Atmospheric correction for turbid coastal and small inland waters using ACOLITE/DSF

Quinten Vanhellemont - Royal Belgian Institute of Natural Sciences

presented at IOCCG Summer Lecture Series 2022



Pléiades-1A 2020-04-09T11:17:13 CPower Wind Farm

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PlanetScope/2498 2022-07-16T10:22:37 Port of Zeebrugge



Atmospheric Correction: Why?

- 1. Satellite imagers capture not only information from the Earth's surface, but also from the atmosphere
- 2. The atmospheric signal depends largely on the sun-sensor geometry, and hence varies through the year and through the day
- 3. Atmospheric aerosols, pressure and gases vary
- Confounding effects: air-water interface glint, non-water adjacency effects, (clouds)



MSG4/SEVIRI 2021-03-30T12:45

Atmospheric Correction: How?

1. Model the atmosphere from ancillary information weather models / measurements / guesses 2. Model the atmosphere from the image lightly constrained water reflectance e.g. assuming NIR/SWIR=0, modeling NIR>0, $\rho w >= 0$ e.g. SeaDAS/I2gen, ESA/OLCI processing, ACOLITE/DSF 3. Model both atmosphere and target from the image modeled water reflectance e.g. POLYMER, C2RCC, NN

MSG4/SEVIRI 2021-03-30T12:45





Atmospheric Correction: How?

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Southern North Sea

Banc D'Arguin

Guinee-Bissau

French Guyana Suriname

Mozambique

pw VIS06 MSG4/SEVIRI 2021-03-30T12:45



L9/OLI 2022-05-18 09:43:09 $\rho_t \text{ RGB}$





Vistula Lagoon, L9/OLI 2022-05-18



Operational Land Imager (OLI) on Landsat 9

- Eight 30 metre bands, one 15 metre band
- 185 km swath width
- 16 day track repeat, but overlap at higher latitudes
- Identical instrument also flying on L8, offset by 8 days

L9/OLI 2022-05-18 09:43:09 ρ_t RGB



Vistula Lagoon, L9/OLI 2022-05-18



L9/OLI computed atmospheric reflectance, excluding pan and cirrus bands. Rayleigh (air molecules) only.

L9/OLI 2022-05-18 09:43:09 ρ_t RGB



Vistula Lagoon, L9/OLI 2022-05-18



Rayleigh and added aerosol particles (maritime type).

L9/OLI 2022-05-18 09:43:09 $\rho_t \text{ RGB}$



DSF assumptions: - aerosols (type, concentration) vary at lower spatial scale than the surface,

- there are some pixels where at least one band has no surface signal, and hence path reflectance can be estimated:



$$\frac{\rho_t}{T_g} = \rho_{path}$$



L9/OLI 2022-05-18 09:43:09 ρ_t RGB



Vistula Lagoon, L9/OLI 2022-05-18



Rayleigh and added aerosol particles (maritime type). Dark spectrum in black, here 1% in each band.

L9/OLI 2022-05-18 09:43:09 ρ_t RGB



Vistula Lagoon, L9/OLI 2022-05-18



Rayleigh and added aerosol particles (maritime type). Dark spectrum in black, here 1% in each band. Estimate τa in each band, select lowest τa

L9/OLI 2022-05-18 09:43:09 ρ_t RGB



Vistula Lagoon, L9/OLI 2022-05-18

Rayleigh and added aerosol particles (maritime type). Dark spectrum in black, here 1% in each band. Estimate τa in each band, select lowest τa

L9/OLI 2022-05-18 09:43:09 ρ_t RGB

Vistula Lagoon, L9/OLI 2022-05-18

Rayleigh and added aerosol particles (maritime type). Dark spectrum in black, here 1% in each band. Estimate τa in each band, select lowest τa

L9/OLI 2022-05-18 09:43:09 $\rho_t \text{ RGB}$

Vistula Lagoon, L9/OLI 2022-05-18

With an estimate of ta and aerosol model, we can compute required parameters from 6SV or LUT:

$$\rho_{path}$$
 $T_d T_u$ S

and compute

 ho_s

L9/OLI 2022-05-18 09:43:09 ρ_s RGB

Vistula Lagoon, L9/OLI 2022-05-18

With an estimate of ta and aerosol model, we can compute required parameters from 6SV or LUT:

$$\rho_{path}$$
 $T_d T_u$ S

and compute

 ho_s

L9/OLI 2022-05-18 09:43:09 ho_w RGB

Vistula Lagoon, L9/OLI 2022-05-18

After masking non-water pixels using a SWIR1 threshold, and applying an optional sun glint correction we obtain pw

