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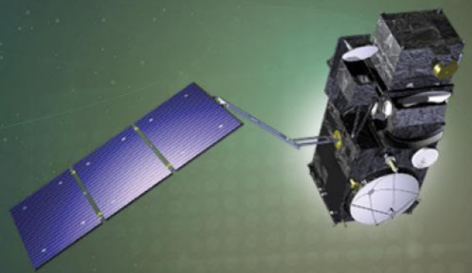


7th Sentinel-3 Validation Team Meeting 2022

18-20 October 2022 | ESA-ESRIN | Frascati (Rm), Italy

A new (validation) approach for systematic monitoring of the Sentinel-3 OLCI cloud mask using low-cost sky cameras

Jan Wevers[1], C. Brockmann[1], J. Scholze[1], A. Santamaria-Artigas[2], S. Skakun[2], E. Vermote[3], F. Niro[4]

[1] Brockmann Consult GmbH, [2] University of Maryland College Park, [3] NASA Goddard Space Flight Center, [4] SERCO c/o ESA-ESRIN

Overview of the talk

- Background
- Objective/Overview
- Validation site and methods preparation
- Validation results
- Current limitations & network extension
- Conclusion

Background

- Validation of satellite-based cloud masks is commonly done by the algorithm developers themselves.
    - ➢Non-independent validation
- A few attempts have been made to objectively inter-compare performances of satellite-based cloud masking algorithms (e.g., Skakun et al. 2021, Zekoll et al. 2021, Tarrio et al. 2020, Hammersson Sanchez et al. 2020, Chi & Zhang 2020).
- All these validations/inter-comparisons are based on different datasets, leading to variable results even if the same algorithm is analyzed.
    - This was shown during the Cloud Mask Intercomparison eXercise (CMIX)
- Most validation datasets are sensor dependent and don’t allow cross-sensor validation of multi-sensor cloud detection algorithms.
- No validation dataset allows for operational constant QC of cloud mask performance.

Goal: An independent validation source for cloud masking algorithms is needed, which is sensor independent and allows operational QC usage

Objective / Overview

- Objective: Define a standard (objective) method to monitor and validate the OLCI Level 2 cloud masking within the Optical Mission Performance Centre (OPT-MPC). To guarantee constant quality of the cloud screening and to provide quality indicators for routine quality assessment (QA).

- Work presented here started in the frame of ESA's Quality assurance framework for earth observation (QA4EO).
  - The objective was to analyse the usage of ground-based sky cameras (SC), as an independent validation source for satellite cloud masking algorithms.
  - The scope of this work was to prototype algorithms and methods to process sky camera data and compare them with satellite-based cloud masks.
  - A successful prototype was developed and tested based on Sentinel-2; Results presented at ESA's Living Planet.
  - Results are documented here: https://doi.org/10.5281/zenodo.6626712 and https://doi.org/10.5281/zenodo.6626802

- In the context of QA4EO and OPT-MPC the approach was adapted to be used with Sentinel-3 OLCI L2 data

Validation site and methods preparation

Instrumentation setup

- A set of two cameras (stereo pair) was setup at La Sapienza University in Rome.
- The cameras use a F
  Omnivision OV564
  view is 194 (horizo
  Distance between
  meters. Currently
  collecting data every minute between 08:00 and 14:00 UTC.
- Sky camera two (Fermi) is located approx. 20m apart from the ceilometer (RAP)
  - comparisons between the RAP and SC based cloud detection

