Concurrent cloud detection methods, assessment and impact on the yield and quality of atmospheric parameters retrieved with IASI

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Summary

The IASI Level 2 (L2) Product Processing Facility (PPF) operated at EUMETSAT's Central Facility routinely retrieves in near-real time (NRT) geophysical parameters from IASI measurements, including temperature and humidity profiles. The cloud detection is a key step before the retrievals of atmospheric parameters, which are nominal with clear-sky radiances. In answer to users' requests, the temperature and humidity profiles retrieved in partially cloud contaminated IASI fields of view (IFOV) were recently added to the L2 products. They are obtained with a linear regression on the radiances principal components (also referred to as EOF retrieval), while clear-sky retrievals are attempted with the optimal estimation method (OEM).

Two clouds tests are essentially used in synergy in the current operational version of the processor, namely the version 5. The first test is based on IASI measurements in the infrared (IR) window region and relies on numerical weather predictions (NWP). The second test uses the collocated cloud imagery from the Advanced Very High Resolution Radiometer (AVHRR), companion of IASI on the Metop satellites. We present here a new test exploiting jointly the AVHRR and IASI measurements with help of artificial neural networks (ANN) trained on a large database of visual assessments and discuss their respective performances.

The current approach for identifying cloud-free IFOVs in the context of concurrent cloud detection methods consists in retaining only the IFOVs classified as clear by all tests. This stringent approach increases the confidence in the clear-sky selection and subsequently in the quality of the retrievals. We show however that such a screening actually excludes a number of clear scenes, with some systematic regional effects, and therefore negatively impacts the regional and overall IASI L2 yield. We introduce here a new clear-sky/cloudiness classification and the notion of confidence in the clear-sky identification.

We then evaluate and compare the performances of different operational and prototype retrieval methods with collocated ECMWF analyses fields for each of these cloudiness classes. This includes results from a joint microwave and IR retrieval algorithm (MWIR) using the measurements from the Advanced Microwave Sounding Unit-A (AMSU-A) and IASI [presented in a separate paper by Hultberg et al.]. Improvements in the overall IASI L2 yield and quality are shown, which are intended for the forthcoming version 6.

A new cloud detection test

The ANN cloud test: [1]

- A training database of about 25000 visual cloudiness assessments
- 4 Neural networks (one for each land/sea and day/night combinations)
- Inputs:
  - AVHRR radiances and clusters information
  - IASI radiances in selected channels
- Output threshold fixed using a cost function minimisation

Performances comparison to currently operational tests

The current configuration (PPF v5) uses two cloud tests:

- the **NWP cloud test**, based on ECMWF forecasts
- the **AVHRR cloud test**, based on AVHRR cloud imagery

Some systematic disagreements can be observed (Figure 1)

