

1. Introduction

ACOLITE bundles the atmospheric correction algorithms and processing software developed at RBINS for aquatic applications of Landsat (5/7/8) and Sentinel-2 (A/B) satellite data. ACOLITE performs both the atmospheric correction and can output several parameters derived from water reflectances. RGB composites and PNG maps can also be generated. ACOLITE was originally implemented in IDL (2014-2017), and has been translated into Python (2018-...). The original IDL implementation is no longer supported or developed.

Please visit the ACOLITE forum (<http://odnature.naturalsciences.be/remsem/acolite-forum/>) or email Quinten (quinten.vanhellemont@naturalsciences.be) for bug reports, support and feature requests. The ACOLITE Python source code is available from github (<https://github.com/acolite/acolite>).

2. Processor overview

ACOLITE is distributed in a compiled binary format through the OD Nature/REMSEM page, and as Python source code through github. ACOLITE can be used in GUI and CLI modes. The GUI offers only limited configuration (file input/output, ROI setting, output parameters and loading/saving of settings files) and is aimed at new users. Full configuration can be done using plain text 'settings files'. These settings files are interpreted both by the GUI and CLI. GUI and CLI use is described below using the binary distribution, but both methods are also available when running from source.

2.1. ACOLITE GUI

Clickable launchers are provided for Linux/Mac (symlink to `dist/acolite/acolite`) and Windows (shortcut to `dist/acolite/acolite.exe`). Alternatively, the ACOLITE GUI can be launched by opening a terminal emulator and launching the `dist/acolite/acolite` binary on Mac/Linux or `dist/acolite/acolite.exe` on Windows.

Figure 1 shows the main ACOLITE GUI window which offers the following configuration:

- Select input: Select the input directory for processing. This should be the directory containing the L1 scene data (e.g. a Landsat bundle or a Sentinel-2 .SAFE file).
- Select output: Select the output directory.
- Region of interest: Input the southern, northern, western and eastern boundaries (in decimal degrees) of the scene to be extracted for processing. If empty the whole scene will be processed.
- L2W parameters: List the required output parameters here, see Section 5 for a full list. If empty, only L1R and L2R files will be generated.
- PNG outputs: Tick boxes for the generation of RGB composites using top-of-atmosphere (ρ_t) or (ρ_s) reflectances, and the generation of PNG maps of the requested L2W parameters.
- Save/Restore: Save the current settings as a text file, or restore settings from a text file.
- Run processing: Start the processing. On Linux and Mac the processing runs in a separate thread that can be stopped using the Stop processing or Exit buttons. On Windows the processing may freeze the GUI and will have to be force quit using the task manager.
- Stop processing: Stop the processing.
- Exit: Quit the GUI.
- Logging output: Feedback from the GUI and processor is displayed here.

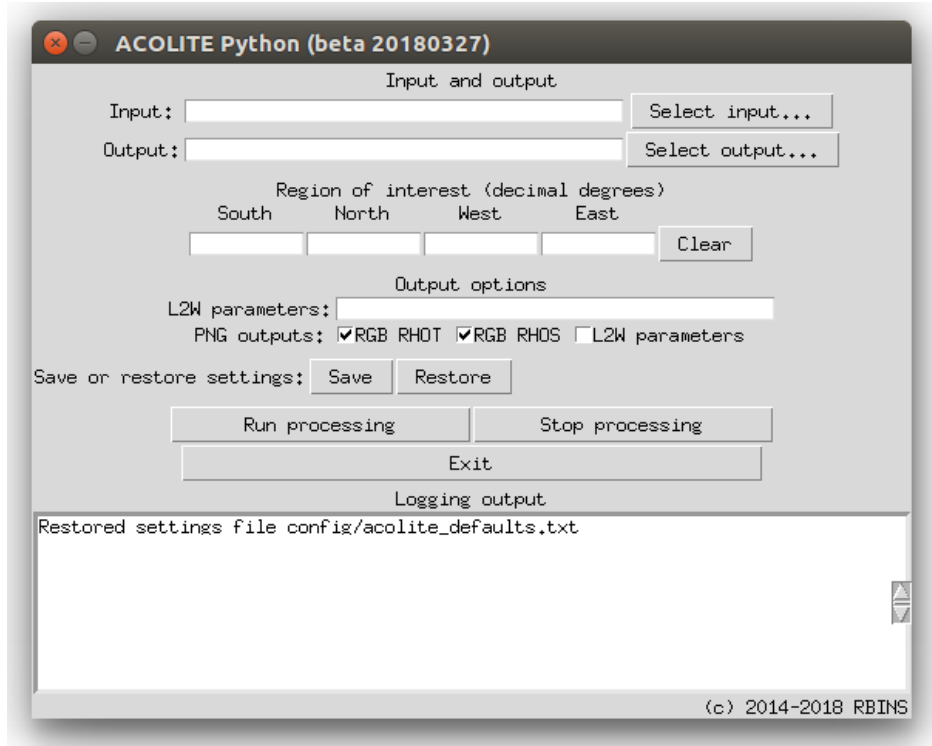


Figure 1: Screenshot from the 20180327 Linux beta version of ACOLITE Python.