Sky cameras are developed by University of Maryland & NASA

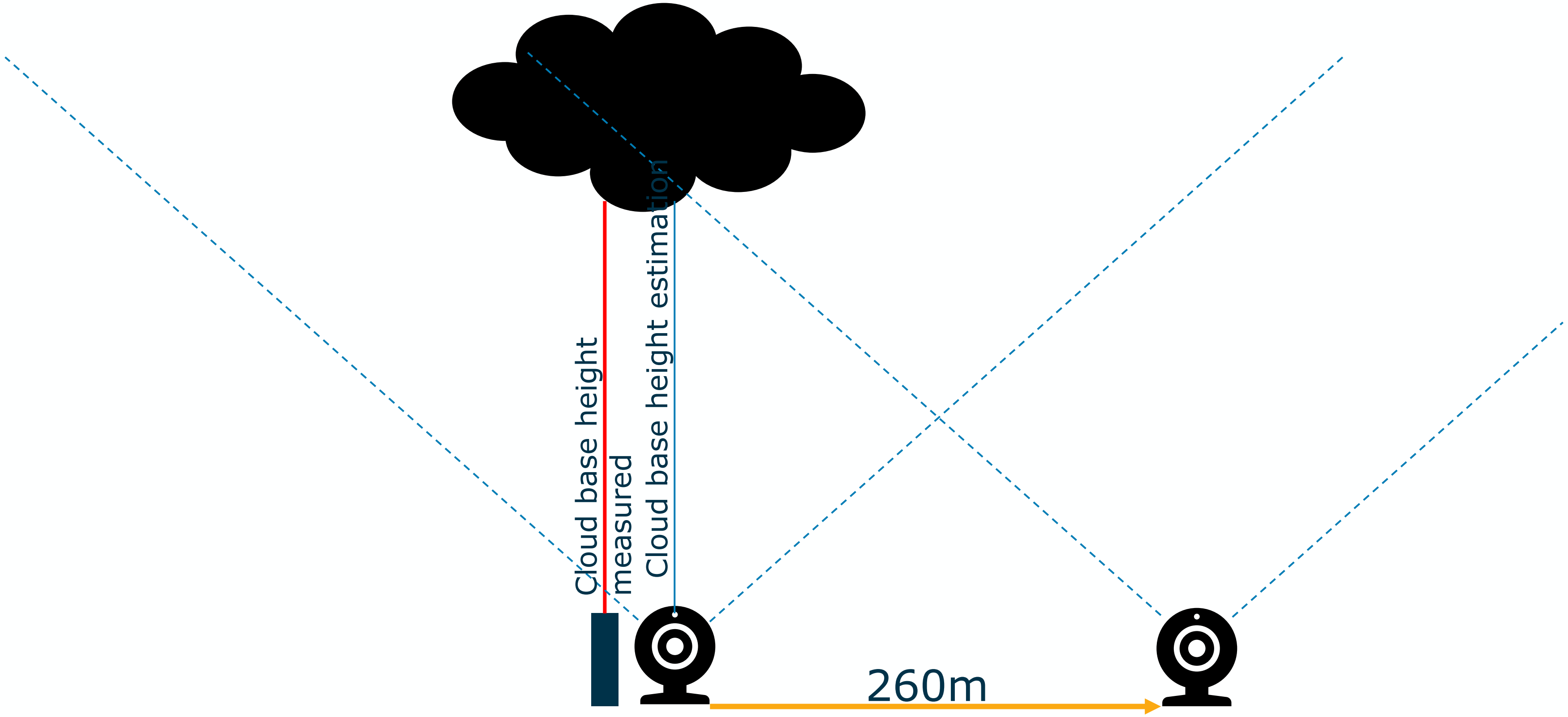
Skakun, S., Vermote, E. F., Santamaria-Artigas, A., Rountree, W. H., & Roger, J. C. (2021). An experimental sky-image-derived cloud validation dataset for Sentinel-2 and Landsat 8 satellites over NASA GSFC. International Journal of Applied Earth Observation and Geoinformation, 95, 102253.


amera 1: Marconi


Sky Camera 2: Fermi

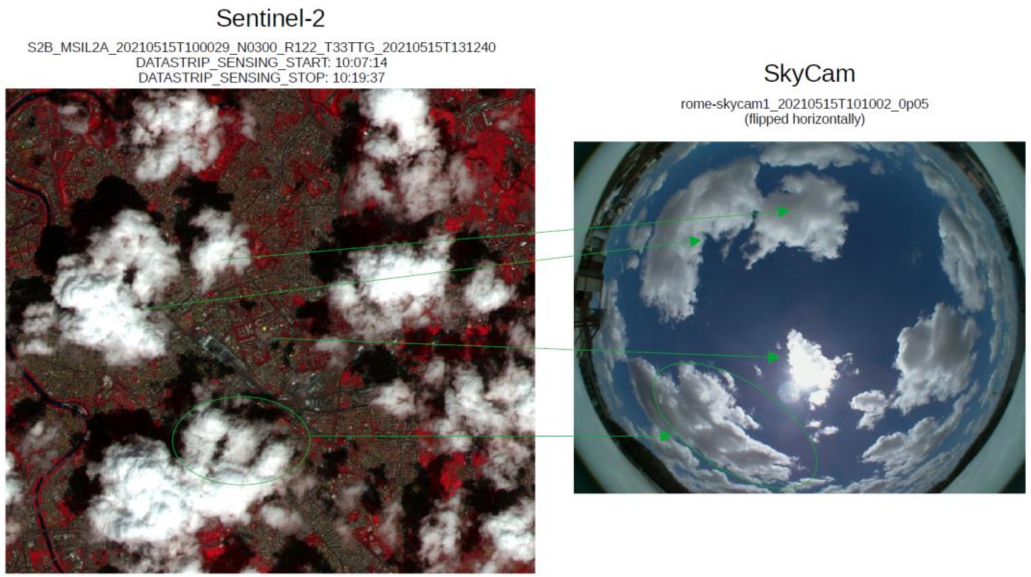

Raymetrics Aerosol Profiler (RAP)

