The MAJA and WASP processors

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MAJA, WASP, what for?

Quantitative applications in optical remote sensing of land surfaces require to account for the processes affecting measured signal along its path through the atmosphere

- radiation in the solar spectrum can be absorbed, diffused or reflected
- by gases, water vapor, clouds, aerosols
- spectrum-wise

MAJA, WASP, what for?

Level-0	Raw signal from instrument detectors
⇓ **Space Agency** ⇓	*Payload Data Ground Segment*
Level-1C	Radiometrically calibrated, ortho-rectified, georeferenced Top-of-atmosphere spectral reflectances
⇓ **MAJA** ⇓	*Cloud screening and atmospheric correction processor*
Level-2A	Land surfaces spectral reflectances, corrected for directional, adjacency and topographic effects, with detailed cloud mask
⇓ **WASP** ⇓	*Synthesis processor*
Level-3A	(almost) cloudless monthly synthesis of land surface reflectances compiled from cloud-free pixels within a time range

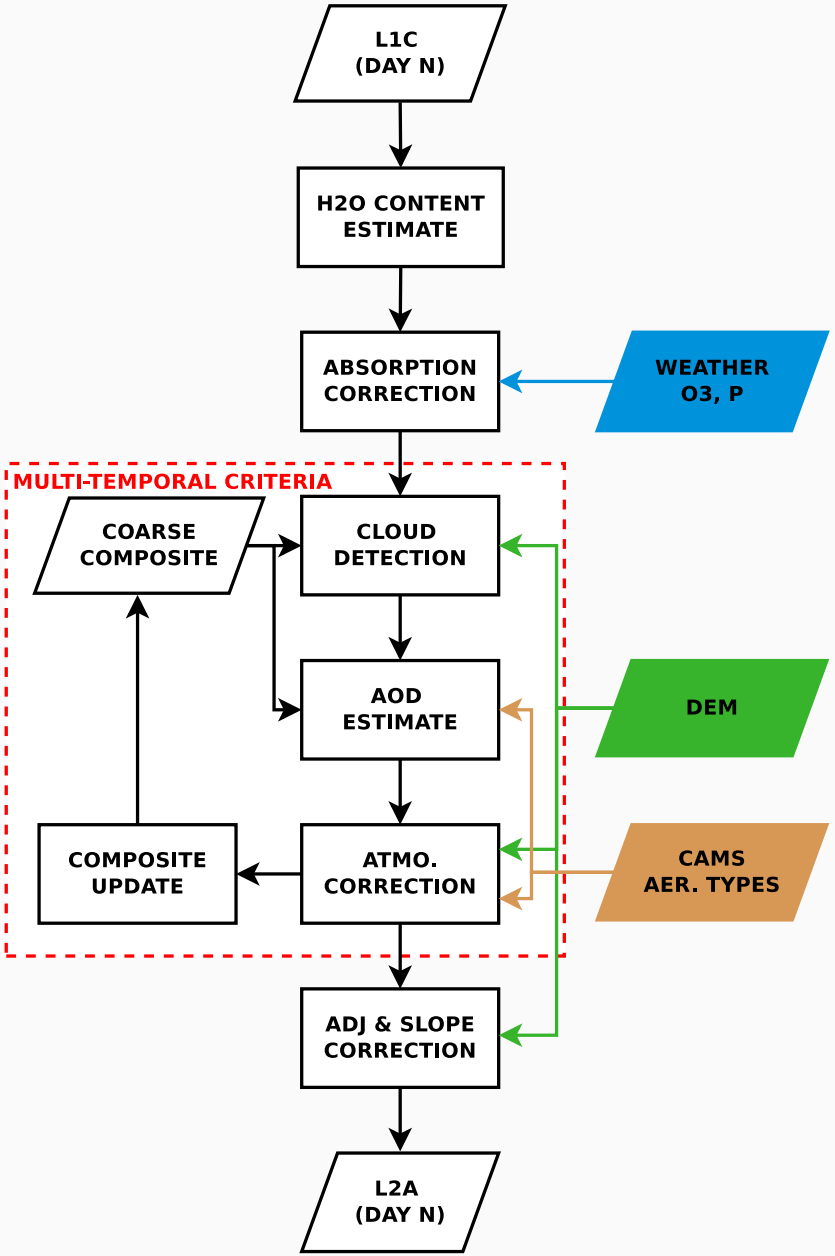
The MAJA processor

MAJA includes:

- cloud and shadow detection
- estimates of water vapour and aerosol content
- atmospheric correction including adjacency and terrain effect correction
- correction of thin cirrus clouds

MAJA uses both multi-spectral and multi-temporal criteria:

- to detect clouds, shadows, water and snow at a coarse resolution
- to compute aerosol optical depth (AOD)



The MAJA processor

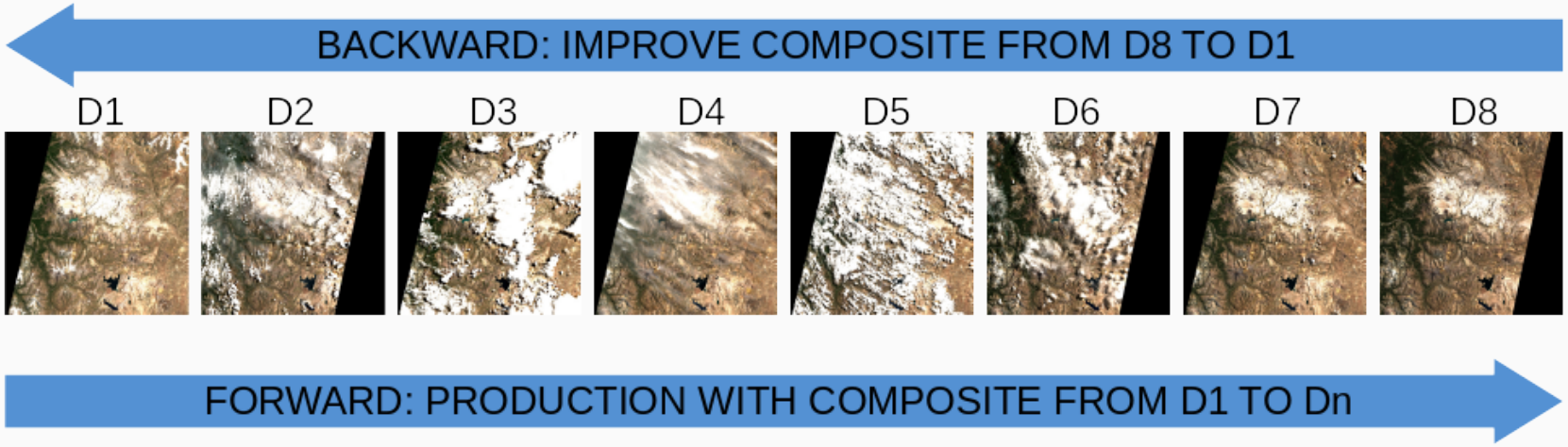
Assumption of the multi-temporal estimate of AOD:

- surface reflectances change slowly with time, but quicly pixel-wise
- AOD varies quickly with time, but smootly pixel-wise

Multi-spectral criteria can still be used to solve ambiguities

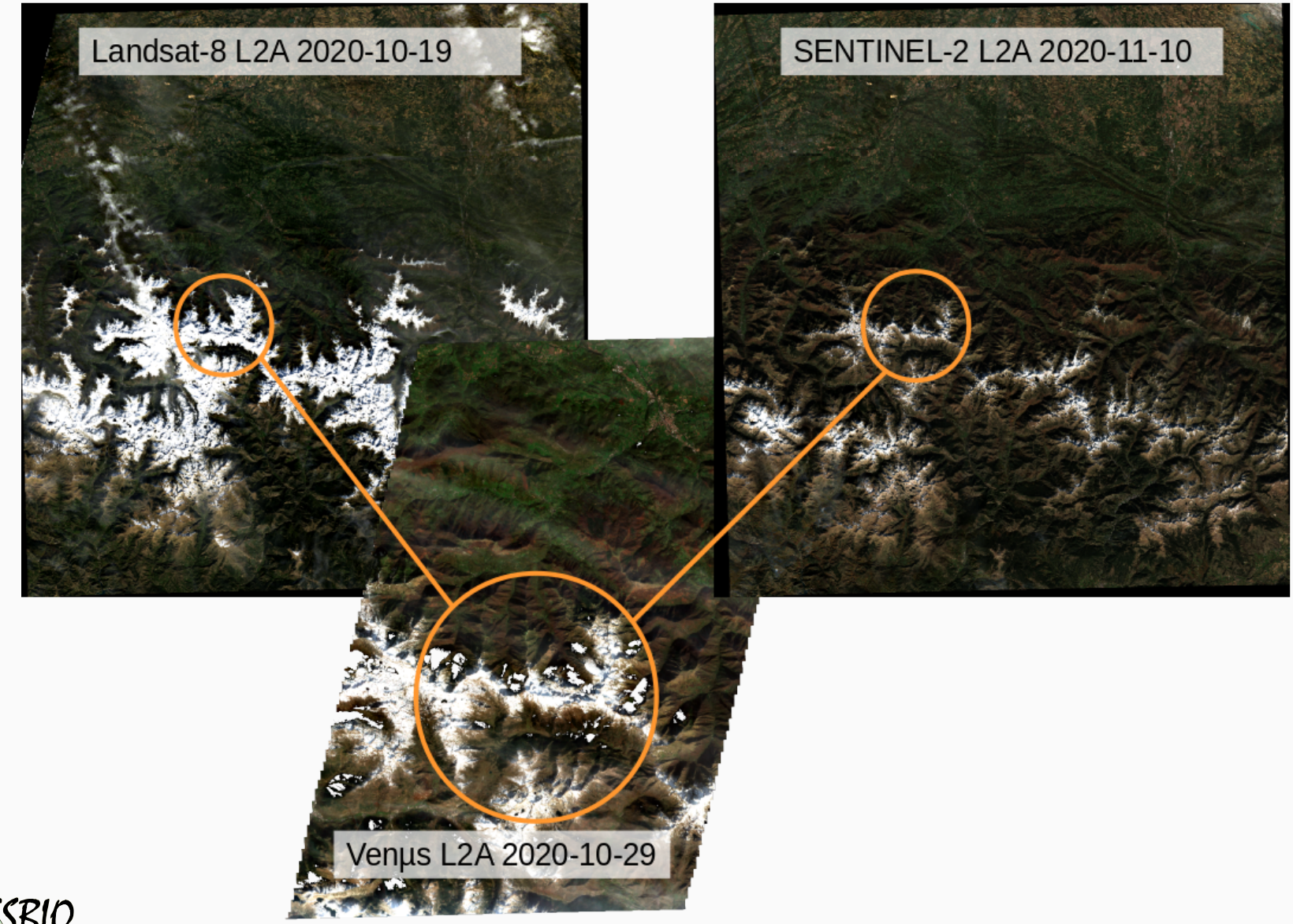
Direct consequences:

- MAJA shouldn't be used to process a single product
- cloud overcast prone areas might be hard to process (*eg*. rainforest)
- sudden change of reflectance might be miss-interpreted (*eg*. field crop harvesting)

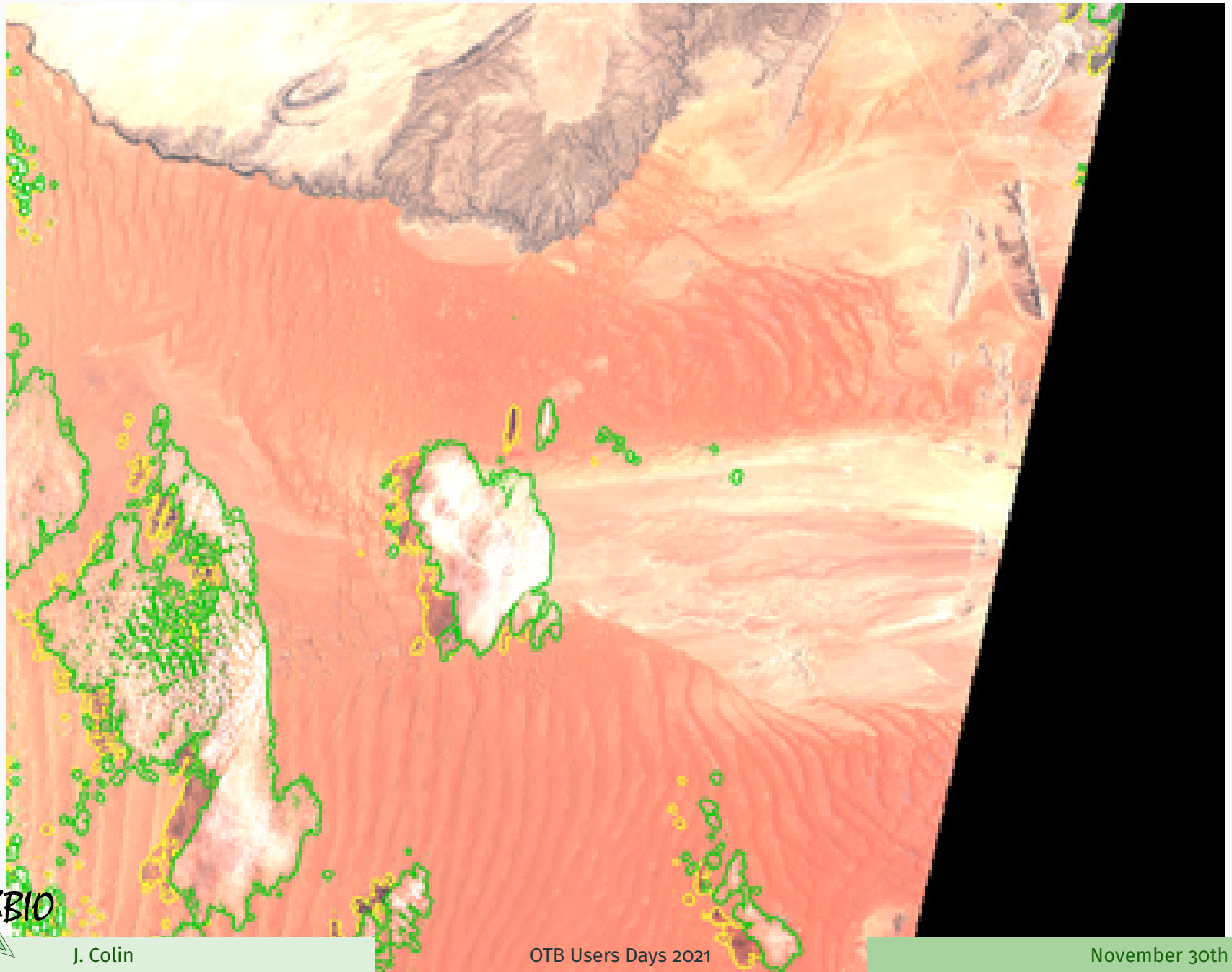


The MAJA processor

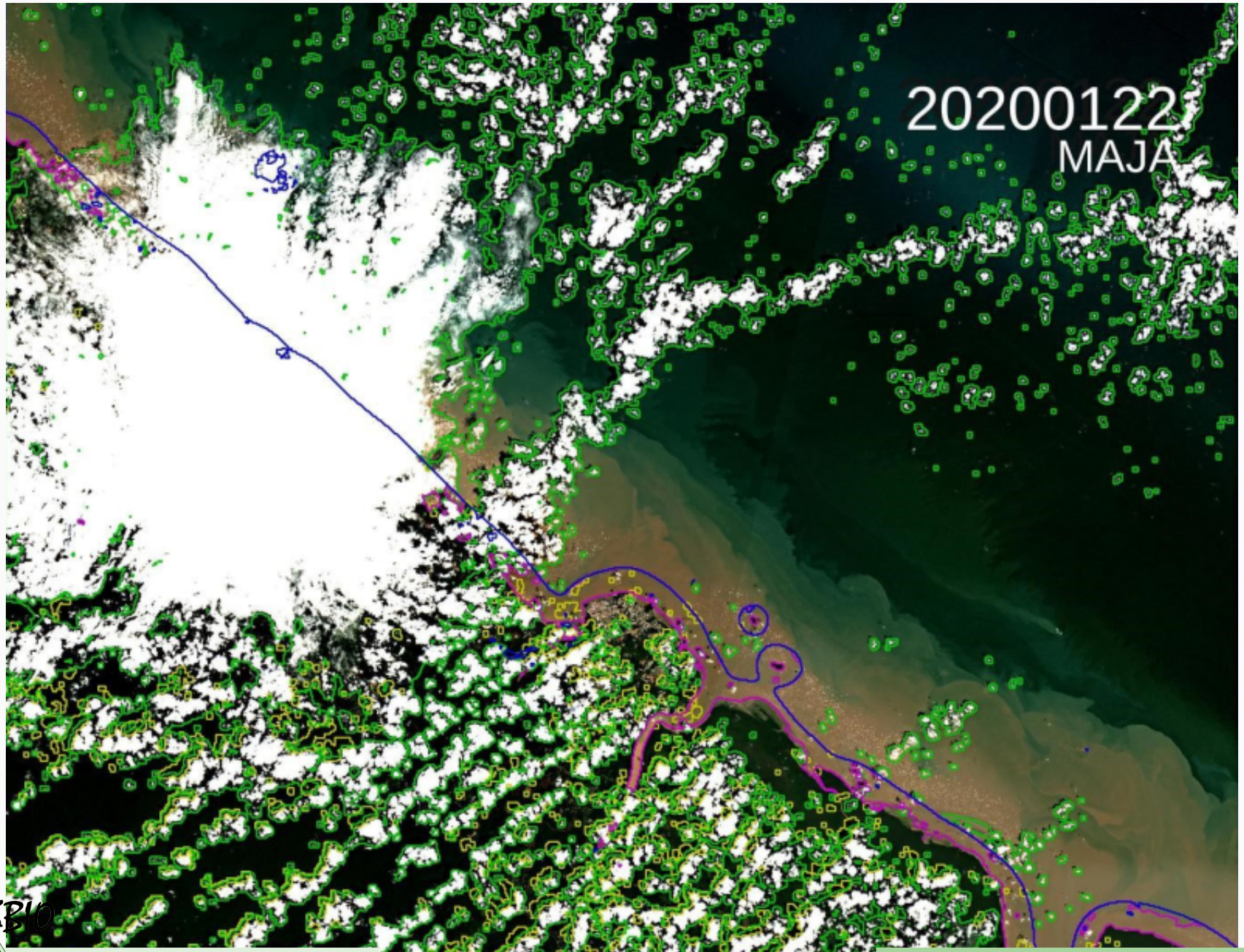
Plugins for SENTINEL-2, Venμs, Landsat-8 (constant observation angle, narrow FOV)