2.2. ACOLITE CLI

The ACOLITE command line interface (CLI) can be launched by opening a terminal emulator and launching `acolite` with the `-cli` flag and the full path to a settings file. The following examples assume you are in the main ACOLITE directory, but the `acolite` binary can be launched from anywhere using its full path. On Linux and Mac:

```
dist/acolite/acolite --cli --settings=settings_file
```

on Windows:

```
dist\acolite\acolite.exe --cli --settings=settings_file
```

Optionally a comma separated list of images (with their full paths) or a text file with paths to the images can be provided with the `-image` flag, on Linux/Mac:

```
dist/acolite/acolite --cli --settings=settings_file --image=image1,image2,imagen
```

and on Windows:

```
dist\acolite\acolite.exe --cli --settings=settings_file --image=image1,image2,imagen
```

2.3. Example settings files

Settings files can be generated with the ACOLITE GUI, or with any text editor. Processing options not provided in the settings file will be set to the defaults (see config/acolite_defaults.txt). Several examples are given below.

A settings file that will output an area around the port of Zeebrugge in the specified directory, with surface reflectance in all bands:

```
## Example settings for Zeebrugge
##
inputfile=/storage/Input/S2A_MSIL1C_20170526T105031_N0205_R051_T31UES_20170526T105518.SAFE
output=/storage/Output/Zeebrugge
limit=51.3,3.0,51.4,3.25
l2w_parameters=rhos_*
```

A settings file that will output an area around the port of Zeebrugge in the specified directory with application of TOA gains and resampling all bands to the 60 m grid:

```
## Example settings for Zeebrugge with gains
##
inputfile=/storage/Input/S2A_MSIL1C_20170526T105031_N0205_R051_T31UES_20170526T105518.SAFE
output=/storage/Output/Zeebrugge
limit=51.3,3.0,51.4,3.25
l2w_parameters=rhos_*

## Apply the preliminary gains by Pahlevan et al. (2017)
gains=True
gains_s2a_msi=0.989,0.9877,1.02133,1.006,1.0266,1.0048,0.97701,1,1,1,1,1,1

## output resolution (S2 only 10, 20, or 60 m)
s2_target_res=60
```

A settings file that will merge four S2 tiles (the paths should be on the same line, separated by commas) for a larger area around Zeebrugge with application of TOA gains and resampling all bands to the 60 m grid:

```
## Example settings for Zeebrugge with gains and merging
##
inputfile=/storage/Input/S2A_MSIL1C_20170526T105031_N0205_R051_T31UES_20170526T105518.SAFE,
/storage/Input/S2A_MSIL1C_20170526T105031_N0205_R051_T31UET_20170526T105518.SAFE,
/storage/Input/S2A_MSIL1C_20170526T105031_N0205_R051_T31UDS_20170526T105518.SAFE,
/storage/Input/S2A_MSIL1C_20170526T105031_N0205_R051_T31UDT_20170526T105518.SAFE
output=/storage/Output/ZeebruggeMerged
limit=51.3,2.90,51.65,3.35
l2w_parameters=rhos_*

## Apply the preliminary gains by Pahlevan et al. (2017)
gains=True
gains_s2a_msi=0.989,0.9877,1.02133,1.006,1.0266,1.0048,0.97701,1,1,1,1,1,1

## output resolution (S2 only 10, 20, or 60 m)
s2_target_res=60

## files given in inputfile will be merged (if from same sensor/orbit/utm zone)
merge_tiles=True
```

2.4. Installation from source

The Python source code is available on github (<https://github.com/acolite/acolite/>) and includes the latest updates. To use the source code a Python 3 environment is needed with the following packages (and their dependencies):

```
matplotlib scipy pyproj gdal netcdf4 pyhdf requests statsmodels basemap pillow scikit-image
```

The git repository can be downloaded through a browser or cloned using git:

```
git clone https://github.com/acolite/acolite
```

ACOLITE can then be launched using Python, with optional command line options as described above:

```
python acolite/acolite.py
```

ACOLITE can be imported in other Python scripts or Jupyter notebooks:

```
import sys, os, time
user_home = os.path.expanduser("~")
sys.path.append(user_home+"/git/acolite")
import acolite as ac
```

The processing can then be integrated in other scripts, e.g. by using a Python dict to provide settings:

```
settings = {"inputfile":"S2A_MSIL1C_20200626T104031_N0209_R008_T31UGV_20200626T125124.SAFE",
"output":"~/Output/",
"dsf_path_reflectance":"tiled", "dsf_tile_dims":[400,400],"s2_target_res":60,
"resolved_geometry":True, "dsf_write_tiled_parameters":False,
"glint_correction":True,"sky_correction_option":"rsky_new","dsf_wave_range":[400,900],
"luts":["PONDER-LUT-201704-MOD1","PONDER-LUT-201704-MOD2"]}

ac.acolite.acolite_run(settings=settings)
```

2.5. *Moving the "data" directory*

The data directory can be moved to a different location if the file config/config.txt is edited appropriately. By default these directories are inside the acolite_py folder:

```
## Data directory
data_dir=data
pp_data_dir=data/PP

## DEM SRTM HGT files
hgt_dir=data/SRTMGL3.003

## MET files
met_dir=data/MET
```

3. Atmospheric correction

3.1. Overview

ACOLITE Python includes two atmospheric correction algorithms, the default "Dark Spectrum Fitting" or DSF algorithm (Vanhellemont and Ruddick, 2018; Vanhellemont, 2019, 2020) and the older "Exponential extrapolation" or EXP algorithm (Vanhellemont and Ruddick, 2014, 2015, 2016). The use of the DSF is recommended, but the EXP is included for completeness. The adaptation and applicability of the DSF to Landsat and Sentinel-2 is described in Vanhellemont (2019, 2020).

