ACIX II - CMIX

Atmospheric Correction &-
Cloud Masking
Inter-comparison eXercises

WHY?

OPEN ACCESS

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

S W
C D

The objective was to point out:

- **Strengths & Weaknesses**
- **Commonalities & Differences**

How?

12

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

19

Study Sites
spread worldwide based on the AERONET stations

200

Image Scenes
processed acquired by Sentinel-2 and Landsat-8

20

Months
to complete the exercise and publish the results in a scientific journal

How?

Definition of the inter-comparison protocol

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

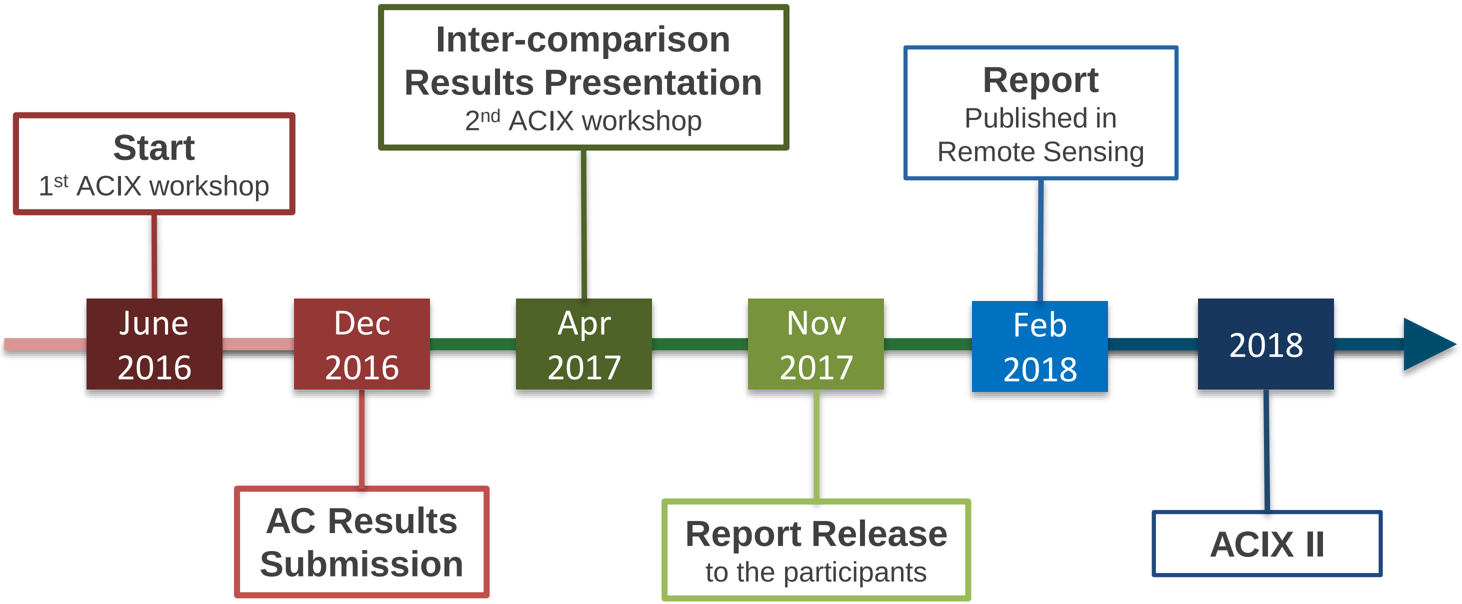
Application of the AC processors

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

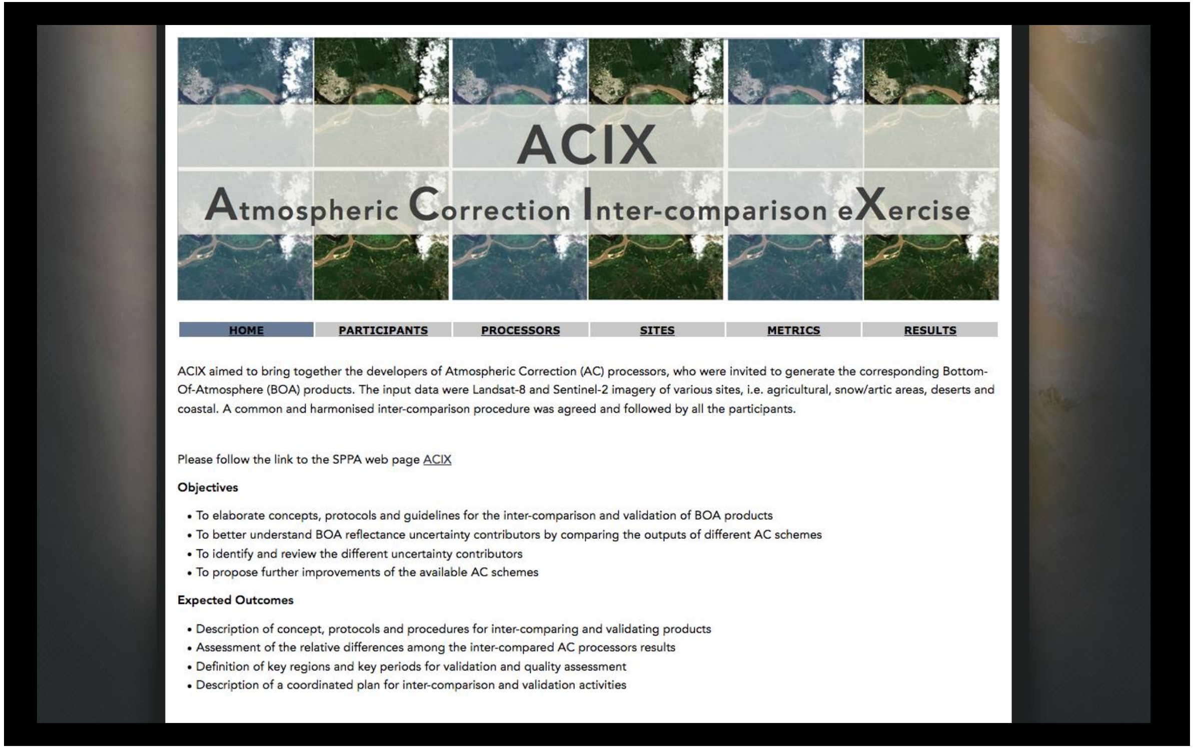
Coordinators
processed the AC results and assessed the inter-comparison metrics. The results presented and discussed with the participants.

WHEN?


Start
1st ACIX workshop
June 2016
Dec 2016
AC Results Submission
Inter-comparison Results Presentation
2nd ACIX workshop
Apr 2017
Nov 2017
Report Release
to the participants
Report
Published in Remote Sensing
Feb 2018
2018
ACIX II

Results Publication

http://calvalportal.ceos.org/projects/acix



ACIX

Atmospheric Correction Inter-comparison eXercise

HOME | PARTICIPANTS | PROCESSORS | SITES | METRICS | RESULTS

ACIX aimed to bring together the developers of Atmospheric Correction (AC) processors, who were invited to generate the corresponding Bottom-Of-Atmosphere (BOA) products. The input data were Landsat-8 and Sentinel-2 imagery of various sites, i.e. agricultural, snow/artic areas, deserts and coastal. A common and harmonised inter-comparison procedure was agreed and followed by all the participants.

Please follow the link to the SPPA web page ACIX

Objectives

- To elaborate concepts, protocols and guidelines for the inter-comparison and validation of BOA products
- To better understand BOA reflectance uncertainty contributors by comparing the outputs of different AC schemes
- To identify and review the different uncertainty contributors
- To propose further improvements of the available AC schemes

Expected Outcomes

- Description of concept, protocols and procedures for inter-comparing and validating products
- Assessment of the relative differences among the inter-compared AC processors results
- Definition of key regions and key periods for validation and quality assessment
- Description of a coordinated plan for inter-comparison and validation activities

