# A continuous record of Land surface reflectance from MODIS Aqua/Terra and Sentinel 3 OLCI/SLTSTR

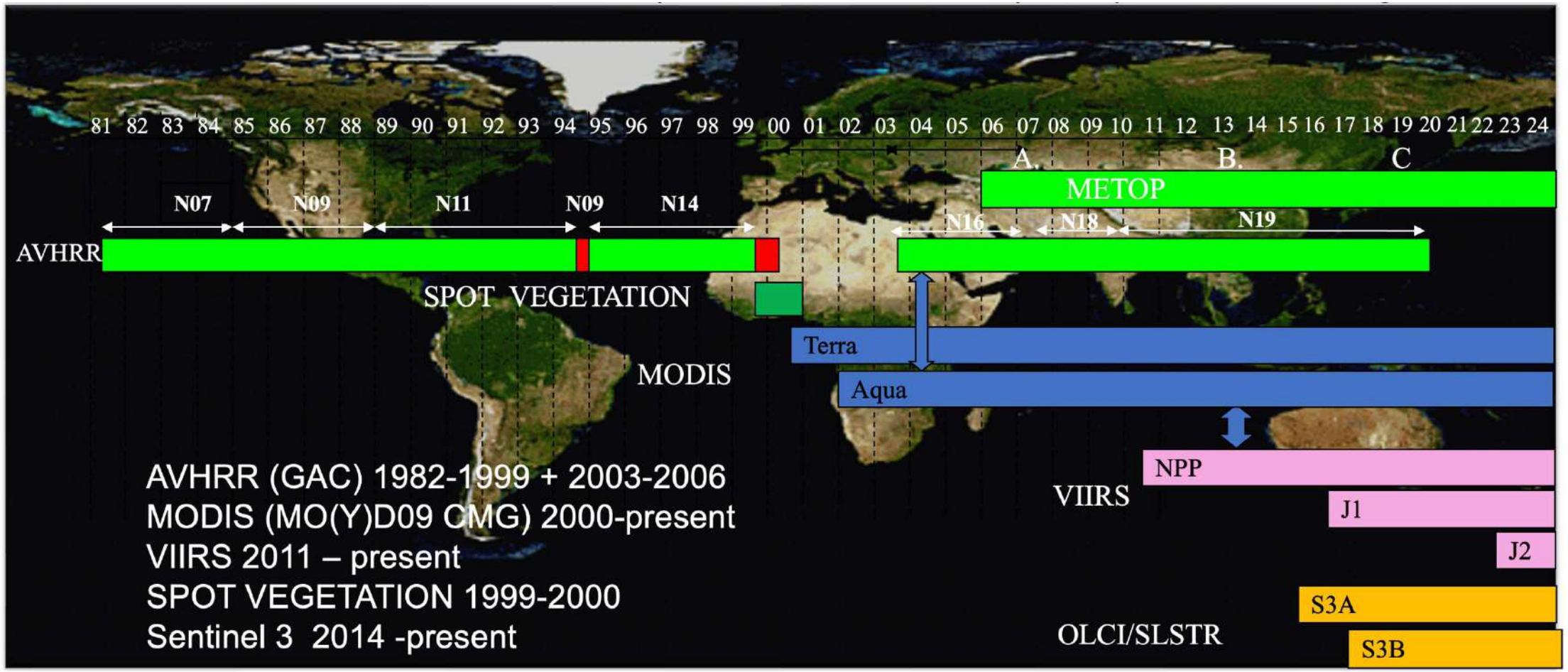
Vermote et al.

NASA/GSFC

9Th Sentinel-3 Validation Team Meeting 30 March-01 April 2026, ESA-ESRIN, Frascati (Rome), Italy

# A Land Climate Data Record

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




https://ltdr.modaps.eosdis.nasa.gov

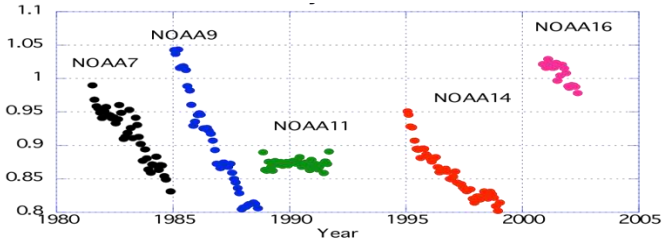
*Emphasis on data consistency – characterization rather than degrading/smoothing the data*

# Land Climate Data Record (Approach)

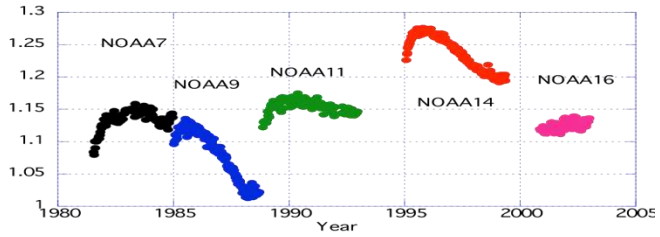
*Needs to address geolocation,calibration, atmospheric/BRDF correction issues*

## CALIBRATION

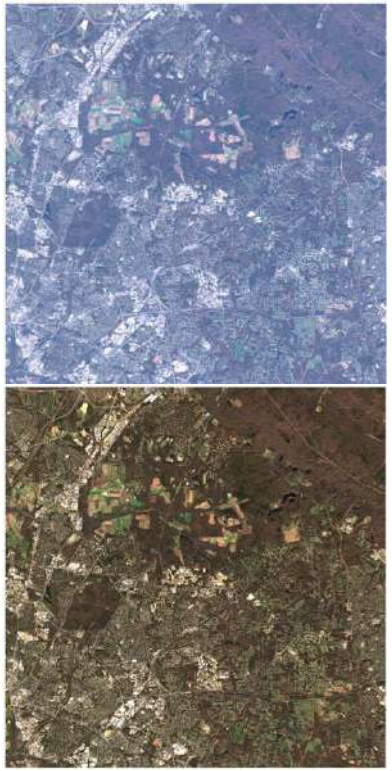
Degradation in channel 1
(from Ocean observations)



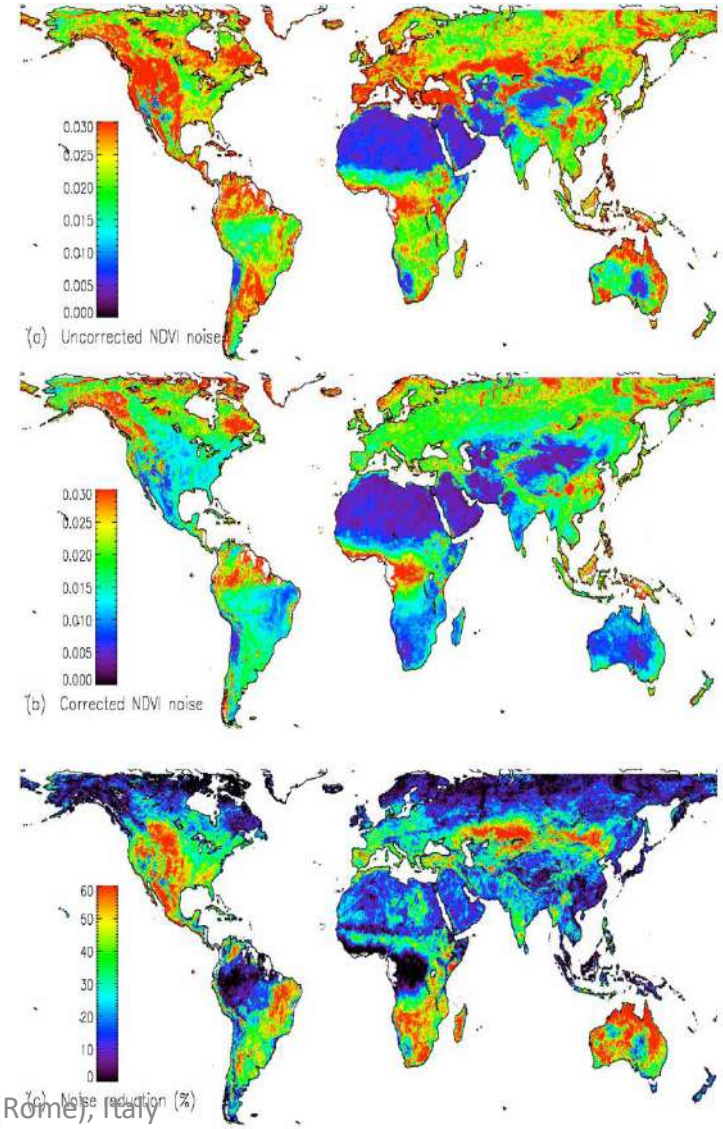

Channel1/Channel2 ratio
(from Clouds observations)

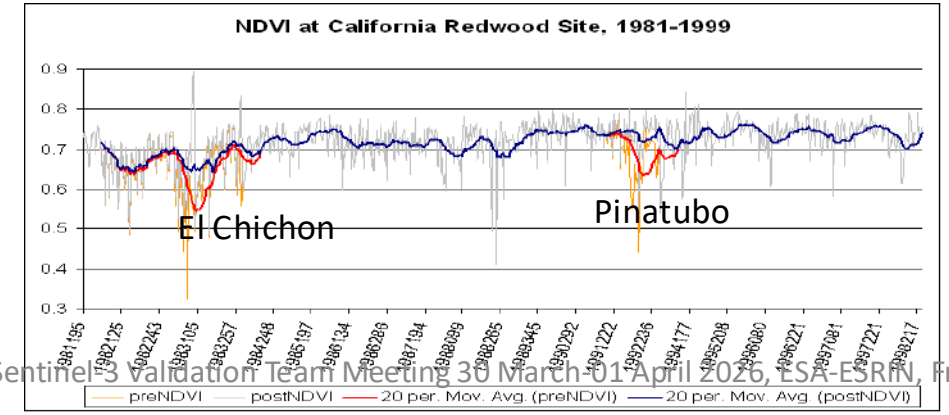



## ATMOSPHERIC CORRECTION



## BRDF CORRECTION

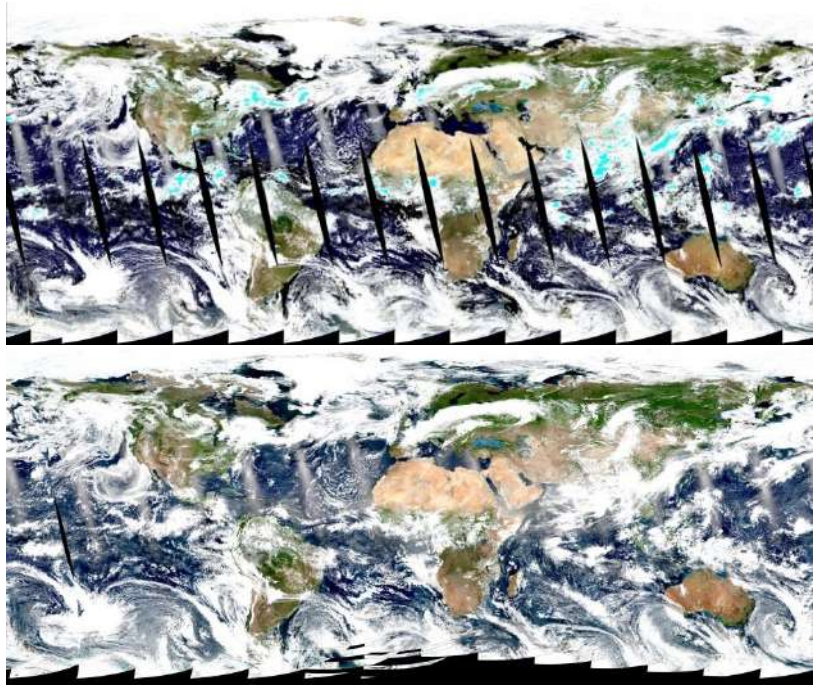


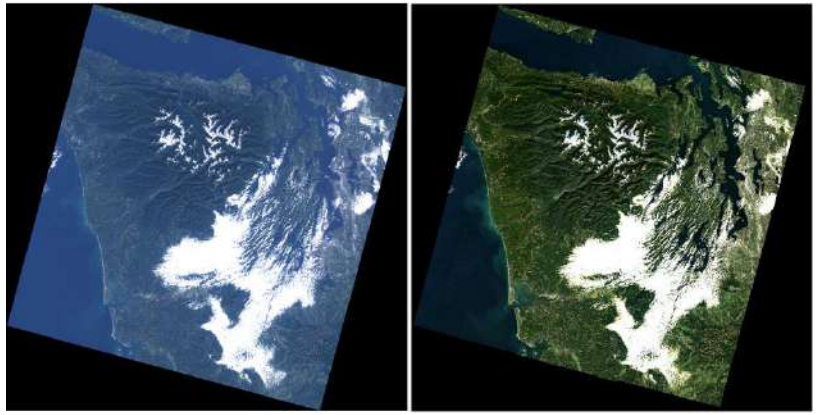
# Atmospheric correction (AC)

- 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.

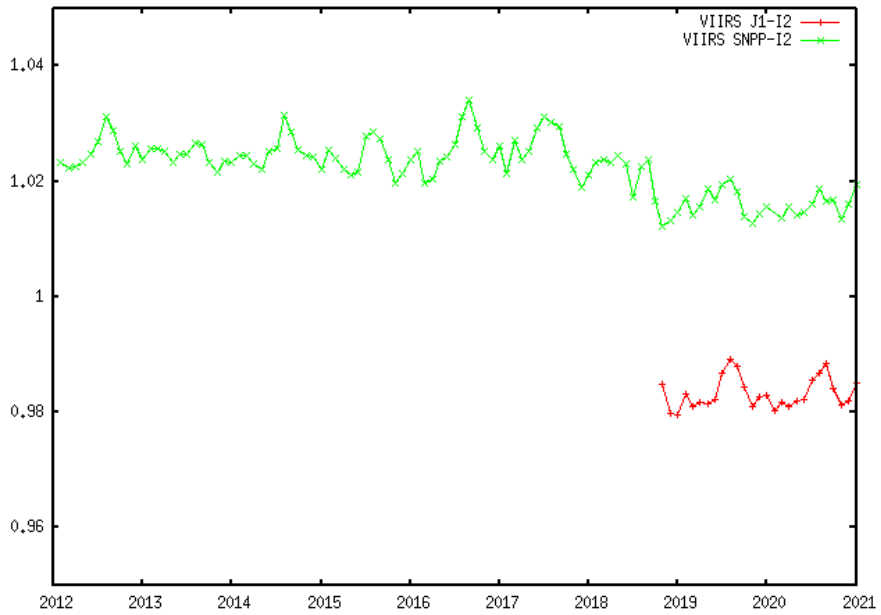
The MODIS **Collection 6 AC algorithm** relies on

