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## RTTOV v13 Graphical User Interface


Pascal Brunel, Jean-Luc Piriou,  
Pascale Roquet, Jérôme Vidot

Météo-France

This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 7 December 2016, between EUMETSAT and the Met Office, UK, by one or more partners within the NWP SAF. The partners in the NWP SAF are the Met Office, ECMWF, DWD and Météo France.


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Change record			
Version	Date	Author / changed by	Remarks
1	06/09/2016	P. Roquet	First version
2	02/05/2017	P. Roquet	note about matplotlib version
3	07/03/2018	P. Roquet	Updates for version 12.2
4	11/02/2019	P. Roquet	Updates for version 12.3
5	20/02/20	P. Roquet	Updates for version 13.0
6	18/09/20	P. Roquet	Note about wxpython installation
7	19/10/20	J. Hocking	Updates after DRR
8	20/09/21	P. Roquet	Clarification about 1D-VAR window input parameters
9	16/11/21	P. Roquet	Updates after DDR
10	04/11/22	P. Roquet	Updates for version 13.2

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## 1. Introduction

This document explains how to install and run the graphical user interface of RTTOV: RTTOV GUI. This interface allows the user to modify an atmospheric profile, run RTTOV for a given instrument to produce the radiances and brightness temperatures, and display instantaneously the results.

With RTTOV GUI, the user will be able to:

- load and modify an atmospheric profile (gas content, aerosol content, cloud content)
- change surface parameters and options
- load an emissivity and a BRDF atlas
- run the direct model and display the results (simulated radiances, brightness temperatures and, if computed, reflectances).
- run the Jacobian model (RTTOV-K) and display the results (derived T and gas content and Tskin only)
- run PC-RTTOV (direct and Jacobian model)
- perform an 1DVAR retrieval

What users cannot not do with RTTOV GUI:

- run the adjoint model (AD) or tangent linear model (TL)
- enter/modify cloud or aerosol optical parameters profile for each channel (rttov\_cld\_opt\_param and rttov\_aer\_opt\_param options)
- enter/modify the cloud liquid water content of a profile for MW simulations
- run RTTOV-SCATT (the MW scattering model)

A large enough screen (at least 1400x900) is strongly recommended, as RTTOV GUI produces many windows and some of them can be large.



We also encourage users to refer the RTTOV User Guide.

### 1.1. Installation

#### 1.1.1. Python environment

Using RTTOV GUI requires the following software to be installed:

- python3 (version 3.9)
- wx python version 4.2.0
- numpy (<https://numpy.org/>)
- matplotlib with backend\_wxagg (<http://matplotlib.org/>)

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- h5py (<http://www.h5py.org/>)
- pypubsub (<https://pypi.org/project/PyPubSub/>)
- attrdict 2.0.1 (needed by wxpython 4.2.0)

The easiest way to get to install the python packages is to create a dedicated python environment with pipenv or conda and then install all the required python packages with the file named requirements.txt (with pip) or the file rttovguienv.yml (with conda). Both files are available under the gui directory.

Exemple :

**with pip:**

```
pip install [ --user] -r requirements.txt
```

**with conda:**

You can use the script `install_python_for_gui.sh` to install the python conda environment (python 3.9). This script will download the miniconda installer and install python and create a python environment named `rttovgui` in a directory named `miniconda3` in your `HOME` directory. This script will also modify your `.bashrc` file. The installation of this miniconda environment requires ~2.9 Go of disk space. You can change the `PREFIX` variable in the script and “prefix” in the `rttovguienv.yml` file (last line) to provide an alternative emplacement for the python installation.

You can also use the commands from the script to install the python environment by yourself.

If the installation of python3.9 is not suitable for your installation, you can use the conda yaml file for python 3.7: `rttovguienv_python3.7.yml`

**Note:** Python 3.10 or Python 3.11 are not recommended: wxpython and attrdict are not ready for these recent versions of python.

### 1.1.2. Compilation


Once the python environment is activated you can compile RTTOV with the `rttov_compile.sh` script as explained in the RTTOV v13 users guide and answer “y” to the question asking if you want RTTOV GUI to be compiled. Note that conda usually has its own versions of the HDF5 libraries (for example under `~/miniconda3/lib/`). It is recommended to compile RTTOV against the conda version of these libraries to avoid library version mismatches.

Do not forget to define your `LD_LIBRARY_PATH` environment variable, this is required at run time for the GUI.

For example:

```
export LD_LIBRARY_PATH=<hdf5_install_dir>/lib:${LD_LIBRARY_PATH}
```

If you specify an installation directory relative to top-level RTTOV directory different than default,

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change the symbolic link to the `rttov_gui_f2py.so` library in the `<PATH_TO_RTTOV>/gui` directory.

### 1.1.3.Example profile datasets

Optional: RTTOV GUI uses either ascii or hdf5 files for the profile variables. To convert the RTTOV test profiles to hdf5, go to the `rttov_test/profile-datasets` directory and run the following commands:

```
./run_convert_test2python.sh
./run_convert_python2hdf5.sh
```

These ascii and hdf5 profiles are included in the package so it is not necessary to run these scripts.

### 1.1.4.Starting the GUI

Modify the `gui/rttov_gui.env` configuration file (see next section).

Then you can run the RTTOV GUI with the following commands:

```
source ./rttov_gui.env
./rttovgui
```

### 1.1.5. MacOS

On MacOS, it is recommended to add to your `~/.bash_profile`:

```
export LC_ALL=en_US.UTF-8
export LANG=en_US.UTF-8
```



in order to avoid problems with matplotlib (unknown locale:UTF-8)

### 1.1.6.Alternative install from a Dockerfile:

If you do not want to install RTTOV and Python, and if you have Docker you can clone the `rttovgui-docker` project:

```
git clone https://gitlab.com/nwpsaf/rttovgui-docker.git
```

and follow the instructions given by the `README.md` file.

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## 2. RTTOV GUI User Manual

### 2.1. Configuration files

The `rttov_gui.env` file contains mandatory environment variables which are used by RTTOV GUI. This file must be customized to your specific installation.

Example of `rttov_gui.env` file:

```
# RTTOV GUI Environment
#
# Mandatory variables:
# -----

# RTTOV GUI installation directory

RTTOV_GUI_PREFIX= # absolute path to the rttov/gui directory e.g.
/home/user/rttov13/gui
export RTTOV_GUI_PREFIX

PATH=${RTTOV_GUI_PREFIX}:$PATH
export PATH

PYTHONPATH=${RTTOV_GUI_PREFIX}:${PYTHONPATH}
export PYTHONPATH

# Optional environment variables: (the defaults are usually OK)
# -----

# Directory for rttov emissivity and BRDF atlases: this should be the directory
# containing the emis_data/ and brdf_data/ directories which hold the atlas
# datasets



RTTOV_GUI_EMISS_DIR=${RTTOV_GUI_PREFIX}/../
export RTTOV_GUI_EMISS_DIR

# Working directory (for rttov gui temporary files)

RTTOV_GUI_WRK_DIR=$HOME/.rttov
export RTTOV_GUI_WRK_DIR

# Default directory for rttov coefficient files

RTTOV_GUI_COEFF_DIR=${RTTOV_GUI_PREFIX}/../rtcoef_rttov13
export RTTOV_GUI_COEFF_DIR
```

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```
# Default directory for profile files

RTTOV_GUI_PROFILE_DIR=${RTTOV_GUI_PREFIX}/../rttov_test/profile-datasets-hdf
export RTTOV_GUI_PROFILE_DIR

system_info=`uname -s`
if [ ${system_info} = "Linux" ]
then
    export cmdpython=python
else
    echo "It seems that Linux is not your system..."
    echo "for python we will use pythonw"
    echo "correct this if necessary"
    export cmdpython=pythonw
fi

# -----

# If you installed the Python dependencies using conda the following can be
# ignored.
# Otherwise you may need to specify the location of your wxPython installation:

# WXPYTHON_PREFIX=    # Directory where wxPython is installed

# PYTHONPATH and LD_LIBRARY_PATH: these must point to your wxPython installation

# PYTHONPATH=${WXPYTHON_PREFIX}/lib/python2.7/site-packages/wx-3.0-gtk2:${WXPYTHON_PREFIX}/lib/python2.7/site-packages/:${PYTHONPATH}
# export PYTHONPATH

# LD_LIBRARY_PATH=${WXPYTHON_PREFIX}/wxpython/lib:${LD_LIBRARY_PATH}
# export LD_LIBRARY_PATH
```

## 2.2. File created by the RTTOV GUI


The RTTOV GUI software will create hdf5 files in its working directory defined by the RTTOV\_GUI\_WRK\_DIR environment variable (~/.rttov by default.). Be aware that if you want to run several instances of RTTOV GUI at the same time, you have to use a different working directory for each instance.



All of these files are encoded in the HDF5 format. It is possible to look at them using the hdfview software for instance. Exporting data to text file is also feasible using the h5dump command.

These files are:

- profile.h5: contains the profile (gas content, aerosol content, cloud content), surface information and RTTOV options.
- surface.h5: contains information about the surface emissivity / reflectance used as input and computed by RTTOV or modified by user.

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- `radr.h5`: contains radiances computed by a run of RTTOV.
- `trns.h5`: contains transmittance computed by a run of RTTOV.
- `kmat.h5`: contains the K matrix computed by a run of RTTOV\_K
- `pc.h5`: contains the pcscores computed by a run of RTTOV\_PC.
- `pckmat.h5`: contains the K\_PC matrix computed by a run of RTTOV\_PC\_K
- `tmpFileErr.log`: error log file from the last run of RTTOV.
- `tmpFileOut.log`: output log file from the last run of RTTOV.
- `rttovgui.log`: RTTOV GUI log file.

### 2.3. *Starting the GUI*

As explained in section 1.1, RTTOV GUI can be started by the following commands:

```
source ./rttov_gui.env
./rttovgui&
```

The RTTOV main window is launched (see Figure 2.3.1): it allows you to load coefficient files (through the RTTOV menu), to open a profile (through the File menu), to modify options, profile and surface parameters if wanted (through the dedicated windows available through the Windows menu) and to run the RTTOV direct model (through the RTTOV menu). The application log is displayed in this main window.



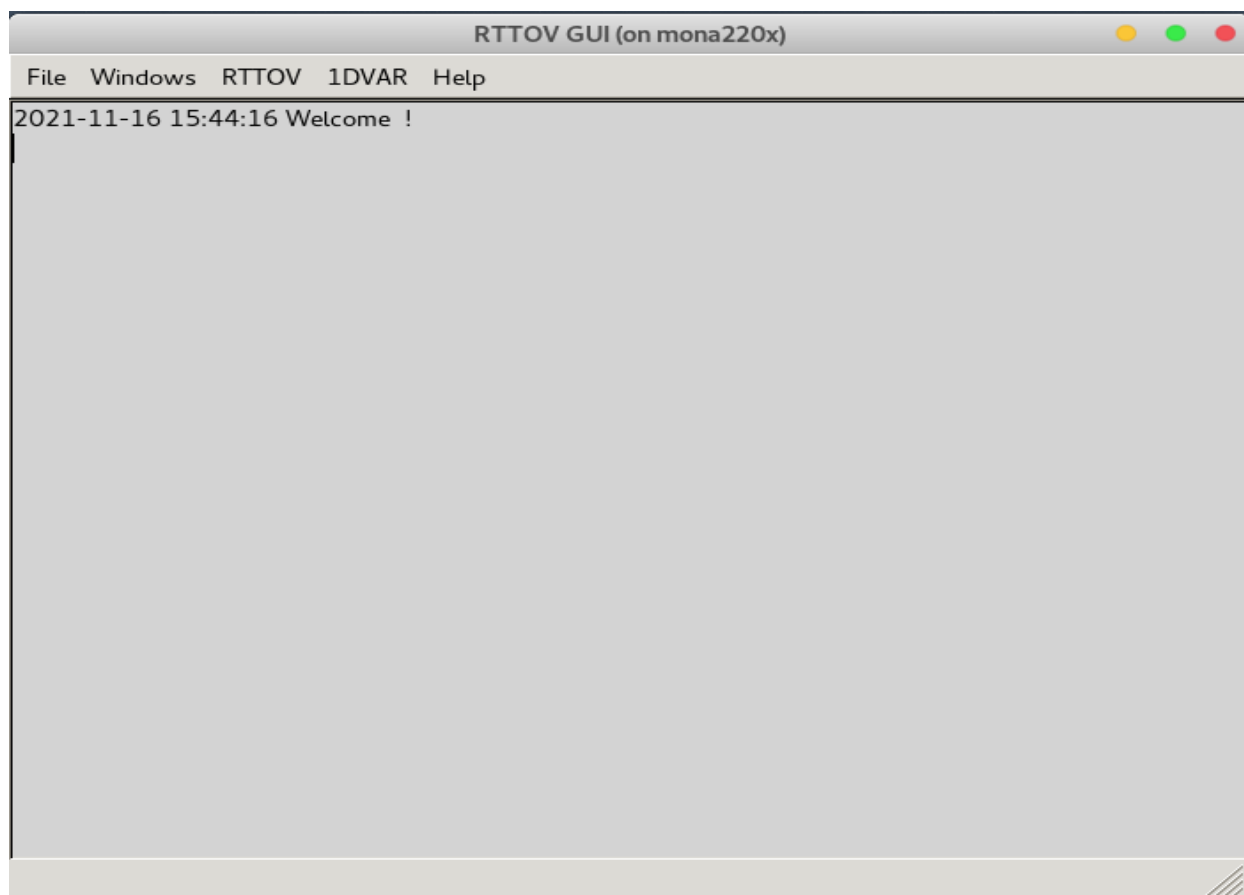


Figure 2.3.1: main window

## 2.4. Loading RTTOV coefficient files

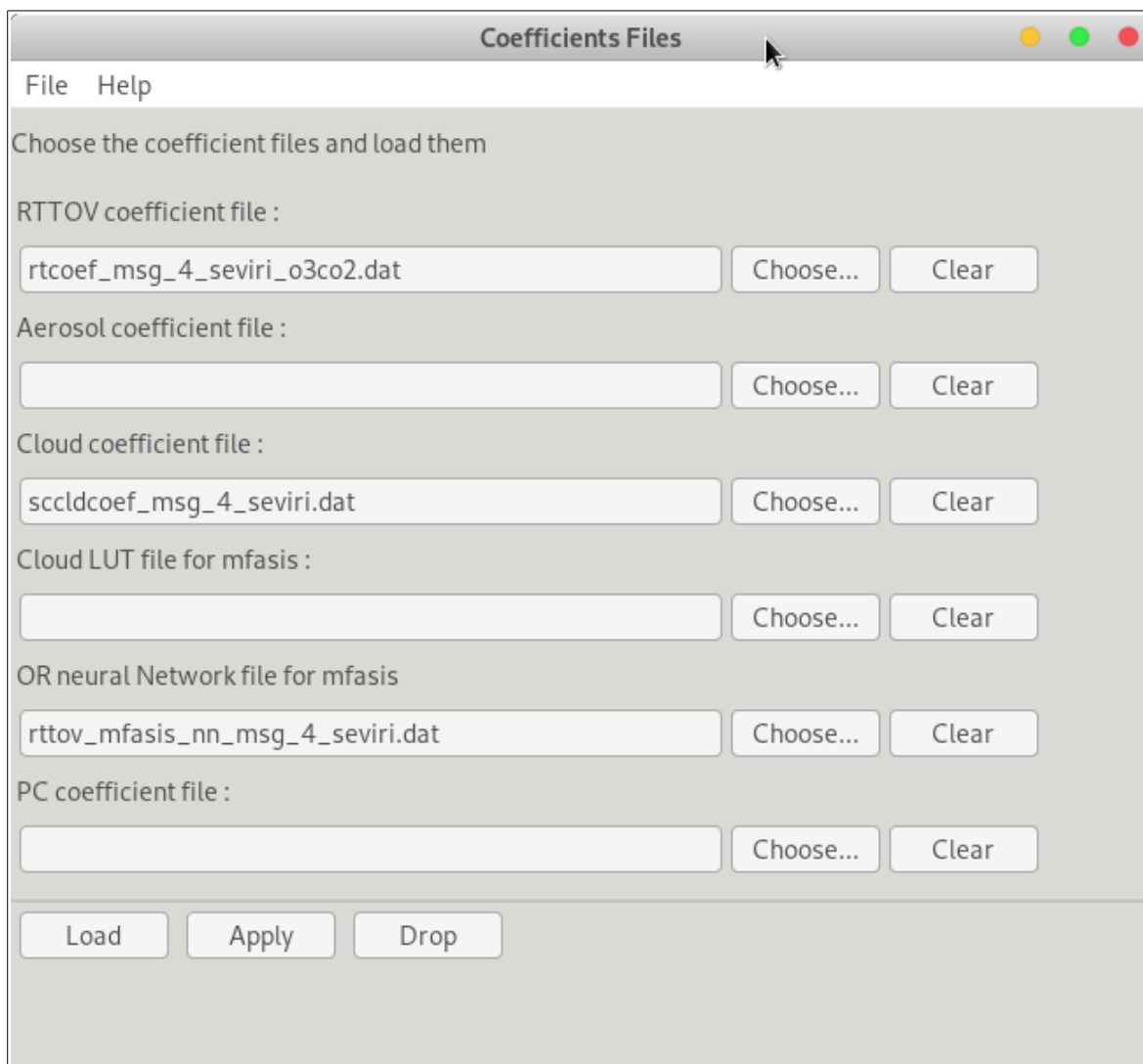
The first step is to choose the instrument with which you want to work. For this purpose, you have to pick up a coefficient file using the RTTOV menu “Load coefficient” (Figure 2.4.1).

You must choose a file by clicking on the Choose button.

A RTTOV coefficient file is always mandatory. If you want to work with aerosols you must choose an aerosol coefficient file, and if you want to work with clouds, you must choose a cloud coefficient file. For simulation with clouds, for some instruments you can choose a MFASIS Cloud LUT or a MFASIS Neural Network file to perform a visible MFASIS cloud scattering simulation (for this you will also need to select the corresponding VIS\_SCATT\_MODEL in the option windows). If you choose a MFASIS Cloud LUT and a MFASIS Neural Network file, the MFASIS Cloud LUT will not be loaded. The MFASIS Neural Network file has the priority and will be loaded.

All the coefficient files must be compatible (an error message will be displayed if it is not the caserun mfasis).

Once your choices have been made, you can load the coefficient files by clicking on the “Load” button, or by clicking on the “File” menu and selecting the “Load coefficients” menu item.



**Coefficients Files**

File Help

Choose the coefficient files and load them

RTTOV coefficient file :

rtcoef\_msg\_4\_seviri\_o3co2.dat Choose... Clear

Aerosol coefficient file :

Choose... Clear

Cloud coefficient file :

scldcoef\_msg\_4\_seviri.dat Choose... Clear

Cloud LUT file for mfasis :

Choose... Clear

OR neural Network file for mfasis

rttov\_mfasis\_nn\_msg\_4\_seviri.dat Choose... Clear

PC coefficient file :

Choose... Clear

Load Apply Drop

*Figure 2.4.1: coefficient files window*

When the coefficient files are successfully loaded by RTTOV an information window appears (Figure 2.4.2). The log in the main window provides some information from the coefficient files such as the wave numbers and the reference temperatures of the instrument.

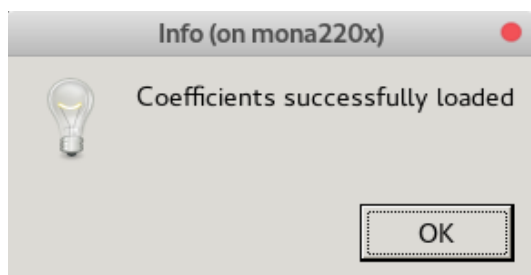


Figure 2.4.2: successful coefficient files loading message

## 2.5. Open a Profile

The item “Open Profile” of the “File” menu of the main window allows you to open a profile (Figure 2.5.1). You must first select an appropriate file. If a profile file contains several profiles, you will be asked to choose the profile number (Figure 2.5.2)

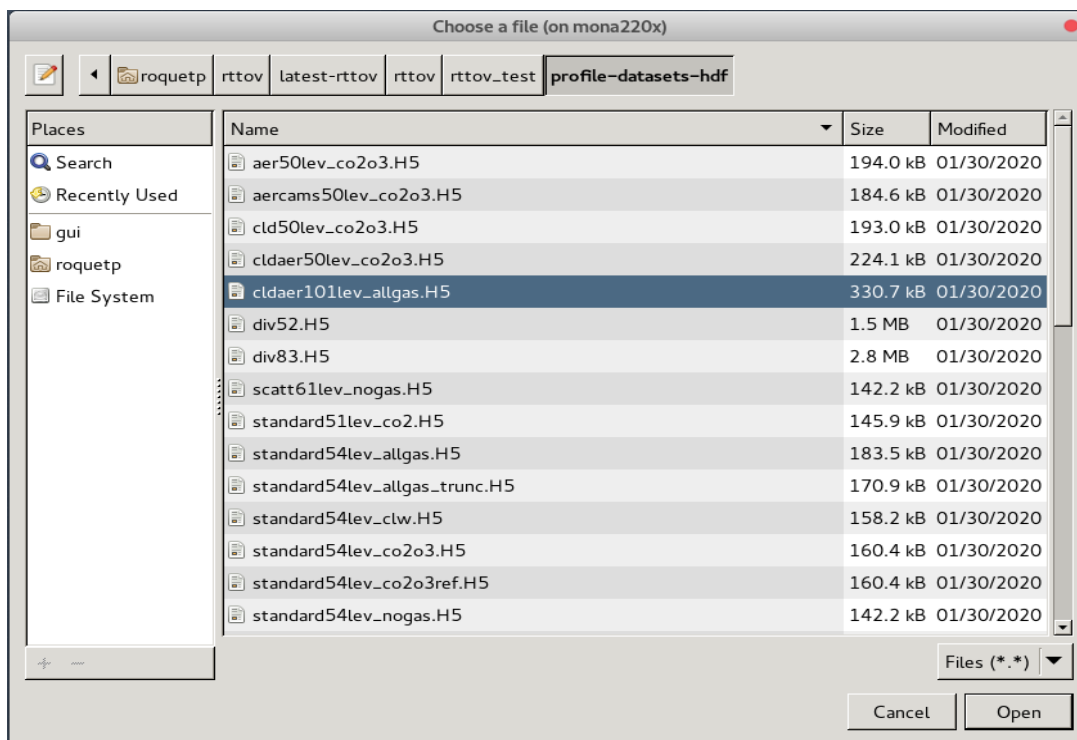


Figure 2.5.1: select a profile

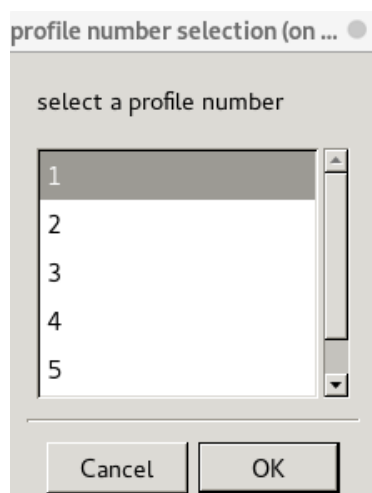


Figure 2.5.2: selection window

## 2.6. Modifying the options

The RTTOV options can be modified through the “Options Editor” window. Select “Options Editor Window” from the “Windows” menu of the main window (Figure 2.6.1).

The RTTOV options which can be modified are part of the option structure of RTTOV, described in the RTTOV v13 User Guide (Annex O). The help menu of the Options editor window gives you some information. Some options are unavailable depending to the loaded coefficient files or the profile content. The options are organised by themes and by tabs in the Options Editor window.

### General RT options:

Each “data” option (“ozone\_data”, “co2\_data”, “n2o\_data”, “co\_data”, “ch4\_data” and “so2\_data”) is enabled only if the RTTOV coefficient file has been computed for the corresponding gas. (See in the RTTOV User Guide about the four flavours of predictors used for the coefficients files).

