SENTINEL-2 SEN2COR: L2A PROCESSOR FOR USERS

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ABSTRACT

Sen2Cor is a Level-2A (L2A) processor which main purpose is to correct single-date Sentinel-2 Level-1C products from the effects of the atmosphere in order to deliver a Level-2A surface reflectance product.

This paper provides a description of L2A products contents and format. It presents also the different ways to run and configure the Sen2Cor processor and provides up-to-date information about the Sen2Cor release status and early validation results at the time of the Living Planet Symposium 2016.

1. INTRODUCTION

The Sentinel-2 Mission Performance Centre or MPC is the entity within the Sentinel-2 ground segment responsible for monitoring the product quality. The MPC (Fig. 1) relies on three teams of Expert Support Laboratories (ESL) to perform the calibration and validation activities: L1_CAL for the calibration of the instrument, L1_VAL for the validation of L1 products and the ESL L2A in charge of the calibration of the L2A processor and the validation of the L2A products.

Figure 1. Sentinel-2MPC consortium and actors.

Telespazio France is leading these L2A Cal/Val activities with the strong support of DLR for the validation, the organization of in-situ campaigns and the collection of reference data for validation.

The main processing steps of the Sen2Cor processor are recalled in Fig. 2. Level-2A processing is applied to granules of Top-Of-Atmosphere (TOA) Level-1C ortho-image reflectance products. The processing starts with the Cloud Detection and Scene Classification followed by the retrieval of the Aerosol Optical Thickness (AOT) and the Water Vapour (WV) content from the L1C image. The final step is the TOA to Bottom-Of-Atmosphere (BOA) conversion. Sen2Cor also includes several options that can be activated like cirrus correction, terrain correction, adjacency correction and empirical BRDF-corrections.

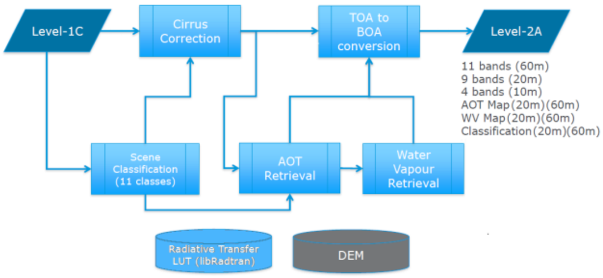

Figure 2. Sen2Cor main processing steps.

Sen2Cor relies on two main auxiliary data: the Radiative Transfer Look-Up Tables and the Digital Elevation Model (DEM), which one is not embedded in the Sen2Cor software but can be provided by the user in DTED format. The user can also rely on the default SRTM DEM.

L2A outputs are a Scene Classification (SCL) image together with Quality Indicators for cloud and snow probabilities, AOT and WV maps and the surface (or BOA) reflectance images which are provided at different spatial resolutions (60m, 20m and 10m).

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2. L2A PRODUCT STRUCTURE & CONTENT

The structure of the L2A product is strictly based on the structure of the L1C product with some differences that are highlighted in green on Fig. 3. The main difference is that the IMG_DATA folder contains three directories: one for each resolution at 60m, 20m, and 10m. The scene classification tile is available at the root of the IMG_DATA folder at 20m or 60m depending on the type of processing that was selected.

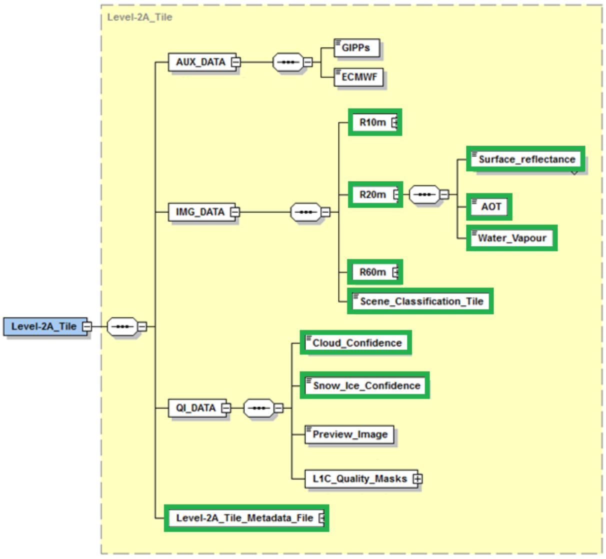

Figure 3. L2A Tile directory structure

2.1. L2A Scene Classification Module Outputs

The main output of the Cloud Screening and Scene Classification module consists in a Scene Classification map (Fig. 4) divided in 11 classes as shown on legend in Fig. 5.

