Land Surface Reflectance Code (LaSRC) status and ACIX-II Land

E. Vermote[1], S. Skakun[2,1] , J.C. Roger[2,1]

[1]NASA Goddard Space Flight Center Code 619

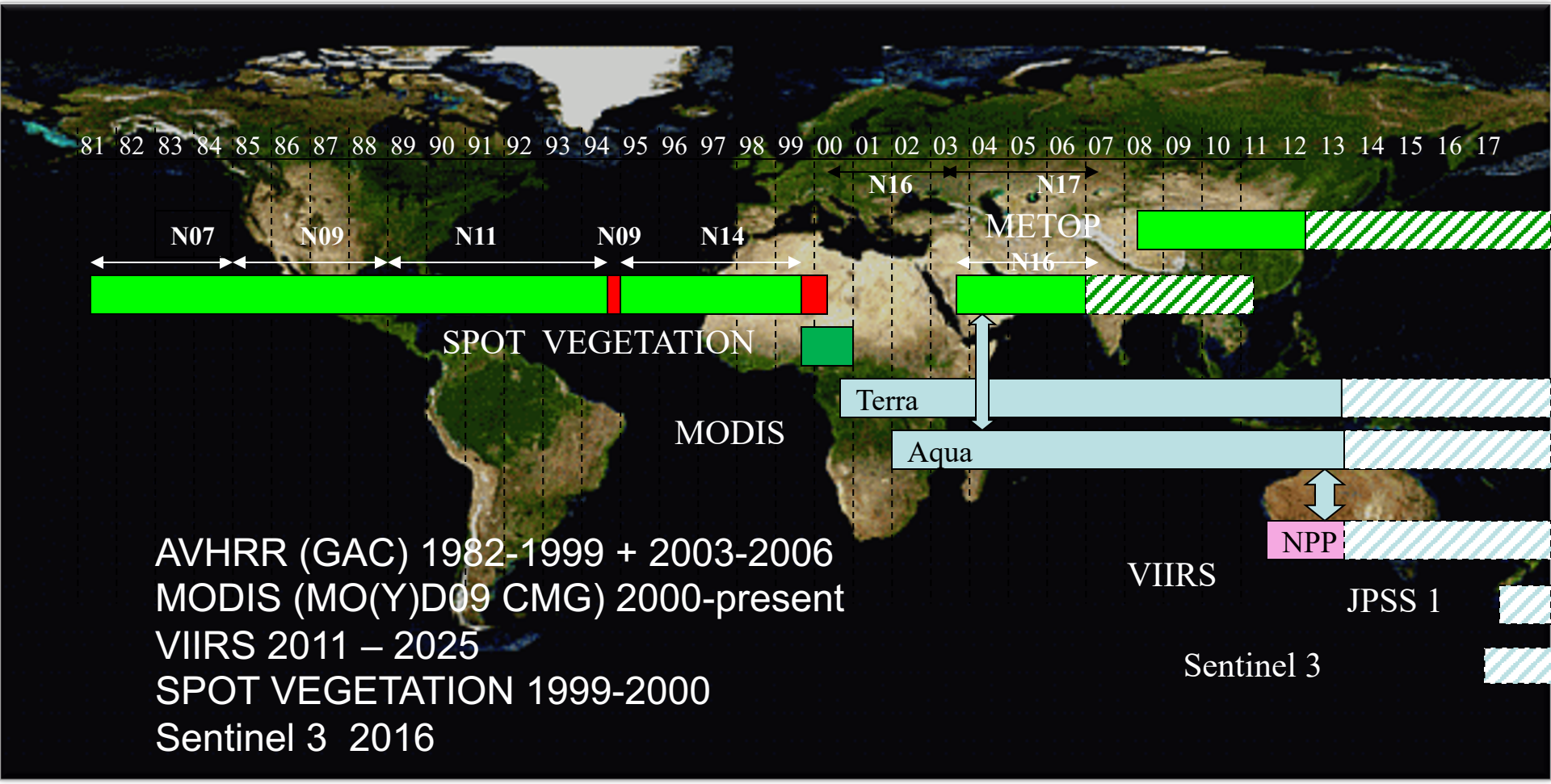
[2]Department of Geographical Sciences, University of Maryland

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Landsat Science Team Meeting Webinar Series, Webex, November 18, 2020

A Land Climate Data Record

Multi instrument/Multi sensor Science Quality Data Records used to quantify trends and changes

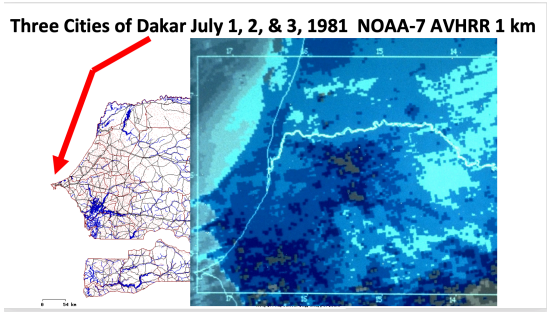


Emphasis on data consistency – characterization rather than degrading/smoothing the data

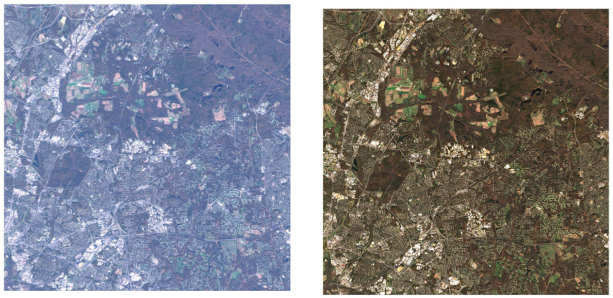
Land Climate Data Record (Approach)

Needs to address geolocation, calibration, atmospheric/BRDF correction issues

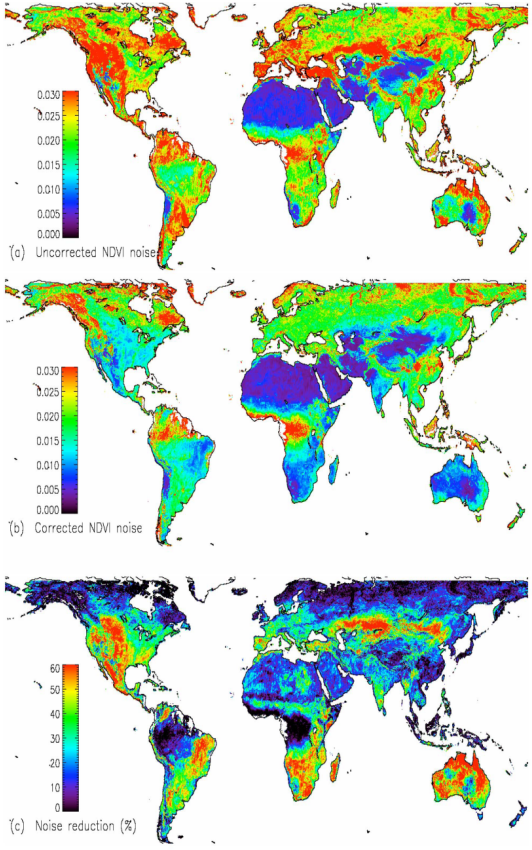
GEOLOCATION



ATMOSPHERIC CORRECTION

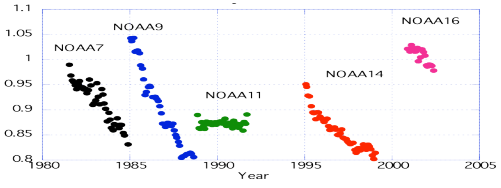


BRDF CORRECTION

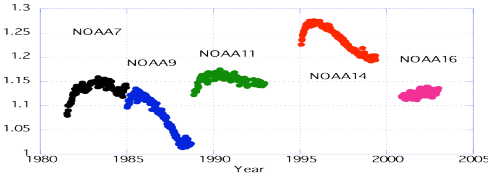


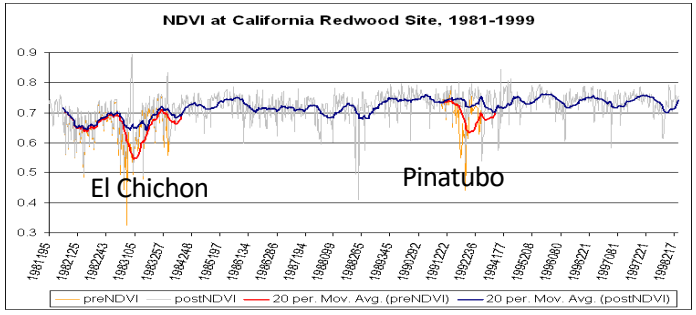
CALIBRATION

Degradation in channel 1
(from Ocean observations)



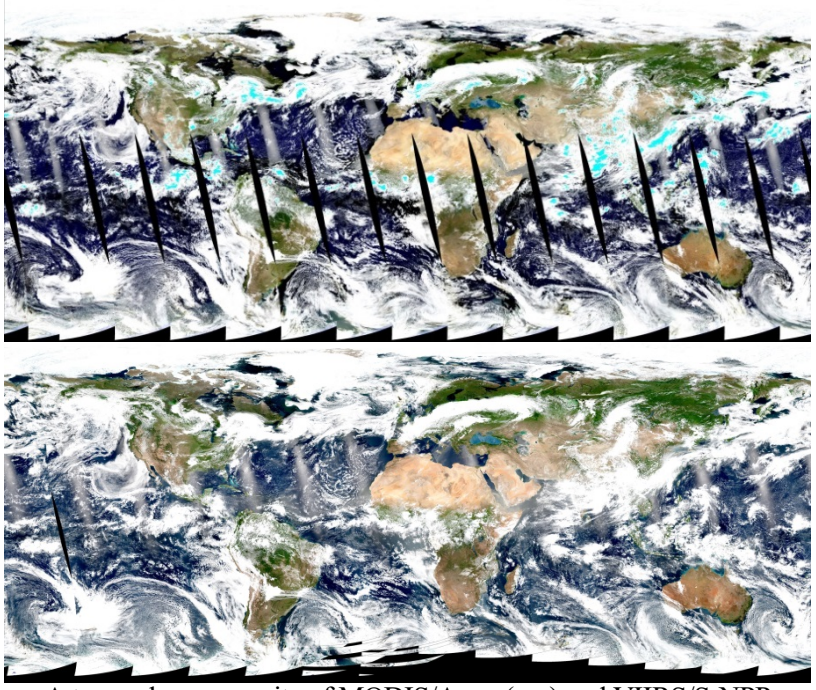
Channel1/Channel2 ratio
(from Clouds observations)



