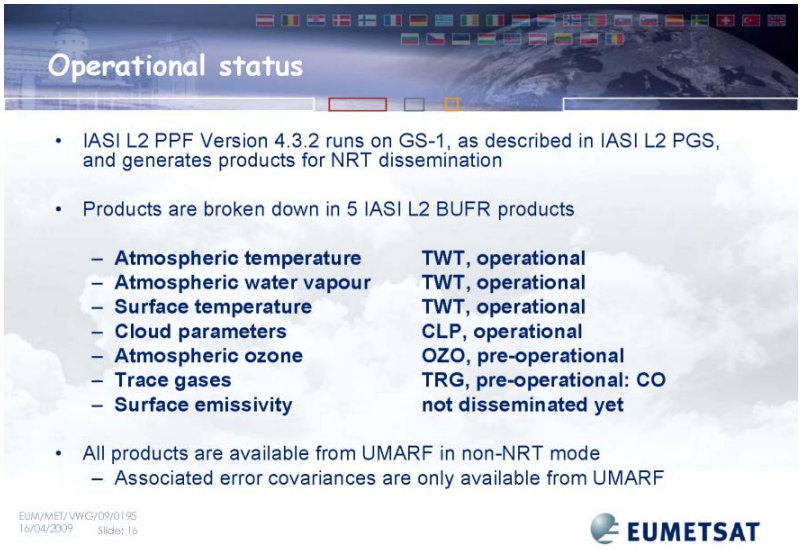
Operational status
• IASI L2 PPF Version 4.3.2 runs on GS-1, as described in IASI L2 PGS, and generates products for NRT dissemination
• Products are broken down in 5 IASI L2 BUFR products
– Atmospheric temperature TWT, operational
– Atmospheric water vapour TWT, operational
– Surface temperature TWT, operational
– Cloud parameters CLP, operational
– Atmospheric ozone OZO, pre-operational
– Trace gases TRG, pre-operational: CO
– Surface emissivity not disseminated yet
• All products are available from UMARF in non-NRT mode
– Associated error covariances are only available from UMARF
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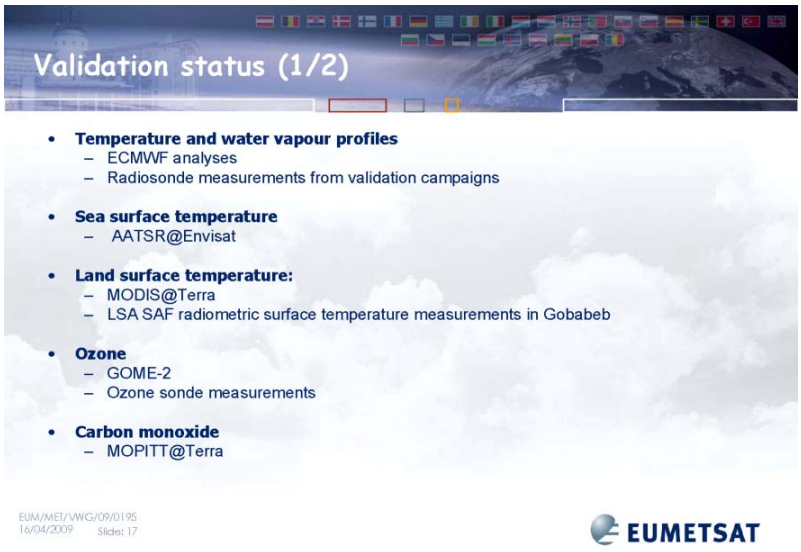
Validation status (1/2)
• Temperature and water vapour profiles
– ECMWF analyses
– Radiosonde measurements from validation campaigns
• Sea surface temperature
– AATSR@Envisat
• Land surface temperature:
– MODIS@Terra
– LSA SAF radiometric surface temperature measurements in Gobabeb
• Ozone