3.2. DSF options

3.2.1. Aerosol correction

The DSF computes atmospheric path reflectance (ρ_{path}) based on multiple dark targets in the scene or subscene, with no a priori defined dark band. For each band the darkest object is estimated from the offset from an OLS fit to the first thousand pixels in the histogram, and a "dark spectrum", ρ_{dark} is created. A Continental or Maritime aerosol model is chosen based on the lowest RMSD between the observed ρ_{dark} and the retrieved ρ_{path} for the two closest fitting bands. Two settings for the DSF are implemented:

1. A fixed ρ_{path} option, which computes a single ρ_{path} for the scene or subscene (if limits for a ROI are provided).
2. A tiled ρ_{path} option, which divides the full scene in approximately 6x6 km tiles and interpolates retrieved ρ_{path} . Note that processing time for this option is much longer than for the fixed ρ_{path} option.

3.2.2. Glint correction

The DSF uses the bands and pixels giving the lowest estimate of aerosol optical thickness over the processed region or tile. This allows for an estimation of the atmospheric path reflectance that is relatively insensitive to sun glint. The sun glint signal will however still be present in the resulting surface reflectance. A sun glint correction option is included, which by default uses the SWIR bands to estimate the glint signal, as in Harmel et al. (2018). The implementation and performance is discussed in Vanhellemont (2019).

3.3. EXP options

The EXP uses Rayleigh corrected reflectance in two bands to estimate the aerosol reflectance (ρ_{am}). By default the two SWIR bands are used, and ρ_{am} is estimated in the 2.2 μm band and extrapolated to the VIS and NIR bands using an exponential function and the ratio of 1.6 μm to 2.2 μm Rayleigh corrected reflectances.

The band set can be changed (see further) to include NIR/SWIR and red/NIR options, that both use a fixed ϵ due to non-zero ρ_w in at least one of the bands. The red/NIR option needs to assume a water reflectance model, for which by default the similarity spectrum is used. For the SWIR based correction, options are included for processing with variable and fixed ϵ and ρ_{am} .

3.4. Outputs

The atmospheric correction procedure generates two NetCDF files containing reflectance data: (1) Level 1, top-of-the atmosphere reflectances, L1R and (2) Level 2, surface reflectances, L2R. Based on these files the RGB composites are generated, and derived parameters are computed.

4. Processing options

This section lists most of the processing options that can be specified in a user generated settings file. The default setting is given for each option.

4.1. General options

inputfile=

Scene or comma separated list of scenes to be processed. Full paths to the scene directory (Landsat bundle or Sentinel-2 .SAFE file) have to be specified. The comma separated list has to be on a single line. Compressed files (e.g. from EarthExplorer) have to be extracted.

output=

Directory where outputs will be generated. Will be created if it does not exist.

limit=

Comma separated list of the bounding box coordinates in decimal degrees in S,W,N,E order. If empty, the full scene will be processed.

aerosol_correction=dark_spectrum

The aerosol correction (DSF or EXP) to use. See below for algorithm specific options. Options: dark_spectrum, exponential

l2w_parameters=

Comma separated list of the output parameters to be computed. See section 5 for a full list. If empty, only L1R and L2R files will be generated.

runid=

An identifier for the current processing run. An identifier based on date/time is generated if empty.

4.1.1. Masking

l2w_mask=True

Controls whether the L2W output parameters will be masked. Options: True/False

l2w_mask_wave=1600

Wavelength (nm) for the non-water masking. The closest band will be selected.

l2w_mask_threshold=0.0215

Threshold for the non-water masking. Pixels with ρ_t in the masking band above this threshold will be masked.

l2w_mask_water_parameters=True

Controls whether water specific parameters are to be masked. Options: True/False

l2w_mask_negative_rhow=True

Controls whether pixels with negative reflectances are to be masked. Options: True/False

l2w_mask_cirrus=True

Enable masking of cirrus clouds using the band around 1375 nm. OLI and MSI only. Options: True/False

l2w_mask_cirrus_threshold=0.005

Threshold for the cirrus masking. Pixels with ρ_t 1375 nm above this threshold will be masked.

4.1.2. Ancillary data

ancillary_data=True

Controls whether ancillary data is to be used for retrieving ozone, water vapour and atmospheric pressure. Options: True/False

gas_transmittance=True

Controls whether gas transmittances (ozone and water) are computed for each band. Options: True/False

uoz_default=0.3

Fixed/fallback value for ozone concentration in cm^{-1} . This value will be used if the ancillary data is disabled or unavailable and gas_transmittance=True.

uwv_default=1.5

Fixed/fallback value for water vapour concentration in g/cm^2 . This value will be used if the ancillary data is disabled or unavailable and `gas_transmittance=True`.

pressure=None

Fixed atmospheric pressure value. Defaults to normal pressure (1013.25 mbar) if equal to None and if no ancillary data is used.

elevation=None

Elevation to compute atmospheric pressure according to a normal atmosphere.

lut_pressure=True

Controls the pressure interpolation for the atmospheric LUTs, uses the normal pressure LUT if False. Options: True/False

dem_pressure=False

Controls whether pressure is to be computed from DEM elevation. Options: True/False

dem_pressure_percentile=25

Determine pressure from this percentile of DEM in the ROI/scene.