### VIS/IR-only RT options:

These options are available only for VIS/IR instruments.

The “addsolar” option is disabled if the standard coefficient file does not contain solar channels.


The “addclouds” option is enabled if a cloud coefficient file has been loaded and the profile holds cloud content.

The “addaerosl” option is enabled if an aerosols coefficient file has been loaded and the profile holds aerosol content.

“ir\_scatt\_model” is enabled only if addclouds or addaerosl option has been selected.

“vis\_scatt\_model” is enabled only if addclouds or addaerosl option has been selected and addsolar option has been selected.

The “dom” options (“dom\_nstreams”, “dom\_accuracy” and “dom\_opdep\_threshold”) are enabled only if the ir\_scatt\_model and/or vis\_scatt\_model options are enabled and the DOM model is

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selected for either or both. The "dom\_rayleigh" option is only available when vis\_scatt\_model is DOM and a V13 coefficient file is loaded with a corresponding cloud or aerosol coefficient file.

### PC-RTTOV options:

These options can be enabled only if a PC-RTTOV coefficient file is loaded. If "addpc" is ticked, the options "ipcbnd", "ipcreg" and "addradrec" become available. And in this case, PC-RTTOV will be used. Choosing "addradrec" allows the computation of reconstructed radiances, and therefore this checkbox is linked to the "switchrad" option.

### MW-only RT options:

These options can only be modified if a microwave instrument is used. These options are:  
"fastem\_version" which allows you to choose the version of the FASTEM model.  
"supply\_foam\_fraction" which allows you to give the ocean foam fraction but the foam fraction has to be modified in the surface window.

Once you have made your choices for the options, you have to save them for the run by clicking the "Apply" button.

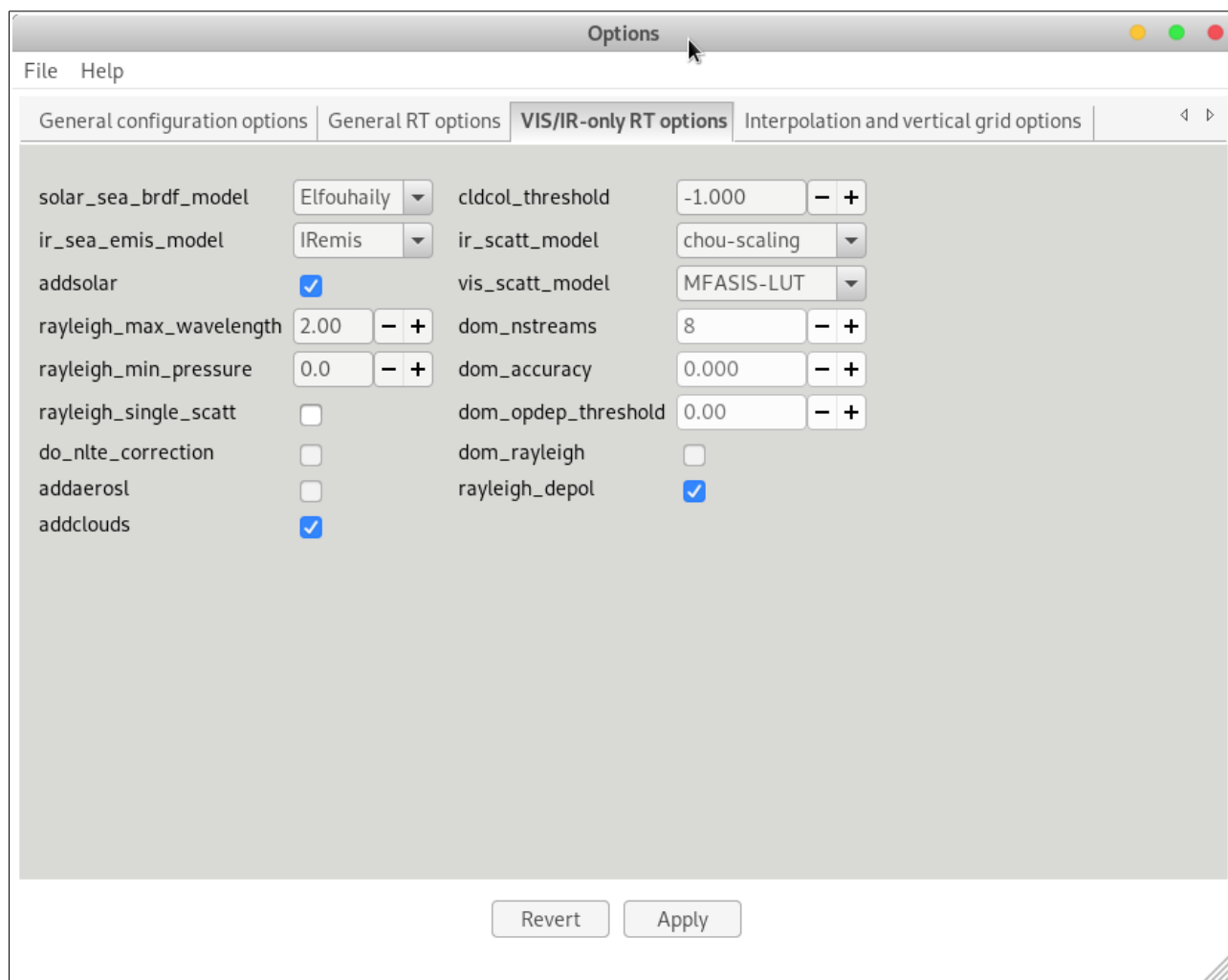


Figure 2.6.1: Options Editor window

## 2.7. Modifying the profile

The profile can be modified through the profile editor window. Select “Profile Editor Window” from the “Windows” menu of the main window.

Figure 2.7.1 provides an example of the profile editor window showing the atmospheric gas profiles.

Figures 2.7.2 and 2.7.3 provide examples for aerosol and cloud profiles respectively. Aerosol components and cloud types are described in the RTTOV users guide.

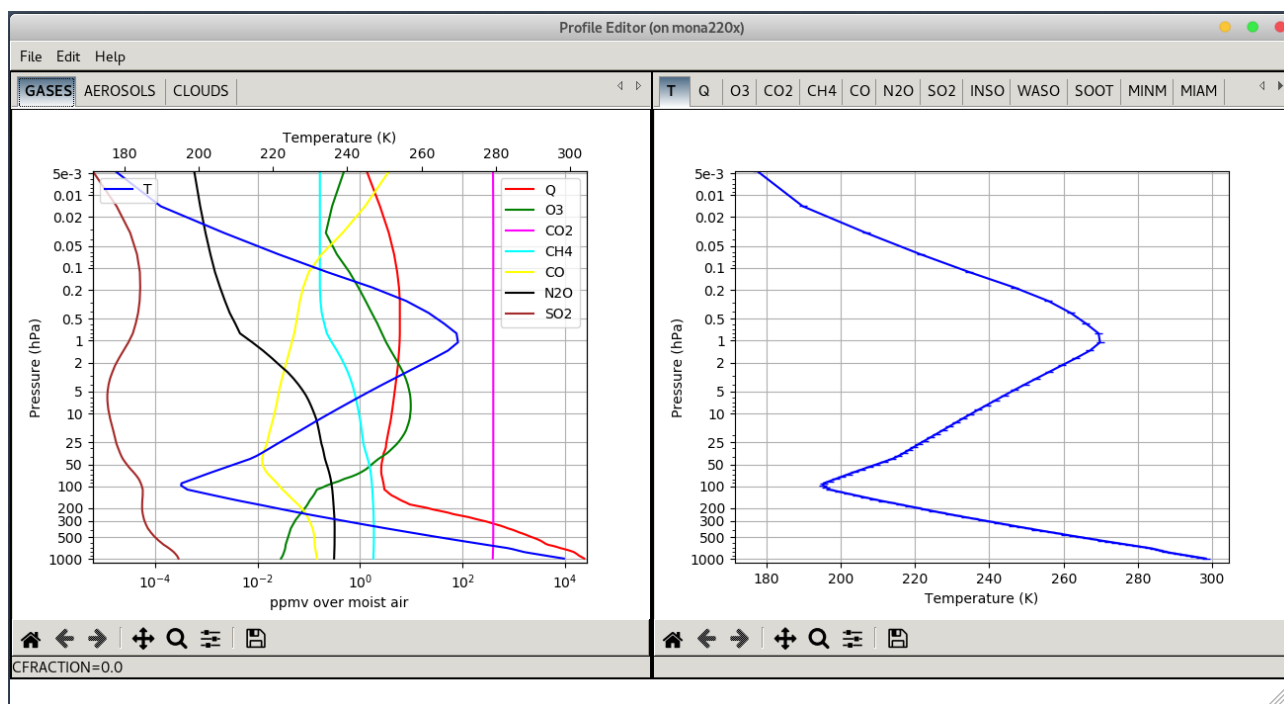


Figure 2.7.1: Profile Editor window for gases

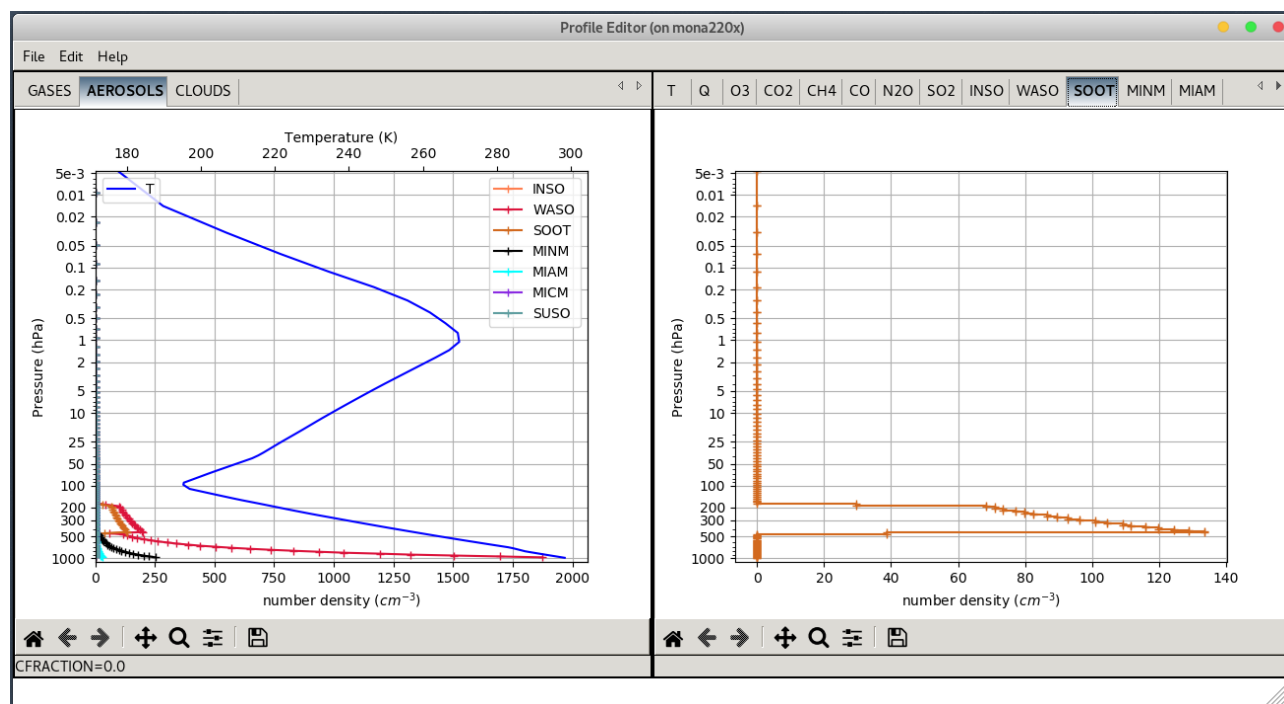


Figure 2.7.2: Profile Editor window for aerosols

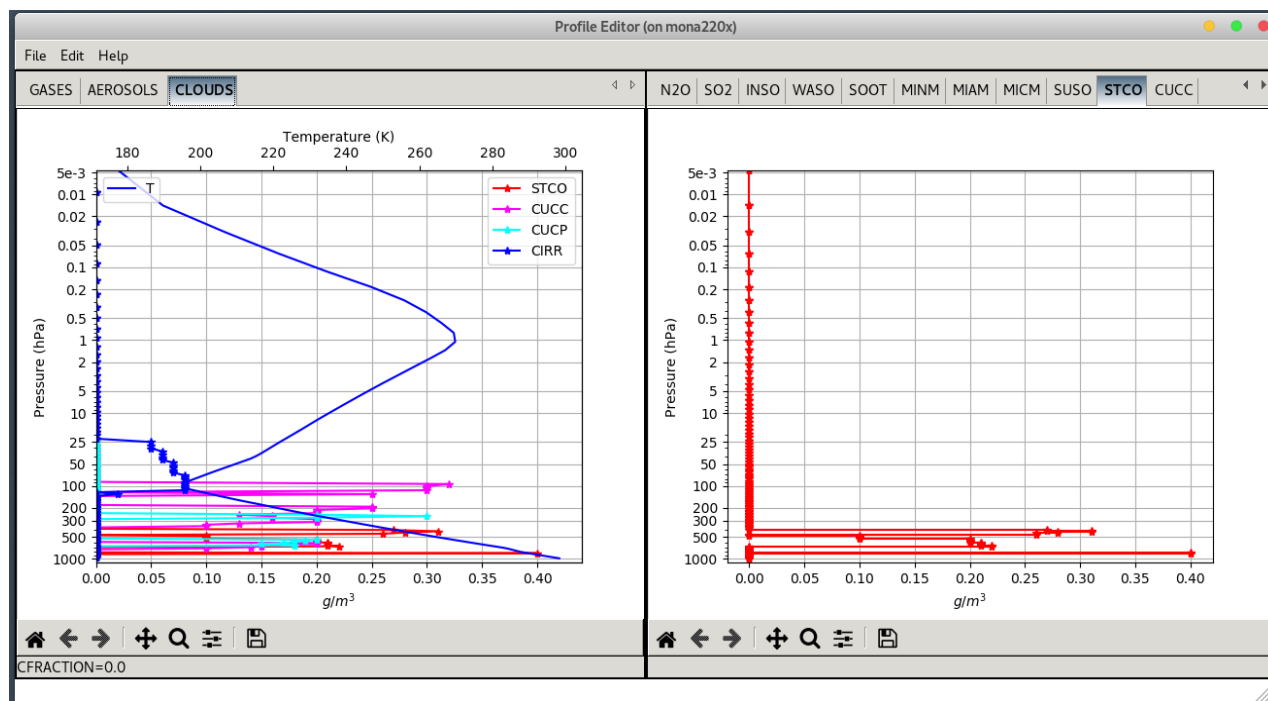


Figure 2.7.3: Profile Editor window for clouds

The left hand panel of the window shows the atmospheric components profiles grouped by type: Gases, Aerosols and Clouds. The Temperature profile is always drawn on the three types of panel. On the right hand panel of the window, the different components profiles are drawn separately. You can modify the profile by hand by clicking in the panel. For that, select and visualize a component profile on the right panel. Click the middle button or the right button to modify the profile. The closer point on a profile pressure level or layer is moved to the new value. The left panel is also updated. Use the zoom widget of the matplotlib toolbar to zoom in or to zoom out.



matplotlib toolbar

Finally, apply your changes or save the profile for the next run of RTTOV.

### Edit menu functionalities:

Undo: undo the last modification of the curve.

Redo: redo the last modification of the curve.

Insert: For aerosols or clouds only, a click moves or creates a new point.

Remove: For aerosols or clouds only, a click removes the nearest point of a layer.

Change profile values: Apply  $\text{scale} \times \text{value} + \text{offset}$  on the profile values between P min and P max.

Edit X axis: This menu item allows to modify the X axis bounds.

Add gas: With this menu item it is possible to add a gas.

