Atmospheric Correction in Sentinel-2 Simplified Level 2 Product Prototype Processor: Technical Aspects of Design and Implementation

Aliaksei Makarau[1], Rudolf Richter[1], Tobias Storch[1], Peter Reinartz[1], and Luca Galli[2]

[1]German Aerospace Center (DLR), Münchnerstr. 20, Weßling, Germany, [2]Advanced Computer Systems (ACS), Via della Bufalotta 378, Rome, Italy

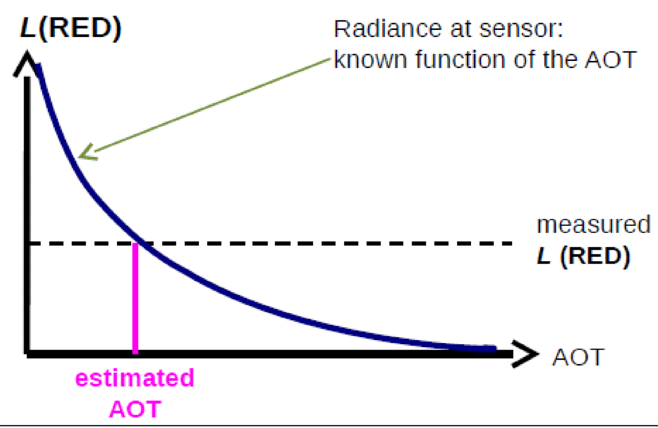
This work presents the scientific and technical aspects of the Level 2A (atmospheric/topographic correction) for the Sentinel-2 Simplified Level 2 Product Prototype Processor (S2 SL2 PPP). The chain is to estimate the following: Aerosol type (AT), Bottom of atmosphere (BOA) reflectance (with cirrus detection and correction), Aerosol optical thickness (AOT), and Water vapor (WV). A selection of bands for the estimation of AT and AOT is necessary. The parameter set is estimated by a sensitivity analysis on a simulated top and bottom of atmosphere reflectance data based on radiative transfer simulations. AOT map and WV map are estimated on the 20m data. Then the maps are resized to the 10m and the 10m BOA reflectance are estimated. The cirrus cloud map is created by the cirrus 1.38 μm band thresholding. Cirrus compensation is performed by correlating the cirrus band reflectance to the reflective region bands and subtraction of the cirrus contribution per band. Validation of the chain is performed given the TOA data (as input) and bottom of atmosphere products (the reference). Estimated reflectance is assessed comparing with the ground truth reflectance. AOT is validated comparing with the AERONET measurement. Cirrus correction is validated using a pair of scenes acquired for the same area with a small time difference. One scene is contaminated by cirrus cloud to be restored, the other is cirrus free and used as the reference. A comparison of the estimated products is performed with an alternative atmospheric correction chain – FLAASH.

Aerosol optical thickness (AOT) estimation: DDV method.

- Detect a special landcover class with a minimal spectral variation over the globe (dense dark vegetation - DDV),
- A correlation between the blue, red, and SWIR reflectance in the DDV pixels is employed to obtain reflectance and radiance in the RED band:

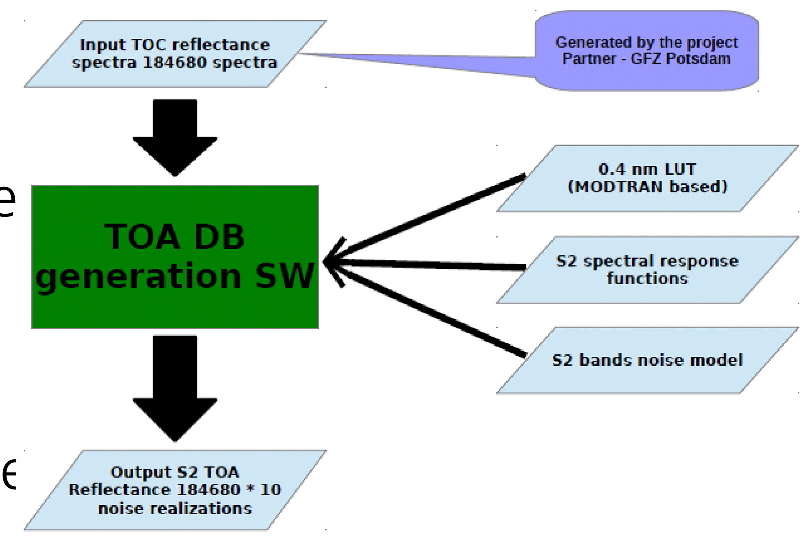
$\rho(RED) = \mathbf{0.5} * \rho(SWIR\ 2.2\mu m) + \mathbf{0.005}$

$L(RED) = Lp + \tau\rho\,(RED)\,E / \pi$



Sensitivity analysis. A top of canopy (TOC) database composed from synthetic (PROSAIL and HYSIMCAR) and real (ASTER library), 0.4-2.5 μm range, 1 nm step. DDV spectra are in.

- TOA database is generated.
- The MODTRAN code is employed to simulate the propagation of the radiance in the atmosphere (midlatitude summer, ozone: 331 DU, CO2: 400 ppmV, trace gases are with the standard settings).
- Resampled to the S2 spectral response functions, best and worst cases.