4.1.3. Various processing

sky_correction=True

Controls the sky reflectance correction. Options: True/False

sky_correction_option=rsky_new

Method to use for the sky reflectance correction. Currently only for all pixels with no distinction between water and non-water. Options: "all" for Rayleigh only reflectance, "rsky_new" for the OSOAA (Chami et al., 2015) based sky reflectance presented in (Vanhellemont, 2020)

merge_tiles=False

Controls whether inputfiles have to be merged before processing. Merging is only supported for scenes from the same orbit and UTM zone, and when a region of interest is specified. Options: True/False

s2_target_res=10

Output resolution of Sentinel-2 products in meter. Options: 10, 20, 60

resolved_angles=False

Interpolate the Sentinel-2 view/illumination geometry grids.

resolved_angles_write=False

Write the interpolated Sentinel-2 view/illumination geometry grids to the L2R file.

4.1.4. Gains

gains=False

Controls the application of sensor specific TOA gains. Options: True/False

gains_l5_tm=1,1,1,1,1

Comma separated list of gains to be used for L5/TM bands 1-5 and 7

gains_l7_etm=1,1,1,1,1

Comma separated list of gains to be used for L7/ETM bands 1-5 and 7

gains_l8_oli=1,1,1,1,1

Comma separated list of gains to be used for L8/OLI bands 1-7

gains_s2a_msi=1,1,1,1,1,1,1,1,1,1

Comma separated list of gains to be used for S2A/MSI bands 1-13

gains_s2b_msi=1,1,1,1,1,1,1,1,1,1

Comma separated list of gains to be used for S2B/MSI bands 1-13

4.2. Output options

4.2.1. File outputs

rgb_rhot=True

Controls the output of RGB PNG files based on ρ_t data. Options: True/False

rgb_rhos=True

Controls the output of RGB PNG files based on ρ_s data. Options: True/False

map_l2w=False

Controls the output of PNG files from the requested L2W parameters. Options: True/False

l2r_export_geotiff=False

Controls the output of L2R GeoTIFF files. Options: True/False

l2w_export_geotiff=False

Controls the output of L2W GeoTIFF files. Options: True/False

export_geotiff_coordinates=False

Controls whether the lat/lon should be also output as GeoTIFF files. Options: True/False

l1r_nc_compression=True

Controls the internal compression of the L1R NetCDF file. Options: True/False

l2r_nc_compression=True

Controls the internal compression of the L2R NetCDF file. Options: True/False

l2w_nc_compression=True

Controls the internal compression of the L2W NetCDF file. Options: True/False

l1r_nc_delete=False

Controls the deletion of the L1R NetCDF file. Options: True/False

l2r_nc_delete=False

Controls the deletion of the L2R NetCDF file. Options: True/False

l2w_nc_delete=False

Controls the deletion of the L2W NetCDF file. Options: True/False

4.2.2. Various

l8_output_bt=False

Controls the output of Landsat 8 at-sensor Brightness Temperature for the TIRS. Will be set to True if BT is among the requested parameters. Options: True/False

xy_output=False

Controls the output of xy Easting and Northing for the UTM projection. Options: True/False

slicing=False

Controls slicing of data to finite values during processing, should speed up and improve memory use for sparse (or custom images). Options: True/False

4.2.3. General mapping options

map_title=True

Controls the title on PNG maps. The title consists of the parameter, satellite sensor and date. Options: True/False

map_projected=False

Controls the annotation of lat/lon on the PNG maps. Datasets will be reprojected and some distortion may occur. Options: True/False

map_raster=False

Options: True/False

map_scalebar=True

Options: True/False

map_scalepos=UL

Position of the scale bar on the PNG maps. Options: UL,UR,LL,LR

map_scalelen=None

Length (in km) of the scale bar. Length is automatically determined if None.

map_scalecolor=White

Colour of the scale bar on the L2W maps. Options: any Python colour name or Hex Color Code

map_scalecolor_rgb=White

Colour of the scale bar on the RGB maps. Options: any Python colour name or Hex Color Code

map_colorbar_edge=True

Controls the blank space for the colour bar. Options: True/False

map_max_dim=1000

The maximum dimension (vertical or horizontal) of the output map. Data are rescaled to this dimension before mapping to reduce memory use.

map_points=None

Full path to a text file with points to be annotated on the PNG maps. Ignored if None. Example of a single point configuration:

```
label=MOW1
lat=51.36
lon=3.12
color=Red
sym=.
label_side=right
```

4.2.4. RGB mapping options

rgb_red_wl=660

The wavelength (nm) for the Red channel in the RGB composite. The band with closest wavelength will be selected.

