

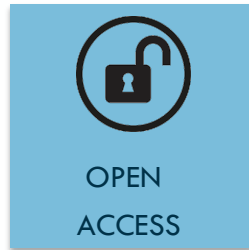
Atmospheric Correction Inter-comparison eXercise (ACIX-II Land): the second implementation of an atmospheric correction assessment for Landsat 8 and Sentinel-2 over land

Georgia Doxani I *Serco for ESA-ESRIN*
Ferran Gascon I *ESA-ESRIN*
Eric Vermote I *NASA GSFC*
Jean-Claude Roger I *NASA GSFC, University of Maryland*
Sergii Skakun I *NASA GSFC, University of Maryland*

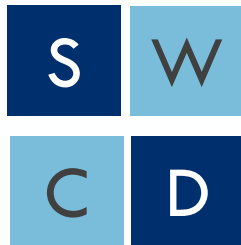
Atmospheric Correction Inter-comparison eXercise (ACIX-II Land): the second implementation of an atmospheric correction assessment for Landsat 8 and Sentinel-2 over land

Alan Collison	I	<i>Planet Labs PBC</i>	Jérôme Louis	I	<i>Telespazio France</i>
Liesbeth De Keukelaere	I	<i>VITO</i>	Fabio Pacifici	I	<i>Maxar</i>
Camille Desjardins	I	<i>CNES</i>	Bringfried Pflug	I	<i>DLR, German Aerospace Center</i>
David Frantz	I	Humboldt-Universität zu Berlin & Earth Observation and Climate Processes	Hervé Poilvé	I	<i>Airbus Defence and Space</i>
Olivier Hagolle	I	<i>CNES/CSEBIO</i>	Didier Ramon	I	<i>HYGEOS</i>
Minsu Kim	I	<i>KBR, Contractor to USGS</i>	Rudolf Richter	I	<i>DLR, German Aerospace Center</i>
			Feng Yin	I	<i>University College London, NCEO</i>

WHY?



Free and open access policy to Sentinel-2 and Landsat-8 imagery has stimulated the development and operational use of AC processors for generating Bottom-of-Atmosphere (BOA) products



The objective is to point out:

- Strengths & Weaknesses
- Commonalities & Differences

How?

Definition of the inter-comparison protocol

Coordinators & Participants discussed all the major points and defined the inter-comparison procedure.

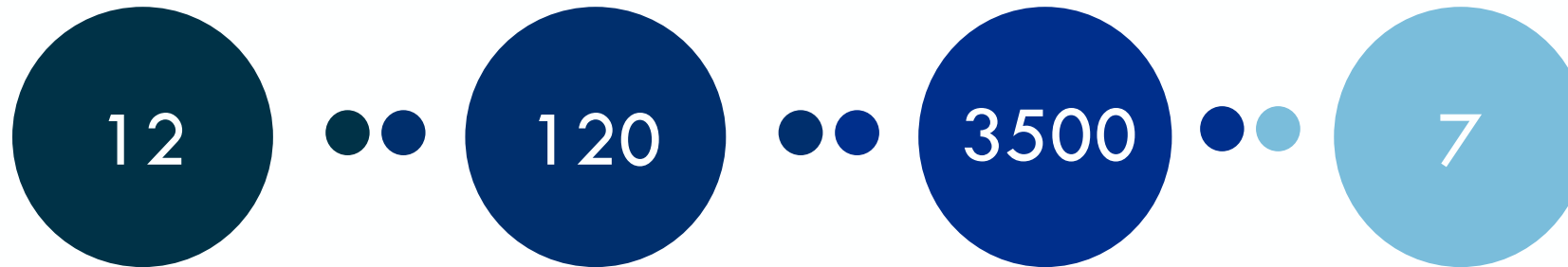
Application of the AC processors

Participants applied their AC schemes on a set of test sites keeping the processing parameters constant. The results were submitted for analysis to ACIX coordinators.

Analysis of the results

Coordinators processed the AC results and assessed the inter-comparison metrics. The results presented and discussed with the participants.

How?



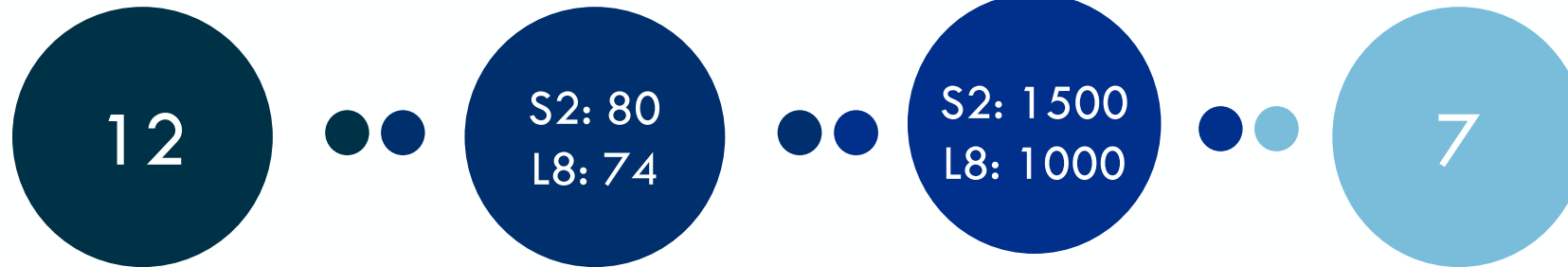
Developer Teams
from various Space Agencies, R&D Companies, Research Institutes and Universities

Study Sites
spread globally based on the AERONET stations (coincident measurements availability)

Image Scenes
to be processed acquired by Sentinel-2A, -2B and Landsat-8

Months
for participants to submit results

How?



Developer Teams
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Study Sites
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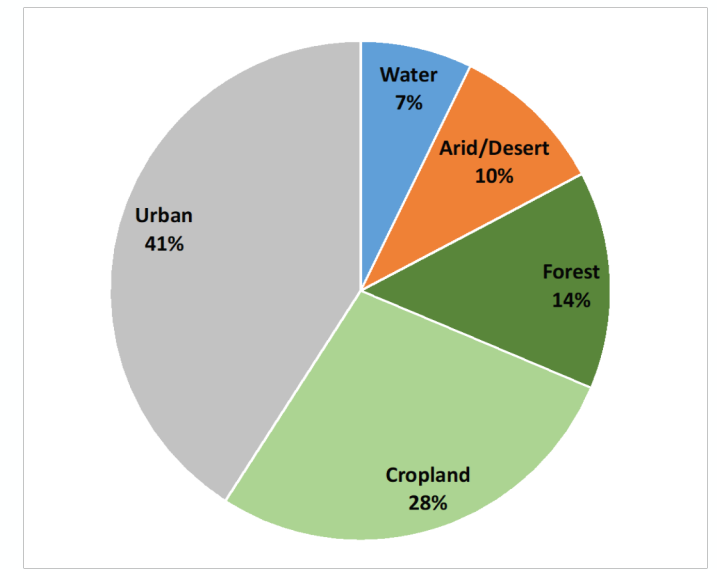
Image Scenes
to be processed
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Sentinel-2A, -2B and
Landsat-8

Months
for participants to
submit results

WHO?

AC Processors	Participants	Organization/Company
AComp	Fabio Pacifici	DigitalGlobe [USA]
ATCOR	Bringfried Pflug	DLR Remote Sensing Technology Institute [Germany]
EMBAC	Kim Minsu	USGS [USA]
FORCE	David Frantz	Humboldt-University [Germany]
iCOR	Liesbeth Dekeukelaere Erwin Wolters	VITO [Belgium]
LaSRC	Eric Vermote Jean-Claude Roger Sergii Skakun	NASA GSFC [USA] Maryland University [USA]
MAJA	Olivier Hagolle Aimé Meygret	CNES/CESBIO [France]
Overland	Hervé Poilvé	Airbus Defence and Space [France]
Planet SR	Alan Collison	Planet [USA]
Sen2Cor	Jérôme Louis Bringfried Pflug	European Space Agency (ESA), Telespazio [France] DLR Remote Sensing Technology Institute [Germany]
SIAC	Feng Yin	University College London [UK]
SMAC-G/MERRA2	Didier Ramon	HYGEOS [France]

WHERE?



