Improving the knowledge of the atmospheric state through the validation of IASI radiances

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ABSTRACT

Improving the quality of atmospheric and surface variables from Thermal InfraRed (TIR) hyperspectral sounders must go hand in hand with that of atmospheric spectroscopy and radiative transfer modeling, not to mention the use of validated level1 products. This allows eliminating inconsistencies that may limit the usefulness of the radiances for inversion or assimilation applications

At LMD, based on: (i) the 4A line by line radiative transfer model; (ii) the GEISA spectroscopic data base - both recognized as reference model and database by CNES for the IASI level1 CAL/VAL activities and deeply involved in the definition of future CNES missions (Microcarb, IASI-NG, MERLIN) -; and (iii) the ARSA climatological and radiosonde database, which, for many years, have been at the leading edge of their specific research fields through continuous validation and updates (http://ara.abct.lmd.polytechnique.fr), we have developed an automatic chain to validate level1 and level2 products.

Concerning the processing of Airs/Aqua or Iasi/MetOp hyperspectral level1, for every month of observation, hundreds of comparisons between clear sky (so called "residuals") are performed globally for various configurations: land, sea, night, day, scan angle. Such residuals are a by-product of the so called "stand alone approach" which together with the relative approach has been used at LMD to assess the consistency and the stability of the level1 radiances (see Scott et al abstract).

Since the mid 80's, at LMD as well as in the international community, the retrieval of level2 products goes through the use of these residuals which aim is to remove not only potential inconsistencies or spurious trends in the observations but also the radiative transfer modeling imperfections - the retrieval of level2 products may be inappropriate independently of the inversion method used.

In this talk, we propose to show how the retrieved level2 atmospheric and surface variables (such as surface temperature, emissivities, greenhouse and trace gases contents) can, in their turn, improve the residuals and thus provide an original validation of both levels. Ultimately, we will evaluate how to assess in some cases to the quasi "zero" levels of these residuals, leading to an iterative approach for improving the knowledge of the state of the atmosphere.

Presentation preference: *ORAL*

Validation of IASI NH_3 columns at the single pixel scale from airborne- and ground-based measurements

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ABSTRACT

Ammonia (NH_3) is an important gas phase precursor species for aerosols, and ammoniated aerosols are significant components of unhealthy fine particulate matter and also exhibit a net cooling effect on climate. IASI column NH_3 measurements provide global coverage at ~ 100 km^2 (nadir) and sub-daily resolution. However, validation of IASI NH_3 measurements has been limited due to a lack of in-situ measurements. Because of the short atmospheric lifetime of NH_3 (~ day), large spatiotemporal gradients further complicate NH_3 IASI validations.

To address these concerns, we have conducted a pixel scale validation of daytime (cloud coverage < 25%) IASI NH_3 columns from surface-, vehicle-, radiosonde-, and aircraft-based measurements during the 2014 NASA DISCOVER-AQ and NSF FRAPPE field experiments in northeast Colorado, USA (July-August 2014). This region includes a diverse range of validation environments such as agricultural areas (Platte River Valley), urban emissions (Denver metropolitan area), and relatively-clean mountain and prairie regions. To minimize horizontal gradients, a narrow spatial window of ±15 km from the IASI centroid was used (corresponding to temporal window of ± 1 hour at the mean boundary layer wind speed of 4 m s^{-1}). Due to the spiral flight tracks of the NASA P3-B aircraft, a majority of the vertical profiles extended from near the ground (1.5 km MSL) to 5.5 km above sea level, the typical flight ceiling of the P3-B aircraft in DISCOVER-AQ. NH_3 concentrations above the flight ceiling were assumed to be zero, consistent with the IASI *a prior* profile.

A total of 58 IASI/in-situ-derived columns were identified within these constraints. The mean relative error of IASI NH_3 columns was 15% lower than those derived from the in-situ measurements. Given the in-situ measurement uncertainties (~25%), mean IASI error (38%) for these cases, and the strong spatial NH_3 gradients observed in this area, the agreement between IASI and in-situ measurement columns is excellent. No systematic bias is observed over IASI column abundances from 8x10^{14} to 4.4x10^{16} molec cm^{-2}. These results present the first pixel scale validation for IASI NH_3 and are at column abundances one order of magnitude lower than previous work with the NASA AURA TES NH_3 columns. Ongoing efforts will examine validations at higher NH_3 column abundances in areas such as the San Joaquin Valley (USA), explore the agreement at different spatiotemporal windows, and quantify the agreement with improved retrieval algorithms.