SkyCam and RAP setup @La Sapienza

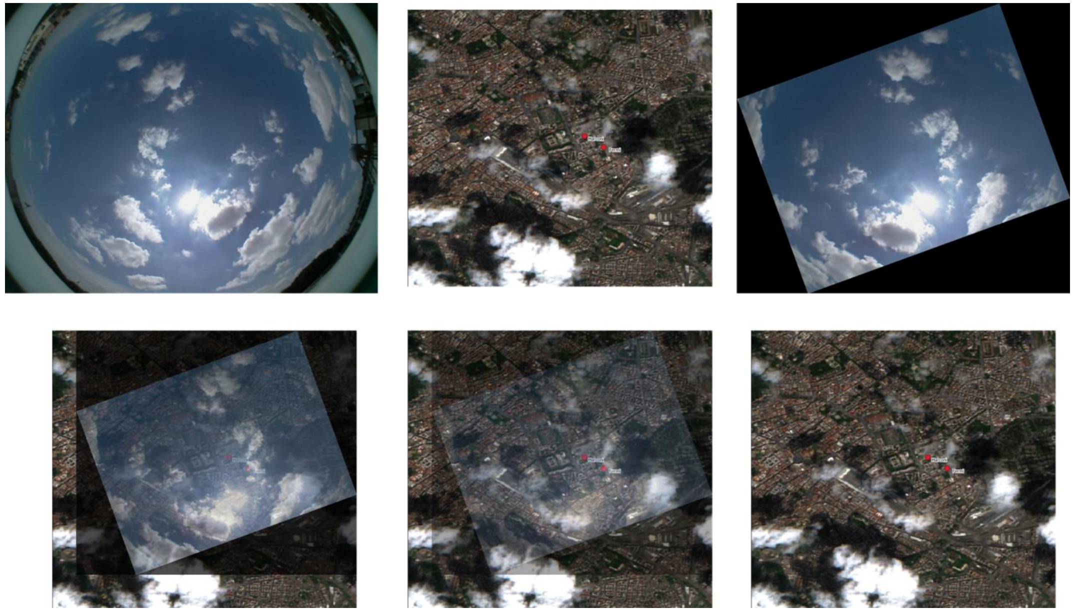


Pre-processing of sky camera data to better match the satellite observations

- Crop: Reduce geometric distortion (increasing outside of the center).
- Rotate: The SCs are installed looking a bit northwest.
- Flip: The SC is looking from the ground up and the satellite does the opposite.


Sentinel-2
S2B_MSIL2A_20210515T100029_N0300_R122_T33TTG_20210515T131240
DATASTRIP_SENSING_START: 10:07:14
DATASTRIP_SENSING_STOP: 10:19:37

SkyCam
rome-skycam1_20210515T101002_0p05
(flipped horizontally)



Example comparing SC with Sentinel-2 data for better understanding of spatial relationships

Finding an appropriate classification method

- A few methods have been tested that have not led to required accuracies.
    - Simple threshol
    - Otsu thresholdi
    - Otsu thresholdi
    - Implementing a ages to improve the resu
    - Brightness inde

- Training of a random
    - 12 to 15 SC ima
    - Polygons repres images.
    - Inside these pol
    - Overall, 11,100 samples for SC1 and 27,300 samples for SC 2 have been collected.

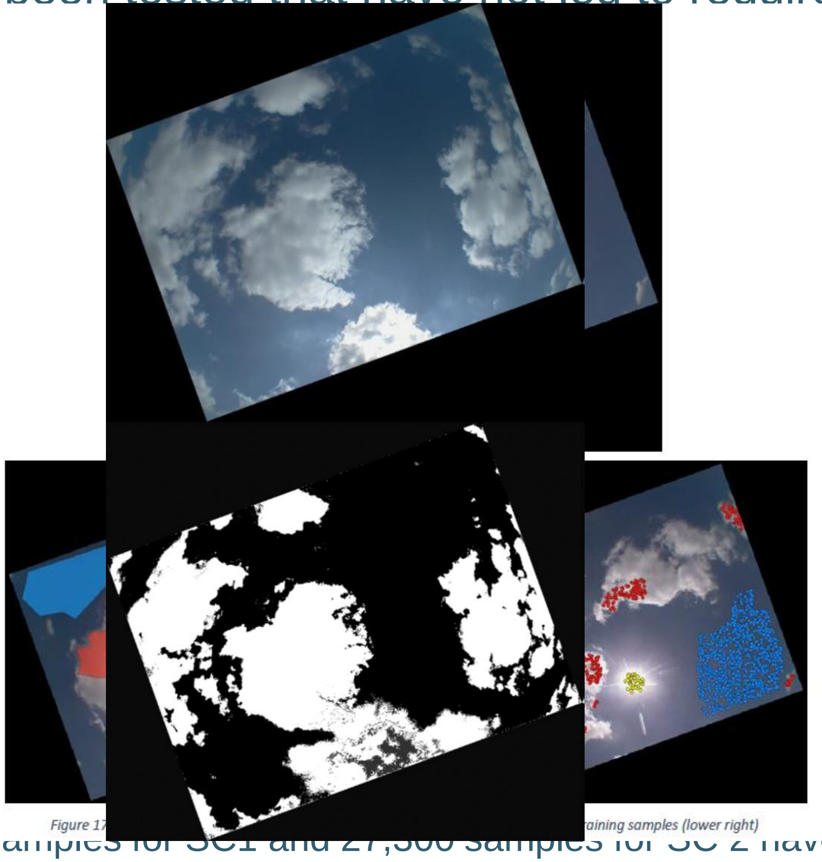


Figure 17 raining samples (lower right)