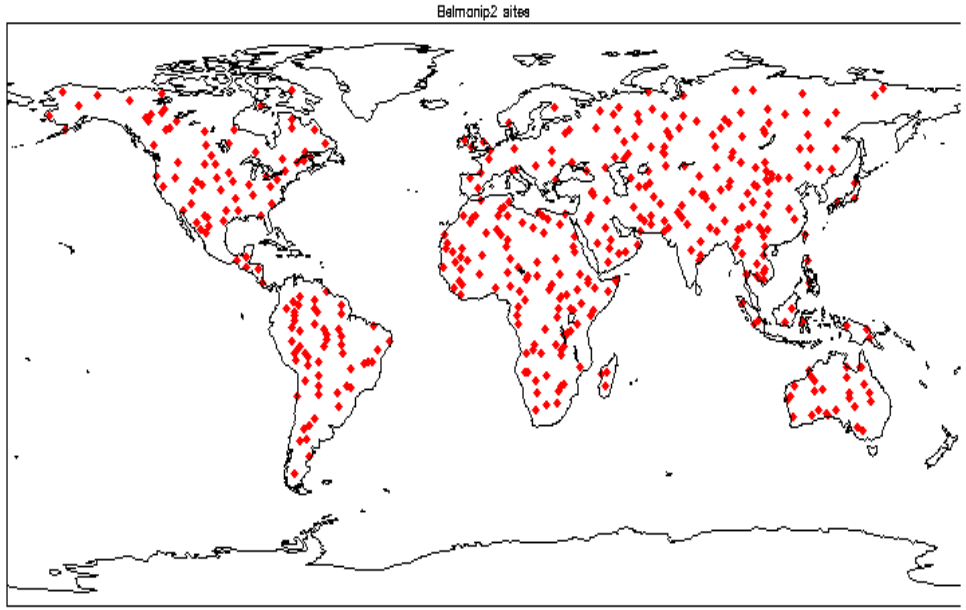
- the use of very accurate (better than 1%) vector radiative transfer modeling of the coupled atmosphere-surface system (6S)
- the inversion of key atmospheric parameters
  - ***Aerosols are processed from Landsat8/Sentinel 2 images***
  - ***Water vapor and ozone from daily MODIS product.***

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

# Datasets

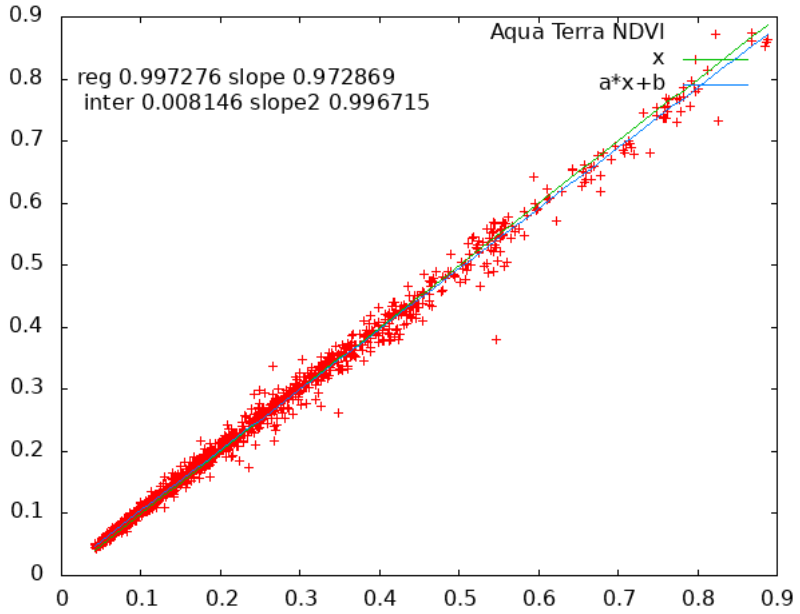
- MODIS Terra, Aqua, S3 (CMG) over Belmanip sites (422) during December 2018.
- Data were corrected for BRDF and normalize to Nadir view sun at 45deg.

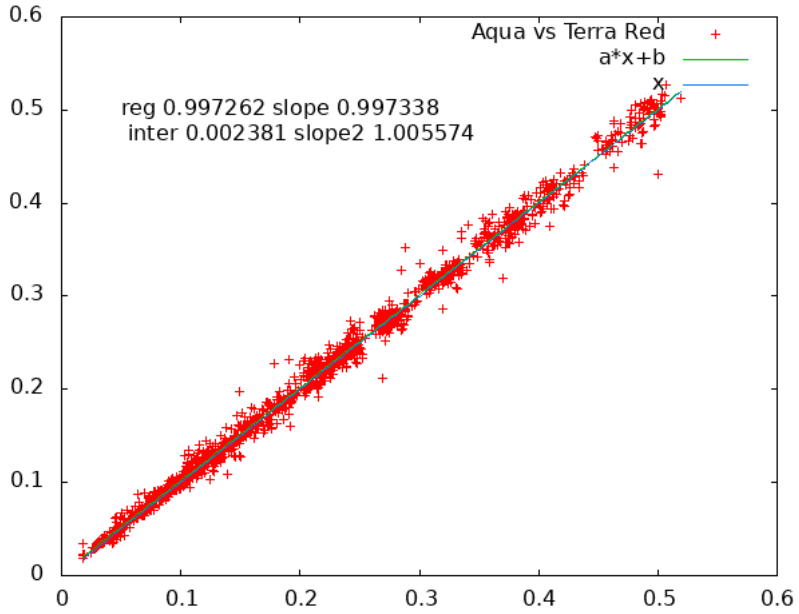


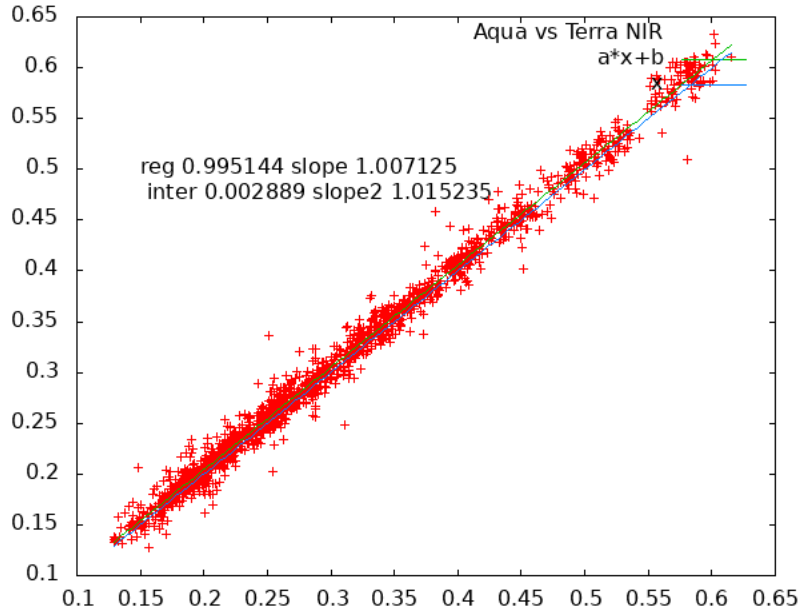




**Automated monthly VIIRS cross comparison (over BELMANIP sites) with MODIS Aqua from 2012. the stability of both VIIRS and MODIS Aqua is excellent in both red and NIR as shown (+/- 0.5%).**

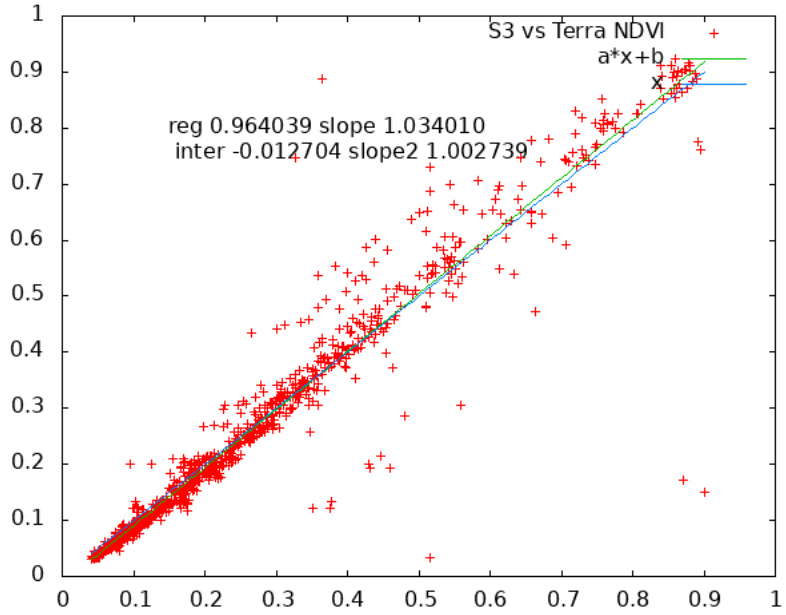
# Scatters plot : Aqua vs Terra Dec 2018

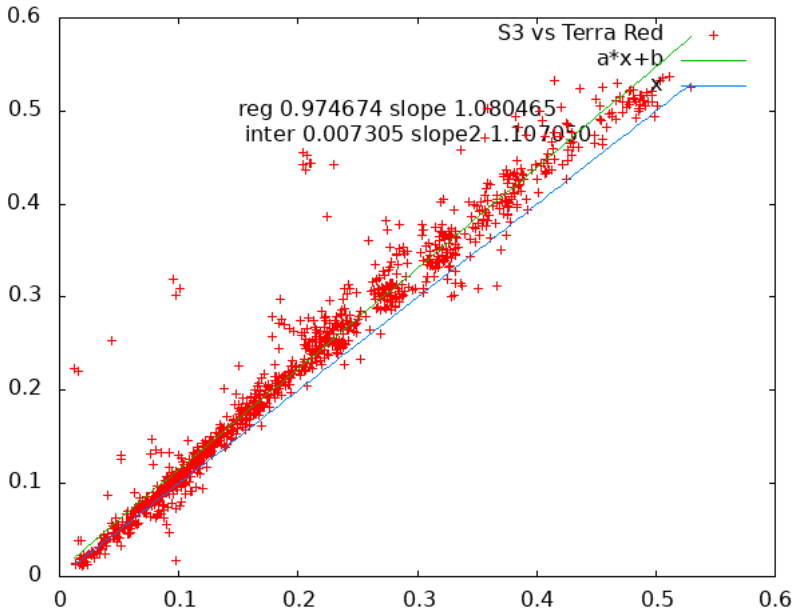


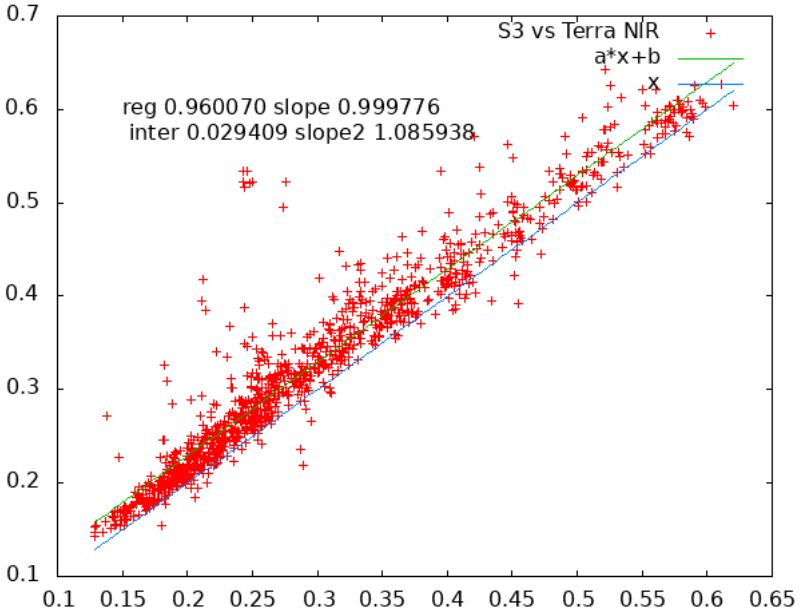



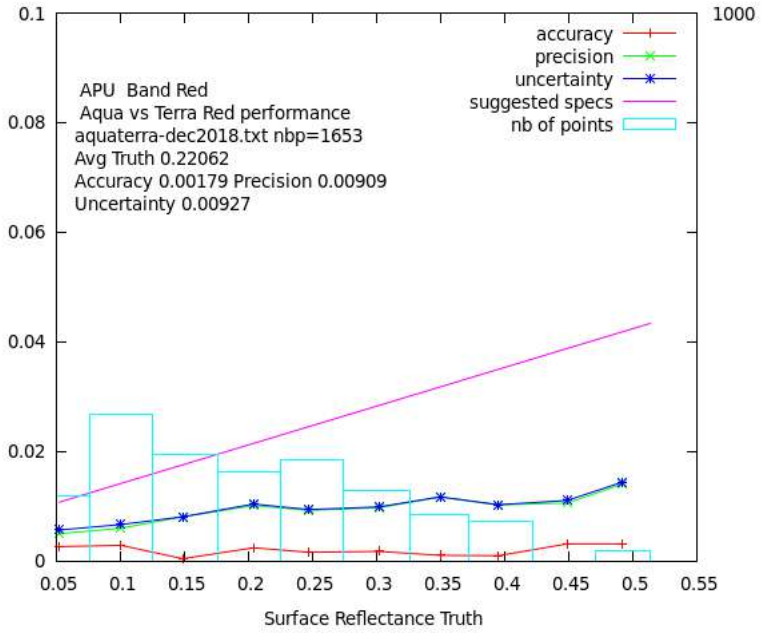
# Scatters plot : S3 SYNERGY SR vs Terra Dec 2018