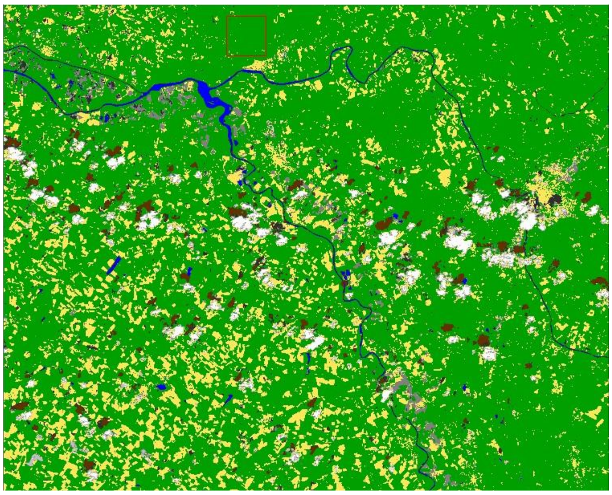

Figure 4. Scene Classification image (L2A subset)

0	No Data (Missing data on projected tiles) (black)	
1	Saturated or defective pixel (red)	
2	Dark features / Shadows (very dark grey)	
3	Cloud shadows (dark brown)	
4	Vegetation (green)	
5	Bare soils / deserts (dark yellow)	
6	Water (dark and bright) (blue)	
7	Cloud low probability (dark grey)	
8	Cloud medium probability (grey)	
9	Cloud high probability (white)	
10	Thin cirrus (very bright blue)	
11	Snow or ice (very bright pink)	

Figure 5. Scene Classification Legend

Together with the Scene Classification map, two quality indicators are provided: a Cloud confidence map and a Snow confidence map (Fig. 6) with values ranging from 0 to 100 (%).

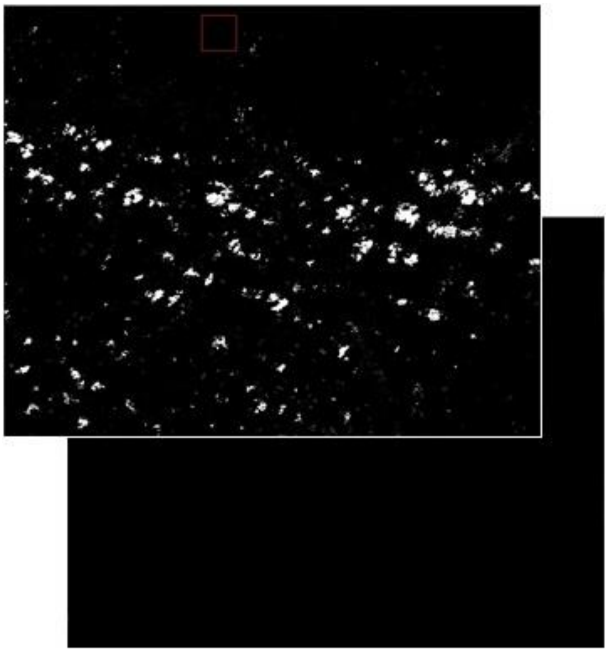

Figure 6. Cloud Confidence and Snow Confidence Quality Indicators (L2A subset)

2.2. L2A Surface Reflectance at 10m

In the R10m directory of the IMG_DATA folder are located the surface reflectance images with 10m spatial resolution for the following bands: B02, B03, B04 and B08. Examples of RGB coloured composition with these bands are shown in Fig.7 and Fig.8.

Figure 7. RGB Composition B04 – B03 –B02
Garonne and Tarn confluence area, France