Figure 14: SC 1 image 26.03.2021

Figure 15: Classification using Otsu threshold after Gaussian filtering

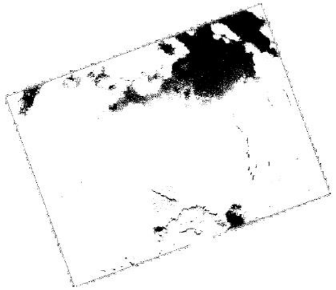
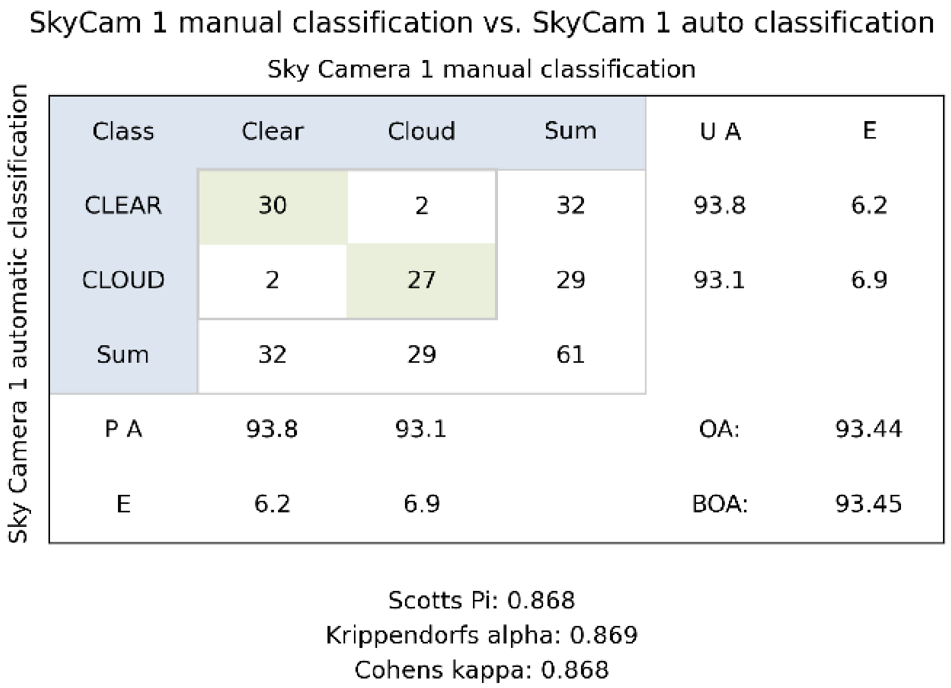


Figure 16: Classification using BI SI method from Letu et al. 2014

Validation results for the RF classifier

- Validation of the RF classifier shows high accuracy (93-96% OA)



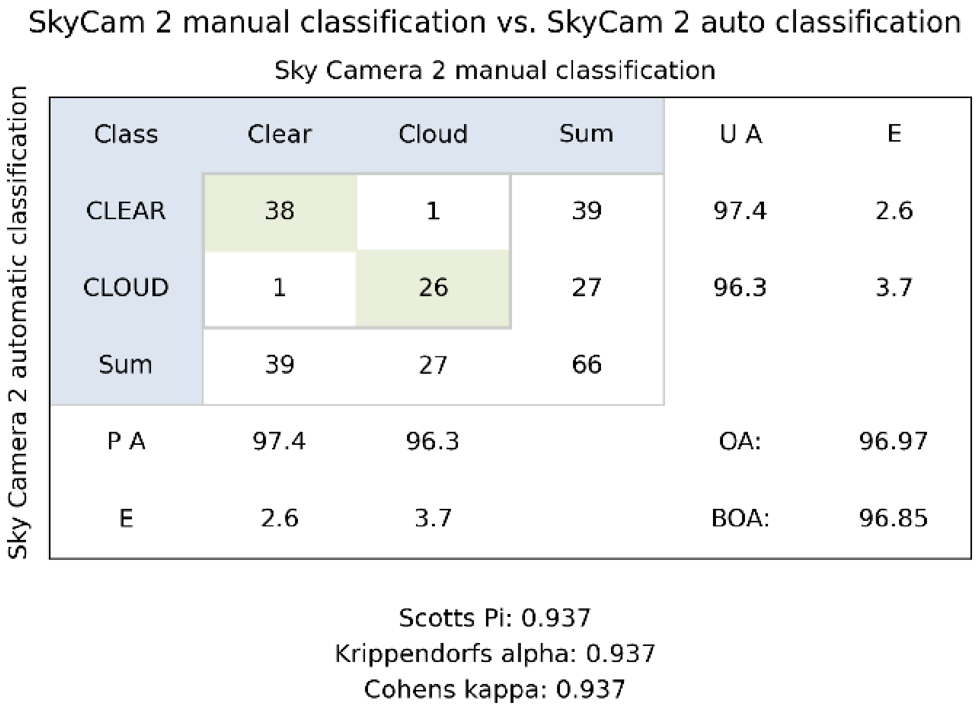
SkyCam 1 manual classification vs. SkyCam 1 auto classification