Results Publication

https://www.mdpi.com/2072-4292/10/2/352

Doxani, G.; Vermote, E.; Roger, J.-C.; Gascon, F.; Adriaensen, S.; Frantz, D.; Hagolle, O.; Hollstein, A.; Kirches, G.; Li, F.; Louis, J.; Mangin, A.; Pahlevan, N.; Pflug, B.; Vanhellemont, Q. Atmospheric Correction Inter-Comparison Exercise. *Remote Sens*. **2018**, 10, 352

remote sensing MDPI

Article

Atmospheric Correction Inter-Comparison Exercise

Georgia Doxani [1,*], Eric Vermote [2,*], Jean-Claude Roger [2,3], Ferran Gascon [4], Stefan Adriaensen [5], David Frantz [6,†], Olivier Hagolle [7], André Hollstein [8], Grit Kirches [9], Fuqin Li [10], Jérôme Louis [11], Antoine Mangin [12], Nima Pahlevan [2,13], Bringfried Pflug [14] and Quinten Vanhellemont [15]

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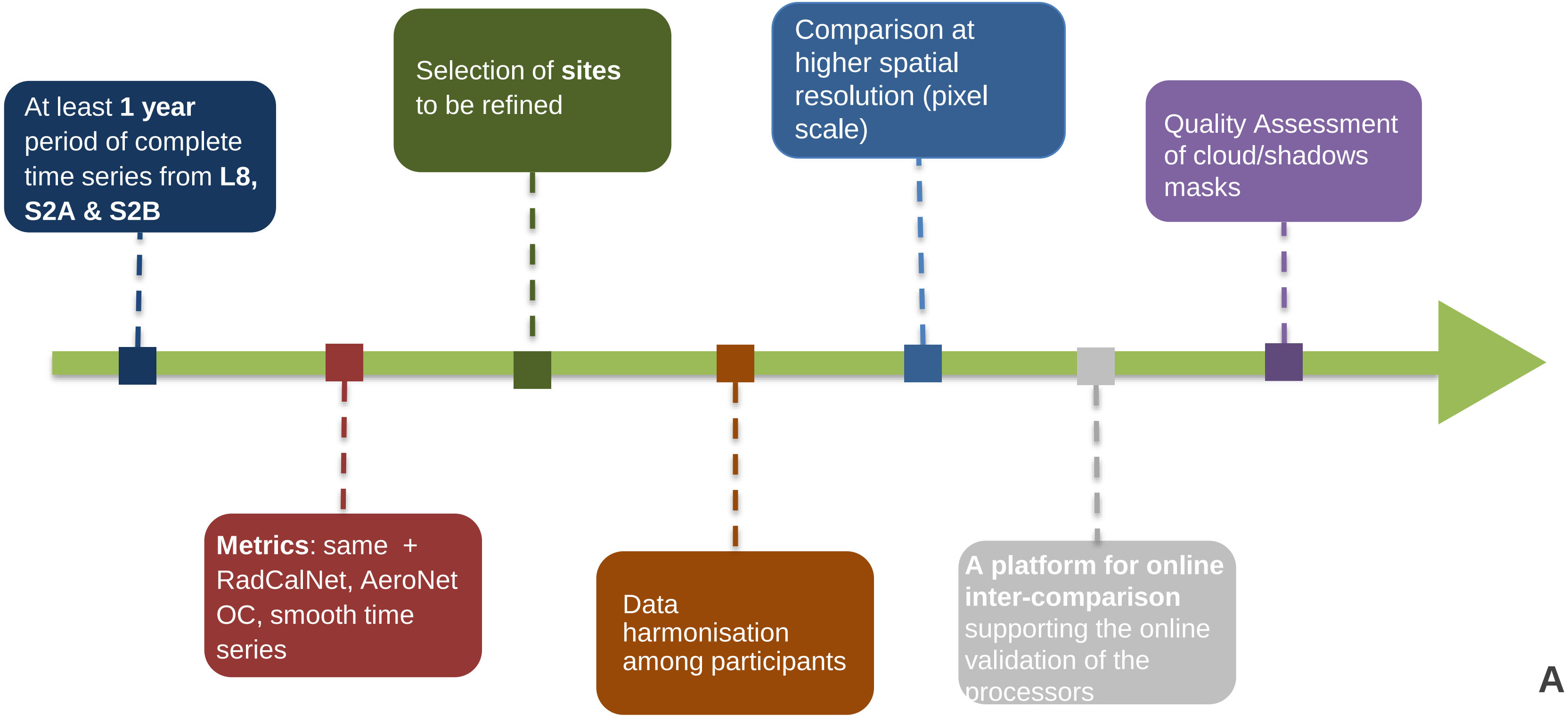
Abstract: The Atmospheric Correction Inter-comparison eXercise (ACIX) is an international initiative with the aim to analyse the Surface Reflectance (SR) products of various state-of-the-art atmospheric correction (AC) processors. The Aerosol Optical Thickness (AOT) and Water Vapour (WV) are also examined in ACIX as additional outputs of AC processing. In this paper, the general ACIX framework is discussed; special mention is made of the motivation to initiate the experiment, the inter-comparison protocol, and the principal results. ACIX is free and open and every developer was welcome to participate. Eventually, 12 participants applied their approaches to various Landsat-8 and Sentinel-2 image datasets acquired over sites around the world. The current results diverge depending on the sensors, products, and sites, indicating their strengths and weaknesses. Indeed, this first implementation of processor inter-comparison was proven to be a good lesson for the developers to learn the advantages and limitations of their approaches. Various algorithm improvements are expected, if not already implemented, and the enhanced performances are yet to be assessed in future ACIX experiments.