– GOME-2
– Ozone sonde measurements
• Carbon monoxide
– MOPITT@Terra
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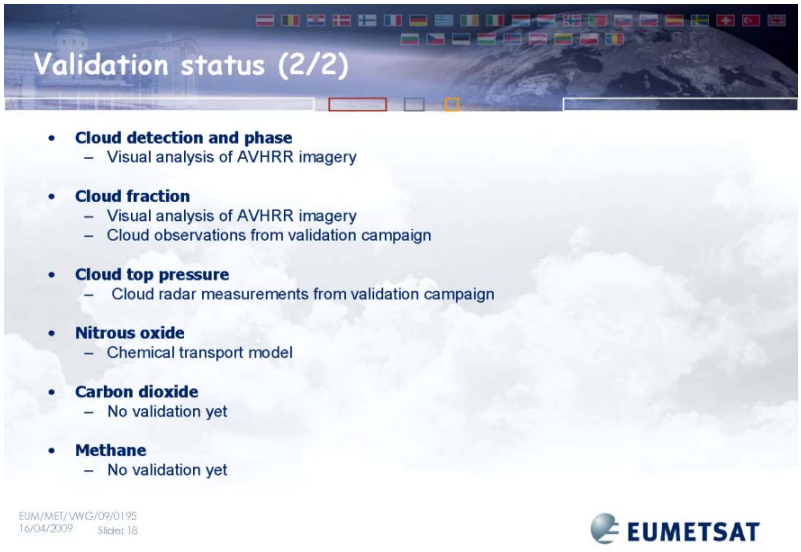
Validation status (2/2)
• Cloud detection and phase
– Visual analysis of AVHRR imagery
• Cloud fraction
– Visual analysis of AVHRR imagery
– Cloud observations from validation campaign
• Cloud top pressure
– Cloud radar measurements from validation campaign
• Nitrous oxide
– Chemical transport model
• Carbon dioxide
– No validation yet
• Methane
– No validation yet
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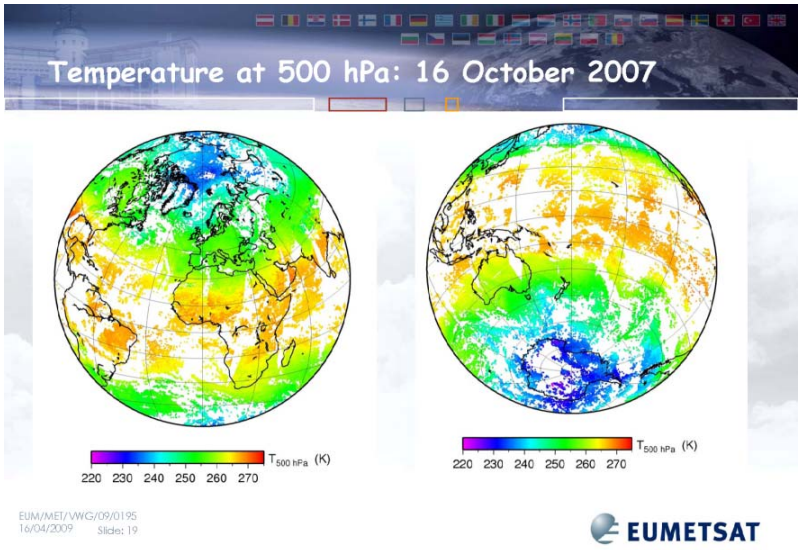
Temperature at 500 hPa: 16 October 2007
$T_{500\ hPa}$ (K)
220 230 240 250 260 270
$T_{500\ hPa}$ (K)
220 230 240 250 260 270
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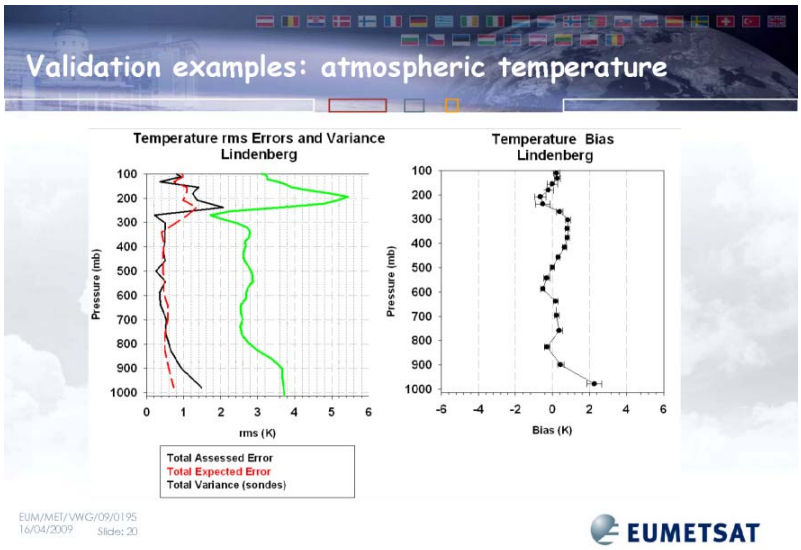
Validation examples: atmospheric temperature
Temperature rms Errors and Variance
Lindenberg
Pressure (mb)
100 200 300 400 500 600 700 800 900 1000
0 1 2 3 4 5 6
rms (K)