Sky Camera 1 manual classification

Sky Camera 1 automatic classification

Class	Clear	Cloud	Sum	U A	E
CLEAR	30	2	32	93.8	6.2
CLOUD	2	27	29	93.1	6.9
Sum	32	29	61		
P A	93.8	93.1		OA:	93.44
E	6.2	6.9		BOA:	93.45

Scotts Pi: 0.868
Krippendorfs alpha: 0.869
Cohens kappa: 0.868



SkyCam 2 manual classification vs. SkyCam 2 auto classification

Sky Camera 2 manual classification

Sky Camera 2 automatic classification

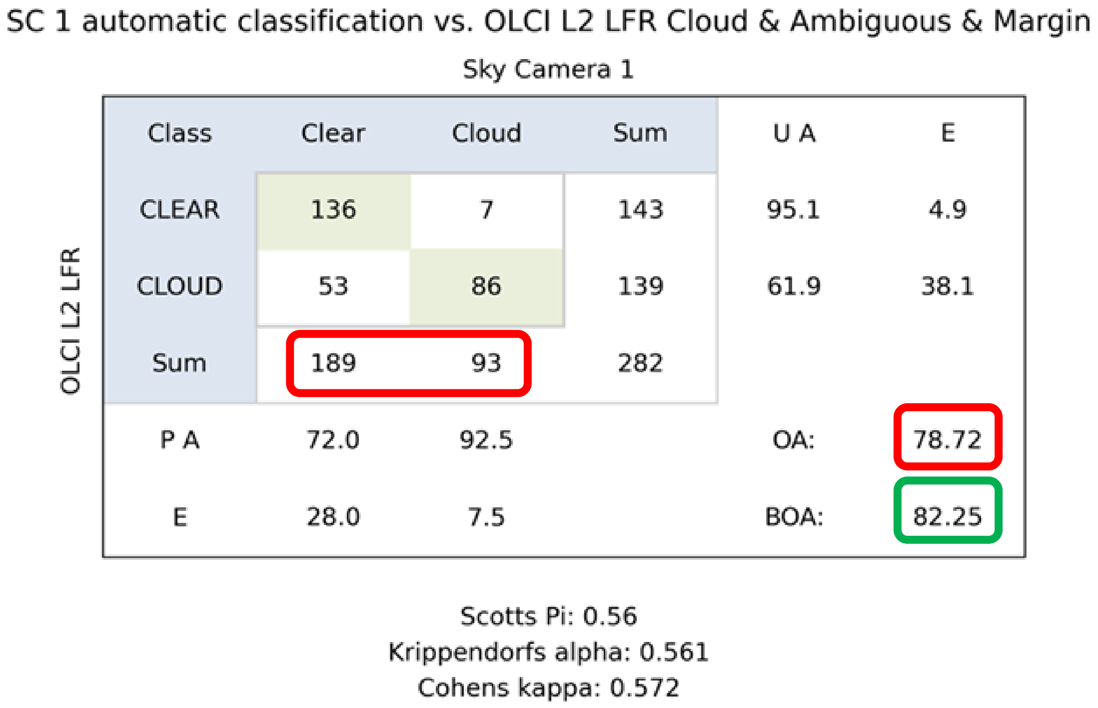
Class	Clear	Cloud	Sum	U A	E
CLEAR	38	1	39	97.4	2.6
CLOUD	1	26	27	96.3	3.7
Sum	39	27	66		
P A	97.4	96.3		OA:	96.97
E	2.6	3.7		BOA:	96.85

Scotts Pi: 0.937
Krippendorfs alpha: 0.937
Cohens kappa: 0.937

Test validation for OLCI – automatic SC classification

- Sentinel-3 OLCI results between 01.01.2021 and 31.12.2021
- 282 matchups
- 1 OLCI pixel over SC site is validated against cloud fraction in window of SC
- SC cloud defined as 50% cloud cover in 500x500 pixel window
- Comparable low OA 78% due to skewed reference
- Calculation of balanced overall accuracy (BOA) can correct for this: 82%
- These numbers are quite comparable with the validation results of OLCI PixBox validation (2021) over land surfaces