Remove gas: With this menu item, it is possible to remove a gas.

Add aerosol: With this menu item, it is possible to add an aerosol model.



Remove aerosol: With this menu item, it is possible to remove an aerosol model.

Add cloud: With this menu item, it is possible to add a cloud.

Remove cloud: With this menu item, it is possible to remove a cloud.

Replace aerosol by clim: With this menu item, it is possible to replace all aerosols by an aerosol climatology. The user is allowed to choose between different types of climatology (see Figure 2.7.4)

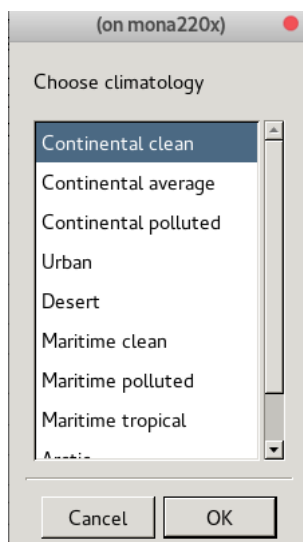


Figure 2.7.4: Climatology choices for aerosols (see RTTOV User Guide for full description)

## 2.8. Editing the surface

The “Surface Editor Windows” allows you to modify the surface parameters of the profile. Select the Surface Editor Window menu item from the windows menu of the main window (Figure 2.8.1).

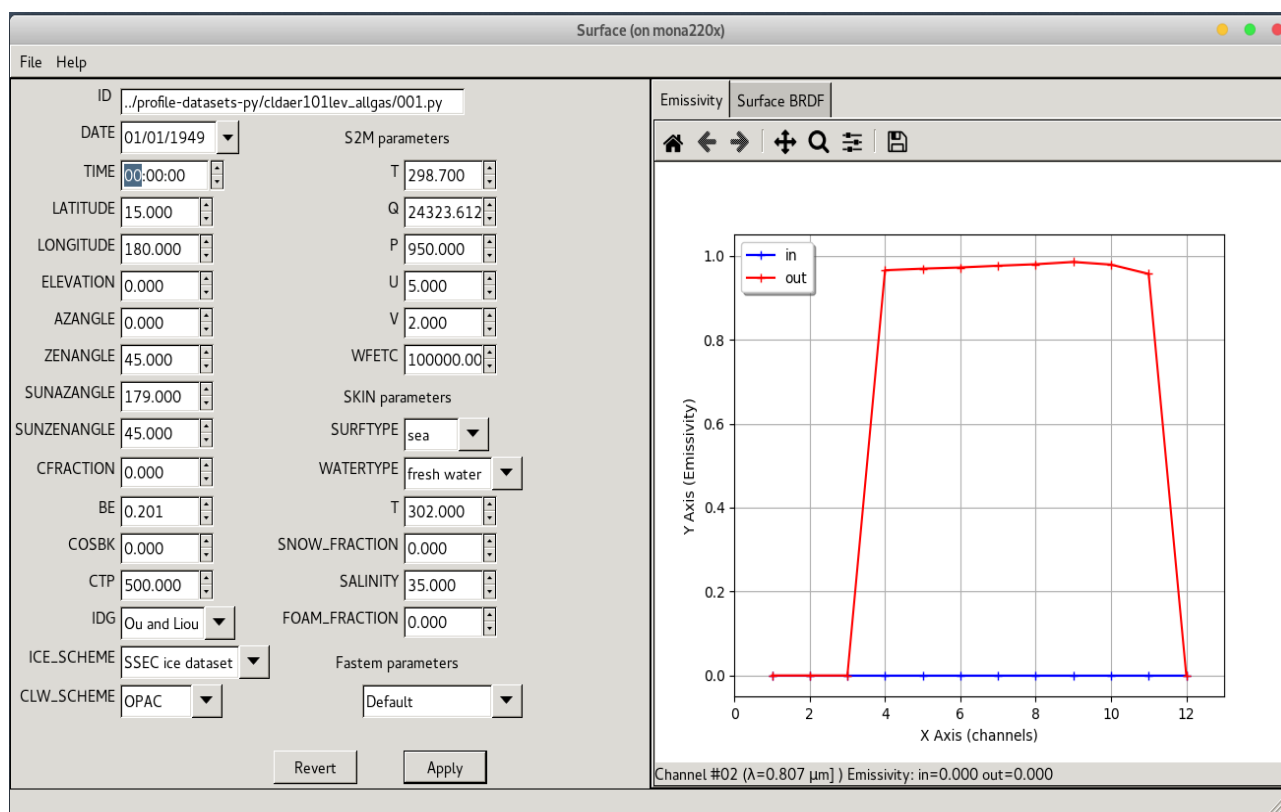
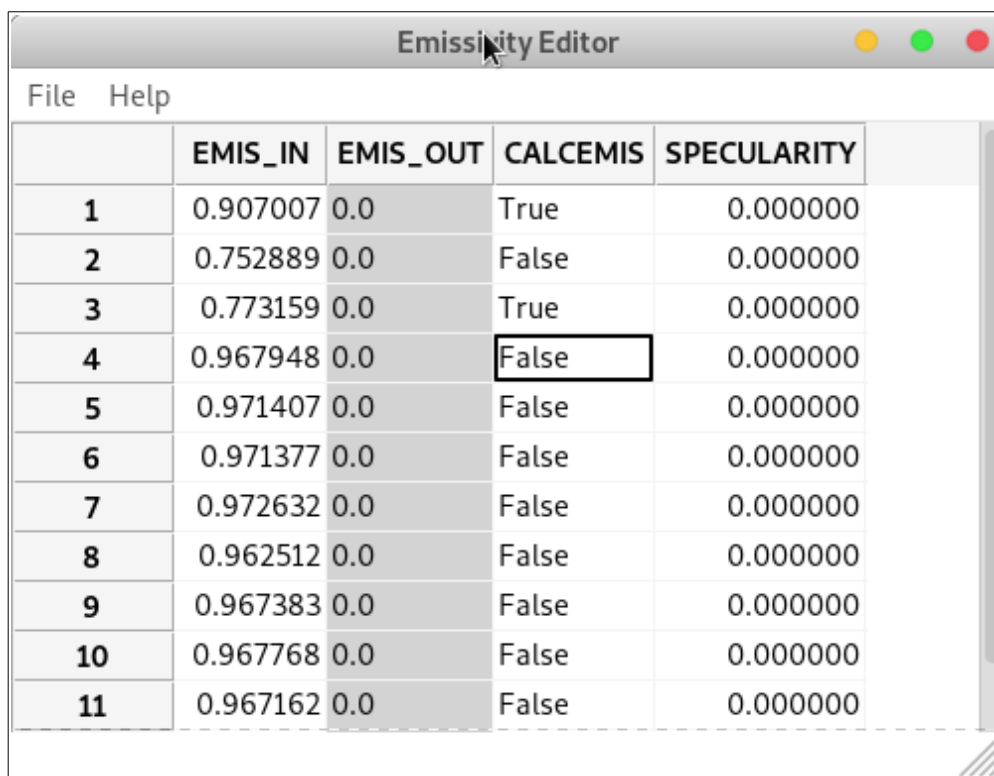


Figure 2.8.1: Surface Editor Window

The File Menu of the Surface Editor Window allows you to load an atlas, or to modify the value of emissivity or reflectance, channel by channel (Figure 2.8.2). The emissivity/reflectance computed values appear in red on the right hand panel. The input values are in blue. If an atlas is loaded, the RTTOV model does not compute the emissivity or reflectance values.

**Please note that the parameter *CFRACTION* (cloud fraction for simple cloud) may have a non-zero value for many of the profiles supplied with RTTOV. This parameter is used for the simple RTTOV cloud scheme (IR/VIS only): see RTTOV User Guide.**



	EMIS_IN	EMIS_OUT	CALCEMIS	SPECULARITY
1	0.907007	0.0	True	0.000000
2	0.752889	0.0	False	0.000000
3	0.773159	0.0	True	0.000000
4	0.967948	0.0	False	0.000000
5	0.971407	0.0	False	0.000000
6	0.971377	0.0	False	0.000000
7	0.972632	0.0	False	0.000000
8	0.962512	0.0	False	0.000000
9	0.967383	0.0	False	0.000000
10	0.967768	0.0	False	0.000000
11	0.967162	0.0	False	0.000000

Figure 2.8.2: Edit Input Emissivity Values. (Tip for check boxes: write 1 for check off, write 0 or nothing otherwise)

## 2.9. Running RTTOV Direct Model and working with the Radiance Window.

It is possible to run the RTTOV direct model. For this purpose, select the RTTOV menu from the main window. Then select « Run direct ». This will save and overwrite the profile being edited and run the direct model (the profile is saved before each run in the RTTOV GUI working directory (`~/rttov/prof.h5`)).

If the run is successful, a new window appears: the radiance window which displays the result of the RTTOV direct model. This window has three tabs: byRun, byChannel, OnePlot. By default the OnePlot tab is opened with the brightness temperatures curve (Figure 2.9.1)

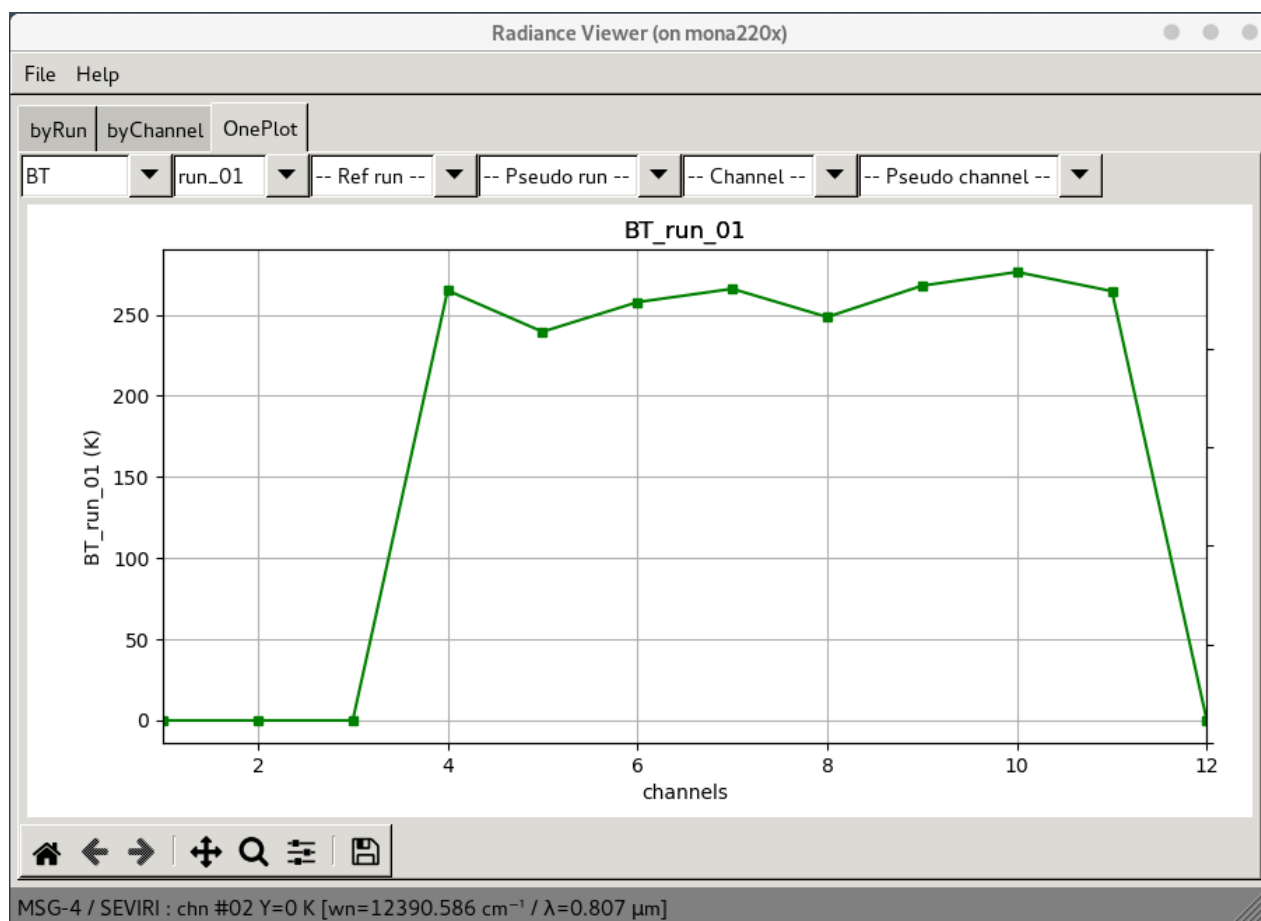



Figure 2.9.1: Radiance window OnePlot tab

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The plots which can be displayed in the radiance window are:

- **TOTAL:** Clear+cloudy top of atmosphere radiance for given cloud top pressure and fraction [-]
- **CLEAR:** Clear sky top of atmosphere radiance (channels) [ $\text{mW} \cdot (\text{cm}^{-1})^{-1} \cdot \text{sr}^{-1} \cdot \text{m}^{-2}$ ]
- **BT:** Brightness temperature equivalent to total radiance [K]
- **BT\_CLEAR:** Brightness temperature equivalent to clear radiance [K]
- **REFL:** Reflectance calculated from total radiance [-]
- **REFL\_CLEAR:** Reflectance calculated from clear radiance [-]

It is possible to choose different types of visualisation:

**OnePlot:** View of one plot (Figure 2.9.1)

In this view you can select:

- **The parameter:** BT, BT\_CLEAR, TOTAL, CLEAR, REFL, REFL\_CLEAR: choose a plot type
- **-- Run --:** to choose a run
- **ref run:** to choose a reference run (for differences and comparison)
- **-- Pseudo Run --:** difference (minus) or overlay (versus) with reference run
- **-- Channel --:** to choose and display only one channel
- **-- Pseudo Channel --:** to display user's made combinations of channels