Total Assessed Error
Total Expected Error
Total Variance (sondes)
Temperature Bias
Lindenberg
Pressure (mb)
100 200 300 400 500 600 700 800 900 1000
-5 -4 -2 0 2 4 6
Bias (K)
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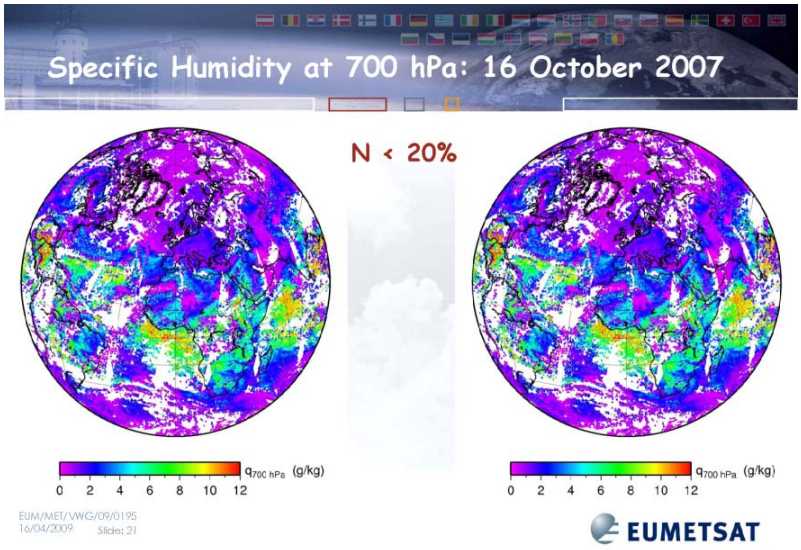
Specific Humidity at 700 hPa: 16 October 2007
N < 20%
$q_{700\ hPa}$ (g/kg)
0 2 4 6 8 10 12
$q_{700\ hPa}$ (g/kg)
0 2 4 6 8 10 12
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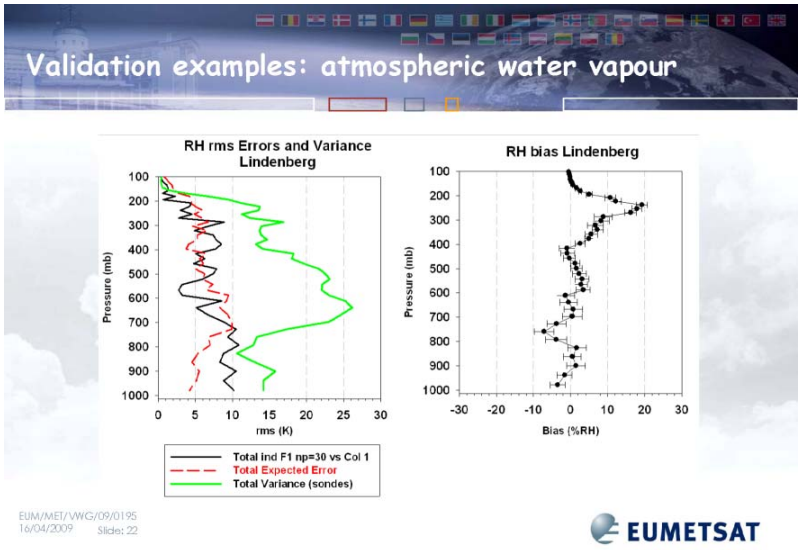
Validation examples: atmospheric water vapour
RH rms Errors and Variance
Lindenberg
Pressure (mb)
rms (K)
RH bias Lindenberg
Bias (%RH)
Total ind F1 np=30 vs Col 1
Total Expected Error
Total Variance (sondes)
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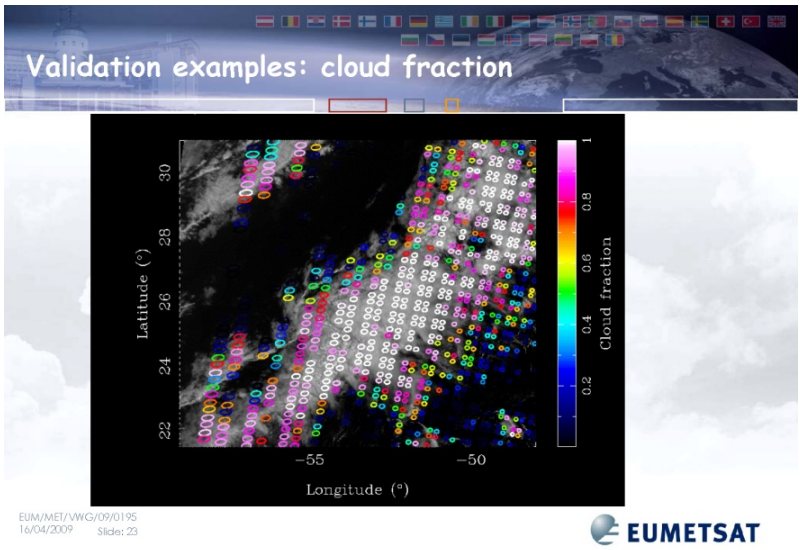
Validation examples: cloud fraction
Latitude (°)
Longitude (°)
Cloud fraction
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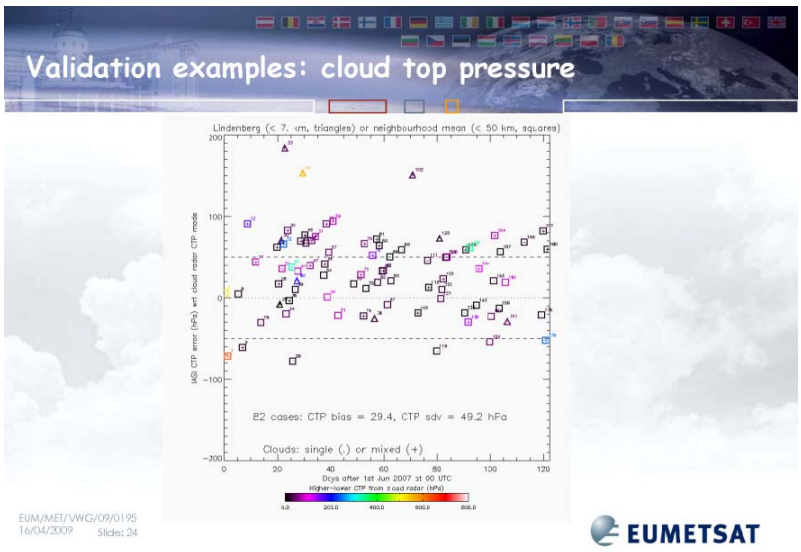
Validation examples: cloud top pressure