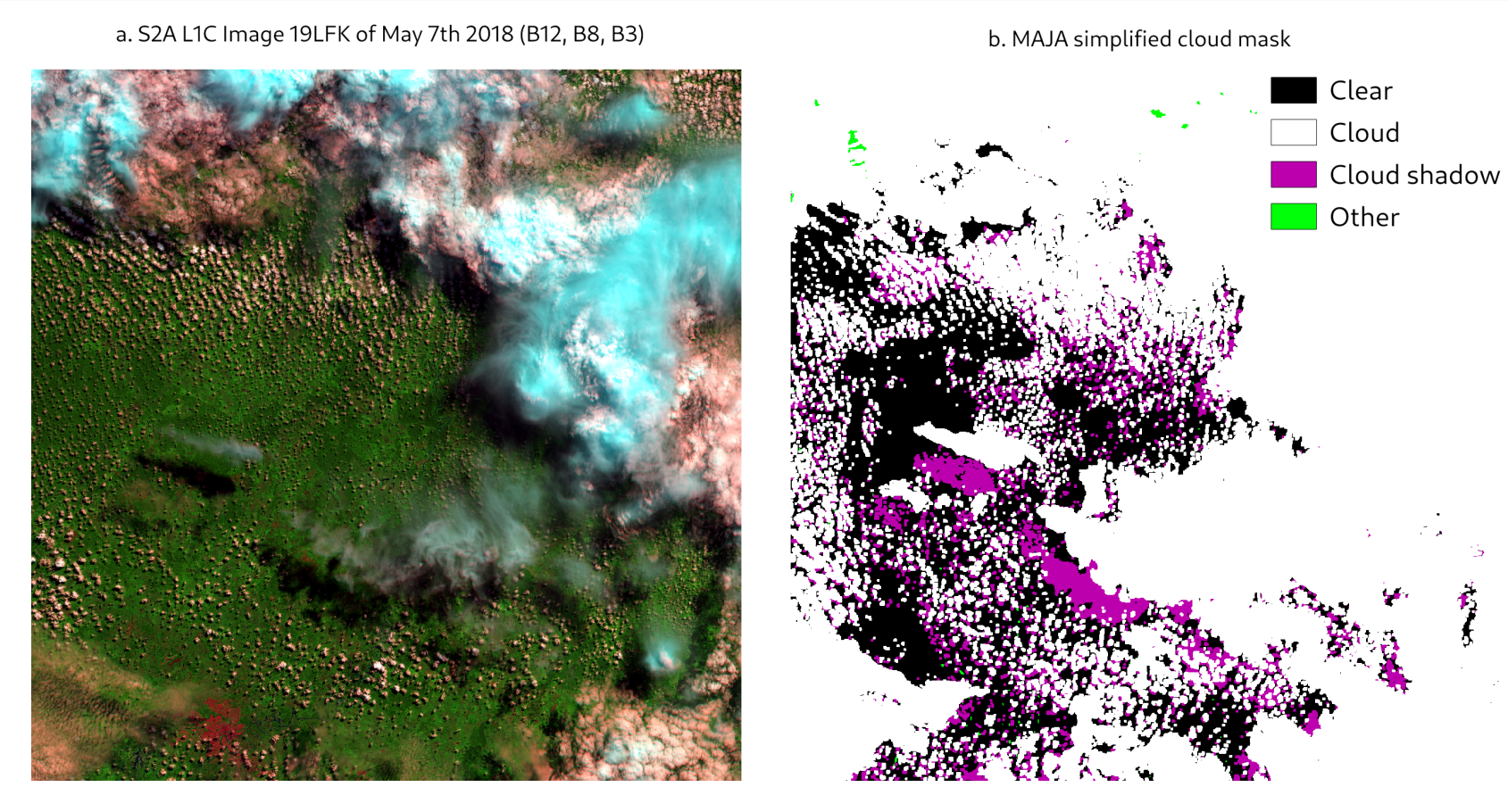
The MAJA processor



The MAJA processor



The MAJA processor



The MAJA cloud mask is conservative: high confidence on "clear pixel"

Dilation of the cloud mask: account for blurred boundary and paralax

The WASP processor

Standard L3 based on Best Available Pixel (BAP) method

- pick the best date during the synthesis period
- artifacts from one pixel to the other, because date changes
- but minimization of Cloud/Atmosphere effects
- similar to EU, Sentinel-2 Global Mosaics (S2GM)

Weighted Average Synthesis Processor (WASP)

- initially developed for Venus Satellite, within sen2agri, adapted to CNES needs
- require good L2A (MAJA does it)
- errors from cloud detection or atmospheric correction are included in L3A product