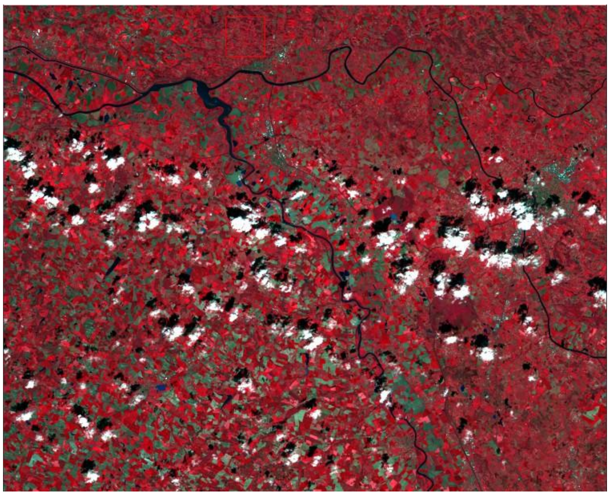

Figure 8. RGB Composition B08 – B04 –B03

2.3. L2A Surface Reflectance at 20m and 60m

In addition to the 10m resolution native bands B02, B03 and B04, the surface reflectances are available at 20m resolution for the following bands: The “red edge” bands B05, B06, B07 (Fig. 9), the NIR band B8A and the two SWIR bands B11 and B12 (Fig. 10).
The “coastal and aerosol” band B01 and the band B09 located in the Water Vapour absorption region are provided at their 60m native resolution together with all other bands at the exception of bands B10 and B08.
Band B10 is not provided in surface reflectance as it does not provide information on the surface and band B08 is replaced by band B8A which provides a narrower spectral band.

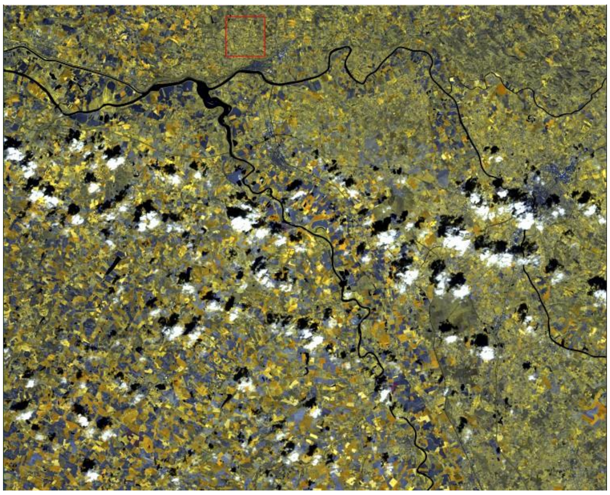

Figure 9. Red Edge Bands
RGB Composition B07 – B06 –B05

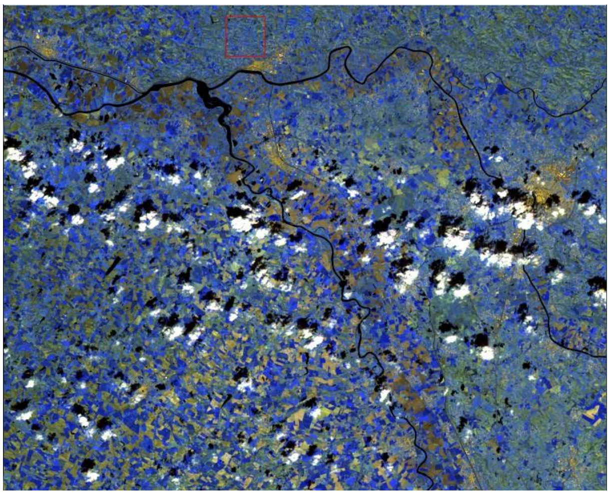

Figure 10. SWIR & NIR bands
RGB Composition B12 – B11 –B8A

2.4. L2A Atmospheric parameters

Sen2Cor atmospheric correction algorithm relies on the APDA (Atmospheric Precorrected Differential Absorption) algorithm [1] to retrieve the Water Vapour content from the L1C image. This algorithm uses a ratio between band B8A and band B09. It is therefore important to have a very good internal resampling that preserves the geolocation accuracy of bands that have different native resolution. Fig. 11 provides an example of a Water Vapour map obtained by Sen2Cor, together with its histogram and colour legend. The quantification value to convert Digital Numbers to Water Vapour column in cm is equal to 1000.

