A generic method for inversion and validation of aerosol and surface reflectance over land: application to Landsat 8 and Sentinel 2

Eric Vermote et al.

[1]NASA Goddard Space Flight Center Code 619

Eric.f.vermote@nasa.gov

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Landsat8/OLI and Sentinel 2 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.

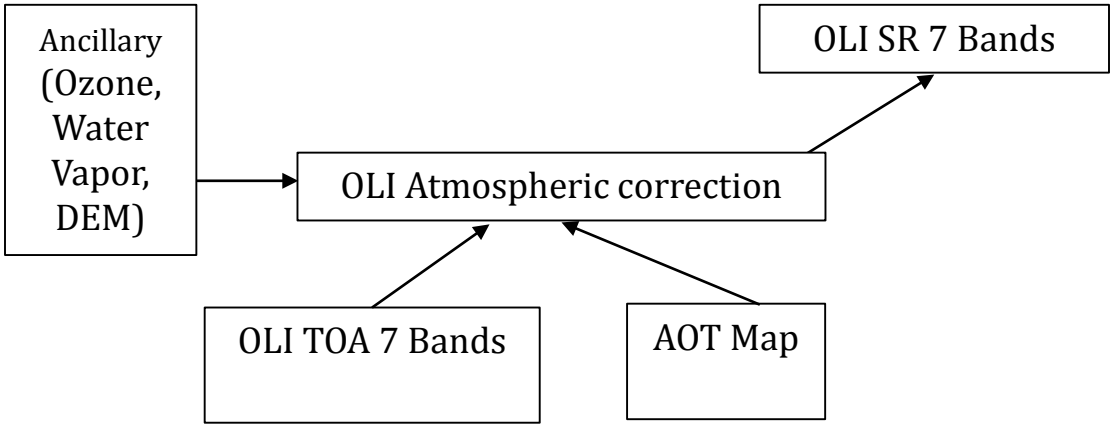
The MODIS **Collection 6 AC algorithm** relies on

- 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 processed from OLI/Sentinel 2 images***
  - ***Water vapor and ozone from daily MODIS product.***

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

Landsat8/OLI and Sentinel 2 Surface Reflectance is largely based on MODIS C6

Flowchart of the Landsat 8 (and Sentinel 2) atmospheric correction scheme



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.

Landsat8/OLI and Sentinel 2 atmospheric correction

Reading **Inputs, LUT** and **Ancillary data**

ρ_{surf} determined (*) using ρ_{atm}, T_{atm} and S_{atm} **from LUT** assuming AOT, Aerosol model and knowing pressure, altitude, water vapor, ozone…

Aerosol Opt. Thick. and **Aerosol model** for each pixel

Using the relationship between the blue surface reflectance (490 nm) and the red surface reflectance (665 nm) known from MODIS, we are able to retrieve the **AOT.**

We loop the AOT until $(\rho_{surf}$ blue / ρ_{surf} red$)_{MSI} = (\rho_{surf}$ blue / ρ_{surf} red$)_{MODIS}$

The retrieved AOT is used to compute the surface reflectance at 443 and 2190 nm. The **aerosol model** is then derived by minimizing the residual.

$$residual = \frac{\sum_{i=1}^{2}\left(\rho_{surf}^{i} - Ratio_{665}^{i} * \rho_{surf}^{665}\right)}{2}$$

Surface reflectance for each pixel and each band

Computation of **surface reflectances** for all channels

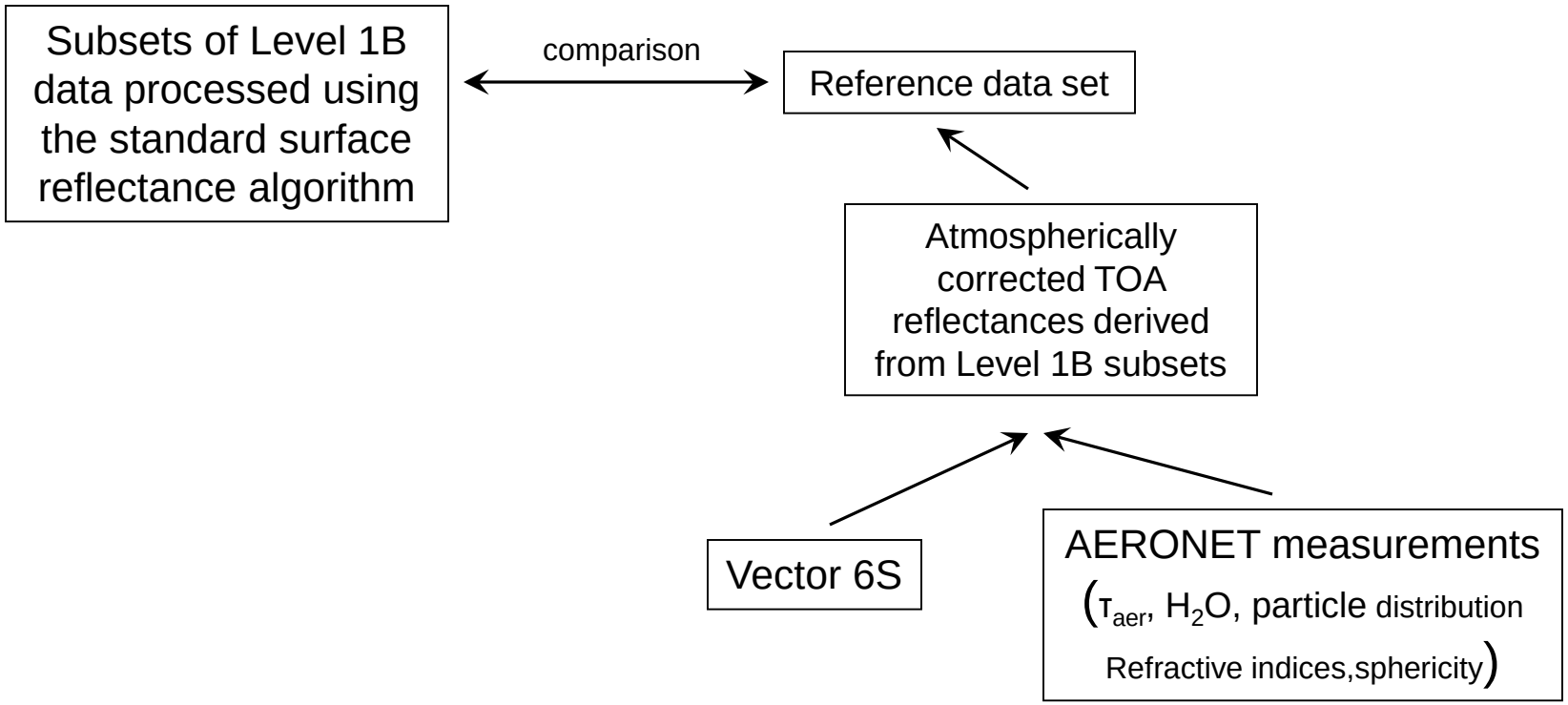
ρ_{surf} determined (*) using ρ_{atm}, T_{atm} and S_{atm} **from LUT** knowing AOT, Aerosol model, pressure, altitude, water vapor, ozone…