Evaluating the atmospheric columns of CH_4 retrieved from space using vertical profiles from aircraft and stratospheric balloons campaigns

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ABSTRACT

Atmospheric greenhouse gas (GHG) retrievals from space observations (GOSAT, IASI, AIRS, OCO-2) require precise information of several parameters to calibrate and validate the measurements. Although ground networks (flasks or FTS) provide high quality measurements, they lack characterizing the variations of GHG along the vertical. Precise and regular vertical profile measurements are thus needed to evaluate the retrieved total or partial gas atmospheric columns.

Two kinds of measurements could be considered to enhance the vertical description of GHG alongside the atmospheric column: (i) aircraft measurements can provide vertical profiles up to 10 km; (ii) stratospheric balloon flights allow GHG measurements from the surface up to 30 km. In particular, balloon measurements offer information in the upper troposphere and stratosphere that is needed to fully validate and interpret total and partial column of methane and carbon dioxide from spaceborne observations.

Here, we will investigate the merits of these two types of measurements to evaluate the gas columns retrieved from IASI using vertical profiles measured either during the HIPPO aircraft campaigns or during the CNES StratoScience balloon campaigns (with measurements from AirCores and pico-SDLA measurements). Due to its sharp decrease from about 1800ppb at 8km to 1000ppb at 20km, we will use methane columns retrieved from IASI as a test-base for highlighting the merits of both approaches. We will use the measured profiles to assess: (i) the sensitivity of Level 1 data to the vertical distribution of methane. In-situ vertical profiles from aircraft and balloon measurements as well as constant and 'standard' profiles will be used to compute IASI spectra with the radiative transfer code 4A/OP and to evaluate the sensitivity of IASI spectra to incomplete knowledge of methane profiles; (ii) the characteristics of Level 2 IASI CH_4 columns and their remaining uncertainties. Finally, we will use the results to suggest strategies for future validation campaigns of science products.

Validation and monitoring of the IASI L2 products at EUMETSAT

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ABSTRACT

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 as well as atmospheric composition, cloud characterisation and surface parameters. In order to monitor the quality of the these products and to validate the algorithms used for their retrieval, we have developed a tool dedicated to the analysis of the IASI L2 products and to the intercomparison of meteorological data.

The tool, developed in Matlab, has been designed to perform several kinds of validation tasks for the IASI L2 products, from the automatic daily monitoring to the long-term comparison campaigns against validation datasets (space-borne, ground-based, model, sondes...). Typical functionalities include the generation of statistics on vertical profiles -including the use of averaging kernels when available-; production of maps to characterise potential regional variations of performances; stratification of the statistics against quality indicator or temporal/spatial differences between the IASI products and correlative data to investigate the collocation error budget etc. Developed with object-oriented programming (OOP), this Matlab tool is generic and highly flexible. In particular, instantiating an intercomparison framework for new types of data requires little development. Consequently this tool is not limited to IASI L2 products and can be easily extended to products from other missions.

This tool is developed and used at EUMETSAT since 2012 and has been yet involved in many projects, including the commissioning of Metop-B, the qualification of the version 6 of the IASI L2 products in September 2014, the validation of subsequent evolutions and the automatic IASI L2 daily monitoring since the v6 release. It is also used to handle IASI L2 data for daily tasks like anomalies investigation, validation during the development and deployment phases, or even for the monitoring of meteorological events.

We present here the tool and some examples of validation and monitoring results, in particular the effect of MHS shutdown in spring 2015, the impact of Metop-A/AMSU's channel 8 degradation on the yield and quality of the "all-sky" retrievals in the IASI L2 v6 processor or the robustness of retrieved temperature and humidity against cloud contamination. We also show the possibilities in terms of long term studies that the reanalyse of the daily monitoring material provide, for example for the analysis of seasonal variations.

VALIASI: IASI OZONE TOTAL COLUMN AMOUNTS AND VERTICAL PROFILES VALIDATED AT SUBTROPICAL, MID-LATITUDE AND POLAR-LATITUDE.