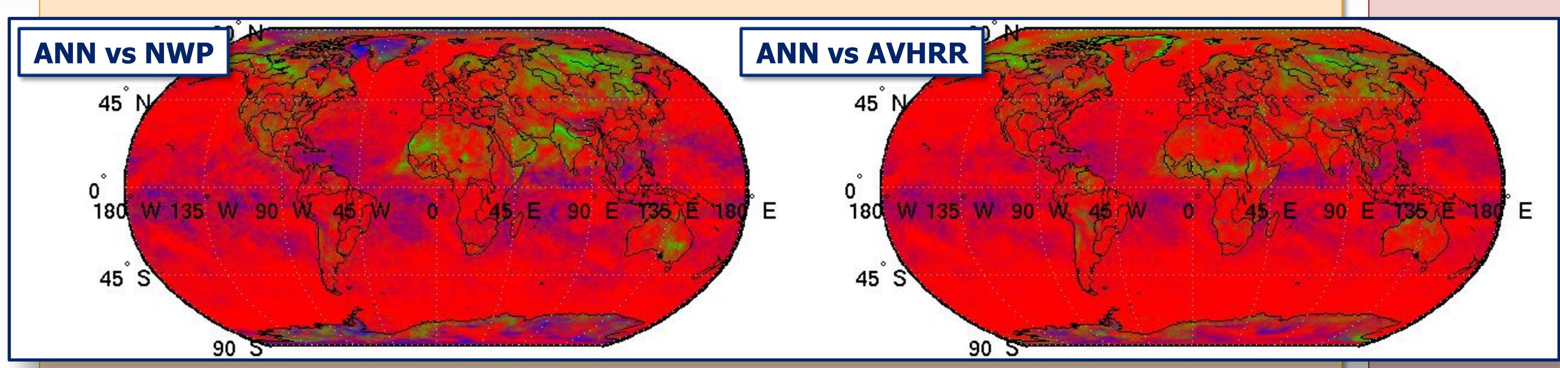

Figure 1: Map of agreement between the new ANN cloud test and the two operational cloud tests. Red: all methods agree. Blue: Clouds detected with ANN test only. Green: Clouds detected with NWP/AVHRR tests only. [19-24 March 2012, day & night]

Reasons for these systematic disagreements:

- **The ANN test is more sensible to small cloud contaminations over oceans but does not detect sand storm well.** This is illustrated with the AVHRR RGB composite in Figure 2 with an example of broken clouds in the inter-tropical ocean (top) and a large sand storm and cloud formation over an arid area in Africa (bottom).