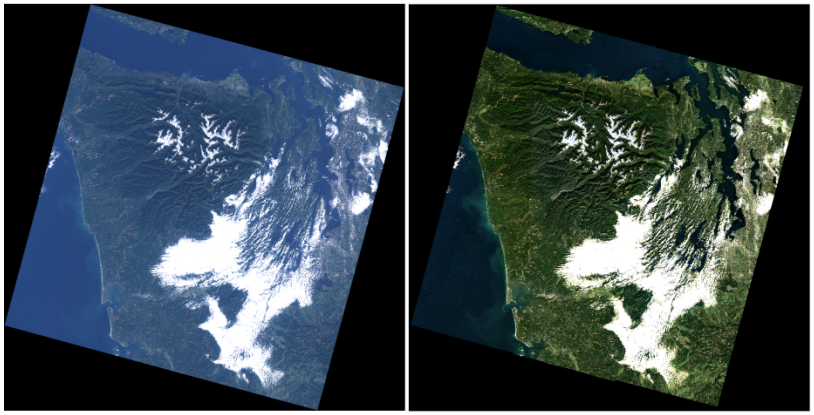


Atmospheric correction (AC)

- Estimate of the **surface spectral reflectance**, as would have been measured at ground level if there were **no atmospheric scattering or absorption**
- Generic approach for AC for multiple sensors
- AC products for EO sensors:
  - MODIS (Terra, Aqua)
    - Products: MOD09, MYD09
  - VIIRS (S-NPP,JPSS1)
    - Products: VNP09
  - OLI (Landsat-8) and MSI (Sentinel-2)
    - LaSRC algorithm/product
    - Harmonization Landsat / Sentinel 2 (HLS) project
    - USGS' on demand SR product for OLI



A true color composite of MODIS/Aqua (*top*) and VIIRS/S-NPP (*bottom*) images acquired on July, 1, 2017



A true color composite of Landsat-8 image without AC (*left*) and with AC (*right*). Image is acquired on October, 14, 2013

Landsat8/OLI and Sentinel 2/MSI Surface Reflectance is largely based on MODIS C6 (LaSRC)

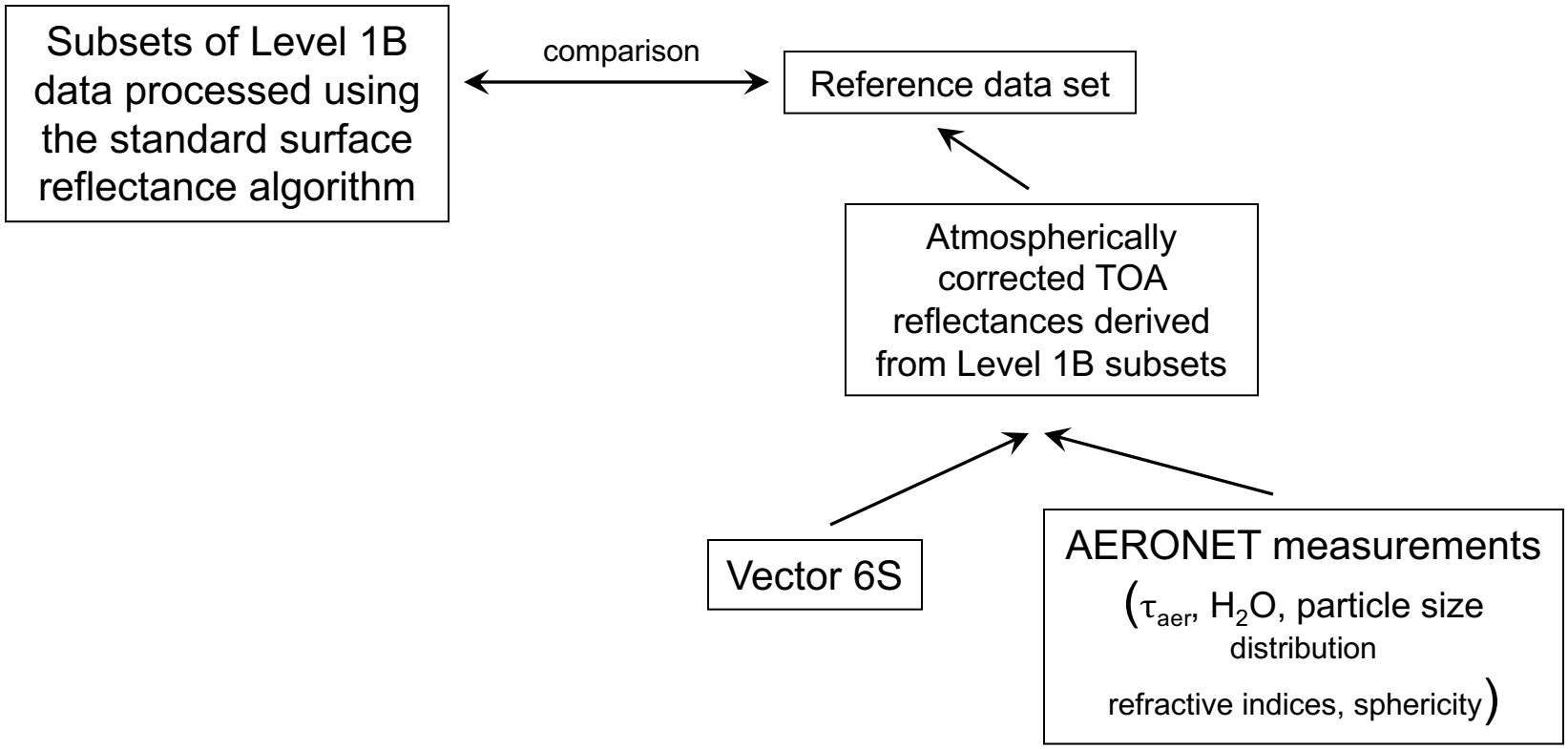
Algorithm reference for L8: Vermote E., Justice C., Claverie M., Franch B., (2016) “Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product", Remote Sensing of Environment, 185,46-56.

The MODIS **Collection 6 AC algorithm** relies on

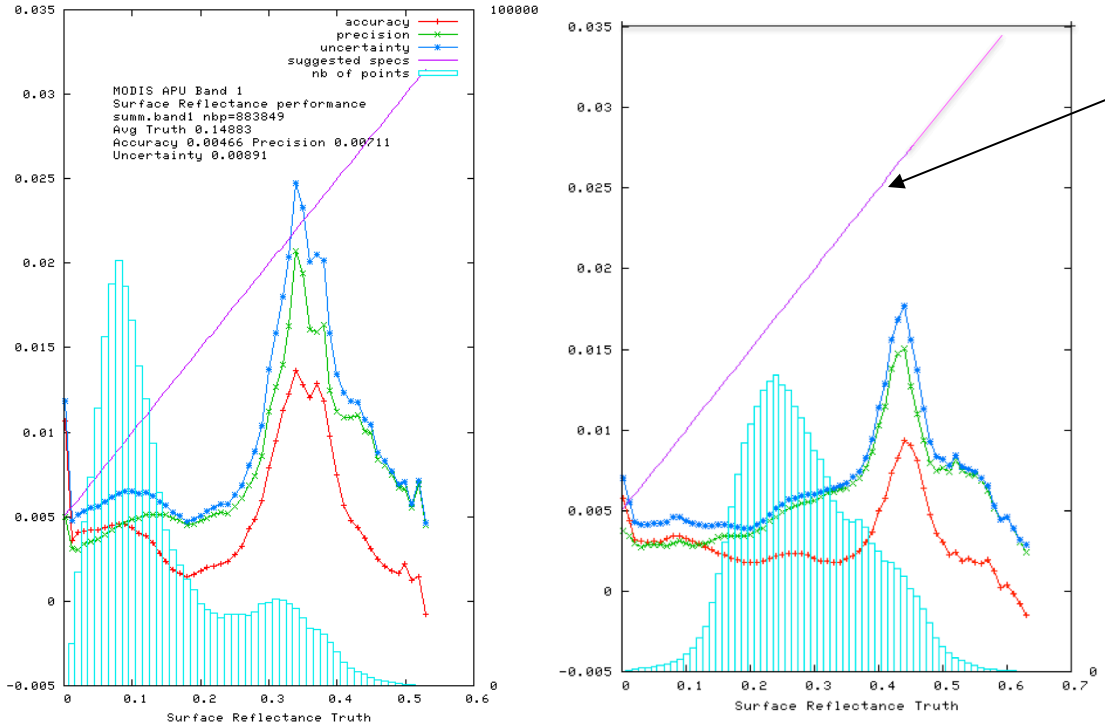
- the use of very accurate (better than 1%) vector radiative transfer modeling of the coupled atmosphere-surface system (6S)
- the inversion of key atmospheric parameters
  - ***Aerosols are retrieved from Landsat8/Sentinel 2 images***
  - ***Water vapor and ozone from daily MODIS product.***

Home page: http://modis-sr.ltdri.org

Methodology for evaluating the performance of Landsat8/Sentinel2 LaSRC product



quantitative assessment of performances (APU) for MODIS



Specification:
Based on error budget for collection 4

E. Vermote and S. Y. Kotchenova, MODIS Directional surface reflectance product: Method, error estimates and validation. 2011. Land Remote Sensing and Global Environmental Change: NASA's Earth Observing System and the Science of ASTER and MODIS. Series: Remote Sensing and Digital Image Processing, Vol. 11, Springer Verlag. 873p. ISBN: 978-1-4419-6748-0

COLLECTION 5: accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (top left), band 2 in the Near Infrared (top right also shown is the uncertainty specification (the line in magenta), that was derived from the theoretical error budget. Data collected from Terra over 200 AERONET sites from 2000 to 2009.

Error budget Example: Calibration Uncertainties

We simulated an error of ±2% in the absolute calibration across all 7 MODIS bands.

Results: The overall error stays under 2% in relative for all aerosol cases considered.