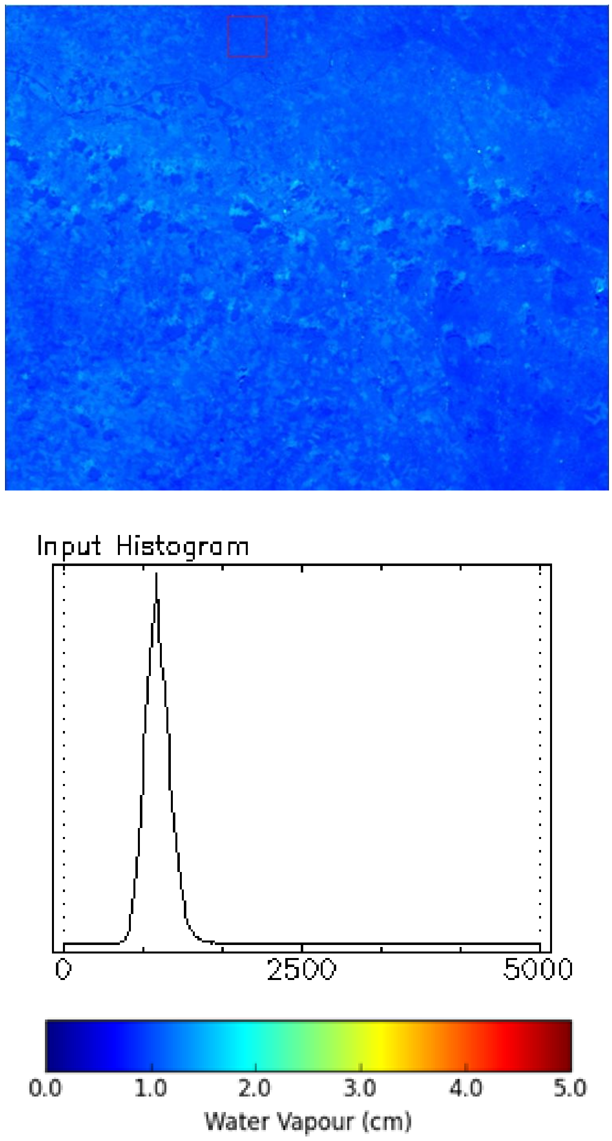

Figure11. Water Vapour Column (cm)
Histogram & Legend

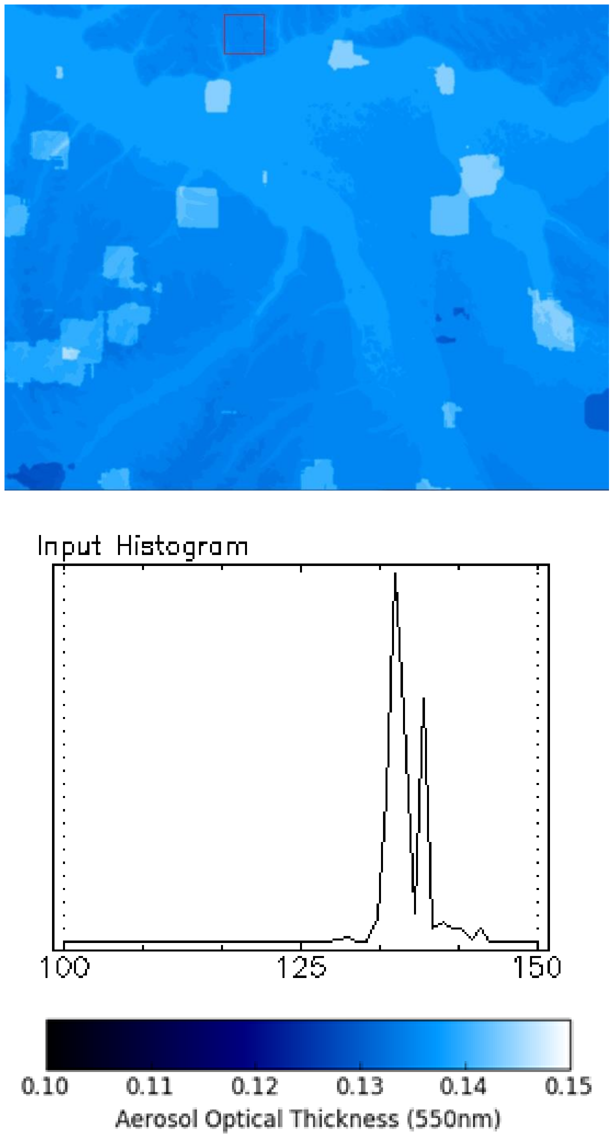

Figure 12. Aerosol Optical Thickness
Histogram & Legend

In the current version 2.2.1 of Sen2Cor, the Aerosol Optical Thickness (AOT) is estimated from the Dark Dense Vegetation (DDV) pixel method introduced by Kaufmann [2]. More details on the Sen2Cor retrieval method are available in [3].