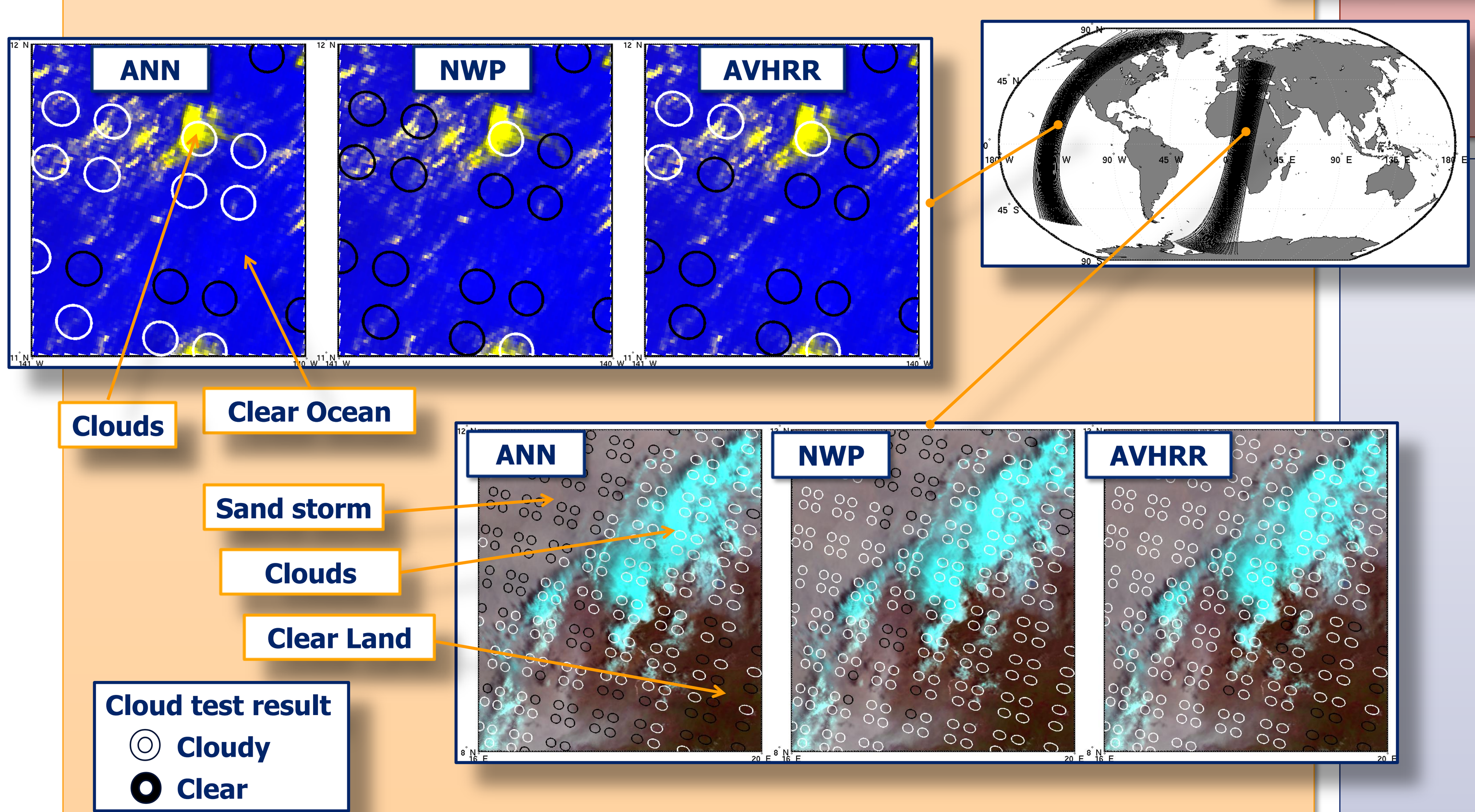

Figure 2: Examples of visual inspections of the IASI cloud test results (black and white footprints) using AVHRR images as background. Top: patchy clouds over Pacific ocean (19/03/2010 day, AVHRR channels: [1 3a 5]) Bottom: sand storm and clouds over Sahel (20/03/2010 day, AVHRR channels: [1 2 3a])

- **The ANN test is more accurate for cloud detection over snow and ice.** The identification of clear pixels was evaluated with collocated Lidar data from CALIOP/Calipso. The agreement with the Lidar cloud sensing for the three methods is shown in Figure 3. It reaches **72% for the ANN,** but is **only of 50% and 55% for the NWP and AVHRR** tests respectively. The occurrence of clear detections with the ANN test (19%) is comparable to the NWP test (21%) and higher than the AVHRR test (11%) but is more reliable.

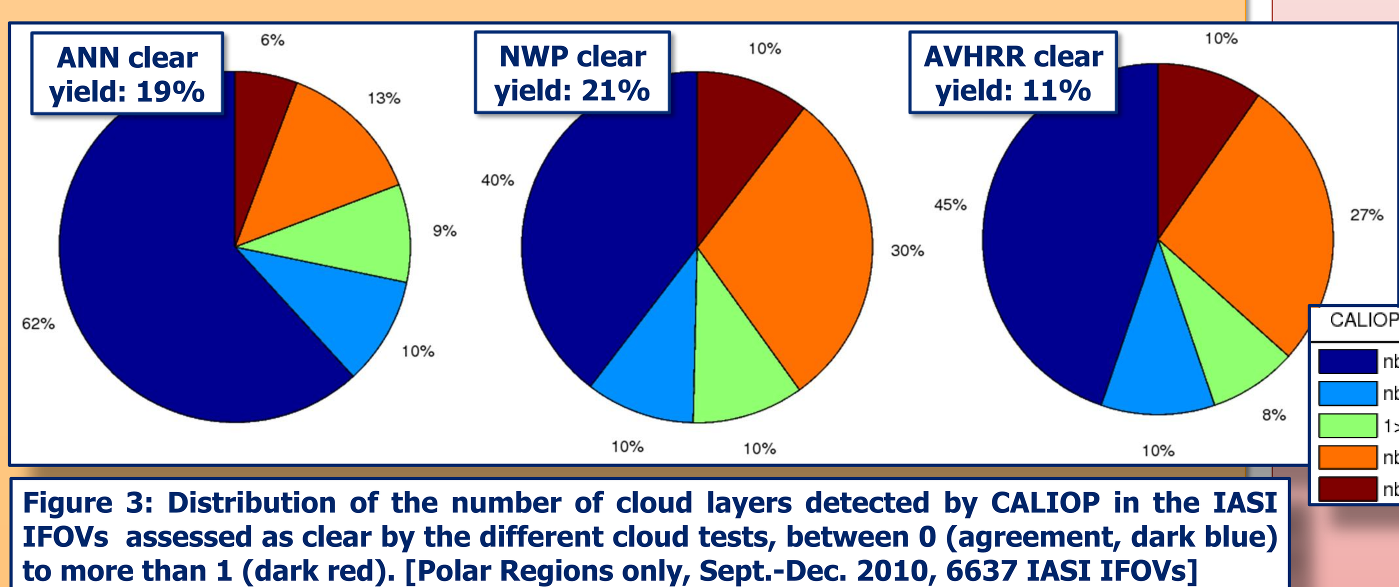

Figure 3: Distribution of the number of cloud layers detected by CALIOP in the IASI IFOVs assessed as clear by the different cloud tests, between 0 (agreement, dark blue) to more than 1 (dark red). [Polar Regions only, Sept.-Dec. 2010, 6637 IASI IFOVs]

A new cloudiness assessment

Why ?

