IASI RETRIEVAL OF TEMPERATURE, WATER VAPOR AND OZONE PROFILES OVER LAND WITH Φ-IASI PACKAGE DURING THE COPS CAMPAIGN

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ABSTRACT

The paper illustrates the application of the IASI Level 2 processor developed at University of Basilicata by the Applied Spectroscopy group (φ-IASI) to IASI data recorded over the land during the COPS (Convective and Orographically-induced Precipitation Study) observation campaign in the period between June and August 2007 over the region at boundaries among France Germany and Switzerland.
IASI Water Vapor profiles retrieved with this methodology are compared with IASI profiles retrieved with the methodology developed at LATMOS (Laboratoire Atmosphères, Milieux, Observations Spatiales) laboratory, co-located GPS tomography, lidar and radiosonde profiles. While, retrieved temperature profiles are compared with radiosonde ones.

1. INTRODUCTION

The infrared atmospheric sounding interferometer (IASI) has been developed in France by the Centre National d'Etudes Spatiales (CNES) and it flies on board the Metop-A (Meteorological Operational Satellite) platform, the first of three satellites of the European Organization for the Exploitation Meteorological Satellite (EUMETSAT) European Polar System (EPS). It was launched in October 2006. The instrument has a spectral coverage extending from 645 to 2760 cm^{-1}, with a sampling interval $\sigma = 0.25$ cm^{-1} for a total of 8461 channels for each single spectrum.
It has been shown that IASI provides data of unprecedented spectral quality and accuracy (see, for example, [1]) and the inversion of its spectral radiances has produced atmospheric profiles for temperature and water vapour that match very well ground based measurements recorded during dedicated calibration/validation (*cal/val*) campaigns such as the Joint Airborne IASI validation Experiment (JAIVEx) which was carried over the Gulf of Mexico during April and May 2007[1].
The IASI level 2 processor developed at University of Basilicata by the applied spectroscopy group (φ-IASI package)[2] has been deployed during several *cal/val* campaigns and it has been shown that its retrieved profiles are in good agreement with ground based measurements ([2, 3]).
In this work the φ-IASI package is applied to IASI data recorded over the land during the COPS (Convective and Orographically-induced Precipitation Study) experiment ([4, 5]). φ-IASI retrieved profiles have been compared with in-situ measurements and with profiles retrieved with the methodology developed at LATMOS (Laboratoire Atmosphères, Milieux, Observations Spatiales) laboratory.
The paper is organized as follows: in the Section 2 we shortly describe the basic aspects of the methodology in φ-IASI package; in Section 3 we briefly give hints and reference for the COPS experiments providing also information and references for the methodology within the LATMOS retrieval technique. Results and discussion are in Section 4.

2. The φ-IASI PACKAGE

The tool φ-IASI is a package intended for the generation of IASI (Infrared Atmospheric Sounding Interferometer) synthetic spectra and for the inversion of geophysical parameters ([2, 6]): temperature and water vapour profiles, low vertical resolution profiles of ozone, carbon monoxide, methane and nitrous oxide. Flow chart in Fig.1 illustrates the structure of the package. It consists in a stand-alone cloud detection scheme (γδσ-IASI) [7], a forward model, σ-IASI [8] and an inverse model, δ-IASI [9].
The forward model σ-IASI is a monochromatic radiative transfer model designed for fast computation of spectral radiance and its derivatives (Jacobian) with respect to a given set of geophysical parameters. It represents a compromise between the accuracy of the exact line-by-line radiative model and the fastness of the hyper-fast radiative transfer model. This compromise is achieved by means of a look-up table of pre-computed pressure dependent monochromatic optical depths and an interpolation procedure. The optical depth look-up-table takes into account also effects depending on the gas concentration, such as the line self-broadening of the water vapour [10].

[1] More information on the Joint Airborne IASI Validation Experiment (Taylor, J.P (P.I.)) are available online: http://badc.nerc.ac.uk/data/jaivex/ access: 8 June 2012.

[2] The home page of the Applied Spectroscopy Group is: http://www.difa.unibas.it/jFM/dlf/Laboratori/ApplSpec/as/home.html access: 8 June 2012.

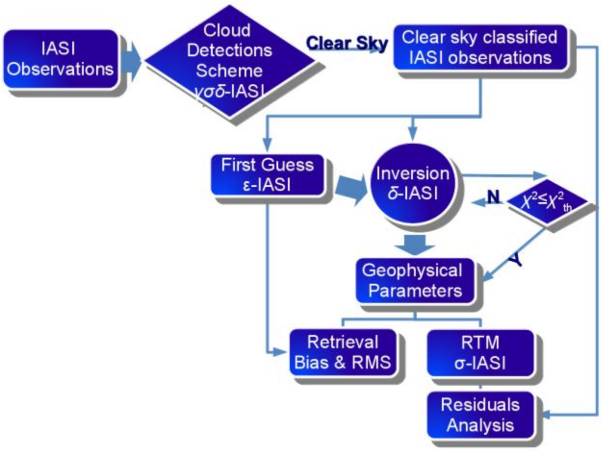

Figure 1. Flow chart for the φ-IASI package.