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Satellite-based sensors can give a complete overview of the O3 global distribution, and therefore contribute fundamental observations for monitoring the atmosphere and for climate research studies (e.g. to quantify the recovery growth of this atmospheric compound). In this context, the IASI (Infrared Atmospheric Sounding Interferometer) is a very relevant sensor as it combines long-term data availability, high quality, global coverage, and good measurement frequency. However, a comprehensive documentation of the IASI data quality and consistency has to be carried out prior to any scientific study.
In this context and within the VALIASI project (VALidation of IASI level 2 products), a EUMETSAT research fellowship, we present this study. The IASI O3 L2 operational product (total column amounts and vertical profiles) generated by the EUMETSAT Polar System with processor version 6 is validated by using the ground-based FTS (Fourier Transform Spectrometer) at three different sites: the subtropical Izaña Observatory (28ºN, 17ºE), the mid-latitude Karlsruhe site (49ºN, 9ºE), and the arctic Kiruna site (68ºN, 20ºE). Special attention will be paid in analyzing the possible impact of latitude or other environmental impact factors.

Preference of presentation: Poster.

Global validation of IASI CO profiles with recent IAGOS data

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ABSTRACT

Carbon monoxide (CO) is a pollutant that affects tropospheric ozone, methane, and carbon dioxide, and as such it plays an important role in both air quality and climate change issues.

With its high spatial coverage and its vertical information content the IASI thermal infrared sounder onboard the polar orbiting satellite MetOp-A offers an unprecedented opportunity for monitoring key atmospheric species at the global scale. At Laboratoire d'Aérologie (LA), CO profiles from IASI are retrieved with the Software for Fast Retrieval of IASI Data (SOFRID). This algorithm is based on the Radiative Transfer model RTTOV coupled with a 1D-Var scheme which allows fast and accurate retrievals well suited for global applications.

In-situ measurements of atmospheric concentrations from aircraft are useful for the validation of satellite remote sensing data. In particular, the use of commercial aircrafts for the study of the chemical composition of the atmosphere makes possible the collection of considerable amounts of observations on the global scale, which cannot be achieved using research aircrafts. Since 1994, the MOZAIC/IAGOS program provides automatic and regular observations of trace gases from a fleet of several long-range in-service aircrafts. These measurements include ozone, water vapor, NOy as well as CO since 2001. The MOZAIC/IAGOS database is therefore a valuable source of information for satellite validation purposes, even more crucial as it documents regions poorly or never sampled by other techniques.

This work exploits the potential of the MOZAIC-IAGOS infrastructure for the validation of IASI-SOFRID CO data using vertical profiles over a large number of airports worldwide for the 2008-2014 period. The methodology of IASI validation with IAGOS includes (i) the selection of collocated IASI pixels for each IAGOS profile (ii) the completion of IAGOS tropospheric profiles in the UTLS and stratosphere with MLS data (iii) the convolution of IAGOS-MLS profiles with IASI averaging kernels. We will present global and multi-annual validation results with a particular focus on areas recently documented by IAGOS observations such as the Middle-East and Eastern Asia.

A Quasi Near-Real Time Operational Validation of IASI Level 2 Trace Gas Products

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The IASI (Infrared Atmospheric Sounding Interferometer) sensor is a key instrument of the EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) Earth observation program, for monitoring atmospheric composition on a long term base. This mission is guaranteed at least for fifteen years through the launched of three sensors onboard the METOP satellite series (MetOp-A and -B launched in 2007 and 2012, respectively, and MetOp-C expected to be launched in 2017).

A full documentation of the IASI data quality and an assessment of the consistency among IASI atmospheric observations and against a reference are required for a proper scientific use of these long term records. With this objective, the Spanish NOVIA project (Towards a Near Operational Validation of IASI level 2 trace gas products, www.novia.aemet.es) was proposed. This presentation summarizes the main results and conclusions of the project. Firstly, the tools and methodology we have developed are presented. These tools perform a quasi near-real time monitoring of the consistency and quality of IASI trace gas Level 2 (L2) operational products (water vapour, ozone, carbon monoxide, carbon dioxide, methane and nitrous oxide) generated by the EUMETSAT Polar System. As reference technique, we have used the ground-based high quality FTS (Fourier Transform Spectrometer) data recorded at Izaña Observatory since 1999. Secondly, the quality assessment of the historic IASI time series is addressed, considering the different IASI L2 processor versions used for retrieving the IASI products: version 4 was released in June 2008, version 5 in September 2010 and version 6 in September 2014.

