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

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Minsu Kim I *KBR, Contractor to USGS*
Jérôme Louis I *Telespazio France*
Fabio Pacifici I *Maxar*
Bringfried Pflug I *DLR, German Aerospace Center*
Hervé Poilvé I *Airbus Defence and Space*
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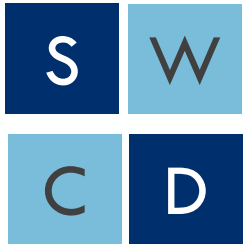
Feng Yin I *University College London, NCEO*

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.

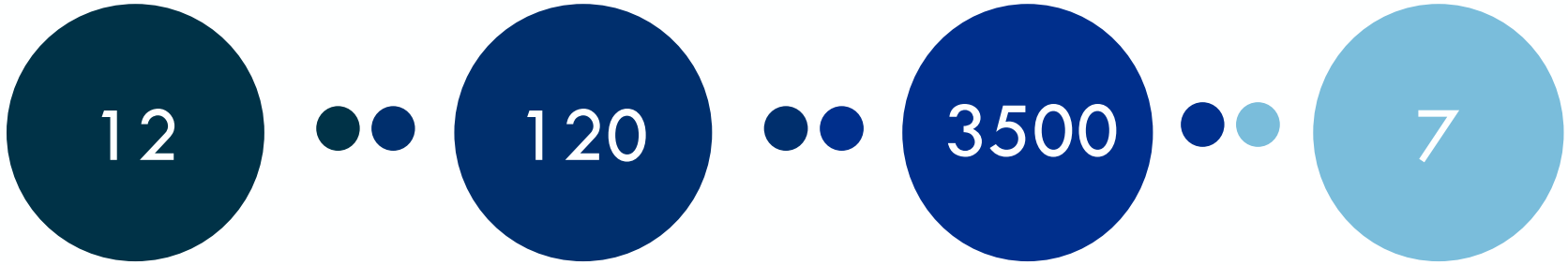
Application of the AC processors

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?



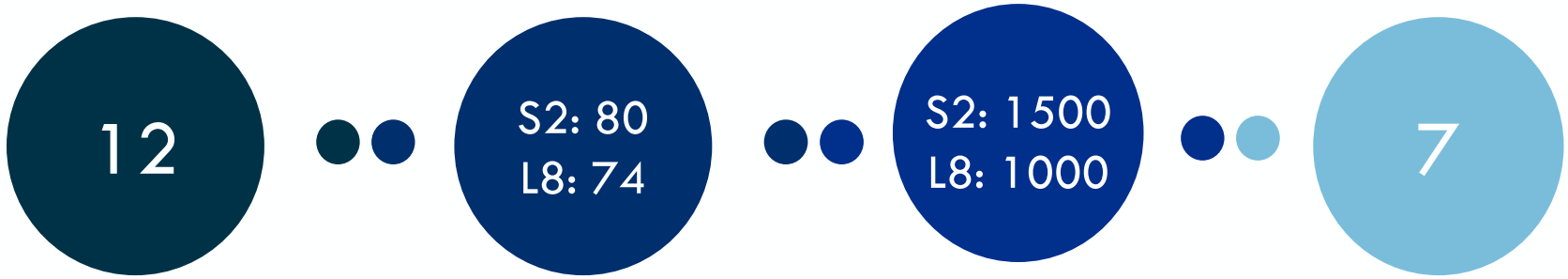
Developer Teams
from various Space Agencies, R&D Companies, Research Institutes and Universities

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?



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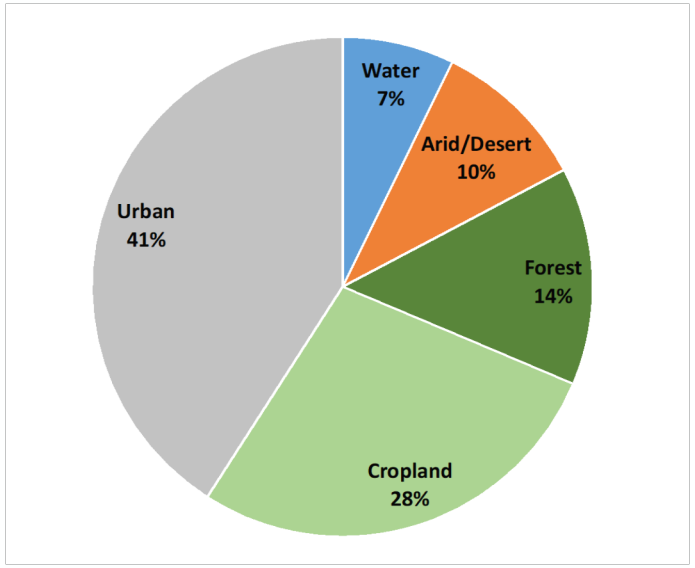
WHO?

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

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

1. Interpolate AERONET values @ λ=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

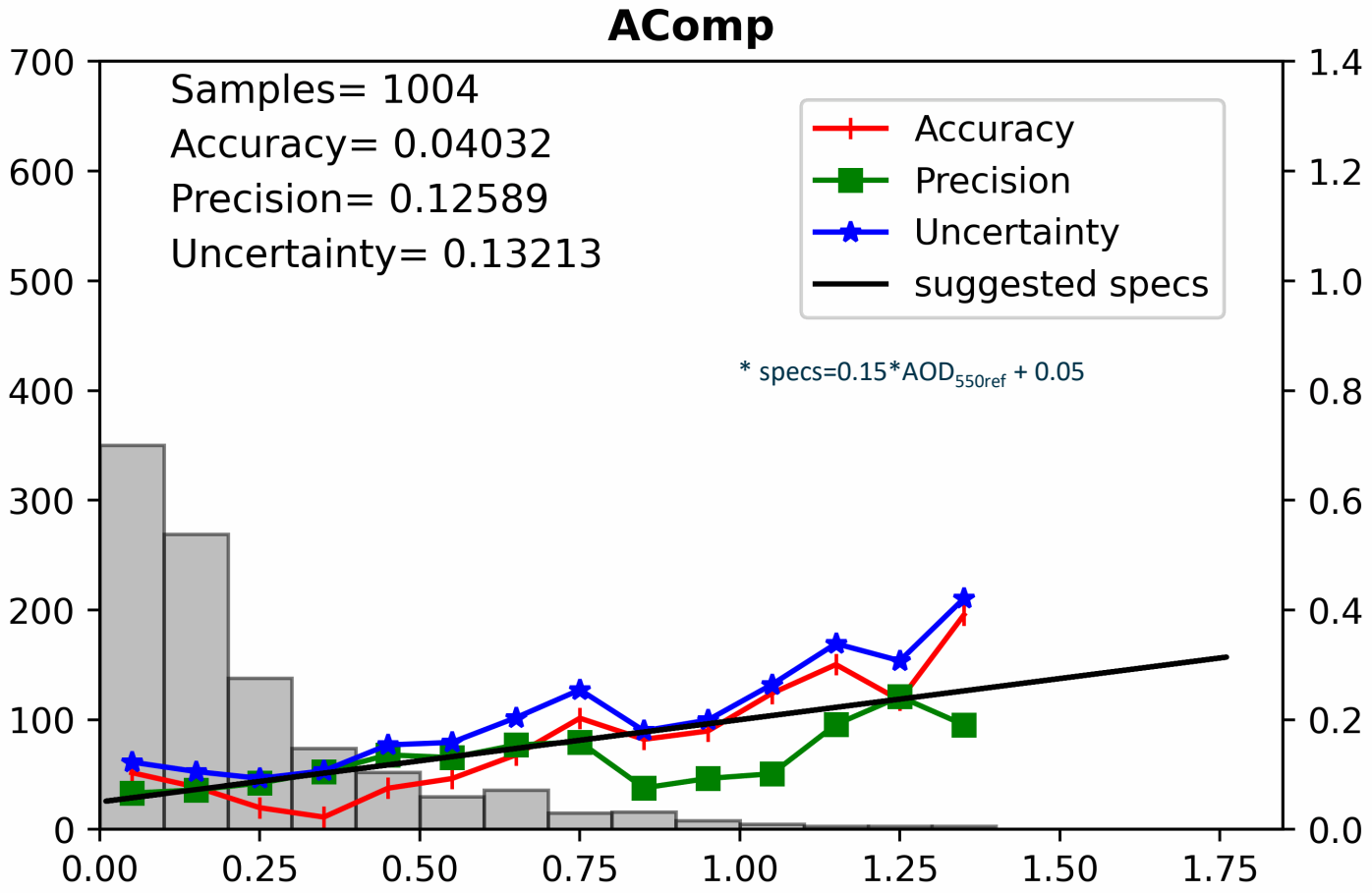
$$Accuracy\ (A):\ A = \frac{1}{n\lambda}\left(\sum_{i=1}^{n\lambda} \Delta\rho_{i,\lambda}^{SR}\right)$$

