Toward a Consistent Climate Data Record Surface Reflectance Product

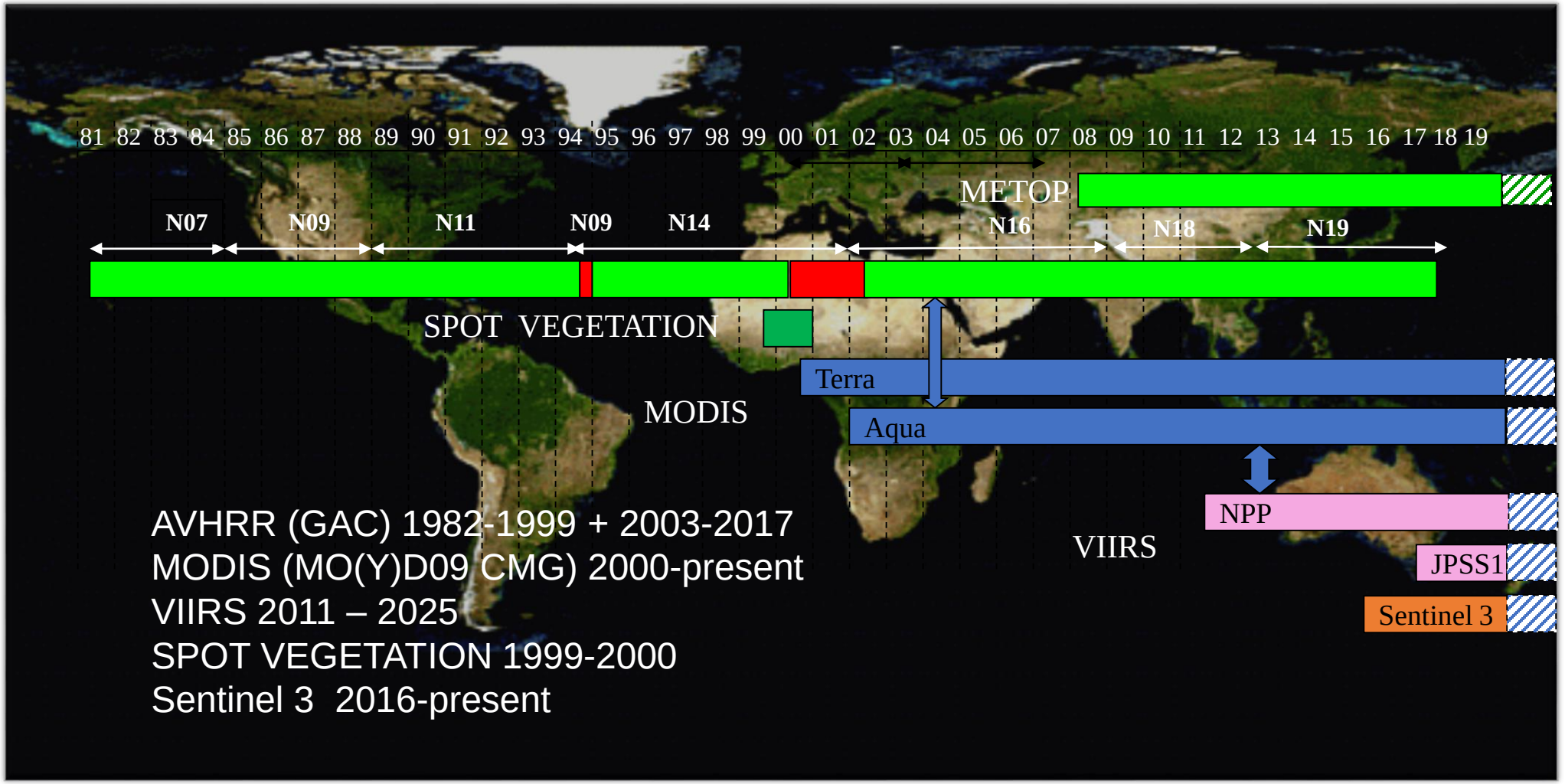
Vermote et al.

NASA/GSFC

VH-RODA & CEOS WGCV SAR 2019 Workshop, Nov 18-22, ESA/ESRIN, Frascati, Italy.

A Land Climate Data Record

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



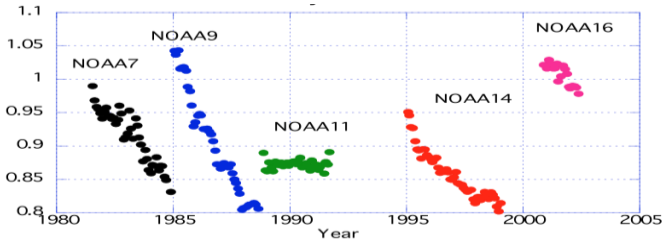
Emphasis on data consistency – characterization rather than degrading/smoothing the data

Land Climate Data Record (Approach)

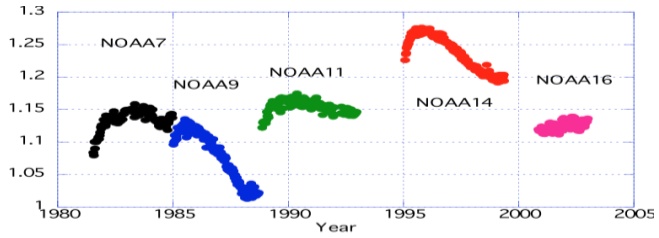
Needs to address geolocation,calibration, atmospheric/BRDF correction issues

CALIBRATION

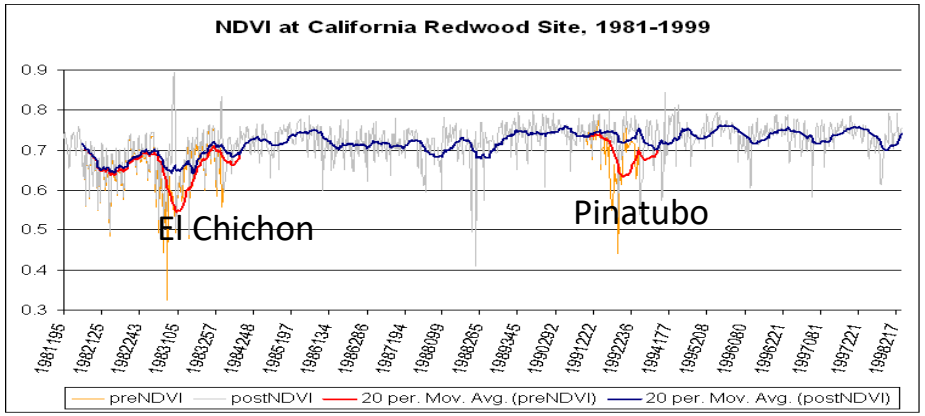
Degradation in channel 1
(from Ocean observations)



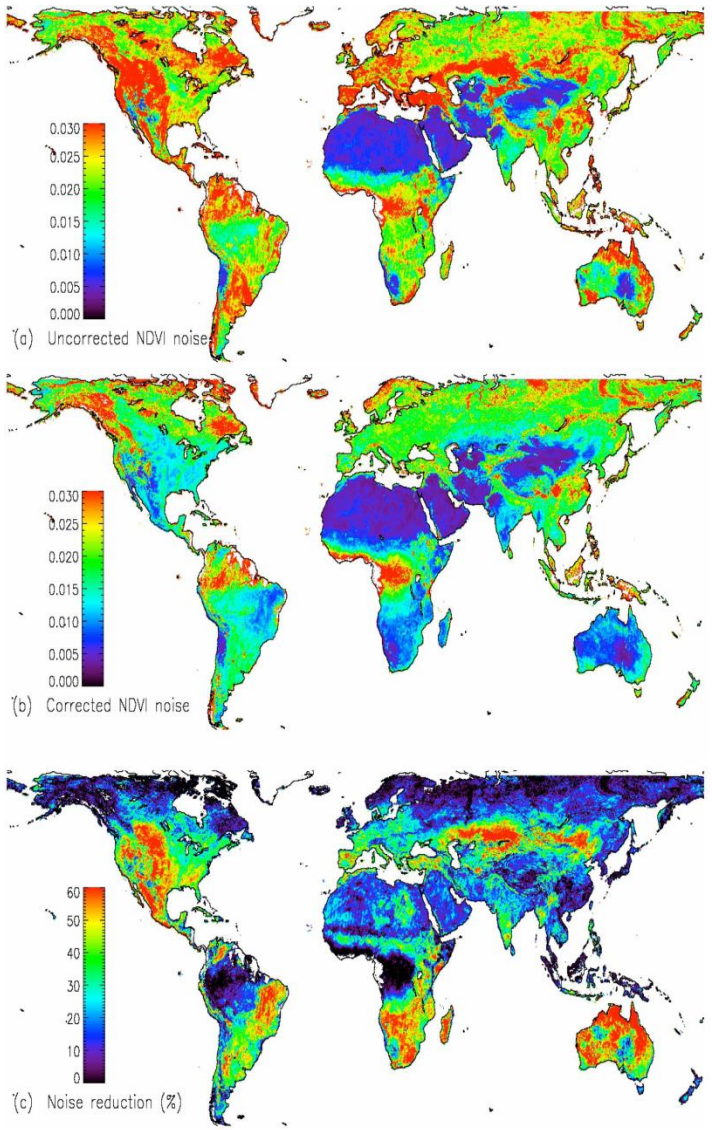
Channel1/Channel2 ratio
(from Clouds observations)



