→ SENTINEL-2 FOR SCIENCE WORKSHOP

SEN2COR: Atmospheric and Topographic Correction of Simulated Level-1C Test Datasets

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- Rudolf Richter, DLR, Germany
- Ferran Gascon, ESA, Italy
- Marc Niezette, Telespazio-VEGA, Germany

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DLR

SEN2COR …

- is a prototype processor for Sentinel-2 Level 2A product generation and formatting;
- performs the tasks of atmospheric-, terrain and cirrus correction of Top-Of- Atmosphere Level 1C input data;
- creates Bottom-Of-Atmosphere, optionally terrain- and cirrus corrected reflectance images;
- additional, Aerosol Optical Thickness-, Water Vapor-, Scene Classification Maps and Quality Indicators for cloud and snow probabilities;
- its product format is equivalent to the Level 1C User Product: JPEG 2000 images, three different resolutions, 60, 20 and 10 m;
- it is written in Python (Anaconda Distribution), makes intensive use of GDAL (**G**eospatial **D**ata **A**bstraction **L**ibrary) and supports Linux, Mac OS X and Windows 64 bit platforms;
- will be integrated into the Sentinel-2 Toolbox.

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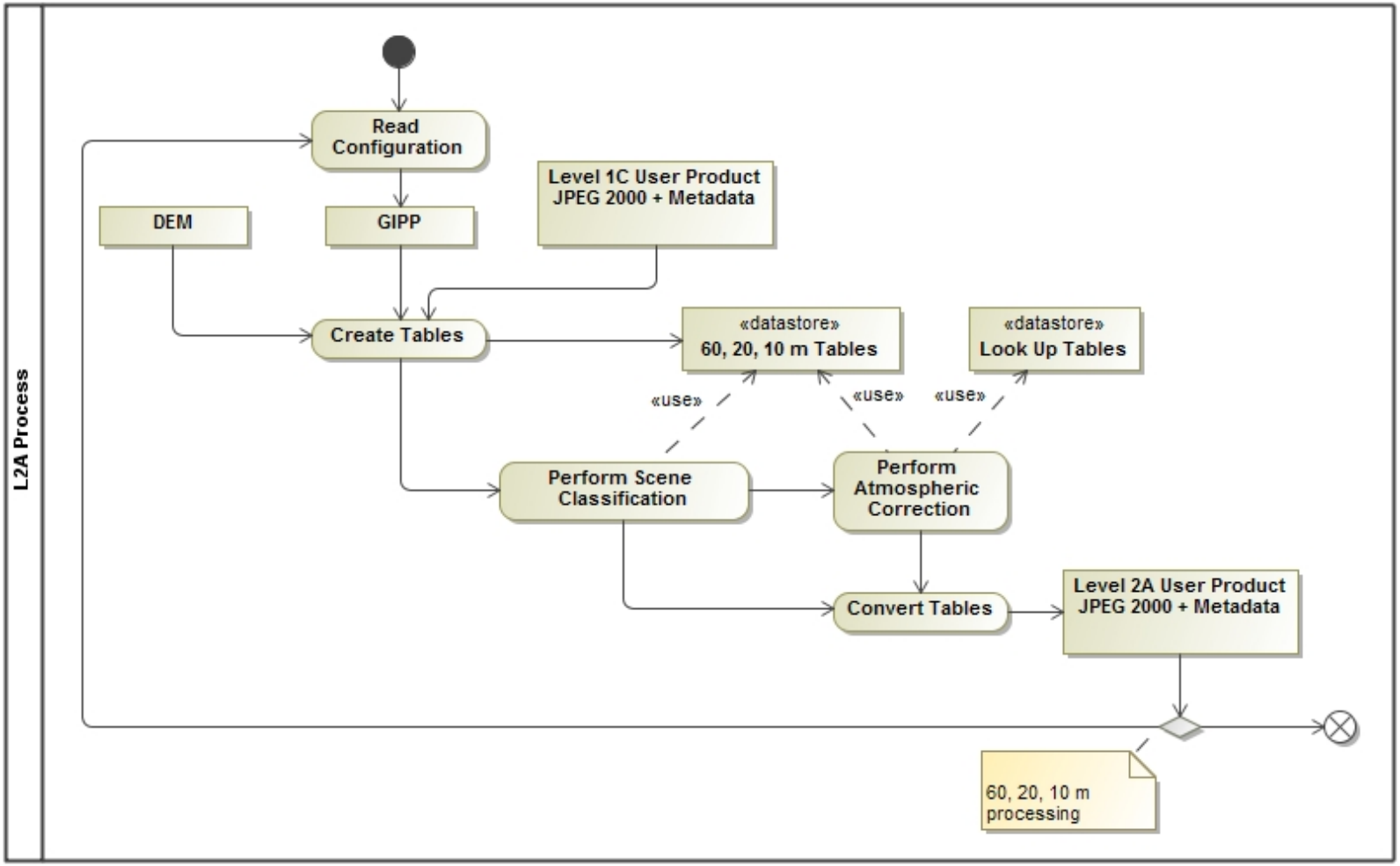
Processing Scheme



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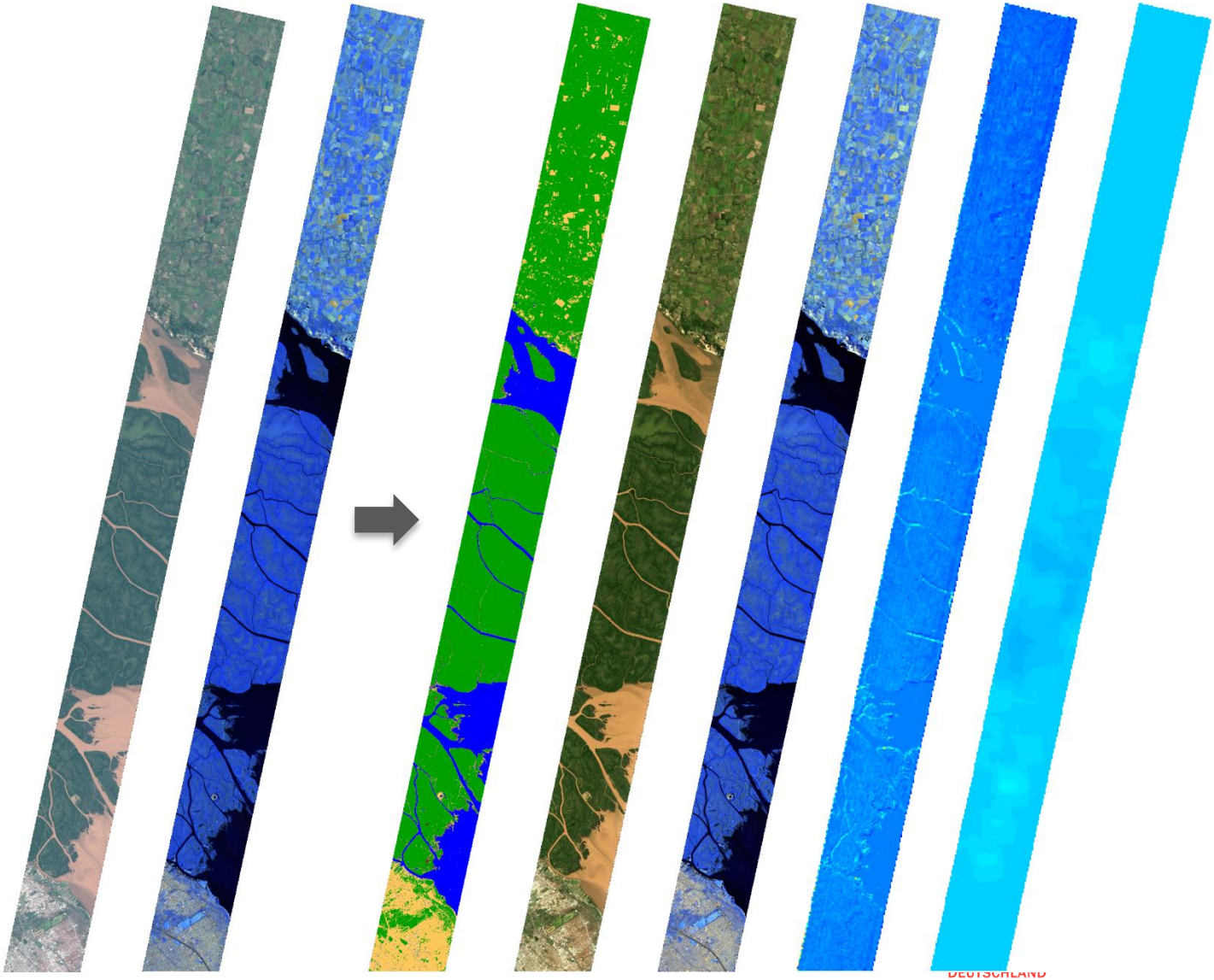
Products

Inputs: Level-1C:

- TOA 04-03-02
- TOA 12-11-8A

Outputs: Level-2A:

- Scene Classification
- BOA 04-03-02
- BOA 12-11-8A
- Water Vapor
- Aerosol Optical Thickness



Simulated Test Data Sets

S2 simulated dataset generated from 21 Hyperion scenes (EO-1 mission)