**byRun :** For each channel, view of all plots with all runs values

In this view you can select:

- **-- Channel --:** to choose a channel
- **-- Pseudo Channel --:** for channels combination: in this text field, user can write a formula (see the example displayed in the text field), which will become a “pseudo channel”.

**byChannel:** For each run, view of all charts with all channels values (Figure 2.9.2)

In this view you can select:

- **-- Run --:** to choose a run (needs at least 2 different runs)
- **-- Pseudo Run --:** to see the difference between with reference run (needs at least 2 different runs ) (Figure 2.9.3)

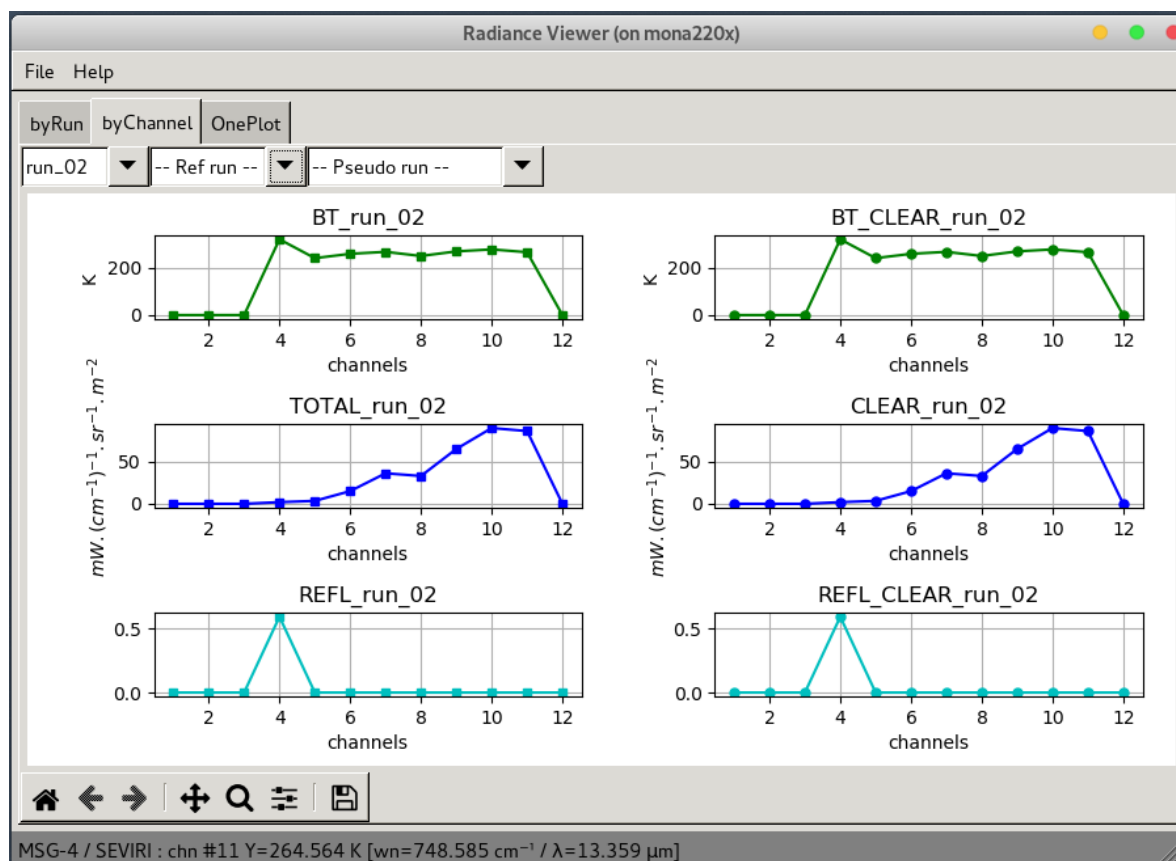


Figure 2.9.2: Radiance window showing differences between two runs of the direct model.

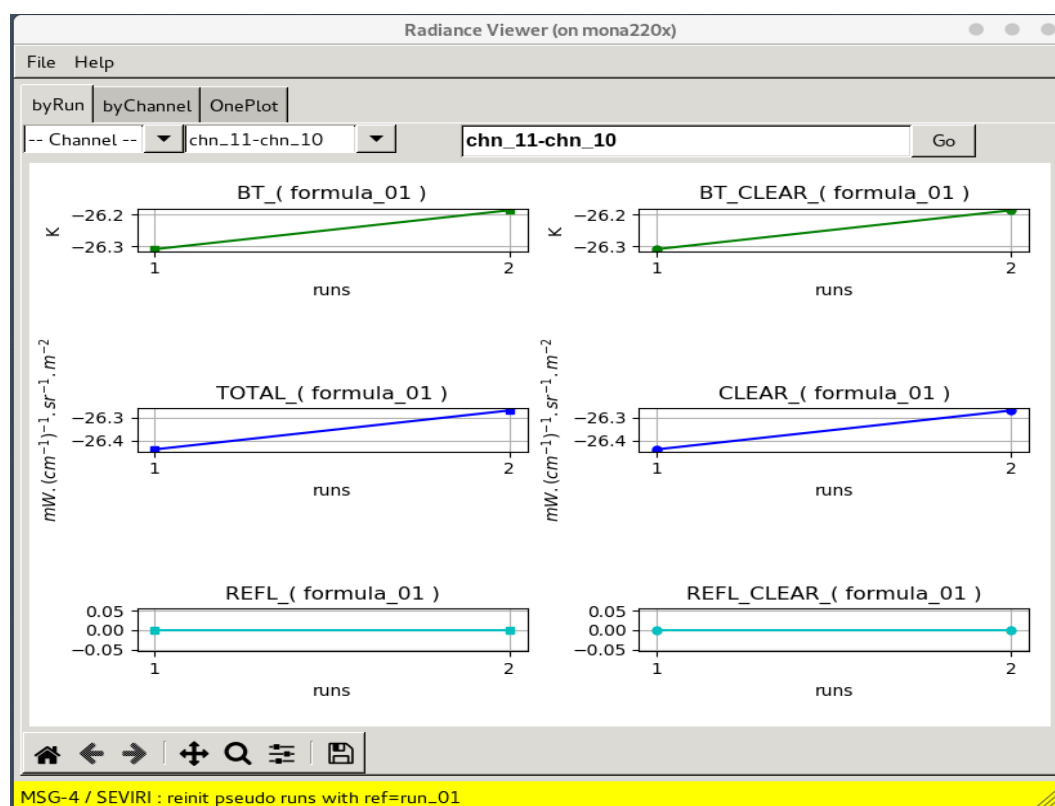


Figure 2.9.3: Radiance window (byRun view with a computed pseudo channel)

For high-resolution sounders such as IASI, AIRS or CrIS, a spectrum is displayed when the direct model is run (fig. 2.9.5).

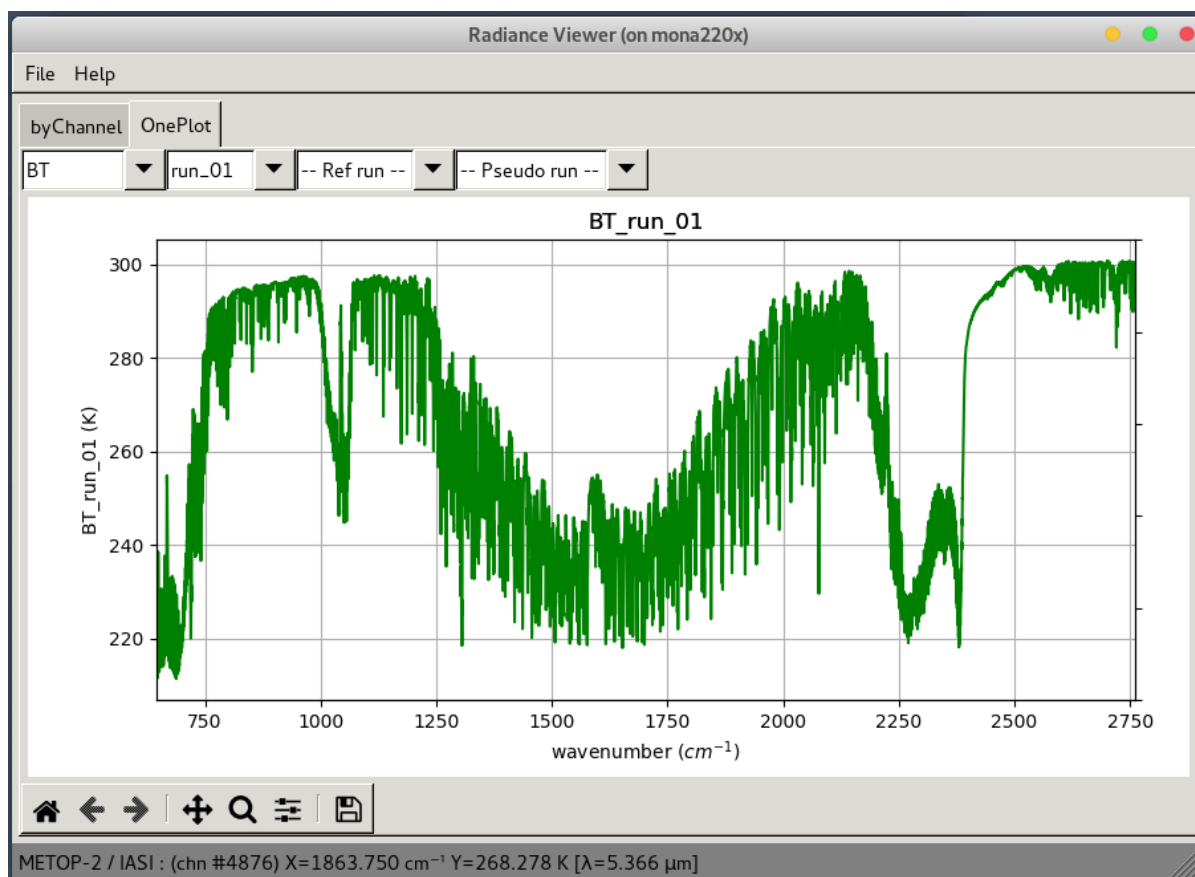


Figure 2.9.5: Radiance window for hyperspectral instruments

For any subsequent run you can select pseudo run such as “run\_02 minus run\_01” or “run\_02 versus run\_01” to see the spectrum differences (see fig. 2.9.6 spectrum difference between run 02 (with “addsolar”) and run 01 (without “addsolar”) for IASI).



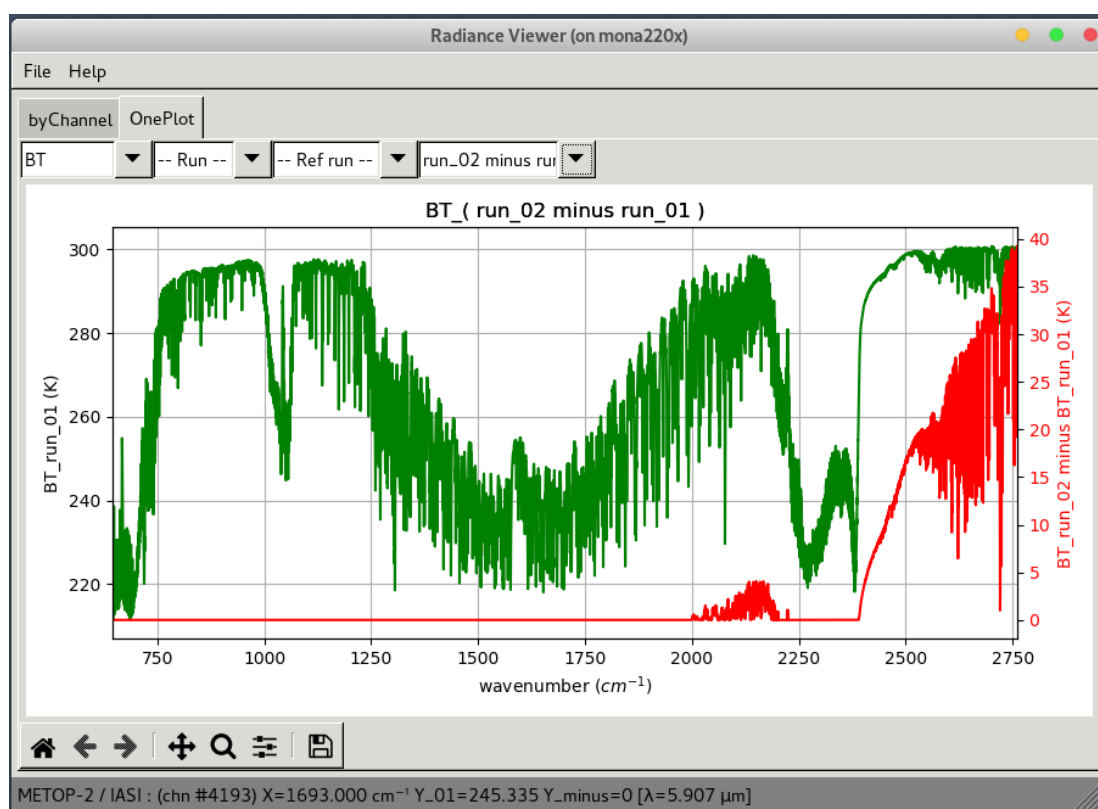


Figure 2.9.6: Radiance window for hyperspectral instruments: difference between 2 runs (with and without addsolar)

### Instrument change:

If you want to run RTTOV with a new instrument, by loading different coefficient files, with an active radiance window displaying the results of a previous RTTOV run, the radiance window becomes obsolete and the GUI will close it.

### Radiance window command line functionality:

It is also possible to launch the radiance window separately from the RTTOV GUI using the `radr.h5` file containing the results of a RTTOV run (this file is kept by default in the `~/rttov` directory):

**python rview/radianceframe.py radr.h5 [radr2.h5 ...]** Interactive navigation:

The toolbar at the bottom of the radiance window is the matplotlib tool bar: it allows you to zoom and navigate in the Figure.

## 2.10. Running RTTOV K and working with the K-Matrix and the Kprofile windows.

It is possible to run the Jacobian model of RTTOV. For this purpose, select the RTTOV menu from the main window and then select “Run RTTOV K”. This will save and overwrite the profile and run

the K model.

If the run is successful, a new window appears: the K-Matrix Window which display the result of the RTTOV K-Model (Figure 2.10.1). With every RTTOV K run, a new window is displayed. Depending on the choice of the switchrad option, the Jacobians are expressed either in radiance unit or in temperature unit by the unit of the considered variable. Example:  $\text{mW} \cdot (\text{cm}^{-1})^{-1} \cdot \text{sr} \cdot \text{m}^{-2} \cdot \text{K}^{-1}$  for the Jacobien of temperature variable and  $\text{mW} \cdot (\text{cm}^{-1})^{-1} \cdot \text{sr} \cdot \text{m}^{-2} \cdot \text{ppmv}^{-1}$  for the Jacobien of gases with switchrad not checked in the option window.

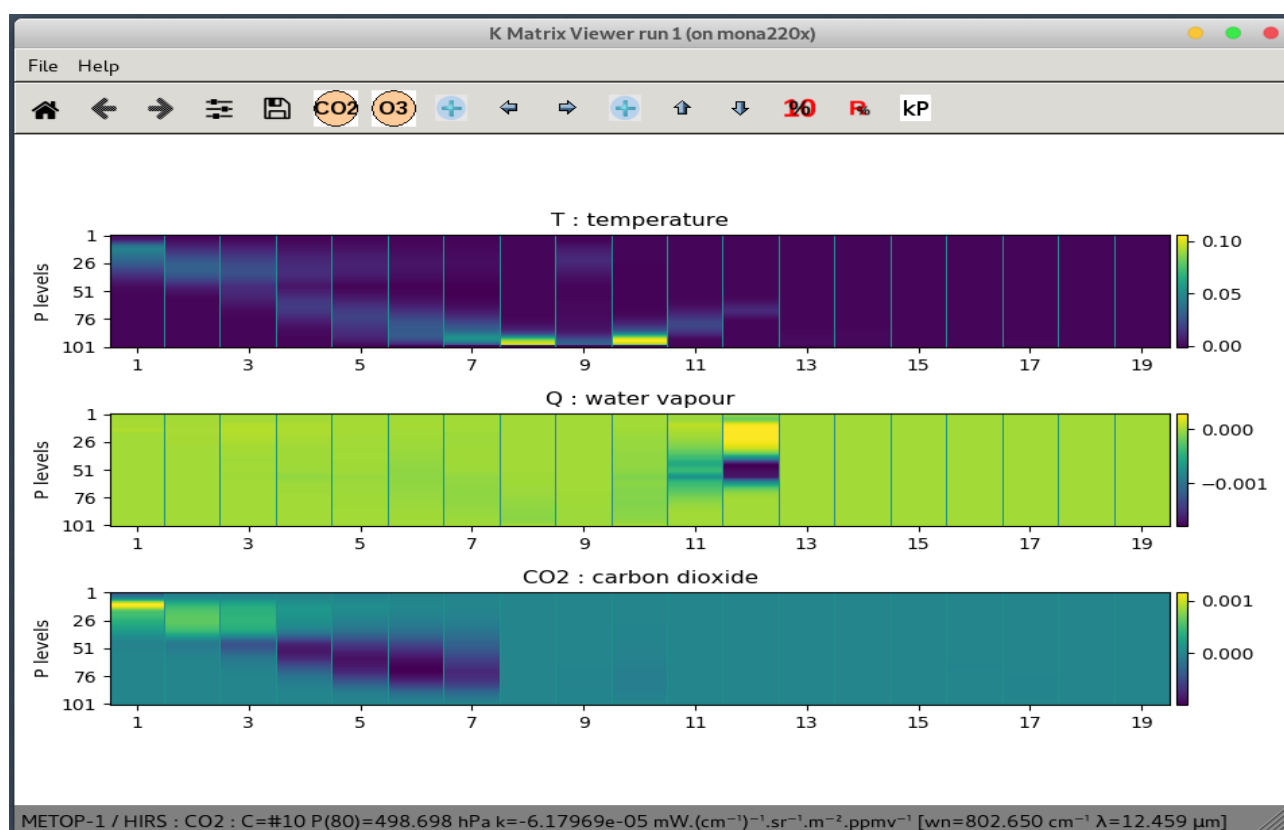


Figure 2.10.1: K-Matrix window

Move the mouse on a channel and enter P on your keyboard to display the K profile (Figure 2.10.2)

Icon Toolbars:



You can also use the Kp icon, in order to choose the channel of the K profile to be displayed.



This icon allows you to multiply by 0.1 all values.



These icons, if present, allow you to display the K matrix for the different gaz.

The K-profile windows allows you to overlay up to four K-profiles from four successive K-run. In the example below (Figure 2.10.2), one can see the impact of the vertical interpolation mode (run 1 with mode 5 (Rochon/Log-lin WF) and run 2 with mode 1 (Rochon/Rochon OD) on the computed K-profile for channel 3 of HIRS.