Current strategy (PPF v5): [2]

- **Cloud-free** pixel if **all tests agree**
- **Clear-sky retrievals with OEM** (best quality)
- **Partly cloudy pixels** processed with a dedicated **EOF regression**, trained with synthetic cloudy radiances [3]

Results:

- Clear-sky products: **good quality** but **low yield**
- Some regions are systematically misclassified as cloudy

The addition of a third concurrent cloud test restricts further the intersection (agreement) space between the three methods. A **more elaborated cloudiness assessment** was developed to subsequently trigger the appropriate retrieval methods in order to **maximise the yield and quality of the IASI L2** products.

How ?

In v6, a **new flag** is introduced to summarise the **cloudiness assessment** and inform the user about the level of confidence in the cloud detection. The flag is based on:

- The 3 cloud test results (ANN, NWP & AVHRR)
- The retrieved IASI cloud parameters: cloud top pressure (CTP) and effective cloud amount (ECA)

ANN	NWP	AVHRR	Cloud parameters	Flag	Retrieval
0	0	0	*No cloud*	Q1	OEM
0	0	1	*No cloud* or ECA<25% | CTP>750hPa	Q2	OEM
:	:	:	ECA>25% & CTP<750hPa	Q3	MWIR
1	1	0	ECA<80%	Q3	MWIR
1	1	1	ECA>80%	Q4	MWIR

Table 1: Logic table of the cloudiness flag introduced in the IASI L2 PPFv6 and the subsequent choice of retrieval methods

