Generation of Look-Up-Tables for the atmospheric correction module of Sentinel-2 Level 2A processor (Sen2Cor) using libRadtran and comparison with MODTRAN

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CONTEXT: The first version of Sen2Cor was delivered with a single Look-up-Table covering different contents of water vapor and a large scale of solar and viewing angles, visibilities and elevations, but limited to mid-summer conditions, with a hypothesis of rural aerosol and a default value of ozone concentration, besides initial computation was performed using out-of-date Sentinel-2A spectral response functions. It has been established that 24 LUTs would be necessary to cover most of atmospheric conditions on Earth for the Sentinel-2 mission: rural & maritime aerosols, winter & summer atmospheres with six different Ozone concentrations. This poster is an overview of the 24 LUTs generation process and the validations results.

LUT GENERATION:

The 24 LUTs generation (see Figure 1) is based on the libRadtran radiative transfer library. Some of them are also generated with MODTRAN for validation purpose. The generation involves the development of scripts that make all the calls to the libraries necessary to fill the LUTs. Optimisations and multithreading are also applied in order to reduce the generation time. 30 days of processing are still needed in order to produce the whole set of 24 LUTs (16 cores server).

VALIDATION STRATEGY:

The validation of the LUTs generated with libRadtran has been done in 3 steps:

1. First LUT: For the first LUT generated 2 references were available:
   - Sen2Cor existing LUT, based on libRadtran
   - Initial LUT, made by DLR, based on MODTRAN
2. Validation against Modtran: 4 LUTs with default ozone concentration, but rural or maritime aerosol, summer or winter condition.
3. Cross-comparison: the 20 remaining LUTs are compared to the 4 LUTs validated against Modtran.

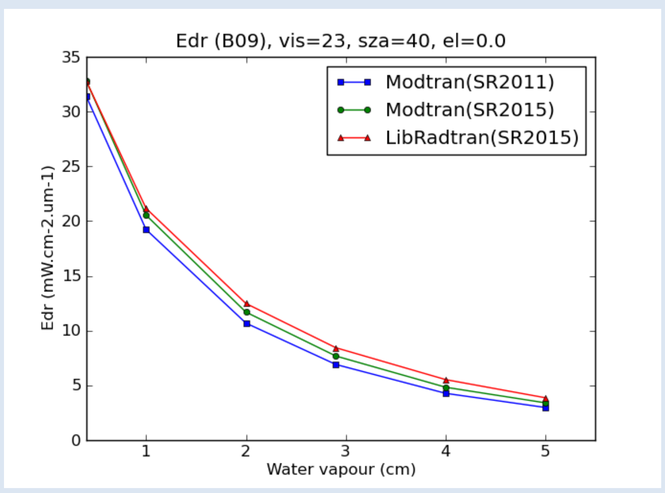
VALIDATION TOOLS (1/2): PLOTS

Each validation process consisted to compare a LUT to another one, considered as a reference.

Fine validation:
A classic approach has been followed by making a great number of plots representing the observed parameter (one of the 6 LUT parameters) as function of the solar zenith angle, the elevation, the visibility, or the wavelength.

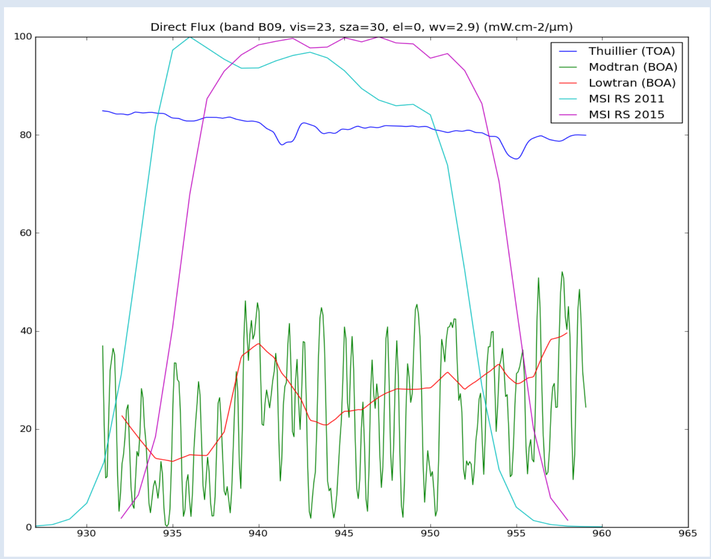
EXAMPLE 1: Water Vapor Sensitivity:

Water vapour retrieval in Sen2Cor runs with B8A and B09 and Edr LUT parameter.



IMPACT OF MODEL BAND AND SPECTRAL RESPONSE:

Example for band B09 comparing spectral responses (SR) of 2011 vs. 2015 and Lowtran model band (libRadtran) vs. Modtran.