On the example shown in Fig. 12, the AOT dynamic has been stretched to emphasize and highlight the slight AOT variations within the image. In this particular case where sufficient DDV pixels are available, the AOT variations are on the order of +/- 0.005. The quantification value to convert Digital Numbers to AOT is equal to 1000.

3. SEN2COR OPERATIONS & CONFIGURATION

3.1. Sen2Cor Operating Modes

Currently there are two ways to run Sen2Cor, either from the SNAP Toolbox or via command line. Once Sen2Cor is installed on your machine and correctly integrated within SNAP as a Third-Party Plugin, you can access Sen2Cor through the Optical -> Thematic Land Processing Menu -> Sen2Cor as shown in Fig.13. The user can select the L1C product to be processed and can select few other processing options from the Graphical User Interface. The resulting L2A product generated is then available by default in the same directory of the L1C product.

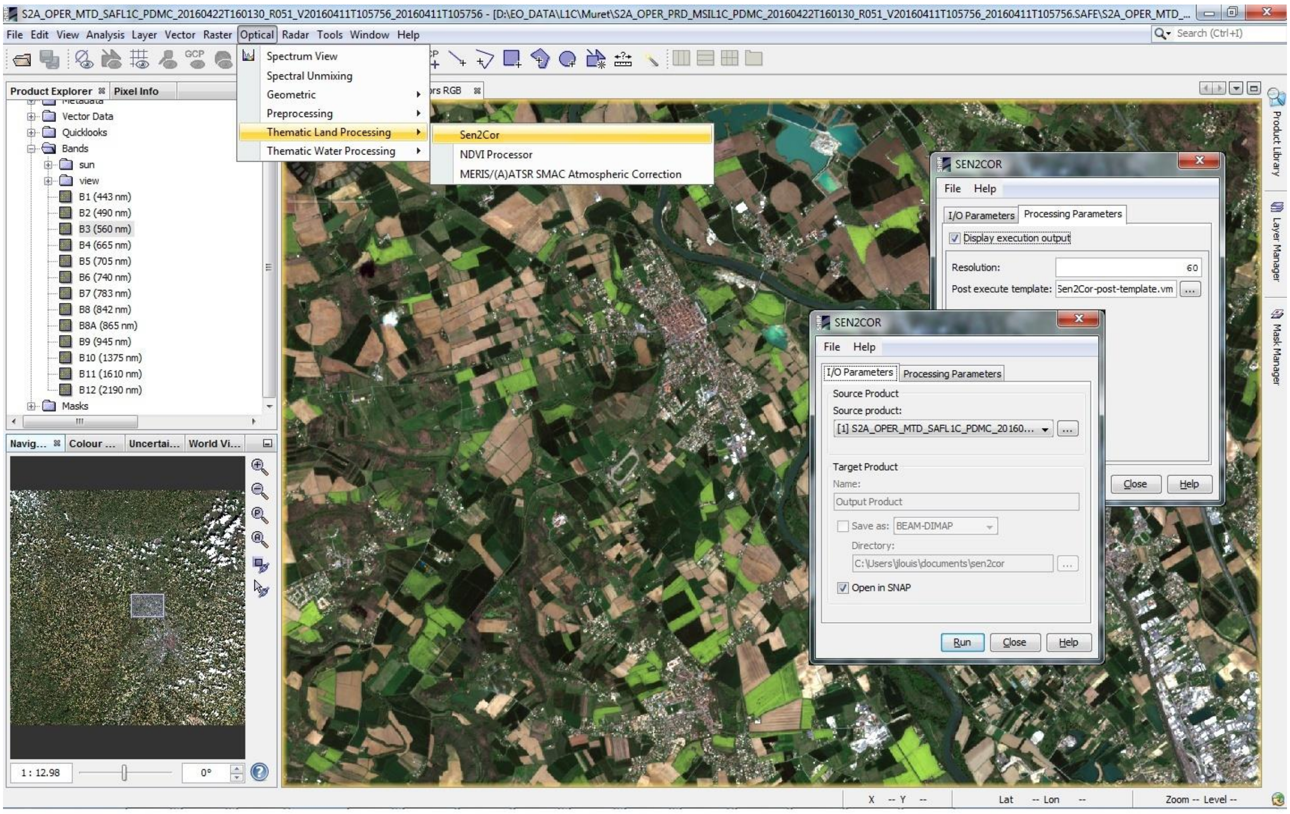

Figure 13. SNAP Sentinel-2 Toolbox

For more experienced users, Sen2Cor is also available through the command line of their operating system (Windows, Mac and Linux). In this operating mode, the full set of processing parameters is available. The user can select: 1) the resolution at which the processing will be done, 2) if Sen2Cor will perform the scene classification only and 3) indicate which particular Sen2Cor configuration file will be used.

