ANALYSIS TOOLS OF IR SIGNATURE IN SE-WORKBENCH-EO

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ABSTRACT:

In the frame of the nEUROn UCAV program, DGA Information Superiority offers a methodological approach to assess the IR stealthness of the technological demonstrator. This approach includes the implementation of a set of tools to compare the measurements and the computations of the UCAV IR signature, through an evolution of the SE-Workbench-EO workshop. At DGA Information Superiority, the SE-Workbench-EO is used to perform multi-sensors simulations. It enables the user to create virtual and realistic multispectral 3D scenes that may contain several types of target, and then generate the physical signal received by a sensor, typically an IR sensor. Recently, DGA Information Superiority launched a project called PRESAGE in order to have at disposal dedicated software enabling to pre-compute physical phenomena leading to the optical and instantaneous thermal state of an aircraft with its plume in stabilized flight. This paper presents the recent evolutions that have been done. The first evolution consists mainly in the integration of new functionalities in SE-SIGNAL-VIEWER. This tool is used to visualize and analyse physical images computed by the ray tracer in SE-Workbench-EO. It allows the user to load images of a sensor moving around a target, and compute statistical data concerning the contrast of the target relative to the background. The second evolution consists in the coupling of the release 5.2 of MODTRAN software, in the SE-Workbench-EO tool "SE-ATMOSPHERE" dedicated to the computation of atmospheric data.

1. INTRODUCTION

The SE-Workbench-EO workshop is used at DGA Information Superiority to perform multi-sensors simulations. It enables the user to create multispectral 3D scenes with moving targets and compute the physical signal at the entrance pupil of a sensor. In the frame of the nEUROn UCAV (Unmanned Combat Air Vehicle) program, OKTAL-SE has developed a set of tools to compare the measurements and the computations of the UCAV IR signature.

Figure 1. nEUROn UCAV

The needs for DGA Information Superiority were to have advanced simulation tools:
- a tool for signature analysis
- an atmospheric tool

This paper describes the evolutions in SE-WORKBENCH-EO to fulfil the requirements of DGA Information Superiority needs. Two software in the SE-WORKBENCH-EO were concerned by the evolutions:
- SE-SIGNAL-VIEWER: tool for the analysis of spectral images
- SE-ATMOSPHERE: tool for the computation of atmospheric data.

2. SE-WORKBENCH-EO

2.1. Overall presentation of the SE-Workbench

The SE-WORKBENCH is a multi-sensor battlefield modelling workbench mainly used by - Defence agencies like French DGA, German BWB, South Korea MoD, Singapore DSO/DSTA and Swedish FOI, - research centres like ONERA, Fraunhofer IOSB and - industrials in and out of France like MBDA, Dassault, LG, STC.
SE-WORKBENCH-EO is the infrared sensor

dedicated part of the SE-WORKBENCH that achieves the synthesis of 3D scene observed by a sensor, in four steps:

- first, the physical characterization of the 3D scene behaviour,
- then, the scenario edition (definition of the objects of the scenario, the 3D scene and objects, assignment of trajectories to moving objects, definition of atmospheric and thermal conditions, parameterization of the sensors),
- then, the computation of the physical radiance signal received by the sensor
- at last, the sensor effects modelling.

The SE-WORKBENCH is entirely based on software products developed by OKTAL-SE and realizes the multi-spectral unification of optronics, electromagnetism and GNSS (Global Navigation Satellite System), using a common kernel and physical extensions assignment both aimed at a unique 3D scene and a common technology. The SE-WORKBENCH is a winning initiative for sharing R&D efforts and federating a user group community that intends to exchange experience and knowledge.

The first development was in 1994 and has been strongly boosted by the French SCALP missile program and the qualification of the IR tracking system. At the beginning, the SE-WORKBENCH was focused on the IR domain. In 2001, an electromagnetic version of the workshop was initiated, with the help of ONERA French research centre, mainly focused on millimetre waves and wide scenes, typically for SAR applications. A new GNSS version for satellite application has started in 2009. The control of the SE-WORBENCH-EO validity domain is based on both a theoretical validation approach (development of physical models, general modelling and simulation knowledge, elementary tests and validity assessment) and a validation process based on comparisons with experiments (SCALP/EG missile [FR], AASM missile [FR]).