$$(*)\quad \rho_{surf} = \frac{Y}{1 + S_{atm}.Y} \quad \text{with} \quad Y = \frac{1}{T_{atm}.tg^{wv}}\left[\left(\frac{\rho_{TOA}}{tg^{O3}.tg^{others}} - \right) - \left(\rho_{atm} - \rho_{ray}\right).tg^{wv/2} - \rho_{ray}\right]$$

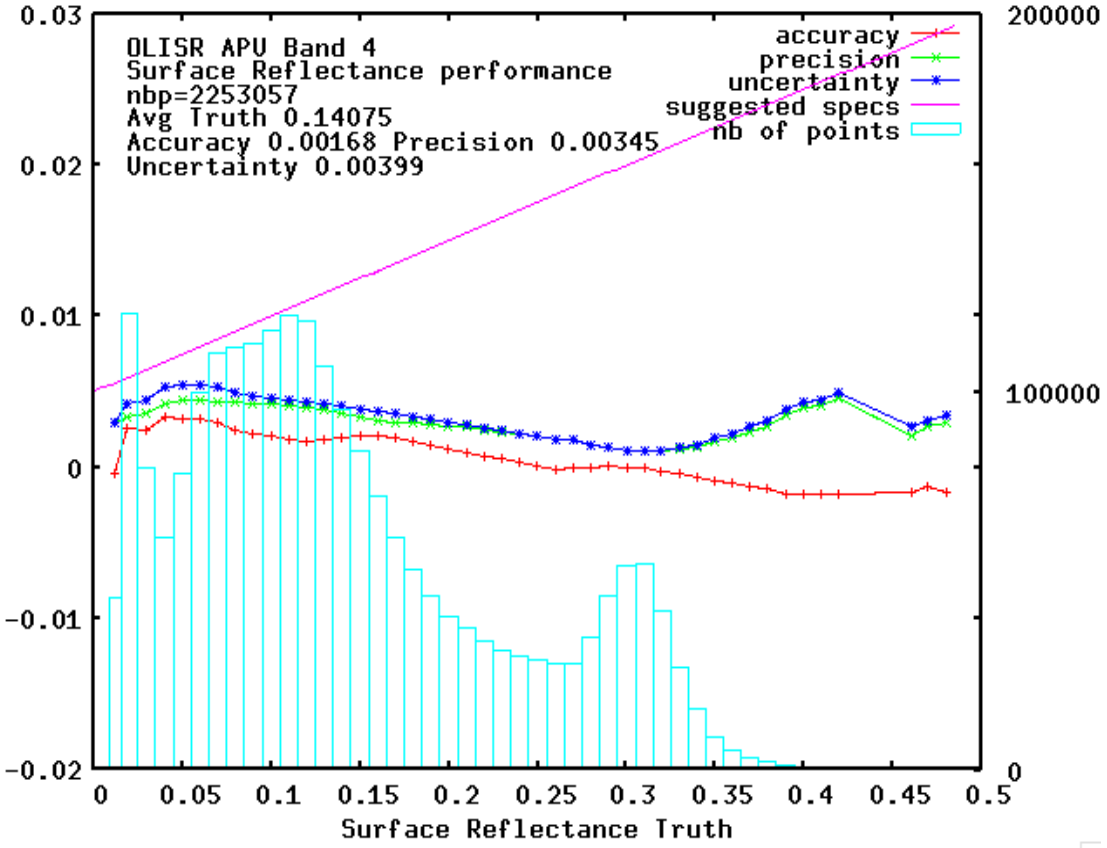
CURRENT STATUS
Atmospheric correction algorithm

- L8 surface reflectance product (V3) available and validated satisfactorily
- Sentinel 2 atmospheric correction algorithm (V2) developed and implemented (preliminary validation through ACIX , cloud mask needs to be implemented)

Methodology for evaluating the performance of Landsat8/Sentinel2



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

This is confirmed by comparison with MODIS

OLI Band	TM LEDAPS (Claverie et al., 2015)			ETM+ LEDAPS (Claverie et al., 2015)			OLI (Vermote et al., 2016)		
	A	P	**U**	A	P	**U**	A	P	**U**
2	7	9	**11**	9	7	**12**	2	6	**6**
3	1	9	**9**	6	9	**11**	3	6	**7**
4	9	10	**14**	1	9	**9**	1	6	**6**
5	5	17	**17**	3	14	**15**	2	12	**12**
7	1	14	**14**	5	15	**16**	9	11	**14**

OLI surface reflectance APU scores expressed in 10^{-3} reflectance (compared to TM and ETM+ surface reflectance APU by Claverie et al. (2015) using Aqua MODIS BRDF and spectrally adjusted surface reflectance CMG product as reference, the OLI surface reflectance was aggregated over the CMG. Band number corresponds to OLI band number designation and equivalent TM/ETM+ bands were reported.

ACIX: CEOS-WGCV Atmospheric Correction Inter-comparison Exercise (ESA/NASA/UMD)

The exercise aims to bring together available AC processors (**actually 14 processors including SEN2COR, MACCS, L8-S2-6SAC, …**) to generate the corresponding SR products.