The land cover types of the AERONET sites

How?



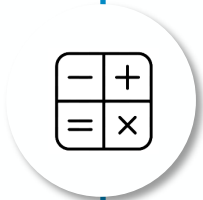


AERONET

AERONET

Estimated AOD (/WV) & compared to Level 1.5 (cloud screened) AERONET data

1. Interpolate AERONET values @ $\lambda=550$ nm using Angstrom Exponent
2. Average AERONET values over time period within ± 15 min from AOD retrieved values (L-8/S-2A, -2B overpass)
3. Average estimated AOD values over an image subset of 9 km x 9 km centred on the AERONET Sunphotometer station



Statistics

- No. of samples
- R^2 (Coefficient of determination)
- RMSE
- bias

Scatterplots and APU Plots

Accuracy, Precision, Uncertainty

$$Accuracy (A): A = \frac{1}{n\lambda} (\sum_{i=1}^{n\lambda} \Delta\rho_{i,\lambda}^{SR})$$

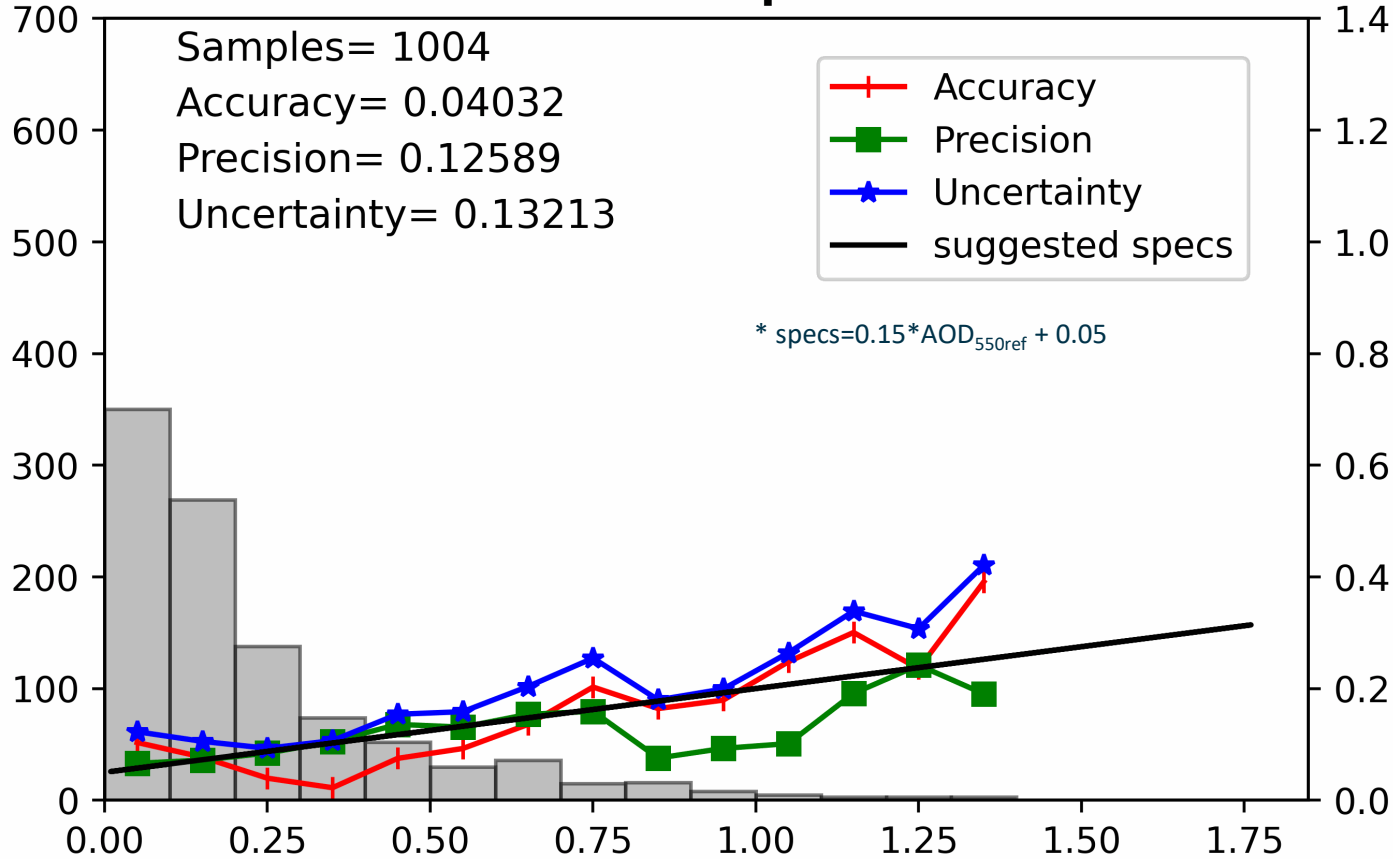
$$Precision (P): P = \sqrt{\frac{1}{(n\lambda-1)} \sum_{i=1}^{n\lambda} (\Delta\rho_{i,\lambda}^{SR} - A)^2}$$

$$Uncertainty (U): U = \sqrt{\frac{1}{n\lambda} \sum_{i=1}^{n\lambda} (\Delta\rho_{i,\lambda}^{SR})^2}$$