Remote Sens. 2018, *10*, 352; doi:10.3390/rs10020352 www.mdpi.com/journal/remotesensing

WAY FORWARD



At least **1 year** period of complete time series from **L8, S2A & S2B**
Metrics: same + RadCalNet, AeroNet OC, smooth time series
Selection of **sites** to be refined
Data harmonisation among participants
Comparison at higher spatial resolution (pixel scale)
A platform for online inter-comparison supporting the online validation of the processors
Quality Assessment of cloud/shadows masks

WAY FORWARD

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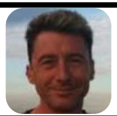
esa

Ferran Gascon

Georgia Doxani

NASA



Eric Vermote

Jean-Claude Roger

Atmospheric Correction Inter-comparison

Processors over LAND

Processors over WATER

Task Co-ordinators

esa

Antoine Mangin

NASA

Nima Pahlevan

Cloud Masking Inter-comparison

Task Co-ordinators

esa

Carsten Brockmann

NASA

Sergii Skakun

How?

Definition of the inter-comparison protocol → **Application of the AC processors** → **Analysis of the results**

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

Participants
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CMIX

ACIX-
Land

ACIX-
Aqua

How?

9

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

5

Validation Datasets
L8Biome (USGS),
S2 Hollstein,
S2/L8 PixBox,
GSFC: LC8/S2A/S2B,
CESBIO

300

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

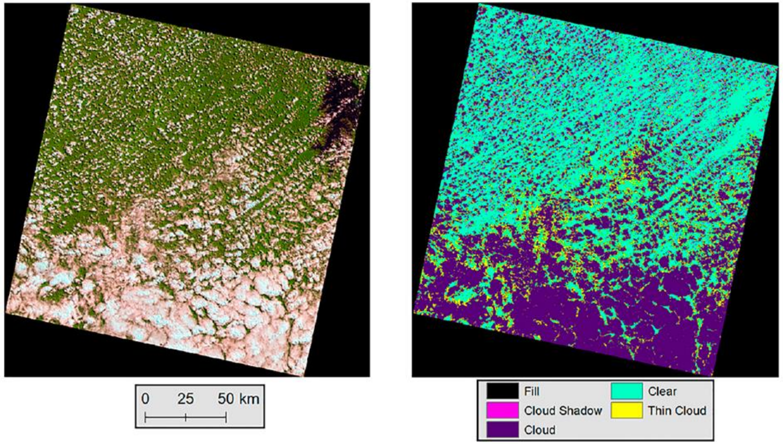
7

Months
for participants/ coordinators to submit/analyse results

How?