Sensitivity analysis.

- DDV pixels selection: B11 or B12 band selection and the thresholds,
- AOT estimation: Blue (B1 or B2) and the SWIR (B11 or B12) bands,
- Aerosol type estimation: Blue (B1 or B2 as estimated for the AOT),

Parameter set estimation:

- Correlation coefficients for the blue-red and red-SWIR bands,
- Cirrus detection thresholds,
- Cirrus correction.

Band combinations to be analyzed: B1/B4, B2/B4, B1/B11, B2/B11, B1/B12, B2/B12, MEAN(B1, B2)/B4, MEAN(B1, B2)/B11, and MEAN(B1, B2)/B12.

Sensitivity analysis outcomes. Sensitivity analysis was done together with the GFZ Potsdam.

- Iterative TOC reflectance thresholds on the SWIR 2.2 μm band are: 5%, 10%, and 12%. 5% threshold – only the DDV pixels are selected.
- No significant difference between the best and worst case instrument response.
- The band combinations with the correlation coefficients are selected:
  - **B4/B11, corr is 0.27** (literature reports correlation 0.25),
  - B2/B4, corr is 0.93 (literature reports correlation 0.5).

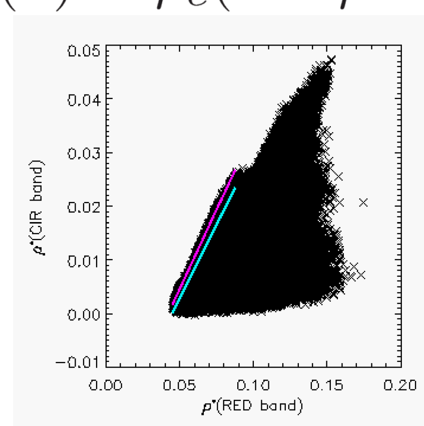
  Literature standard is: B4/B12, corr = 0.5, offset 0.005, or **B4/B11, corr = 0.25**

Cirrus detection.

- Cirrus clouds are in the upper tropo- and lower stratosphere (8-16 km).
- Affects the visible, near infrared, and SWIR range.
- With cirrus band B10 1.38 μm, (ρ* is the TOA reflectance) the following cirrus classes are identified:
  - Thin cirrus: $1.0\% < \rho^* < 1.5\%$,
  - Medium cirrus: $1.5\% \le \rho^* < 2.5\%$,
  - Thick cirrus: $2.5\% \le \rho^*$.

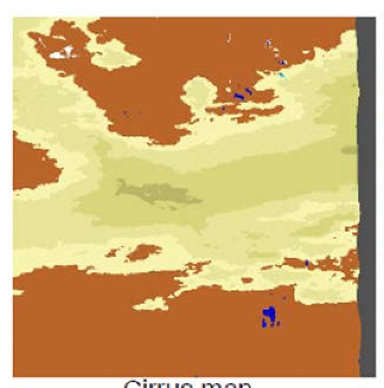
Cirrus removal. A correlation of the cirrus signal at 1.38 μm and the other channels is estimated (a scatterplot):

$$\rho^*(\lambda) = \rho_c(1.38\mu m)/\gamma$$

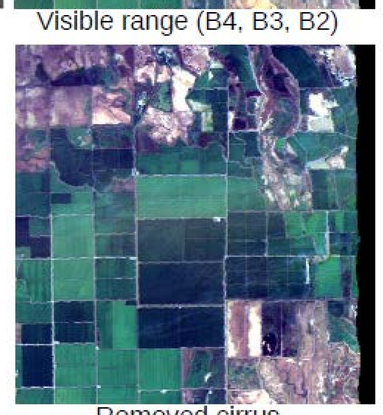


The cirrus contribution is removed from the band:

$$\rho^*(\lambda) = \rho_c(\lambda) + T_c(\lambda)\rho(\lambda)$$
$$\rho^*_{cc}(\lambda) = \rho^*(\lambda) - \rho_c(1.38\mu m)/\gamma$$