--- Sentinel-2

AComp



Accuracy

the degree to which a measured value agrees with the reference value

Mostly inside the suggested specifications
→ unbiased results



Precision

the degree to which repeated measurements agree with each other

Mostly close to specifications



Uncertainty

estimate of amount by which measurement differs from the reference value

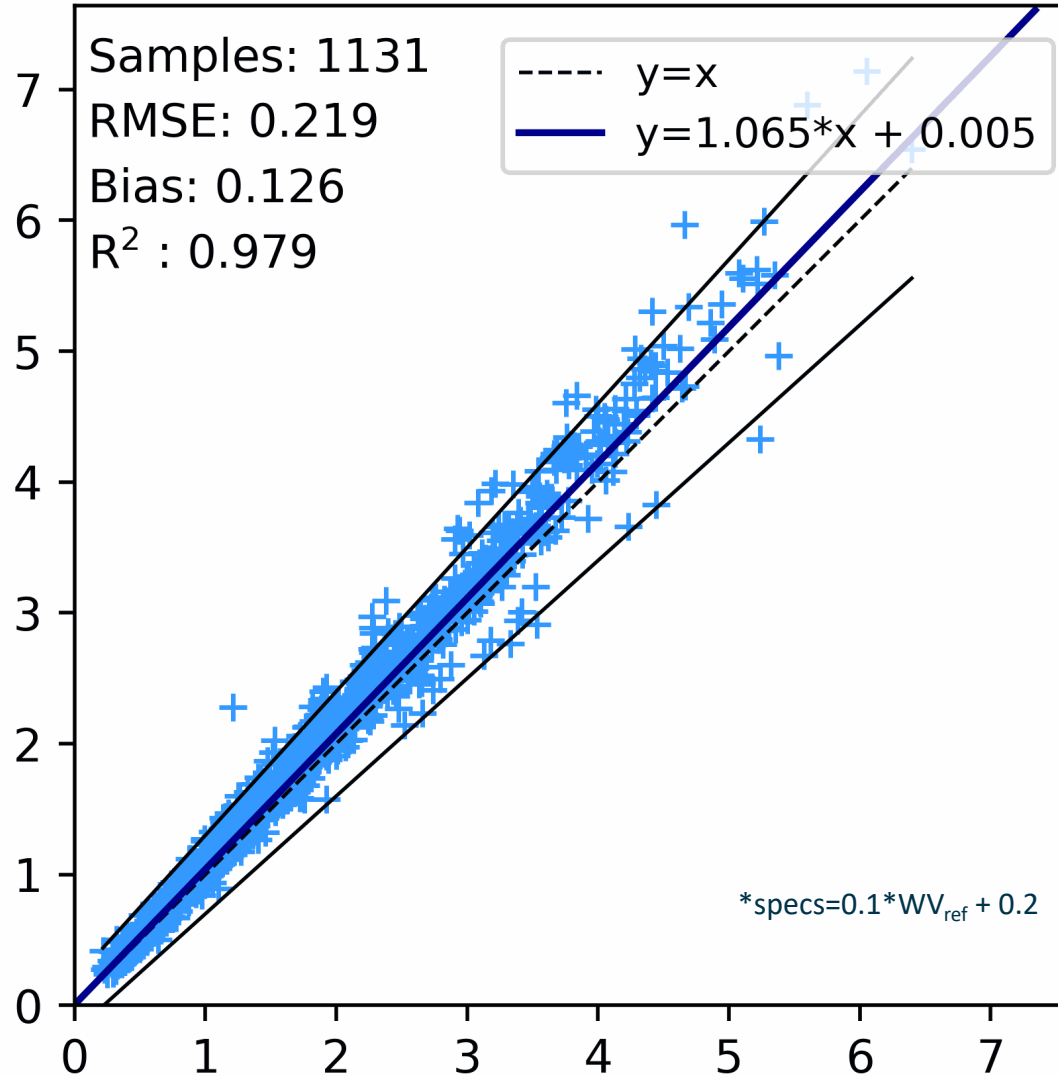
Consistent performance of most processors in retrieving relative light to medium aerosol loading (AOD<0.2)

iCOR and SMACG: lowest U <0.12, SIAC, AComp, MAJA, Sen2Cor: U < 0.14



--- Sentinel-2

ATCOR



Root Mean Square Error

WV retrieval is very accurate

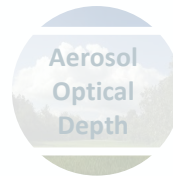
$R^2 > 0.9$ and $RMSE < 0.25$



Percent

More than 90% of the results are falling within the specifications for all the processors except LaSRC (89.5%), SIAC (85%) and FORCE (70%) whose results are more dispersed, mainly for WV values over 3 g/cm².

How?



How?

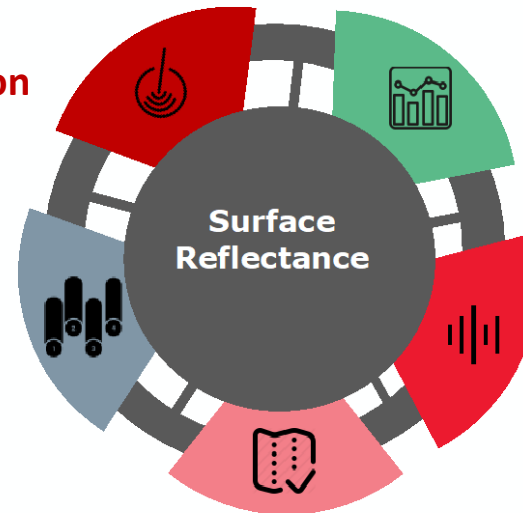


01. Ground based validation

RadCalNet [La Crau] (France), Gobabeb (Namibia)], SR are provided by CNES in the same angular conditions as L8, S2A & S2B

05. SR inter-comparison

Plotting the SR time series per date, band and AC approach.



04. Distance Matrix

Distance Matrix was shaped based on the Euclidean distances calculated for the corresponding bands, dates and sites for every combination of couple of processors

02. AERONET corrected data

AC data generated by 6SV radiative transfer model using AERONET data. AOT, aerosol model and column water vapour will be derived from AERONET sunphotometer measurements and will be used in the radiative transfer model in order to perform the AC of TOA reflectance.

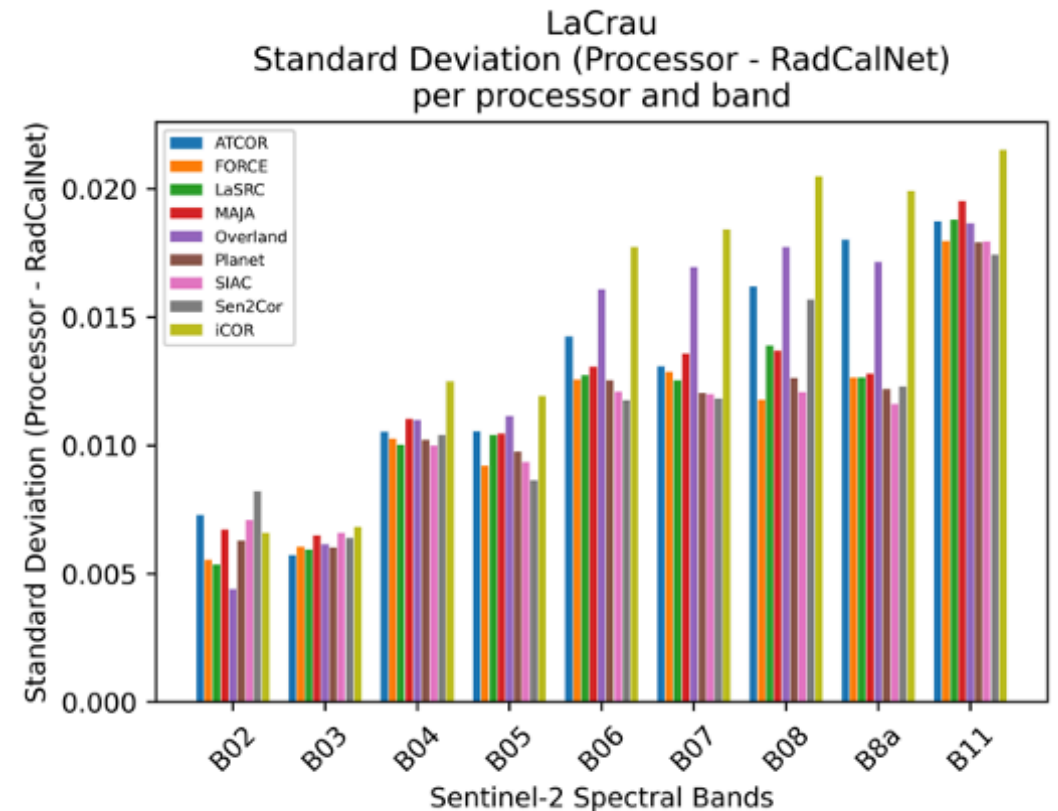
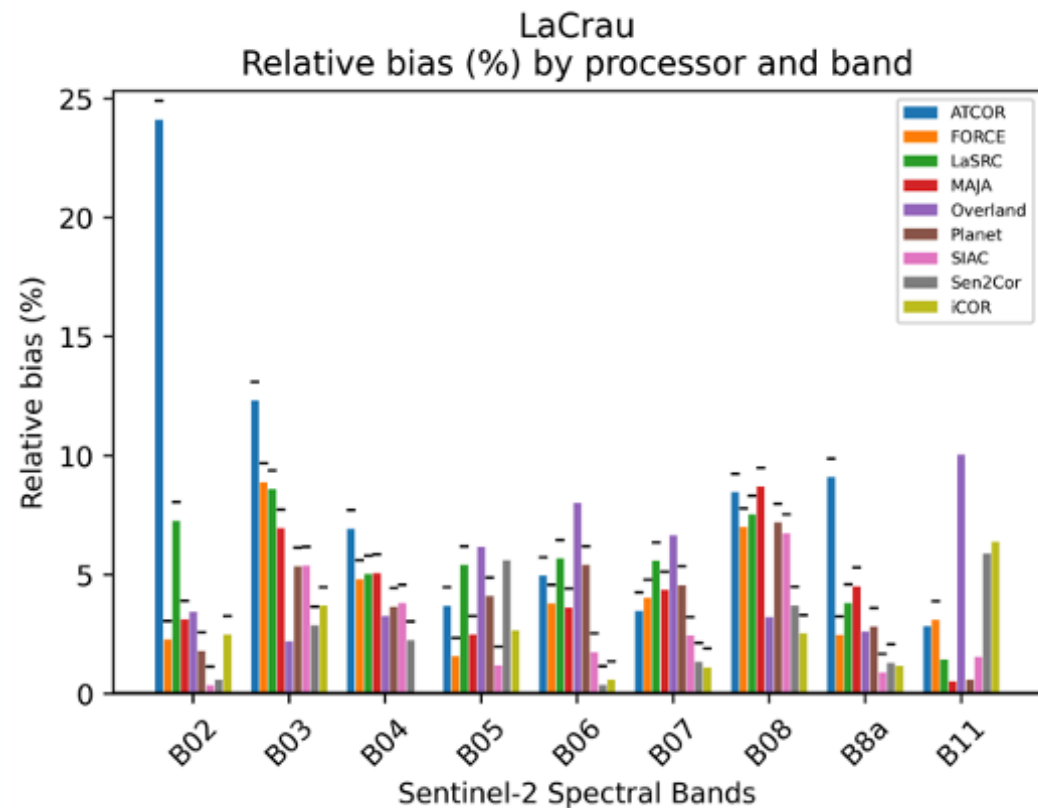
03. Noise Estimation

