Radiative Transfer in the Middle and Upper Atmosphere in the Context of Infrared Satellite Observations of the Lower Atmosphere

Artem G. Feofilov [(1)], R. Armante [(2)], L. Rezac [(3)], A. Kutepov [(4)], V. Capelle [(5)], M. Rey [(6)], A. Nikitin [(7)], and V V. Tyuterev [(8)]

(1, 2, 5) CNRS/IPSL Laboratoire de Météorologie Dynamique
Ecole Polytechnique, Route de Saclay, 91128 Palaiseau, France
(3) Max Planck Institute for Solar System Research
Goettingen, Germany
(4) The Catholic University of America / NASA GSFC
Greenbelt Rd, Greenbelt, MD, USA
(6, 8) GSMA, University of Reims
Reims, France
(7) QUAMER Laboratory of Tomsk University
Tomsk, Russia
EMail: artem.feofilov@lmd.polytechnique.fr

ABSTRACT

In recent decades, more and more advanced satellite sensors have been measuring the Earth's atmosphere, clouds, aerosols, and surface characteristics to enable enhancements in weather prediction, climate monitoring, and environmental change detection. In particular, hyperspectral instruments measuring the thermal infrared part of the spectrum provide a plethora of information about atmospheric temperature, trace gas concentration, clouds, aerosols, and surface in narrow spectral channels. These instruments are usually flying onboard a series of meteorological platforms and are therefore predestined for climate monitoring.

The results obtained in this field are already impressive: mid-tropospheric temperature and humidity profile retrieval with an accuracy of up to 1 K and 10%, respectively; near real-time mapping of chemical species and aerosols; tracking the greenhouse gases, cloud properties retrieval, and the list is not exhaustive.

However, there is a limitation, which does not allow a full usage of all advantages these instruments offer. The problem is linked with the radiation of the atmospheric layers, for which the conditions of local thermodynamic equilibrium (LTE) do not hold, and the populations of vibrational levels deviate from the Boltzmann distribution for the local kinetic temperature. The non-LTE effects strongly limit the exploitation of the channels sensitive to the contribution of the middle and upper atmosphere. For IASI, this applies to the whole 4.3 μm CO_2 band, and certain lines of 15 μm CO_2 band, 6.3 μm H_2O band, and 4.8 μm CO band. For the infrared limb observations of the lower atmosphere, the list is longer.

Even though current retrievals take into account the atmosphere up to the mesopause level, the complexity of the processes governing the vibrational level populations in the upper atmosphere precludes using exact non-LTE calculations. As a result, some channels cannot be used at all or empirical corrections are introduced. This issue has been clearly identified by the radiative transfer community, as well as by atmospheric composition and climate communities.

In this work, we show an approach to applying complex non-LTE models developed in recent years to the operational retrievals in the lower atmosphere.

MIPAS database: New HNO_3 line parameters at 7.6 μm derived from MIPAS satellite measurements

A.Perrin[(1)], J.-M. Flaud,[(1)] M. Ridolfi,[(2)] J. Vander Auwera,[(3)] and M. Carlotti[(4)]

[(1)] ***Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA),*** *UMR 7583 CNRS, Univ. Paris Est Créteil et Paris Diderot, Institut Pierre Simon Laplace, 94010 Créteil, France*

EMail: Agnes.Perrin@lisa.u-pec.fr, Jean-Marie.Flaud@lisa.u-pec.fr

[(2)] ***Dipartimento di Fisica e Astronomia,*** *Università di Bologna, Bologna, Italia &* ***Istituto di Fisica Applicata "N. Carrara" (IFAC) del CNR,*** *50019 Sesto Fiorentino (FI), Italia*

EMail: marco.ridolfi@unibo.it

[(3)] ***Service de Chimie Quantique et Photophysique****, Université Libre de Bruxelles, 1050 Brussels, Belgium*