The WASP processor

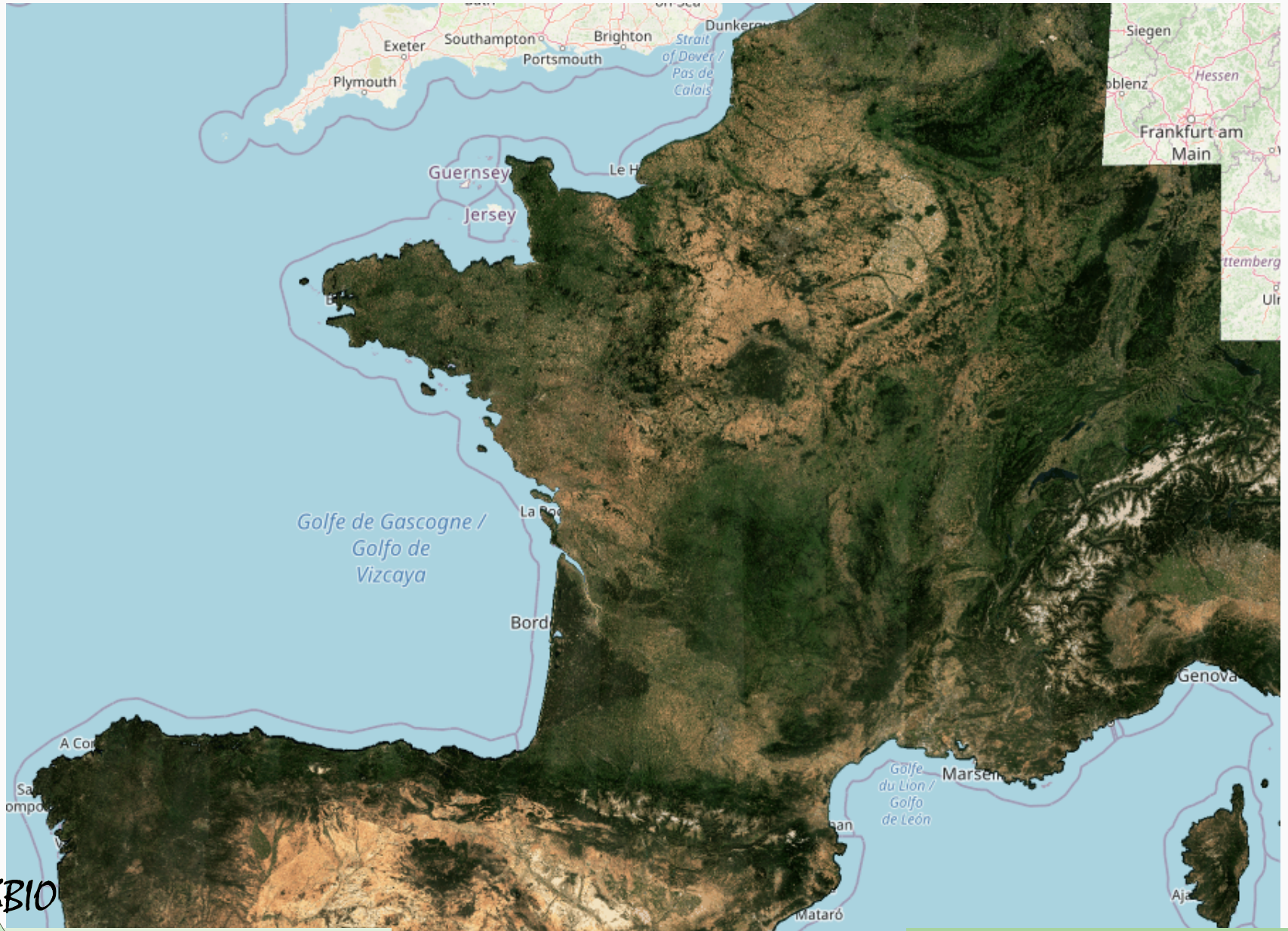
WASP L3A vs ESA S2GM

The WASP processor

WASP L3A vs ESA S2GM

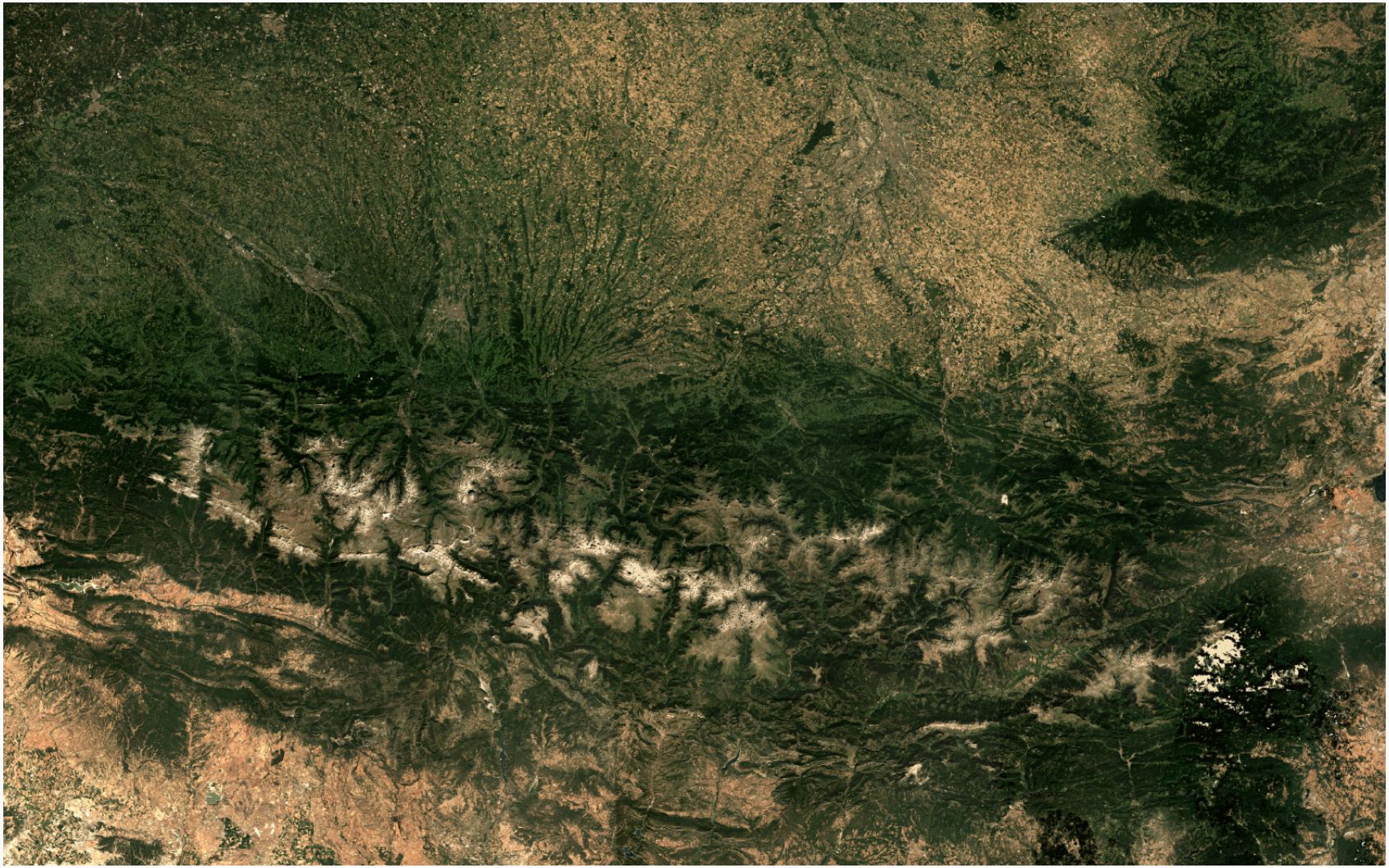
The WASP processor

Mosaic of WASP L3A September 2021



The WASP processor

Mosaic of WASP L3A September 2021



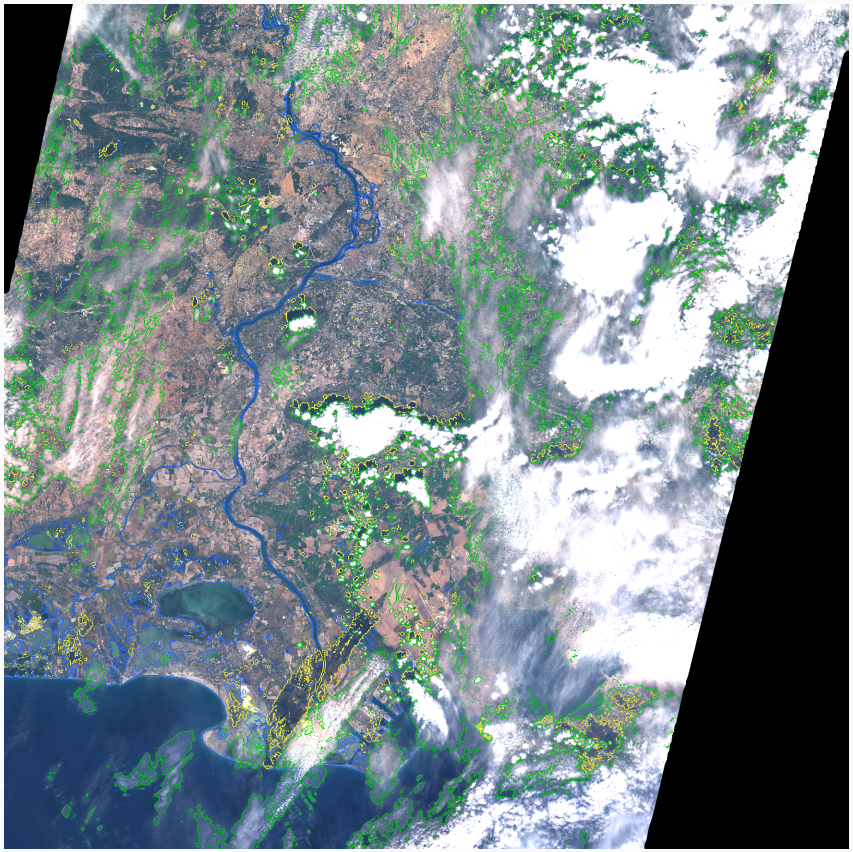
The WASP processor

WASP L3A September 2021

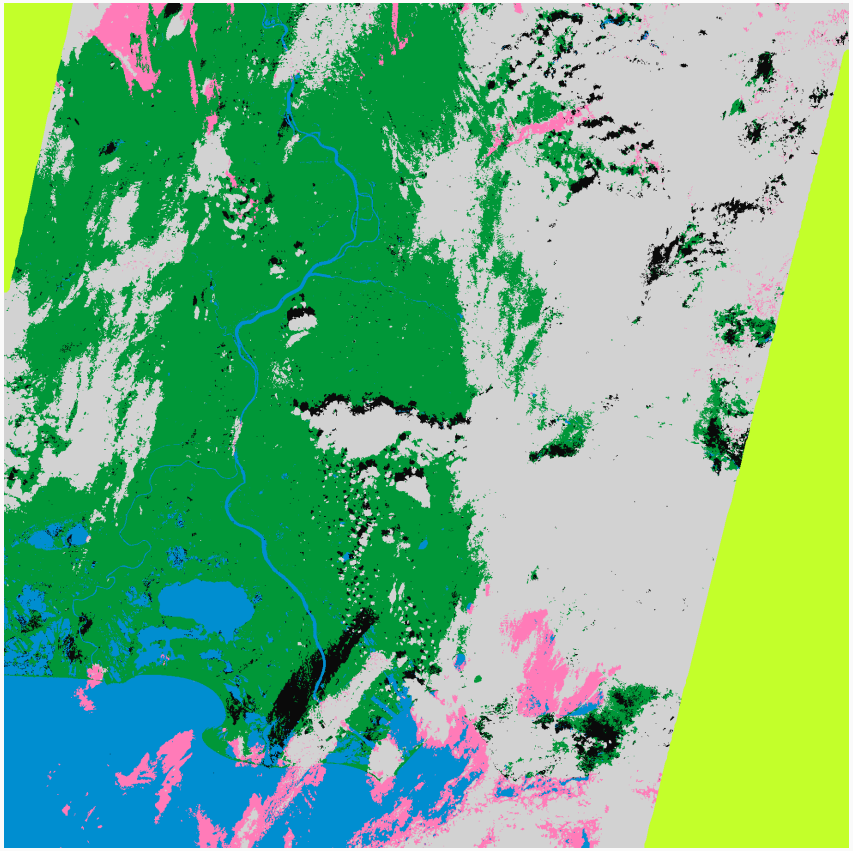
L2A validation: cloud masks

MAJA cloud masks are assessed against a set of 30 reference images generated by active learning based tool (ALCD)

Algorithm trained and controled by an operator

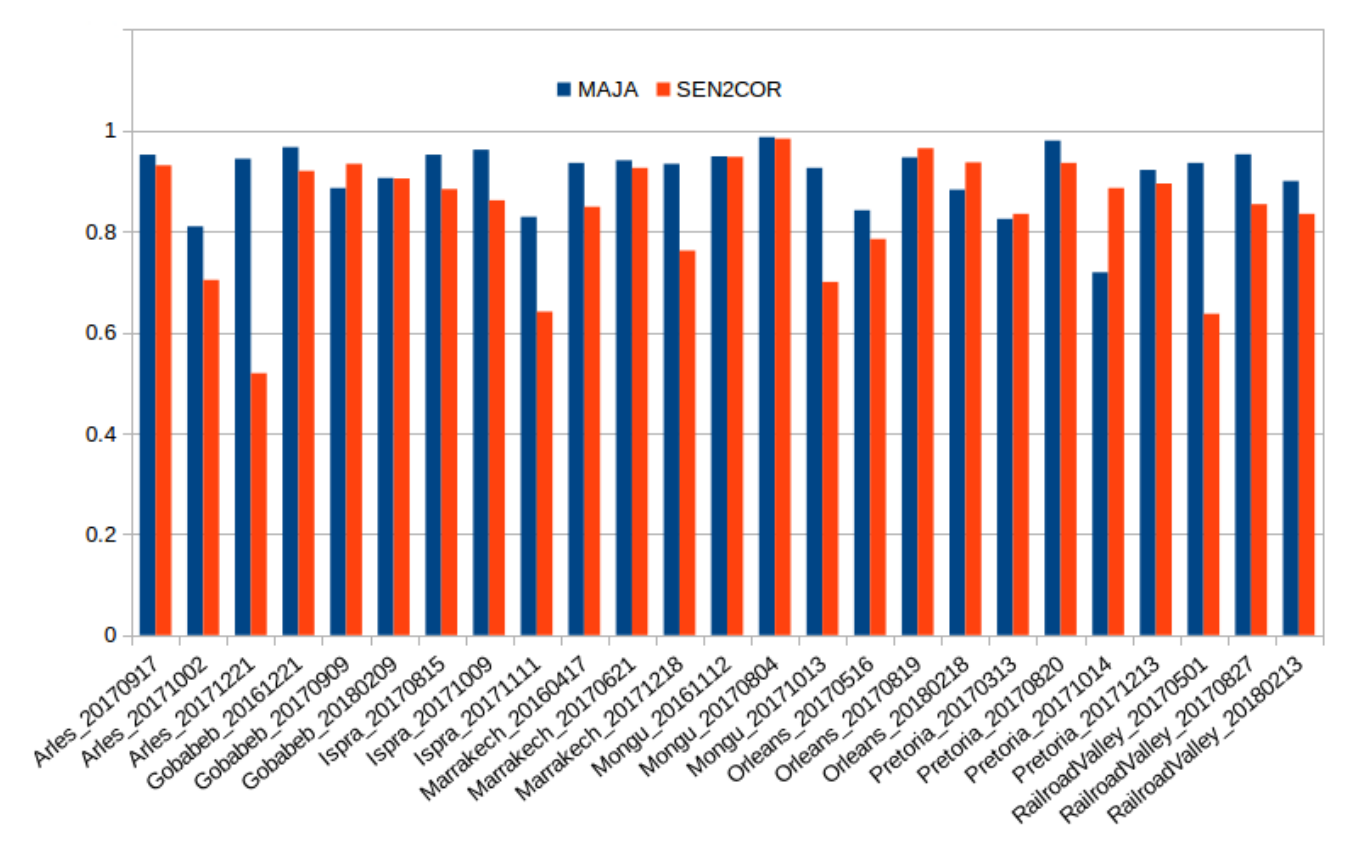


Resulting classified cloud mask over Arles (clouds, shadows, cirrus)



L2A validation: cloud mask

Comparison of cloud mask detection between MAJA (blue) and SEN2COR (red), 1 meaning a perfect match with the reference mask.