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

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

Aerosol Optical Depth

--- Sentinel-2



A Accuracy

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

Mostly inside the suggested specifications

→ unbiased results

P Precision

the degree to which repeated measurements agree with each other

Mostly close to specifications

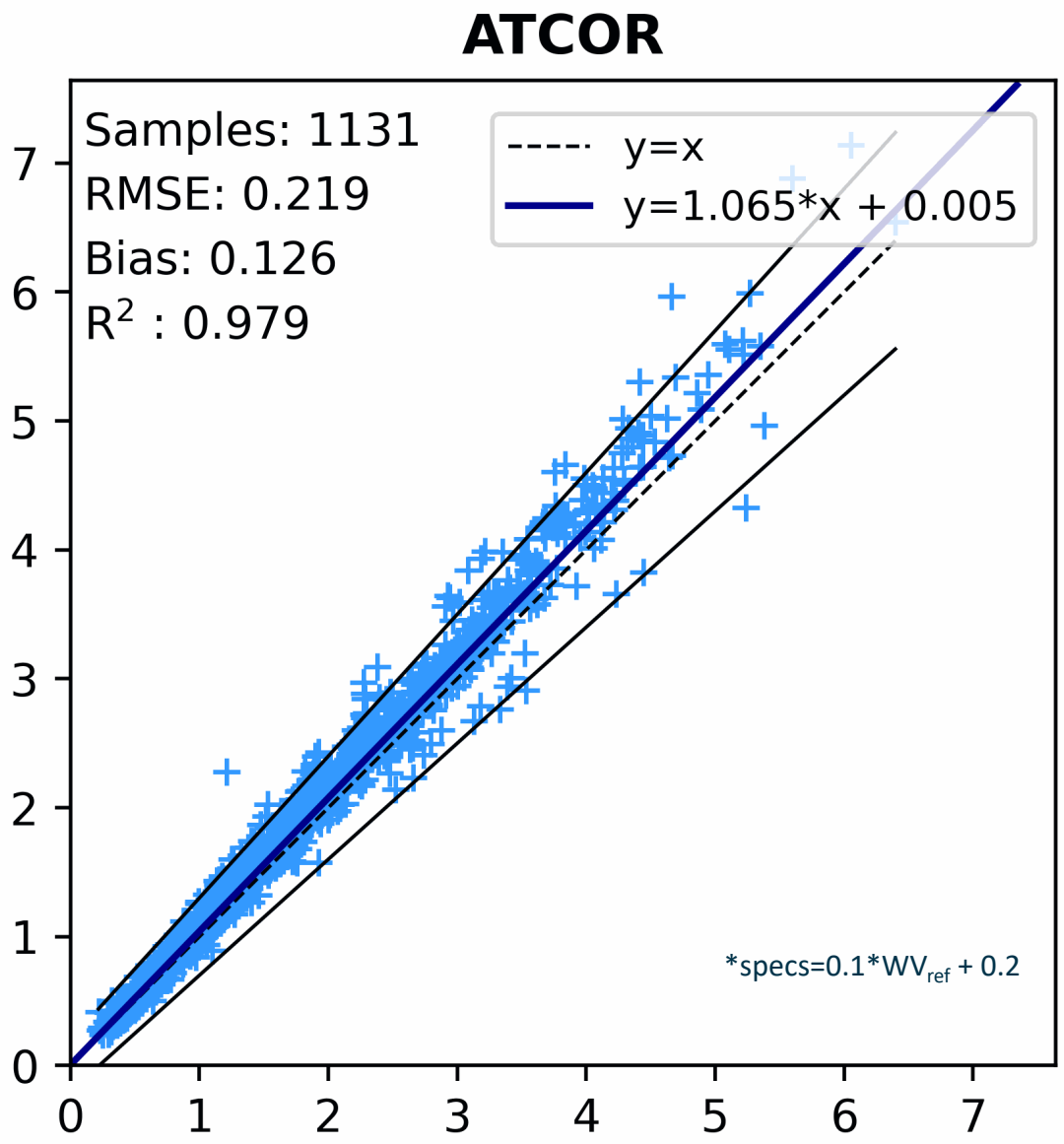
U Uncertainty

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



E

Root Mean Square Error

WV retrieval is very accurate

R^2>0.9 and RMSE<0.25

P

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?

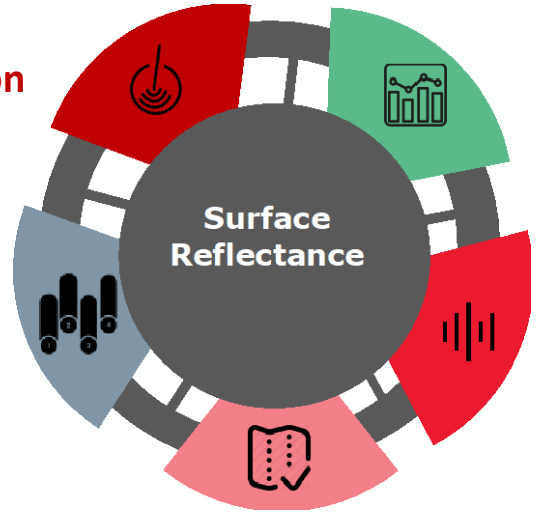
How?

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.