L8Biome (Foga et al. 2016)

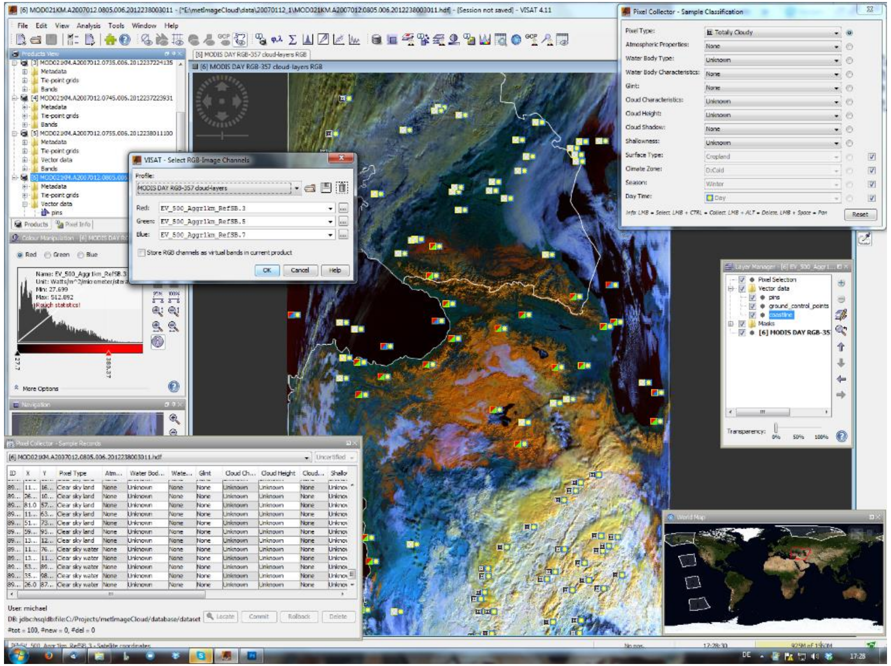
- 96 LC8 scenes, semi-random sampling with Biome stratification
- Photo-interpretation with See5.0
- All pixels are labelled (clear, cloud, cloud shadow, thin cloud)



How?

S2/L8: PixBox data set

- Database to store manually classified pixels.
- Pixel collection supported by dedicated SNAP tool.
- L8 collection: 11 products
- S2 collection: 29 products

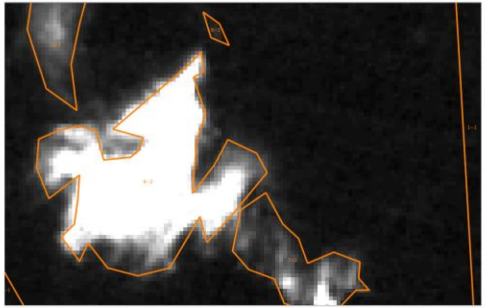


How?

GSFC: LC8/S2A/S2B

- Around 25 scenes labelled.
- Manually labeled polygons assisted by ground photos of sky.
- The same area over GSFC (also Aeronet measurements available), but varying conditions and time period.





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How?

S2 (Hollstein et al. 2016)

- 108 Sentinel-2 scenes
- Photointerpretation
- Selected polygons are labeled manually
- Classes: *clear sky, cloud, cloud shadow, cirrus, water, snow*