Assuming that there is a linear SR variation between two consecutive acquisition days; for three successive observations the statistical difference between, the center measurement and the linear interpolation between the two extremes quantifies the "noise" :

$$Noise(y) = \sqrt{\frac{\sum_{i=1}^{n-2} \left(y_{i+1} - \frac{y_{i+2} - y_i}{d_{i+2} - d_i} (d_{i+1} - d_i) - y_i \right)^2}{N - 2}}$$

01. Ground based validation

La Crau [France]: 44 S2 scenes



Mostly SR **underestimation**

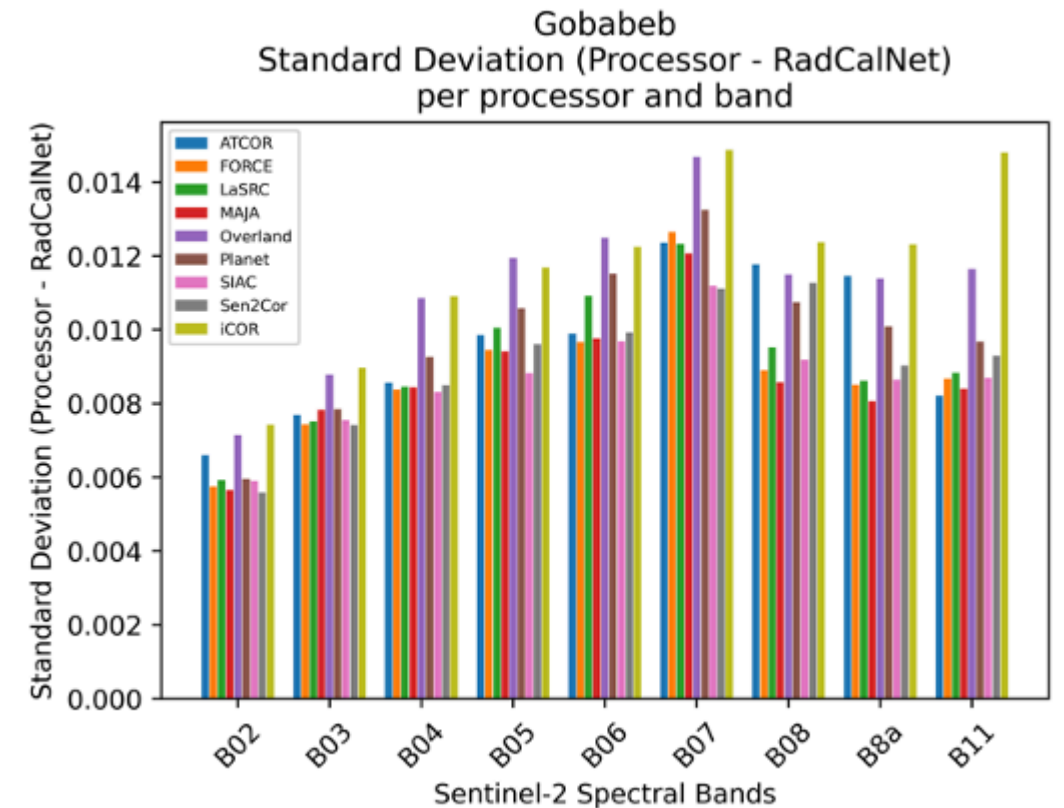
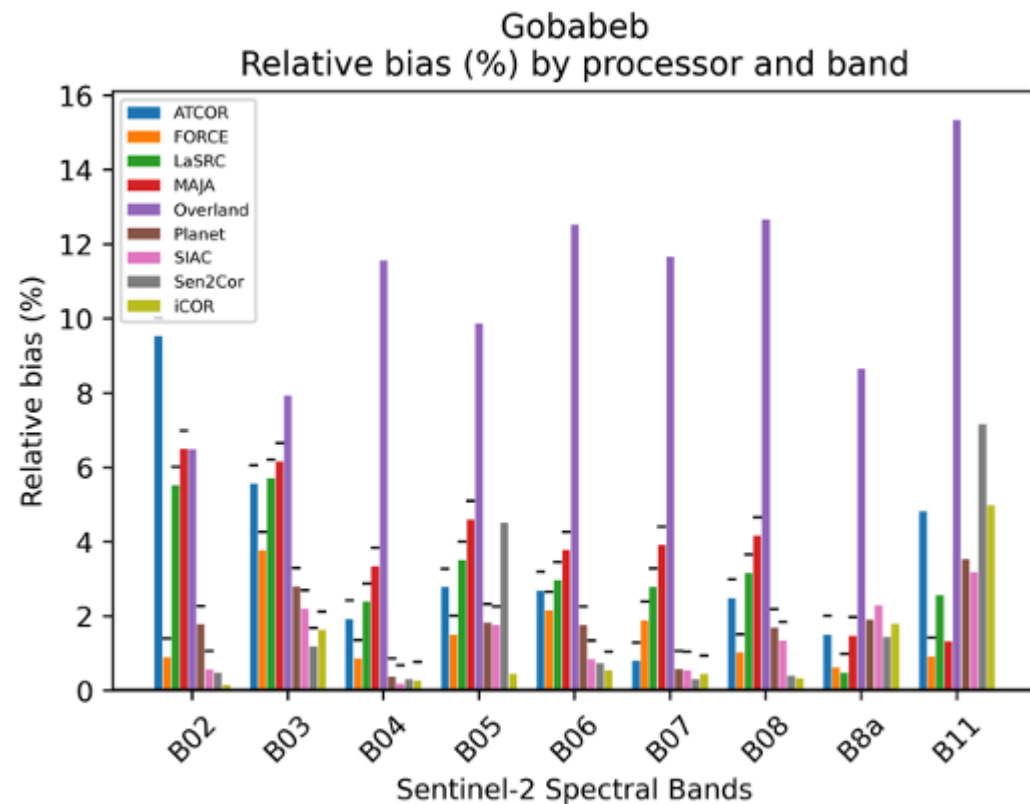
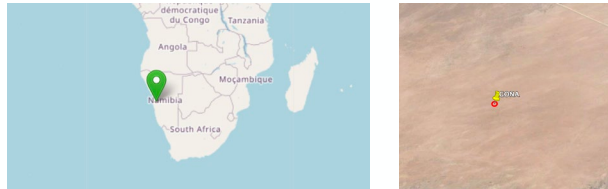
Relative Biases
La Crau $\leq \pm 9\%$