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" :

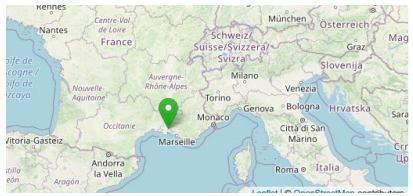
$$Noise(y) = \sqrt{\frac{\sum_{i=1}^{n-2}\left(y_{i+1} - \frac{y_{i+2}-y_i}{d_{i+2}-d_i}\,(d_{i+1}-d_i) - y_i\right)^2}{N-2}}$$

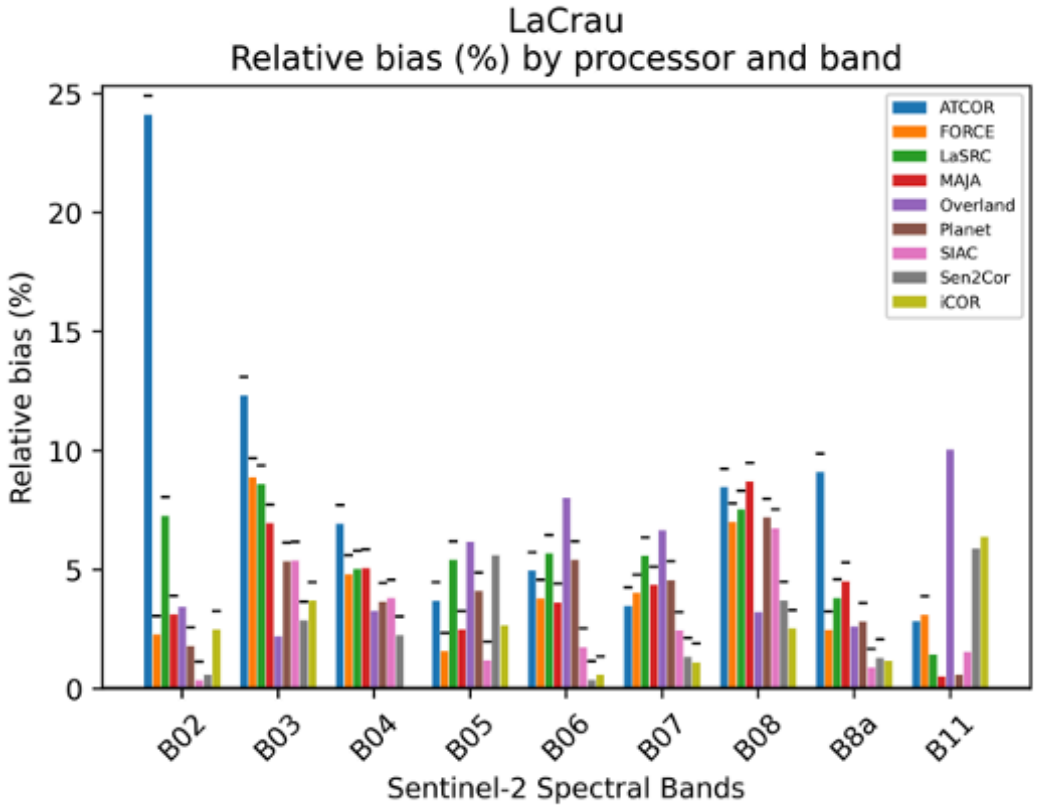
04. Distance Matrix

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

01. Ground based validation

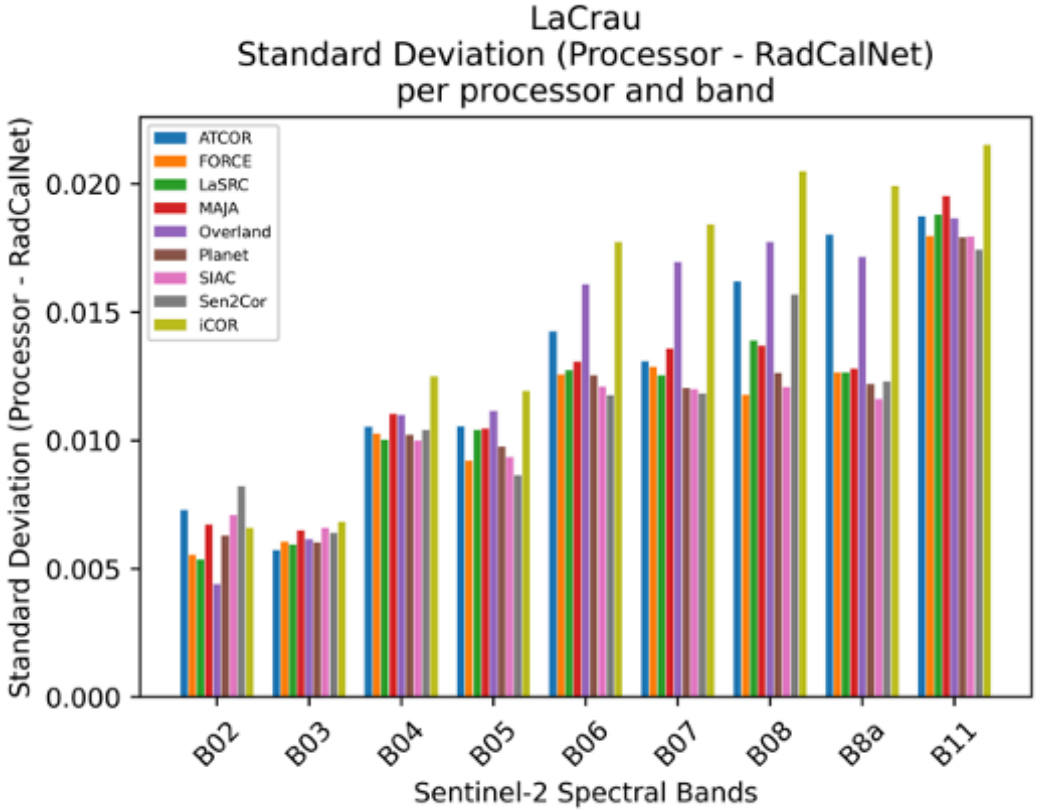
La Crau [France]: 44 S2 scenes





Mostly SR **underestimation**

Relative Biases
La Crau<± 9%

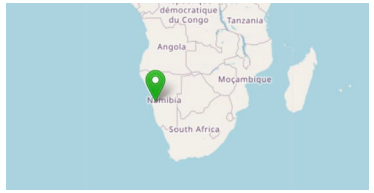


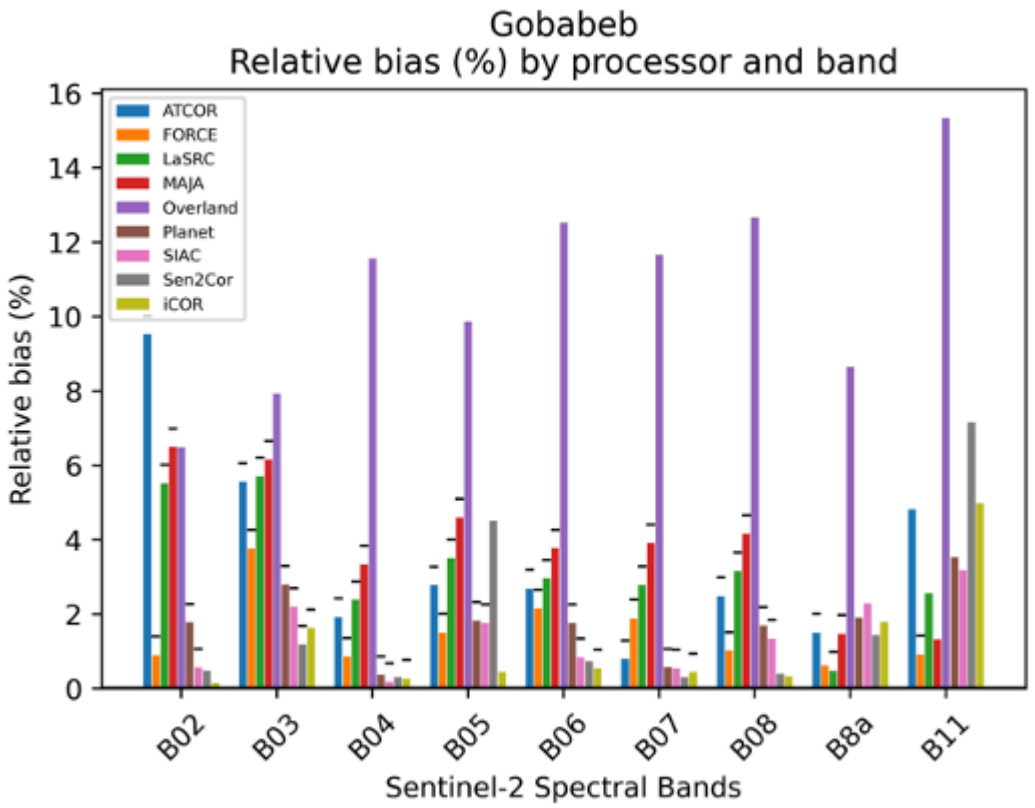
La Crau -> Increasing values from VNIR and SWIR