THE LOOK-UP-TABLE:

6 radiative transfer functions are calculated for different atmospheric conditions, view angles 0° (nadir) and 10° off-nadir, and a range of solar geometries and relative azimuth angles:

Lp	path radiance
Edf	diffuse flux at the sensor = (Tdir + Tdif)*Edif
Edr	direct (beam) irradiance at the sensor = (Tdir+Tdif)*Tsun*E
Tdir	direct transmittance ground-to-sensor
Tdif	diffuse transmittance ground-to-sensor
s	spherical albedo of atmosphere

where:
Edif is the diffuse solar flux at the ground,
Tsun is the sun-to-ground direct transmittance,
E = extraterrestrial solar irradiance.

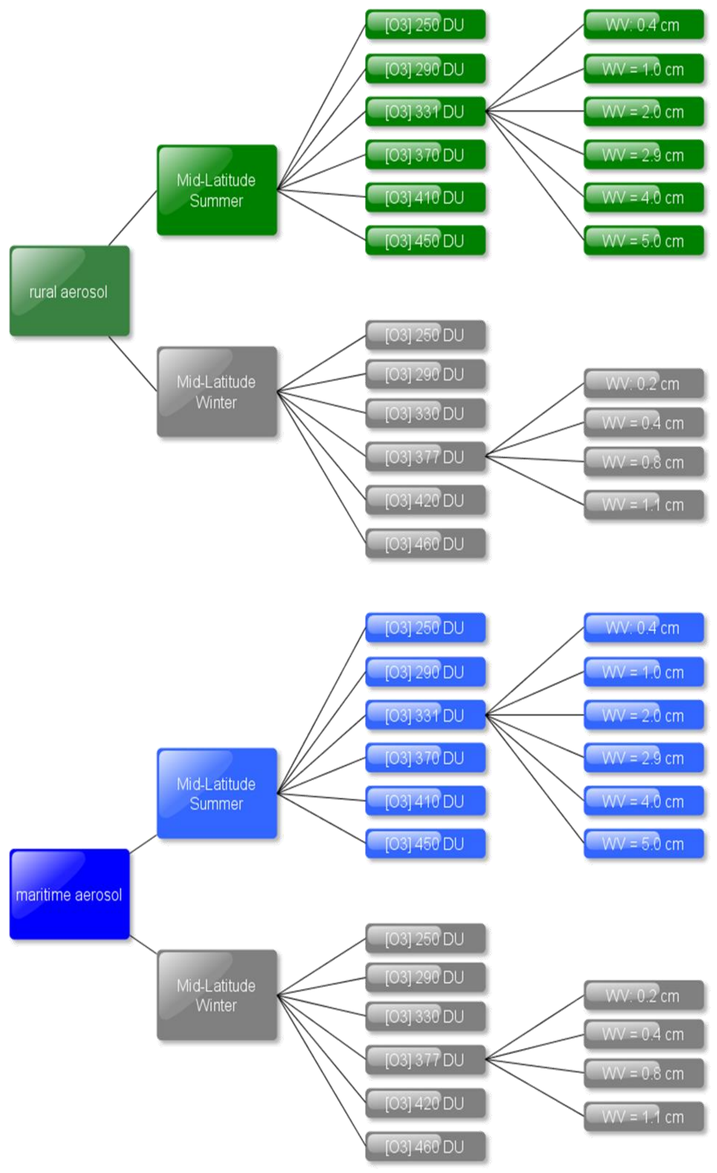


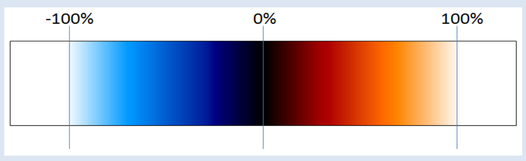
Figure 1 : View of Sen2Cor 24 LUTs

VALIDATION TOOLS (2/2): ERROR MAPS

Global validation:
As the "plots approach" was not global enough to cover an entire LUT and detect potential problem that remains locally, a second approach has been introduced. The error map method consists in computing for each pixel of the 2 LUTs to compare a difference expressed as an error in percentage. Each error is written it in a raster file at the same position than the source pixels. Error is computing as follow:

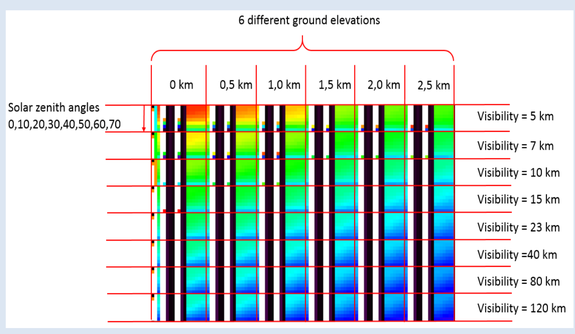
$$error = 100 \times (ref - val) / ref$$

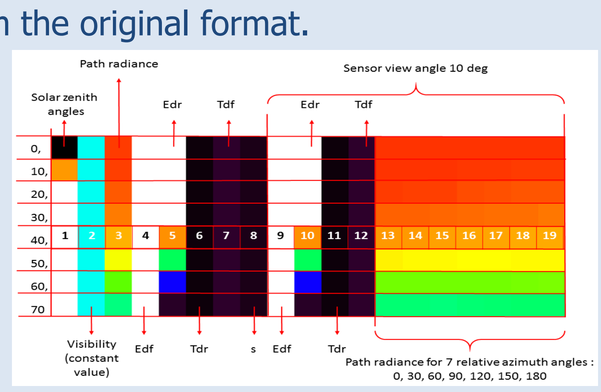
Then a color table is applied making possible to quickly determine the intensity and the sign of the errors.



