4ARTIC :
4A Radiative Transfer Inversion Code

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CONTEXT

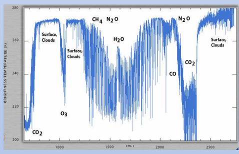
4ARTIC (4A Radiative Transfer – Inversion Code) is a tool developed at CNES **for retrieving gaseous or temperature profiles from atmospheric spectra** and **estimating the performance of an inversion**. This tool has been designed for the Microcarb mission and then has been extended to the thermal infrared domain to **analyze the IASI-NG performances** at level 2.

For several months, an operational version of 4ARTIC with a Graphical User Interface is developed by Thales Services, under the direction of CNES.

The inversion performed by 4ARTIC is coupled with the very accurate **radiative transfer model 4A/OP** :

- A line-by-line radiative transfer model, adapted to high spectral resolution (5.10^{-4} cm^{-1})
- A rapid computation due to a prior creation of an optical thickness database (Atlas)
- A spectral domain applied to SWIR/TIR (600 – 13000 cm^{-1})
- Based on GEISA spectroscopic parameters, regularly updated

The **4A/OP-subroutine** is used in 4ARTIC. Specifically designed for inversion algorithms, it distinctly reduces computation time during iterative call to radiative transfer calculation.



Example of a IASI spectrum

ALGORITHM

The inversion performed by 4ARTIC is based on the **optimal estimation method (OEM)**. This method gives the maximum probability of the a posteriori solution of an inverse problem. The goal is to retrieve a state vector x, which contains geophysical products to retrieve, from *a priori* information, an observed spectrum y, a measurement noise and the Jacobian derived from radiative transfer calculation.

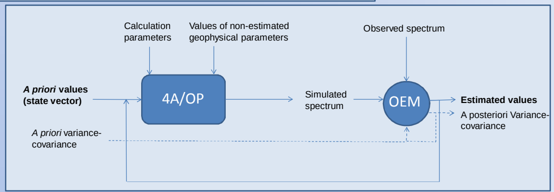
Optimal estimation formalism (Bayesian approach) :

$$x_{i+1} = x_a + (S_a^{-1} + K_i^T S_\varepsilon^{-1} K_i)^{-1} K_i^T S_\varepsilon^{-1} [(y - F(x_i)) + K_i(x_i - x_a)]$$

x_i : state vector at iteration i
x_a : *a priori* state vector
S_a : *a priori* error covariance matrix of state vector
K_i: Jacobian matrix at iteration i
S_ε: error covariance matrix of measurement noise
y: measurement vector
$F(x_i)$: simulated spectrum

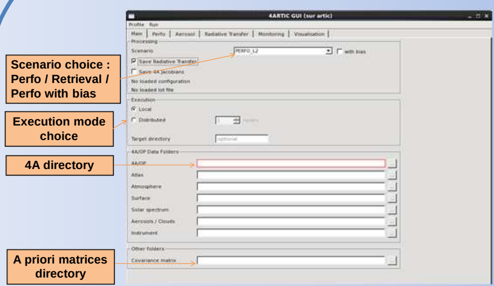
Comment :
The OEM formalism also allows to estimate the performance of the inversion (i.e. the *a posteriori* variance of the state vector) without performing the complete inversion :