L9/OLI 2022-05-18 09:43:09 ρ_w RGB

Vistula Lagoon, L9/OLI 2022-05-18

After masking non-water pixels using a SWIR1 threshold, and applying an optional sun glint correction we obtain pw

L9/OLI 2022-05-18 09:43:09 ρ_w RGB

Vistula Lagoon, L9/OLI 2022-05-18

After masking non-water pixels using a SWIR1 threshold, and applying an optional sun glint correction we obtain pw

S2B/MSI 2022-05-17 09:55:28 ρ_w RGB

Vistula Lagoon, L9/OLI 2022-05-18

After masking non-water pixels using a SWIR1 threshold, and applying an optional sun glint correction we obtain pw

S2B/MSI 2022-05-17 09:55:28 ho_w RGB

Vistula Lagoon, L9/OLI 2022-05-18

After masking non-water pixels using a SWIR1 threshold, and applying an optional sun glint correction we obtain pw

Vistula Lagoon, S2B/MSI 2022-05-17

Vistula Lagoon, S2B/MSI 2022-05-17

Vistula Lagoon, S2B/MSI 2022-05-17

Summary

- DSF originally developed with constraints (and opportunities) presented by 4 band metre-scale imagery, adapted to multi- and hyperspectral imagers
- DSF assumes the aerosol concentration varies at larger spatial scales than the target, and that water reflectance cannot be negative
- DSF can be sensitive to presence of shadows and TOA noise and calibration, and typically selects targets that are too dark, i.e. underestimates the path reflectance, overestimates the surface-level / water reflectance
- Matchup results show good performance in turbid coastal and inland waters. Relative errors become larger for clearer and transitional waters. (not shown)

Running ACOLITE (1) Binaries

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<> Code ① Issues 13 11 Pull requests	🖓 Discussions 🕑 Actions 田 Projects 🖽 Wiki	① Security 🗠 Insights 🕸 Settings	
Releases / 20220222.0			
ACOLITE 20220	222.0 Latest 2 · 127 commits to main since this release) -∽ 348bbdf	Compare 👻 🖉 🖞
Version of the code that went into	o the 20220222.0 binary release. Manual and binary rele	ases for Windows, Mac, and Linux provided.	
▼ Assets 6	Manual is als	o recommended! 🙂	
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realized acolite_py_linux_20220222.0	.tar.gz	485 MB	22 Feb 2022
	tar.gz	338 MB	22 Feb 2022
	ar.gz	390 MB	22 Feb 2022
Source code (zip)			22 Feb 2022
Source code (tar.gz)			22 Feb 2022
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Download binaries for your system from https://github.com/acolite/acolite/releases/latest (currently version 20220222.0)

Extract ACOLITE binary download, and navigate into the directory.

<u>On Windows</u> you can double click the acolite.exe

On Mac and Linux you may need to use a Terminal window to launch acolite:

it View Search Terminal Help

quinten@odn-quinten:~/Downloads\$ tar -xf acolite_py_linux_20220222.0.tar.gz quinten@odn-quinten:~/Downloads\$ cd acolite_py_linux quinten@odn-quinten:~/Downloads/acolite_py_linux\$./acolite

On Mac and Linux you may need to cd into dist/acolite and run ./acolite

On Mac you may need to temporarily disable security measures:

sudo spctl --master-disable

Do not forget to re-enable after:

sudo spctl — master-enable

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	Logging output			
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ACOLITE 20220222.0 Binary on Ubuntu LTS 20.04

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	Run processing Stop processing								
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	(c) 2014-2022 R	BINS							

ACOLITE 20220222.0 Binary on Ubuntu LTS 20.04

Navigate into extracted bundle

Create/select output directory

Note: the first run for a sensor may be slow, as LUTs are downloaded!

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Navigate into extracted bundle

Create/select output directory

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NetCDF files L1R - TOA L2R - BOA L2W - derived parameters

Settings and log files

RGB and parameter PNG files

Running ACOLITE (2) Editing settings

L9_OLI_2022_05_18_09_43_09_190022_L1R_pan.nc L9_OLI_2022_05_18_09_43_09_190022_L1R.nc L9_OLI_2022_05_18_09_43_09_190022_L2R.nc L9_OLI_2022_05_18_09_43_09_190022_L2W.nc acolite_run_20220725_080655_l1r_settings_user.txt acolite_run_20220725_080655_l1r_settings.txt acolite_run_20220725_080655_l2r_settings.txt acolite_run_20220725_080655_log_file.txt L9_OLI_2022_05_18_09_43_09_190022_L1R_rgb_rhot.png L9_OLI_2022_05_18_09_43_09_190022_L2R_rgb_rhos.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_443.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_482.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_561.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_594.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_613.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_654.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_865.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_1608.png L9_OLI_2022_05_18_09_43_09_190022_L2W_rhow_2201.png

Find and copy "I1r_settings_user.txt"

(Don't edit the defaults file!)