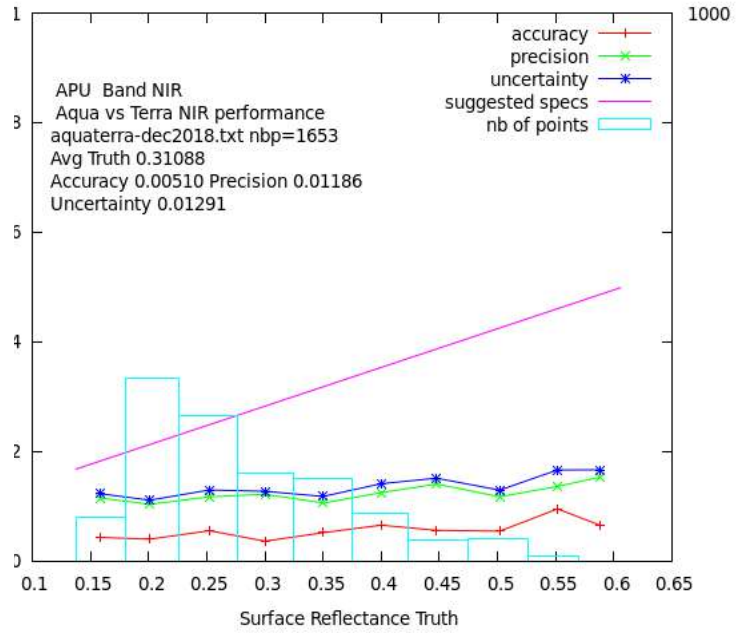


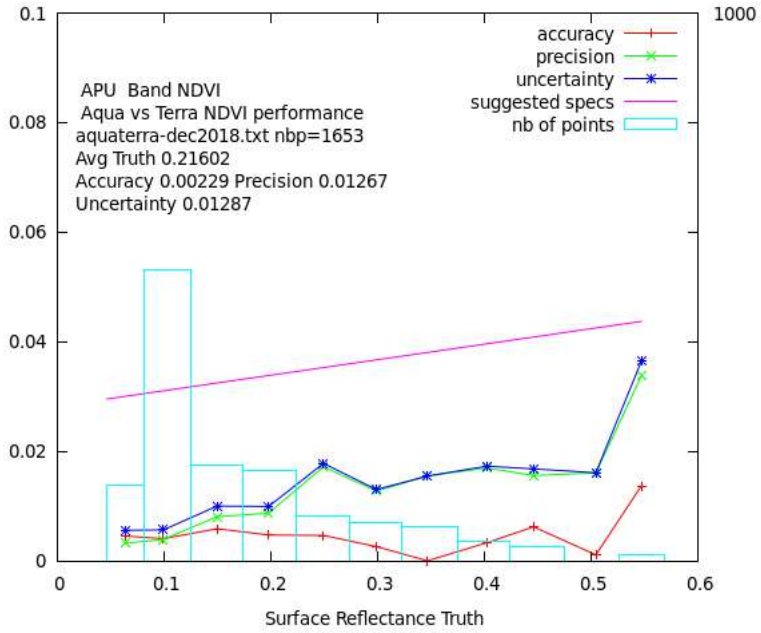



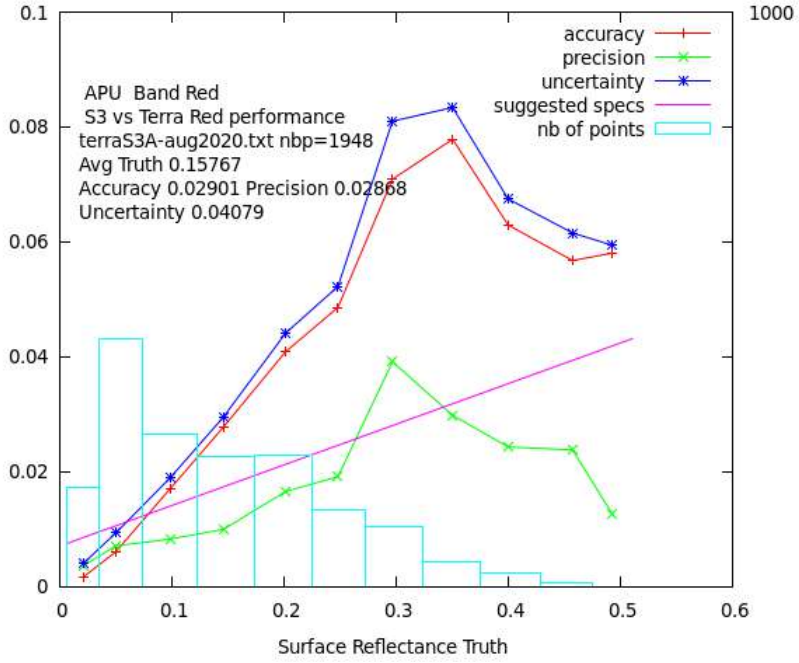



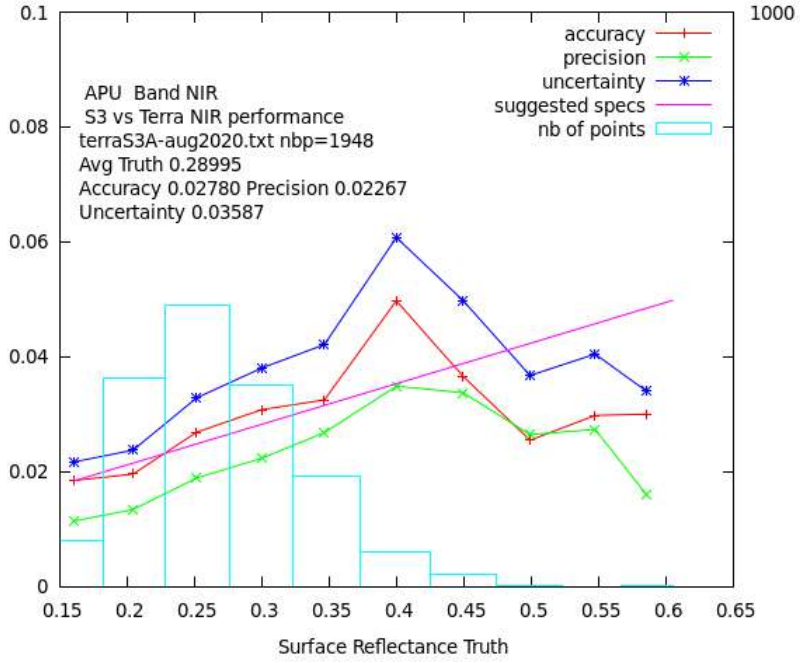
# APU: Aqua vs Terra Dec 2018

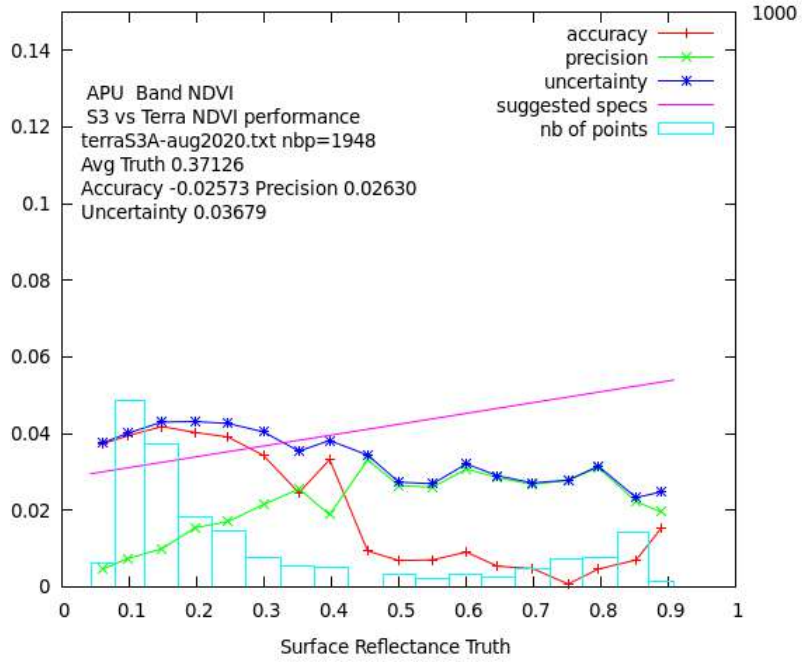


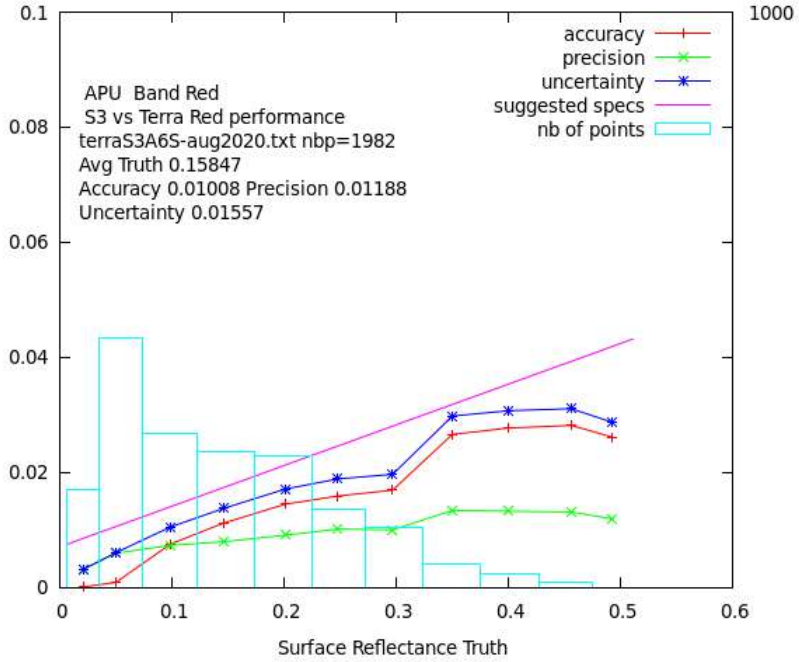



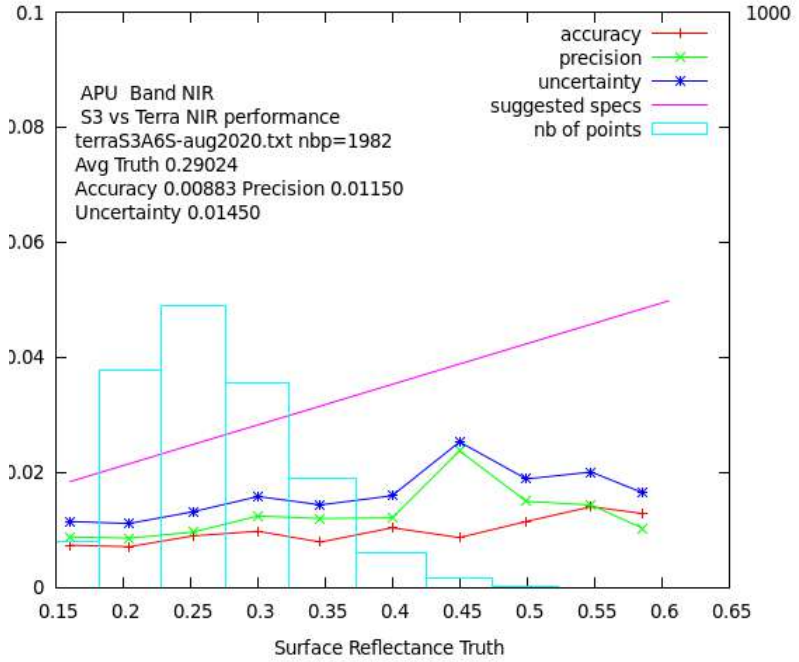


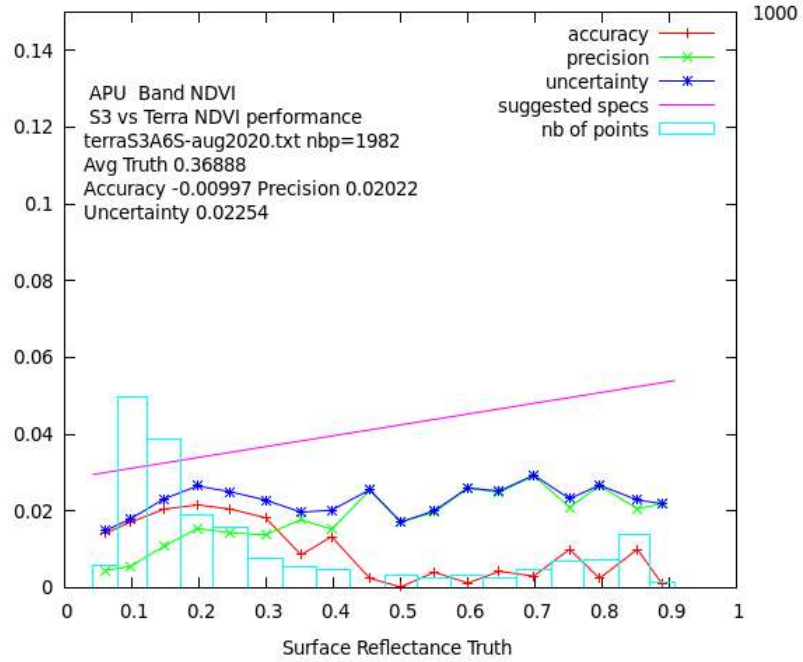




# Sentinel 3 SYNERGY SR versus Terra (APU) Aug 2020

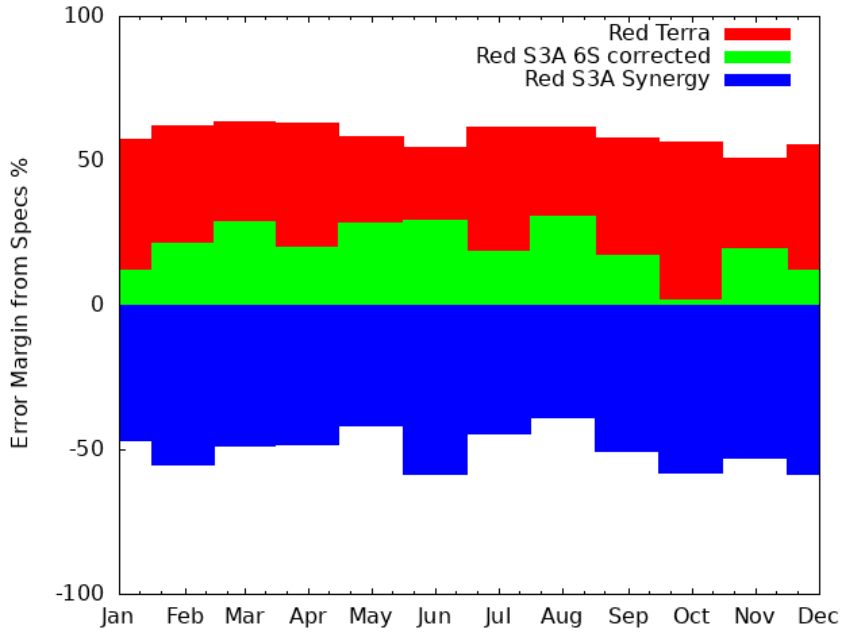


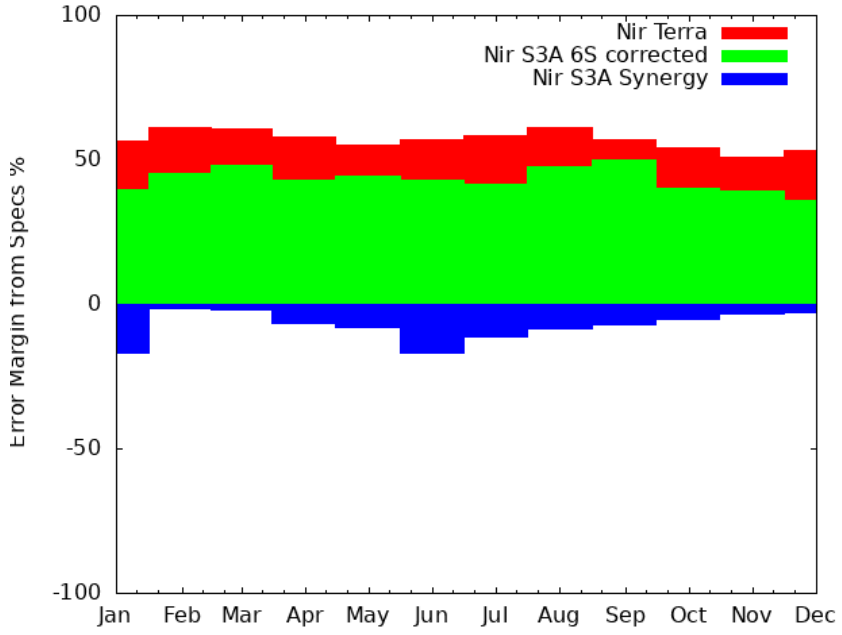