Sky Camera validation over Rome
Using 2021 LFR data



SC 1 automatic classification vs. OLCI L2 LFR Cloud & Ambiguous & Margin

Sky Camera 1

OLCI L2 LFR

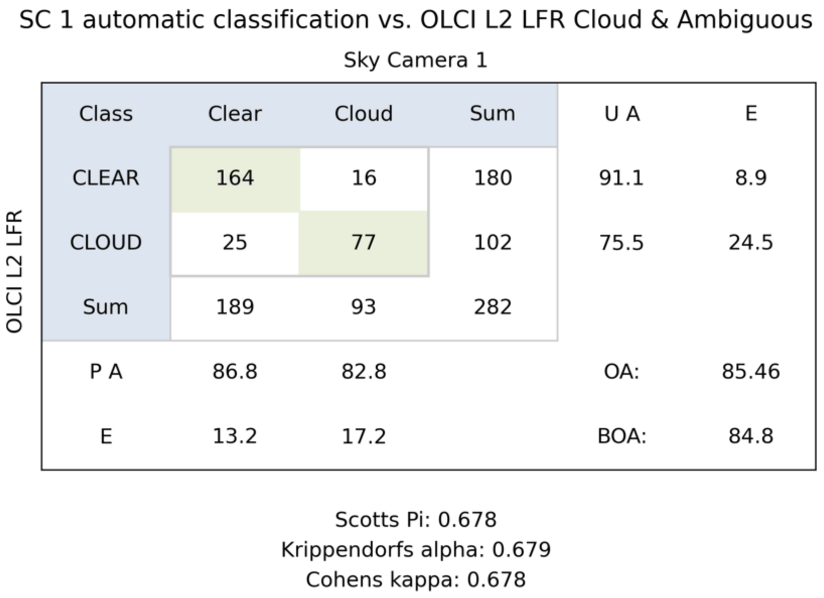
Class	Clear	Cloud	Sum	U A	E
CLEAR	136	7	143	95.1	4.9
CLOUD	53	86	139	61.9	38.1
Sum	189	93	282		
P A	72.0	92.5		OA:	78.72
E	28.0	7.5		BOA:	82.25

Scotts Pi: 0.56
Krippendorfs alpha: 0.561
Cohens kappa: 0.572

Comparing the test validation for OLCI against latest PixBox collection

- PixBox validation is based only on the neural network part of the L2 cloud screening
- BOA is quite comparable
- Skewed distribution of SC classification hinders comparison a bit
    - Rome is often cloud free
    - Tendencies still comparable

Sky Camera validation over Rome Using 2021 LFR data



SC 1 automatic classification vs. OLCI L2 LFR Cloud & Ambiguous

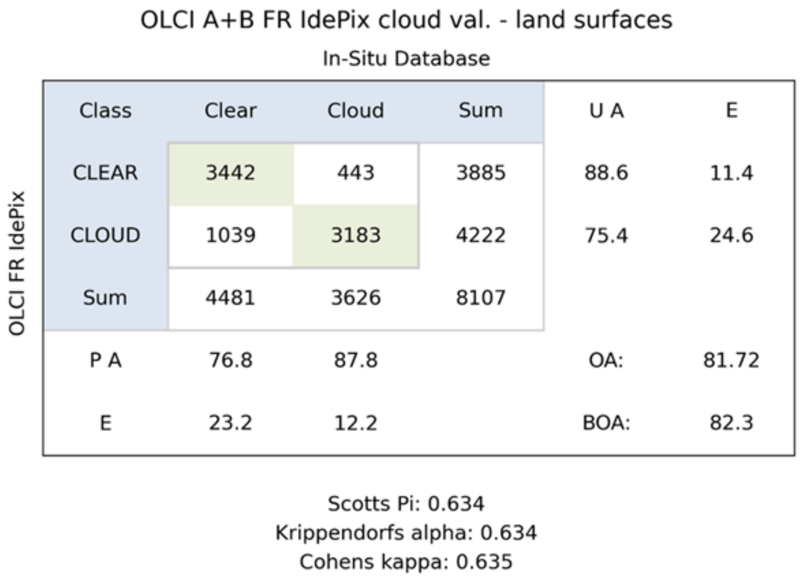
Sky Camera 1

OLCI L2 LFR

Class	Clear	Cloud	Sum	U A	E
CLEAR	164	16	180	91.1	8.9
CLOUD	25	77	102	75.5	24.5
Sum	189	93	282		
P A	86.8	82.8		OA:	85.46
E	13.2	17.2		BOA:	84.8

Scotts Pi: 0.678
Krippendorfs alpha: 0.679
Cohens kappa: 0.678

PixBox validation 2021 using 2018 data over land surfaces



OLCI A+B FR IdePix cloud val. - land surfaces

In-Situ Database

OLCI FR IdePix

Class	Clear	Cloud	Sum	U A	E
CLEAR	3442	443	3885	88.6	11.4
CLOUD	1039	3183	4222	75.4	24.6
Sum	4481	3626	8107		
P A	76.8	87.8		OA:	81.72
E	23.2	12.2		BOA:	82.3