EMail: jauwera@ulb.ac.be

[(4)] ***Dipartimento di Chimica Industriale "Toso Montanari"****, Università di Bologna, 40136 Bologna, Italia*

EMail: massimo.carlotti@unibo.it

ABSTRACT

Improved line positions and intensities have been generated for the 7.6 μm spectral region of nitric acid. They were obtained relying on a recent reinvestigation of the nitric acid band system at 7.6 μm and comparisons of HNO_3 volume mixing ratio profiles retrieved from the "Michelson Interferometer for Passive Atmospheric Sounding" (MIPAS) limb emission radiances in the 11 and 7.6 μm domains. This has led to an improved database called "MIPAS-2015". Comparisons with available laboratory information (individual line intensities, integrated absorption cross sections, and absorption cross sections) show that MIPAS-2015 provides an improved description of the 7.6 m region of nitric acid. This study should help to improve HNO_3 satellite retrievals by allowing measurements to be performed simultaneously in the 11 and 7.6 μm micro-windows. In particular, it should be useful to analyze existing MIPAS and IASI spectra as well as spectra to be recorded by the forthcoming "Infrared Atmospheric Sounding Interferometer – New Generation" (**IASI-NG**) instrument.

All-sky radiative transfer calculations for IASI-NG: the σ-IASI-as code and its applications.

Giuliano Liuzzi [(1)], Guido Masiello [(1)], Carmine Serio [(1)] and Sara Venafra [(1)]

[(1)] ***School of Engineering, University of Basilicata***

Viale Ateneo Lucano, 10, 85100, Potenza, Italy

EMail: giuliano.liuzzi@unibas.it

guido.masiello@unibas.it

carmine.serio@unibas.it

sara.venafra@unibas.it

ABSTRACT

In order to give continuity in the service offered by IASI interferometers, EUMETSAT has scheduled the operativity of a new generation of interferometers, named IASI-NG (IASI New Generation).

IASI-NG is a key payload element of the MetOp-SG (Second Generation), a series of European meteorological polar-orbit satellites. IASI-NG is intended to pursue not only a continuity with IASI monitoring capabilities, but also to provide more advanced technical performances, as far as spectral resolution and signal-to-noise ratio are concerned.

Such new challenging requirements, together with the scientific perspective and monitoring capabilities offered by this new instrument, make of crucial importance the availability of a new, complete radiative transfer model to simulate the radiance as it is observed by IASI-NG.

In this context, we present the new σ-IASI-as ('as' standing for all-sky) radiative transfer code. Like its predecessor σ-IASI, the code is able to calculate both clear and cloudy sky radiances, as well as their Jacobians (i.e. derivatives) with respect to any desired geophysical parameter. In addition, σ-IASI-as can simulate the extinction effect of the most common types of atmospheric aerosols and of clouds via ab-initio Mie calculations, without dramatically affecting the code performances, and can also simulate the contribution due to solar irradiance. We briefly describe the analytical scheme on which the code is based, and its implementation focusing on the next generation of IASI instruments.

Moreover. we document the robustness of the radiative transfer scheme by comparison with the reference line-by-line model LBLRTM v12.2. We will also show some sample simulations and retrievals obtained using σ-IASI-as, with a particular focus on IASI-NG, for which this new model is already available for both operational, sensitivity studies, and research purposes.

RTTOV for hyperspectral IR sounders: Status and future developments

Jérôme Vidot [(1)], Pascal Brunel [(1)], James Hocking [(2)], Marco Matricardi [(3)], David Rundle [(2)], Pascale Roquet [(1)] and Roger Saunders [(2)]

[(1)] ***CMS/Météo-France***
Avenue de Lorraine, F-22300, Lannion, France
jerome.vidot@meteo.fr, pascal.brunel@meteo.fr, pascale.roquet@meteo.fr

[(2)] ***Met-Office***
FitzRoy Road, EX1 3PB, Exeter, United Kingdom
james.hocking@metoffice.gov.uk, david.rundle@metoffice.gov.uk
roger.saunders@metoffice.gov.uk