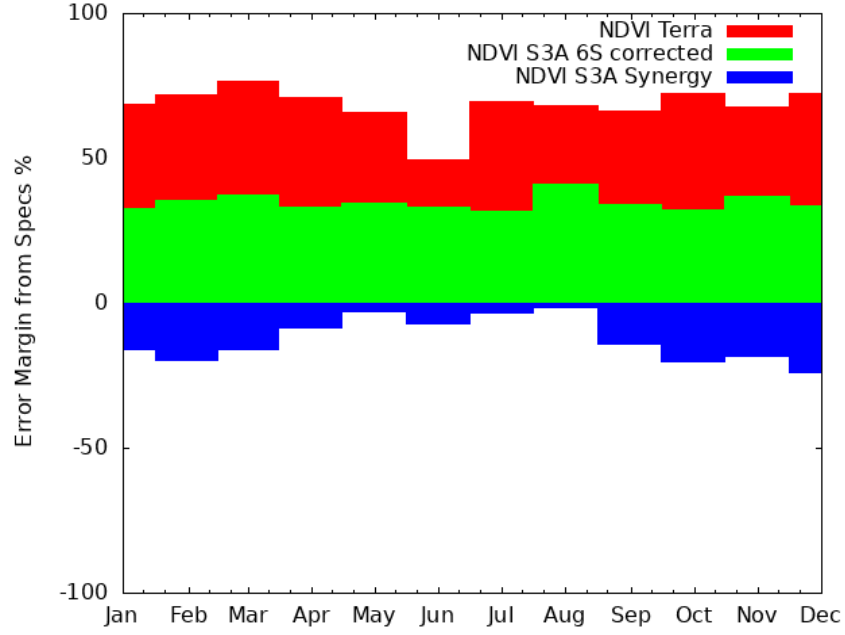



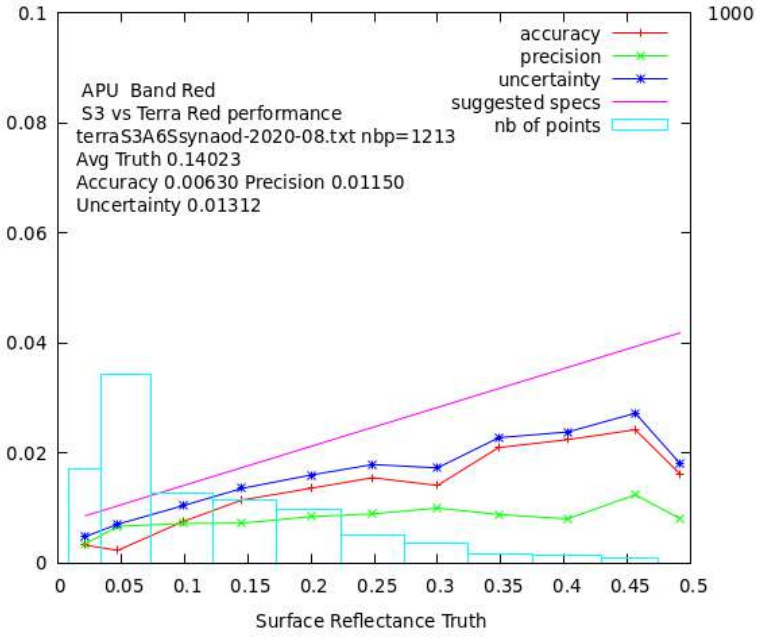

# Sentinel 3 6S-SR versus Terra (APU) Aug 2020

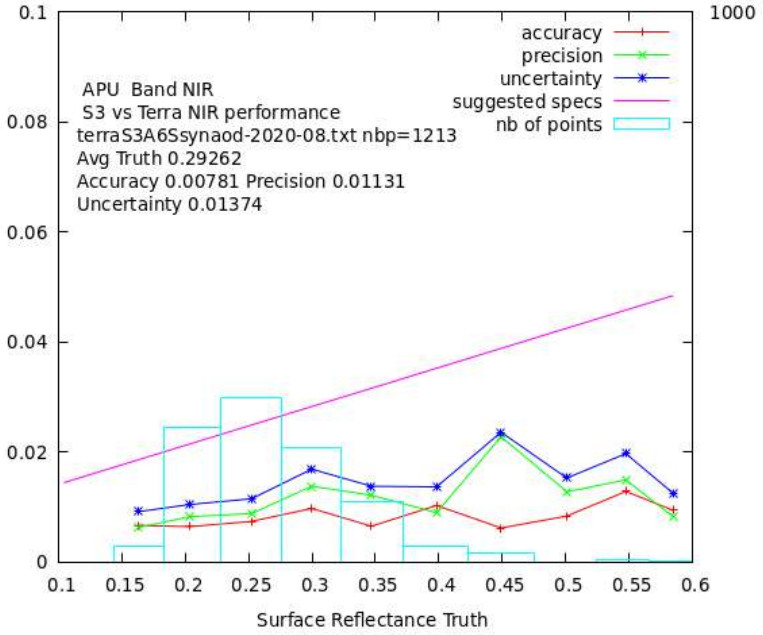
# Summary performances for 2020 (Uncertainty)

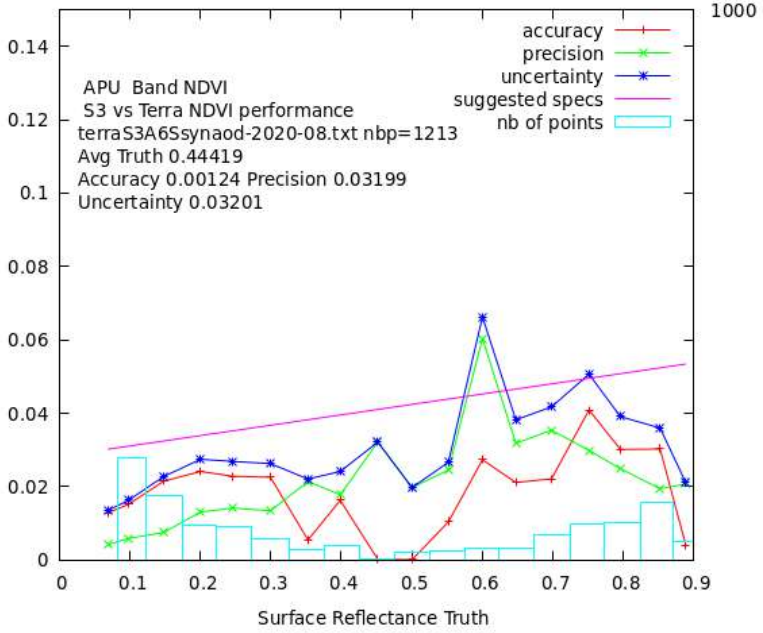


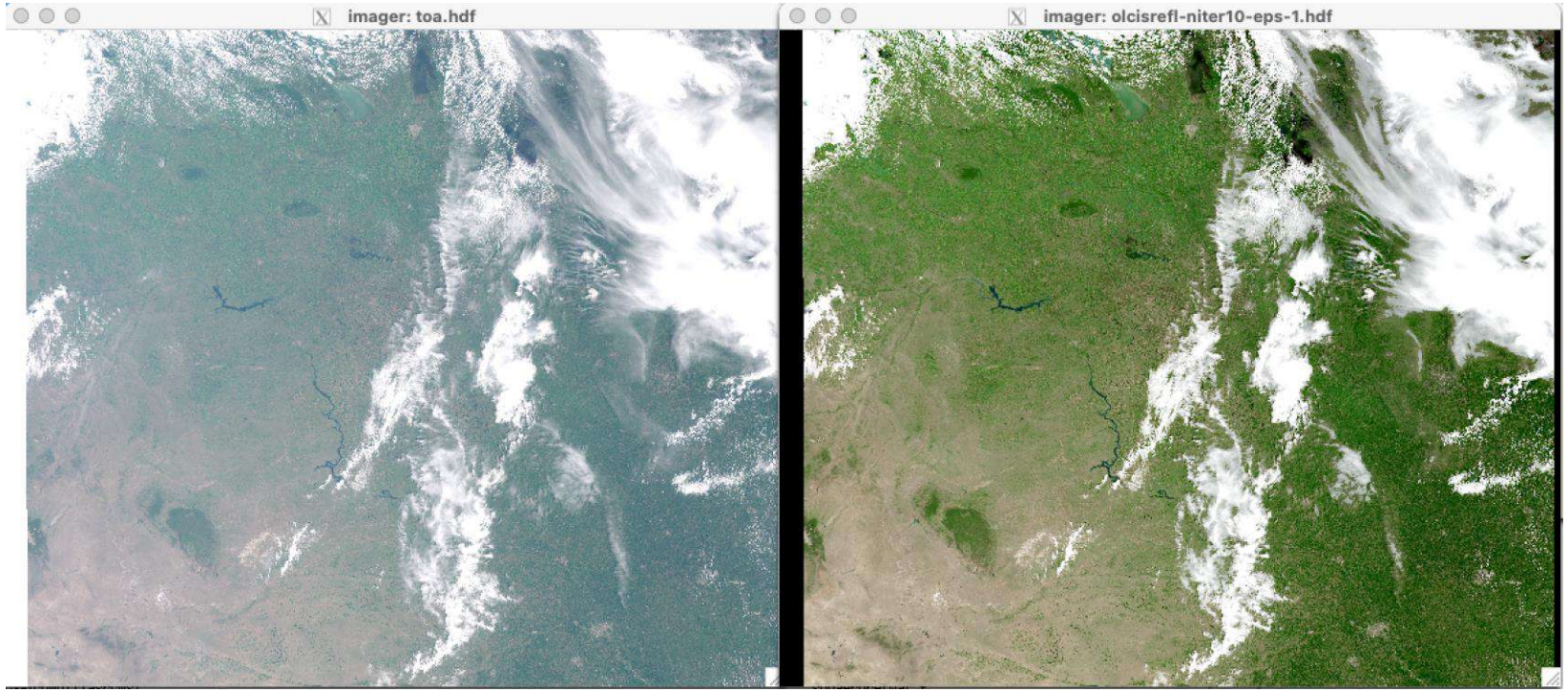



# Sentinel 3 SR (using ESA synergy AOT) versus Terra (APU) Aug 2020 – test for ESA next collection approach

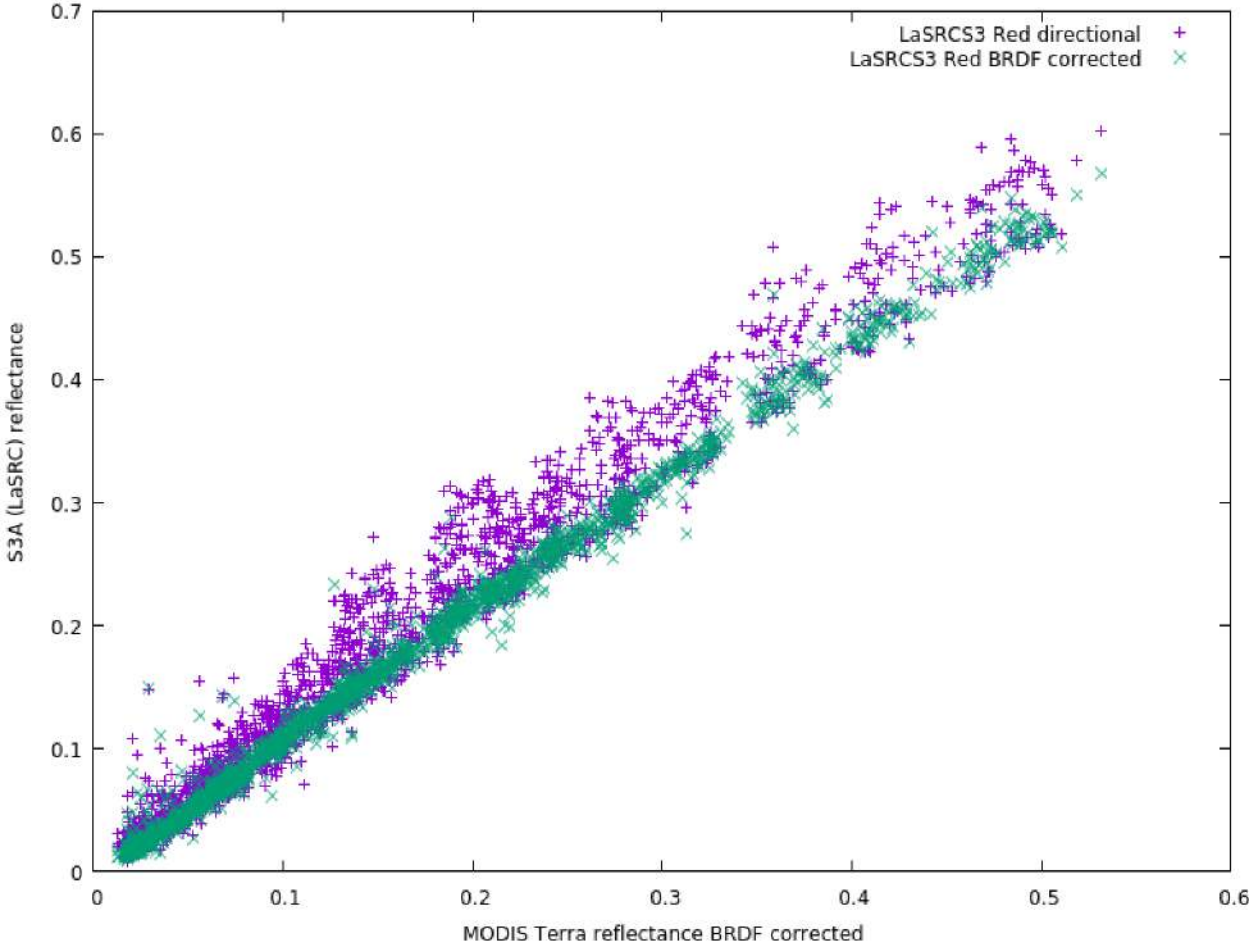
# LaSRC Prototype for S3-OLCI

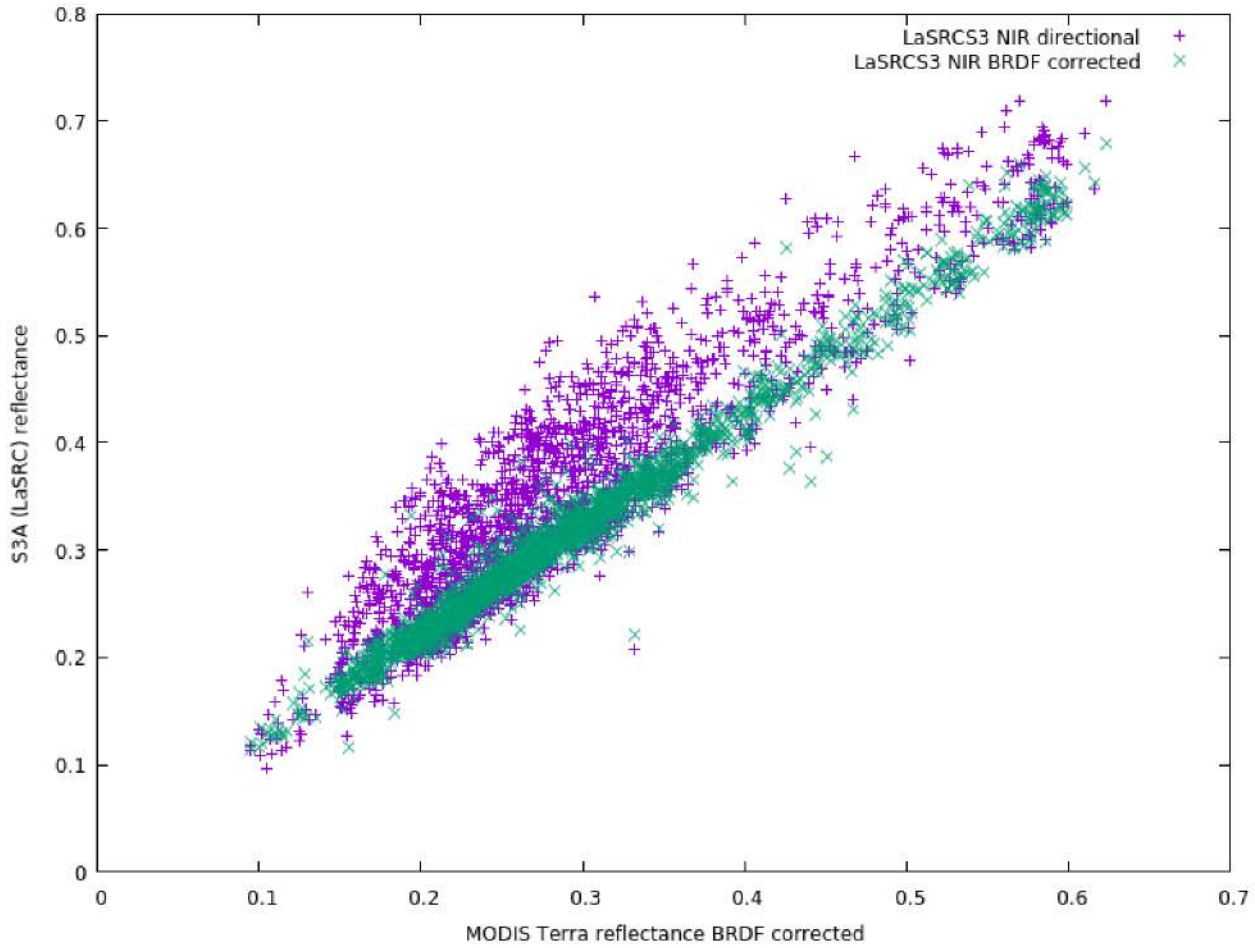



OLCI TOA Reflectance (RGB)