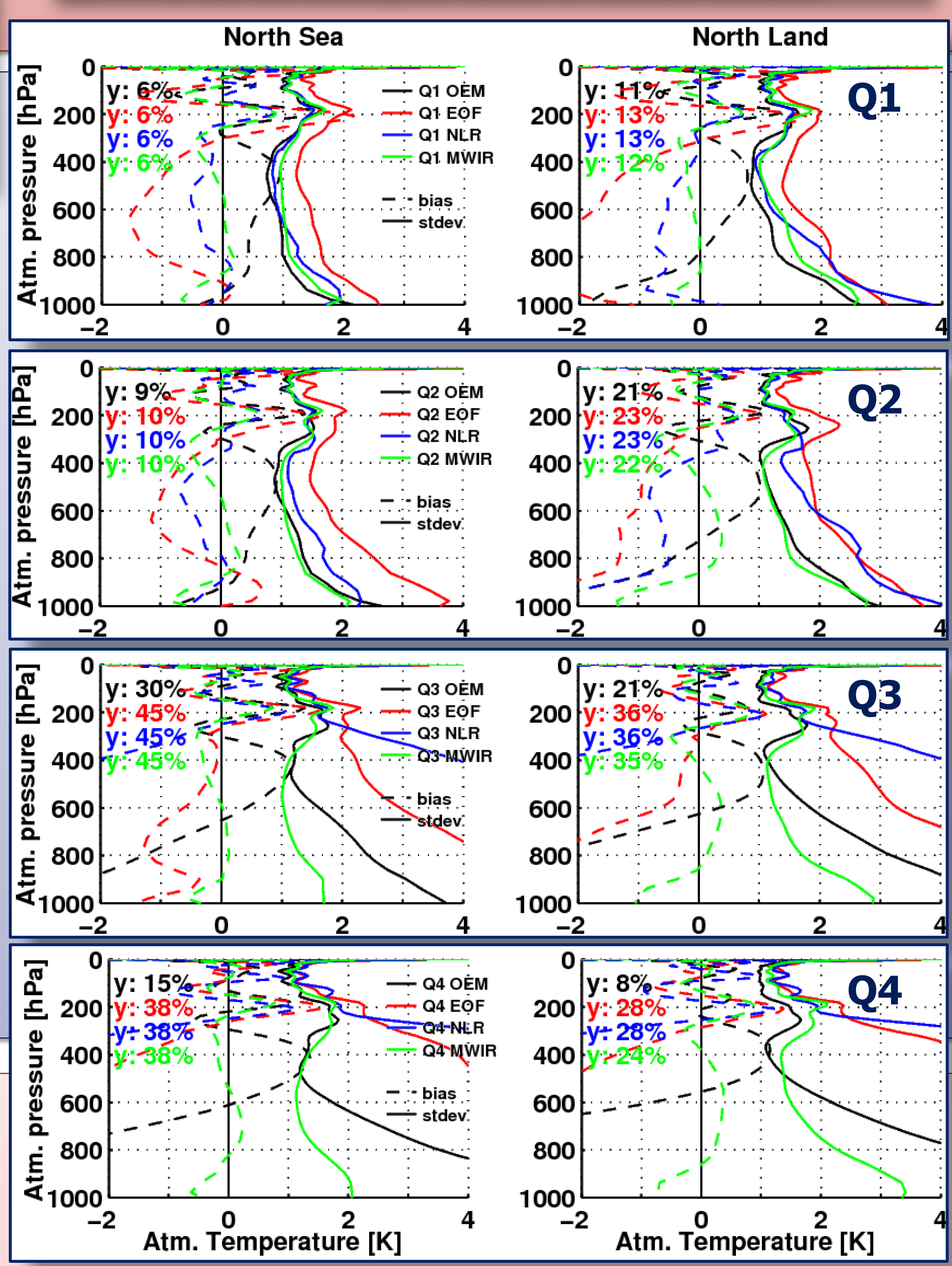

Figure 5: IASI-ECMWF atmospheric temperature bias (dashed line) and standard deviation (plain line) for the two operational methods, the OEM (black) and the EOF (red), and the two prototype methods, the NLR (blue) and the MWIR (green) for the 4 cloud quality classes from Q1 (top) to Q4 (bottom). [19-24 March 2012, day & night, North Land and Sea only]

[1] M. Crapeau, «Validation of the NN-based cloud detection tests for IASI», *EUM/MET/TEN/10/0343*, 2010

[2] T. August *et al.*, «IASI on Metop-A: Operational Level-2 retrievals after five years in orbit», *JQSRT*, 2012

[3] «EPS Ground Segment IASI Level 2 Product Generation Specification», *EPS.SYS.SPE.990013*

[4] Camps-Valls *et al.*, « Nonlinear statistical retrieval of atmospheric profiles from Metop-IASI and MTG-IRS, *IEEE GRS*, 2012

[5] T. Hultberg, «IASI retrievals in the intersection of the signal and forward model subspaces», *IASI Conf. 2013*

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Impact on the IASI L2 clear-sky products

When comparing the performances of the atmospheric temperature retrievals against ECMWF for the current (PPFv5) and the future (PPFv6) clear-sky classes (Figure 5), we can see:

- **The Q1 class** is very close to the current "clear-sky" quality with a slight decrease of the yield,
- **The Q2 class** give very good results when compared to the current "partly cloudy" and at least double the overall clear-sky yield.