La Crau -> Increasing values
from VNIR and SWIR

Stdv Difference
La Crau <math>< 0.02</math>

01. Ground based validation

Gobabeb [Namibia]: 40 S2 scenes



⚙️ Mostly SR **underestimation**

⚙️ **Relative Biases**
Gobabeb $\pm 6\%$

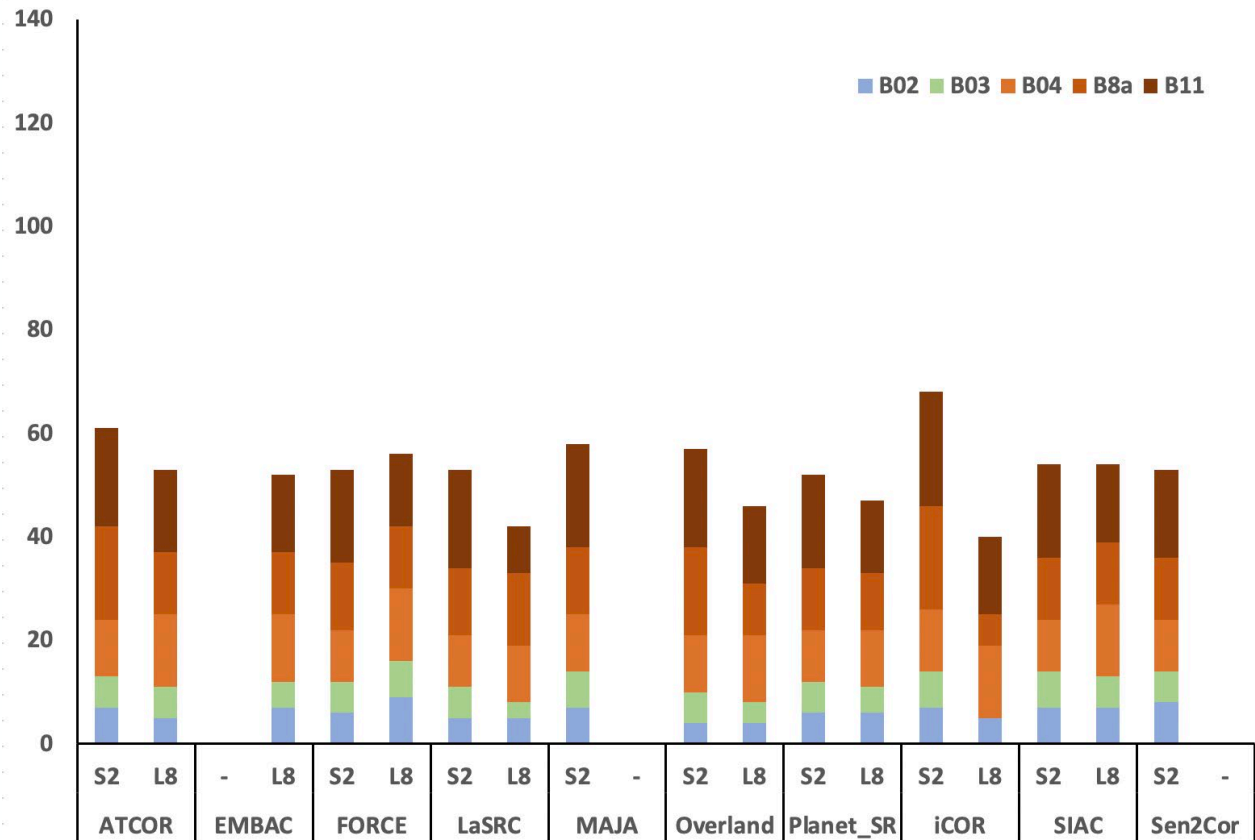
⚙️ Gobabeb -> Increasing values up to B07, improving NIR and SWIR

⚙️ **Stdv Difference**
Gobabeb <math>< 0.01</math>

01. Ground based validation

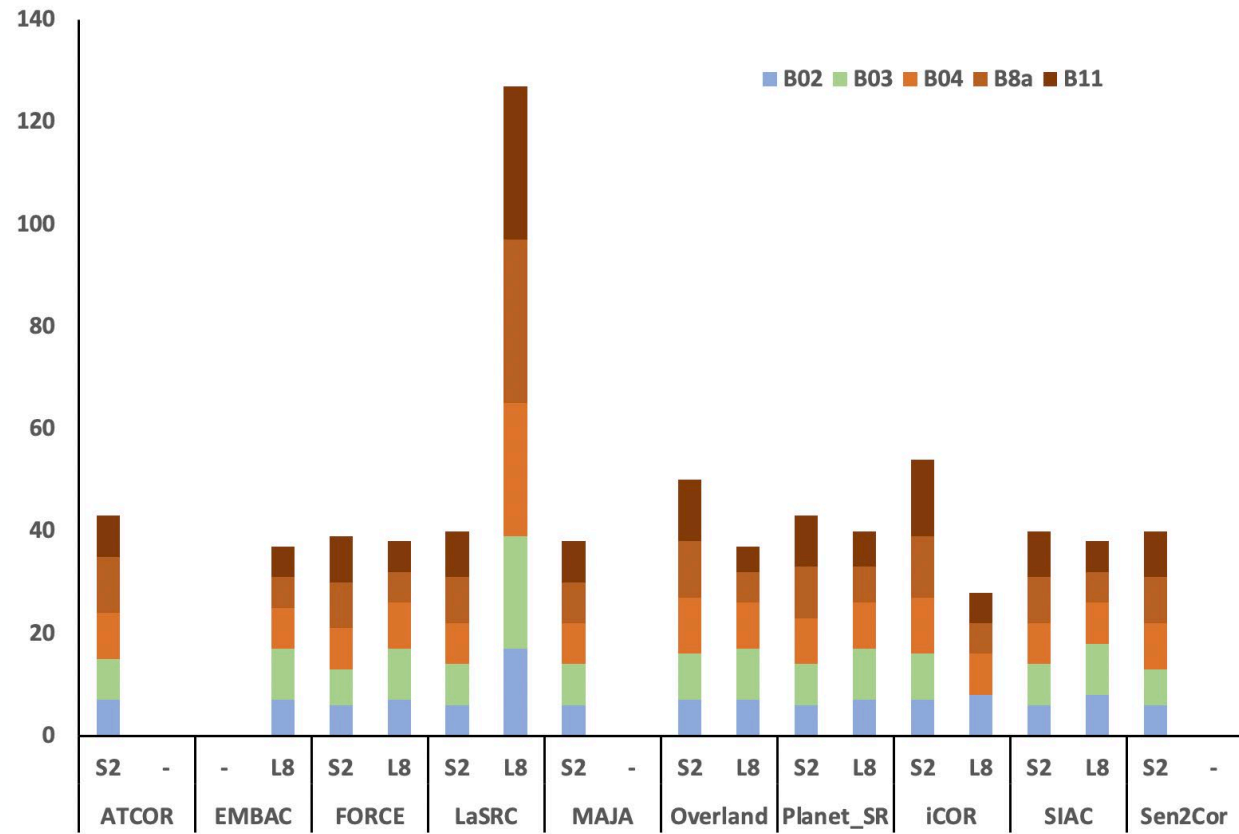
La Crau [France]

