Introduction to the IASI-NG principal component and L2 operational processor

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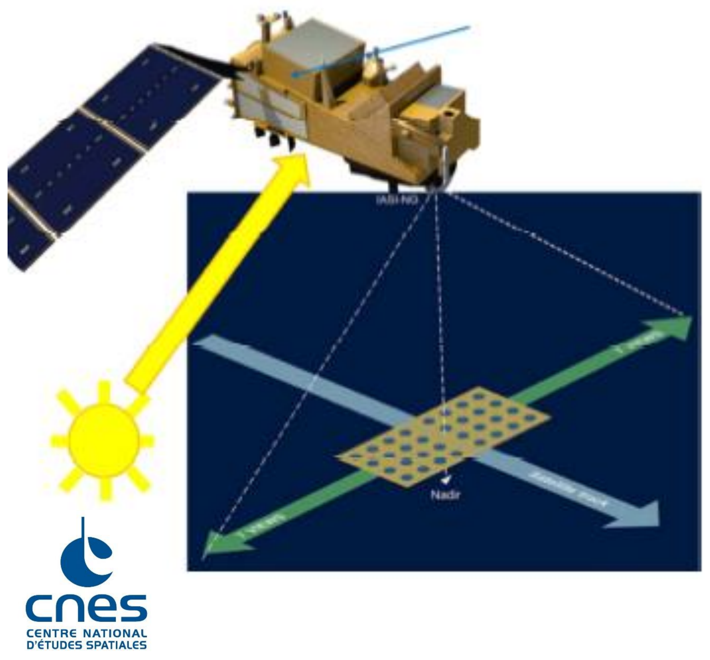
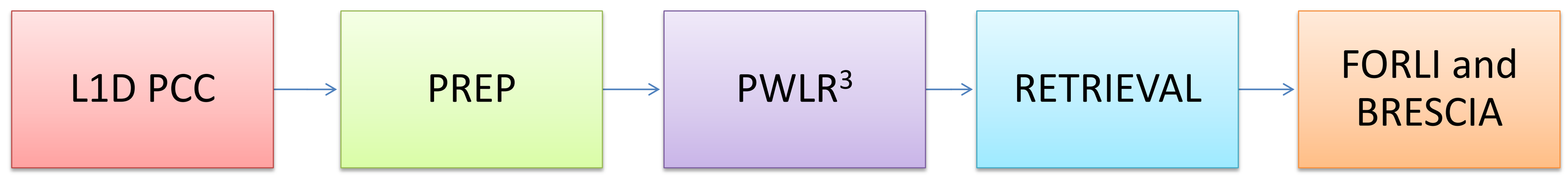


The EPS-SG, EUMETSAT Polar System Second Generation, will provide continuity of observations after EPS in the 2020-2040 time frame. It is Europe's contribution to the future Joint Polar System (JPS), which is agreed to be established together with the National Oceanic and Atmospheric Administration (NOAA) of the United States, following on from the Initial Joint Polar System (IJPS).

The **IASI-NG**, Infrared Atmospheric Sounding Interferometer - New Generation, is the successor instrument of the IASI instruments flown on the EPS/Metop satellites. It will provide hyper-spectral infrared soundings of temperature, water vapour, and trace gases with a spectral resolution of 0.25 cm-1 (twice the spectral resolution of IASI) within the spectral range from 645 to 2760 cm-1. The noise figures of the IASI-NG are half the ones of IASI. As for IASI, the footprint at Nadir is about 12km and the observations will be performed at an average spatial sampling distance of 25 km. Similarly as in EPS, IASI-NG will be accompanied by a microwave sounder (MWS) and a high spatial resolution radiometer (METimage).

The IASI-NG L2 processor has a direct heritage from the operational IASI L2 v6 processor, including BRESCIA and FORLI retrieval functions to generate the EUMETSAT AC SAF products.