2.2. The SE-WORKBENCH-EO architecture

The SE-WORKBENCH-EO is made of different components, as described hereafter, corresponding to the successive steps of a IR sensor simulation that are the modelling of the synthetic environment, the scenario edition, the rendering without the sensor effects and finally the sensor transfer function simulation. Furthermore, the user can do software integration in order to control the generated scenario execution from a remote or custom application. This can be achieved with the help of the SE-TOOLKIT consisting of a set of dedicated libraries and application programming interfaces (API) to help the complex application design and integration.
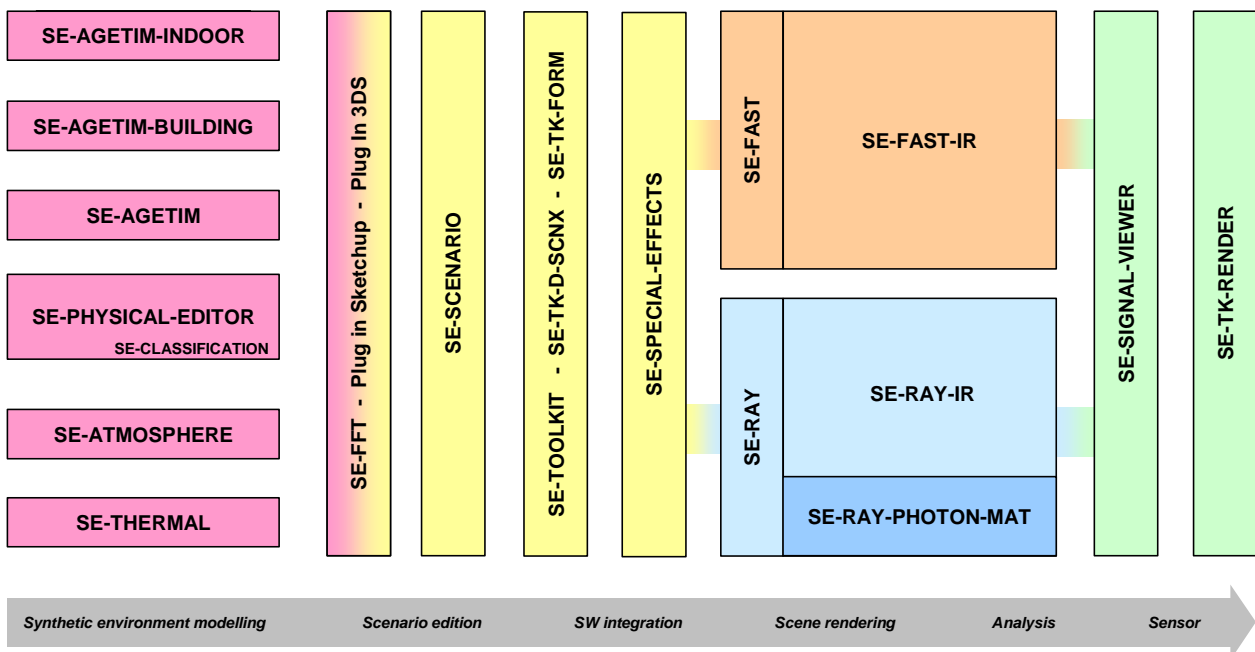

Figure 2. The SE-WORKBENCH-EO components

3. The PRESAGE project

The purpose of this project was to provide realistic aircraft IR signatures of a wide panel of aircrafts.