The input data will be **Landsat-8 and Sentinel-2 imagery** of various test sites, i.e. coastal, agricultural, forest, snow/artic areas and deserts.

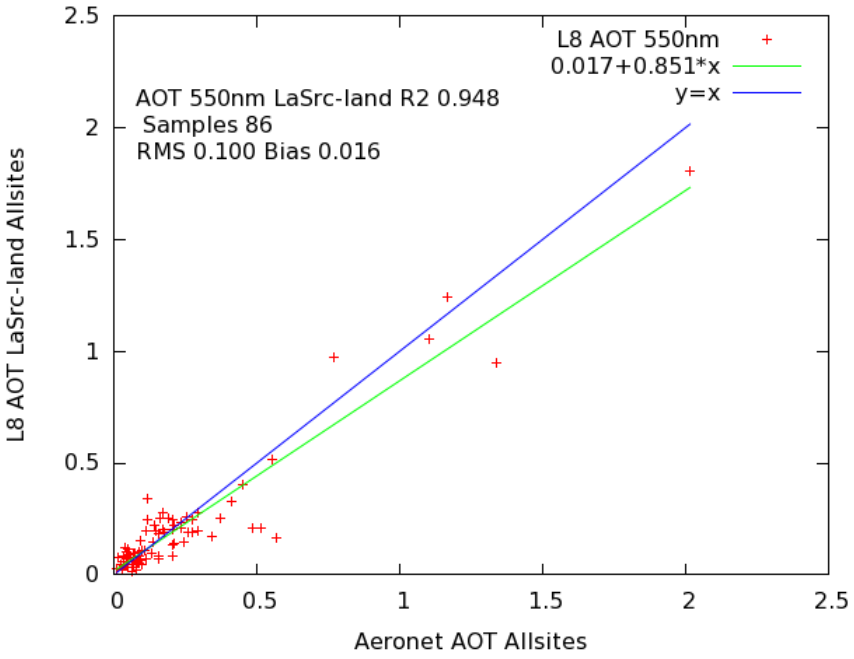
Objectives
- To better understand uncertainties and issues on L8 and S2 AC products
- To propose further improvements of the future AC schemes

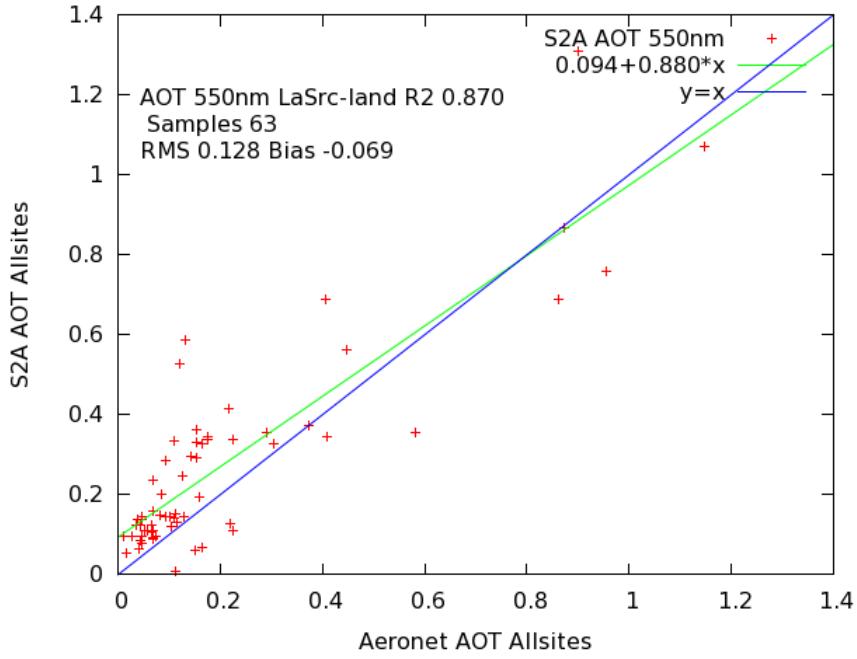
* 1st Workshop in June 21st-22nd 2016 @ University of Maryland: to elaborate concepts, protocols and guidelines for the inter-comparison and validation of SR products

- 2nd workshop in April 2017
- Results to be finalized in fall 2017

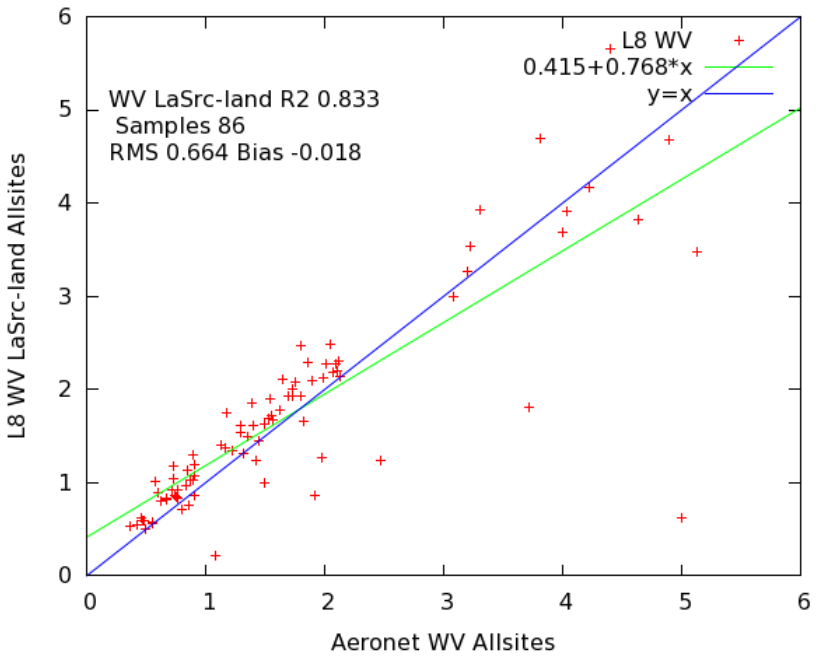
https://earth.esa.int/web/sppa/meetings-workshops/acix