rgb_green_wl=560

The wavelength (nm) for the Green channel in the RGB composite. The band with closest wavelength will be selected.

rgb_blue_wl=480

The wavelength (nm) for the Blue channel in the RGB composite. The band with closest wavelength will be selected.

rgb_min=0.0,0.0,0.0

Comma separated minimum reflectance for linear scaling of the R,G,B channels.

rgb_max=0.15,0.15,0.15

Maximum reflectance for linear scaling of the R,G,B channels.

rgb_pan_sharpen=False

Controls the pan sharpening of the RGB composites from Landsat 7/ETM and Landsat 8/OLI. Options: True/False

4.2.5. L2W mapping options

map_colorbar=True

Controls the plotting of colour bars for the L2W PNG maps. Options: True/False

map_colorbar_orientation=vertical

Controls the orientation of the colour bars. Options: horizontal/vertical

map_auto_range=False

Controls the auto ranging (P5-P95) for the L2W maps. If False the ranges in config/acolite_l2w_labels.txt will be used. Options: True/False

map_fillcolor=LightGrey

Controls the fill colour in the L2W maps. Options: any Python colour name or Hex Color Code

4.3. DSF options

dsf_path_reflectance=fixed

Whether to use the tiled or fixed DSF. Options: fixed, tiled

dsf_wave_range=400,900

Comma separated wavelength range in nm of bands to use in the DSF, e.g. for including (400,2500) or excluding (400,900) the SWIR bands from the fitting. Default: 400,900

4.3.1. Fixed DSF options

dsf_full_scene=False

Controls the origin of the ρ_{dark} when processing a ROI with fixed DSF. By default (False) the ρ_{dark} will be estimated over the ROI. If True, the ρ_{dark} will be estimated over the full scene. Options: True/False

dsf_plot_dark_spectrum=True

Controls the output of plots of the retrieved dark spectrum and estimated path reflectance. Options: True/False

dsf_fixed_aot=None

User specified aerosol optical thickness value at 550 nm. Options: None or float value

dsf_fixed_lut=PONDER-LUT-201704-MOD2

User specified aerosol model for the *dsf_fixed_aot* option. Options: PONDER-LUT-201704-MOD1/PONDER-LUT-201704-MOD2

4.3.2. Tiled DSF options

dsf_tile_dims=None

Comma separated tile size in pixels for the tiled DSF processing. If None, the default 6 km tiling will be used: 600,600 for Sentinel-2 and 200,200 for Landsat

dsf_min_tile_cover=0.10

Minimum coverage of valid pixels in the individual tiles. Tiles with less coverage (typically at the swath edges) will be skipped and interpolated. Options: fraction between 0 and 1

dsf_min_tile_aot=0.01

Minimum aerosol optical thickness (at 550 nm) in a tile. Tiles with lower τ_a will be skipped and interpolated. Typically very low τ_a indicate cloud shadow contamination.

dsf_plot_retrieved_tiles=True

Controls the plotting of a map of the tiled retrieval. Options: True/False

dsf_write_tiled_parameters=False

Controls the output of atmospheric parameters to the NetCDF file. Options: True/False

4.3.3. Glint correction options

glint_correction=False

Controls the glint correction. Options: True/False

glint_force_band=None

Specify the wavelength (nm) where glint reflectance ρ_g is to be estimated. If None, then in each pixel the SWIR band giving the lowest ρ_g at 440 nm will be used.

glint_mask_rhos_band=1600

The wavelength (nm) to determine which pixels need to be glint corrected. The closest band will be selected.

glint_mask_rhos_threshold=0.05

Threshold to determine which pixels need to be glint corrected. Pixels with *glint_mask_rhos_band* > the threshold will not be corrected. (It is noted that ρ_g at 1.6 μm can be larger than 0.05.)

glint_write_rhog_ref=False

Controls the output of the reference glint reflectance to the NetCDF file. Options: True/False

glint_write_rhog_all=False

Controls the output of the glint reflectance in each band to the NetCDF file. Options: True/False

4.3.4. DSF development options

These are specialised options which should not generally be changed by the user.

dsf_spectrum_option=dark_list

Method to choose the ρ_{dark} . Options: dark_list

dsf_list_selection=intercept

Method to select the ρ_{dark} when using the dark_list option.

dsf_model_selection=min_drmsd

Method to choose which aerosol model to use. Options: min_drmsd

extra_ac_parameters=False

Output extra atmospheric parameters. Options: True/False

4.4. EXP options

exp_wave1=1600

First wavelength (nm) for the EXP correction. The closest band will be selected.

exp_wave2=2200

Second wavelength (nm) for the EXP correction. The closest band will be selected.

exp_alpha=None

Ratio of the water reflectances in the two used bands. Only used if no SWIR band is used. If None, the similarity spectrum (Ruddick et al., 2006) is used.

exp_alpha_weighted=True

Controls the band weighting of the similarity spectrum alpha. Options: True/False

exp_epsilon=None

Fixed aerosol epsilon value in the two used bands. If None, the value is determined from the scene according to Vanhellemont and Ruddick (2015).

exp_gamma=None

Fixed transmittance ratio value in the two used bands. If None, the ratio of Rayleigh transmittances is used.

exp_fixed_epsilon=True

Controls whether a fixed or per pixel (only for SWIR/SWIR) epsilon is used. Options: True/False

exp_fixed_epsilon_percentile=50

Percentile to determine the fixed epsilon over the (sub)scene. Options: value between 0 and 100

exp_fixed_aerosol_reflectance=True

Controls whether the aerosol reflectance is fixed over the (sub)scene. Options: True/False

exp_fixed_aerosol_reflectance_percentile=5

Percentile to determine the fixed aerosol reflectance over the (sub)scene. Options: value between 0 and 100

exp_swir_threshold=0.0215

Non-water threshold for the SWIR1 band (at $1.6 \mu m$), used to determine the scene wide fixed epsilon.