It was based on the combination of highly trustable COTS, phenomenological models, NATO validated models and SE-WORKBENCH physics. It offers both non real time and real time rendering (cf. Figure 3), and it is opened to alternative solutions for the specific parts of the modelling process, typically for CFD computation and plume rendering. The validation is based on comparison with other codes (ONERA CRIRA & NIRATAM) and/or with measurements. A commercial version called SE-PLUME with limited features is available.
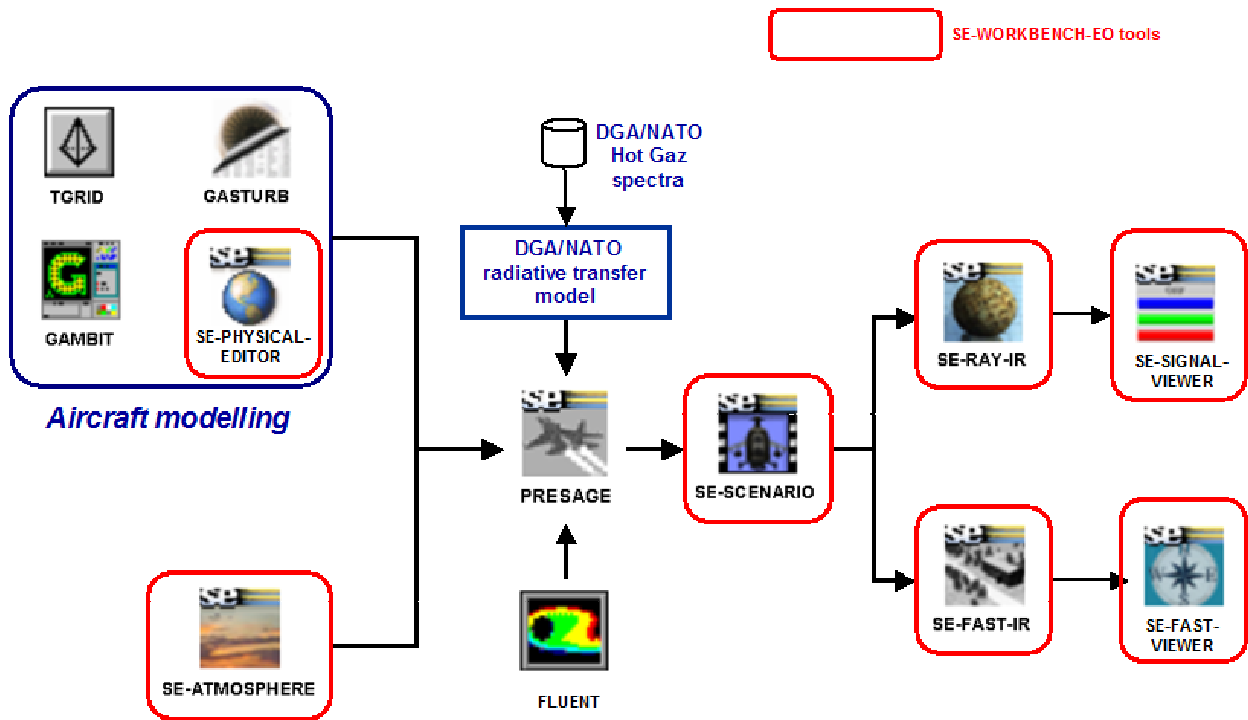
Figure 3. PRESAGE project

4. SE-SIGNAL-VIEWER evolutions

SE-SIGNAL-VIEWER is dedicated to the analysis of physical images (SPS format) computed by SE-RAY-IR (the non real time ray tracing software of SE-WORKBENCH-EO). It allows the user to display information concerning the image:
- spectral radiance,
- irradiance
- or intensity values.

In the display window, the user can define several selections. A selection can be:
- a pixel,
- an area,
- or a grid.