The inverse module δ-IASI has been designed to retrieve simultaneously: skin temperature, atmospheric profiles of temperature, water vapour, ozone and emissivity spectrum [11], by inverting highly resolved infrared radiance. Then, sequentially, it retrieves columnar amount of Carbon Dioxide, Nitrous Oxide, Carbon Monoxide and Methane [12,13].
The algorithm is mostly intended for the IASI, but the code is well suited for any nadir (or zenith) viewing satellite airborne and ground based infrared sensor with a sampling rate in the range of 0.1-2 cm^{-1}. The inversion scheme is based on a Netwon-Raphson scheme in which the Radiative Transfer Equation is step-linearized by Taylor expansion. The scheme is iterated until convergence is reached. The convergence criterion is based on the residual between observed and computed spectra. The first guess state vector for the linearization is based on Empirical Orthogonal Function (EOF) technique [14].

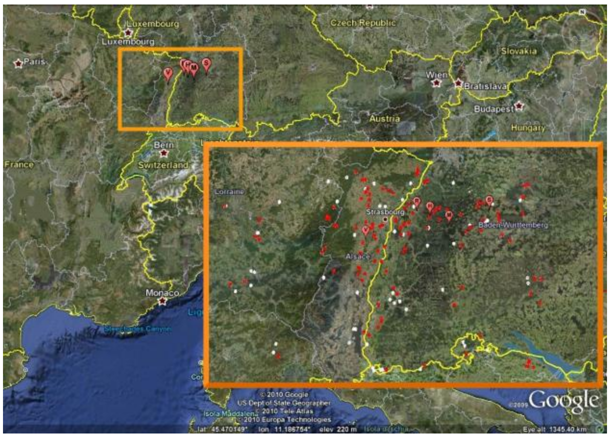

Figure 2. The area of the COPS experiment from Google earth (http://earth.google.com/). The red placemarks indicate the position of the 5 COPS measurement sites. In the zoomed area below the dots indicate the position of the IASI footprints used in our analysis. The red dots indicate the clear sky classified spectra, white dots indicate the cloudy classified spectra.

3. COPS EXPERIMENT

The international field campaign called the Convective and Orographically-induced Precipitation Study (COPS) took place from June to August 2007 in southwestern Germany/eastern France. The main goal of COPS is to advance the quality of forecasts of orographically-induced convective precipitation by four-dimensional observations and modelling of its life cycle.
During the observation campaign, a large number of state-of-the-art active and passive meteorological instruments was operated. The instruments are located at five sites indicated with red placemarks in Fig. 2. Into details the five sites are located (west to east) at the Vosges mountains (supersite V), Rhine valley (supersite R), Hornisgrinde mountain site (supersite H), Murg valley (supersite M) and Deckenpfronn close to Stuttgart (supersite S).
The sites hosted several multi-wavelength passive and active remote-sensing instruments such as advanced radar and lidar systems together with in situ remote-sensing systems such as the Global Positioning System (GPS). A detailed description of the aims of the campaign, the instrumental set ups and its main results can be found in [4,5]. In the following sub-sections we give details on the data used in this exercise.

3.1. IASI Spectra

In this exercise we used a dataset of 174 IASI spectra recorded from 5th July to 30th August 2007 over the region of the 5 COPS sites. The zoomed area in Fig. 2 indicates the footprints of the IASI spectra used in this analysis. The IASI spectra were first classified for clear sky using the module of cloud detection of φ-IASI [7]. According to the module, 133 spectra were classified for clear sky (the red dots in the zoomed area in Fig.2).
The clear sky classified spectra were then inverted for temperature, water vapour, ozone profiles with φ-IASI methodology and 123 of these spectra match the convergence criterion of the methodology.
In this analysis the following spectral ranges have been considered for the inversion of IASI data: 645 to 810, cm^{-1}; 1000 to 1200 cm^{-1}; 1450 to 1950 cm^{-1}. At the IASI sampling rate of 0.25 cm^{-1}, this corresponds to a number of IASI spectral radiances, n=3463. The results in the Figs 3 and 4 have been obtained by setting the emissivity spectrum constant at the value of 0.98.
The convergent IASI spectra (according to φ-IASI methodology) were inverted also with the methodology developed at LATMOS laboratory only for the water vapour profiles.
In this case the profiles are retrieved from the L1C IASI apodized radiance spectra using the *Atmosphit* software developed at Université Libre de Bruxelles, Belgium [15,16,17] based on a line-by-line radiative transfer calculation and Optimal Estimation Method (OEM) [18].