Original "I1r_settings_user.txt"

@ @ @ acolite_run_20220725_080655_l1r_settings_user.txt ~
ACOLITE settings
Written at 2022-07-25 09:10:16
limit=54.5,19.75,54.73,20.17
inputfile=/Users/quinten/Downloads/LC09_L1TP_190022_20220518_20220518_02_T1
output=/Users/quinten/Downloads/Vistula
polygon=
l2w_parameters=rhow_*
rgb_rhot=True
map_l2w=True
map_l2w=True
runid=20220725_080655

New "settings_copy.txt"

ACOLITE settings
Written at 2022-07-25 09:10:16
limit=54.5,19.75,54.73,20.17
inputfile=/Users/quinten/Downloads/LC09_L1TP_190022_20220518_20220518_02_T1
output=/Users/quinten/Downloads/Vistula/
polygon=
l2w_parameters=rhow_*
rgb_rhot=True
rgb_rhos=True
map_l2w=True
runid=20220725_080655
add new settings

output=/Users/guinten/Downloads/Vistula/glint
dsf_residual_glint_correction=True

Added "glint" to output directory Added setting "dsf_residual_glint_correction=True"

	ACOLIT	TE Python	(Generic V	ersion 202	20222.0)		
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ACOLITE 20220222.0 Binary on Ubuntu LTS 20.04

Original L2W output

New L2W output

Running ACOLITE (3) Getting images for your ROI

Define a smallish Region Of Interest, e.g. 0.5°x0.5° get a GeoJSON file from geojson.io

Define a smallish Region Of Interest, e.g. 0.5°x0.5° through South, West, North, East coordinates

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Mission: Sentinel-3		
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Timeliness	Instrument	
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Product Level	Relative Orbit Start [1-	-385]
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Sentinel-2 / 3 data: https://scihub.copernicus.eu/dhus/#/home (Also using sentinelsat / Python API)

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Sentinel-2 / 3 data: https://scihub.copernicus.eu/dhus/#/home (Also using sentinelsat / Python API)

Landsat / Sentinel-2 data: https://earthexplorer.usgs.gov

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science for a changing	world							
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sed as a guide for reference and search purposes only.

Landsat / Sentinel-2 data: https://earthexplorer.usgs.gov ● ● ● ● ■ | • < > D earthexplorer.usgs.gov EE EarthExplorer ≈USGS science for a changing world EarthExplorer Manage Criteria Data Sets Additional Criteria Data Sets Results Search Criteria Summary (Show) 2. Select Your Data Set(s) Check the boxes for the data set(s) you want to search. When done selecting data set(s), click the Additional Criteria or Results buttons below. Click the plus sign next to the category name to show a list of data sets. Use Data Set Prefilter (What's This?) Data Set Search: ISERV E Land Cover 🗄 Landsat [🔲 Landsat Collection 2 Level-3 Science Products Landsat Landsat C2 U.S. Analysis Ready Data (ARD) Landsat Collection 2 Level-2 Landsat Collection 2 Level-1 Collection 2 - 2 🕕 🔣 👛 Landsat 8-9 OLI/TIRS C2 L1 🕕 🔣 🦾 Landsat 7 ETM+ C2 L1 Level-1 🕕 🔣 🦲 Landsat 4-5 TM C2 L1 🕕 🔣 ំ Landsat 1-5 MSS C2 L1 E Landsat C2 Atmospheric Auxiliary Data Landsat Collection 1 Landsat Legacy 1 LCMAP NASA LPDAAC Collections Radar Sentinel Sentinel-2 🖵 🕕 🔣 👛 Sentinel-2 🗄 UAS Vegetation Monitoring Clear All Selected Additional Criteria » Results »