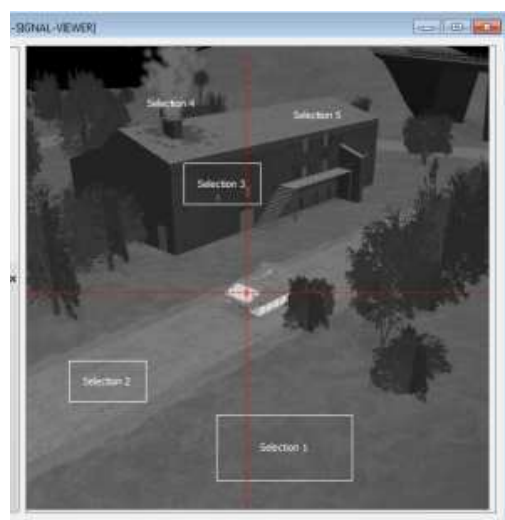Each selection has an identification name.

Figure 4. Examples of selections
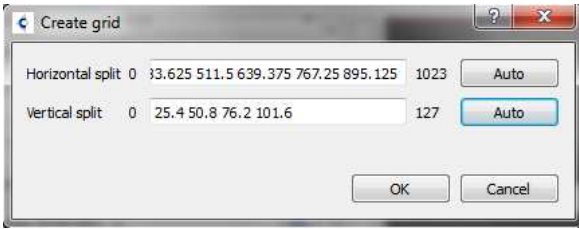
A grid can be regular or irregular.
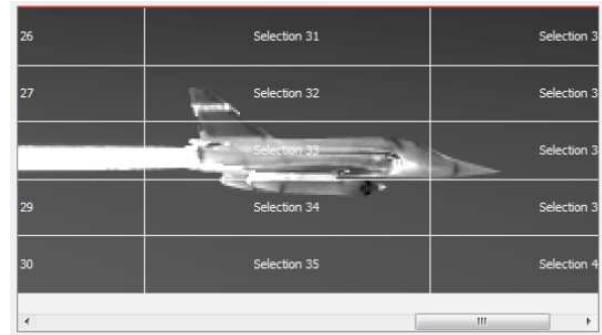

Figure 5. Regular grid parameterisation

The Figure 6 shows an example of a grid with multiple selection areas.

Figure 6. Grid of selections

4.1. Pixel information window

This window displays information concerning the image or selections of the image. Each selected item is associated to one line in the Pixel Information window (cf. Figure 7).

⊙	🔒	▸	Image	Selection	Average	Min	Max	Standard deviation	Median (80%)
⊙	🔓	▸	FARM_MWIR.sps	X1=236 Y1=272 X2=236 Y2=272	4.37323 W/m²/sr				
⊙	🔒	▸	FARM_MWIR.sps	X1=226 Y1=385 X2=363 Y2=457	3.01224 W/m²/sr	2.80685 W/m²/sr	3.21029 W/m²/sr	0.0538624 W/m²/sr	2.99175 W/m²/sr
⊙	🔒	▸	FARM_MWIR.sps	X1=60 Y1=342 X2=145 Y2=387	3.30505 W/m²/sr	3.01672 W/m²/sr	3.43564 W/m²/sr	0.0594268 W/m²/sr	3.2976 W/m²/sr
⊙	🔒	▸	FARM_MWIR.sps	X1=168 Y1=133 X2=231 Y2=155	2.45792 W/m²/sr	2.33333 W/m²/sr	2.51616 W/m²/sr	0.0320982 W/m²/sr	2.45278 W/m²/sr
⊙	🔒	▸	FARM_MWIR.sps	X1=162 Y1=65 X2=162 Y2=65	3.13924 W/m²/sr				
⊙	🔒	▸	FARM_MWIR.sps	X1=317 Y1=75 X2=317 Y2=75	3.09457 W/m²/sr				

Figure 7. Pixel Information window

The list of displayed information can be chosen among a list of information: each selected information is then shown in a dedicated column in the Pixel Information window (cf. Figure 8).