Stdv Difference
La Crau<0.02

01. Ground based validation

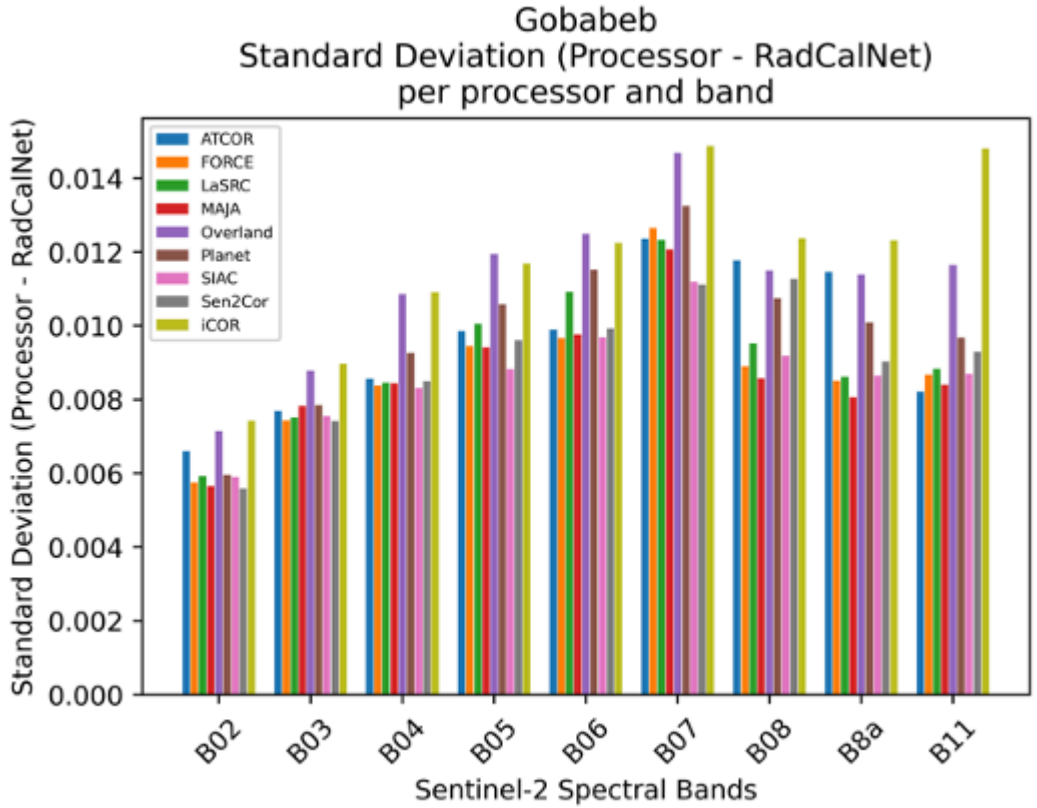
Gobabeb [Namibia]: 40 S2 scenes





Mostly SR **underestimation**

Relative Biases
Gobabeb<± 6%

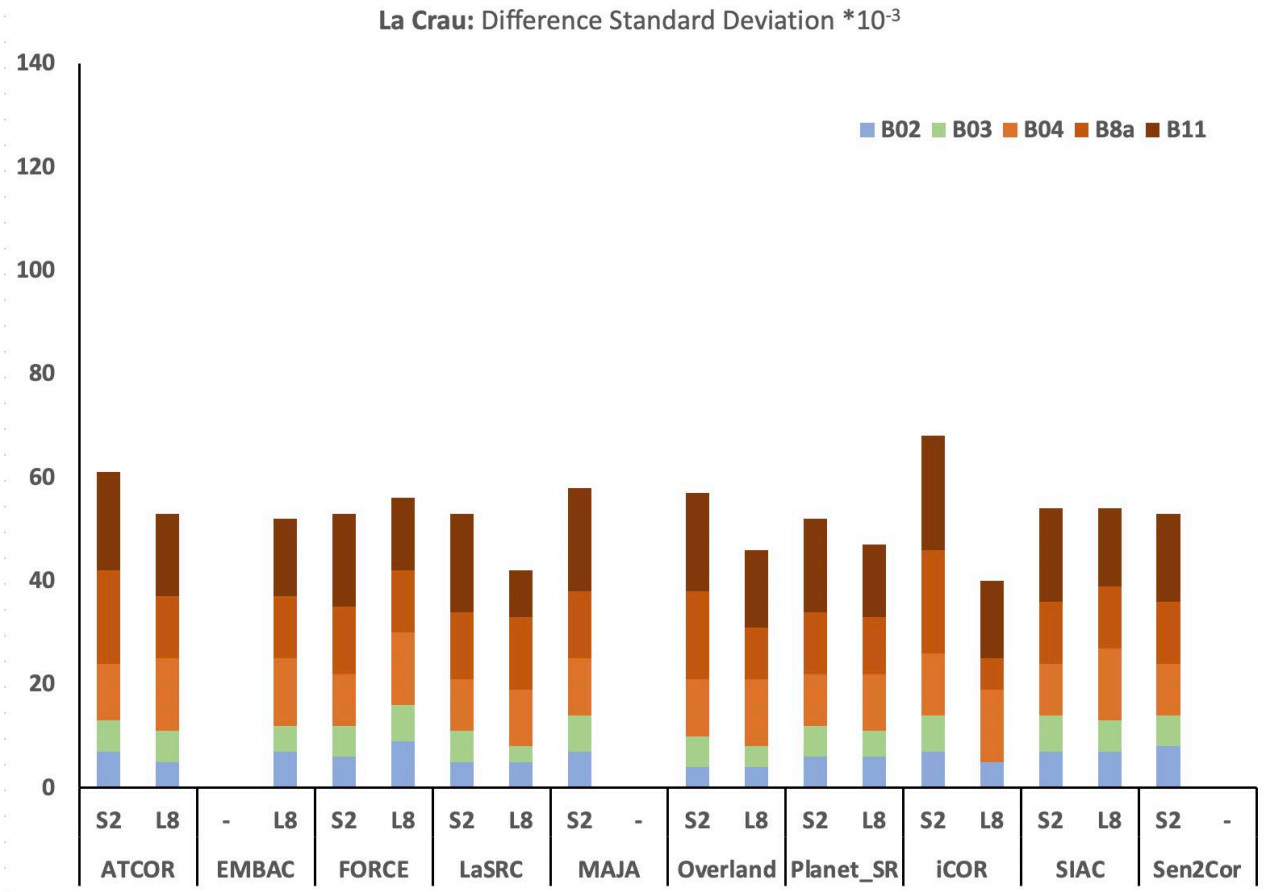