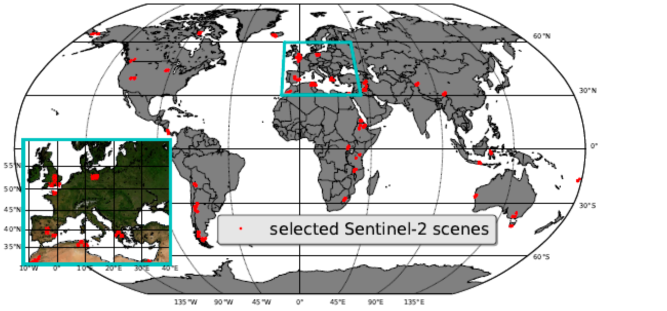
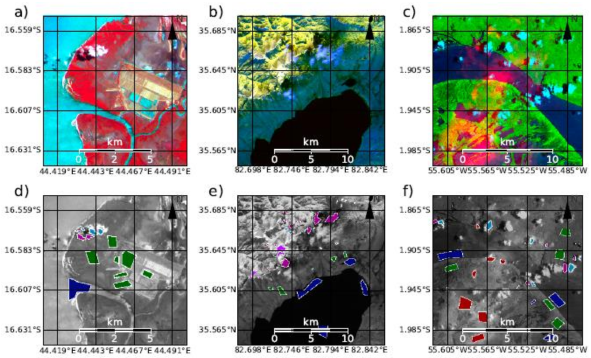


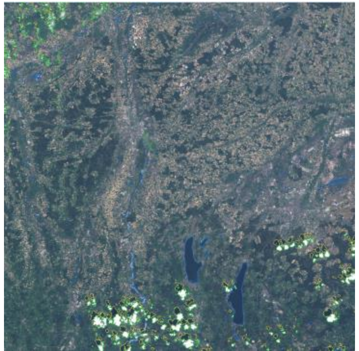
Figure 2. Global distribution of selected Sentinel-2 scenes which are included in the database.

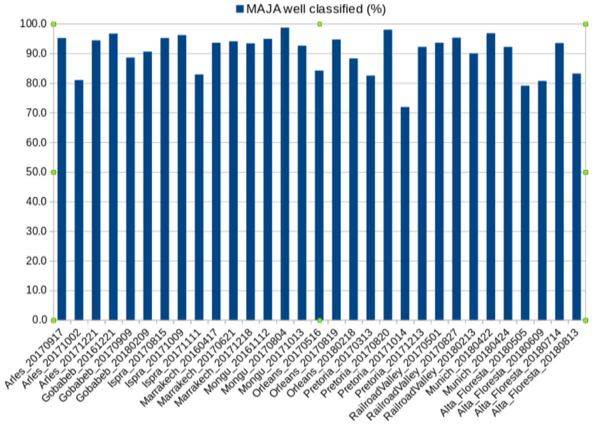


How?

CESBIO

- 31 fully classified images using active learning method (Active Learning for Cloud Detection)
  - Manually supervised and iterative
  - Manual reference points added where first iterations not satisfying
  - Valid/Invalid pixels (an invisible cloud except in cirrus band is valid)
- Data and software are available, can be used to generate reference for ACIX-2 scenes
  - Would save processing for users
  - <2 hours of work per image





How?

IDEALLY

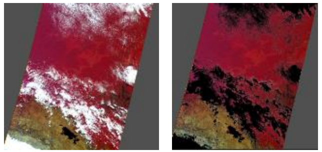
we would get a physical measure like cloud optical thickness or “impact on reflectance“, spectrally resolved

REALISTICALLY

we follow the ‘traditional‘ approach:
CM as an absolute indication on cloudiness

Binary mask for different levels of cloudy/ clear:
proposed classes: Clear, Cloud, Cloud shadows, Thin/(semi)-transparent

RGB | Cloud Mask

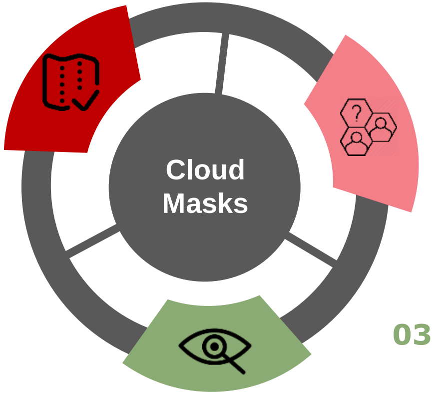


How?

01. Per pixel validation

Confusion matrix & OA, PA, UA

Class	Clear	Cloud	Cloud Shadow	Thin/(semi)-transparent	Row Total	UA
Clear						
Cloud						
Cloud Shadow						
Thin/(semi)-transparent						
Column Total						
PA						OA



02. Per object validation

Oversegmentation, undersegmentation, edge-location, fragmentation and shape

03. Visual inspection

potentially study an impact on SR, especially with transparent/cirrus clouds

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How?