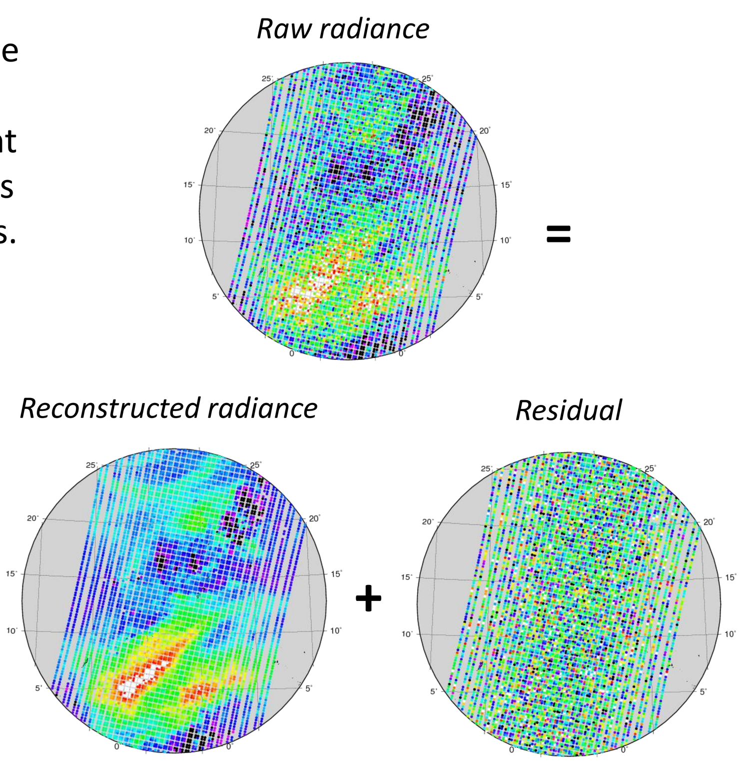
L1D PCC

IASI-NG measurements consist of signal and noise. The IASI-NG L1C measurements are represented as radiances at 16921 wave-numbers, which are spectrally highly correlated. This correlation comes from the signal itself as the noise is spectrally uncorrelated. This redundancy means that the effective rank of the subspace spanned by the signal within the measurements is much lower than the number of channels or in other words, the number of independent pieces of information within the IASI measurements is much smaller than 16921. These are the principal components scores (PCS) computed with the leading eigenvectors representing the variance and covariance of the measurements. Reconstructed radiances can be computed from the PCS, effectively projecting the measurements onto the signal subspace with the result that the signal is preserved while a major part of the noise is suppressed. The difference between the original and the reconstructed radiances is called the reconstruction **residuals** and essentially contain random instrument noise. The residuals are used to compute reconstruction scores. If the reconstruction score for a given spectrum is too high (i.e. exceeds a configurable threshold), there is suspicion that some atmospheric signal could not be represented by the selected leading principal components. An **outlier** flag can be raised for the corresponding pixel. The threshold for the identification of the outliers is different for each detector and depends linearly on the sum of the radiances, to account for the photonic noise.

$$p = E^T N^{-1}(y - \bar{y}) \quad \text{PC scores}$$

$$\tilde{y} = NEp + \bar{y} \quad \text{Reconstructed radiance}$$

E is the eigenvectors matrix, N is the noise normalization matrix and $\bar{y}$ is the mean radiances.



(IASI radiance @1772.75 cm-1 20130717)

Generated products L1D

Product name	Content	Purpose
PCC	IASI-NG Principal Components	NRT dissemination Archive
Score	Reconstruction score	NRT dissemination Archive
Outliers	Identification of the outliers	NRT dissemination Archive
Residuals	For the outliers, the quantised trailing PC scores	NRT dissemination Archive