Landsat / Sentinel-2 data: https://earthexplorer.usgs.gov ••• D arthexplorer.usgs.gov EE EarthExplorer science for a changing world EarthExplorer Manage Criteria Results Results Search Criteria Summary (Show) 4. Search Results If you selected more than one data set to search, use the dropdown to see the search results for each specific data set. Show Result Controls Data Set Click here to export your results » 🛃 Landsat 8-9 OLI/TIRS C2 L1 « First (Previous 1 🗘 of 15 Next > Last > Displaying 1 - 50 of 718 ID: LC08_L1TP_191029_20220720_20220720_02_RT Date Acquired: 2022/07/20 Path: 191 Row: 029 Quicklook 92. 080 ID: LC09_L1TP_192028_20220719_20220719_02_T1 Date Acquired: 2022/07/19 Path: 192 Row: 028 🎁 🖻 🗋 🖤 🕹 🚚 🚫 ID: LC09_L1TP_192029_20220719_20220719_02_T1 Date Acquired: 2022/07/19 Path: 192 Row: 029 🎁 🖻 🔍 💱 🕹 🚚 🛇 ID: LC09_L1TP_191029_20220712_20220712_02_T1 Date Acquired: 2022/07/12 Path: 191 Row: 029 🎽 🕄 🕄 🕲 🕲 🖓 🍰 🚚 🛇 Submit Standing Request » View Item Basket »

The provided maps are not for purchase or for download; they are to be used as a guide for reference and search purposes only.

Landsat / Sentinel-2 data: https://earthexplorer.usgs.gov

Landsat

Running ACOLITE (4) Python

Sort Python environment and dependencies

See also https://github.com/acolite/acolite#dependencies

Create ACOLITE environment in conda (miniconda/Anaconda):

conda create -n acolite -c conda-forge python=3

Activate acolite environment:

conda activate acolite

Install dependencies from conda-forge:

conda install -c conda-forge numpy matplotlib scipy gdal pyproj scikit-image pyhdf pyresample netcdf4 h5py requests pygrib cartopy

Clone ACOLITE code

See also https://github.com/acolite/acolite#installation

Create and change to a suitable directory, e.g.:

makedir \$HOME/git/

cd \$HOME/git/

Clone acolite repo, with low depth:

git clone --depth 1 <u>https://github.com/acolite/acolite</u>

Launch ACOLITE:

cd acolite

python launch_acolite.py

Import ACOLITE code

Note your ACOLITE git directory: /path/to/git/acolite

Example Jupyter Notebook cell: import ACOLITE distribution

In []: ## add git/acolite to path import sys, os user_home = os.path.expanduser("~") sys.path.append(user_home+'/git/acolite') #sys.path.append('/Users/quinten/git/acolite') # use full path alternatively

import ACOLITE import acolite as ac print('ACOLITE version {}'.format(ac.version))

(Note: change the paths to match your system!)

Import ACOLITE code

Example Jupyter Notebook cell: Run processing with custom settings

```
In []: ## make a settings dict – here the example from SLS 2022
        settings = {}
        settings['inputfile'] = '/Users/quinten/Downloads/LC09_L1TP_190022_20220518_20220518_02_T1'
        settings['output'] = '/Users/quinten/Downloads/Output/Vistula/'
        ## use fixed DSF based on 1st percentile, as in the DSF demo/explanation
        settings['dsf_aot_estimate'] = 'fixed'
        settings['dsf_spectrum_option'] = 'percentile'
        settings['dsf_percentile'] = 1
        ## set ROI, note: S, W, N, E order here (i.e. "bottom left" to "upper right")
        settings['limit'] = [54.5, 19.75, 54.73, 20.17]
        ## use only MOD2 - maritime aerosol, as in the DSF demo/explanation
        settings['luts'] = ['ACOLITE-LUT-202110-MOD2']
        settings['resolved geometry'] = False
        ## enable glint correction
        settings['dsf_residual_glint_correction'] = True
        ## output rhot_* and rhow_* to L2W file
        settings['l2w_parameters'] = ['rhot_*', 'rhow_*']
        settings['rgb_rhow'] = True
        ## run with these settings
        ac.acolite.acolite_run(settings)
```

(Note: change the paths to match your system!)

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244	1128	How to get ACOLITE support? by quinten Thu Jul 21, 2022 9:14 am
27	37	ACOLITE 20220222.0 by quinten 🖾 Tue Feb 22, 2022 2:00 pm
33	121	Re: GeoTIFF outputs for Senti by quinten Tue Jun 07, 2022 11:22 am
17	52	Re: Planetscope 8-band imagery by LilianaAr 🛛 Thu Apr 21, 2022 5:14 pm
38	198	Re: Glint correction for Worl by quinten 🛯 Thu Jul 21, 2022 8:44 am

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