Preference of presentation: Poster.

Prime GSICS Corrections, using double-differences of IASI-A and -B against the IR channels of Meteosat/SEVIRI

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ABSTRACT

To achieve the aim of the Global Space-based Inter-Calibration System (GSICS) to ensure consistency among the world's meteorological satellite instruments, an algorithm has been developed to correct the calibration of the infrared channels of geostationary imagers, such as Meteosat/SEVIRI, to be consistent with Metop-A/IASI, as the primary GSICS reference.

This paper introduces the basis of this inter-calibration algorithm, and extends it to combine comparisons from other reference instruments. In particular, double-differences of GSICS Corrections derived using the IASIs on Metop-A and -B are used to define a delta correction, which allows comparisons with multiple references to be combined, based on their relative uncertainties, in a way metrologically consistent with the primary reference, to generate what are referred to as Prime GSICS Corrections. These support the creation of Fundamental Climate Data Records, spanning extended periods with multiple reference instruments.

Particular emphasis will be placed on the analysis of the double differences between Metop-A/IASI and Metop-B/IASI over SEVIRI's relatively broad spectral bands. These results show no significant differences between the calibration of the mid- and short-wave bands of IASI-A and -B were found. However, there are small (<0.05K), but statistically significant differences in the long-wave band, where IASI-B is consistently warmer than IASI-A. These differences are found to be stable over a 2.5 year period starting in March 2013.

Defining Water Vapour Profiles from Nadir Sounders for the GEWEX Water Vapor Assessment

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ABSTRACT

The GEWEX Water Vapor Assessment (G-VAP) was initiated by the GEWEX Data and Assessments Panel (GDAP) with the aim of characterising the current state of the art water vapour products being constructed for climate applications. The result of these efforts is to aid in the selection of suitable water vapour products by GDAP for its production of globally consistent water and energy products.

While legacy satellite observations have produced records of total column water vapour (TCWV), the new generation of nadir hyperspectral infrared sounders such as the Infrared Atmospheric Sounding Interferometer (IASI), Cross-track Infrared Sounder (CrIS) and future missions like IASI-NG will be able to provide a water vapour record with an increased tropospheric resolution spanning at least 30 years. With this in mind, there is a need within G-VAP to characterise water vapour profile products from these sensors for consistent comparisons in the future. In this poster we present the partial column profile concept and its significance for climate analysis. This approach uses the cumulative degrees of freedom as a new concept to define the vertical resolution of the retrieved profile over a series of slab layers. Furthermore, we demonstrate how it can be applied in a consistent manner to inter-comparisons between either other satellite observations or *in situ* measurements.

Evaluation of IASI total ozone accuracy by comparisons with SAOZ and all other satellites measurements in the tropics and at mid-latitudes

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Topic: Validation techniques and intercomparison
Preference: Oral

ABSTRACT

High accuracy global total ozone measurements from space are key data for evaluating the amplitude of ozone depletion, understanding its contribution and consequences on climate change and predicting the future evolution of both ozone and climate. Long series of total ozone data are available, but showing still systematic significant differences between them. Here most recent data available from IASI A and B are compared to SAOZ NDACC UV-Vis ground-based measurements at several stations in the tropics and mid-latitudes, as well as all other satellites data available since the beginning of IASI operations in 2007. The list of satellites includes GOME, SCIAMACHY, GOME2 and OMI reprocessed with the GODFIT V3 (GOME-Type Direct FITing) algorithm developed in the frame of the ESA Ozone Climate Initiative (Lerot et al., 2014), the NASA SBUV v8.6 (McPeters et al., 2013), the NASA-AURA-OMIT and OMID (Levelt et al, 2007).

According to these comparisons, the IASI A-B ozone columns are systematically overestimated by 2 - 6%, depending on the station and the satellite, and the difference between all of them is showing more or less seasonality of amplitude depending also on the satellite and the station.

Mean biases are attributed to smaller ozone absorption cross-sections in the IR compared to the UV and visible and also to longitudinal ozone profiles variations ignored in most satellite retrievals.