Figure 8. Choice of Information

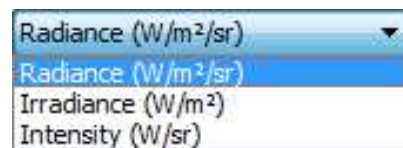The user can select the type of radiometric quantities to be displayed:

Figure 9. Choice of radiometric quantities

Finally, analysis functions have been added. They allow displaying vertical and horizontal variations, histograms, spectral distributions (cf. Figure 10 and Figure 11).
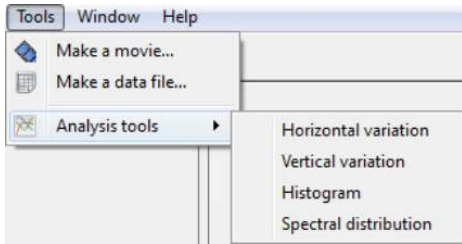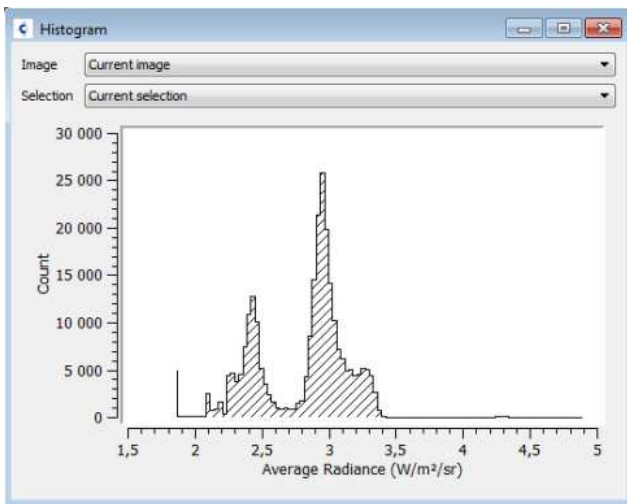
Figure 10. Copy of data

Figure 11. Example of histogram

4.2. Navigation mode

A specific plug-in to SE-SIGNAL-VIEWER has been developed. When loading a sequence of images, a "navigation" file is loaded. The navigation file is a SPS image. 2 kinds of sequences are allowed:
- a temporal sequence of images
- an orbital sequence of images (considering a sensor moving around the target at a given range).

4.2.1. Temporal sequence

The navigation image associated to a temporal sequence of images is an image with a line of pixels. Each pixel represents an image computed at a given date. The colour gives an idea of the value of the IR signature (cf. Figure 12).
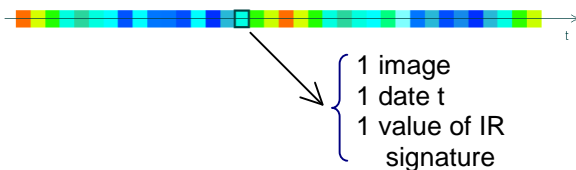
Figure 12. Temporal sequence

4.2.2. Orbital sequence

The navigation image associated to an orbital sequence of images is a rectangular. The X axis of the navigation image represents the head angle, and the Y axis represents the pitch angle (cf. example in *Figure 13*) where head angle varies from 0° to 360° and pitch angle varies from −15° to +30°.
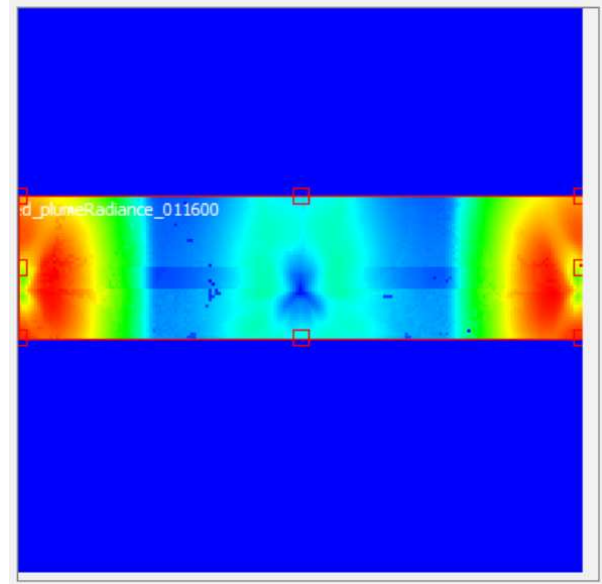

Figure 13. Orbital sequence

Each pixel of the navigation image is associated to a pitch angle and a head angle. These angles define the observation angles of the target. The colour gives an idea of the value of the IR signature.