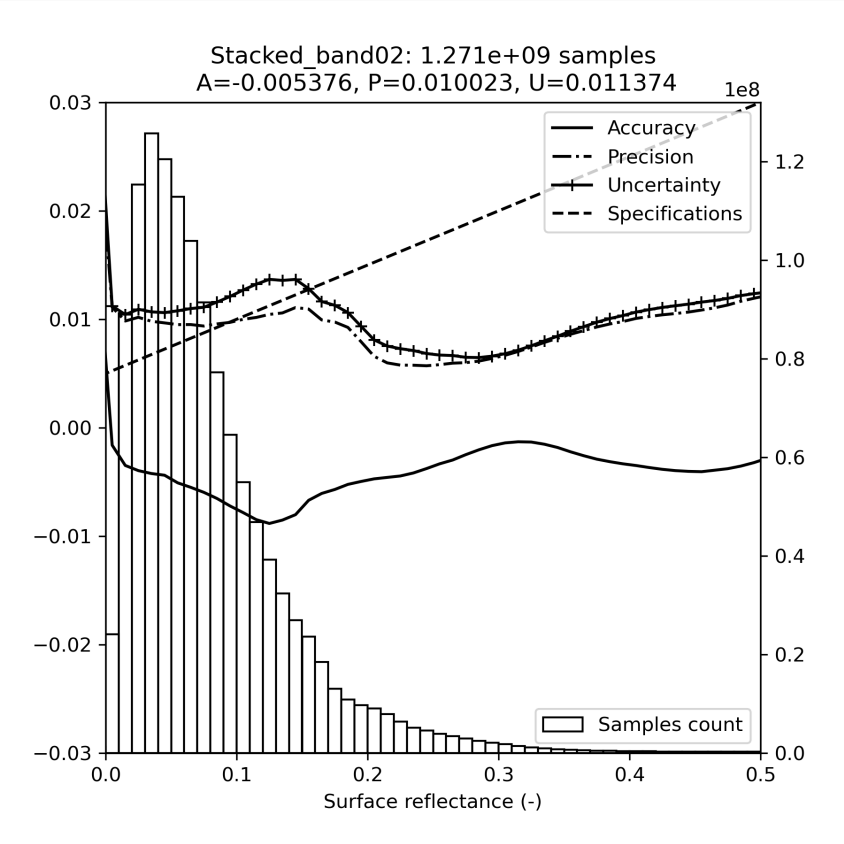


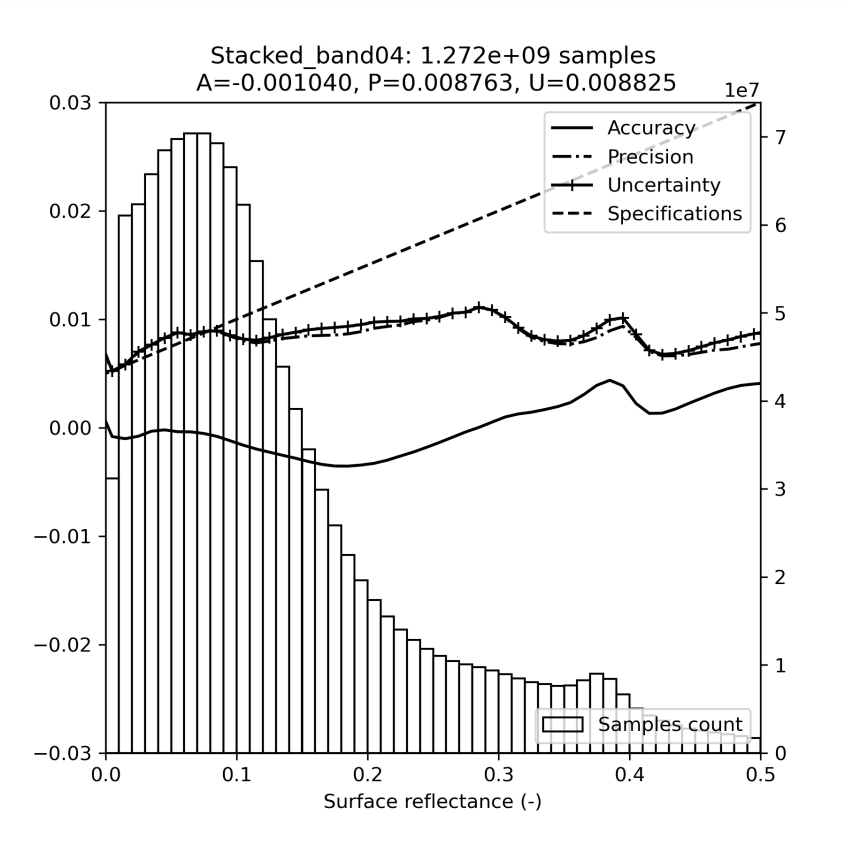
The dataset is shared with the community at https://zenodo.org/record/1460961

L2A validation: surface reflectances

The NASA/ESA Atmospheric Correction Intercomparison Excercice (ACIX-II):

- reference dataset built from 122 sites with Aeronet observations + 6S
- nearly 1.4 billion pixels for Sentinel-2
- MAJA uncertainties of 0.0113 (B2), 0.0096 (B3), 0.0088 (B4), 0.0087 (B8)

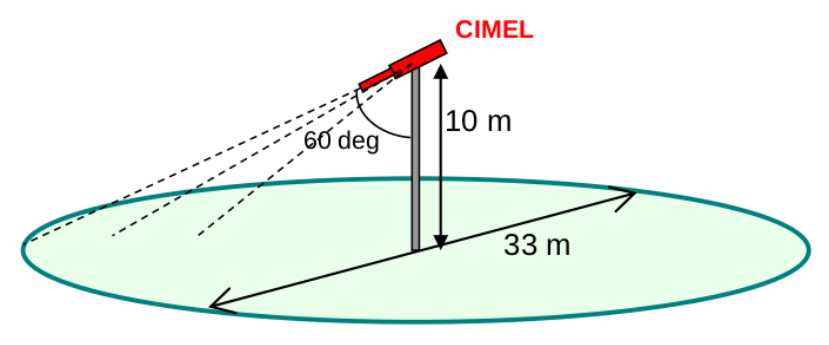


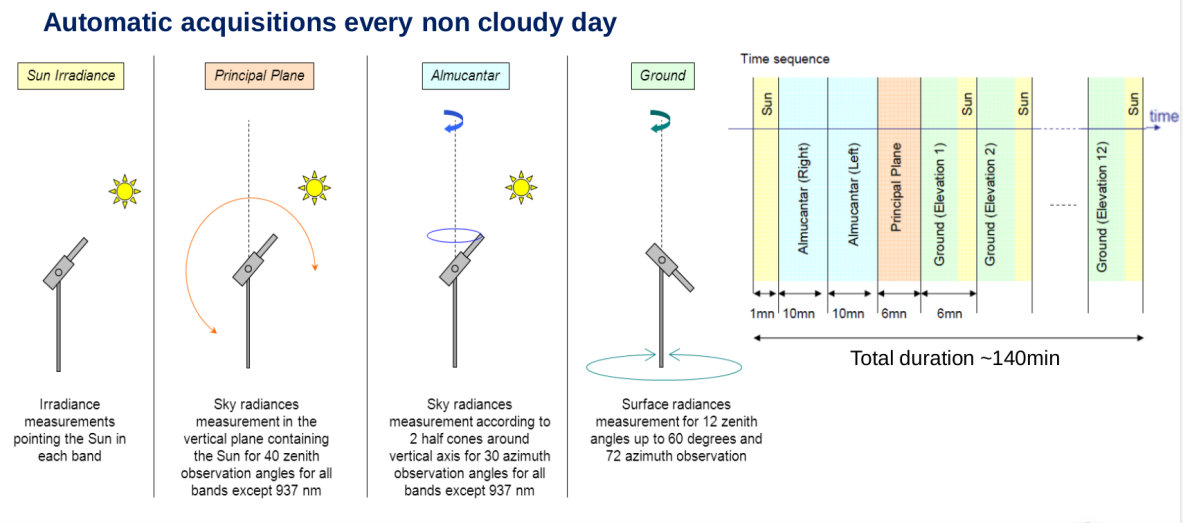


L2A validation: surface reflectances

The Robotic Station for Atmosphere and Surface characterization (ROSAS) designed and implemented by the CNES

CIMEL spectro-photometer, 12 bands from 415 to 1640nm





ROSAS recontructs the actual Bi-Directional Reflectance function (BRDF) only during clear-sky days (figures courtesis of CNES DSO/SI/MO)

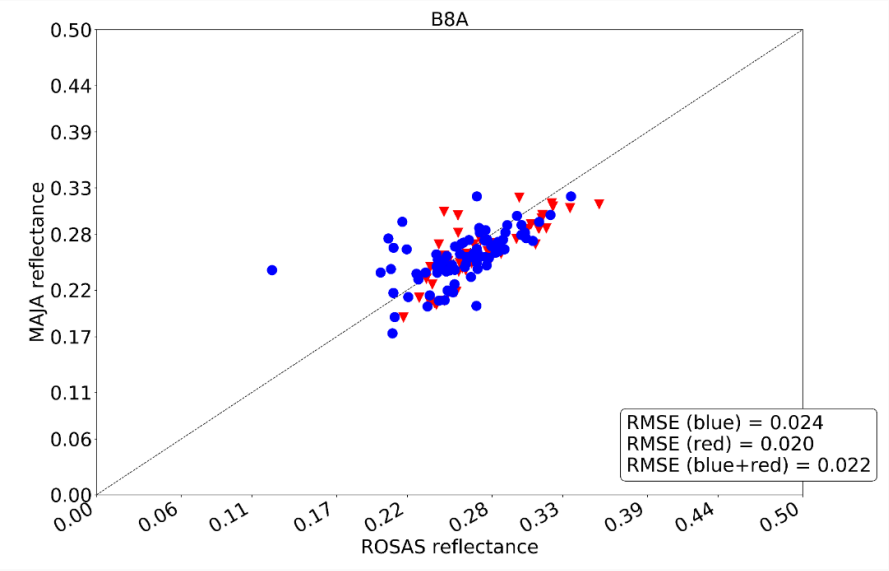
L2A validation: surface reflectances

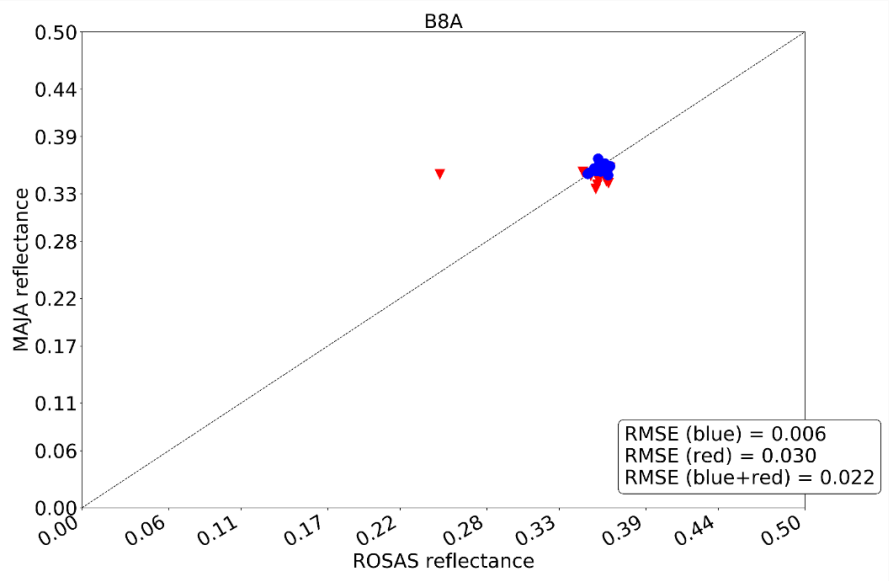
CNES ROSAS stations:

- La Crau, France pebbles and grass, since 1997
- Gobabeb, Namibia, desert sand, since 2017 in cooperation with ESA