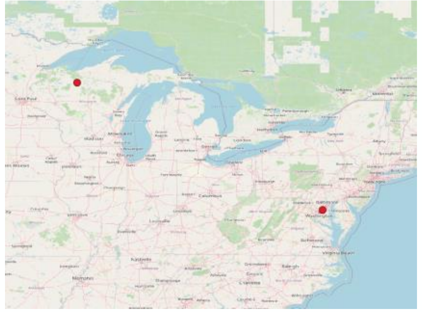
Scotts Pi: 0.634
Krippendorfs alpha: 0.634
Cohens kappa: 0.635

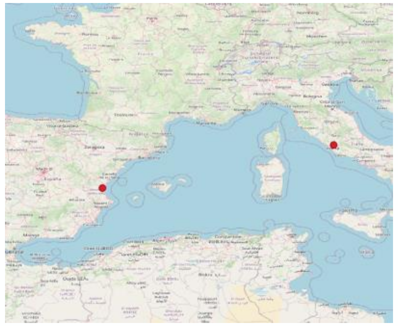
Current limitations

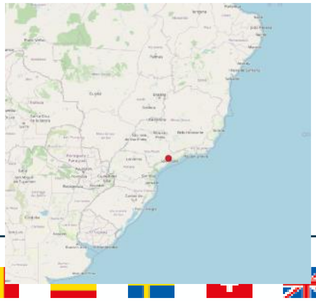
- Algorithm to remove lens distortion no implemented yet
- Best fitting window size needs to be defined
- Best method for integration of classification results within window needs to be defined
- Influence of cloud parallax between OLCI acquisition and sky camera acquisition needs to be analysed
    - Issue for HR sensors like S2
- More sites are required to provide globally representative results.

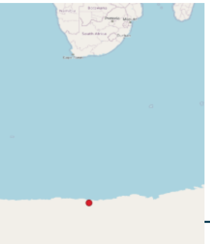
Network extension

- 5 additional sites (6 sites total)
    - Goddard Space Flight Center, USA
    - Park Falls, Wisconsin, USA
    - Valencia, Spain
    - Sao Paulo, Brazil
    - Princess Elisabeth Station, Antarctica



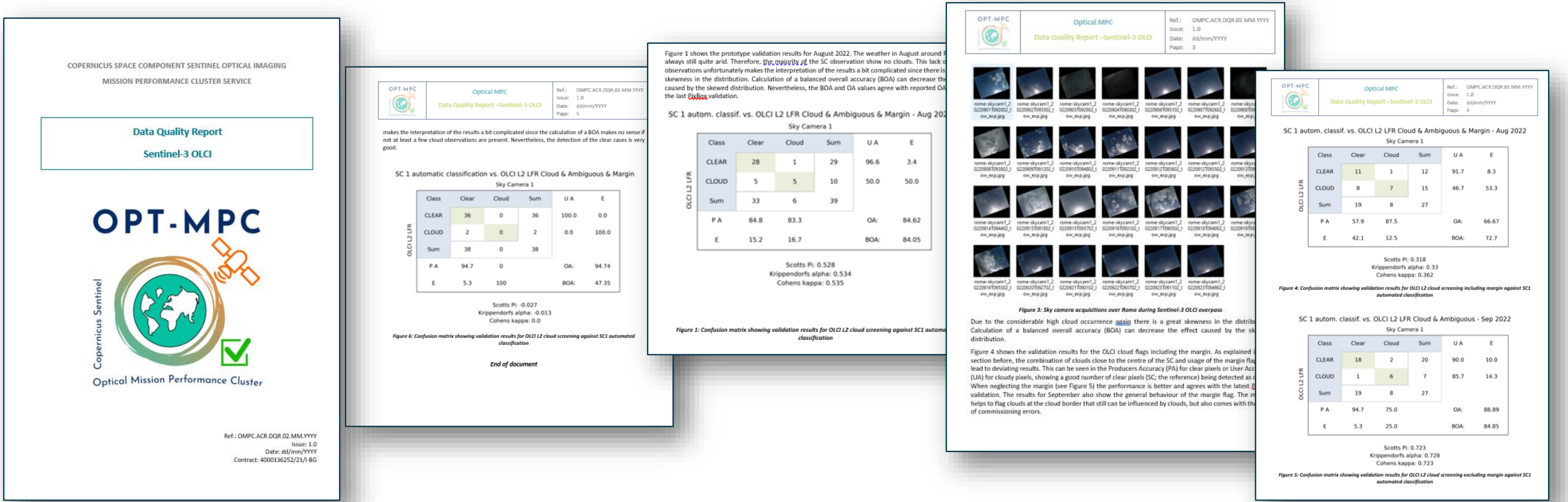






Current use within the OPT-MPC

- The prototype is currently used to provide QA numbers for the monthly Data Quality Reports
- Limited to the Rome site but will be extended to all six sites.