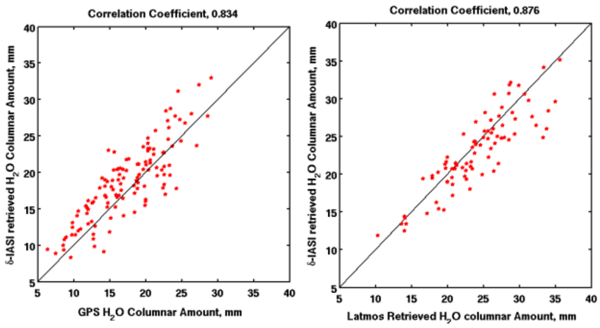

Figure 3. Comparison among IASI retrieved water vapour columnar amount. The scatter plot in the left panel shows on the x-axis the columnar amount from GPS measurements and on the y-axis columnar amount computed with φ-IASI methodology. The same columnar amount is on the y-axis of right panel, while on the x-axis are shown LATMOS columnar amount.

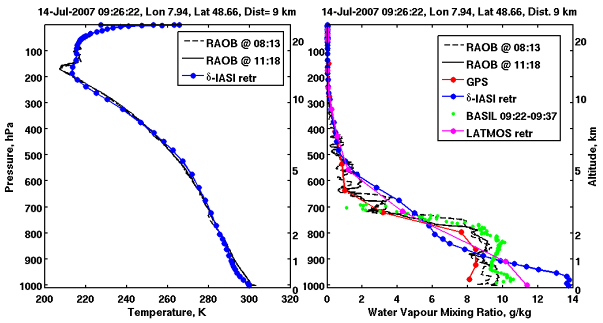

Figure 4. Comparison among IASI retrieved profiles and radiosonde, lidar and GPS measurements. The comparison is for a spectrum recorded July 14th, 9 km far from COPS site R. Comparison for the temperature and water vapour profiles are respectively in the left and right panels. Black lines are the radiosonde, blue dots are the δ-IASI profiles. In the right panel red dots are the GPS profile, magenta dots the LATMOS IASI retrieved profile and the green dots are the BASIL lidar profile.

3.2. GPS Tomography

IASI retrieved profile are compared also with the indirect measurements of the network of GPS stations.

3.3. BASIL Profiles

Selected IASI spectra close to site R were compared with in situ measurements. At site R, the Raman Lidar system BASIL was deployed and operated from 25th May to 30th August 2007, collecting more than 500 hours of measurements, distributed over 58 measurement days and 34 intensive observation periods (IOPs). The major feature of BASIL is represented by its capability to perform high resolution and accurate measurements of atmospheric temperature and water vapour, both in daytime and night-time, based on the application of the rotational and vibrational Raman lidar techniques in the UV [19,20,21].

4. RESULTS AND DISCUSSION

The comparison has been divided in two parts. In the first part we compared water vapour columnar amount. Into details we compare columnar amount of the φ-IASI retrieved profiles with the GPS one and with the LATMOS retrieved columnar amount (Fig. 3). By comparing this quantity we have a quick look on the whole dataset.

In the second part we compared profiles both for temperature and water vapour. In Fig. 4 we show a sample of this comparison for a spectrum recorded the July 14th, 9 km far from the COPS R site. In this case φ-IASI retrieved profile is compared with co-located radiosonde profiles (for the temperature, left panel of Fig. 4) and also with BASIL lidar, GPS and LATMOS IASI retrieved profiles.

Regarding the columnar amount, the φ-IASI products show a good correlation with GPS tomography. In this case we have 123 spectra and the correlation coefficient is 0.83 between the two distribution. The mean value of the φ-IASI products is 21.3 mm, 2.3 mm greater than the GPS one.

The agreement improves comparing φ-IASI and LATMOS products. In this case we have 84 spectra and the correlation coefficient is 0.88. The mean value of φ-IASI products is 22.9 mm, 1.1 mm smaller than the LATMOS one.

Concerning the profiles, the left panel of Fig. 4 shows a very good agreement between φ-IASI temperature profile and radiosonde profile. The agreement among water vapour profiles (right panel of Fig. 4) is good. In this case, as expected, radiosondes and BASIL lidar profiles see more vertical structures, while GPS and IASI retrieved profiles show a smoother behaviour.

5. AKNOWLEDGMENT

IASI has been developed and built under the responsibility of the Centre National d’Etudes Spatiales (CNES, France). It is flown onboard the Metop satellites as part of the EUMETSAT Polar System. The IASI L1 data are received through the EUMETCast near real time data distribution service.

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