3.2. Sen2Cor Configuration

Further configuration of the Sen2Cor algorithm is possible through a configuration file: L2A_GIPP.xml, which the user can edit to set the following main options:

- Parallelization: Number of processes (1,2,…or auto)
- DEM usage: (yes or no)
- Aerosol type: (rural or maritime)
- Atmosphere profile: (Mid-Latitude Summer or Mid-Latitude Winter)
- Ozone Content: Automatic selection (if ECMWF aux data present)
- Cirrus correction (yes or no)

Please refer to the Sen2Cor user manual [4] for a complete list of options to be selectable by the user.

4. SEN2COR RELEASE STATUS

- Version 2.0.6 released in December 2015
- Version 2.2.1 released on May 4, 2016
    - Scene classification improvements
    - Cloud shadow detection evolution
    - Topographic shadow evolutions
    - Snow and water classification improvements
    - Cirrus detection improvements
    - Updated internal resampling method
    - DEM support: SRTM or DEM provided by user in DTED format
    - 24 Look-Up-Tables for extended atmospheric conditions
    - Parallel granule processing

For more details on the new features included in the version 2.2.1, please refer to the software release note [5].

5. SCENE CLASSIFICATION EVOLUTIONS

This chapter provides details about the two main evolutions of the Scene classification algorithm in Sen2Cor version 2.2.1.

5.1. Cloud shadows algorithm

The implementation of the cloud shadow algorithm has been reviewed to allow a proper computation of the cloud shadows for all configuration of solar angles and viewing angles in northern and southern hemispheres. In addition, the dark features identification used as input for the cloud shadow computation has been calibrated to improve the resulting cloud shadow mask. Fig. 14 gives an example of the cloud shadow class appearance in the Scene Classification map.

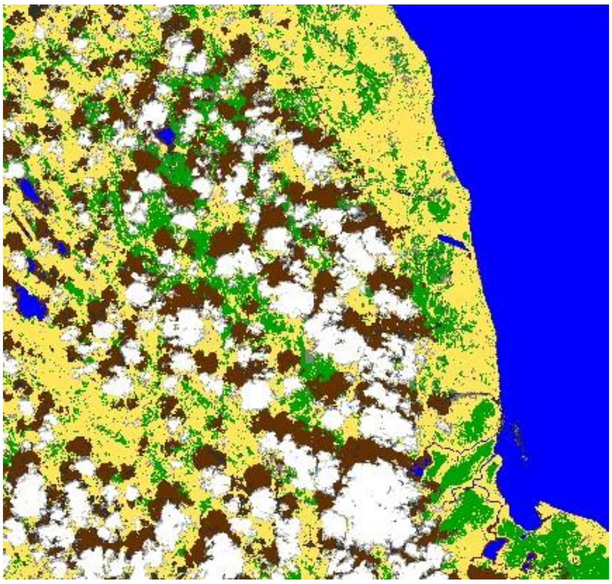

Figure 14. Cloud shadows classification

5.2. Topographic shadows handling

In version 2.2.1 the topographic shadows can now be identified by using an illumination map derived from the solar position and a Digital Elevation Model (DEM). Additionally the DEM slope information is used to filter out water pixels detected on steep slopes. Fig. 15 illustrates this new feature.

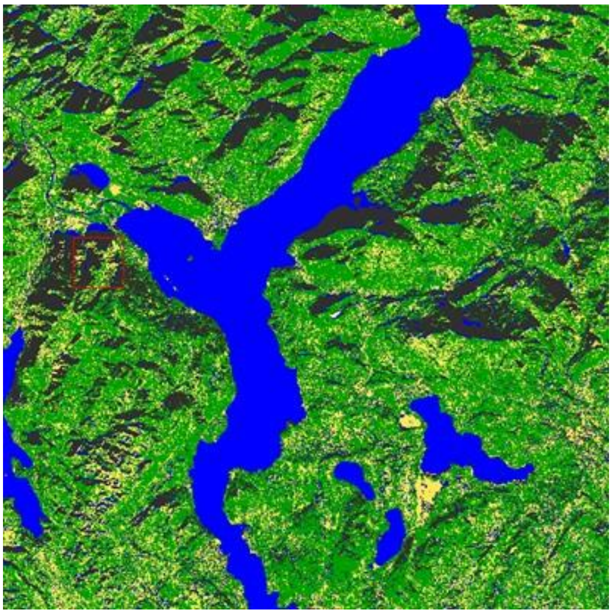

Figure 15. Topographic shadows classification

6. EARLY VALIDATION RESULTS

This chapter presents a summary of the early validation results obtained from the L2A validation team. These results are presented and discussed in more details in [6].