Gobabeb -> Increasing values up to B07, improving NIR and SWIR

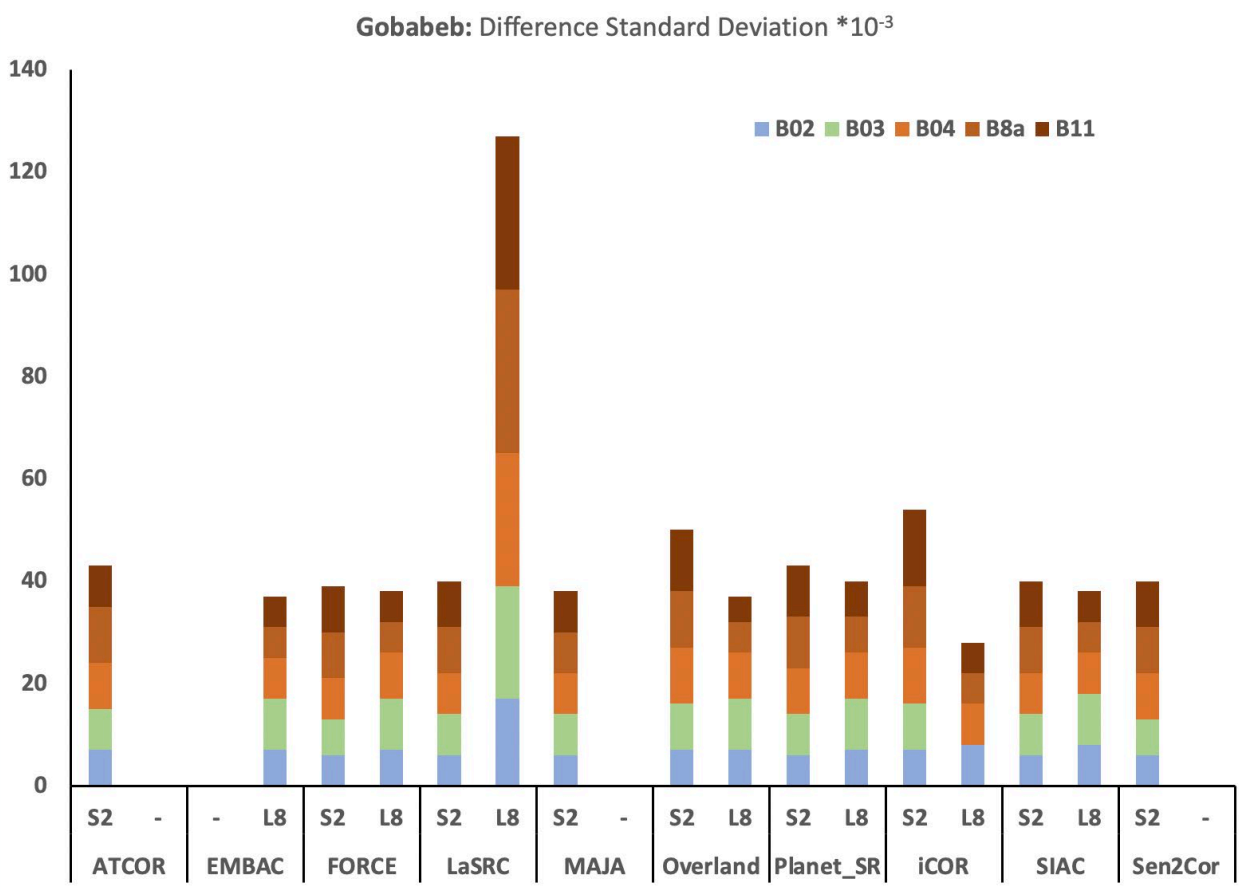
Stdv Difference
Gobabeb<0.01

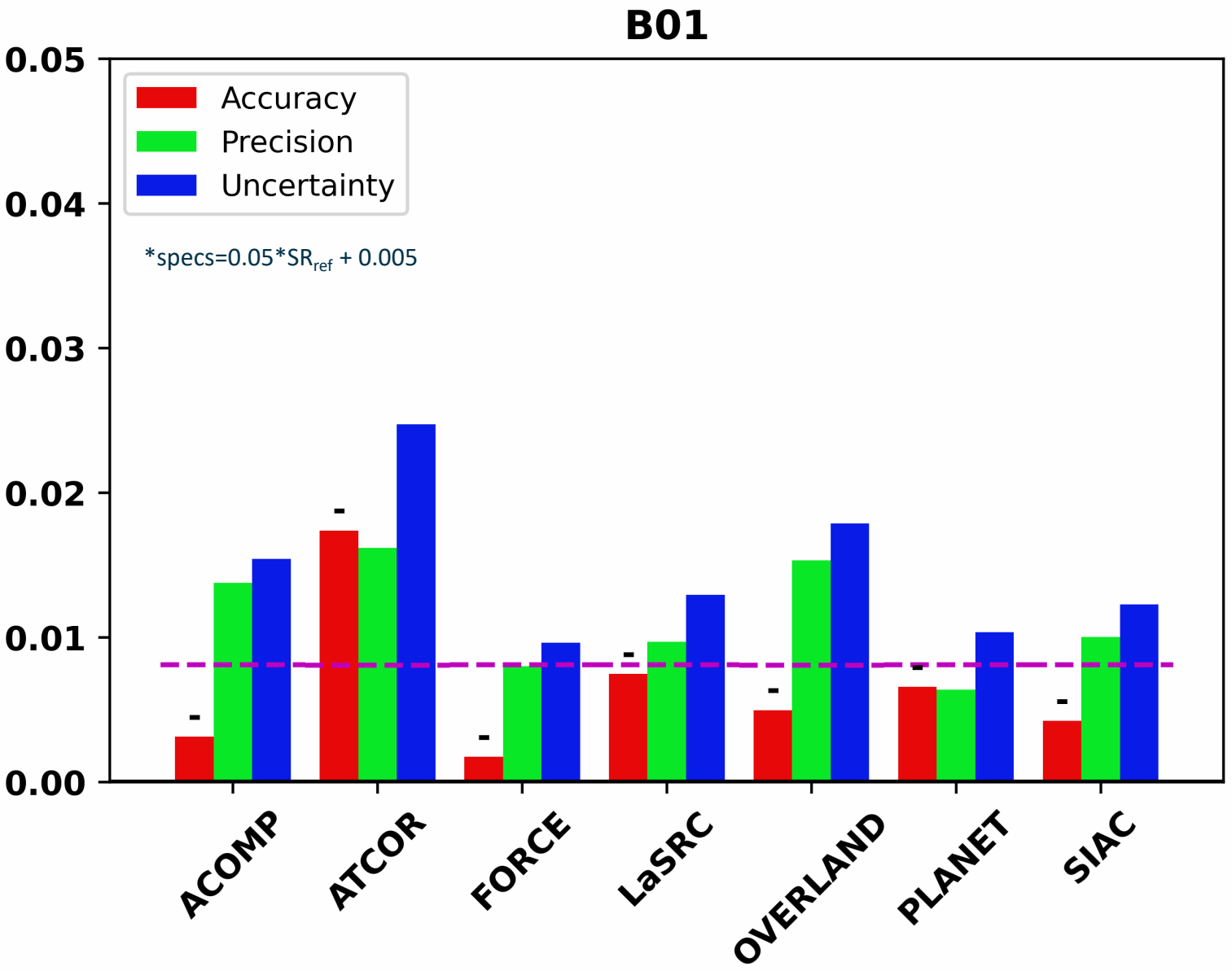
01. Ground based validation

La Crau [France]



Gobabeb [Namibia]