- on different geographical areas, e.g. polar regions, mountainous, forest, agricultural, urban, desert, coastal and tropical,
- on different periods of the year (winter, spring, summer, autumn),
- from an hyperspectral satellite mission (not Airborne)

Some limitations concerning this dataset

- Noise/ vertical striping of Hyperion bands related to Sentinel-2 atmospheric bands B1, B9 & B10
- Hyperion swath width (7.6 km)
- Hyperion resolution (30 m)

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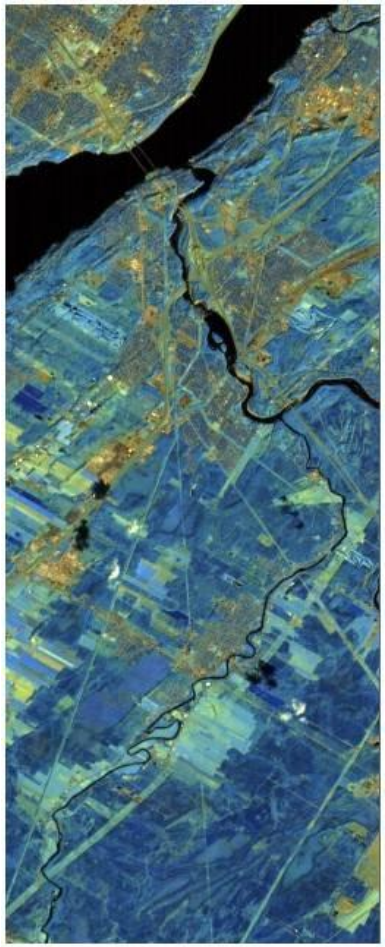
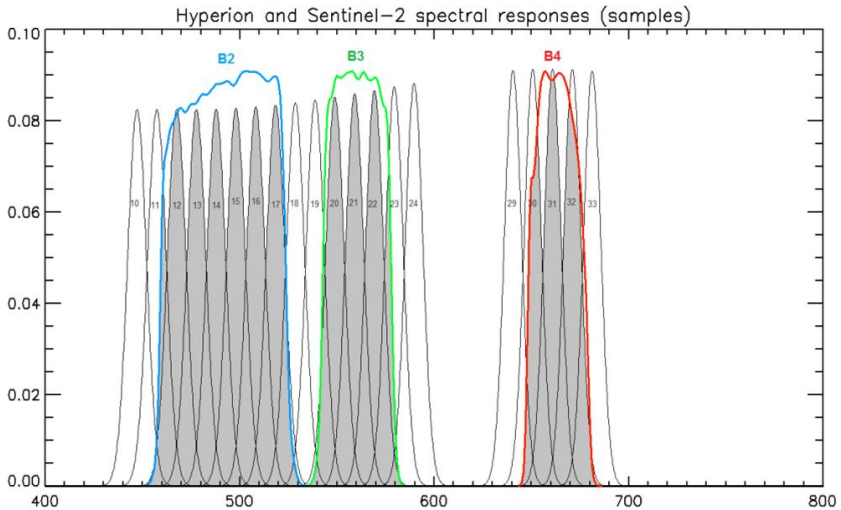
Simulated Scene



(a) Simulated Scene (B4, B3, B2)
(b) Simulated Scene (B12, B11, B8)



Hyperion bands involved in Sentinel-2 aggregation process for S2 - 10 m bands: B2, B3 and B4

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Test Data Sets Used for Evaluation

Name	Region	Zone	Relief	Aerosol type	Cloud Cover	Hyperion orginal product	Acquisition Date
1. Longyearbyen	Norway	Polar N	Mountainous	Maritime	0% to 9%	EO1H2120042003240110PZ	28/08/2003
2.Barrow	Alaska	Polar N	Flat	Maritime	0% to 9%	EO1H0800102005081110KZ	22/03/2005
3.Yakutsk	Russia	Polar N	Flat	Rural	70% to 79%	EO1H1210162009185110T5	04/07/2009
4.Yekaterinburg	Russia	Boreal	Flat	Rural	70% to 79%	EO1H1630202006319110PZ	15/11/2006
5.Fontainebleau	France	Boreal	Flat	Rural	0% to 9%	EO1H1990262004248110PV	04/09/2004
6.Howland2002	United States	Boreal	Flat	Rural	30% to 39%	EO1H0110282002237110PZ	25/08/2002
7.Potenza	Italia	MidlatitudeN	Montainous	Rural	10% to 19%	EO1H1880322012230110PF	17/08/2012
8. Easton	United States	MidlatitudeN	Flat	Rural	0% to 9%	EO1H0140332010204110Pk	23/07/2010
9. Sacol	China	MidlatitudeN	Montainous	Rural	0% to 9%	EO1H1300352011208110Ki	27/07/2011
10. Dahkla	Maroc	subtropicalN	Flat	Maritime	10% to 19%	EO1H2060432003038110PZ	07/02/2003
11. Mukdahan	Thailand	subtropicalN	Flat	Rural	10% to 19%	EO1H1270482006127110PF	07/05/2006
12. Ouagadougou	Burkina Faso	Tropical	Flat	Rural	20% to 29%	EO1H1950512002310110PZ	06/11/2002
13. Mbita	Kenya	Tropical	Flat	Rural	10% to 19%	EO1H1700602011111110K0	21/04/2011
14. Balbina	Brazil	Tropical	Flat	Rural	10% to 19%	EO1H2310622002226110PY	14/08/2002
15. Reunion_St_Denis	France	subtropicalS	Montainous	Maritime	10% to 19%	EO1H1530752009016110P0	16/01/2009
16. RioDeJaneiro	Brazil	subtropicalS	Flat	Rural	30% to 39%	EO1H2170752011051110KF	20/02/2011
17. Skukuza	South Africa	subtropicalS	Flat	Rural	20% to 29%	EO1H1680772009239110K1	27/08/2009
18. Birdsville2005	Australia	subtropicalS	Flat	Rural	0% to 9%	EO1H0980772005229110KF	17/08/2005
19. BuenosAires	Argentina	MidlatitudeS	Flat	Maritime	0% to 9%	EO1H2250832003027112PF	27/01/2003
20. Canberra	Australia	MidlatitudeS	Montainous	Rural	20% to 29%	EO1H0910842008023110K5	23/01/2008
21. RioGallegos	Argentina	Austral	Flat	Rural	0% to 9%	EO1H2280962006098110PP	08/04/2006

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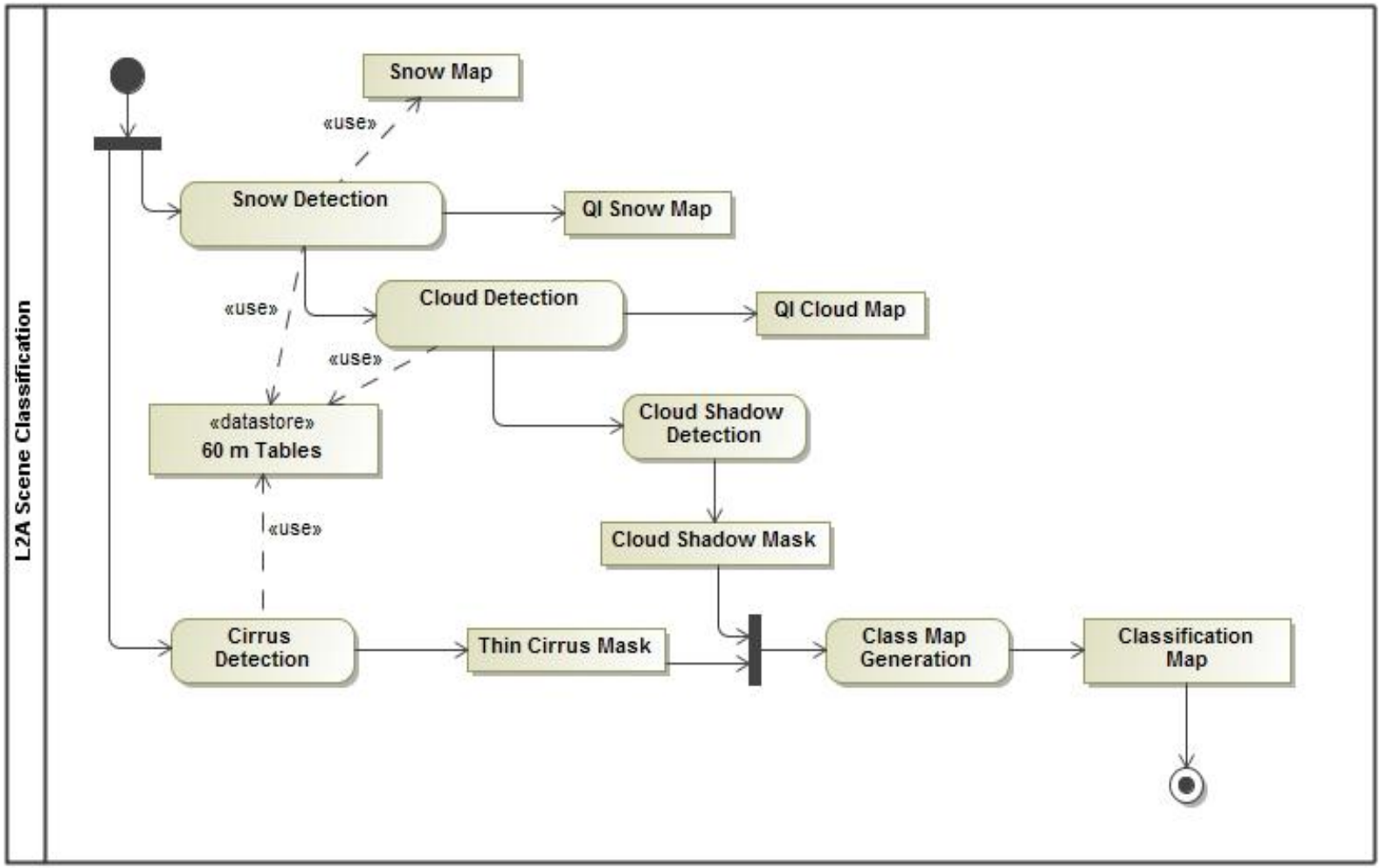
SC Processing Scheme



