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


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 (FOVs) 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 cloud tests are essentially used in synergy in the current operational version of the processor, namely the so-called clear-sky IASI (CSCI) and the AVHRR collocated cloud test. The first test is based on IASI measurements and relies on numerical weather predictions (NWP). The second test uses the collocated cloud imagery from the Advanced Very High Resolution Radiometer (AVHRR), comparison 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 its respective benefits and drawbacks.

The current approach for identifying cloud-free IOVs in the context of concurrent cloud detection methods consists in retaining only the IOVs 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 (PPFv6 using the measurements from the Advanced Microwave Scanning Radiometer (AMSR)-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 25,000 visual cloudiness assessments
- 4 Neural networks (one for each land/sea and day/night combinations)
- Inputs:
  - AVHRR radiances and clouds information
  - IASI radiances in selected channels
- Output threshold fixed using a cost function minimisation

Performance 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 image

Some systematic disagreements can be observed (Figure 1).

Figure 2: Examples of visual inspections of the IASI cloud test results (black and white footprints) using the Metop B satellite.

- Top: patchy clouds over Pacific ocean (19/03/2010 day, AVHRR channels: [1 2 3a])
- Bottom: sand storm and clouds over Sahel (20/03/2010 day, AVHRR channels: [1 2 3a])

 Reasons for these systematic disagreements:

- The ANN test is more sensitive to small cloud contaminations over oceans but does not detect sand storms well.
- The ANN test identifies class as clear under certain conditions.

The ANN test is more accurate for cloud detection over snow and ice. The identification of clear pixels was evaluated with colocated LIDAR data from CALIOP/CALIPS. 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 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.

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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

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

The third concurrent cloud test restricts the intersection (agreement) space between the three methods. A more elaborated cloudiness assessment was developed to subsequently identify 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 3 cloud test results (ANN, NWP & AVHRR)
- The retrieved IASI cloud parameters: cloud top pressure (CTP) and effective cloud amount (ECA)

- The confidence flag is then constructed by a regression analysis of the three cloud test results (Figure 4). The flag is then combined with the two IASI cloud products (Q1 and Q2 in blue). The PPFv5 partly-cloudy retrieval with EOF in red (green) is shown (12/24 March 2012, day & night).

Table 1: Schematic diagram of the cloudiness assessment and the confidence flag (Q1 (red), Q2 in blue). The PPFv5 partly-cloudy retrieval with EOF in red (green) is shown (12/24 March 2012, day & night).

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 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 gives very good results when compared to the current "partly cloudy" and at least double the overall clear-sky yield.

Table 2: Characteristics of the retrieval methods used in the future PPFv6. The Non Linear Regression (NLR) and the Microwave Infrared Radiometer (MIR) will be used for the first time for the IASI L2 PP in the version 6.

The performance assessment of two new methods (NLR and MIR) 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 MIR are of comparable quality in Q1. Thanks to the joint use of MW measurements together with the IR, the quality of the MIR/MW retrievals is not significantly impacted by the presence of clouds (Q3 and Q4).

Conclusion and perspectives

The forthcoming IASI L2 PPv6 will bring major improvements in the field of cloud 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:
  - A new cloud classification algorithm.
- 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.