Presentation of AC Processor **ATCOR**

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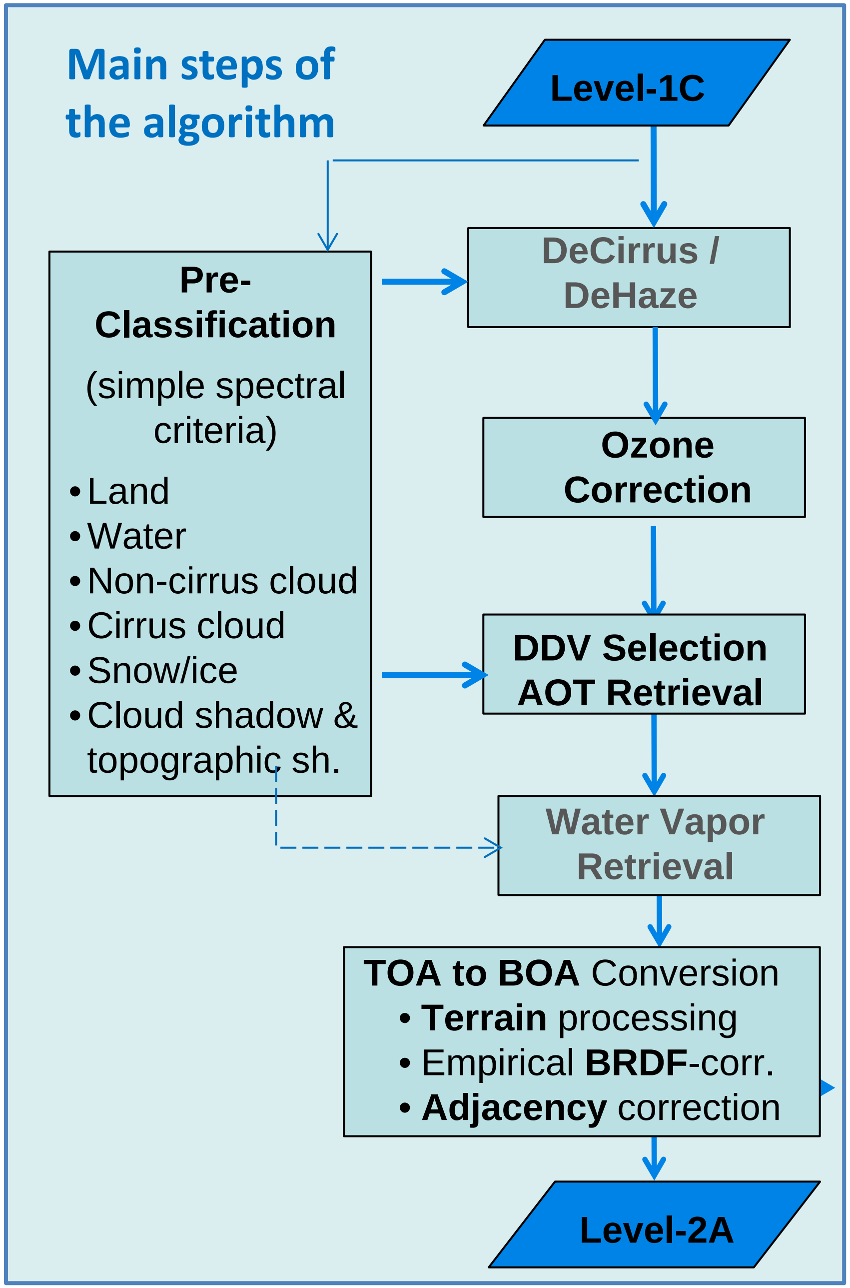
ATCOR Overview

- Processor developed by DLR, first version 1990, continually updated
- Multi-Mission tool, MS and HS satellite and airplane imagery, spectral region 400 – 2500 nm
- Atmospheric correction over land
- Processing on granule level for a single-time dataset
- IDL application
  - Interactive mode
  - Batch mode: configuration by *.inn text file



ATCOR: Inputs

- Level-1C ortho-image Top-Of-Atmosphere (TOA) radiance products
  - Sentinel-2: Reflectance to radiance conversion

- Pre-compiled database of atmospheric Look-up tables
  - Sentinel-2 and Landsat-8 aerosol models:
  - rural/continental & maritime & urban & desert

- Radiative Transfer code: MODTRAN5.4 with HITRAN2013

Look-up-table selection	Default
Aerosol type	Rural
Atm. profile	Set by date (summer, winter)