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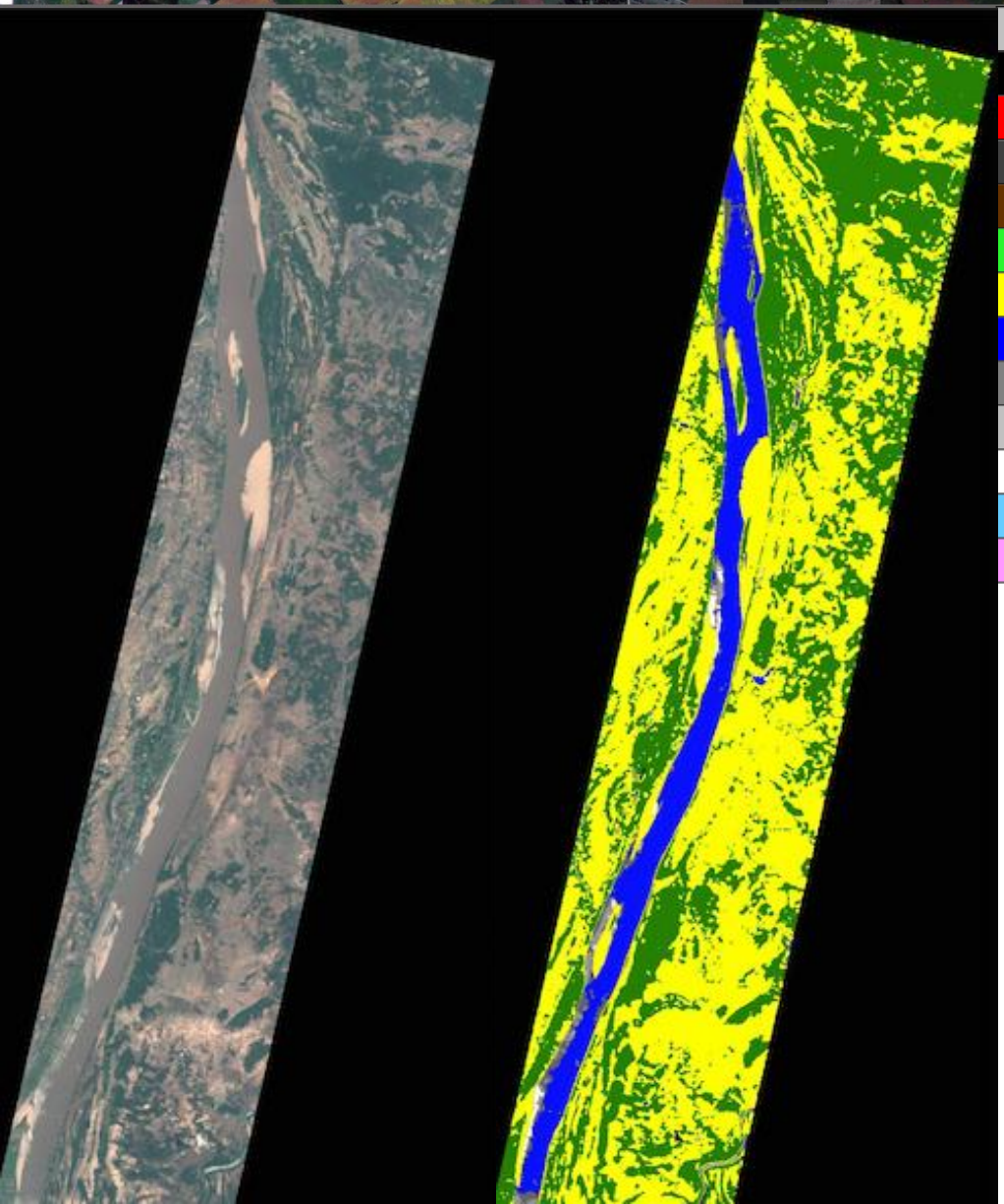
Scene Classification I



Classification
NO_DATA
SATURATED_OR_DEFECTIVE
DARK_AREA_PIXELS
CLOUD_SHADOWS
VEGETATION
BARE_SOILS
WATER
CLOUD_LOW_PROBABILITY
CLOUD_MEDIUM_PROBABILITY
CLOUD_HIGH_PROBABILITY
THIN_CIRRUS
SNOW

Scene 11, Mukdahan, Thailand:

Detection of Water, Vegetation and Bare Soils

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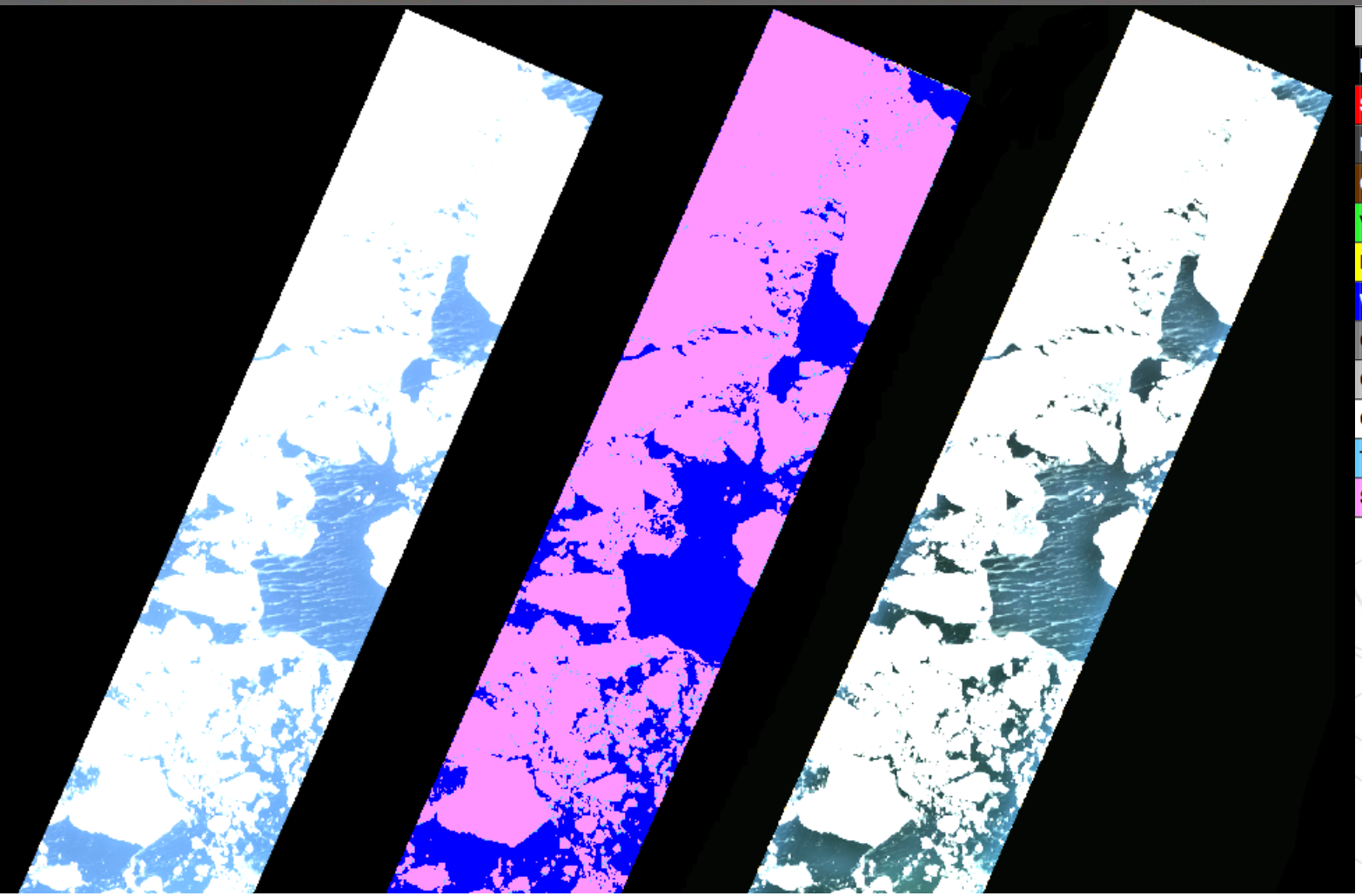
Scene Classification II



Classification
NO_DATA
SATURATED_OR_DEFECTIVE
DARK_AREA_PIXELS
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VEGETATION
BARE_SOILS
WATER
CLOUD_LOW_PROBABILITY
CLOUD_MEDIUM_PROBABILITY
CLOUD_HIGH_PROBABILITY
THIN_CIRRUS
SNOW

Scene 5, Lonyuearbyen, Norway:

Detection of Water and Snow / Ice

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Cloud Shadow Detection

Three Classification Steps to Discriminate Cloud and Terrain Shadow:

- Radiometric input: dark pixel values that are within a certain range, defined by the reflectance spectra of S2 Bands B2, B3, B4, B8, B11, B12 are weighted as cloud shadows, using a minimum distance algorithm on each reflectance pixel of each of the six spectral bands.
- Geometric input: uses position of the sun, sun elevation, azimuth angles, and an empirical model for top-cloud height distribution, to define a probability mask for the location of cloud shadows.
- Terrain information (if DEM available): terrain shadows are more probable in mountainous regions than in flat areas. Threshold can be configured.