ATMOSPHERIC CORRECTION



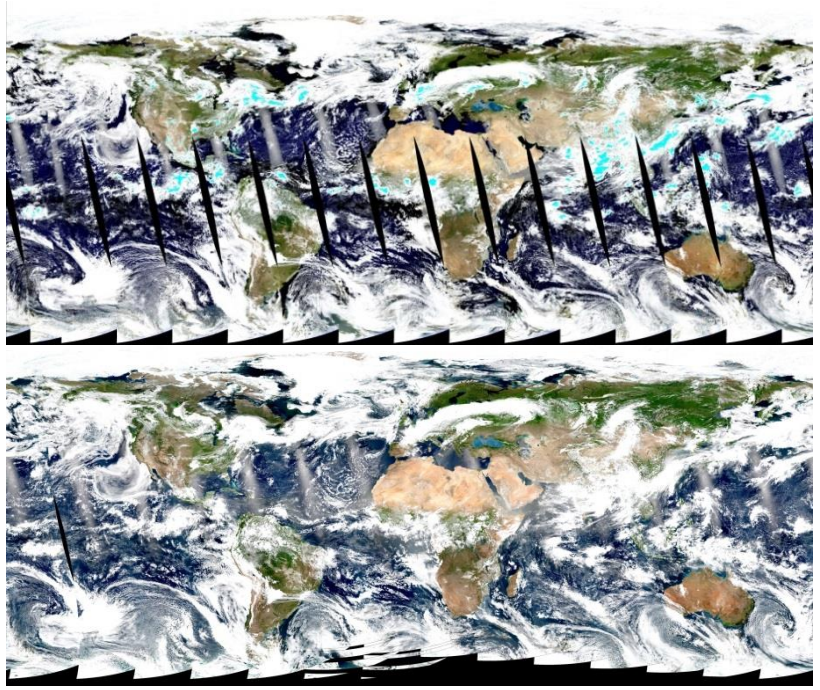
BRDF CORRECTION



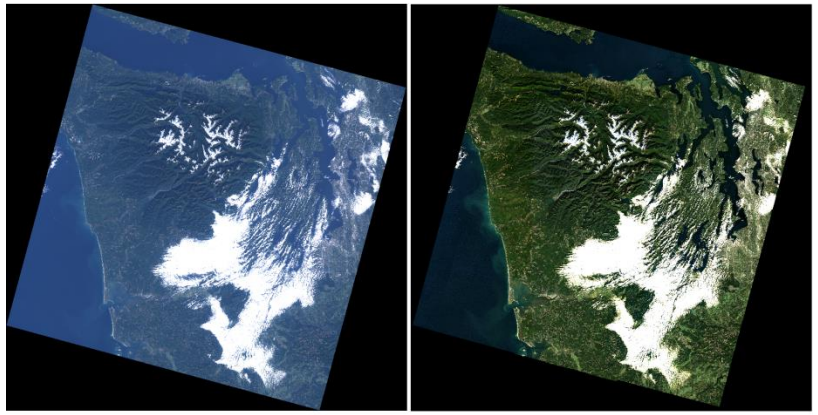
Atmospheric correction (AC)

- 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)
    - 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

(Vermote et al., 2016, *RSE*)



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

LaSRC Surface Reflectance is largely based on MODIS C6

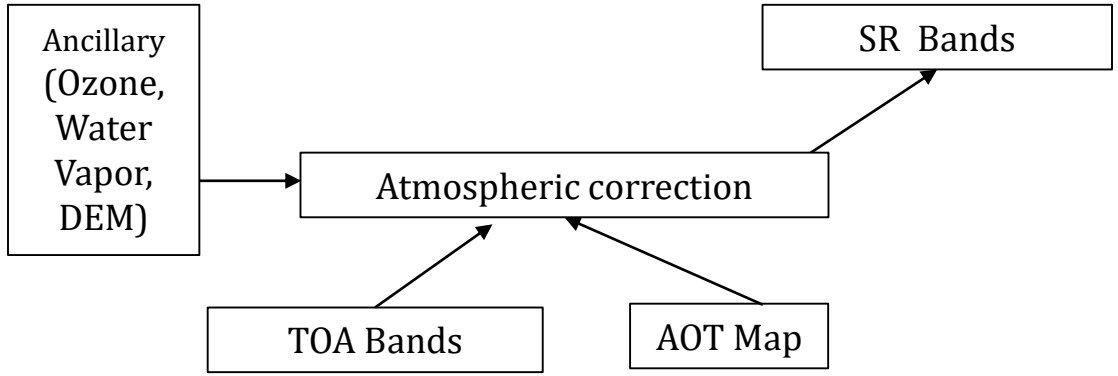
Algorithm reference for L8: Vermote E., Justice C., Claverie M., Franch B., (2016) "Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product", Remote Sensing of Environment, 185,46-56.

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 Landsat8/Sentinel 2 images***
  - ***Water vapor and ozone from daily MODIS product.***

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

Flowchart of the LaSRC 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.

LaSRC 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 $(\rho_{surf}\,\text{blue} / \rho_{surf}\,\text{red})_{MSI} = (\rho_{surf}\,\text{blue} / \rho_{surf}\,\text{red})_{MODIS}$

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.

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

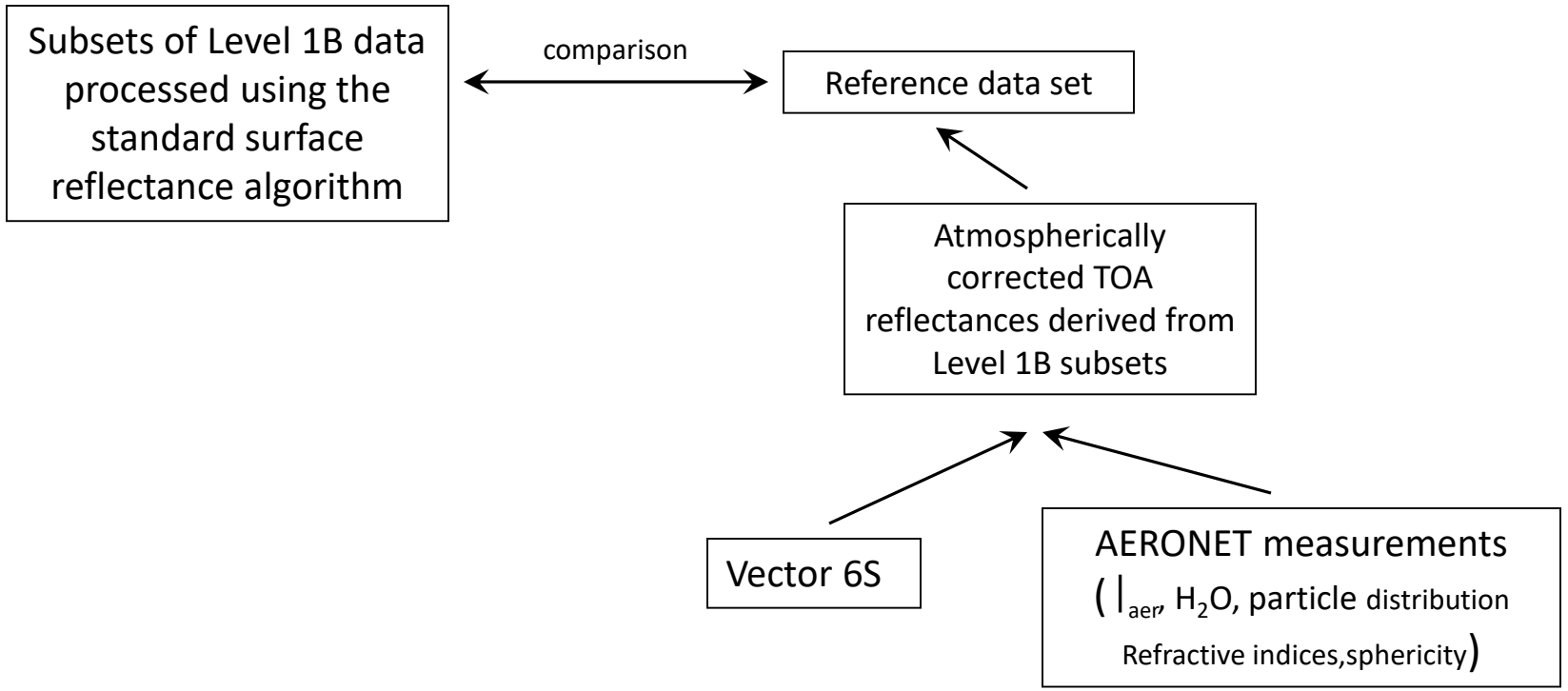
Surface reflectance for each pixel and each band

Computation of **surface reflectances** for all channels

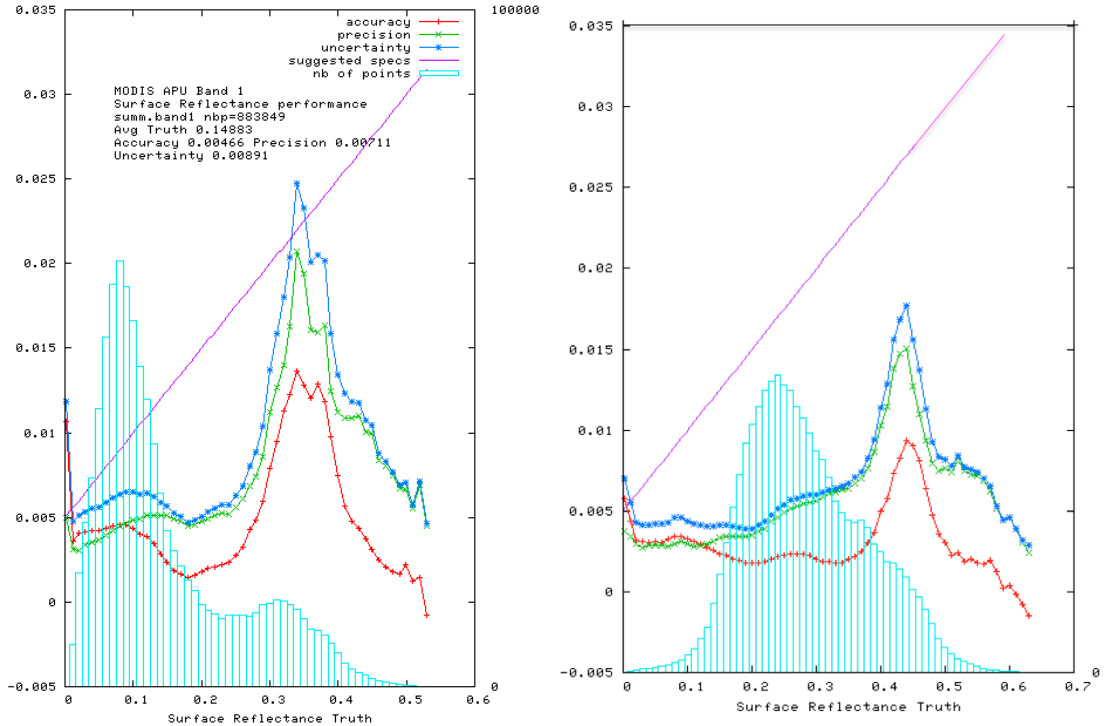
ρ_{surf} determined (*) using ρ_{atm}, T_{atm} and S_{atm} **from LUT** knowing AOT, Aerosol model, pressure, altitude, water vapor, ozone…