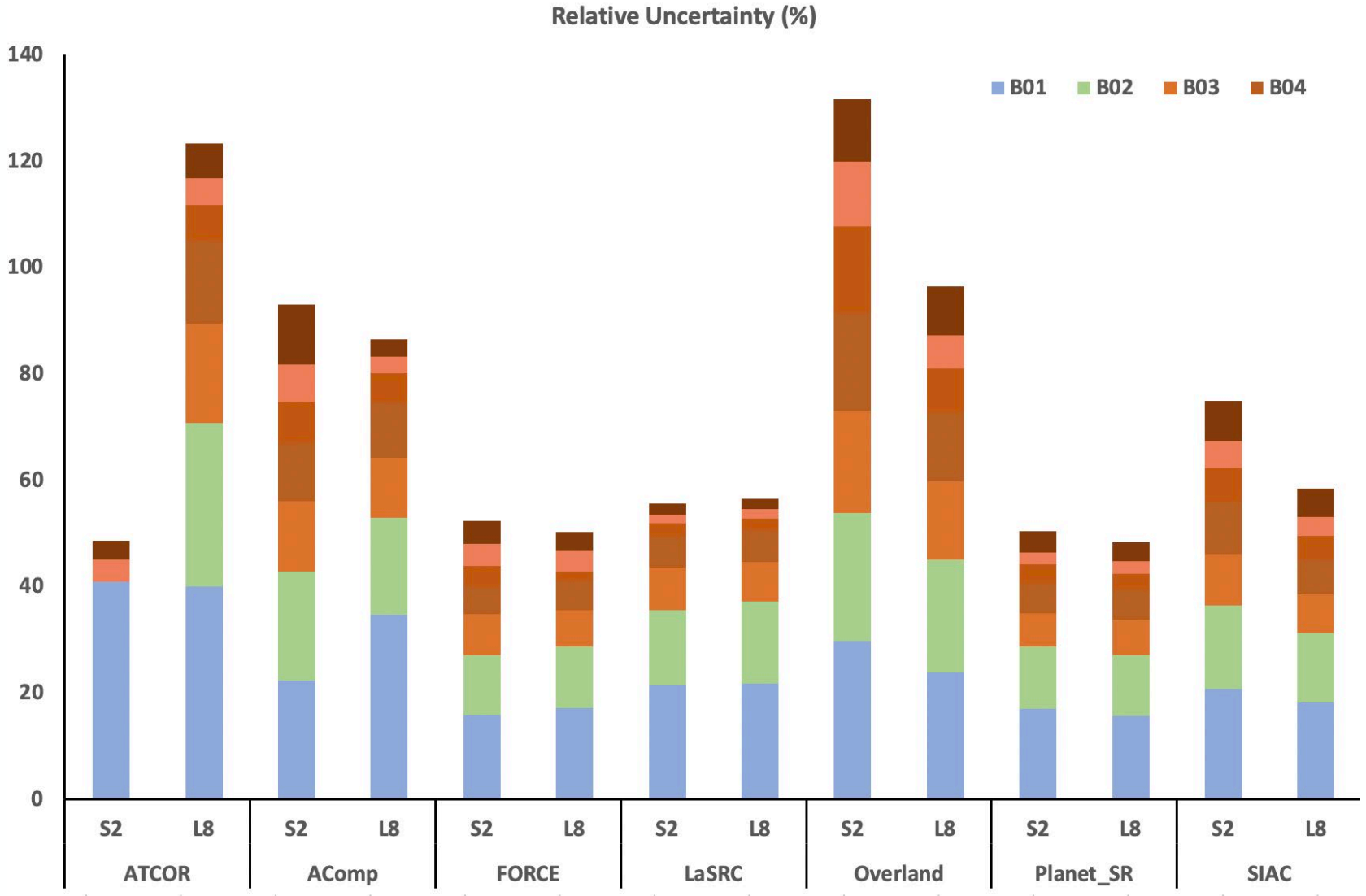




02. AERONET corrected data

- 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



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

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

--- Sentinel-2

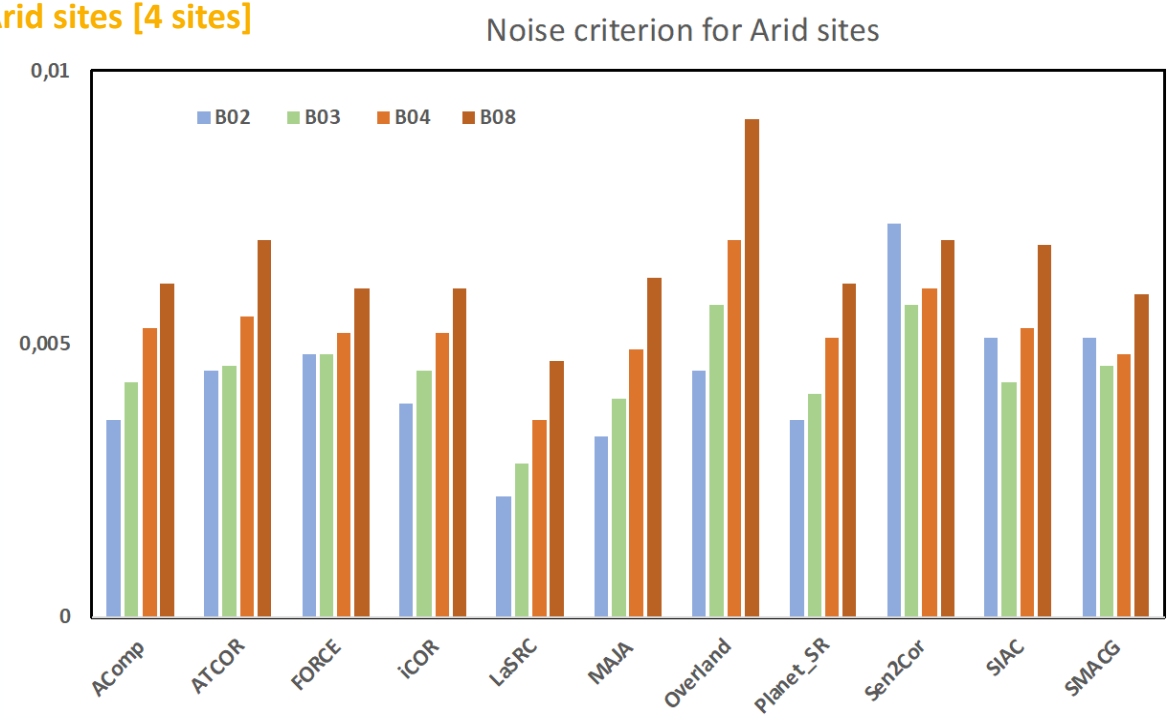
03. Noise Estimation

Only sites with >20 scenes from the same orbit

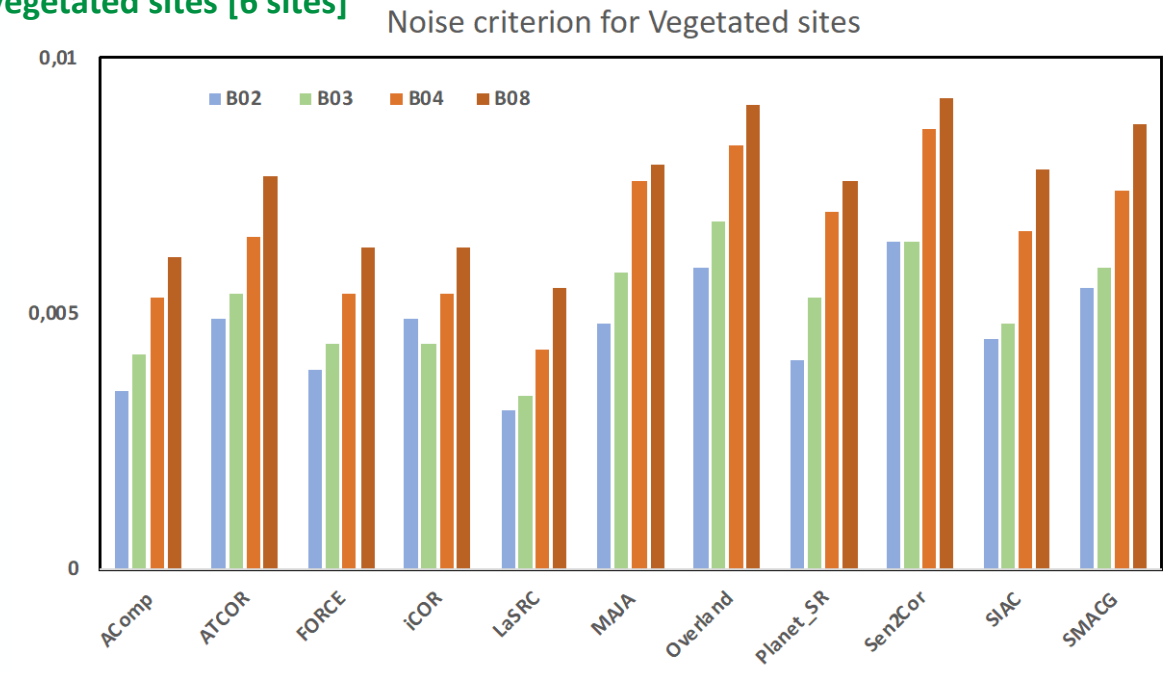
Common sites, dates and quality pixels for all processors [available masks union]