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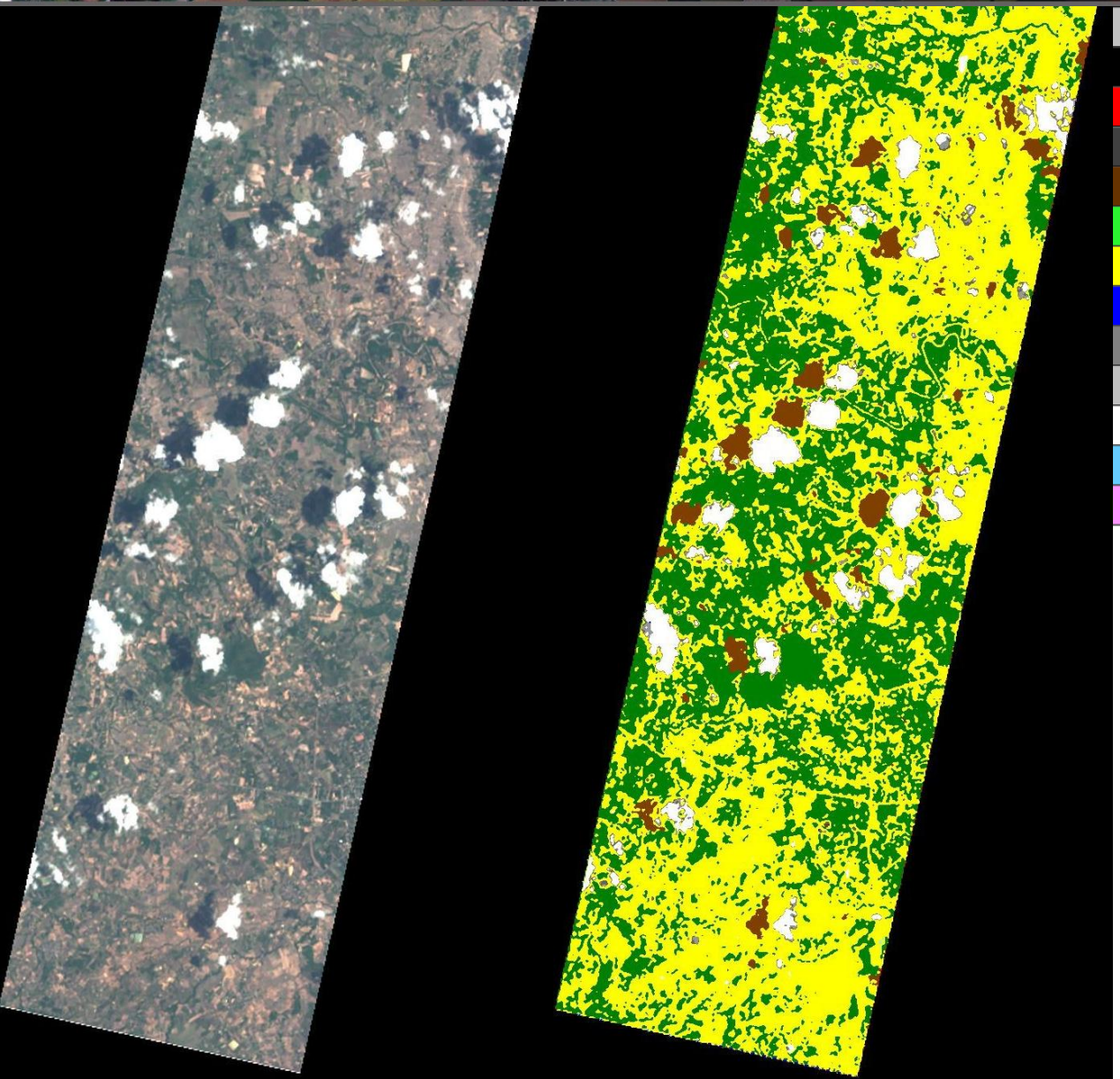
Cloud Shadow Detection



Classification
NO_DATA
SATURATED_OR_DEFECTIVE
DARK_AREA_PIXELS
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CLOUD_LOW_PROBABILITY
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CLOUD_HIGH_PROBABILITY
THIN_CIRRUS
SNOW

Scene 11, Mukdahan, Thailand

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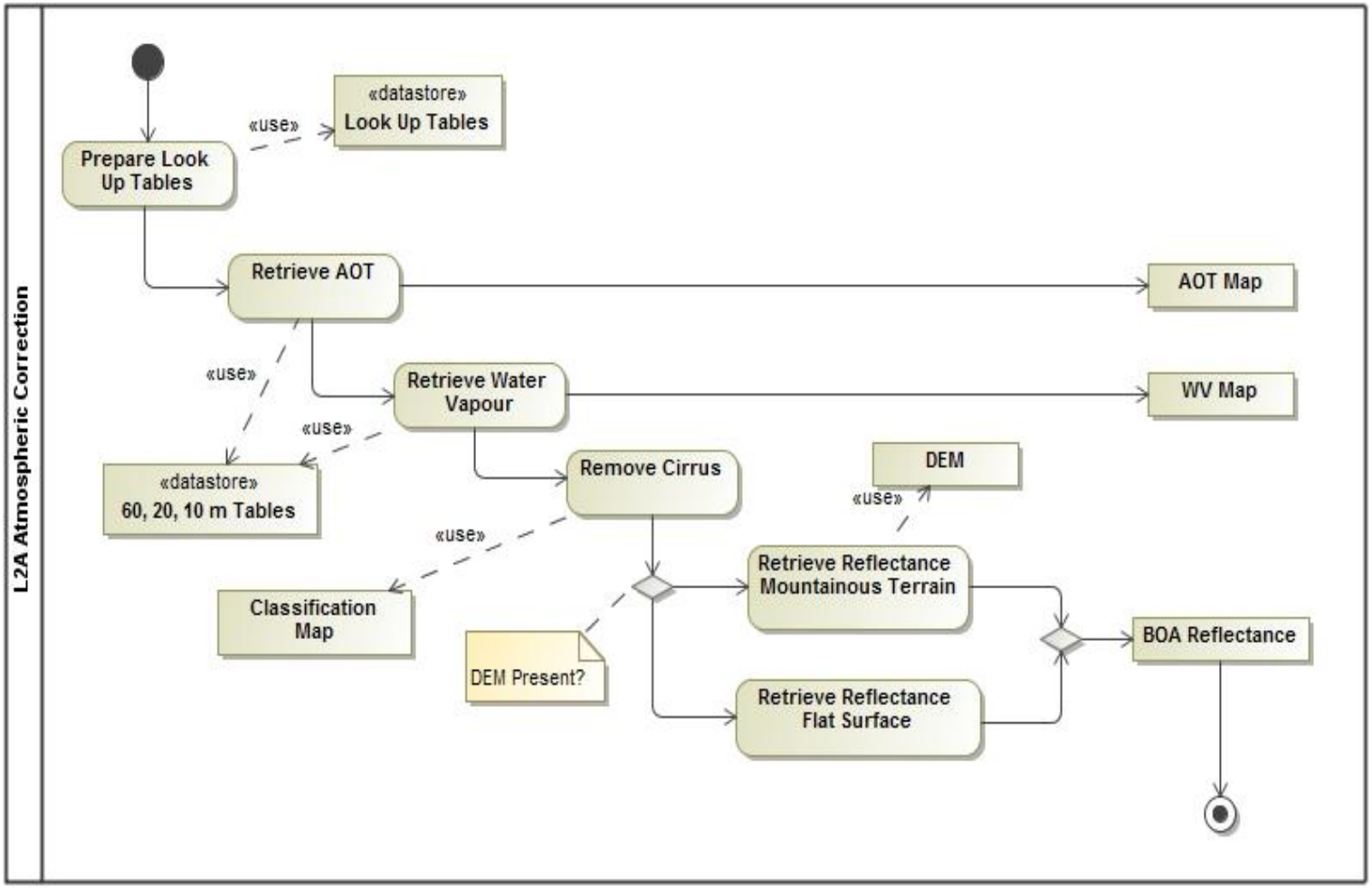
AC Processing Scheme