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

Methodology for evaluating the performance of LaSRC

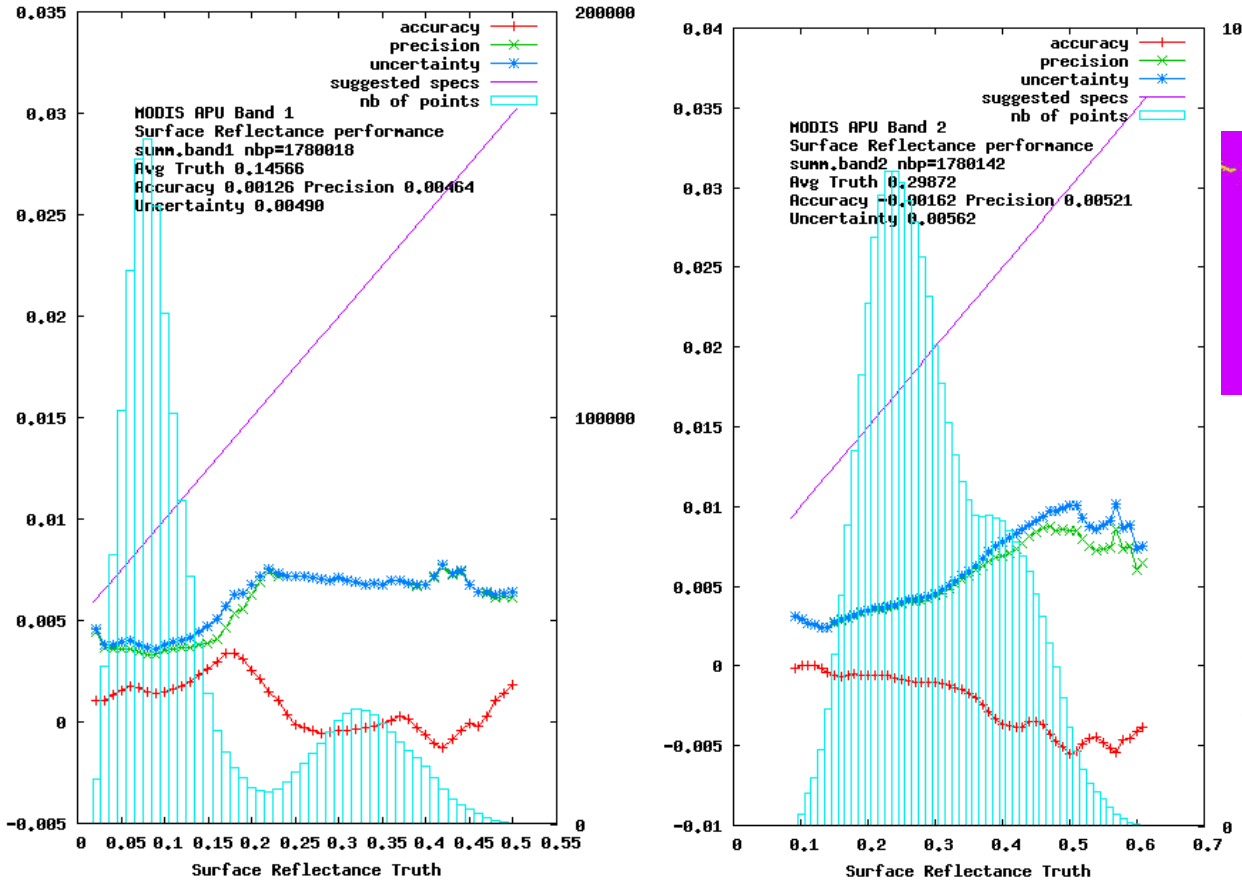


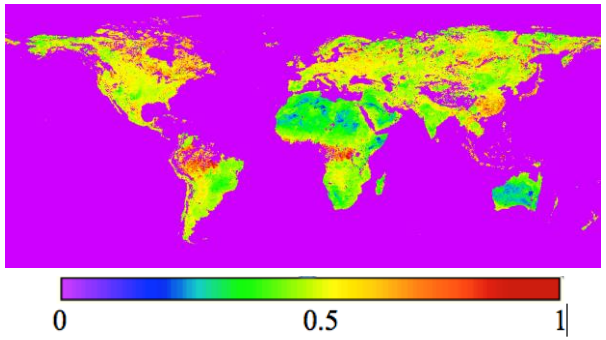
quantitative assessment of performances (APU) for MODIS



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.

Improving the aerosol retrieval in collection 6 reflected in APU metrics

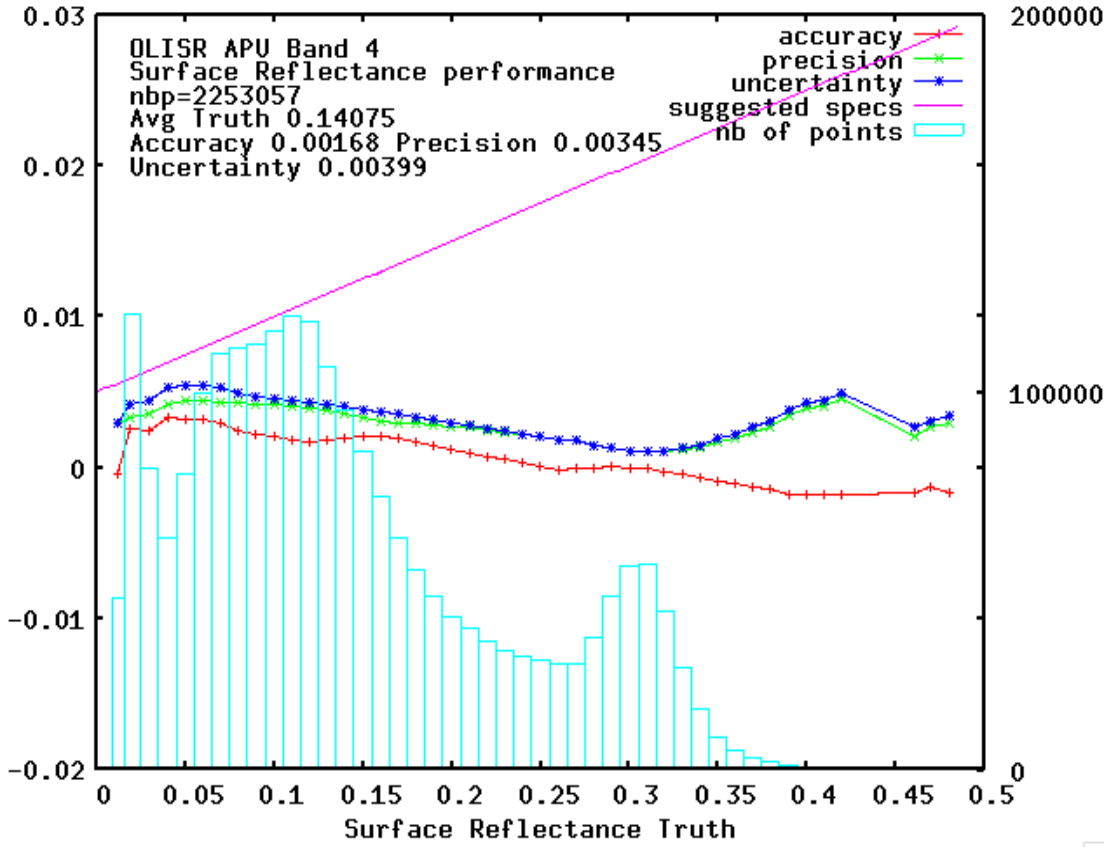




ratio band3/band1 derived using MODIS top of the atmosphere corrected with MISR aerosol optical depth

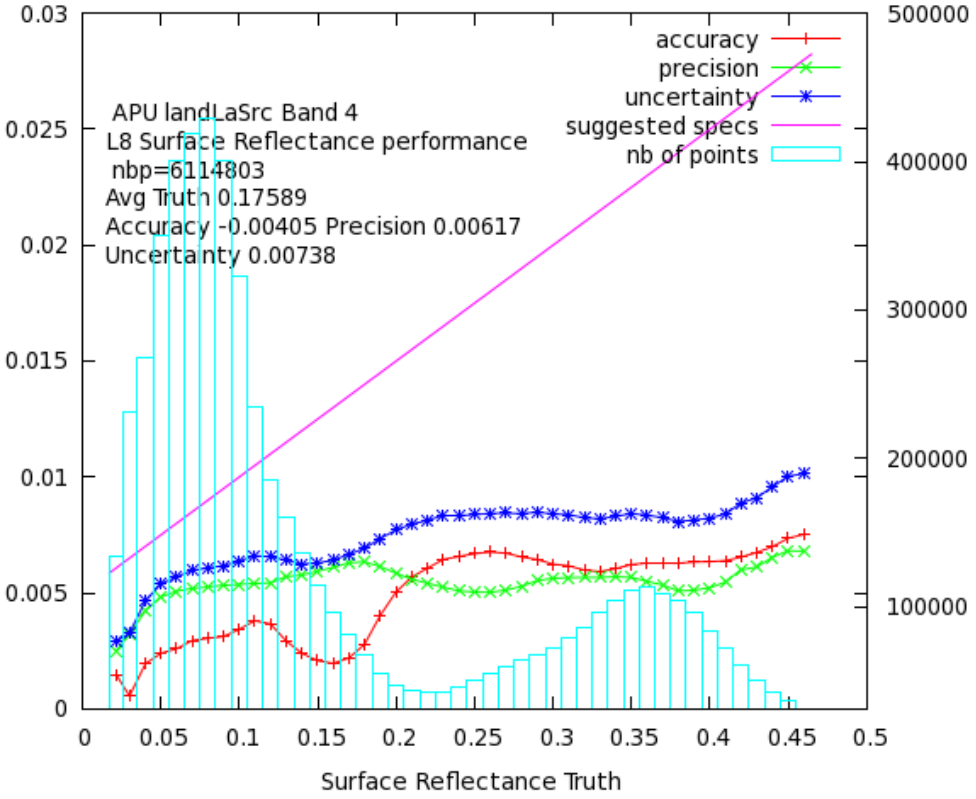
COLLECTION 6: accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (top left), band 2 in the Near Infrared (top right also shown is the uncertainty specification (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.