(*In all study cases, the results are presented in the form of tables and graphs.*)

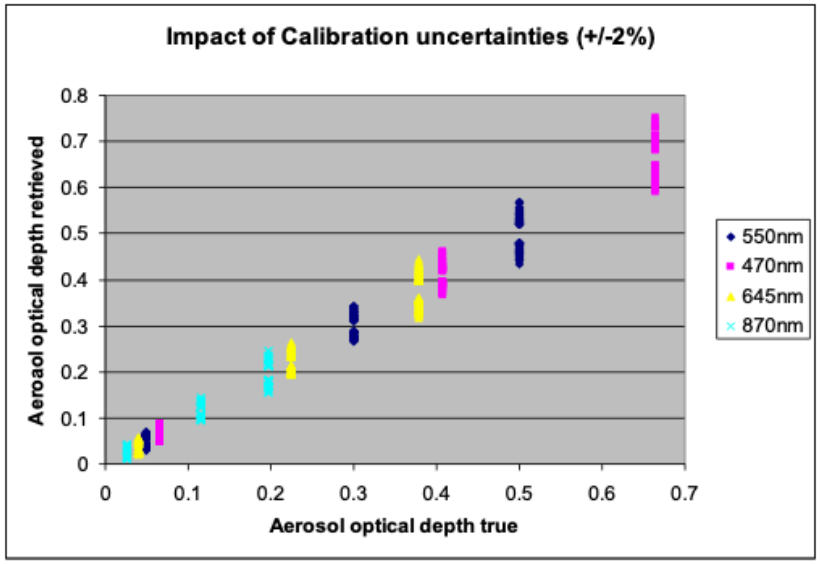


Table (example): Error on the surface reflectance (x 10,000) due to uncertainties in the absolute calibration for the Savanna site.

Central Wavelength (nm)		470	550	645	870	1,240	1,650	2,130
Surface Reflectance ×10,000		400	636	800	2,226	2,880	2,483	1,600
Maximum Error ×10,000	Clear	0013j	0013b	0024i	0065i	0080i	0080i	0080i
	Avg.	0015i	0015i	0030i	0074i	0079i	0070i	0054i
	High	0013d	0011a	0049i	0101i	0098i	0088i	0071i
Minimum Error ×10,000	Clear	0008a	0009j	0016c	0045c	0056f	0048f	0031f
	Avg.	0006c	0004j	0016c	0046c	0058c	0049c	0032c
	High	0001e	0005j	0018c	0048c	0058c	0050c	0032c
Average Error ×10,000	Clear	9	11	17	49	61	56	45
	Avg.	8	11	19	53	63	54	37
	High	6	9	24	63	68	59	42

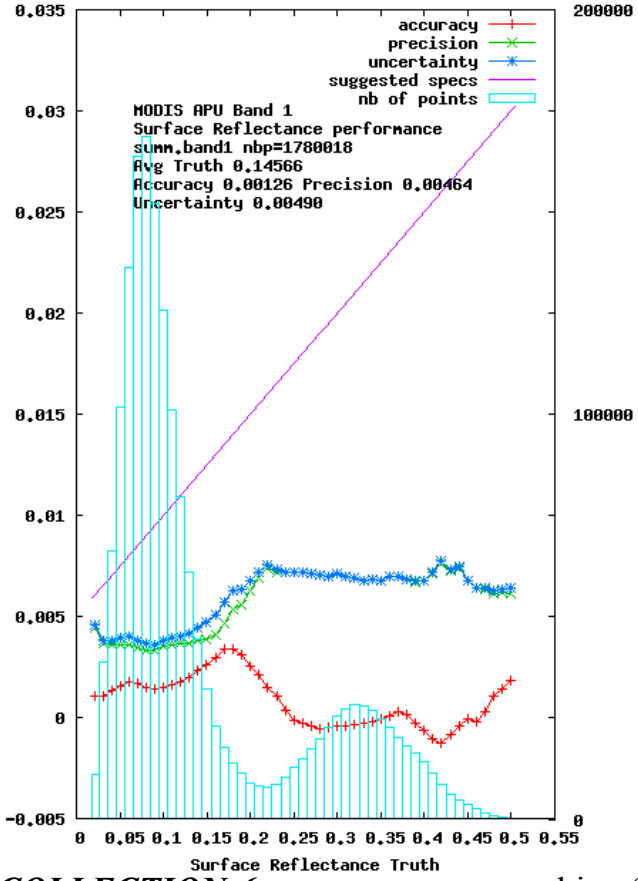
Overall Theoretical Accuracy

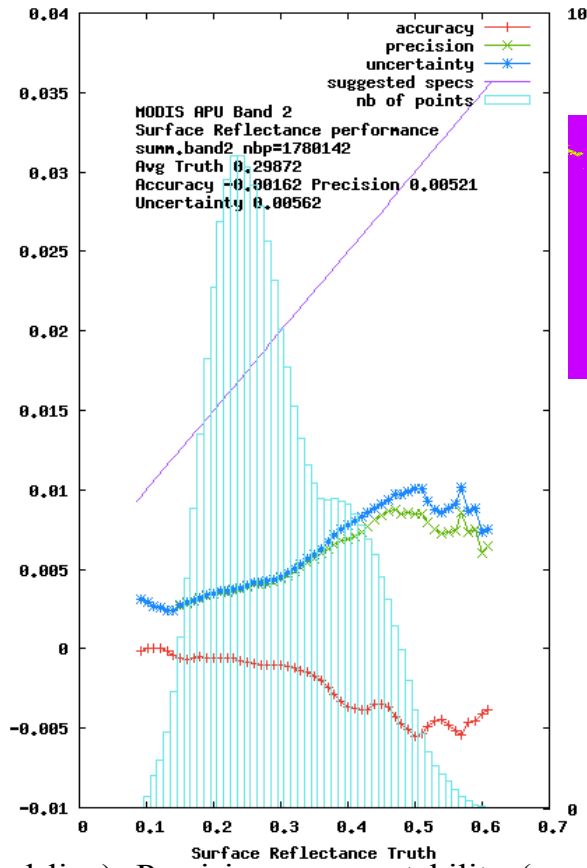
Overall theoretical accuracy of the atmospheric correction method considering the error source on calibration, ancillary data, and aerosol inversion for 3 τaer = {0.05 (clear), 0.3 (avg.), 0.5 (hazy)}:

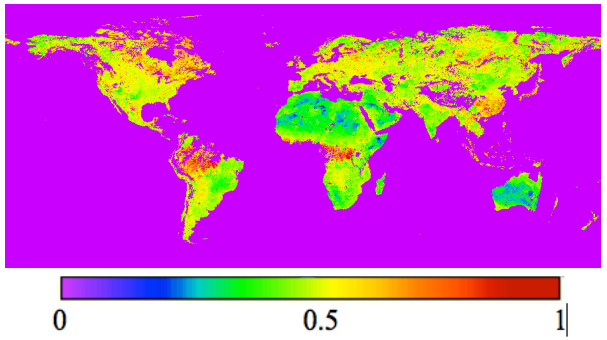
Reflectance/ VI	Forest				Savanna				Semi-arid			
	value	Aerosol Optical Depth			value	Aerosol Optical Depth			value	Aerosol Optical Depth		
		clear	avg	hazy		clear	avg	hazy		clear	avg	hazy
ρ3 (470 nm)	0.012	0.0052	0.0051	0.0052	0.04	0.0052	0.0052	0.0053	0.07	0.0051	0.0053	0.0055
ρ4 (550 nm)	0.0375	0.0049	0.0055	0.0064	0.0636	0.0052	0.0058	0.0064	0.1246	0.0051	0.007	0.0085
ρ1 (645 nm)	0.024	0.0052	0.0059	0.0065	0.08	0.0053	0.0062	0.0067	0.14	0.0057	0.0074	0.0085
ρ2 (870 nm)	0.2931	0.004	0.0152	0.0246	0.2226	0.0035	0.0103	0.0164	0.2324	0.0041	0.0095	0.0146
ρ5 (1240 nm)	0.3083	0.0038	0.011	0.0179	0.288	0.0038	0.0097	0.0158	0.2929	0.0045	0.0093	0.0148
ρ6 (1650 nm)	0.1591	0.0029	0.0052	0.0084	0.2483	0.0035	0.0066	0.0104	0.3085	0.0055	0.0081	0.0125
ρ7 (2130 nm)	0.048	0.0041	0.0028	0.0042	0.16	0.004	0.0036	0.0053	0.28	0.0056	0.006	0.0087
NDVI	0.849	0.03	0.034	**0.04**	0.471	0.022	0.028	0.033	0.248	**0.011**	0.015	0.019
EVI	0.399	0.005	0.006	**0.007**	0.203	0.003	0.005	0.005	0.119	**0.002**	0.004	0.004

The selected sites are Savanna (Skukuza), Forest (Belterra), and Semi-arid (Sevilleta). The uncertainties are considered independent and summed in quadratic.