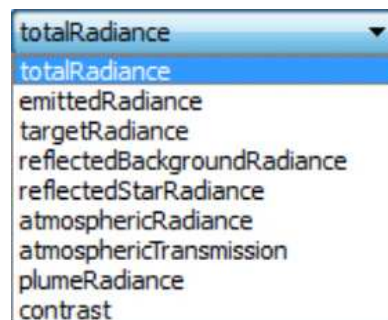The user can choose the signature contributions among the following list:

Figure 14. Choice of signature contribution

In order to compute such a kind of images, a specific tool: SE-RAY-SIR, was developed based on SE-RAY-IR. The GUI of SE-RAY-SIR allows the user to load a .scnx scenario file, a computation type (temporal sequence, or orbital sequence).

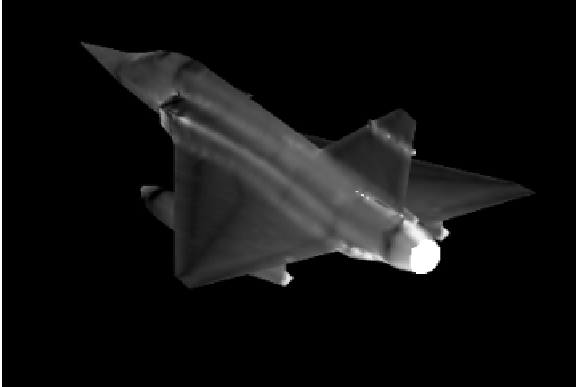Figure 15 and Figure 16 give an example of IR images computed using SE-RAY-SIR.
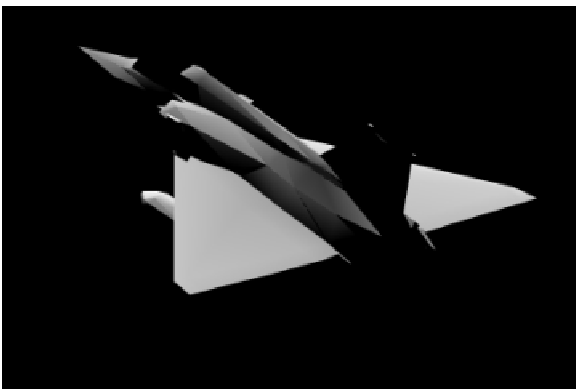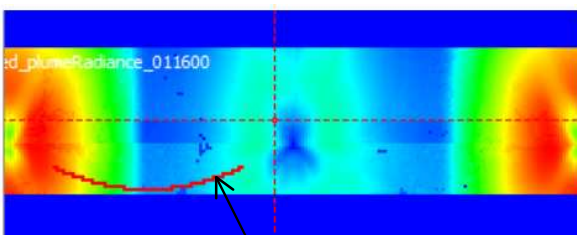
Figure 15. Emitted radiance

Figure 16. Reflected sun radiance

4.2.3. Nodal trajectory

For an orbital sequence, it is possible to give to the sensor a nodal trajectory and to draw the evolution of target angular presentation.