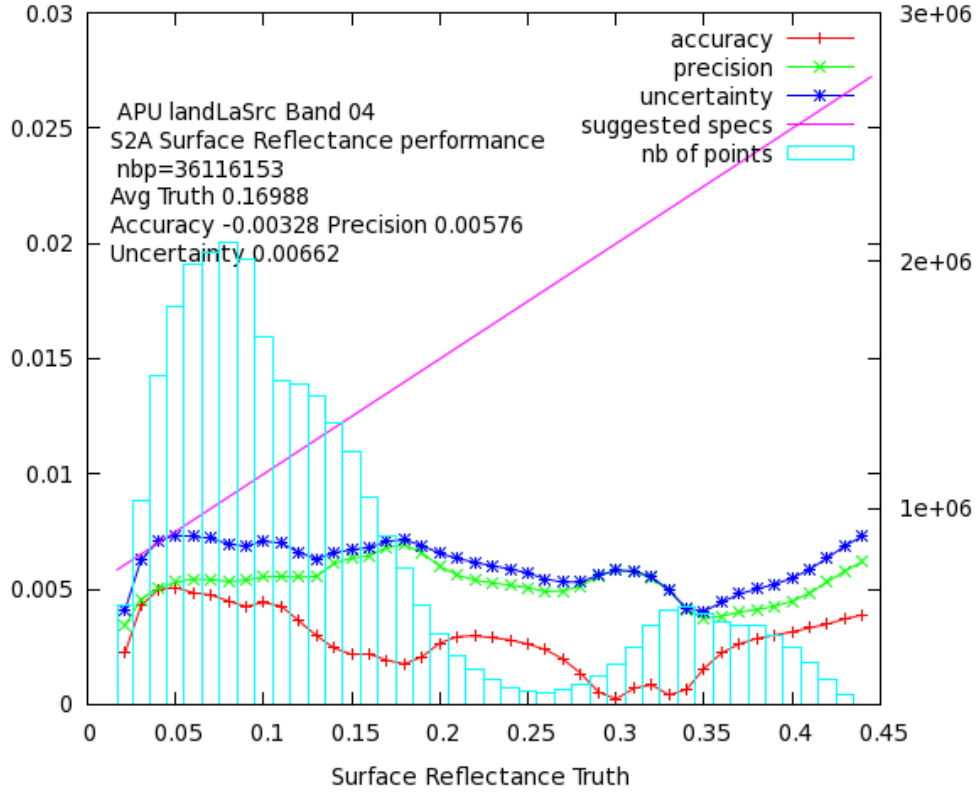
Evaluation of the performance of Landsat8



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

ACIX-I LaSRC performance



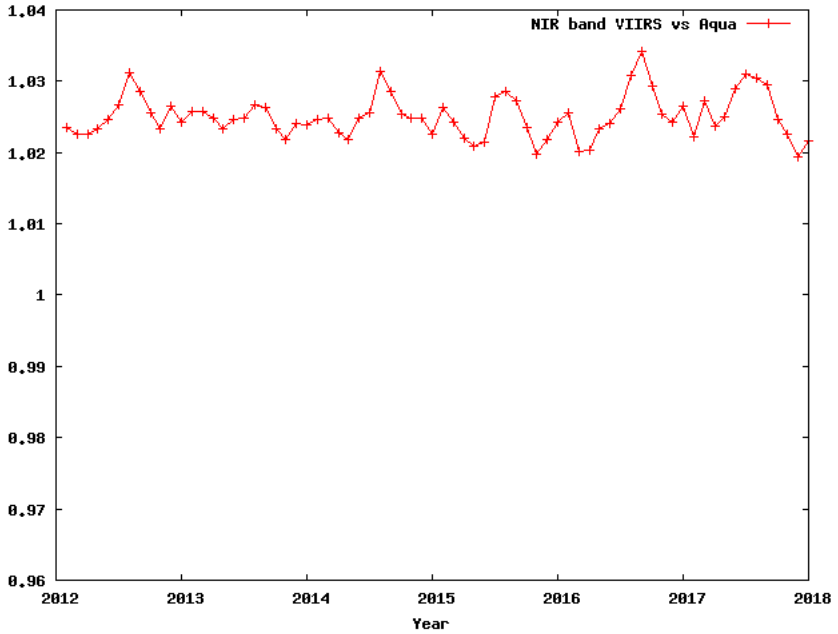


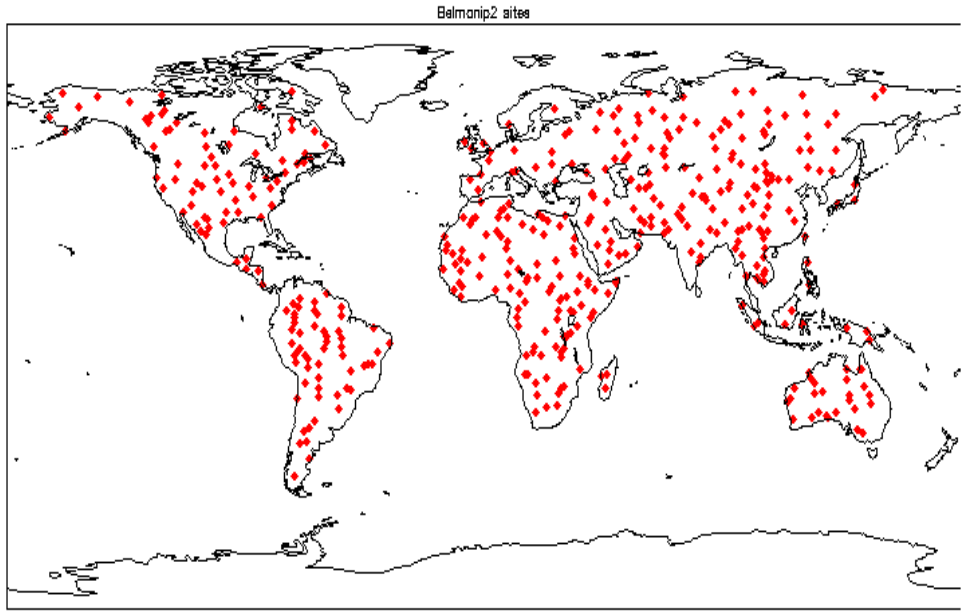
This is confirmed by comparison with MODIS

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.

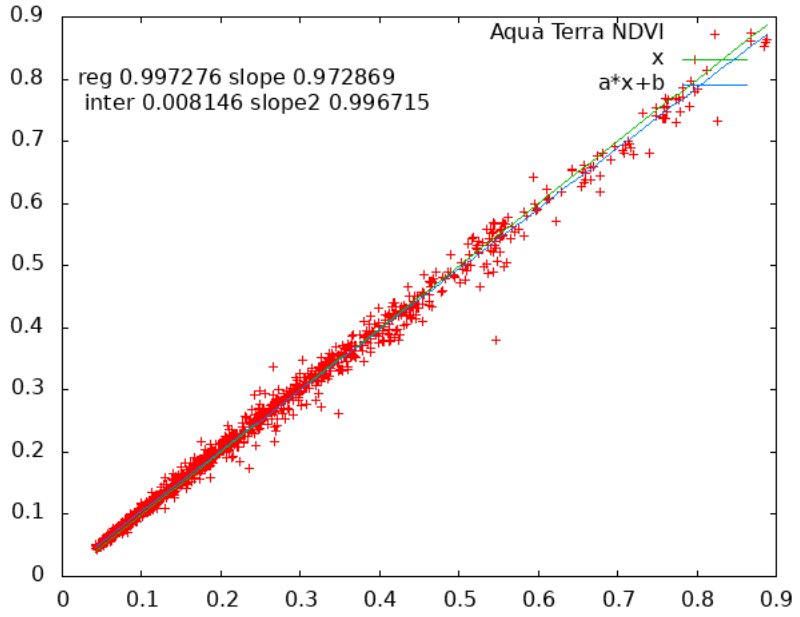
Routine cross-comparison on BELMANIP2 sites

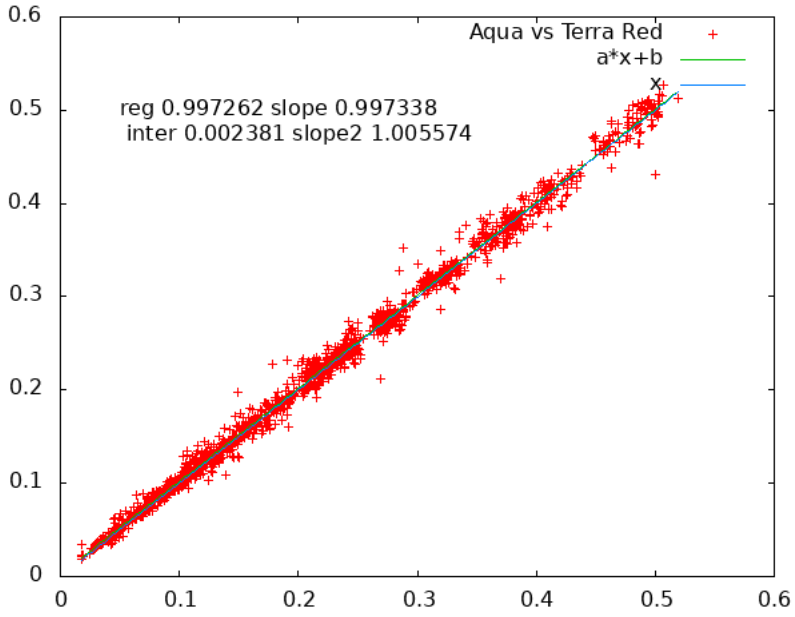


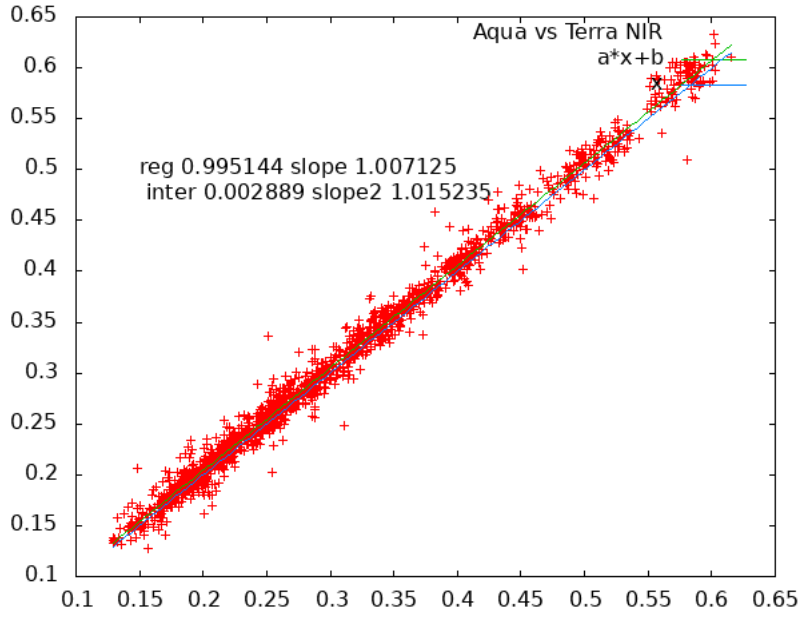


Automated monthly VIIRS cross comparison (over BELMANIP2 sites) with MODIS Aqua from 2012. the stability of both VIIRS and MODIS Aqua is excellent in both red and NIR as shown (+/- 0.5%).