Lindenberg (< 7. km, triangles) or neighbourhood mean (< 50 km, squares)
82 cases: CTP bias = 29.4, CTP sdv = 49.2 hPa
Clouds: single (.) or mixed (+)
Days after 1st Jun 2007 at 00 UTC
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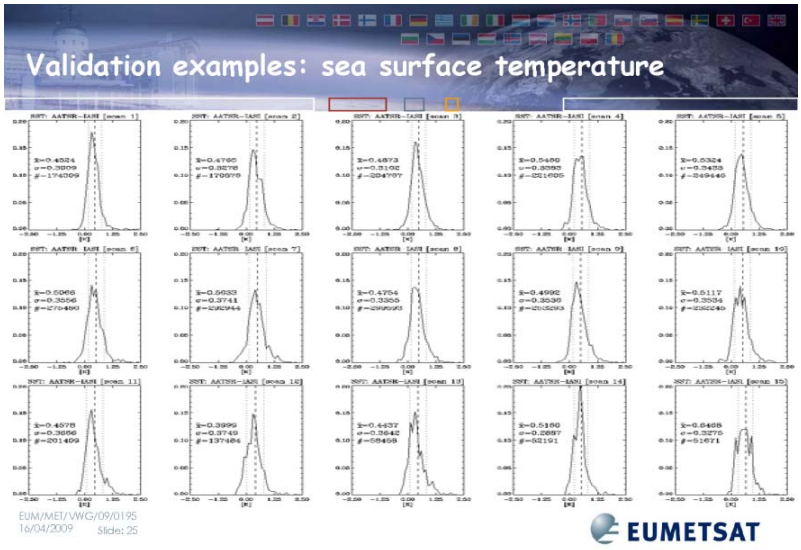
Validation examples: sea surface temperature
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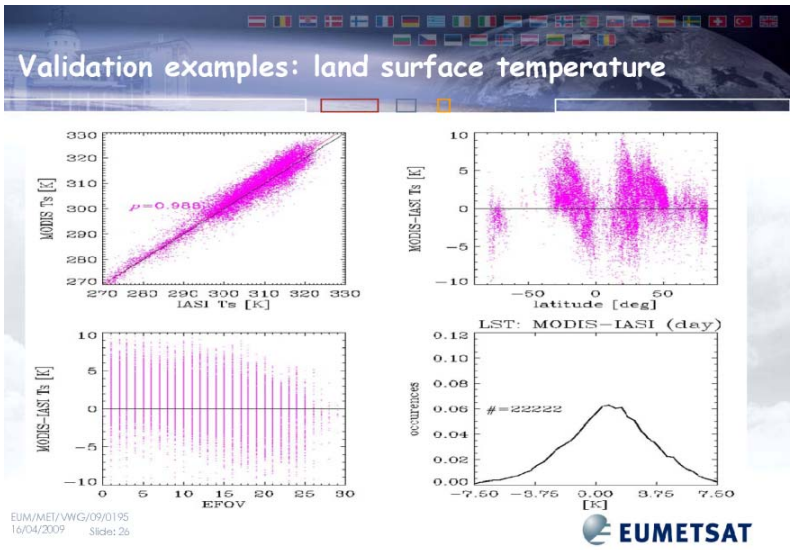
Validation examples: land surface temperature
MODIS Ts [K]
IASI Ts [K]
ρ=0.986
MODIS-IASI Ts [K]
latitude [deg]
EFOV
LST: MODIS−IASI (day)
occurrences
#=222222
[K]
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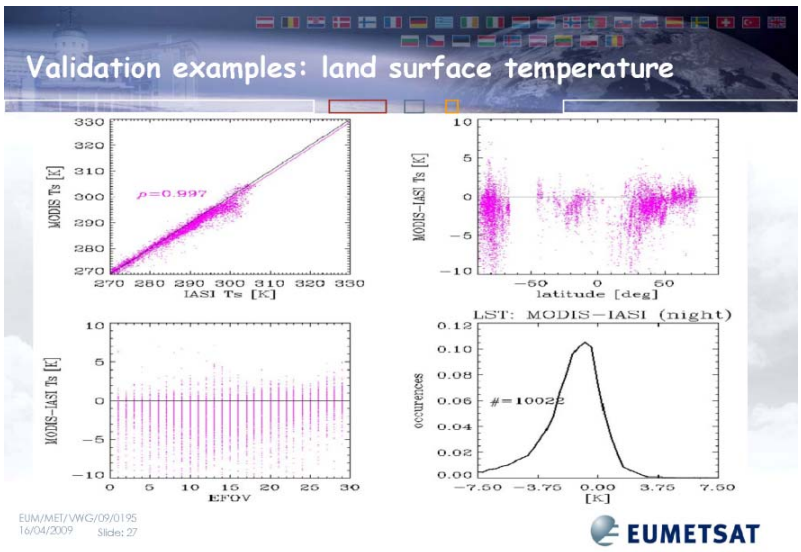
Validation examples: land surface temperature
MODIS Ts [K]
IASI Ts [K]
ρ=0.997
MODIS-IASI Ts [K]
latitude [deg]
EFOV
LST: MODIS−IASI (night)
occurrences
#=10022
[K]
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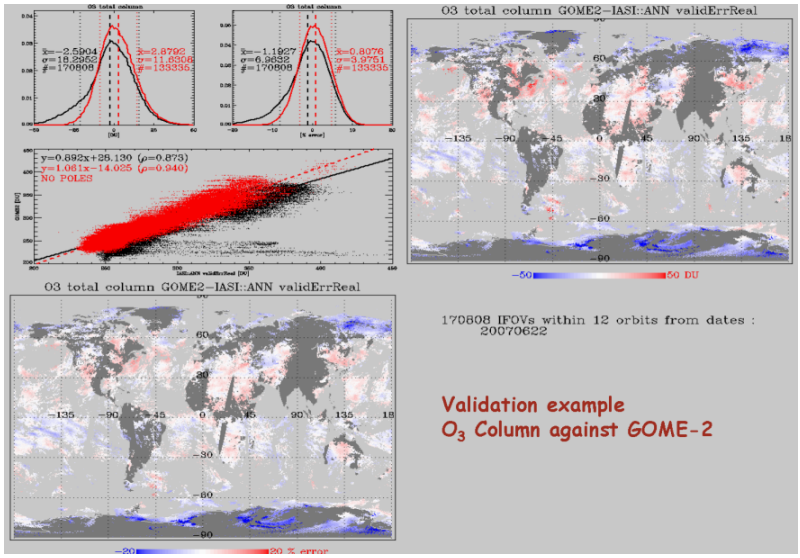
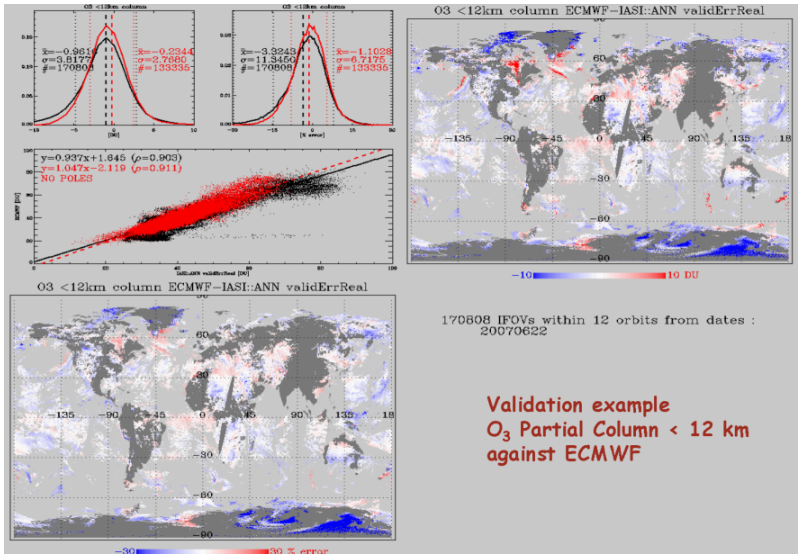
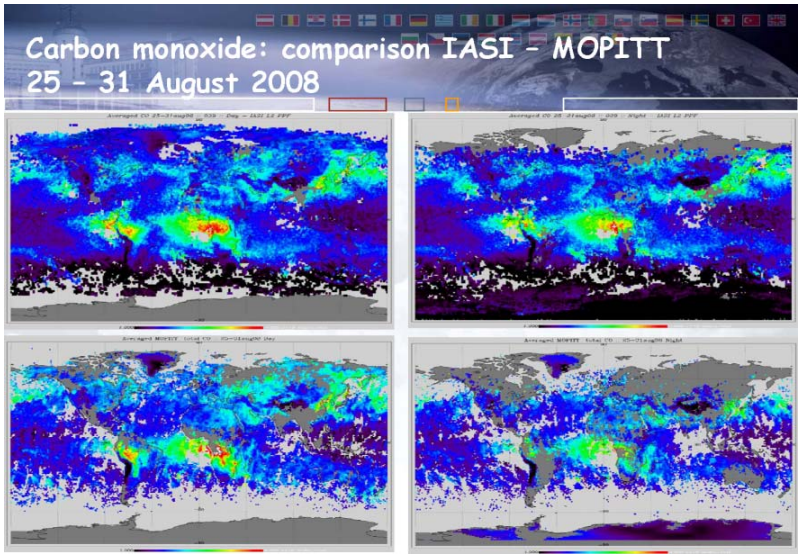