nodal trajectory

Figure 17. Nodal trajectory

SE-SIGNAL-VIEWER then displays statistics along this trajectory and, depending of the integration time of the sensor and its radiance threshold, highlights parts of the trajectory where the target signature is above the threshold,
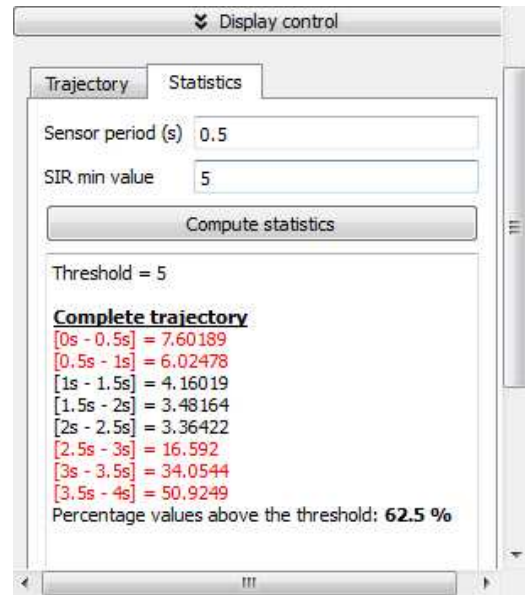

Figure 18. Statistics

5. SE-ATMOSPHERE evolutions

SE-ATMOSPHERE is dedicated to computation of atmospheric data for the thermal software (SE-THERMAL) and for the image simulation tools (SE-RAY-IR and SE-FAST-IR). It has an easy and efficient GUI for the parameterization of all the supported models that allows the parameterization of:

- global parameters: date, latitude, longitude, global atmospheric model, average wind speed, ground altitude, …
- time dependant parameters: haze, clouds, rain, wind (speed and direction), visibility range
- Line of Sight sampling and spectral sampling.
- Atmospheric profiles.

SE-ATMOSPHERE computes solar/lunar spectral irradiance, atmospheric spectral attenuation, sky and ground spectral radiance.

SE-ATMOSPHERE is coupled with very well known and validated atmospheric software such as MODTRAN 4 and MATISSE.

5.1. MODTRAN 5.2 coupling

In the frame of the project, SE-ATMOSPHERE was coupled with MODTRAN 5.2 in so far as the latter offers a better spectral resolution ($0.1cm^{-1}$), new refined spectral data (e.g. Top Of Atmosphere solar data). Times of computation have been improved especially for multiple scattering and radiance computation now takes into account additional molecular species (all HITRAN species are treated).
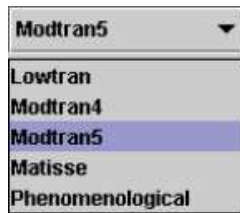
Figure 19. MODTRAN 5 in SE-ATMOSPHERE

5.2. Automatic profile generation using ITU-R P-835-4 recommendation

The ITU-R P-835-4 is a norm that gives models for the automatic computation of the atmospheric profiles of:
- Air temperature
- Pressure
- Humidity

These profiles are computed for different kinds of atmosphere:
- Mean annual global reference atmosphere (based on 1976 US Standard)
- Low-latitude annual reference atmosphere
- Summer mid-latitude reference atmosphere
- Winter mid-latitude reference atmosphere
- Summer high latitude reference atmosphere
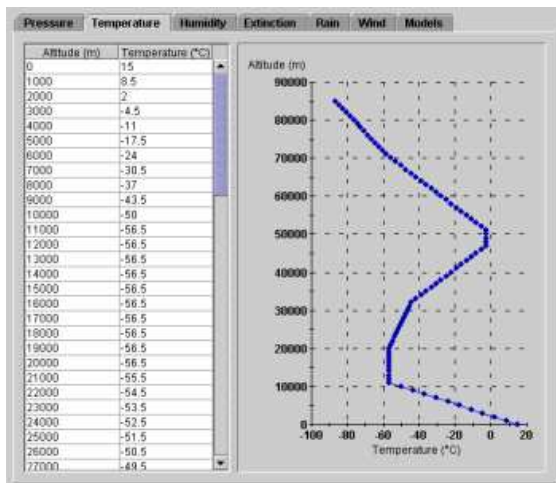- Winter high latitude reference atmosphere