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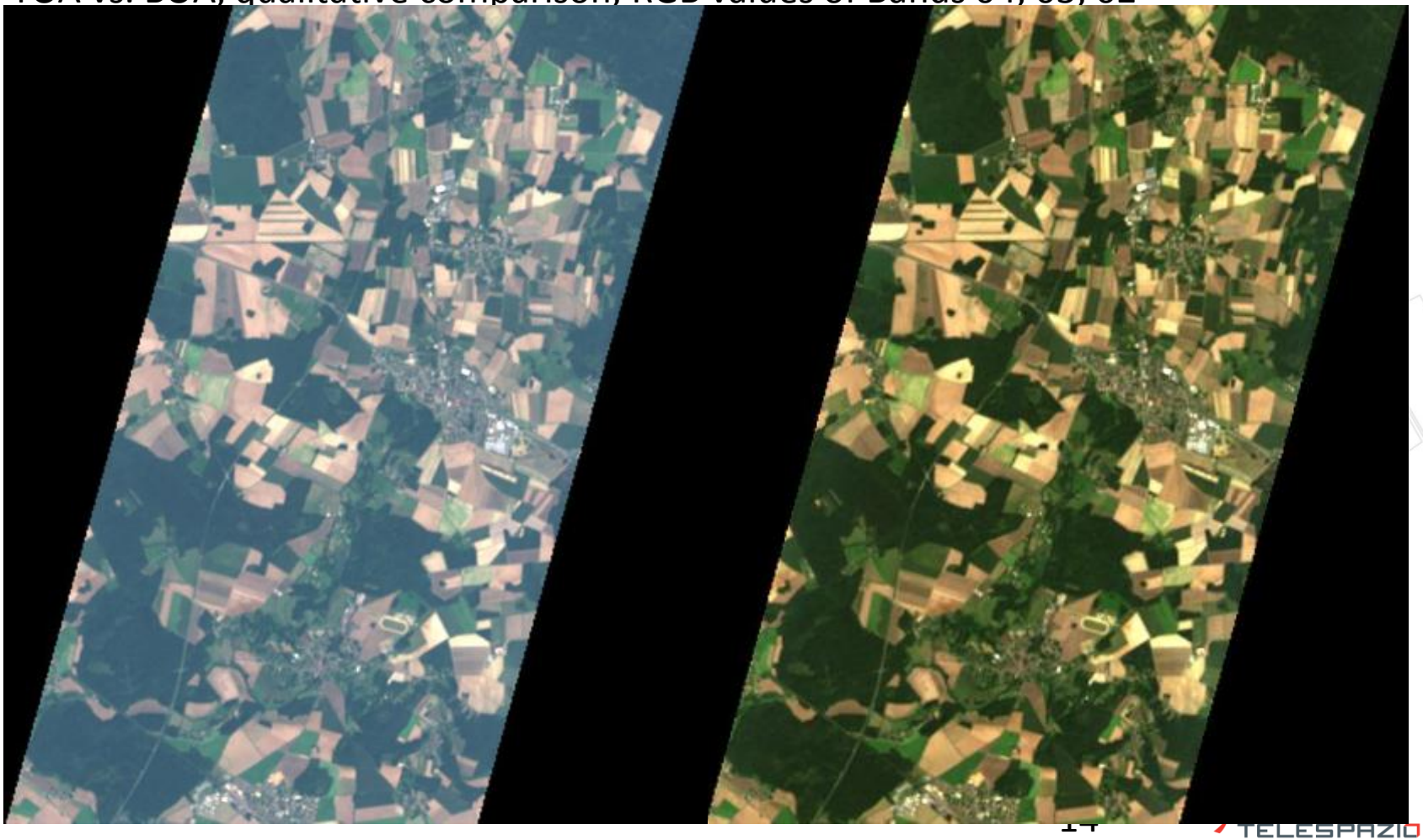
Atmospheric Correction

Scene 5, Fontainebleau:

TOA vs. BOA, qualitative comparison, RGB values of Bands 04, 03, 02



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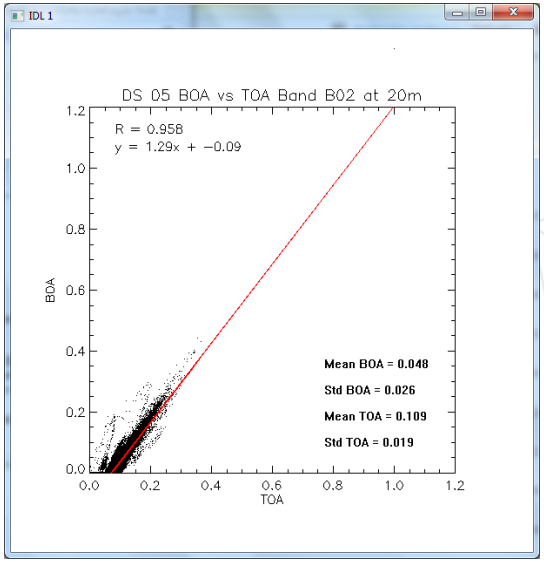
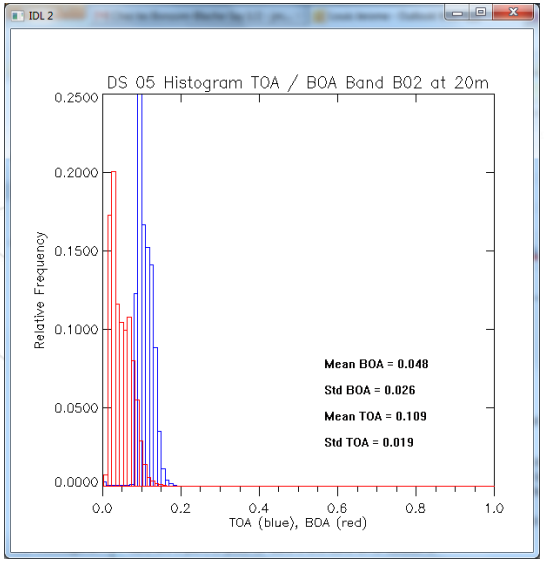
Atmospheric Correction

TOA vs. BOA, Band 02, scatterplot and distribution of reflectance values





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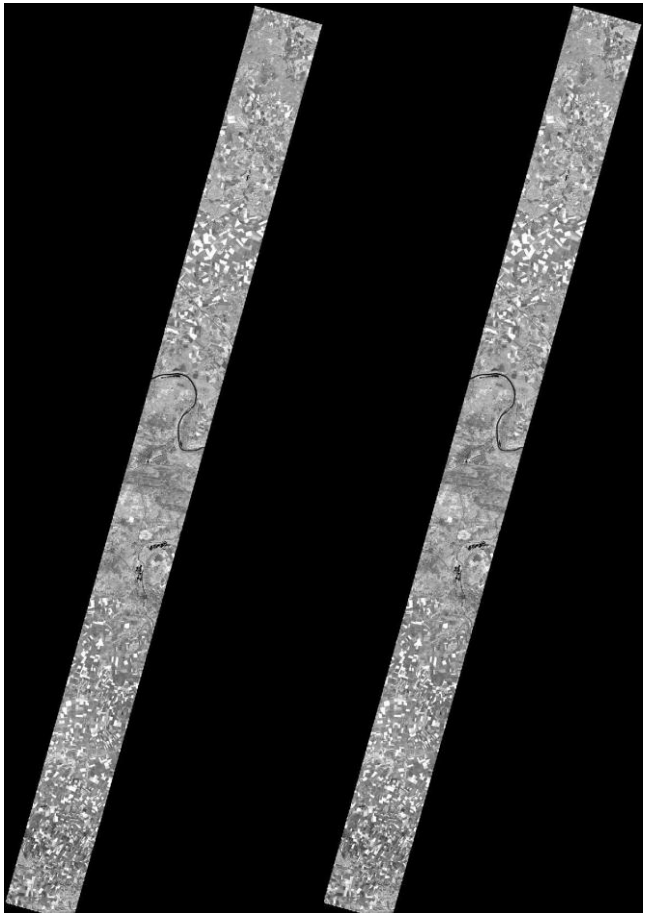
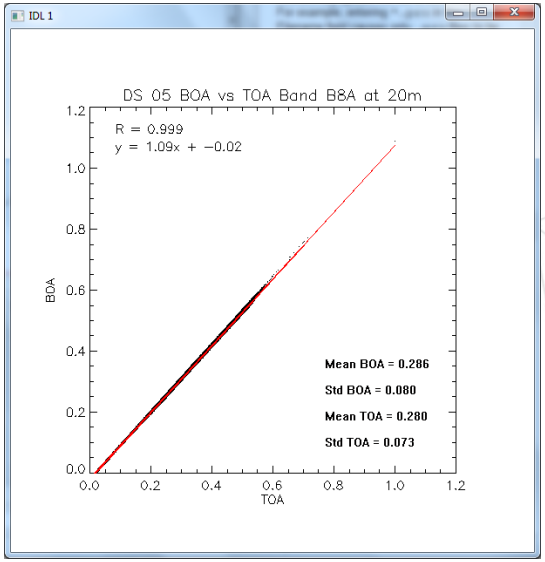
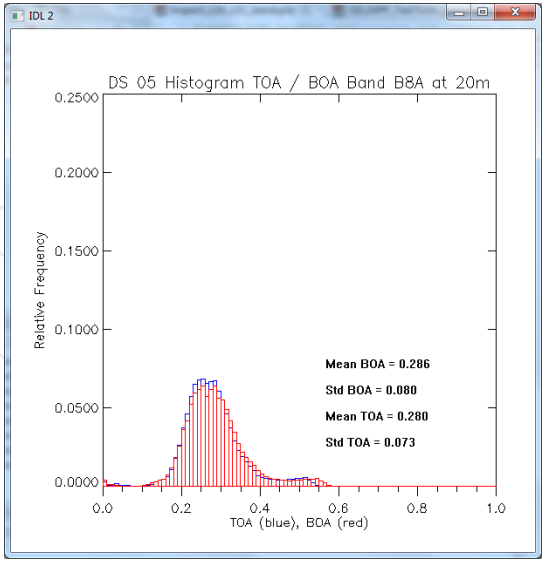
Atmospheric Correction



