4A/OP : A fast and accurate operational forward radiative transfer model
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Abstract
4A is a fast and accurate line-by-line radiative transfer model developed and validated at LMD (Laboratoire de Météorologie Dynamique) for the computation of transmittances, radiances and Jacobians, particularly efficient in terms of accuracy and computation time. Within this frame, and with the support of the CNES (the French Space Agency), NOVELTIS has created an operational version of the code called 4A/OP for distribution to registered users. This version is regularly updated and improved by the LMD, NOVELTIS and CNES. This software is used by several research groups and can be integrated in operational processing chains including inverse problems processing. 4A/OP stands for a high-performance radiative transfer code in the infrared, and recently in the Short Wave InfraRed (SWIR). In particular, 4A/OP was selected by CNES as the official radiative transfer model for MIP-2012, IASI Level 1 and Level 2 operational processing for MetOp-A and MetOp-B. Moreover, 4A-SWIR was selected as the reference code for Microcaviab and is also used for the GOSAT retrievals and spectral calibration. A new version of the software is ready for distribution. After a description of 4A/OP, additional and updated capabilities (spectrometry, scattering) as well as a validation status using IASI Level 3 observations are presented.

4A/OP Operational release for 4A
4A stands for Automated Atmospheric Absorption Atlas. 4A is a fast and accurate line-by-line radiative transfer model particularly efficient in the infrared region of the spectrum. 4A/OP is a user-friendly software for various scientific applications, co-developed by LMD (Laboratoire de Météorologie Dynamique, France) and NOVELTIS with the support of CNES (the French Space Agency).

Why is 4A/OP?
The 4A software package includes the radiative transfer model 4A, initially developed at LMD. The 4A calculation relies on a multi-dimensional interpolation using a pre-built optical thickness database called “Atlases” [1].

- Atlases
4A allows the fast computation of the transmittances and the radiances, thanks to the use of a compact database of the atmospheric and monochromatic optical thicknesses.
• For up to 53 atmospheric molecular species from the latest version of GEISA-11 database (reference mixing ratio profiles).
• For 12 nominal atmospheres (12 temperature profiles, 7 K distant).
• For a spectral range from 0.3 to 50.0 µm.
• For up to 53 atmospheric molecular species from the latest version of GEISA-11 database.
- Radiance computation
1. Interpolation in the atlases (optical thickness profile) given atmospheric condition.
2. Transmission calculation.
3. Interpolation of the radiative transfer equation :  
• High resolution spectrum
4. If necessary, convolution with any instrument function (IF).
5. Convolved spectrum.

The computation is performed in a spherical atmospheric model, user defined observation level for zenith, nadir or limb observations.

4A computes the radiance spectrum in a user-defined spectral domain in the infrared region of the spectrum. The usual domain is between 500 and 3000 cm⁻¹. 4A can be used for a wide variety of surface and aerosol atmospheric conditions, including solar contribution and scattering by aerosols and cirrus (coupled with DISORT).

- 4A/OP output
• High spectral resolution spectra (nominal spectral resolution, 0.05 cm⁻¹).
• Convolved spectra with various types of instrumental functions.
• Jacobians on user-defined layers: partial derivatives of the radiative transfer with respect to the temperature, gas mixing ratio and emissivity. They allow the model coupling with any inversion algorithm for the atmospheric constituent retrieval from infrared radiometers measurements.

Software features
- Graphical User Interface
The 4A/OP GUI allows the user to create a basic 4A/OP input file by selecting values with buttons, pull-down menus, and text fields.
• Running 4A/OP
4A/OP runs on any platform with several Fortran 90 compilers (g77, f90, Intel, gfortran/g++), and has been tested on Sun and Linux PC.

- Run time examples (CPU time)

<table>
<thead>
<tr>
<th>Machine</th>
<th>LMD Athena Grid (10e6 grid points)</th>
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<tbody>
<tr>
<td>Xeon E5-2690 (2.90 GHz)</td>
<td>about 22 s</td>
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- Validation in progress
• Validation of 4A/OP
• Validation on spectroscopy for Merlin
• Validation of 4A/OP on a geometric target of IASI

4A/OP validation at LMD
Validation of 4A/OP through the analysis of Long Time Series of differences between simulated (4A/OP) and observed (IASI) Brightness Temperatures (« deltacs »), IASI bias (2007/2011 for all the channels of B1 and B2).
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4A/OP enhancement
The 4A/OP software is a version of 4A enhanced for distribution to registered users.

Current version : 4A/OP-2012v1.0 (03/2012)
The available operational version includes:
• Regular updating and improvements
• Graphical User Interface (GUI)
• Website http://www.noveltis.fr/4AOP/ including an on-line documentation.
• Distribution with maintenance and assistance: the full software package is available as a freeware product for academic and scientific research.

New updates:
• Scattering for cloud (cirrus) contribution
• New atlas of absorption optical thicknesses
• Improvement of CO₂ line mixing
• New GETSA 2001 spectroscopy pressure shift for H₂O, CO₂ and N₂O
• Update reference gas mixing ratio profile
• Improved TIRS formulation
• Update and improved the GUI

Technical developments
• Further validation with real measurements
• CO₂ Line mixing
• Technical developments
• Speed up in scattering code
• Graphical user interface to include SWIR features.

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References