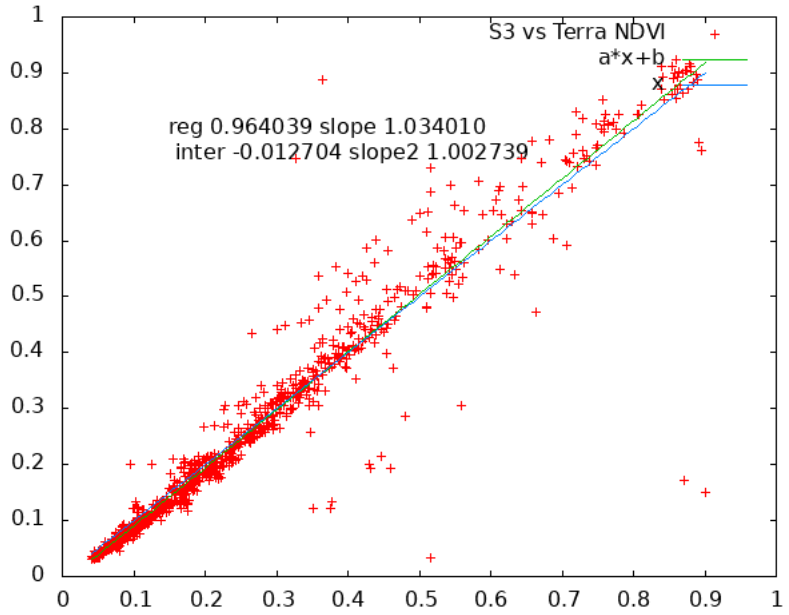
Scatters plot : Aqua vs Terra Dec 2018

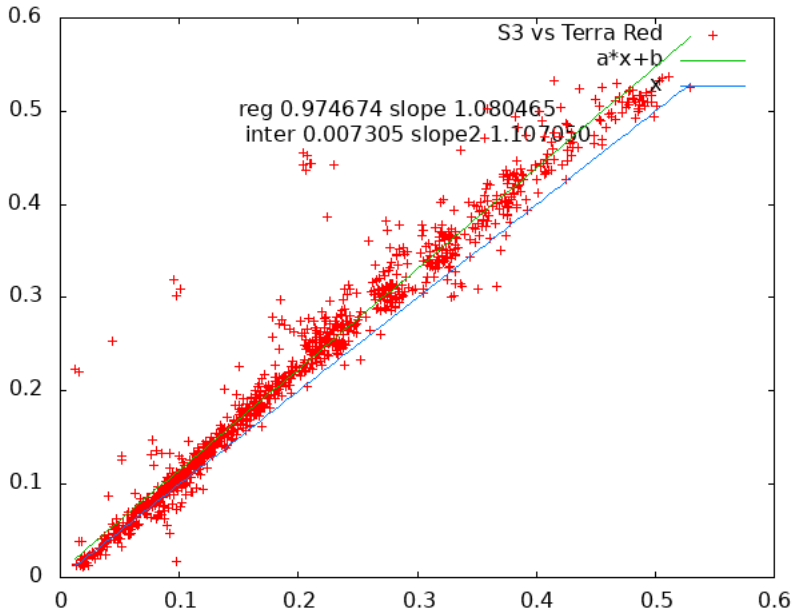


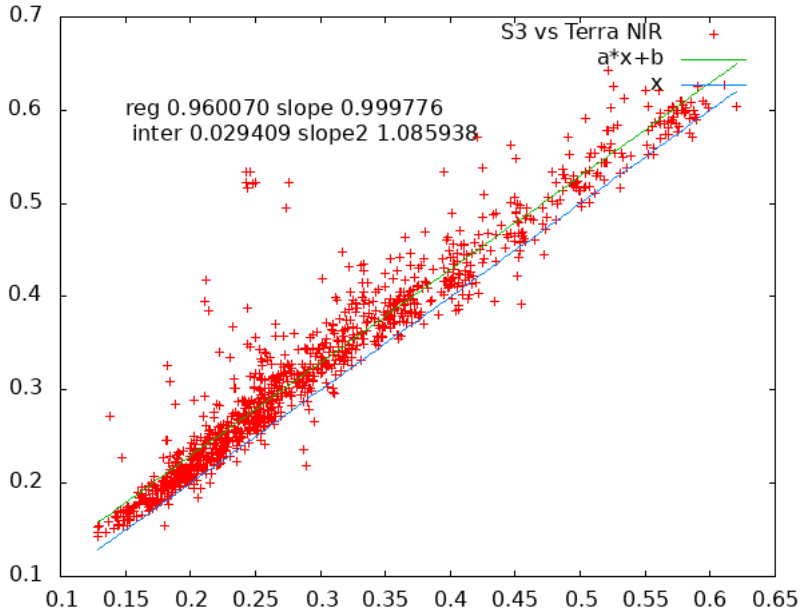




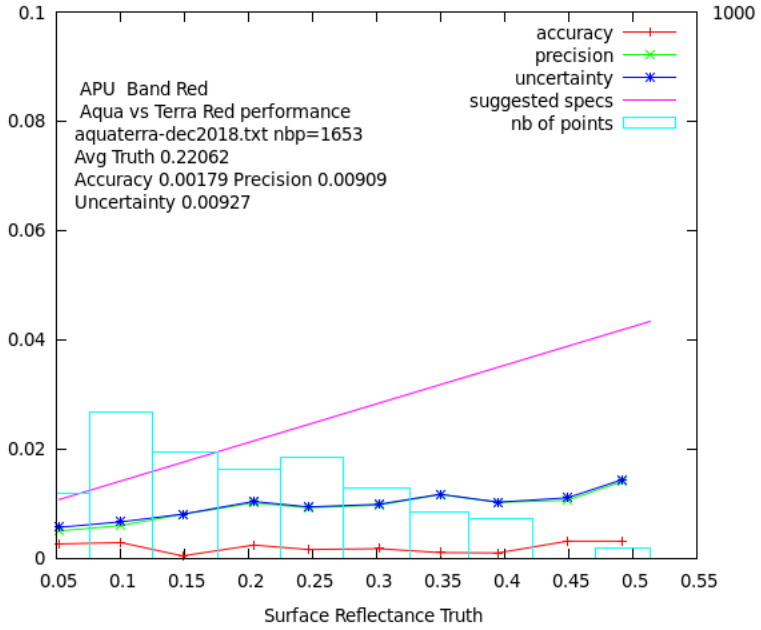
Scatters plot : S3 vs Terra Dec 2018

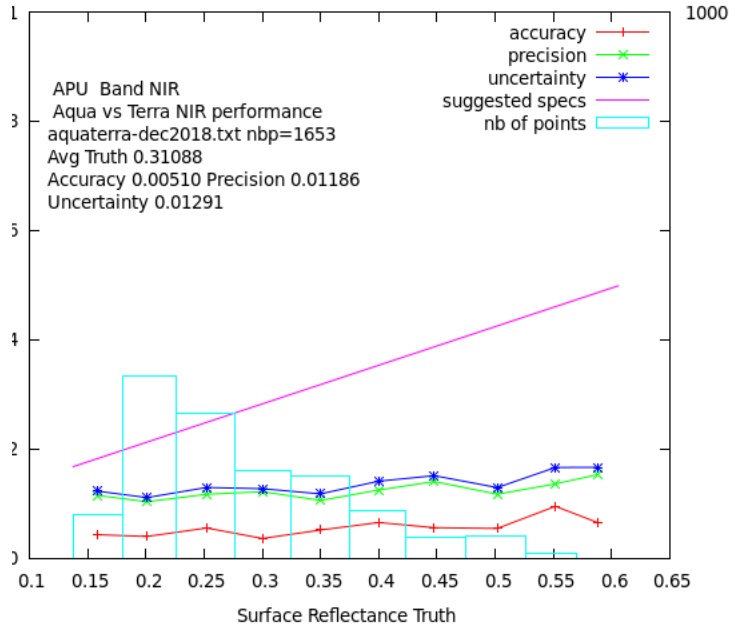


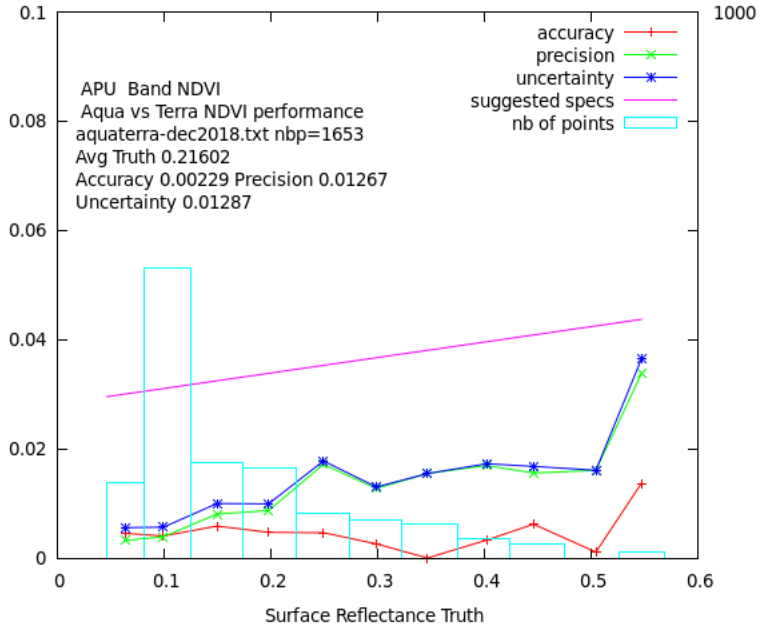




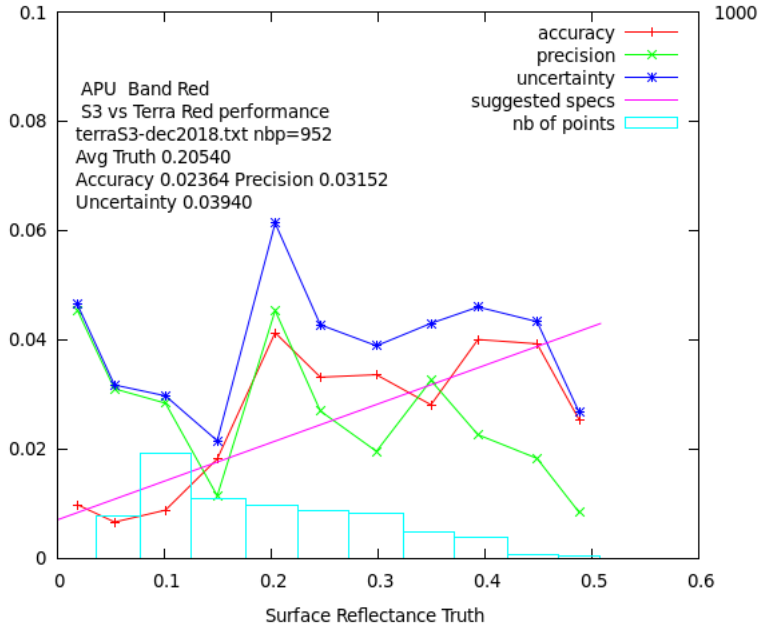
APU: Aqua vs Terra Dec 2018

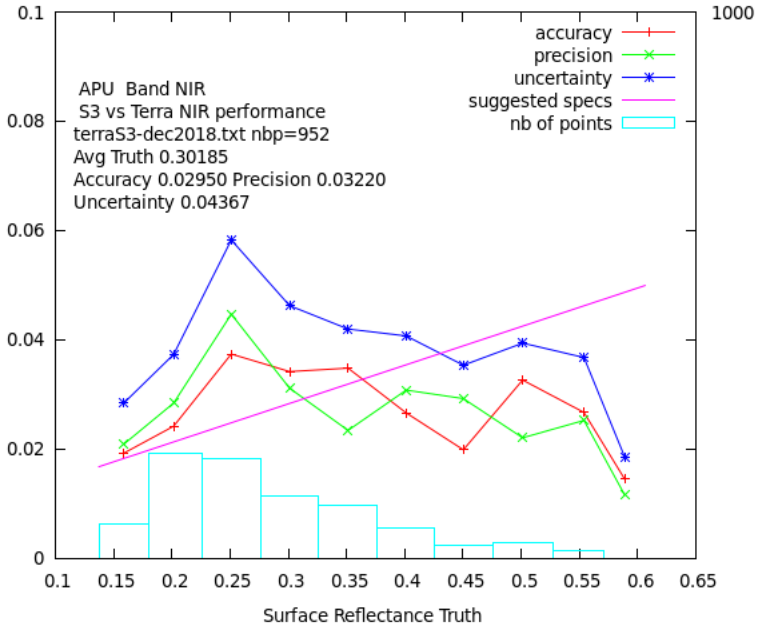


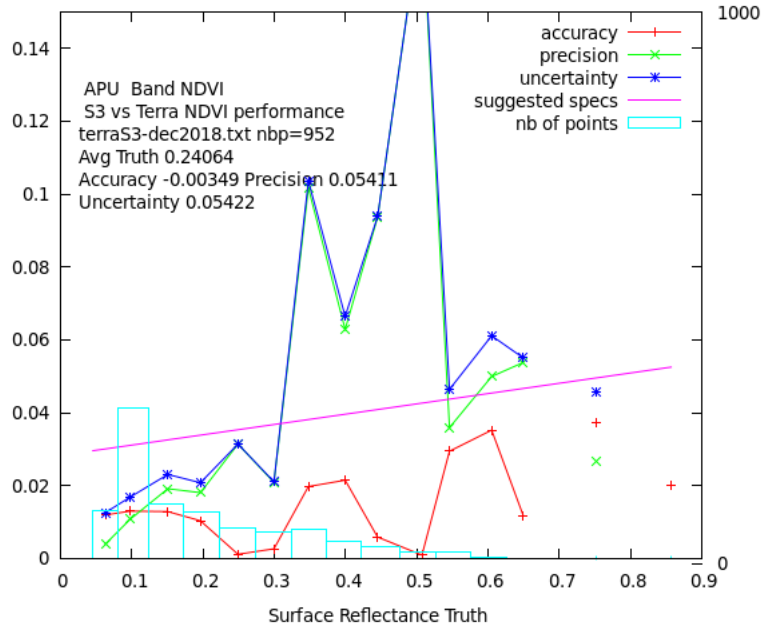




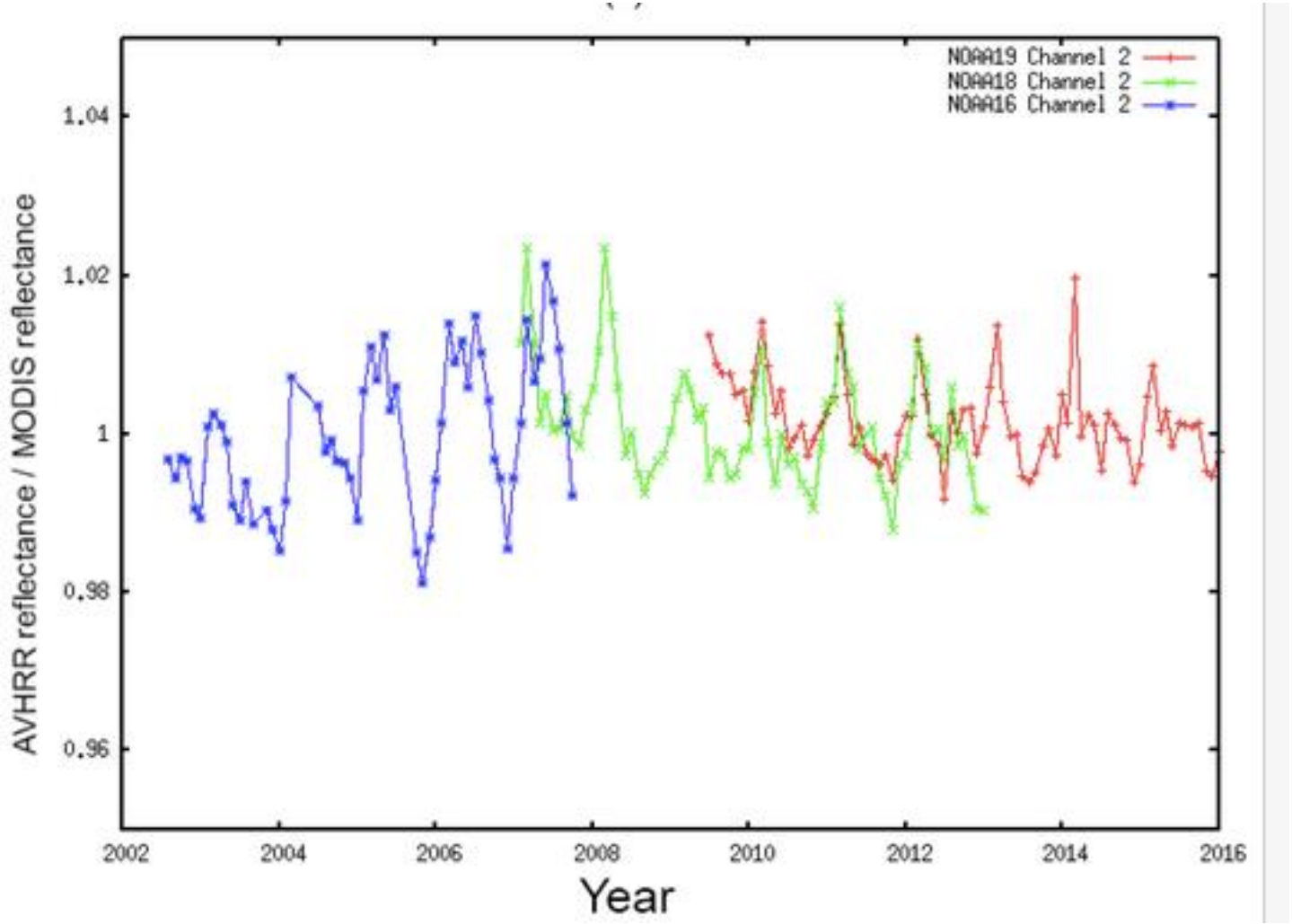
APU: S3 vs Terra Dec 2018



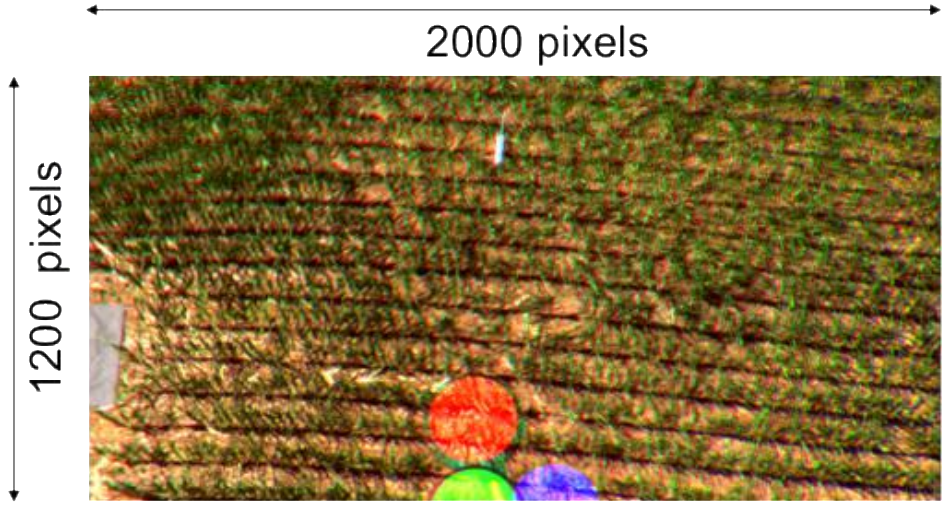