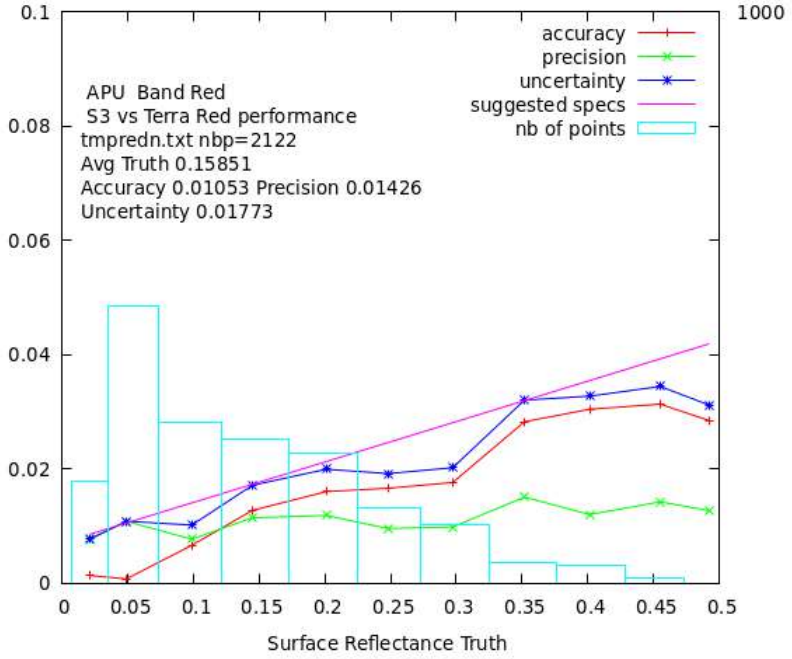
OLCI LaSRC Surface Reflectance (RGB)

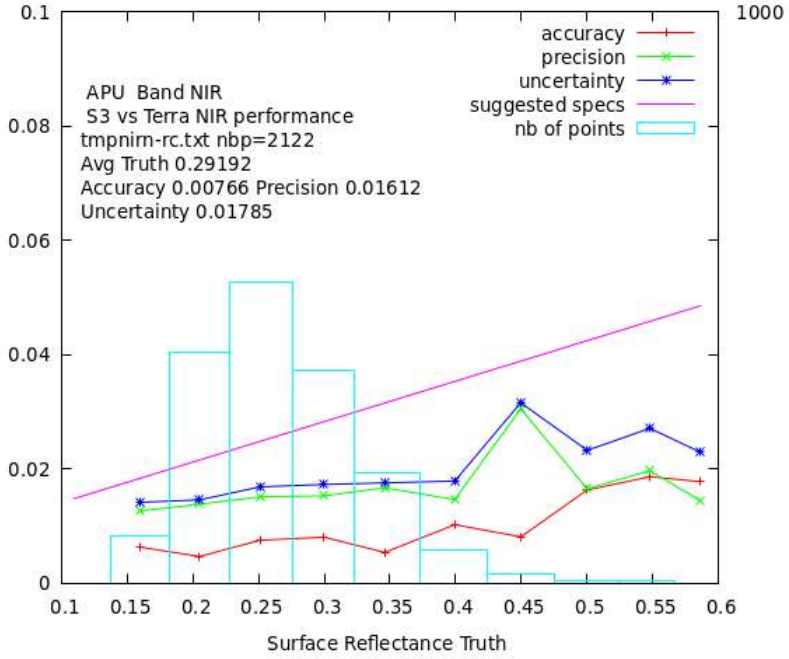
# LaSRC Prototype for S3-OLCI

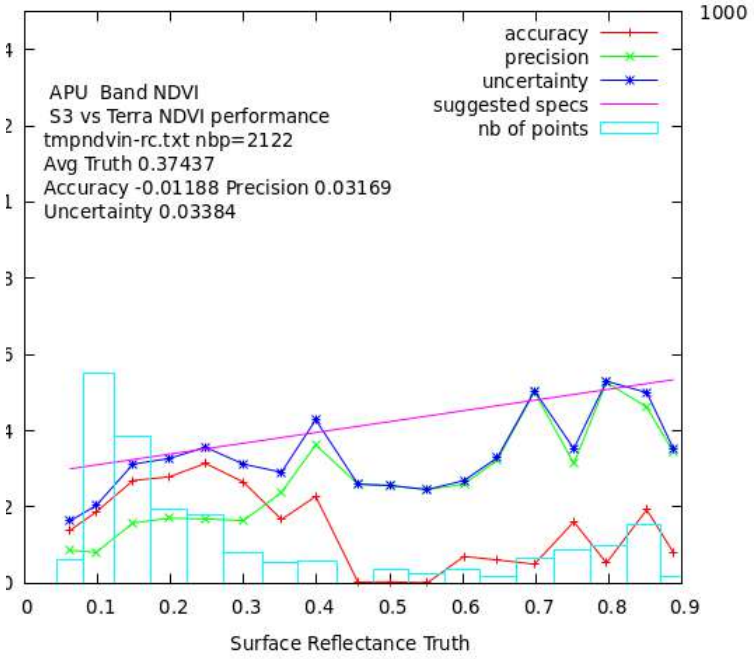



Comparison over BELMANIP2 sites for August 2020



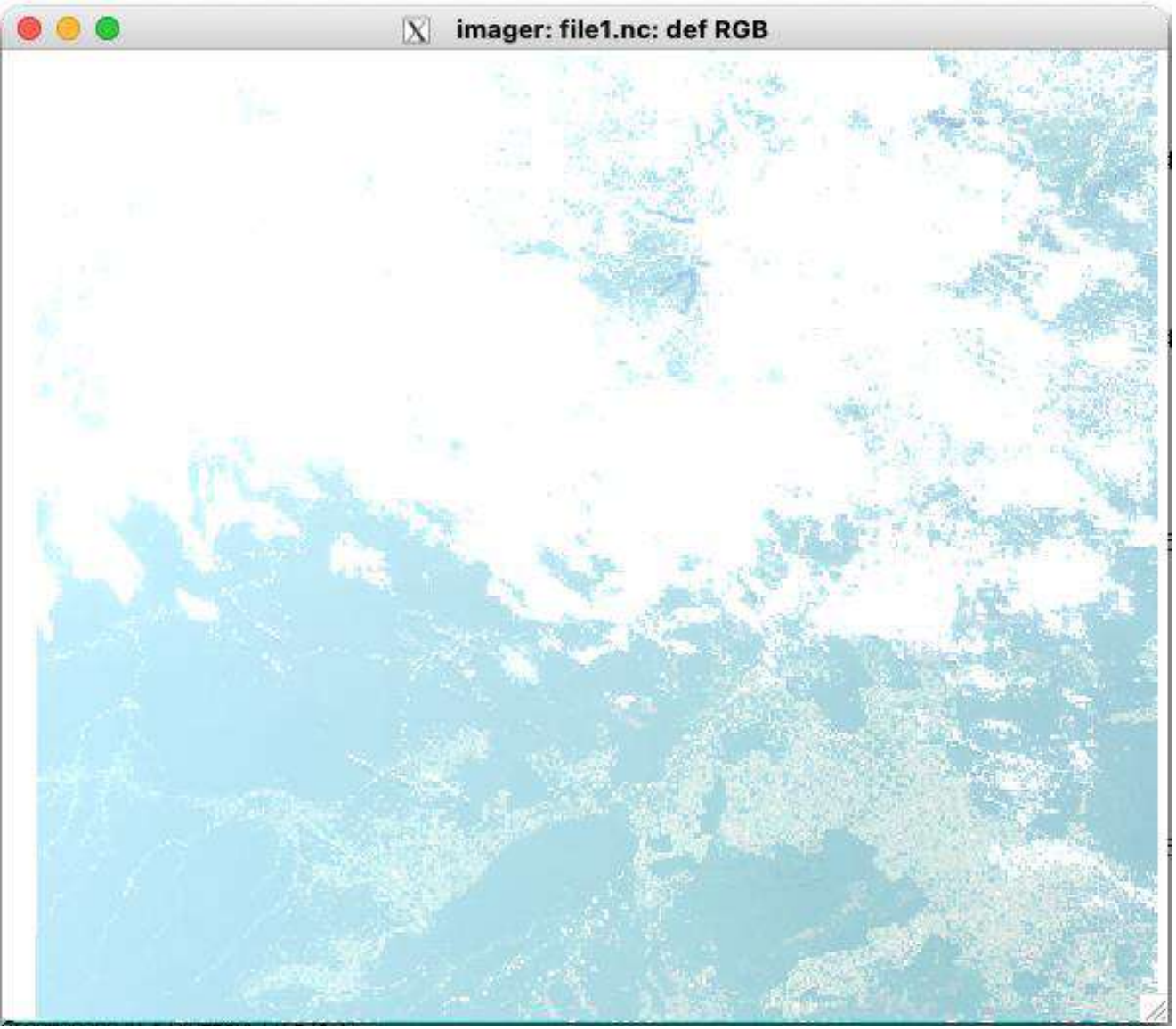




# Sentinel 3 LaSRC-OLCI-SR versus Terra (APU) Aug 2020

# Sentinel 3 MODIS Like prototype

# Use of the EUMETSAT Level 1C (?D) Synergy Product (OLCI+SLSTR)




imager pixel values

Row 2544, column 3432, current resolution 3 -->

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|---|---|---|
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| /Solar/Coordinates/Longitude | -62.957836 | |
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| /Solar/Bands/olci/Oa02 | 5118 | (58.810937) |
| /Solar/Bands/olci/Oa03 | 4111 | (51.749268) |
| /Solar/Bands/olci/Oa04 (B) | 3353 | (38.210789) |
| /Solar/Bands/olci/Oa05 | 2776 | (33.961583) |
| /Solar/Bands/olci/Oa06 (G) | 2890 | (29.009819) |
| /Solar/Bands/olci/Oa07 | 1779 | (18.796914) |
| /Solar/Bands/olci/Oa08 (R) | 1591 | (14.279225) |
| /Solar/Bands/olci/Oa09 * | 1402 | (13.586782) |
| /Solar/Bands/olci/Oa10 | 1472 | (13.227392) |
| /Solar/Bands/olci/Oa11 | 2995 | (25.041194) |
| /Solar/Bands/olci/Oa12 | 8933 | (66.917103) |
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| /Solar/Bands/slstr_an/S1 | 1962 | (35.021701) |
| /Solar/Bands/slstr_an/S2 | 1109 | (16.080500) |
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| /Solar/Bands/slstr_an/S6 | 839 | (0.622538) |
| /Solar/Bands/slstr_ao/S1 | 2467 | (44.035951) |
| /Solar/Bands/slstr_ao/S2 | 1543 | (22.373499) |
| /Solar/Bands/slstr_ao/S3 | 5973 | (53.756998) |
| /Solar/Bands/slstr_ao/S4 | 53 | (0.182956) |
| /Solar/Bands/slstr_ao/S5 | 2134 | (4.818572) |
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| /Solar/Geometry/slstr_ao/OZA | 9.807133 | |
| /Solar/Geometry/slstr_ao/SAA | 44.596104 | |
| /Solar/Geometry/slstr_ao/SZA | 43.684135 | |
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imager pixel values