Improving the aerosol retrieval in collection 6 reflected in APU metrics



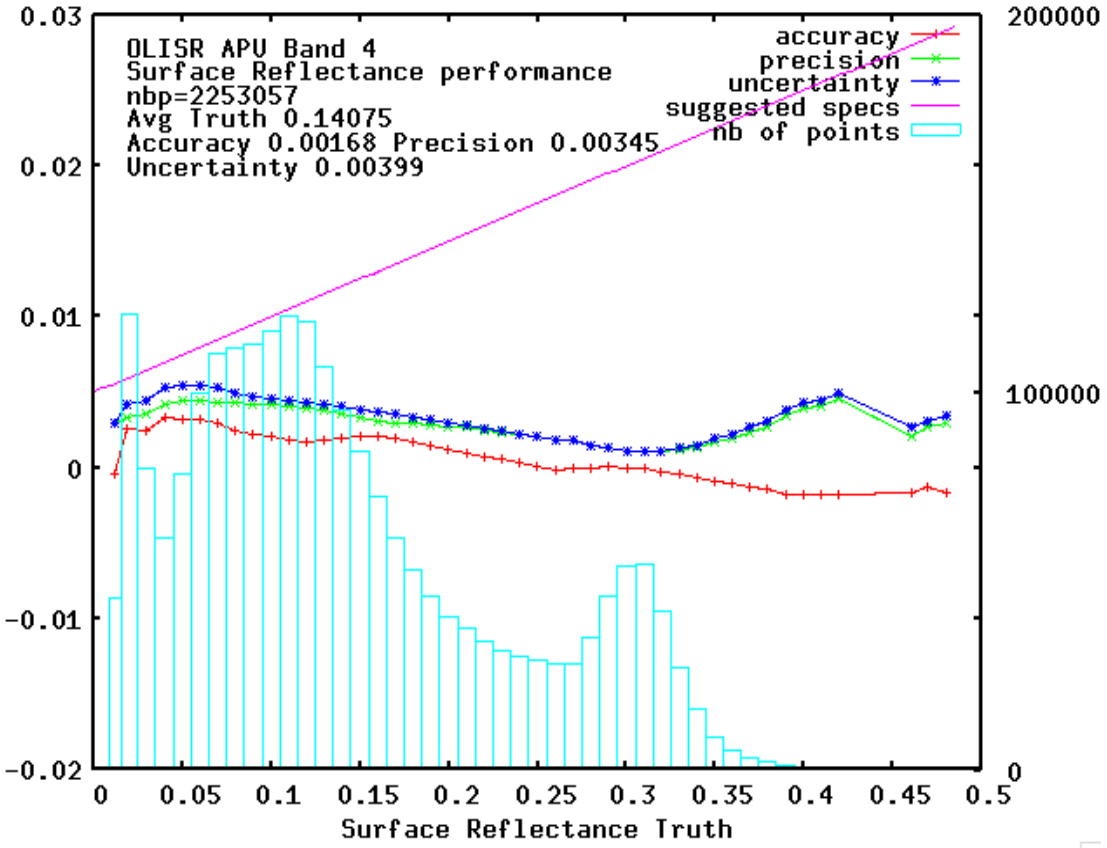




ratio band3/band1 derived using MODIS top of the atmosphere corrected with MISR aerosol optical depth

COLLECTION 6: accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (top left), band 2 in the Near Infrared (top right also shown is the uncertainty specification (the line in magenta), that was derived from the theoretical error budget. Data collected from Terra over 200 AERONET sites for the whole Terra mission.

Evaluation of the performance of Landsat8



The “preliminary” analysis of OLI SR performance in the red band over AERONET is very similar to MODIS Collection 6

ACIX-II

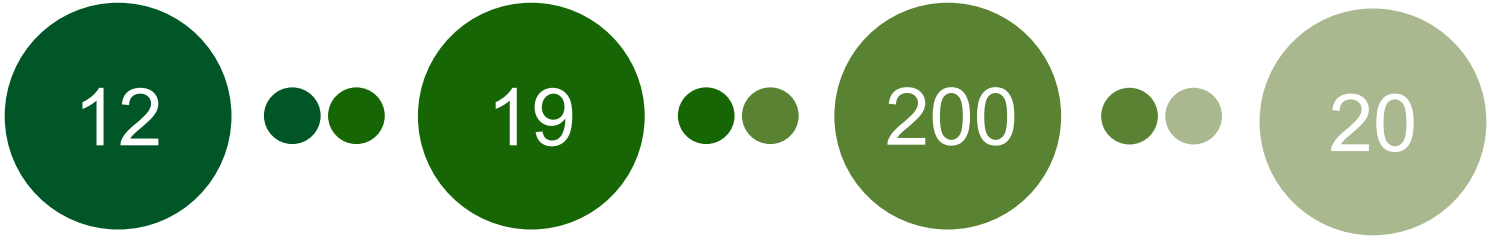
Atmospheric Correction Inter-comparison eXercise

ACIX is an international collaborative initiative to inter-compare a set of atmospheric correction (AC) processors for high-spatial resolution optical sensors. The exercise will focus on Landsat-8 and Sentinel-2 imagery over a set of test areas. The inter-comparison of the derived Bottom-of-Atmosphere (BOA) products is expected to contribute to the understanding of the different uncertainty contributors and help in improving the AC processors

Georgia Doxani | Serco for ESA/ESRIN, Georgia.Doxani@esa.int
Ferran Gascon | ESA/ESRIN, Ferran.Gascon@esa.int
Jean-Claude Roger | University of Maryland/NASA jean-claude.roger@nasa.gov
Eric Vermote | NASA, eric.f.vermote@nasa.gov

Landsat Science Team Meeting Webinar Series, Webex, November 18, 2020

ACIX-I



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

Study Sites
spread worldwide based on the AERONET stations

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

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

ACIX-II -Land

13

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

126

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

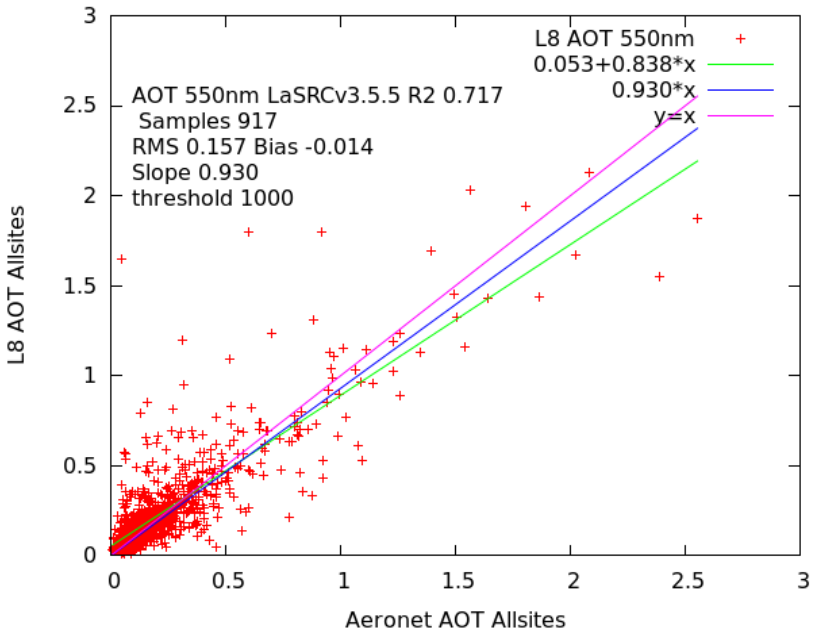
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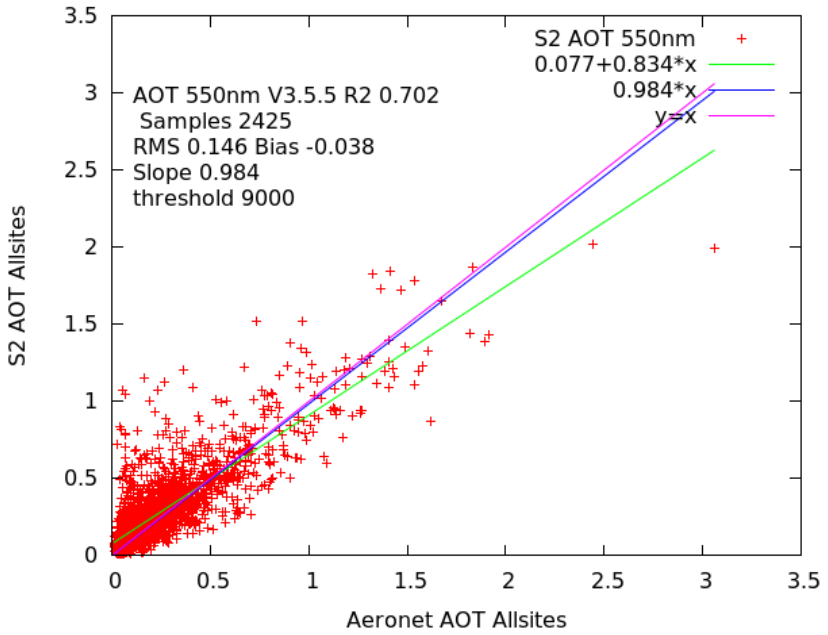
Image Scenes
to be processed acquired by Sentinel-2A, -2B and Landsat-8

7

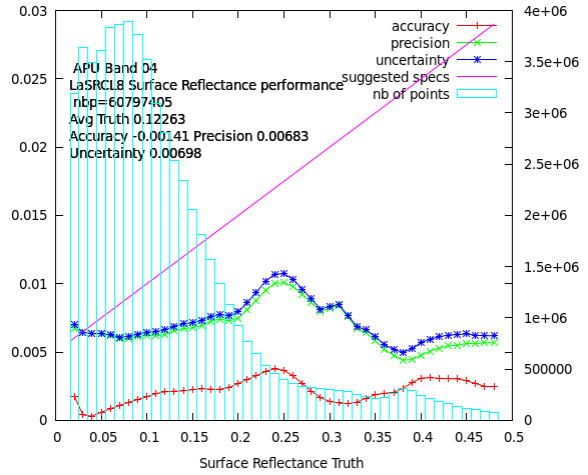
Months
for participants/ coordinators to submit/analyse results