13

Developer Teams
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126

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

6500

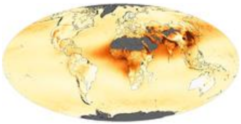
Image Scenes
to be processed acquired by Sentinel-2A, -2B and Landsat-8

7

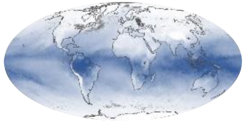
Months
for participants/ coordinators to submit/analyse results

ACIX-Land

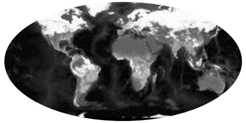
WHAT?



Aerosol Optical Depth



Water Vapour



Surface Reflectance

ACIX-Land

How?

Estimated AOD(/WV) vs AERONET measurements

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 AOD values over an image subset of 9 km x 9 km centred on the AERONET Sunphotometer station

Statistics and Plots

No. of samples

R^2 (Coefficient variation)

r (Pearson's correlation coef.)

A (Accuracy)

P (Precision)

U (Uncertainty)

Max AOT_{550} difference

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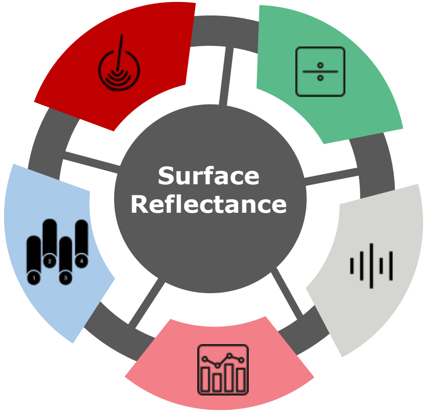
How?



01. Ground based validation

RadCalNet [La Crau (France), Gobabeb (Namibia)], SR are provided by CNES in the same angular conditions as L-8, S-2A & -2B

02. Indices

NDVI, NDWI and EVI based on the SR products. Similar directional effects are in the visible and near infrared bands, and therefore by estimating their ratio the effect is reduced.

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. AERONET corrected data

AC data generated by 6S 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.

05. SR inter-comparison

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

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How?

9

Developer Teams
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15

In-situ data Providers
Together with
≅ 20 AERONET OC sites

4400

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

7

Months
for participants/ coordinators to submit/analyse results

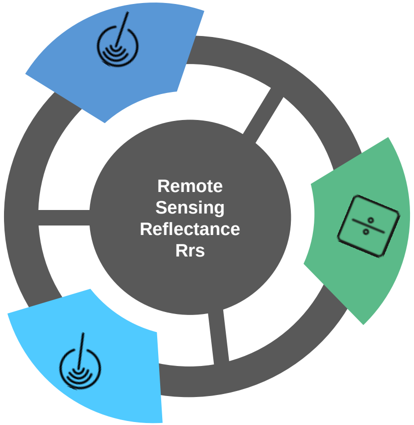
ACIX-Aqua

How?

01. Validation with AERONET-OC Rrs (Phase I)

Match-up Analyses (N ~ 1200)

- Time-diff threshold: +/1 hour
- Avoid adjacency effects due to the structure
- Band shifting/adjustment needed



02. Validation with field-based Rrs (Phase II)

Match-up Analyses (N ~ 3200)