Row 2544, column 3432, current resolution 3 -->

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| /Thermal_Fire/Bands/slstr_an/S9 | 911 | (6.280000) |
| /Thermal_Fire/Bands/slstr_ao/F1 | 1396 | (11.130000) |
| /Thermal_Fire/Bands/slstr_ao/F2 | 847 | (5.640000) |
| /Thermal_Fire/Bands/slstr_ao/S7 | 1419 | (11.360000) |
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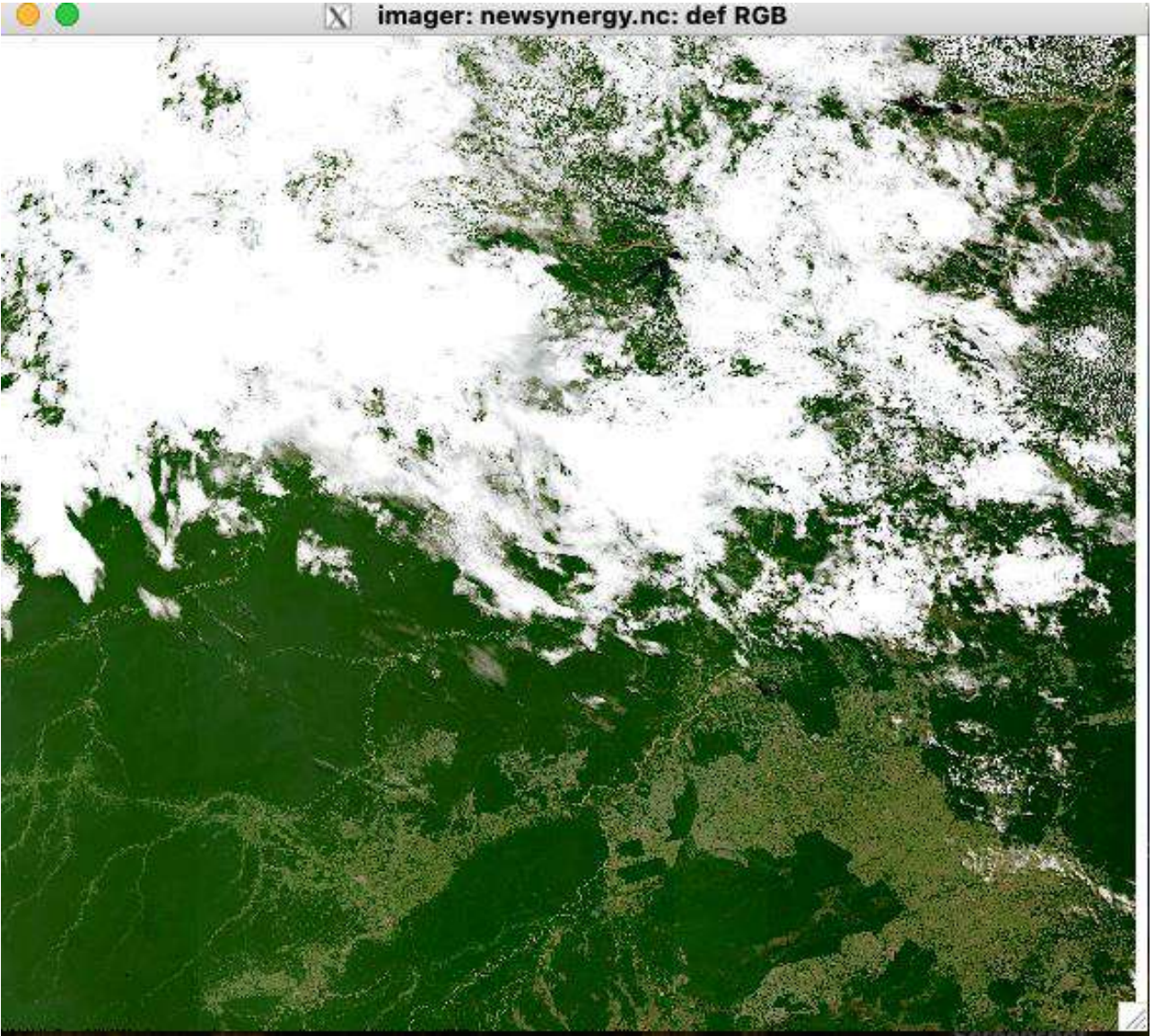
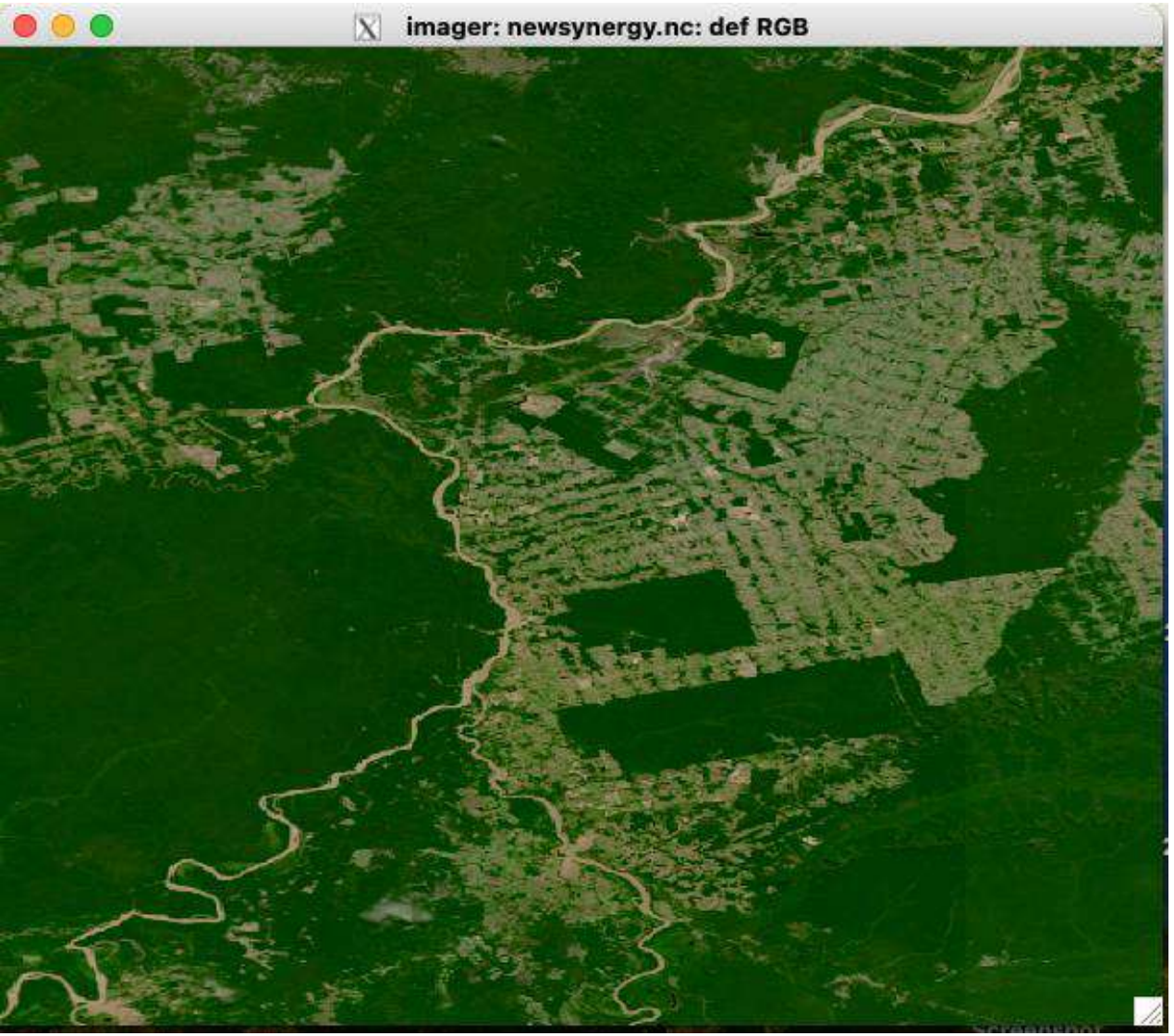
# MODIS Like 7 bands products at 300m (nadir)



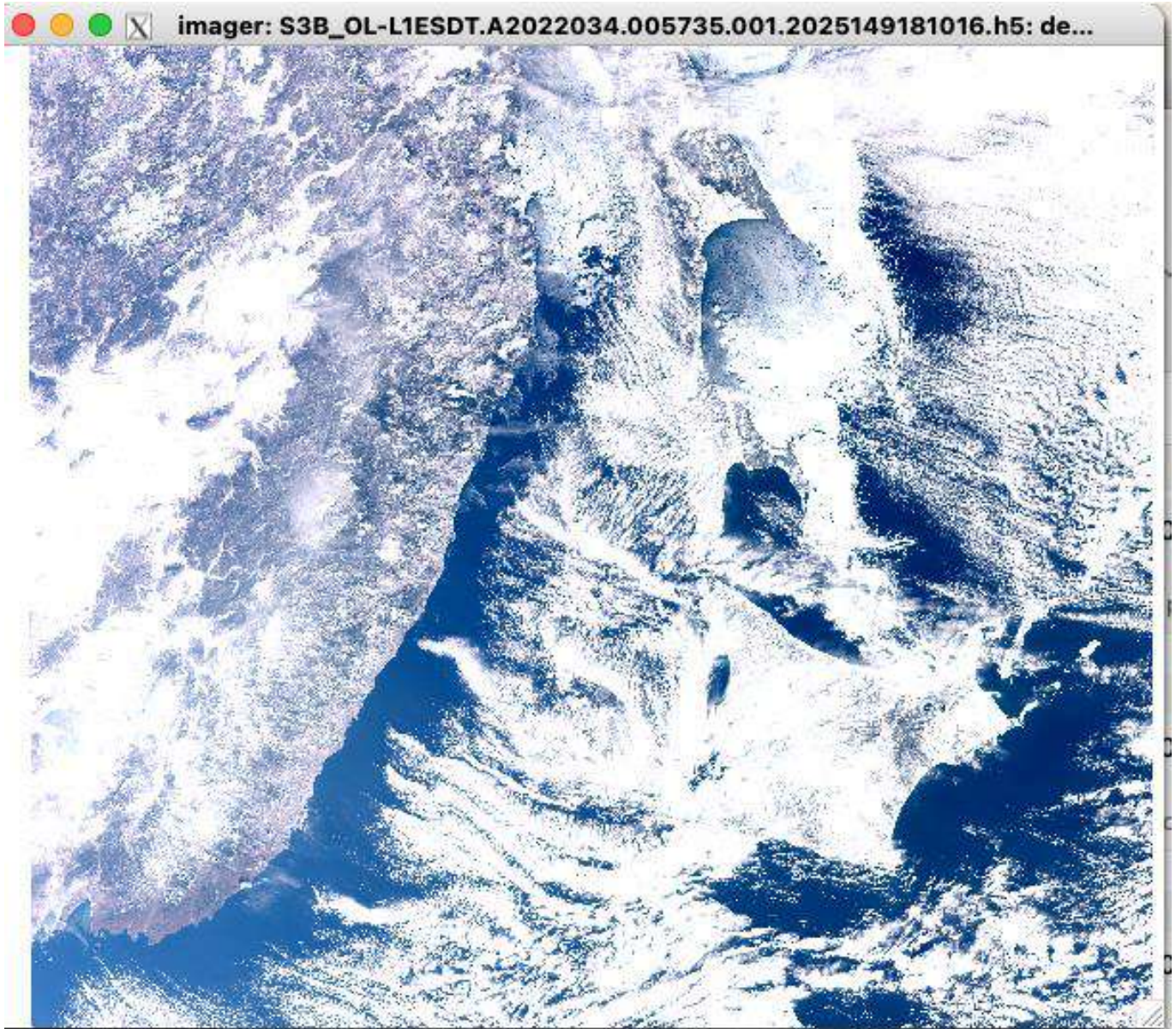

imager pixel values

```
Row 1768, column 2408, current resolution 1 -->
/300m Relative Azimuth Angle            5504  (55.039999)
/300m Solar Zenith Angle                4312  (43.119999)
/300m Surface Reflectance Band Oa17     4891  (0.489100)
/300m Surface Reflectance Band Oa21     5102  (0.510200)
/300m Surface Reflectance Band Oa4  *   3150  (0.315000)
/300m Surface Reflectance Band Oa6 (G)  3226  (0.322600)
/300m Surface Reflectance Band Oa8 (R)  3177  (0.317700)
/300m Surface Reflectance band S5       3251  (3251.000000)
/300m Surface Reflectance band S6       2736  (2736.000000)
/300m View Zenith Angle                 2460  (24.599999)
/Latitude                               -6.017058
/Longitude                              -64.947334
/cloud                              3  (00000011)
/cloud ----- unused                      0  ()
/cloud ----- Aerosol retrieval           0  (succeeded)
/cloud ----- Very high aerosol           1  (yes)
/cloud ----- Cloud                       1  (yes, cloudy)
/ptaero                                 1038  (1.038000)
/ptresi                                 877  (0.877000)
/sol                                    0  (0.000000)
/taero                                  50  (0.050000)
/teps                                   -1000  (-1000.000000)
/titer                                  3  (3.000000)
/tresi                                  988  (0.988000)
```