A**VHR**R cross-comparison over BELMANIP2 sites



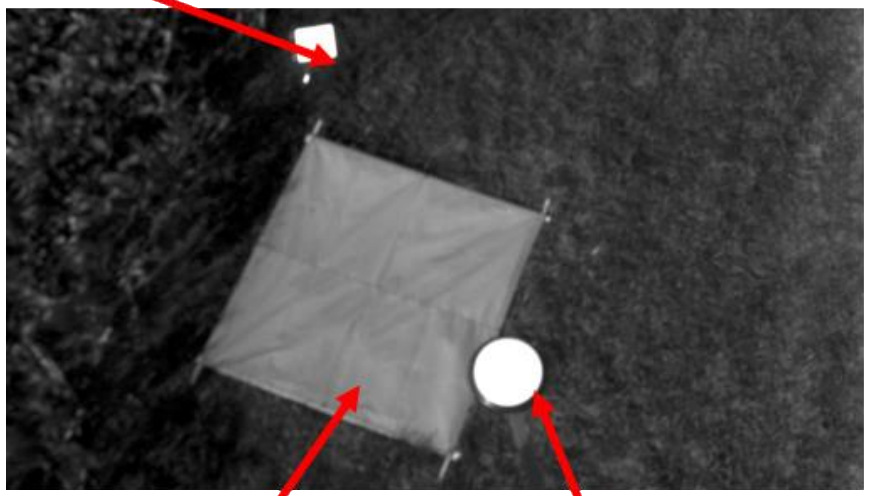
Ground Validation is on going



Measurements were taken 100 feet above the corn field using a boom-lift

Ground Validation is on going

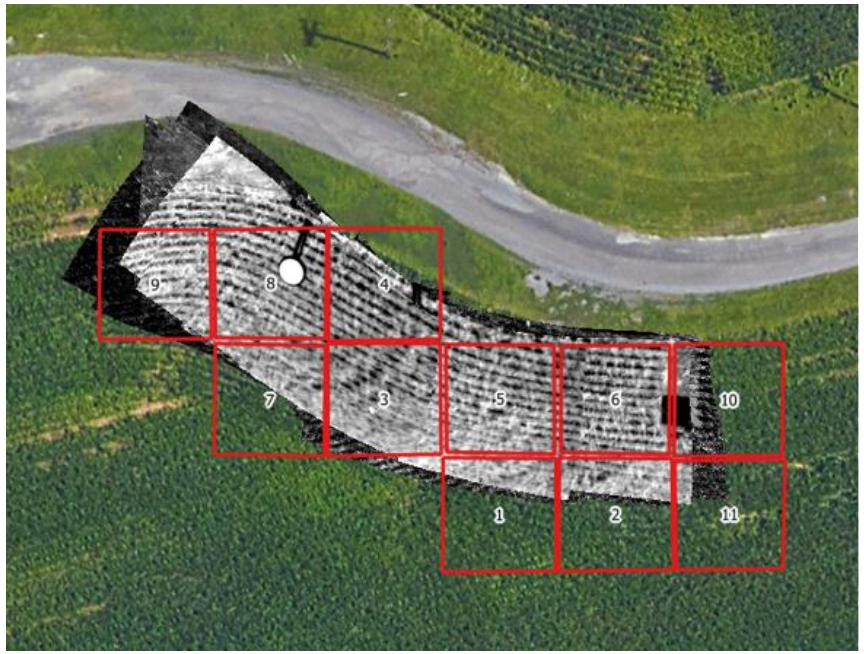
Reflectance retrieval verification: Use in-scene reference targets on the ground (tarp and calibration panel) to compare against reflectance calculation based on 2-inch target.

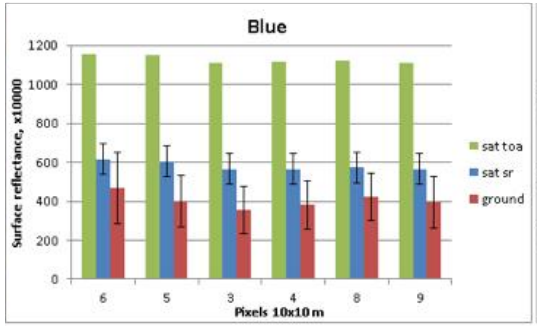


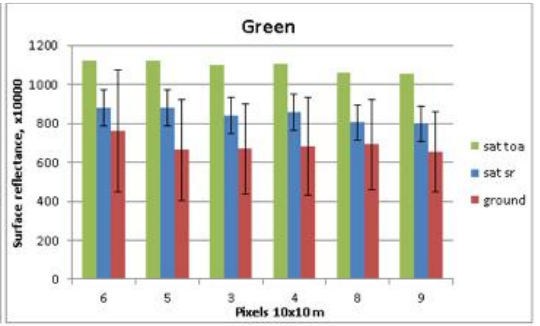
Spectral channel	CAMSIS Tarp	Tarp Ref	CAMSIS CP	CP ref
Blue	0.135	0.13	1.01	0.995