$$\hat{S} = (K^T S_\varepsilon^{-1} K + S_a^{-1})^{-1}$$

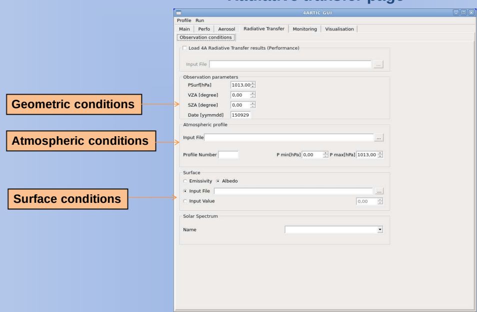


4ARTIC software and Graphical User Interface

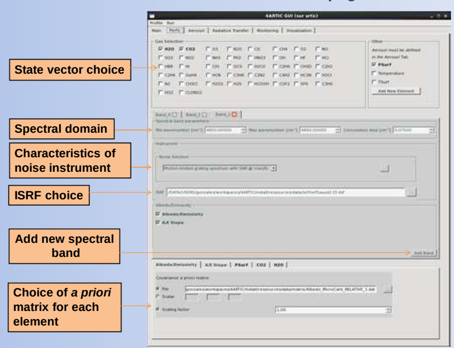
Main page



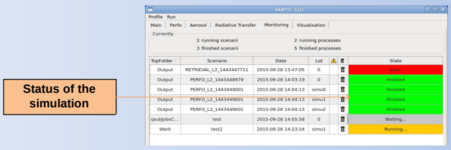
Radiative transfer page



Performance page



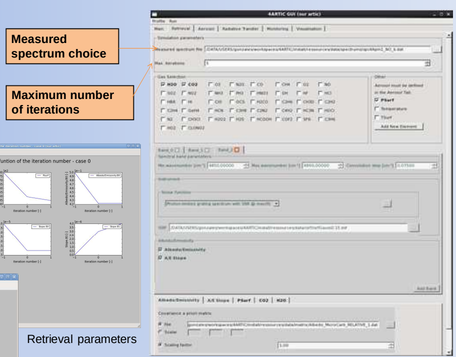
Monitoring page

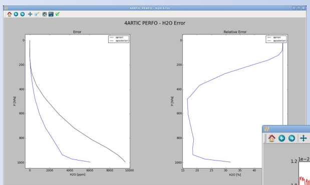


Description
- Developed by Thales in Python (Numpy/SciPy)
- Call to 4A (Fortran) from Python
- User parameters specified via a GUI (PyQt)
- Visualization tools (Maplotlib)
- Simulation can be launched on several calculation nodes
- User manual

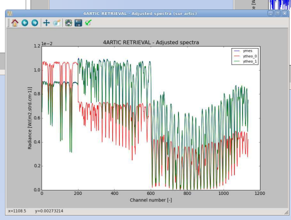
Two functionalities :
- Performance mode
- Retrieval mode

Retrieval page

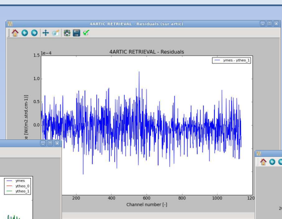




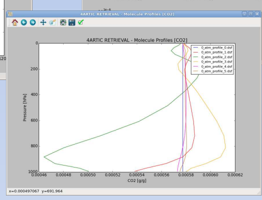
Estimated performance



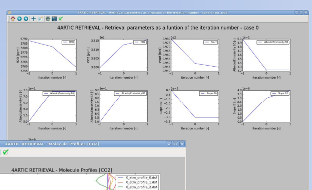
Estimated spectrum



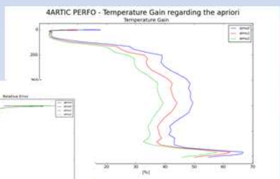
Residuals

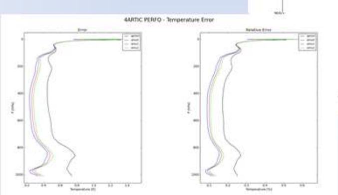


Estimated molecule profiles


Retrieval parameters

IASI-NG applications

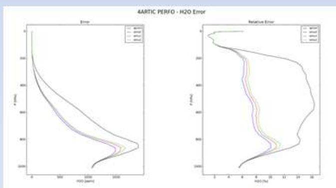


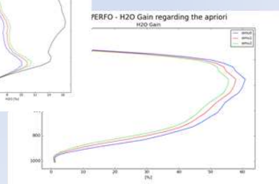


A posteriori error and error gain estimations compared to the *a priori* error for the temperature profile

4ARTIC has been used in many applications for IASI-NG:

- Evaluation of the *a posteriori* error of the state vector for different values of instrumental noise
- Impact of the instrumental noise on the estimation of temperature and water vapor profiles
- Estimation of the *a posteriori* error and gain compared to the *a priori* values for several pressure levels





A posteriori error and error gain estimations compared to the *a priori* error for the water vapor profile