[(3)] ***ECMWF***
Shinfield Park, RG2 9AX, Reading, United Kingdom
marco.matricardi@ecmwf.int

ABSTRACT

We present the status and the future developments of the fast radiative transfer model RTTOV developed and maintained by the EUMETSAT NWP SAF. In this poster we will only focus on hyperspectral infrared (IR) sounders. RTTOV is primarily for the assimilation of satellite radiance observations in NWP models at National Weather Services. It is also used for other operational or research applications such as instrument monitoring, assimilation in reanalysis, physical retrievals, producing simulated satellite imagery, etc. It is also being increasingly used by Universities for their research activities in satellite remote sensing. RTTOV can also be used for teaching and training applications with a dedicated graphical interface. For hyperspectral IR applications, RTTOV is able to simulate current instruments (i.e. AIRS, IASI and CrIS), but also former instruments (IRIS) and the next generation instruments (IASI-NG and MTG-IRS). Simulations include most atmospheric effects (solar contribution, NLTE, aerosol and clouds scattering) and surface emissivity models. We describe here the recent technical and scientific developments of RTTOV v11.3 (i.e., principal component updates, angular correction of land surface emissivity, etc.) and the futures developments for RTTOV v12 (sea surface emissivity model update, variable SO_2, HT-FRTC interface, etc.).

Learning from IASI with RTTOV-GUI

Pascale Roquet[1]

[1] ***Centre de Météorologie Spatiale***
Avenue de Lorraine, B.P. 50747 22307 , Lannion, FRANCE
EMail: pascale.roquet@meteo.fr

ABSTRACT

RTTOV-GUI is the graphical user interface for the fast radiative transfer model RTTOV. This capability was designed for educational purposes. For instance, it has been successfully used in the last ECMWF satellite data assimilation training course. This poster shows several examples of using RTTOV-GUI with IASI or IASI-NG. As an illustration, a user can simulate the impact on the IASI top of atmosphere spectrum and on the IASI jacobians of a modification of all the RTTOV input data, such as vertical atmospheric profile including some trace gases, surface parameters and viewing angles. It is also possible to compare a spectrum computed with reconstructed radiances from PC-RTTOV (the principal component based version of RTTOV) to a spectrum computed by classical RTTOV. Additionally, since RTTOV version 11.3, a 1D-VAR retrieval function based on the NWP SAF package has been implemented. It allows the user to interactively retrieve temperature and water vapour profiles from a background profile, by selecting different IASI channels, and visualise the results.

4A/OP: A fast & accurate operational forward radiative transfer model: application to IASI and IASI-NG solar bands

Emilien Bernard [(1)], B. Tournier [(1)], C. Standfuss [(1)], S. Bijac [(1)],

R. Armante [(2)], V. Capelle [(2)], N.A. Scott [(2)], A. Chédin [(2)],

A. Deschamps [(3)], D. Jouglet [(3)], C. Deniel [(3)]

*[(1)] **NOVELTIS***
153 rue du Lac, F-31670 Labège, France
EMail: emilien.bernard@noveltis.fr

*[(2)] **LMD/CNRS Ecole Polytechnique***
F 91128 Palaiseau, France
EMail: armante@lmd.polytechnique.fr

*[(3)] **CNES***
France
EMail: adrien.Deschamps@cnes.fr

ABSTRACT

4A (Automatized Atmospheric Absorption Atlas) is a fast and accurate line-by-line radiative transfer model developed and validated at LMD for the computation of transmittances, radiances and Jacobians from the far to the near infrared [20 – 0.75 µm], and is particularly efficient in terms of accuracy and computation time (http://ara.abct.lmd.polytechnique.fr/index.php?page=4a)

Within this frame, and now for many years with the support of CNES, NOVELTIS has developed an "operational" version of this code called 4A/OP for distribution to registered users. This version is regularly improved and validated by LMD, NOVELTIS and CNES. It also includes a graphical user interface and reference documentation. The associated Website http://4aop.noveltis.com/ provides an on-line registration form.