La Crau, France

Gobabeb, Namibia



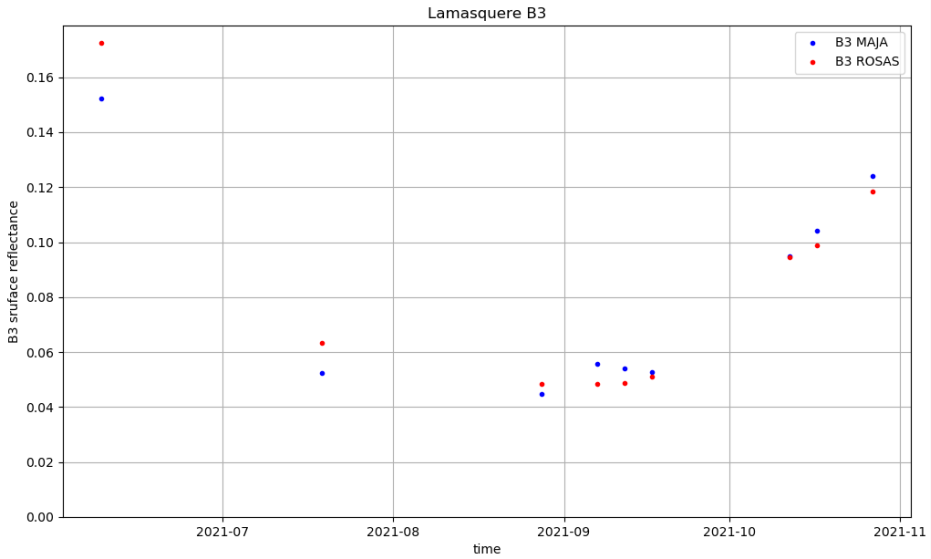


L2A validation: surface reflectances

New CESBIO ROSAS station:

- within a 23ha field crop
- 2-years crop rotation (winter wheat & maize)
- from dark green crop to senecent wheat or bare soil

Lamasquère, France



MAJA Sentinel-2 L2A vs ROSAS during the 2021 maize cycle

Designed to:

- provide a larger range of surface reflectance
- with seasonal and inter-annual cycles
- with a nearby forest for future studies on adjacency effects

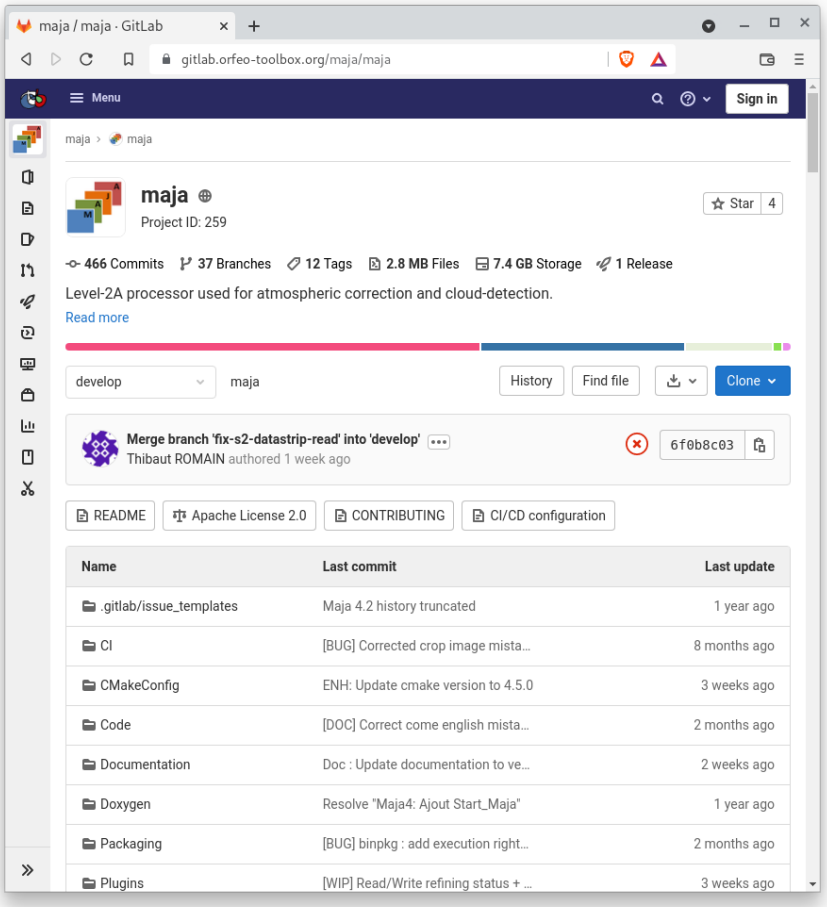
From a research prototype to an operational chain

MAJA's history:

- 2006: research to use time dimension to detect clouds and aerosols
- 2008-2015: development of MACCS (Multi-sensor Atmospheric Correction and Cloud Screening)
- 2016-2017: Maja 1.0 development under a joint consortium CNES-DLR to merge ATCOR (Atmospheric & Topographic Correction) into MACCS
- Since 2017: Maja 2.x, 3.x, 4.x and WASP

And now:

- MAJA coded and maintained by CS-GROUP
- based on OTB, mostly in C++
- since MAJA 4.0, orcherstrator in Python
- continuous effort on validation



Distributed as binaries, and Open Source

From research prototype to operational chain

A growing community of users

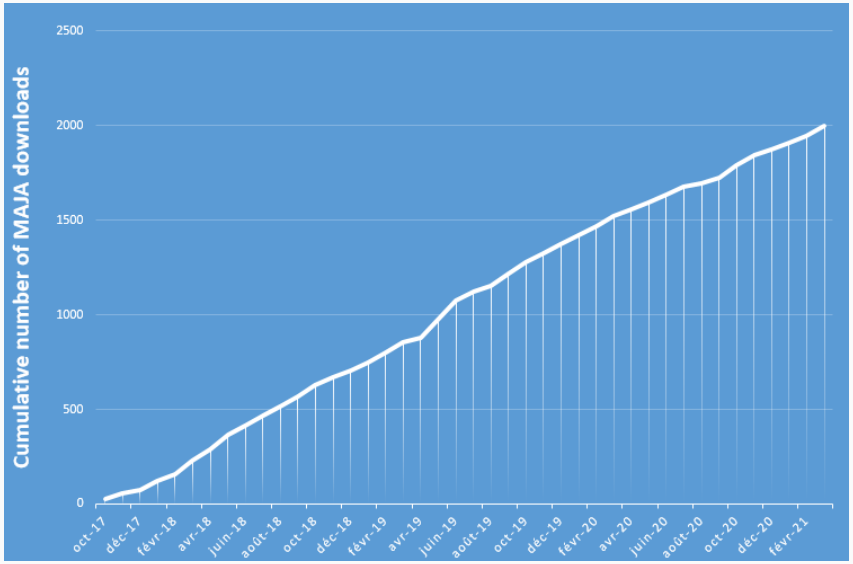
MAJA:

- Under Apache License since version 4.2
- Linux binary: `https://logiciels.cnes.fr/en/node/58?type=desc`
- Source code: `https://gitlab.orfeo-toolbox.org/maja/maja`

WASP:

- Under GPL since version 1.0
- Linux binary: `https://logiciels.cnes.fr/en/node/128?type=desc`
- Source code: `https://gitlab.orfeo-toolbox.org/remote_modules/wasp`

MAJA reached 2000 downloads in 2021, thanks!

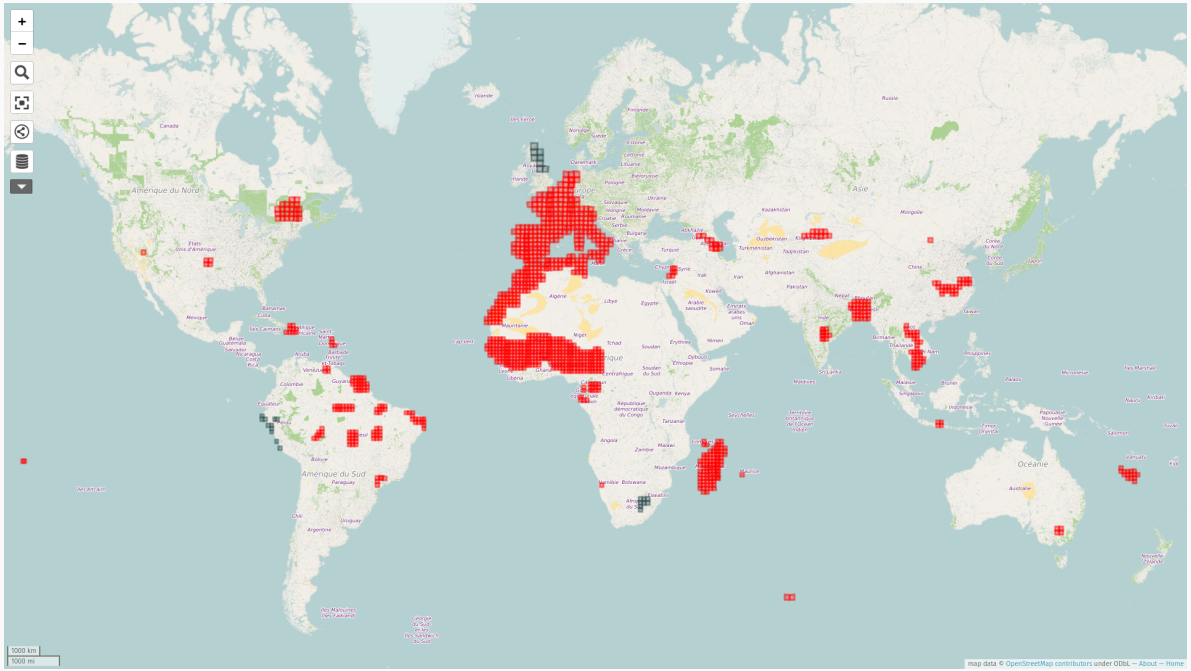


Also available in PEPS: `https://peps.cnes.fr`

Operational institutional use of MAJA and WASP: THEIA

THEIA (the French land data center) uses MAJA and WASP operationaly to produce, among others, Sentinel-2 L2A and L3A data on large regions of the world (about 10 millions square kilometers as of 2021)