COPERNICUS SPACE COMPONENT SENTINEL OPTICAL IMAGING
MISSION PERFORMANCE CLUSTER SERVICE

Data Quality Report
Sentinel-3 OLCI

OPT-MPC
Copernicus Sentinel
Optical Mission Performance Cluster

Ref.: OMPC.ACR.DQR.02.MM.YYYY
Issue: 1.0
Date: dd/mm/YYYY
Contract: 4000136252/21/I-BG

OPT-MPC | Optical MPC
Data Quality Report –Sentinel-3 OLCI | Ref.: OMPC.ACR.DQR.02.MM.YYYY
Issue: 1.0
Date: dd/mm/YYYY
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makes the interpretation of the results a bit complicated since the calculation of a BOA makes no sense if not at least a few cloud observations are present. Nevertheless, the detection of the clear cases is very good.

SC 1 automatic classification vs. OLCI L2 LFR Cloud & Ambiguous & Margin
Sky Camera 1

OLCI L2 LFR

Class	Clear	Cloud	Sum	U A	E
CLEAR	36	0	36	100.0	0.0
CLOUD	2	0	2	0.0	100.0
Sum	38	0	38		
P A	94.7	0		OA:	94.74
E	5.3	100		BOA:	47.35

Scotts Pi: -0.027
Krippendorfs alpha: -0.013
Cohens kappa: 0.0

Figure 6: Confusion matrix showing validation results for OLCI L2 cloud screening against SC1 automated classification

End of document

Figure 1 shows the prototype validation results for August 2022. The weather in August around
always still quite arid. Therefore, the majority of the SC observation show no clouds. This lack
observations unfortunately makes the interpretation of the results a bit complicated since there is
skewness in the distribution. Calculation of a balanced overall accuracy (BOA) can decrease the
caused by the skewed distribution. Nevertheless, the BOA and OA values agree with reported OA
the last PixBox validation.

SC 1 autom. classif. vs. OLCI L2 LFR Cloud & Ambiguous & Margin - Aug 202
Sky Camera 1

OLCI L2 LFR

Class	Clear	Cloud	Sum	U A	E
CLEAR	28	1	29	96.6	3.4
CLOUD	5	5	10	50.0	50.0
Sum	33	6	39		
P A	84.8	83.3		OA:	84.62
E	15.2	16.7		BOA:	84.05

Scotts Pi: 0.528
Krippendorfs alpha: 0.534
Cohens kappa: 0.535

Figure 1: Confusion matrix showing validation results for OLCI L2 cloud screening against SC1 automa
classification

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Data Quality Report –Sentinel-3 OLCI | Ref.: OMPC.ACR.DQR.02.MM.YYYY
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Figure 3: Sky camera acquisitions over Rome during Sentinel-3 OLCI overpass

Due to the considerable high cloud occurrence again there is a great skewness in the distrib
Calculation of a balanced overall accuracy (BOA) can decrease the effect caused by the sk
distribution.

Figure 4 shows the validation results for the OLCI cloud flags including the margin. As explained i
section before, the combination of clouds close to the centre of the SC and usage of the margin fla
lead to deviating results. This can be seen in the Producers Accuracy (PA) for clear pixels or User Acc
(UA) for cloudy pixels, showing a good number of clear pixels (SC; the reference) being detected as c
When neglecting the margin (see Figure 5) the performance is better and agrees with the latest P
validation. The results for September also show the general behaviour of the margin flag. The m
helps to flag clouds at the cloud border that still can be influenced by clouds, but also comes with th
of commissioning errors.

OPT-MPC | Optical MPC
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SC 1 autom. classif. vs. OLCI L2 LFR Cloud & Ambiguous & Margin - Aug 2022
Sky Camera 1

OLCI L2 LFR

Class	Clear	Cloud	Sum	U A	E
CLEAR	11	1	12	91.7	8.3
CLOUD	8	7	15	46.7	53.3
Sum	19	8	27		
P A	57.9	87.5		OA:	66.67
E	42.1	12.5		BOA:	72.7

Scotts Pi: 0.318
Krippendorfs alpha: 0.33
Cohens kappa: 0.362

Figure 4: Confusion matrix showing validation results for OLCI L2 cloud screening including margin against SC1 automated classification

SC 1 autom. classif. vs. OLCI L2 LFR Cloud & Ambiguous - Sep 2022
Sky Camera 1

OLCI L2 LFR

Class	Clear	Cloud	Sum	U A	E
CLEAR	18	2	20	90.0	10.0
CLOUD	1	6	7	85.7	14.3
Sum	19	8	27		
P A	94.7	75.0		OA:	88.89
E	5.3	25.0		BOA:	84.85

Scotts Pi: 0.723
Krippendorfs alpha: 0.728
Cohens kappa: 0.723

Figure 5: Confusion matrix showing validation results for OLCI L2 cloud screening excluding margin against SC1 automated classification

Conclusion

- First prototype testing of validating OLCI cloud mask with SC shows quite comparable results
- The development is still in a prototype phase
- Currently only a few sites exist (six), and all are located over land surfaces
- The development of a complete network will take some time

- The SC approach can be used as a valuable source for routine monitoring of the cloud mask performance -> automated input to the monthly performance reports

Thank you for the attention!