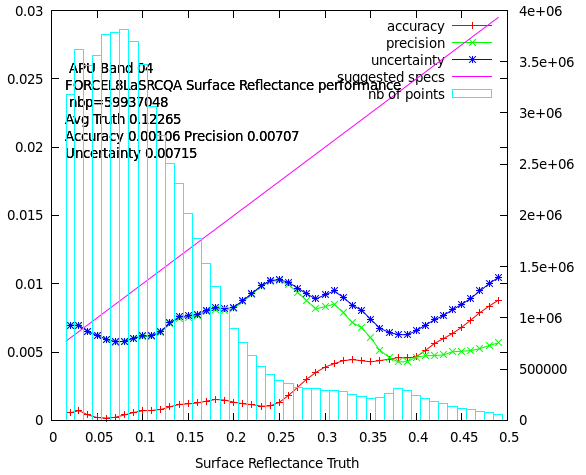
LaSRC 3.5.5 AOT Results

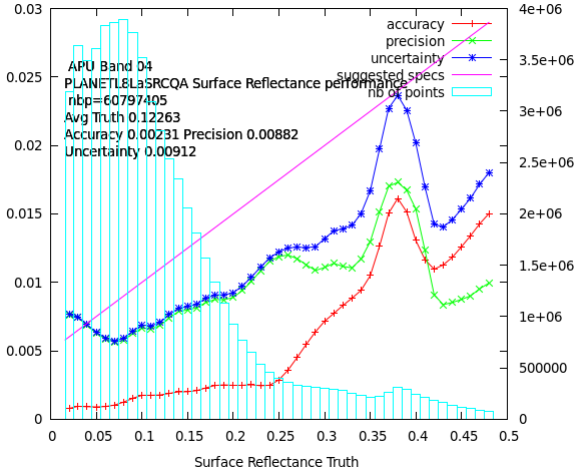


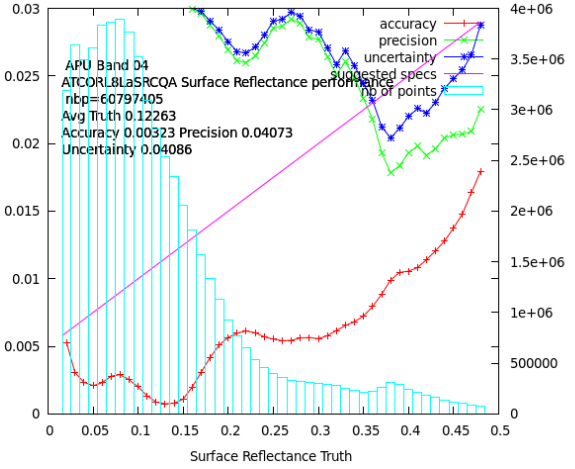


Some APU results in the Red (670nm) Filtered with LaSRC (3.5.5) QA

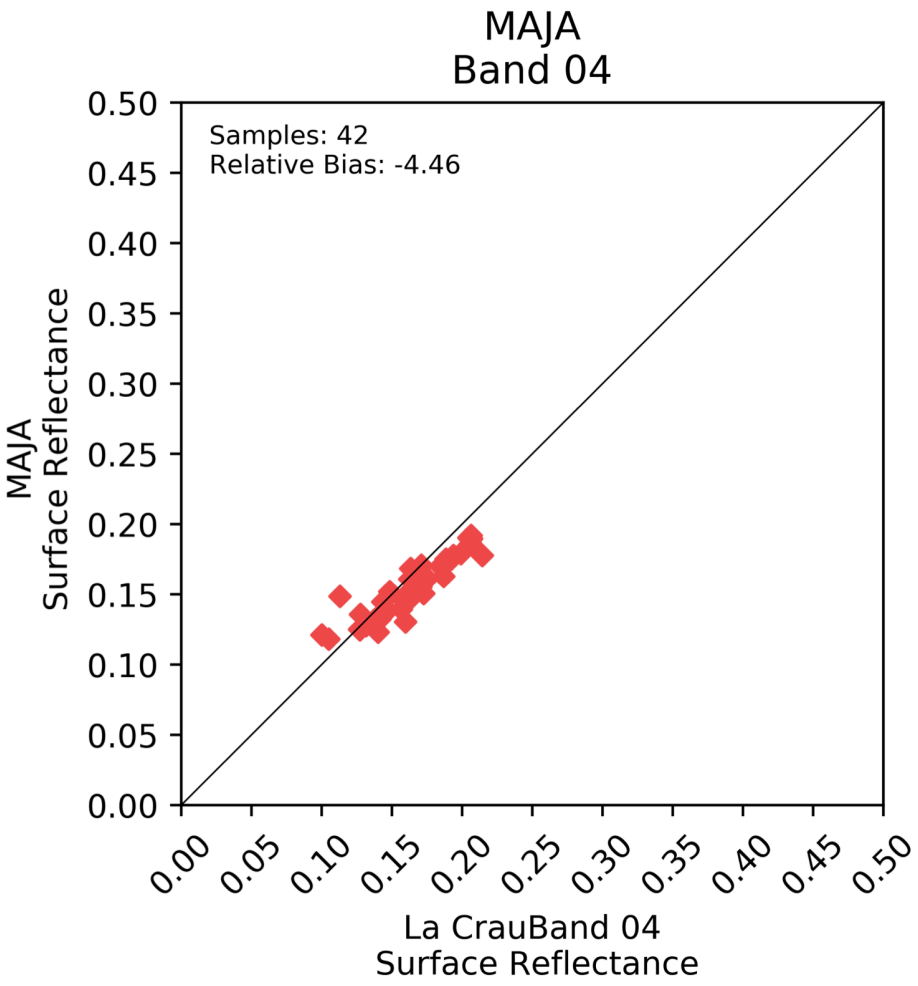


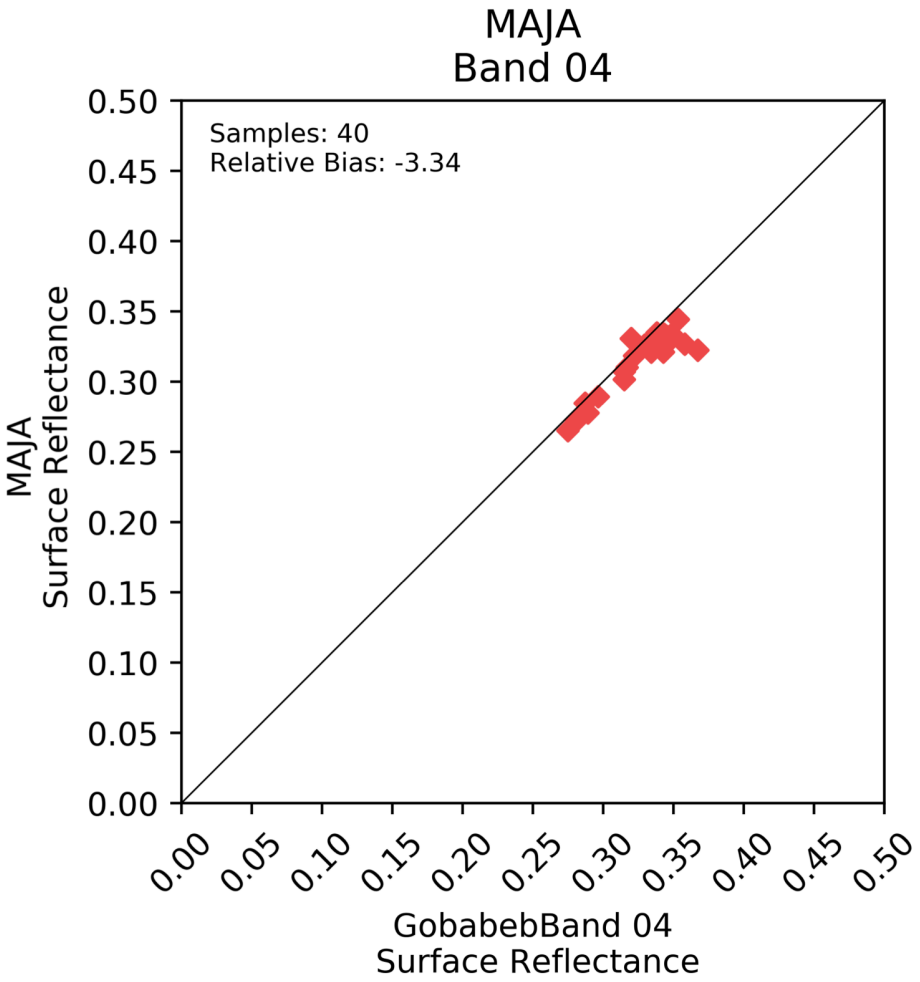






Ground Validation Site (RadCalNet) Analysis


MAJA
Band 04
Samples: 42
Relative Bias: -4.46
MAJA
Surface Reflectance
La CrauBand 04
Surface Reflectance
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50


MAJA
Band 04
Samples: 40
Relative Bias: -3.34
MAJA
Surface Reflectance
GobabebBand 04
Surface Reflectance
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

List of changes in LaSRC 3.5.6 for Sentinel-2

- Fixed **interpolation**, which caused incorrect values in aerosol on the boundaries of the S2 scene
  - Was causing problems, when mosaicking multiples tiles

- For **thick clouds**:
  - Fixed residual calculation (visible using blue and red bands): threshold 0.05
  - Threshold using cirrus band increased to 0.05 (from 0.003)
  - Added adjacent clouds of 6 px @ 10 m

- For **Thin clouds**
  - **Cirrus band threshold** from 0.005 to 0.05

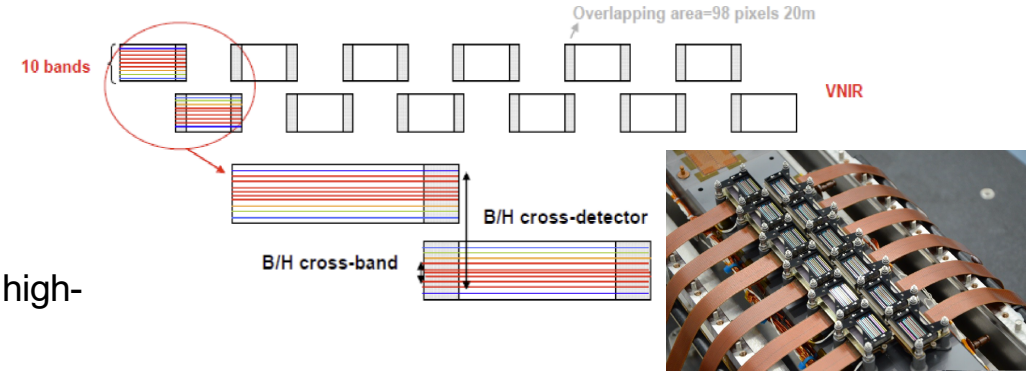
- Added **parallax** feature (*Skakun et al. 2017 IEEE GRSL*):
  - Run for small areas of potential clouds (area < 2000 px)
  - Using blue (B2) and red (B4) bands; not a cloud if subpixel shift < 0.3 px
  - Reduces commission errors for bright targets, e.g. buildings, constructions