- Optional DEM provided by user

cfg. parameter	Default
surface elevation	set if no DEM

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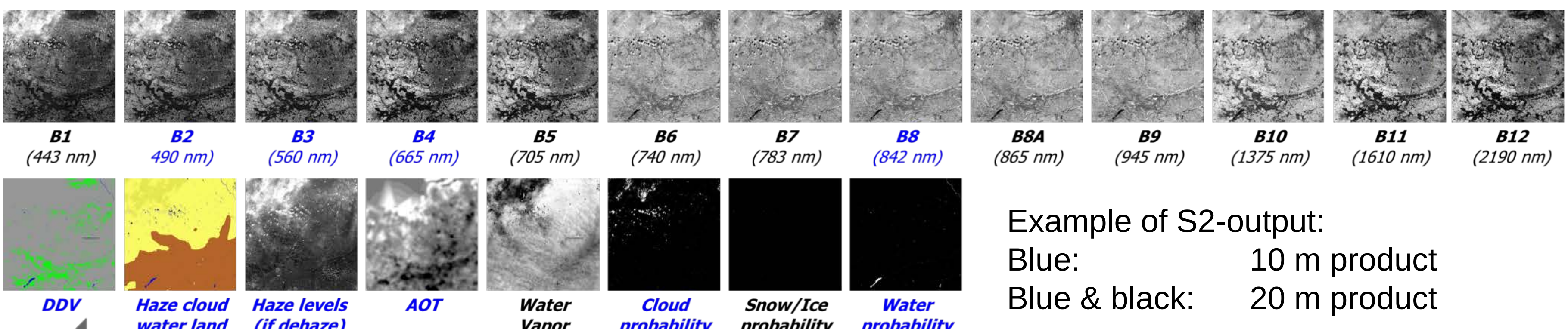
ATCOR: Outputs

- Sentinel-2 (13-band cube 20m; 4-band cube 10m)
- Landsat (30m)

- Bottom-Of-Atmosphere (BOA) corrected reflectance
- Aerosol Optical Thickness@550 nm (AOT) map
- Sentinel-2: Water Vapour (WV) map (resampled 20 m)
- Dense Dark Vegetation (DDV) map
- Haze-Cloud-Water map
- Quality Indicators for cloud, snow and water probabilities



Example of S2-output:
Blue: 10 m product
Blue & black: 20 m product

ATCOR: Processing steps and parameters

- Ozone correction:
  - Applied to bands in 450 – 800 nm with precalculated MODTRAN LUTs
  - Ref: Richter et al., Int. J. Remote Sensing, Vol. 35, 8044-8056 (2014)
- Optional cirrus and haze removal:
  - Cirrus removal:
    uses bands 1.38 µm and 0.66 µm, correction is applied to all bands
  - Haze removal: uses blue/green bands correction for bands 0.4 – 2.5 µm
  - Makarau et al., IEEE TGRS, Vol. 52, 5895-5905 (2014)
  - Makarau et al., IEEE GRSL, Vol. 13, 379-383 (2016)

cfg. parameter	Default
ozone column	
Sentinel-2	from meta data file (ECMWF product TCO3)
Landsat-8	user input, else: 331 DU
Cirrus correction	on
Haze removal	off

AOT(550nm) Retrieval, Part 1: DDV Selection

- S2: uses B12(2.2 µm) & B8a(865 nm)
  L8: uses B7(2.2 µm) & B5(865 nm)

cfg. parameter	Default
Default/Start VIS	23 km

- compute surface ρ(2.2µm) for VIS=23km excluding water.
  (Min. distance of DDV-pixels to clouds = 500 m) Then

a) $0.01 < \rho(2.2\mu m) < 0.05$ If less than 5% of scene pixels DDV, then

b) $0.01 < \rho(2.2\mu m) < 0.10$ If less than 5% of scene pixels DDV, then

c) $0.01 < \rho(2.2\mu m) < 0.12$

d) If < 2% DDV pixels, then set VIS to default value
(VIS=23 km corresponds to AOT=0.32)

e) Check water bodies: if ρ(water, 865 nm) < 0 for more than 1% of pixels, then
- decrease AOT550 until ρ(water, 865 nm) >= 0

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AOT(550nm) Retrieval, Part 2: spectral correlation

Spectral correlation for DDV:
S2: B2(490 nm), B4(665 nm) & B12(2.2 µm)
L8: B2(490 nm), B4(665 nm) & B7(2.2 µm)

- ρ(0.665µm) = 0.5 ρ(2.2µm)
- ρ(0.490µm) = 0.5 ρ(0.665µm) + 0.005
- ρ(0.443µm) = 0.8 ρ(0.490µm)

cfg. parameter	Default
Visibility	Average over VIS of DDV
Ratio red /_swir	0.5
Ratio blue /_red	0.5