# Details and “7,2,1” color composite




# In house Level 1C Synergy generation executable has been developed (in collaboration with EUMETSAT)

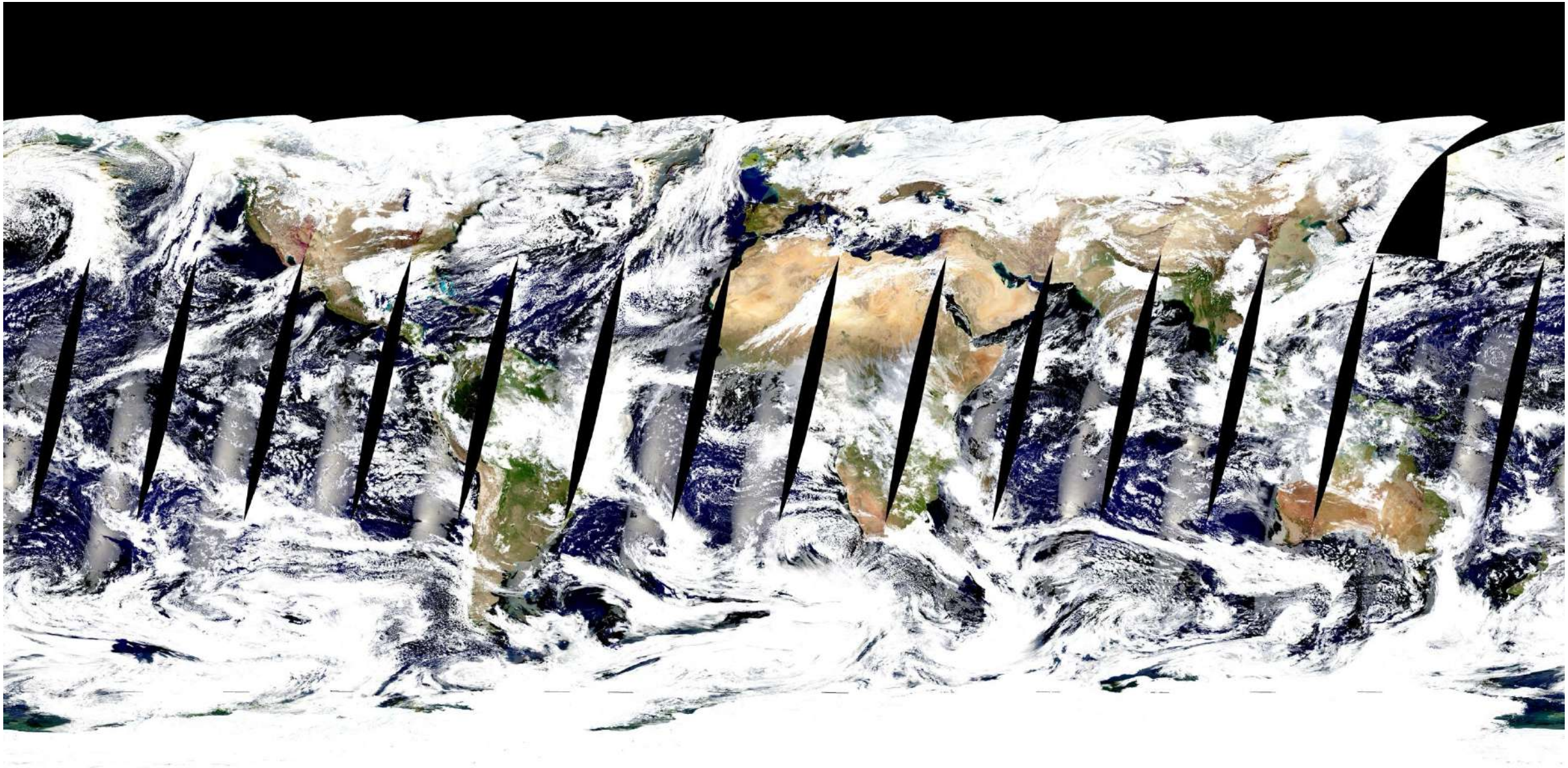



imager pixel values

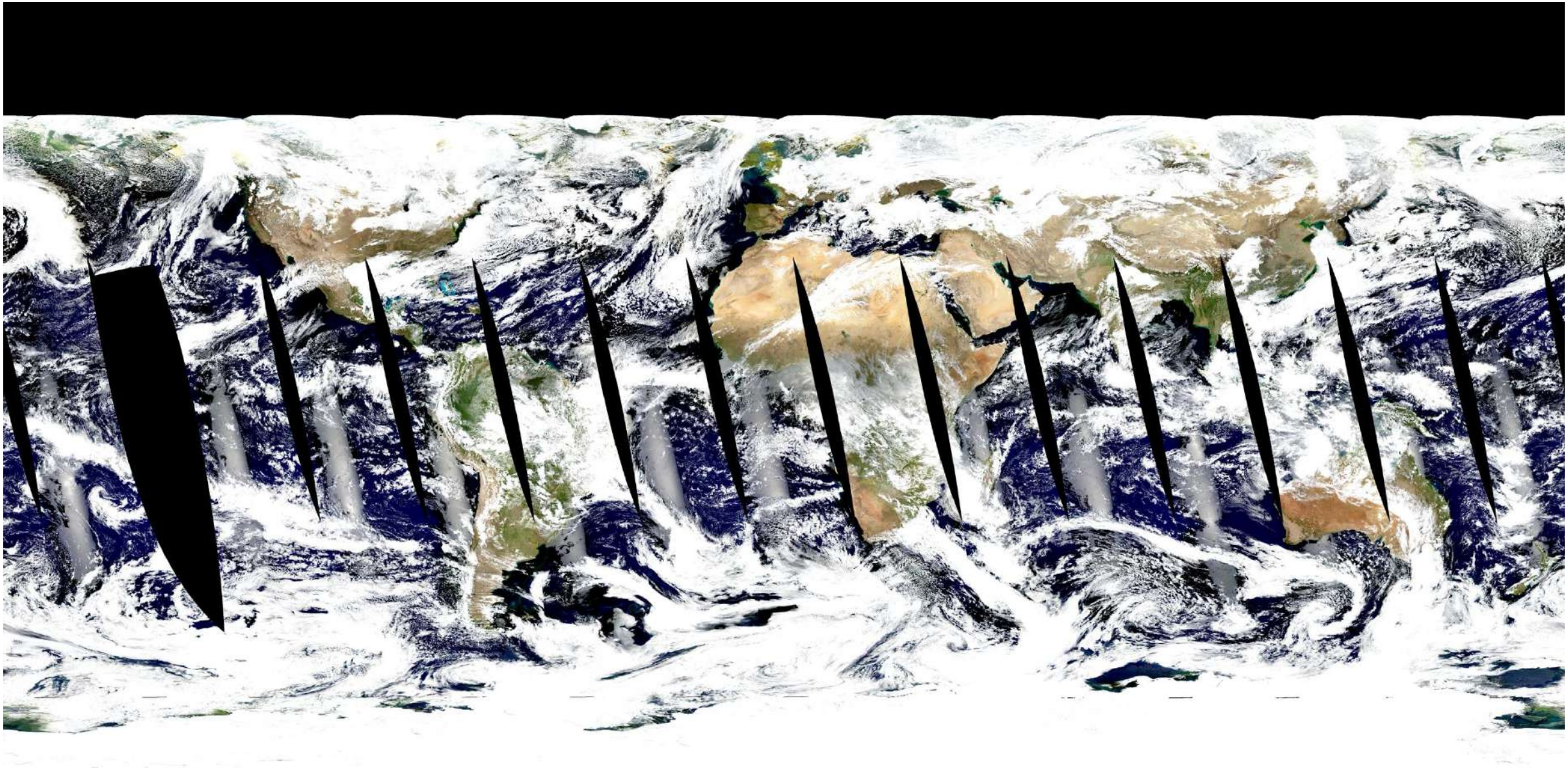
Row 1040, column 2760, current resolution 1 -->

| | |
|---|---|
| /Solar/Coordinates/Latitude | 48.682892 |
| /Solar/Coordinates/Longitude | 142.151413 |
| /Solar/Detectors/Detector_Index | 1685 (1685.000000) |
| /Solar/Flags/quality_flags | 2281701376 (228170137 |
| /Solar/Bands/olci/Oa01 | 7187 (97.994747) |
| /Solar/Bands/olci/Oa02 | 9603 (110.348070) |
| /Solar/Bands/olci/Oa03 | 9684 (121.902191) |
| /Solar/Bands/olci/Oa04 (B) | 10787 (122.928654) |
| /Solar/Bands/olci/Oa05 | 9647 (118.021394) |
| /Solar/Bands/olci/Oa06 (G) | 9879 (99.165398) |
| /Solar/Bands/olci/Oa07 | 8570 (90.550619) |
| /Solar/Bands/olci/Oa08 * | 10604 (95.170901) |
| /Solar/Bands/olci/Oa09 | 9801 (94.981491) |
| /Solar/Bands/olci/Oa10 | 10489 (94.254154) |
| /Solar/Bands/olci/Oa11 | 11227 (93.868943) |
| /Solar/Bands/olci/Oa12 | 12194 (91.345254) |
| /Solar/Bands/olci/Oa13 | 2330 (18.316129) |
| /Solar/Bands/olci/Oa14 | 4408 (33.192240) |
| /Solar/Bands/olci/Oa15 | 9495 (74.849087) |
| /Solar/Bands/olci/Oa16 | 11957 (85.516464) |
| /Solar/Bands/olci/Oa17 | 11961 (72.435816) |
| /Solar/Bands/olci/Oa18 | 11680 (70.477118) |
| /Solar/Bands/olci/Oa19 | 10626 (58.878667) |
| /Solar/Bands/olci/Oa20 | 6906 (35.186069) |
| /Solar/Bands/olci/Oa21 | 12014 (51.564089) |
| /Solar/Bands/slstr_an/S1 | 7080 (7080.000000) |
| /Solar/Bands/slstr_an/S2 | 7699 (7699.000000) |
| /Solar/Bands/slstr_an/S3 | 9296 (9296.000000) |
| /Solar/Bands/slstr_an/S4 | 179 (179.000000) |
| /Solar/Bands/slstr_an/S5 | 4737 (4737.000000) |
| /Solar/Bands/slstr_an/S6 | 4154 (4154.000000) |
| /Solar/Bands/slstr_ao/S1 | 6298 (6298.000000) |
| /Solar/Bands/slstr_ao/S2 | 6366 (6366.000000) |
| /Solar/Bands/slstr_ao/S3 | 7632 (7632.000000) |
| /Solar/Bands/slstr_ao/S4 | 109 (109.000000) |
| /Solar/Bands/slstr_ao/S5 | 2705 (2705.000000) |
| /Solar/Bands/slstr_ao/S6 | 2474 (2474.000000) |
| /Solar/Geometry/olci/OAA | 103.855904 |
| /Solar/Geometry/olci/OZA | 16.498707 |
| /Solar/Geometry/olci/SAA | 152.835648 |
| /Solar/Geometry/olci/SZA | 69.354431 |
| /Solar/Geometry/slstr_an/OAA | 90.565269 |
| /Solar/Geometry/slstr_an/OZA | 17.840555 |
| /Solar/Geometry/slstr_an/SAA | 152.657883 |
| /Solar/Geometry/slstr_an/SZA | 69.453590 |
| /Solar/Geometry/slstr_ao/OAA | 179.927658 |
| /Solar/Geometry/slstr_ao/OZA | 55.040867 |
| /Solar/Geometry/slstr_ao/SAA | 153.221298 |
| /Solar/Geometry/slstr_ao/SZA | 69.246307 |