TOA vs. BOA, Band 8A, scatterplot and distribution of reflectance values





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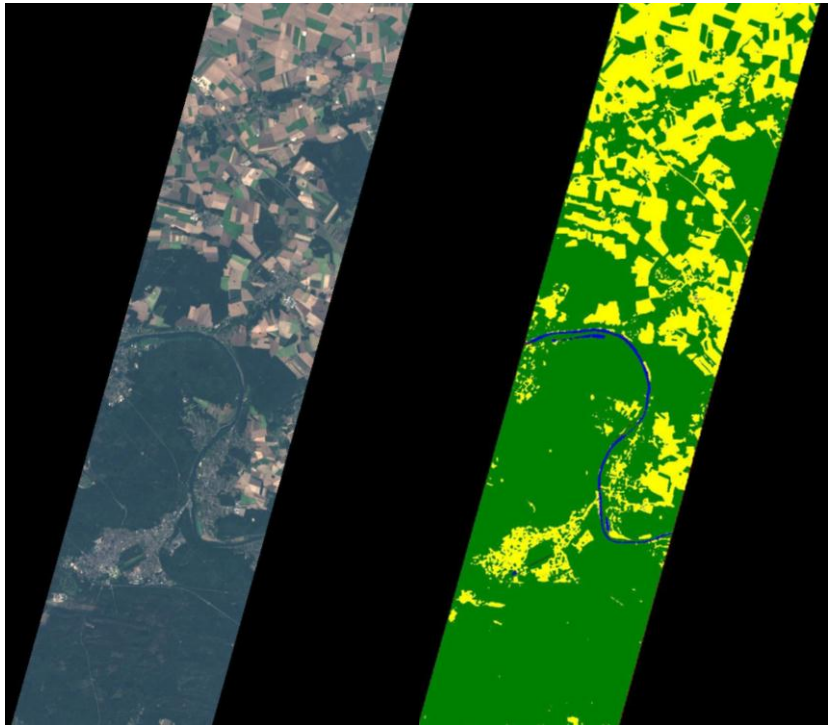
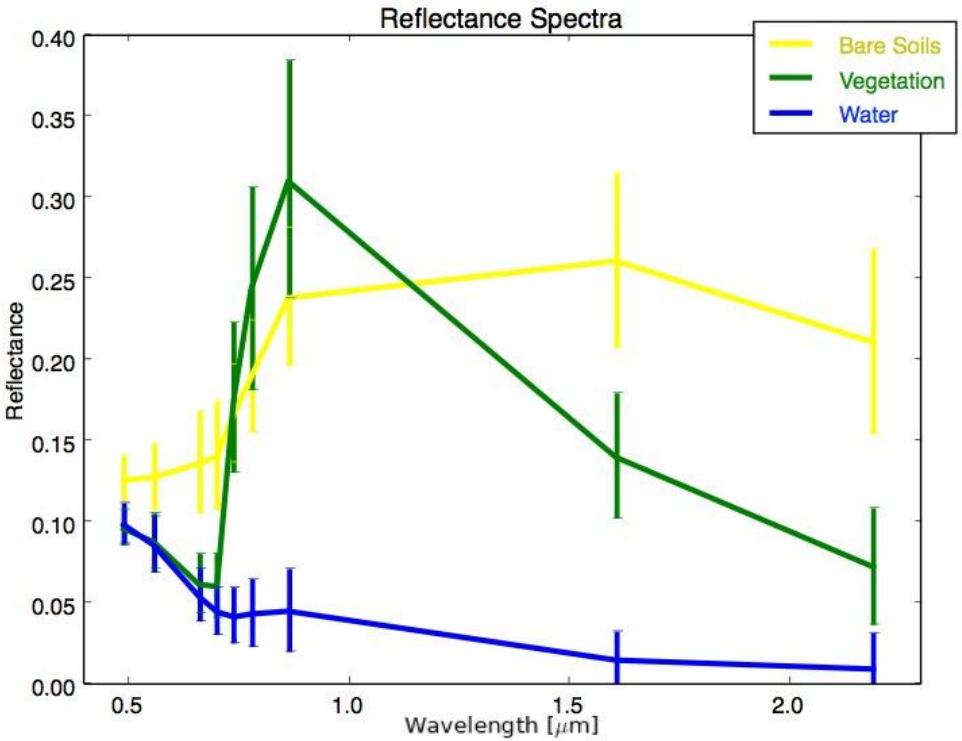
TOA Reflectance Spectra

Scene 5, Fontainebleau, France

for soils, vegetation and water, separated by Scene Classificator





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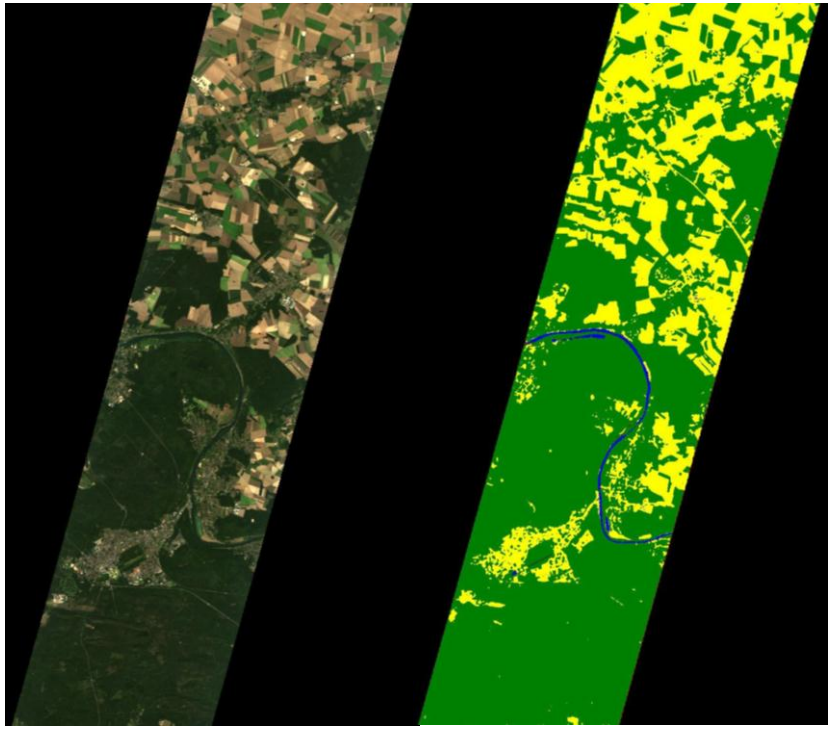
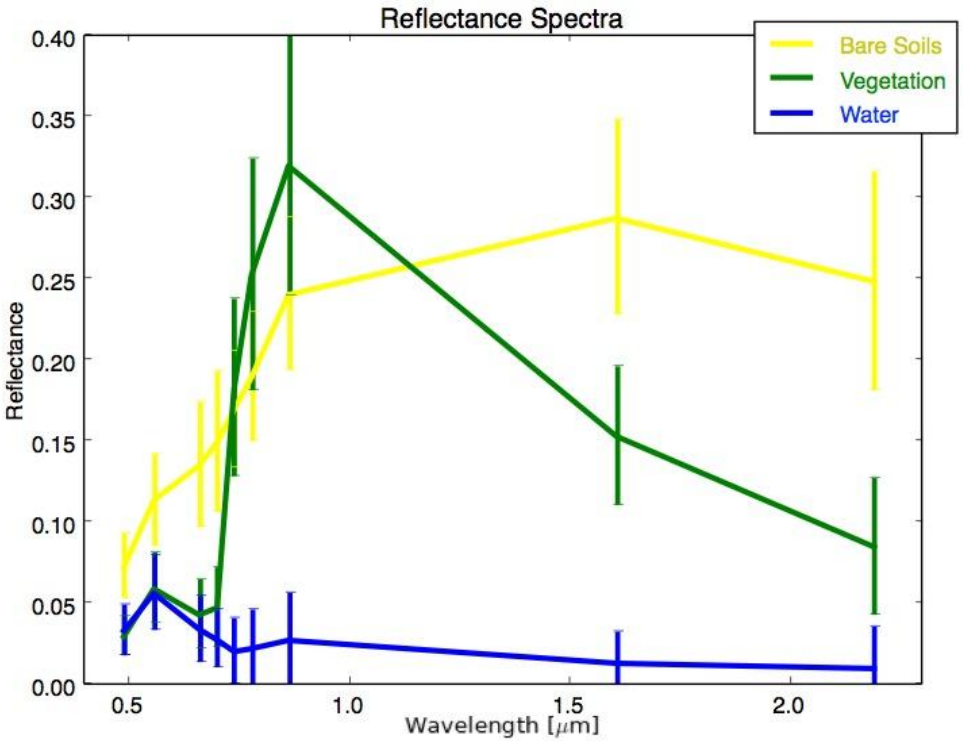
BOA Reflectance Spectra