Green	0.14	0.13	Sat.	0.995
Red	0.15	0.13	0.97	0.995
NIR	0.16	0.11	0.90	0.995

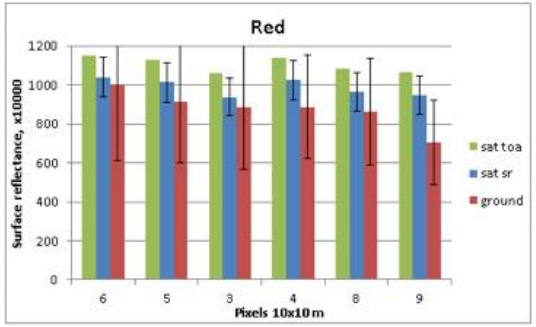
Ground Validation is on going

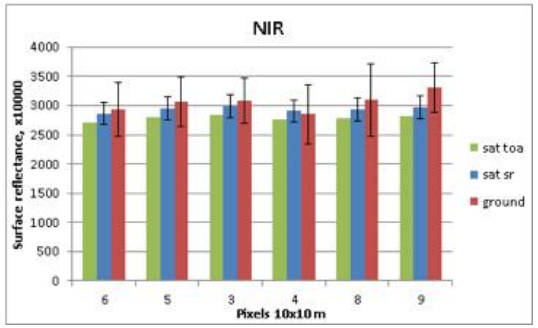
Validation of Sentinel 2 reflectance (from AERONET) :
Example for July 10 2018, AOT ~ 0.1









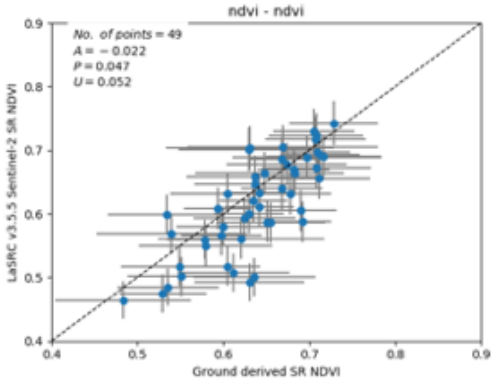


Ground Validation is on going

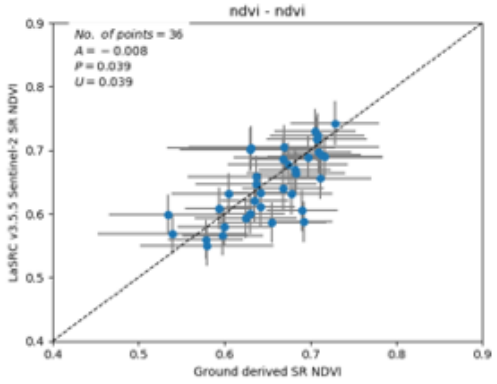
Preliminary multidate comparison:

Date of ground measurements	Date of satellite acquisition	Satellite
20180808	20180809	Sentinel-2A
20180824	20180824	Sentinel-2B
20180829	20180829	Sentinel-2A
20180904	20180903	Sentinel-2B