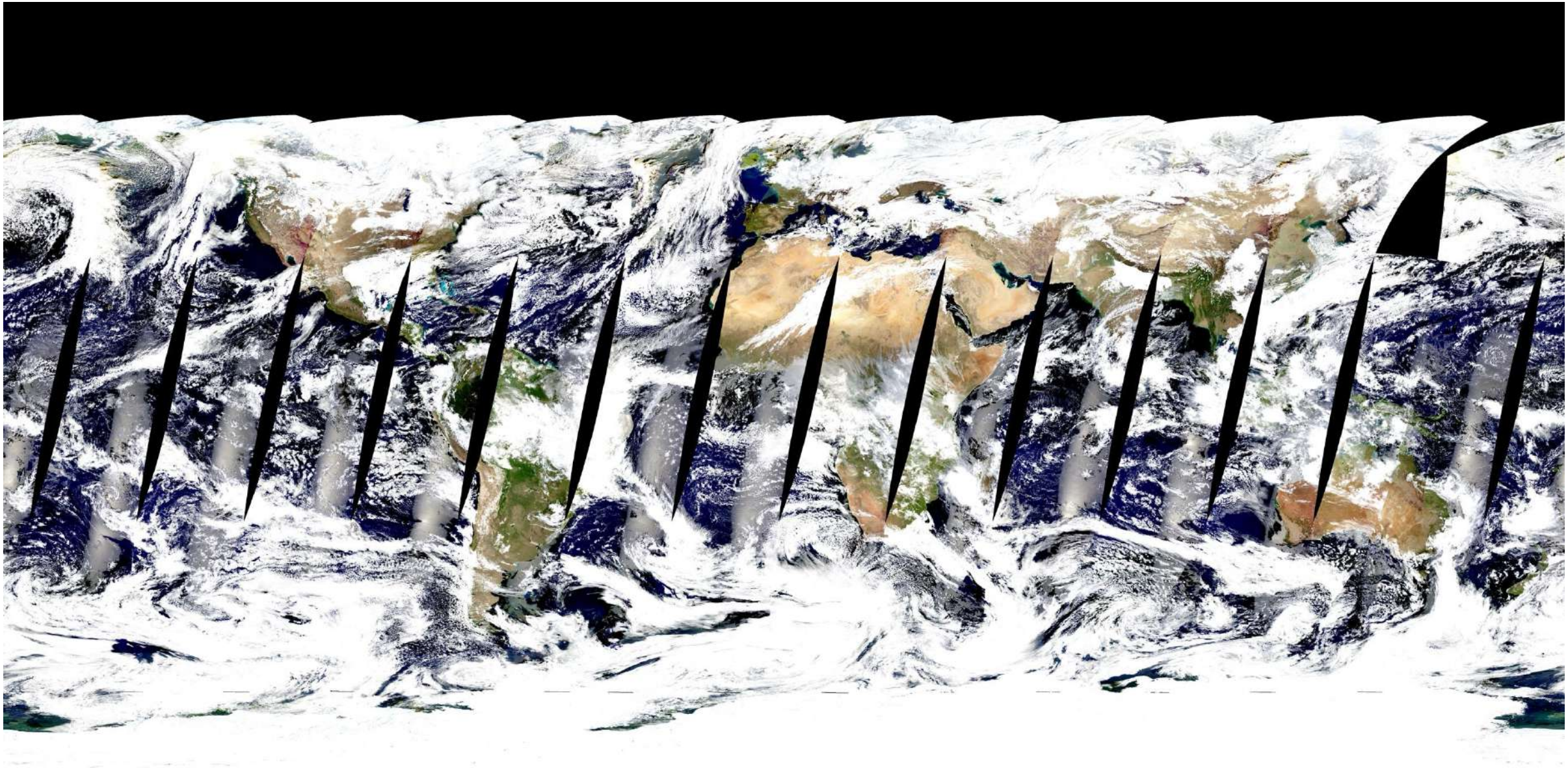
# MODIS Terra Jan 15 2025



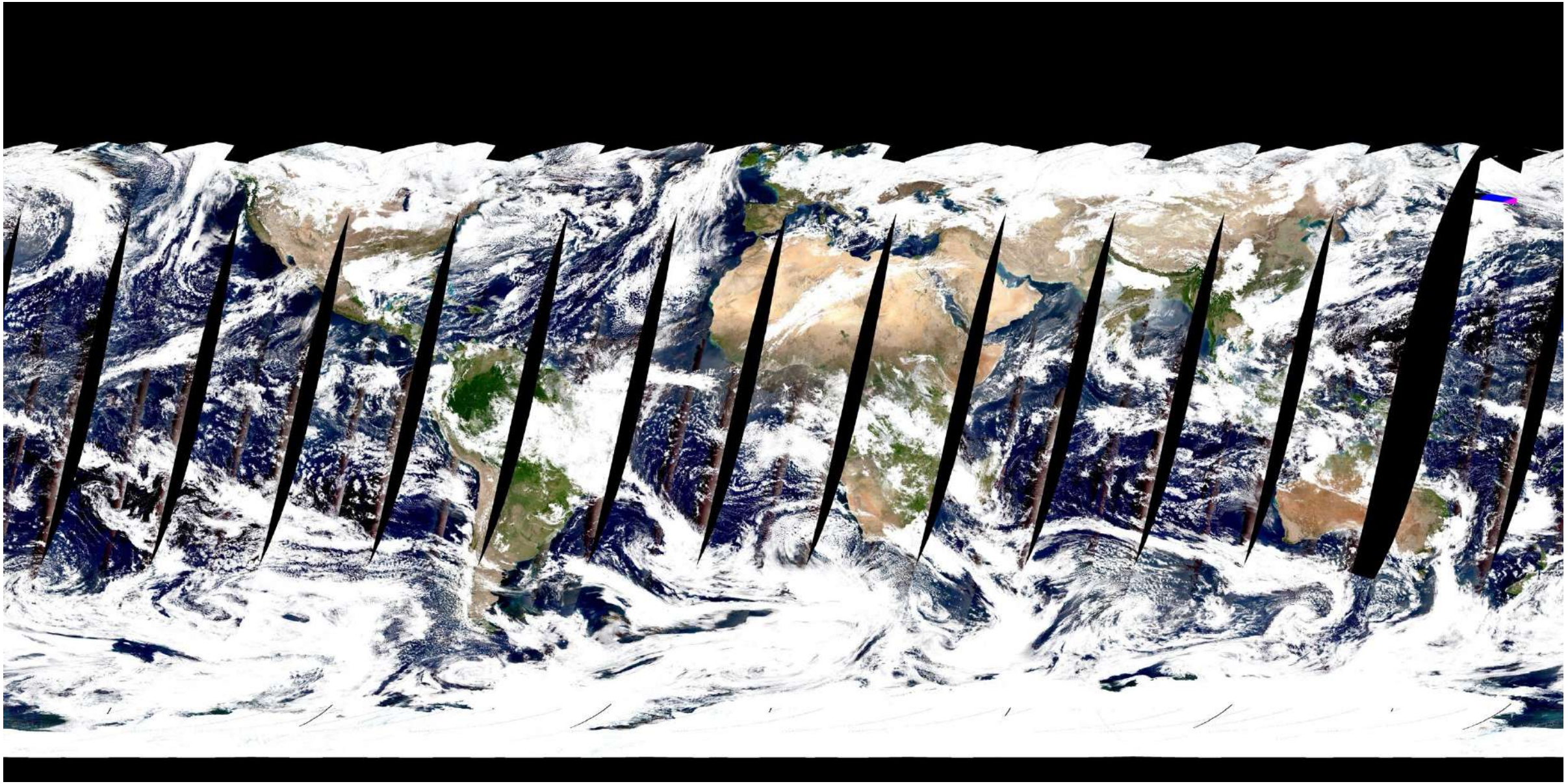
# MODIS Aqua Jan 15 2025



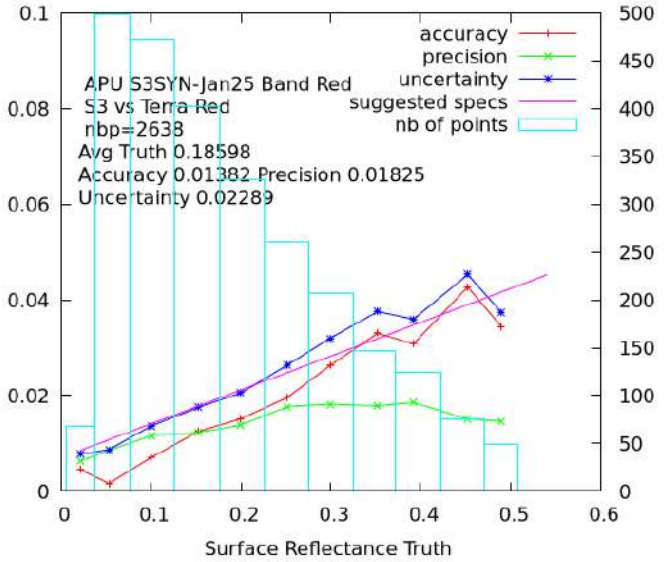
# MODIS Terra Jan 15 2025

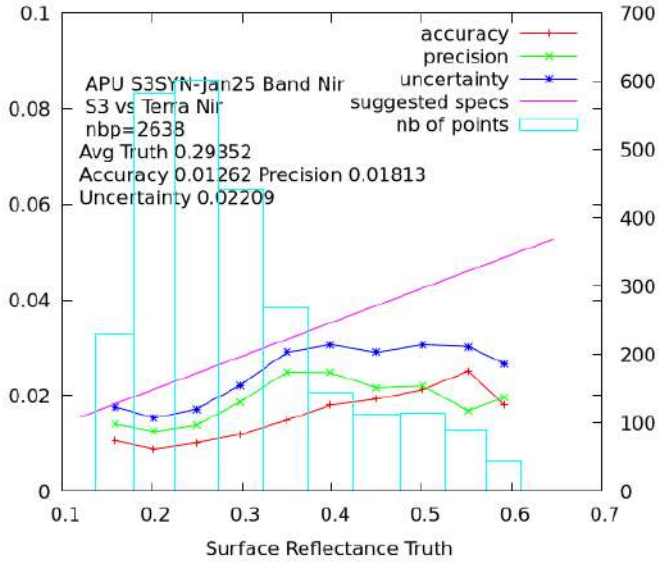


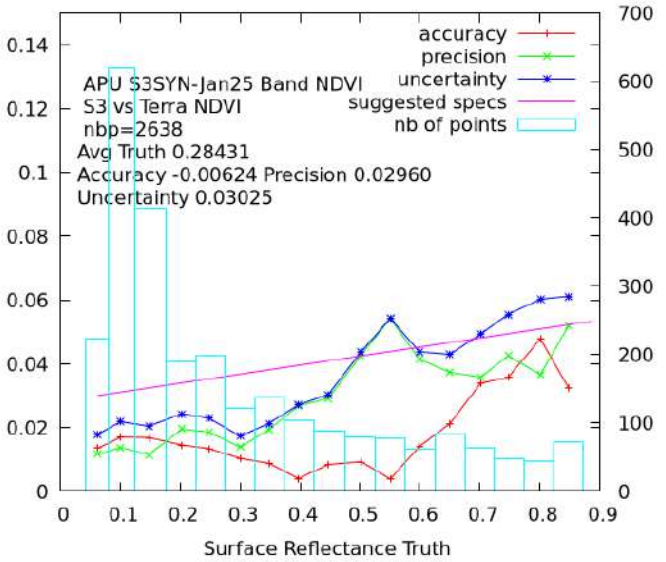
# S3-A-B Jan 15 2025

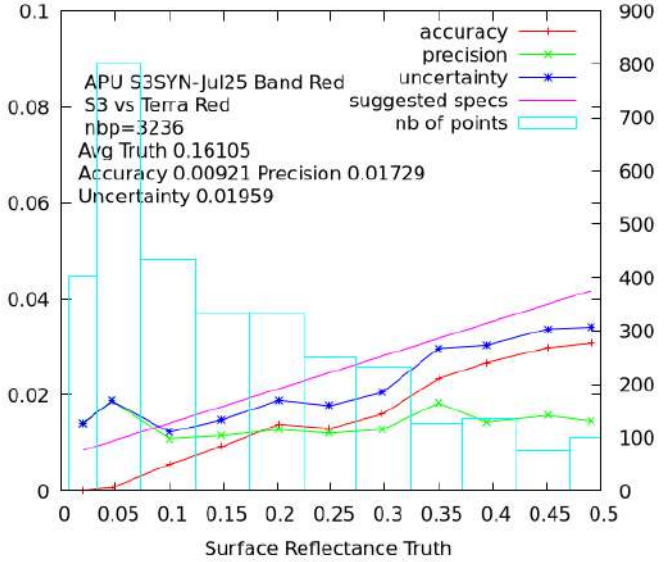


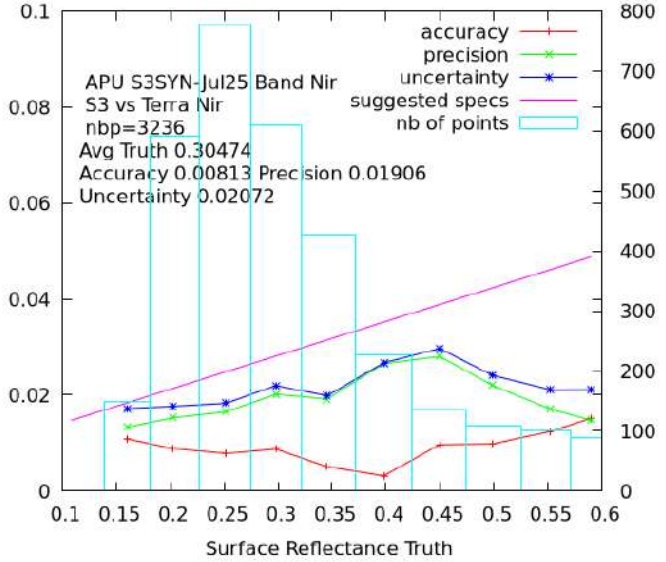
# Performances of the MODIS like prototype under evaluation

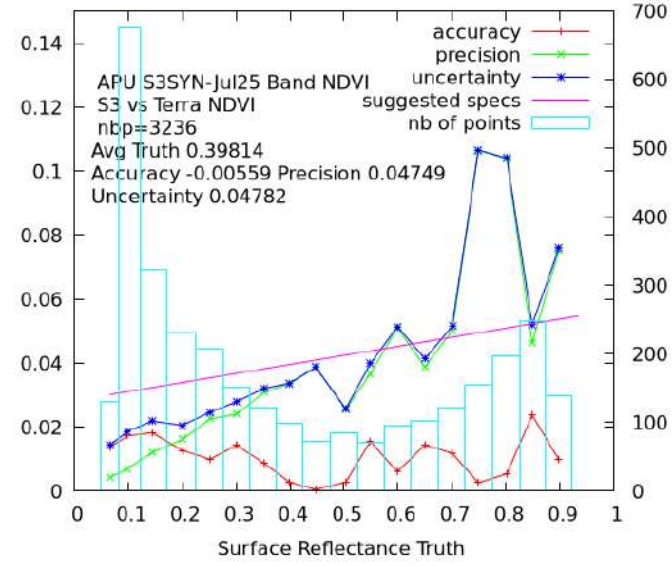


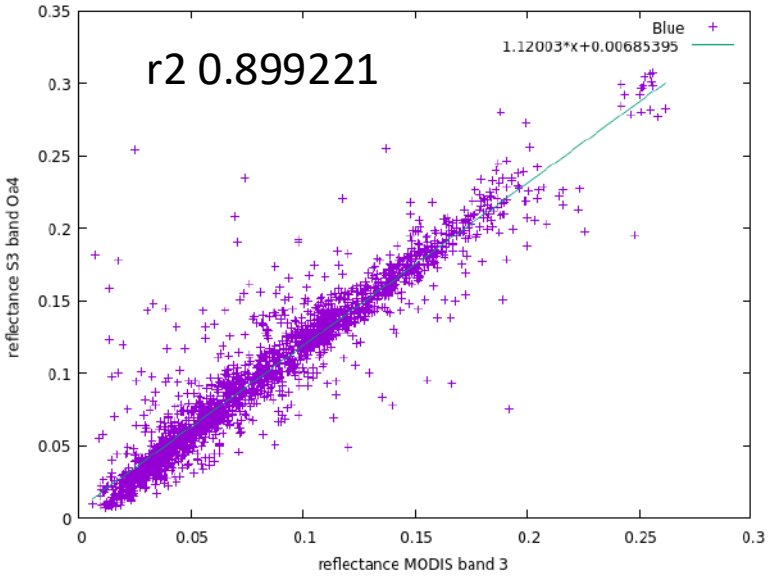



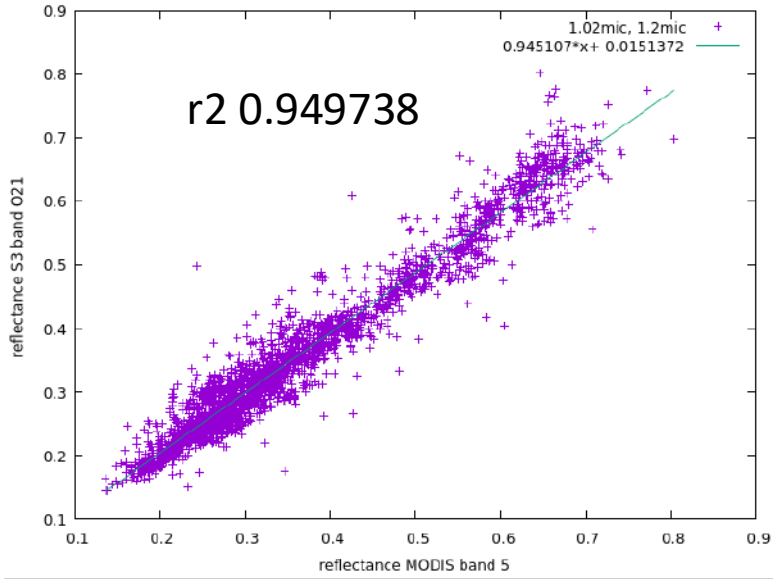



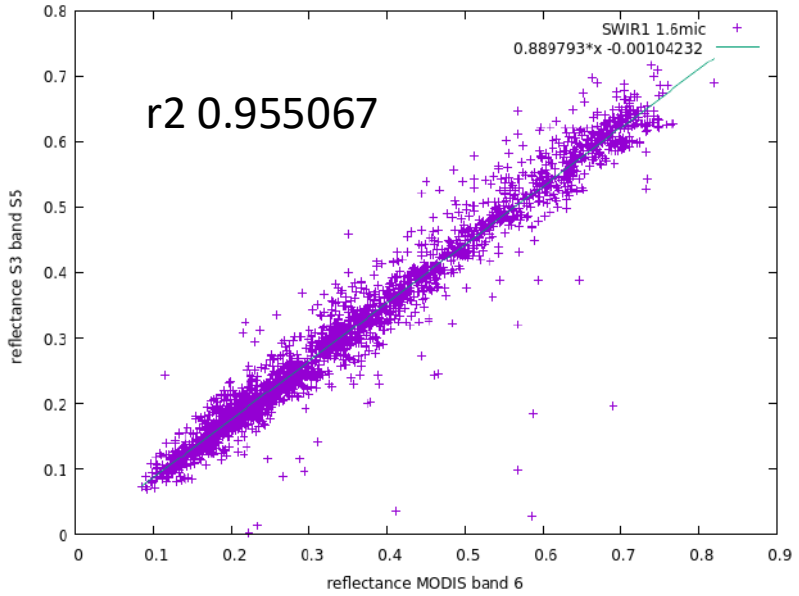



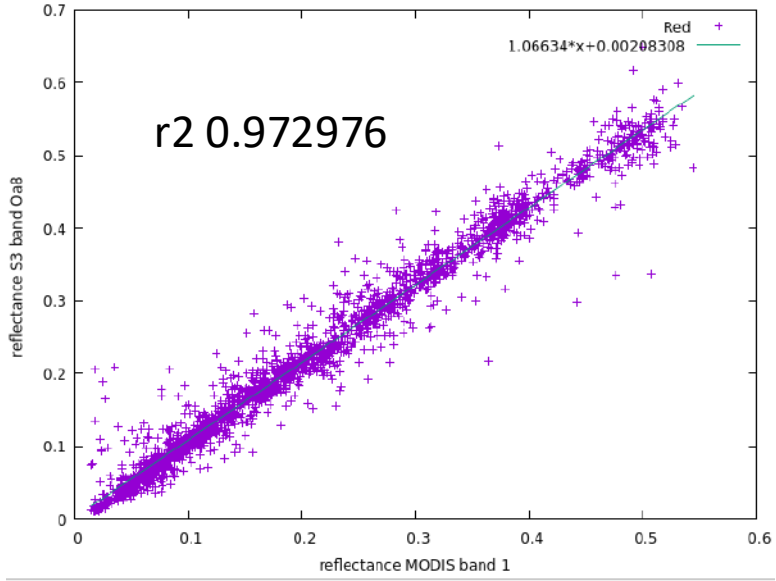



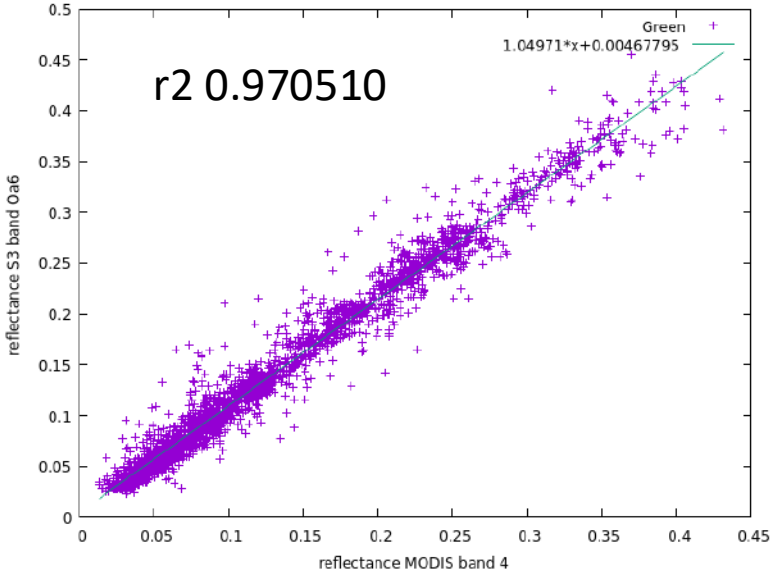
# Performances of the MODIS like prototype under evaluation for extra bands

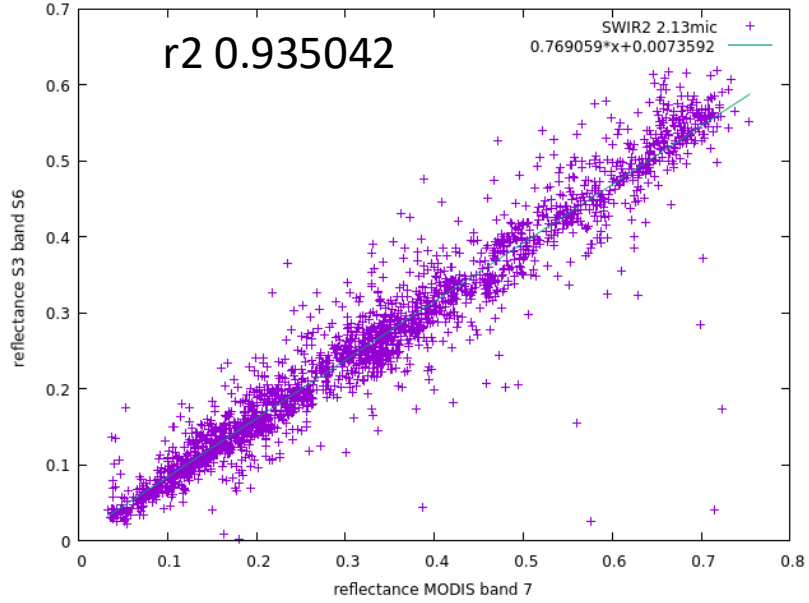


# CONCLUSIONS

- NASA/GSFC is prototyping a S3 LaSRC based SR product to potentially fill the gap from MODIS Terra Decommissioning
- There is clear requirement about SR (APU) to ensure continuity.
- Collocated OLCI and SLSTR is essential (best as possible) to ensure improved cloud screening
- Calibration Harmonization is also a strong requirement (better than 1%)
- A complete package of validation routine activities: AERONET based evaluation, Inter-instrument consistency (BELMANIP type) and Cloud Mask Validation should be developed for S3, VIIRS SR suite