Scene 5, Fontainebleau, France

for soils, vegetation and water, separated by Scene Classificator





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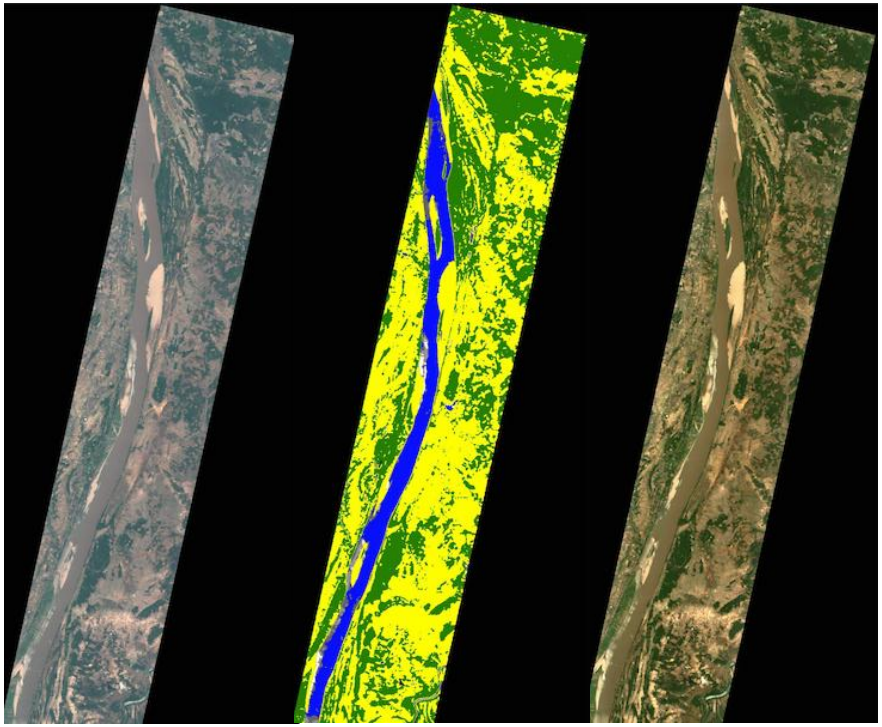
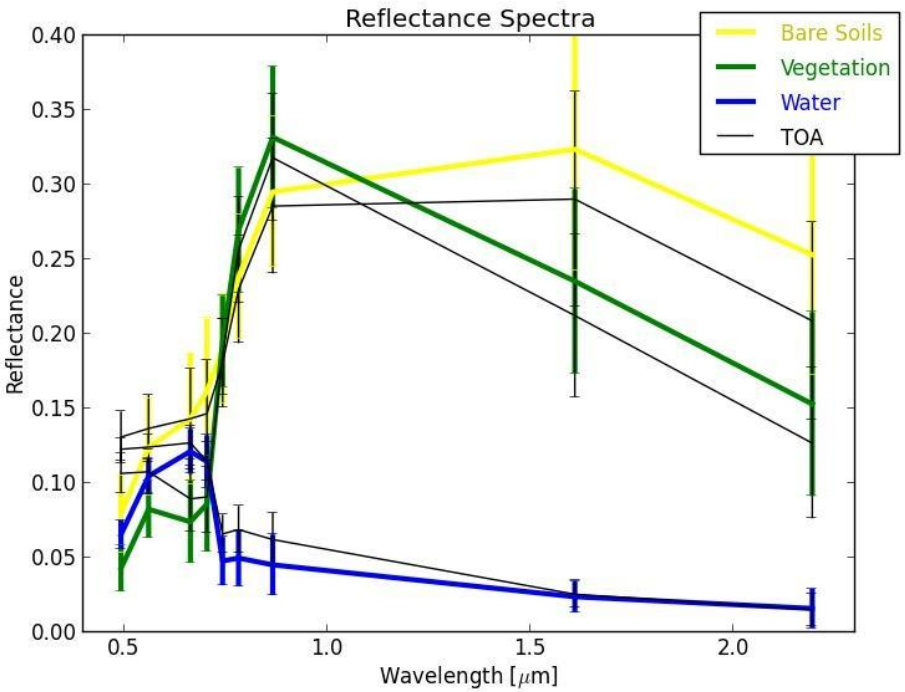
BOA Reflectance Spectra

Scene 11, Mukdahan, Thailand

BOA reflectance spectra for soils, vegetation and water, separated by Scene Classificator. Black: TOA Values





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Terrain Correction Using DEM

- SEN2COR can optionally read SRTM data from a database;
- Works online, during processing or from a private archive;
- Currently, 90m Digital Elevation Database from **CGIAR-CSI** is used: http://www.cgiar-csi.org/
- Reads geo coordinates and angular information from the Level-1C metadata;
- Area of interest is created and fitted to the input images;
- Performed using the **GDAL** libraries from **OSGEO.**

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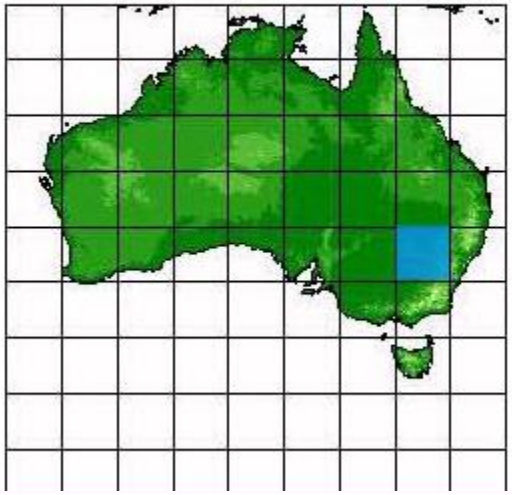
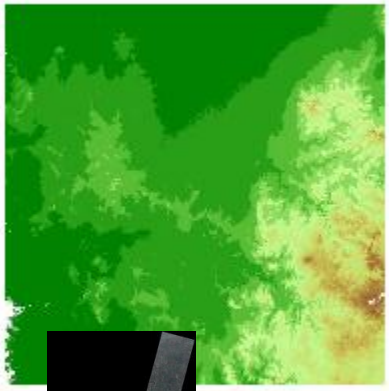
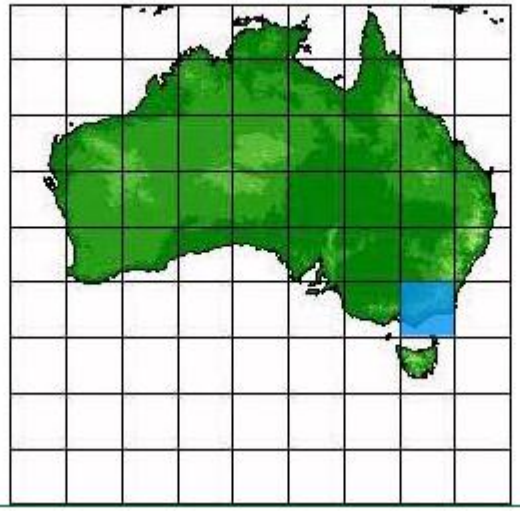
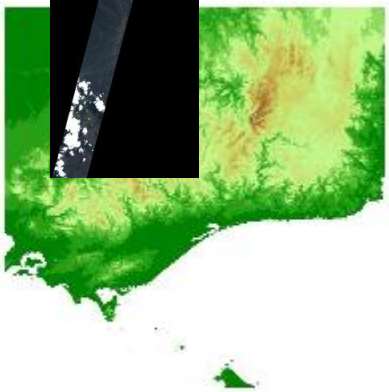
Resampling 2 Different Datasets

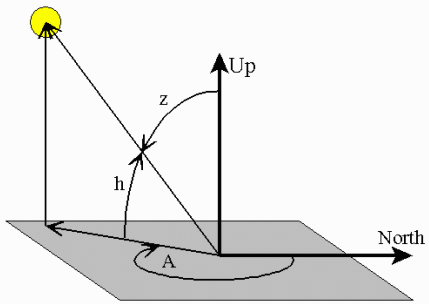
Description	Location	Image
Product : SRTM 90m DEM version 4 **Data File Name :** srtm_66_19.zip **Mask File Name:** srtm_mk_66_19.zip **Latitude min:** 35 S **max:** 30 S **Longitude min:** 145 E **max:** 150 E **Center point :** Latitude 32.50 S Longitude 147.50 E		