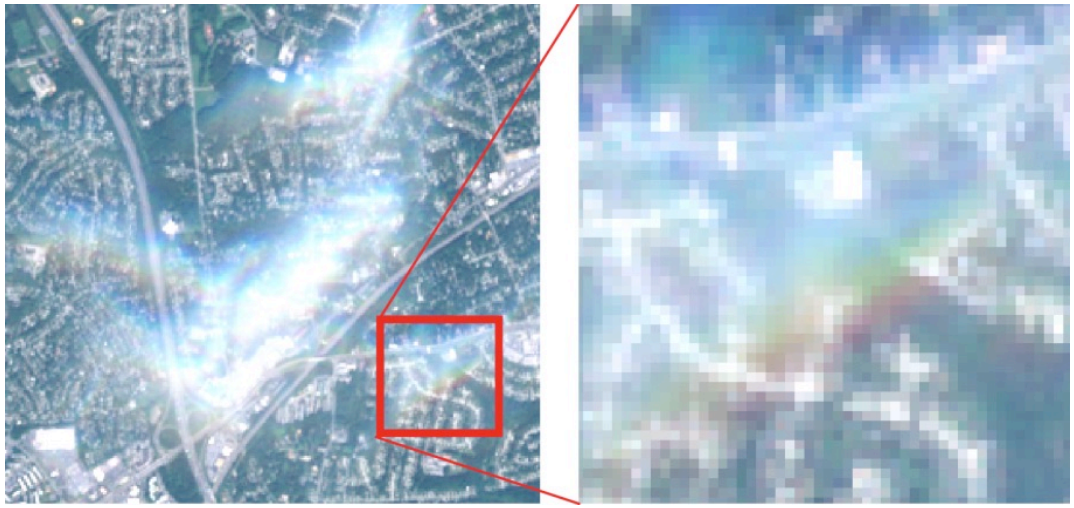
List of changes in LaSRC 3.5.6 for Sentinel-2

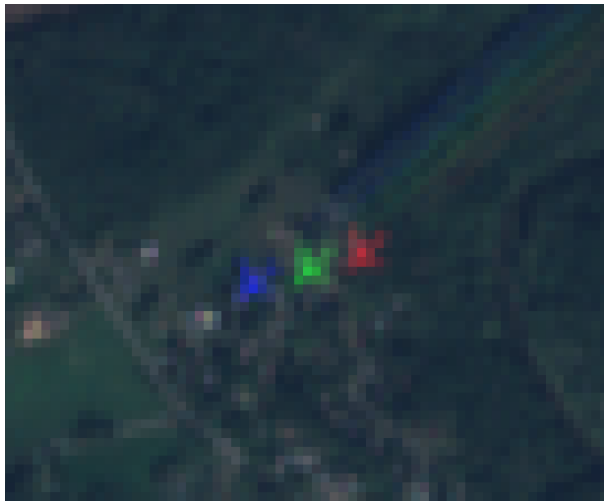
- Fixed **shadow** calculation:
  - Using a flood fill approach (same as in Fmask 4.0 – *Qiu et al. 2019 RSE*)
  - Range of cloud heights is 600 m to 2100 m
- Fixed **water** detection (*Yamazaki et al. 2015 RSE*)
- Fixed **snow** detection (NDSI + checking from *VIIRS ATBD*)
- Fixed processing of **no data** values
  - If at least one band is no data, all no data
  - Different bands have slightly different extent (several pixels) of no data values

Sentinel-2: Cloud screening

- No thermal bands (unlike Landsat 8)
  - Cloud false alarm for bright targets
- Parallax between spectral bands
  - Would introduce a shift for moving and/or high-altitude objects





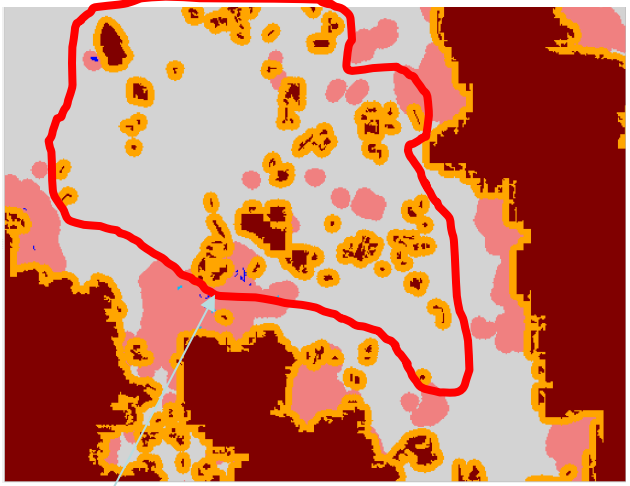


Sentinel-2: Cloud screening

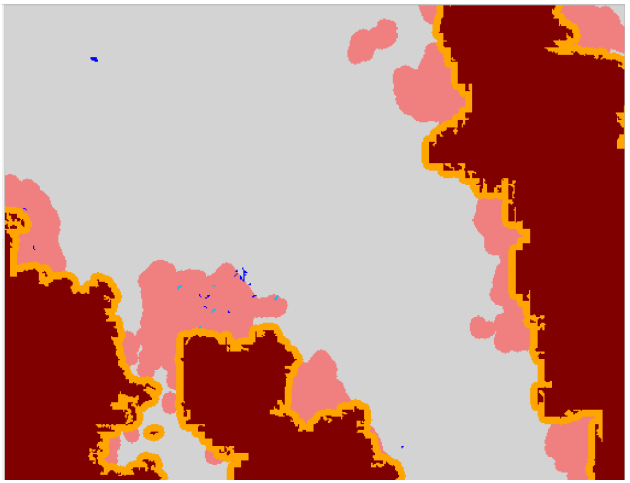
True color: Red-Green-Blue



LaSRC 3.5.6 (no parallax)



LaSRC 3.5.6 (w/ parallax)



False cloud detection (for bright targets)

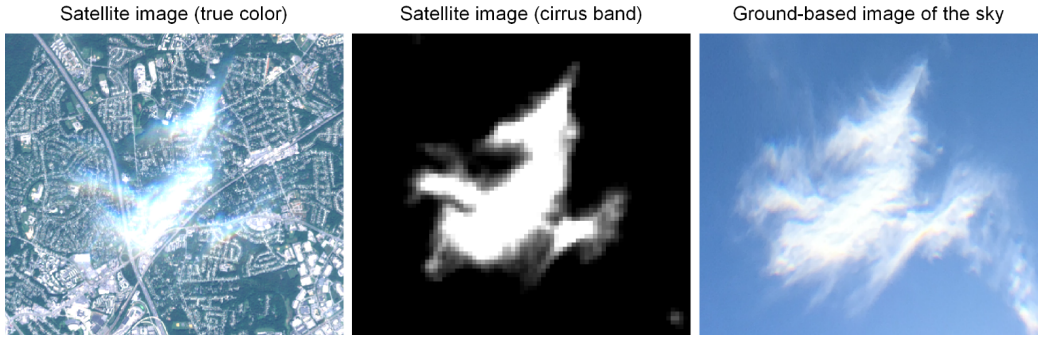
The use of parallax feature allows reduction of cloud commission error

Clear Cloud Shadow

Skakun, S., Vermote, E. F., Artigas, A. E. S., 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.

Cloud validation: SkyCam

- Ground-based skycam
  - For objective validation of satellite-derived cloud masks
  - Proof of concept: manual iphone with fisheye lens over NASA GSFC
  - Current version: automatic, enabling replication over multiple sites
  - Part of validation dataset within CEOS CMIX-1 (Cloud Masking Inter-comparison Exercise)



International Journal of Applied Earth Observations and Geoinformation 95 (2021) 102253

Contents lists available at ScienceDirect

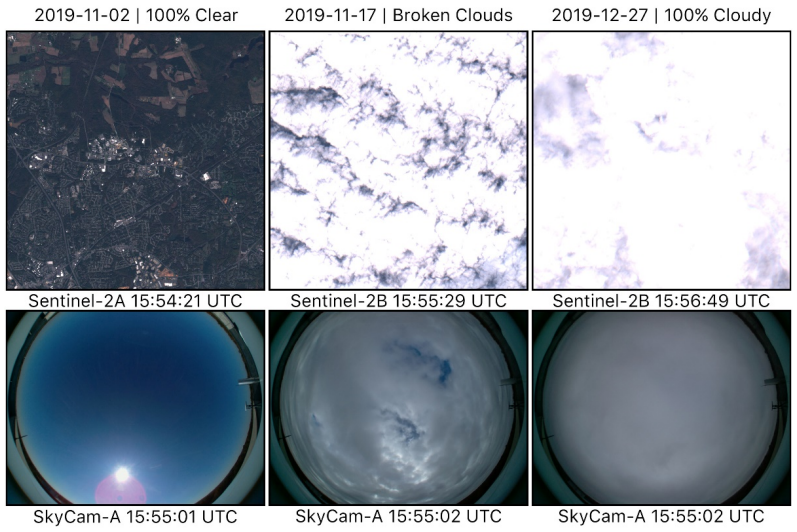
International Journal of Applied Earth Observations and Geoinformation

journal homepage: www.elsevier.com/locate/jag

An experimental sky-image-derived cloud validation dataset for Sentinel-2 and Landsat 8 satellites over NASA GSFC

Sergii Skakun [a,b,c,*], Eric F. Vermote [c], Andres Eduardo Santamaria Artigas [a,c], William H. Rountree [a,c], Jean-Claude Roger [a,c]

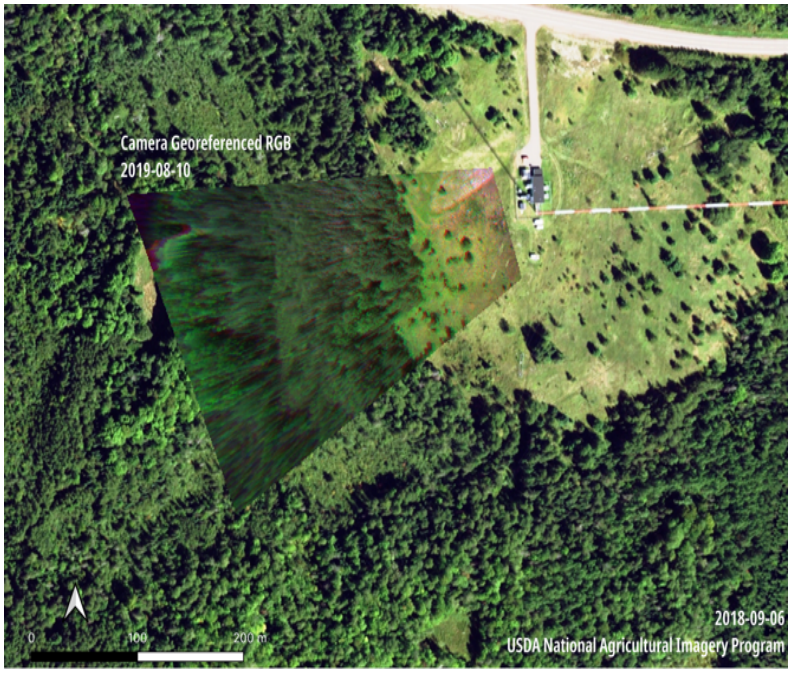
[a] Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA
[b] College of Information Studies (iSchool), University of Maryland, College Park, MD 20742, USA
[c] NASA Goddard Space Flight Center Code 619, 8800 Greenbelt Road, Greenbelt, MD 20771, USA