READING ERROR MAPS

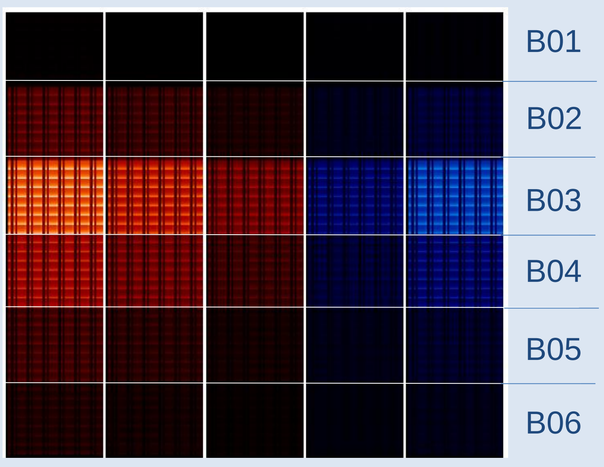
The position of parameters is kept from the original format.



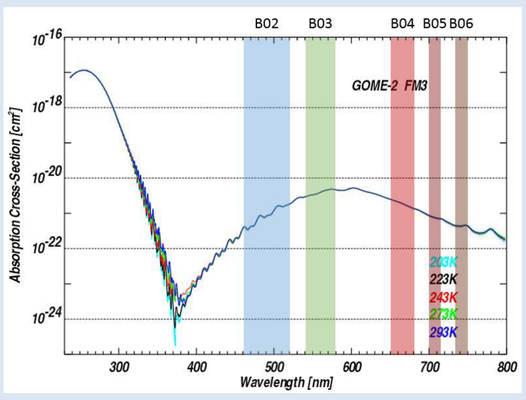


EXAMPLE 1: See Figure 2

EXAMPLE 2: Ozone Sensitivity



libRadtran vs. libRadtran / different ozone



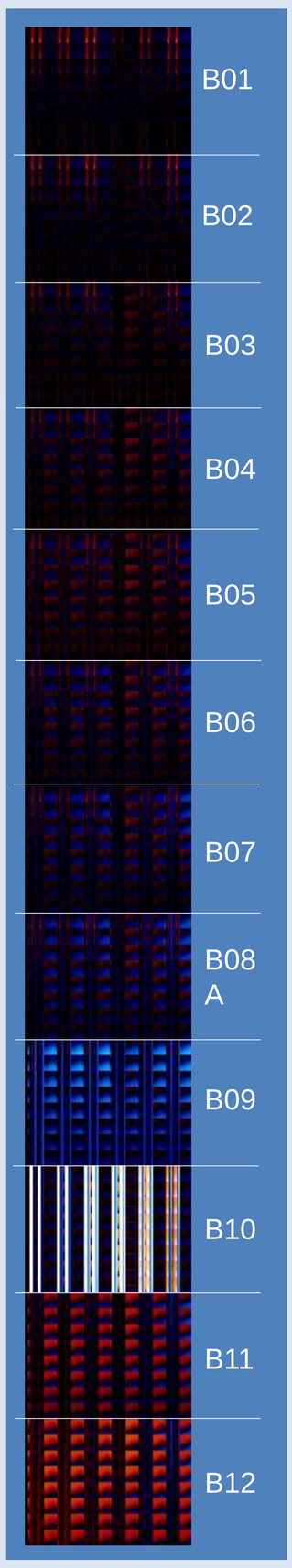


Figure 2 : Error map LUT libRadtran vs LUT MODTRAN

DISCUSSION AND CONCLUSION:

Global status:
Good matching between LUTs generated with libRadtran and Modtran, except for B10 (not involved in atmospheric correction) and B09 located in solar spectrum regions with strong absorption.
Known issues:
B09 comparison differences might introduce a bias in the estimation of the water vapour in Sen2Cor. This issue is closely followed during L2A products validation.
Possible improvements:
Generate LUTs with more accurate band models (« reptran medium » or « reptran fine »), especially for B09. But need also to solve some performance issues about time processing, maybe using clustering or cloud processing.

KEYWORDS: Atmospheric Correction, Sentinel-2, SEN2COR, libRadtran 2.0, MODTRAN 5.3.3

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