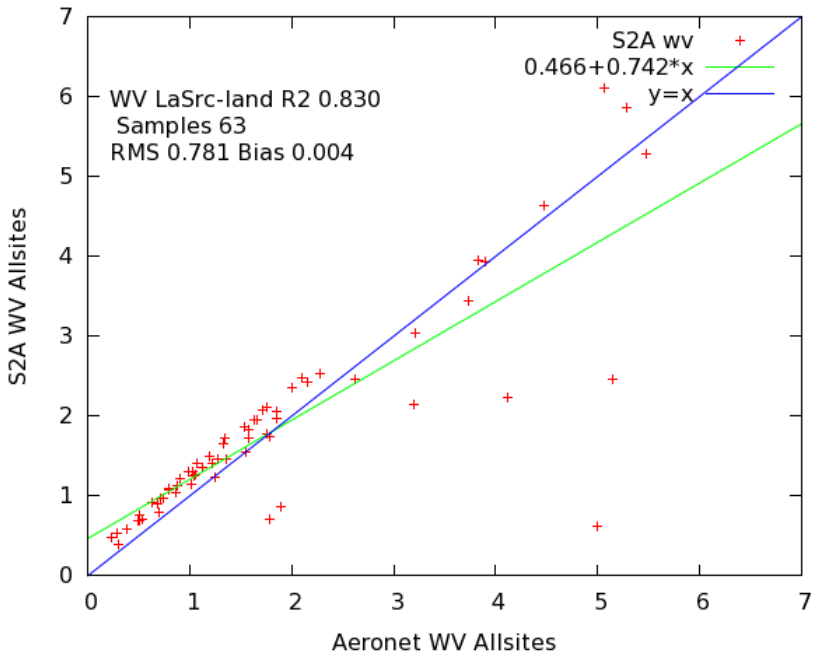
ACIX results for the LaSRC algorithm (L8/S2A) (Land sites only, no cloud)



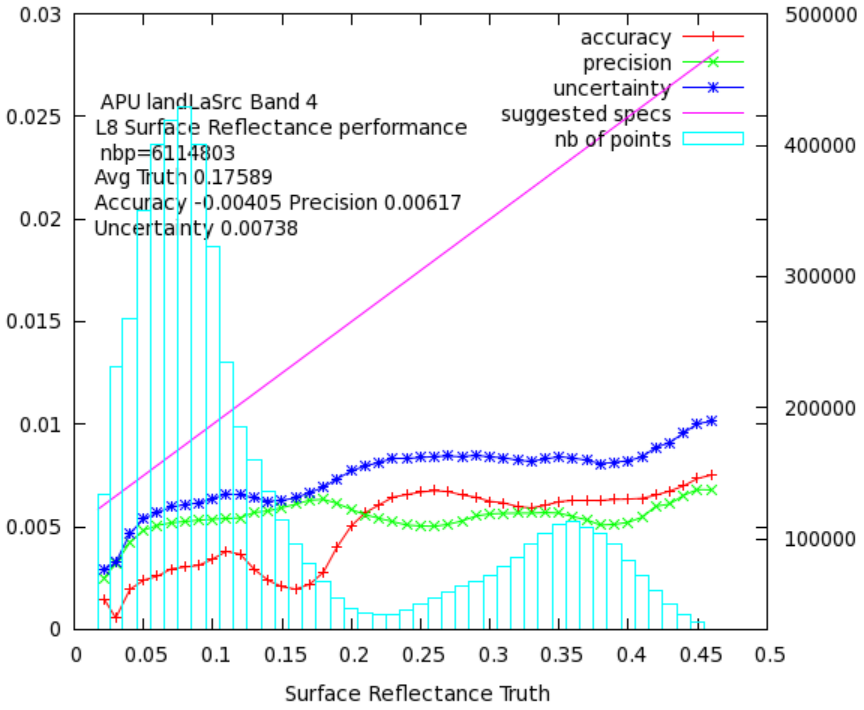


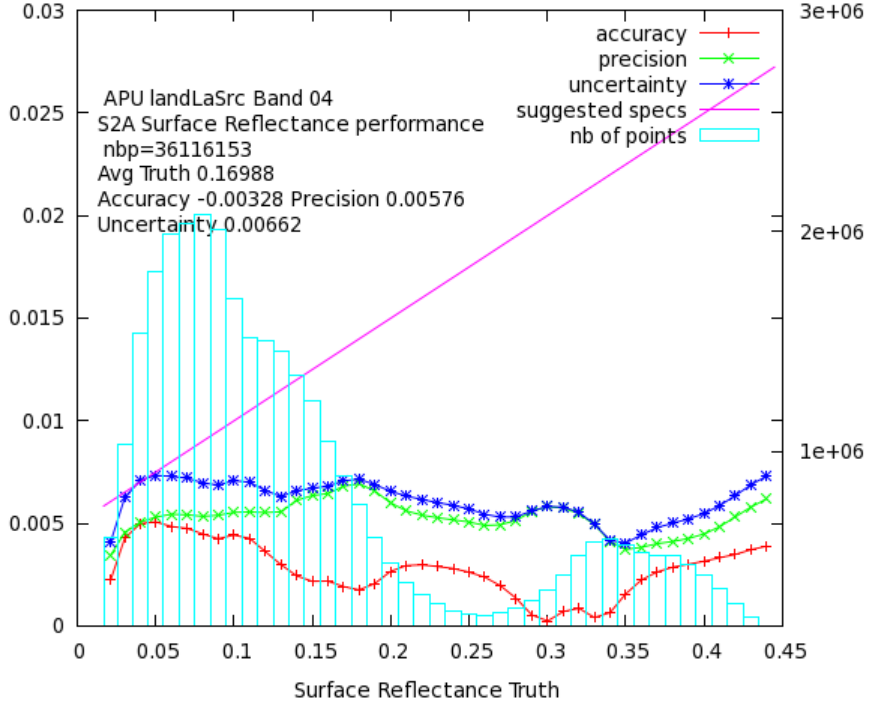
ACIX results for the MODIS SR algorithm (L8/S2A) (Land sites only, no cloud)