This software is used by several research groups and can be integrated in operational processing chains including inverse problems. In particular, 4A/OP is used by CNES as the radiative transfer model for IASI level 1 Cal/Val and level 1 operational processing for Metop-A and Metop-B and deeply involved in the definition of future CNES missions (Microcarb, IASI-NG, MERLIN).

After a description of 4A/OP, the poster is dedicated to the presentation of two studies in the IASI and IASI-NG solar bands.

First, in the frame of the IASI-NG phase B preparation, a preliminary study has been performed concerning the impact on the IASI-NG spectra of the polarization by the particles. Linked to 4A, the multi-scattering radiative transfer code VLIDORT has been used to simulate the IASI-NG spectra in case of scattering by aerosols and cirrus taking into account the polarization. A sensitivity study has showed that the polarization factor is significant in the MWIR region for a desert dust aerosol and sunlight directional effects significantly impact polarization. Based on a geographical distribution of typical aerosols models and on a discretization of the geometry of IASI-NG, the polarization rate has been estimated and the spatial error has been studied. These results will be presented in the poster.

Secondly, related to the conclusions of the GSICS in 2013 that the calibration error between GOES-14 and IASI in the band 3 where the solar influence is not negligible is probably due to the BRDF effect (X. Wu *et al.*, 2009), we started to implement the BRDF contribution in the 4A/OP software. The goal is to show how to improve the simulations in the MWIR by taking into account the BRDF. A first model of BRDF has been implemented characterising the sea-surface in case of glitter. In this poster, we will present the first comparisons between the IASI observations and 4A/OP simulations having included the BRDF contribution.

Comparisons of IASI radiance simulations with LBLRTM, RTTOV, the HT-FRTC and its monochromatic version

Stephan Havemann[(1)], Jean-Claude Thelen[(2)]

(1) Met Office, UK

FitzRoy Road, EX1 3PB, Exeter, United Kingdom of Great Britain

EMail: stephan.havemann@metoffice.gov.uk

(2) Met Office, UK

FitzRoy Road, EX1 3PB, Exeter, United Kingdom of Great Britain

EMail: jean-claude.thelen@metoffice.gov.uk

ABSTRACT

The Havemann-Taylor Fast Radiative Transfer Code (HT-FRTC) allows superfast and very accurate simulations for hyperspectral sensors like IASI, IASI-NG and MTG-IRS. It can even run at ultrahigh spectral resolution down to 10^{-4} cm^{-1}, but it models broadband sensors like MODIS and SEVIRI as well. The underlying concept that makes this possible are principal components at ultrahigh spectral resolution. These principal components which are generated during the code training phase are completely sensor-independent, which means that any number of instruments can be simulated simultaneously in a single run as long as the atmosphere and surface parameters are unchanged. HT-FRTC can simulate clear-sky scenarios and those contaminated by clouds and/or aerosols. The HT-FRTC is part of a variational retrieval system that works with the same principal components and has been successfully used to retrieve atmospheric temperature, trace gases, cloud, aerosol and surface parameters simultaneously.

The HT-FRTC uses the monochromatic gaseous optical properties for the HITRAN gases as provided by LBLRTM12.2. However, the HT-FRTC has its own modules for the clear-sky and scattering radiative transfer. All the radiative transfer calculations in HT-FRTC are monochromatic. It can be used as a monochromatic code in ultra-high resolution or, alternatively, in its fast code version based on principal components, where only a small number of monochromatic radiative transfer calculations are required to calculate the principal component scores. The fast code version can generate an accurate ultra-highly resolved spectrum and simulate any sensor.

RTTOV is another radiative transfer code, which is also based on LBLRTM12.2, however there is no ultra-high-resolution version of RTTOV and the RTTOV calculations are always polychromatic.