- Similar variability of SR over short time amongst al processors for both site types
- LaSRC produces the 'smoothest' time series for both site types

>> Arid sites [4 sites]



>> Vegetated sites [6 sites]



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 ~ 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

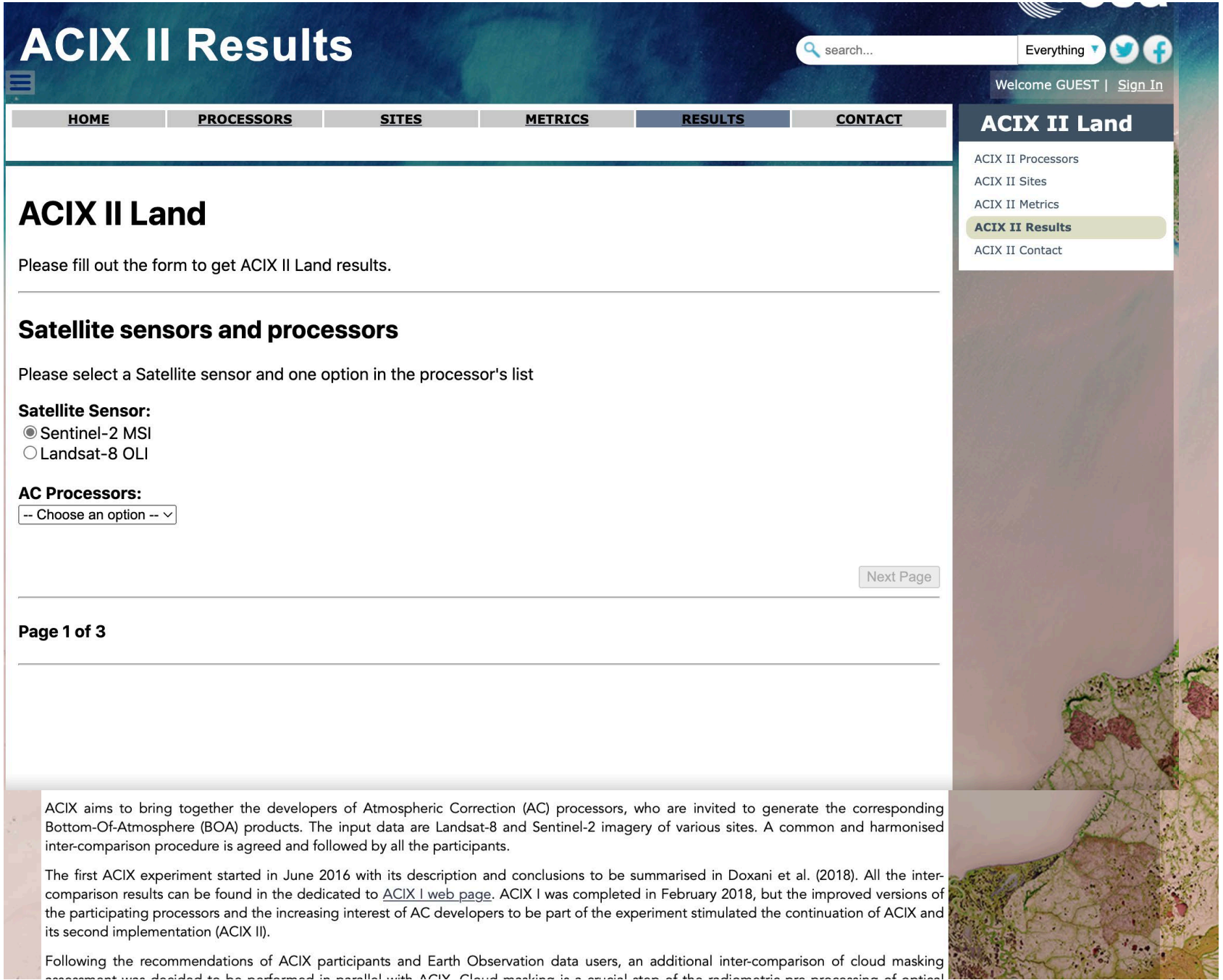
measurements and variance when compared to simulated reference