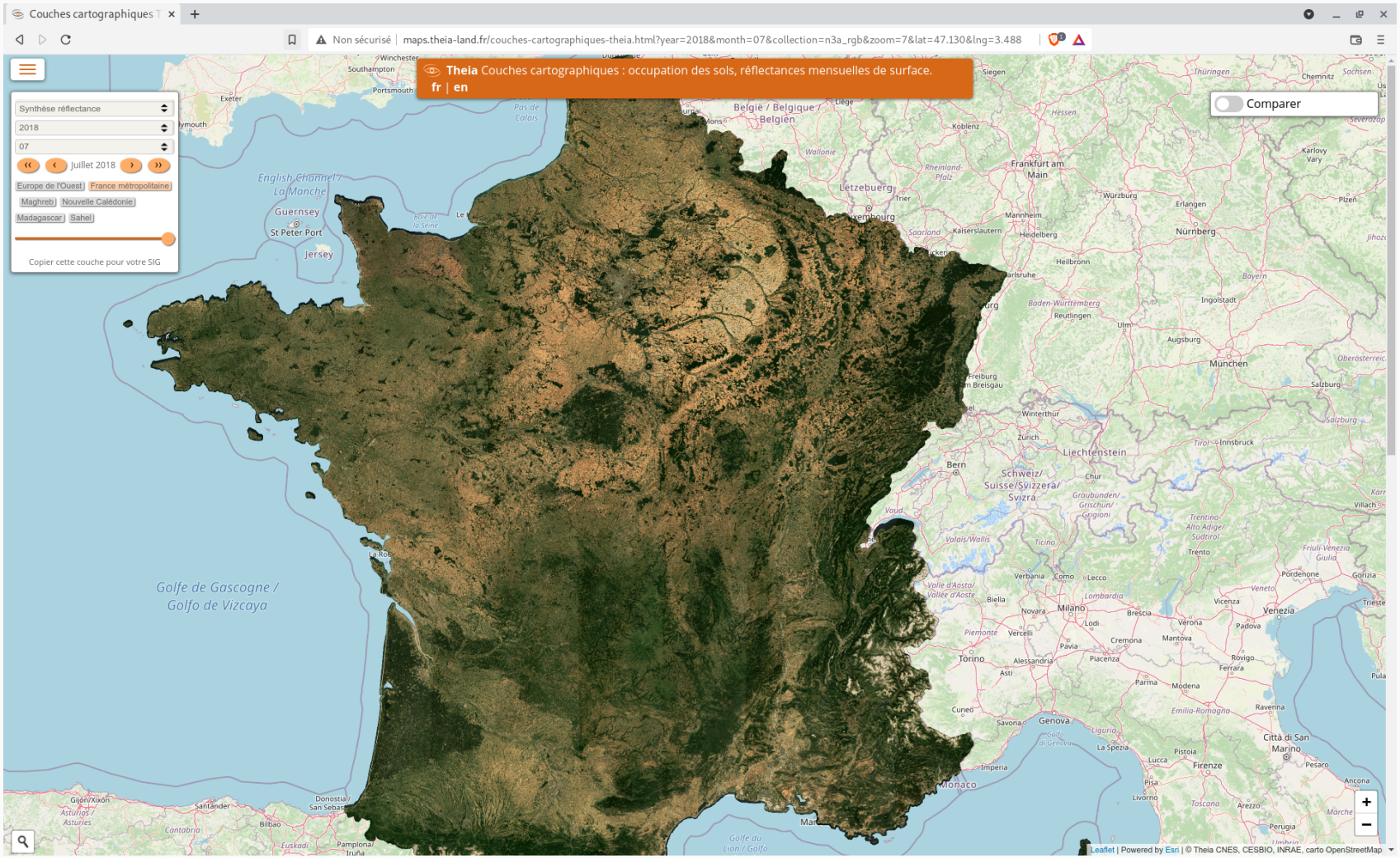
THEIA L2A coverage in 2021



Available for download under open license at `https://theia.cnes.fr`

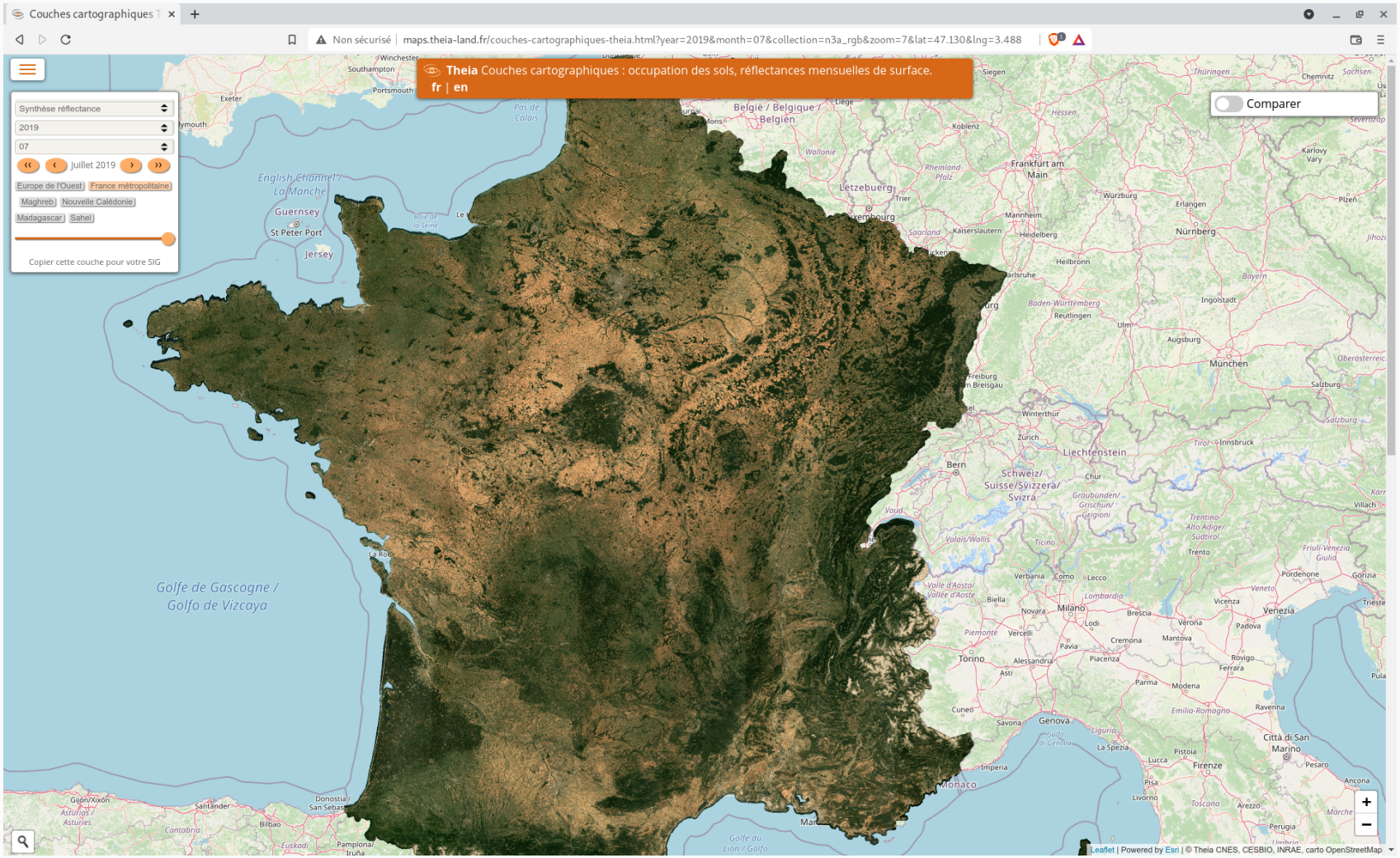
Operational institutional use of MAJA and WASP: THEIA

WASP L3A July 2018



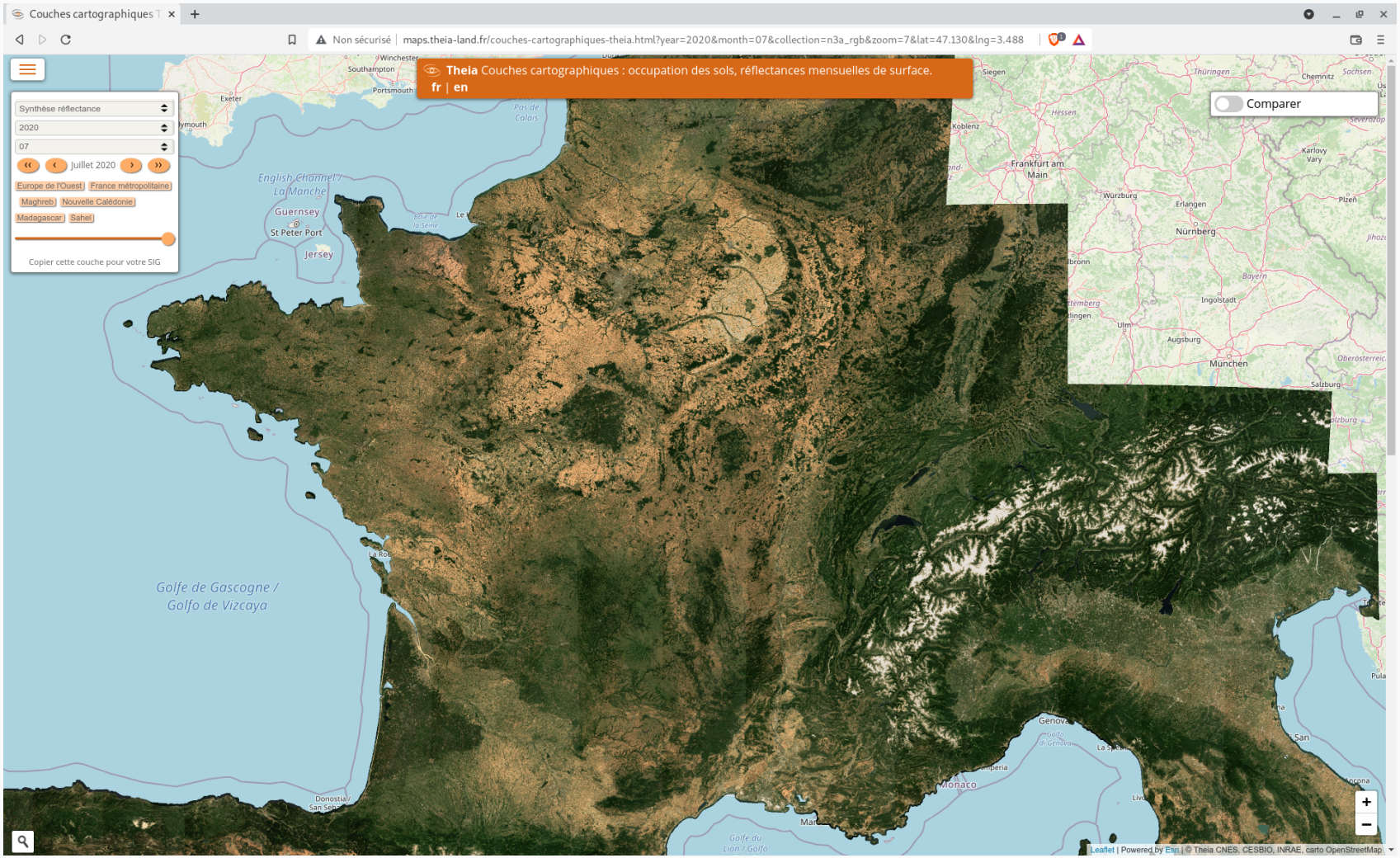
Operational institutional use of MAJA and WASP: THEIA