- calculate VIS [AOT] from ρ(0.665µm)
- Non-reference pixels are assigned the average AOT550 of the DDV pixels (default) or spatial triangulation
- Smoothing of AOT550 map to suppress noise (3 km box)
- Rescale path radiance to match ρ(0.443µm,DDV) & ρ(0.490µm,DDV)

Water Vapor Retrieval

cfg. parameter	Default
WV correction	on
WV over water	Land average
Smooth WV map	100 m

- Atmospheric Precorrected Differential Absorption (APDA) technique
- S2 Bands B8a (865 nm) and B9 (945 nm)

$$R_{APDA} = \frac{L(\rho,945) - L_p(945,W)}{L(\rho,865) - L_p(865)}$$

$$R_{APDA}(W) = a_0 \, exp(-a_1 W^{a_2})$$

Solving for *W* : $$W = \left(\frac{ln(R_{APDA} / a_0}{-a_1} \right)^{1/a_2}$$

Equations are iterated using the precalculated LUTs with W=0.4 – 5.0 cm

Ref: Schläpfer et al. RSE, Vol. 65, 353-366 (1998)

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Surface Reflectance Retrieval

cfg. parameter	Default
Adjacency range	1 km
BRDF correction	No

- All bands except cirrus band

- Flat terrain, 3 steps:
  1. solve RT equation for ρ:

$$L = L_p + \frac{T\ E_g\ \rho^{(1)} / \pi}{1 - \rho^{(1)}\ s}$$

  2. Calculate average (1 – 2 km box):

$$\bar{\rho} = \sum_{i,k=1}^{N} \rho^{(1)}(i,k)$$

  3. Adjacency correction: $\rho(x,y) = \rho^{(1)}(x,y) + q\left\{\rho^{(1)}(x.y) - \bar{\rho}(x,y)\right\}$

- Mountainous terrain: complex, see references for details, DEM required, includes empirical BRDF-correction

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Processing time (Intel 3.5 GHz PC, Ubuntu 14.04)

- Landsat-8 OLI (7711 x 7861 pixels), flat terrain: 2 min
- Rugged terrain (with DEM) 8 min

- Sentinel-2: import of jp2 files 4 min
  conversion into layer-stacked radiance cubes: 13-bands at 20m
  and 4 bands at 10m

- S2 surface reflectance:
  - 13-band cube (5490 x 5490, 20m) 3 / 6 min (flat/DEM)
  - 4-band cube (10980 x 1098, 10m) 2 / 4 min (flat/DEM)

Selected References ATCOR

- Richter, R., Int: J. Remote Sensing, Vol. 11, 159-166, 1990
- Richter, R., Applied Optics, Vol. 37, 4004-415, 1998
- Richter, R., et al., IEEE TGRS, Vol. 49, 1772-1780, 2011
- Richter, R., et al., IJRS, Vol. 32, 2931-2941, 2011
- https://www.rese-apps.com, ATCOR manual, 2016

MAJA - MACCS-ATCOR Joint Algorithm

- Motivation: combination of strengths of MACCS (CNES) and ATCOR (DLR) in a close cooperation of the related developer teams
- Enhancement of ATCOR and MACCS components for an optimized and efficient software solution
- Integration of ATCOR modules into MACCS framework of multi-temporal processing
- Preparation of operational MAJA environment at CNES and DLR in the context of the Sentinel-2 mission

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Thank you!
Bye Bye!

ATCOR: Empirical BRDF correction model for rugged terrain (DEM required)

- Empirical BRDF correction with factor (G) according to following equation:

$$G = \{ \cos(\beta i) / \cos(\beta T) \}b \geq g$$

- where: βi: local solar zenith angle (from metadata, section 0)
  β_T: threshold for surface reflectance (determined by program)
  b: exponent set via options below
  g: Lower boundary of BRDF correction,
  recommended between 0.2 and 0.25 (configuration parameter)

- Options to be selected: next slide

ATCOR: BRDF options

cfg. parameter	Default
BRDF model	21

- Options to be selected:

1: correction with cosine of local solar zenith angle (b=1)

2: correction with sqrt(cos) of local solar zenith angle (b=1/2)

11: ”weak” correction dependent on surface type

for soil/sand with b=1

for vegetation: b=1/3 (λ< 720 nm), and b=3/4 (λ > 720 nm)

12: ”strong” correction dependent on surface type

for soil/sand b=1

for vegetation b=1.0 (λ < 720 nm),and b=3/4 (λ > 720 nm)

21: ”weak” correction dependent on surface type

for soil/sand with b=1/2

for vegetation with b=1/3 (λ < 720 nm), and b=3/4 (λ > 720 nm)

This is the recommended standard yielding good results in most cases.

22: ”strong” correction dependent on surface type

for soil/sand with b=1/2

for vegetation with b=1.0 (λ < 720 nm), and b=3/4 (λ > 720 nm,