Description	Location	Image
Product : SRTM 90m DEM version 4 **Data File Name :** srtm_66_20.zip **Mask File Name:** srtm_mk_66_20.zip **Latitude min:** 40 S **max:** 35 S **Longitude min:** 145 E **max:** 150 E **Center point :** Latitude 37.50 S Longitude 147.50 E		

Fitting Area of Interest

SEN2COR

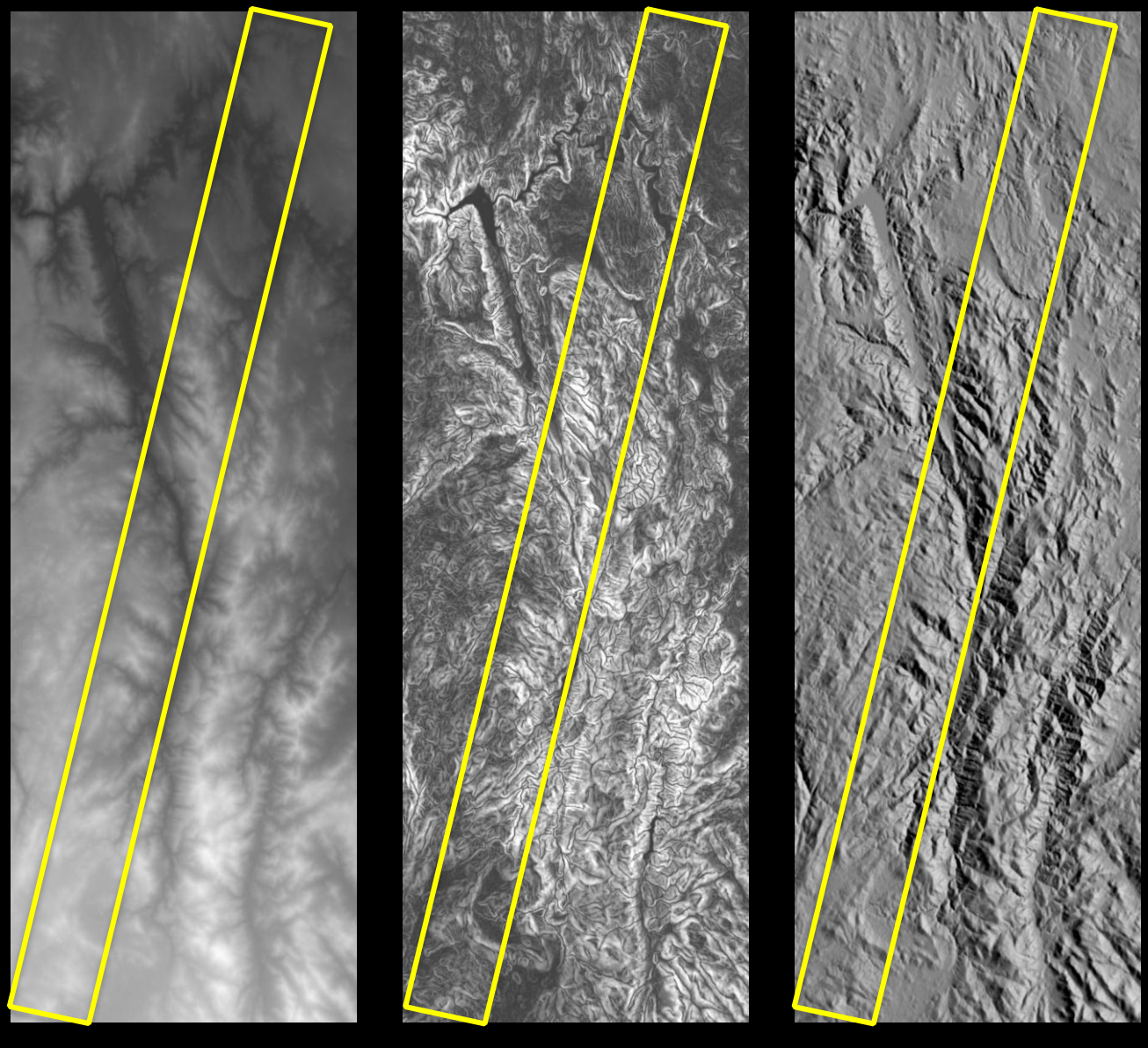
- fits input elevation maps to the area of interest provided by the L1C geographical input data;
- creates slope and illumination maps using L1C solar angular data.



h = elevation angle, measured up from horizon

z = zenith angle, measured from vertical

A = Azimuth angle, measured clockwise from North

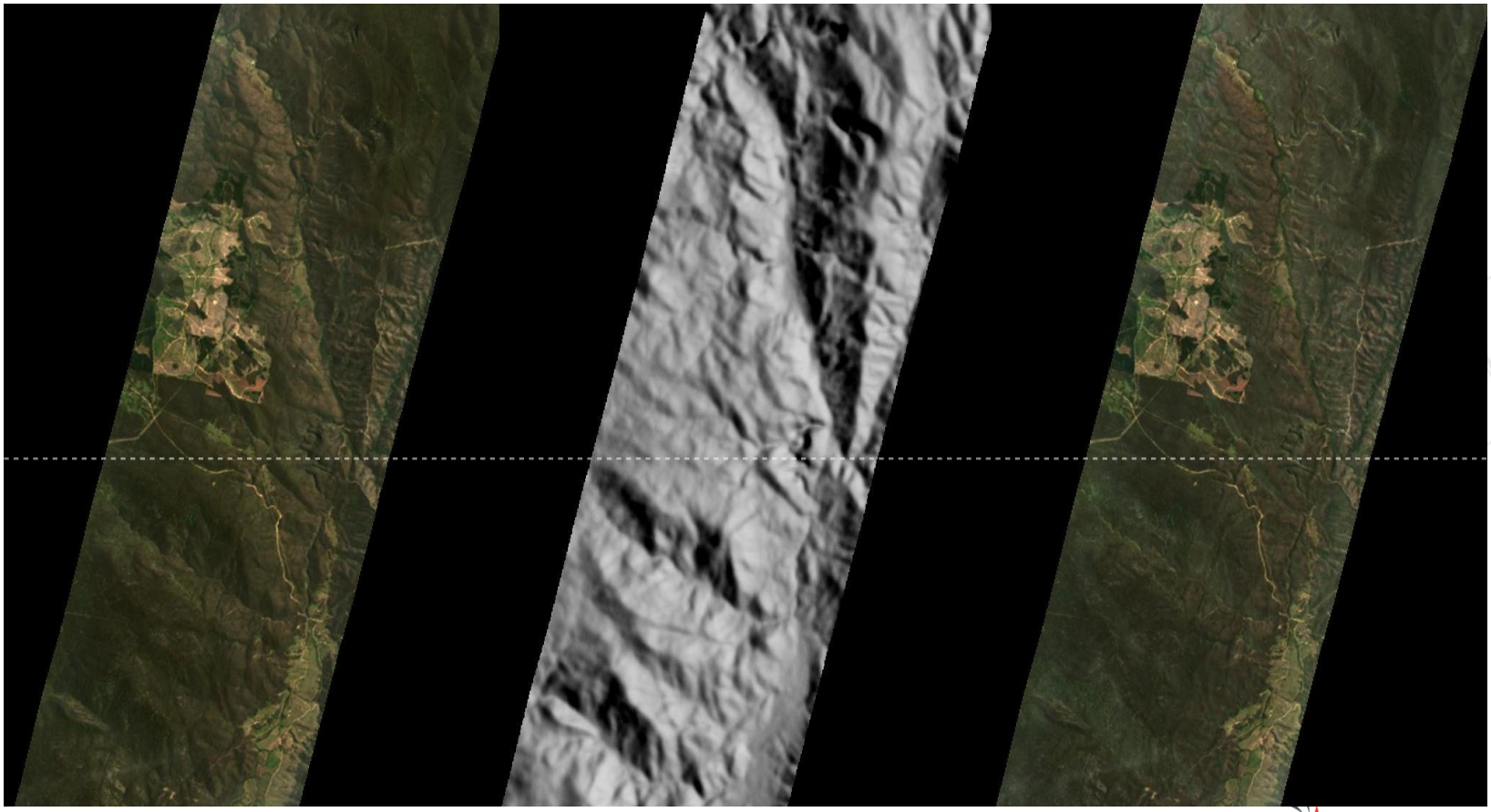


Terrain Correction

Scene 20, Canberra, Australia

Left: BOA, no terrain correction

Right: BOA, using DEM and empirical BRDF correction



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Status and Outlook

- SEN2COR has passed the Acceptance Review successfully during April;
- Final release will be delivered to ESA in June;
- Scientific evaluation will be performed in the framework of the S2 MPC activities;
- Evolutionary Upgrades are foreseen.

Thank you …

- Uwe Mueller-Wilm, Telespazio-VEGA, Germany
- Jerome Louis, Telespazio France
- Rudolf Richter, DLR, Germany
- Ferran Gascon, ESA, Italy
- Marc Niezette, Telespazio-VEGA, Germany

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