6.1. Cloud Screening and Scene Classification

The cloud screening and scene classification validation relies on a visual validation by a set of different users (Fig. 16). The following validation steps are performed:

- Reading images (full granule)
- Stratified random sampling
- Pixel/area labelling by user (visual)
- Creation of reference image
- Precision and confusion matrix

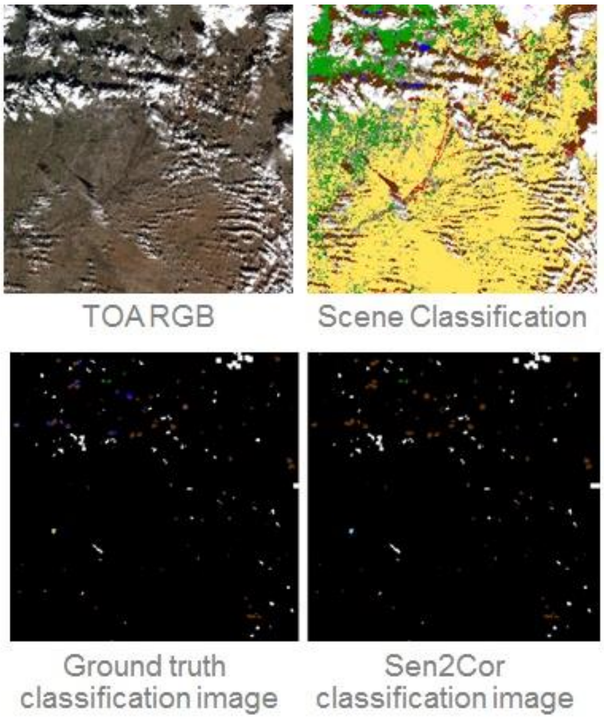

Figure 16. Scene Classification validation Tool

The results obtained with sen2cor 2.2.1 showed a significant improvement of the classification accuracy with respect to previous sen2cor version 2.0.6.

Scene classification works correctly with Sen2Cor with a mean overall accuracy of processed validation examples of (80 ±5) %.

6.2. Aerosol Optical Thickness and Water Vapour

The AOT and Water Vapour validation relies on a comparison of Sen2Cor outputs with sunphotometer (e.g. AERONET) measurements.

The following validation steps are performed:

- Cloudiness check
- Download and process sunphotometer data
- Extract 9×9 km² subset
- Compute AOT statistics over the subset
- Compute WV statistics over the subset

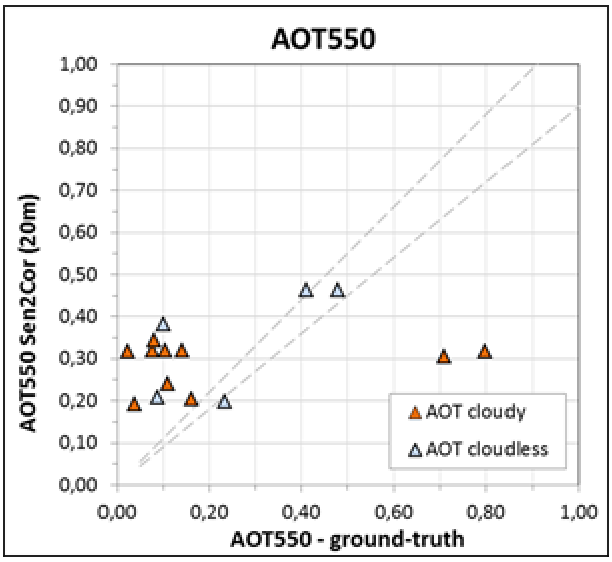

Figure 17. AOT-Validation, Direct comparison Sen2Cor<-> ground reference.