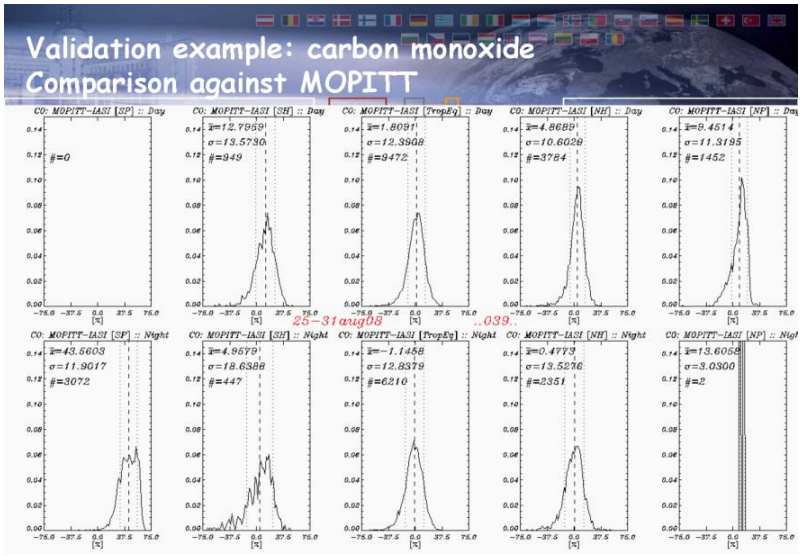

O3 total column
O3 total column
y=0.892x+26.190 (ρ=0.873)
y=1.061x-14.025 (ρ=0.940)
NO POLES
O3 total column GOME2-IASI::ANN validErrReal
O3 total column GOME2-IASI::ANN validErrReal
-50
50 DU
-20
20 % error
170808 IFOVs within 12 orbits from dates : 20070622
Validation example
O3 Column against GOME-2


O3 <12km column
O3 <12km column
y=0.937x+1.845 (ρ=0.903)
y=1.047x-2.119 (ρ=0.911)
NO POLES
O3 <12km column ECMWF-IASI::ANN validErrReal
O3 <12km column ECMWF-IASI::ANN validErrReal
-10
10 DU
-30
30 % error
170808 IFOVs within 12 orbits from dates : 20070622
Validation example
O3 Partial Column < 12 km
against ECMWF


Carbon monoxide: comparison IASI - MOPITT
25 - 31 August 2008



Evaluation of the impact of IASI level-2 products (temperature and humidity retrievals) and comparison to level-1 radiance assimilation

- Estimation of level-2 product error covariance statistics from product-model departures
- Bias-correction defined on 10-degree latitude/longitude grid.