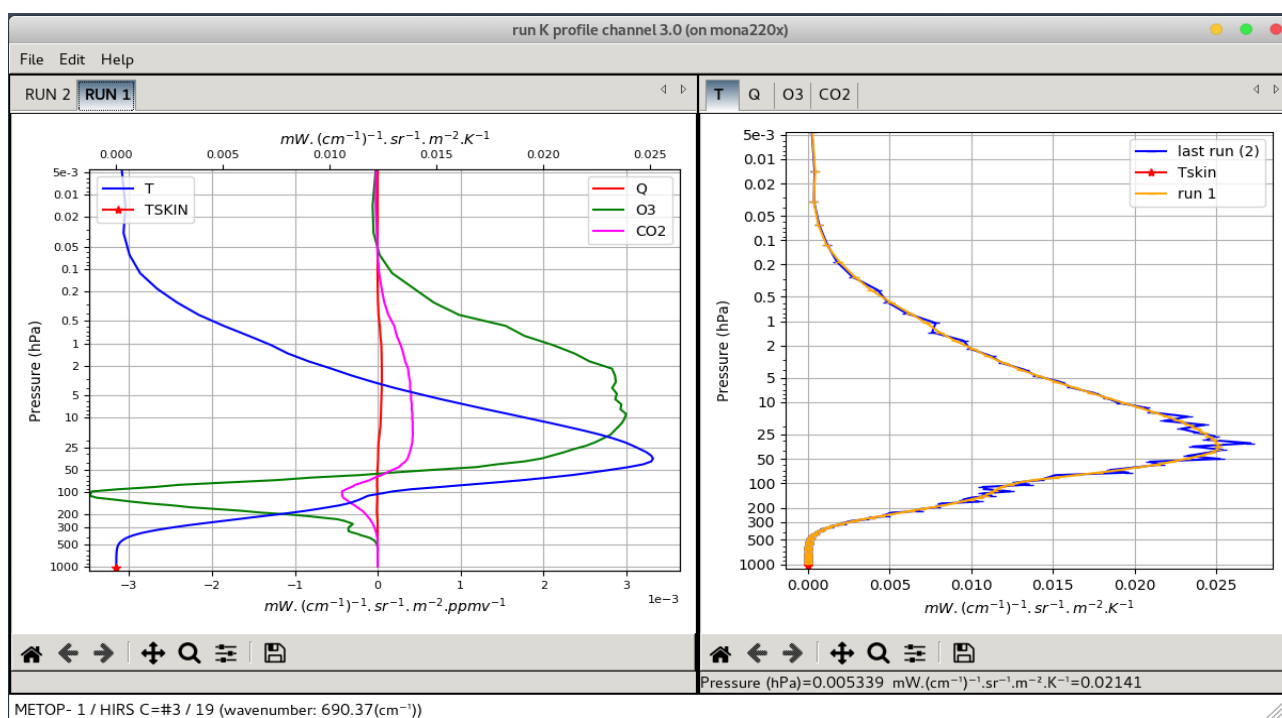


Figure 2.10.2: The K profile window

## 2.11. Running RTTOV PC (Principal Components)

It is possible to run RTTOV PC. For this purpose you have to load a PC coefficient file, and to select the “addpc” option in the Option Window.

Then select “Run RTTOV” . You will be asked to enter the number of Principal Components.

After the run a new window is displayed: the PC SCORES window (Figure 2.11.1).

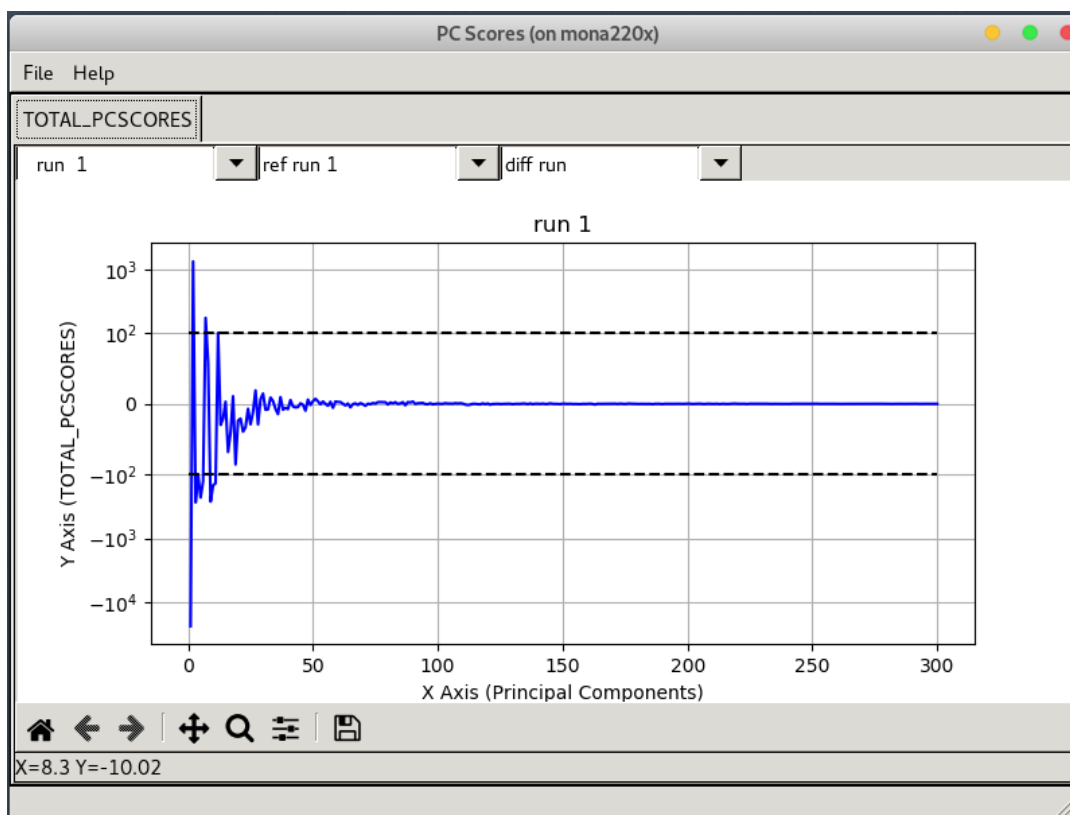


Figure 2.11.1: The PC SCORES window. Note the symmetrical log axis for pcscores. (range [-100,100] is linear)

If you choose the “addradrec” option, in the option window, the result of the RTTOV Run PC is also displayed in the Radiance Window.

## 2.12. Running PC RTTOV K

If you choose to run RTTOV PC K, two windows are displayed: the KPCMatrix Window and the KPC profile window.

The KPC profile window (Figure 2.12.1) allows you to visualize the KPC profiles. You can use the sliders in order to modify the plot (first curve and number of curves to be displayed). With every K PC run, new windows are displayed.

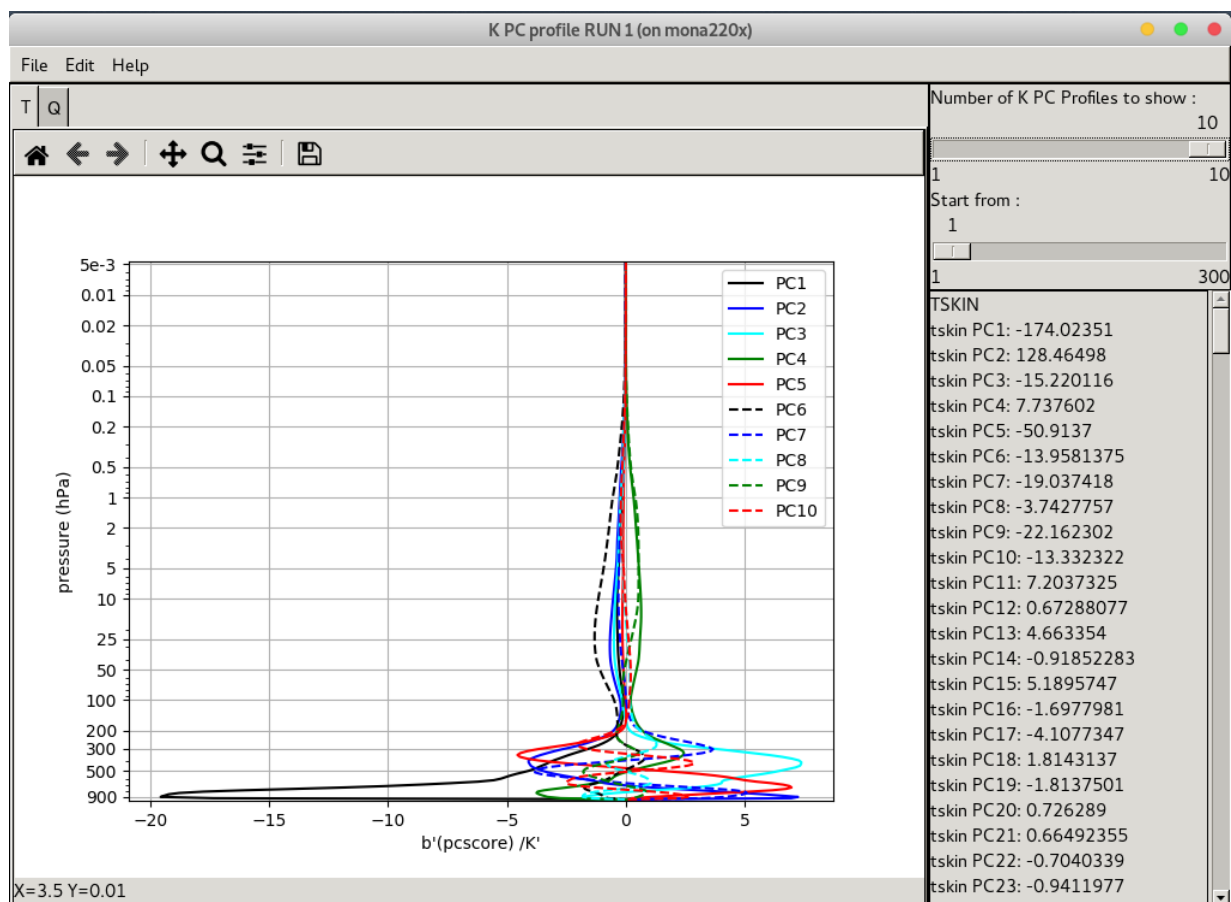


Figure 2.12.1: The K PC profile window

### 3. The 1DVAR functionality

This new functionality was added to RTTOV GUI for the 2015 NWP SAF-ECMWF satellite data assimilation course. Its purpose is to demonstrate to a student how the 1DVAR retrieval works.

The 1DVAR functionality uses Background and Observation error covariances matrices. These matrices are inherited from the NWP-SAF 1DVAR retrieval package and they can be customized if necessary: see the NWP-SAF 1DVAR retrieval package documentation. (<https://nwp-saf.eumetsat.int/site/software/1d-var/>).

In order to use the 1DVAR functionality you must use RTTOV GUI with a 54 levels profile, which once opened from the file menu of the RTTOV GUI main window, will be considered as the background profile. It can be modified with the “profile editor” window.

The covariance observation error matrices come from the 1DVAR therefore the number of permitted instruments for the RTTOV GUI 1DVAR functionality is restricted: AMSUA, MHS, ATMS, HIRS, AIRS, CrIS, IASI, SSMIS. Choose a 54 levels coefficient file among these instruments.

With this 2 prerequisites, the “Configure 1DVAR” command of the “1DVAR” menu of the main window becomes available: select it .

Work now from the “1DVAR” window (Figure 3.1):

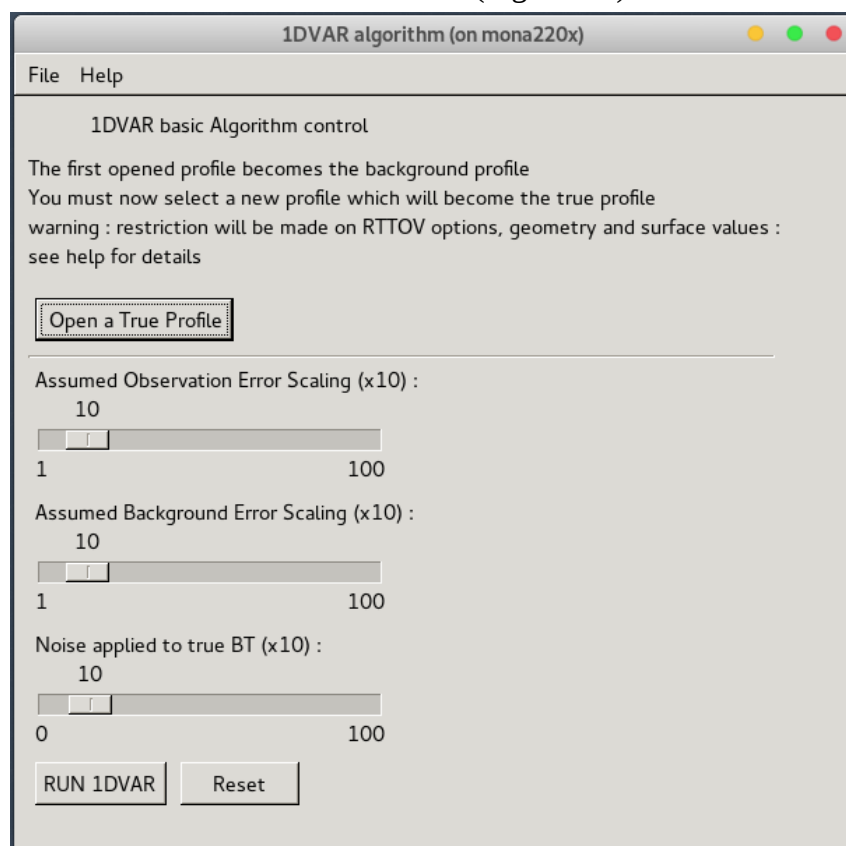


Figure 3.1: 1DVAR Window

1. Click on the “Open a true profile” in order to load what will be considered as the True profile (Xt): This true profile will be used to compute the simulated observed radiances, and to compare with the retrieved profile.
2. Change the value of the scaling factor (fb) for the background errors if necessary
3. Change the value of the scaling factor (fr) for the observation errors if necessary
4. Change the value of the maximum random noise if necessary
5. Click on the “RUN 1DVAR” button

The values of the 3 parameters that can be changed with the sliders are scaled by 10 on the interface to provide decimal precision: this means that if the user selects “85”, for example, with the slider, the actual value used by the algorithm will be 8.5.

The results are displayed in two windows:

- The retrieved profile window (Figure 3.2), the true profile is in black, the background in blue and the retrieval in red.

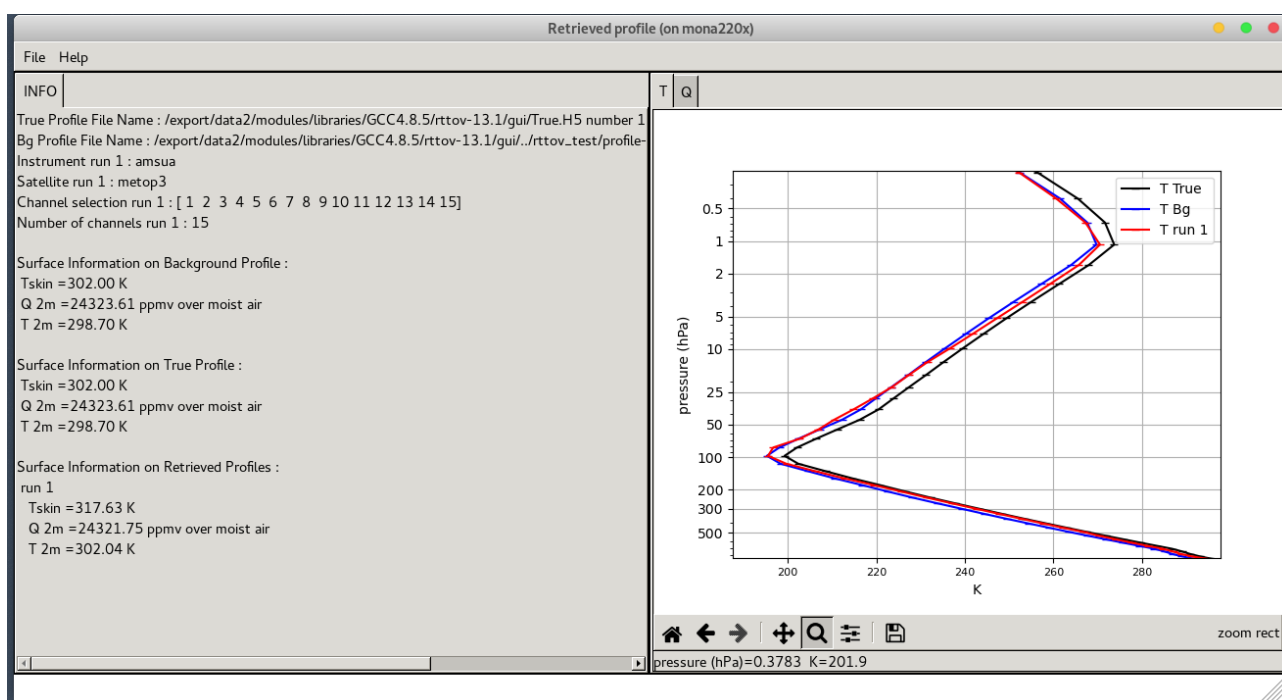


Figure 3.2: Retrieved profile window

- The brightness temperatures window (Figure 3.3), which displays the brightness temperatures obtained with the RTTOV direct model for the true and the background profiles, and the difference (True – Bg).

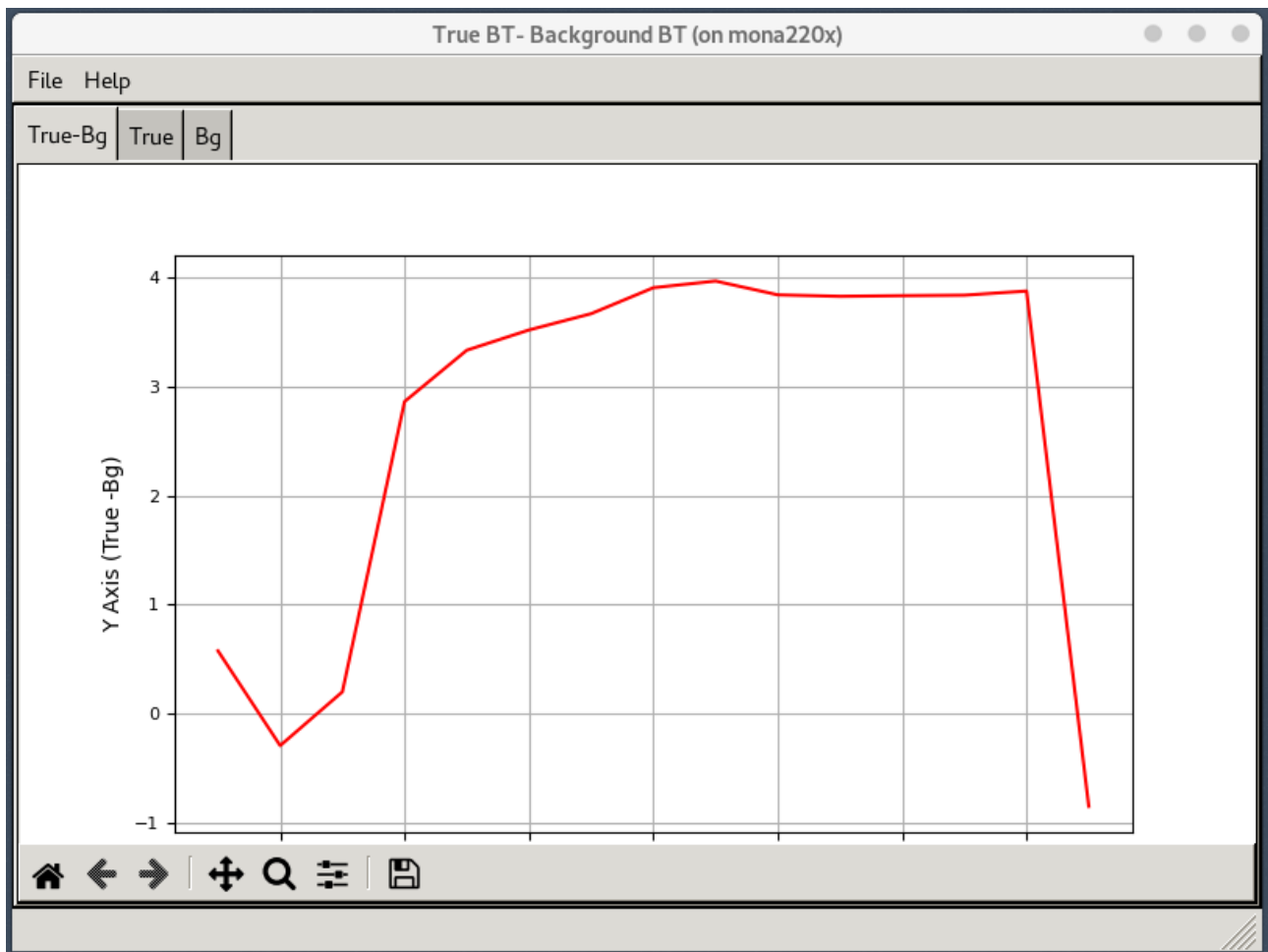


Figure 3.3: Brightness temperatures window

RTTOV GUI allows you to perform a channel selection on the instrument, this functionality can be very useful. Let us see a concrete case:

In order to visualize at which level a specific channel of an instrument may be useful for the retrieval process, you can run RTTOV-K for all channels of an instrument from the RTTOV menu of the main window. RTTOV GUI displays the K Matrix Window. This window shows the results of the Jacobian model for the different channels, for the temperature and for the gases concentrations. In this example (Figure 3.4) of a K matrix window for the METOP-3/AMSUA instrument, one can easily see that the influence of a slight modification of the temperature may be of some importance at the level where the Jacobian is the largest.



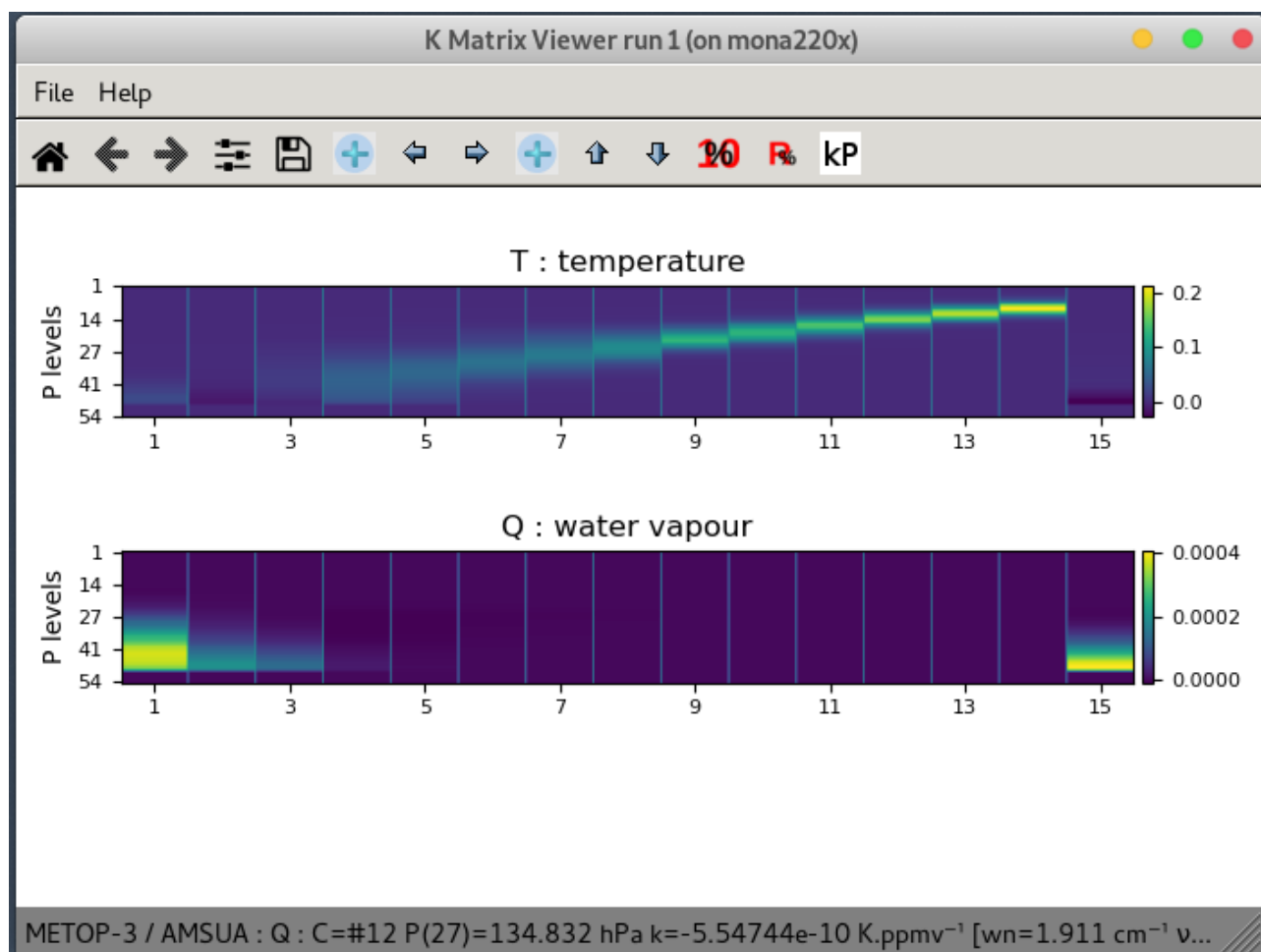


Figure 3.4: K Matrix window for the METOP-3/AMSUA instrument

From the K matrix viewer, the user can, with the “kP button”, select a channel in order to display the K profile. In Figure 3.5, on the K profile window for channel 12 of METOP-3/AMSUA, the peak around 10hPa on the Jacobian of temperature curve is clearly visible: this channel will add some important information in the retrieval process at this level.

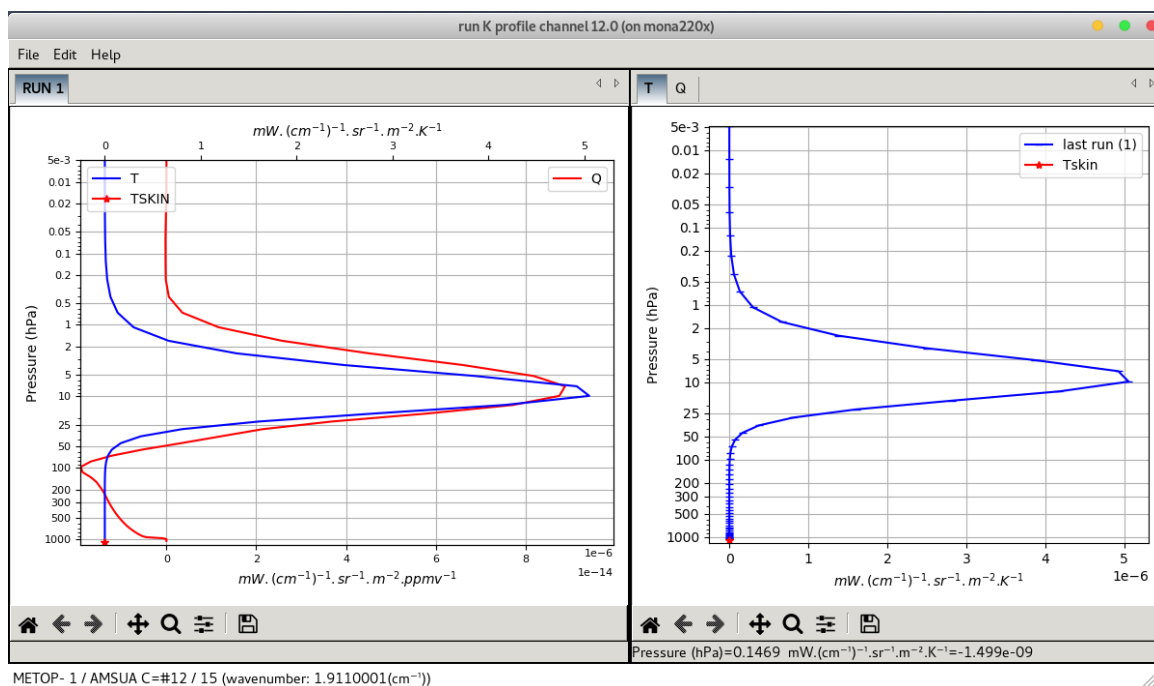


Figure 3.5: K profile window which displays a Jacobian for METOP-3/AMSUA channel 12

From the “RTTOV” menu of the main window, with the “Select Channels” command, the user can perform the channel selection and choose channel 12(Figure 3.6) .

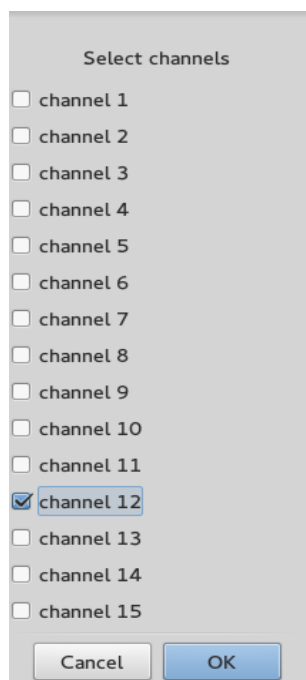


Figure 3.6: The select channels window.

The user can now perform the retrieval with just the METOP-3/AMSUA channel 12. In the Figure 3.7, which is a retrieval for the METOP-3/AMSUA channel 12, one can easily see that the retrieved curve for the temperature adjusts very nicely around 10 hPa.

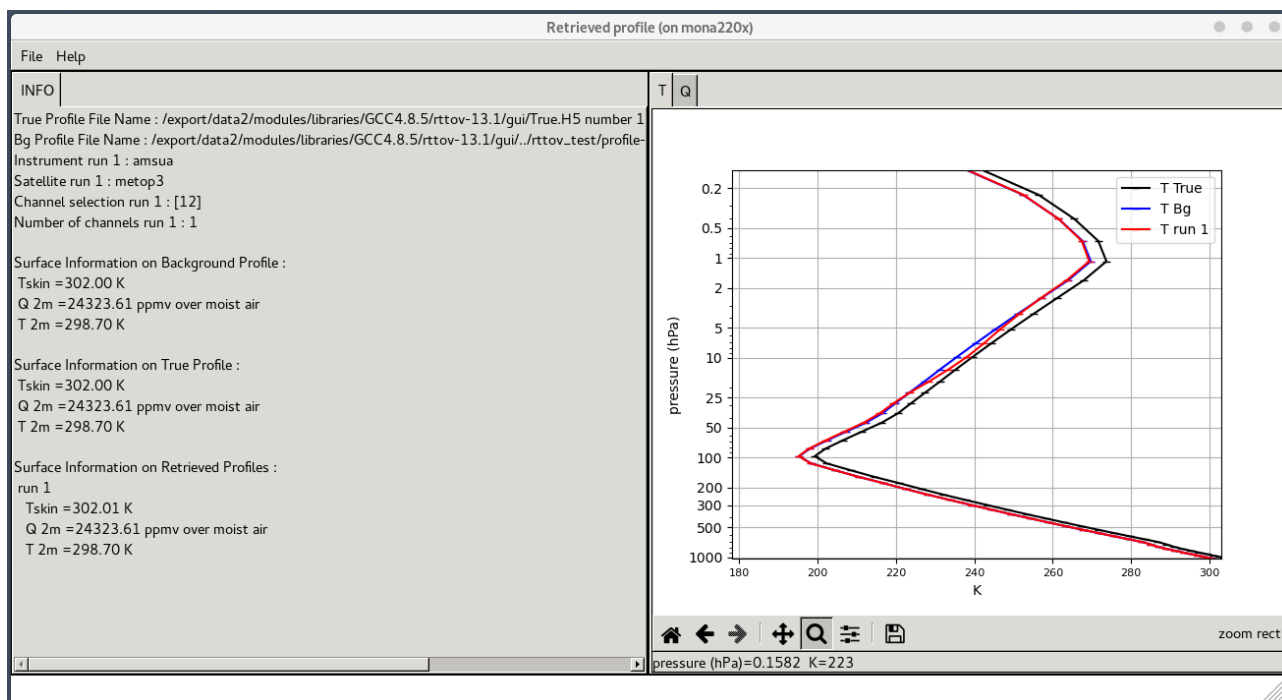




Figure 3.7: Retrieval example (zoomed) with METOP-3/AMSUA channel 12, and a background error scaling of 100.

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### Computations made by RTTOV GUI:

In the calcul below  $X_t$  is the true vertical profile. This vertical profile is never known in the reality. But the purpose is to show with RTTOV GUI, how it is possible to retrieved it from satellite observations. In the reality what are known are the observed brightness temperatures: they can be simulated in this experiment with the direct model of RTTOV from  $X_t$  :

The computation made by RTTOV GUI are:

1. Compute brightness temperatures  $Y_t$  from  $X_t$  (RTTOV direct model)

$$Y_t = \text{RTTOV}_{\text{direct}}(X_t) \quad [1]$$

2. Compute brightness temperatures  $Y_b$  from  $X_b$  (RTTOV direct model)

$$Y_b = \text{RTTOV}_{\text{direct}}(X_b) \quad [2]$$

3. Compute Jacobian matrix  $K$  and transpose  $K^T$  (RTTOV-K model):

$$K = \text{RTTOV-K}(X_b) \quad [3]$$

4. Apply scaling factor to background errors:

$$B = f_b \quad B \quad [4]$$

5. Apply scaling factor to observation errors:

$$R = f_r \quad R \quad [5]$$

6. Compute linear 1DVAR weights  $W$ :

$$W = B K^T [K B K^T + R]^{-1} \quad [6]$$

7. Compute linear 1DVAR retrieved profile  $X_r$ :

$$X_r = X_b + W [(Y_t + N) - Y_b] \quad \text{where } N = \text{random noise vector} \quad [7]$$



## 4. Input Profile file format

The input profiles for the RTTOV GUI can be of two different kind formats. The “native” profile format is HDF5, as the Fortran executable GUI command will only read such format. The other format is an ASCII format made of Python statements for the only necessary variables. The two formats are described below.

### 4.1. HD5 profile file format

The HDF5 profile format allows to store a single profile or a profile dataset such as ECMWF83. It also allows to store RTTOV options.

The HDF5 top level structure is like the following (note all groups and datasets are in capital letters):

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```

/PROFILES                                Group
/PROFILES/0001                          Group    First profile
/PROFILES/0002                          Group    Optional
. . . .
/PROFILES/9999                          Group    Optional
/OPTIONS                                Group    Optional