- Time-diff threshold: Variable
- Resample hyperspectral data

03. Performance metrics

- Measures for Rrs reported as a function of site characteristics (e.g., water types, solar zenith angles):
  - Mean/Median percentage difference
  - Mean/Median absolute difference
  - RMSE / NRMSE, R^2, Linear regression,
  - Accounting for negative retrievals
- Measures for Rrs: reported for a subset of high-fidelity in situ data, i.e., AERONET-OC, in-water field radiometric data within < +/-30min overpass, above-water radiometric data collected under clear skies within < +/-30min overpass and, the entire dataset (excluding suspicious data and/or outliers)
- Spider/Taylor diagram to report the overall performance of each processor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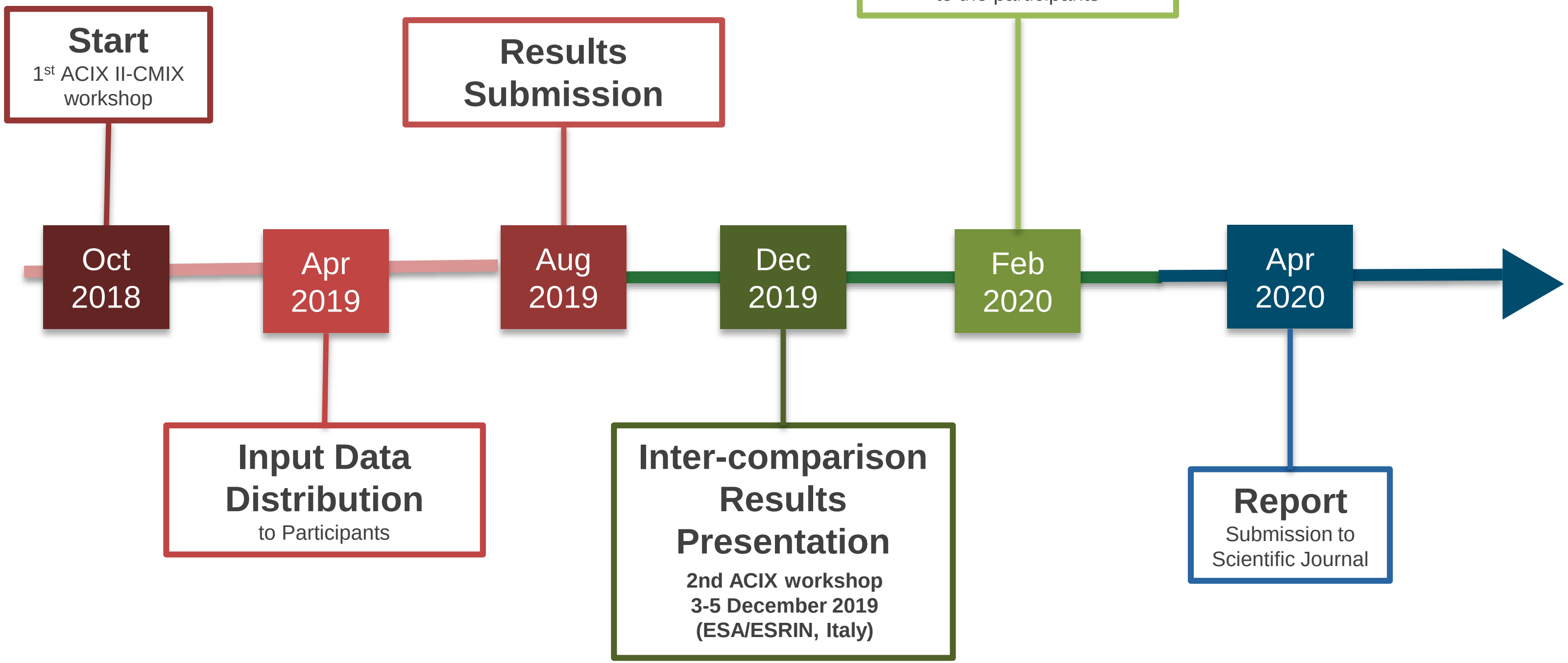
WHEN?


Start
1st ACIX II-CMIX workshop
Oct 2018
Apr 2019
Input Data Distribution
to Participants
Results Submission
Aug 2019
Dec 2019
Inter-comparison Results Presentation
2nd ACIX workshop
3-5 December 2019
(ESA/ESRIN, Italy)
Report Release
to the participants
Feb 2020
Apr 2020
Report
Submission to Scientific Journal

Thank you!

https://earth.esa.int/web/sppa/meetings-workshops/hosted-and-co-sponsored-meetings/acix-ii-cmix-2nd-ws