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

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



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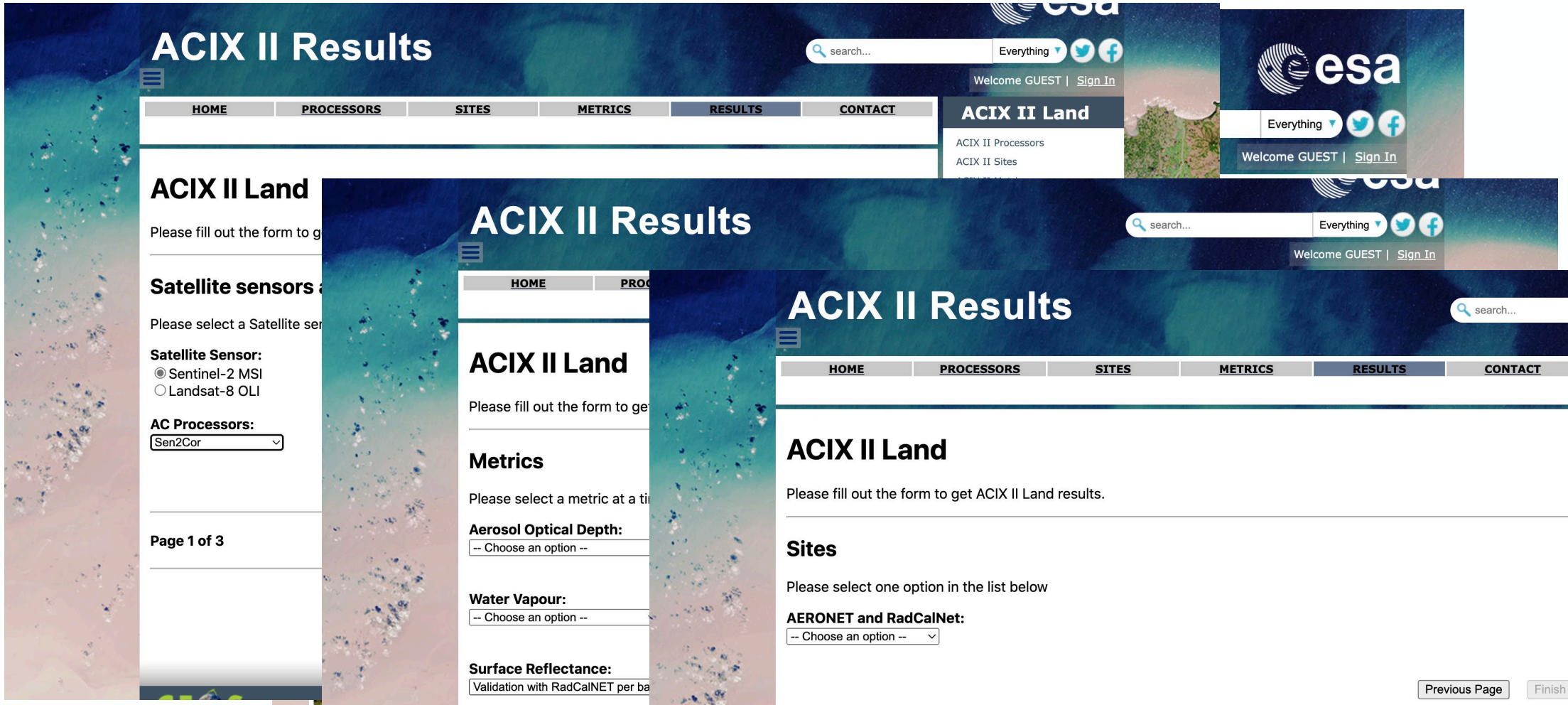
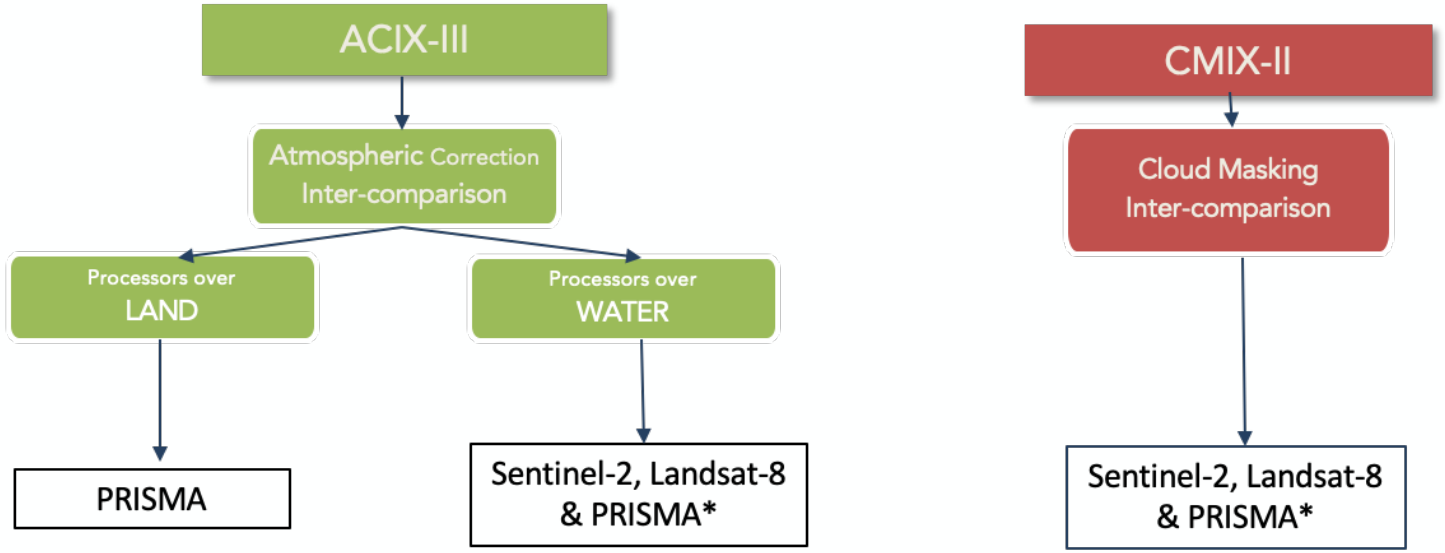


Way Forward



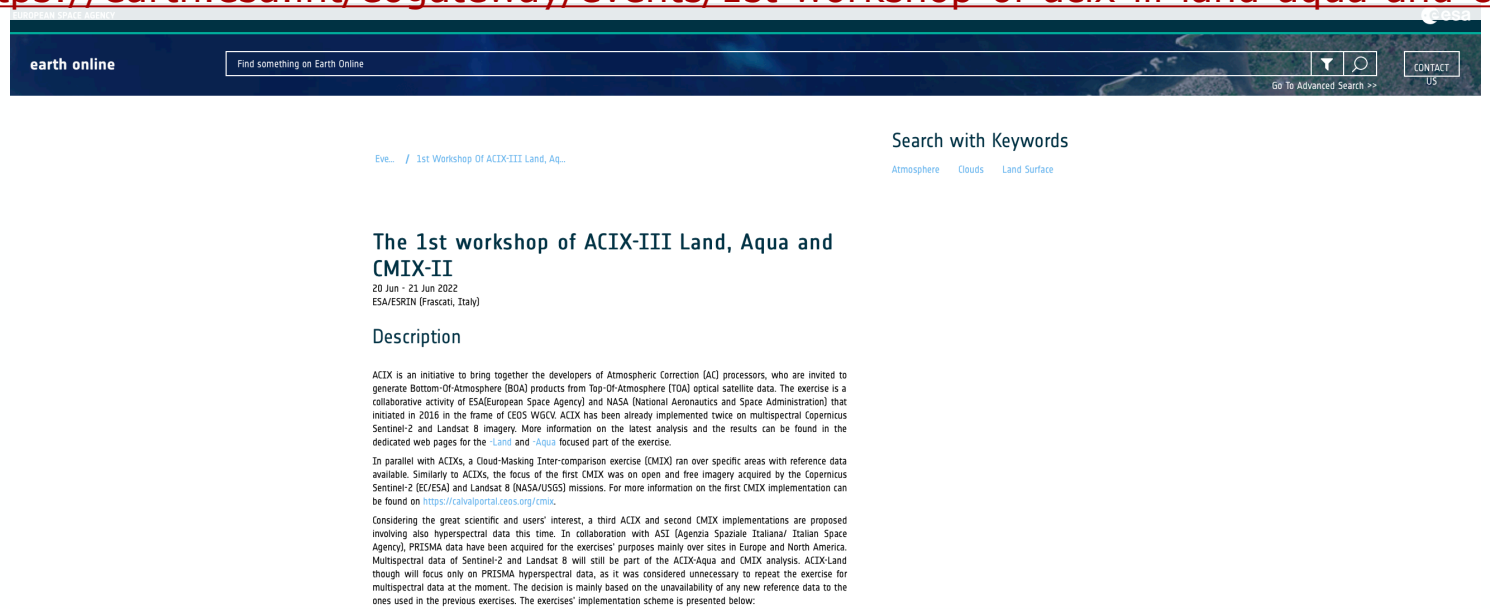
*PRISMA ad-hoc acquisitions over the selected set of sites for each of the exercises will be provided by ASI

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



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/cmix