5. L2W algorithms

ACOLITE Python includes several algorithms for the retrieval of derived parameters. The L2R file is used as an input and an L2W file is generated containing the requested datasets. The L2W file will be used to generate maps from the parameters if requested. The map scaling for each parameter is defined in the config/acolite_l2w_labels.txt file. The included output products and algorithms are:

- **rhof_***: ρ_t , the top-of-atmosphere reflectance as derived from the original input file. A wavelength can be specified, or the asterisk will be expanded to include all available wavelengths. Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **rhos_***: ρ_s , the surface reflectance. A wavelength can be specified, or the asterisk will be expanded to include all available wavelengths. Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **rhow_***: ρ_w , the surface reflectance for water pixels, with a SWIR based mask applied to non-water pixels. A wavelength can be specified, or the asterisk will be expanded to include all available wavelengths. Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **Rrs_***: the remote sensing reflectance (sr^{-1}) for water pixels, $Rrs = \rho_w / \pi$. A wavelength can be specified, or the asterisk will be expanded to include all available wavelengths. Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **rhorc_***: ρ_{rc} , the Rayleigh corrected reflectance. This is the ρ_t with ρ_r removed and corrected for two way Rayleigh transmittance. A wavelength can be specified, or the asterisk will be expanded to include all available wavelengths. Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **spm_nechad**: Suspended Matter Concentration (gm^{-3}) using the algorithm of Nechad et al. (2010). By default the red band will be used, but a wavelength can be specified in the parameter (e.g. spm_nechad_833 for S2B). The parameters from the closest wavelength from the hyperspectral dataset will be used. Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **spm_nechad2016**: Suspended Matter Concentration (gm^{-3}) using the algorithm of Nechad et al. (2010) recalibrated by Bouchra Nechad in September 2016, specifically for Landsat 8 and Sentinel-2. By default the red band will be used, but a wavelength can be specified in the parameter (e.g. spm_nechad2016_833 for S2B). Sensors: L8/OLI, S2A/MSI, S2B/MSI
- **t_nechad**: Turbidity (FNU) using the algorithm of Nechad et al. (2009). The red band will be used with the coefficients published for the MODIS 645 nm band ($A = 228.1$, $C = 0.1641$). A wavelength can be specified after the parameter (e.g. t_nechad_665) or one of the aliases can be used for the red or NIR bands (t_nechad_red, t_nechad_nir). Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **t_nechad2016**: , Turbidity (FNU) using the algorithm of Nechad et al. (2009) recalibrated by Bouchra Nechad in September 2016, specifically for Landsat 8 and Sentinel-2. By default the red band will be used, but a wavelength can be specified in the parameter (e.g. t_nechad2016_833 for S2B). Sensors: L8/OLI, S2A/MSI, S2B/MSI
- **t_dogliotti**: Turbidity (FNU) using the algorithm of Dogliotti et al. (2015). The switching algorithm uses the red band for $\rho_{red} < 0.05$, and the NIR band for $\rho_{red} > 0.07$, with a linear weighing in between. The red and NIR based products can also be output separately (t_dogliotti_red and t_dogliotti_nir). Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **chl_oc2, chl_oc3**: Chlorophyll a concentration ($\mu g/l$) using the blue/green ratio algorithm. The oc2 and oc3 use respectively two and three bands. Coefficients are provided in data/PP/Shared/chl_oc.cfg, and users can add new coefficients in that file. Note that these products should be used with care in coastal and inland waters, especially in the presence of sediments and CDOM. Sensors: L8/OLI, S2A/MSI, S2B/MSI