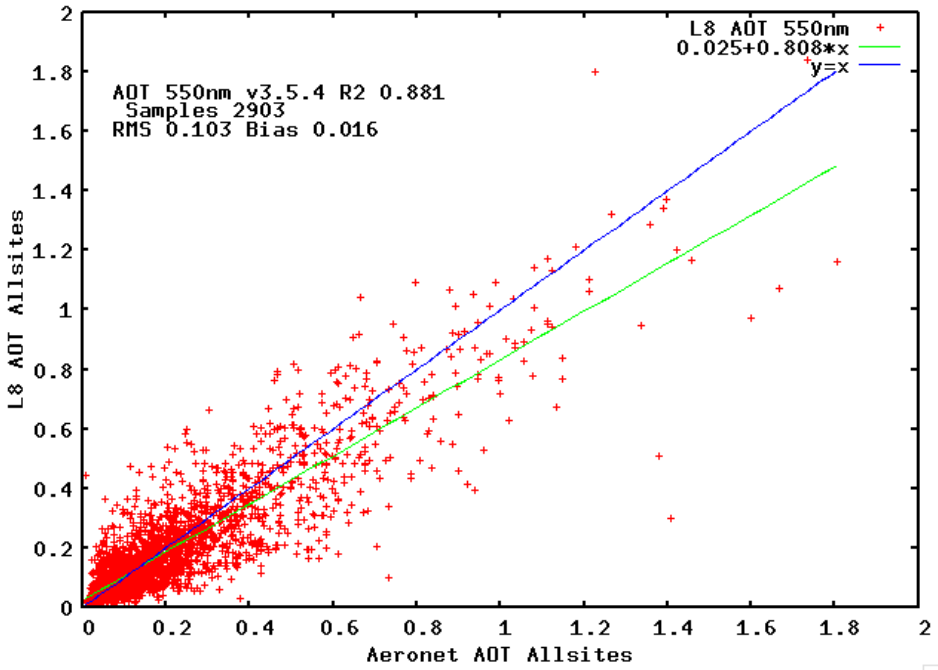


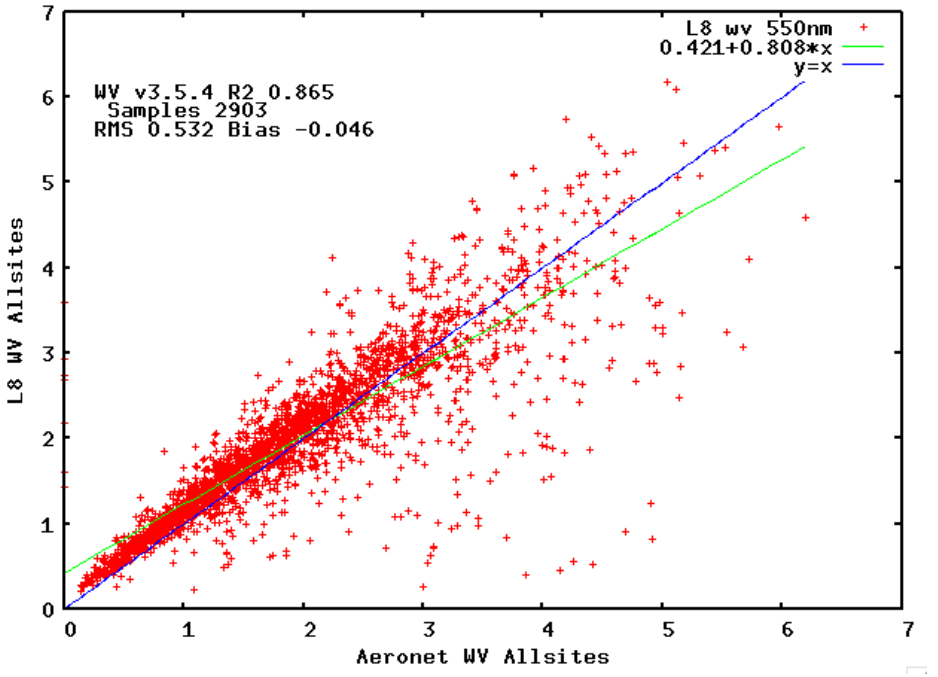
ACIX results for the MODIS SR algorithm (L8/S2A) (Land sites only, no cloud)





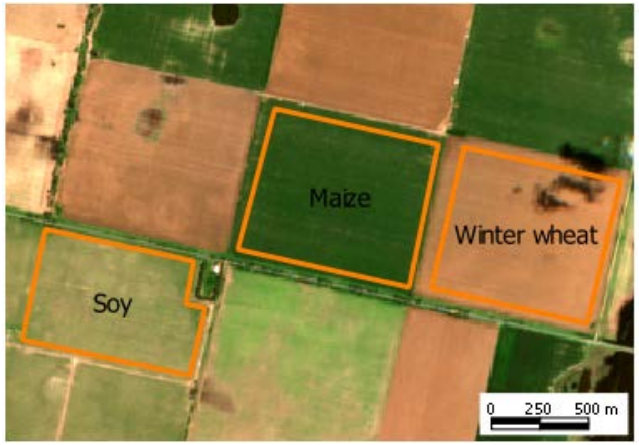
Validation is on-going moving into a systematic routine assesment