La Crau: Difference Standard Deviation *10⁻³

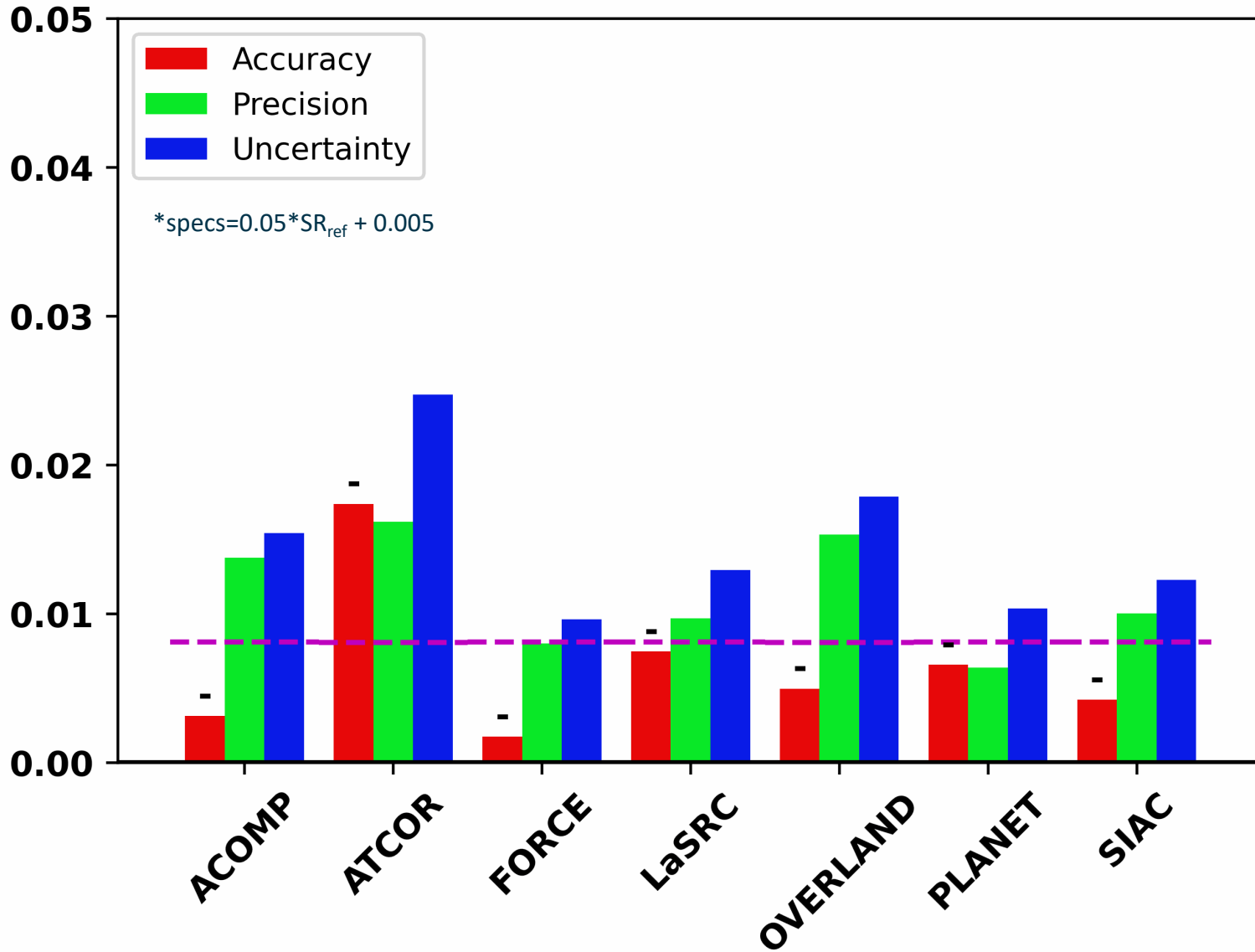


Gobabeb [Namibia]


Gobabeb: Difference Standard Deviation *10⁻³





B01



02. AERONET corrected data

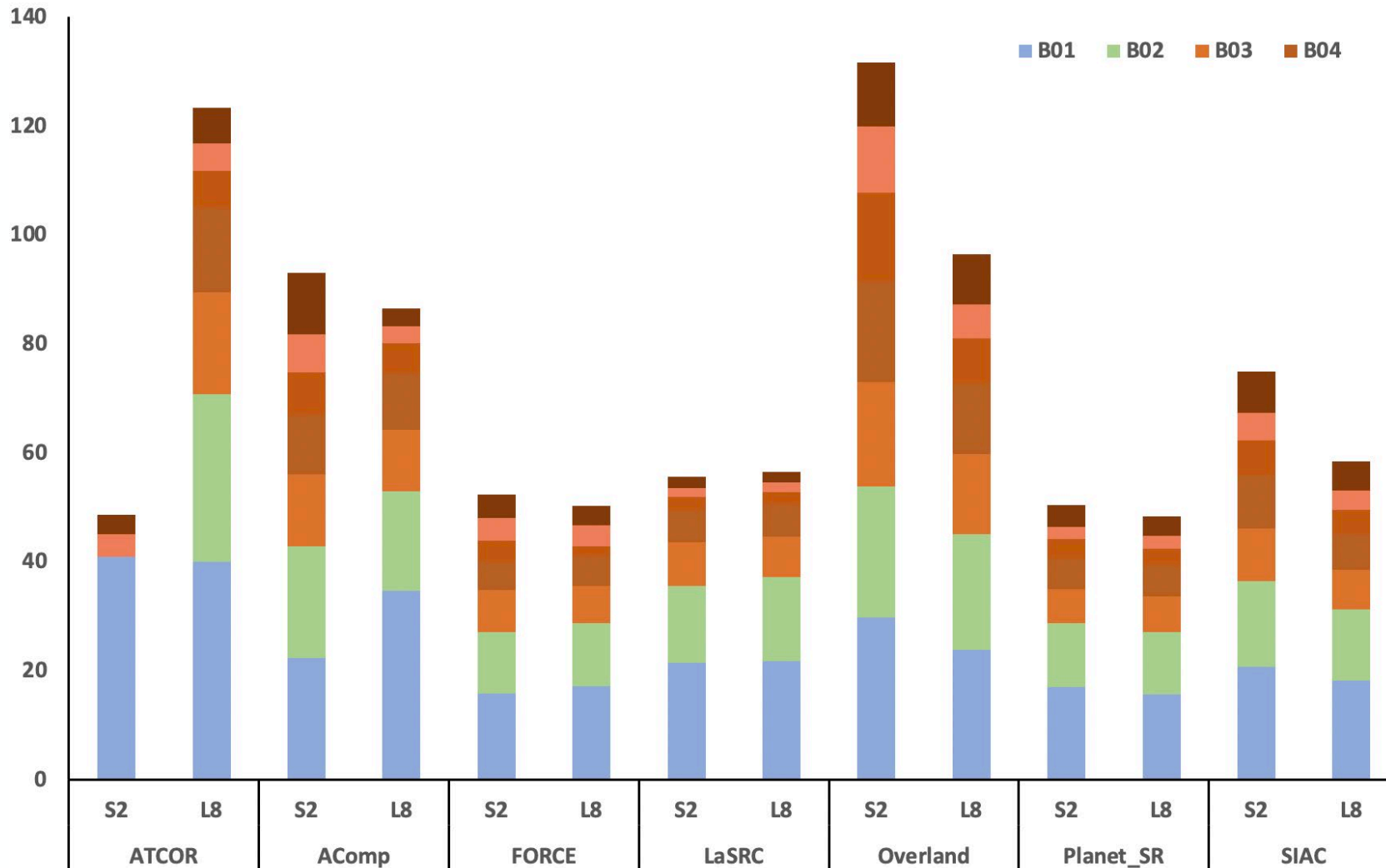
-  Improved results from VNIR (V: B01, B02, B03, B04, (RE/NIR: B05, B06, B07, B08, B8a) to SWIR (B11, B12),

-  **FORCE & Planet** retrievals within the specifications across all bands (not for B01 & B09), similar for **LaSRC and SIAC** (not for B01, B02 & B09)

-  **AComp's** SR retrievals closer to specifications from VNIR to SWIR spectral range, apart from B05 and B12 for which uncertainty exceeds the suggested requirements.