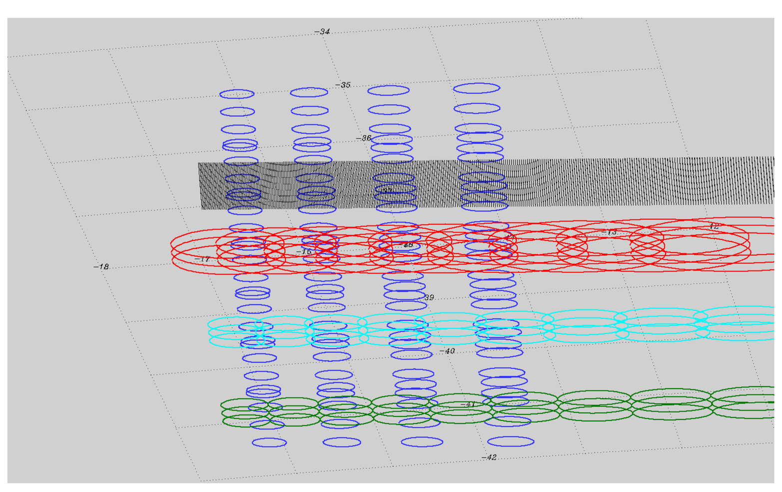
Generated products L2

Product name	Content	Purpose
TWV	Temperature profile	NRT dissemination Archive
TWV	Water vapour profile	NRT dissemination Archive
TWV	Water vapour total column from IAS and MWS	NRT dissemination
SFC	Surface temperature (Sea)	NRT dissemination Archive
SFC	Surface temperature (Land, Ice)	NRT dissemination Archive
SFC	Land and ice surface emissivity	NRT dissemination Archive
CLD	Cloud detection and fractional coverage from VII and IAS	NRT dissemination Archive
CLD	Cloud top phase	NRT dissemination Archive
CLD	Cloud top height/pressure	NRT dissemination Archive
CLD	Cloud drop effective radius at cloud top (by product)	NRT dissemination Archive
CO	Carbon monoxide profile	NRT dissemination Archive
CO	Carbon monoxide partial column	NRT dissemination Archive
GHG	Methane partial column	NRT dissemination Archive
NAC	Nitric acid partial column	NRT dissemination Archive
GHG	Nitrous oxide total column	NRT dissemination Archive
O3	Ozone profile	NRT dissemination Archive
O3	Ozone total column	NRT dissemination Archive
SO2	Sulphur dioxide total column	NRT dissemination Archive

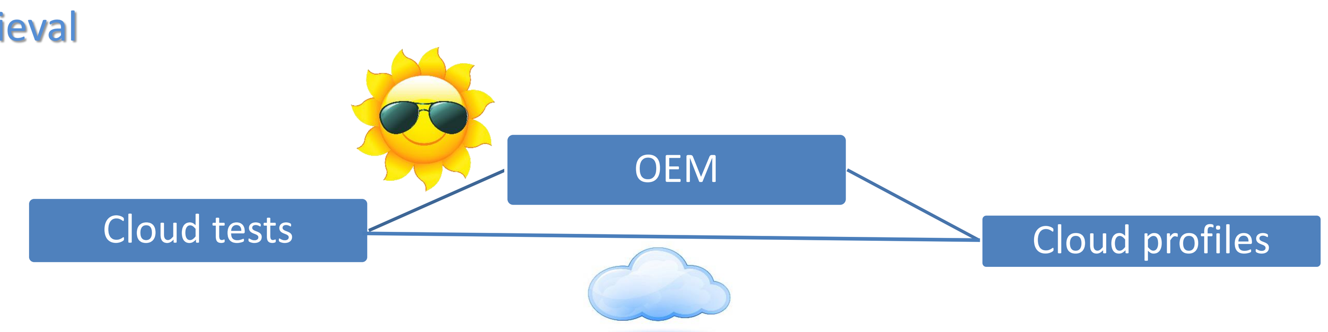
PREP

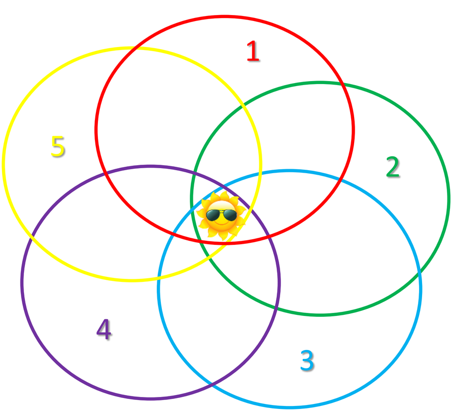
The purpose of the input data preparation is to gather IASI-NG L1D measurements and relevant collocated data in a common file, which serves as input for the further sub-functions. The collocated data includes METimage cluster radiance mean and standard deviations (already included in the IASI-NG L1C files), MWS radiances, ECMWF forecasts data as well as land fraction and surface elevation mean and standard deviation within each IASI-NG field of view.