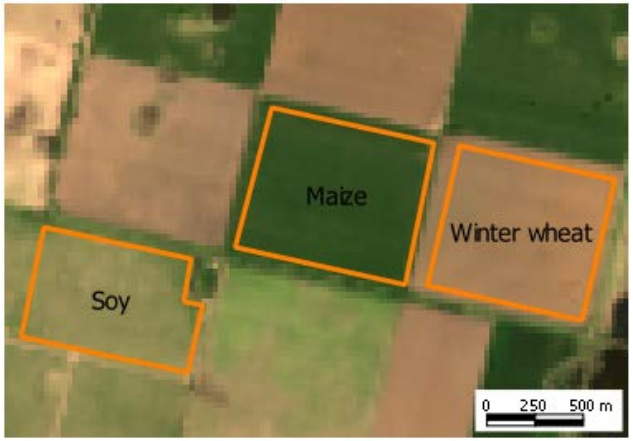


Temporal information is now available at the field level

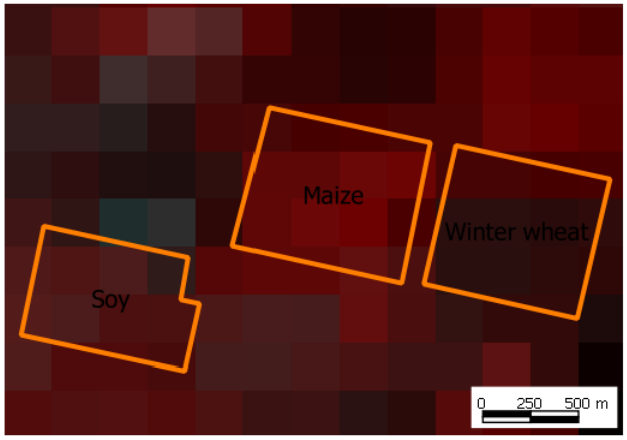
NDVI aggregated at field level (Argentina, S2A tile 20HNH).



Sentinel-2A image acquired on 04-Dec-15, 10m, true color B04-03-02 (SR, scaled 0-0.15)



Landsat-8 image acquired on 04-Dec-15, 30m, true color B4-3-2 (SR, scaled 0-0.15)



MOD09GQ image acquired on 04-Dec-15, 250m, false color B2-1-1, SR

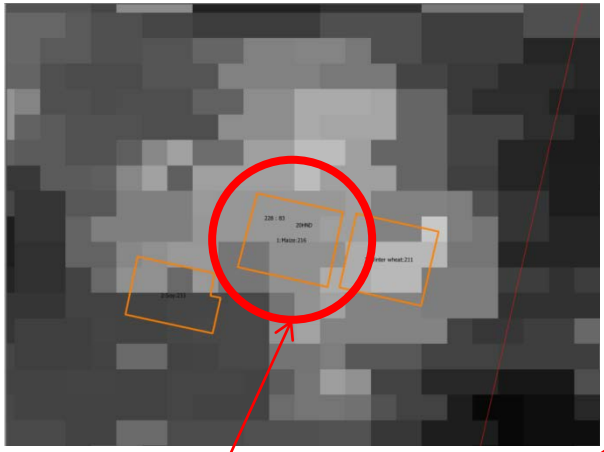
Sentinel-2A image acquired on 23-Jan-16, 10m, true color B04-03-02 (SR, scaled 0-0.15)

Landsat-8 image acquired on 21-Jan-16, 30m, true color B4-3-2 (SR, scaled 0-0.15)

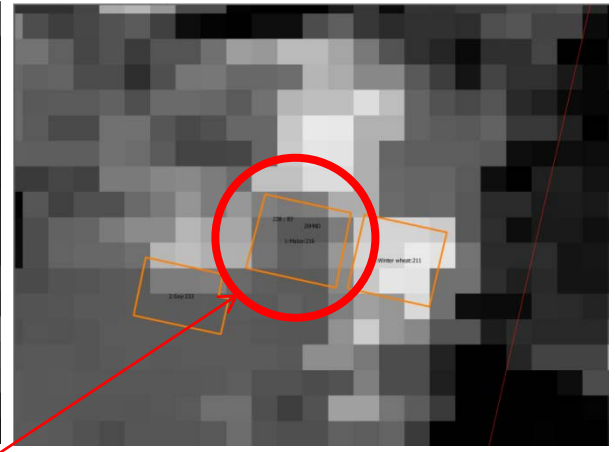
Temporal information is now available at the field level

NDVI aggregated at field level (Argentina, S2A tile 20HNH).

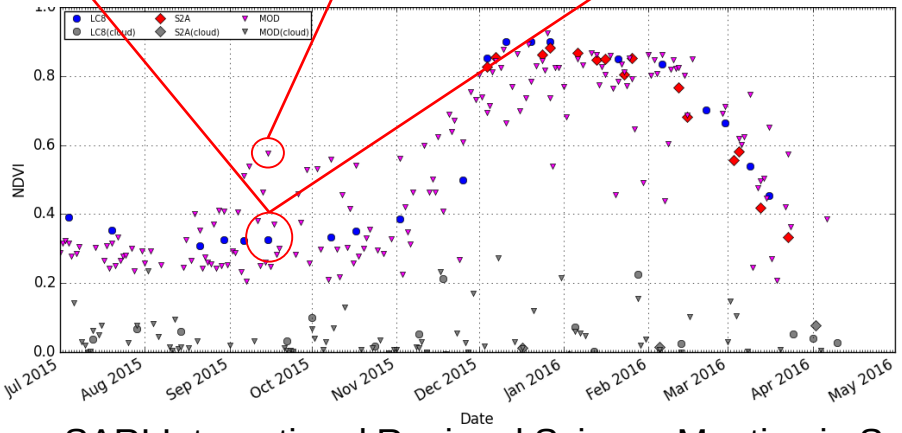
LC8 acquired on **15-Sep-2015** (30m). SR NIR band scaled 0.05-0.55