```

The /PROFILES/0001 group contains a copy of the RTTOV profile structure (see rtov\_type.F90 and RTTOV User's manual). If the HDF5 file contains several profiles they should be numbered continuously and the group name is made of 4 digits with leading zeros. Under the profile number group, the variable names are HDF5 datasets (capital letters), substructures skin and s2m are HDF5 subgroups which contains the relevant variables; see below table.

Name	HDF5 type	Dimension	Comment
ID	Dataset	{SCALAR}	User may give text ID to each profile
DATE	Dataset	{3}	Year Month Day
TIME	Dataset	{3}	Hour Minute Second
NLAYERS	Dataset	{1}	Number of atmospheric layers
NLEVELS	Dataset	{1}	Number of atmospheric levels
CTP	Dataset	{1}	Black body cloud top pressure (hPa)
CFRACTION	Dataset	{1}	Black body cloud fraction (0 - 1) 1 for 100% cloud cover
CLOUD	Dataset	{nlayers,6}	optional
CFRAC	Dataset	{nlayers}	Cloud fraction (0 - 1) 1 for 100% cloud cover
ICEDE	Dataset	{nlayers}	Units for gas profiles :0 or less => ppmv over dry air, 1 => kg/kg over moist air, 2 => ppmv over moist air)
IDG	Dataset	{1}	Scheme for IWC to eff diameter,Dg 1=Ou and Liou; 2=Wyser et al.; 3=Boudala et al; 4=McFarquhar et al.
ICE_SCHEME	Dataset	{1}	ice cloud scheme (1-2)
CLW	Dataset	{nlevels}	optional, not used in GUI

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CLW_SCHEME	Dataset	{1}	liquid cloud scheme (1-2)
CLWDE	Dataset	{nlayers}	liquid water diameter
AEROSOLS	Dataset	{nlayers,13}	optional
P	Dataset	{nlevels}	Pressure (hPa)
T	Dataset	{nlevels}	Temperature
Q	Dataset	{nlevels}	Water vapour
O3	Dataset	{nlevels}	optional Ozone (O3)
CO2	Dataset	{nlevels}	optional
N2O	Dataset	{nlevels}	optional
CO	Dataset	{nlevels}	optional
CH4	Dataset	{nlevels}	optional
SO2	Dataset	{nlevels}	optional
GAS_UNITS	Dataset	{1}	Units for gas profiles :0 or less => ppmv over dry air, 1 => kg/kg over moist air, 2 => ppmv over moist air)
BE	Dataset	{1}	COMMENT = Earth magnetic field strength UNITS = Gauss
COSBK	Dataset	{1}	Cosine of the angle between the Earth magnetic field and wave propagation direction
LATITUDE	Dataset	{1}	Latitude (deg)
LONGITUDE	Dataset	{1}	Longitude (deg)
AZANGLE	Dataset	{1}	Satellite azimuth angle UNITS = degree (0-360 deg; east=90)
ZENANGLE	Dataset	{1}	Satellite zenith angle
SUNAZANGLE	Dataset	{1}	Sun azimuth angle
SUNZENANGLE	Dataset	{1}	Sun zenith angle
ELEVATION	Dataset	{1}	Surface elevaton
MMR_CLDAER	Dataset	{1}	Units for cloud and aerosol profiles 0: g/m <sup>3</sup> (cld); cm <sup>-3</sup> (aer), 1: kg/kg

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<b>S2M</b>	<b>Group</b>		
S2M/O	Dataset	{1}	Ozone
S2M/P	Dataset	{1}	Surface pressure (hPa)
S2M/Q	Dataset	{1}	Water vapour
S2M/T	Dataset	{1}	Temperature (K)
S2M/U	Dataset	{1}	U 10m wind component (m/s)
S2M/V	Dataset	{1}	V 10m wind component (m/s)
S2M/WFETC	Dataset	{1}	Wind fetch (metres)
<b>SKIN</b>	<b>Group</b>		
SKIN/FASTEM	Dataset	{5}	Land/sea-ice surface parameters for fastem
SKIN/FOAM_FRACTION	Dataset	{1}	Ocean foam coverage fraction passed to FASTEM
SKIN/SALINITY	Dataset	{1}	Practical salinity unit ‰ - FASTEM-4/5 only
SKIN/SNOW_FRACTION	Dataset	{1}	Surface snow coverage fraction (0-1). Used only by IR emissivity atlas
SKIN/SOIL_MOISTURE	Dataset	{1}	soil moisture (m <sup>3</sup> /m <sup>3</sup> )
SKIN/SURFTYPE	Dataset	{1}	0=land, 1=sea, 2=sea-ice
SKIN/SALINITY	Dataset	{1}	Practical ocean salinity unit (‰) - FASTEM-4/5/6 only
SKIN/T	Dataset	{1}	Radiative skin temperature (K)
SKIN/WATERTYPE	Dataset	{1}	0=fresh water, 1=ocean water

The /OPTIONS group contains a copy of the RTTOV option structure (see rtov\_type.F90 and RTTOV User's manual). There is only option structure in the HDF5 file even if several profiles are stored in. This /OPTIONS group is optional. All RTTOV option variables should be present. The logical variables are converted to integer datasets where “true” is converted to 1 and “false” converted to 0. Note that the RTTOV options substructures are packed all together in the same group. Here are the OPTIONS dataset names by alphabetic order:

ADDAEROSL	Dataset {SCALAR}
ADDCLOUDS	Dataset {SCALAR}
ADDINTERP	Dataset {SCALAR}
ADDFPC	Dataset {SCALAR}

ADDRADREC	Dataset { SCALAR }
ADDREFRAC	Dataset { SCALAR }
ADDSOLAR	Dataset { SCALAR }
APPLY_REG_LIMITS	Dataset { SCALAR }
CC_LOW_CLOUD_TOP	Dataset { SCALAR }
CH4_DATA	Dataset { SCALAR }
CLDCOL_THRESHOLD	Dataset { SCALAR }
CLOUD_OVERLAP	Dataset { SCALAR }
CLW_CALC_ON_COEF_	Dataset { SCALAR }
CLW_CLOUD_TOP	Dataset { SCALAR }
CLW_DATA	Dataset { SCALAR }
CLW_SCHEME	Dataset { SCALAR }
CO2_DATA	Dataset { SCALAR }
CO_DATA	Dataset { SCALAR }
DOM_ACCURACY	Dataset { SCALAR }
DOM_NSTREAMS	Dataset { SCALAR }
DOM_OPDEP_THRESHOLD	Dataset { SCALAR }
DOM_RAYLEIGH	Dataset { SCALAR }
DO_CHECKINPUT	Dataset { SCALAR }
DO_LAMBERTIAN	Dataset { SCALAR }
DO_NLTE_CORRECTION	Dataset { SCALAR }
DTAU_TEST	Dataset { SCALAR }
FASTEM_VERSION	Dataset { SCALAR }
FIX_HGPL	Dataset { SCALAR }
GRID_BOX_AVG_CLOUD	Dataset { SCALAR }
INTERP_MODE	Dataset { SCALAR }
IPCBND	Dataset { SCALAR }
IPCREG	Dataset { SCALAR }
IR_SCATT_MODEL	Dataset { SCALAR }
IR_SEA_EMIS_MODEL	Dataset { SCALAR }
LAMBERTIAN_FIXED_ANGLE	Dataset { SCALAR }
LGRADP	Dataset { SCALAR }
N2O_DATA	Dataset { SCALAR }
NPCSCORES	Dataset { SCALAR }
OZONE_DATA	Dataset { SCALAR }
PLANE_PARALLEL	Dataset { SCALAR }
RAD_DOWN_LIN_TAU	Dataset { SCALAR }
RAYLEIGH_MAX_WAVELENGTH	Dataset { SCALAR }
RAYLEIGH_MIN_PRESSURE	Dataset { SCALAR }
RAYLEIGH_SINGLE_SCATT	Dataset { SCALAR }
REG_LIMIT_EXTRAP	Dataset { SCALAR }
SO2_DATA	Dataset { SCALAR }
SOLAR_SEA_BRDF_MODEL	Dataset { SCALAR }
SPACETOP	Dataset { SCALAR }
SUPPLY_FOAM_FRACTION	Dataset { SCALAR }



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SWITCHRAD	Dataset {SCALAR}
USER_AER_OPT_PARAM	Dataset {SCALAR}
USER_CLD_OPT_PARAM	Dataset {SCALAR}
USE_Q2M	Dataset {SCALAR}
USE_T2M_OPDEP	Dataset {SCALAR}
VERBOSE	Dataset {SCALAR}
VIS_SCATT_MODEL	Dataset {SCALAR}

## 4.2. ASCII Text profile file

The RTTOV GUI is able to read an ASCII text profile file. This kind of file is made of Python statements for the only necessary variables. Thus the format should respect the Python syntax language. The arrays should be defined as NumPy arrays, the scalars can be pure Python scalars or NumPy variables.

The variable names are the ones described in the RTTOV Users guide for the profile structure (Annex O), capital letters; except for:

- clouds where 2D cloud array is replaced by 1D cloud arrays, one for each cloud short name (table 16 of Users guide)
- aerosols where 2D aerosols array is replaced by 1D aerosol arrays, one for each aerosol short name (table 19 of Users guide)

Units should be the ones described in RTTOV Users Guide for profile structure (Annex O)

3 arrays are mandatory, pressure, temperature and water vapour; all other RTTOV profile variables are optional, they will be set to default values at reading time.

The list of profile variables that can be set by the user is given below; with the default values. Default values aims to a clear atmosphere. Number of levels and layers are deduced from array sizes.

```
# Mandatory arrays: P (hPa), T(K), Q(ppmv) on levels"
self["P"] = numpy.array([...])
self["T"] = numpy.array([...])
self["Q"] = numpy.array([...])


#-----"
# Optional profile variables "
#-----"
```

```
#" Other Gases (ppmv on levels)"
self["O3"] = numpy.array([...])
self["CO2"] = numpy.array([...])
self["CH4"] = numpy.array([...])
self["CO"] = numpy.array([...])
self["N2O"] = numpy.array([...])
self["SO2"] = numpy.array([...])

#" Aerosols (1/cm3 on layers)"
self["INSO"] = numpy.array([...]) # Insoluble
self["WASO"] = numpy.array([...]) # Water soluble
self["SOOT"] = numpy.array([...]) # Soot
self["SSAM"] = numpy.array([...]) # Sea salt (acc mode)
self["SSCM"] = numpy.array([...]) # Sea salt (coa mode)
self["MINM"] = numpy.array([...]) # Mineral (nuc mode)
self["MIAM"] = numpy.array([...]) # Mineral (acc mode)
self["MICM"] = numpy.array([...]) # Mineral (coa mode)
self["MITR"] = numpy.array([...]) # Mineral transported
self["SUSO"] = numpy.array([...]) # Sulphated droplets
self["VOLA"] = numpy.array([...]) # OPAC Volcanic ash
self["VAPO"] = numpy.array([...]) # New Volcanic ash
self["ASDU"] = numpy.array([...]) # Asian dust

#" Clouds (g/m3 on layers)"
self["STCO"] = numpy.array([...]) # Stratus Continental
self["STMA"] = numpy.array([...]) # Stratus Maritime
self["CUCC"] = numpy.array([...]) # Cumulus Continental Clean
self["CUCP"] = numpy.array([...]) # Cumulus Continental Polluted
self["CUMA"] = numpy.array([...]) # Cumulus Maritime
self["CIRR"] = numpy.array([...]) # Cirrus
self["CFRAC"] = numpy.array([...]) # Cloud Fraction (should be set if any cloud)
self["IDG"] = 1 # Scheme for Ice water content
self["ISH"] = 1 # Ice cristal shape

#" Skin variables "
self["SKIN"]["T"] = self["T"][-1] # (K)
```

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```

self["SKIN"]["SURFTYPE"] = 1 # (0=Land, 1=Sea, 2=sea-ice)
self["SKIN"]["WATERTYPE"] = 1 # (0=fresh water, 1=ocean water)
self["SKIN"]["SALINITY"] = 37 # (‰)
self["SKIN"]["FOAM_FRACTION"] = 0.0
self["SKIN"]["SNOW_FRACTION"] = 0.0
self["SKIN"]["FASTEM"] = numpy.array([0., 0., 0., 0., 0.]) # (5 parameters
Land/sea-ice)



#" 2m and 10m air variables "
self["S2M"]["T"] = self["T"][-1] # (K)
self["S2M"]["Q"] = self["Q"][-1] # (ppmv)
self["S2M"]["P"] = self["P"][-1] # (hPa)
self["S2M"]["U"] = 0 # (m/s)
self["S2M"]["V"] = 0 # (m/s)
self["S2M"]["WFETC"] = 100000 # (m)

#" Simple cloud "
self["CTP"] = 500.0 # (hPa)
self["CFRACTION"] = 0.0 # [0,1] Clear sky is the default

#" Viewing geometry "
self["AZANGLE"] = 0. # (deg)
self["ELEVATION"] = 0. # (km)
self["LATITUDE"] = 49.738 # (deg) Lannion is 48.750, -3.470
self["LONGITUDE"] = -3.473 # (deg) Exeter is 50.726, -3.476
self["SUNAZANGLE"] = 0. # (deg)
self["SUNZENANGLE"] = 0. # (deg)
self["ZENANGLE"] = 0. # (deg)

#" Magnetic field "
self["BE"] = 0.3 # (Gauss)
self["COSBK"] = 1.
# units
self["MMR_CLDAER"] = 1 #Cloud/aerosol units: 0: "g/m3", 1: "kg/kg",
#None:"kg/kg"
self["GAS_UNITS"] = 2 #-1: ppmv over dry air, 0: ppmv over dry air,

```

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```

# 1: kg/kg over moist air, 2: ppmv over moist air,
#None: ppmv over moist air

#" Mislaneous "
self["ID"]="This is my profile"
self["DATE"] = numpy.array([2014, 04, 30], dtype=int) # Year, Month, Day
self["TIME"] = numpy.array([12, 0, 0], dtype=int)      # Hour, Minute, Second

```

### 4.3. How to create an HDF5 profile file from Fortran

RTTOV user can create an HDF5 profile file for use in the RTTOV GUI using the associated RTTOV subroutine RTTOV\_HDF\_SAVE. That subroutine allows to store any RTTOV structure in an HDF5 file

For example a main Fortran program that can store a profile dataset and options in the same file would contain the following statements:

```

Use hdf5
Use rttov_hdf_mod
Type(profile_type),      Pointer:: profiles(:)          => NULL()
Type(rttov_options):: opts

CALL OPEN_HDF( .TRUE., ERR )
!... statements that creates the profiles array
!... and statements that fills the options opts
CALL RTTOV_HDF_SAVE( ERR, "PROFILES.H5", '/PROFILES', &
    CREATE=.true., PROFILES = profiles(1:nprofiles))
CALL RTTOV_HDF_SAVE( ERR, "PROFILES.H5", '/OPTIONS', CREATE=.false., &
    OPTIONS = opts )
CALL CLOSE_HDF( ERR )

```


### 4.4. How to create an HDF5 profile file from ASCII text profile file

The ASCII text profile files are Python files. A Python command named `rttov_gui_import_ascii_profile.py` allows the user to convert an ASCII text profile in an HDF5 profile file. This command makes use of RTTOV GUI Python software (Profile class), so cannot be used outside this framework.

```

usage: convert_python2hdf5.py [-h] -i INPUTF [-o OUTPUTF]
                               [-g GROUP] [-v]

```

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Import ASCII profile to HDF5 for RTTOV GUI

optional arguments:

```
-h, --help                show this help message and exit
-i INPUTF, --input-file INPUTF
                           input file name
-o OUTPUTF, --output-file OUTPUTF
                           output file name
-g GROUP, --group GROUP
                           internal HDF5 default is /PROFILES/0001/
-v, --verbose              display profile variables
```

## 5. Reporting bugs

All main RTTOV GUI actions are logged in a file named "rttovgui.log" in the RTTOV\_GUI\_WRK\_DIR directory . If the user encounters an issue during the RTTOV GUI usage, he should exit the program and copy the log file to a new name. Then this log file should be attached to any request to the help-desk or forum.

We encourage the users to share experiences through the RTTOV forum at <https://nwp-saf.eumetsat.int/site/forums/forum/rttov/>