02. AERONET corrected data

Relative Uncertainty (%)



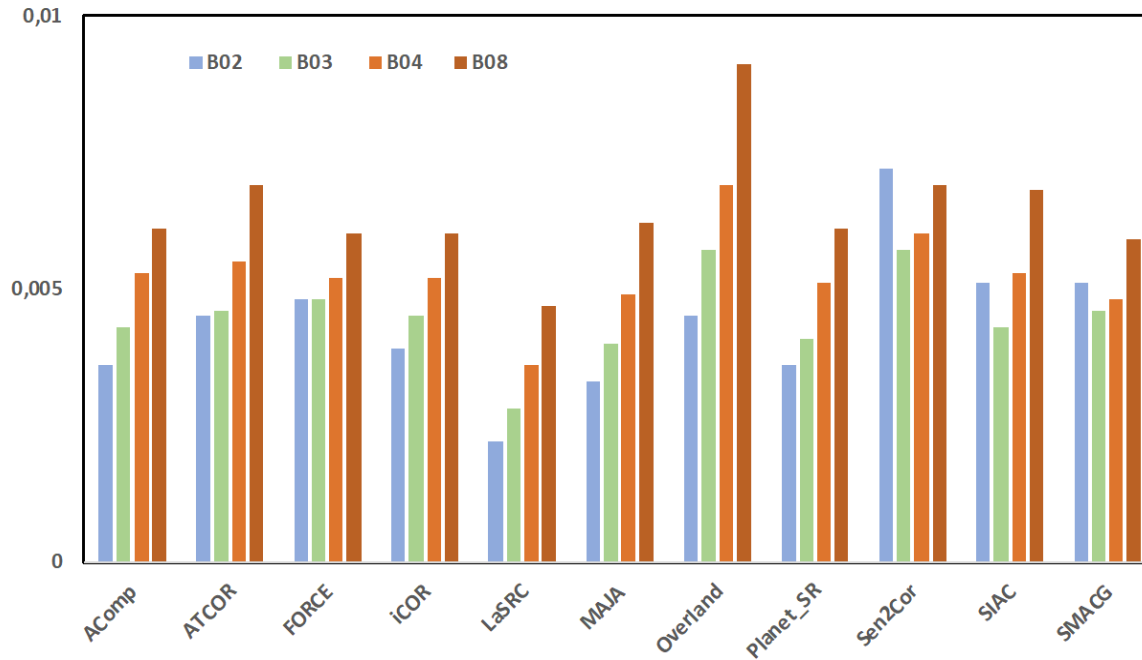
$$rU = 100\% * U/\bar{x}$$

U : uncertainty and
 \bar{x} : the average truth

>> Arid sites [4 sites]

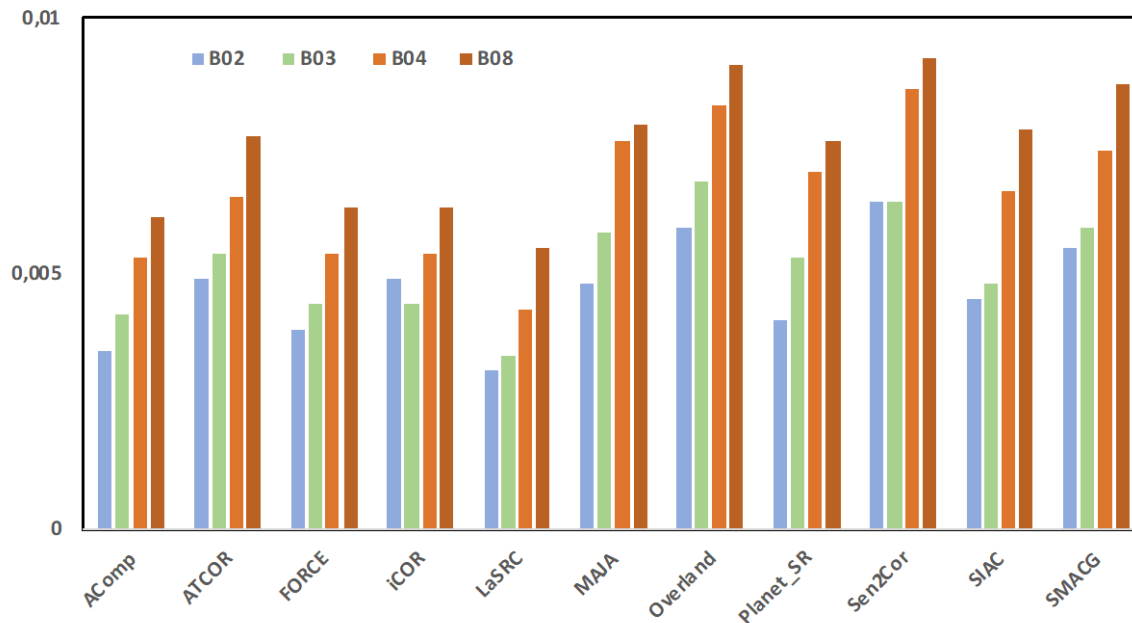
Noise criterion for Arid sites

--- Sentinel-2



>> Vegetated sites [6 sites]

Noise criterion for Vegetated sites



03. Noise Estimation

Only sites with >20 scenes from the same orbit

Common sites, dates and quality pixels for all processors [available masks union]



Similar variability of SR over short time amongst all processors for both site types



LaSRC produces the 'smoothest' time series for both site types

SUMMARY



ACIX-II Land in Numbers

11 processors implemented on 1500 Sentinel-2 scenes over 80 common sites

9 processors implemented on 1000 Landsat 8 scenes over 74 common sites



Aerosol Optical Depth

mostly in moderate agreement with the AERONET reference values, ~ 0.65

$< R^2 < 0.775$ and $\sim 0.115 < RMSE < 0.2$



Water Vapour

strong correlations with the AERONET data, $R^2 > 0.9$ and $RMSE < 0.25$

SUMMARY



Surface Reflectance

RadCalNet measurements: **similar results** for most processors in the SR comparison [La Crau, Gobabeb]

Simulated SR reference using 6SV and AERONET : Overall the results are improving from VNIR to SWIR, variation in the results amongst processors with improved results for the processors using variation of 6S RTM



Overall

No clear superiority - Similar results for most processors when compared to in-situ measurements and variance when compared to simulated reference



Suggestions

More in situ SR measurements are needed (CESBIO agricultural site [RadCalNet], HyperNet)

Some geographical areas were missing (Africa, South America, Australia) & many sites close to big cities, deserts

ACIX II Results

HOME PROCESSORS SITES METRICS RESULTS CONTACT

search... Everything

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ACIX II Land

- ACIX II Processors
- ACIX II Sites
- ACIX II Metrics
- ACIX II Results**
- ACIX II Contact

ACIX II Land

Please fill out the form to get ACIX II Land results.