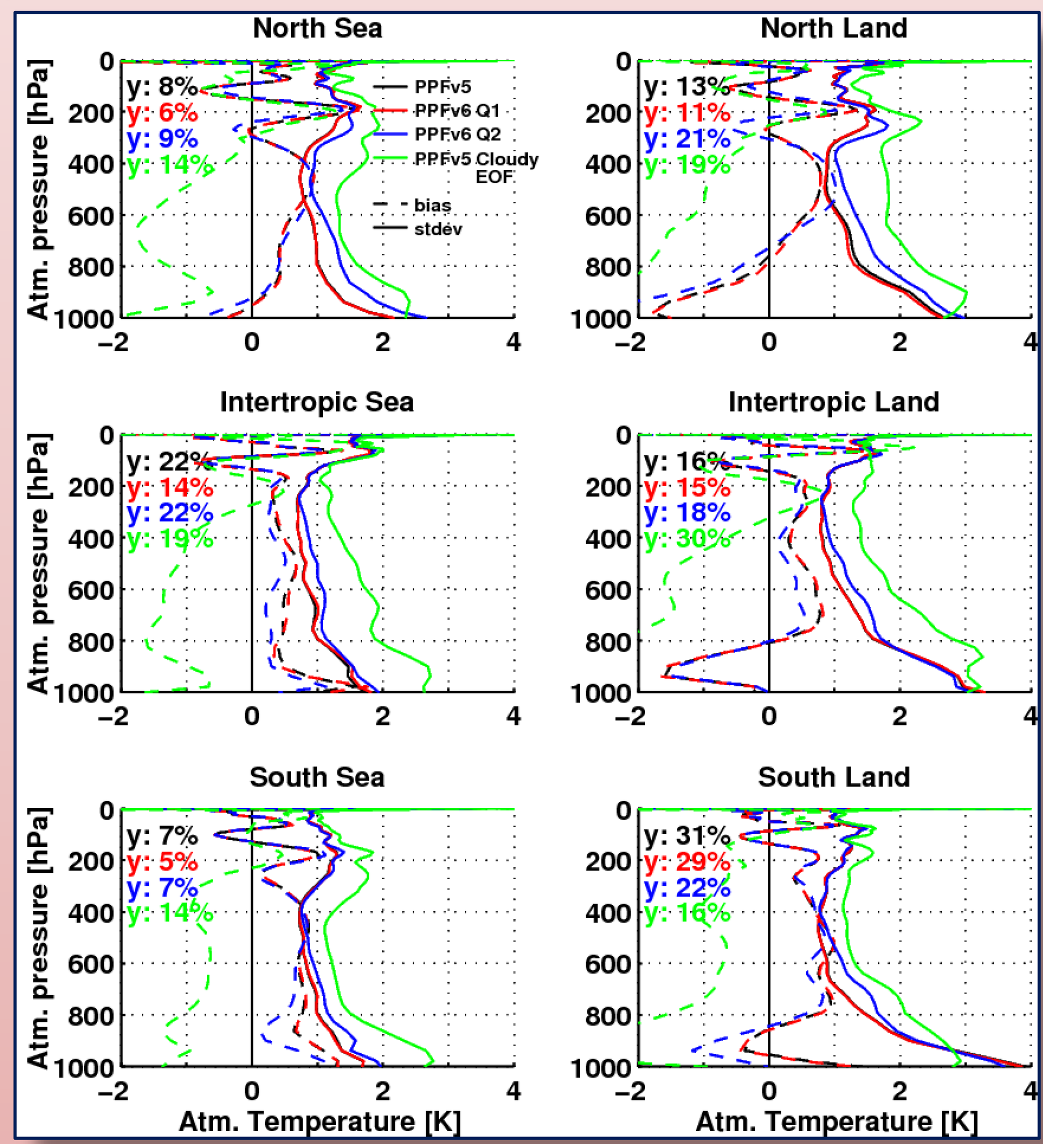

Figure 4: IASI-ECMWF atmospheric temperature bias (dashed line) and standard deviation (plain line) for the unique clear sky class from the PPFv5 (black) and for the two classes from the PPFv6 (Q1 in red, Q2 in blue). The PPFv5 partly-cloudy retrieval with EOF is also shown (green). [19-24 March 2012, day & night]

Retrieval performances for clear and cloudy classes

Method	Inputs	Training set	Applicability
OEM [2]	IASI	-	Clear sky
EOF [3]	IASI	Synthetic spec.	Clear/Cloudy
NLR [4]	IASI	Synthetic spec.	Clear sky
MWIR [5]	AMSU/IASI	Real obs.	Clear/Cloudy

Table 2: characteristics of the retrieval methods used in the future PPFv6. The Non Linear Regression (NLR) and the Microwave-Infrared linear regression (MWIR) will be used for the first time in the IASI L2 PPF in the version 6

The performance assessment of two new methods (NLR and MWIR) and of the two operational ones (OEM and EOF) performed against ECMWF analyses (Figure 5) confirms that the clear sky OEM retrievals are applicable to Q1 and Q2. The statistical methods NLR and MWIR are of comparable quality in Q1. Thanks to the joint use of MW measurements together with the IR, the quality of the MWIR retrievals is not significantly impacted by the presence of clouds (Q3 and Q4).

Conclusion and perspectives

The forthcoming IASI L2 PPFv6 will bring major improvements in the field of clouds detection:

- Addition of a new cloud test improving the detection accuracy, especially over oceans and Polar Regions,
- Development of a new cloud detection scheme bringing:
  - Introduction of a cloudiness assessment flag,
  - Addition of a second quality of clear-sky retrievals (Q2) showing good performances and increasing the overall yield for clear-sky retrievals by a factor two,
  - The cloudy pixels are now divided in two classes according to the cloud cover (Q2 and Q3) and can be processed by a new dedicated retrieval method.

The coming developments will be focused on cloud detection over regions presenting a lower accuracy, especially snow and ice.