- Baseline (conventional + AMV)
- Study period: July-August 2008

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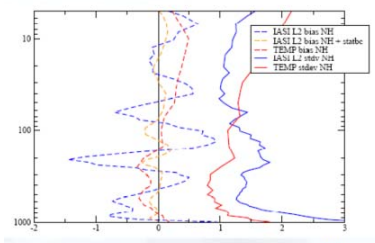
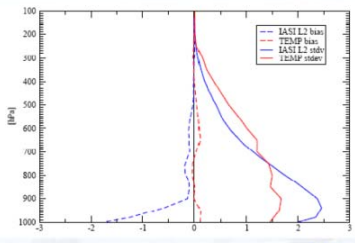
Temperature biases and error stdev-s



Specific humidity biases and error stdev-s



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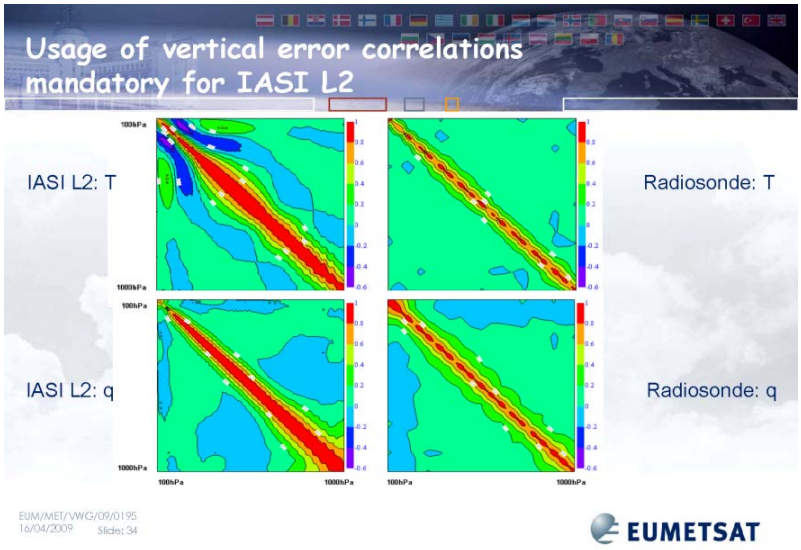
Usage of vertical error correlations mandatory for IASI L2
IASI L2: T
Radiosonde: T
IASI L2: q
Radiosonde: q
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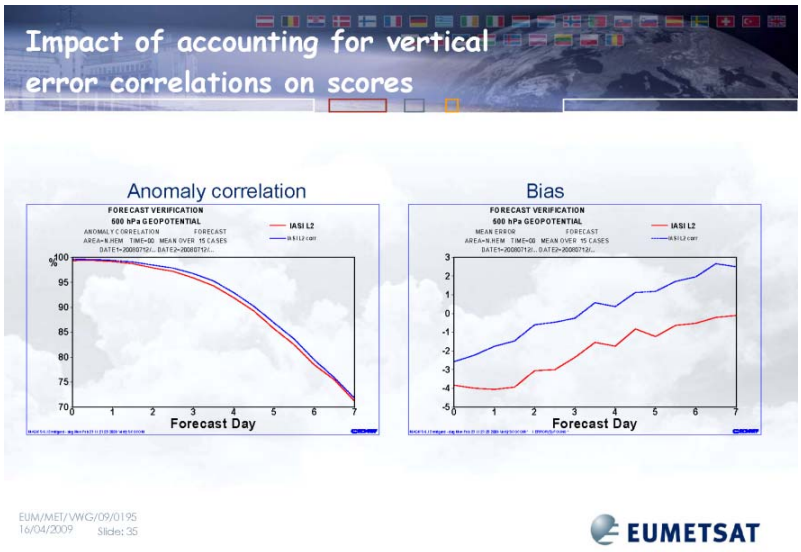
EUMETSAT


Impact of accounting for vertical error correlations on scores
Anomaly correlation
Bias
FORECAST VERIFICATION
500 hPa GEOPOTENTIAL
IASI L2
Forecast Day
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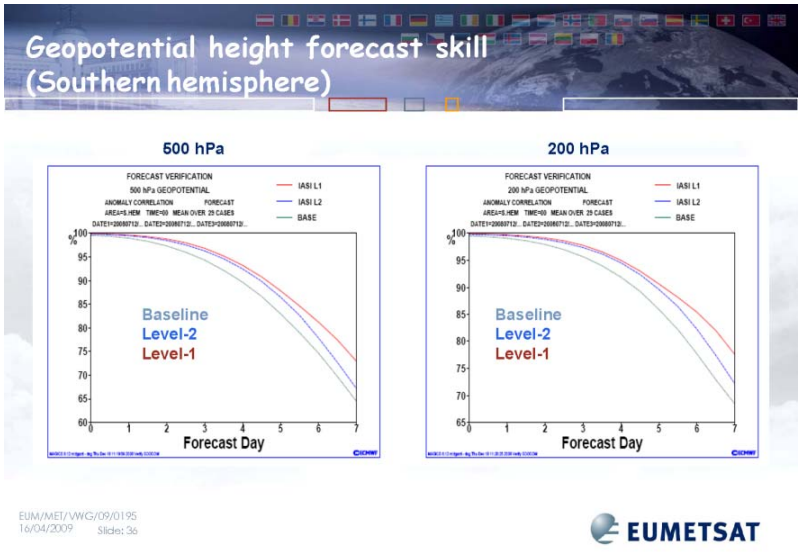
EUMETSAT


Geopotential height forecast skill (Southern hemisphere)
500 hPa
200 hPa
FORECAST VERIFICATION
IASI L1
IASI L2
BASE
Baseline
Level-2
Level-1
Forecast Day