When corrected for mean biases, the seasonality of the differences between IASI, SAOZ and most others is generally smaller than ± 1% that is of the order of magnitude of the dispersion and thus random uncertainty of the measurements, except in a few specific cases:

a) the presence of a larger 2-3% peak IASI-Sat difference in the monthly mean in May at OHP on both IASI A and B suggesting a retrieval error on all IASI data on that month but of totally unknown origin;
b) a larger seasonality of the 4 CCI GOFDIT processed satellites compared to IASI and others suggesting a slight systematic error related to the use of zonal mean O3 profiles climatologies ignoring longitudinal variations;
c) larger dispersion, seasonality and moreover opposite seasonality phase of NPP at southern mid-latitudes indicative of an error in those data files in the southern hemisphere;
d) and, finally, an overestimation of IASI ozone in Reunion Island in coincidence with hurricanes, suggesting that high altitude clouds are not properly removed in the IASI data sets.

Shown in the presentation will be the illustration of the IASI- SAOZ- Sat differences at all SAOZ stations and possible explanations when significant differences are observed.

Radiometric and spectral inter-comparison of IASI:

IASI-A / IASI-B, IASI / AIRS, IASI / CrIS

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ABSTRACT

IASI-A and IASI-B have been in operation respectively on board MetOp-A since June 2007 and MetOp-B since April 2013. The radiometric stability and consistency of both IASI with respect to each other and to the other thermal infrared sounders have important implications for meteorological and climate purposes, including the validity of long data records. IASI-A is considered by the GSICS community as a reference sensor for the radiometric calibration at high spectral resolution.

CNES is in charge of the performances of the two IASI instruments. One of the associated tasks is to compare the calibration of IASI-A with IASI-B and of each IASI with AIRS/Aqua and CrIS/NPP using level 1 observations. We routinely perform statistics on common observations by couples of sensors in order to determine radiometric and spectral biases between sounders. Using several years of IASI data, we now have distance on our results with several seasons and observation conditions.

For IASI-A vs IASI-B, we use the numerous common off-nadir observations with 50 minutes delay. For IASI vs CrIS and AIRS, we use the simultaneous nadir overpasses at high latitudes. In each case soundings are spatially averaged, and radiometry is compared on spectrally broad pseudo-channels and at full spectral resolution (demanding the re-convolution of spectra for IASI vs CrIS and AIRS). Sensitivity studies are presented, for example by pixel number, brightness temperature of geophysical conditions. A spectral inter-comparison between both IASI is also performed, based on the cross-correlation of spectra.

Our results show that the inter-calibration of the five couples is stable, with very low radiometric biases compared to the requirements (<0.1K for IASI-A / IASI-B, <0.2K for IASI / CrIS and IASI / AIRS). The largest biases are observed in the LWIR bands. These results provide feedback on the IASI non-linearity algorithm parameters.

Atmospheric profile retrievals from IASI in the framework of the Concordiasi campaign

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One of the main goals of the Concordiasi campaign was to validate the atmospheric profiles and surface parameters retrieval techniques from satellite sensors and mainly from IASI. During the main field campaign, between September and December 2010, 13 super-pressure balloons from CNES were launched from Mc Murdo. They were fitted with the NCAR dropsounding facility. More than 600 dropsondes were released with various purposes, including coincident Metop overpasses to validate IASI retrievals. In this study, we present retrieval statistics using IASI operational settings. Then new developments (new channel selection, non-diagonal R matrix, etc.) will also be evaluated

Validation IASI Temperature and Humidity Sounding Retrievals over Tropical Atlantic Ocean during PIRATA cruises Using Radiosonde Observations

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Abstract

This article presents the results obtained from the comparison between Infrared Atmospheric Sounding Interferometer (IASI) retrieval profiles and radiosonde data obtained during the PIRATA (Prediction and Research Moored Array in the Tropical Atlantic) campaigns cruises. The Radiosondes were launched from the Brazilian Navy Oceanographic Ship during its transects over the Tropical Atlantic Ocean in order to make the PIRATA buoys maintenance. The radiosonde data include the years 2008 (March-May), 2009 (March-September), 2010 (July-September), 2011 (August-October), 2013 (March-June) and 2014 (July-September). The bias and RMSE (Root Mean Square Error) between the IASI retrieval and radiosonde temperature and humidity vertical profiles are obtained to examine the IASI performance retrieval over the Atlantic Ocean.