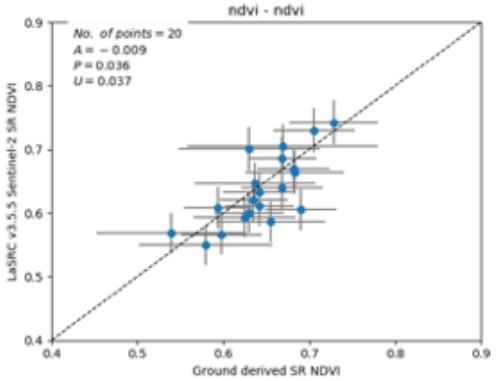
Threshold = 10%



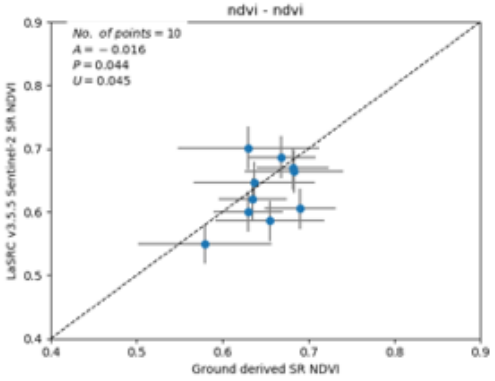
Threshold = 50%



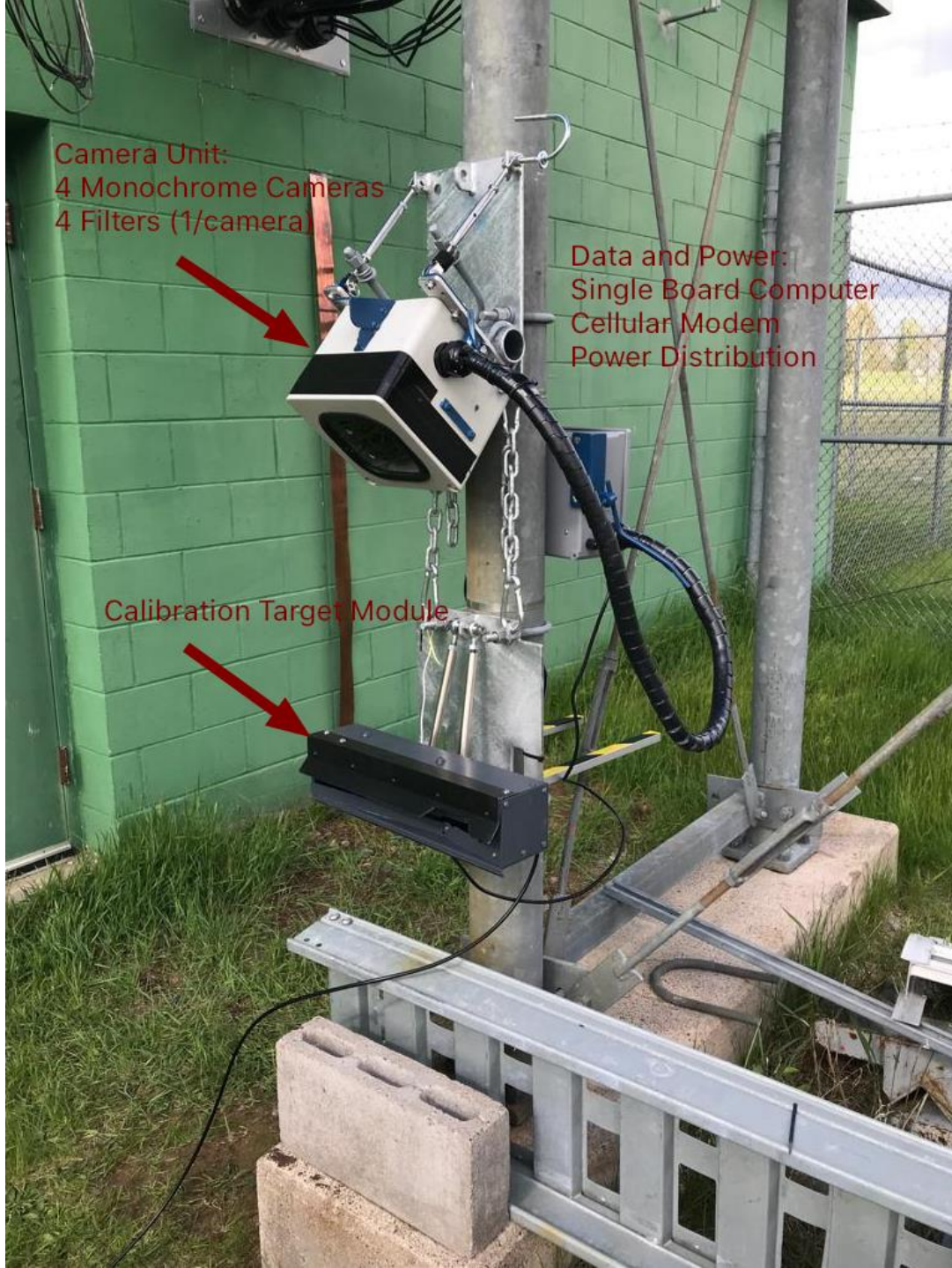
Threshold = 90%



Threshold = 100%



Ground Validation is on going



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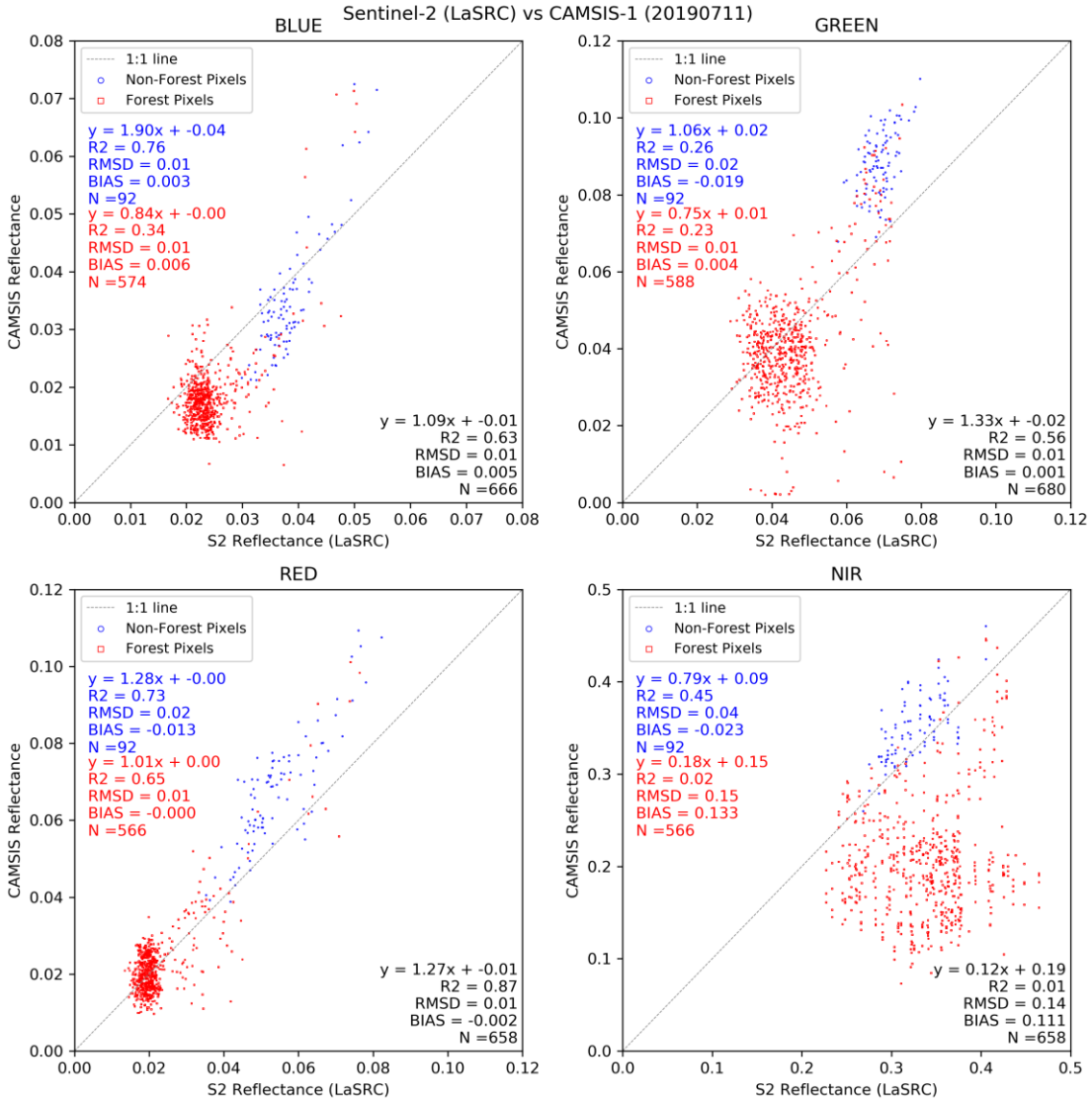

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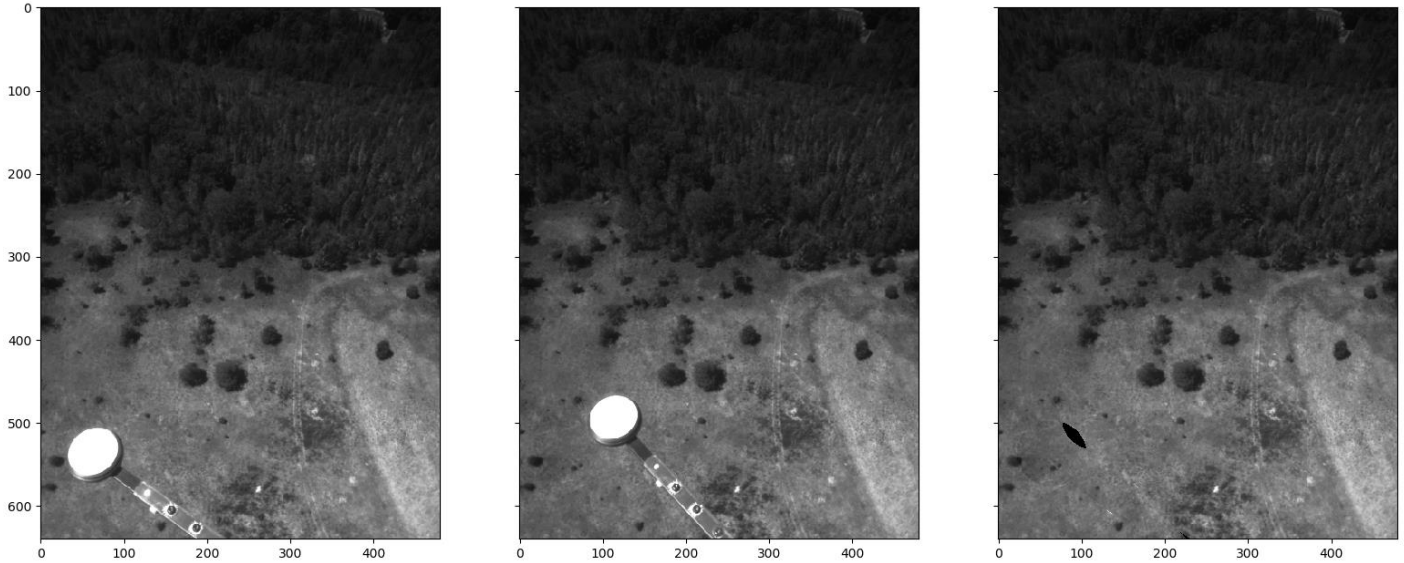

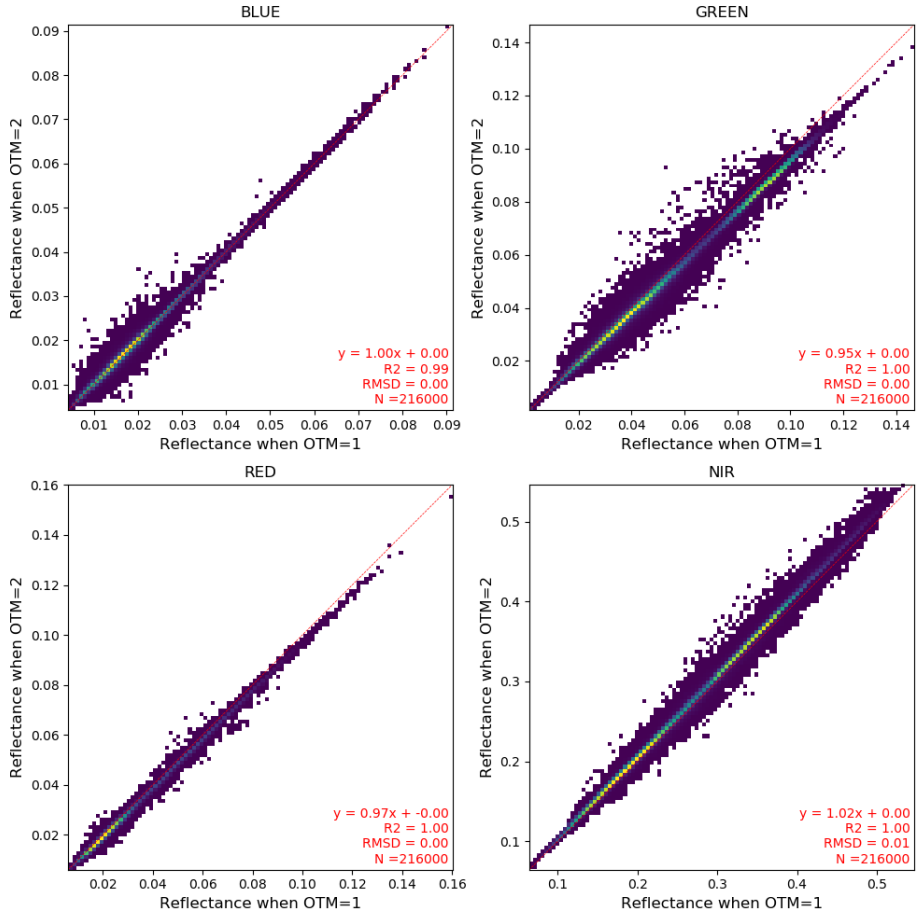

Ground Validation is on going CAMSIS-II / SKYCAM