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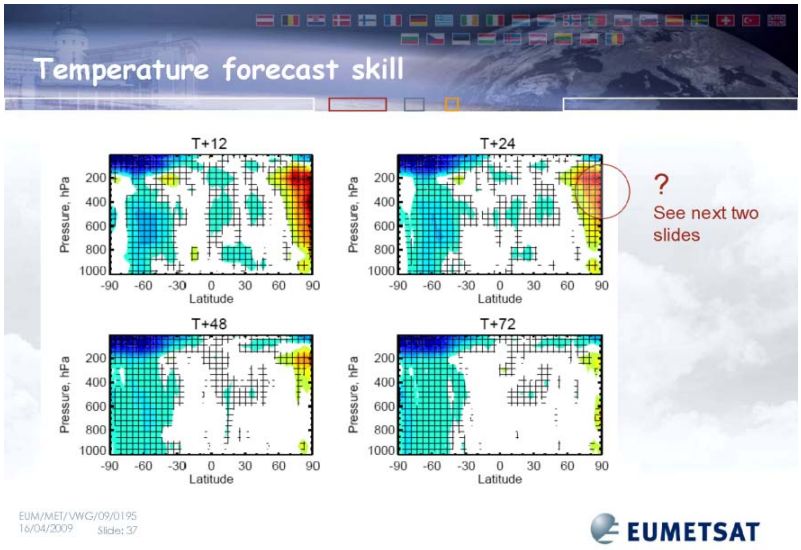
EUMETSAT


Temperature forecast skill
T+12
T+24
T+48
T+72
Pressure, hPa
Latitude
?
See next two slides
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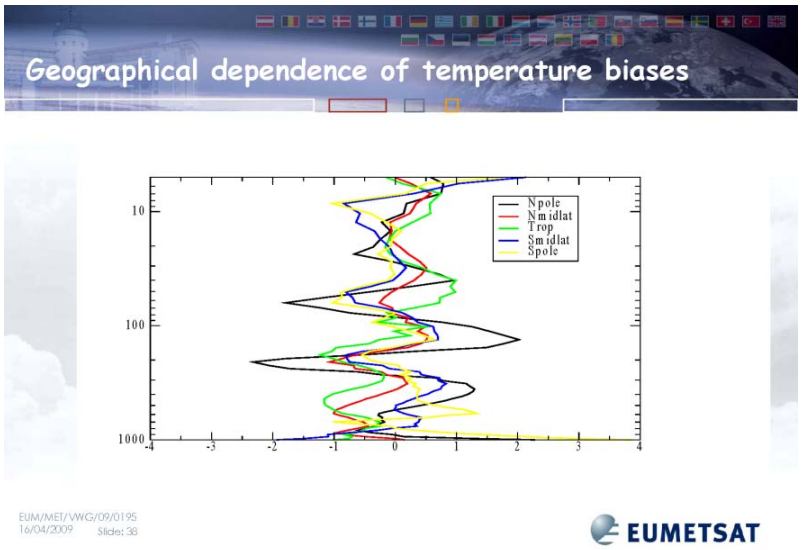
Geographical dependence of temperature biases
Npole
Nmidlat
Trop
Smidlat
Spole
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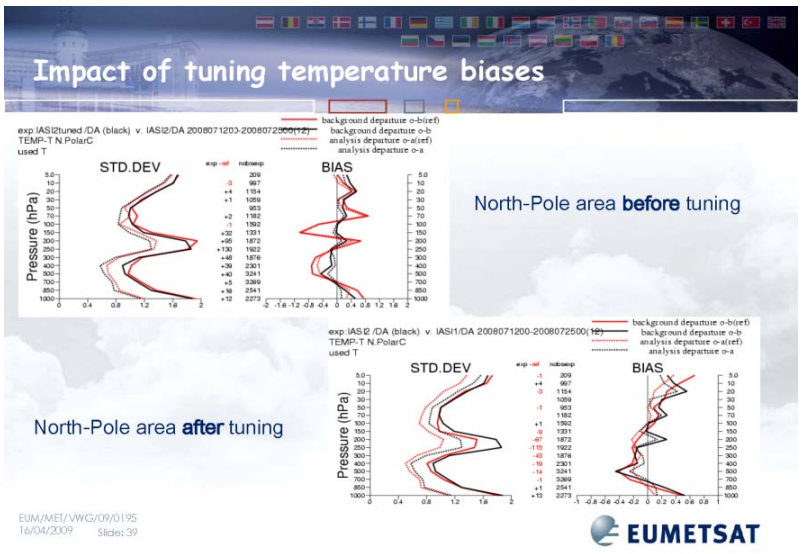
Impact of tuning temperature biases
STD.DEV
BIAS
Pressure (hPa)
North-Pole area before tuning
North-Pole area after tuning
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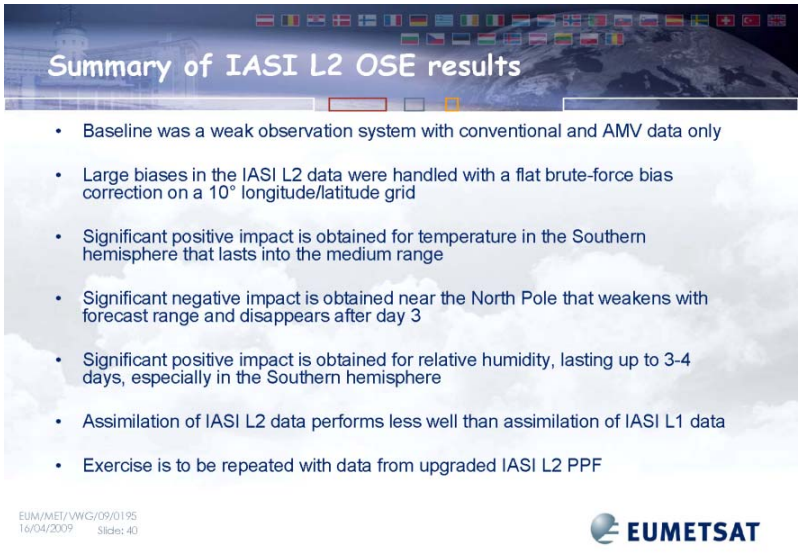
Summary of IASI L2 OSE results
• Baseline was a weak observation system with conventional and AMV data only
• Large biases in the IASI L2 data were handled with a flat brute-force bias correction on a 10° longitude/latitude grid
• Significant positive impact is obtained for temperature in the Southern hemisphere that lasts into the medium range