Typical AOT retrieval uncertainty of about 0.03 was found for cloudless images with Dark Dense Vegetation (DDV) pixels present in the image (Fig. 17). If there are no DDV-pixels in the image, the aerosol estimation fails and a default AOT value is then used.

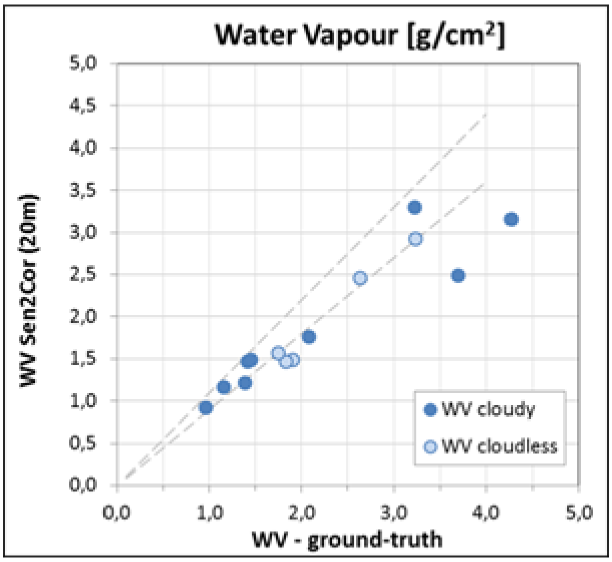

Figure 18. WV-Validation, Direct comparison Sen2Cor<-> ground reference.

Sen2Cor WV estimation agrees well with ground-truth giving a mean difference of 0.3 cm (Fig. 18). Results are less influenced by cloud cover and missing DDV-pixels.

6.3. Surface reflectance

The surface reflectance validation relies on a comparison of Sen2Cor outputs with reference BOA reflectance generated by running atmospheric correction with a constant AOT with the value obtained from AERONET as input.

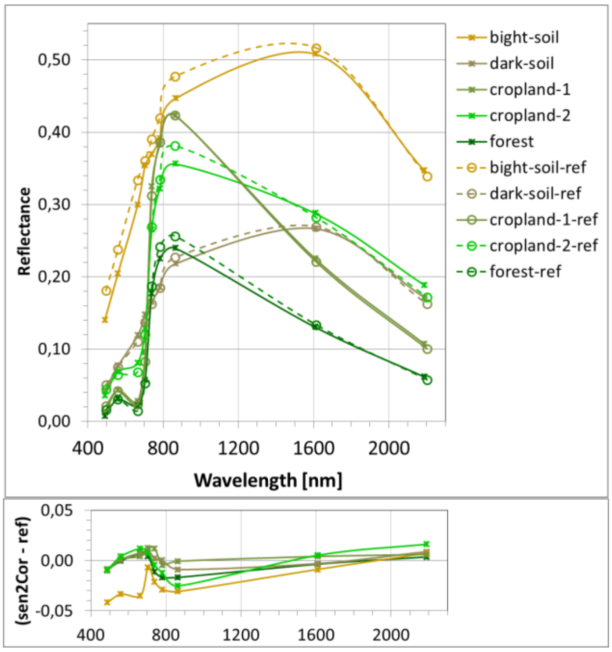

Figure 19. Example of L2A surface reflectance spectra

Sen2Cor produces reasonable spectra for different surface types (Fig. 19) with amount of reflectance difference between Sen2Cor processing and reference up to 0.04. This reflectance uncertainty leads to an NDVI uncertainty up to 0.06.

These early validation results were obtained using a small dataset only. Validation will be continued with a larger dataset covering the full globe and all seasons.

7. CONCLUSION AND OUTLOOK

The SNAP and Sentinel Toolboxes are available from this website: http://step.esa.int/main/download, whereas the Sen2Cor version 2.2.1 is available from: http://step.esa.int/main/third-party-plugins-2/sen2cor.

Further evolutions are foreseen for the Cloud Screening and Scene Classification to further improve the detection of cloud shadows and clouds over water, the snow detection and the cirrus detection in mountainous areas.

Concerning the Atmospheric Correction, the main evolution foreseen is to provide an option to use the L1C ECMWF meteorological data (AOT at 550 nm) as input when the L1C image does not contain enough Dark Dense Vegetation pixels.

8. CREDITS

The authors would like to thank the PI investigators and their staff for establishing and maintaining the AERONET sites used in this investigation.

9. REFERENCES

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