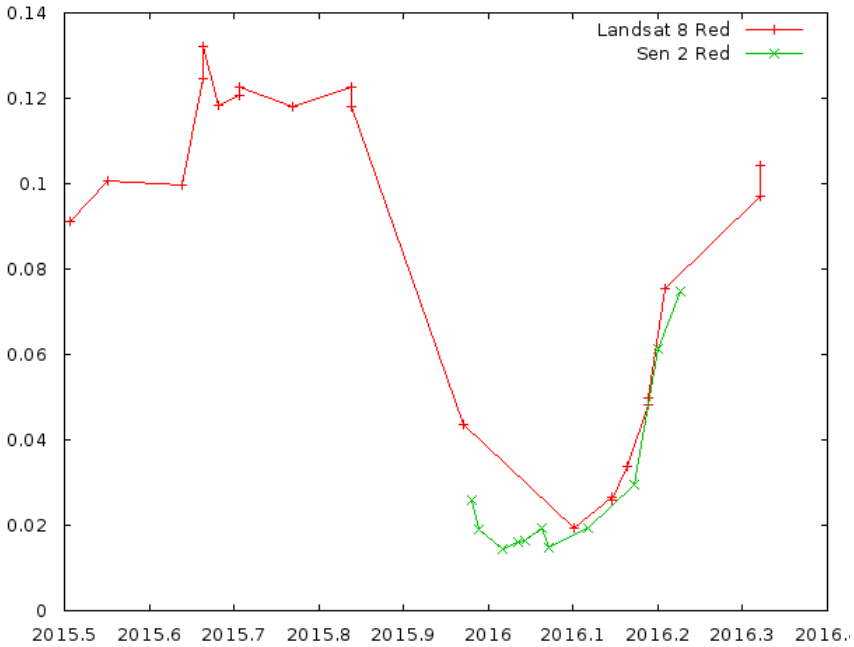
MODIS/Terra (MOD09GQ) acquired on **15-Sep-2015** (250 m). SR NIR band scaled 0.05-0.55

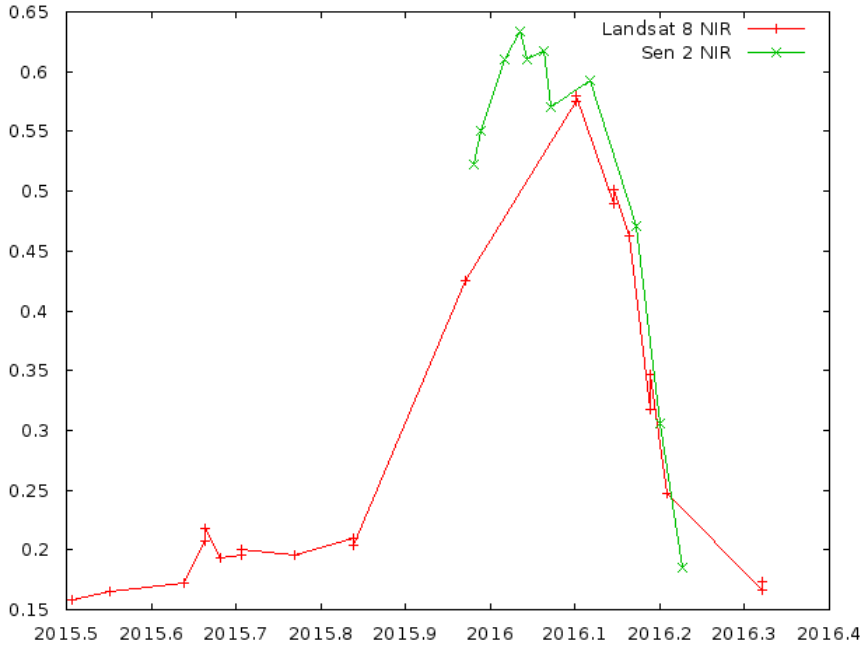


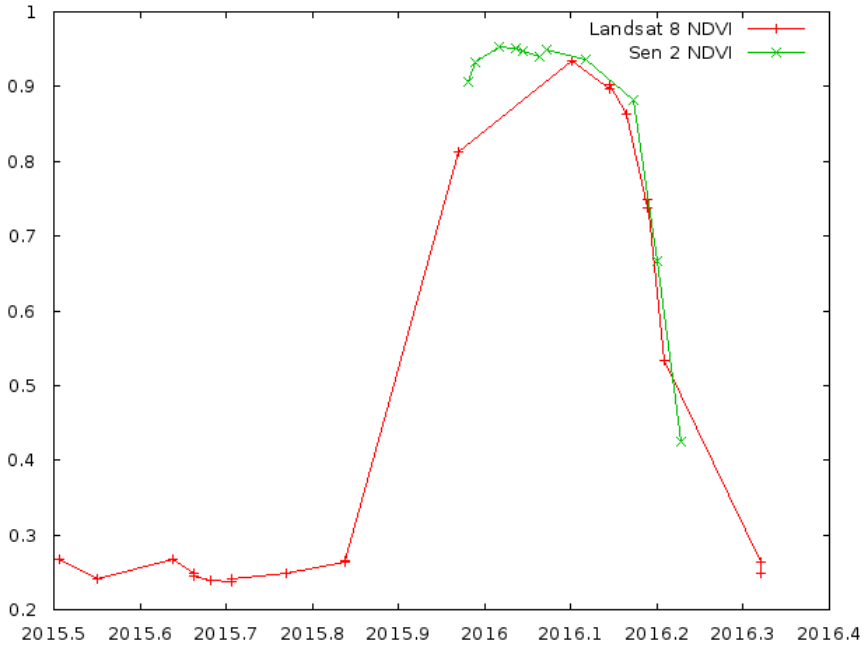
MODIS/Terra (MOD09GQ) acquired on **16-Sep-2015** (250 m). SR NIR band scaled 0.05-0.55



Maize


Landsat 8 Red
Sen 2 Red
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2015.5
2015.6
2015.7
2015.8
2015.9
2016
2016.1
2016.2
2016.3


Landsat 8 NIR
Sen 2 NIR
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
2015.5
2015.6
2015.7
2015.8
2015.9
2016
2016.1
2016.2
2016.3
2016.4