Ground Validation is on going

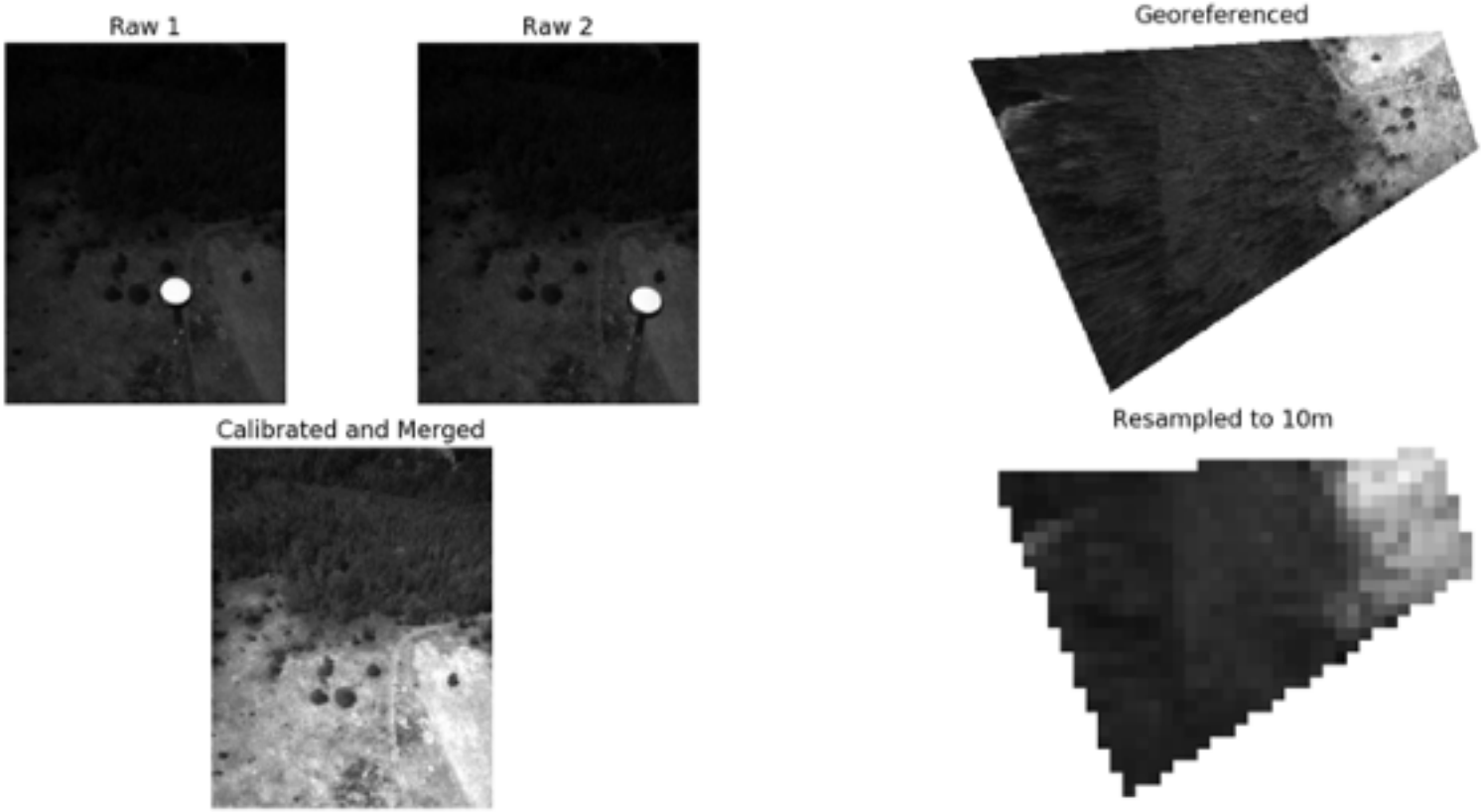


CAMSIS system

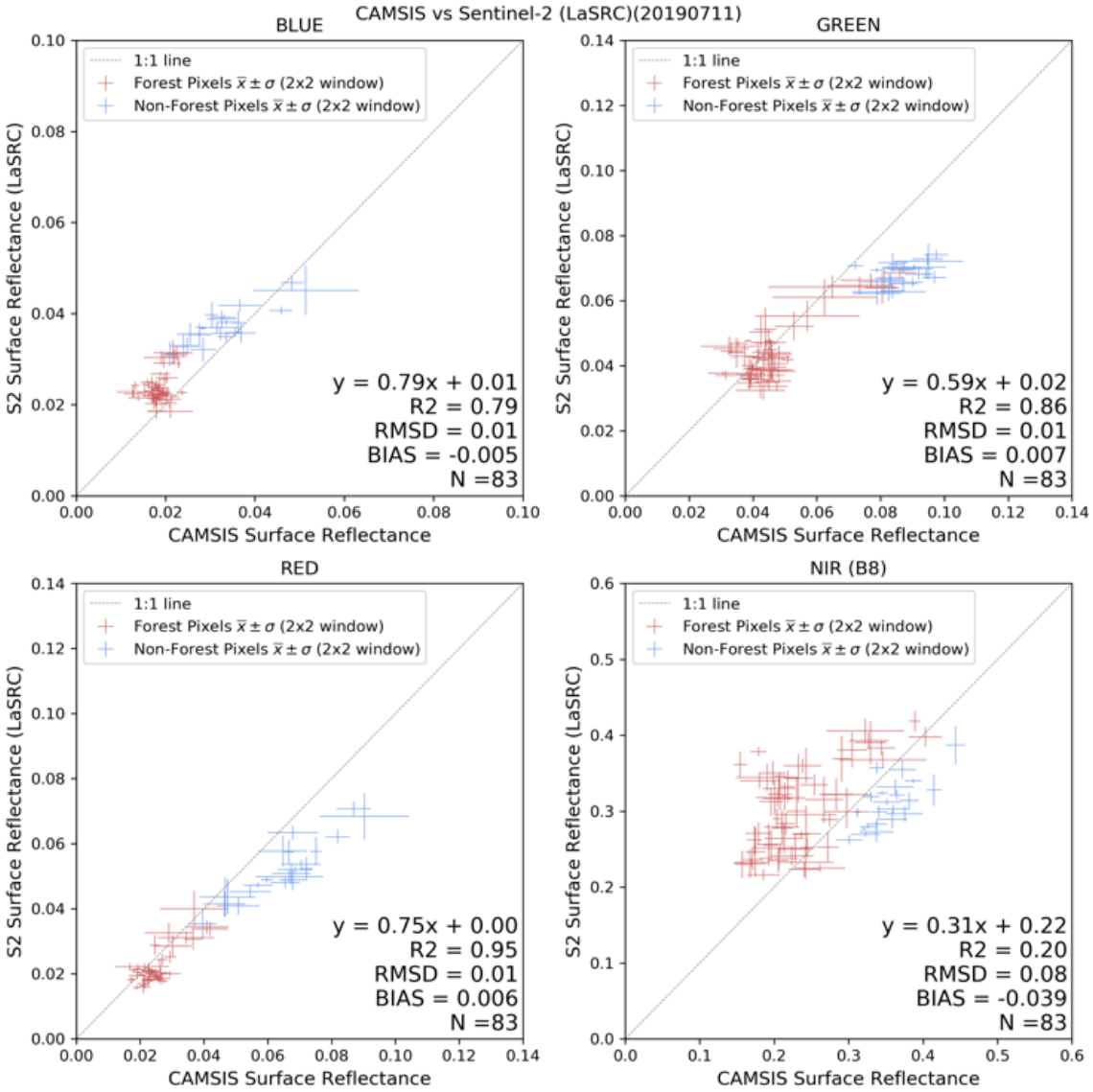


CAMSIS is installed at a height of 123m on a TV tower (WLEF) near Park Falls, WI at the Chequamegon National Forest