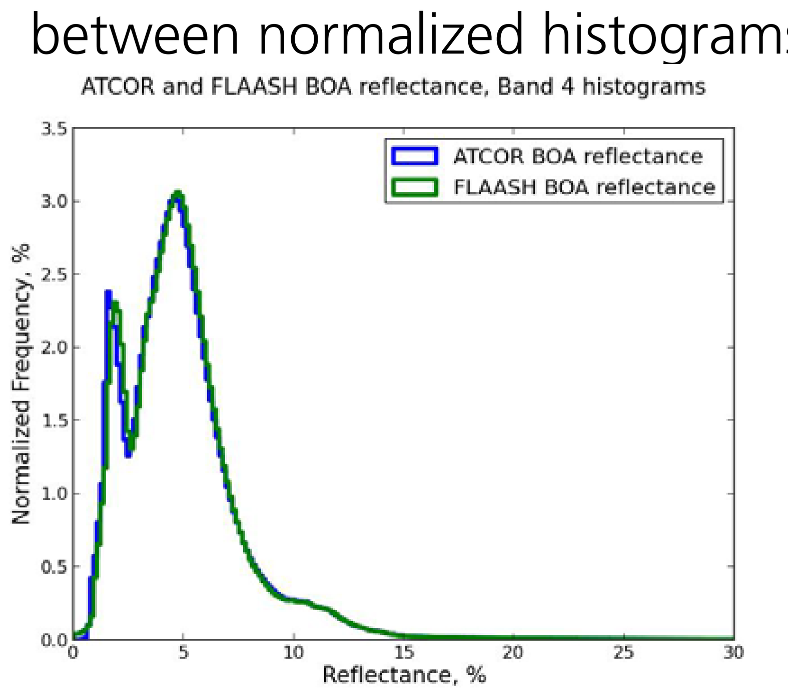

Cirrus map

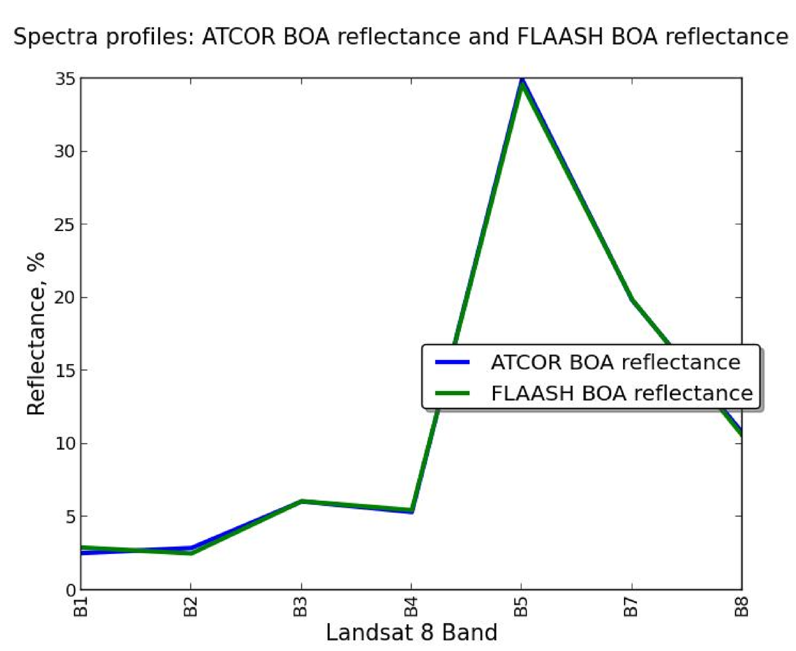

Visible range (B4, B3, B2)


Removed cirrus

Scientific validation: BOA comparison.

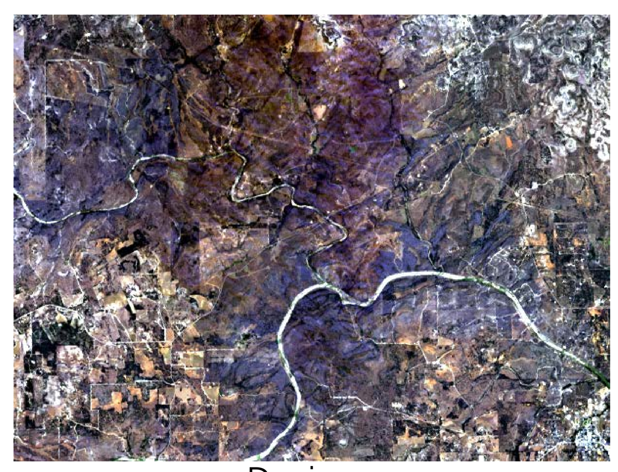
- Reflectance comparison with an alternative well known atmospheric correction chain – FLAASH,
- Test site: ICIPE-Mbita, Acquisition date, time: 21.05.2013, Mean ground elevation, km: 1.125,
- Relative difference: mean value, standard deviation; Euclidean distance between normalized histograms

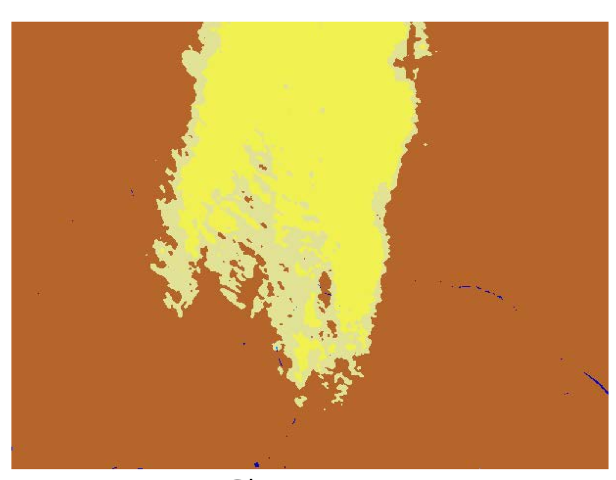




Scientific validation: Cirrus cloud correction accuracy.


Data cirrus, 25.08.2014


Decirrus


Cirrus map


Reference cirrus free, 09.08.2014