• Significant negative impact is obtained near the North Pole that weakens with forecast range and disappears after day 3
• Significant positive impact is obtained for relative humidity, lasting up to 3-4 days, especially in the Southern hemisphere
• Assimilation of IASI L2 data performs less well than assimilation of IASI L1 data
• Exercise is to be repeated with data from upgraded IASI L2 PPF
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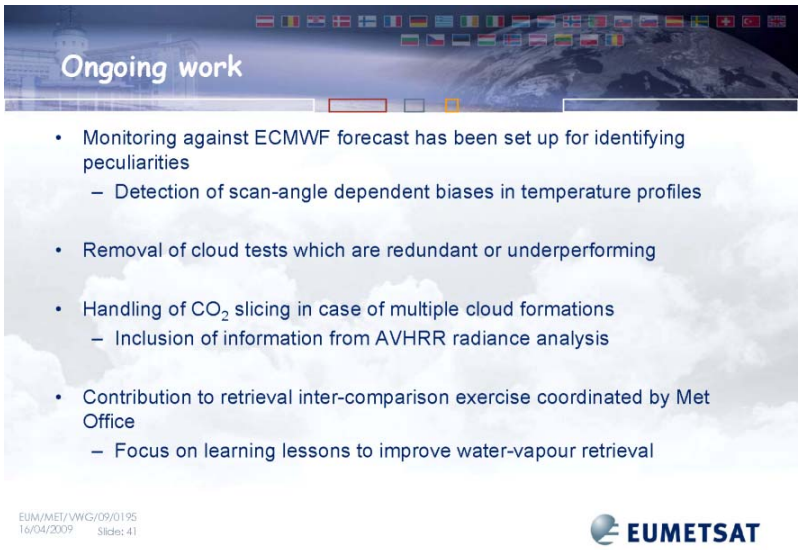
Ongoing work
• Monitoring against ECMWF forecast has been set up for identifying peculiarities
– Detection of scan-angle dependent biases in temperature profiles
• Removal of cloud tests which are redundant or underperforming
• Handling of CO_2 slicing in case of multiple cloud formations
– Inclusion of information from AVHRR radiance analysis
• Contribution to retrieval inter-comparison exercise coordinated by Met Office
– Focus on learning lessons to improve water-vapour retrieval
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