Figure 20. Example of ITU-R-P-834 ed 4 profile

5.3. New functionalities for sensitivity studies

5.3.1. Preview mode

A preview mode has been added to SE-ATMOSPHERE. It allows the user to compute interactively a given LOS (Lines of Sight) and visualize the results. As the computation of atmospheric files is often very time consuming and the signature of an aircraft is sensitive to the atmospheric environment, it is important to set the

best parameterization. The purpose is to tune the sampling of wavelength, altitude, range, elevation and azimuth of the LOS before launching the computation of the complete atmospheric file. The GUI displays curves of comparison between current atmospheric configuration and results from another atmospheric file and allows the possibility to set new samples (cf. Figure 21).
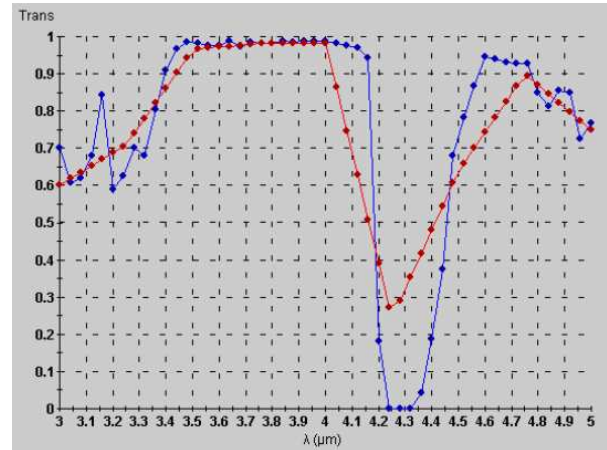

Figure 21. Wavelength sampling

5.3.2. Computation of contrast

SE-ATMOSPHERE offers the possibility to compute contrast between 2 materials set at the extremity of a LOS (cf. Figure 22).
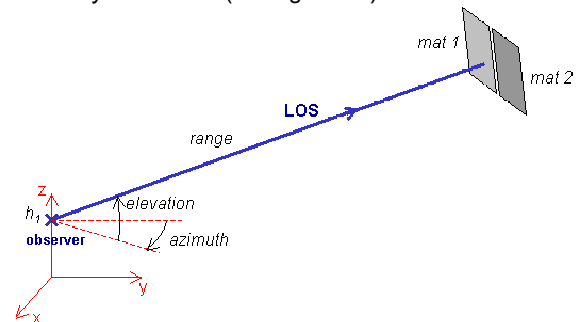

Figure 22. Definition of a LOS

The GUI displays spectral radiance values for the 2 materials (cf. Figure 23).
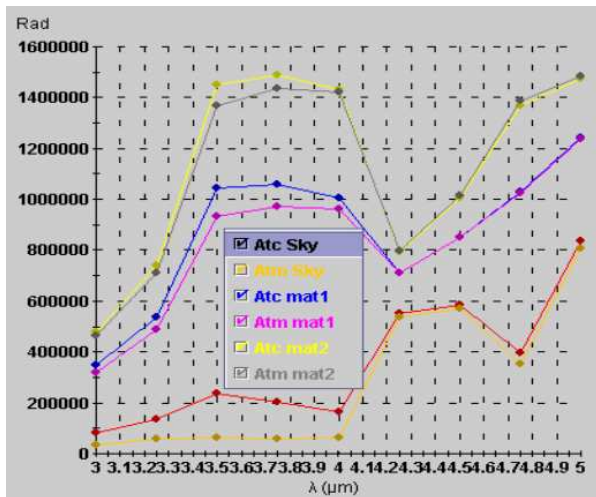
Figure 23. Computation of contrast

6. CONCLUSION

New functionalities have been developed in the SE-WORKBENCH-EO. They concern SE-SIGNAL-VIEWER and SE-ATMOSPHERE tools. These new functionalities will help the user to analyse signature of targets, to study the separate contributions to the global signature.

DGA Information Superiority will namely use these new tools to analyse real signatures of NEURON that will be measured in 2014 during flight trials and to evaluate thanks to those measurements the performance of stealth aircraft signature predictive modelling.

In fact, most of these functionalities will be already available in 2014 SE-WORKBENCH delivery.

7. REFERENCES

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