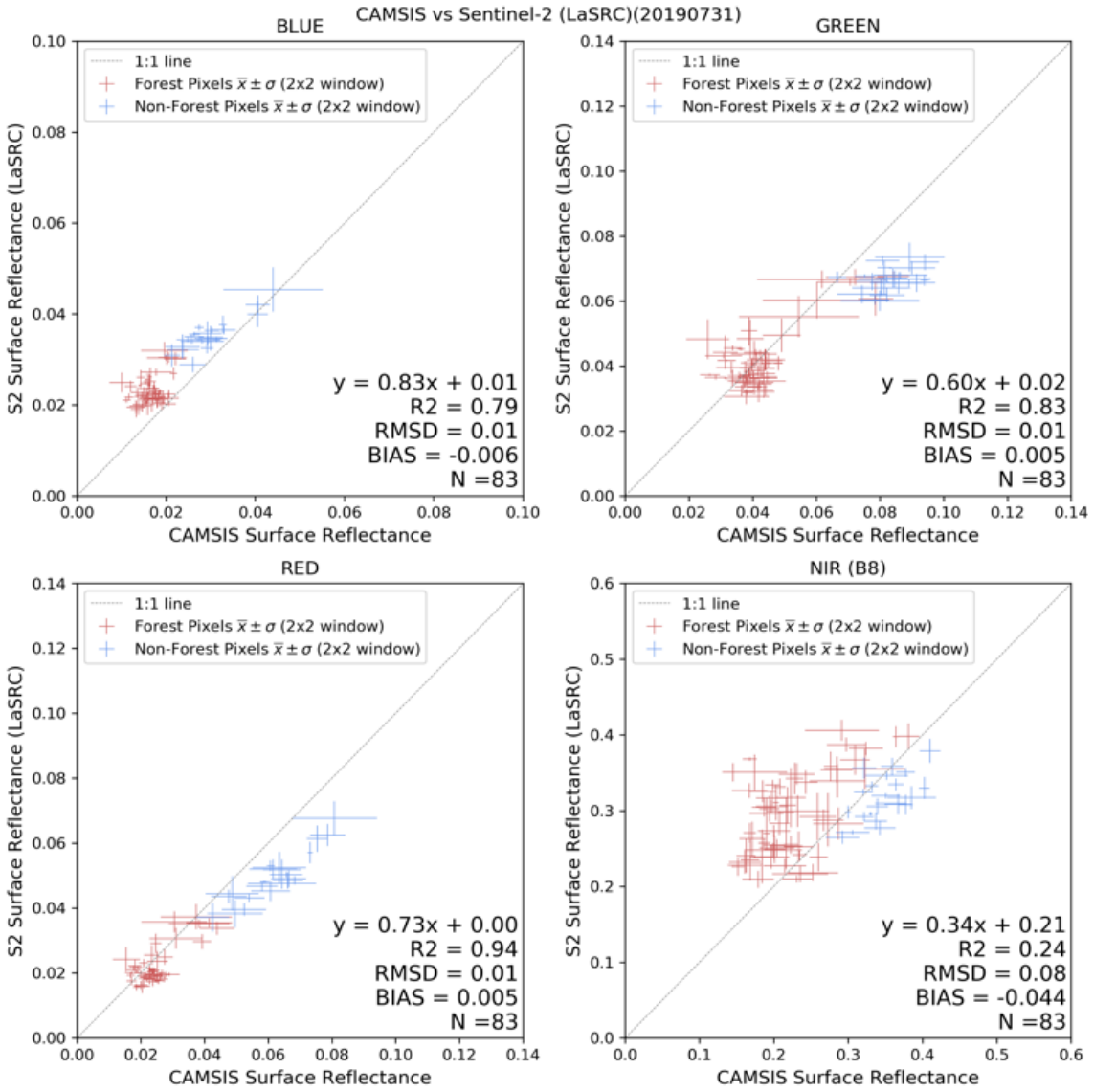
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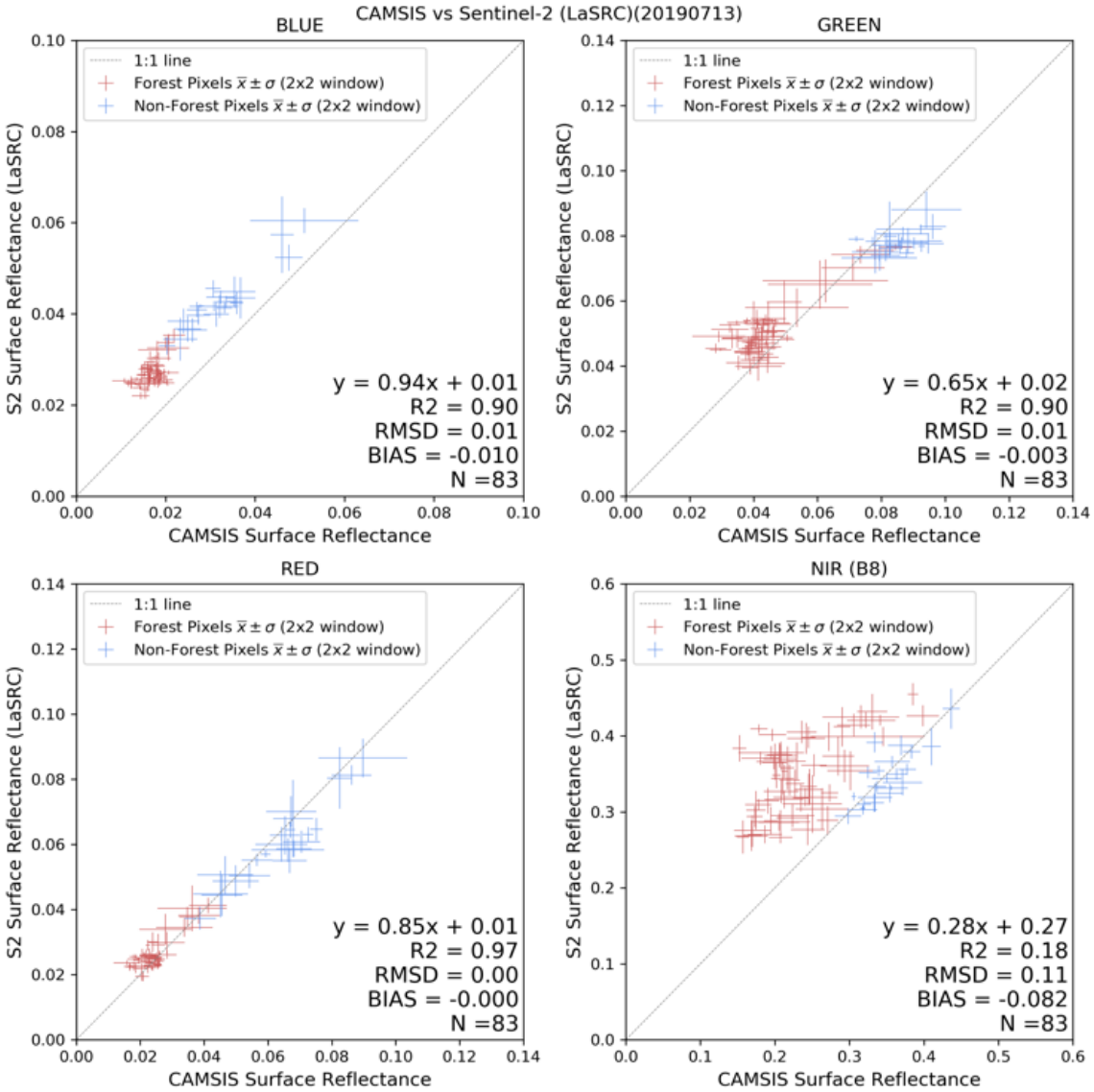
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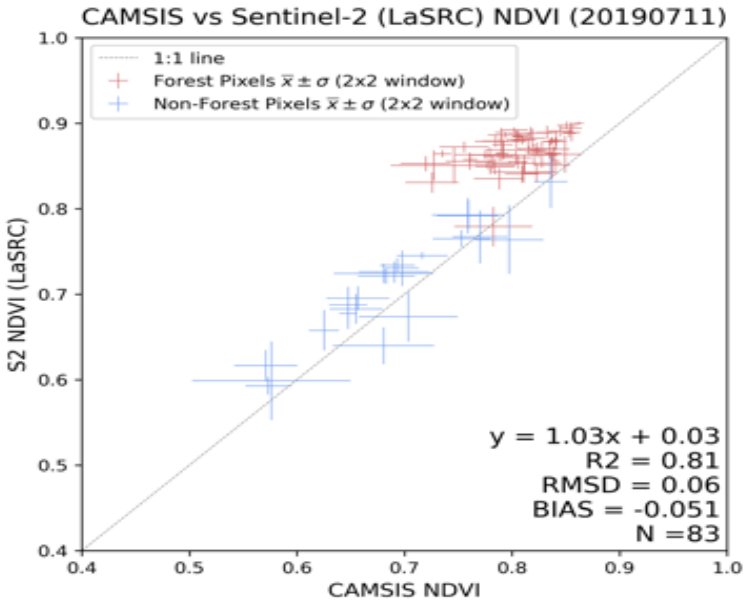
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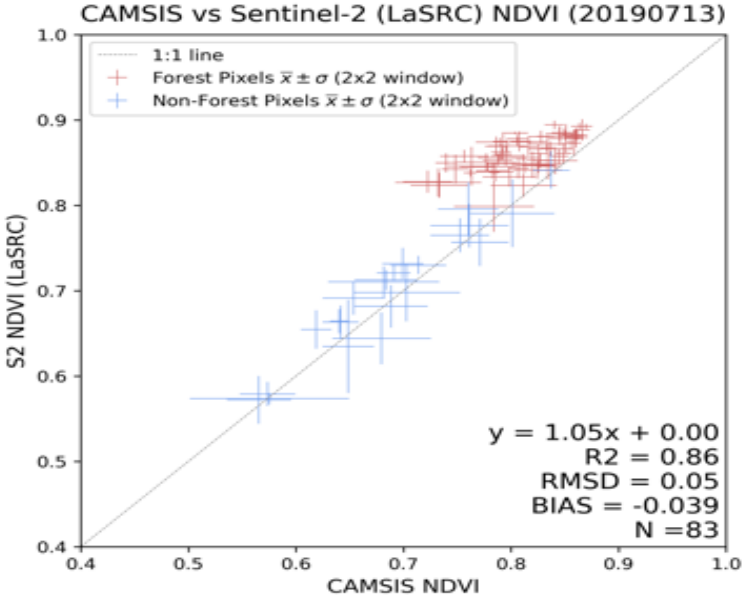


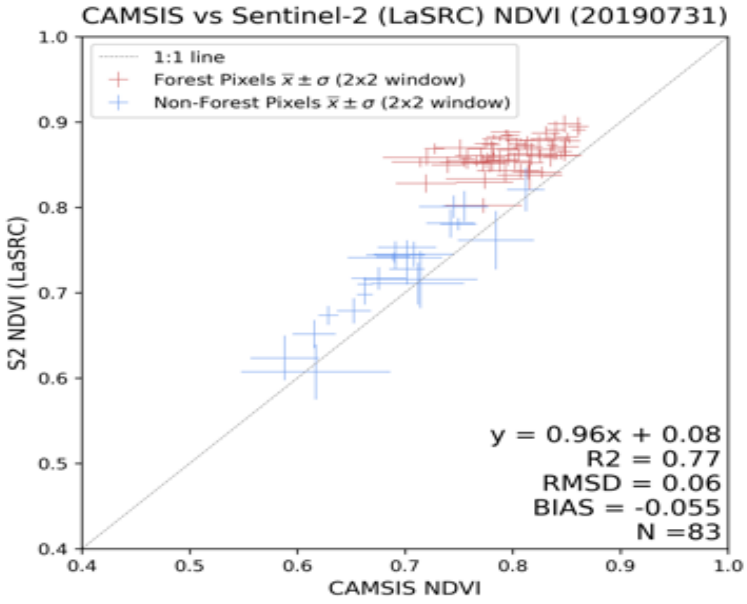
Ground Validation is on going



Ground Validation is on going








Thank You!