- **chl_re_gons, chl_re_gons740**: Chlorophyll a concentration ($\mu g/l$) using the red edge algorithm by Gons et al. (2002) with published coefficients and a mass specific chlorophyll a absorption of 0.015. By default 780 nm (band 6) is used as a reference, but the chl_re_gons740 product uses 740 nm (band 5) on MSI. Output products are by default only produced for waters where $\rho_{s,664} > 0.005$ and $\rho_{s,704}/\rho_{s,664} > 0.63$ (thresholds defined by Héloïse Lavigne). Sensors: S2A/MSI, S2B/MSI
- **chl_re_moses3b, chl_re_moses3b740**: Chlorophyll a concentration ($\mu g/l$) using the three band red edge algorithm by Moses et al. (2012). By default 780 nm (band 6) is used as a reference, but the chl_re_moses3b740 product uses 740 nm (band 5) on MSI. Sensors: S2A/MSI, S2B/MSI
- **chl_re_mishra**: Chlorophyll a concentration ($\mu g/l$) using the Normalised Difference Chlorophyll Index algorithm by Mishra and Mishra (2012). Sensors: S2A/MSI, S2B/MSI
- **ndci**: The Normalised Difference Chlorophyll Index algorithm by Mishra and Mishra (2012). Sensors: S2A/MSI, S2B/MSI
- **slh**: The Scattering Line Height algorithm by Kudela et al. (2015). Sensors: S2A/MSI, S2B/MSI
- **fai, fai_rhot**: The Floating Algal Index by Hu (2009). By default surface reflectance (ρ_s) is used. **fai_rhot** uses the top-of-atmosphere reflectance (ρ_t). Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **fait**: The Floating Algal Index adapted to Turbid waters by Dogliotti et al. (2018). Surface reflectance (ρ_s) is used instead of Rayleigh corrected reflectance. Sensors: L8/OLI, S2A/MSI, S2B/MSI
- **ndvi, ndvi_rhot**: Normalised Difference Vegetation Index. By default surface reflectance (ρ_s) is used. **ndvi_rhot** uses the top-of-atmosphere reflectance (ρ_t). Sensors: L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI
- **a443_qaasw, a490_qaasw, a560_qaasw, a665_qaasw**: absorption outputs from the Quasi-Analytical Algorithm (QAA) of Lee et al. (2002). The qaasw suffix denotes weighted outputs from the version 5 and version 6 of the algorithm, and can be replaced by qaa5 or qaa6 to get the non-weighted outputs from a specific version. Sensors: L8/OLI, S2A/MSI, S2B/MSI
- **bbp443_qaasw, bbp490_qaasw, bbp560_qaasw, bbp665_qaasw**: particulate backscattering outputs from the Quasi-Analytical Algorithm (QAA) of Lee et al. (2002). The qaasw suffix denotes weighted outputs from the version 5 and version 6 of the algorithm, and can be replaced by qaa5 or qaa6 to get the non-weighted outputs from a specific version. Sensors: L8/OLI, S2A/MSI, S2B/MSI
- **kd443_qaasw, kd490_qaasw, kd560_qaasw, kd665_qaasw, kdpar_qaasw**: diffuse attenuation outputs from the Quasi-Analytical Algorithm (QAA) of Lee et al. (2002). The qaasw suffix denotes weighted outputs from the version 5 and version 6 of the algorithm, and can be replaced by qaa5 or qaa6 to get the non-weighted outputs from a specific version. Sensors: L8/OLI, S2A/MSI, S2B/MSI
- **bt10, bt11**: At-sensor brightness temperature from the Thermal Infrared Sensor (TIRS) on Landsat 8. Sensors: L8/TIRS
- **hue_angle**: The Hue Angle ($^{\circ}$) by van der Woerd and Wernand (2018). Sensors: L8/OLI, S2A/MSI, S2B/MSI
- **rhos_613, rhow_613**: Orange *contra*-band reflectances by Castagna et al. (2018, submitted), selecting this parameter will also output the panchromatic band reflectance (rhos_592). Sensors: L8/OLI
- **ohl**: Orange *contra*-band line height by Castagna et al. (2018, submitted), selecting this parameter will also output the orange and panchromatic band reflectances (rhos_592, rhos_613). Sensors: L8/OLI

6. Sensor wavelengths

ACOLITE computes the wavelengths of each sensor by band weighting the RSR. Here a list of wavelengths is provided per sensor. Note that the panchromatic, cirrus and water vapour absorption bands (in *italic*) are skipped for ρ_s computation.

- **L5/TM**: 486, 571, 660, 839, 1678, 2217
- **L7/ETM**: 479, 561, 661, 835, 1650, 2208, 720
- **L8/OLI**: 443, 483, 561, 655, 865, 1609, 2201, 592, *1373*
- **S2A/MSI**: 443, 492, 560, 665, 704, 740, 783, 833, 865, *945, 1373*, 1614, 2202
- **S2B/MSI**: 442, 492, 559, 665, 704, 739, 780, 833, 864, *943, 1377*, 1610, 2186

7. Version history

20210114

- Fixed gdal issue for GeoTIFF outputs

20210106

- Update to latest GitHub codebase
- Added options presented in (Vanhellemont, 2020): removing SWIR bands from aerosol fitting and OSOAA based sky reflectance correction
- Fixed GUI ancillary download issue
- Processing from the Windows GUI can now also be interrupted
- Added options to delete NetCDF files that are produced
- Added support for Collection 2 Landsat 8 data

20190326

- Added correct xrange and yranges to NetCDF global attributes
- Changed Landsat Y subsetting
- Improved Pan band support for merged tiles and orange band computation
- Added support for LO8 files (without TIRS)
- Added strip function to l2w_parameter names in mapping script
- Added some CF convention parameter attributes
- Fixed S2 band naming error during tile merging
- Fixed l2_flags error when masking is disabled
- Fixed plotting of L8 dark spectrum
- Fixed time parsing issue for Landsat files
- Disabled printing of numpy Runtime Warnings