The subject of this contribution are very detailed, global comparisons of LBLRTM, HT-FRTC and RTTOV for the hyperspectral infrared sensors. Most of the examples are for IASI. To obtain meaningful results great care has been taken to run the codes under exactly identical conditions. The codes are compared with each other for a global set of 25000 different atmospheric and surface conditions as provided by the datasets supplied by the NWP-SAF. In addition to the radiances the Jacobians are compared, which are essential for retrievals.

In addition to comparisons between these codes the importance of a number of other factors that may have a bearing on the results of the simulations have been investigated. While RTTOV includes 17 trace gases in total, HITRAN includes many more trace gases and the impact of these extra gases is studied. Also investigated is the influence of the spectral resolution of the monochromatic calculations on the simulations. Finally, even when using the linear-in-tau approximation, the finite vertical resolution in the radiative transfer calculation limits the accuracy of the radiance calculations.

The GEISA spectroscopic database 2015 Edition in the frame of IASI remote sensing applications and IASI-NG phase B studies

Nicole JACQUINET, Raymond ARMANTE, Noëlle SCOTT, Laurent CREPEAU, Anis BOUHDAOUI, Alain CHÉDIN

Contact : nicole.jacquinet@lmd.polytechnique.fr

Tel: +33169335162

Laboratoire de Météorologie Dynamique, CNRS, Ecole polytechnique, Université Paris-Saclay, 91128 Palaiseau, France

The role of molecular spectroscopy in modern atmospheric research has entered a new promising perspective phase for remote sensing applications (meteorology, climatology, chemistry) with the advent of highly sophisticated spaceborne spectroscopic instruments. With the launch of high spectral resolution instruments: like AIRS on board EOS-Aqua (2002), GOSAT (2009), IASI on Metop-A (2006), Metop-B (2012), Metop-C (2018), and Suomi NPP (2011), precision needs on spectroscopic data appear to be more and more important.

Since its 40th birthday (*) in June 2014, the LMD GEISA database (**) (Gestion et Etude des Informations Spectroscopiques Atmosphériques: Management and Study of Atmospheric Spectroscopic Information) has entered a new phase, coupling developments in spectroscopy and radiative transfer modelling, to meet the needs of the international space agencies. GEISA is constantly evolving, taking into account the best available spectroscopic data. It comprises not only the line-by-line parameters database (over 5,000,000 entries) in the spectral range from 10^{-6} to 35,877.031 cm^{-1}, but also two additional sub-databases: on infrared and ultraviolet absorption cross-sections and on microphysical and optical properties of atmospheric aerosols.

GEISA, used as reference basis for IASI Level 1 Cal/Val activities at CNES and at LMD (***), is implemented on the CNES/CNRS/IPSL "AERIS/ESPRI/Ether" Products and Services Centre WEB site: http://www.pole-ether.fr, where all the archived spectroscopic data and related information can be handled through user friendly associated management software facilities. It is used on-line by more than 300 laboratories working in various domains like atmospheric physics, planetology, astronomy, astrophysics.

In the frame of the 2015 GEISA last release and of the work in progress in the CNES-MENINGE scientific group for the future of the IASI instruments (IASI-NG), the current contents and planned evolution of each of the GEISA three sub-databases will be presented. Special emphasis will be given to the evaluation of the quality of some spectroscopic parameters (position, intensity,… as well as to more minor parameters like pressure shift) taken into account some feedbacks from Metrology groups and from groups developing remote sensing instrumentation.

(*) : http://www.lmd.jussieu.fr/geisa2014/
(**) http://ara.abct.lmd.polytechnique.fr/index.php?page=geisa-2
(***) http://ara.abct.lmd.polytechnique.fr/index.php?page=calibration-validation

Proposed topic: Spectroscopy and Radiative TRansfer

Preference of presentation: Poster