IASI-NG, MWS and METimage footprints (swath edge)



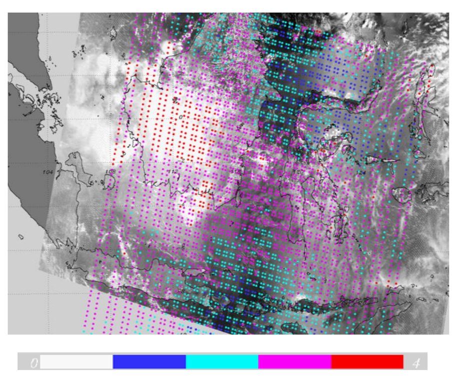
Retrieval





Cloud Tests

1. METimage Test
2. METimage homogemeity
3. Cloud Signal test
4. Aereosol Dust detection
5. Simple Cloud Parameter retrieval



1. Clear
2. Maybe clear
3. Partially cloudy
4. Fully cloudy

Cloud profile

The cloud profile is retrieved by two steps:

- PWLR using the ECMWF CLWC to set the training
- OEM

OEM

Optimal estimation method for clear sky

The optimal estimation retrieval of atmospheric and surface parameters is performed by minimisation of a cost function, J, consisting of two terms, the background (J_x) and the observation (J_y) terms:

$$J = J_x + J_y$$

$$J_x = (x - x_a)^T S_x^{-1}(x - x_a)$$

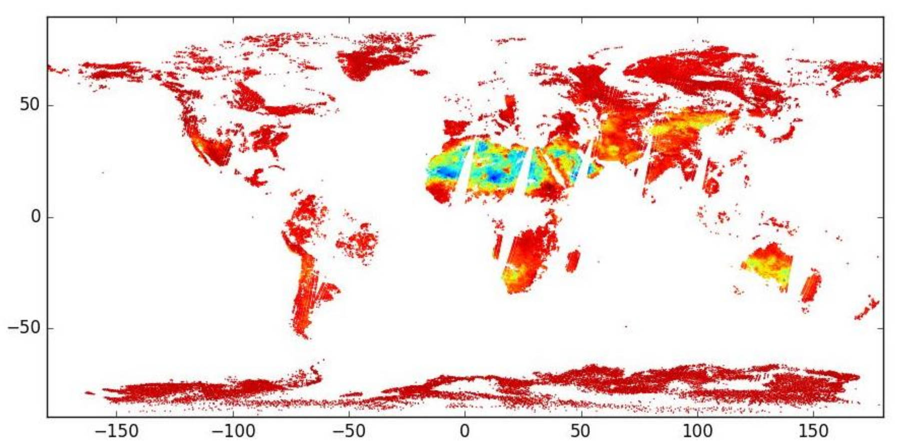
$$J_y = (F(x) - y)^T S_y^{-1}\,(F(x) - y)$$

Where

- x is the state vectors to be retrieved in PC scores:
  $x = \left(t_1, \ldots, t_{n_t}, o_1, \ldots, o_{n_o}, c_1, \ldots, c_{n_c}, e_1, \ldots, e_{n_e}, e_{MW_1}, \ldots, e_{MW_{n_{MW}}}\right)$
- t the temperature profile and the n_t the number of PC scores to reconstruct the temperature profile
- o the ozone profile (n_o number of PC scores)
- c the CO2 profile (n_c number of PC scores)
- e the infrared emissivity profile (n_e number of PC scores)
- e_{MW} the microwave emissivity profile (n_{MW} number of PC scores)
- x_a is the a priori state vector (PWLR³)
- y is the observation vectors and it is a subset of reconstructed radiance (e.g. IASI-NG and MWS radiances) ;
- F(x) is the simulated observations vectors using the forward model (RTTOV) ;
- S_x and S_y are the background error and observation error matrices, respectively. The full matrix S_y is the combined measurement and forward model error.