Satellite sensors and processors

Please select a Satellite sensor and one option in the processor's list

Satellite Sensor:

Sentinel-2 MSI
 Landsat-8 OLI

AC Processors:

-- Choose an option --

Next Page

Page 1 of 3

ACIX aims to bring together the developers of Atmospheric Correction (AC) processors, who are invited to generate the corresponding Bottom-Of-Atmosphere (BOA) products. The input data are Landsat-8 and Sentinel-2 imagery of various sites. A common and harmonised inter-comparison procedure is agreed and followed by all the participants.

The first ACIX experiment started in June 2016 with its description and conclusions to be summarised in Doxani et al. (2018). All the inter-comparison results can be found in the dedicated to [ACIX I web page](#). ACIX I was completed in February 2018, but the improved versions of the participating processors and the increasing interest of AC developers to be part of the experiment stimulated the continuation of ACIX and its second implementation (ACIX II).

Following the recommendations of ACIX participants and Earth Observation data users, an additional inter-comparison of cloud masking assessment was decided to be performed in parallel with ACIX. Cloud masking is a crucial step of the radiometric pre-processing of optical

ACIX II Results


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ACIX II Land

- ACIX II Processors
- ACIX II Sites



ACIX II Land

Please fill out the form to get ACIX II Land results.

Satellite sensors

Please select a Satellite sensor

Satellite Sensor:

Sentinel-2 MSI
 Landsat-8 OLI

AC Processors:

Sen2Cor

Page 1 of 3

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ACIX II Land

Please fill out the form to get ACIX II Land results.

Metrics

Please select a metric at a time

Aerosol Optical Depth:

-- Choose an option --

Water Vapour:

-- Choose an option --

Surface Reflectance:

Validation with RadCalNET per band

Bands:

B04

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ACIX II Results

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ACIX II Land

Please fill out the form to get ACIX II Land results.

Sites

Please select one option in the list below

AERONET and RadCalNet:

-- Choose an option --

Previous Page Finish

Page 3 of 3

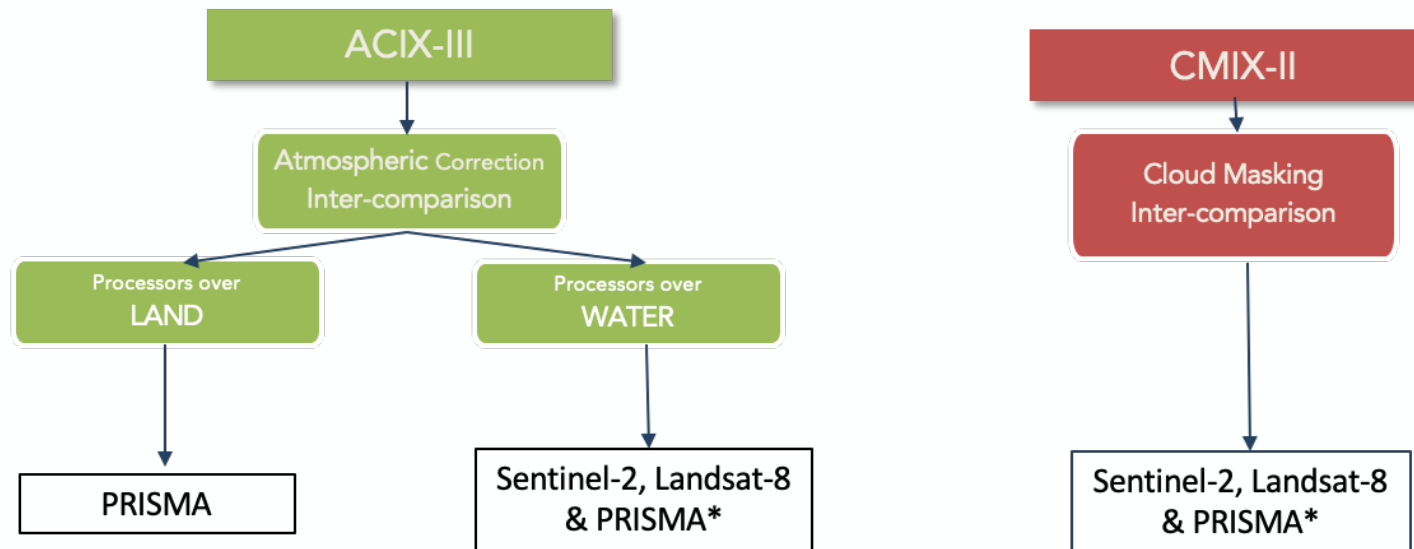
ACIX II Land

- ACIX II Processors
- ACIX II Sites
- ACIX II Metrics
- ACIX II Results**
- ACIX II Contact

comparison results can be found in the dedicated to the participating processors and the increasing interest in its second implementation (ACIX II).

Following the recommendations of ACIX participants, a comparison was decided to be performed in parallel.

WAY FORWARD

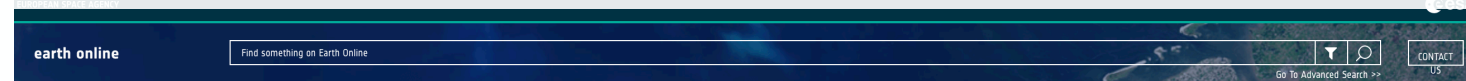


*PRISMA ad-hoc acquisitions over the selected set of sites for each of the exercises will be provided by ASI

WAY FORWARD

1st Workshop ACIX-III Land, Aqua and CMIX-II -- 20-21 June 2022, ESA/ESRIN, Frascati (Italy) --

<https://earth.esa.int/eogateway/events/1st-workshop-of-acix-iii-land-aqua-and-cmix-ii>



Event / 1st Workshop Of ACIX-III Land, Aqua and CMIX-II

Search with Keywords

Atmosphere Clouds Land Surface

The 1st workshop of ACIX-III Land, Aqua and CMIX-II

20 Jun - 21 Jun 2022
ESA/ESRIN (Frascati, Italy)

Description

ACIX is an initiative to bring together the developers of Atmospheric Correction (AC) processors, who are invited to generate Bottom-Of-Atmosphere (BOA) products from Top-Of-Atmosphere (TOA) optical satellite data. The exercise is a collaborative activity of ESA (European Space Agency) and NASA (National Aeronautics and Space Administration) that initiated in 2016 in the frame of CEOS WGOV. ACIX has been already implemented twice on multispectral Copernicus Sentinel-2 and Landsat 8 imagery. More information on the latest analysis and the results' can be found in the dedicated web pages for the [Land](#) and [Aqua](#) focused part of the exercise.

In parallel with ACIXs, a Cloud-Masking Inter-comparison exercise (CMIX) ran over specific areas with reference data available. Similarly to ACIXs, the focus of the first CMIX was on open and free imagery acquired by the Copernicus Sentinel-2 (EE/ESA) and Landsat 8 (NASA/USGS) missions. For more information on the first CMIX implementation can be found on <https://calvalportal.ceos.org/cmix>.

Considering the great scientific and users' interest, a third ACIX and second CMIX implementations are proposed involving also hyperspectral data this time. In collaboration with ASI (Agenzia Spaziale Italiana/ Italian Space Agency), PRISMA data have been acquired for the exercises' purposes mainly over sites in Europe and North America. Multispectral data of Sentinel-2 and Landsat 8 will still be part of the ACIX-Aqua and CMIX analysis. ACIX-Land though will focus only on PRISMA hyperspectral data, as it was considered unnecessary to repeat the exercise for multispectral data at the moment. The decision is mainly based on the unavailability of any new reference data to the ones used in the previous exercises. The exercises' implementation scheme is presented below:

Thank you for your attention!

ACIX-Land:

<https://calvalportal.ceos.org/acix-ii-land>

ACIX-Aqua:

<https://calvalportal.ceos.org/acix-ii-aqua>

CMIX:

<https://calvalportal.ceos.org/cmixon>