WASP L3A July 2019



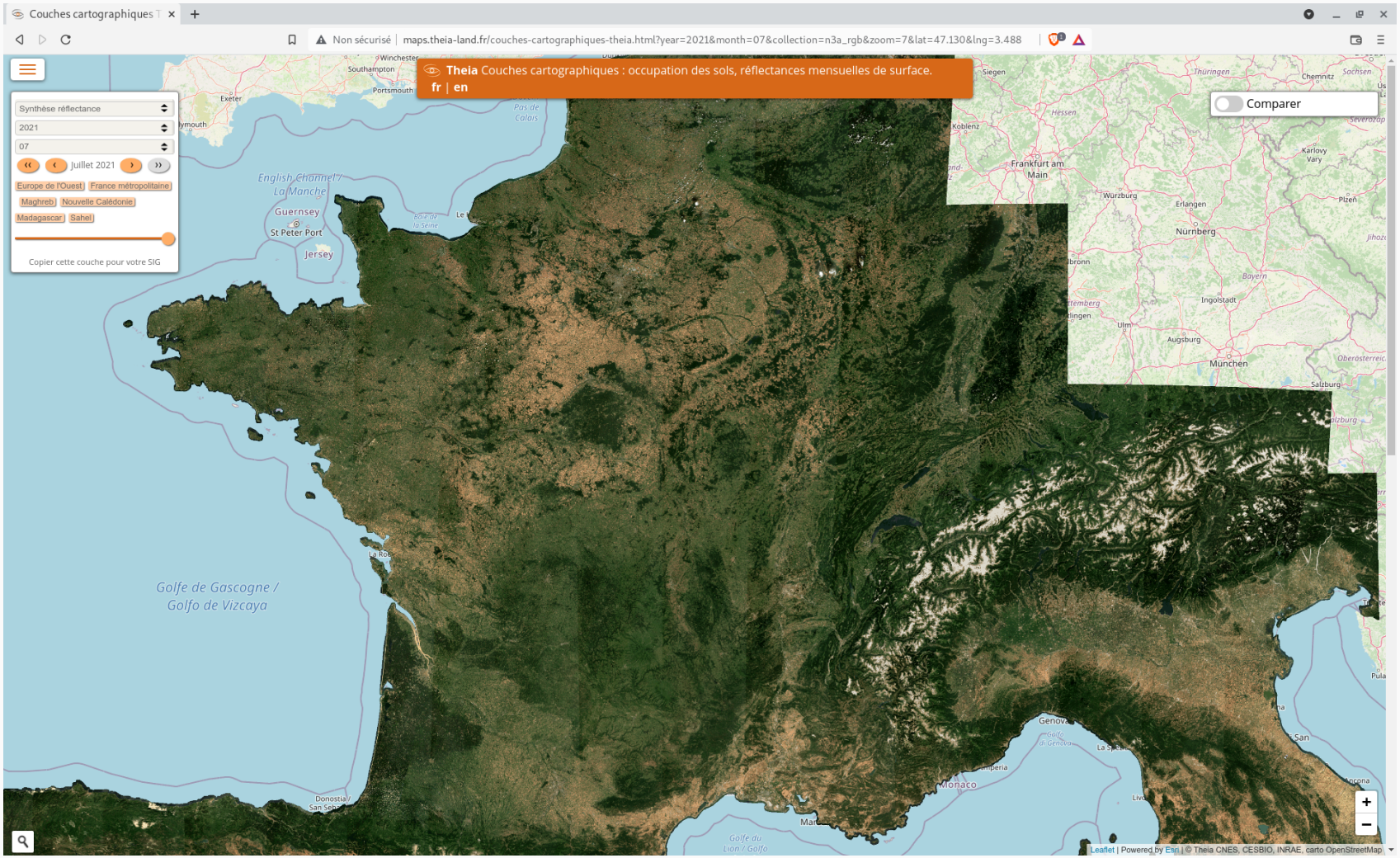
Operational institutional use of MAJA and WASP: THEIA

WASP L3A July 2020



Operational institutional use of MAJA and WASP: THEIA

WASP L3A July 2021



Operational institutional use of MAJA and WASP: DLR

DLR produces Sentinel-2 L2A and L3A over Germany with MAJA and WASP

Products available under Creative Common (files and QGIS geoservice):

- L2A: `https://download.geoservice.dlr.de/S2_L2A_MAJA/files/`
- L3A: `https://download.geoservice.dlr.de/S2_L3A_WASP/files/`

Operational institutional use of MAJA and WASP: Katverket

The Katverket (Norway national Mapping Agency) uses MAJA and WASP to produce a yearly cloud-free mosaic
Products available at:

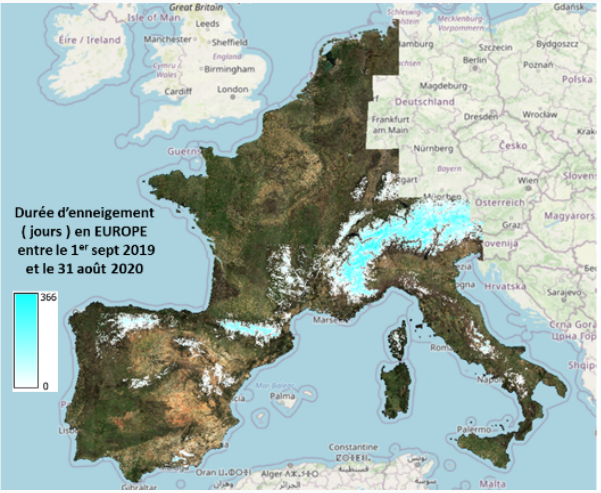
- L2A: `https://norgeibilder.no/`

Cloud-free mosaic 2021

Downstream products

COPERNICUS High Resolution Snow and Ice Monitoring

- MAJA Sentinel-2 L2A + LIS processor
- LIS is developped by CESBIO and Open Source too



Available at `https://land.copernicus.eu/pan-european/biophysical-parameters/high-resolution-snow-and-ice-monitoring`

THEIA Land Cover

- MAJA Sentinel-2 L2A + IOTA2 processor
- IOTA2 is developped by CESBIO and Open Source too

Available at `https://theia.cnes.fr/`

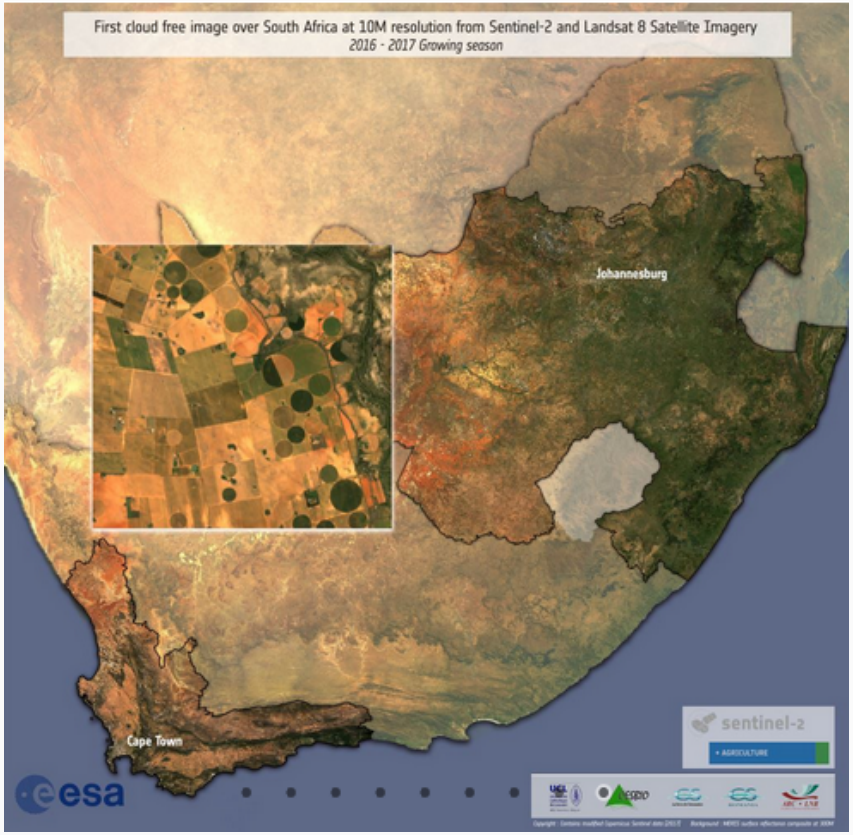
Downstream products

MAJA and WASP are included in Sen2Agri

- national scale agriculture maps
- crop mask, crop type, biophysical variables
- more than 2.4k downloads
- http://www.esa-sen2agri.org/

and Sen4Cap:

- based on sen2agro
- monitor Europe agriculture production
- http://esa-sen4cap.org/



To conclude

What's new, what's next ?

- latest MAJA 4.5 manages with the coming S2 L1C format upgrade
- coming MAJA 4.6 with default coarse resolution at 120m
- on-going research on adjacency correction and improvement of the atmospheric correction part
- MAJA to be in charge of L2A for the 6 VNIR/SWIR bands of Trishna

Take-home message:

- conservative cloud mask
- uncertainty on surface reflectance ≤ 0.01
- L2A/L3A distributed through THEIA for over 10 millions square kilometers
- MAJA and WASP source codes available Open Source
- active development, continuous validation process

References

Visit our blog for more: https://labo.obs-mip.fr/multitemp/

and the following paper

Hagolle et al. (2015)

A Multi-Temporal and Multi-Spectral Method to Estimate Aerosol Optical Thickness over Land, for the Atmospheric Correction of FormoSat-2, LandSat, VENUS and Sentinel-2 Images

Remote Sensing 7(3), 2668 – 2691, https://www.mdpi.com/2072-4292/7/3/2668.