20181210

- Added orange band computation for Landsat 8/OLI, including panchromatic bands output at 30 m
- Added oxygen transmittance
- Added elevation input option
- Added/Fixed SRTM DEM option for elevation computation, missing DEM tiles are printed out
- Added the option to use the resolved S2 view/illumination grids
- Changed import of some Matplotlib features, hopefully allowing map output for EXP processed scenes
- Changed but did not fix download of ancillary data when using the GUI
- Fixed FAIT output on Mac (binary distribution was missing the skimage dependency)

- Fixed output of cirrus band (at TOA)
- Fixed MSI grid naming issue when merging tiles
- Fixed transmittance ratio in glint correction
- Fixed the EXP aerosol correction when L1R NetCDF files are present

20180925

- Explicitly added file encoding to avoid 'file not recognised' errors

20180917

- Added FAIT parameter
- Added glint correction for the DSF
- Added `-nogfx` option for `-cli` runs without graphical environments
- Changed relative path identification so the acolite binary can be launched from anywhere
- Fixed blue band bug after `chl_oc3` computation
- Fixed ancillary data download in Windows binary distribution
- Fixed some settings file parsing errors
- Fixed default scalebar position for projected maps

20180611

- Added simple Rayleigh corrected reflectance product (with no gas and sky correction): $\text{rhorc} = (\text{rhot} - \text{rhor})/\text{ttr}$
- Added support for GeoTIFF outputs of L2R/L2W datasets. NetCDF files are still generated, datasets will be also exported as GeoTIFF (`l2r_export_geotiff=True`, `l2w_export_geotiff=True`)
- Added optional output of UTM x/y easting and northing coordinates (`xy_output=True`)
- Added colour table options (Calgae255 and Planck_Parchment_RGB) and possibility for user defined colour tables
- Added output of `l2_flags` to the L2W file, flags are currently based on SWIR threshold mask (bit 1) and negative rhos (bit 2)
- Added option to disable masking of non-water/bad pixels (`l2w_mask_water_parameters=False`)
- Added option to output 1:1 pixel PNG files; `map_raster=True` (without title, geolocation or colourbar, currently not on Windows)
- Added check for $\text{rhot} < \text{rhor}$ in DSF processing (especially for L5)
- Added pansharpened RGB outputs for L7 and L8
- Added aliases for `t_nechad_red` and `t_nechad_nir` products
- Changed naming of RGB output products to `rgb_rhot` and `rgb_rhos`
- Sentinel-2 wavelengths are now determined from the RSR instead of the provided metadata. This gives consistent naming before and after the Dec 2017 / Jan 2018 RSR update.

- Fixed the crash when no ancillary data is found or when the oceandata server is unreachable. Fallback values will be used if ancillary data access fails.
- Fixed sub pixel geolocation error in the computation of latitude and longitude: Sentinel-2 scene extents are considered to be at pixel edges, Landsat extents at pixel centres, all ACOLITE output coordinates are reported at pixel centre
- Fixed bug when multiple files are present in the GRANULE/IMG_DATA with the same band name (check if files end in jp2)
- Fixed the plotting of Sentinel-2 dark spectrum fitting results

20180419

- Fixed full tile Sentinel-2 geolocation
- Fixed Sentinel-2 relative azimuth within 0-180°
- Datasets are now processed and stored as 32 bit floats, using less RAM and disk space
- Added rhow (rhos with non-water masking) and Rrs (ρ_w / π) datasets
- Wavelengths are now tracked as attributes in the L2W products (rhot, rhos, rhow, Rrs), allowing for the use of the Spectrum Viewer in SNAP
- Skipping unrecognised and dot files in the .SAFE "GRANULE" and "IMG_DATA" directories
- Added support for autoscaling the L2W output maps: add *,* for the range in config/acolite_l2w_labels.txt
- Added new 'map_projected' option to annotate scalebar and add lat/lon to maps, switched to 'Agg' backend in matplotlib
- Relaxed constrains on the band selection for the chl_oc algorithms (for chl_oc3 outputs of S2A/B)
- Added Hue Angle algorithm

20180327 First public beta version of ACOLITE Python.

- Fixed PNG outputs from GUI
- Fixed Landsat 8 bt10 and bt11 outputs from merged tiles
- Added chl_re_gons configuration file and masking

20180312 First internal beta version of ACOLITE Python.

- Implementation is now in Python (3.6)
- New aerosol correction (DSF) with new lookup tables for path reflectance resampled to each of the supported sensors (L5/TM, L7/ETM, L8/OLI, S2A/MSI, S2B/MSI)
- The new spectral response function of Sentinel-2A is now used
- A more robust tile merging option (including Landsat tiles) has been added

20170718 Last release of ACOLITE IDL.

8. Known issues

- **High RAM use when processing full scenes** Processing full scenes is currently very RAM intensive, especially for operations using several bands, such as computing QAA parameters or generating RGB composites. The system may become unresponsive when low on RAM. ACOLITE may segfault if it runs out of RAM when generating the very large RGB composite.
- **Crash when generating full tile RGB composites** When generating full tile RGB composites (especially for Sentinel-2) the program may segfault, due to running out of RAM, or overriding PNG size limits.
- **Large output files** When processing full scenes, very large output files will be generated, about 6 GB for the L1R, and about 8 GB for the L2R files. L2W file size depends on the number of requested parameters (about 0.5 GB/parameter).

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