The iterative minimization method is the **Newton descent algorithm.**

Surface emissivity 05 2016/04/26

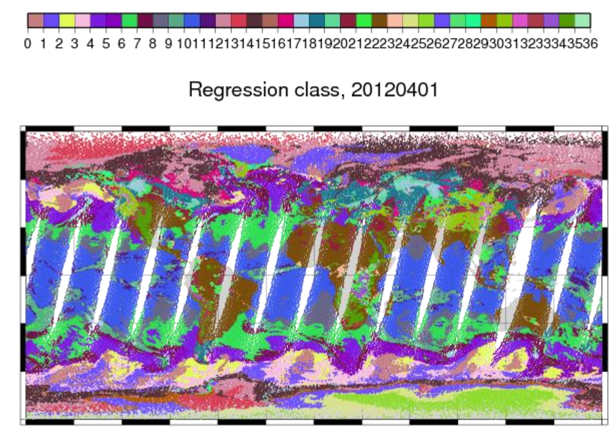


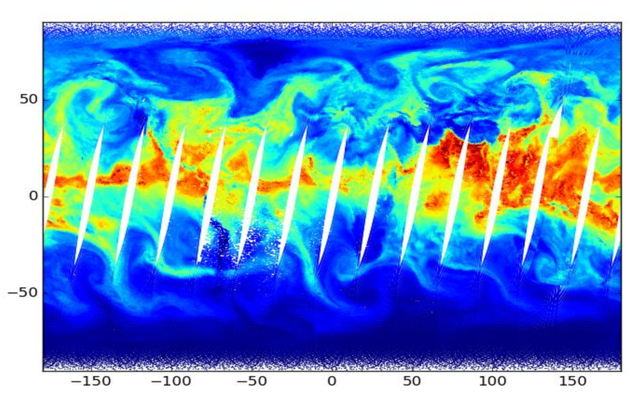
PWLR³

All sky statistical retrieval of temperature, water vapour, ozone, emissivity and green-house gases profiles using IASI-NG with co-located MWS radiances.

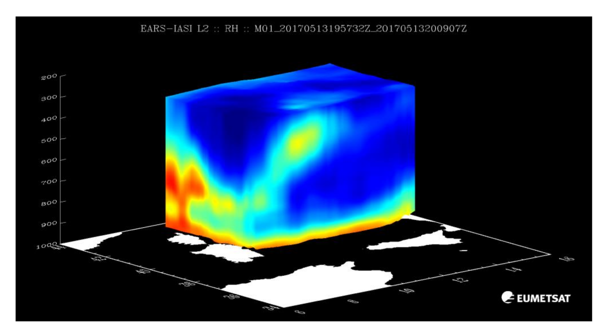
PWLR is a fast, accurate and precise, all sky retrieval of temperature, water vapour, ozone, and surface pressure, which was developed for version 6 of EUMETSAT's operational IASI L2 processor, using IASI as well as co-located AMSU and MHS radiances as inputs. The retrieval is based on linear regression, but in order to capture non-linear relationships between the inputs and the outputs better, the input space is divided into several classes. For each of these classes a separate set of linear regression coefficients is computed from the corresponding subset of the training set, such that overall a piecewise linear function from the input space into the output space is obtained. The training set consists of millions of real measurements paired with co-located ECMWF analysis profiles and the retrieval also computes estimates of the absolute retrieval error for each field of view, which are used as quality indicators.

PWLR³ is an evolution of the PWLR scheme. PWLR³ preserves the single field of view retrievals, but exploits horizontal correlation by using measurements from all four fields of view within each EFOV jointly. A number of further enhancements have also been made, for example a finer classification based on k-means clustering.
The PWLR³ all sky statistical retrievals were introduced operationally the 2nd June 2016 with version 6.2 of EUMETSATs IASI L2 products.