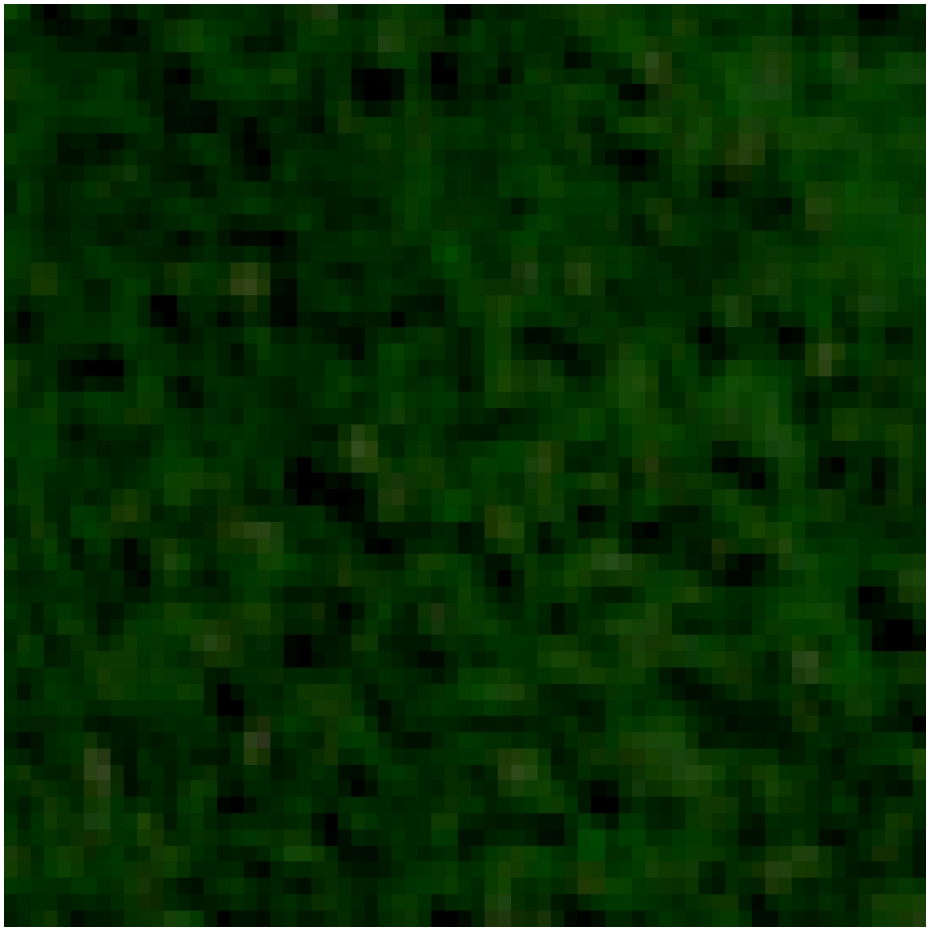

Landsat 8 NDVI
Sen 2 NDVI
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
2015.5
2015.6
2015.7
2015.8
2015.9
2016
2016.1
2016.2
2016.3
2016.4

Multi-temporal observations available over challenging area (Amazon forest) 9kmx9km

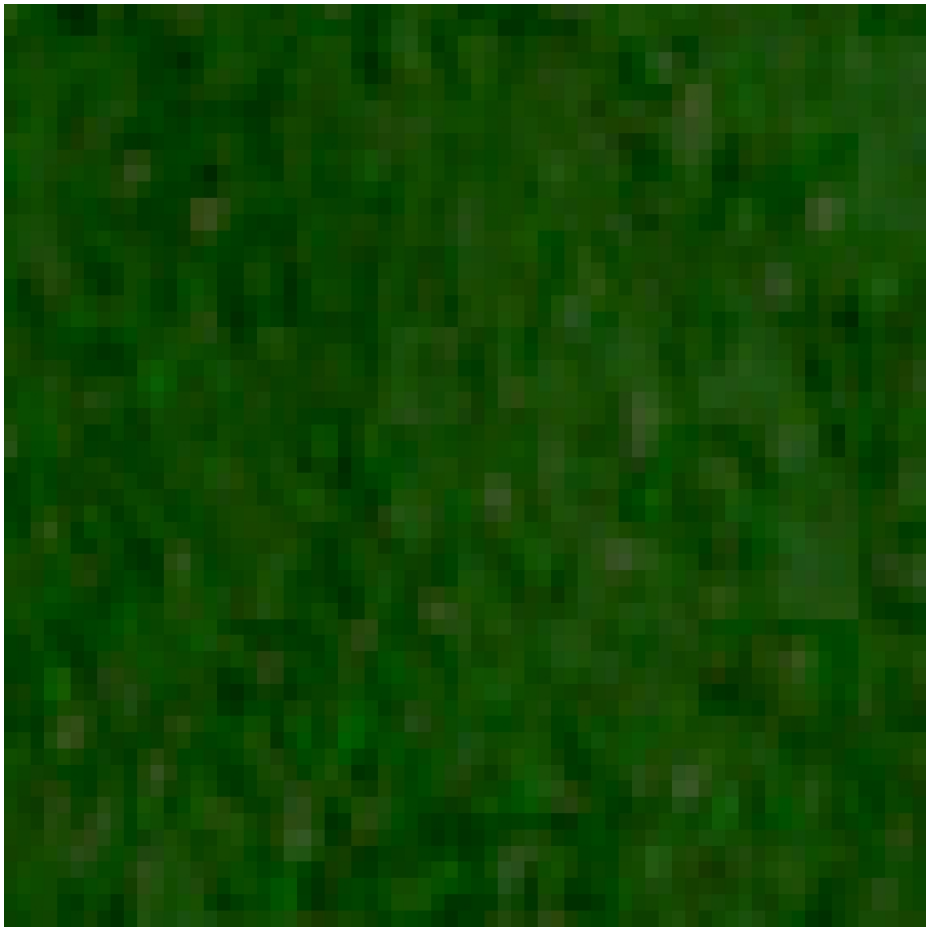
July 1 2016, beginning of dry season
SZA=36 degrees

Sept 19 2016, toward end of dry season
SZA=23 degrees

Multi-temporal observations available over challenging area (Amazon forest) details 500m x500m (10m resolution)



July 1 2016, beginning of dry season
SZA=36 degrees- More shadows!



Sept 19 2016, toward end of dry season
SZA=23 degrees

Conclusions

- Surface reflectance code (LaSRC) is mature and pathway toward validation and automated QA is clearly identified.
- Algorithm is generic and tied to documented validated radiative transfer code so the accuracy is traceable enabling error budget.
- The use of BRDF correction enables easy cross-comparison of different sensors (MODIS,VIIRS,AVHRR, LDCM, Landsat, Sentinel 2 ,Sentinel 3…)
- Preliminary Sentinel 2 surface reflectance validation shows good performance but needs a more extensive study