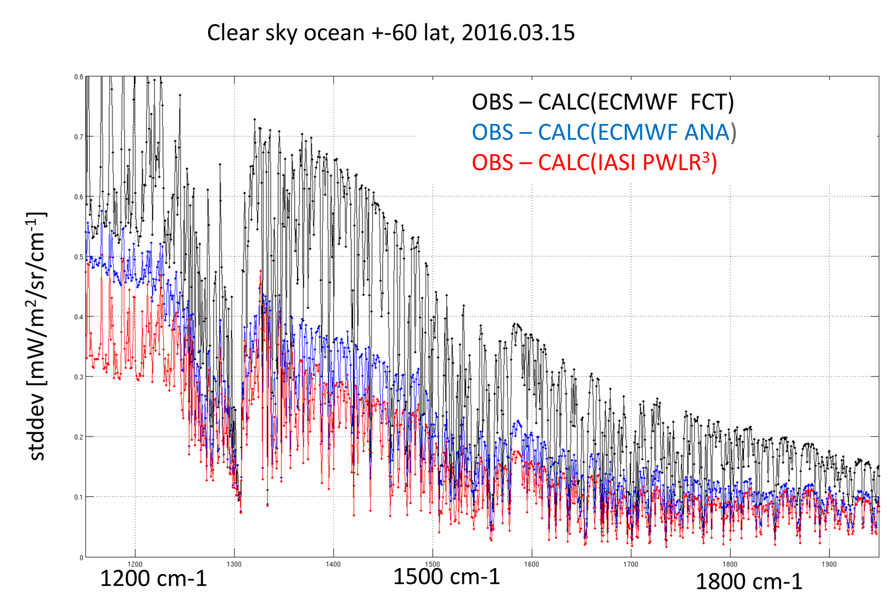




Total column water vapour PWLR³ IASI/AMSU/MHS

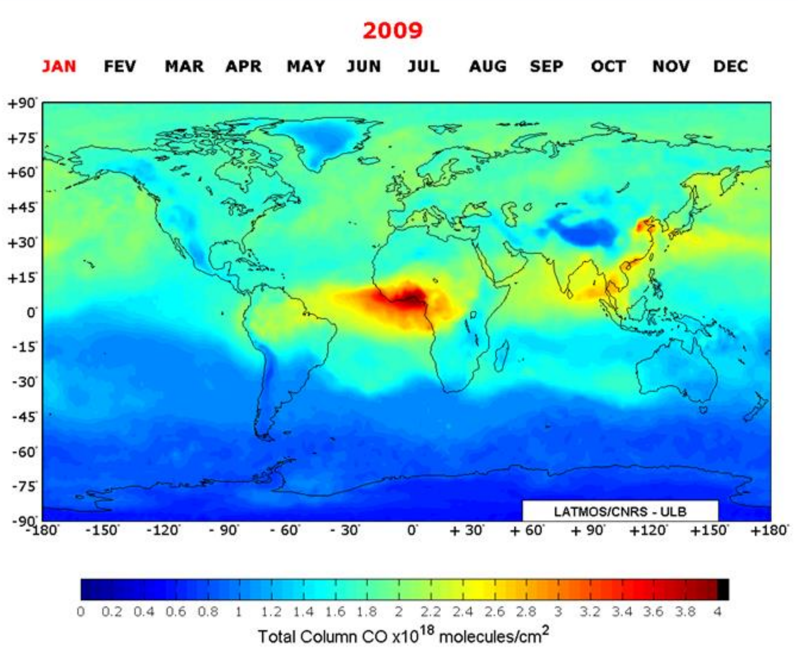


Specific humidity PWLR³ IASI/AMSU/MHS



It is an important advantage that no explicit fitting of the measured radiances is involved, since it implies that a-posteriori analysis of the radiance fit can be used as a valuable complement in the validation of the retrievals.

The figure shows the standard deviation of the obs minus calc residuals computed using profiles from ECMWF forecast and analysis as well as PWLR³ retrievals. Although there is absolutely no explicit minimization of residuals involved in the PWLR³ retrieval, the standard deviation of the residuals are considerably smaller than what is obtained by using ECMWF forecasts or even analysis.



Acknowledge: ULB/LATMOS, Coheur, Clerbaux et al.

FORLI and BRESCIA

Profiles of CO, HNO3 and O3 are retrieved by the FORLI library. The SO2 columnar amount is retrieved by the BRESCIA library. These two libraries are provided by the ***EUMETSAT AC SAF*** and take raw radiance from the L1C as input, rather than the reconstructed radiances from L1D and are built for IASI spectra rather than IASI-NG spectra.
In order to invoke them it is therefore necessary to convert the IASI-NG spectra to IASI-like spectra. After this transformation, the FORLI and BRESCIA libraries has to be applied.
The input profiles of temperature and water vapor are taken from the optimal estimation retrieval (or PWLR).

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